Pearson International Edition

ELEVENTH EDITION

Chemistry

FOR CHANGING TIMES

JOHN W. HILL
DORIS K. KOLB

ELEVENTH EDITION

Chemistry for Changing Times

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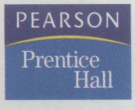

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Doris K. Kolb

(1927–2005)

This eleventh edition of *Chemistry for Changing Times* is dedicated to the memory of Doris K. Kolb, who died of pancreatic cancer on December 20, 2005. Doris has been my esteemed coauthor since the seventh edition.

Doris Jean Kasey was born on August 4, 1927 in Louisville, Kentucky. She received a B.S. degree with a major in chemistry from the University of Louisville and M.S. and Ph.D. degrees from The Ohio State University. She married Kenneth E. Kolb in 1948.

A distinguished scientist, Doris Kolb was the first female Ph.D. employed by Standard Oil of Indiana. She did research that led to a better understanding of the browning of fruits, and she helped establish fundamental standards for pure fatty acids. While at Standard Oil, she helped pioneer a live television program, *Spotlight on Research*, which aired on WTTW in Chicago.

Doris taught at Corning Community College in New York and at Illinois Central College. She was the first recipient of ICC's Outstanding Teacher Award. While at ICC, she developed several courses, mostly for nursing students. Doris joined the faculty at Bradley University in 1986 and taught there until 2005. Her excellence in teaching was further recognized with the prestigious Catalyst Award of the Chemical Manufacturers Association.

Doris was exceptionally active in the American Chemical Society (ACS), holding many offices at the local and national level. Much of her service to the ACS was in the area of chemical education. Most notably, she served for 16 years on the Board of Publications for the *Journal of Chemical Education*, including eight years as chair. She also served as Chair of the ACS Division of Chemical Education. She was a Feature Editor for the *Journal*'s column, "Overhead Projector Demonstrations." Doris authored more than 60 papers, several book chapters, and was coauthor of two books, including this one. She presented more than 50 talks at ACS meetings and organized numerous symposia. In September 2005, she and Ken were recipients of the Division of Chemical Education's Outstanding Service Award.

Doris was a leader in community affairs. She helped establish Planned Parenthood in Peoria and served as its first executive director. She was active with Planned Parenthood for the rest of her life and was honored with the Margaret Sanger Award in 1975 and the Betty Osborne Award in 1991. Doris was also a pioneer in recognizing the effect of smoking on health and helped found Group Against Smokers' Pollution (GASP). She was also active in the Peoria Women's Club, the Peoria Garden Club, the Peoria Symphony Guild, the Peoria Fine Arts Society, and the PEO Sisterhood. She was a member of the Universalist Unitarian Church.

Doris was a poet of some note. Her main interest was humorous poetry. She not only added a touch of fun to *Chemistry for Changing Times*, but she gave readings in many venues and taught independent learning classes in humorous poetry. The last class she taught was a class in poetry in the fall of 2005.

To me, Doris and Ken were friends and helpful supporters long before Doris joined the author team. She has provided much to the spirit and flavor of the book. Doris's contributions to *Chemistry for Changing Times*—and indeed to all of chemistry and chemical education—will live on for many years to come, not only in her publications, but in the hearts and minds of her many students, colleagues, and friends. Let us dedicate our lives, as Doris did hers, to making this world a better place.

John W. Hill

- Each chapter has a category of Collaborative Group Projects as a part of the end-of-chapter exercises. This will make it easy for instructors who want to encourage collaborative work and to make group assignments. In this way, the students' learning of chemistry can be extended far beyond the textbook.
- We have added voice balloons to figures to point out important features. We also use voice balloons in text displays and problem solving to guide the student through the learning process and thus improve the pedagogy.
- The chapter summaries have been organized into a new format, presented by sections, with key terms highlighted in red for easy recognition. Figures and photographs have been included in the summaries to aid the visual learner in revisiting important concepts.
- We have updated the References and Readings at the end of each chapter.
- Keeping in mind that today's student is more visually oriented than ever, we have made extensive changes in the photographs, figures, graphs, and other illustrations.

Applications

Focusing on the importance of providing interesting, relevant applications, we have added several new box features:

- Nanoworld (Chapter 1)
- Cell Phones and Microwaves and Power Lines, Oh My! (Chapter 4)
- A Compound by Any Other Name Would Smell As Sweet . . . (Chapter 5)
- Photochromic Glass (Chapter 8)
- A Closed Ecosystem? (Chapter 12)
- Energy Return on Energy Invested (Chapter 14)
- Infectious Prions: Deadly Protein (Chapter 15)
- Enzymes and Green Chemistry (Chapter 15)
- It's a Drug! No, It's a Food! No, It's . . . a Dietary Supplement! (Chapter 16)
- Chemistry and Athletic Performance (Chapter 18)
- Chemistry of Sports Materials (Chapter 18)
- Cisplatin: The Platinum Standard of Cancer Treatment (Chapter 19)
- Some Chemistry of Love, Trust, and Sexual Fidelity (Chapter 19)
- Renaissance Poisoners and Chemistry and Counterterrorism (Chapter 20)

Visualization

New color photographs and diagrams have been added. Visual material adds greatly to the general appeal of a textbook. Color diagrams can also be highly instructive, and colorful photographs relating to descriptive chemistry do much to enhance the learning process. We have added more illustrations that use both microscopic (molecular) and macroscopic (visual) views to help students visualize chemical phenomena. Some of the figure captions feature questions to focus attention on the concept illustrated in the figure.

Readability

Over the years, students have told us that they have found this textbook easy to read. The language is simple, and the style is conversational. Explanations are clear and easy to understand. The friendly tone of the book has been maintained in this edition. Since the format and the amount of open space on a page also contribute to readability, we have made conscious improvements in the design of this edition. For example, many of the margin notes have been incorporated directly into the text to ensure that pages don't appear to be crowded.

Units of Measurement

The United States continues to use the traditional English system for many kinds of measurement even though the metric system has long been used internationally. A modern version of the metric system, the Système International (SI), is now widely used, especially by scientists. So what units should be used in a text for liberal arts students? In presenting chemical principles, we use primarily metric units. In other parts of the book we use those units that the students are most likely to encounter elsewhere in the same context.

Chemical Structures

The structures of many complicated molecules are presented in the text, especially in the later chapters. These structures are presented mainly to emphasize that they are actually known and to illustrate the fact that substances with similar properties often have similar structures. Students should not feel that they must learn all these structures, but they should take the time to look at them. We hope that they will come to recognize familiar features in these molecules.

Chapter Summaries and Glossary

The chapter summaries have been organized into a new format with key terms highlighted in red. The Glossary (Appendix B) gives definitions of terms that appear in boldface throughout the text. These terms include all key terms highlighted in the chapter summaries.

Questions and Problems

Worked-out Examples and accompanying Exercises are given within almost all of the chapters. Each Example carefully guides the student through the process for solving a particular type of problem. It is then followed by one or more Exercises that allow the student to check his or her comprehension right away. Most Examples are now followed by two Exercises, labeled A and B. The goal in an A Exercise is to apply to a similar situation the method outlined in the Example. In a B Exercise, students often must combine that method with other ideas previously learned. Many of the B Exercises provide a context closer to that in which chemical knowledge is applied, and they thus serve as a bridge between the worked Examples and the more challenging problems at the end of the chapter. The A and B Exercises provide a simple way for the instructor to assign homework that is closely related to the Examples. Answers to all the in-chapter Exercises are given in Appendix C.

The end-of-chapter exercises include

- Review Questions that for the most part simply ask for a recall of material in the chapter.
- A set of matched-pair Problems, arranged according to subject matter from each chapter, with answers to the odd-numbered problems given in Appendix C.
- Additional Problems that are not grouped by type. Some of these are more challenging than the matched-pair Problems and often require a synthesis of ideas from more than one chapter. Other Additional Problems pursue an idea further than is done in the text or introduce new ideas.

Answers to many Review Questions and Additional Problems are also given in Appendix C.

References and Suggested Readings

An updated list of recommended books and articles appears at the end of each chapter. A student whose interest has been sparked by a topic can delve more deeply into the subject in the library. Instructors might also find these lists useful.

Supplementary Materials

The most important learning aid is the teacher. In order to make the instructor's job easier and enrich the education of students, we have provided a variety of supplementary materials.

Print Resources for Students

Student Study Guide (0-13-227113-3). Prepared by Richard Jones of Sinclair Community College. This book assists students through the text material and contains learning objectives, chapter outlines, key terms, and additional problems along with self-tests and answers.

Chemical Investigations for Changing Times, Eleventh Edition (0-13-1755005). Prepared by C. Alton Hassell and Paula Marshall. Contains 56 laboratory experiments and is specifically referenced to *Chemistry for Changing Times*.

Study Card (0-13-239660-2). Prepared by Stacy Brown. This is a concise, quick reference card covering key topics in each chapter of the text. Presented in an easy-to-read format, the *Eleventh Edition Study Card* enables students to master concepts, theories, and facts for exams as well as easily review information on the go.

Print Resources for Instructors

Instructor's Resource Manual (0-13-227115-X). Prepared by Paul Karr and David Pietz of Wayne State College. 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 lecture outlines, answers and solutions to all questions and problems that are not answered by the authors in Appendix C, suggested in-class demonstrations recommended by Doris Kolb, and other suggested resources. The lecture outline is also available in an electronic format.

Instructor's Manual for Chemical Investigations for Changing Times (0-13-227116-8). Prepared by Paula Marshall and C. Alton Hassell. This laboratory manual reference includes notes for experiments, safety regulations, procedural instructions, and specifications for equipment and supplies.

Transparencies (0-13-199002-0). Selected by Terry McCreary and John W. Hill. This set contains 150 full-color acetates.

Test Item File (0-13-227114-1). Prepared by Rill Ann Reuter, Winona State University. The *Test Item File* now contains over 2400 test questions that are referenced to the text.

Media Resources for Students

Chemistry for Changing Times Companion Website with GradeTracker (0-13-243412-1) (http://www.prenhall.com/hill)

- **Key Concepts:** A collection of learning goals and key terms to help students identify what they should know, understand, and be able to do after reading the chapter. Definitions of key terms can be accessed through the online glossary.
- **Review Activities:** A variety of assessment opportunities to help students check their understanding of key concepts with the choice to view helpful hints and receive instant feedback on selected answers. Instructors have the option to assign any of these online self-grading activities for homework credit or simply allow students to work at their own pace toward mastery.
- **Media Enhancements:** Selected review questions are enhanced with media—short movies, animations, and 3D molecules—to help students visualize key concepts. Follow the media icons in the textbook to the Companion Website.

- **Application and Critical Thinking Activities:** Collections of thought-provoking questions designed to involve students in scenarios and independent and collaborative research opportunities that focus on current chemistry issues. Pearson's *Research Navigator™*, included as a *Companion Website* offering, connects students to four exclusive databases of source material, including the EBSCO Academic Journal and Abstract Database, New York Times Search by Subject Archive, "Best of the Web" Link Library, and Financial Times Article Archive and Company Financials, helping students quickly and efficiently make the most of their research time.
- **Green Chemistry:** Online versions of the Green Chemistry activities found in the textbook designed to promote awareness. Students are prompted to communicate their findings in a variety of reporting strategies.

Media Resources for Instructors

Instructor's Resource Center on CD/DVD (0-13-199003-9). Prepared by John Singer and James Noblet. This fully searchable and integrated collection of resources includes everything you need organized in one easy-to-access place. It is designed to help you make efficient and effective use of your lecture preparation time as well as to enhance your classroom presentations and assessment efforts. This package features nearly all of the art from the text, including tables; three pre-built PowerPoint presentations; PDF files of the art for high-resolution printing; all the interactive and dynamic media objects from the *Companion Website*; the *Instructor's Resource Manual*, and a set of "clicker" questions for use with Classroom Response Systems. This CD/DVD set also features a search engine tool that enables you to find relevant resources via a number of different parameters, such as key terms, learning objectives, figure numbers, and resource type. Also included is the TestGen test-generation software and a TestGen version of the Test Item File that enables you to create and tailor exams to your needs, or to create online quizzes for delivery in WebCT, Blackboard, or CourseCompass.

Course Management Options. Prentice Hall offers prebuilt courses in a variety of Course Management systems, each of which lets you easily post your syllabus, communicate with students online or offline, administer quizzes, and record student results and track their progress. **OneKey's online course management content** is all you need to plan and administer your course and includes the best teaching and learning resources all in one place. Conveniently organized by textbook chapter, these compiled resources help you save time and help your students reinforce and apply what they have learned in class. Available resources include Summary with Key Terms, Tools, Research Navigator Web research center, Math Toolkit, Practice Problems, and the Test Item File. Resources from the *Instructor's Resource Center* on CD/DVD are also included. OneKey is available for our nationally hosted CourseCompass course management system. If desired, WebCT and Blackboard cartridges containing only the Test Item File are also available for download. Visit http://www.prenhall.com/cms

CourseCompass™—the easiest way to get your course online! Three clicks and you're up. The course includes media resources from the Instructor's Resource Center on CD/DVD as well as assessment items from the companion website and the Test Item File. Visit www.prenhall.com/demo for details on how to communicate with your students, customize content to meet your course needs, create quizzes and test, track grades, and many more online options.

Blackboard®—for campuses that use the user-friendly system Blackboard, consider a prebuilt course that includes media resources from the Instructor's Resource Center on CD/DVD as well as assessment items from the Companion Website with GradeTracker and the Test Item File. Visit

www.prenhall.com/demo for details on how to communicate with your students, customize content to meet your course needs, create quizzes and tests, track grades, and utilize many more online options.

WebCT®—for campuses that use the sophisticated course management tools of WebCT, the prebuilt course offers everything mentioned previously as well as the ability to create algorithmic questions using WebCT's calculation format.

OneKey content—Along with all the material from the Companion Website with GradeTracker (www.prenhall.com/hill), OneKey includes

- Resources from the Instructor's Resource Center on CD/DVD
- Test bank questions, converted from our TestGen test item file

Acknowledgments

Terry W. McCreary of Murray State University, a distinguished teacher and author, has made many contributions, including preparing the art manuscript, revising the chapter summaries into the new format, reviewing the content of each chapter, and providing invaluable help with new Examples, Exercises, Problems, and all other aspects of the text.

Through the last three decades we have greatly benefited from hundreds of helpful reviews. It would take far too many pages to list all of those reviewers here. Many of you have contributed to the flavor of the book and helped us minimize our errors. Please know that your contributions are deeply appreciated. For the eleventh edition, we are grateful for challenging reviews from

Iffat Ali, *Lakeland Community College*

Stacy Brown, *The Citadel*

Patrick Buick, *Florida Atlantic University*

Susan Collier, *SUNY at Brockport*

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Christopher Truitt, *Texas Tech*

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Martin Zysmilich, *George Washington University*

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Four of the verses that appear in this volume were first published in the *Journal of Chemical Education*. We acknowledge, with thanks, the permission to reprint them here. Doris Kolb wrote those verses plus all of the others.

We also want to thank our colleagues at the University of Wisconsin–River Falls and Bradley University for all their help and support.

We also owe a debt of gratitude to the many creative people at Prentice Hall who have contributed their talents to this edition. Kent Porter Hamann, our chemistry editor, has provided valuable guidance throughout the project. As Chemistry Editorial Assistant, Joya Carlton contributed organizational and editorial skills and kept the entire team up to date on developments. We are grateful to Shari Toron, Production Editor, who excelled in the critical role of keeping the project on schedule; to Assistant Editor Jennifer Hart, who provided careful management of the supplements for the text; to Kathleen Schiaparelli, Beth Sweeten, and Joanne Del Ben in production and Art Director Jonathan Boylan for their diligence and patience in bringing all the parts together to yield a finished work; and to our Media Editor, David Alick, who has brought new facets to the media set accompanying our text. We are indebted to our copy editor Patricia Daly, whose expertise helped improve the consistency of the text; and to proofreader Michael Rossa and accuracy checker Rill Ann Reuter, whose sharp eyes caught many of our errors and typos. We also salute our photo researcher, Jerry Marshall of Truitt & Marshall, who vetted hundreds of images in the search for quality photographic illustrations.

We owe a very special kind of thanks to our wonderful spouses, Ina and Ken. Ina has done typing, library research, and so many other things. Ken has done chapter reviews, made suggestions, and given invaluable help for many editions. Most of all, we are grateful to both of them for their enduring love and their boundless patience. Terry W. McCreary would like to thank his wife, Geniece, and their children, Corinne and Yvette, for their unflagging support, understanding, and love.

Finally, we also thank all those many students whose enthusiasm has made teaching such a joy. It is gratifying to have students learn what you are trying to teach them, but it is a supreme pleasure to find that they want to learn even more. Finally, we want to thank all of you who have made so many helpful suggestions. We welcome and appreciate all your comments, corrections, and criticisms.

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To the Student

Welcome to Our Chemical World!

Chemistry is fun. Through this book, we would like to share with you some of the excitement of chemistry and some of the joy of learning about it. You do not need to exclude chemistry from your learning experiences. Learning chemistry will enrich your life—now and long after this course is over—through a better understanding of the natural world, the technological questions now confronting us, and the choices we must face as citizens within a scientific and technological society.

Learning chemistry involves thinking logically, critically, and creatively. Skills gained in this course can be exceptionally useful in many aspects of your life. You will learn how to use the language of chemistry: symbols, formulas, and equations. More important, you will learn how to obtain meaning from information. The most important thing you will learn is how to learn. Memorized material will quickly fade into oblivion unless it is arranged on a framework of understanding.

Chemistry Directly Affects Our Lives

How does the human body work? How does aspirin cure headaches, reduce fevers, and perhaps lessen the chance of a heart attack or stroke? Is ozone a good thing or a threat to our health? Are iron supplement pills poisonous? Is global warming real? If so, did humans contribute to it, and what are some of the possible consequences? Why do most weight-loss diets seem to work in the short run but fail in the long run? Why do our moods swing from happy to sad? Can a chemical test on urine predict possible suicide attempts? How does penicillin kill bacteria without harming our healthy body cells? Chemists have found answers to questions such as these and continue to seek the knowledge that will unlock still other secrets of our universe. As these mysteries are resolved, the direction of our lives often changes—sometimes dramatically. We live in a chemical world—a world of drugs, biocides, food additives, fertilizers, fuels, detergents, cosmetics, and plastics. We live in a world with toxic wastes, polluted air and water, and dwindling petroleum reserves. Knowledge of chemistry will help you better understand the benefits and hazards of this world and will enable you to make intelligent decisions in the future.

Chemical Dependency

We are all chemically dependent. Even in the womb we depend on a constant supply of oxygen, water, glucose, and a multitude of other chemicals.

Our bodies are intricate chemical factories. They are durable but delicate systems. Innumerable chemical reactions that allow our bodies to function properly are constantly taking place within us. Thinking, learning, exercising, feeling happy or sad, putting on too much weight or not gaining enough, and virtually all life processes are made possible by these chemical reactions. Everything that we ingest is part of a complex process that determines whether our bodies work effectively or not. The consumption of some substances can initiate chemical reactions that will stop body functions. Other substances, if consumed, can cause permanent handicaps, and still others can make living less comfortable. A proper balance of the right foods provides the chemicals and generates the reactions we need in order to function at our best. The knowledge of chemistry that you will soon be gaining will help you better understand how your body works so that you will be able to take proper care of it.

Changing Times

We live in a world of increasingly rapid change. It has been said that the only constant is change itself. At present, we are facing some of the greatest problems that humans have ever encountered, and the dilemmas with which we are now confronted seem to have no perfect solutions. We are sometimes forced to make a best choice among only bad alternatives, and our decisions often provide only temporary solutions to our problems. Nevertheless, if we are to choose properly, we must understand what our choices are. Mistakes can be costly, and they cannot always be rectified. It is easy to pollute, but cleaning up pollution once it is there is enormously expensive. We can best avoid mistakes by collecting as much information as possible and evaluating it carefully before making critical decisions. Science is a means of gathering and evaluating information, and chemistry is central to all the sciences.

Chemistry and the Human Condition

Above all else, our hope is that you will learn that the study of chemistry need not be dull and difficult. Rather, it can enrich your life in so many ways—through a better understanding of your body, your mind, your environment, and the world in which you live. After all, the search to understand the universe is an essential part of what it means to be human.

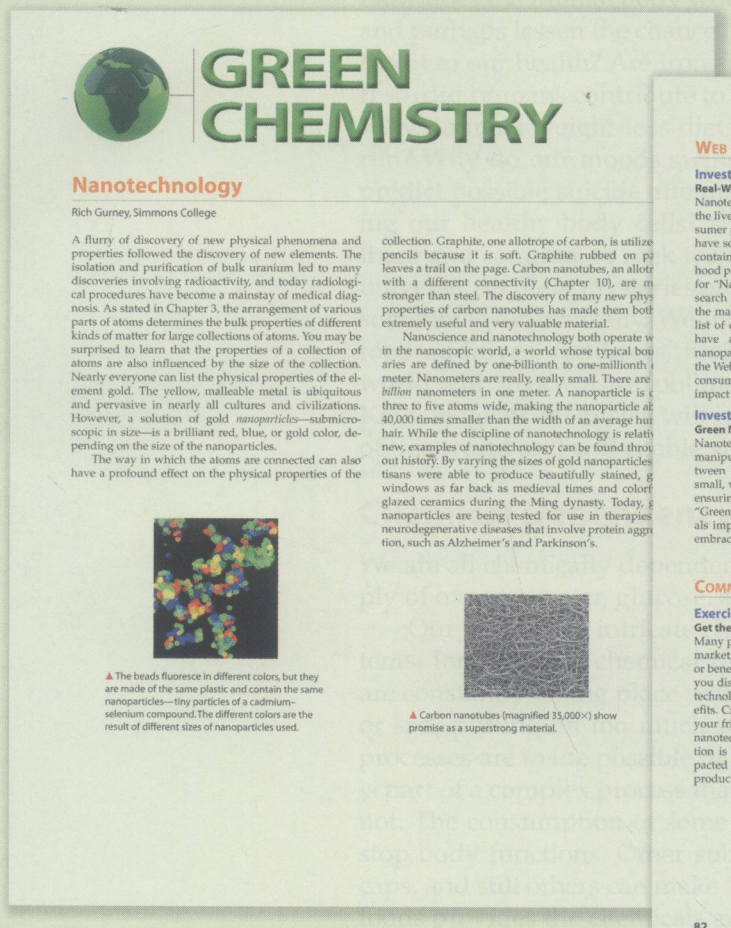
Highlights of the 11th Edition

Chemistry for Changing Times, the most successful book in liberal arts chemistry, defined the course in its first edition. With each subsequent revision, this text has reflected the changing times and the changing needs of the market.

Visually appealing, understandable, and interesting to read, the goal of the eleventh edition of *Chemistry for Changing Times* is to help inform students as scientifically literate consumers and decision-makers. The authors present basic chemical concepts with abundant everyday applications, personalizing the chemistry experience for today's students. In this way, the text focuses students on evaluating information about real-life issues instead of memorizing rigorous theory and mathematics. Important in this new edition is the use of green chemistry as a theme to show the positive impact of chemistry on the future.

Green Chemistry

The concept of **green chemistry** is used throughout the book and appears prominently in the **Green Chemistry** essays at the end of the chapters that include media exercises. ▼



GREEN CHEMISTRY

Nanotechnology

Rich Gurney, Simmons College

A flurry of discovery of new physical phenomena and properties followed the discovery of new elements. The isolation and purification of bulk uranium led to many discoveries involving radioactivity, and today radiological procedures have become a mainstay of medical diagnosis. As stated in Chapter 3, the arrangement of various parts of atoms determines the bulk properties of different kinds of matter for large collections of atoms. You may be surprised to learn that the properties of a collection of atoms are also influenced by the size of the collection. Nearly everyone can list the physical properties of the element gold. The yellow, malleable metal is ubiquitous and pervasive in nearly all cultures and civilizations. However, a solution of gold *nanoparticles*—submicroscopic in size—is a brilliant red, blue, or gold color, depending on the size of the nanoparticles.

The way in which the atoms are connected can also have a profound effect on the physical properties of the

collection. Graphite, one allotrope of carbon, is utilize pencils because it is soft. Graphite rubbed on pa leaves a trail on the page. Carbon nanotubes, an allotr with a different connectivity (Chapter 10), are m stronger than steel. The discovery of many new phys properties of carbon nanotubes has made them both extremely useful and very valuable material.

Nanoscience and nanotechnology both operate w in the nanoscopic world, a world whose typical bou aries are defined by one-billionth to one-millionth meter. Nanometers are really, really small. There are *billion* nanometers in one meter. A nanoparticle is three to five atoms wide, making the nanoparticle ab 40,000 times smaller than the width of an average hur hair. While the discipline of nanotechnology is relati new, examples of nanotechnology can be found throu out history. By varying the sizes of gold nanoparticles tisans were able to produce beautifully stained, g windows as far back as medieval times and colorf glazed ceramics during the Ming dynasty. Today, g nanoparticles are being tested for use in therapies neurodegenerative diseases that involve protein aggr tion, such as Alzheimer's and Parkinson's.

▲ The beads fluoresce in different colors, but they are made of the same plastic and contain the same nanoparticles—tiny particles of a cadmium-selenium compound. The different colors are the result of different sizes of nanoparticles used.

▲ Carbon nanotubes (magnified 35,000×) show promise as a superstrong material.

WEB INVESTIGATIONS

Investigation 1
Real-World Applications of Nanotechnology
Nanotechnology is already having a profound impact on the lives of many people around the world as many consumer products include nanomaterials. You may already have some nanoscale items in your home. Nanoparticle-containing bandages will be arriving in your neighborhood pharmacy before you know it. Do a keyword search for "Nano Materials Consumer Products" using a major search engine to investigate the consumer products on the market that already include nanomaterials. Create a list of consumer products that you or your family may have already encountered. What functions do the nanoparticles serve in these consumer products? Search the Web site of your favorite newspaper to find reports on consumer products containing nanoscale materials. What impact have these consumer products had on our society?

Investigation 2
Green Nanotechnology
Nanotechnology involves the measurement, observation, manipulation, and production of materials usually between 1 and 100 nanometers. If these materials are so small, why should our society be overly concerned with ensuring the field of nanotechnology develops in a "Green" way? How will the manufacture of nanomaterials impact our society if this burgeoning field does not embrace the 12 principles of green chemistry and engineering? Based on your web research of green nanotechnology, which of the 12 principles of green chemistry have the most relevance to this field?

Investigation 3
Microchip Manufacture and Green Solvents
Microprocessors and digital memory chips are both examples of integrated circuits or microchips. These devices can be found in everything from laptop computers to microwave ovens, automobiles to electric toothbrushes. Historically, the fabrication of microchips, via nanotechnology, has required the use of hazardous chemicals and the consumption of large amounts of purified water. SC Fluids Inc., working in collaboration with Los Alamos National Laboratories, designed a greener alternative to the nanofabrication that replaces the hazardous volatile organic solvents with a supercritical carbon dioxide (CO_2) resist remover, SCORR. SC Fluids, Inc. was awarded the Presidential Green Chemistry Challenge Small Business Award in 2002 for this development. Research the term "SC Fluids Scorr" online and determine which of the 12 principles of green chemistry are addressed by this technology. Why would a microchip manufacturing company be interested in adopting the **SCORR** technology? Why is carbon dioxide a greener solvent as compared to volatile organic compounds? In Chapter 17, you will learn about another commercial application of supercritical carbon dioxide—dry cleaning.

COMMUNICATE YOUR RESULTS

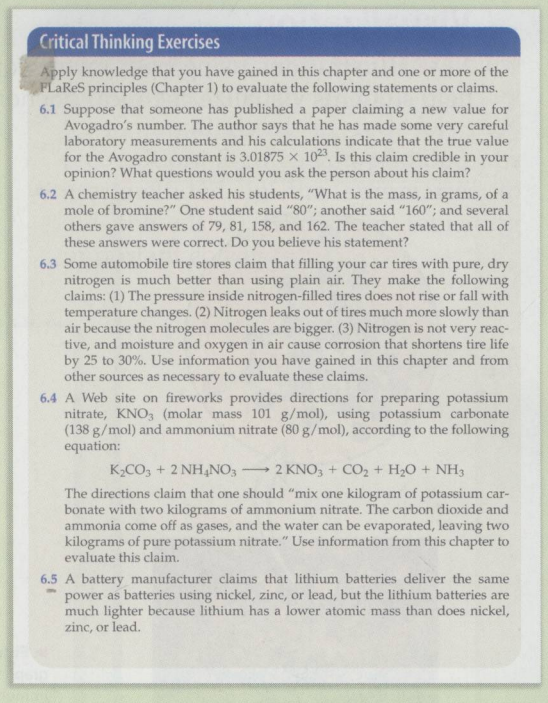
Exercise 1
Get the Word Out
Many products of nanotechnology exist on the consumer market, but most people are not aware of their existence or benefits. Choose one item from the list of products that you discovered in Investigation 1 that incorporate nanotechnology, and research the product to uncover the benefits. Create a one-page pamphlet that you could give to your friends and family members to educate them about nanotechnology in the consumer product. If the information is available, discuss how green chemistry has impacted the creation, development, or manufacture of the product.

Exercise 2
Educate Your Community
While the burgeoning field of nanotechnology is embracing green chemistry and green technology, many members of our global community have not yet appreciated the implications of adopting such methods. Craft a one-page letter to the editor of your local newspaper discussing the importance and need for adopting green practices specifically with respect to the field of nanotechnology.

82

Critical Thinking

Critical Thinking Exercises. Critical thinking is introduced in Chapter 1 and carried throughout the text. At the end of every chapter is an expanded set of Critical Thinking Exercises that encourage students to think critically about and evaluate the most up-to-date, relevant issues. These exercises require the student to apply information and learning from the chapter in both concrete and abstract ways. ▶



Critical Thinking Exercises

Apply knowledge that you have gained in this chapter and one or more of the FLaReS principles (Chapter 1) to evaluate the following statements or claims.

6.1 Suppose that someone has published a paper claiming a new value for Avogadro's number. The author says that he has made some very careful laboratory measurements and his calculations indicate that the true value for the Avogadro constant is 3.01875×10^{23}. Is this claim credible in your opinion? What questions would you ask the person about his claim?

6.2 A chemistry teacher asked his students, "What is the mass, in grams, of a mole of bromine?" One student said "80"; another said "160"; and several others gave answers of 79, 81, 158, and 162. The teacher stated that all of these answers were correct. Do you believe his statement?

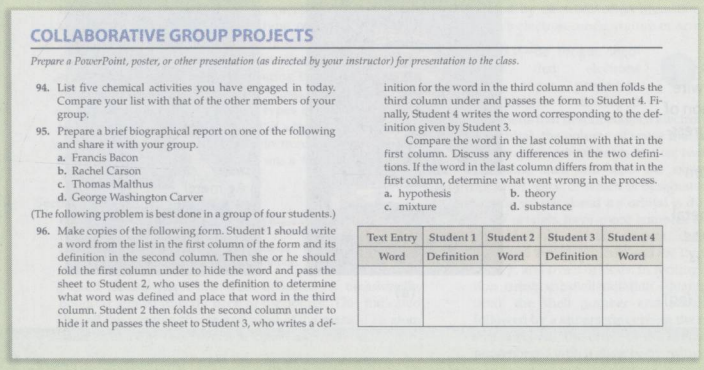
6.3 Some automobile tire stores claim that filling your car tires with pure, dry nitrogen is much better than using plain air. They make the following claims: (1) The pressure inside nitrogen-filled tires does not rise or fall with temperature changes. (2) Nitrogen leaks out of tires much more slowly than air because the nitrogen molecules are bigger. (3) Nitrogen is not very reactive, and moisture and oxygen in air cause corrosion that shortens tire life by 25 to 30%. Use information you have gained in this chapter and from other sources as necessary to evaluate these claims.

6.4 A Web site on fireworks provides directions for preparing potassium nitrate, KNO_3 (molar mass 101 g/mol), using potassium carbonate (138 g/mol) and ammonium nitrate (80 g/mol), according to the following equation:

$$K_2CO_3 + 2\,NH_4NO_3 \longrightarrow 2\,KNO_3 + CO_2 + H_2O + NH_3$$

The directions claim that one should "mix one kilogram of potassium carbonate with two kilograms of ammonium nitrate. The carbon dioxide and ammonia come off as gases, and the water can be evaporated, leaving two kilograms of pure potassium nitrate." Use information from this chapter to evaluate this claim.

6.5 A battery manufacturer claims that lithium batteries deliver the same power as batteries using nickel, zinc, or lead, but the lithium batteries are much lighter because lithium has a lower atomic mass than does nickel, zinc, or lead.



COLLABORATIVE GROUP PROJECTS

Prepare a PowerPoint, poster, or other presentation (as directed by your instructor) for presentation to the class.

94. List five chemical activities you have engaged in today. Compare your list with that of the other members of your group.

95. Prepare a brief biographical report on one of the following and share it with your group.
- **a.** Francis Bacon
- **b.** Rachel Carson
- **c.** Thomas Malthus
- **d.** George Washington Carver

(The following problem is best done in a group of four students.)

96. Make copies of the following form. Student 1 should write a word from the list in the first column of the form and its definition in the second column. Then she or he should fold the first column under to hide the word and pass the sheet to Student 2, who uses the definition to determine what word was defined and place that word in the third column. Student 2 then folds the second column under to hide it and passes the sheet to Student 3, who writes a definition for the word in the third column and then folds the third column under and passes the form to Student 4. Finally, Student 4 writes the word corresponding to the definition given by Student 3.

Compare the word in the last column with that in the first column. Discuss any differences in the two definitions. If the word in the last column differs from that in the first column, determine what went wrong in the process.

- **a.** hypothesis
- **b.** theory
- **c.** mixture
- **d.** substance

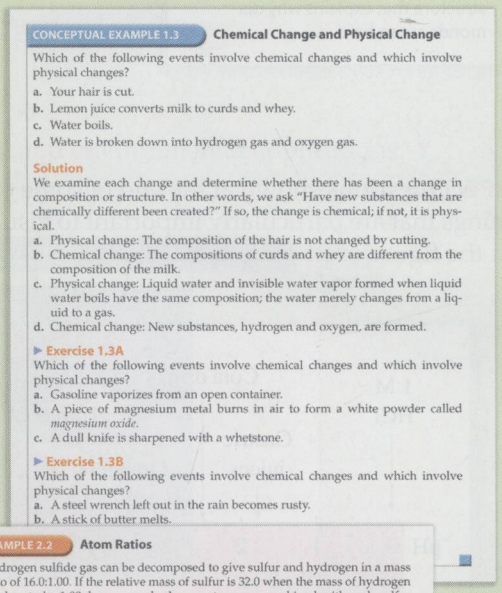
Text Entry	Student 1	Student 2	Student 3	Student 4
Word	Definition	Word	Definition	Word

◀ **NEW Collaborative Group Projects.** These end-of-chapter exercises, which extend student learning of chemistry beyond the text, are available for instructors who want to engage students in collaborative work with group assignments.

Conceptual Problem Solving

Conceptual Examples guide students through the process of learning and understanding important chemical concepts.

- Each Example shows a title indicating the skill being covered.
- Solutions are expanded with more explanation to guide the students through solving the problem.
- **A and B Exercises** are in almost all of the Examples. The **A** Exercise is entirely parallel to the Example; the **B** Exercise requires the student to incorporate information from earlier material. The dual Exercises help the students synthesize their learning into a coherent whole rather than just learning isolated facts.
- **Voice balloons** show students the logic of the problem-solving process. ▶



CONCEPTUAL EXAMPLE 1.3 **Chemical Change and Physical Change**

Which of the following events involve chemical changes and which involve physical changes?

- **a.** Your hair is cut.
- **b.** Lemon juice converts milk to curds and whey.
- **c.** Water boils.
- **d.** Water is broken down into hydrogen gas and oxygen gas.

Solution

We examine each change and determine whether there has been a change in composition or structure. In other words, we ask "Have new substances that are chemically different been created?" If so, the change is chemical; if not, it is physical.

- **a.** Physical change: The composition of the hair is not changed by cutting.
- **b.** Chemical change: The compositions of curds and whey are different from the composition of the milk.
- **c.** Physical change: Liquid water and invisible water vapor formed when liquid water boils have the same composition; the water merely changes from a liquid to a gas.
- **d.** Chemical change: New substances, hydrogen and oxygen, are formed.

▶ **Exercise 1.3A**

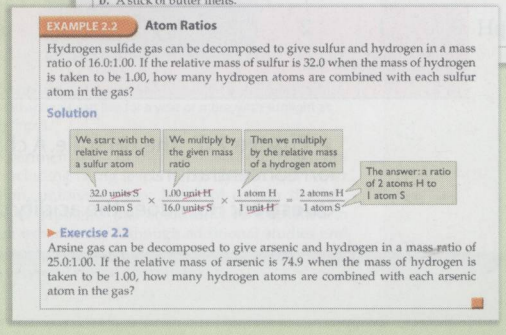
Which of the following events involve chemical changes and which involve physical changes?

- **a.** Gasoline vaporizes from an open container.
- **b.** A piece of magnesium metal burns in air to form a white powder called *magnesium oxide*.
- **c.** A dull knife is sharpened with a whetstone.

▶ **Exercise 1.3B**

Which of the following events involve chemical changes and which involve physical changes?

- **a.** A steel wrench left out in the rain becomes rusty.
- **b.** A stick of butter melts.



EXAMPLE 2.2 **Atom Ratios**

Hydrogen sulfide gas can be decomposed to give sulfur and hydrogen in a mass ratio of 16.0:1.00. If the relative mass of sulfur is 32.0 when the mass of hydrogen is taken to be 1.00, how many hydrogen atoms are combined with each sulfur atom in the gas?

Solution

We start with the relative mass of a sulfur atom. We multiply by the given mass ratio. Then we multiply by the relative mass of a hydrogen atom.

$$\frac{32.0\ \text{units S}}{1\ \text{atom S}} \times \frac{1.00\ \text{unit H}}{16.0\ \text{units S}} \times \frac{1\ \text{atom H}}{1\ \text{unit H}} = \frac{2\ \text{atoms H}}{1\ \text{atom S}}$$

The answer: a ratio of 2 atoms H to 1 atom S

▶ **Exercise 2.2**

Arsine gas can be decomposed to give arsenic and hydrogen in a mass ratio of 25.0:1.00. If the relative mass of arsenic is 74.9 when the mass of hydrogen is taken to be 1.00, how many hydrogen atoms are combined with each arsenic atom in the gas?

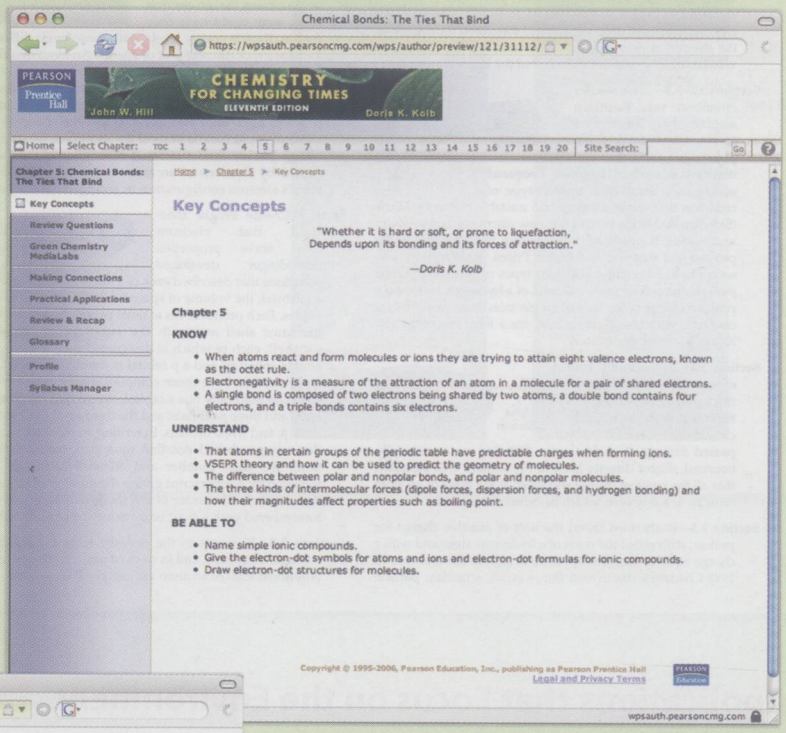
Student Media Resources

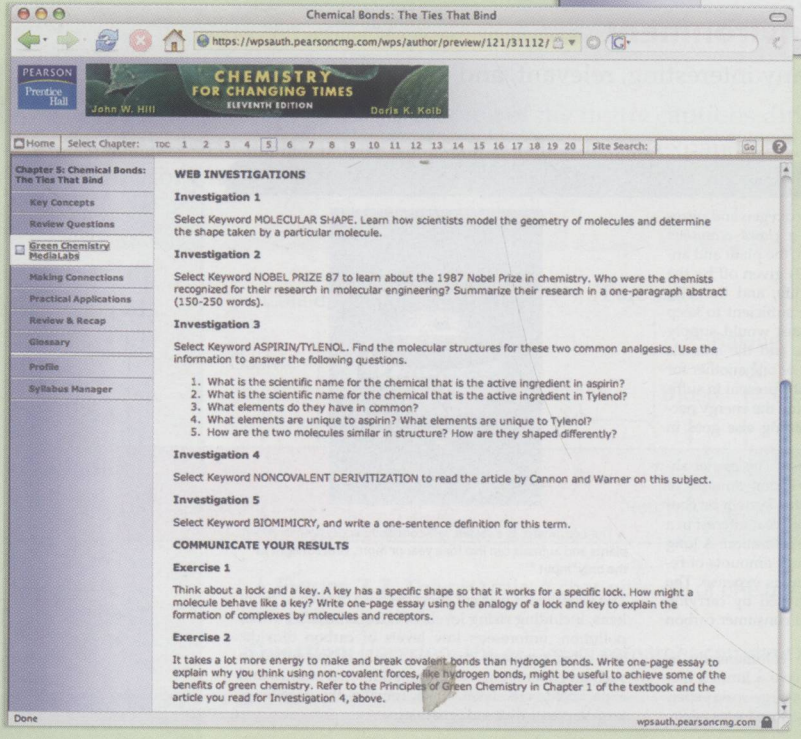
Chemistry for Changing Times excels at identifying the connections between our world and the chemistry that surrounds us. In this edition, John Hill and Doris Kolb continue their legacy of making chemistry exciting and interesting for thousands of students.

Chemistry for Changing Times offers a full package of textbook and Web resources. The Companion Website with GradeTracker *(http://www.prenhall.com/hill)* is designed to complement the text through the use of multiple review, practice, exploration, and assessment activities. Instructors can choose to assign any of the self-grading activities for credit or simply allow students to work at their own pace toward mastery.

Companion Website with GradeTracker

NEW Key Concepts summary statements identify what all students should Know, Understand, and Be Able To do after reading each chapter. The accompanying online glossary means a quick review is only a click away! ▶

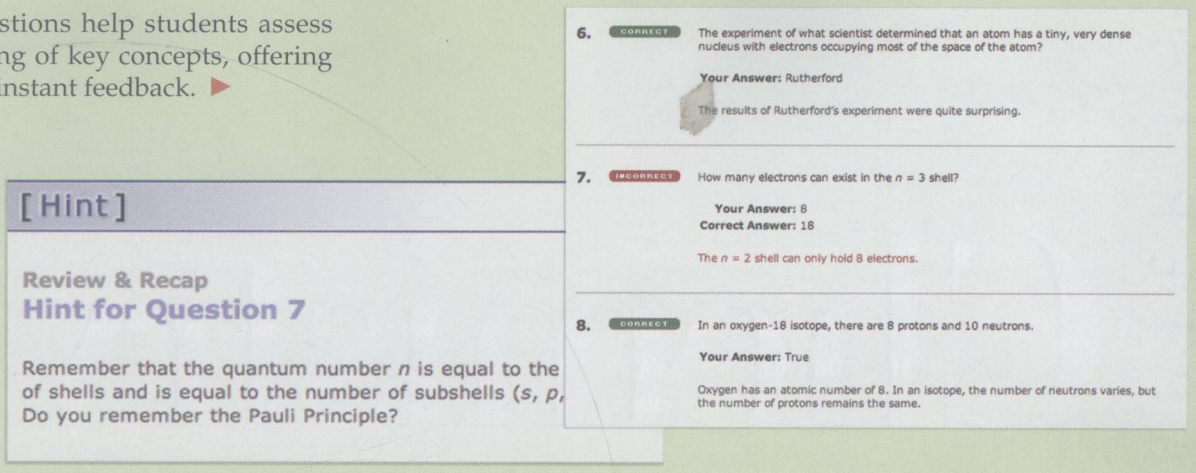




Green Chemistry

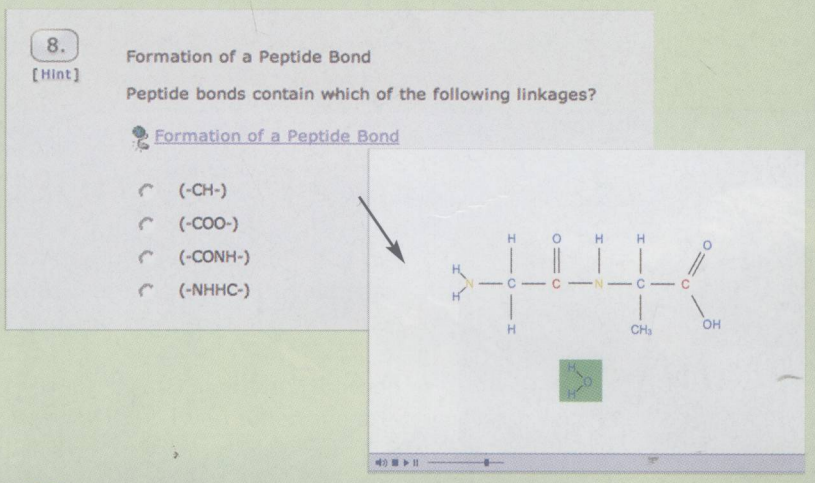
◀**NEW** Online versions of the Green Chemistry activities found in the textbook promote awareness through online research and encourage students to present findings using a variety of strategies.

NEW Review questions help students assess their understanding of key concepts, offering helpful hints and instant feedback. ▶



NEW Critical thinking and application activities help bridge the gap between the textbook and real-world chemistry issues and encourage individual and collaborative research.

Many of the Review Questions have been enhanced with media—animations, movies, and 3D molecules—to help students visualize the concepts presented in the text. Follow the media icons ( ) from the text to the Companion Website with GradeTracker. ▶

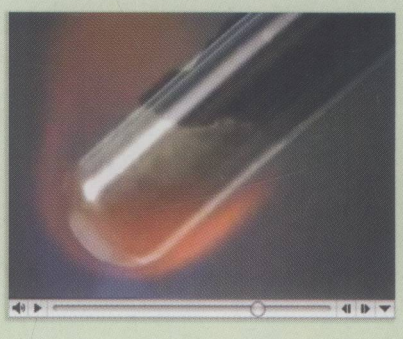


Instructor Media Resources

Classroom Presentation Tools

Instructor's Resource on CD/DVD
(0-13-199003-9)

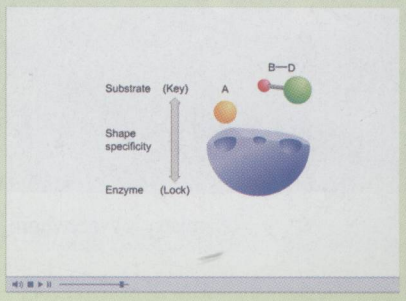
This searchable, integrated book-specific lecture resource features almost all the art from the text, including tables; printable, high-resolution PDF files of all included art; several prebuilt PowerPoint presentations for each chapter, as well as Classroom Response System ("Clicker Questions") slides; the interactive animations, movies, and 3D molecules from the Companion Website; Worked Examples; a Test Item File and TestGen test-generation software; and fully editable lecture outlines from the Instructor's Resource Manual—all in one convenient-to-use resource.



Online Homework/Course Management Options

Prentice Hall offers three content cartridges for online, text-specific course management systems depending on your preferred platform. Hundreds of text-specific problems are provided.

Visit *www.prenhall.com/demo* for details on how to communicate with your students online, customize content to meet your course needs, create online quizzes and tests, track grades, and much more.



CHAPTER 1

Chemistry

Chemistry is everywhere, not just in a laboratory. Chemistry occurs in soil and rocks, in waters, in clouds, and in us.