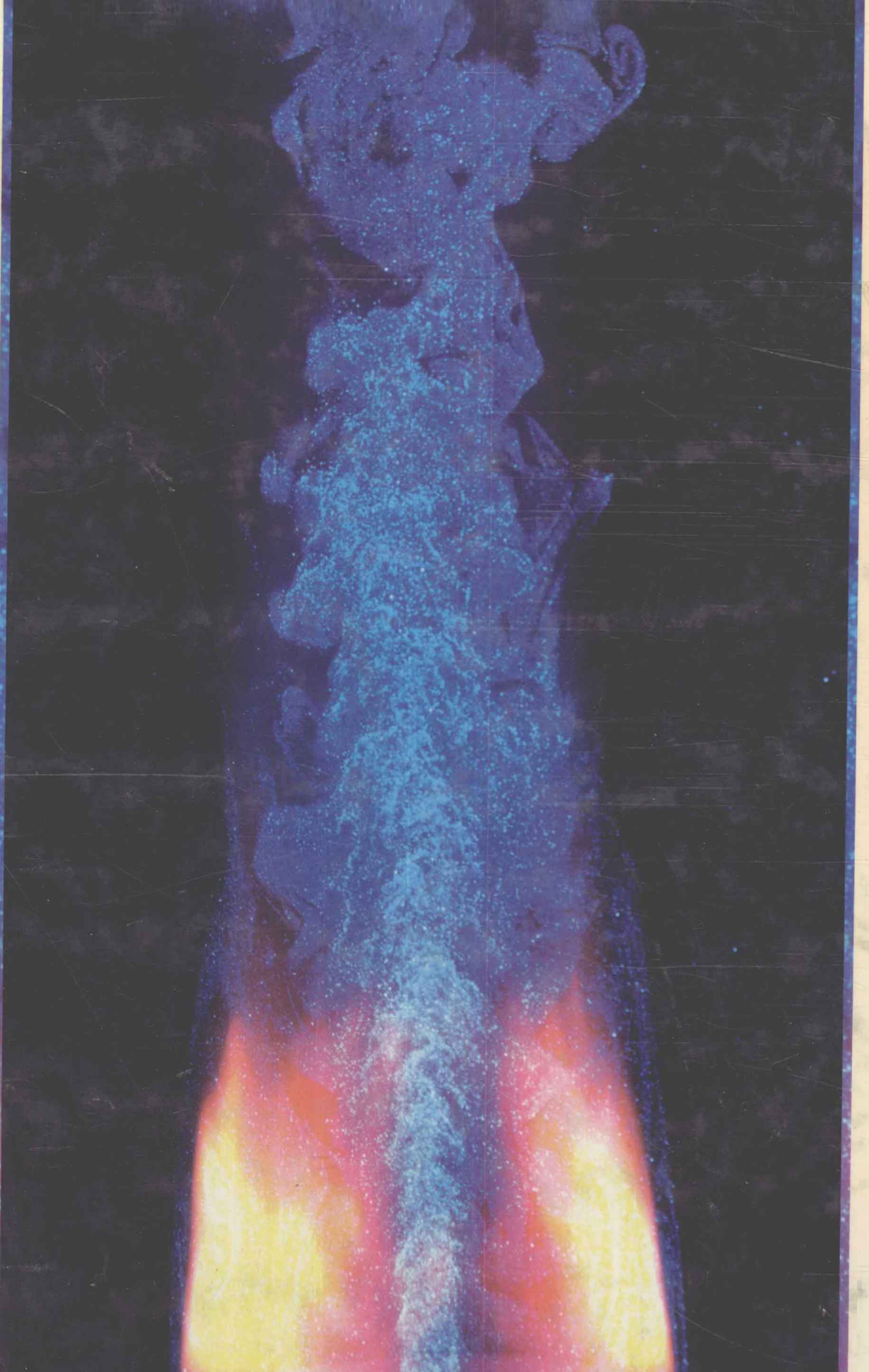

The Chemical World

CONCEPTS AND APPLICATIONS

KOTZ
JOESTEN
WOOD
MOORE

The Chemical World

CONCEPTS AND APPLICATIONS

JOHN C. KOTZ
SUNY Distinguished Teaching Professor
State University of New York
College at Oneonta
Oneonta, New York

MELVIN D. JOESTEN
Professor of Chemistry
Vanderbilt University
Nashville, Tennessee

JAMES L. WOOD
Resource Consultants, Inc.
Brentwood, Tennessee

JOHN W. MOORE
Professor of Chemistry
Director, Institute for Chemical Education
University of Wisconsin-Madison
Madison, Wisconsin

Illustrated by George V. Kelvin

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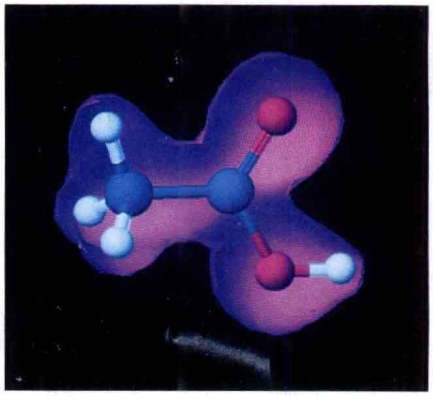
Preface



As authors of a chemistry textbook, we are often asked why books are revised every few years. "There really isn't much new in the theory of chemistry. Don't you just move words around?" The situation is just the opposite. There is a great deal that is new every day in chemistry, and much of it can be understood and appreciated by beginning students. *So, many new developments are often included in new editions, while still describing all the main topics in the theory of chemistry in order to serve the broadest possible audience.* In addition, because chemistry courses in the United States currently emphasize numerical calculations, there are a large number of solved examples, drill problems, and study questions. The result is that books have become longer and longer, and more and more complex.

Many people concerned with chemical education believe that it is time to reverse this trend, that re-examination of the goals of introductory college and university chemistry courses is long overdue, and that several challenges must be addressed:

- Lectures should be fewer.
- Examinations must require critical thinking in addition to numerical problem solving skills.
- Laboratories should be more flexible.
- Concepts and applications should be better integrated into the courses.
- Conceptual problem solving should be emphasized.
- Numerical problem solving should be de-emphasized.

GOALS OF THIS BOOK

Our response to these and other concerns in science education takes the form of this book. The title, THE CHEMICAL WORLD: CONCEPTS AND APPLICATIONS, conveys its principal themes: a broad overview of the concepts of

chemistry and their applications in the world around us. Our goals in this book have been

- To cover the truly important concepts of chemistry.
- To enable students to see how chemistry is done.
- To demonstrate how to solve conceptual as well as numerical problems.
- To convey the sense that chemistry is a dynamic field, a subject with both a fascinating history and continually unfolding new developments.
- To provide an understanding of everyday phenomena.
- To illustrate where chemistry fits among other sciences and technologies.
- To begin to integrate information technology appropriately into the learning process.
- To prepare students to evaluate the risks and benefits of science and technology in modern society.

AUDIENCE

THE CHEMICAL WORLD: CONCEPTS AND APPLICATIONS is a textbook for the introductory course in chemistry for students pursuing further study in science, whether that science is chemistry, biology, engineering, geology, physics, or related subjects. Our assumption is that students beginning this course have had a basic foundation in algebra and in general science. Although undeniably helpful, a previous exposure to chemistry is neither assumed nor required.

PHILOSOPHY AND APPROACH

Only concepts that we believe are truly fundamental to understanding basic chemistry have been included, so that those concepts can be seen more clearly. Topics such as stoichiometry, acid–base chemistry, basic theories of chemical bonding, equilibrium, thermodynamics, kinetics, and electrochemistry are covered. However, when discussing bonding, for example, orbital hybridization and molecular orbital theory are excluded. These theories are of undeniable importance to students in higher level courses in chemistry, and they are introduced in such courses when they are needed. The chemistry that provides a background for biology, geology, nutrition, and engineering can be understood without them.

Many topics in current books are just "there," and there is never enough time to cover them all. So much time is spent on the details of chemical equilibria, kinetics, and thermodynamics, bonding, electrochemistry, and other subjects that the applications of chemical concepts cannot be included. By eliminating some of the details, we have created a book that can be used in its entirety. In order to better integrate the concepts of chemistry with their applications, we have not introduced a principle in this book unless it

is needed later in the book and unless it is placed in the context of its applications. For example, the chapter on solids (Chapter 14) covers not only crystal structure, but also cement, ceramics, superconductors, and the use of silicon in semiconductor devices. A course based on this book will truly be a "general chemistry" course—an introduction to the field of chemistry that will leave students well prepared for further studies in science.

In order to teach both numerical and conceptual problem solving, we have included a number of conceptual problems involving critical thinking skills in addition to plenty of the usual numerical problems.

It is our belief that books will indeed become thinner as some of the functions of textbooks are taken over by computers, video, and related technologies that better show the dynamic nature of chemistry. For this reason we have included in a number of chapters some questions based on the use of a computer program or videodisc.

Finally, we believe that it is important to involve the reader in "doing" chemistry and to show that chemistry can be done with everyday things. For this reason, each chapter includes several "take-home/dorm-room" experiments called ***Chemistry You Can Do.*** These illustrate the topic of the chapter and can be done with simple and familiar chemicals and equipment found at home or on a college campus.

ORGANIZATION

The first chapter, "The Nature of Chemistry," is a description of the science of chemistry and how it is done in principle and in practice. The question of risks and benefits is addressed.

"The Nature of Matter," Chapter 2, introduces the kinetic theory of matter, states of matter, and classification of matter as mixtures or compounds. Some units and numerical quantities important to chemistry are discussed in this context.

The next four chapters—"Chemical Elements" (Chapter 3), "Chemical Compounds" (Chapter 4), "Chemical Reactions," (Chapter 5) and "Stoichiometry" (Chapter 6)—are the basis of all that follows. The fundamental concepts of element, compound, atom, molecule, ion, and chemical change are developed here and placed in the context of applications and their practical importance in chemistry. Simple organic molecules are introduced so that their role in applications can be meaningfully included.

Chapters 7 and 8 describe the most important principles of chemical reactivity. The first of these chapters deals with thermodynamics and the second with kinetics and chemical equilibrium. THE CHEMICAL WORLD differs from other books by introducing these key concepts early so that they can be applied to the chemistry that is discussed subsequently.

The next three chapters—"Electron Configurations, Periodicity and Properties of Elements" (Chapter 9), "Covalent Bonding" (Chapter 10), and "Molecular Geometry and Isomerism" (Chapter 11)—return to the topic of atomic and molecular structure and to the ways that atoms are assembled into molecules. We have not included the theories of orbital hybridization or of molecular orbitals. In addition, some details of atomic structure are ex-

cluded to make room for a description of the role of atomic and molecular structure in determining the chemistry of elements and compounds.

Chapters 12 ("Gases, Intermolecular Forces, and Liquids"), 13 ("Energy, Organic Chemicals, and Polymers"), and 14 ("Solids") are concerned broadly with states of matter. Chapter 13 is unique in a textbook at this level because it covers organic chemicals and their uses early in the text and not as a peripheral subject.

The next three chapters, "Solution Chemistry" (Chapter 15), "The Importance of Acids and Bases" (Chapter 16), and "Electrochemistry" (Chapter 17) include many examples and exercises that focus on practical applications.

Chapters 18 through 21 close the book with topics that provide abundant opportunities for the integration of concepts and applications. First, "Elements from the Land, Sea, and Air" (Chapter 18) shows how electrochemistry and other techniques are used to produce elements and compounds that are important in our economy. Next, we discuss two topics—"Nuclear Chemistry" (Chapter 19) and "Chemistry of the Atmosphere" (Chapter 20)—that are constantly in the news and should be understood by scientifically literate citizens. In Chapter 20, the chemical concepts that bear on air pollution and smog formation, the greenhouse effect, and ozone depletion are fully explored. Finally, Chapter 21 on "Chemistry of Life" describes important and newsworthy topics such as genetic engineering.

FEATURES

Each chapter of the book includes an **introductory paragraph** to give an overview of the chapter and to provide practical reasons why the topics are worth studying. In addition, there are worked **Examples** throughout the text to illustrate important principles and to serve as models for solving Exercises and end-of-chapter problems. In many cases the examples are integrated into the text. There are also **Exercises,** both quantitative and qualitative, that follow many of the examples. Answers to the Exercises are found in Appendix L.

Each chapter also contains at least one ***Chemistry You Can Do*** experiment. This feature encourages students to perform chemistry experiments on their own, using materials readily available at home or on campus. Thought-provoking questions at the conclusion of the open-ended experiments encourage students to consider the reasons for the outcome of the experiment. The results of the experiments and answers to the questions are provided in the instructor's manual.

All chapters have a number of boxed features. ***Portrait of a Scientist*** boxes provide a glimpse into the lives of scientists, both those who helped create the science of chemistry in the past and those who continue the tradition today. ***Deeper Look*** boxes furnish more detailed information on a particular principle or the application of a specific concept. These include "The Wave-Particle Dual Nature of Light" or "What General Conditions Produce Smog?"

Another type of box, ***The Chemical World,*** features excerpts by the late Isidore Adler of the University of Maryland and by Nava Ben-Zvi, of the Hebrew University of Jerusalem, from the popular Annenberg/CPB

telecourse series "The World of Chemistry." These describe such topics as "A Better Aluminum Foil" and "Unraveling the Protein Structure." Each box identifies "The World of Chemistry" videotape in which the material appears.

Finally, the ***News Feature*** boxes show what is happening on the cutting edge of chemistry research. Topics include creating fake fats and isolating potential drugs from frog skin.

This book also contains a number of **full-color original photographs** by Charles D. Winters to create a visual accompaniment to the explanation of principles and applications. Photos are also used in some end-of-chapter Study Questions. In addition, all the art has been drawn by premier scientific illustrator George Kelvin. His use of color and eye for composition and detail make the illustrations and diagrams even more understandable.

We have used **margin notes** to highlight important points and interesting facts, to note topics to be discussed later in the text, and to help locate material. **Boldfaced terms** within the text indicate the introduction of new concepts, and most of these are also defined in the **Glossary/Index.**

At the end of each chapter you will find a section called "In Closing," which lists **goals** and concepts that should be understood after reading the chapter. Each goal is followed by the relevant section number. There are also a number of end-of-chapter **Study Questions,** some illustrated with photographs. They have been chosen to provide a balance between numerical problem-solving questions and conceptual "thought" questions. Question types include review questions, questions classified by category, general questions, and questions that require using the computer programs and videodiscs that are available to adopters of the text. Each chapter may also contain one or more summary questions, which tie in concepts from previous chapters. Answers to questions numbered in boldface are given in Appendix M.

Finally, there are numerous **appendices,** which include problem-solving skills, basic math operations; common units, equivalences and conversion factors; physical constants; naming simple organic compounds and coordination compounds; ionization and solubility constants; reduction potentials; hybridization solutions to in-text exercises; and answers to selected study questions.

SUPPORTING MATERIALS

Written Materials for the Student and Instructor

The **Student Study Guide** by Dean Nelson of the University of Wisconsin-Eau Claire has been designed around the key objectives of the book. Each chapter of the study guide includes study hints, true/false questions, a list of symbols presented in the chapter, a list of terminology, concept maps of the chapter topics, a concept test, a discussion of how the chapter material relates to other chapters, crossword puzzles, and supplementary reading of current interest.

The **Student Solutions Manual** by John Moore and Greg Steinke of the University of Wisconsin-Madison gives detailed solutions to designated end-of-chapter study questions. The manual also contains strategies for problem solving.

The **Student Lecture Outline** by Ronald O. Ragsdale of the University of Utah helps students organize material in the text and serves as a helpful classroom note-taking supplement.

A **Problem Solving Workbook** by Ronald O. Ragsdale provides many multiple-choice questions, most with complete solutions, to help students practice their test-taking and problem-solving skills.

An **Instructor's Resource Manual** by the authors provides solutions to the end-of-chapter study questions. The manual also lists the important objectives for each chapter, gives suggestions for possible ways to organize the course, suggests classroom demonstrations, and explains the results of the "Chemistry You Can Do" experiments and answers the questions about them.

A **Test Bank** provides hundreds of conceptual and numerical problems for use by the instructor. It is available in written, Macintosh, and IBM PC versions.

Overhead Transparencies of 150 figures from the book are available to adopters of the book. In addition, these transparencies as well as those from all other Saunders College Publishing chemistry textbooks are available on the Shakhashiri Chemical Demonstrations videodisc mentioned below. Both the transparencies and the videodisc are available at no charge to the adopters of this book.

Laboratory Manuals

Saunders offers many excellent general chemistry laboratory manuals, all of which can be used in conjunction with THE CHEMICAL WORLD. An instructor's manual is available for each title. In the event that none of these laboratory manuals meets your needs individually, selected experiments can be custom published as a separate laboratory manual, in accordance with Saunders' custom publishing policy. Please contact your local sales representative for more information on custom publishing.

Laboratory Experiments for General Chemistry, second edition, by Harold R. Hunt and Toby F. Block of Georgia Institute of Technology contains experiments that are designed to minimize waste of materials and stress safety. Pre-lab exercises and post-lab questions are included. The manual includes 42 experiments.

Experimentation and Analysis in the Chemistry Laboratory by Daniel Reger of the University of South Carolina, Eugene R. Weiner of the University of Denver, and William Gilkerson of the University of South Carolina presents clear, precise instructions in pre-lab exercises and emphasizes safety throughout. This manual includes 40 experiments.

Chemical Principles in the Laboratory, fifth edition, by Emil J. Slowinski and Wayne Wolsey of Macalaster College and William J. Masterton of the University of Connecticut provides detailed directions and advance study assignments. These thoroughly class-tested experiments were chosen with regard to cost and safety. The manual includes 43 experiments.

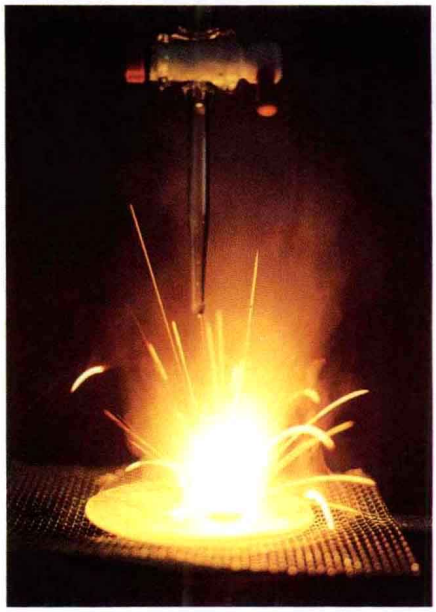
Experiments in General Chemistry by Frank Milio and Nordulf Debye of Towson State University and Clyde Metz of the College of Charleston, is the result of many years of collaboration on the development of laboratory

tested, and attention has been given to cost and safety. This manual contains 44 experiments.

Experimental General Chemistry, second edition, by Carl B. Bishop and Muriel B. Bishop, both of Clemson University, Kenneth Gailey, late of University of Georgia, Athens, and Kenneth Whitten of the University of Georgia, Athens, contains descriptive, quantitative, and instrumental experiments. This manual provides detailed instructions and incorporates helpful notes into the experiments to help students gain confidence. The manual includes 27 experiments.

MULTIMEDIA MATERIALS

Many data in this book are from an extensive computerized collection of information on the chemical elements known as the **KC? Discoverer** database. Data were carefully assembled by a team of chemists, and references are provided, making this an excellent "official" database. Many of the tables herein reflect the information from *KC? Discoverer*, a program and database available for the four different platforms described below. Each is a significant and independent program in its own right but is built around the complete database.



- "*KC? Discoverer* with Knowledgeable Counselor" by Daniel Cabrol, John W. Moore, and Robert C. Rittenhouse for IBM PS/2 or PC-compatibles with at least 640K memory and a hard disk.
- "*KC? Discoverer*" by Aw Feng and Moore, for IBM PC and PC-compatibles.
- "*KC? Discoverer* for the Apple II" by Michael Liebl, for Apple II machines with 128K RAM.
- "The Periodic Table Stack" by Michael Farris for Apple Macintosh, with HyperCard.

These programs are available at no charge to the adopters of the text, or they may be purchased directly from *Journal of Chemical Education: Software (JCE: Software):* Department of Chemistry, University of Wisconsin—Madison, 1101 University Avenue, Madison, WI 53706. For further information on *KC? Discoverer* and its use in the classroom setting, see J. Kotz, *J. Chem. Educ.*, **1989**, *66*, 750.

The Periodic Table Videodisc: Reaction of the Elements by Alton J. Banks is also available in accordance with Saunders' adoption policy or may be purchased from *JCE: Software*. This videodisc is a *visual* database; it shows still and motion images of the elements, their uses, and their reactions with air, water, acids, and bases. It is a particularly useful way to demonstrate chemical reactions in a large lecture room. The videodisc can be operated from a videodisc player by a hand-controlled keypad, a barcode reader, or an interface to a computer running any of the four programs above. When the videodisc is run from a computer, the many additional features of each program become available to users.

Shakhashiri Chemical Demonstration Videotapes contains a unique set of 50 three- to five-minute chemical experiments performed by Bassam

Shakhashiri. These videos bring the drama of chemistry into the classroom. An instructor's manual describes each experiment and includes questions for discussion. The videotapes are available free to adopters of the text. **Saunders General Chemistry Videodisc** contains most of the Shakhashiri demonstrations. In addition to this live-action footage, almost 3000 still images taken from eight of Saunders' general chemistry textbooks, including THE CHEMICAL WORLD, are included on the two-disc set. This videodisc is free upon adoption of any of Saunders' general chemistry texts.

The World of Chemistry Videotapes are based on the television series and telecourse, "The World of Chemistry," with Roald Hoffmann as host. These 26 tapes are each about 30 minutes long and provide introductory material on the principles and applications of chemistry. The tapes may be ordered through the Annenberg Foundation at 1–800–LEARNER ($350).

Demonstrations and animations from The World of Chemistry Videotapes are offered in a streamlined two-videodisc version called **The World of Chemistry: Selected Demonstrations and Animations I and II.** These are available in accordance with Saunders' adoption policy or may be purchased from *JCE: Software.*

Reviewers

The success of any book is due in no small way to the quality of the reviewers of the manuscript. All of the authors of this book have written books before. We all believe that the reviewers listed below are the best we have ever worked with. Many of them believe, as we do, that it is time to change how we teach introductory chemistry, so many went well beyond their charge and produced highly detailed reviews that were invaluable in developing our new approach to the subject. We would especially like to thank Greg Steinke, who provided solutions to the end-of-chapter problems, and Clyde Metz and Donald Kleinfelter, who took extreme care under great time constraints to review the galleys and page proofs for accuracy. A special thanks also to John DeKorte, who wrote the appendix on hybridization. They and all of our other reviewers will find themselves in this book, and it is a pleasure to acknowledge their efforts.

Jon M. Bellama
University of Maryland

Rathindra N. Bose
Kent State University

Mary K. Campbell
Mount Holyoke College

Dewey Carpenter
Louisiana State University

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Brigham Young University

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Hope College

Stanley Williamson
University of California, Santa Cruz

Susan Weiner
West Valley College

R. Terrell Wilson
Virginia Military Institute

Acknowledgments

Preparing this book was an intricate process that took over two years. However, we have had the support and encouragement of family and of some wonderful friends, colleagues, and students.

The editorial staff of Saunders College Publishing has once again been extraordinarily helpful. The project has been enjoyable because of their good humor, friendship, and dedication. Much of the credit goes to our Publisher, John Vondeling. John believes, as we do, that the time has come for a different book for introductory chemistry, and he has been instrumental in bringing this team together to produce just such a book. His support and confidence are greatly appreciated.

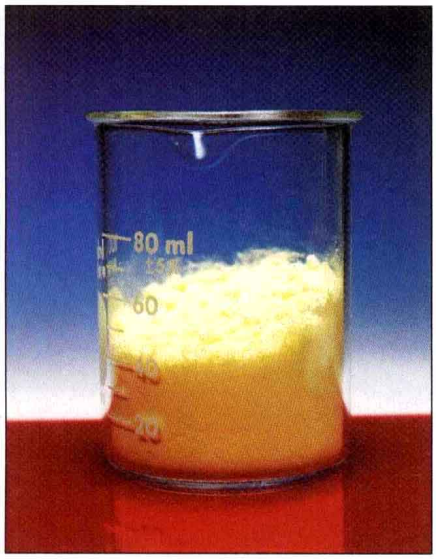
This book was put together in a relatively short time for such a major project, and it simply could not have been done without our two developmental editors, Mary E. Castellion and Jennifer Bortel. Mary is an old hand at editing textbooks, and she worked extraordinarily hard on this project. We believe this book will enjoy a measure of success, and its success is in no small way due to Mary's efforts. Thanks from all of us!

Jennifer Bortel is just beginning her editorial career, which we expect will be a promising one because she has done a wonderful job. She has kept this complicated project organized and helped us meet our deadlines. Her hard work, warmth, and good humor were invaluable in helping us all through the project.

We have worked again with Jay Freedman, who, simply put, is the best copy editor in the business. He was meticulous in helping us prepare this text, and we are again grateful for his efforts.

Carol Field has been our managing editor, and she has been as patient as ever. Her attention to detail is extraordinary, and she keeps all of us calm as deadlines approach. We are pleased that Carol Bleistine was once again the manager of art and design. She has a wonderful sense of color, design, and layout, as this and other books produced by Saunders make clear. Finally, our team is completed by Charlene Squibb, production manager, and Tim Frelick, the director of editing, design, and production, who have kept all of this effort organized.

Many of the color photographs for this edition are the product of the creative eye and mind of Charles D. Winters of Oneonta. He spends countless hours in his studio to get a photograph just right. This book was created in record time, so he has produced excellent work under considerable pres-



sure. It is always a great pleasure to work with Charlie, and one of the authors was especially pleased and honored to be asked to be the best man at Charlie's recent wedding.

The phenomenal drawings in this book were done by George Kelvin, perhaps the finest science illustrator in the United States. His drawings not only illustrate the principles of chemistry, but also are truly works of art.

One goal of this book was to show the many applications of chemistry. This required many color photographs, and meant, therefore, that many photographs had to be found from all over the world. This task was done by Kathrine Kotz. Katie met all of our requests and kept the entire illustrations program on track. We are grateful for her efforts.

Even if a book is very well written and edited, and beautifully illustrated, it may not be successful without effective marketing. Therefore, we are also very pleased to work again with Margie Waldron, one of the most creative and effective—not to mention most pleasant—marketing managers in the publishing world. Margie was assisted by Randi Misher, Marketing Coordinator, and Laura Coaty, Field Product Manager. The marketing team did an impeccable job of conducting market research, helping us refine and test ideas, and getting the book into the right hands.

This book is illustrated with a number of computer-constructed molecular models. All were done using software from CAChe Scientific, Inc. We wish to thank them for their generous grant of this software to JCK.

We wish to express our gratitude to the students and staff of the chemistry department at the University of Wisconsin at Madison for class testing the entire manuscript in 1992 and 1993. Students in Chemistry 103–104 also tried nearly all of the Chemistry You Can Do experiments. Their opinions were invaluable in developing this book.

Many of the Chemistry You Can Do experiments were adapted from activities published by the Institute for Chemical Education as "Fun with Chemistry" volumes I and II. These were originally collected for ICE by Mickey and Jerry Sarquis of Miami University, Ohio. Thomas Kim was responsible for coordinating student comments and suggestions regarding *Chemistry You Can Do.*

Finally, thanks to the many unnamed people and sources from which we received information and advice. The responsibility for the contents of the text, however, rests with us. In spite of our many efforts to produce a perfect book, we are not infallible. Therefore, if you find a better way to explain a concept, a more relevant example or demonstration, or errors in calculations or discussions, please do not hesitate to write us or our editors at Saunders College Publishing.

We hope you enjoy teaching or learning from this book as much as we enjoyed writing it.

John C. Kotz
Oneonta, New York

James L. Wood
Nashville, Tennessee

Melvin D. Joesten
Nashville, Tennessee

John W. Moore
Madison, Wisconsin

August 1993

Contents Overview

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