Science Ch. 14

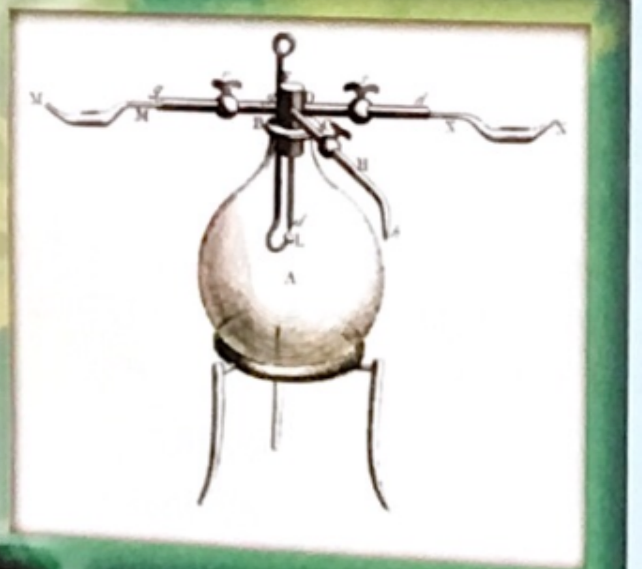
Building Blocks of Matter

Biography

Antoine Lavoisier

In 1782, America was nearing the end of the Revolutionary War. At the same time, another important event was taking place in a laboratory in Paris, France.

The French chemist Antoine Lavoisier was making one of the most important discoveries in science. His experiments showed that the mass of materials before a chemical change was the same as the mass of the materials after the chemical change. These experiments led Lavoisier to conclude that matter cannot be created or destroyed. It can only change from one form to another.



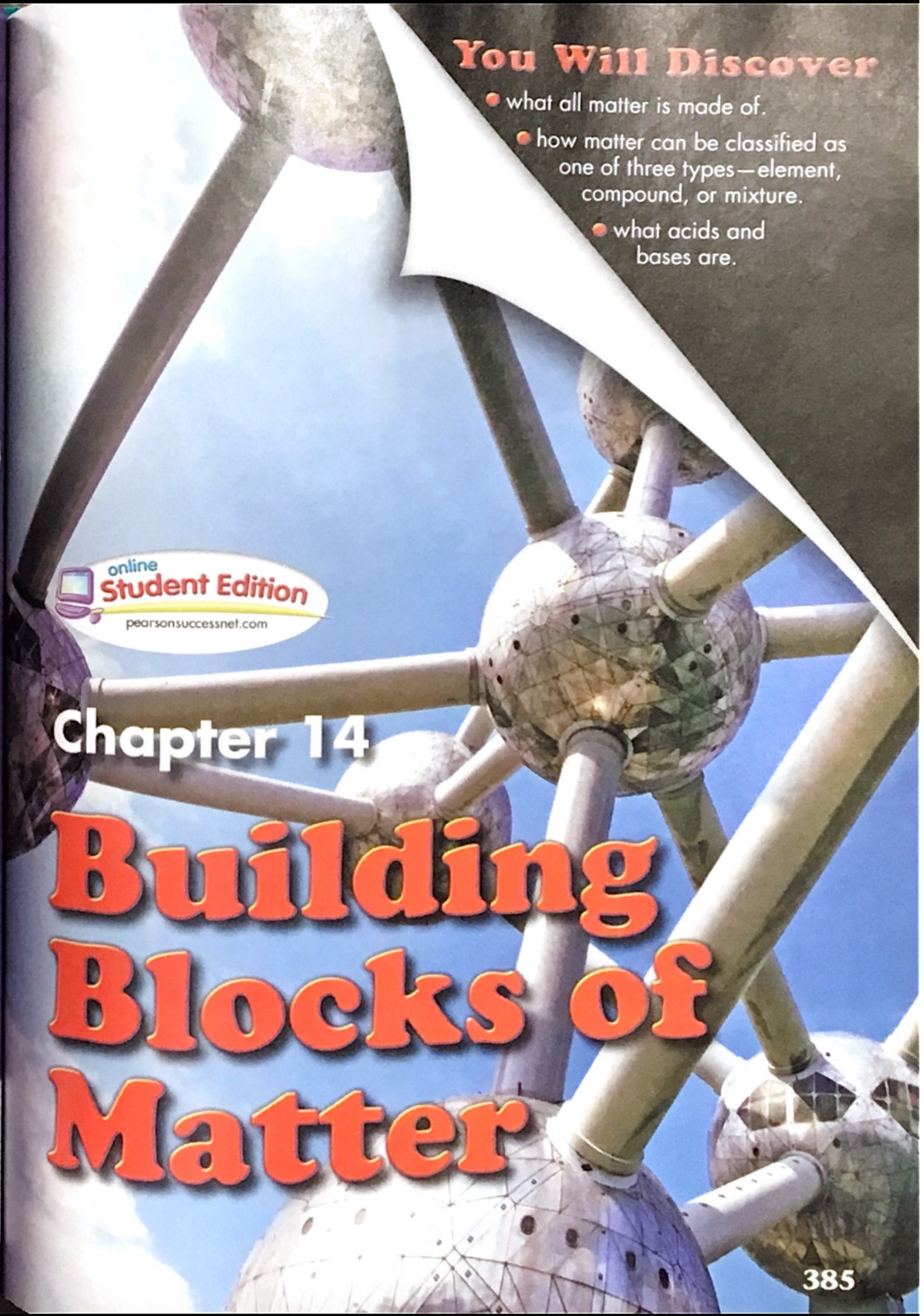
Lavoisier's hydrogen burner (1784) burned hydrogen in air to produce water, which he took as proof that water was a compound of hydrogen.

Lavoisier made many other discoveries. For example, he showed that air is a mixture of gases. He proved that one of these gases, oxygen, is needed to make fire. He also showed that oxygen is needed for breathing and to make metals rust.

Lavoisier could have done much more, but his life ended tragically. After the French Revolution, Lavoisier was arrested and executed because he was part of a company that collected taxes for the government.

Lab zone Take-Home Activity

Lavoisier made important discoveries because he did careful experiments and followed the methods of science. Make a flowchart that shows the methods of science and how they connect to one another.



You Will Discover

- what all matter is made of.
- how matter can be classified as one of three types—element, compound, or mixture.
- what acids and bases are.

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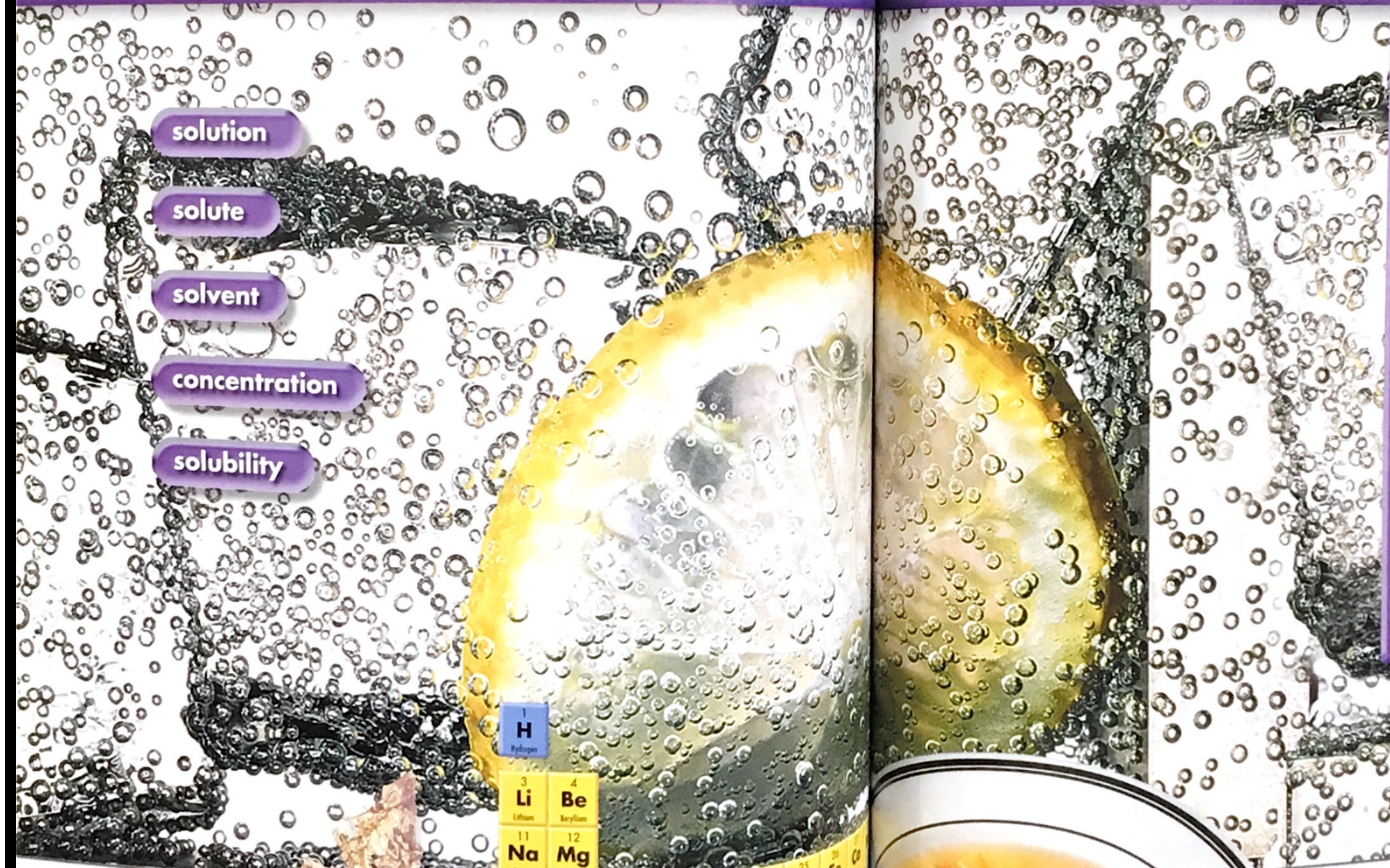
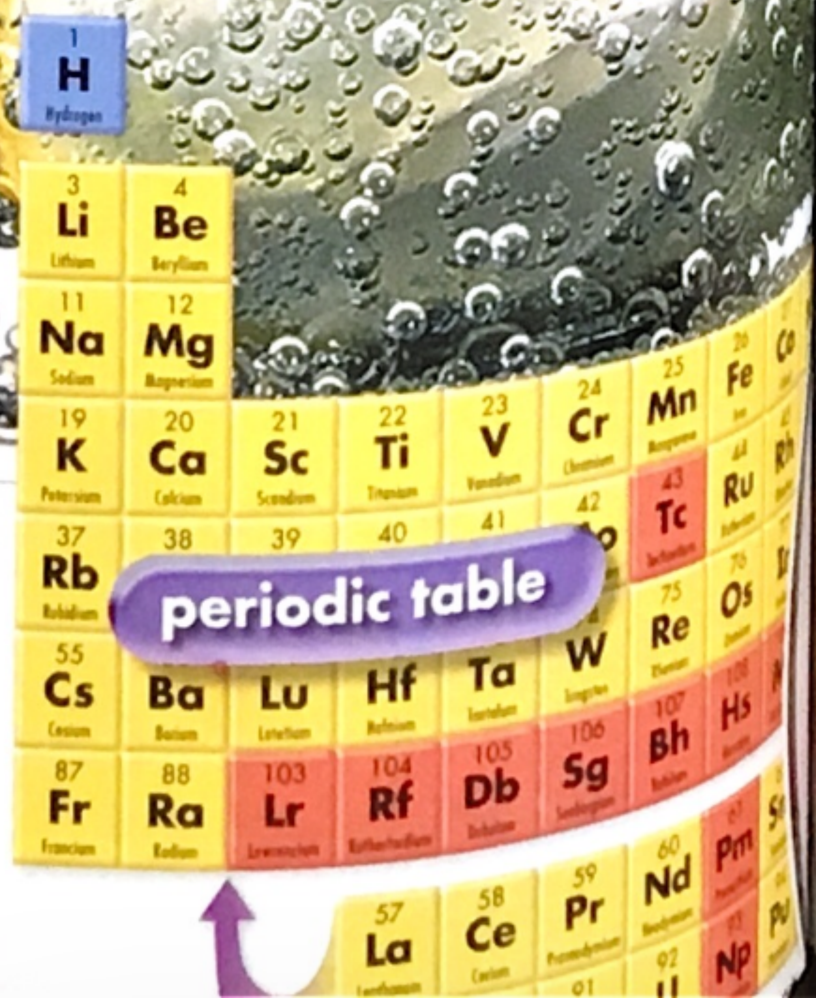
Chapter 14

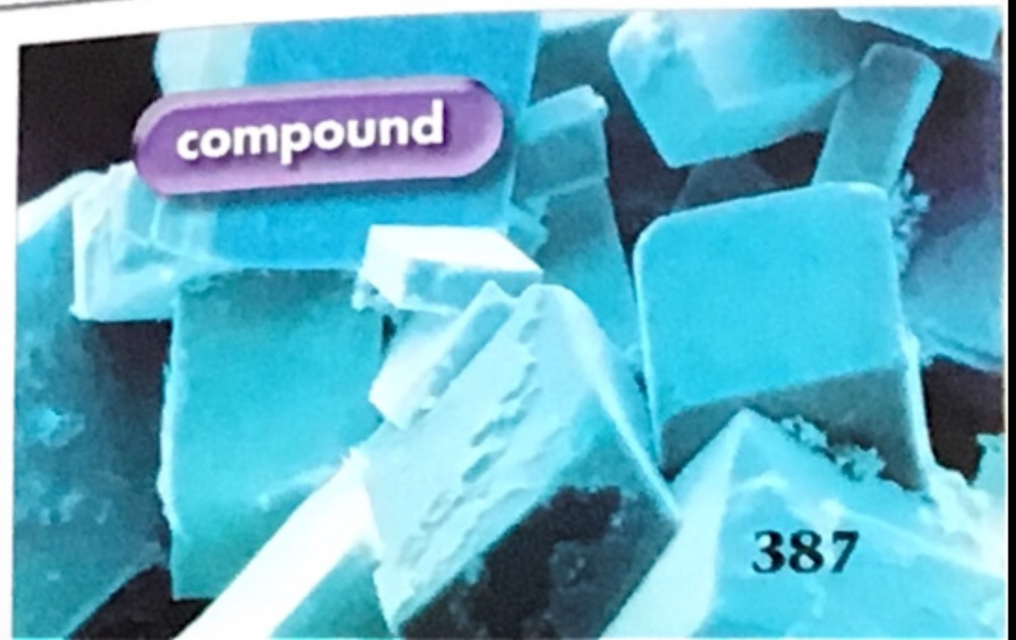
Building Blocks of Matter

Build Background

What do the many types of matter have in common?







Chapter 14 Vocabulary

element page 394

periodic table page 396

compound page 400

mixture page 402

solution page 404

solute page 404

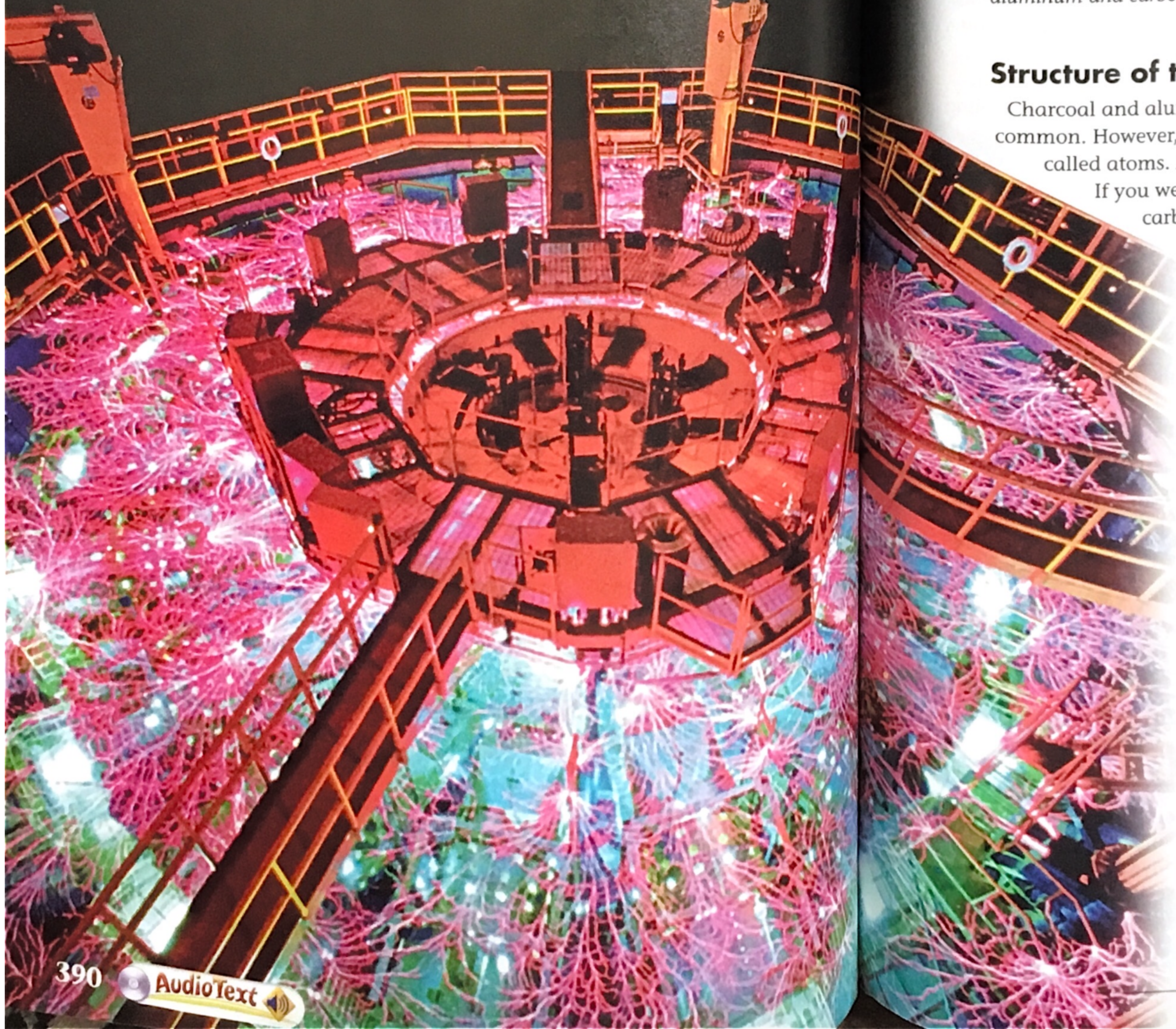
solvent page 404

concentration page 405

solubility page 405

You Are There!

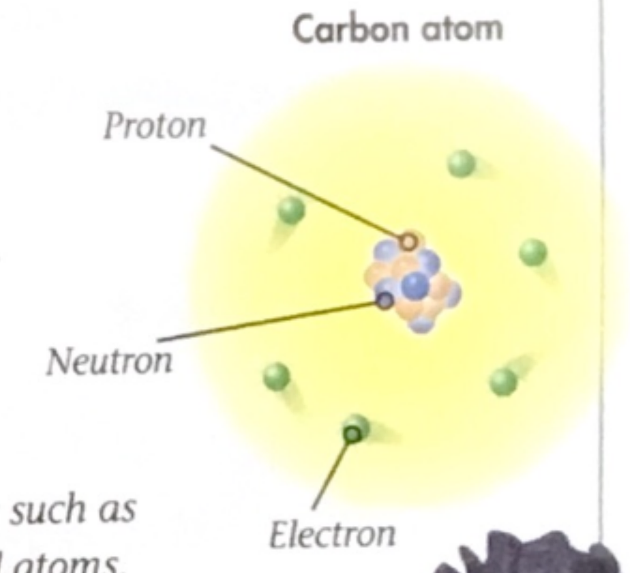
Wow, what a ride! You are riding a tiny atom that's going in a huge circle. Racecar drivers think driving on their track is fun. This ride is awesome! Oh no, you are about to collide with another atom. You can't avoid the collision. Crash! You're now stuck to the other atom. Fantastic! You just created a new substance.



AudioText

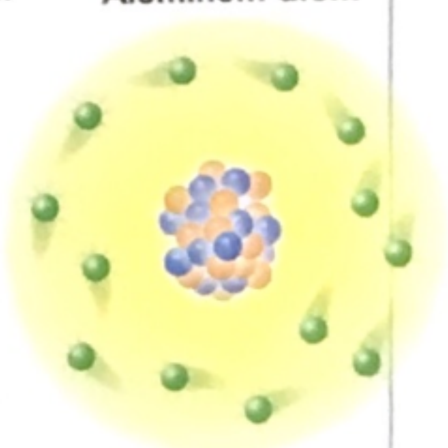
Lesson 1

How did we learn about atoms?



All matter is composed of tiny particles. Pure substances such as aluminum and carbon are made of similar particles called atoms.

Structure of the Atom



Charcoal and aluminum foil do not appear to have anything in common. However, these materials are made up of tiny particles called atoms. An atom is the smallest whole piece of matter. If you were able to see the structure of aluminum or carbon, you would find that it was made from tiny atoms joined together.

Atoms are difficult to study because they are so small, so scientists use models to help picture them. The model of the atom has changed over time as scientists gathered information. Today scientists use the electron cloud model to represent an atom. In the electron cloud model, an atom has two distinct regions—the nucleus and the electron cloud. The nucleus is located in the center of the atom. It is composed of protons and neutrons. A proton is a particle that has a positive charge. A neutron is a particle that has no charge.

The nucleus of an atom is surrounded by the electron cloud. This part of the atom contains electrons and a great deal of empty space. An electron is a particle that has a negative charge. Scientists also have found even smaller particles that compose protons and neutrons. Many details about these particles are still being worked out by scientists.

1. **Checkpoint** Describe the electron cloud model of an atom.
2. **Compare and Contrast** Tell how protons, neutrons, and electrons are alike and different.

History of the Atom

Aristotle was a student of Plato, another Greek philosopher.

Throughout history, people have thought that all matter is made of combinations of a few basic parts. For example, the ancient Greeks thought that all matter was made from four elements—earth, fire, air, and water. Today scientists know that all matter is made of atoms and that atoms are made of smaller particles—protons, neutrons, and electrons. But it took over 2000 years for today's model of the atom to develop. The Greek philosopher Leucippus is usually given credit for thinking of the idea that matter is made of smaller particles. His student, Democritus, further developed the idea and gave the particles the name *atomos,* meaning "indivisible." Atoms, according to Democritus, were all hard solids that could not be destroyed. He thought that all atoms were made of the same material in different sizes and shapes.

Another Greek philosopher, Aristotle, disagreed with Democritus. Aristotle believed that matter could be divided and subdivided indefinitely. Aristotle had many followers, and his ideas about the atom were believed by many until the 17th century.

The Greek ideas about atoms were not based on scientific observation, measurement, or experimentation. The Greeks used mathematics and reasoning to form their ideas. But in 1803, the British scientist John Dalton used scientific experimentation to prove that atoms exist. Dalton's atomic theory stated that all matter is made of atoms that cannot be created, divided, or destroyed.

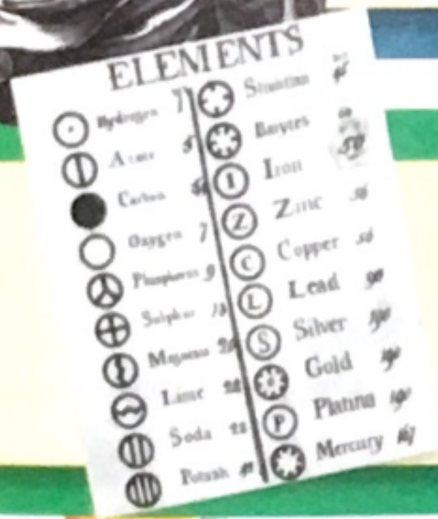
As you can see in the time line on the next page, since Dalton's time, the model of the atom has undergone many changes. As technology has changed throughout the years, more and more information has been discovered. Today the electron cloud model is widely accepted as being a good working model of the atom. But it too may change as scientists learn new information.

✓ Lesson Checkpoint

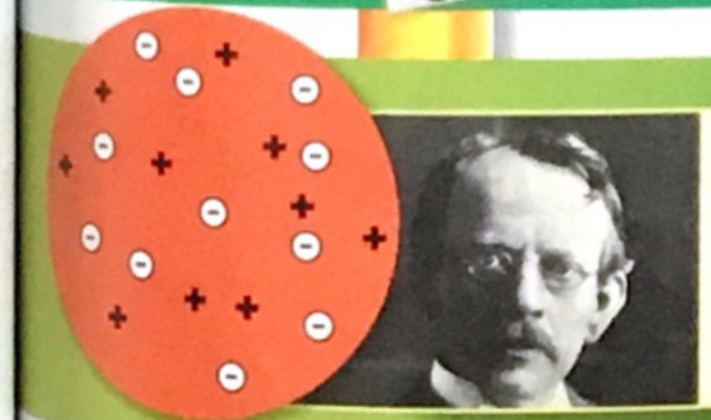
1. What might happen to cause scientists to change the model of the atom?
2. How does the way scientists today develop ideas differ from the way the Greek philosophers developed ideas?
3. **Compare and Contrast** Use a graphic organizer to show how Thomson's model of the atom is like and different from Dalton's model.

A Changing Atomic Model

5th century B.C. Democritus, a Greek philosopher, proposed that all matter was made of indivisible particles called atoms. Aristotle disagreed, and his views were considered correct until John Dalton found proof that atoms exist.

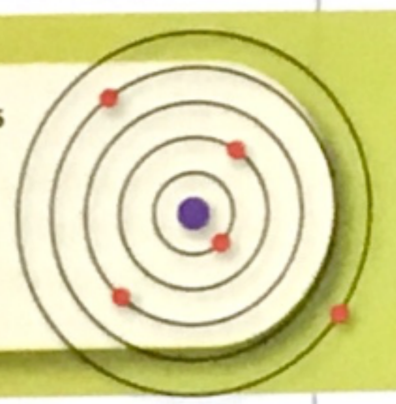


1803 John Dalton proposed that atoms were small solid spheres. His model of the atom resembled a billiard ball.

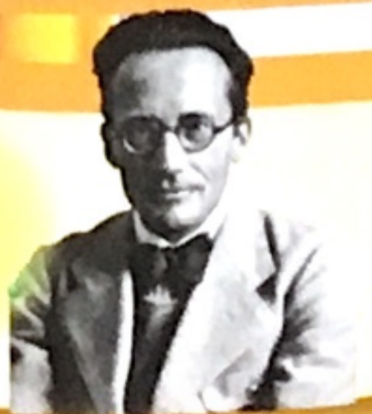


1897 Joseph John Thomson proposed that atoms were positively charged spheres with negatively charged particles embedded into them. This model is often called the plum pudding model. Thomson is credited with discovering the electron.

1911 Ernest Rutherford found that most of the mass of the atom was located in the center of the atom. He called the center a nucleus. His model resembled the solar system. In his model, negatively charged electrons orbit a dense positively charged nucleus.



1913 Niels Bohr proposed that electrons traveled in fixed orbits called shells. Electrons cannot move from one shell to another without gaining or losing energy.



1920s Erwin Schrödinger and Werner Heisenberg proposed the electron cloud model for the atom.

Lesson 2

How are elements grouped?

Scientists classify matter that has similar characteristics. Matter can be classified as elements, compounds, or mixtures. Some compounds also can be classified as acids or bases.

Gold is a metal that is often used in jewelry.

Silver and copper are metals that are used in jewelry and electrical wiring.

Elements

It's amazing to think that all the matter around you is made of tiny atoms. Most things are made of more than one kind of atom. For example, water is made of oxygen atoms and hydrogen atoms. But some kinds of matter, called **elements,** are each made up of only one type of atom. An element cannot be separated into simpler substances by physical or chemical means. Elements that you might be familiar with are carbon, aluminum, gold, silver, and copper. Because each element is made of only one kind of atom, elements are called pure substances. Each pure substance is made of only one kind of particle—in this case, atoms.

Less than 100 different elements occur naturally on Earth. All matter found in nature on Earth and everything that we have found in space is made of these elements. You might wonder how less than 100 different elements can make the seemingly endless variety of matter. It's somewhat like the alphabet. The 26 letters of our alphabet can make all the words in the largest dictionary. In a similar way, elements combine in different ways to form everything that is matter.

Elements and Their Atoms

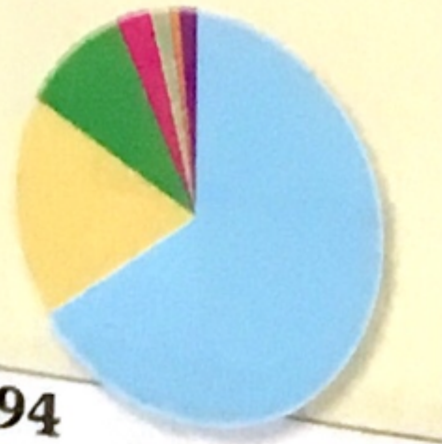
The atoms of each element are different from the atoms of all other elements. And all the atoms of an element are the same. Each element can be identified by the number of protons in the nucleus of its atom. All matter with 79 protons in the nucleus of its atom is gold. All matter with six protons in its nucleus is carbon, and so on.

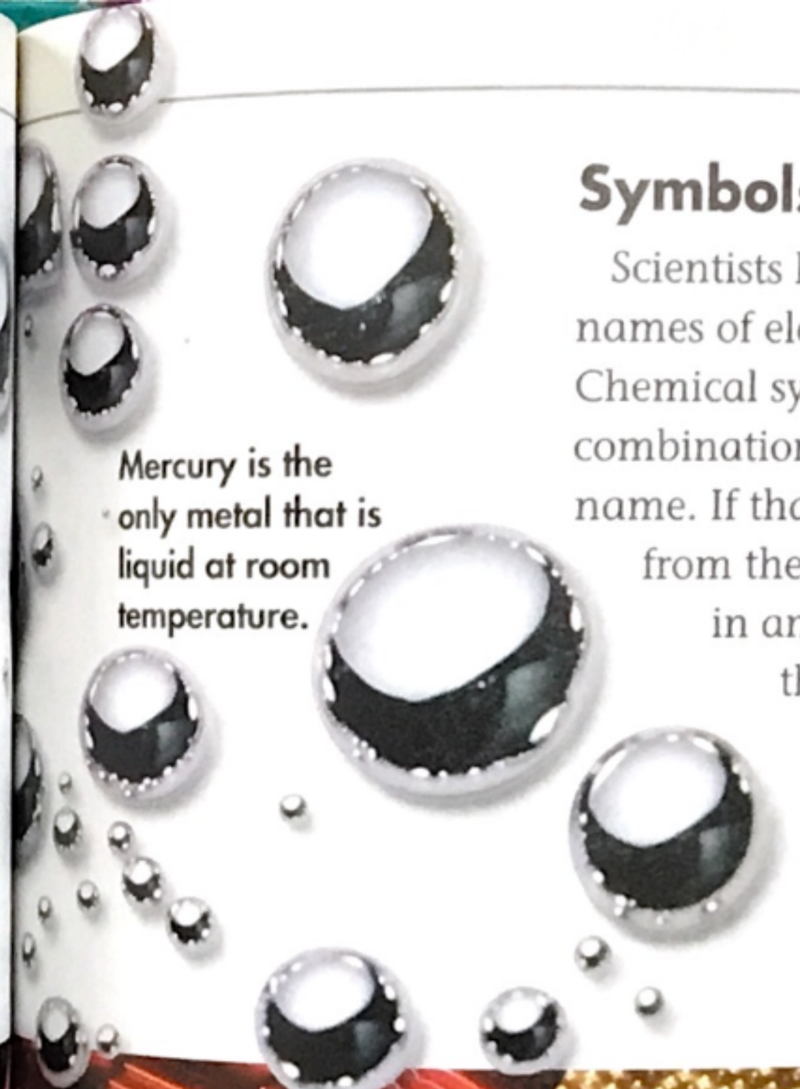
Atoms of elements have no electrical charge because they have the same number of protons and electrons. An element with six protons in its nucleus must also have six electrons in the electron cloud. With six positive charges and six negative charges, the overall charge of the atom is zero.

Elements in the Human Body

All living and nonliving things are composed of elements, including your body. This circle graph shows most of the elements that make up the human body. Notice that your body contains over 60 percent oxygen by mass. Oxygen is found in water, proteins, sugars, and fats in the human body.

- Oxygen 65%
- Carbon 18%
- Hydrogen 10%
- Nitrogen 3%
- Calcium 1.5%
- Phosphorus 1.0%
- Other 1.5%





Mercury is the only metal that is liquid at room temperature.

Symbols for Elements

Scientists have developed a shorthand method for writing the names of elements. Each element has a unique chemical symbol. Chemical symbols are a single letter, or two- or three-letter combinations. Usually, the chemical symbol is the first letter in the name. If that symbol is used by another element, another letter from the name is added. Some elements that were discovered in ancient times were given Greek or Latin names. Some of these elements have symbols from their old name. For example, the symbol for gold is Au for the Latin name *aurum*. Newly discovered elements are given temporary three-letter names based on the Latin name for the number of protons found in the nucleus. You can see the symbols for all the elements on pages 396–397.

The element neon is used in colorful signs.

Classifying Elements

Each element has a unique number of protons and electrons. This unique set of protons and electrons gives each element a unique set of properties. Scientists use these properties to place each element into one of three groups—metals, nonmetals, and metalloids.

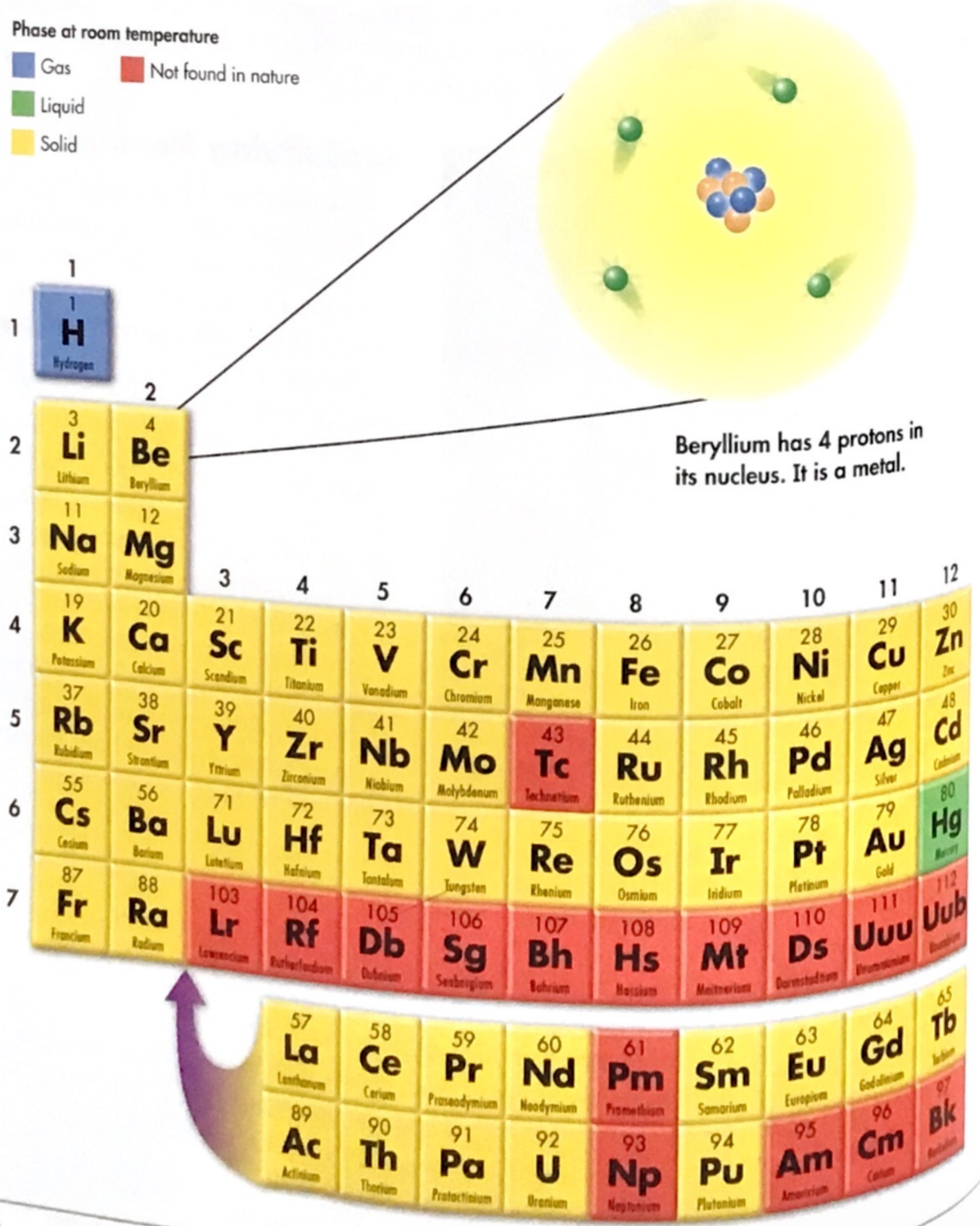
Metals are elements that are usually hard, are good conductors of heat and electricity, and are capable of being drawn into wires and hammered into sheets. Nonmetals are elements that are usually brittle, are poor conductors of heat and electricity, and cannot be hammered into sheets or made into wires. Metalloids are elements that have some properties of both metals and nonmetals.

Silicon is an element that is used to make computer parts.

1. ✓ Checkpoint Atoms often are referred to as the building blocks of matter. Why do you think atoms were given this title?
2. What are the most common elements in the human body?
3. Health in Science Calcium, potassium, and sodium are elements that are required by the body for good health. Find out how each of these elements is used by the body.

The Periodic Table

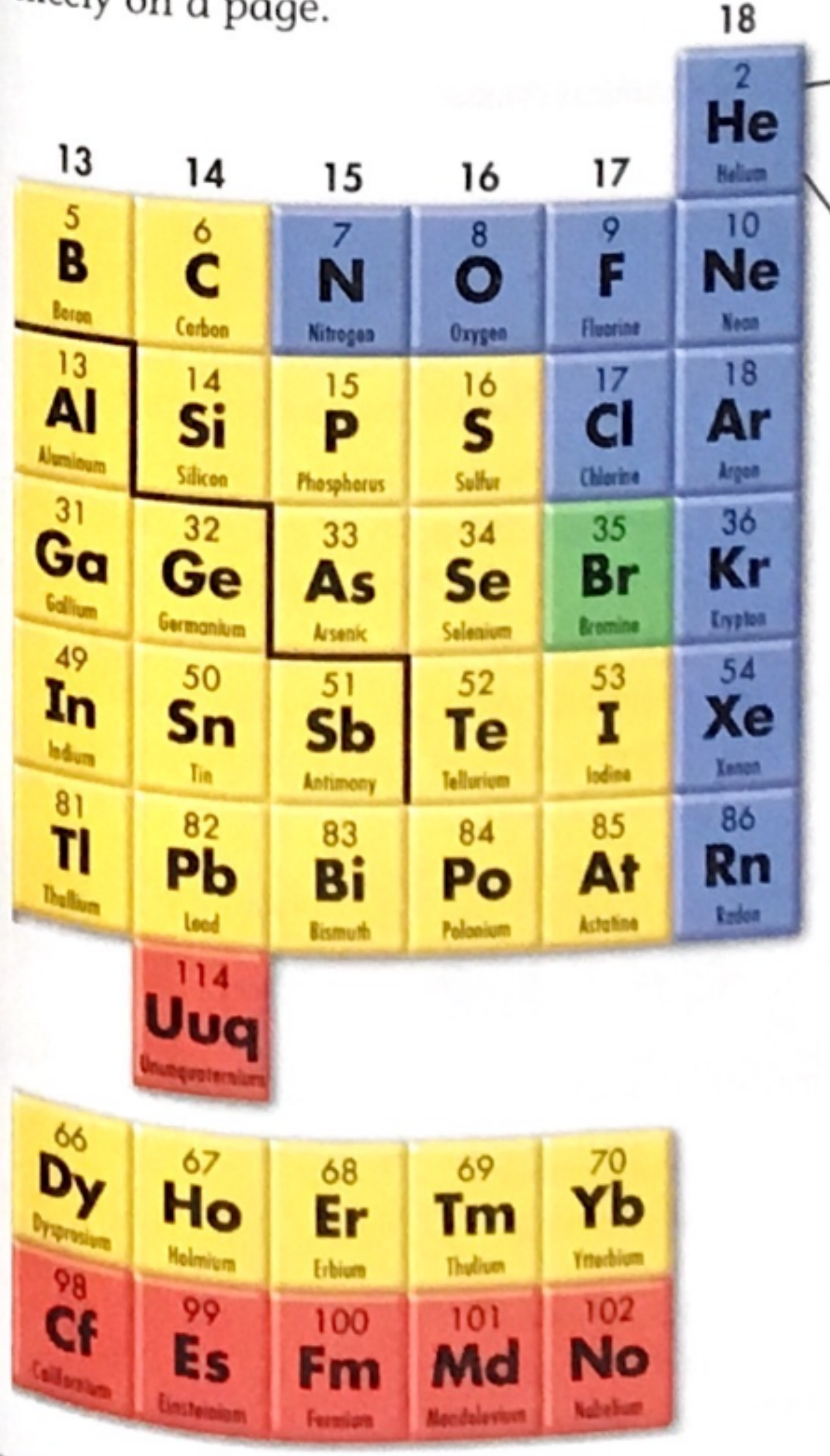
Suppose you go to the bookstore to buy a particular book. When you get there, the books are not organized in any way. Mysteries, autobiographies, and poetry books are all mixed together with other kinds of books. How easily would you be able to find the book you are looking for? Scientists had a similar problem before they came up with a way to organize the elements. Today all of the known elements are organized in the **periodic table.**

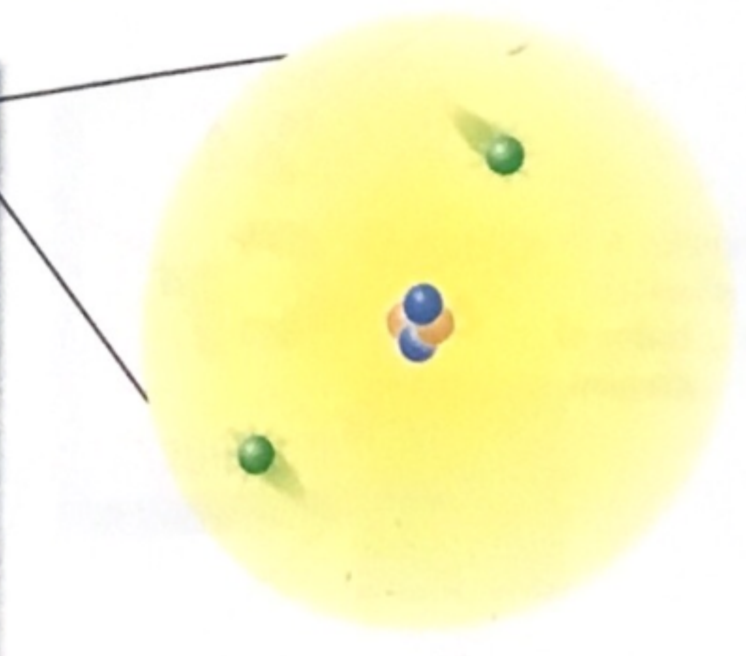


Beryllium has 4 protons in its nucleus. It is a metal.

The periodic table lists the elements in order of increasing atomic number from left to right. The atomic number of an element is the number of protons in the nucleus of its atom. Elements on the left side of the table are metals. Elements on the right side of the table are nonmetals. Metalloids are along each side of the zig-zag line between the metals and nonmetals on the table. Although aluminum is along the zig-zag line, it is not a metalloid. It is a metal. Aluminum is an exception to the rule that all elements touching the zig-zag line are metalloids.

At the bottom of the periodic table are two series of elements called the Lanthanide series and the Actinide series. Look at the atomic number of the first member in the Lanthanide series. Lanthanum, atomic number 57, should follow Barium, atomic number 56 in the table above. The first element in the Actinide series should follow the element radium. These elements are pulled to the bottom of the periodic table for convenience. If these elements were placed in the table above, the table would be extremely wide. These elements are pulled to the bottom of the table so that the periodic table will fit nicely on a page.





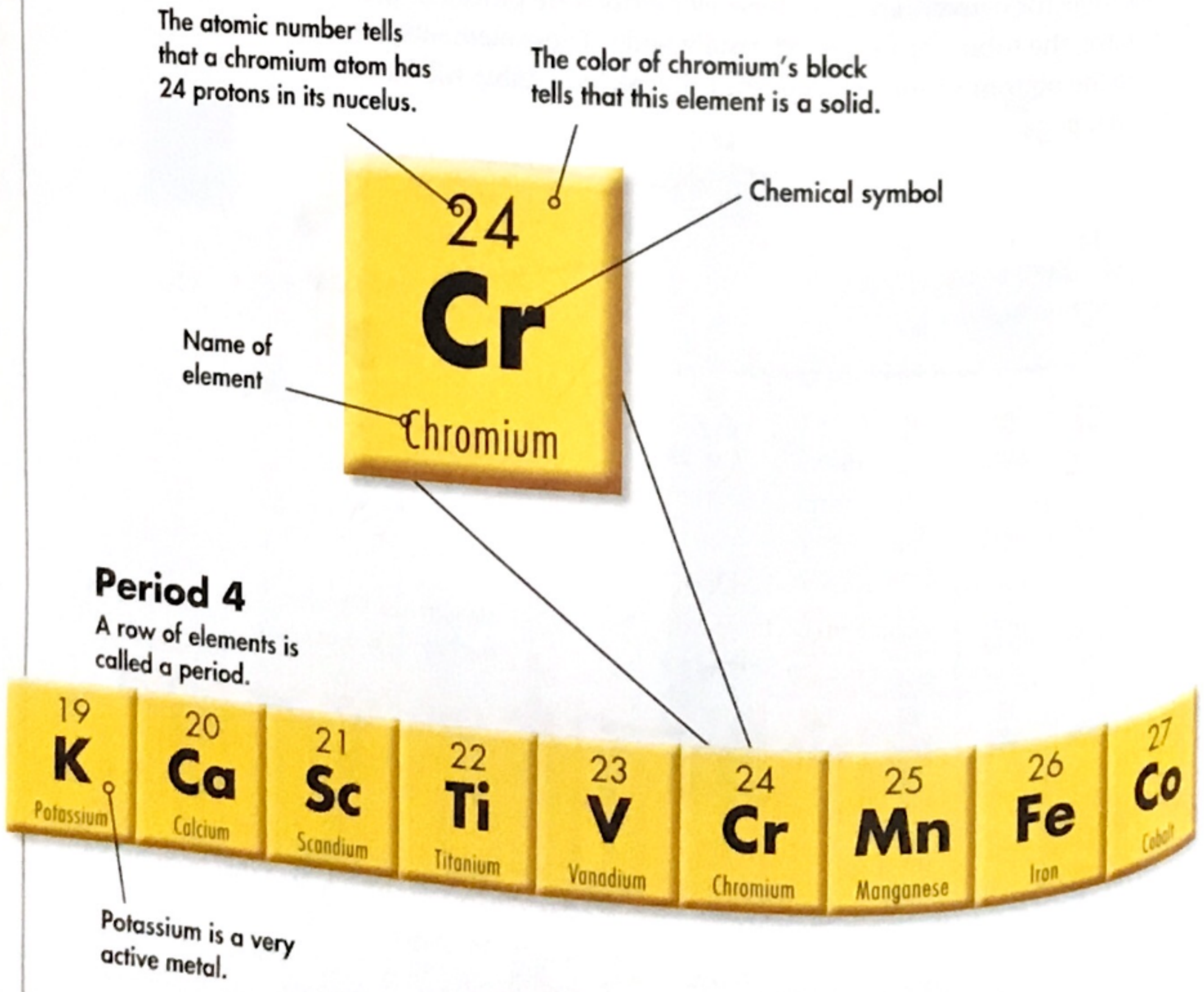
Helium has 2 protons in its nucleus. It is a nonmetal.

1. **Checkpoint** How many protons do the elements beryllium and helium each have?
2. Use the information in the table to draw a model that shows the number of electrons and protons in a lithium atom.
3. **Technology in Science** Scientists have made some elements in the laboratory. Find out which elements scientists made.

Information on the Periodic Table

If you want to find information about a word, you go to a dictionary. If you want information about an element, go to the periodic table. The periodic table contains a great deal of information about the elements. The word *periodic* means "a regular, repeated pattern."

Each individual block in the periodic table contains information about a particular element. Look at the block for chromium to find out what information you can get about each element on the periodic table on pages 396–397. Other periodic tables may give more or less information about each element.



Columns and Rows

The location of an element on the table also gives information about the element's properties. As you move across a row or down a column, the elements' properties change in a predictable way.

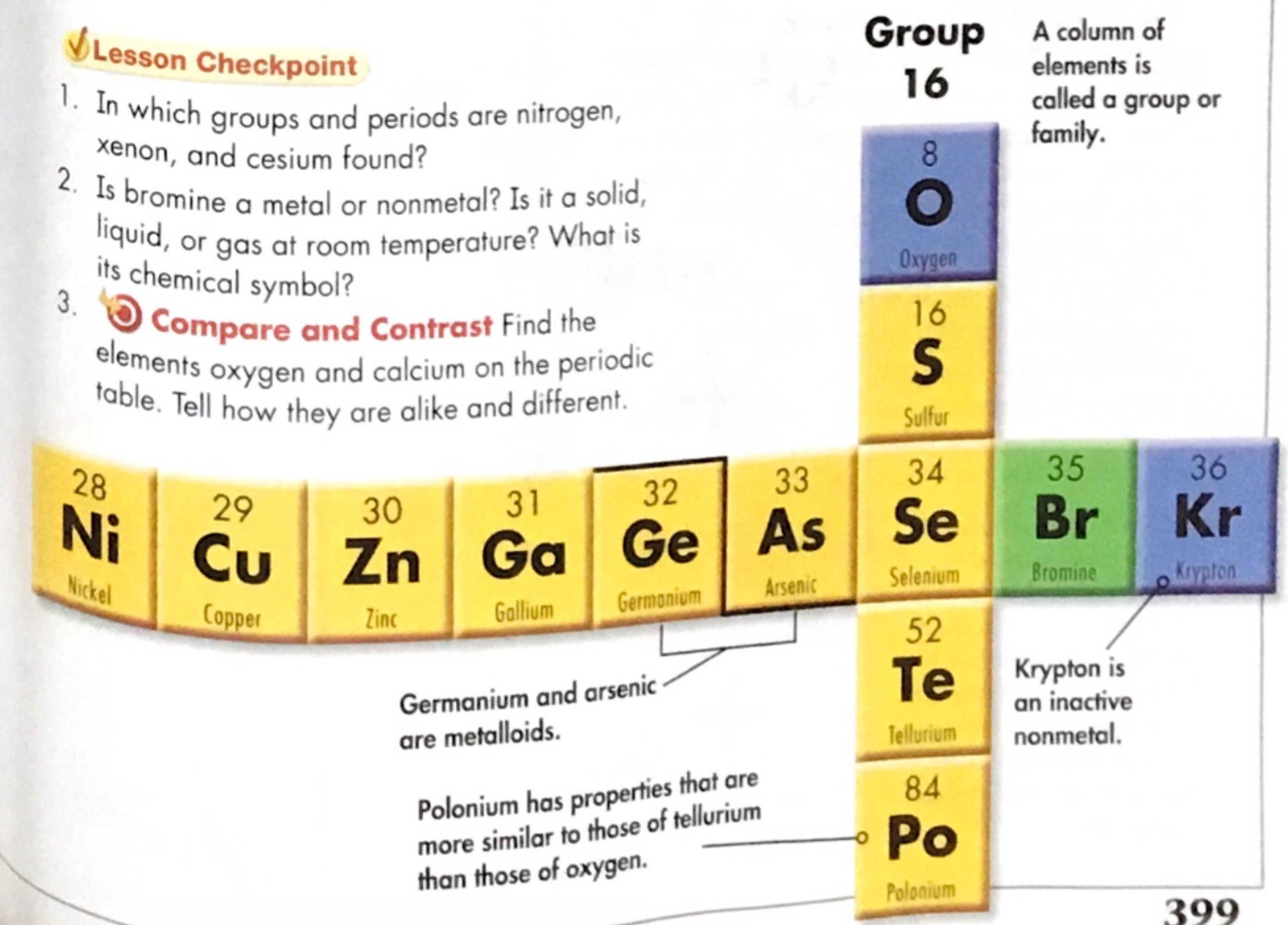
The periodic table has 18 columns. These columns are called groups or families. Like members of a family, elements in a family resemble each other. They react with other substances in similar ways. Groups are numbered from 1 to 18.

The elements in Group 1 are all metals that react strongly with water. Hydrogen is an exception. Its atomic structure is similar to other elements in Group 1, but it does not have similar chemical properties. The elements in Group 18 barely react at all with other elements. They are called inactive elements.

The periodic table's seven rows are called periods. Unlike the elements in a group, the elements in a period have very different properties. For example, the elements in Period 4 change from very active metals to less active metals to metalloids and then to nonmetals. The first element in a period always reacts violently. The last one is always inactive.

Lesson Checkpoint

1. In which groups and periods are nitrogen, xenon, and cesium found?
2. Is bromine a metal or nonmetal? Is it a solid, liquid, or gas at room temperature? What is its chemical symbol?
3. **Compare and Contrast** Find the elements oxygen and calcium on the periodic table. Tell how they are alike and different.



Lesson 3

What are compounds and mixtures?

Elements combine in exact ratios to form compounds. Compounds have properties that differ from the properties of the elements that make them. The substances that form mixtures do not combine in exact ratios. Substances in a mixture retain their own properties.

Atoms Together

The table salt in the picture is different from the elements you read about in Lesson 2. Table salt is made of more than one element. Most atoms found in nature are not found as elements but are found in compounds. A **compound** is a substance composed of two or more elements that are chemically combined to form a new substance with different properties. Table salt is a compound.

Many components of your body are made of compounds. For example, water is a compound, and it makes up about 60 percent of your body. Other compounds, called proteins, make up much of your skin, bones, tendons, and ligaments. Compounds also make up the membranes surrounding the cells in your body and the DNA that determines the traits you inherit.

Each element will react in a different way when it combines with different substances. When sodium combines with chlorine, it forms sodium chloride. But when it combines with water, it reacts violently to form hydrogen gas and sodium hydroxide.

Sodium chloride (table salt)

Sodium hydroxide and hydrogen

Each particle of a compound is made of exactly the same ratio of elements. For example, every particle of table salt contains one atom of sodium combined with one atom of chlorine. Each particle of water is made of two atoms of hydrogen and one atom of oxygen.

The properties of a compound differ from the properties of the elements that form it. Sodium, chlorine, and the sodium chloride they form have very different properties. You might be surprised to learn that the element chlorine is a greenish yellow, poisonous gas. When sodium, a silvery, white metal, combines with chlorine, sodium chloride forms. You eat sodium chloride every day—it's table salt! Table salt has properties that are different from those of sodium and chlorine.

Chemical Formulas

Scientists not only use symbols for elements, they also use symbols for compounds. Every compound has its own chemical formula. A chemical formula consists of two parts—symbols for the elements and subscripts. A chemical formula contains a chemical symbol for every element that is present in a particle of the compound. The subscript tells how many atoms of each element are present. For example, the chemical formula for water is H_2O. The formula tells you that water contains the elements hydrogen and oxygen. The subscript tells you two atoms of hydrogen and one atom of oxygen combine to make water. The subscript for an element follows the element's chemical symbol. The subscript 1 is never written in a chemical formula. If there is no subscript written, then you know that there is only one atom present.

Elements and Compounds in Products

Foods, household chemicals, and over-the-counter medicines have labels on their packaging that identify the elements and compounds in the product. Federal laws tell manufacturers what information is required on each type of product. The labels on over-the-counter medications must give the active and inactive ingredients found in the product. Labels on household chemicals tell the ingredients in the product.

Labels on food packaging list the nutrients that are contained in that food. The elements sodium and potassium are found in these dried apricots. The other nutrients listed are compounds. The compounds listed on this label are compounds found in most living things. Many living things contain fats, carbohydrates, proteins, and water in their cells.

1. **✓Checkpoint** The chemical formula for glucose, a type of sugar, is $C_6H_{12}O_6$. Is glucose an element or a compound? How do you know?
2. How many atoms of hydrogen are in a particle of glucose?
3. **Compare and Contrast** How do the elements sodium and chlorine differ from the table salt they form? How are they alike?

Mixtures

The components of this soup are not chemically combined.

Elements and compounds are two ways matter can be classified. You know that elements contain one type of atom. Compounds are made of two or more atoms combined in fixed ratios. Matter that cannot be classified as an element or a compound is usually a mixture. A **mixture** is a combination of substances in which the atoms of the substances are not chemically combined. Mixtures can be a combination of elements, compounds, or both. Look at the picture on the next page to see how elements and compounds make up sand—a mixture.

Substances in a mixture retain their own properties. For example, the vegetable soup in the picture contains chicken, noodles, celery, carrots, and other vegetables. The vegetables are separate and can be easily identified. The components of a mixture do not have a definite ratio. One bowl of soup may have more carrots than another bowl.

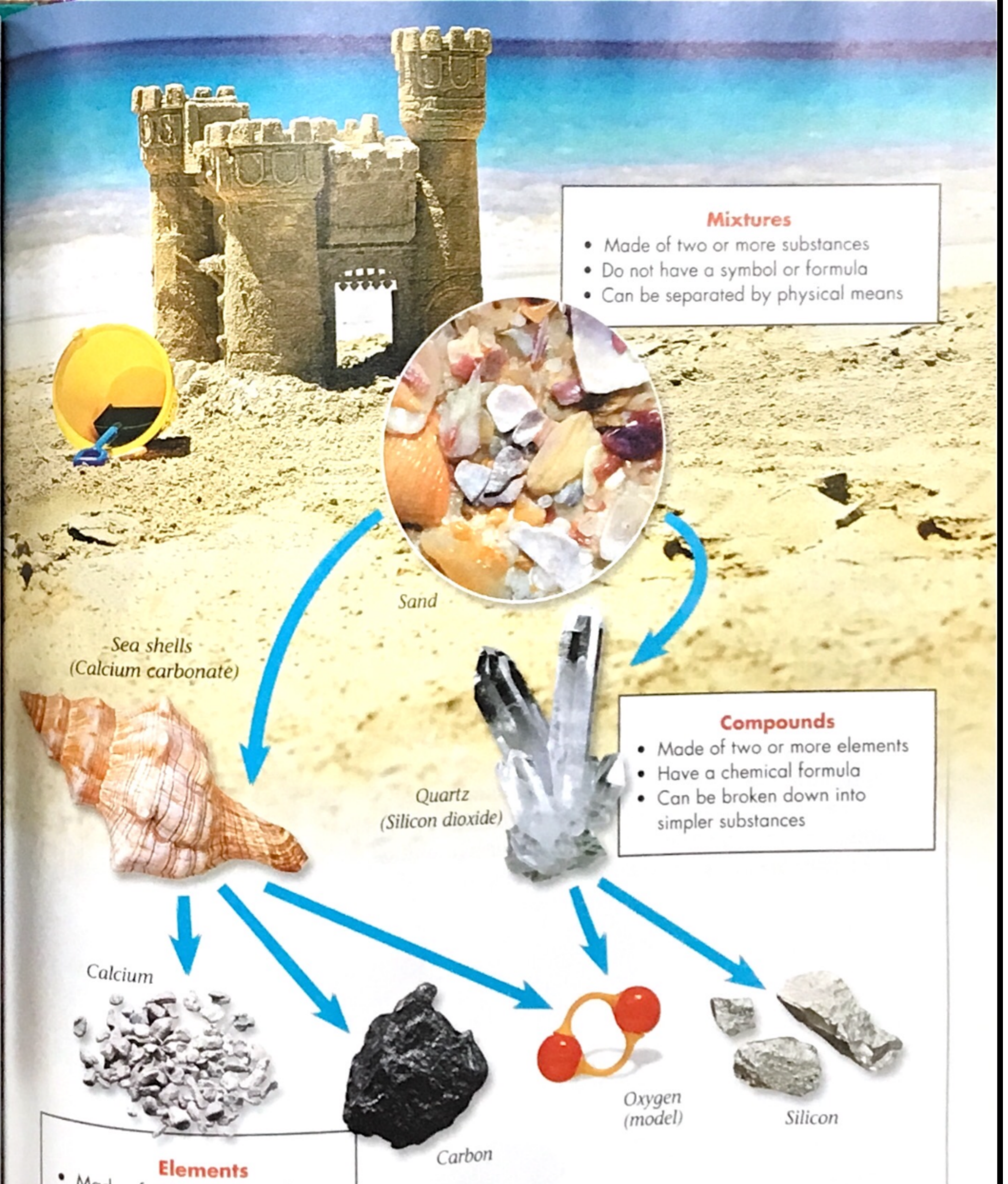
Separating Mixtures

Mixtures also can be easily separated. If you don't like the carrots in the soup, you could easily pick them out. Some mixtures are more difficult to separate because the components are very small. How do you separate a mixture with smaller components, such as salt, iron filings, and sand?

Mixtures can be separated using the physical properties of the substances that it contains. For example, the iron filings in the salt-iron-sand mixture are magnetic. You can separate them from the mixture using a magnet. What remains is a mixture of salt and sand. If you add water to the salt-sand mixture, the salt will dissolve. Then pour the water-salt-sand mixture through a filter paper. The sand will collect on the filter paper. The remaining water-salt mixture can be separated by evaporating the water. Solid salt particles will remain.

A filter can be used to separate components of a mixture. Here the larger particles cannot move through the filter but the smaller water particles can.

The coffee in this pot is a mixture. The coffee can be separated from the water by evaporation.



1. **Checkpoint** What techniques can be used to separate a mixture?
2. **Compare and Contrast** How do the changes that occur when water is mixed with salt differ from the changes that result when water is mixed with sodium?

Acids
- Taste sour (NEVER taste a substance to test for the presence of acids.)
- React strongly with some metals to form new compounds
- Change blue litmus paper to red

Bases
- Taste bitter (NEVER taste a substance to test for the presence of bases.)
- Feel slippery
- Change red litmus paper to blue

Acids and Bases

When you think of acid, you may think of a liquid that burns holes in anything it touches. You may be surprised to learn that many of the foods you eat contain acids—sour candies, pickles, milk, and citrus fruits are just a few. These substances contain weak acids. Your body cells also contain weak acids that help keep the body healthy and alive.

Some acids are strong. They can burn your skin and are poisonous. Touching an acid to identify it is dangerous. Instead, you can use an indicator. An indicator is a compound that changes color in the presence of an acid. For example, acids cause one kind of indicator, blue litmus paper, to change to red.

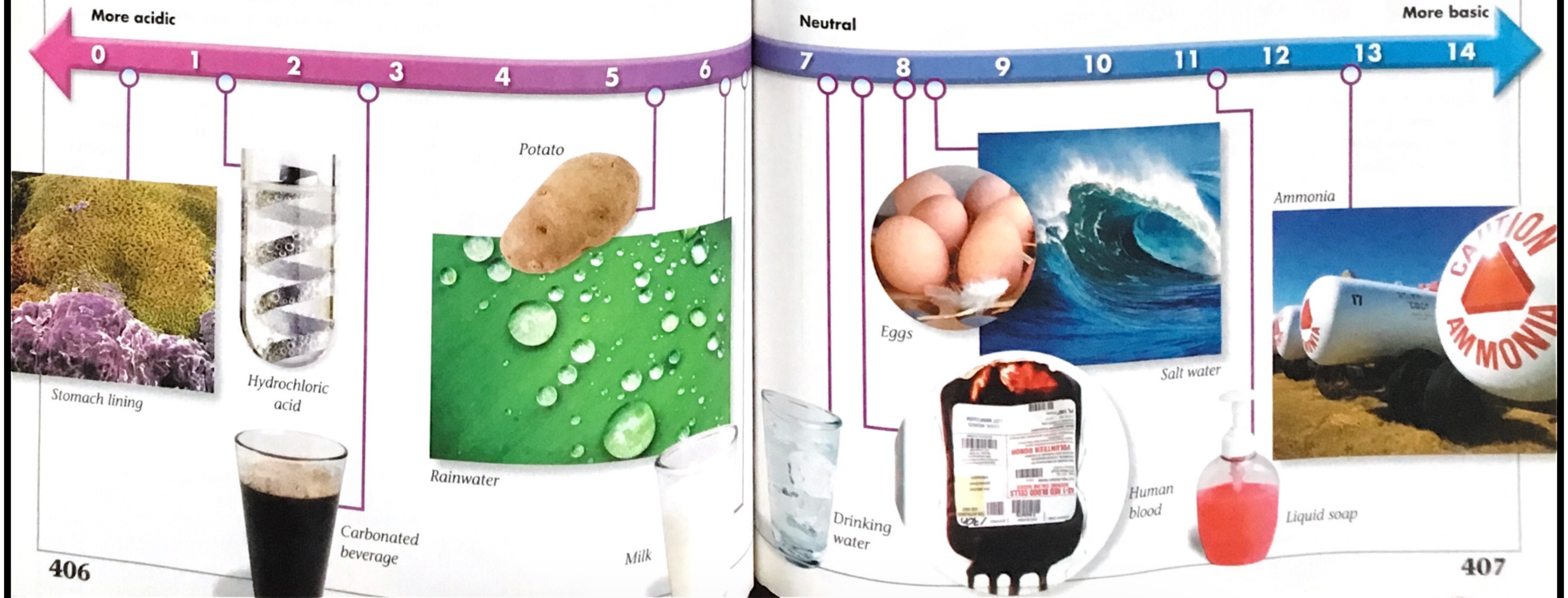
Many products you use contain bases. Shampoo, oven cleaners, and drain cleaners contain bases. Strong bases react strongly with some substances. In fact, strong bases will burn your skin just as strong acids will burn. And they are poisonous. Bases turn red litmus paper blue.

The pH scale

To measure the strength of acids and bases, scientists use a pH scale, similar to the one below. This scale ranges from 0 to 14. Substances with a pH between 0 and 7 are acids. Acids decrease in strength as the number increases. The pH of bases ranges from 7 to 14. The strength of bases increases as the pH number increases. A pH of exactly 7 is neutral.

✓Lesson Checkpoint

1. Explain what you can tell about a compound with the formula $C_6H_{12}O_6$.
2. What is a saturated solution? Use the terms *solute, solvent,* and *dissolve* in your answer.
3. Writing in Science **Persuasive** Write a news article for younger students explaining what acids and bases are and why being careful around them is important.



Math in Science

BALANCING EQUATIONS

Just like a mathematical equation is a short way to show a mathematical relationship, a chemical equation is a short way to describe a chemical reaction. A mathematical equation uses numbers, variables, and operation symbols. A chemical equation uses symbols for elements, formulas for compounds, and the plus sign. Instead of the equal sign, a chemical equation uses an arrow.

When you work with a mathematical equation, you must keep it balanced. Also to accurately show a chemical reaction, a chemical equation must be balanced. The number of atoms of any element must be the same on both sides of the arrow.

The chemical equation for hydrogen reacting with oxygen to form water is shown below. This equation is not yet balanced.

$H_2 + O_2 \longrightarrow H_2O$

The subscripts show that the left side of the equation has 2 atoms of hydrogen and 2 atoms of oxygen. The right side has 2 atoms of hydrogen, but only 1 atom of oxygen.

To balance the equation, 2 atoms of oxygen are needed on the right side, so the number 2 can be written in front of H_2O. This results in doubling everything in the formula H_2O.

$H_2 + O_2 \longrightarrow 2H_2O$

Now there are 2 atoms of oxygen on each side, but the hydrogen atoms are unbalanced. There are 2 on the left, but 4 on the right. Try doubling the number on the left.

$2H_2 + O_2 \longrightarrow 2H_2O$

The equation is now balanced. There are 4 hydrogen atoms on each side and 2 oxygen atoms on each side.

Any number written in front of a formula multiplies the number of atoms of each element. For example, $4H_3PO_4$ has 12 hydrogen atoms, 4 phosphorus atoms, and 16 oxygen atoms.

For each formula, find the number of each kind of atom.

1. $2MgO$
2. $4Fe_2O_3$
3. $2H_2SO_4$

Balance each equation.

4. $Mg + O_2 \longrightarrow MgO$
5. $C + Cl_2 \longrightarrow CCl_4$
6. $Al + O_2 \longrightarrow Al_2O_3$

Lab zone Take-Home Activity

Gather about 25 coins including pennies, nickels, dimes, and quarters. Sort the coins into four piles by denomination. For each pile, count the coins and find the value. Also find the total value. Record the data. Mix up the coins and make four random piles. Count and find the value in each pile and the total. Compare the data with the first count. Which numbers have changed? Which have not? Write a paragraph comparing this activity with balancing the number of atoms in a chemical equation.

Chapter 14 Review and Test Prep

Use Vocabulary

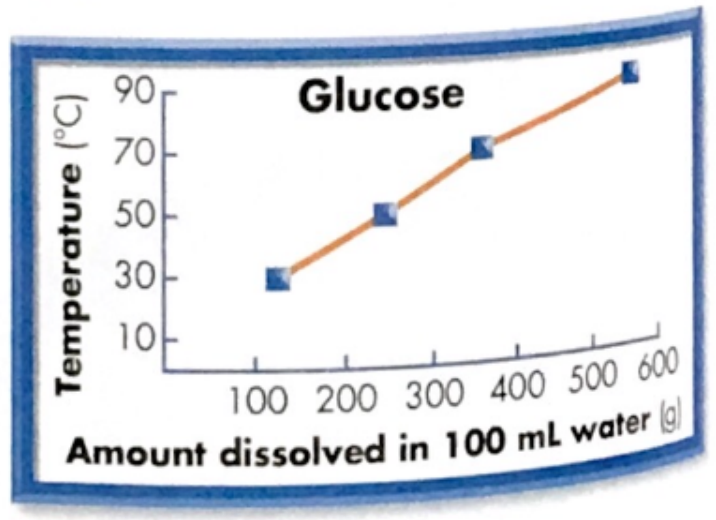
compound (p. 400)	**periodic table** (p. 396)
concentration (p. 405)	**solubility** (p. 405)
element (p. 394)	**solute** (p. 404)
mixture (p. 402)	**solution** (p. 404)
	solvent (p. 404)

Replace the underlined terms with the correct vocabulary terms from the list above.

1. A <u>mixture</u> is a substance composed of two or more elements that are chemically combined.
2. The two parts of a solution are <u>elements</u> and <u>compounds</u>.
3. All of the known elements are organized in the <u>solubility table</u>.
4. Gold, silver, and copper are examples of a <u>compound</u>.
5. A tossed salad is an example of a <u>compound</u>.
6. The measure of the amount of solute dissolved in a solvent is <u>solubility</u>.
7. The maximum amount of solute that can be dissolved in a solute at a particular temperature is <u>concentration</u>.
8. A <u>compound</u> is a mixture that appears to be a single substance.

Explain Concepts

9. Describe the differences between an element, a compound, and a mixture.
10. You have an unknown element that needs to be identified. The element sample has been hammered into a sheet. It is a good conductor of heat. What can you tell about this element? Explain your answer.
11. The graph shows the solubility of glucose, a type of sugar, at different temperatures. How much more sugar could be added to 100 mL of water if its temperature was raised from 50°C to 70°C? What would happen if the 70°C water was cooled to 30°C?

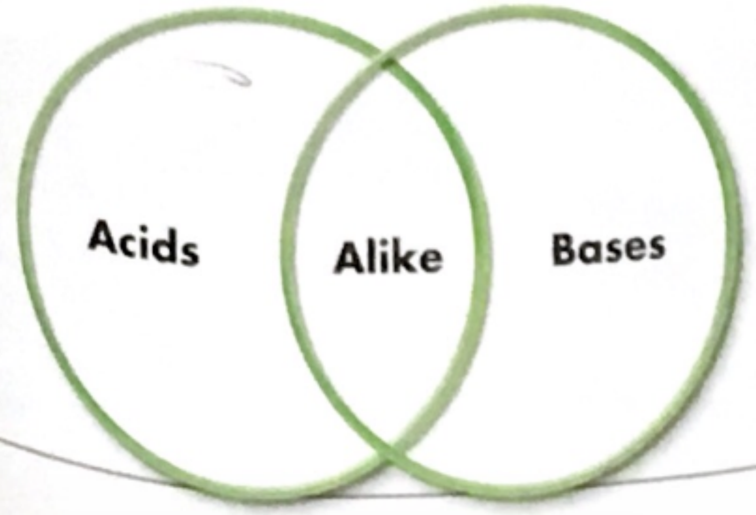


Process Skills

12. **Model** Make a model of a lithium atom showing the correct number and electrical charge of the protons, neutrons, and electrons. Use four neutrons in your model.
13. **Classify** Use the periodic table on pages 396–397 to answer these questions about each element below. What is its group and period numbers? Is the element a metal, nonmetal, or metalloid? Is it a solid, liquid, or gas?
    - lithium
    - tungsten
    - arsenic
    - krypton
14. **Infer** whether each of the following substances are soluble or insoluble in water.
    - sand
    - sugar
    - salt
    - vinegar

Compare and Contrast

15. Make a graphic organizer like the one shown below to compare and contrast acids and bases.



Test Prep

Choose the letter that best completes the statement or answers the question.

16. Which substance is a compound?
    - Ⓐ carbon
    - Ⓑ chlorine
    - Ⓒ sodium chloride
    - Ⓓ sodium
17. Where are the nonmetals located on the periodic table?
    - Ⓕ left side
    - Ⓖ right side
    - Ⓗ along the zig-zag line
    - Ⓘ at the bottom
18. A property of bases is that
    - Ⓐ it feels slippery and has a bitter taste.
    - Ⓑ it reacts strongly with some metals to form new compounds.
    - Ⓒ it tastes sour.
    - Ⓓ it turns blue litmus paper red.
19. Explain why the answer you chose for Question 16 is best. For each of the answers you did not choose, give a reason why it is not the best choice.
20. **Writing in Science** **Expository** Suppose you are writing an article for a local newspaper about solutions. Write a paragraph that could be used in the article describing a solution.