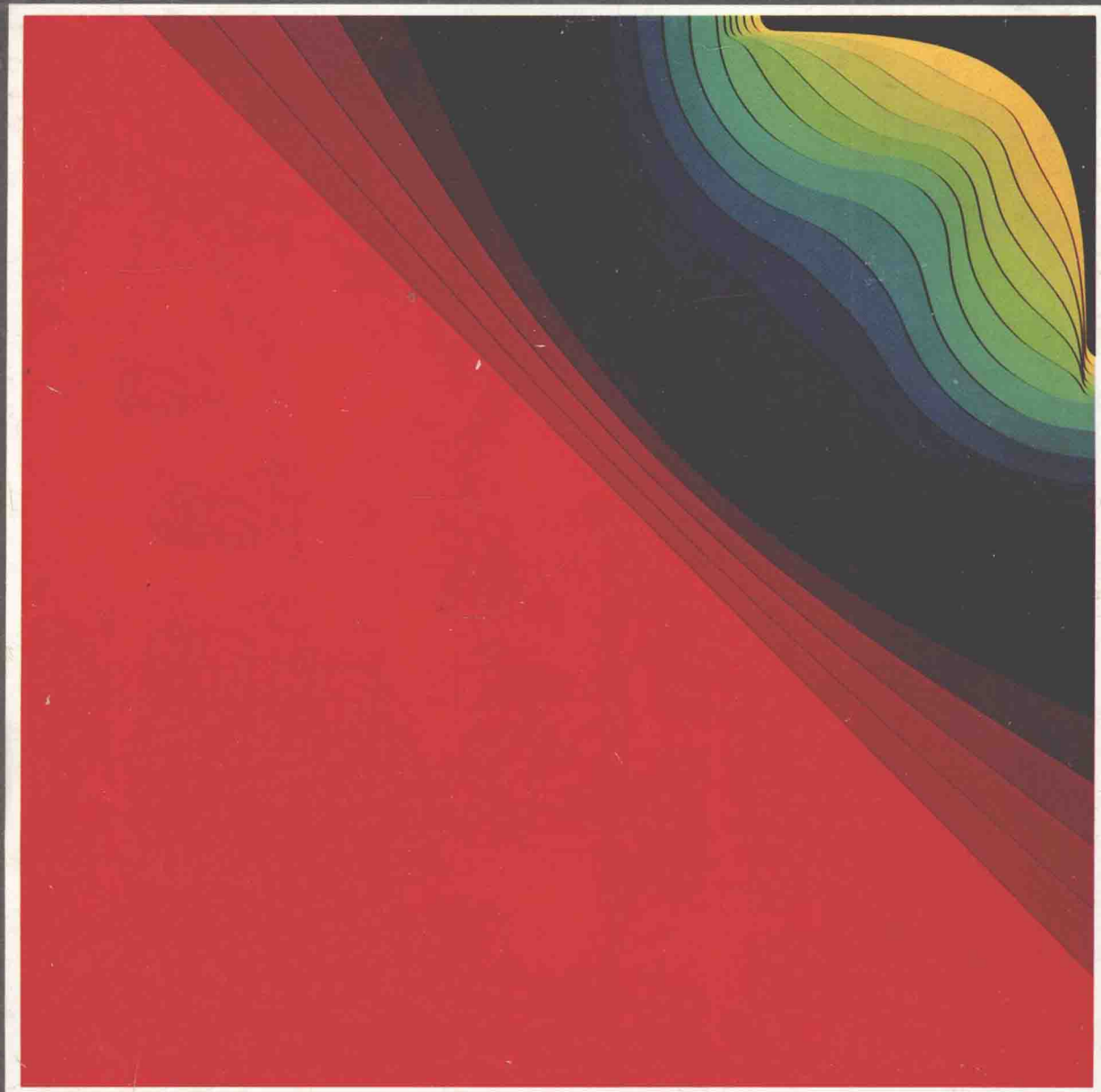


# Fundamentals of General, Organic, and Biological Chemistry



**THIRD EDITION**

**JOHN R. HOLUM**

**JOHN R. HOLUM**

Augsburg College

# **Fundamentals of General, Organic, and Biological Chemistry**

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# **Fundamentals of General, Organic, and Biological Chemistry**

## About the Author

**JOHN HOLUM** is on the faculty of Augsburg College, Minneapolis, MN. He did his undergraduate work at St. Olaf College and earned the Ph.D. (organic chemistry) at the University of Minnesota. Additional studies were taken as sabbatical leaves at California Institute of Technology and Harvard University. In 1974 he was given the Distinguished Teaching Award of the Minnesota Section of the American Chemical Society. He is a member of Phi Beta Kappa, Phi Lambda Upsilon, Sigma Xi, and Sigma Pi Sigma. The National Science Foundation has awarded him several research grants and a Science Faculty Fellowship. He is the author or co-author of several texts in chemistry, all published by John Wiley and Sons, and a reference work, *Topics and Terms in Environmental Problems* (Wiley-Interscience). He has also authored papers for the *Journal of the American Chemical Society*, the *Journal of Organic Chemistry*, and the *Journal of Chemical Education*. He has been active on the Examinations Committee and the Committee on Chemistry for Professional Health Care Students of the Division of Chemical Education of the ACS, and has spoken often at Divisional and Regional meetings, as well as at conferences of the Two-Year College Chemistry Association. His textbooks in chemistry for professional health care students have been widely used in America and abroad for 25 years.

# Preface

This text is intended primarily for students who need to know about the processes of life at the molecular level and whose programs make them limit the scope of this study to two college terms. These students include those who are preparing for careers in the professional health sciences such as nurses and nurse practitioners, medical technologists, histotechnologists, dietitians, nutritionists, inhalation therapists, home economists, physical therapists, teachers of health and physical education, other teachers, and students in the humanities who desire a broader survey of chemistry than is provided by the traditional freshman chemistry course. The text does not assume that chemistry was studied recently at the high school level.

In our use of earlier editions, we found that we can fit the first 10 to 11 chapters into one semester. Thus the first semester provides the introduction to chemical principles and types of inorganic substances — particularly acids, bases, salts, buffers, and their associated equilibria — that must be provided before the study of organic functional groups and biochemistry should begin. We have also found that the remainder of the book can be studied in the second semester where many chapters are shorter than usual, and where not all topics are treated each year in as much depth as the text provides.

For many years the **theme** of our course and the theme of this book and its earlier editions has been the molecular basis of life. We believe that no other text so consciously remains faithful to a consistent theme, and we know from years of experience that students respond with gratitude to the careful effort to make the chemistry they study as relevant as possible to their professional needs. Our students are overwhelmingly career-oriented, and we capitalize on this rather than discourage it. For example, we know that it motivates students to high efforts, as they patiently work their way through atomic and molecular structure — topics that initially seem to be so remote from their careers — to be gently reminded that life does have a molecular basis and we can't talk about it until we know what it means to be a molecule. And we give many hints early in the course of the relevance of this or that topic to the study of life at the molecular level. When acids, bases, and buffers are studied not as things in themselves but as substances whose interactions profoundly affect health, even those students who have most resisted chemistry begin to see and to accept its importance to their professions.

We are seeing an increasing number of professional nurses with an RN certificate but without a B.S. degree who are stepping back into the degree program. To do this at Augsburg College, they must have completed a one-year course in chemistry that includes roughly one term devoted to organic chemistry and biochemistry. With these students, without exception, there is no motivational problem about learning chemistry. As practicing nurses, they have seen how much they have to know about the molecular basis of life and disease. Moreover, for their own professional satisfaction, they *want* to know more chemistry, and some are considerably surprised by this development in their lives.

One major change between this edition and the previous edition occurs in the first 10 chapters. All stoichiometry, including problems associated with molar concentrations, are now consolidated into one chapter, new Chapter 5 ("Quantitative Relationships in Chemical Reactions"). Another important change has been to incorporate old Chapter 9 ("Important Metals and Nonmetals") into other chapters.

When the study of organic chemistry starts, frequent mention is made of the kinds of biological chemicals that happen to have the particular functional group currently being studied, because students appreciate the reminders that the theme of the course continues throughout all of the study of organic chemistry. However, we believe that the most sound pedagogical approach is to introduce these groups, one after the other, as they occur among the *simplest*, monofunctional compounds. Large, complex structures such as glucose or hemoglobin or DNA can be sources of terror rather than wonder when they are introduced too early.

Only the barest minimum organic chemistry is included, because the available time has to be very carefully allotted. Thus alkyl halides are barely mentioned because this system occurs nowhere among the biochemicals to be studied later. Very little is done with aromatic chemistry, because the details of aromatic electrophilic substitution reactions will not be exploited later. (What it means to be *aromatic*, and some of the characteristic reactions of the benzene ring, are studied, because this ring does occur among some amino acids and proteins.) In the first edition we tried to teach the aldol and the Claisen condensations because this chemistry can be applied when we study certain metabolic pathways. We no longer do so, however, because it simply took too much time for the benefit, so these reactions are not presented in this edition.

The emphasis in the chapters on organic chemistry is on the chemical properties of functional groups rather than on strategies for making organic compounds. We emphasize three types of reactants — water, oxidizing agents, and reducing agents — types of reactants that abound in cells. We do look briefly at certain mechanisms of reactions so that students can see that they are rational, that the reactions don't just happen by the operation of "lassos." However, the elaborate paraphernalia of mechanistic terminology that students who go on in chemistry must learn is here kept to the barest of levels. Thus the chapters on organic chemistry do not constitute a survey of organic chemistry such as one might obtain even in just a one-term course. These chapters are wholly devoted to preparing the students using this text for the biochemistry and molecular biology that follows — no more, no less.

Chapters 19 to 29 focus everything that has gone before onto a study of the principal organic substances found in cells — carbohydrates, lipids, proteins, and nucleic acids — and their chief functions as chemicals when they are in cells. Among these chapters are found most of the changes from the preceding edition. Significant portions of what was Chapter 9 in the second edition ("Important Metals and Nonmetals") are now in Chapter 25 ("Extracellular Fluids of the Body") where they work better, pedagogically.

Some changes in the biochemistry chapters make the level of the treatment more realistic for the freshman level. They reflect our own experiences in the classroom. Thus in Chapter 26 ("Biochemical Energetics") we have found that the treatment flows much better when we do not try to relate phosphate group transfer potential to the concept of free energy. Also in Chapter 26, we have reduced the level of the discussion of the chemiosmotic theory by omitting a detailed discussion of the electron flow that follows the involvement of the iron-sulfur protein.

Recent developments in the area of lipoprotein complexes and the transport of cholesterol in the blood prompted a new opening section to Chapter 28 ("Metabolism of Lipids"). Although this material is new, it is not difficult, and future health professionals ought to have a background in this area.

There are innumerable small changes in the text. The preparation of this edition involved a total rewriting of the entire book, sentence by sentence, in an effort to improve its clarity and readability for students. Of course, not every sentence was changed, but every sentence was scrutinized to see if a worthwhile change were warranted.

The design of this edition is similar to that of the previous edition. There are **margin comments**, but there is now more assurance that they are truly marginal and not integrally important to the paragraphs by which they are placed. Some are reminders. Some restate a point. Some are small, illustrative tables to which the neighboring paragraph refers. Some are structures that need not be memorized.

There are **Special Topics** on matters of current interest, and a list is provided following the Contents. One new Special Topic is NMR imaging as a diagnostic tool. Another goes into the probable connection between the regulation of fatty acid catabolism in brown adipose tissue and our ability to eat without gaining excessive weight.

Our overall goal has been to make this text the most modern, up-to-date, and readable college freshman level text in general, organic, and biological chemistry that is available anywhere. We are well aware that perfection is an ever-receding horizon, but we owe our students our finest efforts. We have gone to much greater pains than ever before to produce a zero mechanical defect product. Extra professional help in proofreading and in checking the

answers to Review Exercises and Review Problems has been engaged. As always, the author stands responsible for any errors that remain.

A comprehensive package of instructional materials, described in detail on page xi, is available to help the students. The accompanying laboratory manual has been revised and updated with special attention given to improving the clarity of the experimental directions.

Two packages of computer-aided instructional disks have been prepared to accompany this text. Four-color, overhead transparencies can be obtained. (These are the actual transparencies, not masters that would be used to make them.) A Teachers' Manual includes the answers to all of the Practice Exercises and Review Exercises.

## OTHER DESIGN FEATURES THAT AID STUDENTS

Chemistry is one of the disciplines in which important scientific terms can be sharply defined. We have tried to do so at the first occasion of using the term or as soon thereafter as possible, at or near the place where the **key term** is highlighted by a boldface color treatment. Then our aim has been to use these terms as carefully and consistently as possible. As an aid in reviewing, these terms are listed at the ends of the chapters. Then, at the end of the book, there is a **Glossary** where each of the key terms is defined.

Each chapter has a **Summary** that uses the key terms in a narrative survey. Each main section of each chapter also begins with a **summary statement** that announces what is coming and that serves during test review periods to highlight the major topics.

A new design feature is the use of labels to identify sets of **Review Exercises** that are about a common topic. (These labels replace the Index of Exercises, Questions, and Problems of the previous edition.) Within most chapters are several **Practice Exercises**, and most of these immediately follow a **worked example** that provides a step-by-step description of how to solve a certain kind of problem. The **factor-label** method is used for nearly all computations. The **answers** to all Practice Exercises are found at the back of the book together with the answers to selected Review Exercises. The *Study Guide* that accompanies this book has answers to other Review Exercises.

The **Appendix on Mathematical Concepts** has been enlarged to provide more review of what exponentials are and how to manipulate them. New to this Appendix are discussions of how to use pocket calculators to handle exponentials and to carry out chain operations.

Continuing a long tradition, we have tried to make the **Index** the most thorough, most cross-referenced index in any text of this type.

**JOHN R. HOLUM**

Augsburg College



# Acknowledgments

Over the many years of writing instructional materials, my family — Mary, my wife, and our daughters, Liz, Ann, and Kathryn — have been Gibralters of support. They, rather than teaching or writing, are my career and so such teaching and writing is seen by us as one of the ways by which our family has tried to be of help to others. I am pleased to say “thank you” to them for being such nice people.

Here, at Augsburg College, I have enjoyed many years of support from Dr. Earl Alton, Chemistry Department Chair, and Dr. Charles S. Anderson, President. My freedom to write stems in no small measure from the freedom that these caring people have accorded me.

Nice people abound at John Wiley & Sons, too. They do good work. I think of the special support of my Chemistry Editor, Dennis Sawicki, and of that of the Executive Editor, Clifford Mills. Chief illustrator John Balbalis has been skillful, artistic, and faithful in handling artwork for many years. Picture editor Stella Kupferberg solves problems and makes this facet of production worry-free. The designer, Kevin Murphy, stands in the long Wiley tradition of artistry and imagination. Senior copy editor Bruce Safford smoothly managed the overall conversion of the manuscript into a final book. The copy editor Pam Landau, has been superb in smoothing out stylistic and grammatical problems. And when it comes to error-free competence and an utterly nonabrasive but yet unyielding manager of deadlines, no one surpasses Linda Indig as a supervisor of production. All in all, it's an impressive team, and I count myself to be fortunate indeed for having become associated with John Wiley & Sons in the first place.

Part of the process of preparing a manuscript involves the professional critiques of teachers. I am pleased to acknowledge and to thank the following additional people for their work: Hugh Akers, Associate Professor, Lamar University; Charles E. Bell, Jr., Professor of Chemical Sciences, Old Dominion University; Lois Dalla-Riva, Professor of Chemistry, Golden West College; Dr. Estelle Gearon, Professor of Chemistry, Montgomery College; Dr. Arlin Gyberg, Augsburg College; Dr. Robert G. Martinek, Manager, Chicago Laboratory, Illinois Department of Health; Sandra Olmstead, Professor, Augsburg College; Dr. James R. Paulson, Chemistry Department, University of Wisconsin-Oshkosh; Salvatore Profeta, Jr., Adjunct Professor of Chemistry, Louisiana State University; and Dr. Neal Thorpe, Augsburg College.

**J.R.H.**

# Supplementary Materials for Students and Teachers

The complete package of supplements available to help students study and teachers plan the course and operate the associated laboratory work includes the following:

**Laboratory Manual for Fundamentals of General, Organic, and Biological Chemistry, 3rd edition.** This has been prepared by Professor Sandra Olmsted. An instructor's manual is a section in the general Teachers' Manual described below.

**Study Guide for Fundamentals of General, Organic, and Biological Chemistry, 3rd edition.** This softcover book contains chapter objectives, chapter glossaries, additional worked examples and exercises, sample examinations for each chapter, and the answers to those Review Exercises for which answers are not in the text.

**Teachers' Manual for Fundamentals of General, Organic, and Biological Chemistry, 3rd edition.** This softcover supplement is available to teachers, and it contains all of the usual services for *both the text and the laboratory manual*. Those who adopt this book may also request from John Wiley & Sons a set of questions that can be used to prepare examinations. (The address is given in the next paragraph.)

**Transparencies.** Instructors who adopt this book can receive from John Wiley & Sons, without charge, a set of slides (actual slides, not slide masters), many in color, of several figures and tables in this book. Write to: Chemistry Editor, John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158.

**Computer-Aided Instructional Packages.** Two sets of instructional software are available as supplements, one for the use of students when they are reviewing and the other for their use as pre-lab study material. Professor Richard Cornelius of Wichita State University wrote the lecture-oriented software, and Sandra and Richard Olmsted (Augsburg College) prepared the lab-oriented materials. The latter package has several units that work exceptionally well in classrooms equipped with electronic blackboards. The animated sequences that explain difficult concepts such as mutarotation, DNA-directed polypeptide synthesis, and osmosis are outstanding teaching devices. For further information write to: Chemistry Editor, John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158 or to Prof. Sandra Olmsted, Augsburg College, Minneapolis, MN 55454.

**J.R.H.**

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# Chapter 1

## Goals, Methods, and Measurements



*A goal, an ability to concentrate, a willingness to build bit by bit, and the support of many people all go into education in any field. A sound understanding of the molecular basis of life, the overarching topic of this book, is a building block in many careers.*