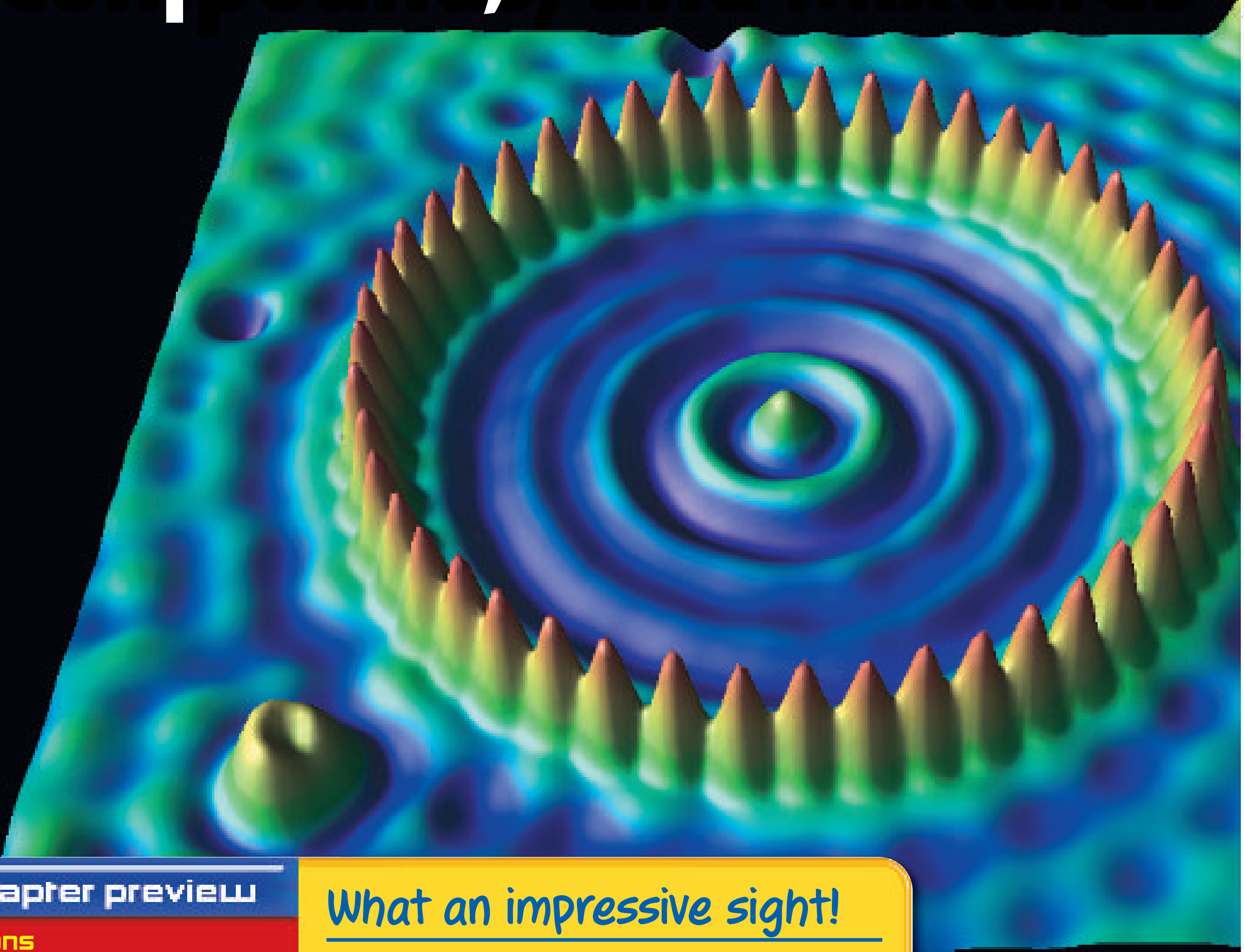
chapter 1

Atoms, Elements, Compounds, and Mixtures



chapter preview

sections

What an impressive sight!

Have you ever seen iron on an atomic level? This is an image of 48 iron atoms surrounding a single copper atom. In this chapter, you will learn about scientists and their discoveries about the nature of the atom.

Science Journal Based on your knowledge, describe what an atom is.

courtesy IBM

Start-Up Activities

Launch LAB

Model the Unseen

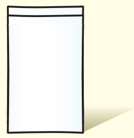
Have you ever had a wrapped birthday present that you couldn't wait to open? What did you do to try to figure out what was in it? The atom is like that wrapped present. You want to investigate it, but you cannot see it easily.

1. Your teacher will give you a piece of clay and some pieces of metal. Count the pieces of metal.
2. Bury these pieces in the modeling clay so they can't be seen.
3. Exchange clay balls with another group.
4. With a toothpick, probe the clay to find out how many pieces of metal are in the ball and what shape they are.
5. **Think Critically** In your Science Journal, sketch the shapes of the metal pieces as you identify them. How does the number of pieces you found compare with the number that were in the clay ball? How do their shapes compare?

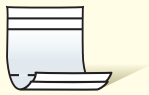
FOLDABLES™ Study Organizer

Parts of the Atom Make the following Foldable to help you organize your thoughts and review parts of an atom.

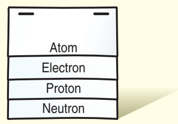
STEP 1 **Collect** two sheets of paper and layer them about 1.25 cm apart vertically. Keep the edges level.



STEP 2 **Fold** up the bottom edges of the paper to form four equal tabs.



STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. Label the flaps *Atom, Electron, Proton,* and *Neutron* as shown.



Read and Write As you read the chapter, describe how each part of the atom was discovered and record other facts under the flaps.

Science Online

Preview this chapter's content and activities at bookk.msscience.com

courtesy IBM

section 1

Models of the Atom

as you read

What You'll Learn

- **Explain** how scientists discovered subatomic particles.
- **Explain** how today's model of the atom developed.
- **Describe** the structure of the nuclear atom.

Why It's Important

All matter is made up of atoms. Atoms make up everything in your world.

Review Vocabulary

matter: anything that has mass and takes up space

New Vocabulary

- element
- electron
- proton
- neutron
- electron cloud

First Thoughts

Do you like mysteries? Are you curious? Humans are curious. Someone always wants to know something that is not easy to detect or to see what can't be seen. For example, people began wondering about matter more than 2,500 years ago. Some of the early philosophers thought that matter was composed of tiny particles. They reasoned that you could take a piece of matter, cut it in half, cut the half piece in half again, and continue to cut again and again. Eventually, you wouldn't be able to cut any more. You would have only one particle left. They named these particles *atoms*, a term that means "cannot be divided." Another way to imagine this is to picture a string of beads like the one shown in **Figure 1.** If you keep dividing the string into pieces, you eventually come to one single bead.

Describing the Unseen The early philosophers didn't try to prove their theories by doing experiments as scientists now do. Their theories were the result of reasoning, debating, and discussion—not of evidence or proof. Today, scientists will not accept a theory that is not supported by experimental evidence. But even if these philosophers had experimented, they could not have proven the existence of atoms. People had not yet discovered much about what is now called chemistry, the study of matter. The kind of equipment needed to study matter was a long way from being invented. Even as recently as 500 years ago, atoms were still a mystery.

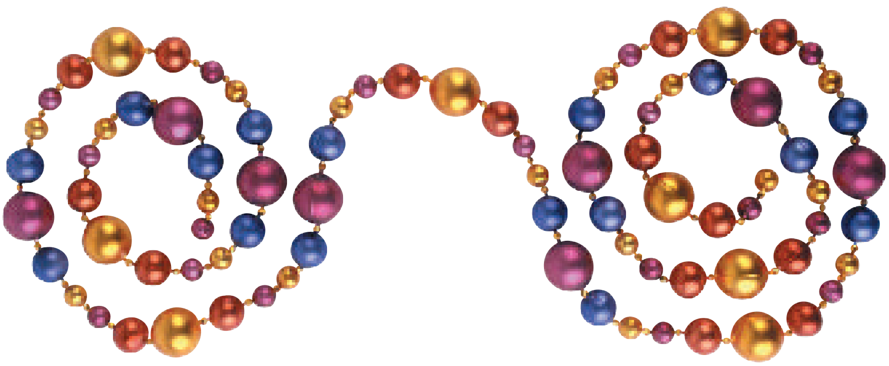


Figure 1 You can divide this string of beads in half, and in half again until you have one, indivisible bead. Like this string of beads, all matter can be divided until you reach one basic particle, the atom.

EyeWire

Figure 2 Even though the laboratories of the time were simple compared to those of today, incredible discoveries were made during the eighteenth century.

A Model of the Atom

A long period passed before the theories about the atom were developed further. Finally during the eighteenth century, scientists in laboratories, like the one on the left in **Figure 2,** began debating the existence of atoms once more. Chemists were learning about matter and how it changes. They were putting substances together to form new substances and taking substances apart to find out what they were made of. They found that certain substances couldn't be broken down into simpler substances. Scientists came to realize that all matter is made up of elements. An **element** is matter made of atoms of only one kind. For example, iron is an element made of iron atoms. Silver, another element, is made of silver atoms. Carbon, gold, and oxygen are other examples of elements.

Dalton's Concept John Dalton, an English schoolteacher in the early nineteenth century, combined the idea of elements with the eariler theory of the atom. He proposed the following ideas about matter: (1) Matter is made up of atoms, (2) atoms cannot be divided into smaller pieces, (3) all the atoms of an element are exactly alike, and (4) different elements are made of different kinds of atoms. Dalton pictured an atom as a hard sphere that was the same throughout, something like a tiny marble. A model like this is shown in **Figure 3.**

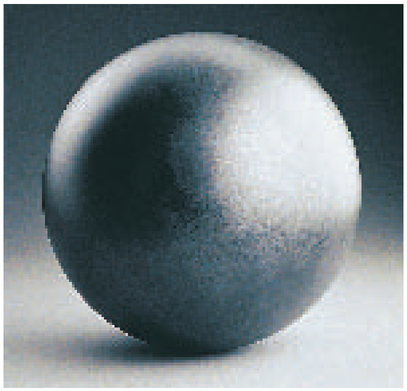


Figure 3 Dalton pictured the atom as a hard sphere that was the same throughout.
Describe *Dalton's theory of the atom.*

Scientific Evidence Dalton's theory of the atom was tested in the second half of the nineteenth century. In 1870, the English scientist William Crookes did experiments with a glass tube that had almost all the air removed from it. The glass tube had two pieces of metal called electrodes sealed inside. The electrodes were connected to a battery by wires.

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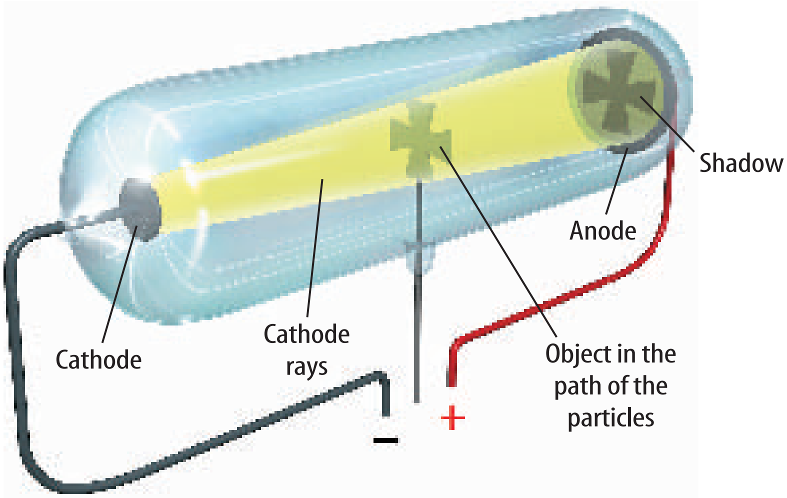
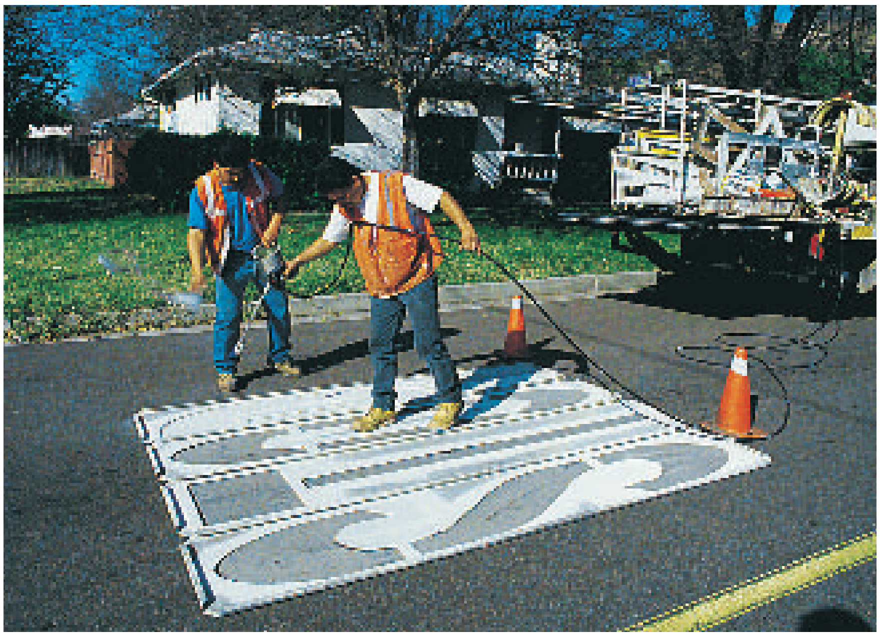
Figure 4 Crookes used a glass tube containing only a small amount of gas. When the glass tube was connected to a battery, something flowed from the negative electrode (cathode) to the positive electrode (anode).
Explain *if this unknown thing was light or a stream of particles.*



A Strange Shadow An electrode is a piece of metal that can conduct electricity. One electrode, called the anode, has a positive charge. The other, called the cathode, has a negative charge. In the tube that Crookes used, the metal cathode was a disk at one end of the tube. In the center of the tube was an object shaped like a cross, as you can see in **Figure 4.** When the battery was connected, the glass tube suddenly lit up with a greenish-colored glow. A shadow of the object appeared at the opposite end of the tube—the anode. The shadow showed Crookes that something was traveling in a straight line from the cathode to the anode, similar to the beam of a flashlight. The cross-shaped object was getting in the way of the beam and blocking it, just like when a road crew uses a stencil to block paint from certain places on the road when they are marking lanes and arrows. You can see this in **Figure 5.**

Figure 5 Paint passing by a stencil is an example of what happened with Crookes' tube, the cathode ray, and the cross.



Cathode Rays Crookes hypothesized that the green glow in the tube was caused by rays, or streams of particles. These rays were called cathode rays because they were produced at the cathode. Crookes' tube is known as a cathode-ray tube, or CRT. **Figure 6** shows a CRT. They were used for TV and computer display screens for many years now.

Reading Check

What are cathode rays?

Discovering Charged Particles

The news of Crookes' experiments excited the scientific community of the time. But many scientists were not convinced that the cathode rays were streams of particles. Was the greenish glow light, or was it a stream of charged particles? In 1897, J.J. Thomson, an English physicist, tried to clear up the confusion. He placed a magnet beside the tube from Crookes' experiments. In **Figure 7,** you can see that the beam is bent in the direction of the magnet. Light cannot be bent by a magnet, so the beam couldn't be light. Therefore, Thomson concluded that the beam must be made up of charged particles of matter that came from the cathode.

Figure 6 The cathode-ray tube got its name because the particles start at the cathode and travel to the anode. At one time, a CRT was in every TV and computer monitor.

The Electron Thomson then repeated the CRT experiment using different metals for the cathode and different gases in the tube. He found that the same charged particles were produced no matter what elements were used for the cathode or the gas in the tube. Thomson concluded that cathode rays are negatively charged particles of matter. How did Thomson know the particles were negatively charged? He knew that opposite charges attract each other. He observed that these particles were attracted to the positively charged anode, so he reasoned that the particles must be negatively charged.

These negatively charged particles are now called **electrons.** Thomson also inferred that electrons are a part of every kind of atom because they are produced by every kind of cathode material. Perhaps the biggest surprise that came from Thomson's experiments was the evidence that particles smaller than the atom do exist.

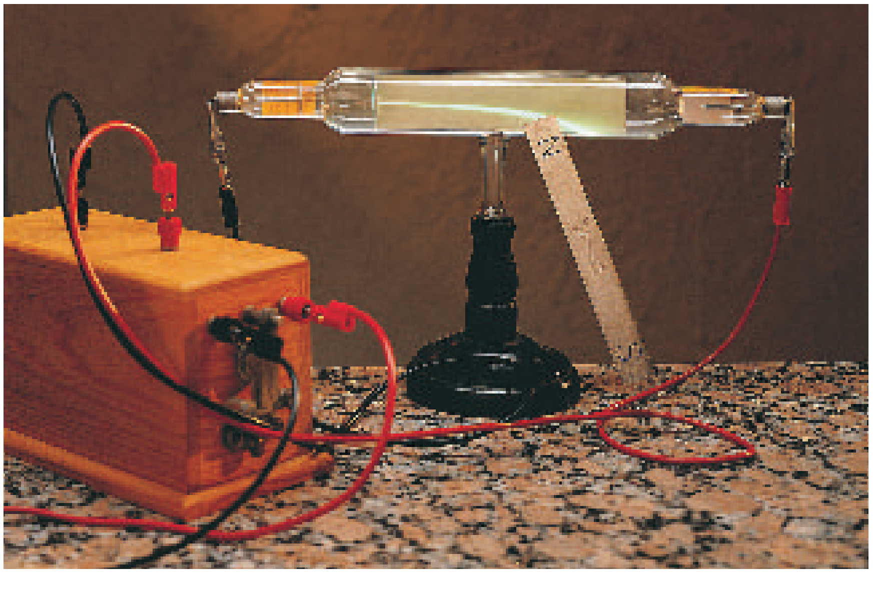


Figure 7 When a magnet was placed near a CRT, the cathode rays were bent. Since light is not bent by a magnet, Thomson determined that cathode rays were made of charged particles.

(t)L.S. Stepanowicz/Panographics, (b)Skip Comer

Figure 8 Modeling clay with ball bearings mixed through is another way to picture the J.J. Thomson atom. The clay contains all the positive charge of the atom. The ball bearings, which represent the negatively charged electrons, are mixed evenly in the clay.
Explain *why Thomson included positive particles in his atomic model.*

Thomson's Atomic Model Some of the questions posed by scientists were answered in light of Thomson's experiments. However, the answers inspired new questions. If atoms contain one or more negatively charged particles, then all matter, which is made of atoms, should be negatively charged as well. But all matter isn't negatively charged. Could it be that atoms also contain some positive charge? The negatively charged electrons and the unknown positive charge would then neutralize each other in the atom. Thomson came to this conclusion and included positive charge in his model of the atom.

Using his new findings, Thomson revised Dalton's model of the atom. Instead of a solid ball that was the same throughout, Thomson pictured a sphere of positive charge. The negatively charged electrons were spread evenly among the positive charge. This is modeled by the ball of clay shown in **Figure 8.** The positive charge of the clay is equal to the negative charge of the electrons. Therefore, the atom is neutral. It was later discovered that not all atoms are neutral. The number of electrons within an element can vary. If there is more positive charge than negative electrons, the atom has an overall positive charge. If there are more negative electrons than positive charge, the atom has an overall negative charge.

Reading Check *What particle did Thomson's model have scattered through it?*

Rutherford's Experiments

A model is not accepted in the scientific community until it has been tested and the tests support previous observations. In 1906, Ernest Rutherford and his coworkers began an experiment to find out if Thomson's model of the atom was correct. They wanted to see what would happen when they fired fast-moving, positively charged bits of matter, called alpha particles, at a thin film of a metal such as gold. Alpha particles, which come from unstable atoms, are positively charged, and so they are repelled by particles of matter which also have a positive charge.

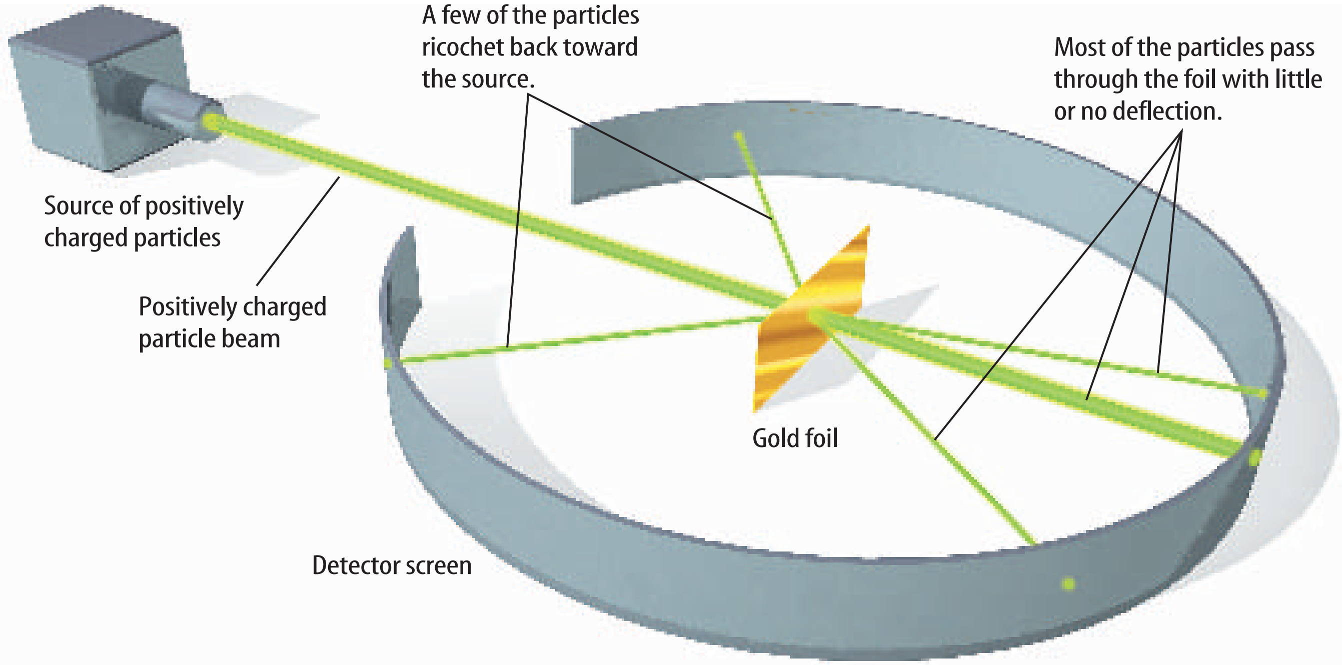
Figure 9 shows how the experiment was set up. A source of alpha particles was aimed at a thin sheet of gold foil that was only 400 nm thick. The foil was surrounded by a fluorescent (floo REH sunt) screen that gave a flash of light each time it was hit by a charged particle.

Expected Results Rutherford was certain he knew what the results of this experiment would be. His prediction was that most of the speeding alpha particles would pass right through the foil and hit the screen on the other side, just like a bullet fired through a pane of glass. Rutherford reasoned that the thin, gold film did not contain enough matter to stop the speeding alpha particle or change its path. Also, there wasn't enough charge in any one place in Thomson's model to repel the alpha particle strongly. He thought that the positive charge in the gold atoms might cause a few minor changes in the path of the alpha particles. However, he assumed that this would only occur a few times.

That was a reasonable hypothesis because in Thomson's model, the positive charge is essentially neutralized by nearby electrons. Rutherford was so sure of what the results would be that he turned the work over to a graduate student.

The Model Fails Rutherford was shocked when his student rushed in to tell him that some alpha particles were veering off at large angles. You can see this in **Figure 9.** Rutherford expressed his amazement by saying, "It was about as believable as if you had fired a 15-inch shell at a piece of tissue paper, and it came back and hit you." How could such an event be explained? The positively charged alpha particles were moving with such high speed that it would take a large positive charge to cause them to bounce back. The uniform mix of mass and charges in Thomson's model of the atom did not allow for this kind of result.

Figure 9 In Rutherford's experiment, alpha particles bombarded the gold foil. Most particles passed right through the foil or veered slightly from a straight path, but some particles bounced right back. The path of a particle is shown by a flash of light when it hits the fluorescent screen.



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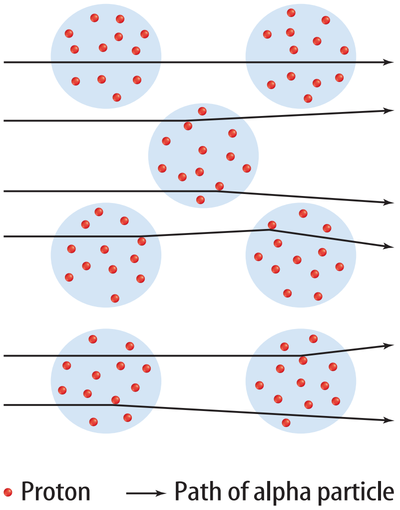


Figure 10 Rutherford thought that if the atom could be described by Thomson's model, as shown above, then only minor bends in the paths of the particles would have occurred.

A Model with a Nucleus

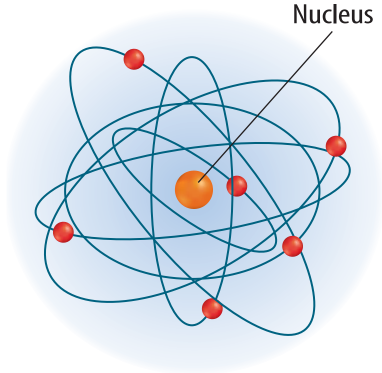
Now Rutherford and his team had to come up with an explanation for these unexpected results. They might have drawn diagrams like those in **Figure 10,** which uses Thomson's model and shows what Rutherford expected. Now and then, an alpha particle might be affected slightly by a positive charge in the atom and turn a bit off course. However, large changes in direction were not expected.

The Proton The actual results did not fit this model, so Rutherford proposed a new one, shown in **Figure 11.** He hypothesized that almost all the mass of the atom and all of its positive charge are crammed into an incredibly small region of space at the center of the atom called the nucleus. Eventually, his prediction was proved true. In 1920 scientists identified the positive charges in the nucleus as protons. A **proton** is a positively charged particle present in the nucleus of all atoms. The rest of each atom is empty space occupied by the atom's almost-massless electrons.

Reading Check *How did Rutherford describe his new model?*

Figure 12 shows how Rutherford's new model of the atom fits the experimental data. Most alpha particles could move through the foil with little or no interference because of the empty space that makes up most of the atom. However, if an alpha particle made a direct hit on the nucleus of a gold atom, which has 79 protons, the alpha particle would be strongly repelled and bounce back.

Figure 11 The nuclear model was new and helped explain experimental results.



Rutherford's model included the dense center of positive charge known as the nucleus.

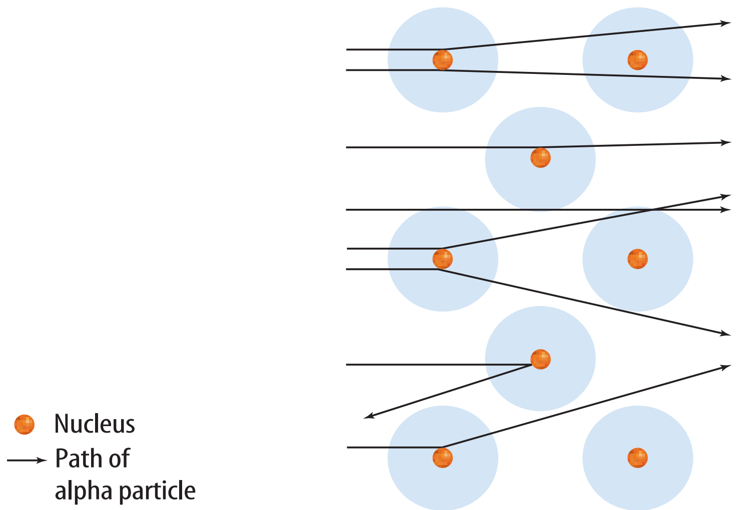


Figure 12 This nucleus that contained most of the mass of the atom caused the deflections that were observed in his experiment.

The Neutron Rutherford's nuclear model was applauded as other scientists reviewed the results of the experiments. However, some data didn't fit. Once again, more questions arose and the scientific process continued. For instance, an atom's electrons have almost no mass. According to Rutherford's model, the only other particle in the atom was the proton. That meant that the mass of an atom should have been approximately equal to the mass of its protons. However, it wasn't. The mass of most atoms is at least twice as great as the mass of its protons. That left scientists with a dilemma and raised a new question. Where does the extra mass come from if only protons and electrons make up the atom?

It was proposed that another particle must be in the nucleus to account for the extra mass. The particle, which was later called the **neutron** (NEW trahn), would have the same mass as a proton and be electrically neutral. Proving the existence of neutrons was difficult though, because a neutron has no charge. Therefore, the neutron doesn't respond to magnets or cause fluorescent screens to light up. It took another 20 years before scientists were able to show by more modern experiments that atoms contain neutrons.

Reading Check *What particles are in the nucleus of the nuclear atom?*

The model of the atom was revised again to include the newly discovered neutrons in the nucleus. The nuclear atom, shown in **Figure 13,** has a tiny nucleus tightly packed with positively charged protons and neutral neutrons. Negatively charged electrons occupy the space surrounding the nucleus. The number of electrons in a neutral atom equals the number of protons in the atom.

Mini LAB

Modeling the Nuclear Atom

Procedure

1. On a sheet of **paper,** draw a circle with a diameter equal to the width of the paper.
2. **Small dots of paper in two colors** will represent protons and neutrons. Using a dab of **glue** on each paper dot, make a model of the nucleus of the oxygen atom in the center of your circle. Oxygen has eight protons and eight neutrons.

Analysis

1. What particle is missing from your model of the oxygen atom?
2. How many of that missing particle should there be, and where should they be placed?

Try at Home

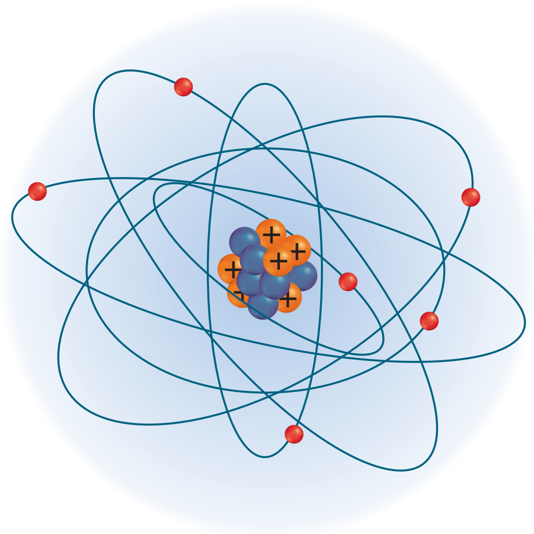


Figure 13 This atom of carbon, atomic number 6, has six protons and six neutrons in its nucleus.
Identify *how many electrons are in the "empty" space surrounding the nucleus.*

Figure 14 If this Ferris wheel in London, with a diameter of 132 m, were the outer edge of the atom, the nucleus would be about the size of a single letter *o* on this page.

Size and Scale Drawings of the nuclear atom such as the one in **Figure 13** don't give an accurate representation of the extreme smallness of the nucleus compared to the rest of the atom. For example, if the nucleus were the size of a table-tennis ball, the atom would have a diameter of more than 2.4 km. Another way to compare the size of a nucleus with the size of the atom is shown in **Figure 14.** Perhaps now you can see better why in Rutherford's experiment, most of the alpha particles went directly through the gold foil without any interference from the gold atoms. Plenty of empty space allows the alpha particles an open pathway.

INTEGRATE Physics

Physicists In the 1920s, physicists began to think that electrons—like light—have a wave/particle nature. This is called quantum theory. Research which two scientists introduced this theory. In your Science Journal, infer how thoughts about atoms changed.

Further Developments

Even into the twentieth century, physicists were working on a theory to explain how electrons are arranged in an atom. It was natural to think that the negatively charged electrons are attracted to the positive nucleus in the same way the Moon is attracted to Earth. Then, electrons would travel in orbits around the nucleus. A physicist named Niels Bohr even calculated exactly what energy levels those orbits would represent for the hydrogen atom. His calculations explained experimental data found by other scientists. However, scientists soon learned that electrons are in constant, unpredictable motion and can't be described easily by an orbit. They determined that it was impossible to know the precise location of an electron at any particular moment. Their work inspired even more research and brainstorming among scientists around the world.

Electrons as Waves Physicists began to wrestle with explaining the unpredictable nature of electrons. Surely the experimental results they were seeing and the behavior of electrons could somehow be explained with new theories and models. The unconventional solution was to understand electrons not as particles, but as waves. This led to further mathematical models and equations that brought much of the experimental data together.

The Electron Cloud Model The new model of the atom allows for the somewhat unpredictable wave nature of electrons by defining a region where the electron is most likely to be found. Electrons travel in a region surrounding the nucleus, which is called the **electron cloud**. The current model for the electron cloud is shown in **Figure 15.** The electrons are more likely to be close to the nucleus rather than farther away because they are attracted to the positive charges of the protons. Notice the fuzzy outline of the cloud. Because the electrons could be anywhere, the cloud has no firm boundary. Interestingly, within the electron cloud, the electron in a hydrogen atom probably is found in the region Bohr calculated.

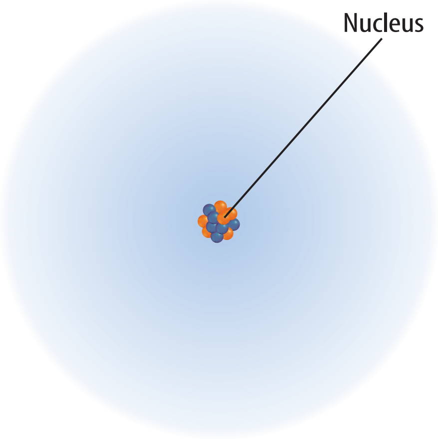


Figure 15 The electrons are more likely to be close to the nucleus rather than farther away, but they could be anywhere. **Explain** *why the electrons woud be closer to the nucleus.*

section 1 review

Summary

Models of the Atom

- Some early philosophers believed all matter was made of small particles.
- John Dalton proposed that all matter is made of atoms that were hard spheres.
- J. J. Thomson showed that the particles in a CRT were negatively charged particles, later called electrons. These were smaller than an atom. He proposed the atom as a sphere of positive charge with electrons spread evenly among the charge.
- In his experiments, Rutherford showed that positive charge existed in a small region of the atom which he called the nucleus. The positive charge was called a proton.
- In order to explain the mass of an atom, the neutron was proposed, an uncharged particle the same mass as a proton and in the nucleus.
- Electrons are now believed to move about the nucleus in an electron cloud.

Self Check

1. **Explain** how the nuclear atom differs from the uniform sphere model of the atom.
2. **Determine** how many electrons a neutral atom with 49 protons has.
3. **Describe** what cathode rays are and how they were discovered.
4. **Think Critically** In Rutherford's experiment, why wouldn't the electrons in the atoms of the gold foil affect the paths of the alpha particles.
5. **Concept Map** Design and complete a concept map using all the words in the vocabulary list for this section. Add any other terms or words that will help create a complete diagram of the section and the concepts in contains.

Applying Math

6. **Solve One-Step Equations** The mass of an electron is 9.11×10^{-28} g. The mass of a proton is 1,836 times more than that of the electron. Calculate the mass of the proton in grams and convert that mass into kilograms.

section 2

The Simplest Matter

as you read

What You'll Learn

- **Describe** the relationship between elements and the periodic table.
- **Explain** the meaning of atomic mass and atomic number.
- **Identify** what makes an isotope.
- **Contrast** metals, metalloids, and nonmetals.

Why It's Important

Everything on Earth is made of the elements that are listed on the periodic table.

Review Vocabulary

mass: a measure of the amount of matter

New Vocabulary

- atomic number
- isotope
- mass number
- atomic mass
- metals
- nonmetals
- metalloids

The Elements

Have you watched television today? TV sets are common, yet each one is a complex system. The outer case is made mostly of plastic, and the screen is made of glass. Many of the parts that conduct electricity are metals or combinations of metals. Other parts in the interior of the set contain materials that barely conduct electricity. All of the different materials have one thing in common. They are made up of even simpler materials. In fact, if you had the proper equipment, you could separate the plastics, glass, and metals into these simpler materials.

One Kind of Atom Eventually, though, you would separate the materials into groups of atoms. At that point, you would have a collection of elements. Recall that an element is matter made of only one kind of atom. At least 115 elements are known and about 90 of them occur naturally on Earth. These elements make up gases in the air, minerals in rocks, and liquids such as water. Examples of naturally occurring elements include the oxygen and nitrogen in the air you breathe and the metals gold, silver, aluminum, and iron. The other elements are known as synthetic elements. These elements have been made in nuclear reactions by scientists with machines called particle accelerators, like the one shown in **Figure 16.** Some synthetic elements have important uses in medical testing and are found in smoke detectors and heart pacemaker batteries.

Figure 16 The Tevatron has a circumference of 6.3 km—a distance that allows particles to accelerate to high speeds. These high-speed collisions can create synthetic elements.

Fermi National Accelerator Laboratory/Science Photo Library/Photo Researchers

Figure 17 When you look for information in the library, a system of organization called the Dewey Decimal Classification System helps you find a book quickly and efficiently.

Dewey Decimal Classification System	
000	Computers, information, and general reference
100	Philosophy and psychology
200	Religion
300	Social sciences
400	Language
500	Science
600	Technology
700	Arts and recreation
800	Literature
900	Philosophy and psychology

The Periodic Table

Suppose you go to a library, like the one shown in **Figure 17,** to look up information for a school assignment. How would you find the information? You could look randomly on shelves as you walk up and down rows of books, but the chances of finding your book would be slim. Not only that, you also would probably become frustrated in the process. To avoid such haphazard searching, some libraries use the Dewey Decimal Classification System to categorize and organize their volumes and to help you find books quickly and efficiently.

Charting the Elements When scientists need to look up information about an element or select one to use in the laboratory, they need to be quick and efficient, too. Chemists have created a chart called the periodic table of the elements to help them organize and display the elements. **Figure 18** shows how scientists changed their model of the periodic table over time.

On the inside back cover of this book, you will find a modern version of the periodic table. Each element is represented by a chemical symbol that contains one to three letters. The symbols are a form of chemical shorthand that chemists use to save time and space—on the periodic table as well as in written formulas. The symbols are an important part of an international system that is understood by scientists everywhere.

The elements are organized on the periodic table by their properties. There are rows and columns that represent relationships between the elements. The rows in the table are called periods. The elements in a row have the same number of energy levels. The columns are called groups. The elements in each group have similar properties related to their structure. They also tend to form similar bonds.

INTEGRATE History

Dewey Decimal System Melvil Dewey is the man responsible for organizing our knowledge and libraries. His working in the Amherst College library led him to propose a method of classifying books. The Dewey Decimal System divides books into ten categories. Since 1876, this classification system has helped us locate information easily.

Tom Stewart/The Stock Market/CORBIS

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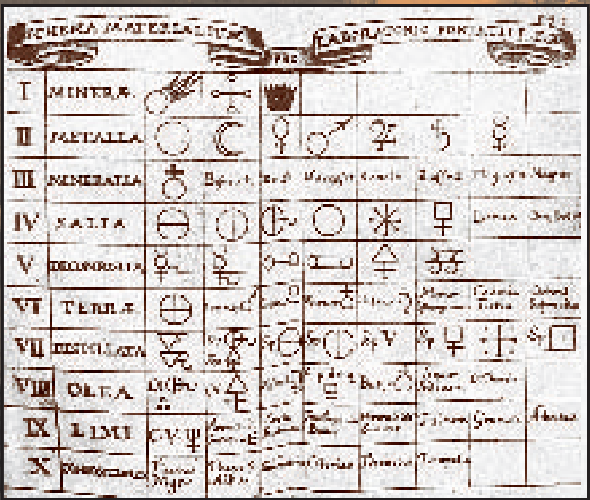
Figure 18

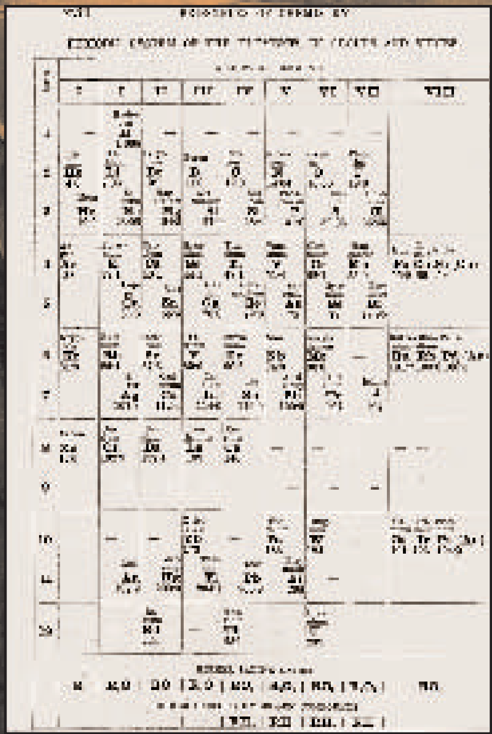
The familiar periodic table that adorns many science classrooms is based on a number of earlier efforts to identify and classify the elements. In the 1790s, one of the first lists of elements and their compounds was compiled by French chemist Antoine-Laurent Lavoisier, who is shown in the background picture with his wife and assistant, Marie Anne. Three other tables are shown here.

John Dalton (Britain, 1803) used symbols to represent elements. His table also assigned masses to each element.



An early alchemist put together this table of elements and compounds. Some of the symbols have their origin in astrology.

Dmitri Mendeleev (Russia, 1869) arranged the 63 elements known to exist at that time into groups based on their chemical properties and atomic weights. He left gaps for elements he predicted were yet to be discovered.



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Identifying Characteristics

Each element is different and has unique properties. These differences can be described in part by looking at the relationships between the atomic particles in each element. The periodic table contains numbers that describe these relationships.

Number of Protons and Neutrons Look up the element chlorine on the periodic table found on the inside back cover of your book. Cl is the symbol for chlorine, as shown in **Figure 19,** but what are the two numbers? The top number is the element's **atomic number.** It tells you the number of protons in the nucleus of each atom of that element. Every atom of chlorine, for example, has 17 protons in its nucleus.

Reading Check *What are the atomic numbers for Cs, Ne, Pb, and U?*

Isotopes Although the number of protons changes from element to element, every atom of the same element has the same number of protons. However, the number of neutrons can vary even for one element. For example, some chlorine atoms have 18 neutrons in their nucleus while others have 20. These two types of chlorine atoms are chlorine-35 and chlorine-37. They are called **isotopes** (I suh tohps), which are atoms of the same element that have different numbers of neutrons.

You can tell someone exactly which isotope you are referring to by using its mass number. An atom's **mass number** is the number of protons plus the number of neutrons it contains. The numbers 35 and 37, which were used to refer to chlorine, are mass numbers. Hydrogen has three isotopes with mass numbers of 1, 2, and 3. They are shown in **Figure 20.** Each hydrogen atom always has one proton, but in each isotope the number of neutrons is different.

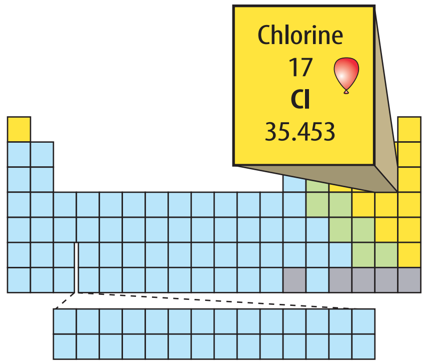
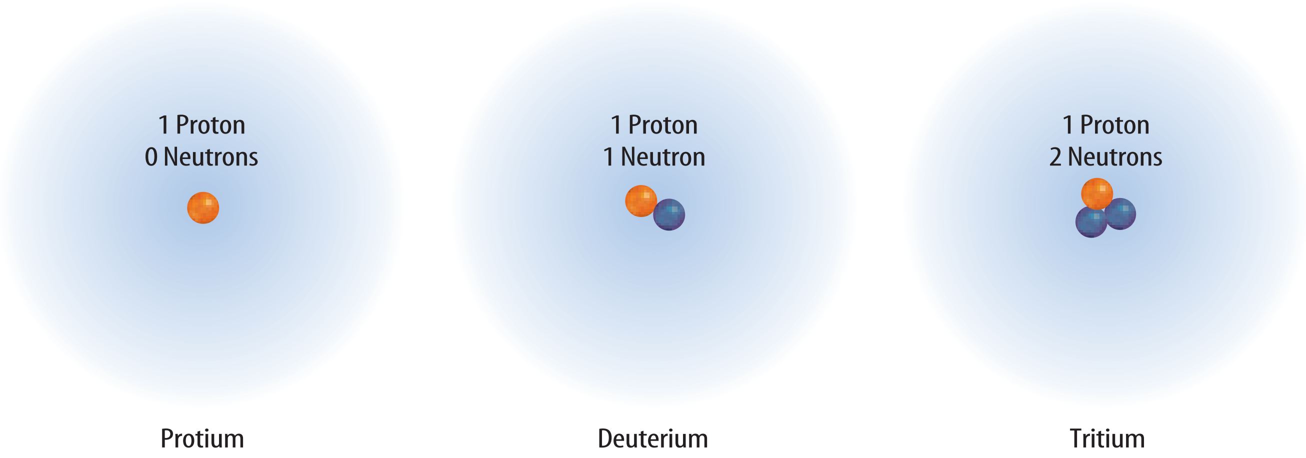


Figure 19 The periodic table block for chlorine shows its symbol, atomic number, and atomic mass.
Determine *if chlorine atoms are more or less massive than carbon atoms.*

Figure 20 Three isotopes of hydrogen are known to exist. They have zero, one, and two neutrons in addition to their one proton. Protium, with only the one proton, is the most abundant isotope.



Circle Graph Showing Abundance of Chlorine Isotopes

Average atomic mass = 35.45 u

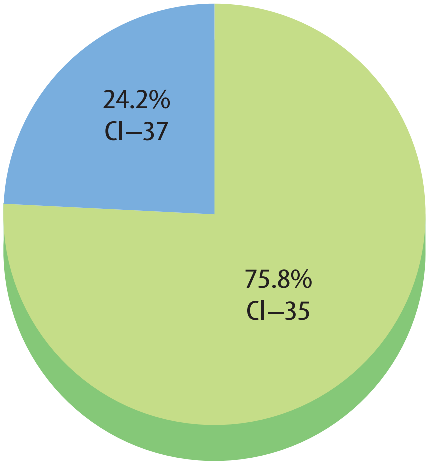


Figure 21 If you have 1,000 atoms of chlorine, about 758 will be chlorine-35 and have a mass of 34.97 u each. About 242 will be chlorine-37 and have a mass of 36.97 u each. The total mass of the 1,000 atoms is 35,454 u, so the average mass of one chlorine atom is about 35.45 u.

Atomic Mass The **atomic mass** is the weighted average mass of the isotopes of an element. The atomic mass is the number found below the element symbol in **Figure 19.** The unit that scientists use for atomic mass is called the atomic mass unit, which is given the symbol u. It is defined as 1/12 the mass of a carbon-12 atom.

The calculation of atomic mass takes into account the different isotopes of the element. Chlorine's atomic mass of 35.45 u could be confusing because there aren't any chlorine atoms that have that exact mass. About 76 percent of chlorine atoms are chlorine-35 and about 24 percent are chlorine-37, as shown in **Figure 21.** The weighted average mass of all chlorine atoms is 35.45 u.

Classification of Elements

Elements fall into three general categories—metals, metalloids (ME tuh loydz), and nonmetals. The elements in each category have similar properties.

Metals generally have a shiny or metallic luster and are good conductors of heat and electricity. All metals, except mercury, are solids at room temperature. Metals are malleable (MAL yuh bul), which means they can be bent and pounded into various shapes. The beautiful form of the shell-shaped basin in **Figure 22** is a result of this characteristic. Metals are also ductile, which means they can be drawn into wires without breaking. If you look at the periodic table, you can see that most of the elements are metals.

Figure 22 The artisan is chasing, or chiseling, the malleable metal into the desired form.

Emmanuel Scorcelletti/Liaison Agency/Getty Images

Other Elements **Nonmetals** are elements that are usually dull in appearance. Most are poor conductors of heat and electricity. Many are gases at room temperature, and bromine is a liquid. The solid nonmetals are generally brittle, meaning they cannot change shape easily without breaking. The nonmetals are essential to the chemicals of life. More than 97 percent of your body is made up of various nonmetals, as shown in **Figure 23.** You can see that, except for hydrogen, the nonmetals are found on the right side of the periodic table.

Metalloids are elements that have characteristics of metals and nonmetals. On the periodic table, metalloids are found between the metals and nonmetals. All metalloids are solids at room temperature. Some metalloids are shiny and many are conductors, but they are not as good at conducting heat and electricity as metals are. Some metalloids, such as silicon, are used to make the electronic circuits in computers, televisions, and other electronic devices.

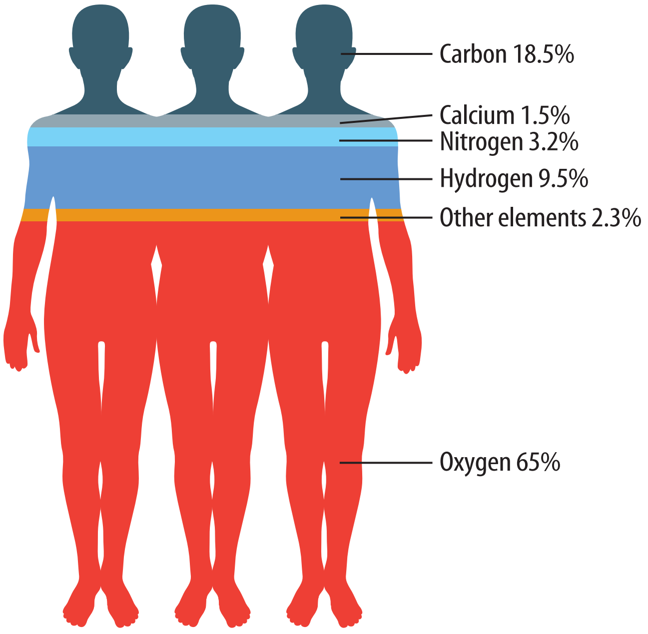


Figure 23 You are made up of mostly nonmetals.

section 2 review

Summary

The Elements

- An element is matter made of only one type of atom.
- Some elements occur naturally on Earth. Synthetic elements are made in nuclear reactions in particle accelerators.

The Periodic Table

- The periodic table arranges and displays all known elements in an orderly way.
- Each element has been given a chemical symbol that is used on a periodic table.

Identifying Characteristics

- Each element has a unique number of protons, called the atomic mass number.
- Isotopes of elements are important when determining the atomic mass of an element.

Classification of Elements

- Elements are divided into three categories based on certain properties: metal, metalloids, and nonmetals.

Self Check

1. **Explain** some of the uses of metals based on their properties.
2. **Describe** the difference between atomic number and atomic mass.
3. **Define** the term *isotope*. Explain how two isotopes of an element are different.
4. **Think Critically** Describe how to find the atomic number for the element oxygen. Explain what this information tells you about oxygen.
5. **Interpret Data** Look up the atomic mass of the element boron in the periodic table inside the back cover of this book. The naturally occurring isotopes of boron are boron-10 and boron-11. Explain which of the two isotopes is more abundant?

Applying Math

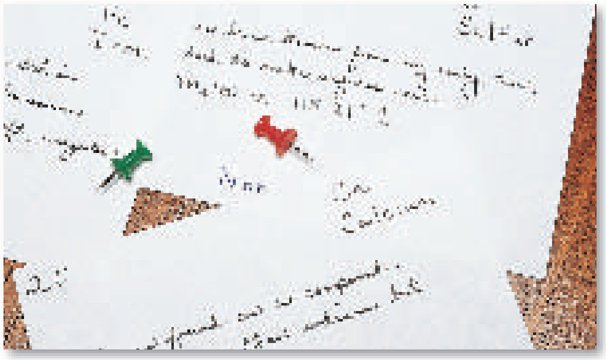
6. **Solve One-Step Equations** An atom of niobium has a mass number of 93. How many neutrons are in the nucleus of this atom? An atom of phosphorus has 15 protons and 15 neutrons in the nucleus. What is the mass number of this isotope?

Science Online bookk.msscience.com/self_check_quiz

LAB

Elements and the Periodic Table

The periodic table organizes the elements, but what do they look like? What are they used for? In this lab, you'll examine some elements and share your findings with your classmates.



Real-World Questions

What are some of the characteristics and purposes of the chemical elements?

Goals

- **Classify** the chemical elements.
- **Organize** the elements into the groups and periods of the periodic table.

Materials

colored markers
large index cards
Merck Index
encyclopedia
*other reference materials
large bulletin board
81/2-in × 14-in paper
thumbtacks
*pushpins

*Alternate materials

Safety Precautions

WARNING: *Use care when handling sharp objects.*

Procedure

1. Select the assigned number of elements from the list provided by your teacher.
2. **Design** an index card for each of your selected elements. On each card, mark the element's atomic number in the upper left-hand corner and write its symbol and name in the upper right-hand corner.
3. **Research** each of the elements and write several sentences on the card about its appearance, its other properties, and its uses.
4. **Classify** each element as a metal, a metalloid, or a nonmetal based upon its properties.
5. **Write** the appropriate classification on each of your cards using the colored marker chosen by your teacher.
6. Work with your classmates to make a large periodic table. Use thumbtacks to attach your cards to a bulletin board in their proper positions on the periodic table.
7. **Draw** your own periodic table. Place the elements' symbols and atomic numbers in the proper locations on your table.

Conclude and Apply

1. **Interpret** the class data and classify the elements into the categories metal, metalloid, and nonmetal. Highlight each category in a different color on your periodic table.
2. **Predict** the properties of a yet-undiscovered element located directly under francium on the periodic table.

Communicating Your Data

Compare and contrast your table with that of a friend. Discuss the differences. **For more help, refer to the Science Skill Handbook.**

Doug Martin

section 3

Compounds and Mixtures

Substances

Scientists classify matter in several ways that depend on what it is made of and how it behaves. For example, matter that has the same composition and properties throughout is called a **substance.** Elements, such as a bar of gold or a sheet of aluminum, are substances. When different elements combine, other substances are formed.

Compounds The elements hydrogen and oxygen exist as separate, colorless gases. However, these two elements can combine, as shown in **Figure 24,** to form the compound water, which is different from the elements that make it up. A **compound** is a substance whose smallest unit is made up of atoms of more than one element bonded together.

Compounds often have properties that are different from the elements that make them up. Water is distinctly different from the elements that make it up. It is also different from another compound made from the same elements. Have you ever used hydrogen peroxide (H_2O_2) to disinfect a cut? This compound is a different combination of hydrogen and oxygen and has different properties from those of water.

Water is a nonirritating liquid that is used for bathing, drinking, cooking, and much more. In contrast, hydrogen peroxide carries warnings on its labels such as *Keep Hydrogen Peroxide Out of the Eyes.* Although it is useful in solutions for cleaning contact lenses, it is not safe for your eyes as it comes from the bottle.

as you read

What You'll Learn

- **Identify** the characteristics of a compound.
- **Compare and contrast** different types of mixtures.

Why It's Important

The food you eat, the materials you use, and all matter can be classified by compounds or mixtures.

Review Vocabulary

formula: shows which elements and how many atoms of each make up a compound.

New Vocabulary

- substance
- compound
- mixture

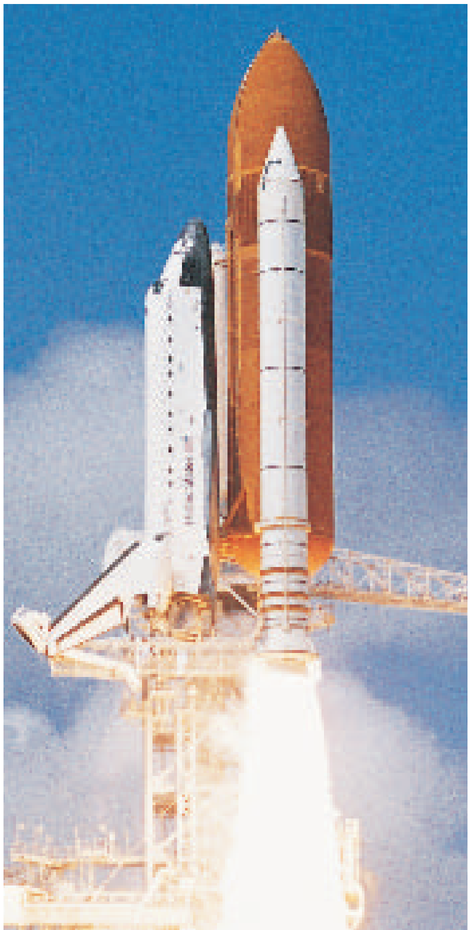
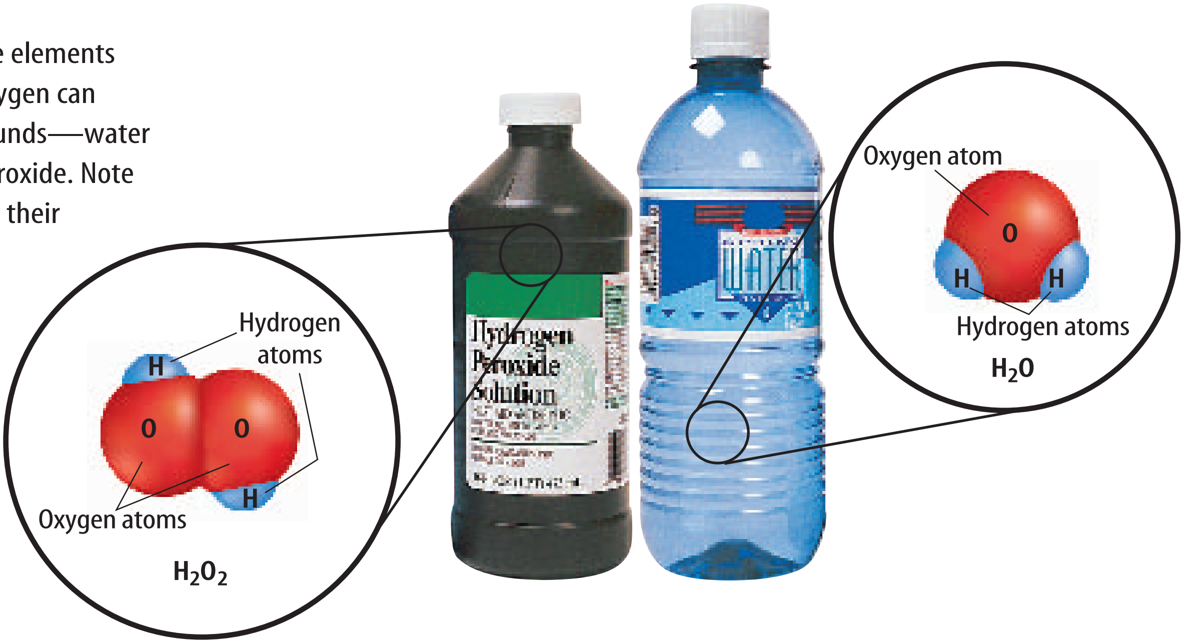


Figure 24 A space shuttle is powered by the reaction between liquid hydrogen and liquid oxygen. The reaction produces a large amount of energy and the compound water.
Explain *why a car that burns hydrogen rather than gasoline would be friendly to the environment.*

NASA

Figure 25 The elements hydrogen and oxygen can form two compounds—water and hydrogen peroxide. Note the differences in their structure.



Compounds Have Formulas What's the difference between water and hydrogen peroxide? H_2O is the chemical formula for water, and H_2O_2 is the formula for hydrogen peroxide. The formula tells you which elements make up a compound as well as how many atoms of each element are present. Look at **Figure 25.** The subscript number written below and to the right of each element's symbol tells you how many atoms of that element exist in one unit of that compound. For example, hydrogen peroxide has two atoms of hydrogen and two atoms of oxygen. Water is made up of two atoms of hydrogen and one atom of oxygen.

Carbon dioxide, CO_2, is another common compound. Carbon dioxide is made up of one atom of carbon and two atoms of oxygen. Carbon and oxygen also can form the compound carbon monoxide, CO, which is a gas that is poisonous to all warm-blooded animals. As you can see, no subscript is used when only one atom of an element is present. A given compound always is made of the same elements in the same proportion. For example, water always has two hydrogen atoms for every oxygen atom, no matter what the source of the water is. No matter what quantity of the compound you have, the formula of the compound always remains the same. If you have 12 atoms of hydrogen and six atoms of oxygen, the compound is still written H_2O, but you have six molecules of H_2O (6 H_2O), not $H_{12}O_6$. The formula of a compound communicates its identity and makeup to any scientist in the world.

Reading Check *Propane has three carbon and eight hydrogen atoms. What is its chemical formula?*

Mini LAB

Comparing Compounds

Procedure

1. Collect the following substances—**granular sugar, rubbing alcohol,** and **salad oil.**
2. Observe the color, appearance, and state of each substance. Note the thickness or texture of each substance.
3. Stir a spoonful of each substance into separate **beakers of hot water** and observe.

Analysis

1. Compare the different properties of the substances.
2. The formulas of the three substances are made of only carbon, hydrogen, and oxygen. Infer how they can have different properties.

Mark Burnett

Mixtures

When two or more substances (elements or compounds) come together but don't combine to make a new substance, a **mixture** results. Unlike compounds, the proportions of the substances in a mixture can be changed without changing the identity of the mixture. For example, if you put some sand into a bucket of water, you have a mixture of sand and water. If you add more sand or more water, it's still a mixture of sand and water. Its identity has not changed. Air is another mixture. Air is a mixture of nitrogen, oxygen, and other gases, which can vary at different times and places. Whatever the proportion of gases, it is still air. Even your blood is a mixture that can be separated, as shown in **Figure 26** by a machine called a centrifuge.

Reading Check *How do the proportions of a mixture relate to its identity?*

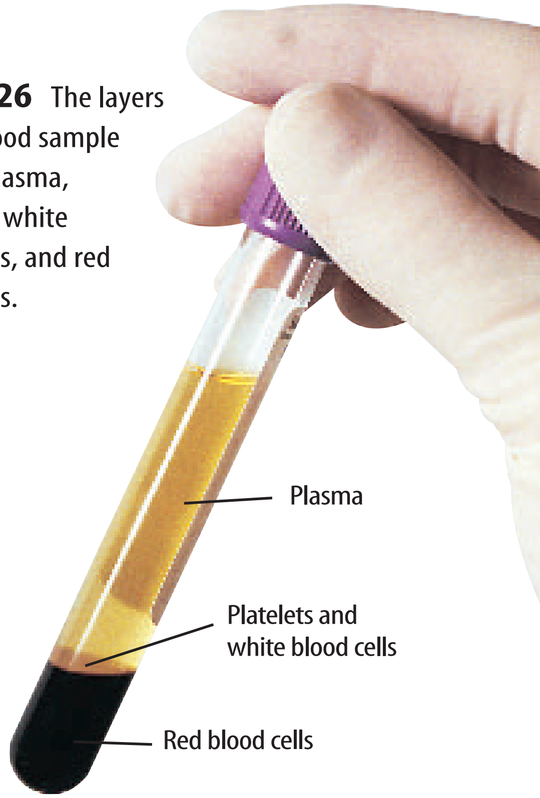


Figure 26 The layers in this blood sample include plasma, platelets, white blood cells, and red blood cells.

Applying Science

What's the best way to desalt ocean water?

You can't drink ocean water because it contains salt and other suspended materials. Or can you? In many areas of the world where drinking water is in short supply, methods for getting the salt out of salt water are being used to meet the demand for fresh water. Use your problem solving skills to find the best method to use in a particular area.

Methods for Desalting Ocean Water

Process	Amount of Water a Unit Can Desalt in a Day (m^3)	Special Needs	Number of People Needed to Operate
Distillation	1,000 to 200,000	lots of energy to boil the water	many
Electrodialysis	10 to 4,000	stable source of electricity	1 to 2 persons

Identifying the Problem

The table above compares desalting methods. In distillation, the ocean water is heated. Pure water boils off and is collected, and the salt is left behind. Electrodialysis uses electric current to pull salt particles out of water.

Solving the Problem

1. What method(s) might you use to desalt the water for a large population where energy is plentiful?
2. What method(s) would you choose to use in a single home?

Klaus Guldbrandsen/Science Photo Library/Photo Researchers

Figure 27 Mixtures are part of your everyday life.

Science Online

Topic: Mixtures

Visit bookk.msscience.com for Web links to information about separating mixtures.

Activity Describe how chemists separate the components of a mixture.

INTEGRATE Life Science

Your blood is a mixture made up of elements and compounds. It contains white blood cells, red blood cells, water, and a number of dissolved substances. The different parts of blood can be separated and used by doctors in different ways. The proportions of the substances in your blood change daily, but the mixture does not change its identity.

Separating Mixtures Sometimes you can use a liquid to separate a mixture of solids. For example, if you add water to a mixture of sugar and sand, only the sugar dissolves in the water. The sand then can be separated from the sugar and water by pouring the mixture through a filter. Heating the remaining solution will separate the water from the sugar.

At other times, separating a mixture of solids of different sizes might be as easy as pouring them through successively smaller sieves or filters. A mixture of marbles, pebbles, and sand could be separated in this way.

(tl)Mark Thayer, (tc)CORBIS, (tr)KS Studios, (bl)Kenneth Mengay/Liaison Agency/Getty Images, ...rth ...P/R... Haynes

Homogeneous or Heterogeneous

Mixtures, such as the ones shown in **Figure 27,** can be classified as homogeneous or heterogeneous. *Homogeneous* means "the same throughout." You can't see the different parts in this type of mixture. In fact, you might not always know that homogeneous mixtures are mixtures because you can't tell by looking. Which mixtures in **Figure 27** are homogeneous? No matter how closely you look, you can't see the individual parts that make up air or the parts of the mixture called brass in the lamp shown. Homogeneous mixtures can be solids, liquids, or gases.

A heterogeneous mixture has larger parts that are different from each other. You can see the different parts of a heterogeneous mixture, such as sand and water. How many heterogeneous mixtures are in **Figure 27?** A pepperoni and mushroom pizza is a tasty kind of heterogeneous mixture. Other examples of this kind of mixture include tacos, vegetable soup, a toy box full of toys, or a tool box full of nuts and bolts.

INTEGRATE Earth Science

Rocks and Minerals Scientists called geologists study rocks and minerals. A mineral is composed of a pure substance. Rocks are mixtures and can be described as being homogeneous or heterogeneous. Research to learn more about rocks and minerals and note some examples of homogeneous and heterogeneous rocks in your Science Journal.

section 3 review

Summary

Substances

- A substance can be either an element or a compound.
- A compound contains more than one kind of element bonded together.
- A chemical formula shows which elements and how many atoms of each make up a compound.

Mixtures

- A mixture contains substances that are not chemically bonded together.
- There are many ways to separate mixtures based on their physical properties.
- Homogeneous mixtures are those that are the same throughout. These types of mixtures can be solids, liquids, or gases.
- Heterogeneous mixtures have larger parts that are different from each other.

Self Check

1. **List** three examples of compounds and three examples of mixtures. Explain your choices.
2. **Describe** a procedure that can be used to separate a liquid homogenous mixture of salt and water.
3. **Identify** the elements that make up the following compounds: H_2SO_4 and $CHCl_3$.
4. **Think Critically** Explain whether your breakfast was a compound, a homogeneous mixture, or a heterogeneous mixture.

Applying Skills

5. **Compare and contrast** compounds and mixtures based on what you have learned from this section.
6. **Use a Database** Use a computerized card catalog or database to find information about one element from the periodic table. Include information about the properties and the uses of the mixtures and/or compounds in which the element is frequently found.

KS Studios

LAB

Mystery Mixture

Goals

- **Test** for the presence of certain compounds.
- **Decide** which of these compounds are present in an unknown mixture.

Materials

test tubes (4)
cornstarch
powdered sugar
baking soda
mystery mixture
small scoops (3)
dropper bottles (2)
iodine solution
white vinegar
hot plate
250-mL beaker
water (125 mL)
test-tube holder
small pie pan

Safety Precautions

WARNING: *Use caution when handling hot objects. Substances could stain or burn clothing. Be sure to point the test tube away from your face and your classmates while heating.*

Real-World Question

You will encounter many compounds that look alike. For example, a laboratory stockroom is filled with white powders. It is important to know what each is. In a kitchen, cornstarch, baking powder, and powdered sugar are compounds that look alike. To avoid mistaking one for another, you can learn how to identify them. Different compounds can be identified by using chemical tests. For example, some compounds react with certain liquids to produce gases. Other combinations produce distinctive colors. Some compounds have high melting points. Others have low melting points. How can the compounds in an unknown mixture be identified by experimentation?

(t)Mark Burnett, (b)Michael Newman/PhotoEdit, Inc.

Procedure

1. Copy the data table into your Science Journal. Record your results carefully for each of the following steps.
2. Again place a small scoopful of cornstarch on the pie pan. Do the same for the sugar and baking soda maintaining separate piles. Add a drop of vinegar to each. Wash and dry the pan after you record your observations.
3. Again place a small scoopful of cornstarch, sugar, and baking soda on the pie pan. Add a drop of iodine solution to each one.
4. Place a small scoopful of each compound in a separate test tube. Hold the test tube with the test-tube holder and with an oven mitt. Gently heat the test tube in a beaker of boiling water on a hot plate.
5. Follow steps 2 through 4 to test your mystery mixture for each compound.

Identifying Presence of Compounds

Substance to Be Tested	Fizzes with Vinegar	Turns Blue with Iodine	Melts When Heated
Cornstarch			
Sugar	Do not write in this book.		
Baking soda			
Mystery mix			

Analyze Your Data

1. **Identify** from your data table which compound(s) you have.
2. **Describe** how you decided which substances were in your unknown mixture.

Conclude and Apply

1. **Explain** how you would be able to tell if all three compounds were not in your mystery substance.
2. **Draw a Conclusion** What would you conclude if you tested baking powder from your kitchen and found that it fizzed with vinegar, turned blue with iodine, and did not melt when heated?

Communicating Your Data

Make a different data table to display your results in a new way. **For more help, refer to the Science Skill Handbook.**

TIME SCIENCE AND HISTORY

SCIENCE CAN CHANGE THE COURSE OF HISTORY!

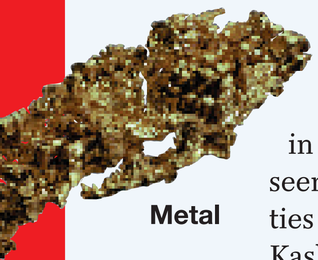
Ancient Views of Matter

Two cultures observed the world around them differently

The world's earliest scientists were people who were curious about the world around them and who tried to develop explanations for the things they observed. This type of observation and inquiry flourished in ancient cultures such as those found in India and China. Read on to see how the ancient Indians and Chinese defined matter.

Indian Ideas

To Indians living about 3,000 years ago, the world was made up of five elements: fire, air, earth, water, and ether, which they thought of as an unseen substance that filled the heavens. Building upon this concept, the early Indian philosopher Kashyapa (kah SHI ah pah) proposed that the five elements could be broken down into smaller units called parmanu (par MAH new). Parmanu were similar to atoms in that they were too small to be seen but still retained the properties of the original element. Kashyapa also believed that each type of parmanu had unique physical and chemical properties.



Parmanu of earth elements, for instance, were heavier than parmanu of air elements. The different properties of the parmanu determined the characteristics of a substance. Kashyapa's ideas about matter are similar to those of the Greek philosopher Democritus, who lived centuries after Kashyapa.

Chinese Ideas

The ancient Chinese also broke matter down into five elements: fire, wood, metal, earth, and water. Unlike the early Indians, however, the Chinese believed that the elements constantly changed form. For example, wood can be burned and thus changes to fire. Fire eventually dies down and becomes ashes, or earth. Earth gives forth metals from the ground. Dew or water collects on these metals, and the water then nurtures plants that grow into trees, or wood.

This cycle of constant change was explained in the fourth century B.C. by the philosopher Tsou Yen. Yen, who is known as the founder of Chinese scientific thought, wrote that all changes that took place in nature were linked to changes in the five elements.

Research Write a brief paragraph that compares and contrasts the ancient Indian and Chinese views of matter. How are they different? Similar? Which is closer to the modern view of matter? Explain.

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

chapter 1 Study Guide

Reviewing Main Ideas

Section 1 Models of the Atom

1. Matter is made up of very small particles called atoms.
2. Atoms are made of smaller parts called protons, neutrons, and electrons.
3. Many models of atoms have been created as scientists try to discover and define the atom's internal structure. Today's model has a central nucleus with the protons and neutrons, and an electron cloud surrounding it that contains the electrons.

Section 2 The Simplest Matter

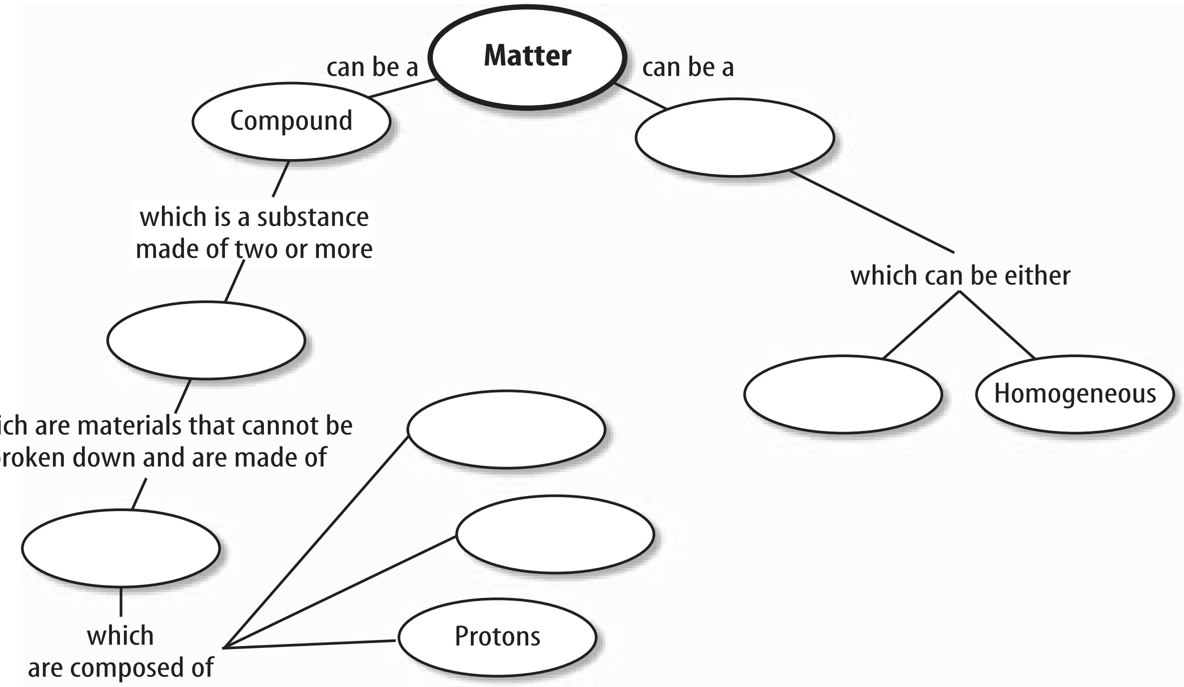
1. Elements are the basic building blocks of matter.
2. An element's atomic number tells how many protons its atoms contain, and its atomic mass tells the average atomic mass of its atoms.
3. Isotopes are two or more atoms of the same element that have different numbers of neutrons.

Section 3 Compounds and Mixtures

1. Compounds are substances that are produced when elements combine. Compounds contain specific proportions of the elements that make them up.
2. Mixtures are combinations of compounds and elements that have not formed new substances. Their proportions can change.

Visualizing Main Ideas

Copy and complete this concept map.



chapter 1 Review

Using Vocabulary

atomic mass p. 22	metal p. 22
atomic number p. 21	metalloid p. 23
compound p. 25	mixture p. 27
electron p. 11	neutron p. 15
electron cloud p. 17	nonmetal p. 23
element p. 9	proton p. 14
isotope p. 21	substance p. 25
mass number p. 21	

Fill in the blanks with the correct word.

1. The _____ is the particle in the nucleus of the atom that carries a positive charge and is counted to identify the atomic number.

2. The new substance formed when elements combine chemically is a(n) _____.

3. The _____ is equal to the number of protons in an atom.

4. The particles in the atom that account for most of the mass of the atom are protons and _____.

5. Elements that are shiny, malleable, ductile, good conductors of heat and electricity, and make up most of the periodic table are _____.

Checking Concepts

Choose the word or phrase that best answers the question.

6. What is a solution an example of?
   A) element
   B) heterogeneous mixture
   C) compound
   D) homogeneous mixture

7. The nucleus of one atom contains 12 protons and 12 neutrons, while the nucleus of another atom contains 12 protons and 16 neutrons. What are the atoms?
   A) chromium atoms
   B) two different elements
   C) two isotopes of an element
   D) negatively charged

8. What is a compound?
   A) a mixture of chemicals and elements
   B) a combination of two or more elements
   C) anything that has mass and occupies space
   D) the building block of matter

9. What does the atom consist of?
   A) electrons, protons, and alpha particles
   B) neutrons and protons
   C) electrons, protons, and neutrons
   D) elements, protons, and electrons

10. In an atom, where is an electron located?
    A) in the nucleus with the proton
    B) on the periodic table of the elements
    C) with the neutron
    D) in a cloudlike formation surrounding the nucleus

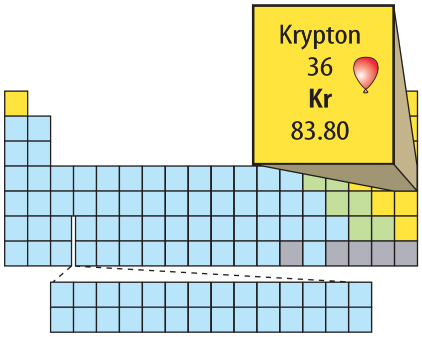
11. How is mass number defined?
    A) the negative charge in an atom
    B) the number of protons and neutrons in an atom
    C) the mass of the nucleus
    D) an atom's protons

12. What are two atoms that have the same number of protons called?
    A) metals
    B) nonmetals
    C) isotopes
    D) metalloids

13. Which is a heterogeneous mixture?
    A) air
    B) brass
    C) a salad
    D) apple juice

Science Online bookk.msscience.com/vocabulary_puzzlemaker
CONTENTS

Use the illustration below to answer questions 14 and 15.



14. According to the figure above, krypton has
A) an atomic number of 84.
B) an atomic number of 36.
C) an atomic mass of 36.
D) an atomic mass of 72.

15. From the figure, the element krypton is
A) a solid. **C)** a mixture.
B) a liquid. **D)** a gas.

Thinking Critically

16. Analyze Information A chemical formula is written to indicate the makeup of a compound. What is the ratio of sulfur atoms to oxygen atoms in SO_2?

17. Determine which element contains seven electrons and seven protons. What element is this atom?

18. Describe what happens to an element when it becomes part of a compound.

19. Explain how cobalt-60 and cobalt-59 can be the same element but have different mass numbers.

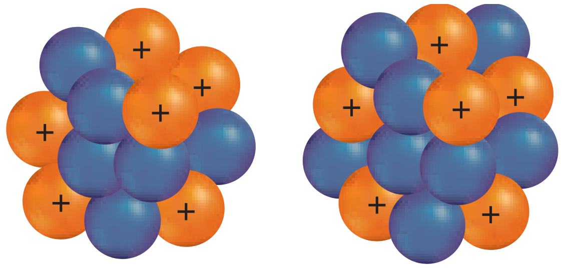
20. Analyze Information What did Rutherford's gold foil experiment tell scientists about atomic structure?

21. Predict Suppose Rutherford had bombarded aluminum foil with alpha particles instead of the gold foil he used in his experiment. What observations do you predict Rutherford would have made? Explain your prediction.

22. Compare and Contrast Aluminum is close to carbon on the periodic table. List the properties that make aluminum a metal and carbon a nonmetal.

23. Draw Conclusions You are shown a liquid that looks the same throughout. You're told that it contains more than one type of element and that the proportion of each varies throughout the liquid. Is this an element, a compound, or a mixture.

Use the illustration below to answer question 24.



24. Interpret Scientific Illustrations Look at the two carbon atoms above. Explain whether or not the atoms are isotopes.

25. Explain how the atomic mass of krypton was determined.

Performance Activities

26. Newspaper Article Research the source, composition, and properties of asbestos. Why was it used in the past? Why is it a health hazard now? What is being done about it? Write a newspaper article to share your findings.

Applying Math

27. Calculate Krypton has six naturally occurring isotopes with atomic masses of 78, 80, 82, 83, 84, and 86. Make a table of the number of protons, electrons, and neutrons in each isotope.

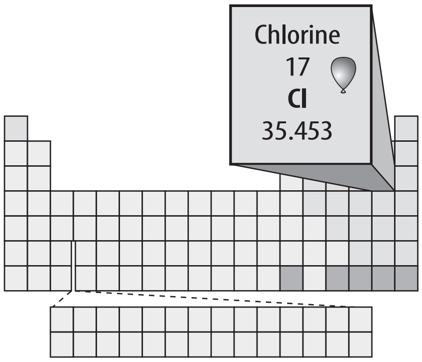
chapter 1 Standardized Test Practice

Part 1 Multiple Choice

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

1. Which of the following has the smallest size?
   A. electron
   B. nucleus
   C. proton
   D. neutron

Use the illustration below to answer questions 2 and 3.



2. The periodic table block shown above lists properties of the element chlorine. What does the number balloon mean?
   A. gas
   B. liquid
   C. solid
   D. synthetic

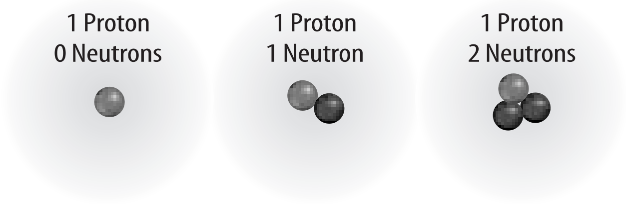
3. According to the periodic table block, how many electrons does an uncharged atom of chlorine have?
   A. 17
   B. 18
   C. 35
   D. 36

Test-Taking Tip

Answer Each Question Never leave any constructed-response answer blank. Answer each question as best as you can. You can receive partial credit for partially correct answers.

4. Which of the following scientists envisioned the atom having a hard sphere that is the same throughout?
   A. Crookes
   B. Dalton
   C. Thomson
   D. Rutherford

Use the illustration below to answer questions 5 and 6.



5. Which of the following correctly identifies the three atoms shown in the illustration above?
   A. hydrogen, lithium, sodium
   B. hydrogen, helium, lithium
   C. hydrogen, hydrogen, hydrogen
   D. hydrogen, helium, helium

6. What is the mass number for each of the atoms shown in the illustration?
   A. 0, 1, 2
   B. 1, 1, 1
   C. 1, 2, 2
   D. 1, 2, 3

7. Which of the following are found close to the right side of the periodic table?
   A. metals
   B. lanthanides
   C. nonmetals
   D. metalloids

8. Which of the following best describes a neutron?
   A. positive charge; about the same mass as an electron
   B. no charge; about the same mass as a proton
   C. negative charge; about the same mass as a proton
   D. no charge; about the same mass as an electron

Part 2 Short Response/Grid In

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

9. Are electrons more likely to be close to the nucleus or far away from the nucleus? Why?

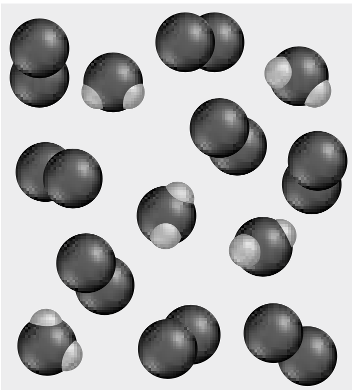
10. How many naturally occurring elements are listed on the periodic table?

11. Is the human body made of mostly metal, nonmetals, or metalloids?

12. A molecule of hydrogen peroxide is composed of two atoms of hydrogen and two atoms of oxygen. What is the formula for six molecules of hydrogen peroxide?

13. What is the present-day name for cathode rays?

Use the illustration below to answer questions 14 and 15.



Enclosed sample of air

14. The illustration above shows atoms of an element and molecules of a compound that are combined without making a new compound. What term describes a combination such as this?

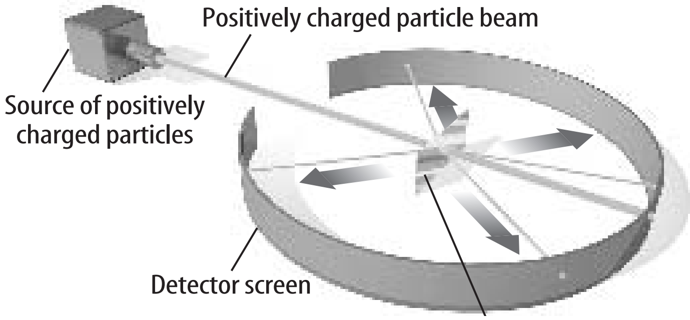
15. If the illustration showed only the element or only the compound, what term would describe it?

Part 3 Open Ended

Record your answers on a sheet of paper.

16. Describe Dalton's ideas about the composition of matter, including the relationship between atoms and elements.

Use the illustration below to answer questions 17 and 18.



17. The illustration above shows Rutherford's gold foil experiment. Describe the setup shown. What result did Rutherford expect from his experiment?

18. What is the significance of the particles that reflected back from the gold foil? How did Rutherford explain his results?

19. Describe three possible methods for separating mixtures. Give an example for each method.

20. Describe the difference between a homogeneous and a heterogeneous mixture.

21. What are the rows and columns on the periodic table called? How are elements in the rows similar, and how are elements in the columns similar?

22. Describe how Thomson was able to show that cathode rays were streams of particles, not light.

23. Describe how the mass numbers, or atomic masses, listed on the periodic table for the elements are calculated.