KOTZ & TREICHEL

Chemistry Chemistry Chemical Reactivity



FIFTH EDITION

Chemistry Chemical Reactivity

Fifth Edition

John C. Kotz

SUNY Distinguished Teaching Professor
State University of New York
College at Opeonta

Paul M. Treichel, Jr.

Professor of Chemistry
University of Wisconsin-Madison

Patrick A. Harman

Art Development and Design



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Preface

This is the Fifth Edition of Chemistry & Chemical Reactivity. The principal goals of the book, beginning with the first edition almost 15 years ago, are to provide a broad overview of the principles of chemistry, the reactivity of the chemical elements and their compounds, and the applications of chemistry. We have organized this approach around the close relation between the observations chemists make in the laboratory and in nature of chemical and physical changes and the way these changes are viewed at the atomic and molecular level.

Another of our goals has been 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 are some reactions in plants and animals and in our environment, and 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 history, music, and literature.

Computers and the World Wide Web are becoming an ever more powerful way to organize and convey information. The first edition of our *Interactive General Chemistry 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. The new version of the CD-ROM, with many new features, is included with this edition of the book. In addition, the online homework system, OWL, which was first used by students at a number of universities during 2001–2002 and is keyed to *Chemistry & Chemical Reactivity*, is an optional part of the learning package.

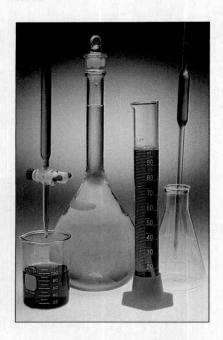
The authors of this book became chemists because, simply put, it is exciting to discover new compounds and find new ways to apply chemical principles. We hope we have conveyed that sense of enjoyment in this book as well as our awe at what is known about chemistry and, just as important, what is not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

AUDIENCE FOR CHEMISTRY & CHEMICAL REACTIVITY, THE INTERACTIVE GENERAL CHEMISTRY CD-ROM, AND OWL

The textbook, CD-ROM, and OWL 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.



Preface



PHILOSOPHY AND APPROACH OF THE BOOK

Starting with the first edition of this book, this book has had two major, but not independent, 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 variations we have followed that order as well. That is not to say that the chapters cannot be used in some other order. For example, the chapter on the behavior of gases (Chapter 12) is 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 often 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 structure and bonding because organic chemistry illustrates the application of models of chemical bonding and molecular structure.

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 whole-heartedly. Therefore, we have tried to describe the elements, their compounds, and their reactions as early and as often as possible in several ways. First, there are numerous color photographs of reactions occurring, of the elements and common compounds, and of common laboratory operations and industrial processes. Second, we have tried to bring material on the properties of elements and compounds as early as possible into the Exercises and Study Questions and to introduce new principles using realistic chemical situations. Finally, relevant highlights are given in Chapters 21 and 22 as a capstone to the principles described earlier.

Additionally, *Current Perspective* attempt to bring relevance and perspective to a study of chemistry. These include such topics as nanotechnology, using isotopes, what it means to be in the "limelight," the importance of sulfuric acid in the world economy, sunscreens, the newly recognized importance of the NO molecule, and LEDs.

Finally, Closer Look boxes describe ideas that form the background to material under discussion or provide another dimension of the subject. For example, in chapter 11 on Organic Chemistry the Closer Look boxes are devoted to a discussion of structural aspects of biochemically important molecules such as amino acids and proteins. In other chapters we delve into molecular modeling and mass spectrometry.

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ORGANIZATION OF THE BOOK

Chemistry & Chemical Reactivity has two overarching themes: Chemical Reactivity and Bonding and Molecular Structure. The chapters on Principles of Reactivity introduce you to the factors that lead chemical reactions to be successful in producing 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. One reason for the enormous advances in chemistry and molecular biology in the last several decades has been an understanding of molecular structure. Thus, sections of the book on Principles of Bonding and Molecular Structure lay the groundwork for understanding these developments. Particular attention is paid to an understanding of the structural aspects of such biologically important molecules as DNA.

The chapters of *Chemistry & Chemical Reactivity* are organized into five sections, each grouping with a common theme.

Part 1: The Basic Tools of Chemistry

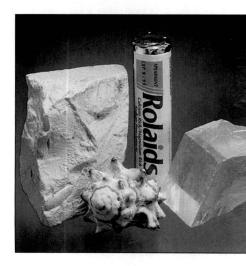
Certain basic ideas and methods form the fabric of chemistry, and these are introduced in Part 1. Chapter 1 defines important terms and is a review of units and mathematical methods. Chapters 2 and 3 introduce basic ideas of atoms, molecules, and ions, and Chapter 2 introduces one of the most important 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.

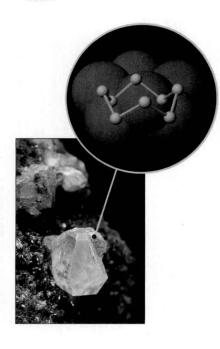
Part 2: The Structure of Atoms and Molecules

The 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, you 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.

In this section of the book you will find the molecular modeling software on the *General Chemistry Interactive CD-ROM* to be especially useful. Models of most of the molecules in the book were done using with programs from CAChe/Fujitsu Group, and we thank them for providing a version for us to use. Portions of this software, and hundreds of models, are included on the CD-ROM along with instructions for their use.





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 16–18, a group of chapters that describes 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 18). To tie together the discussion of chemical equilibria, we again explore thermodynamics in Chapter 19. As a final topic in this section we describe in Chapter 20 a major class of chemical reactions, those involving the transfer of electrons, and the use of these reactions in electrochemical cells.

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 21 is devoted to the chemistry of the representative elements, whereas Chapter 22 is a discussion of the transition elements and their compounds. Finally, Chapter 23 is a brief discussion of nuclear chemistry.

NEW TO THE FIFTH EDITION

Colleagues and students often ask why yet another edition of the book has been prepared. We all understand, however, that even the most successful books can be improved. In addition, our experience in the classroom suggests that student interests change and that there are ever more effective ways to help our students learn chemistry. Therefore, the changes in this edition are focused on those two areas: topics of interest to the majority of our students and new ways to organize the information for effective learning.

Changes in Chapter Organization

Chapter Opening Essay

Each chapter in the book opens with an essay that describes a person, an event, or a development relevant to the subject of the chapter. The objective is to place the chapter's subject in the context of the history of science, of recent events or observations, or questions that students have about the world around them.

Preface

Chapter Goals

A list of 4–6 goals for each chapter is given at the beginning of the chapter. When material relevant to an objective begins within the chapter, the list appears again, and the objective being addressed is highlighted. Students tell us this is useful because it lets them know where they are in the development of the topics, where they have come from, and what topics are yet to come.

"Before You Begin"

This is a list of 2–4 items that you should know, or review, from previous chapters before you begin the new material.

Chapter Focus Pages

The Chapter Focus page illustrates important ideas to be covered in the chapter.

New Layout of Example Problems

All of the Example problems in the book are now divided into 3 or 4 sections. The question is presented as succinctly as possible in the <u>PROBLEMS</u> statement. Next, the <u>STRATEGY</u> section describes generally how the question is to be approached, what data are relevant, and where the student might look in the text for assistance. The third section outlines the <u>SOLUTION</u> to the problem. Finally, if appropriate, there is a <u>COMMENT</u> on the nature of the solution. This represents the way that we ask out students to approach questions.

New Organization of Study Questions

As in previous editions, end-of-chapter Study Questions are basically divided into Review Questions, questions organized according to the relevant section of the chapter, and a list of general questions with no indication of their type. This same organization is followed in this edition. However, more information is now given for questions organized according to chapter section. For questions on a given section or subsection of the chapter, we note which Example questions or Exercises are relevant. Also, we refer to a particular screen or screens of the General Chemistry Interactive CD-ROM. Student feedback on this approach has been extremely positive.

History of Chemistry

We believe it is important for students to put developments in chemistry in their historical context. Therefore, we have included a number of marginal notes with vignettes of historic figures.

Early Coverage of pH

In a number of universities students take only the first semester of general chemistry. One topic previously covered later in the book, but that would be useful for students taking only the first term, is pH. Therefore, the definition of pH and examples of its use are now covered in Chapter 5 as part of the discussion of solution concentration.

Chemical Equilibria

In the four previous editions there were four chapters on chemical equilibria. This subject is now covered in three chapters by reducing slightly the coverage of insoluble compounds and incorporating the topic into a new chapter titled *Other*

Aspects of Aqueous Equilibria (Chapter 18). This new chapter covers buffer solutions, acid-base titrations, and compound solubility.

The Writing Program

A hallmark of the first four editions of *Chemistry & Chemical Reactivity* has been its readability. Nonetheless, the book has been almost completely rewritten with an eye to shortening the material without reducing content coverage or readability.

Revision to Art, Illustrations, and Book Design

For this edition, we have paid particular attention to the art and illustrations. Patrick Harman, the art and design director on the General Chemistry Interactive CD-ROM, was brought into the book project. We believe one reason the earlier version of the CD-ROM was so successful is that it was well designed. Good design leads the user to know clearly how each part of the presentation functions. We wanted to bring this same clarity and ease of use to the book.

To learn how best to improve the illustration program, we spent considerable time talking with students about how they used the book, particularly in regard to the illustrations, look layout, and typography. Based on these discussions, we have paid special attention to the following items.

Molecular Models

We have continued the use of molecular models. However, many ball-and-stick models are now enclosed in a light "screened" version of the space-filling version of the molecule. This gives the student a clear view of the atom-to-atom connections in the molecule as well as a sense of how that molecule fills space. In addition, many of the models are now accompanied by a letter-and-line version of the structure for easier interpretation of the model. And finally, changes in the models used with photos better connect them with the subject of the photo.

Photos

Many photographs in previous editions of the book have been replaced by new photos. (There are roughly 300 new photos by Charles Winters.) One aspect of the revised photo program is to illustrate a sequence of events in a reaction or a chemical analysis. Another aspect of the photo program is that photos are sometimes reused at various places in the book to remind students of a previously covered subject and its relevance to a new topic.

Labeling Photos and Illustrations

Illustrations in science texts can be complex. Also, at times students may be uncertain on what to focus in an illustration. Therefore, we have worked to clarify our illustrations, to make them consistent throughout the book, and, in particular, make them illustrate the connection between the world we can see and the world of atoms, molecules, and ions.

Typography and Book Design

Again from our conversations with students we have made changes in typography and book design. In particular, marginal notes are now titled to highlight their relevance. Also, references to material before or after a topic, and to useful CD-ROM screens, are incorporated into the text.

SUPPORTING MATERIALS FOR STUDENTS

General Chemistry Interactive CD-ROM, version 3.0

This multimedia companion to *Chemistry & Chemical Reactivity* was originally designed by John Kotz and William Vining (University of Massachusetts). William Vining is the primary author of the newest version, and Patrick A. Harman, a design consultant, is now a co-author.

The CD-ROM is divided into chapters that closely follow the organization of *Chemistry & Chemical Reactivity*. Instead of consisting solely of text and illustrations, however, the CD-ROM presents ideas and concepts with which the user can interact. One can watch a reaction in process, 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.

In addition to the descriptive material developed for the earlier edition, the new version of the CD-ROM includes Simulations, Tutorials, and Exercises in which the user can interact with chemical information. For example, the reactants and their concentrations can be changed in a reaction and the effect on reaction rate can be visualized. The user is led through a series of questions on the CD-ROM that lead to fuller understanding of the experiment. So that a student knows when the CD-ROM supports book material, references (such as [CD-ROM, Screen 1.5]) are given at appropriate places in the book.

The CD-ROM also includes molecular modeling software from the CAChe/Fujitsu Group. This software 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.

Additionally, the CD-ROM has a plotting tool, molar mass and molarity calculators, an extensive database of compounds with their thermodynamic properties, and copies of the important tables from the textbook.

Earlier versions of the CD-ROM, used by thousands of students worldwide, were sold separately. The newest version is included in each copy of the textbook.

The ISBN number for the CD-ROM as a stand-alone product is 0-03-035319-X

OWL — Online Web-based Learning System

Learning chemistry takes practice and that usually means completing homework assignments on various sections of the book. The Web-based OWL system presents the student with a series of questions on a given topic and the student responds by indicating a numerical answer or selecting from a menu of choices. The questions are generated from a database of information, so each student in a course is given a different question each time they access a instructional unit. Extensive feedback is available online for each question. Instructors can set up the system to deliver questions on certain dates, specify the number of tries, and specify the number of questions a student must answer successfully before the student is considered to have mastered the topic. Students find it is an excellent way to review for examinations, and studies at the University of Massachusetts-Amherst show a strong correlation between use of the OWL system and course performance.

Use the ISBN number 0-534-45634-0 to order the textbook and OWL.