Science Ch. 13

Matter

Field Trip

Illinois Railway Museum

The Illinois Railway Museum in Union is America's largest railway museum. The museum is a working train yard, with several barns full of locomotives and other train cars. You will find that steam, diesel, and electric engines played a big part in the development of the rail system. All take one form of energy, such as chemical energy from fuel or electrical energy, and change it to mechanical energy to make the trains move.

Loco Illinois

Type
Steam
Diesel
Electric

tives at the lway Museum

Number
25
41
11

Find out more:

Research to find out more about one type of locomotive.

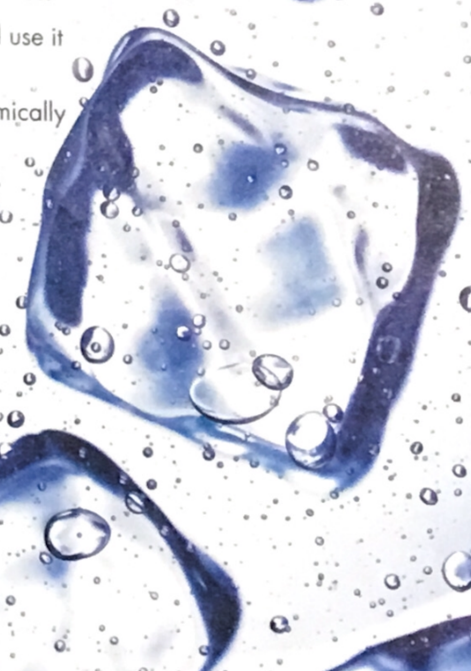
- Find out how your locomotive changes one form of energy to mechanical energy.
- Make a flowchart or draw a diagram to show this process.

Chapter 13

Matter

You Will Discover

- what chemical and physical properties are.
- that a substance has a unique set of chemical and physical properties.
- how to calculate density and use it to identify a substance.
- how matter can change chemically and physically.



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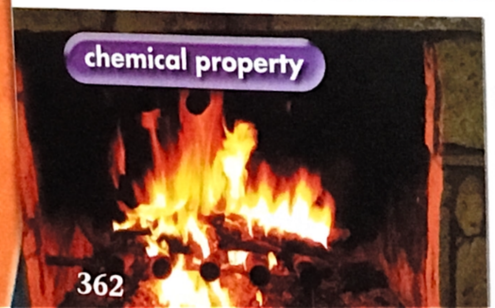
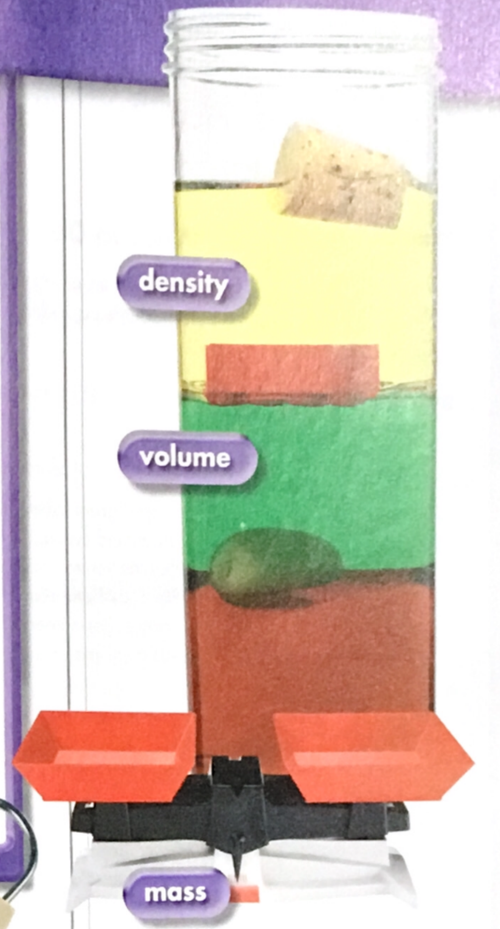
Build Background

How can the properties of matter change?

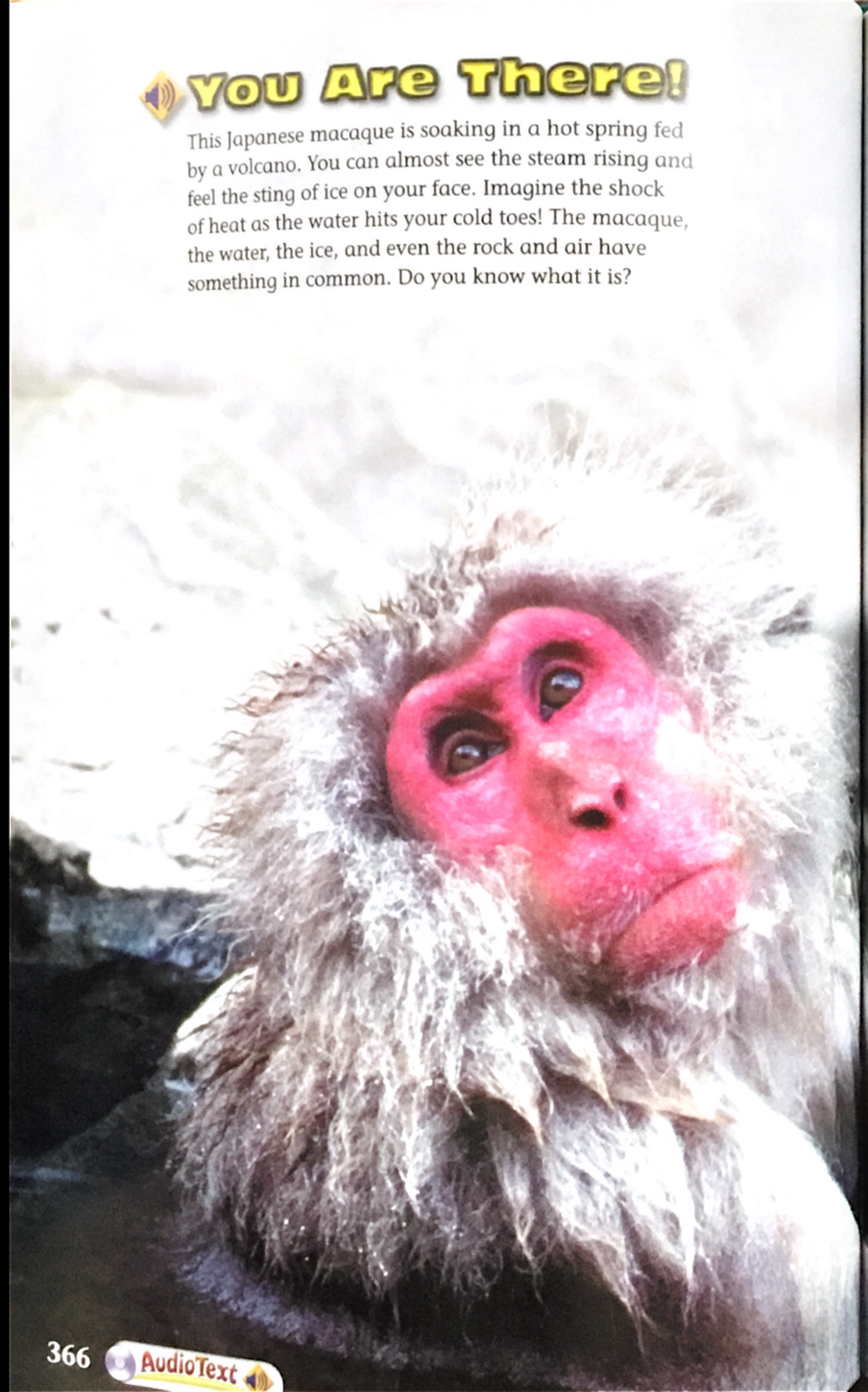


Chapter 13 Vocabulary



You Are There!

This Japanese macaque is soaking in a hot spring fed by a volcano. You can almost see the steam rising and feel the sting of ice on your face. Imagine the shock of heat as the water hits your cold toes! The macaque, the water, the ice, and even the rock and air have something in common. Do you know what it is?



Lesson 1

What is matter?

All matter has volume, mass, density, boiling point, freezing point, and other properties. These properties can be described as physical properties or chemical properties. Matter can change chemically and physically.

Measuring Matter

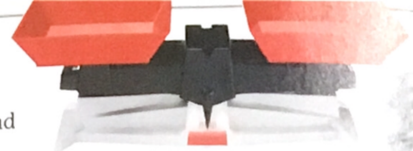
You probably know that the macaque, the rocks, and the water in the picture are matter. But did you know that the air surrounding the macaque also is matter? Matter is anything that has mass and takes up space. Everything you see is matter, whether it is tiny or huge, hard or soft, or even wet or dry. Some matter, such as the air, you can't even see.

Mass is a property of matter that can be measured. An object's **mass** is the amount of matter that makes up that object. Mass is measured in grams. The mass of an object does not depend on the object's shape. A piece of paper has the same mass whether it lies flat, is folded in half, or is shaped into a fancy paper boat.

Volume is another property of matter that you can measure. **Volume** is the amount of space that something takes up. The volume of a liquid is measured in milliliters (mL). A solid's volume is measured in cubic centimeters (cm^3). You can find the volume of some kinds of solids by multiplying the length by the width by the height. For example, a block of iron that measures 2 centimeters by 2 centimeters by 4 centimeters has a volume of 16 cubic centimeters, or 16 cm^3.

1. **Checkpoint** What are you measuring when you measure an object's mass?
2. **Math** in Science What is the volume of a block of wood that measures 1 cm by 4 cm by 2 cm?

Mass and Weight



Balance

People often confuse mass and weight, but they are different properties of matter. Mass is a measure of the amount of matter in an object. The mass of an object stays the same no matter where the object is in the universe. You can find the mass of an object by using a balance.

Weight is a measure of the pull of gravity on an object. Weight can change if the object moves to a place with a different force of gravity. Your mass would be the same on Earth as it is on the Moon. But your weight on Earth is six times greater than it would be on the Moon! Weight is measured with a spring scale in units called newtons. A newton is equal to about a quarter of a pound—a unit of weight you are more likely familiar with.

Spring scale

Density

Did anyone ever ask you this riddle: Which weighs more—a pound of feathers or a pound of lead? Do you know the answer? Both the feathers and the lead weigh the same—one pound. But one pound of feathers would be a lot larger than one pound of lead. How can that be? The reason is that the matter that makes up lead is more tightly packed than the matter that makes up feathers. The lead has a greater density. **Density** is a measure of the amount of matter in a given space. Another way to say this is that density is mass per unit volume.

Think of density this way. Suppose you have a cube of lead that measures one centimeter on each side. Its volume would be one cubic centimeter. Its mass would be 11.35 grams. The same size cube of cork would have the same volume—1 cubic centimeter. But its mass would be smaller—0.24 grams. The particles that make up matter are more tightly packed in the lead than in the cork. The lead cube would be heavier.

Finding the density of a substance is easy if you know its mass and volume. Use this formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \text{ or } \frac{m}{v}$$

For example, suppose you have an object with a mass of 30 grams and its volume is 15 cubic centimeters. What is its density?

$$\text{density} = \frac{m}{v} = \frac{30\text{g}}{15\text{cm}^3} = \frac{2\text{g}}{\text{cm}^3}$$

One cubic centimeter of this substance has a mass of 2 grams.

Can you tell what's happening in this tube? The substances—both liquids and solids—have different densities. A substance that is less dense will float on a substance that is more dense. The densest liquid is on the bottom, and the least dense floats at the top.

Using Density to Identify Substances

By now you might be wondering how knowing the density of a substance is useful. You can use density to identify an unknown substance. Every substance has a particular density. For example, if you have a small cube of lead or a large lead pipe, the density of the lead is the same—11.35 grams per cubic centimeter. Also the density of a particular substance usually differs from that of any other substance.

Suppose you have an unknown piece of metal and want to find out what it is. First, measure its mass and volume, and then use the mass and volume to calculate the density. Once you know the density, you can use a table like the one on this page to identify the metal. If you find that the density of your unknown metal is 10.50 grams per cubic centimeter, what metal do you have?

Checkpoint

1. If you dropped a cork in a container of water, would it sink or float. How do you know?
2. **Math in Science** A block of a substance is 2 cm wide, 1 cm high, and 5 cm long. It has a mass of 6.8 grams. What is its density? Use the table to identify the substance.

Oil is less dense than water, so it floats on the water. That's why oil that is spilled in an accident is likely to wash up onto the beach.

Densities of Common Materials

Material	Density (g/cm^3)
Gold	19.32
Lead	11.35
Silver	10.50
Copper	8.96
Rubber	1.10
Water	1.00
Cork	0.24
Wood	
White oak	0.68
Balsa	0.16

Physical Properties of Matter

Density is just one of the properties that can be used to describe matter. You learned that the density of copper is 8.96 grams per cubic centimeter. Look at the copper in the picture below. What other properties describe copper?

Did you describe copper as shiny and solid? Those are some of copper's physical properties. **Physical properties** of matter are those that can be seen or measured without changing the substance into something else.

The pieces of copper in the picture show two other physical properties. The copper is malleable, which means it can be spread or shaped by being pounded with a hammer or by being forced through rollers. Copper can also be made into wire, which means that it is ductile.

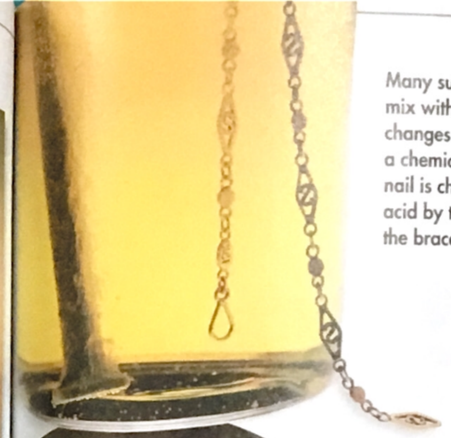
You might recognize copper as the material that makes up electrical wires. That's due to another physical property—its ability to conduct heat or electricity. Wood does not conduct heat or electricity well, which is why cooking spoons are often made of wood.

Other physical properties of matter include whether a substance can be dissolved in other substances, whether it is magnetic, and the temperatures at which the substance freezes and boils. A substance's physical properties are the same no matter how much of the substance there is.

The temperature at which a liquid boils is a physical property.

All pure water freezes and melts at 0°C. The temperatures at which substances freeze and melt are physical properties.

Copper



Many substances are changed when they mix with acids. The specific way a substance changes when mixed with another substance is a chemical property. You can tell that the zinc nail is changing into another substance in the acid by the bubbles it releases. But the gold in the bracelet doesn't change.

We know that wood is flammable, as it is the choice fuel for our fireplaces and bonfires.

Chemical Properties of Matter

Another way to describe matter is to describe its chemical properties. A substance's **chemical properties** tell how the substance forms new substances when it reacts with something else. The wood in the fireplace is burning. As the wood burns, it will change into new substances—ash and gases. A substance's ability to burn is called flammability. Wood is flammable, but iron is not.

Some Common Properties

Substance	Physical Property	Chemical Property
Wood	Does not conduct electricity	Flammable
Iron	Malleable	Combines with oxygen to form rust
Water	Colorless and odorless	Does not burn
Copper	Conducts electricity	Combines with oxygen to form the mineral cuprite

Lesson Checkpoint

1. How do physical properties and chemical properties differ?
2. **Sequence** Use sequence words—*first, next, after,* and *finally*—to explain how to find the density of a substance.
3. **Writing in Science** **Description** Choose an object and write a description of its physical properties.

Lesson 2

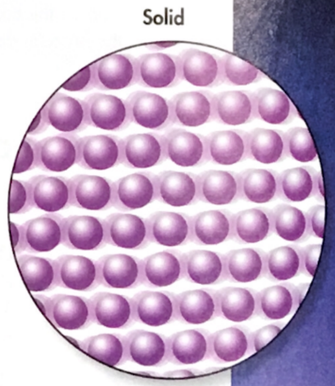
How can matter change?

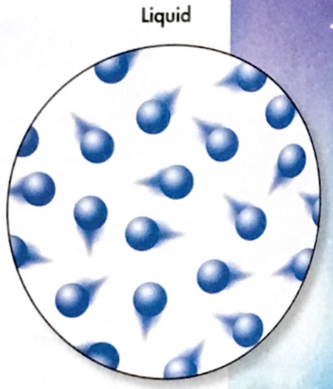
Matter can be in any of four states—solid, liquid, gas, or plasma. Matter can change from one state to another. When these changes take place, the energy of the particles making up a substance changes.

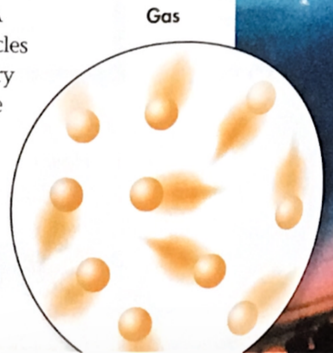
States of Matter

Look closely at your desk. Is it moving? You probably answered that it is not. But there is a buzz of activity in the matter that makes up your desk.

All matter is made up of tiny, moving particles. These particles are too tiny to be seen without a very powerful microscope. The particles constantly move and bump into each other. The speed of the particles and how strongly they are attracted to one another determine whether the matter is a solid, liquid, gas, or plasma. These four forms of matter are called the states of matter. Study the diagrams to the right as you read about solids, liquids, and gases.

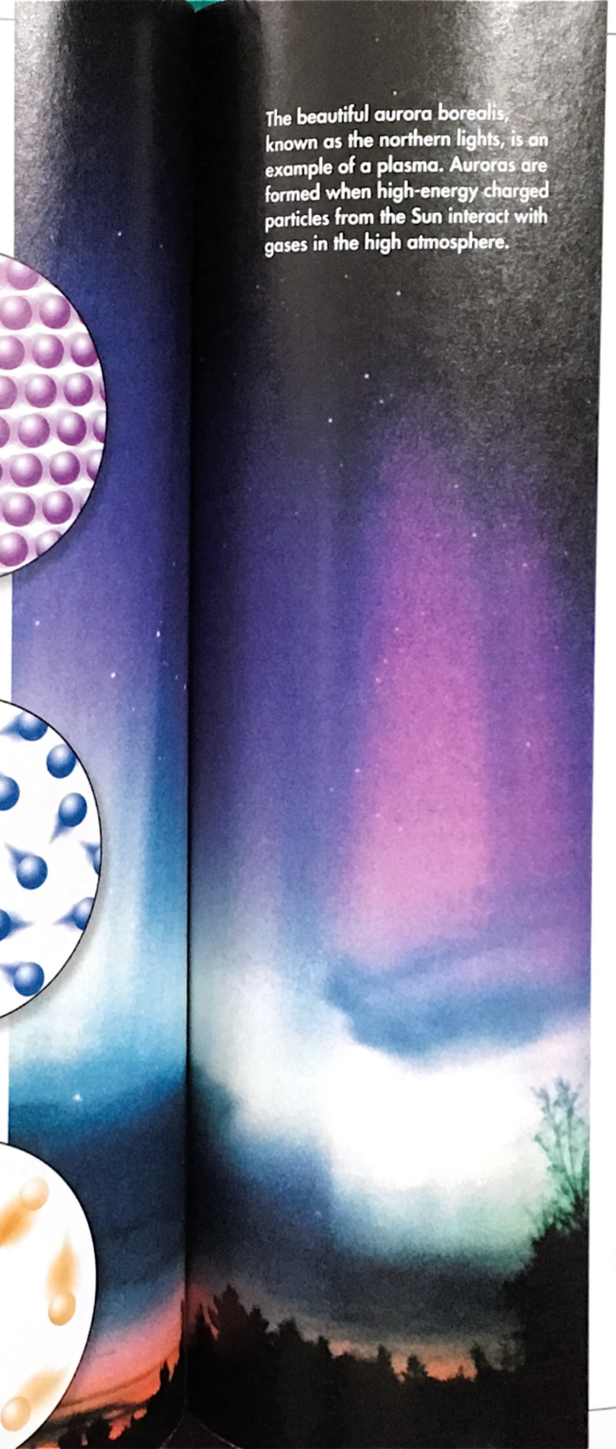






Solids

You can tell the differences among the states of matter by looking at their shape and volume. A solid has a definite shape and volume. Its particles are very close together, and they don't move very fast. A strong attraction for each other holds the particles together. You can move a solid from place to place, but it will still have the same shape and volume. Your chair, the floor, and the hair on your head are examples of solids.



The beautiful aurora borealis, known as the northern lights, is an example of a plasma. Auroras are formed when high-energy charged particles from the Sun interact with gases in the high atmosphere.

Liquids

A liquid has a definite volume but no definite shape. The particles that make up a liquid move fast enough to break through some of the attraction between them. This allows the particles to slide past each other. The result is that a liquid takes the shape of the container that holds it. You can pour a small container of juice into a cup. The shape of the juice will change, but its volume stays the same.

Gases

A gas has no particular shape or volume. Its particles move fast enough to break away from one another, and they move in many different directions. A gas will spread out to take the shape of the container it is in. You can't see the air that you breathe, but it is made up of gases that fill up and take the shape of the room that you are in, or the car, elevator, or plane in which you ride. But gases fill tiny spaces as well: small jars, balloons, or beach balls.

Plasma

Plasma is the state of matter that does not have definite shape or volume. Does that sound like a gas? Plasmas have some properties of gases and some that are different from those of gases. The particles that make up plasmas have electric charges, so plasmas can conduct electricity. Plasmas are found in lightning, fire, welding arcs, and fluorescent and neon light tubes. Plasmas are not common on Earth. But scientists believe that 99 percent of the known matter in the universe, including the Sun, is made of plasma.

Checkpoint

1. How do particles differ in the four states of matter?
2. **Technology in Science** A plasma TV uses plasma to produce pictures on its screen. Find out how plasmas are used to produce the pictures. Report your finding to the class.

Changes of State

If you look around you, you will see that some things are solids, some liquids, and others gases. We are used to seeing oxygen as a gas, iron as a solid, and mercury as a liquid. Why do different substances at the same temperature exist in different states?

Recall that the particles that make up matter have a force of attraction between them. The attractions between particles of some kinds of matter are stronger than those of others. For example, the attraction between the particles that make up iron is stronger than the force of attraction between the particles of oxygen gas in the air. That's why iron is a solid and oxygen is a gas at normal temperatures and pressures.

Temperature can affect the force of attraction between particles. If you heat a substance, its particles will gain energy and move faster. If you add enough heat, the particles will gain enough energy so that they can break some of the force of attraction between them. The solid becomes a liquid. Heat the substance even more and the particles will break completely free of the forces of attraction. The liquid has become a gas.

Gallium is a metal with a melting point so close to normal human body temperature that it would melt in your hand!

Solids melt as their particles gain energy.

Melting and Freezing

Now think about the solid iron and what might happen to it if it were heated to very high temperatures. Eventually the iron would turn to a liquid, which we call molten iron. The process by which a solid becomes a liquid is called melting. A substance becomes a liquid when it is heated to its melting point. The melting point of lead is 327.5ºC—much higher than the melting point of water at 0ºC.

Melting happens when a solid gains heat. What do you think happens if a liquid loses heat? When that happens, its particles slow down and form a solid. This process is called freezing. The temperature at which a substance freezes is its freezing point. A substance freezes and melts at the same temperature. Each substance has a particular melting and freezing point.

A substance will melt more slowly in an insulated container than it will in an open one. The reason is that the insulation slows down the movement of heat into the melting substance.

Mercury
Mercury, a metal, is a liquid at room temperature. Melting/freezing point –39°C Boiling point 356°C

Aluminum
Stacks of shiny aluminum bars are solid at room temperature. Melting/freezing point 660°C Boiling point 2,467°C

Gold
Gold is one of the most desired metals. Melting/freezing point 1,063°C Boiling point 2,966°C

The outside of this can is chilled to the point that the water vapor around it turns from a gas to drops of water.

Boiling

When you boil a pan of water, you might notice that the air around the pan gets more humid. That's because as water is heated, its particles speed up. Eventually, at its boiling point, the water gains enough heat to change to a gas—water vapor. The particles that make up the water have broken free from each other.

If the water particles in the air cool, they lose energy. The particles slow down and move closer together. When they get close enough, their attraction for each other causes them to form a liquid. This change of state from a gas to a liquid is called **condensation.**

Like adding or removing heat, changing the air pressure around a substance can change the substance's energy and cause it to boil or melt. You might think water would never freeze at room temperature, but it would at air pressures 10,000 times higher than normal! And at very low air pressures, water might change from a liquid to a gas without being heated.

Checkpoint

1. How is temperature related to the states of matter?
2. **Sequence** You are given three cups of liquids that look identical. Use sequence words—*first*, *next*, *after*, and *finally*—to explain how you might tell whether the liquids are the same or different.

Physical Changes

When a substance melts or boils, it doesn't change into a different substance. Water is still water, whether it is a solid, a liquid, or a gas. Melting, freezing, and boiling points are physical properties of a substance. A change of state, such as from a solid to a liquid, is a physical change. During a **physical change,** the appearance of a substance changes but its properties stay the same.

In a physical change, the size, shape, or state of the substance changes. Sawing wood, shredding paper, melting wax, and grating a potato are examples of physical changes. Copper ore can be hammered into sheets, and gemstones can be carved into beautiful shapes as a result of physical changes. In each case, the substance does not change into something else.

Sometimes, a substance can look completely different after a physical change. When you dissolve sugar crystals in water, the sugar seems to disappear. But it's still there. Just boil away the water, and you'll find sugar crystals again.

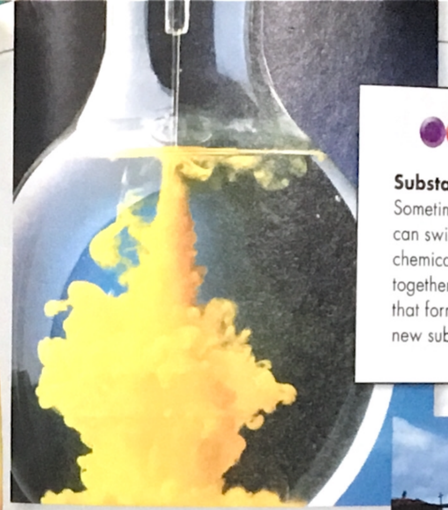
Think about what's happening to this potato. It has been peeled and shredded, but anyone can tell that potatoes are in the pan. Grating causes physical changes, but the potato is the same substance it was at the beginning of the dinner preparations. Cooking causes chemical changes.

Chemical Changes

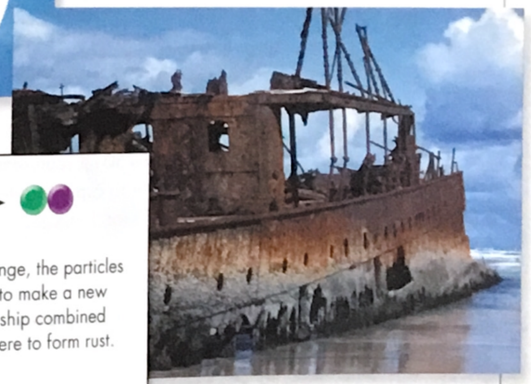
The wax of the candles to the right is melting, which is a physical change. But what about the burning wick? What kind of change is taking place there? When you burn a candle, the substance that makes up the candlewick undergoes a chemical change. During a **chemical change,** one or more substances change into completely new substances with different properties.

The burning candlewick and the oxygen gas in the air undergo a chemical change during burning. The process produces three new substances—ash, carbon dioxide gas, and water vapor. None of the new substances has the same properties as the candlewick or the oxygen gas.

Chemical changes often give clues that they are happening. Heat, light, sound, permanent color change, and fizzing often are caused by a chemical change. What clues can you find in the pictures on the next page?



Substances Switch Places
Sometimes the particles that make up different substances can switch places to make new substances. In this chemical change, two clear substances were mixed together. The result was that one of the new substances that formed is the yellow substance you see. The other new substance dissolves in the water so you can't see it.



Substances Combine
In this type of chemical change, the particles of two substances combine to make a new substance. The metal of the ship combined with oxygen in the atmosphere to form rust.

Substance Breaks Apart
Hydrogen peroxide is made up of hydrogen and oxygen particles. Light can cause a chemical change to take place in which the hydrogen peroxide breaks down into hydrogen gas and oxygen gas.

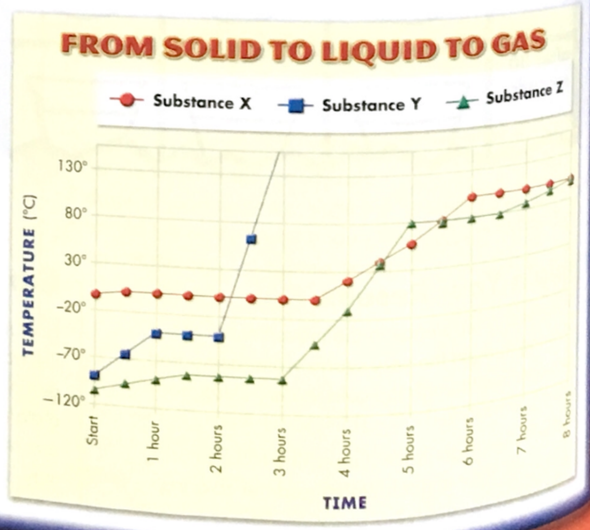
Lesson Checkpoint

1. What happens to the particles that make up water as the water is heated?
2. When water and concrete mix are combined, the material becomes warm and a hard solid forms. Is this a physical change or a chemical change? Explain your reasoning.
3. **Art in Science** Draw pictures to show how the particles in the three states of matter differ.

GRAPHING CHANGES

Scientists often show data for more than one substance on the same graph. A double or triple line graph is helpful for comparing data for two or three substances.

Three solid substances of the same mass were heated at a constant rate. The triple line graph below shows the changes in temperature of each substance. Notice the similar patterns of alternating climbs and plateaus for each line. A plateau represents a period when thermal energy was being added to the substance but there was no change in its temperature. During this time, all the energy being added is used in changing the state of the substance. The first plateau appears when a substance is at its melting point, changing from a solid to a liquid. The second plateau appears when a substance is at its boiling point, changing from a liquid to a gas.



Answer each question. Use the graph on page 380.

1. What is the boiling point of substance Z?
2. Do you think any of these substances could be water? Explain.
3. Substance Y is the densest and substance Z is the least dense. What trend do you see with these substances relating density and boiling point?
4. After 8 hours, substances X and Z are at the same temperature. How would you predict which substance would be hotter after one more hour?
5. Which substance changed from a solid to a liquid the fastest? How could you tell?

Lab zone Take-Home Activity

Caution: *Work with an adult to do this activity.* Add ice to a pan of cold water to make it as cold as you can. Then heat the pan of cold water on the stove. Using a cooking thermometer, measure and record the water's temperature every 30 or 60 seconds. Be sure the thermometer does not touch the pan. Plot your data on a graph. Does your graph follow a pattern similar to those on this page? Can you explain any differences?

Chapter 13 Review and Test Prep

Use Vocabulary

chemical change (p. 376)	**mass** (p. 367)
chemical property (p. 371)	**physical change** (p. 376)
condensation (p. 375)	**physical property** (p. 370)
density (p. 368)	**volume** (p. 367)
	weight (p. 368)

Use the vocabulary term from the list above that best completes each sentence.

1. During a _____, a substance mixes with another substance and changes into completely new substances with different properties.
2. The measure of the mass per unit volume of a substance is its _____.
3. A _____ tells how a substance forms new substances when it mixes with something else.
4. The change of state from a gas to a liquid is called _____.
5. An object's _____ is the amount of space that it takes up.
6. A _____ can be seen or measured without changing the substance into something else.
7. An object's _____ is the amount of matter that makes up that object.
8. During a_____, the appearance of a substance changes but its properties stay the same.
9. The measure of the pull of gravity on an object is its _____.

Explain Concepts

10. How does plasma differ from gases?
11. For each change below, decide if it is a physical change or a chemical change. Then tell how you know.
    - chopping wood
    - chocolate melting
    - a candle burning
    - a nail rusting
12. Using the information in the chart below, calculate the densities for liquids A, B, C, and D. Based on what you already know, which liquid is probably water? If all the liquids were poured into a column (hydrometer) and allowed to separate, what would be their order, from top to bottom?

Liquid	Mass	Volume
A	12.2 g	11.1 mL
B	21.3 g	22.5 mL
C	19.1 g	19.1 mL
D	15.5 g	31.8 mL

Process Skills

13. **Classify** Study the picture of the zinc nail and gold bracelet in vinegar on page 371. Make a list of properties for zinc and for gold. Then classify each property as chemical or physical.

Sequence

14. Describe in sequence what would happen to the particles in an ice cube from the time the cube is heated until the particles form water vapor. Use a graphic organizer like this one.

Test Prep

Choose the letter that best completes the statement or answers the question.

15. When it goes through a chemical change, a substance changes
    - Ⓐ in shape or size.
    - Ⓑ into another substance.
    - Ⓒ in color.
    - Ⓓ into another state of matter.
16. All of the following are physical properties of a substance EXCEPT
    - Ⓕ its form at a given temperature.
    - Ⓖ its density.
    - Ⓗ its boiling point.
    - Ⓘ its flammability.
17. Chemical properties describe how a substance changes when it
    - Ⓐ reacts with another substance.
    - Ⓑ changes into a different state of matter.
    - Ⓒ adds or loses mass.
    - Ⓓ gains or loses energy.
18. Even if you change the mass of a substance, the substance will always have the same
    - Ⓕ weight.
    - Ⓖ volume.
    - Ⓗ pull from gravity.
    - Ⓘ density.
19. Explain why the answer you chose for Question 15 is the best. For each of the answers that you did not choose, give a reason why it is not the best choice.
20. **Writing in Science** **Expository** You have an unknown solid that you would like to identify. Explain how you would use the solid's chemical and physical properties to identify it. Use the terms *mass*, *weight*, *density*, *boiling point*, and *freezing point*.