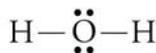


## Chapter 3 Chemical Compounds

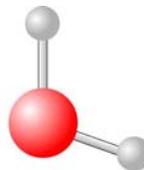
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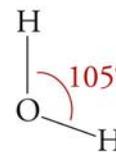
Lewis structure



Space-filling model



Ball-and-stick model



Geometric Sketch

### ◆ Review Skills

#### 3.1 Classification of Matter

#### 3.2 Compounds and Chemical Bonds

- Equal and Unequal Sharing of Electrons
- Transfer of Electrons
- Summary of Covalent and Ionic Bond Formation
- Predicting Bond Type
- Classifying Compounds

#### 3.3 Molecular Compounds

- Molecular Shape
- Liquid Water

#### ***Special Topic 3.1: Molecular Shapes, Intoxicating Liquids, and the Brain***

[Internet: The Structure of Water](#)

#### 3.4 Naming Binary Covalent Compounds

- Memorized Names
- Systematic Names
- Converting Names of Binary Covalent Compounds to Formulas

[Internet: Binary Covalent Nomenclature](#)

### 3.5 Ionic Compounds

- Cations and Anions
- Predicting Ion Charges
- Naming Monatomic Anions and Cations

[Internet: Cation Nomenclature](#)

[Internet: Anion Nomenclature](#)

- Structure of Ionic Compounds
- Polyatomic Ions

[Internet: Oxyanions](#)

- Converting Formulas to Names
- Converting Names of Ionic Compounds to Formulas

[Internet: Ionic Nomenclature](#)

### ◆ Chapter Glossary

[Internet: Glossary Quiz](#)

### ◆ Chapter Objectives

Review Questions

Key Ideas

Chapter Problems

## Section Goals and Introductions

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The Review Skills section for this chapter is very important. Because students are so busy, it's always a battle to keep up, but if you don't keep up in chemistry, you're in real trouble. For this reason, the Review Skills section at the beginning of each chapter tells you what you really need to know (or be able to do) from earlier chapters to understand the chapter you are about to read. They are very important; don't just skip over them.

### Section 3.1 Classification of Matter

*Goal: To show how forms of matter can be classified as elements, compounds, and mixtures.*

This section begins the process of teaching you how to classify matter into the categories of element, compound, and mixture. The distinctions among these categories will become increasingly clear as you study this chapter and Chapter 4. This section also describes how compounds are represented by chemical formulas.

### Section 3.2 Compounds and Chemical Bonds

*Goals*

- *To show how atoms of different elements form links (chemical bonds) between them and to introduce three types of chemical bonding: nonpolar covalent, polar covalent, and ionic.*
- *To show how you can predict whether a pair of atoms will form a covalent bond or an ionic bond.*
- *To show how you can predict whether a chemical formula for a compound represents an ionic compound or a molecular compound.*

We can now take what you have learned about elements in Chapter 2 and expand on it to explain the formation of chemical bonds and chemical compounds. Be sure that you understand the similarities and differences among nonpolar covalent bonds, covalent bonds, and ionic bonds. The most important skills to develop from studying this section are (1) the ability to predict whether atoms of two elements would be expected to form an ionic bond or a covalent bond and (2) the ability to predict whether a chemical formula for a compound represents an ionic compound or a molecular compound. The ability to make these predictions is extremely important for many of the tasks in this chapter and in the chapters that follow.

### Section 3.3 Molecular Compounds

*Goals*

- *To explain the bonding patterns of the nonmetallic elements.*
- *To introduce the concept of molecules, to show how they form, to show how they are described, and to show how the atoms in some molecules are arranged in space.*
- *To describe the structure of liquid water.*

This section begins to describe the formation of molecules, which are collections of atoms held together by covalent bonds. You will find that much of what is introduced here is explained in much more detail in Chapter 12. From this section, you want to gain some understanding of why atoms of the nonmetallic elements form the covalent bonds that they do. Knowing the most common bonding patterns of these atoms (Table 3.1) will help you to predict how nonmetallic atoms combine to form molecules and will help you to draw Lewis

structures that represent these molecules. You will learn how the Lewis structures can be used to predict the geometric arrangement of atoms in molecules.

It is very important that you know the structure of each water molecule and how this affects the nature of liquid water. To understand the process of forming water solutions described in Chapter 4, you need to have a good mental image of the structure of liquid water. The following animation on our Web site will help:

[Internet: The Structure of Water](#)

### Section 3.4 Naming Binary Covalent Compounds

*Goal: To show how to convert between names and formulas for binary covalent compounds.*

This section begins the process of describing how to convert between names and formulas for compounds. How important this is depends on whether or not you are going to take more chemistry classes. For example, if you are going on to take general college chemistry, it's very important that you master this skill. It's much less important if the course for which you are using this text is the last chemistry course you plan to take. Be sure to ask your instructor how much weight will be given to this topic on your exams. There is a tutorial on our Web site that provides practice converting between names and formulas for binary covalent compounds:

[Internet: Binary Covalent Nomenclature](#)

### Section 3.5 Ionic Compounds

*Goals*

- *To show why some atoms gain or lose electrons to form charged particles called ions.*
- *To show how the charges on ions can be predicted.*
- *To describe the structure of ionic solids.*
- *To describe polyatomic ions, which are charged collections of atoms held together by covalent bonds.*

This section is an important one. It provides more detailed information about ions than that found in Chapter 2, including how to predict their charges, how to convert between their names and symbols, and how they combine to form ionic compounds. Our Web site provides a tutorial that provides practice converting between names and formulas for monatomic ions:

[Internet: Cation Nomenclature](#)

[Internet: Anion Nomenclature](#)

All of this information is used extensively in the rest of the book. The section also includes a description of the structure of ionic solids.

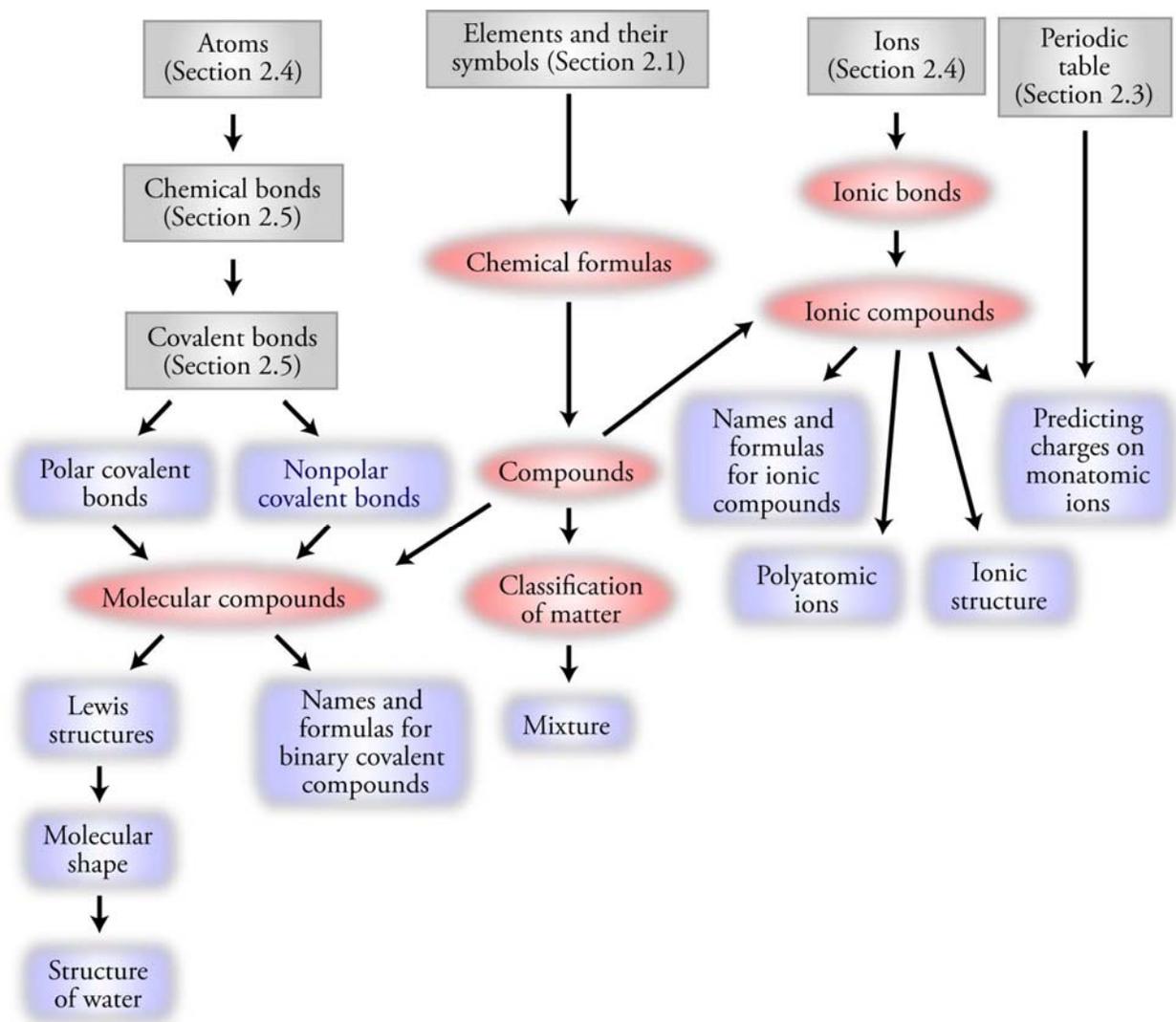
Polyatomic ions (charged collections of atoms held together by covalent bonds) are also described. Your instructor may want to expand on the list of polyatomic ions that you are expected to know. The text assumes that you can convert between the names and symbols for those that are found in Table 3.6. The following section on our Web site gives you a more complete description of polyatomic ions.

[Internet: Oxyanions](#)

The conversion between names and formulas for ionic compounds is described. Be sure to ask your instructor how much weight will be given to this topic on your exams. Our Web site has a tutorial that provides practice converting between names and formulas for ionic compounds:

[Internet: Ionic Nomenclature](#)

## Chapter 3 Map



## Chapter Checklist

- Read the Review Skills section. If there is any skill mentioned that you have not yet mastered, review the material on that topic before reading this chapter.
- Read the chapter quickly before the lecture that describes it.
- Attend class meetings, take notes, and participate in class discussions.
- Work the Chapter Exercises, perhaps using the Chapter Examples as guides.
- Study the Chapter Glossary and test yourself on our Web site:  
[\*Internet: Glossary Quiz\*](#)
- Study all of the Chapter Objectives. You might want to write a description of how you will meet each objective. (Although it is best to master all of the objectives, the following

objectives are especially important because they pertain to skills that you will need while studying other chapters of this text: 3, 4, 8, 9, 13-16, 21-28, 30, 31, 34, 35, and 37.)

- Reread *Sample Study Sheet 3.1: Classification of Matter* and decide whether you will use it or some variation on it to complete the task it describes.
- Memorize the following. (Be sure to check with your instructor to determine how much you are expected to know of the following.)
  - The usual numbers of covalent bonds and lone pairs for the nonmetallic elements.

Group 4A		Group 5A		Group 6A		Group 7A	
4 valence electrons $\cdot\ddot{X}\cdot$		5 valence electrons $\cdot\ddot{X}\cdot$		6 valence electrons $\cdot\ddot{X}\cdot$		7 valence electrons $\cdot\ddot{X}\cdot$	
4 bonds	No lone pairs	3 bonds	1 lone pair	2 bonds	2 lone pairs	1 bond	3 lone pairs
carbon – C $\begin{array}{c}   \\ -\text{C}- \\   \end{array}$		nitrogen – N $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{N}}- \\   \end{array}$		oxygen – O $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{O}}- \\ \cdot\cdot \end{array}$		fluorine – F $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{F}}\cdot \\ \cdot\cdot \end{array}$	
		phosphorus – P $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{P}}- \\   \end{array}$		sulfur – S $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{S}}- \\ \cdot\cdot \end{array}$		chlorine – Cl $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{Cl}}\cdot \\ \cdot\cdot \end{array}$	
				selenium – Se $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{Se}}- \\ \cdot\cdot \end{array}$		bromine – Br $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{Br}}\cdot \\ \cdot\cdot \end{array}$	
						iodine – I $\begin{array}{c} \cdot\cdot \\ -\ddot{\text{I}}\cdot \\ \cdot\cdot \end{array}$	

- Names and formulas of some binary covalent compounds.

Name	Formula	Name	Formula
water	H <sub>2</sub> O	methane	CH <sub>4</sub>
ammonia	NH <sub>3</sub>	ethane	C <sub>2</sub> H <sub>6</sub>
		propane	C <sub>3</sub> H <sub>8</sub>

- Prefixes

Number of atoms	Prefix	Number of atoms	Prefix
1	mon(o)-	6	hex(a)-
2	di-	7	hept(a)-
3	tri-	8	oct(a)-
4	tetr(a)-	9	non(a)-
5	pent(a)-	10	dec(a)-

- Roots of nonmetallic elements

Element	Root	Element	Root	Element	Root	Element	Root
C	carb-	N	nitr-	O	ox-	F	fluor-
		P	phosph-	S	sulf-	Cl	chlor-
		As	arsen-	Se	selen-	Br	brom-
						I	iod-

- Charges on monatomic ions

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li <sup>+</sup>	Be <sup>2+</sup>													N <sup>3-</sup>	O <sup>2-</sup>	F <sup>-</sup>	
Na <sup>+</sup>	Mg <sup>2+</sup>	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	Al <sup>3+</sup>		P <sup>3-</sup>	S <sup>2-</sup>	Cl <sup>-</sup>	
K <sup>+</sup>	Ca <sup>2+</sup>	Sc <sup>3+</sup>					Fe <sup>2+</sup> Fe <sup>3+</sup>			Cu <sup>+</sup> Cu <sup>2+</sup>	Zn <sup>2+</sup>				Se <sup>2-</sup>	Br <sup>-</sup>	
Rb <sup>+</sup>	Sr <sup>2+</sup>	Y <sup>3+</sup>								Ag <sup>+</sup>	Cd <sup>2+</sup>					I <sup>-</sup>	
Cs <sup>+</sup>	Ba <sup>2+</sup>																
Fr <sup>+</sup>	Ra <sup>2+</sup>																

- Names and formulas for polyatomic ions

Ion	Name	Ion	Name	Ion	Name
NH <sub>4</sub> <sup>+</sup>	ammonium	PO <sub>4</sub> <sup>3-</sup>	phosphate	SO <sub>4</sub> <sup>2-</sup>	sulfate
OH <sup>-</sup>	hydroxide	NO <sub>3</sub> <sup>-</sup>	nitrate	C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	acetate
CO <sub>3</sub> <sup>2-</sup>	carbonate				

- To get a review of the most important topics in the chapter, fill in the blanks in the Key Ideas section.
- Work all of the selected problems at the end of the chapter, and check your answers with the solutions provided in this chapter of the study guide.
- Ask for help if you need it.

## Web Resources

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[Internet: The Structure of Water](#)

[Internet: Binary Covalent Nomenclature](#)

[Internet: Cation Nomenclature](#)

[Internet: Anion Nomenclature](#)

[Internet: Oxyanions](#)

[Internet: Ionic Nomenclature](#)

[Internet: Glossary Quiz](#)

## Exercises Key

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**Exercise 3.1 - Classification of Matter:** The label on a container of double-acting baking powder tells us that it contains cornstarch, bicarbonate of soda (also called sodium hydrogen carbonate,  $\text{NaHCO}_3$ ), sodium aluminum sulfate, and acid phosphate of calcium (which chemists call calcium dihydrogen phosphate,  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ). Classify each of the following as a pure substance or a mixture. If it is a pure substance, is it an element or a compound?

*(Obj 3 & 4)*

- a. calcium **element**
- b. calcium dihydrogen phosphate **compound**
- c. double-acting baking powder **mixture**

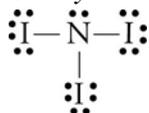
**Exercise 3.2 - Classifying Compounds:** Classify each of the following substances as either a molecular compound or an ionic compound. *(Obj 9)*

- a. formaldehyde,  $\text{CH}_2\text{O}$  (used in embalming fluids)  
**all nonmetal atoms - molecular**
- b. magnesium chloride,  $\text{MgCl}_2$  (used in fireproofing wood and in paper manufacturing)  
**metal-nonmetal - ionic**

**Exercise 3.3 - Drawing Lewis Structures from Formulas:** Draw a Lewis structure for each of the following formulas: (Obj 14)

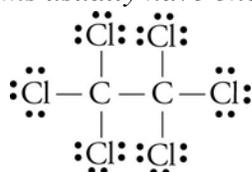
- a. nitrogen triiodide,  $\text{NI}_3$  (explodes at the slightest touch)

*Nitrogen atoms usually have three covalent bonds and one lone pair, and iodine atoms usually have one covalent bond and three lone pairs.*



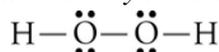
- b. hexachloroethane,  $\text{C}_2\text{Cl}_6$  (used to make explosives)

*Carbon atoms usually have four covalent bonds and no lone pairs, and chlorine atoms usually have one covalent bond and three lone pairs.*



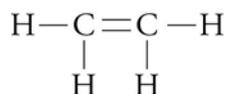
- c. hydrogen peroxide,  $\text{H}_2\text{O}_2$  (a common antiseptic)

*Hydrogen atoms always have one covalent bond and no lone pairs, and oxygen atoms usually have two covalent bonds and two lone pairs.*



- d. ethylene (or ethene),  $\text{C}_2\text{H}_4$  (used to make polyethylene)

*Carbon atoms form four bonds with no lone pairs, and hydrogen atoms form one bond with no lone pairs. To achieve these bonding patterns, there must be a double bond between the carbon atoms.*



**Exercise 3.4 - Naming Binary Covalent Compounds:** Write names that correspond to the following formulas: (Obj 21)

- a.  $\text{P}_2\text{O}_5$       **diphosphorus pentoxide**  
 b.  $\text{PCl}_3$       **phosphorus trichloride**  
 c.  $\text{CO}$       **carbon monoxide**  
 d.  $\text{H}_2\text{S}$       **dihydrogen monosulfide or hydrogen sulfide**  
 e.  $\text{NH}_3$       **ammonia**

**Exercise 3.5 - Writing Formulas for Binary Covalent Compounds:** Write formulas that correspond to the following names: (Obj 21)

- a. disulfur decafluoride       **$\text{S}_2\text{F}_{10}$**   
 b. nitrogen trifluoride       **$\text{NF}_3$**   
 c. propane       **$\text{C}_3\text{H}_8$**   
 d. hydrogen chloride       **$\text{HCl}$**

**Exercise 3.6 - Naming Monatomic Ions:** Write names that correspond to the following formulas for monatomic ions: (Obj 24)

- a.  $\text{Mg}^{2+}$  **magnesium ion**                      c.  $\text{Sn}^{2+}$  **tin(II) ion**  
 b.  $\text{F}^{-}$  **fluoride ion**

**Exercise 3.7 - Formulas for Monatomic Ions:** Write formulas that correspond to the following names for monatomic ions: (Obj 24)

- a. bromide ion  **$\text{Br}^{-}$**                                       c. gold(I) ion  **$\text{Au}^{+}$**   
 b. aluminum ion  **$\text{Al}^{3+}$**

**Exercise 3.8 - Naming Ionic Compounds:** Write the names that correspond to the following formulas: (Obj 30)

- a.  $\text{LiCl}$  **lithium chloride**  
 b.  $\text{Cr}_2(\text{SO}_4)_3$  **chromium(III) sulfate**  
 c.  $\text{NH}_4\text{HCO}_3$  **ammonium hydrogen carbonate**

**Exercise 3.9 - Formulas for Ionic Compounds:** Write the formulas that correspond to the following names: (Obj 30)

- a. aluminum oxide  **$\text{Al}_2\text{O}_3$**   
 b. cobalt(III) fluoride  **$\text{CoF}_3$**   
 c. iron(II) sulfate  **$\text{FeSO}_4$**   
 d. ammonium hydrogen phosphate  **$(\text{NH}_4)_2\text{HPO}_4$**   
 e. potassium bicarbonate  **$\text{KHCO}_3$**

## Review Questions Key

Write in each blank the word or words that best complete each sentence.

- An atom or group of atoms that has lost or gained one or more electrons to create a charged particle is called a(n) **ion**.
- An atom or collection of atoms with an overall positive charge is a(n) **cation**.
- An atom or collection of atoms with an overall negative charge is a(n) **anion**.
- A(n) **covalent** bond is a link between atoms that results from the sharing of two electrons.
- A(n) **molecule** is an uncharged collection of atoms held together with covalent bonds.
- A molecule such as  $\text{H}_2$ , which is composed of two atoms, is called **diatomic**.
- Describe the particle nature of solids, liquids, and gases. Your description should include the motion of the particles and the attractions between the particles.

*See Figures 2.1, 2.2, and 2.4 in the textbook.*

- Describe the nuclear model of the atom.

*Protons and neutrons are in a tiny core of the atom called the nucleus, which has a diameter about 1/100,000 the diameter of the atom. The position and motion of the electrons are uncertain, but they generate a negative charge that is felt in the space that surrounds the nucleus.*

9. Describe the hydrogen molecule,  $H_2$ . Your description should include the nature of the link between the hydrogen atoms and a sketch that shows the two electrons in the molecule.

*The hydrogen atoms are held together by a covalent bond formed due to the sharing of two electrons. See the image of  $H_2$  in Figure 2.13 in the textbook.*

10. Complete the following table.

Element name	Element symbol	Group number on periodic table	Metal, nonmetal, or metalloid?
<b>lithium</b>	Li	<b>1 or 1A</b>	<b>metal</b>
carbon	<b>C</b>	<b>14 or 4A</b>	<b>nonmetal</b>
<b>chlorine</b>	Cl	<b>17 or 7A</b>	<b>nonmetal</b>
oxygen	<b>O</b>	<b>16 or 6A</b>	<b>nonmetal</b>
<b>copper</b>	Cu	<b>11 or 1B</b>	<b>metal</b>
calcium	<b>Ca</b>	<b>2 or 2A</b>	<b>metal</b>
<b>scandium</b>	Sc	<b>3 or 3B</b>	<b>metal</b>

11. Write the name of the group to which each of the following belongs.

- |             |                    |              |                              |
|-------------|--------------------|--------------|------------------------------|
| a. chlorine | <b>halogens</b>    | c. sodium    | <b>alkali metals</b>         |
| b. xenon    | <b>noble gases</b> | d. magnesium | <b>alkaline earth metals</b> |

## Key Ideas Answers

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12. A compound is a substance that contains two or more elements, the atoms of those elements always combining in the same **whole-number ratio**.
14. A chemical formula is a concise written description of the components of a chemical compound. It identifies the elements in the compound by their **symbols** and indicates the relative number of atoms of each element with **subscripts**.
16. Mixtures are samples of matter that contain two or more pure substances and have **variable** composition.
18. Because particles with opposite charges attract each other, there is an attraction between **cations** and **anions**. This attraction is called an ionic bond.
20. The atom in a chemical bond that attracts electrons more strongly acquires a **negative** charge, and the other atom acquires a **positive** charge. If the electron transfer is significant but not enough to form ions, the atoms acquire **partial negative** and **partial positive** charges. The bond in this situation is called a polar covalent bond.
22. When a metallic atom bonds to a nonmetallic atom, the bond is **usually ionic**.
24. The noble gases (group 8A) have an **octet** of electrons (except for helium, which has only two electrons total), and they are so stable that they rarely form chemical bonds with other atoms.

26. The sum of the numbers of covalent bonds and lone pairs for the most common bonding patterns of the atoms of nitrogen, phosphorus, oxygen, sulfur, selenium, and the halogens is **four**.
28. Lewis structures are useful for showing how the atoms in a molecule are connected by covalent bonds, but they do not always give a clear description of how the atoms are **arranged in space**.
30. A space-filling model provides the most accurate representation of the **electron-charge clouds** for the atoms in  $\text{CH}_4$ .
32. As in other liquids, the attractions between water molecules are strong enough to keep them the **same average distance apart** but weak enough to allow each molecule to be **constantly breaking** the attractions that momentarily connect it to some molecules and **forming new attractions** to other molecules.
34. You can recognize binary covalent compounds from their formulas, which contain symbols for only two **nonmetallic** elements.
36. Nonmetallic atoms form anions to get the same number of electrons as the nearest **noble gas**.
38. When atoms gain electrons and form anions, they get **larger**. When atoms lose electrons and form cations, they get significantly **smaller**.
40. It is common for hydrogen atoms to be transferred from one ion or molecule to another ion or molecule. When this happens, the hydrogen atom is usually transferred without its electron, as  $\text{H}^+$ .

## Problems Key

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### Section 3.1 Classification of Matter

42. Classify each of the following as a pure substance or a mixture. If it is a pure substance, is it an element or a compound? Explain your answer. (*Obj's 3 & 4*)
  - a. apple juice  
**mixture** – *variable composition*
  - b. potassium (A serving of one brand of apple juice provides 6% of the recommended daily allowance of potassium.)  
**element and pure substance** – *The symbol K is on the periodic table of the elements. All elements are pure substances.*
  - c. ascorbic acid (vitamin C),  $\text{C}_6\text{H}_8\text{O}_6$ , in apple juice  
*The formula shows the constant composition, so ascorbic acid is a **pure substance**. The three element symbols in the formula indicate a **compound**.*

44. Write the chemical formula for each of the following compounds. List the symbols for the elements in the order that the elements are mentioned in the description.

- a. a compound with molecules that consist of two nitrogen atoms and three oxygen atoms.



- b. a compound with molecules that consist of one sulfur atom and four fluorine atoms.



- c. a compound that contains one aluminum atom for every three chlorine atoms.

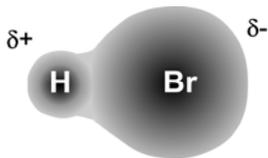


- d. a compound that contains two lithium atoms and one carbon atom for every three oxygen atoms.



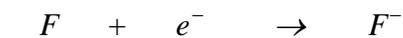
### Section 3.2 Chemical Compounds and Chemical Bonds

46. Hydrogen bromide, HBr, is used to make pharmaceuticals that require bromine in their structure. Each hydrogen bromide molecule has one hydrogen atom bonded to one bromine atom by a polar covalent bond. The bromine atom attracts electrons more than does the hydrogen atom. Draw a rough sketch of the electron-cloud that represents the electrons involved in the bond. (Obj 5)



48. Atoms of potassium and fluorine form ions and ionic bonds in a very similar way to atoms of sodium and chlorine. Each atom of one of these elements loses one electron, and each atom of the other element gains one electron. Describe the process that leads to the formation of the ionic bond between potassium and fluorine atoms in potassium fluoride. Your answer should include mention of the charges that form on the atoms. (Obj 6)

*The metallic potassium atoms lose one electron and form +1 cations, and the nonmetallic fluorine atoms gain one electron and form -1 anions.*



*The ionic bonds are the attractions between  $\text{K}^+$  cations and  $\text{F}^-$  anions.*

50. Explain how a nonpolar covalent bond, a polar covalent bond, and an ionic bond differ. Your description should include rough sketches of the electron clouds that represent the electrons involved in the formation of each bond. (Obj 7)

*See Figure 3.6 in the textbook.*

52. Would you expect the bonds between the following atoms to be ionic or covalent bonds?

(Obj 8)

a. N–O     **covalent...nonmetal-nonmetal**

b. Al–Cl     **ionic...metal-nonmetal**

54. Classify each of the following as either a molecular compound or an ionic compound.

(Obj 9)

a. acetone,  $\text{CH}_3\text{COCH}_3$  (a common paint solvent)

*all nonmetallic atoms - molecular*

b. sodium sulfide,  $\text{Na}_2\text{S}$  (used in sheep dips)     *metal-nonmetal - ionic*

### Section 3.3 Molecular Compounds

56. How many valence electrons does each atom of the following elements have? (Obj 10)

a. Cl     **7** (in group 7A)

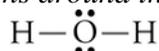
b. C     **4** (in group 4A)

58. Draw electron-dot symbols for each of the following elements and use them to explain why each element has the bonding pattern listed in Table 3.1 in the textbook. (Obj 11)

*Each of the following answers is based on the assumption that nonmetallic atoms tend to form covalent bonds in order to get an octet (8) of electrons around each atom, like the very stable noble gases (other than helium). Covalent bonds (represented by lines in Lewis structures) and lone pairs each contribute two electrons to the octet.*

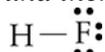
a. oxygen

$\cdot\ddot{\text{O}}\cdot$      *If oxygen atoms form two covalent bonds, they will have an octet of electrons around them. Water is an example:*



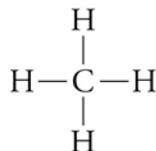
b. fluorine

$\cdot\ddot{\text{F}}\cdot$      *If fluorine atoms form one covalent bond, they will have an octet of electrons around them. Hydrogen fluoride, HF, is an example:*



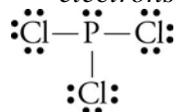
c. carbon

$\cdot\ddot{\text{C}}\cdot$      *If carbon atoms form four covalent bonds, they will have an octet of electrons around them. Methane,  $\text{CH}_4$ , is an example:*

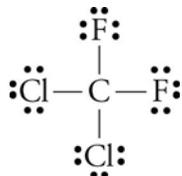


d. phosphorus

$\cdot\ddot{\text{P}}\cdot$      *If phosphorus atoms form three covalent bonds, they will have an octet of electrons around them. Phosphorus trichloride,  $\text{PCl}_3$ , is an example:*



60. The following Lewis structure is for CFC-12, which is one of the ozone-depleting chemicals that has been used as an aerosol can propellant and as a refrigerant. Describe the information given in this Lewis structure. (*Obj 12*)



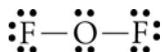
*The molecule contains a carbon atom, two chlorine atoms, and two fluorine atoms. There are two covalent C–Cl bonds and two covalent C–F bonds. The Cl and F atoms have three lone pairs each.*

62. Write the most common number of covalent bonds and lone pairs for atoms of each of the following nonmetallic elements. (*Obj 13*)
- H            **1 bond, no lone pairs**
  - Iodine      **1 bond, 3 lone pairs**
  - sulfur       **2 bonds, 2 lone pairs**
  - N            **3 bonds, 1 lone pair**

64. Draw a Lewis structure for each of the following formulas. (*Obj 16*)

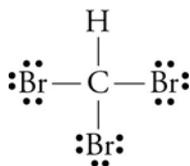
- a. oxygen difluoride, OF<sub>2</sub> (an unstable, colorless gas)

*Oxygen atoms usually have two covalent bonds and two lone pairs, and fluorine atoms have one covalent bond and three lone pairs.*



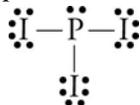
- b. bromoform, CHBr<sub>3</sub> (used as a sedative)

*Carbon atoms usually have four covalent bonds and no lone pairs, hydrogen atoms always have one covalent bond and no lone pairs, and bromine atoms usually have one covalent bond and three lone pairs. The hydrogen atom can be put in any of the four positions.*



- c. phosphorus triiodide, PI<sub>3</sub> (used to make organic compounds)

*Phosphorus atoms usually have three covalent bonds and one lone pair, and iodine atoms usually have one covalent bond and three lone pairs. The lone pair can be placed in any one of the four positions around the phosphorus atom.*

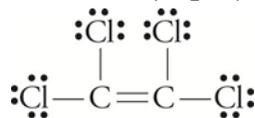


66. Draw Lewis structures for the following compounds by adding any necessary lines and dots to the skeletons given. (*Obj 16*)

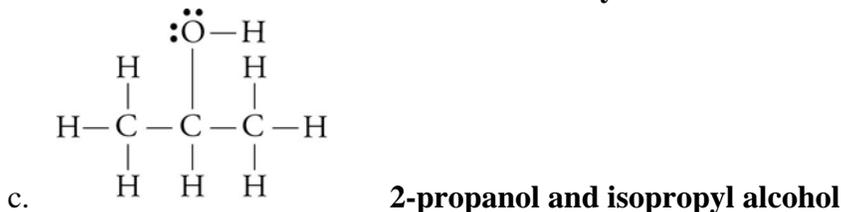
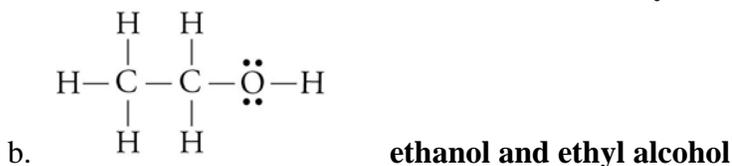
- a. hydrogen cyanide, HCN (used to manufacture dyes and pesticides)



- b. dichloroethene,  $C_2Cl_4$  (used to make perfumes)



68. Write two different names for each of the following alcohols. (Obj's 14 & 15)



70. Compare and contrast the information given in the Lewis structure, the space-filling model, the ball-and-stick model, and the geometric sketch of a methane molecule,  $CH_4$ . (Obj's 19 & 20)

See Figure 3.10 in the textbook. The Lewis structure shows the four covalent bonds between the carbon atoms and the hydrogen atoms. The space-filling model provides the most accurate representation of the electron-charge clouds for the atoms in  $CH_4$ . The ball-and-stick model emphasizes the molecule's correct molecular shape and shows the covalent bonds more clearly. Each ball represents an atom, and each stick represents a covalent bond between two atoms. The geometric sketch shows the three-dimensional tetrahedral structures with a two-dimensional drawing. Picture the hydrogen atoms connected to the central carbon atom with solid lines as being in the same plane as the carbon atom. The hydrogen atom connected to the central carbon with a solid wedge comes out of the plane toward you. The hydrogen atom connected to the carbon atom by a dashed wedge is located back behind the plane of the page.

72. Compare and contrast the information given in the Lewis structure, the space-filling model, the ball-and-stick model, and the geometric sketch of a water molecule,  $H_2O$ . (Obj's 19 & 20)

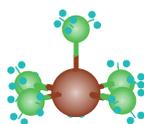
See Figure 3.12 in the textbook. The Lewis structure shows the two O–H covalent bonds and the two lone pairs on the oxygen atom. The space-filling model provides the most accurate representation of the electron-charge clouds for the atoms and the bonding electrons. The ball-and-stick model emphasizes the molecule's correct molecular shape and shows the covalent bonds more clearly. The geometric sketch shows the structure with a two-dimensional drawing.

74. Describe the structure of liquid water. (*Obj 22*)

*Water is composed of  $H_2O$  molecules, which have attractions between the partially positive hydrogen atom of one molecule and the partially negative oxygen atom of the other molecule. See Figure 3.13 in the textbook. Each water molecule is moving constantly, breaking the attractions to some molecules, and making new attractions to other molecules. See Figure 3.14 in the textbook.*

### Section 3.4 Naming Binary Covalent Compounds

76. The compound represented by the ball-and-stick model that follows is used in the processing of nuclear fuels. Although bromine atoms most commonly form one covalent bond, they can form five bonds, as in the molecule shown here, in which the central sphere represents a bromine atom. The other atoms are fluorine atoms. Write this compound's chemical formula and name. List the bromine atom first in the chemical formula. (*Obj 28*)



**$BrF_5$  – bromine pentafluoride**

78. The compound represented by the space-filling model that follows is used to vulcanize rubber and harden softwoods. Write its chemical formula and name. The central ball represents a sulfur atom, and the other atoms are chlorine atoms. List the sulfur atom first in the chemical formula. (*Obj 28*)



**$SCl_2$  – sulfur dichloride**

80. Write the name for each of the following chemical formulas. (*Obj 28*)

- |   |   |
|---|---|
| a. $I_2O_5$ (an oxidizing agent)                    | <b>diiodine pentoxide</b>                       |
| b. $BrF_3$ (adds fluorine atoms to other compounds) | <b>bromine trifluoride</b>                      |
| c. $IBr$ (used in organic synthesis)                | <b>iodine monobromide</b>                       |
| d. $CH_4$ (a primary component of natural gas)      | <b>methane</b>                                  |
| e. $HBr$ (used to make pharmaceuticals)             | <b>hydrogen bromide or hydrogen monobromide</b> |

82. Write the chemical formula for each of the following names. (*Obj 28*)

- |   |                            |
|---|----------------------------|
| a. propane (a fuel in heating torches)                          | <b><math>C_3H_8</math></b> |
| b. chlorine monofluoride (a fluorinating agent)                 | <b><math>ClF</math></b>    |
| c. tetraphosphorus heptasulfide (a dangerous fire risk)         | <b><math>P_4S_7</math></b> |
| d. carbon tetrabromide (used to make organic compounds)         | <b><math>CBr_4</math></b>  |
| e. hydrogen fluoride (an additive to liquid rocket propellants) | <b><math>HF</math></b>     |

## Section 3.5 Ionic Compounds

84. Explain why metals usually combine with nonmetals to form ionic bonds. (Obj 29)

*Because metallic atoms hold some of their electrons relatively loosely, they tend to lose electrons and form cations. Because nonmetallic atoms attract electrons more strongly than metallic atoms, they tend to gain electrons and form anions. Thus, when a metallic atom and a nonmetallic atom combine, the nonmetallic atom often pulls one or more electrons far enough away from the metallic atom to form ions and an ionic bond.*

85. How many protons and electrons do each of the following ions have?

- a.  $\text{Be}^{2+}$       **4 protons and 2 electrons**  
 b.  $\text{S}^{2-}$       **16 protons and 18 electrons**

87. Write the name for each of these monatomic ions. (Obj 31)

- |                     |                         |                     |                                    |
|---------------------|-------------------------|---------------------|------------------------------------|
| a. $\text{Ca}^{2+}$ | <b>calcium ion</b>      | e. $\text{Ag}^+$    | <b>silver ion or silver(I) ion</b> |
| b. $\text{Li}^+$    | <b>lithium ion</b>      | f. $\text{Sc}^{3+}$ | <b>scandium ion</b>                |
| c. $\text{Cr}^{2+}$ | <b>chromium(II) ion</b> | g. $\text{P}^{3-}$  | <b>phosphide ion</b>               |
| d. $\text{F}^-$     | <b>fluoride ion</b>     | h. $\text{Pb}^{2+}$ | <b>lead(II) ion</b>                |

89. Write the formula for each of these monatomic ions. (Obj 30 & 31)

- |                  |                                    |                       |                                    |
|------------------|------------------------------------|-----------------------|------------------------------------|
| a. magnesium ion | <b><math>\text{Mg}^{2+}</math></b> | e. scandium ion       | <b><math>\text{Sc}^{3+}</math></b> |
| b. sodium ion    | <b><math>\text{Na}^+</math></b>    | f. nitride ion        | <b><math>\text{N}^{3-}</math></b>  |
| c. sulfide ion   | <b><math>\text{S}^{2-}</math></b>  | g. manganese(III) ion | <b><math>\text{Mn}^{3+}</math></b> |
| d. iron(III) ion | <b><math>\text{Fe}^{3+}</math></b> | h. zinc ion           | <b><math>\text{Zn}^{2+}</math></b> |

91. Silver bromide, AgBr, is the compound on black and white film that causes the color change when the film is exposed to light. It has a structure similar to that of sodium chloride. What are the particles that form the basic structure of silver bromide? What type of attraction holds these particles together? Draw a rough sketch of the structure of solid silver bromide. (Obj 32)

*The metallic silver atoms form cations, and the nonmetallic bromine atoms form anions. The anions and cations alternate in the ionic solid with each cation surrounded by six anions and each anion surrounded by six cations. See Figure 3.18 in the textbook, picturing  $\text{Ag}^+$  ions in the place of the  $\text{Na}^+$  ions and  $\text{Br}^-$  in the place of the  $\text{Cl}^-$  ions.*

93. Write the name for each of these polyatomic ions. (Obj 34 & 35)

- |                                       |                 |                     |                         |
|---------------------------------------|-----------------|---------------------|-------------------------|
| a. $\text{NH}_4^+$                    | <b>ammonium</b> | c. $\text{HSO}_4^-$ | <b>hydrogen sulfate</b> |
| b. $\text{C}_2\text{H}_3\text{O}_2^-$ | <b>acetate</b>  |                     |                         |

95. Write the formula for each of these polyatomic ions. (Obj 34-36)

- |                    |                                    |                         |                                    |
|--------------------|------------------------------------|-------------------------|------------------------------------|
| a. ammonium        | <b><math>\text{NH}_4^+</math></b>  | c. hydrogen sulfate ion | <b><math>\text{HSO}_4^-</math></b> |
| b. bicarbonate ion | <b><math>\text{HCO}_3^-</math></b> |                         |                                    |

96. Write the name for each of these chemical formulas. (Obj 37)

- |   |                                     |
|---|-------------------------------------|
| a. $\text{Na}_2\text{O}$ (a dehydrating agent)                      | <b>sodium oxide</b>                 |
| b. $\text{Ni}_2\text{O}_3$ (in storage batteries)                   | <b>nickel(III) oxide</b>            |
| c. $\text{Pb}(\text{NO}_3)_2$ (in matches and explosives)           | <b>lead(II) nitrate</b>             |
| d. $\text{Ba}(\text{OH})_2$ (an analytical reagent)                 | <b>barium hydroxide</b>             |
| e. $\text{KHCO}_3$ (in baking powder and fire-extinguishing agents) | <b>potassium hydrogen carbonate</b> |

98. Write the chemical formula for each of the following names. (*Obj 37*)

- a. potassium sulfide (a depilatory) **K<sub>2</sub>S**
- b. zinc phosphide (a rodenticide) **Zn<sub>3</sub>P<sub>2</sub>**
- c. nickel(II) chloride (used in nickel electroplating) **NiCl<sub>2</sub>**
- d. magnesium dihydrogen phosphate (used in fireproofing wood) **Mg(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>**
- e. lithium bicarbonate (in mineral waters) **LiHCO<sub>3</sub>**

100. The ionic compounds CuF<sub>2</sub>, NH<sub>4</sub>Cl, CdO, and HgSO<sub>4</sub> are all used to make batteries. Write the name for each of these compounds. (*Obj 37*)

**copper(II) fluoride (CuF<sub>2</sub>), ammonium chloride (NH<sub>4</sub>Cl), cadmium oxide (CdO), and mercury(II) sulfate (HgSO<sub>4</sub>)**

102. The ionic compounds copper(II) chloride, lithium nitrate, and cadmium sulfide are all used to make fireworks. Write the chemical formulas for these compounds. (*Obj 37*)

**copper(II) chloride (CuCl<sub>2</sub>), lithium nitrate (LiNO<sub>3</sub>), and cadmium sulfide (CdS)**