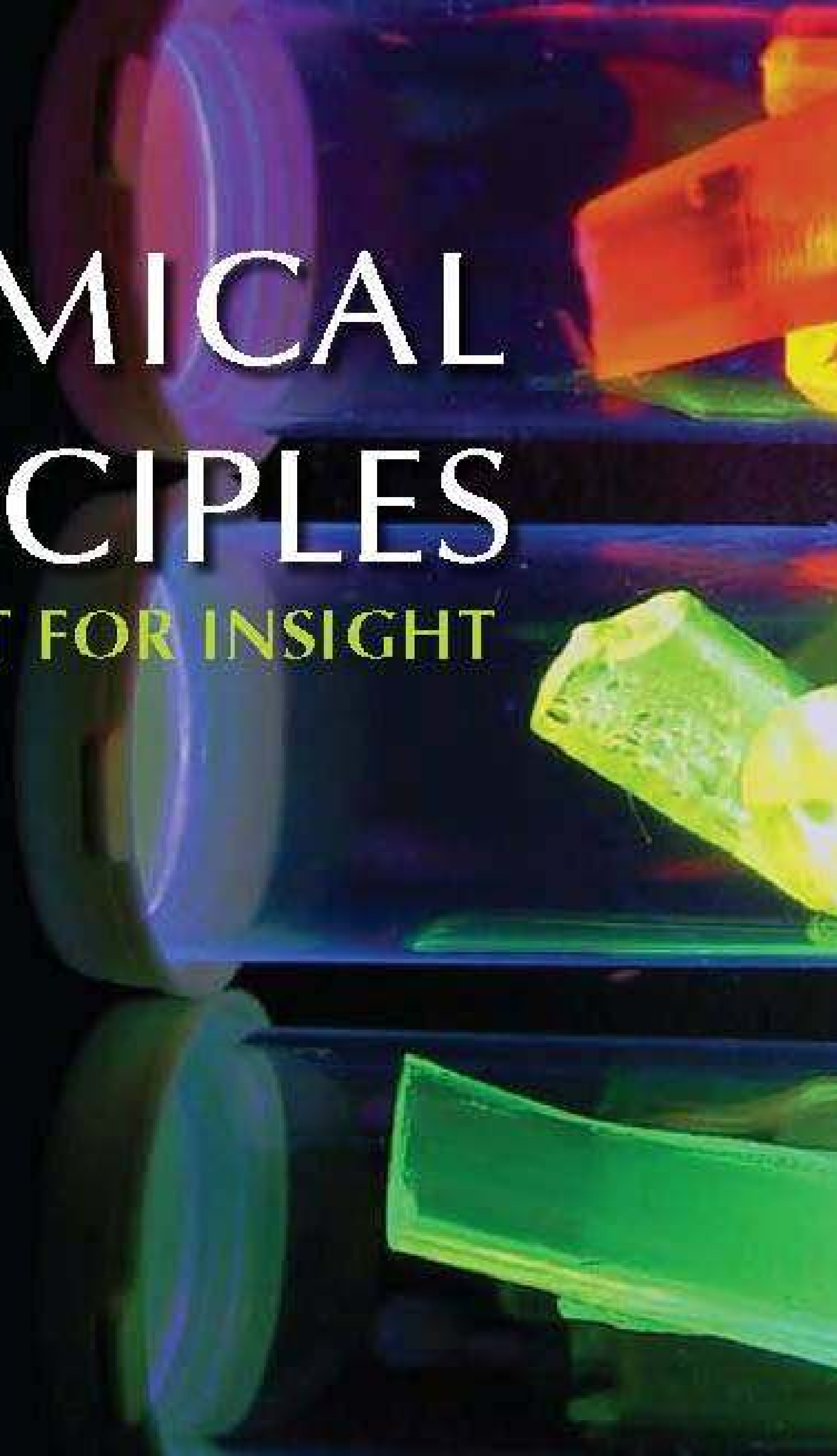
CHEMICAL PRINCIPLES

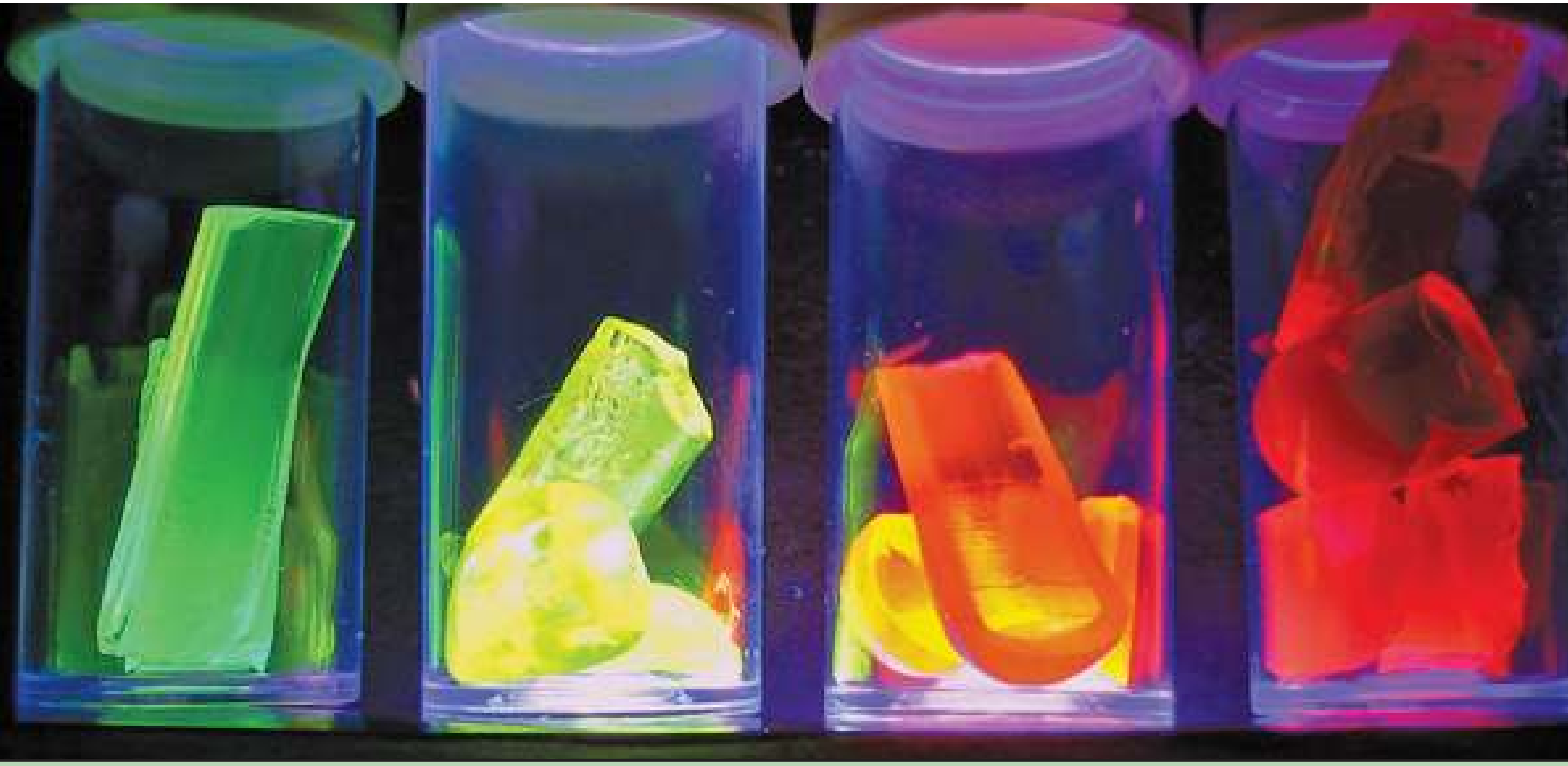
THE QUEST FOR INSIGHT

Fifth Edition



PETER ATKINS / LORETTA JONES

This page intentionally left blank



CHEMICAL PRINCIPLES

The Quest for Insight

FIFTH EDITION

PETER ATKINS
Oxford University

LORETTA JONES
University of Northern Colorado

W. H. Freeman and Company
New York

Publisher: Clancy Marshall
Senior Acquisitions Editor: Jessica Fiorillo
Senior Developmental Editor: Randi Rossignol
Marketing Manager: John Britch
Media and Supplements Editor: Dave Quinn
Assistant Editor: Tony Petrites
Photo Editor: Bianca Moscatelli
Cover/Text Designer: Blake Logan
Senior Project Editor: Georgia Lee Hadler
Copy Editor: Margaret Comaskey
Illustration Coordinator: Bill Page
Illustrations: Peter Atkins with Network Graphics
Production Coordinator: Paul Rohloff
Composition: MPS Limited, A Macmillan Company
Printing and Binding: Quebecor

Library of Congress Control Number:
2009936820
ISBN-13: 978-1-4292-1955-6
ISBN-10: 1-4292-1955-6

Printed in the United States of America
First printing

W. H. Freeman and Company
41 Madison Avenue
New York, NY 10010
Houndmills, Basingstoke RG21 6XS, England
www.whfreeman.com

CONTENTS IN BRIEF

CONTENTS

Chapter 1 ATOMS: THE QUANTUM WORLD

Chapter 2 CHEMICAL BONDS

Chapter 11 ACIDS AND BASES

Chapter 12 AQUEOUS EQUILIBRIA

Chapter 13 ELECTROCHEMISTRY

Chapter 16 THE ELEMENTS: THE d-BLOCK

Chapter 17 NUCLEAR CHEMISTRY

Chapter 18 ORGANIC CHEMISTRY I: THE HYDROCARBONS

LETTER FROM THE AUTHORS

Dear Colleagues,

It is with great pleasure that we offer the fifth edition of *Chemical Principles: The Quest for Insight*. The new edition is designed, like its predecessors, to encourage students to think and to develop a solid understanding of chemistry by first building a qualitative understanding and then showing how to express those qualitative concepts quantitatively.

Because college students often have forgotten much of their high school chemistry, the book begins with a *Fundamentals* section that reviews the basic ideas of chemistry such as nomenclature, concentration, and stoichiometry. The main part of the book starts with an investigation of the structure of the atom, goes on to show how atomic properties determine the types of bonds that atoms form, and then investigates how the properties of molecules and ions contribute to the structure, reactions, and properties of bulk matter.

We have updated much of the content and the format of the periodic table. We have also introduced a new materials chapter following the solid state chapter. This chapter serves as a review of the first five chapters and introduces students to the chemistry that is the basis of the exciting field of nanotechnology. In this chapter students also see how the chemical principles they are learning, even at an early stage in their course, apply to modern research and applications such as ceramic and magnetic materials and electronic components. In later chapters we investigate further properties of materials as new concepts are introduced.

We have enhanced our approach to problem solving to help students develop the kinds of problem-solving skills that experts use. That is, we want students to learn to solve problems as chemists do. Consequently, in the worked examples we begin, where appropriate, with an *Anticipate* section that encourages students to estimate the answer and develop their powers of insight and judgment. Then we present a general *Plan* that encourages readers to collect their thoughts and establish an approach to the problem. After the fully worked out *Solve* section, we encourage students to reflect on their original anticipation in a brief *Evaluate* section. In addition, for a number of calculations we encourage students to organize their thinking by asking *What should we assume?* before proceeding. Almost all the worked examples are accompanied by graphic thumbnail interpretations of each step, which were introduced in the fourth edition as an entirely new way to help students make connections among the different levels of chemical description. The thumbnails have been developed further for this edition.

We hope you will like the scattering of *Thinking points* throughout the text, which are intended to encourage and emphasize our underlying strategy: to get students to think as well as to learn. We have also generated a new art program for a great deal of the book, which we hope will enhance the learning experience by conveying insight into the molecular world.

We are grateful for the feedback and support we have received from those who have used the previous four editions. The suggestions readers have given us have helped us to refine the book and make it more interesting and useful for students. We hope that you and your students find the book to be a refreshing and intriguing introduction to chemistry.

Yours sincerely,

Peter Atkins

Loretta Jones

PREFACE

CHEMICAL PRINCIPLES

This text is designed for a rigorous course in introductory chemistry. Its central theme is to challenge students to think and question while providing a sound foundation in the principles of chemistry.

At the same time, students of all levels benefit from assistance in learning how to think, pose questions, and approach problems. To that end, *Chemical Principles* is organized in a logical way that builds understanding and offers students a wide array of pedagogical support.

ATOMS-FIRST ORGANIZATION

Chemical Principles presents the concepts of chemistry in a logical sequence that enhances student understanding. The **atoms-first sequence** starts with the behavior of atoms and molecules and builds to more complex properties and interactions.

- **Atoms and molecules** come first (including discussions of quantum mechanics and molecular orbitals), providing the foundation for understanding bulk properties and models of gases, liquids, and solids. Chapter 1 has been reorganized in this edition to give readers a gentler introduction to atoms and their structure.
- Next comes an exploration of **thermodynamics and equilibrium,** which builds on a conceptual understanding of entropy and free energy. This integrated presentation lays a common foundation for related concepts and provides a basis for the form of the equilibrium constant.
- **Kinetics** then shows the dynamic nature of chemistry and the crucial role of insight and model building in identifying reaction mechanisms.

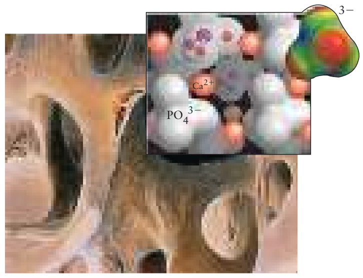


FIGURE 2.8 A micrograph of bone, which owes its rigidity to calcium phosphate. The overlay shows part of the crystal structure of calcium phosphate. Phosphate ions are polyatomic ions; however, as shown in the inset, they are nearly spherical and fit into crystal structures in much the same way as monatomic ions of charge −3.

COVERING THE BASICS

The **Fundamentals** sections, which precede Chapter 1, are identified by green-edged pages. These 13 minichapters provide a streamlined overview of the basics of chemistry. They can be used either to provide a useful, succinct review of basic material to which students can refer for extra help as they progress through the course, or as a concise, quick survey of material before starting on the main text.

Diagnostic Test for the Fundamentals Sections. This test allows instructors to determine what their students understand and where they need additional support. Instructors can then make appropriate assignments from the Fundamentals sections. The test includes 5 to 10 problems for each Fundamentals section. The diagnostic test was created by Cynthia LaBrake at the University of Texas, Austin and can be found on the Instructor's Resource CD ROM and on the Instructor pages of the Web site.

FLEXIBLE MATH COVERAGE

Optional Use of Calculus. The ***How do we do that?*** feature sets off derivations of key equations and encourages students to appreciate the power of mathematics. Almost all the calculus in the text is confined to this feature, so it can easily be avoided or emphasized as the instructor chooses.

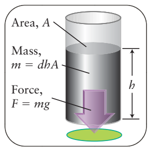
A selection of end-of-chapter exercises that make use of calculus are provided and marked with a **C** .

HOW DO WE DO THAT?

We want to find the relation between the height, h, of the column of mercury in a barometer and the atmospheric pressure, P. Suppose the cross-sectional area of the cylindrical column is A. The volume of mercury in the column is the height of the cylinder times this area, $V = hA$. The mass, m, of this volume of mercury is the product of mercury's density, d, and the volume; so $m = dV = dhA$. The mercury is pulled down by the force of gravity; and the total force that its mass exerts at its base is the product of the mass and the acceleration of free fall (the acceleration due to gravity), g: $F = mg$. Therefore, the pressure at the base of the column, the force divided by the area, is

From $P = F/A$ and $F = mg$:

$$P = \frac{\overbrace{F}^{mg}}{A} = \frac{mg}{A} = \frac{\overbrace{dhA}^{m}\,g}{A} = dhg$$



This equation shows that the pressure, P, exerted by a column of mercury is proportional to the height of the column. Mercury inside a tube sealed at one end and inverted in a pool of mercury will fall until the pressure exerted by the mercury balances the atmospheric pressure. Therefore, the height of the column can be used as a measure of atmospheric pressure.

EXAMPLE 4.3 Using the combined gas law when one variable is changed

Assume that, when you press in the piston of a bicycle pump, the volume inside the pump is decreased from about 100. cm^3 to 20. cm^3 before the air flows into the tire. Suppose that the compression is isothermal; estimate the final pressure of the compressed air in the pump, given an initial pressure of 1.00 atm.

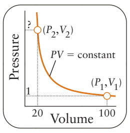
Anticipate The volume is reduced by a factor of 5, so we should expect a fivefold increase in pressure.

PLAN Follow the second procedure in Toolbox 4.1. Only the pressure and volume change, so all other variables cancel, resulting in Boyle's law.

SOLVE

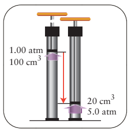
Step 1 Rearrange $P_1V_1/n_1T_1 = P_2V_2/n_2T_2$ to find P_2 by multiplying both sides by n_2T_2/V_2, and set $n_2 = n_1$ (no change in the amount) and $T_2 = T_1$ (no change in temperature):

$$P_2 = \frac{P_1V_1}{n_1T_1} \times \frac{n_2T_2}{V_2} \xrightarrow[T_2 = T_1]{n_2 = n_1} \frac{P_1V_1}{n_1T_1} \times \frac{n_1T_1}{V_2} = P_1 \times \frac{V_1}{V_2}$$



Step 2 Substitute the data:

$$P_2 = (1.00\ \text{atm}) \times \frac{100\ \text{cm}^3}{20\ \text{cm}^3} = 5.0\ \text{atm}$$



Evaluate The final pressure is higher by a factor of 5 (more precisely, 5.0), as expected.

Self-Test 4.8A A sample of argon gas of volume 10.0 mL at 200. Torr is allowed to expand isothermally into an evacuated tube with a volume of 0.200 L. What is the final pressure of the argon in the tube?

[*Answer:* 10.0 Torr]

EMPHASIS ON PROBLEM SOLVING

- ***NEW!*** **Anticipate/Plan/Solve/Evaluate Strategy**. This problem-solving approach encourages students to anticipate or predict what a problem's answer should be and to map out the solution before trying to solve the problem. Following the solution, the original anticipation is evaluated. The accompanying graphics provide the opportunity for visualizing and interpreting each step of the solution and the final result.

- **Self-Tests** occur as pairs throughout the book. They enable students to test their understanding of the material covered in the preceding section or Worked Example. The answer to the first self-test is provided immediately and the answer to the second can be found at the back of the book.

- ***NEW!*** **Thinking Points** encourage students to speculate about the implications of what they are learning and to transfer their knowledge to new situations.

> The relative energies of the d-orbitals are different in complexes with different shapes. For example, in a tetrahedral complex, the three t_2-orbitals point more directly at the ligands than the two e-orbitals do. As a result, in a tetrahedral complex, the t_2-orbitals have a higher energy than the e-orbitals (Fig. 16.29). The ligand field splitting, Δ_T (where the T denotes tetrahedral), is generally smaller than in octahedral complexes, in part because there are fewer repelling ligands.
>
> *Thinking point:* Into what groups do you think the d-orbitals are split in a square-planar complex?

- **Toolboxes** show students how to tackle *major types* of calculations, demonstrating how to connect concepts to problem solving. They are designed as learning aids and handy summaries of key material. Each Toolbox is immediately followed by a related example.

TOOLBOX 7.1 HOW TO USE HESS'S LAW

CONCEPTUAL BASIS

Because enthalpy is a state function, the enthalpy change of a system depends only on its initial and final states. Therefore, we can carry out a reaction in one step or, if that is not convenient, visualize it as the sum of several steps; the reaction enthalpy is the same in each case.

PROCEDURE

To use Hess's law to find the enthalpy of a given reaction, we find a sequence of reactions with known reaction enthalpies that adds up to the reaction of interest.

Step 1 Select one of the reactants in the overall reaction and write down a chemical equation in which it also appears as a reactant.

Step 2 Select one of the products in the overall reaction and write down a chemical equation in which it also appears as a product. Add this equation to the equation written in step 1 and cancel species that appear on both sides of the equation.

Step 3 Cancel unwanted species in the sum obtained in step 2 by adding an equation that has the same substance or substances on the opposite side of the arrow.

Step 4 Once the sequence is complete, combine the standard reaction enthalpies.

In each step, we may need to reverse the equation or multiply it by a factor. Recall from Eq. 16 that, if we want to reverse a chemical equation, we have to change the sign of the reaction enthalpy. If we multiply the stoichiometric coefficients by a factor, we must multiply the reaction enthalpy by the same factor.

This procedure is illustrated in Example 7.9.

CUTTING EDGE CHEMISTRY FOR ALL STUDENTS

Of special interest to **Engineering students:**

- Liquid Crystals (Section 5.15)
- Colloids (Section 9.21)
- Applications of Electrolysis (Section 13.13)
- Fuels (Section 18.9 and Box 7.2)
- Polymerization and Polymers (Sections 19.9–19.12)
- Corrosion (Section 13.14)
- Fuel Cells (Box 13.1 Frontiers of Chemistry)
- Industrial Catalysts (Section 14.15)
- Self Assembling Materials (Box 15.2 Frontiers of Chemistry)
- The whole of Chapter 6, Inorganic Materials

Of special interest to **Biology students:**

- Drugs by Design and Discovery (Box 3.1 Frontiers of Chemistry)
- Gibbs Free Energy Changes in Biological Systems (Section 8.16)
- Colloids (Section 9.21)
- Bio-based and Biomimetic Materials (Section 9.22)
- Homeostasis (Section 10.13)
- Physiological Buffers (Box 12.1 What Has This to Do with . . . Staying Alive?)
- Living Catalysts: Enzymes (Section 14.16)
- Why We Need to Eat d-Metals (Box 16.1 What Has This to Do with . . . Staying Alive?)
- Nuclear Medicine (Box 17.1 What Has This to Do with . . . Staying Alive?)
- The Biological Effects of Radiation (Section 17.6)
- Proteins (Section 19.13)
- Carbohydrates (Section 19.14)
- Nucleic Acids (Section 19.15)

Of special interest to **Environmental Science students:**

- Green Chemistry promotes environmentally sound chemistry. Green chemistry passages in the text and green chemistry end-of-chapter exercises are accompanied by an icon.
- Alternative Fuels (Box 7.2 What Has This to Do with . . . the Environment?)
- Acid Rain and the Gene Pool (Box 11.1 What Has This to Do with . . . the Environment?)
- Protecting the Ozone Layer (Box 14.3 What Has This to Do with . . . the Environment?)
- The Greenhouse Effect (Box 15.1. What Has This to Do with . . . the Environment?)
- Coal (Section 18.10)

dense materials. Branched polymer chains cannot fit together as closely and form weaker, less dense materials (Fig. 19.15). A soft, lightweight body armor has been developed by creating arrays of long polyethylene chains that are closely aligned in the same direction, giving rise to very strong intermolecular forces. This body armor is reported to be 15 times stronger than steel, yet has such a low density that it floats on water. It is also soft and flexible, so it is comfortable to wear (Fig. 19.16).

FIGURE 19.16 Recruits at the New York Police Academy are issued bullet-proof vests. The high-density polyethylene body armor protects law enforcement personnel without restricting movement because it is soft and flexible.

- ***NEW!*** **Chapter 6, Inorganic Materials.** This new chapter reviews the first five chapters and introduces students to the chemistry that is the basis of the exciting new field of nanotechnology. In this chapter students also see how the chemical principles they are learning apply to cutting edge research and applications such as ceramic and magnetic materials and electronic components.

6.11 Ceramics

Many of the materials used in the most advanced technologies are based on a material characteristic of one of the oldest technologies: common clay. Most clays used commercially are oxides of silicon, aluminum, and magnesium. *China clay* contains primarily *kaolinite*, a form of aluminum aluminosilicate that can be obtained reasonably free of the iron impurities that make many clays look reddish brown, and so it is white. However, other clays contain the iron oxides that cause the orange color of terra cotta tiles and flower pots.

The appearance of a flake of clay reflects its internal structure, which is something like an untidy stack of papers (Fig. 6.23). Sheets of tetrahedral silicate units or octahedral units of aluminum or magnesium oxides are separated by layers of water molecules that serve to bind the layers of the flake together. Each flake of clay is surrounded by a double layer of ions that separates the flakes by repelling the like charges on the other flakes. This repulsion allows the flakes to slide past one another and gives the clay the ability to flow in response to stress. As a result, clays can be easily molded.

When clay is baked in a kiln, it forms the hard, tough *ceramic* materials used in firebricks, tiles, and pots as the water is driven out and strong chemical bonds form between the flakes. Large amounts of china clay, which is used to make ceramics such as porcelain and china, are applied in the coating of paper (such as this page) to give a smooth, nonabsorbent surface. Clay was the first substance to be made into a **ceramic,** an inorganic material that has been hardened by heating to a high temperature. Today a wide variety of compounds, often oxides, are used to create ceramics with specific properties.

FIGURE 6.23 The layers of clay particles can be seen in this micrograph. Because the surfaces of these layers have like charges, they repel one another and easily slide past one another, making clay soft and malleable.

MEDIA INTEGRATION

Selected figures and exercises throughout the book are accompanied by **media link icons** that direct students to Web-based resources. These integrated links to the companion Web site are designed to make the text more dynamic and interactive. *Chemical Principles* contains media links to:

- **Living Graphs.** Selected graphs in the text are available in interactive form on the Web site. Students can manipulate parameters and see cause and effect relationships.
- **Animations.** Selected art in the text is supported by media. Students can view motion, three dimensions, and atomic and molecular interactions and learn to visualize like chemists—at a molecular level. To focus their attention, questions on each animation have been added in this edition.
- **Lab Videos.** Video clips of many of the reactions described in the book are provided on the book's Web site.

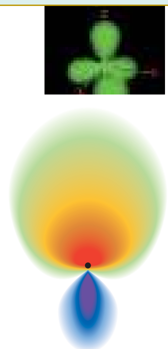


FIGURE 3.13 These contours indicate the amplitude of the sp^3 hybrid orbital wavefunction in a plane that bisects it and passes through the nucleus. The colors indicate the variation of electron density in the orbital: regions of high electron density are red and regions of low electron density blue. Each sp^3 hybrid orbital points toward the corner of a tetrahedron.

Animation 3.13

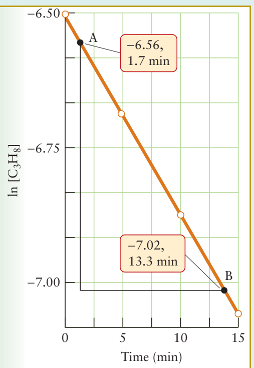


FIGURE 14.11 We can test for a first-order reaction by plotting the natural logarithm of the reactant concentration against time. The graph is linear if the reaction is first order. The slope of the line, which is calculated here for the system in Example 14.4 by using the points A and B, is equal to the negative of the rate constant.

Living Graph 14.11

(a) (b) (c)

FIGURE 15.48 Sulfuric acid is a dehydrating agent. When concentrated sulfuric acid is poured on to sucrose (a), the sucrose, a carbohydrate, is dehydrated (b), leaving a frothy black mass of carbon (c).

Lab Video 15.48

- **Tools.** Tools on the book's Web site allow the study of chemical calculations, graphing, and exploration of periodic properties from different points of view.

- **End-of-Chapter Exercises.** Selected exercises direct students to use media to solve problems.

> **16.98** *cis*-Platin is an anticancer drug with a structure that can be viewed on the Web site. (a) What is the formula and systematic name for the compound *cis*-Platin? (b) Draw any isomers that are possible for this compound. Label any isomers that are optically active. (c) What is the coordination geometry of the platinum atom?

INSTRUCTOR AND STUDENT SUPPORT

We believe a student needs to interact with a concept several times in a variety of scenarios in order to obtain a thorough understanding. With that in mind, W. H. Freeman and Company has developed the most comprehensive student learning package available.

FOR THE INSTRUCTOR

Instructor's Solutions Manual by Carl Hoeger, University of California, San Diego, Laurence Lavelle, University of California, Los Angeles, and Yinfa Ma, University of Missouri-Rolla ISBN: 1-4292-3892-5

The *Instructor's Solutions Manual* contains full, worked-out solutions to all even-numbered exercises. Worked-out solutions for odd-numbered exercises can be found in the *Student Study Guide and Solutions Manual.*

Test Bank by Robert Balahura, University of Guelph, and Mark Benvenuto, University of Detroit Mercy

The *Test Bank* offers over 1400 multiple-choice, fill-in-the-blank, and essay questions, and is available exclusively on the *Instructor's Resource CD*.

Instructor's Resource CD ISBN: 1-4292-5808-X

To help instructors create their own Web sites and prepare dynamic lectures, the CD contains:

- All the illustrations from the text in .jpg files and preformatted PowerPoint slides
- All animations, lab videos, and living graphs from the Book Companion Site
- All solutions to the end-of-chapter exercises, in editable Microsoft Word files
- Diagnostic Test for the Fundamentals sections
- The electronic *Test Bank,* which includes over 1400 multiple-choice, fill-in-the-blank, and essay questions

Electronic Instructor Resources

Instructors can access valuable teaching tools through www.whfreeman.com/chemicalprinciples5e. These password-protected resources are designed to enhance lecture presentations, and include all the illustrations from the textbook (in .jpg and PowerPoint format), Lecture PowerPoint slides, Clicker Questions, and more. There's also a Diagnostic Test for the Fundamentals sections, which allows instructors to determine what their students understand and where they need additional support. Instructors can then make appropriate assignments from the Fundamentals sections. This test includes 5 to 10 problems for each Fundamentals section.

WebAssign Premium

For instructors interested in online homework management, W. H. Freeman and WebAssign have partnered to deliver WebAssign Premium—a comprehensive and flexible suite of resources. Combining the most widely used online homework platform with a wealth of visualization and tutorial resources, WebAssign Premium extends and enhances the classroom experience for instructors and students by combining algorithmically generated versions of selected end-of-chapter questions with a fully interactive eBook at an affordable price. See below for more details, or visit www.webassign.net to sign up for a faculty demo account.

LabPartner Chemistry

W. H. Freeman's latest offering in custom lab manuals provides instructors with a diverse and extensive database of experiments published by W. H. Freeman and Hayden-McNeil Publishing—all in an easy-to-use, searchable online system. With the click of a button, instructors can choose from a variety of traditional and inquiry-based labs. LabPartner Chemistry sorts labs in a number of ways, from topic, title, and author, to page count, estimated completion time, and prerequisite knowledge level. Add content on lab techniques and safety, reorder the labs to fit your syllabus, and include your original experiments with ease. Wrap it all up in an array of bindings, formats, and designs. It's the next step in custom lab publishing—the perfect partner for your course.

FOR THE STUDENT

Student Study Guide and Solutions Manual by John Krenos and Joseph Potenza, Rutgers University, Laurence Lavelle, University of California, Los Angeles, Yinfa Ma, University of Missouri Rolla, and Carl Hoeger, University of California, San Diego ISBN: 1-4292-3135-1

The Student Study Guide and Solutions Manual provides students with a combined manual designed to help them to improve their problem-solving skills, avoid common mistakes, and understand key concepts. After a brief review of each section's critical ideas, students are taken through worked-out examples, try-it-yourself examples, and chapter quizzes, all structured to reinforce chapter objectives and build problem-solving techniques. The solutions manual includes detailed solutions to all odd-numbered exercises in the text.

ACS Molecular Structure Model Set by Maruzen Company, Ltd. ISBN: 0-7167-4822-3

Molecular modeling helps students understand physical and chemical properties by providing a way to visualize the three-dimensional arrangement of atoms. This model set uses polyhedra to represent atoms, and plastic connectors to represent bonds (scaled to correct bond length). Plastic plates representing orbital lobes are included for indicating lone pairs of electrons, radicals, and multiple bonds—a feature unique to this set.

Bridging to the Lab by Loretta Jones, University of Northern Colorado, and Roy Tasker, University of Western Sydney ISBN: 0-7167-4746-4

The *Bridging to the Lab* modules are computer-based laboratory simulations with engaging activities that emphasize experimental design and visualization of structures and processes at the molecular level. The modules are designed to help students connect chemical principles from lecture with their practical applications in the lab. Every module has a built-in accountability feature that records section completion for use in setting grades and a workbook for recording student work.

Used either as pre-laboratory preparation for related laboratory activities or to expose students to additional laboratory activities not available in their program, these modules motivate students to learn by proposing real-life problems in a virtual environment. Students make decisions on experimental design, observe reactions, record data, interpret these data, perform calculations, and draw conclusions from their results. Following a summary of the module, students test their understanding by applying what they have learned to new situations or by analyzing the effect of experimental errors.

For more information, visit www.whfreeman.com/bridgingtothelab

Chemistry Laboratory Student Notebook, Second Edition

ISBN: 0-7167-3900-3

A convenient $8\frac{1}{2} \times 11$, 3-hole-punched format contains 114 pages of graph paper, carbon included. The new edition adds tables and graphs that make the *Notebook* a handy reference as well.

PREMIUM MULTIMEDIA RESOURCES

The *Chemical Principles* Book Companion Site, which can be accessed at www.whfreeman.com/chemicalprinciples5e, also contains a plethora of Premium Student Resources. Students can unlock these resources with the click of a button, putting extensive concept and problem-solving support at their fingertips. Some of the resources available are:

Toolbox Tutorials present major types of calculations, in an interactive format. They demonstrate the connections between concepts and problem solving and are designed as hands-on learning aids and handy summaries of key materials:

ChemCasts replicate the face-to-face experience of watching an instructor work a problem. Using a virtual whiteboard, these video tutors show students the steps involved in solving key worked examples, while explaining the concepts along the way. They are easy to view on a computer screen or download to an iPod.

ChemNews from *Scientific American* provides a streaming newsfeed of the latest articles from *Scientific American*.

The multimedia-enhanced eBook contains the complete text with a wealth of helpful functions. All student multimedia, including the Toolbox Tutorials, ChemCasts, and ChemNews, are linked directly from the eBook pages. Students are thus able to access supporting resources when they need them—taking advantage of the "teachable moment" as they read. Customization functions include instructor and student notes, document linking, and editing capabilities.

Online Learning Environments

The above resources are available in two platforms. WebAssign Premium offers the most effective and widely used online homework system in the sciences, and is designed specifically for those instructors seeking graded homework management. The Student Companion Web site provides student-oriented support materials independent of any homework system.

WEBASSIGN PREMIUM WebAssign Premium

For instructors interested in online homework management, WebAssign Premium features a time-tested, secure online environment already used by millions of students worldwide. Featuring algorithmic problem generation and supported by a wealth of chemistry-specific learning tools, WebAssign Premium for *Chemical Principles, Fifth Edition* presents instructors with a powerful assignment manager and study environment. WebAssign Premium provides the following resources:

- Algorithmically generated problems: Students receive homework problems containing unique values for computation, encouraging them to work out the problems on their own.
- Complete access to the interactive eBook, from a live table of contents, as well as from relevant problem statements.
- Links to Toolbox Tutorials, ChemCasts, and other interactive tools are provided as hints and feedback to ensure a clearer understanding of the problems and the concepts they reinforce.

STUDENT COMPANION WEB SITE

The *Chemical Principles* Book Companion Site, www.whfreeman.com/chemicalprinciples5e, provides a range of tools for problem solving and chemical explorations. They include:

- An interactive Periodic Table of the Elements
- A calculator adapted for solving equilibrium calculations
- Two- and three-dimensional curve plotters
- "Living Graphs," which allow the user to control the parameters
- Animations that allow students to visualize chemical events on a molecular level
- Diagnostic Test for the Fundamentals sections
- Web-based Assessment. An excellent online quizzing bank of multiple-choice questions for each text chapter (not from the test bank). Students receive instant feedback and can take the quizzes multiple times. Instructors can go into a protected Web site to view results by quiz, student, or question, or can get weekly results via e-mail. Excellent for practice testing and/or homework.

ACKNOWLEDGMENTS

We are grateful to the many instructors, colleagues, and students who have contributed their expertise to this edition. We would like above all to thank those who carefully evaluated the fourth edition and commented on drafts of the fifth edition:

Yiyan Bai, *Houston Community College System Central Campus*
Maria Ballester, *Nova Southeastern University*
Patricia D. Christie, *Massachusetts Institute of Technology*
Henderson J. Cleaves, II, *University of California, San Diego*
Ivan J. Dmochowski, *University of Pennsylvania*
Ronald Drucker, *City College of San Francisco*
Christian Ekberg, *Chalmers University of Technology, Sweden*
Bryan Enderle, *University of California, Davis*
David Erwin, *Rose-Hulman Institute of Technology*
Justin Fermann, *University of Massachusetts*
Regina F. Frey, *Washington University*
P. Shiv Halasyamani, *University of Houston*
Jameica Hill, *Wofford College*
Alan Jircitano, *Penn State, Erie*
Gert Latzel, *Riemerling, Germany*
Nancy E. Lowmaster, *Allegheny College*
Matthew L. Miller, *South Dakota State University*
Clifford B. Murphy, *Boston University*
Maureen Murphy, *Huntingdon College*
Enrique Peacock-Lopez, *Williams College*
LeRoy Peterson, Jr., *Francis Marion University*
Tyler Rencher, *Brigham Young University*
Michael Samide, *Butler University*
Gordy Savela, *Itasca Community College*
Lori Slavin, *College of Saint Catherine*
Mike Solow, *City College of San Francisco*
John E. Straub, *Boston University*
Laura Stultz, *Birmingham-Southern College*
Peter Summer, *Lake Sumter Community College*
David W. Wright, *Vanderbilt University*
Mamudu Yakubu, *Elizabeth City State University*
Meishan Zhao, *University of Chicago*

The contributions of the reviewers of the first, second, and third editions remain embedded in the text, so we also wish to renew our thanks to:

Thomas Albrecht-Schmidt, *Auburn University*
Matthew Asplund, *Brigham Young University*
Matthew P. Augustine, *University of California, Davis*
David Baker, *Delta College*
Alan L. Balch, *University of California, Davis*
Mario Baur, *University of California, Los Angeles*
Robert K. Bohn, *University of Connecticut*
Paul Braterman, *University of North Texas*
William R. Brennan, *University of Pennsylvania*
Ken Brooks, *New Mexico State University*
Julia R. Burdge, *University of Akron*
Paul Charlesworth, *Michigan Technological University*
Patricia D. Christie, *Massachusetts Institute of Technology*
William Cleaver, *University of Vermont*
David Dalton, *Temple University*
J. M. D'Auria, *Simon Fraser University*
James E. Davis, *Harvard University*
Walter K. Dean, *Lawrence Technological University*
Jimmie Doll, *Brown University*
Ronald Drucker, *City College of San Francisco*
Jetty Duffy-Matzner, *State University of New York, Cortland*
Robert Eierman, *University of Wisconsin*
Kevin L. Evans, *Glenville State College*
Donald D. Fitts, *University of Pennsylvania*
Lawrence Fong, *City College of San Francisco*
Regina F. Frey, *Washington University*
Dennis Gallo, *Augustana College*
David Harris, *University of California, Santa Barbara*
Sheryl Hemkin, *Kenyon College*
Michael Henchman, *Brandeis University*
Geoffrey Herring, *University of British Columbia*
Timothy Hughbanks, *Texas A&M University*
Paul Hunter, *Michigan State University*
Keiko Jacobsen, *Tulane University*
Robert C. Kerber, *State University of New York, Stony Brook*
Robert Kolodny, *Armstrong Atlantic State University*
Lynn Vogel Koplitz, *Loyola University*
Petra van Koppen, *University of California, Santa Barbara*
Mariusz Kozik, *Canisius College*
Julie Ellefson Kuehn, *William Rainey Harper College*
Cynthia LaBrake, *University of Texas, Austin*
Brian B. Laird, *University of Kansas*
Yinfa Ma, *University of Missouri-Rolla*
Paul McCord, *University of Texas, Austin*
Alison McCurdy, *Harvey Mudd College*
Charles W. McLaughlin, *University of Nebraska*
Patricia O'Hara, *Amherst College*
Noel Owen, *Brigham Young University*
Donald Parkhurst, *The Walker School*
Montgomery Pettitt, *University of Houston*
Joseph Potenza, *Rutgers University*
Wallace Pringle, *Wesleyan University*
Philip J. Reid, *University of Washington*
Barbara Sawrey, *University of California, San Diego*
George Schatz, *Northwestern University*
Paula Jean Schlax, *Bates College*
Carl Seliskar, *University of Cincinnati*
Robert Sharp, *University of Michigan, Ann Arbor*
Peter Sheridan, *Colgate University*
Jay Shore, *South Dakota State University*
Herb Silber, *San Jose State University*
Lee G. Sobotka, *Washington University*
Michael Sommer, *Harvard University*
Nanette A. Stevens, *Wake Forest University*
Tim Su, *City College of San Francisco*
Sara Sutcliffe, *University of Texas, Austin*
Larry Thompson, *University of Minnesota, Duluth*
Dino Tinti, *University of California, Davis*
Sidney Toby, *Rutgers University*
David Vandenbout, *University of Texas, Austin*
Deborah Walker, *University of Texas, Austin*
Lindell Ward, *Franklin College*
Thomas R. Webb, *Auburn University*
Peter M. Weber, *Brown University*
David D. Weis, *Skidmore College*
Ken Whitmire, *Rice University*
James Whitten, *University of Massachusetts, Lowell*
Gang Wu, *Queen's University*
Zhiping Zheng, *University of Arizona*
Marc Zimmer, *Connecticut College*
Martin Zysmilich, *Massachusetts Institute of Technology*

Some contributed in substantial ways. Leroy Laverman, University of California at Santa Barbara, carefully reviewed the entire text and all the art, leading to considerable improvements. Roy Tasker, University of Western Sydney, contributed to the Web site for this book, designed related animations, and selected the icons for the animation media links. Michael Cann, University of Scranton, opened our eyes to the world of green chemistry in a way that has greatly enriched this book. We would also like to thank Nathan Barrows, Arizona State University, for contributing to the Self-Test answers. The supplements authors, especially John Krenos, Joseph Potenza, Laurence Lavelle, Yinfa Ma, and Carl Hoeger, have offered us sample content of Chemical Principles: The Quest for Insight

- **click Sailing Bright Eternity (Galactic Center, Book 6)**
- Care of Wooden Floors here
- *click Slavoj Å½iÅ¾ek (Routledge Critical Thinkers)*
- *click The Rough Guide to Norway (6th Edition) here*
- read online Improving Reading Comprehension of Middle and High School Students (Literacy Studies: Persectives from Cognitive Neurosciences, Linguistics, Psychology and Education, Volume 10) pdf, azw (kindle)
- Sky Strike (The Zone, Book 4) pdf

- http://crackingscience.org/?library/Holy-Spy--A-John-Shakespeare-Mystery--John-Shakespeare-Mystery--Book-7-.pdf
- http://yachtwebsitedemo.com/books/Fueled-By-Failure--Using-Detours-and-Defeats-to-Power-Progress.pdf
- http://www.gateaerospaceforum.com/?library/Lights-On---The-Science-of-Power-Generation.pdf
- http://tuscalaural.com/library/The-Rough-Guide-to-Norway--6th-Edition-.pdf
- http://www.mmastyles.com/books/Improving-Reading-Comprehension-of-Middle-and-High-School-Students--Literacy-Studies--Persectives-from-Cognitive-
- http://kamallubana.com/?library/Sky-Strike--The-Zone--Book-4-.pdf