Chapter 3

Solids, Liquids, and Gases

CALIFORNIA Standards Preview

S 8.3 Each of the more than 100 elements of matter has distinct properties and a distinct atomic structure. All forms of matter are composed of one or more of the elements. As a basis for understanding this concept:

d. Students know the states of matter (solid, liquid, gas) depend on molecular motion.

e. Students know that in solids the atoms are closely locked in position and can only vibrate; in liquids the atoms and molecules are more loosely connected and can collide with and move past one another; and in gases the atoms and molecules are free to move independently, colliding frequently.

S 8.5 Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept:

d. Students know physical processes include freezing and boiling, in which a material changes form with no chemical reaction.

S 8.9 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

b. Evaluate the accuracy and reproducibility of data.

e. Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

In and around this hot spring, water exists as a liquid, solid, and gas. ▶

Video Preview
Discovery Channel School
Solids, Liquids, and Gases

S 8.3.e

Focus on the BIG Idea

How do solids, liquids, and gases differ in the motion of their particles?

Check What You Know

Suppose you leave a towel out on the beach on a hot, sunny day. After a few hours, you return to get the towel. How would the temperature of the towel have changed?

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Suffixes

A suffix is a letter or group of letters added to the end of a word to change its meaning and often its part of speech. For example, the suffix *-ation* added to a verb can form a noun that means "process of" or "action of."

prepare	+	ation	=	preparation
		process of		the process of preparing

In this chapter, you will learn key terms that end in the suffixes *-ation, -ine,* and *-sion*.

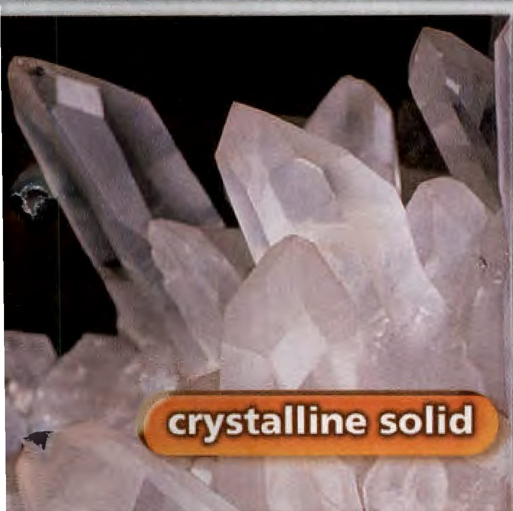
Suffix	Meaning	Part of Speech	Key Terms
-ation	State of, process of, act of	Noun	Vaporization, evaporation, condensation, sublimation
-ine	Consisting of	Adjective	Crystalline
-sion	State of, process of, act of	Noun	Surface tension

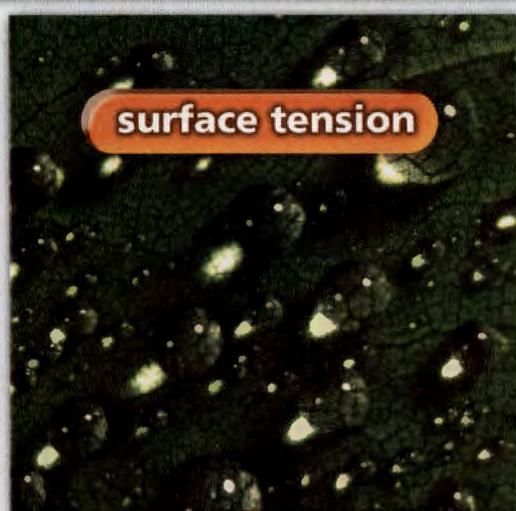
Apply It!

Vapor is another word for gas. Use the chart above to predict the meaning of *vaporization*. Revise your definition as needed.

When you come across an unfamiliar word, look at the suffix to help you determine the meaning. Then check the definition in the glossary or a dictionary.

Chapter 3 Vocabulary





Section 1 (page 90)

solid
crystalline solid
amorphous solid
liquid
fluid
surface tension
viscosity
gas

Section 2 (page 96)

melting
melting point
freezing
vaporization
evaporation
boiling
boiling point
condensation
sublimation

Section 3 (page 103)

pressure
directly proportional
inversely proportional

Interactive Textbook

Build Science Vocabulary *Online*

Visit: PHSchool.com
Web Code: cxj-1030

How to Read Science

Reading Skill

Create Outlines

An outline shows the relationship between main ideas and supporting details. An outline is set up like the one below. Roman numerals show the main topics or headings. Capital letters show the subheadings. Numbers show supporting details and key terms.

Look at the sample outline of the first part of Section 1.

Title → States of Matter

Main topics or topics

Subheadings

Supporting details

States of Matter
I. Solids
    A. Particles in a Solid
        1. Locked in position and can only vibrate
        2. Solids have definite shape and volume
    B. Tyes of Solids
        1. Crystaline solids
            a. Particles form a regular, repeating pattern
            b. Examples: salt, sugar, snow
        2. Amorphous solids
            a. Particles not arranged in a regular pattern
            b. Examples: glass, rubber, plastic
II. Liquids
    A. Particles in a Liquid

Apply It!

1. What are the main topics in this outline?
2. What details support Types of Solids?

Copy the outline above into your notebook. Use the headings, subheadings, and key terms to help you select information to complete the outline for Section 1. Create an outline for Section 3.

Lab zone

Standards Investigation

S 8.3.d

A Story of Changing States

In this chapter, you will learn how particles of matter change from a solid to a liquid to a gas. As you read this chapter, you will build a model that shows these changes.

Your Goal

To create a skit or cartoon that demonstrates how particles of matter behave as they change from a solid to a liquid to a gas and then from a gas to a liquid to a solid

To complete the investigation, you must

- describe what happens to the particles during each change of state
- outline your skit or cartoon in a storyboard format
- illustrate your cartoon or produce your skit

Plan It!

With a group of classmates, brainstorm a list of the properties of solids, liquids, and gases. You'll be working on this investigation as you study this chapter. When you finish Section 2, describe the motion of particles in solids, liquids, and gases, and begin preparing a storyboard. Add information when you finish Section 3, and complete your cartoon or skit at the end of the chapter. Finally, present your completed skit or cartoon to the class.

Section 1

States of Matter

CALIFORNIA Standards Focus

S 8.3.e Students know that in solids the atoms are closely locked in position and can only vibrate; in liquids the atoms and molecules are more loosely connected and can collide with and move past one another; and in gases the atoms and molecules are free to move independently, colliding frequently.

- How can you describe the motion of particles in a solid?
- How can you describe the motion of particles in a liquid?
- How can you describe the motion of particles in a gas?

Key Terms

- solid
- crystalline solid
- amorphous solid
- liquid
- fluid
- surface tension
- viscosity
- gas

Lab zone **Standards Warm-Up**

What Are Solids, Liquids, and Gases?

1. Break an antacid tablet (fizzing type) into three or four pieces. Place them inside a large, uninflated balloon.
2. Fill a 1-liter plastic bottle about halfway with water. Stretch the mouth of the balloon over the top of the bottle, taking care to keep the tablet pieces inside the balloon.
3. Jiggle the balloon so that the pieces fall into the bottle. Observe what happens for about two minutes.
4. Remove the balloon and examine its contents.

Think It Over

Forming Operational Definitions Identify examples of the different states of matter—solids, liquids, and gases—that you observed in this activity. Define each of the three states in your own words.

What are the speed skaters in Figure 1 skating on? You probably answered "ice." But you may have also answered "water." So which is the right answer?

In fact, both answers are correct. "Water" refers to the substance that makes up the skating rink—a compound with the chemical formula H_2O. Depending on the temperature and pressure, water can exist as a solid, liquid, or gas. "Ice" refers to frozen water, or water in solid form.

FIGURE 1
Water as a Solid
Ice, or water in solid form, makes a great surface for skating.
Observing *What useful property does the frozen water have here?*

Your everyday world is full of substances that can be classified as solids, liquids, or gases. Another state of matter, called plasma, is common on the sun and other stars, but does not often occur naturally on Earth. Certain technologies, such as fluorescent lightbulbs, make use of plasma.

Solids, liquids, and gases may be elements, compounds or mixtures. One of the solid forms of the element carbon is diamond. Water is a compound you've seen as both a solid and a liquid. Air is a mixture of gases. Although it's easy to list examples of these three states of matter, defining them is more difficult. To define solids, liquids, and gases, you need to examine their properties.

Solids

What would happen if you were to pick up a solid object, such as a pen or a comb, and move it from place to place around the room? What would you observe? Would the object ever change in size or shape as you moved it? Would a pen become larger if you put it in a bowl? Would a comb become flatter if you placed it on a tabletop? Of course not. A **solid** has a definite shape and a definite volume. If your pen has a cylindrical shape and a volume of 6 cubic centimeters, then it will keep that shape and volume in any position and in any container.

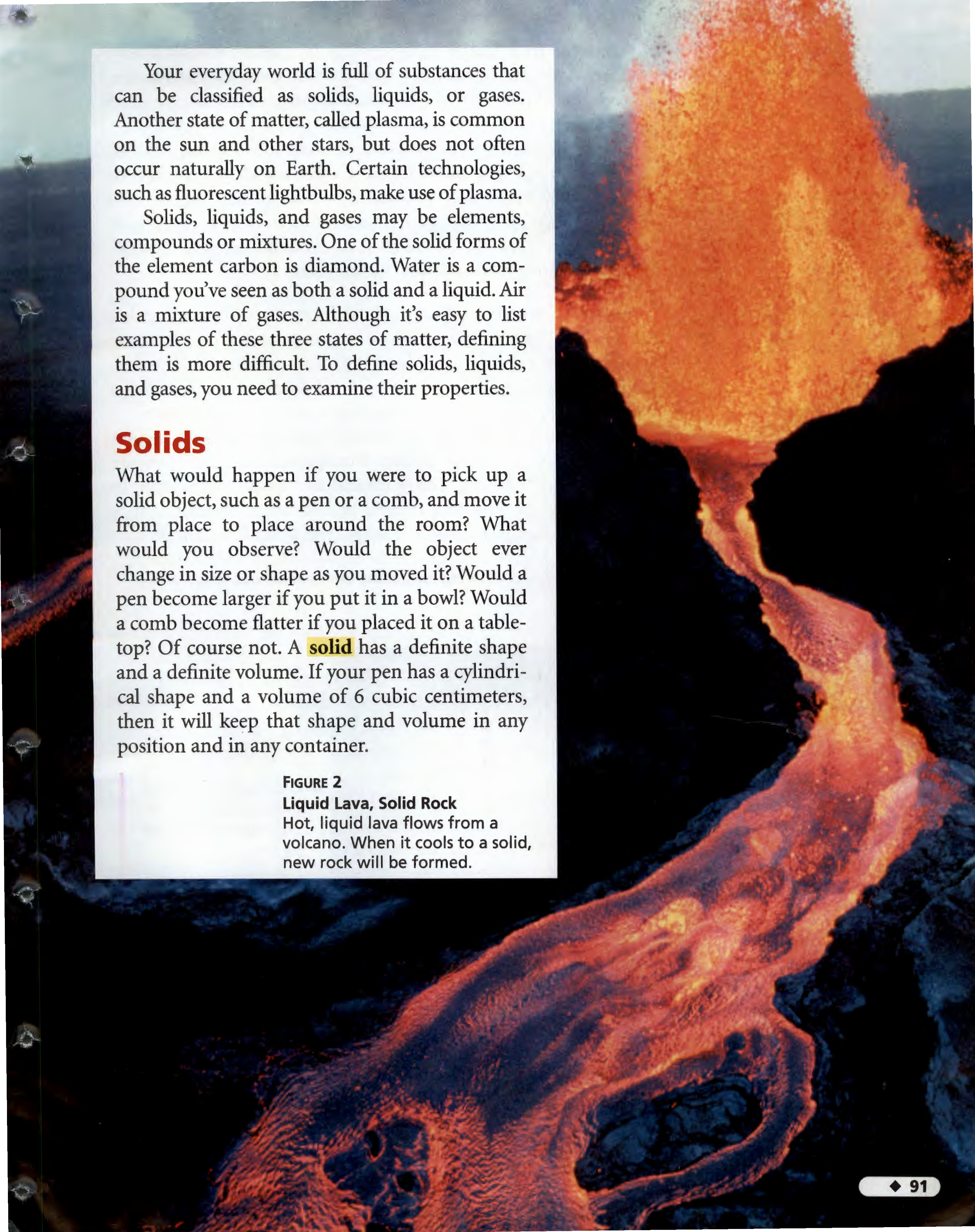


FIGURE 2
Liquid Lava, Solid Rock
Hot, liquid lava flows from a volcano. When it cools to a solid, new rock will be formed.

FIGURE 3
Particle View of a Solid
Particles of a solid vibrate back and forth but are closely locked in position.

Particles in a Solid The particles in a solid are packed very closely together. In addition, each particle is tightly fixed in one position. This fixed, closely packed arrangement causes a solid to have a definite shape and volume.

Do the particles that make up a solid move at all? Yes, but not much. **The particles in a solid are closely locked in position and can only vibrate.** This means that the particles move back and forth slightly, like a group of people running in place. In a solid, the particles have enough energy to vibrate, but not enough to slide past one another.

Types of Solids In many solids, the particles form a regular, repeating pattern. These patterns create crystals. Solids that are made up of crystals are called **crystalline solids** (KRIS tuh lin). Salt, sugar, and snow are examples of crystalline solids. When a crystalline solid is heated, it melts at a specific temperature.

In **amorphous solids** (uh MAWR fus), the particles are not arranged in a regular pattern. Plastics, rubber, and glass are amorphous solids. Unlike a crystalline solid, an amorphous solid does not melt at a distinct temperature. Instead, it may become softer and softer or change into other substances.

Reading Checkpoint **How do crystalline and amorphous solids differ?**

FIGURE 4
Types of Solids
Solids are either crystalline or amorphous.

◀ Quartz is a crystalline solid. Its particles are arranged in a regular pattern.

◀ Butter is an amorphous solid. Its particles are not arranged in a regular pattern.

Go Online
SCILINKS NSTA
For: Links on solids
Visit: www.SciLinks.org
Web Code: cxn-1031

Liquids

A **liquid** has a definite volume but no shape of its own. Without a container, a liquid spreads into a wide, shallow puddle. Like a solid, however, a liquid does have a fixed volume. Suppose you have 100 milliliters of a liquid in a graduated cylinder, as shown in Figure 5. If you pour the liquid into a flask, you still have 100 milliliters. The liquid has the same volume no matter what shape its container has.

Particles in a Liquid In general, the particles in a liquid are packed almost as closely as in a solid. However, the particles in a liquid move freely. **Compared to particles in a solid, the particles in a liquid are more loosely connected and can collide with and move past one another.** As a result, a liquid flows and has no definite shape. A liquid is an example of a **fluid,** meaning a "substance that flows."

You can compare the movement of particles in a liquid to the way you might move a group of marbles around in your hand. Like the particles of a liquid, the marbles slide around one another but stay in contact. In solid or liquid form, the atoms of a substance stay at about the same average distance. So the density of the liquid remains very close to that of the solid.

FIGURE 5
Equivalent Volumes
A liquid takes the shape of its container but its volume does not change.

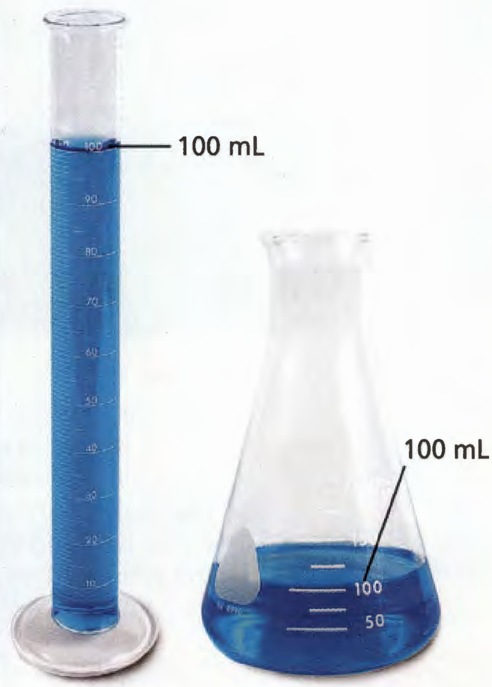


FIGURE 6
Particle View of a Liquid
Particles in a liquid are packed close together, but can collide and move past one another, allowing liquids to flow. **Comparing and Contrasting** *How are liquids and solids alike? How do they differ?*

FIGURE 7
Surface Tension
Water beads up on a leaf due to attractions between the water molecules. Surface tension in water is strong enough to support the weight of an insect.

Lab zone Try This Activity

As Thick as Honey

You can compare the viscosity of two liquids.

1. Place on a table a clear plastic jar three-quarters full of honey and another clear plastic jar three-quarters full of vegetable oil. Make sure that the tops of both jars are tightly closed.
2. Turn the jars upside down at the same time. Observe what happens.
3. Turn the two jars right-side up and again watch what happens.

Drawing Conclusions Which fluid has a greater viscosity? In which liquid do you think the particles are more loosely connected?

Properties of Liquids One characteristic property of liquids is surface tension. **Surface tension** is the result of an inward pull among the molecules of a liquid that brings the molecules on the surface closer together. Perhaps you have noticed that water forms droplets and can bead up on many surfaces, such as the leaf shown in Figure 7. That's because water molecules attract one another strongly. These attractions cause molecules at the water's surface to be pulled slightly toward the water molecules beneath the surface.

Due to surface tension, the surface of water can act like a sort of skin. For example, a sewing needle floats when you place it gently on the surface of a glass of water, but it quickly sinks if you push it below the surface. Surface tension enables the insect in Figure 7 to "walk" on the calm surface of a pond.

Another property of liquids is **viscosity** (vis KAHS uh tee)—a liquid's resistance to flowing. A liquid's viscosity depends on the size and shape of its particles and the attractions between the particles. Some liquids flow more easily than others. Liquids with high viscosity flow slowly. Honey is an example of a liquid with a particularly high viscosity. Liquids with low viscosity flow quickly. Water and vinegar have relatively low viscosities.

Reading Checkpoint **What property of liquids causes water to form droplets?**

Gases

Like a liquid, a gas is a fluid. Unlike a liquid, however, a **gas** can change volume very easily. If you put a gas in a closed container, the gas particles will either spread apart or be squeezed together as they fill that container. Take a deep breath. Your chest expands, and your lungs fill with air. Air is a mixture of gases. When you breathe in, air moves from your nose to your windpipe to your lungs. In each place, the air has a different shape. When you breathe out, the changes happen in reverse.

If you could see the particles that make up a gas, you would see them moving in all directions, as shown in Figure 8. As they move, gas particles spread apart, filling all the space available. Thus, a gas has neither definite shape nor definite volume.

Compared to particles in a liquid, the particles in a gas have more energy of motion. **In gases, the atoms and molecules are free to move independently, colliding frequently.** The distance between particles in a gas is much larger than the distance between particles in a solid or a liquid. You will read more about the behavior of gases in Section 3.

FIGURE 8
Particle View of a Gas
Gas particles move about freely and collide randomly with the walls of a container and with each other. **Predicting** *What will happen if the container lid is removed?*

Section 1 Assessment

S 8.3.e, E-LA: Reading 8.2.0

Target Reading Skill **Create Outlines** In your notebook, complete your outline for Section 1. What supporting details did you include under Properties of Liquids?

Reviewing Key Concepts

1. a. **Defining** What is a solid?
   b. **Describing** How can the motion of particles in a solid be described?
   c. **Comparing and Contrasting** How do crystalline solids differ from amorphous solids?
2. a. **Describing** How may liquids be described in terms of shape and volume?
   b. **Explaining** How do the positions and movements of particles in a liquid help to explain the shape and volume of the liquid?
   c. **Relating Cause and Effect** Explain why a sewing needle can float on the surface of water in a glass.
3. a. **Describing** How can the motion of particles in a gas be described?
   b. **Reviewing** What determines the shape and volume of a gas inside a container?
   c. **Applying Concepts** Use what you know about the particles in a gas to explain why a gas has no definite shape or volume.

Lab zone At-Home Activity

Squeezing Liquids and Gases Show your family how liquids and gases differ. Fill the bulb and cylinder of a turkey baster with water. Seal the end with your finger and hold it over the sink. Have a family member squeeze the bulb. Now empty the turkey baster. Again, seal the end with your finger and have a family member squeeze the bulb. Did the person notice any difference? Use what you know about liquids and gases to explain your observations.

Section 2

Changes of State

CALIFORNIA Standards Focus

S 8.3.d Students know the states of matter (solid, liquid, gas) depend on molecular motion.

S 8.5.d Students know physical processes include freezing and boiling, in which a material changes form with no chemical reaction.

- What happens to a substance during changes between solid and liquid?
- What happens to a substance during changes between liquid and gas?
- What happens to a substance during changes between solid and gas?

Key Terms

- melting
- melting point
- freezing
- vaporization
- evaporation
- boiling
- boiling point
- condensation
- sublimation

Lab zone Standards Warm-Up

What Happens When You Breathe on a Mirror?

1. Obtain a hand mirror. Clean it with a dry cloth. Describe the mirror's surface.
2. Hold the mirror about 15 cm away from your face. Try to breathe against the mirror's surface.
3. Reduce the distance until breathing on the mirror produces a visible change. Record what you observe.

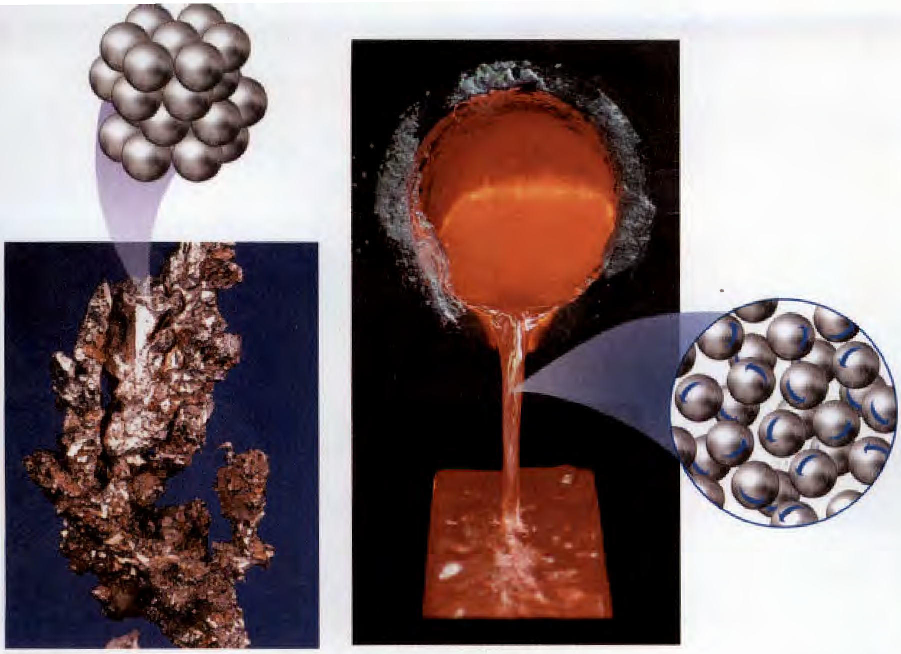
Think It Over

Developing Hypotheses What did you observe when you breathed on the mirror held close to your mouth? How can you explain that observation? Why did you get different results when the mirror was at greater distances from your face?

Picture an ice cream cone on a hot summer day. The ice cream quickly starts to drip onto your hand. You're not surprised. You know that ice cream melts if it's not kept cold. But why does the ice cream melt?

Particles of a substance at a warmer temperature have more thermal energy than particles of that same substance at a cooler temperature. You may recall that thermal energy always flows as heat from a warmer substance to a cooler substance. So, when you take ice cream outside on a hot summer day, it absorbs thermal energy from the air and your hand. The added energy changes the ice cream from a solid to a liquid.

Increased thermal energy turns an ice cream cone into a gooey mess! ▶



Solid silver | Liquid silver

FIGURE 9
Solid to Liquid
In solid silver, the atoms are in a regular, cubic pattern. The atoms in liquid (molten) silver have no regular arrangement.
Applying Concepts *How can a jewelry maker take advantage of changes in the state of silver?*

Changes Between Solid and Liquid

Particles of a liquid have more thermal energy than particles of the same substance in solid form. As a gas, the particles have even more thermal energy. So, a change from solid to liquid involves an increase in thermal energy. A change from liquid to solid is just the opposite: It involves a decrease in thermal energy.

Any change in thermal energy means a change in molecular motion. States of matter depend on molecular motion. For any substance, the freedom of motion of its particles increases from solids to liquids to gases. Resisting this motion are forces of attraction among the particles. The balance between the particles' motions and attractive forces determines the state of matter.

Melting The change in state from a solid to a liquid is called **melting**. In most pure substances, melting occurs at a characteristic temperature called the **melting point**. The melting point of pure water is 0°C. The melting point of table salt is 800.7°C. Note that melting point changes with air pressure.

When a substance melts, the particles in the solid vibrate so fast that they break free from their fixed positions. Think of an ice cube taken from the freezer. The energy to melt the ice comes mostly from the air in the room. At first, the added thermal energy increases the average molecular motion of the water. The molecules vibrate faster, and the temperature of the ice increases. But at 0°C, the temperature of the ice stops increasing. Any added energy causes the water molecules to break out of their positions in crystals and to collide with one another. The ice melts into liquid water.

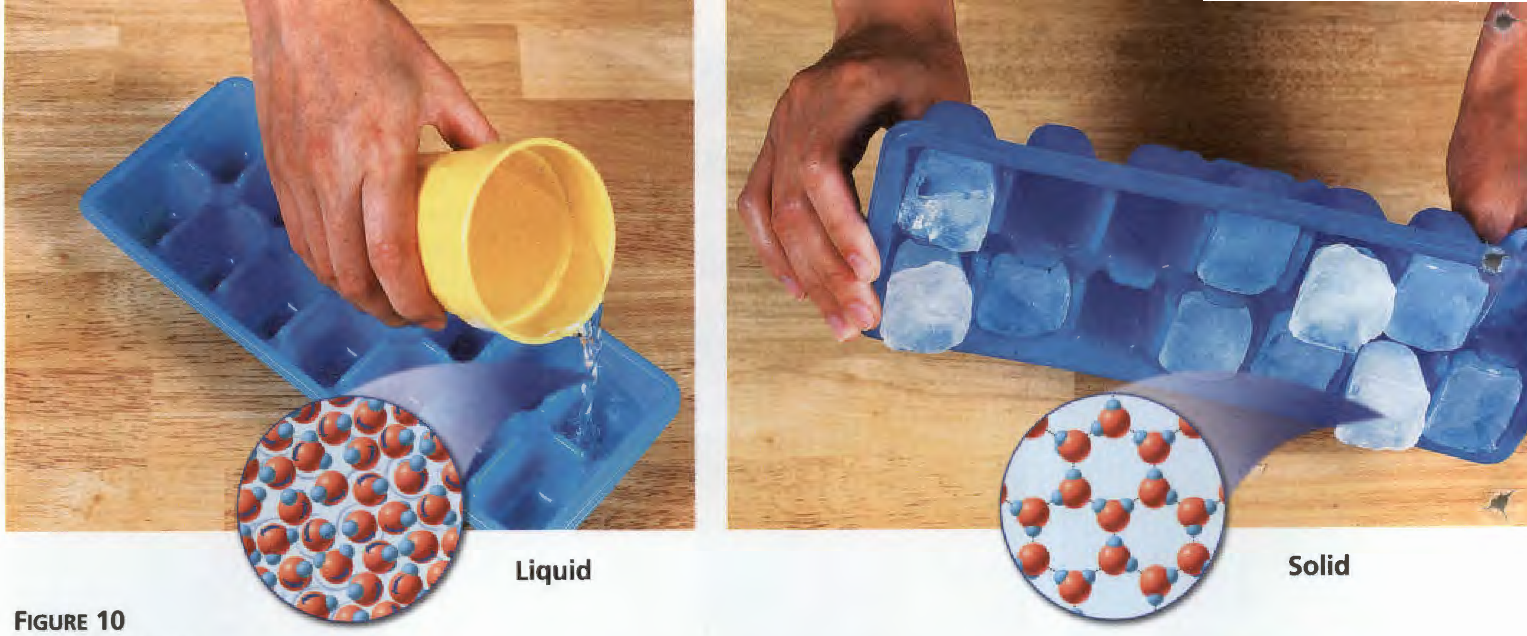


FIGURE 10
Liquid to Solid
Just a few hours in a freezer will change liquid water into a solid.

Freezing The change from a liquid to a solid is called **freezing.** It is just the reverse of melting. **When a substance freezes, the particles in the liquid move so slowly that they begin to take on fixed positions.** Suppose you put liquid water into a freezer. The water loses energy to the cold air in the freezer. The water molecules move more slowly as they lose energy. The freedom of motion of the molecules decreases. Over time, the water becomes solid ice. When water begins to freeze, its temperature remains at 0°C until freezing is complete. The freezing point of water, 0°C, is the same as its melting point.

Note that both melting and freezing are reversible physical changes. They are not chemical changes. Liquid water that freezes is still water. Likewise, ice that melts is still water. Physical changes can usually be undone to recover the original materials unchanged. For example, after melting an ice cube, you can freeze the liquid water to recover the original solid.

Reading Checkpoint **What happens to the particles of a liquid as they lose more and more energy?**

Changes Between Liquid and Gas

Have you ever wondered how clouds form or how puddles dry up after a rain shower? To answer these questions, you need to look at the changes that occur between liquid and gas states.

The change from a liquid to a gas is called **vaporization** (vay puhr ih ZAY shun). **Vaporization takes place when the particles in a liquid gain enough energy to move independently, forming a gas.** As a substance changes from liquid to gas, the relative freedom of motion of its atoms or molecules increases. There are two main types of vaporization—evaporation and boiling.

Lab zone Try This Activity

Keeping Cool

1. Wrap the bulbs of two alcohol thermometers with equal amounts of gauze.
2. Lay the thermometers on a paper towel on a table.
3. Use a medicine dropper to put 10 drops of water on the gauze surrounding the bulb of one thermometer.
4. Using rubbing alcohol rather than water, repeat step 3 with the second thermometer.
5. Read the temperatures on the two thermometers for several minutes.

Interpreting Data Which liquid evaporates faster? Explain your answer.

Evaporation Vaporization that takes place only on the surface of a liquid is called **evaporation** (ee vap uh RAY shun). A shrinking puddle is an example. Water in the puddle gains energy from the ground, the air, or the sun. The added energy enables some of the water molecules on the surface of the puddle to escape into the air, or evaporate.

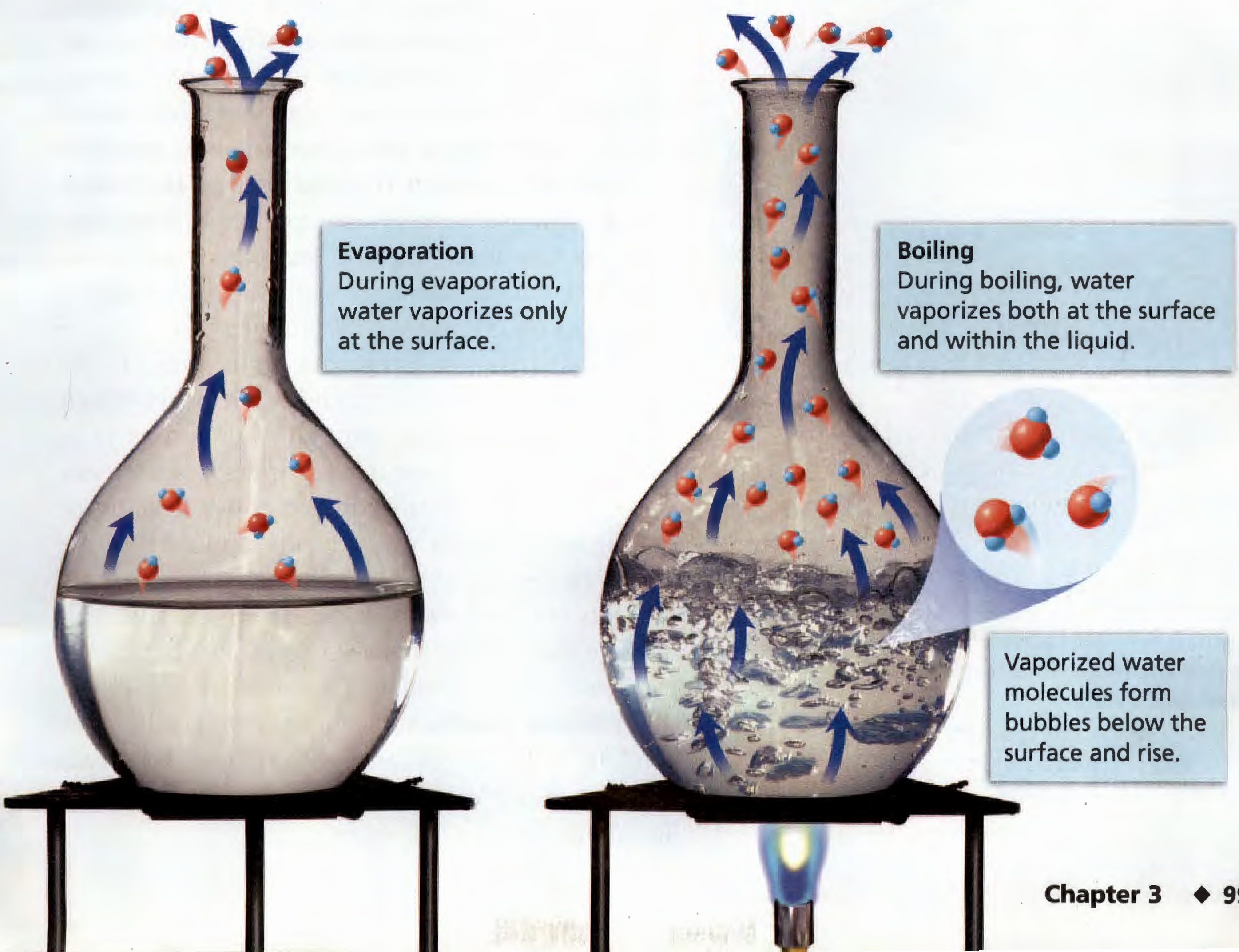
Boiling Have you ever watched a pot of water boiling on a stove? **Boiling** occurs when a liquid changes to a gas below its surface as well as at the surface. When water boils, vaporized water molecules form bubbles below the surface. The bubbles rise and eventually break the surface of the liquid.

The temperature at which a liquid boils is called its **boiling point**. The boiling point of a substance depends on the pressure of the air above it. The lower the pressure, the less energy needed for the particles of the liquid to escape into the air. In places close to sea level, the boiling point of water is 100°C. In the mountains, however, the air pressure is lower, and so is the boiling point of water. In Denver, Colorado, where the elevation is 1,600 meters above sea level, water boils at 95°C. Boiling point is a characteristic property of a substance.

Go Online
SCILINKS NSTA

For: Links on changes of state
Visit: www.SciLinks.org
Web Code: cxn-1032

FIGURE 11
Evaporation and Boiling
Liquids can vaporize in two ways.
Interpreting Diagrams *How do these processes differ?*

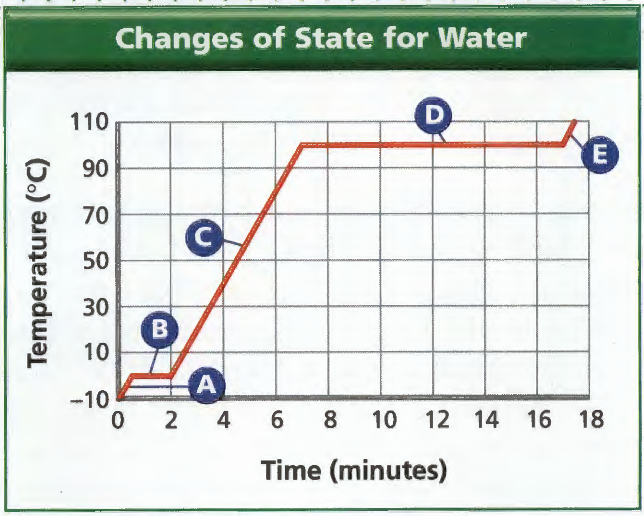


Reviewing Math: Algebra and Functions 7.1.5

Math Analyzing Data

Temperature and Changes of State

A beaker of ice at −10°C was slowly heated to 110°C. The graph shows how the temperature of the water changed over time.



1. **Reading Graphs** What two variables are plotted on the graph?
2. **Reading Graphs** What is happening to the temperature of the water during segment C of the graph?
3. **Interpreting Data** What does the temperature value for segment B represent? For segment D?
4. **Drawing Conclusions** What change of state is occurring during segment B of the graph? During segment D?
5. **Inferring** In which segment, A or E, do the water molecules have more thermal energy? Explain your reasoning.

FIGURE 12
Condensation of Water
Water vapor from a hot shower contacts the cool surface of a bathroom mirror and condenses into liquid water.

Condensation The reverse of vaporization is condensation. **Condensation** is the change in state from a gas to a liquid. You can observe condensation by breathing onto a mirror. When warm water vapor in your breath reaches the cooler surface of the mirror, the water vapor condenses into liquid droplets. **During condensation, the particles in a gas lose enough thermal energy to form a liquid.** The gas particles can no longer overcome the attractive forces among them. As a substance changes from gas to liquid, the relative freedom of motion of its atoms or molecules decreases.

Clouds typically form when water vapor in the atmosphere condenses into liquid droplets. When the droplets get heavy enough, they fall as rain. Note that water vapor is a colorless gas that you cannot see. The steam you see above a kettle of boiling water is not water vapor, and neither are clouds or fog. What you see in those cases are tiny droplets of liquid water suspended in air.

Like the changes between solid and liquid, the changes between liquid and gas are reversible physical processes. When a substance evaporates, boils, or condenses, it changes form with no chemical reaction. For example, when water vapor condenses, the liquid that forms is still water.

Changes Between Solid and Gas

If you live where the winters are cold, you may have noticed that snow seems to disappear even when the temperature stays well below freezing. This change is the result of sublimation. **Sublimation** occurs when the surface particles of a solid gain enough energy that they form a gas. **During sublimation, particles of a solid do not pass through the liquid state as they form a gas.** As a solid substance sublimates into a gas, the relative freedom of motion of its particles increases.

One example of sublimation occurs with dry ice. Dry ice is the common name for solid carbon dioxide. At ordinary atmospheric pressures, carbon dioxide cannot exist as a liquid. So instead of melting, solid carbon dioxide changes directly into a gas. As it changes state, the carbon dioxide absorbs thermal energy. If warmer materials are placed near dry ice, they will lose thermal energy and become colder. For this reason, dry ice can be used to keep things cold when a refrigerator is not available. When dry ice becomes a gas, it cools water vapor in the nearby air. The water vapor then condenses into a liquid, forming fog around the dry ice.

FIGURE 13
Dry Ice
When solid carbon dioxide, called "dry ice," sublimates, it changes directly into a gas. **Predicting** *If you allowed the dry ice to stand at room temperature for several hours, what would be left in the glass dish? Explain.*

Reading Checkpoint **What physical state is skipped during the sublimation of a substance?**

Section 2 Assessment

S 8.3.d, 8.5.d, E-LA: Reading 8.1.0, Writing 8.2.0

Vocabulary Skill **Suffixes** Complete the sentences using the correct word form (*vaporize/ vaporization*). As a pot of water boils, the liquid will ____ and form a gas. Boiling and evaporation are two types of ____.

Reviewing Key Concepts

1. a. **Reviewing** What happens to the particles of a solid as it becomes a liquid?
   b. **Applying Concepts** How does the thermal energy of solid water change as it melts?
   c. **Making Judgments** You are stranded in a blizzard. You need water to drink, and you're trying to stay warm. Should you melt snow and then drink it, or just eat snow? Explain.
2. a. **Describing** What is vaporization?
   b. **Comparing and Contrasting** Name the two types of vaporization. Tell how they are similar and how they differ.
   c. **Relating Cause and Effect** Why does the evaporation of sweat cool your body on a warm day?
3. a. **Identifying** What process occurs as pieces of dry ice gradually get smaller?
   b. **Interpreting Photos** What is the fog you see in the air around the dry ice in Figure 13? Why does the fog form?

Writing in Science

Using Analogies Write a short essay in which you create an analogy to describe particle motion. Compare the movements and positions of people dancing with the motions of water molecules in liquid water and in water vapor.

Lab zone **Skills Lab**

Go Online
PHSchool.com
For: Data sharing
Visit: PHSchool.com
Web Code: cgd-1022

Melting Ice

S 8.3.d, 8.9.b

Problem

How does the temperature of the surroundings affect the rate at which ice melts?

Skills Focus

predicting, interpreting data, inferring

Materials

- stopwatch or timer
- thermometer or temperature probe
- 2 plastic cups, about 200 mL each
- 2 stirring rods, preferably plastic
- ice cubes, about 2 cm on each side
- warm water, about 40°C–45°C
- water at room temperature, about 20°C–25°C

Procedure

1. Read Steps 3–8. Based on your own experience, predict which ice cube will melt faster.
2. In your notebook, make a data table like the one below.
3. Fill a cup halfway with warm water (about 40°C to 45°C). Fill a second cup to the same depth with water at room temperature.
4. Record the exact temperature of the water in each cup. If you are using a temperature probe, see your teacher for instructions.
5. Obtain two ice cubes that are as close to the same size as possible.
6. Place one ice cube in each cup. Begin timing with a stopwatch. Gently stir each cup with a stirring rod until the ice has completely melted.
7. Observe both ice cubes carefully. At the moment one of the ice cubes is completely melted, record the time and the temperature of the water in the cup.
8. Wait for the second ice cube to melt. Record its melting time and the water temperature.

Data Table

Cup	Beginning Temperature (°C)	Time to Melt (s)	Final Temperature (°C)
1			
2			

Analyze and Conclude

1. **Predicting** Was your prediction in Step 1 supported by the results of the experiment? Explain why or why not.
2. **Interpreting Data** In which cup did the water temperature change the most? Explain.
3. **Inferring** The ice absorbed energy as it melted. What was the source of that energy? How did the added energy affect the relative freedom of motion of the water molecules?
4. **Communicating** Write a paragraph describing how errors in measurement could have affected your conclusions in this experiment. Tell what you would do differently if you repeated the procedure. (*Hint*: How well were you able to time the exact moment that each ice cube completely melted?)

Design an Experiment

When a lake freezes in winter, only the top turns to ice. Design an experiment to model the melting of a frozen lake during the spring. *Obtain your teacher's permission before carrying out your investigation.* Be prepared to share your results with the class.

Section 3

The Behavior of Gases

CALIFORNIA
Standards Focus

S 8.3.d Students know the states of matter (solid, liquid, gas) depend on molecular motion.

S 8.9.e Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

- What types of measurements are useful when working with gases?
- How are the volume, temperature, and pressure of a gas related?

Key Terms

- pressure
- directly proportional
- inversely proportional

Lab zone Standards Warm-Up

How Can Air Keep Chalk From Breaking?

1. Stand on a chair and drop a piece of chalk onto a hard floor. Observe what happens to the chalk.
2. Wrap a second piece of chalk in wax paper or plastic food wrap. Drop the chalk from the same height used in Step 1. Observe the results.
3. Wrap a third piece of chalk in plastic bubble wrap. Drop the chalk from the same height used in Step 1. Observe the results.

Think It Over

Inferring Compare the results from Steps 1, 2, and 3. What properties of the air in the bubble wrap accounted for the results in Step 3?

How do you prepare a hot-air balloon for a morning ride? First, you inflate the balloon, using powerful air fans. Then you heat the air inside with propane gas burners. For the balloon and its cargo to rise, the air inside the balloon must be less dense than the air outside the balloon. How does this happen? How can you keep the balloon floating safely through the atmosphere? How can you make it come down when you are ready to land? To answer these questions, you need to understand the relationships among the temperature, pressure, and volume of a gas.

Before a flight, a hot-air balloon is filled with air. ▶

Measuring Gases

How much helium is in the tank in Figure 14? If you don't know the mass of the helium, will measuring the volume of the tank give you the answer? Gases easily contract and expand. To fill the tank, helium was compressed—or pressed together tightly—to decrease its volume. When you use the helium to fill balloons, it fills a total volume of inflated balloons much greater than the volume of the tank. The resulting volume of helium, however, depends on the temperature and air pressure that day. **When working with a gas, it is helpful to know its volume, temperature, and pressure.** So what exactly do these measurements mean?

Volume From Chapter 1, you know that volume is the amount of space that matter fills. Volume is measured in cubic centimeters (cm^3), milliliters (mL), liters (L), and other units. Because gas particles move and fill the space available, the volume of a gas is the same as the volume of its container.

Temperature Hot soup, cold ice packs, warm hands, cool breezes—you are familiar with matter at different temperatures. But what does temperature tell you? Recall that all atoms and molecules are constantly moving. Temperature is a measure of the average energy of motion of the particles of matter. The faster the particles are moving, the greater their energy and the higher the temperature. You might think of a thermometer as a speedometer for molecules.

Even at room temperature, the average speed of particles in a gas is very fast. At about 20°C, the particles in a typical gas travel about 500 meters per second—more than twice the cruising speed of a jet plane!

FIGURE 14
How Much Helium?
A helium tank the height of this girl can fill over 500 balloons!
Interpreting Photos *How is the helium in the tank different from the helium in the balloons?*

Pressure Gas particles constantly collide with one another and with the walls of their container. As a result, the gas pushes on the walls of the container. The **pressure** of the gas is the force of its outward push divided by the area of the walls of the container. Pressure is measured in units of pascals (Pa) or kilopascals (kPa). (1 kPa = 1,000 Pa)

The firmness of a gas-filled object comes from the pressure of the gas. For example, the air inside a fully pumped basketball has a higher pressure than the air outside. This higher pressure is due to a greater number of gas particles per unit volume inside the ball than in the surrounding air.

What would happen if you punctured a hole in the basketball? Air would leak out of the ball through the hole. The pressure inside the ball would decrease, and the ball would become softer. Why does the air inside the ball leak out, rather than the surrounding air flow into the ball?

The higher pressure inside the ball results in gas particles hitting the inner surface of the ball more often. Therefore, gas particles inside the ball reach the hole and escape more often than gas particles outside the ball reach the hole and enter. Thus, many more particles go out than in. The pressure inside drops until it is equal to the pressure outside.

Reading Checkpoint **What units are used to measure pressure?**

Lab zone Try This **Activity**

Under Pressure

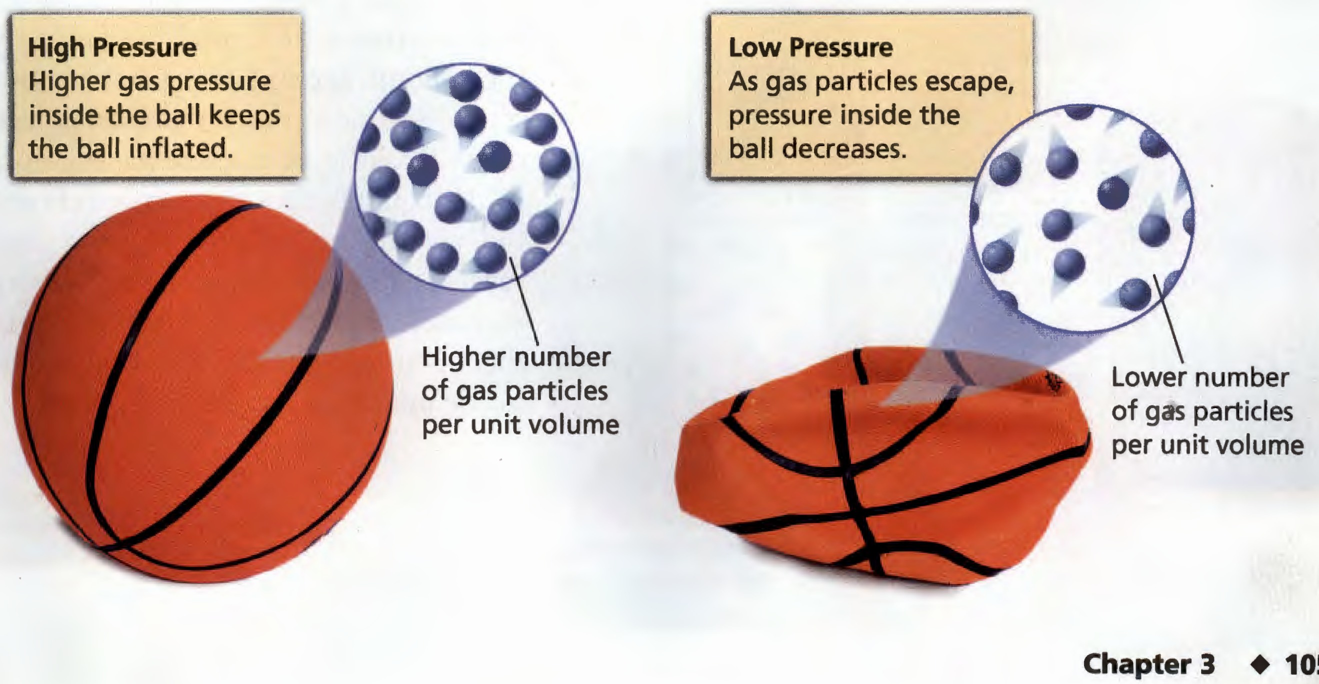
1. Obtain a round, inflatable party balloon and a pushpin.
2. Inflate the balloon and knot the end.
3. Carefully prick a hole in the balloon with a pushpin. Observe what happens.

Inferring Was the air pressure higher inside or outside the balloon? Why did the balloon deflate?

FIGURE 15

A Change in Pressure

A punctured basketball deflates as the gas particles begin to escape.



A A tied, gas-filled balloon is at room temperature.

B The balloon is lowered into liquid nitrogen at –196°C.

C The balloon shrinks as gas volume decreases.

FIGURE 16
Cooling a Balloon
The volume of a gas-filled balloon decreases as temperature decreases, and then increases as temperature increases.

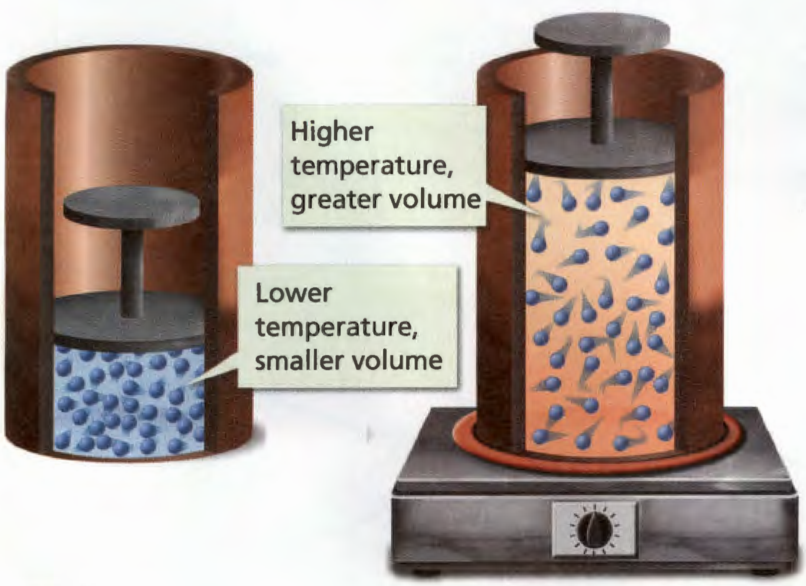
Temperature and Volume

Figure 16 shows what happens when a balloon is slowly lowered into liquid nitrogen at nearly −200°C, then removed. As the air inside the balloon cools, its volume decreases. When the air warms up again, its volume increases. The pressure remains more or less constant because the air is in a flexible container.

Charles's Law French scientist Jacques Charles examined the relationship between the temperature and volume of a gas that is kept at a constant pressure. He measured the volume of a gas at various temperatures in a container that could change volume. **When the temperature of a gas is increased at constant pressure, its volume increases. When the temperature of a gas is decreased at constant pressure, its volume decreases.** This principle is called Charles's law.

Now think again about a hot-air balloon. Heating causes the air inside the balloon to expand. Some of the warm air leaves through the bottom opening of the balloon, keeping the pressure constant. But now the air inside is less dense than the air outside the balloon, so the balloon rises. If the pilot allows the air in the balloon to cool, the reverse happens. The air in the balloon contracts, and more air enters through the opening. The density of the air inside increases, and the balloon sinks.

FIGURE 17
Charles's Law
When the temperature of a gas increases at constant pressure, its volume increases.
Inferring *What happens to the gas particles as the temperature increases?*



D When removed from the nitrogen, the gas warms and the balloon expands.

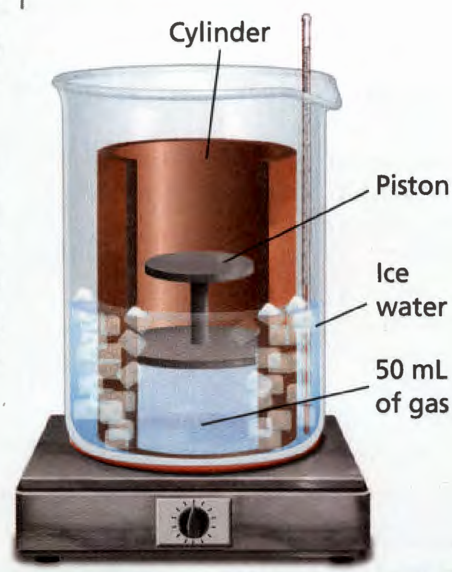
E The balloon is at room temperature again.

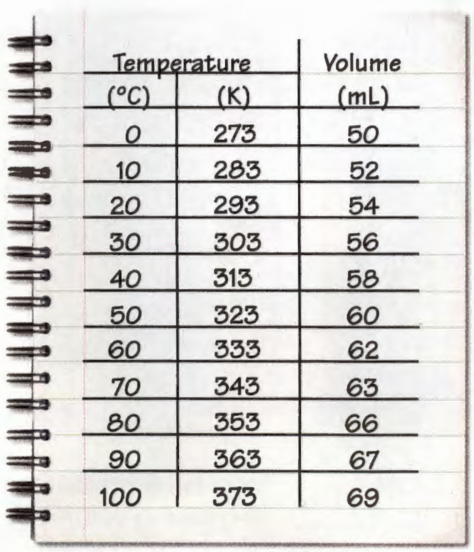
Graphing Charles's Law Suppose you do an experiment to test Charles's law. Figure 18 shows a gas contained in a cylinder with a movable piston. The piston allows the gas to change volume at constant pressure. The experiment begins with 50 mL of the gas in an ice-water bath at 0°C. Then the water is slowly heated. Each time the temperature increases by 10°C, the gas volume is recorded. Note that the temperatures in the data table have been converted into kelvins, the SI unit of temperature. To convert from Celsius degrees to kelvins (K), add 273.

As you can see in the graph of the data, the data points yield a straight line. In fact, if you extended the line downward, it would pass through the origin. When a graph of two variables is a straight line passing through the origin, the variables are said to be **directly proportional** to each other. The graph of Charles's law shows that the volume of a gas is directly proportional to its kelvin temperature under constant pressure.

Reading Checkpoint **How do you convert from Celsius degrees to kelvins?**

FIGURE 18
Linear Trend
As the water bath heats up, the gas inside the cylinder expands. The data show a linear trend. At constant pressure, the volume of a gas is directly proportional to its kelvin temperature.





Temperature (°C)	Temperature (K)	Volume (mL)
0	273	50
10	283	52
20	293	54
30	303	56
40	313	58
50	323	60
60	333	62
70	343	63
80	353	66
90	363	67
100	373	69

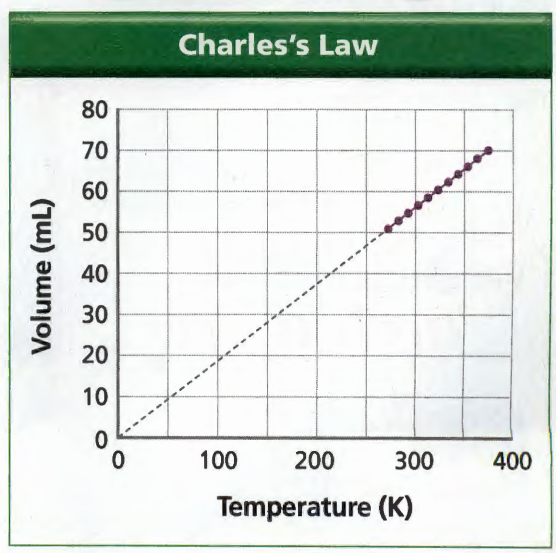


FIGURE 19
Inflating a Tire
A bicycle pump makes use of the relationship between the volume and pressure of a gas.

Pressure and Volume

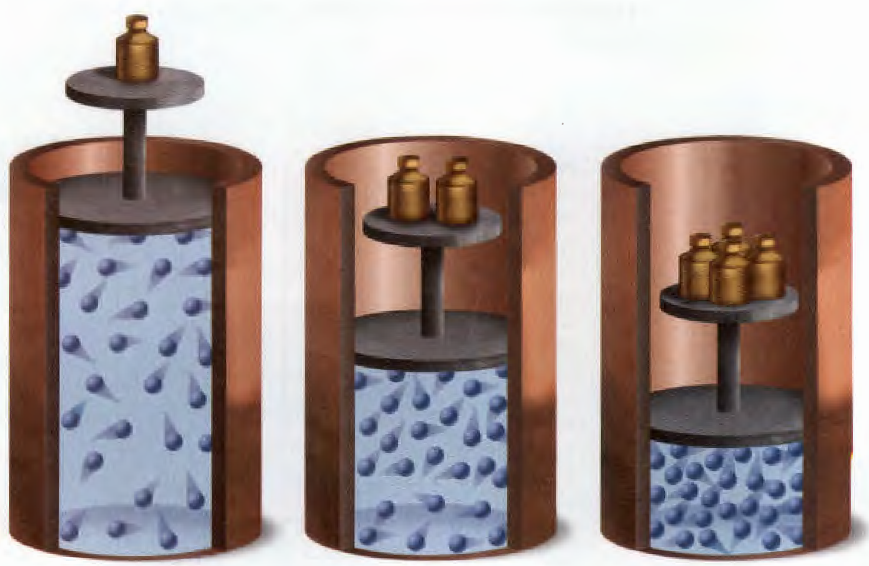
Suppose you use a bicycle pump to inflate a tire. By pressing down on the plunger, you force the gas inside the pump through the rubber tube and out the nozzle into the tire. What happens to the volume of air inside the pump cylinder as you push down on the plunger? What happens to the pressure?

Boyle's Law In the 1600s, the scientist Robert Boyle conducted experiments in an effort to improve air pumps. He measured the volumes of gases at different pressures. Boyle's experiments showed that gas volume and pressure were related. **When the pressure of a gas at constant temperature is increased, the volume of the gas decreases. When the pressure is decreased, the volume increases.** This relationship is called Boyle's Law.

Boyle's law applies to situations in which the volume of a gas is changed. The pressure then changes in the opposite way. For example, as you push down on the plunger of a bicycle pump, the volume of air inside the pump cylinder gets smaller, and the pressure inside the cylinder increases. The increase in pressure forces air into the tire.

Another example of Boyle's law in action involves high-altitude balloons, which are used in the study of the atmosphere. Researchers fill the balloons with only a small fraction of the helium gas that the balloons can hold. As a balloon rises through the atmosphere, the air pressure around it decreases and the balloon expands. If the balloon were fully inflated at takeoff, it would burst before it got very high.

FIGURE 20
Boyle's Law
As weights are added, the gas particles occupy a smaller volume. The pressure increases.



Go Online
active art

For: Gas Laws activity
Visit: PHSchool.com
Web Code: cgp-1023

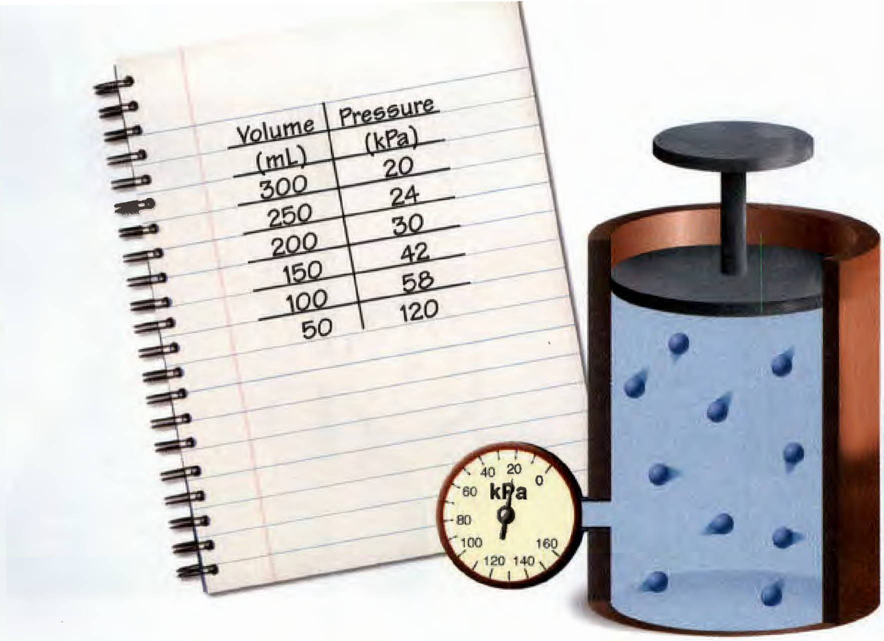


FIGURE 21
Pressure and Gas Volume
Pushing on the top of the piston decreases the volume of the gas. The pressure of the gas increases.
Predicting *What would happen if you pulled up on the piston?*

Graphing Boyle's Law Suppose you conduct an experiment to test Boyle's law. Figure 21 shows a gas contained in a cylinder with a movable piston. A gauge indicates the pressure of the gas inside the cylinder. The experiment begins with the volume of the gas at 300 mL. The pressure of the gas is 20 kPa. Next, the piston is pushed into the cylinder, making the gas volume smaller. The pressure of the gas is recorded after each 50-mL change in volume. Temperature remains constant.

In this experiment, the manipulated variable is volume. In Figure 22, volume is shown on the scale of the horizontal axis from 0 mL to 300 mL. The responding variable is pressure. Pressure is shown on the scale of the vertical axis from 0 kPa to 120 kPa.

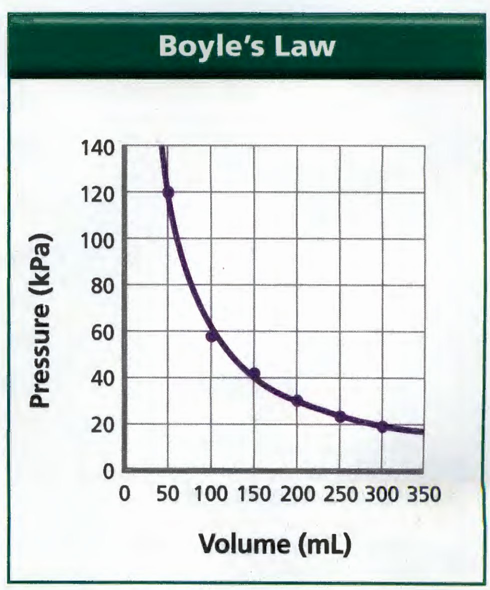
As you can see in the graph, the plotted points lie on a curve, not a straight line. Notice that the curve slopes downward from left to right. It is steep at lower volumes, but it becomes less steep as volume increases. If you multiply the two variables at any point on the curve, you will find that the product does not change.

$$300 \text{ mL} \times 20 \text{ kPa} = 6{,}000 \text{ mL} \cdot \text{kPa}$$
$$250 \text{ mL} \times 24 \text{ kPa} = 6{,}000 \text{ mL} \cdot \text{kPa}$$
$$200 \text{ mL} \times 30 \text{ kPa} = 6{,}000 \text{ mL} \cdot \text{kPa}$$

When the product of two variables is a constant, the variables are **inversely proportional** to each other. The graph for Boyle's law shows that gas pressure is inversely proportional to volume at constant temperature.

Reading Checkpoint **What is the manipulated variable in the pressure-volume experiment?**

FIGURE 22
Nonlinear Trend
The graph of the data from Figure 21 shows a nonlinear trend. The gas pressure is inversely proportional to the volume when temperature is constant.
Calculating *If you reduced the volume of the gas to 25 mL, what would its pressure be?*



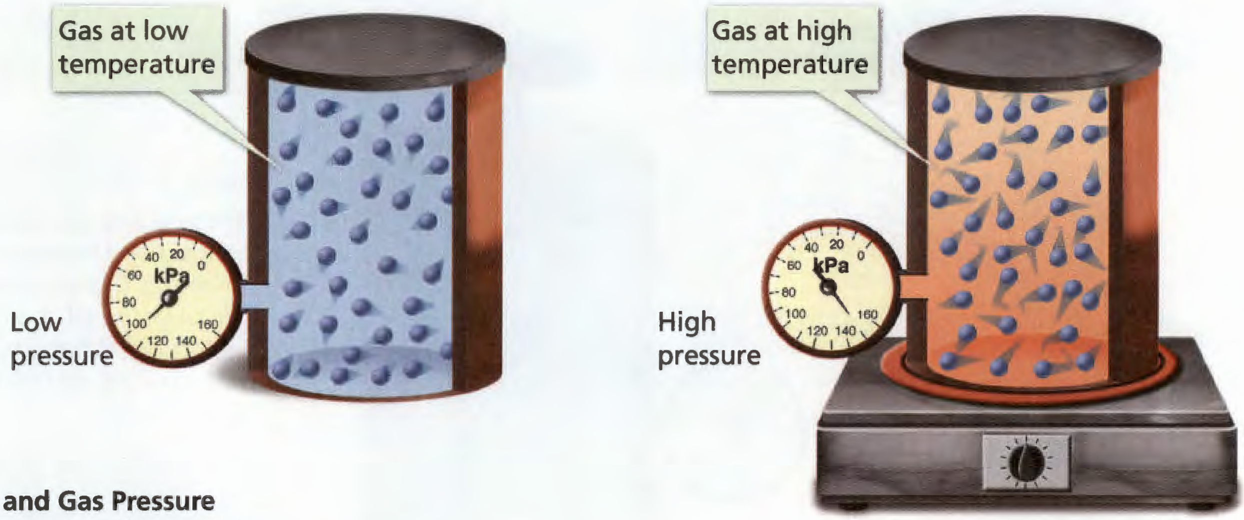


FIGURE 23
Temperature and Gas Pressure
When a gas is heated, the particles move faster and collide more often with each other and with the walls of their container. The pressure of the gas increases.

Pressure and Temperature

If you dropped a few grains of sand onto your hand, you would hardly feel them. But what if you were caught in a sandstorm? Ouch! The sand grains fly around very fast, and they would sting if they hit you. The faster the grains travel, the harder they hit your skin.

Although gas particles are much smaller than sand grains, a sandstorm is a good model for gas behavior. Like grains of sand in a sandstorm, gas particles travel individually and at high speeds (but randomly). The faster the gas particles move, the more frequently they collide with the walls of their container and the greater the force of the collisions.

Increasing Temperature Raises Pressure Recall from Section 2 that the higher the temperature of a substance, the faster its particles are moving. Now you can state a relationship between temperature and pressure. **When the temperature of a gas at constant volume is increased, the pressure of the gas increases. When the temperature is decreased, the pressure of the gas decreases.** Constant volume means that the gas is in a closed, rigid container.

Pressure and Temperature in Action Have you ever looked at the tires of an 18-wheel truck? Because the tires need to support a lot of weight, they are large, heavy, and firm. The inside volume of these tires doesn't vary much. On long trips, especially in the summer, a truck's tires can become very hot. As the temperature increases, so does the pressure of the air inside the tire. If the pressure becomes greater than the tire can hold, the tire will burst. For this reason, truck drivers need to monitor and adjust tire pressure on long trips.

Video Field Trip
Discovery Channel School
Solids, Liquids, and Gases

Reviewing Math: Algebra and Functions 7.1.5

Math Analyzing Data

Graphing Gas Behavior

In an experiment, the temperature of a gas at a constant volume was varied. Gas pressure (in kilopascals) was measured after each 5-kelvin change in temperature. The data from the experiment are shown in the table.

Temperature (K)	Pressure (kPa)
273	8
278	11
283	14
288	17
293	20
298	23

1. **Graphing** Use the data to make a line graph. Plot temperature on the horizontal axis with a scale from 270 K to 300 K. Plot pressure on the vertical axis with a scale from 0 kPa to 25 kPa. (1 kPa = 1,000 Pa)
2. **Interpreting Data** What was the manipulated variable in this experiment?
3. **Interpreting Data** What kind of trend do the data show?
4. **Drawing Conclusions** What happens to the pressure of a gas when temperature is increased at constant volume?

Section 3 Assessment

S 8.3.d, 8.9.e, E-LA: Reading 8.2.0, Math: 7AF1.5

Target Reading Skill **Create Outlines** Review your outline on the Behavior of Gases. What are three important supporting ideas that you should know about measuring gases?

Reviewing Key Concepts

1. a. **Defining** How is gas pressure defined?
   b. **Describing** Describe how the motions of gas particles are related to the pressure exerted by the gas.
   c. **Relating Cause and Effect** Why does pumping more air into a basketball increase the pressure inside the ball?
2. a. **Reviewing** How does Boyle's law describe the relationship between gas pressure and volume?
   b. **Explaining** Explain why increasing the temperature of a gas in a closed, rigid container causes the pressure in the container to increase.
   c. **Applying Concepts** Suppose it is the night before a big parade, and you are in charge of inflating the parade balloons. You just learned that the temperature will rise 15°C between early morning and the time the parade starts. How will this information affect the way you inflate the balloons?

Lab zone At-Home Activity

Finding Graphs Look for graphs in your newspaper or in magazines. Point out to members of your family which variable is the manipulated variable and which is the responding variable for each graph. Then compare any line graphs you have found to the graphs in this section. Which of your graphs show two variables that are directly proportional to each other? Do any show variables that are inversely proportioned?

Lab zone Skills Lab

It's a Gas

S 8.3.e, 8.9.e

Problem

How does the pressure you exert on a syringe affect the volume of the air inside it?

Skills Focus

graphing, predicting, interpreting data, drawing conclusions

Materials

- strong plastic syringe (with no needle), at least 35-cm^3 capacity
- modeling clay
- 4 books of uniform weight

Procedure

1. Make a data table in your notebook like the one below.
2. Lift the plunger of the syringe as high as it will move without going off scale. The volume inside the syringe will then be as large as possible.
3. Seal the small opening of the syringe with a piece of clay. The seal must be airtight.
4. Hold the syringe upright with the clay end on the table. With the help of a partner, place one book on top of the plunger. Steady the book carefully so it does not fall.
5. With the book positioned on the plunger, read the volume shown by the plunger and record it in your data table.
6. Predict what will happen as more books are placed on top of the plunger.
7. Place another book on top of the first book resting on the plunger. Read the new volume and record it in your data table.
8. One by one, place each of the remaining books on top of the plunger. After you add each book, record the volume of the syringe in your data table.
9. Predict what will happen as books are removed from the plunger one by one.
10. Remove the books one at a time. Record the volume of the syringe in your data table after you remove each book.

Data Table			
Adding Books		Removing Books	
Number of Books	Volume (cm^3)	Number of Books	Volume (cm^3)
0		4	
1		3	
2		2	
3		1	
4		0	

Analyze and Conclude

1. **Graphing** Make a line graph of the data obtained from Steps 5, 7, and 8. Show the number of books on the horizontal axis and the volume in cubic centimeters (cm^3) on the vertical axis. Title this Graph 1.
2. **Graphing** Make a second line graph of the data obtained from Step 10. Title this Graph 2.
3. **Predicting** Did the results you obtained support your predictions in Steps 6 and 9? Explain.
4. **Interpreting Data** Compare Graph 2 with Graph 1. How can you explain any differences in the two graphs?
5. **Drawing Conclusions** What does Graph 1 tell you about how the volume of a gas changes with increasing pressure?
6. **Communicating** Write a paragraph explaining how the volume of the gas changed as books were added one by one. Base your explanation on what was happening to the gas particles in the syringe.

Design an Experiment

How could you use ice and warm water to show how the temperature and volume of a gas are related? Design an experiment to test the effect on the volume of a gas when you change its temperature. *Obtain your teacher's permission before carrying out your investigation.*

Chapter 3 Study Guide

The BIG Idea In solids, the particles vibrate in closely packed, fixed positions. In liquids, the particles are loosely connected and collide with one another. In gases, the particles are free to move independently.

1 States of Matter

Key Concepts S 8.3.e

- The particles that make up a solid are closely locked in position and can only vibrate.
- Compared to particles in a solid, the particles in a liquid are more loosely connected and can collide with and move past one another.
- In gases, the atoms and molecules are free to move independently.

Key Terms

solid
crystalline solid
amorphous solid
liquid
fluid
surface tension
viscosity
gas

2 Changes of State

Key Concepts S 8.3.d, 8.5.d

- When a substance melts, the particles in the solid vibrate so fast that they break free from their fixed positions.
- When a substance freezes, the particles in a liquid move so slowly that they begin to take on fixed positions.
- Vaporization takes place when the particles in a liquid gain enough energy to move independently, forming a gas.
- During condensation, the particles in a gas lose enough thermal energy to form a liquid.

Key Terms

melting
melting point
freezing
vaporization
evaporation
boiling
boiling point
condensation
sublimation

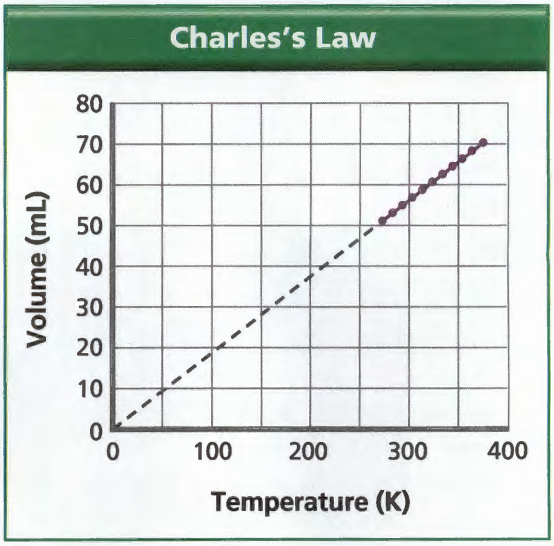
3 The Behavior of Gases

Key Concepts S 8.3.d, 8.9.e

- When working with a gas, it is helpful to know its volume, temperature, and pressure.
- When the temperature of a gas is increased at constant pressure, its volume increases. When the temperature of a gas is decreased at constant pressure, its volume decreases.
- When the pressure of a gas at constant temperature is increased, the volume of the gas decreases. When the pressure is decreased, the volume increases.
- When the temperature of a gas at constant volume is increased, the pressure of the gas increases. When the temperature is decreased, the pressure of the gas decreases.

Key Terms

pressure
directly proportional
inversely proportional



Review and Assessment

Go Online PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cxa-1030

Target Reading Skill

Create Outlines Review Section 2: *Changes of State.* In your notebook, complete the unfinished outline shown to the right. What important supporting ideas should you know about melting and freezing?

Changes of State

I. Changes Between Solid and Liquid
  A. Melting
    1.
    2.
  B. Freezing
    1.
    2.
II. Changes Between Liquid and Gas
  A. Evaporation

Reviewing Key Terms

Choose the letter of the best answer.

1. A substance with a definite volume but no definite shape is a(n)
a. crystalline solid.
b. liquid.
c. gas.
d. amorphous solid.

2. Unlike solids and liquids, a gas will
a. keep its volume in different containers.
b. keep its shape in different containers.
c. expand to fill the space available to it.
d. have its volume decrease when the temperature rises.

3. The process in which a gas cools and becomes a liquid is called
a. evaporation.
b. sublimation.
c. boiling.
d. condensation.

4. The pressure of a gas is the force of its outward push divided by the
a. volume of its container.
b. mass of its container.
c. area of the walls of its container.
d. mass of the gas.

5. Under constant pressure, the volume of a gas and its kelvin temperature are
a. inversely proportional.
b. directly proportional.
c. always equal.
d. not related.

Complete the following sentences so that your answers clearly explain the key terms.

6. Water vapor and vegetable oil are examples of **fluids,** which are defined as __________ .

7. An example of a characteristic property of a substance is its **melting point,** which is ____.

8. The reverse process of melting is **freezing,** in which a liquid __________ .

9. Evaporation and boiling are two types of **vaporization,** in which a liquid __________ .

10. At constant temperature, the volume of a gas and its pressure are **inversely proportional,** which means __________ .

Writing in Science

Explanation Write an introduction to a safety manual for deep-sea divers who use compressed air (scuba) tanks. Explain what air pressure is and what happens to gas molecules when air is compressed.

Video Assessment
Discovery Channel School
Solids, Liquids, and Gases

Review and Assessment

Checking Concepts

11. Describe the motion of particles in a solid.
12. Why are both liquids and gases called fluids?
13. Compare and contrast liquids with high and low viscosities.
14. How is the thermal energy of a substance related to its physical state?
15. Describe four examples of changes in state.
16. What happens to water molecules when water is heated from 90°C to 110°C?
17. What happens to the gas particles when the air in an inflated ball leaks out?
18. How does heating a gas in a rigid container change its pressure?

Thinking Critically

19. **Relating Cause and Effect** Explain why placing a dented table-tennis ball in boiling water is one way to remove the dent in the ball. (Assume the ball has no holes.)
20. **Applying Concepts** When you open a solid room air freshener, the solid slowly loses mass and volume. How do you think this happens?
21. **Interpreting Data** Use the table below that shows the volume and pressure of a gas to predict how a graph of the data would look. How can you describe the relationship between the two variables?

Volume (cm^3)	Pressure (kPa)
15	222
21	159
31	108
50	67

Applying Skills

Use the table to answer Questions 22–24.

The data table tells how much mass of a compound dissolves in 100 mL of water as the temperature of the water is increased. Use the data to construct and interpret a graph.

Temperature (°C)	Mass of Compound Dissolved (g)
0	37
10	47
20	56
30	66
40	75

22. **Graphing** Label each axis of your graph with the appropriate variable, units, and range of values. Then plot the data in a line graph.
23. **Interpreting Data** What does the graph show about the effect of temperature on the amount of the compound that will dissolve in water?
24. **Predicting** Assume the amount of the compound dissolved continues to increase as the water is heated. Predict how many grams will dissolve at 50°C.

Lab zone Standards Investigation

Performance Assessment If you prepared a cartoon, read the captions to the class and discuss the illustrations. If you prepared a skit, perform the skit in front of the class. After you finish your presentation, invite the class to ask questions about your investigation. Be prepared to share the decisions you made in creating your presentation.

CALIFORNIA Standards Practice

Success Tracker™
Online at PHSchool.com

Choose the letter of the best answer.

1. A wet towel is hanging on a clothesline in the sun. The towel dries by the process of
   A boiling.
   B condensation.
   C evaporation.
   D sublimation. **S 8.5.d**

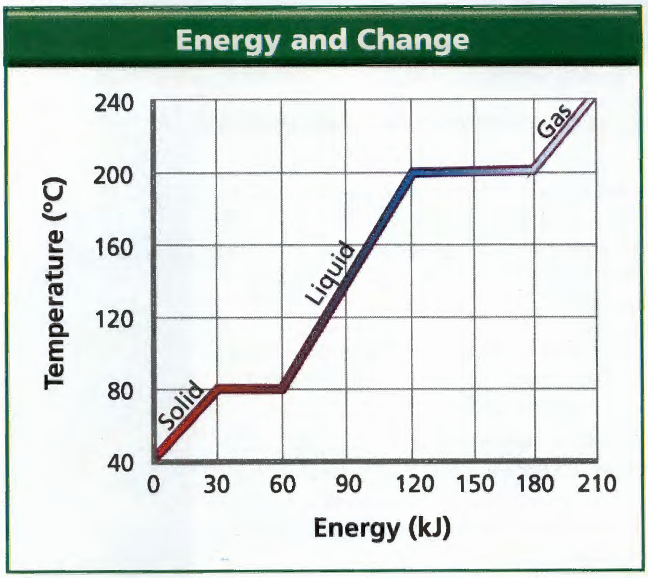
2. Which of the following correctly describes a gas?
   A The particles do not move.
   B The particles are closely locked in position and can only vibrate.
   C The particles are free to move independently, colliding frequently.
   D The particles are closely packed but have enough energy to slide past one another. **S 8.3.e**

3. Which state of matter has both definite volume and definite shape?
   A solid
   B liquid
   C gas
   D plasma **S 8.3.e**

4. As water vapor condenses into liquid water, the relative freedom of motion of the water molecules
   A increases.
   B decreases.
   C stays the same.
   D drops to zero because the particles are no longer moving. **S 8.3.d**

5. A gas at constant temperature is confined to a cylinder with a movable piston. The piston is slowly pushed into the cylinder, decreasing the volume of the gas. The pressure increases. What are the variables in this experiment?
   A temperature and time
   B time and volume
   C volume and pressure
   D pressure and temperature **S 8.9.e**

The graph below shows changes in 1 kg of a crystalline solid as it absorbs energy at a constant rate. Use the graph to answer Questions 6–7.



6. Based on the graph, what is the total amount of energy absorbed by the substance as it changes from a solid at 40°C to a gas?
   A 30 kJ
   B 60 kJ
   C 120 kJ
   D 180 kJ **S 8.3.d**

7. What is the melting point of the substance?
   A 0°C
   B 40°C
   C 80°C
   D 200°C **S 8.5.d**

Apply the BIG Idea

8. Spray cans filled with gas usually have a warning printed on their labels that say, "Store in a cool place." Explain the danger in storing the can near a source of heat. Describe the motion of the gas molecules in the can when they gain thermal energy. **S 8.5.c**