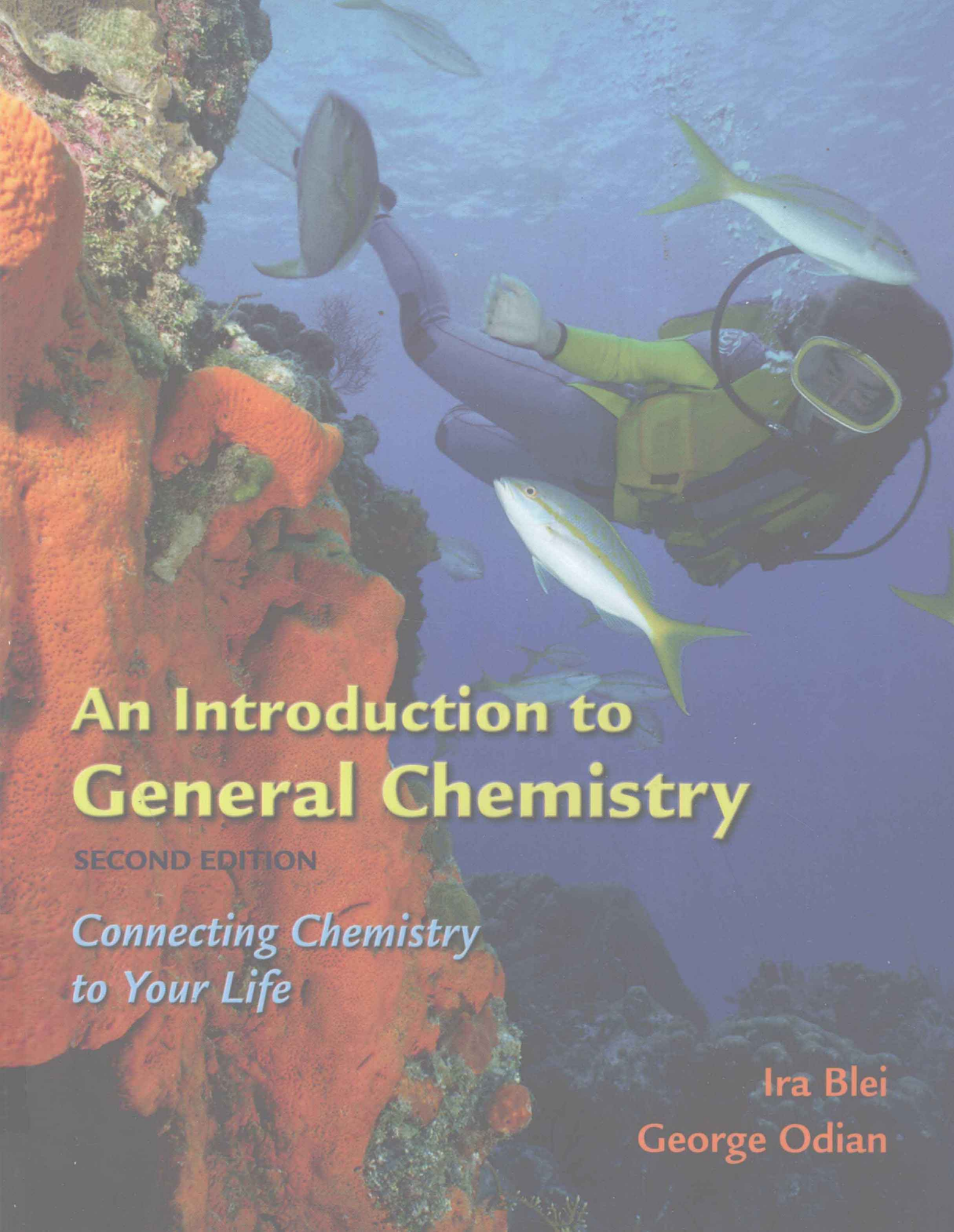

An Introduction to General Chemistry

SECOND EDITION

Connecting Chemistry to Your Life

Ira Blei
George Odian

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George Odian
College of Staten Island
City University of New York

W. H. Freeman and Company • New York

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Atomic Masses of the Elements and Their Symbols

Element	Symbol	Atomic number	Atomic mass (amu)
actinium	Ac	89	[227]
aluminum	Al	13	26.98
americium	Am	95	[243]
antimony	Sb	51	121.76
argon	Ar	18	39.95
arsenic	As	33	74.92
astatine	At	85	[210]
barium	Ba	56	137.33
berkelium	Bk	97	[247]
beryllium	Be	4	9.012
bismuth	Bi	83	208.98
bohrium	Bh	107	[264]
boron	B	5	10.81
bromine	Br	35	79.91
cadmium	Cd	48	112.41
calcium	Ca	20	40.08
californium	Cf	98	[251]
carbon	C	6	12.01
cerium	Ce	58	140.12
cesium	Cs	55	132.91
chlorine	Cl	17	35.45
chromium	Cr	24	52.00
cobalt	Co	27	58.93
copper	Cu	29	63.55
curium	Cm	96	[247]
darmstadtium	Ds	110	[281]
dubnium	Db	105	[262]
dysprosium	Dy	66	162.50
einsteinium	Es	99	[252]
erbium	Er	68	167.26
europium	Eu	63	151.96
fermium	Fm	100	[257]
fluorine	F	9	19.00
francium	Fr	87	[223]
gadolinium	Gd	64	157.25
gallium	Ga	31	69.72
germanium	Ge	32	72.64
gold	Au	79	196.97
hafnium	Hf	72	178.49
hassium	Hs	108	[277]
helium	He	2	4.002
holmium	Ho	67	164.93
hydrogen	H	1	1.0079
indium	In	49	114.82
iodine	I	53	126.90
iridium	Ir	77	192.22
iron	Fe	26	55.85
krypton	Kr	36	83.80
lanthanum	La	57	138.91
lawrencium	Lr	103	[262]
lead	Pb	82	207.21
lithium	Li	3	6.941
lutetium	Lu	71	174.97
magnesium	Mg	12	24.31
manganese	Mn	25	54.94
meitnerium	Mt	109	[268]
mendelevium	Md	101	[258]
mercury	Hg	80	200.59
molybdenum	Mo	42	95.94
neodymium	Nd	60	144.24
neon	Ne	10	20.18
neptunium	Np	93	[237]
nickel	Ni	28	58.69
niobium	Nb	41	92.91
nitrogen	N	7	14.01
nobelium	No	102	[259]
osmium	Os	76	190.23
oxygen	O	8	16.00
palladium	Pd	46	106.42
phosphorus	P	15	30.97
platinum	Pt	78	195.08
plutonium	Pu	94	[244]
polonium	Po	84	[209]
potassium	K	19	39.10
praseodymium	Pr	59	140.91
promethium	Pm	61	[145]
protactinium	Pa	91	231.04
radium	Ra	88	[226]
radon	Rn	86	[222]
rhenium	Re	75	186.21
rhodium	Rh	45	102.91
roentgenium	Rg	111	[272]
rubidium	Rb	37	85.47
ruthenium	Ru	44	101.07
rutherfordium	Rf	104	[261]
samarium	Sm	62	150.36
scandium	Sc	21	44.96
seaborgium	Sg	106	[266]
selenium	Se	34	78.96
silicon	Si	14	28.09
silver	Ag	47	107.87
sodium	Na	11	22.99
strontium	Sr	38	87.62
sulfur	S	16	32.07
tantalum	Ta	73	180.95
technetium	Tc	43	[98]
tellurium	Te	52	127.60
terbium	Tb	65	158.93
thallium	Tl	81	204.38
thorium	Th	90	232.04
thulium	Tm	69	168.93
tin	Sn	50	118.71
titanium	Ti	22	47.87
tungsten	W	74	183.84
uranium	Th	90	238.03
vanadium	Tm	69	50.94
xenon	Sn	50	131.29
ytterbium	Ti	22	173.04
yttrium	W	74	88.91
zinc	U	92	65.41
zirconium	V	23	91.22

Note: The names of elements 112–118 are provisional; brackets [ ] denote the most stable isotope of a radioactive element.
Online at: http://www.iupac.org/publications/pac/2003/pdf/7508x1107.pdf

About the Authors

Ira Blei was born and raised in Brooklyn, New York, where he attended public schools and graduated from Brooklyn College with B.S. and M.A. degrees in chemistry. After receiving a Ph.D. degree in physical biochemistry from Rutgers University, he worked for Lever Brothers Company in New Jersey, studying the effects of surface-active agents on skin. His next position was at Melpar Incorporated, in Virginia, where he founded a biophysics group that researched methods for the detection of terrestrial and extraterrestrial microorganisms. In 1967, Ira joined the faculty of the College of Staten Island, City University of New York, and taught chemistry and biology there for three decades. His research has appeared in the *Journal of Colloid Science,* the *Journal of Physical Chemistry*, and the *Archives of Biophysical and Biochemical Science.* He has two sons, one an engineer working in Berkeley, California, and the other a musician who lives and works in San Francisco. Ira is outdoors whenever possible, overturning dead branches to see what lurks beneath or scanning the trees with binoculars in search of new bird life, and has recently served as president of Staten Island's local Natural History Club.

George Odian is a tried and true New Yorker, born in Manhattan and educated in its public schools, including Stuyvesant High School. He graduated from The City College with a B.S. in chemistry. After a brief work interlude, George entered Columbia University for graduate studies in organic chemistry, earning M.S. and Ph.D. degrees. He then worked as a research chemist for 5 years, first at the Thiokol Chemical Company in New Jersey, where he synthesized solid rocket propellants, and subsequently at Radiation Applications Incorporated in Long Island City, where he studied the use of radiation to modify the properties of plastics for use as components of space satellites and in water-desalination processes. George returned to Columbia University in 1964 to teach and conduct research in polymer and radiation chemistry. In 1968, he joined the chemistry faculty at the College of Staten Island, City University of New York, and has been engaged in undergraduate and graduate education there for three decades. He is the author of more than 60 research papers in the area of polymer chemistry and of a textbook titled *Principles of Polymerization,* now in its fourth edition, with translations in Chinese, French, Korean, and Russian. George has a son, Michael, who is an equine veterinarian practicing in Maryland. Along with chemistry and photography, one of George's greatest passions is baseball. He has been an avid New York Yankees fan for more than five decades.

Ira Blei and George Odian arrived within a year of each other at the College of Staten Island, where circumstances eventually conspired to launch their collaboration on a textbook. Both had been teaching the one-year chemistry course for nursing and other health science majors for many years, and during that time they became close friends and colleagues. It was their habit to have intense, ongoing discussions about how to teach different aspects of the chemistry course, each continually pressing the other to enhance the clarity of his presentation. Out of those conversations developed their ideas for this textbook.

Preface

An Introduction to General Chemistry: Connecting Chemistry to Your Life is designed to be used in a one-semester course in general chemistry. Often, this course precedes a one-semester course in organic and biochemistry or serves as a precursor to other chemistry courses. Our book was written for students who intend to pursue careers as nurses, dieticians, physician's assistants, physical therapists, or environmental scientists.

Goals of This Book

Our chief objective in writing both editions of this book is to promote a better understanding of chemical *principles*—the comprehensive laws that explain how matter behaves—through the use of real-world examples. Students who merely memorize today's scientific information without understanding the basic underlying principles will not be prepared for the demands of the future. On the other hand, students who have a clear understanding of basic physical and chemical phenomena will have the tools that they need to understand new facts and ideas and will be able to incorporate new knowledge into their professional practices in appropriate and meaningful ways.

The other central goal of our book is to introduce students to how the human body works at the level of molecules and ions—that is, to the chemistry of physiological function. Throughout the book, we take every opportunity to illustrate chemical principles with specific examples of biomolecules and with real-world applications having physiological or medical contexts. Our focus in the coverage of general chemistry is on providing clear explication of fundamental chemical principles to prepare students for the exploration of topics in organic chemistry and biochemistry.

In the process of exploring and using chemical principles, we emphasize two major themes throughout: (1) the ways in which intermolecular and intramolecular forces influence the properties of substances and (2) the relations between molecular structures within the body and their physiological function.

New to This Edition

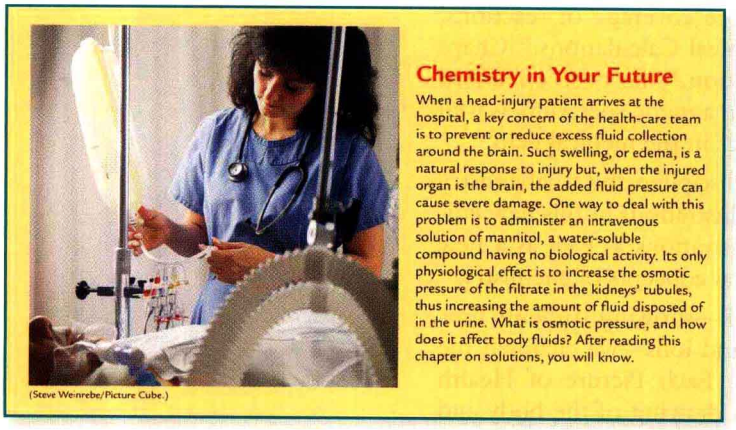
- In response to reviewer recommendations for more coverage of reactions, we added in-depth coverage to Chapter 4, "Chemical Calculations." Chapter 10, "Chemical and Biological Effects of Radiation," has been enhanced by additional discussion of the basics of the electromagnetic spectrum as well as more information on X-rays and their applications in the medical field.
- Because visuals are so important to chemistry as a discipline and to chemistry textbooks, we have taken particular care with the illustrations in this new edition. Chapter 3 is enhanced by several revised illustrations as well as a new figure illustrating electronegativity, one of the central concepts of chemistry.
- In line with the second major goal of this textbook—showing students how the human body works at the level of molecules and ions—we changed the Pictures of Health that appear in most chapters. Each Picture of Health combines a photograph of an actual person with a drawing of the body and

its processes in action, thus showing students how "macroscopic" everyday activities relate to the molecular and ionic activity that goes on within the body. We think that the Picture of Health feature will engage students and that each Picture of Health helps to visually reinforce the concepts described in words in the main text. At the same time, the range of activities shown—from eating cotton candy to farming to playing tennis—highlights chemistry's central role in life.

- We know that students rely on a textbook for review and for test preparation. For that reason, we changed the format of the Summary at the end of each chapter. The new format—a list of short bulleted paragraphs—will make it easier for a student to identify the most important concepts in each chapter.
- We enhanced the more conceptual questions in each chapter. The Expand Your Knowledge category within the Exercise sets will show the students how to synthesize the concepts in the chapter—getting the students to think more like chemists.
- There are three kinds of boxes in this textbook: Chemistry in Depth, Chemistry Within Us, and Chemistry Around Us. Each of these kinds of boxes is designed to give the student more information and an awareness of the myriad applications of chemistry. To enhance the role of these boxes in the classroom and to reinforce their purpose, we added "box exercises" to the Expand Your Knowledge category in the Exercises at the ends of chapters. The box exercises relate to the boxes and the applications in them, and these exercises will draw student's attention to this interesting feature. Look for the flask icons in the Exercise sections. Further, we added new applications or updated information to many of these boxes—demonstrating the dynamism of chemistry and its constant effects on our lives.
- Finally, the design of the new edition brightens the Concept Checklists, making them easier for students to find. The various lists of rules (such as the rules for naming certain compounds) are now that much easier to find, too, inasmuch as they follow a similar checklist format. We wanted our readers to be able to navigate our book easily, and its clean and logical design will help them to do so.

Pedagogical Features

The features of this book are **applications, problem-solving strategies, visualization,** and **learning tools,** in a real-world context to connect chemistry to students' lives.

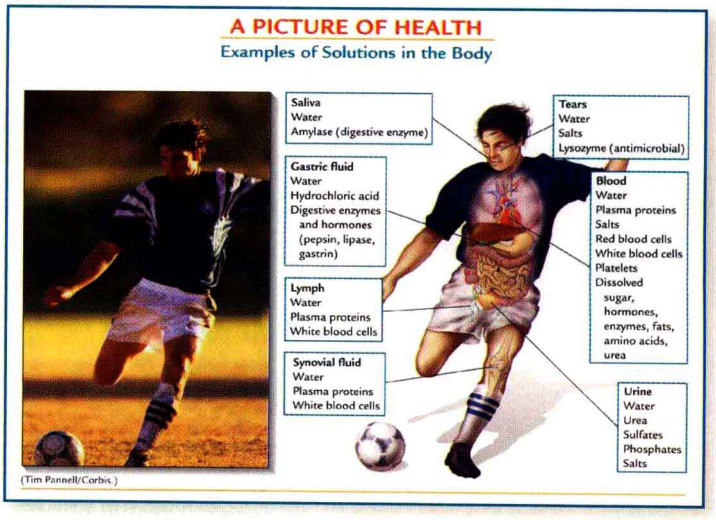


Making Connections with Applications

Students are motivated to learn a subject if they are convinced of its fundamental importance and personal relevance. Examples of the relevance of chemical concepts are woven into the text and emphasized through several key features.

Chemistry in Your Future A scenario at the beginning of each chapter describes a typical workplace situation that illustrates a practical, and usually professional, application of the contents of that chapter. A link to the book's Web site leads the student to further practical information.

A Picture of Health This completely revised series of drawings and photographs shows how chapter topics apply to human physiology and health.



Three Categories of Boxes A total of 35 boxed essays, divided into three categories, broaden and deepen the reader's understanding of basic ideas. Icons in the exercise sets reinforce the use of these practical essays.

Chemistry Within Us These boxes describe applications of chemistry to human health and well-being.

Chemistry Around Us These boxes describe applications of chemistry to our everyday life (including commercial products) and to biological processes in organisms other than humans.

Chemistry in Depth These boxes provide a more detailed description of selected topics, ranging from chromatography to the quantitative aspects of equilibrium systems.

Making Connections Through Problem Solving

Learning to work with chemical concepts and developing problem-solving skills are integral to understanding chemistry. We help students develop these skills.

Example 8.7 **Using Le Chatelier's principle**

Suppose some $N_2O_4(g)$ were added to the following equilibrium system: $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$. What would the effect on the equilibrium mixture be?

Solution

The stress on the disturbed equilibrium mixture would be relieved and equilibrium would be reestablished by a reduction in the N_2O_4 concentration, which would lead to an increase in the NO_2 concentration. The reaction would shift to the right. However, note that both the N_2O_4 and the NO_2 concentrations would now be greater than in the preceding equilibrium state.

Problem 8.7 Suppose some $H_2(g)$ were added to the following reaction: $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$. What would the effect on the equilibrium mixture be?

In-Chapter Examples Nearly 140 in-chapter examples with step-by-step solutions, each followed by a similar in-chapter problem, allow students to verify and practice their skills.

End-of-Chapter Exercises More than 700 end-of-chapter exercises are divided into three categories:

- **Paired Exercises** are arranged according to chapter sections; each odd-numbered paired exercise is followed by an even-numbered exercise of the same type.
- **Unclassified Exercises** do not reference specific chapter sections but test the student's overview of chapter concepts.
- **Expand Your Knowledge Exercises** challenge students to expand their problem-solving skills by applying them to more-complex questions or to questions that require the integration of material from different chapters.

Expand Your Knowledge

Note: The icons denote exercises based on material in boxes.

9.76 The ion-product of water increases as temperature increases. Is the dissociation of water an exothermic or an endothermic reaction?

9.77 What is a conjugate acid–base pair?

9.78 What is the meaning of pH?

9.79 Suppose the capacity of your stomach to be 2.00 L and its pH to be 1.50. How many grams of the antacid sodium bicarbonate, $NaHCO_3$, would be necessary to bring the pH of your stomach to 7.00?

9.80 How would you prepare a buffer to maintain the pH of an aqueous solution as close to pH 5.00 as possible? (Consult Table 9.5.)

9.81 Calculate the pH of a 0.010 *M* aqueous solution of sodium acetate at 25°C (see Box 9.1).

9.82 Calculate the pH of a 0.010 *M* aqueous solution of ammonium chloride at 25°C (see Box 9.1).

9.83 Use the ionization constant in Table 9.4 to calculate the osmotic pressure of a 0.0050 *M* aqueous solution of formic acid at 25°C.

what species are present in the solution, and what is the relation of the pH to the pK_a of acetic acid?

9.86 Would the pH at the equivalence point of the titration in Exercise 9.85 be 7.00? Explain your answer.

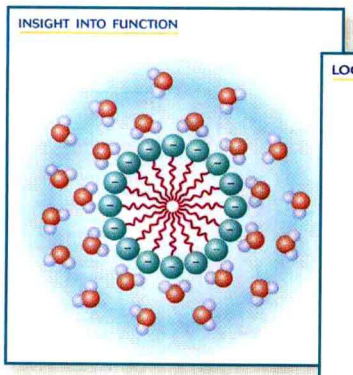
9.87 Arrange the pH values of the following 0.010 *M* aqueous solutions in the order highest to lowest: Na_3PO_4, Na_2HPO_4, NaH_2PO_4.

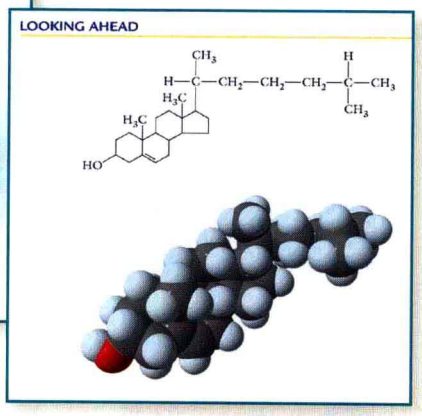
9.88 Your laboratory instructor provides you with four solutions. She tells you that they are equimolar solutions of monoprotic weak acids. You are to measure the pH of each solution and correlate them with their dissociation constants, smallest to largest. The list with their pH values is (1) 6.65; (2) 3.41; (3) 4.82; (4) 2.85.

9.89 What can you say about the relative basic strengths of the anions produced by the step-by-step dissociation of diprotic or triprotic acids such as carbonic acid or phosphoric acid?

9.90 Write equations that describe the acid–base reactions of each of the following pairs of Brønsted–Lowry acids and bases. (a) H_2O and NH_2^-, (b) H_2O and HS^-, (c) HCNO and NH_3, (d) HNO_2 and CH_3COO^-.

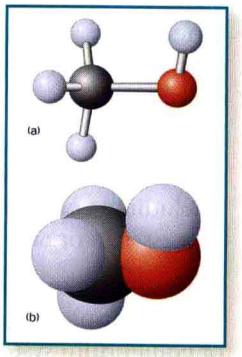
Answers to Odd-Numbered Exercises are supplied at the end of the book. Step-by-step solutions to the odd-numbered exercises are supplied in the *Student Solutions Manual*. Step-by-step solutions to even-numbered exercises are supplied in the *Instructor's Resource Manual*. Step-by-step solutions to in-chapter problems are supplied in the *Study Guide*.



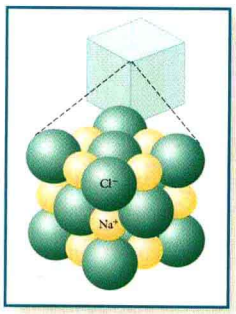


Making Connections Through Visualization

Illustrations Illustrations and tables have been carefully chosen or designed to support the text and are carefully labeled for clarity. Special titles on certain illustrations—Insight into Properties, Insight into Function, and Looking Ahead—emphasize the use of secondary attractive forces and molecular structure as unifying themes throughout the book.



Ball-and-Stick and Space-Filling Molecular Models Molecular structures of compounds, especially organic compounds, offer students considerable interpretive challenge. Throughout the book, two-dimensional molecular structures are supported by generous use of ball-and-stick and space-filling molecular models to aid in the visualization of three-dimensional structures of molecules.

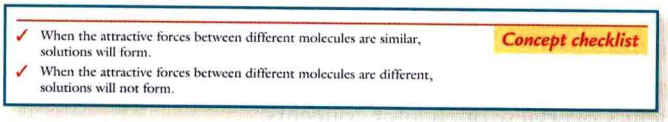


Functional Use of Color Color is used functionally and systematically in schematic illustrations and equations to draw attention to key changes or components and to differentiate one key component from another. For example, in molecular models, the carbon, hydrogen, oxygen, and nitrogen atoms are consistently illustrated in black, white, red, and blue, respectively. In structural representations of chemical reactions, color is used to highlight the parts of the molecule undergoing change. The strategic use of color makes complex chemical concepts less daunting and easier to understand.

Making Connections by Using Learning Tools

Learning Objectives Each chapter begins with a list of learning objectives that preview the skills and concepts that students will master by studying the chapter. Students can use the list to gauge their progress in preparing for exams.

Concept Checklists The narrative is punctuated with short lists serving to highlight or summarize important concepts. They provide a periodic test of comprehension in a first reading of the chapter, as well as an efficient means of reviewing the chapter's key points.



Rules Rules for nomenclature, balancing reaction equations, and other important procedures are highlighted so that students can find them easily when studying or doing homework.

» Chapter 8 describes the role of kinetic energy in a chemical reaction.

Cross-References Cross-referencing in the text and margins alerts students to upcoming topics, suggests topics to review, and draws connections between material in different parts of the book.

Chapter Summaries Serving as a brief study guide, the Summary at the end of each chapter points out the major concepts presented in each section of the chapter.

Key Words Important terms are listed at the end of each chapter and keyed to the pages on which their definitions appear.

Organization

An Introduction to General Chemistry: Connecting Chemistry to Your Life

To understand the molecular basis of physiological functioning, students must have a thorough grounding in the fundamental concepts of general chemistry. Chapter 1 describes the qualitative and quantitative tools of chemistry. It is followed by a consideration of atomic and molecular structure and chemical bonding in Chapters 2 and 3. In Chapter 4, the major types of chemical reactions are presented, along with the quantitative methods for describing the mass relations in those reactions. Chapters 5 and 6 consider the physical properties of molecules and the nature of the interactions between them. Chapter 7 examines the properties of solutions, particularly diffusion and osmotic phenomena. A study of chemical kinetics and equilibria, in Chapter 8, also considers some basic aspects of enzyme function. Chapter 9 treats acids and bases, critical for an understanding of physiological function. Chapter 10 deals with the effects of the interaction of radiation with biological systems and with the use of radiation in medical diagnosis and therapy.

Flexibility for Chemistry Courses

We recognize that all introductory courses are not alike. For that reason, we offer this text in three versions, so you can choose the option that is right for you:

- *General, Organic, and Biochemistry* (ISBN 0-7167-4375-2)—the comprehensive 26-chapter text
- *An Introduction to General Chemistry* (ISBN 0-7167-7073-3)—10 chapters that cover the core concepts in general chemistry
- *Organic and Biochemistry* (ISBN 0-7167-7072-5)—16 chapters that cover organic and biochemistry plus two introductory chapters that review general chemistry

For further information on the content in each of these versions, please visit our Web site: http://www.whfreeman.com/bleiodian2e.

Supplements

A mouse icon in the margins of the textbook indicates that a resource on the book's companion Web site (www.whfreeman.com/bleiodian2e) accompanies that section of the book. Animations, simulations, videos, and more resources found on the book's companion site help to bring the book to life. Its practice tools such as interactive quizzes help students review for exams.

For Students

Student Solutions Manual, by Mark D. Dadmun of the University of Tennessee–Knoxville, contains complete solutions to the odd-numbered end-of-chapter exercises.

Study Guide, by Marcia L. Gillette of Indiana University, Kokomo, provides reader friendly reinforcement of the concepts covered in the textbook. Includes chapter outlines, hints, practice exercises with answers, and more.

General, Organic, and Biochemistry Laboratory Manual, Second Edition, by Sara Selfe of Edmonds Community College.

For Instructors

Instructor's Resource Manual, by Mark D. Dadmun of the University of Tennessee–Knoxville, contains complete solutions to the even-numbered end-of-chapter exercises, chapter outlines, and chapter overviews.

New! Enhanced Instructor's Resource CD-ROM To help instructors create lecture presentations, Web sites, and other resources, this CD-ROM allows instructors to search and export the following resources by key term or chapter: all text images; animations, videos, PowerPoint, and more found on the Web site; and the printable electronic Instructor's Manual (available in Microsoft

For Students (continued)

Web Site, www.whfreeman.com/bleiodian2e, offers a number of features for students and instructors including online study aids such as quizzes, molecular visualizations, chapter objectives, chapter summaries, Web review exercises, flashcards, Web-linked exercises, molecules in the news, and a periodic table.

For Instructors (continued)

Word format), which can be fully edited and includes answers to even-numbered end-of-chapter questions.

Test Bank, by Margaret G. Kimble of Indiana University–Purdue University, contains more than 2500 multiple-choice, fill-in-the-blank, and short-answer questions, available in both print and electronic formats.

More than 200 **Overhead Transparencies.**

Instructor's Web Site, which is password-protected, contains student resources, laboratory information, and PowerPoint files.

Course Management Systems (WebCT, Blackboard) As a service to adopters, electronic content will be provided for this textbook, including the instructor and student resources in either WebCT or Blackboard formats.

Acknowledgments

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