STEVEN S. ZUMDAHL

Chemical Principles

THIRD EDITION

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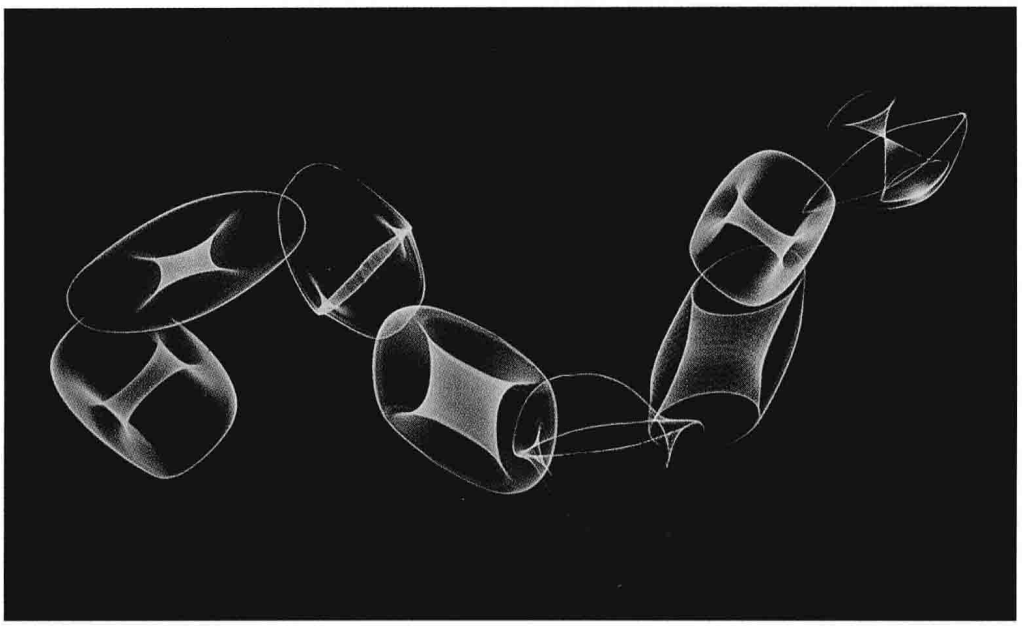
Steven S. Zumdahl

University of Illinois



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Preface

Chemistry is a fascinating and important subject that grows more diverse by the hour. Making this complex subject accessible to students without distortion is the challenge of the chemical educator, especially at the introductory level. *Chemical Principles,* Third Edition, provides a rigorous but understandable introduction to chemistry. It emphasizes conceptual understanding, the importance of models, and thoughtful problem solving.

Chemical Principles is based on my experience at the University of Illinois teaching an accelerated general chemistry course for chemical sciences majors and other students who require a rigorous introductory course. These students typically have excellent credentials and an excellent aptitude for chemistry, but have had only limited exposure to the fundamental concepts of chemistry. Although they may know how to solve stoichiometry and gas problems when they arrive in my course, these students typically lack a thorough understanding of the chemical principles that underlie these applications. This is not because they have had inadequate preparation in high school; instead, I believe it results from the nature of chemistry itself—a subject that even chemists realize requires several passes before real mastery can take place.

So my point in writing this text is to produce a book that does not assume that students already know how to think like chemists. These students will do complicated and rigorous thinking eventually, but they must be brought to that point gradually. Thus this book covers the advanced topics (in gases, atomic theory, thermodynamics, and so on) that one expects in a course for chemical sciences majors, but it starts with the fundamentals, and then builds to the level required for more complete understanding. Chemistry is not the result of an inspired vision. It is the product of countless observations and many attempts, using logic and trial and error, to account for these observations. In this book I try to develop key chemical concepts in the same way—to show the observations first and then discuss the models that have been constructed to explain the observed behavior. I hope students will practice "thinking like a chemist" by carefully studying the observations to see if they can follow the thought process, rather than just jumping ahead to the equation or model that will follow.

In *Chemical Principles,* Third Edition, I take advantage of the excellent math skills that these students typically possess. As a result, there are fewer worked-out examples than would be found in most mainstream books. The end-of-chapter problems cover a wide range—from drill exercises to difficult problems, some of which would challenge the average senior chemistry major. Thus instructors can tailor the problem assignments to the level appropriate for their students.

This text maintains a student-friendly approach without being patronizing. In addition, to demonstrate the importance of chemistry in real life, I have incorporated throughout the book a number of applications and recent advances in essay form.

New to This Edition

I am pleased that the first two editions of this text were all received and that the users did not recommend major changes. We have refined the discussions in areas where that was needed, and have added several new applications boxes, such as "Instant Mirrors" and "Playing Tag," that emphasize the environment, materials, and engineering sciences. We have also thoroughly revised the end-of-chapter problems. In order to expand the number and variety of problems, we have added two new categories—Discussion Questions and Challenge Problems—to the ends of chapters. Discussion Questions provide material for instructors who wish to do more active learning activities. The questions are designed to provoke discussion of fundamental concepts that students often misunderstand.

In general I have continued the emphasis on scientific models that has characterized this text since the beginning. Specifically, I have rewritten the sections on bonding that deal with hybridization, particularly in connection with *d* orbital participation. I used this as an example of how data can be interpreted in different ways leading to different models. Further, many of the illustrations have been reconceived for additional visual clarification of chemical concepts and many have been rerendered to achieve a new standard of accuracy and clarity.

We are also pleased to offer two innovative CD-ROMs in conjunction with the new edition. *The Instructor's Version of Chemistry: Interactive 2.0* contains many of the drawings from the text along with animations, videos, and molecular models and an easy-to-use classroom presentation software package. The second CD-ROM, *Chemistry: Interactive 2.0,* offers electronic practice problems, a review of key topics, and animations and molecular modeling to enhance students' understanding of molecular-level phenomena.

What's It Like to Be a Chemical Professional?

The most unusual chapter in this text is Chapter 1, which discusses what it means to be a chemical professional. I have included this material because students, especially freshmen, know very little about possible careers in the chemical sciences and tend not to think about these issues until it's time for them to start looking for jobs. In addition, they do not realize the incredible diversity of opportunities that exist in the chemical sciences or how often the typical person changes jobs. To inform students about these issues, Chapter 1 discusses some typical careers, as well as some typical problems confronted by someone working in the chemical sciences.

Organization

The early chapters in this book deal with chemical reactions. Stoichiometry is covered in Chapters 3 and 4, with special emphasis on reactions in

aqueous solutions. The properties of gases are treated in Chapter 5, followed by coverage of gas phase equilibria in Chapter 6. Acid-base equilibria are covered in Chapter 7, and Chapter 8 deals with additional aqueous equilibria. Thermodynamics is covered in two chapters: Chapter 9 deals with thermochemistry and the first law of thermodynamics; Chapter 10 treats the topics associated with the second law of thermodynamics. The discussion of electrochemistry follows in Chapter 11. Atomic theory and quantum mechanics are covered in Chapter 12, followed by two chapters on chemical bonding (Chapters 13 and 14). Chemical kinetics is discussed in Chapter 15, followed by coverage of solids and liquids in Chapter 16, and the physical properties of solutions in Chapter 17. A systematic treatment of the descriptive chemistry of the representative elements is given in Chapters 18 and 19, and of the transition metals in Chapter 20. Chapters 21–23 cover topics in nuclear chemistry, organic chemistry, and biochemistry, respectively.

Flexibility of Topic Order

Instructors have several options for arranging the material to complement their syllabi. For example, the section on gas phase and aqueous equilibria (Chapters 6–8) could be moved to any point later in the course. The chapters on thermodynamics can be separated: Chapter 9 can be used early in the course, with Chapter 10 later. In addition, the chapters on atomic theory and bonding (Chapters 12–14) can be used near the beginning of the course. In summary, an instructor who wants to cover atomic theory early and equilibrium later might prefer the following order of chapters: 1–5, 9, 12, 13, 14, 10, 11, 6, 7, 8, 15–23. An alternative order might be: 1–5, 9, 12, 13, 14, 6, 7, 8, 10, 11, 15–23. The point is that the chapters on atomic theory and bonding (12–14), thermodynamics (9, 10), and equilibrium (6, 7, 8) can be moved around quite easily. In addition, the kinetics chapter (Chapter 15) can be covered at any time after bonding. It is also possible to use Chapter 21 (on nuclear chemistry) much earlier—after Chapter 12, for example—if desired.

Mathematical Level

This text assumes a solid background in algebra. All of the mathematical operations required are described in Appendix 1 or are illustrated in worked-out examples. A knowledge of calculus is not required for use of this text. Differential and integral notations are used only where absolutely necessary and are explained where they are used, as in Section 10.2 and Section 15.1.

Supplements

An extensive learning and teaching package has been designed to make this book more useful to both student and instructor.

For the Student

- *Chemistry: Interactive 2.0*, an exciting new CD-ROM product, supports the goals of the third edition by helping students visualize molecular behavior and manipulate molecules in three dimensions. Animations, videos, molecular

models, and problem-solving tutorials are included. The problems tutorial will also be available on floppy disks. See your Houghton Mifflin sales representative for more information.

- *Study Guide,* by Paul B. Kelter of the University of Nebraska, Lincoln. Written to be a self-study aid for students, this guide includes alternate strategies for solving problems, supplemental explanations for the most difficult material, and self-tests. There are approximately 400 worked examples and 800 practice problems (with answers) designed to give students mastery and confidence.
- *Partial Solutions Guide,* by Thomas J. Hummel and Steven S. Zumdahl, both of the University of Illinois, Urbana, provides detailed solutions for half of the end-of-chapter exercises (designated by the blue question numbers) using the strategies emphasized in the text. To ensure the accuracy of the solutions, this supplement and the *Complete Solutions Guide* were checked independently by several instructors.

For the Instructor

- *Chemistry: Interactive 2.0, Instructor's Edition,* is a CD-ROM product that contains the animations, videos, and molecular models that appear on the student version of the CD-ROM. In addition, transparency acetates from the text are included in electronic form, along with a simple-to-use classroom presentation program. The disc is specifically designed to allow instructors to facilitate active learning and to enhance multimedia classroom presentations. The classroom presentation program and electronic versions of the transparencies are also available on floppy disks. See your Houghton Mifflin sales representatives for additional information.
- *Complete Solutions Guide,* by Thomas J. Hummel and Steven S. Zumdahl, presents detailed solutions for all of the end-of-chapter exercises in the text for the convenience of faculty and staff involved in instruction and for instructors who wish their students to have solutions for all exercises. Departmental approval is required for the sale of the *Complete Solutions Guide* to students.
- *Instructor's Guide with Test Item File,* by Steven S. Zumdahl, Susan Arena Zumdahl, Thomas J. Hummel, and Donald J. DeCoste (available to adopters), offers a printed version of more than 2000 exam questions referenced to the appropriate text section. Questions are in multiple-choice, open-ended, and true-false formats.
- *Computerized Testing* presents the *Test Item File* questions in a computerized testing program by ESATest. Instructors can produce chapter tests, midterms, and final exams easily and with excellent graphics capability. The instructor can also edit existing questions and add new ones as desired, or preview questions on screen and add them to the test with a single keystroke. The testing program is available for DOS, Windows, and Macintosh computers.
- *Transparencies,* in a full-color set of 255, are available to adopters of the third edition of the text. Figures and tables were selected from *Chemical Principles,* Third Edition and *Chemistry,* Fourth Edition (also by Steven S. Zumdahl).

- *Houghton Mifflin Chemistry Videodisc* contains video clips of lecture demonstrations and animations of important chemical processes and concepts that can be used in classroom presentations. The disc is available free to adopters of the third edition.
- *Houghton Mifflin Videotapes Series A, B, C, and D* provide over 100 lecture demonstrations performed by John Luoma, Cleveland State University; John J. Fortman and Rubin Battino, Wright State University; Patricia L. Samuel, Boston University; and Paul Kelter, University of Nebraska, Lincoln. Series C demonstrations appear on the Houghton Mifflin videodisc as well.

Acknowledgments

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I greatly appreciate the efforts of Tom Hummel from the University of Illinois who managed the revision of the end-of-chapter exercises and problems and the solutions manuals. Tom's extensive knowledge of general chemistry and high standards of accuracy assure the quality of the problems and solutions in this text. I am grateful also to Don DeCoste of the University of Illinois for many discussions about how students learn chemistry and for creating the discussion questions. Many thanks also go to Regina Frey from Washington University in Saint Louis who contributed some very interesting and challenging end-of-chapter problems. Finally I am deeply grateful to my multitalented wife, Susan Arena Zumdahl, for her cheerful help on all facets of this project and for making life fun. My thanks and love go to Leslie, Whitney, Scott, and Jessica for their love and support.

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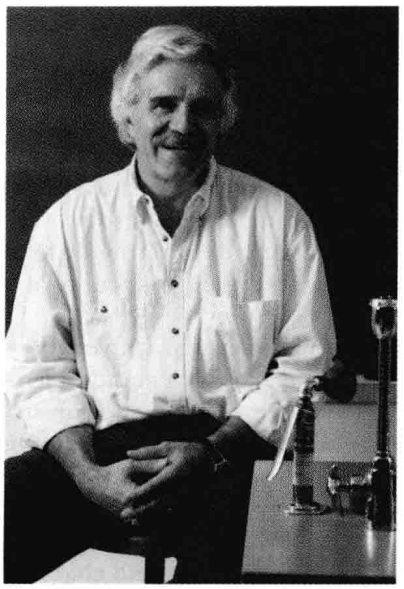
About the Author



STEVEN S. ZUMDAHL received his B.S. degree in Chemistry from Wheaton College (Illinois) in 1964 and his Ph.D. in Chemistry from the University of Illinois, Urbana, in 1968.

In 25 years of teaching he has been a faculty member at the University of Colorado, Boulder; Parkland College (Illinois); and the University of Illinois, Urbana. Currently he is Professor and Associate Head of Chemistry and Director of Undergraduate Programs in Chemistry at the University of Illinois. In 1994 Dr. Zumdahl received the National Catalyst Award from the Chemical Manufacturers Association in recognition of his contribution to chemical education in the United States.

Professor Zumdahl is known at the University of Illinois for his rapport with students and for his outstanding teaching ability. During his tenure at the University, he has received the University of Illinois Award for Excellence in Teaching, the Liberal Arts and Sciences College Award for Distinguished Teaching, and the School of Chemical Sciences Teaching Award (five times).

Dr. Z., as he is known to his students, greatly enjoys "mechanical things," including bicycles and cars. He collects and restores classic automobiles, having a special enthusiasm for vintage Corvettes.

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