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6 The Periodic Table

Big idea ELECTRONS AND THE STRUCTURE OF ATOMS

6.1 Organizing the Elements

For students using the Foundation edition, assign problems 1–12.

Essential Understanding Although Dmitri Mendeleev is often credited as the father of the periodic table, the work of many scientists contributed to its present form.

Reading Strategy

Compare and Contrast Organizing information in a table helps you compare and contrast several topics at one time. For example, you might compare and contrast different groups of elements. As you read, ask yourself, "How are they similar? How are they different?"

As you read Lesson 6.1, use the compare and contrast table below. Fill in the table with *increases or decreases* to show the patterns of the listed periodic trends.

	Across a period	Down a group
Metallic	***decreases***	***increases***
Nonmetallic	***increases***	***decreases***
Atomic number	***increases***	***increases***

EXTENSION **On a blank periodic table, use arrows and labels to illustrate the results in your compare and contrast table.**

Lesson Summary

Searching for an Organizing Principle As more and more elements were discovered, scientists needed a way to classify them.

- Elements were first classified according to their properties.

Mendeleev's Periodic Table Mendeleev developed the first periodic table, arranging elements according to a set of repeating, or periodic, properties.

- Elements were also placed in order, according to increasing atomic mass.
- Mendeleev used his table to predict the properties of yet undiscovered elements.

Today's Periodic Table Today's periodic table is a modification of Mendeleev's periodic table.

- The modern periodic table arranges elements by increasing atomic number.
- Periodic law states that when elements are ordered by increasing atomic number, their chemical and physical properties repeat in a pattern.

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Metals, Nonmetals, and Metalloids Within the periodic table, elements are classified into three large groups based on their properties.

- Metals are good conductors and many are ductile and malleable.
- Nonmetals are mostly gases whose properties are opposite to those of metals.
- Metalloids can behave like metals or nonmetals, depending on the conditions.

After reading Lesson 6.1, answer the following questions.

Searching for an Organizing Principle

1. How many elements had been identified by the year 1700? *13*
2. What caused the rate of discovery to increase after 1700?
   Chemists began to use scientific methods to search for elements.
3. What did chemists use to sort elements into groups?
   Chemists used the properties of elements.

Mendeleev's Periodic Table

4. Who was Dmitri Mendeleev?
   He was a Russian chemist and teacher who developed a periodic table of elements.
5. What property did Mendeleev use to organize the elements into a periodic table?
   Mendeleev arranged the elements in order of increasing atomic mass.
6. Is the following sentence true or false? Mendeleev used his periodic table to predict the properties of undiscovered elements. *true*

Today's Periodic Table

7. How are the elements arranged in the modern periodic table?
   The elements are arranged in order by increasing atomic number.
8. Is the following statement true or false? The periodic law states that when elements are arranged in order of increasing atomic number, there is a periodic repetition of physical and chemical properties. *true*

Metals, Nonmetals, and Metalloids

9. Explain the color coding of the squares in the periodic table in Figure 6.4.
   Yellow squares contain metals; blue squares contain nonmetals; green squares contain metalloids.
10. Which property below is NOT a general property of metals?

a. ductile
b. poor conductor of heat
c. malleable
d. high luster

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11. Is the following statement true or false? The variation in properties among metals is greater than the variation in properties among nonmetals. ***false***

12. Under some conditions, a metalloid may behave like a ***metal***. Under other conditions, a metalloid may behave like a ***nonmetal***.

6.2 Classifying the Elements

For students using the Foundation edition, assign problems 1–13.

Essential Understanding A periodic table shows much information about an element in an element's square, and arranges elements by their electron configuration.

Lesson Summary

Reading the Periodic Table An element's square has the element's symbol and name, atomic number and mass, and electron configuration.

- The elements are grouped into alkali metals, alkaline earth metals, and halogens.

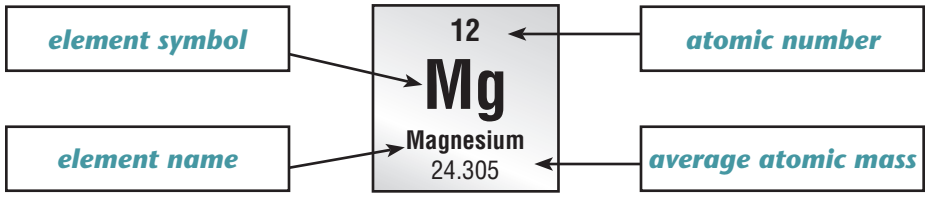
Electron Configurations in Groups The properties of elements are largely determined by the arrangement of electrons, or electron configuration, in each atom.

- Based on their electron configurations, elements are classified as noble gases, representative elements, transition metals, or inner transition metals.

After reading Lesson 6.2, answer the following questions.

Reading the Periodic Table

1. Label the sample square from the periodic table below. Use the labels *element name, element symbol, atomic number,* and *average atomic mass.*



2. List three things, other than the name, symbol, atomic number, and average atomic mass, you can discover about an element using the periodic table in Figure 6.9.

   a. ***state at room temperature***

   b. ***number of electrons in each energy level***

   c. ***whether an element is found in nature***

Electron Configurations in Groups

3. Is the following sentence true or false? The subatomic particles that play the key role in determining the properties of an element are electrons. ***true***

4. Why are Group A elements called representative elements?

   They exhibit a wide range of physical and chemical properties.

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5. Classify each of the following elements as a(n) *alkali metal, alkaline earth metal, halogen,* or *noble gas.*

a. sodium ***alkali metal***

b. chlorine ***halogen***

c. calcium ***alkaline earth metal***

d. fluorine ***halogen***

e. xenon ***noble gas***

f. potassium ***alkali metal***

6. For elements in each of the following groups, how many electrons are in the highest occupied energy level?

a. Group 3A ***3*** **b.** Group 1A ***1*** **c.** Group 8A ***8***

7. Complete the table about classifying elements according to the electron configuration of their highest occupied energy level.

Category	Description of Electron Configuration
Noble gases	***s or p sublevels are filled***
Representative elements	***s or p sublevels are only partially filled***
Transition metals	*s* sublevel and nearby *d* sublevel contain electrons
Inner transition metals	*s* sublevel and nearby *f* sublevel contain electrons

8. Circle the letter of the elements found in the *p* block.

a. Groups 1A and 2A and helium

b. Groups 3A, 4A, 5A, 6A, 7A, and 8A except for helium

c. transition metals

d. inner transition metals

Match the category of elements with an element from that category.

c **9.** noble gases

a **10.** representative elements

d **11.** transition metals

b **12.** inner transition metals

a. gallium

b. nobelium

c. argon

d. vanadium

13. Use Figure 6.9. Write the electron configurations for the following elements.

a. magnesium $1s^2 2s^2 2p^6 3s^2$

b. cobalt $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$

c. sulfur $1s^2 2s^2 2p^6 3s^2 3p^4$

6.3 Periodic Trends

For students using the Foundation edition, assign problems 1–7, 11, 14, 19–24.

Essential Understanding An element's properties are related to its position on the periodic table, and these properties follow trends on the table.

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Lesson Summary

Trends in Atomic Size Atomic size is an atom's atomic radius, or one-half the distance between two like atoms when they are joined together.

- Atomic size generally increases from top to bottom within a group because the number of energy levels increases.
- Atomic size decreases from left to right across a period because electrons are added to the same energy level and are pulled closer to the nucleus by increasing numbers of protons.

Ions Ions form when atoms gain or lose electrons.

- A positively charged cation forms when an atom loses one or more electrons.
- A negatively charged anion forms when an atom gains one or more electrons.

Trends in Ionization Energy Ionization energy is a measure of how much energy is required to remove an electron from an atom.

- First ionization energy is the amount of energy required to remove one electron from a neutral atom.
- Ionization energy tends to decrease from top to bottom within a group and increase from left to right across a period.

Trends in Ionic Size Trends in ionic size are based on the fact that metals tend to lose electrons, and nonmetals tend to gain electrons.

- A cation is smaller than the atom that formed it; an anion is larger than the atom that formed it.
- Ionic size generally increases from top to bottom within a group and decreases from left to right across a period.

Trends in Electronegativity Electronegativity is a measure of an atom's ability to attract an electron when the atom is bonded to another atom.

- The trends in electronegativity are similar to the trends in ionization energy.
- Electronegativity tends to decrease from top to bottom within a group and to increase from left to right across a period.

BUILD Math Skills

Reading a Graph A graph is a visual way to interpret or understand data. A graph shows relationships that exist among the data.

The title of the graph tells you what information the graph shows. The *x*-axis is the horizontal axis and the *y*-axis is the vertical axis. Examine each axis to find what each one represents and what units are used.

The two main types of graphs are bar graphs and line graphs.

Turn the page to learn more about reading a graph.

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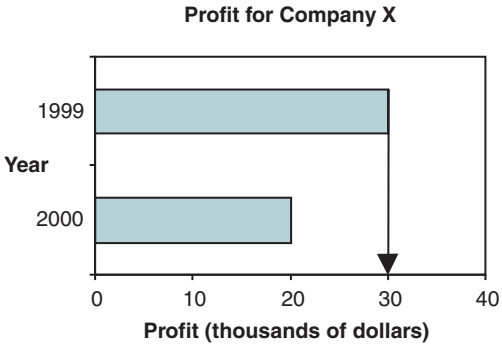
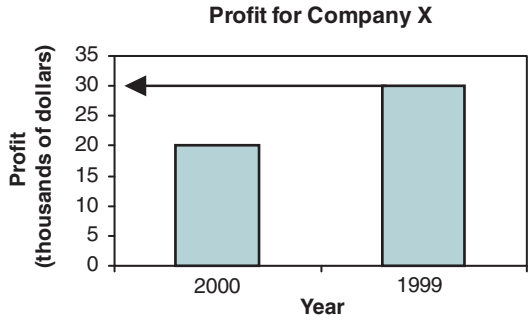
A bar graph has bars that run horizontally or vertically. To obtain data for a horizontal bar graph, you will need to match the end of the bar to the information on the horizontal axis at the bottom. The title of the vertical axis tells what the bar represents. To obtain data for a vertical bar graph, compare the end of the bar to the information on the vertical axis to the side. The title of the vertical axis tells what the bar represents.

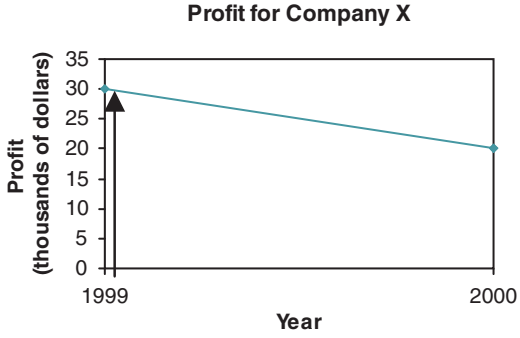




The graphs above provide the same information, but in two different ways. Look at the horizontal bar graph for the year 1999. Follow the end of the bar to the bottom axis and you will see that Company X made a profit of $30,000. The same data can be found on the vertical bar graph by following the end of the bar for year 1999 to the vertical axis.

A line graph shows points connected by a line. Each point has a corresponding value for both the horizontal and vertical axes. If you are given a value on the horizontal axis, you can find the point corresponding to that value on the vertical axis.

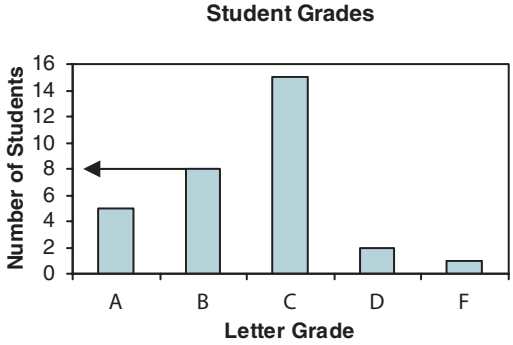
To find out how much profit Company X made in 1999, you would first locate year 1999 on the horizontal axis. Next, you would find the corresponding point on the vertical axis. The value that point represents on the vertical axis is the profit for 1999. In this example, the profit is $30,000.



Sample Problem Use the bar graph to determine how many students earned a B in the class.

Follow the end of the bar representing the letter grade B to the vertical axis.

The value on the vertical axis is 8, which means that 8 students received a B in that class.



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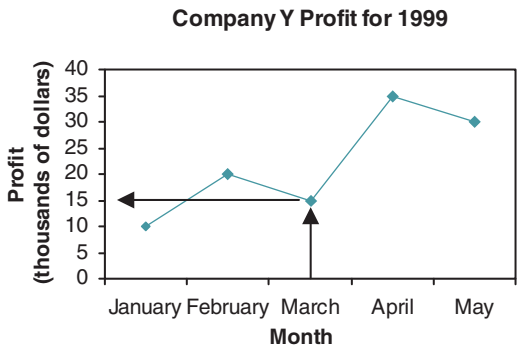
Sample Problem Determine how much profit Company Y made in March of 1999.

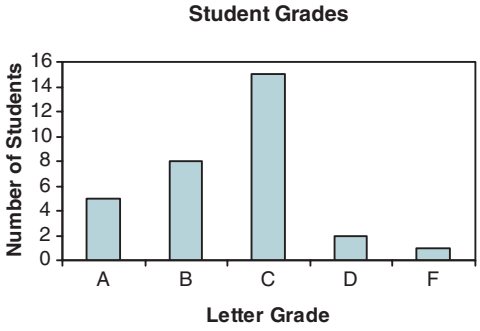
Locate the point associated with March and determine the value on the vertical axis.

The value on the vertical axis is 15, which means that Company Y made $15,000 in profit.



Now it's your turn to practice interpreting graphs. Remember to examine the title and the units and labels of each axis to understand what the graph is representing.

Use the bar graph below to answer the following questions.



1. How many students received an A?

   5 students

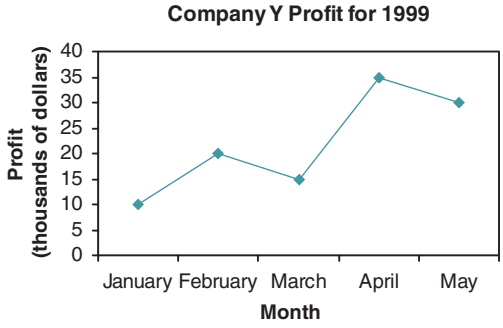
2. How many students passed the class with a D or higher?

   30 students

3. What grade did the highest number of students receive?

   Letter grade C

For the line graph below, answer the following questions.



4. How much did Company Y make for the month of May?

   $30,000

5. In what month did Company Y make the most profit?

   April

6. How much did Company Y make for all 5 months?

   $110,000

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After reading Lesson 6.3, answer the following questions.

Trends in Atomic Size

7. What are the atomic radii for the following molecules?

Hydrogen
atomic radius =
30 pm

Oxygen
atomic radius =
66 pm

Nitrogen
atomic radius =
70 pm

Chlorine
atomic radius =
102 pm

8. What is the general trend in atomic size within a group? Across a period?

The atomic size increases within a group as atomic number increases. The atomic size decreases from left to right across a period.

9. What are the two variables that affect atomic size within a group?

a. *the charge on the nucleus* **b.** *the number of occupied energy levels*

10. For each pair of elements, circle the element with the larger atom.

a. helium and (argon) **b.** (potassium) and argon

Ions

11. What is an ion? *an atom or group of atoms that has a positive or negative charge*

12. How are ions formed? *An ion is formed when electrons are transferred between atoms.*

13. An ion with a positive charge is called a(n) *cation*; an ion with a negative charge is called a(n) *anion*.

14. Complete the table about anions and cations.

	Anions	Cations
Charge	*negative*	*positive*
Metal/Nonmetal	*nonmetal*	*metal*
Minus sign/Plus sign	*minus sign*	*plus sign*

Trends in Ionization Energy

15. *Ionization energy* is the energy required to overcome the attraction of protons in the nucleus and remove an electron from a gaseous atom.

16. Why does ionization energy tend to decrease from top to bottom within a group?

Atomic size increases from top to bottom within a group. The nuclear charge has a smaller effect on the electrons in the highest occupied energy level, so less energy is required to remove an electron.

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17. Why does ionization energy tend to increase as you move across a period?

The nuclear charge increases across a period but the shielding effect remains constant. There is greater attraction of the electrons to the nucleus and more energy is required to remove an electron.

18. There is a large increase in ionization energy between the second and the third ionization energies of a metal. What kind of ion is the metal likely to form? Include the charge in your answer. *an ion with a 2+ charge*

Trends in Ionic Size

19. Metallic elements tend to *lose* electrons and form *positive* ions. Nonmetallic elements tend to *gain* electrons and form *negative* ions.

20. Circle the letter of the statement that is true about ion size.

a. Cations are always smaller than the neutral atoms from which they form.

b. Anions are always smaller than the neutral atoms from which they form.

c. Within a period, a cation with a greater charge has a larger ionic radius.

d. Within a group, a cation with a higher atomic number has a smaller ionic radius.

21. Which ion has the larger ionic radius: Ca^{2+} or Cl^- ? *Cl^-*

Trends in Electronegativity

22. Use Table 6.2. What trend do you see in the relative electronegativity values of elements within a group? Within a period?

The electronegativity values decrease as you move from top to bottom within a group, but increase as you move from left to right across a period.

23. Circle the letter of each statement that is true about electronegativity values.

a. The electronegativity values of the transition elements are all zero.

b. The element with the highest electronegativity value is sodium.

c. Nonmetals have higher electronegativity values than metals.

d. Electronegativity values can help predict the types of bonds atoms form.

24. Use Figure 6.24. Circle the letter of each property for which aluminum has a higher value than silicon.

a. first ionization energy

b. atomic radius

c. electronegativity

d. ionic radius

Guided Practice Problems

Answer the following questions about Practice Problem 9.

Use Figure 6.9 and Figure 6.13 to write the electron configurations of the following elements:

a. carbon **b.** strontium **c.** vanadium

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Analyze

a. What is the number of electrons for each element?

C *6* Sr *38* V *23*

b. What is the highest occupied energy sublevel for each element, according to its position on the periodic table? Remember that the energy level for the *d* block is always one less than the period.

C *2p* Sr *5s* V *3d*

c. According to its position on the periodic table, how many electrons does each element have in the sublevel listed above?

C *2* Sr *2* V *3*

Solve

d. Begin filling in electron sublevels. Start from the top left and move right across each period in Figure 6.13 until you reach the highest occupied sublevel for each element. Make sure the *d* block is in the correct energy level.

C $1s^2 2s^2 2p^2$

Sr $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$

V $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

e. Add all the superscripts in the electron configurations to check your answers. This sum should equal the atomic number for that element.

C *2 + 2 + 2 = 6, the atomic number of C*

Sr *2 + 2 + 6 + 2 + 6 + 10 + 2 + 6 + 2 = 38, the atomic number of Sr*

V *2 + 2 + 6 + 2 + 6 + 3 + 2 = 23, the atomic number of V*

Apply the Big idea

Make a seating chart for students in your class. Seat students according to their birth months and first names.

a. Survey your class and write down the first name and birth month of each student.

b. Make a seating chart with six columns. Label each column with the name of two consecutive months, starting with January/February and ending with November/December.

c. Place student names in the appropriate column in alphabetical order from top to bottom.

1. Suppose a new student named Maria joins the class. Her birthday is in August. Where would she sit?

She would sit in the July/August column where Maria falls alphabetically.

2. What other categories might you use to seat students?

Sample answer: favorite day of the week and height

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6 Self-Check Activity

For Questions 1–11, complete each statement by writing the correct word or words. If you need help, you can go online.

6.1 Organizing the Elements

1. Early scientists first sorted elements into groups according to their ***properties*** _____.

2. In Mendeleev's periodic table, elements were arranged by increasing ***atomic mass*** _____.

3. Currently, elements are arranged on the periodic table according to increasing ***atomic number*** _____.

4. Each element is either a metal, a(n) ***nonmetal*** _____, or a metalloid.

6.2 Classifying the Elements

5. The periodic table contains much information about the elements, including their ***symbols*** _____, names, and information about the structure of their atoms.

6. Elements can be sorted into groups with similar properties based on their ***electron configurations*** _____.

6.3 Periodic Trends

7. Atomic size increases from top to bottom within a(n) ***group*** _____ and from left to right across a(n) ***period*** _____ of the periodic table.

8. ***Ions*** _____ with a positive or negative charge forms when electrons are transferred from one atom to another.

9. The first ionization energy of atoms tends to ***decrease*** _____ from top to bottom within a group and ***increase*** _____ from left to right across a period.

10. When an atom loses one or more electrons to form an ion, the ion is ***smaller*** _____ than the original atom; when an atom gains one or more electrons to form an ion, the ion is ***larger*** _____ than the original atom.

11. Trends in electronegativity follow the same pattern as trends in ***first ionization energy*** _____.

If You Have Trouble With…											
Question	1	2	3	4	5	6	7	8	9	10	11
See Page	160	161	162	164	167	170	174	176	177	179	181

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Review Vocabulary

Match each of the following with its location on the periodic table, using letters a–i. Use each choice only once.

a **1.** alkali metals

g **2.** alkaline earth metals

b **3.** halogens

i **4.** inner transition metals

e **5.** metalloids

c **6.** metals

f **7.** noble gases

d **8.** nonmetals

h **9.** transition metals

Use the letters j–m to show periodic trends in the following properties. The arrows point in the direction the properties increase. Two letters should be in each blank.

k, l **10.** atomic radius

m, j **11.** electronegativity

m, j **12.** ionization energy

k, l **13.** size of anion

m, l **14.** size of cation