chapter 3

Matter and Its Changes

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chapter preview

sections

1. Physical Properties and Changes
2. Chemical Properties and Changes
   - *Lab* *Liquid Layers*
   - *Lab* *Fruit Salad Favorites*
   - *Virtual Lab* *How can a type of material be identified by its physical and chemical properties?*

An Underwater Flame?

Wendy Craig Duncan carried the Olympic flame underwater on the way to the 2000 Summer Olympics in Sydney, Australia. How many different states of matter can you find in this picture? In this chapter, you will learn about the four states of matter, and the physical and chemical properties of matter.

Science Journal How many states of matter do you see in this photo? List as many as you can.

Start-Up Activities

Launch LAB

Can you classify pennies by their properties?

Your teacher has given you a collection of pennies. It is your task to separate these pennies into groups. In this chapter, you will learn how to identify things based on their physical and chemical properties. With an understanding of these principles of matter, you will discover how things are classified or put into groups.

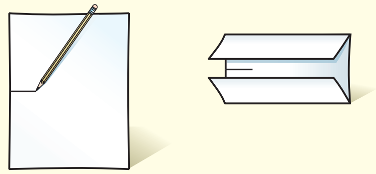
1. Observe the collection of pennies.
2. Choose a characteristic that will allow you to separate the pennies into groups.
3. Classify and sort each penny based on the chosen feature. Tally your data in a frequency table.
4. Explain how you classified the pennies. Compare your system of classification with those of others in the classroom.
5. **Think Critically** Write a paragraph in your Science Journal explaining how your group classified its pennies. What other requirements could have been used to classify the pennies?

Science Online — Preview this chapter's content and activities at red.msscience.com

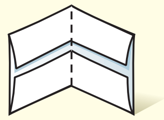
FOLDABLES™ Study Organizer

Properties of Matter Make the following Foldable to help you organize your thoughts into clear categories about properties of matter.

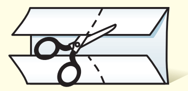
STEP 1 **Draw** a mark at the midpoint of a sheet of paper along the side edge. Then **fold** the top and bottom edges in to touch the midpoint.



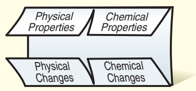
STEP 2 **Fold** in half from side to side.



STEP 3 **Turn** the paper vertically. **Open and cut** along the inside fold lines to form four tabs.



STEP 4 **Label** each tab as shown.



Classify Before you read the chapter, define each term on the front of the tabs. As you read the chapter, correct your definitions and write about each under the appropriate tab. Use the information in your Foldable to compare and contrast physical and chemical properties of matter. Write about each on the back of the tabs.

AFP/CORBIS

section 1

Physical Properties and Changes

as you read

What You'll Learn

- **Identify** physical properties of matter.
- **Explain** why materials with different masses have different densities.
- **Observe** water displacement to determine volume.
- **Describe** the states of matter.
- **Determine** how temperature changes affect substances.
- **Classify** matter using physical properties.

Why It's Important

Observing physical properties will help you interpret the world around you.

Review Vocabulary

mass: amount of matter in an object

New Vocabulary

- physical property
- matter
- physical change
- density
- states of matter
- melting point
- boiling point

Using Your Senses

As you look in your empty wallet and realize that your allowance isn't coming anytime soon, you decide to get an after-school job. You've been hired at the new grocery store that will open next month. They are getting everything ready for the grand opening, and you will be helping make decisions about where things will go and how they will be arranged.

When you come into a new situation or have to make any kind of decision, what do you usually do first? Most people would make some observations. Observing involves seeing, hearing, tasting, touching, and smelling.

Whether in a new job or in the laboratory, you use your senses to observe materials. Any characteristic of a material that can be observed or measured without changing the identity of the material is a **physical property.** However, it is important to never taste, touch, or smell any of the materials being used in the lab without guidance, as noted in **Figure 1.** For safety reasons you will rely mostly on other observations.

Figure 1 For safety reasons, in the laboratory you usually use only two of your senses—sight and hearing. Many chemicals can be dangerous to touch, taste, and smell.

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Figure 2 The identity of the material does not necessarily depend on its color. Each of these bottles is made of high-density polyethylene (HDPE).
Describe *a physical change that can be applied to the bottles.*

Physical Properties

On the first day of your new job, the boss gives you an inventory list and a drawing of the store layout. She explains that every employee is going to give his or her input as to how the merchandise should be arranged. Where will you begin?

You decide that the first thing you'll do is make some observations about the items on the list. One of the key senses used in observing physical properties is sight, so you go shopping to look at what you will be arranging.

Color and Shape Everything that you can see, touch, smell, or taste is matter. **Matter** is anything that has mass and takes up space. What things do you observe about the matter on your inventory list? The list already is organized by similarity of products, so you go to an aisle and look.

Color is the first thing you notice. The laundry detergent bottles you are looking at come in every color. Maybe you will organize them in the colors of the rainbow. You make a note and look more closely. Each bottle or box has a different shape. Some are square, some rectangular, and some are a free-form shape. You could arrange the packages by their shape.

When the plastic used to make the packaging is molded, it changes shape. However, the material is still plastic. This type of change is called a physical change. It is important to realize that in a **physical change**, the physical properties of a substance change, but the identity of the substance does not change. Notice **Figure 2.** The detergent bottles are made of high-density polyethylene regardless of the differences in the physical properties of color or shape.

Reading Check *What is matter?*

Science Online

Topic: Physical Properties
Visit red.msscience.com for Web links to information about classifying matter by its physical properties.

Activity Choose three objects in the room around you. Try to describe them using as many different physical properties as you can. Pass your description to another classmate and see if they are able to identify the object.

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Length and Mass Some properties of matter can be identified by using your senses, and other properties can be measured. How much is there? How much space does it take up?

One useful and measurable physical property is length. Length is measured using a ruler, meterstick, or tape measure, as shown in **Figure 3.** Objects can be classified by their length. For example, you could choose to organize the French bread in the bakery section of your store by the length of the loaf. But, even though the dough has been shaped in different lengths, it is still French bread.

Back in the laundry aisle, you notice a child struggling to lift one of the boxes of detergent. That raises a question. How much detergent is in each box? Mass is a physical property that describes the amount of material in an object. Some of the boxes are heavy, but, the formula of the detergent hasn't changed from the small box to the large box. Organizing the boxes by mass is another option.

Volume and Density Mass isn't the only physical property that describes how much of something you have. Another measurement is volume. Volume measures the amount of space an object takes up. Liquids usually are measured by volume. The juice bottles on your list could be organized by volume.

Another measurable physical property related to mass and volume is **density**—the amount of mass a material has in a given volume. You notice this property when you try to lift two things of equal volume that have different masses. Density is found by dividing the mass of an object by its volume.

$$\text{density} = \text{mass/volume, or } D = m/V$$

Science Online

Topic: Density

Visit red.msscience.com for Web links to information about density.

Activity Find three objects in the room that are about the same size. This might be a pencil eraser, a necklace pendant, and a small rock sample. Determine the density of each object. Is density dependent on size?

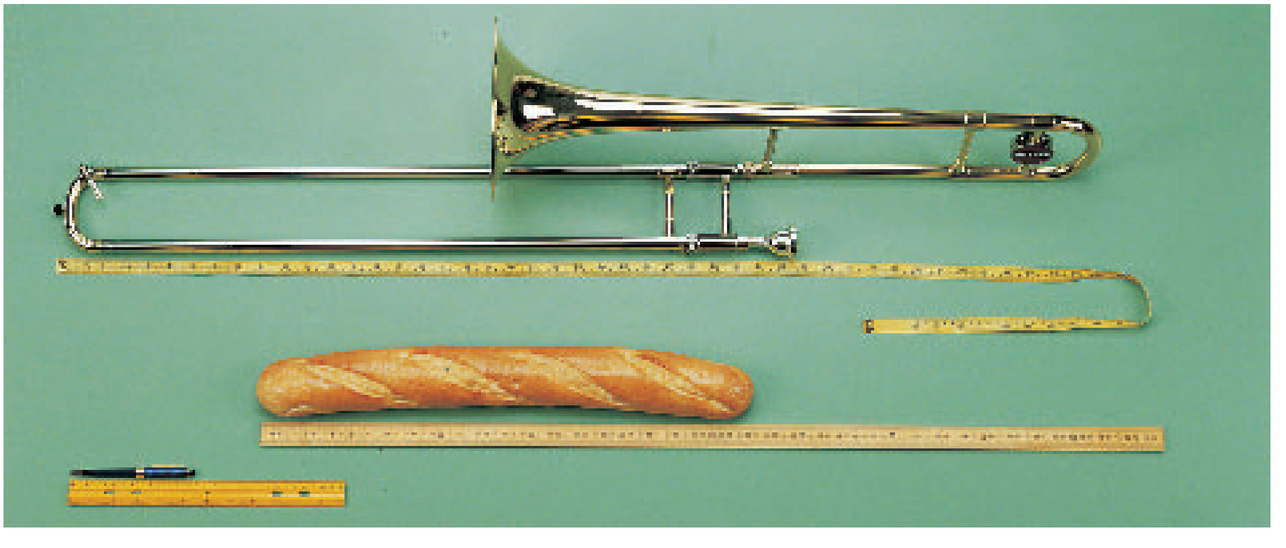

Figure 3 The length of any object can be measured with the appropriate tool.

Describe *how you would measure the length of your school building.*

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Figure 4 These balls take up about the same space, but the bowling ball on the left has more mass than the kickball on the right. Therefore, the bowling ball is more dense.

Same Volume, Different Mass **Figure 4** shows two balls that are the same size but not the same mass. The bowling ball is more dense than the kickball. The customers of your grocery store will notice the density of their bags of groceries if the baggers load all of the canned goods in one bag and put all of the cereal and napkins in the other.

The density of a material stays the same as long as pressure and temperature stay the same. Water at room temperature has a density of 1.00 g/cm^3. However, when you do change the temperature or pressure, the density of a material can change. Water kept in the freezer at 0°C is in the form of ice. The density of that ice is 0.9168 g/cm^3. Has the identity of water changed? No, but something has changed.

Reading Check *What two properties are related in the measurement of density?*

States of Matter

How does water change when it goes from 20°C to 0°C? It changes from a liquid to a solid. The four **states of matter** are solid, liquid, gas, and plasma (PLAZ muh). The state of matter of a substance depends on its temperature and pressure. Three of these states of matter are things you talk about or experience every day, but the term *plasma* might be unfamiliar. The plasma state occurs at very high temperatures and is found in fluorescent (floo RE sunt) lightbulbs, the atmosphere, and in lightning strikes.

As you look at the products to shelve in your grocery store, you might make choices of classification based on the state of matter. The state of matter of a material is another physical property. The liquid juices all will be in one place, and the solid, frozen juice concentrates will be in another.

Mini LAB

Determining Volume

Procedure

1. Find **three objects of the same size.** For example: a marble, a rubber ball, and a wood sphere.
2. Fill a **100-mL graduated cylinder** with 50 mL of **water.**
3. Submerge one object into the graduated cylinder and record the new water level. Empty the graduated cylinder.
4. Repeat steps 2 and 3 for the remaining two objects.

Analysis

1. Which of the three items displaced the most water? Which displaced the least?
2. What does this tell you about the volume of the objects?
3. What other quantities would you measure to determine the density of each object?

Moving Particles Matter is made up of moving particles. The state of matter is determined by how much energy the particles have. The particles of a solid vibrate in a fixed position. They remain close together and give the solid a definite shape and volume. The particles of a liquid are moving much faster and have enough energy to slide past one another. This allows a liquid to take the shape of its container. The particles of a gas are moving so quickly that they have enough energy to move freely away from other particles. The particles of a gas take up as much space as possible and will spread out to fill any container. **Figure 5** illustrates the differences in the states of water.

Particles of matter move faster as higher temperatures are applied. To demonstrate this, fill one beaker with cold water and another with very hot water. Add ten drops of food coloring. Observe in which beaker the color becomes uniform first.

Changes of State You witness a change of state when you place ice cubes in a cup and they melt. You still have water but in another form. The opposite physical change happens when you put liquid water in ice-cube trays and pop them in your freezer. The water doesn't change identity—only the state it is in.

For your job, you will need to make some decisions based on the ability of materials to change state. You don't want all the frozen items thawing out and becoming slushy liquid. You also don't want some of the liquids to get so cold that they freeze.

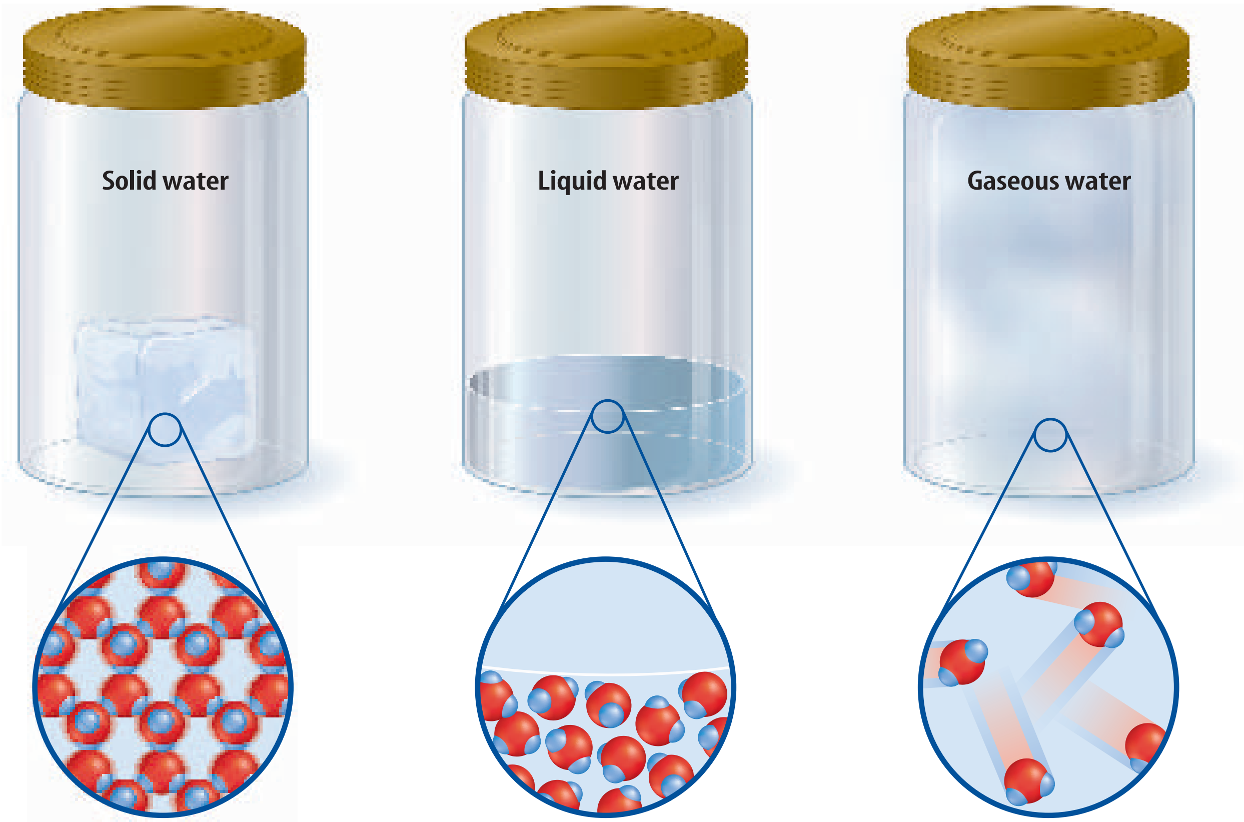


Figure 5 Water can be in three different states: solid, liquid, and gas. The molecules in ice are tightly packed and vibrate in place, but in liquid water they can slip past each other because they have more energy to move. In water vapor, they move freely all around the container with even more energy.

Melting and Boiling Points At what temperature will water in the form of ice change into a liquid? The temperature at which a solid becomes a liquid is its **melting point.** The melting point of a pure substance does not change with the amount of the substance. This means that a small sliver of ice and a block of ice the size of a house both will melt at 0°C. Lead always melts at 327.5°C. When a substance melts, it changes from a solid to a liquid. This is a physical change, and the melting point is a physical property.

At what temperature will liquid water change to a gas? The **boiling point** is the temperature at which a substance in the liquid state becomes a gas. Each pure substance has a unique boiling point at atmospheric pressure. The boiling point of water is 100°C at atmospheric pressure. The boiling point of nitrogen is −195.8°C, so it changes to a gas when it warms after being spilled into the open air, as shown in **Figure 6.** The boiling point, like the melting point, does not depend on the amount of the substance.

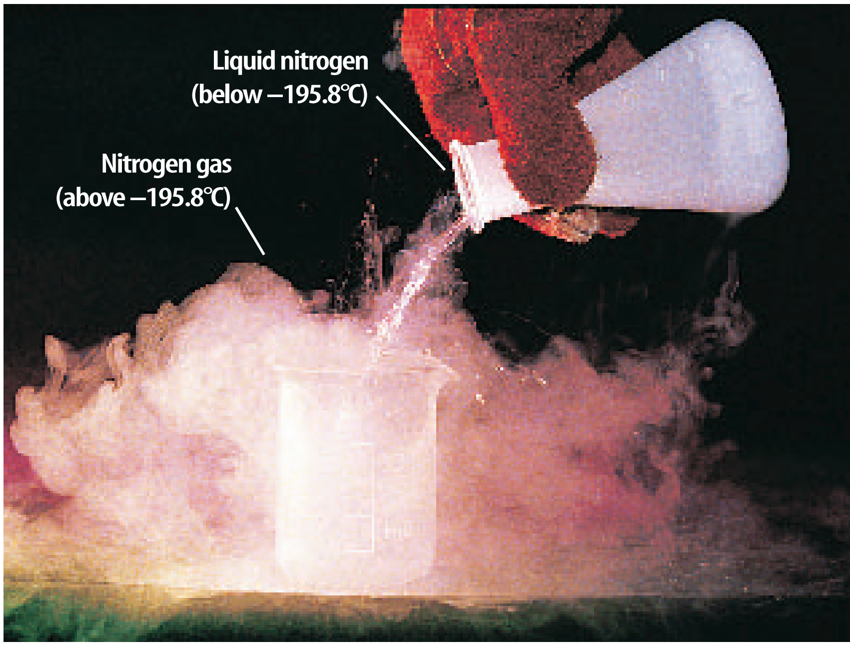


Figure 6 When liquid nitrogen is poured from a flask, you see an instant change to gas because nitrogen's boiling point is −195.8°C, which is much lower than room temperature.

Reading Check *What physical change takes place at the boiling point?*

However, the boiling point and melting point can help to identify a substance. If you observe a clear liquid that boils at 56.1°C at atmospheric pressure, it is not water. Water boils at 100°C. If you know the boiling points and melting points of substances, you can classify substances based on those properties.

Metallic Properties

Other physical properties allow you to classify substances as metals. You already have seen how you can classify things as solids, liquids, or gases or according to color, shape, length, mass, volume, or density. What properties do metals have?

How do metals look? Often the first thing you notice about something that is a metal is its shiny appearance. This is due to the way light is reflected from the surface of the metal. This shine is called luster. New handlebars on a bike have a metallic luster. Words to describe the appearance of nonmetallic objects are *pearly*, *milky*, or *dull*.

INTEGRATE Language Arts

Rock Descriptions When geologists describe rocks, they use specific terms that have meaning to all other scientists who read their descriptions. To describe the appearance of a rock or mineral, they use the following terms: *metallic*, *adamantine*, *vitreous*, *resinous*, *pearly*, *silky*, and *greasy*. Research these terms and write a definition and example of each in your Science Journal.

Figure 7 This artist has taken advantage of the ductility of metal by choosing wire as the medium for this sculpture.

Uses of Metals Metals can be used in unique ways because of some of the physical properties they have. For example, many metals can be hammered, pressed, or rolled into thin sheets. This property of metals is called malleability (mal lee uh BIH luh tee). The malleability of copper makes it an ideal choice for artwork such as the Statue of Liberty. Many metals can be drawn into wires as shown in **Figure 7.** This property is called ductility (duk TIH luh tee). The wires in buildings and most electrical equipment and household appliances are made from copper. Silver and platinum are also ductile.

You probably observe another physical property of some metals every day when you go to the refrigerator to get milk or juice for breakfast. Your refrigerator door is made of metal. Some metals respond to magnets. Most people make use of that property and put reminder notes, artwork, and photos on their refrigerators. Some metals have groups of atoms that can be affected by the force of a magnet, and they are attracted to the magnet because of that force. The magnet in **Figure 8** is being used to select metallic objects.

Figure 8 This junkyard magnet pulls scrap metal that can be salvaged from the rest of the debris. It is sorting by a physical property.

At the grocery store, your employer might think about these properties of metals as she looks at grocery carts and thinks about shelving. Malleable carts can be dented. How could the shelf's attraction of magnets be used to post advertisements or weekly specials? Perhaps the prices could be fixed to the shelves with magnetic numbers. After you observe the physical properties of an object, you can make use of those properties.

Using Physical Properties

In the previous pages, many physical properties were discussed. These physical properties—such as appearance, state, shape, length, mass, volume, ability to attract a magnet, density, melting point, boiling point, malleability, and ductility—can be used to help you identify, separate, and classify substances.

For example, salt can be described as a white solid. Each salt crystal, if you look at it under a microscope, could be described as having a three-dimensional cubic structure. You can measure the mass, volume, and density of a sample of salt or find out if it would attract a magnet. These are examples of how physical properties can be used to identify a substance.

Figure 9 Coins can be sorted by their physical properties. Sorting by size is used here.
Identify *three other properties that can be used to sort coins.*

Sorting and Separating When you do laundry, you sort according to physical properties. Perhaps you sort by color. When you select a heat setting on an iron, you classify the clothes by the type of fabric. When miners during the Gold Rush panned for gold, they separated the dirt and rocks by the density of the particles. **Figure 9** shows a coin sorter that separates the coins based on their size. Iron filings can be separated from sand by using a magnet.

INTEGRATE Life Science

Scientists who work with animals use physical properties or characteristics to determine the identity of a specimen. They do this by using a tool called a dichotomous (di KAH tuh mus) key. The term *dichotomous* refers to two parts or divisions. Part of a dichotomous key for identifying hard-shelled crabs is shown on the next page in **Figure 10.** To begin the identification of your unknown animal, you are given two choices. Your animal will match only one of the choices. In the key in **Figure 10,** you are to determine whether or not your crab lives in a borrowed shell. Based on your answer, you are either directed to another set of choices or given the name of the crab you are identifying.

VISUALIZING DICHOTOMOUS KEYS

Figure 10

Whether in the laboratory or in the field, scientists often encounter substances or organisms that they cannot immediately identify. One approach to tracking down the identity of such "unknowns" is to use a dichotomous key, such as the one shown. The key is designed so a user can compare physical properties or characteristics of the unknown substance or organism—in this case, a crab—with characteristics of known organisms in a stepwise manner. With each step, a choice must be made. Each choice leads to subsequent steps that guide the user through the key until a positive identification is made.

Dichotomous Key

1.	A.	Lives in a "borrowed" shell (usually some type of snail shell)	Hermit Crab
	B.	Does not live in a "borrowed" shell	go to #2
2.	A.	Shell completely overlaps the walking legs	Box Crab
	B.	Walking legs are exposed	Kelp Crab

Can you identify the three crabs shown here by following this dichotomous key?

(l)Steve Kaufman/CORBIS, (tr)Tom McHugh/Photo Researchers, (br)Fred Bavendam/Minden Pictures

CONTENTS

Everyday Examples Identification by physical properties is a subject in science that is easy to observe in the real world. Suppose you volunteer to help your friend choose a family pet. While visiting the local animal shelter, you spot a cute dog. The dog looks like the one in **Figure 11.** You look at the sign on the cage. It says that the dog is male, one to two years old, and its breed is unknown. You and your friend wonder what breed of dog he is. What kind of information do you and your friend need to figure out the dog's breed? First, you need a thorough description of the physical properties of the dog. What does the dog look like? Second, you need to know the descriptions of various breeds of dogs. Then you can match up the description of the dog with the correct breed. The dog you found is a white, medium-sized dog with large black spots on his back. He also has black ears and a black mask around his eyes. The manager of the shelter tells you that the dog is close to full-grown. What breed is the dog?

Narrowing the Options To find out, you may need to research the various breeds of dogs and their descriptions. Often, determining the identity of something that is unknown is easiest by using the process of elimination. You figure out all of the breeds the dog can't be. Then your list of possible breeds is smaller. Upon looking at the descriptions of various breeds, you eliminate small dog and large dog breeds. You also eliminate breeds that do not contain white dogs. With the remaining breeds, you might look at photos to see which ones most resemble your dog. Scientists use similar methods to determine the identities of living and nonliving things.

Figure 11 Physical descriptions are used to determine the identities of unknown things.
Observe *What physical properties can be used to describe this dog?*

section 1 review

Summary

Physical Properties

- Physical properties include color, shape, length, mass, volume, and density.

States of Matter

- There are four states of matter.
- Matter can change from one state of matter to another.
- State of matter is determined by how much energy the particles have.

Using Physical Properties

- Substances can be classified according to their physical properties.

Self Check

1. **Identify** the physical properties of this textbook.
2. **List** the four states of matter. Describe each and give an example.
3. **Explain** how water might have two different densities.
4. **Think Critically** Which evaporates more quickly—rubbing alcohol that has been refrigerated or unrefrigerated?

Applying Math

5. **Solve One-Step Equations** Nickel has a density of 9.8 g/cm^3. Lead has a density of 11.3 g/cm^3. If both samples have a volume of 4 cm^3, what are the masses of each?

Science Online red.msscience.com/self_check_quiz

section 2

Chemical Properties and Changes

as you read

What You'll Learn

- **Recognize** chemical properties.
- **Identify** chemical changes.
- **Classify** matter according to chemical properties
- **Describe** the law of conservation of mass.

Why It's Important

Knowing the chemical properties will allow you to distinguish differences in matter.

Review Vocabulary

heat: a form of energy that flows from a warmer object to a cooler object

New Vocabulary

- chemical property
- chemical change
- law of conservation of mass

Ability to Change

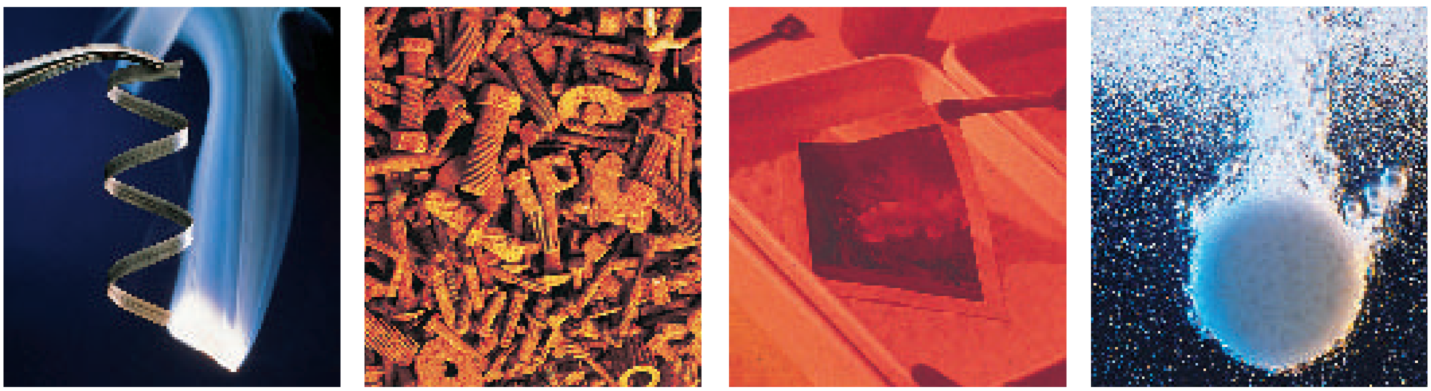
It is time to celebrate. You and your coworkers have cooperated in classifying all of the products and setting up the shelves in the new grocery store. The store manager agrees to a celebration party and campfire at the nearby park. Several large pieces of firewood and some small pieces of kindling are needed to start the campfire. After the campfire, all that remains of the wood is a small pile of ash. Where did the wood go? What property of the wood is responsible for this change?

All of the properties that you observed and used for classification in the first section were physical properties that you could observe easily. In addition, even when those properties changed, the identity of the object remained the same. Something different seems to have happened in the bonfire example.

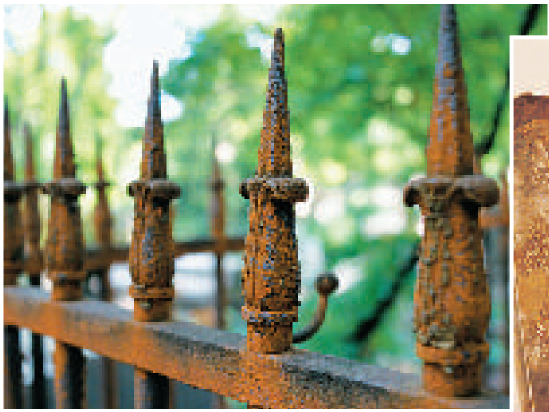
Some properties do indicate a change of identity for the substances involved. A **chemical property** is any characteristic that gives a substance the ability to undergo a change that results in a new substance. **Figure 12** shows some properties of substances that can be observed only as they undergo a chemical change.

Reading Check *What does a chemical property give a substance the ability to do?*

Figure 12 These are four examples of chemical properties.



Flammability | Reacts with oxygen | Reacts with light | Reacts with water



An untreated iron gate will rust.

Silver dishes develop tarnish.

Figure 13 Many kinds of interactions with oxygen can occur. Copper sculptures develop a green patina, which is a mixture of copper compounds.

Common Chemical Properties

You don't have to be in a laboratory to see the changes that take place because of chemical properties. These are called chemical changes. A **chemical change** is a change in the identity of a substance due to the chemical properties of that substance. A new substance or substances are formed as a result of such a change.

The campfire you enjoyed to celebrate the opening of the grocery store resulted in chemical changes. The oxygen in the air reacted with the wood to form a new substance called ash. Wood can burn. This chemical property is called flammability. Some products have warnings on their labels about keeping them away from heat and flame because of the flammability of the materials. Sometimes after a campfire you see stones that didn't burn around the edge of the ashes. These stones have the chemical property of being incombustible.

Common Reactions An unpainted iron gate, such as the one shown in **Figure 13,** will rust in time. The rust is a result of oxygen in the air reacting with the iron and causing corrosion. The corrosion produces a new substance called iron oxide, also known as rust. Other chemical reactions occur when metals interact with other elements. The middle photo shows tarnish, the grayish-brown film that develops on silver when it reacts with sulfur in the air. The ability to react with oxygen or sulfur is a chemical property. The photo on the right shows another example of this chemical property.

Have you ever sliced an apple or banana and left it sitting on the table? The brownish coloring that you notice is a chemical change that occurs between the fruit and the oxygen in the air. Those who work in the produce department at the grocery store must be careful with any fruit they slice to use as samples. Although nothing is wrong with brown apples, they don't look appetizing.

INTEGRATE Health

Enzyme Research
Researchers have discovered an enzyme in fruit that is involved in the browning process. They are doing experiments to try to grow grapevines in which the level of this enzyme, polyphenol oxidase (PPO), is reduced. This could result in grapes that do not brown as quickly. Write a paragraph in your Science Journal about why this would be helpful to fruit growers, store owners, and customers.

Heat and Light Vitamins often are dispensed in dark-brown bottles. Do you know why? Many vitamins will change when exposed to light. This is a chemical property. They are protected in those colored bottles from undergoing a chemical change with light.

Some substances are sensitive to heat and will undergo a chemical change only when heated or cooled. One example is limestone. Limestone is generally thought of as unreactive. Some limestone formations have been around for centuries without changing. However, if limestone is heated, it goes through a chemical change and produces carbon dioxide and lime, a chemical used in many industrial processes. The chemical property in this case is the ability to change when heated.

Another chemical property is the ability to change with electrical contact. Electricity can cause a change in some substances and decompose some compounds. Water is one of those compounds that can be broken down with electricity.

Something New

The important difference in a chemical change is that a new substance is formed. Because of chemical changes, you can enjoy many things in life that you would not have experienced without them. What about that perfect, browned marshmallow you roasted at the campfire? A chemical change occurred as a result of the fire to make the taste and the appearance different.

Sugar is normally a white, crystalline substance, but after you heat it over a flame, it turns to a dark-brown caramel. A new substance has been formed. Sugar also can undergo a chemical change when sulfuric acid is added to it. The new substance has obviously different properties from the original, as shown in **Figure 14.**

If eggs, sugar, flour, and other ingredients didn't change chemically through baking, you couldn't enjoy birthday cake. Cake begins as liquid and ends as solid. The baked cake clearly has different properties.

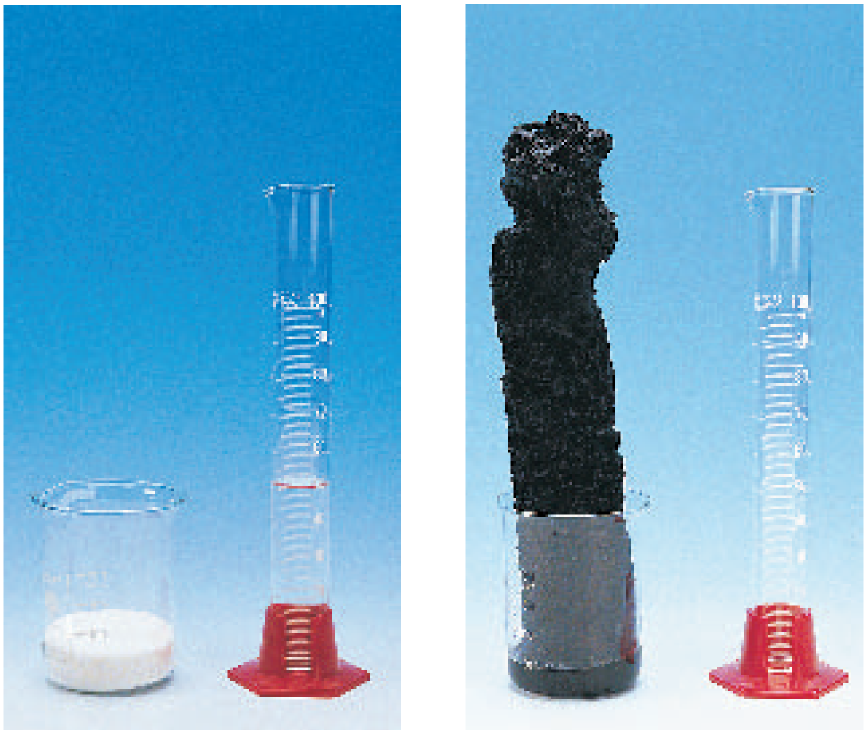


Figure 14 When sugar and sulfuric acid combine, a chemical change occurs and a new substance forms. During this reaction, the mixture foams and a toxic gas is released, leaving only water and air-filled carbon behind.

Matt Meadows

Signs of Change How do you know that you have a new substance? Is it just because it looks different? You could put a salad in a blender and it would look different, but a chemical change would not have occurred. You still would have lettuce, carrots, and any other vegetables that were there to begin with.

You can look for signs when evaluating whether you have a new substance as a result of a chemical change. Look at the piece of birthday cake in **Figure 15.** When a cake bakes, gas bubbles form and grow within the ingredients. Bubbles are a sign that a chemical change has taken place. When you look closely at a piece of cake, you can see the airholes left from the bubbles.

Other signs of change include the production of heat, light, smoke, change in color, and sound. Which of these signs of change would you have seen or heard during the campfire?

Figure 15 The evidence of a chemical change in the cake is the holes left by the air bubbles that were produced during baking. **Identify** *other examples of a chemical change.*

Is it reversible? One other way to determine whether a physical change or a chemical change has occurred is to decide whether or not you can reverse the change by simple physical means. Physical changes usually can be reversed easily. For example, melted butter can become solid again if it is placed in the refrigerator. A figure made of modeling clay, like the one in **Figure 16,** can be smashed to fit back into a container. However, chemical changes can't be reversed using physical means. For example, the ashes in a fireplace cannot be put back together to make the logs that you had to start with. Can you find the egg in a cake? Where is the white flour?

Reading Check *What kind of change can be reversed easily?*

Figure 16 A change such as molding clay can be undone easily.

(t)Ralph Cowan, (others)Aaron Haupt

Table 1 Comparing Properties

Physical Properties	color, shape, length, mass, volume, density, state, ability to attract a magnet, melting point, boiling point, malleability, ductility
Chemical Properties	flammability; reacts with: oxygen, water, vinegar, etc; reacts in the presence of electricity, light, heat, etc.

Classifying According to Chemical Properties

Classifying according to physical properties is often easier than classifying according to chemical properties. **Table 1** summarizes the two kinds of properties. The physical properties of a substance are easily observed, but the chemical properties can't be observed without changing the substance. However, once you know the chemical properties, you can classify and identify matter based on those properties. For example, if you try to burn what looks like a piece of wood but find that it won't burn, you can rule out the possibility that it is wood.

In a grocery store, the products sometimes are separated according to their flammability or sensitivity to light or heat. You don't often see the produce section in front of big windows where heat and light come in. The fruit and vegetables would undergo a chemical change and ripen too quickly. You also won't find the lighter fluid and rubbing alcohol near the bakery or other places where heat and flame could be present.

Architects and product designers have to take into account the chemical properties of materials when they design buildings and merchandise. For example, children's sleepwear and bedding can't be made of a flammable fabric. Also, some of the architects designing the most modern buildings are choosing materials like titanium because it does not react with oxygen like many other metals do.

Mini LAB

Observing Yeast

Procedure

1. Observe a **tablespoon** of **dry yeast** with a **magnifying lens.** Draw and describe what you observe.
2. Put the yeast in 50 mL of **warm,** not hot, **water.**
3. Compare your observations of the dry yeast with those of the wet yeast.
4. Put a pinch of **sugar** in the water and observe for 15 minutes.
5. Record your observations.

Analysis

1. Are new substances formed when sugar is added to the water and yeast? Explain.
2. Do you think this is a chemical change or a physical change? Explain.

Try at Home

The Law of Conservation of Mass

It was so convenient to turn the firewood into the small pile of ash left after the campfire. You began with many kilograms of flammable substances but ended up with just a few kilograms of ash. Could this be a solution to the problems with landfills and garbage dumps? Why not burn all the trash? If you could make such a reduction without creating undesirable materials, this would be a great solution.

Mass Is Not Destroyed Before you celebrate your discovery, think this through. Did mass really disappear during the fire? It appears that way when you compare the mass of the pile of ashes to the mass of the firewood you started with. The **law of conservation of mass** states that the mass of what you end with is always the same as the mass of what you start with.

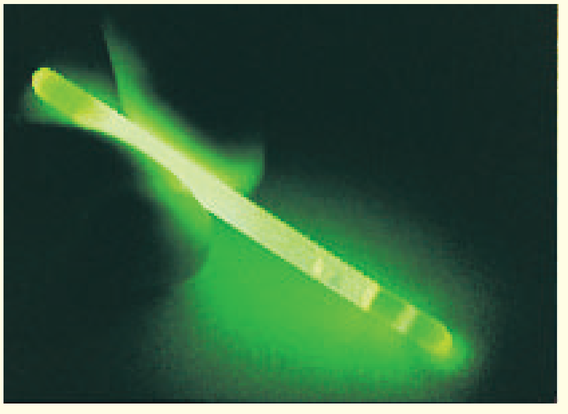
This law was first investigated about 200 years ago, and many investigations since then have proven it to be true. One experiment done by French scientist Antoine Lavoisier was a small version of a campfire. He determined that a fire does not make mass disappear or truly get rid of anything. The question, however, remains. Where did the mass go? The ashes aren't heavy enough to account for the mass of all of the pieces of firewood.

Where did the mass go? If you look at the campfire example more closely, you see that the law of conservation of mass is true. When flammable materials burn, they combine with oxygen. Ash, smoke, and gases are produced. The smoke and gases escape into the air. If you could measure the mass of the oxygen and all of the original firewood that was burned and compare it to the remaining mass of the ash, smoke, and gas, they would be equal.

Applying Science

Do light sticks conserve mass?

Light sticks often are used on Halloween to light the way for trick-or-treaters. They make children visible to drivers. They also are used as toys, for camping, marking trails, emergency traffic problems, by the military, and they work well underwater. A light stick contains two chemicals in separate tubes. When you break the inner tube, the two chemicals react producing a greenish light. The chemicals are not toxic, and they will not catch fire.



Identifying the Problem

In all reactions that occur in the world, mass is never lost or gained. This is the law of conservation of mass. An example of this phenomenon is the light stick. How can you prove this?

Solving the Problem

Describe how you could show that a light stick does not gain or lose mass when you allow the reaction to take place. Is this reaction a chemical or physical change? What is your evidence?

Jeff J. Daly/Visuals Unlimited

Figure 17 This reaction demonstrates the law of conservation of mass. Although a chemical change has occurred and new substances were made, the mass remained constant.

Before and After Mass is not destroyed or created during any chemical change. The law of conservation of mass is demonstrated in **Figure 17.** In the first photo, you see one substance in the flask and a different substance contained in a test tube inside the flask. The total mass is 16.150 g. In the second photo, the flask is turned upside down. This allows the two substances to mix and react. Because the flask is sealed, nothing is allowed to escape. In the third photo, the flask is placed on the balance again and the total mass is determined to be 16.150 g. If no mass is lost or gained, what happens in a reaction? Instead of disappearing or appearing, the particles in the substances rearrange into different combinations with different properties.

section 2 review

Summary

Common Chemical Properties

- A new substance, or substances, form(s) as a result of a chemical change.
- Exposure to oxygen, heat, and light can cause chemical reactions.

Something New

- Physical changes can be reversed. Chemical changes cannot be reversed.
- Substances can be classified according to their chemical properties.

The Law of Conservation of Mass

- Mass is not gained or lost during a chemical reaction.

Self Check

1. **Define** What is a chemical property? Give four examples.
2. **Identify** some of the signs that a chemical change has occurred.
3. **Think Critically** You see a bright flash and then flames during a class demonstration. Is this an example of a physical change or a chemical change? Explain.

Applying Math

4. **Solving One-Step Equations** A student heats 4.00 g of a blue compound, which reacts completely to produce 2.56 g of a white compound and an unknown amount of colorless gas. What is the mass of this gas?

Timothy Fuller
Science Online red.msscience.com/self_check_quiz
CONTENTS

LAB

Liquid Layers

Why must you shake up a bottle of Italian salad dressing before using it? Have you observed how the liquids in some dressings separate into two distinct layers? In this lab, you will experiment with creating layers of liquids.

Real-World Question

What would several liquids and solids of different densities look like when put into the same container?

Goals

- **Create** layers of liquids using liquids of different densities.
- **Observe** where solids of different densities will rest in the liquid layers.
- **Infer** the densities of the different materials.

Materials

250-mL beaker
graduated cylinder
corn syrup
glycerin
water
corn oil
rubbing alcohol
penny
wood sphere
rubber ball

Safety Precautions

Procedure

1. Pour 40 mL of corn syrup into your beaker.
2. Slowly pour 40 mL of glycerin into the beaker. Allow the glycerin to trickle down the sides of the container and observe.
3. Slowly pour 40 mL of water into the beaker and observe.
4. Repeat step 3 with 40 mL of corn oil and then 40 mL of rubbing alcohol.
5. Carefully drop the penny, wood sphere, and rubber ball into the beaker and observe where these items come to a stop.

Conclude and Apply

1. **Draw and Label** In your Science Journal, draw a picture of the liquids and solids in your beaker. Label your diagram.
2. **Describe** what happened to the five liquids when you poured them into the beaker. Why did the liquids behave this way?
3. If water has a density of 1 g/cm^3, infer the relative densities of the rest of the materials.
4. **List** the liquids and solids in order from the highest density to the lowest density.

Communicating Your Data

Draw a labeled poster of the substances you placed in your beaker. Research the densities of each substance and include these densities on your poster. **For more help, refer to the Science Skill Handbook.**

John Evans

LAB

Design Your Own

Fruit Salad Favorites

Goals

- **Design** an experiment that identifies physical changes and chemical changes in fruit.
- **Observe** whether chemical changes can be controlled.

Possible Materials

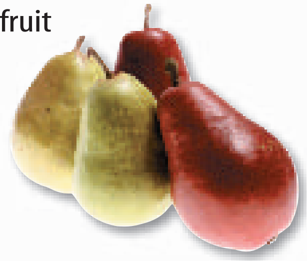
bananas
apples
pears
plastic or glass mixing bowls (2)
lemon/water solution (500 mL)
paring knife

Safety Precautions

WARNING: *Be careful when working with sharp objects. Always keep hands away from sharp blades. Never eat anything in the laboratory.*

Real-World Question

When you are looking forward to enjoying a tasty, sweet fruit salad at a picnic, the last thing you want to see is brown fruit in the bowl. What can you do about this problem? Your teacher has given you a few different kinds of fruit. It is your task to perform a test in which you will observe a physical change and a chemical change. Can a chemical change be controlled?



Form a Hypothesis

Based on your reading and observations, state a hypothesis about whether you can control a chemical change.

Test Your Hypothesis

Make a Plan

1. As a group, agree upon the hypothesis and decide how you will test it. Identify what results will confirm the hypothesis.
2. **List** each of the steps you will need in order to test your hypothesis. Be specific. Describe exactly what you will do in each step. List all of your materials.
3. Prepare a data table in your Science Journal or on a computer for your observations.
4. Read the entire investigation to make sure all steps are in logical order.
5. **Identify** all constants, variables, and controls of the investigation.

(apples)Aaron Haupt, (others)John A. Rizzo/PhotoDisc

Follow Your Plan

1. Ask your teacher to approve your plan and choice of constants, variables and controls before you start.
2. Perform the investigation as planned.
3. While doing the investigation, record your observations and complete the data table you prepared in your Science Journal.

Analyze Your Data

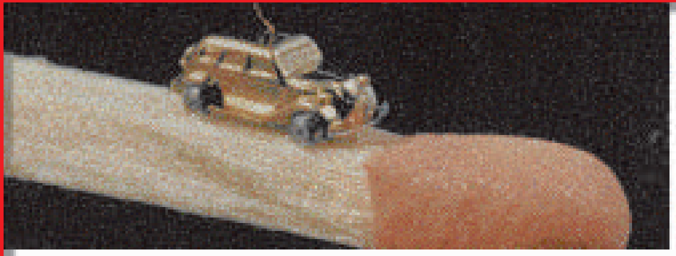
1. **Compare and contrast** the changes you observe in the control and the test fruit.
2. **Compare** your results with those of other groups.
3. What was your control in this investigation?
4. What are your variables?
5. Did you encounter any problems carrying out the investigation?
6. Do you have any suggestions for changes in a future investigation?

Conclude and Apply

1. Did the results support your hypothesis? Explain.
2. **Describe** what effect refrigerating the two salads would have on the fruit.
3. What will you do with the fruit from this experiment? Could it be eaten?

Communicating Your Data

Write a page for an illustrated cookbook explaining the benefits you found in this experiment. Include drawings and a step-by-step procedure. **For more help, refer to the Science Skill Handbook.**



The Road to Understanding Matter

What a Ride!

Front wheel drive, a powerful motor, and a smooth ride are characteristics to look for in an automobile. This car, developed by Nippondenso, packs it all under a gold plated hood. At 4.78 mm long, this car is about the size of a grain of rice! Created to show the power and potential of technology applied to unimaginably small objects, this car demonstrates a fraction of the knowledge scientists have gained in exploring matter on a very small scale.

Matter Mileposts

Philosophers and scientists have speculated about the building blocks of matter for centuries. Around 425 B.C., the Greek Democritis used the term "atomos" to describe the indivisible particles making up matter of all types.

While early thinkers typically lacked the ability to test their theories, later technological advances applied to the study of matter moved science from the realm of the philosophical to the quantitative. In the 1700's, scientists experimented with gases, a type of matter difficult to confine and hard to study. Their findings eliminated the last of the old Greek notions and laid the foundation for modern chemistry.

It was the work of French scientist Antoine Lavoisier (1743–1794) which earned him the title "Father of Modern Chemistry." By focusing on measurable, quantifiable data, he forever changed the way science was conducted. Lavoisier's experiments with gases led to the development of the law of conservation of mass, a cornerstone of modern chemistry which helps explain what happens to matter during chemical change.

A Changing Road Map

In the 1930's, scientists used the first particle accelerators to reveal the composition of the atom. These machines accelerate subatomic particles, like electrons, to speeds close to the speed of light. Collisions at this speed cause these particles to shatter, and provide the opportunity to detect and analyze the smaller particles which comprise them.

Once thought to be the smallest building blocks, the proton, neutron, and electron are now joined by other subatomic particles groups, including quarks. Scientists currently believe the quark is the most fundamental particle. Studying particles created in particle accelerators is difficult because most exist for less than a billionth of a second.

As the technology behind these powerful machines advances, current hypotheses will undergo revision. The nature of scientific study is to build upon and extend, while sometimes uprooting, commonly held theories. Experimentation to discover the building blocks of matter is no exception.

Investigate Research the two types of particle accelerators. Compare how they work and their sizes. Describe what scientists learn about atomic structure using these machines. Use the link to the right or your school's media center to get started.

Science Online
For more information, visit red.msscience.com/time

(t)Denso/Rex Features, (b)Alexander Tsiaras/Photo Researchers

Reviewing Main Ideas

Section 1 Physical Properties and Changes

1. Any characteristic of a material that can be observed or measured is a physical property.
2. The four states of matter are solid, liquid, gas, and plasma. The state of matter is determined by the energy the particles have.
3. Color, shape, length, mass, volume, density, melting point, boiling point, are common physical properties.
4. In a physical change the properties of a substance change but the identity of the substance always stays the same.
5. You can classify materials according to their physical properties.

Section 2 Chemical Properties and Changes

1. Chemical properties give a substance the ability to undergo a chemical change.
2. Common chemical properties include: ability to burn, reacts with oxygen, reacts with heat or light, and breaks down with electricity.
3. In a chemical change substances combine to form a new material.
4. The mass of the products of a chemical change is always the same as the mass of what you started with.
5. A chemical change results in a substance with a new identity, but matter is not created or destroyed.

Visualizing Main Ideas

Copy and complete the following table comparing properties of different objects.

Properties of Matter

Type of Matter	Physical Properties	Chemical Properties
Log		
Pillow		
Bowl of cookie dough	Do not write in this book.	
Book		
Glass of orange juice		

chapter 3 Review

Using Vocabulary

boiling point p. 75
chemical change p. 81
chemical property p. 80
density p. 72
law of conservation of mass p. 85
matter p. 71
melting point p. 75
physical change p. 71
physical property p. 70
states of matter p. 73

Fill in the blanks with the correct vocabulary word or words.

1. The ________ is the temperature at which matter in a solid state changes to a liquid.
2. ________ is a measure of the mass of an object in a given volume.
3. A(n) ________ is easily observed or measured without changing the object.
4. ________ result in a new substance and cannot be reversed by physical means.
5. Solid, liquid, and gas are all examples of ________.

Checking Concepts

Choose the word or phrase that best answers the question.

6. Which of the following is an example of a physical change?
   A) tarnishing **C)** burning
   B) rusting **D)** melting

7. Which of the following is a sign that a chemical change has occurred?
   A) smoke **C)** change in shape
   B) broken pieces **D)** change in state

8. When iron reacts with oxygen, what substance is produced?
   A) tarnish **C)** patina
   B) rust **D)** ashes

9. What statement describes the physical property of density?
   A) the distance between two points
   B) how light is reflected from an object's surface
   C) the amount of mass for a given volume
   D) the amount of space an object takes up

10. Which of the choices below describes a boiling point?
    A) a chemical property
    B) a chemical change
    C) a physical property
    D) a color change

11. What property is described by the ability of metals to be hammered into sheets?
    A) mass
    B) density
    C) volume
    D) malleability

12. Which of these is a chemical property?
    A) size **C)** flammability
    B) density **D)** volume

13. Which describes what volume is?
    A) the area of a square
    B) the amount of space an object takes up
    C) the distance between two points
    D) the temperature at which boiling begins

14. What kind of change results in a new substance being produced?
    A) chemical **C)** physical
    B) mass **D)** change of state

15. What is conserved during any change?
    A) color **C)** identity
    B) volume **D)** mass

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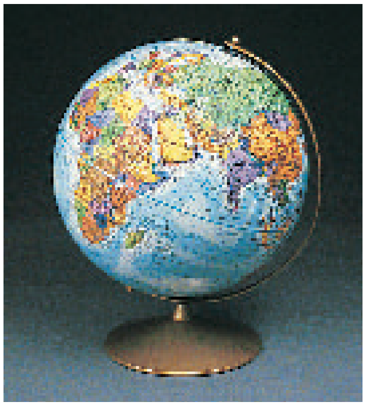
CONTENTS

Thinking Critically

16. **Explain** Use the law of conservation of mass to explain what happens to atoms when they combine to form a new substance.

17. **Describe** the four states of matter. How are they different?

18. **Observe** A globe is placed on your desk and you are asked to identify its physical properties. How would you describe the globe?



19. **Evaluate** What information do you need to know about a material to find its density?

20. **Classify** the following as a chemical or physical change: an egg breaks, a newspaper burns in the fireplace, a dish of ice cream is left out and melts, and a loaf of bread is baked.

21. **Draw Conclusions** List the physical and chemical properties and changes that describe the process of scrambling eggs.

22. **Infer** Concrete is formed through a chemical reaction of sand, gravel, crushed stones, and water. Do the starting materials have the same properties as the end materials? Give two examples to support your response.

23. **Describe** In terms of particle movement explain how increasing temperature changes water in the solid state.

24. **Concept Map** Use a spider map to organize and define physical properties of matter. Include the concepts of color, shape, length, density, mass, states of matter, volume, density, melting point, and boiling point.

Performance Activities

25. **Comic Strip** Create a comic strip demonstrating a chemical change in a substance. Include captions and drawings that demonstrate your understanding of the law of conservation of mass.

Applying Math

26. **Measure in SI** Find the density of the piece of lead that has a mass of 49.01 g and a volume of 4.5 cm^3.

Use the table below to answer question 27.

Density

Sample	Mass	Volume	Density
A	3.0 g	6.5 cm^3	
B	1.2 g	1.1 cm^3	
C	4.5 g		0.88 g/cm^3
D	125 g		0.36 g/cm^3
E		85 cm^3	2.3 g/cm^3
F		10 cm^3	0.75 g/cm^3

27. **Density** Copy and complete the table by supplying the missing information.

28. **Density** Using the formula for density evaluate if two samples with the same volume, but different densities will have the same mass. Give two sample calculations to support your answer.

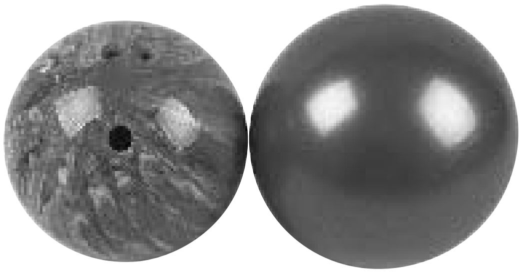
Elaine Shay

Part 1 Multiple Choice

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

1. Which of these is NOT a physical property?
   A. volume **C.** density
   B. mass **D.** flammability

Use the illustration below to answer questions 2 and 3.



2. Which statement about the bowling ball and the kickball shown above is TRUE?
   A. These balls have nearly equal densities.
   B. These balls have nearly equal masses.
   C. These balls have nearly equal volumes.
   D. One of these balls exists as a different state of matter than the other.

3. A hole is punched in the kickball. Most of the air escapes and the ball collapses and shrinks. What happens to the ball?
   A. The mass of the ball increases.
   B. The volume of the ball decreases.
   C. The volume of the ball increases.
   D. The mass of the ball does not change.

4. Which term is a physical property that describes the amount of matter in an object?
   A. mass **C.** volume
   B. density **D.** state of matter

Test-Taking Tip

Be Relaxed and Focused Stay calm during the test. If you feel yourself getting nervous, close your eyes, and take five slow, deep breaths.

5. Which step in the process of making a cake results in a chemical change?
   A. breaking an egg and removing the contents from the shell
   B. melting butter
   C. mixing sugar and flour
   D. baking a cake in the oven

Use the illustration below to answer questions 6 and 7.

6. The particles in the jar labeled A represent a
   A. solid. **C.** gas.
   B. liquid. **D.** plasma.

7. If the material in the jars are all a form of H_2O, then jar C must be
   A. liquid water. **C.** ice.
   B. water vapor. **D.** pure oxygen.

8. When mercury (II) oxide, HgO, is heated, liquid mercury (Hg) and oxygen (O_2) are produced.

$2HgO \rightarrow 2Hg + O_2$	
Beginning mass of HgO	216 grams
Mass of Hg after heating	200 grams
Mass of O_2 after heating	? grams

According to the law of conservation of mass, what mass of O_2 is generated?
   A. 0 g **C.** 200 g
   B. 216 g **D.** 16 g

Part 2 Short Response/Grid In

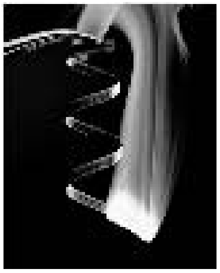
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. Choose an object in the room and describe its physical properties as completely as possible.

10. Compare the density of two sponges: Dry Sponge A has a mass of 60 g. Moist Sponge B has a mass of 90 g. The volume of each sponge is 180 cm^3.

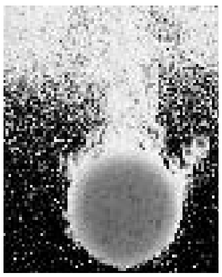
11. Describe the key properties of metals. Identify something you own which is made of metal. How has a metallic property made it possible to create or use this item?

Use the photos below to answer questions 12 and 13.



A

B



C

12. What type of change is occurring in each picture? Describe the signs of the change.

13. How do chemical and physical changes differ? What signs indicate a chemical change? What signs indicate a physical change?

Part 3 Open Ended

Record your answers on a sheet of paper.

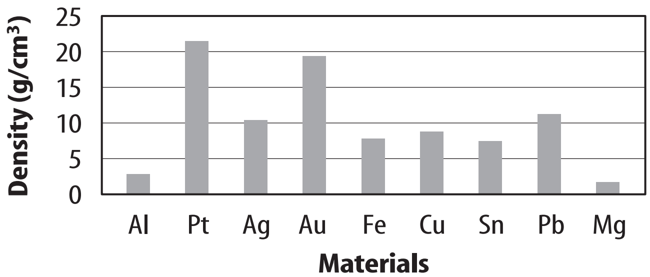
14. You are asked to determine the identity of an unknown element. How will you use the properties of the element to discover its identity?

15. Based on the way particles move in solid, liquid, and gas phases of matter, describe what happens when solid water (ice) gradually changes to water as a gas (water vapor).

16. Making bread is an example of a chemical change. Describe the properties of the starting materials and the finished product.

Use the graph below to answer questions 17 and 18.

Density of Materials at 20° Celsius



17. Rank the materials shown from most to least dense.

18. Imagine the graph had the title: *Density of Materials at 5° Celsius.* How and why would the graph look different?

19. Your teacher asks you to change a piece of paper both physically and chemically. Describe what you could do to show these two things.

20. An oil and vinegar salad dressing recipe calls for 20 mL of oil and 20 mL of vinegar. Would the oil and vinegar have equal densities? Predict if the oil and vinegar have the same mass.