After you read this section, you should be able to answer these questions:

- How are elements arranged on the periodic table?
- What are metals, nonmetals, and metalloids?
- What patterns are shown by the periodic table?

What Are Patterns of Elements?

By the 1860s, scientists had discovered more than 60 different elements. As they studied these elements, the scientists saw that some elements had properties that were very similar. For example, sodium and potassium are both metals that can explode if put into water. On the other hand, gold and silver are stable metals that react very slowly with water.

To understand the elements, chemists needed a way to organize what they knew about these elements. If the properties of elements formed a pattern, it would help scientists understand how elements interact with one another. A Russian chemist, Dmitri Mendeleev, discovered a pattern in 1869.

Mendeleev wrote the names of the elements and their properties on cards. When he arranged the cards in order of increasing atomic mass, he found that a pattern developed. He put elements that had similar properties in the same vertical column. See the table below.

<table>
<thead>
<tr>
<th>Hydrogen</th>
<th>Lithium 7</th>
<th>Beryllium 9</th>
<th>Boron 11</th>
<th>Carbon 12</th>
<th>Oxygen 16</th>
<th>Fluorine 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium 23</td>
<td>Magnesium 24</td>
<td>Aluminum 27</td>
<td>Silicon 28</td>
<td>Sulfur 32</td>
<td>Chlorine 35</td>
<td></td>
</tr>
<tr>
<td>Potassium 39</td>
<td>Calcium 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The elements were placed in order by atomic mass. Sodium is similar to lithium and potassium, so they are in the same column. The same is true for elements in the other columns.

National Science Education Standards
PS 1b

STUDY TIP

Clarifying Concepts Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

READING CHECK

1. Describe What discovery allowed Mendeleev to make his periodic table?

TAKE A LOOK

2. Make a Prediction Look at the pattern of atomic masses of the elements. Predict where element X (atomic mass 31) and element Y (atomic mass 14) should be placed. Write X or Y in the correct boxes in the table.
Say It

Discuss Many things occur in patterns that are periodic. In groups of three or four, discuss things in your life or in the world around you that occur at regular intervals. How many different types of patterns can you think of?

TAKE A LOOK

3. Identify Look at Mendeleev’s chart. How many new elements did he predict that would be discovered later?

How Were The Patterns Used?

Mendeleev found that the pattern repeated several times. He started a new row with an element whose properties, such as reactivity, were similar to lithium. Then all the elements in the first column reacted in a similar way. All the elements in the second row also had similar properties.

The pattern continued across the table, and then was repeated for elements in the third row, forming a periodic pattern. Periodic means “happening at regular intervals.”

Mendeleev found that the pattern of elements repeated after every seven elements. His table became known as the periodic table of the elements. The figure below shows part of a chart that Mendeleev made using his periodic table. Notice that there are several question marks beside atomic masses.

Mendeleev used question marks to note elements that he thought would be found later.

When all the known elements were placed on the chart, there seemed to be gaps in the pattern. Mendeleev left blanks in his periodic table where these gaps appeared. He predicted that elements would be discovered that would fill these blanks.

By 1886, the gaps in the table had been filled by newly discovered elements. These elements had the properties that Mendeleev had predicted. The table below compares one of Mendeleev’s predictions with the actual element, germanium, discovered in 1871.

<table>
<thead>
<tr>
<th>Properties of Germanium</th>
<th>Mendeleev’s predictions (1869)</th>
<th>Actual properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic mass</td>
<td>70 amu</td>
<td>72.6 amu</td>
</tr>
<tr>
<td>Density*</td>
<td>5.5 g/cm³</td>
<td>5.3 g/cm³</td>
</tr>
<tr>
<td>Appearance</td>
<td>dark gray metal</td>
<td>gray metal</td>
</tr>
<tr>
<td>Melting point*</td>
<td>high</td>
<td>937°C</td>
</tr>
</tbody>
</table>

* at room temperature and pressure

Copyright © by Holt, Rinehart and Winston. All rights reserved.
What Does The Modern Periodic Table Look Like?

The first periodic table included only 63 elements. Today, scientists know about more than 100 elements, although some of them are very rare. The modern table contains information that is similar to Mendeleev’s, but there are some differences.

Mendeleev’s periodic table showed the elements in order of atomic mass. A few of the elements did not appear to fall in the right order. Mendeleev placed them where he thought they should be based on their properties. He thought that better atomic mass measurements would correct the problem.

In 1914, scientists began using atomic numbers. An atomic number is the number of protons in an atom. The elements were all in the right place when they were ordered by atomic number instead of atomic mass. The figure below shows a modern periodic table.

Each row of elements, from left to right, is called a period. The physical and chemical properties of elements in a period follow the same pattern as those of the periods above and below. Each column of elements (top to bottom) is called a group. Elements in a group tend to have similar chemical and physical properties. Groups are sometimes called families.

Atoms of elements in Groups 1 and 2 have the same number of valence electrons as their group number.

Atoms of elements in Groups 13–18 have 10 fewer valence electrons than their group number. However, helium atoms have only 2 valence electrons.

Atoms of elements in Groups 3–12 do not have a rule relating their valence electrons to their group number.

5. Explain Why is atomic number a better property for organizing the elements than atomic mass?

6. Describe How many groups and how many periods does the modern periodic table have? Hint: hydrogen and helium should be counted as in the first period.
How Are the Elements on the Table Classified?

When you look at the elements on the periodic table, there are three classes of elements. Usually, the classes of elements are related to the number of electrons in the outer energy level, the valence electrons. The number of valence electrons increases from left to right in a period. Based on their properties, the elements are classified as:

- **metals** - the lighter shade to the left and center of the periodic table
- **nonmetals** - the darker shade to the right side of the table
- **metalloids** - the region shown on either side of a zigzag line between the metals and nonmetals
- **inert gases** - Group 18 on the periodic table

**METALS**

When you look at the periodic table, you can see that most of the elements are metals. Most metal atoms have few electrons in their outer energy levels. Except for mercury, which is a liquid, metals are solids at room temperature. The figure below shows some of the properties of metals.

**Properties of Metals**

- **Metals tend to be shiny,** such as the reflective surface of this mirror.
- **Most metals are ductile,** which means they can be drawn into thin wires, such as these copper wires. All metals are good conductors of electrical current.
- **Most metals are malleable,** which means they can be flattened without shattering, such as a piece of aluminum foil.
- **Most metals are good conductors of heat** (thermal energy), such as the iron in this griddle.
**NONMETALS**

Nonmetals are found on the right side of the table. Atoms of most nonmetals have a nearly full outer energy level. Many of the nonmetal elements are gases at room temperature. In general, the properties of nonmetals are the opposite of the properties of metals. Some of the properties of nonmetals are described in the figure below.

**METALLOIDS**

Metalloids are the elements found on either side of the zigzag line between metals and nonmetals. Their outer energy levels are about half filled. Metalloids have some properties of metals and some properties of nonmetals, as described in the figure below.

**Properties of Nonmetals and Metalloids**

- Nonmetals are not malleable or ductile. Solid nonmetals, such as carbon in the graphite of pencil lead, are brittle and will break or shatter when hit with a hammer.

- Boron, a metalloid, is almost as hard as a diamond and is also very brittle. At high temperatures, it is a good conductor of electric current.

**What Information Is on the Periodic Table?**

The next page is a more detailed look at parts of the periodic table. It includes the two groups to the left side of the table and the six groups to the right. Each element occupies one block that includes information about that element. This includes the element’s name, its atomic number, and its atomic mass.

Each block also shows the chemical symbol of the element. This is a one or two letter abbreviation that represents that element in a chemical formula. These symbols are used in the chemical formulas for compounds. If you see an unfamiliar symbol in a formula, you can use the periodic table to identify the element.
TAKE A LOOK
12. List What are the four pieces of information about an element that are shown on the periodic table?

---

Each square on the periodic table of elements includes the element’s name, chemical symbol, atomic number, and atomic mass.

**Critical Thinking**
13. Analyze Relationships Scientists can make atoms of large elements which have not been previously known. Identify an element that would have similar properties to an atom that has 118 protons.
How Do You Read The Table?

On the previous page, the top figure shows how to read a square on the periodic table. The symbol for the element is generally the largest item on a periodic table. In this table, the atomic number is above the symbol. The name of the element and the atomic mass are below it.

Notice that for elements with one-letter symbols, the symbol is always capitalized. For elements with two-letter symbols, the first letter is capitalized and the second letter is lower case. Three-letter symbols represent elements with temporary names.

The bottom figure shows part of the periodic table. In order to fit onto the page, it only shows eight groups of elements. All of the elements follow the **periodic law**. The periodic law states that the repeating chemical and physical properties change periodically with the elements’ atomic numbers. An atomic number is the number of protons in an atom of the element.

Although the atomic number increases from left to right in every period, the atomic mass does not necessarily do so. There are several places where the atomic mass of an element is greater than that of the element to its right. An example is tellurium and iodine in Period 5.

Most tellurium atoms have at least two more neutrons than iodine atoms have. That is why the atomic mass of tellurium is higher than the atomic mass of iodine, even though iodine has one more proton.

**Finding the Atomic Number**

<table>
<thead>
<tr>
<th>Atomic Number:</th>
<th>Number of protons:</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Si Silicon 28.1</td>
<td></td>
</tr>
<tr>
<td>86 Rn Radon (222)</td>
<td></td>
</tr>
<tr>
<td>92 U Uranium 238.0</td>
<td></td>
</tr>
</tbody>
</table>

**TAKE A LOOK**

15. Identify Use the information from the periodic table boxes to write the atomic number and number of protons for each element. Fill in the blanks in the figure to the left.
SECTION VOCABULARY

- **group**: a vertical column of elements in the periodic table; elements in a group share chemical properties
- **period**: in chemistry, a horizontal row of elements in the periodic table
- **periodic**: describes something that occurs or repeats at regular intervals
- **periodic law**: the law that states that the repeating chemical and physical properties of elements change periodically with the atomic numbers of the elements

1. **Compare**  Which elements would likely have similar properties: two elements in the same group, or two elements in the same period?

2. **Organize**  Fill in the table below with the correct classification of element.

<table>
<thead>
<tr>
<th>Location</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left side and center of periodic table</td>
<td></td>
</tr>
<tr>
<td>Right side of periodic table</td>
<td></td>
</tr>
<tr>
<td>Zigzag line toward right side of periodic table</td>
<td></td>
</tr>
</tbody>
</table>

3. **Identify Relationships**  Use the periodic table to answer this question: Are the properties of rubidium (Rb) more similar to those of cesium (Cs) or those of strontium (Sr)? Explain your answer.

4. **Apply Concepts**  Use the periodic table on page 218 to identify the elements in the following compounds: PbS, KBr, RaO

5. **Apply Concepts**  Use the periodic table to determine whether each element is a metal or a nonmetal: sodium (Na), krypton (Kr), phosphorus (P)
CHAPTER 5 THE PERIODIC TABLE

SECTION 1 ARRANGING THE ELEMENTS
1. He found a pattern in the properties of elements.
2. Top box: Y
   Bottom box: X
3. 3
4. 2.6 amu higher than predicted
5. Every atom of a particular element has the same atomic number, but atomic mass depends on the number of neutrons.
6. 7 periods, 18 groups
7. metals, nonmetals, metalloids, inert gases
8. Metals are shiny, malleable, ductile, and good electric current and heat conductors.
9. Nonmetals have nearly full outer energy levels, but metals have only one or two electrons in their outer energy level.
10. There should be a circle around “brittle” or “very brittle.”
11. a one or two letter abbreviation that identifies an element
12. Name, symbol, atomic number, atomic mass
13. Rn, Xe, Kr, Ar, Ne, or He
14. an element with a temporary name and symbol
15. 14, 14, 86, 86, 92, 92

Review
1. two elements in the same group
2. Location                     Classification
   Left side and center of periodic table  metal
   Right side of periodic table           nonmetal
   Zig-zag line toward right side of periodic table  metalloid
3. The properties of rubidium are more like those of cesium because they are both in Group 1, but strontium is in Group 2.
4. PbS—lead and sulfur, KBr—potassium and bromine, RaO—radium and oxygen
5. sodium—metal, krypton—nonmetal, phosphorus—nonmetal

SECTION 2 GROUPING THE ELEMENTS
1. They have the same number of electrons in the outer energy level, so they react in similar ways.
2. lithium, 3, sodium, 11, potassium, 19, rubidium, 17, cesium, 55, francium, 87
3. They need to lose two electrons instead of the one electron that alkali metals lose.
4. 112
5. mercury
6. 5, 13, 31, 49, 81, 113
7. It is a lightweight, strong metal.
8. carbon
9. N and P
10. Sulfur is a brittle, yellow solid.
11. fluorine, 9, chlorine, 17, bromine, 35, iodine, 53, astatine, 65
12. the noble gases
13. In the current model, noble gases have a filled outer energy level, so the theory predicts they would not be reactive. This agrees with observations.
14. Although, like the alkali metals, it loses one electron, it has properties more like those of the nonmetals.

Review
1. Both groups are one electron away from having a stable, full outer electron energy level. Alkali metals need to lose one electron; halogens need to gain one electron.
2. Top blank box: elements
   Middle blank box: groups
   Bottom blank boxes, from left to right: alkali metals, halogens, noble gases, metals, metalloids, nonmetals
3. Because they are so unreactive, there was no way to detect the noble gases chemically.
4. All of the nonmetals have outer energy levels that are at least half filled, so they don’t tend to lose electrons easily.