

Study Tip

Write and answer questions about the content of the chapter. For Chapter 7, you might ask the following questions, which require you to summarize the information contained in the chapter. **What information does the electron dot structure of an element provide?** (*the number of valence electrons around the atom*) **In most cases, what is the stable electron configuration of an elemental ion?** (*In most cases, a stable configuration is characterized by an octet of valence electrons; the configuration is isoelectronic with that of a noble gas.*) **Why does NaCl dissolved in water conduct electricity?** (*In water, the ionic compound breaks apart into Na^+ and Cl^- ions that are free to move in the solution.*) **What is the theory of bonding in pure metals?** (*metal cations held together by a pool of mobile valence electrons*)

Interactive Textbook

If your class subscribes to the Interactive Textbook with ChemASAP, your students can go online to access an interactive version of the Student Edition and a self-test.

with **ChemASAP****Key Concepts****7.1 Ions**

- To find the number of valence electrons in an atom of a representative element, simply look at its group number.
- Atoms of the metallic elements tend to lose their valence electrons, leaving a complete octet in the next-lowest energy level. Atoms of some nonmetallic elements tend to gain electrons to achieve a complete octet.
- An atom's loss of valence electrons produces a positively charged cation.
- The gain of electrons by a neutral atom produces negatively charged anion.

7.2 Ionic Bonds and Ionic Compounds

- Although they are composed of ions, ionic compounds are electrically neutral.
- Most ionic compounds are crystalline solids at room temperature, and they generally have high melting points. Ionic compounds can conduct an electric current when melted or dissolved in water.

7.3 Bonding in Metals

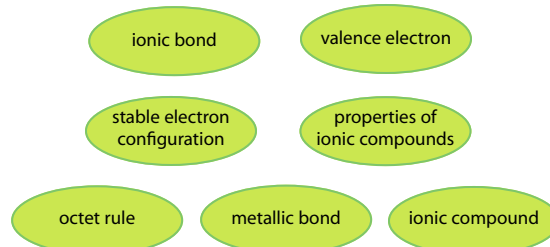
- The valence electrons of metal atoms can be modeled as a sea of electrons.
- Metal atoms are arranged in very compact and orderly patterns.
- Alloys are important because their properties are often superior to those of their component elements.

Vocabulary

- alloys (p. 203)
- chemical formula (p. 195)
- coordination number (p. 198)
- electron dot structure (p. 188)
- formula unit (p. 195)
- halide ion (p. 192)
- ionic bonds (p. 194)
- ionic compounds (p. 194)
- metallic bonds (p. 201)
- octet rule (p. 188)
- valence electron (p. 187)

Organizing Information

Use these terms to construct a concept map that organizes the major ideas of this chapter.

**Interactive Textbook**

Concept Map 7 Solve the Concept Map with the help of an interactive guided tutorial.

with **ChemASAP****Chapter Resources****Print**

- Core Teaching Resources**, Chapter 7, *Practice Problems, Vocabulary Review, Quiz, Chapter Test A, Chapter Test B*

Technology

- Computer Test Bank**, Chapter 7 Test
- Interactive Textbook with ChemASAP**, Chapter 7

Reviewing Content

7.1 Ions

30. Describe two ways that an ion forms from an atom.
31. State the number of electrons either lost or gained in forming each ion.
- | | |
|---------------------|---------------------|
| a. Br^- | b. Na^+ |
| c. As^{3-} | d. Ca^{2+} |
| e. Cu^+ | f. H^- |
32. Name each ion in Problem 31. Identify each as an anion or a cation.
33. Define valence electrons.
34. How many electrons does each atom have? What group is each in?
- | | |
|---------------|------------|
| a. nitrogen | b. lithium |
| c. phosphorus | d. barium |
| e. bromine | f. carbon |
35. Write electron dot structures for each of the following elements.
- | | |
|-------|-------|
| a. Cl | b. S |
| c. Al | d. Li |
36. How many electrons must each atom lose to attain a noble-gas electron configuration?
- | | |
|-------|-------|
| a. Ca | b. Al |
| c. Li | d. Ba |
37. Write the formula for the ion formed when each of the following elements loses its valence electrons.
- | | |
|-------------|--------------|
| a. aluminum | b. lithium |
| c. barium | d. potassium |
| e. calcium | f. strontium |
38. Why do nonmetals tend to form anions when they react to form compounds?
39. What is the formula of the ion formed when the following elements gain or lose valence electrons and attain noble-gas configurations?
- | | |
|-------------|---------------|
| a. sulfur | b. sodium |
| c. fluorine | d. phosphorus |
40. How many electrons must be gained by each of the following atoms to achieve a stable electron configuration?
- | | |
|-------|------|
| a. N | b. S |
| c. Cl | d. P |

7.2 Ionic Bonds and Ionic Compounds

41. Which of the following pairs of atoms would you expect to combine chemically to form an ionic compound?
- | | |
|-------------|-------------|
| a. Li and S | b. O and S |
| c. Al and O | d. F and Cl |
| e. I and K | f. H and N |
42. Identify the kinds of ions that form each ionic compound.
- | |
|--|
| a. calcium fluoride, CaF_2 |
| b. aluminum bromide, AlBr_3 |
| c. lithium oxide, Li_2O |
| d. aluminum sulfide, Al_2S_3 |
| e. potassium nitride, K_3N |
43. Explain why ionic compounds are electrically neutral.
44. Which of the following pairs of elements will not form ionic compounds?
- | |
|------------------------|
| a. sulfur and oxygen |
| b. sodium and calcium |
| c. sodium and sulfur |
| d. oxygen and chlorine |
45. Write the formula for the ions in the following compounds.
- | | |
|--------------------|-----------------------------|
| a. KCl | b. BaSO_4 |
| c. MgBr_2 | d. Li_2CO_3 |
46. Most ionic substances are brittle. Why?
47. Explain why molten MgCl_2 does conduct an electric current although crystalline MgCl_2 does not.

7.3 Bonding in Metals

48. Explain briefly why metals are good conductors of electricity.
49. Name the three crystal arrangements of closely packed metal atoms. Give an example of a metal that crystallizes in each arrangement.
50. Name some alloys that you have used or seen today.
51. Explain why the properties of all steels are not identical.

50. Answers will vary and could include tableware, steel in cars and buses, high-speed dental drill bits, solder in stereos and televisions, and structural steel in buildings.
51. The properties of the steel will vary according to its composition. In addition to iron, steel can contain varying amounts of carbon and such metals as chromium, nickel, and molybdenum.

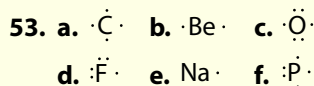
Reviewing Content

30. by gaining or losing electrons
31. a. gain of 1 electron
b. loss of one electron
c. gain of 3 electrons
d. loss of 2 electrons
e. loss of 1 electron
f. gain of 1 electron
32. a. bromide, anion
b. sodium, cation
c. arsenide, anion
d. calcium, cation
e. copper, cation
f. hydride, anion
33. electrons in the highest occupied energy level
34. a. 7, 5A b. 3, 1A c. 15, 5A
d. 56, 2A e. 35, 7A f. 6, 4A
35. a. $\cdot\ddot{\text{Cl}}\cdot$ b. $\cdot\ddot{\text{S}}\cdot$ c. $\cdot\ddot{\text{Al}}\cdot$ d. $\text{Li}\cdot$
36. a. 2 b. 3 c. 1 d. 2
37. a. Al^{3+} b. Li^+ c. Ba^{2+} d. K^+
e. Ca^{2+} f. Sr^{2+}
38. Most nonmetals gain 1, 2, or 3 electrons to achieve a noble-gas electron configuration.
39. a. S^{2-} b. Na^+ c. F^- d. P^{3-}
40. a. 3 b. 2 c. 1 d. 3
41. a, c, e
42. a. $\text{Ca}^{2+}, \text{F}^-$ b. $\text{Al}^{3+}, \text{Br}^-$ c. $\text{Li}^+, \text{O}^{2-}$
d. $\text{Al}^{3+}, \text{S}^{2-}$ e. $\text{K}^+, \text{N}^{3-}$
43. The positive charges balance the negative charges.
44. a, b, d
45. a. K^+, Cl^- b. $\text{Ba}^{2+}, \text{SO}_4^{2-}$
c. $\text{Mg}^{2+}, \text{Br}^-$ d. $\text{Li}^+, \text{CO}_3^{2-}$
46. Their network of electrostatic attractions and repulsions forms a rigid structure.
47. Ions are free to move in molten MgCl_2 .
48. They have many mobile valence electrons. Electrons in the current replace the electrons leaving the metal.
49. body-centered cubic: Na, K, Fe, Cr, or W; face-centered cubic: Cu, Ag, Au, Al, or Pb; hexagonal close-packed: Mg, Zn, or Cd

Understanding Concepts

52.

| Group number | Valence electrons lost or gained | Formula of ion |
|--------------|----------------------------------|------------------|
| 1A | 1 | Na ⁺ |
| 2A | 2 | Ca ²⁺ |
| 3A | 3 | Al ³⁺ |
| 5A | 3 | N ³⁻ |
| 6A | 2 | S ²⁻ |
| 7A | 1 | Br ⁻ |



54. For the representative elements the number of electrons in the electron dot structure is the group number.

55. It has lost valence electrons.

56. It has gained valence electrons.

57. a. oxygen atom, sulfur atom, oxide ion, sulfide ion

b. sodium ion, potassium ion, sodium atom, potassium atom

58. a. $1s^22s^22p^63s^23p^63d^6$

b. $1s^22s^22p^63s^23p^63d^7$

c. $1s^22s^22p^63s^23p^63d^8$

59. a. $1s^22s^22p^63s^23p^63d^3$

b. $1s^22s^22p^63s^23p^63d^4$

c. $1s^22s^22p^63s^23p^63d^5$

60. They have little chemical reactivity; their outermost occupied energy levels are filled.

61. a. Br⁻ b. H⁻ c. As³⁻ d. Se²⁻

62. All have the noble-gas configuration of $1s^22s^22p^63s^23p^6$.

63. All are $1s^22s^22p^6$. All have the same configuration as neon.

64. fluorine, chlorine, bromine, and iodine; Group 7A, 7 valence electrons

65. a. $1s^22s^22p^63s^23p^6$

b. $1s^22s^22p^6$;

Each has a noble-gas electron configuration

Understanding Concepts

52. Construct a table that shows the relationship among the group number, valence electrons lost or gained, and the formula of the cation or anion produced for the following metallic and nonmetallic elements: Na, Ca, Al, N, S, Br.

53. Write electron dot formulas for the following atoms.

- a. C b. Be
 c. O d. F
 e. Na f. P

54. Show the relationship between the electron dot structure of an element and the location of the element in the periodic table.

55. In terms of electrons, why does a cation have a positive charge?

56. Why does an anion have a negative charge?

57. The spheres below represent the relative diameters of atoms or ions. Rearrange the sequences in a. and b. so the relative sizes of the particles correspond to the increasing size of the particles as shown in the illustration.



- a. oxygen atom, oxide ion, sulfur atom, sulfide ion
 b. sodium atom, sodium ion, potassium atom, potassium ion

58. Write electron configurations for the 2+ cations of these elements.

- a. Fe b. Co
 c. Ni

59. Write electron configurations for the 3+ cations of these elements.

- a. chromium b. manganese
 c. iron

60. The atoms of the noble gas elements are stable. Explain.

61. Write the formula for the ion formed when each element gains electrons and attains a noble-gas configuration.

- a. Br b. H
 c. As d. Se

62. Write electron configurations for these atoms and ions, and comment on the result.

- a. Ar b. Cl⁻
 c. S²⁻ d. P³⁻

63. Write electron configurations for the following and comment on the result.

- a. N³⁻ b. O²⁻
 c. F⁻ d. Ne

64. Name the first four halogens. What group are they in, and how many valence electrons does each have?

65. Write complete electron configurations for the following atoms and ions. For each group, comment on the results.

- a. Ar, K⁺, Ca²⁺
 b. Ne, Na⁺, Mg²⁺, Al³⁺

66. If ionic compounds are composed of charged particles (ions), why isn't every ionic compound either positively or negatively charged?

67. Which of the following substances are most likely not ionic?

- a. H₂O b. Na₂O
 c. CO₂ d. CaS
 e. SO₂ f. NH₃

68. Can you predict the coordination number of an ion from the formula of an ionic compound? Explain.

69. Metallic cobalt crystallizes in a hexagonal close-packed structure. How many neighbors will a cobalt atom have?

70. Explain how hexagonal close-packed, face-centered cubic, and body-centered cubic unit cells are different from one another.

71. The properties of all samples of brass are not identical. Explain.

66. The positively charged cations exactly balance the negatively charged anions.

67. a, c, e, f

68. No, the packing of ions in a crystalline structure depends on a number of factors including the relative sizes of the ions. The coordination number of an element can vary from compound to compound.

69. 12

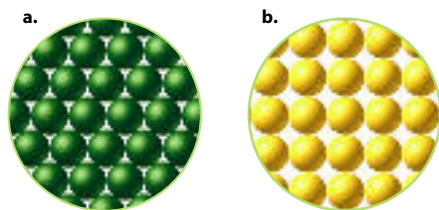
70. Hexagonal close-packed units cells have twelve neighbors for every atom or ion.

Face-centered cubic unit cells also have twelve neighbors for every atom or ion, with an atom or ion in the center of each face. Body-centered cubic units cells have eight neighbors for every atom or ion, with an atom or ion at the center of each cube.

71. Brass is a mixture of copper and zinc. The properties of a particular sample of brass will vary with the relative proportions of the two metals.

Critical Thinking

72. What is the relationship between the number of electrons in the valence shells in an electron configuration diagram for an atom and the number of dots in the corresponding electron dot structure?
73. Why are many elements more stable as ions than they are as atoms?
74. Describe the formation of a cation that is an exception to the octet rule. In your description, compare the electron configuration of the cation to the electron configurations of the nearest noble gases.
75. Is it accurate to describe sodium chloride (NaCl) as consisting of individual particles, each made up of one Na^+ cation and one Cl^- anion? Explain your answer.
76. How do the motions of sodium ions and chloride ions in molten sodium chloride differ from the motions of these ions in sodium chloride crystals?
77. How atoms and ions are arranged in crystals is not just dependent on size. The spheres in each atomic window below are identical in size. The windows have exactly the same area. In which window are the spheres more closely packed? Explain your reasoning.

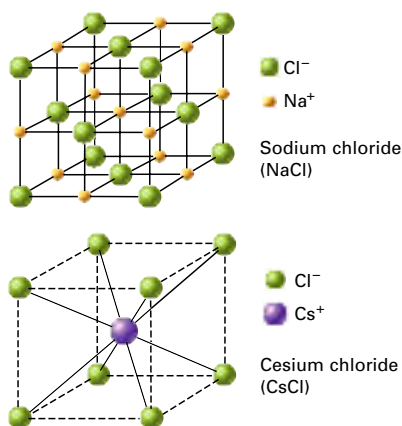


78. Two physical properties of metals are ductility and malleability. Explain these properties based on what you know about the valence electrons of metal atoms.
79. Compare and contrast the physical and chemical characteristics of metals and ionic compounds.

79. Both metals and ionic compounds are composed of ions. Both are held together by electrostatic bonds. Metals always conduct electricity, and ionic compounds conduct only when melted or in water solution. Ionic compounds are composed of cations and anions, but metals are composed of cations and free-floating valence electrons. Metals are ductile, but ionic compounds are brittle.

Concept Challenge

80. Classify each atom in the following list. Will each atom form a cation or an anion? Or is it chemically unreactive? For the atoms that do form ions during a chemical reaction, write the number of electrons the atom will gain or lose.
- lithium
 - sodium
 - neon
 - chlorine
 - magnesium
81. The chemically similar alkali metal chlorides NaCl and CsCl have different crystal structures, whereas the chemically different NaCl and MnS have the same crystal structures. Why?



82. Silver crystallizes in a face-centered cubic arrangement. A silver atom is at the edge of each lattice point. The length of the edge of the unit cell is 0.4086 nm. What is the atomic radius of silver?
83. List the elements that are used to make each alloy.
- brass
 - sterling silver
 - bronze
 - stainless steel
 - surgical steel
 - spring steel

Assessment 209

Critical Thinking

72. Each dot in the electron dot structure represents a valence electron in the electron configuration diagram.
73. By gaining or losing electrons the atoms of elements achieve a noble-gas electron configuration.
74. An atom of silver has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^1$. To achieve the configuration of the preceding noble gas, krypton, a silver atom would have to lose eleven electrons and form Ag^{11+} . To achieve the configuration of the following noble gas xenon, a silver atom must gain seven electrons and form Ag^{7-} . Because ions with such high charges are unlikely, silver does not achieve a noble-gas configuration. However, if a silver atom loses its $5s^1$ electron, the result is an outer electron configuration of eighteen electrons, written as $4s^2 4p^6 4d^{10}$. This configuration is favored and stable. It is known as a pseudo-noble-gas configuration.
75. No, sodium chloride is composed of equal numbers of sodium ions and chloride ions; the ions are in a 1:1 ratio. Each sodium ion is surrounded by chloride ions, and each chloride is surrounded by sodium ions.
76. In sodium chloride crystals the sodium and chloride ions vibrate about fixed points; in the molten state, the ions are free to move.
77. The spheres are more closely packed in (a); there is less empty space in (a), and a rough count shows 25 spheres in (a) compared with 22 spheres in (b).
78. Metals are ductile (can be drawn into wires) and malleable (can be hammered into shapes). These changes are possible because a metal consists of metal cations in a sea of valence electrons. When subjected to pressure, the cations easily slide past one another.

Concept Challenge

80. a. cation: lose $1e^-$ b. cation: lose $1e^-$
 c. unreactive d. anion: gain $1e^-$
 e. cation: lose $2e^-$
81. Na^+ and Cs^+ differ greatly in size. Na^+ and Cl^- are similar in size to Mn^{2+} and S^{2-} .
82. 0.1445 nm
83. a. Cu, Zn b. Ag, Cu c. Cu, Sn d. Fe, Cr, Ni, C
 e. Fe, Cr, Ni, Mo f. Fe, Cr, C

Cumulative Review

84. Organic chemistry is the study of chemicals containing carbon; inorganic chemistry is the study of chemicals that do not contain carbon.
85. an analytical chemist
86. use insulation
87. a, b, and d are chemical changes; c is a physical change
88. b and e; c is not a mixture, it is a pure substance
89. a. liquid, vapor
b. vapor
c. liquid, vapor
d. liquid, vapor
90. a. 56.6 g
b. 0.0048 m
c. 1.81 L
d. 4.0×10^3 mg
91. b
92. -269°C
93. 27.0 cm^3
94. a. ${}_{30}^{64}\text{Zn}$ b. ${}_{17}^{37}\text{Cl}$ c. ${}_{1}^3\text{H}$
d. ${}_{20}^{40}\text{Ca}$
95. 14 amu
96. Each of the isotopes has 8 protons and 8 electrons; oxygen-16 also has 8 neutrons, oxygen-17 has 9 neutrons, and oxygen-18 has 10 neutrons.
97. a. 1
b. 3
c. 1
d. 5
98. a. N, $1s^2 2s^2 2p^3$
b. Be, $1s^2 2s^2$
c. P, $1s^2 2s^2 2p^6 3s^2 3p^2$
d. K, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
99. chlorine, Cl, $1s^2 2s^2 2p^6 3s^2 3p^5$
100. a. 5×10^{-7} m
b. the visible region, green
101. a. K, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
b. Al, $1s^2 2s^2 2p^6 3s^2 3p^1$
c. S, $1s^2 2s^2 2p^6 3s^2 3p^4$
d. Ba, $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6 6s^2$
102. the electron
103. sodium (Na), cesium (Cs), rubidium (Rb), lithium (Li)

Cumulative Review

84. How is organic chemistry distinguished from inorganic chemistry? (Chapter 1)
85. What is the name given to a chemist who studies the composition of matter? (Chapter 1)
86. Explain an easy way to conserve energy. (Chapter 1)
87. Classify the following as chemical or physical changes. (Chapter 2)
- a. Cookies are baked.
b. A firefly emits light.
c. A figure is carved from wood.
d. Caramel is made from sugar.
88. Which of the following is not a homogeneous mixture? (Chapter 2)
- a. gold ring
b. spaghetti sauce
c. cane sugar
d. window glass
e. river water
f. bottled water
89. What physical state(s) can each of the following substances become as you raise its temperature? (Chapter 2)
- a. silver b. gasoline
c. ice d. wax
90. Round each measurement to the number of significant figures indicated in parentheses. (Chapter 3)
- a. 56.55 g (3) b. 0.004 849 m (2)
c. 1.8072 L (3) d. 4.007×10^3 mg (2)
91. Which of the following linear measurements is the longest? (Chapter 3)
- a. 6×10^4 cm b. 6×10^6 mm
c. 0.06 km d. 6×10^9 nm
92. Helium has a boiling point of 4 K. This is the lowest boiling point of any liquid. Express this temperature in degrees Celsius. (Chapter 3)
93. The density of silicon is 2.33 g/cm^3 . What is the volume of a piece of silicon that has a mass of 62.9 g? (Chapter 3)
94. Express the composition of each atom in shorthand form. (Chapter 4)
- a. zinc-64 b. chlorine-37
c. hydrogen-3 d. calcium-40
95. An atom of carbon and an atom of element Z together have a mass of 6 amu less than double the mass of an atom of oxygen. If an atom of oxygen has a mass of 16 amu and the mass of an atom of carbon is 12 amu, what is the mass of an atom of element Z? (Chapter 4)
96. Determine the number of protons, electrons, and neutrons in each of the three isotopes of oxygen. (Chapter 4)
97. How many orbitals are in the following sublevels? (Chapter 5)
- a. 4s sublevel b. 2p sublevel
c. 3s sublevel d. 4d sublevel
98. Give the symbol for each element and write the electron configuration for each atom. (Chapter 5)
- a. nitrogen b. beryllium
c. phosphorus d. potassium
99. An atom of an element has 17 electrons. Give the name and symbol of the element and write the complete electron configuration. (Chapter 5)
100. A beam of electromagnetic radiation has a wavelength of 500 nm. (Chapter 5)
- a. What is this wavelength in meters?
b. In what region of the spectrum is this?
101. Give the symbol of the element and the complete electron configuration of the element found at each location in the periodic table. (Chapter 6)
- a. Group 1A, period 4
b. Group 3A, period 3
c. Group 6A, period 3
d. Group 2A, period 6
102. Which subatomic particle plays the most important role in chemistry? (Chapter 6)
103. Give the name and symbol of two elements that have properties similar to those of potassium. (Chapter 6)

Standardized Test Prep

Test-Taking Tip

Read through all answers before making your choice Even if you find an answer that looks correct, continue reading until you have looked at every answer. There may be more than once correct response, or one may be better than another. Also, "all of the above" may be a possible answer. If you stop reading too soon as you find an answer that is correct, you won't notice this option.

Select the choice that best answers each question or completes each statement.

- Which of these is not an ionic compound?
 - KF
 - Na_2SO_4
 - SiO_2
 - Na_2O
- Which statements are correct when barium and oxygen react to form an ionic compound?
 - Barium atoms lose 2 electrons and form a cation.
 - Oxygen atoms form oxide anions (O^{2-}).
 - In the compound the ions are present in a one-to-one ratio.
 - I and II only
 - II and III only
 - I and III only
 - I, II, and III
- How many valence electrons does arsenic have?
 - 5
 - 4
 - 3
 - 2
- For which compound name is the incorrect formula given?
 - magnesium iodide, MgI_2
 - potassium selenide, K_2Se
 - calcium oxide, Ca_2O_2
 - aluminum sulfide, Al_2S_3
- Which electron configuration represents a nitride ion?
 - $1s^2 2s^2 3s^2 4s^2$
 - $1s^2 2s^2 2p^3$
 - $1s^2 2s^2 2p^6$
 - $1s^2$
- When a bromine atom gains an electron
 - a bromide ion is formed.
 - the ion formed has a 1-charge.
 - the ion formed is an anion.
 - all the above are correct.

The lettered choices below refer to Questions 7–10. A lettered choice may be used once, more than once, or not at all.

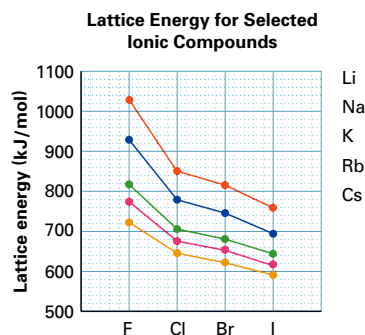
- gains two electrons
- loses two electrons
- gains three electrons
- loses one electron
- gains one electron

Which choice describes what happens as each of the following elements forms its ion?

- iodine
- magnesium
- cesium
- phosphorus

Use the description and the graph to answer Questions 11–13.

Lattice energy is the energy required to change one mole of a crystalline, ionic solid to gaseous ions. The graph below shows the lattice energy for ionic compounds formed between selected alkali metals and halogens.



- For a given alkali metal, what is the trend in lattice energy as the atomic radius of the halogens increases?
- For a given halogen, what is the trend in lattice energy as the atomic radius of the alkali metals increases?
- Complete this sentence. "As the atomic radius of either the halogen or the alkali metal increases, the lattice energy _____."

STANDARDIZED TEST PREP

- c
- d
- a
- c
- c
- d
- (E)
- (B)
- (D)
- (C)
- Because the atomic radius increases moving down the halogen group, the lattice energy decreases.
- Lattice energy decreases as the atomic radius of the alkali metal increases.
- decreases