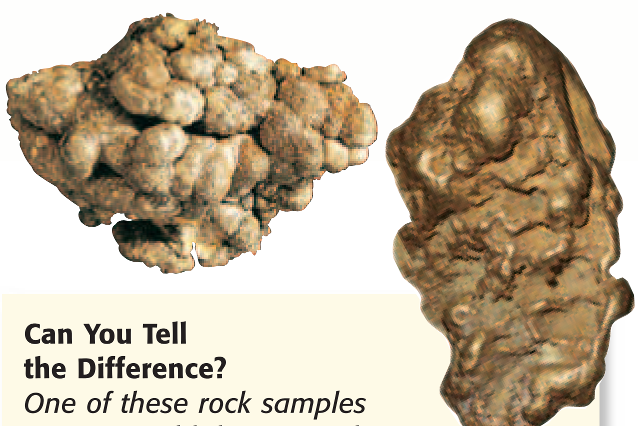
CHAPTER 2

The Properties of Matter

Imagine . . .

The year is 1849. You are one of thousands of people who have come to California to prospect for gold. You left home several months ago in the hopes of striking it rich. But so far, no luck. In fact, you've decided that if you don't find gold today, you're going to pack up your things and head back home.

You swing your pickax into the granite bedrock, and a bright flash catches your eye. The flash is caused by a shiny yellow chunk sticking out of the rock. When you first started prospecting, such a sight made you catch your breath. Now you just sigh. More fool's gold, you think.



Can You Tell the Difference?
One of these rock samples contains gold that is worth hundreds of dollars. The other rock sample contains iron pyrite that is worth about . . . well, nothing.

Fool's gold is the nickname for iron pyrite (PIE RIET), a mineral that looks like gold and is found in the same areas of California where gold is found. But iron pyrite differs from gold in several ways. When hit with a hammer, iron pyrite shatters into pieces, and sparks fly everywhere. Gold just bends when it is hit, and no sparks are produced. Iron pyrite also produces foul-smelling smoke when it is heated. Gold does not.

You perform a few quick tests on your shiny find. When you hit it with a hammer, it bends but does not shatter, and no sparks are produced. When you heat it, there is no smoke or odor. You start to get excited. You'll have to perform a few more tests when you get back to town, but this time you're almost certain that you've struck gold. Congratulations! Your knowledge of the different characteristics, or properties, of fool's gold and real gold has finally paid off.

In this chapter you'll learn more about the many different properties that objects can have and why these properties are important to know.

What Do You Think?

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

1. What is matter?
2. What is the difference between a physical property and a chemical property?
3. What is the difference between a physical change and a chemical change?

Investigate!

Sack Secrets

In this activity, you will test your skills in determining the identity of an object based on its properties.

Procedure

1. You and two or three of your classmates will receive a **sealed paper sack** with a number on it. Write the number in your ScienceLog. Inside the sack is a **mystery object.** Do not open the sack!
2. For 5 minutes, make as many observations as you can about the object. You may shake the sack, touch the object through the sack, listen to the object in the sack, smell the object through the sack, and so on. Be sure to write down your observations.

Analysis

3. At the end of 5 minutes, take a couple of minutes to discuss your findings with your partners.
4. With your partners, list the object's properties, and make a conclusion about the object's identity. Write your conclusion in your ScienceLog.
5. Share your observations, list of properties, and conclusion with the class. Now you are ready to open the sack.
6. Did you properly identify the object? If so, how? If not, why not? Write your answers in your ScienceLog, and share them with the class.

Section 1

What Is Matter?

NEW TERMS

matter	gravity
volume	weight
meniscus	newton
mass	inertia

OBJECTIVES

- Name the two properties of all matter.
- Describe how volume and mass are measured.
- Compare mass and weight.
- Explain the relationship between mass and inertia.

Here's a strange question: What do you have in common with a toaster?

Do you give up? Okay, here's another question: What do you have in common with a steaming bowl of soup or a bright neon sign?

You are probably thinking these are trick questions. After all, it is hard to imagine that a human—you—has anything in common with a kitchen appliance, some hot soup, or a glowing neon sign.

From a scientific point of view, however, you have at least one characteristic in common with these things. You, the toaster, the bowl, the soup, the steam, the glass tubing, and the glowing gas are all made of matter. In fact, everything in the universe that you can touch (even if you cannot see it) is made of matter. For example, DNA, microscopic bacteria, and even air are all made of matter. But what is matter exactly? If so many different kinds of things are made of matter, you might expect the definition of the word *matter* to be complicated. But it is really quite simple. **Matter** is anything that has volume and mass.

Matter Has Volume

All matter takes up space. The amount of space taken up, or occupied, by an object is known as the object's **volume.** The sun, shown in **Figure 1,** has volume because it takes up space at the center of our solar system. Your fingernails have volume because they occupy space at the end of your hands. (The less you bite them, the more volume they have!) Likewise, the Statue of Liberty, the continent of Africa, and a cloud all have volume. And because these things have volume, they cannot share the same space at the same time. Even the tiniest speck of dust takes up space, and there's no way another speck of dust can fit into that space without somehow bumping the first speck out of the way. Try the QuickLab on this page to see for yourself that matter takes up space—even matter you can't see.

Figure 1 *The volume of the sun is about 1,000,000 (1 million) times larger than the volume of the Earth.*

QuickLab

Space Case

1. Crumple a **piece of paper,** and fit it tightly in the bottom of a **cup** so that it won't fall out.
2. Turn the cup upside down. Lower the cup straight down into a **large beaker or bucket** half-filled with **water** until the cup is all the way underwater.
3. Lift the cup straight out of the water. Turn the cup upright and observe the paper. Record your observations in your ScienceLog.
4. Now punch a small hole in the bottom of the cup with the point of a **pencil.** Repeat steps 2 and 3.
5. How do these results show that air has volume? Record your explanation in your ScienceLog.

Liquid Volume Locate the Great Lakes on a map of the United States. Lake Erie, the smallest of the Great Lakes, has a volume of approximately 483,000,000,000,000 (483 trillion) liters of water. Can you imagine that much liquid? Well, think of a 2 liter bottle of soda. The water in Lake Erie could fill more than 241 trillion of those bottles. That's a lot of water! On a smaller scale, a can of soda has a volume of only 355 milliliters, which is approximately one-third of a liter. The next time you see a can of soda, you can read the volume printed on the can. Or you can check its volume by pouring the soda into a large measuring cup from your kitchen, as shown in **Figure 2,** and reading the scale at the level of the liquid's surface.

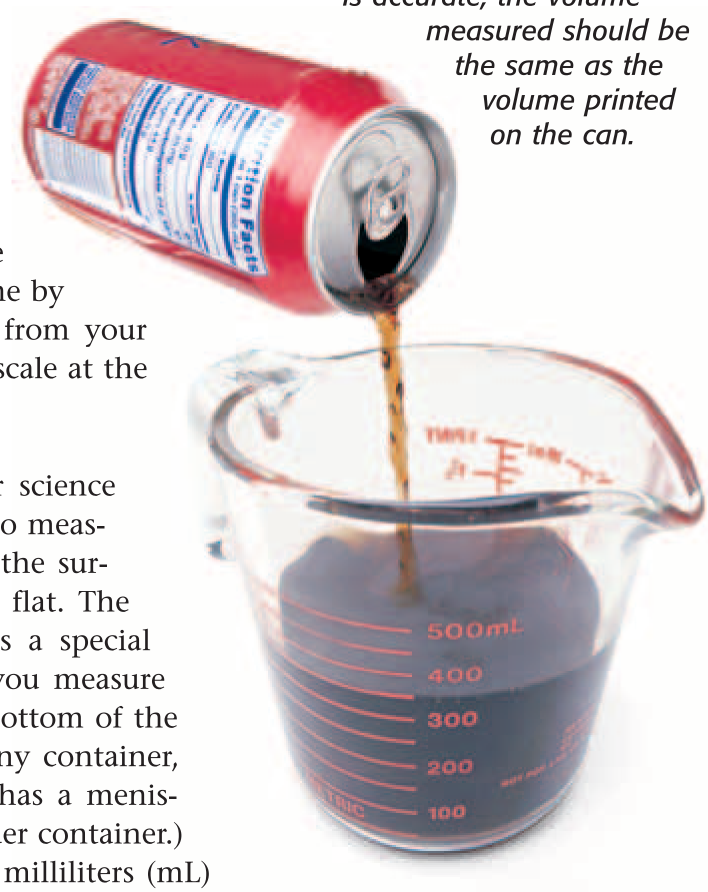


Figure 2 *If the measurement is accurate, the volume measured should be the same as the volume printed on the can.*

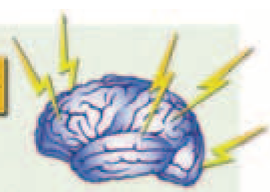
Measuring the Volume of Liquids In your science class, you'll probably use a graduated cylinder to measure the volume of liquids. Keep in mind that the surface of a liquid in a graduated cylinder is not flat. The curve that you see at the liquid's surface has a special name—the **meniscus** (muh NIS kuhs). When you measure the volume of a liquid, you must look at the bottom of the meniscus, as shown in **Figure 3.** (A liquid in any container, including a measuring cup or a large beaker, has a meniscus. The meniscus is just too flat to see in a wider container.)

Liters (L) and milliliters (mL) are the units used most often to express the volume of liquids. The volume of any amount of liquid, from one raindrop to a can of soda to an entire ocean, can be expressed in these units.

Figure 3 *To measure volume correctly, read the scale at the lowest part of the meniscus (as indicated) at eye level.*

Measuring the Volume of Solids What would you do if you wanted to measure the volume of this textbook? You cannot pour this textbook into a graduated cylinder to find the answer (sorry, no shredders allowed!). In the MathBreak activity on the next page, you will learn an easy way to find the volume of any solid object with rectangular sides.

BRAIN FOOD



The volume of a typical raindrop is approximately 0.09 mL, which means that it would take almost 4,000 raindrops to fill a soda can.

MATH BREAK

Calculating Volume

A typical compact disc (CD) case has a length of 14.2 cm, a width of 12.4 cm, and a height of 1.0 cm. The volume of the case is the length multiplied by the width multiplied by the height:

$$14.2 \text{ cm} \times 12.4 \text{ cm} \times 1.0 \text{ cm} = 176.1 \text{ cm}^3$$

Now It's Your Turn

1. A book has a length of 25 cm, a width of 18 cm, and a height of 4 cm. What is its volume?
2. What is the volume of a suitcase with a length of 95 cm, a width of 50 cm, and a height of 20 cm?
3. For additional practice, find the volume of other objects that have square or rectangular sides. Compare your results with those of your classmates.

The volume of any solid object, from a speck of dust to the tallest skyscraper, is expressed in cubic units. The term *cubic* means "having three dimensions." (A *dimension* is simply a measurement in one direction.) The three dimensions that are used to find volume are length, width, and height, as shown in **Figure 4.**

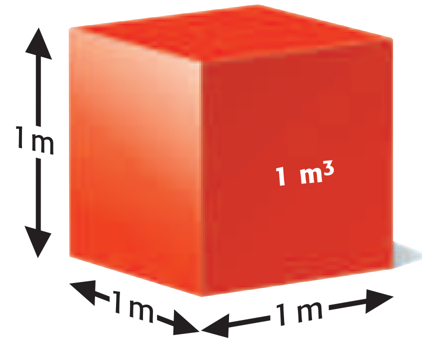


Figure 4 *A cubic meter has a height of 1 m, a length of 1 m, and a width of 1 m, so its volume is 1 m × 1 m × 1 m = 1 m³.*

Cubic meters (m^3) and cubic centimeters (cm^3) are the units most often used to express the volume of solid items. In the unit abbreviations m^3 and cm^3, the *3* to the upper right of the unit shows that the final number is the result of multiplying three quantities of that unit.

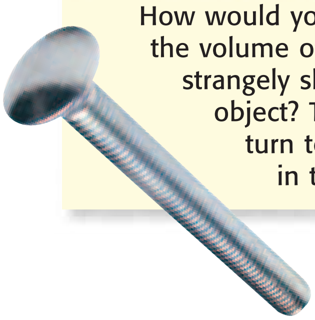
You now know that the volumes of solids and liquids are expressed in different units. So how can you compare the volume of a solid with the volume of a liquid? For example, suppose you are interested in determining whether the volume of an ice cube is equal to the volume of water that is left when the ice cube melts. Well, lucky for you, 1 mL is equal to 1 cm^3. Therefore, you can express the volume of the water in cubic centimeters and compare it with the original volume of the solid ice cube. The volume of any liquid can be expressed in cubic units in this way. (However, keep in mind that in SI, volumes of solids are never expressed in liters or milliliters.)

Measuring the Volume of Gases How do you measure the volume of a gas? You can't hold a ruler up to a gas to measure its dimensions. You can't pour a gas into a graduated cylinder. So it's impossible, right? Wrong! A gas expands to fill its container. If you know the volume of the container that a gas is in, then you know the volume of the gas.

Matter Has Mass

Another characteristic of all matter is mass. **Mass** is the amount of matter in a given substance. For example, the Earth contains a very large amount of matter and therefore has a large mass. A peanut has a much smaller amount of matter and thus has a smaller mass. Remember, even something as small as a speck of dust is made of matter and therefore has mass.

LabBook



How would you measure the volume of this strangely shaped object? To find out, turn to page 520 in the LabBook.

An object's mass can be changed only by changing the amount of matter in the object. Consider the bowling ball shown in **Figure 5.** Its mass is constant because the amount of matter in the bowling ball never changes (unless you use a sledgehammer to remove a chunk of it!). Now consider the puppy. Does its mass remain constant? No, because the puppy is growing. If you measured the puppy's mass next year or even next week, you'd find that it had increased. That's because more matter—more puppy—would be present.

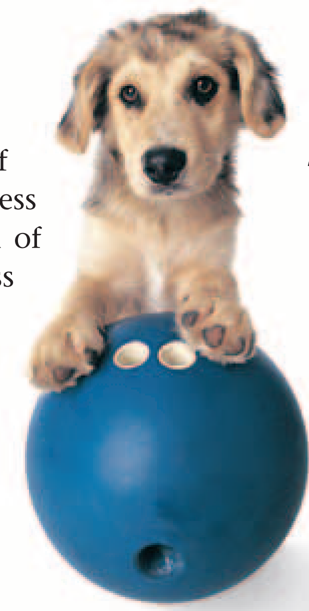
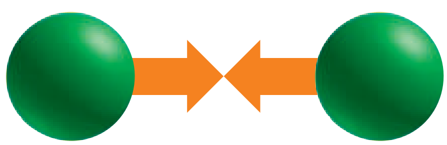


Figure 5 *The mass of the bowling ball does not change. The mass of the puppy increases as more matter is added—that is, as the puppy grows.*

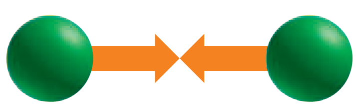
The Difference Between Mass and Weight

Weight is different from mass. To understand this difference, you must first understand gravity. **Gravity** is a force of attraction between objects that is due to their masses. This attraction causes objects to experience a "pull" toward other objects. Because all matter has mass, all matter experiences gravity. The amount of attraction objects experience toward each other depends on two things—the masses of the objects and the distance between them, as shown in **Figure 6.**

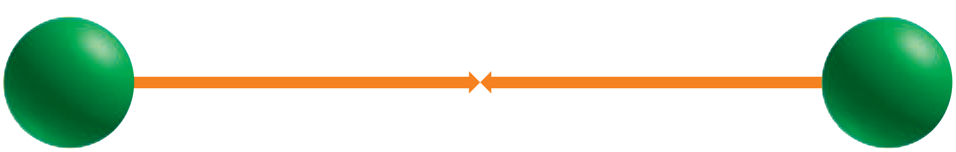
Figure 6 How Mass and Distance Affect Gravity Between Objects



a Gravitational force (represented by the width of the arrows) is large between objects with large masses that are close together.



b Gravitational force is smaller between objects with smaller masses that are close together than between objects with large masses that are close together (as shown in **a**).



c An increase in distance reduces gravitational force between two objects. Therefore, gravitational force between objects with large masses (such as those in **a**) is less if they are far apart.

Explore

Imagine the following items resting side by side on a table: an elephant, a tennis ball, a peanut, a bowling ball, and a housefly. In your ScienceLog, list these items in order of their attraction to the Earth due to gravity, from least to greatest amount of attraction. Follow your list with an explanation of why you arranged the items in the order that you did.

life science CONNECTION

The mineral calcium is stored in bones, and it accounts for about 70 percent of the mass of the human skeleton. Calcium strengthens bones, helping the skeleton to remain upright against the strong force of gravity pulling it toward the Earth.

May the Force Be with You Gravitational force is experienced by all objects in the universe all the time. But the ordinary objects you see every day have masses so small (relative to, say, planets) that their attraction toward each other is hard to detect. Therefore, the gravitational force experienced by objects with small masses is very slight. However, the Earth's mass is so large that the attraction of other objects to it is great. Therefore, gravitational force between objects and the Earth is great. In fact, the Earth is so massive that our atmosphere, satellites, the space shuttle, and even the moon experience a strong attraction toward the Earth. Gravity is what keeps you and everything else on Earth from floating into space.

So What About Weight? **Weight** is simply a measure of the gravitational force on an object. Consider the brick in **Figure 7.** The brick has mass. The Earth also has mass. Therefore, the brick and the Earth are attracted to each other. A force is exerted on the brick because of its attraction to the Earth. The weight of the brick is a measure of this gravitational force.

Now look at the sponge in Figure 7. The sponge is the same size as the brick, but its mass is much less. Therefore, the sponge's attraction toward the Earth is not as great, and the gravitational force on it is not as great. Thus, the *weight* of the sponge is less than the *weight* of the brick.

Because the attraction that objects experience decreases as the distance between them increases, the gravitational force on objects—and therefore their weight—also decreases as the distance increases. For this reason, a brick floating in space would weigh less than it does resting on Earth's surface. However, the brick's mass would be the same in space as it is on Earth.

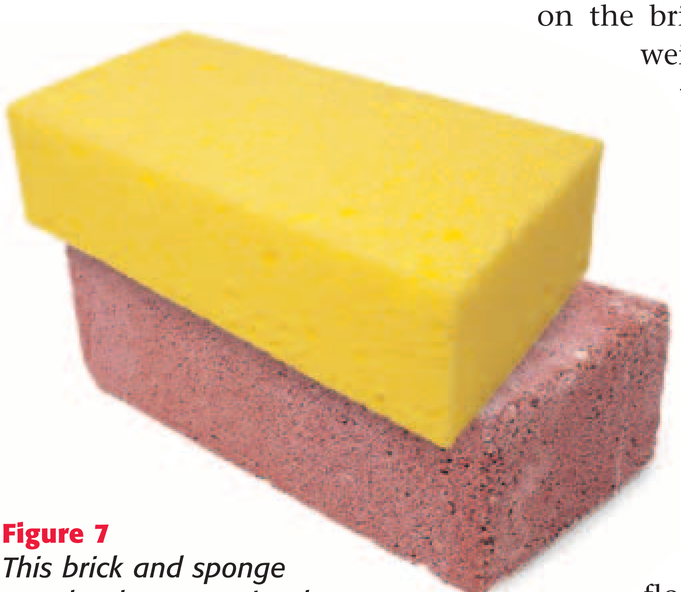


Figure 7
This brick and sponge may be the same size, but their masses, and therefore their weights, are quite different.

Massive Confusion Back on Earth, the gravitational force exerted on an object is about the same everywhere, so an object's weight is also about the same everywhere. Because mass and weight remain constant everywhere on Earth, the terms *mass* and *weight* are often used as though they mean the same thing. But using the terms interchangeably can lead to confusion, especially if you are trying to measure these properties of an object. So remember, weight depends on mass, but weight is not the same thing as mass.

across the sciences CONNECTION

Some scientists think that there are WIMPs in space. Find out more on page 56.

Measuring Mass and Weight

The SI unit of mass is the kilogram (kg), but mass is often expressed in grams (g) and milligrams (mg) as well. These units can be used to express the mass of any object, from a single cell in your body to the entire solar system. Weight is a measure of gravitational force and must be expressed in units of force. The SI unit of force is the **newton (N).** So weight is expressed in newtons.

A newton is approximately equal to the weight of a 100 g mass on Earth. So if you know the mass of an object, you can calculate its weight on Earth. Conversely, if you know the weight of an object on Earth, you can determine its mass. **Figure 8** summarizes the differences between mass and weight.

Figure 8 **Differences Between Mass and Weight**

Mass is . . .

- a measure of the amount of matter in an object.
- always constant for an object no matter where the object is in the universe.
- measured with a balance (shown below).
- expressed in kilograms (kg), grams (g), and milligrams (mg).

Weight is . . .

- a measure of the gravitational force on an object.
- varied depending on where the object is in relation to the Earth (or any other large body in the universe).
- measured with a spring scale (shown above).
- expressed in newtons (N).

Self-Check

If all of your school books combined have a mass of 3 kg, what is their total weight in newtons? Remember that 1 kg = 1,000 g. *(See page 596 to check your answer.)*

APPLY

Ordinary bathroom scales are spring scales. Many scales available today show a reading in both pounds (a common though not SI unit of weight) and kilograms. How does such a reading contribute to the confusion between mass and weight?

Mass Is a Measure of Inertia

Which do you think would be easier to pick up and throw, a soccer ball or a bowling ball? Well, you could probably throw the soccer ball clear across your backyard, but the bowling ball would probably not go very far. What's the difference? The difference has to do with inertia (in UHR shuh). **Inertia** is the tendency of all objects to resist any change in motion. Because of inertia, an object at rest (like the soccer ball or the bowling ball) will remain at rest until something causes it to move. Likewise, a moving object continues to move at the same speed and in the same direction unless something acts on it to change its speed or direction.

So why do we say that mass is a measure of inertia? Well, think about this: An object with a large mass is harder to start in motion and harder to stop than an object with a smaller mass. This is because the object with the large mass has greater inertia. For example, imagine that you are going to push a grocery cart that has only one potato in it. No problem, right? But suppose the grocery cart is filled with potatoes, as in **Figure 9.** Now the total mass—and the inertia—of the cart full of potatoes is much greater. It will be harder to get the cart moving and harder to stop it once it is moving. So an object with a large mass has greater inertia than an object with a smaller mass.

Figure 9 *Why is a cartload of potatoes harder to get moving than a single potato? Because of inertia, that's why!*

REVIEW

1. What are the two properties of all matter?
2. How is volume measured? How is mass measured?
3. **Analyzing Relationships** Do objects with large masses always have large weights? Explain your reasoning.

Section 2

Describing Matter

NEW TERMS

physical property
density
chemical property
physical change
chemical change

OBJECTIVES

- Give examples of matter's different properties.
- Describe how density is used to identify different substances.
- Compare physical and chemical properties.
- Explain what happens to matter during physical and chemical changes.

Have you ever heard of the game called "20 Questions"? In this game, your goal is to determine the identity of an object that another person is thinking of by asking questions about the object. The other person can respond with only a "yes" or "no." If you can identify the object after asking 20 or fewer questions, you win! If you still can't figure out the object's identity after asking 20 questions, you may not be asking the right kinds of questions.

What kinds of questions should you ask? You might find it helpful to ask questions about the properties of the object. Knowing the properties of an object can help you determine the object's identity, as shown below.

Explore

With a partner, play a game of 20 Questions. One person will think of an object, and the other person will ask yes/no questions about it. Write the questions in your ScienceLog as you go along. Put a check mark next to the questions asked about physical properties. When the object is identified or when the 20 questions are up, switch roles. Good luck!

Physical Properties

Some of the questions shown above help the asker gather information about *color* (Is it orange?), *odor* (Does it have an odor?), and *mass* and *volume* (Could I hold it in my hand?). Each of these properties is a physical property of matter. A **physical property** of matter can be observed or measured without changing the identity of the matter. For example, you don't have to change what the apple is made of to see that it is red or to hold it in your hand.

You rely on physical properties all the time. For example, physical properties help you determine whether your socks are clean (odor), whether you can fit all your books into your backpack (volume), or whether your shirt matches your pants (color). The table below lists some more physical properties that are useful in describing or identifying matter.

More Physical Properties

Physical property	Definition	Example
Thermal conductivity	The ability to transfer thermal energy from one area to another	Plastic foam is a poor conductor, so hot chocolate in a plastic-foam cup will not burn your hand.
State	The physical form in which a substance exists, such as a solid, liquid, or gas	Ice is water in its solid state.
Malleability (MAL ee uh BIL uh tee)	The ability to be pounded into thin sheets	Aluminum can be rolled or pounded into sheets to make foil.
Ductility (duhk TIL uh tee)	The ability to be drawn or pulled into a wire	Copper is often used to make wiring.
Solubility (SAHL yoo BIL uh tee)	The ability to dissolve in another substance	Sugar dissolves in water.
Density	Mass per unit volume	Lead is used to make sinkers for fishing line because lead is more dense than water.

Spotlight on Density Density is a very helpful property when you need to distinguish different substances. There are some interesting things you should know about density. Look at the definition of density in the table above—mass per unit volume. If you think back to what you learned in Section 1, you can define density in other terms: **density** is the amount of matter in a given volume, as shown in **Figure 10.**

Figure 10 *A golf ball is more dense than a table-tennis ball because the golf ball contains more matter in a similar volume.*

To find an object's density (D), first measure its mass (m) and volume (V). Then use the following equation:

$$D = \frac{m}{V}$$

Units for density are expressed using a mass unit divided by a volume unit, such as g/cm^3, g/mL, kg/m^3, and kg/L.

Using Density to Identify Substances Density is a useful property for identifying substances for two reasons. First, the density of a particular substance is always the same at a given pressure and temperature. For example, the helium in a huge airship has a density of 0.0001663 g/cm^3 at 20°C and normal atmospheric pressure. You can calculate the density of any other sample of helium at that same temperature and pressure—even the helium in a small balloon—and you will get 0.0001663 g/cm^3. Second, the density of one substance is usually different from that of another substance. Check out the table below to see how density varies among substances.

Densities of Common Substances*

Substance	Density (g/cm^3)	Substance	Density (g/cm^3)
Helium (gas)	0.0001663	Copper (solid)	8.96
Oxygen (gas)	0.001331	Silver (solid)	10.50
Water (liquid)	1.00	Lead (solid)	11.35
Iron pyrite (solid)	5.02	Mercury (liquid)	13.55
Zinc (solid)	7.13	Gold (solid)	19.32

** at 20°C and normal atmospheric pressure*

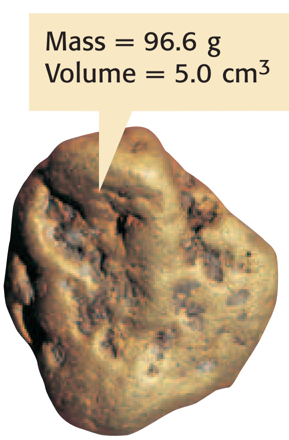


Figure 11 *Did you find gold or fool's gold?*

Do you remember your imaginary attempt at gold prospecting? To make sure you hadn't found more fool's gold (iron pyrite), you could compare the density of a nugget from your sample, shown in **Figure 11,** with the known densities for gold and iron pyrite at the same temperature and pressure. By comparing densities, you'd know whether you'd actually struck gold or been fooled again.

MATH BREAK

Density

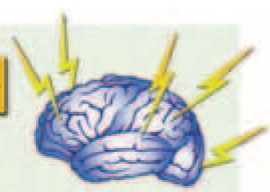
You can rearrange the equation for density to find mass and volume as shown below:

$$D = \frac{m}{V}$$

$$m = D \times V \qquad V = \frac{m}{D}$$

1. Find the density of a substance with a mass of 5 kg and a volume of 43 m^3.
2. Suppose you have a lead ball with a mass of 454 g. What is its volume? (Hint: Use the table at left.)
3. What is the mass of a 15 mL sample of mercury? (Hint: Use the table at left.)

BRAIN FOOD



Pennies minted before 1982 are made mostly of copper and have a density of 8.85 g/cm^3. In 1982, a penny's worth of copper began to cost more than one cent, so the U.S. Department of the Treasury began producing pennies using mostly zinc with a copper coating. Pennies minted after 1982 have a density of 7.14 g/cm^3. Check it out for yourself!

Figure 12 *The yellow liquid is the least dense, and the green liquid is the densest.*

Liquid Layers What do you think causes the liquid in **Figure 12** to look like it does? Is it magic? Is it trick photography? No, it's differences in density! There are actually four different liquids in the jar. Each liquid has a different density. Because of these differences in density, the liquids do not mix together but instead separate into layers, with the densest layer on the bottom and the least dense layer on top. The order in which the layers separate helps you determine how the densities of the liquids compare with one another.

The Density Challenge Imagine that you could put a lid on the jar in the picture and shake up the liquids. Would the different liquids mix together so that the four colors would blend into one interesting color? Maybe for a minute or two. But if the liquids are not soluble in one another, they would start to separate, and eventually you'd end up with the same four layers.

The same thing happens when you mix oil and vinegar to make salad dressing. But what do you think would happen if you added more oil? What if you added so much oil that there was several times as much oil as there was vinegar? Surely the oil would get so heavy that it would sink below the vinegar, right? Wrong! No matter how much oil you have, it will always be less dense than the vinegar, so it will always rise to the top. The same is true of the four liquids shown in Figure 12. Even if you add more yellow liquid than all of the other liquids combined, all of the yellow liquid will rise to the top. That's because density does not depend on how much of a substance you have.

LabBook

Experiment for yourself with liquid layers on page 523 in the LabBook.

APPLY

The grease separator shown here is a kitchen device that cooks use to collect the best meat juices for making gravies. Based on what you know about density, describe how a grease separator works. Be sure to explain why the spout is at the bottom.

REVIEW

1. List three physical properties of water.
2. Why does a golf ball feel heavier than a table-tennis ball?
3. Describe how you can determine the relative densities of liquids.
4. **Applying Concepts** How could you determine that a coin is not pure silver?

Chemical Properties

Physical properties such as density, color, and mass are not the only properties that describe matter. **Chemical properties** describe a substance based on its ability to change into a new substance with different properties. For example, a piece of wood can be burned to create new substances (ash and smoke) with very different properties from the original piece of wood. Therefore, wood has the chemical property of *flammability*—the ability to burn. A substance that does not burn, such as gold, has the chemical property of nonflammability. Other common chemical properties include reactivity with oxygen, reactivity with acid, and reactivity with water. (The word *reactivity* just means that when two substances get together, something can happen.)

Like physical properties, chemical properties can be observed with your senses. However, chemical properties aren't as easy to observe. For example, you can observe the flammability of wood only while the wood is burning. Likewise, you can observe the nonflammability of gold only when you try to burn it and it won't burn. But a substance always has its chemical properties, even when you are not observing them. Therefore, a piece of wood is flammable even when it's not burning.

Some Chemical Properties of Car Maintenance Look at the old car shown in **Figure 13.** Its owner calls it Rust Bucket. Why has this car rusted so badly while some other cars the same age remain in great shape? Knowing about chemical properties can help answer this question.

Most car bodies are made from steel, which consists mostly of iron. Iron has many favorable physical properties, including strength, malleability, hardness, and a high melting point. Iron also has many favorable chemical properties, including nonreactivity with oil and gasoline. All in all, steel is a good material to use for car bodies. It's not perfect, however, as you can probably tell from the car shown here.

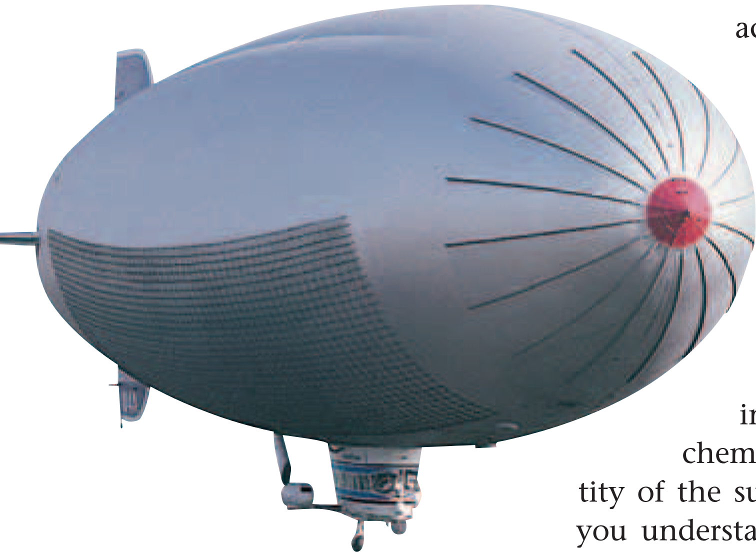
Figure 13 Rust Bucket *One unfavorable chemical property of iron is its reactivity with oxygen. When iron is exposed to oxygen, it rusts. If left unprotected, the iron will eventually rust away.*

Physical vs. Chemical Properties

You can describe matter by both physical and chemical properties. The properties that are most useful in identifying a substance, such as density, solubility, and reactivity with acids, are its characteristic properties. The *characteristic properties* of a substance are always the same whether the sample you're observing is large or small. Scientists rely on characteristic properties to distinguish substances and to separate them from one another. **Figure 14** describes some physical and chemical properties.

It is important to remember the differences between physical and chemical properties. You can observe physical properties without changing the identity of the substance. You can observe chemical properties only in situations in which the identity of the substance could change. The table below can help you understand the distinction between physical and chemical properties.

Figure 14 *Substances have different physical and chemical properties.*



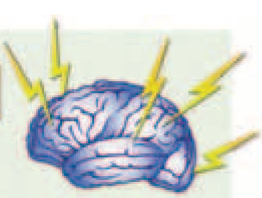
a Helium is used in airships because it is less dense than air and is nonflammable.

b If you add bleach to water that is mixed with red food coloring, the red color will disappear.

Comparing Physical and Chemical Properties

Substance	Physical property	Chemical property
Helium	less dense than air	nonflammable
Wood	grainy texture	flammable
Baking soda	white powder	reacts with vinegar to produce bubbles
Powdered sugar	white powder	does not react with vinegar
Rubbing alcohol	clear liquid	flammable
Red food coloring	red color	reacts with bleach and loses color
Iron	malleable	reacts with oxygen
Tin	malleable	reacts with oxygen

BRAIN FOOD



Bending a bar of tin produces a squealing sound known as a tin cry.

Physical Changes Don't Form New Substances

A **physical change** is a change that affects one or more physical properties of a substance. For example, if you were to break a piece of chalk in two, you would be changing its physical properties of size and shape. But no matter how many times you break it, the chalk is still chalk. In other words, the chemical properties of the chalk remain unchanged. Each piece of chalk would still produce bubbles if you placed it in vinegar.

Melting is another example of a physical change, as you can see in **Figure 15.** Still another physical change occurs when a substance dissolves into another substance. If you dissolve sugar in water, the sugar seems to disappear into the water. But the identity of the sugar does not change. If you taste the water, you will notice that the sugar is still there. It has just undergone a physical change. See the chart below for some more examples of physical changes.

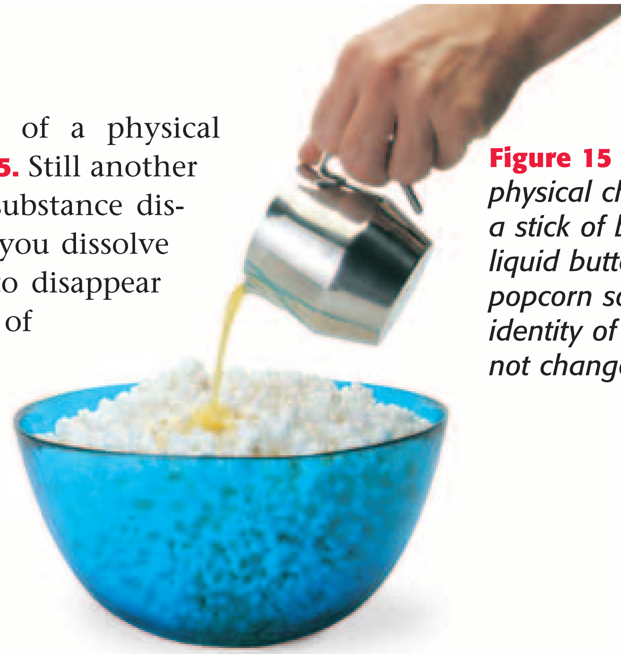


Figure 15 *It took a physical change to turn a stick of butter into the liquid butter that makes popcorn so tasty, but the identity of the butter did not change.*

More Examples of Physical Changes	
■ Freezing water for ice cubes	■ Crushing an aluminum can
■ Sanding a piece of wood	■ Bending a paper clip
■ Cutting your hair	■ Mixing oil and vinegar

Can Physical Changes Be Undone? Because physical changes do not change the identity of substances, they are often easy to undo. If you leave butter out on a warm counter, it will undergo a physical change—it will melt. Putting it back in the refrigerator will reverse this change by making it solid again. Likewise, if you create a figure, such as a dragon or a person, from a lump of clay, you drastically change the clay's shape, causing a physical change. But because the identity of the clay does not change, you can crush your creation and form the clay back into the shape it was in before.

Chemical Changes Form New Substances

A **chemical change** occurs when one or more substances are changed into entirely new substances. The new substances have a different set of properties from the original substances. Chemical changes will or will not occur as described by the chemical properties of substances. But don't confuse chemical changes with chemical properties—they are not the same thing. A chemical property describes a substance's ability to go through a chemical change; a chemical change is the actual process in which that substance changes into another substance. You can observe chemical properties only when a chemical change might occur. Try the QuickLab on this page to learn more about chemical changes.

QuickLab

Changing Change

1. Place a folded **paper towel** in a **small pie plate.**
2. Pour **vinegar** into the pie plate until the entire paper towel is damp.
3. Place **two or three shiny pennies** on top of the paper towel.
4. Put the pie plate in a place where it won't be bothered, and wait 24 hours.
5. Describe the chemical change that took place.
6. Write your observations in your ScienceLog.

Figure 16 *Each of these ingredients has different physical and chemical properties.*

A fun (and delicious) way to see what happens during chemical changes is to bake a cake. When you bake a cake, you combine eggs, flour, sugar, butter, and other ingredients as shown in **Figure 16.** Each ingredient has its own set of properties. But if you mix them together and bake the batter in the oven, you get something completely different. The heat of the oven and the interaction of the ingredients cause a chemical change. As shown in **Figure 17,** you get a cake that has completely different properties than any of the ingredients. Some more examples of chemical changes are shown below.

Figure 17 *Chemical changes produce new substances with different properties.*

Examples of Chemical Changes

Soured milk smells bad because bacteria have formed new substances in the milk.

Effervescent tablets bubble when the citric acid and baking soda in them react in water.

The hot gas formed when hydrogen and oxygen join to make water helps blast the space shuttle into orbit.

The Statue of Liberty is made of shiny, orange-brown copper. But the metal's interaction with carbon dioxide and water has formed a new substance, copper carbonate, and made this landmark lady green over time.

Clues to Chemical Changes Look back at the bottom of the previous page. In each picture, there is at least one clue that signals a chemical change. Can you find the clues? Here's a hint: chemical changes often cause color changes, fizzing or foaming, heat, or the production of sound, light, or odor.

In the cake example, you would probably smell the sweet aroma of the cake as it baked. If you looked into the oven, you would see the batter rise and turn brown. When you cut the finished cake, you would see the spongy texture created by gas bubbles that formed in the batter (if you baked it right, that is!). All of these yummy clues are signals of chemical changes. But are the clues and the chemical changes the same thing? No, the clues just result from the chemical changes.

Can Chemical Changes Be Undone? Because new substances are formed, you cannot reverse chemical changes using physical means. In other words, you can't uncrumple or iron out a chemical change. Imagine trying to un-bake the cake shown in **Figure 18** by pulling out each ingredient. No way! Most of the chemical changes in your daily life, such as a cake baking or milk turning sour, would be difficult to reverse. However, some chemical changes can be reversed under the right conditions by other chemical changes. For example, the water formed in the space shuttle's rockets could be split back into hydrogen and oxygen using an electric current.

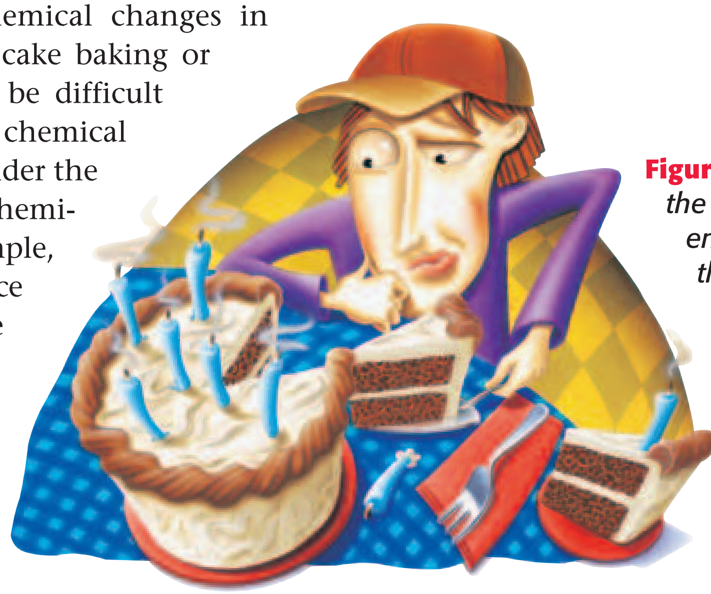


Figure 18 *Looking for the original ingredients? You won't find them—their identities have changed.*

environmental science CONNECTION

When fossil fuels are burned, a chemical change takes place involving sulfur (a substance in fossil fuels) and oxygen (from the air). This chemical change produces sulfur dioxide, a gas. When sulfur dioxide enters the atmosphere, it undergoes another chemical change by interacting with water and oxygen. This chemical change produces sulfuric acid, a contributor to acid precipitation. Acid precipitation can kill trees and make ponds and lakes unable to support life.

REVIEW

1. Classify each of the following properties as either physical or chemical: reacts with water, dissolves in acetone, is blue, does not react with hydrogen.
2. List three clues that a chemical change might be taking place.
3. **Comparing Concepts** Describe the difference between physical changes and chemical changes in terms of what happens to the matter involved in each kind of change.