

Organic Chemistry

SECOND EDITION

G. Marc Loudon

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Purdue University



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Preface

This book was written because I have for several years felt the need for a text that corresponds more closely than other texts to the course I teach. Although it is organized along tried-and-true functional-group lines, the book contains some unique features that have served me well in both my teaching and my learning of organic chemistry.

I have had four major concerns in both the initial writing and the revision of this text: *readability*, *type of presentation*, *organization*, and *scientific accuracy*.

READABILITY

In addition to the writing style, some of the devices used to enhance readability are:

1. **Use of common analogies** to aid in the understanding of difficult topics. Two of the many examples can be found on pages 437 and 606.
2. **Use of numerous figures and diagrams** to illustrate important concepts.
3. **Frequent cross-referencing** to assist students in finding the initial discussion of seminal topics. This technique is illustrated on page 963, just below Eq. 22.93.
4. **Framing of problems in humorous or "real-life" contexts.** Problem 31 on page 32 and Problem 32 on page 577 demonstrate this approach.
5. **Guidance on how to solve problems.** This takes several forms: worked-out examples, as on pages 407–408, 500, and 513; hints as in Problem 35, page 362; and detailed lists of leading questions that show students the path to an answer without revealing the answer outright, as in the box at the top of page 177. This guidance is extended in the Study Guide–Solutions Manual, in which the problem-solving approaches parallel those in the text.

6. **Frequent summaries and recapitulations of key ideas.** These also take several forms. There are the end-of-chapter "Key Ideas" summaries, which bring together important concepts from within the chapter. In a number of sections, important points are brought together with numbered lists, as on page 354. And there are appendices at the end of the text that summarize rules of nomenclature, key spectroscopic information, acidity and basicity data, and synthetic methods. Because I try to discourage students (not always successfully) from memorizing tables of reactions, I have moved reaction summaries out of the text and into the Study Guide–Solutions Manual supplement. I encourage students to make their own summaries and check them against those in the supplement.

7. **Use of a second color within chemical equations** to show contrasts and changes. The scheme on page 943 is illustrative of the literally hundreds of examples of this technique within the text. Labeling with color the groups that change in a reaction draws a student's attention to the point of the equation. Yet this is not done in every equation, because students must learn to look for themselves. To avoid confusion, we intentionally avoided the use of a four-color presentation within equations, compound names, and spectra.

8. **Presentation of historical sketches in anecdotal style**, as opposed to dry biographical data. Examples of such sketches are found at the bottom of pages 782 and 936. The purpose of these is to stress that chemistry is a human endeavor, and that the road to discovery is often paved with serendipity and humor. Screened boxes have been used to set these "asides" apart from the text.

During the writing of this book, I have tried to anticipate the questions of a student studying organic chemistry for the first time. The book has benefitted from the questions that my own students have posed to me. I have tried to challenge the student to think about the subject rather than simply memorizing it. I have endeavored to write under the conviction that we must continue to confront our students not only with the factual material of organic chemistry, but also with the considerable intellectual beauty and challenge of the subject.

TYPE OF PRESENTATION

A number of elements of the presentation used in this text are worth special comment.

1. I have chosen a mechanistic approach within the overall functional-group framework of the text. This emphasis is consonant with the recognition by many teachers of organic chemistry that the only way for students to truly learn the subject is for them to see the unifying elements that connect what at first appear to be unrelated phenomena. Thus, students learn a given reaction more easily when its mechanistic connection to an earlier reaction is apparent. The benefit of this approach is that students can understand why organic reactions occur as they do. They can make reasonable predictions about the outcome of unknown reactions. In contrast, students who view each reaction as an isolated entity court a nearly impossible task in trying to learn organic chemistry by virtual rote memorization. To assist with this mechanistic approach, I have not only presented, but also *thoroughly explained*, the "curved-arrow" formalism, I have required that students master it, and I have *used it consistently* throughout the text. I have also stressed both Lewis and Brønsted acid-base properties of organic compounds, not only because these topics are important in their

own right (how many organic reactions incorporate acid-base steps in their mechanisms?), but also because these concepts can be logically extended in many cases to the prediction of chemical reactivity.

2. One of the key elements in the presentation of organic chemistry by any textbook is the *mechanistic centerpiece*—the reaction used to introduce the notions of mechanism, such as multi-step reactions, reaction free-energy diagrams, reactive intermediates, rate-determining step, and the like. The traditional vehicle for this purpose has been free-radical halogenation of alkanes. I have felt that since most of the common organic reactions encountered by students are polar reactions, the mechanistic centerpiece should also be a polar reaction. I have chosen to use for this purpose polar additions to alkenes, because an unsymmetrical alkene can in principle undergo two competing addition reactions. We can evaluate the relative merits of the two reaction pathways by a direct comparison of carbocation stabilities and, invoking Hammond's postulate, transition-state stabilities; the issue is not complicated by relative stabilities of starting materials, because the starting materials are the same for both pathways.

Free-radical reactions are not ignored, but only postponed until students have a chance to master the essentials of polar reactions. At the proper time, free-radical reactions (and the corresponding "fishhook" formalism) are introduced and thoroughly discussed.

3. More than 1300 problems of both the in-text and end-of-chapter variety are provided. These range in difficulty from simple drill-type problems to problems that will challenge the best students.

4. There is a thorough discussion of stereochemistry. The subject is introduced early and strongly reinforced throughout the text, both in discussions of reactions and in problems. The application of stereochemistry to chemical reactions (Chapter 7), and group equivalence and nonequivalence (Chapter 10) are two stereochemical topics whose treatments are particularly unique to this text.

5. I have introduced an important topic too-often ignored in undergraduate texts: solvents in organic chemistry, and the relationship of gas-phase chemistry to solvent effects. The level of this discussion is introductory, appropriate for the beginning undergraduate.

6. I have presented a thorough approach to defining and understanding oxidation and reduction in organic chemistry.

7. There are biological applications of appropriate chemistry, not set apart in "special topics" chapters, but instead included in sections adjacent to the related laboratory chemistry. In these examples, I have not forgotten that this is a chemistry text, not a biochemistry text; and the underlying theme of these sections is not the details of the biology involved, but rather the close analogy of biological chemistry to laboratory reactions.

8. Nomenclature is treated thoroughly in this book because I believe that after students finish a first course in organic chemistry, they should be able to construct a systematic name for any simple organic compound.

9. Finally, I have tried to indicate the important role of organic chemistry in today's economy, and have discussed some of the key social issues surrounding organic chemistry (pollution and chemical carcinogenesis, to name two). Since we teach so many non-majors, I believe that they must leave our classes convinced that organic chemistry is a potent economic force, and that embodied within the discipline is the capacity to solve a number of social problems, not just to create them.

ORGANIZATION

In this edition, I have grouped reactions of alkenes, alkyl halides, alcohols, ethers, epoxides, thiols, and sulfides together in early chapters. I have two reasons for this strategy: first, the chemistry of these groups is strongly interrelated; and second, a substantial amount of nonhydrocarbon chemistry can be covered in the early part of the course. Following an interlude dealing with spectroscopy (which could be placed anywhere with little adjustment in a course using this text), I return to concepts of resonance and aromaticity by considering dienes, aromatic compounds, and allylic/benzylic reactivity. Then comes carbonyl chemistry, where I have consolidated a discussion of enols, enolate ions, and condensation reactions in a special chapter. This is followed by amine and heterocycle chemistry. The text closes with pericyclic reactions, amino acid and peptide chemistry, and finally, sugar and nucleic acid chemistry.

SCIENTIFIC ACCURACY

Each topic in this book was researched back into the original or review literature. In the preface to the first edition I stated that it would be presumptuous to state that this book is free of factual errors—and I am glad I made that statement! I have endeavored to correct the errors that I, my students, and my colleagues have found, and I am indebted to the many people who have sent concrete suggestions for sharpening the accuracy of the text.

CHANGES TO THE SECOND EDITION

How is the second edition different from the first? To begin with, the book is considerably shorter. Using the format of the first edition as a frame of reference, the equivalent of about three hundred pages of material has been cut. About a hundred pages of these savings have been expended in design considerations—in opening up the layout to give it a less “dense” look. The result is a text that is nearly two hundred pages shorter and more visually digestible than the first edition—and this including a new chapter on pericyclic reactions. What was deleted from the first edition? First, I cut a number of the more difficult problems. (This edition still has more problems than any other text.) Second, I deleted several spectra that I viewed as redundant. Third, I consolidated several topics. For example, the section on mass spectrometry has been included in the chapter with infrared spectroscopy, and the level of presentation has been reduced somewhat. Finally, a few topics have been deleted. I became personally convinced from my own teaching that these changes would be beneficial, and I believe that they have enhanced the usability of the text without altering the positive qualities of the first edition.

The text has seen some reorganization, much of which was discussed above. In addition, much of the art has been totally redesigned, with the introduction of considerably more airbrushed drawings, and the use of ball-and-stick models instead of line formulas in situations calling for stereochemical detail.

The treatment of organic synthesis has been reorganized. Instead of concentrating a single discussion within a detailed chapter near the end of the text, I have

considered the strategy of organic synthesis much earlier, in Chapters 10 and 11, points at which students have accumulated just enough reactions in their repertoire that they can begin to construct relatively simple multistep syntheses. The concepts of these sections are continually reinforced within several later chapters in the discussions of reactions that are particularly useful in synthesis. Some of the deletions in this edition are of synthetically redundant reactions. For example, I have deleted the reaction of carboxylic acids with organolithium reagents—a perfectly useful reaction, but one which, at the beginner's level of expertise, offers no advantages over other methods of ketone synthesis.

SUPPLEMENTS

Another important change is that we have provided a completely redesigned and rewritten *Study Guide—Solutions Manual*. Assembled into an attractive format with modern desktop-publishing technology, this supplement contains glossaries, conceptual outlines, and summary tables, as well as a solution to every problem in the text. As with the previous edition, *transparencies* of key diagrams from the text are available for classroom teaching purposes.

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There are many whom I wish to acknowledge for their assistance in the preparation of this text. I am indebted to my Department Chairman, Professor John M. Cassady, for providing encouragement as well as an environment in which this text could be completed expeditiously. I am grateful to my departmental colleagues Mark Cushman, John Schwab, Del Knevel, and Joe Stowell, as well as to chemistry faculty Harry Morrison, Bob Benkeser, and Jim Brewster for providing corrections, consultations, and suggestions for improvement. I am indebted to Professor John Pinzelik, Chemistry Librarian at Purdue, and to Professor Theodora Andrews, and their staffs for frequent assistance throughout the preparation of both editions. Several reviewers were helpful in this revision, particularly Professor Charles Wilcox of Cornell University; Professor Maitland Jones of Princeton University; Professor John Wiseman of the University of Michigan; Professor Jay Bardole of Vincennes University; Robert Belloli of California State University—Fullerton; Jed Fisher of the University of Minnesota; John Hogg and Tammy Tiner of Texas A & M University; Michael Rathke of Michigan State University; Grant Taylor of the University of Louisville; and most especially, Professor Ron Magid of the University of Tennessee, whose constant attention to accuracy and detail from start to finish, not to mention good humor, were very important to me throughout the project. In addition, I am indebted to the many students who used the first edition and offered constructive advice—including those who called from other universities.

The relationship between author and publisher has been exceptionally gratifying. I would particularly acknowledge David Chelton for his extremely useful guidance as Developmental Editor; Audre Newman, who helped develop the art program; Steve Mautner, my editor who guided the revision through the manuscript phase; Diane Bowen, my present editor at Benjamin-Cummings, who has been a valued fountain of advice and encouragement; and Pat Waldo, Deborah Gale, and Mimi Hills of "Partners

in Publishing," who guided the second edition through the production phase with expertise and good humor.

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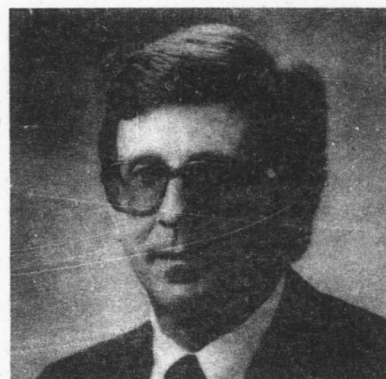
Finally, and most importantly, I acknowledge the love and support of my family, to whom this book is dedicated.

My wish for this text is that students and professors will enjoy using this text as much as I have enjoyed writing it!

West Lafayette, Indiana
October 1987

G. M. L.

About the Author



Marc Loudon received his B. S. (Magna Cum Laude) in chemistry from Louisiana State University in 1964 and his Ph.D. in organic chemistry from the University of California, Berkeley, where he worked with Professor Donald S. Noyce. After two years of post-doctoral work with Professor Daniel E. Koshland in the Biochemistry Department at Berkeley, Dr. Loudon joined the faculty of the Chemistry Department at Cornell University, where he taught organic chemistry to both preprofessional students and science majors. He received the Clark Award for Distinguished Teaching in 1976. Since 1977, Dr. Loudon has been at Purdue University, where he is presently professor of Medicinal Chemistry. At Purdue, Dr. Loudon has twice won the Professor Henry Heine Award for his teaching of organic chemistry.

Dr. Loudon's research interests are in the application of organic chemistry to biological problems, particularly in the peptide/protein field; development of antineoplastic agents for cancer chemotherapy; and the mechanisms of organic reactions, particularly those in aqueous solution.

Dr. Loudon is an accomplished organist and has performed professionally in the San Francisco Area, at Cornell University, and in Indiana. He also enjoys playing competitive tennis and has participated in several tournaments with no success whatsoever.

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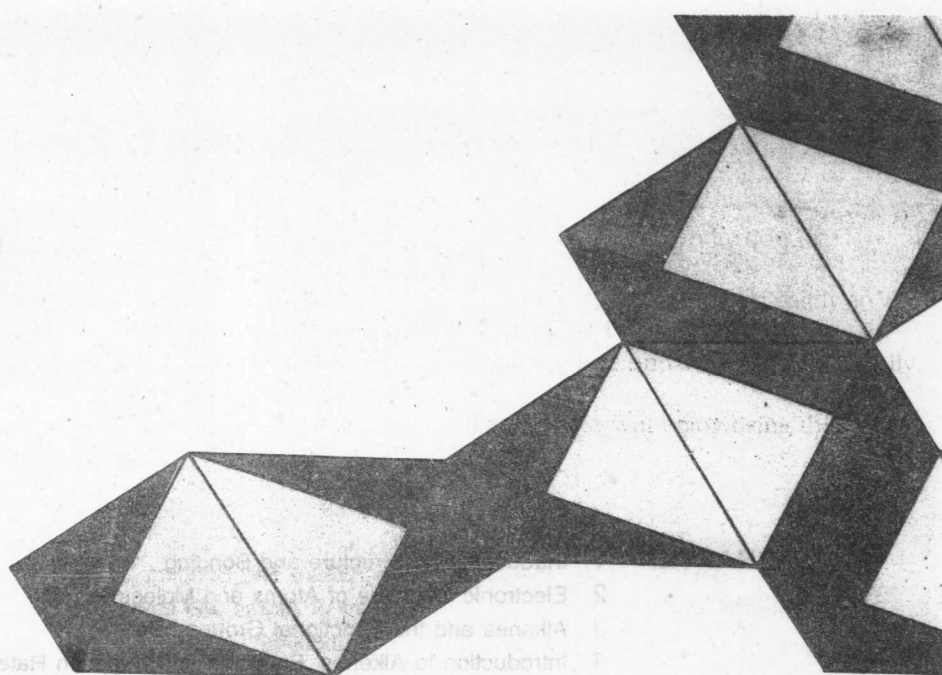
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