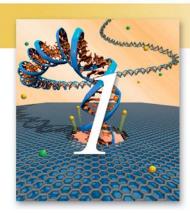
Contents in Brief

To the AP Student and Teacher xxv
AP Correlation xxvi
1 Chemistry: The Study of Change 1
2 Atoms, Molecules, and Ions 38
3 Mass Relationships in Chemical Reactions 75
4 Reactions in Aqueous Solutions 118
5 Gases 172
6 Thermochemistry 230
7 Quantum Theory and the Electronic Structure of Atoms 276
8 Periodic Relationships Among the Elements 328
9 Chemical Bonding I: Basic Concepts 370
10 Chemical Bonding II: Molecular Geometry and Hybridization of Atomic Orbitals 414
11 Intermolecular Forces and Liquids and Solids 467
Physical Properties of Solutions 520
13 Chemical Kinetics 564
14 Chemical Equilibrium 623
15 Acids and Bases 668
16 Acid-Base Equilibria and Solubility Equilibria 722
17 Entropy, Free Energy, and Equilibrium 778
18 Electrochemistry 814
19 Nuclear Chemistry 864
20 Chemistry in the Atmosphere 902
Metallurgy and the Chemistry of Metals 932
Nonmetallic Elements and Their Compounds 958
23 Transition Metals Chemistry and Coordination Compounds 996
24 Organic Chemistry 1027
25 Synthetic and Natural Organic Polymers 1060
Appendix 1 Derivation of the Names of Elements A-1
Appendix 2 Units for the Gas Constant A-7
Appendix 3 Thermodynamic Data at 1 atm and 25°C A-8
-FF 5 Thermodynamic 2 and at 1 and all 20 C 11 O

Appendix 4 Mathematical Operations A-13

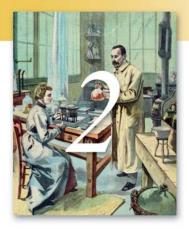
List of Applications xv List of Animations xvi Preface xvii To the AP Student and Teacher xxv AP Correlations xxvi



Chemistry: The Study of Change 1

- **1.1** Chemistry: A Science for the Twenty-First Century 2
- **1.2** The Study of Chemistry 2
- **1.3** The Scientific Method 4
- **1.4** Classifications of Matter 6
- **1.5** The Three States of Matter 9
- **1.6** Physical and Chemical Properties of Matter 10
- **1.7** Measurement 12
- **1.8** Handling Numbers 18
- **1.9** Dimensional Analysis in Solving Problems 23
- **1.10** Real-World Problem Solving: Information, Assumptions, and Simplifications 27

Key Equations 28 Summary of Facts & Concepts 29 Key Words 29 Questions & Problems 29



Atoms, Molecules, and Ions 38

- **2.1** The Atomic Theory 39
- **2.2** The Structure of the Atom 40
- **2.3** Atomic Number, Mass Number, and Isotopes 46
- **2.4** The Periodic Table 48
- **2.5** Molecules and Ions 50
- **2.6** Chemical Formulas 52
- **2.7** Naming Compounds 56
- **2.8** Introduction to Organic Compounds 65

Key Equation 67 Summary of Facts & Concepts 67 Key Words 67 Questions & Problems 68



Mass Relationships in Chemical Reactions 75

- **3.1** Atomic Mass 76
- 3.2 Avogadro's Number and the Molar Mass of an Element 77
- 3.3 Molecular Mass 81
- **3.4** The Mass Spectrometer 84
- **3.5** Percent Composition of Compounds 85
- **3.6** Experimental Determination of Empirical Formulas 88
- **3.7** Chemical Reactions and Chemical Equations 90
- **3.8** Amounts of Reactants and Products 95
- **3.9** Limiting Reagents 99
- **3.10** Reaction Yield 103

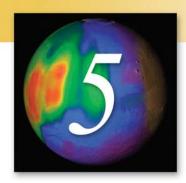
Key Equations 106 Summary of Facts & Concepts 106 Key Words 107 Questions & Problems 107



Reactions in Aqueous Solutions 118

- **4.1** General Properties of Aqueous Solutions 119
- **4.2** Precipitation Reactions 121
- **4.3** Acid-Base Reactions 126
- **4.4** Oxidation-Reduction Reactions 132
- **4.5** Concentration of Solutions 145
- **4.6** Gravimetric Analysis 149
- **4.7** Acid-Base Titrations 151
- **4.8** Redox Titrations 155

Key Equations 157 Summary of Facts & Concepts 157 Key Words 158 Questions & Problems 158

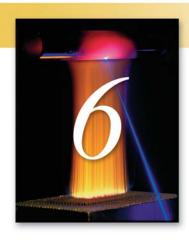


Gases 172

- **5.1** Substances That Exist as Gases 173
- **5.2** Pressure of a Gas 174
- **5.3** The Gas Laws 178
- **5.4** The Ideal Gas Equation 184
- **5.5** Gas Stoichiometry 193
- **5.6** Dalton's Law of Partial Pressures 195
- **5.7** The Kinetic Molecular Theory of Gases 202
- **5.8** Deviation from Ideal Behavior 210

Key Equations 213 Summary of Facts & Concepts 214 Key Words 214 Questions & Problems 215

Contents vii



Thermochemistry 230

- **6.1** The Nature of Energy and Types of Energy 231
- **6.2** Energy Changes in Chemical Reactions 232
- **6.3** Introduction to Thermodynamics 234
- **6.4** Enthalpy of Chemical Reactions 240
- **6.5** Calorimetry 246
- **6.6** Standard Enthalpy of Formation and Reaction 254
- **6.7** Heat of Solution and Dilution 260

Key Equations 263 Summary of Facts & Concepts 263 Key Words 263 Questions & Problems 264



Quantum Theory and the Electronic Structure of Atoms 276

- **7.1** From Classical Physics to Quantum Theory 277
- **7.2** The Photoelectric Effect 281
- **7.3** Bohr's Theory of the Hydrogen Atom 284
- **7.4** The Dual Nature of the Electron 289
- **7.5** Quantum Mechanics 293
- **7.6** Quantum Numbers 297
- **7.7** Atomic Orbitals 299
- **7.8** Electron Configuration 303
- **7.9** The Building-Up Principle 310

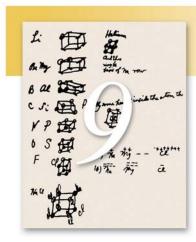
Key Equations 315 Summary of Facts & Concepts 316 Key Words 317 Questions & Problems 317



Periodic Relationships Among the Elements 328

- **8.1** Development of the Periodic Table 329
- **8.2** Periodic Classification of the Elements 331
- **8.3** Periodic Variation in Physical Properties 335
- **8.4** Ionization Energy 342
- **8.5** Electron Affinity 347
- **8.6** Variation in Chemical Properties of the Representative Elements 349

Key Equation 361 Summary of Facts & Concepts 361 Key Words 362 Questions & Problems 362

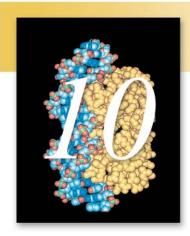


Chemical Bonding I: Basic Concepts 370

- **9.1** Lewis Dot Symbols 371
- **9.2** The Ionic Bond 372
- **9.3** Lattice Energy of Ionic Compounds 374
- **9.4** The Covalent Bond 379
- **9.5** Electronegativity 382
- **9.6** Writing Lewis Structures 386
- **9.7** Formal Charge and Lewis Structure 389
- **9.8** The Concept of Resonance 392
- **9.9** Exceptions to the Octet Rule 394
- **9.10** Bond Enthalpy 400

Key Equation 405 Summary of Facts & Concepts 405 Key Words 405 Questions & Problems 405

Contents ix



Chemical Bonding II: Molecular Geometry and Hybridization of Atomic Orbitals 414

- **10.1** Molecular Geometry 415
- **10.2** Dipole Moments 425
- **10.3** Valence Bond Theory 431
- **10.4** Hybridization of Atomic Orbitals 433
- **10.5** Hybridization in Molecules Containing Double and Triple Bonds 442
- **10.6** Molecular Orbital Theory 445
- **10.7** Molecular Orbital Configurations 448
- 10.8 Delocalized Molecular Orbitals 454

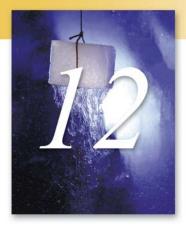
Key Equations 458 Summary of Facts & Concepts 458 Key Words 458 Questions & Problems 459



Intermolecular Forces and Liquids and Solids 467

- 11.1 The Kinetic Molecular Theory of Liquids and Solids 468
- **11.2** Intermolecular Forces 469
- **11.3** Properties of Liquids 475
- **11.4** Crystal Structure 478
- 11.5 X-Ray Diffraction by Crystals 486
- **11.6** Types of Crystals 488
- **11.7** Amorphous Solids 494
- **11.8** Phase Changes 495
- **11.9** Phase Diagrams 505

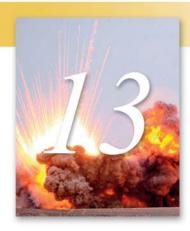
Key Equations 510
Summary of Facts & Concepts 510
Key Words 511
Questions & Problems 511



Physical Properties of Solutions 520

- **12.1** Types of Solutions 521
- **12.2** A Molecular View of the Solution Process 522
- **12.3** Concentration Units 524
- **12.4** The Effect of Temperature on Solubility 529
- **12.5** The Effect of Pressure on the Solubility of Gases 531
- **12.6** Colligative Properties of Nonelectrolyte Solutions 534
- **12.7** Colligative Properties of Electrolyte Solutions 546
- **12.8** Colloids 548

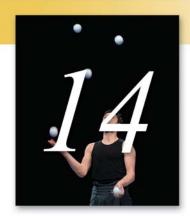
Key Equations 551 Summary of Facts & Concepts 551 Key Words 552 Questions & Problems 552



Chemical Kinetics 564

- **13.1** The Rate of a Reaction 565
- **13.2** The Rate Law 573
- 13.3 The Relation Between Reactant Concentration and Time 577
- **13.4** Activation Energy and Temperature Dependence of Rate Constants 590
- **13.5** Reaction Mechanisms 596
- **13.6** Catalysis 601

Key Equations 610 Summary of Facts & Concepts 610 Key Words 611 Questions & Problems 611



Chemical Equilibrium 623

- **14.1** The Concept of Equilibrium and the Equilibrium Constant 624
- **14.2** Writing Equilibrium Constant Expressions 627
- **14.3** The Relationship Between Chemical Kinetics and Chemical Equilibrium 639
- **14.4** What Does the Equilibrium Constant Tell Us? 640
- **14.5** Factors That Affect Chemical Equilibrium 646

Key Equations 656 Summary of Facts & Concepts 656 Key Words 657 Questions & Problems 657

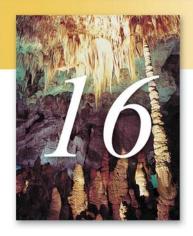


Acids and Bases 668

- 15.1 Brønsted Acids and Bases 669
- **15.2** The Acid-Base Properties of Water 670
- **15.3** pH—A Measure of Acidity 672
- **15.4** Strength of Acids and Bases 675
- 15.5 Weak Acids and Acid Ionization Constants 679
- **15.6** Weak Bases and Base Ionization Constants 687
- **15.7** The Relationship Between the Ionization Constants of Acids and Their Conjugate Bases 689
- **15.8** Diprotic and Polyprotic Acids 690
- **15.9** Molecular Structure and the Strength of Acids 694
- **15.10** Acid-Base Properties of Salts 698
- **15.11** Acid-Base Properties of Oxides and Hydroxides 704
- 15.12 Lewis Acids and Bases 706

Key Equations 710
Summary of Facts & Concepts 711
Key Words 711
Questions & Problems 711

Contents xi



Acid-Base Equilibria and Solubility Equilibria 722

- **16.1** Homogeneous versus Heterogeneous Solution Equilibria 723
- **16.2** The Common Ion Effect 723
- **16.3** Buffer Solutions 726
- **16.4** Acid-Base Titrations 732
- **16.5** Acid-Base Indicators 741
- **16.6** Solubility Equilibria 744
- **16.7** Separation of Ions by Fractional Precipitation 751
- **16.8** The Common Ion Effect and Solubility 753
- 16.9 pH and Solubility 755
- 16.10 Complex Ion Equilibria and Solubility 758
- **16.11** Application of the Solubility Product Principle to Qualitative Analysis 763

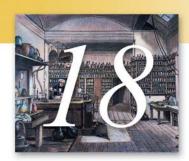
Key Equation 765 Summary of Facts & Concepts 766 Key Words 766 Questions & Problems 766



Entropy, Free Energy, and Equilibrium 778

- **17.1** The Three Laws of Thermodynamics 779
- 17.2 Spontaneous Processes 779
- **17.3** Entropy 780
- **17.4** The Second Law of Thermodynamics 785
- **17.5** Gibbs Free Energy 791
- **17.6** Free Energy and Chemical Equilibrium 798
- **17.7** Thermodynamics in Living Systems 802

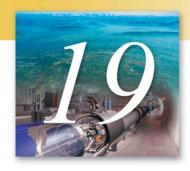
Key Equations 805 Summary of Facts & Concepts 805 Key Words 805 Questions & Problems 806



Electrochemistry 814

- **18.1** Redox Reactions 815
- 18.2 Galvanic Cells 818
- 18.3 Standard Reduction Potentials 820
- **18.4** Thermodynamics of Redox Reactions 826
- **18.5** The Effect of Concentration of Cell Emf 829
- **18.6** Batteries 834
- **18.7** Corrosion 840
- 18.8 Electrolysis 843

Key Equations 850 Summary of Facts & Concepts 850 Key Words 851 Questions & Problems 851



Nuclear Chemistry 864

- **19.1** The Nature of Nuclear Reactions 865
- **19.2** Nuclear Stability 867
- **19.3** Natural Radioactivity 872
- **19.4** Nuclear Transmutation 876
- **19.5** Nuclear Fission 879
- **19.6** Nuclear Fusion 885
- **19.7** Uses of Isotopes 888
- **19.8** Biological Effects of Radiation 890

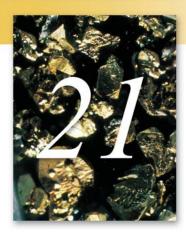
Key Equations 892 Summary of Facts & Concepts 893 Key Words 894 Questions & Problems 894



Chemistry in the Atmosphere 902

- **20.1** Earth's Atmosphere 903
- **20.2** Phenomena in the Outer Layers of the Atmosphere 906
- **20.3** Depletion of Ozone in the Stratosphere 908
- **20.4** Volcanoes 913
- **20.5** The Greenhouse Effect 914
- **20.6** Acid Rain 918
- **20.7** Photochemical Smog 921
- **20.8** Indoor Pollution 923

Summary of Facts & Concepts 926 Key Words 927 Questions & Problems 927

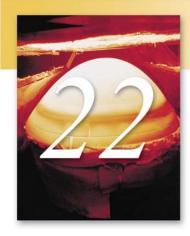


Metallurgy and the Chemistry of Metals 932

- **21.1** Occurrence of Metals 933
- **21.2** Metallurgical Processes 934
- **21.3** Band Theory of Electrical Conductivity 941
- **21.4** Periodic Trends in Metallic Properties 943
- 21.5 The Alkali Metals 944
- **21.6** The Alkaline Earth Metals 948
- **21.7** Aluminum 950

Summary of Facts & Concepts 954 Key Words 954 Questions & Problems 954

Contents xiii



Nonmetallic Elements and Their Compounds 958

- **22.1** General Properties of Nonmetals 959
- **22.2** Hydrogen 960
- **22.3** Carbon 965
- 22.4 Nitrogen and Phosphorus 969
- 22.5 Oxygen and Sulfur 977
- 22.6 The Halogens 984

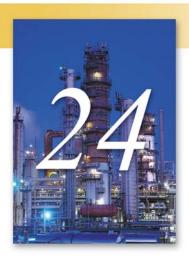
Summary of Facts & Concepts 991 Key Words 991 Questions & Problems 992



Transition Metals Chemistry and Coordination Compounds 996

- **23.1** Properties of the Transition Metals 997
- 23.2 Chemistry of Iron and Copper 1000
- **23.3** Coordination Compounds 1002
- **23.4** Structure of Coordination Compounds 1007
- 23.5 Bonding in Coordination Compounds: Crystal Field Theory 1011
- 23.6 Reactions of Coordination Compounds 1017
- **23.7** Applications of Coordination Compounds 1018

Key Equation 1022 Summary of Facts & Concepts 1022 Key Words 1022 Questions & Problems 1023



Organic Chemistry 1027

- 24.1 Classes of Organic Compounds 1028
- **24.2** Aliphatic Hydrocarbons 1028
- **24.3** Aromatic Hydrocarbons 1041
- **24.4** Chemistry of the Functional Groups 1044

Summary of Facts & Concepts 1052 Key Words 1053 Questions & Problems 1053



Synthetic and Natural Organic Polymers 1060

25.1 Properties of Polymers 1061

25.2 Synthetic Organic Polymers 1061

25.3 Proteins 1067

25.4 Nucleic Acids 1075

Summary of Facts & Concepts 1079 Key Words 1079 Questions & Problems 1079

Appendix 1 Derivation of the Names of Elements A-1

Appendix 2 Units for the Gas Constant A-7

Appendix 3 Thermodynamic Data at 1 atm and 25°C A-8

Appendix 4 Mathematical Operations A-13

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