CONTENTS

Preface 13
To the Student 17
About the Authors 18

1 Chemistry

27

- 1.1 Science and Technology: The Roots of Knowledge 28
- 1.2 Science: Reproducible, Testable, Tentative, Predictive, and Explanatory 30
- 1.3 Science and Technology: Risks and Benefits 33
- 1.4 Solving Society's Problems: Scientific Research 36
- 1.5 Chemistry: A Study of Matter and Its Changes 38
- 1.6 Classification of Matter 42
- 1.7 The Measurement of Matter 45
- 1.8 Density 51
- 1.9 Energy: Heat and Temperature 53
- 1.10 Critical Thinking 56

GREEN CHEMISTRY Green Chemistry: Reimagining Chemistry for a Sustainable World

Summary 59 • Review Questions 60 • Problems 61 • Additional Problems 63 • Critical Thinking Exercises 65 • Collaborative Group Projects 65

CHEMISTRY® HOME Rainbow Density Column 66

2 Atoms

67



- 2.1 Atoms: Ideas from the Ancient Greeks 68
- 2.2 Scientific Laws: Conservation of Mass and Definite Proportions 69
- 2.3 John Dalton and the Atomic Theory of Matter 73
- 2.4 The Mole and Molar Mass 75

100

- 2.5 Mendeleev and the Periodic Table 80
- 2.6 Atoms and Molecules: Real and Relevant 82

GREEN CHEMISTRY It's Elemental

Summary 85 • Review Questions 86 • Problems 86 • Additional Problems 88 • Critical Thinking Exercises 89 • Collaborative Group Projects 89

CHEMISTRY@HOME Reaction in a Bag: Demonstrating the Law of Conservation of Matter 90

3 Atomic Structure 91

- 3.1 Electricity and the Atom 92
- 3.2 Serendipity in Science: X-Rays and Radioactivity 95
- 3.3 Three Types of Radioactivity 96
- 3.4 Rutherford's Experiment: The Nuclear Model of the Atom 98
- 3.5 The Atomic Nucleus 99
- 3.6 Electron Arrangement: The Bohr Model 102
- 3.7 Electron Arrangement: The Quantum Model 107
- 3.8 Electron Configurations and the Periodic Table 110

GREEN CHEMISTRY Clean Energy from Solar Fuels

Summary 115 • Review Questions 116 • Problems 117 • Additional Problems 118 • Critical Thinking Exercises 119 • Collaborative Group Projects 119

CHEMISTRY@HOME Birthday Candle Flame Test 120

4 Chemical Bonds 121

- 4.1 The Art of Deduction: Stable Electron Configurations 122
- 4.2 Lewis (Electron-Dot) Symbols 123
- 4.3 The Reaction of Sodium and Chlorine 125
- 4.4 Using Lewis Symbols for Ionic Compounds 127
- 4.5 Formulas and Names of Binary Ionic Compounds 130
- 4.6 Covalent Bonds: Shared Electron Pairs 133
- 4.7 Unequal Sharing: Polar Covalent Bonds 135
- 4.8 Polyatomic Molecules: Water, Ammonia, and Methane 139
- 4.9 Polyatomic Ions 140
- 4.10 Rules for Writing Lewis Formulas 142
- 4.11 Molecular Shapes: The VSEPR Theory 147
- **4.12** Shapes and Properties: Polar and Nonpolar Molecules 151

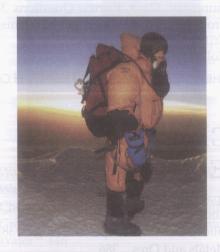
GREEN CHEMISTRY Green Chemistry and Chemical Bonds

Summary 155 • Review Questions 157 • Problems 157 • Additional Problems 159 • Critical Thinking Exercises 160 • Collaborative Group Projects 160

CHEMISTRY@HOME Molecular Shapes: Please Don't Eat the Atoms! 161

5 Chemical Accounting

162



- 5.1 Chemical Sentences: Equations 163
- 5.2 Volume Relationships in Chemical Equations 167
- 5.3 Avogadro's Number and the Mole 169
- 5.4 Molar Mass: Mole-to-Mass and Mass-to-Mole Conversions 172
- 5.5 Solutions 178

GREEN CHEMISTRY Atom Economy

Summary 184 • Review Questions 185 • Problems 185 • Additional Problems 187 • Critical Thinking Exercises 188 • Collaborative Group Projects 188

CHEMISTRY@HOME Cookie Equations 189

6 Gases, Liquids, Solids ... and Intermolecular Forces

190

- 6.1 Solids, Liquids, and Gases 191
- 6.2 Comparing Ionic and Molecular Substances 193

- 6.3 Forces between Molecules 194
- 6.4 Forces in Solutions 197
- 6.5 Gases: The Kinetic–Molecular Theory 199
- 6.6 The Simple Gas Laws 200
- 6.7 The Ideal Gas Law 206

GREEN CHEMISTRY Supercritical Fluids

Summary 209 • Review Questions 210 • Problems 210 • Additional Problems 212 •

Critical Thinking Exercises 213 • Collaborative Group Projects 213

CHEMISTRY@HOME Blow Up My Balloon 214

Acids and Bases 215

- 7.1 Acids and Bases: Experimental Definitions 216
- 7.2 Acids, Bases, and Salts 218
- 7.3 Acidic and Basic Anhydrides 222
- 7.4 Strong and Weak Acids and Bases 224
- 7.5 Neutralization 226
- 7.6 The pH Scale 227
- 7.7 Buffers and Conjugate Acid–Base Pairs 231
- 7.8 Acids and Bases in Industry and in Daily
 Life 232

GREEN CHEMISTRY Acids and Bases-Greener Alternatives

Summary 236 • Review Questions 237 • Problems 238 • Additional Problems 239 • Critical Thinking Exercises 240 •

Collaborative Group Projects 240

CHEMISTRY@HOME Acids and Bases and pH, Oh
My! 241

8 Oxidation and Reduction

242

- 8.1 Oxidation and Reduction: Four Views 243
- 8.2 Oxidizing and Reducing Agents 250
- 8.3 Electrochemistry: Cells and Batteries 251
- 8.4 Corrosion and Explosion 257
- 8.5 Oxygen: An Abundant and Essential Oxidizing Agent 260
- 8.6 Some Common Reducing Agents 263
- 8.7 Oxidation, Reduction, and Living Things 265

GREEN CHEMISTRY Green Redox Catalysis

Summary 268 • Review Questions 269 • Problems 269 • Additional Problems 271 •

Critical Thinking Exercises 273 • Collaborative Group Projects 273

CHEMISTRY@HOME Light My Fruit 274

9 Organic Chemistry 275



- 9.1 Aliphatic Hydrocarbons 277
- 9.2 Aromatic Compounds: Benzene and Its Relatives 286
 - 9.3 Halogenated Hydrocarbons: Many Uses, Some Hazards 287
 - 9.4 The Functional Group 289
 - 9.5 Alcohols, Phenols, and Ethers 291
 - 9.6 Aldehydes and Ketones 296
 - 9.7 Carboxylic Acids and Esters 298
 - 9.8 Nitrogen-Containing Compounds: Amines and Amides 301

GREEN CHEMISTRY The Art of Organic Synthesis: Green Chemists Find a Better Way

Summary 306 • Review Questions 307 • Problems 307 • Additional Problems 310 • Critical Thinking Exercises 311 • Collaborative Group Projects 311

CHEMISTRY@HOME Saturate This! 312

10 Polymers

313

- 10.1 Polymerization: Making Big Ones Out of LittleOnes 314
- 10.2 Polyethylene: From the Battle of Britain to Bread Bags 315
- 10.3 Addition Polymerization: One + One + One + ... Gives One! 319
- 10.4 Rubber and Other Elastomers 323
- 10.5 Condensation Polymers 325
- 10.6 Properties of Polymers 330
- 10.7 Plastics and the Environment 331

GREEN CHEMISTRY Life-Cycle Impact Assessment of New Products

Summary 336 • Review Questions 337 • Problems 337 • Additional Problems 338 • Critical Thinking Exercises 340 • Collaborative Group Projects 340

CHEMISTRY@HOME Polymer Bouncing Ball 341

11 Nuclear Chemistry 342

- 11.1 Natural Radioactivity 343
- 11.2 Nuclear Equations 346
- 11.3 Half-Life and Radioisotopic Dating 350
- 11.4 Artificial Transmutation 354
- 11.5 Uses of Radioisotopes 355
- 11.6 Penetrating Power of Radiation 358
- 11.7 Energy from the Nucleus 360
- 11.8 Nuclear Bombs 364
- 11.9 Uses and Consequences of Nuclear Energy 368

GREEN CHEMISTRY Can Nuclear Power Be Green?

Summary 371 • Review Questions 372 •

Problems 373 • Additional Problems 375 •

Critical Thinking Exercises 376 • Collaborative Group Projects 376

CHEMISTRY@HOME The Brief Half-Life of Candy 377

12 Chemistry of Earth

378

- 12.1 Spaceship Earth: Structure and Composition 379
- 12.2 Silicates and the Shapes of Things 381
- 12.3 Metals and Ores 386
- 12.4 Earth's Dwindling Resources 390

GREEN CHEMISTRY Critical Supply of Key Elements

Summary 394 • Review Questions 395 •

Problems 395 • Additional Problems 396 •

Critical Thinking Exercises 397 • Collaborative Group Projects 397

CHEMISTRY@HOME Fizzy Flintstones, Crumbling Calcium Carbonate 398

13 Air

399

- 13.1 Earth's Atmosphere: Divisions and Composition 400
- 13.2 Chemistry of the Atmosphere 401
- 13.3 Pollution through the Ages 404
- 13.4 Automobile Emissions 408
- 13.5 Photochemical Smog: Making Haze While the Sun Shines 411
- 13.6 Acid Rain: Air Pollution → Water Pollution 414
- 13.7 The Inside Story: Indoor Air Pollution 416
 - 13.8 Stratospheric Ozone: Earth's Vital Shield 418
 - 13.9 Carbon Dioxide and Climate Change 420
- 13.10 Who Pollutes? Who Pays? 426

GREEN CHEMISTRY It's Not Easy Being Green

Summary 430 • Review Questions 431 • Problems 431 • Additional Problems 433 • Critical Thinking Exercises 434 • Collaborative Group Projects 434

CHEMISTRY@HOME Let the Sun Shine 435

14 Water

436



- 14.1 Water: Some Unique Properties 437
- 14.2 Water in Nature 440
- 14.3 Chemical and Biological Contamination 444
- **14.4** Groundwater Contamination → Tainted Tap Water 446
- 14.5 Water: Who Uses It and How Much? 448
- 14.6 Making Water Fit to Drink 449
- 14.7 Wastewater Treatment 454

GREEN CHEMISTRY Fate of Chemicals in the Water Environment

Summary 458 • Review Questions 459 • Problems 459 • Additional Problems 460 • Critical Thinking Exercises 461 • Collaborative Group Projects 461

CHEMISTRY@HOME Disappearing Dilution 462

15 Energy

463

- 15.1 Our Sun, a Giant Nuclear Power Plant 464
- 15.2 Energy and Chemical Reactions 466
- 15.3 Reaction Rates 469
- 15.4 The Laws of Thermodynamics 470
- 15.5 Power: People, Horses, and Fossils 472
- 15.6 Coal: The Carbon Rock of Ages 474
- 15.7 Natural Gas and Petroleum 477
- 15.8 Convenient Energy 483
- 15.9 Nuclear Energy 485
- 15.10 Renewable Energy Sources 489

GREEN CHEMISTRY Where Will We Get the Energy?

Summary 498 • Review Questions 499 • Problems 499 • Additional Problems 501 •

Critical Thinking Exercises 502 • Collaborative Group Projects 502

CHEMISTRY@HOME Some Like It Hot and Some Like It Cool! 503

16 Biochemistry

504

- 16.1 Energy and the Living Cell 505
- 16.2 Carbohydrates: A Storehouse of Energy 507
- 16.3 Fats and Other Lipids 510
- 16.4 Proteins: Polymers of Amino Acids 513
- 16.5 Structure and Function of Proteins 517
- 16.6 Nucleic Acids: Parts, Structure, and Function 523
- 16.7 RNA: Protein Synthesis and the Genetic Code 528
- 16.8 The Human Genome 530

GREEN CHEMISTRY Green Chemistry and Biochemistry

Summary 535 • Review Questions 536 • Problems 536 • Additional Problems 538 • Critical Thinking Exercises 539 • Collaborative Group Projects 540

CHEMISTRY@HOME DNA Dessert 541

17 Food

542

- 17.1 Carbohydrates in the Diet 543
- 17.2 Fats and Cholesterol 546
- 17.3 Proteins: Muscle and Much More 551
- 17.4 Minerals, Vitamins, and Other Essentials 552
- 17.5 Starvation, Fasting, and Malnutrition 558
- 17.6 Flavorings: Spicy and Sweet 559
- 17.7 Other Food Additives: Beneficial or Dangerous? 562
- 17.8 Problems with Our Food 567

GREEN CHEMISTRY The Future of Food Waste – A Green Chemistry Perspective

Summary 570 • Review Questions 572 • Problems 572 • Additional Problems 573 •

Critical Thinking Exercises 575 • Collaborative Group Projects 575

CHEMISTRY@HOME How Sweet It Is to Be Fermented by You! 576

Hungry World 676

GREEN CHEMISTRY Safer Pesticides through 18 Drugs 577 Biomimicry and Green Chemistry Summary 679 • Review Questions 680 • Problems 680 • Additional Problems 681 • Critical Thinking Exercises 682 • Collaborative Group Projects 682 CHEMISTRY@HOME Wash Away the Weeds 683 21 Household Chemicals 684 Cleaning with Soap 685 21.1 Scientific Drug Design 578 18.1 Pain Relievers: From Aspirin to Oxycodone 580 21.2 Synthetic Detergents 690 18.2 Laundry Auxiliaries: Softeners and Drugs and Infectious Diseases 21.3 18.3 Bleaches 695 Chemicals against Cancer 592 18.4 All-Purpose and Special-Purpose Cleaning 21.4 Hormones: The Regulators 595 18.5 Products 696 18.6 Drugs for the Heart 602 Solvents, Paints, and Waxes 699 21.5 Drugs and the Mind 604 18.7 Cosmetics: Personal-Care Chemicals 701 21.6 Drugs and Society 618 18.8 GREEN CHEMISTRY Practicing Green Chemistry at GREEN CHEMISTRY Green Pharmaceutical Production Home Summary 621 • Review Questions 623 • Summary 714 • Review Questions 715 • Problems 623 • Additional Problems 625 • Problems 715 • Additional Problems 717 • Critical Thinking Exercises 626 • Critical Thinking Exercises 718 • Collaborative Group Projects 627 Collaborative Group Projects 718 CHEMISTRY@HOME Heal My Heartburn 628 CHEMISTRY@HOME Happy Hands 719 Fitness and Health 629 22 Poisons Calories: Quantity and Quality 630 Natural Poisons 721 22.1 Vitamins, Minerals, Fluids, and Electrolytes 632 19.2 Poisons and How They Act 722 22.2 Weight Loss: Diets and Exercise 637 19.3 22.3 More Chemistry of the Nervous System 728 19.4 Measuring Fitness 640 22.4 The Lethal Dose 730 Some Muscular Chemistry 642 19.5 The Liver as a Detox Facility 732 22.5 Drugs, Athletic Performance, and the Brain 646 19.6 22.6 Carcinogens and Teratogens 734 GREEN CHEMISTRY Your Fitness Benefits the Planet 22.7 Hazardous Wastes 738 Summary 650 • Review Questions 651 • GREEN CHEMISTRY Designing Safer Chemicals with Problems 652 • Additional Problems 653 • Green Chemistry Critical Thinking Exercises 653 • Summary 742 • Review Questions 743 • Collaborative Group Projects 654 Problems 743 • Additional Problems 744 • CHEMISTRY@HOME Pumping Iron for Breakfast 655 Critical Thinking Exercises 745 • Collaborative Group Projects 745 20 Chemistry Down on CHEMISTRY@HOME Salty Seeds 746 the Farm 656 Appendix: Review of Measurement and Mathematics 747 Farming with Chemicals: Fertilizers 658 20.1 Glossary 761 The War against Pests 663 Brief Answers to Selected Problems 769 Herbicides and Defoliants 671 Credits 789 20.4 Sustainable Agriculture 674 Index 793 Looking to the Future: Feeding a Growing,