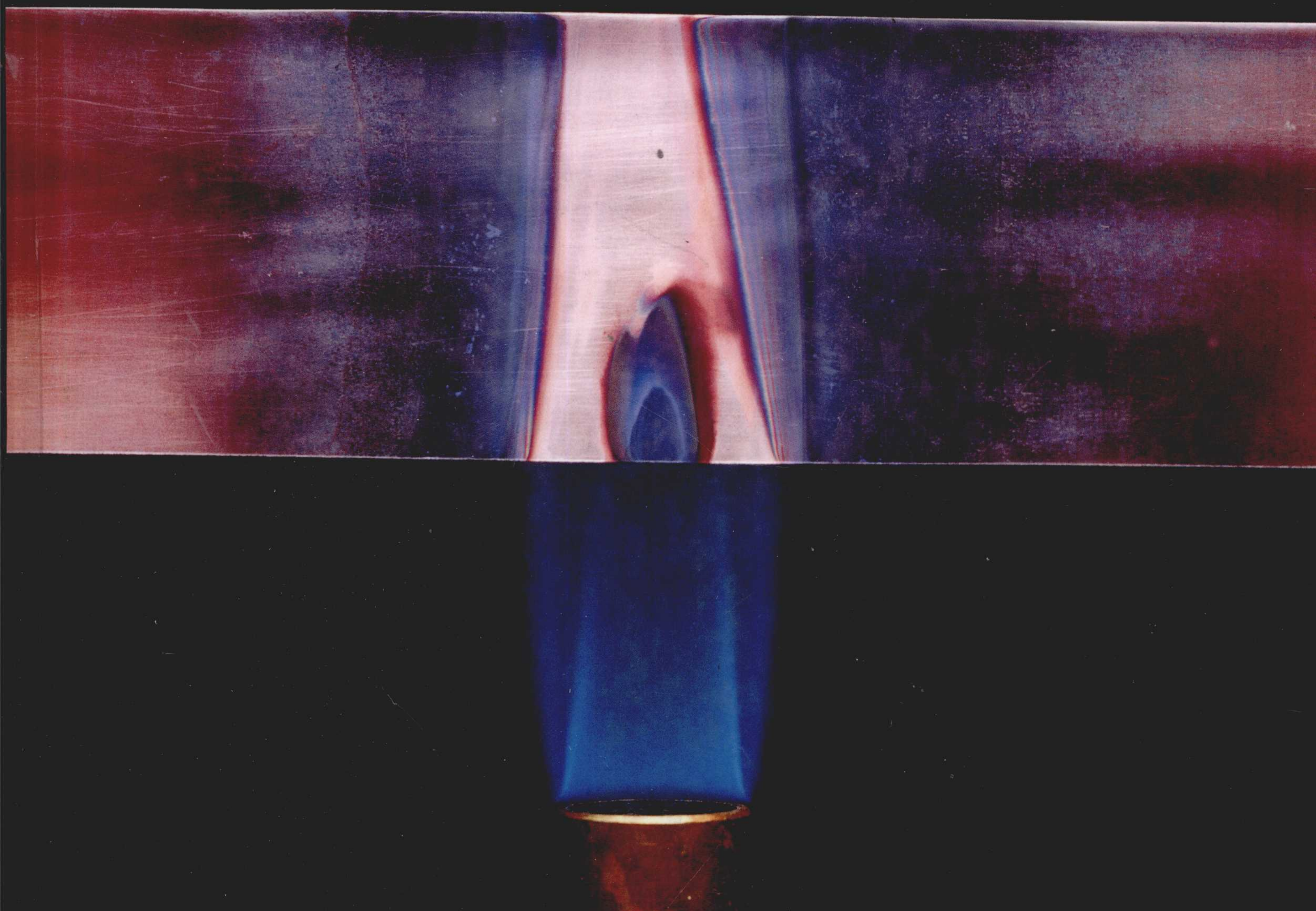
# GENERAL CHEMISTRY

3rd Edition



UMLAND BELLAMA

# General Chemistry

**THIRD EDITION**

**Jean B. Umland**

*University of Houston—Downtown*

**Jon M. Bellama**

*University of Maryland—College Park*

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The cover photo shows a strip of copper in the flame of a laboratory burner. In the reducing portion of the flame (blue cone), the copper oxide coating on the strip has been reduced to metallic copper. In the oxidizing portion of the flame outside the blue cone, a film of copper oxides has formed on the surface of the copper.



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*To students,*
*both those whom I have taught personally*
*and those who have used and will use this book.*

J.B.U.

*To my parents, Edey J. and Jane I. Bellama,*
*who first created an environment of encouragement*
*of intellectual pursuits,*
*and to my wife, Elaine E. Bellama,*
*who with her love has created an atmosphere*
*in which my love of knowledge has come to fruition.*

J.M.B.

# About the Authors

JEAN B. UMLAND is a graduate of Swarthmore College and obtained her Ph.D. from the University of Wisconsin–Madison. Although her degree is in organic chemistry, she took all the course work required for a doctorate in physical chemistry, and her thesis research could equally well have been classified as physical chemistry. She began her teaching career at Mount Holyoke College, and also taught at Union College, Cranford, New Jersey, a two-year community college, before moving to the University of Houston–Downtown in 1975. She has worked in industry for American Cyanamid Company and Exxon Research and Engineering. Dr. Umland has just begun her fourth term on the First-Term General Chemistry Committee of the Examinations Institute of the American Chemical Society Division of Chemical Education. She served on the Scientific Advisory Committee for the new Welch Chemistry Hall at the Houston Museum of Natural Science, which opened in the Fall of 1993. The first edition of this book was used as a reference by the museum staff who prepared the exhibits, and was also used to train docents. In 1994, Dr. Umland received the Teaching Award at the University of Houston–Downtown and an Enron Teaching Excellence Award.

JON M. BELLAMA is a graduate of Allegheny College, Meadville, Pennsylvania, and obtained his Ph.D. in inorganic chemistry from the University of Pennsylvania. During his tenure at the University of Maryland–College Park he has served as director of the general chemistry program and as University of Maryland site director for the Institute of Chemical Education for the training of both pre-college chemistry and science teachers. Dr. Bellama serves as a faculty consultant to the Advanced Placement Program in chemistry of the Educational Testing Service, and is known for his demonstration lectures and for incorporating cooperative learning techniques into chemistry courses. He has received a variety of teaching awards including the 1991 Maryland Commission of Higher Education statewide award for innovation in teaching. Dr. Bellama was a Senator J.W. Fulbright scholar in Czechoslovakia in 1991–92 and has written or edited several research monographs on carbon-functional organosilicon chemistry, metals and organometals in the aquatic environment, and two-dimensional nuclear magnetic resonance spectroscopy.

# Preface

## TO STUDENTS

This book has been written to help you learn chemistry. Chemistry is one of the most useful subjects you will ever study. Of course, we're prejudiced, but we also think that it is one of the most interesting, and hope that you will come to think so too.

Chemistry is useful because it is central to the other sciences and to engineering as well as to life itself. In addition, your study of chemistry should help you to develop a logical approach to solving problems that is applicable to all kinds of problems, not just chemical problems.

As you begin, take a few minutes to get acquainted with this book. On the endpapers inside the front cover and on the last leaf are tables of information that you will find useful, including a listing of "Where to find it" that gives the numbers of the pages where important information may be found. As usual, the table of contents is at the front and the index at the back. Each chapter begins with a chapter outline and a paragraph or two telling about the subject of the chapter. Then there are brief discussions of why the material in the chapter is important to you, and what you already know about the subject. You will probably be surprised to learn how much you do already know about chemistry from your everyday life, even if this is your first formal chemistry course. The main part of the chapter helps you to build on what you already know. The early sections usually include examples and discussions of chemical properties and behavior that will help you understand the theories presented later in the chapter.

Throughout the chapters, you will find *drawings*, *photographs*, and *graphs* that illustrate the material being discussed in the text. Study these and their captions carefully because they relate directly to the concepts you are learning. You may see some of the reactions again in lab.

*Marginal notes* without logos are used to present related information without interrupting the flow of the discussion. A key to the logos used for marginal notes is at the left.

*Learning hints—often a reminder of related material or a main idea.*

*References to a related module of the Discover Chemistry CD-ROM in the pocket inside the back cover.*

*Examples of ways to check your work.*

*Safety notes concerning both everyday life and chemistry laboratories.*

Besides building on what you know, another main theme of this text is the need for a thoughtful, logical approach to problem-solving. The book provides you with lots of assistance in developing your problem-solving skills. In each chapter, many *Sample Problems* demonstrate the use of each important concept or skill, using step-by-step explanations; *Practice Problems* let you check your understanding as you go along.

The *Summary* at the end of each chapter resembles a glossary in narrative form and gives the terms a meaning in context. Use it for a general review of the chapter content. If you can't remember the meaning of a term defined in an earlier chapter, use the index at the back of the book to find the definition. Seeing the term defined in context will help fix it in your mind.

The *Additional Practice Problems* are similar to the Practice Problems in the chapter. Try to work them without referring to the book. If you get stuck, look at the end of a problem for the section number (in parentheses) to which the problem is related; then restudy that section.

The *Stop and Test Yourself* questions are multiple-choice questions covering the basic skills and concepts in the chapter. Check your answers in Appendix H before going on to the higher-level problems that follow.

The *Putting Things Together* problems require you to combine skills from more than one section of the chapter and from different chapters.

The *Applications* problems deal with real-world applications of chemistry. These problems challenge you to demonstrate your mastery of chemical concepts and problem-solving skills.

Answers to the blue-numbered problems are available in Appendix H. Other appendices help you learn chemical nomenclature, review mathematics, and give you data you will need to solve problems. Solutions to the problems with blue numbers are in the *Student Solutions Manual*. Answers and solutions to the problems with **black** numbers may be available to you if your instructor wants you to have them. Answers and solutions to problems with red numbers are on the book's web site. Also available at the web site are practice quizzes and related links to topics discussed in each chapter.

## Advice on Studying

**1.** Find other students who are in your class to study with.

**2.** Schedule a regular time to study each day. Don't wait until the week before an exam to begin studying. The athletes on your favorite team practice regularly; they do *not* stay up all night the night before the big game. In chemistry, explanations are usually based on concepts and skills learned previously; don't let yourself get behind.

**3.** Do the assignments before coming to class. Read slowly and carefully. Try to understand, not memorize. (However, some memorization is necessary; you cannot learn to think without knowing something to think about. Use flash cards for memorization.) Make sure you understand the worked-out examples, and do the in-chapter problems and check your answers to them in Appendix H as you go along. (The answers are in the appendix so that you don't see them too soon accidentally, and to help you resist the temptation to peek.) Write down any questions you have so you don't forget to ask them when you get to class.

**4.** After each class, review what you have just learned before beginning the next assignment.

**5.** Pay careful attention to vocabulary. An important part of a first course in any subject is learning the meaning of the terms used in the field (which, unfortunately, do not always mean the same thing they do in everyday life or in other fields). In this book, new terms are in **boldface type** and are defined (in *italics*) and explained as simply and accurately as possible. Most are also included in the summary at the end of the chapter. If you do not remember the meaning of a term when you meet it again later, use the index to find the definition. The index also includes references to other places where the term is used, which may be helpful in reviewing. If you come across unfamiliar words, look up their meaning in a dictionary.

**6.** If the amount of material to be learned seems overwhelming, use the first chapter of the Study Guide to learn how to organize it. Different people have different learning styles so a number of different methods of organization are described using examples from the first chapters of this book. Choose the ones that suit *you*.

**7.** If you are having difficulty, *use* the help that's available—your instructor's and teaching assistant's office hours, for example. Many colleges and universities also have computer programs, videodiscs, videotapes, CD-ROMs and other materials to assist you, as well as services such as reading and math labs, in addition to other software that your instructor may make available to you.

**8.** The *Discover Chemistry* CD-ROM that comes with this text offers additional information on most topics as well as a wealth of interactive practice problems that help you visualize difficult concepts and hone your problem-solving skills. in the margin identifies where text-related material can be found on the CD-ROM. A subscription to InfoTrac® College Edition also comes with the text and provides full articles from numerous chemistry and general science periodicals.

In writing this book, we have done our best to make chemistry both understandable and interesting. Please let us know where we have succeeded and where we have failed so that we can do better in the fourth edition. Good luck!

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# TO INSTRUCTORS

## Audience

This book is intended for a full-year general chemistry course for pre-engineering students, pre-health profession students, and science majors, including chemistry majors. It assumes that students know how to solve basic algebraic equations; however, no previous study of chemistry or physics is assumed.

In our experience, most students are studying general chemistry for two reasons: (1) to learn the chemistry needed for their other courses and future professions; (2) to learn how to think scientifically. The second goal is often unconscious but is no less important than the first. These goals have influenced our overall approach, as well as many particular aspects of this book.

## Approach

For students to learn to think scientifically, they must first have something to think about; therefore, in this text, descriptive chemistry and theory are integrated. Reactions, which we believe are the heart of chemistry, are introduced in Chapter 1, and are the subject of much of Chapters 4, 8, 11, and 21. Throughout the book marginal notes and footnotes, colored photographs, Related Topic boxes, and Applications problems supply a wealth of facts about chemicals and chemical reactions. Both important inorganic compounds and common organic compounds are used as examples, and applications include astronomy, biochemistry, biology, environmental chemistry, geology, industrial chemistry and materials science, as well as everyday life. In the last four chapters, where the descriptive chemistry of both inorganic and organic compounds is the main focus, we have tried to pull together the material from earlier chapters as much as possible. Students only master material by meeting it several times in different contexts.

## Readability

To make the material as easy as possible to understand, definitions and explanations are written in familiar words: "make easier" rather than "facilitate," for instance. Transitions between topics are smooth. The last paragraph of Section 8.4 on p. 278 is an example. Also, more detail is often provided than in other texts. For example, most texts simply list rules about the number of significant figures; this text explains where the rules come from. We find that students who understand the rules are more willing and better able to follow them. We think that one of students' major problems in understanding chemistry is their lack of information that authors and instructors assume is common knowledge. In the writing and in the presentation of problem-solving, we are careful not to make assumptions or to leave out or combine steps. Just as a stranger needs more detailed directions than someone who is familiar with a town, beginning students need more details to understand chemical concepts than people trained in the field.

## What's New in the Third Edition

In revising the text for its third edition, our major goal has been to build on existing strengths and to respond to the many helpful suggestions made by instructors and students who have used the first two editions. After reading the detailed comments provided by the reviewers of the second edition, we carefully went over every line of the entire book correcting the seemingly inevitable mistakes, fine-tuning some parts and completely rewriting others for greater clarity. In addition, we changed the positions of some topics, and all information was updated where appropriate. The more extensive changes that were made are noted in the Table of Contents of the Annotated Instructor's Edition.

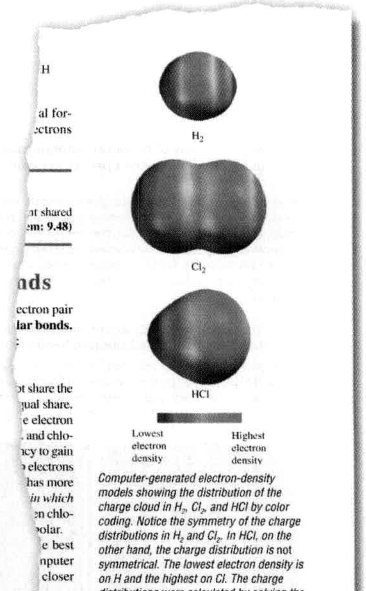
Users of the text have consistently praised its in-chapter and end-of-chapter pedagogy, and we have built upon this solid base in the present edition. Each in-chapter Practice Problem now references a related Additional Practice Problem at the end of the chapter, creating paired problems for all basic skills and concepts. In addition, we have included many more Additional Practice Problems in this edition. Some of these problems (noted by red numbers) now come with answers and solutions available to students via the Umland/Bellama student web site (http://www.brookscole.com/umland.html).

A goal from the first edition has been to help students develop a strong conceptual understanding of the material. Beginning with the second edition and extended with this third edition, we have included numerous problems and exercises that challenge students to translate their understanding of the mass behavior represented symbolically by chemical equations into an understanding of what is happening at the molecular level.

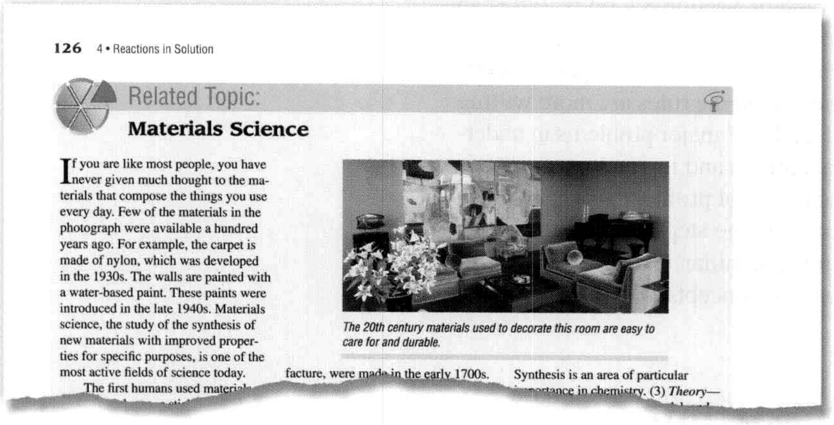
Conceptual understanding is just one part of the larger need to process new information and assess it in light of what is already known. Recently, the ability to read and think critically has become even more important with the explosion of information (and sometimes misinformation) available to students on the World Wide Web. With this in mind, we have included a new type of problem, entitled What's Wrong?, at the end of each chapter as an opportunity to practice this skill. These problems ask students to find and correct mistakes in material previously published in books, magazines, newspapers, or on the Web, or often written as answers to test questions.

Molecular models have been an integral part of the text's art program since the first edition, and in this edition we have introduced the use of **electron-density models** as an alternative way to visualize the electronic structure of matter. These diagrams are used both in the text and in end-of-chapter conceptual-based problems (see, for example, p. 341).

Previous users of the book have praised the way that the text emphasizes the relevancy of chemistry to diverse fields. The Related Topics are one obvious source of




*Computer-generated electron-density models showing the distribution of the charge cloud in $H_2$, $Cl_2$, and HCl by color coding. Notice the symmetry of the charge distributions in $H_2$ and $Cl_2$. In HCl, on the other hand, the charge distribution is not symmetrical. The lowest electron density is on H and the highest on Cl. The charge distributions were calculated by solving the Schrödinger equation.*



126 4 • Reactions in Solution

Related Topic:
**Materials Science**

If you are like most people, you have never given much thought to the materials that compose the things you use every day. Few of the materials in the photograph were available a hundred years ago. For example, the carpet is made of nylon, which was developed in the 1930s. The walls are painted with a water-based paint. These paints were introduced in the late 1940s. Materials science, the study of the synthesis of new materials with improved properties for specific purposes, is one of the most active fields of science today.
The first humans used materi...

*The 20th century materials used to decorate this room are easy to care for and durable.*

facture, were made in the early 1700s. Synthesis is an area of particular ...portance in chemistry. (3) *Theory—*

such connections, and these boxes have been updated where appropriate. In addition, new Related Topics (for example, see the box on Materials Science, p. 126) have been added. The relevancy message is also illuminated through the text's Guest Essays (see the discussion later in this Preface under Special Features). Guest Essayists new to this edition are Senator Bill Frist, Astronaut Bernard Harris, Biochemist Lynda Jordan, Molecular Modeler Mark Murcko, and Materials Scientist Milton Mathis. Finally, new Applications problems based on scientific news and research findings published since the second edition have been added.

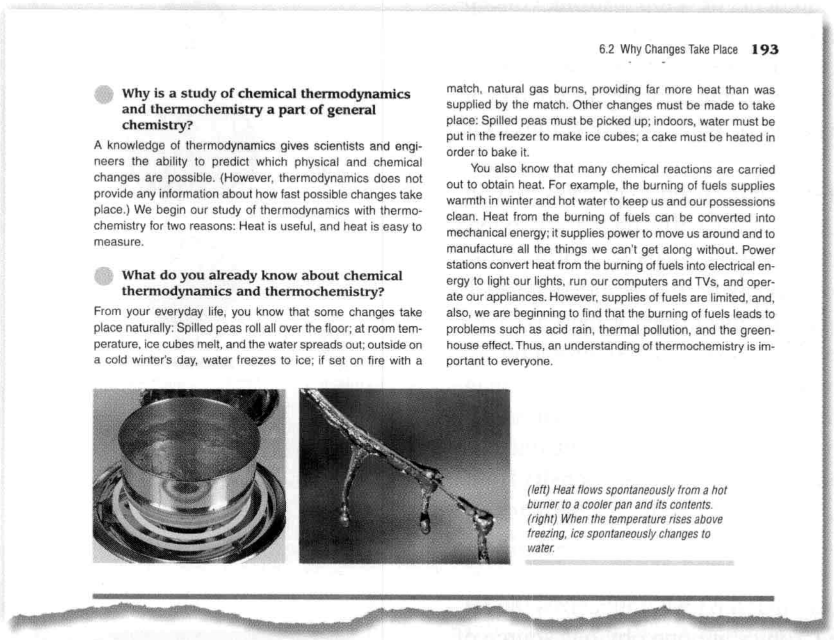
The most obvious addition to the book's contents is the inclusion of a dedicated biochemistry chapter (Chapter 23) that includes all four of the most important types of biomolecules—proteins, polysaccharides, nucleic acids, and lipids—as well as a discussion of energy in living systems. Simple biochemical topics are integrated into the discussion of fundamental topics in Chapters 1–19. The Related Topics on liquid crystals (pp. 452–453) and nitric oxide (p. 376) are examples. The biochemistry chapter includes new Related Topics on Prions and Combinatorial Chemistry.

Finally, as in the first two editions, we have striven to address and correct common textbook errors. For example, see the treatment of immiscible liquids as an entropy effect (pp. 485–486).

# Organization

## Chapter Organization

Each chapter starts with a preview of its contents and ends with a summary. At the beginning of each chapter is a "sales pitch" based on the answers to two questions that any student might reasonably pose. The first answer tells the student why the chapter is part of the study of general chemistry and why he or she should be interested in learning what is in the chapter. The answer to the second question reminds the student what he or she already knows about the subject from everyday experience and, in later chapters, from previous study. Next some relevant experimental observations are introduced and students are led to generalizations about the data. Theory to explain the generalizations is developed last. That is, the scientific method is repeatedly illustrated, not just described in the first chapter and then forgotten. Our intention was to involve students in the discovery process and let them experience the "Aha!" feeling; we think that this is the best way for them to learn how science works and why scientists enjoy their work. Students who have used the text have responded to this approach and have commented favorably.



6.2 Why Changes Take Place **193**

**Why is a study of chemical thermodynamics and thermochemistry a part of general chemistry?**

A knowledge of thermodynamics gives scientists and engineers the ability to predict which physical and chemical changes are possible. (However, thermodynamics does not provide any information about how fast possible changes take place.) We begin our study of thermodynamics with thermochemistry for two reasons: Heat is useful, and heat is easy to measure.

**What do you already know about chemical thermodynamics and thermochemistry?**

From your everyday life, you know that some changes take place naturally: Spilled peas roll all over the floor; at room temperature, ice cubes melt, and the water spreads out; outside on a cold winter's day, water freezes to ice; if set on fire with a match, natural gas burns, providing far more heat than was supplied by the match. Other changes must be made to take place: Spilled peas must be picked up; indoors, water must be put in the freezer to make ice cubes; a cake must be heated in order to bake it.

You also know that many chemical reactions are carried out to obtain heat. For example, the burning of fuels supplies warmth in winter and hot water to keep us and our possessions clean. Heat from the burning of fuels can be converted into mechanical energy; it supplies power to move us around and to manufacture all the things we can't get along without. Power stations convert heat from the burning of fuels into electrical energy to light our lights, run our computers and TVs, and operate our appliances. However, supplies of fuels are limited, and, also, we are beginning to find that the burning of fuels leads to problems such as acid rain, thermal pollution, and the greenhouse effect. Thus, an understanding of thermochemistry is important to everyone.

*(left) Heat flows spontaneously from a hot burner to a cooler pan and its contents. (right) When the temperature rises above freezing, ice spontaneously changes to water.*

## Text Organization

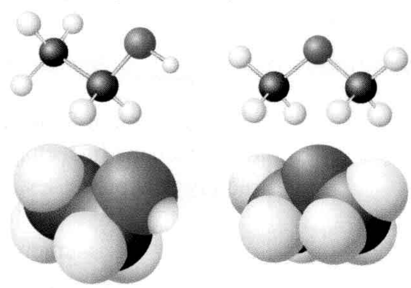
Most general chemistry texts cover measurement and significant figures in the first chapter. This book begins with an introduction to **chemical reactions**, so that the first lessons—where students form their impression of the subject—are more interesting. A whole chapter is devoted to measurement to emphasize the importance of this subject. Advances in our ability to measure underlie most recent scientific advances. Early chapters provide plenty of material for laboratory work involving chemical reactions as well as for quantitative experiments.

The concepts of **enthalpy**, **entropy**, and **rate** are introduced early (Chapter 6), and used again and again throughout the book. Entropy is as important as, if not more important than, enthalpy in determining whether a change will take place and should, we feel, have equal time. However, because experimental measurement of enthalpy changes is much simpler than experimental measurement of entropy changes, enthalpy is treated quantitatively in Chapter 6, whereas a quantitative treatment of entropy is postponed until Chapter 17. The quantitative treatment of **kinetics** follows thermodynamics because, just as shooting at a moving target is harder than shooting at a stationary one, kinetics is more difficult than thermodynamics. (If you prefer kinetics earlier, it can be done before Chapter 14.)

In some texts, gases are covered just before liquids and solids. But since the material on gases forms the basis for the atomic theory, it is presented here before atomic theory. As solids can't very well precede chemical bonding, gases and solids are separated. If you prefer gases just before liquids and solids, Chapter 5 can be postponed.

We have tried to write an organic chapter that will give students an idea of what modern **organic chemistry** is about and how the organic chemistry of carbon fits into the rest of chemistry. This approach seems preferable to trying to cram the reactions of all the major classes of compounds into one chapter as is often done. Organic compounds are introduced early (Section 3.9) and used repeatedly as examples throughout the book. However, the organic chapter is near the end so that it can *use* the material discussed earlier, especially kinetics and stereochemistry. One has only to glance at the abstracts of the papers from the Organic Division of any meeting to see the importance of chirality in contemporary organic chemistry. Therefore, stereoisomerism comes early in Chapter 22. *If models are used*, stereochemistry is very concrete and our students do not find it difficult.

…ether, are called **isomers**. Iso… …ures; the same atoms are joined together in different ways.



(a) Ethyl alcohol (b) Dimethyl ether

**Figure 3.4** Ball-and-stick *(top)* and space-filling *(bottom)* models of the isomeric compounds ethyl alcohol and dimethyl ether. The molecular formula of both compounds is $C_2H_6O$ but the atoms are joined together differently.

Industrial representatives claim that the primary topic that is missing from college chemistry courses is a treatment of polymers. Certainly, the things that non-chemistry majors or even non-science students will read about in the popular press will frequently involve synthetic polymers, and the general pervasiveness of polymers in everyday life makes an introduction of this topic essential. Polymers are first mentioned in Problem 3.100. They are discussed briefly in Section 9.11 and again in more depth at the end of the organic chapter. The biochemistry chapter provides a concise introduction to the properties of the three most important classes of biopolymers (proteins, carbohydrates, and nucleic acids).

Throughout the writing of this text, many reviewers mentioned topics that they felt were valuable but optional. These **optional topics** are usually located at the ends of chapters so that they may be easily assigned for reading only, or omitted entirely.

See, for example, the section on the calculation of atomic and ionic radii and Avogadro's number in Chapter 12, or the section on colloids in Chapter 13. Later chapters do not assume knowledge of material in these optional sections.

# Problems and Problem-Solving

## In-Chapter Problems



nonstandard conditions as we will see in Section 19.3. Sample Problem 19.1 illustrates the calculation of a standard cell potential from standard half-cell reduction potentials in Table 19.1.

**SAMPLE PROBLEM**

**19.1** Calculate the standard cell potential, $E^\circ_{cell}$, for the reaction

$$2Ag(s) + Cu^{2+} \longrightarrow 2Ag^{+} + Cu(s)$$

and predict whether this reaction will take place spontaneously.

**SOLUTION** The standard potential for a cell is the difference between the reduction potentials of the two half-cells that make up the cell (equation 19.2):

$$E^\circ_{cell} = E^\circ_{half\text{-}cell\ of\ reaction} - E^\circ_{half\text{-}cell\ of\ oxidation} \quad (19.2)$$

For the reaction in this problem, the half-cell of reduction is $Cu^{2+} + 2e^- \longrightarrow Cu(s)$, and the half-cell of oxidation is $Ag^+ + e^- \longrightarrow Ag(s)$ and

$$E^\circ_{cell} = E^\circ_{Cu^{2+}/Cu(s)} - E^\circ_{Ag^+/Ag(s)} \quad (19.5)$$

From Table 19.1, $E^\circ_{Cu^{2+}/Cu(s)} = +0.34$ V and $E^\circ_{Ag^+/Ag(s)} = +0.80$ V. Substitution of these values in equation 19.5 gives

$$E^\circ_{cell} = +0.34\ V - (+0.80\ V) = -0.46\ V$$

Because $E^\circ_{cell}$ is negative, reaction is nonspontaneous.

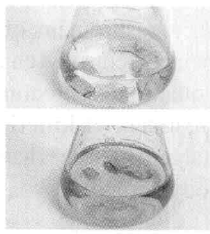
***Check:*** The diagonal relationship can be used to check the sign of the value obtained for $E^\circ_{cell}$

$$Ag^+ + e^- \longrightarrow Ag(s) \quad 0.80$$

$$Cu^{2+} + 2e^- \longrightarrow Cu(s) \quad 0.34$$

In Table 19.1, $Cu^{2+}$ in the left column is *below* Ag(s) in the right column; reaction between $Cu^{2+}$ and Ag(s) is not spontaneous, and the sign of $E^\circ_{cell}$ should be negative, as it is.

When ... table of standard electrod... ...tials to predict whether a reaction



Top: *Copper metal immediately after being placed in 1 M $HNO_3$.* Bottom: *Eight hours later. The surface of the copper has been etched, and the solution shows the blue color of $Cu^{2+}$ (aq).*

*Notice that you can calculate a cell potential by changing the sign for the half-reaction that takes place in the reverse direction from the one shown in Table 19.1 and adding. Some general chemistry instructors prefer to calculate cell potentials in this way.*

*Always check to be sure your work is reasonable.*

Many worked-out **Sample Problems** are presented as examples throughout the chapters. Some teach students to use pictures and graphs—things experienced scientists usually do but students do not. In the Sample Problems, we have tried to teach students to use a thoughtful and logical approach to problem-solving rather than simply memorizing procedures or using dimensional analysis as a substitute for thought. Dimensional analysis is stressed as a way to check answers, and the importance of checking work is emphasized by the "reasonableness checks" that conclude many Sample Problems.

An example has not been included for every kind of problem, however. Where we feel that the explanation in the text is adequate, we ask the student to answer questions without a Sample Problem. Students need to realize that they are supposed to be learning to solve problems, not just to follow an example. The concentration of Sample Problems decreases toward the end of the book; by the time they reach the final chapters, students should need worked-out examples only for completely new processes.

**PRACTICE PROBLEMS**

**4.16** How should each be represented in an ionic equation for a reaction that takes place in aqueous solution? (a) calcium carbonate, (b) nitric acid, (c) acetic acid, (d) magnesium chloride, (e) iron(II) hydroxide. **(Matching Problem: 4.53)**

**4.17** The molecular equation for the reaction between hydrogen sulfide gas and a solution of zinc(II) nitrate in water is $H_2S(g) + Zn(NO_3)_2(aq) \longrightarrow ZnS(s) + 2HNO_3(aq)$. (a) Write the complete ionic equation. (b) Which ions are spectator ions? (c) Write the net ionic equation. (d) Give the molecular formula for another soluble zinc salt that will give the same net reaction. **(Matching Problem: 4.54)**

**4.18** Write complete and net ionic equations for the reactions in Practice Problem 4.15. **(Matching Problem: 4.55)**

Ionic equations are often used to describe reactions between electrolytes. However, molecular equations are necessary in practical work in the laboratory and industry. You cannot measure out barium ions separately from some kind of negative ions;

In the chapters, Sample Problems are usually followed by one or more **Practice Problems.** These give students a chance to work problems similar to the examples and to reinforce their understanding of skills and concepts. We have included more problems than usual within the chapter text because in-chapter problems encourage students to be active, not passive, readers. Students who work through the in-chapter problems will gain a much better understanding of concepts and skills than those who simply read the text. All Practice Problems are paired with the end-of-chapter Additional Practice Problems. Answers to all of the in-chapter problems appear in Appendix H, and solutions are available in the *Student Solutions Manual.*

## End-of-Chapter Problems

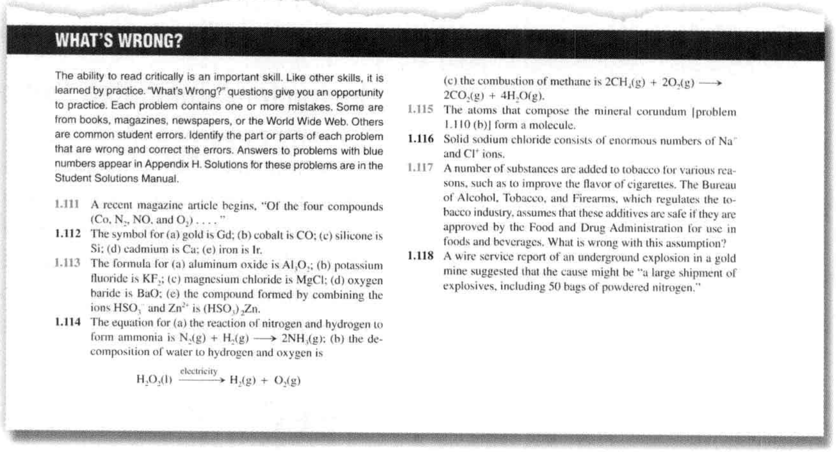
The end-of-chapter problems begin with **Additional Practice Problems.** These are drill-and-practice, similar in difficulty and covering the same skills as the in-chapter problems. These Additional Practice Problems are numbered in continuous sequence with the in-chapter Practice Problems. Approximately 85% of them are followed by a parenthetical notation indicating the section of the chapter to which the problem refers. Not all of these problems are classified, however; classifying problems is an important skill that students need to practice. The section or sections to which each unclassified problem relates are available on the instructor's web site to aid you in assigning a good selection of problems.

The next group of problems is called **Stop and Test Yourself.** It is a multiple choice self-test covering the basic skills and concepts from the chapter so that students can quickly check their readiness to go on to the higher-level problems that follow. Also, skill in taking this type of test is important to many students (for admission to medical school, for example), and they need practice. Answers appear in Appendix H, along with the number of the section to be re-studied if the student answers the question incorrectly. The answers are explained in the *Student Solutions Manual.* The self-tests are in the book, not in the *Study Guide,* because the students who most need the self-tests are, in our experience, those least likely to use ancillaries.

The self-test is followed by **Putting Things Together** problems. Many students can do all of the individual operations, but have trouble putting them together. The Putting Things Together problems help students become better problem-solvers by requiring them to combine material from different sections of the current chapter or material from the current chapter with material from earlier chapters.

Next come **Applications** problems in which students must apply chemical skills and concepts to real-world problems. These problems appear after students have had a lot of practice with "generic" problems.

Finally, the last group of problems are called **What's Wrong?** and are new to this edition. Throughout all scientific disciplines, there has been an increasing consensus that students need practice on critically assessing what they read. These problems address this need by asking students to identify and correct mistakes in previously published materials.



**WHAT'S WRONG?**

The ability to read critically is an important skill. Like other skills, it is learned by practice. "What's Wrong?" questions give you an opportunity to practice. Each problem contains one or more mistakes. Some are from books, magazines, newspapers, or the World Wide Web. Others are common student errors. Identify the part or parts of each problem that are wrong and correct the errors. Answers to problems with blue numbers appear in Appendix H. Solutions for these problems are in the Student Solutions Manual.

1.111 A recent magazine article begins, "Of the four compounds (Co, $N_2$, NO, and $O_2$) . . . ."

1.112 The symbol for (a) gold is Gd; (b) cobalt is CO; (c) silicone is Si; (d) cadmium is Ca; (e) iron is Ir.

1.113 The formula for (a) aluminum oxide is $Al_3O_2$; (b) potassium fluoride is $KF_2$; (c) magnesium chloride is MgCl; (d) oxygen baride is BaO; (e) the compound formed by combining the ions $HSO_3^-$ and $Zn^{2+}$ is $(HSO_3)_2Zn$.

1.114 The equation for (a) the reaction of nitrogen and hydrogen to form ammonia is $N_2(g) + H_2(g) \longrightarrow 2NH_3(g)$; (b) the decomposition of water to hydrogen and oxygen is

$$H_2O_2(l) \xrightarrow{\text{electricity}} H_2(g) + O_2(g)$$

(c) the combustion of methane is $2CH_4(g) + 2O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(g)$.

1.115 The atoms that compose the mineral corundum [problem 1.110 (b)] form a molecule.

1.116 Solid sodium chloride consists of enormous numbers of $Na^-$ and $Cl^+$ ions.

1.117 A number of substances are added to tobacco for various reasons, such as to improve the flavor of cigarettes. The Bureau of Alcohol, Tobacco, and Firearms, which regulates the tobacco industry, assumes that these additives are safe if they are approved by the Food and Drug Administration for use in foods and beverages. What is wrong with this assumption?

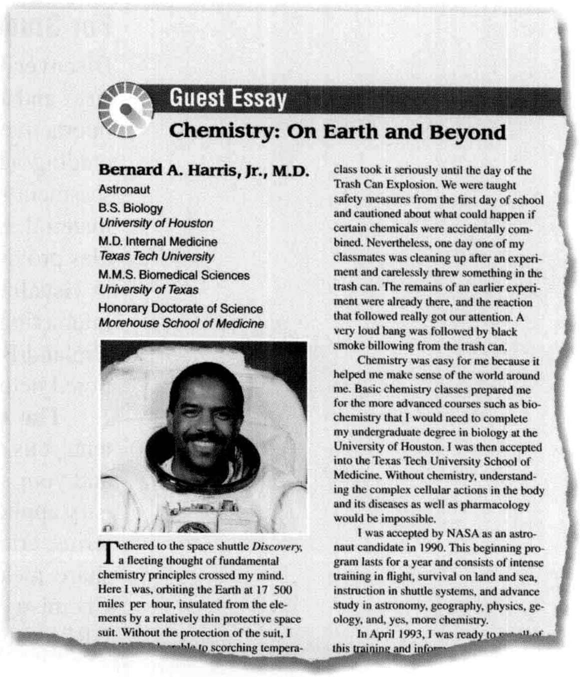
1.118 A wire service report of an underground explosion in a gold mine suggested that the cause might be "a large shipment of explosives, including 50 bags of powdered nitrogen."

The end-of-chapter problems range from simple to fairly challenging so that the level of the course can be tailored to suit different audiences. Many more problems are provided than any student will have time to do so that problem assignments can be varied from year to year. Solutions to all the in-chapter Practice Problems and end-of-chapter problems (with blue numbers) are given in the *Student Solutions Manual,* for the benefit of instructors who like their students to have solutions available. (For the same problems presented in the *Student Solutions Manual,* the answers only are provided in Appendix H.) Answers and solutions to Additional Practice Problems with red numbers are on the book's web site. Answers and solutions to the remaining end-of-chapter problems are given in the *Instructor's Solutions Manual* and therefore are available only to students whose instructors want them to have them.

# Special Features

## Guest Essays

Guest Essays between the chapters give students perspective on the importance of chemistry to life after college. In these, people of various backgrounds and ages (some not much older than most students) reflect on their experiences in general chemistry, and describe the role of chemistry in their work. *Every student* should be able to find a role model. As students study chemistry throughout the year, these essays encourage



**Guest Essay**

**Chemistry: On Earth and Beyond**

**Bernard A. Harris, Jr., M.D.**
Astronaut
B.S. Biology
*University of Houston*
M.D. Internal Medicine
*Texas Tech University*
M.M.S. Biomedical Sciences
*University of Texas*
Honorary Doctorate of Science
*Morehouse School of Medicine*

Tethered to the space shuttle *Discovery,* a fleeting thought of fundamental chemistry principles crossed my mind. Here I was, orbiting the Earth at 17 500 miles per hour, insulated from the elements by a relatively thin protective space suit. Without the protection of the suit, I ... to scorching tempera-

class took it seriously until the day of the Trash Can Explosion. We were taught safety measures from the first day of school and cautioned about what could happen if certain chemicals were accidentally combined. Nevertheless, one day one of my classmates was cleaning up after an experiment and carelessly threw something in the trash can. The remains of an earlier experiment were already there, and the reaction that followed really got our attention. A very loud bang was followed by black smoke billowing from the trash can.

Chemistry was easy for me because it helped me make sense of the world around me. Basic chemistry classes prepared me for the more advanced courses such as biochemistry that I would need to complete my undergraduate degree in biology at the University of Houston. I was then accepted into the Texas Tech University School of Medicine. Without chemistry, understanding the complex cellular actions in the body and its diseases as well as pharmacology would be impossible.

I was accepted by NASA as an astronaut candidate in 1990. This beginning program lasts for a year and consists of intense training in flight, survival on land and sea, instruction in shuttle systems, and advance study in astronomy, geography, physics, geology, and, yes, more chemistry.

In April 1993, I was ready to ... this training and ...

them to believe that they can succeed and remind them that an understanding of chemistry can lead to many opportunities and be of value in many different careers.

### Accuracy

Research has shown that even competent scientists retain wrong information and inefficient ways of doing things if they learn them first. Material simplified for beginning students should be correct; those who go on in science should not have to unlearn anything. Therefore, in addition to the usual reviews by teachers of general chemistry, many chapters have also been reviewed by chemists who are specialists in the area concerned, and by colleagues in related fields such as astronomy, biology, geology, and physics. We have tried very hard to avoid "common textbook errors" and to use the best available data. The treatment of the relationship between solubility and solubility product constant (pp 642–650), which has been cited in a recent paper as the only appropriate treatment of this topic in a general chemistry text (see p. 643 for reference), is an example. Where the treatment is different from that in other texts, references to the literature are given in the *Instructor's Annotated Edition.*

### Instructor's Annotated Edition

We have prepared a special edition of the text for the use of instructors. The Instructor's Annotated Edition contains marginal comments in magenta to signal the location of related material, to explain why a particular approach is used, to cite references to the chemical literature, and so forth. Most of these red notes to instructors are derived from "dialogues" that were carried on between the reviewers and ourselves through many drafts of the text. In addition, new to this edition are transparency icons that identify the figures, tables, and boxes that are included in the transparency package.

## Supplements

An extensive package of supplements is available to support both the instructor and the student. It includes:

### For Students

**Discover Chemistry CD-ROM, Version 2.0** by Jeffrey Appling (Clemson University) and David Frank (California State University, Fresno). This dynamic, highly interactive multimedia tool now contains newly developed Web-based resources, including additional topic modules (e.g., organic chemistry, nuclear chemistry), assessment tools, hot links to the best online chemical sites, and real-world chemistry material. Hundreds of exercises and practice problems on fully interactive topic modules provide a "virtual tutor" environment for chemistry students, providing practice in visualizing difficult concepts, changing parameters and predicting outcomes, and interacting with a variety of graphical models and experimental setups. Icons in the Umland/Bellama text direct students to modules on Discover Chemistry where additional help and assessment can be found.

**The Chemistry Resource Center** Arranged according to the table of contents, this complete network of online resources is specifically designed to support you and your students. The resource center provides monthly updates on relevant chemistry applications, as well as practice quizzes for each chapter, flash cards for glossary terms, critical thinking exercises, news groups, and a forum in which professors can share ideas on teaching chemistry. Also featured is a demonstration of Discover Chemistry 2.0 and solutions to the end-of-chapter problems numbered in red. The URL is http://chemistry.brookscole.com/umland.html

**InfoTrac® College Edition** A fully searchable, online university library that includes full articles from more than 700 scholarly and popular periodicals. Publications date back as many as four years. This online university library is available at any time of day or night.

**Study Guide** by Kenneth J. Hughes of the University of Wisconsin. Each chapter includes a review of the text material followed by sample problems. Chapters conclude with diagnostic self-test questions and a variety of practice problems. Outline solutions are provided for all practice problems. An introductory chapter on reading and learning scientific material has been written with specific reference to the textbook; it provides practical strategies for learning chemistry, with particular emphasis on vocabulary.

**Student Solutions Manual** by Juliette Bryson of Los Positas College and Jean B. Umland of University of Houston–Downtown. This manual provides complete solutions to all of the in-chapter practice problems and all of the end-of-chapter problems indicated by blue numbers.

**Essential Math for Chemistry** by David Ball of Cleveland State University. This workbook is written to help students learn or review the math skills required for success in general chemistry. Numerous examples and exercises give students extensive opportunity for practice.

**Experiments in General Chemistry: Laboratory Manual to Accompany General Chemistry, 3rd ed.** by Steven L. Murov of Modesto Junior College. This manual contains 34 experiments, corresponding to material covered in the main text, along with pre-laboratory exercises, discussion sections, and detailed appendices. The presentation often uses an "inquiry" approach and emphasizes connections between text topics and lab experiences. Safe laboratory practices are emphasized, and the use of hazardous substances is limited to the minimum amount required for reliable results.

## For Instructors

**Instructor's Solutions Manual** by Juliette Bryson of Los Positas College and Jean B. Umland of the University of Houston–Downtown. This manual contains solutions to all problems from the main text that do not appear in the Student Solutions Manual.

**Instructor's Guide for Experiments in General Chemistry: Laboratory Manual to Accompany General Chemistry, 3rd ed.** by Steven L. Murov of Modesto Junior College. The Instructor's Manual gives answers to the pre-laboratory exercises, guidance on conducting the 34 laboratory experiments, lists of recommended equipment, chemicals and safety measures, and detailed appendices.

**Instructor's Resource Manual (on the Web)** by Jean B. Umland and Jon M. Bellama of the University of Maryland. This supplement provides a variety of information, including suggestions for adapting the text to courses of different organizations, lengths, levels, and emphasis; section number references for all unclassified problems; additional text sections for reproduction as handouts; suggested classroom demonstrations; and other resources.

**Test Manual** by Jon M. Bellama. The test manual contains over 2400 questions in multiple-choice format. The questions are arranged into pre-printed test forms, with answers, for each chapter in the main text.

**Transparency Acetates** Over 200 transparency acetates containing illustrations, tables, and figures from the main text.

**Thomson World Class Network** includes a repository of learning modules, combined with a robust instructional system to deliver interactive teaching and learning via the Web.

**Thomson World Class Learning and Testing Tools** A fully integrated suite of test creation, delivery, and classroom management tools, including World Class Test and Test Online and World Class Management software. It enables the instructor to create tailor-made tests, post and/or administer them online, and manage classroom records and results.

**ChemLink** A lecture tool designed to help the instructor create dynamic presentations by assembling lecture notes, images, animation, sounds, QuickTime movies, and items from the publisher's database on CD-ROM or the Internet. Presentations can be saved to a word processor or converted to HTML and posted to the Web.

**General Chemistry Powerpoint CD-ROM** by James K. Hardy of the University of Akron. Available for Macintosh and Windows, the General Chemistry CD-ROM contains more than 1200 colorful electronic transparencies for use in lecture. Clearly labeled images are grouped into topical units and include animations. Images may be edited using Powerpoint 4.0.

**Videodisc** The General Chemistry videodisc contains demonstrations and experiments that are difficult, expensive, or dangerous to perform in class. Most of the experiment footage is original, developed specifically for this text. Much of the artwork from the text is also included, with animation when motion is inherent to the concept.

**Tutorial Videotapes** Instructional tapes on Graphing Scientific Information and Using a Scientific Calculator have been created for this text by Michael Clay of the College of San Mateo.

## Acknowledgments

Keith Dodson, who was developmental editor for the first two editions, acted as sponsoring editor for this edition. The familiarity with the book that he brought with him has been invaluable to us as we adapted to our new publisher and to everyone else who has worked on the third edition. Thanks are also due to Sue Ewing, who assembled the answer appendix, Cheryl Carrington, who designed the cover, and to the production team—Marjorie Sanders at Brooks/Cole and Rob Anglin, production editor, Justin Menza, photo researcher, Phil Gaskill, page layout specialist, and Christina Della Bartolomea, copyeditor, at Electronic Publishing Services. In order to benefit students, textbooks must be sold. Therefore we also want to thank Heather Woods for her early work in promotion, Steve Catalano, marketing manager, and Christine Davis and Jean Thompson in advertising. As always, we are very grateful to Julie Bryson for writing the solutions manuals and for her many helpful criticisms of text and problems.

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We especially appreciate the participation of the guest essayists and their commitment to giving students a perspective on the diverse careers that can emerge from an educational background in chemistry. Nancy Conti deserves special thanks for her work in coordinating these essays.

Last, but certainly not least, we express our sincere gratitude to the reviewers for this edition who offered their various perspectives and insights on how to make this edition of the text work even better for students: Mary H. Bailey, The Ohio State University; David W. Ball, Cleveland State University; Thomas A. Beinecke, Concordia University-Wisconsin; Amina El-Ashmawy, Collin County Community College; Ellen R. Fisher, Colorado State University; Eugene B. Grimley III, Elon College; Gordon Eggleton, Southeastern Oklahoma State University; Ed Hach, Saint Bonaventure University; Ronald Johnson, Emory University; B. Kenneth Robertson, University of Missouri, Rolla; Martha Joseph, Westminster College; Vaughan Pultz, Truman State University; Kathryn Rowberg, Purdue Calumet; Nicholas H. Snow, Seton Hall University; Richard C. Ulsh, University of Pittsburgh at Johnstown; and William H. Zoller, University of Washington.

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