CHAPTER 3

States of Matter

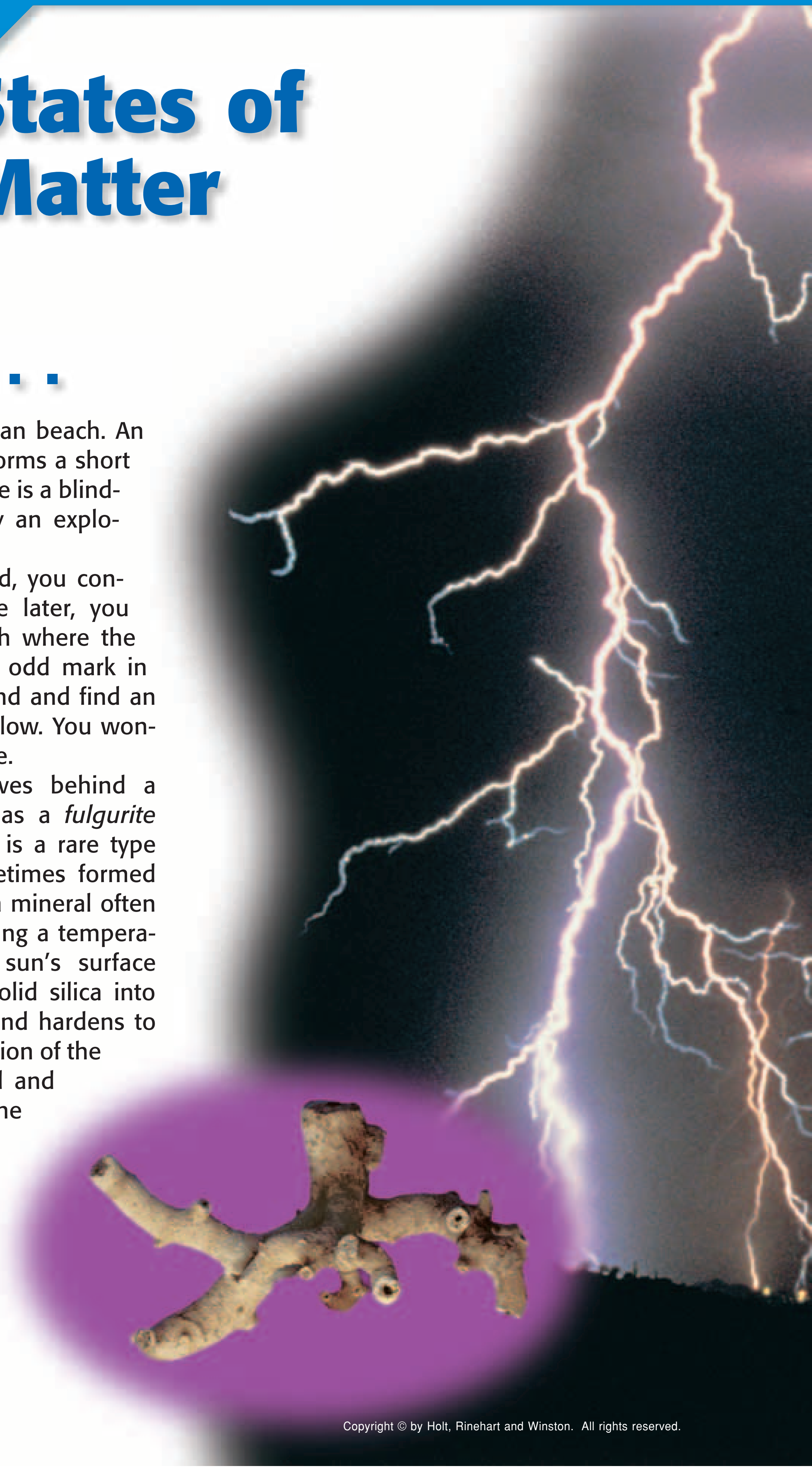
Imagine . . .

You are jogging along an ocean beach. An immense black storm cloud forms a short distance ahead. Suddenly there is a blinding flash of light followed by an explosion of thunder.

As the storm moves inland, you continue your jog. A short time later, you arrive at the section of beach where the storm passed. You notice an odd mark in the sand. You dig into the sand and find an object like the one shown below. You wonder what this object could be.

Lightning sometimes leaves behind a strange calling card known as a *fulgurite* (FUHL gyoo RIET). A fulgurite is a rare type of natural glass that is sometimes formed when lightning strikes silica, a mineral often found in soil or sand. Producing a temperature equal to that of the sun's surface (33,000°C), lightning melts solid silica into liquid. The silica then cools and hardens to become glass. The transformation of the silica from a solid to a liquid and back to a solid happens in the blink of an eye!

The physical changes that occur in the manufacture of glass are identical to those that occur when a fulgurite is created. The process, however, is very different.



Instead of lightning, glass makers use a large oven to heat the silica and other ingredients. Once this mixture becomes a liquid, it is removed from the oven and formed into a desired shape. The shaping process must happen quickly, before the liquid glass freezes into solid. By controlling the physical change between liquid glass and solid glass, known as a *change of state,* glass makers create the windows, light bulbs, and bottles you use every day. Read on to discover more about the states of matter.

Vanishing Act

In this activity, you will use rubbing alcohol to investigate a change of state.

Procedure

1. Pour **rubbing alcohol** into a small **plastic cup** until it just covers the bottom of the cup.
2. Moisten the tip of a **cotton swab** by dipping it into the alcohol in the cup.
3. Rub the cotton swab on the palm of your hand.
4. Record your observations in your ScienceLog.
5. Wash your hands thoroughly.

Analysis

6. Explain what happened to the alcohol.
7. Did you feel a sensation of hot or cold? If so, how do you explain what you observed?
8. Record your answers in your ScienceLog.

What Do You Think?

In your ScienceLog, try to answer the following questions based on what you already know:

1. What are the four most familiar states of matter?
2. Compare the motion of the particles in a solid, a liquid, and a gas.
3. Name three ways matter changes from one state to another.

Section 1

Four States of Matter

NEW TERMS

states of matter
solid
liquid
gas
pressure
Boyle's law
Charles's law
plasma

OBJECTIVES

- Describe the properties shared by particles of all matter.
- Describe the four states of matter discussed here.
- Describe the differences between the states of matter.
- Predict how a change in pressure or temperature will affect the volume of a gas.

Figure 1 shows a model of the earliest known steam engine, invented about A.D. 60 by Hero, a scientist who lived in Alexandria, Egypt. This model also demonstrates the four most familiar states of matter: solid, liquid, gas, and plasma. The **states of matter** are the physical forms in which a substance can exist. For example, water commonly exists in three different states of matter: solid (ice), liquid (water), and gas (steam).

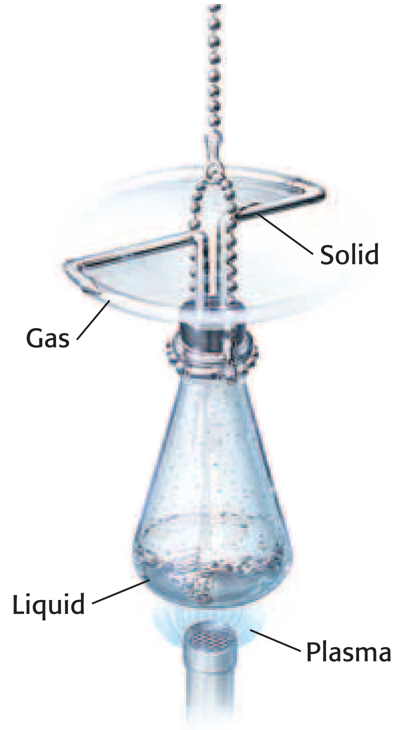


Figure 1 *This model of Hero's steam engine spins as steam escapes through the nozzles.*

Moving Particles Make Up All Matter

Matter consists of tiny particles called atoms and molecules (MAHL i KYOOLZ) that are too small to see without an amazingly powerful microscope. These atoms and molecules are always in motion and are constantly bumping into one another. The state of matter of a substance is determined by how fast the particles move and how strongly the particles are attracted to one another. **Figure 2** illustrates three of the states of matter—solid, liquid, and gas—in terms of the speed and attraction of the particles.

Figure 2 **Models of a Solid, a Liquid, and a Gas**

Particles of a solid do not move fast enough to overcome the strong attraction between them, so they are held tightly in place. The particles vibrate in place.

Particles of a liquid move fast enough to overcome some of the attraction between them. The particles are able to slide past one another.

Particles of a gas move fast enough to overcome nearly all of the attraction between them. The particles move independently of one another.

Solids Have Definite Shape and Volume

Look at the ship in **Figure 3.** Even though it is in a bottle, it keeps its original shape and volume. If you moved it to a larger bottle, the shape and volume of the ship would not change. Scientifically, the state in which matter has a definite shape and volume is **solid.** Because the particles of a substance in the solid state are very close together, the attraction between them is stronger than the attraction between the particles of the same substance in the liquid or gaseous state. The atoms or molecules in a solid are still moving, but they do not move fast enough to overcome the attraction between them. Each particle vibrates in place because it is locked in position by the particles around it.

Figure 3 *Because this ship is a solid, it does not take the shape of the bottle.*

Two Types of Solids Solids are often divided into two categories—*crystalline* and *amorphous* (uh MOHR fuhs). Crystalline solids have a very orderly, three-dimensional arrangement of atoms or molecules. The particles are arranged much like the seats in a movie theater. That is, the particles are in a repeating pattern of rows. Examples of crystalline solids include iron, diamond, and ice. Amorphous solids are composed of atoms or molecules that are in no particular order. The particles in an amorphous solid are arranged like people attending a concert in a park. That is, each particle is in a particular spot, but the particles are in no particular pattern. Examples of amorphous solids include rubber and wax. **Figure 4** illustrates the differences in the arrangement of particles in these two solids.

Explore

Imagine that you are a particle in a solid. Your position in the solid is your chair. In your ScienceLog, describe the different types of motion that are possible even though you cannot leave your chair.

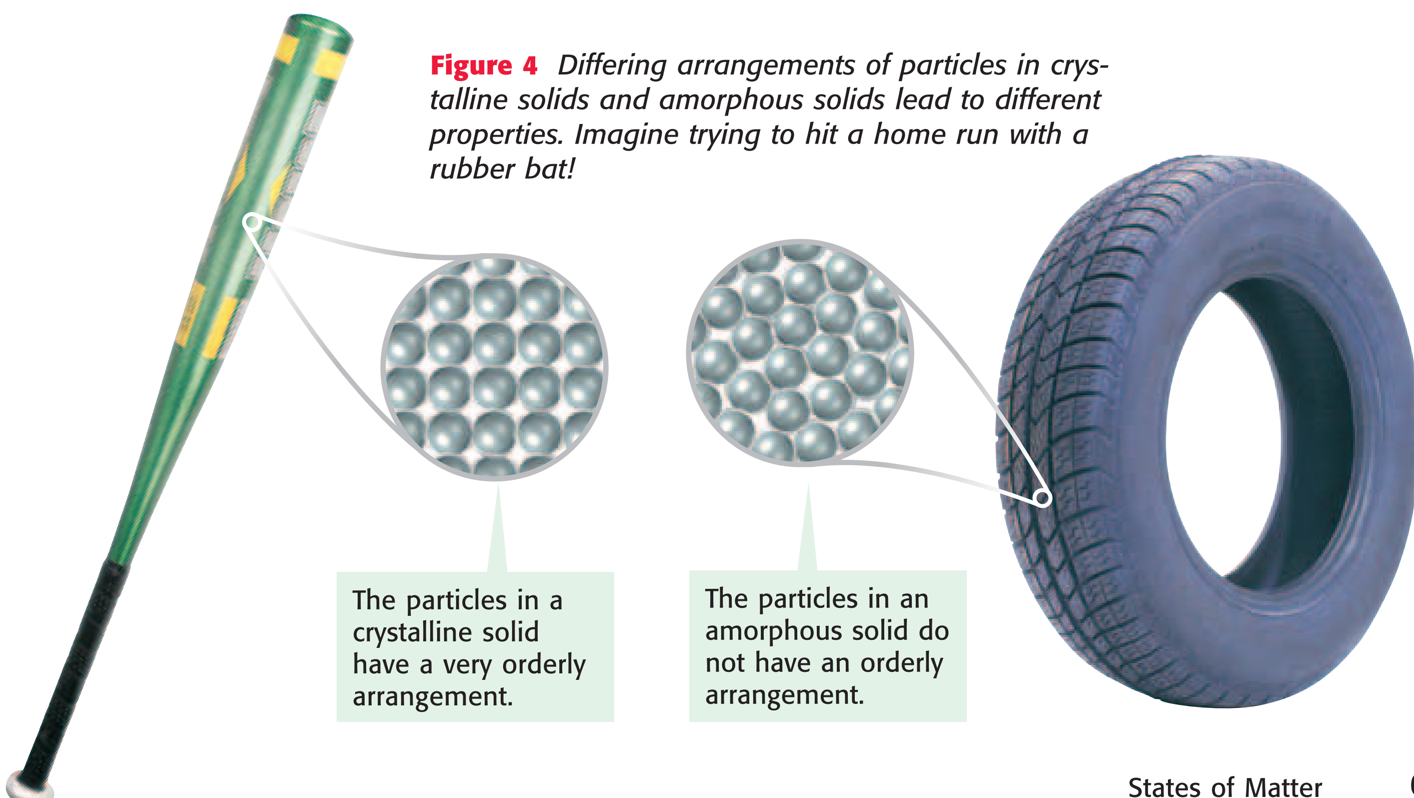


Figure 4 *Differing arrangements of particles in crystalline solids and amorphous solids lead to different properties. Imagine trying to hit a home run with a rubber bat!*

Figure 5 *Particles in a liquid slide past one another until the liquid conforms to the shape of its container.*

Liquids Change Shape but Not Volume

You already know from your own experience that a liquid will conform to the shape of whatever container it is put in. You are reminded of this every time you pour yourself a glass of juice. The state in which matter takes the shape of its container but has a definite volume is **liquid.** The atoms or molecules in liquids move fast enough to overcome some of the attractions between them. The particles slide past each other until the liquid takes the shape of its container. **Figure 5** shows how the particles in juice might look if they were large enough to see.

Even though liquids change shape, they do not readily change volume. You have also experienced this for yourself. You know that a can of soda contains a certain volume of liquid regardless of whether you pour it into a large container or a small one. **Figure 6** illustrates this point using a beaker and a graduated cylinder.

Figure 6 *Even when liquids change shape, they don't change volume.*

Because the particles in liquids are close to one another, it is difficult to push them closer together. This makes liquids ideal for use in hydraulic (hie DRAW lik) systems to do work. For example, brake fluid is the liquid used in the brake systems of cars. Stepping on the brake pedal applies a force to the liquid. It is easier for the particles in the liquid to move away rather than to be squeezed closer together. Therefore, the fluid pushes the brake pads outward against the wheels. The force of the brake pads pushing against the wheels slows the car.

BRAIN FOOD

The Boeing 767 Freighter, a type of commercial airliner, has 187 km (116 mi) of hydraulic tubing.

Two Properties of Liquids Two other important properties of liquids are *surface tension* and *viscosity* (vis KAHS uh tee). Surface tension is the force acting on the particles at the surface of a liquid that causes the liquid to form spherical drops, as shown in **Figure 7.** Different liquids have different surface tensions. For example, rubbing alcohol has a lower surface tension than water, but mercury has a higher surface tension than water.

Viscosity is a liquid's resistance to flow. In general, the stronger the attractions between a liquid's particles are, the more viscous the liquid is. Think of the difference between pouring honey and pouring water. Honey flows more slowly than water because it has a higher viscosity than water.

Figure 7 *Liquids form spherical drops as a result of surface tension.*

Gases Change Both Shape and Volume

The last time you saw balloons being filled with helium gas, did you wonder how many balloons could be filled from a single metal cylinder of helium? The number may surprise you. One cylinder can fill approximately 700 balloons. How is this possible? After all, the volume of the metal cylinder is equal to the volume of only about five inflated balloons.

To answer this question, you must know that the state in which matter changes in both shape and volume is **gas.** The atoms or molecules in a gas move fast enough to break away completely from one another. Therefore, the particles of a substance in the gaseous state have less attraction between them than particles of the same substance in the solid or liquid state. The particles move independently of one another, colliding frequently with one another and with the inside of the container as they spread out. So in a gas, there is empty space between particles.

The amount of empty space in a gas can change. For example, the helium in the metal cylinder consists of atoms that have been forced very close together, as shown in **Figure 8.** As the helium fills the balloon, the atoms spread out, and the amount of empty space in the gas increases. As you continue reading, you will learn how this empty space is related to pressure.

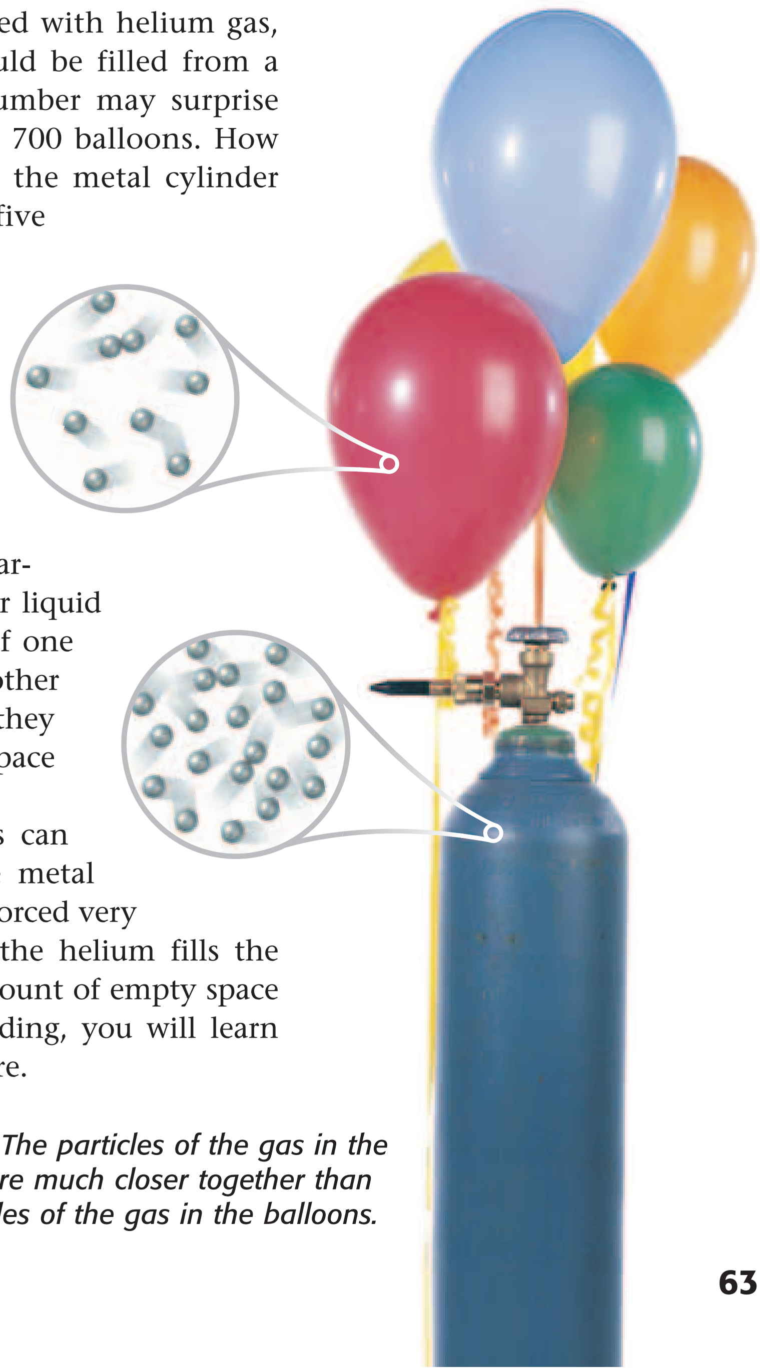


Figure 8 *The particles of the gas in the cylinder are much closer together than the particles of the gas in the balloons.*

Gas Under Pressure

Pressure is the amount of force exerted on a given area. You can think of this as the number of collisions of particles against the inside of the container. Compare the basketball with the beach ball in **Figure 9.** The balls have the same volume and contain particles of gas (air) that constantly collide with one another and with the inside surface of the balls. Notice, however, that there are more particles in the basketball than in the beach ball. As a result, more particles collide with the inside surface of the basketball than with the inside surface of the beach ball. When the number of collisions increases, the force on the inside surface of the ball increases. This increased force leads to increased pressure.

Self-Check

How would an increase in the speed of the particles affect the pressure of gas in a metal cylinder? *(See page 596 to check your answer.)*

Figure 9 *Both balls shown here are full of air, but the pressure in the basketball is higher than the pressure in the beach ball.*

REVIEW

1. List two properties that all particles of matter have in common.
2. Describe solids, liquids, and gases in terms of shape and volume.
3. Why can the volume of a gas change?
4. **Applying Concepts** Explain why you would pump up a flat basketball.

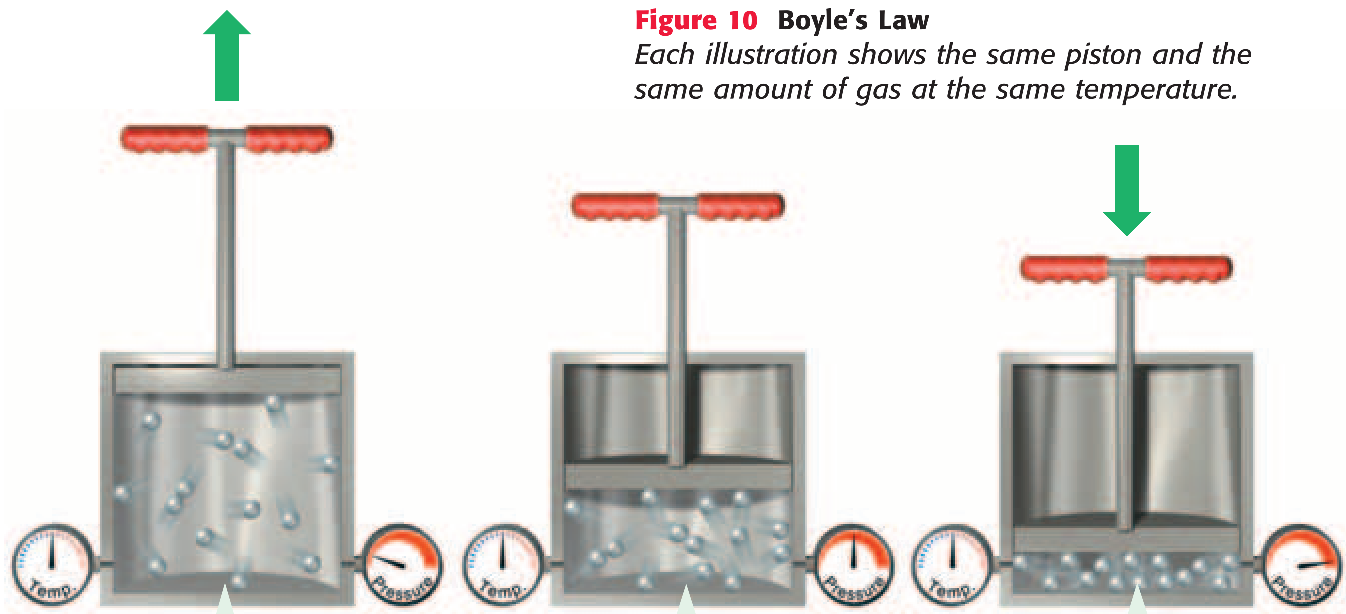
Laws Describe Gas Behavior

Earlier in this chapter, you learned about the atoms and molecules in both solids and liquids. You learned that compared with gas particles, the particles of solids and liquids are closely packed together. As a result, solids and liquids do not change volume very much. Gases, on the other hand, behave differently; their volume can change by a large amount.

It is easy to measure the volume of a solid or liquid, but how do you measure the volume of a gas? Isn't the volume of a gas the same as the volume of its container? The answer is yes, but there are other factors, such as pressure, to consider.

Boyle's Law Imagine a diver at a depth of 10 m blowing a bubble of air. As the bubble rises, its volume increases. By the time the bubble reaches the surface, its original volume will have doubled due to the decrease in pressure. The relationship between the volume and pressure of a gas is known as Boyle's law because it was first described by Robert Boyle, a seventeenth-century Irish chemist. **Boyle's law** states that for a fixed amount of gas at a constant temperature, the volume of a gas increases as its pressure decreases. Likewise, the volume of a gas decreases as its pressure increases. Boyle's law is illustrated by the model in **Figure 10.**

Figure 10 **Boyle's Law**
Each illustration shows the same piston and the same amount of gas at the same temperature.



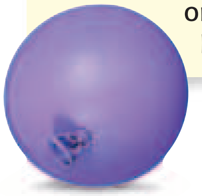
Lifting the plunger decreases the pressure of the gas. The particles of gas collide less often with the walls of the piston as they spread farther apart. The volume of the gas increases as the pressure decreases.

Releasing the plunger allows the gas to change to an intermediate volume and pressure.

Pushing the plunger down increases the pressure of the gas. The particles of gas collide more often with the walls of the piston as they are forced closer together. The volume of the gas decreases as the pressure increases.

LabBook

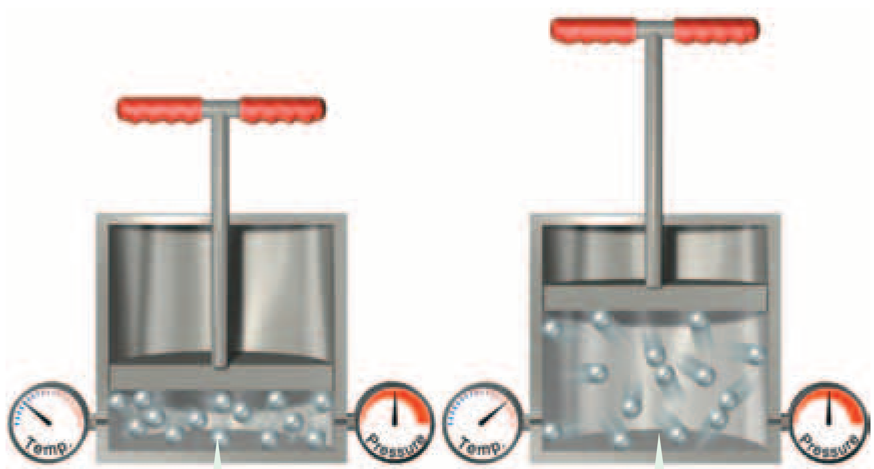
See Charles's law in action for yourself using a balloon on page 526 of the LabBook.



Weather balloons demonstrate a practical use of Boyle's law. A weather balloon carries equipment into the atmosphere to collect information used to predict the weather. This balloon is filled with only a small amount of gas because the pressure of the gas decreases and the volume increases as the balloon rises. If the balloon were filled with too much gas, it would pop as the volume of the gas increased.

Charles's Law An inflated balloon will also pop when it gets too hot, demonstrating another gas law—Charles's law. **Charles's law** states that for a fixed amount of gas at a constant pressure, the volume of the gas increases as its temperature increases. Likewise, the volume of the gas decreases as its temperature decreases. Charles's law is illustrated by the model in **Figure 11.** You can see Charles's law in action by putting an inflated balloon in the freezer. Wait about 10 minutes, and see what happens!

Figure 11 Charles's Law
Each illustration shows the same piston and the same amount of gas at the same pressure.



Lowering the temperature of the gas causes the particles to move more slowly. They hit the sides of the piston less often and with less force. As a result, the plunger enters the piston and the volume of the gas decreases.

Raising the temperature of the gas causes the particles to move more quickly. They hit the sides of the piston more often and with greater force. As a result, the plunger is pushed upward and the volume of the gas increases.

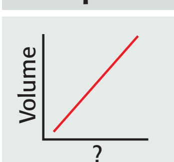
MATH BREAK

Gas Law Graphs

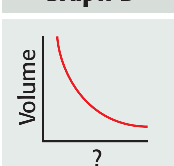
Each graph below illustrates a gas law. However, the variable on one axis of each graph is not labeled. Answer the following questions for each graph:

1. As the volume increases, what happens to the missing variable?
2. Which gas law is shown?
3. What label belongs on the axis?
4. Is the graph linear or nonlinear? What does this tell you?

Graph A

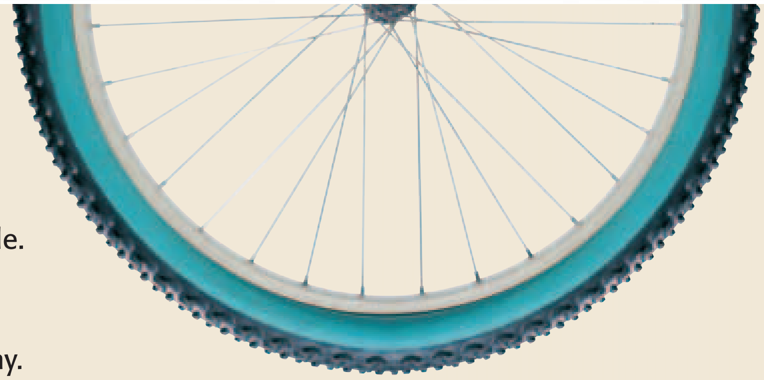


Graph B



APPLY

One of your friends overinflated the tires on her bicycle. Use Charles's law to explain why she should let out some of the air before going for a ride on a hot day.



Plasmas

The sun and other stars are made of the most common state of matter in the universe, called plasma. **Plasma** is the state of matter that does not have a definite shape or volume and whose particles have broken apart.

Plasmas have some properties that are quite different from the properties of gases. Plasmas conduct electric current, while gases do not. Electric and magnetic fields affect plasmas but do not affect gases. In fact, strong magnets are used to form a magnetic "bottle" to contain very hot plasmas that would destroy any other container.

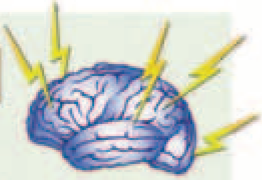
Here on Earth, natural plasmas are found in lightning and fire. The incredible light show in **Figure 12,** called the aurora borealis (ah ROHR uh BOHR ee AL is), is a result of plasma from the sun causing gas particles in the upper atmosphere to glow. Artificial plasmas, found in fluorescent lights and plasma balls, are created by passing electric charges through gases.

Figure 12 *Auroras, like the aurora borealis seen here, form when high-energy plasma collides with gas particles in the upper atmosphere.*

REVIEW

1. When scientists record the volume of a gas, why do they also record the temperature and the pressure?
2. List two differences between gases and plasmas.
3. **Applying Concepts** What happens to the volume of a balloon left on a sunny windowsill? Explain.

BRAIN FOOD



Even though plasmas are rare on Earth, more than 99 percent of the known matter in the universe is in the plasma state.

Section 2

Changes of State

NEW TERMS

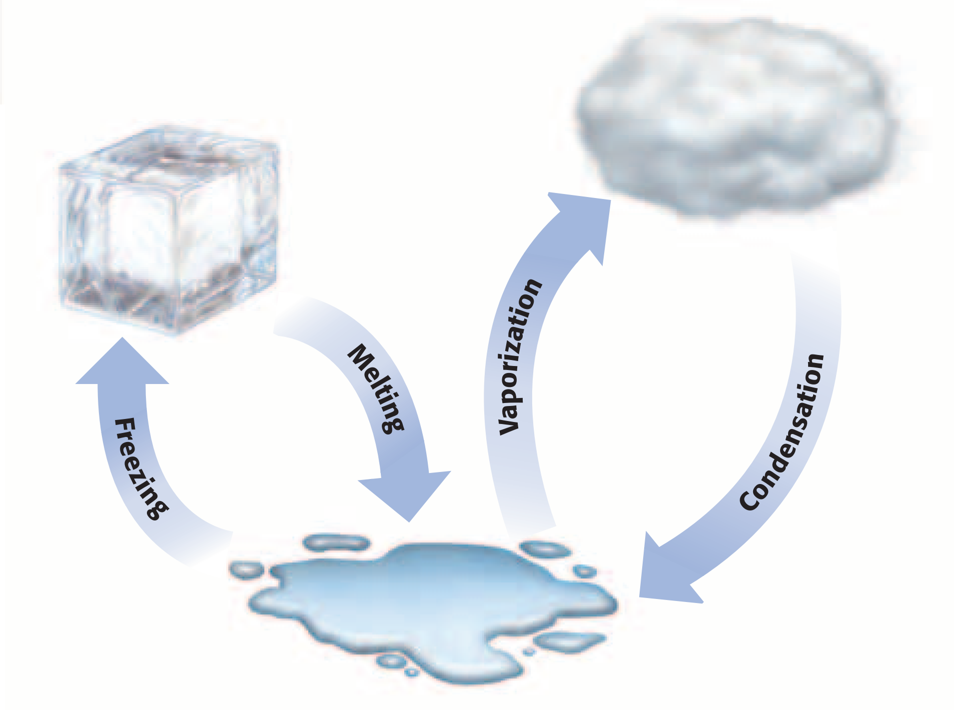
change of state
melting
endothermic
freezing
exothermic
vaporization
evaporation
boiling
condensation
sublimation

OBJECTIVES

- Describe how substances change from state to state.
- Explain the difference between an exothermic change and an endothermic change.
- Compare the changes of state.

A **change of state** is the conversion of a substance from one physical form to another. All changes of state are physical changes. In a physical change, the identity of a substance does not change. In **Figure 13,** the ice, liquid water, and steam are all the same substance, water. In this section, you will learn about the four changes of state illustrated in Figure 13 as well as a fifth change of state called *sublimation* (SUHB li MAY shuhn).

Figure 13 *The terms in the arrows are changes of state. Water commonly goes through the changes of state shown here.*



During a change of state, the energy of a substance changes. The *energy* of a substance is related to the motion of the particles of the substance. For example, the molecules in the liquid water in Figure 13 move faster than the molecules in the ice. Therefore, the liquid water has more energy than the ice.

If energy is added to a substance, the particles of the substance move faster. If energy is removed from a substance, the particles of the substance move slower. The *temperature* of a substance is a measure of the speed of the particles and therefore is a measure of the energy of a substance. For example, the steam shown above has a higher temperature than the liquid water, so the particles in the steam have more energy than the particles in the liquid water. A transfer of energy, known as *heat,* causes the temperature of a substance to change, which can lead to a change of state.

Want to learn how to get power from changes of state? Steam ahead to page 79.

Melting: Solids to Liquids

Melting is the change of state from a solid to a liquid. This is what happens when an ice cube melts. **Figure 14** shows a metal called gallium melting. What is unusual about this metal is that it melts at around 30°C. Because your normal body temperature is about 37°C, gallium would reach its melting point right in your hand!

The *melting point* of a substance is simply the temperature at which the substance changes from a solid to a liquid. The melting points of substances vary widely. As you know, the melting point of gallium is 30°C. Common table salt, however, has a melting point of 801°C.

Most substances have a unique melting point. Melting point can be used with other data to identify a substance. Because the melting point does not change with different amounts of the substance, the melting point is considered a *characteristic property* of a substance.

For a solid to melt, the particles must overcome some of their attractions to other particles. When a solid is at its melting point, any energy it absorbs increases the motion of the atoms or molecules until some of them overcome the attractions that hold them in place. Melting is an **endothermic** change because energy is absorbed, or taken in, by the substance as it changes state.

Figure 14 *Even though gallium is a metal, it would not be very useful as jewelry!*

Freezing: Liquids to Solids

Freezing is the change of state from a liquid to a solid. The temperature at which a liquid changes into a solid is its *freezing point*. Freezing is the reverse process of melting, so freezing and melting occur at the same temperature, as shown in **Figure 15.**

For a liquid to freeze, the motion of the atoms or molecules must slow to the point where attractions between them overcome the motion. The particles are pulled into a more ordered arrangement. When a liquid is at its freezing point, removing energy causes the particles to begin locking into place. Freezing is an **exothermic** change because energy is removed from, or taken out of, the substance as it changes state.

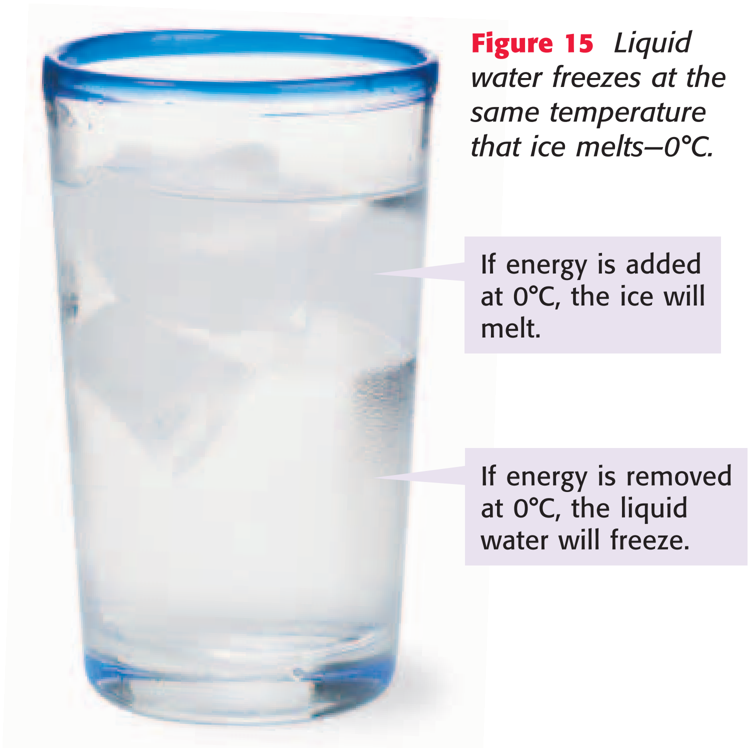


Figure 15 *Liquid water freezes at the same temperature that ice melts—0°C.*

Vaporization: Liquids to Gases

One way to experience vaporization (VAY puhr i ZAY shuhn) is to iron a shirt—carefully!—using a steam iron. You will notice steam coming up from the iron as the wrinkles are eliminated. This steam results from the vaporization of liquid water by the iron. **Vaporization** is simply the change of state from a liquid to a gas.

Boiling is vaporization that occurs throughout a liquid. The temperature at which a liquid boils is called its *boiling point*. Like the melting point, the boiling point is a characteristic property of a substance. The boiling point of water is 100°C, whereas the boiling point of liquid mercury is 357°C. **Figure 16** illustrates the process of boiling and a second form of vaporization, evaporation (ee VAP uh RAY shuhn).

Evaporation is vaporization that occurs at the surface of a liquid below its boiling point, as shown in Figure 16. When you perspire, your body is cooled through the process of evaporation. Perspiration is mostly water. Water absorbs energy from your skin as it evaporates. You feel cooler because your body transfers energy through heat to the water. Evaporation also explains why water in a glass placed on a table disappears after several days.

Self-Check

Is vaporization an endothermic or exothermic change? *(See page 596 to check your answer.)*

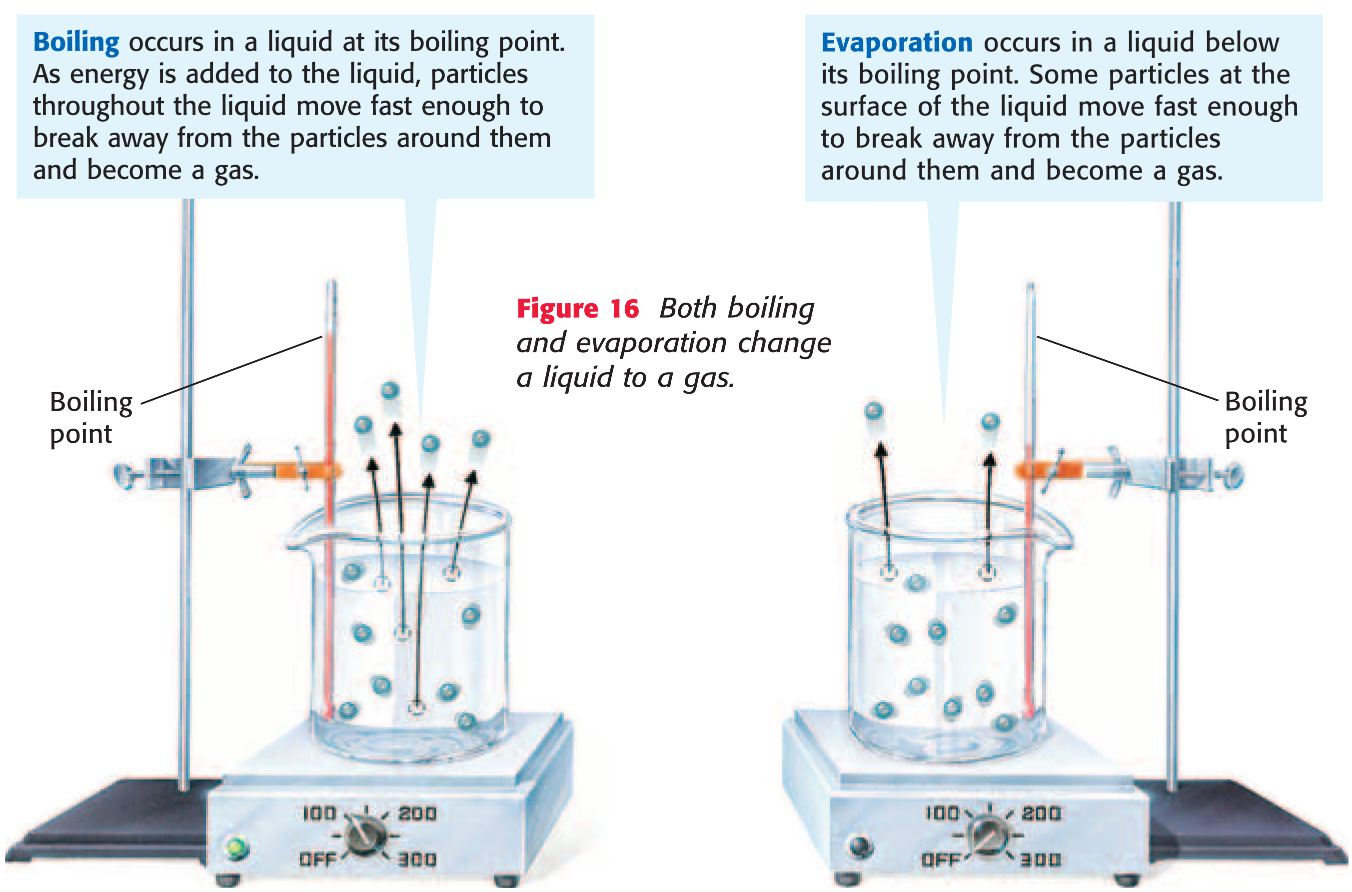


Figure 16 *Both boiling and evaporation change a liquid to a gas.*

Pressure Affects Boiling Point Earlier you learned that water boils at 100°C. In fact, water only boils at 100°C at sea level, where the atmospheric pressure is 101,000 Pa. A pascal (Pa) is simply the SI unit for pressure. It is a force of 1 N exerted over an area of 1 m^2. Atmospheric pressure is caused by the weight of the gases that make up the atmosphere. Atmospheric pressure varies depending on where you are in relation to sea level because the higher you go above sea level, the less air there is above you. The atmospheric pressure is lower at higher elevations. If you were to boil water at the top of a mountain, the boiling point would be lower than 100°C. For example, Denver, Colorado, is 1.6 km (1 mi) above sea level. Water boils in Denver at about 95°C. You can make water boil at an even lower temperature by doing the QuickLab at right.

Condensation: Gases to Liquids

Look at the cool glass of lemonade in **Figure 17.** Notice the beads of water on the outside of the glass. These form as a result of condensation. **Condensation** is the change of state from a gas to a liquid. The *condensation point* of a substance is the temperature at which the gas becomes a liquid and is the same temperature as the boiling point at a given pressure. Thus, at sea level, steam condenses to form water at 100°C—the same temperature at which water boils.

For a gas to become a liquid, large numbers of atoms or molecules must clump together. Particles clump together when the attraction between them overcomes their motion. For this to occur, energy must be removed from the gas to slow the particles down. Therefore, condensation is an exothermic change.

Figure 17 *Gaseous water in the air will become liquid when it contacts a cool surface.*

QuickLab

Boiling Water Is Cool

1. Remove the cap from a **syringe.**
2. Place the tip of the syringe in the **warm water** provided by your teacher. Pull the plunger out until you have 10 mL of water in the syringe.
3. Tightly cap the syringe.
4. Hold the syringe, and slowly pull the plunger out.
5. Observe any changes you see in the water. Record your observations in your ScienceLog.
6. Why are you not burned by the boiling water in the syringe?

across the sciences CONNECTION

The amount of gaseous water that air can hold decreases as the temperature of the air decreases. As the air cools, some of the gaseous water condenses to form small drops of liquid water. These drops form clouds in the sky and fog near the ground.

Sublimation: Solids Directly to Gases

Look at the solids shown in **Figure 18.** The solid on the left is ice. Notice the drops of liquid collecting as it melts. On the right, you see carbon dioxide in the solid state, also called dry ice. It is called dry ice because instead of melting into a liquid, it goes through a change of state called sublimation. **Sublimation** is the change of state from a solid directly into a gas. Dry ice is colder than ice, and it doesn't melt into a puddle of liquid. It is often used to keep food, medicine, and other materials cold without getting them wet.

For a solid to change directly into a gas, the atoms or molecules must move from being very tightly packed to being very spread apart. The attractions between the particles must be completely overcome. Because this requires the addition of energy, sublimation is an endothermic change.

Figure 18 *Ice melts, but dry ice, on the right, turns directly into a gas.*

Comparing Changes of State

As you learned in Section 1 of this chapter, the state of a substance depends on how fast its atoms or molecules move and how strongly they are attracted to each other. A substance may undergo a physical change from one state to another by an endothermic change (if energy is added) or an exothermic change (if energy is removed). The table below shows the differences between the changes of state discussed in this section.

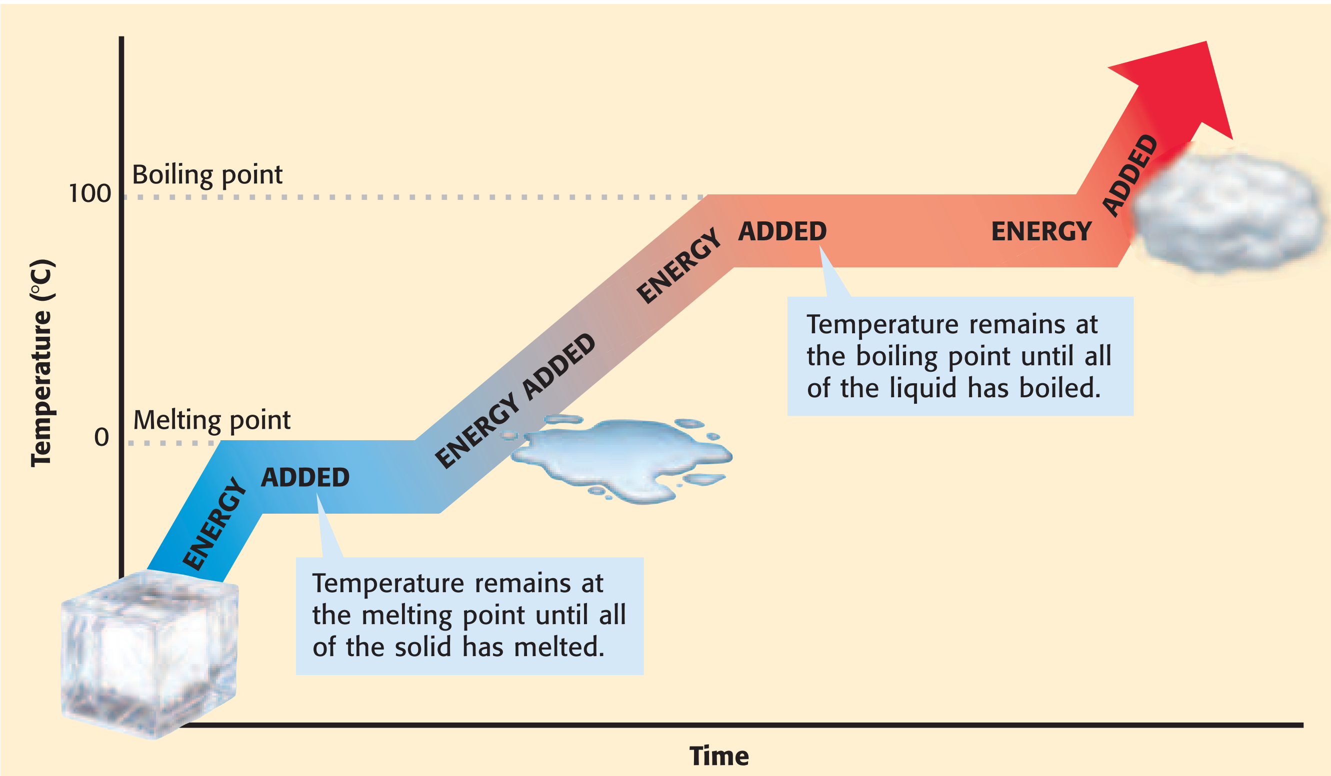
Summarizing the Changes of State

Change of state	Direction	Endothermic or exothermic?	Example
Melting	solid → liquid	endothermic	Ice melts into liquid water at 0°C.
Freezing	liquid → solid	exothermic	Liquid water freezes into ice at 0°C.
Vaporization	liquid → gas	endothermic	Liquid water vaporizes into steam at 100°C.
Condensation	gas → liquid	exothermic	Steam condenses into liquid water at 100°C.
Sublimation	solid → gas	endothermic	Solid dry ice sublimes into a gas at −78°C.

Temperature Change Versus Change of State

When most substances lose or absorb energy, one of two things happens to the substance: its temperature changes or its state changes. Earlier in the chapter, you learned that the temperature of a substance is a measure of the speed of the particles. This means that when the temperature of a substance changes, the speed of the particles also changes. But while a substance changes state, its temperature does not change until the change of state is complete, as shown in **Figure 19.**

Figure 19 **Changing the State of Water**



REVIEW

1. Compare endothermic and exothermic changes.
2. Classify each change of state (melting, freezing, vaporization, condensation, and sublimation) as endothermic or exothermic.
3. Describe how the motion and arrangement of particles change as a substance freezes.
4. **Comparing Concepts** How are evaporation and boiling different? How are they similar?

Chapter Highlights

SECTION 1

Vocabulary

states of matter *(p. 60)*
solid *(p. 61)*
liquid *(p. 62)*
gas *(p. 63)*
pressure *(p. 64)*
Boyle's law *(p. 65)*
Charles's law *(p. 66)*
plasma *(p. 67)*

Section Notes

- The states of matter are the physical forms in which a substance can exist. The four most familiar states are solid, liquid, gas, and plasma.
- All matter is made of tiny particles called atoms and molecules that attract each other and move constantly.
- A solid has a definite shape and volume.
- A liquid has a definite volume but not a definite shape.
- A gas does not have a definite shape or volume. A gas takes the shape and volume of its container.
- Pressure is a force per unit area. Gas pressure increases as the number of collisions of gas particles increases.
- Boyle's law states that the volume of a gas increases as the pressure decreases if the temperature does not change.
- Charles's law states that the volume of a gas increases as the temperature increases if the pressure does not change.
- Plasmas are composed of particles that have broken apart. Plasmas do not have a definite shape or volume.

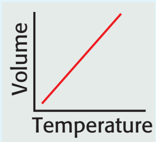
Labs

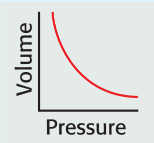
Full of Hot Air! *(p. 526)*

Skills Check

Math Concepts

GRAPHING DATA The relationship between measured values can be seen by plotting the data on a graph. The top graph shows the linear relationship described by Charles's law—as the temperature of a gas increases, its volume increases. The bottom graph shows the nonlinear relationship described by Boyle's law—as the pressure of a gas increases, its volume decreases.





Visual Understanding

PARTICLE ARRANGEMENT Many of the properties of solids, liquids, and gases are due to the arrangement of the atoms or molecules of the substance. Review the models in Figure 2 on page 60 to study the differences in particle arrangement between the solid, liquid, and gaseous states.

SUMMARY OF THE CHANGES OF STATE Review the table on page 72 to study the direction of each change of state and whether energy is absorbed or removed during each change.

SECTION 2

Vocabulary

change of state *(p. 68)*
melting *(p. 69)*
endothermic *(p. 69)*
freezing *(p. 69)*
exothermic *(p. 69)*
vaporization *(p. 70)*
boiling *(p. 70)*
evaporation *(p. 70)*
condensation *(p. 71)*
sublimation *(p. 72)*

Section Notes

- A change of state is the conversion of a substance from one physical form to another. All changes of state are physical changes.
- Exothermic changes release energy. Endothermic changes absorb energy.
- Melting changes a solid to a liquid. Freezing changes a liquid to a solid. The freezing point and melting point of a substance are the same temperature.
- Vaporization changes a liquid to a gas. Boiling occurs throughout a liquid at the boiling point. Evaporation occurs at the surface of a liquid, at a temperature below the boiling point.
- Condensation changes a gas to a liquid.
- Sublimation changes a solid directly to a gas.
- Temperature does not change during a change of state.

Labs

Can Crusher *(p. 527)*
A Hot and Cool Lab *(p. 528)*

internetconnect

GO TO: go.hrw.com

Visit the **HRW** Web site for a variety of learning tools related to this chapter. Just type in the keyword:

KEYWORD: HSTSTA

GO TO: www.scilinks.org

Visit the **National Science Teachers Association** on-line Web site for Internet resources related to this chapter. Just type in the ***sci*LINKS** number for more information about the topic:

TOPIC: Forms and Uses of Glass	***sci*LINKS NUMBER:** HSTP055
TOPIC: Solids, Liquids, and Gases	***sci*LINKS NUMBER:** HSTP060
TOPIC: Natural and Artificial Plasma	***sci*LINKS NUMBER:** HSTP065
TOPIC: Changes of State	***sci*LINKS NUMBER:** HSTP070
TOPIC: The Steam Engine	***sci*LINKS NUMBER:** HSTP075

Chapter Review

USING VOCABULARY

For each pair of terms, explain the difference in meaning.

1. exothermic/endothermic
2. Boyle's Law/Charles's Law
3. evaporation/boiling
4. melting/freezing

UNDERSTANDING CONCEPTS

Multiple Choice

5. Which of the following best describes the particles of a liquid?
   - **a.** The particles are far apart and moving fast.
   - **b.** The particles are close together but moving past each other.
   - **c.** The particles are far apart and moving slowly.
   - **d.** The particles are closely packed and vibrate in place.

6. Boiling points and freezing points are examples of
   - **a.** chemical properties.
   - **b.** physical properties.
   - **c.** energy.
   - **d.** matter.

7. During which change of state do atoms or molecules become more ordered?
   - **a.** boiling
   - **b.** condensation
   - **c.** melting
   - **d.** sublimation

8. Which of the following describes what happens as the temperature of a gas in a balloon increases?
   - **a.** The speed of the particles decreases.
   - **b.** The volume of the gas increases and the speed of the particles increases.
   - **c.** The volume decreases.
   - **d.** The pressure decreases.

9. Dew collects on a spider web in the early morning. This is an example of
   - **a.** condensation.
   - **b.** evaporation.
   - **c.** sublimation.
   - **d.** melting.

10. Which of the following changes of state is exothermic?
    - **a.** evaporation
    - **b.** sublimation
    - **c.** freezing
    - **d.** melting

11. What happens to the volume of a gas inside a piston if the temperature does not change but the pressure is reduced?
    - **a.** increases
    - **b.** stays the same
    - **c.** decreases
    - **d.** not enough information

12. The atoms and molecules in matter
    - **a.** are attracted to one another.
    - **b.** are constantly moving.
    - **c.** move faster at higher temperatures.
    - **d.** All of the above

13. Which of the following contains plasma?
    - **a.** dry ice
    - **b.** steam
    - **c.** a fire
    - **d.** a hot iron

Short Answer

14. Explain why liquid water takes the shape of its container but an ice cube does not.

15. Rank solids, liquids, and gases in order of decreasing particle speed.

16. Compare the density of iron in the solid, liquid, and gaseous states.