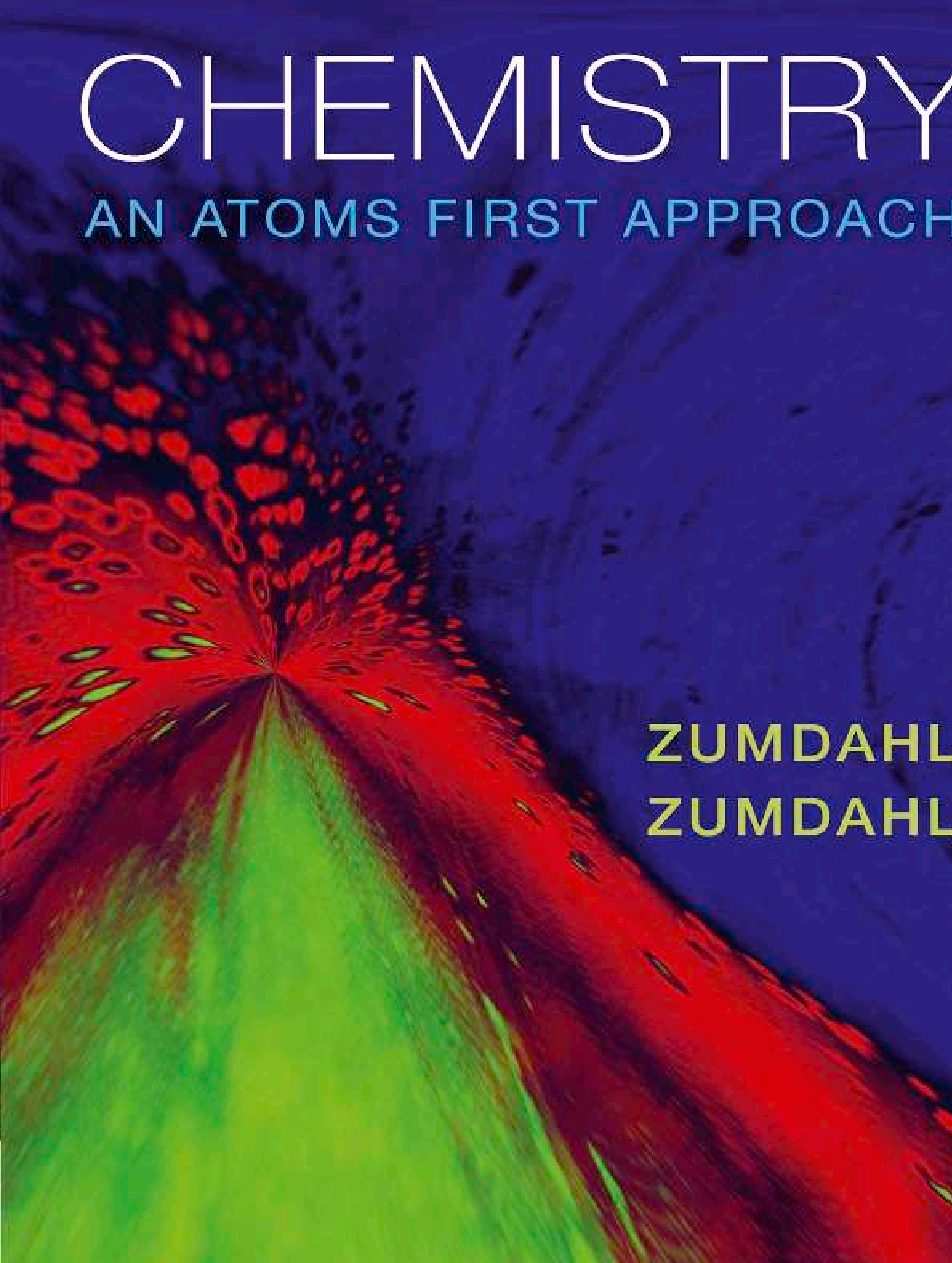
CHEMISTRY
AN ATOMS FIRST APPROACH

ZUMDAHL
ZUMDAHL



Periodic Table of the Elements

Alkaline earth metals

Alkali metals

Transition metals

metals

1 (1A)	2 (2A)	3	4	5	6	7	8	9	10	11	12	13 (3A)	14 (4A)	15 (5A)	16 (6A)
1 **H** 1.008															
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)
87 **Fr** (223)	88 **Ra** 226	89 **Ac†** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)	112 **Cn** (285)	113 **Uut**	114 **Uuq**	115 **Uup**	

*Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9
†Actinides	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)

Group numbers 1–18 represent the system recommended by the International Union of Pure and Applied Chemistry.

Table of Atomic Masses*

Element	Symbol	Atomic Number	Atomic Mass	Element	Symbol	Atomic Number	Atomic Mass	Element
Actinium	Ac	89	[227]§	Gold	Au	79	197.0	Promethium
Aluminum	Al	13	26.98	Hafnium	Hf	72	178.5	Protactinium
Americium	Am	95	[243]	Hassium	Hs	108	[265]	Radium
Antimony	Sb	51	121.8	Helium	He	2	4.003	Radon
Argon	Ar	18	39.95	Holmium	Ho	67	164.9	Rhenium
Arsenic	As	33	74.92	Hydrogen	H	1	1.008	Rhodium
Astatine	At	85	[210]	Indium	In	49	114.8	Roentgenium
Barium	Ba	56	137.3	Iodine	I	53	126.9	Rubidium
Berkelium	Bk	97	[247]	Iridium	Ir	77	192.2	Ruthenium
Beryllium	Be	4	9.012	Iron	Fe	26	55.85	Rutherfordium
Bismuth	Bi	83	209.0	Krypton	Kr	36	83.80	Samarium
Bohrium	Bh	107	[264]	Lanthanum	La	57	138.9	Scandium
Boron	B	5	10.81	Lawrencium	Lr	103	[260]	Seaborgium
Bromine	Br	35	79.90	Lead	Pb	82	207.2	Selenium
Cadmium	Cd	48	112.4	Lithium	Li	3	6.9419	Silicon
Calcium	Ca	20	40.08	Lutetium	Lu	71	175.0	Silver
Californium	Cf	98	[251]	Magnesium	Mg	12	24.31	Sodium
Carbon	C	6	12.01	Manganese	Mn	25	54.94	Strontium
Cerium	Ce	58	140.1	Meitnerium	Mt	109	[268]	Sulfur
Cesium	Cs	55	132.90	Mendelevium	Md	101	[258]	Tantalum
Chlorine	Cl	17	35.45	Mercury	Hg	80	200.6	Technetium
Chromium	Cr	24	52.00	Molybdenum	Mo	42	95.94	Tellurium
Cobalt	Co	27	58.93	Neodymium	Nd	60	144.2	Terbium
Copernicium	Cn	112	[285]	Neon	Ne	10	20.18	Thallium
Copper	Cu	29	63.55	Neptunium	Np	93	[237]	Thorium
Curium	Cm	96	[247]	Nickel	Ni	28	58.69	Thulium
Darmstadtium	Ds	110	[271]	Niobium	Nb	41	92.91	Tin
Dubnium	Db	105	[262]	Nitrogen	N	7	14.01	Titanium
Dysprosium	Dy	66	162.5	Nobelium	No	102	[259]	Tungsten
Einsteinium	Es	99	[252]	Osmium	Os	76	190.2	Uranium
Erbium	Er	68	167.3	Oxygen	O	8	16.00	Vanadium
Europium	Eu	63	152.0	Palladium	Pd	46	106.4	Xenon
Fermium	Fm	100	[257]	Phosphorus	P	15	30.97	Ytterbium
Fluorine	F	9	19.00	Platinum	Pt	78	195.1	Yttrium
Francium	Fr	87	[223]	Plutonium	Pu	94	[244]	Zinc
Gadolinium	Gd	64	157.3	Polonium	Po	84	[209]	Zirconium
Gallium	Ga	31	69.72	Potassium	K	19	39.10	
Germanium	Ge	32	72.59	Praseodymium	Pr	59	140.9	

*The values given here are to four significant figures where possible.

§A value given in parentheses denotes the mass of the longest-lived isotope.

BROOKS/COLE
CENGAGE Learning™

Chemistry: An Atoms First Approach
Steven S. Zumdahl, Susan A. Zumdahl

Executive Editor: Lisa Lockwood
Developmental Editor: Rebecca Heider
Assistant Editor: Jon Olafsson
Editorial Assistant: Krista Mastroianni
Senior Media Editor: Lisa Weber
Media Editor: Stephanie Van Camp
Marketing Manager: Nicole Hamm
Marketing Assistant: Kevin Carroll
Marketing Communications Manager: Linda Yip
Content Project Manager: Teresa L. Trego
Design Director: Rob Hugel
Art Director: John Walker
Print Buyer: Judy Inouye
Rights Acquisitions Specialist: Don Schlotman
Production Service: Graphic World Inc.
Text Designers: Diane Beasley and Jerilyn Bockorick
Photo Researcher: Sharon Donahue
Text Researcher: Sue Howard
Copy Editor: Graphic World Inc.
OWL producers: Stephen Battisti, Cindy Stein, David Hart (Center for Educational Software Development, University of Massachusetts, Amherst)
Illustrators: Graphic World Inc. and Patricia Rossi
Cover Designer: RHDG | Reizebos Holzbaur Design
Cover Image: © SciencePhoto/Photolibrary
Compositor: Graphic World Inc.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706.

For permission to use material from this text or product,
submit all requests online at **www.cengage.com/permissions.**
Further permissions questions can be e-mailed to
permissionrequest@cengage.com.

Library of Congress Control Number: 2010937408

ISBN-13: 978-0-8400-6532-2

ISBN-10: 0-8400-6532-9

Brooks Cole
20 Davis Drive
Belmont, CA 94002-3098
USA

Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Locate your local office at **www.cengage.com/global.**

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Brooks/Cole, visit **www.cengage.com/brookscole**

Purchase any of our products at your local college store or at our preferred online store **www.CengageBrain.com.**

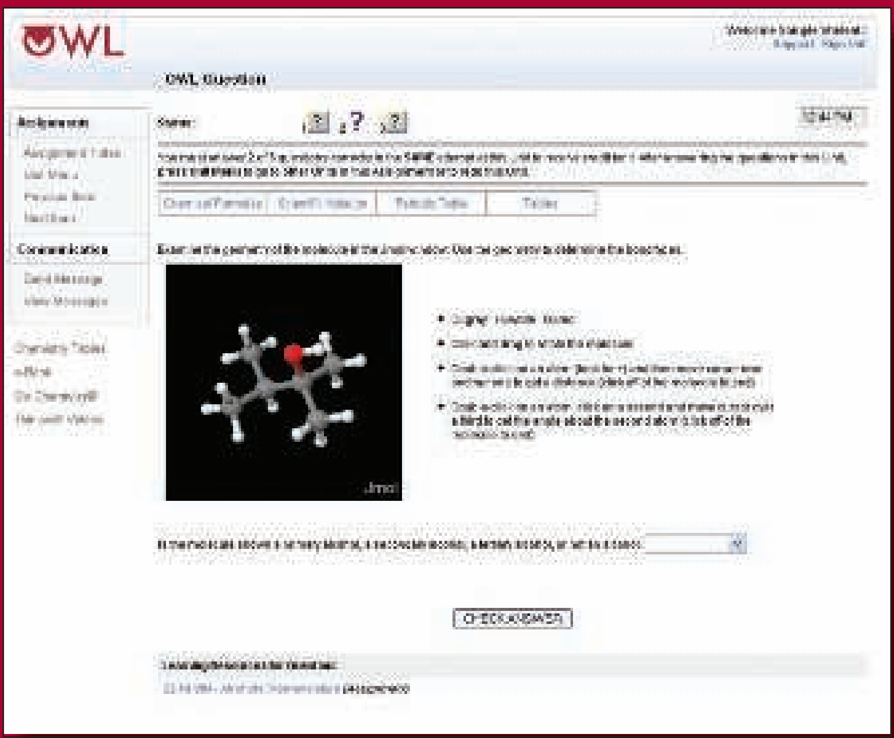
Printed in the United States of America
1 2 3 4 5 6 7 14 13 12 11 10

This page intentionally left blank

Online Web Learning

Get a Better Grade in Chemistry!

Log in now to the #1 online homework and tutorial system for chemistry. Score better on exams, get homework help, and more!



- **Master chemistry and improve your grade** using OWL's step-by-step tutorials, interactive simulations, and homework questions that provide instant answer-specific feedback. Available 24/7.
- **Learn at your own pace with OWL**, a study smart system that ensures you've mastered each concept before you move on.
- **Access an e-version of your textbook** enhanced with videos and animations, highlighting, the ability to add notes, and more.

To get started, use the access code that may have been packaged with your text or purchase access online. Check with your instructor to verify that OWL is required for your course before purchasing.

www.cengage.com/OWL

© Jan Pietruszka/Shutterstock.com

Chemistry

An Atoms First Approach

Steven S. Zumdahl
University of Illinois

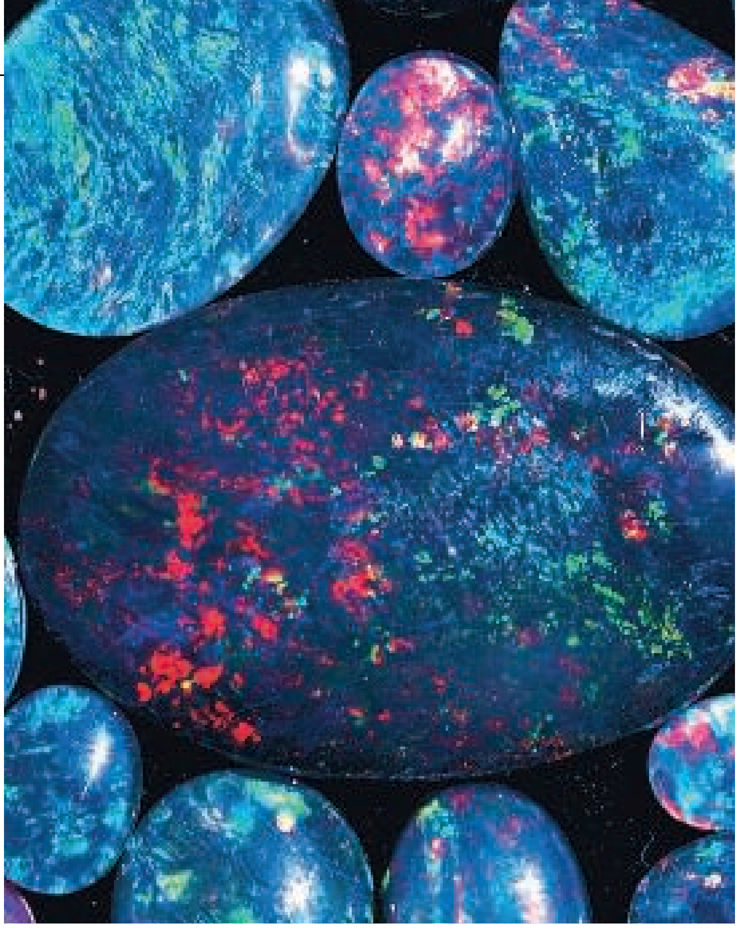
Susan A. Zumdahl
University of Illinois

BROOKS/COLE
CENGAGE Learning™

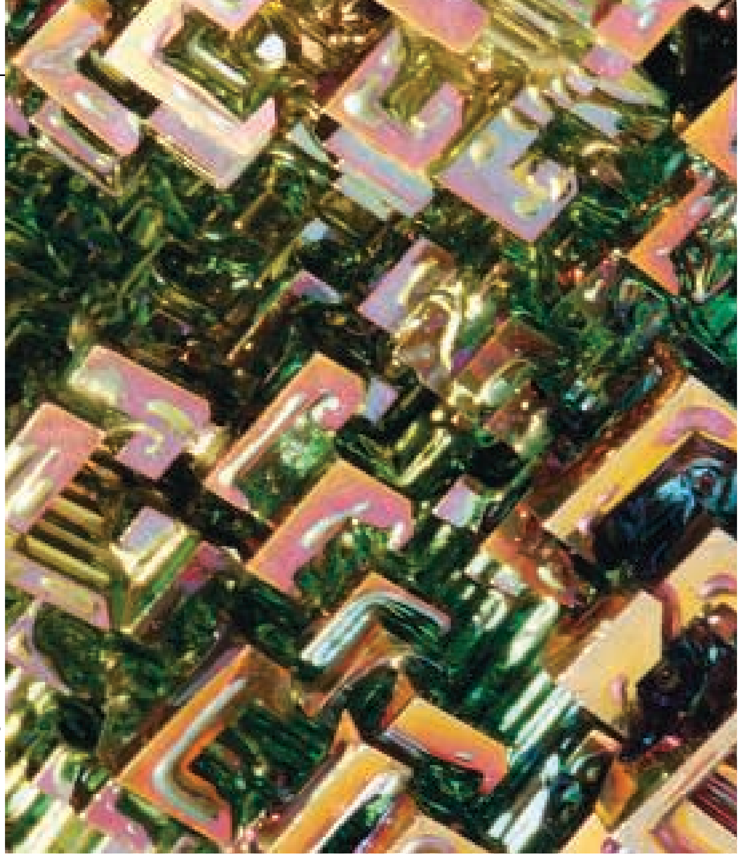
Australia • Brazil • Japan • Korea • Mexico • Singapore • Spain • United Kingdom • United States

contents

Image Source


Horizon International/Alamy

Adam Jones/Danita Delimont


© Walter Geiersperger/Corbis

John Warbuton-Lee/Danita Delimont

Features of *Chemistry: An Atoms First Approach*

Conceptual learning and problem solving have been fundamental to our approach in *Chemistry* through eight successful editions. Our philosophy is to help students learn to think like a chemist so they can apply the process of problem solving to all aspects of their lives.

In ***Chemistry: An Atoms First Approach,*** we have reexamined the now traditional order of topics in *Chemistry* and have adopted an approach that begins with the atom and proceeds from there through the concepts of molecules, structure, and bonding, to more complex materials and their properties. Because this approach differs from what students have typically experienced in their high school course, it should encourage the student to focus on conceptual learning early in the course, rather than rely on memorization and a "plug and chug" method of problem solving that even the best students can fall back on when confronted with familiar material. The ***Atoms First*** organization provides an excellent opportunity for students to utilize the tools of critical thinkers: to ask questions, to apply rules and models and to evaluate outcomes.

In our reorganization, we have given careful consideration to the flow of the narrative within the new topics and the unified story this organization provides. Here are some of the organizational changes and our rationale for them:

- Chapter R provides a review of units, significant figures, and dimensional analysis that can be used at any time, depending on the level of the course and the backgrounds of the students. This material should be familiar to the student, so we've identified it as review.
- Chapter 1 has been re-organized to provide an introduction to the key components of the story—the atom, atomic structure, energy, and the mole.
- Chapter 2 initiates the plan of going from the simple to the complex. Atoms form the basis for our understanding of chemical properties. Rather than starting with reactions, we begin with atoms and build to the more complex structures before we consider the details of stoichiometry. Also, the concept of atoms provides a valuable starting point in the development and use of models that we will emphasize throughout the text.
- Chapter 3 covers counting by weighing, atomic masses, the mole, and an introduction to chemical equations. It is our view that the more complicated aspects of stoichiometry can be delayed with no important disadvantages. We believe that students receive enough background in stoichiometry in their high school courses to support most quantitative first-term lab experiments. However, it seems clear to us that some topics traditionally covered with stoichiometry need to be emphasized early in the course. These topics are needed to support the usual type of lab program and the studies of energy and gases, liquids, and solids that follow.
- It is logical to cover the fundamental ideas of bonding in Chapter 4 because bonding concepts explain how atoms are tied together and are needed to explain the composition and structure of more complex materials.
- This leads to a discussion in Chapter 5 of the detailed models of bonding and structure.
- Chemical Energy remains as Chapter 6, although the concept has been briefly introduced in Chapter 1 (Section 1.8) to support the treatment of atomic theory and bonding. A more detailed study of energy is needed at this point to support the treatment of gases, liquids, and solids in Chapters 7 and 8.
- Stoichiometry is covered in greater detail in Chapter 9. For those instructors who wish to cover all of stoichiometry early in the course, this can be easily done by inserting Chapters 9 and 10 after Chapter 3 in this text. This order provides early coverage of atomic theory followed by a complete treatment of stoichiometry and reactions in solutions.

In addition to organizational changes, *Chemistry: An Atoms First Approach* includes the following new and updated pedagogical features:

- *Problem-Solving Strategies* help students learn to solve problems by thinking them through rather than brute-force memorizing. Section 6.2, "Learning to Solve Problems," emphasizes the importance of thoughtful, creative problem solving. The section emphasizes to students that thinking through a problem produces more long-term, meaningful learning that can be applied to "real life" than memorizing steps that apply only to a particular type of problem. To help students adopt this way of thinking we have organized the problem-solving process in terms of

"Where are we going?'

"How do we get there?" and

"Reality Check," which prompts students to check whether their answer makes sense.

As we proceed in the text, we gradually shift more responsibility to the students to think through the examples so that they do not become overly dependent on our help.

- ***Problem-Solving Strategy*** boxes to help students focus on particular aspects of problem solving.
- ***Concept Summary*** boxes help the students organize their thinking about crucial concepts.
- ***Interactive Examples*** encourage students to think their way through the example instead of passively reading through the solution.
- ***Visual Exercises*** in the end-of-chapter problems have been greatly increased and are now called out with an icon. While it is important that students know how to solve quantitative problems, it is just as important that they learn to visualize chemical concepts. Visual Exercises highlight a conceptual approach to the learning of chemistry. Many of these problems take an "atomic view" of matter so that students can appreciate the usefulness of the atomic model in understanding macroscopic properties. Other problems ask the student to interpret graphs or to explain figures. The underlying goal is to provide students with opportunities to demonstrate a conceptual understanding of fundamental chemical principles.

Hallmarks of *Chemistry: An Atoms First* Approach

- *Chemistry: An Atoms First Approach* contains numerous discussions, illustrations, and exercises aimed at *overcoming misconceptions.* It has become increasingly clear from our own teaching experience that students often struggle with chemistry because they misunderstand many of the fundamental concepts. In this text, we have gone to great lengths to provide illustrations and explanations aimed at giving students a more accurate picture of the fundamental ideas of chemistry. In particular, we have attempted to represent the microscopic world of chemistry so that students have a picture in their minds of "what the atoms and molecules are doing." The art program along with the animations emphasize this goal. We have also placed a larger emphasis on the qualitative understanding of concepts before quantitative problems are considered. Because using an algorithm to correctly solve a problem often masks misunderstanding—when students assume they understand the material because they got the right "answer"—it is important to probe their understanding in other ways. In this vein, the text includes a number of *Active Learning Questions* at the end of each chapter that are intended for group discussion. It is our experience that students often learn the most when they teach each other. Students are forced to recognize their own lack of understanding when they try and fail to explain a concept to another student.
- With a strong *problem-solving orientation,* this text talks to students about how to approach and solve chemical problems. We emphasize a thoughtful, logical approach rather than simply memorizing procedures. In particular, an innovative method is given for dealing with acid–base equilibria, the material the typical student finds most difficult and frustrating. The key to this approach involves first deciding what species are present in solution, then thinking about the chemical properties of these species. This method provides a general framework for approaching all types of solution equilibria.
- The text contains *almost 300 Examples,* with more given in the text discussions, to illustrate general problem-solving strategies. When a specific strategy is presented, it is summarized in a Problem-Solving Strategy box and the *Example* that follows it reinforces the use of the strategy to solve the problem. In general, we emphasize the use of conceptual understanding to solve problems rather than an algorithm-based approach.
- We have presented a thorough *treatment of reactions* that occur in solution, including acid–base reactions. This material appears in Chapter 10, "Types of Chemical Reactions and Solution Stoichiometry," directly after the chapter on chemical stoichiometry, to emphasize the connection between solution reactions and chemical reactions in general. Chapter 10 also includes oxidation–reduction reactions and balancing by oxidation state, because a large number of interesting and important chemical reactions involve redox processes.
- *Descriptive chemistry* and chemical principles are thoroughly integrated in this text. Chemical models may appear sterile and confusing without the observations that stimulated their invention. On the other hand, facts without organizing principles may seem overwhelming. A combination of observation and models can make chemistry both interesting and understandable. In the chapter on the chemistry of the elements we have used tables and charts to show how properties and models correlate. Descriptive chemistry is presented in a variety of ways—as applications of principles in separate sections, in Examples and exercises, in photographs, and in *Chemical Connections.*
- Throughout the book a strong *emphasis on models* prevails. Coverage includes how they are constructed, how they are tested, and what we learn when they inevitably fail. Models are developed naturally, with pertinent observation always presented first to show why a particular model was invented.
- *Chemical Connections* boxes present applications of chemistry in various fields and in our daily lives. Margin notes

in the *Instructor's Annotated Edition* also highlight many more *Chemical Connections* available on the student website.

- We offer end-of-chapter exercises for every type of student and for every kind of homework assignment: questions that promote group learning, exercises that reinforce student understanding, and problems that present the ultimate challenge with increased rigor and by integrating multiple concepts. We have included biochemistry problems to make the connection for students in the course who are not chemistry majors.
- Judging from the favorable comments of instructors and students who have used our books, the text seems to work very well in a variety of courses. We are especially pleased that *readability* is cited as a key strength when students are asked to assess our textbooks.

Supporting Materials

For the Instructor

Supporting instructor materials are available to qualified adopters. Please consult your local Cengage Learning, Brooks/Cole representative for details. Visit this book's companion site, accessible from www.cengagebrain.com, to:

- See samples of materials
- Request a desk copy
- Find your local representative
- Download electronic files of the *Instructor's Resource Guide* for the textbook, *Instructor's Resource Guide for Experimental Chemistry,* and other helpful materials for instructors and students.

PowerLecture with Diploma® Testing and JoinIn™ Instructor's CD/DVD package (ISBN-13: 978-0-840-06587-6) PowerLecture is a one-stop digital library and presentation tool that includes:

- **Prepared Microsoft® PowerPoint® Lecture Slides** that cover all key points from the text in a convenient format with art, photographs, and animations. You can enhance the slides with your own materials or with additional interactive video and animations on the DVD for personalized, media-enhanced lectures.
- **Image libraries** in PowerPoint and JPEG formats that contain electronic files for all text art, most photographs, and all numbered tables in the text. These files can be used to create your own transparencies or PowerPoint lectures.
- **JoinIn "Clicker" Questions** written specifically for using *Chemistry* with the classroom response system of your choice to seamlessly display student answers.
- ***Complete Solutions Manual*** (Thomas J. Hummel, University of Illinois, Urbana-Champaign): The *Complete Solutions Manual* contains detailed solutions to all of the end-of-chapter problems with the exception of the *For Review Questions,* available on the student website, and a discussion of the *Active Learning Questions* as found in the online *Instructor's Resource Guide.* This supplement is intended for the instructor's convenience.
- **Sample chapters** from the *Student Solutions Manual*
- ***Instructor's Resource Guide*** for the textbook and for *Experimental Chemistry: An Atoms First Approach* (see detailed description on page xii)
- ***Diploma® Testing*** combines a flexible test-editing program with comprehensive gradebook functions for easy administration and tracking. With *Diploma Testing,* instructors can administer tests via print, network server, or the web. Questions can be selected based on their chapter/section, level of difficulty, question format, algorithmic functionality, topic, learning objective, and five levels of key words. With *Diploma Testing* you can:
  - Choose from more than 2500 test items designed to measure the concepts and principles covered in the text.
  - Ensure that each student gets a different version of the problem by selecting from preprogrammed algorithmic questions.
  - Edit or author algorithmic or static questions that integrate into the existing bank, becoming part of the question database for future use.
  - Choose problems designated as single-skill (easy), multi-skill (moderate), and challenging and multi-skill (difficult).
  - Customize tests to assess the specific content from the text.
  - Create several forms of the same test where questions and answers are scrambled.

OWL for General Chemistry

OWL with Cengage YouBook 24-Month Instant Access
ISBN-13: 978-0-8400-6336-6
OWL with Cengage YouBook 6-Month Instant Access
ISBN-13: 978-1-111-37600-0
By Roberta Day and Beatrice Botch of the University of Massachusetts, Amherst, and William Vining of the State University of New York at Oneonta. **OWL** Online Web Learning offers more assignable, gradable content (including end-of chapter questions specific to this textbook) and more reliability and flexibility than any other system. OWL's powerful course management tools allow instructors to control due dates, number of attempts, and whether students see answers or receive feedback on how to solve problems. OWL includes the **Cengage YouBook**, a Flash-based eBook that is interactive and customizable. It features a text edit tool that allows instructors to modify the textbook narrative as needed. With the Cengage YouBook, instructors can quickly re-order entire

sections and chapters or hide any content they don't teach to create an eBook that perfectly matches their syllabus. Instructors can further customize the Cengage YouBook by publishing web links. It also includes animated figures, video clips, highlighting, notes, and more.

Developed by chemistry instructors for teaching chemistry, OWL is the only system specifically designed to support **mastery learning**, where students work as long as they need to master each chemical concept and skill. OWL has already helped hundreds of thousands of students master chemistry through a wide range of assignment types, including tutorials, interactive simulations, and algorithmically generated homework questions that provide instant, answer-specific feedback.

OWL is continually enhanced with online learning tools to address the various learning styles of today's students such as:

- **Quick Prep** review courses that help students learn essential skills to succeed in General and Organic Chemistry
- **Jmol** molecular visualization program for rotating molecules and measuring bond distances and angles
- **Go Chemistry®** mini video lectures on key concepts that students can play on their computers or download to their video iPods, smart phones, or personal video players

In addition, when you become an OWL user, you can expect service that goes far beyond the ordinary. For more information or to see a demo, please contact your Cengage Learning representative or visit us at www.cengage.com/owl.

Interactive Examples Interactive Examples in OWL offer the student a new way to learn to solve chemistry problems. Students often tell us that examples seem so straightforward when they read the text, but they struggle to solve end-of-chapter problems. These new Interactive Examples guide students using a question-based process that requires student input at each step and highlights problem-solving techniques. Students can work these Interactive Examples multiple times to help them master the problem-solving process, receiving slightly different examples on each student attempt.

ChemWork *ChemWork* assignments in OWL provide students an opportunity to determine whether they can solve problems of the type that they might see on an exam. These problems are designed for students to use in one of two ways:

1. As homework problems to assess their problem-solving ability and understanding of the chapter concepts
2. As a capstone assignment to determine their level of understanding in preparation for an exam

Students who can solve a problem without assistance can proceed directly to the answer and receive congratulations. However, a student who needs help can receive assistance through a series of hints. The process is modeled after the way the instructor would help a student with a homework problem in his or her office. The hints are usually in the form of interactive questions that burrow down through the problem-solving process to allow the student to figure out just where he or she is going wrong. The student is guided through the process but does not receive a correct answer or a solution from the system when a student gets stuck; rather it encourages the student to continue working on the problem by working through the hints. The goal is to help the students get to the correct answer and then to congratulate them on their success. *ChemWork* is parameterized both chemically and numerically so each student in the course receives a unique set of problems.

Instructor's Resource Guide (Donald J. DeCoste, University of Illinois, Urbana-Champaign) Available on the instructor companion site and on PowerLecture, this downloadable manual includes a section of notes for teaching assistants, suggested solutions for the *Active Learning Questions* from the textbook, and amplifications of strategies used in various chapters.

Instructor's Resource Guide for Experimental Chemistry: An Atoms First Approach (James Hall, University of Massachusetts, Lowell) Available on the instructor companion site and on PowerLecture, this PDF manual contains tips on running experiments, approximate times for each experiment, and answers to all prelab and postlab questions posed in the laboratory guide.

Cengage Learning Custom Solutions Develop personalized text solutions to meet your course needs. Match your learning materials to your syllabus and create the perfect learning solution—your customized text will contain the same thought-provoking, scientifically sound content, superior authorship, and stunning art that you've come to expect from Cengage Learning, Brooks/Cole texts, yet in a more flexible format. Visit www.cengage.com/custom to start building your book today.

For the Student

Visit CengageBrain.com To access these and additional course materials, please visit www.cengagebrain.com. At the CengageBrain.com home page, search for the ISBN (from the back cover of your book) using the search box at the top of the page. This will take you to the product page where these resources can be found. (Instructors can log in at login.cengage.com.)

OWL **OWL for General Chemistry** See the description above in the Instructor's Supporting Materials section.

OWL Quick Prep for General Chemistry (Instant Access 90 Days ISBN-13: 978-0-495-56030-2) Quick Prep is a self-paced online short course that helps students succeed in general chemistry. Students who completed Quick Prep through an organized class or self-study averaged almost a full letter grade higher in their subsequent general chemistry course than those who did not. Intended to be taken prior to the start of the semester, Quick Prep is appropriate for both underprepared students and for students who seek a review of basic skills and concepts. Quick Prep features an assessment quiz to focus students on the concepts they need to study to be prepared for general chemistry. Quick Prep is approximately 20 hours of instruction delivered through OWL with no textbook required and can be completed at any time in the student's schedule. Professors can package a printed access card for Quick Prep with the textbook or students can purchase instant access at www.cengagebrain.com. To view an OWL Quick Prep demonstration and for more information, visit www.cengage.com/chemistry/quickprep.

Go Chemistry® for General Chemistry (ISBN-13: 978-0-495-38228-7) Pressed for time? Miss a lecture? Need more review? Go Chemistry for General Chemistry is a set of 27 downloadable mini video lectures. Developed by award-winning chemists, Go Chemistry helps you quickly review essential topics—whenever and wherever you want! Each video contains animations and problems and can be downloaded to your computer desktop or portable video player (like iPod or iPhone) for convenient self study and exam review. Selected Go Chemistry videos have e-flashcards to briefly introduce a key concept and then test student understanding of the basics with a series of questions. The Cengage YouBook in OWL includes Go Chemistry videos. Professors can package a printed access card for Go Chemistry with the textbook. Students can enter ISBN 978-0-495-38228-7 at www.cengagebrain.com to download two free videos or to purchase instant access to the 27-video set or individual videos.

CengageBrain.com App Now, students can prepare for class anytime and anywhere using the CengageBrain.com application developed specifically for the Apple iPhone® and iPod touch®, which allows students to access free study materials—book-specific quizzes, flashcards, related Cengage Learning materials, and more—so they can study the way they want, when they want to . . . even on the go. For more information about this complimentary application, please visit www.cengagebrain.com.

Student Companion Website This site includes samples of selected student supplements, as well as a glossary, flashcards, and an interactive periodic table. Accessible from www.cengagebrain.com.

Student Solutions Manual (Thomas J. Hummel, University of Illinois, Urbana-Champaign) (ISBN-13: 978-0-840-06583-4) This manual provides detailed solutions for half of the end-of-chapter exercises (designated by the blue question numbers), using the strategies emphasized in the text. This supplement has been thoroughly checked for precision and accuracy. Answers to the *For Review* questions can be found on the student website.

Experimental Chemistry: An Atoms First Approach (James Hall, University of Massachusetts, Lowell) (ISBN-13: 978-0-840-06585-8) This lab manual provides an extensively revised laboratory program compatible with the text. The 61 experiments present a wide variety of chemistry, and many experiments offer choices of procedures. Safety is strongly emphasized throughout the program.

***Essential Algebra for Chemistry Students,* Second Edition** (David W. Ball, Cleveland State University) (ISBN-13 978-0-495-01327-3) This short book is intended for students who lack confidence and/or competency in their essential mathematics skills necessary to survive in general chemistry. Each chapter focuses on a specific type of skill and has worked-out examples to show how these skills translate to chemical problem solving. Includes references to OWL, our web-based tutorial program, offering students access to online algebra skills exercises.

***Survival Guide for General Chemistry with Math Review and Proficiency Questions,* Second Edition** (Charles H. Atwood, University of Georgia) (ISBN-13: 978-0-495-38751-0) Intended to help students practice for exams, this survival guide shows how to solve difficult problems by dissecting them into manageable chunks. The guide includes three levels of proficiency questions—A, B, and minimal—to quickly build confidence as students master the knowledge they need to succeed in the course.

For the Laboratory

Brooks/Cole Cengage Learning Lab Manuals We offer a variety of printed manuals to meet all your general chemistry laboratory needs. Instructors can visit the chemistry site at www.cengage.com/chemistry for a full listing and description of these laboratory manuals and laboratory notebooks. All Cengage Learning lab manuals can be customized for your specific needs.

Apple, iPhone, iPod touch, and iTunes are trademarks of Apple Inc., registered in the U.S. and other countries.

Signature Labs . . . for the customized laboratory Signature Labs combines the resources of Brooks/Cole, CER, and OuterNet Publishing to provide you unparalleled service in creating your ideal customized lab program. Select the experiments and artwork you need from our collection of content and imagery to find the perfect labs to match your course. Visit www.signaturelabs.com or contact your Cengage Learning representative for more information.

Acknowledgments

This book represents the efforts of many talented and dedicated people. We particularly want to thank Charles Hartford, Publisher, for his vision and oversight of the project. Charlie's knowledge of the field and enthusiasm has contributed immensely to the success of our textbooks. We also want to thank Teresa Trego, Senior Content Project Manager, who did an excellent job of coordinating the production of a very complex project. We also especially appreciate the dedication of Rebecca Heider, Senior Development Editor, who managed the development process in a very supportive and organized manner. We are also grateful for the excellent work of Lisa Weber, Senior Media Editor, and Stephanie VanCamp, Associate Media Editor. In addition, Jon Olafsson, Assistant Editor, did an outstanding job of communicating with us and of coordinating the print supplements.

We are especially grateful to Tom Hummel, University of Illinois at Urbana-Champaign, who managed the end-of chapter problems and the solutions manuals. We greatly appreciate the outstanding work of Don DeCoste, University of Illinois at Urbana-Champaign, who created the Visual Exercises, and Gretchen Adams, University of Illinois at Urbana-Champaign, who created the Interactive Examples. We are deeply indebted to these two colleagues who contribute in so many ways to our various projects. We are also very grateful to Jim Hall, University of Massachusetts–Lowell, for creating the excellent laboratory manual for the text. We are extremely appreciative of Jim's creative and accurate work over many years on many of our projects.

Thanks to others who supplied valuable assistance for this text: John Walker, Art Director; Sharon Donahue, Photo Researcher; Nicole Hamm, Senior Marketing Manager; and Kevin Carroll, Marketing Coordinator.

We are especially thankful to all of the reviewers who participated in different aspects of the development process from reviewing chapters to providing feedback on the development of new features. We sincerely appreciate all of these suggestions.

David Boatright, *University of West Georgia*
Gene Carlisle, *West Texas A&M University*
Tsun-Mei Chang, *University of Wisconsin–Parkside*
Charles Cox, *Georgia Institute of Technology*
Michelle Driessen, *University of Minnesota*
Amina El-Ashmawy, *Collin College*
Deborah Exton, *University of Oregon*
David Geiger, *SUNY-College at Geneseo*
Jon Hardesty, *Collin County Community College*
Jennie Mayer, *Bellevue College*
Katherine Parks, *Motlow State Community College*
Casey Raymond, *SUNY Oswego*
David Smith, *New Mexico State University*
Lydia Tien, *Monroe Community College*
Wayne Wesolowski, *University of Arizona*
David Zax, *Cornell University*

to the student

As you jump into the study of chemistry we hope that you will find our text helpful and interesting. Our job is to present the concepts and ideas of chemistry in a way you can understand. We hope to encourage you in your studies and to help you learn to solve problems in ways you can apply in all areas of your professional and personal lives.

Our main goal is to help you learn to become a truly creative problem solver. Our world badly needs people who can "think outside the box." Our focus is to help you learn to think like a chemist. Why would you want to do that? Chemists are great problem solvers. They use logic, trial and error, and intuition—along with lots of patience—to work through complex problems. Chemists make mistakes, as we all do in our lives. The important thing that a chemist does is to learn from the mistakes and to try again. This "can do" attitude is useful in all careers.

In this book we develop the concepts in a natural way: The observations come first and then we develop models to explain the observed behavior. Models help us to understand and explain our world. They are central to scientific thinking. Models are very useful, but they also have limitations, which we will point out. By understanding the basic concepts in chemistry we lay the foundation for solving problems.

Our main goal is to help you learn a thoughtful method of problem solving. True learning is more than memorizing facts. Truly educated people use their factual knowledge as a starting point—a basis for creative problem solving. Our strategy for solving problems is explained in Section 6.2. To solve a problem we ask ourselves questions, which help us think through the problem. We let the problem guide us to the solution. This process can be applied to all types of problems in all areas of life.

As you study the text, use the *Examples* and the problem-solving strategies to help you. The strategies are boxed to highlight them for you and the *Examples* show how these strategies are applied.

After you have read and studied each chapter of the text you'll need to practice your problem-solving skills. To do this we have provided plenty of review questions and end-of-chapter exercises. Your instructor may assign these on paper or online; in either case, you'll want to work with your fellow students. One of the most effective ways to learn chemistry is through the exchange of ideas that comes from helping one another. The online homework assignments will give you instant feedback and, in print, we have provided answers to some of the exercises in the back of the text. In all cases, your main goal is not just to get the correct answer, but to understand the process for getting the answer. Memorizing solutions for specific problems is not a very good way to prepare for an exam (or to solve problems in the real world!).

To become a great problem solver you'll need these skills:

1. Look within the problem for the solution. (Let the problem guide you.)
2. Use the concepts you have learned along with a systematic, logical approach to find the solution.
3. Solve the problem by asking questions and learn to trust yourself to think it out.

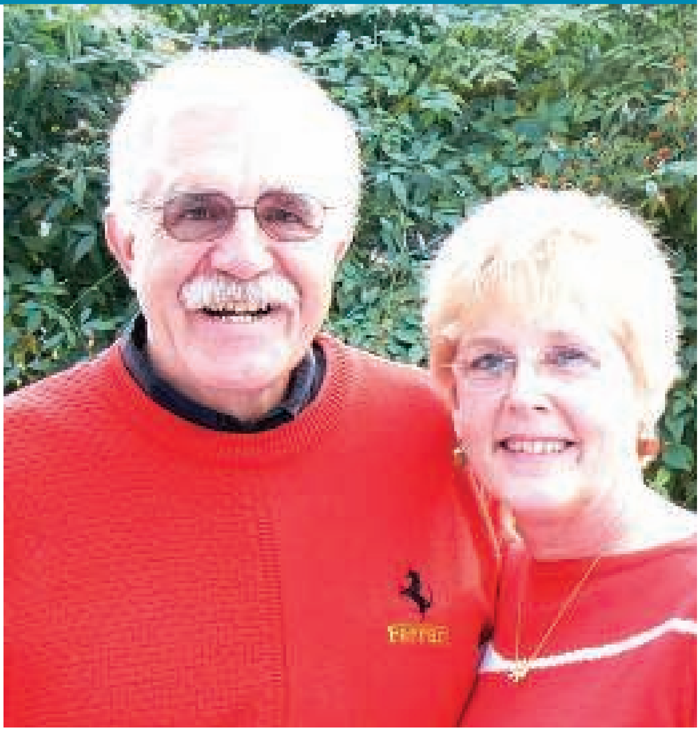
You will make mistakes, but the important thing is to learn from these errors. The only way to gain confidence is to practice, practice, practice and to use your mistakes to find your weaknesses. Be patient with yourself and work hard to understand rather than simply memorize.

We hope you'll have an interesting and successful year learning to think like a chemist!

Steve and Susan Zumdahl

This page was intentionally left blank

about the authors



Steven S. Zumdahl earned a B.S. in Chemistry from Wheaton College (IL) and a Ph.D. from the University of Illinois, Urbana-Champaign. He has been a faculty member at the University of Colorado–Boulder, Parkland College (IL), and the University of Illinois at Urbana-Champaign (UIUC), where he is Professor Emeritus. He has received numerous awards, including the National Catalyst Award for Excellence in Chemical Education, the University of Illinois Teaching Award, the UIUC Liberal Arts and Sciences Award for Excellence in Teaching, UIUC Liberal Arts and Sciences Advising Award, and the School of Chemical Sciences Teaching Award (five times). He is the author of several chemistry textbooks. In his leisure time he enjoys traveling and collecting classic cars.

Susan A. Zumdahl earned a B.S. and M.A. in Chemistry at California State University–Fullerton. She has taught science and mathematics at all levels, including middle school, high school, community college, and university. At the University of Illinois at Urbana-Champaign, she developed a program for increasing the retention of minorities and women in science and engineering. This program focused on using active learning and peer teaching to encourage students to excel in the sciences. She has coordinated and led workshops and programs for science teachers from elementary through college levels. These programs encourage and support active learning and creative techniques for teaching science. For several years she was director of an Institute for Chemical Education (ICE) field center in Southern California and she has authored several chemistry textbooks. Susan spearheaded the development of a sophisticated web-based electronic homework system for teaching chemistry. She enjoys traveling, classic cars, and gardening in her spare time—when she is not playing with her grandchildren.

This page was intentionally left blank