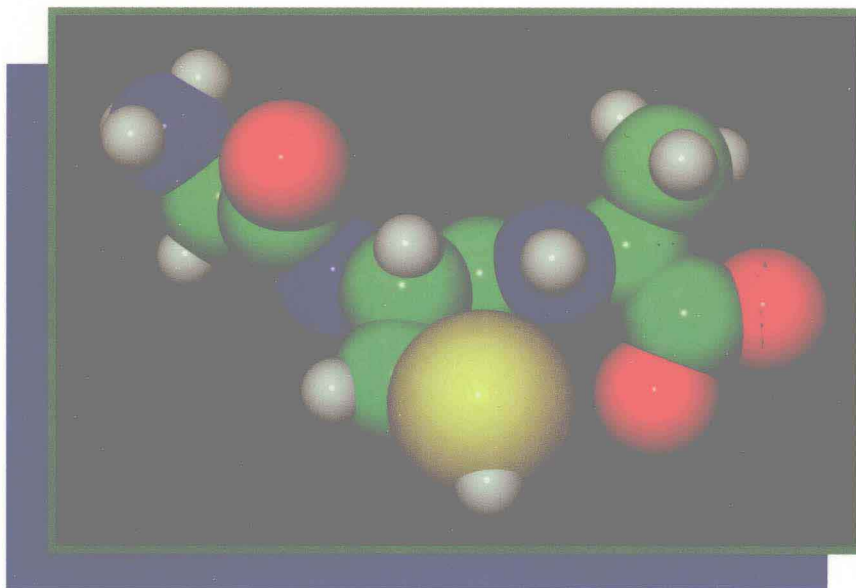


Organic Chemistry



Third Edition
L.G. WADE, JR.

Third Edition

Organic Chemistry

L. G. Wade, Jr.
Whitman College



Prentice Hall
Englewood Cliffs, New Jersey 07632

WADE, L. G.

Organic chemistry/L. G. Wade, Jr. — 3rd ed.

p. cm.

Includes index.

ISBN 0-13-301631-5

1. Chemistry, Organic. I. Title.

QD251.2.W33 1995

547—dc20

94-24693

CIP

Editorial/production supervision: *Barbara Martine Cappuccio*

Acquisitions editor: *Deirdre Cavanaugh*

Interior design and page layout: *Lorraine Mullaney*

Cover design: *Tessie Lou*

Manufacturing buyer: *Lori Bulwin/Alan Fischer*

Managing editor: *Kathleen Schiaparelli*

Director of production and manufacturing: *David W. Riccardi*

Copy editor: *Barbara Ligouri*

Supplements editor: *Mary Hornby*

Editorial assistant: *Veronica Wade*



© 1995, 1991, 1987 by Prentice-Hall, Inc.

A Simon & Schuster Company

Englewood Cliffs, New Jersey 07632

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

COVER ART: BioGrafx

A computer-generated representation of a tripeptide, glycylcysteylalanine. In this representation, carbon is green, hydrogen is white, nitrogen is blue, oxygen is red, and sulfur is yellow.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-0301631-5

Prentice-Hall International (UK) Limited, *London*

Prentice-Hall of Australia Pty. Limited, *Sydney*

Prentice-Hall Canada, Inc., *Toronto*

Prentice-Hall Hispanoamericana, S.A., *Mexico*

Prentice-Hall of India Private Limited, *New Delhi*

Prentice-Hall of Japan, Inc., *Tokyo*

Simon & Schuster Asia Pte. Ltd., *Singapore*

Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

To
my Students and Colleagues
at Whitman College

To the Student

As you begin your study of organic chemistry, you might feel overwhelmed by the number of compounds, names, reactions, and mechanisms that confront you. You may even wonder whether you can learn all this material in a single year. The most important function of a textbook is to organize the material to show that most of organic chemistry consists of a few basic principles and many extensions and applications of these principles. Relatively little memorization is required if you grasp the major concepts and develop flexibility in applying those concepts. Frankly, I have a poor memory, and I hate memorizing lists of information. I don't remember the specifics of most of the reactions and mechanisms in this book, but I can work them out by remembering a few basic principles, like "alcohol dehydrations usually go by E1 mechanisms."

Still, some facts and fundamental principles (probably about ten to twenty) in each chapter must be learned to serve as the working "vocabulary" of that chapter. As a student I learned this the hard way, when I made a **D** on my second organic chemistry exam because I had neglected to learn the important terms. In writing this book, I've tried to point out a small number of important facts and principles that should be learned to prepare for solving problems. For example, in studying nuclear magnetic resonance one might memorize thousands of chemical shifts, but Table 12-3 lists only about a dozen representative values that can be learned and used to solve most problems.

Don't try to memorize your way through this course. It doesn't work; you have to know what's going on so you can apply the material. Also, don't think (like I did) that you can get by without memorizing *anything*. Read the chapter, listen carefully to the lectures, and *work the problems*. The problems will tell you whether you know the material. If you can do the problems, you should do well on the exams. If you can't do the problems, you probably won't be able to do the exams, either. If you keep having to look up something to do the problems, that item is a good one to learn.

Here are some hints I give my students at the beginning of the course:

1. Read the material in the book before the lecture (expect 13–15 pages per lecture). Knowing what to expect and what is in the book, you can take fewer notes and spend more time listening and understanding the lecture.
2. Before the next lecture, review your notes and the book, and do the in-chapter problems. Also, read the material for the next lecture.
3. If you are confused about something, visit your instructor during office hours immediately, before you fall behind. Bring your attempted solutions to problems with you to show your instructor where you are having trouble.
4. To study for the exam, begin by reviewing each chapter and your notes, then

concentrate on the end-of-chapter problems. Also use old exams for practice, if available.

Remember the two “golden rules” of organic chemistry:

1. **DON'T GET BEHIND!** The course moves too fast, and it's hard to catch up.
2. **WORK LOTS OF PROBLEMS.** Everyone needs the practice, and problems show where you need more work.

Study Aids

Several kinds of study aids are provided to emphasize and review the most important points.

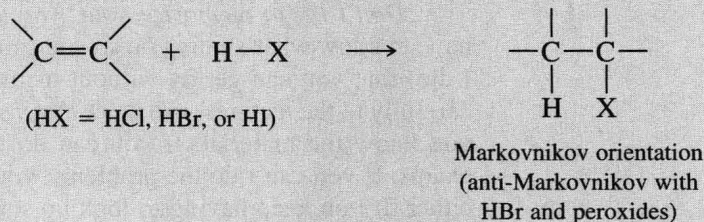
Summary Tables. Whenever a large amount of material lends itself to a concise summary, a summary table (highlighted by a blue background) is provided to compare and contrast this material. For example, a summary table on p. 266 compares the factors affecting S_N1 and S_N2 reactions, and another summary table (p. 281) contrasts $E1$ and $E2$ reactions.

Reaction Summaries. At the conclusion of each section on syntheses or reactions of a functional group (“Reactions of Alkenes,” for example), a summary table is provided for efficient review. Each summary, highlighted by a blue background, includes cross-references to reactions that are discussed elsewhere.

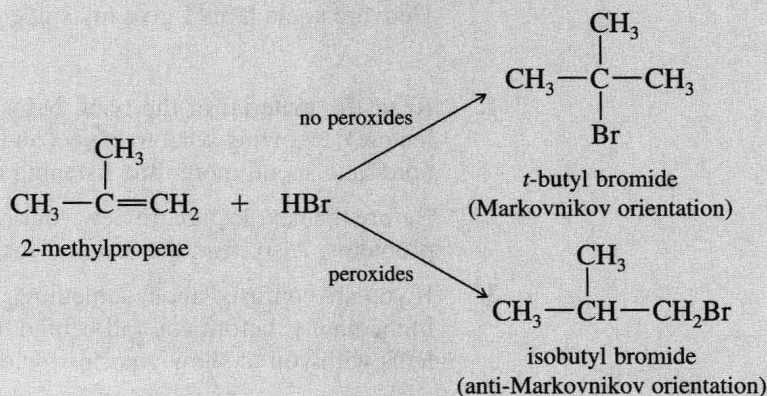
SUMMARY: The Reactions of Alkenes

1. Electrophilic additions

a. Addition of hydrogen halides (Section 8-3)



Example

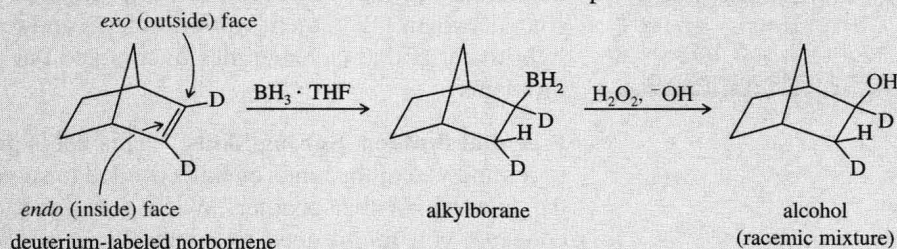


Problems. The in-chapter problems appear right after the relevant sections of the text. These problems provide immediate review and reinforcement of the material as it is learned, helping to make sure you understand each section well enough before moving on to the next. Later, end-of-chapter problems promote additional review and practice. Your instructor may choose to assign specific problems that reflect the emphasis of the lectures. Problems with red stars (*) are more difficult problems that require extra thought and perhaps some extension of the material presented in the chapter.

Solved Problems. Where appropriate, solved problems (highlighted by a gray background) are provided to show how you might approach a particular type of problem and what kind of answer is expected. For example, a solved problem might work through a mechanism to show how it is broken down into individual steps and how red curved arrows show movement of electrons.

SOLVED PROBLEM 8-4

A norbornene molecule labeled with deuterium is subjected to hydroboration-oxidation. Give the structures of the intermediates and products.



SOLUTION The syn addition of BH_3 across the double bond of norbornene takes place mostly from the more accessible outside (*exo*) face of the double bond. Oxidation gives a product with both the hydrogen atom and the hydroxyl group in *exo* positions. (The less accessible inner face of the double bond is called the *endo* face.)

Glossaries. Each chapter ends with a glossary that defines and explains technical terms introduced in that chapter. New terms defined in the glossary are printed in boldface the first time they appear in the chapter. The glossaries serve not only as dictionaries, but also as study aids for reviewing the material. They will help to jog your memory as you go over the definitions and make sure you understand and can use all the new terms.

Problem-Solving Strategies. The problem-solving strategies (highlighted by a green background) suggest methods for approaching complicated problems, such as those that require proposing mechanisms and developing multistep syntheses. Students often have trouble seeing how to approach problem solving, and these strategies are meant to help you break the problem down into simpler pieces. Although organic chemistry cannot be broken down into a rote process that guarantees an answer, experienced chemists instinctively approach problems in ways that are more likely to lead to solutions. The suggestions in the problem-solving discussions approximate what an experienced chemist is likely to do in approaching these problems. They serve as a starting point, not a guaranteed route to the answers.

PROBLEM SOLVING: Organic Synthesis

Alkyl halides are readily made from other compounds, and the halogen atom is easily converted to other functional groups. This flexibility makes alkyl halides useful as reagents and intermediates for organic synthesis. **Organic synthesis** is the preparation of desired compounds from readily available materials. Synthesis is one of the major areas of organic chemistry, and nearly every chapter of this book involves organic synthesis in some way. A synthesis may be a simple one-step reaction, or it may involve many steps and incorporate a subtle strategy for assembling the correct carbon skeleton with all the functional groups in the right positions.

Many of the problems in this book are synthesis problems. In some synthesis problems, you are asked to show how to convert a given starting material to the desired product. There are obvious one-step answers to some of these problems.

PROBLEM-SOLVING HINT

Look for a hydrogen trans to the leaving group; then see if the hydrogen and the leaving group can become diaxial.

Problem-Solving Hints. These suggestions (green boxes in the art column at the left of the page) are provided to remind you of facts or principles that are likely to be useful for solving common types of problems. These are the tips I give my own students when I help them work problems and review for exams. These hints highlight material that is sometimes overlooked but plays an important role in solving problems.

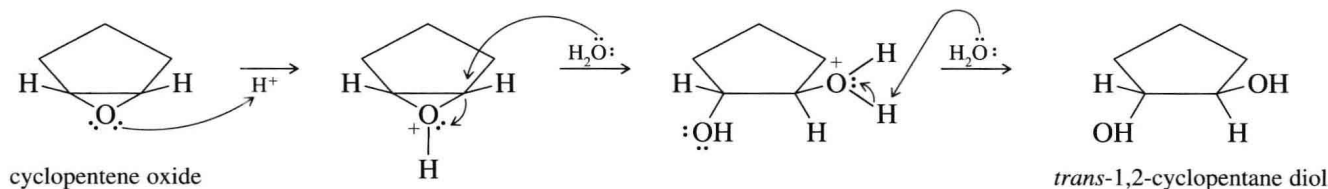
Essential Problem-Solving Skills. This list is provided at the end of each chapter to remind you of the kinds of skills needed to solve typical problems associated with the material in that chapter. When you finish a chapter, this list can point out concepts you might need to review, or it might suggest types of problems and solutions you might not have considered. Reviewing the problem-solving skills is often a good prelude to doing the end-of-chapter problems.

Four-Color Printing. This book is printed with four colors of ink to help you find and organize the material. Color is used to highlight major features for easy location. For example, the blue backgrounds of summary tables and reaction summaries were shown above. The gray background for solved problems, the green background for problem-solving strategies, and the green boxes for problem-solving hints and essential problem-solving skills were also shown above. Other features that are set off by color:

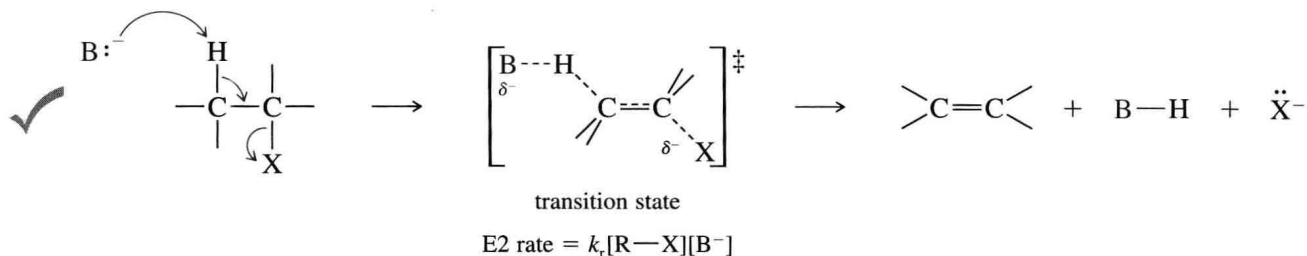
1. Key definitions and rules are in blue type.

MARKOVNIKOV'S RULE The addition of a proton acid to the double bond of an alkene results in a product with the acid proton bonded to the carbon atom that already holds the greater number of hydrogen atoms.

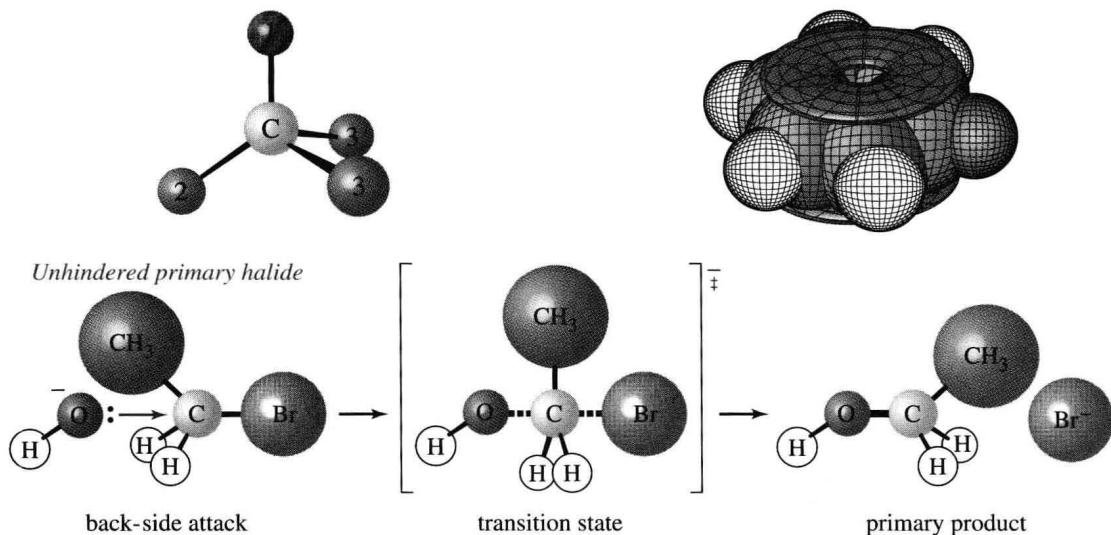
2. Curved red arrows are used throughout for "electron pushing," to show the flow of electrons through the course of a reaction.



3. Important general reactions are highlighted by a check mark in the margin. Nucleophiles are often printed in blue and electrophiles in green.



The variety of available colors makes it possible to highlight and distinguish key aspects of reactions, structures, and molecular drawings, to distinguish atoms and bonds within molecules and transition states.



Supplements Solutions Manual

Brief answers to many of the in-chapter problems are given at the back of this book. These answers are sufficient for a student on the right track, but they are of limited use to one who is having difficulty working the problems. The *Solutions Manual*, prepared by Jan W. Simek of California Polytechnic State University, contains worked-out solutions to all the problems. These solutions also give helpful hints on how to approach each kind of problem. This supplement is a useful aid for any student, and it is particularly valuable for students who feel they understand the material but need more help with problem solving. The *Solutions Manual* also includes an Appendix summarizing the IUPAC system of nomenclature.

Molecular Models

Every organic chemistry student needs a set of molecular models. These models are used to demonstrate a multitude of principles, including stereochemistry, ring strain, conformations of cyclic and acyclic systems, and many others. Many different kinds of models are available. Framework models have the advantage of flexible bonds that can form strained systems, with the amount of bend in the bonds giving a

qualitative idea of the amount of strain. Space-filling models do a better job of showing steric effects with bulky substituents. In most cases, instructors help students choose models that effectively illustrate the most important principles.

I am always interested in hearing from students using this book. If you have any suggestions about how the book might be made better, or if you've found an error, please let me know. (L. G. Wade, Whitman College, Walla Walla, WA, 99362). I take students' suggestions seriously, and hundreds of them now appear in this book. For example, Whitman student Brian Lian suggested Figure 21-20, and University of Minnesota student (and racing driver) Jim Coleman gave me the facts on methanol use at Indianapolis.

Good luck with your study of organic chemistry. I'm certain you will enjoy this course, especially if you let yourself relax and develop an interest in how organic compounds influence our lives. My goal in writing this book has been to make the process a little easier: to build the concepts logically on top of each other, so they flow naturally from one to the next. The hints and suggestions for problem-solving have helped my students in the past, and I hope some of them will help you to learn and use the material. Even if your memory is worse than mine (highly unlikely), you should be able to do well in organic chemistry. I hope this will be a good learning experience for all of us.

To the Instructor

In writing the first edition of this text, my goal was to produce a modern, readable text that uses the most effective techniques of presentation and review. The second edition extended and refined that goal, with substantial rewriting and reorganization and with the addition of several new features. This third edition incorporates even more refinements than the second, with major revisions in the organization, writing, and graphics. Some of the more obvious changes are:

1. The chapters are reorganized to place stereochemistry earlier, allowing its use throughout the other chapters, and particularly in the chapter on nucleophilic substitutions and eliminations.
2. Much of the writing has been revised to enhance clarity and simplicity, and to eliminate unnecessary repetition. Several new topics have been added, and others have been expanded and updated.
3. The graphics are entirely new, with computer-generated art used throughout the book. I hope the new art will help students to get more of a tangible, intuitive feel for the molecules and processes represented by the art.
4. The popular problem-solving essays introduced in the second edition have been rewritten and expanded to enhance consistency and cover more topics.
5. New features have been added, including about 140 problem-solving hints that alert students to facts and principles that make it easier to solve particular kinds of problems.
6. More problems and solved problems have been added, with emphasis on road-map problems, problems using stereochemistry, and challenging starred problems.

The entire book has been microedited, with many large passages rewritten to enhance clarity. As in the first edition, each new topic is introduced carefully and explained thoroughly. Whenever possible, illustrations help students visualize each physical concept, and many in-chapter problems give immediate reinforcement as students work through each chapter.

The emphasis continues to be on *chemical reactivity*. Chemical reactions are introduced as soon as possible, and each functional group is considered in view of its reactivity toward electrophiles, nucleophiles, oxidants, reductants, and other reagents. “Electron-pushing” mechanisms are stressed throughout as a means of explaining and predicting this reactivity. Structural concepts such as stereochemistry and spectroscopy are thoroughly treated as useful techniques that enhance the fundamental study of chemical reactivity.

Organization This book maintains the traditional organization that concentrates on one functional group at a time while comparing and contrasting the reactivity of different functional groups. Reactions are emphasized, beginning with Lewis acid-base reactions in Chapter 1, continuing with thermodynamics and kinetics in Chapter 4, and covering most of the important substitution, addition, and elimination reactions in the three chapters following stereochemistry.

Spectroscopic techniques (IR, MS, and NMR) are covered in Chapters 11 and 12, so that they will be covered in the first semester. This early coverage is needed to allow effective use of spectroscopy in the laboratory. Still, a large amount of organic chemistry has been covered before this digression into structure determination. The principles of spectroscopy are practiced and reinforced in later chapters, where the characteristic spectral features of each functional group are summarized and reinforced by practice problems.

Key Features **Flexibility of Coverage**

No two instructors teach organic chemistry in exactly the same way. This book covers all the fundamental topics in detail, building each new concept on those that come before. Many topics may be given more or less emphasis at the discretion of the instructor. Examples of these topics are ^{13}C NMR spectroscopy, ultraviolet spectroscopy, conservation of orbital symmetry, nucleic acids, and the special topics chapters: lipids and synthetic polymers.

Another area of flexibility is in the problems. The wide-ranging problem sets review the material from several viewpoints, and more study problems are provided than most students are able to complete. This large variety allows the instructor to select the most appropriate problems for the individual course.

Up-To-Date Treatment

In addition to the classical reactions, this book covers many techniques and reactions that have more recently gained wide use among practicing chemists. Molecular-orbital theory is introduced early and used to explain electronic effects in conjugated and aromatic systems, pericyclic reactions, and ultraviolet spectroscopy. Carbon-13 NMR spectroscopy is treated as the routine tool it has become in most research laboratories. Many of the newer synthetic techniques are also included, such as the Birch reduction, DIBAH reduction of esters, alkylation of 1,3-dithianes, and oxidations using pyridinium chlorochromate.

Reaction Mechanisms

Reaction mechanisms are important in all areas of organic chemistry, but they are difficult for many students. Students fall into the trap of memorizing a mechanism while not understanding why it proceeds as it does. This book stresses the principles

used to predict mechanisms. Problem-solving sections develop basic techniques for approaching mechanism problems and they work to minimize rote memorization. These techniques emphasize deciding whether the reaction is acidic, basic, or free radical in nature, then breaking it down into Lewis acid-base interactions and using “arrow pushing” to illustrate these individual steps.

Introduction to Mechanisms Using Free-Radical Halogenation

The advantages and disadvantages of using free-radical halogenation to introduce reaction mechanisms have been debated for many years. The principal objection to free-radical halogenation is that it is not a useful synthetic reaction. But useful reactions such as nucleophilic substitution and additions to alkenes are complicated by participation of the solvent and other effects. Gas-phase free-radical halogenation allows a clearer treatment of kinetics and thermodynamics, as long as its disadvantages as a synthetic reaction are carefully discussed and the student is aware of the limitations.

Organic Synthesis

Organic synthesis is stressed throughout this book, with progressive discussions of the process involved in developing a synthesis. *Retrosynthetic analysis* is emphasized, and the student learns to work backward from the target compound and forward from the starting materials to find a common intermediate. Several new problem-solving discussions of organic synthesis have been added, emphasizing how one approaches a multistep synthesis.

Typical yields have been provided for many synthetic reactions, although I hope students will not misuse these numbers. Too often students consider the yield of a reaction to be a fixed characteristic just as the melting point of a compound is fixed. In practice, many factors affect product yields, and literature values for apparently similar reactions often differ by a factor of 2 or more. The yields given in this book are *typical* yields that a good student with excellent technique might obtain.

Spectroscopy

Spectroscopy is one of the most important tools of the organic chemist. This book develops the theory for each type of spectroscopy and then discusses the characteristic spectral features. The most useful and dependable characteristics are summarized into a small number of rules of thumb that allow the student to interpret most spectra without looking up or memorizing large tables of data. For reference use, extensive tables of NMR and IR data and a more complete version of the Woodward-Fieser rules for UV are provided as appendices.

This approach is particularly effective with ultraviolet spectroscopy, ^{13}C NMR, and mass spectrometry. Practical rules are given to help students see what information is available in the spectrum and what spectral characteristics usually correspond to what structural features. Sample problems show how the information from various spectra is combined to propose a structure. The emphasis is on helping students develop an intuitive feel for using spectroscopy to solve structural problems.

Nomenclature

IUPAC nomenclature is stressed throughout the book, but common nomenclature is also discussed and used to develop students' familiarity. Teaching only the IUPAC nomenclature might be justifiable, but such an approach would handicap students in

their further study and use of the literature. Much of the literature of chemistry, biology, and medicine uses common names such as methyl ethyl ketone, isovaleric acid, methyl *t*-butyl ether, γ -aminobutyric acid, and ϵ -caprolactam. This book emphasizes why systematic nomenclature is often preferred, yet it encourages familiarity with common names as well.

Instructor Supplements

Transparencies, demonstration models, and a test (computerized and in manual format) bank are available for instructors using this textbook. Contact your Prentice Hall representative for details.

I've enjoyed working on this new edition, and I hope it's much better than the second edition. I've tried to make this book as error-free as possible, but I'm sure some errors have slipped by. If you find errors, or have suggestions about how the book might be made better, please let me know. (L. G. Wade, Whitman College, Walla Walla, WA, 99362) Errors can be fixed quickly, in the next printing. I've already started a file of possible changes and improvements for the fourth edition, and I hope many of the current users will contribute suggestions to this file. I hope this book makes your job easier and helps more of your students to succeed. That's the most important reason I wrote it.

Acknowledgments

I am pleased to thank the many talented people who helped with this revision. Particular thanks are due to Mary Ginsburg, who made thousands of useful suggestions throughout the writing and revision process, and who helped to shape this new edition. Special thanks are also due to Jan W. Simek, author of the *Solutions Manual*, who made a multitude of useful and perceptive suggestions.

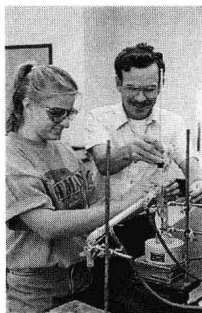
Throughout the production process, I have relied on technical advice from several additional sources. Nicholas R. Natale, University of Idaho; Joyce Brockwell, Northwestern University; Joe Jeffers, Ouachita Baptist University; Douglass F. Taber, University of Delaware; Graham Darling, McGill University; Mike Jensen, University of North Dakota; David Nelson, University of Wyoming; and Frank J. Creegan, Washington College; helped by checking the galleys, and Sarah Baird (Whitman College) checked the galleys from the viewpoint of a student. Although I did not adopt all their suggestions, most of them were helpful and contributed to the quality of the final product. I would also like to thank the other reviewers of this edition for their valuable insight and commentary: David W. Boykin, Georgia State University; Henry Abrash, California State University-Northridge; Suzanne T. Purrington, North Carolina State University; Jay Bardole, Vincennes University; Michael Rathke, Michigan State University; Warren V. Sherman, Chicago State University; W. J. leNoble, State University of New York at Stony Brook; David A. Boyajian, Palomar College; Edward Alexander, San Diego Mesa College; Eric L. Trump, Emporia State University; Daniel P. Weeks, Northwestern University; and Nathan C. Miller, University of South Alabama.

Finally, I want to thank the people at Prentice Hall whose dedication and flexibility contributed to the completion of this project. As acquisitions editor, Deirdre Cavanaugh kept the project moving, ensured the needed resources were available, and made many useful comments and suggestions. Ray Mullaney, editor-in-chief of College Book Editorial Development, made many useful suggestions in the revision, as he had also done for the first two editions. Lorraine Mullaney put the pages together, with an enormous number of equations, figures, and tables that all had to be placed to allow easy reference, yet make efficient use of the space on the

page. Production editor Barbara Martine kept the production process organized, on track, and on schedule. It has been a pleasure working with all of these thoroughly professional and competent people.

L. G. Wade, Jr.

About the Author



L. G. “Skip” Wade decided to become a chemistry major during his sophomore year at Rice University, while taking organic chemistry from Professor Ronald M. Magid. After receiving his B.A. from Rice in 1969, Wade went on to Harvard University where he did research with Professor James D. White. While at Harvard, he served as the Head Teaching Fellow for the organic laboratories and was strongly influenced by the teaching methods of two master educators, Professors Leonard K. Nash and Frank H. Westheimer.

After completing his Ph.D. at Harvard in 1974, Dr. Wade joined the chemistry faculty at Colorado State University. Over the course of fifteen years at Colorado State, Dr. Wade taught organic chemistry to thousands of students working toward careers in all areas of biology, chemistry, human medicine, veterinary medicine, and environmental studies. He also authored research papers in organic synthesis and in chemical education, as well as eleven books reviewing current research in organic synthesis. Since 1989, Dr. Wade has been a chemistry professor at Whitman College, where he teaches organic chemistry and pursues research interests in organic synthesis and forensic chemistry. Dr. Wade received the A. E. Lange Award for Distinguished Science Teaching at Whitman in 1993.

Dr. Wade’s interest in forensic science has led him to testify as an expert witness in court cases involving drugs and firearms, and he has worked as a police firearms instructor, drug consultant, and boating safety officer. He also enjoys repairing and restoring old violins and bows, which he has done professionally for about twenty years.

Brief Contents

	Preface	xix
1	Introduction and Review	1
2	Structure and Properties of Organic Molecules	39
3	Structure and Stereochemistry of Alkanes	83
4	The Study of Chemical Reactions	131
5	Stereochemistry	174
6	Alkyl Halides: Nucleophilic Substitution and Elimination	228
7	Structure and Synthesis of Alkenes	299
8	Reactions of Alkenes	336
9	Structure and Synthesis of Alcohols	390
10	Reactions of Alcohols	432
11	Infrared Spectroscopy and Mass Spectrometry	477
12	Nuclear Magnetic Resonance Spectroscopy	525
13	Ethers and Epoxides	593
14	Alkynes	627
15	Conjugated Systems, Orbital Symmetry, and Ultraviolet Spectroscopy	664
16	Aromatic Compounds	709
17	Reactions of Aromatic Compounds	753
18	Ketones and Aldehydes	809
19	Amines	867
20	Carboxylic Acids	937
21	Carboxylic Acid Derivatives	979
22	Additions and Condensations of Enols and Enolate Ions	1041
23	Carbohydrates and Nucleic Acids	1103
24	Amino Acids, Peptides, and Proteins	1164
25	Lipids	1211
26	Synthetic Polymers	1231
	Appendices	1253
	Answers	S1
	Index	II

Contents

Preface xix
About the Author xxix

1 Introduction and Review

1

1-1	The Origins of Organic Chemistry	1
1-2	Principles of Atomic Structure	2
1-3	Bond Formation: The Octet Rule	6
1-4	Lewis Structures	7
1-5	Multiple Bonding	8
1-6	Electronegativity and Bond Polarity	9
1-7	Formal Charges	10
1-8	Ionic Structures	13
1-9	Resonance Structures	13
1-10	Structural Formulas	17
1-11	Molecular Formulas and Empirical Formulas	20
1-12	Arrhenius Acids and Bases	22
1-13	Brønsted-Lowry Acids and Bases	23
1-14	Lewis Acids and Bases	30

2 Structure and Properties of Organic Molecules

39

2-1	Wave Properties of Electrons in Orbitals	39
2-2	Molecular Orbitals	41
2-3	Pi Bonding	44
2-4	Hybridization and Molecular Shapes	45
2-5	Drawing Three-Dimensional Molecules	49
2-6	General Rules of Hybridization and Geometry	50
2-7	Rotation of Single Bonds	55
2-8	Rigidity of Double Bonds	56
2-9	Structural Isomerism	56
2-10	Stereoisomerism	57
2-11	Polarity of Bonds and Molecules	59
2-12	Intermolecular Attractions and Repulsions	61
2-13	Polarity Effects on Solubilities	66