Preface xx

1 **Chemistry Methods and Measurement 1**

2 **The Composition and Structure of the Atom 33**

3 **Elements, Atoms, Ions, and the Periodic Table 57**

4 **Structure and Properties of Ionic and Covalent Compounds 81**

5 **Calculations and the Chemical Equation 117**

6 **States of Matter: Gases, Liquids, and Solids 149**

7 **Reactions and Solutions 175**

8 **Chemical and Physical Change: Energy, Rate, and Equilibrium 205**

9 **Charge-Transfer Reactions: Acids and Bases and Oxidation-Reduction 237**

10 **The Nucleus, Radioactivity, and Nuclear Medicine 269**

11 **An Introduction to Organic Chemistry: The Saturated Hydrocarbons 295**

12 **The Unsaturated Hydrocarbons: Alkenes, Alkynes, and Aromatics 323**

13 **Alcohols, Phenols, Thiols, and Ethers 355**

14 **Aldehydes and Ketones 383**

15 **Carboxylic Acids and Carboxylic Acid Derivatives 407**

16 **Amines and Amides 439**

17 **Carbohydrates 467**

18 **Lipids and Their Functions in Biochemical Systems 495**

19 **Protein Structure and Function 533**

20 **Enzymes 565**

21 **Carbohydrate Metabolism 599**

22 **Aerobic Respiration and Energy Production 635**

23 **Fatty Acid Metabolism 665**

24 **Introduction to Molecular Genetics 691**

Appendixes 729
Glossary 769
Answers to Selected Problems 785
Credits 821
Index 823

1 Chemistry: Methods and Measurement 1

CHEMISTRY CONNECTION:
Chance Favors the Prepared Mind 2

1.1 The Discovery Process 3
Chemistry 3
Major Areas of Chemistry 3
The Scientific Method 3

A HUMAN PERSPECTIVE:
The Scientific Method 4

Models in Chemistry 5
Science and Technology 6

1.2 Data, Results, and Units 6

1.3 Measurement in Chemistry 7
English and Metric Units 7
Unit Conversion: English and Metric Systems 9
Conversion of Units within the Same System 9
Conversion of Units from One System to Another 11

1.4 Error, Accuracy, Precision, and Uncertainty 13

1.5 Significant Figures and Scientific Notation 14
Significant Figures 14
Recognition of Significant Figures 15
Scientific Notation 16
Significant Figures in Calculation of Results 17
Rounding Off Numbers 19

1.6 Experimental Quantities 20
Mass 20
Length 21
Volume 21
Time 22
Temperature 22
Energy 23
Concentration 24
Density and Specific Gravity 24

A HUMAN PERSPECTIVE:
Food Calories 25

A CLINICAL PERSPECTIVE:
Diagnosis Based on Waste 28

Summary 28
Key Terms 29
Questions and Problems 30
Critical Thinking Problems 31

2 The Composition and Structure of the Atom 33

CHEMISTRY CONNECTION:
Curiosity, Science, and Medicine 34

2.1 Matter and Properties 34
Matter and Physical Properties 34
Matter and Chemical Properties 35
Intensive and Extensive Properties 36
Classification of Matter 37

2.2 Matter and Structure 39
Atomic Structure 39
Isotopes 41
Ions 44

2.3 Development of the Atomic Theory 44
Dalton's Theory 44
Subatomic Particles: Electrons, Protons, and Neutrons 45
The Nucleus 46
Light and Atomic Structure 47
The Bohr Atom 49

2.4 Modern Atomic Theory 50

A Human Perspective:
Atomic Spectra and the Fourth of July 51

An Environmental Perspective:
Electromagnetic Radiation and Its Effects on Our Everyday Lives 52

Summary 54
Key Terms 54
Questions and Problems 55
Critical Thinking Problems 56

3 Elements, Atoms, Ions, and the Periodic Table 57

Chemistry Connection:
Managing Mountains of Information 58

3.1 The Periodic Law and the Periodic Table 58
Numbering Groups in the Periodic Table 60
Periods and Groups 61
Metals and Nonmetals 61
Atomic Number and Atomic Mass 61

A Medical Perspective:
Copper Deficiency and Wilson's Disease 62

3.2 Electron Arrangement and the Periodic Table 63
Valence Electrons 63
The Quantum Mechanical Atom 66
Energy Levels and Sublevels 66
Electron Configuration and the Aufbau Principle 68
Abbreviated Electron Configurations 70

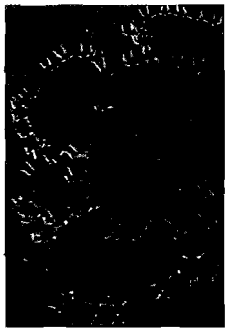
3.3 The Octet Rule 71
Ion Formation and the Octet Rule 71

A Clinical Perspective:
Dietary Calcium 73

3.4 Trends in the Periodic Table 73
Atomic Size 74
Ion Size 74
Ionization Energy 74
Electron Affinity 76

Summary 77
Key Terms 77
Questions and Problems 77
Critical Thinking Problems 79

4 Structure and Properties of Ionic and Covalent Compounds 81



Chemistry Connection:
Magnets and Migration 82

4.1 Chemical Bonding 82
Lewis Symbols 83
Principal Types of Chemical Bonds: Ionic and Covalent 83
Polar Covalent Bonding and Electronegativity 85

4.2 Naming Compounds and Writing Formulas of Compounds 86
Ionic Compounds 87
Covalent Compounds 92

4.3 Properties of Ionic and Covalent Compounds 94
Physical State 94
Melting and Boiling Points 94
Structure of Compounds in the Solid State 94

A Human Perspective:
How the Elements Came into Being 95

Solutions of Ionic and Covalent Compounds 95

4.4 Drawing Lewis Structures of Molecules and Polyatomic Ions 95
Lewis Structures of Molecules 95

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

Lewis Structures of Polyatomic Ions 99
Lewis Structure, Stability, Multiple Bonds, and Bond Energies 102
Lewis Structures and Resonance 103
Lewis Structures and Exceptions to the Octet Rule 104
Lewis Structures and Molecular Geometry; VSEPR Theory 106
Lewis Structures and Polarity 110

4.5 Properties Based on Molecular Geometry 112
Solubility 112
Boiling Points of Liquids and Melting Points of Solids 113

Summary 114
Key Terms 115
Questions and Problems 115
Critical Thinking Problems 116

5 Calculations and the Chemical Equation 117

CHEMISTRY CONNECTION:
The Chemistry of Automobile Air Bags 118

5.1 The Mole Concept and Atoms 119
The Mole and Avogadro's Number 119
Calculating Atoms, Moles, and Mass 120

5.2 Compounds 123
The Chemical Formula 123

5.3 The Mole Concept Applied to Compounds 124

5.4 The Chemical Equation and the Information It Conveys 126
A Recipe for Chemical Change 126
Features of a Chemical Equation 127
The Experimental Basis of a Chemical Equation 127

5.5 Balancing Chemical Equations 128

5.6 The Extent of Chemical Reactions 132

A CLINICAL PERSPECTIVE:
Carbon Monoxide Poisoning: A Case of Combining Ratios 133

5.7 Calculations Using the Chemical Equation 133
General Principles 133
Use of Conversion Factors 134
The Limiting Reactant Problem 140
Theoretical and Percent Yield 141

A MEDICAL PERSPECTIVE:
Pharmaceutical Chemistry: The Practical Significance of Percent Yield 144

Summary 144
Key Terms 145
Questions and Problems 146
Critical Thinking Problems 148

6 States of Matter: Gases, Liquids, and Solids 149

CHEMISTRY CONNECTION:
The Demise of the Hindenburg 150

6.1 The Gaseous State 151
Ideal Gas Concept 151
Measurement of Gases 151
Boyle's Law 152
Charles's Law 154

A CLINICAL PERSPECTIVE:
Autoclaves and the Gas Laws 156

Combined Gas Law 156
Avogadro's Law 158
Molar Volume of a Gas 159
Gas Densities 159
The Ideal Gas Law 160
Dalton's Law of Partial Pressures 162
Kinetic Molecular Theory of Gases 162

AN ENVIRONMENTAL PERSPECTIVE:
The Greenhouse Effect and Global Warming 163

Ideal Gases Versus Real Gases 164

6.2 The Liquid State 164
Compressibility 165
Viscosity 165
Surface Tension 165

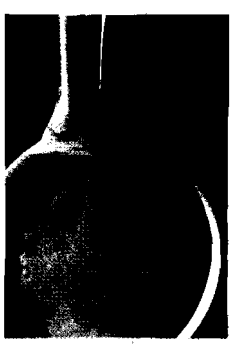
A CLINICAL PERSPECTIVE:
Blood Gases and Respiration 166

Vapor Pressure of a Liquid 166
Van der Waals Forces 167
Hydrogen Bonding 167

6.3 The Solid State 169
Properties of Solids 169
Types of Crystalline Solids 169

Summary 170
Key Terms 171
Questions and Problems 171
Critical Thinking Problems 173

7 Reactions and Solutions 175



CHEMISTRY CONNECTION:
Seeing a Thought 176

7.1 Writing Chemical Reactions 177
Combination Reactions 177
Decomposition Reactions 177
Replacement Reactions 177

7.2 Types of Chemical Reactions 178
Precipitation Reactions 178
Reactions with Oxygen 180
Acid–Base Reactions 180
Oxidation-Reduction Reactions 180

7.3 Properties of Solutions 181
General Properties of Liquid Solutions 181
Solutions and Colloids 182
Degree of Solubility 183
Solubility and Equilibrium 183
Solubility of Gases: Henry's Law 183

7.4 Concentration of Solutions: Percentage 184
Weight/Volume Percent 184

A Human Perspective:
Scuba Diving: Nitrogen and the Bends 185

Weight/Weight Percent 186

7.5 Concentration of Solutions: Moles and Equivalents 187
Molarity 187
Dilution 188
Representation of Concentration of Ions in Solution 190

7.6 Concentration-Dependent Solution Properties 191
Vapor Pressure Lowering 191
Freezing Point Depression and Boiling Point Elevation 192
Osmotic Pressure 193

7.7 Water as a Solvent 196

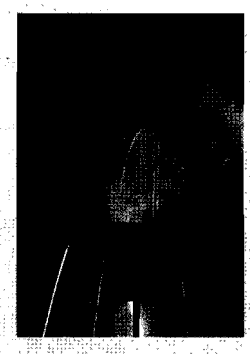
7.8 Electrolytes in Body Fluids 197

A Human Perspective:
An Extraordinary Molecule 198

A Clinical Perspective:
Hemodialysis 200

Summary 200
Key Terms 202
Questions and Problems 202
Critical Thinking Problems 203

8 Chemical and Physical Change: Energy, Rate, and Equilibrium 205



Chemistry Connection:
The Cost of Energy? More Than You Imagine 206

8.1 Thermodynamics 206
The Chemical Reaction and Energy 207
Exothermic and Endothermic Reactions 207
Enthalpy 208
Spontaneous and Nonspontaneous Reactions 209
Entropy 209
Free Energy 210

A Human Perspective:
Triboluminescence: Sparks in the Dark with Candy 211

8.2 Experimental Determination of Energy Change in Reactions 212

8.3 Kinetics 215
The Chemical Reaction 216
Activation Energy and the Activated Complex 216
Factors That Affect Reaction Rate 217

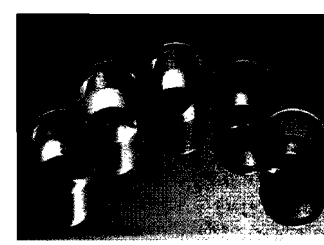
A Clinical Perspective:
Hot and Cold Packs 218

Mathematical Representation of Reaction Rate 221

8.4 Equilibrium 223
Rate and Reversibility of Reactions 223
Physical Equilibrium 223
Chemical Equilibrium 225
The Generalized Equilibrium-Constant Expression for a Chemical Reaction 226
LeChatelier's Principle 230

Summary 233
Key Terms 234
Questions and Problems 234
Critical Thinking Problems 235

9 Charge-Transfer Reactions: Acids and Bases and Oxidation–Reduction 237



Chemistry Connection:
Drug Delivery 238

9.1 Acids and Bases 239
Arrhenius Theory of Acids and Bases 239
Brønsted–Lowry Theory of Acids and Bases 239
Conjugate Acids and Bases 240

9.2 Solutions of Acids and Bases 244
Strengths of Acids and Bases 244
The Dissociation of Water 243
The pH Scale 244
The Importance of pH and pH Control 249

9.3 Reactions between Acids and Bases 249
Neutralization 249

An Environmental Perspective:
Acid Rain 252

Polyprotic Substances 252

9.4 Acid–Base Buffers 254
The Buffer Process 254
Addition of Base (OH^-) to a Buffer Solution 254
Addition of Acid (H_3O^+) to a Buffer Solution 255
Preparation of a Buffer Solution 255

A Clinical Perspective:
Control of Blood pH 258

9.5 Oxidation–Reduction Processes 258
Oxidation and Reduction 258

A Clinical Perspective:
Oxidizing Agents for Chemical Control of Microbes 259

Applications of Oxidation and Reduction 260

A Clinical Perspective:
Electrochemical Reactions in the Statue of Liberty and in Dental Fillings 261

Biological Processes 262
Voltaic Cells 262

A Medical Perspective:
Turning the Human Body into a Battery 264

Electrolysis 265

Summary 266
Key Terms 266
Questions and Problems 267
Critical Thinking Problems 268

10 The Nucleus, Radioactivity, and Nuclear Medicine 269

Chemistry Connection:
An Extraordinary Woman in Science 270

10.1 Natural Radioactivity 271
Alpha Particles 271
Beta Particles 272
Gamma Rays 272
Properties of Alpha, Beta, and Gamma Radiation 272

10.2 Writing a Balanced Nuclear Equation 273
Alpha Decay 273
Beta Decay 274
Gamma Production 274
Predicting Products of Nuclear Decay 274

10.3 Properties of Radioisotopes 275
Nuclear Structure and Stability 275
Half-Life 276

10.4 Nuclear Power 277
Energy Production 277
Nuclear Fission 278
Nuclear Fusion 278
Breeder Reactors 280

10.5 Radiocarbon Dating 280

An Environmental Perspective:
Nuclear Waste Disposal 281

10.6 Medical Applications of Radioactivity 282
Cancer Therapy Using Radiation 282
Nuclear Medicine 282
Making Isotopes for Medical Applications 284

10.7 Biological Effects of Radiation 285

A Clinical Perspective:
Magnetic Resonance Imaging 286

Radiation Exposure and Safety 286

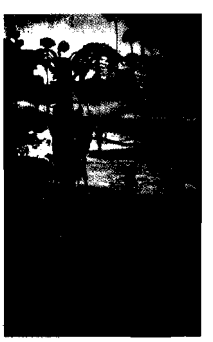
10.8 Detection and Measurement of Radiation 288
Nuclear Imaging 288
Computer Imaging 288
The Geiger Counter 289
Film Badges 289

10.9 Units of Radiation Measurement 289
The Curie 290
The Roentgen 290
The Rad 290
The Rem 290

An Environmental Perspective:
Radon and Indoor Air Pollution 291

Summary 291
Key Terms 291
Questions and Problems 291
Critical Thinking Problems 294

11 An Introduction to Organic Chemistry: The Saturated Hydrocarbons 295



Chemistry Connection:
The Origin of Organic Compounds 296

11.1 The Chemistry of Carbon 297
Important Differences between Organic and Inorganic Compounds 298
Families of Organic Compounds 299

11.2 Alkanes 300
Structure and Physical Properties 300
Alkyl Groups 302
Nomenclature 304

Constitutional Isomers 307

An Environmental Perspective:
Oil-Eating Bacteria 309

11.3 Cycloalkanes 309
cis-trans Isomerism in Cycloalkanes 311

11.4 Conformations of Alkanes and Cycloalkanes 313

11.5 Reactions of Alkanes and Cycloalkanes 314
Combustion 314

A Medical Perspective:
Polyhalogenated Hydrocarbons Used as Anesthetics 315

Halogenation 315

Summary of Reactions 317
Summary 317
Key Terms 317
Questions and Problems 318
Critical Thinking Problems 321

12 The Unsaturated Hydrocarbons: Alkenes, Alkynes, and Aromatics 323

Chemistry Connection:
A Cautionary Tale: DDT and Biological Magnification 324

12.1 Alkenes and Alkynes: Structure and Physical Properties 325

12.2 Alkenes and Alkynes: Nomenclature 326

12.3 Geometric Isomers: A Consequence of Unsaturation 329

12.4 Reactions Involving Alkenes 332
Hydrogenation: Addition of H_2 to an Alkene 332
Halogenation: Addition of X_2 to an Alkene 334
Hydration: Addition of H_2O to an Alkene 336
Hydrohalogenation: Addition of HX to an Alkene 337
Oxidation Reactions 339
Addition Polymers of Alkenes 339

A Human Perspective:
Life without Polymers? 340

12.5 Aromatic Hydrocarbons 342
Structure and Properties 342
Nomenclature 343

A Human Perspective:
Aromatic Compounds and Carcinogenesis 346

Reactions Involving Benzene 346

12.6 Heterocyclic Aromatic Compounds 347

Summary of Reactions 348
Summary 349
Key Terms 350
Questions and Problems 350
Critical Thinking Problems 352

13 Alcohols, Phenols, Thiols, and Ethers 355

Chemistry Connection:
Fetal Alcohol Syndrome 356

13.1 Alcohols: Structure and Physical Properties 357

13.2 Alcohols: Nomenclature 358
I.U.P.A.C. Names 358
Common Names 359

13.3 Medically Important Alcohols 360

13.4 Classification of Alcohols 361

13.5 Reactions Involving Alcohols 363
Preparation of Alcohols 363
Dehydration of Alcohols 366
Oxidation Reactions 368

13.6 Oxidation and Reduction in Living Systems 370

A Human Perspective:
Alcohol Consumption and the Breathalyzer Test 371

A Clinical Perspective:
Multistep Organic Synthesis 372

13.7 Phenols 373

13.8 Ethers 374

13.9 Thiols 376

Summary of Reactions 378
Summary 379
Key Terms 379
Questions and Problems 379
Critical Thinking Problems 382

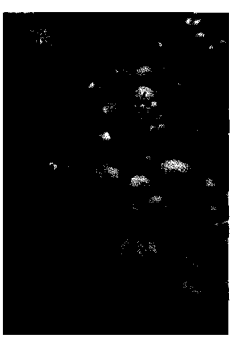
14 Aldehydes and Ketones 383

Chemistry Connection:
Genetic Complexity from Simple Molecules 384

14.1 Structure and Physical Properties 385

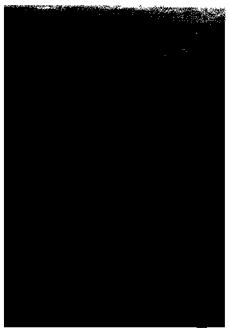
14.2 I.U.P.A.C. Nomenclature and Common Names 386
Naming Aldehydes 386
Naming Ketones 389
14.3 Important Aldehydes and Ketones 390
14.4 Reactions Involving Aldehydes and Ketones 391
Preparation of Aldehydes and Ketones 391
A Clinical Perspective:
Aldehydes in Medicine 392
Oxidation Reactions 393
Reduction Reactions 395
Addition Reactions 396
Keto–Enol Tautomers 398
Aldol Condensation 399
A Human Perspective:
The Chemistry of Vision 401
Summary of Reactions 402
Summary 403
Key Terms 404
Questions and Problems 404
Critical Thinking Problems 406

15 Carboxylic Acids and Carboxylic Acid Derivatives 407



Chemistry Connection:
Wake Up, Sleeping Gene 408
15.1 Carboxylic Acids 409
Structure and Physical Properties 409
Nomenclature 410
Some Important Carboxylic Acids 414
Reactions Involving Carboxylic Acids 415
An Environmental Perspective:
Garbage Bags from Potato Peels 416
15.2 Esters 418
Structure and Physical Properties 418
Nomenclature 419
Reactions Involving Esters 419
15.3 Acid Chlorides and Acid Anhydrides 424
Acid Chlorides 424
Acid Anhydrides 426
15.4 Nature's High-Energy Compounds: Phosphoesters and Thioesters 429
A Human Perspective:
Carboxylic Acid Derivatives of Special Interest 430
Summary of Reactions 433
Summary 434
Key Terms 434
Questions and Problems 434
Critical Thinking Problems 437

16 Amines and Amides 439



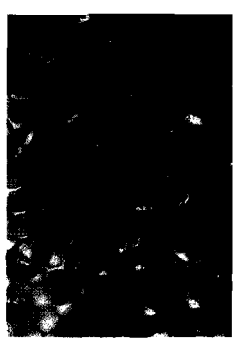
Chemistry Connection:
The Nicotine Patch 440
16.1 Amines 441
Structure and Physical Properties 441
Nomenclature 445
A Clinical Perspective:
Medically Important Amines 447
Reactions Involving Amines 448
A Medical Perspective:
Secondary Amines and Cancer 451
Quaternary Ammonium Salts 452
16.2 Heterocyclic Amines 452
16.3 Amides 454
A Human Perspective:
Amines and the Central Nervous System 455
Structure and Physical Properties 456
Nomenclature 456
Reactions Involving Amides 456
A Clinical Perspective:
Medically Important Amides 457
16.4 A Preview of Amino Acids, Proteins, and Protein Synthesis 460
Summary of Reactions 461
Summary 462
Key Terms 462
Questions and Problems 462
Critical Thinking Problems 465

17 Carbohydrates 467

Chemistry Connection:
Chemistry Through the Looking Glass 468
A Human Perspective:
Tooth Decay and Simple Sugars 470

17.1 Types of Carbohydrates 471
17.2 Monosaccharides 471
Nomenclature 471
Stereoisomers 472
Some Important Monosaccharides 473
Reducing Sugars 480
17.3 Disaccharides 481
Maltose 482
Lactose 482
Sucrose 483
A Human Perspective:
Blood Transfusions and the Blood Group Antigens 484
17.4 Polysaccharides 485
Starch 485
Glycogen 487
Cellulose 487
A Clinical Perspective:
The Bacterial Cell Wall 488
A Medical Perspective:
Monosaccharide Derivatives and Heteropolysaccharides of Medical Interest 490
Summary 492
Key Terms 492
Questions and Problems 492
Critical Thinking Problems 493

18 Lipids and Their Functions in Biochemical Systems 495



Chemistry Connection:
Life-Saving Lipids 496
18.1 Biological Functions of Lipids 496
18.2 Fatty Acids 498
Structure and Properties 498
Chemical Reactions of Fatty Acids 501
Eicosanoids: Prostaglandins, Leukotrienes, and Thromboxanes 503
18.3 Glycerides 505
Neutral Glycerides 505
Phosphoglycerides 507
18.4 Nonglyceride Lipids 509
Sphingolipids 509
A Clinical Perspective:
Disorders of Sphingolipid Metabolism 510
Steroids 512
A Human Perspective:
Anabolic Steroids and Athletics 513
A Clinical Perspective:
Steroids and the Treatment of Heart Disease 515
Waxes 516
18.5 Complex Lipids 516
18.6 The Structure of Biological Membranes 519
Fluid Mosaic Structure of Biological Membranes 519
Membrane Transport 522
A Clinical Perspective:
Antibiotics That Destroy Membrane Integrity 524
Energy Requirements for Transport 528
Summary 529
Key Terms 529
Questions and Problems 530
Critical Thinking Problems 531

19 Protein Structure and Function 533

Chemistry Connection:
Angiogenesis Inhibitors: Proteins that Inhibit Tumor Growth 534
19.1 Cellular Functions of Proteins 535
19.2 The α-Amino Acids 535
19.3 The Peptide Bond 539
A Human Perspective:
The Opium Poppy and Peptide Synthesis in the Brain 542
19.4 The Primary Structure of Proteins 543
19.5 The Secondary Structure of Proteins 544
α-Helix 544
β-Pleated Sheet 546
19.6 The Tertiary Structure of Proteins 546
A Human Perspective:
Collagen: A ProteinThat Makes Us Strong 548
19.7 The Quaternary Structure of Proteins 549
19.8 An Overview of Protein Structure and Function 551
19.9 Myoglobin and Hemoglobin 552
Myoglobin and Oxygen Storage 552
Hemoglobin and Oxygen Transport 552

A Medical Perspective:
Immunoglobulins: Proteins That Defend the Body 554

Oxygen Transport from Mother to Fetus 556
Sickle Cell Anemia 557

19.10 Denaturation of Proteins 557

19.11 Dietary Protein and Protein Digestion 560

Summary 562
Key Terms 563
Questions and Problems 563
Critical Thinking Problems 564

20 Enzymes 565

Chemistry Connection:
Super Hot Enzymes and the Origin of Life 566

20.1 Nomenclature and Classification 567
Nomenclature of Enzymes 567
Classification of Enzymes 568

20.2 The Effect of Enzymes on the Activation Energy of a Reaction 571

20.3 The Effect of Substrate Concentration on Enzyme-Catalyzed Reactions 572

20.4 The Enzyme–Substrate Complex 573

20.5 Specificity of the Enzyme–Substrate Complex 574

20.6 The Transition State and Product Formation 575

A Clinical Perspective:
The AIDS Test 576

20.7 Cofactors and Coenzymes 579

20.8 Environmental Effects 581
Effect of pH 581
Effect of Temperature 583

20.9 Regulation of Enzyme Activity 584
Allosteric Enzymes 584
Feedback Inhibition 586
Zymogens 586

20.10 Inhibition of Enzyme Activity 587
Irreversible Inhibitors 587
Reversible, Competitive Inhibitors 587

A Clinical Perspective:
Enzymes, Nerve Transmission, and Nerve Agents 588

Reversible, Noncompetitive Inhibitors 590

20.11 Proteolytic Enzymes 590

A Clinical Perspective:
Enzymes, Isoenzymes, and Myocardial Infarction 592

20.12 Uses of Enzymes in Medicine 594

Summary 595
Key Terms 596
Questions and Problems 597
Critical Thinking Problems 598

21 Carbohydrate Metabolism 599

Chemistry Connection:
The Man Who Got Tipsy from Eating Pasta 600

21.1 ATP: The Cellular Energy Currency 601

21.2 Overview of Catabolic Processes 604
Stage I: Hydrolysis of Dietary Macromolecules into Small Subunits 604
Stage II: Conversion of Monomers into a Form That Can Be Completely Oxidized 606
Stage III: The Complete Oxidation of Nutrients and the Production of ATP 607

21.3 Glycolysis 608
An Overview 608
Reactions of Glycolysis 609
Regulation of Glycolysis 615

21.4 Fermentations 616
Lactate Fermentation 616
Alcohol Fermentation 617

21.5 The Pentose Phosphate Pathway 618

21.6 Gluconeogenesis: The Synthesis of Glucose 619

21.7 Glycogen Synthesis and Degradation 621
The Structure of Glycogen 621
Glycogenolysis: Glycogen Degradation 621
Glycogenesis: Glycogen Synthesis 624

A Human Perspective:
Fermentations: The Good, the Bad, and the Ugly 626

Compatibility of Glycogenesis and Glycogenolysis 628

A Human Perspective:
Glycogen Storage Diseases 630

Summary 631
Key Terms 631

Questions and Problems 631
Critical Thinking Problems 632

22 Aerobic Respiration and Energy Production 635

CHEMISTRY CONNECTION:
Mitochondria from Mom 636

22.1 **The Mitochondria 637**
Structure and Function 637
Origin of the Mitochondria 637

A HUMAN PERSPECTIVE:
Exercise and Energy Metabolism 638

22.2 **Conversion of Pyruvate to Acetyl CoA 638**

22.3 **An Overview of Aerobic Respiration 641**

22.4 **The Citric Acid Cycle (The Krebs Cycle) 642**
Reactions of the Citric Acid Cycle 642

22.5 **Control of the Citric Acid Cycle 645**

22.6 **Oxidative Phosphorylation 646**
Electron Transport Systems and the Hydrogen Ion Gradient 646
ATP Synthase and the Production of ATP 647
Summary of the Energy Yield 648

A HUMAN PERSPECTIVE:
Brown Fat: The Fat That Makes You Thin? 650

22.7 **The Degradation of Amino Acids 652**
Removal of α-Amino Groups: Transamination 652
Removal of α-Amino Groups: Oxidative Deamination 654
The Fate of Amino Acid Carbon Skeletons 654

22.8 **The Urea Cycle 656**
Reactions of the Urea Cycle 656

22.9 **Overview of Anabolism: The Citric Acid Cycle as a Source of Biosynthetic Intermediates 659**

Summary 661
Key Terms 662
Questions and Problems 662
Critical Thinking Problems 663

23 Fatty Acid Metabolism 665

CHEMISTRY CONNECTION:
Obesity: A Genetic Disorder? 666

23.1 **Lipid Metabolism in Animals 667**
Digestion and Absorption of Dietary Triglycerides 667
Lipid Storage 668

23.2 **Fatty Acid Degradation 670**
An Overview of Fatty Acid Degradation 670

A HUMAN PERSPECTIVE:
Losing Those Unwanted Pounds of Adipose Tissue 672

The Reactions of β-Oxidation 674

23.3 **Ketone Bodies 677**
Ketosis 677
Ketogenesis 678

A CLINICAL PERSPECTIVE:
Diabetes Mellitus and Ketone Bodies 680

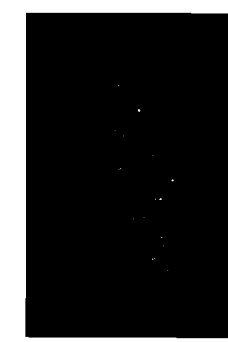
23.4 **Fatty Acid Synthesis 682**
A Comparison of Fatty Acid Synthesis and Degradation 682

23.5 **The Regulation of Lipid and Carbohydrate Metabolism 684**
The Liver 684
Adipose Tissue 685
Muscle Tissue 685
The Brain 686

23.6 **The Effects of Insulin and Glucagon on Cellular Metabolism 686**

Summary 688
Key Terms 688
Questions and Problems 688
Critical Thinking Problems 689

24 Introduction to Molecular Genetics 691



CHEMISTRY CONNECTION:
Molecular Genetics and Detection of Human Genetic Disease 692

24.1 **The Structure of the Nucleotide 693**
Chemical Composition of DNA and RNA 693
Nucleotide Structure 693

24.2 **The Structure of DNA and RNA 696**
DNA Structure: The Double Helix 696

A CLINICAL PERSPECTIVE:
Fooling the AIDS Virus with "Look-Alike" Nucleotides 698

RNA Structure 699

24.3 **DNA Replication 700**

24.4 Information Flow in Biological Systems 701
Classes of RNA Molecules 702
Transcription 703
Post-transcriptional Processing of RNA 705

24.5 The Genetic Code 707

24.6 Protein Synthesis 708
The Role of Transfer RNA 709
The Process of Translation 711

24.7 Mutation, Ultraviolet Light, and DNA Repair 713
The Nature of Mutations 713
The Results of Mutations 713
Mutagens and Carcinogens 714
Ultraviolet Light Damage and DNA Repair 714

A Clinical Perspective:
The Ames Test for Carcinogens 715

Consequences of Defects in DNA Repair 716

24.8 Recombinant DNA 716
Tools Used in the Study of DNA 716

A Human Perspective:
DNA Fingerprinting 720

Genetic Engineering 721

24.9 Polymerase Chain Reaction 723

A Medical Perspective:
α_1-Antitrypsin and Familial Emphysema 724

Summary 725
Key Terms 726
Questions and Problems 727
Critical Thinking Problems 728

Appendixes 729
Glossary 769
Answers to Selected Problems 785
Credits 821
Index 823