

Contents

Perspectives xii
Preface xiv

GENERAL CHEMISTRY

1 Chemistry: Methods and Measurement 1

- 1.1 The Discovery Process 2
 - Chemistry 2
 - Major Areas of Chemistry 2
 - The Scientific Method 3
 - Data and Results 4
 - Models in Chemistry 4
 - A Human Perspective: The Scientific Method* 5
- 1.2 The Classification of Matter 6
 - States of Matter 6
 - Physical Properties and Physical Change 7
 - Chemical Properties and Chemical Change 7
 - Intensive and Extensive Properties 8
 - Composition of Matter 9
- 1.3 The Units of Measurement 11
 - Mass 12
 - Length 12
 - Volume 13
 - Time 13
- 1.4 The Numbers of Measurement 14
 - Significant Figures 14
 - Recognition of Significant Figures 15
 - Scientific Notation 15
 - Error, Accuracy, Precision, and Uncertainty 16
 - Significant Figures in Calculation of Results 17
 - Exact (Counted) and Inexact Numbers 20
 - Rounding Off Numbers 20
- 1.5 Unit Conversion 20
 - Problem-Solving Strategies 20
 - Converting Between Units 21
 - The Factor-Label Method 21
 - A Medical Perspective: Curiosity and the Technology that Leads to Discovery* 26
- 1.6 Additional Experimental Quantities 26
 - Temperature 27
 - Energy 28
 - A Human Perspective: Food Calories* 29
 - Concentration 30
 - Density and Specific Gravity 30
 - A Medical Perspective: Assessing Obesity: The Body-Mass Index* 34
 - A Human Perspective: Quick and Useful Analysis* 35
 - Chapter Map 36
 - Summary 37
 - Answers to Practice Problems 38

Questions and Problems 38
Critical Thinking Problems 42

2 The Structure of the Atom and the Periodic Table 43

- 2.1 Composition of the Atom 44
 - Electrons, Protons, and Neutrons 44
 - Isotopes 46
- 2.2 Development of Atomic Theory 48
 - Dalton's Theory 48
 - Chemistry at the Crime Scene: Microbial Forensics* 49
 - Evidence for Subatomic Particles: Electrons, Protons, and Neutrons 50
 - Evidence for the Nucleus 50
- 2.3 Light, Atomic Structure, and the Bohr Atom 52
 - Light and Atomic Structure 52
 - Green Chemistry: Electromagnetic Radiation and Its Effects on Our Everyday Lives* 54
 - The Bohr Atom 55
 - Modern Atomic Theory 55
 - A Human Perspective: Atomic Spectra and the Fourth of July* 56
- 2.4 The Periodic Law and the Periodic Table 57
 - Numbering Groups in the Periodic Table 58
 - Periods 59
 - Metals and Nonmetals 59
 - A Medical Perspective: Copper Deficiency and Wilson's Disease* 60
 - Information Contained in the Periodic Table 60
- 2.5 Electron Arrangement and the Periodic Table 61
 - The Quantum Mechanical Atom 61
 - Principal Energy Levels, Sublevels, and Orbitals 62
 - Electron Configurations 63
 - Guidelines for Writing Electron Configurations of Atoms 64
 - Electron Configurations and the Periodic Table 67
 - Shorthand Electron Configurations 67
- 2.6 Valence Electrons and the Octet Rule 69
 - Valence Electrons 69
 - The Octet Rule 70
 - Ions 70
 - Ion Formation and the Octet Rule 70
 - A Medical Perspective: Dietary Calcium* 72
- 2.7 Trends in the Periodic Table 73
 - Atomic Size 73
 - Ion Size 73
 - Ionization Energy 74
 - Electron Affinity 75
 - Chapter Map 76
 - Summary 77
 - Answers to Practice Problems 78
 - Questions and Problems 78
 - Critical Thinking Problems 81

3 Structure and Properties of Ionic and Covalent Compounds	83	Classifying Chemical Reactions	145
3.1 Chemical Bonding	84	Writing Precipitation Reactions as Net Ionic Equations	147
Lewis Symbols	84		
Principal Types of Chemical Bonds:			
Ionic and Covalent	84		
<i>A Medical Perspective: Unwanted Crystal Formation</i>	88		
Polar Covalent Bonding and Electronegativity	89		
3.2 Naming Compounds and Writing Formulas of Compounds	91	4.5 Calculations Using the Chemical Equation	148
Ionic Compounds	91	General Principles	148
Covalent Compounds	96	Use of Conversion Factors	149
3.3 Properties of Ionic and Covalent Compounds	98	<i>A Human Perspective: The Chemistry of Automobile Air Bags</i>	152
Physical State	98	<i>A Medical Perspective: Carbon Monoxide Poisoning: A Case of Combining Ratios</i>	155
Melting and Boiling Points	98	Theoretical and Percent Yield	157
Structure of Compounds in the Solid State	98	<i>A Medical Perspective: Pharmaceutical Chemistry: The Practical Significance of Percent Yield</i>	158
Solutions of Ionic and Covalent Compounds	98	Chapter Map	159
<i>A Medical Perspective: Rebuilding our Teeth</i>	99	Summary	160
3.4 Drawing Lewis Structures of Molecules and Polyatomic Ions	99	Answers to Practice Problems	161
Lewis Structures of Molecules	99	Questions and Problems	161
<i>A Medical Perspective: Blood Pressure and the Sodium Ion/Potassium Ion Ratio</i>	102	Critical Thinking Problems	164
Lewis Structures of Polyatomic Ions	104		
Lewis Structure, Stability, Multiple Bonds, and Bond Energies	107	5 States of Matter: Gases, Liquids, and Solids	165
Isomers	107		
Lewis Structures and Resonance	108	5.1 The Gaseous State	166
Lewis Structures and Exceptions to the Octet Rule	110	Ideal Gas Concept	166
Lewis Structures and Molecular Geometry; VSEPR Theory	112	Measurement of Gases	167
Periodic Structural Relationships	115	Kinetic Molecular Theory of Gases	167
Lewis Structures and Polarity	117	<i>A Human Perspective: The Demise of the Hindenburg</i>	168
3.5 Properties Based on Electronic Structure and Molecular Geometry	119	Properties of Gases and the Kinetic Molecular Theory	168
Solubility	119	Boyle's Law	169
Boiling Points of Liquids and Melting Points of Solids	119	Charles's Law	170
Chapter Map	121	Combined Gas Law	172
Summary	122	Avogadro's Law	174
Answers to Practice Problems	122	Molar Volume of a Gas	175
Questions and Problems	123	Gas Densities	175
Critical Thinking Problems	126	The Ideal Gas Law	176
		Dalton's Law of Partial Pressures	178
4 Calculations and the Chemical Equation	127	<i>Green Chemistry: The Greenhouse Effect and Global Climate Change</i>	179
4.1 The Mole Concept and Atoms	128	Ideal Gases Versus Real Gases	180
The Mole and Avogadro's Number	128		
Calculating Atoms, Moles, and Mass	130	5.2 The Liquid State	180
4.2 The Chemical Formula, Formula Mass, and Molar Mass	133	Compressibility	180
The Chemical Formula	133	Viscosity	180
Formula Mass and Molar Mass	134	<i>A Medical Perspective: Blood Gases and Respiration</i>	181
4.3 The Chemical Equation and the Information It Conveys	136	Surface Tension	181
A Recipe for Chemical Change	136	Vapor Pressure of a Liquid	182
Features of a Chemical Equation	137	van der Waals Forces	183
The Experimental Basis of a Chemical Equation	137	Hydrogen Bonding	183
Strategies for Writing Chemical Equations	138	<i>Chemistry at the Crime Scene: Explosives at the Airport</i>	184
4.4 Chemical Equations Represent Chemical Change	139		
Balancing Chemical Equations	140	5.3 The Solid State	185
		Properties of Solids	185
		Types of Crystalline Solids	185
		<i>A Human Perspective: Gemstones</i>	187
		Sublimation of Solids	187
		Chapter Map	188
		Summary	189
		Answers to Practice Problems	189
		Questions and Problems	190
		Critical Thinking Problems	192

- 12 Alcohols, Phenols, Thiols, and Ethers 405**
- 12.1 Alcohols: Structure and Physical Properties 407
- 12.2 Alcohols: Nomenclature 409
IUPAC Names 409
Common Names 410
- 12.3 Medically Important Alcohols 411
Methanol 411
Ethanol 411
A Medical Perspective: Fetal Alcohol Syndrome 412
2-Propanol 412
1,2-Ethandiol 412
1,2,3-Propanetriol 413
- 12.4 Reactions Involving Alcohols 413
Preparation of Alcohols 413
Dehydration of Alcohols 415
Oxidation Reactions 416
- 12.5 Oxidation and Reduction in Living Systems 419
Chemistry at the Crime Scene: Drinking and Driving 421
- 12.6 Phenols 421
Kitchen Chemistry: Spicy Phenols 422
A Medical Perspective: Resveratrol: Fountain of Youth? 424
- 12.7 Ethers 424
- 12.8 Thiols 427
Kitchen Chemistry: The Magic of Garlic 430
Chapter Map 431
Summary of Reactions 432
Summary 432
Answers to Practice Problems 433
Questions and Problems 434
Critical Thinking Problems 438
- 13 Aldehydes and Ketones 439**
- 13.1 Structure and Physical Properties 441
- 13.2 IUPAC Nomenclature and Common Names 442
Naming Aldehydes 442
Naming Ketones 444
- 13.3 Important Aldehydes and Ketones 447
- 13.4 Reactions Involving Aldehydes and Ketones 449
Preparation of Aldehydes and Ketones 449
A Medical Perspective: Formaldehyde and Methanol Poisoning 450
Oxidation Reactions 450
Reduction Reactions 452
A Human Perspective: Alcohol Abuse and Antabuse 453
Addition Reactions 455
Kitchen Chemistry: The Allure of Truffles 456
Keto-Enol Tautomers 459
Chapter Map 461
Summary of Reactions 462
Summary 462
Answers to Practice Problems 463
Questions and Problems 464
Critical Thinking Problems 468
- 14 Carboxylic Acids and Carboxylic Acid Derivatives 469**
- 14.1 Carboxylic Acids 471
Structure and Physical Properties 471
Nomenclature 472
Chemistry at the Crime Scene: Carboxylic Acids and the Body Farm 476
Green Chemistry: Garbage Bags from Potato Peels? 478
Some Important Carboxylic Acids 478
Reactions Involving Carboxylic Acids 481
- 14.2 Esters 484
Structure and Physical Properties 484
Nomenclature 484
Reactions Involving Esters 485
A Human Perspective: The Chemistry of Flavor and Fragrance 488
A Human Perspective: Detergents 492
- 14.3 Acid Chlorides and Acid Anhydrides 494
Acid Chlorides 494
Acid Anhydrides 495
- 14.4 Nature's High-Energy Compounds: Phosphoesters and Thioesters 498
A Human Perspective: Carboxylic Acid Derivatives of Special Interest 500
Chapter Map 501
Summary of Reactions 502
Summary 502
Answers to Practice Problems 503
Questions and Problems 505
Critical Thinking Problems 509
- 15 Amines and Amides 511**
- 15.1 Amines 513
Structure and Physical Properties 513
Nomenclature 516
Medically Important Amines 519
Reactions Involving Amines 520
Chemistry at the Crime Scene: Methamphetamine 523
Quaternary Ammonium Salts 525
- 15.2 Heterocyclic Amines 525
- 15.3 Amides 527
Kitchen Chemistry: Browning Reactions and Flavor: The Maillard Reaction 528
Structure and Physical Properties 528
Nomenclature 529
Medically Important Amides 529
Reactions Involving Amides 531
A Medical Perspective: Semisynthetic Penicillins 532
- 15.4 A Preview of Amino Acids, Proteins, and Protein Synthesis 534
- 15.5 Neurotransmitters 535
Catecholamines 535
A Medical Perspective: Opiate Biosynthesis and the Mutant Poppy 536
Serotonin 536
Histamine 538
 γ -Aminobutyric Acid and Glycine 538

Acetylcholine 539
Nitric Oxide and Glutamate 540
Chapter Map 540
Summary of Reactions 541
Summary 541
Answers to Practice Problems 542
Questions and Problems 542
Critical Thinking Problems 546

Structure and Properties 584
Eicosanoids: Prostaglandins, Leukotrienes,
and Thromboxanes 587
Omega-3 Fatty Acids 589

17.3 Glycerides 590
Neutral Glycerides 590
Chemical Reactions of Fatty Acids and Glycerides 592
Phosphoglycerides 595
*Chemistry at the Crime Scene: Adipocere
and Mummies of Soap* 597

17.4 Nonglyceride Lipids 598
Sphingolipids 598
Steroids 600
*A Medical Perspective: Disorders
of Sphingolipid Metabolism* 601
*A Medical Perspective: Steroids
and the Treatment of Heart Disease* 602
Waxes 604

17.5 Complex Lipids 605

17.6 The Structure of Biological Membranes 608
Fluid Mosaic Structure of Biological Membranes 608
A Medical Perspective: Liposome Delivery Systems 610
Chapter Map 612
Summary 613
Answers to Practice Problems 613
Questions and Problems 615
Critical Thinking Problems 616

18 Protein Structure and Function 617

**18.1 Protein Building Blocks:
The α -Amino Acids 618**
Structure of Amino Acids 618
Stereoisomers of Amino Acids 619
Classes of Amino Acids 620

18.2 The Peptide Bond 622
*A Human Perspective: The Opium Poppy
and Peptides in the Brain* 625

18.3 The Primary Structure of Proteins 626

18.4 The Secondary Structure of Proteins 626
 α -Helix 627
 β -Pleated Sheet 628

18.5 The Tertiary Structure of Proteins 629
*A Medical Perspective: Collagen, Cosmetic Procedures,
and Clinical Applications* 631

18.6 The Quaternary Structure of Proteins 632

18.7 An Overview of Protein Structure and Function 633

18.8 Myoglobin and Hemoglobin 634
Myoglobin and Oxygen Storage 634
Hemoglobin and Oxygen Transport 634
Oxygen Transport from Mother to Fetus 635
Sickle Cell Anemia 636

18.9 Proteins in the Blood 636

18.10 Denaturation of Proteins 637
Temperature 637
pH 638
Kitchen Chemistry: Egg Foams: Meringues and Soufflés 639

BIOCHEMISTRY

16 Carbohydrates 547

16.1 Types of Carbohydrates 548

16.2 Monosaccharides 550
*A Medical Perspective: Tooth Decay
and Simple Sugars* 551

16.3 Stereoisomers and Stereochemistry 552
Stereoisomers 552
Rotation of Plane-Polarized Light 553
The Relationship Between Molecular Structure
and Optical Activity 554
Fischer Projection Formulas 554
Racemic Mixtures 556
Diastereomers 556
Meso Compounds 557
The D- and L- System of Nomenclature 558

16.4 Biologically Important Monosaccharides 559
Glucose 559
Fructose 563
Galactose 564
Ribose and Deoxyribose, Five-Carbon Sugars 564
Reducing Sugars 565
Kitchen Chemistry: The Chemistry of Caramels 566

16.5 Biologically Important Disaccharides 567
Maltose 568
Lactose 568
Sucrose 568
Chemistry at the Crime Scene: Blood Group Antigens 570

16.6 Polysaccharides 570
Starch 570
Glycogen 571
Cellulose 572
*A Medical Perspective: Monosaccharide Derivatives
and Heteropolysaccharides of Medical Interest* 573
Chapter Map 574
Summary 575
Answers to Practice Problems 576
Questions and Problems 577
Critical Thinking Problems 579

17 Lipids and Their Functions in Biochemical Systems 581

17.1 Biological Functions of Lipids 582
*A Medical Perspective: Lifesaving
Lipids* 583

17.2 Fatty Acids 584

Organic Solvents 639
A Medical Perspective: Immunoglobulins: Proteins
That Defend the Body 640
Detergents 641
Heavy Metals 641
Mechanical Stress 641

18.11 Dietary Protein and Protein Digestion 641
Chapter Map 643
Summary 644
Answers to Practice Problems 645
Questions and Problems 645
Critical Thinking Problems 647

19 Enzymes 649

19.1 Nomenclature and Classification 650
Classification of Enzymes 650
Nomenclature of Enzymes 652
Kitchen Chemistry: Transglutaminase:
aka Meat Glue 655

**19.2 The Effect of Enzymes on the Activation
Energy of a Reaction 656**

**19.3 The Effect of Substrate Concentration
on Enzyme-Catalyzed Reactions 657**

19.4 The Enzyme-Substrate Complex 658

19.5 Specificity of the Enzyme-Substrate Complex 659

19.6 The Transition State and Product Formation 660
A Medical Perspective: HIV Protease Inhibitors
and Pharmaceutical Drug Design 662

19.7 Cofactors and Coenzymes 663

19.8 Environmental Effects 666
Effect of pH 666
A Medical Perspective: α_1 -Antitrypsin
and Familial Emphysema 667
Effect of Temperature 667

19.9 Regulation of Enzyme Activity 668
Allosteric Enzymes 669
Feedback Inhibition 670
Proenzymes 670
Protein Modification 670

19.10 Inhibition of Enzyme Activity 671
Irreversible Inhibitors 671
Chemistry at the Crime Scene: Enzymes,
Nerve Agents, and Poisoning 672
Reversible, Competitive Inhibitors 672
Reversible, Noncompetitive Inhibitors 674

19.11 Proteolytic Enzymes 675

19.12 Uses of Enzymes in Medicine 676
Chapter Map 679
Summary 679
Answers to Practice Problems 681
Questions and Problems 681
Critical Thinking Problems 683

20 Introduction to Molecular Genetics 684

20.1 The Structure of the Nucleotide 685
Chemical Composition of DNA
and RNA 686
Nucleosides 686
Nucleotide Structure 687

20.2 The Structure of DNA and RNA 688
DNA Structure: The Double Helix 688
Chromosomes 690
RNA Structure 692
A Medical Perspective: Molecular Genetics and Detection
of Human Genetic Disorders 693

20.3 DNA Replication 693
Bacterial DNA Replication 695
Eukaryotic DNA Replication 696

20.4 Information Flow in Biological Systems 698
Classes of RNA Molecules 698
Transcription 698
Post-transcriptional Processing of RNA 700

20.5 The Genetic Code 702

20.6 Protein Synthesis 703
The Role of Transfer RNA 705
The Process of Translation 705

20.7 Mutation, Ultraviolet Light, and DNA Repair 708
The Nature of Mutations 708
The Results of Mutations 708
Mutagens and Carcinogens 709
Ultraviolet Light Damage and DNA Repair 709
A Medical Perspective: The Ames
Test for Carcinogens 710
Consequences of Defects in DNA Repair 711

20.8 Recombinant DNA 711
Tools Used in the Study of DNA 711
Genetic Engineering 714

20.9 Polymerase Chain Reaction 717

20.10 The Human Genome Project 717
Genetic Strategies for Genome Analysis 717
Chemistry at the Crime Scene: DNA Fingerprinting 718
DNA Sequencing 718
A Medical Perspective: A Genetic Approach
to Familial Emphysema 720
Chapter Map 722
Summary 723
Questions and Problems 724
Critical Thinking Problems 726

21 Carbohydrate Metabolism 727

21.1 ATP: The Cellular Energy Currency 728

21.2 Overview of Catabolic Processes 731
Stage I: Hydrolysis of Dietary Macro-
molecules into Small Subunits 732

Stage II: Conversion of Monomers into a Form That Can Be Completely Oxidized 732
Stage III: The Complete Oxidation of Nutrients and the Production of ATP 732

21.3 Glycolysis 733

An Overview 733
Biological Effects of Genetic Disorders of Glycolysis 735
Reactions of Glycolysis 736
Entry of Fructose into Glycolysis 740
A Medical Perspective: High Fructose Corn Syrup 741
Regulation of Glycolysis 741

21.4 Fermentations 742

Lactate Fermentation 742
Alcohol Fermentation 743
A Human Perspective: Fermentations: The Good, the Bad, and the Ugly 744

21.5 The Pentose Phosphate Pathway 744

21.6 Gluconeogenesis: The Synthesis of Glucose 746

21.7 Glycogen Synthesis and Degradation 748

The Structure of Glycogen 748
Glycogenolysis: Glycogen Degradation 748
Glycogenesis: Glycogen Synthesis 750
A Medical Perspective: Diagnosing Diabetes 752
Compatibility of Glycogenesis and Glycogenolysis 754
A Human Perspective: Glycogen Storage Diseases 755
Chapter Map 756
Summary 756
Questions and Problems 757
Critical Thinking Problems 760

22 Aerobic Respiration and Energy Production 761

22.1 The Mitochondria 762

Structure and Function 762
Origin of the Mitochondria 763
A Human Perspective: Exercise and Energy Metabolism 764

22.2 Conversion of Pyruvate to Acetyl CoA 764

22.3 An Overview of Aerobic Respiration 767

22.4 The Citric Acid Cycle (The Krebs Cycle) 768

Biological Effects of Disorders of the Citric Acid Cycle 768
Reactions of the Citric Acid Cycle 769

22.5 Control of the Citric Acid Cycle 772

22.6 Oxidative Phosphorylation 774

Electron Transport Systems and the Hydrogen Ion Gradient 774
ATP Synthase and the Production of ATP 775
Summary of the Energy Yield 775
A Human Perspective: Brown Fat: The Fat That Makes You Thin? 776

22.7 The Degradation of Amino Acids 778

Removal of α -Amino Groups: Transamination 779
Removal of α -Amino Groups: Oxidative Deamination 780
The Fate of Amino Acid Carbon Skeletons 782

22.8 The Urea Cycle 782

Reactions of the Urea Cycle 782
A Medical Perspective: Pyruvate Carboxylase Deficiency 785

22.9 Overview of Anabolism: The Citric Acid Cycle as a Source of Biosynthetic Intermediates 786

Chapter Map 788
Summary 789
Answers to Practice Problems 790
Questions and Problems 790
Critical Thinking Problems 792

23 Fatty Acid Metabolism 793

23.1 Lipid Metabolism in Animals 794

Digestion and Absorption of Dietary Triglycerides 794
Lipid Storage 795
A Medical Perspective: Obesity: A Genetic Disorder? 797

23.2 Fatty Acid Degradation 798

An Overview of Fatty Acid Degradation 798
The Reactions of β -Oxidation 799
A Medical Perspective: Carnitine: The Fat Mover 802

23.3 Ketone Bodies 804

Ketosis 805
Ketogenesis 805
A Human Perspective: Losing Those Unwanted Pounds of Adipose Tissue 807

23.4 Fatty Acid Synthesis 808

A Comparison of Fatty Acid Synthesis and Degradation 808

23.5 The Regulation of Lipid and Carbohydrate Metabolism 810

The Liver 810
A Medical Perspective: Diabetes Mellitus and Ketone Bodies 811
Adipose Tissue 812
Muscle Tissue 812
The Brain 813

23.6 The Effects of Insulin and Glucagon on Cellular Metabolism 813

Chapter Map 815
Summary 816
Answers to Practice Problems 816
Questions and Problems 817
Critical Thinking Problems 818

Glossary G-1
Answers to Odd-Numbered Problems AP-1
Credits C-1
Index I-1