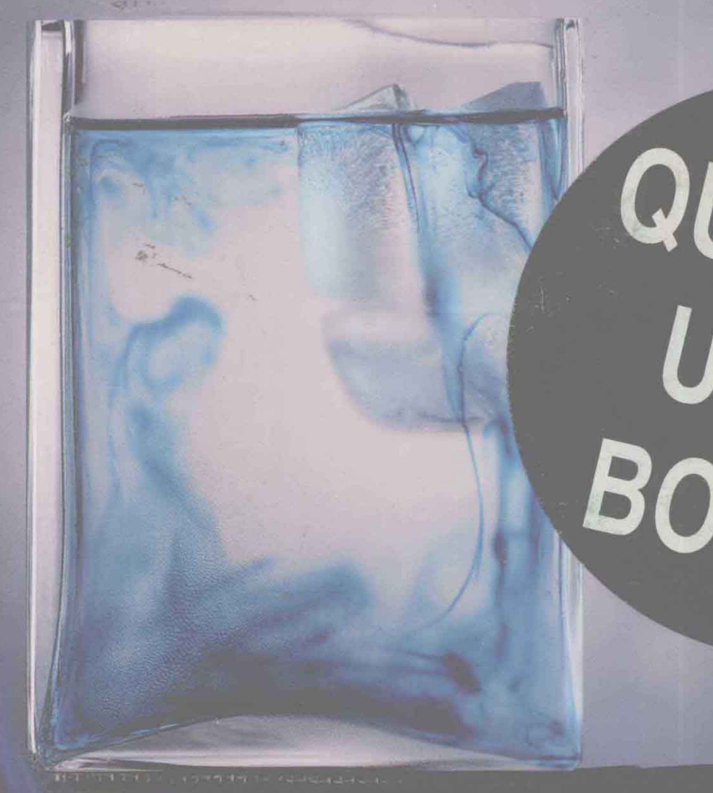
CHEMISTRY

THE PRACTICAL SCIENCE



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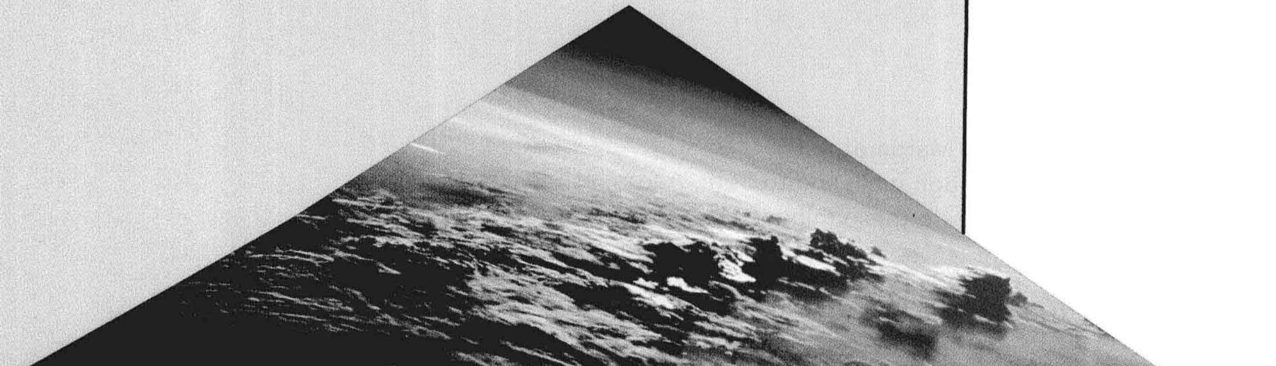

Chemistry

The Practical Science

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To Barb, Kristie, and Margaret,
who are with us through it all, and to Seth, Aaron, Jamie, David, and Alison, for whom we do these things

To Jim Carr,
master craftsman of the finest teachers

Publisher: Charles Hartford
Development Editor: Rebecca Berardy Schwartz
Assistant Editors: Amy Galvin, Liz Hogan
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Senior Manufacturing Buyer: Karen B. Fawcett
Marketing Manager: Laura McGinn
Marketing Assistant: Kris Bishop

Printed in the U.S.A.

Library of Congress Control Number: 2006927034

Instructor's examination copy
ISBN-10: 0-618-82860-5
ISBN-13: 978-0-618-82860-9

For orders, use student text ISBNs
ISBN-10: 0-618-00072-0
ISBN-13: 978-0-618-00072-2

123456789–CRK–10 09 08 07 06

Preface

To the Instructor

We are excited to be presenting you with a different kind of textbook—one that is written from the standpoint of *how chemists really teach in the twenty-first century*. It is our aim to complement your teaching style by giving your students a teacher's viewpoint in print. This book is about the questions we ask when we teach chemistry. It focuses on the "big ideas" of chemistry that we, as chemists, found so appealing that we chose a career in this field. For example, we explore the periodic table, the energy exchanges that accompany all chemical changes, the ideas of quantum mechanics (science is about probability, not perfection), and how we can use Le Châtelier's principle to control the extent of chemical reactions. These are just some of the ideas we want students to grasp deeply when we say, "*Here's what it means to think like a chemist.*"

A Framework of Interwoven Applications

In addition to our commitment to sharing the big ideas that define science in general and chemistry in particular, we write from the belief that chemistry is vitally important to the world in which we live. In this text, we present chemistry in the context of how it is related to our everyday lives by interweaving the concepts of chemistry with their uses in the chemical industry, the human body, and the environment. For example, a discussion of the energy changes that occur in chemical reactions is entwined with how these concepts are used in the U.S. space shuttle program. The discussion of kinetics is applied to the fate of pesticides in the environment. We view chemistry's applications in society as fundamentally good, and we note that when the use of chemistry has led to unfortunate consequences (especially for the environment), chemistry has also been used to clean up the mess. This focus on the *vital role* that the ideas and practice of chemistry have in our day-to-day lives is written into the storyline of the text. We mean it when we say that this textbook is *applications-based.*

An Interrogative Style

In our classrooms, we enjoy raising questions with our students, both because we like to hear their ideas and because raising questions is a key characteristic that defines the curious minds of scientists. We wrote our textbook to reflect an interrogative style, in which questions addressed to the student—often the same questions we ask in our own lectures—begin various topics. This approach involves students in the discussion, encourages them to pose questions about their world, and nurtures their curiosity about science and how it applies to society. This approach recurs throughout every chapter, as we continue to engage the student in what is most fundamental to practicing scientists: questioning the world around them.

Problem-Solving Approach

Our discussions are geared to science majors and unfold in the context of how they and their classmates will need to apply chemistry to their lives to solve problems. Our approach to problem solving helps students think critically by encouraging them to ask the right questions and frame them in such a way as to solve a problem effectively. Then, once the problem is solved, the text guides students in evaluating whether their answers make sense. The in-chapter *Exercises* include worked-out *Solutions* and are framed with a variety of pedagogical aids.

- *First Thoughts* engage the student.
- Worked-out *Solutions* guide the student step-by-step through the problem.
- *Further Insights* extend the concept.
- *Practice Problems* give students additional problems, to which answers are provided at the back of the book.
- The *list of corresponding end-of-chapter problems* at the end of each *Exercise* directs students to more practice.

These *Exercises* demonstrate how scientists think about problems and show how we work through a problem to arrive at an answer by asking questions.

Chapter Organization

Chapter 12 (Carbon) and Chapter 13 (Modern Materials) are strategically placed in the middle of this text for many reasons. The theme of the organic chapter (structure changes lead to changes in function and properties) logically follows the introduction of the topics on structural bonding models. The materials chapter logically follows the sequence of chapters on gases (Chapter 10) and liquids (Chapter 11). In addition, the placement of these chapters at the end of a typical semester of undergraduate chemistry allows the instructor the opportunity to end the semester on these applied topics of chemistry. The topical order is flexible, and these chapters can easily be taught in a different sequence than represented in the textbook.

The Bottom Line

Our applications-based and interrogative approach has resulted in a book that *students will actually read* and that reflects how *teachers really teach*. Here, then, as we say at the end of every chapter in the text, is *The Bottom Line*—in this case, a concise list of the main features of the textbook:

- **Applications** of chemistry are interwoven within the concepts of chemistry. Students often ask "Why do I need to know this?," so we have shown, at every opportunity, how chemistry is a part of our world.
- An **interrogative style** encourages students to be inquisitive about their world both locally and globally and involves them in discussing and learning concepts that are important to chemistry.
- Our **problem-solving approach** helps students to first think about a problem, to next approach the problem in a logical manner in order to arrive at a solution efficiently, and then to think beyond the calculation to uncover related information about the concepts that are being explored.
- A **practical, student-friendly pedagogy** includes writing that involves students and offers many opportunities for review (such as in the *Here's What We Know So Far* sections and *The Bottom Line* summaries). In addition, **visually engaging illustrations** clearly represent concepts for students and illustrate the vital connection of the world of the atom to the world in which we live.
- A **dynamic, contemporary art program** appeals to today's students, who expect exciting and visually appealing graphics. This program features molecular-level illustrations of key concepts to help students connect microscale activity

to macroscale phenomena. In addition, electrostatic potential maps use vibrant color to show how electron density changes across a molecule.

- **Technology and print resources** accommodate a variety of student learning styles and help instructors more easily manage homework by creating assignable activities that can be graded automatically in an online environment.

We hope that you and your students will enjoy reading and working with this textbook as much as we enjoyed writing it.

To the Student

Please allow us, for a moment, to share with you what happens on the first day of class in our own first-year chemistry classrooms. Often, we spend some time meeting as many of you as we can—beginning to know your names, learning your majors, and finding out why you have enrolled in our chemistry course. We then tell a few stories about ourselves, because part of studying together is seeing each other's very human side. During the entire year, we attempt to learn more about each other in order to make this new and exciting journey into chemistry a shared trip—where we ask each other questions, find answers, make connections, and discover why this wonderful subject is so useful for us to understand. By the same token, insofar as it is possible to share a bit of ourselves and our own sense of the beauty of this subject, we have tried to do so in this textbook.

In many ways, our presentation of material in this book is quite similar to the way we teach in class. We will share with you the big ideas of chemistry, and, because we all want to know "why we need to know this," we will discuss how the concepts of chemistry are applied to real-world issues, such as manufacturing processes, the blastoff of a rocket, the interaction of pharmaceuticals with the blood, and the age of life itself. We will then ask questions that lead to an explanation of how we know these things.

Our book has two overriding goals. The first is to help you appreciate the depth and breadth of chemistry. The second goal is to encourage you to make connections between concepts in chemistry and the world in which we live. "How do we know?" is one of the most vital questions, no matter what your field of study. In chemistry, we often say that asking good, focused questions is vital to "thinking like a chemist." *Knowing how to know* and *wanting to know* are two essential traits of successful, independent learning that not only are crucial to your study of chemistry but also will really pay off for a lifetime.

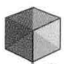
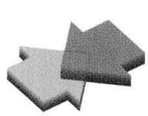
As you read this book (and we do believe that it can be read as a wonderful story of chemistry), look for the places where we raise questions. Ask yourself why we raise each question at the point where we do. What is the key idea? Why is this useful to know? What can I now figure out that I was not able to before? What connections can I make? What have I learned?

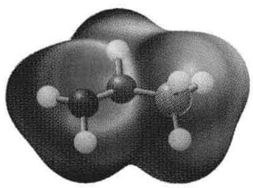
It is true that chemistry can be quite challenging and that persistence is necessary. Daily reading and study are the keys, and making a serious investment with your heart as well as your head will pay off in an understanding of chemistry as well as in the enjoyment of learning. If this book enhances your desire to learn more about the world around you, then we've been successful—and so have you.

These are the very things that we say to our own students. And then, together, we start doing chemistry. Let's go!

Paul Kelter
Michael Mosher
Andrew Scott

Features of the Text

Feature	Purpose	Example	What Is It?
Integrated applications  Application CHEMICAL ENCOUNTERS: Energy Choices	To demonstrate why students need to know each concept	See page 197.	■ An application opens each chapter. ■ *Chemical Encounters* present major applications that are emphasized as themes and listed in the Table of Contents and chapter outlines. ■ Application icons highlight major applications in the text narrative.
Key questions within the chapter about energy: **What is energy?** uttle store energy and release it hin molecules and compounds?	To model the interrogative approach in chemistry and to encourage students to think critically	See page 168.	■ Important questions are highlighted throughout the text.
Exercises within the chapter **EXERCISE 5.3** The First Law of Thermodynamics Calculate the change in the energy of a system if 51.	To help students think critically about questions and practice solving problems in chemistry	See page 178.	Features of in-chapter *Exercises:* ■ *First Thoughts* engage the student. ■ Worked-out *Solutions* are shown. ■ *Further Insights* extend the concept. ■ Additional *Practice* problems are provided. ■ Corresponding end-of-chapter problems are listed.
Here's What We Know So Far	To provide multiple opportunities for student review throughout each chapter	See pages 175 and 186.	■ Key concepts are reviewed in bulleted lists throughout the chapter.
The Bottom Line		See page 200.	■ Important concepts are summarized at the end of each chapter.
Boxed features 	To provide detailed applications of chemistry concepts outside of the flow of the text discussion	See page 14.	■ *How Do We Know?* features demonstrate the use of key chemical concepts in medicine, research, and other applications.
		See page 62.	■ *NanoWorld / MacroWorld* essays focus on how the interactions at the molecular level translate into explanations of chemistry at the macro level.
		See page 116.	■ *Issues and Controversies* essays explore current, controversial topics related to science.

Feature	Purpose	Example	What Is It?
Illustrations and photos  Methylhydrazine	To engage visual learners, help clarify key concepts, offer examples of real-world applications, and demonstrate the connections between the macroworld and the microworld	See page 195.	■ Art and photos appear throughout each chapter and within end-of-chapter problems.
End-of-chapter problems	To promote student review and comprehension of material To provide instructors with numerous ways to meet student and course needs	See pages 118–123.	Features of end-of-chapter problems: ■ *Skill Review* helps students practice applying specific concepts via paired problems. ■ *Chemical Applications and Practices* provide paired problems within the context of the real world. ■ *Comprehensive Problems* test students' mastery of concepts in the chapter. ■ *Thinking Beyond the Calculation* provides rigorous, cumulative, and conceptual problems based on multiple concepts.

3.3 Working with Moles

Skill Review

17. Which of these quantities of sodium chloride (NaCl) contains the greatest mass?
0.100 mol 4.2 × 10^{23} formula units 1.60 g

18. Which of these quantities of acetaminophen ($C_8H_9NO_2$) contains the greatest mass?
0.550

19. Conve
a. 65.(

procedure produced 100 atoms of meitneriu
moles is this? What would be the mass of the s

Chemical Applications and Practices

29. Iron is essential for the transport of oxygen
body and for energy production through sever
cycles.
a. What is the mass, in grams, of one atom of
b. The recommended dietary allowance (RDA

tion. Student B obtains an 85.0% yield in the same reaction. Can you now determine which student obtained the greater mass of the product? Explain, or justify your answer.

Comprehensive Problems

87. Review the vitamin C controversy discussed in this chapter. How is it possible that a compound can be both good and bad for your health?

Thinking Beyond the Calculation

98. Xylene (ZIGH-leen) is an important organic molecule isolated from petroleum oil. It is often used as a thinner for oil-based paints.
a. Elemental analysis of a sample of xylene shows that the mass percent of carbon is 90.51% and the mass percent of hydrogen is 9.49%. What is the empirical formula of xylene?

Appendixes	To provide students with a ready source of useful data in chemistry To provide instructors with data that can be used to construct problems that meet specific course needs	See page A1.	■ Eight appendixes appear at the back of the book.

Learning Resources for Students

An extensive print and media package has been designed to assist students in working problems, visualizing molecular-level interactions, and building study strategies to fully comprehend concepts.

Technology for Students

- **Your Guide to an A** with passkey is the portal to all of the premium student resources available from the Online Study Center (*college.hmco.com/pic/kelter*). From the Online Study Center, students will have access to *Visualizations* (animated molecular concepts and lab demonstration videos), *interactive tutorials, electronic flashcards, ACE practice tests,* and *over 50 hours of video lessons from Thinkwell.* These resources will help students prepare for class, study for quizzes and exams, and improve their grade. If students have bought a used textbook, they can purchase *Your Guide to an A* separately.
  - ***Visualizations*** Animations and videos bring chemical concepts to life with animated molecular-level interactions and lab demonstrations. Each animation and video includes practice questions to test the student's knowledge of that concept.
  - ***Tutorials*** These interactive tutorials guide students from preparation to comprehension using a variety of learning techniques, including preview and practice questions, concept overviews, animated demonstrations, and interactive activities.
  - ***Video Lessons from Thinkwell*** Over 50 hours of video lessons are delivered via streaming video. Each 8- to 10-minute mini-lecture features a chemistry expert lecturing on key topics. These lessons combine video, audio, and whiteboard examples to help students understand and review concepts.

  Also included in the Online Study Center are an *interactive periodic table, molecule library of chemical structures,* and *Careers in Chemistry page,* which has links to career information in industry, education, medicine, law, and other fields. A passkey is not required to access these resources.

- **Eduspace®, Houghton Mifflin's Complete Online Learning Tool,** features all of the student resources included within the *Online Study Center* (described above), such as *tutorials, Visualizations, video lessons from Thinkwell, flashcards,* and *ACE practice tests,* as well as *text-specific end-of-chapter problems, ChemWork online homework assignments,* an online multimedia eBook, and SMARTHINKING—live, online tutoring. End-of-chapter problems include helpful links to equations, tables, and art from the textbook for student review, as well as links to the online multimedia eBook.

  Also available are *ChemWork* assignments that help students begin to think and solve problems like chemists. As students work through unique, individual assignments, a series of gradual interactive hints guide them through the problem-solving process to help them arrive at a solution. *ChemWork* exercises go beyond the typical online homework system because they are designed to help students approach the problems in much the same way as if an instructor were sitting right next to them—directing them when they get stuck but not giving them the answer. These *ChemWork* problems also are automatically graded and recorded in the grade book.

  The online multimedia eBook available within Eduspace integrates reading textbook content with interactive media. Students can visualize molecular concepts, work through interactive *tutorials,* watch *video lessons,* practice problem solving, and quiz themselves on key terms by clicking the embedded icons within the eBook.

- **Live, Online Tutoring available through SMARTHINKING®** provides personalized, text-specific tutoring during peak study hours when students need it most (terms and conditions subject to change; some limits apply). It allows students to use a powerful whiteboard with full scientific notation and graphics to interact with a live e-structor; submit a question to get a response, usually within 24 hours; view past online sessions, questions, or essays in an archive on their personal academic homepage; and view their tutoring schedule. E-structors help students with the process of problem solving rather than supply answers. SMARTHINKING® is available through Eduspace or, upon instructor request, with new copies of the student textbook.

Print Supplements: For Students

- The **Study Guide,** by Gretchen M. Adams (University of Illinois at Urbana-Champaign) and Frank J. Torre (Springfield College), expands on the problem-solving methods of the textbook with *First Thoughts, Solutions,* and *Further Insights* to help students further understand concepts that are particularly difficult. Each chapter of the guide includes 45–50 exercises for additional student practice. Tables and section descriptions also are included.
- The **Student Solutions Manual,** by Scott A. Darveau (University of Nebraska at Kearney), 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.
- The **Lab Manual,** by James Almy (Cornell University), offers a unique mix of both traditional and guided-inquiry experiments. This mix of experiments gives the instructor power in choosing the student's level of autonomy in the laboratory, and guidelines for use of these two types of experiments is discussed extensively in the "To the Instructor" section of the manual. Students will find each experiment to be clear, engaging, and thought-provoking. The front of the manual, with the sections "To the Student," "Safety," and "How to Use Lab Equipment," and the appendixes give students a solid base of knowledge (and instructors a solid base of comfort) to perform well in the laboratory.

Resources for Instructors

A complete suite of customizable teaching tools accompanies *Chemistry: The Practical Science.* Whether online or via CD, these integrated resources are designed to save you time and help make class preparation, presentation, assessment, and course management more efficient and effective.

Technology: For Instructors

- The **Media Integration Guide for Instructors** gives an overview of instructor and student media resources available with the text, provides the passkey to the *Online Teaching Center,* and includes the instructor CD's: *HM Testing*™ (*powered by Diploma*®) and *HM ClassPresent*™. Throughout the guide, recommendations are given that suggest how, why, and when to use the media offered in this program.
- **HM Testing™ (powered by Diploma®)** combines a flexible test-editing program with a comprehensive grade-book function for easy administration and tracking. With *HM Testing,* instructors can administer tests via print, network server, or the web. Questions can be selected based on chapter, section, topic,

format, and level of difficulty. Instructors also have the option of accessing the test bank content from *Eduspace*. With *HM Testing* you can

- Choose from over 2000 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 the 777 algorithmic questions within the computerized test bank.
- Edit or author algorithmic questions.
- Choose problems designated as single-skill (easy), multi-skill (moderate), and challenging and multi-skill (difficult). Create questions, which then become part of the question database for future use.
- Customize tests to assess the specific content from the text.
- Create several forms of the same test where questions and answers are scrambled.

The *Complete Solutions Manual* files are included on this CD.

- **HM ClassPresent™ General Chemistry CD-ROM** features animations and video demonstrations arranged by chapter and topic. *HM ClassPresent* provides a library of high-quality, scaleable lab demonstration videos and animations covering core chemistry concepts. The resources within it can be browsed by thumbnail and description or searched by chapter, title, or keyword. Instructors can export the animations and videos to their own computers or use them for presentation directly from the CD. Full transcripts accompany all audio commentary to reinforce visual presentations and to accommodate different learning styles.
- **Online Teaching Center** (*college.hmco.com/pic/kelter*) includes everything instructors need to develop lectures: *Lecture Outline PowerPoint slides; virtually all of the text figures, tables, and photos* available in PPT slides and digital files; the *Instructor's Resource Manual* for both the main text and *Lab Manual* (PDF formats); *transparencies* (PDF format); animation and videos; and Classroom Response System (CRS) content.
  - *Lecture Outline PowerPoint slides* include lecture outlines, animations and video demonstrations, art from the textbook, and questions to gauge students' comprehension.
  - *Classroom Response System (CRS) content* transforms traditional lectures into student-centered learning environments that promote peer interaction and collaboration. The instructor has a formative assessment tool that provides real-time feedback when the histogram of student responses to the questions is displayed. CRS offers a dynamic way to facilitate interactive learning with students—perform immediate assessments, deliver quick quizzes, gauge comprehension, and take class attendance easily. These text-specific slides pose multiple-choice questions to students and challenge them to answer using wireless "clickers." Questions are conceptual and quantitative, and many also include applications. A variety of responses display anonymously in a bar graph, pie chart, or other graphic and can be exported to a grade book. (Additional hardware and software are required. Contact your sales representative for more information.)
- **Eduspace®, Houghton Mifflin's Complete Online Learning Tool,** is an instructor's "one-stop" resource for all course material. Through Eduspace, instructors have access to all of the media included within the Online Teaching and the Online Study Centers, plus additional homework problems and assignments. This additional content includes *algorithmic end-of-chapter problems* and *ChemWork assignments*. Text-specific end-of-chapter problems are automatically graded and include links to equations, tables, and art from the textbook, as well as optional hints that link to the *online multimedia eBook*. The majority of the end-of-chapter problems are algorithmically generated, ensuring that each student receives a different version. *ChemWork*'s interactive assignments help students

learn the process of problem solving with a series of interactive hints as they work through the assignments and are graded automatically. Multiple, randomizing versions of each assignment ensure that students do not get the same one. *ChemWork* is designed to help students think about problems in much the same way as if you, the instructor, were sitting right next to them—guiding them when they get stuck but not giving them the answer. SMARTHINKING®, live, online tutoring, is also included through Eduspace for students.

Eduspace includes all of Blackboard's powerful tools for teaching and learning, as well as customized functions that allow instructors to tailor these materials to their specific needs. Instructors can select, create, and post homework assignments and tests, communicate with students in a variety of ways, track student progress, and manage their portfolio of course work in the grade book.

- **Online Course Content for Blackboard® and WebCT** allows delivery of text-specific content online using your institution's local course management system. Through these course management systems, Houghton Mifflin offers access to all assets within Eduspace, such as *ChemWork, end-of-chapter problems, tutorials, video lessons,* and other resources.

Print Supplements: For Instructors

- The **Complete Solutions Manual,** by Scott A. Darveau (University of Nebraska at Kearney), includes every solution to the end-of-chapter problems using the strategies emphasized in the text. This supplement has been thoroughly checked for precision and accuracy.

Acknowledgments

We would like to thank the following friends and colleagues whose professional skills, understanding, and commitment have made this textbook possible.

Frank Torre and Gretchen Adams, dear friends both, thanks for your work on the study guide and for Frank's work on the PowerPoint slides. Frank, continue to work for peace and fly high. Gretchen, you throw like a guy.

Scott Darveau, how lucky we are to have you on our team. Thanks for putting together the solutions manual and offering so much valued counsel during the construction of this text.

Jeff Woodford and Jason Overby, many thanks for your excellent work on the test bank. Jeff, your work as a reviewer of the manuscript was marvelous. Mike Perona, we are grateful for your exceptional eye on the manuscript review as well.

Margaret Asirvatham, valued friend and colleague, thanks for your ability to peer into the future with your work on the clickers. Estelle Lebeau and Linda Bush, thank you for your many efforts in helping us to put our problems online into Eduspace. Laura Pence, teller of great stories, thank you for helping us to make our story come alive.

We also thank Laura McGinn, our marketing manager, for helping others to see what we have written; Andrea Cava, project editor, who was so good at keeping the process together over three continents; Connie Day, copyeditor, for her careful attention to detail; Cia Boynton, designer, for the attractive and flexible design; Jessyca Broekman, art development editor, to whom we owe much thanks for developing the lovely art program for the text; Naomi Kornhauser, for finding the photos that have added so much to the story; and Charles Hartford, vice president and publisher, for overseeing the project. Thanks also to Liz Hogan and Amy Galvin, assistant editors; Chip Cheek, editorial assistant; and Lynne Blaszak, senior media producer.

Special thanks to two who will be our friends forever: Richard Stratton and Katherine Greig, always with the right words to say and always there, no matter where our separate paths might take us.

Finally, thanks to Rebecca Berardy Schwartz, kindred spirit, confidante, soul-sister, and top-notch developmental editor. Thanks, Rebecca, for knowing so well that communicating science requires both the brain and the heart.

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We sincerely appreciate our colleagues' help in reviewing the text and instructor and student resources.

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Developing effective problem-solving skills using an interrogative approach

The problem-solving approach encourages students to first think about the problem, use logic to arrive at a solution efficiently, and then think beyond the calculation to uncover related information about the concepts being explored. Worked-out examples throughout the text reflect this problem-solving method with a **Question**, followed by a series of **First Thoughts**, a worked-out **Solution**, **Further Insights**, and a **Practice** problem.

EXERCISE 5.3 **The First Law of Thermodynamics**

Calculate the change in the energy of a system if 51.8 J of work is done *by* the system with an associated heat loss of 12.3 J.

First Thoughts

We must pay particular attention to the sign conventions for heat and work in this problem. In this case, work is done by the system. Is this work positive or negative? A useful system to keep in mind is you! That is, when you do work—by running, dancing, or even moving your textbooks from one class to the next—you are using energy. After the process of moving your body or your books, you have less energy than you had before, so the work has a "−" sign. Similarly, the 51.8 J of work done by the system means that its energy change, w_{system}, is −51.8 J. The energy loss as heat *by the system* (such as that accompanying your run as your body tries to stay cool) also has a "−" sign, so $q_{system} = -12.3$ J.

Solution

From the standpoint of the system,

$$\Delta U = q + w$$

$$\Delta U = -12.3\text{ J} + (-51.8\text{ J}) = -64.1\text{ J}$$

Further Insights

We want to reinforce the point that there is no such thing as heat or work within a system. In other words, *a system does not contain heat or work.* Rather, heat and work exist only as *types of energy transfer* between the system and the surroundings. Work is done by or on a system to move it through a distance. A system can transfer 64.1 J of energy as heat and work. It does not contain 64.1 J of heat and work.

PRACTICE 5.3

Calculate the change in the energy of a system if 84.7 J of work is done on the system, with an associated loss of energy as heat of 39.9 J.

See Problems 11–14, 19, 20, and 89.

HERE'S WHAT WE KNOW SO FAR

- There are three natural forces: the gravitational, electroweak, and strong nuclear forces.
- Potential energy is the energy stored within a system.
- Kinetic energy is the energy associated with motion.
- The law of conservation of energy states that energy can be neither created nor destroyed. Instead, it just moves between the system and the surroundings and can be transformed from one form to another.
- Work and heat are two ways in which energy can move between the system and the surroundings.
- The flow of energy as heat from the system to the surroundings involves an exothermic process. An endothermic process involves the flow of energy as heat from the surroundings to the system.
- Changes in the energy of a reaction can be studied by examining a reaction profile diagram.

Additional aids for student comprehension include **Here's What We Know So Far** in-chapter summaries, **The Bottom Line** bulleted reviews of key chapter topics, and **Key Words**.

The text models an interrogative style of learning through investigation by posing questions to the students to introduce various topics. These **highlighted questions** appear throughout the chapter and prompt students to think critically about topics.

Dilution

How do municipal water treatment plant workers prepare water so that it contains a fluoride ion concentration of about 1 part per million? They use a concentrated source of fluorine, hydrofluorosilicic acid, H_2SiF_6 ("HFSA"), which they then dilute in the drinking water. HFSA reacts with water in a fairly complex way that releases fluoride ion into the water. In Ireland, a company in the town of New Ross,

Engaging students through integrated applications

Interwoven throughout the chapter, chemistry concepts are explained through the use of real-world examples. Application icons throughout the text show at a glance where chemical concepts are applied.

Application
CHEMICAL ENCOUNTERS: Setting the Stage with the Space Shuttle

A space shuttle launch is an awe-inspiring demonstration of the ability of energy to transport humans and material away from Earth's surface with an eye toward planetary exploration. The energy to launch the craft and its crew comes from the explosive violence of chemical reactions. When these reactions are used in a carefully controlled way, they can lift the massive shuttle (which weighs in at a robust 2,000,000 kg), the booster rockets, and the fuel tank and propel the ship into orbit hundreds of miles above Earth in a very brief 10-minute ride.

Two chemical reactions, indicated in Figure 5.1, power the launch of the space shuttle. The combustion of hydrogen gas (the combination of hydrogen and oxygen to form water) takes place in the main engines. At the same time, the solid rocket boosters attached to the sides of the shuttle release a host of products resulting from the oxidation of aluminum by ammonium perchlorate, though we show only the primary equation here.

Main engi

Boosters:

As the
ergy that
cle is quie
booster ro

4. Diagram, using circles for atoms, a crystal of KCl versus the same crystal of KCl dissolved in water.

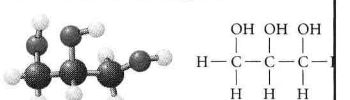
Chemical Applications and Practices

5. Earth's oceans contain tons of dissolved sodium chloride. Yet, when a ship develops an oil leak, almost none of the oil dissolves in the ocean. Explain this phenomenon.

6. When an ion dissolves, it is surrounded by a hydration sphere. If water molecules surrounded the ion so that the hydrogen portion of the water was closer to the ion, would the ion most likely be a cation or an anion?

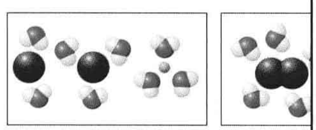
7. Pure water does not conduct an electric current. However, aqueous solutions of some compounds do form solutions that conduct electricity. Explain why the presence of some solutes converts nonconducting water into a conducting solution.

8. Glycerin can be produced as a by-product in soap making. The compound dissolves so easily in water that
water from the air. This latter characteristic is wh
is often found in many skin lotions. As glyceri
the water, the skin can be kept moist. Glycerin's st
shown below. What aspects of glycerin's structure
most to its ease of dissolving in water?



Glycerin

9. A conductivity-testing apparatus, such as the one
this chapter, possesses a light bulb whose brightness
to how much current is flowing through it (and als
the solution.) A small, but measurable, amount
must be present before the bulb becomes visibly
What effect would this characteristic of the appa



12. Which of the following would best represent
water?

Applications are also found in How Do We Know? and NanoWorld / MacroWorld features, chapter openers, photos, and end-of-chapter exercises. Students will see how chemistry connects to their lives, their future careers, and their world.

How do we know?

The moons of Jupiter

The moons of the outer planets make most elegant chemical laboratories, because conditions on these worlds are so very different from those here at home. When we look at photos of Jupiter's moons, Europa and Ganymede (Figure 11.17), we see some vexing geological features. How do we know what caused these features? We can't visit the moons, at least not directly. However, our space probes can gather various types of electromagnetic radiation—including light, ultraviolet radiation, and X-rays—that give us data from which to draw conclusions.

The probes' data seem to show that deep within the surface of these moons, there are layers of ice, each in a different phase, mixed with rocks. The phase diagram of water that we showed as Figure 11.18 is inadequate to account for the low temperatures and massive pressures found within these moons. A more comprehensive phase diagram for water, emphasizing its solid phases, is given as Figure 11.20. The ice that is made in our kitchen freezer or found in an ice storm—what we might call "normal ice"—is technically called Ice Ih. Its structure is shown in Figure 11.21. There are 11 other forms of ice that have been made in the laboratory or simulated by computer.

The phase diagram shows that as the temperature and pressure inside the moons change, different types of ice are formed. Each ice has its own density. As layers form versions of ice of different densities, they form the geological features, such as cracking and grooves, that we see on the surface of these incredible satellites. Part of the task of scientists is to develop phase diagrams that tell us about the conditions at which each type of ice exists.

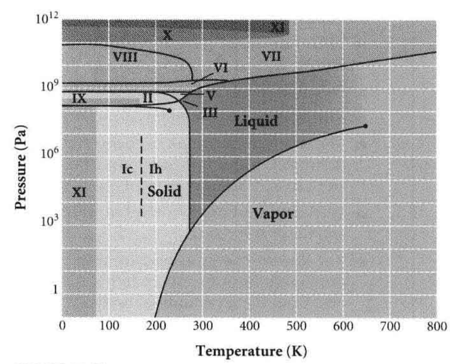


FIGURE 11.20

This is an expanded phase diagram for water, taking into account the phase changes among the various solid (ice) forms. These forms of ice are thought to occur in layers beneath the surface of some of the moons of the outer planets.

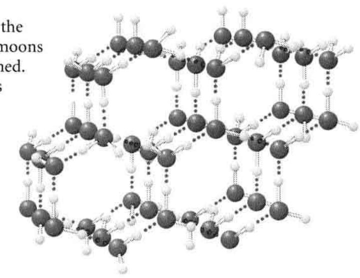


FIGURE 11.21

The arrangement of water molecules within a crystal of "normal" ice (Ice Ih).

Dynamic, contemporary art program

This contemporary art and photo program appeals to tech-savvy students who expect exciting and visually appealing graphics regardless of medium.

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FIGURE 4.10

To visualize the idea of parts per million, per billion, and per trillion, consider that one drop of ink could be placed in these quantities of water. (a) Placing that drop of ink in a 12-gallon bucket results in 1 ppm. (b) Placing it in a tanker truck results in 1 ppb. (c) Placing it in a 12-million-gallon reservoir results in 1 ppt.

(a) (b) (c)

...tly different way. As an example, ...C_6Cl_6), a pesticide used on wheat ...ns that the maximum allowable ...$_6$ per billion grams of solution.

...Cl_6 / ...tion

...ake the key assumption that *the* ...*that of water,* then

$$...s = \frac{1 \text{ g solution}}{1 \text{ mL solution}}$$

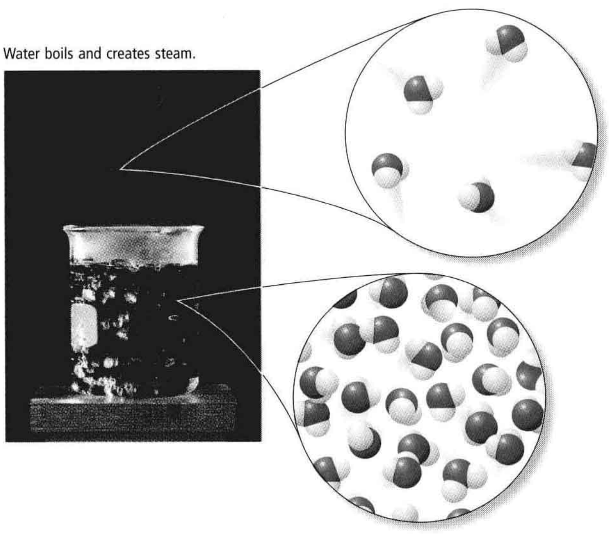
...n of hexachlorobenzene as the

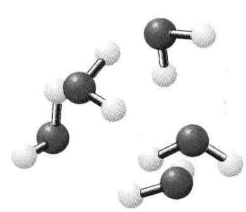
$$= \frac{10^{-6}\text{ g } C_6Cl_6}{\text{L solution}} = \frac{1\ \mu\text{g } C_6Cl_6}{\text{L solution}}$$

...ions, we can express parts per

11.2 A Closer Look at Intermolecular Forces | 445

Water boils and creates steam.





Five molecules of liquid water interact with each other. Note the positions of the hydrogen atoms. They are being shared with neighboring oxygen atoms.

Molecular-level illustrations of key concepts help students connect nanoscale activity to macroscale phenomena.

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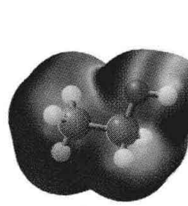
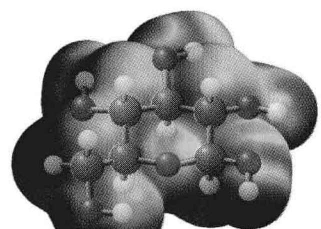
An electrostatic potential map of glucose and ethanol. The electrostatic potential is plotted on the surface of a computer-generated model of the molecules. Note how the electron density is distributed in each molecule, and compare these models to that of water (Figure 4.3).



Ethanol



D-glucose

In addition, **electrostatic potential maps** use vibrant color to show how electron density changes across a molecule.

Comprehensive end-of-chapter materials

Focus Your Learning

The answers to the odd-numbered problems appear at the back of the book.

Section 4.1 Water—A Most Versatile Solvent

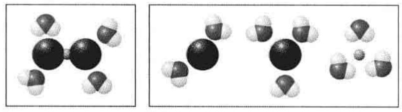
Skill Review

1. Explain how water molecules can dissolve both cations and anions.
2. Why doesn't pure water conduct an electric current?
3. Explain what is meant by the term *hydration sphere*?
4. Diagram, using circles for atoms, a crystal of KCl versus the same crystal of KCl dissolved in water.

Section 4.2 The Concentration of Solutions

Skill Review

11. Which of the following would best represent $MgCl_2$ dissolved in water?



(a) (b)

A wealth of end-of-chapter problems test students' understanding of key concepts and problem-solving skills. They include **Skill Review and Chemical Applications and Practices**, organized by chapter sections and in matched pairs.

Comprehensive Problems

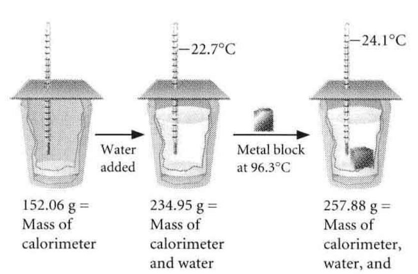
85. Individual atoms and molecules are so small that they have very low values of kinetic energy. However, given their mass and velocity, it is possible to calculate the value. What is the kinetic energy of an oxygen molecule (O_2) in air that you are breathing if its velocity is 460 m/s? Would you expect a nitrogen molecule (N_2) moving at the same speed to have more or less kinetic energy than the oxygen molecule? Explain.
86. Distinguish between the two terms in each of the following pairs:
   a. Heat and temperature
   b. System and surroundings
   c. Exothermic and endothermic
   d. q and ΔU

tions of muffins) are needed to provide 1 joule?

93. a. Suppose you are heating water (225 g) in a mug that you have placed in a microwave oven. As you wait to add the instant hot chocolate, please calculate, from the following data, the amount of energy as heat that the water has absorbed: The original water temperature was 15.0°C. When you remove the mug of hot water, you find that the temperature has risen to 98°C.
   b. What additional information would you need in order to determine the heat absorbed by the mug?
94. You have just removed a hot cheese pizza from the oven, and all of the ingredients are presumably at the same temperature. Without waiting for it to cool, you take a bite of the pizza. As you bite the pizza, the bread is hot on your tongue but does not burn. However, as you continue to bite, pizza sauce (mostly tomatoes and water) squeezes out and burns the roof of your mouth. Which has the higher specific heat,

Increasing in difficulty are **Comprehensive Problems** that test the students' mastery of concepts in the chapter.

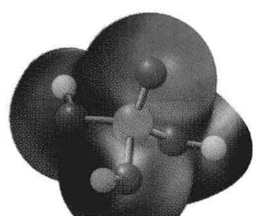
96. A student's coffee cup calorimeter, including the water it contains, has been calibrated in a manner similar to that described in Problem 46. The heat capacity was found to be 55.5 $\frac{J}{°C}$. If a 65.8-g sample of an unknown metal, at 100.0°C, was placed in the calorimeter initially at 25°C, and an equilibrium temperature of 29.1°C was reached, what is the specific heat of the metal?
97. The foods we eat provide fuel to keep us alive. Burning a 0.500-g sample of vegetable oil provides enough heat to raise the temperature of a calorimeter by 2.5 K. Assuming the heat capacity of the calorimeter to be 7.5 $\frac{kJ}{K}$, determine the heat of combustion for 1 g of the oil.
98. A student performs the experiment shown graphically here. What is the specific heat of the block of metal used in the experiment? (Assume that the heat capacity of the empty calorimeter is 7.5 $\frac{J}{°C}$.)



Thinking Beyond the Calculation

99. Phosphoric acid is used in many soft drinks to add tartness. This acid can be prepared through the following reaction:

$$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$$



Phosphoric acid

   a. If the value of ΔH for the reaction is −453 kJ, what is the value of ΔH for the reverse of the reaction?
   b. What is the value of ΔH for this reaction if 10.0 g of phosphoric acid is produced?
   c. Is this reaction endothermic or exothermic?
   d. If 1.50 g of $P_4O_{10}(s)$ and 2.50 mL of water were mixed, how many grams of phosphoric acid would result?
   e. What is the enthalpy change for the process outlined in part d?
   f. If 10.0 g of P_4O_{10} were mixed with 1.00 kg of water at 25.0°C, what would be the final temperature of the water?

Thinking Beyond the Calculation provides rigorous, cumulative, and conceptual problems based on multiple concepts.