chapter 3

Properties and Changes of Matter

The BIG Idea

Matter is classified by physical and chemical properties and changes.

Volcanic Eruptions

At very high temperatures deep within Earth, solid rock melts. One of the properties of rock is its state—solid, liquid, or gas. As lava changes from a liquid to a solid, what happens to its properties? In this chapter, you will learn about physical and chemical properties and changes of matter.

Science Journal Think about what happens when you crack a glow stick. What types of changes are you observing?

Start-Up Activities

Launch LAB

The Changing Face of a Volcano

When a volcano erupts, it spews lava and gases. Lava is hot, melted rock from deep within the Earth. After it reaches the Earth's surface, the lava cools and hardens into solid rock. The minerals and gases within the lava, as well as the rate at which it cools, determine the characteristics of the resulting rocks. In this lab, you will compare two types of volcanic rock.

1. Obtain similar-sized samples of the rocks obsidian (ub SIH dee un) and pumice (PUH mus) from your teacher.
2. Compare the colors of the two rocks.
3. Decide which sample is heavier.
4. Look at the surfaces of the two rocks. How are the surfaces different?
5. Place each rock in water and observe.
6. **Think Critically** What characteristics are different about these rocks? In your Science Journal, make a table that compares your observations.

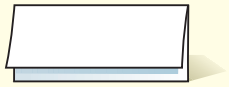
ScienceOnline

Preview this chapter's content and activities at bookk.msscience.com

FOLDABLES™ Study Organizer

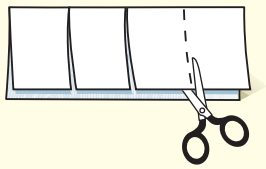
Changes of Matter Make the following Foldable to help you organize your thoughts about properties and changes.

STEP 1 **Fold** a sheet of paper in half lengthwise. Make the back edge about 1.25 cm longer than the front edge.

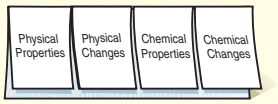


STEP 2 **Fold** in half, then fold in half again to make three folds.

STEP 3 **Unfold and cut** only the top layer along the three folds to make four tabs.



STEP 4 **Label** the tabs as shown.



Find Main Ideas As you read the chapter, write information about matter's physical and chemical properties and changes.

James L. Amos/CORBIS

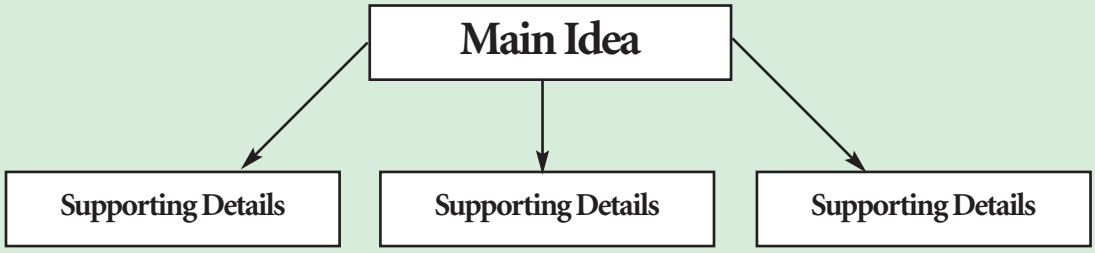
Get Ready to Read

Identify the Main Idea

1 Learn It! Main ideas are the most important ideas in a paragraph, section, or chapter. Supporting details are facts or examples that explain the main idea. Understanding the main idea allows you to grasp the whole picture.

2 Picture It! Read the following paragraph. Draw a graphic organizer like the one below to show the main idea and supporting details.

> Some physical properties describe the appearance of matter. You can detect many of these properties with your senses. For example, you can see the color and shape of the ride at the fair. You can also touch it to feel its texture. You can smell the odor or taste the flavor of some matter.
>
> *—from page 73*



3 Apply It! Pick a paragraph from another section of this chapter and diagram the main ideas as you did above.

Reading Tip

To help understand a difficult paragraph, identify the main idea and then identify the supporting details.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D		Statement	After You Read A or D
	1	A physical property can be observed with your senses.	
	2	State, density, melting point, and boiling point are chemical properties.	
	3	The ability to attract some metal objects is a physical property of lodestone.	
	4	Mass, weight, and volume are size-dependent properties.	
	5	A change of state is a chemical change.	
	6	A color change is a sign of a chemical change.	
	7	The release of energy is a sign of a physical change.	
	8	If the chemical composition of a substance changes, it has undergone a chemical change.	
	9	When wood burns, it undergoes a chemical change.	

Science Online

Print out a worksheet of this page at bookk.msscience.com

section 1

Physical and Chemical Properties

as you read

What You'll Learn

- **Identify** physical and chemical properties of matter.
- **Classify** objects based on physical properties.

Why It's Important

Understanding the different properties of matter will help you to better describe the world around you.

Review Vocabulary

matter: anything that has mass and takes up space

New Vocabulary

- physical property
- chemical property

Physical Properties

It's a busy day at the state fair as you and your classmates navigate your way through the crowd. While you follow your teacher, you can't help but notice the many sights and sounds that surround you. Eventually, you fall behind the group as you spot the most amazing ride you have ever seen. You inspect it from one end to the other. How will you describe it to the group when you catch up to them? What features will you use in your description?

Perhaps you will mention that the ride is large, blue, and made of wood. These features are all physical properties, or characteristics, of the ride. A **physical property** is a characteristic that you can observe without changing or trying to change the composition of the substance. How something looks, smells, sounds, or tastes are all examples of physical properties. In **Figure 1** you can describe and differentiate all types of matter by observing their properties.

Reading Check *What is a physical property of matter?*

Figure 1 All matter can be described by physical properties that can be observed using the five senses.
Identify *the types of matter you think you could see, hear, taste, touch, and smell at the fair.*

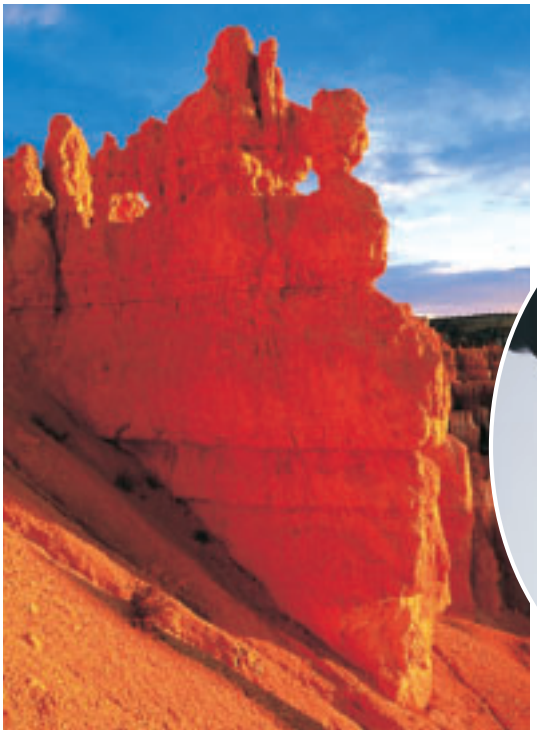
Fred Habegger from Grant Heilman

Using Your Senses Some physical properties describe the appearance of matter. You can detect many of these properties with your senses. For example, you can see the color and shape of the ride at the fair. You can also touch it to feel its texture. You can smell the odor or taste the flavor of some matter. (You should never taste anything in the laboratory.) Consider the physical properties of the items in **Figure 2.**

Figure 2 Some matter has a characteristic color, such as this sulfur pile. You can use a characteristic smell or taste to identify these fruits. Even if you didn't see it, you could probably identify this sponge by feeling its texture.

State To describe a sample of matter, you need to identify its state. Is the ride a solid, a liquid, or a gas? This property, known as the state of matter, is another physical property that you can observe. The ride, your chair, a book, and a pen are examples of matter in the solid state. Milk, gasoline, and vegetable oil are examples of matter in the liquid state. The helium in a balloon, air in a tire, and neon in a sign are examples of matter in the gas state. You can see examples of solids, liquids, and gases in **Figure 3.**

Perhaps you are most familiar with the three states of water. You can drink or swim in liquid water. You use the solid state of water, which is ice, when you put ice cubes in a drink or skate on a frozen lake. Although you can't see it, water in the gas state is all around you in the air.



This rock formation is in the solid state.

The oil flowing out of a bottle is in the liquid state.

Figure 3 The state of a sample of matter is an important physical property.

This colorful sign uses the element neon, which is generally found in the gaseous state.

Mini LAB

Measuring Properties

Procedure

1. Measure the mass of a **10-mL graduated cylinder.**
2. Fill the graduated cylinder with **water** to the 10-mL mark and remeasure the mass of the graduated cylinder with the water.
3. Determine the mass of the water by subtracting the mass of the graduated cylinder from the mass of the graduated cylinder and water.
4. Determine the density of water by dividing the mass of the water by the volume of the water.

Analysis

1. Why did you need to measure the mass of the empty graduated cylinder?
2. How would your calculated density be affected if you added more than 10 mL of water?

Figure 4 A spring scale is used to measure an object's weight.

Size-Dependent Properties Some physical properties depend on the size of the object. Suppose you need to move a box. The size of the box would be important in deciding if you need to use your backpack or a truck. You begin by measuring the width, height, and depth of the box. If you multiply them together, you calculate the box's volume. The volume of an object is the amount of space it occupies.

Another physical property that depends on size is mass. Recall that the mass of an object is a measurement of how much matter it contains. A bowling ball has more mass than a basketball. Weight is a measurement of force. Weight depends on the mass of the object and on gravity. If you were to travel to other planets, your weight would change but your size and mass would not. Weight is measured using a spring scale like the one in **Figure 4.**

Size-Independent Properties Another physical property, density, does not depend on the size of an object. Density measures the amount of mass in a given volume. To calculate the density of an object, divide its mass by its volume. The density of water is the same in a glass as it is in a tub. The density of an object will change, however, if the mass changes and the volume remains the same. Another property, solubility, also does not depend on size. Solubility is the number of grams of one substance that will dissolve in 100 g of another substance at a given temperature. The amount of drink mix that can be dissolved in 100 g of water is the same in a pitcher as it is when it is poured into a glass. Size-dependent and independent properties are shown in **Table 1.**

Melting and Boiling Point Melting and boiling point also do not depend upon an object's size. The temperature at which a solid changes into a liquid is called its melting point. The temperature at which a liquid changes into a gas is called its boiling point. The melting and boiling points of several substances, along with some of their other physical properties, are shown in **Table 2.**

Table 1 Properties of Matter

Physical Properties	
Dependent on sample size	mass, weight, volume
Independent of sample size	density, melting/boiling point, solubility, ability to attract a magnet, state of matter, color

Table 2 Physical Properties of Several Substances

Substance	State	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Solubility in cold water (g/100 mL)
Ammonia	gas	0.7710	-78	-33	89.9
Bromine	liquid	3.12	-7	59	4.17
Calcium carbonate	solid	2.71	1,339	898	0.0014
Iodine	solid	4.93	113.5	184	0.029
Potassium hydroxide	solid	2.044	360	1,322	107
Sodium chloride	solid	2.17	801	1,413	35.7
Water	liquid	1	0	100	—

Magnetic Properties

Some matter can be described by the specific way in which it behaves. For example, some materials pull iron toward them. These materials are said to be magnetic. The lodestone in **Figure 5** is a rock that is naturally magnetic.

Other materials can be made into magnets. You might have magnets on your refrigerator or locker at school. The door of your refrigerator also has a magnet within it that holds the door shut tightly.

Reading Check *What are some examples of physical properties of matter?*

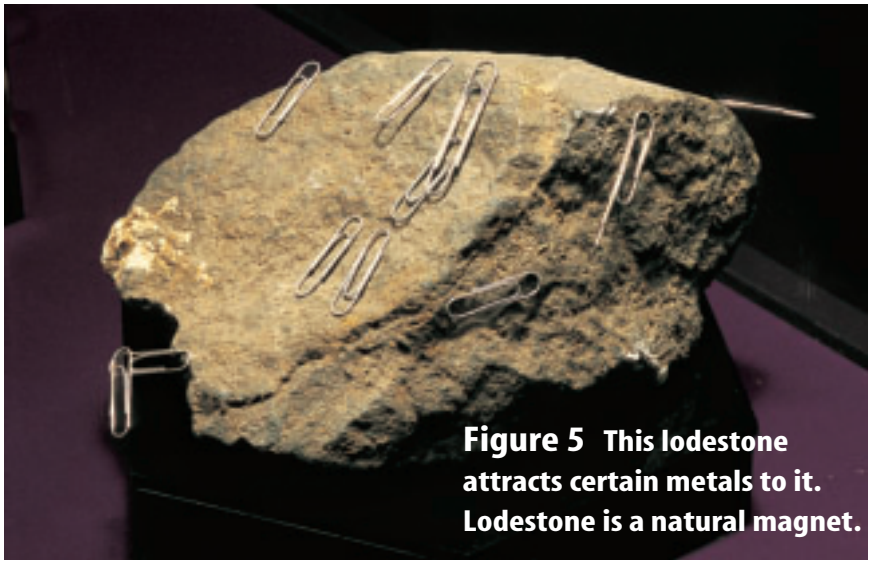


Figure 5 This lodestone attracts certain metals to it. Lodestone is a natural magnet.

Gary Retherford/Photo Researchers

Mini LAB

Identifying an Unknown Substance

Procedure

1. Obtain data from your teacher (mass, volume, solubility, melting or boiling point) for an unknown substance(s).
2. Calculate density and solubility in units of g/100 mL for your unknown substance(s).
3. Using Table 2 and the information you have, identify your unknown substance(s).

Analysis

1. Describe the procedure used to determine the density of your unknown substance(s).
2. Identify three characteristics of your substance(s).
3. Explain how the solubility of your substance would be affected if the water was hot.

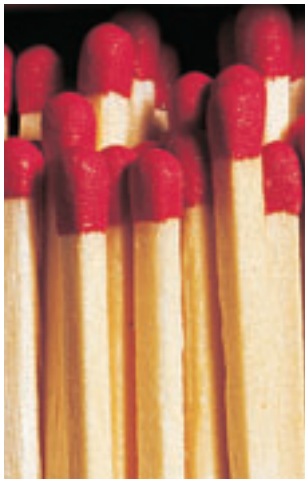


Figure 6 Notice the difference between the new matches and the matches that have been burned. The ability to burn is a chemical property of matter.

ScienceOnline

Topic: Measuring Matter

Visit bookk.msscience.com for Web links to information about methods of measuring matter.

Activity Find an object around the house. Use two methods of measuring matter to describe it.

Chemical Properties

Some properties of matter cannot be identified just by looking at a sample. For example, nothing happens if you look at the matches in the first picture. But if someone strikes the matches on a hard, rough surface they will burn, as shown in the second picture. The ability to burn is a chemical property. A **chemical property** is a characteristic that cannot be observed without altering the substance. As you can see in the last picture, the matches are permanently changed after they are burned. Therefore this property can be observed only by changing the composition of the match. Another way to define a chemical property, then, is the ability of a substance to undergo a change that alters its identity. You will learn more about changes in matter in the following section.

section 1 review

Summary

Physical Properties

- Matter exists in solid, liquid, and gaseous states.
- Volume, mass, and weight are size-dependent properties.
- Properties such as density, solubility, boiling and melting points, and ability to attract a magnet are size-independent.
- Density relates the mass of an object to its volume.

Chemical Properties

- Chemical properties have characteristics that cannot be observed without altering the identity of the substance.

Self Check

1. **Infer** How are your senses important for identifying physical properties of matter?
2. **Describe** the physical properties of a baseball.
3. **Think Critically** Explain why solubility is a size-independent physical property.
4. **Compare and Contrast** How do chemical and physical properties differ?

Applying Math

5. **Solve One-Step Equations** The volume of a bucket is 5 L and you are using a cup with a volume of 50 mL. How many cupfuls will you need to fill the bucket? Hint: 1 L = 1,000 mL

ScienceOnline bookk.msscience.com/self_check_quiz

LAB

Finding the Difference

Real-World Question

You can identify an unknown object by comparing its physical and chemical properties to the properties of identified objects.

Goals

- **Identify** the physical properties of objects.
- **Compare and contrast** the properties.
- **Categorize** the objects based on their properties.

Materials

meterstick
spring scale
block of wood
metal bar or metal ruler
plastic bin
drinking glass
water
rubber ball
paper
carpet
magnet
rock
plant or flower
soil
sand
apple (or other fruit)
vegetable
slice of bread
dry cereal
egg
feather

Safety Precautions

Procedure

1. List at least six properties that you will observe, measure, or calculate for each object. Describe how to determine each property.
2. In your Science Journal, create a data table with a column for each property and rows for the objects.
3. Complete your table by determining the properties for each object.

Timothy Fuller

Conclude and Apply

1. **Describe** Which properties were you able to observe easily? Which required making measurements? Which required calculations?
2. **Compare and contrast** the objects based on the information in your table.
3. **Draw Conclusions** Choose a set of categories and group your objects into those categories. Some examples of categories are large/medium/small, heavy/moderate/light, bright/moderate/dull, solid/liquid/gas, etc. Were the categories you chose useful for grouping your objects? Why or why not?

Communicating Your Data

Compare your results with those of other students in your class. **Discuss** the properties of objects that different groups included on their tables. Make a large table including all of the objects that students in the class studied.

section 2

Physical and Chemical Changes

as you read

What You'll Learn

- **Compare** several physical and chemical changes.
- **Identify** examples of physical and chemical changes.

Why It's Important

From modeling clay to watching the leaves turn colors, physical and chemical changes are all around us.

Review Vocabulary

solubility: the amount of a substance that will dissolve in a given amount of another substance

New Vocabulary

- physical change
- vaporization
- condensation
- sublimation
- deposition
- chemical change
- law of conservation of mass

Physical Changes

What happens when the artist turns the lump of clay shown in **Figure 7** into bowls and other shapes? The composition of the clay does not change. Its appearance, however, changes dramatically. The change from a lump of clay to different shapes is a physical change. A **physical change** is one in which the form or appearance of matter changes, but not its composition. The lake in **Figure 7** also experiences a physical change. Although the water changes state due to a change in temperature, it is still made of the elements hydrogen and oxygen.

Changing Shape Have you ever crumpled a sheet of paper into a ball? If so, you caused physical change. Whether it exists as one flat sheet or a crumpled ball, the matter is still paper. Similarly, if you cut fruit into pieces to make a fruit salad, you do not change the composition of the fruit. You change only its form. Generally, whenever you cut, tear, grind, or bend matter, you are causing a physical change.

Figure 7 Although each sample looks quite different after it experiences a change, the composition of the matter remains the same. These changes are examples of physical changes.

Dissolving What type of change occurs when you add sugar to iced tea, as shown in **Figure 8?** Although the sugar seems to disappear, it does not. Instead, the sugar dissolves. When this happens, the particles of sugar spread out in the liquid. The composition of the sugar stays the same, which is why the iced tea tastes sweet. Only the form of the sugar has changed.

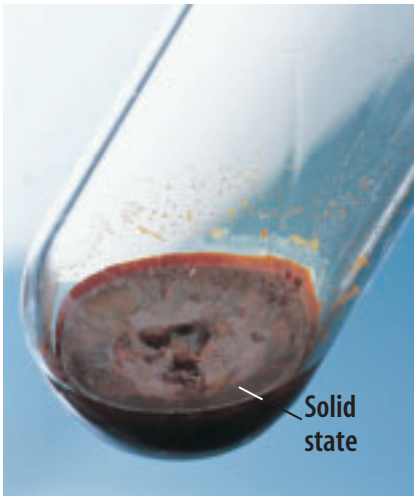
Figure 8 Physical changes are occurring constantly. The sugar blending into the iced tea is an example of a physical change. **Define** *What is a physical change?*

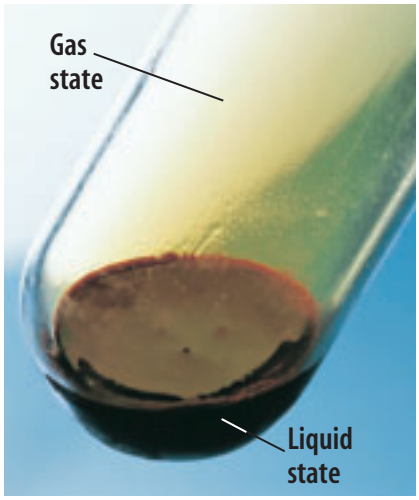
Changing State Another common physical change occurs when matter changes from one state to another. When an ice cube melts, for example, it becomes liquid water. The solid ice and the liquid water have the same composition. The only difference is the form.

Matter can change from any state to another. Freezing is the opposite of melting. During freezing, a liquid changes into a solid. A liquid also can change into a gas. This process is known as **vaporization.** During the reverse process, called **condensation,** a gas changes into a liquid. **Figure 9** summarizes these changes.

In some cases, matter changes between the solid and gas states without ever becoming a liquid. The process in which a solid changes directly into a gas is called **sublimation.** The opposite process, in which a gas changes into a solid, is called **deposition.**

Figure 9 Look at the photographs below to identify the different physical changes that bromine undergoes as it changes from one state to another.





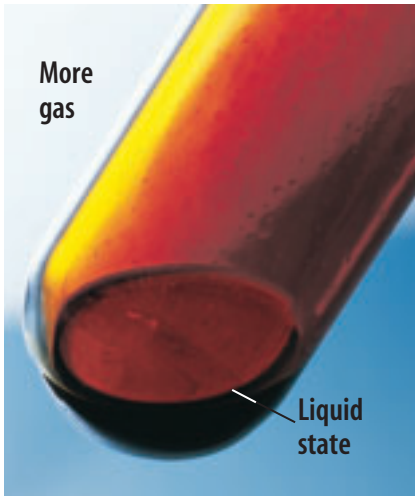


Figure 10 These brilliant fireworks result from chemical changes.
Define *What is a chemical change?*

Chemical Changes

It's the Fourth of July in New York City. Brilliant fireworks are exploding in the night sky. When you look at fireworks, such as these in **Figure 10,** you see dazzling sparkles of red and white trickle down in all directions. The explosion of fireworks is an example of a chemical change. During a **chemical change,** substances are changed into different substances. In other words, the composition of the substance changes.

You are familiar with another chemical change if you have ever left your bicycle out in the rain. After awhile, a small chip in the paint leads to an area of a reddish, powdery substance. This substance is rust. When iron in steel is exposed to oxygen and water in air, iron and oxygen atoms combine to form the principle component in rust. In a similar way, silver coins tarnish when exposed to air. These chemical changes are shown in **Figure 11.**

Reading Check ***How is a chemical change different from a physical change?***

Figure 11 Each of these examples shows the results of a chemical change. In each case, the substances that are present after the change are different from those that were present before the change.

Figure 12 In the fall, the chlorophyll in this tree's leaves undergoes a chemical change into colorless chemicals. This allows the red pigment to be seen.

Signs of Chemical Changes

Physical changes are relatively easy to identify. If only the form of a substance changes, you have observed a physical change. How can you tell whether a change is a chemical change? If you think you are unfamiliar with chemical changes, think again.

INTEGRATE Life Science

You have witnessed a spectacular chemical change if you have seen the leaves on a tree change from green to bright yellow, red, or orange. But, it is not a change from a green pigment to a red pigment, as you might think. Pigments are chemicals that give leaves their color. In **Figure 12,** the green pigment that you see during the summer is chlorophyll (KLOHR uh fihl). In autumn, however, changes in temperature and rainfall amounts cause trees to stop producing chlorophyll. The chlorophyll already in the leaves undergoes a chemical change into colorless chemicals. Where do the bright fall colors come from? The pigments that produce fall colors have been present in the leaves all along. However, in the summer, chlorophyll is present in large enough amounts to mask these pigments. In the fall, when chlorophyll production stops, the bright pigments become visible.

Color Perhaps you have found that a half-eaten apple turns brown. The reason is that a chemical change occurs when the apple is exposed to air. Maybe you have toasted a marshmallow or a slice of bread and watched them turn black. In each case, the color of the food changes as it is cooked because a chemical change occurs.

Science Online

Topic: Recognizing Chemical Changes

Visit bookk.msscience.com for Web links to information about how chemical equations can be used to model chemical changes.

Activity Describe the chemical reactions that are involved in making and baking a yeast bread.

Mini LAB

Comparing Changes

Procedure

1. Separate a piece of **fine steel wool** into two halves.
2. Dip one half in **tap water.**
3. Place each piece of steel wool on a separate **paper plate** and let them sit overnight.

Analysis

1. Did you observe any changes in the steel wool? If so, describe them.
2. If you observed changes, were they physical or chemical? How do you know?

Try at Home

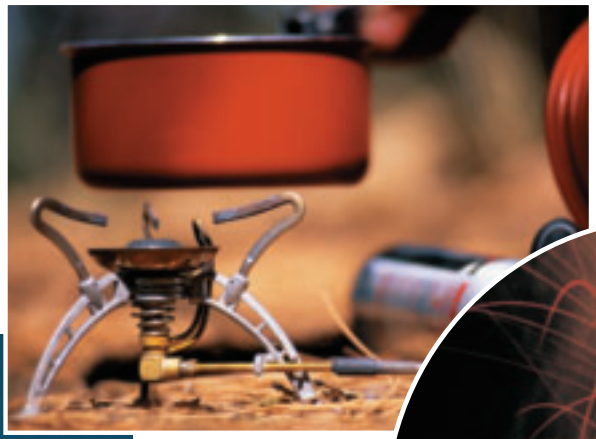
Figure 13 Cake batter undergoes a chemical change as it absorbs energy during cooking.

Energy Another sign of a chemical change is the release or gain of energy by an object. Many substances must absorb energy in order to undergo a chemical change. For example, energy is absorbed during the chemical changes involved in cooking. When you bake a cake or make pancakes, energy is absorbed by the batter as it changes from a runny mix into what you see in **Figure 13.**

Another chemical change in which a substance absorbs energy occurs during the production of cement. This process begins with the heating of limestone. Ordinarily, limestone will remain unchanged for centuries. But when it absorbs energy during heating, it undergoes a chemical change in which it turns into lime and carbon dioxide.

Energy also can be released during a chemical change. The fireworks you read about earlier released energy in the form of light that you can see. As shown in **Figure 14,** a chemical change within a firefly releases energy in the form of light. Fuel burned in the camping stove releases energy you see as light and feel as heat. You also can see that energy is released when sodium and chlorine are combined and ignited in the last picture. During this chemical change, the original substances change into sodium chloride, which is ordinary table salt.

Figure 14 Energy is released when a firefly glows, when fuel is burned in a camping stove, and when sodium and chlorine undergo a chemical change to form table salt.



Odor It takes only one experience with a rotten egg to learn that they smell much different than fresh eggs. When eggs and other foods spoil, they undergo chemical change. The change in odor is a clue to the chemical change. This clue can save lives. When you smell an odd odor in foods, such as chicken, pork, or mayonnaise, you know that the food has undergone a chemical change. You can use this clue to avoid eating spoiled food and protect yourself from becoming ill.

Gases or Solids Look at the antacid tablet in **Figure 15.** You can produce similar bubbles if you pour vinegar on baking soda. The formation of a gas is a clue to a chemical change. What other products undergo chemical changes and produce bubbles?

Figure 15 also shows another clue to a chemical change—the formation of a solid. A solid that separates out of a solution during a chemical change is called a precipitate. The precipitate in the photograph forms when a solution containing sodium iodide is mixed with a solution containing lead nitrate.

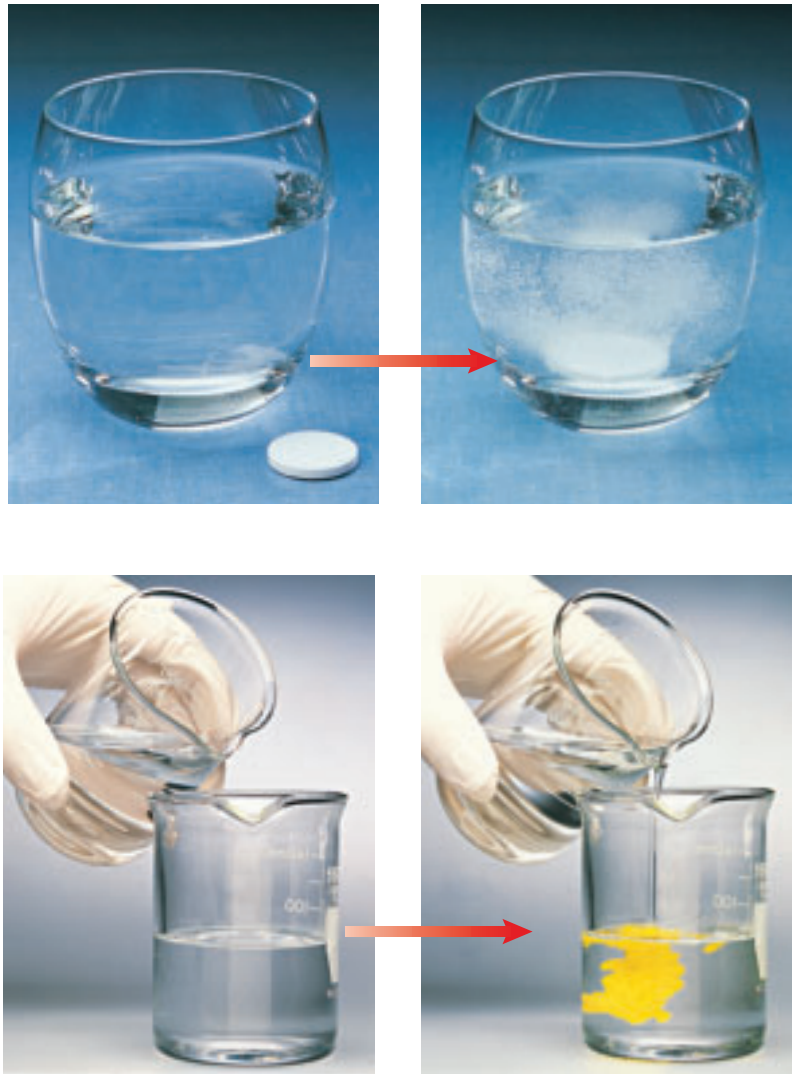


Figure 15 The bubbles of gas formed when this antacid tablet is dropped into water indicate a chemical change. The solid forming from two liquids is another sign that a chemical change has taken place.

INTEGRATE Astronomy

Meteoroid A meteoroid is a chunk of metal or stone in space. Every day, meteoroids enter Earth's atmosphere. When this happens, the meteoroid burns as a result of friction with gases in the atmosphere. It is then referred to as a meteor, or shooting star. The burning produces streaks of light. The burning is an example of a chemical change. In your Science Journal, infer why most meteoroids never reach Earth's surface.

Figure 16 As wood burns, it turns into a pile of ashes and gases that rise into the air.
Determine *Can you turn ashes back into wood?*

Not Easily Reversed How do physical and chemical changes differ from one another? Think about ice for a moment. After solid ice melts into liquid water, it can refreeze into solid ice if the temperature drops enough. Freezing and melting are physical changes. The substances produced during a chemical change cannot be changed back into the original substances by physical means. For example, the wood in **Figure 16** changes into ashes and gases that are released into the air. After wood is burned, it cannot be restored to its original form as a log.

Think about a few of the chemical changes you just read about to see if this holds true. An antacid tablet cannot be restored to its original form after being dropped in water. Rotten eggs cannot be made fresh again, and pancakes cannot be turned back into batter. The substances that existed before the chemical change no longer exist.

Reading Check ***What signs indicate a chemical change?***

Applying Math — Solve for an Unknown

CONVERTING TEMPERATURES Fahrenheit is a non-SI temperature scale. Because it is used so often, it is useful to be able to convert from Fahrenheit to Celsius. The equation that relates Celsius degrees to Fahrenheit degrees is: $(°C \times 1.8) + 32 = °F$. What is 15°F on the Celsius scale?

Solution

1. *This is what you know:*
   - temperature = 15°F
   - $(°C \times 1.8) + 32 = °F$
2. *This is what you need to find out:*
   - temperature in degrees Celsius
3. *This is the procedure you need to use:*
   - $(°C \times 1.8) + 32 = °F$
   - $°C = (°F - 32)/1.8$
   - $°C = (15 - 32)/1.8 = -9.4°C$
4. *Check your answer:*
   Substitute the Celsius temperature into the original equation. Did you calculate the Fahrenheit temperature that was given?

Practice Problems

1. Water is being heated on the stove at 156°F. What is this temperature on the Celsius scale?
2. The boiling point of ethylene glycol is 199°C. What is the temperature on the Fahrenheit scale?

ScienceOnline For more practice, visit bookk.msscience.com/math_practice

Chemical Versus Physical Change

Now you have learned about many different physical and chemical changes. You have read about several characteristics that you can use to distinguish between physical and chemical changes. The most important point for you to remember is that in a physical change, the composition of a substance does not change and in a chemical change, the composition of a substance does change. When a substance undergoes a physical change, only its form changes. In a chemical change, both form and composition change.

When the wood and copper in **Figure 17** undergo physical changes, the original wood and copper still remain after the change. When a substance undergoes a chemical change, however, the original substance is no longer present after the change. Instead, different substances are produced during the chemical change. When the wood and copper in **Figure 17** undergo chemical changes, wood and copper have changed into new substances with new physical and chemical properties.

Physical and chemical changes are used to recycle or reuse certain materials. **Figure 18** discusses the importance of some of these changes in recycling.

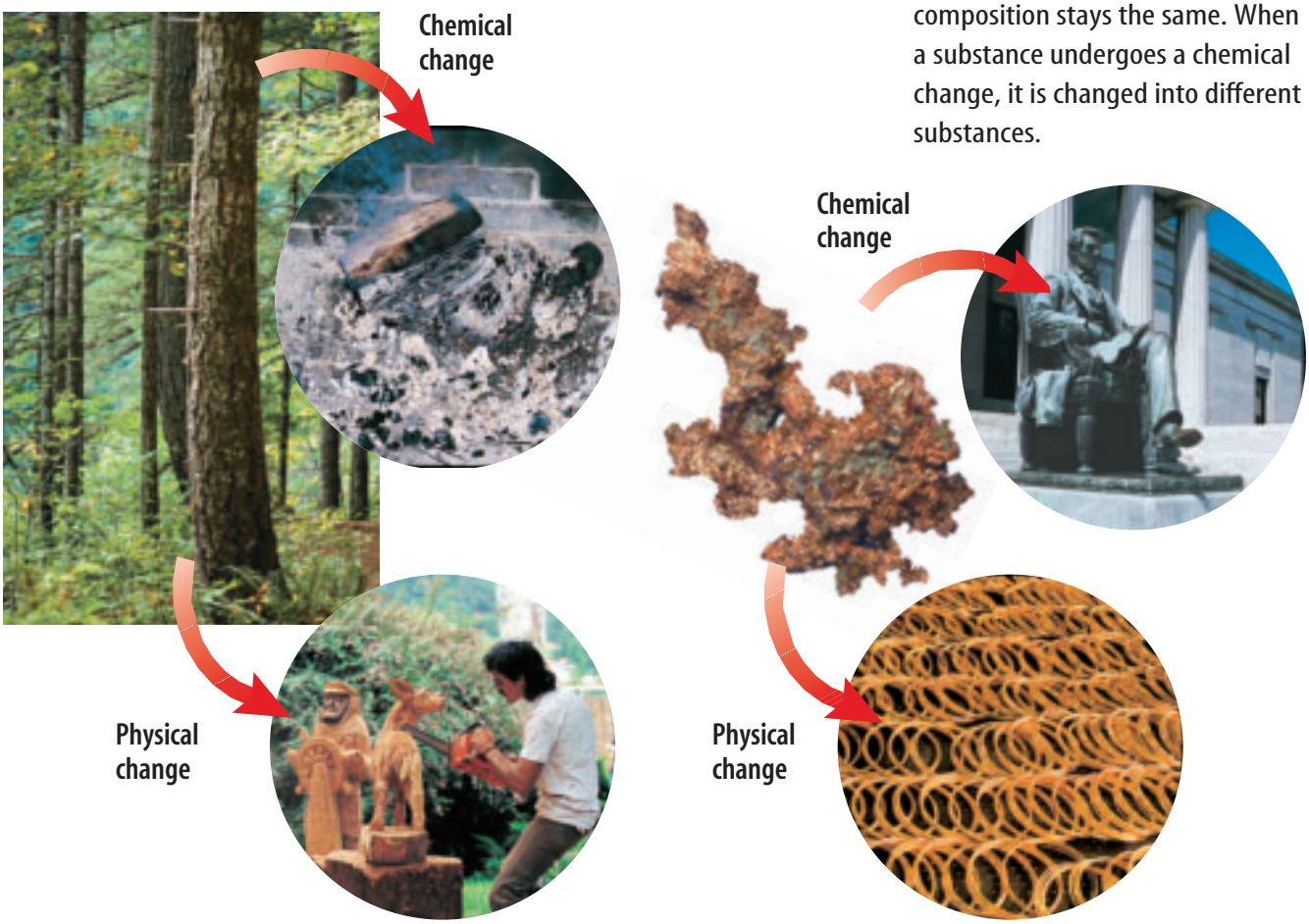


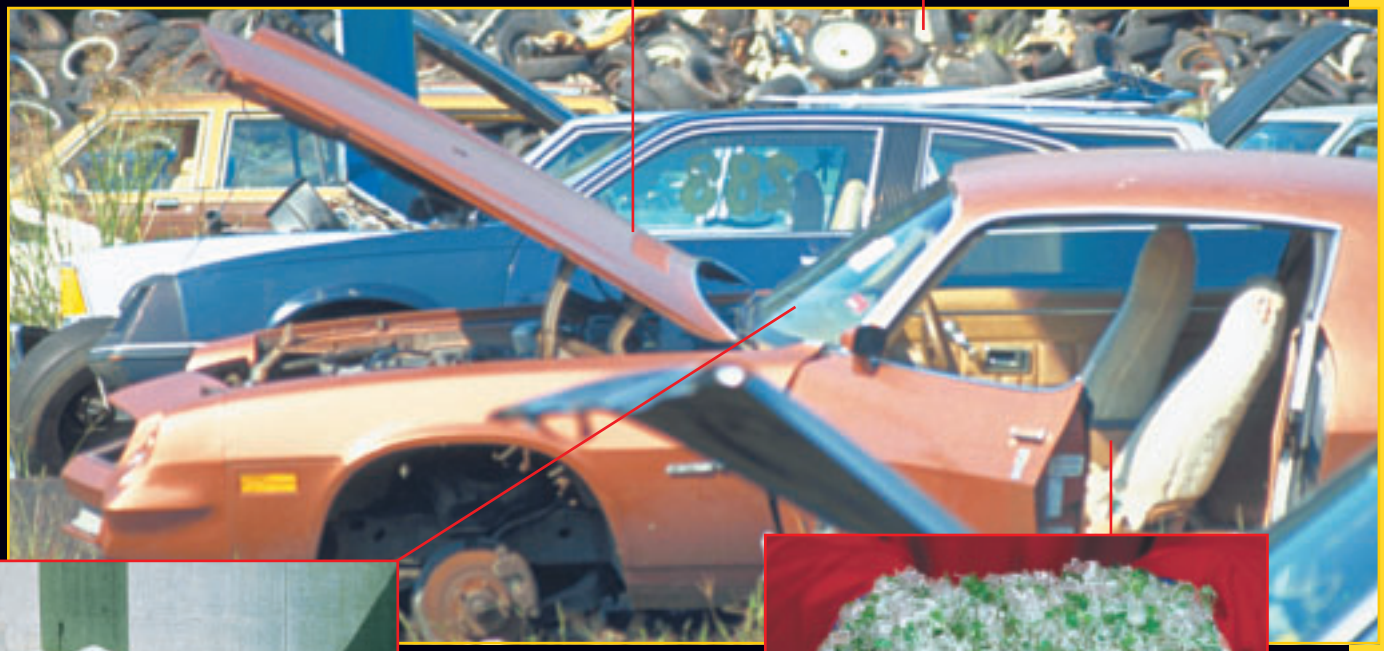
Figure 17 When a substance undergoes a physical change, its composition stays the same. When a substance undergoes a chemical change, it is changed into different substances.

Figure 18

Recycling is a way to separate wastes into their component parts and then reuse those components in new products. In order to be recycled, wastes need to be physically—and sometimes chemically—changed. The average junked automobile contains about 62 percent iron and steel, 28 percent other materials such as aluminum, copper, and lead, and 10 percent rubber, plastics, and various materials.

◀ Rubber tires can be shredded and added to asphalt pavement and playground surfaces. New recycling processes make it possible to supercool tires to a temperature at which the rubber is shattered like glass. A magnet can then draw out steel from the tires and other parts of the car.

▼ After being crushed and flattened, car bodies are chopped into small pieces. Metals are separated from other materials using physical processes. Some metals are separated using powerful magnets. Others are separated by hand.



◀ Glass can be pulverized and used in asphalt pavement, new glass, and even artwork. This sculpture, named *Groundswell,* was created by artist Maya Lin using windshield glass.

▲ Some plastics can be melted and formed into new products. Others are ground up or shredded and used as fillers or insulating materials.

Conservation of Mass

During a chemical change, the form or the composition of the matter changes. The particles within the matter rearrange to form new substances, but they are not destroyed and new particles are not created. The number and type of particles remains the same. As a result, the total mass of the matter is the same before and after a physical or chemical change. This is known as the **law of conservation of mass.**

This law can sometimes be difficult to believe, especially when the materials remaining after a chemical change might look quite different from those before it. In many chemical changes in which mass seems to be gained or lost, the difference is often due to a gas being given off or taken in. When the candle burns in **Figure 19,** gases in the air combine with the candle wax. New gases are formed that go into the air. The mass of the wax, which is burned and the gases that combine with the wax equal the mass of the gases produced by burning.

The scientist who first performed the careful experiments necessary to prove that mass is conserved was Antoine Lavoisier (AN twan • luh VWAH see ay) in the eighteenth century. It was Lavoisier who recognized that the mass of gases that are given off or taken from the air during chemical changes account for any differences in mass.

Figure 19 The candle lost mass when it was burned. The mass lost by the candle combined with the gases in the air to form new substances. As a result, mass was not created or destroyed.

section 2 review

Summary

Physical Changes

- The form of matter, its shape or state, is altered during a physical change.
- The composition of matter remains the same.

Chemical Changes

- Both form and composition of matter are altered during a chemical change.
- Some signs of a chemical change are altered color, energy, odor, and formation of a gas or solid.
- Chemical changes are not easily reversed.

Conservation of Mass

- The total mass of the matter is the same before and after a physical or chemical change.

Self Check

1. **List** five physical changes that you can observe in your home.
2. **Determine** what kind of change occurs on the surface of bread when it is toasted.
3. **Infer** How is mass conserved during a chemical change?
4. **Think Critically** A log is reduced to a small pile of ash when it burns. Explain the difference in mass between the log and the ash.

Applying Math

5. **Solve One-Step Equations** Magnesium and oxygen undergo a chemical change to form magnesium oxide. How many grams of magnesium oxide will be produced when 0.486 g of oxygen completely react with 0.738 g of magnesium?

LAB

Design Your Own

Battle of the Toothpastes

Goals

- **Observe** how toothpaste helps prevent tooth decay.
- **Design** an experiment to test the effectiveness of various types and brands of toothpaste.

Possible Materials

3 or 4 different brands and types of toothpaste
drinking glasses or bowls
hard-boiled eggs
concentrated lemon juice
apple juice
water
artist's paint brush

Safety Precautions

Real-World Question

Your teeth are made of a compound called hydroxyapatite (hi DRAHK see A puh tite). The sodium fluoride in toothpaste undergoes a chemical reaction with hydroxyapatite to form a new compound on the surface of your teeth. This compound resists food acids that cause tooth decay, another chemical change. In this lab, you will design an experiment to test the effectiveness of different toothpaste brands. The compound found in your teeth is similar to the mineral compound found in eggshells. Treating hard-boiled eggs with toothpaste is similar to brushing your teeth with toothpaste. Soaking the eggs in food acids such as vinegar for several days will produce similar conditions as eating foods, which contain acids that will produce a chemical change in your teeth, for several months.

Form a Hypothesis

Form a hypothesis about the effectiveness of different brands of toothpaste.

Test Your Hypothesis

Make a Plan

1. **Describe** how you will use the materials to test the toothpaste.
2. **List** the steps you will follow to test your hypothesis.
3. **Decide** on the length of time that you will conduct your experiment.

Matt Meadows

4. **Identify** the control and variables you will use in your experiment.
5. **Create** a data table in your Science Journal to record your observations, measurements, and results.
6. **Describe** how you will measure the amount of protection each toothpaste brand provides.

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Conduct** your experiment as planned. Be sure to follow all proper safety precautions.
3. **Record** your observations in your data table.

Analyze Your Data

1. **Compare** the untreated eggshells with the shells you treated with toothpaste.
2. **Compare** the condition of the eggshells you treated with different brands of toothpaste.
3. **Compare** the condition of the eggshells soaked in lemon juice and in apple juice.
4. **Identify** unintended variables you discovered in your experiment that might have influenced the results.

Conclude and Apply

1. **Identify** Did the results support your hypothesis? Describe the strengths and weaknesses of your hypothesis.
2. **Explain** why the eggshells treated with toothpaste were better-protected than the untreated eggshells.
3. **Identify** which brands of toothpaste, if any, best protected the eggshells from decay.
4. **Evaluate** the scientific explanation for why adding fluoride to toothpaste and drinking water prevents tooth decay.
5. **Predict** what would happen to your protected eggs if you left them in the food acids for several weeks.
6. **Infer** why it is a good idea to brush with fluoride toothpaste.

Communicating Your Data

Compare your results with the results of your classmates. **Create** a poster advertising the benefits of fluoride toothpaste.

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SCIENCE Stats

Strange Changes

Did you know...

... A hair colorist is also a chemist!

Colorists use hydrogen peroxide and ammonia to swell and open the cuticle-like shafts on your hair. Once these are open, the chemicals in hair dye can get into your natural pigment molecules and chemically change your hair color. The first safe commercial hair color was created in 1909 in France.

... Americans consume about 175 million kg of sauerkraut each year.

During the production of sauerkraut, bacteria produce lactic acid. The acid chemically breaks down the material in the cabbage, making it translucent and tangy.

Applying Math There are 275 million people in the United States. Calculate the average amount of sauerkraut consumed by each person in the United States in one year.

... More than 450,000 metric tons of plastic packaging are recycled each year in the U.S.

Discarded plastics undergo physical changes including melting and shredding. They are then converted into flakes or pellets, which are used to make new products. Recycled plastic is used to make clothes, furniture, carpets, and even lumber.

Projected Recycling Rates by Material, 2000

Material	1995 Recycling	Proj. Recycling
Paper/Paperboard	40.0%	43 to 46%
Glass	24.5%	27 to 36%
Ferrous metal	36.5%	42 to 55%
Aluminum	34.6%	46 to 48%
Plastics	5.3%	7 to 10%
Yard waste	30.3%	40 to 50%
Total Materials	**27.0%**	**30 to 35%**

Find Out About It

Every time you cook, you make physical and chemical changes to food. Visit bookk.msscience.com/science_stats or to your local or school library to find out what chemical or physical changes take place when cooking ingredients are heated or cooled.

Reviewing Main Ideas

Section 1 Physical and Chemical Properties

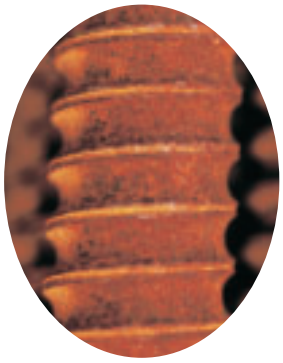
1. Matter can be described by its characteristics, or properties, and can exist in different states—solid, liquid, or gas.
2. A physical property is a characteristic that can be observed without altering the composition of the sample.
3. Physical properties include color, shape, smell, taste, and texture, as well as measurable quantities such as mass, volume, density, melting point, and boiling point.
4. A chemical property is a characteristic that cannot be observed without changing what the sample is made of.

Section 2 Physical and Chemical Changes

1. During a physical change, the composition of matter stays the same but the appearance changes in some way.
2. Physical changes occur when matter changes from one state to another.
3. A chemical change occurs when the composition of matter changes.
4. Signs of chemical change include changes in energy, color, odor, or the production of gases or solids.
5. According to the law of conservation of mass, mass cannot be created or destroyed.

Visualizing Main Ideas

Copy and complete the following concept map on matter.



chapter 3 Review

Using Vocabulary

chemical change p. 80
chemical property p. 76
condensation p. 79
deposition p. 79
law of conservation of mass p. 87
physical change p. 78
physical property p. 72
sublimation p. 79
vaporization p. 79

Use what you know about the vocabulary words to answer the following questions. Use complete sentences.

1. Why is color a physical property?
2. What is a physical property that does not change with the amount of matter?
3. What happens during a physical change?
4. What type of change is a change of state?
5. What happens during a chemical change?
6. What are three clues that a chemical change has occurred?
7. What is an example of a chemical change?
8. What is the law of conservation of mass?

Checking Concepts

Choose the word or phrase that best answers the question.

9. What changes when the mass of an object increases while volume stays the same?
   A) color **C)** density
   B) length **D)** height
10. What word best describes the type of materials that attract iron?
    A) magnetic **C)** mass
    B) chemical **D)** physical
11. Which is an example of a chemical property?
    A) color **C)** density
    B) mass **D)** ability to burn
12. Which is an example of a physical change?
    A) metal rusting **C)** water boiling
    B) silver tarnishing **D)** paper burning
13. What characteristic best describes what happens during a physical change?
    A) composition changes
    B) composition stays the same
    C) form stays the same
    D) mass is lost
14. Which is an example of a chemical change?
    A) water freezes **C)** bread is baked
    B) wood is carved **D)** wire is bent
15. Which is NOT a clue that could indicate a chemical change?
    A) change in color
    B) change in shape
    C) change in energy
    D) change in odor
16. What property stays the same during physical and chemical changes?
    A) density
    B) shape
    C) mass
    D) arrangement of particles

Use the illustration below to answer question 17.

A.

B.

17. Which is an example of a physical change and which is a chemical change?

Thinking Critically

18. Draw Conclusions When asked to give the physical properties of a painting, your friend says the painting is beautiful. Why isn't this description a true scientific property?

19. Draw Conclusions You are told that a sample of matter gives off energy as it changes. Can you conclude which type of change occurred? Why or why not?

20. Describe what happens to mass during chemical and physical changes. Explain.

21. Classify Decide whether the following properties are physical or chemical.
- **a.** Sugar can change into alcohol.
- **b.** Iron can rust.
- **c.** Alcohol can vaporize.
- **d.** Paper can burn.
- **e.** Sugar can dissolve.

Use the table below to answer question 22 and 23.

Physical Properties

Substance	Melting Point (°C)	Density (g/cm^3)
Benzoic acid	122.1	1.075
Sucrose	185.0	1.581
Methane	−182.0	0.466
Urea	135.0	1.323

22. Determine A scientist has a sample of a substance with a mass of 1.4 g and a volume of 3.0 mL. According to the table above, which substance might it be?

23. Conclude Using the table above, which substance would take the longest time to melt? Explain your reasoning.

24. Determine A jeweler bends gold into a beautiful ring. What type of change is this? Explain.

25. Compare and Contrast Relate such human characteristics as hair and eye color and height and weight to physical properties of matter. Relate human behavior to chemical properties. Think about how you observe these properties.

Performance Activities

26. Write a Story Write a story describing an event that you have experienced. Then go back through the story and circle any physical or chemical properties you mentioned. Underline any physical or chemical changes you included.

Applying Math

27. Brick Volume What is the volume of a brick that is 20 cm long, 10 cm wide, and 3 cm high?

28. Density of an Object What is the density of an object with a mass of 50 g and a volume of 5 cm^3?

Use the table below to answer question 29.

Mineral Samples

Sample	Mass	Volume
A	96.5 g	5 cm^3
B	38.6 g	4 cm^3

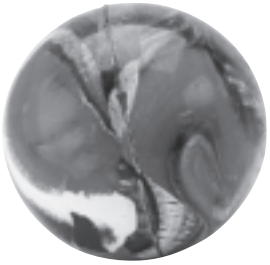
29. Density of Gold The density of gold is 19.3 g/cm^3. Which sample is the gold?

30. Ammonia Solubility 89.9 g of ammonia will dissolve in 100 mL of cold water. How much ammonia is needed to dissolve in 1.5 L of water?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the photograph below to answer questions 1 and 2.



1. Which of the following could you do to the ball in the photograph above to cause a chemical change?
A. cut in half **C.** flatten
B. paint **D.** burn

2. Which of the following physical properties of the ball is size independent?
A. density **C.** volume
B. mass **D.** weight

3. Each of the following procedures results in the formation of bubbles. Which of these is a physical change?
A. pouring an acid onto calcium carbonate
B. dropping an antacid tablet into water
C. heating water to its boiling point
D. pouring vinegar onto baking soda

4. Which of the following occurs as you heat a liquid to its boiling point?
A. condensation **C.** vaporization
B. melting **D.** freezing

Test-Taking Tip

Essay Questions Spend a few minutes listing and organizing the main points that you plan to discuss. Make sure to do all of this work on your scratch paper, not on the answer sheet.

5. During an experiment, you find that you can dissolve 4.2 g of a substance in 250 mL of water at 25°C. How much of the substance would you predict that you could dissolve in 500 mL of water at the same temperature?
A. 2.1 g **C.** 6.3 g
B. 4.2 g **D.** 8.4 g

6. Which of the following is a chemical reaction?
A. making ice cubes
B. toasting bread
C. slicing a carrot
D. boiling water

7. When you make and eat scrambled eggs, many changes occur to the eggs. Which of the following best describes a chemical change?
A. crack the eggs
B. scramble the eggs
C. cook the eggs
D. chew the eggs

Use the table below to answer questions 8 and 9.

Physical Properties of Bromide	
Density	3.12 g/cm^3
Boiling point	59°C
Melting point	–7°C

8. According to the table above, what is the mass of 4.34 cm^3 of bromine?
A. 0.719 g **C.** 7.46 g
B. 1.39 g **D.** 13.5 g

9. At which of the following temperatures is bromine a solid?
A. –10°C **C.** 40°C
B. 10°C **D.** 80°C

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. A precipitate is one clue that a chemical change has occurred. What is a precipitate and when is it observed?

Use the photo below to answer questions 11 and 12.

11. The photograph above shows a rusted chain. Explain why rusting is a physical or a chemical change.

12. What are some physical properties of the rusty chain that you can see? What are some physical properties that you can't see?

13. You measure the density of a 12.3-g sample of limestone as 2.72 g/cm^3. What is the density of a 36.9 g sample?

14. A scientist measures the masses of two chemicals. He then combines the chemicals and measures their total mass. The total mass is less than the sum of each individual mass. Has this violated the law of conservation of mass? Explain what might have happened when the chemicals were combined.

15. A scientist measures 275 mL of water into a beaker. She then adds 51.0 g of lead into the beaker. After the addition of the lead, the volume of water in the beaker increases by 4.50 mL. What is the density of the lead?

Part 3 Open Ended

Record your answers on a sheet of paper.

16. Suppose you have a gas in a closed container. Explain what would happen to the mass and density of the gas if you compressed it into half the volume.

17. Color change is an indication that a chemical change may have occurred. Mixing yellow and blue modeling clay makes green modeling clay. Is this a chemical reaction? Explain why or why not.

18. At a temperature of 40°C, you find that 40 g of ammonium chloride easily dissolves in 100 mL of water. When you stir 40 g of potassium chloride into a beaker containing 100 mL of water at 40°C, you find that some of the potassium chloride remains in the bottom of the beaker. Explain why this occurs and how to make to make the remaining potassium chloride dissolve.

Use the photo below to answer questions 19 and 20.

19. What would happen if you left the glass of cold water shown in the photograph above in the hot Sun for several hours? Describe how some physical properties of the water would change.

20. What properties of the water would not change? Explain why the density of the water would or would not change.