BRIEF CONTENTS

LOSSARY

Tables of Selected L

Theoretical Vield and Percentage Vield

ABOUT THE AUTHORS VII

PREFACE XIX

- A Very Brief History of Chemistry 1
- 1 Scientific Measurements 25
- 2 Elements, Compounds, and the Periodic Table 67
- 3 The Mole and Stoichiometry 113
- 4 Molecular View of Reactions in Aqueous Solutions 161
- 5 Oxidation–Reduction Reactions 219
- 6 Energy and Chemical Change 259
- 7 The Quantum Mechanical Atom 307
- 8 The Basics of Chemical Bonding 361
- 9 Theories of Bonding and Structure 413
- 10 Properties of Gases 477
- 11 Intermolecular Attractions and the Properties of Liquids and Solids 533
- 12 Mixtures at the Molecular Level: Properties of Solutions 595
- 13 Chemical Kinetics 647
- 14 Chemical Equilibrium 713
- 15 Acids and Bases: A Molecular Look 759
- 16 Acid-Base Equilibria in Aqueous Solutions 791
- 17 Solubility and Simultaneous Equilibria 847
- 18 Thermodynamics 887
- 19 Electrochemistry 935
- 20 Nuclear Reactions and Their Role in Chemistry 991
- 21 Metal Complexes 1033
- 22 Organic Compounds, Polymers, and Biochemicals 1065

X BRIEF CONTENTS

- APPENDIX A Review of Mathematics A-1
- APPENDIX B Answers to Practice Exercises and Selected Problems A-7
- APPENDIX C Tables of Selected Data A-29
- GLOSSARY G-1
- INDEX I-1

A Molecular View of Reactions in Aqueous Solutions 9 Theories of Bonding and Structure 2 Mixtures at the Molecular Level: Properties of Solutions 13 Chemical Kinetics sar T Solubility and Simultaneous Equilibria valama lotahi re

1. Scientific Measurements 25

ABOUT THE AUTHORS vii PREFACE xix

A Very Brief History 0 of Chemistry 1

Chemistry's Important Concepts 2 0.1 Stars, Supernovas, and the Elements 3 0.2 Elements and the Earth 6 0.3

Nomenclature of Molecular Compounds 99 2.8 Summary 104 **Tools for Problem Solving** 105 **Review Questions** 105 Review Problems 107 Additional Exercises 110 Exercises in Critical Thinking 111

CONTENTS

The Mole and Stoichiometry 113

Dalton's Atomic Theory 8 0.4 Internal Structure of the Atom 9 0.5 Summary 21 Tools for Problem Solving 22 Review Questions 22 Review Problems 23 Additional Exercises 24 Exercises in Critical Thinking 24

Scientific Measurements 25

Laws and Theories: The Scientific Method 1.1 26

- Matter and Its Classifications 28 1.2
- **Physiochemical Properties** 32 1.3
- Measurement of Physiochemical Properties 34 1.4
- Laboratory Measurements 44 1.5

The Mole and Avogadro's Constant 114 3.1 The Mole, Formula Mass, and Stoichiometry 3.2 120 **Chemical Formula and Percentage** 3.3 **Composition 124 Determining Empirical and Molecular** 3.4 Formulas 126 **Stoichiometry and Chemical Equations** 134 3.5 Limiting Reactants 142 3.6 **Theoretical Yield and Percentage Yield** 146 3.7 Summary 150 **Tools for Problem Solving** 151 **Review Questions** 152 Review Problems 153 Additional Exercises 158 Exercises in Critical Thinking 159

Molecular View of Reactions in

Dimensional Analysis 49 1.6 **Density and Specific Gravity** 53 1.7 Summary 60 Tools for Problem Solving 61 Review Questions 61 Review Problems 63 Additional Exercises 65 Exercises in Critical Thinking 66

2 Elements, Compounds, and the Periodic Table 67

The Periodic Table 2.1 68

- 2.2 Metals, Nonmetals, and Metalloids 71
- 2.3 Molecules and Chemical Formulas 74
- 2.4 Chemical Reactions and Chemical Equations 81
- 2.5

- **Aqueous Solutions** 161
- **Describing Aqueous Solutions** 162 4.1 **Electrolytes and Nonelectrolytes** 4.2 164 **Balanced Equations for Ionic Reactions** 4.3 166 Concept of Acids and Bases 170 4.4 Naming Acids and Bases 178 4.5 **Double Replacement (Metathesis) Reactions** 4.6 179 **Concentration of Solution** 191 4.7 Solution Stoichiometry 197 4.8 **Titrations and Chemical Analysis** 202 4.9 Summary 209 Tools for Problem Solving 210 Review Questions 211 **Review Problems** 212 Additional Exercises 216

T.10 Periodic Table and Peoperties of the Elements Can.







CONTENTS XII

Oxidation-Reduction 5 Reactions 219

Redox Reactions 220 5.1 **Balancing Redox Equations** 227 5.2 Acids as Oxidizing Agents 233 5.3 Redox Reactions of Metals 236 5.4 Molecular Oxygen as an Oxidizing Agent 241 5.5 Stoichiometry of Redox Reactions 245 5.6 Summary 249 Tools for Problem Solving 250 Review Questions 251 **Review Problems** 252 Additional Exercises 255 Multi-Concept Problems 256 Exercises in Critical Thinking 257

Summary 355 Tools for Problem Solving 356 Review Questions 356 Review Problems 357 Additional Exercises 359 Multi-Concept Problems 359 Exercises in Critical Thinking 359

8 The Basics of Chemical Bonding 361

Energy Requirements for Bond 8.1 Formation 362

Energy and Chemical Change 6 259

- Energy: The Ability to Do Work 260 6.1
- Heat, Temperature, and Internal Energy 263 6.2
- Measuring Heat 267 6.3
- **Energy of Chemical Reactions** 272 6.4
- Heat, Work, and the First Law of 6.5 Thermodynamics 274
- Heats of Reaction 278 6.6
- **Thermochemical Equations** 284 6.7
- Hess's Law 286 6.8
- Standard Heats of Reaction 291 6.9

- Ionic Bonding 363 8.2
- **Octet Rule and Electron Configurations of** 8.3 lons 367
- Lewis Symbols and Structures of Ionic 8.4 Compounds 371
- Covalent Bonds 373 8.5
- Bond Polarity and Electronegativity 378 8.6
- Lewis Structures 383 8.7
- **Resonance Structures** 394 8.8
- **Covalent Compounds of Carbon** 398 8.9 Summary 406 Tools for Problem Solving 407 Review Questions 407 Review Problems 409 Additional Exercises 411 Multi-Concept Problems 411 Exercises in Critical Thinking 411

Summary 299 **Tools for Problem Solving** 300 **Review Questions** 301 Review Problems 303 Additional Problems 305 Multi-Concept Problems 306 Exercises in Critical Thinking 306

- The Quantum Mechanical Atom 307
- **Electromagnetic Radiation** 308 7.1
- Line Spectra and the Rydberg Equation 316 7.2
- The Bohr Theory 319 7.3
- The Wave Mechanical Model 321 7.4
- Quantum Numbers of Electrons in Atoms 327 7.5
- Electron Spin 330 7.6

- Theories of Bonding and 9
- Structure 413
- Five Basic Molecular Geometries 414 9.1
- **Molecular Shapes and the Valence Shell Electron** 9.2 Pair Repulsion (VSEPR) Model 417
- Molecular Structure and Dipole Moments 426 9.3
- Valence Bond Theory 430 9.4
- **Hybrid Orbitals and Molecular Geometry** 434 9.5
- Hybrid Orbitals and Multiple Bonds 445 9.6
- Molecular Orbital Theory Basics 451 9.7
- **Delocalized Molecular Orbitals** 458 9.8
- Bonding in Solids 459 9.9
- Bonding of the Allotropes of the Elements 461 9.10 Summary 468
- **Energy Levels and Ground State Electron** 7.7 **Configurations** 331
- **Periodic Table and Ground State Electron** 7.8

Configurations 334

Atomic Orbitals: Shapes and Orientations 340 7.9 Periodic Table and Properties of the Elements 344 7.10

Tools for Problem Solving 469 Review Questions 471 Review Problems 472 Nomenclature of Ionic Co Additional Exercises 474 Multi-Concept Problems 475 Exercises in Critical Thinking 475

10 Properties of Gases 477

10.1 A Molecular Look at Gases 478

- 10.2 Measurement of Pressure 479
- 10.3 Gas Laws 484
- **10.4 Stoichiometry Using Gas Volumes 490**
- 10.5 Ideal Gas Law 495
- 10.6 Dalton's Law of Partial Pressures 503
- 10.7 Kinetic Molecular Theory of Gases 513
- 10.8 Real Gases 518
- 10.9 Compressibility Factor 51910.10 Law of Corresponding States 522
- Summary **524** Tools for Problem Solving **525**

12.3 Solubility as a Function of Temperature 604
12.4 Henry's Law 606
12.5 Concentration Units 608
12.6 Colligative Properties 615
12.7 Heterogeneous Mixtures 633
Summary 639
Tools for Problem Solving 640
Review Questions 641
Review Problems 642
Additional Problems 644
Multi-Concept Problems 644
Exercises in Critical Thinking 645

13 Chemical Kinetics 647

Review Questions 525 Review Problems 527 Additional Problems 529 Multi-Concept Problems 530 Exercises in Critical Thinking 531

11 Intermolecular Attractions and the Properties of Liquids and Solids 533

11.1 Intermolecular Forces 534

- **11.2 Intermolecular Forces and Physical Properties 543**
- 11.3 Changes of State and Dynamic Equilibria 549
- 11.4 Vapor Pressures of Liquids and Solids 551
- 11.5 Boiling Points of Liquids 553

13.1 Factors that Affect the Rate of Chemical Change 648 Measuring Reaction Rates 650 13.2 Rate Laws 656 13.3 13.4 Integrated Rate Laws 665 13.5 Molecular Basis of Collision Theory 676 **13.6** Molecular Basis of Transition State Theory 679 Activation Energies 682 13.7 13.8 Mechanisms of Reactions 687 13.9 Catalysts 694 Summary 700 Tools for Problem Solving 701 Review Questions 702 Review Problems 705 Additional Exercises 708 Multi-Concept Problems 710 Exercises in Critical Thinking 711 14 Chemical Equilibrium 713 Dynamic Equilibrium in Chemical Systems 714 14.1 Equilibrium Laws 717 14.2 **Equilibrium Laws Based on Pressures or** 14.3 **Concentrations** 721 Equilibrium Laws for Heterogeneous Reactions 725 14.4 14.5 Position of Equilibrium and the Equilibrium Constant 726 Equilibrium and Le Châtelier's Principle 728 14.6 Calculating Equilibrium Constants 733 14.7 **Using Equilibrium Constants to Calculate** 14.8 **Concentrations** 736 Summary 750

11.6 Energy and Changes of State 555 Phase Diagrams 559 11.7 Le Châtelier's Principle and Changes of State 11.8 563 **11.9** Determining Heats of Vaporization 565 11.10 Structures of Crystalline Solids 567 **11.11** Determining the Structure of Solids 575 11.12 Crystal Types and Physical Properties 578 Summary 584 **Tools for Problem Solving** 586 Review Questions 586 Review Problems 589 Tools for Problem Solving Additional Exercises 591 Multi-Concept Problems 592 **Exercises in Critical Thinking** 593

12 Mixtures at the Molecular Level:

Properties of Solutions 595

12.1 Intermolecular Forces and the Formation of Solutions 596
12.2 Heats of Solution 600 Tools for Problem Solving Review Questions Review Problems Additional Exercises Multi-Concept Problems Exercises in Critical Thinking

CONTENTS xiv

15 Acids and Bases: A Molecular LOOK 759

- Brønsted-Lowry Acids and Bases 760 15.1
- Strengths of Brønsted-Lowry Acids and 15.2 Bases 765
- **15.3** Periodic Trends in the Strengths of
 - Acids 768
- 15.4 Lewis Acids and Bases 774
- **15.5** Acid–Base Properties of Elements and Their Oxides 778
- **Advanced Ceramics and Acid-Base** 15.6

Summary 881 Tools for Problem Solving 881 Review Questions 881 Review Problems 882 Additional Exercises 885 Multi-Concept Problems 886 Exercises in Critical Thinking 886

18 Thermodynamics 887

18.1 First Law of Thermodynamics 888 Spontaneous Change 892 18.2 Entropy 894 18.3

Chemistry 781 Summary 786 Tools for Problem Solving 786 **Review Questions** 787 Review Problems 788 Additional Exercises 789 Multi-Concept Problems 790 Exercises in Critical Thinking 790

16 Acid–Base Equilibria in Aqueous Solutions 791

Water, pH, and "p" Notation 792 16.1 pH of Strong Acid and Base Solutions 797 16.2 Ionization Constants, K_a and K_b 798 16.3

Determining K_a and K_b Values 803 16.4

16.5 pH of Weak Acid and Weak Base Solutions 806

18.4 Second Law of Thermodynamics 899 18.5 Third Law of Thermodynamics 903 Standard Free Energy Change, ΔG° 906 18.6 Maximum Work and ΔG 909 18.7 Free Energy and Equilibrium 912 18.8 **18.9** Equilibrium Constants and ΔG° 918 18.10 Bond Energies 921 Summary 927 Tools for Problem Solving 928 **Review Questions** 929 Review Problems 930 Additional Exercises 933 Multi-Concept Problems 934 Exercises in Critical Thinking 934

19 Electrochemistry

16.6 Acid-Base Properties of Salt Solutions 811 **Buffer Solutions** 815 16.7 16.8 Polyprotic Acids 822 16.9 Acid-Base Titrations 828 Summary 837 Tools for Problem Solving 838 Review Questions 839 Review Problems 841 Additional Exercises 843 Multi-Concept Problems 844 Exercises in Critical Thinking 844

Constant **17** Solubility and Simultaneous Equilibria 847

17.1 Equilibria in Solutions of Slightly Soluble Salts 848

19.1 Galvanic (Voltaic) Cells 936 19.2 Cell Potentials 941 **19.3** Utilizing Standard Reduction Potentials 948 **19.4** E_{cell}° and ΔG° **953 19.5** Cell Potentials and Concentrations **956 19.6** Electricity **962** Electrolytic Cells 968 19.7 **19.8** Electrolysis Stoichiometry **974 19.9** Practical Applications of Electrolysis **978** Summary 983 Tools for Problem Solving 984 **Review Questions** 984 Review Problems 986 Additional Exercises 988 Multi-Concept Problems 989

935

Solubility of Basic Salts 859 17.2 Equilibria in Solutions of Metal Oxides and 17.3 Sulfides 862 Selective Precipitation 865 17.4 Equilibria Involving Complex Ions 872 17.5 **Complexation and Solubility 876** 17.6

Exercises in Critical Thinking 989

20 Nuclear Reactions and Their Role in Chemistry 991

Law of Conservation of Mass-Energy 992 20.1 Nuclear Binding Energy 994 20.2

CONTENTS XV

Radioactivity 996 20.3 Band of Stability 1003 20.4 **Transmutation 1006** 20.5 **Measuring Radioactivity** 1009 20.6 **Medical and Analytical Applications** 20.7 of Radionuclides 1013 Nuclear Fission and Fusion 1018 20.8 Summary 1026 Tools for Problem Solving 1027 Review Questions 1028 Review Problems 1029 Additional Exercises 1031 Multi-Concept Problems 1032 Exercises in Critical Thinking 1032

22 Organic Compounds, Polymers, and Biochemicals 1065

- 22.1 Organic Structures and Functional Groups 1066 22.2 Hydrocarbons: Structure, Nomenclature, and Reactions 1071 22.3 Organic Compounds Containing Oxygen 1079 22.4 Organic Derivatives of Ammonia 1086 22.5 Organic Polymers 1088 22.6 Carbohydrates, Lipids, and Proteins 1095 22.7 Nucleic Acids, DNA, and RNA 1104 Summary **1109** Tools for Problem Solving 1110

21 Metal Complexes 1033

Complex lons 1034 21.1 Metal Complex Nomenclature 1040 21.2 **Coordination Number and Structure** 1042 21.3 Isomers of Metal Complexes 1045 21.4 Bonding in Metal Complexes 1049 21.5 **Biological Functions of Metal Ions** 1056 21.6 Summary 1059 Tools for Problem Solving 1060 Review Questions 1060 Review Problems 1062 Additional Exercises 1064 Multi-Concept Problems 1064 Exercises in Critical Thinking 1064 and deriver and derrent Affelds | Runaway Reactions:

Review Questions 1111 Review Problems 1114 Additional Exercises 1117 Multi-Concept Problems 1118 Exercises in Critical Thinking 1118

APPENDICES

Review of Mathematics APPENDIX A A-1 Answers to Practice APPENDIX B **Exercises and Selected** Problems A-7 Tables of Selected Data APPENDIX C A-29

G-1 GLOSSARY

INDEX 1-1

