Lesson 1

Properties of Matter

Look and Wonder

This hot air balloon is pretty big, yet it easily floats in the air above the Red Sea in Egypt. How is this possible?

Explore

Which has mor

Form a Hypothesis

Which do you think has
or the tennis ball? Does
an object larger? Does it
your answer as a hypoth
increases, then an object

Test Your Hypothes

1. **Measure** Place one
Record how high the
tape, then remove th
water! Next place the
water and record the
dependent variable.
2. Place the objects on
pan balance. Which i
independent variable
3. Repeat all your meas
your answers.

Draw Conclusions

4. **Analyze** Did the he
water higher? Why
has more matter? Di
hypothesis?

Explore More

What if you were given
popcorn and a small ba
of popcorn kernels. Wh
have more matter? For
Then analyze and write

Read and Learn

Main Idea

Matter can be described by many different properties.

Vocabulary

mass, p. 480
weight, p. 481
volume, p. 481
matter, p. 481
density, p. 482
buoyancy, p. 483

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Reading Skill

Classify

How can you describe matter?

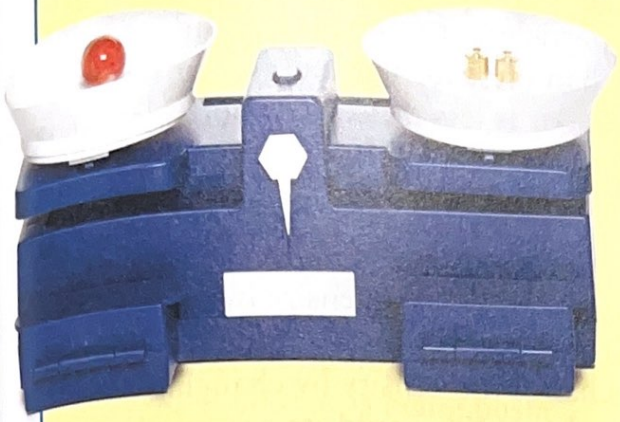
Pretend you have lost your backpack. You want to describe your backpack to your friends so they can help you look for it. How could you describe it so that they know which one is yours? You could say how large the backpack is, or how many things there are inside. You could talk about its color, texture, or hardness. In each case you are describing a *property* (PROP•uhr•tee) of the backpack. A property is something that can be observed about an object or a group of objects. Properties of matter can describe the amount of matter or what that matter is like.

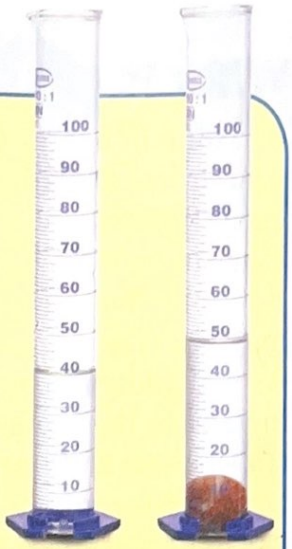
Mass

One way to describe the backpack would be its mass. **Mass** (mas) is the amount of matter in an object. This property compares the amount of matter in a sample to standard amounts. Mass can be measured on an equal pan balance. Gravity pulls on the standard pieces and on the sample. When the balance levels out, the amount of matter in the sample and the standard pieces must be the same. Mass is measured in kilograms or grams. One kilogram is equal to 1000 grams. Adding up the grams of mass in the standard pieces gives the mass of the sample in grams. The mass of an object is always equal to the sum of the masses of the pieces of the object.

The sum of all the masses in the backpack, plus the backpack itself, is equal to the mass of the full backpack.

Measuring Matter





Read a Photo

What is the volume of the marble?

Clue: What is the water level before and after the marble is in the cylinder?

Weight

Try holding a marble in one hand and a basketball in the other—they feel different. It is harder to hold up the basketball. You are feeling the weight of each ball. **Weight** (wayt) is how strongly gravity pulls on an object. If an object has more mass, it will also have more weight. Weight is measured in Newtons (N). One Newton is equal to 0.225 pounds (lbs) in the English system. Gravity is greater on planets with more mass, so an object's weight depends on the planet it is on. An object's mass, in contrast, is the same on different planets.

Volume

Mass and weight describe the amount of matter in an object, but what about its size? **Volume** (VOL•yewm) measures how much space matter takes up. A marble's volume makes the water level rise when you place it in a graduated cylinder. Matter in the marble takes up space and pushes water out of the way. The change in the water level when an object is placed under water tells us the object's volume. Volumes of liquid are often measured in milliliters (mL) by using a graduated cylinder, a beaker, or a measuring cup. The volume of solids is usually measured in cubic centimeters (cm^3). A volume of 1 cm^3 equals 1 mL.

Now that you understand mass and volume, we can use the best definition for matter. **Matter** (MAT•uhr) is anything that has mass and volume. That is a broad definition! Almost everything in the world around you is matter.

Quick Check

Classify Which units are used to measure weight, mass, and volume?

Critical Thinking How could you change an object's volume without changing its mass?

What is density?

Think of a large empty box with a lid. It has a large volume, but little mass. If you place a few marbles in it, it has more mass but the same volume. Add more marbles and you get more mass, but the volume stays the same. As you add more marbles, you are increasing the box's density. **Density** (DEN•si•tee) is the amount of mass for each cm^3 (or mL) of a substance. To calculate a sample's density, you divide its mass by its volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

A marble and a rubber ball can be about the same size. Which do you think is denser? The marble has more particles, or more mass, inside of it than the ball. The ball has air inside of it. Air is less dense than both glass and rubber. These observations tell you that the marble is denser than the ball.

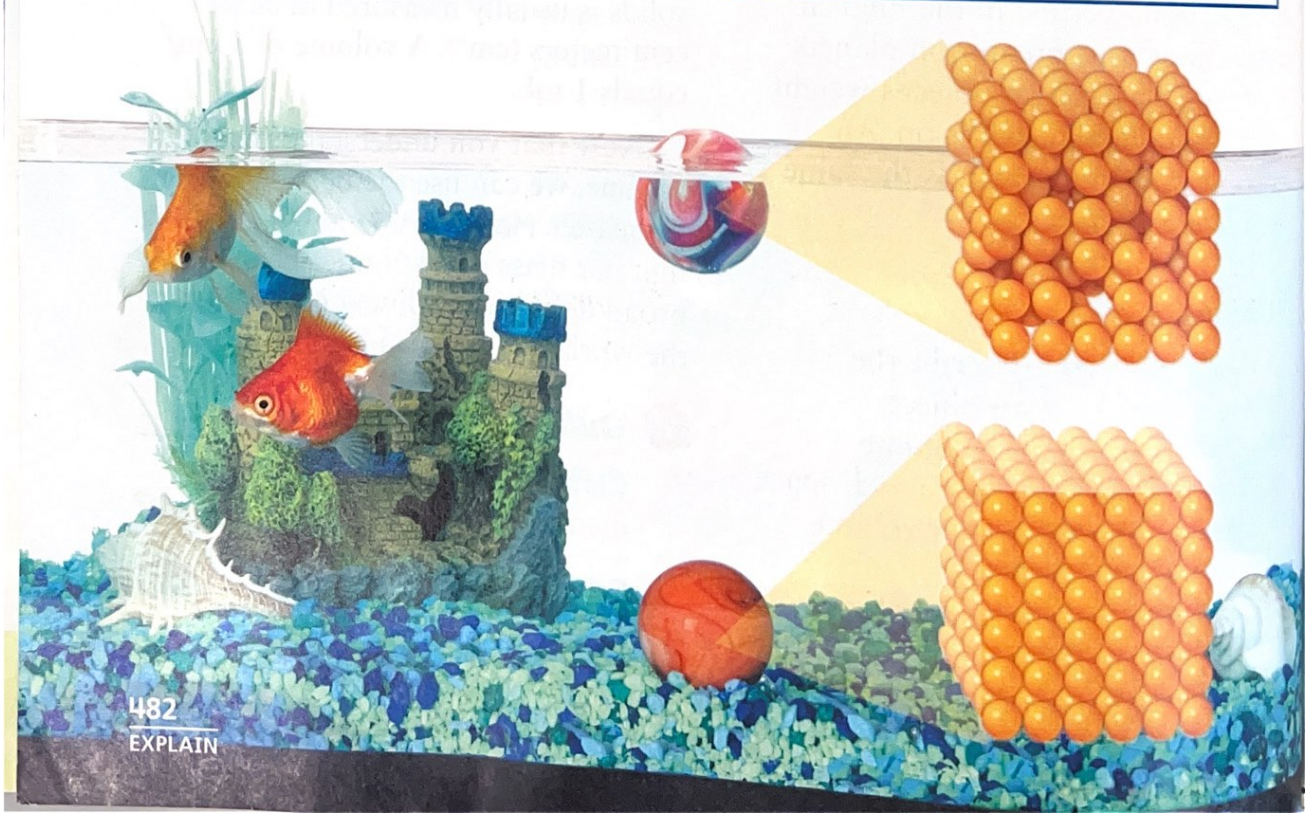
With boxes and other containers you can change density by adding more mass inside. You could also change the density by changing the volume. You could stretch, crush, or bend the container to let air out or in. Most matter, however, acts like the marble. You cannot add more mass to the inside, nor can you stretch it. Its density will always be the same.

Read a Diagram

How would you represent the density of water?

Clue Look at the density of the marble that sinks and the ball that floats.

Density and Water



Floating and Sinking

When an object is placed in a fluid, gravity pulls the object down. In order for the object to go down, the fluid must move out of the way. What would happen if the fluid was denser and did not get out of the way? The object would stop sinking . . . it would float!

Objects can float as a result of buoyancy (BOY•uhn•see). **Buoyancy** is the resistance to sinking. It occurs because the fluid that is being pushed out of the way pushes back on the object. If an object is denser than the fluid, the object can push harder and it sinks. If the fluid is denser than the object, the fluid can push harder and the object floats.

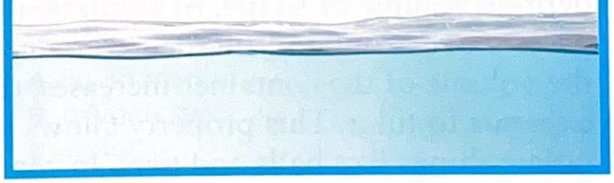
Buoyancy depends on density. So, if you change the mass or volume of an object, you can change whether or not it will float. If you have a toy boat and keep adding mass to it, it will sink. Buoyancy also depends on shape. A block of aluminum will sink, but an aluminum canoe will float. Why? The canoe's shape holds in air so that it acts like it has a density less than that of water. But a canoe full of water instead of air would sink.

Many fluids also have a property called *surface tension* (SUR•fis TEN•shuhn). In water, every particle pulls itself toward the other particles. This attraction creates a "skin" on the surface. This skin is what surface tension means. If an object is spread over the surface it can rest on this skin even if it would not normally float. If an object is not spread out enough, it will break the skin and sink.

Quick Lab

Too Dense to Float?

1. **Make a Model** You will need three models. The first should be a triangle cut from a paper towel. The second will be a plastic cup. The third will be a foam cup.
2. Place all three objects in water. The triangle should lie flat on the water. The two cups should be placed with the open end down. Which ones sink? Record your answers.
3. Add liquid detergent to the water to break up the surface tension. Do any models sink?
4. Have your teacher poke evenly spaced holes in each model. Do any models sink now?
5. **Infer** Which models could float simply because of their density? Which models were helped by their shape or were on top of the water due to surface tension?



Quick Check

Classify Which properties depend on shape, volume, or mass?

Critical Thinking How would you design a boat to carry large masses across the ocean?

FACT The density of an object depends on the type of material.

What forms can matter have?

A *state of matter* is one of the three common forms that matter can take: solid, liquid, or gas. You interact with these states of matter every day. Desks and books are solids. The water you drink is a liquid. The sky and the air you breathe are made of gases. Each state has its own properties.

The particles in a solid have very little freedom to move. The particles just vibrate in place. A solid stays in a definite shape with a definite volume no matter what container it is in. A rock is a good example. The shape and volume will not change unless something changes the solid, such as if it is broken or heated. Many solids, like table salt, have regular shapes like cubes. In general, a solid is the densest state of matter.

In a liquid, particles move more freely than in a solid. The particles are close together but they can flow past each other. This flowing allows a liquid to take the shape of its container. So liquids have a definite volume but not a definite shape. In general a liquid is the second densest state of matter. Water, however, is denser as a liquid than as a solid.

Gas particles are not close together and can move past each other very easily. A gas has no definite volume or shape. At room temperature, gases move around to fill their container. If the volume of the container increases, the gas expands to fill it. This property allows gases to inflate things like balls and tires. In general, a gas is the least dense state of matter.

Quick Check

Classify Which states of matter have a definite shape? Which states of matter have a definite volume?

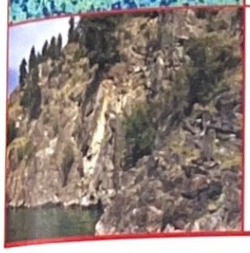
Critical Thinking What would happen to the particles in each state if you tried to squeeze them?

Lesson Review

Visual Summary

Samples of **matter** can be described by properties such as **mass, volume,** and **weight**.

Density measures the mass per volume and determines **buoyancy.**



Matter can exist in one of three common states: **solid**, **liquid** or **gas.**

Make a FOLDABLES™ Study Guide

Make a Trifold Book. Use the titles shown. Summarize what you have learned in each box. Draw sketches to illustrate your understanding.

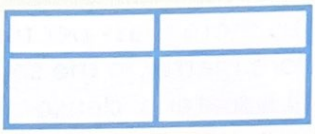
Main Idea	What I learned...	Sketches
Samples of matter can be...		
Density measures...		
Matter can exist in...		

Think, Talk, and Write

1. **Main Idea** How could you predict if a block of plastic will float in water?

2. **Vocabulary** How strongly gravity pulls on an object's mass is the object's _____.

3. **Classify** Which properties do solids and liquids share? Which are different?



4. **Critical Thinking** Would a balance on the Moon, which has one-sixth the gravity of Earth, still read masses correctly? Why or why not?

5. **Test Prep** **Which property measures the space taken up by an object?**
   - **A** hardness
   - **B** mass
   - **C** volume
   - **D** weight

6. **Test Prep** **Which sample most likely has the lowest density?**
   - **A** liquid mercury
   - **B** oxygen gas
   - **C** water
   - **D** gold metal

Writing Link

Descriptive Writing

Pick a piece of matter inside your classroom. Research and then describe it according to the properties and states of matter.

Math Link

Density and Volume

You have 80 mL of water. How many hollow cubes that are 2 cm on a side could you fill?

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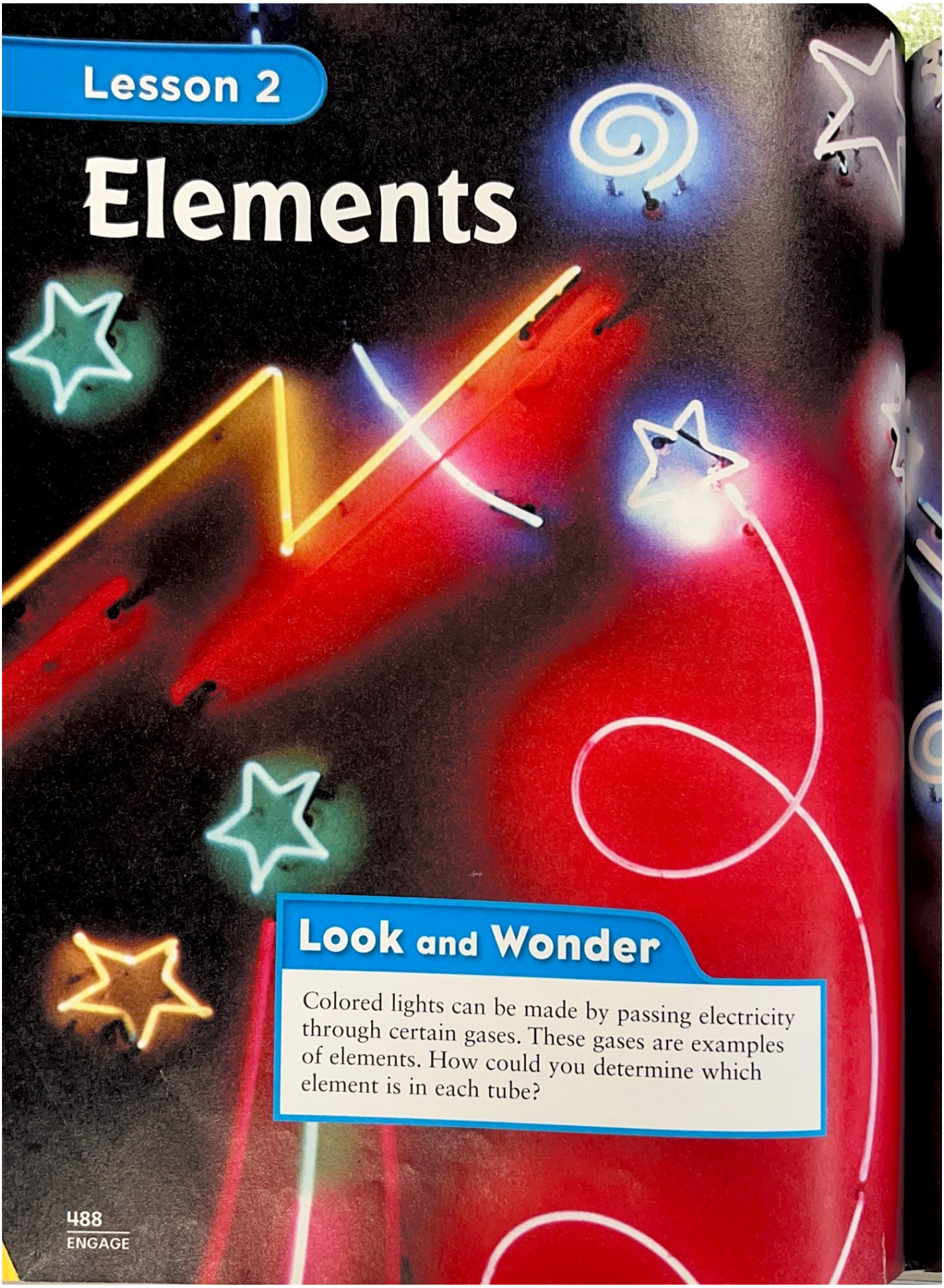
Lesson 2

Elements



Look and Wonder

Colored lights can be made by passing electricity through certain gases. These gases are examples of elements. How could you determine which element is in each tube?

Read and Learn

Main Idea

All matter is made of elements.

Vocabulary

element, p. 490
metal, p. 491
atom, p. 491
nucleus, p. 492
proton, p. 492
neutron, p. 492
electron, p. 492
molecule, p. 493

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Reading Skill

Main Idea and Details

Main Idea	Details

What is matter made of?

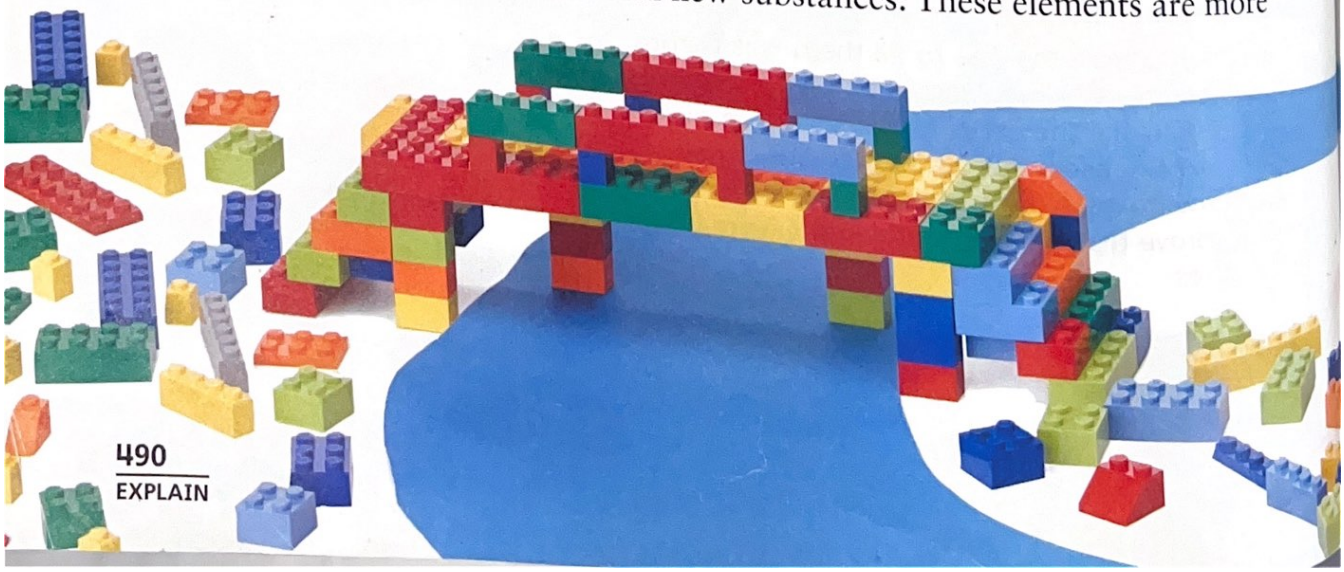
The toy models in the photograph stand for different things. If you took the models apart, though, you would get the same basic building blocks. If you mix the blocks together you cannot tell which model a block came from. In a similar way, all matter is made of the same set of building blocks: the chemical elements (EL•uh•muhnts). An **element** is a material that cannot be broken down into anything simpler by chemical reactions.

The ancient Greek philosopher Aristotle believed all matter is made of the elements earth, air, water, and fire. Modern scientists know that Aristotle's elements are not true elements. Fire is not matter. Air and earth are made up of many different materials, not just one. Water can be broken down into simpler substances: hydrogen and oxygen. Hydrogen and oxygen, however, cannot be broken down into simpler substances by using chemical reactions. This tells us that hydrogen and oxygen are elements.

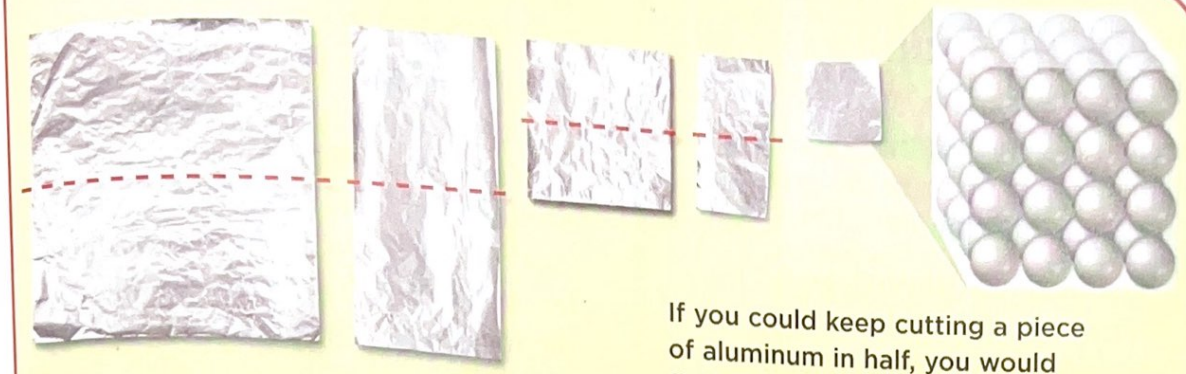
Today, scientists know of just over 112 elements with different properties. Three important properties of elements are: state of matter at room temperature, the way they combine with other elements, and whether they are metals, nonmetals, or metalloids.

Most elements are solid, some are gases, and a few are liquid at room temperature. Some elements are more likely to combine with other elements to form new substances. These elements are more

Matter is made of elements just like these models are made of the same building blocks.



Aluminum Atoms



If you could keep cutting a piece of aluminum in half, you would find that it is made of atoms.

chemically reactive (KEM•i•kuhl•ee ree•AK•tiv). Magnesium, for example, is very reactive and is used in fireworks.

Metals (MET•uhlz) are elements that share common properties like shiny luster, conductivity, and flexibility. Nonmetals are elements that are dull, poor conductors, and brittle. Elements with properties in between are called *metalloids* (MET•uh•loydz).

Smaller and Smaller

If you cut a piece of an element in half, will it still be an element? Yes, the two halves have the same properties as the original element. What if you kept cutting it in half, again and again? Eventually you would have the smallest piece of element possible. John Dalton proposed in 1803 that elements are made of tiny particles. He believed that these particles could not be cut into smaller pieces. Today, we know that Dalton's particles do exist—we call them atoms (AT•uhmz). An **atom** is the smallest unit of an element that retains the properties of that element.

Magnesium adds brightness to fireworks.

Quick Check

Main Idea and Details What do we mean when we say that matter is made of basic building blocks?

Critical Thinking When two elements combine to form a new substance, is the new substance an element? Why or why not?

What are atoms and molecules made of?

Atoms are made up of even smaller particles. These particles are not elements, but they are the same for every type of atom.

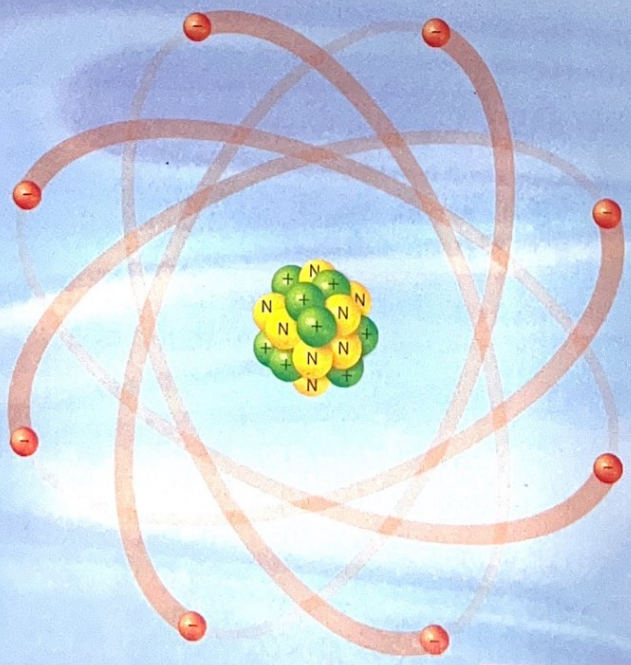
The **nucleus** (NEW•klee•uhs) is the center of an atom. It is made up of protons (PROH•tonz) and neutrons (NEW•tronz). The **proton** is a particle with one unit of positive electric charge. The number of protons in an atom is called the *atomic number* (uh•TOM•ik) and determines which element it is. The **neutron** is a particle with no electric charge—it is neutral.

Atoms also contain **electrons** (i•LEK•tronz), which are smaller particles with one unit of negative electric charge each. Electrons move around in the space outside the nucleus. Most of an atom is empty space. Usually, the numbers of electrons and protons are equal, so atoms have no overall charge.

Protons and neutrons have about the same mass. This mass is called an *atomic mass unit (amu)*. Electrons are smaller and have about 1,800 times less mass than 1 amu. If you add up the mass of all the particles in an atom, you get the atom's *atomic mass*. In an oxygen atom, there are 8 protons, 8 neutrons (usually), and 8 electrons, so its atomic mass is about 16 amu.

In 1913, Niels Bohr pictured an atom's electrons moving around the nucleus like planets moving around a star. Today, we know that the real picture is more complex. The electrons around the nucleus act in many ways like a cloud of electric charge.

Bohr Model Atom



Read a Diagram

Which element is this an atom of?

Clue: It has 8 protons, 8 electrons, and 8 neutrons.

LOG ON *Science in Motion* Watch how to model an atom at www.macmillanmh.com

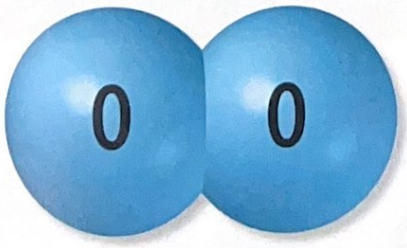
FACT Atoms are mostly space. The nucleus inside an atom is like a pebble inside a baseball stadium.

Molecules

When you snap toy bricks together to make something, many parts act as one part. The same thing happens for atoms when they form molecules (MOL•uh•kyewlz). **Molecules** are particles with more than one atom joined together. Most of the atoms in the world exist as part of a molecule, not on their own. Objects in the world are just many molecules grouped together.

When a molecule forms from elements, atoms link together through their electrons. This causes molecules to have different properties from their elements. With about 112 elements, the number of different kinds of molecules that can be made is nearly infinite. Molecules allow those few elements to combine into different materials and provide all the variety around you.

Scientists describe molecules by combining letters and numbers into a *chemical formula*. The letters tell which type of elements are in the molecule. The numbers are known as *subscripts*, and they describe the amount of each element. The oxygen we breathe is a molecule formed by two oxygen atoms and its chemical formula is O_2.



The oxygen molecule is made of two oxygen atoms that are joined together.

Quick Lab

Inside Atoms and Molecules

⚠ **Be Careful.** Don't eat the marshmallows!

1. **Make a Model** Use toothpicks to join 8 large pink marshmallows (protons) to 8 large green marshmallows (neutrons) to form the nucleus of an oxygen atom. Add 8 small marshmallows around the outside as electrons.
2. Make another oxygen atom or share with another student. Use 2 pipe cleaners to join the atoms by 2 electrons. This is an oxygen molecule (O_2).
3. How do the shapes of your model atoms compare to the diagrams in this book?
4. **Communicate** Draw pictures of your atoms and molecule that show their actual shapes better.
5. In a molecule, electrons move and are sometimes traded between atoms. How could you represent this in your model?

Quick Check

Main Idea and Details How are atoms and molecules different?

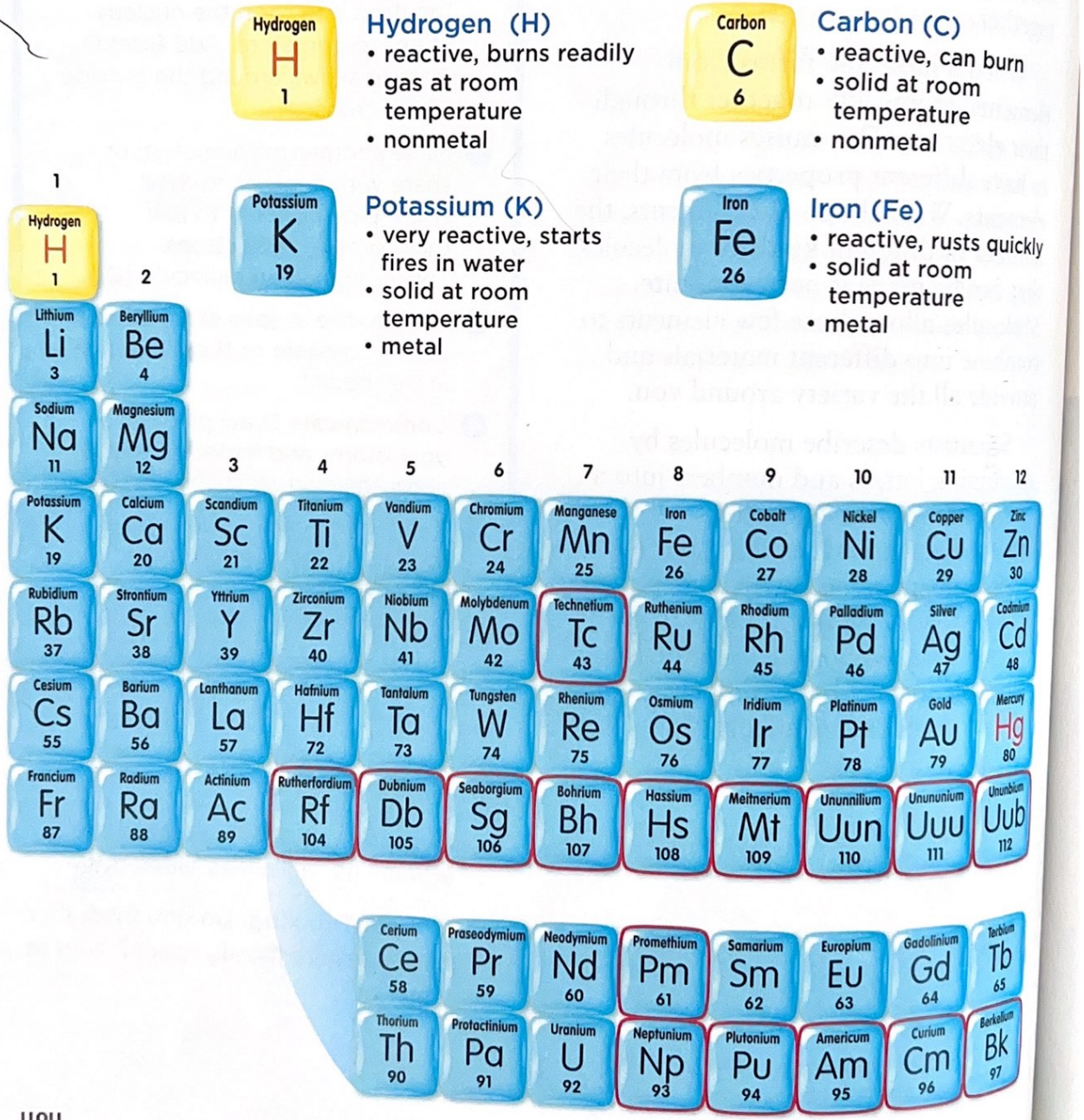
Critical Thinking Do you think that molecules are mostly space? Why or why not?

How are elements grouped?

Each chemical element has a name and a symbol. The symbols for most elements are one or two letters. The first letter is always a capital. Second letters are never capitals. Recently discovered elements have temporary symbols with three letters.

Symbols may look like an element's English name, like C for carbon. Many come from ancient names, such as Au for gold, whose Latin name is *aurum*.

The Periodic Table of Elements



The element symbols are the same letters used in chemical formulas.

In 1869, Dmitri Mendeleev made element index cards. He ordered the cards from lightest to heaviest. This led him to a discovery—the properties of the elements repeat in cycles! He made the cycles of elements into rows in a table. Each column contains elements with similar chemical properties. Mendeleev's table is called a *periodic table* (peer•ee•OD•ik) because the properties repeat in cycles (periods).

Silicon
Si
14

Silicon (Si)
- not very reactive
- solid at room temperature
- metalloid

KEY

Sodium
Na
11

- Element name
- Element symbol
- Atomic number
- metal
- metalloid
- nonmetal
- artificial

State at Room Temperature (20°C)

Black: solid

Red: liquid

Orange: gas

Read a Diagram

Is mercury a metal or a nonmetal? At 20°C, is it a solid, a liquid, or a gas?

Clue: What does the color of its box or symbols tell you?

Quick Check

Main Idea and Details What is an element's symbol?

Critical Thinking Why do you think that elements 58–71 and 90–103 are placed where they are?

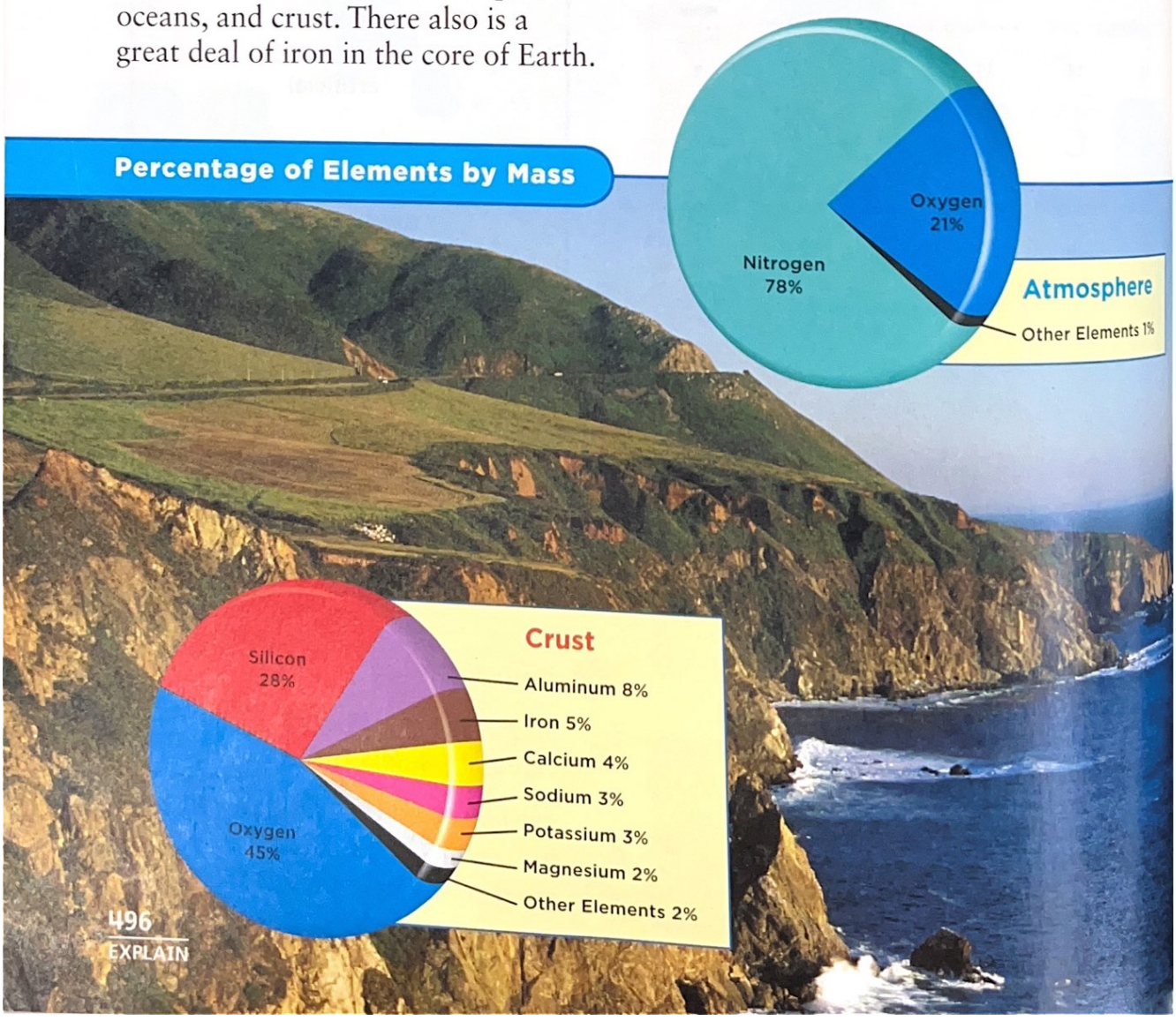
Which are the most common elements?

In space, the most common elements by far are hydrogen and helium. These 2 elements make up 98 percent of the mass of the universe. On Earth, hydrogen is common in water. However, helium is found only in very small amounts on Earth.

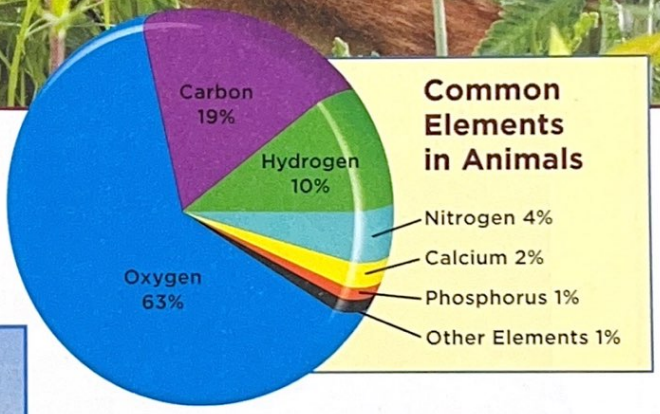
Elements of Earth

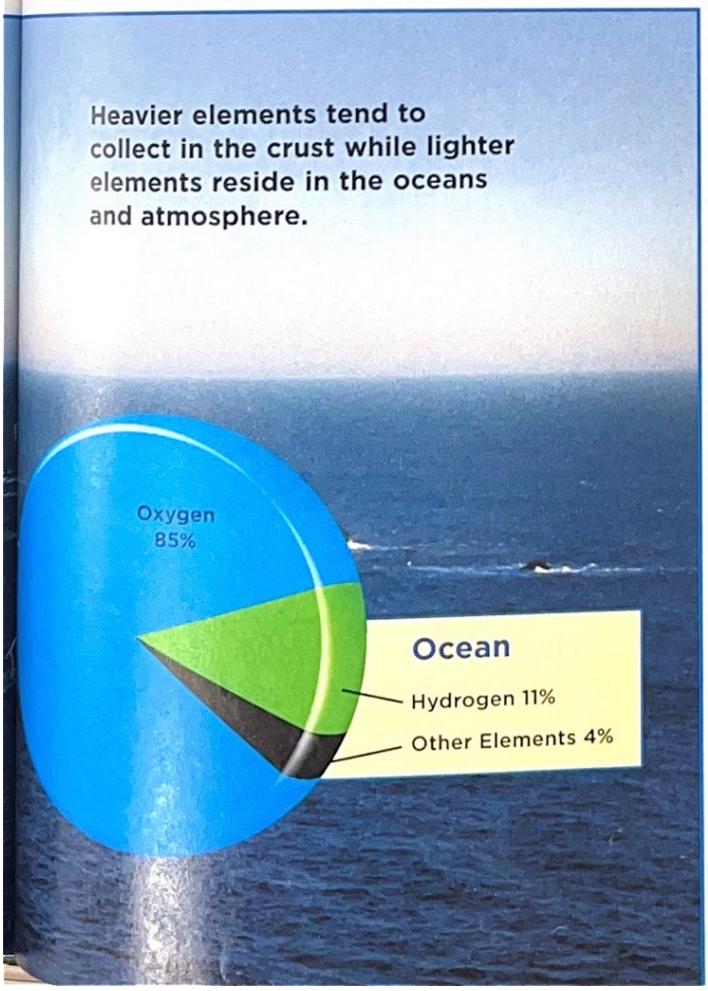
Along with hydrogen, the elements oxygen, silicon, aluminum, nitrogen, iron, and calcium are common on Earth. The graph shows the amounts of these elements in the atmosphere, oceans, and crust. There also is a great deal of iron in the core of Earth. Scientists think the inner core is solid iron with a layer of liquid iron surrounding it.

Just like all matter, plants and animals are made of elements. The amounts of elements are shown in the graph. Much of the oxygen and hydrogen come from water. In fact, about 60 percent of animal body weight is water! Most animal bodies are made from carbon, oxygen, hydrogen, nitrogen, phosphorus, and a dash of chlorine and sulfur. Bones and teeth contain most of the calcium shown in the graph.



▲ Plants and animals are mainly made of carbon, hydrogen, and oxygen.





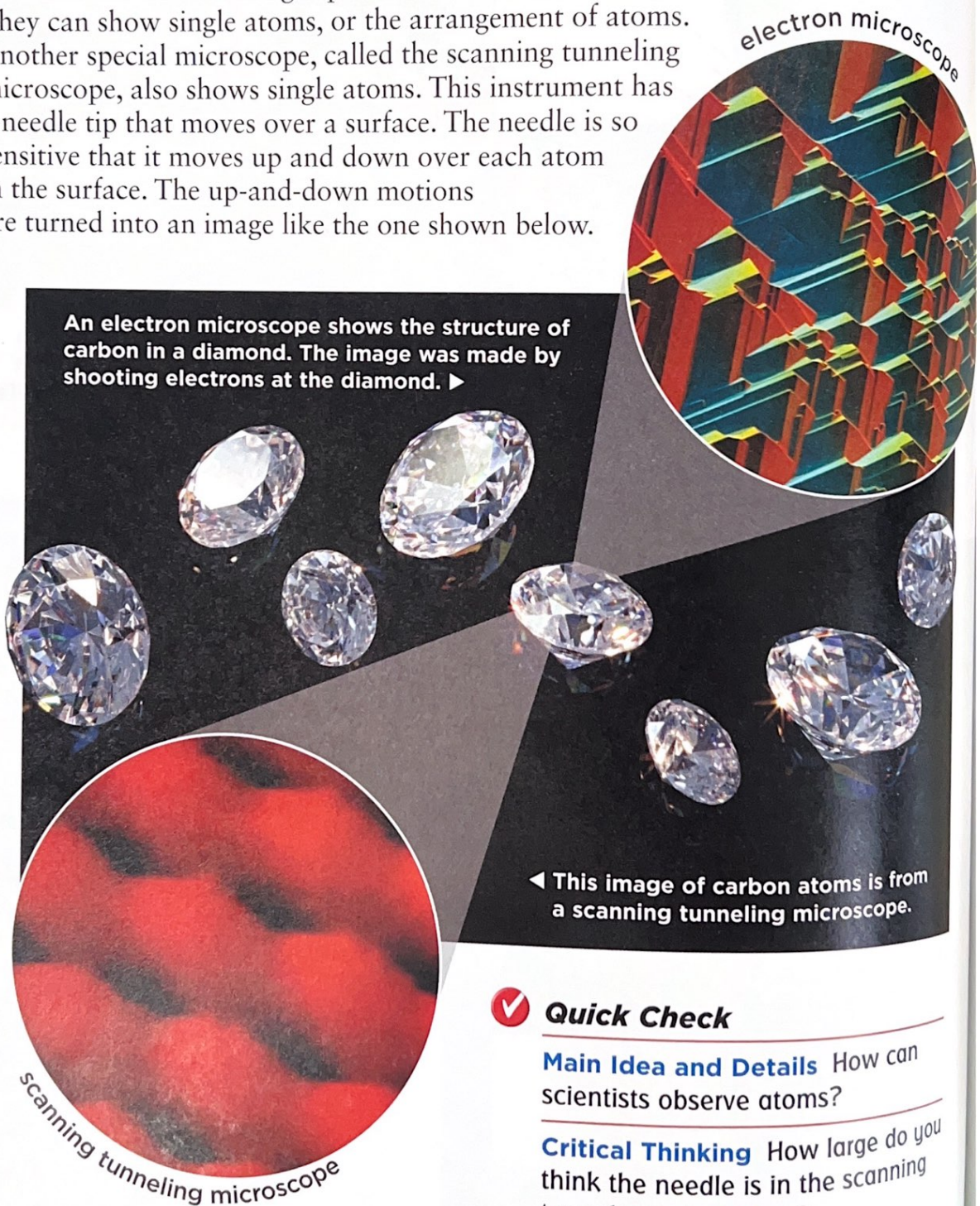
Quick Check

Main Idea and Details Why are oxygen and hydrogen so common in animals and on Earth?

Critical Thinking Why do you think Earth's crust has a more diverse set of elements than the ocean or atmosphere?

How do we examine elements?

Atoms are incredibly small. A single hydrogen atom is only 0.0000000001 meters across—that's around 1 millionth the width of a human hair! Even large molecules are too small to be seen with an ordinary light microscope. Special electron microscopes use electrons instead of light particles to examine a sample. They can show single atoms, or the arrangement of atoms. Another special microscope, called the scanning tunneling microscope, also shows single atoms. This instrument has a needle tip that moves over a surface. The needle is so sensitive that it moves up and down over each atom in the surface. The up-and-down motions are turned into an image like the one shown below.



Quick Check

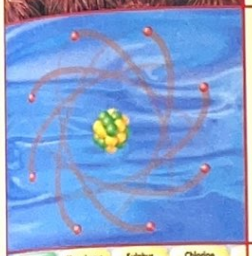
Main Idea and Details How can scientists observe atoms?

Critical Thinking How large do you think the needle is in the scanning tunneling microscope?

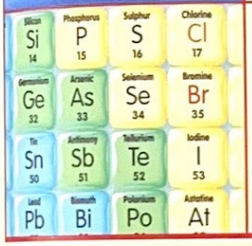
Lesson Review

Visual Summary

Matter is made of **elements**.



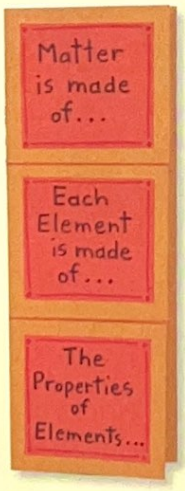
Each element is made of one type of **atom**.



The properties of elements allow them to be organized into a **periodic table**.

Make a FOLDABLES™ Study Guide

Make a Three-Tab Book. Use the titles shown. Summarize the topic under each tab.



Think, Talk, and Write

1. **Main Idea** How could you tell if a sample of matter is an element?

2. **Vocabulary** The smallest particle of an element is a(n) _____.

3. **Main Idea and Details** What are atoms like on the inside?

Main Idea	Details

4. **Critical Thinking** Does a scanning tunneling microscope let you see atoms like you might see tiny beads? Why or why not?

5. **Test Prep** **Which element is MOST LIKELY to conduct heat and electricity?**
   - **A** nitrogen
   - **B** aluminum
   - **C** helium
   - **D** oxygen

6. **Test Prep** **Which element is MOST LIKELY to be dull?**
   - **A** carbon
   - **B** aluminum
   - **C** mercury
   - **D** sodium

Writing Link

Explanatory Writing

Pretend that John Dalton is still alive. Write a letter to him explaining what parts of his ideas about atoms were right and what parts had to be changed.

Math Link

Finding Oxygen

The mass of a sample of air is made of 23.2% oxygen. To obtain 46.4 kilograms of pure oxygen, how many kilograms of air would be needed?

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