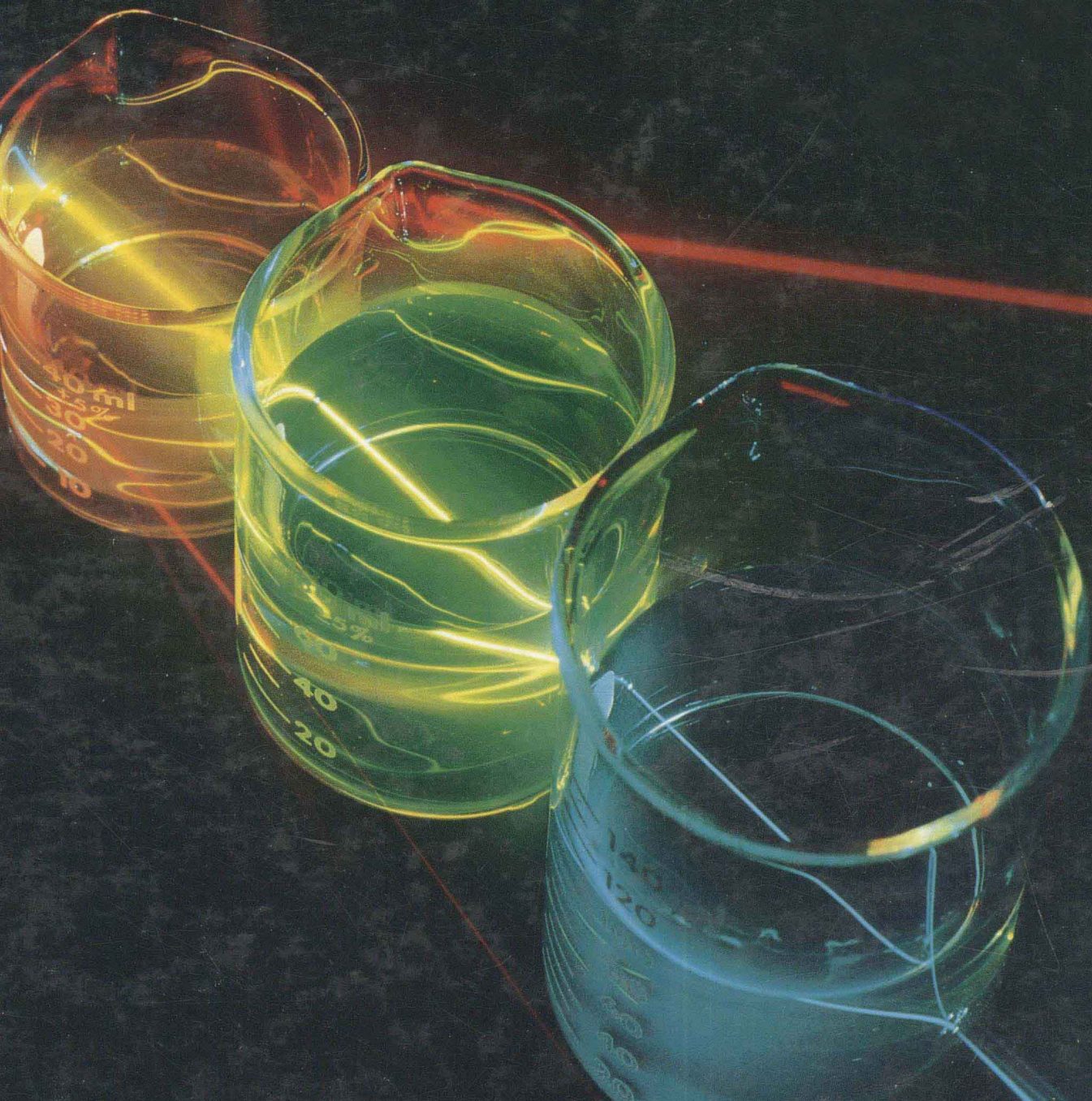


SECOND EDITION • JG

GENERAL CHEMISTRY



SECOND EDITION

GENERAL CHEMISTRY

Darrell D. Ebbing

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CONSULTING EDITOR:

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Values for atomic weights listed in the periodic table on the inside front cover of this book are from the IUPAC report "Atomic Weights of the Elements 1983," *Pure and Applied Chemistry*, Vol. 56, No. 6 (June 1984), pp. 653–674.

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Periodic Table of Elements

Main-Group Elements

	1 IA								
1	1 H 1.00794	2 IIA							
2	3 Li 6.941	4 Be 9.01218							
3	11 Na 22.98977	12 Mg 24.305							
			3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 IIIB
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055
6	55 Cs 132.9054	56 Ba 137.33	57 La* 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22
7	87 Fr (223)	88 Ra (226)	89 Ac** (227)	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (267)

1	Atomic number
H	Symbol
1.00794	Atomic weight

Transition Metals



Metal



Metalloid



Nonmetal

*Lanthanides

**Actinides

58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.36
90 Th 232.0381	91 Pa (231)	92 U 238.0289	93 Np (237)	94 Pu (244)

Main-Group Elements

										18 VIIIA					
										2 He 4.002602					
										13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	
										5 B 10.811	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.998403	10 Ne 20.179
										13 Al 26.98154	14 Si 28.0855	15 P 30.97376	16 S 32.066	17 Cl 35.453	18 Ar 39.948
10	11 IB	12 IIB													
28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80							
46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.710	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.29							
78 Pt 195.08	79 Au 196.9665	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)							

GENERAL CHEMISTRY

FOREWORD

Chemistry is the science that concerns the study of matter from an atomic or molecular perspective. An understanding of chemistry helps to foster practical developments in medicine and health care products, structural materials, energy and food production, and microelectronics. Darrell Ebbing's second edition of *General Chemistry* represents our best effort to provide a text that teaches the principles of chemistry and how to apply them. The second edition is a new book in many respects. The project started in earnest in late 1984, when it was becoming clear that *General Chemistry* would be a successful book for learning chemistry. This new edition builds on the strengths of the first edition, but has been changed in ways that qualitatively enhance the learning experience.

My function as Consulting Editor for the second edition of *General Chemistry* has been to assist Darrell Ebbing in creating the best book for the study of chemistry. I have read and criticized new material, suggested additional topics, helped develop the art program, and evaluated reviewer and user criticisms to help formulate improvements in the text. Together with the entire publishing team, I have attempted to enhance Darrell Ebbing's text. We have produced a new book with balance, consistency, and accuracy. I believe that the book is an excellent path to understanding chemistry.

A glance through the text will reveal that full color has been used throughout, in order to provide more descriptive content. I feel that the presentation of actual chemicals, instrumentation, and equipment brings the subject of chemistry to life. Many of the ideas for the new, original photographs were conceived by Darrell Ebbing and me in an effort to genuinely coordinate the written text material with photographs. Although photographs do not replace the actual experience of seeing a demonstration or performing an experiment yourself, they do make the text material easier to follow. The introduction of full color in this edition of *General Chemistry* has been executed in a way that builds interest in learning the principles that underlie many chemical processes.

A thorough consideration of this second edition of *General Chemistry* will reveal a continued emphasis on learning about the foundations and frontiers of chemistry through a problem-solving approach. The text is rich in problems, ranging from simple extensions of worked-out examples to problems requiring the use of several principles. There has been an effort to improve the quality, quantity, and

range of problems. In this regard the text, by itself, can be used to learn how to apply an understanding of chemistry to solving problems faced in the real world.

Since the first edition of this book, which appeared in early 1984, several events have occurred that have riveted attention to science and technology. The industrial accident in Bhopal, India, in December, 1984; the space shuttle tragedy in January, 1986; the Chernobyl nuclear plant incident in April, 1986; and the continuing mystery of the disease called acquired immune deficiency syndrome (AIDS) are all subjects that have directly affected the lives of many people and are likely to have lasting consequences. Learning about chemistry can help to understand these problems. In *General Chemistry* we have presented chemistry principles with many applications that will help the student of chemistry to have a better perspective on current world problems.

Chemistry is a changing discipline. It historically has been a science associated with a large industry. This remains true today. But recent exciting fundamental advances in chemistry and the other sciences provide unprecedented opportunities for worthwhile practical developments. In the Fall of 1985 the National Academy Press published "Opportunities in Chemistry," the first detailed assessment of the field of chemistry in twenty years. The report, involving over two years of effort from hundreds of academic, industrial, and government leaders, highlights the new opportunities in the research frontiers of chemical reactivity, catalysis, chemistry of life processes, environmental chemistry, and chemistry under extreme conditions. *General Chemistry* provides an entry point that builds opportunities for students to contribute to the science of chemistry at an early stage in their careers. It is remarkable how *doing new chemistry*, not just learning what others have done, becomes possible after only a brief exposure to the principles of chemistry presented in *General Chemistry*.

Mark S. Wrighton

PREFACE

The enthusiastic response of instructors and students to the first edition of this text has been most gratifying and encourages me in the belief that we have succeeded in fulfilling the objectives we set for the text. Those objectives were (1) to explain principles as clearly as possible by always relating abstract concepts to specific real-world events; (2) to present topics in a logical, yet flexible, order; and (3) to offer an abundance of meaningful instructional aids, particularly with respect to problem-solving. The plan for the second edition therefore was to retain the main features and organization of the first edition while improving the exposition where appropriate and adding some instructional features that would further the original objectives of the text.

SOME FEATURES OF THE TEXT

Three particularly noteworthy areas of the text are the problem-solving program, the student study aids, and the flexible presentation of descriptive chemistry.

Problem-Solving Program

Instructors repeatedly cite problem-solving as one of their principal concerns in teaching general chemistry. We felt that this concern could be made less of a burden for both the instructor and the student if the text presented an overall problem-solving program that was consistently followed. Every problem-solving skill is introduced as an *Example*, in which the student is led through the reasoning involved in working out a particular type of problem. The skill featured in each solved Example has been selected to represent a specific category of problems encountered frequently by students of general chemistry. Each Example is accompanied by an *Exercise*, a similar problem that will immediately test the student's understanding of the skill presented in the Example. (Some Exercises are unaccompanied by an Example because the calculations required are explained thoroughly within the main text and are not sufficiently complex to justify a formal Example.) At the end of each Exercise is a list of the corresponding end-of-chapter

practice problems that allow the student to master the specific problem-solving skill.

The *Checklist for Review* at the end of each chapter includes a list of *Key Equations* and a list of *Operational Skills*. Each operational skill states what is needed and what is to be solved for a problem type and includes a reference to the Examples that illustrate the skill.

The *Review Questions* at the end of each chapter are designed to test the student's understanding of concepts and theory. The end-of-chapter problems test the student's command of problem-solving and are in matched pairs (the odd-numbered problems, numbered in blue type, are answered at the end of the book). The problems are divided into three groups: *Practice Problems*, *Additional Problems*, and *Cumulative-Skills Problems*. The Practice Problems are keyed to a particular topic or skill by heading; the Additional Problems are not. Difficult problems in both groups are starred. The last category, the Cumulative-Skills Problems, require the student to combine skills learned in the chapter with those from previous chapters. By their nature, these problems are challenging (some more so than others). The over 2600 in-chapter exercises and end-of-chapter problems in the book, plus 252 worked-out examples, provide extensive opportunity for a thorough grounding in problem-solving.

It should be noted that page numbers for tables of data and other information needed for problem-solving are listed under *Locations of Important Information* on the inside back cover of the book.

Student Study Aids

In addition to the problem-solving program, the text provides numerous instructional aids. Each chapter opens with an outline of the chapter to indicate to instructors and students the scope of material covered. The chapter text begins with the presentation of a "theme problem," which provides a concrete, tangible application of the principles covered in the chapter. The theme establishes a unifying thread that is returned to throughout the chapter to clarify abstract concepts with a practical, real-world example. Important terms are set in boldface type and are accompanied by an explicit definition set in italic type. Key concepts and equations, set in blue type, direct the student's attention to the foundations of problem-solving. Pertinent discussions that appear in other parts of the book are cross-referenced in marginal notes.

Additional end-of-chapter instructional aids help the student to review the material presented in the chapter. The list of *Important Terms* includes section numbers or pages following each term to indicate where in the chapter the word is defined and used. (These terms and some additional ones are gathered in a *Glossary* at the end of the book.) The *Summary of Facts and Concepts* summarizes the theory presented in the chapter, and the *Operational Skills*, as already mentioned, summarizes the problem-solving skills.

Flexible Treatment of Descriptive Chemistry

Chemistry is an experimental science, and descriptive chemistry is an important part of the subject. Until recently this descriptive component has been minimized.

Although its importance is now realized, no consensus has been reached on how best to teach the material. This text provides a flexible treatment of descriptive chemistry, which gives instructors leeway in choosing how this aspect of chemistry should be handled. We have incorporated descriptive chemistry throughout the main text where appropriate and have provided interesting information in the marginal notes and the problems. A *Profile of a Chemical* series was added to the first five chapters of the text to introduce some descriptive chemistry early in the book. Finally, descriptive chemistry is treated at length in seven chapters (Chapters 13 and 14, Chapters 23 through 27), which the instructor can use to the extent desired. Also, the chapter on reactions in aqueous solutions (Chapter 10) provides the basis for much of the descriptive chemistry treated in general chemistry.

CHANGES MADE IN THIS EDITION

Several new features were added in this edition. The book is now in full color, with over 140 color photographs. Color is also used in many of the line drawings. While color can be an attractive feature of any textbook, in chemistry it serves a pedagogical function as well. Dramatic color changes often accompany important chemical reactions, and chemical substances themselves may be vividly colored.

Another feature of this revision is the highlighting of the definitions of all of the important terms. As in the first edition, each important term is given in bold-face type, but in this edition every important term is defined explicitly, in most cases in the sentence in which the term is introduced, and the definition is given in italic type.

As noted earlier, six Profiles introduce the chemistry of some basic chemicals. These are presented as optional asides (in brown boxes). Fifteen other optional asides or special topics are presented in blue boxes throughout the text.

Another added feature is a set of cumulative-skills problems at the end of most chapters. These problems combine skills from earlier chapters and should be extremely useful in developing students' problem-solving skills. The addition of these problems further strengthens the overall problem-solving program of the book.

Finally, a list of key equations was added to the end-of-chapter *Checklist for Review*.

The chapter organization of the first edition was retained except that thermochemistry is now treated earlier (in Chapter 5). Reviewers of the manuscript were enthusiastic about this earlier placement of thermochemistry. Nevertheless, many instructors may still wish to delay the treatment of this topic. I have written the chapters that follow with this option in mind. Where a discussion employs the notation ΔH , it is explained that this quantity is the heat of reaction. This explanation, together with the brief treatment of energy given in Chapter 1, is sufficient for understanding the accompanying text. Where an in-depth knowledge of thermochemistry is needed (in the discussion relating lattice energies to other energy quantities), the exposition is given as an Aside that can be easily omitted.

Three chapters were extensively rewritten. Chapter 2 was rewritten to emphasize the experimental basis of atomic theory. In addition, the chapter now includes a brief introduction to the periodic table and a discussion of the nomenclature of simple compounds. Both additions strengthen the treatment of descriptive chemistry. Chapter 10, on reactions in aqueous solutions, was rewritten to improve the

exposition of acids and bases and to strengthen the discussion of redox reactions. Chapter 11, on liquids and solids, was reorganized to improve the sequencing of topics and to again underscore the experimental basis of chemistry.

COMPLETE INSTRUCTIONAL PACKAGE

This textbook is complemented by a complete package of instructional materials:

Study Guide for General Chemistry, Joan I. Senyk, Larry K. Krannich, and James R. Braun. This student study guide contains extra explanations as well as additional worked-out examples, problems, and questions. It also contains solutions to all within-chapter exercises in the text.

Solutions Manual for General Chemistry, George H. Schenk and Darrell D. Ebbing. This manual provides answers to all Review Questions and worked-out solutions to all Exercises and Problems.

Experiments in General Chemistry, Rupert Wentworth. New to this edition, this laboratory manual contains experiments specifically correlated to the text.

Qualitative Analysis and Ionic Equilibrium, George H. Schenk and Darrell D. Ebbing. This manual covers the chemical principles and the laboratory procedures needed for the qualitative analysis portion of the general chemistry laboratory.

Computer Strategies for the Chemistry Student, Leonard Soltzberg. This is a text for teaching students how to program computers using BASIC to solve chemistry problems.

The following additional items are available to instructors: the *Instructors Manual and Test Bank for General Chemistry*; a computerized version of the test bank, available for the Apple II and IBM PC; a call-in testing service; a set of 150 transparencies of illustrations and tables from the text; the *Instructors Manual for Experiments in General Chemistry*; and the *Computer Assisted Blackboard* by Leonard Soltzberg, software designed for assisting in lecture demonstrations.

ACKNOWLEDGMENTS

When I began writing the first edition of this text, it was my intention to complete the project in three years. It was some time before I realized it would take much longer, and still later before I realized it would never really be truly finished. More surprising to me, however, was the number of people needed to shape a manuscript of this sort into a bound book. The final text was indisputably influenced by its many reviewers, and I remain indebted to them for taking the time from their busy schedules to contribute to whatever success this book will have. Those who reviewed various parts of the manuscript or proof for the second edition are:

John J. Alexander, University of Cincinnati
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Bruce Ault, University of Cincinnati
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versity	James R. Wright, United States Air Force
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nesota	

My special thanks again go to Mark Wrighton, whose incisive mind and wry wit have kept this project on an even keel. The program of color photographs added in this edition owes much to his efforts. And the cover photograph was Mark's in conception and realization. His and Debbie's hospitality on my visits to Boston and Cambridge are much appreciated. Also, many thanks to J. J. and to Rebecca for entertaining me while I was visiting their parents.

Patricia Mabrouk, at M.I.T., did much of the day-to-day laboratory work that was needed to bring the color photography program to fruition. At its best, photography is frustrating, and color photography can be maddening. I am pleased that she was willing to give her time to this effort, which is so important to this edition.

Joan Senyk and Larry Krannich sent many helpful corrections to me while they were working on the study guide and I thank them. Rupert Wentworth, I am happy to note, agreed to write a laboratory manual correlated to the text. Rupert also contributed directly to the form of the second edition text by participating in some early planning sessions. It was indeed a pleasure working with him.

My colleagues at Wayne State University were again very helpful in numerous ways. George Schenk consented to undertake the task of checking the solutions to all of the exercises and problems. It was a truly monumental task, and he appears to have remained enthusiastic to the finish.

Whenever I had a question about laboratory matters, I turned to Joe Oravec. He never failed to come up with an answer, even if that meant doing the experiment. My many thanks to Joe. Paula Youngberg and Lynne Hitchcock helped in many of the chores associated with manuscript preparation. Their precision work made my task easier and contributed to a more accurate text.

I dedicate this book to my extended family: to my wife Jean; to my son Russell; to my daughters Julie and Linda and their husbands Tony and Brad; and finally to the next generation Trevor and Warren, who can look forward to exploring the marvels of chemistry.

Darrell D. Ebbing

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