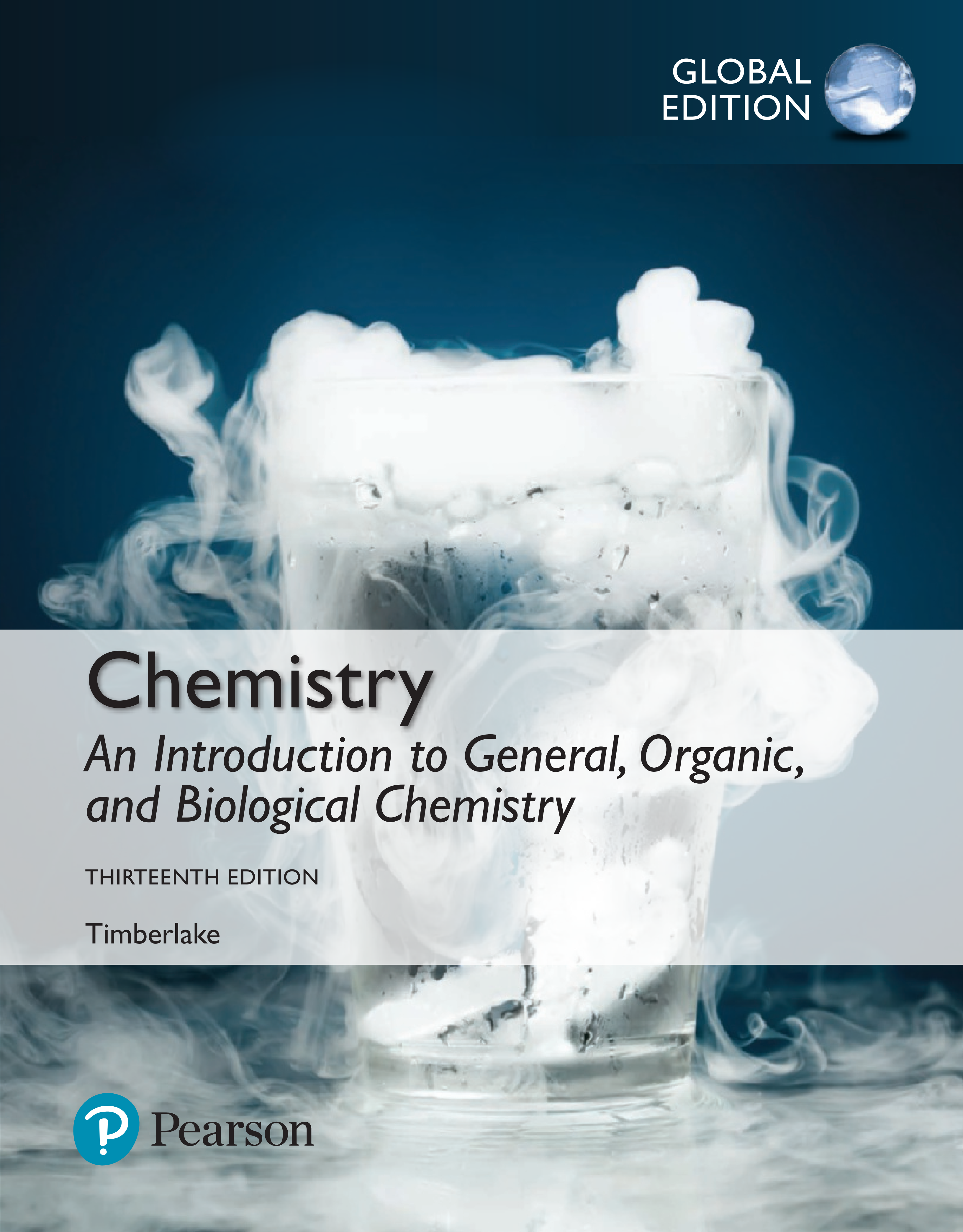

GLOBAL EDITION

Chemistry

An Introduction to General, Organic, and Biological Chemistry

THIRTEENTH EDITION

Timberlake

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CHEMISTRY

An Introduction to General, Organic, and Biological Chemistry

CORE CHEMISTRY SKILL

Writing the Names and Formulas for Molecular Compounds

Names and Formulas of Molecular Compounds

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. **TABLE 6.10** lists prefixes used in naming molecular compounds.

The names of molecular compounds need prefixes because several different compounds can be formed from the same two nonmetals. For example, carbon and oxygen can form two different compounds, carbon monoxide, CO, and carbon dioxide, CO_2, in which the number of atoms of oxygen in each compound is indicated by the prefixes *mono* or *di* in their names.

When the vowels *o* and *o* or *a* and *o* appear together, the first vowel is omitted, as in carbon monoxide. In the name of a molecular compound, the prefix *mono* is usually omitted, as in NO, nitrogen oxide. Traditionally, however, CO is named carbon monoxide. **TABLE 6.11** lists the formulas, names, and commercial uses of some molecular compounds.

TABLE 6.10 Prefixes Used in Naming Molecular Compounds

1	mono	6	hexa
2	di	7	hepta
3	tri	8	octa
4	tetra	9	nona
5	penta	10	deca

TABLE 6.11 Some Common Molecular Compounds

Formula	Name	Commercial Uses
CO_2	Carbon dioxide	Fire extinguishers, dry ice, propellant in aerosols, carbonation of beverages
CS_2	Carbon disulfide	Manufacture of rayon
N_2O	Dinitrogen oxide	Inhalation anesthetic, "laughing gas"
NO	Nitrogen oxide	Stabilizer, biochemical messenger in cells
SO_2	Sulfur dioxide	Preserving fruits, vegetables; disinfectant in breweries; bleaching textiles
SF_6	Sulfur hexafluoride	Electrical circuits
SO_3	Sulfur trioxide	Manufacture of explosives

ENGAGE

Why are prefixes used to name molecular compounds?

SAMPLE PROBLEM 6.9 Naming Molecular Compounds

TRY IT FIRST

Name the molecular compound NCl_3.

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	NCl_3	name	prefixes

STEP 1 **Name the first nonmetal by its element name.** In NCl_3, the first nonmetal (N) is nitrogen.

STEP 2 **Name the second nonmetal by using the first syllable of its element name followed by *ide*.** The second nonmetal (Cl) is named chloride.

STEP 3 **Add prefixes to indicate the number of atoms (subscripts).** Because there is one nitrogen atom, no prefix is needed. The subscript 3 for the Cl atoms is shown as the prefix *tri*. The name of NCl_3 is nitrogen trichloride.

STUDY CHECK 6.9

Name each of the following molecular compounds:

a. $SiBr_4$ **b.** Br_2O

ANSWER

a. silicon tetrabromide **b.** dibromine oxide

TEST

Try Practice Problems 6.47 to 6.50

Writing Formulas from the Names of Molecular Compounds

In the name of a molecular compound, the names of two nonmetals are given along with prefixes for the number of atoms of each. To write the formula from the name, we use the symbol for each element and a subscript if a prefix indicates two or more atoms.

SAMPLE PROBLEM 6.10 Writing Formulas for Molecular Compounds

TRY IT FIRST

Write the formula for the molecular compound diboron trioxide.

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	diboron trioxide	formula	subscripts from prefixes

STEP 1 Write the symbols in the order of the elements in the name.

Name of Element	Boron	Oxygen
Symbol of Element	B	O
Subscript	2 (di)	3 (tri)

STEP 2 Write any prefixes as subscripts. The prefix *di* in *di*boron indicates that there are two atoms of boron, shown as a subscript 2 in the formula. The prefix *tri* in *tri*oxide indicates that there are three atoms of oxygen, shown as a subscript 3 in the formula.

B_2O_3

STUDY CHECK 6.10

Write the formula for the molecular compound iodine pentafluoride.

ANSWER

IF_5

TEST

Try Practice Problems 6.51 to 6.54

Summary of Naming Ionic and Molecular Compounds

We have now examined strategies for naming ionic and molecular compounds. In general, compounds having two elements are named by stating the first element name followed by the name of the second element with an *ide* ending. If the first element is a metal, the compound is usually ionic; if the first element is a nonmetal, the compound is usually molecular. For ionic compounds, it is necessary to determine whether the metal can form more than one type of positive ion; if so, a Roman numeral following the name of the metal indicates the particular ionic charge. One exception is the ammonium ion, NH_4^+, which is also written first as a positively charged polyatomic ion. Ionic compounds having three or more elements include some type of polyatomic ion. They are named by ionic rules but have an *ate* or *ite* ending when the polyatomic ion has a negative charge.

In naming molecular compounds having two elements, prefixes are necessary to indicate two or more atoms of each nonmetal as shown in that particular formula (see **FIGURE 6.4**).

SAMPLE PROBLEM 6.11 Naming Ionic and Molecular Compounds

TRY IT FIRST

Identify each of the following compounds as ionic or molecular and give its name:

a. K_3P **b.** $NiSO_4$ **c.** SO_3

SOLUTION

a. K_3P, consisting of a metal and a nonmetal, is an ionic compound. As a representative element in Group 1A (1), K forms the potassium ion, K^+. Phosphorus, as a representative element in Group 5A (15), forms a phosphide ion, P^{3-}. Writing the name of the cation followed by the name of the anion gives the name potassium phosphide.

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

TEST

Try Practice Problems 6.55 and 6.56

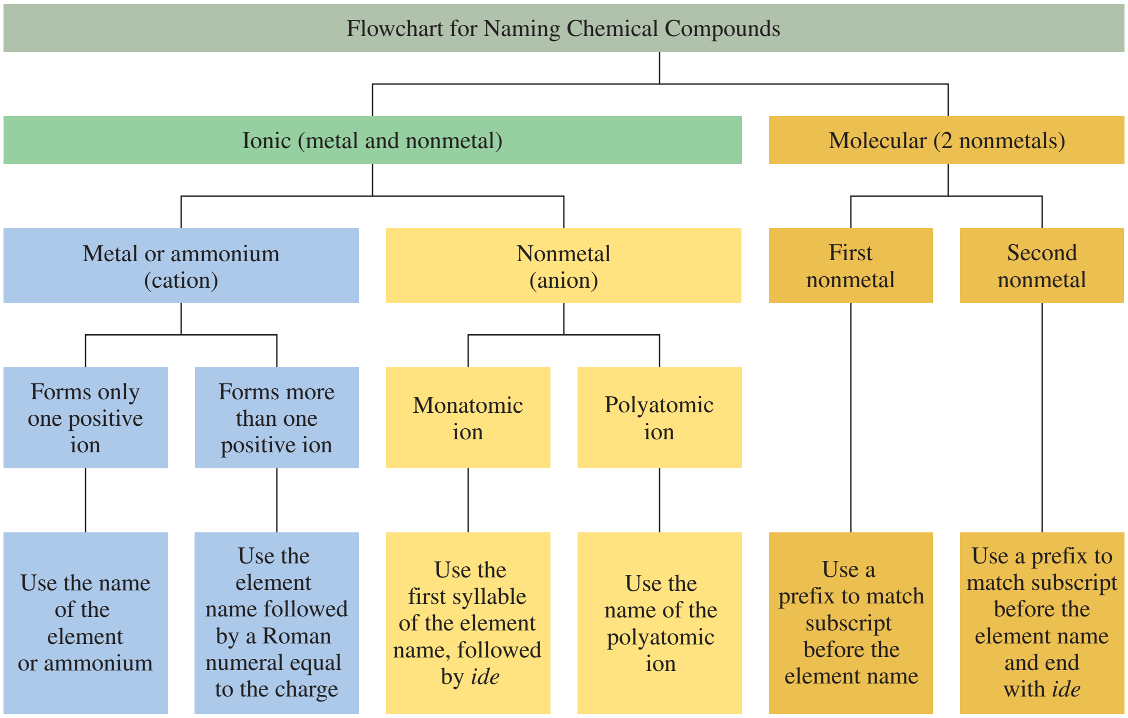


FIGURE 6.4 A flowchart illustrates naming for ionic and molecular compounds.

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

PRACTICE 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_2 **b.** Si_2Br_6 **c.** TiO_2 **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 trifluoride **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

Clinical 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

6.6 Lewis Structures for Molecules

REVIEW

Drawing Lewis Symbols (4.7)

LEARNING GOAL Draw the Lewis structures for molecular compounds with single and multiple bonds.

Now we can investigate more complex chemical bonds and how they contribute to the structure of a molecule. *Lewis structures* use Lewis symbols to diagram the sharing of valence electrons for single and multiple bonds in molecules.

Lewis Structure for the Hydrogen Molecule

The simplest molecule is hydrogen, H_2. When two H atoms are far apart, there is no attraction between them. As the H atoms move closer, the positive charge of each nucleus attracts the electron of the other atom. This attraction, which is greater than the repulsion between the valence electrons, pulls the H atoms closer until they share a pair of valence electrons (see **FIGURE 6.5**). The result is called a *covalent bond*, in which the shared electrons give the stable electron arrangement of He to *each* of the H atoms. When the H atoms form H_2, they are more stable than two individual H atoms.

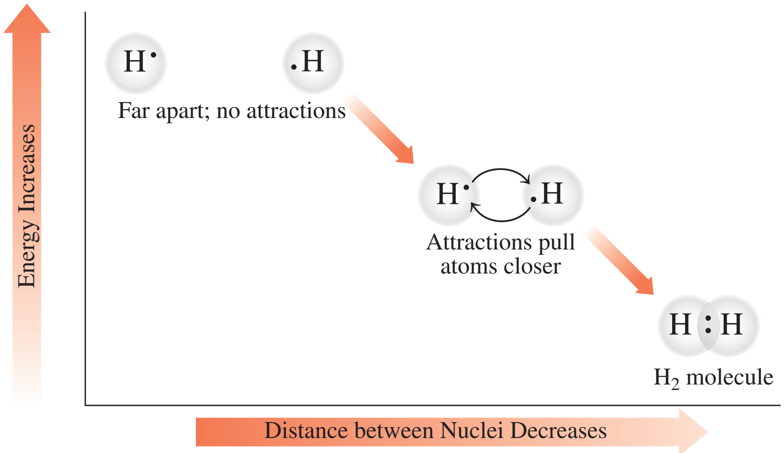
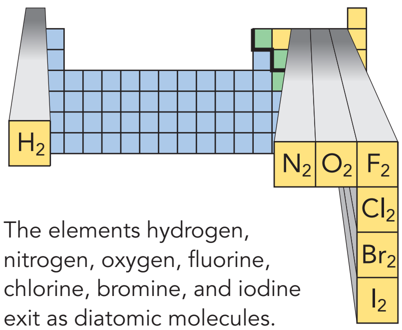


FIGURE 6.5 A covalent bond forms as H atoms move close together to share electrons.

What determines the attraction between two H atoms?

Lewis Structures for Molecular Compounds

A molecule is represented by a **Lewis structure** in which the valence electrons of all the atoms are arranged to give octets, except for hydrogen, which has two electrons. The shared electrons, or *bonding pairs*, are shown as two dots or a single line between atoms. The nonbonding pairs of electrons, or *lone pairs*, are placed on the outside. For example, a fluorine molecule, F_2, consists of two fluorine atoms, which are in Group 7A (17), each with seven

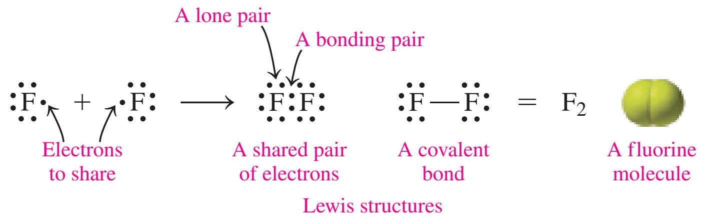


The elements hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, and iodine exit as diatomic molecules.

TABLE 6.12 Elements That Exist as Diatomic Molecules

Diatomic Molecule	Name
H_2	Hydrogen
N_2	Nitrogen
O_2	Oxygen
F_2	Fluorine
Cl_2	Chlorine
Br_2	Bromine
I_2	Iodine

valence electrons. In the Lewis structure for the F_2 molecule, each F atom achieves an octet by sharing its unpaired valence electron.



Hydrogen (H_2) and fluorine (F_2) are examples of nonmetal elements whose natural state is diatomic; that is, they contain two like atoms. The elements that exist as diatomic molecules are listed in **TABLE 6.12**.

Drawing Lewis Structures

The number of electrons that a nonmetal atom shares and the number of covalent bonds it forms are usually equal to the number of electrons it needs to achieve a stable electron arrangement.

To draw the Lewis structure for CH_4, we first draw the Lewis symbols for carbon and hydrogen.

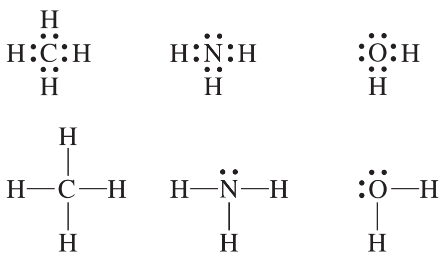
Then we determine the number of valence electrons needed for carbon and hydrogen. When a carbon atom shares its four electrons with four hydrogen atoms, carbon obtains an octet and each hydrogen atom is complete with two shared electrons. The Lewis structure is drawn with the carbon atom as the central atom, with the hydrogen atoms on each of the sides. The bonding pairs of electrons, which are single covalent bonds, may also be shown as single lines between the carbon atom and each of the hydrogen atoms.

TABLE 6.13 gives examples of Lewis structures and molecular models for some molecules.

TABLE 6.13 Lewis Structures for Some Molecular Compounds

CH_4	NH_3	H_2O

Lewis Structures



Molecular Models

Methane molecule   Ammonia molecule   Water molecule

CORE CHEMISTRY SKILL
Drawing Lewis Structures

SAMPLE PROBLEM 6.12 Drawing Lewis Structures

TRY IT FIRST

Draw the Lewis structure for PCl_3, phosphorus trichloride, used commercially to prepare insecticides and flame retardants.

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	PCl_3	Lewis structure	total valence electrons

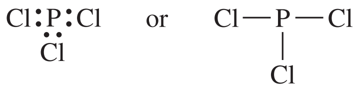
STEP 1 **Determine the arrangement of atoms.** In PCl_3, the central atom is P because there is only one P atom.

Cl P Cl
Cl

STEP 2 **Determine the total number of valence electrons.** We use the group number to determine the number of valence electrons for each of the atoms in the molecule.

Element	Group	Atoms		Valence Electrons	=	Total
P	5A (15)	1 P	×	5 e^-	=	5 e^-
Cl	7A (17)	3 Cl	×	7 e^-	=	21 e^-
		Total valence electrons for PCl_3			=	26 e^-

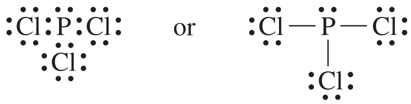
STEP 3 **Attach each bonded atom to the central atom with a pair of electrons.** Each bonding pair can also be represented by a bond line.



Six electrons (3 × 2 e^-) are used to bond the central P atom to three Cl atoms. Twenty valence electrons are left.

26 valence e^- − 6 bonding e^- = 20 e^- remaining

STEP 4 **Use the remaining electrons to complete octets.** We use the remaining 20 electrons as lone pairs, which are placed around the outer Cl atoms and on the P atom, such that all the atoms have octets.



STUDY CHECK 6.12

Draw the Lewis structure for Cl_2O.

ANSWER

TEST

Try Practice Problems 6.57 and 6.58

Double and Triple Bonds

Up to now, we have looked at bonding in molecules having only single bonds. In many molecular compounds, atoms share two or three pairs of electrons to complete their octets. Double and triple bonds form when the number of valence electrons is not enough to complete the octets of all the atoms in the molecule. Then one or more lone pairs of electrons from the atoms attached to the central atom are shared with the central atom. A **double bond** occurs when two pairs of electrons are shared; in a **triple bond**, three pairs of electrons are shared. Atoms of carbon, oxygen, nitrogen, and sulfur are most likely to form multiple bonds.

Atoms of hydrogen and the halogens do not form double or triple bonds. The process of drawing a Lewis structure with multiple bonds is shown in Sample Problem 6.13.

SAMPLE PROBLEM 6.13 Drawing Lewis Structures with Multiple Bonds

TRY IT FIRST

Draw the Lewis structure for carbon dioxide, CO_2, in which the central atom is C.

SOLUTION GUIDE

ANALYZE THE PROBLEM	Given	Need	Connect
	CO_2	Lewis structure	total valence electrons

STEP 1 **Determine the arrangement of atoms.** O C O