PREFACE

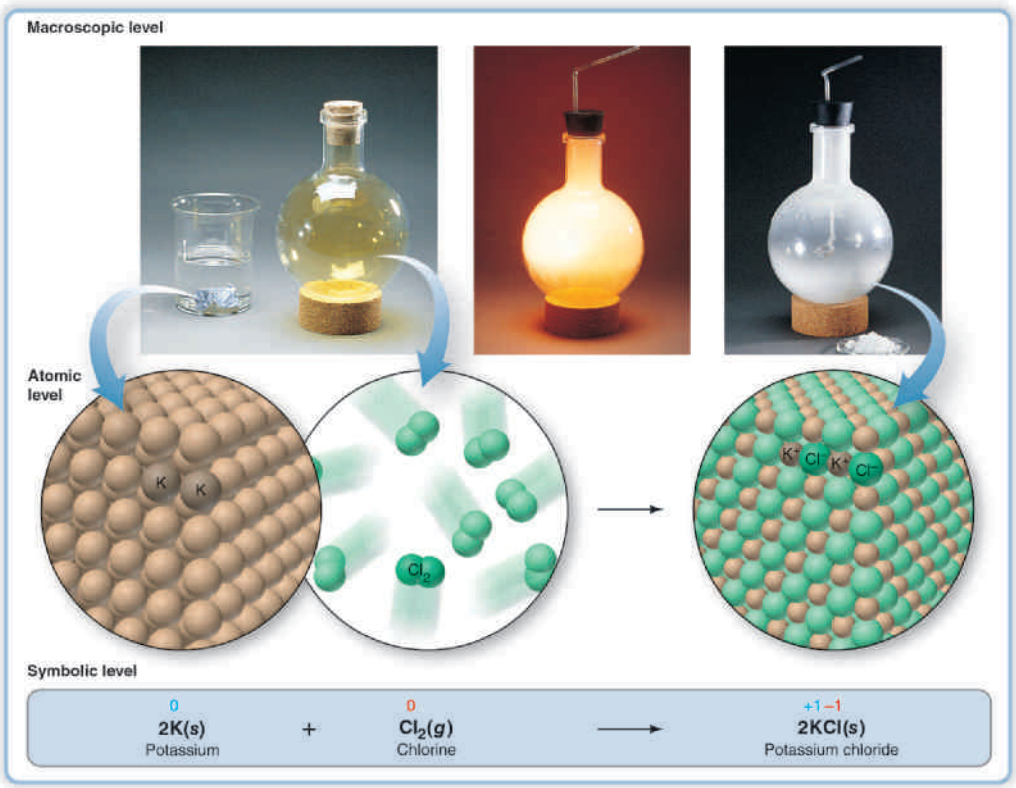
Chemistry is so crucial to an understanding of medicine and biology, environmental science, and many areas of engineering and industrial processing that it has become a requirement for an increasing number of academic majors. Furthermore, chemical principles lie at the core of some of the key societal issues we face in the 21st century—dealing with climate change, finding new energy options, and supplying nutrition and curing disease on an ever more populated planet.

SETTING THE STANDARD FOR A CHEMISTRY TEXT

The seventh edition of *Chemistry: The Molecular Nature of Matter and Change* maintains its standard-setting position among general chemistry textbooks by evolving further to meet the needs of professor and student. The text still contains the most accurate molecular illustrations, consistent step-by-step worked problems, and an extensive collection of end-of-chapter problems. And changes throughout this edition make the text more readable and succinct, the artwork more teachable and modern, and the design more focused and inviting. The three hallmarks that have made this text a market leader are now demonstrated in its pages more clearly than ever.

Visualizing Chemical Models—Macroscopic to Molecular

Chemistry deals with observable changes caused by unobservable atomic-scale events, requiring an appreciation of a size gap of mind-boggling proportions. One of the text's goals coincides with that of so many instructors: to help students visualize chemical events on the molecular scale. Thus, concepts are explained first at the macroscopic level and then from a molecular point of view, with pedagogic illustrations always placed next to the discussions to bring the point home for today's visually oriented students.



Thinking Logically to Solve Problems

The problem-solving approach, based on the four-step method widely accepted by experts in chemical education, is introduced in Chapter 1 and employed *consistently* throughout the text. It encourages students to *plan* a logical approach to a problem, and only then proceed to *solve* it. Each sample problem includes a *check,* which fosters the habit of "thinking through" both the chemical and the quantitative reasonableness of the answer. Finally, for *practice* and reinforcement, each sample problem is now followed immediately by *two* similar follow-up problems. And, *Chemistry* marries problem solving to visualizing models with molecular-scene problems, which appear not only in homework sets, as in other texts, but also in the running text, where they are worked out stepwise.

SAMPLE PROBLEM 3.9 Determining an Empirical Formula from Masses of Elements

Problem Analysis of a sample of an ionic compound yields 2.82 g of Na, 4.35 g of Cl, and 7.83 g of O. What are the empirical formula and the name of the compound?

Plan This problem is similar to Sample Problem 3.8, except that we are given element *masses* that we must convert into integer subscripts. We first divide each mass by the element's molar mass to find the amount (mol). Then we construct a preliminary formula and convert the amounts (mol) to integers.

Solution Finding amount (mol) of each element:

$$\text{Amount (mol) of Na} = 2.82\ \cancel{\text{g Na}} \times \frac{1\ \text{mol Na}}{22.99\ \cancel{\text{g Na}}} = 0.123\ \text{mol Na}$$

$$\text{Amount (mol) of Cl} = 4.35\ \cancel{\text{g Cl}} \times \frac{1\ \text{mol Cl}}{35.45\ \cancel{\text{g Cl}}} = 0.123\ \text{mol Cl}$$

$$\text{Amount (mol) of O} = 7.83\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 0.489\ \text{mol O}$$

Constructing a preliminary formula: $Na_{0.123}Cl_{0.123}O_{0.489}$

Converting to integer subscripts (dividing all by the smallest subscript):

$$Na_{\frac{0.123}{0.123}}Cl_{\frac{0.123}{0.123}}O_{\frac{0.489}{0.123}} \longrightarrow Na_{1.00}Cl_{1.00}O_{3.98} \approx Na_1Cl_1O_4, \quad \text{or} \quad NaClO_4$$

The empirical formula is $NaClO_4$; the name is sodium perchlorate.

Check The numbers of moles seem correct because the masses of Na and Cl are slightly more than 0.1 of their molar masses. The mass of O is greatest and its molar mass is smallest, so it should have the greatest number of moles. The ratio of subscripts, 1/1/4, is the same as the ratio of moles, 0.123/0.123/0.489 (within rounding).

FOLLOW-UP PROBLEMS

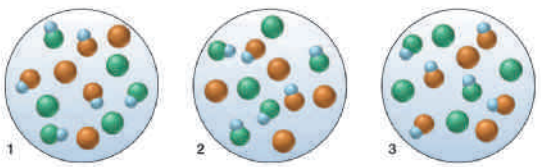
3.9A A sample of an unknown compound is found to contain 1.23 g of H, 12.64 g of P, and 26.12 g of O. What is the empirical formula?

3.9B An unknown metal M reacts with sulfur to form a compound with the formula M_2S_3. If 3.12 g of M reacts with 2.88 g of S, what are the names of M and M_2S_3? [*Hint:* Determine the amount (mol) of S, and use the formula to find the amount (mol) of M.]

SOME SIMILAR PROBLEMS 3.42(b), 3.43(b), 3.46(b), and 3.47(b)

SAMPLE PROBLEM 18.6 Using Molecular Scenes to Predict the Net Direction of an Acid-Base Reaction

Problem Given that 0.10 *M* HX *(blue and green)* has a pH of 2.88, and 0.10 *M* HY *(blue and orange)* has a pH of 3.52, which scene best represents the final mixture after equimolar solutions of HX and Y^- are mixed?



Plan A stronger acid and base yield a weaker acid and base, so we have to determine the relative acid strengths of HX and HY in order to choose the correct molecular scene. The concentrations of the acid solutions are equal, so we can pick the stronger acid directly from the pH values of the two acid solutions. Because the stronger acid reacts to a greater extent, fewer molecules of it will be in the scene than molecules of the weaker acid.

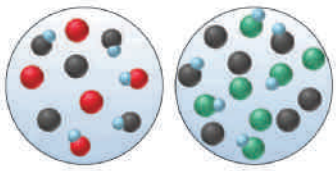
Solution The HX solution has a lower pH (2.88) than the HY solution (3.52), so we know right away that HX is the stronger acid and Y^- is the stronger base. Therefore, the reaction of HX and Y^- has a $K_c > 1$, which means the equilibrium mixture will have more HY than HX. Scene 1 has equal numbers of HX and HY, which would occur if the acids were of equal strength, and scene 2 shows fewer HY than HX, which would occur if HY were stronger. Therefore, only scene 3 is consistent with the relative acid strengths.

FOLLOW-UP PROBLEMS

18.6A The left-hand scene in the margin represents the equilibrium mixture after 0.10 *M* solutions of HA *(blue and red)* and B^- *(black)* react: Does this reaction have a K_c greater or less than 1? Which acid is stronger, HA or HB?

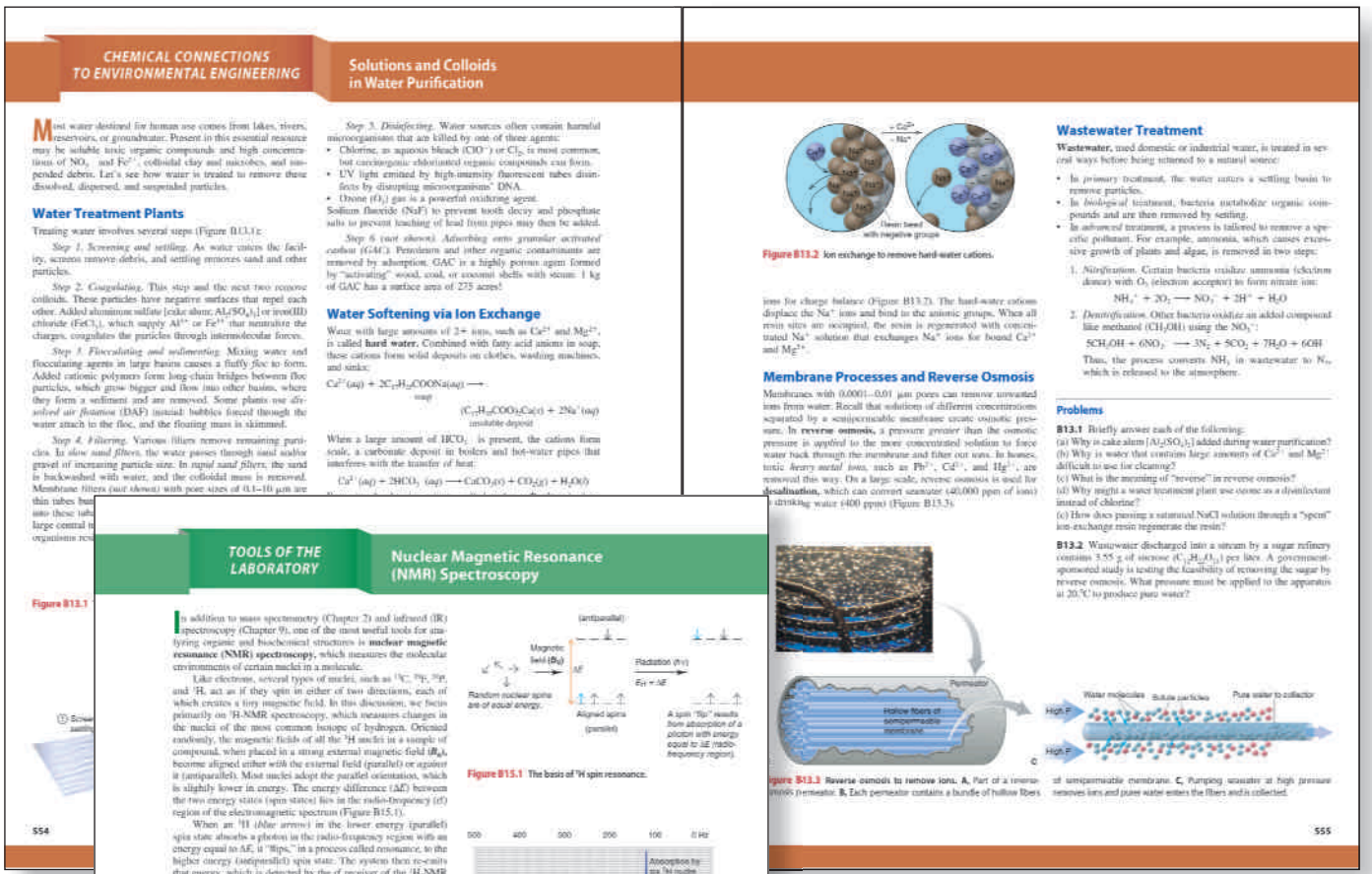
18.6B The right-hand scene depicts an aqueous solution of two conjugate acid-base pairs: HC/C^- and HD/D^-. HD is a stronger acid than HC. What colors represent the base C^- and the base D^-? Does the reaction between HC and D^- have a K_c greater or less than 1?

A SIMILAR PROBLEM 18.39



Applying Ideas to the Real World

As the most practical science, chemistry should have a textbook that highlights its countless applications. Moreover, today's students may enter emerging chemistry-related hybrid fields, like biomaterials science or planetary geochemistry, and the text they use should point out the relevance of chemical concepts to such related sciences. The *Chemical Connections* and *Tools of the Laboratory* boxed essays (which include problems for added relevance), the more pedagogic margin notes, and the many applications woven into the chapter content are up-to-date, student-friendly features that are directly related to the neighboring content.


CHEMICAL CONNECTIONS TO ENVIRONMENTAL ENGINEERING

Solutions and Colloids in Water Purification

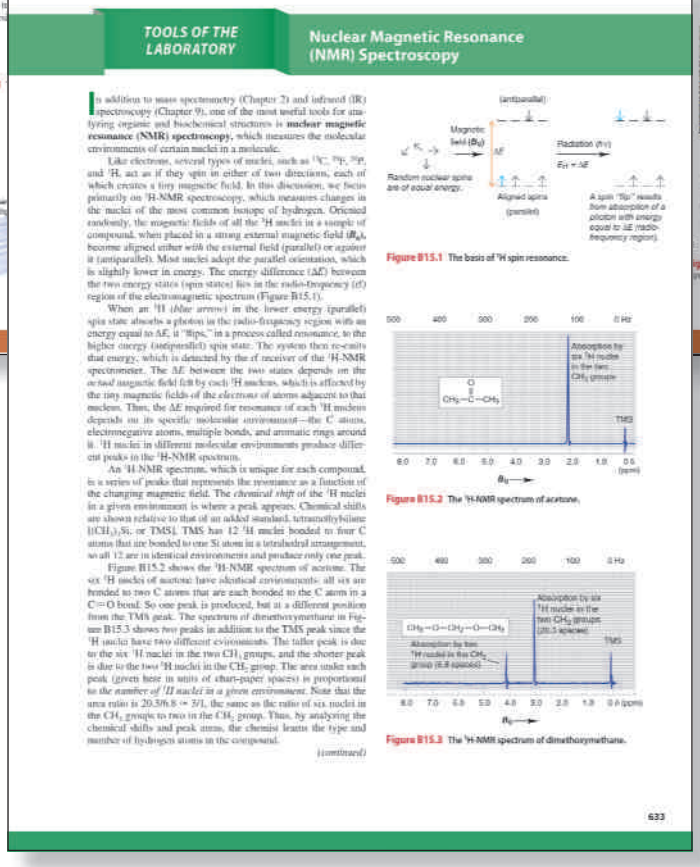
Water Treatment Plants

Water Softening via Ion Exchange

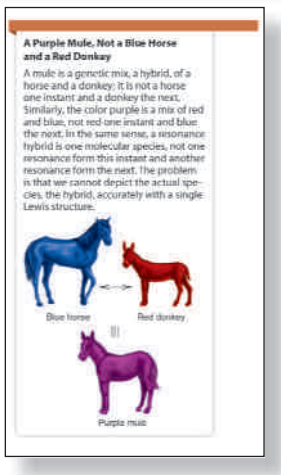
Membrane Processes and Reverse Osmosis

Wastewater Treatment

Problems


TOOLS OF THE LABORATORY

Nuclear Magnetic Resonance (NMR) Spectroscopy


A Purple Mule, Not a Blue Horse and a Red Donkey

Reinforcing through Review and Practice

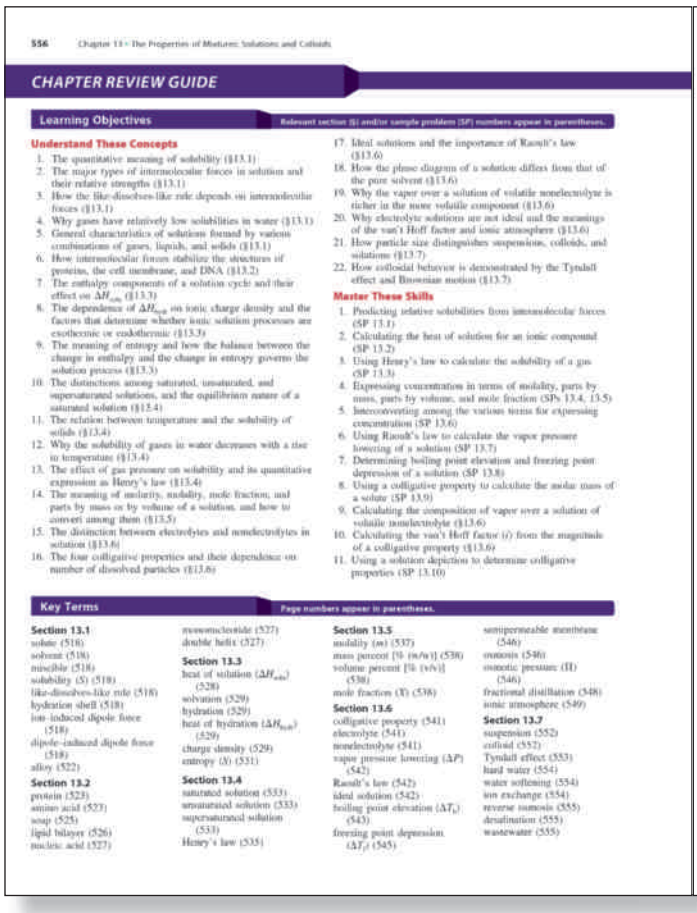
A favorite feature, the section summaries that conclude every section restate the major ideas concisely and immediately (rather than postponing such review until the end of the chapter).

A rich catalog of study aids ends each chapter to help students review the content:

- **Learning Objectives,** with section and/or sample problem numbers, focus on the concepts to understand and the skills to master.
- **Key Terms,** boldfaced and defined within the chapter, are listed here by section (with page numbers), as well as being defined in the *Glossary.*
- **Key Equations and Relationships** are highlighted and numbered within the chapter and listed here with page numbers.
- **Brief Solutions to Follow-up Problems** triple the number of worked problems by providing multistep calculations at the end of the chapter, rather than just numerical answers at the back of the book.

Summary of Section 9.1

- Nearly all naturally occurring substances consist of atoms or ions bonded to others. Chemical bonding allows atoms to lower their energy.
- Ionic bonding occurs when metal atoms transfer electrons to nonmetal atoms, and the resulting ions attract each other and form an ionic solid.
- Covalent bonding is most common between nonmetal atoms and usually results in individual molecules. Bonded atoms share one or more pairs of electrons that are localized between them.
- Metallic bonding occurs when many metal atoms pool their valence electrons into a delocalized electron "sea" that holds all the atoms in the sample together.
- The Lewis electron-dot symbol of a main-group atom shows valence electrons as dots surrounding the element symbol.
- The octet rule says that, when bonding, many atoms lose, gain, or share electrons to attain a filled outer level of eight (or two) electrons.



556 Chapter 13 • The Properties of Mixtures: Solutions and Colloids

CHAPTER REVIEW GUIDE

Learning Objectives

Relevant section (§) and/or sample problem (SP) numbers appear in parentheses.

Understand These Concepts

1. The quantitative meaning of solubility (§13.1)
2. The major types of intermolecular forces in solution and their relative strengths (§13.1)
3. How the like-dissolves-like rule depends on intermolecular forces (§13.1)
4. Why gases have relatively low solubilities in water (§13.1)
5. General characteristics of solutions formed by various combinations of gases, liquids, and solids (§13.1)
6. How intermolecular forces stabilize the structures of proteins, the cell membrane, and DNA (§13.2)
7. The enthalpy components of a solution cycle and their effect on ΔH_{soln} (§13.3)
8. The dependence of ΔH_{hyd} on ionic charge density and the factors that determine whether ionic solution processes are exothermic or endothermic (§13.3)
9. The meaning of entropy and how the balance between the change in enthalpy and the change in entropy governs the solution process (§13.3)
10. The distinctions among saturated, unsaturated, and supersaturated solutions, and the equilibrium nature of a saturated solution (§13.4)
11. The relation between temperature and the solubility of solids (§13.4)
12. Why the solubility of gases in water decreases with a rise in temperature (§13.4)
13. The effect of gas pressure on solubility and its quantitative expression as Henry's law (§13.4)
14. The meaning of molarity, molality, mole fraction, and parts by mass or by volume of a solution, and how to convert among them (§13.5)
15. The distinction between electrolytes and nonelectrolytes in solution (§13.6)
16. The four colligative properties and their dependence on number of dissolved particles (§13.6)
17. Ideal solutions and the importance of Raoult's law (§13.6)
18. How the phase diagram of a solution differs from that of the pure solvent (§13.6)
19. Why the vapor over a solution of volatile nonelectrolyte is richer in the more volatile component (§13.6)
20. Why electrolyte solutions are not ideal and the meanings of the van't Hoff factor and ionic atmosphere (§13.6)
21. How particle size distinguishes suspensions, colloids, and solutions (§13.7)
22. How colloidal behavior is demonstrated by the Tyndall effect and Brownian motion (§13.7)

Master These Skills

1. Predicting relative solubilities from intermolecular forces (SP 13.1)
2. Calculating the heat of solution for an ionic compound (SP 13.2)
3. Using Henry's law to calculate the solubility of a gas (SP 13.3)
4. Expressing concentration in terms of molality, parts by mass, parts by volume, and mole fraction (SPs 13.4, 13.5)
5. Interconverting among the various terms for expressing concentration (SP 13.6)
6. Using Raoult's law to calculate the vapor pressure lowering of a solution (SP 13.7)
7. Determining boiling point elevation and freezing point depression of a solution (SP 13.8)
8. Using a colligative property to calculate the molar mass of a solute (SP 13.9)
9. Calculating the composition of vapor over a solution of volatile nonelectrolyte (§13.6)
10. Calculating the van't Hoff factor (i) from the magnitude of a colligative property (§13.6)
11. Using a solution depiction to determine colligative properties (SP 13.10)

Key Terms

Page numbers appear in parentheses.

Section 13.1
solute (518)
solvent (518)
miscible (518)
solubility (*S*) (518)
like-dissolves-like rule (518)
hydration shell (518)
ion–induced dipole force (518)
dipole–induced dipole force (518)
alloy (522)

Section 13.2
protein (523)
amino acid (523)
soap (525)
lipid bilayer (526)
nucleic acid (527)
nucleoside (527)
double helix (527)

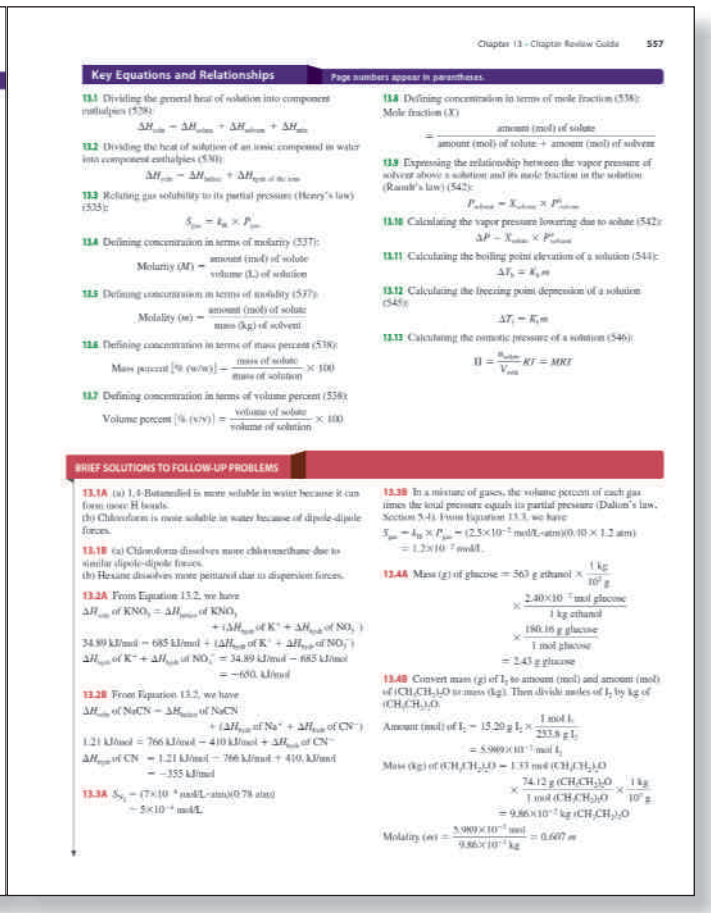
Section 13.3
heat of solution (ΔH_{soln}) (528)
solvation (529)
hydration (529)
heat of hydration (ΔH_{hyd}) (529)
charge density (529)
entropy (*S*) (531)

Section 13.4
saturated solution (533)
unsaturated solution (533)
supersaturated solution (533)
Henry's law (535)

Section 13.5
molality (*m*) (537)
mass percent [% (m/m)] (538)
volume percent [% (v/v)] (538)
mole fraction (*X*) (538)

Section 13.6
colligative property (541)
electrolyte (541)
nonelectrolyte (541)
vapor pressure lowering (ΔP) (542)
Raoult's law (542)
ideal solution (542)
boiling point elevation (ΔT_b) (543)
freezing point depression (ΔT_f) (545)
semipermeable membrane (546)
osmosis (546)
osmotic pressure (Π) (546)
fractional distillation (548)
ionic atmosphere (549)

Section 13.7
suspension (552)
colloid (552)
Tyndall effect (553)
hard water (554)
water softening (554)
ion exchange (554)
reverse osmosis (555)
desalination (555)
wastewater (555)



Chapter 13 • Chapter Review Guide 557

Key Equations and Relationships

Page numbers appear in parentheses.

13.1 Dividing the general heat of solution into component enthalpies (528):

$$\Delta H_{soln} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix}$$

13.2 Dividing the heat of solution of an ionic compound in water into component enthalpies (530):

$$\Delta H_{soln} = \Delta H_{lattice} + \Delta H_{hyd\ of\ the\ ions}$$

13.3 Relating gas solubility to its partial pressure (Henry's law) (535):

$$S_{gas} = k_H \times P_{gas}$$

13.4 Defining concentration in terms of molarity (537):

$$\text{Molarity } (M) = \frac{\text{amount (mol) of solute}}{\text{volume (L) of solution}}$$

13.5 Defining concentration in terms of molality (537):

$$\text{Molality } (m) = \frac{\text{amount (mol) of solute}}{\text{mass (kg) of solvent}}$$

13.6 Defining concentration in terms of mass percent (538):

$$\text{Mass percent [\% (w/w)]} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

13.7 Defining concentration in terms of volume percent (538):

$$\text{Volume percent [\% (v/v)]} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

13.8 Defining concentration in terms of mole fraction (538): Mole fraction (X)

$$= \frac{\text{amount (mol) of solute}}{\text{amount (mol) of solute + amount (mol) of solvent}}$$

13.9 Expressing the relationship between the vapor pressure of solvent above a solution and its mole fraction in the solution (Raoult's law) (542):

$$P_{solvent} = X_{solvent} \times P^{\circ}_{solvent}$$

13.10 Calculating the vapor pressure lowering due to solute (542):

$$\Delta P = X_{solute} \times P^{\circ}_{solvent}$$

13.11 Calculating the boiling point elevation of a solution (544):

$$\Delta T_b = K_b m$$

13.12 Calculating the freezing point depression of a solution (545):

$$\Delta T_f = K_f m$$

13.13 Calculating the osmotic pressure of a solution (546):

$$\Pi = \frac{n_{solute}}{V_{soln}} RT = MRT$$

BRIEF SOLUTIONS TO FOLLOW-UP PROBLEMS

13.1A (a) 1,4-Butanediol is more soluble in water because it can form more H bonds.
(b) Chloroform is more soluble in water because of dipole-dipole forces.

13.1B (a) Chloroform dissolves more chloromethane due to similar dipole-dipole forces.
(b) Hexane dissolves more pentanol due to dispersion forces.

13.2A From Equation 13.2, we have

$$\Delta H_{soln} \text{ of } KNO_3 = \Delta H_{lattice} \text{ of } KNO_3 + (\Delta H_{hyd} \text{ of } K^+ + \Delta H_{hyd} \text{ of } NO_3^-)$$
$$34.89 \text{ kJ/mol} = 685 \text{ kJ/mol} + (\Delta H_{hyd} \text{ of } K^+ + \Delta H_{hyd} \text{ of } NO_3^-)$$
$$\Delta H_{hyd} \text{ of } K^+ + \Delta H_{hyd} \text{ of } NO_3^- = 34.89 \text{ kJ/mol} - 685 \text{ kJ/mol} = -650. \text{ kJ/mol}$$

13.2B From Equation 13.2, we have

$$\Delta H_{soln} \text{ of NaCN} = \Delta H_{lattice} \text{ of NaCN} + (\Delta H_{hyd} \text{ of } Na^+ + \Delta H_{hyd} \text{ of } CN^-)$$
$$1.21 \text{ kJ/mol} = 766 \text{ kJ/mol} - 410 \text{ kJ/mol} + \Delta H_{hyd} \text{ of } CN^-$$
$$\Delta H_{hyd} \text{ of CN} = 1.21 \text{ kJ/mol} - 766 \text{ kJ/mol} + 410. \text{ kJ/mol} = -355 \text{ kJ/mol}$$

13.3A $S_{O_2} = (7\times10^{-4} \text{ mol/L-atm})(0.78 \text{ atm}) = 5\times10^{-4} \text{ mol/L}$

13.3B In a mixture of gases, the volume percent of each gas times the total pressure equals its partial pressure (Dalton's law, Section 5.4). From Equation 13.3, we have

$$S_{gas} = k_H \times P_{gas} = (2.5\times10^{-5} \text{ mol/L-atm})(0.10 \times 1.2 \text{ atm}) = 1.2\times10^{-5} \text{ mol/L}$$

13.4A Mass (g) of glucose = 563 g ethanol $\times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{2.40\times10^{-2} \text{ mol glucose}}{1 \text{ kg ethanol}} \times \frac{180.16 \text{ g glucose}}{1 \text{ mol glucose}} = 2.43 \text{ g glucose}$

13.4B Convert mass (g) of I_2 to amount (mol) and amount (mol) of $(CH_3CH_2)_2O$ to mass (kg). Then divide moles of I_2 by kg of $(CH_3CH_2)_2O$.

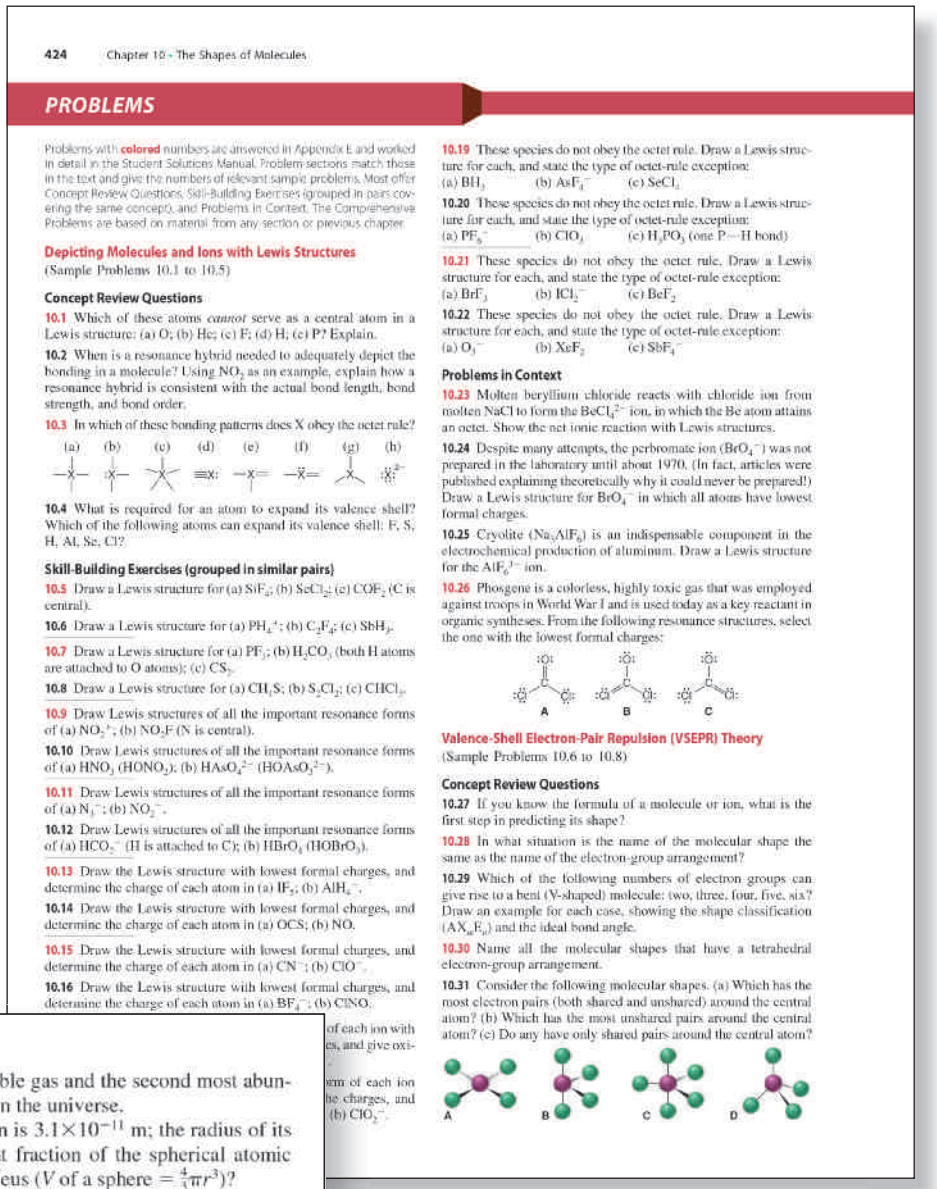
$$\text{Amount (mol) of } I_2 = 15.20 \text{ g } I_2 \times \frac{1 \text{ mol } I_2}{253.8 \text{ g } I_2} = 5.989\times10^{-2} \text{ mol } I_2$$

$$\text{Mass (kg) of } (CH_3CH_2)_2O = 1.33 \text{ mol } (CH_3CH_2)_2O \times \frac{74.12 \text{ g } (CH_3CH_2)_2O}{1 \text{ mol } (CH_3CH_2)_2O} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 9.86\times10^{-2} \text{ kg } (CH_3CH_2)_2O$$

$$\text{Molality } (m) = \frac{5.989\times10^{-2} \text{ mol}}{9.86\times10^{-2} \text{ kg}} = 0.607 \, m$$

Finally, an exceptionally large number of qualitative, quantitative, and molecular-scene problems end each chapter. Four types of problems are presented—three by chapter section, with comprehensive problems following:

- **Concept Review Questions** test qualitative understanding of key ideas.
- **Skill-Building Exercises** are grouped in similar pairs, with one of each pair answered in the back of the book. A group of similar exercises may begin with explicit steps and increase in difficulty, gradually weaning the student from the need for multistep directions.
- **Problems in Context** apply the skills learned in the skill-building exercises to interesting scenarios, including realistic examples dealing with industry, medicine, and the environment.
- **Comprehensive Problems,** mostly based on realistic applications, are more challenging and rely on material from any section of the current chapter or any previous chapter.



424 Chapter 10 • The Shapes of Molecules

PROBLEMS

Problems with **colored** numbers are answered in Appendix E and worked in detail in the Student Solutions Manual. Problem sections match those in the text and give the numbers of relevant sample problems. Most offer Concept Review Questions, Skill-Building Exercises (grouped in pairs covering the same concept), and Problems in Context. The Comprehensive Problems are based on material from any section or previous chapter.

Depicting Molecules and Ions with Lewis Structures

(Sample Problems 10.1 to 10.5)

Concept Review Questions

10.1 Which of these atoms *cannot* serve as a central atom in a Lewis structure: (a) O; (b) He; (c) F; (d) H; (e) P? Explain.

10.2 When is a resonance hybrid needed to adequately depict the bonding in a molecule? Using NO_2 as an example, explain how a resonance hybrid is consistent with the actual bond length, bond strength, and bond order.

10.3 In which of these bonding patterns does X obey the octet rule?

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

10.4 What is required for an atom to expand its valence shell? Which of the following atoms can expand its valence shell: F, S, H, Al, Se, Cl?

Skill-Building Exercises (grouped in similar pairs)

10.5 Draw a Lewis structure for (a) SiF_4; (b) $SeCl_2$; (c) COF_2 (C is central).

10.6 Draw a Lewis structure for (a) PH_4^+; (b) C_2F_4; (c) SbH_3.

10.7 Draw a Lewis structure for (a) PF_3; (b) H_2CO_3 (both H atoms are attached to O atoms); (c) CS_2.

10.8 Draw a Lewis structure for (a) CH_4S; (b) S_2Cl_2; (c) $CHCl_3$.

10.9 Draw Lewis structures of all the important resonance forms of (a) NO_2^+; (b) NO_2F (N is central).

10.10 Draw Lewis structures of all the important resonance forms of (a) HNO_3 ($HONO_2$); (b) $HAsO_4^{2-}$ ($HOAsO_3^{2-}$).

10.11 Draw Lewis structures of all the important resonance forms of (a) N_3^-; (b) NO_2^-.

10.12 Draw Lewis structures of all the important resonance forms of (a) HCO_2^- (H is attached to C); (b) $HBrO_4$ ($HOBrO_3$).

10.13 Draw the Lewis structure with lowest formal charges, and determine the charge of each atom in (a) IF_5; (b) AlH_4^-.

10.14 Draw the Lewis structure with lowest formal charges, and determine the charge of each atom in (a) OCS; (b) NO.

10.15 Draw the Lewis structure with lowest formal charges, and determine the charge of each atom in (a) CN^-; (b) ClO^-.

10.16 Draw the Lewis structure with lowest formal charges, and determine the charge of each atom in (a) BF_4^-; (b) ClNO.

10.19 These species do not obey the octet rule. Draw a Lewis structure for each, and state the type of octet-rule exception: (a) BH_3 (b) AsF_3^- (c) $SeCl_4$

10.20 These species do not obey the octet rule. Draw a Lewis structure for each, and state the type of octet-rule exception: (a) PF_5 (b) ClO_3 (c) H_3PO_3 (one P—H bond)

10.21 These species do not obey the octet rule. Draw a Lewis structure for each, and state the type of octet-rule exception: (a) BrF_3 (b) ICl_2^- (c) BeF_2

10.22 These species do not obey the octet rule. Draw a Lewis structure for each, and state the type of octet-rule exception: (a) O_3^- (b) XeF_2 (c) SbF_4^-

Problems in Context

10.23 Molten beryllium chloride reacts with chloride ion from molten NaCl to form the $BeCl_4^{2-}$ ion, in which the Be atom attains an octet. Show the net ionic reaction with Lewis structures.

10.24 Despite many attempts, the perbromate ion (BrO_4^-) was not prepared in the laboratory until about 1970. (In fact, articles were published explaining theoretically why it could never be prepared!) Draw a Lewis structure for BrO_4^- in which all atoms have lowest formal charges.

10.25 Cryolite (Na_3AlF_6) is an indispensable component in the electrochemical production of aluminum. Draw a Lewis structure for the AlF_6^{3-} ion.

10.26 Phosgene is a colorless, highly toxic gas that was employed against troops in World War I and is used today as a key reactant in organic syntheses. From the following resonance structures, select the one with the lowest formal charges:

A B C

Valence-Shell Electron-Pair Repulsion (VSEPR) Theory

(Sample Problems 10.6 to 10.8)

Concept Review Questions

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

10.28 In what situation is the name of the molecular shape the same as the name of the electron-group arrangement?

10.29 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 for each case, showing the shape classification (AX_nE_m) and the ideal bond angle.

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

10.31 Consider the following molecular shapes. (a) Which has the most electron pairs (both shared and unshared) around the central atom? (b) Which has the most unshared pairs around the central atom? (c) Do any have only shared pairs around the central atom?

A B C D

Comprehensive Problems

2.119 Helium is the lightest noble gas and the second most abundant element (after hydrogen) in the universe.
(a) The radius of a helium atom is 3.1×10^{-11} m; the radius of its nucleus is 2.5×10^{-15} m. What fraction of the spherical atomic volume is occupied by the nucleus (V of a sphere $=\frac{4}{3}\pi r^3$)?
(b) The mass of a helium-4 atom is 6.64648×10^{-24} g, and each of its two electrons has a mass of 9.10939×10^{-28} g. What fraction of this atom's mass is contributed by its nucleus?

2.120 From the following ions (with their radii in pm), choose the pair that forms the strongest ionic bond and the pair that forms the weakest:

Ion:	Mg^{2+}	K^+	Rb^+	Ba^{2+}	Cl^-	O^{2-}	I^-
Radius:	72	138	152	135	181	140	220

2.121 Give the molecular mass of each compound depicted below, and provide a correct name for any that are named incorrectly.

(a) boron fluoride (Br, F) (b) monosulfur dichloride (S, Cl)
(c) phosphorus trichloride (P, Cl) (d) dinitride pentoxide (O, N)

OPTIMIZING THE TEXT

The modern chemistry student's learning experience is changing dramatically. To address the changes that students face, a modern text partnered with a suite of robust electronic tools must continue to evolve. With each edition, students and instructors alike have been involved in refining this text. From one-on-one interviews, focus groups, and symposia, as well as extensive chapter reviews and class tests of the previous edition, we learned that everyone praises the pioneering molecular art, the stepwise problem-solving approach, the abundant mix of qualitative, quantitative, and applied end-of-chapter problems, and the rigorous *and* student-friendly coverage of mainstream topics.

Global Changes to Every Chapter

Our revision for this edition has gone further than ever to optimize the text. We completed the distillation of the text and the annotation of the illustrations so appreciated in the previous edition, and created an inviting, easy-to-follow page design. But, when professors *and* students were asked what they wanted most in a new edition, the answer inevitably cited more good problems, so that became a major focus. We are delighted to introduce the seventh edition of *Chemistry: The Molecular Nature of Matter and Change,* which takes several major steps closer to perfecting its content and approach.

Learning ideas through focused writing and content presentation. Once again, every discussion has been revised to optimize clarity, readability, and the conciseness and directness of the presentation. The use of additional subheads, numbered (and titled) paragraphs, and bulleted (and titled) lists that was introduced in the sixth edition has been completed in the seventh.

Applying ideas with an enhanced problem-solving approach. The much admired—and copied—four-part problem-solving format (plan, solution, check, follow-up) is still used throughout, in both data-based *and* molecular-scene *Sample Problems*. But, many changes make the seventh edition a problem-solving "powerhouse." Each sample problem now includes ***two*** *Follow-up Problems:* as professors requested, the first closely matches the worked-out problem, so the student gains confidence, while the second varies a bit to test comprehension. As always, a thoroughly worked-out *Brief Solution* for each follow-up problem appears at the end of the chapter (rather than providing just a numerical answer in a distant end-of-book appendix, as is typical). As students requested, for more practice, each sample problem now lists *Some Similar Problems* within the end-of-chapter problem set. Moreover, some remaining pedagogic gaps have been filled with 22 *new* sample problems: thus, the seventh edition has over 250 sample problems and over 500 follow-up problems.

Re-learning ideas with annotated illustrations. The innovative three-level figures and other art that raised the bar for molecular visualization in chemistry textbooks is still present. Many existing figures have been revised and several new ones added to create an even better teaching tool. And, continuing the innovation of last edition, wherever appropriate, figure legends have been turned into simple captions and their content into clarifying annotations within the figures themselves.

Easier studying with attractive and functional page design and layout. A more open layout with three-dimensional accents engages students by focusing attention on section heads, sample problems, tables, and other important features, while maintaining clean margins. The orderly presentation fosters easier viewing and studying and allows the intimate placement of figures and tables in relation to the discussion.

Mastering the content with abundant end-of-chapter problem sets. With the more open design for improved readability, traditional and molecular-scene problems updated and revised, and many new problems added, these problem sets are more extensive than in most other texts. They provide students and teachers with abundant choices in a wide range of difficulty and real-life scenarios.

Content Changes to Individual Chapters

The major revision that created this seventh edition of *Chemistry* included key improvements to nearly every chapter:

- **Chapter 1** has been rearranged so that units are now discussed *before* the problem-solving approach and unit conversions are introduced. The chapter includes a *new sample problem* on converting units raised to a power.
- **Chapter 2** now clarifies the meaning of mass fraction and introduces IUPAC's new recommendations on atomic-mass ranges. It presents the periodic table updated with the latest atomic masses and includes a *new sample problem* on identifying an element from its Z value.
- **Chapter 3** includes more information in its road maps, and road maps in later chapters also have these enhancements. Sample problems on calculating mass percent of an element and the mass of an element have been carefully revised. The section on calculations for reactions in solution has been moved to Chapter 4.
- **Chapter 4** introduces many types of reactions in solution, so it was thoroughly revised to, more logically, include the

material on molarity and solution stoichiometry previously in Chapter 3. The table on solubility rules was revised, and a new table focuses on the reactions of strong versus weak acids in strong base. *Two new sample problems* show how to determine the amount of ions in solution and the amounts of reactants and products in a precipitation reaction. And two sample problems from the last edition were combined to show the logical relation of their material. Balancing redox reactions by the oxidation-number method was deleted, but balancing them by the half-reaction method is covered in the electrochemistry chapter (Chapter 21).

- **Chapter 5** includes *two new sample problems* that apply various combinations of the individual gas laws, and it provides a derivation of Graham's law.
- **Chapter 6** includes *a new sample problem* on calculating *PV* work.
- **Chapter 7** incorporates carefully revised atomic and continuous spectra throughout.
- **Chapter 8** contains a new table on changes in Z_{eff} within the sublevels of an atom.
- **Chapter 9** includes *a new sample problem* on predicting relative lattice energy and a revised figure on the properties of the covalent bond.
- **Chapter 10** has pedagogic improvements to several figures and expanded coverage in two sample problems.
- **Chapter 12** includes *two new sample problems,* one on the use of phase diagrams to predict phase changes and the other on determining the number of particles in a unit cell and the coordination number.
- **Chapter 13** presents *a new sample problem* on calculating an aqueous ionic heat of solution.
- **Chapter 14** incorporates in its unique Family Portraits all the updated atomic masses and newly synthesized elements that fill out the periodic table.
- **Chapter 16** includes revisions to two important figures and *two new sample problems,* one on rate laws and the molecularity of elementary steps and the other on intermediates and the correlation of rate laws and mechanism.
- **Chapter 17** contains *a new sample problem* on writing a reaction quotient from the balanced equation, and two important figures have been revised.
- **Chapter 18** has undergone major improvements. It has *two new sample problems,* one on calculating hydronium and hydroxide ion concentrations in strong acids and bases and the other on finding the percent dissociation of a weak acid. Several summarizing tables were revised to display reactions, and a key figure was revised. Also, the discussion was rearranged to present the material on acids in a clearer sequence.
- **Chapter 19** incorporates improvements to several key figures, as well as a new figure that summarizes the effects of added acid or base to buffer-component concentration and pH.
- **Chapter 20** has clearer discussions of measuring the change in entropy and of free energy and work, as well as *a new sample problem* on the relationship between ΔG° and K.
- **Chapter 21** includes *a new sample problem* on using $E^\circ_{\text{half-cell}}$ to find E°_{cell}, as well as much clearer discussions of the activity series of the metals, the electrolysis of aqueous salts, and the stoichiometry of electrolysis.
- **Chapter 23** has improvements to many figures as well as *a new sample problem* on finding the coordination number and ion charge in a coordination compound.
- **Chapter 24** provides *a new sample problem* on calculating the specific activity and decay constant of a radionuclide.

Innovative Topic and Chapter Presentation

While the topic sequence coincides with that used in most mainstream courses, built-in flexibility allows a wide range of differing course structures:

For courses that follow their own topic sequence, the general presentation, with its many section and subsection breaks and bulleted lists, allows topics to be rearranged, or even deleted, with minimal loss of continuity.

For courses that present several chapters, or topics within chapters, in different orders:

- Redox balancing by the oxidation-number method (formerly covered in Chapter 4) has been removed from the text, and the half-reaction method is covered with electrochemistry in Chapter 21, but it can easily be taught with Chapter 4.
- Gases (Chapter 5) can be covered in sequence to explore the mathematical modeling of physical behavior or, with no loss of continuity, just before liquids and solids (Chapter 12) to show the effects of intermolecular forces on the three states of matter.

For courses that want an atoms-first approach for some of the material, Chapters 7 through 13 move smoothly from quantum theory (7) through electron configuration (8), bonding models (9), molecular shape (10), VB and MO bonding theories (11), intermolecular forces in liquids and solids (12), and solutions (13). Immediate applications of these concepts appear in the discussions of periodic patterns in main-group chemistry (Chapter 14) and in the survey of organic chemistry (Chapter 15). Some instructors have also brought forward the coverage of transition elements and coordination compounds (23) as further applications of bonding concepts. (Of course, Chapters 14, 15, and 23 can just as easily remain in their more traditional placement later in the course.)

For courses that want biological/medical applications, many chapters highlight these topics, including the role of intermolecular forces in biomolecular structure (12), the

chemistry of polysaccharides, proteins, and nucleic acids (including protein synthesis, DNA replication, and DNA sequencing) (15), as well as introductions to enzyme catalysis (16), biochemical pathways (17), and trace elements in protein function (23).

For courses that want engineering applications of physical chemistry topics, Chapters 16 through 21 cover kinetics (16), equilibrium in gases (17), acids and bases (18), and aqueous ionic systems (19) and entropy and free energy (20) as they apply to electrochemical systems (21), all in preparation for coverage of the elements in geochemical cycles, metallurgy, and industry in Chapter 22.

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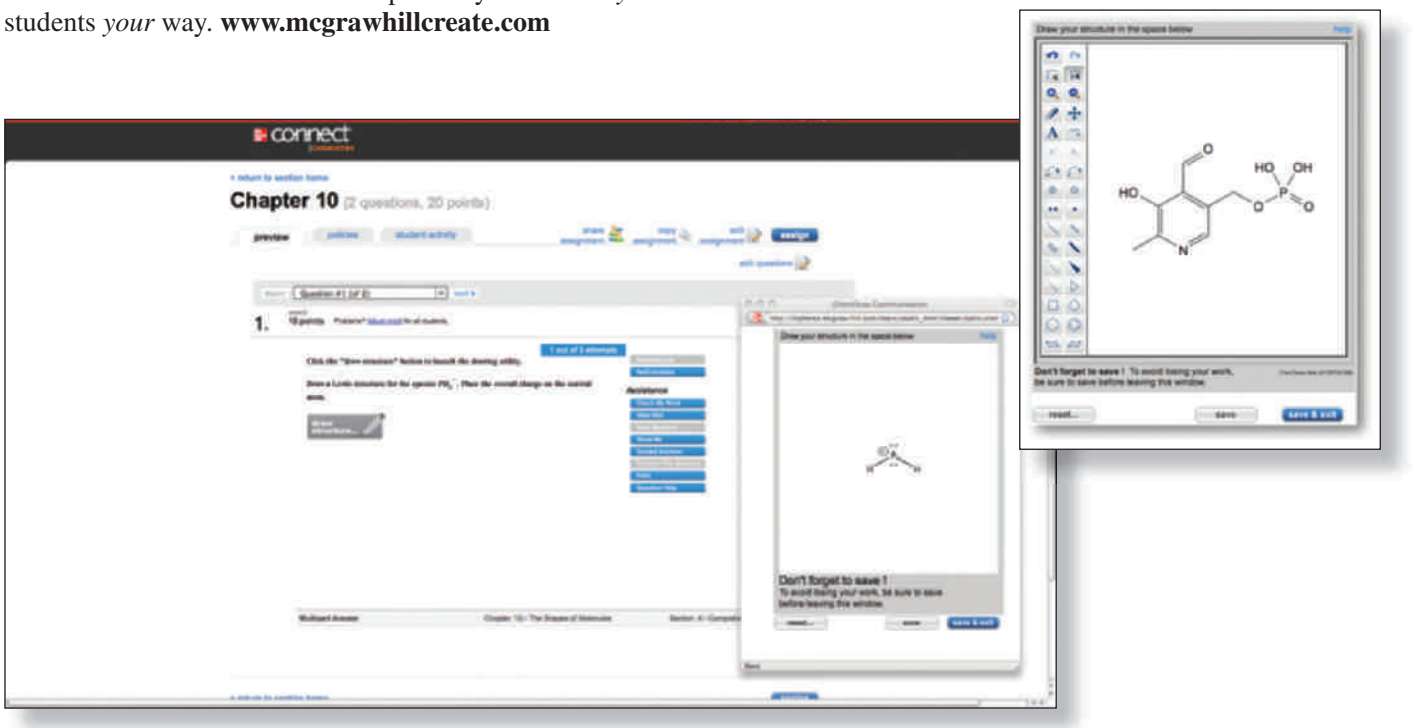
McGraw-Hill Create™ is another way to implement innovative chapter presentation. With Create, you can easily rearrange chapters, combine material from other content sources, and quickly upload content you have written, such as your course syllabus or teaching notes. Find the content you need in Create by searching through thousands of leading McGraw-Hill textbooks. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. Order a Create book, and you'll receive a complimentary print review copy in 3–5 business days or a complimentary electronic review copy (eComp) via e-mail in minutes. Go to www.mcgrawhillcreate.com today and register to experience how McGraw-Hill Create empowers you to teach *your* students *your* way. **www.mcgrawhillcreate.com**

LEARNING RESOURCES

Mc Graw Hill Education connect® CHEMISTRY

McGraw-Hill Connect® Chemistry provides online presentation, assignment, and assessment solutions. It connects your students with the tools and resources they'll need to achieve success. With Connect Chemistry, you can deliver assignments, quizzes, and tests online. A robust set of questions, problems, and interactive figures are presented and aligned with the textbook's learning goals. The integration of **ChemDraw by PerkinElmer,** the industry standard in chemical drawing software, allows students to create accurate chemical structures in their online homework assignments. As an instructor, you can edit existing questions and write entirely new problems. Track individual student performance—by question, assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard—and much more. **ConnectPlus Chemistry** provides students with all the advantages of Connect Chemistry, plus 24/7 online access to an eBook. This media-rich version of the book is available through the McGraw-Hill Connect platform and allows seamless integration of text, media, and assessments. To learn more, visit **www.mcgrawhillconnect.com.**



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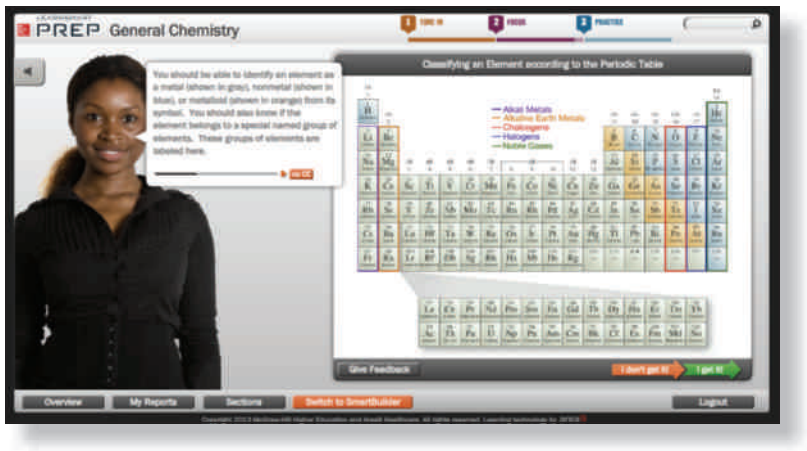


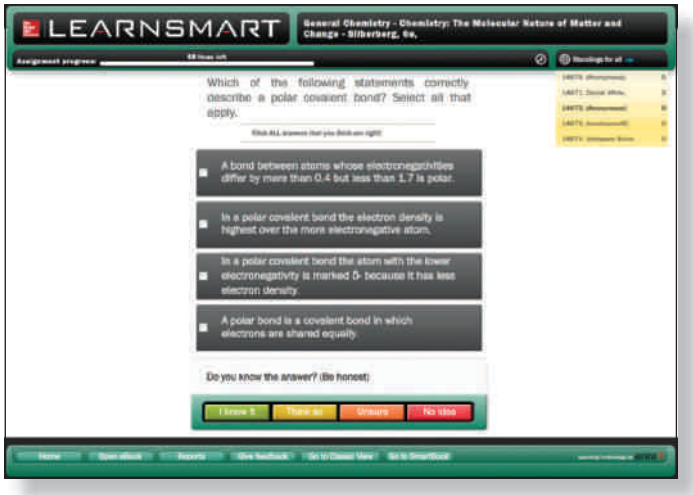
Fueled by LearnSmart—the most widely used and intelligent adaptive learning resource—**LearnSmart Prep** is designed to get students ready for a forthcoming course by quickly and effectively addressing prerequisite knowledge gaps that may cause problems down the road.

By distinguishing what students know from what they don't, and honing in on concepts they are most likely to forget, LearnSmart Prep maintains a continuously adapting learning path individualized for each student, and tailors content to focus on what the student needs to master in order to have a successful start in the new class.

This revolutionary technology is available only from McGraw-Hill Education and for hundreds of course areas, including general and organic chemistry, as part of the LearnSmart Advantage series.

LEARNSMART®

McGraw-Hill LearnSmart™ is available as a stand-alone product or as an integrated feature of McGraw-Hill Connect® Chemistry. It is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. This innovative study tool also has features that allow instructors to see exactly what students have accomplished and a built-in assessment tool for graded assignments. Visit the following site for a demonstration: **www.mhlearnsmart.com.**



SMARTBOOK™

Powered by the intelligent and adaptive LearnSmart engine, **SmartBook** is the first and only continuously adaptive reading experience available. Distinguishing what students know from what they don't, and honing in on concepts they are most likely to forget, SmartBook personalizes content for each of them. Reading is no longer a passive and linear experience but an engaging and dynamic one, in which students are more likely to master and retain important concepts, coming to class better prepared.

SmartBook includes powerful reports that identify specific topics and learning objectives students need to study. These valuable reports also provide instructors with insight into how students are progressing through textbook content and are useful for identifying class trends, focusing precious class time, providing personalized feedback to students, and tailoring assessment.

How does SmartBook work? Each SmartBook contains four components: Preview, Read, Practice, and Recharge. Starting with a preview of each chapter and key learning objectives, students read the material and are guided to topics on which they need the most practice based on their responses to a continuously adapting diagnostic. Reading and practice continue until SmartBook directs students to review—or recharge—important material they are most likely to forget to ensure concept mastery and retention.

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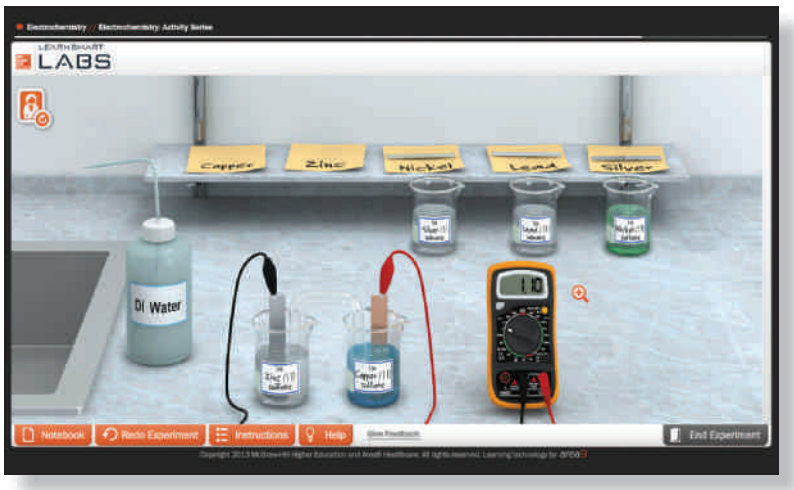
THE Virtual Lab Experience



Based on the same world-class, superbly adaptive technology as LearnSmart, **McGraw-Hill LearnSmart Labs** is a must-see, outcomes-based lab simulation. It assesses a student's knowledge and adaptively corrects deficiencies, allowing the student to learn faster and retain more knowledge with greater success.

First, a student's knowledge is adaptively leveled on core learning outcomes: Questioning reveals knowledge deficiencies that are corrected by the delivery of content that is conditional on a student's response. Then, a simulated lab experience requires the student to think and act like a scientist: Recording, interpreting, and analyzing data using simulated equipment found in labs and clinics. The student is allowed to make mistakes—a powerful part of the learning experience! A virtual coach provides subtle hints when needed, asks questions about the student's choices, and allows the student to reflect on and correct those mistakes. Whether your need is to overcome the logistical challenges of a traditional lab, provide better lab prep, improve student performance, or make your online experience one that rivals the real world, LearnSmart Labs accomplishes it all. Learn more at **www.mhlearnsmart.com.**

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Presentation Tools

Accessed from your textbook's Connect website, the presentation tools include McGraw-Hill–owned photos, artwork, animations, and other types of media that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials for classroom purposes. The visual resources in this collection include the following:

- **Art** Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. In addition, all files have been inserted into PowerPoint slides for ease of lecture preparation.
- **Photos** The photo collection contains digital files of photographs from the text, which can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text has been saved in electronic form for use in classroom presentations and/or materials.
- **Animations** Numerous full-color animations illustrating important processes are also provided. Harness the visual impact of concepts in motion by importing these files into classroom presentations or online course materials.

PowerPoint materials can also be accessed through your textbook's Connect website:

- **PowerPoint Lecture Outlines** Ready-made presentations that combine art and lecture notes are provided for each chapter of the text.
- **PowerPoint Slides** For instructors who prefer to create their lectures from scratch, all illustrations, photos, sample problems, and tables have been inserted into blank PowerPoint slides, arranged by chapter.

Computerized Test Bank

Prepared by Walter Orchard, Professor Emeritus of Tacoma Community College, over 2300 test questions that accompany *Chemistry: The Molecular Nature of Matter and Change* are available utilizing Brownstone's *Diploma* testing software. *Diploma's* software allows you to quickly create a customized test using McGraw-Hill's supplied questions or by writing your own. *Diploma* allows you to create your tests without an Internet connection—just download the software and question files directly to your computer.

Instructor's Solutions Manual

This supplement, prepared by MaryKay Orgill of the University of Nevada, Las Vegas, contains complete, worked-out solutions for *all* the end-of-chapter problems in the text. It can be found within the Instructors' Resources, on the Connect website.

Cooperative Chemistry Laboratory Manual

Prepared by Melanie Cooper of Clemson University, this innovative manual features open-ended problems designed to simulate experience in a research lab. Working in groups, students investigate one problem over a period of several weeks, so they might complete three or four projects during the semester, rather than one preprogrammed experiment per class. The emphasis is on experimental design, analytic problem solving, and communication.

Student Study Guide

This valuable study guide, prepared by Libby Bent Weberg, is designed to help students recognize learning style; understand how to read, classify, and create a plan for solving a problem; and practice problem-solving skills. For each section of each chapter, the guide provides study objectives and a summary of the corresponding text. Following the summary are sample problems with detailed solutions. Each chapter has true-false questions and a self-test, with all answers provided at the end of the chapter.

Student Solutions Manual

This supplement, prepared by MaryKay Orgill of the University of Nevada, Las Vegas, contains detailed solutions and explanations for all problems in the main text that have colored numbers.

Animations for MP3/iPod

A number of animations are available for downloading to an MP3 player or iPod through the textbook's Connect website.