



A VISUAL TOUR THROUGH THE FEATURES OF THE TEXT

Many pedagogical tools are interwoven throughout the chapters to guide students on their learning journey.

Chapter Openers

Each chapter begins with a thought-provoking *opener figure and legend* that relate to the main topic of the chapter. The chapter opening page also contains the *Chapter Outline* that shows the sequence of topics and subtopics, and the final paragraph of the introduction, called *In This Chapter*, ties the main topics to the outline. In the margin next to the introduction, *Concepts and Skills to Review* refers to key material from earlier chapters that you should understand before you start reading the current one.





Atmospheric Excitement Charged particles (electrons and positive ions) in the solar wind collide with and excite atoms in the atmosphere, which then relax and emit the glorious light of an aurora. As you'll see in this chapter, TV screens and neon signs work by the same principle.

Quantum Theory and Atomic Structure

<p>7.1 The Nature of Light Wave Nature of Light Particle Nature of Light</p> <p>7.2 Atomic Spectra Bohr Model of the Hydrogen Atom Energy States of the Hydrogen Atom</p>	<p>7.3 The Wave-Particle Duality of Matter and Energy Wave Nature of Electrons and Particles Nature of Photons Heisenberg Uncertainty Principle</p>	<p>7.4 The Quantum-Mechanical Model of the Atom The Atomic Orbital Quantum Numbers Shapes of Atomic Orbitals The Special Case of the Hydrogen Atom</p>
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Over a few remarkable decades—from around 1850 to 1950—a revolution took place as how we view the makeup of the universe. • But revolutions in science are not the violent upheavals of political overthrows. Rather, flaws appear in an established model as conflicting evidence mounts, a startling discovery or two widens the flaws into cracks, and the conceptual structure crumbles gradually from its inconsistencies. New insight, verified by experiment, then guides the building of a model more consistent with reality. So it was when Lavoisier's theory of combustion superseded the phlogiston model; when Dalton's atomic theory established the idea of individual units of matter, and when Rutherford's nuclear model substituted atoms with rich internal structure for "billiard balls" or "plum puddings." In this chapter, you will see this process unfold again with the development of modern atomic theory.

Almost as soon as Rutherford proposed his nuclear model, a major problem arose. A nucleus and an electron attract each other, so if they are to remain apart, the energy of the electron's motion (kinetic energy) must balance the energy of attraction (potential energy). However, the laws of classical physics had established that a negative particle moving in a curved path around a positive one must emit radiation and thus lose energy. If this requirement applied to atoms, why didn't the orbiting electron lose energy continuously and spiral into the nucleus? Clearly, if electrons behaved the way classical physics predicted, all atoms would have collapsed eons ago! The behavior of subatomic matter seemed to violate real-world experience and accepted principles.

The breakthroughs that soon followed Rutherford's model forced a complete rethinking of the classical picture of matter and energy. In the macroscopic world, the two are distinct. Matter occurs in chunks you can hold and weigh, and you can change the amount of matter in a sample piece by piece. In contrast, energy is "massless," and its quantity changes in a continuous manner. Matter moves in specific paths, whereas light and other types of energy travel in diffuse waves. As soon as 20th-century scientists probed the subatomic world, however, these clear distinctions between particulate matter and wavelike energy began to fade.

IN THIS CHAPTER . . . We discuss quantum mechanics, the theory that explains our current picture of atomic structure. We consider the wave properties of energy and then examine the theories and experiments that led to a quantized, or particulate, model of light. We see why the light emitted by excited hydrogen (H) atoms—the atomic spectrum—suggests an atom with distinct energy levels, and we look briefly at how atomic spectra are applied to chemical analysis. Wave-particle duality, which reveals two faces of matter and of energy, leads us to the current model of the H atom and the quantum numbers that identify the regions of space an electron occupies in an atom. In Chapter 8, we'll consider atoms that have more than one electron and relate electron number and distribution to chemical behavior.

7.1 THE NATURE OF LIGHT

Visible light is one type of **electromagnetic radiation** (also called **electromagnetic energy** or **radiant energy**). Other familiar types include x-rays, microwaves, and radio waves. All electromagnetic radiation consists of energy propagated by means of electric and magnetic fields that alternately increase and decrease in intensity as they move through space. This classical wave model distinguishes clearly between waves and particles; it is essential for understanding why rainbows form, how magnifying glasses work, why objects look distorted under water, and many other everyday observations. But it cannot explain observations on the atomic scale because, as you'll shortly, in that unfamiliar realm, energy behaves as though it consists of particles!

Concepts & Skills to Review before you study this chapter

- discovery of the electron and atomic structure (Section 2.4)
- major features of atomic structure (Section 2.5)
- changes in energy state of a system (Section 4.1)

History for the Human Mind The invention of the car, radio, and airplane (invented a feeling of estimated human ability and the discovery of x-rays, radioactivity, the electron, and the atomic nucleus led to the sense that the human mind would soon unravel all of nature's mysteries. In fact, some people were convinced that few, if any, mysteries remained.

1855 Röntgen discovers x-rays.
1869 Mendeleev discovers radioactivity.
1897 Thomson discovers the electron.
1898 Curie discovers radium.
1900 Planck proposes theory of the quantum.
1900 Planck develops quantum theory.
1901 Maxwell invents the radio.
1903 Wright brothers fly an airplane.
1905 Einstein publishes special relativity.
1905 Einstein publishes relativity and photon theory.
1906 S. Davis develops modern dance.
1906 Mies van der Rohe develops modern art.
1907 Schrodinger and Heisenberg develop quantum mechanics.
1911 Rutherford presents nuclear model.
1913 Bohr proposes atomic model.
1914 to 1918 World War I is fought.
1923 Compton demonstrates photon momentum.
1924 De Broglie publishes wave theory of matter.
1926 Schrodinger develops wave equation.
1927 Heisenberg presents uncertainty principle.
1932 Chadwick discovers the neutron.

Problem Solving

A worked-out *sample problem* appears whenever an important new concept or skill is introduced, and the problem-solving approach helps you think through all problems logically and systematically. The stepwise approach, based on the universally accepted four-step approach of plan, solve, check, and practice, is used consistently for every sample problem in the text. These steps are as follows:

- **Plan:** analyzes the problem so that you can use what is known to find what is unknown. This step develops the habit of thinking through the solution before performing calculations. Most quantitative problems are accompanied in the margin by a *roadmap*, a flow diagram that leads you visually through the planned steps for each specific problem.
- **Solution:** presents the calculation steps *in the same order* as they are discussed in the plan and shown in the roadmap.
- **Check:** fosters the habit of going over your work with a rough calculation to make sure the answer is both chemically and mathematically reasonable—a great way to avoid careless errors. In many cases, following the check is a *Comment* that provides an additional insight, alternative approach, or common mistake to avoid.
- **Follow-up Problem:** presents a similar problem to provide immediate practice, with an abbreviated multistep solution appearing at the end of the chapter.

In this edition, in addition to sample problems involving only calculations, a large number of **molecular-scene sample problems** utilize depictions of chemical species to solve quantitative problems.

SAMPLE PROBLEM 3.16 Calculating Mass of Solute in a Given Volume of Solution

PROBLEM A buffered solution maintains acidity as a reaction occurs. In living cells, phosphate ions play a key buffering role, so biochemists often study reactions in such solutions. How many grams of solute are in 1.75 L of 0.460 M sodium hydrogen phosphate?

PLAN We know the solution volume (1.75 L) and molarity (0.460 M), and we need the mass of solute. We use the known quantities to find the amount (mol) of solute and then convert moles to grams with the solute molar mass, as shown in the roadmap.

SOLUTION Calculating moles of solute in solution:

$$\text{Moles of Na}_2\text{HPO}_4 = 1.75 \text{ L-soln} \times \frac{0.460 \text{ mol Na}_2\text{HPO}_4}{1 \text{ L-soln}} = 0.805 \text{ mol Na}_2\text{HPO}_4$$

Converting from moles of solute to grams:

$$\text{Mass (g) Na}_2\text{HPO}_4 = 0.805 \text{ mol Na}_2\text{HPO}_4 \times \frac{141.96 \text{ g Na}_2\text{HPO}_4}{1 \text{ mol Na}_2\text{HPO}_4} = 114 \text{ g Na}_2\text{HPO}_4$$

CHECK The answer seems to be correct: ~1.8 L of 0.5 mol/L contains 0.9 mol, and 150 g/mol \times 0.9 mol = 135 g, which is close to 114 g of solute.

FOLLOW-UP PROBLEM 3.16 In biochemistry laboratories, solutions of sucrose (table sugar, C₁₂H₂₂O₁₁) are used in high-speed centrifuges to separate the parts of a biological cell. How many liters of 3.30 M sucrose contain 135 g of solute?

SAMPLE PROBLEM 3.18 Visualizing Changes in Concentration

PROBLEM The top circle at right represents a unit volume of a solution. Draw a circle representing a unit volume of the solution after each of these changes:

(a) For every 1 mL of solution, 1 mL of solvent is added.

(b) One third of the solution's total volume is boiled off.

PLAN Given the starting solution, we have to find the number of solute particles in a unit volume after each change. The number of particles per unit volume, N , is directly related to moles per unit volume, M , so we can use a relationship similar to Equation 3.9 to find the number of particles to show in each circle. In (a), the volume increases, so the final solution is more dilute—fewer particles per unit volume. In (b), some solvent is lost, so the final solution is more concentrated—more particles per unit volume.

SOLUTION (a) Finding the number of particles in the dilute solution, N_{dil} :

$$N_{\text{dil}} \times V_{\text{dil}} = N_{\text{conc}} \times V_{\text{conc}}$$

thus, $N_{\text{dil}} = N_{\text{conc}} \times \frac{V_{\text{conc}}}{V_{\text{dil}}} = 8 \text{ particles} \times \frac{1 \text{ mL}}{2 \text{ mL}} = 4 \text{ particles}$

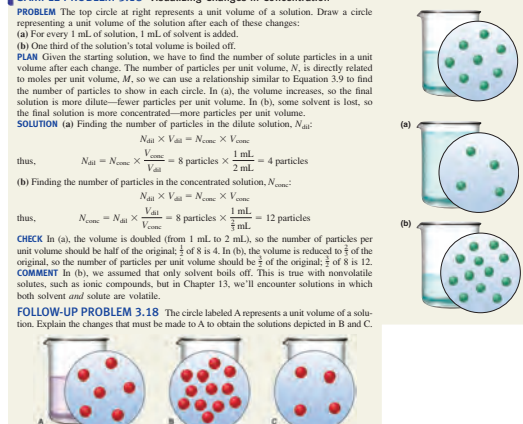
(b) Finding the number of particles in the concentrated solution, N_{conc} :

$$N_{\text{dil}} \times V_{\text{dil}} = N_{\text{conc}} \times V_{\text{conc}}$$

thus, $N_{\text{conc}} = N_{\text{dil}} \times \frac{V_{\text{dil}}}{V_{\text{conc}}} = 8 \text{ particles} \times \frac{1 \text{ mL}}{\frac{1}{3} \text{ mL}} = 24 \text{ particles}$

CHECK In (a), the volume is doubled (from 1 mL to 2 mL), so the number of particles per unit volume should be half of the original; $\frac{1}{2}$ of 8 is 4. In (b), the volume is reduced to $\frac{1}{3}$ of the original, so the number of particles per unit volume should be $\frac{3}{1}$ of the original; $\frac{3}{1}$ of 8 is 24. **COMMENT** In (b), we assumed that only solvent boils off. This is true with nonvolatile solutes, such as ionic compounds, but in Chapter 13, we'll encounter solutions in which both solvent and solute are volatile.

FOLLOW-UP PROBLEM 3.18 The circle labeled A represents a unit volume of a solution. Explain the changes that must be made to A to obtain the solutions depicted in B and C.



Applications

Tools of the Laboratory essays describe the key instruments and techniques that chemists use in modern practice to obtain the data that underlie their theories.

Chemical Connections to Genetics and Forensics

DNA Sequencing and Fingerprinting

A breakthrough in one of the most interesting and important applications of chemistry is the use of DNA fingerprinting. This technique has revolutionized forensic science and has become a standard tool in the laboratory. The DNA code is made up of four chemical building blocks, known as the bases: adenine (A), thymine (T), guanine (G), and cytosine (C). The sequence of these bases determines the genetic information encoded in the DNA. This information is passed from parent to offspring and is unique to each individual. DNA fingerprinting is the process of identifying a person's unique DNA sequence. This is done by comparing the DNA sequence of a suspect with the DNA sequence of a crime scene sample. The DNA sequence of a crime scene sample is obtained by extracting DNA from a sample of biological material, such as a fingerprint, and then sequencing it. The DNA sequence of a suspect is obtained by extracting DNA from a sample of biological material, such as a blood sample, and then sequencing it. The DNA sequence of a crime scene sample and the DNA sequence of a suspect are compared. If the two sequences are identical, the suspect is likely the person who left the fingerprint. DNA fingerprinting is a powerful tool for identifying suspects in criminal cases and for identifying victims in disaster cases. It is also used in paternity testing and in the study of human evolution.

Figure B13.17 Forensic fingerprint analysis. The image shows a fingerprint being analyzed using a laser light source. The laser light is directed at the fingerprint, and the reflected light is captured by a camera. The camera captures the unique ridges and valleys of the fingerprint, which are then analyzed using a computer program. The computer program compares the fingerprint to a database of fingerprints and identifies the suspect.

Chemical Connections essays show the interdisciplinary nature of chemistry by applying chemical principles directly to related scientific fields, including physiology, geology, biochemistry, engineering, and environmental science.

Gallery features show how common and unusual substances and processes relate to chemical principles. You'll learn how a towel dries you, why bubbles in a drink are round, why contact-lens rinse must have a certain concentration, and many other intriguing facts about everyday applications.

Atmosphere-Biosphere Redox Interconnections

The diverse organisms that make up the biosphere interact intimately with the gases of the atmosphere. Powered by solar energy, green plants reduce atmospheric CO₂ and incorporate the C atoms into their own substance. In the process, O atoms in O₂ are oxidized and released to the air as O₂. Certain microbes that live on plant roots reduce N₂ to NH₃ and from compounds that the plant uses to make its proteins. Other microbes that feed on dead plants and animals oxidize the proteins and release N₂ again. Animals eat plants and other animals, use O₂ to oxidize their food, and return CO₂ and H₂O to the air.

Margin notes are brief, lively explanations that apply ideas presented in the text. You'll learn how water controls the temperature of your body and our planet, how crime labs track illegal drugs, how gas behavior affects lung function, how fat-free chips and decaf coffee are made, in addition to handy tips for memorizing relationships, and much more.

Illustrated Summaries of Facts and Concepts

The multipage *Interchapter* is a Perspective on the Properties of the Elements that reviews major concepts from Chapters 7–13, covering atomic and bonding properties and their resulting effects on element behavior.

Group 6A(16): The Oxygen Family

Key Atomic and Physical Properties

Group 6A(16): The Oxygen Family

Atomic Properties

- Group number: 16
- Valence electrons: 6
- Common oxidation states: -2, +2, +4, +6
- Electronegativity: 2.2 (O), 2.0 (S), 2.2 (Se), 2.4 (Te), 2.1 (Po)
- Atomic radius: 60 pm (O), 100 pm (S), 115 pm (Se), 135 pm (Te), 140 pm (Po)
- Ionization energy: 1312 kJ/mol (O), 1000 kJ/mol (S), 841 kJ/mol (Se), 619 kJ/mol (Te), 480 kJ/mol (Po)
- Electron affinity: 141 kJ/mol (O), 200 kJ/mol (S), 220 kJ/mol (Se), 190 kJ/mol (Te), 183 kJ/mol (Po)

Physical Properties

- State at room temperature: Gas (O), Solid (S, Se, Te, Po)
- Color: Colorless (O), Yellow (S), Red (Se), Black (Te, Po)
- Odor: Odorless (O), Pungent (S, Se, Te, Po)
- Boiling point: 90 K (O), 321 K (S), 415 K (Se), 512 K (Te), 625 K (Po)
- Melting point: 5 K (O), 385 K (S), 402 K (Se), 478 K (Te), 527 K (Po)
- Density: 1.43 g/L (O), 2.07 g/cm³ (S), 4.48 g/cm³ (Se), 6.24 g/cm³ (Te), 9.32 g/cm³ (Po)
- Crystal structure: Molecular (O, S, Se), Metallic (Te, Po)

Group 6A(16): The Oxygen Family

Some Reactions and Compounds

Important Reactions

Hydrogen and oxidation of the elements (E) appear in reactions 1 and 2. Redox reactions are indicated by E and O.

$$E + H_2 \rightarrow EH_2$$

$$E + O_2 \rightarrow EO_2$$

The other elements in the group are oxidized by O₂ to form EO₂ and EO₃.

$$E + O_2 \rightarrow EO_2$$

$$E + O_3 \rightarrow EO_3$$

Important Compounds

Water (H₂O) is the single most important compound in Earth's atmosphere. It is a polar molecule and is essential for life. Other important compounds include hydrogen peroxide (H₂O₂), sulfur dioxide (SO₂), sulfur trioxide (SO₃), selenium dioxide (SeO₂), selenium trioxide (SeO₃), tellurium dioxide (TeO₂), and tellurium trioxide (TeO₃).

Characteristics of Chemical Bonding

Types of Bonding

- Ionic bonding:** Results from the attraction between oppositely charged ions. It is the strongest type of bonding and is found in salts.
- Covalent bonding:** Results from the sharing of electron pairs between atoms. It is found in most organic and inorganic molecules.
- Metallic bonding:** Results from the delocalized electrons in a metal lattice. It is found in metals and alloys.

Strength of Bonding

The strength of bonding is related to the distance between the nuclei of the bonded atoms. The closer the nuclei are to each other, the stronger the bonding is. The strength of bonding is also related to the electronegativity of the atoms involved. The greater the electronegativity difference between the atoms, the stronger the bonding is.

Properties of Liquids

Surface Tension

Surface tension is the property of a liquid that allows it to resist an external force. It is caused by the cohesive forces between the molecules of the liquid. Surface tension is measured in units of force per unit length.

Capillary Action

Capillary action is the ability of a liquid to rise or fall in a narrow tube. It is caused by the adhesive forces between the liquid and the walls of the tube. Capillary action is used in many applications, such as in the transport of water in plants and in the operation of a water meter.

Family Portraits (within Chapter 14) display the atomic and physical properties of each main group of elements and present their representative chemical reactions and some important compounds.

Tools of the Laboratory

Spectrophotometry in Chemical Analysis

The use of spectral data to identify and quantify substances is essential to modern chemical analysis. The visible spectrum of light is the range of wavelengths that the human eye can see. The visible spectrum is divided into four regions: violet, blue, green, and red. The visible spectrum is used in many applications, such as in the analysis of the composition of stars and in the study of the structure of molecules. Spectrophotometry is the process of measuring the intensity of light at different wavelengths. It is used in many applications, such as in the analysis of the concentration of a solution and in the study of the structure of molecules.

Figure B7.1 Flame tests and fireworks. A, In general, the color of the flame is characteristic of the element being analyzed. B, The colors of the fireworks are caused by the presence of different metal ions. C, The colors of the fireworks are caused by the presence of different metal ions.

Figure B7.2 Emission and absorption spectra of sodium ions. The emission spectrum of sodium ions shows two bright lines in the yellow region. The absorption spectrum of sodium ions shows two dark lines in the yellow region.

Properties of Liquids

Surface Tension

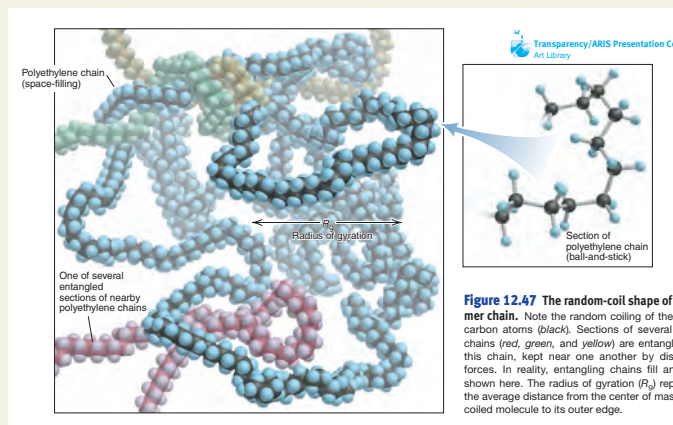
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Capillary Action

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Three-Level Illustrations

A hallmark of this text, the three-level illustrations help you connect the macroscopic and molecular levels of reality with the symbolic level in the form of a chemical equation.

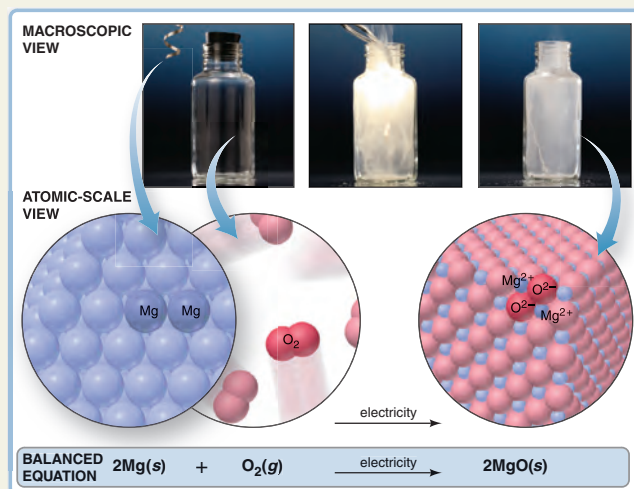


Accurate, Cutting-Edge Molecular Models

Author and illustrator worked side by side to create ground-breaking visual representations.

Page Layout

Author and pager collaborated on page layout to ensure that all figures, tables, margin notes, and sample problems are as close as possible to their related text.

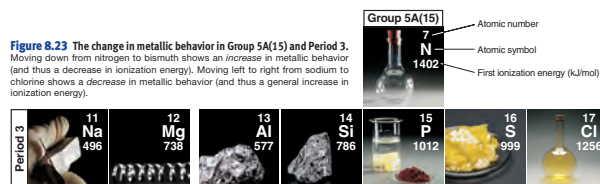


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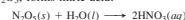
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Some metals and many metalloids form oxides that are **amphoteric**; they can act as acids or as bases in water.

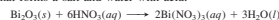
Figure 8.24 classifies the acid-base behavior of some common oxides, focusing once again on the elements in Group 5A(15) and Period 3. Note that *as the elements become more metallic down a group, their oxides become more basic*. In Group 5A, dinitrogen pentoxide, N_2O_5 , forms nitric acid:



Tetraphosphorus decoxide, P_4O_{10} , forms the weaker acid H_3PO_4 :



The oxide of the metalloid arsenic is weakly acidic, whereas that of the metalloid antimony is weakly basic. Bismuth, the most metallic of the group, forms a basic oxide that is insoluble in water but that forms a salt and water with acid:



Note that *as the elements become less metallic across a period, their oxides become more acidic*. In Period 3, sodium and magnesium form the strongly basic oxides Na_2O and MgO . Metallic aluminum forms amphoteric aluminum oxide (Al_2O_3), which reacts with acid or with base:



Silicon dioxide is weakly acidic, forming a salt and water with base:



The common oxides of phosphorus, sulfur, and chlorine form acids of increasing strength: H_3PO_4 , H_2SO_4 , and HClO_4 .

				5A (15)		
				N_2O_5		
3	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3
			As_2O_3		Cl_2O_7	Ar
			Sb_2O_3			
			Bi_2O_3			

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Figure 8.24 The trend in acid-base behavior of element oxides. The trend in acid-base behavior for some common oxides of Group 5A(15) and Period 3 elements is shown as a gradation in color (red = acidic; blue = basic). Note that the metalloids form basic oxides and the nonmetals form acidic oxides. Aluminum forms an oxide (purple) that can act as an acid or as a base. Thus, as atomic size increases, ionization energy decreases, and oxide basicity increases.

Section Summaries and Chapter Perspective

Concise summary paragraphs conclude each section, immediately restating the major ideas just covered. Each chapter ends with a brief perspective that places its topics in the context of previous and upcoming chapters.

Section Summary

A stepwise process converts a molecular formula into a Lewis structure, a *two-dimensional* representation of a molecule (or ion) that shows the placement of atoms and distribution of valence electrons among bonding and lone pairs. • When two or more Lewis structures can be drawn for the same relative placement of atoms, the actual structure is a hybrid of those resonance forms. • Formal charges are often useful for determining the most important contributor to the hybrid. • Electron-deficient molecules (central Be or B) and odd-electron species (free radicals) have less than an octet around the central atom but often attain an octet in reactions. • In a molecule (or ion) with a central atom from Period 3 or higher, the atom can hold more than eight electrons because it is larger and uses *d* orbitals to expand its valence shell.

Chapter Review Guide

A rich assortment of study aids ends each chapter to help you review its content.

- Learning Objectives are listed, with section and/or sample problem numbers, to focus you on key concepts and skills.
• Key Terms that are boldfaced within the chapter are listed here by section (with page numbers) and defined again in the end-of-book Glossary.
• Key Equations and Relationships are screened and numbered within the chapter and listed here with page numbers.
• Highlighted Figures and Tables are listed with page numbers so that you can review their essential content.
• Brief Solutions to Follow-up Problems double the number of worked problems by offering multistep calculations at the end of the chapter, rather than just numerical answers at the back of the book.

Key Equations and Relationships (continued)
27.3 Finding the overall K for a reaction sequence
27.4 Finding K of a reaction from K of the reverse reaction
27.5 Finding K of a reaction multiplied by a factor
27.6 Relating K based on pressure or K based on concentrations
Highlighted Figures and Tables
Brief Solutions to FOLLOW-UP PROBLEMS

CHAPTER REVIEW GUIDE: The following sections provide many aids to help you study this chapter.
Learning Objectives: These are concepts and skills you should know after studying this chapter.
Understand These Concepts: 1. The distinction between the speed (rate) and the extent of a reaction (thermodynamics)
Master These Skills: 1. Writing the reaction quotient (Q) from a balanced equation

End-of-Chapter Problems

An exceptionally large number of problems end each chapter. These include three types of problems keyed by chapter section followed by a number of comprehensive problems:

PROBLEMS

Problems with colored numbers are answered in Appendix E and worked in detail in the Student Solutions Manual.

Atomic Properties and Chemical Bonds

- Concept Review Questions
9.1 In general terms, how does each of the following atomic properties influence the metallic character of the main-group elements in a period?
9.2 Three ions are represented below. What is the predominant type of intramolecular bonding in each?
9.3 What is the relationship between the tendency of a main-group element to form a monatomic ion and its position in the periodic table?
9.4 Which member of each pair is more metallic?
9.5 Which member of each pair is less metallic?
9.6 State the type of bonding—ionic, covalent, or metallic—you would expect in each.
9.7 State the type of bonding—ionic, covalent, or metallic—you would expect in each.
9.8 State the type of bonding—ionic, covalent, or metallic—you would expect in each.
9.9 State the type of bonding—ionic, covalent, or metallic—you would expect in each.
9.10 Draw a Lewis electron-dot symbol for each.
9.11 Draw a Lewis electron-dot symbol for each.
9.12 Draw a Lewis electron-dot symbol for each.
9.13 Draw a Lewis electron-dot symbol for each.
9.14 Give the group number and general electron configuration of an element with each electron-dot symbol.
9.15 Give the group number and general electron configuration of an element with each electron-dot symbol.

The Ionic Bonding Model

- Concept Review Questions
9.16 H energy is required to form monatomic ions from metals and nonmetals, why do ionic compounds exist?
9.17 (a) In general, how does the lattice energy of an ionic compound depend on the charges and sizes of the ions?
9.18 When gaseous Na+ and Cl- ions form gaseous NaCl ion pairs, 548 kJ/mol of energy is released.
9.19 To form S2- ions from gaseous sulfur atoms requires 214 kJ/mol, but these ions exist in solids such as K2S.
9.20 Use condensed electron configurations and Lewis electron-dot symbols to depict the ions formed from each of the following atoms, and predict the formula of their compound.
9.21 Use condensed electron configurations and Lewis electron-dot symbols to depict the ions formed from each of the following atoms, and predict the formula of their compound.
9.22 Identify the main group to which X belongs in each ionic compound formula.
9.23 Identify the main group to which X belongs in each ionic compound formula.

- Problems in Context
10.50 Because both tin and carbon are members of Group 14A(14), they form structurally similar compounds.
10.51 In the gas phase, phosphorus pentachloride exists as separate molecules.
Molecular Shape and Molecular Polarity
• Concept Review Questions
10.52 For molecules of general formula AXn, where n >= 2, how do you determine if a molecule is polar?
10.53 How can a molecule with polar covalent bonds not be polar? Give an example.

- Concept Review Questions test your qualitative understanding of key ideas.
• Skill-Building Exercises are presented in pairs that cover a similar idea, with one of each pair answered in the back of the book.
• Problems in Context apply the skills learned in the Skill-Building Exercises to interesting scenarios, including examples from industry, medicine, and the environment.
• Comprehensive Problems, based on realistic applications, are more challenging and rely on concepts and skills from any section of the current chapter or from previous chapters.

Moreover, in this edition, 140 molecular-scene problems are included.

Comprehensive Problems
10.61 In addition to ammonia, nitrogen forms three other hydrides: hydrazine (N2H4), diazene (N2H2), and tetrazene (N4H4).
10.62 Draw a Lewis structure for each species.
10.63 Give the molecular shape of each species in Problem 10.62.
10.64 Consider the following reaction of silicon tetrafluoride.
(a) Which depiction below best illustrates the change in molecular shape around Si?
(b) Give the name and AXnEz designation of each shape in the depiction chosen in part (a).