EXERCISES

Reading Questions
1. List three properties of the elements that are useful in sorting the elements.
2. Do you expect carbon, C, to be more similar to nitrogen, N, oxygen, O, or silicon, Si? Why?

Reason and Apply
3. WEB RESEARCH Use a reference book or the Internet to look up the average atomic masses and properties of silicon, Si, germanium, Ge, tin, Sn, phosphorus, P, antimony, Sb, sulfur, S, and selenium, Se.
   a. Organize these elements in rows and columns.
   b. List two properties that the elements in each column have in common.
4. WEB RESEARCH Use a reference book or the Internet to look up some of the properties of iron, barium, and phosphorus. Explain why nails are made of iron but they are never made of barium or phosphorus.
5. Suppose you have equal amounts of calcium, Ca, in two beakers. You react the calcium in one beaker with oxygen, O, and the other with sulfur, S. The reaction with oxygen forms the compound calcium oxide, CaO.
   a. What do you predict is the chemical formula of the compound formed from the reaction between calcium and sulfur?
   b. Which compound has more mass, the compound containing calcium and oxygen, or the compound containing calcium and sulfur? Explain your thinking.
6. WEB RESEARCH Use a computer to research Dmitri Mendeleyev, the Russian chemist credited with the discovery of the periodic table of the elements. Write a brief paragraph describing Mendeleyev's life and work. Include how he became a chemistry professor and how he came up with the idea for the periodic table.
7. Find at least two different versions of the periodic table and bring a copy of each to class.
   a. Write down what you think makes these two versions similar to each other.
   b. Write down what you think makes these two versions different from each other.

LESSON 10 Breaking the Code The Periodic Table

Think About It
The elements copper, Cu, and gold, Au, share many similarities. Both are relatively unreactive elements. They are soft so it is easy to bend and shape them. They are called coinage metals because they have been made into coins by many cultures. Copper and gold have high values as jewelry because they remain shiny for many years. Is the similarity in their properties related to their locations on the periodic table?

What information does the periodic table reveal about the elements?
To answer this question, you will explore
1. The Modern Periodic Table
2. Trends in Properties

Exploring the Topic
1. The Modern Periodic Table
Scientists have detected around 114 different elements on the planet. Each is unique. Yet, groups of elements have similar properties. Recall from Lesson 9: Create a Table that Dmitry Mendeleev constructed a table based on patterns in the properties of the elements. His table has been replaced over the decades with many updated versions, such as the one shown on pages 44 and 45. The modern periodic table is a storehouse of valuable information about the elements. Over time you will learn how to make use of the information that is contained there.

Element Squares
Each element has a square on the periodic table. Within each square is information about that element including its name and symbol. The whole number in each square is called the atomic number. Hydrogen is the first element in the table and has the atomic number 1. Helium is the second element and has the atomic number 2. Each atomic number corresponds to a different element.

The decimal number in each square on the periodic table square is the average atomic mass in amu.

Here is a square from the periodic table.
Periodic Table of the Elements

Main Group Elements

- Group IA (except for hydrogen, H)
- Group IIA
- Group IIIA
- Group IIIIB
- Group IV A
- Group VA
- Group VIA
- Group VIIA
- Group VIIIB
- Group VIII

Lanthanides

- La Lanthanum (138.9)
- Ce Cerium (140.1)
- Pr Praseodymium (140.9)
- Nd Neodymium (144.2)
- Pm Promethium (145)
- Sm Samarium (150.4)

Actinides

- Ac Actinium (227)
- Th Thorium (232.0)
- Pa Protactinium (231.0)
- U Uranium (238.0)
- Np Neptunium (237)
- Pu Plutonium (244)

Metals

- Metals
- Nonmetals
- Solids
- Liquids
- Gases

Aqueous Number

- Symbol
- Name
- Average atomic mass

Halogen

- B Boron 10.81
- C Carbon 12.01
- N Nitrogen 14.03
- O Oxygen 16.00
- F Fluorine 19.00
- Ne Neon 20.18
- Al Aluminum 26.98
- Si Silicon 28.09
- P Phosphorus 30.97
- S Sulfur 32.07
- Cl Chlorine 35.45
- Ar Argon 39.95

Noble Gases

- Kr Krypton 83.80
- Xe Xenon 131.3

- Rn Radon 222

- No Neon 40

- Ne Neutron 2

Lesson 10: Breaking the Code
Parts of the Periodic Table
Most modern periodic tables have 18 vertical columns and 7 horizontal rows. The vertical columns are also called groups, or families. Hydrogen, H, is in Group 1A, along with lithium, Li, and five other elements in that column. Some of the groups have specific names as shown below.

The horizontal rows of the table are called periods because patterns repeat periodically, or over and over again, in each row. There are only two elements in Period 1, hydrogen and helium. However, there are eight elements in Periods 2 and 3, and 18 elements in Period 4.

Chemists also have names for sections of the periodic table. Between Group 2A and Group 3A, for example, is where the transition elements fit in.

In addition, there are two rows of elements usually shown at the bottom of the table. These elements are called the lanthanides and actinides. If you examine the atomic numbers of these elements, you’ll see that they belong in the sixth and seventh rows. If they were included where they belong, the table would look like this.

Most periodic tables show them at the bottom so everything will fit onto one page.

2 Trends in Properties
Once the elements are arranged according to their general properties, many other patterns or trends can be found. These three drawings illustrate some of the trends contained within the periodic table.

Solids, Liquids, and Gases
Most of the elements are solids at room temperature. There are several elements that are gases at room temperature, and only a few that are liquids at or near room temperature.

Metals, Metalloids, and Nonmetals
The majority of the elements are metals. On most periodic tables there is a stair-step line that divides the table. Metals are found to the left and nonmetals are
found to the right of the stair-step line. The elements found along the stair-step line are called **metalloids**. Metalloids have properties similar to those of both metals and nonmetals.

**Example 1**

**Iodine, I**

- Find iodine, I, on the periodic table.
- a. Find iodine’s atomic number, average atomic mass, period, and group.
- b. Would you expect iodine to be a solid, liquid, or gas at room temperature?
- c. Is iodine a metal, metalloid, or nonmetal? How can you tell?
- d. Do you expect iodine to be reactive? Explain.

**Solution**

- Iodine is in the lower-right area of the main group elements.
- a. The atomic number is 53. Average atomic mass is 126.9 amu. Iodine is in Period 5 and Group 7A, halogens.
- b. Iodine is a gas at room temperature.
- c. Iodine is a nonmetal, because it is to the right of the stair-step line.
- d. Yes, you can expect it to be reactive, though not as reactive as elements above it in Group 7A.

**Example 2**

**Coinage Metals**

Which element would make the best coin: phosphorus, P; silver, Ag; potassium, K; or xenon, Xe? Explain your thinking.

**Solution**

- Xenon, Xe, is a gas, so it is definitely not a candidate for making a coin.
- Phosphorus, P, is a nonmetal that is dull and brittle. It would be difficult to shape into a coin. Silver, Ag, is a shiny, malleable metal, so it would make the best coin. Potassium, K, is also a metal, but it is too soft and reactive, so it would not make a good coin. A good coin should not react with other substances.

**Key Terms**

- atomic number
- group
- alkali metals
- alkaline earth metals
- halogens
- noble gases
- periods
- main group elements
- transition elements
- lanthanides
- actinides
- metals
- nonmetals
- metalloids

**Lesson Summary**

**What information does the periodic table reveal about the elements?**

The periodic table is an organized chart of the elements. Each element square contains valuable information, including the element name, symbol, atomic number, and average atomic mass. These elements are arranged in vertical columns called groups, or families, and horizontal rows called periods. Most elements are solids and metals, except for those in the upper right of the table. The most reactive elements are located in the lower left and upper right of the table, excluding the noble gases in the last column on the right, which are unreactive.
A World of Particles

All matter is composed of tiny particles called atoms. Based on their observations, chemists agree that atoms themselves are composed of even tinier structures, a nucleus and electrons orbiting around it. What are atoms and what does their structure tell you about matter?

In this section, you will study
- models of the atom
- how atoms differ from one another
- nuclear reactions
- how elements are created

LESSON 11 Atomic Pudding Models of the Atom

Think About It
The drawing depicts a very tiny sample of gold taken from a gold ring.

The spheres in the cube of gold are so small that they cannot be seen. What are the spheres, and what does this drawing tell you about the element gold?

How are the smallest bits of matter described?
To answer this question, you will explore
1. Atoms: Small Bits of Matter
2. Models of the Atom
3. Simple Atomic Model

Exploring the Topic
1. Atoms: Small Bits of Matter
Imagine you break a piece of matter in half, and then break it in half again and again. How many times can you do this? Can you keep going, getting ever smaller? Around 460 B.C.E., the Greek philosopher Democritus wondered the same thing. He thought that if he could just keep breaking matter in half he would eventually end up with the smallest bit of matter possible.

Democritus proposed that all matter was composed of tiny particles that could not be divided further. Today we use the word atom to describe these bits of matter. Of course, atoms are too small to actually be seen. Democritus’ idea was disregarded for the next two thousand years, in part, because Democritus did not have evidence to support it.

In 1803, the British scientist John Dalton suggested that the idea of atoms could help explain why elements come together in specific ratios when they form compounds. He imagined atoms of different elements combining to form compounds in the ratios specified by the chemical formulas of the compounds. For example, to form the compound titanium sulfide, $TiS_2$, titanium and sulfur atoms combine in a 1:2 ratio.

Dalton had more than an idea about atoms. He conducted experiments and made observations to back up his idea. His observations provided strong evidence to support his explanation of how matter behaves.
In science, the word “theory” indicates that an explanation is supported by overwhelming evidence. The word “theory” allows room for doubt and revision, but indicates a greater degree of certainty than the word does in everyday use. The atomic theory states that all matter is made up of atoms. The atomic theory helps us make accurate predictions about the behavior of matter.

2 Models of the Atom
Since Dalton’s time, scientists have created many models to describe atoms and their parts. Models are simplified representations of something you want to explain. For example, a model airplane is a small representation of a larger aircraft. Models take many forms. They can be a plan, a physical structure, a drawing, a mathematical equation or even a mental image. A model that represents the structure of an atom is called an atomic model.

Dalton pictured the atom as a hard, solid sphere. Over the next two hundred years, scientists gathered evidence to support and expand on Dalton’s model of the atom. It became clear that the atom was more than just a solid sphere.

EXPERIMENT 1
In 1803, John Dalton studied how elements combine chemically to form compounds. He observed that elements combine in whole-number ratios to form compounds and that matter is not created or destroyed in chemical reactions. Dalton reasoned that elements are made of tiny, indivisible spherical particles called atoms.

EXPERIMENT 2
In 1897, J.J. Thomson, a British scientist, zapped atoms with electricity. He observed that negatively charged particles were removed. Thomson reasoned that atoms contain negatively charged particles, which he called electrons.

EXPERIMENT 3
In 1911, Ernest Rutherford, a New Zealand-born scientist, shot tiny positively charged particles, called alpha particles, at thin gold foil. He observed that most of the alpha particles went through the foil, but a few bounced back. Rutherford reasoned that there must be something small, massive, and positively charged in an atom, which he called the nucleus.

EXPERIMENT 4
In 1913, Niels Bohr, a Danish scientist, developed a model of the atom that explained the light given off when elements are exposed to flame or electric fields. He observed that only certain colors of light are given off. For example, hydrogen atoms give off red, blue-green, and blue light. Bohr reasoned that the electrons orbit around the nucleus at different distances like planets orbiting the Sun. The electrons in these orbits have different energies. When an electron falls from an outer to an inner orbit, the color of the light given off depends on the energies of the two orbits.

EXPERIMENT 5
In 1918, Rutherford made a further contribution. He found he could use alpha particles as bullets to knock off small positively charged particles, which he called protons. He reasoned that the nucleus must be a collection of protons.

EXPERIMENT 6
In 1927, Werner Heisenberg, a German scientist, proposed a cloud model of the atom. Heisenberg suggested that the location of an electron could not be specified precisely. Instead, it is only possible to talk about the probability of where an electron might be. This led to a cloud model of the atom; the electron cloud indicates where you will most likely find a single electron.

EXPERIMENT 7
In 1922, a British physicist, James Chadwick, found that the nucleus also included uncharged, or neutral, particles, which he called neutrons. He reasoned that the neutrons were important in holding the positively charged protons together.
But how did scientists gather evidence about something too small to be seen? Scientists found they could learn more about atoms and their structure by shooting small pieces of matter at them or by heating them in a flame. Observations from these experiments provided evidence that helped scientists make changes and refine the model of the atom.

The model of the atom was refined and changed as new evidence was gathered. This is what science is all about—a continual process of gathering new knowledge to improve our understanding of the world.

3 Simple Atomic Model

All of the models have something valuable to offer in terms of visualizing matter at an atomic level. At right is a simple atomic model of an atom. In the very center of the atom is the nucleus. The nucleus consists of positively charged protons, and neutrons, which have no charge. The electrons are even tinier than the protons and neutrons, and they orbit the nucleus. In this particular atom the electrons are located at two different distances from the nucleus. Each electron has a charge of +1. The neutrons are neutral and thus have no charge. Each proton has a charge of +1. A neutral atom has no overall charge. It has equal numbers of positive protons and negative electrons.

Lesson Summary

How are the smallest bits of matter described?

Long ago, some philosophers imagined that matter was made up of tiny particles called atoms. Over time, scientists gathered evidence from experimental observations to create models of the atom. Today we know the atom is made up of protons, neutrons, and electrons. The protons and neutrons are in the center of the atom, in the nucleus. Electrons are outside the nucleus. They are much smaller than the protons and neutrons. In a neutral atom, the positive charges on the protons are equal to the negative charges on the electrons.

Exercises

Reading Questions

1. What evidence caused Thomson to change Dalton’s solid sphere model into the plum pudding model?
2. What evidence caused Rutherford to change Thomson’s plum pudding model into the nuclear model?
3. What evidence caused Bohr to change Rutherford’s nuclear model into the solar system model?

Reason and Apply

4. Positive and negative charges are attracted to one another. Which of the following are attracted to a negative charge: an electron, a proton, a neutron, a nucleus, an atom? Explain your thinking.
5. Hydrogen and helium are different elements. How can you use the plum pudding model to show how atoms of the two elements might be different from one another?
6. Suppose you discovered protons shortly after Thomson discovered electrons. How would you revise the plum pudding model to include protons? Draw a picture of your revised model of the atom.
7. Draw a solar system model showing one electron, one proton, and one neutron.
8. WEB RESEARCH Use the Internet or other resource to find out how the size of an atom compares with the size of its nucleus. Is the diameter of an atom 10 times, 1,000 times, or 100,000 times the diameter of the nucleus?
9. The nuclear model and the solar system model both show atoms with electrons circling around the nucleus.
   a. How do these two models differ?
   b. How are these two models similar?
   c. How can you refine the solar system model so that the atoms do not look flat?
10. WEB RESEARCH The ancient Greeks discarded the atomic theory because there was no evidence to support it. Try to provide evidence that atoms do indeed exist. Use the Internet to help you.
11. The ancient Greeks claimed that atoms were the smallest pieces of matter. Were they correct? Explain your thinking.
12. Give an example that shows how science is a process of gathering evidence and refining models.
Every proton in every atom, whether it is an atom of gold or an atom of oxygen, has the same mass. Scientists assign a value of one atomic mass unit, 1 amu, to the mass of a single proton. Neutrons have almost exactly the same mass as protons, so each neutron also has a mass of 1 amu. To determine the mass of a single atom, you add the number of protons and neutrons.

How Many Neutrons?
If you look at the atomic models, you will notice that the numbers of protons and electrons are exactly the same as the atomic number, but the number of neutrons is sometimes different from the number of protons. So, how can the periodic table tell you how many neutrons are in an atom? If you know the mass of an atom and you know how many protons it has, you can find out how many neutrons it has by subtracting the number of protons from the atomic mass.

Average Atomic Mass
It turns out that not every atom of an element is identical. So, the decimal number in each square of the periodic table is the average atomic mass of that element in atomic mass units, amu. This number can also be used to estimate the number of neutrons in a nucleus. Simply subtract the atomic number (number of protons) from the average atomic mass and round the result. For example, lithium has an average atomic mass of 6.941 amu, so a typical lithium atom probably has a mass of 7 amu. The atomic number of lithium is 3, so there are 3 protons. This accounts for 3 amu of the mass. The other 4 amu must be due to 4 neutrons.

In Lesson 13: Subatomic Heavyweights, you will investigate how the average atomic mass is arrived at and how atoms of an element may differ from one another.

Important to Know
When considering atomic mass, it is necessary to know whether you are focusing on the mass of one particular atom or the average mass of a group of atoms.

The Periodic Table and Atomic Models
To draw an atomic model of a specific element, you must know the numbers of protons, neutrons, and electrons. You find this information on the periodic table.
This illustration shows you how to get information about atomic structure from each square of the periodic table to build a basic atomic model of an element.

### HISTORY CONNECTION

Ernest Rutherford, a New Zealand-born scientist, is generally credited with the discovery of the proton. He was awarded the Nobel Prize in Chemistry in 1908, and his image appears on the New Zealand 100 dollar note.

### Example

**Copper and Gold Atoms**

How is an atom of gold, Au, different from an atom of copper, Cu?

**Solution**

You can find the information you need on the periodic table. The atomic number of copper is 29. So neutral copper atoms have 29 protons and 29 electrons.

### Lesson Summary

**How are the atoms of one element different from those of another element?**

The periodic table reveals information about atomic structure. The atomic number of an element is equal to the number of protons in each of its atoms. The atomic number is also equal to the number of electrons in a neutral atom of an element. You can identify an element by the number of protons in the nucleus of an atom of the element. The protons and neutrons account for almost all the mass of an atom. Therefore, the mass of an atom in amu is approximately equal to the number of protons plus the number of neutrons. You can estimate the number of neutrons in an atom by subtracting the number of protons from the average atomic mass.

To estimate the number of neutrons in the atom, round the atomic mass to 64 and subtract the atomic number.

*Number of protons = 29*

*Number of electrons = 29*

*Number of neutrons = 35*

You can follow the same steps for gold atoms.

*Number of protons = 79*

*Number of electrons = 79*

*Number of neutrons = 118*

So a gold atom has 50 more protons, 50 more electrons, and about 83 more neutrons than a copper atom.
EXERCISES

Reading Questions
1. What does the atomic number tell you?
2. What does the atomic mass tell you?

Reason and Apply
3. If you have a sample of atoms and each atom has 12 protons in its nucleus, which element do you have?
4. If you want to identify an element, what one piece of information would you ask for? Explain your thinking.
5. Why does carbon, C, have a larger atomic mass than boron, B, even though they each have six neutrons?
6. Make a table like the one below. Use a periodic table to fill in the missing information.

<table>
<thead>
<tr>
<th>Element</th>
<th>Chemical Symbol</th>
<th>Atomic Number</th>
<th>Number of Protons</th>
<th>Number of Electrons</th>
<th>Number of Neutrons</th>
<th>Average Atomic Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>nickel</td>
<td>Ne</td>
<td>28</td>
<td>15</td>
<td>15</td>
<td>40</td>
<td>62.28</td>
</tr>
</tbody>
</table>

7. Draw a simple atomic model for an atom of neon, Ne.
8. Place the following elements in order from lowest number of protons to highest number of protons: S, Mg, N, Na, Se, Sr. Then give the following information about a neutral atom of each: name, atomic number, number of protons, number of electrons, group number.

Lesson 13 Subatomic Heavyweights

Isotopes

Think About It
It might surprise you that all atoms of the element copper are not exact replicas of one another. Although all copper atoms have many similarities, their masses can differ by 1 or 2 amu. What is the same and what is different about these atoms?

How can atoms of the same element be different?
To answer this question, you will explore
1. Isotopes
2. Average Atomic Mass

Exploring the Topic

1. Isotopes

Variations in the Nucleus
Carbon is the sixth element on the periodic table. Its average atomic mass is listed as 12.01 amu. Why is the atomic mass listed as 12.01 rather than simply as 12?
Most of the carbon atoms that are found in nature do have a mass of 12 amu. However, for every 100 carbon atoms, it is typical to find one carbon atom with a mass of 13 amu and even more rarely a carbon atom with a mass of 14 amu. This makes the average atomic mass 12.01 amu. Consider the structures of these three varieties of carbon atom. A model of each is shown here.

[Diagram showing carbon-12, carbon-13, and carbon-14 isotopes]

The difference in the number of neutrons in the nucleus of each atom.

Compare the nucleus of each atom. Each has 6 protons. That is what makes them all carbon atoms. Recall that each atom of an element has the same number of protons as every other atom of that element.
However, one carbon atom has 6 neutrons, another carbon atom has 7 neutrons, and the third has 8 neutrons. The mass of an atom is the sum of the number of protons and neutrons, so one carbon atom has a mass of 12 amu and the others
have masses of 13 and 14 amu. These atoms are referred to as carbon-12, carbon-13, and carbon-14 to show that they are all atoms of carbon but have different masses.

Atoms of an element that have different numbers of neutrons are called isotopes. Carbon has three isotopes. In nature, almost all the elements have at least two isotopes. A few elements have as many as ten isotopes.

**Isotope Symbols**

Symbols for the three isotopes of carbon are shown below. Notice that the mass of each isotope is shown as a superscript number (on top). This number is a whole number. It is the sum of the numbers of protons and neutrons in the atom and is sometimes called the mass number. The subscript number (on the bottom) is the atomic number of the element, in this case, 6. The number of neutrons in each atom is equal to the top number minus the bottom number.

**Isotope Symbols for Carbon**

![Isotope Symbols for Carbon](image)

These three isotopes are virtually identical in their properties. For example, they all form the same compounds.

**TECHNOLOGY CONNECTION**

A mass spectrometer is used to determine the isotopic composition of an element. It makes an extremely accurate measurement of the mass of an individual atom, using the principle that a heavier particle will travel a straighter path through a magnetic field than a lighter particle.

**Average Atomic Mass**

You may have noticed that the average atomic mass values in each square of the periodic table are decimal numbers, usually to the nearest hundredth of a unit. These values are averages of the masses of the isotopes in a sample. For example, neon has an average atomic mass of 20.18 amu. How is this average calculated?

![Average Atomic Mass](image)

About 90% of all neon atoms have an atomic mass of 20 amu, 9% have an atomic mass of 22 amu, and 1% have an atomic mass of 21 amu. By considering a random sample of 100 neon atoms, you can calculate their average atomic mass like this:

\[
\text{average atomic mass} = \frac{\text{total mass}}{\text{number of atoms}} = \frac{(90)(20 \text{ amu}) + (9)(22 \text{ amu}) + (1)(21 \text{ amu})}{100} = 20.19 \text{ amu}
\]

As you can see, this number is nearly identical to 20.18, the average atomic mass listed for neon on the periodic table.

The percentage of each isotope of an element that occurs in nature is called the natural abundance of the isotope. For example, the natural abundance of neon-20 is about 90.48%.

**Important to Know** The mass of an isotope refers to the mass of a single specific atom of an element. The average atomic mass given on the periodic table is the average of the masses of all the isotopes in a large sample of that element.

**Example**

**Isotopes of Copper**

There are two different isotopes of copper. The isotope names and symbols are given here.

<table>
<thead>
<tr>
<th>Cu-63</th>
<th>Cu-65</th>
</tr>
</thead>
<tbody>
<tr>
<td>copper-63</td>
<td>copper-65</td>
</tr>
</tbody>
</table>

a. Explain why both symbols have 29 as the bottom number.
b. Explain how the two isotopes are different from each other.
c. Scientists have found the natural abundances of each isotope: 69% copper-63 and 31% copper-65. Explain why the average atomic mass listed on the periodic table for copper is 63.55.

**Solution**

a. Copper's atomic number is 29, so both isotope symbols have a subscript 29 indicating 29 protons.
b. The two isotopes have different atomic masses. Both isotopes have 29 protons, so copper-63 has 34 neutrons and copper-65 has 36 neutrons.
c. You could consider a sample of 100 atoms of copper and calculate their average mass. The average mass of the 100 atoms is determined by adding the masses of the 100 atoms and dividing this total by 100.

\[
\frac{69(63 \text{ amu}) + 31(65 \text{ amu})}{100} = \frac{6362 \text{ amu}}{100} = 63.6 \text{ amu}
\]

This is very close to the value found on the periodic table.
Alternatively, you can convert each isotope’s percent natural abundance to a decimal number, then multiply this by the isotope’s mass number. Do this for each isotope, then add the products:

\[
69\% = \frac{69}{100} = 0.69 \quad 31\% = \frac{31}{100} = 0.31
\]

\[
(0.69)(63 \text{ amu}) + (0.31)(65 \text{ amu}) = 63.6 \text{ amu}
\]

**Lesson Summary**

**How can atoms of the same element be different?**

Elements are composed of nearly identical atoms, each with the same number of protons. However, not every atom of an element has the same number of neutrons in its nucleus. Atoms of an element with different numbers of neutrons are called isotopes. Because neutrons account for part of the mass of an atom, isotopes have different masses. The average atomic mass is an average of the masses of all the different isotopes, taking natural abundance into account.

**EXERCISES**

**Reading Questions**

1. Explain the differences between atomic number and atomic mass.
2. Explain the difference between the average atomic mass given on the periodic table and the mass of an atom.

**Reason and Apply**

3. How are potassium-39, potassium-40, and potassium-41 different from each other? Write the isotope symbols for the three isotopes of potassium.
4. How many protons, neutrons, and electrons are in each?
   a. fluorine-23
   b. $^{59}$Co
   c. molybdenum-96
5. An isotope of iron, Fe, has 26 protons and 32 neutrons.
   a. What is the approximate mass of this isotope?
   b. How would you write the symbol for this isotope?
6. Find the element phosphorus, P, on the periodic table.
   a. What is the average atomic mass of phosphorus?
   b. What is its atomic number?
   c. Predict which isotope you would find in greatest abundance for phosphorus.
7. Chlorine, Cl, is 76% chlorine-35 and 24% chlorine-37. Determine the average atomic mass of chlorine.
8. Lithium, Li, is 7.6% lithium-6 and 92.4% lithium-7. Determine the average atomic mass of lithium.
9. Which isotope of nitrogen is found in nature? Explain your reasoning.
   A. $^{14}$N  
   B. $^{15}$N  
   C. $^{15}$N

Unit I ALCHEMY  Section III A World of Particles