HOW CAN I SMELL THINGS FROM A DISTANCE?

Particle Nature of Matter and Phase Changes

IQWST LEADERSHIP AND DEVELOPMENT TEAM

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Investigating and Questioning Our World
through Science and Technology
(IQWST)

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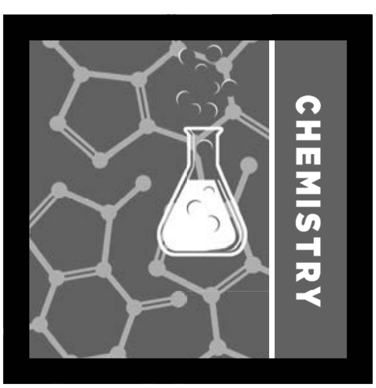

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ART

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Lesson 7

Spectrum—*Wikipedia, The Free Encyclopedia*

Contents

SCIENTIFIC PRINCIPLES

A scientific principle states a scientific idea that is believed to be true based on evidence. As your class decides on new principles in this unit, add them to the list.

SCIENTIFIC PRINCIPLES

SCIENTIFIC PRINCIPLES

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DRIVING QUESTION NOTES

Use these sheets to organize and record ideas that will help you answer the Driving Question or your own original questions.

DRIVING QUESTION NOTES

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Activity 1.1 & 1.2—Can You Smell What I Smell? *and* Developing an Initial Model

What Will We Do?

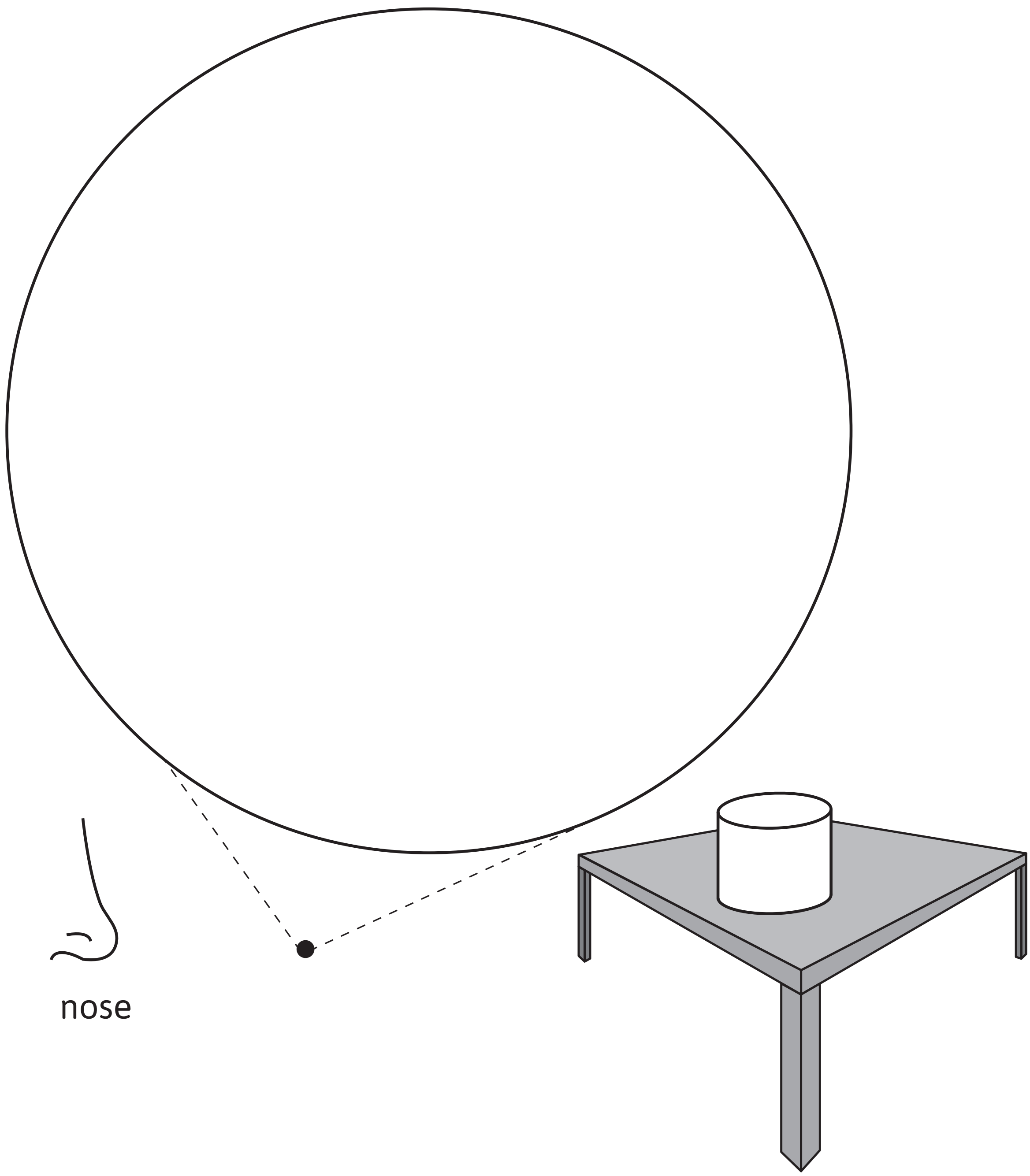
We will develop a model to show what makes up an odor and use the model to explain how an odor gets from one place to another.

Procedure

☐ a. Describe what happens when your teacher opens the jar.

Making Sense

1. Imagine that you have a special instrument that allows you to see what makes up odor. The large circle in the following drawing represents a spot that is magnified many times, so you can see it up close. Create a model of what you would see if you could focus on one tiny spot in the area between the jar and your nose.
2. Label the parts of your model so someone who looks at it will know what the parts represent.



3. A model can be used to explain something. How can your model help you explain how people smell odors? Describe what your model shows about odors.

Lesson 1 Reading One—Can You Smell What I Smell?

Getting Ready

Close your mouth and breathe in through your nose. What do you smell? Smelling is one way that your body takes in information. You take in good odors and bad odors through your nose. Most people like to smell food baking in the oven, but most people do not like the odors from their garbage.

Make a list of a few odors that you like, and a few odors that you do not like.

Odors I Like	Odors I Don't Like

Your list can help you think about how odors affect you. In this lesson you will read about a bad odor that scientists use to keep your family safe. When you finish reading, you should be able to tell why it is important to understand odors. You should also be able to tell whether all odors move in the same way.

Smelling Odors from Across the Room

In class, you smelled materials that were in closed containers. As your teacher opened each jar, you probably did not smell anything right away. After a while, you could smell each odor. Maybe you did not even have to see the material to guess what was in the jar. People who sat closer to the jars smelled the odors more quickly than people who sat far away from the jars. Each odor had to move to reach each person's nose.

Do All Odors Move the Same Way?

All odors move in the same way whether they are in a classroom, a house, or outdoors. All odors move away from a material and become part of the air. In this unit, you will investigate how odors move from one place to another as part of the air. Then they get to your nose. Why is this important? The next section describes a time when odor is very important to your safety.

You Need Your Nose!

Look at your list of odors. Did you list any odors from something burning? For example, you might like the smell of burning leaves or campfires. However, if you smell something burning inside your house, that is probably not good. Odors can signal good things, or they can signal problems. Have you ever smelled spoiled milk, meat, or vegetables? Once the odor of spoiled food reaches your nose, you probably will not eat the food. Spoiled food can make you sick, so the bad odor warns you not to eat it. The odor seems to turn on an alarm in your brain that says danger.

Have you ever smelled rotten eggs? Rotten eggs stink. Scientists have learned how to use rotten egg odor to keep people safe. Here is how: Human noses cannot smell natural gas. (Scientists use the word *odorless* to describe materials that people cannot smell.) But human noses can smell a material called mercaptan. *Mercaptan* has a rotten egg odor. When scientists add mercaptan to natural gas, the odor moves with the other gases that make up air.

You might have smelled mercaptan if your house uses natural gas for heating or cooking. If you have ever turned on the stove, but the burner does not light quickly, then you may have smelled the rotten egg odor. When you suddenly smell rotten eggs, you know that something is wrong. Natural gas is safe most of the time, but if something goes wrong, the gas could be dangerous. A leak of natural gas into the air, for example, can be dangerous. Scientists used their understanding of odors and how they move to make it safe for people to heat their homes with natural gas.

It Is Your Turn to Ask Questions

All people notice things about the world by making observations. People use their senses to see, taste, smell, touch, and hear what is around them. When people notice something, they are making observations. Sometimes people think about what they see, and they wonder about why or how something happens. Scientists do this, too. They make observations and ask questions. As an example, think about rainbows. At one time, scientists probably observed rainbows and asked questions such as, Why are rainbows always the same colors? Why do rainbows appear when it rains but not on other days? Through their questions and observations, scientists found that light from the sun enters raindrops and bends in slightly different directions. People see the bent light as colors in the shape of a rainbow.

What questions do you have about odors? Maybe you wonder what is moving in the air when people smell the rotten egg smell of natural gas. Maybe you wonder how scientists add odor to a material. Maybe you have a question about something on your list of odors that you like or do not like. Make a list of questions about odors that you are interested in learning the answers to. (A good way to start questions is often with the word “how” or “why.”)

Lesson 1 Reading Two—How Can Models Help Me Understand Odors?

Getting Ready

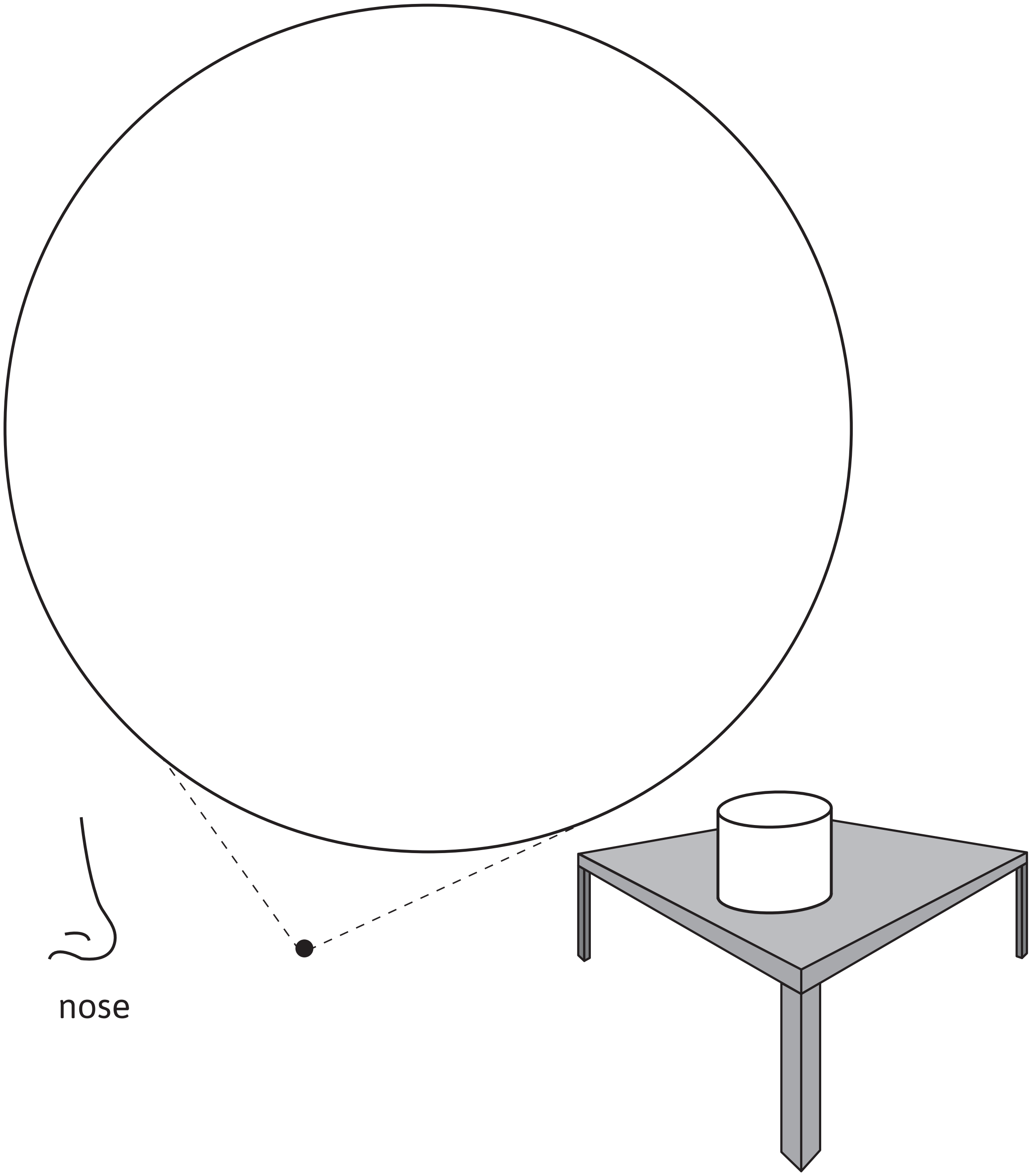
In science, models are helpful in many ways. In general, scientists develop models and use them to explain phenomena. For example, light travels too fast for people to see it moving; however, you can model how light moves. A model can help people understand and explain how people see. In this unit, you will model how people smell odors. Your nose detects odors even if you cannot see them. Your model can help you understand how people smell odors even though they cannot see odors. In this lesson, you will learn more about odors and modeling odors.

How Many Different Odors Can You Smell?

When you eat an orange, you usually can smell the orange odor. Every time your nose is near an orange, you smell a similar odor. You will not smell that odor when you smell the air around other fruits. Bananas, apples, lemons, and kiwis all have different odors. Your nose can tell the difference. In fact, people's noses can detect about 10,000 different odors.

Look back at the list of odors you made. Choose one odor from your list. You can choose an odor you like or one that you do not like. Draw the source of the odor in the diagram. Then, in the circle, draw a model of what you would see if you could look at a tiny spot between the source and your nose. Imagine that you are using a special instrument that lets you see the smallest parts of the odor. Be sure to label the parts of your model.

Sometimes the model you imagine in your head is difficult to represent with a drawing. Sometimes what you imagine is difficult to explain with words. Often, it is easier to use words and drawings to explain phenomena. In this unit, you will draw models and write about them. As you study in science, you will sometimes change your models. Scientists do this, too. When you learn new information, you sometimes need to revise your old model.



Why Would Someone Change a Model?

A model that helps you describe what you know about odors today might not help you explain what you learn about odors later in this unit. Your model might stay the same or it might change as you learn new information. It is okay if you change your model. It is okay if you keep the same model. It is important to make sure that the model you use can help you explain the different phenomena you experience.

Here is an example of using different models. If you asked a scientist to describe the continents on Earth, that person could use a globe or a map.

A map and a globe can both be good models. If you had to explain why the temperature in Alaska is cold for most of the year, a globe would be more helpful than a flat map. Different models work better for different purposes.

How Are All Odors Similar?

In class you drew a model of what makes up an odor if you could actually see the odor. In this reading, you drew a model of a different odor. Wherever you are—in a classroom, outside, on a bus, at home—you can smell odors because they become part of the air. All odors that humans smell have that in common—they all move as part of the air.

How Are Odors Different?

Even though all of the 10,000 odors people can smell go from a source into the air to their noses, each odor is very different. Think about that. What makes an odor that you like different from an odor you do not like? Write your ideas about why you think various odors are different from each other.

Activity 2.1—Can Something Have Mass Even if I Cannot Feel It?

What Will We Do?

We will use a deflated and an inflated ball to help us determine whether air has mass.

SAFETY

Be careful not to overinflate the ball.

Procedure

You are going to determine the mass of a ball when it is deflated. Then you are going to inflate the ball, adding air to it.

☐ a. Predict: What do you think will happen to the mass of the ball when you add air to it?

The mass of the ball will increase/decrease/stay the same when I add air to it. (Choose one.)

☐ b. Explain your prediction. Why do you expect that to happen?
☐ c. Use a scale to measure the mass of the ball without air (deflated ball).
☐ d. Record your data in the chart.
☐ e. Use a hand pump to pump air into the ball.
☐ f. Use a scale to find the mass of the same ball after you have added air to it (inflated ball). Use tape or a jar lid to keep the ball from rolling off the scale.
☐ g. If you used anything to hold the ball on the scale, subtract the mass of it from the mass of the inflated ball.
☐ h. Record your data in the chart.
☐ i. Subtract the mass of the deflated ball (ball without air) from the mass of the inflated ball (ball with air). Record the difference in the last row of the chart.

Data

Mass of the Inflated Ball	
Mass of the Deflated Ball	
Mass of the Inflated Ball Minus the Mass of the Deflated Ball	

Making Sense

How would you convince someone who is absent today that air has mass?

Lesson 2 Reading One—Can Something Have Mass Even if I Cannot Feel It?

Getting Ready

Do you ever eat popcorn? Even if you do not eat it, you probably know how popcorn smells. These items all have strong odors:

- Popcorn
- Oranges
- Gasoline
- Nail polish remover

Even though materials can be very different in some ways, they can be similar in other ways. These items have strong odors, but those odors are very different. Today you will read about other similarities between materials like these. To help you think about comparing materials, you will read about popcorn first.

How Can I Describe How Much Popcorn I Have?

If you go to the movies and you are hungry, you might want a lot of popcorn. Another time, you might only want a little. If you want a lot of popcorn, you ask for a large—enough popcorn to fill a large container. If you want just a little, you ask for a small—enough popcorn to fill a small container. Outside of science class you can use the sizes of the containers to describe the amount of popcorn. Words like *small* and *large* can be useful.

In science, describing amounts of material by the size of the container is sometimes difficult. Even though you get a lot of popcorn in a large container, you do not get exactly the same amount every time. The number of pieces will not always be the same. So instead of using phrases like *a lot*, *a little*, *large*, or *small*, scientists use a measurement called *mass*. Mass is a measure of the amount of material. In science, you can measure mass using a scale or balance.

The amount of popcorn in the large container can be described as 200g. The amount of popcorn in the small container can be described as 80g. You know the amount of popcorn in each container is different because the masses are different.

80 grams

200 grams

Determining the Mass of a Sample

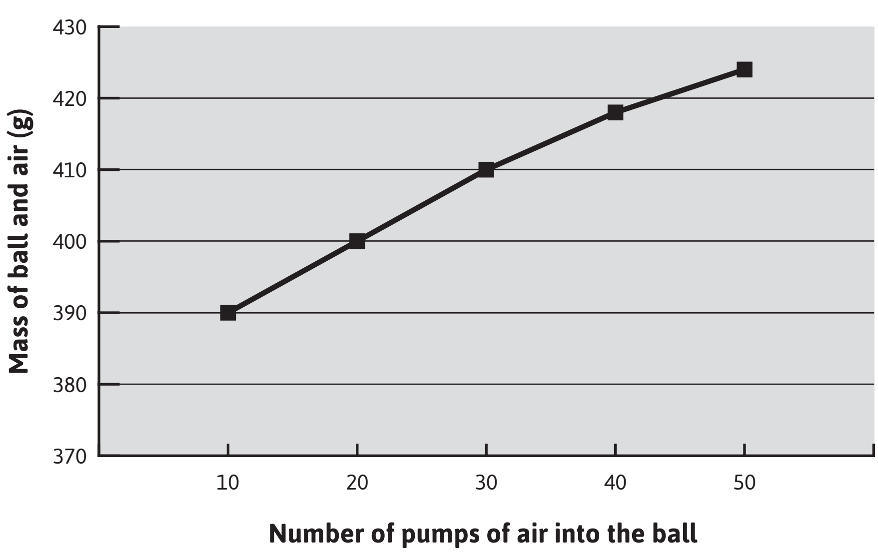
In class you measured mass using an amount of material that scientists would call a *sample*. Have you ever been in an ice-cream store that allows you to taste different flavors? They use tiny spoons to give you a sample so you can decide whether you like a flavor or not. You might see your grandpa taste a sample of food he is cooking to be sure it tastes just right. A sample is not a specific amount. A sample means that you take a part of something instead of taking the whole thing. In class you may have measured a sample of sugar, not a whole bag of sugar. Sampling is an important way that scientists and you can test materials.

How Do I Measure a Sample of Air?

You observed in class that mass can be large or small depending on the amount in the sample. It was probably easy to tell that materials like milk and sugar have mass. You could even guess that anything you can see and feel will have mass. Think about things you cannot see or feel, like odors or air.

Even though you cannot see or feel air, you observed that it has mass. You measured the mass of a ball when it was deflated (it had very little air in it). Then you measured the mass when the ball was inflated (it was full of air). Refer to the graph of what you might have observed. Because air was the only thing you were adding to the ball, and because the mass increased as you added air, then air must have mass. Some people in another class measured the mass of the ball before pumping air into it, like you did in class. They also measured the mass of the ball after pumping air into it 10, 20, 30, 40, and 50 times. Once they collected data, they put the measurements into a graph like this one.

Mass of Ball When Pumping Air into It



This type of graph is called a *line graph*. The points on this graph are measurements someone recorded. Sometimes drawing a line through the points helps people see a relationship between two things. This line shows the relationship between the number of pumps of air and the mass of the ball. What relationship between the mass and the number of pumps of air does this graph show?

Here are two ways to write about the relationship. First, fill in the blanks so the sentence describes the relationship correctly.

As the ______________________ increases, the _______________ increases.

Second, finish the sentence below so that the statement makes sense with what you see in the graph.

As the students pumped more air into the ball, ____________________________.

Activity 2.2—Measuring Volume

Your teacher will provide instructions for this page.

Activity 2.3—
What Happens to My Lungs When I Breathe In Air?

Your teacher will provide instructions for this page.

Lesson 2 Reading Two—What Happens to My Lungs When I Breathe in Air?

Getting Ready

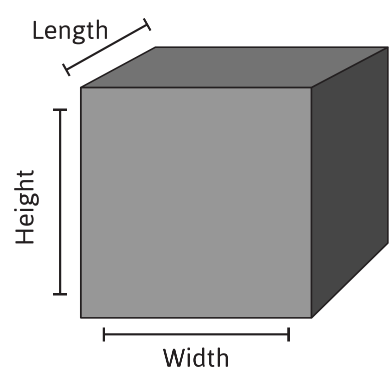
Breathe in. Now breathe out. Breathe in one more time. Notice what happens to your chest as you breathe in and out. One reason your chest gets bigger is that your lungs expand as they fill with air. Why your lungs expand has to do with another characteristic of air—air has volume. This reading will help you learn more about volume. It also will help you understand why volume and mass are important in science.

Characteristics of Air: Air Has Volume

When people say *volume*, they are often talking about sound. Your grandpa might ask you to turn up the volume on the television. Your mother might ask you to turn down the volume on the radio. These are both ways to use the word *volume*. Another way to talk about volume is to describe how much space something takes up.

The volume of a material is similar to its size. For example, balloons that are filled with air can be many different sizes. Look at this image of a hot-air balloon. The larger the balloon, the more space it takes up. You could say that a larger balloon has more volume than a smaller balloon.

Measuring Volume



You may have also heard the word *volume* in math class. When you determine the volume of a cube or sphere, you figure out how much space it takes up. One way to determine the volume of a cube is by multiplying its length times its width times its height (l x w x h). You used that same method in science class when you calculated the volume of a block of wood or a container that holds water.

In class you measured the volume of things that you can feel. Even though you cannot feel air in the same way, you observed that air has volume. Your teacher used an empty flask to show that air takes up space. The top of the flask was covered except for two holes. One hole had a tube in it. Your teacher put a clamp on the tube so nothing could go in or out of the flask unless it went through the first hole. Your teacher tried to pour water into the flask through the first hole, but the water could not go in the flask. The air in the flask took up all the space. When your teacher took the clamp off the tube, the water went in one hole and pushed the air out the other hole. As long as the air could be pushed out, the flask could fill with water.

Try This at Home

You can do an activity at home to illustrate the phenomenon that your teacher did in class. All you need is a sink or bathtub with some water in it and a cup or drinking glass. The best cup for this activity is one that you can see through. Turn the cup upside down and push it straight down into the water. What happens inside the cup? Water cannot go in very far because the cup is already filled with air. Try scrunching a paper towel and putting it in the bottom of the glass. (The paper towel has to be able to stay in the bottom when you tip the glass upside down.)

Then, put the glass upside down into the water again. What happens?

Even if you did this activity in class, you can do it at home to show somebody else. You can also explain to them what you have learned about air. Air takes up space. That means air has volume.

Does Air Always Have Mass and Volume?

Trying the activity at home shows that air has volume even when it is not in a flask in science class. It is important to understand that the air around you always has mass, and it always has volume. It does not matter whether the air is in a ball or in a tire. It does not matter whether the air is in a classroom, in a house, or in the whole outdoors.

Do you think that odors have volume? It is difficult to test odors because they become part of the air. You cannot separate them with instruments you have in class. Do you think that odors take up space? Why?

What Is Similar among Air, an Odor, a Wooden Block, and Milk?

Your investigations in class have shown that there are two similarities among air, an odor, a wooden block, and milk:

1. They all have mass, which means that you can measure the amount of each one.
2. They all have volume, which means that each one takes up space.

You can see and feel the wooden block and the milk, so it was probably easy to tell that they have mass and volume. The mass of the ball increased when you put more air into it, which means that air has mass. Air also took up the space of the flask so that water could not flow in. That means that air has volume.

Most things that you see and use in class, at home, or outside have mass and volume. If you can see it, touch it, breathe it in, taste it, or smell it, then it probably has mass and volume. Scientists call materials that have both mass and volume *matter*. Matter is anything that has mass and volume. You could say an odor, air, a wooden block, and milk are similar because they are all matter.

Why Does Matter Matter?

You probably already use the word *matter* outside of science class. If your friend asks, “Do you want a pizza or a sub for lunch?” you might answer, “It doesn’t matter.” Scientists use the word *matter* that way, too. They use the word *matter* differently when studying materials. In science, when you call a material *matter*, you are telling someone that the material has mass and volume.

All things that are matter also have other characteristics in common. In the next lesson, you will investigate air and odors, and observe other characteristics that all types of matter have in common.

Activity 3.1—Investigating Matter

What Will We Do?

We will investigate what happens to menthol as it heats and cools.

SAFETY

- Never taste any object in the science lab. Even if the substance is familiar and edible, the science equipment and surfaces may be contaminated.
- You will work with glass and with a hot plate in this activity. Both are safe if handled properly. Both can be dangerous if not handled properly. Keep hair and sleeves away from hot plates.
- Wear safety goggles during this activity.

Procedure

☐ a. Describe your observations of the menthol in the flask.

☐ b. Predict: What do you think will happen to the menthol as you heat it on the hot plate?

☐ c. Place 5g of menthol in the 125mL flask.
☐ d. Place the flask on the hot plate.
☐ e. Cover the flask with a watch glass, and place ice cubes on the top of the glass.
☐ f. Turn the hot plate on at the lowest level possible.
☐ g. Heat the flask with the menthol. As soon as you notice something begin to change, turn off the hot plate. Ask for your teachers' help in setting the flask aside so that it can cool. Record your observations in the appropriate space below.
☐ h. Continue to observe the menthol as it cools. Again record your observations.
☐ i. Observe the watch glass and the upper rim of the flask. Record your observations again.

Observations

1. Describe what you saw happen to the menthol as you heated it.

2. Describe what you saw happen to the menthol as it cooled.

Making Sense

1. How does your prediction compare to what you observed?

2. Look at the watch glass covering the flask. What do you think the material on it and on the flask is? How did the material get there?

3. Can menthol exist in more than one form? Use observations from this activity as evidence to support your response.

Lesson 3 Reading One—Three Forms of Matter—Solid, Liquid, and Gas

Getting Ready

Think about eating a bowl of cold cereal for breakfast. What types of matter would be part of your breakfast? Are there any solids? Are there any liquids? Are there any gases?

List the type of matter and the state of matter it is in.

In class, you observed materials in three forms—solid, liquid, and gas. Scientists call each form a state of matter. A *state* is the physical form in which a material can exist. As you read, think about how you can tell which state of matter a material is in and underline ideas that can help you decide.

What Determines the State of Matter a Material Is In?

You live in a world of solids, liquids, and gases. You breathe in a gas, and you breathe out a gas. You eat solid matter. You drink liquid matter. As you have been thinking about matter, you have been considering the state in which you usually find each material. You usually find materials at room temperature. Room temperature is not when you cook something on the stove. It is not when you leave something in the refrigerator overnight. It is probably helpful for you to just think about room temperature as the temperature around you as you sit in your classroom.

Characteristics of a Solid: Can You Grab It, Hold It, or Poke It with Your Fingers?

You can determine what state a material is in based on its characteristics. A fork is a solid. An apple is a solid. A rock is a solid. You can hold each of these solids in your hand. A large rock may be too big for you to hold. If you had a sample of rock, you could hold it in your hand. You can grab a piece of each of these things. You cannot grab and hold a piece of the air. You cannot grab and hold a piece of milk. You can grab and hold a piece of wood. Apples, rocks, and wood are matter in a solid form.

Here is another test. If you had a big glass bowl and you put a solid into the bowl, the solid would stay in its original shape. A rock would sit in the bowl and look like the same rock. Solids have a fixed shape. Fixed shape means that they stay the same until you do something like break or crush them. Another way to think about solids is that you cannot poke your finger into them. Push your finger against your desk or tabletop. It is a solid. Your finger will not go through it. Floors and walls are solids. A glass bottle, a plastic bottle, and a soda pop can are solids. Sidewalks, driveways, and roads are solids. Poking your finger into something is not a perfect test, but it can help you with the idea of many solids. You will be learning more in this unit about why you cannot poke your finger into most solids but can poke your finger into liquids and gases.

Characteristics of a Liquid: Does It Change Shape When You Pour It?

Liquids do not have a fixed shape. That means they do not hold the shape they are in. In the picture, you can see that the milk is in one shape as it pours out of the jug and a different shape in the glass. You could do this at home. Measure one cup of liquid water (or milk) and pour it into a tall glass. Then measure another one cup, and pour it into a short glass. You will notice that the liquid in the two glasses is in the shape of the glass. Someone might be fooled and think that there is more liquid in the tall glass. However, what really is happening is that the liquid water takes the shape of the glass and fits into it. It spreads out more in the wide, short glass, so it might seem like less liquid. Liquids take the shape of the container they are in. They do not hold the same shape when you pour them.

Characteristics of Gases

Gases can be difficult to study because you cannot see most of them. However, gases are all around you. Gases do some of the same things that liquids do. You have already learned that air has volume; it takes up space. When air takes up space, it also takes the shape of its container. A room is like a big container. The air in the room you are in right now is taking the shape of the room. It is filling every corner. If you are reading outdoors or in a car, air is filling that space too. Everywhere you look there is air, even though you cannot see it.

All types of gases take up the space of their containers. When gases fill the space of a container, gases also take the shape of the container. If you had a balloon in the shape of a star and you filled it with air, the air would spread into the star shape and fill it to each point. When a material is in the gas phase, it has characteristics that are similar to air. The same thing would happen if you filled the balloon with a different gas, such as helium gas. You have probably seen helium-filled balloons in many shapes. Gases fill the volume of their container.

Compare the States of Matter

In the space below, compare the three states of matter. Be sure to tell what is alike and what is different about them. You can make a chart, a web, a drawing, or you can write sentences.

Activity 3.2—Why Does Water Have Many Names?

What Will We Do?

We will investigate water as it changes from one state to another.

Predict

Prediction 1: What do you think will happen when ice is heated?

Prediction 2: What do you think will happen when liquid water is heated?

Prediction 3: What do you think will happen when a watch glass is put over boiling water?

Making Sense

1. How do your predictions compare to what you observed?

2. You have now heated and cooled menthol and water. Based on what you have observed, can one kind of matter (like menthol or water) exist in three different states? Explain your ideas.

3. Provide examples of phase changes that you are familiar with in your daily life.

Lesson 3 Reading Two—What Needs to Happen to a Material so that I Can Smell It?

Getting Ready

Think about materials you can smell that are usually in different states of matter and write your ideas in the space provided. You could use items off the list you made of odors you like and odors you do not like.

As you read, consider this question: What state of matter does a material have to be in for you to smell it? When you have finished reading, you should be able to describe how the state of matter is important in smelling odors.

What Is the Difference between States of Matter and Phases of Matter?

You have learned that solids, liquids, and gases are called states of matter. They can also be called *phases of matter*.

When two different words are used to describe the same thing, it can be confusing. Outside of science class, people also have more than one name for things. People use words like *small* and *little* to mean the same thing. They use *couch* and *sofa* to describe the same piece of furniture. In science, *state of matter* and *phase of matter* both refer to the physical forms that matter can be in. You are studying three states or phases: solid, liquid, and gas.

If You Cannot See Water as a Gas, How Do You Know It Is There?

In class you learned that when water is in the gas phase, it is in the air. Water as a gas is called *water vapor*. Your eyes do not detect water vapor. Your nose does not detect water vapor either. You might think this is a little confusing because when water boils on the stove, you see steam. When you take a hot shower, you see steam. Steam is not the same as water vapor. You will learn more about steam soon. It is important to know that water in the gas phase is water vapor. You cannot see it or smell it, but sometimes you can feel it.

Have you ever heard a weather forecaster on TV describe the day as humid? Maybe you have heard people say that the air feels moist or sticky. Sometimes people say it is hard to breathe when the air seems heavy. Some people say that humidity makes their hair frizzy. These are all ways of talking about water vapor in the air. *Humid* is a word to describe a large amount of water in the air. The water is in the gas phase, so you do not see it, but you feel it. You might have felt the water on your skin on a hot, humid day where you live. You may have traveled somewhere else and felt it. Humidity is one way that people can detect water in the gas phase in the air around them.

When Are the Characteristics of Solids, Liquids, and Gases Important?

People use the characteristics of the states of matter and phase changes in ways that you might not think about. One example is making candles. People who make candles use the characteristics of solids and liquids to create different shapes and sizes. First, they melt solid wax to make a candle. Things melt when a solid material turns into a liquid material—when it changes phases. The process is called a *phase change*. A solid material becomes a liquid material by melting. (This is one example of a phase change.)

When candle wax is liquid, it is easy to pour. A candlemaker pours the liquid wax into a container. Containers can be many shapes and many sizes. The liquid wax takes the shape of the container it is poured into. Then the wax freezes. Freezing is another phase change. When a liquid material turns into a solid material, it changes phases. A liquid material becomes a solid material by freezing. (Freezing is another example of a phase change.)

Candles Do Not Have to Be Frozen

If you were a little confused by that part about freezing, it is a good time to stop and say to yourself, “That does not make sense.” If you have seen a candle store in a mall, or if you have candles in your house, you know that they do not need to be frozen to keep their shape. They can sit on tables without having to be in the freezer. This is another time that a word you use outside of science class might confuse you. Scientists eat frozen ice cream, just like you. Scientists also put liquid water in the freezer to turn it into ice cubes. Scientists might describe winter weather as freezing cold. However, scientists also have another meaning for freezing that is not about being cold. *Freezing* is the name for the phase change from the liquid to solid state. Not all liquids have to be frozen by cold temperatures. Some liquids, like liquid candle wax, can freeze without being put in the freezer. Instead, liquid candle wax freezes as it cools from a hot liquid to a solid at room temperature, so freezing is a phase change that does not always mean something is cold.

How Can States of Matter Help Me Answer the Driving Question?

When you smell something, you are detecting something in the air. The odors you smell are materials in the gaseous state. The menthol investigation showed that odors can exist in three states. You first saw the menthol in the solid state. Then, as you heated it, two phase changes happened. First, the solid menthol melted and became liquid. Then, some of the liquid menthol changed into a gas. You could not see menthol in the gaseous state, but you might have observed two things:

1. It was easier to smell menthol odor when it was a gas.
2. Tiny crystals formed on the glass, away from where the menthol was heated.

These two observations are evidence that the material that makes up menthol changed into a gas and traveled. You observed menthol in all three states of matter. The same thing is true of other matter. The candle wax you just read about can exist in all three states of matter. Water can exist in all three states. In fact, all matter can exist as a solid, a liquid, and a gas.

Quiz Yourself

Look around you and think about this: How can some things be solids, some things be liquids, and some things be gases at the same time? You might be sitting on a solid chair. You might be drinking a liquid soda pop. You are breathing gaseous oxygen in the air. Think about the activities you did in class and the ideas you read about.

What determines whether a material is in a solid, liquid, or gaseous state?

Activity 4.1—How Can I Model the Things Gases Do?

What Will We Do?

We will investigate more things about air, and then we will create models to represent what happens.

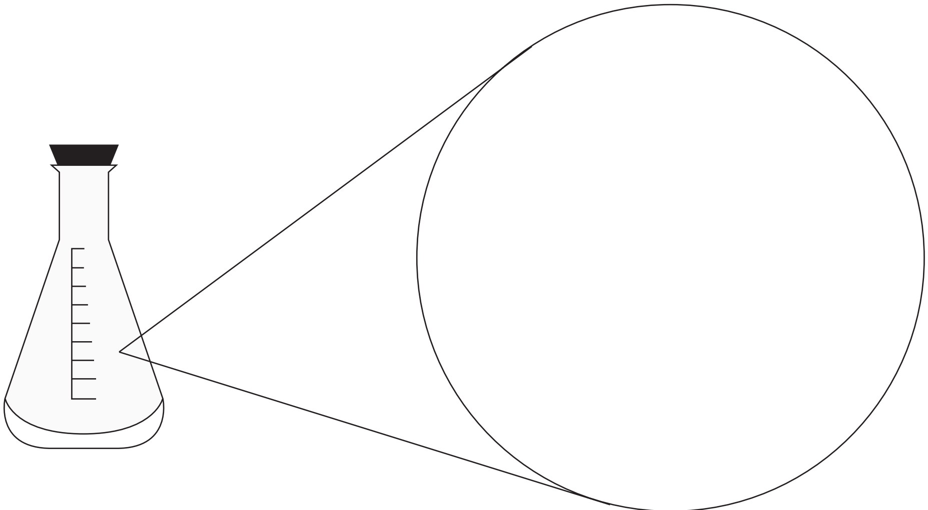
Creating Models

If you had a special instrument that would allow you to see the smallest parts of air, what would it look like if you could focus on one tiny spot inside the flask?

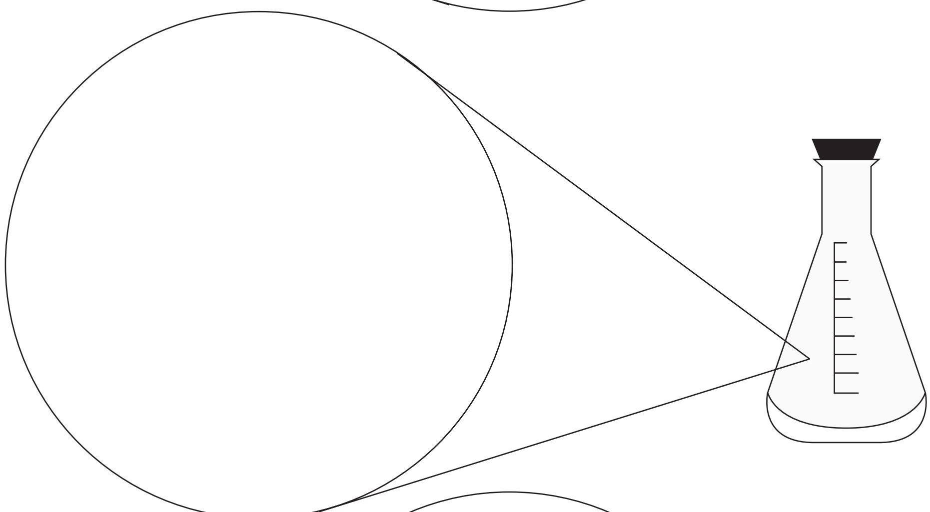
Create three models using the diagrams on the next page:

1. Model 1: Air in a flask
2. Model 2: Air in a flask after some air has been removed
3. Model 3: Air in a flask after lots more air has been added

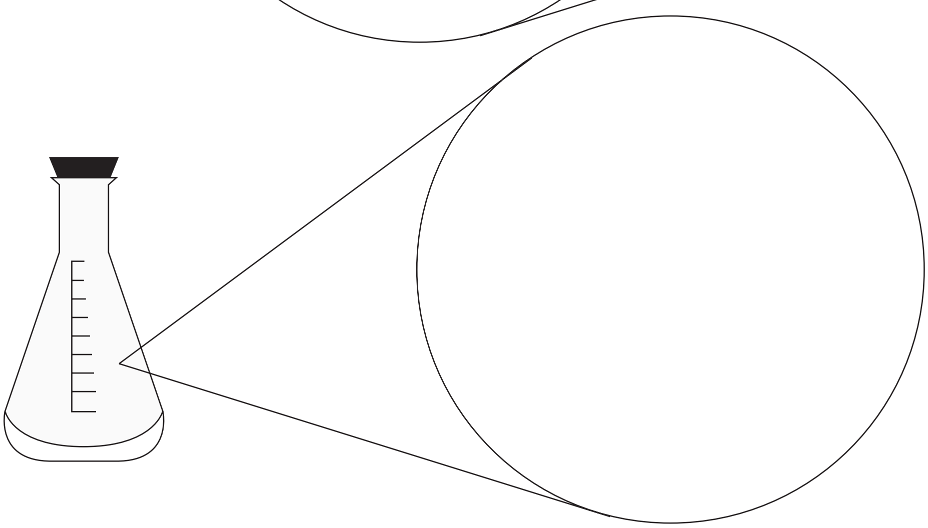
Create a key to show what the parts of your models represent.



Model 1



Model 2



Model 3

Making Sense

1. What characteristic of gases did you observe in this activity?

2. How do your models show that air takes the shape of the container it is in? Explain your ideas.

Lesson 4 Reading One—How Can I Model the Things Gases Do?

Getting Ready

Have you ever played in a pool or lake and tried to stay underwater as long as you could? Maybe you can hold your breath a long time underwater. Maybe you can only hold your breath for a few seconds. Imagine what it would be like if you did not have to worry about holding your breath underwater. Imagine if you could breathe underwater just like you breathe out of the water. Scuba divers use air tanks to help them breathe underwater. In this reading, you will learn about which characteristics of air make it possible to breathe underwater with scuba tanks.

You Can Take Some Air out of a Scuba Tank

One of the ways scuba tanks work is by having someone add air. When a tank is empty, more air can be added to it. As a scuba diver breathes, they take some air out of the tank, but some air stays in the container. Imagine if the only way to take air out of a tank was to take all of it out. If that were true, then scuba divers would need one tank for each breath they would take underwater. However, that is not the case. Scuba divers can take hundreds of breaths from one tank of air. That is because when they take a breath, scuba divers are only taking some air out of the tank. The rest of the air stays in the tank.

You Can Add More Air into a Scuba Tank

In class you observed air being added into a flask. People who make scuba tanks put a lot of air into the tanks. You can add air into many other things. For example, you also have to fill tires with air so you can ride your bike. You have to add air into an air mattress until it is filled enough so you can sleep on it. You also add air to a beach ball if you want to play with it.

Describe what happens to the air as you blow up an inflatable beach toy or an air mattress. Imagine that you are trying to describe the process to another student who was absent from school and does not know what you know about air. Make sure you describe what it means to add air to something.

Activity 5.1 & 5.2—What Else Can Gases Do? *and* Developing Models

What Will We Do?

We will use a large syringe to investigate two more characteristics of air. We will also create models of what we would see if we could look at the air inside the syringe up close.

Procedure

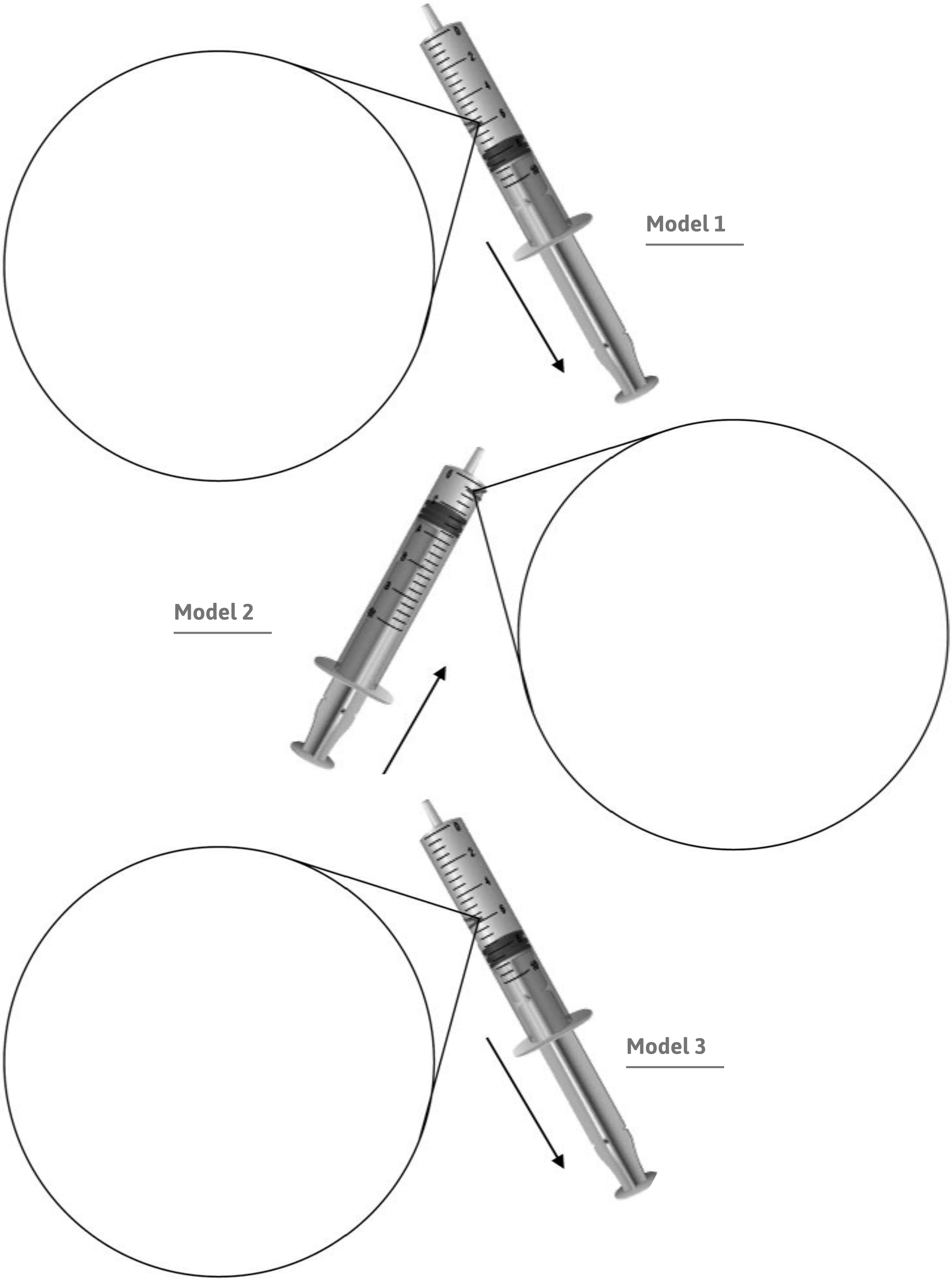
☐ a. Fill the syringe with air by pulling the plunger back halfway.
☐ b. Block the end of the syringe with your finger.
☐ c. While keeping the end of the syringe blocked with your finger, push the plunger in as muchas you can.
☐ d. While still blocking the end of the syringe, pull the plunger back as far as possible, but not all the way out.

Creating Models

If you had a special instrument that would allow you to see inside the syringe, what would the smallest parts of air look like? Create models of what you would see if you focused on one tiny spot:

Model 1: When the syringe is filled with air
Model 2: After pushing the plunger in
Model 3: After pulling the plunger back

Draw a key that explains what the parts of your models represent.



Making Sense

1. Compare Models 1, 2, and 3. (Be sure to describe the details of each model.)

2. Why was it important during this activity to keep the end of the syringe blocked by your finger?

3. Use your model to describe to your friend what compression means.

4. Use your model to describe to your friend what expansion means.

Lesson 5 Reading One—How Can I Model the Things Gases Do?

Getting Ready

Think about a sponge used for cleaning. If you have a sponge at home, you can use it to do this activity. Hold a wet sponge in one hand and squish it. Squeezing the sponge makes it smaller. You might be able to squeeze a large sponge to fit in one hand. Because you can push (or press) the sponge, you can say that the sponge can be compressed.

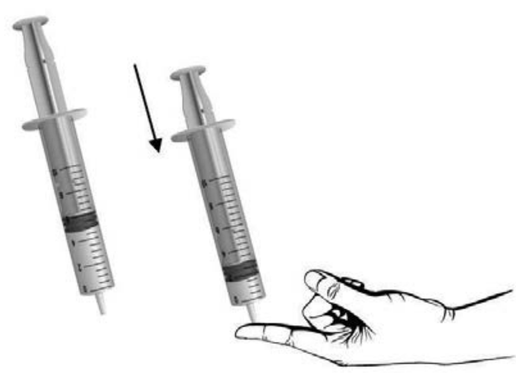
Think about what happens when you compress a sponge with your hand. Then think about opening your hand. The sponge will expand and open back up into its original shape. Sponges are not the only things that can compress and expand. In this reading, you will learn how air can compress and expand, a little like a sponge.

What Happens to Air When I Push a Syringe of Air?

In Lesson 2 you learned that air takes up space. When you compress air, you squeeze the air into a smaller space. Imagine you took all of the air that normally fills your closet and squeezed it into a container that can sit on your desk. To make air fit into a smaller volume, you compress the air. Scuba tanks have compressed air in them. In fact, the air in a closet could be compressed so that it fits into a small tank for scuba divers to carry on their backs.

Squeezing or compressing air may sound strange. It is hard to grab a handful of air like you grab a sponge or a handful of sponges. In class you saw that you can compress air. First you pulled the handle of a syringe to fill the syringe with air. Then, you placed one finger on the opening of the syringe so that the air could not come out. Finally, you pushed the handle of the syringe.

It was impossible to push the syringe in all the way. When you pushed the handle of the syringe, you were pressing all of the air into a tiny space. You were compressing the air. Air compressed when it could not go anywhere else. You might have noticed that it was difficult to keep your finger on the opening of the syringe when you pushed on the handle. Keeping a finger on the opening was very important. You were not



When you push the syringe handle, you are pressing the air in the syringe, making the air compress (squeeze into a smaller volume).

allowing any air to escape. Even though no air left the syringe, you were able to still push the handle.

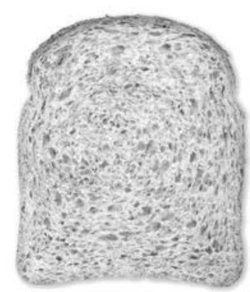
When you push the syringe handle, you are pressing the air in the syringe, making the air compress (squeeze into a smaller volume).

Is Compression Related to What I Know about Pressure?

Look at all of the forms of the word *compress* in this section. Words like *compress*, *compression*, and *compressing* all contain the word *press*. That may help you remember what compression is. Compression is related to the way you already might use the word *press* outside of science. You probably also have some ideas about pressure. As you pressed the syringe handle down, you felt pressure in two places. You felt a push on the finger that was blocking the hole. You also felt a push on the finger that was pushing the plunger down. This push is called *pressure*. Pressure is caused by millions and millions of particles hitting against a surface. When you pushed the plunger down, many more particles were hitting against the surfaces because they had been pushed into a smaller space. The increased number of particles caused the increased pressure.

Another way to increase pressure is to add more particles to a container. This makes sense because more particles hit against the sides. When you pumped more air into the ball in class, you increased the pressure inside the ball. You might already know that you can measure the pressure inside a ball or a bike tire with something called a *pressure gauge*. It measures the pressure caused by the number of particles hitting in a certain spot.

What Could Air Be Made of if I Can Compress It?



Think of some other things that you can compress. You can compress foam balls, sponges, and bread so they have less volume. You can compress these objects because there are small spaces in them. You can see small holes in bread. When you squeeze it, the material that makes up the bread comes together and there are fewer spaces between the bread. Squeezing bread can be a model of compression. Bread can be compressed because of the small spaces inside and through it.

Squeezing a sponge can also be a model of compression. Tiny spaces allow sponges to be compressed. You have seen that you can compress things that have spaces in the material, like bread and sponges.

Do you think there are spaces in the material that makes up air? Explain your ideas.

What Happens to Air When I Pull on a Syringe?

You used a syringe to show something else that air does. First you pushed the handle and observed that air can be compressed. Then you tried to pull the handle of the syringe when your finger blocked the opening. You realized that you could only pull the handle out part of the way. As you pulled the syringe handle, you observed that air can also expand. Expanding is the opposite of compressing. When something expands, its volume increases. You have learned that volume is the space a material occupies. When you pulled the syringe handle, you made a larger space for the air to occupy. The air then expanded to fill that extra space.

When the space inside your lungs increases as you breathe in, more air can move into your lungs. When you pulled the handle of the syringe, you made more space. Your finger was on the opening and did not allow more air to go in. Instead, the air already in the syringe expanded and spread out into a larger volume.

When you pull the syringe handle, you are increasing the volume of the syringe. The air then expands (spreads out into a larger volume).

What Happens to Air When You Push More Air into a Container?

You might already know that compressing air (making the volume of air smaller) is not the only way to squeeze air. You can also squeeze air when you add more air into a container that is already full of air. Have you ever played with a water blaster or seen one advertised on television? Water blasters are plastic guns that shoot water. For fun, people can soak each other with water on a hot day. A stream of water comes out only if you pump in air.

When you first begin pumping air into the gun, it is easy, and you can pump the air pretty fast. After a short time, it becomes harder and harder to pump more air into it. Why is that?

As you pump, you compress the air that is already in the container, and you add more air. The more air you pump into the container, the more that the air inside the container gets compressed. When you pump more and more air into a small container, you are demonstrating that air can be added.

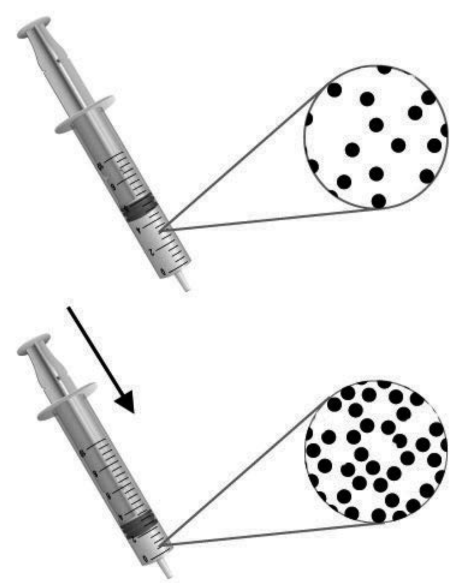
Is a Sponge a Good Model of Air?

It is helpful to use a sponge as a model of compression and expansion. You know that the sponge can compress because of all the small spaces in it. You might guess that air also compresses because of small spaces within air. However, one single sponge does not show everything that air does. For example, you read what happens to air when you add or subtract it from a container.

You also saw in class how air can be added to or taken away from a container. These are characteristics of air that a sponge cannot model. So even though a sponge is a good model of compression and expansion, a sponge is not a good model of air.

How Does the Pieces Model Help You Explain Expansion and Compression?

Look at the diagram of pushing a syringe, featured earlier in the lesson. If you looked at air using a special instrument, the big circle shows what you might see. If air is made of tiny pieces, then there can be spaces between the pieces. These tiny pieces of air are particles. When you pushed the syringe, the air compressed. The second drawing shows that when the air compressed, the particles moved closer together. Because the same number of particles squeezed into a smaller space, the pressure on your finger increased. You felt this as a push back against your finger.



When you compress air, the space between the particles gets smaller.

The opposite happened to the particles when you pulled on the syringe handle. As you pulled the syringe handle back, you created more space for the air to move into. The air particles spread out to take up the extra space. Because the same number of particles spread out in a larger space, the pressure decreased. This model of air as pieces or particles is called the *particle model*.

Can the Particle Model Represent Odors in Air?

You already know that when you smell something, it is because an odor is in the air. You have learned that odors have to be in the gaseous phase for humans to smell them. So you could use the particle model to explain odors in air. For example, when you smell an orange, you are smelling particles that started in the orange but then changed into a gas and moved into the air.

You might have other questions about air and odors being made of small pieces called particles. For example, you might wonder what the difference is between air particles and odor particles. You might wonder whether materials in other states of matter are made of particles. What questions do you have now?

Activity 5.3—Developing and Using a Consensus Model

What Will We Do?

We will develop a consensus model and use it to explain the behavior of gases when they are not in the syringe.

Activity 6.1—Comparing Two Clear Liquids

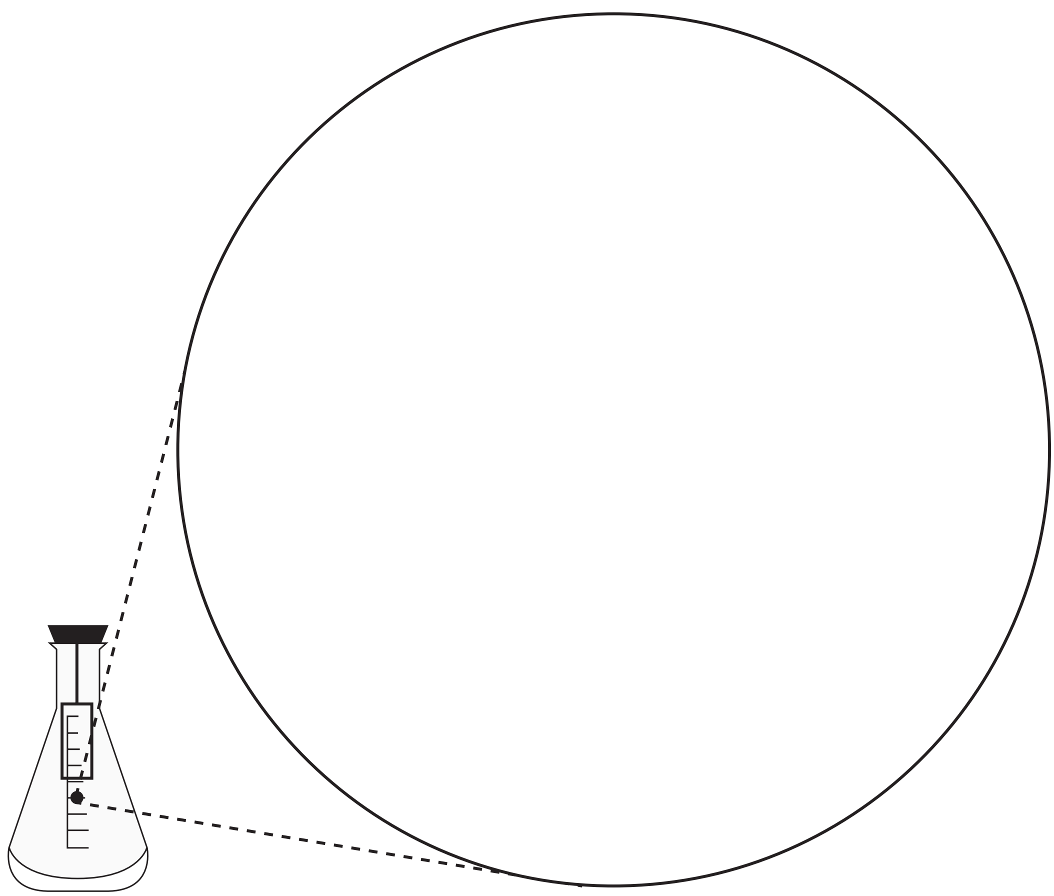
What Will We Do?

We will create a model that helps explain how paper changes color even though it does not touch the substance it is detecting.

Procedure

Imagine you have a special instrument that allows you to see up close the area between the liquid ammonia and the indicator paper. The large circle represents a magnified area inside the flask. In the circle, create a model of what you could see between the ammonia and the indicator paper.

Make a key that tells what the symbols in your model represent.



Making Sense

1. Imagine a friend is looking at your model. Describe how your model can be used to explain what happened in this activity.

2. What is your model unable to show?

3. What makes the paper change color? (Hint: Think about phase changes.)

Lesson 6 Reading One—In What Ways Do People Use Detectors?

Getting Ready

Today you used a special kind of paper to test two liquids. When the paper changed color, it meant that something had happened. The paper could be called a *detector* because it detected a change. List some other types of detectors that you have heard of or that you know about.

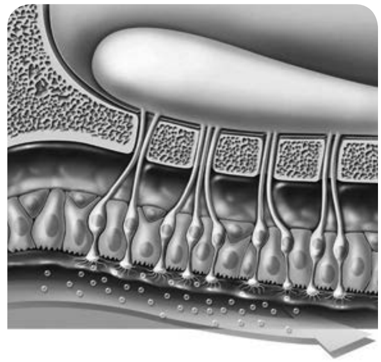
Detector	How Does It Work?

How Does Your Nose Work as a Detector?

Imagine breathing in and smelling brownies in the oven. How did you detect the odor? Now that your model represents air and odors as particles, you can use your model to help you explain how people smell odors.

As you breathe in through your nose, you force particles in the air to move through your nostrils. They go past the nasal cavity. You can see the nasal cavity in the diagram. It is the shaded part beneath the brain and behind the nose. The nasal cavity is where humans detect odors.

In the nasal cavity, odor particles match with receptors. Receptors are like the part of a lock into which a key fits. Specific odor particles fit into a specific receptor like a key fits into only a certain lock. When an odor particle matches with a receptor, a signal goes to the brain and tells it that a certain odor is in the air.



Why Do I Only Sometimes Smell Odors?

One reason why your nose may not detect every odor is because there may not be enough of the specific particles in the air. Another reason is that human noses can only detect certain types of particles. The particles of some materials match with receptors in your nose, but particles of other materials do not match any receptors. You may have guessed that odors that do not match with receptors in your nose are called *odorless*.

In Lesson 1, you learned that natural gas, by itself, is odorless. It is made of particles that your nose cannot detect. A material with particles your nose can detect is added to help you recognize when natural gas is in the air. The particles that make up the rotten egg odor fit with receptors in your nasal cavity. Those receptors send a signal to your brain that you smell rotten eggs in the air.

Are There Other Odorless Materials?

Another type of odorless gas is carbon monoxide. When cars are turned on, the burning gasoline produces carbon monoxide. Furnaces in your house also make carbon monoxide. Carbon monoxide does not explode like natural gas can, but it is very dangerous in another way.

You already know that people need oxygen to live and that you get oxygen by breathing in air. Usually when you breathe in air, the blood in your body carries the oxygen particles to all areas in your body. When carbon monoxide is in the air, your blood takes the carbon monoxide particles instead of the oxygen particles. Some parts of your body will not get the oxygen they need to keep working. At first, the lack of oxygen might make you feel faint. After awhile, it can kill you. Cars come with books that tell about the dangers of carbon monoxide. The warning you see here is from one of them.

Danger in Real Life

Sometimes people forget to turn cars off in their garages, and the carbon monoxide can build up in the air and move (like odors) into the house. Other times people's furnaces do not work properly, and carbon monoxide can move through the house. Next you will read information that tells about people who were exposed to carbon monoxide because their furnaces were not working properly. As you read, think about these questions.

1. How do carbon monoxide particles travel in the air?
2. Why can't your nose detect carbon monoxide in your house?

One newspaper reported the story of a family that could have died because of carbon monoxide poisoning. The three children had flu symptoms for two days. When they continued to vomit and feel nauseated, the family went to the hospital. Doctors diagnosed the problem as carbon monoxide poisoning. Everyone in the family had to take in fresh oxygen for several hours. As you have learned, their blood was missing the oxygen that all cells of their body needed.

Some amount of carbon monoxide in the air is safe. The safe level is 39 parts per million. When investigators went to the family's home, they found a furnace that needed repair. The carbon monoxide level in the home was 180 parts per million. After the furnace had been repaired, their home was safe again. People use appliances that emit carbon monoxide all the time. As long as ventilation is good and appliances are working properly, this is not a danger. In the winter, when doors and windows are kept closed, the danger can increase.

Symptoms of carbon monoxide poisoning include headaches, shortness of breath, lightheadedness, nausea, and vomiting. As you might know, some of these are also symptoms of flu or food poisoning. There is a way to be alerted when the problem is not just bacteria or virus.

Many stores sell carbon monoxide detectors. They work like smoke alarms. The alarms let out a loud noise when they detect levels of carbon monoxide in the air that are dangerous. They are made to detect a colorless, odorless gas that people cannot detect with their eyes or their nose.

How Important Are Detectors?

It is very important for people to be able to tell when carbon monoxide is present. When a dangerous gas is odorless, then people cannot rely on their nose to warn them. People need other ways to detect odorless gases. For example, carbon monoxide can be present as coal miners dig deep underground. In the past, miners would use small birds called canaries to help them. Canaries are colorful, and they are easy to see in dark areas like mines. Canaries chirp and sing a lot. They are small and have tiny lungs, so canaries are affected by carbon monoxide much sooner than people are. The miners used the canaries as detectors. When the canaries stopped chirping, the miners knew that there was too much carbon monoxide in the air. The miners then left the mine.

Think of another way that people can detect carbon monoxide is in the air. Write your idea in the space below.

The question at the beginning of today's reading is, "In what ways do people use detectors?" Why is it important to understand particles in order to invent detectors?

Activity 6.2—How Does the Odor Get to My Nose?

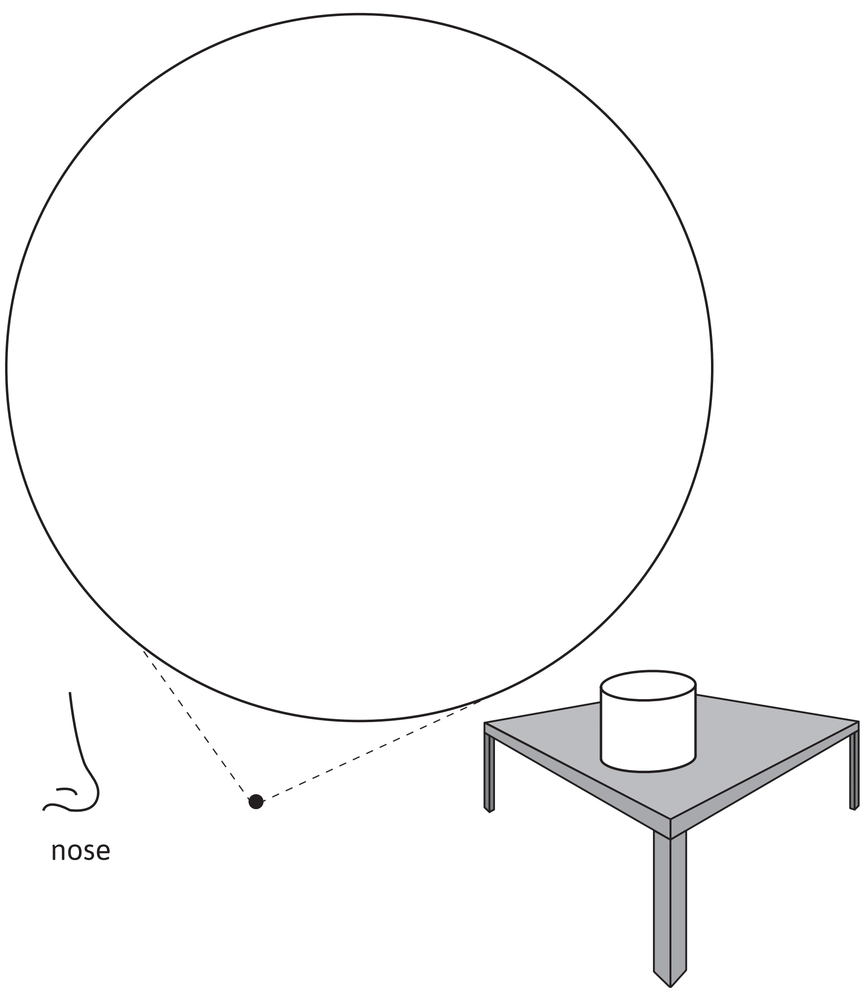
What Will We Do?

We will revise our models from Lesson 1 to explain more about how an odor moves from a source to our noses.

Procedure

Imagine that you have a special instrument that allows you to see what makes up odor. The large circle in the drawing represents a spot that is magnified many times, so you can see it up close. Create a model of what you would see if you could focus on one tiny spot in the area between the jar and your nose.

Make a key that tells what the symbols in your model represent.



Making Sense

1. Imagine that a friend was looking at your model. Use your model to explain how an odor can be smelled from across the room.

2. What is your model unable to show?

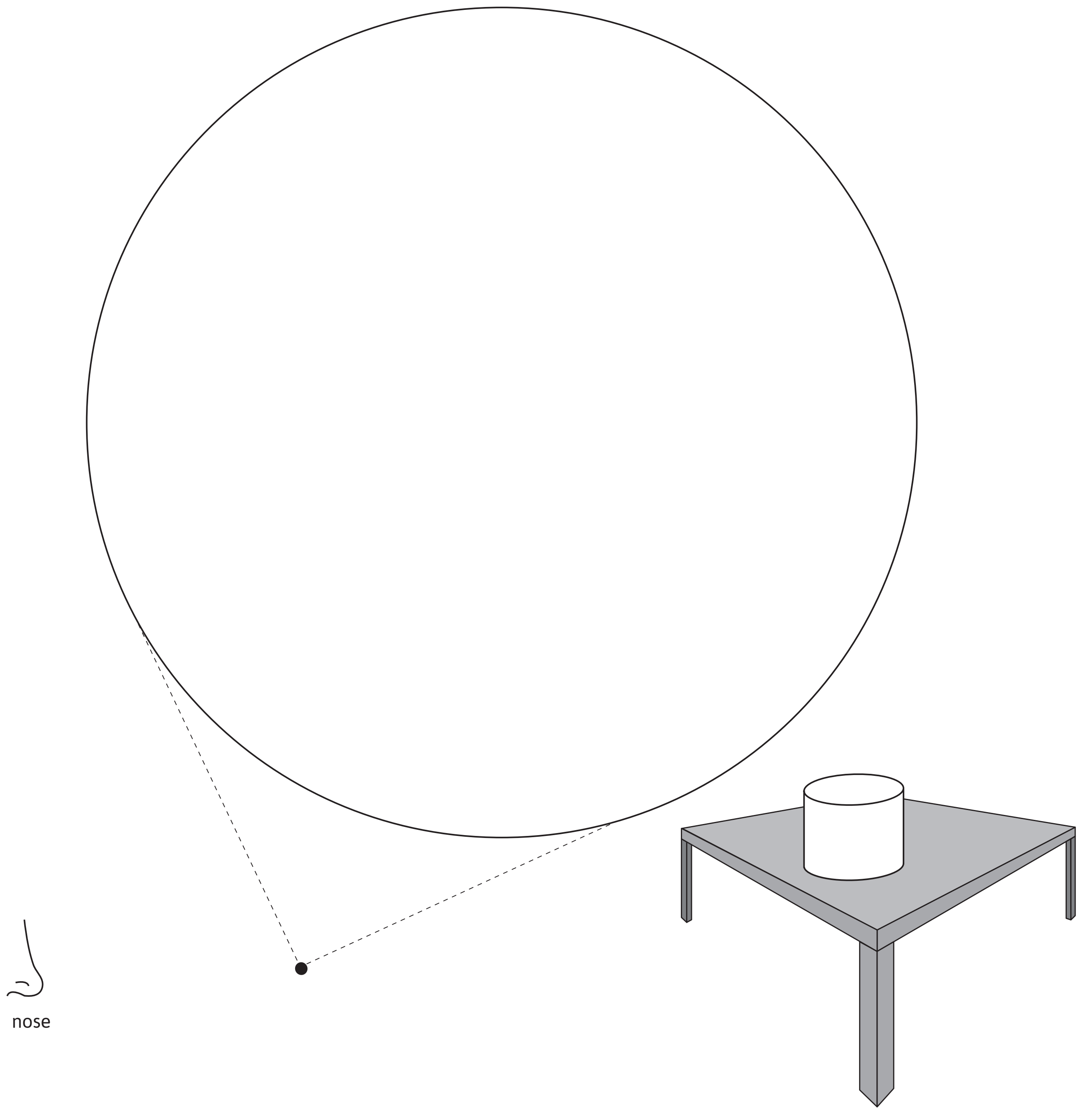
3. How is this model different from the first model you created in Lesson 1?

4. What new ideas have you included in this model?

Make a key that tells what the symbols in your model represent.

A consensus model of how smell travels should include

- air particles
- odor particles
- empty space between the particles
- particles in motion



Lesson 6 Reading Two—Are All Types of Matter Made of Particles?

Getting Ready

Your nose can only detect things in the gaseous state, so think about this: How can you smell a liquid cup of coffee or solid pieces of popcorn? After this reading, you will use what you know about particles to describe how you can smell liquids and solids.

What Are Liquids and Solids Made Of?

You have learned that air is matter in the gaseous state. Air is made of particles. You also know that all matter can be observed in one of three states—as a solid, a liquid, or a gas. In fact, all matter—solid, liquid, or gas—is made of particles. Your skin, your blood, and the air you breathe out are made of particles. The odor on your breath, whether it smells like garlic, peppermint, or chocolate chip cookies, is filled with odor particles. The plants outside the window, the chair you are sitting on—everything is made of particles. You might have learned that all plants and animals are made of cells. That is true, but cells are made of particles, too.

Moving between States of Matter

The liquid coffee that people drink is made of particles. Before you can smell coffee, some of the particles have to change from the liquid to the gaseous state. Not all of the particles in a cup of coffee go into the air. Some stay in the liquid state, and others go into the air in a gaseous state. You may not have thought about this yet, but you can actually observe some materials in more than one state of matter at the same time.

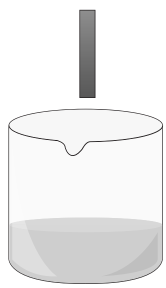
An example is gasoline. When you go to a gas station you might see liquid gasoline on the ground. Liquid gasoline also moves from the pump into the gas tank. At the same time, you can smell a gasoline odor. You smell it because some of the particles that make up gasoline go into the air.

Using Detectors besides Your Nose

Scientists and engineers have invented many tools to detect the presence of certain materials. Those materials can be in solid, liquid, or gaseous states. In class you used one type of detector called indicator paper. You used indicator paper to detect materials in liquid and gaseous states. First, your teacher dipped indicator paper into a clear liquid called acetic acid. When the indicator paper touched the liquid, its color changed from orange to red. Then your teacher held another indicator paper in the air, over the liquid acetic acid. The indicator paper did not touch the liquid, but it still changed color from orange to red. The paper did not have to touch the liquid to change color. The indicator paper showed that the same type of particles that made up the acetic acid were also in the air. Some acetic acid particles were in a liquid state at the same time that other acetic acid particles were in the gaseous state. The fact that the paper changed color is evidence that the particles were moving. Some of the particles needed to move in the air between the surface of the liquid and the paper. If the particles had not done that, there would be no acetic acid particles in the air to make the paper change color.

Detecting Different Liquids

In class your teacher also used indicator paper to test two clear liquids. Each liquid looked the same. If you smelled the air around the liquids, you noticed that their odors were different. Whether



The indicator paper changing color in the air is evidence that the particles in the gas state moved in the air around the paper.

you could smell them or not, the indicator paper provided evidence that the liquids were different.

Indicator paper changes to a specific color when certain types of particles touch it. The same piece of indicator paper turns blue when dipped in ammonia, and red when dipped in acetic acid. The fact that the same paper turned a different color in each liquid was evidence that the liquids were made of different particles. Indicator papers are one way to measure whether materials are the same or different.

Do you know an adult who drinks coffee, tea, soda pop, or another beverage? Think about that person and picture them in your mind. Write a description to help that person understand how they can smell their favorite beverage even though it is a liquid.

Activity 7.1—
Gases All Look the Same to Me

What Will We Do?

We will look at visual representations of what gases would look like if we had the instruments to look at them up close.

Procedure

☐ a. Write the name of each gas you are viewing in the column on the left.

☐ b. As you look at each gas, put an X in the column of each color you see. Make a small x if you see a "skinny" band of that color. Make a large X if you see a wider band of that color.

Type of Gas	Red	Orange	Yellow	Green	Blue	Violet

Making Sense

What did you learn about gases when you saw their emission spectra?

Lesson 7 Reading One—How Can I Tell Whether Things that Look the Same Really Are the Same?

Getting Ready

Imagine that you are holding two glasses of soda pop. In one hand, you have a glass of regular soda pop, and in the other hand, you have a glass of diet soda pop. How can you tell which one is which? Write a few words to describe how each one might look, taste, and feel. You can describe any flavor of soda pop.

Regular Soda Pop	Diet Soda Pop

Look at the words you wrote to describe the drinks. Did you write any of the same words on both lists? For example, maybe you wrote *liquid* or *cold* on both lists. Maybe you wrote the same color on both lists. Those words describe each drink, but they will not help you tell the two drinks apart. Did you write any words that describe differences? For example, did you write anything about the taste? Some ways of describing are better than others when you need to tell materials apart.

Today's reading is about describing materials. Describing carefully is important to scientists. As you read, think about

- how scientists describe materials.
- why scientists describe materials.
- when being able to describe materials is important outside of science class.

How Do I Know Whether Things that Look the Same Really Are the Same?

Have you ever tasted something that turned out to be different from what you expected? For example, if you thought you were going to eat salty popcorn but someone gave you sweetened kettle corn, the taste would be a big surprise. Salted popcorn and sweetened kettle corn look alike, but their taste is very different. Another example is milk. If you like skim milk but someone gives you whole milk, you can taste the difference. Maybe you have tasted iced tea without sugar when you were expecting it to be sweetened.

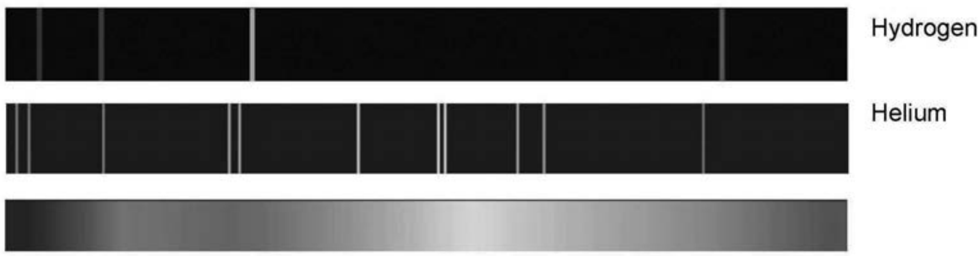
Can you think of an example of when you thought you knew what a food would taste like but you were wrong? If you can think of an example, write it here.

When you look at these drinks side by side, they look alike. You cannot tell if they are alike or different unless you do something to test them. Sometimes you have to taste foods to know what they are. Scientists also need to do something to learn more about a material. They would not taste unknown materials, but they could test materials in other ways.

Testing Whether Materials that Look the Same Really Are the Same

In class, you observed the emission spectra of gases by seeing pictures of what they would look like if a tube of each gas was connected to a power supply. You noticed that the number, color, and width of the bars of color that would be seen through C-spectra film were different for each gas. You could say that the pattern of light for each gas was different.

The following picture shows what you would see if you looked at hydrogen and helium gases. Alongside the gases is a full spectrum of light, which has all the colors. Notice that each band from the gases matches to a color on the light spectra. Also notice that the pattern of light from hydrogen is different from the pattern of helium gas.



The pattern for each gas could be thought of as a fingerprint. Every person has a unique fingerprint, and every gas has a unique print too. The number, color, and width of each bar is unique to each gas. You can tell what an unknown gas is if you know its color pattern. You can tell one gas from another like fingerprints tell one person from another.

Before learning about the gases, if you saw them in sealed tubes you might think they were all the same. All of them are clear and colorless. The emission spectra of each gas was evidence that they were different. The tests gave information so that you could

- describe each gas.
- tell whether the gases were the same or different.

Why Is Describing Important?

When people want to make something, the characteristics of the materials they use are important. For example, think about a pencil. The end that you write with is made of graphite. Graphite is good for pencils because of its characteristics. Graphite is a black solid that is very soft. When you press graphite against paper, it leaves a dark mark. For pencils, the hardness, color, and texture of the part that writes are important. These characteristics of materials are called *properties*.

What Makes Something a Property?

Think about how you have heard the word *property* in your everyday life. What meanings do you know for property? People sometimes use property to mean a piece of land. Anything people own could also be called their property. Your shoes are your property and so is your backpack. You can also think about property another way. Instead of thinking about property as something you own, think of property as something that is a part of you. Think about a property as a characteristic that describes you. The color of your eyes or the shade of your skin is a characteristic of you. Other people might have the same color eyes or shade of skin that you do, but your eye and skin color, plus other characteristics, make you unique. A property of a material is like that. Every material has properties you can use to describe it. Graphite is used in pencils because of its soft texture and dark color.

One property you observed in class is color. Every material has a color that is the same no matter what size sample you take of that material. For example, the color of each gas, if you had seen a tube full of each gas, would be the same. The gases would all appear clear and colorless. If you did an investigation with these gases in a week, each gas would still look clear. If you used a large or small sample of each gas, each sample would still be clear. You observed the pattern of light bands for each gas. The pattern for each gas, if you tested it the same way, would also be the same another day as it was today. Properties are characteristics of a material that stay the same for any size sample you use in class.

Do you think odor is a property? Explain your ideas.

Lesson 7 Reading Two—Detectors Work because of Properties

Getting Ready

On the first day of this unit, you talked about your nose as a detector for odors. In another lesson, you learned about detecting carbon monoxide in the air. In Lesson 5, you used indicator paper as a detector to show two things:

- whether particles of ammonia or acetic acid were in the air.
- which container held ammonia and which held acetic acid.

One material turned the indicator paper blue, and the other material turned it red. The indicator paper detected two different materials. Scientists developed indicator paper based on properties of materials. All detectors are made based on the properties of materials. The following ideas were taken from a website about health. Read about a detector that shows you when you are getting sick or that shows why you might have headaches.

You will see some words that you do not know in this article. When you focus on what you want to learn, sometimes you do not need to know every single word to understand the important ideas. Read the article and try to learn the answers to these three questions.

1. What does the device detect?
2. How does the device detect?
3. What is a “smell print”?

Electronic "Nose" Can Detect Pneumonia

How do researchers use the idea that different types of particles make up air? A device the size of a TV remote control can detect some infections by analyzing the particles in a patient's breath. The device is known as the *electronic nose*. It is also called an *e-nose*. Does this sound like a science fiction story? Although it is not approved for medical use, the e-nose is already used by food and beverage companies to determine if food is spoiled. Soon doctors could make use of the e-nose to detect some types of diseases.

The e-nose is a fast, cheap, and easy way to detect pneumonia in patients. To use the e-nose, a patient exhales into an oxygen mask connected to it. The e-nose can detect certain molecules in the patient's breath. Bacteria colonies are made of particular types of molecules. They also have characteristic odors, so they have a "smell print" similar to a fingerprint. To be useful, the e-nose needs to be sensitive to differences between harmless and harmful bacteria. It also needs to detect different types of illnesses. For example, doctors can find it challenging to detect sinus infections. A sinus infection and pneumonia have different smell prints because they are made up of different molecules. The e-nose could eventually help doctors to diagnose these and other diseases based on what scientists know about molecules.

Suppose that a new student moved to your school and started in your science class today. The new student has not learned yet what properties are and why they are important in science.

Write a summary of what you think are the most important things a new student should know about properties in order to catch up with your class.

When you ride across a bridge, you probably care whether it is made of aluminum or a stronger metal. Properties of materials matter in many ways—to scientists and to other people.

Activity 8.1—Investigating Elements

What Will We Do?

We will observe, describe, and do some tests with a group of substances called *elements*.

> **!** **SAFETY GUIDELINES**
>
> The edges of the strips of metal can be sharp. Handle them carefully.

Procedure

☐ a. On the next page, record the name of each element your teacher gives you. Also write its chemical symbol.

1. Describe the state of matter.
2. Describe the color of each element.
3. Perform a scratch test. Try to make a small scratch on each strip using the edge of one of the other strips. If a strip of one element scratches another strip, then the first one is harder than the one it scratches. Record your results in the hardness column.

☐ b. Your teacher will do a test on some of the elements to measure a property called malleability.

Record the results.

Element	Symbol	State of Matter	Properties		
			Color	Hardness	Malleability
				Scratches: Is scratched by:	
				Scratches: Is scratched by:	
				Scratches: Is scratched by:	
				Scratches: Is scratched by:	
				Scratches: Is scratched by:	

Making Sense

1. What do you notice about these elements and their properties?

2. How do you know which of the metals is the most hard and which is the least hard?

3. Number the metals in order from the least hard (1) to the hardest (5).

4. Identify two elements that are different from each other. Use data from your investigation to explain how you know that they are different.

Activity 8.2—What Are Elements Made Up Of?

Your teacher will provide instructions for this page.

Activity 8.3—Elements and Atoms

Your teacher will provide instructions for this page.

Lesson 8 Reading One—Why Is the Periodic Table of the Elements Important?

Getting Ready

Imagine that you need to go shopping for bread, milk, and ice cream. Would you find all of these items in the same aisle of the grocery store? You already know that items in a store are organized based on certain characteristics. Different kinds of bread are all in the same aisle. However, ice cream, milk, and bread are in different aisles for important reasons. Ice cream needs to stay frozen. Milk needs to stay cold but not frozen. Bread needs to stay at room temperature. Food in a grocery store is arranged in a way that works for the characteristics of the items. When you go to the store, you can find what you need because you understand how things are arranged.

Scientists also organize things in ways that are useful to them. Today, you will read about one way that chemists organize elements like the ones you have been studying.

What Is the Periodic Table of the Elements?

In 1869 Dmitri Mendeleev, a chemist, created the first periodic table as a way to organize all 61 elements known at that time. The periodic table of the elements is a way that scientists organize elements according to important characteristics. The modern periodic table has more than 100 elements. In fact, new elements are still being discovered.

The Periodic Table of the Elements

- alkali metals
- alkaline metals
- other metals
- transition metals
- lanthanoids
- actinoids
- metalloids
- nonmetals
- halogens
- noble gases
- unknown elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfer	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cæsium	56 Ba Barium	71 Lu Lutetium	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium	103 Lr Lawrencium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadium	111 Rg Roentgenium	112 Cn Copernicium	113 Uut Ununtrium	114 Uuq Ununquadium	115 Uup Ununpentium	116 Uuh Ununhexium	117 Uus Ununseptium	118 Uuo Ununoctium

57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium
89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	02 No Nobelium

Exploring the Periodic Table of the Elements

Read the names of the elements in the periodic table. Draw a circle around elements you have heard of.

What do you notice about the elements you have heard of? Do you see any patterns?

What Is Important about Elements?

In class you have been examining elements. You have learned that each element is made up of only one type of atom. Gold is made of only gold atoms. Hydrogen is made of only hydrogen atoms. Also, you have tested a few elements to learn about properties such as hardness and malleability. In the periodic table, each element is listed by its name and its chemical symbol. Look closely at the top row. On the left, you can see hydrogen and its chemical symbol (H). Hydrogen is a nonmetal. You also know that it is a gas at room temperature and that it is colorless. Depending on why you are studying an element or what you want to use it for, different properties and characteristics are more important than others.

What Elements Do I Know?

You have already studied the element oxygen and used a capital O when you wrote about it in class. O makes sense for oxygen, but not all chemical symbols are so obvious. Below is a list of a few elements that can be used to make jewelry. Find each one in the periodic table and write its chemical symbol.

Element	Symbol
Gold	
Nickel	
Silver	
Platinum	

As you can see, the symbol does not always match the name of the element. This is because when the period table of the elements was created, Latin was the language scientists used. The Latin name for iron is *ferrum*. Iron's chemical symbol is Fe. Elements that were named long ago still keep their Latin symbols.

What Characteristics Are Used to Arrange the Elements?

Elements with the same properties are listed in columns, called *groups* or *families*. Argon (Ar) and xenon (Xe) are in the same family with neon (Ne) and helium (He). These elements are all gases at room temperature, which you know from looking at the emission spectra photographs.

You will learn more about the arrangement of elements in high school. For now, it is important to realize that the elements are arranged according to properties related to the mass of their atoms. They repeat according to a periodic trend, which is how the table got its name. Chemists still use this table for classifying, comparing, and organizing elements. As a science student, you might use it mostly to help you learn elements and their chemical symbols, or to begin to look for patterns across the elements you are studying in class. The Periodic Table of the Elements is an important tool for chemists who use and study different materials.

Lesson 8 Reading Two—What Makes Elements Different from One Another?

Getting Ready

Imagine that this box represents a small block of gold. How many gold atoms do you think are in a block of gold the size of this box?

I think there would be ______________ atoms in a block of gold this size. In this reading, you will find out how small atoms are. You will also learn how knowing about atoms can help you explain why elements are different from each other.

What Makes Silver Different from Sulfur?

You have learned that all materials are matter, and all matter is made of particles. Scientists call those particles *atoms*. You learned that the materials you observed in class were made of different types of atoms. Gold is made of gold atoms. Silver is made of silver atoms. Sulfur is made of sulfur atoms. Different materials are different because they are made of different types of atoms.

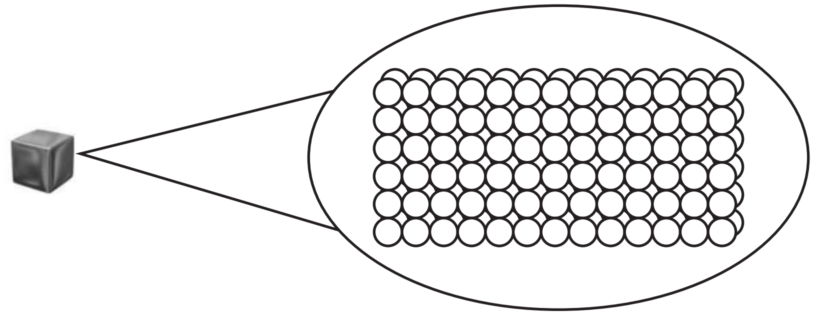
When Is Something an Element?

Everything is made of atoms. In class you learned that some materials are made of only one type of atom all the way through. When a material is made of only one type of atom, scientists call it an *element*. A sample of pure gold is an element because it is made of only gold atoms. The oxygen gas that you breathein the air is an element because it is made of only oxygen atoms. Elements are also special because each one has the same name as the atoms it is made of. Iron is made of only iron atoms. The same is true for all the elements. This block of gold would be made of only gold atoms. Each circle you see represents gold atoms. Now you know that each one of these circles would be filled with billions of gold atoms. This is one way to represent atoms, but it is not a perfect way.

How Big Is an Atom?

Atoms are smaller than you can imagine. If you packed atoms into a piece of gold, you could pack in about 1,077 sextillion atoms—1,077,000,000,000,000,000,000. It would take you your whole life to count to 1,077 sextillion. It would take a long time and a lot of pieces of paper to draw a model to show that many atoms.

This diagram is one way to represent the atoms that make up the block of gold. When you see a diagram like this, you need to imagine that you could magnify a tiny spot 100 million times. This diagram shows only a few of the 1,077 sextillion atoms that make up the whole block. How close was your guess at the beginning of this reading?



Can I Ever See an Atom?

Atoms are too small for a human's eye to detect. Atoms are too small to see even with a microscope like the ones you use in class. The following diagrams can help you think about the size of an atom. You can see an insect, like a wasp or an ant, with your eye. When you can see something without any help, people sometimes refer to that as the naked eye. If you wanted to see an insect more closely, you could use a magnifying glass. If you wanted to see it even more closely, you could look at the insect's wing using a regular (light) microscope. You could also look at a piece of your own hair with your eyes. You could examine it even more closely if you used a light microscope. A cell is something you cannot see with your eyes or with a magnifying glass. You can only see cells with a light microscope. You can also only see bacteria with a light microscope.

Naked Eye

Regular (Light) Microscope

Electron Microscope

However, a light microscope will not help you see things that are even smaller. Viruses and atoms are much smaller than cells or bacteria. They are too small to see with the naked eye, with a magnifying glass, or with a light microscope. Viruses and atoms are so small that scientists need to use a special type of instrument to detect them. These are called *electron microscopes*.

Sometimes people think that atoms are the same size as bacteria or cells, but atoms are much, much smaller. In fact, bacteria and cells are made up of billions and billions of atoms. Think about this: People are made of cells. Cells are made of atoms. If a small block of gold has about 1,077 sextillion atoms, then the number of atoms you are made of is too big to imagine.

Check your understanding about elements and atoms by circling the correct answer below.

Gold is an element because

A. it has 1,077 sextillion atoms in a small block.

B. it is a metal.

C. it is made up of only gold atoms.

Activity 9.1–Comparing Models in Two- and Three-Dimensions

What Will We Do?

We will use gumdrops to model some of the molecules that make up air—nitrogen, oxygen, carbon dioxide, and water.

SAFETY GUIDELINES

! Never taste any object in the science lab. Even if the substance is familiar and edible, do not attempt to taste it because the science equipment and surfaces it has touched may be contaminated.

Procedure

☐ a. Color the circles in the key to represent the colors of gumdrops you will use to represent each type of atom.

☐ b. Each member of your group should create a gumdrop model of one of following molecules: oxygen, nitrogen, carbon dioxide, or water.

☐ c. After class discussion, answer: Air is made up of what percentage of each type of molecule?

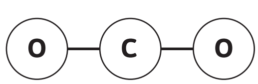
Key

O = oxygen atom

N = nitrogen atom

C = carbon atom

H = hydrogen atom



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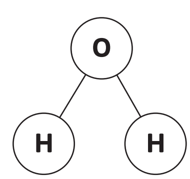

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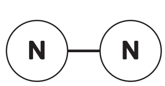

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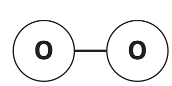

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Making Sense

1. Join with another group. How would you use your individual molecules to create a model of air?

2. What are the limitations of your model?

3. How would you revise your model to show that odor is also a component of air?

Lesson 9 Reading One—What Kinds of Particles Do I Breathe, and What Are They Made Of?

Getting Ready

When you breathe in air, what is going into your lungs? You probably know that your body takes in oxygen by breathing in air. What else do you breathe in? What do you breathe out? Make two lists in the chart below.

When I breathe in air, I am breathing in . . .		When I breathe out, I am breathing out . . .	

As you read, you will learn more about what particles are part of the air you breathe in and out. You will also learn what types of atoms make up these particles.

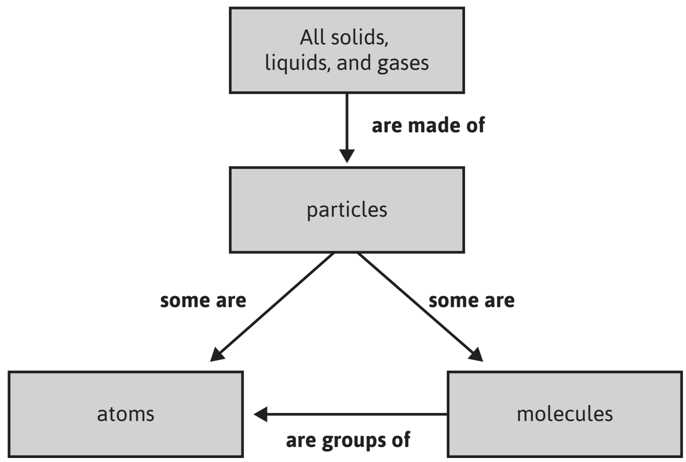
What Kinds of Particles Are in the Air You Breathe In?

You have been thinking a lot about odors and air. If odors are part of the air, then you must breathe them in when you take a breath. Odors could be on your "breathe in" list. You could also put odors on your "breathe out" list. For example, think about bad breath. Bad breath is what you smell when someone breathes out odor particles.

In Lesson 3 you observed water going into the air as it changed from a liquid to a gaseous state. Water particles from lakes and puddles also go into the air. When you breathe in air, you must also breathe in water particles, but air is only made of a small amount of water. Most of the air is made up of nitrogen. When you breathe out onto a cold window or on a mirror, you see the window fog up. It fogs up because what you breathe out has water in it. All animals breathe out carbon dioxide, so carbon dioxide is part of the air. You may have listed other particles that are part of the air, too.

What Are the Particles in Air Made Of?

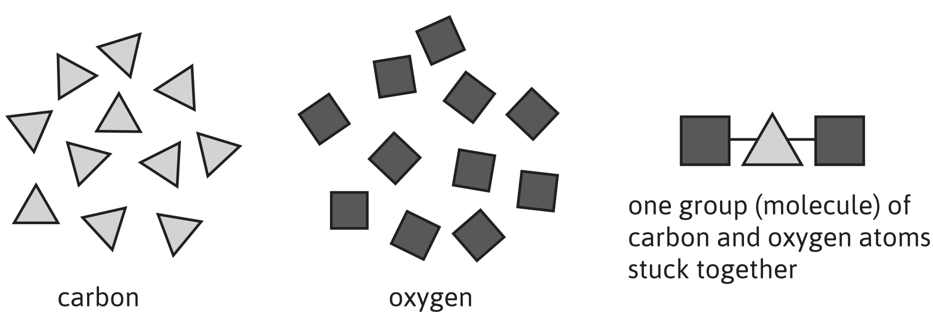
You also could have written on your list that you breathe atoms and molecules. Some of the particles in air are single atoms. Atoms of argon make up a small fraction of air. Other particles that are part of the air are groups of atoms joined together. These particles are called molecules. Molecules are made of two (or more) atoms joined together. The atoms in a molecule stay together when the material changes states. Molecules do not come apart during phase changes. The following diagram is another way to show how matter, particles, atoms, and molecules are related. If you follow one of the arrows, from one box to the next, you will come up with the following ideas:



- All solids, liquids, and gases are made of particles.
- Some particles are single atoms.
- Other particles are molecules.
- Molecules are groups of atoms.

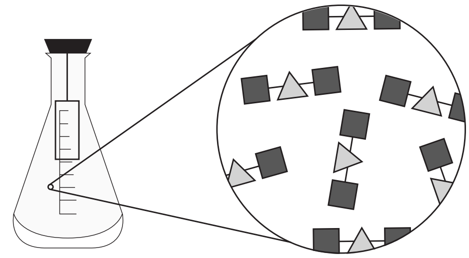
What Do the Particles I Breathe In and Out Look Like?

You breathe molecules in, and you breathe them out. In the last lesson, you learned that oxygen is an element. That means it is made up of only of oxygen atoms. The other materials that make up air are not elements. They are made of different types of atoms. Carbon dioxide is one material that is made of two different types of atoms—carbon atoms and oxygen atoms.



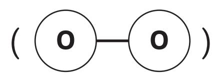
You cannot see molecules of any kind. Models can help you think about how atoms of different types are grouped together. Look at the model of the two types of atoms that make up a carbon dioxide molecule. Triangles represent carbon atoms. Squares represent oxygen atoms. In the image, you see a single carbon dioxide molecule. It is made up of two atoms of oxygen and one atom of carbon.

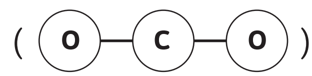
You have learned that billions of particles make up all matter. The substance called *carbon dioxide* is not just one molecule. Even a very tiny sample of carbon dioxide is made of billions of molecules. This next image represents only a few molecules, but it is important to understand that billions of molecules make up only a tiny dot of carbon dioxide.



If you could look at a tiny sample of carbon dioxide gas with a special microscope, you would see billions of carbon-oxygen molecules.

In class you used gumdrops and toothpicks to create models of some of the molecules that make up air. You might have noticed that some molecules can be made of the same type of atoms, and some are made of different types of atoms. One molecule of oxygen is made of two oxygen atoms. One carbon dioxide molecule is made of two different types of atoms—one carbon and two oxygen.





What Is the Best Way to Model Atoms and Molecules?

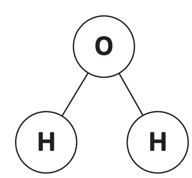
A model is a way to represent something. For your gumdrop models, it did not matter what color gumdrops you used. If you used a blue gumdrop to represent oxygen that does not mean oxygen atoms are really blue. Atoms can be represented by different shapes and colors. Squares, dots, and gumdrop shapes are three ways to represent atoms. You can probably think of others. You can represent molecules joining together in different ways, too. In class you used toothpicks. In the previous models, there are lines connecting the atoms. All of these ways to model atoms and molecules in a substance help you understand something your eye cannot see.

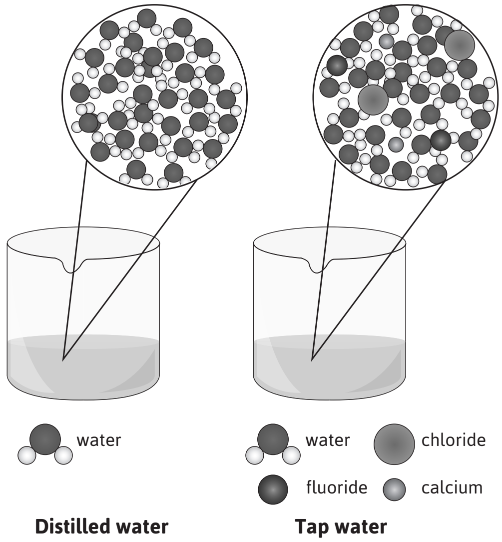
Who Cares about Atoms and Molecules Outside of Science Class?

Think about all the materials you use at home. You use materials to clean yourself, such as soap, shampoo, a towel, and a toothbrush. You use paper materials to blow your nose, to write on, and to read from. All of these are made of different types of molecules. By knowing about atoms and molecules, scientists can create new materials. In Lesson 1, you read about scientists adding molecules of mercaptan (rotten egg odor) to natural gas to keep people safe. Another way that atoms and molecules are important in the real world is when choosing water to drink. Some water is safe to swim in and to drink, but some water is not safe. Knowing about atoms and molecules is important in knowing about safe water.

What Is in the Water I Drink?

Pure water, which is also called *distilled water*, is made of only water molecules. You can buy distilled water at the grocery store. Scientists represent one molecule of water as H_2O. That representation shows that a water molecule is made of two hydrogen atoms and one oxygen atom. In class, you created a gumdrop model of water that looked like the one here.





Pure water is made of only water molecules. When something is made of only one type of particle, it is called a *pure substance*. It is pure because no other type of particle is mixed with it. You can see in the model here that distilled water is a pure substance. There is only one type of particle in pure water—water molecules.

Water molecules are made of two types of atoms—hydrogen atoms and oxygen atoms. The atoms join together to form water molecules. Pure water is a substance because it is made of the same kind of molecule all the way through. The diagram shows pure, distilled water on the left. You can buy pure water in stores, but you do not get pure, distilled water when you turn on a faucet. Water from the faucet (which some people call *tap water*) has other substances in it. The water you drink from a faucet is a mixture. A mixture is a material that has more than one type of particle in it. In the drawing of tap water, you can see that some of those particles are molecules and some are single atoms. The model shows that tap water is a mixture. Notice in the diagram that besides water molecules, tap water can have other substances in it, like fluoride. Sometimes cities add sodium fluoride to water. Scientists and dentists have found that fluoride helps prevent tooth decay or cavities. Some homes do not have fluoride in their water, but many homes in cities do. People who live in rural areas probably get their water from a well that does not have extra fluoride. If you drink bottled water, look closely at the label. Are you drinking a substance or drinking a mixture?

What can I conclude about substances and mixtures?

Some things are mixtures. Some things are substances. What is air? What are odors?

In class you modeled the molecules that make up air. You saw that air is made up of nitrogen, oxygen, carbon dioxide, water molecules, and other materials. In fact, most things that you use, see, feel, taste, and eat are mixtures. Things that you smell might also be mixtures. A specific odor, like the minty scent of menthol, is made of one type of molecule. It is a pure substance. Scents from flowers, fruit, and perfumes are usually many different substances mixed into one scent. Air is a mixture of odor molecules plus many other types of molecules.

Choose three of the sentence starters below, and finish the sentence based on today's reading.

1. I already knew

2. I was surprised to learn

3. I thought it was interesting that

4. A question I would like to ask is

Activity 9.2—Summarizing the Idea of “Odors in the Air”

Your teacher will provide instructions for this page.

Activity 10.1—Why Do Substances Have Different Odors?

What Will We Do?

We will smell several unknown materials, guess what they are, and then examine models of the molecules that make up each one.

> **SAFETY GUIDELINES**
>
> Use a wafting technique to smell the substances.

Prediction

Would you expect substances with very different odors to be made of the same type of atoms? Explain your ideas.

Procedure

- ☐ a. At each station, record what you think the odor is in the “Smells like . . .” column.
- ☐ b. Look at the card at each station carefully. Record the types of atoms that make up each molecule.
- ☐ c. Before you move to the next station, smell the cup of coffee beans. This will “reset” your nose.
- ☐ d. During the class discussion, your teacher will tell you what to write in the last column.

Data

Station	Smells like . . .	Type of Atoms That Make Up Each Molecule	Odor actually is . . .
1			
2			
3			
4			
5			
6			

Making Sense

1. What do you notice about the type of atoms that each molecule is made of?

2. How does your prediction compare with what you learned?

3. As you look at the handout, what do you notice about how the atoms are connected in each molecule?

4. Think about your responses to these questions to answer the following question: Why do different substances have different odors?

Lesson 10 Reading One—Why Does One Odor Smell Different from Another Odor?

Getting Ready

Do you use any products at home that smell minty? Look around your house. Maybe your toothpaste, for example, smells like mint.

List some minty-smelling products in the space below.

Next, if you have a minty-smelling product, read the list of ingredients on the label. Put a star by the products that have one of these ingredients: menthol, camphor, or eucalyptus.

You probably did not know that there is a Smell and Taste Research Foundation in the United States where scientists study humans' sense of smell. One scientist, for example, has learned that the smell of peppermint can help athletes perform better. People work out differently when they smell peppermint. They work out longer and harder.

Scientists know, too, that the effect also depends on whether a person likes an odor. Green apple odor can help with migraine headaches. However, it might not be helpful to someone who does not like the scent of green apples. Some people smell lavender to make them feel more relaxed. Many people burn scented candles or use air fresheners to put an odor they like into the air. Can you imagine other ways that odors could be helpful? For example, what if you could smell a scent that would help you wake up in the morning? Because scientists learn about the atoms and molecules that make up odors, they can then manipulate odors to benefit other people.

In class you smelled many different substances. You tried to identify where they might come from based on their odors. For instance, you smelled a material that has an odor like peppermint. That material was menthol. You have probably smelled menthol when brushing your teeth or chewing gum. Menthol is used in soaps, toothpaste, chewing gum, and cough drops. Substances with a minty odor are added to the products you use so that you will like to smell them. Menthol is one of the many substances you smelled in class.

Remember that humans can smell about 10,000 different odors.

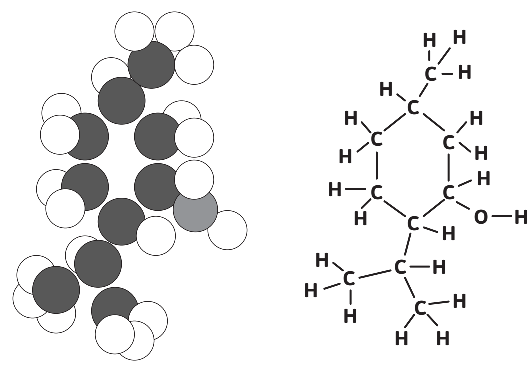
Before you read further, write a prediction. What makes one substance, like menthol, different from another substance, like camphor?

What Makes One Odor Smell Different from Another Odor?

All of the substances you smelled in class had different odors, so you knew that they must be different substances. If two substances are different, then either

A. the type of atoms they are made of are different,
B. the numbers of each type of atom are different, or
C. the atoms are connected to each other in different ways.

When you hold a tiny bit of menthol, you are holding billions of menthol molecules. The following figures show two ways to represent one menthol molecule. The one on the left shows atoms of a menthol molecule as circles. Circles touching each other represent atoms that are connected to each other. The menthol molecule on the right shows atoms as letters. The letters connect with lines to represent the atoms.



Types of Atoms

- C = carbon atom
- O = oxygen atom
- H = hydrogen atom

These two models can help you see what makes up the material that you smell. Both models show the type and number of each atom.

There are three types of atoms in menthol: oxygen, carbon, hydrogen. There are 31 atoms in one menthol molecule: 10 carbon, 1 oxygen, 20 hydrogen.

The menthol models also show the arrangement of the atoms. They show which atoms are joined to other atoms and where each atom is in the molecule. For example, notice that every carbon atom is connected to a hydrogen atom. Look at the two models closely, and describe two more things you notice about how the atoms are arranged. One way to start might be to find the oxygen atom in each model.

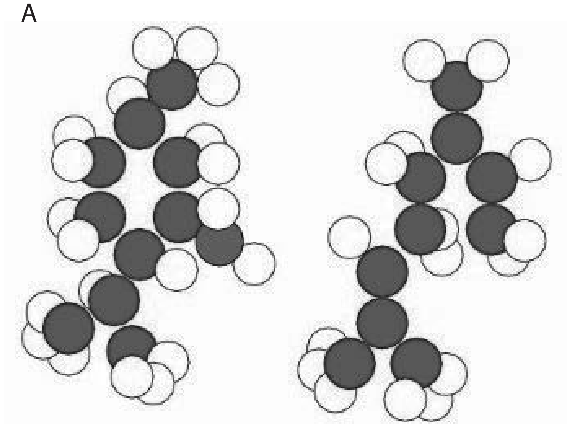
What can you say about how it is arranged in the molecule?

Comparing Different Ways to Represent Molecules

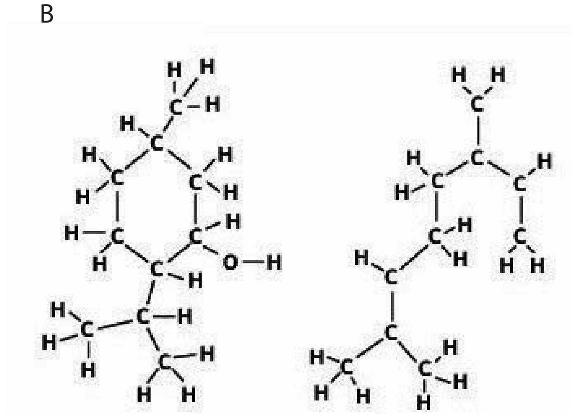
The menthol you smelled in class can be found in the peppermint plant. A p eppermint plant also contains other substances that help to make it smell minty. One of them is called *myrcene*.

As you read this section, you will use models to compare a menthol and a myrcene molecule. Start by looking at models A and B. Each model shows a different way to represent one menthol molecule and one myrcene molecule. Notice how the diagrams use different symbols for the molecules. In model A, the atoms are represented by circles. In model B, atoms are represented by letters.

A



B



Types of Atoms

C = carbon atom

O = oxygen atom

H = hydrogen atom

Notice how a menthol molecule is similar to, and different from, a myrcene molecule. The models show you how the two substances are different. The substances have different names because of those differences.

How Are the Two Substances from the Same Plant Different?

Count the number of carbon atoms in each molecule. What do you notice? Look at how the carbon atoms are arranged. What do you notice about the hydrogen atoms? What do you notice about the oxygen atoms? The differences you can see in these models explain how and why menthol and myrcene are different substances. They both have minty odors, but they are not the same substance.

Which Model Would You Use?

Sometimes it is more helpful to use a model with atoms represented by circles that touch. Sometimes it is more helpful to see a model with letters and lines that connect them. How useful a model is depends on what you are using it for. The following questions will help you think about this a little more.

Which model would you use to help someone understand how menthol is different from myrcene? What do you think makes that model best for explaining that menthol and myrcene are different substances?

Activity 11.1—How Can I Make Molecules Move Faster?

What Will We Do?

We will investigate hot and cold liquid ammonia and determine how long it takes gaseous ammonia to reach the indicator paper at different temperatures. Then we will develop models and use them to explain our observations.

Predictions

Your teacher will put one test tube of liquid ammonia into a warm water bath and another tube into a cold water bath. What do you predict that the particles will do? Choose *A*, *B*, or *C*. Then explain why you expect that to happen.

a. The ammonia particles in the warm water will reach the indicator paper first.
b. The ammonia particles in the cold water will reach the indicator paper first.
c. The ammonia particles in warm and cold water will reach the indicator paper at the same time.

Procedure

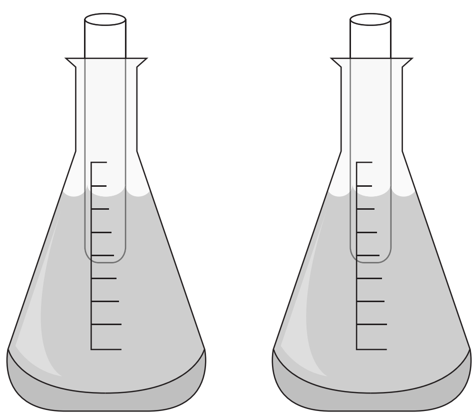
☐ a. Observe what happens when one tube is in the cold water bath.
☐ b. Record your observations and the time in the data table.

Data

	Time in Seconds	Observations
Cold Water Bath		
Hot Water Bath		

Making Sense

1. A friend who was absent missed seeing what happened in this activity. Develop a molecular model that shows what happened.



2. Use your model to explain to your friend how the ammonia in this activity behaved in the two conditions.

Activity 11.2—How Else Can I Model Odor Moving?

Your teacher will provide instructions for this page.

Lesson 11 Reading One—How Can I Make Particles Move Faster?

Getting Ready

Today's reading is about molecules, temperature, and energy. These are important ideas in science, but they can be difficult to understand. Before you start reading, decide whether you think each statement is true or false.

Before Reading			After Reading	
T	F	Particles in a gas are always moving.	T	F
T	F	As temperature increases, particles move faster.	T	F
T	F	As temperature increases, particles move faster and their energy increases.	T	F
T	F	Particles are always moving, but the speed of the particles can be different.	T	F

As you read, focus on temperature, energy, and how particles move.

How Do Particles in Air Move?

Imagine the billions of particles moving in one tiny bit of air. The molecules that make up the air are always moving. They move until they hit each other. Then they bounce off and go in a different direction. Air particles never stop moving. They are always bumping into each other and bouncing off.

Even though particles never stop moving, they can move quickly or they can move slowly. You might have learned in math class that the distance an object travels in a certain amount of time is called the *speed* of the object. Cars measure speed in miles per hour (MPH) or kilometers per hour (KPH). A gauge like the one in the picture shows the number of miles (the distance) that the car moves in one hour (the amount of time). Driving 40 miles per hour means that in one hour, the car will go 40 miles if it is always moving at the same speed. A car might go 25, 40, 55, or 70 miles in an hour. Particles can also move at different speeds. Particles in a gas move much faster than cars can move. The average speed of air particles is 1,100 miles per hour or 1,770 kilometers per hour. At that speed, it seems like particles would travel far, but they do not. They do not because they bump into other particles and change direction.

Another Way to Think about the Speed of Atoms and Molecules

Think about watching a bat hitting a baseball. Imagine the bat as one particle in the air. Imagine the baseball as another particle. When the pitcher throws the ball, the ball moves at a very fast speed. If the batter swings the bat at a slow speed, then the ball will bounce off the bat and move away slowly. If the batter swings the bat at a fast speed, then the ball will bounce off the bat faster. If you know about baseball, think about trying to bunt or trying to hit a home run. To make the ball go farther, the batter needs to swing the bat faster. The speed of the bat and the speed of the ball before they hit affect how fast the ball moves after it hit the bat.

Particles move a little bit like the bat and ball. The speed of the particles affects how fast they can bounce away from each other. A bat and ball are only two particles. Think of what happens when billions of particles move and bounce off each other at once.

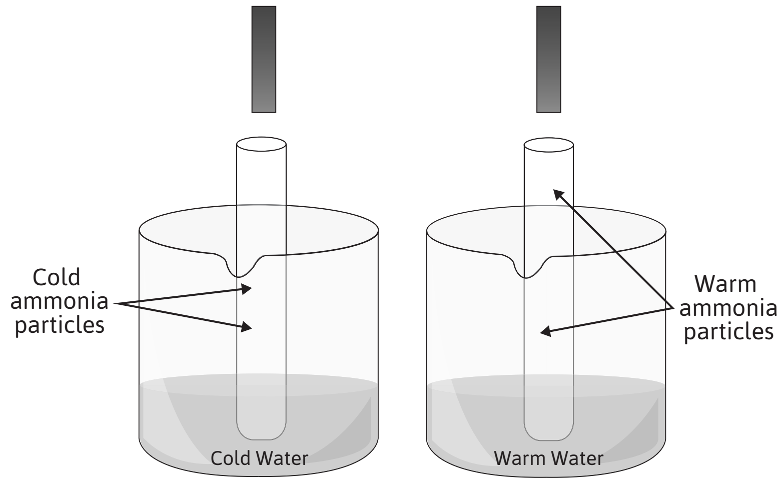
What Happens to the Speed of Particles When They Are Warm or Cold?

You investigated this question by testing how temperature is related to the speed at which particles move.

This investigation used two containers. One test tube held cool ammonia. Another test tube held warm ammonia. Indicator paper was held above the opening of each test tube. You observed that the indicator paper near the warm ammonia changed to dark blue much sooner than the indicator near the cool ammonia.

Why Did the Indicator Papers Change Color at Different Times?

In this investigation, temperature was the only variable that was different between the two containers. In both test tubes, the ammonia particles bounced around among the air particles. Indicator paper was the detector that provided data. When it changed color, the indicator paper provided evidence that ammonia particles had moved out of the test tube. You saw that the indicator paper above the warm ammonia changed color sooner. The paper also provided evidence that the speed of the ammonia and air particles in the warm test tube must have been faster than the speed of the cold ammonia and air particles.



This investigation showed that molecules move at different speeds. The speed of particles is related to temperature.

What Does the Temperature of a Substance Tell about the Speed of Its Particles?

Scientists call *temperature* the average speed of molecules in a substance. This is true for all substances. When a thermometer measures the air temperature, it measures the average speed of the molecules that make up the air around the thermometer.

Here is another way to think about molecules and temperature: When you heat a substance, the particles in that substance move faster. When their energy increases, they move faster, their energy increases. This was true about the ammonia that you saw in class, and it is true about all substances. When you heat a substance, several things happen:

1. The particles move faster.
2. Their energy increases.
3. Faster-moving particles hit into each other harder.
4. Faster-moving particles bounce off each other harder and move further apart.
5. As most of the particles that make up the substance move faster, the temperature of the substance increases.

Now that you have finished reading, go back to the beginning and circle whether each statement is true or false. Did any of your ideas change? If the answer is yes, use evidence from your investigation to explain why your ideas have now changed.

Activity 12.1—What Happens When Gases Are Cooled and Heated?

What Will We Do?

We will use a balloon to investigate how temperature affects the volume of gases.

Predictions

1. What will happen to a balloon filled with air when you cool the balloon in ice?

2. What will happen to the balloon when you let it warm up again?

Procedure

☐ a. Observe what happens to the balloon when it is placed in dry ice.
☐ b. Describe your observations.

☐ c. Observe what happens to the balloon when it is taken out of the dry ice.
☐ d. Describe your observations.

Making Sense

1. How do your predictions compare with what you observed?

2a. Draw a particle model to explain the process of what happened to the balloon when it was cooled and as it warmed to room temperature. (Hint: When you want to show a change, you need to represent the object before and after something changed. For this model, you need to draw a cool balloon and a warm balloon.)

2b. Describe your model in words.

Lesson 12 Reading One—How Can the Volume of a Balloon Change without Removing or Adding Air?

Getting Ready

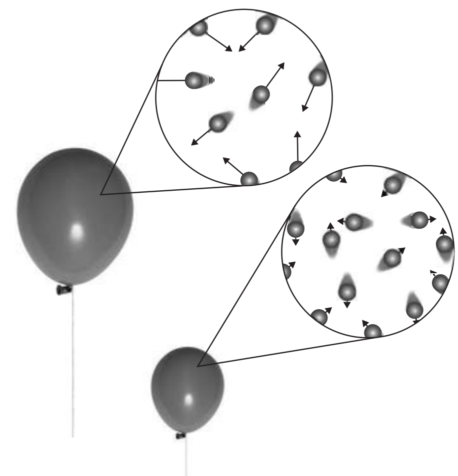
Do you ever eat popcorn? Before popcorn pops, the kernels are hard. How does a hard kernel become soft, fluffy, white popcorn that is easy to chew? Popcorn pops because each kernel contains water. As you heat popcorn, the water molecules inside each kernel move faster. As they move faster, the molecules collide (hit) each other harder. The more they are heated, the faster the molecules move. They soon have so much energy that they create a lot of pressure inside the tiny kernel. The molecules hit against the material that makes up the kernel with so much speed that the kernel breaks open and pops.

What happens inside a popcorn kernel is related to the speed of particles, energy, temperature, and pressure. The reasons that a popcorn kernel pops are the same reasons that a balloon shrinks and expands as the molecules inside of it are heated and cooled. Sometimes, it is a challenge to connect experiences that seem very different. What happens inside a balloon and what happens inside a popcorn kernel can both be explained by knowing the behavior of particles. As you read, think about how your observations of a balloon in class would apply to a balloon even if it were filled with a different gas.

What Happens Inside a Balloon When It Is Cooled and Warmed?

In class you saw a balloon filled with gas. You observed what happened when you put the balloon inside a cold container. The balloon got smaller. Then you let the balloon warm up, and it got bigger. What would happen if the balloon were filled with a different gas instead of the gases that make up air?

Imagine that the balloons in the following model are filled with helium. In this model, arrows represent how fast the particles are moving. Longer arrows mean the particles are moving faster. Shorter arrows mean they are moving more slowly. Can you tell which one represents a cold balloon and which one represents a warm balloon?



The balloon on the left shows how helium atoms might move if the balloon were in a warm room. If you put the same balloon into a freezer, the atoms might move like the ones on the right. Many things happen as you warm and cool a balloon.

Notice the following four things:

1. the temperature of the balloon (warm or cold)
2. the size of the balloon (larger or smaller)
3. the speed of the atoms (faster or slower)
4. the number of atoms in the tiny spot that is magnified (more or fewer)

If you could see one tiny amount of helium gas in each balloon, you would notice many differences between their atoms. For example, in the balloon on the left, the warm helium atoms would be moving faster and bouncing farther away from each other. The atoms would also collide with the particles the balloon is made of. A balloon can stretch if something pushes against it. As the gas particles push the balloon, they make the balloon stretch, and it gets larger.

Balloons and Popcorn Kernels

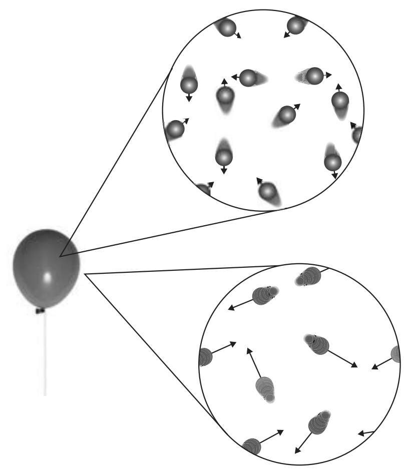
You already know that gases take the shape of their container. As more gas is added to a balloon, the pressure against the sides of the balloon increases. The gas particles move further apart and push against the sides of the balloon. The balloon stretches a little more, and the gas particles move apart to fill the space of the container. If you add more gas, the balloon expands again because the particles continue to bounce off each other and fill the space. You probably know, however, that a balloon can only stretch so far. If you put more gas into a balloon than it can stretch to hold, the balloon will break. Does this remind you of popcorn? When a container cannot hold any more gas but you try to put more in (like a balloon), or you keep heating the gas so that it keeps expanding (like water vapor in a kernel), the container can break. A balloon and a popcorn kernel both pop.

Cooling a Balloon

If you tie a balloon shut and then put it in ice, the particles slow down. They do not have as much energy. They still collide with each other and with the sides of the balloon, but they do not collide as hard. Think about the bat and baseball that you read about in the last lesson. As the helium in the balloon cools, the particles move more slowly. They do not push against the side of the balloon as hard. They still fill the space of the balloon, but because they are moving more slowly and bouncing less far apart, they put less pressure on the sides of the balloon, and the balloon gets smaller.

Why Does It Look Like the Balloons Have Different Numbers of Atoms?

One thing might be confusing. It might look like the warm balloon contains fewer atoms, but remember that the balloon you saw in class was closed. No air was added to it, and no air could escape. The number of atoms in each balloon stayed the same. The number of atoms looks different because the diagram represents a tiny spot inside each balloon. In a warm balloon, the atoms would be farther apart, so fewer of them would be in a tiny spot. Because the atoms are closer together in the cool balloon, you could see more of them in a tiny spot. The number of atoms does not change. What you would see when you focus on a tiny spot, if you had an instrument that would let you see atoms, is whether they are closer together or farther apart.



What Are the Air Molecules outside the Balloon Doing?

You have learned about the particles inside the balloon, but you know that air molecules are also moving in the room outside of the balloon. This diagram shows what the gas molecules were doing inside and outside the balloon. As particles were moving inside the balloon, particles were also moving outside the balloon.

What would you expect to happen to the molecules inside the balloon if the balloon sat in a warm room all day? Explain your ideas.

Activity 12.2—A Physical Model of Heating and Cooling a Gas

Your teacher will provide instructions for this page.

Activity 13.1 *and* 13.2—What Happens to Bromine as It Is Cooled or Heated? *and* USING THE MODEL TO PREDICT

What Will We Do?

We will observe the element *bromine* and develop models to explain what we see as we heat it and cool it.

Prediction

Your teacher (or a video) will demonstrate changing the temperature of a glass tube filled with bromine. What do you expect to happen as the bromine in the tube is cooled? What do you expect to happen as the bromine in the tube is heated?

What I notice about the bromine tube at room temperature:

Procedure

☐ a. Observe what happens as the bromine is cooled. Record your observations.

☐ b. Observe what happens as the bromine is warmed to room temperature. Record your observations.

Making Sense

1. If you had a special instrument that would allow you to see the molecules of bromine, what would the bromine in the tube look like before and after it had been cooled?

2. Evaporation is the process of a substance going from the liquid state into the gaseous state. Use your models to explain evaporation.

Activity 13.3 *and* 13.4—What Happens When Water Boils? *and* Where Did the Water Come From?

What Will We Do?

We will use our particle model of matter to explain some everyday observations.

Prediction

Use what you know about particles to predict what will happen when gaseous water is cooled.

Procedure

☐ a. Look closely at the cup of icy water. What do you notice? Record your observations.

☐ b. Look at the cup of water at room temperature. What do you notice? Record your observations.

Making Sense

1. Use what you know about particles (refer to your particle model) to explain the differences you observed in the two cups.

2. Condensation is the process of a substance in the gaseous phase going into the liquid phase. Explain condensation using a particle model.

3. Compare evaporation and condensation.

4. Using the particle model, explain why water forms on the outside of a cold can of soda pop. (Hint: Be sure to tell where the water on the outside of the can comes from.)

Lesson 13 Reading One—How Do Substances Become Part of the Air?

Getting Ready

Here are three phenomena with something in common:

1. Water boils on the stove, and the amount of water in the pan decreases.
2. Wet clothes hang on a clothesline and get dry.
3. After it rains, puddles form on the ground, but they get smaller over time.

Can you tell what all three of these statements have in common? They all occur because water molecules can move from the liquid to the gas phase. In this reading, you will learn more about water changing phases. You will also learn that understanding water and phase changes relates to pancakes and waffles.

Water Changes Phases in Everyday Life

When you take a bath or shower and dry yourself with a towel, the towel gets wet. If you hang the towel up and then feel it at the end of the day, the towel will not be as wet. If it hangs up overnight, it will be dry by the next day. How does a towel dry? As a towel hangs, fast moving air molecules collide with water molecules on the towel. Some of these collisions make the water molecules move faster. They move so fast that they can leave the towel and go into the air. The word for this process is *evaporation*.

Another example of water evaporating happens in a puddle after it rains. If you measured the amount of water in a puddle, and every hour you went back and measured the amount of water again, you would notice the puddle getting smaller. You might have thought that the puddle got smaller because the water soaked into the breaks or went into the cracks of the breaks. Some of the water could do that, but a lot of the water evaporates. Water molecules on the surface of the puddle move fast enough to move into the gaseous state. Evaporation is the process of a liquid going into the gaseous phase without boiling. This occurs because molecules on the surface of the liquid collide with faster-moving molecules in the air. These collisions provide enough energy to change the liquid to gas.

What Else Evaporates?

In class you saw liquid bromine evaporate. Unlike gaseous water, which is invisible, bromine has a reddish-brown color. You saw bromine in the gaseous state and the liquid state. First, you watched bromine gas condense into a liquid. Second, you saw liquid bromine evaporate back into a gas. You also drew models to show how substances like bromine can condense and evaporate. Some odors also start as liquid substances that evaporate. An example is fragrance oils that are put in candles, air fresheners, or perfume. If you leave liquid fragrance in a cup or saucer, the substance will evaporate into the air. The entire liquid does not go to the gaseous state all at once. Instead, some of the molecules on the surface of the substance go into the air in a process called *evaporation*.

Imagine that someone puts liquid fragrance oil in a saucer. Imagine that you could focus a special instrument on the surface of the liquid where the air and the liquid touch each other. In the space below, draw what you would see if you could look at a tiny spot.

Now, imagine that you walked away for a couple of hours. When you came back, some of the liquid had evaporated. If you kept the instrument focused on the same area, draw what you would see after some of the fragrance evaporated.

How Hot Can I Heat Water?

In class you heated water and measured the temperature. The more you heated the water, the higher the temperature of the water got. Then the temperature of the water stopped increasing. It stayed at 100°C even though you continued to heat the water. How can a substance stay at a certain temperature even though it is being heated? Why doesn't the water get hotter and hotter?

You know that if the temperature of a substance increases, then the speed of the particles also increases. The particles move faster. The opposite also happens. If the temperature does not increase, then that means the speed of the particles does not increase. You saw that the temperature of water did not increase once it reached 100°C. That means the water molecules continued to move around, but they did not move faster. Something else must have been happening to the water molecules as they continued to gain energy.

All of the energy was being used to make the water particles separate from each other, and turn into water vapor. Liquid water particles became gaseous water particles. This is called boiling. Boiling happens at a specific temperature. The boiling point of water is 100°C (or 212°F). That temperature is the point at which all of the water molecules begin to separate from each other and change to a gaseous state.

Outside of science class, when are boiling and evaporation important?

Do you ever eat pancakes, waffles, or French toast with syrup? Maple syrup is made using the processes you have just read about. Maple syrup comes from the sap inside of maple trees. Read the following information that tells about maple syrup. As you read, underline the parts that describe how boiling and evaporation are used to make syrup. Before you read, you should know that the article refers to boiling sap in an evaporator. It might sound like boiling and evaporating are the same, but you know that they are two different processes. When you read, keep in mind what you have already learned.

Phase Changes in Everyday Life: Maple Syrup

Many people use maple syrup on pancakes or waffles. Where does maple syrup come from? It starts with sap from maple trees. During the summer, chlorophyll in the leaves of maple trees uses energy from the sun, water, and carbon dioxide from the air to produce sap. The trees store the sap in their bark and wood. They use the sap they make as food to grow and live. In the spring, as the tree warms up, the sap begins to flow throughout the tree. Have you ever noticed a tree with liquid dripping down its bark?

Maple syrup farmers drill a small hole into the trunk of a mature sugar maple tree. They then hammer a spout into the tree and hang a bucket to catch the sap that runs out through the hole. Farmers can drill several holes into a tree. They have learned how many to drill so the tree still has sap for its own food.

People do not use the sap right out of the tree on their pancakes. Some ideas you have learned so far will help you think about what happens next.

Farmers pour the sap into trays where it is boiled. As the sap boils, the water in it evaporates. As the water evaporates, the sap becomes thicker. When much of the water has evaporated and the temperature reaches just over 100°C (which is the boiling point of pure water) the sap turns into syrup. The farmers look for signs to let them know the sap is turning into syrup. The sap becomes darker, an amber color, and the bubbles that start small become large and look like little explosions as the gaseous water escapes into the air. The final step is to make sure the syrup is cleaned by filtering it. Then, the syrup is poured into containers and delivered to grocery stores.

Native Americans used a different process. Because they understood what happens when water freezes, they used a freezing process to make maple syrup. Once they got the sap from the trees, they let it freeze on cold nights in shallow containers. In the morning, they threw away the ice. They then let the sap freeze again, and they threw away the ice. They repeated the process until thick syrup formed in the containers. This method makes the sweetest, clearest syrup.

Both of these processes used ideas you have studied in class about freezing and boiling. Luckily for people who like maple syrup, every year maple trees begin the process of making sap again.

Lesson 13 Reading Two—Where Do Drops of Water Come From?

Getting Ready

Have you ever looked up and seen white streaks in the sky behind a jet? What do you think those white streaks could be?

In this reading, you will learn the answer. Before you read about jets, you will read about other experiences you have with the same phenomenon all around you.

Why Can I Sometimes See My Breath?

Have you ever talked with someone when it is cold outside and you can see your breath? Your breath looks like a cloud. On warm days, your breath is invisible. Why can you see your breath on cool days but not on warm days? The inside of your mouth is warm, so the air inside of it is warm too. One of the things you breathe out is water in the gaseous state. The gaseous water you breathe out is warmer than the cool gases in the air. When your warm breath and the cold air meet outside your mouth, some of the water from your breath cools quickly. The water becomes cold enough that it condenses into tiny drops of liquid water.

When any gas condenses, all the particles that were once spread out in the gaseous state get closer together. In the example of your breath, the water molecules are first spread out as a gas. The water molecules you breathe out lose energy and move so much slower that they sort of clump together to become liquid water. These clumps are made of so many molecules that you can see them as tiny water drops. A lot of these tiny drops all together look like a small cloud. When you see that little cloud, you might say that you can see your breath.

Where Else Can I See Water Condense?

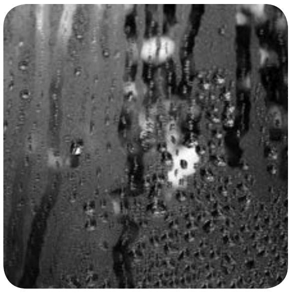
You have probably seen another phenomenon that happens because of water condensing. Have you ever opened a freezer when the room is warm? If the room is warm, you see something that looks like a cloud of smoke when you open a freezer door. You are really seeing gaseous water molecules that condense into liquid water. When you open the door, the cool air from the freezer meets and mixes with the hot air outside. The hot air outside becomes cool. Gaseous water molecules in the warm air become so cool that they condense into tiny water drops. All of the tiny drops floating in the air look like smoke or a small cloud.

Sometimes, so many water molecules condense that you can see big water drops. If you leave a cold soda pop can on the table, small drops form on the outside of the can. Some people might think that the can leaks. They might think that the liquid on the outside came from inside the can. This phenomenon happens for the same reason as the example you just read. Water molecules in air touch the cold can. When this happens, gaseous water molecules lose their energy to the atoms at the surface of the can. This makes the water molecules move slower and clump together. The gaseous water condenses into droplets of liquid water on the can.

What Are Those Trails behind Airplanes?

If you thought that the white lines you see in the sky behind a jet are a type of cloud, you were right. In fact, those white streaks are called *contrails* (short for *condensation trails*). A contrail forms because one of the substances that jet engines make is water. The water is released into the air in the gaseous state. Water in the gaseous state is called *water vapor*. You cannot see water vapor. The air high up in the sky is very cold. You just read what happens when cold air and gaseous water meet. The water condenses into a lot of tiny drops of liquid water. The drops of water are the contrails—lines that look like clouds in the sky.

Explaining Other Phenomena with Condensation



Seeing your breath, contrails, and water droplets on a cold beverage can are examples of water changing from the gaseous state to the liquid state.

You can use your model of gaseous air to explain all of these examples. Your model shows that air is made of particles, and the movement of particles (faster or slower) is related to temperature. When water boils on the stove, the kitchen window might fog up. When you take a hot shower, fog might cover the bathroom mirror. Why does that happen?

Using your model of air, describe what happens so that fog appears on a mirror when you take a shower.

Activity 14.1–What Happens to Molecules of a Liquid at Higher Temperatures?

What Will We Do?

We will observe what happens to water when we heat it. Then we will create a model to help explain our observations.

Prediction

What do you think will happen to the volume of cool water after you heat it?

SAFETY GUIDELINES

- Wear safety goggles.
- Be cautious when heating water. Water has a boiling point of 100°C (212°F). Never touch hot beakers. Beakers filled with too much water may boil over.
- Do not taste any of the materials.

Procedure

☐ a. Pour cool water into a flask. Make sure that the line on the flask's neck marks the bottom of the meniscus of the water in the flask.
☐ b. Measure the water temperature, and record it in the Data section.
☐ c. Put the flask on a hot plate. Heat the water, but do not let it boil.
☐ d. Turn the hot plate off as soon as you notice a change. Do not let the temperature get higher than 165°F.
☐ e. Observe the volume of the hot water. Record your observations.

Data

Temperature of water before heating: __________
Temperature of water after heating: __________
Observations of the volume:

Observations of the volume after heating:

Making Sense

1. How did your prediction compare with your observations?

2. Use your particle model to explain your data. (How can the physical model you used in class help you explain what happened?)

Lesson 14 Reading One—How Do Odor Molecules Move?

Getting Ready

Have you ever thought about how sharks catch their prey? Fish smell odor molecules in the water, and people smell odor molecules in the air. Before you read today's lesson, think about this: Sharks find their food in the water by detecting blood.

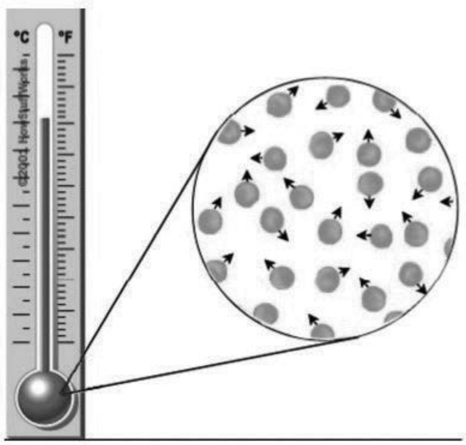
How do blood molecules move in water? Describe how you think blood molecules move in water so that a shark can smell them.

The investigations in class and this reading will help you learn how molecules can move in water so that fish can smell odors. First, you will read about how molecules of liquid move in a thermometer.

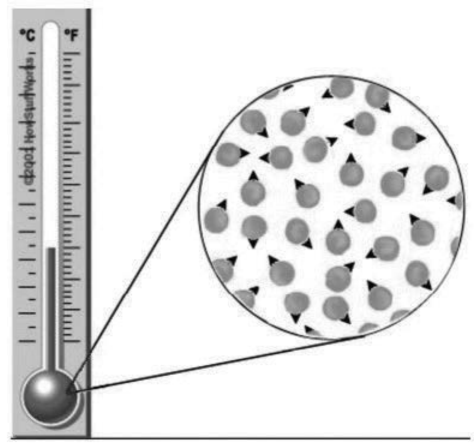
How Does a Thermometer Work?

Some people use a bulb thermometer at home. This type of thermometer can measure body temperature when someone is sick. Some people use this type of thermometer to measure the temperature outside.

When the air is warm, the liquid in the thermometer rises up the tube. When the air is cold, the liquid falls down the tube. You can tell the temperature by looking at the number closest to the top of the red liquid. Bulb thermometers work because the liquid in the thermometer takes up more space as the temperature of the room increases. The liquid takes up less space in the bulb when the temperature of the room decreases. As you read about liquids and the volume (space) that liquids occupy, you will learn more about how bulb thermometers work.



The liquid in this thermometer has particles that move faster. They are farther from each other. Because the particles have greater speed, the liquid has greater volume.



The liquid in this thermometer has particles that move slower. They are close together. Because the particles have lower speed, the liquid has less volume.

How Does the Volume of a Liquid Change?

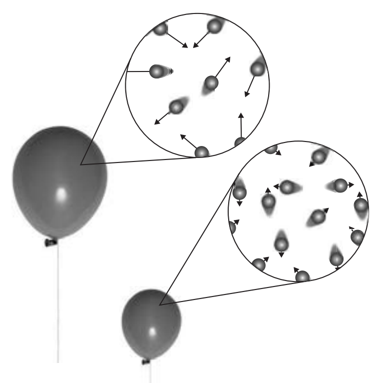
In class, you saw the volume increase when you heated water. You learned that the reason water changes volume is because the molecules that make up water move faster or slower. The volume of hot and cold water changes for two reasons:

1. The speed of the molecules is different in hot and cold water.
2. The space between the molecules is different in hot and cold water.

Think about a bulb thermometer. When the thermometer measures 60°F/15.5°C, the molecules are moving at a certain speed. When you cool the liquid, the molecules move at a slower speed.

Compare Cooling Liquids and Cooling Gases

What happens to particles when cooling a liquid is very similar to what happens when you cool a gas. In Lesson 10, you learned what happens to the particles inside a balloon when helium gas cools. As a gas cools, the particles move more slowly. When the particles move more slowly, they do not bounce off each other as hard, and the balloon shrinks. This diagram shows the particles of helium before and after cooling a balloon, as an example.



Activity 14.2—Which Liquid Moves Faster?

What Will We Do?

We will use our particle model to explain how food coloring spreads in water at different temperatures.

Prediction

Use your particle model to predict whether food coloring will move faster in hot or cold water. Why do you make this prediction?

SAFETY

Be careful with the hot plate and hot water. Do not pick up the hot beaker with your bare hands.

Procedure

☐a. Use a thermometer to measure the temperature of the cold water. Record the measurement in the data table on the next page.
☐b. Be prepared with a stopwatch to measure how long it takes for the food coloring to get halfway through the water in the beaker.
☐c. Squeeze a drop of food coloring into the cold water. Record the time.
☐d. Use the hot plate to heat the other beaker of water. Use the thermometer to heat the water about 20°C higher than when you started the activity. Turn the hot plate off. Record the temperature.
☐e. Be prepared with the stopwatch again.
☐f. Squeeze a drop of food coloring into the warm water.
☐g. Record how long it takes for the food coloring to get halfway through the water in the beaker.

Data

Beaker	Temperature (°C)	Time to Reach Halfway	Describe How the Food Coloring Spreads
Cold Water			
Hot Water			

Making Sense

1. How does your prediction compare with what you observed?

2a. What does an increase in temperature tell you about the movement of molecules in a liquid?

2b. How does this compare to what you learned about gases?

3. Explain how the model helped you to understand what you observed in this activity.

Lesson 14 Reading Two—How Does an Oven Make Hot Chocolate Hot?

Getting Ready

Have you ever heated milk or water to make hot chocolate? In the space below, describe what happens to the molecules in the liquid when you heat them to make hot chocolate.

This reading is about ways to heat food. You have learned that as liquids are heated, the molecules that make up the liquids move faster. As you read, think about how an oven makes molecules move.

How Does an Oven Heat Food?

Regular ovens use hot air to heat food. When you turn on an oven, you can sometimes see the coils get hot, or you can see a flame. Both of these warm the air as molecules in the air collide with a hot surface. Hot air in the oven then heats the food. Fast-moving molecules in the air collide with the molecules on the surface of the food. The collisions make molecules in the food move faster. Remember that the faster the molecules move, the more energy they have. As the food molecules get more energy from the hot air molecules around them, the food gets hotter. However, the food molecules do not all move faster at once. The ones on the outside edges of the food start moving faster and colliding with the food molecules on the inside. It takes time for the food to become warm all the way to the center.

How Do Microwave Ovens Work?

Microwave ovens do not use hot air to heat food. Instead, they work by heating food with a form of light that your eyes cannot detect, called *microwaves*. When you turn on a microwave oven, a device in the oven makes microwaves. The microwaves reflect off the walls of the oven and move in the oven in all directions. Microwaves, like all light, are a form of energy. As microwaves pass through food, they are absorbed by molecules in the food. Their energy gets transferred to the food molecules, causing them to move faster. For example, microwaves make the water molecules in food move back and forth about a million times a second. Those molecules then collide with the rest of the food molecules. When the molecules in the food move faster, the food heats because the molecules in the food have more energy.

Microwave ovens heat food faster than regular ovens because microwaves can make the molecules in the food move faster all at once. You do not have to wait for each food molecule to move faster one by one, starting from the ones on the outside, like in regular ovens. This is why it takes less time to heat something in a microwave oven.

Try This at Home

A good way to be sure you have learned something is to try to explain it to someone else. As you explain to someone else, you figure out what you know and what you still find confusing.

Try to explain to someone at home how ovens work to heat pizza, or to heat something. Use language you think will help the person really understand how molecules move as they are heated.

Activity 15.1—What Happens to the Molecules as a Solid Melts?

What Will We Do?

We will observe wax melting. Then we will develop models that explain what the molecules do as a substance melts.

Prediction

1. Predict what will happen to the wax when it is heated.

2. Describe what happens to the molecules that make up wax when it is heated.

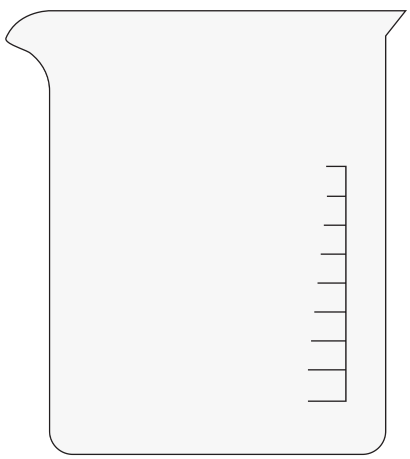
Observations

Observe what happens when the candle is placed in a hot water bath. Record your observations.

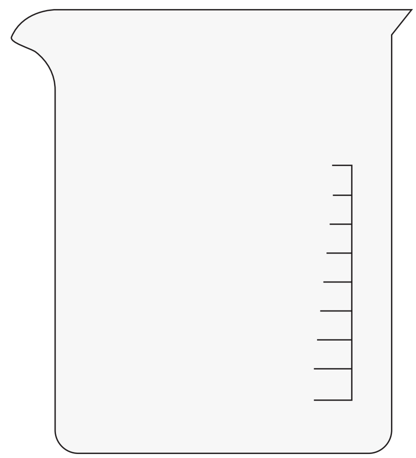
Making Sense

1. How does your prediction compare to what you observed?

2. Imagine that you have a special instrument that would allow you to see the molecules of the solid wax up close. In the beaker, draw what you would see.



3. Imagine that you have a special instrument that would allow you to see the molecules of the liquid wax up close. In the beaker, draw what you would see.



4. Imagine that a friend was looking at your model. Describe how your model explains what happened.

Lesson 15 Reading One—What Happens to Molecules When a Substance Melts?

Getting Ready

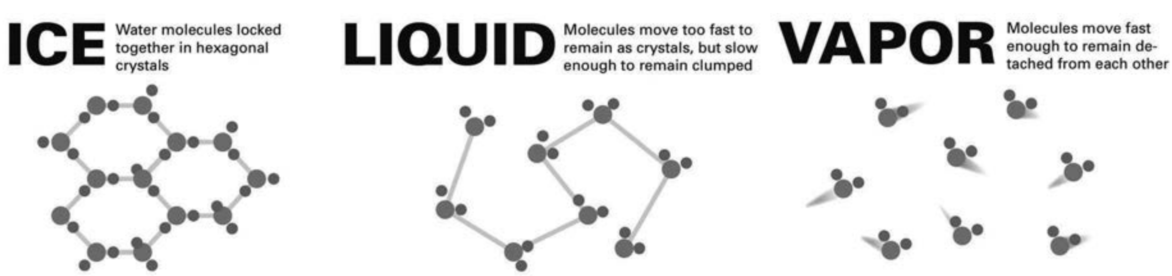
Ice cream melts. Butter melts. You have probably observed both of these. You probably have not seen a glacier melting. Glaciers are like big rivers of ice. They are found on every continent except Australia. The glacier in this picture curves around the land.

Maybe you have heard that the world's glaciers are getting smaller. It is probably easier to think about a glacier getting smaller if you think about watching an ice cube melt. As you read about the molecules in an ice cube, think about how what you are reading might apply to glaciers too.

What Happens When I Put Ice in a Glass of Soda Pop?

Many people like their drinks cold. One way to make a drink cold is to put ice cubes in it. When you put ice in a warm drink, the ice melts and the drink gets colder.

The following diagram can help you think about what happens to the molecules when ice sits in a glass of warm liquid. At first, the molecules that make up ice are in a specific arrangement.



They are in the solid state, so they only move back and forth and cannot move past other molecules. The warm liquid molecules surrounding the ice collide with and bounce off the ice molecules. When the faster-moving molecules in the liquid state (the beverage) collide with the molecules in the solid state, the molecules in the solid state move a little faster, and those in the liquid state move a little slower. Some of the ice molecules start to move so fast that they start moving past each other. The solid water begins to change into liquid water when the ice molecules start to move past each other. Another way to say that a substance changes from the solid state to the liquid state is to say it melts. The ice continues to melt as more ice molecules move fast enough to slide past each other. This continues until all of the solid water changes to liquid water. When ice melts, the molecules do not change, they just move faster.

Why Does a Drink Get Cold When the Ice Cubes Melt?

In class you saw that when you heated candle wax, the wax changed from the solid state to the liquid state. Wax is a solid at room temperature. It needs to be heated to become a liquid. When wax is heated, the wax molecules move faster. When they move fast enough so that they can slide past each other, the wax melts into a liquid.

Ice cubes also need to be heated to melt. An ice cube is heated by a warm drink. The warm beverage particles can move past each other and collide with the molecules that make up the ice cube. Those collisions can make the ice cube molecules move faster. The collisions can also make the warm drink particles move slower. As the drink particles continue to collide into the ice cube molecules, they move slower and the liquid cools down. When you put ice in a warm glass of soda pop, as the ice melts it also cools your soda pop. Your particle model can explain how liquids cool.

How Is Melting a Property of a Substance?

Have you ever melted butter in a frying pan or spread butter on hot corn on the cob? Butter starts to melt when it reaches a temperature of 32.3°C or 90.1°F. This temperature is called the melting point of butter. *Melting point* is the temperature at which a solid substance starts to become a liquid. Once a solid reaches its melting point, it stays at the same temperature until it is completely melted. Solid butter stays at 32.3°C or 90.1°F until it is completely melted. During that time, the energy used to melt the butter is breaking attractions between the molecules, not heating the substance even more. The temperature stays the same until all the attractions between molecules are broken, which means the substance is completely melted. Then the substance can get hotter.

The melting point of a substance is a property of that substance. Remember that a property of a substance is characteristic of that substance. That means that the melting point is the same no matter how much of the substance is in your sample. A spoonful of butter melts faster than a whole stick of butter. However, both of them start to melt at the same melting point.

What Happens to Molecules as Something Freezes?

If you live in the northern part of the United States, you have felt how cold winters can be. Often people say, "It's freezing outside!" when it really is not freezing, it is just very cold. When it is actually "freezing cold," interesting things happen to the moisture in the air. For example, if the air is cold enough, rain can become freezing rain. Liquid water freezes at 32°F or 0°C. When liquid water freezes, it changes into a solid. The molecules that make up liquid water do not move fast enough to slide past each other. Instead, the molecules slow down to the point that they stay in a fixed place. They vibrate instead of moving fast enough to move past each other. That is what happens to liquid rain if it is cold enough. At about 32°F or 0°C it freezes and becomes "freezing rain" or sleet.

In a previous lesson, your class created a human model of states of matter. You changed a liquid to a gas. This is called *boiling*.

Describe how people could move their bodies to show what happens to water molecules when liquid water freezes and changes to ice.

How Do Melting and Freezing Explain Why Glaciers Are Getting Smaller?

Glaciers can shrink and grow depending on the climate of an area. Temperature is important in determining whether glaciers will grow or shrink. In fact, scientists have shown that Earth's surface temperature has risen by about 1°F or 0.6°C over the past 100 years. Scientists believe that the increase in temperature may be causing glaciers to get smaller each year.

Explain why scientists would think an increase in temperature would cause glaciers to get smaller. Remember that glaciers are huge pieces of ice. Use ideas you learned in this lesson, including melting, freezing, and water molecules.

The models you have used to explain how substances condense, boil, evaporate, melt, and freeze can also be used to explain many other phenomena, like shrinking glaciers. In the next lesson, you will read how models of particles can help explain even more things in the world.

Activity 15.2—Does Menthol Have to Melt Before I Smell It?

What Will We Do?

We will develop models and use them to explain what happens to molecules during a phase change.

Prediction

What do you expect solid dry ice to do at room temperature?

Procedure

☐ a. Your teacher will break solid carbon dioxide (dry ice) into pieces. It will be sitting on a piece of paper towel.

☐ b. Record your observations in the Data section.

Data

Making Sense

1. Use your particle model to explain what happened to the dry ice.

2. Use your observations and your particle model to explain why you can smell a solid.

Part II: Creating Models

3. Choose one of the following substances: wax, menthol, water, bromine, or CO_2.

The substance I chose is __________

Imagine that you have a special instrument that would allow you to see the molecules of the substance you chose really close.

a. Draw models of the substance in the solid, liquid, and gaseous states. What would you see in each state? Include a description of your models.

b. Share your models with your group. How are your models similar? How are they different?

Lesson 15 Reading Two—How Can I Smell Something that Is Solid?

Getting Ready

In class you observed menthol. Menthol is a white solid with a strong odor. Another white solid with a strong odor is a mothball. People use mothballs to keep moths from chewing on their wool clothes. The odor of mothballs keeps moths away.

For humans to smell a material, some of the material has to be in the gaseous state. When you hold solid mothballs, you can smell them. How do mothball molecules in the solid state get into the air?

In the space below, describe what you think could be happening to the mothball molecules in the solid state so that humans can smell them.

This reading explains the different ways substances can change phases and how you can smell mothballs that are in the solid state.

How Can Mothball Molecules Go into the Air from the Solid State?

One explanation of how you can smell a solid substance is that the solid melts into a liquid, and then the molecules evaporate into the air. Mothballs do not melt at room temperature. Instead, mothball molecules can go from the solid state right to the gaseous state. They skip the liquid state. You know that melting happens when all of the particles of a substance move fast enough to slide past each other. The molecules of mothballs are unusual. They can move fast enough so that they go right into the gaseous phase before the substance melts. When a substance skips the melting phase, and changes from the solid state right into the gaseous state, scientists say it sublimes. The process is called *sublimation*. Remember when molecules change state, they remain the same molecules. They move faster, but they do not change.

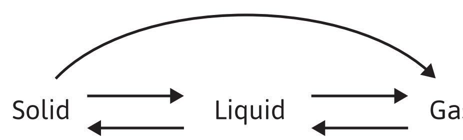
In class you observed another substance that sublimes. You saw carbon dioxide go from the solid state to the gaseous state. Carbon dioxide has to be very cold to be in the solid state. Some people call carbon dioxide dry ice because in the solid state it is very cold and looks like ice. In fact, it is even colder than ice. When solid carbon dioxide gets warm, it does not melt like ice melts. Instead, it turns into a gas at room temperature. When carbon dioxide sublimes, no liquid carbon dioxide remains in the spot where the solid was. The spot is dry. So when carbon dioxide sublimes, no liquid carbon dioxide forms.

How Many Ways Can a Substance Change Phases?

So far you learned a substance can change phases

> from a solid to a liquid—and—from a liquid to a solid, and
> from a liquid to a gas—and—from a gas to a liquid.

Now you know a substance may be able to change into the gas state without first melting. You can show this by grouping the states of matter together and then using another arrow to show that solids can go directly to the gaseous state.



How Does a Snowflake Form?

Snowflakes aren't an example of sublimation, but they are another interesting phenomenon. You have learned many ideas that can help you understand how a snowflake forms. First, remember that one component of air is gaseous water. Water particles get into the air, as a gas, when water evaporates from oceans, lakes, and rivers. Plants also give off water. It is humid in tropical areas because of the gaseous water that plants add to the air. And, every time an animal exhales, water particles go into the atmosphere in its breath. A snowflake begins with all of these gaseous water particles in the air.

As the air begins to cool, so do the water particles. In general, the particles begin to slow down. They condense, forming very tiny clusters of water. When this process happens near the ground, the particles condense on grass or other surfaces as dew. In the atmosphere high above the ground, the water particles condense onto dust particles that are in the air. Each tiny drop contains at least one dust particle. When you see a cloud, you are looking at a huge collection of liquid water and dust droplets suspended in air.

In the winter, when the temperature is below freezing, clouds are still mostly made of liquid water droplets. Although water typically freezes at 0°C (32°F), it can become super-cooled. Super-cooled water is still in a liquid state below its freezing point. When it gets even colder, around–10°C (14°F), the water and dust droplets begin to freeze. This is the start of a snowflake. As the droplet freezes, it becomes a tiny piece of ice surrounded by liquid water. As more of the liquid freezes on the surface of the ice piece, the ice grows to form a snowflake. At a certain point, the snowflake becomes heavy enough to fall. Once on the ground, the snow melts, the water evaporates, and the process starts over.

Look at how the ideas you have learned can help you explain how a snowflake forms. Liquid water evaporates into the air because of fast-moving water particles. The water particles then condense as they cool and move more slowly. As water particles condense, they grow into snowflakes. There the process starts over as the water that makes up a melted snowflake evaporates back into the air. This is the value of science! Science explains everyday events in the world around you.

Whenever you read about a process that has several steps, you might have a hard time figuring out what happens first, second, and third. It can be helpful to draw the steps to help yourself make sense of what you are reading. Try it in the following space. You could draw things like water droplets, molecules evaporating, snowflakes, clouds, and arrows. You could also use the words, or use words and pictures.

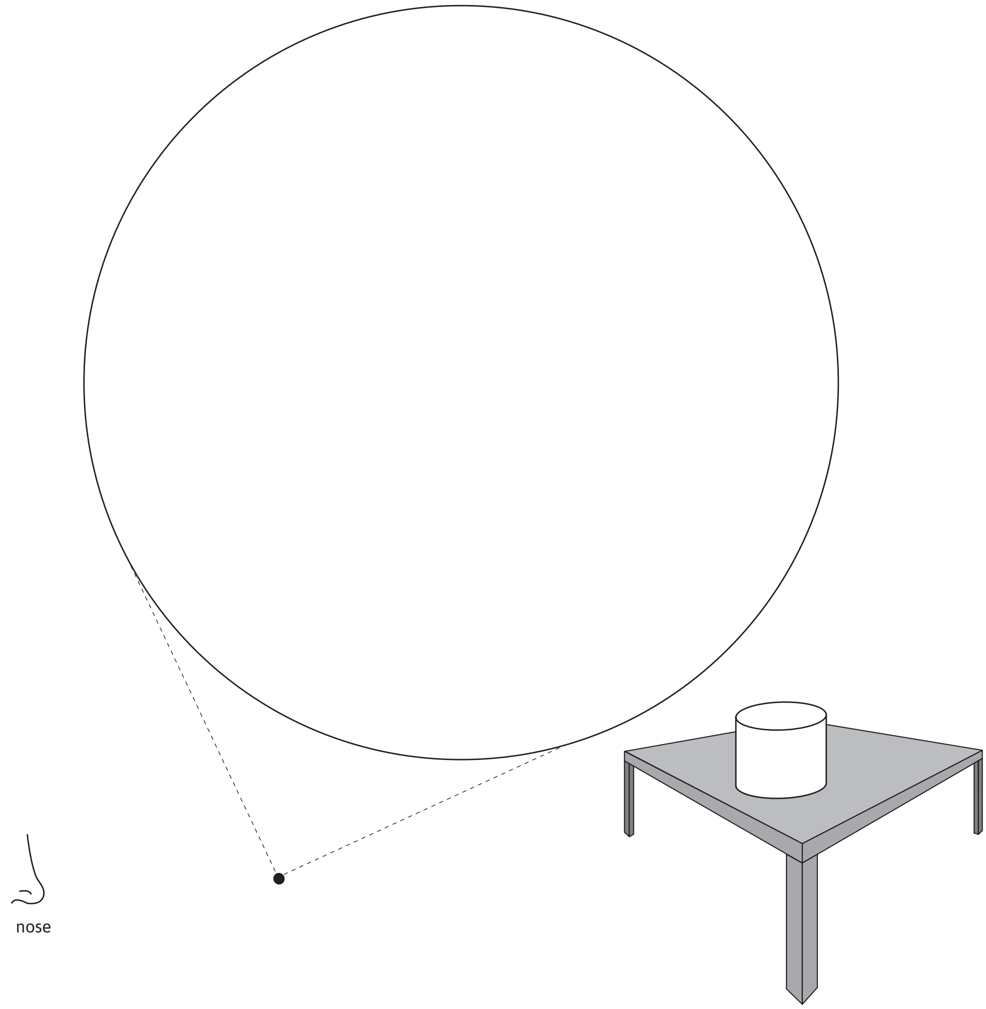
Activity 16.1—Building a Consensus Model of Matter

What Will We Do?

We will develop one more model of how odors travel. This time, we will use all of the information we learned in this unit.

A. Constructing Individual Models

1. Imagine that you have a special instrument that allows you to see what makes up odor. The large circle in the drawing represents a spot that is magnified many times, so you can see it up close. Create a model of what you would see if you could focus on one tiny spot in the area between the jar and your nose.



2. Label the parts of your model.
3. Imagine a friend of yours from a different science class was looking at your model. Describe for your friend how your model helps to explain how he or she smells odor from across the room.

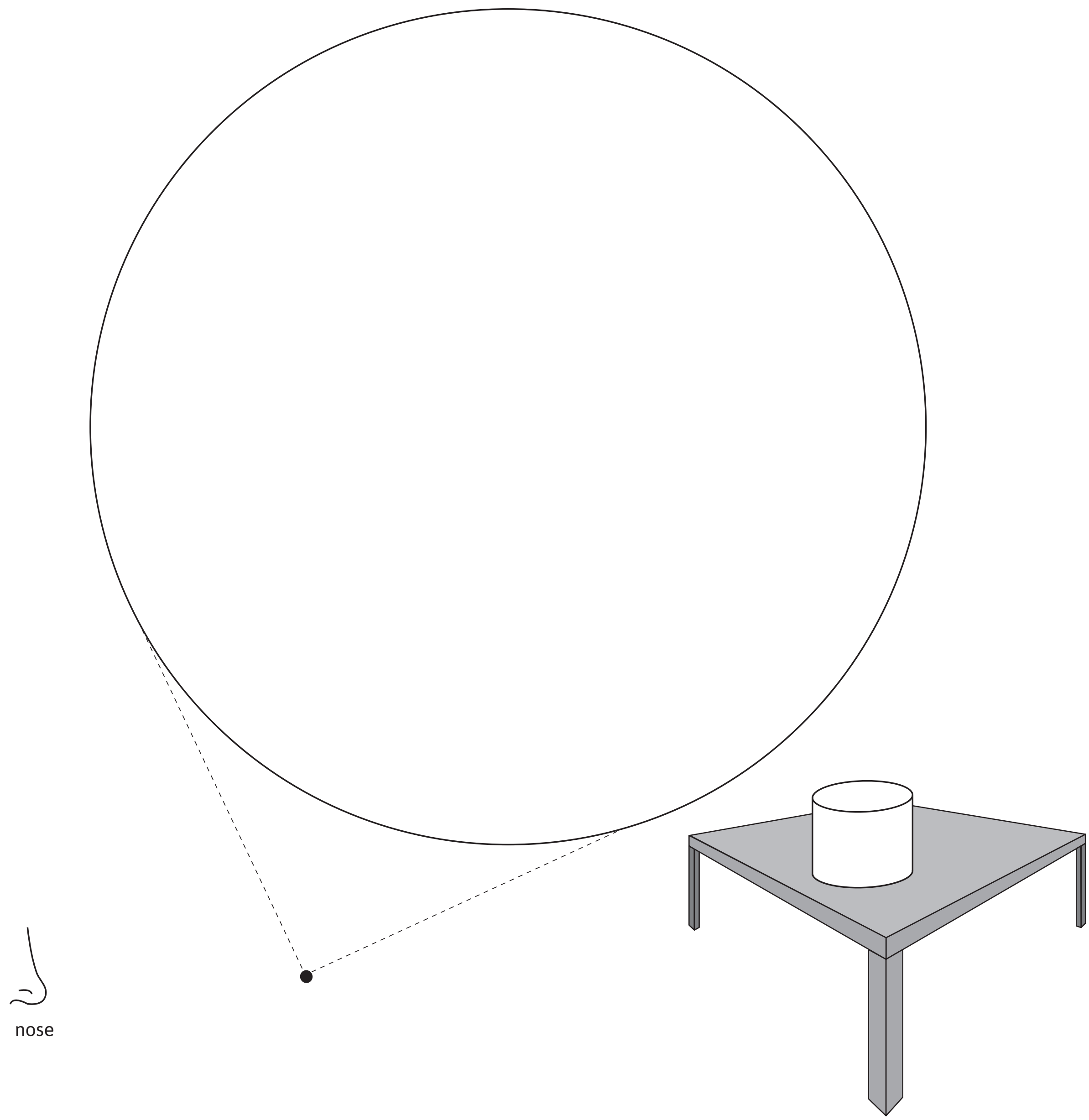
4. How is this model different from the ones you created during Lessons 1 and 5? How has your model changed?

B. Constructing Group Models

Working in your group, create a model that is consistent with everything you have learned about air and odors. A good model needs to be consistent with evidence from observations. Draw what you would see between the jar and your nose if you had an instrument that would allow you to see the smallest parts of air.

Consensus Model

1. Label the parts of your model.



2. Additional features of the consensus model are the following:

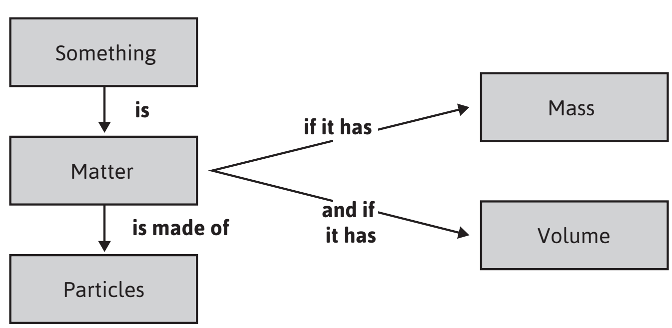
Lesson 16 Reading One—Summarizing This Unit: What Have I Learned about Matter?

Many ideas you discussed in this unit can help you answer the question, How Can I Smell Things from a Distance? For example, you learned the following:

- Matter is anything that has mass and volume.
- All matter is made of tiny particles that cannot be seen even by powerful light microscopes. Even odors are made of particles. So are trees, milk, iced tea, and you!
- Some of these particles are atoms. Some atoms stick together to form molecules.
- Molecules of different substances have a different type of atoms, a different number of atoms, or a different arrangement of atoms.
- Different substances have different properties because they are made of different atoms.
- The particles (atoms or molecules) are always moving. They collide into other particles.
- How fast particles move relates to their state of matter (solid, liquid, or gas).
- When a substance changes states, the molecules or atoms that it is made up of do not change their composition. Only the speed of the molecules changes.
- The faster particles move, the higher the temperature of the substance.

Look again at the ideas previously bulleted. Are any of these ideas still confusing? A map that shows how ideas connect to one another can help people understand ideas better.

Look at this diagram. It maps the first two bold ideas about matter. If you start reading at the "something" box and follow the arrows, you will read, "Something is matter if it has mass and if it has volume." If you follow the arrow below the "matter" box, you will read, "Matter is made of particles."



You have learned a lot about matter. You have also used your model of molecules to figure out that many substances can be in a liquid, solid, or gaseous state. You have read about the many ways scientists have used the particle model of matter to investigate phenomena and solve problems.

Activity 16.2—What Else Can My Model Explain?

What Will We Do?

We will use our consensus model, and everything we have learned to explain a real-life situation that we did not study in class.

Procedure

☐ a. Read the scenario.

☐ b. Summarize the scenario in 2–3 sentences. Hint: Think about classmates who did not read your article. What are the main ideas that will help them learn what the article is about?

☐ c. Describe how understanding the particle nature of matter is important in your scenario. Answer questions A, B, and C below.

1. What substances are involved in your scenario? What is the source of that substance? What detects the substance?

2. How does the substance reach the detector? What states of matter are involved in the scenario?

3. How is heating or cooling important in your scenario?

☐ d. All of the scenarios present a problem related to a different substance. Think about the substance and the problem, and do one of the following:
1. Create a solution to the problem with that substance.
2. Describe a different way that the substance in the article could be used.

☐ e. What new questions do you have? What else would you like to know now that you have read this article?

Scenario 1: How Can I Keep Mosquitoes from Biting Me?

Many people use lotions or sprays to keep mosquitoes from biting them. These products are called repellants because they repel insects. That means they keep insects away. The repellants that work the best contain chemicals that can also be harmful to people. So, scientists keep investigating new ways to repel mosquitoes.

Read this scenario, and think about how scientists are using their understanding of the particle model of matter to solve this problem.

Do you think frogs get bitten by mosquitoes? The answer is no. Some frogs produce a substance in their bodies that can keep mosquitoes away. Some researchers discovered a natural repellant in green tree frogs. They took the liquid from the frog's skin and put it on mice. It kept mosquitoes away from the mice. Scientists thought that the substance produced by frogs could be used by people to keep mosquitoes from biting. Unfortunately, the substance has a terrible odor. Although it would be a natural repellant, it would not only repel mosquitoes but also other people!

Although most mosquito bites just make people itch, some mosquito bites can carry serious diseases like malaria. Some mosquitoes carry a parasite that the mosquito passes on through its saliva when it draws blood from a human. The parasite multiplies in the liver of a person and eventually circulates into the blood system where it causes the red blood cells to break down. So, scientists continue to explore new mosquito repellants to keep people safer.

Scenario 2: Peanut Allergies

Do you know someone with a peanut allergy? Some people have severe reactions to peanuts. Their faces might swell up, or they might find it difficult to breathe. Their blood pressure might drop to dangerous levels. A person could actually die from eating peanuts. People with severe food allergies often carry an EpiPen®. An EpiPen contains medicine that gets injected by "stabbing" it into a person's thigh. It is designed so that the medicine can start to work quickly.

People with peanut allergies try to avoid eating peanuts or anything containing peanut oil. But, it is not always easy. Many foods are made in factories that use peanuts. You may have seen a warning: "This product is made in a factory that processes peanuts." That is a company's way to show that they do not know if a food will cause problems for someone with a peanut allergy. Sometimes peanuts are in foods that you do not expect, like salads or cookies. An even larger problem is that some people cannot even be near peanuts! Once a package of peanuts is opened, it is dangerous for some people even if they do not eat the peanuts. Breathing the air around peanuts can be dangerous. One person told a story of having her mother kiss her on her face after the mother ate peanuts, and the girl had an allergic reaction. She had to go to the hospital because of it!

Scenario 3: How Can a Skunk Smell Be Helpful?

Many people who celebrate Christmas decorate trees in their yards and houses. Many businesses sell trees for people to buy and decorate. However, instead of buying a tree, some people steal trees by cutting them down when no one is looking. Use your understanding of the particle model of matter to understand how one place is trying to stop people from cutting down their trees.

Who would want to make a tree smell like a skunk? In Minnesota, people came up with this idea after several big fir trees were stolen in the night. Someone came up with idea to spray the trees with a skunk smell to keep thieves from cutting down the trees. The groundskeeper who came up with the idea admitted that people might still cut down trees, but he thought it might prevent thieves from taking some trees. Also, the odor might not be very potent in the cold weather, but once the tree was inside a warm room, the skunk smell would permeate the room. So, at least if people did steal the trees, they would experience a big consequence! Hopefully, it also meant that thieves would realize that it was not worth it to steal trees—at least from this place!

Scenario 4: Can I Stop Garbage Odors from Smelling So Bad?

When people whose job it is to drive garbage trucks go "on strike," they stop doing their jobs until a problem that is important to them is solved. When garbage truck drivers stop working, garbage piles up. The longer trash piles up, the stinkier it gets. Use your understanding of the particle model of matter to help you think about why that happens.

What causes odor from trash? The bacteria that break down the food in trash produce a waste product that contains molecules that are released into the air. Because warming the trash influences how fast bacteria grow, the hotter it gets, the more bacteria are formed. In fact, for every 10-degree rise in temperature, bacterial growth rates double. As more bacteria are produced, they produce more gases from rotting garbage that contains meat, vegetables, and soiled diapers. In fact, the process produces so much gas that even if the garbage bags are tied really tightly, the gases build up pressure and can escape from tied garbage bags. Unfortunately, not only do the gases smell, they also send out a message to flies that lay eggs in decaying material and to rats that are attracted to the trash as a food source and because the bags make good hiding places.

Decaying meat sends out the worst smell. Bacteria convert decaying meat into products like hydrogen sulfide—similar to compounds found in skunk spray—and methyl mercaptan, the odor added to natural gas to help gas company workers find gas leaks. Although these molecules smell bad, they do not present a health risk. What concerns waste management and health officials are the flies and rats that rotting food attracts. Rats and flies can spread disease.