

# CHEMISTRY



The Molecular Nature of Matter and Change

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Tour!***

Second Edition

Silberberg

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# Chemistry: The Molecular Nature of Matter and Change, Second Edition

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by Martin S. Silberberg

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## Improvements in Pedagogy and Art

The second edition of Silberberg's *Chemistry* retains the clear writing style, strong problem-solving approach, and outstanding art program that received such high praise from users of the first edition. Some of the many improvements include:

- Every chapter extensively revised for clarity and directness.
- Opening Chapter Outline shows detailed list of topics.
- Concepts and Skills to Review from earlier chapters displayed at first paragraph of chapter.
- Discussions include many more subheads, displayed summaries, and lists of key ideas.
- All Chemical Connections and Tools of the Chemistry Laboratory boxes updated.
- New Margin Notes and Galleries.
- Every Sample Problem, Plan, and Check revised for clarity and updated to include more informative roadmaps.
- Highlighted Figures and Tables clearly displayed and listed at the end of each chapter.
- Numbered list of learning objectives end every chapter.
- End-of-chapter problems divided explicitly into types, with many molecular problems added and hundreds of new problems written.
- Enhanced art program.
- Many macro-to-molecular figures added to enhance pedagogy.
- Many molecular figures added that employ advanced modeling software to simultaneously display space-filling shape, ball-and-stick arrangement, and regions of relative electron density.
- Many photos added to demonstrate relevance.
- Page layout places figure and text nearby, with many figures wrapped by related text so students read and see simultaneously.

## Organizational Changes

The text retains a flexible topic sequence perfectly suited to most modern courses, but several changes in chapter sequence and organization enhance the presentation:

- Discussion of Lewis structures moved from Chapter 9 to Chapter 10. Thus, Chapter 9 compares three types of bonding, and Chapter 10 focuses on depicting molecules.
- Discussion of valence-bond and molecular-orbital theories moved from Chapter 10 to its own new Chapter 11.
- Discussion of element behavior in nature and industry moved up to immediately follow and apply electrochemical principles.
- Nuclear chemistry moved back to (Chapter 24) the end of the text.

## Major Content Changes

- **Chapter 1** introduces macro-molecular theme in discussion of physical states.
- **Chapter 2** introduces Coulomb's Law in bonding discussion for later use in Chapters 8 and 9.
- **Chapter 4** completely revised to highlight the three major reaction types (precipitation, acid-base, and redox). Introduction of Bronsted-Lowry proton transfer concept. Major new subsection on activity series of metals.
- **Chapter 5** includes discussion of planetary atmospheres.
- **Chapter 8** includes revised discussion on shielding and penetration that applies Coulomb's law.
- **Chapter 9** compares ionic, covalent, and metallic bonding models.
- **Chapter 10** covers molecular shape from Lewis structure to VSEPR and molecular dipole. New Gallery on unusual new molecular shapes (fullerenes, nanotubes, cubanes, dendrimers).
- **Chapter 11** devoted to valence-bond and molecular-orbital theories of covalent bonding.
- **Chapter 12** includes major new section on advanced materials (liquid crystals, electronic semiconductors, modern ceramics, nanotechnology).
- **Chapter 13** contains more explicit coverage of entropy in solution behavior. New Gallery on colligative properties in nature and industry.
- **Chapter 16** has greater emphasis on molecular visualization of transition state.

## Brief Table of Contents

## Overview of Chapter Content

- 1 Keys to the Study of Chemistry
  - 2 The Components of Matter
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  - 6 Thermochemistry: Energy Flow and Chemical Change
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- 14 Periodic Patterns in the Main-Group Elements: Bonding, Structure, and Reactivity
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  - 16 Kinetics: Rates and Mechanisms of Chemical Reactions
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  - 22 The Elements in Nature and Industry
  - 23 The Transition Elements and Their Coordination Compounds
  - 24 Nuclear Reactions and Their Applications
- Appendix A Common Mathematical Operations in Chemistry
- Appendix B Standard Thermodynamic Values of Selected Substances
- Appendix C Answers to Selected Problems

**Chapters 1-6: Chemical Fundamentals.** The first block of chapters introduces the science of chemistry and covers some of the key concepts and skills students will use throughout the course. Topics include:

- The origins of chemistry, the scientific approach, the use of units in calculations, and the relevance of chemistry in everyday life.
- The historical development of atomic structure, an introduction to chemical bonding in the context of the periodic table, and the chemical language of compound names and formulas.
- Balancing equations and the quantitative relationships among amount, mass, and number of chemical entities of a substance.
- A first look at the types and essential nature of chemical change, with emphasis on precipitation, acid-base, and redox reactions.
- The physical behavior of gases and the molecular models that explain it.
- The relationship between heat released or absorbed and chemical change.

**Chapters 7-13: Atomic and Molecular Structure.** The second block of chapters highlights the emergence of physical and chemical behavior from the properties of atoms and molecules. Each chapter in this block builds upon the previous one. Topics include:

- The development of quantum theory and its application to modern atomic structure.
- The electronic structure of the atoms and how element properties recur throughout the periodic table.
- A comparison of ionic, covalent, and metallic bonding, their basis in atomic properties, and their manifestation in the properties of substances.
- The visualization of molecular shape and polarity from Lewis structures to VSEPR theory.
- The valence-bond and molecular-orbital treatments of covalent bonding.
- The influence of atomic properties and molecular shape on intermolecular forces and the physical properties of liquids and solids.
- The impact of intermolecular forces on the properties of solutions and the quantitative treatment of concentration.

**The Interchapter and Chapters 14 and 15. Descriptive Inorganic and Organic Chemistry.** Learning how the elements and their compounds actually behave makes concepts from earlier chapters come alive. This novel approach to descriptive chemistry can be covered here or at any later point in the course

- The Interchapter consists of concise text and summarizing illustrations to provide a unique conceptual overview of the major points from Chapters 7-13.
- Chapter 14 applies these earlier principles to all the main-group elements. Attractive, informative Family Portraits highlight key properties, reactions, and uses of the elements.
- Chapter 15 grounds organic chemistry in the atomic properties of carbon. Names, structures, and reaction patterns are covered, with a focus on common themes and major discussions of synthetic and biopolymers.

**Chapters 16-21: Dynamic aspects of chemical change.** The fourth block of chapters covers essential areas of physical chemistry and their applications. Topics include:

- The field of chemical kinetics, with emphasis on the information sequence of a kinetic study, how to devise reaction mechanisms, and the action of catalysts.
- The reversibility of reactions is covered in three chapters: the first emphasizes the nature of equilibrium in gaseous systems, the second deals with the three key models of acid-base behavior, and the third examines buffers, slightly soluble salts, and complex ions.
- The thermodynamic driving force behind all reactions and its connection with free energy and the work obtainable from a spontaneous change.
- The application of thermodynamic principles to electrochemical cells in the laboratory, in everyday practical devices, and in organisms.

**Chapters 22-24: Special Topics.** A final block of chapters covers specialized applications of chemistry. Topics include:

- The principles of kinetics, equilibrium, and thermodynamics (Chapters 16-21) applied to key environmental and industrial aspects of the elements.
- The principles of atomic trends and molecular structure applied to the transition elements and their unique types of compounds.
- The exploration of nuclear behavior, with applications to medicine, engineering, energy production, and many other fields.

**Biochemistry extensively integrated.** Instead of presenting biochemistry in a final, often-skipped chapter, the text includes more central biochemical ideas than other texts and incorporates them throughout to exemplify concepts in discussions, margin notes, boxed essays, and chapter problems. Moreover, a major portion of Chapter 15 is devoted to the structure and function of biological macromolecules.

# Thinking Logically to Solve Problems

A critical aspect of Silberberg's **Chemistry: The Molecular Nature of Matter and Change** employs modern learning strategies that enable students to develop a logical approach to solving problems by reasoning toward, not memorizing, a solution.

## Four-Part Approach to Solving Problems

### 1) Plan

After a Problem is stated, it is analyzed and the steps are verbally planned to show how to move from what is known to what is unknown. Thus, the student thinks through the solution before performing calculations. Many solution plans include "roadmaps", block diagrams that guide the student visually through the calculation steps.

### 2) Solve

Next, the plan is executed by naming each step and then carrying out the calculation.

### 3) Check

The next step is to check that the answer makes sense both chemically and mathematically. Sometimes a "Comment" appears about common pitfalls or alternative approaches.

### 4) Practice

A Follow-up Problem that requires the same procedure to solve appears immediately after the sample problem.

Wherever an important new skill or concept is introduced, a worked-out sample problem appears. It incorporates a four-part problem-solving approach that helps the student analyze the given information and plan a strategy, work out a solution, check its reasonableness, and practice the skills learned.

#### 5.3 The Gas Laws and Their Experimental Foundations

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#### Sample Problem 5.2 Applying the Volume-Pressure Relationship

**PROBLEM** An apprentice of Boyle finds that the air trapped in a J tube occupies 24.8 cm<sup>3</sup> at 1.12 atm. By adding mercury to the tube, he increases the pressure on the trapped air to 2.64 atm. Assuming constant temperature, what is the new volume of air (in L)?

**PLAN** We must find the final volume ( $V_2$ ) in liters, given the initial volume ( $V_1$ ), initial pressure ( $P_1$ ), and final pressure ( $P_2$ ). The temperature and amount of gas are fixed. We convert the units of  $V_1$  from cm<sup>3</sup> to mL and then to L, rearrange the ideal gas law to the appropriate form, and solve for  $V_2$ . We can predict the direction of the change: since  $P$  increases,  $V$  will decrease; thus,  $V_2 < V_1$ . (Note the two-part roadmap.)

**SOLUTION** Summarizing the gas variables:

$$P_1 = 1.12 \text{ atm} \qquad P_2 = 2.64 \text{ atm} \\ V_1 = 24.8 \text{ cm}^3 \text{ (convert to L)} \qquad V_2 = \text{unknown} \qquad T \text{ and } n \text{ remain constant}$$

Converting  $V_1$  from cm<sup>3</sup> to L:

$$V_1 = 24.8 \text{ cm}^3 \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.0248 \text{ L}$$

Arranging the ideal gas law and solving for  $V_2$ : At fixed  $n$  and  $T$ , we have

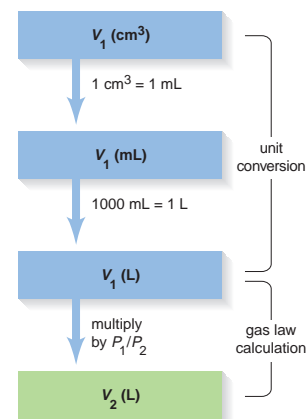
$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2} \qquad \text{or} \qquad P_1 V_1 = P_2 V_2$$

$$V_2 = V_1 \times \frac{P_1}{P_2} = 0.0248 \text{ L} \times \frac{1.12 \text{ atm}}{2.64 \text{ atm}} = \mathbf{0.0105 \text{ L}}$$

**CHECK** As we predicted,  $V_2 < V_1$ . The pressure more than doubled, so  $V_2$  should be less than  $\frac{1}{2} V_1$  ( $0.0105/0.0248 < \frac{1}{2}$ ).

**COMMENT** Predicting the direction of the change provides another check on the problem setup: To make  $V_2 < V_1$ , we must multiply  $V_1$  by a number less than 1. This means the ratio of pressures must be less than 1, so the larger pressure ( $P_2$ ) must be in the denominator,  $P_1/P_2$ .

**Follow-up Problem 5.2** A sample of argon gas occupies 105 mL at 0.871 atm. If the temperature remains constant, what is the volume (in L) at 26.3 kPa?



#### Answers to Follow-up Problems

$$3.1 \text{ (a) Moles of C} = 315 \text{ mg C} \times \frac{1 \text{ g}}{10^3 \text{ mg}} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} \\ = 0.0262 \text{ mol C}$$

$$\text{(b) Mass (g) of Mn} = 3.22 \times 10^{20} \text{ Mn atoms} \\ \times \frac{1 \text{ mol Mn}}{6.022 \times 10^{23} \text{ Mn atoms}} \times \frac{54.94 \text{ g Mn}}{1 \text{ mol Mn}} \\ = 2.94 \times 10^{-2} \text{ g Mn}$$

$$3.2 \text{ (a) Mass (g) of P}_4\text{O}_{10} = 4.65 \times 10^{22} \text{ molecules P}_4\text{O}_{10} \\ \times \frac{1 \text{ mol P}_4\text{O}_{10}}{6.022 \times 10^{23} \text{ molecules P}_4\text{O}_{10}} \times \frac{283.88 \text{ g P}_4\text{O}_{10}}{1 \text{ mol P}_4\text{O}_{10}} \\ = 21.9 \text{ g P}_4\text{O}_{10}$$

$$\text{(b) No. of P atoms} = 4.65 \times 10^{22} \text{ molecules P}_4\text{O}_{10} \\ \times \frac{4 \text{ atoms P}}{1 \text{ molecule P}_4\text{O}_{10}} = 1.86 \times 10^{23} \text{ P atoms}$$

## End-of-Chapter Solutions to Follow-Up Problems

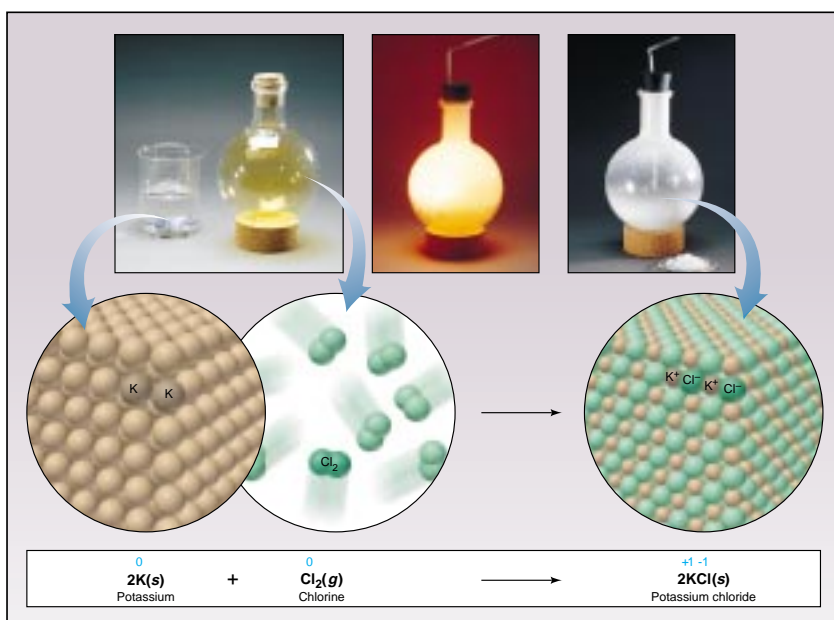
Answers to the Follow-Up Problems are actually brief solutions, not just the numerical answers seen in other texts. This feature effectively doubles the number of worked out sample problems.

# Visualizing the Models of Chemistry

The second edition of **Chemistry**, like the first, is based on the central theme that matter and its changes are ultimately molecular in nature. A powerful illustration program works together with clear text discussions to emphasize this theme. The interplay between words and art helps students learn to magnify scenes in their imagination, as chemists do, thus bridging the mind-boggling gap between the events we see and those that cause them. The art program is so conceptual that, together with extensive figure legends, it provides another way for students to study.

4.4 Counting Reactants and Products in Precipitation, Acid-Base, and Redox Processes

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**Figure 4.15** Three views of a combination reaction between elements. When the metal potassium and the nonmetal chlorine react, they form the solid ionic compound potassium chloride. The photos (top) present the view the chemist sees in the

laboratory. The blow-up arrows lead to an atomic-scale view (middle); the stoichiometry is indicated by the more darkly colored spheres. The balanced redox equation is shown with oxidation numbers (bottom).

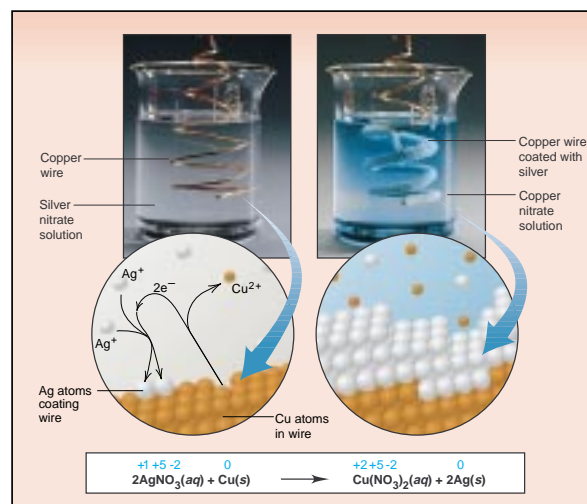
## Three-Level Depictions of Chemical Events

Expanding upon the innovative approach originated in the first edition, the art program frequently juxtaposes photographs of a chemical process with accurate molecular views of it. The equation that symbolically and quantitatively describes it is also presented.

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Chapter 4 The Major Classes of Chemical Reactions

**Figure 4.19** Three views of copper displacing silver ions from solution. More reactive metals can displace less reactive ones from solution. In this single-displacement reaction, Cu atoms become  $\text{Cu}^{2+}$  ions and leave the wire, as they transfer electrons to two  $\text{Ag}^+$  ions that become Ag atoms and coat the wire: the laboratory view (top), the atomic view (middle), and the balanced redox equation (bottom).





# Applying Chemistry to the Real World

**N**o other science is as relevant to everyday life as chemistry, and numerous examples of this relevance are woven throughout the text discussions, some of which are highlighted by these displayed features.

## Tools of the Chemistry Laboratory

### Mass Spectrometry

Mass spectrometry, the most powerful technique for measuring the mass and abundance of charged particles, is an outgrowth of electric and magnetic deflection studies on atoms formed in cathode ray experiments. When a high-energy electron collides with an atom of neon-20, for example, one of the atom's electrons is knocked away and the resulting particle has one positive charge,  $\text{Ne}^+$  (Figure 2.A). Therefore, its mass:charge ratio ( $m/e$ ) equals the mass divided by  $1+$ . These  $m/e$  values are measured to identify the masses of different isotopes of an element.

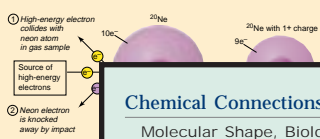


Figure 2.A

Figure 2.B depicts the core of one type of mass spectrometer and the data it provides. The sample is introduced and vaporized (if liquid or solid), then bombarded by high-energy electrons to form positively charged particles. These are attracted toward a series of negatively charged plates with slits in them, and some particles pass through into an evacuated tube exposed to a magnetic field. As the particles zoom through this region, they are deflected according to their  $m/e$ ; the lightest particles are deflected most.

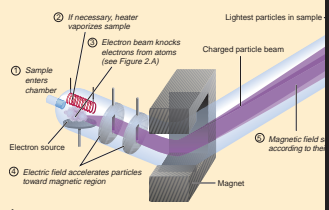


Figure 2.B The mass spectrometer and its data. A, The instrument separates charged particles on the basis of their mass/charge ratios ( $m/e$ ). Atmospheric neon sample, in very exact work, the spectrometer can be tuned to measure  $m/e$  values to decimal places. B, Mass spectral data from the sample show the abundance of each particle present. The three peaks correspond to three neon isotopes. C, The data are recalculated to show the percent abundance of each particle. D, The mass spectrum protein molecule.

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## Boxed Essays

**Tools of the Chemistry Laboratory** essays describe key instruments and techniques in modern practice to show students that models depend on careful measurement.

### Chemical Connections Chemistry in Physiology

#### Molecular Shape, Biological Receptors, and the Sense of Smell

In a very simple sense, a biological cell is a membrane-bound sack filled with molecular shapes interacting in an aqueous fluid. As a result of the magnificent internal organization of cells, many complex processes in an organism begin when a molecular "key" fits into a correspondingly shaped molecular "lock." The key can be a relatively small molecule circulating in a body fluid, whereas the lock is usually a large molecule, known as a biological receptor, that is often found embedded in a cell membrane. The receptor contains a precisely shaped cavity, or *receptor site*, that is exposed to the passing fluid. Thousands of molecules collide with this site, but when one with the correct shape (that is, the molecular key) lands on it, the receptor "grabs" it through intermolecular attractions, and the biological response begins.

Let's see how this fitting together of molecular shapes operates in the sense of smell (olfaction). A substance must have certain properties to have an odor. An odorless molecule travels through the air, so it must come from a gas or a volatile liquid or solid. To reach the receptor, it must be soluble, at least to a small extent, in the thin film of aqueous solution that lines the nasal passages. Most important, the odorous molecule, or a portion of it, must have a shape

that fits into one of the olfactory receptor sites that cover the nerve endings deep within the nasal passage (Figure 10.A). When this happens, the resulting nerve impulses travel from these endings to the brain, which interprets the impulses as a specific odor.

In the 1950s, the stereochemical theory of odor (*stereo* means "three-dimensional") was introduced to explain the relationship between odor and molecular shape. Its basic premise is that a molecule's shape (and sometimes its polarity), but *not* its composition, is the primary determinant of its odor. According to this theory, there are seven primary odors, each corresponding to one of seven different types of olfactory receptor sites. The seven odors are camphor-like, musky, floral, minty, ethereal, pungent, and putrid. (The last two odors depend on molecular polarity more than shape, and their receptors have partial charges opposite to those of the molecules landing there.) Figure 10.B shows the proposed shapes of three of the seven receptor sites, each occupied by a molecule having the associated odor.

Several predictions of this original version of the theory have been verified by experiment. If two substances fit the same receptors, they should have the same odor, even if

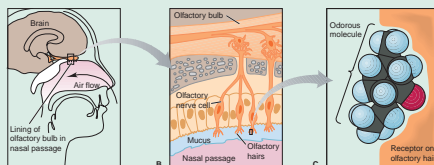


Figure 10.A The location of olfactory receptors within the nose. A, The olfactory area lies at the top of the nasal passage very close to the brain. Air containing the odorous molecules is sniffed in, warmed, moistened, and channelled toward this region. B, A blow-up of the region shows olfactory nerve cells and their

hairlike endings protruding into the liquid-coated nasal passage. C, A further blow-up shows a receptor on one of the endings containing an odorous molecule that matches its shape. This particular molecule has a minty odor.



Figure 10.B Shapes of some olfactory receptor sites. Three of the seven proposed olfactory receptors are shown with a molecule having that odor occupying the site.



**Imagine an Earth Without Water** Liquid water has an unusually high specific heat capacity of nearly  $4.2 \text{ J/g} \cdot \text{K}$ , about six times that of rock ( $\sim 0.7 \text{ J/g} \cdot \text{K}$ ). If the Earth were devoid of oceans, the Sun's energy would heat a planet composed of rock. It would take only  $0.7 \text{ J}$  of energy to increase the temperature of each gram of rock by  $1 \text{ K}$ . Daytime temperatures would soar. The oceans also limit the temperature drop when the Sun sets, because the energy absorbed during the day is released at night. If the Earth had a rocky surface, temperatures would be frigid every night.

## Margin Notes

More than 140 short, lively marginal essays focus on everyday and industrial examples, fascinating analogies, comparisons of scale, and historical themes, all consistently played out in the context of the chemical principles.

## Galleries

These illustrated summaries show how molecules and products in everyday life relate to chemical principles. Students will see how molecules range in size, how ball-point pens work, why gas bubbles are round, how flashlight batteries operate, and many other interesting applications of chemical ideas.

### Picturing Molecules

The most exciting thing about learning chemistry is training your mind to imagine a molecular world, one filled with tiny objects of various shapes. Molecules are depicted in a variety of useful ways, as shown below for the water molecule:

Chemical formulas show only the relative numbers of atoms.

Electron-dot and bond-line formulas show a bond between atoms as either a pair of dots or a line.

Ball-and-stick models show atoms as spheres and bonds as sticks, with accurate angles and relative sizes, but distances are exaggerated.

Space-filling models are accurately scaled-up versions of molecules, but they do not show bonds.

Electron-density models show the ball-and-stick model within the space-filling shape and color the regions of high (red) and low (blue) electron charge.

Many household items, such as butane, acetic acid, and aspirin, consist of somewhat larger molecules. The biologically essential molecule here is larger still.

Very large molecules, called macromolecules, can be synthetic, like nylon, or natural, like DNA, and typically consist of thousands of atoms.

Nylon-66 ( $\sim 15,000$  amu), relatively small, synthetic macromolecule used to make textiles.

Aspirin ( $\text{C}_9\text{H}_8\text{O}_4$ , 180.15 amu), most common pain reliever in the world.

Acetic acid ( $\text{C}_2\text{H}_4\text{O}_2$ , 60.05 amu), component of vinegar.

Home ( $\text{C}_{30}\text{H}_{48}\text{FN}_2\text{O}_2$ , 476.69 amu), part of the blood protein hemoglobin, which carries oxygen through the body.

Diethyl sebacate ( $\text{C}_{20}\text{H}_{40}\text{O}_4$ , 344.52 amu), cellular macromolecule that contains genetic information.

Carbon monoxide ( $\text{CO}$ , 28.01 amu), toxic component of car exhaust and cigarette smoke.

Nitrogen dioxide ( $\text{NO}_2$ , 46.01 amu), exhaust and contributes to smog and acid rain.

Sulfur dioxide ( $\text{SO}_2$ , 64.07 amu), forms from burning coal in power plants, contributes to acid rain.

Water ( $\text{H}_2\text{O}$ , 18.02 amu), essential for life.

Butane ( $\text{C}_4\text{H}_{10}$ , 58.12 amu), fuel for cigarettes lighters and camping stoves.

# Reinforcing the Concepts of Chemistry

Education experts advise that reinforcement of concepts is crucial to learning. Some of the ways **Chemistry** provides this reinforcement are shown by these features.

392 Chapter 10 The Shapes of Molecules

Valence-Shell Electron-Pair Repulsion (VSEPR) Theory and Molecular Shape (Sample Problems 10.7 to 10.9)

**■ Concept Review Questions**

10.36 If you know the formula of a molecule or ion, what is the first step in predicting its shape?







10.37 In what situations is the name of the molecular shape the same as the name of the electron-group arrangement? 10.38 Which of the following numbers of electron groups can give rise to a bent (V-shaped) molecule: two, three, four, five, six? Draw an example with the shape classification (AX<sub>n</sub>E<sub>m</sub>) and ideal bond angle in each case.

10.39 Name all the molecular shapes that have a tetrahedral electron-group arrangement.

10.40 Why aren't lone pairs included with surrounding bonded groups when describing the molecular shape?

10.41 Use wedge-line perspective drawings (if necessary) to sketch the atom positions in a general molecule of formula (not shape class) AX<sub>n</sub> that has the following shapes: (a) V shaped; (b) trigonal planar; (c) trigonal bipyramidal; (d) T shaped; (e) trigonal pyramidal; (f) square pyramidal.

10.42 What would you expect to be the electron-group arrangement around atom A in each of the following cases? For each arrangement, give the ideal bond angle and the direction of any expected deviation:

(a)  (b)  (c)  (d)   
 (e)  (f) 




**■ Skill-Building Exercises (paired)**

10.43 Determine the electron-group arrangement, molecular shape, and ideal bond angle(s) for each of the following: (a) O<sub>3</sub>; (b) H<sub>3</sub>O<sup>+</sup>; (c) NF<sub>3</sub>.




10.44 Determine the electron-group arrangement, molecular shape, and ideal bond angle(s) for each of the following: (a) SO<sub>2</sub>; (b) N<sub>2</sub>O (N central); (c) CH<sub>2</sub>Cl<sub>2</sub>.

10.45 Determine the electron-group arrangement, molecular shape, and ideal bond angle(s) for each of the following: (a) SO<sub>2</sub>; (b) N<sub>2</sub>O (N central); (c) CH<sub>2</sub>Cl<sub>2</sub>.

10.47 Name the shape and give the AX<sub>n</sub>E<sub>m</sub> classification and ideal bond angle(s) for each of the following general molecules:

(a)  (b)  (c) 

10.48 Name the shape and give the AX<sub>n</sub>E<sub>m</sub> classification and ideal bond angle(s) for each of the following general molecules:

(a)  (b)  (c) 

10.49 Determine the shape, ideal bond angle(s), and the direction of any deviations from these angles for each of the following: (a) ClO<sub>2</sub>; (b) PF<sub>5</sub>; (c) SeF<sub>6</sub>; (d) KrF<sub>2</sub>.

10.50 Determine the shape, ideal bond angle(s), and the direction of any deviations from these angles for each of the following: (a) ClO<sub>2</sub>; (b) IF<sub>3</sub>; (c) SeO<sub>2</sub>; (d) TeF<sub>4</sub>.

10.51 Determine the shape around each central atom in each molecule, and explain any deviation from ideal bond angles: (a) CH<sub>3</sub>OH; (b) N<sub>2</sub>O<sub>4</sub> (O<sub>2</sub>NNO<sub>2</sub>).

10.52 Determine the shape around each central atom in each molecule, and explain any deviation from ideal bond angles: (a) H<sub>3</sub>PO<sub>4</sub> (no H—P bond); (b) CH<sub>3</sub>—O—CH<sub>2</sub>CH<sub>3</sub>.







10.53 Determine the shape around each central atom in each molecule, and explain any deviation from ideal bond angles: (a) CH<sub>3</sub>COOH; (b) H<sub>2</sub>O<sub>2</sub>.

10.54 Determine the shape around each central atom in each molecule, and explain any deviation from ideal bond angles: (a) H<sub>2</sub>SO<sub>3</sub> (no H—S bond); (b) N<sub>2</sub>O<sub>5</sub> (ONNO<sub>2</sub>).




10.55 Arrange the following AF<sub>3</sub> species in order of increasing F—A—F bond angles: BF<sub>3</sub>, BeF<sub>2</sub>, CF<sub>2</sub>, NF<sub>2</sub>, OF<sub>2</sub>.

10.56 Arrange the following ACl<sub>2</sub> species in order of decreasing Cl—A—Cl bond angles: SCl<sub>2</sub>, OCl<sub>2</sub>, PCl<sub>3</sub>, SiCl<sub>4</sub>, SiCl<sub>2</sub>F<sub>2</sub>.

10.57 State ideal values for each of the bond angles in each molecule and where you expect deviations:

(a)  (b)  (c)   
 (d)  (e)  (f) 

10.58 State ideal values for each of the bond angles in each molecule and where you expect deviations:

(a)  (b)  (c) 

**■ Problems in Context**

10.59 Because both tin and carbon are members of Group 4A(14), they form structurally similar compounds. However, tin exhibits a greater variety of structures because it forms several ionic species. Predict the shapes and ideal bond angles, including any deviations, for the following: (a) Sn(CH<sub>3</sub>)<sub>4</sub>; (b) SnCl<sub>4</sub>; (c) Sn(CH<sub>3</sub>)<sub>2</sub>; (d) SnF<sub>2</sub>; (e) SnF<sub>4</sub>.

10.60 In the gas phase, phosphorus pentachloride exists as separate molecules. In the solid phase, however, the compound is composed of alternating PCl<sub>4</sub><sup>+</sup> and PCl<sub>6</sub><sup>-</sup> ions. What change(s) in molecular shape occur(s) as PCl<sub>5</sub> solidifies? How does the Cl—P—Cl angle change?

Molecular Shape and Molecular Polarity (Sample Problem 10.10)

**■ Concept Review Questions**

10.61 For molecules of general formula AX<sub>n</sub> (where n > 2), how do you determine if a molecule is polar?

10.62 How can a molecule with polar covalent bonds fail to be a polar molecule? Give an example.

10.63 Explain in general why the shape of a biomolecule is important to its function.

## End-of-Chapter Problem Solving

An exceptionally large number of problems follow each chapter. Three types of problems are keyed by chapter section:

### • Concept Review Questions

These test students' qualitative understanding of key ideas in the chapter.

### • Skill-Building Exercises

Written in pairs, with one of each pair answered in the back of the book, these exercises begin simply and increase in difficulty, gradually weaning the student from multi-step directions.

This **Weaning Process** is a distinguishing feature of the text and demonstrates the pedagogy consciously built into the sequence of problems. For example, within a series of stoichiometry problems in Chapter 3, the first pair gives balanced equations and numbered steps, the second pair gives unbalanced equations and numbered steps, the third gives unbalanced equations and no steps, the fourth gives word equations and no steps, and the fifth pair requires a sequence of two equations and gives word equations and no steps.

### • Problems in Context

These problems apply the learned skills to interesting scenarios, including examples from industry, medicine, and the environment.

### • Comprehensive Problems

Following the section-based problems is a large group of more challenging problems based on concepts and skills from any section and/or earlier chapter.

## Key Terms, Key Equations, and Highlighted Figures and Tables

This chapter end matter lists important displayed material from in-chapter discussions, including bold-faced terms (also defined in the Glossary), numbered equations, and figures/tables that cover major concepts.

## For Review and Reference

### Key Terms

	Section 3.3	Section 3.4	Section 3.5
stoichiometry	chemical equation	overall (net) equation	solute
Section 3.1	reactant	limiting reactant	solvent
mole (mol)	product	theoretical yield	concentration
Avogadro's number	balancing (stoichiometric)	side reaction	molarity (M)
molar mass (M)	coefficient	actual yield	
Section 3.2		percent yield (% yield)	
combustion analysis			

### Key Equations and Relationships

- 3.1 Number of entities in one mole (p. 89):  
 1 mole contains  $6.022 \times 10^{23}$  entities (to 4 significant figures)
- 3.2 Converting amount (mol) to mass using  $M$  (p. 93):  

$$\text{Mass (g)} = \text{no. of moles} \times \frac{\text{no. of grams}}{1 \text{ mol}}$$
- 3.3 Converting mass to amount (mol) using  $\frac{1}{M}$  (p. 93):  

$$\text{No. of moles} = \text{mass (g)} \times \frac{1 \text{ mol}}{\text{no. of grams}}$$
- 3.4 Converting amount (mol) to number of entities (p. 93):  

$$\text{No. of entities} = \text{no. of moles} \times \frac{6.022 \times 10^{23} \text{ entities}}{1 \text{ mol}}$$
- 3.5 Converting number of entities to amount (mol) (p. 93):  

$$\text{No. of moles} = \text{no. of entities} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ entities}}$$

### Highlighted Figures and Tables

- These figures (F) and tables (T) provide a quick review of key ideas.
- T3.1 Summary of mass terminology (p. 91)
- T3.2 Information contained in a formula (p. 93)
- F3.3 Summary of mass-mole-number relationships for elements and compounds (p. 94)
- T3.5 Information contained in a balanced equation (p. 107)
- F3.8 Summary of mass-mole-number relationships in a chemical reaction (p. 109)
- F3.11 Summary of mass-mole-number-volume relationships in solution (p. 117)
- F3.14 Overview of mole-mass-number relationships (p. 122)

### Section Summary

To explain the line spectrum of atomic hydrogen, Bohr proposed that the atom's energy is quantized because the electron's motion is restricted to fixed orbits. The electron can move from one orbit to another only if the atom absorbs or emits a photon whose energy equals the difference in energy levels (orbits). Line spectra are produced because these energy changes correspond to photons of specific wavelength. Bohr's model predicted the H atom spectrum but could not predict that of any other atom because electrons do not have fixed orbits. Despite this, Bohr's idea that atoms have quantized energy levels is a cornerstone of our current model. Spectrophotometry is an instrumental technique in which emission and absorption spectra are used to identify and measure concentrations of substances.

## Section Summaries

Instead of having a long summary appended to a chapter, each section concludes with a clear paragraph or two that immediately restates the major ideas covered.