CONTENTS

Preface xii			
Acknowledgmer	ts xvi		
Chapter 1	The Science of Chemistry 1		
	1.1 Chemistry—A Scientific Discipline 1		
	1.2 Scientific Research and Technology 2		
	1.3 The Scope of Chemistry and Chemical Technology 4		
	1.4 How Chemists Discover Things—The Scientific Method 4		
	Experiments, Observations, and Data 5		
	Scientific Facts 6		
	Scientific Laws 6		
	Scientific Hypotheses 7		
	Scientific Theories 8		
	1.5 The Limitations of the Scientific Method 9		
	1.6 The Limitations of Science 11		
	Summary 11 • Key Terms 12 • Practice Problems 12 Multiple-Choice Practice Test 14		
Chapter 2	Numbers from Measurements 16		
	2.1 The Importance of Measurement 16		
	2.2 Exact and Inexact Numbers 17		
	2.3 Accuracy, Precision, and Error 17		
	2.4 Uncertainty in Measurements 19		
	2.5 Significant Figures 21		
	2.6 Significant Figures and Mathematical Operations 26		
	Rounding Off Numbers 26		
	Operational Rules for Mathematical Operations 28		
	Significant Figures and Exact Numbers 33		
	Multiplication by a Small Whole Number 33		
	2.7 Scientific Notation 35		
	Exponents 36		
	Converting from Decimal to Scientific Notation 37		
	Significant Figures and Scientific Notation 39		
	Converting from Scientific to Decimal Notation 39		
	Uncertainty and Scientific Notation 41		
	2.8 Mathematical Operations in Scientific Notation 41		
	Multiplication in Scientific Notation 42		
	Division in Scientific Notation 44		
	Addition and Subtraction in Scientific Notation 45		
	Summary 47 • Key Terms 48 • Practice Problems 48		
	Multiple-Choice Practice Test 56		
Chapter 3	Unit Systems and Dimensional Analysis 58		
	3.1 The Metric System of Units 58		
	SI Units 59		
	Metric System Prefixes 60		
	3.2 Metric Units of Length 61		
	3.3 Metric Units of Mass 61		
	3.4 Metric Units of Volume 62		
	3.5 Units in Mathematical Operations 65		
	3.6 Conversion Factors 65		
	English-to-English Conversion Factors 66		
	Metric-to-Metric Conversion Factors 67		
	Metric-to-English and English-to-Metric Conversion Factors 67		
	3.7 Dimensional Analysis 69		
	Metric-to-Metric Conversion Factor Use 69		

English-to-English Conversion Factor Use 73 English-to-Metric and Metric-to-English Conversion Factor Use 74 Units Involving More Than One Type of Measurement 78 3.8 Density 80 Using Density as a Conversion Factor 82 3.9 Equivalence Conversion Factors Other Than Density 84 Concentration and Dosage Relationship Conversion Factors 84 Rate Relationship Conversion Factors 85 Cost Relationship Conversion Factors 86 3.10 Percentage and Percent Error 87 Using Percentage as a Conversion Factor 87 Percent Error 90 3.11 Temperature Scales 92 Temperature Readings and Significant Figures 96 Summary 96 • Key Terms 97 • Practice Problems 97 Multiple-Choice Practice Test 105 Basic Concepts About Matter Chapter 4 107 4.1 Chemistry—The Study of Matter 107 4.2 Physical States of Matter 108 4.3 Properties of Matter 109 Physical and Chemical Properties 109 Intensive and Extensive Properties 111 4.4 Changes in Matter 111 Use of the Terms Physical and Chemical 113 4.5 Pure Substances and Mixtures 114 4.6 Heterogeneous and Homogeneous Mixtures 115 Use of the Terms Homogeneous and Heterogeneous 116 4.7 Elements and Compounds 118 4.8 Discovery and Abundance of the Elements 121 THE HUMAN SIDE OF CHEMISTRY 1: Joseph Priestley (1733–1804) 122 4.9 Names and Chemical Symbols of the Elements 123 THE HUMAN SIDE OF CHEMISTRY 2: Jöns Jakob Berzelius (1779–1848) 123 4.10 The Atom 125 THE HUMAN SIDE OF CHEMISTRY 3: John Dalton (1766–1844) 126 4.11 The Molecule 128 4.12 Natural and Synthetic Compounds 132 4.13 Chemical Formulas 132 Summary 135 • Key Terms 136 • Practice Problems 136 Multiple-Choice Practice Test 144 Subatomic Particles, Isotopes, and Nuclear Chemistry 146 Chapter 5 5.1 Subatomic Particles: Protons, Neutrons, and Electrons 146 Arrangement of Subatomic Particles within an Atom 147 Charge Neutrality of an Atom 148 Size Relationships within an Atom 148 Additional Subatomic Particles 149 5.2 Atomic Number and Mass Number 149 Atomic Number 149 Mass Number 150 Subatomic Particle Makeup of an Atom 150 5.3 lsotopes 152 5.4 Atomic Masses 156 Relative Mass 157 Average Atom 158 Weighted Averages 159 Mass Spectrometry Experiments 162

5.5 Evidence Supporting the Existence and Arrangement of Subatomic Particles
163
Discharge Tube Experiments
163
Metal Foil Experiments
165

	5.6 Nuclear Stability and Radioactivity 166
	THE HUMAN SIDE OF CHEMISTRY 4: Ernest Rutherford (1871–1937) 167
	5.7 Half-Life: A Measure of Nuclear stability 169
	5.8 The Nature of Natural Radioactive Emissions 172
	5.9 Equations for Radioactive Decay 173
	Alpha-Particle Decay 173
	Beta-Particle Decay 174
	Gamma-Ray Emission 174
	5.10 Transmutation and Bombardment Reactions 175
	Synthetic Elements 176
	5.11 Positron Emission and Electron Capture 176
	5.12 Neutron-to-Proton Ratio and Type of Radioactive Decay 180
	5.13 Radioactive Decay Series 181
	Summary 182 • Key Terms 183 • Practice Problems 184 Multiple-Choice Practice Test 194
Chapter 6	Electronic Structure and Chemical Periodicity 197
chapter o	6.1 The Periodic Law 197
	6.2 The Periodic Table 198
	Periods and Groups of Elements 198
	THE HUMAN SIDE OF CHEMISTRY 5: Dmitri Ivanovich Mendeleev (1834–1907) 199
	The Shape of the Periodic Table 202
	6.3 The Energy of an Electron 203
	THE HUMAN SIDE OF CHEMISTRY 6: Envin Schrödinger (1887–1961) 205
	6.4 Electron Shells 205
	6.5 Electron Subshells 206
	6.6 Electron Orbitals 208
	Electron Spin 210
	6.7 Electron Configurations 210
	Aufbau Principle 210
	Aufbau Diagram 210
	Writing Electron Configurations 211
	Condensed Electron Configurations 214
	6.8 Orbital Diagrams 216
	6.9 Electron Configurations and the Periodic Law 218
	6.10 Electron Configurations and the Periodic Table 219
	6 11 Classification Systems for the Elements 224
	6.12 Chemical Periodicity 226
	Metallic and Nonmetallic Character 227
	Atomic Size 228
	Summary 230 Key Terms 231 Practice Problems 231
	Multiple-Choice Practice Test 239
Chapter 7	Chemical Bonds 241
	7.1 Types of Chemical Bonds 241
	7.2 Valence Electrons and Lewis Symbols 242
	THE HUMAN SIDE OF CHEMISTRY 7: Gilbert Newton Lewis (1875–1946) 245
	7 3 The Octet Rule 246
	7.4 The Jonic Bond Model 246
	7.5 The Sign and Magnitude of Jonic Charge 249
	Isoelectronic Species 251
	7.6 Lewis Structures for Jonic Compounds 252
	7.7 Chemical Formulas for Jonic Compounds 254
	7.8 Structure of Ionic Compounds 256
	7.9 Polyatomic lons 257
	7.10 The Covalent Bond Model 259
	7.11 Lewis Structures for Molecular Compounds 260
	7.12 Single Double and Triple Covalent Bonds 262
	7.13 Valence Electron Count and Number of Covalent Bonds Formed 264
	7.14 Coordinate Covalent Bonds 265

0	
	7.15 Resonance Structures 266
	7 16 Systematic Procedures for Drawing Lewis Structures 268
	7 17 Molecular Geometry 272
	Floctron Pairs vorsus Electron Groups 274
	Molecules with Two VSEPP Electron Groups 274
	Molecules with Two VSEPR Electron Groups 275
	Molecules with Three VSEPR Electron Groups 2/5
	Molecules with Four VSEPR Electron Groups 276
	7.18 Electronegativity 279
	THE HUMAN SIDE OF CHEMISTRY 8: Linus Carl Pauling (1901–1994) 280
	7.19 Bond Polarity 282
	7.20 Molecular Polarity 285
	Summary 288 • Key Terms 289 • Practice Problems 290
	Multiple-Choice Practice Test 301
Chapter 8	Chemical Nomenclature 303
	8.1 Classification of Compounds for Nomenclature Purposes 303
	8.2 Types of Binary Ionic Compounds 304
	8.3 Nomenclature for Binary Ionic Compounds 306
	Fixed-Charge Binary Ionic Compounds 306
	Variable-Charge Binary Ionic Compounds 308
	8.4 Nomenclature for Ionic Compounds Containing Polyatomic Ions 313
	8.5 Nomenclature for Binary Molecular Compounds 318
	8.6 Nomenclature for Acids 321
	8.7 Nomenclature Rules—A Summary 326
	Summary 329 • Key Terms 329 • Practice Problems 329
	Multiple-Choice Practice Test 336
Chapter 9	Chemical Calculations: The Mole Concept and Chemical Formulas 338
	9.1 The Law of Definite Proportions 338
	THE HUMAN SIDE OF CHEMISTRY 9: Joseph-Louis Proust (1754–1826) 339
	9.2 Calculation of Formula Masses 342
	9.3 Significant Figures and Atomic Mass 344
	9.4 Percent Composition of a Compound 346
	9.5 The Mole: The Chemist's Counting Unit 348
	THE HUMAN SIDE OF CHEMISTRY 10: Lorenzo Romano Amedeo Carlo Avogadro
	(1776–1856) 349
	9.6 The Mass of a Mole 352
	Summary of Mass Terminology 356
	9.7 Significant Figures and Avogadro's Number 357
	9.8 Relationship between Atomic Mass Units and Gram Units 358
	9 9 The Mole and Chemical Formulas 359
	9 10 The Mole and Chemical Calculations 362
	9 11 Purity of Samples 368
	9.12 Empirical and Molecular Formulas 370
	9.13 Determination of Empirical Formulas 371
	Empirical Formulas from Direct Analysis Data 272
	Empirical Formulas from Indirect Analysis Data 572
	9 14 Determination of Molocular Formulas, 279
	5.14 Determination of Molecular Formulas 576
	Multiple-Choice Practice Test 394
Chapter 10	Chemical Calculations Involving Chemical Equations 396
	10.1 The Law of Conservation of Mass 396
	THE HUMAN SIDE OF CHEMISTRY 11: Antoine-Laurent Lavoisier (1743–1794) 397
	10.2 Writing Chemical Equations 398
	10.3 Chemical Equation Coefficients 399
	10.4 Balancing Procedures for Chemical Equations 401
	10.5 Special Symbols Used in Chemical Equations 406

- 10.6 Classes of Chemical Reactions 407
 - Synthesis Reactions 408
 - Decomposition Reactions 408

Single-Replacement Reactions 409 Double-Replacement Reactions 409 Combustion Reactions 410

10.7 Chemical Equations and the Mole Concept 412

10.8 Balanced Chemical Equations and the Law of Conservation of Mass 415

10.9 Calculations Based on Chemical Equations—Stoichiometry 416

10.10 The Limiting Reactant Concept 421

10.11 Yields: Theoretical, Actual, and Percent 426

10.12 Simultaneous and Sequential Chemical Reactions 429

Combining Sequential Chemical Reaction Equations into a Single Overall Chemical Reaction Equation 431

Summary 432 • Key Terms 433 • Practice Problems 433 Multiple-Choice Practice Test 445

Chapter 11 States of Matter 448

11.1 Factors That Determine Physical State 448

- 11.2 Property Differences among Physical States 450
- 11.3 The Kinetic Molecular Theory of Matter 451
- 11.4 The Solid State 452
- 11.5 The Liquid State 452
- 11.6 The Gaseous State 453
- 11.7 A Comparison of Solids, Liquids, and Gases 454
- 11.8 Endothermic and Exothermic Changes of State 454
- 11.9 Heat Energy and Specific Heat 455 Heat Energy Units 455 Specific Heat 457
- 11.10 Temperature Changes as a Substance Is Heated 461
- 11.11 Energy and Changes of State 462
- 11.12 Heat Energy Calculations 465
- 11.13 Evaporation of Liquids 468 Rate of Evaporation and Temperature 469
- Evaporation and Equilibrium 471
- 11.14 Vapor Pressure of Liquids 471
- 11.15 Boiling and Boiling Points 472 Factors That Affect Boiling Point 473
- 11.16 Intermolecular Forces in Liquids 474 Dipole–Dipole Interactions 475 Hydrogen Bonds 476 London Forces 478 Ion–Dipole Interactions 479 Ion–Ion Interactions 479

11.17 Hydrogen Bonding and the Properties of Water 480 Vapor Pressure 480 Thermal Properties 481 Density 482 Surface Tension 484

Summary 485 • Key Terms 486 • Practice Problems 486 Multiple-Choice Practice Test 493

Chapter 12 Gas Laws 495

- 12.1 Properties of Some Common Gases 495
- 12.2 Gas Law Variables 496

Pressure Readings and Significant Figures 500

- 12.3 Boyle's Law: A Pressure–Volume Relationship 501
 - THE HUMAN SIDE OF CHEMISTRY 12: Robert Boyle (1627–1691) 501
- 12.4 Charles's Law: A Temperature–Volume Relationship 505 THE HUMAN SIDE OF CHEMISTRY 13: Jacques Alexandre César Charles (1746–1823) 506
- 12.5 Gay-Lussac's Law: A Temperature–Pressure Relationship 509
 - THE HUMAN SIDE OF CHEMISTRY 14: Joseph Louis Gay-Lussac (1778–1850) 509

|--|--|

12.7 Avogadro's Law 514

12.8 An Ideal Gas 517

12.9 The Ideal Gas Law 518

12.10 Modified Forms of the Ideal Gas Law Equation 521

The Molar Mass of a Gas 522

The Density of a Gas 523

- Using Density to Calculate Molar Mass 524
- 12.11 Volumes of Gases in Chemical Reactions 525
- 12.12 Volumes of Gases and the Limiting Reactant Concept 528
- 12.13 Molar Volume of a Gas 529

Standard Temperature and Standard Pressure Conditions532Using Molar Volume to Calculate Density532

- 12.14 Chemical Calculations Using Molar Volume 534
- 12.15 Mixtures of Gases 540
- 12.16 Dalton's Law of Partial Pressures 542

Summary 550 • Key Terms 551 • Practice Problems 552 Multiple-Choice Practice Test 564

Chapter 13 Solu

Solutions 566

13.1 Characteristics of Solutions 566

13.2 Solubility 567

Effect of Temperature on Solubility 567

Effect of Pressure on Solubility 568

- Terminology for Relative Amount of Solute in a Solution 569 Aqueous and Nonaqueous Solutions 570
- 13.3 Solution Formation 570
 - Factors Affecting the Rate of Solution Formation 571

13.4 Solubility Rules 571

- 13.5 Solution Concentrations 573
- 13.6 Concentration: Percentage of Solute 574 Using Percent Concentrations as Conversion Factors 576
- 13.7 Concentration: Parts per Million and Parts per Billion 579
- 13.8 Concentration: Molarity 581

Using Molarity as a Conversion Factor 583

- 13.9 Concentration: Molality 587
- 13.10 Dilution 593
- 13.11 Molarity and Chemical Equations 596
- 13.12 Calculations Involving Volume: A Summary 601

Summary 601 • Key Terms 602 • Practice Problems 602 Multiple-Choice Practice Test 611

Chapter 14

Acids, Bases, and Salts 614

14.1 Arrhenius Acid–Base Theory 614

- THE HUMAN SIDE OF CHEMISTRY 15: Svante August Arrhenius (1859–1927) 616
- 14.2 Brønsted–Lowry Acid–Base Theory 616
- 14.3 Conjugate Acids and Bases 618
- Amphiprotic Substances 620
- 14.4 Mono-, Di-, and Triprotic Acids 620
- 14.5 Strengths of Acids and Bases 622
- 14.6 Salts 625
- 14.7 Reactions of Acids 626 Reaction with Metals 626 Reaction with Bases 627 Reaction with Carbonates and Bicarbonates
 - Reaction with Carbonates and Bicarbonates 628
- 14.8 Reactions of Bases 628
- 14.9 Reactions of Salts 628 Reaction with Metals 629
- Reaction with Acids 629
 - Reaction with Bases 630
 - Reaction of Salts with Each Other 630

	14.10 Self-Ionization of Water 632
	Ion Product Constant for Water 633
	Effect of Solutes on Water Self-Ionization 633
	Effect to Temperature on Water Self-Ionization 634
	Acidic, Basic, and Neutral Solutions 635
	14.11 The pH Scale 635
	Integral pH Values 636
	Nonintegral pH Values 637
	14.12 Hydrolysis of Salts 641
	Types of Salt Hydrolysis 642
	Chemical Equations for Salt Hydrolysis Reactions 643
	14.13 Buffers 645
	Chemical Equations for Buffer Action 646
	14 14 Acid–Base Titrations 648
	Summary 650 Key Terms 651 Practice Problems 651
	Multiple-Choice Practice Test 659
Chapter 15	Chemical Equations: Net Ionic and Oxidation-Reduction 661
chapter 15	15.1 Types of Chamical Equations 661
	15.2 Electrolytes 662
	15.2 Electrolytes 662
	15.3 Ionic and Net Ionic Equations 663
	15.4 Oxidation–Reduction Terminology 667
	15.5 Oxidation Numbers 669
	15.6 Redox and Nonredox Chemical Reactions 674
	15.7 Balancing Oxidation–Reduction Equations 677
	15.8 Oxidation Number Method for Balancing Redox Equations 677
	15.9 Half-Reaction Method for Balancing Redox Equations 683
	15.10 Disproportionation Reactions 690
	15.11 Stoichiometric Calculations Involving Ions 693
	Summary 697 • Key Terms 698 • Practice Problems 698
A STATE OF A STATE OF A	Multiple-Choice Practice Test 705
Chapter 16	Reaction Rates and Chemical Equilibrium 708
	16.1 Collision Theory 708
	Molecular Collisions 709
	Activation Energy 709
	Collision Orientation 709
	16.2 Endothermic and Exothermic Chemical Reactions 710
	16.3 Factors That Influence Chemical Reaction Rates 711
	Physical Nature of Reactants 711
	Reactant Concentration 712
	Reaction Temperature 713
	Presence of Catalysts 713
	16.4 Chemical Equilibrium 714
	16.5 Equilibrium Mixture Stoichiometry 716
	16.6 Equilibrium Constants 718
	16.7 Equilibrium Position 721
	16.8 Temperature Dependency of Equilibrium Constants 722
	16.9 Le Châtelier's Principle 723
	THE HUMAN SIDE OF CHEMISTRY 16: Henri-Louis Le Châtelier (1850–1936) 723
	Concentration Changes 724
	Temperature Changes 725
	Pressure Changes 725
	Addition of a Cataluct 726
	16 10 Forcing Chamical Poactions to Completion 727
	Summer 729 a Key Terms 720 a Death and Terms 720
	Multiple Choice Practice Test 726
ilossany 720	woruple-choice Fractice test 730
DSWOR to Odd	and the second of the second
Uld-l	Numbered Problems and All Self-Test Problems 7/5

Index 763