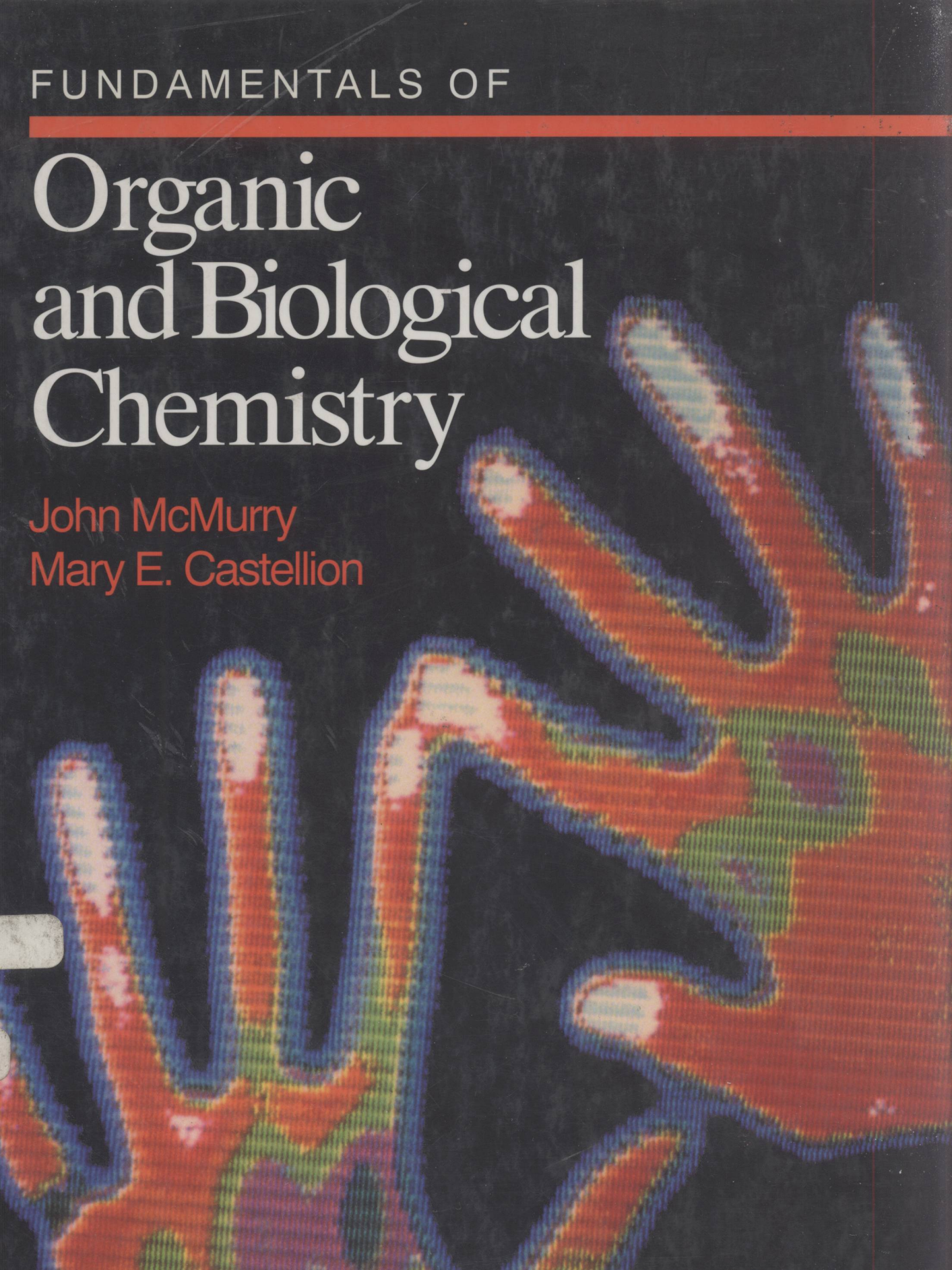
FUNDAMENTALS OF

Organic and Biological Chemistry

John McMurry
Mary E. Castellion



Fundamentals of Organic and Biological Chemistry

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Prentice Hall, Englewood Cliffs, New Jersey 07632

Library of Congress Cataloging-in-Publication Data
McMurry, John.
Fundamentals of organic and biological chemistry / John McMurry,
Mary E. Castellion.
p. cm.
Includes index.
ISBN 0-13-293085-4
1. Chemistry. 2. Chemistry, Organic. 3. Biochemistry.
I. Castellion, Mary E. II. Title.
QD31.2.M3878 1994
547—dc20 93-39094
CIP

Editor-in-Chief: Tim Bozik
Acquisitions Editor: Paul Banks
Marketing Manager: Kelly McDonald
Design Director: Florence Dara Silverman
Cover and Interior Designer: Bruce Kensellaer, Meryl Poweski
Manufacturing Buyer: Trudy Pisciotti
Supplements Editor: Mary Hornby
Production Editor: Susan Fisher
Illustrations by Vantage Art
Photo Research Coordinator: Lorinda Morris-Nantz
Photo Researcher: Tobi Zausner
Cover photo by Dr. R. Clark & M. Goff/Photo Researchers

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Photo credits and acknowledgments appear on pages A–48 and A–49, which constitute a continuation of the copyright page.

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

ISBN 0-13-293085-4

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*

PERIODIC CHART OF THE ELEMENTS

Period	Group 1A 1	2A 2	Transition Metals 3	4	5	6	7	8	9	10	11	12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 Hydrogen H 1.00797																	2 Helium He 4.0026
2	3 Lithium Li 6.941	4 Beryllium Be 9.0122											5 Boron B 10.81	6 Carbon C 12.011	7 Nitrogen N 14.0067	8 Oxygen O 15.9994	9 Fluorine F 18.9984	10 Neon Ne 20.183
3	11 Sodium Na 22.9898	12 Magnesium Mg 24.305											13 Aluminum Al 26.9815	14 Silicon Si 28.086	15 Phosphorus P 30.9738	16 Sulfur S 32.06	17 Chlorine Cl 35.453	18 Argon Ar 39.944
4	19 Potassium K 39.098	20 Calcium Ca 40.078	21 Scandium Sc 44.955	22 Titanium Ti 47.88	23 Vanadium V 50.942	24 Chromium Cr 51.996	25 Maganese Mn 54.938	26 Iron Fe 55.847	27 Cobalt Co 58.933	28 Nickel Ni 58.69	29 Copper Cu 63.546	30 Zinc Zn 65.39	31 Gallium Ga 69.72	32 Germanium Ge 72.61	33 Arsenic As 74.922	34 Selenium Se 78.96	35 Bromine Br 79.904	36 Krypton Kr 83.80
5	37 Rubidium Rb 85.468	38 Strontium Sr 87.62	39 Yttrium Y 88.906	40 Zirconium Zr 91.22	41 Niobium Nb 92.906	42 Molybdenum Mo 95.94	43 Technetium Tc (98)	44 Ruthenium Ru 101.07	45 Rhodium Rh 102.906	46 Palladium Pd 106.4	47 Silver Ag 107.868	48 Cadmium Cd 112.41	49 Indium In 114.82	50 Tin Sn 118.91	51 Antimony Sb 121.75	52 Tellurium Te 127.60	53 Iodine I 126.905	54 Xenon Xe 131.29
6	55 Cesium Cs 132.905	56 Barium Ba 137.33	* 57 Lanthanum La 138.91	72 Hafnium Hf 178.49	73 Tantalum Ta 180.948	74 Tungsten W 183.85	75 Rhenium Re 186.207	76 Osmium Os 190.2	77 Iridium Ir 192.22	78 Platinum Pt 195.08	79 Gold Au 196.967	80 Mercury Hg 200.59	81 Thallium Tl 204.383	82 Lead Pb 207.2	83 Bismuth Bi 208.980	84 Polonium Po (209)	85 Astatine At (210)	86 Radon Rn (222)
7	87 Francium Fr (223)	88 Radium Ra 226.025	† 89 Actinium Ac 227.028	104 Unnilquadium Unq (261)	105 Unnilpentium Unp (262)	106 Unnilhexium Unh (263)	107 Unnilseptium Uns (262)	108 Unniloctium Uno (265)	109 Unnilennium Une (266)									

6 Carbon C 12.011 — Atomic number, Name, Symbol, Atomic weight[a]

* Lanthanide series	58 Cerium Ce 140.12	59 Praseodymium Pr 140.908	60 Neodymium Nd 144.24	61 Promethium Pm (147)	62 Samarium Sm 150.36	63 Europium Eu 151.96	64 Gadolinium Gd 157.25	65 Terbium Tb 158.924	66 Dysprosium Dy 162.50	67 Holmium Ho 164.930	68 Erbium Er 167.26	69 Thulium Tm 168.934	70 Ytterbium Yb 173.04	71 Lutetium Lu 174.97
† Actinide series	90 Thorium Th 232.038	91 Protactinium Pa 231.036	92 Uranium U 238.029	93 Neptunium Np (237)	94 Plutonium Pu (244)	95 Americium Am (243)	96 Curium Cm (247)	97 Berkelium Bk (247)	98 Californium Cf (251)	99 Einsteinium Es (254)	100 Fermium Fm (257)	101 Mendelevium Md (258)	102 Nobelium No (259)	103 Lawrencium Lr (260)

[a] Numbers in parentheses are mass numbers of the most stable or best-known isotope of radioactive elements.

LIST OF ELEMENTS WITH THEIR SYMBOLS AND ATOMIC WEIGHTS

	Symbol	Atomic number	Atomic weight[a]		Symbol	Atomic number	Atomic weight[a]		Symbol	Atomic number	Atomic weight[a]
Actinium	Ac	89	227.0278	Holmium	Ho	67	164.9304	Rhenium	Re	75	186.207
Aluminum	Al	13	26.98154	Hydrogen	H	1	1.0079	Rhodium	Rh	45	102.9055
Americium	Am	95	(243)	Indium	In	49	114.82	Rubidium	Rb	37	85.4678
Antimony	Sb	51	121.75	Iodine	I	53	126.9045	Ruthenium	Ru	44	101.07
Argon	Ar	18	39.948	Iridium	Ir	77	192.22	Rutherfordium[b]	Rf	104	(261)
Arsenic	As	33	74.9216	Iron	Fe	26	55.847	Samarium	Sm	62	150.36
Astatine	At	85	(210)	Krypton	Kr	36	83.80	Scandium	Sc	21	44.9554
Barium	Ba	56	137.33	Lanthanum	La	57	138.9055	Selenium	Se	34	78.96
Berkelium	Bk	97	(247)	Lawrencium	Lr	103	(260)	Silicon	Si	14	28.0855
Beryllium	Be	4	9.01218	Lead	Pb	82	207.2	Silver	Ag	47	107.8682
Bismuth	Bi	83	208.9804	Lithium	Li	3	6.941	Sodium	Na	11	22.98977
Boron	B	5	10.81	Lutetium	Lu	71	174.967	Strontium	Sr	38	87.62
Bromine	Br	35	79.904	Magnesium	Mg	12	24.305	Sulfur	S	16	32.06
Cadmium	Cd	48	112.41	Manganese	Mn	25	54.9380	Tantalum	Ta	73	180.9479
Calcium	Ca	20	40.078	Mendelevium	Md	101	(258)	Technetium	Tc	43	(98)
Californium	Cf	98	(251)	Mercury	Hg	80	200.59	Tellurium	Te	52	127.60
Carbon	C	6	12.011	Molybdenum	Mo	42	95.94	Terbium	Tb	65	158.9254
Cerium	Ce	58	140.12	Neodymium	Nd	60	144.24	Thallium	Tl	81	204.383
Cesium	Cs	55	132.9054	Neon	Ne	10	20.179	Thorium	Th	90	232.0381
Chlorine	Cl	17	35.453	Neptunium	Np	93	237.0482	Thulium	Tm	69	168.9342
Chromium	Cr	24	51.996	Nickel	Ni	28	58.69	Tin	Sn	50	118.71
Cobalt	Co	27	58.9332	Niobium	Nb	41	92.9064	Titanium	Ti	22	47.88
Copper	Cu	29	63.546	Nitrogen	N	7	14.0067	Tungsten	W	74	183.85
Curium	Cm	96	(247)	Nobelium	No	102	(259)	Unnilennium[b]	Une	109	(266)
Dysprosium	Dy	66	162.50	Osmium	Os	76	190.2	Unnilhexium[b]	Unh	106	(263)
Einsteinium	Es	99	(254)	Oxygen	O	8	15.9994	Unniloctium[b]	Uno	108	(265)
Erbium	Er	68	167.26	Palladium	Pd	46	106.42	Unnilpentium[b]	Unp	105	(262)
Europium	Eu	63	151.96	Phosphorus	P	15	30.97376	Unnilquadium[b]	Unq	104	(261)
Fermium	Fm	100	(257)	Platinum	Pt	78	195.08	Unnilseptium[b]	Uns	107	(262)
Fluorine	F	9	18.998403	Plutonium	Pu	94	(244)	Uranium	U	92	238.0289
Francium	Fr	87	(223)	Polonium	Po	84	(209)	Vanadium	V	23	50.9415
Gadolinium	Gd	64	157.25	Potassium	K	19	39.0983	Xenon	Xe	54	131.29
Gallium	Ga	31	69.72	Praseodymium	Pr	59	140.9077	Ytterbium	Yb	70	173.04
Germanium	Ge	32	72.61	Promethium	Pm	61	(145)	Yttrium	Y	39	88.9059
Gold	Au	79	196,9665	Protactinium	Pa	91	231.0359	Zinc	Zn	30	65.39
Hafnium	Hf	72	178.49	Radium	Ra	88	226.0254	Zirconium	Zr	40	91.22
Helium	He	2	4.00260	Radon	Rn	86	(222)				

[a] Numbers in parentheses are mass numbers of the most stable or best-known isotope of radioactive elements.

[b] The official name and symbol have not been agreed to. The names for elements 106, 107, 108, and 109 represent their atomic numbers, as in un (1) nil (0). hex (6) = unnilhexium (Unh) for element 106.

Preface

To provide an introduction to organic chemistry and to the chemistry of living things—that is the goal of this textbook. The writing style, content, and organization are directed toward students with career goals in the allied health sciences and toward students seeking to know something about chemistry's role in our complex society.

Teaching chemistry is a challenging activity, just as learning chemistry is challenging. Teaching chemistry all the way from What is an atom? to How do we get energy from glucose? is especially difficult. Conversations with many teachers who face this challenge show that there are just about as many approaches to it as there are teachers. This textbook is designed for the one-semester course in organic and biological chemistry for students who have already had an introduction to general chemistry.

The chapters here are drawn from the organic and biological chemistry portions of *Fundamentals of General, Organic, and Biological Chemistry,* our textbook for the two-semester course. By varying the topics covered and the time devoted to them, each teacher can change the focus of the one-semester course to meet their students individual needs. Our unique biochemistry sequence, described below, allows for an unusual degree of flexibility with this material.

Because an understanding of bonding and acid-base chemistry is so important to success with this material, we have provided appendices on these subjects (Appendix A, Chemical Bonds; Appendix B, Acids and Bases). Marginal notes direct students to the appendices for independent review. The two appendices are written in such a manner that, as an alternative, they can be the basis for class lectures on these topics.

In addition, about 50 new marginal notes have been added to this one-semester text. The purpose of these notes is to provide support for students who may need reminders of essential concepts from their introduction to chemistry.

Most students in this course have their sights set well beyond academic concerns and the laboratory bench. They want to know why: Why must I study organic chemistry?

Why are molecular shapes important for me as a nurse, a farmer, or an informed citizen? We have therefore endeavored at every step along the way to place chemistry in the context of applications and everyday life. To meet this challenge, we have written about these matters in the mainstream of the text as well as in the Application and Interlude sections. With the intent of gaining student confidence, our writing style is relaxed and friendly, and we have included many visual and verbal study aids.

ORGANIZATION

The six *organic chemistry* chapters provide a concise overview of the subject and focus on what students must know in order to get on with the study of biochemistry. Nomenclature rules are included with the introduction to hydrocarbons (Chapters 1 and 2) and thereafter are kept to a minimum. The functional group chapters (Chapters 3–6) emphasize the structures and properties relevant to biomolecules and profile commonly encountered compounds. The chapter on amines presents their numerous biological roles and, by preceding the carboxylic acids chapter, allows amide chemistry to be covered with that of related carboxylic acid derivatives.

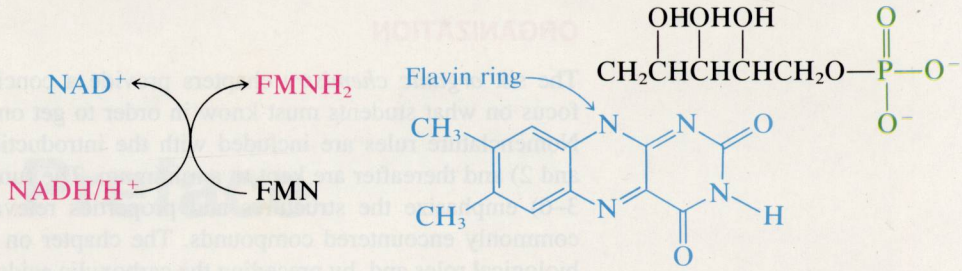
Our effort to allow for flexibility is especially evident in the *biological chemistry* chapters, where *structure and function are integrated.* Protein structure (Chapter 7) is followed by enzyme chemistry and biochemical energy (Chapters 8 and 9). Then come carbohydrates and their metabolism, lipids and their metabolism, and protein metabolism. If your time for biochemistry is limited, stop with Chapter 9 on biochemical energy, and your students will have an excellent preparation in the essentials of metabolism. To carry the metabolism story further, cover the next two chapters on carbohydrates and their metabolism (Chapters 10 and 11). And if you want to cover all classes of biomolecules and their metabolism, you will find a thorough, integrated treatment in Chapters 7–14. Nutrition is not treated as yet another separate subject, but is integrated with the discussion of each type of biomolecule. In the last two chapters, we cover subjects that we've found are an essential part of the course to many of you, but optional to others—Nucleic Acids and Protein Synthesis in Chapter 15 and Body Fluids in Chapter 16. Throughout, we have made every effort to provide up-to-date coverage, recognizing that biological chemistry is a most rapidly advancing area of science.

KEY FEATURES

Applications and Interludes A wide variety of special topics are covered in over 50 Application and Interlude sections. These sections provide thorough coverage—whether the topics are just assigned for additional reading or incorporated in the course, students can gain a reasonable understanding of each topic. Representative subjects (a complete list precedes the Preface) include *everyday chemistry* (Detergents; Sweetness; The Biochemistry of Running), *environmental and societal issues* (Chlorofluorocarbons and the Ozone Layer; Is It Poisonous or Isn't It?), *health and medical applications* (Barbiturates; Ethyl Alcohol as a Drug and Poison; Glucose Tolerance Test), and *modern applied chemistry* (Magnetic Resonance Imaging; Antioxidants; Prodrugs). Questions on the Applications and Interludes are provided in a separate section at the end of each chapter.

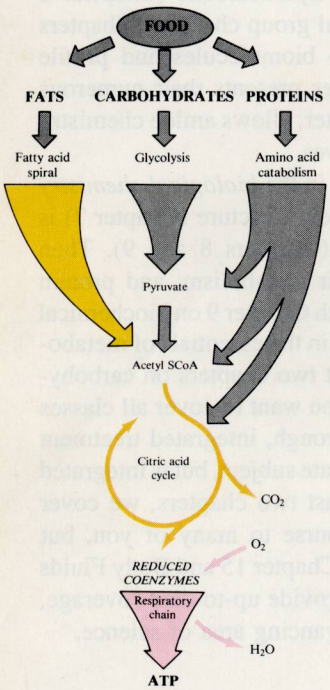
Color Photos Each chapter opens with a photo chosen to generate curiosity about the chapter subject. Then, throughout each chapter, photos are used to enhance understanding and appreciation for the subject matter.

Graphics Molecular structures, chemical equations, and charts and diagrams have been highlighted with color to emphasize their meaning. Many topics in organic and biological chemistry become much clearer when the reacting parts of molecules are color coded. For example, color has been used consistently to highlight phosphate groups in biomolecules and to distinguish energy-rich forms of such molecules as ATP and reduced coenzymes (red) from their lower energy counterparts, ADP and oxidized coenzymes (blue).

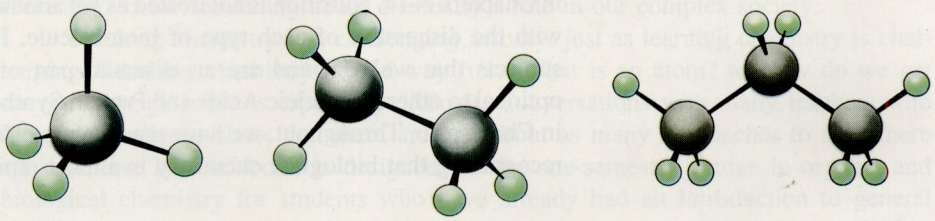


Flavin mononucleotide (FMN)

Nowhere are graphics more important than in clarifying the complexities of biochemical pathways and we believe our graphics are the best ever offered to students in this course. Our overall metabolism diagram has been adapted as a logo and is repeated as appropriate with the topic under discussion highlighted.



Computer-Generated Structures Computer-generated molecular models are used extensively in the organic and biological chapters, both for their accuracy in portraying the three-dimensional structures of molecules and for their visual appeal.



Problem Solving The problem solving skills essential to this course are illustrated with clearly explained and worked out Solved Problems. Solved Problems are all followed by related Practice Problems, and most text sections include additional practice problems to provide an immediate test of understanding. Practice Problems are answered at the back of the book.

PEDAGOGY

Introduction and Goals Each chapter begins with a brief introductory overview, followed by a list of goals for the student to keep in mind while studying.

Marginal Definitions Key terms are boldfaced in the text on their first use, and the definition of each term is provided in the margin nearby for easy review.

Marginal Notes Brief marginal notes provide reminders of essential concepts from introductory chemistry.

Glossary The definitions of all key terms are collected in alphabetical order in the Glossary at the back of the book.

Summaries Certain complex topics are summarized immediately after their presentation in bulleted statement lists. Each chapter ends with a clear, concise summary that reviews key points, with essential terms highlighted in boldface type.

Review Problems The end-of-chapter Review Problems provide approximately 1000 questions and problems: 400 on organic chemistry, and 600 on biological chemistry.

Appendices and Reference Tables The first two appendices provide review of essential topics from introductory chemistry: Chemical Bonds, and Acids and Bases. Other Appendices provide a review of exponential notation and useful conversion factors. The reference tables inside the cover display for easy reference the periodic table, an alphabetical list of elements, the structural features of important families of organic molecules, and a list of important tables and diagrams in the text.

Index The index is designed to be especially useful by including both general and specific citations and by the absence of cross reference entries without page numbers.

SUPPLEMENTS

Study Guide and Solutions Manual, by Susan McMurry. This companion volume answers all in-text and end-of-chapter problems and explains in detail how the answers are obtained. The solutions and data have been carefully prepared and reviewed for accuracy and coordination with the textbook. Chapter summaries, study hints, and self-test materials for each chapter are included.

Instructor's Resource Manual, by Theodore Sakano, and **Prentice Hall Test Manager** The *Manual* includes chapter overviews, lecture outlines, learning objectives, suggested readings, and 1500 multiple choice test questions. The *Test Manager* provides these questions on disk in either IBM® or MacIntosh® format and includes an editing feature that allows questions to be added or changed.

Laboratory Manual and Instructor's Manual to Laboratory Manual, by Scott Mohr and Susan Griffin The *Laboratory Manual* provides 24 laboratory experiments adaptable to either two- or three-hour laboratory periods. The *Instructor's Manual* includes detailed descriptions of all necessary chemicals, supplies, and equipment, as well as answers to pre-lab questions, typical student results, and completed report forms.

How to Study Chemistry, by Vernon Burger This free supplement contains problem-solving strategies, helpful hints for learning and achieving success in chemistry, and a mathematics review.

Transparencies A set of 100 two-color and four-color transparencies from this and other Prentice Hall chemistry texts is available.

Additional resources A collection of timely news stories from *The New York Times,* described elsewhere in the opening pages of this book, and several video packages are available upon adoption. For further information please contact your local Prentice Hall sales representative.

ACKNOWLEDGMENTS

It is a pleasure to thank the many people whose help and suggestions were so valuable in preparing *Fundamentals of General, Organic, and Biological Chemistry,* on which this book is based. We especially thank Leslie Kinsland, University of Southwestern Louisiana, for her assistance with questions and problems. The persons listed below provided many excellent suggestions after reviewing all or part of the manuscript. In particular, John M. Daly, Leland Harris, Larry Jackson, Gloria G. Lyle, and Les Wynston travelled across the country to make significant contributions for which we are very grateful, and Larry Jackson helped out with the special topic boxes for Chapter 16.

James N. Beck
McNeese State University

Richard E. Beitzel
Bemidji State University

Rodney Buyer
Hope College

John M. Daly
Bellarmine College

Lindsley Foote (Retired)
Western Michigan State University

Leland Harris
University of Arizona

Kenneth I. Hardcastle
California State University, Northridge

Merrill Hugo
Shasta College

Larry L. Jackson
Montana State University

Gloria G. Lyle
University of Texas, San Antonio

Frank R. Milio
Towson State University

Danny V. White
American River College

Karen Wiechelman
University of Southwestern Louisiana

Donald W. Williams
Hope College

Leslie Wynston
California State University, Long Beach

In addition, the book benefited from the careful reading of galley proofs by Clyde Metz, College of Charleston, and by Leland Harris, University of Arizona. During production, the persistence and professionalism of John Morgan, Production Editor, Prentice Hall; Tobi Zausner, Photo Researcher; and Diane Koromhas, Layout Artist were greatly appreciated. We further extend our thanks to Susan Fisher, Production Editor for this book, and to everyone on the capable staff of Prentice Hall, both those named on the copyright page and the many others who worked and continue to work for the success of our books.

A Note to the Student

Here you are, about to study organic and biological chemistry, perhaps for the first time. The topics you are about to study will be useful in all health-related professions and in many business endeavors. The chemistry you are introduced to in this book will also be useful in exercising judgment in everyday life. Newspapers and magazines are filled with chemistry-related stories about protecting the environment, about new materials designed to improve the quality of life, and about drugs that promise to revolutionize medical care. The better you understand such matters, the better you will be able to function in today's society.

The following suggestions should prove helpful in your study:

Don't read the text immediately. As you begin each new chapter, look it over first. Read the introductory paragraphs and familiarize yourself with the chapter goals. Find out what topics are covered, and take a look at the illustrations—to get a feel for the topics at hand. Then turn to the end of the chapter and read the summary. You'll be in a much better position to learn new material if you first have a general idea of where you're going.

Work the problems. The problems are designed to give you practice in the skills necessary to understand and use chemistry. There are no shortcuts here. The sample problems illustrate the skills, the in-chapter practice problems provide immediate practice, and the end-of-chapter problems provide additional drill. Brief answers to in-chapter practice problems and most even-numbered review problems are given at the end of this book.

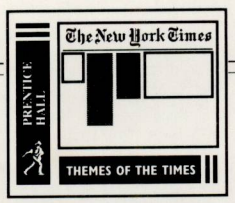
Use the study guide. Complete answers and explanations for all problems, along with chapter outlines, additional study hints, and self-tests, are given in the *Study Guide and Solutions Manual* that accompanies this text. The *Study Guide* can be extremely

useful when you're working problems and when you're studying for an exam. Investigate what's there now so you'll know where to find help when you need it.

Ask questions. Faculty members and teaching assistants are there to help you learn. Don't hesitate because you think a question might be stupid or silly. If it's something you need to know to get on with understanding chemistry, it's always a good question.

Many of the words and symbols that lie ahead in this book may at first seem strange to you. We urge you not to let their unfamiliarity cause you to lose sight of your goals: to learn about the amazing kinds of chemistry that keep us all alive and well, and to understand the impact of chemistry on everyday life.

John McMurry
Mary E. Castellion



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Through this program, the core subject matter provided in the text is supplemented by a collection of time-sensitive articles from one of the world's most distinguished newspapers, *The New York Times*. These articles demonstrate the vital, ongoing connection between what is learned in the classroom and what is happening in the world around us.

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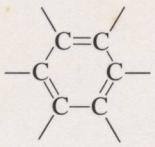
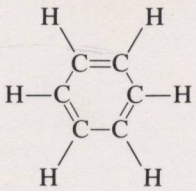
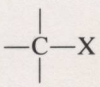
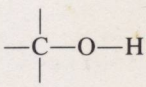
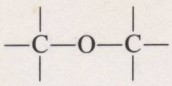
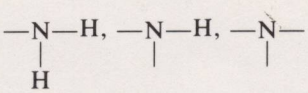
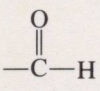
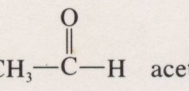
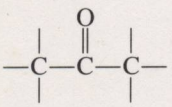
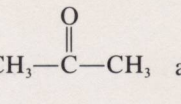
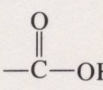
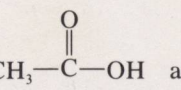
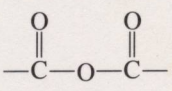
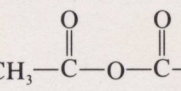
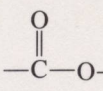
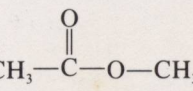
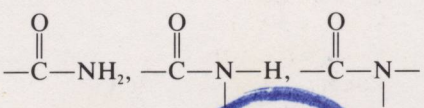
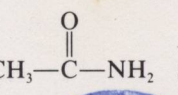
Prentice Hall and *The New York Times* are proud to co-sponsor THEMES OF THE TIMES. We hope it will make the reading of both textbooks and newspapers a more dynamic, involving process.

SOME IMPORTANT FAMILIES OF ORGANIC MOLECULES

Family Name	Functional Group Structure[a]	Simple Example	Name Ending
Alkane	(contains only C—H and C—C single bonds)	CH_3CH_3 ethane	*-ane*
Alkene		$H_2C{=}CH_2$ ethylene	*-ene*
Alkyne	—C≡C—	H—C≡C—H acetylene (ethyne)	*-yne*
Arene		 benzene	none
Alkyl halide[b]		CH_3—Cl methyl chloride	none
Alcohol		CH_3—OH methyl alcohol (methanol)	*-ol*
Ether		CH_3—O—CH_3 dimethyl ether	none
Amine		CH_3—NH_2 methylamine	*-amine*
Aldehyde		 acetaldehyde (ethanal)	*-al*
Ketone		 acetone	*-one*
Carboxylic acid		 acetic acid	*-ic acid*
Anhydride		 acetic anhydride	none
Ester		 methyl acetate	*-ate*
Amide		 acetamide	*-amide*

[a] The bonds whose connections aren't specified are assumed to be attached to carbon or hydrogen atoms in the rest of the molecule.
[b] X = F, Cl, Br, or I.

ELEMENTS ESSENTIAL FOR HUMAN LIFE

Element	Symbol	Function
Carbon	C	These four elements are present throughout all living organisms.
Hydrogen	H	
Oxygen	O	
Nitrogen	N	
Calcium	Ca	Necessary for growth of teeth and bones
Chlorine	Cl	Necessary for maintaining salt balance in body fluids
Chromium	Cr	Aids in carbohydrate metabolism
Cobalt	Co	Component of vitamin B-12
Copper	Cu	Necessary to maintain blood chemistry
Fluorine	F	Aids in development of teeth and bones
Iodine	I	Necessary for thyroid function
Iron	Fe	Necessary for oxygen-carrying ability of blood
Magnesium	Mg	Necessary for bones, teeth, and muscle and nerve action
Manganese	Mn	Necessary for carbohydrate metabolism and bone formation
Molybdenum	Mo	Component of enzymes necessary for metabolism
Phosphorus	P	Necessary for growth of bones and teeth; present in DNA/RNA
Potassium	K	Component of body fluids; necessary for nerve action
Selenium	Se	Aids in vitamin E action and fat metabolism
Sodium	Na	Component of body fluids; necessary for nerve and muscle action
Sulfur	S	Component of proteins; necessary for blood clotting
Zinc	Zn	Necessary for growth, healing, and overall health

TABLES AND FIGURES USEFUL FOR REFERENCE

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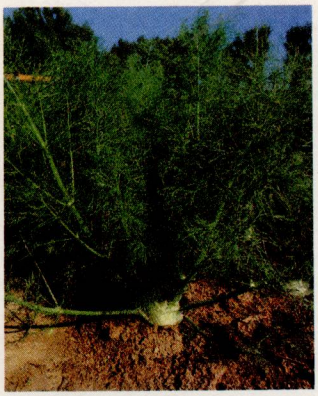

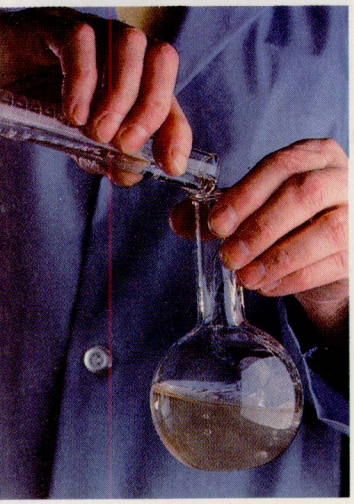

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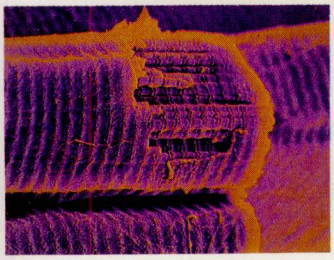

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