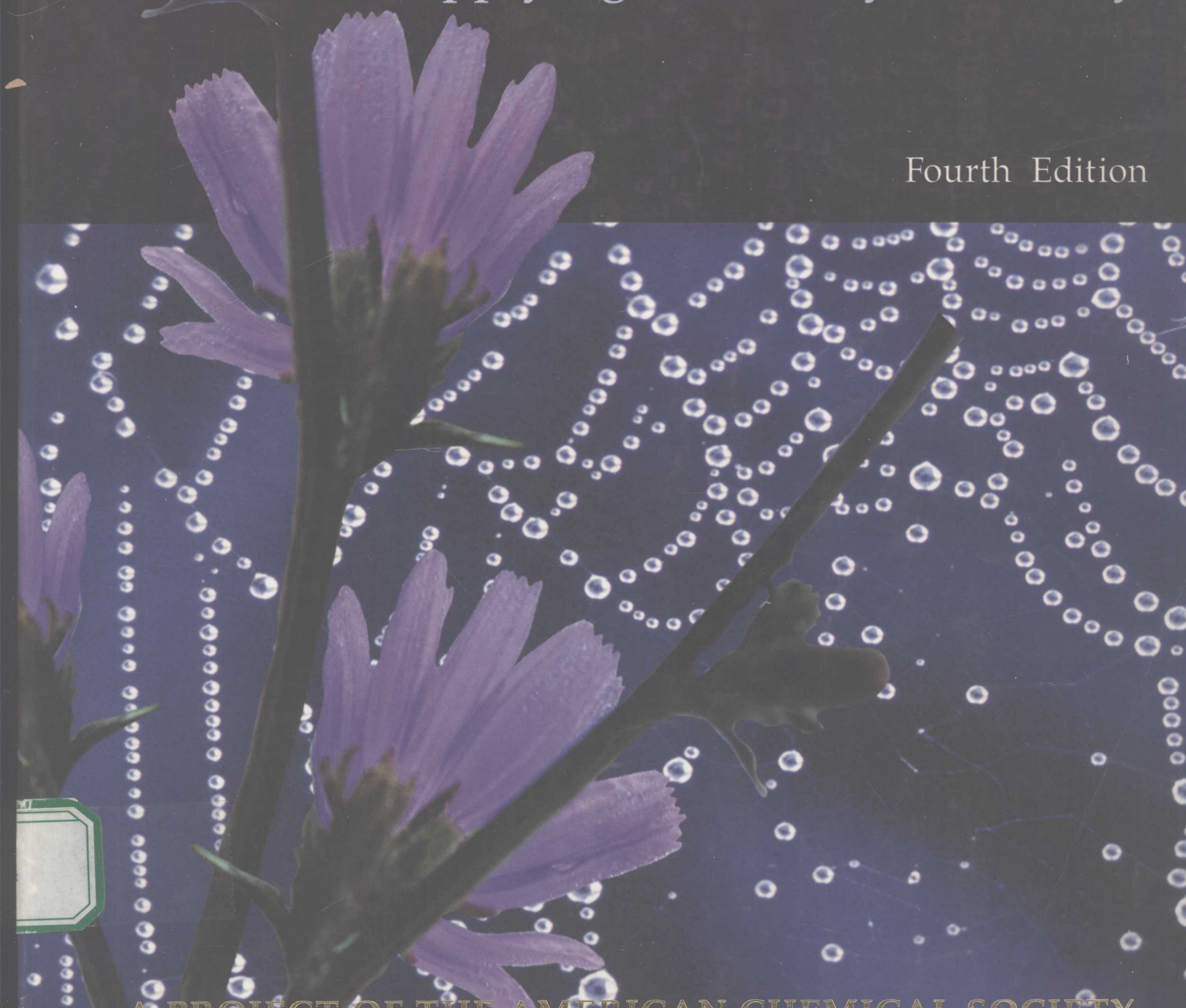
CHEMISTRY *in* CONTEXT

Applying Chemistry to Society

Fourth Edition



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Chemistry in Context

Applying Chemistry to Society

Fourth Edition

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Preface

Following in the tradition of its first three editions, the goal of *Chemistry in Context,* fourth edition, is to establish chemical principles on a need-to-know basis within a contextual framework of significant social, political, economic, and ethical issues. We believe that by using this approach, students not majoring in a science develop critical thinking ability, the chemical knowledge and competence to better assess risks and benefits, and the skills that lead them to be able to make informed and reasonable decisions about technology-based issues. The word "context" derives from the Latin word meaning "to weave." Thus, the spider web motif on the cover, used for the first three editions, continues with this edition because a web exemplifies the complex connections between chemistry and society.

Chemistry in Context is not a traditional chemistry book for non-science majors. In this book, chemistry is woven into the web of life. The chapter titles of *Chemistry in Context* reflect today's technological issues and the chemistry principles imbedded within them. Global warming, alternate fuels, nutrition, and genetic engineering are examples of such issues. To understand and respond thoughtfully in an informed manner to these vitally important issues, students must know the chemical principles that underlie the socio-technological issues. This book presents those principles as needed, in a manner intended to better prepare students to be well-informed citizens.

Organization

The basic organization and premise remain the same as in previous editions. The focal point of each chapter is a real-world societal issue with significant chemical context. The first six chapters are core chapters in which basic chemical principles are introduced and expanded upon on a need-to-know basis. These six chapters provide a coherent strand of issues focusing on a single theme—the environment. Within them, a foundation of necessary chemical concepts is developed from which other chemical principles are derived in subsequent chapters. Chapters 7 and 8 consider alternate (non-fossil fuel) energy sources—nuclear power, fuel cells, batteries, and photovoltaics. The emphases in the remaining chapters are carbon-based issues and chemical principles related to polymers, drugs, nutrition, and genetic engineering. Thus, one-third of the text has an organic/biochemistry flavor. These latter chapters provide students with the opportunity to focus on additional interests beyond the core topics, as time permits. Most users teach seven to nine chapters in a typical one-semester course.

All content has been thoroughly updated. Tables, figures, and data are as up to date as possible using a printed format. Icons within the chapters direct the student to the Internet to get the latest information from the Web for answering questions and evaluating the information obtained from the Web.

Chapter 8 has been refocused to concentrate on electron transfers in chemical reactions, leading to an expansion of the coverage of fuel cells, including their latest designs, modern batteries, and photovoltaics.

Pedagogy

This text abounds in helpful pedagogy for students. The Chapter Overview, Conclusion, Chapter Summary, and Marginal Notes are study tools for the student. The Chapter Overview and Conclusion draw together the major themes at the beginning and end of each chapter. The Chapter Summary calls attention to the most important skills and applications developed in the chapter. Marginal Notes are used to succinctly summarize and emphasize key points or to link to sections in other chapters.

The in-chapter features—**Your Turn, Consider This,** and **Sceptical Chymist**—are activities to practice skills, to raise issues for thought, and to use critical thinking in extending and applying chemical principles. **Your Turn** activities provide opportunities for students to practice a skill or calculation that has been illustrated in the text. **Consider This** questions are decision-making activities requiring risk-benefit analysis, consideration of opposing viewpoints, speculation on the consequences of a particular action, or formulation and defense of a personal position. The **Sceptical Chymist** activities require analytical skills in response to various statements and assertions made in the popular media. These activities take their title, and its peculiar spelling, from an influential book written in 1661 by Robert Boyle, an important scientist and an early investigator of the properties of air.

Icons for Green Chemistry, the Web Exercises, and Figures Alives link special content in the text and the extension exercises on the *Chemistry in Context* Online Learning Center. Green chemistry is integrated within the text. The icon pulls the student attention to examples in which green chemical principles are applied. A web icon identifies each Consider This or Sceptical Chymist activity in which students should go to the Chemistry in Context Online Learning Center for further exploration. For the Figures Alive! interactives, the icon is adjacent to the text figure featured in the interactive. The icon signals the student to go to the Online Learning Center and learn by doing the interactive activities associated with the figure and its extensions.

Problem Solving

There are two main locations of problem-solving activities in *Chemistry in Context.*

The in-chapter problems are the Your Turn, Consider This, and Sceptical Chymist activities, as described earlier.

End-of-chapter problems are divided into three categories. *Emphasizing Essentials* are questions to practice and sharpen chemistry skills developed in the chapter. *Concentrating on Concepts* questions focus on chemical concepts and their relationships to the socio-technological topics under discussion. Questions in the *Exploring Extensions* category present a challenge to go beyond the textbook material by providing an opportunity to extend and integrate skills, concepts, and communication. The latter two categories of questions also incorporate the use of the Internet as a source of data and opinions. The questions with blue numbers are answered in Appendix 5.

Media

- *Web Exercises*—Continued from the third edition, the Web exercises use the Internet to answer various questions posed in many of the Consider This and Sceptical Chymist activities, as well as in chapter-end questions. Web-based exercises allow students to apply information to their own lives, use real-time data, get up-to-date information, and evaluate controversies using the Web. The Web presents students with the opportunity and responsibility to critically evaluate Web information among web sites of widely differing quality and validity. Many of the Web-based activities are linked to the *Chemistry in Context* web site (www.mhhe.com/physsci/chemistry/cic/).
- *Supplemental Readings*—These are listed on the *Chemistry in Context* web site rather than in the text so that updates can be provided in a timely way.
- **NEW!** *Figures Alive!*—These interactive materials in multimedia format are tied to a figure in each chapter. Each Figures Alive! interactive allows students to better understand the concepts in the figure by using interactive web exercises to develop this knowledge. The activities are based upon the same categories as the chapter-end problems—Emphasizing Essentials, Concentrating on Concepts, and Exploring Extensions.
- **NEW!** *Quiz Questions*—This set of questions allows students to test their knowledge of the material pre-

sented. Questions based on skills and concepts presented in the chapter give students a quick assessment of their knowledge and what they need to study further.

As with previous editions, a very detailed *Instructor's Resource Guide* (IRG) is available, compiled by Marcia Gillette. Unlike its predecessors, which were printed, the fourth edition's IRG is available only on the *Chemistry in Context* web site. For those whose course includes a laboratory component, a *Laboratory Manual,* compiled and edited by Wilmer Stratton, is available. The experiments use microscale equipment (wellplates and Beral-type pipets) and common materials. Cooperative/collaborative laboratory experiments are included.

It is always a pleasure to bring a new textbook or new edition to fruition. But the work is not done by just one individual. It is a team effort, one comprised of the work of many talented individuals. We have been fortunate to have the continuing, unstinting support of Sylvia Ware, Director of the ACS Division of Education and International Activities, who helped to create the first edition of *Chemistry in Context*. We also recognize the able assistance of Dr. Jerry Bell and Dr. Marta Gmurczyk of that ACS Education Division office. The McGraw-Hill team has been superb in all aspects of the project. Kent Peterson (Publisher) leads this outstanding team of Shirley Oberbroeckling (Senior Developmental Editor, Chemistry), Vicki Krug (Senior Project Manager), Phil Meek (Senior Media Producer), and Stacy Patch (Senior Media Project Manager), a team that does its job with the enviable combination of high quality and good humor.

The fourth edition is the product of a collaborative effort among writing team members—Catherine Middlecamp, Lucy Pryde Eubanks, Norbert Pienta, and Conrad Stanitski. This is the maiden voyage in this realm for Norbert Pienta, a new co-author and colleague. We have benefited from his diverse expertise.

We are very excited by the new features of this fourth edition, which exemplify how we continue to "press the envelope" to bring chemistry in creative, appropriate ways to non-science majors, while being honest to the science. We look forward to your comments.

Conrad Stanitski
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March 2002

Instructor Resources

Instructor's Resource Guide

The *Instructors Resource Guide,* edited by Marcia Gillette (Indiana University—Kokomo), can be found on the Online Learning Center under Instructor Resources. Included:

- A chemical topic matrix provides listing of chemical principles commonly covered.
- Course syllabi give some indication about the scope, pace, and scheduling of the course.
- Topical Essays give a variety of background material and pragmatic suggestions for teaching strategies and student development goals.
- Answers are given for suggested responses to many of the open-ended questions in the Consider This activities and the solutions to the in-chapter and chapter-end exercises and questions.
- Provides the instructors guide for the laboratory experiments.

Online Learning Center (www.mhhe.com/cic)

The Online Learning Center (OLC) is a comprehensive, book-specific web site offering excellent tools for both the instructor and the student. Instructors can create an interactive course with the integration of this site, and a secured Instructor Center stores their essential course materials to save prep time before class. This Instructor Center offers the Instructors Resource Guide. The Student Center offers Web Exercises, Figures Alive! interactives, and quiz questions. The Online Learning Center content has been created for use in PageOut, WebCT, and Blackboard course management systems.

Digital Content Manager

The Digital Content Manager is a multimedia collection of visual resources allowing instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and quizzes, dynamic course web site content, and/or attractive printed support materials. The Digital Content Manager is a cross-platform CD containing an image library, photo library, and a table library.

Transparency Set

The transparency set contains selected four-color illustrations from the text reproduced on acetate for overhead projection.

Course Management Systems

PageOut is specifically designed to help you with your individual course needs. PageOut assists you in integrating your syllabus with *Chemistry in Context* and state-of-the-art new media tools. At the heart of PageOut you find integrated multimedia and a full-scale Online Learning Center.

The content from the Online Learning Center is available in WebCT and Blackboard on request to your sales representative.

Student Resources

Laboratory Manual

The laboratory manual, compiled and edited by Wilmer Stratton, includes experiments using microscale equipment and common materials. The experiments have been chosen and designed to reflect and amplify the contents of *Chemistry in Context*. Chemical information about the world around us can be obtained with simple chemical equipment and procedures.

Online Learning Center

The Online Learning Center (OLC) (www.mhhe.com/cic) is a comprehensive, exclusive web site that provides the student access to the Web-related activities in selected Consider This and Sceptical Chymist questions marked by the icon and the end-of-chapter questions marked by icon.

New to the Online Learning Center is the Figures Alive! interactives (marked by an icon near the figure in the text) that lead students through the discovery of various layers of knowledge inherent in the figure.

The web site also includes quizzing and other study tools for the students.

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Guided Tour

Real-Life Applications

The material is presented to students in a manner that demonstrates how chemistry actually impacts their lives. The focal point of each chapter is a real-word societal issue with significant chemical context.

198 **Chapter Five**

A "Right-to-Know" Report about a community's water supply.

So begins an article entitled "On Tap or Bottled, Pursuing Purer Water" that appeared in the personal health column of the *New York Times.* Similar questions about water quality may be raised about your water supply, even about the water supply for your college or university. You may even have received a Right-To-Know Report, also called a Consumer Confidence Report. The Safe Drinking Water Act as amended in 1996 mandates that such reports be delivered once a year to consumers of water from community water systems, public or private. As a person studying chemistry, you are in a good position to understand the meaning of the measurements being reported and the standards of quality that must be met. You might be asked to help friends or family understand the measurements and conclusions reached in a report they might receive about their water quality.

Such reports raise a number of questions that we address in this chapter. What is a regulated chemical and what are its maximum levels allowed in drinking water? How do such chemicals get into drinking water? Should we be concerned about any of them? Who establishes the rules? What are the major provisions of the Safe Drinking Water Act of 1996? What options are there for alternative sources of drinking water? In particular, why is bottled water cited as the most likely alternative? Are all water filtration systems equally effective?

Water is, indeed, a special compound. In spite of its commonness, this colorless liquid called water is amazing stuff. The noted anthropologist and essayist Loren Eiseley speaks poetically of the wonders of it: "If there is magic on this planet, it is contained in water . . . Its substance reaches everywhere; it touches the past and prepares the future; it moves under the poles and wanders thinly in the heights of the air." Arguably, water is the most important chemical compound on the face of the Earth. In fact, it covers about 70% of that face, giving the planet the lovely blue color in the famous "blue marble" photos taken from outer space by astronauts. Water is essential to all living species; without it humans would die within a week. Our bodies are approximately 60% water, blood is at least 50% water, and a human brain is an astonishing 77% water! Water is so important to life as we know it that speculation about life elsewhere in the universe hinges first and foremost on the availability of water. Water refreshes us, dominates weather systems, provides for many types of recreation on and in it, and even gives us aesthetic and relaxing pleasures.

• See the opening of Chapter 1 for a "Blue Marble" photo.

CHAPTER OVERVIEW

Although we generally take water for granted, it is a remarkable chemical compound with unique properties that account for its essential life-supporting role. In this chapter, we will consider water from the perspective of those who drink it. First a question of aesthetics: What makes a glass of water pleasing to the eye and to the palate? There is more to water, however, than can be seen or tasted. Unseen impurities in water, depending on their identities and amounts, can impart a crisp, fresh taste or produce an unpleasant illness. And so, we next look at water as a solvent and at some of the things that may be dissolved in drinking water. How much of a substance dissolves in water makes concentration an important part of the story. The concentrations of substances dissolved in water can be expressed in several ways, including descriptions of the extremely low concentrations. To better comprehend aqueous solutions and why some sub-

In-Chapter Features

Your Turn, Consider This, and *Sceptical Chymist* are activities to practice skills, to raise issues for thought, and to use critical thinking in extending and applying chemical principles. *Your Turn* activities provide opportunities for students to practice a skill or calculation that has been illustrated in the text. *Consider This* questions are decision-making activities requiring risk-benefit analysis, consideration of opposing viewpoints, speculation on the consequences of a particular action, or formulation and defense of a personal position. The *Sceptical Chymist* activities require analytical skills in response to various statements and assertions made in the popular media.

Protecting the Ozone Layer 67

If more high-energy photons reach the surface of the Earth from the Sun, the potential for significant biological damage increases. All evidence shows that the average stratospheric ozone concentration has dropped significantly in the last 20 to 30 years. This phenomenon has been documented in many regions of the world, using data gathered from high-flying aircraft, ground-based systems, and satellites. Later in this chapter we will explore the special reasons why the observed percent ozone depletion is the greatest in the Antarctic. However, stratospheric ozone depletion means that the ability of the atmosphere to screen out UV radiation with wavelengths below 320 nm has decreased. Although this has happened to varying extents in different regions, living things are now exposed to greater intensities of potentially damaging radiation. Scientists have made calculations predicting that a given percent decrease in stratospheric ozone will increase the flux of biologically damaging UV radiation by twice that percentage. For example, a 6% decrease in stratospheric ozone could mean a 12% rise in skin cancer, especially the more easily treated form, non-melanoma skin cancers such as basal cell and squamous cell cancers. This condition is considerably more common among Caucasians than among those with more heavily pigmented skin. People of African and Indian origin are better equipped to withstand the high levels of UV radiation in the intense sunlight that strikes the Earth near the equator.

There is good evidence linking the incidence of non-melanoma skin cancers, the intensity of UV radiation, and latitude. For example, the disease generally becomes more prevalent as one moves farther south in the Northern Hemisphere (Figure 2.11).

2.17 Consider This: Geography of Skin Cancer

Many generations of immigrants have come to the United States. There are fair-skinned Northern Europeans, for example, who have settled in the area around San Antonio, TX; there are many other equally fair-skinned immigrants who have settled in the area around Seattle. Based on Figure 2.11, compare their relative risks of developing skin cancer. Identify several other factors that may affect the risk for any individual in these two populations.

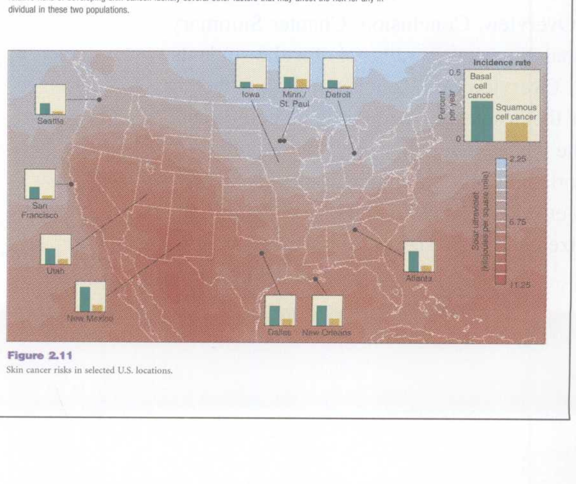
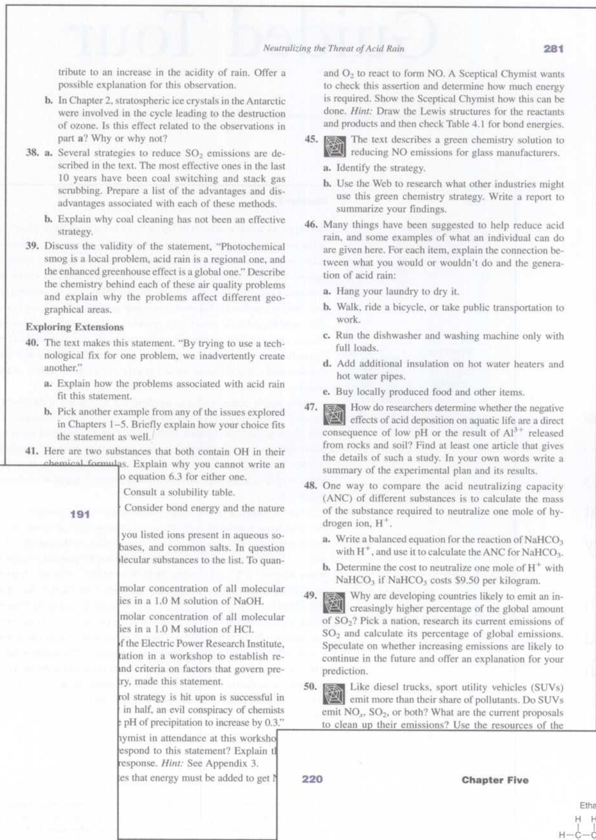


Figure 2.11
Skin cancer risks in selected U.S. locations.

Problem Solving

There are two main locations of problem-solving activities in *Chemistry in Context.* In-chapter problem solving is located in the *Your Turn, Consider This,* and *Sceptical Chymist* activities. End-of-chapter questions are divided into three categories—Emphasizing Essentials, Concentrating on Concepts, and Exploring Extensions.


Neutralizing the Threat of Acid Rain 281

tribute to an increase in the acidity of rain. Offer a possible explanation for this observation.

b. In Chapter 2, stratospheric ice crystals in the Antarctic were involved in the cycle leading to the destruction of ozone. Is this effect related to the observations in part a? Why or why not?

38. a. Several strategies to reduce SO_2 emissions are described in the text. The most effective ones in the last 10 years have been coal switching and stack gas scrubbing. Prepare a list of the advantages and disadvantages associated with each of these methods.

b. Explain why coal cleaning has not been an effective strategy.

39. Discuss the validity of the statement, "Photochemical smog is a local problem, acid rain is a regional one, and the enhanced greenhouse effect is a global one." Describe the chemistry behind each of these air quality problems and explain why the problems affect different geographical areas.

Exploring Extensions

40. The text makes this statement. "By trying to use a technological fix for one problem, we inadvertently create another."

a. Explain how the problems associated with acid rain fit this statement.

b. Pick another example from any of the issues explored in Chapters 1–5. Briefly explain how your choice fits the statement as well.

41. Here are two substances that both contain OH in their chemical formulas. Explain why you cannot write an ... o equation 6.3 for either one.

... Consult a solubility table.

... Consider bond energy and the nature ...

... you listed ions present in aqueous so... bases, and common salts. In question ... lecular substances to the list. To quan...

... molar concentration of all molecular ... ies in a 1.0 M solution of NaOH.

... molar concentration of all molecular ... ies in a 1.0 M solution of HCl.

... f the Electric Power Research Institute, ... tation in a workshop to establish re... nd criteria on factors that govern pre... ry, made this statement.

... rol strategy is hit upon is successful in ... in half, an evil conspiracy of chemists ... pH of precipitation to increase by 0.3."

... hymist in attendance at this worksho... espond to this statement? Explain ... response. *Hint:* See Appendix 3.

... es that energy must be added to get N...

and O_2 to react to form NO. A Sceptical Chymist wants to check this assertion and determine how much energy is required. Show the Sceptical Chymist how this can be done. *Hint:* Draw the Lewis structures for the reactants and products and then check Table 4.1 for bond energies.

45. The text describes a green chemistry solution to reducing NO emissions for glass manufacturers.

a. Identify the strategy.

b. Use the Web to research what other industries might use this green chemistry strategy. Write a report to summarize your findings.

46. Many things have been suggested to help reduce acid rain, and some examples of what an individual can do are given here. For each item, explain the connection between what you would or wouldn't do and the generation of acid rain:

a. Hang your laundry to dry it.

b. Walk, ride a bicycle, or take public transportation to work.

c. Run the dishwasher and washing machine only with full loads.

d. Add additional insulation on hot water heaters and hot water pipes.

e. Buy locally produced food and other items.

47. How do researchers determine whether the negative effects of acid deposition on aquatic life are a direct consequence of low pH or the result of Al^{3+} released from rocks and soil? Find at least one article that gives the details of such a study. In your own words write a summary of the experimental plan and its results.

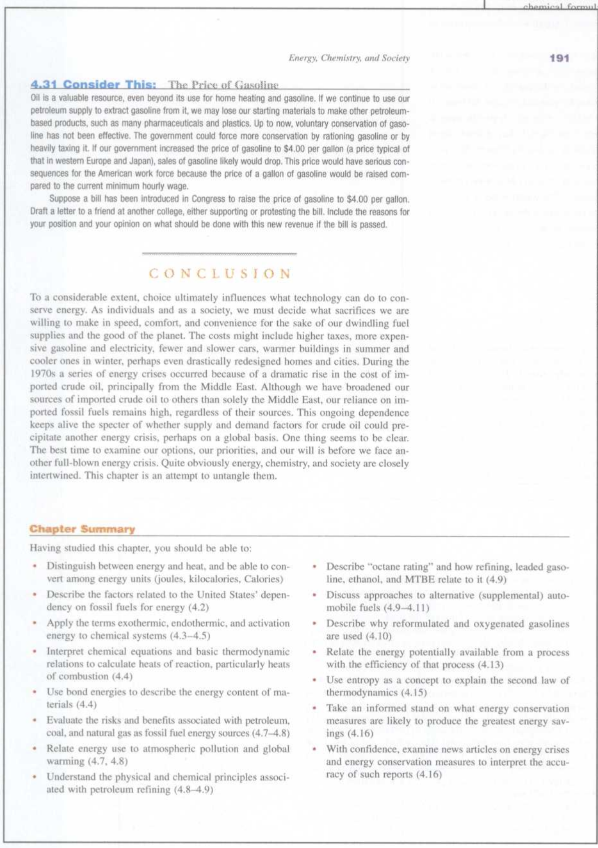
48. One way to compare the acid neutralizing capacity (ANC) of different substances is to calculate the mass of the substance required to neutralize one mole of hydrogen ion, H^+.

a. Write a balanced equation for the reaction of $NaHCO_3$ with H^+, and use it to calculate the ANC for $NaHCO_3$.

b. Determine the cost to neutralize one mole of H^+ with $NaHCO_3$ if $NaHCO_3$ costs $9.50 per kilogram.

49. Why are developing countries likely to emit an increasingly higher percentage of the global amount of SO_2? Pick a nation, research its current emissions of SO_2 and calculate its percentage of global emissions. Speculate on whether increasing emissions are likely to continue in the future and offer an explanation for your prediction.

50. Like diesel trucks, sport utility vehicles (SUVs) emit more than their share of pollutants. Do SUVs emit NO_x, SO_2, or both? What are the current proposals to clean up their emissions? Use the resources of the ...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4.31 Consider This: The Price of Gasoline

Oil is a valuable resource, even beyond its use for home heating and gasoline. If we continue to use our petroleum supply to extract gasoline from it, we may lose our starting materials to make other petroleum-based products, such as many pharmaceuticals and plastics. Up to now, voluntary conservation of gasoline has not been effective. The government could force more conservation by rationing gasoline or by heavily taxing it. If our government increased the price of gasoline to $4.00 per gallon (a price typical of that in western Europe and Japan), sales of gasoline likely would drop. This price would have serious consequences for the American work force because the price of a gallon of gasoline would be raised compared to the current minimum hourly wage.

Suppose a bill has been introduced in Congress to raise the price of gasoline to $4.00 per gallon. Draft a letter to a friend at another college, either supporting or protesting the bill. Include the reasons for your position and your opinion on what should be done with this new revenue if the bill is passed.

CONCLUSION

To a considerable extent, choice ultimately influences what technology can do to conserve energy. As individuals and as a society, we must decide what sacrifices we are willing to make in speed, comfort, and convenience for the sake of our dwindling fuel supplies and the good of the planet. The costs might include higher taxes, more expensive gasoline and electricity, fewer and slower cars, warmer buildings in summer and cooler ones in winter, perhaps even drastically redesigned homes and cities. During the 1970s a series of energy crises occurred because of a dramatic rise in the cost of imported crude oil, principally from the Middle East. Although we have broadened our sources of imported crude oil to others than solely the Middle East, our reliance on imported fossil fuels remains high, regardless of their sources. This ongoing dependence keeps alive the specter of whether supply and demand factors for crude oil could precipitate another energy crisis, perhaps on a global basis. One thing seems to be clear. The best time to examine our options, our priorities, and our will is before we face another full-blown energy crisis. Quite obviously energy, chemistry, and society are closely intertwined. This chapter is an attempt to untangle them.

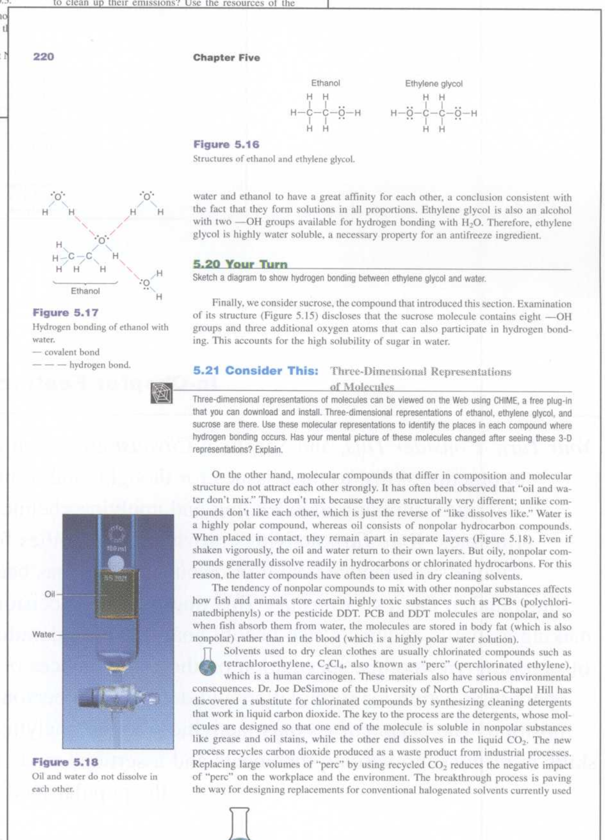
Chapter Summary

Having studied this chapter, you should be able to:

- Distinguish between energy and heat, and be able to convert among energy units (joules, kilocalories, Calories)
- Describe the factors related to the United States' dependency on fossil fuels for energy (4.2)
- Apply the terms exothermic, endothermic, and activation energy to chemical systems (4.3–4.5)
- Interpret chemical equations and basic thermodynamic relations to calculate heats of reaction, particularly heats of combustion (4.4)
- Use bond energies to describe the energy content of materials (4.4)
- Evaluate the risks and benefits associated with petroleum, coal, and natural gas as fossil fuel energy sources (4.7–4.8)
- Relate energy use to atmospheric pollution and global warming (4.7, 4.8)
- Understand the physical and chemical principles associated with petroleum refining (4.8–4.9)
- Describe "octane rating" and how refining, leaded gasoline, ethanol, and MTBE relate to it (4.9)
- Discuss approaches to alternative (supplemental) automobile fuels (4.9–4.11)
- Describe why reformulated and oxygenated gasolines are used (4.10)
- Relate the energy potentially available from a process with the efficiency of that process (4.13)
- Use entropy as a concept to explain the second law of thermodynamics (4.15)
- Take an informed stand on what energy conservation measures are likely to produce the greatest energy savings (4.16)
- With confidence, examine news articles on energy crises and energy conservation measures to interpret the accuracy of such reports (4.16)

Pedagogy

Chapter Overview, Conclusion, Chapter Summary, and Marginal Notes are study tools for the students. The Chapter Overview and Conclusion draw together the major themes at the beginning and end of each chapter. The Chapter Summary calls attention to the most important skills and applications developed in the chapter. Marginal Notes are used to succinctly summarize and emphasize key points or to link to sections in other chapters.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Ethanol / Ethylene glycol

Figure 5.16 Structures of ethanol and ethylene glycol.

Figure 5.17 Hydrogen bonding of ethanol with water. — covalent bond; – – – hydrogen bond.

water and ethanol to have a great affinity for each other, a conclusion consistent with the fact that they form solutions in all proportions. Ethylene glycol is also an alcohol with two —OH groups available for hydrogen bonding with H_2O. Therefore, ethylene glycol is highly water soluble, a necessary property for an antifreeze ingredient.

5.20 Your Turn

Sketch a diagram to show hydrogen bonding between ethylene glycol and water.

Finally, we consider sucrose, the compound that introduced this section. Examination of its structure (Figure 5.15) discloses that the sucrose molecule contains eight —OH groups and three additional oxygen atoms that can also participate in hydrogen bonding. This accounts for the high solubility of sugar in water.

5.21 Consider This: Three-Dimensional Representations of Molecules

Three-dimensional representations of molecules can be viewed on the Web using CHIME, a free plug-in that you can download and install. Three-dimensional representations of ethanol, ethylene glycol, and sucrose are there. Use these molecular representations to identify the places in each compound where hydrogen bonding occurs. Has your mental picture of these molecules changed after seeing these 3-D representations? Explain.

On the other hand, molecular compounds that differ in composition and molecular structure do not attract each other strongly. It has often been observed that "oil and water don't mix." They don't mix because they are structurally very different; unlike compounds don't like each other, which is just the reverse of "like dissolves like." Water is a highly polar compound, whereas oil consists of nonpolar hydrocarbon compounds. When placed in contact, they remain apart in separate layers (Figure 5.18). Even if shaken vigorously, the oil and water return to their own layers. But oily, nonpolar compounds generally dissolve readily in hydrocarbons or chlorinated hydrocarbons. For this reason, the latter compounds have often been used in dry cleaning solvents.

The tendency of nonpolar compounds to mix with other nonpolar substances affects how fish and animals store certain highly toxic substances such as PCBs (polychlorinatedbiphenyls) or the pesticide DDT. PCB and DDT molecules are nonpolar, and so when fish absorb them from water, the molecules are stored in body fat (which is also nonpolar) rather than in the blood (which is a highly polar water solution).

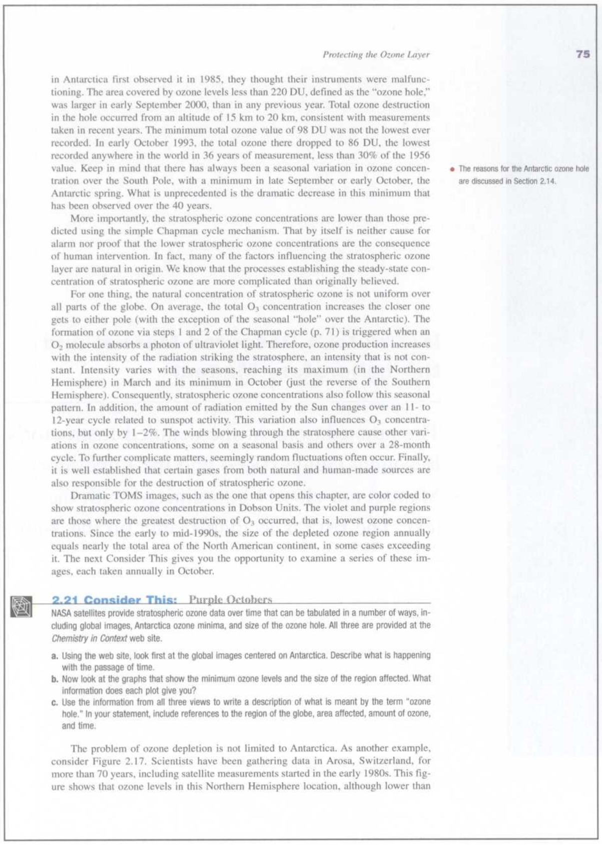
Solvents used to dry clean clothes are usually chlorinated compounds such as tetrachloroethylene, C_2Cl_4, also known as "perc" (perchlorinated ethylene), which is a human carcinogen. These materials also have serious environmental consequences. Dr. Joe DeSimone of the University of North Carolina-Chapel Hill has discovered a substitute for chlorinated compounds by synthesizing cleaning detergents that work in liquid carbon dioxide. The key to the process are the detergents, whose molecules are designed so that one end of the molecule is soluble in nonpolar substances like grease and oil stains, while the other end dissolves in the liquid CO_2. The new process recycles carbon dioxide produced as a waste product from industrial processes. Replacing large volumes of "perc" by using recycled CO_2 reduces the negative impact of "perc" on the workplace and the environment. The breakthrough process is paving the way for designing replacements for conventional halogenated solvents currently used

Oil / Water

Figure 5.18 Oil and water do not dissolve in each other.

Green Chemistry

Green chemistry principles are introduced and used repeatedly to demonstrate creative contemporary chemical approaches that minimize and prevent generation of hazardous substances. An icon identifies areas within the text where green chemistry principles are discussed.



in Antarctica first observed it in 1985, they thought their instruments were malfunctioning. The area covered by ozone levels less than 220 DU, defined as the "ozone hole," was larger in early September 2000, than in any previous year. Total ozone destruction in the hole occurred from an altitude of 15 km to 20 km, consistent with measurements taken in recent years. The minimum total ozone value of 98 DU was not the lowest ever recorded. In early October 1993, the total ozone there dropped to 86 DU, the lowest recorded anywhere in the world in 36 years of measurement, less than 30% of the 1956 value. Keep in mind that there has always been a seasonal variation in ozone concentration over the South Pole, with a minimum in late September or early October, the Antarctic spring. What is unprecedented is the dramatic decrease in this minimum that has been observed over the 40 years.

- The reasons for the Antarctic ozone hole are discussed in Section 2.14.

More importantly, the stratospheric ozone concentrations are lower than those predicted using the simple Chapman cycle mechanism. That by itself is neither cause for alarm nor proof that the lower stratospheric ozone concentrations are the consequence of human intervention. In fact, many of the factors influencing the stratospheric ozone layer are natural in origin. We know that the processes establishing the steady-state concentration of stratospheric ozone are more complicated than originally believed.

For one thing, the natural concentration of stratospheric ozone is not uniform over all parts of the globe. On average, the total O_3 concentration increases the closer one gets to either pole (with the exception of the seasonal "hole" over the Antarctic). The formation of ozone via steps 1 and 2 of the Chapman cycle (p. 71) is triggered when an O_2 molecule absorbs a photon of ultraviolet light. Therefore, ozone production increases with the intensity of the radiation striking the stratosphere, an intensity that is not constant. Intensity varies with the seasons, reaching its maximum (in the Northern Hemisphere) in March and its minimum in October (just the reverse of the Southern Hemisphere). Consequently, stratospheric ozone concentrations also follow this seasonal pattern. In addition, the amount of radiation emitted by the Sun changes over an 11- to 12-year cycle related to sunspot activity. This variation also influences O_3 concentrations, but only by 1–2%. The winds blowing through the stratosphere cause other variations in ozone concentrations, some on a seasonal basis and others over a 28-month cycle. To further complicate matters, seemingly random fluctuations often occur. Finally, it is well established that certain gases from both natural and human-made sources are also responsible for the destruction of stratospheric ozone.

Dramatic TOMS images, such as the one that opens this chapter, are color coded to show stratospheric ozone concentrations in Dobson Units. The violet and purple regions are those where the greatest destruction of O_3 occurred, that is, lowest ozone concentrations. Since the early to mid-1990s, the size of the depleted ozone region annually equals nearly the total area of the North American continent, in some cases exceeding it. The next Consider This gives you the opportunity to examine a series of these images, each taken annually in October.

2.21 Consider This: Purple Octobers

NASA satellites provide stratospheric ozone data over time that can be tabulated in a number of ways, including global images, Antarctica ozone minima, and size of the ozone hole. All three are provided at the *Chemistry in Context* web site.

a. Using the web site, look first at the global images centered on Antarctica. Describe what is happening with the passage of time.
b. Now look at the graphs that show the minimum ozone levels and the size of the region affected. What information does each plot give you?
c. Use the information from all three views to write a description of what is meant by the term "ozone hole." In your statement, include references to the region of the globe, area affected, amount of ozone, and time.

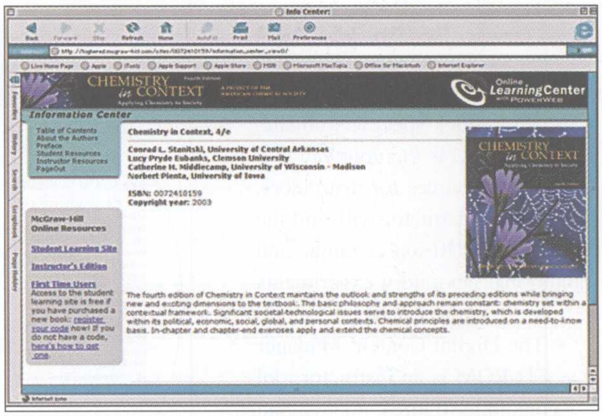
The problem of ozone depletion is not limited to Antarctica. As another example, consider Figure 2.17. Scientists have been gathering data in Arosa, Switzerland, for more than 70 years, including satellite measurements started in the early 1980s. This figure shows that ozone levels in this Northern Hemisphere location, although lower than

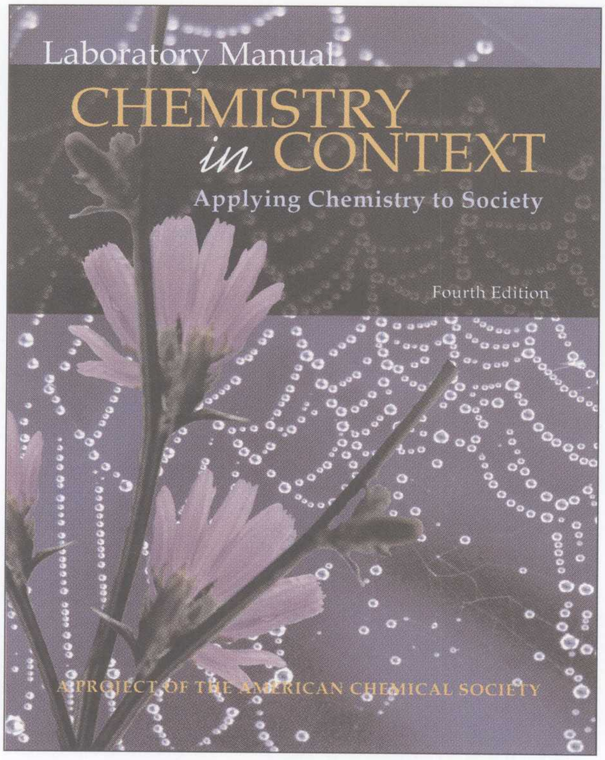
Web-based Activities

Web-based activities are built into the in-chapter and chapter-end questions. Students can explore a variety of issues, including evaluating the accuracy of various web sites. The Web icon marks the activities and questions.

Online Learning Center

The *Chemistry in Context* Online Learning Center is a vital component of *Chemistry in Context* and contains an abundance of information for the student and the instructor. Students use Web exercises and Figures Alive! interactives that are integrated into the text. New to this edition is the addition of quiz questions for student self-assessment.





Instructor's Resource Manual and the Laboratory Manual

The new editions of the detailed Instructor's Resource Guide (IRG) and the Laboratory Manual are closely coordinated with the text. The IRG is available only on the Web.

Instructor Media

- Online Learning Center (OLC) is a secure, book-specific web site. The OLC is the doorway to a library of resources for instructors. The instructor will find the Instructor's Resource Guide and additional laboratory experiments in the Instructor Center.
- The Digital Content Manager CD-ROM is an instructor tool containing figures, photos, and tables from the text to use in PowerPoint presentations.
- Course Management Systems—PageOut, WebCT, and Blackboard—are available.

Brief Contents

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