Chapter 18
Atoms and Elements

Introduction to Chapter 18

What does matter look like at its most basic level? This question has intrigued people for thousands of years. In this chapter, you will learn about atoms, how they are put together, how many kinds of atoms exist, and how people keep track of the different kinds of atoms.

Investigations for Chapter 18

18.1 Atomic Structure
How was the size of an atom’s nucleus determined?

You will use indirect measurement to find the radius of a circle, and compare your work with the classic experiment used to find the radius of an atomic nucleus.

18.2 Comparing Atoms
What are atoms and how are they put together?

You will construct models of several kinds of atoms using the atom-building game.

18.3 The Periodic Table of Elements
What does atomic structure have to do with the periodic table?

You will learn how different kinds of atoms (the elements) are arranged in the periodic table of elements. You will play Atomic Challenge, a game that will test your skills in reading the periodic table.
Learning Goals

In this chapter, you will:

✓ Use indirect measurement to determine the radius of a circle.
✓ Build models of atoms.
✓ Research one of the historical atomic models.
✓ Understand how atoms of each element differ.
✓ Describe the forces that hold an atom together.
✓ Use the concept of electron shells to arrange electrons in atomic models.
✓ Understand how elements are organized in the periodic table.
✓ Use the periodic table to identify the atomic number and mass numbers of each element.
✓ Calculate the numbers of protons and neutrons in each stable isotope of an element.

Vocabulary

atomic mass  electron  mass number  proton
atomic mass units  energy levels  neutron  strong nuclear force
atomic number  group of elements  nucleus  subatomic particles
atomic theory  isotopes  periodic table of elements  valence electrons
chemical symbol
18.1 Atomic Structure

All matter is formed from atoms. Atoms, by themselves or combined with other atoms in molecules, make up everything that we see, hear, feel, smell, and touch. An individual atom is so small that one cell in your body contains 100 trillion atoms, and a speck of dust contains many more atoms than that. As small as they are, atoms and molecules are the building blocks of every type of matter. A few hundred incredibly tiny atoms of gold have the same density as a bar of gold. A few hundred very tiny molecules of water have the same density as a cup of water. In this section you will find out about atoms and learn about the historical experiments that helped scientists understand atomic structure.

Inside an atom

Protons, neutrons, and electrons

Atoms and molecules are called the building blocks of matter because if you attempt to break down an atom, you no longer have gold or water or any other recognizable substance. If broken apart, almost all atoms contain three smaller particles called protons, neutrons, and electrons. Because these particles are even smaller than an atom, they are called subatomic particles. These three types of particles are arranged in an atom as shown in Figure 18.2.

How are protons, neutrons, and electrons arranged within an atom?

Protons and neutrons cluster together in the atom’s center, called the nucleus. The electrons move in the space around the nucleus. No one is able to say exactly where an electron is at any one time. A useful analogy is that electrons buzz around the nucleus much like bees around a hive. Some people describe each electron as a wave; just as the vibration of a guitar string exists all along the string, the electrons exist at all the shaded points in Figure 18.2.

Subatomic particles

Protons, neutrons, and electrons are called subatomic particles. The proton is positive, the electron is negative, and the neutron is electrically neutral. Protons and neutrons have about the same mass. Each is about 2,000 times the mass of an electron. Since protons and neutrons exist in the nucleus, almost all the mass of an atom is concentrated there. These properties helped scientists figure out the atomic structure.

Figure 18.1: What do atoms look like? What are they made out of? These questions have been asked by scientists ever since 400 BC, when Democritus (a Greek philosopher) proposed the existence of atoms.

Figure 18.2: An atom has a nucleus with one or more protons and neutrons and one or more energy levels occupied by electrons. The shaded area around the outside of the atom represents the places the electrons might be. A good analogy is that electrons “buzz” around the nucleus in energy levels like bees around a hive.
How big are atoms?

Atoms are very small
An atom and its parts are much smaller than a meter. The diameter of an atom is $10^{-10}$ (0.0000000001) meter, whereas an electron is smaller than $10^{-18}$ (0.000000000000000001) meter. Comparatively, this means that an electron is 10 million times smaller than an atom! The diameter of a nucleon (a proton or neutron) is a distance that is equal to one fermi. This unit (equal to $10^{-15}$ meter) is named for Enrico Fermi, an Italian-born physicist who studied the nucleus of the atom. For his work with neutrons, he received the Nobel Prize for physics in 1938.

Most of the atom is empty space
You may be surprised to learn that most of the atom is actually empty space: If the atom was the size of your classroom, then the nucleus would be the size of a grain of sand in the center of the room.

John Dalton and the atomic theory

As early as 400 BC, Greek philosophers proposed the atomic theory. This theory states that all matter is composed of tiny particles called atoms. Many centuries later, English chemist and physicist John Dalton (1766-1844) was one of the first scientists to set out to gather evidence for the idea. Dalton was a remarkable person. Born into a family too poor to send him to school, young John educated himself and, at age 12, became a schoolteacher. He grew to be one of the leading scientists of his time.

In 1808, Dalton published a detailed atomic theory that contained the following important points:

1. Each element is composed of extremely small particles called atoms.
2. All atoms of a given element are identical.
3. Atoms of different elements have different properties, including mass and chemical reactivity.
4. Atoms are not changed by chemical reactions, but merely rearranged into different compounds.
5. Compounds are formed when atoms of more than one element combine.
6. A compound is defined by the number, type (element), and proportion of the constituent atoms.

Dalton’s atomic theory laid the groundwork for later atomic models, and over time, his original theory has been expanded and updated.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Diameter (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>atom</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>nucleus</td>
<td>$10^{-14}$</td>
</tr>
<tr>
<td>proton</td>
<td>$10^{-15}$</td>
</tr>
<tr>
<td>neutron</td>
<td>$10^{-15}$</td>
</tr>
<tr>
<td>electron</td>
<td>$10^{-18}$</td>
</tr>
</tbody>
</table>

Figure 18.3: Diameters of an atom and its subatomic particles.

Weather & atomic theory

One of John Dalton’s interests was weather (he kept detailed records for 57 years), and that led him to study gases. He studied the evaporation of water into the air and was able to understand that the process increased gas pressure. From these observations of pressure, and from other experiments, he gathered evidence about the structure of matter.
The changing model of the atom

The current model of the atom represents our current understanding of atomic structure. This model is one of a series of models constructed by people as they learned new information about atoms. New information enabled people to update and change their ideas about how the atom is constructed.

The name atom comes from Democritus, a Greek philosopher (circa 460-370 BC) who proposed that matter is made up of small particles, which he called atoms (from the Greek word atomos, or indivisible). His model describes atoms as small particles that differ in size and shape, that combine in different configurations, and that are constantly in motion. Many of Democritus’ ideas were based on logical thinking.

The idea that theories need to be supported by evidence—often gathered in carefully controlled experiments—became important in the 1600s. Then scientists began to design experiments to support or disprove ideas proposed by earlier thinkers such as Democritus. John Dalton (see previous page) was a chemist who experimented with different gases. His careful measurements gave him repeatable evidence that matter is made up of atoms. His model of the atom is a tiny hard sphere.

The idea that atoms might contain smaller particles came about through a series of observations of cathode ray tubes, devices that were early versions of fluorescent and neon lights. Julius Plucker, a German physicist (1801-1868), and William Crooks, an English physicist and chemist (1832-1919), and his countryman and fellow physicist Joseph John Thomson (1856-1940) conducted many of these experiments. They showed that different gases placed in the tubes generated streams of particles and conducted current.

From these experiments Thomson identified the electron, which carries a negative charge. Thomson knew that atoms were electrically neutral, so he proposed that the atom was a positive sphere with negative electrons embedded in it like raisins in a roll or bun (Figure 18.4). The positive sphere and the negative electrons had an equal and opposite amount of charge, so the atom was neutral.

In 1911 in England, physicists Ernest Rutherford (1871-1937), Hans Geiger (1882-1945), and Ernest Marsden (1889-1970), used high-speed, lightweight atoms called alpha particles (generated by radioactive material), to bombard very thin pieces of gold foil. Most of the alpha particles passed through the foil and hit a screen behind it. But surprisingly, some of them bounced back ((Figure 18.5). They must have hit areas of the foil with greater density!
Rutherford hypothesized that an atom must be made up of mostly empty space, allowing most of the alpha particles to pass through the foil. In the center of the atom, he suggested, was a tiny core called a nucleus, which contained positively-charged protons. This is where most of the mass must be found. The lighter electrons occupied the area between the nucleus and the edge of the atom. However, Rutherford did not have enough information to describe the electrons’ location more fully.

Danish physicist Niels Bohr (1885-1962) used information about the nature of the emission of light by heated objects to update Rutherford’s model. He described electrons as moving around the nucleus in fixed orbits that have a set amount of energy (Figure 18.6). Bohr’s model of the electron orbits is still used in many analyses of the atom. However, other 20th century experiments have shown that radiating waves can behave like particles in motion, and particles in motion can behave like waves (Figure 18.7).

In 1923, Louis de Broglie (1892-1987), a French physicist, showed how to analyze a moving particle as a wave. In 1926, Austrian physicist Erwin Schrödinger (1887-1961) built on de Broglie’s work and treated electrons as three-dimensional waves. He developed a mathematical description of electrons in atoms that is called the quantum mechanical model of the atom. It is also called the electron cloud model, because his mathematical description cannot be described easily either in words or pictures, so a cloud represents the probability of electron position.

There still remained a serious problem with the atomic model, a problem Rutherford had identified so many years earlier: missing mass. In 1932, James Chadwick, an English physicist working in Rutherford’s laboratory, finally solved the problem. He identified the third important subatomic particle, the neutron. Chadwick (1891-1974) based his work on earlier experiments by French physicists Irene and Frederic Joliot-Curie.

Understanding what is inside an atom has motivated many thousands of scientists and thinkers. What some of them discovered along the way changed the world, influencing not only theoretical spheres such as many of the sciences, philosophy, logic, and other areas, but also those subjects’ practical applications. So many new technological developments of the late 20th century have been made possible by atomic research that the present era is often referred to as the “atomic age.”
18.2 Comparing Atoms

As you know, some substances are made up of only one kind of atom and these substances are called elements. You already know something about a number of elements—you’ve heard of hydrogen, helium, silver, gold, aluminum, copper, lead, and carbon, for example.

Exactly how does one element differ from another? This information is important. Over the centuries chemists, physicians, technologists, and inventors have used this knowledge to create everything from better medicines to beautiful jewelry.

How people figured out why the elements are different from each other is one of the most fascinating stories in science. It brings together the work of physicists, who studied the structure of the atom, and chemists, who studied how elements react and combine.

Atomic number

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of protons determines an element</td>
<td>Remember that atoms are themselves composed of protons, electrons, and neutrons. Through intense study of the structure of the atom, people discovered that it is the number of protons that distinguishes an atom of one element from the atom of another element.</td>
</tr>
<tr>
<td>Can you change the number of protons?</td>
<td>All atoms of the same element will have the same number of protons, and atoms of different elements will have different numbers of protons. Adding or removing a proton from an atom usually takes (or releases) huge amounts of energy. Therefore, most atoms are very stable. Even if atoms bond or break apart during chemical reactions, the number of protons in each atom always remains the same. The atoms themselves are only rearranged in different combinations.</td>
</tr>
<tr>
<td>What is the atomic number?</td>
<td>Because the number of protons in an atom remains the same during physical and chemical changes, we can refer to each element by the number of protons its atoms contain. This unique number is called the atomic number. Atomic numbers start at 1, with the element hydrogen, and go up by one until 111, the element unununium. The heaviest elements (those with the highest atomic numbers) have been created in a laboratory and have not been seen in nature.</td>
</tr>
</tbody>
</table>
In addition to the atomic number, every atomic nucleus can be described by its mass number. The mass number is equal to the total number of protons plus neutrons in the nucleus of an atom. Recall that atoms of the same element have the same number of protons. Atoms of the same element can have different numbers of neutrons.

Chemists arrange the elements in a table called the periodic table of elements. If you look at the periodic table in the back cover of this book, you will notice that the atomic number increases by one whole number at a time. This is because you add one proton at a time for each element. The atomic masses however, increase by amounts greater than one (Figure 18.10). This difference is due to the neutrons in the nucleus. Neutrons add mass to the atom, but do not change its atomic number (or charge).

The total number of protons and neutrons in the nucleus of an atom is called the mass number. Sometimes, the mass number of an element is included in the symbol. By convention, the mass number is written as a superscript above the symbol and the atomic number as a subscript below the symbol (Figure 18.11). You can find the number of neutrons by subtracting the atomic number from the mass number. How many neutrons does the carbon atom in Figure 18.11 have?

Many elements have atoms with different numbers of neutrons. These different forms of the same element are called isotopes. Isotopes are atoms of the same element that have different numbers of neutrons. Because of this, the notation shown in Figure 18.11 is called isotope notation.

The three isotopes of hydrogen are shown here.
Example: finding the number of neutrons

Example: How many neutrons are present in an atom of carbon that has a mass number of 14?

Solution: The mass number is the number of protons plus the number of neutrons.

(1) You are asked for the number of neutrons.

(2) You are given that it is carbon-14. Carbon has 6 protons.

(3) The relationship is \( n + p = \text{mass number} \)

(4) Solve for \( n \)

\[
 n = \text{mass number} - p
\]

(5) Plug in numbers and get answer

\[
 n = 14 - 6 = 8
\]

There are 8 neutrons in a carbon-14 nucleus.

How many different elements are possible?

Why aren’t there infinite numbers of elements?

Why aren’t there infinite numbers of elements, each with an atomic number greater than the one before it? The answer may lie in the forces that keep a nucleus together. Remember that positive charges repel each other. In the nucleus, however, positive protons and neutral neutrons sit side by side. Because the protons are repelling each other, they (and the nucleus) should fly apart!

What holds the nucleus of an atom together?

The nucleus stays together because there is another force acting that is stronger than the repulsion of the protons for each other. Because it is stronger than the electromagnetic force, scientists call it the strong nuclear force. Unlike gravity, which can reach millions of miles, the strong force only acts on very short distances. The effective distance for the strong force is so short, we do not feel it outside the nucleus of an atom.
How are electrons arranged in atoms?

Neutral atoms have the same number of electrons as protons

Atoms are electrically neutral. An atom of helium has an atomic number of 2 and two protons in its nucleus. A neutral atom of helium would therefore have two electrons, which stay close to the nucleus because the positive protons and the negative electrons attract each other. An atom of silver has an atomic number of 47 and 47 protons in its nucleus. A neutral atom of silver would therefore have 47 electrons. Are these electrons randomly placed or are they organized in some way?

Electrons are found in the electron cloud

Electrons are never all in one place at the same time. Instead, they literally buzz around the nucleus at a very fast rate, or frequency. Because of this behavior, we can refer to the entire space that electrons occupy as the electron cloud (Figure 18.13).

The electron cloud is divided into energy levels

The current model of the atom describes the area of the electron cloud that each electron occupies as an energy state. The farther away from the nucleus the electron is found, the higher its energy state. Therefore, the electron cloud is divided into energy levels. The first energy level is closest to the nucleus and has the lowest energy. Electrons that occupy this level are at a lower energy state than electrons that occupy the second energy level, which is farther from the nucleus. Each energy level can hold up to a certain number of electrons (Figure 18.14). Sometimes, when an atom absorbs enough energy, some of its electrons “jump” to a higher energy level. When they fall back to their normal energy level, light is released with a frequency equal to the amount of energy the atom absorbed.

Energy levels can overlap

Like the layers of an onion, as the energy levels extend farther from the nucleus, they get larger in diameter and can hold more electrons. The maximum number the first four levels can hold is shown in Figure 18.14.

Energy levels

<table>
<thead>
<tr>
<th>Energy level</th>
<th>Number of possible electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st level</td>
<td>2</td>
</tr>
<tr>
<td>2nd level</td>
<td>8</td>
</tr>
<tr>
<td>3rd level</td>
<td>8</td>
</tr>
<tr>
<td>4th level</td>
<td>18</td>
</tr>
</tbody>
</table>

Energy levels are overlapped. In fact, each energy level is subdivided into smaller regions called orbitals. Some orbitals in the third energy level may have higher energy than some in the fourth and so on. Scientists have found out exactly which orbitals are occupied, and by how many electrons, in all 111 elements. You will explore this concept in greater detail in future chemistry courses.
Fireworks and electron energy levels

Almost everyone enjoys the bright colors, noise, and drama of fireworks. The loud noises are caused by a black powder that explodes when burned. What causes the colors? The answer to this question is directly related to energy levels and the strict rules that govern how electrons act around a nucleus.

Electrons will fill up the lowest energy level first, because they are attracted to the nucleus. But just as we can lift a marble to the top of a hill, energy can be used to move an electron farther away from the nucleus. When fireworks burn at a high heat, the energy provided by the heat is absorbed by the atoms and the electrons jump up to higher energy levels. This process is called electron excitation.

When an electron falls back down to its original position, energy is released in the form of electromagnetic radiation, including light. The release of electromagnetic energy that occurs when the electrons fall down into a lower-energy position is called emission.

Because electromagnetic radiation is a wave, it comes in different frequencies. Some frequencies we can see with our eyes and we call those frequencies light. As you remember from the last unit, light of different frequencies we see as different colors.

Because of the arrangement of the energy levels surrounding an atom, excited electrons can release electromagnetic radiation in a range of frequencies. The trick in building fireworks is to find materials that release radiation at the right frequency for us to see. These materials are metal salts, which are combinations of metal ions with other ions. With energy input, these metal ions release electromagnetic radiation at wavelengths that we see as colors. The colors we see from different elements are listed in Figure 18.16.

The fact that different elements, when heated, can release different colors of light tells us that energy levels in an atom have specific amounts of energy. For example, the wavelengths for different colors are approximately: 610 nanometers for red; 579 for yellow; 546 for green; 436 for blue; and 405 for purple.

The discovery around 1900 that electrons exist at set energy levels changed the way people looked at the physical world. Before then, people believed that objects could have any amount of energy. The idea that electrons exist at set energy levels has redefined the field of physics and led us to a much deeper understanding of the way the physical universe works. This idea is known as quantum theory.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>copper</td>
<td>green</td>
</tr>
<tr>
<td>barium</td>
<td>yellow-green</td>
</tr>
<tr>
<td>sodium</td>
<td>yellow</td>
</tr>
<tr>
<td>calcium</td>
<td>red-orange</td>
</tr>
<tr>
<td>strontium</td>
<td>bright red</td>
</tr>
</tbody>
</table>

Figure 18.15: What causes all the different colors in fireworks? Electrons!

Figure 18.16: Metals used in fireworks.
18.3 The Periodic Table of Elements

Before people understood the internal structure of the atom, they were able to identify elements by how they acted chemically. In this section, you will learn how chemists summarize the properties of elements in the periodic table of elements, and how an element’s chemistry and structure are related.

Groups of elements

Elements and compounds

In 1808, John Dalton published his theory that all materials were made up of atoms, and that atoms can bond together in different combinations. He supported his theory with experimental results. This work provoked two important questions. Which substances were elements, made up of only one kind of atom? Which substances were compounds, made up of combinations of atoms?

How many elements are there?

In the 18th through 20th centuries, new theories, technologies, and scientific discoveries motivated chemists to find and catalog all the elements that make up our universe. To do so, they had to carefully observe substances in order to identify them, and then try to break them apart by any possible means. If a substance could be broken apart, then they had even more work to do: They observed and tried to break apart each of those materials. If a substance could not be further broken apart, then it most probably was an element.

We now know of 111 different kinds of elements, and the search for new ones continues. Scientists try to build elements with even more protons (called superheavy elements) to determine the limits of the internal structure of the atom.

Elements that are part of the same group act alike

As chemists worked on determining which substances were elements, they noticed that some elements acted very much like other elements. For example, one atom of some metals always reacts with two atoms of oxygen. Chemists called these similar elements a group of elements.

By keeping track of how each element reacted with other elements, chemists soon identified a number of groups. At the same time, they also began figuring out ways to determine the relative masses of different elements. Soon chemists were organizing this information into tables. The modern periodic table of elements is descended from the work of these early chemists.
The periodic table of elements

If you read across the rows of the table, the elements are listed in order of increasing atomic number and weight. Each row indicates how many electrons are in each region of the electron cloud. As you remember, the electrons of an atom are found in an electron cloud around the nucleus. The electron cloud is divided into energy levels. By looking at the row number, you can figure out how many energy levels are filled and how many electrons are partially filling each region of the energy levels. For example, carbon, in row 2, has a filled energy level 1 and four electrons in energy level 2. You know that carbon has four electrons in energy level 2 because it is the fourth element in row 2. Recall that higher energy levels overlap, so this system becomes more complex the higher you go up on the periodic table. The outermost region of the electron cloud contains the valence electrons and is called the valence shell.

Because the most stable forms of atoms have either full or empty valence shells, the groups of elements relate to the way the valence shells of each element are filled. For example, the last column contains the group known as the noble gases. They don’t react easily with any other elements, because this group has atoms with completely filled valence shells. We will study valence electrons in the next chapter.
Chapter 18

Reading the periodic table

As you just learned, the arrangement of each element in the periodic table conveys a lot of information about it. The individual listing can tell us even more about the element. A periodic table may show some, or, as in Figure 18.17, all of the information for each element.

Chemical symbol The **chemical symbol** is an abbreviation of the element’s name. Unlike the abbreviations for a U.S. state, these symbol-abbreviations are not always obvious. Many are derived from the element’s name in a language such as Latin or German. In Figure 18.17, Ag is the chemical symbol for the element silver. Its symbol comes from the Latin word for silver, *argentum*. Note that the first letter in the symbol is upper case and the second is lower case. Writing symbols this way allows us to represent all of the elements without getting confused. There is a big difference between the element cobalt, with its symbol Co, and the compound carbon monoxide, written as CO. What is the difference between Si and SI?

Atomic number As you learned in the last section, the atomic number is the number of protons all atoms of that element have in their nuclei. If the atom is neutral, it will have the same number of electrons as well.

Mass numbers The mass number of an element is the total number of protons and neutrons in the nucleus. In Figure 18.17, you see that silver has two mass numbers, 107 and 109. This means that there are two types of silver atoms, one that has 47 protons and 60 neutrons, and one that has 47 protons and 62 neutrons. Forms of the same element with different mass numbers are called isotopes.

Atomic mass Although the mass number of an isotope and the atomic number of an element are always whole numbers because they simply count numbers of particles, the **atomic mass** of an element is not. The atomic mass is the average mass of all the known isotopes of the element. It takes into consideration the relative abundance of the various isotopes. The atomic mass of an element is expressed in **atomic mass units**, or amu. *Each atomic mass unit is defined as the mass of 1/12 the mass of a carbon-12 atom* (6 protons and 6 neutrons in the nucleus, plus 6 electrons outside the nucleus). Since carbon consists of a mixture of naturally occurring isotopes, the atomic mass of carbon is not exactly 12 amu. You will learn more about how atomic mass is determined in the next chapter.

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**Table 18.1**

<table>
<thead>
<tr>
<th>element</th>
<th>symbol</th>
<th>origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>copper</td>
<td>Cu</td>
<td>cuprium</td>
</tr>
<tr>
<td>gold</td>
<td>Au</td>
<td>aurum</td>
</tr>
<tr>
<td>iron</td>
<td>Fe</td>
<td>ferrum</td>
</tr>
<tr>
<td>lead</td>
<td>Pb</td>
<td>plumbum</td>
</tr>
<tr>
<td>potassium</td>
<td>K</td>
<td>kalium</td>
</tr>
<tr>
<td>silver</td>
<td>Ag</td>
<td>argentum</td>
</tr>
<tr>
<td>sodium</td>
<td>Na</td>
<td>natrium</td>
</tr>
<tr>
<td>tin</td>
<td>Sn</td>
<td>stannum</td>
</tr>
</tbody>
</table>

**Figure 18.17**: Some periodic tables give you the information shown above.

**Figure 18.18**: The symbols for some elements don’t always obviously match their names.
# Chapter 18 Review

## Vocabulary review

Match the following terms with the correct definition. There is one extra definition in the list that will not match any of the terms.

<table>
<thead>
<tr>
<th>Set One</th>
<th>Set Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. proton</td>
<td>1. atomic number</td>
</tr>
<tr>
<td>a. Particle with no charge that exists in nucleus of most atoms</td>
<td>a. Equal to (\frac{1}{12}) the mass of a carbon-12 atom</td>
</tr>
<tr>
<td>2. neutron</td>
<td>2. strong nuclear force</td>
</tr>
<tr>
<td>b. Negatively charged particle that exists in nucleus of atom</td>
<td>b. A way to refer to an element; describes the number of protons in the nucleus</td>
</tr>
<tr>
<td>3. electron</td>
<td>3. energy levels</td>
</tr>
<tr>
<td>c. Center of atom, contains most of atom’s mass</td>
<td>c. The reason that an atom’s protons don’t break its nucleus apart</td>
</tr>
<tr>
<td>4. subatomic particles</td>
<td>4. atomic mass</td>
</tr>
<tr>
<td>d. Negatively charged particle that exists in space surrounding an atom’s nucleus</td>
<td>d. The process that moves electrons away from the nucleus</td>
</tr>
<tr>
<td>5. nucleus</td>
<td>5. atomic mass unit</td>
</tr>
<tr>
<td>e. Positively charged particle that exists in nucleus of atom</td>
<td>e. How electrons are arranged around an atom</td>
</tr>
<tr>
<td>f. Tiny bits of matter that are the building blocks of an atom</td>
<td>f. The average mass of all of the known isotopes of an element</td>
</tr>
</tbody>
</table>

| Set Three                                    |                                              |
|----------------------------------------------|                                              |
| 1. group of elements                         | a. Atoms of the same element which have different numbers of neutrons in the nucleus |
| 2. periodic table                            | b. A unit equal to one-twelfth of the mass of carbon-12 |
| 3. chemical symbol                           | c. Elements with similar properties, listed in a single column on the periodic table |
| 4. mass number                               | d. The total number of protons and neutrons in the nucleus of an atom |
| 5. isotope                                   | e. A chart of the elements, arranged to provide information about each element’s behavior |
|                                              | f. The abbreviation for the name of an element |
Concept review

1. Draw a pictorial model of an atom that has 5 protons, 5 neutrons, and 5 electrons. Label the charge of each subatomic particle. What element is this?

2. Two atoms are placed next to each other. Atom A has 6 protons, 6 neutrons, and 5 electrons. Atom B has 6 protons, 7 neutrons, and 6 electrons. Are atoms A and B different elements? How do you know?

3. Why don’t the protons in a nucleus repel each other and break the atom apart?

4. Do scientists suspect that there is an infinite number of elements, just waiting to be discovered? What evidence might they give to support such a hypothesis?

Problems

1. How many electron shells would be completely filled by a neutral atom of calcium? How many electrons would be left over?

2. How many electron shells would be completely filled by a neutral xenon atom? How many electrons would be left over?

3. Which element is more likely to combine with other elements, calcium or xenon? How do you know?

4. Use the periodic table on the inside cover of your textbook to answer the following questions:
   a. A magnesium atom will react with two chlorine atoms to form magnesium chloride, MgCl₂. Name two other elements that are likely to react with chlorine in a similar manner.
   b. How many completely full electron shells do the elements in the third row contain? Are there any exceptions?

5. For each of the nuclei shown below, do the following:
   a. Name the element.
   b. Give the mass number.
   c. Show the isotope notation.

Applying your knowledge

1. Make a poster illustrating models of the atom scientists have proposed since the 1800s. Explain how each model reflects the new knowledge that scientists gained through their experiments. When possible, comment on what they learned about charge, mass, and location of subatomic particles.

2. Choose an atom and make a three-dimensional model of its structure, using the Bohr model. Choose different materials to represent protons, neutrons, and electrons. Attach a key to your model to explain what each material represents.