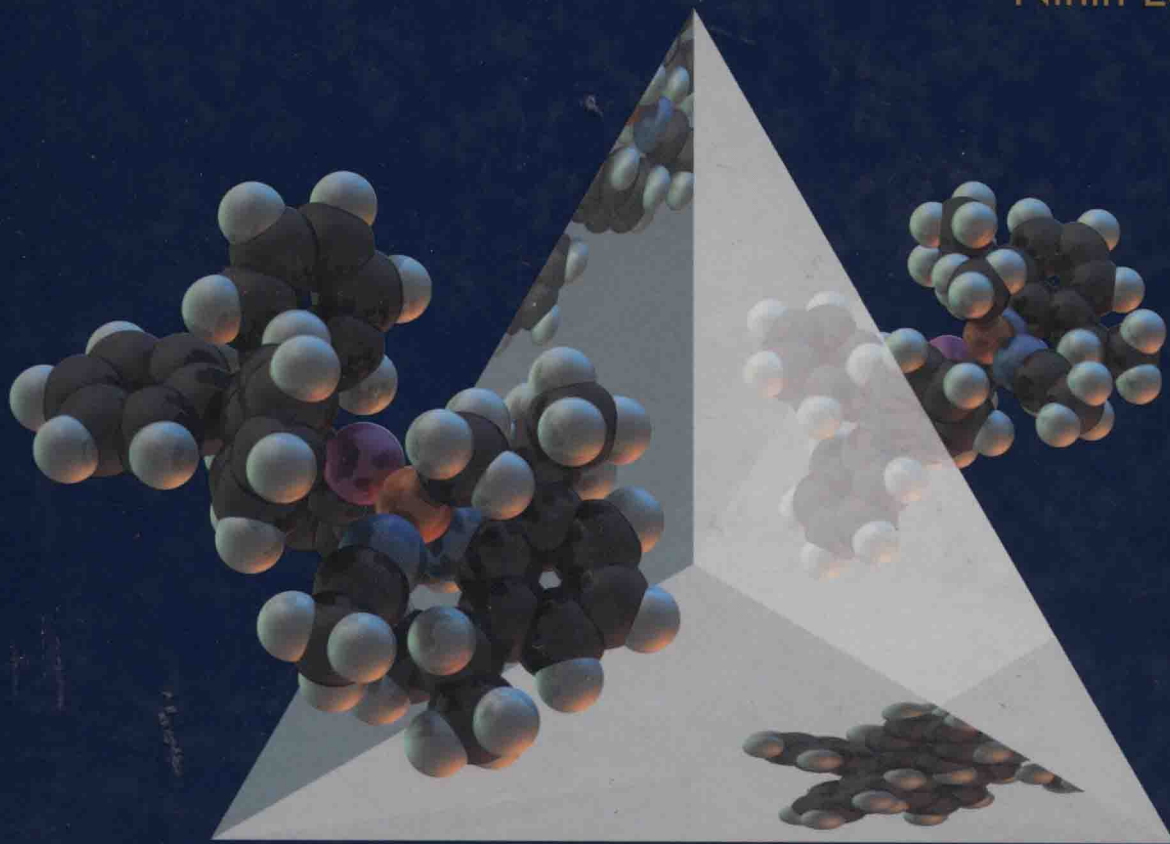




CHEMISTRY

THE CENTRAL SCIENCE

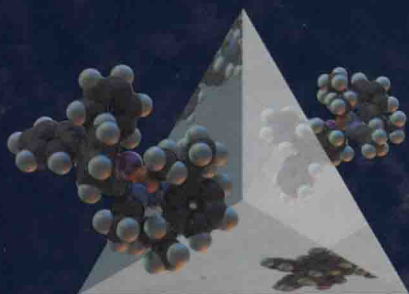
Ninth Edition



Brown

LeMay

Bursten



ABOUT THE COVER

The molecular models shown in the center foreground represent a type of catalyst developed at the California Institute of Technology by Professor R. Grubbs and colleagues. This catalyst, which has a nickel atom at its molecular center, is an example of an organometallic compound—a molecule that contains a carbon atom bonded directly to a metal atom.

Catalysts are compounds that speed up the rates of chemical reactions without themselves being consumed in the reaction. As a result, small amounts of effective catalysts can be used to produce large quantities of desired chemical products. This molecule catalyzes the formation of highly similar, highly linear, long chains of the polymer polyethylene. Synthetic polymers like polyethylene are widely used in all aspects of modern life, but it has traditionally been difficult to make polyethylene of this uniform quality. The development of new catalysts to produce materials with novel and useful properties is one of the many ways in which the science of chemistry contributes to society.

Access the Central Science Live Website at www.prenhall.com/Brown9. The enclosed CD-ROM is designed to enhance the speed and performance of the Website.

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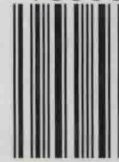
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The Central Science

Ninth Edition

Theodore L. Brown

University of Illinois at Urbana-Champaign

H. Eugene LeMay, Jr.

University of Nevada, Reno

Bruce E. Bursten

The Ohio State University

Julia R. Burdge

Florida Atlantic University

Prentice
Hall

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Upper Saddle River, New Jersey 07458

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Senior Editor: Nicole Folchetti

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Art Studio: Artworks: Senior Manager: Patty Burns/Production Manager: Ronda Whitson

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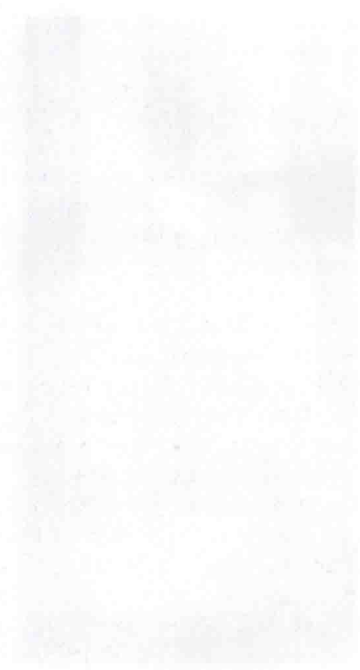
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Chemistry



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



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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 importance of chemistry in their major areas of study, as well as in their daily lives. We believe that students are more enthusiastic about learning chemistry when they see its importance to their own goals and interests. With this in mind, we have included interesting and significant applications of chemistry. At the same time, the text provides the background in modern chemistry that students need to serve their professional interests, and, as appropriate, to prepare for more advanced chemistry courses.

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

Third, we feel that if the text is to support your role as teacher effectively, it must be addressed to the students. 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, including carefully placed descriptions of problem-solving strategies. Together, we have over a hundred years of teaching experience. We hope this is evident in our pacing and choice of examples.

Organization

In the present edition the first five chapters give a largely macroscopic, phenomenological view of chemistry. The basic concepts introduced—such as nomenclature, stoichiometry, and thermochemistry—provide necessary background for many of the laboratory experiments usually performed in general chemistry. We believe that an early introduction to thermochemistry is desirable because so much of our understanding of chemical processes is based on considerations of energy change. Thermochemistry is also important when we come to a discussion of bond enthalpies.

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 an applications 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 a 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.


Our chapter sequence provides a fairly standard organization, but we recognize that not everyone teaches all the topics in exactly the order we have chosen. We have therefore made sure 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 redox reactions in Section 4.4. Finally, some instructors like to cover organic chemistry (Chapter 25) right after bonding (Chapter 9). With the exception of the discussion of stereochemistry (which is introduced in Section 24.3), this, too, is a seamless move.

We have always attempted to introduce students to descriptive organic and inorganic chemistry by integrating examples throughout the text. You will find pertinent and relevant examples of “real” chemistry woven into all 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 organic and inorganic chemistry in the end-of-chapter exercises.

Changes in this Edition

Our major goal in the ninth 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 received from the faculty and students who used the eighth edition. Students appreciate the student-friendly style of writing, and we have preserved this style in the ninth edition. Sections that have seemed most difficult to students have in many cases been rewritten and augmented with improved artwork. In order to make the text easier for students to use, we have tried for an even more open, clean design in the layout of the book.

We have also continued to strengthen the art program, to better convey the beauty, excitement, and concepts of chemistry to students. The expanded use of computer-generated molecular art gives students a greater sense of molecular architecture through ball-and-stick and space-filling representations of molecules. In addition, we have added charge distribution maps in selected cases where we believe they can enhance student understanding. We have continued a greater emphasis on three-dimensional representations in the line art. Our goal continues to be to use color and photos to emphasize important points, to focus the student’s attention, and to give the text an uncluttered, inviting look.

We still emphasize concept-oriented learning throughout the text. A new feature in this edition is the What’s Ahead summary at the opening of each chapter. What’s Ahead gives the student a brief overview of the major ideas and relationships that the chapter will cover. We expect that students will begin their study of the chapter with more confidence for having a sense of the direction in which their study will take them. *Concept links* () continue to provide easy-to-see cross-references to pertinent material covered earlier in the text. The essays titled *Strategies in Chemistry*, which provide advice to students on problem solving and “thinking like a chemist,” continue to be an important feature. We have added more conceptual exercises to the end-of-chapter exercises. The Integrative Exercises, which give students the opportunity to solve more challenging problems that integrate concepts from the present chapter with those of previous chapters, have also been increased in number.

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 eighth edition. We maintain our focus on the positive aspects of chemistry, 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.

You'll also find that we've:

- Revised the end-of-chapter Exercises, with particular focus on the black-numbered exercises (those not answered in the Appendix).
- Integrated more conceptual questions into the end-of-chapter material. For the convenience of instructors, these are identified by the annotation in the Annotated Instructor's Edition, but not in the student edition of the text.
- Updated the eMedia Exercises in the end-of-chapter material. These exercises take advantage of the integrated media components and extend student's understanding, using the advantages that interactive, media-rich presentations offer.
- Continued the practice of using a Student Activity icon in the margins to indicate where students can extend understanding of a concept or topic by looking at an activity located on the Web site or the Accelerator CD-ROM.
- Carried the stepwise, Analyze, Plan, Solve, Check, problem-solving strategy into a majority of the Sample Exercises of the book to provide additional guidance in problem solving.
- Added dual-column problem-solving strategies in selected Sample Exercises that outline the process underlying mathematical calculations to teach students how to better perform mathematical calculations.
- Reviewed and revised all chapters based on feedback from reviewers and users. For example, we have:
 - Added a brief introduction to organic chemistry in Chapter 2.
 - Improved the presentation of the first law of thermodynamics in Chapter 5.
 - Expanded the discussion of superconductivity in Chapter 12.
 - Revised the introductory treatment of equilibrium to eliminate the artificial distinction between equilibrium constants in gas and aqueous phases.
 - Added a new section on Green Chemistry, which focuses on the environmental impacts of chemical processes.
 - Improved the treatment of coordination compounds in Chapter 24.

Please see the next pages for more specific details about how the Ninth Edition's integrated learning program will help your students succeed.

Supplements

For the Instructor

- **Annotated Instructor's Edition (with Guide to Print and Media Resources)** (0-13-038168-3) This special instructor's edition provides marginal notes

and information for instructors and TAs, including MediaPortfolio and transparency icons, suggested lecture demonstrations, teaching tips, and background references from the chemical education literature for key topics.

- **Solutions to Exercises (0-13-009798-5)** Full solutions to all end-of-chapter exercises in the text are provided. With an instructor's permission, this manual may be made available to students.
- **Instructor's Resource Manual (0-13-009802-7)** This useful guide describes all the different resources available to instructors and shows how to integrate them into your course. Organized by chapter, this manual offers detailed lecture outlines and complete descriptions of all available lecture demonstrations, the animated concept sequences, all video demonstrations, common student misconceptions, and much more.
- **Test Item File (0-13-009792-6)** The Test Item File now provides a selection of more than 3800 test questions, a 25% increase over the previous version.
- **TestGen-EQ (0-13-009793-4)** New testbank software designed with algorithmic questions in mind. This computerized version of the Test Item File includes electronic versions of all 3800 test questions. TestGen-EQ allows you to create and tailor exams to your own needs and includes tools for course management, algorithmic question generation, and administering tests over a local area network.
- **Transparencies (0-13-009794-2)** Two-hundred seventy-six full-color images, more than ever before, are included in an easy-to-use binder. For each transparency, we've made the type even larger for easier viewing in large classrooms.
- **Central Science Live—Companion Web site <http://www.prenhall.com/brown>** The Companion Web site is the focal point for access to the media suite. Instructors can use the Syllabus Manager to administer a date-driven syllabus, including on-line homework assignments or other activities. You can have your students practice their reading comprehension and skills in the Problem Solving Center, peruse the Web for chapter-related resources, or view the Student Activities referred to in the text. If you have adopted the use of the Premium Access Code to the Web site, the eChapters, media-rich presentations that echo the book, are also available to your students. Standard and Premium Access Codes are available; contact your Prentice Hall representative for more information.
- **MediaPortfolio (0-13-009805-1)** An instructor CD/DVD set that contains almost all the art from the text, more than 30 lab demonstration video segments, and more than a 100 animations of core concepts. Using the included MediaPortfolio software, instructors can browse for figures and other media elements by thumbnail and description, as well as search by key word or title. In addition, all of the Student Activities available on the student Accelerator CD are available on the instructor CD/DVD, as well. The images and videos can be cut and pasted, or dragged into your MS PowerPoint® lecture presentation or other documents. The set also contains the Instructor's Resource Manual in MS Word® format, a pre-built PowerPoint Presentation for every chapter, as well as all the responsive media elements specifically developed for *Chemistry: The Central Science, Ninth Edition*.
- **Course Management Options** Prentice Hall provides support for course management systems that are most popular at institutions today, including WebCT®, WebAssign®, BlackBoard®, and Pearson Education's own CourseCompass® (powered by BlackBoard). Course management systems allow complete course administration, including roster and gradebook management, distribution of course materials, setup and maintenance of bulletin boards and announcements, and other tasks.

Prentice Hall can provide the content for a complete chemistry course tailored to *Chemistry: The Central Science, Ninth Edition*, and your course can even include the entire text on-line. In addition to the gallery of animations, we provide quizzing and testing material and a wide range of customizing options. For example, instructors can edit questions, modify/delete/add to the testing database, categorize material by level of difficulty, award different point values for different problems, and give partial credit.

See <http://www.prenhall.com/demo> for a demonstration of our course management options.

- **PH GradeAssist** PH GradeAssist is a new homework and assignment system that allows students unlimited practice with problems that are algorithmically generated and media-enhanced. Instructors can administer quizzes and assignments, control the content and assignment parameters, and receive assignments and view performance statistics with the built-in gradebook.

In addition, Prentice Hall has partnered with WebAssign, an online system that specializes in the administration of on-line homework. For information on this system, contact your PH representative.

For the Lab

- **Laboratory Experiments (Nelson/Kemp) (0-13-009797-7)** This manual includes 41 finely tuned experiments chosen to introduce students to basic lab techniques and to illustrate core chemical principles. It contains pre-lab questions and detachable report sheets. This new edition has been revised to correlate more tightly with the text. Safety and disposal information has also been updated.
- **Annotated Instructor's Edition to Laboratory Experiments (0-13-009803-5)** This AIE combines the full student lab manual with front and back appendices covering the proper disposal of chemical waste, safety instructions for the lab, descriptions of standard lab equipment and materials, answers to questions, and more.

For the Student

- **Central Science Live**—The media suite for the Ninth Edition consists of two components that can stand alone or work in concert: the Companion Web site and the Accelerator CD. Access to the materials on the Companion Web site are available through both Standard and Premium Access Codes. Many of the rich media assets available on *Central Science Live* are available on both the CD and on the Web site, and if used together, logging into the Web site provides a rapid, seamless, fully integrated experience for the student.

Central Science Live—Companion Web site <http://www.prenhall.com/brown> Now even more integrated and easier to use, this innovative on-line resource center is designed specifically to support and enhance *Chemistry: The Central Science, Ninth Edition*. Now the front-door for Central Science Live, it features:

- A Problem-Solving Center, where students have access to more than 2000 additional problems—including algorithmically generated questions and non-multiple-choice questions—all organized by chapter, each with specific hints and detailed feedback. Also included are cumulative quizzes and MCAT review questions.
- A Visualizing Molecules module, with pre-built 3-D models of molecules discussed in the text that can be manipulated in real time and displayed in different representations.

- Constantly updated Current Topics Module, linking your students to recently published articles from the lay press, and a Web Resources Center that links your students to other carefully selected, chemistry-related Web sites.
- A Student Activities module, with hundreds of movies, animations, and interactive simulations that help students discover chemistry. The movies show real chemistry being performed in demonstrations, the animations focus on molecular processes that can't be seen any other way, and the interactive simulations allow students to do experiments and draw conclusions based on simulated experimental results.
- eChapters, available only on the Premium version of the Web site, which are short synopses of the chapter material, written to include and point to the many Student Activities available in eMedia Chemistry, and including interactive and algorithmically generated self-assessment questions and worked examples. Many students find this an excellent way to preview or review the chapter material in the textbook.
- An eBook (electronic version of the full textbook) enables students to link directly from Web-based activities and from eChapters to the appropriate sections of the text. This allows students to work through Web exercises without having the actual text in front of them.

Central Science Live—Accelerator CD This book-specific companion to *Chemistry: The Central Science*, Ninth Edition, presents core chemistry content in a dynamic and interactive way. Designed for students, it includes:

- Over 60 short, narrated animations presenting selected topics that are more easily conveyed in a visual fashion, and over 30 laboratory demonstration video clips showing chemistry in live action.
 - Over 100 Student Activities, responsive activities and simulations that allow students to learn by taking the initiative, changing conditions, adjusting variables, and establishing trends.
 - MediaPortfolio software that allows thumbnail browsing, as well as search capabilities for words and media types, with links to text content.
- **Solutions to Red Exercises (0-13-009799-3)** Full solutions to all of the red-numbered exercises in the text are provided. (Short answers to red exercises are found in the appendix of the text).
 - **Solutions to Black Exercises (0-13-009790-X)** Full solutions to all of the black-numbered exercises in the text are provided.
 - **Student's Guide (0-13-009795-0)** This book assists students through the text material with chapter overviews, learning objectives, review of key terms, cumulative chapter review quizzes, and self-tests. Included are answers to all *Student's Guide* exercises. Chapter summaries are correlated to those in the Instructor's Resource Manual.
 - **Math Review Toolkit (0-13-009801-9)** This free book reinforces the skills necessary to succeed in chemistry. It is keyed specifically to chapters in *Chemistry: The Central Science*, Ninth Edition, and includes additional mathematics review, problem-solving tools and examples, and a section on writing for the laboratory.
 - **Lecture Notebook (0-13-038169-1)** This lecture notebook contains the art from the text with notetaking sections to obviate the need for students to spend time re-drawing figures in lecture and instead, concentrate on taking notes.
 - **Prentice Hall/The New York Times "Themes of the Times"—Chemistry** This innovative program is designed to bring current and relevant applications into the classroom. Adopters of *Chemistry: The Central Science*, Ninth Edition, are eligible to receive these unique "mini-newspapers" that bring together

a collection of the latest and best chemistry articles from the highly respected pages of *The New York Times*. (Updated twice annually.)

- **Prentice Hall Molecular Model Set for General and Organic Chemistry (0-13-955444-0)** This ball-and-stick model kit is designed for use in general chemistry and the student's next course in organic chemistry. It includes trigonal bipyramidal and octahedral atom centers as well as 14 carbon atoms.

To the Student

Chemistry: The Central Science, Ninth Edition, has been written to introduce you to modern chemistry. During the many years that 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 both. We have provided details of the features of this text in the "walk-through" on pages xxviii–xxxiii. 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 success in your study of chemistry:

Don't fall behind! In your chemistry course, new topics will build on material already presented. If you don't keep up in your reading and problem solving, you will find it much harder to follow the lectures and discussions on current topics. "Cramming" just before an exam has been shown to be an ineffective way to study any subject, chemistry included.

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 what your instructor regards as the most important material to learn. Use your lecture notes in conjunction with this text; that's 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