GENERAL CHEMISTRY

JOHN B. RUSSELL

SECOND EDITION

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PREFACE

TO THE STUDENT

I have written this book for several reasons. I hope that using it will help you to equip yourself with a knowledge base that will prove valuable wherever your life takes you. In addition, I hope that your study of chemistry provides you with a foundation that will help you understand, and perhaps solve, some of the problems caused by a burgeoning population in a world of dwindling resources. Finally, I hope to convey to you some of the enthusiasm, excitement, and pleasure that chemistry has given me.

SPECIAL FEATURES

As you read this book, you will find a number of special features that you may find useful as you develop your personal techniques for studying chemistry.

CHAPTER OUTLINES Have you ever begun reading a chapter of a textbook and wondered what the title really meant and where the chapter would lead? Every chapter in this book starts with a *Chapter Outline.* Each outline can be useful for two purposes: First, when you begin reading the chapter, it provides an overview of the chapter's scope, organization, and principal thrust, which can enhance your ability to follow the flow of ideas as you work your way through the chapter. Second, returning to the outline and rereading it can be a useful technique for reviewing the chapter's contents.

"CONSIDER THIS" SECTIONS As you read this book, you will find a number of sections entitled *Consider This* that are set off from the main body of the discussion. Most of these are inserted at places where I know from experience that some students tend to get "off the track." In most of these sections, I describe the concept under discussion using slightly different language, or I present it from an alternate viewpoint. (Sometimes, considering an unfamiliar idea from more than one perspective provides a useful intuitive feeling for the idea.) A few of the *Consider This* sections offer an additional comment that, although not essential to your understanding of a concept, provides a sidelight that may enhance your appreciation of the concept.

NOMENCLATURE NOTES The word "nomenclature" refers to a method or system of naming things. Not only is precise chemical nomenclature essential for

accurate communication of chemical ideas, but a knowledge of precise chemical nomenclature actually assists the learning process to an extent that is often underestimated by students. In this book, chemical nomenclature is introduced by small measures in special sections set off as *Nomenclature Notes,* one of which is inserted in the text whenever the topic about to be discussed requires it. All of the material on nomenclature is summarized in Appendix B.

GLOSSARY OF IMPORTANT TERMS You will find a *Glossary of Important Terms* in Appendix A. I have tried to make this as complete as possible. Be prepared to refer to it any time you feel uncertain about the meaning of a particular term or concept.

SUMMARIES At the end of each chapter in this book you will find a *Summary* that highlights the main ideas in the chapter. These can be valuable for reviewing the material in the chapter. Read each summary, and see if all the ideas in it "fit together" for you. If they don't, go back into the chapter and restudy the unclear concepts.

STUDYING AND LEARNING CHEMISTRY

Most of your study habits and techniques were probably formed when you were in high school, perhaps before, and you are undoubtedly aware of the importance of keeping up with your coursework. I am reminded of the old story of the student in an American history class who reached down to retrieve a dropped pencil and missed the Civil War. Chemistry doesn't move along that fast, but because concepts tend to build upon previous concepts, if you get very far behind you may soon find yourself lost. And catching up can be very difficult. Keep up!

You will find some suggestions for effective study techniques at the end of Section 1-1.

A REQUEST

As a chemist and teacher, my greatest thrill comes when I see one of my students surmount a mental obstacle and master a challenging concept. In writing this book, I have tried to help *you* overcome such obstacles. If you're inclined to do so, won't you drop me a line and tell me where you think this book was especially helpful, and if it failed you, how? Some of the best advice I've received has been from students. (My address is at the end of this *Preface.*)

TO THE INSTRUCTOR

PHILOSOPHY

One of my principal purposes in writing this textbook has been to describe to its readers those aspects of physical reality that are revealed by chemistry. Another is to give the student a measure of useful chemical intuition. I hope to teach the student a variety of practical chemical skills.

The principal focus of this book is on the basics, the foundational concepts upon which the student can build in order to succeed, both in subsequent courses in chemistry and in other fields, and in his or her life's endeavors. This is done by presenting chemistry in a way that is simultaneously rigorous and user-friendly, to use a term that is currently popular.

The students enrolled in the typical general chemistry course comprise a remarkably heterogeneous group. They vary greatly in their backgrounds in science and math, in their reading comprehension, in their study habits, and in their motivations. In view of such a wide diversity, it is clear that no single approach to the teaching of chemistry can be equally successful with all students. However, I believe that this problem can be minimized, and the organization and many of the features of this text are designed to do so.

ORGANIZATION

The topic of stoichiometry is introduced early in this text (Chapter 2), and it includes an introduction to solution stoichiometry. This permits incorporation of stoichiometric experiments in the laboratory curriculum early in the term. (The instructor may elect to delete the material on solution stoichiometry; Section 12-6 presents a more rigorous discussion of this topic.) The chapter on stoichiometry is followed immediately by a short chapter on thermochemistry. This permits the early introduction of the ΔH terminology, which greatly enhances the discussion of many subsequent topics, such as ionization energy, electron affinity, bond energy, lattice energy, Born-Haber calculations, and so forth. The properties of ideal and real gases are discussed in Chapter 4, soon enough to allow inclusion of gas-related experiments in the early stages of the laboratory.

Chapters 5 (The Atom) and 6 (Electrons) begin a modified micro-to-macro sequence. These provide the foundation for Chapter 7 (Chemical Periodicity), which includes a brief introduction to descriptive inorganic chemistry emphasizing metal-nonmetal differences. Chemical bonding is introduced in Chapter 8, in which the emphasis is on the basics of ionic and covalent bonding, the octet rule, Lewis structures, molecular geometry (VSEPR theory), and molecule polarity. (More advanced concepts, including those of orbital overlap, hybrid orbitals, and molecular orbitals are postponed until Chapter 19.) The properties of the solid state, both ideal and defect, are described in Chapter 9. The behavior of liquids is described in Chapter 10, along with changes of state, phase diagrams, and Le Châtelier's principle (as applied to phase equilibria).

Chapters 11 and 12 are intended to focus the student's attention on the properties of solutions, especially those of aqueous solutions. Chapter 12 discusses the common types of aqueous-solution reactions and introduces systematic procedures for writing net ionic equations. (Such equations are used throughout the book whenever they are appropriate.)

Chemical kinetics is discussed in Chapter 13, which serves as a conceptual foundation for Chapter 14 (Chemical Equilibrium). (The problem of how to describe kinetic mechanisms that involve equilibrium steps has been solved by delaying discussion of such mechanisms until a special section devoted to them in the chapter on equilibrium.) Chapters 15 and 16 describe aqueous-solution equilibria (acid-base, solubility, and complex-ion) in detail. Chemical thermo-

dynamics is introduced in Chapter 17, culminating with a description of the approach to the equilibrium state in terms of the Gibbs valley. Electrochemistry is discussed in Chapter 18 and includes a special description of the relationship between electrolytic and galvanic cells.

As has been mentioned above, the more advanced aspects of chemical bonding are described in Chapter 19. This completes the laying of a conceptual foundation for a systematic discussion of descriptive inorganic chemistry in Chapters 20 (The Nonmetals), 21 (The Representative Metals and Metalloids), and 22 (The Transition Metals). A survey of organic compounds and some of their characteristic reactions is offered in Chapter 23, and the final chapter in the book is a brief one on nuclear processes.

The problem of how and when to discuss descriptive chemistry in an introductory text is a perennial one. In order to lay an adequate, extensive theoretical foundation, this book delays a systematic discussion of descriptive inorganic chemistry until Chapters 20 through 22. It is thus possible to base the descriptions of all the elements discussed in these chapters on the same uniform, solid base. This does not mean that all descriptive chemistry is ignored in the earlier chapters. For example, as has been mentioned above, Chapter 7 (Chemical Periodicity) includes a comparison of the properties of the metals and the nonmetals. Furthermore, whenever mention of specific properties or behavior is appropriate for illustrating a concept or principle, it has been included. In addition, applications of chemistry to the "real world" are described at appropriate points.

The organization of this text has been carefully planned to allow for variation in individual teacher preferences. For example, gases (Chapter 4) might easily be covered immediately preceding solids, liquids, and changes of state (Chapters 9 and 10). With a little compensation, the coverage of thermochemistry (Chapter 3) could be delayed. Chemical kinetics (Chapter 13) could be covered at almost any time before Chapter 20. The more advanced aspects of bonding (Chapter 19) could be introduced immediately after Chapter 8. Finally, many resequencings of parts of chapters could be successfully accomplished according to the preferences of the individual instructor.

ADDITIONAL FEATURES

Many of the features of this text have been discussed under *To the Student,* above. The following additional features will be of interest to the instructor.

EXAMPLES AND PARALLEL PROBLEMS About 200 worked-out *Examples* of chemical calculations are included within the chapters. Following each of these is a *Parallel Problem,* which is based on the same concept as the *Example* but for which only the answer is given. Many students tend to follow through sample calculations with a "Yes, I see how it's done" attitude, and it is not until a quiz or exam that he or she discovers that the self-confidence was premature. It is not possible for most students to learn chemistry merely by reading (or hearing) about it. It is necessary for them to actively engage their minds by doing problems themselves. Each *Parallel Problem* is provided so that the student can test his or her understanding immediately after following the preceding *Example.* (In many cases, the *Parallel Problem* is not merely a duplicate of the *Example* with different numbers, and so merely memorizing a method may not enable the student to obtain the correct answer.)

ILLUSTRATIONS There is a difficult problem that faces the teacher of general chemistry, one which is associated with the level of abstraction of some topics. For example, it is difficult for many students to visualize the three-dimensional nature of atomic and molecular orbitals. The illustration program in this text has been carefully planned, in part to counter the problem of visualizing the abstract. It includes full-color drawings, graphs, computer-generated representations, and photographs. The use of color accomplishes more than just an enhancement of the appearance of the pages; it also makes complex art work representing abstract constructs and objects much easier for the student to understand.

END-OF-CHAPTER PROBLEMS Approximately 1,200 *Problems* are provided at the chapter ends. Roughly half of the numerical problems are marked by square bullets, which identify those problems for which answers are given in Appendix J.

APPENDIXES Appendixes covering a variety of material follow the last chapter in the text. Appendixes A (Glossary of Important Terms) and J (Answers to Selected Numerical Problems) have already been mentioned. Worthy of special note are Appendixes B (Units, Constants, and Conversion Equations), C (Chemical Nomenclature), D (Mathematical Operations), and E (Clark's Method for Writing Lewis Structures). The rest of the appendixes provide numerical reference data in a number of areas.

INDEX The *index* at the end of this text is unusually complete and has been designed to be especially easy to use. In it, the student is always immediately directed to a page reference, never to a cross reference. (This makes the index a little longer than usual, but much more convenient to use.)

TREATMENT OF COMMON "PROBLEM AREAS" A feature of this text, one that is not immediately obvious from a superficial perusal, is the way some of the common "problem areas" are handled. Some of the topics included in all introductory courses always seem to cause an inordinate amount of difficulty to some students. These include stoichiometry, covalent bonding, solid-state structures, the writing of net ionic equations, chemical kinetics, chemical thermodynamics, and electrochemistry. In this book, these "problem areas" are developed somewhat more slowly and deliberately than is customary in most introductory texts. It should be emphasized that this has been done without compromising the overall level of rigor.

SUPPLEMENTS

The following supplementary materials are available for use with this text:

FOR THE STUDENT

STUDENT STUDY GUIDE by Norman Eatough, California Polytechnic State University, San Luis Obispo: emphasizes the principles of chemistry over the descriptive, but includes both. Examples and explanations illustrate all mathematical operations and difficult concepts in the text.

STUDENT SOLUTIONS MANUAL by Roger Weiss, Humboldt State University: provides complete worked-out solutions to all square bulleted problems in the text.

CHEMISTRY AT WORK IN THE UNITED STATES by Charles Kline: provides information on the chemical industry in the United States. Three volumes are available on a regional basis.

FOR THE INSTRUCTOR

INSTRUCTOR SOLUTIONS MANUAL by Roger Weiss, Humboldt State University: provides complete worked-out solutions to all problems in the text.

TEST BANK: supplies a printed test file including over 1,000 exam questions in both multiple-choice and short-answer formats.

R-H TEST: offers a computerized version of the printed test bank (available for IBM and Macintosh)

VIDEODISC: provides a mode of integrated visual classroom, laboratory, or study center support through a variety of photos, computer graphics, short films, and videos.

OVERHEAD TRANSPARENCIES Approximately 150 full-color acetates of key illustrations from the text.

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Finally, I must acknowledge the contributions that my students have made to this book. The teaching–learning process is indeed a two-way interaction, and I thank them for all they have taught me.

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OVERLEAF

A rural scene in eastern Pennsylvania. *All* the world is composed of chemicals.

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