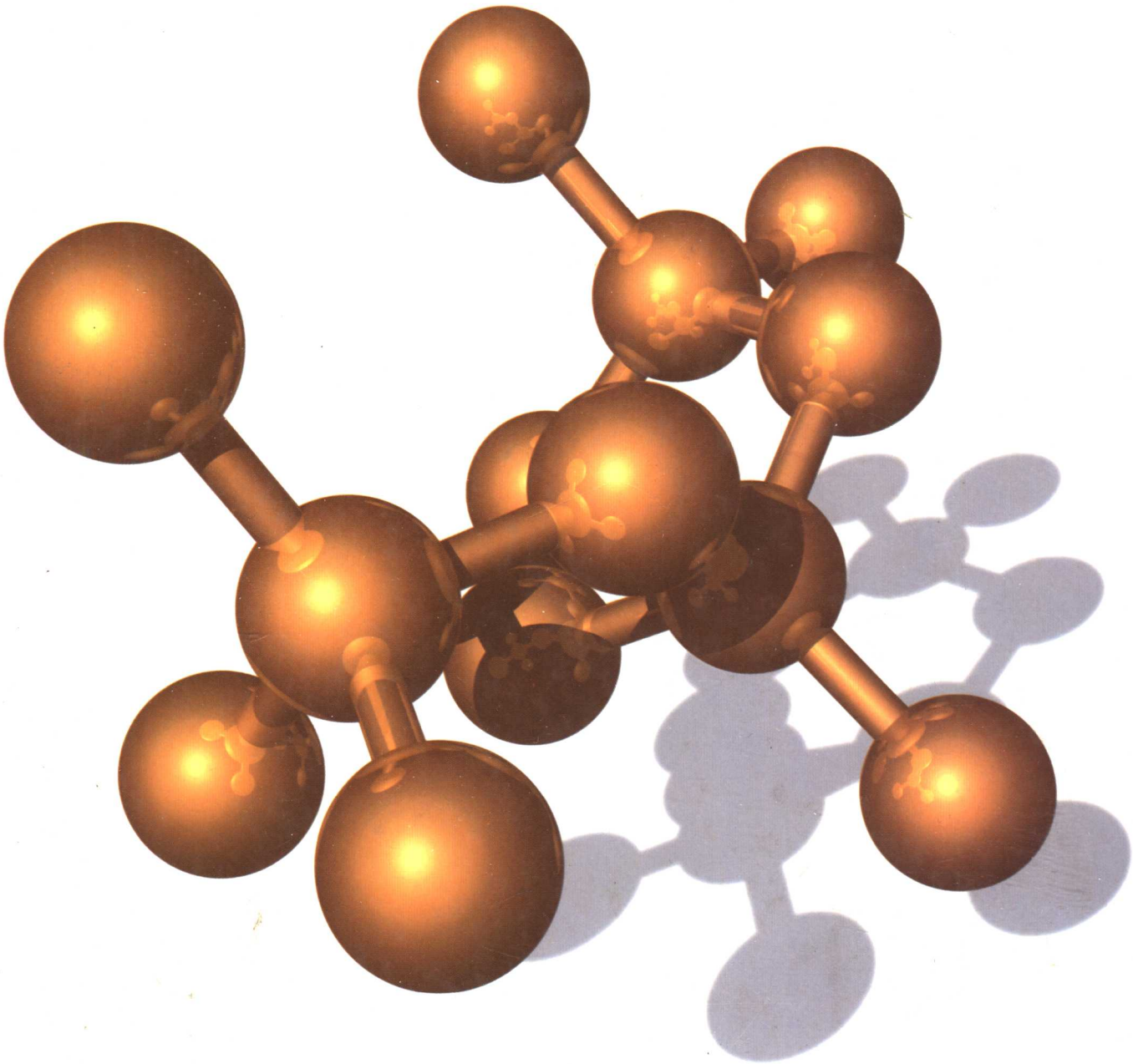
SEVENTH EDITION

CHEMISTRY

THE CENTRAL SCIENCE



BROWN LEMAY BURSTEN

CHEMISTRY

The Central Science

SEVENTH EDITION

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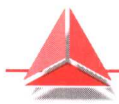
To our students, whose enthusiasm and curiosity have often inspired us, and whose questions and suggestions have sometimes taught us.

Brief Contents

Chemical Applications and Essays

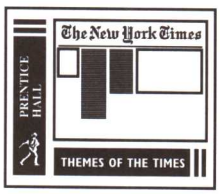
Chemistry at Work



A Closer Look

Chemistry and Life

Strategies in Chemistry



The New York Times and Prentice Hall are sponsoring *Themes of the Times*, a program designed to enhance student access to current information of relevance in the classroom.

Through this program, the core subject matter provided in the text is supplemented by a collection of time-sensitive articles from one of the world's most distinguished newspapers, *The New York Times*. These articles demonstrate the vital, ongoing connection between what is learned in the classroom and what is happening in the world around us.

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Prentice Hall and *The New York Times* are proud to cosponsor *Themes of the Times*. We hope it will make the reading of both textbooks and newspapers a more dynamic, involving process.

Preface

To the Instructor

Philosophy

Throughout the evolution of this text, certain goals have guided our writing efforts. The first is that a text should 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 permits, to bring in interesting and significant applications of the subject matter. 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.

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 22–25). 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 partic-

ular, 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 22–25. We also incorporate descriptive chemistry in the end-of-chapter exercises.

Changes in this Edition

Our major goal in the seventh 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 sixth edition. Students have appreciated the *student-friendly* style of writing, and we have preserved this style in the seventh 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 a *totally revamped art program* that will better convey the beauty, excitement, and concepts of chemistry to students. The new program of *computer-generated molecular art* gives students a greater sense of molecular architecture through ball-and-stick and space-filling representations of molecules. *New molecular art* combined with photographs emphasize the relationship between macroscopic matter and its microscopic, molecular structure. *Line art* has been enhanced significantly, with a greater emphasis on three-dimensional representations. *New photographs* have been added throughout the book. Our goal continues to be to use color to emphasize important points, to focus the student's attention, and to make the text attractive and inviting without being distracting.

We continue to emphasize concept-oriented learning throughout the text. *Sample Exercises* have been rewritten with more explicit explanations of the thought processes involved. *Concept links* continue to provide easy-to-see cross-references to pertinent material earlier in the text. The series of essays entitled *Strategies in Chemistry*, which provide advice to students on problem solving and "thinking like a chemist," have been rewritten and enhanced. A new series of end-of-chapter exercises, called *Integrative Exercises*, give students the opportunity to solve problems that integrate concepts from the present chapter with those of previous chapters.

The seventh edition is *shorter by one chapter* than the sixth edition. This change was achieved by combining Chapters 22 and 23 of the sixth edition into a *unified chapter on the descriptive chemistry of the nonmetallic elements*. Some of the material from Chapters 22 and 23 was brought forward to earlier chapters to give students an even better sense of descriptive chemistry earlier in the text.

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. *New essays* in our well-received *Chemistry at Work* and *Chemistry*

and Life series emphasize world events, scientific discoveries, and medical breakthroughs that have occurred since publication of the sixth edition. We continue our *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.

To the Student

Chemistry: The Central Science, Seventh 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, excitement, 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.

Advice for Learning and Studying Chemistry

Learning chemistry requires both the assimilation of many new concepts and the development of analytical skills. In this text, we have provided you with numerous tools to help you succeed in your chemistry course. We have provided details of the features of this text in the "walk-through" on pages xxvii–xxx. You will find it helpful to examine those features.

As you proceed through your course in chemistry, it is important for you to develop good study habits to help you in the learning process. We offer the following tips for your success in your study of chemistry:

Keep up with your studying day to day. In your chemistry course, new chemistry will build on material already presented. 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. It is essential to recognize those concepts and skills that are particularly important. Listen intently to the guidance and emphasis provided by your instructors. 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. Your lecture notes will provide you with a clear and concise record of the required material, and will contain the insight and expertise provided by your instructors. Using you lecture notes in conjunction with this text will be your best way to determine which material to study.

Skim topics in the text before they are covered in lecture. Reviewing a topic before lecture will make it easier for you to take good notes. First read the Introduction and Summary, then quickly read through the chapter, skipping Sample Exercises and supplemental sections. Pay attention to the titles of sections and

subsections, which give you an awareness 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 attention to the concepts presented and to the application of these concepts in the Sample Exercises. Once you think you understand a Sample Exercise, test your understanding by working the accompanying Practice Exercise.

Attempt all of the assigned end-of-chapter exercises. Working the exercises that have been selected by your instructor 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, try to resist checking the Solutions Manual (if you have one) until you have made a sincere effort to solve the exercise yourself. If you really get stuck on an exercise, however, get help from your instructor, your teaching assistant, or from another student. Spending more than 20 minutes on a single exercise is rarely effective unless you know that it is particularly challenging.

The bottom line is to work hard, study effectively, and use the tools that are available to you, including this textbook. We want to help you learn more about the world of chemistry and why it is the *central science.*

Supplements

For the Instructor

- **Annotated Instructor's Edition (0-13-578345-3)** This invaluable resource provides learning goals, transparency icons, references, and suggested points of emphasis. This edition has been rejuvenated with many new references.
- **MATTER: The Visual Presentation Resource CD ROM *IBM* (0-13-596909-3); *Macintosh* (0-13-700006-5)** This CD ROM includes over 50 animated concept sequences written and developed by Theodore L. Brown, a host of video laboratory demonstrations, a number of current and informative *ABC News* video segments, over 300 still illustrations, and a version 3.0 of *Chemistry Presentation Manager* for expert navigation.
- **Instructor's Resource Manual for Media and Print Material (0-13-578287-2)** This useful resource guide describes all the different resources available and shows how to integrate them into your course. Organized around *Chemisty: The Central Science,* this manual offers the following: detailed lecture outlines, complete descriptions of all available lecture demonstrations, complete descriptions of the animated concept sequences, complete descriptions of all video applications and much more! A quick reference card allows for easy topical cross-referencing.
- **Laboratory Demonstration Videos (0-13-129158-0)** by David Humphreys, McMaster University. This 2-cassette series contains approximately 100 brief laboratory demonstrations of experiments that may be either too expensive or too dangerous to show in the classroom.
- **Chemical Concepts and Techniques Video (0-13-338666-X)** This 100-minute videotape has been developed specifically for use in conjunction with *Chemistry: The Central Science.* Divided into ten segments of 10 minutes each, the video highlights important concepts of chemistry through a variety of visual media including electron microscopy and computer animation.

- **ABC News/Prentice Hall Video Library (0-13-578428-X)** This unique video library contains brief segments (5-20 minute) from award-winning shows such as *20/20*, *World News Tonight*, and *The American Agenda*. This innovative resource shows chemical principles at work and teaches students to critically analyze media messages based on their scientific knowledge.
- **Chemical Animation Video Series (0-13-719022-0)** This collection of over 50 animated concept sequences written and developed by Theodore L. Brown shows chemistry in action. These expertly produced animation sequences provide students with a view of matter and its transformation beyond what can be illustrated on the printed page.
- **Transparencies (0-13-578394-1)** Contains approximately 200 full-color transparencies.
- **Prentice Hall Custom Test/Test Item File.** ***Macintosh*** **(0-13-578378-X);** ***Windows*** **(0-13-578386-0);** ***Test Item File (Hard Copy Manual)*** **(0-13-578303-8)** Prepared by Michael Hampton, University of Central Florida, these banks consist of over 2500 multiple-choice questions and are available in PHCustom Test for Windows or Macintosh platform as well as in a paperback format. PHCustom Test allows you to create and tailor exams to your own needs.
- **Solutions to Exercises (0-13-578311-9); Solutions to Black Exercises (0-13-578337-2); Solutions to Red Exercises (0-13-578329-1)** by Roxy Wilson of the University of Illinois, Urbana-Champaign. These manuals contain the worked-out solutions to the end-of-chapter exercises in the book. With instructor permission, these manuals may be made available to students.
- **Laboratory Experiments (0-13-578360-7)** by John Nelson and Kenneth Kemp, both of the University of Nevada. This market-leading volume of 40 experiments now includes two new, student-tested experiments (Phosphorus in Plant Food and Analysis of Bleach). With each edition, the authors take particular care to improve safety measures and ensure that the experiments are sensitive to the environment. This group of experiments can be used with *Chemistry: The Central Science* or as a stand-alone text.
- **Annotated Instructor's Edition for Lab Experiments (0-13-578352-6)**

For the Student

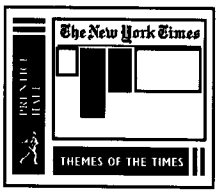
- ***Chemistry: CentralScienceLIVE*** **Online Learning and Exploration Center (HTTP://www.prenhall.com/brown)** Designed with the student in mind, this World Wide Web site offers a wealth of activities that intend to both improve student performance on exams and enrich their understanding of chemistry. There are three main centers in the site:

  Problem-Solving Center The Problem-Solving Center is the core of the project. The goal of this area is simple but essential—to help students develop problem-solving skills and perform better on tests. Students work exercises online, receive immediate feedback, get graded results, and have online access to the pages of *Chemistry: The Central Science*.

  Atoms and Molecules Visualization Center In this center, students engage in visualization tutorials and can access an archive of common molecules discussed in the text. Also, throughout the online version of *Chemistry: The Central Science*, molecules are often hot; that is, the student can click on a molecule, visualize it, and rotate it in 3 dimensions.

Current Topics in Chemistry Here, students read current newsworthy articles and apply their understanding of the basic principles of chemistry. Each article contains chemical information of what's discussed in the article; online links to the appropriate pages of *Chemistry: The Central Science;* a number of questions that assess student understanding; and links for further research.

- **The Prentice Hall Interactive General Chemistry CD ROM (0-13-598012-7)** This student tutorial provides an interactive study environment for students to enhance their understanding of a number of core chemical concepts. In this dynamic program, the student is able to interact with and visualize chemical concepts in ways that are not possible through traditional learning programs.
- **LOGAL Chemistry Explorer Runtime Simulation Software version 2.0 (MAC: 0-13-719014-x; WIN: 0-13-719006-9)** This award-winning simulation software allows the user to explore the molecular world in over 75 interactive experiments by altering parameters and exploring "what if" scenarios. Developed directly from figures and exercises/examples found on the pages of *Chemistry: The Central Science,* the simulations are useful for student use and lecture presentations.
- **Student Guide (0-13-578295-3)** by James C. Hill, California State University, Sacramento. The Student Guide has proved to be a student-friendly resource that improves student performance. Each chapter is keyed to the text and follows a basic format that includes an overview of the chapter, topical summaries, study exercises, integrative exercises, and sectional tests.
- **Math Review Toolkit (0-13-727272-3)** Part One of the Toolkit contains a chapter-by-chapter math review tailored to *Chemistry: The Central Science;* Part Two provides brief information on writing in chemistry and on chemistry careers. It also highlights the value of chemistry training in business and other careers not specifically related to chemistry. Available free to students upon adoption of the text.



- **The New York Times/Prentice Hall *Themes of the Times* supplement** This newspaper-format supplement brings together a collection of recent chemistry articles from the pages of *The New York Times.* This free supplement, available in quantity through your local representative, encourages students to make connections between what's taught in the classroom and the world around them.

Acknowledgments

This book owes its final shape and form to the assistance and hard work of many people. Several colleagues helped us immensely by sharing their insights, reviewing our initial writing efforts, or providing suggestions for improving the text. We would especially like to thank the following:

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We would also like to express our deep gratitude to our colleagues at Prentice Hall who have worked so hard to make this edition possible: Ben Roberts, our chemistry editor, who contributed imagination and energy to this edition; Carol Trueheart, our development editor, whose combination of creativity, intellect, patience, and attention to detail were invaluable to this revision; Yvonne Gerin, our photo researcher, whose ability to find exactly the right photograph was a continual source of amazement and delight; and Susan Fisher, our production editor, who managed the myriad responsibilities of bringing the design, photos, artwork, and writing together with efficiency and good cheer.

Many others deserve special recognition for their roles in the complex task of putting together this textbook: Richard Megna and Kip Peticolas (Fundamental Photographs), whose photographs helped us try to bring chemistry to life for students; Roxy Wilson (University of Illinois) for performing the difficult job of developing the Solutions Manual for the text; Donald Kleinfelter (University of Tennessee) and Robert Nelson (Georgia Southern University) for their careful proofreading and criticism; and Linda Brunauer (Santa Clara University) for her marvelous efforts in preparing the Annotated Instructor's Edition of the text.

We offer a special thanks to all the students and faculty who gave us comments and suggestions about *Chemistry: The Central Science*, Sixth Edition. You will see many of your suggestions incorporated into the seventh edition.

Finally, we thank our families and friends for their love, support, and patience as we brought this edition to completion.

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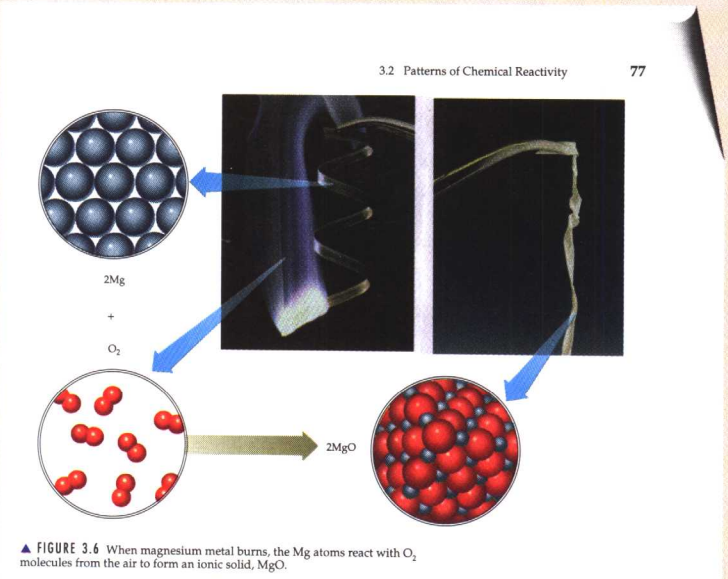
A Student's Guide to Using this Text

The following pages will walk you through some of the main features of this text. The book was designed with you, the student, in mind. We hope you enjoy your study of chemistry—"the central science."

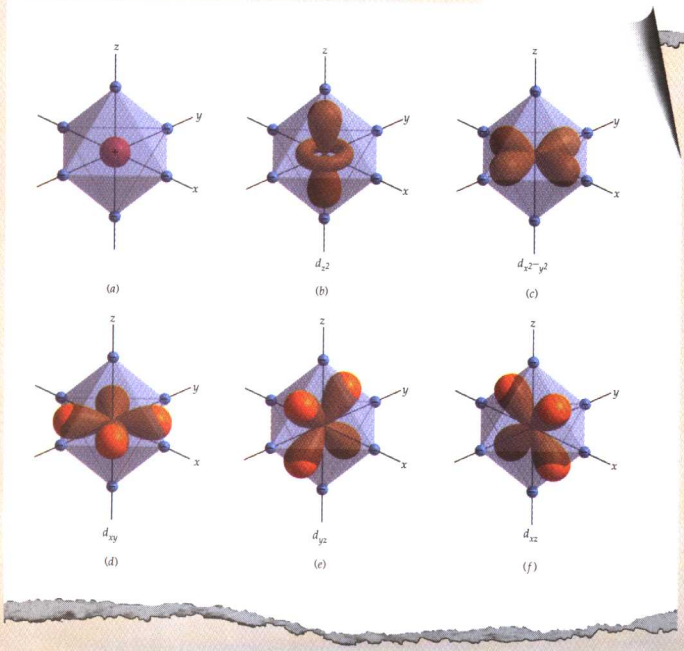
Chemistry is a visual science, and visualization is key to success. The illustrations in **CHEMISTRY: The Central Science** *have been carefully designed to enhance your understanding. Photographs and drawings provide you with striking visual presentations of important experiments, ideas, and applications.*

COMPOUND ILLUSTRATIONS

These illustrations combine photographs and molecular art. They will give you a better sense of the relationships between the macroscopic properties of matter and their underlying microscopic structure at the atomic and molecular levels.



▲ FIGURE 3.6 When magnesium metal burns, the Mg atoms react with O_2 molecules from the air to form an ionic solid, MgO.



MOLECULAR ILLUSTRATIONS

Computer-generated renditions of molecules and materials provide accurate visual representations of matter at the atomic level. These drawings will help you visualize molecules in three dimensions and will enhance your understanding of molecular architecture.

Learning chemistry requires the assimilation of many chemical concepts and the development of analytical skills. We have designed **CHEMISTRY: The Central Science** *to help you develop problem-solving skills and techniques rather than merely memorizing isolated facts.*

STRATEGIES IN CHEMISTRY

Strategies in Chemistry boxes teach you how to analyze information and organize your thoughts. They are designed to help you improve both your problem-solving ability and critical-thinking skills.

Strategies in Chemistry

Problem Solving

One aspect of chemistry is being able to deal with "word problems," problems that are stated verbally, but have a numerical answer. The key to success in problem solving is practice. As you practice, you will find that you can improve your skills by following these steps:

Step 1. Analyze the problem. Read the problem carefully for understanding. What does it say? Draw any picture or diagram that will help you visualize the problem. Write down the data you are given. Also, identify the quantity that you need to obtain (the unknown), and write it down.

Step 2. Develop a plan for solving the problem. Consider the possible paths between the given information and the unknown. What principles or equations relate the known data to the unknown? Recognize that some data may not be given explicitly in the problem; you may be expected to know certain quantities (such as Avogadro's number) or look them up in tables (such as atomic weights). Recognize also that your plan may involve a single step or a series of steps with intermediate answers.

Step 3. Solve the problem. Use the known information and suitable equations or relationships to solve for the unknown. Be careful with significant figures, signs, and units.

Step 4. Check the solution. Read the problem again to make sure you have found all the solutions asked for in the problem. Does your answer make sense? That is, is the answer outrageously large or small, or is it in the ballpark? Finally, are the units and significant figures correct?

Sample Exercise 3.7

Calculate the number of C atoms in 0.350 mol of $C_6H_{12}O_6$.

SOLUTION Let's examine this question using the problem-solving steps in the Strategies in Chemistry essay on page 85.

Analysis: We are given 0.350 mol of $C_6H_{12}O_6$. Thus, we know both the amount of the substance and its chemical formula. The unknown is the number of C atoms in this sample.

Plan: Avogadro's number provides the conversion factor between the number of moles of $C_6H_{12}O_6$ and the number of molecules of $C_6H_{12}O_6$. Once we know the number of molecules of $C_6H_{12}O_6$, we can use the chemical formula, which tells us that each molecule of $C_6H_{12}O_6$ contains 6 C atoms. Thus, we convert moles of $C_6H_{12}O_6$ to molecules of $C_6H_{12}O_6$ and then determine the number of atoms of C from the number of molecules of $C_6H_{12}O_6$:

$$\text{mol } C_6H_{12}O_6 \longrightarrow \text{molecules } C_6H_{12}O_6 \longrightarrow \text{atoms C}$$

Solve:

$$\text{C atoms} = (0.350 \cancel{\text{ mol } C_6H_{12}O_6}) \left(\frac{6.02 \times 10_{23} \cancel{\text{ molecules}}}{1 \cancel{\text{ mol } C_6H_{12}O_6}}\right) \left(\frac{6 \text{ C atoms}}{1 \cancel{\text{ molecule}}}\right)$$

$$= 1.26 \times 10^{24} \text{ C atoms}$$

Check: The magnitude of our answer is reasonable; it is a large number about the magnitude of Avogadro's number. Because we were asked for the number of C atoms, the units of our answer are correct. The given data had 3 significant figures, so our answer has 3 significant figures.

WORKED SOLUTIONS

The solutions to Sample Exercises are carefully developed to demonstrate the step-by-step strategy within the solution. They will help you understand and assimilate the thought processes involved in solving the exercise. Each Sample Exercise is followed by a similar Practice Exercise, for which only the answer is given. The Practice Exercises will give you instant feedback regarding your understanding of key concepts.

SUMMARY/KEY TERMS

The summary at the end of each chapter highlights the major concepts, and important equations, section by section. Every key term presented in the chapter is shown in boldface in the summary. This section gives you the opportunity to reinforce your learning of the chapter before working the exercises.

FOR REVIEW

Summary and Key Terms

Introduction and Section 5.1 Thermodynamics is the study of energy and its transformations. In this chapter we have focused on thermochemistry, the transformations of energy—especially heat—during chemical reactions. Energy is the capacity to do work or to transfer heat. Work is the energy expended to move an object against a force. Heat is the energy that is transferred from a hotter object to a colder one.

The energy of objects exists in two forms: **Kinetic energy** is the energy due to motion of the object, and **potential energy** is the energy that an object possesses by virtue of its position relative to other objects. For example, an electron in motion near a proton has kinetic energy because of its motion and potential energy due to its electrostatic attraction to the proton. The SI unit of energy is the **joule** (J): 1 J = 1 kg-m^2/s^2. Another common energy unit is the **calorie** (cal), which was originally defined as the quantity of energy necessary to increase the temperature of 1 g of water by 1°C: 1 cal = 4.184 J.

To study thermodynamic properties, we define a specific amount of matter as the **system**. Everything outside of the system is the **surroundings**. A closed system can exchange energy, but not matter, with the surroundings.

Section 5.2 The internal energy of a system is the sum of all the kinetic and potential energies of its component

END-OF-CHAPTER EXERCISES

Paired Exercises: The first section of exercises is grouped according to topic, in the same order in which topics are presented in the chapter. These exercises are presented in matched pairs that test your understanding of the same concept. The answers to ***all*** of the odd-numbered paired exercises are given in the back of the book.

Additional Exercises: The paired exercises are followed by a series of Additional Exercises, many of which draw on multiple concepts from within the chapter. The Additional Exercises give you the opportunity to see how well you have learned all the material presented in the chapter. Answers are provided in the back of the book for those exercises that are numbered in red. More challenging exercises are indicated by brackets around the exercise number.

3.25 **(a)** Define the term *mole*. **(b)** What is Avogadro's number and how is it related to the mole? **(c)** What is the relationship between the formula weight of a substance and its molar mass?

3.26 **(a)** What is the mass, in grams, of a mole of ^{12}C? **(b)** How many carbon atoms are present in a mole of ^{12}C? **(c)** What is the mass, in grams, of a single ^{12}C atom?

3.27 A sample of glucose, $C_6H_{12}O_6$, contains 4.0×10^{22} atoms of carbon. **(a)** How many atoms of hydrogen does it contain? **(b)** How many molecules of glucose does it contain? **(c)** How many moles of glucose does it contain? **(d)** What is the mass of this sample in grams?

3.28 A sample of the female sex hormone estradiol, $C_{18}H_{24}O_2$, contains 3.0×10^{20} atoms of hydrogen. **(a)** How many atoms of carbon does it contain? **(b)** How many molecules of estradiol does it contain? **(c)** How many moles of estradiol does it contain? **(d)** What is the mass of this sample in grams?

Integrative Exercises

[7.75] Moseley established the concept of atomic number by studying X rays emitted by the elements. The X rays emitted by some of the elements have the following wavelengths:

Element	Wavelength (Å)
Ne	14.610
Ca	3.358
Zn	1.435
Zr	0.786
Sn	0.491

(a) Calculate the frequency, ν, of the X rays emitted by each of the elements, in Hz. **(b)** Using graph paper (or suitable computer software) plot the square root of ν versus the atomic number of the element. What do you observe about the plot? **(c)** Explain how the plot in part (b) allowed Moseley to predict the existence of undiscovered elements. **(d)** Use the result from part (b) to predict the X-ray wavelength emitted by iron. **(e)** A particular element emits X rays with a wavelength of 0.980 Å. What element do you think it is?

[7.76] One way to measure ionization energies is *photoelectron spectroscopy* (PES), a technique based on the photoelectric effect. ∞ (Section 6.2) In PES, monochromatic light is shined on a sample, causing electrons to be ejected. The kinetic energy of the ejected electrons is

Integrative Exercises: Integrative Exercises connect concepts from the present chapter with those of preceding chapters. These exercises help you gain a deeper understanding of how chemistry fits together. Integrative Exercises also serve as an overall review of important concepts.