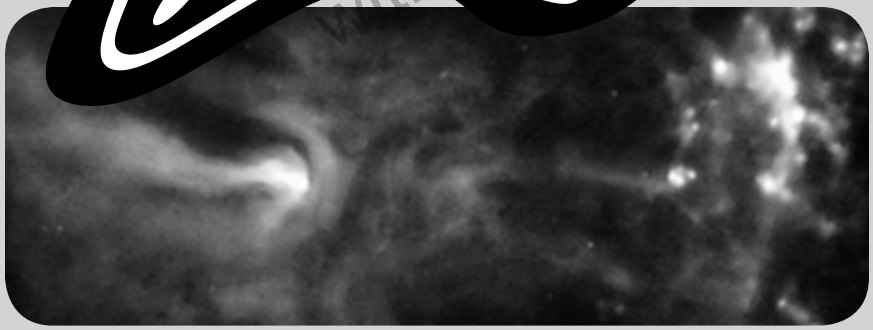
FOCUS ON SCIENCE

Mass, Density, and Properties of Matter

Advanced Level



The dense remains of a massive star light up surrounding gases.
(Image: NASA/CXC/SAO/P Slane et al)

Physical Science
Interactions Between Matter and Energy

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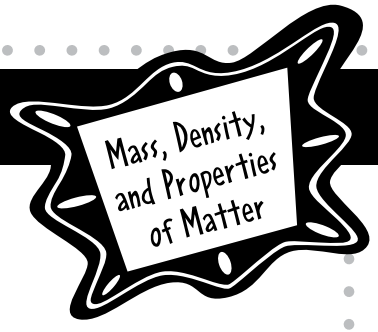


Scientific Inquiry

Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

Carry out their research proposals, recording observations and measurements (e.g., lab notes, audiotape, computer disk, videotape) to help assess the explanation.

Physical Science

Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.

Solubility can be affected by the nature of the solute and solvent, temperature, and pressure. The rate of solution can be affected by the size of the particles, stirring, temperature, and the amount of solute already dissolved.

Characteristic properties can be used to identify different materials, and separate a mixture of substances into its components. For example, iron can be removed from a mixture by means of a magnet. An insoluble substance can be separated from a soluble substance by such processes as filtration, settling, and evaporation.

Density can be described as the amount of matter that is in a given amount of space. If two objects have equal volume, but one has more mass, the one with more mass is denser.

All matter is made up of atoms. Atoms are far too small to see with a light microscope.

Atoms and molecules are perpetually in motion. The greater the temperature, the greater the motion.

Atoms may join together in well-defined molecules or may be arranged in regular geometric patterns.

Interactions among atoms and/or molecules result in chemical reactions.

The atoms of any one element are different from the atoms of other elements.

There are more than 100 elements. Elements combine in a multitude of ways to produce compounds that account for all living and nonliving substances. Few elements are found in their pure form.

The periodic table is one useful model for classifying elements. The periodic table can be used to predict properties of elements (metals, nonmetals, noble gases).

English Language Arts

The following is a selective listing of the competencies and indicators addressed in this book.

Word Recognition

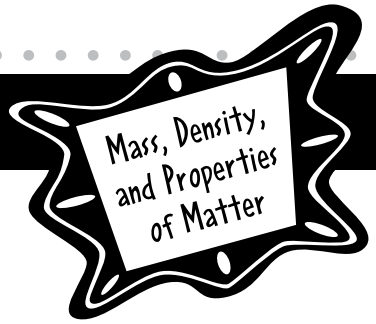
- Use word recognition skills and strategies quickly,accurately, and automatically when decoding unfamiliar words

Background Knowledge and Vocabulary Development

- Use self-monitoring strategies to identify specific vocabulary difficulties that disrupt comprehension,and employ an efficient course of action, such asusing a known word base or a resource such as aglossary to resolve the difficulty

Comprehension Strategies

- Use a variety of strategies (e.g., summarizing,forming questions, visualizing, and making connections) to support understanding of texts read



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How to Help Your Students Make the Best Use of This Book

Encourage students to develop nonfiction literacy skills by completing the Active Reader activities. Also encourage them to . . .

- Underline main ideas in paragraphs.
- Circle details that support the main ideas.
- Write down questions as they read.
- Circle key words as well as unfamiliar words.

Printing Instructions

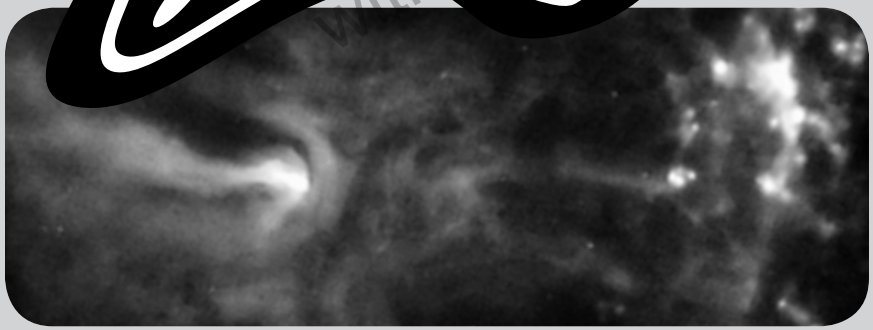
Student Book: print pages 5–36

Assessments: print pages 37–40

Answer Key: print pages 41–44

FOCUS ON SCIENCE

Mass, Density, and Properties of Matter

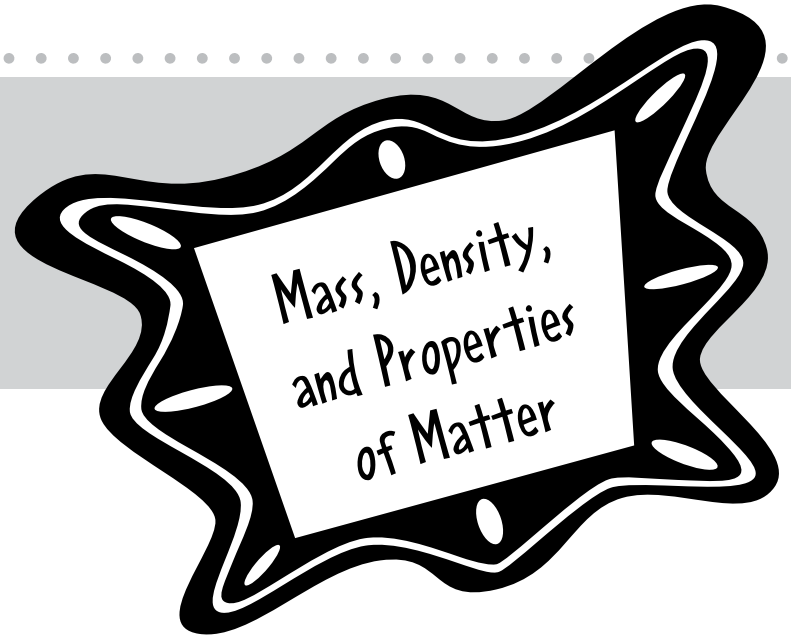


The ultra dense remains of a massive star light up surrounding gases.
(Image: NASA/CXC/SAO/P Slane et al)

How do the properties and interactions of matter and energy explain physical and chemical change?

Have you ever found an object that was unfamiliar to you? You probably used your senses—sight, touch, feel, smell, and hearing—to figure out what it was.

One thing is for sure: the object was made of matter. Matter is anything with mass that takes up space. All matter has four basic properties: mass, weight, volume, and density. Do you know what each of these are? Read on to find out and learn more about the properties of matter.



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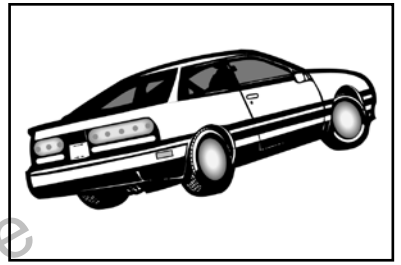
Build Background

Predict



Objects made of different substances can be the same shape and size. Or they can be the same weight. But they are not usually the same size and the same weight.

The toy car in the picture at the right is made of plastic. It doesn't weigh very much. If it were made of metal it might look the same. But, it would weigh a lot more. Answer the questions below about size and weight.

1. **Which is heavier: a kilogram of feathers or a kilogram of bricks?** _____
2. **Which takes up more space: a kilogram of bricks or a kilogram of feathers?** _____
3. **Which is heavier: a liter of cement or a liter of sand?** _____
4. **Which is bigger: a quart of milk or a liter of milk?** _____

Brainstorm

Some things will float in water. Others will sink. Fill in the chart with the names of things you think will float or sink.

Float	Sink

Starting Points

Key Vocabulary

Rate Your Knowledge

The words listed below have to do with the properties of matter. Each word is important, but some of them may be new to you. Rate your knowledge of each one by checking the appropriate column. Give the definition if you know the word. After completing this book, come back to this page and write the definitions of words you did not know.

	I don't know it.	I've seen it, but I'm not sure what it means.	I know it well, it means...
cubic centimeter			
density			
inertia			
gram			
mass			
matter			
ratio			
volume			
weight			

Starting Points

Key Vocabulary

Use Context

The same word can have different meanings depending on the context in which it is used. Explain how the underlined word has different meanings in each pair of sentences.

1. The Thanksgiving parade had many <u>floats</u>.
   A kite <u>floats</u> in the wind.

2. The kitchen <u>sink</u> is full of dishes.
   Bricks <u>sink</u> in water.

3. The <u>volume</u> on the TV was very loud.
   The <u>volume</u> of the milk in the carton was one gallon.

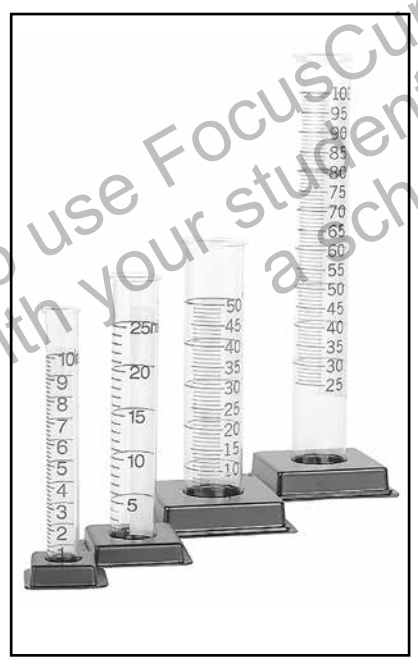
Starting Points

Key Concepts

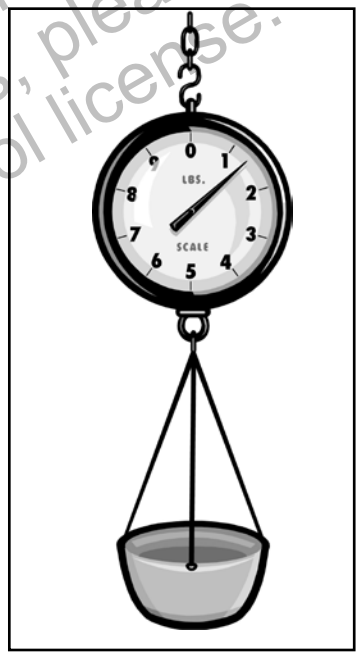
Making Measurements

When we want to know more about something we often measure it. For example, will a new table you just purchased fit through the kitchen door? You can measure the width of the table and the width of the door to find out. Or imagine that you've just packed your suitcase for vacation. It looks massive but the airline guidelines say each piece of luggage must be under 50 lbs. Will you need to take some things out? You can weigh the suitcase and find out how heavy it is.

Measuring requires tools such as balances, spoons of a known size, and rulers. Scientists use special tools like the ones shown below to measure things. Measurements can be taken in different units of measure. Scientists usually use the metric system, also known as the International System of Units, or SI. Units of measure in the metric system include meters, liters, and grams.



A graduated cylinder is used to measure liquids and powders.



A Newton scale is used to measure weight.

ACTIVE READER

1 Explain *Use what you know about mass to explain what* massive *means.*

_____

_____

_____

2 Identify *What is something that is very heavy, but not very big?*

_____

_____

_____

Chapter 1 Mass, Weight, and Volume

FOCUS Mass and weight are not the same. As you read this section, find out how mass and weight are different and learn how to measure them.

Measuring Matter

Mass and weight are often confused. **Mass** is a measure of how much matter makes up an object. **Weight** is a measure of the gravitational attraction between that mass and another object.

When we step on a bathroom scale to weigh ourselves, gravity is at work. The scale actually measures the gravitational attraction between two bodies: yours and Earth. Gravitational attraction depends on two things: the masses of the two objects attracted and the distance between them. In fact, if you weren't so close to Earth, the gravitational attraction wouldn't be as strong and you wouldn't weigh as much. Mountain climbers weigh less at the top of Mt. Everest than they do at sea level because they are farther away from the center of Earth. Gravitational attraction decreases the farther away from an object you are.

Similarly, astronauts weigh about one-sixth of their Earth weight on the Moon. This is because the mass of the Moon is much less than that of Earth.

The weight of an object depends on where it is located relative to another object and the mass of that object.

In space, humans weigh less, though their mass stays the same.

ACTIVE READER

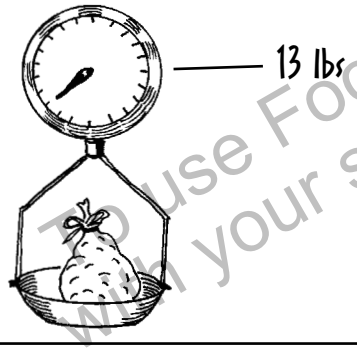
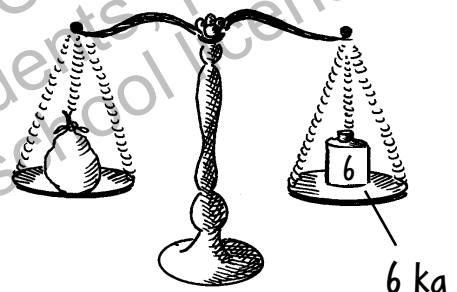
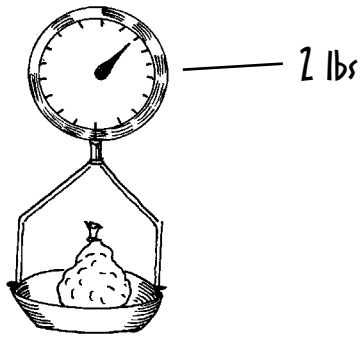
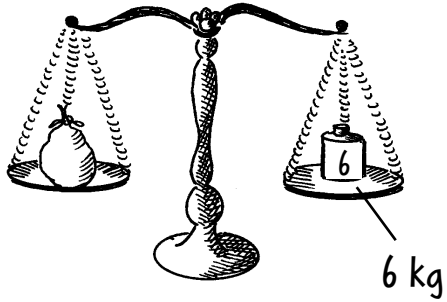
1 Summarize *What is the difference between mass and weight?*

Measuring for Weight and Mass

The following example shows how weight and mass are different.

The scale shown in Diagram A is used to measure weight. It shows that the bag of beans weighs about 13 pounds. If the beans were measured on the moon, the scale would show that the beans weigh a bit more than two pounds.

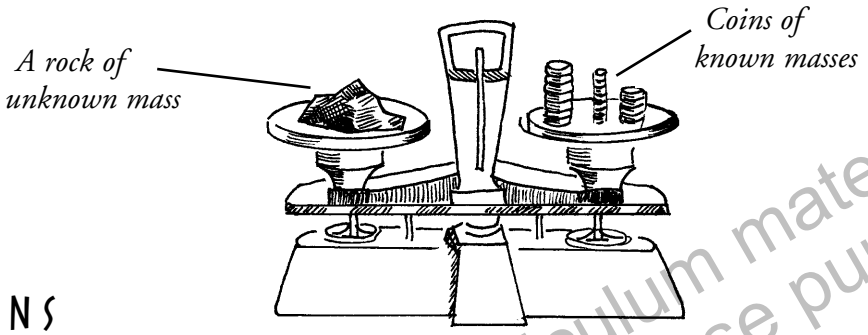
The measuring tool shown in Diagram B is a balance, which is used to measure mass. On one side are the beans. A six kilogram cylinder of metal is needed on the other side to balance the beans. This means the beans have a mass of six kilograms. If the beans were measured on the moon, the two pans would balance only if the same cylinder of metal was used. Since the moon's gravity acts on the beans, the balance, and the metal in the same way, the effect of the change in gravity is cancelled out. The mass of the beans is six kilograms no matter where they are measured.

	Diagram A: Measuring Weight	Diagram B: Measuring Mass
On the Earth		
On the Moon		

Good to Know

The tools shown in the diagrams are used for different purposes. They also use different units of measure. We typically measure weight in ounces and pounds using the U.S. customary system. We measure mass in grams and kilograms using the metric system. There are about 2.2 kilograms (kg) in one pound (lb).

There are different kinds of balances. But, they all work the same way: an unknown mass is balanced by a known mass. The object whose mass is unknown is placed on one side. Masses of known amounts are placed on the other side until the two sides balance. Then, the known masses are added together. This is the mass of the unknown object.



FOCUS QUESTIONS

Use the information in the box below to answer the questions.

Masses of Various Coins		
Dime: 2.0 grams	Penny: 2.5 grams	Nickel: 5.0 grams

1. Using a balance, you find that a rock has a mass equal to three pennies and a dime. Explain how to calculate the mass of the rock. What is the mass of the rock?

2. You have three dimes, six pennies and two nickels. What is the mass of these coins?

ACTIVE READER

1 Summarize *What are the steps involved in using a balance to find the mass of an object?*

2 Hypothesize *If you think that your balance isn't working correctly, what might you do to test it?*

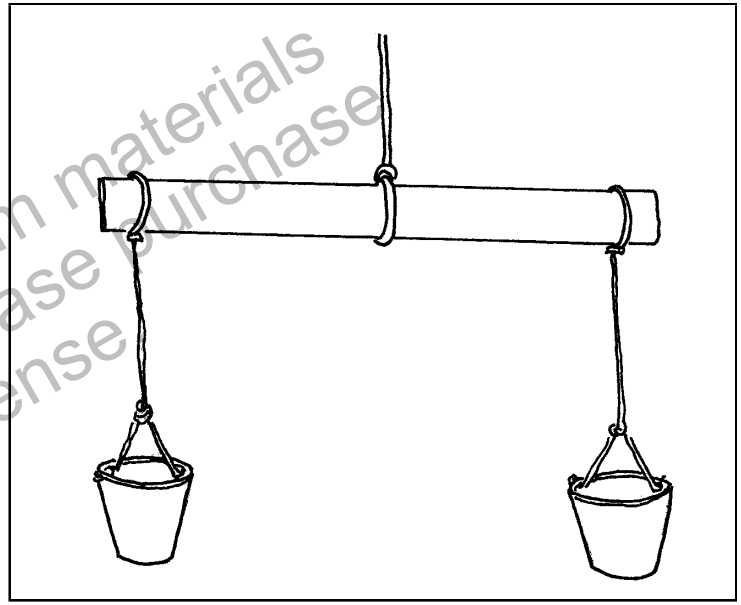
Hands On Science

Make a Balance

Here's how to make a simple balance you can use to find the mass of small objects.

Materials

- **two paper cups**
- **string**
- **ruler**
- **pennies**
- **small objects to measure**



Making a simple balance lets you measure the mass of small objects.

Procedure

1. **Carefully punch two small holes across from each other in the paper cups. A pencil point works well for making the holes.**
2. **Make a handle on each cup by tying a piece of string, about 30 cm (12 in), through each of the holes.**
3. **Cut two more pieces of string about 30 cm long. Tie one of the strings to the ruler at the 2.5 cm (1 in) mark. Tie the other string to the 27.5 cm (11 in) mark.**
4. **Tie the cups to the ends of the ruler strings.**
5. **Tie a length of string, 30–45 cm (12–18 in), to the middle of the ruler.**
6. **Once you have done this, hold the balance up by the string in the middle of the ruler. If one side hangs lower than the other, move the middle string slowly toward the side that is lower. Once the sides are even, your balance is ready to use.**
7. **Follow the steps described on the next page to put your balance to work.**

Hands On Science

Using the Balance

1. **Use U.S. pennies for the known masses. A penny made in 1982 or after has a mass of about 2.5 grams; pennies made before 1982 have a mass of 3.0 grams.**
2. **Place a small object of unknown mass in one cup. Add pennies to the other cup until the two cups balance. Then count the pennies and add up the mass. Repeat with five more objects.**
3. **Record your results in the chart below.**

Object	Number of Pennies	Mass in Grams

FOCUS

This section explains more about mass and weight and how they are related. Read carefully to find out which one is dependent on the other.

Natural Forces

Of the four general properties of matter (mass, weight, volume, and density), mass is probably the most important. Mass, the amount of matter in an object, never changes unless matter is physically removed from the object. The mass of an object interacts with natural forces, such as gravity.

Gravity

How does the force of gravity affect matter? Imagine that you were to jump out of an airplane. Before you open your parachute, you and Earth experience gravitational attraction and you feel yourself rushing toward Earth. You move faster and faster as gravity pulls you toward the center of Earth. You accelerate as the speed of your body relative to Earth increases. Scientists define weight as mass multiplied by the **acceleration** caused by gravity. Weight, then, depends on mass and gravity.

As you learned in the previous section, mass is measured in the metric system using grams and kilograms. However, in the metric system all forces are measured in **Newtons**. Since weight on Earth is essentially the force of Earth pulling on the mass of another object, weight is also measured in Newtons. On the surface of Earth, an object with a mass of 1 kilogram weighs 9.8 Newtons. Study the chart below and read the Good to Know feature at the right to find the missing number.

Measuring a Rock with a Mass of 1 Kilogram

	Metric System	U.S. Customary System
Mass	1.0 kilogram	?
Weight on the Surface of Earth	9.8 Newtons	2.2 pounds
Weight on the Surface of the Moon	1.6 Newtons	5.9 ounces

ACTIVE READER

1 Recall *What is one difference between the U.S. customary system of measurement and the metric system?*

_____

_____

_____

_____

Good to Know

In the metric system, we measure weight in Newtons and mass in grams and kilograms. (The Newton is named after the famous scientist, Isaac Newton.) In the U.S. customary system, we measure weight in pounds and ounces. But, in the U.S. customary system, the unit of measure for mass, slug, is rarely used. A rock with a mass of 1 kilogram has a mass of 0.069 slug when measured in U.S. customary units.

Inertia

In addition to weight, the mass of an object is also related to that object's **inertia**. Inertia is a quality that all matter possesses. It is the resistance the object has to any change in motion. The more mass an object has, the harder it is to get it moving or to stop it from moving. In other words, the more mass an object has, the greater its inertia.

Think about the energy required to put a space probe into outer space. The rockets used to launch probes into space are huge—the size of a tall building. A rocket sitting on its launch pad has a lot of mass. Gravity is working on it, too. It takes a lot of energy to get it off its launch pad and into space. The energy required to launch a rocket carrying a space probe must be greater than the effect of both inertia and gravity.

Once the probe is moving in space and far away from the effects of Earth's gravity, it doesn't take any energy at all to keep it moving. Keep in mind that inertia is a resistance to change. An object in motion wants to stay in motion. An object at rest wants to stay at rest. If you want to stop its motion or change its direction, you will have to fire up a booster rocket and use some energy to overcome inertia.

ACTIVE READER

1 Hypothesize *If moving objects stay in motion because of inertia, then what causes a bicycle roll to a stop if you stop pedaling?*

_____

_____

_____

_____

_____

_____

_____

FOCUS QUESTIONS

1. **Of mass and weight, which is dependent on the other?** _____
2. **Of mass and weight, which does not depend on location?** _____
3. **Explain the difference between mass and weight in your own words.**

_____

_____

_____

_____

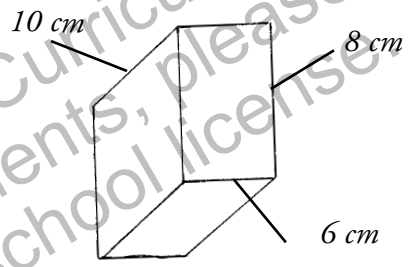
FOCUS

This section explains that volume is a measure of the space that an object takes up. Read to find out how to calculate the volume of a cube.

Volume

Volume is how much space an object takes up. Scientists use the metric system to measure volume. Solids are usually measured in cubic centimeters, and liquids in milliliter and liters. 1 milliliter (mL) = 1 cubic centimeter (cm^3 or cc). Cups and gallons may be more familiar to you than liters or cubic centimeters because they are used in the U.S. customary system.

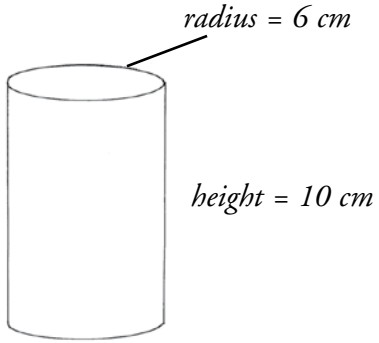
The volume of an object can be found in several ways depending on its shape. For shapes like cubes and boxes volume is easy to find using this formula: width x depth x height = volume.



The volume of this box is:

_____ x _____ x _____ = _____

Finding the volume of an object can be thought of like this: find the area of its base and then multiply that area by its height. Consider the shape at the right, a cylinder. Its base is a circle. The area of a circle is πr^2, where π is the Greek letter pi and r is the radius of the circle. (There are an infinite, or never-ending, number of decimal places in pi. In most calculations it is expressed as 3.14.) You can find the volume of cylinders using this formula: height x pi x $radius^2$.



The volume of this cylinder is:

_____ x _____ x _____ = _____

ACTIVE READER

1 Explain *What do you need to know to find the volume of a rectangular box?*

_____

_____

_____

2 Monitor *What is the approximate value of pi?*

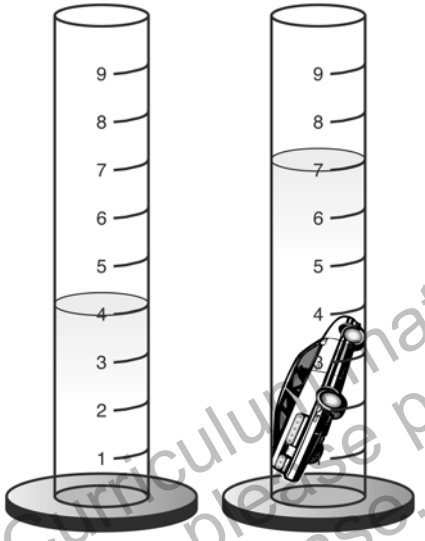
_____

Web Quest

Archimedes was a mathematician who lived in Ancient Greece more than 2,000 years ago. He discovered pi. Archimedes found that the ratio of the circumference of a circle to its diameter was always the same number. Do a web search to learn how Archimedes made his calculations.

Some objects, like rocks or toy cars, are not uniform in shape. How do you find their volume? You measure how much they cause water to rise.

Fill a graduated cylinder with a known amount of water. Record the level of the water. Place the object in the water. Record how much the water level increases. The difference between the two measurements is the volume of the object.



FOCUS QUESTIONS

1. **What are two ways scientists measure volume?**

2. **What role does water play in measuring the volume of objects with non-uniform shapes?**

ACTIVE READER

1 Hypothesize *What would happen if you used milk or soda to find the volume of a non-uniform shaped object?*

Good to Know

Q: What is the volume of a pizza that has a radius of z and a height of a?

A: (pi)(z)(z)(a)

Web Quest

How could you find the volume of a pyramid, a baseball, or an ice cream cone? What formula would you use? Search the web to find out.

Think Like A Scientist

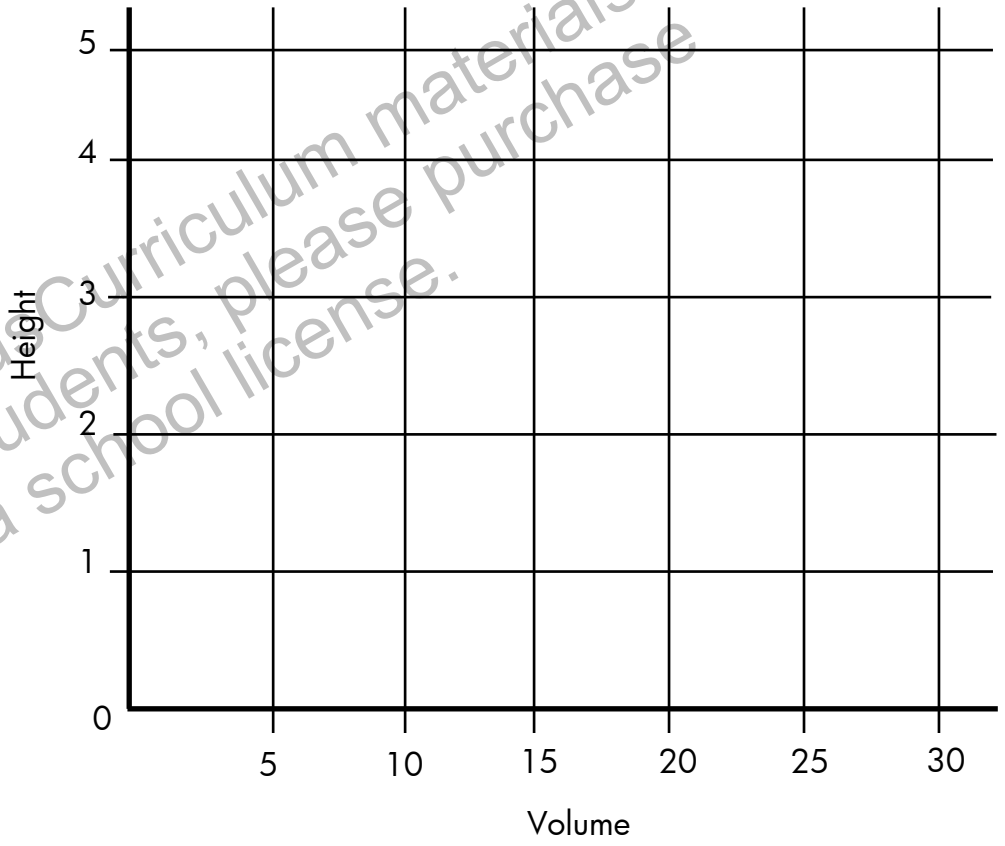
Changing Volumes

What happens when the area of the base of a cylinder stays the same, but its height changes? Calculate the volumes in Table 1 and plot your results on the graph on this page. Then, consider what will happen when the height stays the same but the radius of the base of the cylinder changes. Calculate the volume in Table 2 on the next page and plot your results on the graph. To make your calculations and graphing easier, let $\pi = 3$. This will have no effect on the shape of your graph.

Table 1

Area = 6 cm^2

Height (cm)	Volume (cm^3)
1	
2	
3	
4	
5	



1. **Use this graph of height verses volume to estimate the volume of a cylinder that has a height of 3.5 cm.**

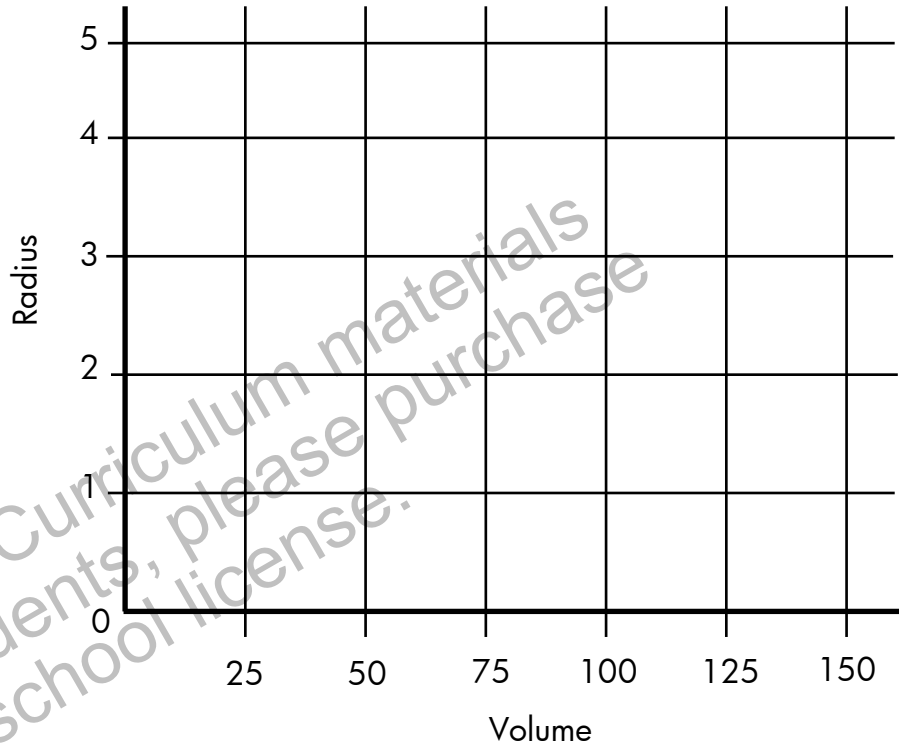
_____

Think Like A Scientist

Changing Volumes *(continued)*

Table 2
Height = 2 cm

Radius (cm)	Volume (cm^3)
1	
2	
3	
4	
5	



2. How does the volume change when the radius of a cylinder changes?

_____

_____

3. Why do the graphs have different shapes?

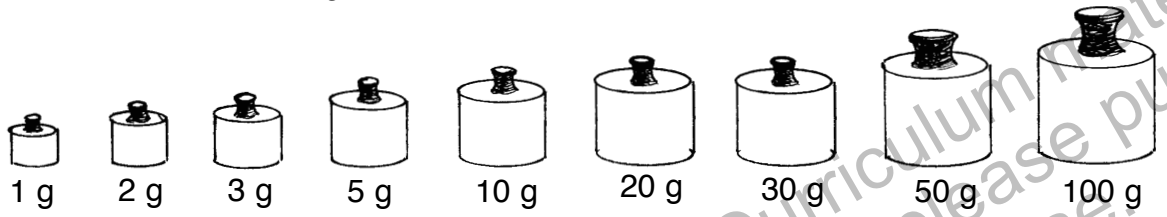
_____

_____

Stop and Think

This page will help you summarize what you have read so far. Base your answer to question 1 on the illustration below and your knowledge of science.

Using a balance and a set of cylinders with known masses, you have measured the mass of a rock and found it to be 47 g. The set of cylinders with known masses is shown below.



1. Which combination of cylinders balances the mass of the rock?

(1) 2 g, 5 g, 10 g, 20 g
(2) 3 g, 5 g, 10 g, 30 g,
(3) 2 g, 5 g, 10 g, 30 g
(4) 5 g, 10 g, 20 g, 30 g

2. Which statement is true about the mass and weight of an object?

(1) Weight sometimes changes while mass stays the same.
(2) Mass sometimes changes while weight stays the same.
(3) Both mass and weight can change sometimes.
(4) Both mass and weight can never change.

Dear Ms. Understanding,

My scale says that I weigh 75 pounds, or 34 kg. I thought that pounds were for weight and kilograms for mass. And what about Newtons? Does any of this really make any difference?

Worried in Port Washington

Dear Worried,

Because the force of gravity acting on us doesn't change much unless we are on the top of high mountains or out in space, some people use mass and weight interchangeably. Those people aren't scientists like you and me! Personally, I think that scales use pounds because the English unit for mass is the slug! Ick!

Ms. Understanding

Chapter 2 Density

FOCUS

As you read this section find out what density means. Look for examples of things in our world that have different densities.

Calculating Density

The **density** of an object is a measure of how tightly packed its mass is into the space it takes up. What happens if you put a bottle of water into the freezer? If you have ever done this, you know that water expands when it freezes. If the water you freeze is in a glass bottle, the ice may actually break the glass as it forms. Why does this happen? When water freezes, it takes up more space. It becomes less dense. Ice floats in water for this reason.

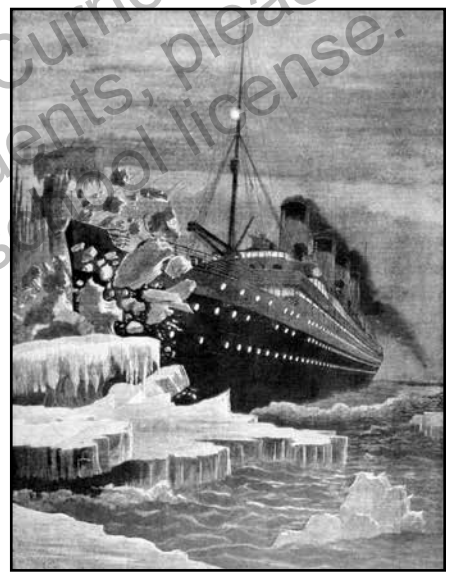
Density can be determined by creating a ratio. A **ratio** is a comparison often expressed as a fraction or a decimal. Density is the ratio between the mass of an object and its volume:

density = mass / volume.

Let's look at an example using water. If you have 100 grams of water, the volume is 100 milliliters. Its density is 100 g / 100 mL = 1.0 g/mL. But if you freeze that same 100 grams of water, its volume will increase by about 9 percent. The density of ice is 100 g / 109 mL = 0.92 g/mL.

Iceberg!

Knowing the density of ice can tell us the size of a floating iceberg. An iceberg can present a hazard to ships because only one-tenth of it is above water. This is because of the slight difference in the densities of ice and sea water. Comparing their densities results in a ratio of 9/10—the amount of an iceberg that is underwater.



The Titanic ran into an iceberg on its first trip across the Atlantic Ocean and sank.

ACTIVE READER

1 Explain *What must be true about the density of an object if it floats in water?*

_____

_____

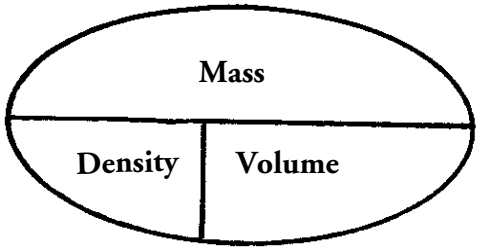
_____

_____

Good to Know

Densities can change under some conditions. If the temperature and/or pressure changes, so will density. When air and water get very, very cold, their densities increase. In the ocean, less dense water floats on top of more dense water. Pilots and meteorologists need to know about the density of the air because it influences weather patterns and the ability of an airplane to fly.

Density can often be used to identify an object. For example, it can be difficult to tell the difference between gold and other shiny yellow metals just by looking at them. Measuring the density of a metal can help you determine what it is.



However, density cannot be measured directly. It is what scientists call a *derived measurement.* It is derived from two direct measurements: mass and volume.

When two of the terms are known, it's easy to find the third one using a magic circle. Look at the magic circle to the right. Cover up the term you want to find. For example, to find the density of an object when its mass and volume are known, cover up "density." What's left is mass over volume, which tells you to divide the mass by the volume to find the density.

Archimedes and the King's Crown

Knowing how to find density can be very useful. The first person to understand this was Archimedes, one of the best mathematicians in the ancient world.

Over 2,000 years ago, a Greek king came to Archimedes with a problem. He had ordered a crown made of gold. When the crown was finished, the king suspected that the goldsmith had only put gold on the outside of the crown, stealing the rest of it. The king wanted Archimedes to find out if the crown was made of pure gold.

At first Archimedes was not sure how to answer the king. Then, one day while he was taking a bath, he discovered the answer. Archimedes noticed that the water level in the tub rose as he sat down in the tub. According to legend, when he saw the water rise, he jumped out of the tub and ran through the streets shouting, *eureka! Eureka* is Greek for "I have found it."

Archimedes discovered how to measure density.

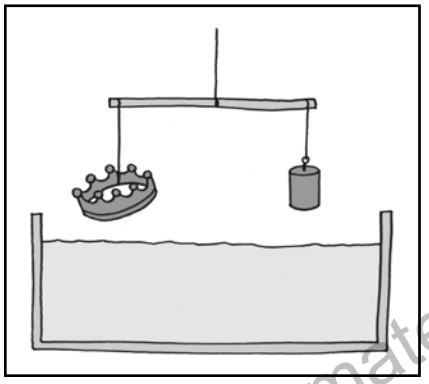
ACTIVE READER

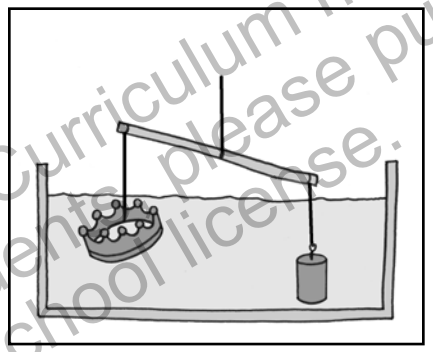
1 Explain *What is a derived measurement?*

2 Predict *Which item will be more dense: a sheet of paper or a sheet of cardboard? Hold them up to the light. Which lets in more light? Why?*

Archimedes then measured the mass of the crown and measured out the same amount of gold in the form of a bar. He placed the crown on one side of a balance and the gold on the other. Then he lowered the two objects into a tub of water. If the crown were made of pure gold, the two masses would have the same volume and density and would balance. If they did not balance, then their volumes and densities would be different.

Sure enough, the pure gold was more dense than the crown, proving that the goldsmith had tried to cheat the king. The goldsmith had taken care to make the crown equal to the mass of the gold the king had given him. But he did not know that the volume had to be the same, too.





ACTIVE READER

1 Estimate *The density of gold is 19.2 g/cm³. If you have 96 g of gold, what is its volume in cubic centimeters?*

_____

2 Recall *Why did the volume of the crown have to be the same as the volume of the gold?*

_____

_____

FOCUS QUESTIONS

1. Which two measurements did Archimedes need to know in order to calculate the density of the crown?

_____

2. Why does ice float in water?

_____

_____

Think Like A Scientist

Sink or Float?

Use the information in the table to answer the questions below.

Substance	Density (g/cm^3)
Balsa wood	0.11 – 0.14
Bamboo	0.3 – 0.4
Ice	0.93
Fresh water	1.00
Sea water	1.03
Aluminum	2.7
Steel	7.8
Gold	19.2

1. Balsa wood and bamboo float in water. How do they compare with the density of fresh water?

2. Aluminum and steel sink in water. How do their densities compare with salt water?

3. Write a rule for how to tell if something will sink or float in either fresh or salt water.

Stop and Think

This page will help you summarize what you have read so far. Base your answers to questions 1 and 2 on the table below and on your knowledge of science.

Common Rocks and Minerals

Rock or Mineral	Density (g/cm^3)
dry sand	1.6
wet sand	1.9
limestone	2.5–2.8
quartz	2.65
sandstone	2.3
shale	2.4–2.8

1. **You have collected a rock sample you suspect is shale. The only information you have about it is its density, which is 2.6 g/cm^3. Can you be sure you have a sample of shale and not some other mineral or rock? Explain why.**

_____

2. **If the density of the sample is 2.95 g/cm^3 would you be able to determine the type of mineral it is using only the above table?**

_____

3. **How is density calculated?**

(1) dividing volume by weight
(2) multiplying volume and mass
(3) dividing mass by volume
(4) multiplying volume by weight

Dear Ms. Understanding,

I bought some soda on sale. They were on sale because the labels were missing from the outside of the cans. Some are supposed to be diet sodas. I want to know which ones are diet sodas, but I don't want to open the cans to find out. Is this possible?

Surprised in Stuyvesant Town

Dear Surprised,

Your question has to do with density. Diet sodas are less dense than non-diet sodas because they do not have sugar. If you place the cans in a sink full of water, the diet sodas will float.

Ms. Understanding

Chapter 3 Other Properties of Matter

FOCUS

As you read this section find out about other properties of matter that are unique and set one type of matter apart from another.

Unique Characteristics

Some properties of matter are directly observable using your senses. You can look at an object that is unfamiliar to you and note its color. You can smell it to see if it has a particular odor. You can feel its texture: Is it smooth or scratchy? You can describe its state: Is it a solid, liquid, or gas?

Describing properties of matter sometimes depends on size. For example, weight, mass, and volume all vary depending on the size of the object in question. A large piece of coal has a greater mass, weight, and volume than a smaller piece of coal. Density, however, is different. A large piece of coal will have the same density as a smaller piece of coal.

Color, texture, state, mass, weight, volume, and density are all physical properties. What other physical properties, besides density, do not change when the amount of matter changes? Melting point, boiling point, solubility, streak, and magnetism are a few.

Properties like these that are unique to different types of matter help us identify unfamiliar objects. If you have two pieces of shiny yellow metal, determining their masses will not help you figure out if one of them is gold. However, measuring the density of each will, as will these:

Property	Definition
melting point	the temperature at which a solid changes to a liquid
boiling point	the temperature at which a liquid changes to a gas
solubility	the amount of a substance that will dissolve in a given quantity of water
streak	the color of a mineral when it is crushed and powdered
magnetism	the ability of a material to attract or repel another

ACTIVE READER

1 Infer *Why is it important not to taste unknown substances you are studying?*

_____

_____

_____

_____

Good to Know

Properties that depend on a certain quantity of matter are called *extensive* properties. Those that hold true for any quantity of a particular type of matter are called *intensive* properties. Mass and volume, for example, are extensive properties. Density is intensive. The more you know about the intensive properties of a substance, the easier it will be to identify that substance.

Solubility

The ability of one substance to dissolve in another, such as water, is called solubility. For example, when you mix sugar and lemon juice in water to make lemonade, the sugar dissolves so that it can't be seen and the lemon juice molecules spread evenly throughout the water. Sugar and lemon juice are soluable in water. In this example, sugar and lemon juice are called the **solutes** and water is called the **solvent**.

The amount of a solute that can dissolve in a solvent can vary because of factors such as how much you stir, temperature, pressure, and the amount of solute already present in the solvent. In other words, if you add more and more sugar to a batch of lemonade, there will come a point at which no more sugar will dissolve in the water. Usually, the greater the temperature of the solvent, the more of a solid solute it can dissolve. However, this is not true for all substances. Sometimes increased temperature means less solubility.

If you have ever tried to make a solution out of oil and water, you know that oil is not soluble in water. The two substances won't mix together no matter how hard you try. When petroleum leaks out of an underwater well or a tanker, the oily substance doesn't mix with the water. Instead, it floats on the surface.

Keep in mind that solubility is a physical characteristic of matter. This means that the solutes and solvent in a solution can be separated. Neither will be permanently changed. Processes such as filtration, settling, and evaporation are used to separate solutes from solvents.

Chemical Properties

Some properties of matter can't be directly observed without changing the substance into something new. For example, wood will burn if it is heated to a certain temperature. The temperature at which wood burns is a characteristic property of that wood, but it is not possible to observe that characteristic without actually burning the wood. The temperature at which wood burns is a chemical property because it has to do with the structure of the substance itself.

The ability of a metal to rust is another example of a chemical property. Rusting is a chemical reaction involving oxygen that takes place among atoms in the substance.

ACTIVE READER

1 Explain *What is the difference between a solute and a solvent?*

_____

_____

_____

2 Predict *Could you dissolve more sugar in iced tea or hot tea? Why?*

_____

_____

_____

_____

_____

_____

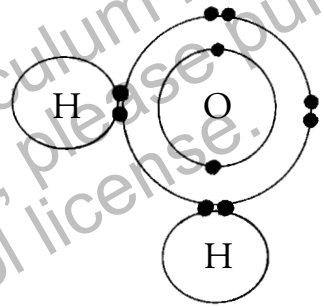
_____

Elements, Mixtures, and Compounds

When we think of the structure of a substance, we think of how the atoms that make up that substance are organized. A substance that is made up of a single type of atom is called an **element**. Gold is an element, as are oxygen and hydrogen. There are 94 elements that occur naturally on Earth and a few more that have been created in a laboratory.

The atoms in each element are unique. The core, or nucleus, of an atom is made up of *protons* and *neutrons*. The atoms of each element have a certain number of protons. Hydrogen atoms have one proton, for example. Most hydrogen atoms have no neutrons, but a few have one or two. These different versions of hydrogen are called **isotopes**. Oxygen atoms have 8 protons. Most have 8 neutrons, but a few have 9 or 10.

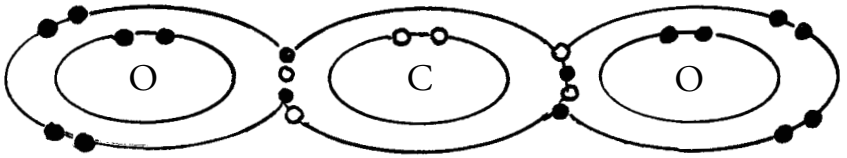
Atoms also have electrons that surround the nucleus. Atoms of different elements sometimes bond together by sharing electrons. This creates a **chemical compound**. A chemical compound is a substance made of two or more elements whose atoms are bonded together and arranged in a certain way. Water, for example, is a compound because it consists of hydrogen and oxygen atoms arranged in a certain way. The chemical formula for water is H_2O, indicating that there are two hydrogen atoms bonded to each oxygen atom.



A water molecule

Carbon dioxide (CO_2) is also a compound. It consists of one carbon atom bonded to two oxygen atoms. The compound as a whole has a set of chemical and physical properties.

Most of the substances we encounter in our everyday lives are mixtures of two or more elements, compounds, or other substances. The air we breathe, for example, is a mixture of nitrogen, oxygen, carbon dioxide, water vapor, a few other gases, and sometimes some dust. Each of the components of a mixture has its own unique physical and chemical properties.



Carbon dioxide consists of one carbon atom bonded to two oxygen atoms.

ACTIVE READER

1 Monitor *Underline all the names of elements on this page.*

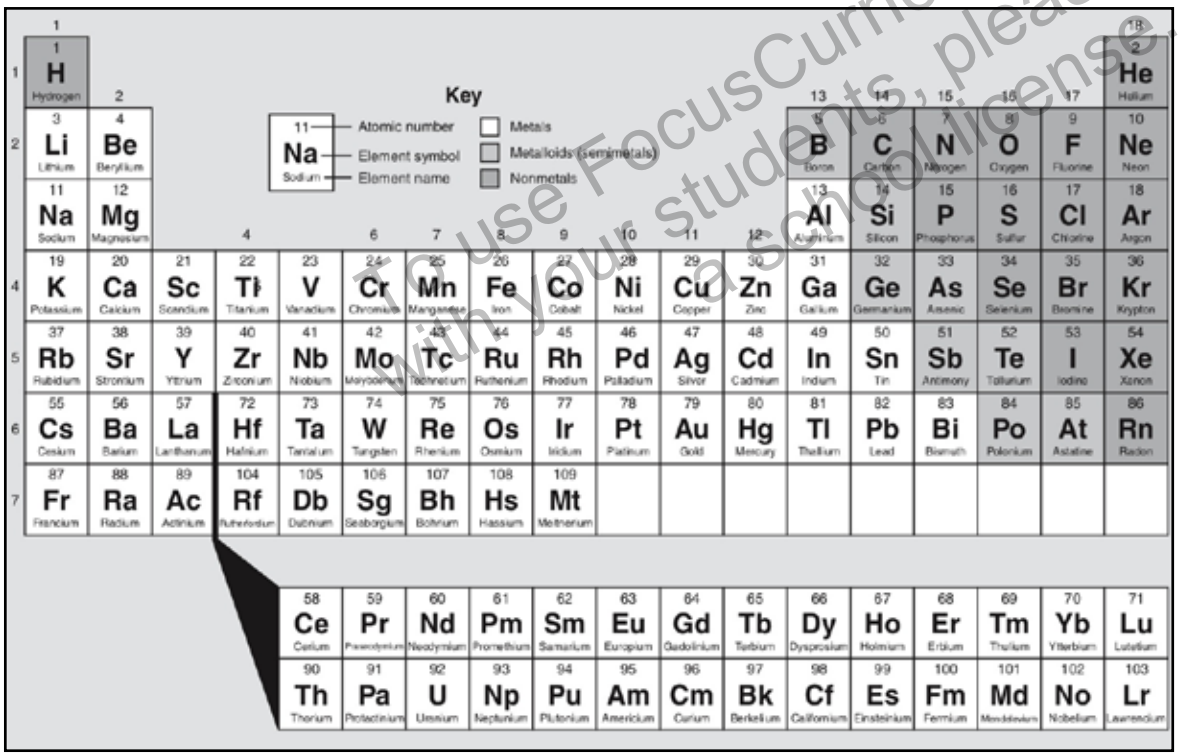
2 Explain *What is the difference between an element and an isotope?*

The Periodic Table of Elements

In the 1860's, a scientist named Dmitri Mendeleev organized the elements into a table by their mass. The mass of an element depends on the number of protons and neutrons the nucleus contains. The lightest element, hydrogen, has only one proton in its nucleus. Its atomic number, then, is 1. Helium contains two protons, so its atomic number is 2, and so on.

Elements have the same number of electrons as protons. The electrons spin around the nucleus in layers, or shells. The number of electrons in the outermost shell has a lot to so with certain properties including how chemically active the element is. Only two electrons can share the layer closest to the nucleus. There can be up to eight electrons in each of the next two layers.

The rows in the table represent the arrangement of electrons. Since hydrogen has one electron and helium has two, those two are the only elements found in the first row. The next two rows have eight elements each because those elements contain up to eight electrons in their outermost shell.



ACTIVE READER

1 Infer *The chemical name for CO_2 is carbon dioxide. What does the prefix di- mean?*

2 Contrast *How are compounds and mixtures different?*

3 Apply *A salad contains lettuce, tomatoes, carrots and salad dressing. Is a salad a compound or a mixture?*

The columns of the Periodic Table of Elements reflect the outermost shell of the elements. The number of outer shell electrons determines which atoms can bond with which other atoms. For example, hydrogen has only one electron in its outer shell, which can contain only two electrons. So, it can bond with other atoms. Helium, on the other hand, has two electrons in its outer shell. Its outer shell is full. Notice that helium (He) is located in row 18 on the Periodic Table. All of the other elements in that row are also gases and also have complete outermost shells. These are called the inert, or noble gases, because they do not react with other elements.

In a similar way, elements with similar characteristics are grouped together in the Periodic Table. Copper (Cu), silver (Ar), and gold (Au) are all shiny metals, for example. They appear together in row 11.

FOCUS QUESTION

1. If a substance undergoes a change in state it may change, for example, from a liquid to a solid. When this happens, can its properties change? If not, explain why. If so, give an example.

ACTIVE READER

1 Infer *Carbon and oxygen can form a compound called carbon dioxide. What does that tell you about the carbon atom?*

Stop and Think

This page will help you summarize what you have read so far. Use the tip to help you answer the questions.

Tip:
Categorize all the properties mentioned in this book into two groups: those that are unique to different types of matter and those that are not.

1. There are two rocks on the table. They both look black and shiny. One rock is about twice as big as the other rock. Which test would best tell you whether they are the same substance?

(1) holding them to see if they feel the same
(2) determining their mass using a balance scale
(3) crushing the rocks and examining the color of their powder
(4) measuring how much water is displaced when each rock is placed in water

2. Which of the following properties measures how much of a substance can dissolve in water?

(1) streak
(2) solubility
(3) magnetism
(4) boiling point

3. Water is a compound made of hydrogen and oxygen. Its chemical formula is H_2O. What does H_2O mean?

(1) Two hydrogen atoms are bonded to one oxygen atom.
(2) Two hydrogen electrons are bonded to one oxygen electron.
(3) There are two oxygen electrons and one hydrogen electron.
(4) There are two oxygen atoms bonded to one hydrogen atom.

Dear Ms. Understanding,

My friend in Colorado says that it takes less time for water to boil there than it takes in Pennsylvania. I thought that boiling point was one of those properties that didn't change. Can you help?

A Chef in Chautauqua

Dear Chef,

Your friend is right—elevation affects the boiling point of water. You probably live at or near sea level in Pennsylvania. Let's assume your friend lives at 5,000 feet above sea level, in the mountains.

At sea level, water boils at 100 °C (212 °F). At 5,000 feet, water boils at 95 °C (203 °F). This change is due to the change in atmospheric pressure. What's important to remember is that the boiling point of water does not change based on quantity.

Ms. Understanding

Glossary

acceleration – increase in the speed of an object

balance – a tool used to measure mass

boiling point – the temperature at which a liquid changes to a gas

chemical compound – a substance made of two or more elements whose atoms are bonded together and arranged in a certain way

density – a measure of how tightly an object's mass is packed into the space it takes up

element – a substance that is made up of a single type of atom

inertia – the resistance an object has to any change in motion

magnetism – the ability of a material to attract or repel another

mass – a measure of how much matter, or "stuff" makes up an object

melting point – the temperature at which a solid changes to a liquid

Newtons – units used to measure force

ratio – a comparison often expressed as a fraction or a decimal

solubility – the amount of a substance that will dissolve in a given quantity of water

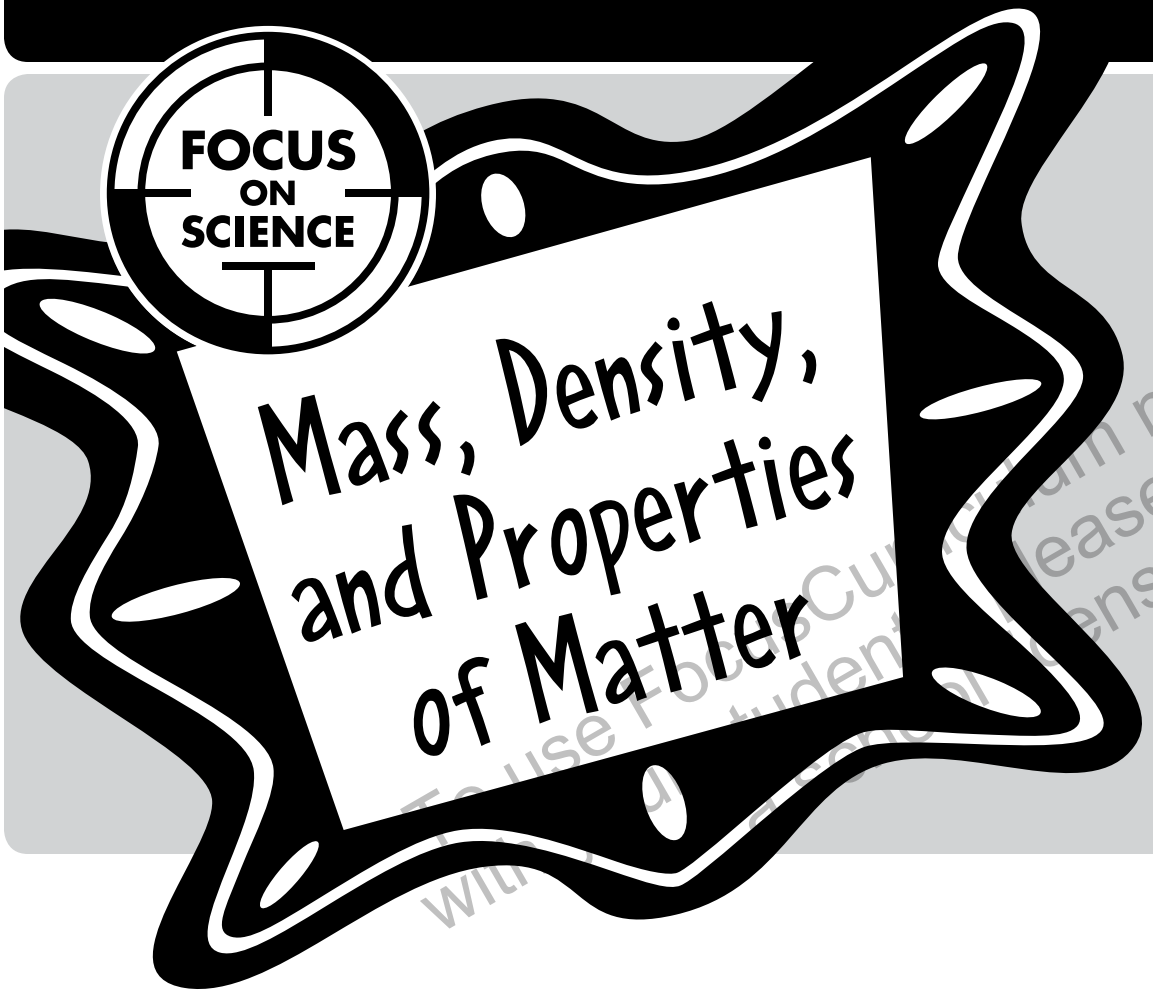
solute – a substance that can dissolve when mixed with another

solvent – a substance that dissolves another resulting in a solution

streak – the color of a mineral when it is crushed and powdered

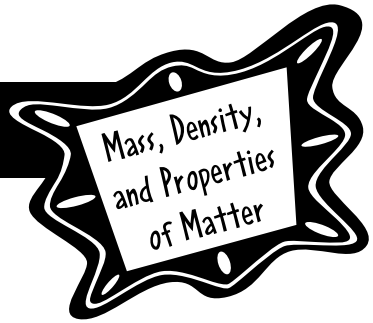
volume – the amount of space occupied by an object

weight – a measure of the gravitational force on an object



Assessments

Check Understanding



In the Answer Document on this page, mark your answer in the row of circles for each question by filling in the circle that has the same number as the answer you have chosen.

1. What happens to the density of an object if its volume increases?

   (1) The density increases.
   (2) The density decreases.
   (3) The density remains the same.
   (4) The density cannot be determined with the information given.

2. What is mass measured in?

   (1) grams
   (2) inches
   (3) meters
   (4) cubic centimeters

3. The density of aluminum is 2.7 g/cm^3. How many grams are in 40.5 cc of aluminum?

   (1) 15 g
   (2) 109 g
   (3) 40.5 g
   (4) 25 g

4. Air has a density of about 0.0012 g/cc. A balloon filled with helium floats in the air.

   What does this tell about the density of helium?

   (1) There is not enough information to make a statement about its density.
   (2) Its density is more than 0.0012 g/cm^3.
   (3) Its density is less than 0.0012 g/cm^3.
   (4) Its density is 0.0012 g/cm^3.

Answer Document

1.	①	②	③	④		3.	①	②	③	④
2.	①	②	③	④		4.	①	②	③	④

Check Understanding

Base your answers to questions 5 and 6 on the table below and on your knowledge of science.

Substance	Density (g/cm^3)
air	0.0013
oak	0.85
aluminum	2.7
salt	2.16
water	1.0

5. Five boxes have the same volume. Each box is filled with a different material from the table at the left. You cannot open or see inside the boxes. What tools would you use to determine the mass and volume of each box?

_____

_____

_____

_____

_____

_____

6. How would you determine the density of each box?

_____

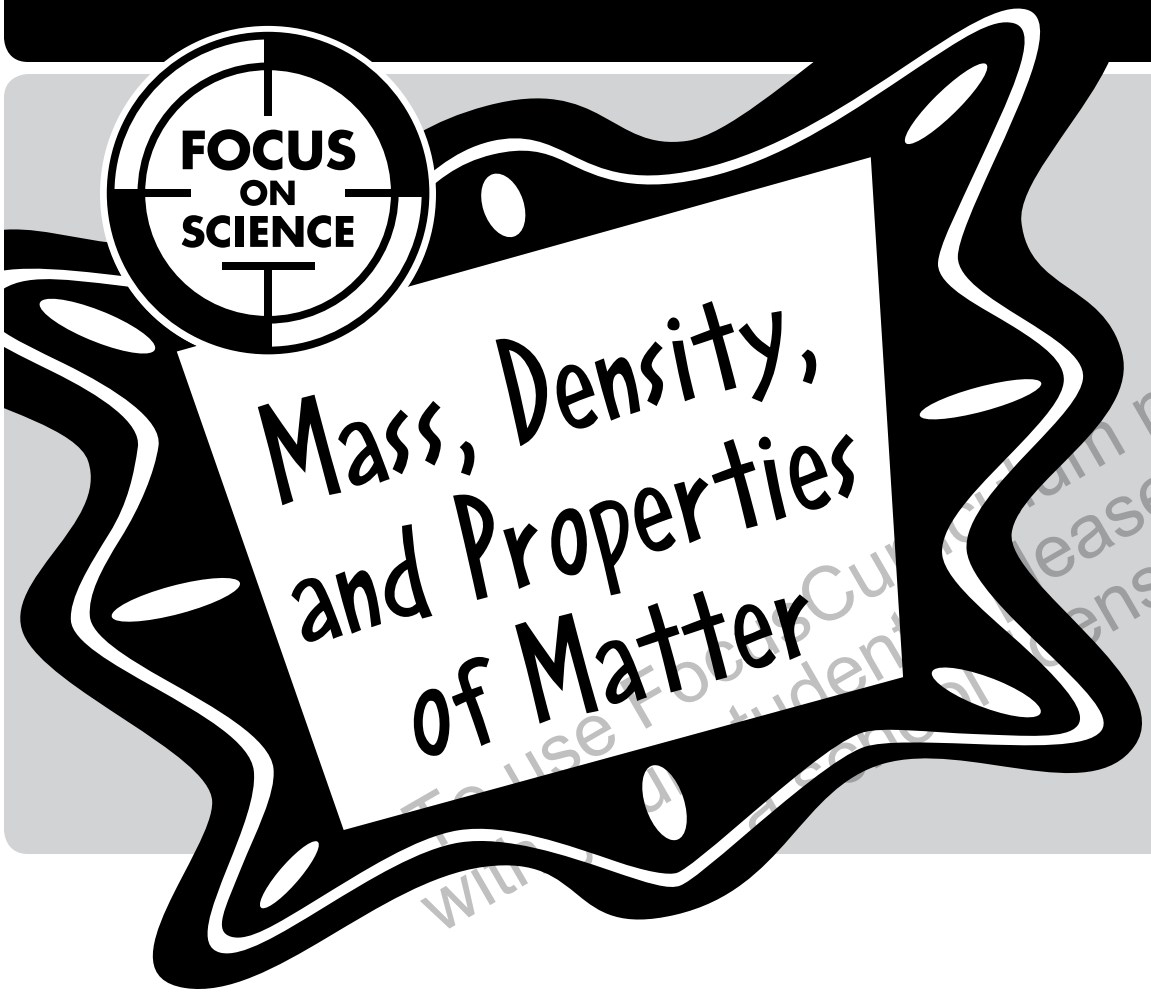
_____

_____

_____

_____

_____



Answer Key

Answer Key

Page 8: Starting Points
Build Background
Predict: 1. They are the same; a kilogram is a kilogram regardless of what the substance is.; 2. The feathers take up more space.; 3. A liter of cement is heavier.; 4. A quart is slightly larger than a liter.
Brainstorm: Answers will vary.

Page 9: Starting Points
Key Vocabulary
Rate Your Knowledge: Answers will vary.

Page 10: Starting Points
Key Vocabulary
Use Context: 1. In the first sentence, floats is a noun that means "decorated displays in a parade." In the second sentence, floats is a verb that means "glides."; 2. In the first sentence, sink is a noun that describes where people wash dishes. In the second sentence, sink is a verb that means "do not float.";
3. In the first sentence, volume means "loudness." In the second sentence, volume means "quantity."

Page 11: Starting Points
Key Concepts
Active Reader: 1. Answers will vary.
2. Answers will vary.

Page 12: Chapter 1
Active Reader: 1. Mass is the measure of matter in an object. Weight is the measure of gravitational attraction between mass and another object.

Page 14: Chapter 1
Active Reader: 1. Place object of unknown mass on one side of the scale. Place masses of known amounts on the other side. When the sides balance, add together the known masses. This is the mass of the unknown object. 2. Sample answer: Instead of using an object of unknown mass, use two objects whose mass you know to be equal. The scale is broken if it does not balance.
Focus Questions: 1. Add the mass of the coins together. Three pennies are 7.5 grams. Two nickles are 10 grams. One dime is 2 grams. So the mass of the rock is 19.5 grams.; 2. The total mass is 31 grams.

Page 16: Chapter 1
Hands On Science: Make a Balance: Results will vary depending on objects used.

Page 17: Chapter 1
Active Reader: 1. The U.S. customary system usually measures weight. The metric system usually measures mass.

Page 18: Chapter 1
Active Reader: 1. Answers will vary but should mention friction as the force stopping the bicycle.
Focus Questions: 1. weight; 2. mass; 3. Sample answer: Mass is the amount of matter an object contains; it is unchanging. Weight is affected by the amount of mass an object has as well as the amount of gravitational attraction.

Page 19: Chapter 1
Active Reader: 1. The width, depth, and height of an object; 2. 3.14
Paragraph 1: Volume of box: 10 cm x 8 cm x 6 cm = 480 cc;
Paragraph 2: Volume of cylinder: 3.14 x. 10 cm x $(6\text{ cm})^2$ = 1130.4 cc (rounded: 1,130 cc)

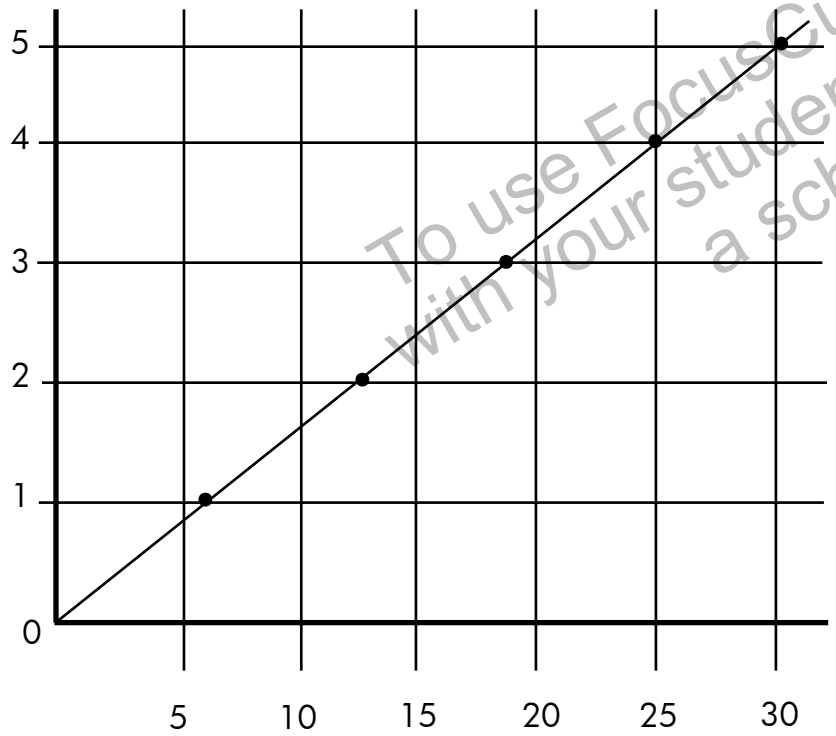
Page 20: Chapter 1
Active Reader: 1. The volume would be the same because any liquid will be displaced by the same amount.
Focus Questions: 1. Scientists can find the area of an object's base and multiply that area by its height. Or scientists can measure how much objects cause water to rise.; 2. Water can show how much volume an object takes up. First you measure the volume of the water alone. Then you measure the volume of the water with the object inside. Subtract the two measurements and you have the volume of the object.

Answer Key

Page 21: Chapter 1 Think Like a Scientist:

Table 1
Area = 6 cm^2

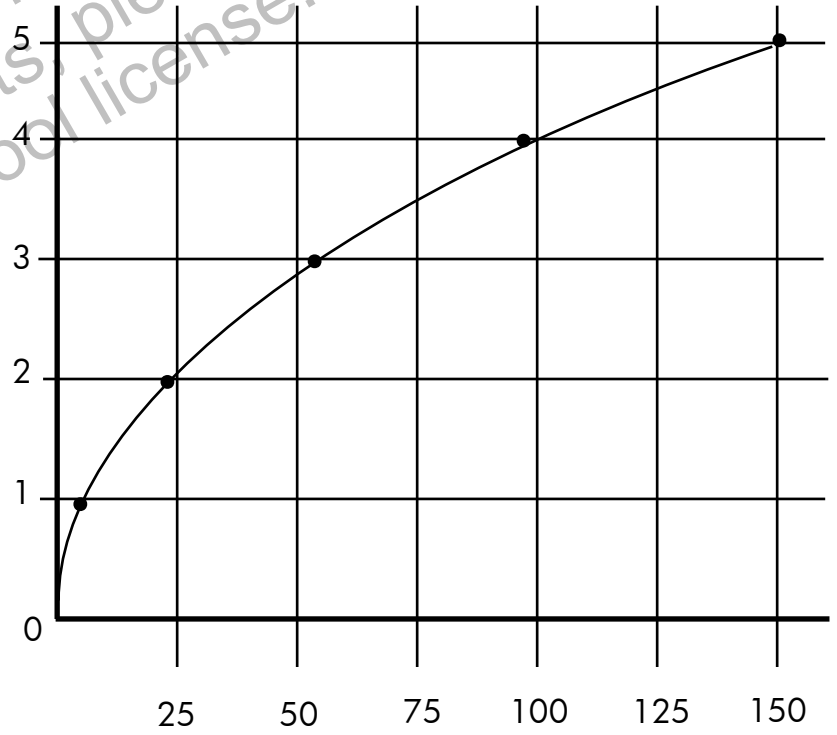
Height (cm)	Volume (cm^3)
1	6
2	12
3	18
4	24
5	30



Page 22: Chapter 1 Think Like a Scientist:

Table 2
Height = 2 cm

Radius (cm)	Volume (cm^3)
1	6
2	24
3	54
4	96
5	150



Answer Key

Page 21: Chapter 1
Think Like a Scientist:
1. 21 cc (The answer will depend on how carefully the student draws the graph.)

Page 22: Chapter 1
Think Like a Scientist:
2. Volume increases by the square of the radius.; 3. The volumes increase at different rates.

Page 23: Chapter 1
Stop and Think
1. (3); 2. (1)

Page 24: Chapter 2
Active Reader: 1. It is less dense than water.

Page 25: Chapter 2
Active Reader: 1. It is a measurement that cannot be measured directly. It comes from other direct measurements.; 2. A sheet of cardboard lets in less light and will be more dense. It has more mass than the sheet of paper but they have a similar volume.

Page 26: Chapter 2
Active Reader: 1. Volume = 5 cm^3; 2. So that the density of the crown equals the density of the gold.
Focus Questions: 1. Mass and volume; 2. Ice floats because it is less dense than water.

Page 27: Chapter 2
Think Like a Scientist: Sink or Float?
1. Balsa wood and bamboo are less dense than water.; 2. Aluminum and steel are more dense than water.; 3. Objects that have densities less than water will float. Objects that have densities greater than water will sink.

Page 28: Chapter 2
Stop and Think
1. No, because other rocks and minerals listed in the table have densities that fall with the range of densities of shale.; 2. No, because the chart doesn't list any minerals with a density higher than 2.8 g/cm.; 2. (3)

Page 29: Chapter 3
Active Reader: 1. The substance could be toxic.

Page 30: Chapter 3
Active Reader: 1. A solute is a substance that dissolves in a solvent.; 2. Hot tea would dissolve more sugar because higher temperature usually means greater solubility.

Page 31: Chapter 3
Active Reader: 1. Underline: oxygen, gold, hydrogen; 2. An element is made up of a single type of atom. An isotope is one version of an element.

Page 32: Chapter 3
Active Reader: 1. two; 2. A compound has its own physical and chemical properties. In a mixture, each component has its own unique physical and chemical properties.; 3. Mixture

Page 33: Chapter 3
Active Reader: 1. The outermost shell of a carbon atom is not complete.
Focus Question: 1. Yes, its properties can change. For example, when water is in a solid state, as ice, it is more dense than in its liquid form.

Page 34: Chapter 3
Stop and Think
1. (3); 2. (2); 3. (1)

Page 39: Assessments
Check Understanding
1. (3); 2. (4); 3. (2); 4. (3)

Page 40: Assessments
Check Understanding
5. Sample answer: Use a balance to find the mass of each box. Use a ruler to find the dimensions of the box and solve the equation to find the volume of each box.; 6. Write and solve equations to find the density of each box. Density = Mass/Volume