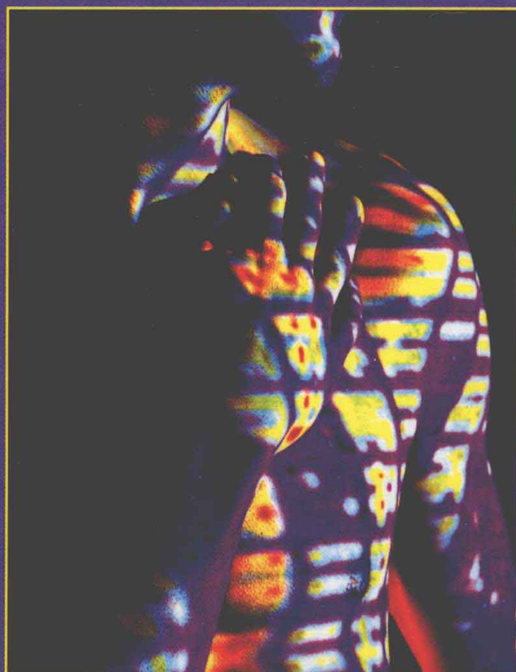
FUNDAMENTALS OF GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY

JOHN R. HOLUM

SIXTH EDITION



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JOHN R. HOLUM
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JOHN WILEY & SONS, INC.
New York / Chichester / Weinheim
Brisbane / Singapore / Toronto

Cover Photos	inset: © Bob Sacha background: Courtesy Affymetrix, Santa Clara, California
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This book was set in Caslon 224 Book by Progressive Information Technologies, Inc. and printed and bound by Von Hoffmann Press. The cover was printed by The Lehigh Press, Inc.

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Holum, John R.
Fundamentals of general, organic, and biological chemistry / John R. Holum. — 6th ed.
p. cm.
Includes index.
ISBN 0-471-17574-9 (cloth :alk. paper)
1. Chemistry. I. Title.
QD31.2.H62 1997
540—dc21 97-15451
CIP

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

PREFACE

This book is about nature and about human life at their molecular levels. It's meant for two kinds of students. Many plan on post-university careers in any one of the health sciences. Others are liberal arts or general education students who sense that *chemical* knowledge underlies the current and upcoming advances in the sciences that will most affect their health and inform their business, political, and ecological judgments.

A course built around this text is more truly a *general* chemistry course than any other because students experience the excitement of learning during the first year about how life works at the molecular level. And they'll also be introduced to how genetic engineering is done and how the genetic code will help biochips become major information carriers.

SIXTH EDITION FEATURES

"This Chapter in Context" Units Weave an *Awareness* of Relevance into Each Chapter To many students, the topics in the first several chapters seem remote from the molecular basis of life, and it's hard for them to stay motivated. Teachers know that *relevance motivates,* and students want relevance. The first section of Chapter 1 gives an overview of the entire book. Beginning with Chapter 2, each chapter then opens with a short unit called "This Chapter in Context." A new feature in this edition, it broadly surveys "where we have been" and "where we are going."

Students readily grant that basic concepts and vocabulary usually form an essential background in any field, so frequent reminders of relevance are helpful. Moreover, many interactions between health and the environment require little if any knowledge of biochemistry. When sports enthusiasts, for example, first learn how buffers are essential to breathing, their respect improves for all of the concepts that are background for the study of buffers. (One senior physical education major even told me that he wished he had gone into chemistry! Imagine that.)

***Interaction* Units Apply Chemistry to Life** This would be a good time to look at a special index, the index to Interactions. We used to call these units "Special Topics," but the new term better suggests that chemistry does interact with many topics of current interest. We've had many such topics in the past. Among the *new* Interactions of this edition are the following.

1.1	Scurvy, Lime Juice, Ascorbic Acid, and the Scientific Method
6.1	Air Bags
6.2	Breathing at High Altitude
6.4	Surfactant Replacement Therapy for Preterm Babies
7.1	The Environment Friendly Solvent, Liquid CO_2
10.6	Chornobyl—An Explosion That Shook the World
11.2	Enlisting Microbes Against Oil Spills
13.1	Ethyl Alcohol and Alcoholism
19.3	Fake Fat—How Olestra Escapes Digestion

20.2 Mad Cows, Prions, and Protein Shapes

22.1 Melatonin—Hope or Hype?

22.2 Nicotine—Hijacker of Acetylcholine Receptors

24.3 Biochips, Breast Cancer, and the No-Name Protein

27.3 Leptin, Mice, and Humans

Environmentally significant Interactions that have carried over with updating include discussions of the greenhouse effect, acid rain, ozone in smog, and the ozone hole.

Among the deleted Special Topics are those on solubility products and on the interrelating calculations involving pH, $[H^+]$, and K_a.

Traditional General Chemistry Topics Make Up Chapters 1 to 10 We cannot go into the molecular basis of life without knowing about molecules as well as several fundamental concepts concerning the structure and properties of matter in general. As long as students retain confidence that a topic, no matter how seemingly remote, relates somehow to their interest in life and health, their motivation is enhanced. Acids, bases, and buffers are studied, for example, because the acid–base status of the body is a matter of life and death. Any teacher realizes, of course, that acids, bases, and buffers cannot be studied without a good background in formulas, structures, equations, solutions, and equilibria.

For future health care professionals there is no more important topic in the entire book than the acid–base status of the blood and how this relates to the respiratory gases. It's a topic that not only is used as background in later courses, it is also the only chemistry topic that truly carries over beyond formal schooling to careers. Virtually all medical emergencies seen by health care professionals in emergency rooms, operating rooms, and critical care units involve the blood gases, respiration, and blood buffers. Ask topflight nurses if this is right (or read almost any issue of *The American Journal of Nursing*); that's how I first became aware of the importance of this topic.

We've changed the first ten chapters in the following ways. All changes reflect a desire to accomplish two goals: to control the book's length, and to make the level more appropriate for current students. Stoichiometry has been moved later, from being Chapter 3 to being Chapter 5. This enables a more unified treatment of atomic and molecular structure. The treatment of redox reactions has been shortened and made simpler by removing old Chapter 10 and consolidating the basic vocabulary of such reactions in Chapter 4.

Old Section 1.6 ("Accuracy, Error, Uncertainty, and Precision") has been shortened and folded into a new section (1.4, "Physical Quantities, Measurement, and Significant Figures.") This places the topic on significant figures earlier where it better supports the discussion of scientific notation.

Old Section 2.4 ("Heat and the Thermal Properties of Matter") has also been shortened (and renamed "Heat"). The discussion of heat capacity has been eliminated. The concept of specific heat is retained. Heats of vaporization and fusion are now in chapter 6 ("States of Matter and the Kinetic Theory").

A new section (2.5, "Heat and Molecular Kinetic Energy") delivers on requests turned up by reviewers, namely, getting the concept of molecular kinetic energy earlier than in the chapter on gases.

I have deleted the topics of hybrid atomic orbitals both here and in the chapters on organic chemistry. VSEPR theory is all that we need to account for molecular geometry at this level. And I have always believed that the chemistry of the double bond can be adequately taught in a course such as this without the mention of pi bonds. (It's easy to point out that a double bond must be a region of higher electron density than a single bond and so would be more attractive to an electron-seeking reactant, like the hydrogen ion.)

The mathematical treatment of the gas laws has been shortened as I have shifted to the use of the combined gas law as the only one that students need for the more relevant gas law calculations. The discussion of Dalton's law is also reduced by omitting its application to the collection of gases over water.

In Chapter 7 ("Solutions and Colloids"), following an excellent suggestion by a reviewer, I have added a summary of all of the forces of attraction that we've studied so students can review these in one place.

Chapters 11 to 17 Survey the Functional Groups of Organic Chemistry Deemed Most Essential to the Study of Biochemistry The wedding between the theme of the course and the limitation of time results in a very abbreviated survey of organic chemistry. Some of the major topics developed in even a one-term course of "regular" organic chemistry have had to be excluded, topics like the theory of resonance, nucleophilic substitution reactions, the Grignard synthesis, and many others. I have stressed only those functional groups that occur widely among the molecules of life and their reactions with four kinds of compounds: acids, bases, oxidizing agents, and reducing agents. I have provided some mechanisms because organic reactions otherwise seem too much like magic, and their learning becomes merely rote. Some mechanisms (those of acid catalyzed alcohol dehydration, aldol condensation, and Claisen ester condensation) have been moved to Appendix D. Teachers who want to omit them anyway will find it easier now. Teachers who want to include them may do so whenever they deem them most appropriate. (For example, I've preferred to discuss the aldol condensation not in the aldehyde chapter but in the chapter on the metabolism of carbohydrates where the reaction actually applies.)

Chapters 18 to 29 Constitute One Illustration after Another of the Molecular Basis of Life Carbohydrates, lipids, and proteins begin this closing section of the book. Because of their importance to all that follows, I next take up enzymes (Chapter 21). Hormones and neurotransmitters come next, this time in a separate chapter (22). Then come the extracellular fluids of the body (Chapter 23). The chapter on nucleic acids (24) has been considerably updated in its discussion of viruses, recombinant DNA technology, and the applications of genetic engineering to medicine (including biochip technology).

Biochemical energetics (Chapter 25), after an overview, first takes up the citric acid cycle. This time I've given descriptive *chemical* labels, like ""dehydration" "oxidation," and so forth, to the various steps. The discussion of the respiratory chain has been rewritten in an effort to make it easier. Then come treatments of the metabolism of carbohydrates (Chapter 26), lipids (Chapter 27), and proteins (Chapter 28). With all of this background, the study of nutrition (Chapter 29) is made much easier.

Many Design Features Aid Students There are frequent **margin comments** to restate a point, offer data, or simply remind.

Key terms are highlighted in boldface at those places where they are defined and then discussed. A complete **glossary** of these terms plus a few others appears at the end of the book. The ***Study Guide*** that accompanies this book also has individual chapter glossaries.

Each section of a chapter begins with a **headline.** This is *not* a one-sentence summary of the section but rather a lead-in to the beginning of the section that tries to state the section's major point.

Each chapter has a **Summary** that uses key terms in a narrative manner. The summaries are not necessarily organized in the same order in which the material occurs in the various chapter sections. The summaries assume that the sections have been studied so that the needed vocabulary is in place. The summaries thus illustrate that the pedagogy for first-time learning is not necessarily the same as that for reviewing.

The chapters in the first two-thirds of the book have several **worked examples.** In those involving calculations, the **factor-label** method is exploited. These examples generally have labeled parts, such as "Problem," "Analysis," "Solution," and "Check." Thus, immediately after the statement of the *problem* comes the *analysis.* What is the problem really asking? In a multistep solution, what must be done first? Then comes the *solution.* We want to encourage students to see that *solving* a problem (figuring out what to do) occurs *before* the calculations. Following the "Solution" section of an example there is often a "Check" section. "Does the *size* of the answer make sense?" This takes the student back over the problem and encourages the use of the mind (as opposed to a mechanical use of factor-labels) to see the sense of the analysis and the solution. Among problems in the organic chapters, "Check" sections help students to learn how to double-check their answers.

Nearly all worked examples are followed by **Practice Exercises,** which encourage immediate reinforcements of skills learned in the examples. Answers to all Practice Exercises are in Appendix E. A copious number of **Review Exercises** closes each chapter, including some that are "additional." These are not identified by topic, and some require the use of material from earlier chapters. Thus you will find stoichiometry problems scattered throughout the book.

SUPPLEMENTARY MATERIALS FOR STUDENTS AND TEACHERS

The complete package of supplements that are available to help students study and teachers teach includes the following.

***Laboratory Manual for Fundamentals of General, Organic, and Biological Chemistry,* sixth edition.** This is a revised edition prepared by Dr. Sandra Olmsted, Augsburg College. An *Instructor's Manual* to this laboratory manual is a section of the general Teachers' Manual described below.

***Study Guide for Fundamentals of General, Organic, and Biological Chemistry,* sixth edition.** Each chapter of this softcover book contains a discussion of what are the "must study and master" topics. There are also chapter glossaries, additional worked examples and exercises, sample examinations, and the answers to all of the Review Exercises.

***Teachers' Manual for Fundamentals of General, Organic, and Biological Chemistry,* sixth edition.** This softcover supplement is available to teachers. It contains all the usual services for *both the text and the laboratory manual.*

Test Bank. Available in both hard copy and software (Macintosh© and IBM© compatible) versions, this test resource contains roughly 1000 questions.

Transparencies. Instructors who adopt this book may obtain from Wiley, without charge, a set of color transparencies that duplicate key illustrations from the text.

ACKNOWLEDGMENTS

My wife Mary has been my strongest supporter, and I am deeply grateful to this wonderful woman now stricken by a brain aneurysm. Our daughters, Liz, Ann, and Kathryn, have also been strong champions, and I thank them for what they have meant to Mary and me. These daughters have sometimes asked me "How did you do it all these years?" My answer has always been, "It wouldn't have been remotely possible without the strong support of your mother."

At Augsburg College, I always enjoyed unstinting encouragement from the Chair of the Chemistry Department, who was then Dr. Earl Alton (and is now Assistant Academic Dean), and from Dr. Charles Anderson, then President. Dr. Arlin Gyberg, Dr. Joan Kunz (current Chair), and Dr. Sandra Olmsted of the Chemistry Department all have been important sources of suggestions and corrections.

Extraordinarily nice people abound at John Wiley & Sons. I think particularly of my Editor, Clifford Mills, Editorial Assistant, Alicia Solis, and Supplements' Editor, Jennifer Yee.

The overall design was the responsibility of Maddy Lesure, with whom I have worked with pleasure on this and other books. Edward Starr has been skillful, artistic, and faithful in handling the line drawing art work. Hilary Newman, Photo Editor, produced such a rich supply of outstanding choices for photographs that my choosing became difficult, yet exciting and pleasurable. Elizabeth Swain has long served splendidly in managing the copy editing, and now has capably supervised the production, surely one of the most difficult jobs in textbook publishing.

Two outstanding proofreaders saved me from innumerable embarrassments—Connie Parks and Dr. Sandra Olmsted. It's hard to imagine that any errors remain but, based on experience, no doubt some do. They are now entirely my responsibility. Please use a letter to my Chemistry Editor to let me know about them.

The professional critiques of many teachers are part of the process of preparing a manuscript. I am most pleased to acknowledge and to thank the following people for their work.

Robert Ake
Old Dominion University

Margaret Asirvatham
University of Colorado/Boulder

David Ball
Cleveland State University

Muriel Bishop
Clemson University

Ronald Bost
North Central Texas College

Lorraine Brewer
University of Arkansas

Sybil Burgess
University of North Carolina, Wilmington

Jack Dalton
Boise State University

Henry Fisher
University of Rhode Island

Arlin Gyberg
Augsburg College

Donald Harriss
University of Minnesota/Duluth

Larry Jackson
Montana State University

Herman Knoche
University of Nebraska—Lincoln

John Meisenheimer
Eastern Kentucky University

Sandra Olmsted
Augsburg College

Nancy Paisley
Montclair State University

Richard Petersen
University of Memphis

Fred Schell
University of Tennessee/Knoxville

Ram Singhal
Wichita State University

Joan Stover
South Seattle Community College

Kent Thomas
Kansas-Newman College

Atilla Tuncay
Indiana University Northwest

Ruiess Van Fossen Bravo
Indiana University of Pennsylvania

Justine Walhout
Rockford University

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California State University/ Long Beach

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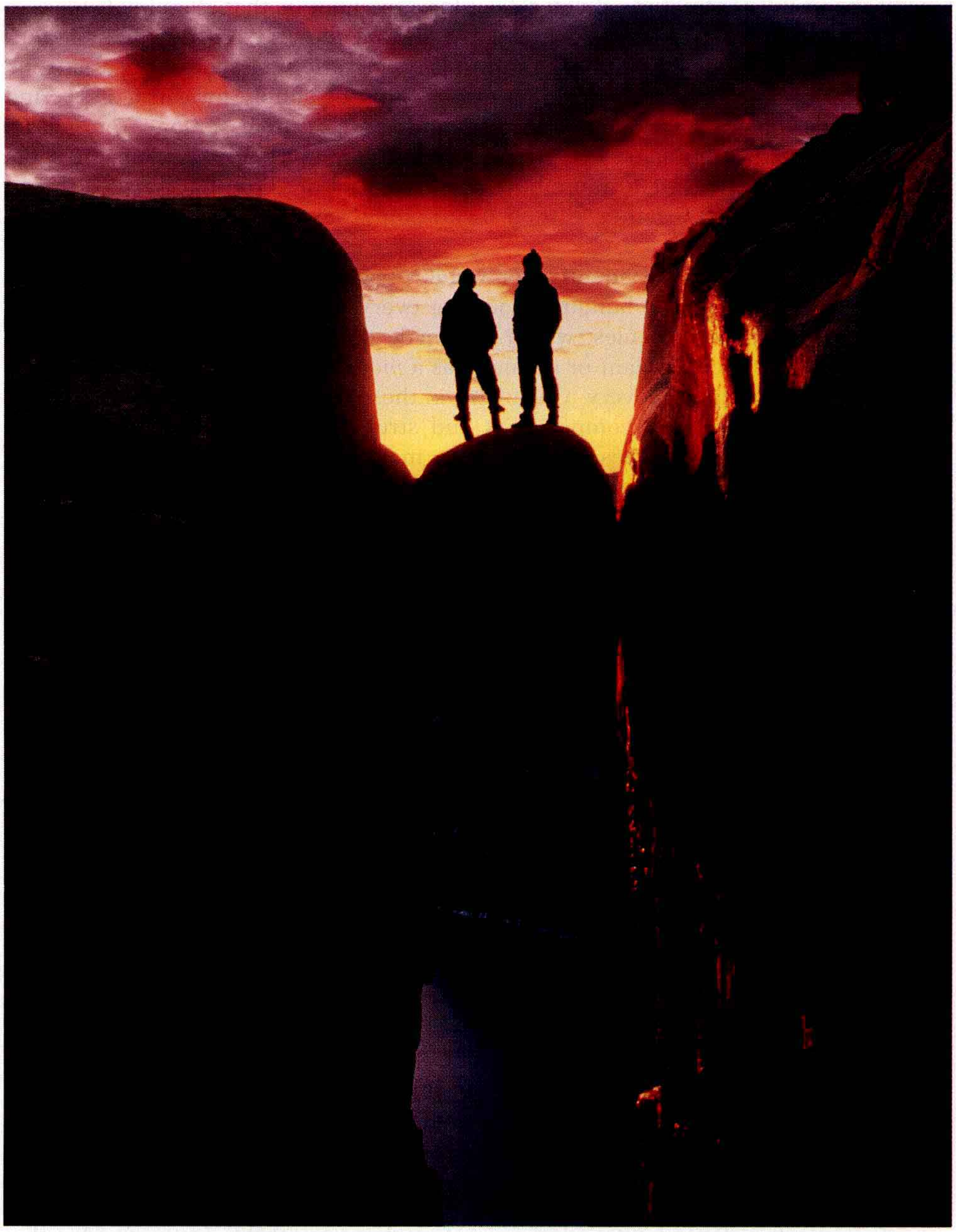
CONTENTS

INDEX TO INTERACTIONS

1

GOALS, METHODS, AND MEASUREMENTS



When the living body is in health, all of the forces of nature, even at the molecular level of life, are more or less in balance, as these two hikers no doubt unconsciously assume as they view the sunset over the Lysefjord, Norway.

1.1 CHEMISTRY AND THE MOLECULAR BASIS OF LIFE

The theme of this book is the molecular basis of life.

One of the wonders of nature, if you reflect for a moment, is that all animals have so much in common. We infer this particularly in what they take in. Virtually all animals use air and water, for example, and those of a variety of species eat the same kinds of food. Many species around the world prosper simply by eating grass and hay. Vultures, lions, and humans can all obtain essential nourishment from cattle. Both a kitten and a human baby prosper on milk. Somewhere, it seems, at some deep level of existence, there must be a common pool of parts that all species can tap and then put back together in their own unique ways. What are these common parts?

The shared parts are evidently not whole organs or tissues, but much, much smaller things that are the building blocks of everything else. They are extremely tiny particles, called molecules, which are made of even smaller particles, called atoms. All of life, whether plant or animal, has a *molecular* basis, and chemistry has been the route to this discovery. **Chemistry** is the study of that part of nature that bears on substances, their compositions and structures, and their abilities to be changed into other substances. There are so many different substances, however, that we must develop a plan of study or lose our way.

■ Well over 9 million chemical substances are known.

Molecules, Like Maps, Can Be Read When the Keys or Map Signs Are Known Life at the molecular level involves molecules and chemical reactions that often are complicated. The symbols we use for molecules, however, are actually less complex than many symbol systems you have already mastered, such as map symbols. The symbols for molecules are like those of maps because the same pieces of molecules, like molecular "map signs," occur over and over again in different situations. When you learn these "signs" among simple substances, you'll be amazed (and relieved!) to see how easy it is to study some of nature's most complicated molecules.

■ The atoms of all matter are made of varying combinations of three extremely tiny particles: electrons, protons, and neutrons.

Molecules, as we said, are made of atoms, so to understand molecules we must first learn about atoms and how their own (even tinier) parts get reorganized into molecules. Hence, the study of atomic and molecular structure occurs mainly in the first few chapters of the book. Here also is essential background about several common substances that are highly important to all living systems, such as acids, bases, salts, and solutions.

As you study chemistry, keep before you a major goal, namely, to learn how nature works at the molecular level. You'll be surprised at how enjoyable knowing this can be (of all things!). People who know how nature works have a window on the inner beauty of nature of which others are not even aware. So expect to be surprised by beauty in unexpected places. Expect also to learn how chemistry is in service to society in a surprising number of ways—and thus is in service to many careers. They include medicine, nursing, dentistry, veterinary science, dietetics, nutrition, inhalation therapy, physical and occupational therapy, public health, science education, pharmacy, clinical lab work, crime lab work, consumer products safety, agriculture, forestry, home economics, engineering, and many others. Little wonder that chemistry is often referred to as the *central science*.