

**BIG Idea**

The properties of an element are determined by the composition of its atoms.

17.1 Structure of the Atom

MAIN Idea Protons and neutrons are located in an atom's nucleus, and electrons are located in an electron cloud surrounding the nucleus.

17.2 Masses of Atoms

MAIN Idea All atoms of the same element have the same number of protons but can have different numbers of neutrons.

17.3 The Periodic Table

MAIN Idea Atoms of elements that are in the same group on the periodic table contain the same number of outer energy level electrons.

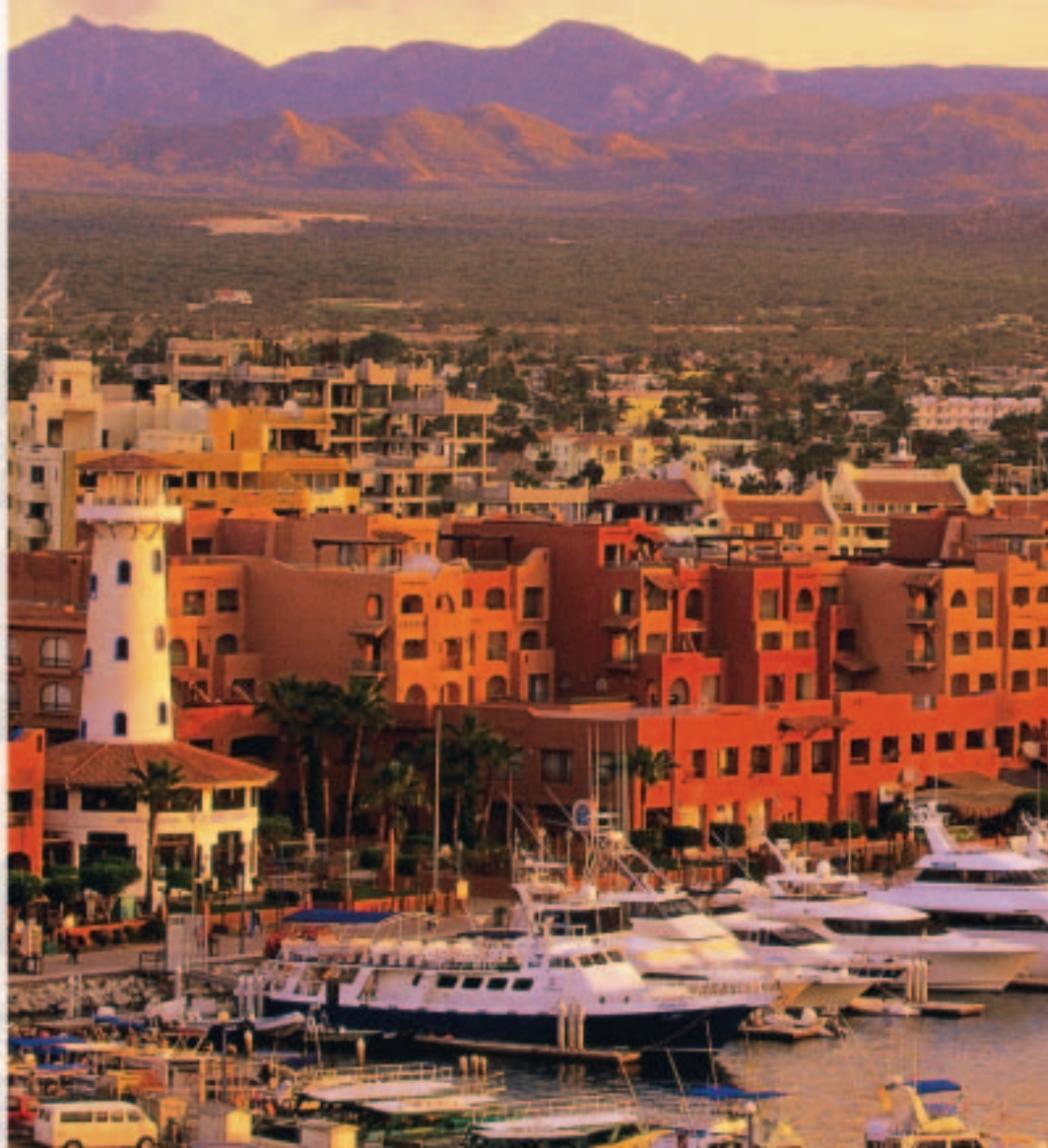
Atoms Compose All Things — Great and Small

Everything in this photo and the universe is composed of tiny particles called atoms. You will learn about atoms and their components—protons, neutrons, electrons, and quarks.

Science Journal

In your Science Journal, write a few paragraphs about what you know about atoms.



Properties of Atoms and the Periodic Table



Start-Up Activities



Inferring What You Can't Observe

How do detectives solve a crime when no witnesses saw it happen? How do scientists study atoms when they cannot see them? In situations such as these, techniques must be developed to find clues to answer the question. Do the lab below to see how clues might be gathered.  

1. Take an envelope from your teacher.
2. Place an assortment of dried beans in the envelope and seal it. **WARNING:** *Do not eat any lab materials.*
3. Trade envelopes with another group.
4. Without opening the envelope, try to figure out the types and number of beans that are in the envelope. Record a hypothesis about the contents of the envelope in your Science Journal.
5. After you record your hypothesis, open the envelope and see what is inside.
6. **Think Critically** Describe the contents of your envelope. Was your hypothesis correct?

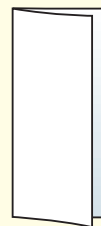


Preview this chapter's content and activities at gpscience.com

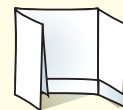
FOLDABLES™ Study Organizer

Atoms You have probably studied atoms before. Make the following Foldable to help identify what you already know, what you want to know, and what you learned about atoms.

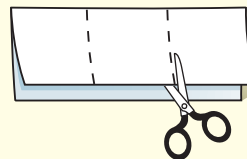
- STEP 1** **Fold** a vertical sheet of paper from side to side. Make the front edge about 1.25 cm shorter than the back edge.



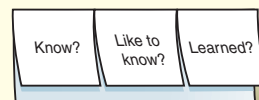
- STEP 2** **Turn** lengthwise and **fold** into thirds.



- STEP 3** **Unfold and cut** only the top layer along both folds to make three tabs.



- STEP 4** **Label** each tab as shown.



Identify Questions Before you read the chapter, write what you already know about atoms under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.



Structure of the Atom

Reading Guide

What You'll Learn

- **Identify** the names and symbols of common elements.
- **Identify** quarks as subatomic particles of matter.
- **Describe** the electron cloud model of the atom.
- **Explain** how electrons are arranged in an atom.

Why It's Important

Everything that you see, touch, and breathe is composed of tiny atoms.



Review Vocabulary

element: substance with atoms that are all alike

New Vocabulary

- atom
- nucleus
- proton
- neutron
- electron
- quark
- electron cloud

Scientific Shorthand

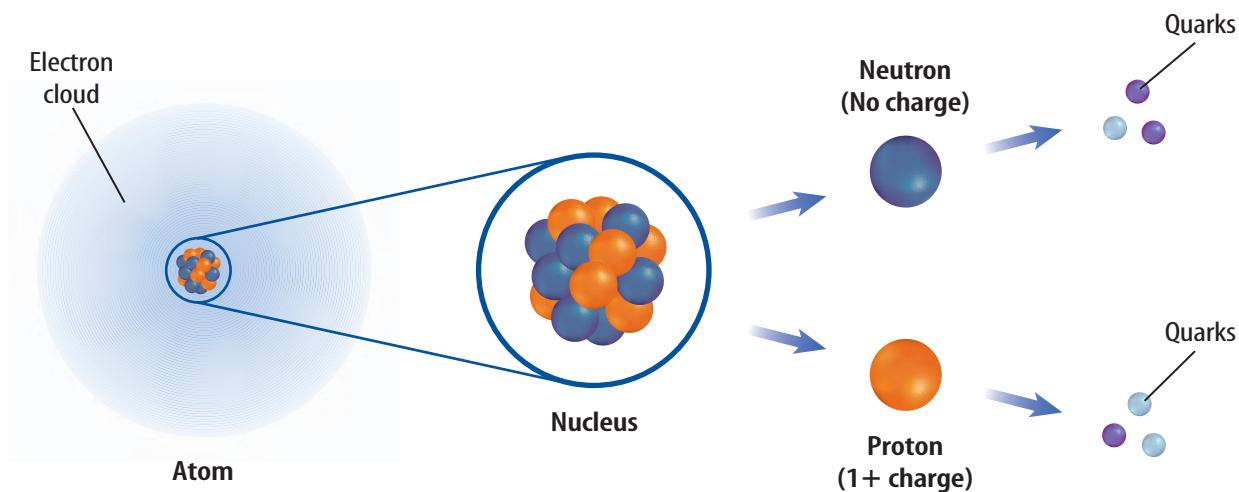
Do you have a nickname? Do you use abbreviations for long words or the names of states? Scientists also do this. In fact, scientists have developed their own shorthand for dealing with long, complicated names.

Do the letters C, Al, Ne, and Ag mean anything to you? Each letter or pair of letters is a chemical symbol, which is a short or abbreviated way to write the name of an element. Chemical symbols, such as those in **Table 1**, consist of one capital letter or a capital letter plus one or two small letters. For some elements,

the symbol is the first letter of the element's name. For other elements, the symbol is the first letter of the name plus another letter from its name. Some symbols are derived from Latin. For instance, *Argentum* is Latin for "silver." Elements have been named in a variety of ways. Some elements are named to honor scientists, for places, or for their properties. Other elements are named using rules established by an international committee. Regardless of the origin of the name, scientists derived this international system for convenience. It is much easier to write H for hydrogen, O for oxygen, and H₂O for dihydrogen oxide (water). Because scientists worldwide use this system, everyone understands what the symbols mean.

Table 1 Symbols of Some Elements

Element	Symbol	Element	Symbol
Aluminum	Al	Iron	Fe
Calcium	Ca	Mercury	Hg
Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Gold	Au	Potassium	K
Hydrogen	H	Sodium	Na



Atomic Components

An element is matter that is composed of one type of **atom**, which is the smallest piece of matter that still retains the property of the element. For example, the element silver is composed of only silver atoms and the element hydrogen is composed of only hydrogen atoms. Atoms are composed of particles called protons, neutrons, and electrons, as shown in **Figure 1**. Protons and neutrons are found in a small, positively-charged center of the atom called the **nucleus** that is surrounded by a cloud containing electrons. **Protons** are particles with an electrical charge of $1+$. **Neutrons** are neutral particles that do not have an electrical charge. **Electrons** are particles with an electrical charge of $1-$. Atoms of different elements differ in the number of protons they contain.



Reading Check

What are the particles that make up the atom and where are they located?

Quarks—Even Smaller Particles

Are the protons, electrons, and neutrons that make up atoms the smallest particles that exist? Scientists hypothesize that electrons are not composed of smaller particles and are one of the most basic types of particles. Protons and neutrons, however, are made up of smaller particles called **quarks**. So far, scientists have confirmed the existence of six uniquely different quarks. Scientists theorize that an arrangement of three quarks held together with the strong nuclear force produces a proton. Another arrangement of three quarks produces a neutron. The search for the composition of protons and neutrons is an ongoing effort.

Figure 1 The nucleus of the atom contains protons and neutrons that are composed of quarks. The proton has a positive charge and the neutron has no charge. A cloud of negatively charged electrons surrounds the nucleus of the atom.



Topic: Particle Research

Visit gpscience.com for Web links to information about particle research at Fermi National Accelerator Laboratory.

Activity Write a paragraph describing the information that you found at the site.



Figure 2 The Tevatron is a huge machine. The aerial photograph of Fermi National Accelerator Laboratory shows the circular outline of the Tevatron particle accelerator. The close-up photograph of the Tevatron gives you a better view of the tunnel.

Infer Why is such a long tunnel needed?



Figure 3 Bubble chambers can be used by scientists to study the tracks left by subatomic particles.



Finding Quarks To study quarks, scientists accelerate charged particles to tremendous speeds and then force them to collide with—or smash into—protons. This collision causes the proton to break apart. The Fermi National Accelerator Laboratory, a research laboratory in Batavia, Illinois, houses a machine that can generate the forces that are required to collide protons. This machine, the Tevatron, shown in **Figure 2**, is approximately 6.4 km in circumference. Electric and magnetic fields are used to accelerate, focus and collide the fast-moving particles.

The particles that result from the collision can be detected by various collection devices. Often, scientists use multiple collection devices to collect the most possible information about the particles created in a collision. Just as police investigators can reconstruct traffic accidents from tire marks and other clues at the scene, scientists are able to examine and gather information about the particles, as shown in **Figure 3**. Scientists use inference to identify the subatomic particles and to reveal information about each particle's inner structure.

The Sixth Quark Finding evidence for the existence of the quarks was not an easy task. Scientists found five quarks and hypothesized that a sixth quark existed. However, it took a team of nearly 450 scientists from around the world several years to find the sixth quark. The tracks of the sixth quark were hard to detect because only about one billionth of a percent of the proton collisions performed showed the presence of a sixth quark—typically referred to as the *top* quark.



Models—Tools for Scientists

Scientists and engineers use models to represent things that are difficult to visualize—or picture in your mind. You might have seen models of buildings, the solar system, or airplanes. These are scaled-down models. Scaled-down models allow you to see either something too large to see all at once, or something that has not been built yet. Scaled-up models are often used to visualize things that are too small to see. To give you an idea of how small the atom is, it would take about 24,400 atoms stacked one on top of the other to equal the thickness of a sheet of aluminum foil. To study the atom, scientists have developed scaled-up models that they can use to visualize how the atom is constructed. For the model to be useful, it must support all of the information that is known about matter and the behavior of atoms. As more information about the atom is collected, scientists change their models to include the new information.



Reading Check

Explain how models can simplify science.

The Changing Atomic Model You know now that all matter is composed of atoms, but this was not always known. Around 400 B.C., Democritus proposed the idea that atoms make up all substances. However, another famous Greek philosopher, Aristotle, disputed Democritus's theory and proposed that matter was uniform throughout and was not composed of smaller particles. Aristotle's incorrect theory was accepted for about 2,000 years. In the 1800s, John Dalton, an English scientist, was able to offer proof that atoms exist.

Dalton's model of the atom, a solid sphere shown in **Figure 4**, was an early model of the atom. As you can see in **Figure 5**, the model has changed somewhat over time. Dalton's modernization of Aristotle's idea of the atom provided a physical explanation for chemical reactions. Scientists could then express these reactions in quantitative terms using chemical symbols and equations.

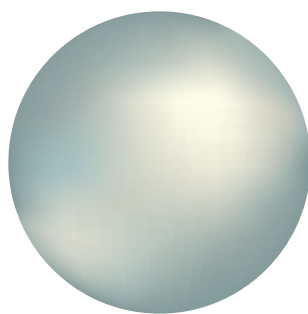


Figure 4 John Dalton's atomic model was a simple sphere.



Modeling an Aluminum Atom

Procedure

1. Arrange thirteen 3-cm circles cut from **orange paper** and fourteen 3-cm circles cut from **blue paper** on a **flat surface** to represent the nucleus of an atom. Each orange circle represents one proton, and each blue circle represents one neutron.
2. Position two holes punched from **red paper** about 20 cm from your nucleus.
3. Position eight punched holes about 40 cm from your nucleus.
4. Position three punched holes about 60 cm from your nucleus.

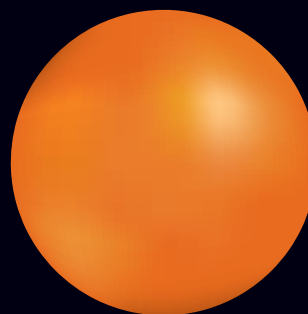
Analysis

1. How many protons, neutrons, and electrons does an aluminum atom have?
2. Explain how your circles model an aluminum atom.
3. Explain why your model does not accurately represent the true size and distances in an aluminum atom.

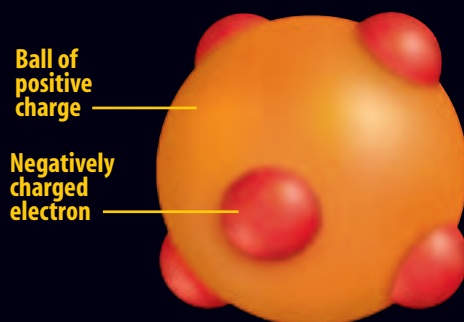


Figure 5

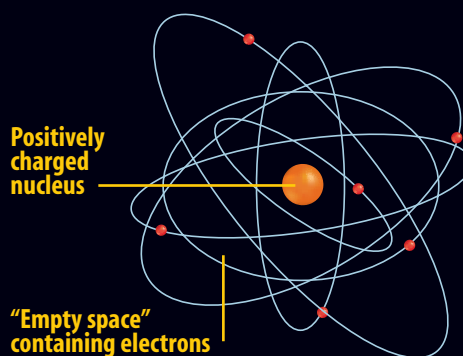
The ancient Greek philosopher Democritus proposed that elements consisted of tiny, solid particles that could not be subdivided (A). He called these particles *atomos*, meaning “uncuttable.” This concept of the atom’s structure remained largely unchallenged until the 1900s, when researchers began to discover through experiments that atoms were composed of still smaller particles. In the early 1900s, a number of models for atomic structure were proposed (B-D). The currently accepted model (E) evolved from these ideas and the work of many other scientists.



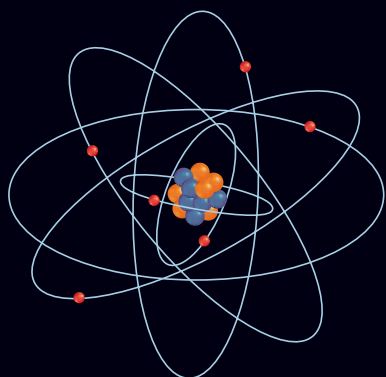
A DEMOCRITUS'S
UNCUTTABLE ATOM



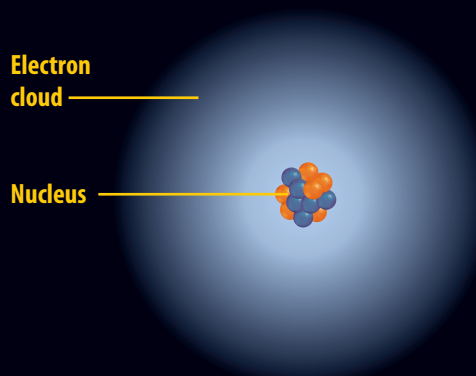
B **THOMSON MODEL, 1904** English physicist Joseph John Thomson inferred from his experiments that atoms contained small, negatively charged particles. He thought these “electrons” (in red) were evenly embedded throughout a positively charged sphere, much like chocolate chips in a ball of cookie dough.



C **RUTHERFORD MODEL, 1911** Another British physicist, Ernest Rutherford, proposed that almost all the mass of an atom—and all its positive charges—were concentrated in a central atomic nucleus surrounded by electrons.



D **BOHR MODEL, 1913** Danish physicist Niels Bohr hypothesized that electrons traveled in fixed orbits around the atom’s nucleus. James Chadwick, a student of Rutherford, concluded that the nucleus contained positive protons and neutral neutrons.



E **ELECTRON CLOUD MODEL, CURRENT** According to the currently accepted model of atomic structure, electrons do not follow fixed orbits but tend to occur more frequently in certain areas around the nucleus at any given time.



The Electron Cloud Model By 1926, scientists had developed the electron cloud model of the atom that is in use today. An **electron cloud** is the area around the nucleus of an atom where its electrons are most likely found. The electron cloud is 100,000 times larger than the diameter of the nucleus. In contrast, each electron in the cloud is much smaller than a single proton.

Because an electron's mass is small and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom. Picture the spokes on a moving bicycle wheel. They are moving so quickly that you can't pinpoint any single spoke. All you see is a blur that contains all of the spokes somewhere within it. In the same way, an electron cloud is a blur containing all of the electrons of the atom somewhere within it. **Figure 6** illustrates what the electron cloud might look like.

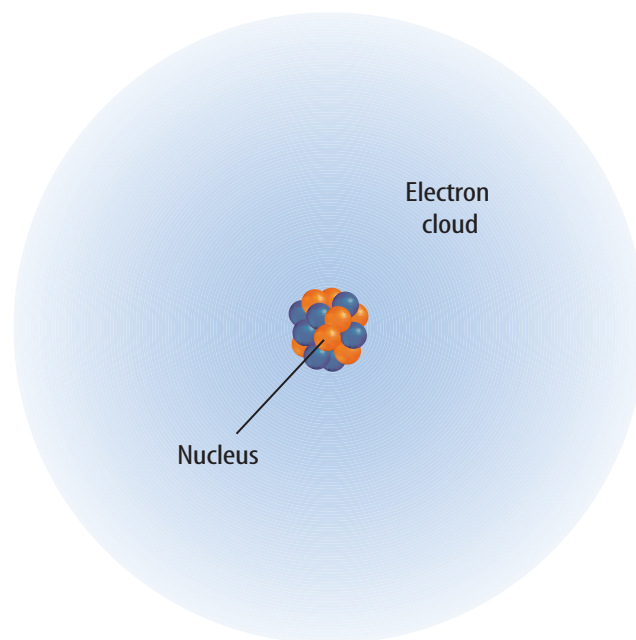


Figure 6 The electrons are located in an electron cloud surrounding the nucleus of the atom.

section 1 review

Summary

Scientific Shorthand

- Scientists use chemical symbols as shorthand when naming elements.

Atomic Components

- Atoms are composed of small particles that have known charges.
- The particles that make up the atom are located in predictable locations within the atom.

Quarks—Even Smaller Particles

- So far, scientists have confirmed the existence of six different quarks.

Models—Tools for Scientists

- Models are used by scientists to simplify the study of concepts and things.
- The current atomic model is an accumulation of over two hundred years of knowledge.
- The electron cloud model is the current atomic model.

Self Check

1. **List** the chemical symbols for the elements carbon, aluminum, hydrogen, oxygen, and sodium.
2. **Identify** the names, charges, and locations of three kinds of particles that make up an atom.
3. **Identify** the smallest particle of matter. How were they discovered?
4. **Describe** the electron cloud model of the atom.
5. **Think Critically** Explain how a rotating electric fan might be used to model the atom. Explain how the rotating fan is unlike an atom.

Applying Math

6. **Use Numbers** The mass of a proton is estimated to be 1.6726×10^{-24} g and the mass of an electron is estimated to be 9.1093×10^{-28} g. How many times larger is the mass of a proton compared to the mass of an electron?
7. **Calculate** What is the difference between the mass of a proton and the mass of an electron?



Masses of Atoms

Reading Guide

What You'll Learn

- **Compute** the atomic mass and mass number of an atom.
- **Identify** the components of isotopes.
- **Interpret** the average atomic mass of an element.

Why It's Important

Some elements naturally exist in more than one form—radioactive and nonradioactive.



Review Vocabulary

mass: amount of matter in an object

New Vocabulary

- atomic number
- mass number
- isotope
- average atomic mass

Table 2 Subatomic Particle Masses

Particle	Mass (g)
Proton	1.6726×10^{-24}
Neutron	1.6749×10^{-24}
Electron	9.1093×10^{-28}

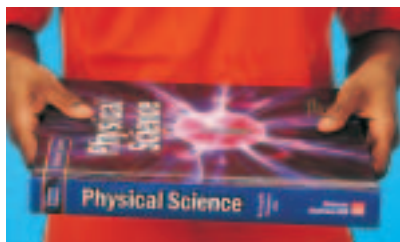


Figure 7 If you held a textbook and placed a paper clip on it, you wouldn't notice the added mass because the mass of a paper clip is small compared to the mass of the book. In a similar way, the masses of an atom's electrons are negligible compared to an atom's mass.

Atomic Mass

The nucleus contains most of the mass of the atom because protons and neutrons are far more massive than electrons. The mass of a proton is about the same as that of a neutron—approximately 1.6726×10^{-24} g, as shown in **Table 2**. The mass of each is approximately 1,836 times greater than the mass of the electron. The electron's mass is so small that it is considered negligible when finding the mass of an atom, as shown in **Figure 7**.

If you were asked to estimate the height of your school building, you probably wouldn't give an answer in kilometers. The number would be too cumbersome to use. Considering the scale of the building, you would more likely give the height in a smaller unit, meters. When thinking about the small masses of atoms, scientists found that even grams were not small enough to use for measurement. Scientists need a unit that results in more manageable numbers. The unit of measurement used for atomic particles is the atomic mass unit (amu). The mass of a proton or a neutron is almost equal to 1 amu. This is not coincidence—the unit was defined that way. The atomic mass unit is defined as one-twelfth the mass of a carbon atom containing six protons and six neutrons. Remember that the mass of the carbon atom is contained almost entirely in the mass of the protons and neutrons that are located in the nucleus. Therefore, each of the 12 particles in the nucleus must have a mass nearly equal to one.



Reading Check

Where is the majority of the mass of an atom located?

**Table 3 Mass Numbers of Some Atoms**

Element	Symbol	Atomic Number	Protons	Neutrons	Mass Number	Average Atomic Mass*
Boron	B	5	5	6	11	10.81 amu
Carbon	C	6	6	6	12	12.01 amu
Oxygen	O	8	8	8	16	16.00 amu
Sodium	Na	11	11	12	23	22.99 amu
Copper	Cu	29	29	34	63	63.55 amu

*The atomic mass units are rounded to two decimal places.

Protons Identify the Element You learned earlier that atoms of different elements are different because they have different numbers of protons. In fact, the number of protons tells you what type of atom you have and vice versa. For example, every carbon atom has six protons. Also, all atoms with six protons are carbon atoms. Atoms with eight protons are oxygen atoms. The number of protons in an atom is equal to a number called the **atomic number**. The atomic number of carbon is six. Therefore, if you are given any one of the following—the name of the element, the number of protons in the element, or the atomic number of the element, you can determine the other two.

 **Reading Check** Which element is an atom with six protons in the nucleus?

Mass Number The **mass number** of an atom is the sum of the number of protons and the number of neutrons in the nucleus of an atom. Look at **Table 3** and see if this is true.

If you know the mass number and the atomic number of an atom, you can calculate the number of neutrons. The number of neutrons is equal to the atomic number subtracted from the mass number.

$$\text{number of neutrons} = \text{mass number} - \text{atomic number}$$

Atoms of the same element with different numbers of neutrons can have different properties. For example, carbon with a mass number equal to 12, or carbon-12, is the most common form of carbon. Carbon-14 is present on Earth in much smaller quantities. Carbon-14 is radioactive and carbon-12 is not.



Carbon Dating Living organisms on Earth contain carbon. Carbon-12 makes up 99 percent of this carbon. Carbon-13 and carbon-14 make up the other one percent. Which isotopes are archaeologists most interested in when they determine the age of carbon-containing remains? Explain your answer in your Science Journal.

Isotopes

Not all the atoms of an element have the same number of neutrons. Atoms of the same element that have different numbers of neutrons are called **isotopes**. Suppose you have a sample of the element boron. Naturally occurring atoms of boron have mass numbers of 10 or 11. How many neutrons are in a boron atom? It depends upon the isotope of boron to which you are referring. Obtain the number of protons in boron from the periodic table. Then use the formula on the previous page to calculate the number of neutrons in each boron isotope. You can determine that boron can have five or six neutrons.



Reading Check

Uranium-238 has 92 protons. How many neutrons does it have?

Applying Science

Radioactive Isotopes Help Tell Time

Atoms can be used to measure the age of bones or rock formations that are millions of years old. The time it takes for half of the radioactive atoms in a piece of rock or bone to change into another element is called its half-life. Scientists use the half-lives of radioactive isotopes to measure geologic time.

Half-Lives of Radioactive Isotopes

Radioactive Element	Changes to This Element	Half-Life
uranium-238	lead-206	4,460 million years
potassium-40	argon-40, calcium-40	1,260 million years
rubidium-87	strontium-87	48,800 million years
carbon-14	nitrogen-14	5,715 years

Identifying the Problem

The table above lists the half-lives of a sample of radioactive isotopes and into which elements they change. For example, it would take 5,715 years for half of the carbon-14 atoms in a rock to change into atoms of nitrogen-14. After another 5,715 years, half of the remaining carbon-14 atoms will change, and so on. You can use these radioactive clocks to measure different periods of time.

Solving the Problem

1. How many years would it take half of the rubidium-87 atoms in a piece of rock to change into strontium-87? How many years would it take for 75% of the atoms to change?
2. After a long period, only 25% of the atoms in a rock remained uranium-238. How many years old would you predict the rock to be? The other 75% of the atoms are now which radioactive element?



Identifying Isotopes Models of two isotopes of boron are shown in **Figure 8**. Because the numbers of neutrons in the isotopes are different, the mass numbers are also different. You use the name of the element followed by the mass number of the isotope to identify each isotope: boron-10 and boron-11. Because most elements have more than one isotope, each element has an average atomic mass. The **average atomic mass** of an element is the weighted-average mass of the mixture of its isotopes. For example, four out of five atoms of boron are boron-11, and one out of five is boron-10. To find the weighted-average or the average atomic mass of boron, you would solve the following equation:

$$\frac{4}{5}(11 \text{ amu}) + \frac{1}{5}(10 \text{ amu}) = 10.8 \text{ amu}$$

The average atomic mass of the element boron is 10.8 amu. Note that the average atomic mass of boron is close to the mass of its most abundant isotope, boron-11.

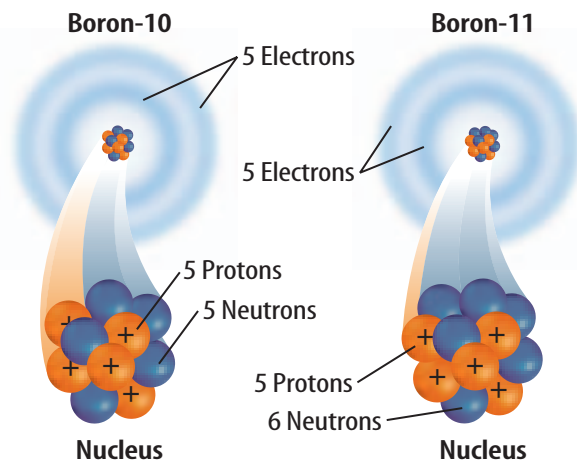


Figure 8 Boron-10 and boron-11 are two isotopes of boron. These two isotopes differ by one neutron.

Explain why these atoms are isotopes.

section 2 review

Summary

Atomic Mass

- The nucleus contains most of the mass of an atom.
- The mass of a proton and neutron are approximately equal.
- The mass of an electron is considered negligible when finding the mass of an atom.
- The unit of measurement for atomic particles is the atomic mass unit.
- The carbon-12 isotope was used to define the atomic mass unit.
- The number of protons identifies the element.

Isotopes

- Atoms of the same element with different numbers of neutrons are called isotopes.
- The average atomic mass of an element is the weighted-average mass of the mixture of isotopes.

Self Check

1. **Identify** the mass number and atomic number of a chlorine atom that has 17 protons and 18 neutrons.
2. **Explain** how the isotopes of an element are alike and how are they different.
3. **Explain** why the atomic mass of an element is an average mass.
4. **Explain** how you would calculate the number of neutrons in potassium-40.
5. **Think Critically** Chlorine has an average atomic mass of 35.45 amu. The two naturally occurring isotopes of chlorine are chlorine-35 and chlorine-37. Why does this indicate that most chlorine atoms contain 18 neutrons?

Applying Math

6. **Use Numbers** If a hydrogen atom has 2 neutrons and 1 proton, what is its mass number?
7. **Use Tables** Use the information in **Table 2** to find the mass in kilograms of each subatomic particle.



The Periodic Table

Reading Guide

What You'll Learn

- **Explain** the composition of the periodic table.
- **Use** the periodic table to obtain information.
- **Explain** what the terms *metal*, *nonmetal*, and *metalloid* mean.

Why It's Important

The periodic table is an organized list of the elements that compose all living and nonliving things that are known to exist in the universe.

Review Vocabulary

chemical property: any characteristic of a substance that indicates whether it can undergo a certain chemical change

New Vocabulary

- periodic table
- group
- electron dot diagram
- period

Figure 9 Mendeleev discovered that the elements had a periodic pattern in their chemical properties. Notice the question marks in his chart. These were elements that had not been discovered at that time.

Organizing the Elements

On a clear evening, you can see one of the various phases of the Moon. Each month, the Moon seems to grow larger, then smaller, in a repeating pattern. This type of change is periodic. *Periodic* means “repeated in a pattern.” The days of the week are periodic because they repeat themselves every seven days. The calendar is a periodic table of days and months.

In the late 1800s, Dmitri Mendeleev, a Russian chemist, searched for a way to organize the elements. When he arranged all the elements known at that time in order of increasing atomic masses, he discovered a pattern. **Figure 9** shows Mendeleev's early periodic chart. Chemical properties found in lighter elements could be shown to repeat in heavier elements. Because the pattern repeated, it was considered to be periodic. Today, this arrangement is called a periodic table of elements. In the **periodic table**, the elements are arranged by increasing atomic number and by changes in physical and chemical properties.

Handwritten notes on the left: "Менделѣевъ", "Периодическая таблица", "1869", "Д. Менделѣевъ"

H=1	Li=7	Na=23	K=39	Rb=85	Cs=132
Be=9	B=10	Al=27	Ga=70	In=75	Tl=204
C=12	N=14	O=16	F=19	Br=80	I=127
Si=28	P=31	S=32	Se=78	Te=128	
Ca=40	Sc=45	Ti=48	V=51	Cr=52	Mn=55
Fe=56	Ni=59	Cu=63	Zn=65	As=75	Sb=120
Co=59	Pd=106	Ag=108	Cd=112	Sn=119	Pb=207
Nb=94	Mo=96	Ru=101	Rh=103	Pd=106	
Zr=91	Nb=94	Mo=96	Ru=101	Rh=103	
Y=89	Zr=91	Nb=94	Mo=96	Ru=101	
La=138	Ce=140	Pr=140	Nd=144	Pm=145	
Sm=150	Eu=152	Gd=157	Tb=159	Dy=163	
Er=167	Tm=169	Yb=173	Lu=175		
Th=232	Pa=231	U=238	Np=237	Pu=244	
Ac=227	Th=232	Pa=231	U=238	Np=237	
La=138	Ce=140	Pr=140	Nd=144	Pm=145	
Sm=150	Eu=152	Gd=157	Tb=159	Dy=163	
Er=167	Tm=169	Yb=173	Lu=175		
Th=232	Pa=231	U=238	Np=237	Pu=244	
Ac=227	Th=232	Pa=231	U=238	Np=237	

**Table 4 Mendeleev's Predictions**

Predicted Properties of Ekasilicon (Es)	Actual Properties of Germanium (Ge)
<i>Existence Predicted—1871</i>	<i>Actual Discovery—1886</i>
Atomic mass = 72	Atomic mass = 72.61
High melting point	Melting point = 938°C
Density = 5.5 g/cm ³	Density = 5.323 g/cm ³
Dark gray metal	Gray metal
Density of EsO ₂ = 4.7 g/cm ³	Density of GeO ₂ = 4.23 g/cm ³

Mendeleev's Predictions Mendeleev had to leave blank spaces in his periodic table to keep the elements properly lined up according to their chemical properties. He looked at the properties and atomic masses of the elements surrounding these blank spaces. From this information, he was able to predict the properties and the mass numbers of new elements that had not yet been discovered. **Table 4** shows Mendeleev's predicted properties for germanium, which he called ekasilicon. His predictions proved to be accurate. Scientists later discovered these missing elements and found that their properties were extremely close to what Mendeleev had predicted.

 **Reading Check** *How did Mendeleev organize his periodic chart?*

Improving the Periodic Table Although Mendeleev's arrangement of elements was successful, it did need some changes. On Mendeleev's table, the atomic mass gradually increased from left to right. If you look at the modern periodic table, shown in **Table 5**, you will see several examples, such as cobalt and nickel, where the mass decreases from left to right. You also might notice that the atomic number always increases from left to right. In 1913, the work of Henry G.J. Moseley, a young English scientist, led to the arrangement of elements based on their increasing atomic numbers instead of an arrangement based on atomic masses. This new arrangement seemed to correct the problems that had occurred in the old table. The current periodic table uses Moseley's arrangement of the elements.

 **Reading Check** *How is the modern periodic table arranged?*



Organizing a Personal Periodic Table

Procedure

1. Collect as many of the following items as you can find: feather, penny, container of water, pencil, dime, strand of hair, container of milk, container of orange juice, square of cotton cloth, nickel, crayon, quarter, container of soda, golf ball, sheet of paper, baseball, marble, leaf, paper clip.
2. Organize these items into several columns based on their similarities to create your own periodic table.

Analysis

1. Explain the system you used to group your items.
2. Were there any items on the list that did not fit into any of your columns?
3. Infer how your activity modeled Mendeleev's work in developing the periodic table of the elements.



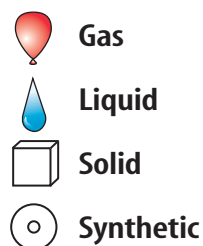


PERIODIC TABLE OF THE ELEMENTS

Columns of elements are called groups. Elements in the same group have similar chemical properties.

1	2	3	4	5	6	7	8	9
1 Hydrogen 1 H 1.008	2 Helium 2 He 4.003							
2 Lithium 3 Li 6.941	3 Beryllium 4 Be 9.012							
3 Sodium 11 Na 22.990	4 Magnesium 12 Mg 24.305							
4 Potassium 19 K 39.098	5 Calcium 20 Ca 40.078	6 Scandium 21 Sc 44.956	7 Titanium 22 Ti 47.867	8 Vanadium 23 V 50.942	9 Chromium 24 Cr 51.996	10 Manganese 25 Mn 54.938	11 Iron 26 Fe 55.845	12 Cobalt 27 Co 58.933
5 Rubidium 37 Rb 85.468	6 Strontium 38 Sr 87.62	7 Yttrium 39 Y 88.906	8 Zirconium 40 Zr 91.224	9 Niobium 41 Nb 92.906	10 Molybdenum 42 Mo 95.94	11 Technetium 43 Tc (98)	12 Ruthenium 44 Ru 101.07	13 Rhodium 45 Rh 102.906
6 Cesium 55 Cs 132.905	7 Barium 56 Ba 137.327	8 Lanthanum 57 La 138.906	9 Hafnium 72 Hf 178.49	10 Tantalum 73 Ta 180.948	11 Tungsten 74 W 183.84	12 Rhenium 75 Re 186.207	13 Osmium 76 Os 190.23	14 Iridium 77 Ir 192.217
7 Francium 87 Fr (223)	8 Radium 88 Ra (226)	9 Actinium 89 Ac (227)	10 Rutherfordium 104 Rf (261)	11 Dubnium 105 Db (262)	12 Seaborgium 106 Sg (266)	13 Bohrium 107 Bh (264)	14 Hassium 108 Hs (277)	15 Meitnerium 109 Mt (268)

Element — Hydrogen
Atomic number — 1
Symbol — H
Atomic mass — 1.008
State of matter — Gas



The first three symbols tell you the state of matter of the element at room temperature. The fourth symbol identifies elements that are not present in significant amounts on Earth. Useful amounts are made synthetically.

Rows of elements are called periods. Atomic number increases across a period.

The arrow shows where these elements would fit into the periodic table. They are moved to the bottom of the table to save space.

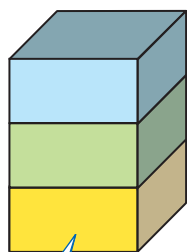
Lanthanide series

Actinide series

Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.908	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36
Thorium 90 Th 232.038	Protactinium 91 Pa 231.036	Uranium 92 U 238.029	Neptunium 93 Np (237)	Plutonium 94 Pu (244)

Topic: Periodic Table Updates

Visit gpscience.com for updates to the periodic table.



Metal

Metalloid

Nonmetal

The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.

			13	14	15	16	17	18
			Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Helium 2 He 4.003
			Aluminum 13 Al 26.982	Silicon 14 Si 28.086	Phosphorus 15 P 30.974	Sulfur 16 S 32.065	Chlorine 17 Cl 35.453	Neon 10 Ne 20.180
10	11	12						
Nickel 28 Ni 58.693	Copper 29 Cu 63.546	Zinc 30 Zn 65.409	Gallium 31 Ga 69.723	Germanium 32 Ge 72.64	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Argon 18 Ar 39.948
Palladium 46 Pd 106.42	Silver 47 Ag 107.868	Cadmium 48 Cd 112.411	Indium 49 In 114.818	Tin 50 Sn 118.710	Antimony 51 Sb 121.760	Tellurium 52 Te 127.60	Iodine 53 I 126.904	Krypton 36 Kr 83.798
Platinum 78 Pt 195.078	Gold 79 Au 196.967	Mercury 80 Hg 200.59	Thallium 81 Tl 204.383	Lead 82 Pb 207.2	Bismuth 83 Bi 208.980	Polonium 84 Po (209)	Astatine 85 At (210)	Xenon 54 Xe 131.293
Darmstadtium 110 Ds (281)	Roentgenium 111 Rg (272)	Ununbium * 112 Uub (285)		Ununquadium * 114 Uuq (289)				Radon 86 Rn (222)

* The names and symbols for elements 112 and 114 are temporary. Final names will be selected when the elements' discoveries are verified.

Europium 63 Eu 151.964	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.925	Dysprosium 66 Dy 162.500	Holmium 67 Ho 164.930	Erbium 68 Er 167.259	Thulium 69 Tm 168.934	Ytterbium 70 Yb 173.04	Lutetium 71 Lu 174.967
Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Nobelium 102 No (259)	Lawrencium 103 Lr (262)



INTEGRATE Career

Research Physicist The study of nuclear interactions is shared by chemists and physicists. Research physicists use their knowledge of the physical laws of nature to explain the behavior of the atom and its composition. Explain in your Science Journal why physicists would study the amount of energy that electrons contain.

The Atom and the Periodic Table

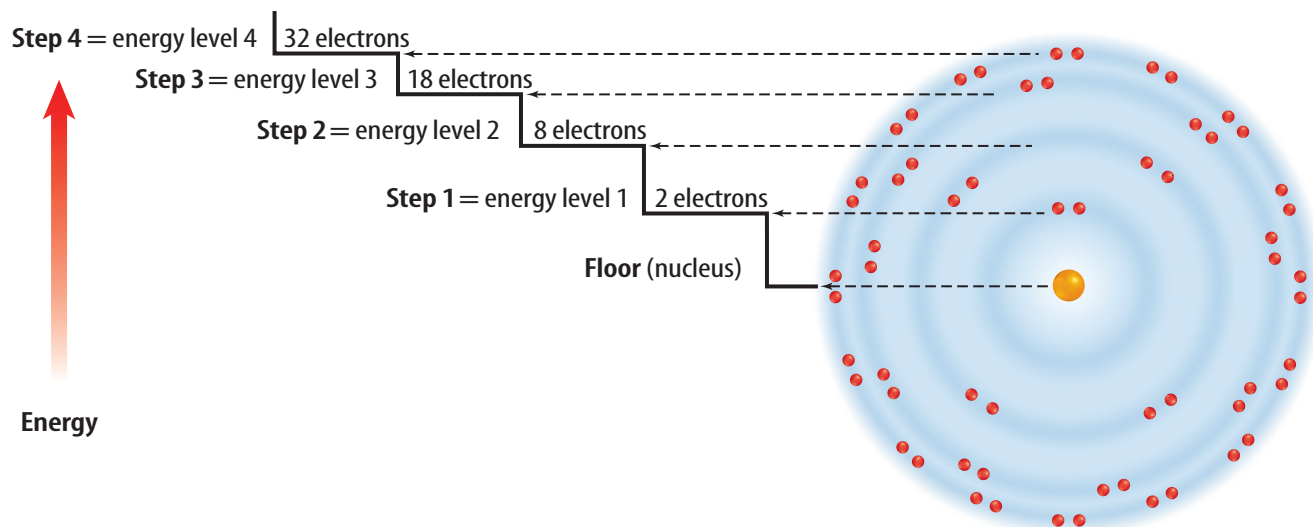
Objects often are sorted or grouped according to the properties they have in common. This also is done in the periodic table. The vertical columns in the periodic table are called **groups**, or families, and are numbered 1 through 18. Elements in each group have similar properties. For example, in Group 11, copper, silver, and gold have similar properties. Each is a shiny metal and a good conductor of electricity and heat. What is responsible for the similar properties? To answer this question, look at the structure of the atom.

Electron Cloud Structure You have learned about the number and location of protons and neutrons in an atom. But where are the electrons located? How many are there? In a neutral atom, the number of electrons is equal to the number of protons. Therefore, a carbon atom, with an atomic number of six, has six protons and six electrons. These electrons are located in the electron cloud surrounding the nucleus.

Scientists have found that electrons within the electron cloud have different amounts of energy. Scientists model the energy differences of the electrons by placing the electrons in energy levels, as in **Figure 10**. Energy levels nearer the nucleus have lower energy than those levels that are farther away. Electrons fill these energy levels from the inner levels (closer to the nucleus) to the outer levels (farther from the nucleus).

Elements that are in the same group have the same number of electrons in their outer energy level. It is the number of electrons in the outer energy level that determines the chemical properties of the element. It is important to understand the link between the location on the periodic table, chemical properties, and the structure of the atom.

Figure 10 Energy levels in atoms can be represented by a flight of stairs. Each stair step away from the nucleus represents an increase in the amount of energy within the electrons. The higher energy levels contain more electrons.





Energy Levels These energy levels are named using numbers one to seven. The maximum number of electrons that can be contained in each of the first four levels is shown in **Figure 10**. For example, energy level one can contain a maximum of two electrons. Energy level two can contain a maximum of eight electrons. Notice that energy levels three and four contain several electrons. A complete and stable outer energy level will contain eight electrons. In elements in periods three and higher, additional electrons can be added to inner energy levels although the outer energy level contains only eight electrons.

Rows on the Table Remember that the atomic number found on the periodic table is equal to the number of electrons in an atom. Look at **Figure 11**. The first row has hydrogen with one electron and helium with two electrons both in energy level one. Because energy level one is the outermost level containing an electron, hydrogen has one outer electron. Helium has two outer electrons. Recall from **Figure 10** that energy level one can hold only two electrons. Therefore, helium has a full or complete outer energy level.

The second row begins with lithium, which has three electrons—two in energy level one and one in energy level two. Lithium has one outer electron. Lithium is followed by beryllium with two outer electrons, boron with three, and so on until you reach neon with eight outer electrons. Again, looking at **Figure 10**, energy level two can only hold eight electrons. Therefore, neon has a complete outer energy level. Do you notice how the row in the periodic table ends when an outer energy level is filled? In the third row of elements, the electrons begin filling energy level three. The row ends with argon, which has a full outer energy level of eight electrons.



Reading Check

How many electrons are needed to fill the outer energy level of sulfur?

Hydrogen 1 H	
Lithium 3 Li	Beryllium 4 Be
Sodium 11 Na	Magnesium 12 Mg

Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 S	Chlorine 17 Cl	Argon 18 Ar



Topic: Atomic Energy Level Structure

Visit gpscience.com for Web links to information about the structure of atomic energy levels.

Activity Draw a diagram that details how the energy levels are structured.

Figure 11 One proton and one electron are added to each element as you go across a period in the periodic table.

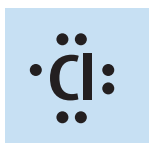
Explain what the elements in the last column share in relation to their outer energy levels.



Figure 12 The elements in Group 1 have one electron in their outer energy level. This electron dot diagram represents that one electron.



Figure 13 Electron dot diagrams show the electrons in an element's outer energy level.



The electron dot diagram for Group 17 consists of three sets of paired dots and one single dot.

Electron Dot Diagrams Did you notice that hydrogen, lithium, and sodium have one electron in their outer energy level? Elements that are in the same group have the same number of electrons in their outer energy level. These outer electrons are so important in determining the chemical properties of an element that a special way to represent them has been developed. American chemist G. N. Lewis created this method while teaching a college chemistry class. An **electron dot diagram** uses the symbol of the element and dots to represent the electrons in the outer energy level. **Figure 12** shows the electron dot diagram for Group 1 elements. Electron dot diagrams are used also to show how the electrons in the outer energy level are bonded when elements combine to form compounds.

Same Group—Similar Properties The elements in Group 17, the halogens, have electron dot diagrams similar to chlorine, shown in **Figure 13**. All halogens have seven electrons in their outer energy levels. Since all of the members of a group on the periodic table have the same number of electrons in their outer energy level, group members will undergo chemical reactions in similar ways.

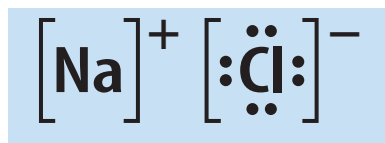
A common property of the halogens is the ability to form compounds readily with elements in Group 1. Group 1 elements have only one electron in their outer energy level. **Figure 13** shows an example of a compound formed by one such reaction. The Group 1 element, sodium, reacts easily with the Group 17 element, chlorine. The result is the compound sodium chloride, or NaCl—ordinary table salt.

Not all elements will combine readily with other elements. The elements in Group 18 have complete outer energy levels. This special configuration makes Group 18 elements relatively unreactive. You will learn more about why and how bonds form between elements in the later chapters.

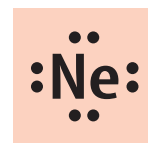


Reading Check

Why do elements in a group undergo similar chemical reactions?



Sodium combines with chlorine to give each element a complete outer energy level in the resulting compound.



Neon, a member of Group 18, has a full outer energy level. Neon has eight electrons in its outer energy level, making it unreactive.



Regions on the Periodic Table

The periodic table has several regions with specific names. The horizontal rows of elements on the periodic table are called **periods**. The elements increase by one proton and one electron as you go from left to right in a period.

All of the elements in the blue squares in **Figure 14** are metals. Iron, zinc, and copper are examples of metals. Most metals exist as solids at room temperature. They are shiny, can be drawn into wires, can be pounded into sheets, and are good conductors of heat and electricity.

Those elements on the right side of the periodic table, in yellow, are classified as nonmetals. Oxygen, bromine, and carbon are examples of nonmetals. Most nonmetals are gases, are brittle, and are poor conductors of heat and electricity at room temperature. The elements in green are metalloids or semimetals. They have some properties of both metals and nonmetals. Boron and silicon are examples of metalloids.

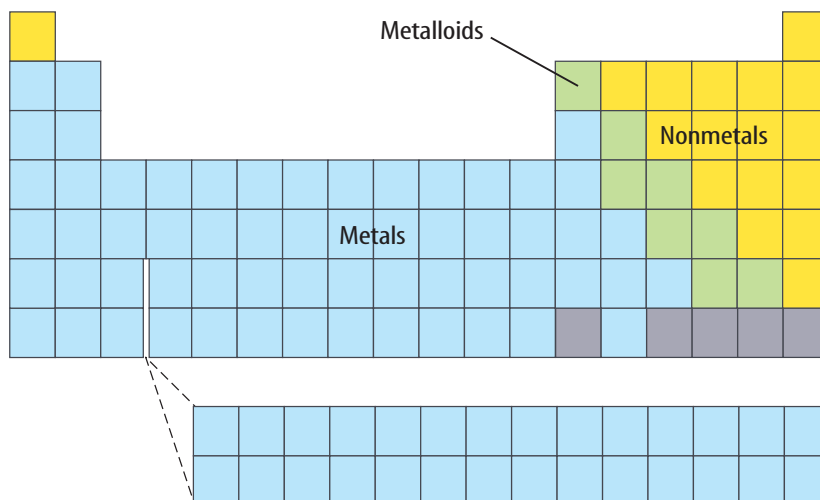


Reading Check

What are the properties of the elements located on the left side of the periodic table?

A Growing Family Scientists around the world are continuing their research into the synthesis of elements. In 1994, scientists at the Heavy-Ion Research Laboratory in Darmstadt, Germany, discovered element 111. As of 1998, only one isotope of element 111 has been found. This isotope had a life span of 0.002 s. In 1996, element 112 was discovered at the same laboratory. As of 1998, only one isotope of element 112 has been found. The life span of this isotope was 0.00048 s. Both of these elements are produced in the laboratory by joining smaller atoms into a single atom. The search for elements with higher atomic numbers continues. Scientists think they have synthesized elements 114 and 116. However, the discovery of these elements has not yet been confirmed.

Figure 14 Metalloids are located along the green stair-step line. Metals are located to the left of the metalloids. Nonmetals are located to the right of the metalloids.



Topic: New Elements

Visit gpscience.com for Web links to information about newly synthesized elements.

Activity Write a paragraph explaining how several new elements were synthesized and who synthesized them.

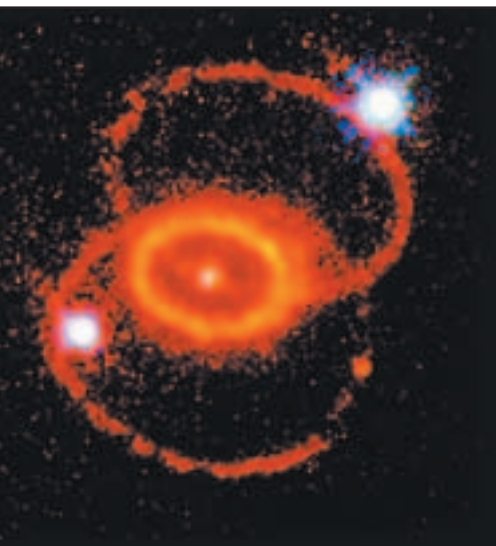


Figure 15 Scientists think that some elements are found in nature only within stars.

Elements in the Universe



Using the technology that is available today, scientists are finding the same elements throughout the universe. They have been able to study only a small portion of the universe, though, because it is so vast. Many scientists believe that hydrogen and helium are the building blocks of other elements. Atoms join together within stars to produce elements with atomic numbers greater than 1 or 2—the atomic numbers of hydrogen and helium. Exploding stars, or supernovas, shown in **Figure 15**, give scientists evidence to support this theory. When stars go supernova a mixture of elements, including the heavy elements such as iron, are flung into the galaxy. Many scientists believe that supernovas have spread the elements that are found throughout the universe. Promethium, technetium, and elements with an atomic number above 92 are rare or are not found on Earth. Some of these elements are found only in trace amounts in Earth's crust as a result of uranium decay. Others have been found only in stars.

section 3 review

Summary

Organizing the Elements

- Mendeleev organized the elements using increasing atomic mass and chemical and physical properties.
- Mendeleev left blank spaces in his table to allow for elements that were yet undiscovered.
- Moseley corrected the problems in the periodic table by arranging the elements in order of increasing atomic number.

The Atom and the Periodic Table

- The vertical columns in the periodic table are known as groups or families. Elements in a group have similar properties.
- Electrons within the electron cloud have different amounts of energy.

Regions of the Periodic Table

- The periodic table is divided into these regions: periods, metals, nonmetals, and metalloids.
- Scientists around the world are continuing to try to synthesize new elements.

Self Check

1. **Identify** Use the periodic table to find the name, atomic number, and average atomic mass of the following elements: N, Ca, Kr, and W.
2. **List** the period and group in which each of these elements is found: nitrogen, sodium, iodine, and mercury.
3. **Classify** each of these elements as a metal, a nonmetal, or a metalloid and give the full name of each: K, Si, Ba, and S.
4. **Think Critically** The Mendeleev and Mosely periodic charts have gaps for the as-then-undiscovered elements. Why do you think the chart used by Mosely was more accurate at predicting where new elements would be placed?

Applying Math

5. **Make a Graph** Construct a circle graph showing the percentage of elements classified as metals, metalloids, and nonmetals. Use markers or colored pencils to distinguish clearly between each section on the graph. Record your calculations in your Science Journal.

A Periodic Table of Foods

Real-World Question

Mendeleev's task of organizing a collection of loosely related items probably seemed daunting at first. How will using your favorite foods to create your own periodic table be similar to the task that Mendeleev had?

Goals

- **Organize** 20 of your favorite foods into a periodic table of foods.
- **Analyze** and **evaluate** your periodic table for similar characteristics among groups or family members on your table.
- **Infer** where new foods added to your table would be placed.

Materials

11 × 17 paper
12- or 18-inch ruler
colored pencils or markers

Procedure

1. **List** 20 of your favorite foods and drinks.
2. **Describe** basic characteristics of each of your food and drink items. For example, you might describe the primary ingredient, nutritional value, taste, and color of each item. You also could identify the food group of each item such as fruits/vegetables, grains, dairy products, meat, and sweets.
3. **Create** a data table to organize the information that you collect.
4. Using your data table, construct a periodic table of foods on your 11 × 17 sheet of paper. Determine which characteristics you will use to group your items. Create families (columns) of food and drink items that share similar characteristics on your table.



For example, potato chips, pretzels, and cheese-flavored crackers could be combined into a family of salty tasting foods. Create as many groups as you need, and you do not need to have the same number of items in every family.

Conclude and Apply

1. **Evaluate** the characteristics you used to make the groups on your periodic table. Do the characteristics of each group adequately describe all the family members? Do the characteristics of each group distinguish its family members from the family members of the other groups?
2. **Analyze** the reasons why some items did not fit easily into a group.
3. **Infer** why chemists have not created a periodic table of compounds.

Communicating Your Data

Construct a bulletin board of the periodic tables of foods created by the class. How are the tables similar?

What's in a name?

Goals

- **Research** the names and symbols of various elements.
- **Study** the methods that are used to name elements and how they have changed through time.
- **Organize** your data by making your own periodic table.
- **Study** the history of certain elements and their discoveries.
- **Create** a table of your findings and communicate them to other students.

Data Source



Visit gpscience.com/internet_lab for more information on naming elements, elements' symbols, and the discovery of new elements, and for data from other students.

Real-World Question

The symbols used for different elements sometimes are easy to figure out. After all, it makes sense for the symbol for carbon to be C and the symbol for nitrogen to be N. However, some symbols aren't as easy to figure out. For example, the element silver has the symbol Ag. This symbol comes from the Latin word for silver, *Argentum*. How are symbols and names chosen for elements?

Make a Plan

1. Make a list of particular elements you wish to study.
2. **Compare and contrast** these elements' names to their symbols.
3. **Research** the discovery of these elements. Do their names match their symbols? Were they named after a property of the element, a person, their place of discovery, or a system of nomenclature? What was that system?



Using Scientific Methods

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Visit the Web site provided for links to different sites about elements, their history, and how they were named.
3. **Research** these elements.
4. Carefully record your data in your Science Journal.



Analyze Your Data

1. **Record** in your Science Journal how the symbols for your elements were chosen. What were your elements named after?
2. Make a periodic table that includes the research information on your elements that you found.
3. Make a chart of your class's findings. Sort the chart by year of discovery for each element.
4. How are the names and symbols for newly discovered elements chosen? Make a chart that shows how the newly discovered elements will be named.

Conclude and Apply


1. **Compare** your findings to those of your classmates. Did anyone's data differ for the same element? Were all the elements in the periodic table covered?
2. **Explain** the system that is used to name the newly discovered elements today.
3. **Explain** Some elements were assigned symbols based on their name in another language. Do these examples occur for elements discovered today or long ago?

Communicating Your Data

Find this lab using the link below. Post your data in the table provided. **Compare** your data to those of other students. Combine your data with those of other students to complete your periodic table with all of the elements.




gpscience.com/internet_lab

A CHILLING
STORY

A scientist inspects an ice core sample from the Greenland Ice Sheet. The samples are stored in a freezer at -36°C .

Picture this: It's 1361. A ship from Norway arrives at a Norwegian settlement in Greenland. The ship's crew hopes to trade its cargo with the people living there. The crew gets off the ship. They look around. The settlement is deserted. More than 1,000 people had vanished!

New evidence has shed some light on the mysterious disappearance of the Norse settlers. The evidence came from a place on the Greenland Ice Sheet over 600 km away from the settlement. This part of Greenland is so cold that snow never melts. As new snow falls, the existing snow is buried and turns to ice.



By drilling deep into this ice, scientists can recover an ice core.

Air bubbles and dirt trapped in ice provide clues to Earth's past climate.

The core is made up of ice formed from snow-falls going way, way back in time.

By measuring the ratio of oxygen isotopes in the ice core, scientists can estimate Greenland's past air temperatures. The cores provide a detailed climate history going back over 80,000 years. Individual ice layers can be dated much like tree rings to determine their age, and the air bubbles trapped within each layer are used to learn about climate variations. Dust and pollen trapped in the ice also yield clues to ancient climates.

A Little Ice Age

Based on their analysis, scientists think the Norse moved to Greenland during an unusually warm period. Then in the 1300s, the climate started to cool and a period known as the Little Ice Age began. The ways the Norse hunted and farmed were inadequate for survival in this long chill. Since they couldn't adapt to their colder surroundings, the settlers died out.

Research Report Evidence seems to show that Earth is warming. Rising temperatures could affect our lives. Research global warming to find out how Earth may change. Share your report with the class.



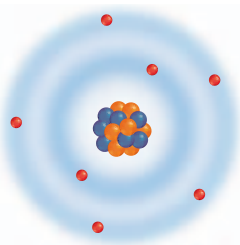
Science online

For more information, visit
gpscience.com/time

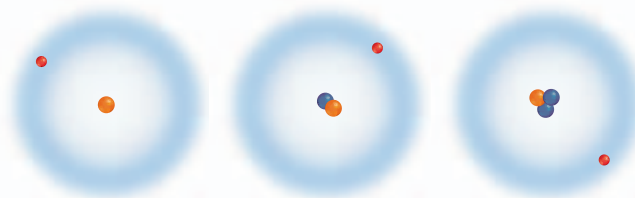
Reviewing Main Ideas

Section 1 Structure of the Atom

1. A chemical symbol is a shorthand way of writing the name of an element.
2. An atom consists of a nucleus made of protons and neutrons surrounded by an electron cloud as shown in the figure to the right.
3. Quarks are particles of matter that make up protons and neutrons.
4. The model of the atom changes over time. As new information is discovered, scientists incorporate it into the model.

**Section 2 Masses of Atoms**

1. The number of neutrons in an atom can be computed by subtracting the atomic number from the mass number.
2. The isotopes of an element are atoms of that same element that have different numbers of neutrons. The figure below shows the isotopes of hydrogen.



3. The average atomic mass of an element is the weighted-average mass of the mixture of its isotopes. Isotopes are named by using the element name, followed by a dash, and its mass number.

Section 3 The Periodic Table

1. In the periodic table, the elements are arranged by increasing atomic number resulting in periodic changes in properties. Knowing that the number of protons, electrons, and atomic number are equal gives you partial composition of the atom.
2. In the periodic table, the elements are arranged in 18 vertical columns, or groups, and seven horizontal rows, or periods.
3. Metals are found at the left of the periodic table, nonmetals at the right, and metalloids along the line that separates the metals from the nonmetals as shown below.

4. Elements are placed on the periodic table in order of increasing atomic number. A new row on the periodic table begins when the outer energy level of the element is filled.

FOLDABLES

Use the Foldable that you made at the beginning of the chapter to help you review properties of atoms and the periodic table.

Using Vocabulary

atom p.507	mass number p.513
atomic number p.513	neutron p.507
average atomic mass p.515	nucleus p.507
electron p.507	period p.523
electron cloud p.511	periodic table p.516
electron dot diagram p.522	proton p.507
group p.520	quark p.507
isotope p.514	

Fill in the blanks with the correct word or words.

- Mendeleev created an organized table of elements called the _____.
- Two elements with the same number of protons but a different number of neutrons are called _____.
- _____ is the weighted-average mass of all the known isotopes for an element.
- The positively charged center of an atom is called the _____.
- The particles that make up protons and neutrons are called _____.
- A(n) _____ is a horizontal row in the periodic table.
- The _____ is the sum of the number of protons and neutrons in an atom.
- In the current model of the atom, the electrons are located in the _____.
- Which is a term for a pattern that repeats?
 - isotopic
 - metallic
 - periodic
 - transition
- Which of the following is an element that would have similar properties to those of neon?
 - aluminum
 - argon
 - arsenic
 - silver
- Which of the following terms describes boron?
 - metal
 - metalloid
 - noble gas
 - nonmetal
- How many outer-level electrons do lithium and potassium have?
 - 1
 - 2
 - 3
 - 4
- Which of the following is NOT found in the nucleus of an atom?
 - proton
 - neutron
 - electron
 - quark
- The halogens are located in which group?
 - 1
 - 11
 - 15
 - 17
- In which of the following states is nitrogen found at room temperature?
 - gas
 - metalloid
 - metal
 - liquid
- Which of the elements below is a shiny element that conducts electricity and heat?
 - chlorine
 - sulfur
 - hydrogen
 - magnesium
- The atomic number of Re is 75. The atomic mass of one of its isotopes is 186. How many neutrons are in an atom of this isotope?
 - 75
 - 111
 - 186
 - 261

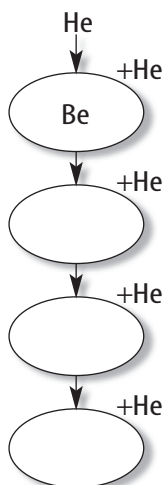
Checking Concepts

Choose the word or phrase that best answers the question.

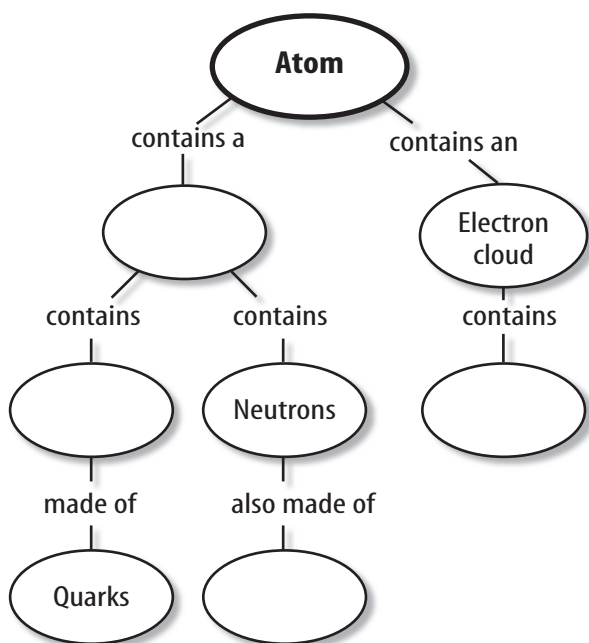
- In which state of matter are most of the elements to the left of the stair-step line in the periodic table?
 - gas
 - liquid
 - plasma
 - solid

Interpreting Graphics

19. As a star dies, it becomes more dense. Its temperature rises to a point where He nuclei are combined with other nuclei. When this happens, the atomic numbers of the other nuclei are increased by 2 because each gains the two protons contained in the He nucleus. For example, Cr fuses with He to become Fe. Copy and complete the concept map showing the first four steps in He fusion.



20. Copy and complete the concept map below.



Thinking Critically

21. **Infer** Lead and mercury are two pollutants in the environment. From information about them in the periodic table, determine why they are called heavy metals.

22. **Explain** why it is necessary to change models as new information becomes available.
23. **Infer** Why did scientists choose carbon to base the atomic mass unit? Which isotope of carbon did they use?
24. **Infer** Ge and Si are used in making semiconductors. Are these two elements in the same group or the same period?
25. **Explain** Using the periodic table, predict how many outer level electrons will be in elements 114, 116, and 118. Explain your answer.
26. **Infer** Ca is used by the body to make bones and teeth. Sr-90 is radioactive. Ca is safe for people and Sr-90 is hazardous. Why is Sr-90 hazardous to people?

Applying Math

27. **Solve One-Step Equations** The atomic number of Yttrium is 39. The atomic mass of one of its isotopes is 89. How many neutrons are in an atom of this isotope?

Use the table below for question 28.

Electrons per Energy Level	
Energy Level	Maximum Number of Electrons
1	2
2	
3	
4	

28. **Use Tables** Use the information in **Figure 10** to determine how many electrons should be in the 2nd, 3rd, and 4th energy levels for Argon, atomic number 18. Copy and complete the table above with the number of electrons for each energy level.



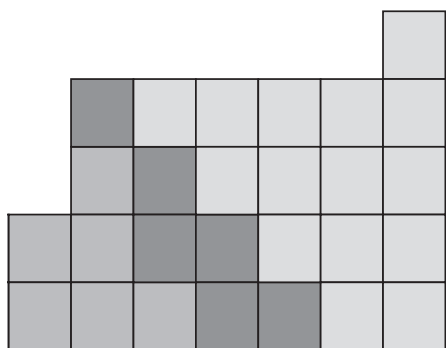
Physical Science EOC Practice

Part 1 Multiple Choice

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

- Atoms of different elements are different because they have different numbers of what type of particle? **SPS1a**
 A. electrons C. protons
 B. photons D. neutrons
- Which group of elements on the periodic table do not combine readily with other elements? **SPS4b**
 A. Group 1 C. Group 17
 B. Group 2 D. Group 18

Use the illustration below to answer questions 3 and 4.



- What is the name by which the elements along the stair-step line, darkly shaded on the periodic table shown above, are known? **SPS4a**
 A. lanthanides C. metals
 B. metalloids D. nonmetals
- Which of the regions shown on the periodic table contains mostly elements that are gases at room temperature? **SPS4a**
 A. region 1 C. region 3
 B. region 2 D. region 4
- Which scientist proposed the idea that atoms make up all substances? **SCSh9c**
 A. Aristotle C. Democritus
 B. Dalton D. Galileo

Use the table below to answer questions 6 and 7.

Element	Electrons in a Neutral Atom	Electrons in Outer Energy Level
Carbon	6	4
Oxygen	8	6
Neon	10	8
Sodium	11	1
Chlorine	17	7

- The table above lists properties of some elements. Which element in the table has a complete outer energy level? **SPS4b**
 A. carbon C. neon
 B. oxygen D. sodium
- Which element would you expect to be located in Group 1 of the periodic table? **SPS4b**
 A. oxygen C. sodium
 B. neon D. chlorine
- How many quarks have been found to exist? **SCSh9c**
 A. six C. ten
 B. eight D. twelve
- The element nickel has five naturally occurring isotopes. Which of the following describes the relationship of these isotopes? **SPS1a**
 A. same mass, same atomic number
 B. same mass, different atomic number
 C. different mass, same atomic number
 D. different mass, different atomic number

Test-Taking Tip

Partial Credit Never leave any open ended answer blank. Answer each question as best as you can. Often, you can receive partial credit for partially correct answers.

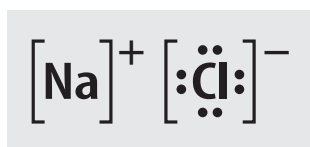
Question 20 If you have some of the particles mixed up, try to write as much as you remember.

Part 2 Short Response/Grid In

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

10. According to the periodic table, an atom of lead has an atomic number of 82. How many neutrons does lead-207 have?
11. About three out of four chlorine atoms are chlorine-35, and about one out of four are chlorine-37. What is the average atomic mass of chlorine?

Use the illustration below to answer questions 12 and 13.

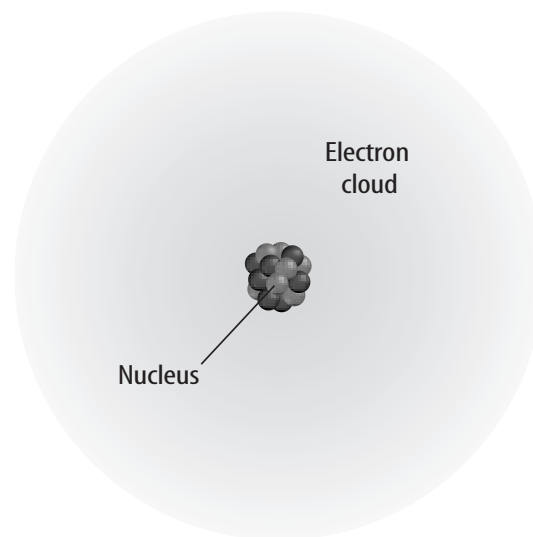


12. The electron dot diagram above shows how a sodium atom, Na, combines with a chlorine atom, Cl, to form sodium chloride. What do the + and the – symbols indicate in the diagram?
13. What do the dots around the chlorine atom indicate?
14. Why isn't the mass of the electron included in the mass of an atom on the periodic table?
15. What determines the chemical properties of an element?
16. What property of radioactive isotopes can scientists use to determine the age of bones or rock formations?
17. The atomic mass for silicon is listed as 28.09 amu on the periodic table. A student claims that no silicon atom has this atomic mass. Is this true? Explain why or why not.

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustration below to answer questions 18 and 19.



18. The illustration above shows the currently accepted model of atomic structure. Describe this model.
19. Compare and contrast the model shown above with Bohr's model of an atom.
20. Describe the composition of protons, neutrons, and electrons.
21. How can you use the periodic table to determine the average number of neutrons an element has, even though the number of neutrons is not listed?
22. Describe the concept of energy levels and how they relate to the placement of elements on the periodic table.
23. Explain the importance of the rows in the periodic table's organization of elements.
24. Describe how Dalton's modernization of the ancient Greek's ideas of element, atom, and compound provided a basis for understanding chemical reactions. Give an example.