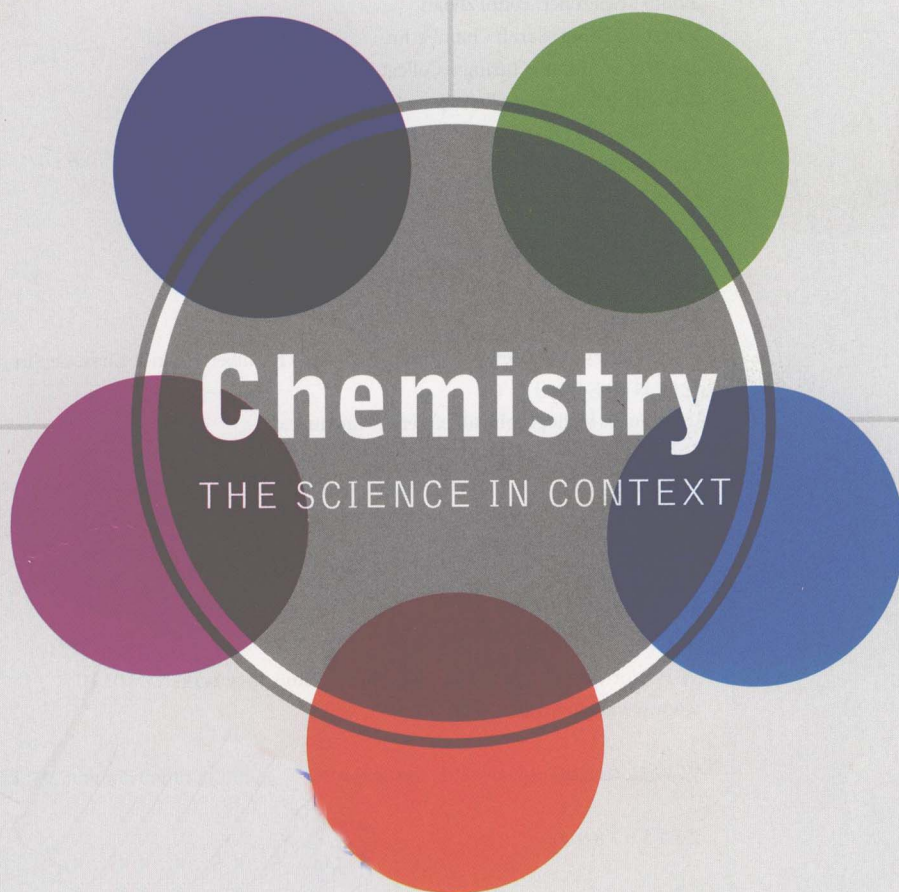


Chemistry

THE SCIENCE IN CONTEXT



Thomas R. Gilbert Rein V. Kirss Geoffrey Davies



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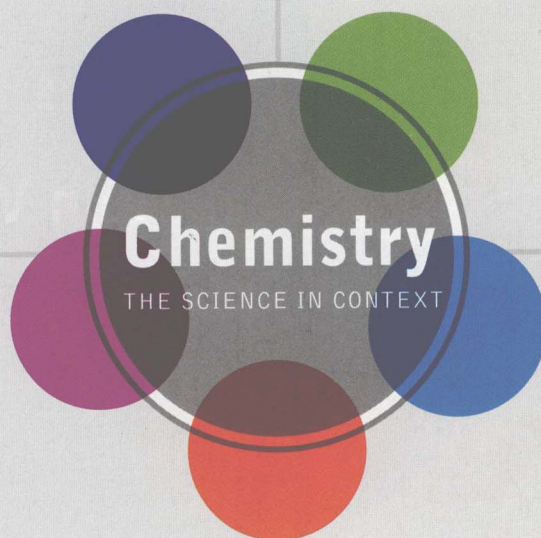
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To our families

Thomas R. Gilbert has a B.S. in chemistry from Case Western Reserve University in 1951. He received his M.S. in chemistry from M.I.T. in 1953. After 10 years with the Research Department of the New England Petroleum Administration in Boston, he joined the faculty in Northampton, Massachusetts, where he is currently Associate Professor of Chemistry and Director of the Graduate Program in Chemistry. He is also Associate Director for Academic Affairs of the School of Education. His research interests are in environmental analytical chemistry and in the chemistry of natural products. He teaches general and organic chemistry for majors and non-majors. He is also co-author of a textbook on environmental chemistry, published by McGraw-Hill. He is also co-author of a textbook on analytical chemistry, published by McGraw-Hill.

Thomas R. Gilbert has a B.S. in chemistry from Case Western Reserve University in 1951. He received his M.S. in chemistry from M.I.T. in 1953. After 10 years with the Research Department of the New England Petroleum Administration in Boston, he joined the faculty in Northampton, Massachusetts, where he is currently Associate Professor of Chemistry and Director of the Graduate Program in Chemistry. He is also Associate Director for Academic Affairs of the School of Education. His research interests are in environmental analytical chemistry and in the chemistry of natural products. He teaches general and organic chemistry for majors and non-majors. He is also co-author of a textbook on environmental chemistry, published by McGraw-Hill. He is also co-author of a textbook on analytical chemistry, published by McGraw-Hill.

Geoffrey Davies has a B.Sc. (Hons.) and D.Sc. degree in chemistry from Birmingham University, England. He joined the faculty at Northampton University in 1971 after postgraduate research on the kinetics of organic reactions at the University of Bristol and the University of Kent at Canterbury. He is now Professor of Chemistry and Director of the School of Chemistry. His research group has explored experimental and theoretical aspects of the kinetics of organic reactions, particularly in the area of the kinetics of the reaction of organic peroxides with organic compounds. He is also co-author of a textbook on organic chemistry, published by McGraw-Hill. He is also co-author of a textbook on physical chemistry, published by McGraw-Hill.

1981, 1982, and 1983

About the Authors



Thomas R. Gilbert has a B.S. in chemistry from Clarkson College and a Ph.D. in analytical chemistry from M.I.T. After 10 years with the Research Department of the New England Aquarium in Boston, he joined the faculty of Northeastern University, where he is currently Associate Professor of Chemistry and Education and Associate Director for Academic Affairs of the School of Education. His research interests are in environmental analytical chemistry and science education. He teaches general and analytical chemistry for majors other than chemistry, as well as graduate courses in analytical and environmental chemistry; he also conducts professional-development workshops and preservice courses in science education for pre-K–12 teachers.



Rein V. Kirss received both a B.S. in chemistry and a B.A. in history in 1981 as well as an M.A. in chemistry in 1982 from SUNY Buffalo. He received his Ph.D. in inorganic chemistry from the University of Wisconsin-Madison in 1986, where the seeds for this textbook were undoubtedly planted. After 2 years of postdoctoral study at the University of Rochester, he spent a year at Advanced Technology Materials, Inc., before returning to academics at Northeastern University in 1989. He is an associate professor of chemistry with an active research interest in organometallic chemistry. In addition to this textbook, he is coauthor with Thomas Gilbert of *Why Chemistry?*



Geoffrey Davies has B.Sc., Ph.D., and D.Sc. degrees in chemistry from Birmingham University, England. He joined the faculty at Northeastern University in 1971 after postdoctoral research on the kinetics of very rapid reactions at Brandeis University, Brookhaven National Laboratory, and the University of Kent at Canterbury. He is now Matthews Distinguished University Professor at Northeastern. His research group has explored experimental and theoretical redox chemistry, alternative fuels, transmetalation reactions, tunable metal-zeolite catalysts and, most recently, the chemistry of humic substances, the essential brown animal and plant metabolites in sediments, soils, and water. He edits a column on experiential and study-abroad education in the *Journal of Chemical Education* and a book series on humic substances. He is a Fellow of the Royal Society of Chemistry and was awarded Northeastern's Excellence in Teaching Award in 1981, 1993, and 1999.

Preface

Understanding chemical principles leads to a better understanding of a diverse range of issues, from environmental concerns to health-care choices to the geopolitics of resource use. Although few of the students who take general chemistry are planning careers in the chemical sciences, many are interested in these and other issues that are connected to chemistry. The challenge facing those of us who teach general chemistry is how to effectively make these connections. It is important that we do because students truly learn chemical principles only when they construct their own meaning of them, and that construction process requires a desire to construct as well as familiar foundation material on which to build. Introducing chemical principles in discussions of issues drawn from the physical and social sciences can provide both the desire to create meaning and the foundation on which to create it. It also delivers the message that chemistry truly is the central science. Many of us base our teaching on this principle. *Chemistry: The Science in Context* was written to support that teaching.

This book evolved from a supplement called *Why Chemistry?*, which we wrote in the early 1990s to connect the chemical principles in a standard general chemistry book to contemporary issues. After a number of years of teaching with this combination of materials, we decided that our students would be best served by a single textbook that seamlessly weaves the themes and issues in *Why Chemistry?* into the main narrative of a general chemistry textbook.

Thus, *Chemistry: The Science in Context* presents innovation within a familiar framework. The breadth of coverage and level of detail are appropriate for a general chemistry audience of science, pre-med, and engineering majors, but its blend of chemical principles with an interesting story line is distinctive. The book is innovative in several ways:

It is contextual.

Chemistry: The Science in Context brings chemistry alive by introducing chemical principles within the context of issues and topics that interest students, incorporating ideas and applications from fields as diverse as biology, nutrition, environmental sciences, astronomy, and geology. Chemical principles are presented as they are needed to explain the atomic and molecular foundations of the topics under discussion. This approach makes chemistry both more interesting and more relevant to other courses in which the students are enrolled, illustrating that chemistry is truly the central science. This innovative book is both engaging


and comprehensive, and it is adaptable to a wide range of courses and syllabi. Sample exercises and end-of-chapter problems include many conceptual and open-ended questions, some of them quite challenging, but they are interspersed with traditional quantitative problems. By providing this balance of conceptual questions and quantitative problem solving, we achieve the mathematical rigor of a traditional course while enhancing the students' understanding of important concepts.

It makes connections to the other sciences.

Chemistry is inherently interesting to most chemistry professors but seems boring or irrelevant to many students because few textbooks do an effective job of building intellectual bridges to biology, environmental sciences, and other areas that interest them. *Chemistry: The Science in Context* builds these bridges by incorporating themes that span the sciences. The first chapter, for example, defines terms and introduces data-manipulation techniques—unit conversions, significant figures, and so forth—in a discussion of the origins of the universe and topics drawn from cosmology and particle physics. These connections and others show the centrality of chemistry among the sciences. They also exemplify hot areas of current scientific inquiry. As former American Chemical Society president Ron Breslow and many others have pointed out, the greatest growth in chemical research is taking place at its intellectual borders: in molecular biology and the synthesis and characterization of advanced materials. These themes should therefore receive more than parenthetical treatment in general chemistry textbooks. Connections to other sciences are interwoven throughout the chapters, reinforcing concepts and themes that span the sciences. In addition, there is a capstone chapter on materials chemistry, and biochemistry is woven into several chapters.

Its contextual threads provide a more coherent view of chemistry.

General chemistry is often presented as a grab bag of seemingly unconnected topics. This textbook addresses that problem in several ways. The book has an overarching theme that might be called the “evolution of matter”: from the formation of subatomic particles, to nuclei of progressively bigger mass, to atomic structure, to theories of molecular bonding, and finally to the formation of nat-

ural and synthetic polymers. Important connections between topics are highlighted with a Connections icon  and marginal annotation. Among the organizational improvements is the presentation of atomic structure within the context of a discussion of how compounds are formed and why elements have the properties that they do. A unique section on energy presents a cohesive view of thermochemistry and thermodynamics. Descriptive chemistry is integrated into each chapter in “The Chemistry of...” boxes that relate to the chemical and contextual topics. A more complete description of the contents of each chapter appears in “How This Book Is Organized.”

It emphasizes the spirit of inquiry that is a hallmark of science.

Chemistry: The Science in Context fosters a spirit of inquiry by emphasizing the importance of developing good questions and by describing how scientists figure things out and how our understanding of the chemical principles has evolved through time. Many textbooks present chemistry as a collection of facts and problem-solving algorithms to be learned or at least memorized. Throughout our book, we try to explain how our understanding of the properties of matter has evolved. Students are frequently asked why a statement is true or why an outcome was observed. As they engage in these intellectual exercises, they begin to acquire a conceptual understanding of chemical principles and a fascination for science (and chemistry) as a way of understanding how nature works and why chemical reactions take place. The emphasis on inquiry is highlighted in a magazine-style format. This feature helps students build the skills to move away from exclusive reliance on memorization and toward conceptual understanding.

PEDAGOGICAL FEATURES

The text incorporates several teaching aids that help students identify important chemical ideas and make connections between them. Sample Exercises lead students through solutions in a conversational and interactive way, helping them build confidence in their own problem-solving skills, which they can test in the paired Practice Exercises. Concept Tests probe students' understanding

of chemical principles, and both conceptual and quantitative exercises are featured in extensive end-of-chapter problem sets. Details of the pedagogical features appear in the section titled “How to Use This Book.”

HOW THIS BOOK IS ORGANIZED

Descriptive chemistry is integrated into each chapter in “The Chemistry of...” boxes, which relate to the chemical and contextual topics. See page xx for a list of these boxes.

Chapter 1 Matter and Its Origins An examination of the theories for the creation of the Universe is the context for introducing basic concepts about matter, atoms, and the scientific method. The properties and energy of electromagnetic radiation (light) are introduced as needed to evaluate the supporting evidence for the Big Bang theory. The importance and limitations (significant figures, accuracy, and precision) of measurements are described as well as the common units and their interconversion.

Chapter 2 Nuclear Chemistry and the Origins of the Elements This optional chapter offers a unique opportunity to grab students’ interest early in the course because it is new material for most students. Fusion, fission, and the energies associated with these processes are used to explain the origins of the elements. Nuclear chemistry is often front-page news and offers many opportunities to relate nuclear chemistry to medical and other technologies.

Chapter 3 Electrons and Electromagnetic Radiation This chapter examines the historical development of the nuclear and electronic structure of atoms. The properties of light introduced in Chapter 1 are used to trace the evolution of electronic structure from the Bohr model to the quantum mechanical picture. The chapter is constructed in a fashion that allows it to be taught after Chapters 4 and 5.

Chapter 4 Stoichiometry and the Formation of Earth Chapter 4 begins to assemble atoms of elements into compounds in the context of how the solar system

and Earth were formed some 4.5 billion years ago. The nomenclature of binary compounds and those with polyatomic anions, determination of percent composition, and empirical formulas are illustrated by using compounds found in Earth’s core, mantle, and crust (lithosphere). Stoichiometric relations in chemical reactions and limiting reagents are introduced through a discussion of chemistry of Earth’s primitive atmosphere.

Chapter 5 Solution Chemistry and the Hydrosphere Earth’s oceans and other bodies of water (hydrosphere) serve as the context for solution chemistry. The composition of seawater and fresh water is used to introduce concentration units. The properties of electrolytes, their effect on the colligative properties of solution, and solution stoichiometry (titrations) are presented by using environmental themes. The classification of chemical reactions (acid–base, redox, precipitation, and ion exchange) in solution is discussed in the context of chemical weathering and other reactions that have altered the composition of Earth’s surface and that control the composition of natural waters.

Chapter 6 Chemical Bonding and Atmospheric Molecules Small molecules in Earth’s upper atmosphere are the context for the introduction of covalent bonding, Lewis structures, resonance, and molecular-orbital theory. Ozone and carbon dioxide are featured prominently because of students’ familiarity with issues of air quality and depletion of the ozone layer. Electron diffraction is used to provide experimental evidence for the molecular structures presented in this chapter.

Chapter 7 Molecular Shape and the Greenhouse Effect As a continuation of the theme of Chapter 6, trace molecules in the lower atmosphere (nitrogen and sulfur oxides) are used to examine Lewis structures that do not follow the octet rule. Evidence for odd-electron molecules is presented in an optional section of ESR spectroscopy. Concerns about global warming on this planet create the need to explain why carbon dioxide is such a potent greenhouse gas in an optional section on IR spectroscopy. The explanation also includes coverage of polarity, molecular geometry, (VSEPR) valence-bond theory, hybrid orbitals, and permanent dipole moments.

Chapter 8 Properties of Gases and the Air That We Breathe

Continuing the discussion of atmospheric compounds, we turn to the properties of gases on the molecular level. The ideal-gas law and Boyle's, Charles's, Dalton's, and Graham's laws are presented in the context of the air that we breathe and the changes that a mountaineer experiences as a function of elevation or a diver experiences as a function of depth. The solubility of gases is relevant in both situations. Kinetic molecular theory leads us to the behavior of real gases and a consideration of the interactions between molecules.

Chapter 9 Intermolecular Forces and Liquids: Water, Nature's Universal Solvent

We begin by considering the intermolecular forces responsible for deviations from ideal-gas behavior and for the formation of liquids. Water, nature's universal solvent, is a natural context for this discussion. We also examine the role of intermolecular forces on physical properties (boiling point, vapor pressure, viscosity, and capillary action) of water and seawater, a solution first encountered in Chapter 5. The chapter ends with an introduction to phase diagrams, setting the stage for the investigation of solids.

Chapter 10 The Solid State: A Molecular View of Gems and Minerals

The solid-state structures (unit cells and close-packed structures) of ionic and covalent compounds (network solids) are described by using examples drawn from earlier chapters. Evaporated seawater produces binary ionic compounds, whereas Earth's crust contains more-complicated structures. The origin, location, and occupancy of holes in close-packed structures are described. The band theory of bonding in solid materials is presented, as well as other theories of metallic bonding. This chapter also examines the structure and color (crystal field theory) of gemstones as examples of valuable materials obtained from the crust.

Chapter 11 Thermochemistry and the Quest for Energy

Students are introduced to thermochemistry by examining the combustion of familiar fuels: natural gas and propane. This chapter covers the origin of the heat of combustion (bond energies), heats of formation, the flow of heat to and from a system, enthalpy, and work. Calorimetry and Hess's law are presented as meth-

ods of determining the enthalpies of reaction. The calculation of fuel values appears late in the chapter. A connection is made to the problems associated with combustion (CO_2) mentioned in Chapters 6 and 7, and the possibility of using alternate fuels is discussed.

Chapter 12 Energy and Organic Chemistry

This introductory organic chemistry chapter builds on the topics introduced in Chapter 11 in the context of issues related to the availability and environmental impact of gasoline consumption. The structures (isomerism) and nomenclature of alkanes, alkenes, alkynes, and aromatic hydrocarbons present in hydrocarbon fuels are described. The structure and function of carbohydrates and cellulose in wood and wood products (alcohols, methane from the biomass) also are explored. Hydrogen and hydrogen storage are discussed as a possible solution to energy needs.

Chapter 13 Entropy and Free Energy and Fueling the Human Engine

This chapter begins with the question of why endothermic reactions take place as a way of introducing the concepts of entropy, free energy, and the connection between enthalpy, entropy, temperature, and free energy. A consideration of the thermodynamics of solution allows for a review of intermolecular forces, whereas a discussion of proteins and fats reviews the role of Hess's law in determining how carbohydrates, proteins, and fats are catabolized and in determining the free energy of these processes.

Chapter 14 Chemical Kinetics and Urban Air Pollution

This chapter continues the discussion of the environmental impacts of fossil-fuel combustion begun in Chapter 11. With smog formation as the context, the kinetics of nitrogen oxide formation are examined. With a careful choice of reactions, average and instantaneous rates are contrasted. Both the method of initial rates and the integrated rate laws are introduced. The role of mechanism on the rate law is presented. The effect of temperature and catalysts on reaction rates is described, and the potential for heterogeneous catalysis to reduce smog formation is discussed.

Chapter 15 Chemical Equilibrium and Why Smog Persists

The reactions responsible for smog formation reach equilibrium, a convenient context for introducing

the concepts of equilibrium, equilibrium constants, and the related calculations without disrupting the story begun in Chapter 14. Le Châtelier's principle is applied to important reactions in the troposphere. We make the connection between equilibrium constants and free energy, which is possible only by the introduction of ΔG two chapters earlier.

Chapter 16 Equilibrium in the Aqueous Phase and Acid Rain

Shifting our focus from gas-phase nitrogen oxides to sulfur oxides, acid-base equilibrium is introduced in the context of acid precipitation. The calculation of pH for strong acid solutions (SO_2 forming sulfuric acid) and weak acids (CO_2 forming carbonic acid) is directly related to combustion processes described just a few chapters earlier. The effects of acid precipitation allow the introduction of buffers and solubility products (K_{sp}) for crust minerals. Titrations, first introduced in Chapter 5, are revisited. Weak bases present in the environment serve to introduce base equilibria.

Chapter 17 Electrochemistry and Electrical Energy

In this chapter, electrochemistry is presented as a solution to the problems associated with hydrocarbon combustion. The oxidation-reduction reactions that take place in batteries are discussed in the context of electric vehicles and portable electronic devices. The amount of electricity available (EMF) and the effects of concentration (Nernst equation) and temperature on the cell potential are described. The chapter ends with a section of fuel-cell technology, bringing to a close the story begun in Chapter 11 on energy use in industrial societies.

Chapter 18 Materials Chemistry: Past, Present, and Future

The observation that humans have relied on metals, ceramics, and fibers for millennia serves to organize a discussion of materials. The Copper and Bronze Ages form the context for an introduction to metallurgy, followed by a description of the iron and steel revolution. The structures and properties of alloys are presented as they appear in this historical sequence. A description of ceramic materials from clays to alumina to ceramic superconductors follows a similar historical progression. A discussion of the structure of natural fibers (silk, wool, and cotton) reviews the structures

of proteins presented in Chapter 13. Synthetic clothing fibers (nylon and polypropylene) serve as the context for discussing both addition and chain-polymerization reactions.

SUPPLEMENTS

For Instructors

Instructor's Resource Manual This thoughtfully developed resource helps teachers to integrate a multidisciplinary and contextual narrative approach into existing lectures and to apply this approach in helping to develop students' conceptual understanding and quantitative problem-solving skills. This manual includes lecture outlines and objectives, ideas for classroom demonstrations and discussion, a guide to available media resources, and more.

Transparencies Contains 275 color acetates.

Norton Media Library CD-ROM This collection of PowerPoint slides includes editable lecture outlines, all of the drawings from the textbook, selected photographs, and animations suitable for classroom display. Available on adoption.

Norton Resource Library This online resource offers Web-ready materials for your WebCT, Blackboard, or personal course page. Contents include test and quiz questions, lecture outlines, images from the textbook, animations, and elements from the student Web site. Available on adoption.

Test Item File The Test Item File includes approximately 2000 multiple-choice questions.

Computerized Test Item File This resource includes questions from the Test Item File and the Study Guide. Available for Macintosh and Windows.

Solutions Manual Worked solutions to all of the end of chapter problems are available for adopters. This item is not for sale. A separate student solutions manual contains solutions for the even-numbered end-of-chapter problems.

For Students

Student Web site (www.wwnorton.com/chemistry). Developed specifically for *Chemistry: The Science in Context*, this student resource includes helpful review materials, self-tests, animations, and assignable exercises that emphasize key concepts and help students build problem-solving skills.

Student CD-ROM An enhanced version of the Student Web site is also available in a convenient offline format.

Solutions Manual, Student Version Worked solutions to the even-numbered end-of-chapter problems are available for students.

Study Guide This resource includes helpful review materials, problem-solving tutorials, worked problems, additional exercises and solutions, and multiple-choice self-tests.

Acknowledgments

We are very grateful for the assistance of many people in taking this book from the concept stage to the shelf. First and foremost, we wish to thank our wives, Carla Verschoor (Wellesley College) and Beth Gilbert, for their patience, support, and suggestions during the writing of this text. We thank our children, Michael, Alex, and Emily Verschoor-Kirss; Michael, Christina, and Victoria Gilbert; and Warwick, Russell, and Claire Davies, for tolerating our absence and for helping us keep this project in perspective.

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tient and helpful advice. John Goodwin of Coastal Carolina University and Brian Gilbert of Linfield College brought creative energy and experience to the development of our Test-Item File. Through their careful scrutiny of the problems and writing of solutions, our Northeastern University colleague Ed Witten, along with Dan Durfey of the Naval Academy Preparatory School, helped us to refine the problem sets and strengthen the text. We were fortunate to draw on the experience of many individuals in creating our Instructor's Resource Manual: Alexander Pines of University of California at Berkeley, David Laws of The Lawrenceville School, Sandra Laursen of University of Colorado at Boulder, Sharon Anthony of The Evergreen State College, Tricia Ferrett of Carleton College, George Lisensky of Beloit College, and Heather Mernitz of Tufts University.

This book has benefited greatly from the care and thought that our many reviewers, listed on the next page, gave to their readings of our earlier drafts, both in written reviews and at focus groups. Their responses, questions, and concerns illuminated the task at hand and forced us to be clearer, more careful, and more creative. Several reviewers merit special mention for reading large sections of the text and providing invaluable guidance in the overall development of the text. We are particularly grateful to Professors Mortimer Hoffman, Kenneth Robertson, and David Laws for their thoughtful and detailed comments.

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			Thomas R. Gilbert
			Rein V. Kirss
			Geoffrey Davies
			Northeastern University, Boston

To the Student

HOW TO USE THIS BOOK

Here you will find a description of the major pedagogical features that have been carefully constructed to help you get the most out of your study of chemistry. A familiarity with the uses of these features will greatly aid you as you read and study from this book. We hope you will find them useful.

● **Chapter Title** Each chapter has a title and a subtitle, emphasizing the chemistry, on the one hand, and the "contextual" theme on the other.

● **Connections** Connections between important chemistry topics are illustrated schematically at the beginning of each chapter. Within the text, icons are paired with marginal notations to reinforce these connections.

5 Solution Chemistry
And the Hydrosphere

Earth's oceans and chemical reactions in solutions are essential to life as we know it.

Cross-Chapter Connections

A Look Ahead

In this chapter, chemical weathering and the processes that transform Earth's crust serve as an introduction to reactions in solution—particularly reactions between substances dissolved in nature's universal solvent, water. We examine solution concentration scales, the properties of solutions, and several categories of reactions in solution—including oxidation-reduction, neutralization, precipitation, hydrolysis, and ion exchange. This chapter completes our introduction to chemical reactions, chemical equations, and stoichiometry.

5.1 EARTH: THE WATER PLANET

From Chapter 4, we know that gases released by volcanic activity helped form Earth's primordial atmosphere. A major component of that atmosphere was water vapor. As Earth cooled, this vapor condensed and fell as torrents of highly acidic rain. Chemical reactions with the minerals of Earth's crust formed more water, and even more may have come from extraterrestrial sources, such as comets. A rare combination of atmospheric composition and proximity to the

Chapter Outline and "A Look Ahead" Each chapter begins with an outline that presents the organization of the chapter and a section called "A Look Ahead" that previews the major chemistry topics and contextual themes that are introduced in each chapter.

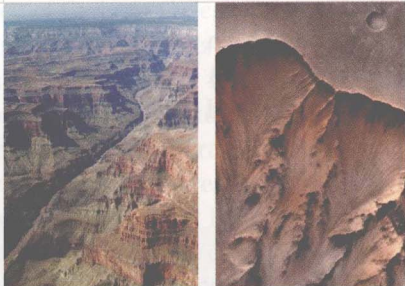
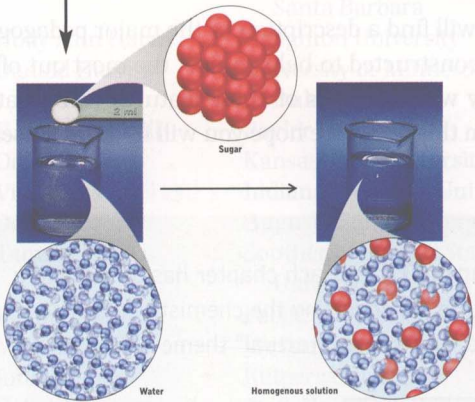
- 5.1 Earth: The Water Planet
- 5.2 Solution Concentration and Molarity
- 5.3 Electrolytes and Nonelectrolytes
- 5.4 Colligative Properties of Solutions
 - Dalton's law of partial pressures
 - Boiling point elevation and freezing point depression
 - The van't Hoff factor
 - Measuring molar mass
- 5.5 Introduction to Oxidation-Reduction Processes
 - Oxidation numbers
 - Balancing redox reactions
- 5.6 Acid-Base and Net Ionic Equations
 - Acid-Base Chemistry
 - THE ALKALINE EARTH METALS
- 5.7 Precipitation Reactions
- 5.8 Ion Exchange
- 5.9 Titrations
- 5.10 Colloids

Extensive Illustration Program

Clear and informative drawings illustrate important concepts, and many of the photographs are annotated to clearly illustrate their relevance to chemistry.

What a Chemist Sees

Visualization at the molecular level is crucial to understanding chemistry. "What a Chemist Sees" drawings dramatically illustrate the molecular perspective, pairing a microscopic view with a macroscopic view.

210	CHAPTER 5 Solution Chemistry and the Hydrosphere	5.1 Earth: The Water Planet	211
 <p>FIGURE 5.1 Arizona's Grand Canyon is a dramatic example of how Earth's surface is continually modified by flowing water. Similar topographic features observed on Mars suggest that water once flowed on the Martian surface.</p>		 <p>FIGURE 5.2 What a Chemist Sees. Adding sugar (solute) to water (solvent) produces a homogeneous solution of sugar molecules (red) evenly distributed among water molecules (blue).</p>	
<p>CONNECTION: The possibility of life on other planets in our solar system was discussed in Section 1.4.</p> <p>sun eventually allowed Earth to become the "water planet" as depressions in its crust filled with about 1.5×10^{21} liters of nature's universal solvent, liquid H_2O. Life exists on our planet because liquid water exists here. The current debate about the existence of life elsewhere in our solar system and in other planetary systems in the universe hinges on the prospect of liquid water existing on those heavenly bodies. For example, the belief that Martian meteorites collected in Antarctica (see Chapter 1) may contain fossilized forms of life is linked to evidence that there may have been water on the surface of Mars in the distant past (Figure 5.1). The biochemical reactions of all living cells require the presence of liquid water, and so an understanding of the chemistry of life requires an understanding of the principles of chemical reactions between substances dissolved in water.</p> <p>All natural waters, be they salt water or fresh water, contain ionic and molecular compounds dissolved in H_2O. When an element or compound dissolves in another, a solution is formed. Solutions are homogeneous mixtures of two or more substances (Figure 5.2; see Chapter 1 to review the classifications of matter, including heterogeneous and homogeneous mixtures). The substance present in a solution in the greatest proportion (in number of moles) is called the solvent; the other ingredients are called solutes. When the solvent is water, the solution is an aqueous solution. The solvent is often a liquid, but it doesn't have to be. In Chapter 4, we considered the complex composition of Earth's crust. Many of the minerals of which it is made are examples of solid solutions: uniform mixtures of substances in the solid state that do not have the fixed composition of a pure substance.</p> <p>Seawater is sometimes called salt water, but that name may be misleading. Seawater is not just a solution of common table salt ($NaCl$). In fact, it is not a true</p> <p>CONNECTION: The classification of mixtures as homogeneous and heterogeneous was introduced in Section 1.1.</p>		<p>solution at all. Although seawater does contain an array of dissolved ionic and molecular compounds, it also contains undissolved matter, including fine-grained sediments suspended by wave action near coastlines or soil eroded by rivers and streams. In some parts of the ocean, most of the suspended matter in seawater is biological, including microscopic plants known as phytoplankton.</p> <p>Suspended particulate matter is not likely to be distributed uniformly throughout a seawater sample: large, dense particles will slowly settle to the bottom of the container in which the sample of seawater is stored. Thus, seawater is really a heterogeneous mixture (Figure 5.3). If we remove the particles by passing a sample of seawater through a filter (Figure 5.4), we will have a clear, homogeneous mixture, or solution, of just the dissolved components. Suspended particles make any liquid turbid, meaning that a beam of light passing through the liquid will be scattered by the particles in suspension, as shown in Figures 5.5 and 5.6. The presence of phytoplankton also imparts the green color characteristic of biologically productive ocean (and fresh) water.</p> <p>CONNECTION: Rules for naming binary compounds such as $NaCl$ are described in Section 4.2.</p> <p>Turbidity is the tendency of liquids containing suspended solids to scatter light.</p>	

Connections Icons are paired with marginal annotations to reinforce cross-chapter connections.

Chemistry Checkpoints

Marginal notations emphasize key chemical concepts and terms. These checkpoints reinforce the importance of these concepts and terms and facilitate review of the chapter. All key terms are defined here, as well as in the glossary at the end of the book.