The Periodic Table and Periodic Law

Section 6.1 Development of the Modern Periodic Table

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Problem Solving Lab

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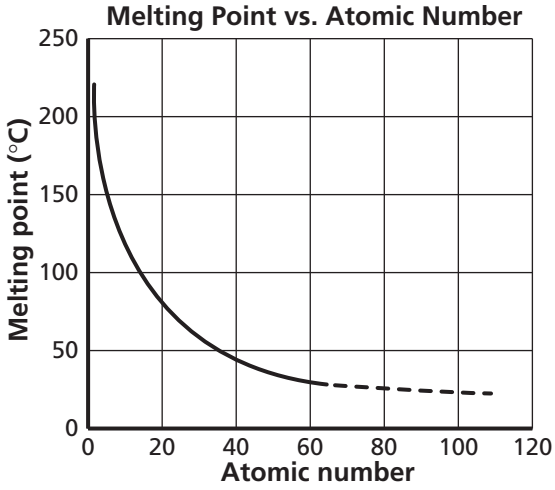
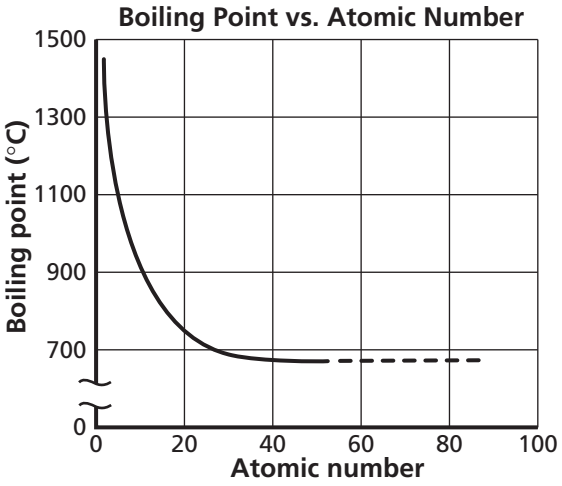
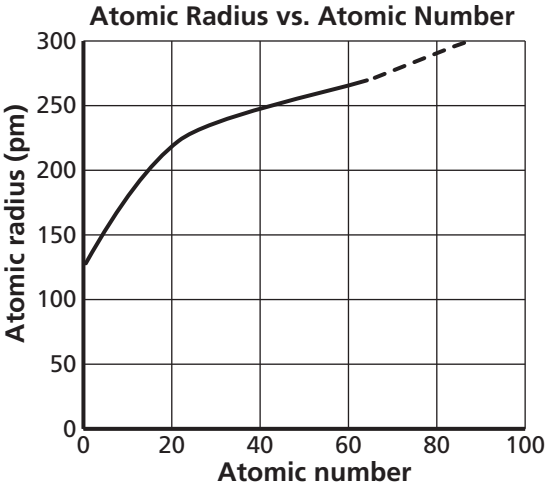
Alkali Metals Data			
Element	**Melting Point (°C)**	**Boiling Point (°C)**	**Radius (pm)**
Lithium	180.5	1347	152
Sodium	97.8	897	186
Potassium	63.3	766	227
Rubidium	39.31	688	248
Cesium	28.4	674.8	248
Francium	?	?	?

1. Devise an approach that clearly displays the trends for each of the properties given in the table and allows you to extrapolate a value for francium. Use the periodic law as guide.

A graph of each property versus atomic number is the best approach. By extending the data curve through to francium's atomic number of 87, its radius, melting point, and boiling point can be determined. R ≈ 280–290 pm, MP ≈ 25°C, and BP ≈ 675°C.







2. Predict wheather francium is a solid, a liquid, or a gas. How can you support your prediction?

Francium is probably a liquid at room temperature. Its melting point is probably below 20°C, according to the trend shown in the table.

3. Infer which column of data represents the greatest possible error in making a prediction. Explain.

The radius prediction is most inaccurate. The affect of the principal energy level on the radius is harder to extrapolate accurately because it varies from period to period.

4. Determine why producing 1 million francium atoms per second is not enough to make measurements, such as density of boiling point.

Even one million atoms collected together as a solid are microscopic. A grain of salt contains about 10^{15} sodium atoms.

Section 6.1 Assessment

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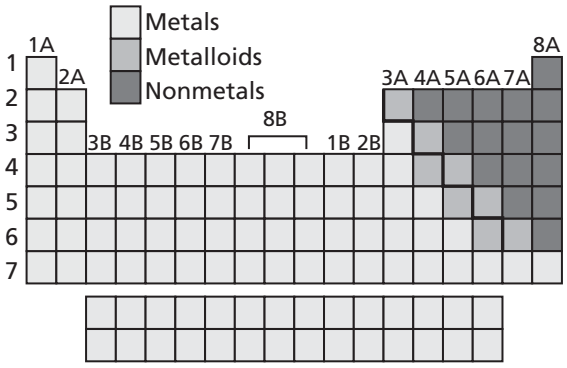
1. Describe the development of the modern periodic table. Include contributions made by Lavoisier, Newlands, Mendeleev, and Moseley.

Lavoisier organized a list of the known elements of his day as four categories. Newlands was the first to organize the elements and show that properties repeated in a periodic way. Mendeleev and Meyer proposed periodic tables showing a relationship between atomic mass and elemental properties. Moseley organized the elements by atomic number instead of atomic mass.

2. Sketch a simplified version of the periodic table, and indicate the location of metals, nonmetals, and metalloids.

A simplified table should resemble the figure.



3. Describe the general characteristics of metals, nonmetals, and metalloids.

Metals are generally shiny, ductile, malleable, and good conductors of heat and electricity. Nonmetals are gases or are dull, brittle, and poor conductors of heat and electricity. Metalloids have physical properties of both metals and nonmetals.

4. Identify each of the following as a representative element or a transition element.

a. lithium (Li)

representative

b. platinum (Pt)

transition

c. promethium (Pm)

transition

d. carbon (C)

representative

5. Compare For each of the given elements, list two other elements with similar chemical properties.

a. iodine (I)

any other group 17 element

b. barium (Ba)

any other group 2 element

c. iron (Fe)

any other group 8 element

6. Compare According to the periodic table, which two elements have an atomic mass less than twice the atomic number?

hydrogen and oxygen

7. Interpret data A company plans to make an electronic device. They need to use an element that has chemical behavior similar to that of silicon (Si) and lead (Pb). The element must have a mass greater than that of sulfur (S), but less than that of cadmium (Cd). Use the periodic table to determine the element the company could use.

germanium (Ge)

Section 6.2 Classification of the Elements

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Practice Problems

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8. Without using the periodic table, determine the group, period, and block of an atom with the following electron configurations.

a. $[Ne]3s^2$ **b.** $[He]2s^2$

c. $[Kr]5s^24d^{10}5p^5$

Electron Configuration	Group	Period	Block
a. $[Ne]3s^2$	2	3	s
b. $[He]2s^2$	2	2	s
c. $[Kr]5s^24d^{10}5p^5$	17	5	p

9. What are the symbols for the elements with the following valence electron configurations?

a. s^2d^1

Sc, Y, La, Ac

b. s^2p^3

N, P, As, Sb, Bi

c. s^2p^6

Ne, Ar, Kr, Xe, Rn

10. Challenge Write the electron configuration of the following elements.

a. the group 2 element in the fourth period

$1s^22s^22p^63s^23p^64s^2$

b. the group 12 element in the fourth period

$1s^22s^22p^63s^23p^64s^23d^{10}$

c. the noble gas in the fifth period

$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^6$

d. the group 16 element in the second period

$1s^22s^22p^4$

Section 6.2 Assessment

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11. Explain what determines the blocks in the periodic table.

The energy sublevel being filled defines the blocks in the periodic table.

12. Determine in which block of the periodic table are the elements having the following valence electron configurations.

a. s^2p^4

p-block

b. s^1

s-block

c. s^2d^1

d-block

d. s^2p^1

p-block

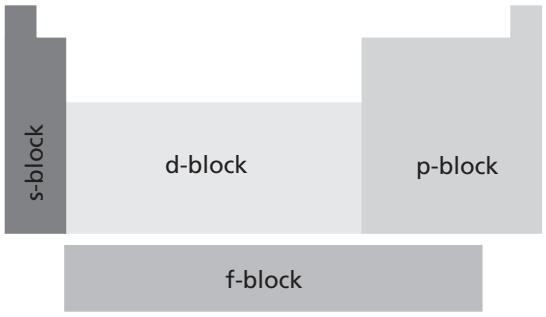
13. Infer Xenon, a nonreactive gas used in strobe lights, is a poor conductor of heat and electricity. Would you expect xenon to be a metal, a nonmetal, or a metalloid? Where would you expect it to be on the periodic table? Explain.

Nonmetal; the nonreactive gases are noble gases in group 18 on the right of the periodic table

14. Explain why elements within a group have similar chemical properties.

Because they have the same valence electron configuration.

15. Model Make a simplified sketch of the periodic table and label the s-, p-, d-, and f-blocks.



Sketches should look similar to Figure 6.8.

Section 6.3 Periodic Trends

pages 187–194

Practice Problems

page 189

16. Which has the largest atomic radius: magnesium (Mg), silicon (Si), sulfur (S), or sodium (Na)? The smallest?

largest: Na

smallest: S

17. The figure below shows helium, krypton, and radon. Which one is krypton? How can you tell?

B. The atomic radius increases when going down a group so helium is the smallest and radon is the biggest.

18. Can you determine which of two unknown elements has the larger radius if the only known information is that the atomic number of one of the elements is 20 greater than the other? Explain.

No. If all you know is that the atomic number of one element is 20 greater than that of the other, then you will be unable to determine the specific groups and periods that the elements are in. Without this information, you cannot apply the periodic trends in atomic size to determine which element has the larger radius.

19. Challenge Determine which of the following has the largest atomic radius:

a. the element in period 2, group 1; or the element in period 3, group 18

the element in period 2, group 1

b. the element in period 5, group 2; or the element in period 3, group 16

the element in period 5, group 2

c. the element in period 3, group 14; or the element in period 6, group 15

the element in period 6, group 15

d. the element in period 4, group 18; or the element in period 2, group 16

the element in period 4, group 18

Section 6.3 Assessment

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20. Explain how the period and group trends in atomic radii are related to electron configuration.

Atomic radii increase down a group as electrons are added to higher energy levels and inner core electrons shield the valence electrons from the increased nuclear charge. Atomic radii decrease across a period as increased nuclear charge coupled with unchanging shielding by inner core electrons pulls the valence electrons (being added to the same energy level) closer to the nucleus.

21. Indicate whether fluorine or bromine has a larger value for each of the following properties.

a. electronegativity

fluorine

b. ionic radius

bromine

c. atomic radius

bromine

d. ionization energy

fluorine

22. Explain why it takes more energy to remove the second electron from a lithium atom than it does to remove the fourth electron from a carbon atom.

Lithium's second removed electron is an inner core electron, not a valence electron. Carbon's fourth removed electron is still a valence electron.

23. Calculate Determine the difference in electronegativity, ionic radius, atomic radius, and first ionization energy for oxygen and beryllium.

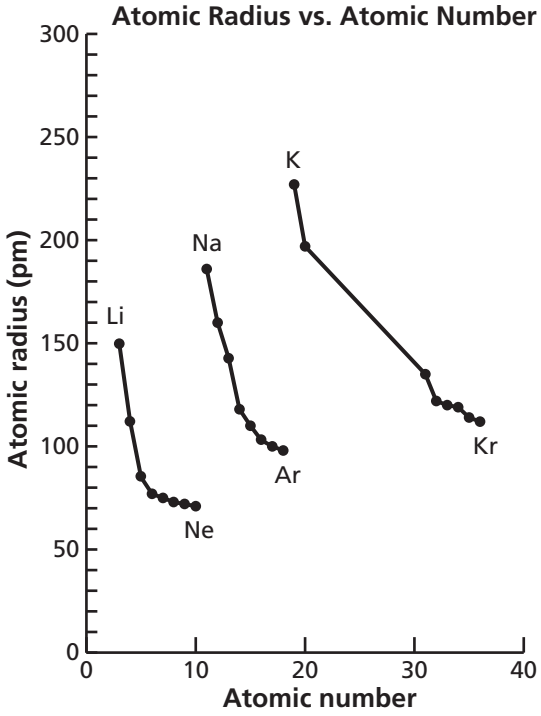
electronegativity: 3.44 − 1.57 = 1.87

ionic radius: 140 pm − 31 pm = 109 pm

atomic radius: 73 pm − 112 pm = −39 pm

first ionization energy: 1310 kJ/mol − 900 kJ/mol = 410 kJ/mol

24. Make and Use Graphs Graph the atomic radii of the representative elements in periods 2, 3, and 4 versus their atomic numbers. Connect the points of elements in each period, so that there are three separate curves on the graph. Summarize the trends in atomic radii shown on your graph. Explain.



In general, atomic radii decrease across a period due to increased nuclear charge; they increase down a group due to valence electrons placed in larger orbitals belonging to higher principal energy levels.

Chapter Assessment

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Section 6.1

Mastering Concepts

25. Explain how Mendeleev's periodic table was in error.

Mendeleev used atomic mass instead of atomic number to order the elements. This resulted in some elements being out of order.

26. Explain the contribution of Newlands's law of octaves to the development of the modern periodic table.

Newlands introduced the idea of periodically repeating properties.

27. Lothar Meyer and Dmitri Mendeleev both proposed similar periodic tables in 1869. Why is Mendeleev generally given credit for the periodic table?

Mendeleev's work was published first; he did more to show periodic trends; and he predicted properties of several yet-to-be-discovered elements.

28. What is the periodic law?

When the elements are arranged by increasing atomic number, there is a periodic repetition of their chemical and physical properties.

29. Describe the general characteristics of metals.

Metals are generally dense, solid, shiny, ductile, malleable, and good conductors of heat and electricity.

30. What are the general properties of a metalloid?

Metalloids have properties intermediate between metals and nonmetals.

31. Identify each of the following as a metal, nonmetal, or metalloid.

a. oxygen

nonmetal

b. barium

metal

c. germanium

metalloid

d. iron

metal

32. Match each item on the left with its corresponding group on the right.

a. alkali metals **2**

b. halogens **4**

c. alkaline earth metals **3**

d. noble gases **1**

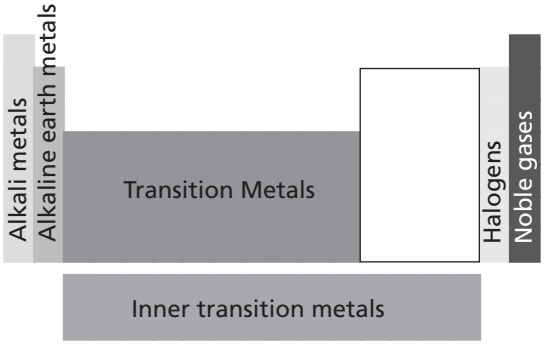
1. group 18

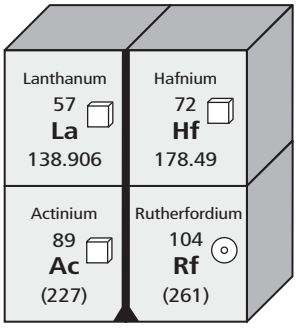
2. group 1

3. group 2

4. group 17

33. Sketch a simplified periodic table and use labels to identify the alkali metals, alkaline earth metals, transition metals, inner transition metals, noble gases, and halogens.





34. Explain what the dark line running down the middle of **Figure 6.19** indicates.

The line indicates that the lanthanide and actinide series of elements would be at that location if there were enough horizontal room on the page.

35. Give the chemical symbol of each of the following elements.

a. a metal used in thermometers

Hg

b. a radioactive gas used to predict earthquakes; the noble gas with the greatest atomic mass

Rn

c. a coating for food cans; it is the metal in group 14 with the lowest atomic mass

Sn

d. transition metal that is used to make burglar-proof vaults; also the name of a coin

Ni

36. If a new halogen and a new noble gas were discovered, what would their atomic numbers be?

The halogen would have atomic number 117. The noble gas would have atomic number 118.

Mastering Problems

37. If the periodic table were arranged by atomic mass, which of the first 55 elements would be ordered differently than they are in the existing table?

Argon and potassium would be switched. Cobalt and nickel would be switched. Tellurium and iodine would be switched.

38. New Heavy Element If scientists discovered an element with 117 protons. What would be its group and period? Would it to be a metal, a metalloid, or a nonmetal?

group 17, period 7; metalloid

39. Naming New Elements Recently discovered elements that have not been fully verified are given temporary names using the prefix words in **Table 6.6**

0	1	2	3	4
nil	un	b(i)	tr(i)	quad

5	6	7	8	9
pent	hex	sept	oct	en(n)

Based on this system, write temporary names for elements 117–120.

ununseptium, ununoctium, ununennium, unbinilium

40. Give the chemical symbol for each element.

a. the element in period 3 that can be used in making computer chips because it is a metalloid

Si

b. the group 13, period 5 metal used in making flat screens for televisions

In

c. an element used as a filament in light bulbs; it has the highest atomic mass of any non-synthetic element in group 6

W

Section 6.2

Mastering Concepts

41. Household Products Why do the elements chlorine, used in laundry bleach, and iodine, a nutrient added to table salt, have similar chemical properties?

They have the same valence electron configuration (s^2p^5).

42. How is the energy level of an atom's valence electrons related to the period it is in on the periodic table?

The energy level of an atom's valence electrons equals its period number.

43. How many valence electrons does each of the noble gases have?

All noble gases have eight valence electrons, except for helium, which has two.

44. What are the four blocks of the periodic table?

s-, p-, d-, and f-block

45. What electron configuration has the greatest stability?

ns^2np^6, where n is the energy level

46. Explain how an atom's valence electron configuration determines its place on the periodic table.

Elements in a given column have the same number of valence electrons. The energy level of an atom's valence electrons determines its period.

47. Write the electron configuration for the element fitting each of the following descriptions.

a. the metal in group 15 that is part of compounds often found in cosmetics

Bi: $[Xe]6s^2 4f^{14} 5d^{10} 6p^3$

b. the halogen in period 3 that is part of a bleaching compound used in paper production

Cl: $[Ne]3s^2 3p^5$

c. the transition metal that is a liquid at room temperature; is sometimes used in outdoor security lights

Hg: $[Xe]6s^2 4f^{14} 5d^{10}$

48. Determine the group, period, and block in which each of the following elements is located in the periodic table.

a. $[Kr]5s^2 4d^1$

group 3, period 5, d-block

b. $[Ar]4s^2 3d^{10} 4p^3$

group 15, period 4, p-block

c. $[He]2s^2 2p^6$

group 18, period 2, p-block

d. $[Ne]3s^2 3p^1$

group 13, period 3, p-block

49. Given any two elements within a group, is the element with the larger atomic number likely to have a larger or smaller atomic radius than the other element?

larger

50. Table 6.7 shows the number of elements in the first five periods of the periodic table.

Number of Elements in Periods 1-5

Period	1	2	3	4	5
Number of Elements	2	8	8	18	18

Explain why some of the periods have different numbers of elements.

The first energy level has only the s sublevel. The second and third energy levels have only the s and p sublevels. The fourth and fifth energy levels have s, p, and d sublevels.

51. Coins One of the transition groups is often called the coinage group because at one time many coins were made of these metals. Which group is this? What elements in this group are still used in many U.S. coins today?

group 11; copper, silver, gold

52. Do any of the halogens have their valence electrons in orbitals of the same energy level? Explain.

No. Each halogen is in a different period; therefore, each has its valence electrons in orbitals of a different energy level.

53. The transition elements have their valence electrons in orbitals of more than one energy level, but the representative elements have their valence electrons in orbitals of only one energy level. Show this by using the electron configurations of a transition element and a representative element as examples.

Possible answer: The electron configuration of chlorine (a representative element) is $[Ne]\ 3s^2 3p^5$, which has its valence electrons in orbitals of the third energy level. The electron configuration of iron (a transition element) is $[Ar]4s^2 3d^6$, which has its valence electrons in orbits of both the third and fourth energy levels.

Mastering Problems

54. Fireworks Barium is a metal that gives a green color to fireworks. Write the electron configuration for barium. Classify it according to group, period, and block in the periodic table.

Its electron configuration is $[Xe]6s^2$. It is in group 2, period 6, s block.

55. Headphones Neodymium magnets can be used in stereo headphones because they are both powerful and lightweight. Write the electron configuration for neodymium. In which block of the periodic table is it?

Its electron configuration is $[Xe]6s^2 4f^4$. It is in the f block of elements.

56. Soda Cans The metal used to make soda cans has the electron configuration $[Ne]3s^2 3p^1$. Identify the metal and give its group, period, and block in the periodic table.

The metal is aluminum. It is in group 13, period 3, p block.

57. Identify each missing part of **Table 6.8.**

Electron Configuration

Period	Group	Element	Electron Configuration
3	**a.**	Mg	$[Ne]3s^2$
4	14	Ge	**b.**
c.	12	Cd	$[Kr]5s^2 4d^{10}$
2	1	**d.**	$[He]2s^1$

a. 2

b. $[Ar]4s^2 3d^{10} 4p^2$

c. 5

d. Li

Section 6.3

Mastering Concepts

58. What is ionization energy?

Ionization energy is the energy needed to remove an electron from a neutral atom in its gaseous state.

59. An element forms a negative ion when ionized. On what side of the periodic table is the element located? Explain.

Elements on the right side of the periodic table gain electrons to gain a stable octet.

60. Of the elements magnesium, calcium, and barium, which forms the ion with the largest radius? The smallest? What periodic trend explains this?

Ba^{2+} is the largest; Mg^{2+} is the smallest; ionic size increases down a group.

61. Explain why each successive ionization of an electron requires a greater amount of energy.

With each removed electron, there are fewer electrons to shield the remaining electrons from the electrostatic force of attraction of the nucleus. The increased nuclear attraction makes it more difficult to remove subsequent electrons.

62. How does the ionic radius of a nonmetal compare with its atomic radius? Explain the change in radius.

The ionic radius of a nonmetal is larger than its neutral atom. Nonmetals tend to gain electrons in the atom's current energy level; these additional electrons repel each other and increase the size of the ion.

63. Explain why atomic radii decrease as you move left-to-right across a period.

Atomic radii decrease left-to-right because the nuclear charge increases as the shielding of inner core electrons remains constant. The increased attraction of the nucleus for its electrons pulls the electrons inward, resulting in a decreased atomic size.

64. Which element in each pair has the larger ionization energy?

a. Li, N

N

b. Kr, Ne

Ne

c. Cs, Li

Li

65. Explain the octet rule. Why are the first period elements, hydrogen and helium, exceptions to the octet rule?

The ns^2np^6 electron configuration, known as the octet configuration, contains eight electrons and generally has the lowest energy and is the most stable. Atoms gain, lose, or share electrons in order to obtain the stable octet configuration.

They have a complete energy level with just two valence electrons.

66. Use **Figure 6.20** to answer each of the following questions. Explain your reasoning for each answer.

a. If A is an ion and B is an atom of the same element, is the ion a positive or negative ion?

The ion is negative. A negative ion is always larger than its atom.

b. If A and B represent the atomic radii of two elements in the same period, what is their correct order (left-to-right)?

A is to the left of B. Atomic radius in a period decreases left-to-right.

c. If A and B represent the ionic radii of two elements in the same group, what is their correct order (top-to-bottom)?

A is below B. Ionic radius increases down a group.

67. How many valence electrons do elements in group 1 have? Group 18?

1; 8

68.

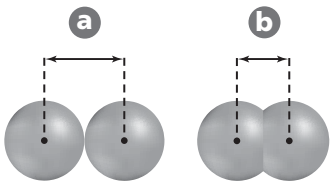


Figure 6.21 shows two ways to define an atomic radius. Describe each method, and identify when each is used.

Method A is used for a metal. The atomic radius is half the distance between two adjacent nuclei in a crystal of the metal. Method B is used for a nonmetal that occurs as a molecule. The atomic radius is half the distance between nuclei of identical atoms that are bonded together.

69. The electron configuration of a chlorine atom is $[Ne]3s^23p^5$. When it gains an electron and becomes an ion, its electron configuration changes to $[Ne]3s^23p^6$, or [Ar], the electron configuration for argon. Has the chlorine atom changed to an argon atom? Explain.

No; the electron configurations of a chlorine ion and an argon atom are the same, but the chlorine ion still has 17 protons and retains its identity as chlorine.

Mastering Problems

70. Sport Bottles Some sport bottles are made of Lexan, a plastic containing a compound of the elements chlorine, carbon, and oxygen. Order these elements from greatest to least according to atomic radius and ionic radius.

atomic radius: chlorine, carbon, oxygen
ionic radius: chlorine, oxygen, carbon

71. Contact Lenses Soft contact lenses are made of silicon and oxygen atoms bonded together. Create a table listing the atomic and ionic electron configurations, and the atomic and ionic radii for silicon and oxygen. When silicon bonds with oxygen, which atoms become larger and which become smaller? Why?

	Silicon	Oxygen
Atomic electron configuration	$[Ne]3s^23p^2$	$[He]2s^22p^4$
Ionic electron configuration	[Ne]	[Ne]
Atomic radius ($\times 10^{-12}$ meters)	118	73
Ionic radius ($\times 10^{-12}$ meters)	41	140

When silicon and oxygen bond, silicon atoms become smaller as they lose electrons. Oxygen atoms become larger as they gain electrons.

72. Artificial Sweetener Some diet sodas contain the artificial sweetener aspartame, a compound containing carbon, nitrogen, oxygen, and other atoms. Create a table showing the atomic and ionic radii of carbon, nitrogen, and oxygen. (Assume the ionization states shown in Figure 6.14.) Use the table to predict whether the sizes of carbon, nitrogen, and oxygen atoms increase or decrease in size when they form bonds in aspartame.

Element	Atomic radius ($\times 10^{-12}$ m)	Ionic radius ($\times 10^{-12}$ m)
Carbon	77	15
Nitrogen	75	146
Oxygen	73	140

Carbon atoms decrease in size. Nitrogen and oxygen atoms increase in size.

Mixed Review

73. Define an ion.

An ion is an atom that has lost or gained one or more electrons.

74. Explain why the radius of an atom cannot be measured directly.

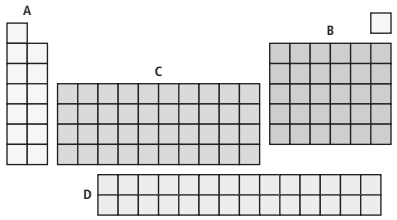
Because an atom has no definite boundary.

75. What is the metalloid in period 2 of the periodic table that is part of compounds used as water softeners?

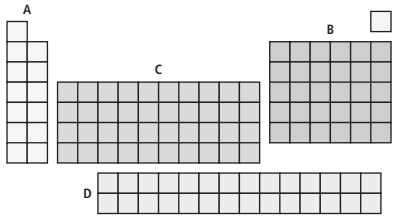
boron

76. Which would you expect to have the greatest electronegativity, cesium, a Group 1 element used in infrared lamps, or bromine, a halogen used in fire-fighting compounds? Why?

Bromine; electronegativity tends to increase from left to right across the periodic table.



77. Figure 6.22 shows different sections of the periodic table. Give the name of each section, and explain what the elements in each section have in common.



A is the s-block elements, with a full or partly-filled s orbitals. B is the p-block elements, with full or partly-filled p orbitals. C is the d-block elements, with full or partly-filled d orbitals. D is the f-block elements, with full or partly filled f orbitals.

78. Which element in each pair is more electronegative?

a. K, As

As

b. N, Sb

N

c. Sr, Be

Be

79. Explain why the s-block of the periodic table is two groups wide, the p-block is six groups wide, and the d-block is ten groups wide.

The s block represents the filling of the s orbital, which holds a maximum of two electrons. The p-block represents the filling of the three p orbitals, which hold a maximum of six electrons. The d-block represents the filling of the five d orbitals, which hold a maximum of ten electrons.

80. Most of the atomic masses in Mendeleev's table are different from today's values. Explain why?

Scientists have refined their methods for measuring atomic masses.

81. Arrange the elements oxygen, sulfur, tellurium, and selenium in order of increasing atomic radii. Is your order an example of a group trend or a period trend?

The order is O, S, Se, and Te. This is an example of a group trend.

82. Milk The element with the electron configuration $[Ar]4s^2$ is an important mineral in milk. Identify this element's group, period, and block in the periodic table.

The element calcium is in group 2, period 4, s-block.

83. Why are there no p-block elements in the first period of the periodic table?

The p orbital does not exist for energy level 1. The first energy level consists only of a single s orbital that holds a maximum of two electrons.

84. Jewelry What are the two transition metals that are used in making jewelry and are the group 11 elements with the lowest atomic masses?

copper and silver

85. Which has the largest ionization energy, platinum, an element sometimes used in dental crowns, or cobalt, an element that provides a bright blue color to pottery?

platinum

Think Critically

86. Apply Sodium forms a 1+ ion, while fluorine forms a 1− ion. Why don't these two elements form 2+ and 2− ions, respectively?

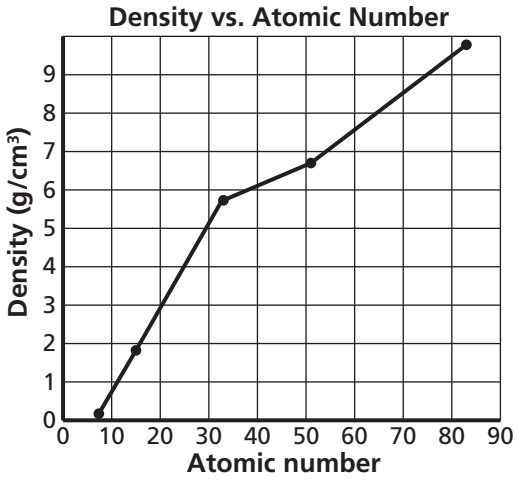
Both ions have the configuration $1s^2 2s^2 2p^6$, a stable, noble gas configuration.

87. Make and Use Graphs The densities of the group 15 elements are given in **Table 6.9.** Plot density versus atomic number and state any trends you observe.

Group 15 Density Data

Element	Atomic Number	Density (g/cm^3)
Nitrogen	7	1.25×10^{-3}
Phosphorus	15	1.82
Arsenic	33	5.73
Antimony	51	6.70
Bismuth	83	9.78

The graph should show density increasing with increasing atomic number. Note that the density of nitrogen is so low because it is the only element that exists as a gas (the others are solids).



88. Generalize The outer-electron configurations of elements in group 1 of the periodic table can be written as ns^1, where n refers to the element's period and its principal energy level. Develop a similar notation for other groups of the representative elements.

Group 2, ns^2; Group 13, ns^2np^1; Group 14, ns^2np^2; Group 15, ns^2np^3; Group 16, ns^2np^4; Group 17, ns^2np^5; Group 18, ns^2np^6

89. Identify A period 3 representative element is part of the rough material on the side of a match box used for lighting matches. Table 6.10 shows the ionization energies for this element.

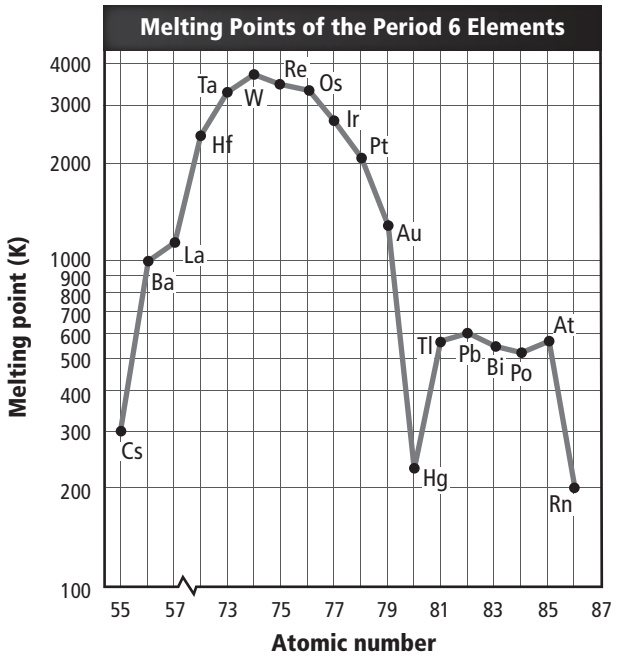
Ionization Energies in kJ/mol

Number	1st	2nd	3rd	4th	5th	6th
Ionization energy	1010	1905	2910	4957	6265	21238

Use the information in the table to infer the identity of the element. Explain.

Phosphorus; the jump in ionization energy after the 5th level indicates that the element has five valence electrons.

90. Interpret Data The melting points of the period 6 elements are plotted versus atomic number in **Figure 6.23.** Determine the trends in melting point by analyzing the graph and the orbital configurations of the elements. Form a hypothesis that explains the trends.



For the d-block elements, the highest values occur for half-filled and near half-filled d orbitals. (W with a configuration of $5d^6$ has the highest melting point.) Relating to Hund's rule, it seems that metallic bonding strengthens as the number of unpaired electrons increases, reaching a maximum when the orbital is half-filled. Note that Hg and Rn have no unpaired electrons and substantially lower melting points. For the p-block elements (81–86), again the elements with unpaired p electrons tend to have higher melting points.

Challenge Problem

91. Ionization energies are expressed in kilojoules per mole (one mole contains 6.02×10^{23} atoms), but the energy to remove an electron from a gaseous atom is expressed in joules. Use the values given in **Table 6.6** to calculate the energy, in joules, required to remove the first electron from an atom of Li, Be, B, and C. Then, use the relationship 1 eV = 1.60×10^{-19} J to convert the values to electron volts.

Li: 8.64×10^{-19} J, or 5.4 eV

Be: 1.50×10^{-18} J, or 9.38 eV

B: 1.33×10^{-18} J, or 8.31 eV

C: 1.81×10^{-18} J, or 11.3 eV

Lithium:

$$520\ \frac{\text{kJ}}{\text{mol}} \times \frac{1000\ \text{J}}{\text{kJ}} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \text{atoms}} = 8.64 \times 10^{-19}\ \text{J}$$

$$8.64 \times 10^{-19}\ \text{J} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} = 5.40\ \text{eV}$$

Beryllium:

$$900\ \frac{\text{kJ}}{\text{mol}} \times \frac{1000\ \text{J}}{\text{kJ}} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \text{atoms}} = 1.50 \times 10^{-18}\ \text{J}$$

$$1.50 \times 10^{-18}\ \text{J} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} = 9.38\ \text{eV}$$

Boron:

$$800\ \frac{\text{kJ}}{\text{mol}} \times \frac{1000\ \text{J}}{\text{kJ}} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \text{atoms}} = 1.33 \times 10^{-18}\ \text{J}$$

$$1.33 \times 10^{-18}\ \text{J} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} = 8.31\ \text{eV}$$

Carbon:

$$1090\ \frac{\text{kJ}}{\text{mol}} \times \frac{1000\ \text{J}}{\text{KJ}} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \text{atoms}} = 1.81 \times 10^{-18}\ \text{J}$$

$$1.81 \times 10^{-18}\ \text{J} \times \frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}} = 11.3\ \text{eV}$$

Cumulative Review

92. Define matter. Identify whether or not each of the following is a form of matter. (Chapter 1)

a. microwaves

no

b. helium inside a balloon

yes

c. heat from the Sun

no

d. velocity

no

e. a speck of dust

yes

f. the color blue

no

Matter is anything that has mass and takes up space.

93. Convert the following mass measurements as indicated. (Chapter 2)

a. 1.1 cm to meters

1.1×10^{-2} m

b. 76.2 pm to millimeters

7.62×10^{-8} mm

c. 11 mg to kilograms

1.1×10^{-5} kg

d. 7.23 micrograms to kilograms

7.23×10^{-9} kg

94. How is the energy of a quantum of emitted radiation related to the frequency of the radiation? (Chapter 5)

The energy of a quantum equals the frequency times Planck's constant.

95. What element has the ground-state electron configuration of $[Ar]4s^2 3d^6$? (Chapter 5).

iron

Additional Assessment

Writing in Chemistry

96. Triads In the early 1800s, German chemist J. W. Dobereiner proposed that some elements could be classified into sets of three, called triads. Research and write a report on Dobereiner's triads. What element comprised the triads? How were the properties of elements within a triad similar?

Dobereiner noticed that the atomic weight of strontium fell midway between the atomic weights of calcium and barium, elements that possessed similar chemical properties. He also studied the halogen triad composed of chlorine, bromine, and iodine and the alkalimetal triad made up of lithium, sodium, and potassium. Dobereiner proposed that nature contained triads of elements in which the middle element (when ordered by atomic weight) had properties that were an average of the other two members.

97. Affinity Electron affinity is another periodic property of the elements. Write a report on what electron affinity is, and describe its group and period trends.

Students will find that electron affinity (EA) is the energy change that accompanies one mole of electrons being added to one mole of gaseous atoms of ions. With many irregularities (and excluding the noble gases), first electron affinity (EA_1) generally decreases from top to bottom within a group and increases from left to right within a period.

Document-Based Questions

Mendeleev's original periodic table is remarkable given the knowledge of elements at that time, and yet it is quite different from the modern version. Compare Mendeleev's table, shown in **Table 6.11,** with the modern periodic table shown in **Figure 6.5.**

Data obtained from: Dmitri Mendeleev, *The Principles of Chemistry,* 1891.

Groups of Elements

Series	0	I	II	III	IV	V	VI	VII	VIII
1	–	H	–	–	–	–	–	–	
2	He	Li	Be	B	C	N	O	F	
3	Ne	Na	Mg	Al	Si	P	S	Cl	
4	Ar	K	Ca	So	Ti	V	Cr	Mn	Fe
5		Cu	Zn	Ga	Ge	As	Se	Br	Co Ni(Cu)
6	Kr	Rb	Sr	Y	Zr	Nb	Mo	–	Ru
7		Ag	Cad	In	Sn	Sb	Te	I	Rh Pd(Ag)
8	Xe	Cs	Ba	La	–	–	–	–	–
9		–	–	–	–	–	–	–	–
10	–	–	–	Yb	–	Ta	W	–	Os
11		Au	Hg	Tl		Bi	–	–	Ir Pt(Au)
12	–	–	Rd	–	Th	–	U		

98. Mendeleev placed the noble gases on the left of his table. Why does placement on the right of the modern table make more sense?

Placing them on the right has the representative elements ordered from left to right as orbitals of the energy levels are filled, ending on the right with noble gases, which have filled outer orbitals.

99. Which block on Mendeleev's table was most like today's placement? Which block was least like today's placement? Why?

He had the s block most like today's table, and the f block least like today's table. The s-block elements were most known in his time, but little was known about the f-block elements.

100. Most of the atomic masses in Mendeleev's table differ from today's values. Why do you think this is so?

Scientists have refined their methods for measuring atomic masses.

Standardized Test Practice

pages 202–203

1. Elements in the same group of the periodic table have the same

a. number of valence electrons
b. physical properties
c. number of electrons
d. electron configuration

a

2. Which statement is NOT true?

a. The atomic radius of Na is less the atomic radius of Mg.
b. The electronegativity of C is greater than the electronegativity of B.
c. The ionic radius of Br^- is greater than the atomic radius of Br.
d. The first ionization energy of K is greater than the first ionization energy of Rb.

d

3. What is the group, period, and block of an atom with the electron configuration $[Ar]4s^23d^{10}4p^4$?

a. group 14, period 4, d-block
b. group 16, period 3, p-block
c. group 14, period 4, p-block
d. group 16, period 4, p-block

d

Use the table below to answer Questions 4 and 5.

Characteristics of Elements

Element	Block	Characteristic
X	s	soft solid; reacts readily with oxygen
Y	p	gas at room temperature; forms salts
Z	–	inert gas

4. In which group does Element X most likely belong?

a. 1
b. 17
c. 18
d. 4

a

5. In which block is Element Z most likely found?

a. s-block
b. p-block
c. d-block
d. f-block

b

Use the table below to answer Questions 6 and 7.

Percent Composition By Mass of Selected Nitrogen Oxides

Compound	Percent Nitrogen	Percent Oxygen
N_2O_4	30.4%	69.6%
N_2O_3	?	?
N_2O	63.6%	36.4%
N_2O_5	25.9%	74.1%

6. What is the percent nitrogen in the compound N_2O_3?

a. 44.75%
b. 46.7%
c. 28.1%
d. 36.8%

d

N: 2 × 14.0 g = 28.0 g; O: 3 × 16.0 g = 48.0 g; 28.0 g + 48.0 g = 76.0 g

$$\frac{28.0\ \text{g}}{76.0\ \text{g}} \times 100 = 36.8\%\ \text{nitrogen}$$

7. A sample of nitrogen oxide contains 1.29 g of nitrogen and 3.71 g of oxygen. Which compound is this most likely to be?

a. N_2O_4
b. N_2O_3
c. N_2O
d. N_2O_5

d

1.29 g + 3.71 g = 5.00 g;

N: $\frac{1.29\ \text{g}}{5.00\ \text{g}} \times 100 = 25.8\%$

O: $\frac{3.71\ \text{g}}{5.00\ \text{g}} \times 100 = 74.2\%$; **$N_2O_5$**

8. On the periodic table, metalloids are found only in

a. the d-block
b. groups 13 through 17
c. the f-block
d. groups 1 and 2

b

9. Which group is composed entirely of nonmetals?

a. 1
b. 13
c. 15
d. 18

d

10. It can be predicted that element 118 would have properties similar to a(n)

a. alkali earth metal
b. halogen
c. metalloid
d. noble gas

d

Short Answer

11. Write the electron configuration for the element arsenic (As).

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

12. Write the nuclear decay equation for the beta decay of iodine-131.

$^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}\beta$

13. Two students are identifying a sample of tap water. Student A says that tap water is a mixture, while Student B says that it is a compound. Which student is correct? Justify your answer.

Since this is tap water, Student A is correct. Tap water contains the compound water along with dissolved gases and minerals. Only pure H_2O would be considered a compound.

Extended Response

Use the table below to answer Questions 14 and 15.

Successive Ionization Energies for Selected Period 2 Elements, in kJ/mol

Element	Li	Be	B	C
Valence e-	1	2	3	4
First ionization energy	520	900	800	1090
Second ionization energy	7300	1760	2430	2350
Third ionization energy		14,850	3660	4620
Fourth ionization energy			25,020	6220
Fifth ionization energy				37,830

14. Correlate the biggest jump in ionization energy to the number of valence electrons in each atom.

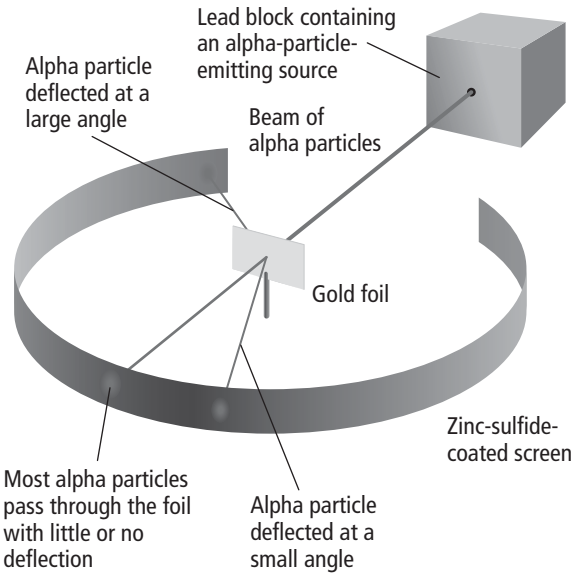
It is easier to remove valence electrons from a partially filled shell. For lithium, it requires much more energy to remove the second electron than the first because the second electron is part of a completely filled outer shell. Its removal causes the atom to become unstable, and therefore requires a great deal of energy to remove.

15. Predict which ionization energy will show the largest jump for magnesium. Explain your answer.

Magnesium will have its largest increase in ionization energy for the third ionization energy. The first two ionization energies are how much energy it requires to remove magnesium's two valence electrons. The third ionization energy will disrupt a complete octet, and therefore requires a lot more energy.

SAT Subject Test: Chemistry

For Questions 16–19, answer true or false for the first statement, and true or false for the second statement. If the second statement is a correct explanation of the first statement, write CE.



16. Some particles bounce off the gold foil	BECAUSE	the nucleus is negatively charged.
17. Some particles bounce off the gold foil	BECAUSE	they hit protons in the nucleus.
18. Many particles pass through the gold foil	BECAUSE	atoms are made of protons, neutrons, and electrons.
19. The symbol for an alpha particle is ^4_2He	BECAUSE	protons and neutrons have about the same mass.

16. T, F

17. T, T, CE

18. T, T

19. T, T