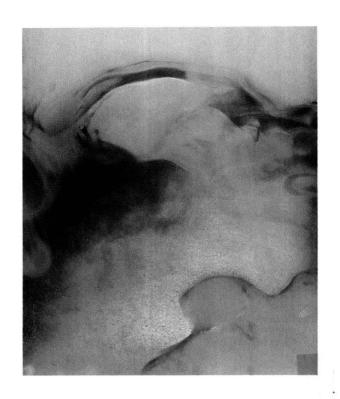
CHEMICAL PRINCIPLES

STEVEN S. ZUMDAHL

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PREFACE

In a time when there is great concern about the dwindling numbers of chemical sciences majors, those of us who teach freshman chemistry must show that our discipline is accessible, fascinating, and important—one that offers very diverse, but always interesting and challenging, job opportunities. We must also let our own enthusiasm for our discipline show clearly as we provide our students with the rigorous and challenging introduction they need to proceed successfully through a demanding curriculum. This is what I have tried to do in *Chemical Principles*.

This text 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 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 very complex subject that 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 science majors, but it starts with the fundamentals, and then builds to the level required for more complete understanding.

In Chemical Principles, 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 a mainstream book. However, 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.

Finally, instead of being written in the style typical of a physical chemistry text (which, of course, is aimed at juniors), this book 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 chemistry in essay form.

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

Preface

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 jobs, as well as some typical problems confronted by someone working in the chemical sciences. I have also included profiles of some real people—several young professionals who are pursuing diverse careers.

Organization

The order in which topics are discussed in this book is traditional for high-level general chemistry courses. The early chapters 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

Although this text will be easiest to use in the order written, 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.

Acknowledgments

The successful completion of this book is due to the efforts of many people. Kent Porter Hamann, Editorial Director, Science, has done a masterful job of spearheading this project. Kent's incredible knowledge of chemistry publishing, coupled with her high standards and endless supplies of energy and enthusiasm have made this project a real pleasure. In addition, I greatly appreciate the efforts of Anne Starr, Production Editor, who certainly has one of the most difficult jobs known to humankind. Anne has done a superb job of coordinating a very complex project, always with calm and good humor.

I am especially grateful to my multitalented wife Eunice, who performed a myriad of vital roles in connection with this project: typing the original manuscript, painstakingly checking galleys and page proofs, and most important, being a constant source of support, moral and otherwise. Eunice has provided innumerable suggestions that have greatly improved this book and, as always, has been a real partner in this enterprise.

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I greatly appreciate the efforts of Tom Hummel from the University of Illinois who carefully read the end-of-chapter exercises, and provided many suggestions for improving their clarity. Tom also checked the answers that appear at the end of the book and provided a very thorough accuracy review of all the solutions in the Solutions Manual.

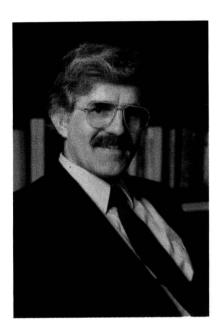
My thanks also go to Ken Brooks from the University of Illinois, who collaborated in writing the end-of-chapter exercises, wrote the Solutions Manual for these exercises, provided many helpful suggestions concerning the content of the text, and who has been a good friend through many projects.

Many other people at D. C. Heath contributed in very important ways to this project. Jim Porter Hamann, Senior Marketing Manager, provided invaluable feedback from the marketplace and a great deal of enthusiastic general support; Billie Ingram and Susan McDermott, Photo Editors, who showed real creativity in securing photos for this text; Henry Rachlin, Designer, who developed a functional and attractive design; and Elizabeth Gale and Joanne Williams, Editorial Assistants, without whose help this book never would have been completed.

The sales reps play a vital role in the life of a text like this one. They furnish valuable information from the marketplace as the text is developed, and then they explain the goals and strengths of the finished text to the potential users. I extend my special thanks to these talented and energetic people.

Finally, I owe much to the following people who reviewed the manuscript: J. Aaron Bertrand, Georgia Institute of Technology; Ernest R. Davidson, Indiana University; James E. Davis, Harvard University; Jack D. Graybeal, Virginia Polytechnic Institute and State University; John E. Harriman, University of Wisconsin—Madison; and John S. Hutchinson, Rice University. These people provided thoughtful, constructive criticism that helped immensely in producing a useful, accurate text. Their contribution to this book cannot be overestimated.

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 23 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 Associate Head of the Chemistry Department and Professor of Chemistry as well as Director of Undergraduate Chemistry Programs at the University of Illinois.

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 (three times).

Dr. Z., as he is known to his students, is an avid collector of classic automobiles. He has recently restored a 1957 Corvette (which is parked in his study) and is now restoring a 1963 Corvette which was his daily transportation for more than 20 years.

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Chemists and Chemistry



CHEMISTRY. It is a word that evokes various, and often dramatic, responses in people. It is a word that is impossible to define concisely, because the field is so diverse, and its practitioners perform such an incredible variety of jobs. Chemistry mainly deals with situations in which the nature of a substance is changed by altering its composition: entirely new substances are synthesized or the properties of existing substances are enhanced.

There are many misconceptions about the practitioners of chemistry. Many people picture a chemist as a solitary figure who works in a laboratory and does not talk to anyone else for days at a time. Nothing could be further from the truth. Many chemists do indeed work in laboratories but rarely by themselves. A typical day for a modern chemist would be spent as a member of a team solving a particular problem important to his/her company. This team might consist of chemists from various specialities: chemical engineers, development specialists, and possibly even lawyers. Figure 1.1 represents the people and organizations with which typical laboratory chemists might expect to interact in the course of their jobs.

On the other hand, many persons trained as chemists do not perform actual laboratory work but may work as patent lawyers, financial analysts, plant managers, salespeople, personnel managers, and so on. Also, it is quite common for a person trained as a chemist to have many different jobs during a career. This will become obvious to you as you read the profiles of chemists at the end of this chapter.

The goal of this chapter is to introduce some of the important aspects of chemistry not typically discussed in connection with learning chemistry. In the remainder of this text we will concentrate on the formal discipline of chemistry—its observations, theories, and applications. In this first chapter we briefly discuss what it means to be a chemist, biochemist, or chemical engineer, and point out some of the opportunities that exist for someone trained in the chemical sciences. This discussion of opportunities is by no means exhaustive. Its purpose is to give some appreciation for the great variety of interesting jobs available to a person with a chemical sciences background. We include an introduction to the world of commercial chemistry and provide a couple of specific examples of the types of problems confronted by the practitioners of the

- 1.1 Thinking Like a Chemist
- 1.2 A Real-World Chemistry Problem
- 1.3 The Scientific Method
- 1.4 Industrial Chemistry
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