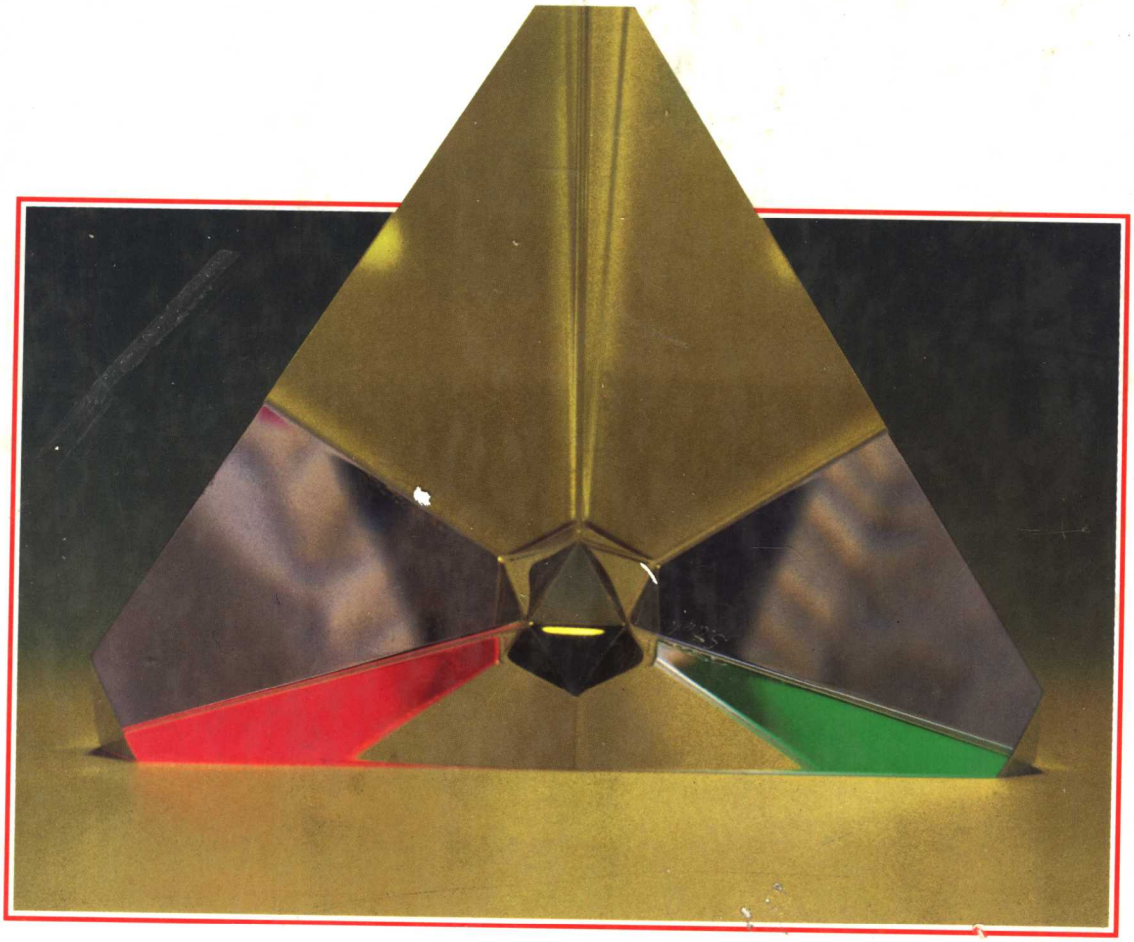
CHEMISTRY

THE CENTRAL SCIENCE



BROWN ▲ LEMAY ▲ BURSTEN

SIXTH EDITION

Sixth Edition

CHEMISTRY
The Central Science

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Preface

To the Student

Chemistry: The Central Science, Sixth Edition, has been written to introduce you to modern chemistry. During the many years we have been practicing chemists, we have found chemistry to be an exciting intellectual challenge and an extraordinarily rich and varied part of our cultural heritage. We hope that as you advance in your study of chemistry, you will share with us some of that enthusiasm and appreciation. We also hope that you will come to realize the importance of chemistry in your everyday life. As authors, we have, in effect, been engaged by your instructor to help you learn chemistry. Based on the comments of students and instructors who have used this book in its previous editions, we believe that we have done that job well. Of course, we expect the text to continue to evolve through future editions. We invite you to write to us to tell us what you like about the book, so that we will know where we have helped you most. Also, we would like to learn of any shortcomings, so that we might further improve the book in subsequent editions. Our addresses are given at the end of the Preface.

Using this Text

Learning chemistry requires both the assimilation of many new concepts and the development of analytical skills. To assist you in these goals, we have interspersed throughout the text hundreds of *Sample Exercises.* Each exercise illustrates the use of a key concept or skill. The accompanying solution illustrates the reasoning required to answer the exercise. Paired with every Sample Exercise is a *Practice Exercise,* which addresses the same concept. You can test your understanding by working the Practice Exercise and comparing your answer with the one that is given.

To help you visualize abstract ideas, we have included *full-color illustrations,* including photographs, diagrams, conceptual artwork, and graphs. Several important concepts and calculations are presented schematically through the use of *flow diagrams.* We believe you will find the illustrations and their captions to be very helpful as you read the text.

Four kinds of *supplemental essays* appear throughout the text to aid and enrich your studies. The *Chemistry at Work* sections discuss interesting applications of the concepts in the text to everyday life. The *Chemistry and Life* essays emphasize the integration of basic chemical concepts in biology and medicine. The essays titled *A Closer Look* augment the chapter material by

delving more deeply into a topic. Finally, in the essays titled *Strategies in Chemistry,* we offer some general advice on how to succeed in learning chemistry.

At the end of each chapter you will find a *Summary* that points out the chapter highlights. The list of *Key Terms* gives the vocabulary that has been introduced in the chapter. The terms listed here are printed in boldface type in the chapter and also appear in the end-of-book *Glossary.*

The *Exercises* at the end of each chapter test your understanding of the material. Many exercises are grouped according to topic, and they are also arranged in matched pairs. Both exercises in a pair deal with the same principle or procedure, so if you have difficulty with a particular exercise, its companion will provide you with further practice. The answer to one member of each pair is given in a section at the back of the book. *Additional exercises* appear at the end of each chapter's exercise set. The additional exercises test your ability to solve problems that are not identified by topic. These exercises often combine ideas from more than one part of the chapter. The additional exercises and the matched-pair exercises whose answers appear near the end of the book are numbered in color. The more challenging exercises are marked with brackets.

Finally, you should note that there are several *Appendices* near the back of the book, as well as useful tables in the front and back inside covers.

Supplemental Materials

Because we realize that you will encounter challenging material in this course, Prentice Hall has made available to you several valuable supplements. One key supplement is *Chemistry Explorer Software,* an interactive software program that is based on worked examples and problems from the book. *Chemistry Explorer Software* enables you to simulate experiments on your computer and manipulate different elements of these experiments to see how they affect the results. This software also provides graphs and spreadsheets to help you analyze data. Thus, *Chemistry Explorer Software* is a valuable tool for helping you learn the basic concepts and skills you will need in your chemistry course.

Of particular use to chemistry students is the *Student's Guide* by James C. Hill of California State University. The student guide follows the same chapter sequence as the text. Each chapter in the guide contains an overview, topical summaries and additional exercises, and tests for each chapter section.

Advice for Studying Chemistry

Keep up with your studying day to day. New material builds on the old. It is important not to fall behind; if you do, you will find it much harder to follow the lectures and discussions on current topics. Trying to "cram" just before an exam is generally a very ineffective way to study chemistry.

Focus your study. The amount of information you will receive in your chemistry course can sometimes seem overwhelming. The number of facts and details in a first course in chemistry is enough to challenge any student, and it is essential to recognize those concepts and skills that are particularly important. Listen intently for what your lecturer and teaching assistant emphasize. Pay attention to the skills stressed in the sample exercises and homework assignments. Notice the italicized statements in the text, and study the concepts presented in the chapter summaries.

Keep good lecture notes, so that you have a clear and concise record of the required material. You will find it easier to take useful notes if you *skim topics in the text before they are covered in lecture.* To skim a chapter, first read the introduction and summary. Then quickly read through the chapter, skipping Sample Exercises and supplemental sections. Pay attention to section heads and subheads, which give you a feeling for the scope of topics. Avoid the feeling that you must learn and understand everything right away.

After lecture, *carefully read the topics covered in class.* You will probably need to read assigned material more than once to master it. As you read, pay particular attention to the Sample Exercises. Once you think you understand a Sample Exercise, test your understanding by working the accompanying Practice Exercise.

Finally, *attempt all of the assigned end-of-chapter exercises.* Working out these exercises provides necessary practice in recalling and using the essential ideas of the chapter. You cannot learn merely by observing; you must be a participant. In particular, there is little value in merely copying answers from the Solutions Manual or from another student. If, however, you really get stuck on a problem, get help. Spending more than 20 minutes on a single exercise is rarely effective unless you know that it is particularly challenging.

To the Instructor

Philosophy

Throughout the evolution of this text, certain goals have guided our writing efforts. The first is that a text should endeavor to show students the usefulness of chemistry in their major areas of study as well as in the world around them. It has been our experience that as students become aware of the importance of chemistry to their own goals and interests, they become more enthusiastic about learning the subject. With this in mind, we have attempted, as much as space and our imaginations permit, to bring in interesting and significant applications of the subject matter. We attempt to show that chemistry is indeed the *central science.* At the same time, of course, we seek to provide students with the necessary background in modern chemistry for their specialized studies, including more advanced chemistry courses.

Second, we want to show not only that chemistry provides the basis for much of what goes on in our world, but that it is a vital, continually developing science. We have tried to keep the book up-to-date in terms of new concepts and applications and to convey some of the excitement of the field.

Third, we feel that any text should be written to the students and not just to their instructors. We have sought to keep our writing clear and interesting and the book attractive and well illustrated. Furthermore, we have provided numerous in-text study aids for students. A more subtle aspect of this student orientation is the care we have taken to describe problem-solving strategies.

Organization

In the present edition, the first five chapters give a largely macroscopic, phenomenological view of chemistry. They introduce basic concepts, such as nomenclature, stoichiometry, and thermochemistry, that provide the necessary

background for many of the laboratory experiments usually performed in general chemistry. Chapter 4 gives a brief, early treatment of chemical reactions in aqueous solutions.

The next four chapters (Chapters 6–9) deal with electronic structure and bonding. The focus then changes to the next level of the organization of matter: the states of matter (Chapters 10 and 11) and solutions (Chapter 13). Also included in this section is a chapter on the chemistry of modern materials (Chapter 12), which builds on the student's understanding of chemical bonding and intermolecular interactions and their relationships to the properties of matter.

The next several chapters examine the factors that determine the speed and extent of chemical reactions: kinetics (Chapter 14), equilibria (Chapters 15–17), thermodynamics (Chapter 19), and electrochemistry (Chapter 20). Also in this section is an optional chapter on environmental chemistry (Chapter 18), in which the concepts developed in preceding chapters are applied to a discussion of the atmosphere and hydrosphere.

After a discussion of nuclear chemistry (Chapter 21), the final chapters survey the chemistry of nonmetals, metals, organic chemistry, and biochemistry (Chapters 22–26). These chapters are developed in a parallel fashion and can be treated in any order.

Although our chapter sequence provides a fairly standard organization, we recognize that not everyone teaches all of the topics in exactly our order. We have therefore structured our writing so that instructors can make common changes in teaching sequence with no loss in student comprehension. In particular, many instructors prefer to introduce gases (Chapter 10) after stoichiometry or after thermochemistry rather than with states of matter. The chapter on gases has been written to permit this change with *no* disruption in the flow of material. It is also possible to treat the balancing of redox equations (Sections 20.1 and 20.2) earlier, after the introduction of oxidation numbers in Section 8.10, or even with the introduction to redox reactions in Section 4.6.

We have always attempted to introduce students to *descriptive chemistry* by integrating examples throughout the text. You will find pertinent and relevant examples of "real" chemistry woven into all of the chapters as a means to illustrate principles and applications. Some chapters, of course, more directly address the properties of elements and their compounds, especially Chapters 4, 7, 12, 18, and 22–26. We also incorporate descriptive chemistry in the end-of-chapter exercises.

Changes in this Edition

Our major goal in the sixth edition has been to strengthen an already strong textbook while retaining its effective and popular style. The traditional strengths of *Chemistry: The Central Science* include its clarity of writing, its scientific accuracy and currency, its strong end-of-chapter exercises, and its consistency in level of coverage.

In making changes to this edition, we have tried to be responsive to the feedback we have received from the faculty and students who used the fifth edition. Students have appreciated the *student-friendly* style of writing, and we have preserved this style in the sixth edition. Sections that struck students as hard to follow have been rewritten and, when possible, augmented with improved artwork. In order to make the text easier for students to use, we have maintained a *clean design* in the layout of the book.

The text also contains *improvements in artwork* that help convey the beauty and excitement of chemistry. The program of *molecular art and line diagrams* has been improved to help students better visualize three-dimensional concepts on a two-dimensional page. *New photographs* have been added throughout the book. Our goal has been to use color in a nondistracting way to help emphasize important points, to focus the student's attention, and to make the text attractive and inviting.

We have increased the emphasis on concept-oriented learning throughout the text. *Sample exercises* have been rewritten with more explicit explanations of the thought processes and intermediate calculations. *Flow diagrams* are used whenever possible to provide a visual summary of critical concepts and important relationships. A new icon used in the text, *concept links,* provides easy-to-see cross-references to pertinent earlier material in the text. New essays titled *Strategies in Chemistry* emphasize paradigms used to learn chemistry more effectively and to provide advice on problem solving. The essay at the end of Chapter 26 reminds students that the introductory course is only the beginning of the excitement of learning chemistry.

In response to shifts in student interests, the text contains *greater emphasis on chemistry in the life sciences.* Much of the material that was contained previously in a separate chapter on biochemistry (Chapter 27 of the fifth edition) has been incorporated in earlier chapters. New essays titled *Chemistry and Life* underscore the importance of basic chemical concepts in biology and medicine. In Chapter 26 of the sixth edition, *organic chemistry and biochemistry are combined,* which allows a smoother transition between these two advanced topics. The chapter has been written to allow an instructor to teach only the organic chemistry portion if desired.

We have kept the text fresh by keeping it *current.* References to current events help students relate their studies of chemistry with their everyday life experiences. Students are exposed to new developments in chemistry, such as the excitement surrounding the discovery of buckminsterfullerene. Finally, the sixth edition has an *increased focus on the positive aspects of chemistry,* but without neglecting the problems that can arise in an increasingly technological world. Our goal is to help students appreciate the real-world perspective of chemistry and the ways in which chemistry affects their lives.

Supplements

To accompany the text, Prentice Hall has assembled a very thorough supplements package that will benefit both you and your students. In addition to our standard supplements such as the study guide and laboratory manual, we now offer a number of multimedia items. The key supplements are described below.

- ***Chemistry Explorer Software*** This is an interactive simulation program based on worked problems and examples from the text. It allows students to manipulate variables and physical parameters in performing experiments to observe how these manipulations affect the results. It also provides data analysis tools such as spreadsheets and graphs.

- ***Prentice Hall Chemistry Laserdisc*** This "visual encyclopedia" combines demonstration experiments, still images from both the text and outside sources, molecular animations, and brief application segments emphasizing new frontiers in chemistry.
- ***Prentice Hall Multimedia Chemistry Presenter*** The laserdisc and the Explorer software can be used separately, or they can be combined through *Prentice Hall Multimedia Chemistry Presenter.* This modular classroom presentation tool organizes and drives the media components and allows the instructor to customize available resources.
- ***Prentice Hall/The New York Times Themes of the Times*** To emphasize the importance and relevance of chemistry in everyday life, we once again offer this unique supplement produced through the joint efforts of Prentice Hall and *The New York Times. Themes of the Times* consists of a series of *Times* articles relating to chemistry that are reproduced to resemble an actual edition of the *Times.*
- ***Solutions to Exercises*** by Roxy Wilson of the University of Illinois. This manual contains the answers to the end-of-chapter exercises in the book. Three different versions are available: one with answers to all the black-numbered questions; one with answers to all the red-numbered questions; and one with answers to all the questions. With the instructor's permission these manuals may be made available to students.
- ***Instructor's Resource Manual*** Available in both electronic and paper formats, this manual provides detailed lecture outlines on a chapter-by-chapter basis. Also, lecture schedules to accommodate a two-semester or three-quarter sequence, or a schedule emphasizing descriptive chemistry, provide a quick guide to assignments. Other useful features of the *Instructor's Resource Manual* are the complete lecture demonstrations referenced in the Annotated Instructor's Edition, cross-referencing of all other supplements available for Brown/LeMay/Bursten, weekly quizzes, and chapter summaries. By providing the *Instructor's Resource Manual* electronically we hope to give you quick access to a wealth of material that can be immediately personalized to your needs. Call up a given chapter outline on your computer screen, annotate it to fit your needs, and print it out.
- ***Student's Guide*** Authored by James C. Hill of California State University, Sacramento, the student guide has proved over the years to be an excellent companion volume to *Chemistry: The Central Science.* Each chapter is keyed to the text material and follows a basic format that includes an overview of the chapter, topical summaries and additional exercises, study exercises, and sectional tests.
- ***Chemical Problem Solving Using Dimensional Analysis,*** 3rd Ed., by Robert Nakon. This supplement provides hundreds of problems for the student to work, and their solutions.
- ***Laboratory Experiments,*** by John Nelson and Kenneth Kemp. This long-established and time-tested volume contains 40 experiments, all of them retained or refined from previous editions.

- ***Instructor's Edition to the Laboratory Experiments*** This manual contains the student's version of the lab manual plus answers to all questions, tips on safety and disposal of chemicals, suggestions for handling of chemicals and equipment, and related information.
- ***Introduction to Semimicro Qualitative Analysis,*** 7th Ed., by J. J. Lagowski and C. H. Sorum. This is a valuable tool for instructors who emphasize qualitative analysis in their general chemistry courses. This supplement consists of two parts. Part One focuses on the theories and techniques behind qualitative analysis; Part Two contains a number of time-tested experiments.
- ***Transparency Pack*** Prentice Hall can make available approximately 240 full-color acetates, all of them taken from the text.
- ***The Prentice Hall Test Manager 2.0*** **and** ***Test Item File*** These supplements now consist of over 2500 items, available in paperback or on floppy disk, for IBM® and MacIntosh® computers. As a major innovation, Test Manager allows you to add your own questions and to automatically alternate ordering of questions. New features of Test Manager 2.0 include complete control over print options as well as export of tests to Word or WordPerfect. In addition, telephone testing services are available.
- ***Chemical Concepts and Techniques Video*** A 100-minute videotape has been specifically developed for use in conjunction with Brown/LeMay/Bursten. Divided into ten segments of 10 minutes each, the video highlights important concepts of chemistry through a variety of visual media including electron microscopy, computer animation, and other tape technology.
- ***Chemistry Toolkit*** Available at no additional charge. Part One of the Toolkit consists of a chapter-by-chapter guide to the mathematics used throughout the Sixth Edition. Part Two is a guide to career planning and chemistry. It highlights the value of chemistry training in business and other careers not specifically related to chemistry. Part Three looks at the special requirements of writing in chemistry, focusing particularly on the lab notebook.
- ***Spreadsheet Chemistry*** by Gary Breneman and Jerry Parker. Finally, in the software category, a very special book is available for use in conjunction with EXCEL®. *Spreadsheet Chemistry* provides a means for quickly calculating numerical results from theory, experimental data, and questions posed about changes in conditions that govern chemical systems. Topics addressed include electron distribution in atoms and molecules, thermodynamic quantities, ideal- and real-gas behaviors, and oxidation-reduction reactions.

To receive a copy of any of these supplements, please contact your local sales representative.

Acknowledgments

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by sharing their insights and criticizing our initial writing efforts. We would like especially to thank the following:

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Finally, our thanks to all the students and faculty who gave us comments and suggestions about *Chemistry: The Central Science,* Fifth Edition. You will see many of your suggestions incorporated into the sixth edition.

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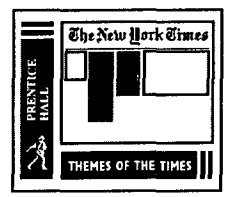

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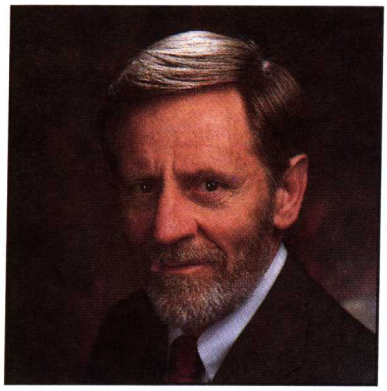
About the Authors



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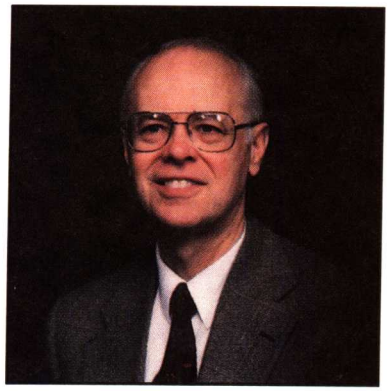
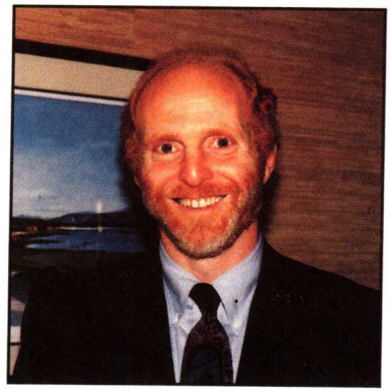


H. Eugene LeMay, Jr., received his B.S. degree in Chemistry from Pacific Lutheran University (Washington) and his Ph.D. in Chemistry in 1966 from the University of Illinois (Urbana). He then joined the faculty of the University of Nevada, Reno, where he is currently Professor of Chemistry and Freshman-Chemistry Coordinator. He has also served as Associate Chairman and Acting Chairman of the Chemistry Department. He has enjoyed Visiting Professorships at the University of North Carolina at Chapel Hill, at the University College of Wales in Great Britain, and at U.C.L.A.

Professor LeMay is a popular and effective teacher, who has taught thousands of students during nearly 30 years of university teaching. Known for the clarity of his lectures and his sense of humor, he has received several university awards for his teaching at both the undergraduate and graduate levels, including the University Distinguished Teacher of the Year Award. When not teaching and writing, Professor LeMay enjoys time with his family, photography, and hiking.



Bruce E. Bursten received his Ph.D. from the University of Wisconsin in 1978. Following two years as a National Science Foundation Postdoctoral Fellow at Texas A&M University, he joined the faculty of The Ohio State University, where he is currently Professor of Chemistry.

Professor Bursten has been a Camille and Henry Dreyfus Foundation Teacher-Scholar and an Alfred P. Sloan Foundation Research Fellow. At Ohio State, he has received the University Distinguished Teaching Award, the Arts and Sciences Student Council Outstanding Teaching Award, and the University Distinguished Scholar Award. In addition to his teaching and research activities, he presently serves as Secretary of the Division of Inorganic Chemistry of the American Chemical Society.

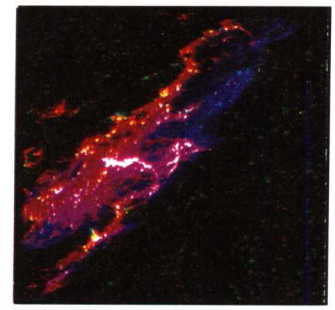
Contents

Preface xxii
About the Authors xxxi

1 Introduction: Some Basic Concepts 1

1.1 INTRODUCTION TO MATTER 2
Substances 5 Physical and Chemical Properties 5
Physical and Chemical Changes 5 Mixtures 6
1.2 ELEMENTS AND COMPOUNDS 9
Elements 10 Compounds 10
1.3 UNITS OF MEASUREMENT 11
Length and Mass 13 Temperature 13 Derived SI Units 15
Volume 15 Density 16 Intensive and Extensive Properties 19
1.4 UNCERTAINTY IN MEASUREMENT 19
Precision and Accuracy 19 Significant Figures 20
Significant Figures in Calculations 21
1.5 DIMENSIONAL ANALYSIS 23
Summary of Dimensional Analysis 25

Summary 27 Key Terms 28 Exercises 28


Dr. John R. Dickle/Science Photo Library/Photo Researchers

2 Atoms, Molecules, and Ions 32

2.1 THE ATOMIC THEORY OF MATTER 33
2.2 THE DISCOVERY OF ATOMIC STRUCTURE 35
Cathode Rays and Electrons 35 Radioactivity 38
The Nuclear Atom 39
2.3 THE MODERN VIEW OF ATOMIC STRUCTURE 41
Isotopes, Atomic Numbers, and Mass Numbers 43
2.4 THE PERIODIC TABLE 44

Richard Megna/Fundamental Photographs

2.5 MOLECULES AND IONS 48
Molecules and Chemical Formulas 48 Molecular, Empirical, and Structural Formulas 49 Ions 50 Predicting Ionic Charges 52 Ionic Compounds 53

2.6 NAMING INORGANIC COMPOUNDS 55
Ionic Compounds: Cations 55 Ionic Compounds: Anions 56 Acids 59 Molecular Compounds 61

Summary 61 Key Terms 62 Exercises 62

3 Stoichiometry: Calculations with Chemical Formulas and Equations 67

3.1 CHEMICAL EQUATIONS 68

3.2 PATTERNS OF CHEMICAL REACTIVITY 71
Using the Periodic Table 72 Combustion in Air 72 Combination and Decomposition Reactions 73

3.3 ATOMIC AND MOLECULAR WEIGHTS 75
The Atomic Mass Scale 75 Average Atomic Masses 76 Formula and Molecular Weights 77 Percentage Composition from Formulas 79

3.4 THE MOLE 79
Molar Mass 80 Interconverting Masses, Moles, and Numbers of Particles 82

BMW

3.5 EMPIRICAL FORMULAS FROM ANALYSES 84
Molecular Formula from Empirical Formula 85 Combustion Analysis 86

3.6 QUANTITATIVE INFORMATION FROM BALANCED EQUATIONS 88

3.7 LIMITING REACTANTS 92
Theoretical Yields 95

Summary 96 Key Terms 97 Exercises 97

4 Aqueous Reactions and Solution Stoichiometry 104

4.1 SOLUTION COMPOSITION 106
Molarity 106 Dilution 108

4.2 ELECTROLYTES 109
Strong and Weak Electrolytes 110

4.3 ACIDS, BASES, AND SALTS 112
Bases 112 Salts 113
Identifying Strong and Weak Electrolytes 114 Neutralization Reactions 115

4.4 IONIC EQUATIONS 115

4.5 METATHESIS REACTIONS 117
Precipitation Reactions 118 Solubility Rules 118
Reactions in Which a Weak Electrolyte or Nonelectrolyte Forms 120
Reactions in Which a Gas Forms 121
4.6 REACTIONS OF METALS 124
Oxidation and Reduction 124 Oxidation of Metals by Acids and Salts 125 The Activity Series 126
4.7 SOLUTION STOICHIOMETRY 128
Titrations 131

Summary 134 Key Terms 134 Exercises 135

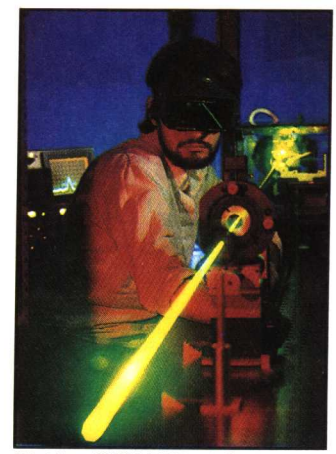
5 Energy Relationships in Chemistry: Thermochemistry 139

5.1 THE NATURE OF ENERGY 140
Kinetic and Potential Energy 141 Energy Units 141
Systems and Surroundings 142 Lowering the Energy of the System 142
5.2 THE FIRST LAW OF THERMODYNAMICS 143
Internal Energy 143 Relating ΔE to Heat and Work 144
State Functions 144
5.3 HEAT AND ENTHALPY CHANGES 146
Enthalpy 147
5.4 ENTHALPIES OF REACTION 147
5.5 CALORIMETRY 152
Heat Capacity and Specific Heat 152 Constant-Pressure Calorimetry 153 Bomb Calorimetry (Constant-Volume Calorimetry) 154
5.6 HESS'S LAW 156
5.7 ENTHALPIES OF FORMATION 159
Using Enthalpies of Formation to Calculate Enthalpies of Reaction 160
5.8 FOODS AND FUELS 162
Foods 162 Fuels 164 Other Energy Sources 167

Summary 167 Key Terms 168 Exercises 169

6 Electronic Structure of Atoms 174

6.1 THE WAVE NATURE OF LIGHT 175
6.2 QUANTUM EFFECTS AND PHOTONS 178
The Photoelectric Effect 180
6.3 BOHR'S MODEL OF THE HYDROGEN ATOM 181
Line Spectra 181 Bohr's Model 184



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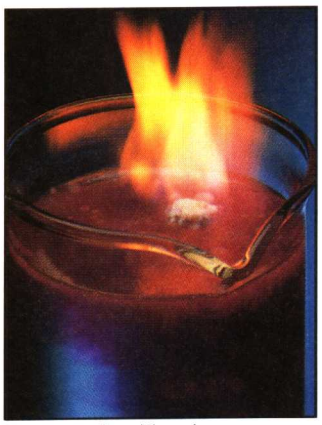
6.4 THE DUAL NATURE OF THE ELECTRON 186
The Uncertainty Principle 187
6.5 QUANTUM MECHANICS AND ATOMIC ORBITALS 189
Orbitals and Quantum Numbers 190
6.6 REPRESENTATIONS OF ORBITALS 192
The *s* Orbitals 192 The *p* Orbitals 193 The *d* and *f* Orbitals 194
6.7 ORBITALS IN MANY-ELECTRON ATOMS 195
Effective Nuclear Charge 196 Energies of Orbitals 196
Electron Spin and the Pauli Exclusion Principle 197
6.8 ELECTRON CONFIGURATIONS 199
Writing Electron Configurations 199
6.9 ELECTRON CONFIGURATIONS AND THE PERIODIC TABLE 204

Summary 208 Key Terms 209 Exercises 210



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7 Periodic Properties of the Elements 215

7.1 DEVELOPMENT OF THE PERIODIC TABLE 216
7.2 ELECTRON SHELLS IN ATOMS 218
7.3 SIZES OF ATOMS 220
7.4 IONIZATION ENERGY 221
Periodic Trends in Ionization Energies 223
7.5 ELECTRON AFFINITIES 224
7.6 METALS, NONMETALS, AND METALLOIDS 226
Metals 227 Nonmetals 229 Metalloids 231 Trends in Metallic and Nonmetallic Character 231
7.7 GROUP TRENDS: THE ACTIVE METALS 232
Group 1A: The Alkali Metals 233 Group 2A: The Alkaline Earth Metals 236
7.8 GROUP TRENDS: SELECTED NONMETALS 238
Hydrogen 238 Group 6A: The Oxygen Family 238
Group 7A: The Halogens 240 Group 8A: The Noble Gases 243

Summary 244 Key Terms 244 Exercises 245

8 Basic Concepts of Chemical Bonding 249

8.1 LEWIS SYMBOLS AND THE OCTET RULE 251
8.2 IONIC BONDING 252
Energetics of Ionic Bond Formation 253 Electron Configurations of Ions 254 Polyatomic Ions 256