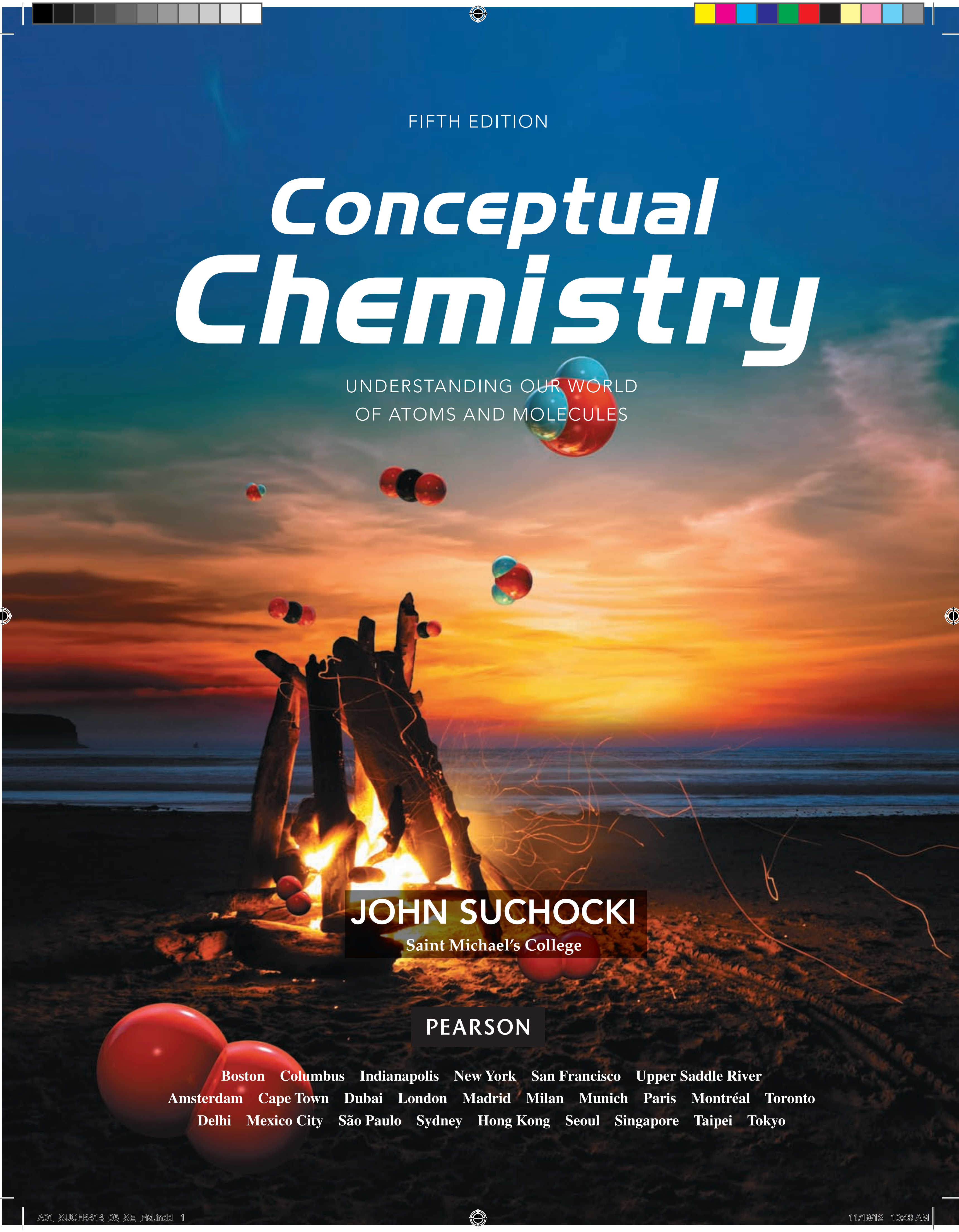

FIFTH EDITION

Conceptual Chemistry

UNDERSTANDING OUR WORLD OF ATOMS AND MOLECULES

JOHN SUCHOCKI
Saint Michael's College

PEARSON

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To:

NEIL DEGRASSE TYSON

For Carrying the Candle

ABOUT THE AUTHOR

John obtained his Ph.D. in organic chemistry from Virginia Commonwealth University. He worked as a postdoctoral fellow in pharmacology at the Medical College of Virginia before moving to Hawaii to become a tenured professor at Leeward Community College, where his interests turned to science education and the development of distance learning programs as well as student-centered learning curricula. In addition to writing *Conceptual Chemistry*, John is the chemistry and astronomy coauthor of the college and high school editions of *Conceptual Physical Science* and *Conceptual Integrated Science* with physicist Paul Hewitt and others. John is currently an adjunct professor at Saint Michael's College in Colchester, Vermont. He also produces science multimedia through his company Conceptual Productions, and writes and illustrates award-winning science-oriented children's books. John is also an avid songwriter who produces music through his recording label CPro Music.

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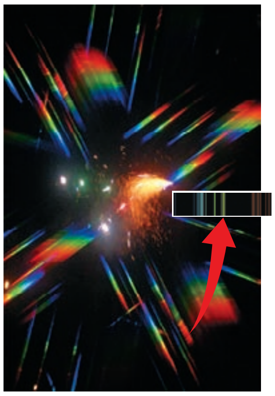

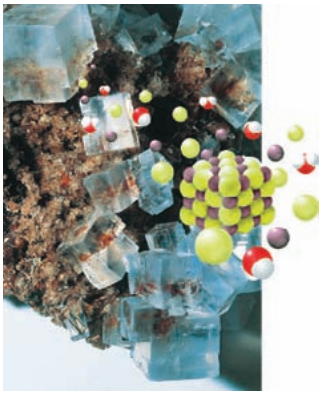

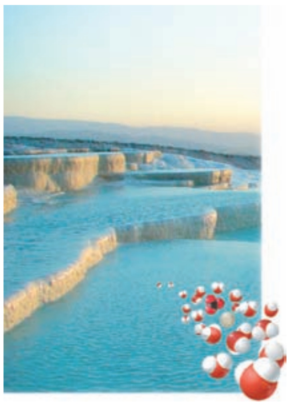

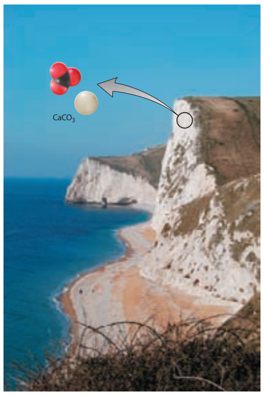


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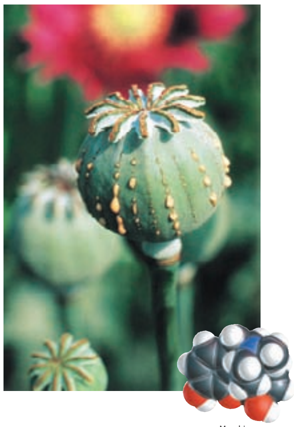

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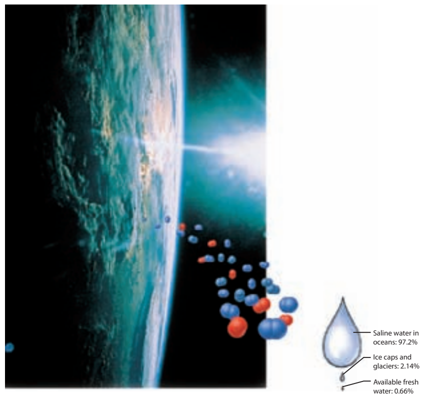

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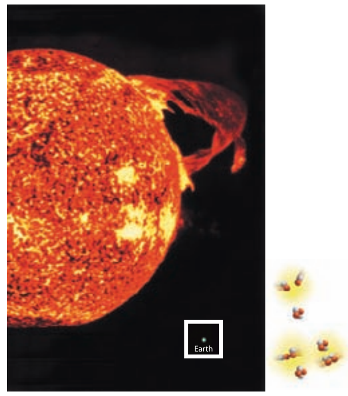

THE CONCEPTUAL CHEMISTRY PHOTO ALBUM

Conceptual Chemistry is a very personal book, as reflected in the many photographs of the author's family and friends that grace its pages. Key to its inception is John's uncle and mentor, Paul Hewitt, author of *Conceptual Physics*, who appears on page 13. On Uncle Paul's lap is John's son Evan Suchocki (pronounced su-HOCK-ee, with a silent *c*), who, as a toddler, sums up the book with his optimistic message.

Taking advantage of water's high heat of vaporization is John's wife, Tracy, who is seen fearlessly walking over hot coals on page 250 and smelling the fragrant-filled balloon on page 27. She is seen again with their oldest child, Ian, on page 100, and again with their second child Evan on page 64. Their third child, Maitreya Rose, is showcased both as a fetus and as a baby on page 430, with her mother on page 410, and as a 2-year-old holding the cellulose- and color-rich Vermont autumn leaves on page 404. She appears yet again in the Chapter 12 opening photograph on page 354 and with her good friend Annabelle Creech as they brush their teeth on page 169. About to enjoy his favorite beverage—by the liter—is son Evan on page 16. He appears again on page 45, using balloons to demonstrate the relationship between the volume of a gas and its temperature. Also, their beloved dog, Sam, shows off his great panting skills on page 240.

Members of John's extended family have also made their way onto the pages of *Conceptual Chemistry.* Nephew Graham Orr is seen on page 76 drinking water both as a child and as a grown-up college student. Exploring the microscopic realm with the uncanny resolution of electron waves is cousin George Webster, who is seen on page 110 alongside his own scanning electron microscope. Cousin Gretchen Hewitt demonstrates her taste for chips on page 410, and brother-in-law Peter Elias smells the camphor of a freshly cut Ping Pong® ball on page 383. Of John's dear friends, we see Rinchen Trashi looking through the spectroscope on page 105 and Nikki Church excited by the carbonation of water on page 219.

The photographs of the children of many of John's friends also grace this book. Ayano Jeffers-Fabro is the adorable girl hugging the tree on page 12. Helping us to understand the nature of DNA in the Chapter 13 opener on page 396 are Daniel and Jacob Glassman-Vinci. Makani Nelson, on page 398, provides us with a fine example of a human body full of cells and biomolecules. Look also for Makani's cameo appearance in the opening montage video at ConceptualChemistry.com.

TO THE STUDENT

Welcome to the world of chemistry—a world where everything around you can be traced to these incredibly tiny particles called *atoms.* Chemistry is the study of how atoms combine to form materials. By learning chemistry, you gain a unique perspective of what things are made of and why they behave as they do.

Chemistry is a science with a practical outlook. By understanding and controlling the behavior of atoms, chemists have been able to produce a broad range of new and useful materials—alloys, fertilizers, pharmaceutical products, polymers, computer chips, recombinant DNA, and more. These materials have raised our standard of living to unprecedented levels. Learning chemistry, therefore, is worthwhile simply because of the impact this field has on society. More important, with a background in chemistry, you can judge for yourself whether available technologies are in harmony with the environment and with what you believe to be proper.

This book presents chemistry conceptually, focusing on the concepts of chemistry with little emphasis on calculations. Although sometimes wildly bizarre, the concepts of chemistry are straightforward and accessible—all it takes is the desire to learn. What you will gain from your efforts, however, may be more than new knowledge about your environment and your personal relation to it—you may improve your learning skills and become a better thinker! But remember, as with any other form of training, you'll only get out of your study of chemistry as much as you put into it. I enjoy chemistry, and I know you can too. So put on your boots and let's explore this world from the perspective of its fundamental building blocks.

Good chemistry to you!

TO THE INSTRUCTOR

As instructors, we share a common desire for our teaching efforts to have a long-lasting, positive impact on our students. We focus, therefore, on what we think is most important for students to learn. For students taking liberal arts chemistry courses, certain learning goals are clear. Those students should become familiar with—and perhaps even interested in—the basic concepts of chemistry, especially those that apply to their daily lives. They should understand, for example, how soap works and why ice floats on water. They should be able to distinguish between stratospheric ozone depletion and global climate change and know what it takes to ensure a safe drinking water supply. Along the way, they should learn how to think about matter in regards to atoms and molecules. Furthermore, by studying chemistry, students should come to understand the methods of scientific inquiry and become better equipped to pass this knowledge along to future generations. In short, these students should become citizens of above-average scientific literacy.

These are noble goals, and it is crucial that we do our best to achieve them. I have come to realize, however, that these feats are not what my former students usually cherish most from having taken a course in chemistry. Rather, it is the personal development they experienced through the process.

As all science educators know, chemistry—with its many abstract concepts—is fertile ground for the development of higher-level thinking skills. Thus, it seems reasonable to share this valuable scientific offering—tempered to an appropriate level—with all students. Liberal arts students, like all other students, come to college not just to learn specific subjects, but also to grow personally. In fact, I would argue that this personal growth is the most vital commodity of a college education. This growth should include improvements in analytical and verbal reasoning skills, along with a boost in self-confidence from having successfully met well-placed challenges. The value of our teaching, therefore, rests not only on our ability to help students learn chemistry but also on our ability to help them learn about themselves.

You will find in this book the standard discussions of the applications of chemistry, as shown in the table of contents. True to its title, this textbook also builds a conceptual base from which students may view nature more perceptively by helping them visualize the behavior of atoms and molecules and showing them how this behavior gives rise to our macroscopic environment. Numerical problem-solving skills and memorization are not stressed. Instead, chemistry concepts are developed in a storytelling fashion, with the frequent use of analogies and tightly integrated illustrations and photographs. Follow-up end-of-chapter questions are designed to challenge students' understanding of concepts and their ability to synthesize and articulate conclusions. Concurrent with helping students learn chemistry, *Conceptual Chemistry* aims to be a tool by which students can learn how to become better thinkers and reach their personal goals of self-discovery.

Explore the world from a chemistry perspective

Chapter-opening features introduce chemistry concepts in a real-world context, setting the stage for the chapter.

The chemical reactions going on in your body are quite similar to those going on within burning wood. In both cases, the products are carbon dioxide, water, and energy.

11

Oxidations and Reductions Charge the World

THE MAIN IDEA

Oxidation is the loss of electrons, and reduction is the gain of electrons.

What do our bodies have in common with the burning of a campfire or the rusting of old farm equipment? Why does silver tarnish? How can aluminum restore tarnished silver? Why is it unwise for people with metal fillings in their teeth to bite down on aluminum foil? How are metals produced from minerals? How do batteries work, and what is their source of energy? What are fuel cells, and how do they generate electricity so efficiently? How do photovoltaic cells convert sunlight into electricity? Why is hydrogen such an environmentally friendly fuel but not itself a source of energy? The answers to all these questions involve a class of reactions called *oxidation-reduction* reaction. These reactions are similar to the acid-base reactions you learned about in the previous chapter in that they both involve the transfer of subatomic particles between reactants. For acid-base reactions, these subatomic particles are typically protons. Oxidation-reduction reactions, by contrast, involve the transfer of electrons.

▲ The chemical reactions going on in your body are quite similar to those going on within burning wood. In both cases, the products are carbon dioxide, water, and energy.

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HANDS ON Chemistry

The Cool Rubber Band

Predict what happens to the temperature of a rubber band as it is stretched. Predict what happens to the temperature of a stretched rubber band as it relaxes.

PROCEDURE

1. Stretch a rubber band while holding it to your lower lip, which you will find is sensitive to small temperature changes.
2. Relax the stretched rubber band that is in contact with your lower lip.

ANALYZE AND CONCLUDE

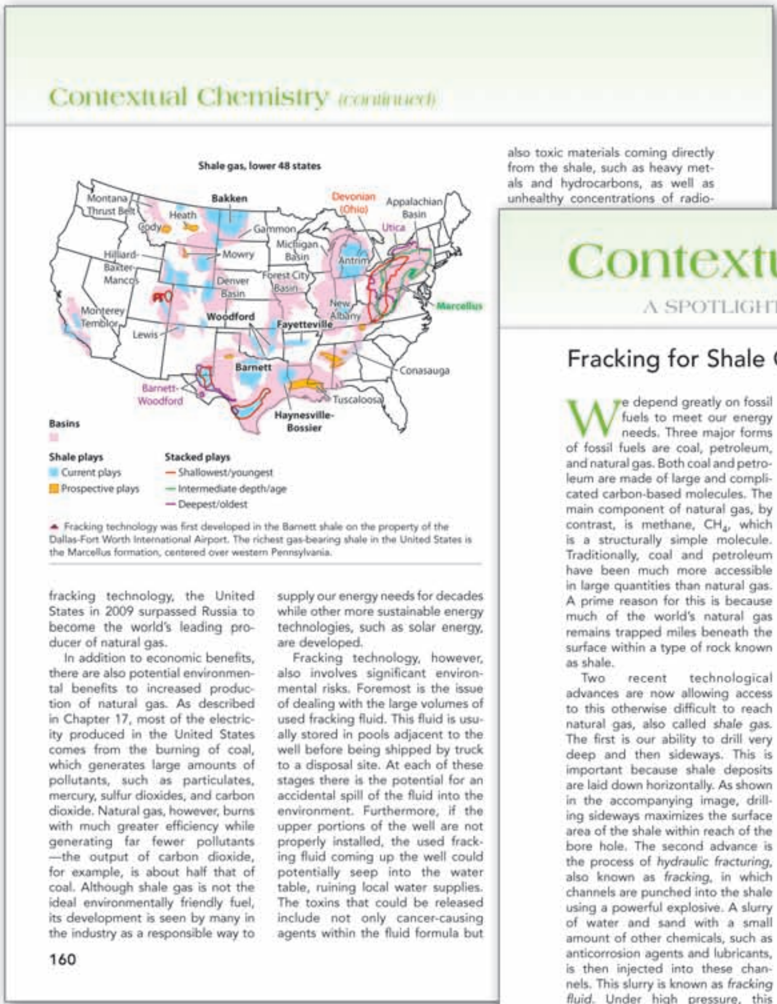
1. Does the speed at which you stretch the rubber band make a difference?
2. You touch your hand to the forehead of someone with a fever. You feel that his or her forehead is hot. How does your hand feel to the person with the fever?
3. If the contracting rubber band causes your lip to cool down, what does your lip do to the contracting rubber band?
4. A hammer is hanging by a stretched rubber band. Hot air is then blown over the rubber band with a hair dryer. Is the hammer lifted upward or does it drop downward?
5. True or False: Experiments often raise more questions than they answer.

Hands On Chemistry

Each chapter opens with a hallmark Hands On Chemistry activity that allows the student to experience concepts related to chemistry outside the formal lab setting. Using common household ingredients and equipment, these activities guide students step-by-step through experiments that bring concepts alive.

Engage students with chemistry-related issues

Essays highlight chemistry concepts within the context of our society and lives.



Contextual Chemistry *(continued)*

▲ Fracking technology was first developed in the Barnett shale on the property of the Dallas-Fort Worth International Airport. The richest gas-bearing shale in the United States is the Marcellus formation, centered over western Pennsylvania.

fracking technology, the United States in 2009 surpassed Russia to become the world's leading producer of natural gas.

In addition to economic benefits, there are also potential environmental benefits to increased production of natural gas. As described in Chapter 17, most of the electricity produced in the United States comes from the burning of coal, which generates large amounts of pollutants, such as particulates, mercury, sulfur dioxides, and carbon dioxide. Natural gas, however, burns with much greater efficiency while generating far fewer pollutants—the output of carbon dioxide, for example, is about half that of coal. Although shale gas is not the ideal environmentally friendly fuel, its development is seen by many in the industry as a responsible way to supply our energy needs for decades while other more sustainable energy technologies, such as solar energy, are developed.

Fracking technology, however, also involves significant environmental risks. Foremost is the issue of dealing with the large volumes of used fracking fluid. This fluid is usually stored in pools adjacent to the well before being shipped by truck to a disposal site. At each of these stages there is the potential for an accidental spill of the fluid into the environment. Furthermore, if the upper portions of the well are not properly installed, the used fracking fluid coming up the well could potentially seep into the water table, ruining local water supplies. The toxins that could be released include not only cancer-causing agents within the fluid formula but also toxic materials coming directly from the shale, such as heavy metals and hydrocarbons, as well as unhealthy concentrations of radio-

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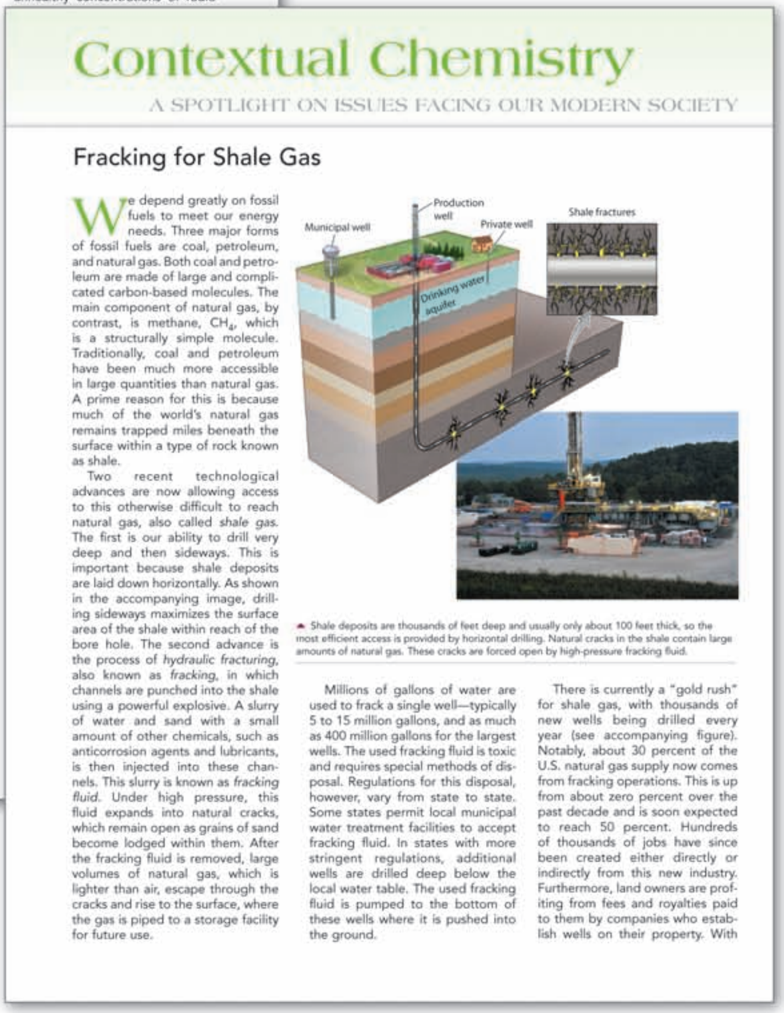


Contextual Chemistry

A SPOTLIGHT ON ISSUES FACING OUR MODERN SOCIETY

Fracking for Shale Gas

We depend greatly on fossil fuels to meet our energy needs. Three major forms of fossil fuels are coal, petroleum, and natural gas. Both coal and petroleum are made of large and complicated carbon-based molecules. The main component of natural gas, by contrast, is methane, CH_4, which is a structurally simple molecule. Traditionally, coal and petroleum have been much more accessible in large quantities than natural gas. A prime reason for this is because much of the world's natural gas remains trapped miles beneath the surface within a type of rock known as shale.

Two recent technological advances are now allowing access to this otherwise difficult to reach natural gas, also called *shale gas*. The first is our ability to drill very deep and then sideways. This is important because shale deposits are laid down horizontally. As shown in the accompanying image, drilling sideways maximizes the surface area of the shale within reach of the bore hole. The second advance is the process of *hydraulic fracturing*, also known as *fracking*, in which channels are punched into the shale using a powerful explosive. A slurry of water and sand with a small amount of other chemicals, such as anticorrosion agents and lubricants, is then injected into these channels. This slurry is known as *fracking fluid*. Under high pressure, this fluid expands into natural cracks, which remain open as grains of sand become lodged within them. After the fracking fluid is removed, large volumes of natural gas, which is lighter than air, escape through the cracks and rise to the surface, where the gas is piped to a storage facility for future use.

▲ Shale deposits are thousands of feet deep and usually only about 100 feet thick, so the most efficient access is provided by horizontal drilling. Natural cracks in the shale contain large amounts of natural gas. These cracks are forced open by high-pressure fracking fluid.

Millions of gallons of water are used to frack a single well—typically 5 to 15 million gallons, and as much as 400 million gallons for the largest wells. The used fracking fluid is toxic and requires special methods of disposal. Regulations for this disposal, however, vary from state to state. Some states permit local municipal water treatment facilities to accept fracking fluid. In states with more stringent regulations, additional wells are drilled deep below the local water table. The used fracking fluid is pumped to the bottom of these wells where it is pushed into the ground.

There is currently a "gold rush" for shale gas, with thousands of new wells being drilled every year (see accompanying figure). Notably, about 30 percent of the U.S. natural gas supply now comes from fracking operations. This is up from about zero percent over the past decade and is soon expected to reach 50 percent. Hundreds of thousands of jobs have since been created either directly or indirectly from this new industry. Furthermore, land owners are profiting from fees and royalties paid to them by companies who establish wells on their property. With

Contextual Chemistry Essays

Contextual Chemistry essays follow each chapter complete with discussion questions. These essays focus on chemistry-related issues that lend themselves to controversy. An essay can serve as a starting point for a student project or as a centerpiece for in-class student discussion groups. Expanded in this edition, new essay topics include Global Climate Change, Fracking for Shale Gas, and Genetically Modified Foods.

Checkpoints guide the way to conceptual understanding

Ideas across the chapter are reinforced with checkpoints that help synthesize ideas.

CONCEPT CHECK

Is there gravity on the Moon?

CHECK YOUR ANSWER Yes, absolutely! The Moon exerts a downward gravitational pull on any body near its surface, as evidenced by the fact that astronauts were able to land and walk on the Moon. This NASA photograph shows an astronaut jumping. Without gravity, this jump would have been his last, because he would never have come down.

Boxed Concept Checks

Boxed Concept Checks pose a question followed by an immediate answer. This question-and-answer format reinforces the chemistry concept under discussion, solidifying the ideas presented before the student moves on to new concepts.

maximum number of electrons that the shell representing that period can hold.

Notice how electrons in the outermost shell begin to pair only after that shell is half filled. Carbon, for example, has four outer-shell electrons, none of which are paired. This differs from how an energy-level diagram is filled. For example, the second shell consists of the 2*s* and 2*p* orbitals, which, as shown in Figure 4.29, have different energy levels. Therefore, you might expect carbon's lower energy 2*s* orbital to fill with two paired electrons. In an advanced chemistry course,

READING CHECK

When do electrons in the outermost shell of an atom begin to pair with each other?

Reading Checks

In-the-margin Reading Checks flag key points, directing the student to a key sentence within each section of a chapter and remind students to reflect on them at the end of the section.

CALCULATION CORNER SCUBA DIVING AND HOT AIR BALLOONS

We can express Boyle's Law and Charles's Law mathematically as follows:

$$P_1V_1 = P_2V_2 \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Boyle's Law — Charles's Law

Here P_1, V_1, and T_1 represent an original pressure, volume, and temperature, respectively, while P_2, V_2, and T_2 represent a new pressure, volume, and temperature, respectively. Each of the preceding equations contains four variables. For such equations, if three of the variables are known we can calculate the fourth (assuming all temperatures are expressed in kelvins).

EXAMPLE

What would be the new volume of a 1.00 liter balloon if it were brought from sea level, where the air pressure is 1.00 atmosphere, to an altitude of 2500 meters, where air pressure is about 0.743 atmospheres? Assume there is no change in temperature. (As we explore in Chapter 16, the "atmosphere" is a common unit of pressure and is equal to the average atmospheric pressure at sea level.)

$$P_1 = 1.00\,\text{atm}$$
$$P_2 = 0.743\,\text{atm}$$
$$V_1 = 1.00\,\text{liter}$$
$$V_2 = ?$$

Use algebra to rearrange the equation for Boyle's Law to solve for V_2:

$$\begin{aligned} V_2 &= P_1V_1/P_2 \\ &= (1.00\,\text{atm})(1.00\,\text{liter})/(0.743\,\text{atm}) \\ &= 1.35\,\text{liters} \end{aligned}$$

YOUR TURN

1. A scuba diver swimming underwater in the ocean breathes compressed air at a pressure of 2 atmospheres. If she holds her breath while returning to the surface, by how much might the volume of her lungs increase?

2. A 5.00-liter rubber balloon is submerged 5.00 meters under ocean water, where its new volume is measured to be 3.38 liters. Show that the pressure at this depth is 1.48 atmospheres.
3. A perfectly elastic 419-liter balloon is heated from 25°C (298 K) to 50°C (323 K). To what new volume does it expand?
4. A hot air balloon 401,000 liters in volume is warmed from 298 K to 398 K. As the air inside the balloon expands, it is unable to stretch the fabric, which is not very elastic. Instead, the expanded air escapes out of a hole placed at the top of the balloon. Show that 135,000 liters of air escapes.
5. Air has a density of 1.18 g/L. Show that the hot air balloon in the previous question is now lighter by 159 kilograms, which helps the balloon to rise.

The answers for Calculation Corners appear at the end of each chapter.

Calculation Corners

Calculation Corners in selected chapters provide practice in the quantitative-reasoning and basic math skills needed to perform chemical calculations. None of the calculations involves skills beyond fractions, percentages, or basic algebra.

Turn classroom concepts into real-world applications

Features in the text stimulate classroom discussions, engaging students in a real-world understanding of chemistry.

> **EXPLAIN THIS**
>
> *What is found between two adjacent molecules of a gas?*

NEW! Explain This

Explain This questions activate prior knowledge, illustrate intriguing applications of concepts, and serve as the catalyst for lively classroom discussion. Answers appear in the instructor's manual.

> **CHEMICAL CONNECTIONS**
>
> How is a raindrop connected to a campfire?

NEW! Chemical Connections

In-the-margin Chemical Connections ask students to uncover the link between two seemingly unrelated materials or processes. Answers appear in the instructor's manual.

> **FOR YOUR INFORMATION**
>
> Astronomers have recently discovered an expired star that has a solid core made of diamond. This star-sized diamond measures about 4000 kilometers wide, which amounts to about 10 billion trillion trillion carats. It has been named "Lucy," after The Beatles song "Lucy in the Sky with Diamonds." In about 7 billion years, our own star, the Sun, is also likely to crystallize into a huge diamond ball.

For Your Information

For Your Information paragraphs in the margins are included in each chapter and highlight interesting information relating to the adjacent chapter content.

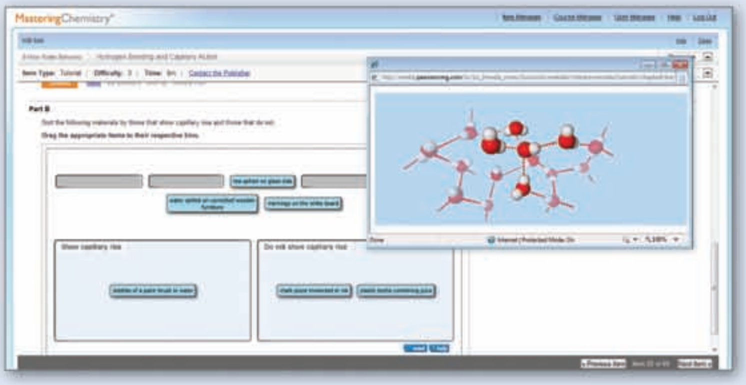
MasteringChemistry®

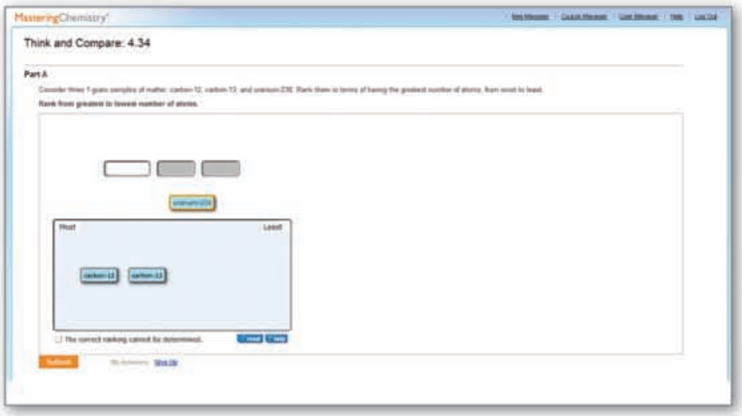
Engaging Experiences

The Mastering platform is the most effective and widely used online homework, tutorial, and assessment system for the sciences. The Mastering system helps instructors maximize class time with easy-to-assign, customizable, and automatically graded assessments that motivate students to learn outside of class and arrive prepared for lecture.

Student Tutorials

Student Tutorials guide students through the toughest topics in chemistry with individualized coaching. These self-paced tutorials coach students with hints and feedback specific to their individual misconceptions.





End-of-chapter Problems

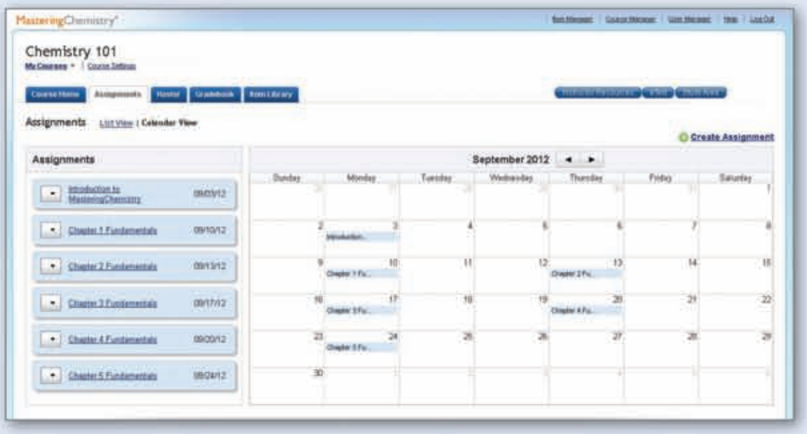
End-of-chapter problems from the text are now easily assignable within MasteringChemistry to help students prepare for the types of questions that may appear on a test.

Reading Check Questions

In-the-margin Reading Check questions can be assigned in MasteringChemistry, allowing instructors to assign reading and test students on their comprehension of chapter content.

Easy to get started. Easy to use.

MasteringChemistry® provides a rich and flexible set of course materials to get you started quickly.



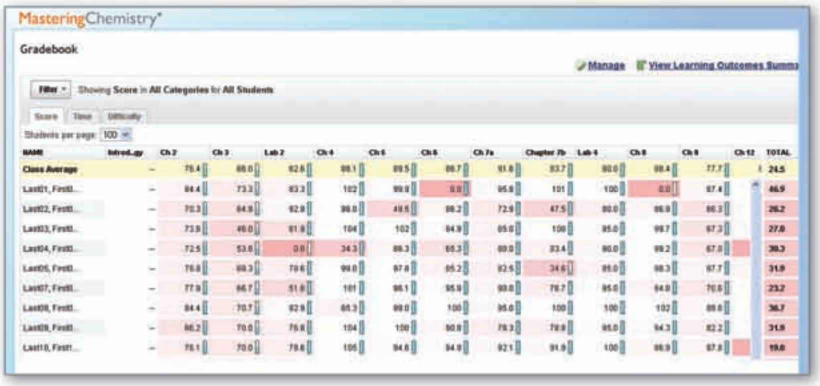
NEW! Calendar Features

The Course Home default page now features a Calendar View displaying upcoming assignments and due dates.

- Instructors can schedule assignments by dragging and dropping the assignment onto a date in the calendar. If the due date of an assignment needs to change, instructors can drag the assignment to the new due date and change the "available from and to dates" accordingly.
- The calendar view gives students a syllabus-style overview of due dates, making it easy to see all assignments due in a given month.

Gradebook

Every assignment is automatically graded. Shades of red highlight vulnerable students and challenging assignments.



NEW! Learning Outcomes

Let Mastering do the work in tracking student performance against your learning outcomes:

- Add your own or use the publisher provided learning outcomes.
- View class performance against the specified learning outcomes.
- Export results to a spreadsheet that you can further customize and share with your chair, dean, administrator, or accreditation board.

WHAT'S NEW IN THIS EDITION?

Notably, the organization of content in this fifth edition is similar to that of the fourth edition. Thus, for instructors already using the fourth edition, changes to a course syllabus will be minimal. Under the hood, however, this fifth edition is a major upgrade, especially in terms of its readability, accuracy, and new pedagogical features. Equally as important, the book has been updated to reflect current events, such as the 2011 earthquake and tsunami, and recent advances in science and technology, such as the success of immunotherapies against cancer and the development of hydraulic fracturing for shale gas.

This latest edition sports a new and modern-looking layout. Integrated into the design are learning objectives appearing alongside each chapter section heading. Each learning objective begins with an active verb that specifies what students should be able to do after studying that section, such as "Calculate the energy released by a chemical reaction." These section-specific learning objectives are further integrated into the Mastering Chemistry online tutorial and assessment tool.

Appearing beneath each section heading is an "Explain This" question. These questions would be fairly difficult for students to answer without having read the chapter section. Some require that students recall earlier material. Others reveal interesting applications of chemistry concepts. In all cases, the Explain This question should serve as a launching point for classroom discussion. The answers to these questions appear in the *Instructor Manual.*

Also new to this edition, appearing in the margins of each chapter, are a set of questions that ask students to find the chemical connection between seemingly unrelated materials or processes. Such a "Chemical Connection" question is featured on the back cover of this textbook, where students are asked how a campfire is connected to the Sun. Students tend to struggle with these riddle-like questions, which probe into their understanding of atoms and molecules. These questions are best presented in class, where students will have fun thinking aloud with their classmates. You can expect to hear many creative answers. The author's answers are published in the *Instructor Manual*.

Changes have also been made to the end-of-chapter (EOC) material. Most importantly, each question was reviewed for quality and, as needed, either rewritten or replaced. All questions are now sorted by learning objectives, as shown in a grid appearing at the beginning of the EOC material. The hands-on chemistry activities are now called "Confirm the Chemistry" to highlight their important role in the learning cycle. The more challenging "Think and Explain" questions are now organized by section number to facilitate the assigning of homework.

By popular demand, all 17 chapters are now included in the printed edition. Furthermore, the "Contextual Chemistry" essays have been updated and new ones written so that one of these essays now appears at the end of each chapter.

Content Changes to the Fifth Edition

- New Contextual Chemistry Essays appear throughout the text. One at the end of Chapter 1 uses the topic of global climate change to highlight the ever-important role of science in society. This essay sets the stage for a more thorough discussion of global climate change now appearing in Chapter 16. Another new essay that appears after Chapter 5 discusses the issues involved in hydraulic fracturing and explains how this technology has boosted the United States in becoming the world's leading producer of natural gas. Also, the new essay on genetically modified foods appearing after Chapter 15 was developed out of material that appeared in Chapter 15 of the fourth edition.

- A discussion of atomic orbitals, energy level diagrams, and electron configurations has been included in Chapter 4 to help students understand the structure of the atom as well as atomic behavior. These concepts are then summarized in a revised discussion of Pauling's "argonian" shell model, which is now called the *noble gas shell model* to distinguish it from the traditional shell model used to describe principal quantum states. Placed at the end of Chapter 4 and not discussed in subsequent chapters, this noble gas shell model can easily be skipped, which is advisable for courses designed to prepare students for advanced chemistry. For the non-science-oriented student, however, this model provides valuable insight into the nature of the periodic table, electron-dot structures, and chemical bonding.

Other content changes include the following:

- The discussion of wastewater treatment was moved from Chapter 7 to Chapter 16.
- New material on ocean acidification was written for Chapter 10.
- The section on the greenhouse effect and global climate change was moved to Chapter 16, where it fits with the strong focus on atmospheric chemistry.
- Discussions on angiogenesis inhibitors and other monoclonal antibodies were added to Chapter 14, which also features a more accurate description of the reuptake inhibiting modes of action for amphetamines and cocaine.
- A description of neonicotinoids, now the most widely used insecticides, and their benefits and risks was added to Chapter 15.
- Notably, Chapters 16 and 17 are the most "fact-heavy" chapters. Much research went into updating and cross-referencing the accuracy of the data presented in these chapters. Furthermore, the content of Section 17.3 now focuses on the issues of the nuclear industry, which allowed for removal of the discussion of nuclear fusion that was redundant with the content of Chapter 5. Chapter 17 also features a new subsection on the history and current state of the aging North American power grid.

Changes to the Supplements

The **Conceptual Chemistry Alive! (CCAlive!)** video lecture series, featuring the author's lecture presentations, downloadable worksheets, and many other study resources, continues to be upgraded on a regular basis. A social media component, for example, now lets students work together in study groups that can be moderated by an instructor or a teaching assistant. Also, the author's class journal (blog), where he describes his current classroom activities, is also available to registered instructors. The video lecture series can also be found online in MasteringChemistry and at ConceptualChemistry.com.

The Conceptual Chemistry Laboratory Manual now sports a new lab on Charles' Law. Also, the Mastering Chemistry online homework system has been revised to match the significant changes that were created in the end-of-chapter material of the textbook.

Supplements Available with the Fifth Edition

For the Student

MasteringChemistry® with Pearson eText MasteringChemistry® from Pearson has been designed and refined with a single purpose in mind: to help educators create that moment of understanding with their students. The Mastering platform delivers engaging, dynamic learning opportunities—focused on your course objectives and responsive to each student's progress—that are proven to help students absorb course material and understand difficult concepts. By complementing your teaching with our engaging technology and content, you can be confident that your students will arrive at that moment—the moment of true understanding.

The Conceptual Chemistry Alive! (CCAlive!) video lecture series, featuring the author's lecture presentations is available in MasteringChemistry and at ConceptualChemistry.com along with many other important study resources such as downloadable worksheets and practice quizzes. Each video lecture averages only 7 minutes in length, but there are over 200 of them, spanning the table of contents of the textbook. These video lectures are best thought of as the "talking textbook," in which students get to see and hear the concepts of chemistry. CCAlive! complements the textbook as a means of delivering the content of chemistry. This, in turn, supports the instructor who is seeking to dedicate his or her classes to student-centered learning activities such as Process-Oriented Guided Inquiry Learning (POGIL).

Explorations in Conceptual Chemistry: A Student Activity Workbook (0-321-68172-X) was written by Jeffrey Paradis of California State University, Sacramento. This manual features hands-on activities that help students learn by doing chemistry in a discovery-based team environment. The *Student Activity Manual* is also available in the Pearson Custom Library.

The Laboratory Manual (0-321-80453-8) was written by John Suchocki and Donna Gibson, of Chabot College. The *Laboratory Manual* features experiments tightly correlated to the chapter content. Each lab consists of objectives, a list of materials needed, a discussion, the procedure, and report sheets.

For the Instructor

MasteringChemistry® with Pearson eText MasteringChemistry® from Pearson has been designed and refined with a single purpose in mind: to help educators create that moment of understanding with their students. The Mastering platform delivers engaging, dynamic learning opportunities—focused on your course objectives and responsive to each student's progress—that are proven to help students absorb course material and understand difficult concepts. By complementing your teaching with our engaging technology and content, you can be confident that your students will arrive at that moment—the moment of true understanding.

- By providing answer-specific feedback and coaching, the MasteringChemistry® tutorial system helps students figure out where they are going wrong when problem solving. By offering feedback specific to students' incorrect answers, MasteringChemistry® tutorials coach 92 percent of students to the correct answer.
- The program enables instructors to compare their class performance with the national average on specific questions or topics. At a glance, instructors can see class distribution of grades, time spent, most difficult problems, most difficult steps, and even most common answers.
- Pearson eText gives students access to the text whenever and wherever they can access the Internet. The eText pages look just like the printed text and include powerful interactive and customization functions. This product does not include the bound book.

Instructor Resource Materials (0-321-80450-3) This integrated collection of resources was designed to help you make efficient and effective use of your time. Resources feature art from the text, including figures and tables in JPEG format, as well as three prebuilt PowerPoint® presentations per chapter. The first presentation contains the images, figures, and tables embedded in the PowerPoint® slides, and the second presentation includes a complete lecture outline. The final presentation consists of approximately 15–25 Clicker questions per chapter. A TestGen® version of the Test Bank, which allows you to create and tailor exams to your particular needs, is also offered. All of these resources can be downloaded from the Instructor Resource Center found at www.pearsonhighered.com/chemistry.

The **TestGen® Computerized Test Bank** (0-321-80452-X) Prepared by John Suchocki and his wife, Tracy, the Test Bank contains more than 2100 multiple-choice questions from which to choose in creating your own tests and quizzes. These files are also available in Microsoft® Word format and can be downloaded from the Instructor Resource Center, found at www.pearsonhighered.com/chemistry.

Instructor Manual (0-321-80451-1) Written by John Suchocki, the *Instructor Manual* contains sample syllabi, teaching tips, suggested demonstrations, and answers to all end-of-chapter questions. It is an important resource for the instructor who is seeking to implement student-centered learning techniques such as "student-centered circles" and "minute quizzes."

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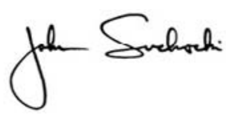
To the struggling student, thank you for your learning efforts—you are on the road to making this world a better place.

Much effort has gone into keeping this textbook error-free and accurate. However, some errors or inaccuracies may have escaped our notice. Forwarding such errors or inaccuracies to me would be greatly appreciated. Your questions, general comments, and criticisms are also welcome. I look forward to hearing from you.



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