Basic Chemistry

Second Edition

Zumdahl

Basic Chemistry
Second Edition

Steven S. Zumdahl
University of Illinois

D.C. Heath and Company
Lexington, Massachusetts Toronto

Address editorial correspondence to:

D. C. Heath and Company
125 Spring Street
Lexington, MA 02173

Editorial Director: Kent Porter Hamann
Developmental Editor: Barbara Withington Meglis
Production Editor: Cormac Joseph Morrissey
Designer: Alwyn R. Velásquez
Photo Researcher: Martha L. Shethar
Art Editor: Janet Theurer, Alwyn R. Velásquez
Production Coordinator: Lisa Merrill
Permissions Editor: Margaret Roll
Project Consultant: Richard E. Morel

Cover: Charlotte Raymond / Photo Researchers, Inc.

Published simultaneously in Canada.

Printed in the United States of America.

International Standard Book Number: 0–669–32858–8

10 9 8 7 6

PREFACE

Our goal for this revision is to continue to make introductory chemistry accessible to students who have little or no background in chemistry. The central question that formed the basis of the first edition of this text is still the focus, What can we do to make this material understandable and interesting to students?

We as chemical educators are discouraged by how little our students really seem to understand about our subject, and we are concerned about the dwindling number of chemistry majors. Many educators have suggested that one factor contributing to these problems is that we as chemists have made chemistry too abstract and too sterile—that is, we do not spend enough time dealing with "real chemistry" and how it applies to the lives of our students. We have addressed these issues in this text in several ways, and we hope that our approach will not only help your students understand the subject but also generate interest in science in general.

Emphasis on Reaction Chemistry

We continue to emphasize chemical reactions early in the book, leaving the more abstract material on orbitals for later chapters. In a course where students encounter chemistry for the first time and lack an appreciation for the elegance of atomic theory, it seems especially important that we present the chemical nature of matter before we discuss the theoretical intricacies of atoms and orbitals. Reactions, on the other hand, are inherently interesting to students and can help us draw the students to chemistry. In particular, reactions can form the basis for fascinating classroom demonstrations and laboratory experiments.

We have therefore chosen to emphasize reactions before going on to the details of atomic structure. Relying only on very simple ideas about the atom, Chapters 6–8 represent a thorough treatment of chemical reactions, including how to recognize a chemical change and what a chemical equation means. The properties of aqueous solutions are discussed in detail, and careful attention is given to precipitation and acid–base reactions. In addition, a simple treatment of oxidation–reduction reactions is given. The material on reactions is covered in three short chapters, allowing students to digest it in small doses with lots of end-of-chapter problems while giving instructors considerable flexibility in covering it. These three chapters should provide a solid foundation, relatively early in the course, for reaction-based laboratory experiments.

For instructors who feel it is essential to introduce orbitals early in the course, prior to chemical reactions, the chapters on atomic theory and bonding (Chapters 11–12) can be covered directly after Chapter 4. The book was written to be flexible in this way because we realize that many instructors have a strong preference about when to introduce orbitals.

Development of Problem-Solving Skills

Problem solving seems to be somewhat of a cliche in chemical education. We all want our students to develop real problem-solving skills. In fact, this was a central focus of the first edition of this text. We have maintained this feature in the second edition, and although we do not expect miracles, we feel that the approach will help students become better problem solvers.

In the second edition, we have expanded the number of end-of-chapter exercises. As in the first edition, we have set up the end-of-chapter exercises in pairs. Exercises numbered in blue are in "matched pairs," meaning that the two horizontally aligned problems address similar topics. An "Additional Problems" section, marked by red numbers, includes further practice in chapter concepts as well as more challenging problems. Answers for all even-numbered exercises appear in a special section at the end of the book.

One reason chemistry is difficult for beginning students is that they often do not possess the mathematical skills that are required. Thus we have paid careful attention to fundamental mathematical skills, such as using scientific notation, rounding off to the correct number of significant figures, and rearranging equations to solve for a particular quantity. And we have been very careful to follow the rules we have set down, so as not to confuse the students.

Attitude plays a crucial role in achieving success in problem solving. Students must learn that a systematic, thoughtful approach to problems is better than brute force memorization. We try to establish this attitude early in the book, using temperature conversions as a vehicle in Chapter 2. Throughout the book we encourage an approach that starts with trying to represent the essence of the problem by using symbols and/or diagrams and ends with thinking about whether the answer makes sense. We approach new concepts by carefully working through the material before we give mathematical formulas or overall strategies. We try to encourage a thoughtful step-by-step approach rather than the premature use of algorithms. Once we have provided the necessary foundation, we highlight important rules and processes in skill development boxes so that students can locate them easily.

In the second edition, we have expanded the number of end-of-chapter exercises. As in the first edition, we have set up the end-of-chapter exercises in pairs. Exercises numbered in blue are in "matched pairs," meaning that the two horizontally aligned problems address similar topics. An "Additional Problems" section, marked by red numbers, includes further practice in chapter concepts as well as more challenging problems. Answers for all even-numbered exercises appear in a special section at the end of the book.

Handling the Language of Chemistry and Applications

We have gone to great lengths to make this book "student friendly" and have received enthusiastic feedback from students who've used it.

As in the first edition, we present here a very systematic and thorough treat-

ment of chemical nomenclature. Once this framework is established, students can progress through the book comfortably.

Along with chemical reactions, applications form an important part of descriptive chemistry. Because students are interested in the impact that chemistry has on their lives, we have included many "Chemistry in Focus" boxes, which describe current applications of chemistry. These special interest boxes cover topics such as the relationship of elemental distributions to the disappearance of the dinosaurs, the application of diamond coatings to plastic, alternative fuels, and the greenhouse effect.

Visual Impact of Chemistry

Responding to instructors' requests to include graphic illustrations of chemical reactions, phenomena, and processes, our four-color design enables color to be used functionally, thoughtfully, and consistently to help students understand chemistry and to make the subject more inviting to them. In the second edition, we have modified the photo program to include only those photos that illustrate a chemical reaction or phenomenon or make a connection between chemistry and the real world.

Three Choices of Coverage

For the convenience of instructors, three versions of the second edition are available: one paperback version and two hardbound versions. *Basic Chemistry,* Second Edition, a paperback text, provides basic coverage of chemical concepts and applications through solution chemistry and has 15 chapters. *Introductory Chemistry,* Second Edition, a hardbound text, expands the coverage to 19 chapters with the addition of radioactivity and nuclear energy. Finally, *Introductory Chemistry: A Foundation,* Second Edition, a hardbound text, has 21 chapters with the final two chapters providing a brief introduction to organic and biological chemistry.

Features New to this Edition

We were pleased to receive an overwhelmingly positive response to the first edition of this text. The recommendation made most frequently by reviewers of the first edition was to leave the book alone. With that in mind, we intentionally left much of the text unchanged in the second edition. We only made changes such as the following that we hope will further enhance the text.

- We expanded the number of end-of-chapter questions and problems. Answers to the even-numbered questions and problems are in the back of the text.
- In response to reviewer requests, we streamlined the photo program to include only photos that are pedagogically important to the discussion.

- We introduced a new art feature, the periodic table icons. Some of the more common elements are highlighted in periodic table icons designed to remind students about the position of selected elements in the periodic table and to allow students to become more familiar with the periodic table over the course of the semester.
- We expanded the number of end-of-chapter questions and problems. Answers to the even-numbered questions and problems are in the back of the text.
- In response to reviewer requests, we streamlined the photo program to include only photos that are pedagogically important to the discussion.

Supplements for the Text

A comprehensive teaching and learning package accompanies all three versions of the text:

Study Guide by Iris Stovall
Solutions Guide by James F. Hall
Complete Solutions Guide by James F. Hall
Introductory Chemistry in the Laboratory by James F. Hall
Instructor's Resource Guide for Introductory Chemistry in the Laboratory by James F. Hall
Test Item File
Computerized Testing
Heath Chemistry Lecture Demonstrations
Transparencies

Another item that may be of interest to you is our microscale lab text, *Chemical Investigations: A Laboratory Text for Introductory Chemistry* by Jerry A. Bell.

We have worked hard to make this book and its supplements clear, interesting, and accurate. We would appreciate any comments that would make the book more useful to students and instructors.

Acknowledgments

This book represents the collaborative efforts of many talented and dedicated people to whom I owe much. I am especially grateful to my wife, Eunice, who was a true partner in this project: processing words, proofreading, offering constructive criticism, and providing support in many different ways. I also greatly appreciate the support and friendship of Kent Porter Hamann, Editorial Director, whose consummate professionalism, unreasonable optimism, and unerring judgment concerning level and content have proved invaluable in producing this book. I am also grateful to Barbara Meglis, Developmental Editor, who greatly improved the manuscript in many different ways. Dick Morel, Project Consultant, also contributed enormously to this edition through his insight and creativity in making the text better than it was before.

My thanks go also to Cory Morrissey, Production Editor, who did a really excellent job in the face of a very tight schedule. The creative design by Alwyn Velásquez maintained the airy, nonthreatening appearance of the first edition. Thanks also to Martha Shethar, Photo Researcher, for the beautiful chapter openers and other in-text photos.

Jim Hall of the University of Lowell, Project Consultant, contributed in many different ways to the success of this project. In particular, I appreciate his help with the end-of-chapter problems and his care in getting everything right.

I am grateful to Bruce Zimmerli for hiring dedicated people and for insisting on high quality. My thanks also go to Tom Flaherty, Jeff Lasser, and Jim Porter Hamann for their unswerving enthusiasm for this book and for their extraordinary knowledge of the market. I want to express special appreciation to the D. C. Heath "book reps," a bunch of bright, stimulating people who have provided much valuable feedback and a good deal of fun over the last several years.

My sincerest appreciation goes to the following users of the first edition who reviewed the text in preparation for the revision: Gerald Berkowitz, Erie Community College; John L. Burmeister, University of Delaware; Terry L. Eyrich, Merced College; John Foster, Arizona State University; Marcia L. Gillette, Indiana University-Kokomo; Catherine Hagen Howard, Texarkana College; Jeffrey A. Hurlbut, Metropolitan State College of Denver; Lawrence S. Lynn, St. Louis Community College at Meramec; William T. Nolan, Oakland Community College; Stuart A. Nowinski, Glendale Community College; Paul O'Brien, West Valley College; Virginia M. Shepler, Ferris State University; Sol Shulman, Illinois State University; William Steele, Penn State University; Bradley M. Stone, San Jose State University.

My thanks also go to the following reviewers of the first edition manuscript at various stages of development: Melvin L. Anderson, Lake Superior State University; John T. S. Andrews, Hiram College; Stanley L. Ashbaugh, Orange Coast College; Caroline L. Ayers, East Carolina University; Edith S. Bartley, Tarrant County Junior College; Paul P. Blanchette, Saint Mary's College of Maryland; Ruth J. Bowen, California State Polytechnic University; Ben B. Chastain, Samford University; James Coke, University of North Carolina at Chapel Hill; Ellene Tratras Contis, Eastern Michigan University; W. Dan Covey, L. A. Pierce College; Jerry A. Driscoll, University of Utah; Vicky D. Ellis, Gulf Coast Community College; Gordon J. Ewing, New Mexico State University; Robert D. Farina, Western Kentucky University; K. Thomas Finley, State University of New York, College at Brockport; David V. Frank, Ferris State University; Barbara B. Frohardt, Oakland Community College; Patrick M. Garvey, Des Moines Area Community College; Sue Griffin, Boston University; John Grove, South Dakota State University; Michael D. Hatlee, Briar Cliff College; H. William Hausler, Madison Area Technical College; Don B. Hilton, University of Lowell; Y. C. Jean, University of Missouri—Kansas City; Joseph M. Kanamueller, Western Michigan University; M. Christine Kerr, Montgomery College; Robert C. Kowerski, College of San Mateo; Leslie J. Lovett, West Virginia University; Douglas L. Magnus, Saint Cloud State University; David M. Manuta, Shawnee State University; Ruth P. Manuta, Shawnee State University; Valerie C. Meehan, City College of San Francisco; Kenneth E. Miller, Milwaukee Area Technical College; Patricia Milliken Wilde, Triton College; Jerry L. Mills, Texas Tech University; Steven L. Murov, Modesto Junior College; Laurie B. O'Connor, Chabot College; Lucy T. Pryde, Southwestern College; Fred Redmore, Highland Community College; Agatha Riehl, College of Saint Scholastica; Dan D.

Scott, Middle Tennessee State University; Edmund E. Sorman, Mesa College; Vernon J. Thielmann, Southwestern Missouri State University; Eugene Thomas, California State University—Chico; Frina S. Toby, Rutgers—The State University; Mary S. Vennos, Essex Community College; George H. Wahl, Jr., North Carolina State University; William J. Wasserman, Seattle Central Community College; James H. Weber, University of New Hampshire; John A. Weyh, Western Washington University; Thomas M. Willard, Florida Southern College; Linda Woodward, University of Southwestern Louisiana; Mervat E. Zewail, Cerritos Community College.

S. S. Z.

BRIEF CONTENTS

CONTENTS