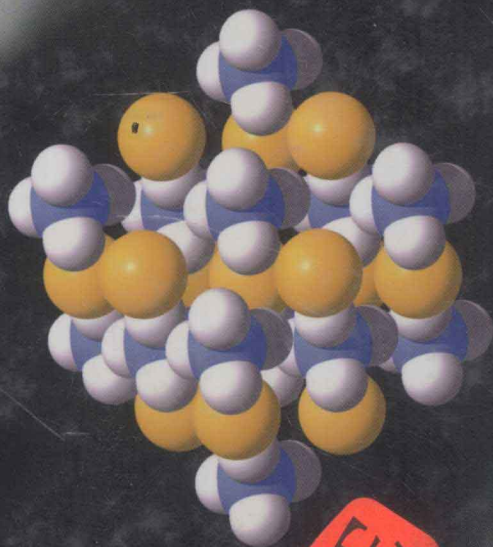


# CHEMISTRY

## *& Chemical Reactivity*

Fourth Edition



**RIPE**

KOTZ & TREICHEL



# CHEMISTRY & *Chemical Reactivity*

•  
*Fourth Edition*

JOHN C. KOTZ

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SAUNDERS GOLDEN SUNBURST SERIES

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*To Katie, David, and Peter*

*To Isabel, David, and Janet*

JOHN C. KOTZ

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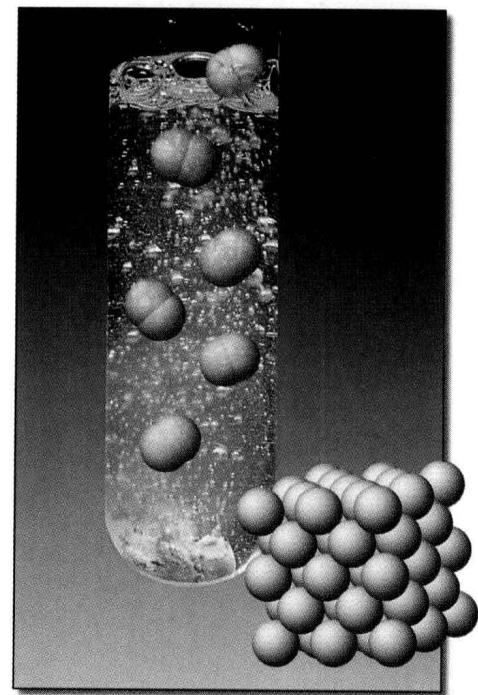
# Preface

This is the fourth edition of *CHEMISTRY & CHEMICAL REACTIVITY*. The principal theme of the book, beginning with the first edition more than 10 years ago, is to provide a broad overview of the principles of chemistry and the reactivity of the chemical elements and their compounds. This edition, however, brings a new organization to that theme: the close relation between the macroscopic observations we make of chemical and physical changes, the symbols we use to describe those changes, and the way we view those changes at the atomic and molecular levels.

In addition to a fresh viewpoint on chemistry, we want to convey a sense of chemistry as a field that not only has a lively history but also one that is currently dynamic, with important new developments on the horizon. Furthermore, we want to provide some insight into the chemical aspects of the world around us. What materials are important to our economy? What chemical reactions take place in plants and animals and in our environment? What role do chemists play in protecting the environment? By tackling the principles leading to answers to these questions, you can come to a better understanding of nature and to an appreciation for consumer products. Indeed, one of the objectives of this book is to provide the tools needed for you to function as a chemically literate citizen. Learning something of the chemical world is just as important as understanding some basic mathematics and biology—and as important as having an appreciation for fine music and literature.

We are also pleased that this edition will again be offered with the *Saunders Interactive General Chemistry CD-ROM*. Computers have become a more and more powerful way to organize and convey information. The first edition of our CD-ROM has been used by thousands of students worldwide and is the most successful attempt to date to allow students to interact with chemistry. Additional interactivity will be available in an expanded version of the CD-ROM with the incorporation of *ActivChemistry*, software that allows you to design and perform simulated laboratory experiments. Finally, the disks again include portions of the molecular modeling tools from the Oxford Molecular Group. (Models of virtually every chemical compound mentioned in this book are contained in a library on the CD-ROM and can be viewed with the modeling software.) The CD-ROM package—two disks and an accompanying *Workbook*—is available for purchase with the textbook or as a stand-alone product.

The authors of this book became chemists because, simply put, it is exciting to discover new compounds and to find new ways to apply chemical principles. In this book, we hope we have conveyed that sense of enjoyment as well as our awe at what is known about chemistry, and, just as important, what is not known!

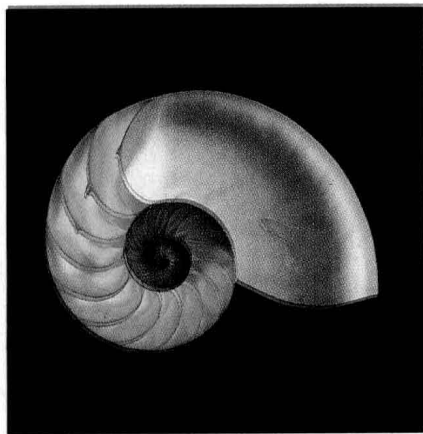


## AUDIENCE FOR *CHEMISTRY & CHEMICAL REACTIVITY* AND THE SAUNDERS INTERACTIVE GENERAL CHEMISTRY CD-ROM

The textbook and CD-ROM are designed for introductory courses in chemistry for students interested in further study in science, whether that science is biology, chemistry,

engineering, geology, physics, or related subjects. Our assumption is that students beginning this course have had some preparation in algebra and in general science. Although undeniably helpful, a previous exposure to chemistry is neither assumed nor required.

## PHILOSOPHY AND APPROACH OF THE BOOK



When the first edition of this book was planned, we had two major, but not independent, goals. This edition has these same goals. The first was to construct a book that students would enjoy reading and that would offer, at a reasonable level of rigor, chemistry and chemical principles in a format and organization typical of college and university courses today. Second, we wanted to convey the utility and importance of chemistry by introducing the properties of the elements, their compounds, and their reactions as early as possible and by focusing the discussion as much as possible on these subjects.

A glance at the introductory chemistry texts currently available shows that there is a generally common order of treatment of chemical principles used by educators. With a few minor changes we have followed that order as well. That is not to say that the chapters cannot be used in some other order. For example, although the behavior of gases is often studied early in a chemistry course, the chapter on this topic (Chapter 12) has been placed with chapters on liquids, solids, and solutions because it logically fits with these other topics. It can easily be read and understood, however, after covering only the first four or five chapters of the book.

The discussion of organic chemistry (Chapter 11) is typically left to one of the final chapters in chemistry textbooks. We believe, however, that the importance of organic compounds in biochemistry and in the chemical industry means that we should present that material earlier in the sequence of chapters. Therefore, it follows the chapters on bonding theories because organic chemistry illustrates well the application of models of chemical bonding and molecular structure.

In addition, one of the authors of this text often teaches much of the material on equilibria involving insoluble solids (Chapter 19) before acid-base equilibria (Chapters 17 and 18), and introduces kinetics (Chapter 15) and thermodynamics (Chapter 20) as a unit, after all of the material on equilibria. Although chapters are loosely organized into groups with common themes, we have made every attempt to make individual chapters as independent as possible.

The order of topics in the text was also devised to introduce as early as possible the background required for the laboratory experiments usually done in general chemistry courses. For this reason, chapters on chemical and physical properties, common reaction types, and stoichiometry begin the book. In addition, because an understanding of energy is so important in the study of chemistry, thermochemistry is introduced in Chapter 6.

The American Chemical Society has been urging educators to put “chemistry” back into introductory chemistry courses. As inorganic chemists, we agree wholeheartedly. Therefore, we have tried to describe the elements, their compounds, and their reactions as early and as often as possible in three ways. First, there are numerous color photographs of reactions occurring, of the elements and common compounds, and of common laboratory operations and industrial processes. Furthermore, we have tried to bring material on the properties of elements and compounds into the Exercises and Study Questions as early as possible and to introduce new principles using realistic chemical situations. In general, the descriptive chemistry of the elements has been treated in two ways. First, much has been woven into the book. Second, relevant highlights are given in Chapters 22 and 23 as a capstone to the principles described earlier.

Additionally, special sections called *Current Perspectives* and *A Closer Look* attempt to bring relevance and perspective to a study of chemistry. These include such topics as “Science and Flight 800” (The Nature of Chemistry); “Coral and Broken Bones” (Chapter



1); “Essential Elements” (Chapter 2); “Diet Soda—What’s in It?” (Chapter 3); “What to Take for an Upset Stomach” (Chapter 4); “It’s in the Bag—Thermodynamics and Consumer Products” (Chapter 6); “Magnetic Resonance Imaging” (Chapter 8); “Why Sweeteners are Sweet” (Chapter 9); “UV Radiation, Skin Damage, and Sunscreens” (Chapter 11); “The Chemistry of Survival” (Chapter 14); “Depletion of Stratospheric Ozone” (Chapter 15); and “Lead Pollution, Ancient and Modern” (Chapter 22).

## ORGANIZATION OF THE BOOK

*Chemistry & Chemical Reactivity* is organized in two ways. First, there are chapters that are especially important in carrying the themes of the book. That is, there are chapters on the *Principles of Reactivity*, and there are others on *Bonding and Molecular Structure*.

The chapters on *Principles of Reactivity* are intended to introduce you to the factors that lead chemical reactions to successfully produce products. Thus, under this topic you will study common types of reactions, the energy involved in reactions, and the factors that affect the speed of a reaction.

The *Principles of Bonding and Molecular Structure* are particularly important. If you page through the book you will notice the abundance of molecular models, most of them drawn by computer. (They were done with programs from Oxford Molecular Group, and we thank them for providing the latest versions for us to use. Portions of this software are included on the CD-ROM and a model of virtually every molecule in the book is included on the CD-ROM.) As described in several places in the book [among them in *An Introduction—The Nature of Chemistry; Computer Molecular Modeling* (Chapter 3); and Chapters 9 through 11], an understanding of molecular structures is one cornerstone of modern chemistry. Using the latest laboratory techniques for uncovering molecular structures, and computer programs that generate revealing portraits of structures, chemists have enormous insight into the ways molecules react.

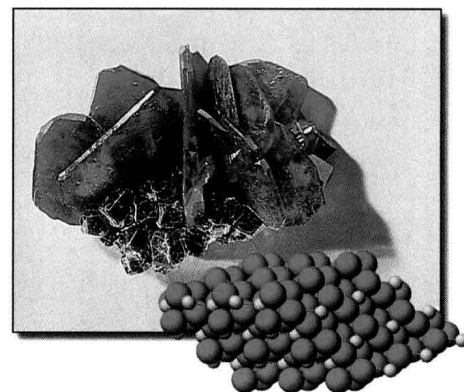
Second, the book is divided into five parts, each with a grouping of chapters with a common theme.

### Part 1: The Basic Tools of Chemistry

Certain basic ideas and methods form the fabric of chemistry, and these are introduced in Part 1. Chapter 1 defines important terms and is a review of units and mathematical methods. Chapters 2 and 3 introduce basic ideas of atoms and molecules, and Chapter 2 introduces one of the most important organizational devices of chemistry, the periodic table. In Chapters 4 and 5 we begin to discuss the principles of chemical reactivity and to introduce the numerical methods used by chemists to extract quantitative information from chemical reactions. Chapter 6 is an introduction to the energy involved in chemical processes.

### Part 2: The Structure of Atoms and Molecules

The major goal of this section is to outline the current theories of the arrangement of electrons in atoms and some of the historical developments that led to these ideas (Chapters 7 and 8). With this background, we can understand why atoms and their ions have different chemical and physical properties. This discussion is tied closely to the arrangement of elements in the periodic table so that these properties can be recalled and predictions made. In Chapter 9 we discuss for the first time how the electrons of atoms in a molecule lead to chemical bonding and the properties of these bonds. In addition, we show how to derive the three-dimensional structure of simple molecules. Finally, Chapter 10 considers the major theories of chemical bonding in more detail.





This part of the book is completed with a discussion of organic chemistry (Chapter 11), primarily from a structural point of view. Organic chemistry is such an enormous area of chemistry that we cannot hope to cover it in detail in this book. Therefore, we have focused on compounds of particular importance, including synthetic polymers, and the structures of these materials.

### Part 3: States of Matter

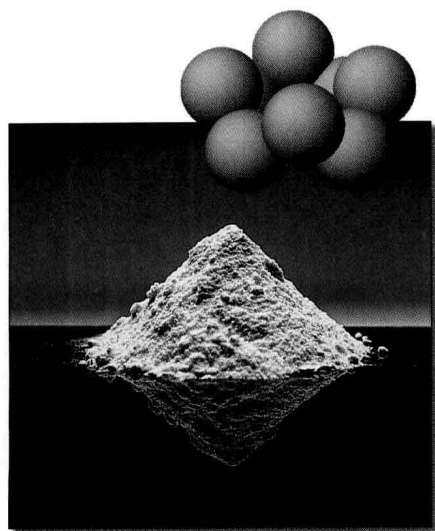
The behavior of the three states of matter—gases, liquids, and solids—is described in that order in Chapters 12 and 13. The discussion of liquids and solids is tied to gases through the description of intermolecular forces, with particular attention given to liquid and solid water. Chapter 13 also considers the solid state, an area of chemistry currently undergoing a renaissance. In Chapter 14 we talk about the properties of solutions, intimate mixtures of gases, liquids, and solids.

### Part 4: The Control of Chemical Reactions

This section is wholly concerned with the *Principles of Reactivity*. Chapter 15 examines the important question of the rates of chemical processes and the factors controlling these rates. With this in mind, we move to Chapters 16 through 19, a group of chapters that consider chemical reactions at equilibrium. After an introduction to equilibrium in Chapter 16, we highlight the reactions involving acids and bases in water (Chapters 17 and 18) and reactions leading to insoluble salts (Chapter 19). To tie together the discussion of chemical equilibria, we again explore thermodynamics in Chapter 20. As a final topic in this section we describe in Chapter 21 a major class of chemical reactions, those involving the transfer of electrons, and the use of these reactions in cells that produce a voltage.

### Part 5: The Chemistry of the Elements and Their Compounds

Although the chemistry of the various elements has been described throughout the book to this point, Part 5 considers this topic in a more systematic way. Chapter 22 is devoted to the chemistry of the representative elements, whereas Chapter 23 is a discussion of the transition elements and their compounds. Finally, Chapter 24 is a brief discussion of nuclear chemistry.



### PHILOSOPHY AND APPROACH OF THE SAUNDERS INTERACTIVE GENERAL CHEMISTRY CD-ROM

The CD-ROM was designed to take advantage of what computers do best: allow the user to *interact* with information. Therefore, our goal was to produce “an interactive movie about the book.” The material in each chapter is presented in a series of “screens,” each of which presents an idea or concept and allows the user to interact with the information in some manner—by seeing video of a reaction in progress, by changing a variable in a chemical experiment and watching what happens to the system, or by listening to important tips and ideas about ways to understand a concept or to solve a problem. In addition, you will see practicing chemists describe how the topic of the chapter applies to their work.

Version 2.5 of the CD-ROM will accompany the fourth edition of *CHEMISTRY & CHEMICAL REACTIVITY*. Its core is identical to Versions 2.0 and 2.1. No significant alterations have been made in the material, with the exception of the addition of *ActioChemistry*. This software package, which allows the student to design and perform simulated chemistry laboratory experiments, has been integrated into the screens of the previous version of the CD-ROM.

The CD-ROM is a complete learning environment for chemistry. In addition to the interactive presentation, which covers virtually the entire field of chemistry, it offers programs for plotting information, molecular modeling software from Oxford Molecular Group, and a library of the hundreds of molecular structures mentioned in this book, structures that can be viewed with this software.

## NEW TO THIS EDITION

When we finish an edition of this book, we wonder what we can possibly do to change and improve the book. The answer is always that much can be done, and many changes have been made for this edition.

- Chapters 1 through 5 have been reorganized and completely rewritten. The flow of topics in Chapter 1 (*Matter and Measurement*) has been improved.
- Discussion of the concept of the “mole” has been consolidated in Chapter 3 (*Molecules and Compounds*).
- The core concept of chemical stoichiometry has been introduced in Chapter 4 (*Chemical Equations and Stoichiometry*) rather than in Chapter 5, as in the third edition.
- The material on types of chemical reactions has been reorganized in Chapter 5 (*Reactions in Aqueous Solution*). Particular attention has been paid to helping students learn to write net ionic equations.
- The discussion of ionic bonding has been consolidated in Chapter 9.
- The chapter on organic chemistry (Chapter 11) has been rewritten and reorganized to give even greater emphasis to chemical bonding and structure.
- The nature of the solution process (Chapter 14) has been rewritten to give more attention to the role of entropy.
- The important subject of catalysis has been moved forward in Chapter 15 (*Chemical Kinetics*) as an introduction to reaction mechanisms.



## FEATURES AND LEARNING AIDS IN THE BOOK

### Icons



This icon alerts the student to discussions that are focused on the relationship of macroscopic observations, the symbolic representation of those ideas, and their explanation at the particulate (atomic and molecular) level.



Marginal annotations tie the text to the appropriate section of the *Saunders Interactive General Chemistry CD-ROM*.



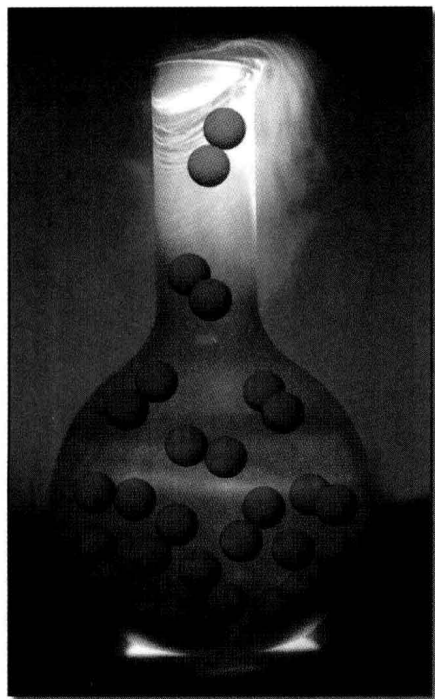
Molecular models in the book were created with software from the Oxford Molecular Group. This icon reminds the student that the models in that section are found on the *Saunders Interactive General Chemistry CD-ROM* and/or the *Saunders World Wide Web Site* (<http://www.saunderscollege.com>). Models of essentially all molecules, as well as ionic, molecular, network, and metallic solids, are found on the CD-ROM or on the Web site.



This icon points out useful sites on the World Wide Web.



This icon points to a place earlier in the book where a relevant principle is described.



## Problem Solving

### *Worked Examples and Solved Problems*

Several hundred worked-out Examples serve as models for solving end-of-chapter problems. The detailed solutions are developed using the technique of dimensional analysis, and answers are highlighted. Examples are followed by similar Exercises, the solutions to which are in Appendix N.

### *Problem-Solving Flow Diagrams*

Scattered throughout the book and in the Examples are problem-solving flow diagrams. These diagrams help organize the information contained in the problems.

### *End-of-Chapter Study Questions*

The end-of-chapter Study Questions, some of which are illustrated with photographs and molecular models, include review questions, questions classified by type, and general questions. The classified problems are in matched pairs. Even-numbered questions have a bold-faced number, and the solution is given in Appendix O and in the *Student Solutions Manual*.

### *Conceptual Questions*

These questions ask the student to think through the solution to a question or problem. Calculations are generally not involved.

### *Challenging Questions*

Students can try their newly acquired skills on questions that involve more detailed calculations or an even deeper understanding.

### *Summary Questions*

Summary questions tie together the concepts from the current chapter with those in previous chapters.

### *Questions from the Interactive General Chemistry CD-ROM*

The workbook that accompanies the *Saunders Interactive General Chemistry CD-ROM* contains hundreds of questions that focus the student's attention on understanding chemistry. Some of these questions have been organized and rewritten to fit the topics in this book. Virtually all require the student to draw conclusions by observing an experiment or chemical process.

### *Problem-Solving Tips and Ideas*

From years of teaching chemistry, we have found that students make certain errors in solving problems and that they have specific difficulties. These "Tips and Ideas" pass on our experience to the student.

## Essays on History and Current Issues

### *Historical Perspective*

These essays, about the lives of important scientists, both living and dead, provide some insight into the historical background of chemistry. They are intended to help the student see the human side of chemistry and to learn how ideas and concepts develop.

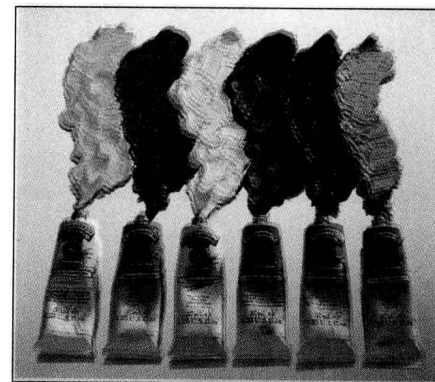
### *Current Perspectives*

Scattered about the book are a number of essays that describe the applications of chemistry in the world today, from the current controversy over banning chlorine to the uses of buckyballs in medicine.

## Illustrations

### *Full-Color Photography and Molecular Models*

Over 600 full-color photos are included, each chosen specifically for this book. These photos illustrate common elements, compounds, and minerals as well as reactions and other processes in progress.



### *Molecular Models*

Wherever appropriate we have included computer-generated models of the molecules involved in chemical reactions or that are being illustrated in a photograph. (See page xxix for the color scheme used in these models.) Most of these models are found on the *Saunders Interactive General Chemistry CD-ROM* and/or on the *Saunders Chemistry Web Site* (at <http://www.saunderscollege.com>). Software on the CD-ROM and software that can be downloaded from the World Wide Web allow the student to rotate these models, change the type of model (ball and stick or space-filling), and measure bond angles and bond distances. (See page xx for more on the *Saunders Chemistry Web Site*.)

### *Art*

The art for this edition is almost entirely new. Color has been used to make the diagrams as attractive and meaningful as possible. In addition, color is used pedagogically.

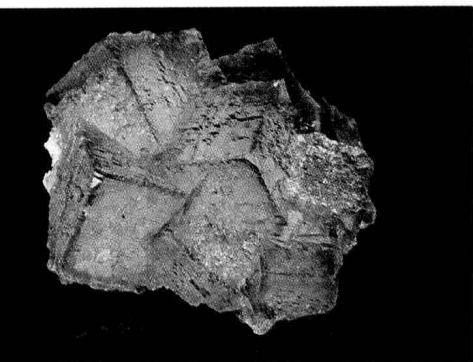
- In the periodic tables in the text, main group metals are shown in red, transition metals in yellow, metalloids in gray, and nonmetals in green.
- A common color scheme is used in the illustration of molecular models (see page xxix of this text).

## Other Features

- Each chapter ends with *Chapter Highlights*, a summary of the important concepts, equations, and key terms.
- Boxes titled “A Closer Look” delve deeper into topics closely related to the subject being discussed. They are meant to provide a more detailed discussion of a subject or a look at ideas used in chemical research.
- Appendices at the back of the book include a review of mathematical methods, a table of conversion factors, important constants, and a glossary of terms in the combined index/glossary. Inside the back cover are short tables of useful constants, a listing of the more useful data tables in the book, and a list of the “top 25” chemicals.



## SUPPORTING MATERIALS FOR STUDENTS



**Saunders Interactive General Chemistry CD-ROM, Version 2.5 with ActivChemistry**, a multimedia companion to *CHEMISTRY & CHEMICAL REACTIVITY*, was originally designed by John Kotz and William Vining, University of Massachusetts, and produced by Archipelago Productions. Divided into chapters, which closely follow the organization of *CHEMISTRY & CHEMICAL REACTIVITY*, the CD-ROM presents ideas and concepts with which the user can interact. One can watch a reaction in progress, change a variable in an experiment and experience the result, follow stepwise solutions to problems, explore the periodic table, and listen to tips and suggestions on problem solving and understanding concepts. The CD-ROM includes original graphics, over 100 video clips of chemical experiments, which are enhanced by sound and narration, and several hundred molecular models and animations.

The CD-ROM also includes molecular modeling software from Oxford Molecular Group that can be used to view hundreds of models, rotate the models for a fuller understanding of their structures, and measure bond lengths and bond angles.

The CD-ROM has been used by thousands of students worldwide since its introduction in 1996. It can be purchased as a package with the textbook or as a stand-alone product.

The **World Wide Web Site** includes molecular models, on-line activities, problem-solving, quizzing, and information about chemistry, to name just a few of the things that can be found at <http://www.saunderscollege.com>. Tap into the Math Review section to brush up on math skills.

**Pocket Guide** by John DeKorte, Glendale Community College, contains useful summaries of each text section, as well as helpful problem-solving reminders and tips.

**Student Study Guide** by Paul Hunter, Michigan State University, has been designed around the key objectives of the book. It provides section summaries, review questions and answers, study questions and problems with answers, crossword puzzles, and a sample test at the end of each of the five parts of the book.

**Student Solutions Manual** by Alton Banks, North Carolina State University, contains detailed solutions to the even-numbered, end-of-chapter Study Questions.

**Student Lecture Outline** by Ronald Ragsdale, University of Utah, is an aid in organizing the material in the text.

## SUPPORTING MATERIALS FOR INSTRUCTORS

**Instructor's Resource Manual** by Susan Young, Hartwick College, suggests alternative organizations of the course, classroom demonstrations, and worked-out solutions to odd-numbered, end-of-chapter Study Questions.

**PowerPoint™ Slide Presentation** comprises several years of class lectures by author John Kotz. Hundreds of slides that cover the entire year of introductory chemistry have been created for lecture presentations. They use the full power of PowerPoint™ and incorporate videos, animations, and photos from the *Saunders Interactive General Chemistry CD-ROM*. Professors can customize their lecture presentations by adding their own slides or by deleting or changing existing slides. The PowerPoint™ files are available on the Saunders Chemistry World Wide Web Site.

The **World Wide Web Site** also includes an Instructor's Section that gives professors access to lecture notes and chapter-by-chapter outlines, among other things. The PowerPoint™ slides are available in this section.

The **1999 Instructor's Resource CD-ROM** is a dynamic lecture tool containing imagery from Saunders 1999 chemistry titles. It can be used in conjunction with commercial presentation software such as PowerPoint™, Persuasion™, and Podium™. The CD-ROM is for both Macintosh and Windows platforms.

The **Overhead Transparency Set** is a collection of 150 full-color transparencies with sizable labels for viewing in large lecture halls. The illustrations chosen are those most often used in the classroom, and most are marked with an icon in the Instructor's Annotated Edition of the text.

A **Test Bank** by Ronald O. Ragsdale, University of Utah, contains over 1100 new, multiple-choice questions and numerous fill-in questions for each chapter.

**ExaMaster+™ Computerized Test Bank** is the software version of the printed Test Bank. Instructors can create thousands of questions in a multiple-choice format. A command reformats the multiple-choice questions into short-answer questions. Problems can be added or modified, and graphics can be added. ExaMaster can be used to record and graph student grades. Available in both Macintosh and Windows formats.

**Chemical Principles in the Laboratory** by Emil Slowinski and Wayne Wolsey of Macalester College, and William Masterton of the University of Connecticut, provides detailed directions and study assignments. The manual contains 42 experiments that have been thoroughly class-tested and selected with regard to safety and cost. An Instructor's Manual provides lists of equipment and chemicals needed for each experiment.

**CalTech Chemistry Animation Project (CAP)** is a set of six video units that cover the chemical topics of Atomic Orbitals, Valence Shell Electron Pair Repulsion Theory, Crystals and Unit Cells, Molecular Orbitals in Diatomic Molecules, Periodic Trends, and Hybridization and Resonance.

**Periodic Table Videodisc: Reactions of the Elements** by Alton Banks, North Carolina State University, features still and live footage of the elements, their uses, and their reactions with air, water, acids, and bases. Available to qualified adopters. Also available in CD-ROM format through JCE:Software, Chemistry Department, University of Wisconsin, Madison, WI 53706, (800) 991-5534.

**Shakhashiri Chemical Demonstration Videotapes** feature Bassam Shakhashiri of the University of Wisconsin-Madison performing 50 three- to five-minute chemical demonstrations. An accompanying Manual describes each demonstration and includes discussion questions.

## Other Supporting Materials

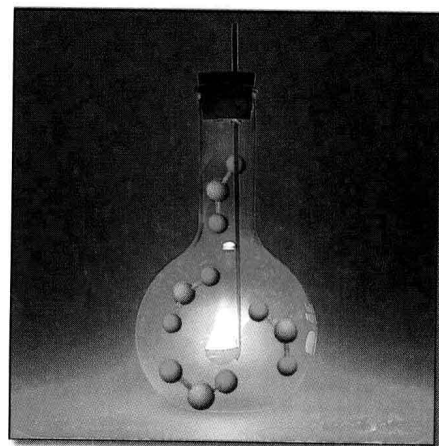
The marginal notations in the Instructor's Annotated Edition of the book list a number of resources. Sources of some of these materials are:

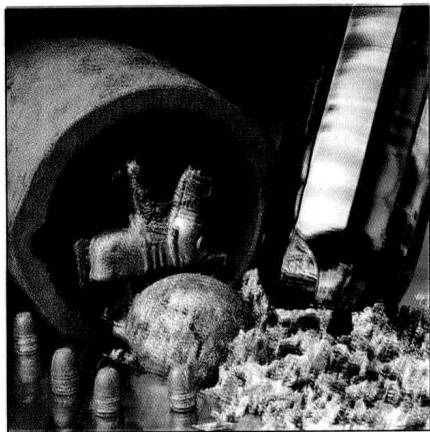
### Videodiscs

*Chem Demos I and II* and *The World of Chemistry—Selected Demonstrations and Animations*, Volumes I and II, are available from JCE:Software, Chemistry Department, University of Wisconsin, Madison, WI 53706, (800) 991-5534.

### Chemical Demonstrations

B. Z. Shakhashiri, *Chemical Demonstrations—A Handbook for Teachers of Chemistry*, University of Wisconsin Press, Madison, WI. Four volumes have been published.





L. R. Summerlin and J. L. Ealy, Jr., *Chemical Demonstrations—A Sourcebook for Teachers*, Volume 1, American Chemical Society, Washington, D.C., 1988.

L. R. Summerlin, C. L. Borgsford, and J. B. Ealy, *Chemical Demonstrations—A Sourcebook for Teachers*, Volume 2, American Chemical Society, Washington, D. C., 1988.

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# Acknowledgments

Preparing the fourth edition of *Chemistry & Chemical Reactivity* took almost eighteen months of continuous effort. However, as in our work on the first three editions, we have had the support and encouragement of our families and of some wonderful friends, colleagues, and students.

## SAUNDERS COLLEGE PUBLISHING

The editorial staff of Saunders College Publishing has once again been extraordinarily helpful. The project has benefitted from their good humor, friendship, and dedication. Much of the credit goes to our Publisher, John Vondeling. We have worked with John for many years and have become fast friends. His support and confidence are greatly appreciated. Not only does he understand publishing, but he knows a thing or two about a good trout stream.

The Developmental Editors for this edition were Beth Rosato and Sarah Fitz-Hugh. In addition to being very pleasant colleagues, they kept the project organized and focused. In addition, they were trusted friends and confidants. We greatly appreciate their efforts to make this a successful book.

Our Project Editor for this edition was Robin Bonner. Her attention to detail, her energy, and her enthusiasm for the project will surely help make this edition as successful as previous editions.

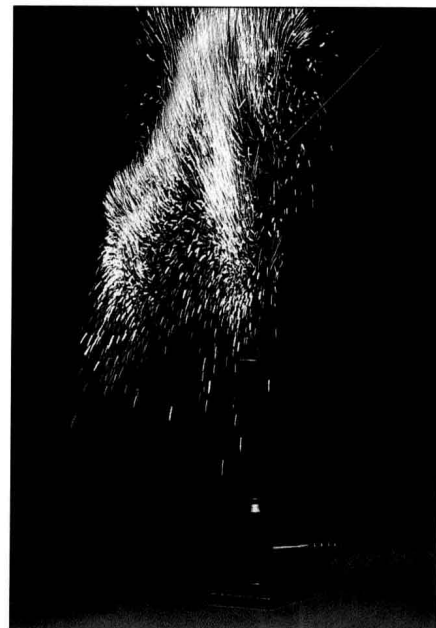
No book can be successful without proper marketing. Pauline Mula was new to this edition, and she was a delight to work with. She was knowledgeable about the market and worked tirelessly to bring the book to everyone's attention.

Caroline McGowan was in charge of the art and design program at Saunders College Publishing. Her assistance was invaluable in helping us learn how to produce art for the book, in helping to ensure that we had chosen appropriate materials, and in designing the final product. All agree it is a beautiful book.

Our team at Saunders College Publishing is completed with Emily Barrosse, Vice President and Publisher, and Charlene Squibb, Production Manager. We appreciate their patience, creativity, and organizational skills.

## PHOTOGRAPHY AND ART

Most of the color photographs for this edition were again beautifully done by Charles D. Winters of Oneonta. He produced dozens of new images for this book, often under great deadline pressure. His work gets better and better, and he has added a new dimension by using software tools to combine photographs with molecular models, often with stunningly beautiful results. We have worked with Charlie for some years and have become close friends. We listen to his jokes, both new and old—and always forget them. When we finish the book, we look forward to a kayaking trip.





We are very pleased to have Susan Young back in Oneonta, New York, where she is now on the faculty at Hartwick College. Susan produced the molecular models for the book using software from the Oxford Molecular Group and worked with the authors and Charlie Winters to design the models for the composite illustrations. In addition, she read the manuscript, the galley and page proofs, and generally provided good advice. We simply could not have done this project without Susan's help, creativity, good humor, and energy.

## OXFORD MOLECULAR GROUP

Several years ago CAChe Scientific, Inc. made a grant of a Molecular Modeling Worksystem to author John Kotz. This software has been used heavily by students at Oneonta in general and inorganic chemistry courses. More recently, the Oxford Molecular Group made a gift of Personal CAChe systems to John Kotz and Charles Winters. These systems were used to prepare the molecular models for this book and the CD-ROM. The people at CAChe—especially George Purvis and Leo Brown—have been extremely helpful, and we wish to acknowledge their support with gratitude.

## OTHERS

Bill Vining, a former student of John Kotz and now a member of the Chemistry Department at the University of Massachusetts, has contributed creatively to this and the previous edition. Bill and John Kotz collaborated on the CD-ROM and wrote the *Workbook* that accompanies the CD-ROM set. Questions on the CD-ROM for this book have been drawn from the *Workbook*, and we wish to acknowledge Bill's contribution.

Publishing a book is a complicated process, and a large team of people is needed to carry out the task. At least one more member of our team deserves special thanks: Katie Kotz kept the work in Oneonta, New York, and Madison, Wisconsin—photography, text preparation, and photo research—organized. Her organizational skills and her expertise in maintaining a large database of information have been invaluable. In addition, she has been the wonderful wife of one of the authors for 37 years.

