Launch Lab
Hidden Information

Much of the fun of receiving a wrapped gift is trying to figure out what is inside before you open it. Chemists have had similar experiences trying to determine the structure of the atom. How good are your skills of observation and inference?

For a lab worksheet, use your StudentWorks™ Plus Online.

Make a three-tab book. Label it as shown. Use it to organize your notes on atoms.
THEME FOCUS Structures and Properties of Matter
Atoms are classified based on their physical and chemical properties.

BIG Idea The properties of an element are determined by the structure of its atoms.

Section 1 • Structure of the Atom
Section 2 • Masses of Atoms
Section 3 • The Periodic Table
Concepts in Motion
Interactive Table

Chapter 16 • Properties of Atoms and the Periodic Table

Structure of the Atom

Main Idea Protons and neutrons form the nucleus of an atom, and electrons occupy a space surrounding the nucleus.

Real-World Reading Link Try to picture an outer belt freeway system of a large city that measures thirty kilometers in diameter. This freeway outer belt represents the size of an atom. The nucleus of that same atom is represented by a small fish tank in the center of the city.

Scientific Shorthand

Do you use abbreviations for long words, street addresses, or the names of states? Scientists also use abbreviations. In fact, scientists have developed their own shorthand for naming the elements. Do the letters C, Al, Ne, and Au mean anything to you? Each letter or pair of letters is a chemical symbol, which is a short or abbreviated 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 lowercase 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. The chemical symbol for silver is Ag.

Elements are named in a variety of ways. Some elements are named to honor scientists, for places, or for their properties. For example, the element curium was named to honor Pierre and Marie Curie, scientists who researched radioactivity. Other elements, like germanium, were named after a country. Regardless of the origin of the name, scientists derived the international system of symbols for convenience. It is much easier to write H for hydrogen, O for oxygen, and H₂O for dihydrogen monoxide (water). Because scientists worldwide use this system, everyone recognizes what these symbols represent.

Table 1 Symbols of Common Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Al</td>
<td>Iron</td>
<td>Fe</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>Mercury</td>
<td>Hg</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>Nitrogen</td>
<td>N</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>Sodium</td>
<td>Na</td>
</tr>
</tbody>
</table>

SC.912.P.8.4: Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have.

SC.912.N.3.1: Explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have.

SC.912.N.3.5: Describe the function of models in science, and identify the wide range of models used in science.
Subatomic Particles

An element is matter that is composed of only one type of atom. An atom is the smallest particle of an element that retains the element’s properties. For example, the element iron is composed of only iron atoms and the element hydrogen is composed of only hydrogen atoms. Atoms are composed of even smaller particles—subatomic particles—called protons, neutrons, and electrons, as shown in Figure 1. The small, positively charged center of the atom is called the nucleus. The nucleus contains protons and neutrons. Protons are particles in the nucleus with an electric charge of 1+. The number of protons in the nucleus is unique for each element. Neutrons are electrically neutral particles in the nucleus; they do not have a charge. Electrons are particles with an electric charge of 1−. They occupy the space surrounding the nucleus of an atom.

**Reading Check** Identify the three types of subatomic particles.

**Quarks—even smaller particles** Are the protons, electrons, and neutrons that make up atoms the smallest particles that exist? Scientists have inferred that protons and neutrons are composed of smaller particles called quarks. Electrons, however, are not made of smaller particles. So far, scientists have confirmed the existence of six uniquely different quarks. A particular arrangement of three of these quarks produces a proton. Another arrangement of three quarks produces a neutron. The search for the composition of protons and neutrons is a continuing effort.

**Figure 1** The nucleus of the atom contains protons and neutrons. The proton has a positive charge, and the neutron has no charge. Protons and neutrons are themselves composed of quarks. Electrons occupy a space surrounding the nucleus, which is called the electron cloud.

**Compare and contrast protons, neutrons, and electrons.**

**Vocabulary**

**Word Origin**

Atom comes from the Greek word atomos, meaning indivisible or uncuttable. The basic building block of all matter is the atom.

**Foldables**

Incorporate information from this section into your Foldable.
The search for quarks  To study quarks, scientists accelerate charged particles to tremendous speeds and then force them to collide with—or smash into—protons. These collisions cause the protons to break apart. The Fermi National Accelerator Laboratory in Batavia, Illinois, houses a machine that can generate the forces that are required to create this type of collision. This particle accelerator, called the Tevatron, is shown in Figure 2. Electric and magnetic fields inside the Tevatron are used to accelerate, focus, and collide fast-moving particles.

The Large Hadron Collider (LHC), also shown in Figure 2, is a particle accelerator in Geneva, Switzerland. The ultimate goal of the LHC is to discover new particles and to further explain the formation of the universe.

Scientists use a variety of collection devices to obtain detailed information about the particles created in a collision. Just as police investigators can reconstruct traffic accidents from tire marks and other evidence at the scene, scientists are able to examine data collectors for evidence of the tiniest of particles. Scientists use inference to identify subatomic particles and to reveal information about each particle’s structure. For example, the wire chambers in Figure 3 help scientists examine the varying tracks made by different types of particles formed in high-speed collisions.

The sixth quark  Finding evidence for the existence of quarks was not an easy task. Scientists discovered five quarks and hypothesized that a sixth quark existed. However, it took several years for a team of nearly 450 scientists from around the world 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 objects or ideas that are difficult to visualize or to picture in your mind. You might have seen models or blueprints of buildings, planetary models of the solar system, or even a model airplane. These are scaled-down models. Scaled-down models allow you to see something that is too large to visualize all at once or something that has not yet been built.

Scaled-up models are often used to visualize things that are too small to see. Models of atoms are examples of scaled-up models. To give you an idea of how small the atom is, it would take about 50,000 aluminum 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 an atom. For a model of the atom to be useful, it must support the accepted ideas about atomic structure and behavior. As new discoveries about atoms are made, scientists must include these new details in the model.

The atomic model

You now know that all matter is composed of atoms, but this was not always accepted as truth. Around 400 B.C., the Greek philosopher Democritus proposed the idea that atoms are tiny particles that make up all matter. Another philosopher, Aristotle, disputed Democritus’s idea and proposed that matter was uniform throughout and was not composed of such small particles. Aristotle’s incorrect idea was accepted for about 2,000 years. In the 1800s, the English scientist John Dalton was able to present evidence to suggest that atoms exist.

Dalton’s atomic theory, highlighted in Table 2, led to his model of the atom. This model has changed somewhat over time with further investigations by other scientists, as shown on the next page in Figure 4. Dalton’s modernization of Democritus’ idea of the atom provided a physical explanation for chemical reactions. Due to this discovery, scientists could finally express these reactions in quantitative terms using chemical symbols and equations.

Table 2

Dalton’s Atomic Theory

- Matter is composed of extremely small particles called atoms.
- Atoms are indivisible and indestructible.
- Atoms of a given element are identical in size, mass, and chemical properties.
- Atoms of a specific element are different from those of another element.
- Different atoms combine in simple whole-number ratios to form compounds.
- In a chemical reaction, atoms are separated, combined, or rearranged.

Section 1 • Structure of the Atom
Visualizing the Early Atomic Models

The currently accepted model of the atom evolved from the ideas and the work of many scientists.

400 B.C. Democritus Model  Democritus first proposed that elements consisted of tiny, solid particles that could not be subdivided. He called these particles \textit{atomos}, meaning “uncuttable.” Democritus’s ideas were criticized by Aristotle, who believed that empty space could not exist. Because Aristotle was one of the most influential philosophers of his time, Democritus’s atomic theory was rejected.

1904 Thomson Model  English physicist Joseph John Thomson proposed a model that consisted of a spherical atom containing 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.

1911 Rutherford Model  English physicist Ernest Rutherford proposed that all the positive charge of an atom was concentrated in a central atomic nucleus that was surrounded by electrons.

1913 Bohr Model  Danish physicist Niels Bohr hypothesized that electrons traveled in fixed orbits. The electrons could jump between orbits as they absorbed or released specific amounts of energy. The Bohr model worked very well for hydrogen, but did not work as well for atoms with many electrons.
The electron cloud model  By 1926, scientists developed the electron cloud model of the atom, which is the model that is accepted today. An electron cloud is the area around the nucleus of an atom where electrons are most likely to be found. The electron cloud is 100,000 times larger in diameter than the diameter of the nucleus of an atom. In contrast, each electron in the cloud is significantly smaller in mass than a single proton or single neutron.

Reading Check  Explain the difference between the Bohr model and the electron cloud model.

Because an electron’s mass is negligible compared to the nucleus and the electron is moving so quickly around the nucleus, it is impossible to describe its exact location in an atom at any moment. Picture the spokes on a moving bicycle wheel. The spokes are moving so quickly that you cannot pinpoint any single spoke in the wheel. All that you see is a blur that contains all the spokes somewhere within it. In a similar way, an electron cloud is a blur of activity containing all of an atom’s electrons somewhere within it. Figure 5 illustrates the location of the nucleus and the electron cloud in the electron cloud model of the atom.

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**Section 1 Review**

**Section Summary**
- Scientists use chemical symbols to abbreviate element names.
- Atoms are composed of protons, neutrons, and electrons.
- Scientists have confirmed the existence of six different quarks.
- The electron cloud model is the current atomic model.

1. **MAIN IDEA** Identify the names, charges, and locations of three types of subatomic particles that make up an atom.
2. **Identify** the chemical symbols for the elements carbon, aluminum, hydrogen, oxygen, and sodium.
3. **Describe** how quarks were discovered.
4. **Think Critically** Explain how a rotating electric fan might be used to model the atom. Explain how the rotating fan is unlike an atom.

**Apply Math**

5. **Estimate** A proton’s mass is estimated to be $1.6726 \times 10^{-24}$ g, and the mass of an electron is estimated to be $9.1093 \times 10^{-28}$ g. How many times larger is the mass of a proton compared to the mass of an electron?
Masses of Atoms

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

**Real-World Reading Link** You are probably aware that numbers are often used for identification. For example, a computer can be identified by its IP address and a cell phone by its phone number. Similarly, elements are identified by a number—the number of protons in the nucleus.

**Atomic Mass**

The nucleus contains almost all of the atom’s mass because protons and neutrons are far more massive than electrons. The mass of a proton is roughly the same as that of a neutron—about $1.67 \times 10^{-24}$ g, as shown in Table 3. The mass of each is more than 1,800 times greater than the mass of the electron. The electron’s mass is so small that it can be ignored when evaluating the mass of an atom.

If you were asked to estimate the height of your school building, you would probably not give an answer in kilometers. Considering the scale of the building, you would more likely give the height in meters. When thinking about the mass of an atom, scientists discovered that even grams were not small enough to use for measurement. Scientists needed a more manageable unit.

The unit of measurement used to quantify an atom’s mass 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 of the mass of a carbon atom containing six protons and six neutrons, as shown in Figure 6. Remember that the mass of an atom is contained almost entirely in the mass of the protons and neutrons in the nucleus. Therefore, each of the 12 particles in the carbon nucleus must have a mass nearly equal to 1 amu.

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>$1.6726 \times 10^{-24}$</td>
</tr>
<tr>
<td>Neutron</td>
<td>$1.6749 \times 10^{-24}$</td>
</tr>
<tr>
<td>Electron</td>
<td>$9.1093 \times 10^{-28}$</td>
</tr>
</tbody>
</table>

**Table 3: Subatomic Particle Masses**
Atomic number  Recall that an element is made of one type of atom. What determines the type of atom? In fact, the number of protons identifies the type of atom. For example, every carbon atom has six protons. Also, any atom with six protons is a carbon atom. Atoms of different elements have different numbers of protons. For example, atoms with eight protons are oxygen atoms.

The number of protons in an atom’s nucleus is equal to its atomic number. The atomic number of carbon is six. Oxygen has an atomic number equal to eight, as shown in Table 4. Therefore, if you are given any one of the following—the name of the element, the number of protons for the element, or the atomic number of the element—you can identify the other two. For example, if your teacher asked you to identify an atom with an atomic number of 11, you would know that the atom has eleven protons and it is sodium, as indicated in Table 4.

Reading Check  Interpret Table 4 to identify the element and the atomic number of the element with 29 protons.

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.

\[
\text{Mass number} = \text{number of protons} + \text{number of neutrons}
\]

For example, you can calculate the mass number of the copper atom listed in Table 4: 29 protons plus 34 neutrons equals a mass number of 63.

Also, if you know the mass number and the atomic number of an atom, you can calculate the number of neutrons in the nucleus. The number of neutrons is equal to the mass number minus the atomic number. In fact, if you know two of the three numbers—mass number, atomic number, number of neutrons—you can always calculate the third.
Isotopes

Atoms of the same element can have different mass numbers. For example, carbon atoms can have a mass number of 12 and also a mass number of 14. The number of protons for each element never changes. So, for an atom’s mass number to differ, the number of neutrons must change. Atoms of the same element that have different numbers of neutrons are called isotopes.

To identify isotopes, scientists write the name of the element followed by the element’s mass number. Carbon with a mass number of 12 is written as carbon-12. Carbon-12 has six protons and six neutrons. Carbon-14 has six protons and eight neutrons. Carbon-12 and carbon-14 are isotopes of the element carbon. Some properties of carbon-12 and carbon-14 are unique due to differences in the number of neutrons that each element contains. For example, carbon-14 is radioactive, but carbon-12 is not.

Suppose you have a sample of the element boron. Naturally occurring isotopes of boron have mass numbers of 10 or 11. How many neutrons does each isotope contain? Locate boron in Table 4 on the previous page and determine the number of protons in an atom of boron. You can then calculate that boron-10 has 5 neutrons and boron-11 has 6 neutrons.

Half-Lives of Radioactive Isotopes

<table>
<thead>
<tr>
<th>Parent Isotope</th>
<th>Daughter Isotope</th>
<th>Half-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium-238</td>
<td>Lead-206</td>
<td>4,470 billion years</td>
</tr>
<tr>
<td>Potassium-40</td>
<td>Argon-40, calcium-40</td>
<td>1,260 billion years</td>
</tr>
<tr>
<td>Rubidium-87</td>
<td>Strontium-87</td>
<td>48,800 billion years</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>Nitrogen-14</td>
<td>5,730 years</td>
</tr>
</tbody>
</table>

How can radioactive isotopes help tell time?

Some isotopes are radioactive, which means they decay over time. The time that it takes for half of the radioactive isotope to decay into another isotope is called its half-life. Scientists use the half-lives of radioactive isotopes to measure geologic time.

Identify the Problem

The table to the right shows the half-lives of some radioactive isotopes (parent isotopes) and the isotopes into which they decay (daughter isotopes). For example, it would take 5,730 years for half of the carbon-14 atoms in a sample to change into atoms of nitrogen-14. After another 5,730 years, half of the remaining carbon-14 atoms will change, and so on. Because the number of carbon-14 atoms change while the number of carbon-12 atoms do not, the ratio of the number of carbon-14 atoms to carbon-12 atoms can be used to determine the length of time that has passed.

Solve 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 three-quarters of the atoms to change?
2. After a long period, only one-quarter of the parent uranium-238 atoms in a sample of rock remain. How many years old would you predict the rock to be?
Average atomic mass  How do scientists account for and represent the different atomic masses of isotopes? As an example, models of two naturally occurring isotopes of boron are shown in Figure 7. Because most elements, including boron, naturally occur as more than one isotope, each element can be described by an average atomic mass of the isotopes. The average atomic mass of an element is the weighted average mass of all naturally occurring isotopes of an element, measured in atomic mass units (amu), according to their natural abundances.

For example, eighty percent or four out of five atoms of boron are boron-11 and twenty percent or one out of five is boron-10. The following calculation gives the weighted average of these two masses.

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

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

Reading Check  Define average atomic mass and explain how it is calculated.

Figure 7 Boron-10 and boron-11 are two isotopes of boron. These two isotopes differ by one neutron. Like boron, most naturally occurring elements have more than one naturally occurring isotope. Explain why these atoms are isotopes.

Section 2  Review

Section Summary

- Protons and neutrons make up most of an atom’s mass.
- Each element has a unique number of protons.
- 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 all naturally occurring isotopes of that element.

6. **MAIN IDEA** Determine the mass number and the atomic number of a chlorine atom that has 17 protons and 18 neutrons.

7. **Explain** how the isotopes of an element are alike and how are they different.

8. **Explain** why the atomic mass of an element is a weighted-average mass.

9. **Calculate** the number of neutrons in potassium-40.

10. **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. Do most chlorine atoms contain 18 neutrons or 20 neutrons? Why?

11. **Determine** Use the information in Table 3 to determine the mass in kilograms of each subatomic particle.

Assessment  Online Quiz
The Periodic Table

**MAIN Idea** Atoms of elements that are in the same group on the periodic table have similar physical and chemical properties.

**Real-World Reading Link** It is easier to find matching pairs of shoes or clean shirts when your closet is neat and tidy. Like a tidy closet, elements are organized in rows and columns on the periodic table to make it easy for chemists to infer their physical and chemical properties.

**Organizing the Elements**

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

In the late 1800s, a Russian chemist named Dmitri Mendeleev presented a way to organize all the known elements. While studying the physical and chemical properties of the elements, Mendeleev found that these properties repeated in predictable patterns based on an element’s atomic mass. Because the pattern repeated, it was considered to be periodic.

**Figure 8** shows one of Mendeleev’s early periodic charts. Mendeleev arranged elements in rows based on increasing atomic mass and in columns based on elements that shared similar physical and chemical properties. Today, this arrangement is called the periodic table of elements. In the modern periodic table, the elements are arranged by increasing atomic number—not atomic mass—and by periodic changes in physical and chemical properties.

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**Infer** What do the question marks in Mendeleev’s chart represent?
Mendeleev’s predictions  Mendeleev had to leave blank spaces in his periodic table. He studied the physical and chemical properties and the atomic masses of the elements surrounding all the blank spaces. From this information, he was able to predict the probable properties and the atomic masses for the missing elements that had not yet been discovered. Table 5 shows a few of Mendeleev’s predicted physical and chemical properties for germanium, which he called ekasilicon. His predictions proved to be accurate when compared to the actual properties of germanium. Scientists later confirmed the identities of missing elements and found that their properties were similar to what Mendeleev had suggested.

Changes in the periodic table  Although Mendeleev’s arrangement of the elements was a success, it required some changes. The atomic mass gradually increased from left to right on Mendeleev’s table. If you look at the modern periodic table, in Figure 9, on the next page, you can locate instances where atomic mass decreases from left to right, such as nickel and cobalt.

You might also observe that the atomic number always increases from left to right. In 1913, a young English scientist named Henry G.J. Moseley arranged all the known elements based on increasing atomic number instead of atomic mass. This new arrangement seemed to solve the problem of fluctuating mass. The modern periodic table uses Moseley’s arrangement of the elements.

Reading Check  Explain how Mendeleev organized his periodic table.

### Table 5  Mendeleev’s Predictions

<table>
<thead>
<tr>
<th>Predicted Properties of Ekasilicon (Es)</th>
<th>Actual Properties of Germanium (Ge)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existence Predicted: 1871</strong></td>
<td><strong>Actual Discovery: 1886</strong></td>
</tr>
<tr>
<td>Atomic mass = 72</td>
<td>Atomic mass = 72.61</td>
</tr>
<tr>
<td>High melting point</td>
<td>Melting point = 938°C</td>
</tr>
<tr>
<td>Density = 5.5 g/cm³</td>
<td>Density = 5.323 g/cm³</td>
</tr>
<tr>
<td>Dark-gray metal</td>
<td>Gray metal</td>
</tr>
<tr>
<td>Density of EsO₂ = 4.7 g/cm³</td>
<td>Density of GeO₂ = 4.23 g/cm³</td>
</tr>
</tbody>
</table>

SC.912.P.8.4: Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within. SC.912.N.3.5: Describe the function of models in science, and identify the wide range of models used in science.

## MiniLab

### Organize Elements

**Procedure**

1. Read the procedure and safety information, and complete the lab form.
2. Make a set of element cards based on fictitious elements provided in the table below.
3. Organize the cards by increasing atomic mass, and start placing them in a 3 × 4 grid.
4. Place each card based on its properties and leave gaps where necessary. Make a table reflecting your arrangement of cards.

### Analysis

1. Describe the trends for color in your new table across rows and down columns.
2. Describe similar trends for mass in your new table. Explain your placement of any elements that do not fit the trend.
3. Predict the placement of a newly found element, Ph, which is a deep-pink gas. What would be an expected range for the mass of Ph?
Figure 9  The Periodic Table of the Elements

PERIODIC TABLE OF THE ELEMENTS

Hydrogen 1  H  1.008
Lithium 3  Li  6.941
Sodium 11  Na  22.990
Potassium 19  K  39.098
Rubidium 37  Rb  85.468
Cesium 55  Cs  132.905
Francium 87  Fr  223

Beryllium 4  Be  9.012
Magnesium 12  Mg  24.305

Lanthanum 57  La  138.905
Actinium 90  Th  232.038

Row 1

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

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.

The number in parentheses is the mass number of the longest lived isotope for that element.

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

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.

Columns of elements are called groups. Elements in the same group have similar chemical properties.
The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>9.0127</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>10.811</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>12.011</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>14.007</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>15.999</td>
</tr>
<tr>
<td>Fluorine</td>
<td>F</td>
<td>18.998</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>20.180</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>4.003</td>
</tr>
<tr>
<td>Lanthanum</td>
<td>La</td>
<td>138.9055</td>
</tr>
<tr>
<td>Actinium</td>
<td>Ac</td>
<td>227.028</td>
</tr>
<tr>
<td>Thorium</td>
<td>Th</td>
<td>232.0381</td>
</tr>
<tr>
<td>Protactinium</td>
<td>Pa</td>
<td>231.0359</td>
</tr>
<tr>
<td>Uranium</td>
<td>U</td>
<td>238.0289</td>
</tr>
<tr>
<td>Plutonium</td>
<td>Pu</td>
<td>244.0920</td>
</tr>
</tbody>
</table>

*The names and symbols for elements 113, 114, 115, 116, and 118 are temporary. Final names will be selected when the elements' discoveries are verified.*
The Atom and the Periodic Table

The modern periodic table consists of boxes, each containing information such as element name, symbol, atomic number, and atomic mass. A typical box is shown in Figure 10. As you have learned, elements on the periodic table are organized based on similarities in their physical and chemical properties. The horizontal rows of elements in the periodic table are called *periods* and are numbered 1 through 7. The vertical columns in the periodic table are called *groups* (also called families), and they are numbered 1 through 18. Elements in each group share similar properties. For example, the elements in group 11—including copper, silver, and gold—are all similar. Each element is a shiny metal and a good conductor of heat and electricity. Why are these elements so similar?

**Electron cloud structure** You have learned about the nucleus of an atom and the fact that protons and neutrons are located there. But where are the electrons? How many are there? Because an atom does not have an overall charge, the number of electrons is equal to the number of protons. Therefore, a carbon atom has six protons and six electrons. An oxygen atom has eight protons and eight electrons. Electrons are located in an area surrounding the nucleus called the electron cloud.

**Energy Levels** Scientists have discovered that electrons within the electron cloud have different amounts of energy. Scientists model the energy differences between electrons by placing electrons in energy levels, as shown in Figure 11. Electrons located in energy levels close to the nucleus have less energy than electrons in energy levels farther away. Electrons occupy energy levels in a predictable pattern from the inner to the outer levels.

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*Figure 10* Each box on the periodic table contains information such as the element's name, its atomic number, its chemical symbol, its atomic mass, and its state of matter.

**Evaluate** What is the atomic mass of oxygen?
Elements in the same group have the same number of electrons in their outermost energy levels. These electrons are called valence electrons. It is the number of valence electrons that determines the chemical properties of each individual element. It is important to understand the relationship between the location of an element in the periodic table, the element’s chemical properties, and the element’s atomic structure.

**Rows on the periodic table** Energy levels coincide with the number of rows on the periodic table. These energy levels are named using numbers one to seven. The maximum number of electrons that can be placed in each of the first four levels is shown in Figure 11. For example, energy level one can hold a maximum of two electrons. Energy level two can hold a maximum of eight electrons. For energy levels two and higher, the outer energy level is stable when it holds eight electrons. Notice, however, that energy levels three and four can contain more than eight electrons. The way in which energy levels split into sublevels allows for energy levels three and higher to contain more than eight electrons. These additional electrons are added to inner sublevels; the outer energy level is still stable when it contains eight electrons.

**Filling the first row** Remember that the atomic number found on the periodic table is equal to the number of electrons in a neutral atom. Look at the elements in Figure 12. 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 energy level containing an electron, hydrogen has one outer electron. Helium has two outer electrons. Recall from Figure 11 that energy level one can hold a maximum of two electrons. Therefore, helium has a full outer energy level and is chemically stable.

**Figure 12** One proton and one electron are added to each element as you travel across a row on the periodic table. When a certain level is complete—as with helium and neon—the next electron added starts a new row. Explain how the elements in each group are similar.

**MiniLab**

**Model an Aluminum Atom**

**Procedure**

1. Read the procedure and safety information, and complete the lab form.
2. Arrange thirteen 3-cm diameter circles cut from orange paper and fourteen 3-cm diameter 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.
3. Position two holes punched from red paper about 20 cm from your nucleus.
4. Position eight punched holes in pairs about 40 cm from your nucleus.
5. Position three punched holes individually about 60 cm from your nucleus.

**Analysis**

1. Explain how your circles model an aluminum atom.
2. Explain why your model does not accurately represent the true size and distance between particles in an aluminum atom.
**Figure 13** The elements in group 1 have one electron in their outermost energy levels.

**Filling higher rows** The second row starts with lithium, which has three electrons—two in the first energy level and one in the second energy level. Lithium is followed by beryllium with two outer electrons, boron with three, and so on. Neon has a complete outermost energy level with eight outer electrons. Electrons begin filling energy level three for elements in the third row. The row ends with argon, which has eight outer electrons.

**Electron dot diagrams** Elements in the same group have the same number of electrons in their outermost energy levels. These electrons determine the chemical properties of an element. They are so significant that American chemist G.N. Lewis created a diagram to represent an element’s outermost electrons while teaching a college chemistry class. An electron dot diagram uses the chemical symbol of an element surrounded by dots to represent the number of electrons in the outermost energy level. **Figure 13** shows the electron dot diagrams for the group 1 elements.

**Same group—similar properties** The electron dot diagrams for the elements in group 1 show that all members of a group have the same number of outermost electrons. Remember that the number of outermost electrons determines the chemical properties for each element.

A common chemical property of group 1 metals is the tendency to react with nonmetals in group 17. The nonmetals in group 17 have electron dot diagrams similar to chlorine, as shown in **Figure 14**. For example, the group 1 element sodium reacts easily with the group 17 element chlorine. The result is the formation of the compound sodium chloride (NaCl)—ordinary table salt.

**Group 18** Not all elements will combine easily with other elements. The elements in group 18 have complete outermost energy levels, meaning that they cannot hold any more electrons. This special configuration makes many of the group 18 elements unreactive. **Figure 14** shows the electron dot diagram for neon, a member of group 18.
Regions of the Periodic Table

The periodic table has areas with specific names. Recall that the horizontal rows of elements are called periods. The elements increase by one proton and one electron as you move from left to right across a period.

All the elements in the blue squares in Figure 15 are metals. Iron, zinc, and copper are examples of a few common metals. Most metals occur 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.

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

New elements  Scientists around the world continue their research into the synthesis of elements. In 1994, scientists at the Heavy Ion Research Laboratory in Darmstadt, Germany, discovered element 111. The International Union of Pure and Applied Chemistry (IUPAC) confirmed the discovery in 2003. The name Roentgenium (Rg) was officially approved in 2004. Element number 112 was discovered at the same laboratory. Synthesis of the element was reported in 1996. IUPAC confirmed the discovery in 2009, and the element was officially named Copernicium (Cn) in 2010. These elements are produced in the laboratory by joining smaller atoms into a single, larger atom. The search for elements with higher atomic numbers continues. Scientists think that they have synthesized elements 113, 114, 115, 116, and 118.
Elements in the Universe

With the development of new technologies, scientists have been able to study the chemistry of the universe. Because the universe is so vast, they have been able to study only a small section of the universe. However, scientists have learned that many of the same elements are found throughout the universe. These include lightweight elements, such as hydrogen and helium, and heavier elements, such as silicon, oxygen, and iron.

Many scientists think that hydrogen and helium are the building blocks of all other elements. Atoms fuse together within stars to produce heavier elements with atomic numbers greater than the atomic numbers of hydrogen and helium. Exploding stars, called supernovas, like the one shown in Figure 16, provide evidence to support this theory.

When stars explode, a mixture of elements, including heavy elements like iron, are expelled into the galaxy. Many scientists think that supernovas have scattered heavy, naturally occurring elements throughout the universe. Promethium, technetium, and elements with atomic numbers greater than 92 are rare or are not found on Earth. Some of these elements, such as neptunium and plutonium, are found only in trace amounts in Earth’s crust as a result of uranium decay. Others have been found only in stars.

Figure 16 The Crab Nebula is a remnant of a supernova that occurred in A.D. 1054. This is now an area of expanding gas and elements that will be incorporated into newly forming stars.

Section 3 Review

Section Summary

- Mendeleev organized the elements based on atomic mass and chemical and physical properties.
- Moseley built upon Mendeleev’s periodic table by further organizing elements by increasing atomic number.
- Elements in the same vertical column on the periodic table are known as a group. They share similar physical and chemical properties.
- Elements in the same horizontal row on the periodic table are known as a period. They have the same number of energy levels.
- Elements on the periodic table are classified as metals, nonmetals, or metalloids.

12. **Main Idea** Identify Use the periodic table to find the name, atomic number, atomic mass, and the number of outermost electrons for each of the following elements: N, P, As, and Sb.

13. **Provide** the symbol, the group number, and the period of each of the following elements: nitrogen, sodium, iodine, and mercury.

14. **Classify** each of the following elements as a metal, a nonmetal, or a metalloid and give the full name of each element: K, Si, and S.

15. **Think Critically** The Mendeleev and Moseley periodic charts had gaps for undiscovered elements. Why do you think the chart used by Moseley was more accurate at predicting where new elements would be placed?

Apply Math

16. **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.
### LAB

**A Periodic Table of Foods**

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

**Background:** Mendeleev’s task of organizing a collection of loosely related items probably seemed daunting at first. But as he searched for patterns and similarities, the task became more manageable and organized. Look for similarities and patterns as you create a periodic table.

**Question:** How does organizing your favorite foods to create your own periodic table resemble the task that Mendeleev took on?

**Preparation**

**Materials**
- 11 × 17 paper
- metric ruler
- colored pencils or markers

**Procedure**

1. Read the procedure and safety information, and complete the lab form.
2. Create a list of 20 of your favorite food and drink items.
3. Describe basic characteristics of each of these items. For example, you might describe the primary ingredient, nutritional value, taste, and color of each item. You could also identify the food group to which each item belongs, such as fruits, vegetables, grains, dairy products, meat, and sweets.
4. Create a data table to organize the information that you collect.
5. Construct a periodic table of foods on an 11 × 17 sheet of paper. Determine which characteristics you will use to organize your items. Create groups (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 as a group of salty-tasting foods. Create as many groups as you need. You do not need to have the same number of items in every group.

**Conclude and Apply**

1. **Evaluate** the characteristics you used to create groups on your periodic table. Do the characteristics of each group adequately describe each of its members? Do the characteristics of each group distinguish its members from the members of another group?
2. **Explain** the way your rows of food are organized.
3. **Analyze** the reasons why some items did not necessarily fit into a group.
4. **Infer** why chemists have not created a periodic table of compounds.

**Communicate Your Data**

**Construct** a bulletin board of the periodic tables of foods created by the class. Are the tables similar? Why or why not?

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**SC.912.P.8.5:** Relate properties of atoms and their position in the periodic table to the arrangement of their electrons. **SC.912.N.1.6:** Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied. **SC.912.N.3.5:** Describe the function of models in science, and identify the wide range of models used in science.
Objectives

- Investigate the physical and chemical properties of various elements.
- Differentiate between the properties of metals, nonmetals, and metalloids.

Background: Metals, nonmetals, and metalloids can be classified based on differences in their physical and chemical properties. Consider what you have learned about metals and nonmetals to make a prediction about what physical and chemical properties that you might expect the metalloids to have.

Question: Does a pattern emerge that appears to be based on the arrangement of elements in the periodic table?

Procedure

1. Read the procedure and safety information, and complete the lab form.
2. Create a table to record the physical and chemical properties of each element.
3. Observe and record the appearance (physical state, color, luster, and texture) of the element sample in each test tube without removing the stoppers.
4. Remove a small sample of each of the elements contained in a plastic dish, and place it on a hard surface. Gently tap each element sample with a small hammer. If the element is malleable, it will flatten. If it is brittle, it will shatter. Record your results. WARNING: Brittle samples may shatter into sharp pieces.
5. Use the conductivity tester to determine which elements conduct electricity. Clean the electrodes with water, and dry them before testing each element. Record your results.
6. Label each test tube with the symbol for one of the elements in the plastic dishes. Using a graduated cylinder, add 5 mL of water to each test tube.

Materials

- stoppered test tube (6)
- plastic dishes containing small samples of each element
- conductivity apparatus
- 1.0M HCl
- small hammer
- test tubes (6)
- test tube rack
- 10-mL graduated cylinder
- spatula
- glass-marking pencil

Safety Precautions

WARNING: Never test chemicals by tasting.
7. Use a spatula to put a small amount of each element into the corresponding test tube. Record any indication that a chemical reaction might have occurred.

8. Add 5 mL of 1.0 M HCl to each test tube. Observe each test tube for at least 1 minute. The formation of bubbles or the production of heat is evidence of a reaction between the acid and the element. Record your observations. **WARNING:** 1.0 M HCl is harmful to the skin, eyes, and clothing.

9. Dispose of all materials as instructed.

**Analyze Your Data**

1. **Classify** Use the table below and your observations to classify each of your samples as a metal, a nonmetal, or a metalloid.

**Data Table**

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Physical State</th>
<th>Color</th>
<th>Luster</th>
<th>Texture</th>
<th>Conducts Electricity</th>
<th>Reacts with Water</th>
<th>Reacts with 1.0 M HCl</th>
</tr>
</thead>
</table>

**Conclude and Apply**

1. **Model** Create a periodic table of the elements examined in the lab. Place elements with like physical and chemical characteristics in the same column.

2. **Compare** your periodic table to the actual periodic table of the elements. How are they alike? How are they different?

3. **Infer** Describe any trends among the elements that you observed in the lab.

4. **Explain** the steps that you would take to classify an unknown element as a metal, a nonmetal, or a metalloid.

**Data Table**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>• malleable&lt;br&gt;• good conductors of electricity&lt;br&gt;• lustrous&lt;br&gt;• silver or white&lt;br&gt;• many react with acids</td>
</tr>
<tr>
<td>Nonmetals</td>
<td>• solids, liquids, or gases&lt;br&gt;• do not conduct electricity&lt;br&gt;• do not react with acids&lt;br&gt;• brittle</td>
</tr>
<tr>
<td>Metalloids</td>
<td>• shared properties of metals and nonmetals</td>
</tr>
</tbody>
</table>

**Research** metal and nonmetal resources that can be used to build a home. Create a brochure highlighting each element and how it is used in home construction.
Cassini-Huygens Mission

Scientists made discoveries from data sent back to Earth during the Cassini-Huygens Mission. The mission studied Saturn, shown in Figure 1, and its moons, including Titan. Scientists hope to learn more about the conditions that first supported life on Earth by studying Titan.

Titan’s atmosphere Larger than Mercury and Pluto, Titan is the only moon in our solar system that has a thick nitrogen-rich atmosphere. From data collected during the Cassini-Huygens Mission, scientists learned that Titan’s atmosphere is ten times denser than Earth’s atmosphere today.

But many scientists think the composition of Earth’s early atmosphere was different from today’s atmosphere. That is, Earth’s early atmosphere did not contain much oxygen until photosynthesizing cyanobacteria produced it. Similarly, Titan’s atmosphere contains no oxygen. It is 95 percent nitrogen and 5 percent methane. However, sunlight is breaking down methane in Titan’s atmosphere to form hydrocarbons that are similar to those that make up energy sources for life on Earth.

Figure 1 Titan, Saturn’s largest satellite, casts a shadow on Saturn’s surface.

Liquid on the surface The Cassini-Huygens Mission also found that there are rivers and lakes of liquid ethane and methane on Titan’s surface, as shown in Figure 2. Scientists determined that Titan has a methane cycle similar to Earth’s water cycle, meaning that methane evaporates, condenses, and returns to Titan’s surface as precipitation. After Earth, Titan is only the second celestial body in our solar system found to have liquid on its surface. Scientists also found evidence of liquid and frozen water mixed with ammonia on Titan.

A new mission In June 2008, the focus and name of the mission changed. The Cassini Equinox Mission studies how seasonal changes affect Titan’s atmosphere and its surface features, such as rivers and lakes. The mission is also studying Enceladus, another of Saturn’s moons. Cassini found an icy plume filled with organic chemicals shooting from Enceladus’s south pole. Scientists will continue to learn about Titan and Enceladus from the new data.

Figure 2 Lakes of methane and ethane vary seasonally on Titan.

WebQuest Many studies are part of the Cassini-Huygens Mission. Work with a small group to research and create a presentation about one aspect of the mission. Present your findings to the class.
**Section 1 Structure of the Atom**

- atom (p. 489)
- electron (p. 489)
- electron cloud (p. 493)
- neutron (p. 489)
- nucleus (p. 489)
- proton (p. 489)
- quark (p. 489)

**MAIN Idea**

Protons and neutrons form the nucleus of an atom, and electrons occupy a space surrounding the nucleus.

- Scientists use chemical symbols to abbreviate element names.
- Atoms are composed of protons, neutrons, and electrons.
- Scientists have confirmed the existence of six different quarks.
- The electron cloud model is the current atomic model.

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**Section 2 Masses of Atoms**

- atomic number (p. 495)
- average atomic mass (p. 497)
- isotope (p. 496)
- mass number (p. 495)

**MAIN Idea**

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

- Protons and neutrons make up most of an atom's mass.
- Each element has a unique number of protons.
- 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 all naturally occurring isotopes of that element.

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**Section 3 The Periodic Table**

- electron dot diagram (p. 504)
- group (p. 502)
- period (p. 502)
- periodic table (p. 498)

**MAIN Idea**

Atoms of elements that are in the same group on the periodic table have similar physical and chemical properties.

- Mendeleev organized the elements based on atomic mass and chemical and physical properties.
- Moseley built upon Mendeleev’s periodic table by further organizing elements by increasing atomic number.
- Elements in the same vertical column on the periodic table are known as a group. They share similar physical and chemical properties.
- Elements in the same horizontal rows on the periodic table are known as a period. They have the same number of energy levels.
- Elements on the periodic table are classified as metals, nonmetals, or metalloids.
Use Vocabulary

Complete each sentence with the correct term from the Study Guide.

17. Two elements with the same number of protons but a different number of neutrons are called _______.

18. _______ is the weighted-average mass of all the known isotopes for an element.

19. The positively charged center of an atom is called the _______.

20. The particles that make up protons and neutrons are called _______.

21. A(n) _______ is a horizontal row in the periodic table.

22. The _______ is the sum of the number of protons and neutrons in an atom.

23. In the current model of the atom, the electrons are located in the _______.

Check Concepts

24. Most of the elements to the left of the stair-step line in the periodic table exist as _______ at room temperature.
   A) gases                C) plasmas
   B) liquids              D) solids

25. What is the term for a repeating pattern?
   A) isotopic              C) periodic
   B) metallic             D) transition

26. Which element has properties that are similar to neon?
   A) aluminum             B) argon
   C) arsenic              D) silver

27. Which term describes boron?
   A) metal                C) noble gas
   B) metalloid            D) nonmetal

28. How many outermost electrons do lithium and potassium have?
   A) 1                    C) 3
   B) 2                    D) 4

29. Which of the following is NOT found in the nucleus of an atom?
   A) proton               C) electron
   B) neutron              D) quark

Use the figure below to answer question 30.

30. Which atomic model is represented in the figure above?
   A) Democritus Model
   B) Dalton Model
   C) Rutherford Model
   D) Thomson Model

31. In which of the following states is nitrogen found at room temperature?
   A) gas                   C) metal
   B) plastic               D) liquid

32. Which of the elements below is a shiny element that conducts heat and electricity?
   A) chlorine              C) hydrogen
   B) sulfur                D) magnesium

33. 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?
   A) 75                    C) 186
   B) 111                   D) 261
34. Copy and complete the concept map below.

![Concept Map](image)

**35. Construct** As a star dies, it becomes denser. Its temperature rises to a point where helium (He) nuclei fuse 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, chromium (Cr) fuses with He to become iron (Fe). Copy and complete the concept map showing the first four steps in He fusion.

He → a. → b. → c. → d.

37. **Explain** why it is necessary to change models as new information becomes available.

38. **Theme Focus** **Infer** If you discovered a new element, what steps would you follow to classify it?

39. **Infer** Germanium and silicon are used in making semiconductors. Locate each element on the periodic table and explain why they are not efficient conductors.

40. **Big Idea** **Infer** Calcium-40 and strontium-90 are isotopes. Calcium-40 is used by the body to make bones and teeth. Strontium-90 is radioactive. Calcium-40 is safe for people, and strontium-90 is hazardous. Why is strontium-90 hazardous to people?

41. **Solve 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 42.

<table>
<thead>
<tr>
<th>Energy Level</th>
<th>Maximum Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>a.</td>
</tr>
<tr>
<td>3</td>
<td>b.</td>
</tr>
<tr>
<td>4</td>
<td>c.</td>
</tr>
</tbody>
</table>

42. **Use Tables** Use the information in Figure 11 to determine how many electrons should be in the second, third, and fourth energy levels for argon, atomic number 18. Copy and complete the table above with the number of electrons for each energy level.

**Think Critically**

36. **Infer** Lead and mercury are two environmental pollutants. Why are they called heavy metals?
Multiple Choice

1. What particle identifies each particular element?
   A. electrons  
   B. photons  
   C. protons  
   D. quarks

2. Which group of elements on the periodic table is unreactive?
   A. group 1  
   B. group 2  
   C. group 17  
   D. group 18

5. The periodic table is organized into columns called
   A. groups  
   B. categories  
   C. periods  
   D. rows

6. The table above shows electron arrangements of some elements. Which element in the table has a complete outermost energy level?
   A. carbon  
   B. oxygen  
   C. neon  
   D. sodium

7. Which element would you expect to be located in group 1 of the periodic table?
   A. oxygen  
   B. neon  
   C. sodium  
   D. chlorine

8. How many quarks have been found?
   A. 6  
   B. 8  
   C. 10  
   D. 12

9. The element nickel has five naturally occurring isotopes. Which of the following describes the relationship of these isotopes?
   A. same mass, same atomic number  
   B. same mass, different atomic number  
   C. different mass, same atomic number  
   D. different mass, different atomic number

Use the table below to answer questions 6 and 7.

<table>
<thead>
<tr>
<th>Element</th>
<th>Electrons in a Neutral Atom</th>
<th>Electrons in the Outer Energy Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Oxygen</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Neon</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Sodium</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Chlorine</td>
<td>17</td>
<td>7</td>
</tr>
</tbody>
</table>
Short Response

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? SC.912.P.8.4

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?

Use the figure below to answer question 12.

![Na⁺Cl⁻]

12. What does the above diagram represent? What do the dots represent? SC.912.P.8.5


14. Silicon’s atomic mass 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. SC.912.P.8.4

15. 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? SC.912.P.8.4

Extended Response

Record your answers on a sheet of paper. Use the figure below to answer questions 16 and 17.

![Bohr’s model of an atom]

16. The illustration above shows the currently accepted model of atomic structure. Describe this model. SC.912.P.8.4

17. Compare and contrast the model shown above with Bohr’s model of an atom. SC.912.P.8.4

18. Describe the concept of energy levels and how they relate to the organization of elements on the periodic table. SC.912.P.8.5

19. Describe how Dalton’s modernization of the ancient Greeks’ ideas of elements, atoms, and compounds provided a basis for understanding chemical reactions. Give an example. SC.912.N.2.4