

### Contents

Perspectives xiii Preface xv

### **GENERAL CHEMISTRY**

## 1 Chemistry: Methods and Measurement 1

### 1.1 The Discovery Process 2

Chemistry 2

Major Areas of Chemistry 2

A Medical Perspective: Curiosity,

Science, and Medicine 3

The Scientific Method 4

Models in Chemistry 4

A Human Perspective: The Scientific Method 5

### 1.2 Matter and Properties 6

Data and Results 6

States of Matter 7

Matter and Physical Properties 7

Matter and Chemical Properties 8

Intensive and Extensive Properties 9

Classification of Matter 10

### 1.3 Significant Figures and Scientific Notation 11

Significant Figures 11

Recognition of Significant Figures 12

Scientific Notation 13

Error, Accuracy, Precision, and Uncertainty 14

Significant Figures in Calculation of Results 15

Exact (Counted) and Inexact Numbers 17

Rounding Off Numbers 17

### 1.4 Units and Unit Conversion 18

English and Metric Units 18

Unit Conversion: English and Metric Systems 19

Conversion of Units Within the Same System 19

Conversion of Units from One System to Another 21

### 1.5 Experimental Quantities 23

Mass 23

Length 24

Volume 24

Time 25

Temperature 25

Energy 27

Concentration 27

### A Human Perspective: Food Calories 28

Density and Specific Gravity 29

### A Medical Perspective: Assessing Obesity:

The Body-Mass Index 31

iv

A Human Perspective: Quick and Useful Analysis 33

Summary 33

Key Terms 34

Questions and Problems 35

Critical Thinking Problems 37

### 2 The Structure of the Atom and the Periodic Table 39

### 2.1 Composition of the Atom 40

Electrons, Protons, and Neutrons 40 Isotopes 42

**Chemistry at the Crime** 

Scene: Microbial Forensics 44

### 2.2 Development of Atomic Theory 45

Dalton's Theory 46

Evidence for Subatomic Particles: Electrons, Protons, and

Neutrons 46

Evidence for the Nucleus 46

### 2.3 Light, Atomic Structure, and the Bohr Atom 47

Light and Atomic Structure 47

Green Chemistry: Electromagnetic Radiation and Its

Effects on Our Everyday Lives 49

The Bohr Atom 50

A Human Perspective: Atomic Spectra and the Fourth

of July 51

Modern Atomic Theory 52

### 2.4 The Periodic Law and the Periodic Table 53

Numbering Groups in the Periodic Table 54

Periods and Groups 55

Metals and Nonmetals 55

### A Medical Perspective: Copper Deficiency and Wilson's

Disease 56

Atomic Number and Atomic Mass 56

### 2.5 Electron Arrangement and the Periodic Table 57

The Quantum Mechanical Atom 58

Principal Energy Levels, Sublevels, and Orbitals 58

Electron Configurations 60

Guidelines for Writing Electron Configurations 60

Electron Configurations and the Periodic Table 64

### 2.6 Valence Electrons and the Octet Rule 65

Valence Electrons 65

The Octet Rule 66

Shorthand Electron Configurations 66

Ions 67

Ion Formation and the Octet Rule 67

A Medical Perspective: Dietary Calcium 69







Contents

### 2.7 Trends in the Periodic Table 70

Atomic Size 70 Ion Size 70 Ionization Energy 71 Electron Affinity 72 Summary 73 Key Terms 74

Questions and Problems 74 Critical Thinking Problems 77

### **3** Structure and Properties of Ionic and Covalent Compounds 79

### 3.1 Chemical Bonding 80

Lewis Symbols 80 Principal Types of Chemical Bonds: Ionic and Covalent 80



Crystal Formation 83

Polar Covalent Bonding and Electronegativity 84

### 3.2 Naming Compounds and Writing Formulas of Compounds 86

Ionic Compounds 86 Covalent Compounds 91

### 3.3 Properties of Ionic and Covalent Compounds 93

Physical State 93 Melting and Boiling Points 93

A Medical Perspective: Rebuilding Our Teeth 94

Structure of Compounds in the Solid State 94 Solutions of Ionic and Covalent Compounds 94

### 3.4 Drawing Lewis Structures of Molecules and Polyatomic Ions 95

Lewis Structures of Molecules 95

### A Medical Perspective: Blood Pressure and the Sodium Ion/Potassium Ion Ratio 96

Lewis Structures of Polyatomic Ions 98 Lewis Structure, Stability, Multiple Bonds, and Bond Energies 101

Isomers 102

Lewis Structures and Resonance 103

Lewis Structures and Exceptions to the Octet Rule 105 Lewis Structures and Molecular Geometry; VSEPR

Theory 106

Periodic Structural Relationships 108 Lewis Structures and Polarity 111

### 3.5 Properties Based on Electronic Structure and Molecular Geometry 113

Solubility 113

Boiling Points of Liquids and Melting Points of Solids 114

Summary 115 Key Terms 116

Questions and Problems 117

Critical Thinking Problems 119

### 4 Calculations and the Chemical Equation 121

### 4.1 The Mole Concept and Atoms 122

The Mole and Avogadro's Number 122 Calculating Atoms, Moles, and Mass 124



### 4.2 The Chemical Formula, Formula Mass, and Molar Mass 127

The Chemical Formula 127 Formula Mass and Molar Mass 128

### 4.3 The Chemical Equation and the Information It Conveys 131

A Recipe for Chemical Change 131 Features of a Chemical Equation 131 The Experimental Basis of a Chemical Equation 132 Strategies for Writing Chemical Equations 132

### 4.4 Chemical Equations Represent Chemical Change 134

Balancing Chemical Equations 134 Classifying Chemical Reactions 139 Writing Precipitation Reactions as Net Ionic Equations 141

### 4.5 Calculations Using the Chemical Equation 143

General Principles 143

Use of Conversion Factors 144

A Human Perspective: The Chemistry of Automobile Air Bags 146

A Medical Perspective: Carbon Monoxide Poisoning: A Case of Combining Ratios 149

Theoretical and Percent Yield 151

A Medical Perspective: Pharmaceutical Chemistry: The Practical Significance of Percent Yield 152

Summary 154 Key Terms 155 Questions and Problems 155 Critical Thinking Problems 157

### 5 States of Matter: Gases, Liquids, and Solids 159

### 5.1 The Gaseous State 160

Ideal Gas Concept 160 Measurement of Gases 161 Kinetic Molecular Theory of Gases 162



Properties of Gases and the Kinetic Molecular Theory 162

A Human Perspective: The Demise of the Hindenburg 162

Boyle's Law 163 Charles's Law 165 Combined Gas Law 167 Avogadro's Law 168 Molar Volume of a Gas 169





Gas Densities 169 The Ideal Gas Law 170

Dalton's Law of Partial Pressures 172

Green Chemistry: The Greenhouse Effect and Global Climate Change 173

Ideal Gases Versus Real Gases 174

### 5.2 The Liquid State 174

Compressibility 174 Viscosity 174

A Medical Perspective: Blood Gases and

Respiration 175 Surface Tension 175 Vapor Pressure of a Liquid 176 van der Waals Forces 177

Chemistry at the Crime Scene: Explosives at the

Airport 177 Hydrogen Bonding 178

5.3 The Solid State 179

Properties of Solids 179

Types of Crystalline Solids Sublimation of Solids 181

Summary 182 Key Terms 182 Questions and Problems 182 Critical Thinking Problems 184

### **6** Solutions 185

### 6.1 Properties of Solutions 186

General Properties of Liquid Solutions 187 Solutions and Colloids 187 Degree of Solubility 188 Solubility and Equilibrium 189 Solubility of Gases: Henry's Law 189

A Human Perspective: Scuba Diving: Nitrogen and the

### 6.2 Concentration Based on Percent by Mass 191

Mass/Volume Percent 191 Mass/Mass Percent 192 Parts Per Thousand (ppt) and Parts Per Million (ppm) 193

### 6.3 Concentration Based on Moles 194

Molarity 195 Dilution 196

### 6.4 Concentration-Dependent Solution Properties 198

Vapor Pressure Lowering 198 Freezing Point Depression and Boiling Point Elevation 199

Calculating Freezing Points and Boiling Points of Aqueous Solutions 200

Osmotic Pressure, Osmosis, and Osmolarity 202

A Medical Perspective: Oral Rehydration Therapy 205

### 6.5 Aqueous Solutions 206

Water as a Solvent 206

A Human Perspective: An Extraordinary Molecule 207

Electrolytes in Solution 208

Biological Effects of Electrolytes in Solution 210

A Medical Perspective: Hemodialysis 211

Summary 212 Key Terms 213 Questions and Problems 213 Critical Thinking Problems 215

### 7 Energy, Rate, and Equilibrium 217

### 7.1 Thermodynamics 218

The Chemical Reaction and Energy 218 The First Law of Thermodynamics 219

Green Chemistry: Twenty-first

Century Energy 221

The Second Law of Thermodynamics 222

Free Energy 224

A Medical Perspective: Hot and Cold Packs 225

### 7.2 Experimental Determination of Energy Change in Reactions 226

#### 7.3 Kinetics 229

Chemical Kinetics 229

Activation Energy and the Activated Complex 230 Factors That Affect Reaction Rate 231 Mathematical Representation of Reaction Rate 233

A Human Perspective: Too Fast or Too Slow? 236

### 7.4 Equilibrium 237

Rate and Reversibility of Reactions 237 Physical Equilibrium 237 Chemical Equilibrium 238 The Generalized Equilibrium Constant Expression for a Chemical Reaction 238

Using Equilibrium Constants 242 LeChatelier's Principle 243

A Human Perspective: Light-Sensitive Glasses 246

Summary 246 Key Terms 247 Questions and Problems 247 Critical Thinking Problems 249

#### 8 Acids and Bases and **Oxidation-Reduction** 251

### 8.1 Acids and Bases 252

Arrhenius Theory of Acids and Bases 252 Brønsted-Lowry Theory of Acids and

Bases 253

Acid-Base Properties of Water 253 Acid and Base Strength 253 Conjugate Acids and Bases 254

The Dissociation of Water 257









Contents vii

### 8.2 pH: A Measurement Scale for Acids and Bases 258

A Definition of pH 258
Measuring pH 258
Calculating pH 259

The Importance of pH and pH Control 263

A Medical Perspective: Drug Delivery 263

### 8.3 Reactions Between Acids and Bases 264

Neutralization 264 Polyprotic Substances 266

Green Chemistry: Acid Rain 267

### 8.4 Acid-Base Buffers 268

The Buffer Process 268

Addition of Base or Acid to a Buffer Solution 269

Preparation of a Buffer Solution 270

The Henderson-Hasselbalch Equation 273

A Medical Perspective: Control of Blood pH 273

### 8.5 Oxidation-Reduction Processes 274

Oxidation and Reduction 274

A Medical Perspective: Oxidizing Agents for Chemical

Control of Microbes 275

Applications of Oxidation and Reduction 276

Biological Processes 277 Voltaic Cells 278

A Medical Perspective: Electrochemical Reactions in the Statue of Liberty and in Dental Fillings 280

Electrolysis 280 Summary 281

Key Terms 282

Questions and Problems 282 Critical Thinking Problems 284

## **9** The Nucleus, Radioactivity, and Nuclear Medicine 285

### 9.1 Natural Radioactivity 286

Alpha Particles 287
Beta Particles and Positrons 287
Gamma Rays 288
Properties of Alpha, Beta, Positron, and Gamma Radiation 288

A Human Perspective: Origin of the Elements 289

### 9.2 Writing a Balanced Nuclear Equation 289

Alpha Decay 289
Beta Decay 290
Positron Emission 290
Gamma Production 290

Predicting Products of Nuclear Decay 291

### 9.3 Properties of Radioisotopes 292

Nuclear Structure and Stability 292 Half-Life 292

A Human Perspective: An Extraordinary Woman in

Science 295 Radiocarbon Dating 295

#### 9.4 Nuclear Power 296

Energy Production 296 Nuclear Fission 296

Green Chemistry: Nuclear Waste Disposal 298

Nuclear Fusion 298 Breeder Reactors 298

### 9.5 Medical Applications of Radioactivity 299

Cancer Therapy Using Radiation 299

Nuclear Medicine 299

Making Isotopes for Medical Applications 300

A Medical Perspective: Magnetic Resonance Imaging 302

### 9.6 Biological Effects of Radiation 303

Radiation Exposure and Safety 303

### 9.7 Measurement of Radiation 305

Nuclear Imaging 305 Computer Imaging 305 The Geiger Counter 305 Film Badges 306

Units of Radiation Measurement 306

Green Chemistry: Radon and Indoor Air Pollution 307

Summary 307 Key Terms 308

Questions and Problems 309 Critical Thinking Problems 310

### **ORGANIC CHEMISTRY**

### 10 An Introduction to Organic Chemistry: The Saturated Hydrocarbons 311

### 10.1 The Chemistry of Carbon 312

Important Differences Between Organic and Inorganic Compounds 313

Families of Organic Compounds 314

**Green Chemistry:** Frozen Methane: Treasure or Threat? 315

### 10.2 Alkanes 317

Structure and Physical Properties 317 Alkyl Groups 321

**Chemistry at the Crime Scene:** Arson and Alkanes 323 Nomenclature 323

**Green Chemistry:** Oil-Eating Microbes 325 Constitutional or Structural Isomers 328

### 10.3 Cycloalkanes 330

cis-trans Isomerism in Cycloalkanes 331

### 10.4 Conformations of Alkanes and Cycloalkanes 334

Alkanes 334 Cycloalkanes 334

Green Chemistry: The Petroleum Industry and Gasoline Production 335





viii Contents

10.5 Reactions of Alkanes and Cycloalkanes 336

Combustion 336 Halogenation 337

A Medical Perspective: Polyhalogenated Hydrocarbons

Used as Anesthetics 339

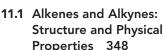
Summary of Reactions 340

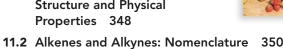
Summary 340 Key Terms 340

Questions and Problems 341

Critical Thinking Problems 345

11 The Unsaturated Hydrocarbons:
Alkenes, Alkynes, and Aromatics 347





A Medical Perspective: Killer Alkynes in Nature 354

11.3 Geometric Isomers: A Consequence of Unsaturation 356

11.4 Alkenes in Nature 361

11.5 Reactions Involving Alkenes and Alkynes 361

 $\begin{array}{lll} \mbox{Hydrogenation: Addition of $H_2$} & 363 \\ \mbox{Halogenation: Addition of $X_2$} & 365 \\ \mbox{Hydration: Addition of $H_2$O} & 367 \\ \mbox{Hydrohalogenation: Addition of HX} & 370 \\ \mbox{Addition Polymers of Alkenes} & 372 \\ \end{array}$ 

A Human Perspective: Life Without Polymers? 373

Green Chemistry: Plastic Recycling 374

11.6 Aromatic Hydrocarbons 374

Structure and Properties 376 Nomenclature 376 Polynuclear Aromatic Hydrocarbons 379 Reactions Involving Benzene 380

11.7 Heterocyclic Aromatic Compounds 381

Summary of Reactions 382 Summary 383 Key Terms 383 Questions and Problems 383 Critical Thinking Problems 387

## 12 Alcohols, Phenols, Thiols, and Ethers 389

**12.1** Alcohols: Structure and Physical Properties 391

12.2 Alcohols: Nomenclature 392
I.U.P.A.C. Names 392
Common Names 393



12.3 Medically Important Alcohols 394

A Medical Perspective: Fetal Alcohol Syndrome 395

12.4 Classification of Alcohols 396

12.5 Reactions Involving Alcohols 397

Preparation of Alcohols 397 Dehydration of Alcohols 400

Chemistry at the Crime Scene: Fingerprinting 401

Oxidation Reactions 402

12.6 Oxidation and Reduction in Living

Systems 405

**Chemistry at the Crime Scene:** Drinking and Driving 407

12.7 Phenols 407

12.8 Ethers 408

12.9 Thiols 411

Kitchen Chemistry: The Magic of Garlic 413

Summary of Reactions 415 Summary 416 Key Terms 416 Questions and Problems 416 Critical Thinking Problems 420

## 13 Aldehydes and Ketones 421

13.1 Structure and Physical Properties 423

13.2 I.U.P.A.C. Nomenclature and Common Names 425

Naming Aldehydes 425 Naming Ketones 427

13.3 Important Aldehydes and Ketones 430

13.4 Reactions Involving Aldehydes and Ketones 432

Preparation of Aldehydes and Ketones 432 Oxidation Reactions 432

**A Medical Perspective:** Formaldehyde and Methanol Poisoning 433

A Human Perspective: Alcohol Abuse and Antabuse 436

Reduction Reactions 436

A Medical Perspective: That Golden Tan Without the Fear of Skin Cancer 438

Addition Reactions 439 Keto-Enol Tautomers 442 Aldol Condensation 443

Summary of Reactions 444 Summary 445

Key Terms 446

Questions and Problems 446 Critical Thinking Problems 449







Contents ix

A Medical Perspective: Opiate Biosynthesis and the

### 14 Carboxylic Acids and Carboxylic Acid Derivatives 451

### 14.1 Carboxylic Acids 453

Structure and Physical Properties 453 Nomenclature 454

### **Chemistry at the Crime**

Scene: Carboxylic Acids and the Body Farm 458

**Green Chemistry:** Garbage Bags from Potato Peels? 460 Some Important Carboxylic Acids 460 Reactions Involving Carboxylic Acids 463

### 14.2 Esters 466

Structure and Physical Properties 466 Nomenclature 466 Reactions Involving Esters 468

**A Human Perspective:** The Chemistry of Flavor and Fragrance 470

### 14.3 Acid Chlorides and Acid Anhydrides 476

Acid Chlorides 476 Acid Anhydrides 479

## 14.4 Nature's High-Energy Compounds: Phosphoesters and Thioesters 482

A Human Perspective: Carboxylic Acid Derivatives of Special Interest 484

Summary of Reactions 485 Summary 486

Key Terms 486

Key Ierms 460

Questions and Problems 486 Critical Thinking Problems 491

### **15** Amines and Amides 493

### 15.1 Amines 495

Structure and Physical Properties 495 Nomenclature 498 Medically Important Amines 501 Reactions Involving Amines 502

### Chemistry at the Crime Scene: Methamphetamine 505

Quaternary Ammonium Salts 507

### 15.2 Heterocyclic Amines 507

### 15.3 Amides 509

Structure and Physical Properties 510 Nomenclature 510 Medically Important Amides 512

**A Medical Perspective:** Semisynthetic Penicillins 513 Reactions Involving Amides 513

## 15.4 A Preview of Amino Acids, Proteins, and Protein Synthesis 516

### 15.5 Neurotransmitters 517

Catecholamines 517 Serotonin 517



### Questions and Problems 523 Critical Thinking Problems 526

**BIOCHEMISTRY** 

γ-Aminobutyric Acid and Glycine 520

Nitric Oxide and Glutamate 521

Summary of Reactions 522

### 16 Carbohydrates 529

16.1 Types of Carbohydrates 530

Mutant Poppy 518

Histamine 519

Acetylcholine 520

Summary 522

Key Terms 523

16.2 Monosaccharides 532

A Medical Perspective: Tooth Decay and Simple Sugars 533

16.3 Stereoisomers and Stereochemistry 534

Stereoisomers 534

Rotation of Plane-Polarized Light 535

The Relationship Between Molecular Structure and Optical Activity 536

Fischer Projection Formulas 536

Racemic Mixtures 538

Diastereomers 538

Meso Compounds 539

The D- and L- System of Nomenclature 540

### 16.4 Biologically Important Monosaccharides 541

Glucose 541

Fructose 545

Galactose 546

Ribose and Deoxyribose, Five-Carbon Sugars 547

Reducing Sugars 547

### 16.5 Biologically Important Disaccharides 549

Maltose 550 Lactose 550

Chemistry at the Crime Scene: Blood Group

Antigens 551

Sucrose 552

### 16.6 Polysaccharides 553

Starch 553 Glycogen 553

Glycogen 555

Cellulose 554

### A Medical Perspective: Monosaccharide Derivatives and Heteropolysaccharides of Medical Interest 555

Summary 556 Key Terms 557

Questions and Problems 557 Critical Thinking Problems 559





Contents

- 17 Lipids and Their Functions in Biochemical Systems 561
- 17.1 Biological Functions of Lipids 562
  - A Medical Perspective: Lifesaving Lipids 563
- 17.2 Fatty Acids 564

X

Structure and Properties 564
Chemical Reactions of Fatty Acids 567
Eicosanoids: Prostaglandins, Leukotrienes, and Thromboxanes 570
Omega-3 Fatty Acids 572

17.3 Glycerides 574

Neutral Glycerides 574 Phosphoglycerides 575

Chemistry at the Crime Scene: Adipocere and Mummies of Soap 577

17.4 Nonglyceride Lipids 578

Sphingolipids 578 Steroids 580

A Medical Perspective: Disorders of Sphingolipid Metabolism 581

A Medical Perspective: Steroids and the Treatment of Heart Disease 582 Waxes 584

- 17.5 Complex Lipids 585
- 17.6 The Structure of Biological Membranes 588

A Medical Perspective: Liposome Delivery

Fluid Mosaic Structure of Biological Membranes 588

Systems 590

Summary 592

Key Terms 593

Questions and Problems 593

Critical Thinking Problems 594

- 18 Protein Structure and Function 595
- **18.1** Protein Building Blocks: The α-Amino Acids 596 Structure of Amino Acids 596

Stereoisomers of Amino Acids 597

A Medical Perspective: Proteins in the Blood 598 Classes of Amino Acids 598

- 18.2 The Peptide Bond 601
  - A Human Perspective: The Opium Poppy and Peptides in the Brain 602
- 18.3 The Primary Structure of Proteins 605
- **18.4** The Secondary Structure of Proteins 605

α-Helix 606 β-Pleated Sheet 607



- 18.5 The Tertiary Structure of Proteins 608
  - A Medical Perspective: Collagen, Cosmetic Procedures, and Clinical Applications 610
- 18.6 The Quaternary Structure of Proteins 610
- **18.7** An Overview of Protein Structure and Function 612
- 18.8 Myoglobin and Hemoglobin 613

Myoglobin and Oxygen Storage 613 Hemoglobin and Oxygen Transport 613 Oxygen Transport from Mother to Fetus 614 Sickle Cell Anemia 615

18.9 Denaturation of Proteins 615

Temperature 616 pH 616

**A Medical Perspective:** Immunoglobulins: Proteins That Defend the Body 618

Organic Solvents 618 Detergents 618 Heavy Metals 618

Mechanical Stress 619

18.10 Dietary Protein and Protein Digestion 619

Summary 621 Key Terms 622 Questions and Problems 622 Critical Thinking Problems 624

- **19** Enzymes 625
- 19.1 Nomenclature and Classification 626

Classification of Enzymes 626 Nomenclature of Enzymes 630

- 19.2 The Effect of Enzymes on the Activation Energy of a Reaction 631
- 19.3 The Effect of Substrate Concentration on Enzyme-Catalyzed Reactions 632
- 19.4 The Enzyme-Substrate Complex 633
- 19.5 Specificity of the Enzyme-Substrate Complex 634
- 19.6 The Transition State and Product Formation 635

**A Medical Perspective:** HIV Protease Inhibitors and Pharmaceutical Drug Design 637

- 19.7 Cofactors and Coenzymes 637
- 19.8 Environmental Effects 641

Effect of pH 641 Effect of Temperature 641

A Medical Perspective:  $\alpha_1$ -Antitrypsin and Familial Emphysema 642

19.9 Regulation of Enzyme Activity 643

Allosteric Enzymes 643 Feedback Inhibition 644





Contents xi

Proenzymes 645 Protein Modification 646

### 19.10 Inhibition of Enzyme Activity 646

Irreversible Inhibitors 646

Reversible, Competitive Inhibitors 647

**Chemistry at the Crime Scene:** Enzymes, Nerve Agents, and Poisoning 648

Reversible, Noncompetitive Inhibitors 649

#### 19.11 Proteolytic Enzymes 650

A Medical Perspective: Enzymes and Acute Myocardial Infarction 651

### 19.12 Uses of Enzymes in Medicine 652

Summary 653 Key Terms 654 Questions and Problems 655 Critical Thinking Problems 657

### 20 Introduction to Molecular Genetics 659

## 20.1 The Structure of the Nucleotide 660

Nucleotide Structure 661

## 20.2 The Structure of DNA and RNA 663

DNA Structure: The Double Helix 663 Chromosomes 665

A Medical Perspective: Molecular Genetics and Detection of Human Genetic Disorders 667 RNA Structure 667

### 20.3 DNA Replication 668

Bacterial DNA Replication 668 Eukaryotic DNA Replication 671

### 20.4 Information Flow in Biological Systems 672

Classes of RNA Molecules 672
Transcription 673
Post-transcriptional Processing of RNA 674

### 20.5 The Genetic Code 676

### 20.6 Protein Synthesis 678

The Role of Transfer RNA 678
The Process of Translation 679

### 20.7 Mutation, Ultraviolet Light, and DNA Repair 682

The Nature of Mutations 682 The Results of Mutations 683

### A Medical Perspective: The Ames Test for

Carcinogens 684

Mutagens and Carcinogens 685 Ultraviolet Light Damage and DNA Repair 685 Consequences of Defects in DNA Repair 685

### 20.8 Recombinant DNA 685

Tools Used in the Study of DNA 685 Genetic Engineering 687



### 20.10 The Human Genome Project 691

### Chemistry at the Crime Scene: DNA

Fingerprinting 692

Genetic Strategies for Genome Analysis 692

DNA Sequencing 693

### A Medical Perspective: A Genetic Approach to Familial

Emphysema 694

Summary 695 Key Terms 696 Questions and Problems 697 Critical Thinking Problems 698

### 21 Carbohydrate Metabolism 701

## 21.1 ATP: The Cellular Energy Currency 702

## 21.2 Overview of Catabolic Processes 705

Stage I: Hydrolysis of Dietary Macromolecules into Small Subunits 706

Stage II: Conversion of Monomers into a Form That Can Be Completely Oxidized 708

Stage III: The Complete Oxidation of Nutrients and the Production of ATP  $\,\,$  708

### 21.3 Glycolysis 708

An Overview 708 Reactions of Glycolysis 710

A Medical Perspective: Genetic Disorders of

Glycolysis 712

Regulation of Glycolysis 715

A Human Perspective: Fermentations: The Good, the

Bad, and the Ugly 716

#### 21.4 Fermentations 716

Lactate Fermentation 716 Alcohol Fermentation 718

### 21.5 The Pentose Phosphate Pathway 719

## 21.6 Gluconeogenesis: The Synthesis of Glucose 719

### 21.7 Glycogen Synthesis and Degradation 722

The Structure of Glycogen 722 Glycogenolysis: Glycogen Degradation 722

Glycogenolysis: Glycogen Degradation 72: Glycogenesis: Glycogen Synthesis 724

**A Medical Perspective:** Diagnosing Diabetes 727 Compatibility of Glycogenesis and Glycogenolysis 729

### A Human Perspective: Glycogen Storage

Diseases 730

Summary 730 Key Terms 731

Questions and Problems 731 Critical Thinking Problems 733





xii Contents

22 Aerobic Respiration and Energy Production 735

# **22.1 The Mitochondria 736**Structure and Function **736**

Origin of the Mitochondria 737 **A Human Perspective:** Exercise and Energy Metabolism 738



- 22.2 Conversion of Pyruvate to Acetyl CoA 738
- 22.3 An Overview of Aerobic Respiration 741
- **22.4** The Citric Acid Cycle (The Krebs Cycle) 742
  Reactions of the Citric Acid Cycle 742
- 22.5 Control of the Citric Acid Cycle 745
- 22.6 Oxidative Phosphorylation 747

Electron Transport Systems and the Hydrogen Ion Gradient 747

A Human Perspective: Brown Fat: The Fat That Makes You Thin? 748

ATP Synthase and the Production of ATP 750 Summary of the Energy Yield 750

### 22.7 The Degradation of Amino Acids 751

Removal of  $\alpha$ -Amino Groups: Transamination 752 Removal of  $\alpha$ -Amino Groups: Oxidative Deamination 753

The Fate of Amino Acid Carbon Skeletons 755

### 22.8 The Urea Cycle 755

Reactions of the Urea Cycle 755

**A Medical Perspective:** Pyruvate Carboxylase Deficiency 758

### 22.9 Overview of Anabolism: The Citric Acid Cycle as a Source of Biosynthetic Intermediates 759

Summary 761 Key Terms 761 Questions and Problems 762 Critical Thinking Problems 763



## 23.1 Lipid Metabolism in Animals 766

Digestion and Absorption of Dietary Triglycerides 766 Lipid Storage 767

**A Medical Perspective:** Obesity: A Genetic Disorder? 769

### 23.2 Fatty Acid Degradation 770

An Overview of Fatty Acid Degradation 770The Reactions of  $\beta$ -Oxidation 771

A Human Perspective: Losing Those Unwanted Pounds of Adipose Tissue 774

### 23.3 Ketone Bodies 777

Ketosis 777 Ketogenesis 777

### 23.4 Fatty Acid Synthesis 779

A Comparison of Fatty Acid Synthesis and Degradation 779

### 23.5 The Regulation of Lipid and Carbohydrate Metabolism 781

The Liver 781 Adipose Tissue 781

**A Medical Perspective:** Diabetes Mellitus and Ketone Bodies 782

Muscle Tissue 783 The Brain 784

### 23.6 The Effects of Insulin and Glucagon on Cellular Metabolism 784

Summary 786 Key Terms 786 Questions and Problems 786 Critical Thinking Problems 788

Glossary G-1

Answers to Odd-Numbered Problems AP-1

Credits C-1



