6.2.2 Classify elements based on electron configuration.

**Guide for Reading**

- **Key Concepts**
  - What type of information can be displayed in a periodic table?
  - How can elements be classified based on their electron configurations?

**Vocabulary**
- alkali metals
- alkaline earth metals
- halogens
- noble gases
- representative elements
- transition metal
- inner transition metal

**Reading Strategy**

- **Connecting to Your World**
  - Students can reflect on the importance of understanding the periodic table and electron configurations in everyday life. For example, understanding the periodic table can help in identifying the properties of elements and their potential uses in various applications.

- **Focus**
  - Students will learn about the layout and organization of the periodic table, focusing on how elements are classified based on their electron configurations.

- **Objectives**
  - Describe the information in a periodic table.
  - Classify elements based on electron configuration.

- **Use Visuals**
  - Remind students the periodic table is a valuable tool for organizing and understanding the properties of elements.

- **Section Resources**
  - Print: Reading and Study Workbook, Section 6.2
  - Core Teaching Resources, Section 6.2 Review, Transparencies, 767-769
  - Laboratory Manual, Lab 9

- **Technology**
  - Interactive Textbook with ChemASAP, Assessment 6.2
  - Go Online, Section 6.2

- **Answers to...**
  - There are 11 protons in the nucleus and 11 electrons in the three occupied energy levels.
Section 6.2 (continued)

Use Visuals

Figure 6.9 Have students examine the periodic table and find the types of information that the table provides. Summarize suggestions on the board. Examples include element name, atomic number, average atomic mass, and physical state at atmospheric pressure and room temperature.

Discuss

Have students examine the periodic table and determine the accuracy of this statement: Atomic mass always increases as atomic number increases. (The trend is generally true, but there are exceptions. For example, the atomic numbers of Ca, Ni, and Cu increase by one unit (27, 28, 29), but Ni has the lowest average atomic mass of these three elements.)

Facts and Figures

Element Nomenclature

Names suggested by those who create new elements must be approved by the International Union of Pure and Applied Chemistry (IUPAC). The process can be lengthy. For example, the names chosen for elements 104–108 by the nomenclature committee of IUPAC in 1994 were not those endorsed by the American Chemical Society (ACS). After years of negotiation, a compromise resulted in the names that appear in the periodic table. Elements beyond 111 have been discovered but are not yet named. Element 110 was discovered in 1994 by a team of scientists in Darmstadt, Germany. The IUPAC Council voted formal approval of the name darmstadtium (Ds) on August 16, 2003.
### Periodic Table

#### Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Symbol</th>
<th>Mass Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkelium</td>
<td>97</td>
<td>Bk</td>
<td>247.07</td>
</tr>
<tr>
<td>Californium</td>
<td>98</td>
<td>Cf</td>
<td>251.04</td>
</tr>
<tr>
<td>Einsteinium</td>
<td>99</td>
<td>Es</td>
<td>252.04</td>
</tr>
<tr>
<td>Fermium</td>
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<td>Fm</td>
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</tr>
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<td>101</td>
<td>Md</td>
<td>258.04</td>
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<tr>
<td>Nobelium</td>
<td>102</td>
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<td>259.04</td>
</tr>
<tr>
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<td>260.04</td>
</tr>
<tr>
<td>Rutherfordium</td>
<td>104</td>
<td>Rf</td>
<td>262.04</td>
</tr>
<tr>
<td>Dubnium</td>
<td>105</td>
<td>Db</td>
<td>268.04</td>
</tr>
<tr>
<td>Seaborgium</td>
<td>106</td>
<td>Sg</td>
<td>270.04</td>
</tr>
<tr>
<td>Bohrium</td>
<td>107</td>
<td>Bh</td>
<td>272.04</td>
</tr>
<tr>
<td>Hassium</td>
<td>108</td>
<td>Hs</td>
<td>277.04</td>
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<tr>
<td>Meitnerium</td>
<td>109</td>
<td>Mt</td>
<td>280.04</td>
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<tr>
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<td>Curium</td>
<td>96</td>
<td>Cm</td>
<td>247.06</td>
</tr>
</tbody>
</table>

*The atomic masses in parentheses are the mass numbers of the longest-lived isotope of elements for which a standard atomic mass cannot be defined.*
Electron Configurations in Groups

Discuss

Lead a class discussion on electron configurations of noble gases and representative elements. Select some elements and have students write out the electron configurations for those elements. Have students compare the electron configurations for all the elements in a single group. Ask students to identify similarities. (Noble gases are sometimes classified as representative elements because they are in the p block of elements.)

FYI

The term valence electron will be introduced in Chapter 7.

Electron Configurations in Groups

Electrons play a key role in determining the properties of elements. So there should be a connection between an element’s electron configuration and its location in the periodic table. Elements can be sorted into noble gases, representative elements, transition metals, or inner transition metals based on their electron configurations. You may want to refer to Figure 6.9 as you read about these classes of elements.

The Noble Gases

The blimp in Figure 6.10 is filled with helium. Helium is an example of a noble gas. The noble gases are the elements in Group 8A of the periodic table. These nonmetals are sometimes called the inert gases because they rarely take part in a reaction. The electron configurations for the first four noble gases in Group 8A are listed below.

<table>
<thead>
<tr>
<th>Element</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium (He)</td>
<td>1s2</td>
</tr>
<tr>
<td>Neon (Ne)</td>
<td>1s22s22p6</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>1s22s22p63s23p6</td>
</tr>
<tr>
<td>Krypton (Kr)</td>
<td>1s22s22p63s23p63d10</td>
</tr>
</tbody>
</table>

In atoms of representative elements, the s and p sublevels are completely filled with electrons. Chapter 7 will explain how this arrangement of electrons is related to the relative inactivity of the noble gases.

The Representative Elements

Figure 6.11 shows the portion of the periodic table containing Groups 1A through 7A. Elements in these groups are often referred to as representative elements because they display a wide range of physical and chemical properties. Some are metals, some are nonmetals, and some are metalloids. Most of them are solids, but a few are gases at room temperature, and one, bromine, is a liquid.

In atoms of representative elements, the s and p sublevels of the highest occupied energy level are not filled. Look at the electron configurations for lithium, sodium, and potassium. In atoms of these Group 1A elements, there is only one electron in the highest occupied energy level. The electron is in an s sublevel.

<table>
<thead>
<tr>
<th>Element</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium (Li)</td>
<td>1s1</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>1s22s22p6</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>1s22s22p63s23p64s1</td>
</tr>
</tbody>
</table>

In atoms of carbon, silicon, and germanium, in Group 4A, there are four electrons in the highest occupied energy level.

<table>
<thead>
<tr>
<th>Element</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (C)</td>
<td>1s22s22p2</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>1s22s22p63s23p24s24p2</td>
</tr>
<tr>
<td>Germanium (Ge)</td>
<td>1s22s22p63s23p24s24p24d10</td>
</tr>
</tbody>
</table>

For any representative element, its group number equals the number of electrons in the highest occupied energy level.

Why are noble gases sometimes referred to as inert gases?
Section 6.2 Classifying the Elements

Differences in Reactivity of Metals

Purpose
Students observe differences in the reactivity of magnesium, tin, and copper.

Materials
0.2 M HCl; 6 large test tubes; test tube rack; small pieces of clean magnesium, tin, and copper; matches; wood splint

Safety
Wear goggles for this demo.

Procedure
Place three large test tubes in a test tube rack. To each test tube, add a small, clean piece of a different metal—magnesium, tin, and copper. Carefully add some of the 0.2 M HCl to each test tube and invert a test tube over it. Point out the appearance of bubbles. After a while, carefully ignite the hydrogen in the inverted test tube from the magnesium or tin reaction.

Expected Outcome
The magnesium and tin react with the HCl producing hydrogen. The hydrogen ignites with an explosive pop. The copper shows no sign of reaction.

Answers to...
Figure 6.10 Helium is less dense than air.

Checkpoint
They rarely take part in a reaction.
Transition Elements

In the periodic table, the B groups separate the A groups on the left side of the table from the A groups on the right side. Elements in the B groups, which provide a connection between the two sets of representative elements, are referred to as transition elements. There are two types of transition elements—transition metals and inner transition metals. They are classified based on their electron configurations.

The transition metals are the Group B elements that are usually displayed in the main body of a periodic table. Copper, silver, gold, and iron are transition metals. In atoms of a transition metal, the highest occupied s sublevel and a nearby d sublevel contain electrons. These elements are characterized by the presence of electrons in d orbitals.

The inner transition metals appear below the main body of the periodic table. In atoms of an inner transition metal, the highest occupied s sublevel and a nearby f sublevel generally contain electrons. The inner transition metals are characterized by f orbitals that contain electrons. Before scientists knew much about inner transition metals, people began to refer to them as rare-earth elements. This name is misleading because some inner transition metals are more abundant than other elements.

Blocks of Elements If you consider both the electron configurations and the positions of the elements in the periodic table, another pattern emerges. In Figure 6.12, the periodic table is divided into sections, or blocks, that correspond to the highest occupied sublevels. The s block contains the elements in Groups 1A and 2A and the noble gas helium. The p block contains the elements in Groups 3A, 4A, 5A, 6A, 7A, and 8A, with the exception of helium. The transition metals belong to the d block, and the inner transition metals belong to the f block.

You can use Figure 6.12 to help determine electron configurations of elements. Each period on the periodic table corresponds to a principal energy level. Say an element is located in period 5. You know that the s and p sublevels in energy levels 1 and 2 are filled with electrons. You read across period 5 from left to right to complete the configuration. For transition elements, electrons are added to a d sublevel with a principal energy level that is one less than the period number. For the inner transition metals, the principal energy level of the f sublevel is two less than the period number. This procedure gives the correct electron configurations for most atoms.

Figure 6.12 This diagram classifies elements into blocks according to sublevels that are filled or filling with electrons. Interpreting Diagrams in the highest occupied energy level of a halogen atom, how many electrons are in the p sublevel?
**CONCEPTUAL PROBLEM 6.1**

**Using Energy Sublevels to Write Electron Configurations**

Nitrogen is an element that organisms need to remain healthy. However, most organisms cannot obtain nitrogen directly from air. A few organisms can convert elemental nitrogen into a form that can be absorbed by plant and animal cells. These include bacteria that live in lumps called nodules on the roots of legumes. The photograph shows the nodules on a bean plant. Use Figure 6.12 to write the electron configuration for nitrogen (N), which has atomic number 7.

1. **Analyze** Identify the relevant concepts.
   For all elements, the atomic number is equal to the total number of electrons. For a representative element, the highest occupied energy level is the same as the number of the period in which the element is located. From the group in which the element is located, you can tell how many electrons are in this energy level.

2. **Solve** Apply concepts to this situation.
   Nitrogen is located in the second period of the periodic table and in the third group of the p block. Nitrogen has seven electrons. Based on Figure 6.12, the configuration for the two electrons in the first energy level is 1s². The configuration for the five electrons in the second energy level is 2s²2p³.

**Practice Problems**

8. Use Figure 6.9 and Figure 6.12 to write the electron configurations of the following elements.
   a. carbon
   b. strontium
   c. vanadium
   (Hint: Remember that the principal energy level number for elements in the d block is always one less than the period number.)

9. List the symbols for all the elements whose electron configurations end as follows. Each n represents an energy level.
   a. ns²np³
   b. ns²np⁴
   c. ns²np⁵
   d. ns²np⁶nd²(n+1)s²

---

**Section 6.2 Assessment**

10. **Key Concept** What information can be included in a periodic table?

11. **Key Concept** Into what four classes can elements be sorted based on their electron configurations?

12. Why do the elements potassium and sodium have similar chemical properties?

13. Classify each element as a representative element, transition metal, or noble gas.
   a. 1s²2s²2p³3s²3p⁵
   b. 1s²2s²2p³3s²3p⁴
   c. 1s²2s²2p³3s³

14. Which of the following elements are transition metals: Cu, Sr, Cd, Au, Al, Ge, Co?

15. How many electrons are in the highest occupied energy level of a Group 5A element?

---

**6.2 Section Assessment**

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---

**Section 6.2 Assessment**

10. symbols and names of the elements; atomic number and average atomic mass; information about electron configuration

11. representative elements, noble gases, transition metals, and inner transition metals

12. They are in the same group and have the same number of electrons in the highest occupied energy level.

13. a. noble gas
   b. transition metal
   c. representative element

14. Cu, Cd, Au, Co

15. 5

---

**CONCEPTUAL PROBLEM 6.1 Answers**

8. a. 1s²2s²2p²
   b. 1s²2s²2p³3s²3p⁶3d¹04s²4p⁶5s²
   c. 1s²2s²2p³3s²3p²4s²

9. a. B, Al, Ga, In, Ti
   b. F, Cl, Br, I, At
   c. Ti, Zr, Hf, Rf

**Practice Problems Plus**

Chapter Review problems 34 and 35 are related to Conceptual Problem 6.1.

---

**ASSESS**

**Evaluate Understanding**

Call out pairs of elements in the same group and have students write their electron configurations. This activity can be made into a game where groups compete with other groups to come up with the answer first. Students should eventually be able to write the electron configurations quickly.

**Reteach**

To reinforce the relationship between configurations and position in the periodic table, provide configurations and ask students to identify and locate the elements. Ask students to explain which parts of a configuration proved most useful for determining the identity.

---

When atoms of a noble gas are energized, electrons move into higher energy levels. When the electrons return to lower energy levels, they emit light of specific frequencies. Each noble gas has a unique emission spectrum based on its unique electron configuration.
True Colors

Purpose

The connection of this Technology & Society to Chapter 6 content may not be immediately obvious. It presents an important application of transition metals. Many pigments depend on the tendency of most transition metals to form colored compounds.

Background

Paint is used to cover or hide a surface to which it is applied, decorate a surface, or protect a surface. Egg yolk (in egg tempera paint), gum Arabic (in water colors and gouache), and linseed oil (oil paint) are examples of binders. Many pigments depend on the tendency of transition metals to form colored compounds.

The bison painting is from the Altamira Caves in Spain (about 12,000 B.C.). Although the oldest known paintings are about 35,000 years old, archaeologists in Zambia found pigments and paint grinding equipment that were between 350,000 and 400,000 years old. Some prehistoric artists chemically altered pigments before applying them to cave walls. About one quarter of the samples from Troubat Cave in the Pyrenees were heated in an open fire.

Natural pigments: A prehistoric artist had a limited choice of colors — black from charcoal and red, brown, and yellow from oxides of iron in Earth's crust. These oxides or oxides of other pigments are often referred to as earth tones.

Prehistoric art: Around 14,000 years ago, an artist painted this bison on the ceiling of a cave in Spain. It is about two meters long.

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Comparing and Contrasting

Describe at least three differences between the cave painting and the painting by Jacob Lawrence.

Paint consists essentially of a pigment, a binder, and a liquid in which the other components are dissolved or dispersed. The liquid keeps the mixture thin enough to flow. The binder attaches the paint to the surface being painted, and the pigment determines the color. Pigments may be natural or manufactured. They may be inorganic or organic. The same pigment can be used in a water-based or oil-based paint.

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Comparing and Contrasting

Describe at least three differences between the cave painting and the painting by Jacob Lawrence.

Natural pigments: A prehistoric artist had a limited choice of colors — black from charcoal and red, brown, and yellow from oxides of iron in Earth's crust. These oxides or oxides of other pigments are often referred to as earth tones.

Prehistoric art: Around 14,000 years ago, an artist painted this bison on the ceiling of a cave in Spain. It is about two meters long.

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From pigments to paint
Artists mixed manufactured pigments with binders and solvents to make paint. Although premixed paints became available around 1800, some artists, including Jacob Lawrence, continued to mix their own paints.

Manufactured pigments
Alchemists (and then chemists) made pigments that don’t exist in nature. They also made purer versions of natural pigments. Many of these pigments contain transition metals.

Coding Scheme for Paints
Because pigments with the same common name can contain different substances, the Society of Dyers and Colourists in London and the American Association of Textile Chemists and Colorists established a standard coding scheme for pigments. Manufacturers agreed to list both common pigment names and color index codes on labels. See the table below for the composition and codes for the pigments shown on p. 169.

<table>
<thead>
<tr>
<th>Pigment Name</th>
<th>Chemical Formula</th>
<th>Color Index Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red iron oxide</td>
<td>iron(III) oxide, Fe$_2$O$_3$</td>
<td>PR 101</td>
</tr>
<tr>
<td>Cadmium orange</td>
<td>solid solution of cadmium selenide, CdSe, and cadmium sulfate, CdSO$_4$</td>
<td>PO 20</td>
</tr>
<tr>
<td>Cobalt yellow</td>
<td>potassium cobalt nitrite, K$_3$(Co(NO$_2$)$_6$)$\cdot$H$_2$O</td>
<td>PY 40</td>
</tr>
<tr>
<td>Zinc white</td>
<td>zinc oxide, ZnO</td>
<td>PW 4</td>
</tr>
<tr>
<td>Chromium oxide green</td>
<td>chromium(III) oxide, Cr$_2$O$_3$</td>
<td>PG 17</td>
</tr>
<tr>
<td>Cobalt blue</td>
<td>cobalt(II) aluminate, Co(AlO$_2$)$_2$</td>
<td>PB 28</td>
</tr>
<tr>
<td>Manganese violet</td>
<td>manganese ammonium pyrophosphate, Mn(III)NH$_4$P$_2$O$_7$</td>
<td>PV 16</td>
</tr>
</tbody>
</table>

Answers to...
Comparing and Contrasting
Possible differences include the subject matter, the range of colors, and the anonymity of the artist who painted in the cave.