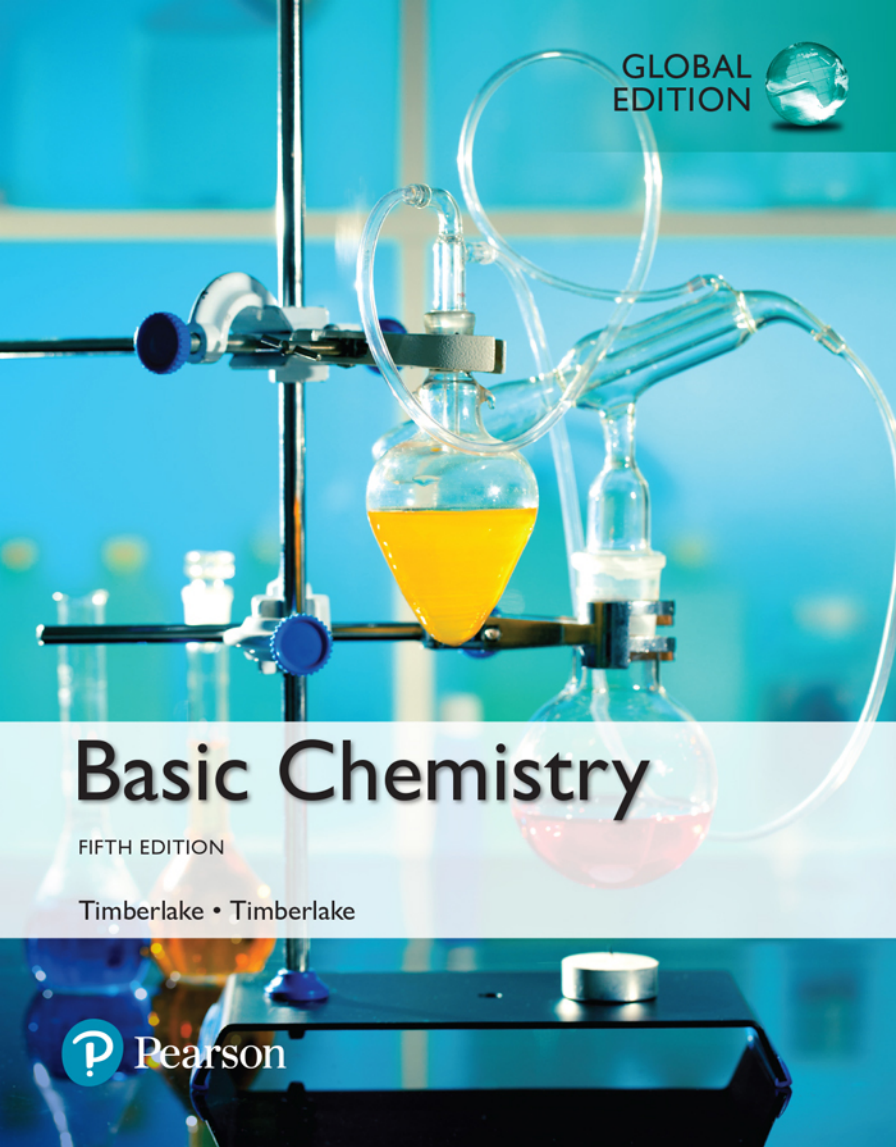

Basic Chemistry

FIFTH EDITION

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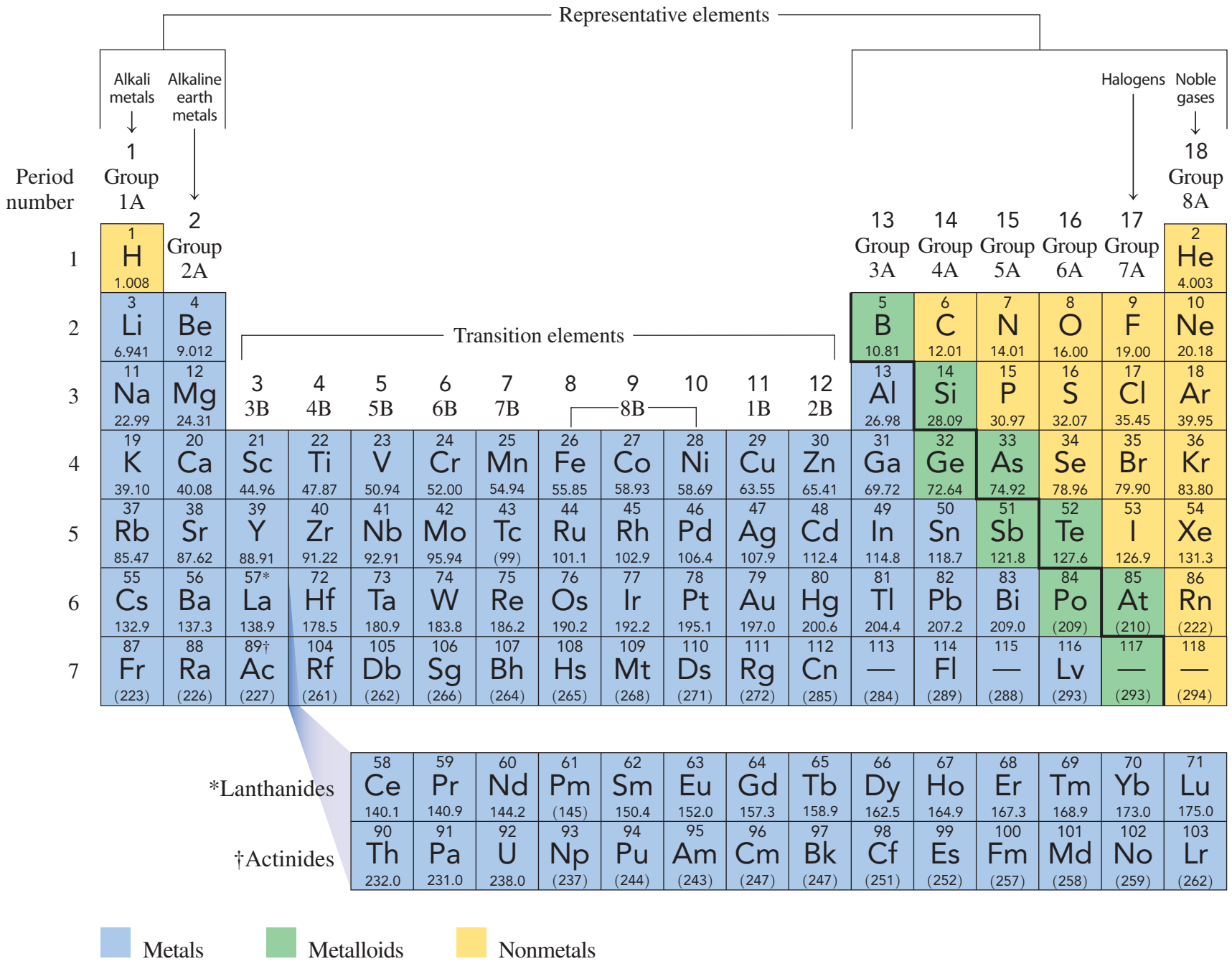
Periodic Table of Elements



ENGAGE

Why is sodium phosphate an ionic compound and diphosphorus pentoxide a molecular compound?

b. $NiSO_4$, consisting of a cation of a transition element and a polyatomic ion SO_4^{2-}, is an ionic compound. As a transition element, Ni forms more than one type of ion. In this formula, the 2− charge of SO_4^{2-} is balanced by one nickel ion, Ni^{2+}. In the name, a Roman numeral written after the metal name, nickel(II), specifies the 2+ charge. The anion SO_4^{2-} is a polyatomic ion named sulfate. The compound is named nickel(II) sulfate.

c. SO_3 consists of two nonmetals, which indicates that it is a molecular compound. The first element S is sulfur (no prefix is needed). The second element O, oxide, has subscript 3, which requires a prefix *tri* in the name. The compound is named sulfur trioxide.

STUDY CHECK 6.11

What is the name of $Fe(NO_3)_3$?

ANSWER

iron(III) nitrate

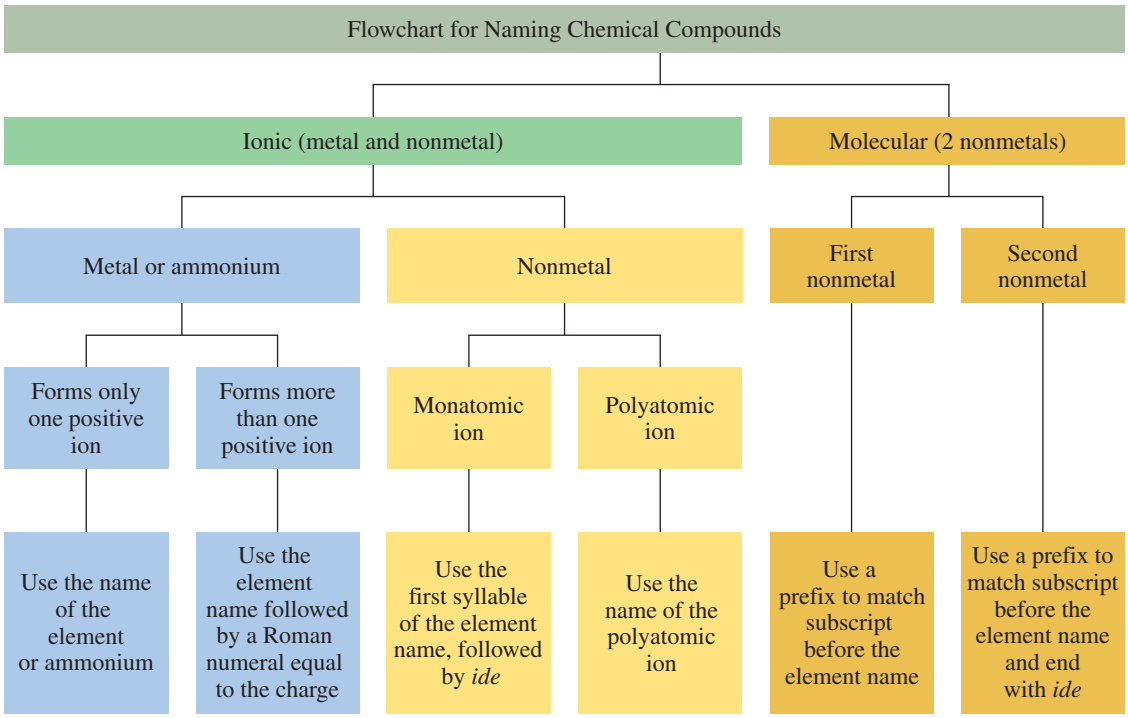


FIGURE 6.4 ▶ A flowchart illustrates naming for ionic and molecular compounds.

Why are the names of some metal ions followed by a Roman numeral in the name of a compound?

QUESTIONS AND PROBLEMS

6.5 Molecular Compounds: Sharing Electrons

LEARNING GOAL Given the formula of a molecular compound, write its correct name; given the name of a molecular compound, write its formula.

6.47 Name each of the following molecular compounds:

a. PBr_3 **b.** Cl_2O **c.** CBr_4
d. HF **e.** NF_3

6.48 Name each of the following molecular compounds:

a. CS_2 **b.** P_2O_5 **c.** SiO_2
d. PCl_3 **e.** CO

6.49 Name each of the following molecular compounds:

a. N_2O_3 **b.** Si_2Br_6 **c.** P_4S_3
d. PCl_5 **e.** SeF_6

6.50 Name each of the following molecular compounds:

a. SiF_4 **b.** IBr_3 **c.** CO_2
d. N_2F_2 **e.** N_2S_3

6.51 Write the formula for each of the following molecular compounds:

a. carbon tetrachloride **b.** carbon monoxide
c. phosphorus trichloride **d.** dinitrogen tetroxide

6.52 Write the formula for each of the following molecular compounds:
a. sulfur dioxide **b.** silicon tetrachloride
c. iodine trifluoride **d.** dinitrogen oxide

6.53 Write the formula for each of the following molecular compounds:
a. oxygen difluoride **b.** boron trichloride
c. dinitrogen trioxide **d.** sulfur hexafluoride

6.54 Write the formula for each of the following molecular compounds:
a. sulfur dibromide **b.** carbon disulfide
c. tetraphosphorus hexoxide **d.** dinitrogen pentoxide

Applications

6.55 Name each of the following ionic or molecular compounds:
a. $Al_2(SO_4)_3$, antiperspirant
b. $CaCO_3$, antacid
c. N_2O, "laughing gas," inhaled anesthetic
d. $Mg(OH)_2$, laxative

6.56 Name each of the following ionic or molecular compounds:
a. $Al(OH)_3$, antacid
b. $FeSO_4$, iron supplement in vitamins
c. NO, vasodilator
d. $Cu(OH)_2$, fungicide

Follow Up

COMPOUNDS AT THE PHARMACY

A few days ago, Richard went back to the pharmacy to pick up aspirin, $C_9H_8O_4$, and acetaminophen, $C_8H_9NO_2$. He also wanted to talk to Sarah about a way to treat his sore toe. Sarah recommended soaking his foot in a solution of Epsom salts, which is magnesium sulfate. Richard also asked Sarah to recommend an antacid for his upset stomach and an iron supplement. Sarah suggested an antacid that contains calcium carbonate and aluminum hydroxide, and iron(II) sulfate as an iron supplement. Richard also picked up toothpaste containing tin(II) fluoride, and carbonated water, which contains carbon dioxide.

Applications

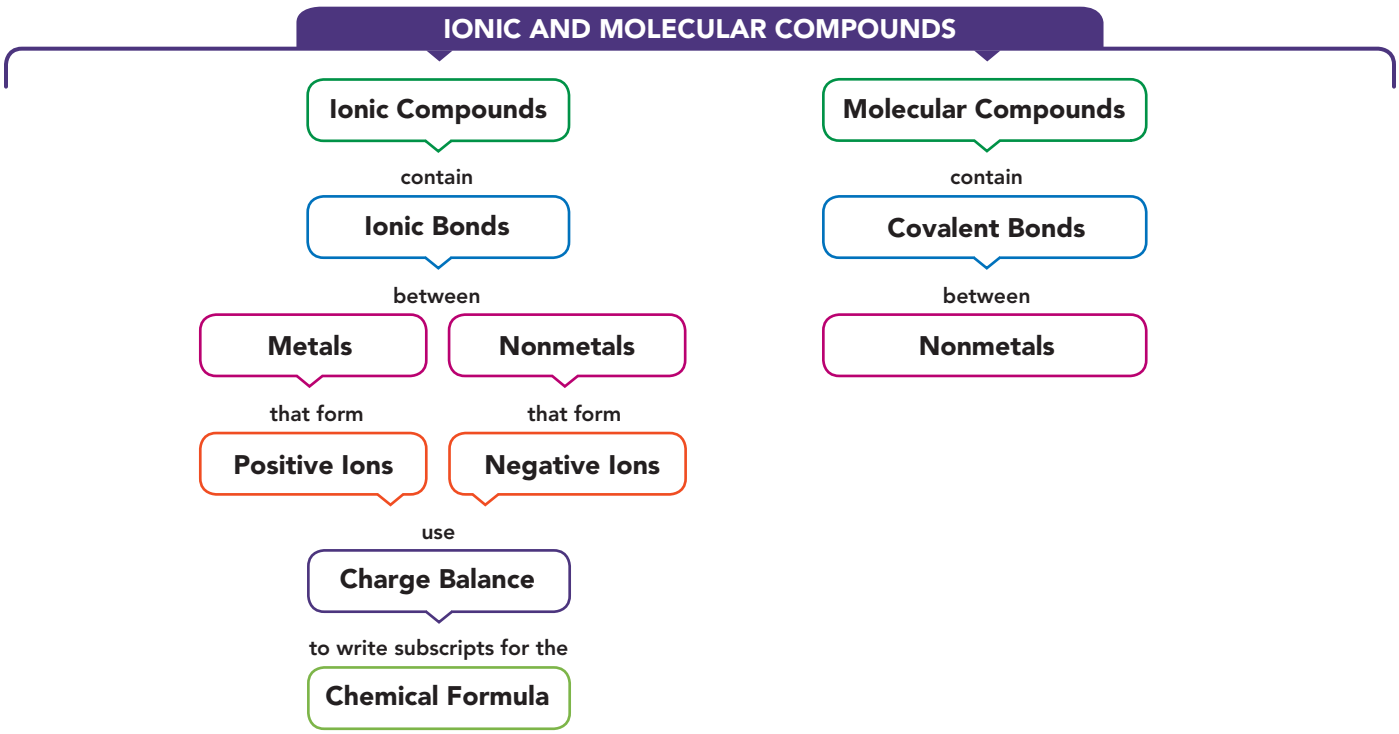
6.57 Write the chemical formula for each of the following:
a. magnesium sulfate **b.** tin(II) fluoride
c. aluminum hydroxide

6.58 Write the chemical formula for each of the following:
a. calcium carbonate **b.** carbon dioxide
c. iron(II) sulfate

6.59 Identify each of the compounds in problem 6.57 as ionic or molecular.

6.60 Identify each of the compounds in problem 6.58 as ionic or molecular.

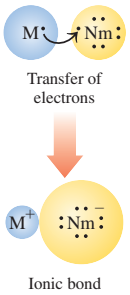
CONCEPT MAP



CHAPTER REVIEW

6.1 Ions: Transfer of Electrons

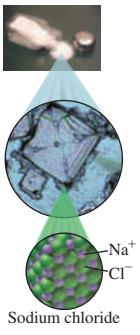
LEARNING GOAL Write the symbols for the simple ions of the representative elements.



- The stability of the noble gases is associated with a stable electron configuration in the outermost energy level.
- With the exception of helium, which has two electrons, noble gases have eight valence electrons, which is an octet.
- Atoms of elements in Groups 1A to 7A (1, 2, 13 to 17) achieve stability by losing, gaining, or sharing their valence electrons in the formation of compounds.
- Metals of the representative elements lose valence electrons to form positively charged ions (cations): Group 1A (1), 1+, Group 2A (2), 2+, and Group 3A (13), 3+.
- When reacting with metals, nonmetals gain electrons to form octets and form negatively charged ions (anions): Groups 5A (15), 3−, 6A (16), 2−, and 7A (17), 1−.

6.2 Ionic Compounds

LEARNING GOAL Using charge balance, write the correct formula for an ionic compound.

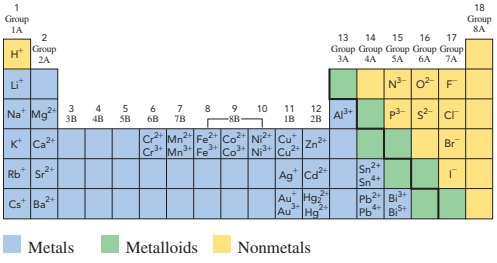


Sodium chloride

- The total positive and negative ionic charge is balanced in the formula of an ionic compound.
- Charge balance in a formula is achieved by using subscripts after each symbol so that the overall charge is zero.

6.3 Naming and Writing Ionic Formulas

LEARNING GOAL Given the formula of an ionic compound, write the correct name; given the name of an ionic compound, write the correct formula.



- In naming ionic compounds, the positive ion is given first followed by the name of the negative ion.
- The names of ionic compounds containing two elements end with *ide*.
- Except for Ag, Cd, and Zn, transition elements form cations with two or more ionic charges.
- The charge of the cation is determined from the total negative charge in the formula and included as a Roman numeral immediately following the name of the metal that has a variable charge.

6.4 Polyatomic Ions

LEARNING GOAL Write the name and formula for an ionic compound containing a polyatomic ion.


Ca^{2+} SO_4^{2-} Sulfate ion

- A polyatomic ion is a covalently bonded group of atoms with an electrical charge; for example, the carbonate ion has the formula CO_3^{2-}.
- Most polyatomic ions have names that end with *ate* or *ite*.
- Most polyatomic ions contain a nonmetal and one or more oxygen atoms.
- The ammonium ion, NH_4^+, is a positive polyatomic ion.
- When more than one polyatomic ion is used for charge balance, parentheses enclose the formula of the polyatomic ion.

6.5 Molecular Compounds: Sharing Electrons

LEARNING GOAL Given the formula of a molecular compound, write its correct name; given the name of a molecular compound, write its formula.

1	mono
2	di
3	tri
4	tetra
5	penta

- In a covalent bond, atoms of nonmetals share valence electrons such that each atom has a stable electron configuration.
- The first nonmetal in a molecular compound uses its element name; the second nonmetal uses the first syllable of its element name followed by *ide*.
- The name of a molecular compound with two different atoms uses prefixes to indicate the subscripts in the formula.

KEY TERMS

anion A negatively charged ion such as Cl^-, O^{2-}, or SO_4^{2-}.

cation A positively charged ion such as Na^+, Mg^{2+}, Al^{3+}, or NH_4^+.

chemical formula The group of symbols and subscripts that represents the atoms or ions in a compound.

covalent bond A sharing of valence electrons by atoms.

ion An atom or group of atoms having an electrical charge because of a loss or gain of electrons.

ionic charge The difference between the number of protons (positive) and the number of electrons (negative) written in the upper right corner of the symbol for the element or polyatomic ion.

ionic compound A compound of positive and negative ions held together by ionic bonds.

molecular compound A combination of atoms in which stable electron configurations are attained by sharing electrons.

molecule The smallest unit of two or more atoms held together by covalent bonds.

octet A set of eight valence electrons.

octet rule Elements in Groups 1A to 7A (1, 2, 13 to 17) react with other elements by forming ionic or covalent bonds to produce a stable electron configuration, usually eight electrons in the outer shell.

polyatomic ion A group of covalently bonded nonmetal atoms that has an overall electrical charge.

CORE CHEMISTRY SKILLS

The chapter section containing each Core Chemistry Skill is shown in parentheses at the end of each heading.

Writing Positive and Negative Ions (6.1)

- In the formation of an ionic bond, atoms of a metal lose and atoms of a nonmetal gain valence electrons to acquire a stable electron configuration, usually eight valence electrons.
- This tendency of atoms to attain a stable electron configuration is known as the octet rule.

Example: State the number of electrons lost or gained by atoms and the ion formed for each of the following to obtain a stable electron configuration:

a. Br **b.** Ca **c.** S

Answer: **a.** Br atoms gain one electron to achieve a stable electron configuration, Br^-.

b. Ca atoms lose two electrons to achieve a stable electron configuration, Ca^{2+}.

c. S atoms gain two electrons to achieve a stable electron configuration, S^{2-}.

Writing Ionic Formulas (6.2)

- The chemical formula of a compound represents the lowest whole-number ratio of the atoms or ions.
- In the chemical formula of an ionic compound, the sum of the positive and negative charges is always zero.
- Thus, in a chemical formula of an ionic compound, the total positive charge is equal to the total negative charge.

Example: Write the formula for magnesium phosphide.

Answer: Magnesium phosphide is an ionic compound that contains the ions Mg^{2+} and P^{3-}.

Using charge balance, we determine the number(s) of each type of ion.

$$3(2+) + 2(3-) = 0$$

$3Mg^{2+}$ and $2P^{3-}$ give the formula Mg_3P_2.

Naming Ionic Compounds (6.3)

- In the name of an ionic compound made up of two elements, the name of the metal ion, which is written first, is the same as its element name.
- For metals that form two or more ions, a Roman numeral that is equal to the ionic charge is placed in parentheses immediately after the name of the metal.
- The name of a nonmetal ion is obtained by using the first syllable of its element name followed by *ide*.

Example: What is the name of PbS?

Answer: This compound contains the S^{2-} ion which has a 2− charge.

For charge balance, the positive ion must have a charge of 2+.

$$Pb? + (2-) = 0; \quad Pb = 2+$$

Because lead can form two different positive ions, a Roman numeral (II) is used in the name of the compound: lead(II) sulfide.

Writing the Names and Formulas for Molecular Compounds (6.5)

- When naming a molecular compound, the first nonmetal in the formula is named by its element name; the second nonmetal is named using the first syllable of its element name followed by *ide*.
- When a subscript indicates two or more atoms of an element, a prefix is shown in front of its name.

Example: Name the molecular compound BrF_5.

Answer: Two nonmetals share electrons and form a molecular compound. Br (first nonmetal) is bromine; F (second nonmetal) is fluoride. In the name for a molecular compound, prefixes indicate the subscripts in the formulas. The subscript 1 is understood for Br. The subscript 5 for fluoride is written with the prefix *penta*. The name is bromine pentafluoride.

UNDERSTANDING THE CONCEPTS

The chapter sections to review are shown in parentheses at the end of each question.

6.61 **a.** Why does calcium form a Ca^{2+} ion instead of a Ca^+ ion? (6.1)

b. What is the electronic configuration of Ca^{2+}?

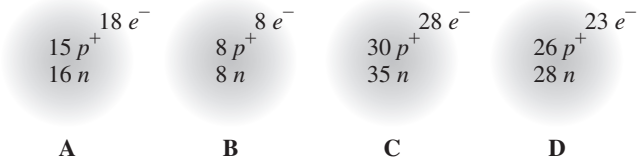
c. Which element has the same electronic configuration as Ca^{2+}?

6.62 **a.** Why does fluorine form an F^- ion instead of an F^+ ion? (6.1)

b. What is the electronic configuration of F^-?

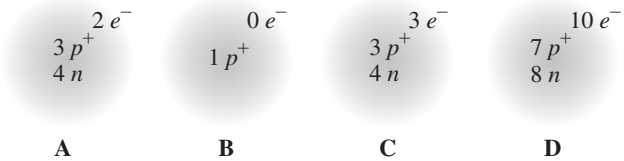
c. Which element has the same electronic configuration as F^-?

6.63 Identify each of the following atoms or ions: (6.1)



A **B** **C** **D**

6.64 Identify each of the following atoms or ions: (6.1)

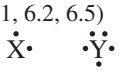


A **B** **C** **D**

6.65 Consider the following Lewis symbols for elements X and Y: (6.1, 6.2, 6.5)

a. What are the group numbers of X and Y?
b. Will a compound of X and Y be ionic or molecular?
c. What ions would be formed by X and Y?
d. What would be the formula of a compound of X and Y?
e. What would be the formula of a compound of X and sulfur?
f. What would be the formula of a compound of Y and chlorine?
g. Is the compound in part **f** ionic or molecular?

6.66 Consider the following Lewis symbols for elements X and Y: (6.1, 6.2, 6.5)



a. What are the group numbers of X and Y?
b. Will a compound of X and Y be ionic or molecular?
c. What ions would be formed by X and Y?
d. What would be the formula of a compound of X and Y?
e. What would be the formula of a compound of X and sulfur?
f. What would be the formula of a compound of Y and chlorine?
g. Is the compound in part **f** ionic or molecular?

6.67 Using each of the following electron configurations, give the formulas of the cation and anion that form, the formula for the compound they form, and its name. (6.2, 6.3)

Electron Configurations		Cation	Anion	Formula of Compound	Name of Compound
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	$1s^2 2s^2 2p^4$				
$1s^2 2s^1$	$1s^2 2s^2 2p^6 3s^2 3p^5$				
$1s^2 2s^2 2p^2$	$1s^2 2s^2 2p^6 3s^2 3p^4$				

6.68 Using each of the following electron configurations, give the formulas of the cation and anion that form, the formula for the compound they form, and its name. (6.2, 6.3)

Electron Configurations		Cation	Anion	Formula of Compound	Name of Compound
$1s^2 2s^2 2p^6 3s^2 3p^1$	$1s^2 2s^2 2p^5$				
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$	$1s^2 2s^2 2p^3$				
$1s^2 2s^2$	$1s^2 2s^2 2p^4$				

ADDITIONAL QUESTIONS AND PROBLEMS

6.69 Write the name for the following: (6.1)
a. N^{3-} **b.** Mg^{2+} **c.** O^{2-} **d.** Al^{3+}

6.70 Write the name for the following: (6.1)
a. K^+ **b.** Na^+ **c.** Ba^{2+} **d.** Cl^-

6.71 Consider an ion with the symbol X^{3+} and the electronic configuration $1s^2 2s^2 2p^6$. (6.1, 6.2, 6.3)
a. What is the group number of the element X?
b. What is the element X?
c. What is the Lewis symbol of this element?
d. What is the formula of the compound formed from X and phosphate?

6.72 Consider an ion with the symbol Z^- and the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$. (6.1, 6.2, 6.3)
a. What is the group number of the element Z?
b. What is the element Z?
c. What is the Lewis symbol of this element?
d. What is the formula of the compound formed from a nickel(II) ion and Z?

6.73 Rust consists of iron(III) oxide and some iron(III) hydroxide. (6.1, 6.2, 6.3, 6.4)
a. What is the symbol of iron(III) ion?
b. How many protons and electrons are there in this ion?
c. What is the formula of iron(III) oxide?
d. What is the formula of iron(III) hydroxide?

6.74 Some ionic compounds such as strontium carbonate and barium chlorate are used as colorant in fireworks. (6.1, 6.2, 6.3, 6.4)
a. What are the symbols of strontium and barium ions?
b. How many protons and electrons are there in a strontium ion?
c. What is the formula of strontium carbonate?
d. What is the formula of barium chlorate?

6.75 Write the formula for each of the following ionic compounds: (6.2, 6.3)
a. silver bromide **b.** calcium fluoride
c. aluminum sulfide **d.** calcium phosphate
e. iron (II) chloride **f.** magnesium nitride

6.76 Write the formula for each of the following ionic compounds: (6.2, 6.3)
a. nickel(III) oxide **b.** iron(III) sulfide
c. lead(II) sulfate **d.** chromium(III) iodide
e. lithium nitride **f.** gold(I) oxide

6.77 Name each of the following molecular compounds: (6.5)
a. SF_4 **b.** PH_3 **c.** BBr_3
d. PF_5 **e.** Cl_2O_7 **f.** P_2O_5

6.78 Name each of the following molecular compounds: (6.5)
a. B_2H_6 **b.** ClF_3 **c.** NO_2
d. CCl_4 **e.** PCl_3 **f.** N_2O_5

6.79 Write the formula for each of the following molecular compounds: (6.5)
a. carbon monoxide
b. phosphorous pentabromide
c. iodine heptafluoride
d. sulfur trioxide

6.80 Write the formula for each of the following molecular compounds: (6.5)
a. sulfur dibromide **b.** carbon dioxide
c. nitrogen trichloride **d.** sulfur tetrafluoride

6.81 Classify each of the following as ionic or molecular, and give its name: (6.3, 6.5)
a. Na_2CO_3 **b.** NH_3 **c.** $AlBr_3$
d. CS_2 **e.** BN **f.** Ca_3P_2

6.82 Classify each of the following as ionic or molecular, and give its name: (6.3, 6.5)
a. $Al_2(CO_3)_3$ **b.** ClF_5 **c.** BCl_3
d. Mg_3N_2 **e.** ClO_2 **f.** $CrPO_4$

6.83 Write the formula for each of the following: (6.3, 6.4, 6.5)
a. tin(II) carbonate **b.** lithium phosphide
c. silicon tetrachloride **d.** manganese(III) oxide
e. tetraphosphorus triselenide **f.** calcium bromide

6.84 Write the formula for each of the following: (6.3, 6.4, 6.5)
a. dinitrogen monoxide **b.** lithium carbonate
c. magnesium hydroxide **d.** sodium acetate

CHALLENGE QUESTIONS

The following groups of questions are related to the topics in this chapter. However, they do not all follow the chapter order, and they require you to combine concepts and skills from several sections. These questions will help you increase your critical thinking skills and prepare for your next exam.

6.85 Complete the following table for atoms or ions: (6.1)

Atom or Ion	Number of Protons	Number of Electrons	Electrons Lost/ Gained
K^+			
	12 p^+	10 e^-	
	8 p^+		2 e^- gained
		10 e^-	3 e^- lost

6.86 Complete the following table for atoms or ions: (6.1)

Atom or Ion	Number of Protons	Number of Electrons	Electrons Lost/ Gained
	30 p^+		2 e^- lost
	36 p^+	36 e^-	
	16 p^+		2 e^- gained
		46 e^-	4 e^- lost

6.87 X denotes elements in period 2. Identify X in each of the following ionic compounds: (6.2)
a. XNO_3 **b.** Al_2X_3 **c.** $X(HSO_4)_2$

6.88 X denotes elements in period 3. Identify X in each of the following ionic compounds: (6.2)
a. $XHCO_3$ **b.** Ba_3X_2 **c.** XPO_4

6.89 Classify each of the following as ionic or molecular, and name each: (6.2, 6.3, 6.4, 6.5)
a. Li_2HPO_4 **b.** ClF_3 **c.** $Mg(ClO_2)_2$
d. NF_3 **e.** $Ca(HSO_4)_2$ **f.** $KClO_4$
g. $Au_2(SO_3)_3$

6.90 Classify each of the following as ionic or molecular, and name each: (6.2, 6.3, 6.4, 6.5)
a. $FePO_3$ **b.** Cl_2O_7 **c.** $Ca_3(PO_4)_2$
d. PCl_3 **e.** $Al(ClO_2)_3$ **f.** $Pb(C_2H_3O_2)_2$
g. $MgCO_3$

ANSWERS

Answers to Selected Questions and Problems

6.1 **a.** 1 **b.** 2 **c.** 3 **d.** 1 **e.** 2

6.3 **a.** 2 e^- lost **b.** 3 e^- gained **c.** 1 e^- gained
d. 1 e^- lost **e.** 1 e^- gained

6.5 **a.** Li^+ **b.** F^- **c.** Mg^{2+} **d.** Fe^{3+}

6.7 **a.** 29 protons, 27 electrons **b.** 34 protons, 36 electrons
c. 35 protons, 36 electrons **d.** 26 protons, 23 electrons

6.9 **a.** Cl^- **b.** Cs^+ **c.** N^{3-} **d.** Ra^{2+}

6.11 **a.** lithium **b.** calcium
c. gallium **d.** phosphide

6.13 **a.** 8 protons, 10 electrons **b.** 19 protons, 18 electrons
c. 53 protons, 54 electrons **d.** 11 protons, 10 electrons

6.15 **a** and **c**

6.17 **a.** Na_2O **b.** $AlBr_3$ **c.** Ba_3N_2
d. MgF_2 **e.** Al_2S_3