

Caret

Denniston

Topping

Foundations of Inorganic, Organic, & Biological Chemistry

Foundations of Inorganic, Organic, & Biological Chemistry

ROBERT L. CARET

Towson State University

KATHERINE J

STON

Towson State

JOSEPH J. TOPPING

Towson State University



WCB/McGraw-Hill

A Division of The McGraw-Hill Companies

Book Team

Editor Megan Johnson Developmental Editor John Berns Publishing Services Coordinator Julie Avery Kennedy

Vice President and General Manager Beverly Kolz
Vice President, Publisher Earl McPeek
Vice President, Director of Sales and Marketing Virginia S. Moffat
Vice President, Director of Production Colleen A. Yonda
National Sales Manager Douglas J. DiNardo
Marketing Manager Jane Ducham
Advertising Manager Janelle Keeffer
Production Editorial Manager Renée Menne
Publishing Services Manager Karen J. Slaght
Royalty/Permissions Manager Connie Allendorf

President and Chief Executive Officer G. Franklin Lewis
Senior Vice President, Operations James H. Higby
Corporate Senior Vice President, President of WCB Manufacturing Roger Meyer
Corporate Senior Vice President and Chief Financial Officer Robert Chesterman

Cover Image © by Irving Geis

Copyediting, Design, Permissions, and Production by York Production Services

Composition by York Graphic Services

The credits section for this book is on page 574 and is considered an extension of the copyright page.

Copyright @ 1995 The McGraw-Hill Companies, Inc. All rights reserved

Library of Congress Catalog Card Number: 94-71225

ISBN 0-697-21242-4

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

Printed in the United States of America

To Liz, For standing by me.

RLC

To my parents, Peg and Guy, who taught me that I could do anything if I tried hard enough.

And to Andrew and Amanda, whom I hope to teach the same lesson.

KJD

In memory of my parents, Virginia and Joseph, for all their support.

And to John Topping, a very special uncle.

JJT

Preface

AUDIENCE

Foundations of Inorganic, Organic, & Biological Chemistry serves two primary audiences: those students in health-related majors who will be challenged to cover all of chemistry in one semester, as well as students who take a one semester survey course as a foundation. This course necessarily emphasizes applications. Students are exposed to the practical aspects of chemistry as they relate to the health sciences and the environment. Therefore, Foundations of Inorganic, Organic, & Biological Chemistry strikes a balance between theoretical and practical chemistry, while emphasizing material unique to health-related studies. It is written at a level intended for the student whose goals in life do not include a mastery of chemistry, but for whom an understanding of the principles and their practical applications is a necessity.

PHILOSOPHY

Chemistry is a unified discipline. In this text we will, of course, treat the individual disciplines of inorganic, organic, and biological chemistry. However, the emphasis will be on the integration of these areas to help the student understand the inter-relatedness of these three disciplines. We believe this approach will provide a sound foundation in the principles of chemistry. At the same time, the students will learn that life is not a magical property, but rather is the result of a set of chemical reactions that obey the laws of chemistry (and physics). We want the students to develop a "feel" for each of the following concepts:

- the importance of chemistry in the normal biochemical function of the cell and the body as a whole.
- the medical ramifications that result when such reactions go awry.
- the action of drugs in the body.
- the application of chemistry to alleviate disease and suffering.

Indeed, these are the aspects of chemistry that are most critical in health-related occupations.

The approach to writing the book has been to provide an interesting and logical sequence that will develop the very basic principles of inorganic and organic chemistry and an in-depth understanding of the basic biological molecules that make up the cell and the biochemical reactions that allow it to function.

ORGANIZATION AND CONTENT

When organizing the contents of this text one of our major concerns was the challenge of covering all aspects of inorganic, organic, and biological chemistry in a meaningful way—in a single semester. One approach we have adopted is to closely tie together the related topics of organic and biochemistry. In this way the chemistry of a class of organic molecules need only be covered once. Then it can be immediately applied to the appropriate class of biological molecules. We have tried to avoid the temptation to cover "a little of everything" or to present material for its own sake. Topics have been chosen or omitted on the basis of whether or not the material will be useful to the students in later chapters or in their future careers.

We have attempted to provide a comfortable flow of material and have maintained a rather traditional organization. The first eight chapters supply the type of background that is generally found in a two semester science major's chemistry course, but the material is intended to be covered in less than one half a semester. The chapters that follow (Chapters 9 and 10) present the fundamental principles of organic chemistry: basics of nomenclature, hydrocarbon structure and chemistry, and common functional groups. Immediately thereafter we introduce the more biochemistry-oriented, organic chemistry. Specifically, carbohydrate chemistry (Chapter 11) immediately follows the discussion of alcohols, ketones, and aldehydes (Chapter 10). This allows the students to apply what they have just learned about ketones and aldehydes to the important group of biological molecules

xvi Preface

that are polyhydroxyketones and polyhydroxyaldehydes. Chapter 13 (Lipids) builds on the material presented in Chapter 12 (Carboxylic Acids). Chapter 15 (Protein Structure and Enzymes) naturally follows Chapter 14 (Amines and Amides). This intermingling of organic and biochemistry softens the boundary between the two areas. Furthermore, this approach allows the instructor to begin coverage of biochemistry earlier in the course. This provides a solution to one of the common problems encountered in teaching this type of course, namely, that there is so much material that it is difficult to adequately cover the focal point of the course—the biochemistry. The book is designed to allow the instructor flexibility in the organization of the course. For instance, the instructor may choose to teach the discipline of chemistry sequentially: inorganic chemistry (Chapters 1–8), organic chemistry (Chapters 9, 10, 12, and 14), and biochemistry (Chapters 11, 13, 15-19). Alternatively, the instructor may choose to follow the organization of the text, alternating the study of organic and biological molecules characterized by a particular functional group.

PEDAGOGY

The text includes a variety of pedagogical devices. In designing these we asked ourselves the question, "If we were students, what would help us organize and understand the material covered in this chapter?" We chose the following pedagogical supports:

- 1. **Learning Goals:** Students have the opportunity to preview the material and become aware of the information and ideas that they are expected to learn. These chapter goals are also useful as a self-test after the chapter has been read.
- Detailed Chapter Outline: Topics are divided and subdivided in outline form to help students organize the material in their own minds. These chapter outlines also give the instructor a quick summary of the topics found in the chapter and help to organize lecture material.
- Boxed Readings—A "Chemistry Connection": These
 beginning essays connect the content of each chapter to an
 interesting application.
- 4. Perspectives relate the chapter subject matter to the real world. Depending on the nature of the topic, these are called Human, Clinical, Medical, or Environmental Perspectives. The perspectives provide practical and relevant applications of the chemistry covered in the text.
- 5. In-Chapter Examples, Solutions, and Problems: Because problem-solving is most easily learned by example and practice, we have included throughout the text a number of examples that show the student, step-by-step, precisely how to properly determine the correct answer. Whenever possi-

- ble, the solved examples are followed by in-text problems that allow the students to test their mastery of the information just covered and to build self-confidence.
- 6. In-Chapter and End-of-Chapter Problems: These include a wide variety of problems. The answers to the odd-numbered questions will be found in the back of the book as reinforcement for students as they develop problem-solving skills. However, students must then be able to apply the same principles to the related even-numbered problem.
- 7. Chapter Cross-References: Often a discussion in the text demands an understanding of key principles and concepts described previously. These cross-references are also used to alert students to upcoming topics that require an understanding of the information currently being studied and help students locate the pertinent background material.
- Detailed End-of-Chapter Summary: These summaries serve as a "mini-study guide." Each covers the major concepts in the chapter.
- End-of-Chapter Key Terms: Each key term is accompanied by the chapter section number so that students can quickly find the definition in the text.
- End-of-Chapter Vocabulary Quiz: There is a set of ten vocabulary review questions at the end of each chapter. These will help students learn the language of chemistry.
- 11. **End-of-Book Glossary of Key Terms:** All new terms are in boldface and each term is defined in the alphabetized glossary at the end of the textbook.
- 12. Appendix Material: Appendixes have been selected because the information will be useful to students in doing basic work or because they extend information introduced in the chapter.

Appendix A: Review of Mathematics Applied to Problem-Solving in Chemistry

Appendix B: Table of Formula Weights

Appendix C: Stereochemistry and Stereoisomers Revisited

Appendix D: Lipid-Soluble Vitamins

Appendix E: Water-Soluble Vitamins

Appendix F: Minerals and Cellular Function

Answers to the Odd-Numbered Questions and Problems Answers to the Vocabulary Quizzes

- 13. Color Coding Scheme: Because it is difficult for students to understand the chemical changes that occur in complex reactions, we have color coded reactions so that chemical groups being added or removed in a reaction can be quickly and clearly seen. This is particularly useful in the organic and biochemistry chapters.
- 14. **Illustrations:** Each chapter is amply illustrated using figures, tables, and chemical formulas. All of these illustrations are carefully annotated for clarity.

Supplementary Materials

An extensive supplemental package has been designed to support this text. It includes the following elements.

- Instructor's Manual: The Instructor's Manual contains the
 printed test item file, solutions to the even-numbered problems, and a list of the transparencies. Written by the authors,
 this unique ancillary also contains suggestions for organizing lectures, additional "Perspectives," and a list of each
 chapter's key problems and concepts.
- Student's Study Guide/Solutions Manual: A separate Student's Study Guide/Solution Manual is available. It contains the answers and complete solutions for the odd-numbered problems. It also offers students a variety of exercises and keys for testing their comprehension of basic, as well as difficult, concepts.
- Transparencies: A set of over 100 transparencies is available to help the instructor coordinate the lecture with key illustrations from the text.
- Customized Transparency Service: For those adopters interested in receiving acetates of text figures not included in the standard transparency package, a select number of acetates will be custom made upon request.
- 5. Microtest: This computerized classroom management system/service includes a database of test questions, reproducible student self-quizzes, and a grade-recording program. Disks are available for IBM and Macintosh computers, and require no programming experience.
- 6. Laboratory Manual: Written by Charles H. Henrickson, Larry C. Byrd, and Norman W. Hunter, all of Western Kentucky University, "Experiments in Inorganic, Organic, and Biochemistry," carefully and safely guides students through the process of scientific inquiry. The manual features 26 self-contained experiments that can easily be reorganized to suit individual course needs. In addition, you can delete experiments and/or add your own materials to create a custom manual to fit your students' precise needs.
- Laboratory Resource Guide: This helpful prep guide contains the hints that the authors have learned over the years to ensure student success.
- 8. Is Your Math Ready for Chemistry? Developed by Walter Gleason of Bridgewater State College, this unique booklet provides a diagnostic test that measures your students' math ability. Part II of the booklet provides helpful hints on the necessary math skills needed to successfully complete a chemistry course.

- 9. **Problem Solving Guide to General Chemistry:** Written by Ronald DeLorenzo of Middle Georgia College, this exceptional supplement provides your students with over 2,500 problems and questions. The guide holds students' interests by integrating the solution of chemistry problems with real-life applications, analogies, and anecdotes.
- 10. How to Study Science: Written by Fred Drewes of Suffolk County Community College, this excellent workbook offers students helpful suggestions for meeting the considerable challenges of a science course. It offers tips on how to take notes and how to overcome science anxiety. The book's unique design helps to stir critical thinking skills, while facilitating careful notetaking on the part of the student.
- 11. **Exploring Chemistry Video Tapes:** Narrated by Ken Hughes of the University of Wisconsin-Oshkosh, the tapes provide six hours of laboratory demonstrations. Many of the demonstrations are of high interest experiments, too expensive or dangerous to be performed in the typical freshman laboratory.
- 12. **Doing Chemistry Videodisc:** This critically acclaimed image database contains 136 experiments and demonstrations. It can be used as a prelab demonstration of equipment setup, laboratory techniques, and safety precautions. It may also be used as a substitute for lab experiences for which time or equipment is not available.
- 13. ChemTALK Lecture Presentation Software: This unique presentation software contains lecture outlines and numerous color illustrations and animations designed to bring the basic concepts of chemistry to life. Three software programs have been developed to be used in a variety of introductory courses including general chemistry, preparatory chemistry, and allied health chemistry. The programs are available on both Windows and Macintosh formats. Less cumbersome than writing on a blackboard, this software will allow you to present material to your students at the pace that you choose, while integrating full-color illustrations and animations into your lecture. Students may purchase the corresponding lecture notebook which contains all the material from the software. Using the notebook to follow the lecture, students will spend more time listening and absorbing information.
- 14. Student Study Art Notebook: Free with each new text, the Student Study Art Notebook contains all of the full color art included in the transparency set. The notebook allows students to focus on the lecture rather than trying to recopy art being displayed in class.

Acknowledgments

We are grateful to our families, whose patience and support made it possible for us to undertake this project. We thank our colleagues at Wm. C. Brown Publishers especially our Developmental Editor, John Berns, and our Acquisitions Editor, Megan Johnson. We also thank Molly Kelchen, Editorial Secretary, and Julie Kennedy, Publishing Services Coordinator, who have worked quietly behind the scenes to ensure that the book is both accurate and elegant. Finally we extend our sincere gratitude and appreciation to Mary Jo Gregory of York Production Services. She and her colleagues guided us patiently through the winding paths of textbook publication; they have prodded us gently to meet our deadlines; and, above all, they have always insisted on excellence in the quality of the science, the writing, the artwork, and the overall process of publication.

Johanne Artman Del Mar College Tom J. Baldus

Northwest Iowa Community College

John T. Barbas

Valdosta State University

Thomas Berke

Brookdale Community College

Michael J. Collins

Viterbo College, LaCrosse, Wisconsin

Brian E. Cox

Cochise College Jack L. Dalton

Boise State University

Cheryl Donlon

Northeast Iowa Community College

John Ferrara

Cuyahoga Community College

Patrick Flash

Kent State—Ashtabula Campus

Bill Flurkey

Indiana State University

A. Fredrick Goellner

CCCAC—South Campus

Craig R. Johnson

Carlow College

Betty Klapper

Columbus State Community College

F. H. Kruse

University of Toledo

Stephen L. Monts

Kankakee Community College

Deb Nycz

Broward Community College

Fred Redmore

Highland Community College

Art Serianz

St. Ambrose University

Frank B. Slezak

Mercer County Community College

David Speckhard

Loras College

Justine Walhout

Rockford College

Alan S. Wingrove

Towson State University

Brief Contents

I	Chemistry: Methods and Measurement 1	
2	The Structure of the Atom and the Periodic Table	29
3	Structure and Properties of Ionic and Covalent	
	Compounds 56	

- 4 Calculations and the Chemical Equation 83
- 5 Energy Relationships and States of Matter 104
- 6 Solutions 132
- 7 Chemical Reactions 152
- 8 Radioactivity and Nuclear Medicine 176
- 9 An Introduction to Organic Chemistry: The Hydrocarbons 197
- 10 Oxygen- and Sulfur-Containing Compounds 230
- 11 Carbohydrates 259
- 12 Carboxylic Acids and Carboxylic Acid Derivatives 283
- 13 Lipids 304
- 14 Amines and Amides 327
- 15 Protein Structure and Enzymes 345

- 16 Carbohydrate Metabolism 386
- 17 Aerobic Respiration and Energy Production 412
- 18 Fatty Acid Metabolism 435
- 19 Introduction to Molecular Genetics 459

APPENDIXES 494

- A Review of Mathematics Applied to Problem Solving in Chemistry 494
- B Table of Formula Weights 504
- C Stereochemistry and Stereoisomers Revisited 506
- D Lipid-Soluble Vitamins 512
- E Water-Soluble Vitamins 517
- F Minerals and Cellular Function 523

Glossary 526

Answers to Selected Problems 540

Index 561

Credits 574

Detailed Contents

1Chemistry: Methods and Measurement 1



CHEMISTRY CONNECTION: Chance Favors the Prepared Mind 2
INTRODUCTION 2

1.1 Chemistry: An Overview 3

Definition of Chemistry 3 Major Areas of Chemistry 3

1.2 The Methodology 3

The Scientific Method 3 Science and Technology 5

1.3 Data, Results, and Units 6

1.4 Measurement in Chemistry 6

English and Metric Units 6
Unit Conversion: English and Metric Systems 8
Conversion of Units within the Same System 8
Conversion of Units from One System to Another 10

1.5 Error, Accuracy, Precision, and Uncertainty 11

1.6 Significant Figures and Scientific Notation 12

Significant Figures 12
Recognition of Significant Figures 13
Scientific Notation 14
Significant Figures in Calculation of Results 15
Rounding Off Numbers 17

1.7 Experimental Quantities 17

Mass 18 Length 19 Volume 19 Time 19
Temperature 19
Energy 21
Concentration 21

A HUMAN PERSPECTIVE: Food Calories 22
Density and Specific Gravity 22

A CLINICAL PERSPECTIVE: Diagnosis Based on Waste 25

Summary 25 Key Terms 26 Questions and Problems 26 Vocabulary Quiz 28

2

The Structure of the Atom and the Periodic Table 29



CHEMISTRY CONNECTION: Curiosity, Science, and Medicine 30
INTRODUCTION 30

2.1 Matter and Properties 30

Matter and Physical Properties 30
Matter and Chemical Properties 31
Intensive and Extensive Properties 32
Classification of Matter 32

2.2 Matter and Structure 33

Atomic Structure 33

2.3 Development of the Atomic Theory 36

Dalton's Theory 36 Electrons, Protons, and Neutrons 37

The Nucleus 37 The Bohr Atom 37

2.4 Modern Atomic Theory 38

2.5 The Periodic Law and the Periodic Table 38

AN ENVIRONMENTAL PERSPECTIVE: Electromagnetic Radiation and Its Effects on Our Everyday Lives 40

Periods and Families 41 Metals and Nonmetals 42 Atomic Number and Atomic Mass 42 Electron Arrangement and the Periodic Table 43

2.6 Valence Electrons 43

The Octet Rule 46 Ion Formation and the Octet Rule 46

2.7 Trends in the Periodic Table 48

Atomic Size 48 Ion Size 49 Ionization Energy 49

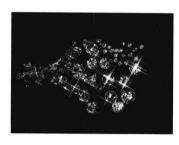
A MEDICAL PERSPECTIVE: Copper Deficiency and Wilson's Disease 50

Electron Affinity 51

Summary 52 Key Terms 53 Questions and Problems 53 Vocabulary Quiz 55

3 Structure and

Properties of Ionic and Covalent Compounds 56



CHEMISTRY CONNECTION: Magnets and Migration 57 INTRODUCTION 57

3.1 Chemical Bonding 57

Lewis Symbols 57

Types of Chemical Bonds: Ionic and Covalent 58

3.2 Naming Compounds and Writing Formulas of Compounds 60

Ionic Compounds 60 Covalent Compounds 64

3.3 Properties of Ionic and Covalent Compounds 65

Physical State 66 Melting and Boiling Points 66 Structure of Compounds in the Solid State 66 Solutions of Ionic and Covalent Compounds 66

3.4 Drawing Lewis Structures of lons and Molecules 66

A CLINICAL PERSPECTIVE: Blood Pressure and the Sodium/Potassium Ratio 67

Lewis Structure, Stability, Multiple Bonds, and Bond Energies 70 Lewis Structures and Molecular Geometry 71

Lewis Structures and Polarity 75

3.5 Properties Based on Molecular Geometry 78

Solubility 78

Boiling Points of Liquids and Melting Points of Solids 78

Summary 79 Key Terms 80 Questions and Problems 80 Vocabulary Quiz 82

4

Calculations and the Chemical Equation 83



CHEMISTRY CONNECTION: The Chemistry of Automobile Air Bags 84 INTRODUCTION 84

4.1 The Mole Concept and Atoms 84

The Mole and Avogadro's Number 85 Calculating Atoms, Moles, and Mass 86

4.2 Compounds 88

The Chemical Formula 88

4.3 The Mole Concept Applied to Compounds 89

4.4 The Chemical Equation and the Information It Conveys 90

A Recipe for Chemical Change 90 Features of a Chemical Equation 90 The Experimental Basis of a Chemical Equation 91

A CLINICAL PERSPECTIVE: Magnetic Resonance Imaging 92

4.5 Balancing Chemical Equations 92

4.6 Calculations Using the Chemical Equation 95

General Principles 95 Use of Conversion Factors 96

Summary 100 Key Terms 101 Questions and Problems 101 Vocabulary Quiz 103

5

Energy Relationships and States of Matter 104



CHEMISTRY CONNECTION: Getting Nothing for Something 105 INTRODUCTION 105

5.1 Thermodynamics 105

The Chemical Reaction and Energy 106
Exothermic and Endothermic Reactions: Enthalpy 106
Spontaneous and Nonspontaneous Reactions 107
Entropy 107
Free Energy 107

5.2 Experimental Determination of Energy Change in Reactions 107

A HUMAN PERSPECTIVE: Triboluminescence: Sparks in the Dark with Candy 108

A CLINICAL PERSPECTIVE: Hot and Cold Packs 111

5.3 Kinetics 111

The Chemical Reaction 112
Activation Energy and the Activated Complex 112
Experimental Factors Affecting the Rate of Reaction 113

5.4 Chemical Equilibrium and the Reversibility of Reactions 114

The Concept of Equilibrium 114
Reversibility of Chemical and Physical Processes 114
The Equilibrium Constant 115
LeChatelier's Principle 116

5.5 Energy and the States of Matter 117

5.6 The Gaseous State 117

The Gas Laws 117 Ideal Gases Versus Real Gases 124

5.7 The Liquid State 124

Compressibility 124 Viscosity 124

A CLINICAL PERSPECTIVE: Blood Gases and Respiration 125

Surface Tension 125 Vapor Pressure of a Liquid 125 Hydrogen Bonding 126

5.8 The Solid State 128

Properties of Solids 128
Types of Crystalline Solids 128

Summary 129
Key Terms 130
Questions and Problems 130
Vocabulary Quiz 131

6 Solutions 132



CHEMISTRY CONNECTION: Drug Delivery 133 INTRODUCTION 133

6.1 Properties of Solutions 133

General Properties of Liquid Solutions 134 Solutions and Colloids 134 Degree of Solubility 135 Solubility and Equilibrium 135 Solubility of Gases: Henry's Law 136

6.2 Concentration of Solutions: Percentage 136

Weight-Volume Percent 136

A HUMAN PERSPECTIVE: Scuba Diving: Nitrogen and the Bends 137

Volume-Volume Percent 138 Weight-Weight Percent 138

6.3 Concentration of Solutions: Moles and Equivalents 139

Molarity 139

Representation of Concentration of Ions in Solution 142

6.4 Concentration-Dependent Solution Properties 143

Vapor Pressure Lowering 143
Freezing Point Depression and Boiling
Point Elevation 143
Osmotic Pressure 144

6.5 Water as a Solvent 146

6.6 Electrolytes in Blood 147

A HUMAN PERSPECTIVE: An Extraordinary Molecule 148

Summary 149 Key Terms 150 Questions and Problems 150 Vocabulary Quiz 151

7 Chemical Reactions 152



CHEMISTRY CONNECTION: Seeing a Thought 153 INTRODUCTION 153

7.1 Classification of Chemical Reactions 153

Combination Reactions 154
Decomposition Reactions 154
Replacement Reactions 154

7.2 Types of Chemical Reactions 155

Precipitation Reactions 155
Reactions with Oxygen 156
Acid-Base and Oxidation-Reduction Reactions 157

7.3 Acids and Bases 157

AN ENVIRONMENTAL PERSPECTIVE: The Greenhouse Effect and Global Warming 158

Learning the Terminology 158 Arrhenius Theory of Acids and Bases 158 Brönsted-Lowry Theory of Acids and Bases 159

7.4 Solutions of Acids and Bases 160

Strength of Acids and Bases 160 The Dissociation of Water 161 The pH Scale 161 The Importance of pH and pH Control 166 Neutralization 166

7.5 Acid-Base Buffers 168

The Buffer Process 168
Addition of Base (OH⁻) to a Buffer Solution 169
Addition of Acid (H₃O⁺) to a Buffer Solution 169

7.6 Oxidation-Reduction Processes 169

Oxidation and Reduction 169

AN ENVIRONMENTAL PERSPECTIVE: Acid Rain 170
Oxidation and Reduction Reactions 171

A CLINICAL PERSPECTIVE: Control of Blood pH 172

Summary 173 Key Terms 173 Questions and Problems 174 Vocabulary Quiz 174



Radioactivity and Nuclear Medicine 176



CHEMISTRY CONNECTION: An Extraordinary Woman in Science 177
INTRODUCTION 177

8.1 Natural Radioactivity 178

Alpha Particles 178 Beta Particles 178 Gamma Rays 179

Properties of Alpha, Beta, and Gamma Radiation 179

8.2 Writing a Balanced Nuclear Equation 180

Alpha Decay 180
Beta Decay 180
Gamma Production 180
Predicting Products of Nuclear Decay

Predicting Products of Nuclear Decay 180

8.3 Properties of Radioisotopes 181

Nuclear Structure and Stability 181 Half-Life 182 Energy Production 183 Radiocarbon Dating 184

AN ENVIRONMENTAL PERSPECTIVE: Nuclear Waste Disposal 185

8.4 Medical Applications of Radioactivity 185

Cancer Therapy Using Radiation 185 Nuclear Medicine 186 Making Isotopes for Medical Applications 187

8.5 Biological Effects of Radiation 188

Radiation Exposure and Safety 189

8.6 Detection and Measurement of Radiation 190

Nuclear Imaging 190

AN ENVIRONMENTAL PERSPECTIVE: Radon and Indoor Air Pollution 191

Computer Imaging 191 The Geiger Counter 191 Film Badges 192

8.7 Units of Radiation Measurement 193

The Curie 193
The Roentgen 193
The Rad 193
The Rem 193

Summary 194 Key Terms 194 Questions and Problems 195 Vocabulary Quiz 196

9

An Introduction to Organic Chemistry: The Hydrocarbons 197



CHEMISTRY CONNECTION: The Origin of Organic Compounds 198 INTRODUCTION 198

9.1 The Chemistry of Carbon 199

Important Differences between Organic and Inorganic Molecules 200
Families of Organic Compounds 201

9.2 Alkanes 203

Structure and Physical Properties 203 Nomenclature 204 Structural Isomers 207

AN ENVIRONMENTAL PERSPECTIVE: Oil-Eating Bacteria 209

Cycloalkanes 209

Reactions of Alkanes and Cycloalkanes 211

A MEDICAL PERSPECTIVE: Polyhalogenated Hydrocarbons Used as Anesthetics 212

AN ENVIRONMENTAL PERSPECTIVE: DDT and Biological Magnification 213

9.3 Alkenes and Alkynes 214

Structure and Physical Properties 214
Nomenclature 216
Geometric Isomers: A Consequence of Unsaturation 217
Reactions Involving Alkenes 218

9.4 Aromatic Hydrocarbons 222

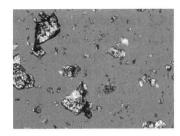
Structure and Physical Properties 222 Nomenclature 222

A HUMAN PERSPECTIVE: Aromatic Compounds and Carcinogenesis 223

Summary of Reactions 224
Summary 225
Key Terms 225
Questions and Problems 226
Vocabulary Quiz 229

10

Oxygen- and Sulfur-Containing Organic Compounds 230



CHEMISTRY CONNECTION: Fetal Alcohol Syndrome 231 INTRODUCTION 231

10.1 Alcohols 232

Structure and Physical Properties 232 Nomenclature 233 Medically Important Alcohols 234 Classification of Alcohols 235 Reactions Involving Alcohols 236

10.2 Phenols 238

A HUMAN PERSPECTIVE: Alcohol Consumption and the Breathalyzer Test 239

10.3 Ethers 240 10.4 Thiols 241

10.5 Aldehydes and Ketones 243

Structure and Physical Properties 243 Nomenclature 243 Important Aldehydes and Ketones 245

A CLINICAL PERSPECTIVE: Aldehydes in Medicine 246

Reactions Involving Aldehydes and Ketones 246

A HUMAN PERSPECTIVE: The Chemistry of Vision 253

Summary of Reactions 254
Summary 255
Key Terms 255
Questions and Problems 255
Vocabulary Quiz 258

11Carbohydrates 259



CHEMISTRY CONNECTION: Chemistry Through the Looking Glass 260
INTRODUCTION 260

11.1 Types of Carbohydrates 262

11.2 Monosaccharides 262

Nomenclature 262 Stereoisomers 263 Some Important Monosaccharides 264 Reducing Sugars 270

11.3 Oligosaccharides 271

Maltose 271 Lactose 271

A HUMAN PERSPECTIVE: Blood Transfusions and the Blood Group Antigens 272

Sucrose 274

11.4 Polysaccharides 275

Starch 275

A HUMAN PERSPECTIVE: Tooth Decay and Simple Sugars 276

Glycogen 276

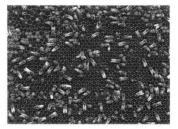
A CLINICAL PERSPECTIVE: The Bacterial Cell Wall 278

Cellulose 278

Summary 280
Key Terms 280
Questions and Problems 281
Vocabulary Quiz 282

12

Carboxylic Acids and Carboxylic Acid Derivatives 283



CHEMISTRY CONNECTION: Wake Up, Sleeping Gene 284 INTRODUCTION 284

12.1 Carboxylic Acids 285

Structure and Physical Properties 285

Nomenclature 286

Some Important Carboxylic Acids 289

Reactions Involving Carboxylic Acids 289

AN ENVIRONMENTAL PERSPECTIVE: Garbage Bags from Potato Peels 290

12.2 Esters 293

Structure and Physical Properties 293 Nomenclature 293 Reactions Involving Esters 294

12.3 Nature's High-Energy Compounds: Phosphoesters and Thioesters 295

A HUMAN PERSPECTIVE: Carboxylic Acid Derivatives of Special Interest 296

Summary of Reactions 299
Summary 300
Key Terms 300
Questions and Problems 300
Vocabulary Quiz 303

13 Lipids 304



CHEMISTRY CONNECTION: Life-Saving Lipids 305 INTRODUCTION 305

13.1 Biological Functions of Lipids 305

13.2 Fatty Acids 307

Structure and Properties 307 Chemical Reactions of Fatty Acids 308 Prostaglandins 309

13.3 Glycerides 310

Neutral Glycerides 310 Phosphoglycerides 312

A CLINICAL PERSPECTIVE: Antibiotics That Destroy Membranes 316

13.4 Nonglyceride Lipids 317

Sphingolipids 317 Steroids 317

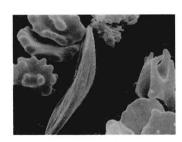
A HUMAN PERSPECTIVE: Anabolic Steroids and Athletics 318

A CLINICAL PERSPECTIVE: Steroids and the Treatment of Heart Disease 320

Waxes 320

13.5 Complex Lipids 321 Summary 324 Key Terms 324 Questions and Problems 325 Vocabulary Quiz 326

14
Amines and
Amides 327



CHEMISTRY CONNECTION: The Nicotine Patch 328 INTRODUCTION 328

14.1 Amines 328

Structure and Physical Properties 328 Nomenclature 330

A CLINICAL PERSPECTIVE: Medically Important Amines 331

Reactions Involving Amines 333 Quaternary Ammonium Salts 334

A MEDICAL PERSPECTIVE: Secondary Amines and Cancer 335

14.2 Heterocyclic Amines 335

14.3 Amides 336

A HUMAN PERSPECTIVE: Amines and the Central Nervous System 337

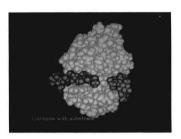
Structure and Physical Properties 337 Nomenclature 338

A CLINICAL PERSPECTIVE: Medically Important Amides 339

Reactions Involving Amides 339

Summary of Reactions 341
Summary 342
Key Terms 342
Questions and Problems 342
Vocabulary Quiz 344

15Protein Structure and Enzymes 345



CHEMISTRY CONNECTION: Can Radioactive Antibodies Cure Cancer? 346 INTRODUCTION 346

15.1 Cellular Functions of Proteins 346

15.2 The Complex Design of Proteins 347

α-Amino Acids 347

A HUMAN PERSPECTIVE: The Opium Poppy and Peptide Synthesis in the Brain 348

The Peptide Bond 351
Primary Structure of Proteins 353
Secondary Structure of Proteins 356
Tertiary Structure of Proteins 356
Quaternary Structure of Proteins 357

15.3 Myoglobin and Hemoglobin 358

Myoglobin and Oxygen Storage 358

A MEDICAL PERSPECTIVE: Immunoglobulins: Proteins That Defend the Body 360

Hemoglobin and Oxygen Transport 360 Oxygen Transport from Mother to Fetus 360

15.4 The Effect of Temperature and pH on Proteins 362

The Effect of Temperature 362
The Effect of pH 363

15.5 Enzymes: Nomenclature and Classification 364

Nomenclature of Enzymes 364 Classification of Enzymes 365

15.6 Enzyme-Catalyzed Reactions 367

Effect of Enzymes on the Activation Energy of a Reaction 367

Effect of Substrate Concentration on Enzyme-Catalyzed Reactions 367
The Enzyme-Substrate Complex 368
Enzyme Specificity 369

The Transition State and Product Formation 370

Cofactors and Coenzymes 371

A CLINICAL PERSPECTIVE: Enzymes, Isoenzymes, and Myocardial Infarction 374

Factors That Affect Enzyme Activity 376

15.7 Inhibition of Enzyme Activity 377

Irreversible Inhibition 377 Competitive Inhibition 377

15.8 Use of Enzymes in Medicine 378

15.9 Dietary Protein and Protein Digestion 379

A CLINICAL PERSPECTIVE: The AIDS Test 380

Summary 382 Key Terms 383 Questions and Problems 383 Vocabulary Quiz 385

16CarbohydrateMetabolism 386



CHEMISTRY CONNECTION: The Man Who Got Tipsy from Eating Pasta 387
INTRODUCTION 387

16.1 ATP: The Cellular Energy Currency 387

16.2 Overview of Catabolic Processes 390

Stage I: Hydrolysis of Dietary Macromolecules into Small Subunits 390

Stage II: Conversion of Monomers into a Form That Can Be Completely Oxidized 390

Stage III: The Complete Oxidation of Nutrients and the Production of ATP 391

16.3 Glycolysis 392

An Overview 392 Reactions of Glycolysis 395

16.4 Fermentations 400

Lactate Fermentation 400 Alcohol Fermentation 400

16.5 Gluconeogenesis: The Synthesis of Glucose 401

16.6 Glycogen Synthesis and Degradation 403

A HUMAN PERSPECTIVE: Fermentations: The Good, the Bad, and the Ugly $\ \, 404$

Glycogenolysis: Glycogen Degradation 404

Glycogenesis: Glycogen Synthesis 405 Compatibility of Glycogenesis and Glycogenolysis 406

A HUMAN PERSPECTIVE: Glycogen Storage Diseases 407

16.7 Conversion of Pyruvate to Acetyl CoA 407 Summary 409 Key Terms 410 Questions and Problems 410 Vocabulary Quiz 411

17 erobic Re

Aerobic Respiration and Energy Production 412



CHEMISTRY CONNECTION: Mitochondria from Mom 413 INTRODUCTION 413

17.1 The Mitochondria 413

Structure and Function 413

A HUMAN PERSPECTIVE: Exercise and Energy Metabolism 414

Origin of the Mitochondria 414

17.2 An Overview of Aerobic Respiration 416

17.3 The Citric Acid Cycle (The Krebs Cycle) 416

Reactions of the Citric Acid Cycle 417 Summary of the Energy Yield 420

17.4 Oxidative Phosphorylation 420

Electron Transport Systems and the Hydrogen Ion Gradient 421

ATP Synthase and the Production of ATP 422

17.5 Degradation of Amino Acids 423

Removal of α -Amino Groups: Transamination 423

A HUMAN PERSPECTIVE: Brown Fat: The Fat That Makes You Thin? 424

Removal of α -Amino Groups: Oxidative Deamination 427

The Fate of Amino Acid Carbon Skeletons 427

17.6 The Urea Cycle 428

Reactions of the Urea Cycle 428

17.7 Overview of Anabolism: The Citric Acid Cycle as a Source of Biosynthetic Intermediates 430

Summary 432 Key Terms 432 Questions and Problems 433 Vocabulary Quiz 434 18 Fatty Acid Metabolism 436



CHEMISTRY CONNECTION: Is Obesity a Genetic Disease? 436
INTRODUCTION 436

18.1 Lipid Metabolism in Animals 436

Digestion and Absorption of Dietary Fats 436 Lipid Storage 438

18.2 Fatty Acid Degradation 439

An Overview of Fatty Acid Degradation 439

A HUMAN PERSPECTIVE: Losing Those Unwanted Pounds of Adipose Tissue 440

The Reactions of β -Oxidation 443

18.3 Ketone Bodies 446

Ketosis 446 Ketogenesis 447

18.4 Fatty Acid Synthesis 449

A Comparison of Fatty Acid Synthesis and Degradation 449

A CLINICAL PERSPECTIVE: Diabetes Mellitus and Ketone Bodies 450

18.5 The Regulation of Lipid and Carbohydrate Metabolism 452

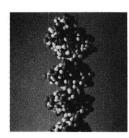
The Liver 452 Adipose Tissue 453 Muscle Tissue 453 The Brain 454

18.6 The Effects of Insulin and Glucagon on Cellular Metabolism 455

Summary 456 Key Terms 456 Questions and Problems 457 Vocabulary Quiz 458

19

Introduction to Molecular Genetics 459



CHEMISTRY CONNECTION: A World Without Human Genetic Disease? 460 INTRODUCTION 460

19.1 The Structure of the Nucleotide 460

Chemical Composition of DNA and RNA 460 Nucleotide Structure 461

19.2 The Structure of DNA and RNA 463

DNA Structure: The Double Helix 463

A CLINICAL PERSPECTIVE: Fooling the AIDS Virus with "Look-Alike" Nucleotides 466

RNA Structure 467

19.3 DNA Replication 468

19.4 Information Flow in Biological Systems 469

Classes of RNA Molecules 469 Transcription 470 RNA Splicing 472

19.5 The Genetic Code 473

19.6 Protein Synthesis 476

The Role of Transfer RNA 476
The Process of Translation 478

19.7 Mutation, Ultraviolet Light, and DNA Repair 480

The Nature of Mutations 480
The Results of Mutations 480

A CLINICAL PERSPECTIVE: The Ames Test for Carcinogens 481

Mutagens and Carcinogens 482 Ultraviolet Light, Mutation, and DNA Repair 482 Consequences of Defects in DNA Repair 483

19.8 Recombinant DNA 483

Tools Used in the Study of DNA 483

A HUMAN PERSPECTIVE: DNA Fingerprints: Admissible in Court? 486

Genetic Engineering 487

A MEDICAL PERSPECTIVE: The New Genetics and Human Genetic Disease 490

Summary 491 Key Terms 492 Questions and Problems 492 Vocabulary Quiz 493

APPENDIXES 494

- A Review of Mathematics Applied to Problem Solving in Chemistry 494
- B Table of Formula Weights 504
- C Stereochemistry and Stereoisomers Revisited 506
- D Lipid-Soluble Vitamins 512
- E Water-Soluble Vitamins 517
- F Minerals and Cellular Function 523

Glossary 526

Answers to Selected Problems 540

Index 561

Credits 574