

Contents

Applications and Interludes xv

Preface xvii

A Note to the Student xxv

1 Matter, Energy, and Life 1

- 1.1 Chemistry: The Central Science 2
- 1.2 States of Matter 4
- 1.3 Classification of Matter 5
- 1.4 Chemical Elements 7
- 1.5 Names and Symbols for Elements 8
 - Application: A Chemical Reaction* 8
 - Application: What's in a Name?* 10
- 1.6 Energy 12
 - Interlude: Chemicals, Toxicity, and Risk* 13
 - Summary 14
 - Additional Problems 15

2 Measurements in Chemistry 18

- 2.1 Physical Quantities 19
- 2.2 Measuring Mass 21
- 2.3 Measuring Length and Volume 23
 - Application: Apothecary Units* 24
- 2.4 Measurement and Significant Figures 25
- 2.5 Scientific Notation 27

- 2.6 Rounding Off Numbers 29
- 2.7 Calculations: Converting a Quantity from One Unit to Another 32
- 2.8 Problem Solving 34
- 2.9 Measuring Temperature 36
- 2.10 Heat and Energy 38
- 2.11 Density 39
 - Application: Measuring Body Fat* 40
- 2.12 Specific Gravity 42
 - Interlude: Powers of 10* 43
 - Summary 44
 - Additional Problems 44

3 Atoms and the Periodic Table 48

- 3.1 Atomic Theory 49
- 3.2 Composition of Atoms 52
- 3.3 Isotopes and Atomic Weight 53
- 3.4 Location of Electrons in Atoms 55
- 3.5 Electron Configurations 57
- 3.6 The Periodic Table 61
 - Application: Chernobyl and Cesium* 62
- 3.7 Characteristic Properties of Groups of Elements 64
- 3.8 Electron Configurations and the Periodic Table 68
 - Interlude: Are Atoms Real?* 71
 - Summary 72
 - Additional Problems 73

4 Ionic Compounds 76

- 4.1 Ions 77
- 4.2 Periodic Properties and Ion Formation 79
- 4.3 Ionic Bonds 80
- 4.4 Properties of Ionic Compounds 81
Application: Homeostasis 82
- 4.5 Ions and the Octet Rule 83
- 4.6 Electron-Dot Symbols 85
- 4.7 Ions of Some Common Elements 86
Application: Biologically Important Ions 88
- 4.8 Naming Ions 88
- 4.9 Polyatomic Ions 90
- 4.10 Formulas of Ionic Compounds 91
- 4.11 Naming Ionic Compounds 93
- 4.12 H^+ and OH^- Ions: An Introduction to Acids and Bases 95
Interlude: Minerals and Gems 97
Summary 98
Additional Problems 99

5 Molecular Compounds 102

- 5.1 Covalent Bonds 103
- 5.2 Covalent Bonds, the Octet Rule, and the Periodic Table 106
- 5.3 Multiple Covalent Bonds 109
- 5.4 Coordinate Covalent Bonds 110
- 5.5 Molecular and Structural Formulas 111
Application: Coordinate Covalent Bonds and Living Organisms 112
- 5.6 Drawing Lewis Structures 113
- 5.7 The Shapes of Molecules 117
- 5.8 Polar Covalent Bonds and Electronegativity 122
- 5.9 Polar Molecules 124
- 5.10 Naming Binary Molecular Compounds 125
Application: Carbon Monoxide: A Surprising Molecule 126

- 5.11 Properties of Molecular Compounds 127
Interlude: Polymers: How Big Can a Molecule Be? 129
Summary 130
Additional Problems 130

6 Chemical Reactions: Classification and Mass Relationships 134

- 6.1 Chemical Equations 135
- 6.2 Balancing Chemical Equations 137
- 6.3 Avogadro's Number and the Mole 139
- 6.4 Gram-Mole Conversions 141
- 6.5 Mole Relationships from Chemical Equations 143
- 6.6 Mass Relationships from Chemical Equations 145
- 6.7 Percent Yield 147
- 6.8 Classes of Chemical Reactions 148
- 6.9 Precipitation Reactions and Rules for Solubility 149
Application: Gout and Kidney Stones: Problems in Solubility 150
- 6.10 Acids, Bases, and Neutralization Reactions 152
- 6.11 Net Ionic Equations 153
- 6.12 Redox Reactions 154
- 6.13 Recognizing Redox Reactions 156
- 6.14 Organic Redox Reactions 159
Interlude: Photography: A Series of Redox Reactions 162
Summary 163
Additional Problems 164

7 Chemical Reactions: Energy, Rates, and Equilibrium 168

- 7.1 Heat Changes During Chemical Reactions 169
- 7.2 Exothermic and Endothermic Reactions 170
Application: Energy From Food 172
- 7.3 Why Do Chemical Reactions Occur? Free Energy 175

- 7.4 How Do Reactions Occur? Reaction Rates 179
- 7.5 Effect of Temperature, Concentration, and Catalysts on Reaction Rates 181
Application: Regulation of Body Temperature 184
- 7.6 Reversible Reactions and Chemical Equilibrium 184
- 7.7 Equilibrium Equations and Equilibrium Constants 186
- 7.8 LeChâtelier's Principle: The Effect of Changing Conditions on Equilibria 189
Interlude: Nitrogen Fixation 193
Summary 194
Additional Problems 195

8 Gases, Liquids, and Solids 198

- 8.1 States of Matter Revisited 199
- 8.2 Gases and the Kinetic-Molecular Theory 201
- 8.3 Pressure 201
- 8.4 Partial Pressure and Dalton's Law 203
- 8.5 Boyle's Law: The Relation Between Pressure and Volume 205
- 8.6 Charles's Law: The Relation Between Volume and Temperature 207
- 8.7 Gay-Lussac's Law: The Relation Between Pressure and Temperature 208
- 8.8 The Combined Gas Law 209
Application: Inhaled Anesthetics 210
- 8.9 Avogadro's Law: The Relation Between Volume and Amount 212
- 8.10 The Universal Gas Law 214
- 8.11 Intermolecular Forces: Dipole-Dipole and London Forces 215
- 8.12 Intermolecular Forces: Hydrogen Bonds 218
- 8.13 Liquids 219
Application: Water 220
- 8.14 Solids 223
- 8.15 Changes of State 224
Interlude: Bone and Biomaterials 225

- Summary 226
Additional Problems 227

9 Solutions 230

- 9.1 Mixtures and Solutions 231
- 9.2 The Solution Process 233
- 9.3 Solid Hydrates 235
- 9.4 Solubility 236
- 9.5 The Effect of Temperature on Solubility 237
- 9.6 The Effect of Pressure on Solubility: Henry's Law 239
Application: Breathing and Oxygen Transport 240
- 9.7 Units of Concentration 242
- 9.8 Dilution 248
- 9.9 Ions in Solution: Electrolytes 250
- 9.10 Body Electrolytes: Equivalents and Milliequivalents 251
- 9.11 Some Properties of Solutions 253
- 9.12 Osmosis and Osmotic Pressure 254
Application: Dialysis 256
- 9.13 Colloids 257
Interlude: Timed-Release Medications 259
Summary 260
Additional Problems 261

10 Acids and Bases 264

- 10.1 Acids and Bases in Aqueous Solution: A Review 265
- 10.2 Some Common Acids and Bases 266
- 10.3 The Brønsted-Lowry Definition of Acids and Bases 267
- 10.4 Water as Both an Acid and a Base 269
- 10.5 Some Common Acid-Base Reactions 270
Application: Ulcers and Antacids 272
- 10.6 Acid and Base Strength 274
- 10.7 Acid-Dissociation Constants 277
- 10.8 Dissociation of Water 278
- 10.9 Measuring Acidity in Aqueous Solution: pH 279

Application: pH of Body Fluids 282

10.10 Working With pH 282

10.11 Laboratory Determination of Acidity 283

10.12 Buffer Solutions 284

10.13 Buffers in the Body 287

10.14 Equivalents of Acids and Bases: Normality 289

10.15 Titration 290

10.16 Acidity and Basicity of Salt Solutions 292

Interlude: Acid Rain 293

Summary 294

Additional Problems 295

11 Nuclear Chemistry 298

11.1 The Discovery and Nature of Radioactivity 299

11.2 Stable and Unstable Isotopes 301

11.3 Nuclear Decay 302

Application: Medical Uses of Radioactivity 304

11.4 Radioactive Half-Life 306

11.5 Radioactive Decay Series 307

11.6 Ionizing Radiation 308

11.7 Detecting Radiation 310

11.8 Measuring Radiation 311

11.9 Artificial Transmutation 313

Application: Body Imaging 314

11.10 Nuclear Fission and Nuclear Fusion 316

Interlude: Archaeological Radiocarbon Dating 320

Summary 321

Additional Problems 322

12 Introduction to Organic Chemistry: Alkanes 324

12.1 The Nature of Organic Molecules 325

12.2 Families of Organic Molecules: Functional Groups 327

12.3 The Structure of Organic Molecules: Alkanes and Their Isomers 331

Application: Natural Versus Synthetic 334

12.4 Drawing Organic Structures 334

12.5 The Shapes of Organic Molecules 336

Application: Displaying Molecular Shapes 338

12.6 Naming Alkanes 339

12.7 Properties of Alkanes 345

12.8 Reactions of Alkanes 346

12.9 Cycloalkanes 348

12.10 Drawing and Naming Cycloalkanes 350

Interlude: Petroleum 352

Summary 353

Summary of Reactions 353

Additional Problems 354

13 Alkenes, Alkynes, and Aromatic Compounds 358

13.1 Alkenes 360

13.2 Naming Alkenes and Alkynes 360

13.3 The Structure of Alkenes: Cis-Trans Isomerism 363

Application: The Chemistry of Vision 366

13.4 Properties of Alkenes and Alkynes 366

13.5 Reactions of Alkenes and Alkynes 368

13.6 How an Alkene Addition Reaction Occurs 373

13.7 Alkene Polymers 374

13.8 Aromatic Compounds and the Structure of Benzene 376

Application: Polycyclic Aromatic Hydrocarbons and Cancer 378

13.9 Naming Aromatic Compounds 378

13.10 Reactions of Aromatic Compounds 381

Interlude: Why We See Color 383

Summary 384

Summary of Reactions 384

Additional Problems 386

14 Some Compounds with Oxygen, Sulfur, or a Halogen 390

14.1 Alcohols, Phenols, and Ethers 391

14.2 Some Common Alcohols 393

- 14.3 Naming Alcohols 394
 14.4 Properties of Alcohols 397
 14.5 Reactions of Alcohols 398
Application: Ethyl Alcohol as a Drug and a Poison 402
 14.6 Phenols 402
 14.7 Acidity of Alcohols and Phenols 404
 14.8 Ethers 405
Application: Antioxidants 406
 14.9 Some Common Ethers 407
 14.10 Thiols and Disulfides 408
 14.11 Halogen-Containing Compounds 409
Interlude: Chlorofluorocarbons and the Ozone Hole 411
 Summary 412
 Summary of Reactions 413
 Additional Problems 413

15 Amines 418

- 15.1 Amines 419
 15.2 Properties of Amines 421
Application: Chemical Information 422
 15.3 Heterocyclic Nitrogen Compounds 425
 15.4 Basicity of Amines 427
 15.5 Amine Salts 429
Application: Organic Compounds in Body Fluids and the "Solubility Switch" 430
 15.6 Amines in Biomolecules 432
 15.7 Amines in Plants: Alkaloids 433
 15.8 Amines in Drugs 435
Interlude: Prodrugs 438
 Summary 439
 Summary of Reactions 439
 Additional Problems 440

16 Aldehydes and Ketones 444

- 16.1 The Carbonyl Group 445
 16.2 Naming Aldehydes and Ketones 447
 16.3 Properties of Aldehydes and Ketones 448

- 16.4 Some Common Aldehydes and Ketones 449
Application: Opening the Door to the Age of Plastics 450
 16.5 Oxidation of Aldehydes 453
Application: Is It Poisonous or Isn't It? 454
 16.6 Reduction of Aldehydes and Ketones 456
 16.7 Addition of Alcohols: Hemiacetals and Acetals 458
 16.8 Aldol Reaction of Aldehydes and Ketones 464
Interlude: Chemical Warfare Among the Insects 466
 Summary 467
 Summary of Reactions 467
 Additional Problems 469

17 Carboxylic Acids and Their Derivatives 473

- 17.1 Properties of Carboxylic Acids and Their Derivatives 474
 17.2 Naming Carboxylic Acids and Their Derivatives 477
Application: Acids for the Skin 482
 17.3 Some Common Carboxylic Acids 484
 17.4 Acidity of Carboxylic Acids 485
Application: Acid Salts as Food Additives 486
 17.5 Reactions of Carboxylic Acids: Ester and Amide Formation 488
 17.6 Some Common Esters 492
 17.7 Hydrolysis of Esters and Amides 495
 17.8 Acid Anhydrides 497
 17.9 Phosphoric Acid Derivatives 498
 17.10 Organic Reactions 501
Application: Nitrate Esters for Treating Angina 502
Interlude: Polyamides and Polyesters 504
 Summary 505
 Summary of Reactions 506
 Additional Problems 507

18 Amino Acids and Proteins 512

- 18.1 An Introduction to Biochemistry 513
- 18.2 Protein Structure: An Overview 515
- 18.3 Amino Acids 516
- 18.4 Acid–Base Properties of Amino Acids 518
- 18.5 Handedness 520
- 18.6 Molecular Handedness and Amino Acids 521
- 18.7 Primary Protein Structure 523
Application: Protein Analysis by Electrophoresis 526
- 18.8 Shape-Determining Interactions in Proteins 529
Application: Protein Structure—Insulin Has Led the Way 530
- 18.9 Secondary Structure of Proteins 533
Application: Determining Protein Structure 534
- 18.10 Tertiary and Quaternary Structures of Proteins 536
- 18.11 Classification of Proteins 539
- 18.12 Chemical Properties of Proteins 541
Interlude: The Food Pyramid and Proteins in the Diet 542
Summary 545
Additional Problems 546

19 Enzymes, Vitamins, and Chemical Messengers 549

- 19.1 Enzymes 550
- 19.2 Enzyme Structure 552
- 19.3 Enzyme Classification 553
- 19.4 Enzyme Specificity 556
- 19.5 How Enzymes Work 557
- 19.6 Effect of Temperature and pH on Enzymes 559
- 19.7 Effect of Enzyme and Substrate Concentration on Enzyme Activity 561
Application: Enzymes in Medical Diagnosis 562
- 19.8 Enzyme Inhibition 564
- 19.9 Enzyme Regulation: Feedback and Allosteric Control 567

- 19.10 Enzyme Regulation: Zymogens and Genetic Control 568
- 19.11 Vitamins 569
- 19.12 Chemical Messengers 574
- 19.13 Hormones and the Endocrine System 575
Application: Vitamins, Minerals, and Food Labels 576
- 19.14 How Chemical Messengers Work: Epinephrine and Fight-or-Flight 580
- 19.15 Neurotransmitters 581
Interlude: A Drug Family 584
Summary 586
Additional Problems 587

20 The Generation of Biochemical Energy 590

- 20.1 Energy and Life 591
- 20.2 Free Energy and Biochemical Reactions 592
- 20.3 Cells and Their Structure 594
- 20.4 An Overview of Metabolism and Energy Production 597
- 20.5 Strategies of Metabolism: ATP and Energy Transfer 599
Application: Basal Metabolism 600
- 20.6 Strategies of Metabolism: Metabolic Pathways and Coupled Reactions 601
- 20.7 Strategies of Metabolism: Oxidized and Reduced Coenzymes 604
- 20.8 The Citric Acid Cycle 607
- 20.9 The Electron Transport Chain and ATP Production 610
- 20.10 Superoxide Ion and Other Oxygen By-Products 614
Application: Diets, Babies, and Hibernating Bears 614
Interlude: Plants and Photosynthesis 616
Summary 617
Additional Problems 617

21 Carbohydrates 620

- 21.1 Classification of Carbohydrates 621
- 21.2 Handedness of Carbohydrates 622

- 21.3 The D and L Families of Sugars:
Drawing Sugar Molecules 625
- 21.4 Structure of Glucose and Other
Monosaccharides 627
*Application: Carbohydrates in the
Diet* 630
- 21.5 Some Important Monosaccharides 633
- 21.6 Reactions of Monosaccharides 635
*Application: Glucose in Blood and
Urine* 636
- 21.7 Some Important Disaccharides 638
- 21.8 Variations on the Carbohydrate
Theme 641
*Application: Cell Surface Carbohydrates
and Blood Type* 642
- 21.9 Some Important Polysaccharides 645
Interlude: Tooth Decay 647
Summary 648
Additional Problems 649

22 Carbohydrate Metabolism 653

- 22.1 Digestion of Carbohydrates 654
- 22.2 Glucose Metabolism: An Overview 655
- 22.3 Glycolysis 657
- 22.4 Entry of Other Sugars into
Glycolysis 662
- 22.5 The Fate of Pyruvate 662
- 22.6 Energy Output in Complete Catabolism
of Glucose 665
- 22.7 Regulation of Glucose Metabolism and
Energy Production 666
- 22.8 Metabolism in Fasting and
Starvation 668
- 22.9 Metabolism in Diabetes Mellitus 668
*Application: Glycogen Storage
Diseases* 670
- 22.10 Glycogen Metabolism: Glycogenesis and
Glycogenolysis 670
Application: Glucose Tolerance Test 672
- 22.11 Gluconeogenesis: Glucose from
Noncarbohydrates 673
- 22.12 The Pentose Phosphate Pathway 675
Interlude: Biochemistry of Running 676

- Summary 678
Additional Problems 679

23 Lipids 681

- 23.1 Structure and Classification of
Lipids 682
- 23.2 Fatty Acids and their Esters 683
Application: Lipids in the Diet 686
- 23.3 Properties of Fats and Oils 687
- 23.4 Chemical Reactions of
Triacylglycerols 689
Application: Detergents 690
- 23.5 Glycerophospholipids and Cell
Membranes 692
- 23.6 Sphingolipids and Other Cell Membrane
Lipids 694
- 23.7 Cell Membranes 696
- 23.8 Transport Across Cell Membranes 699
- 23.9 Steroids 701
Application: Cardiac Glycosides 702
- 23.10 Steroid Hormones 702
- 23.11 Eicosanoids: Prostaglandins and
Leukotrienes 705
*Application: Abuse of Steroids and
Steroid Alternatives* 706
*Interlude: Chemical
Communication* 708
Summary 708
Additional Problems 709

24 Lipid Metabolism 712

- 24.1 Digestion of Triacylglycerols 713
- 24.2 Triacylglycerol Metabolism: An
Overview 716
- 24.3 Storage and Mobilization of
Triacylglycerols 718
*Application: Nutritional Value of
Medium-Chain Triglycerides* 720
- 24.4 Activation, Membrane Transport, and
Oxidation of Fatty Acids 720
- 24.5 Energy from Fatty Acid Oxidation 723

- 24.6 Ketone Bodies and Ketoacidosis 725
Application: The Liver, Clearinghouse for Metabolism 726
- 24.7 Biosynthesis of Fatty Acids 728
Interlude: Lipids and Atherosclerosis 730
Summary 732
Additional Problems 732

- 26.11 Gene Mutation and Hereditary Disease 776
Application: The Human Genome Project 778
- 26.12 Recombinant DNA 779
Interlude: Biotechnology and Agriculture 781
Summary 783
Additional Problems 784

25 Protein and Amino Acid Metabolism 734

- 25.1 Protein Digestion 735
- 25.2 Amino Acid Metabolism: An Overview 735
- 25.3 Amino Acid Catabolism: Removal of the Amino Group 737
- 25.4 The Urea Cycle 741
- 25.5 Amino Acid Catabolism: Fate of the Carbon Atoms 743
Application: Nitrogen Balance and Kwashiorkor 744
- 25.6 Biosynthesis of Nonessential Amino Acids 745
Interlude: Xenobiotics 746
Summary 748
Additional Problems 748

27 Body Fluids 786

- 27.1 Body Water and Its Solutes 787
Application: Keeping Skin Hydrated 790
- 27.2 Fluid Balance 791
- 27.3 Blood 792
- 27.4 Plasma Proteins, White Blood Cells, and Immunity 794
Application: The Blood-Brain Barrier 796
- 27.5 Blood Clotting 799
Application: Organ Cryopreservation 800
- 27.6 Red Blood Cells and Blood Gases 801
- 27.7 The Kidney and Urine Formation 806
- 27.8 Urine Composition and Function 807
Interlude: Automated Clinical Laboratory Analysis 809
Summary 811
Additional Problems 812

26 Nucleic Acids and Protein Synthesis 750

- 26.1 DNA, Chromosomes, and Genes 751
- 26.2 Composition of Nucleic Acids 752
- 26.3 The Structure of Nucleic Acid Chains 756
- 26.4 Base Pairing in DNA: The Watson-Crick Model 758
- 26.5 Nucleic Acids and Heredity 761
- 26.6 Replication of DNA 762
Application: Serendipity and the Polymerase Chain Reaction 764
- 26.7 Structure and Function of RNA 767
- 26.8 Transcription: RNA Synthesis 768
Application: Viruses and AIDS 770
- 26.9 The Genetic Code 772
- 26.10 Translation: Transfer RNA and Protein Synthesis 772

Appendixes A1

- A Scientific Notation A1
- B Conversion Factors A4
- C The Henderson-Hasselbalch Equation and Amino Acids A5

Glossary A7

Selected Answers to Problems A17

Photo/Illustration Credits A28

Index A30