

CONTENTS

Preface xiii

PART 1 Fundamentals of Chemistry for Environmental Engineering and Science 1

CHAPTER 1 Introduction 3

- 1.1 Water 4
- 1.2 Wastewater and Water Pollution Control 5
- 1.3 Industrial and Hazardous Wastes 6
- 1.4 Air Pollution and Global Environmental Change 7
- 1.5 Summary 9

CHAPTER 2 Basic Concepts from General Chemistry 10

- 2.1 Elements, Symbols, Atomic Weights, Gram Atomic Weights 10
- 2.2 Compounds, Formulas, Formula Weights, Gram Molecular Weights, Mole, Equivalent Weights, Equivalent 11
- 2.3 Avogadro's Number 13
- 2.4 Valency, Oxidation State, and Bonding 13
- 2.5 Nomenclature 16
- 2.6 Chemical Equations: Weight Relationships and Conservation of Mass and Charge 17

- 2.7 Oxidation-Reduction Equations 18
- 2.8 Metals and Nonmetals 24
- 2.9 The Gas Laws 24
- 2.10 Solutions 27
- 2.11 Equilibrium and Le Chatelier's Principle 29
- 2.12 Activity and Activity Coefficients 30
- 2.13 Variations of the Equilibrium Relationship 32
- 2.14 Ways of Shifting Chemical Equilibria 42
- 2.15 Amphoteric Hydroxides 45
Problems 46
References 51

CHAPTER 3 Basic Concepts from Physical Chemistry 52

- 3.1 Introduction 52
- 3.2 Thermodynamics 52
- 3.3 Vapor Pressure of Liquids 63
- 3.4 Surface Tension 64
- 3.5 Binary Mixtures 66
- 3.6 Solutions of Solids in Liquids 69
- 3.7 Membrane Processes: Osmosis and Dialysis 71
- 3.8 Principles of Solvent Extraction 74
- 3.9 Electrochemistry 76
- 3.10 Chemical Kinetics 86
- 3.11 Catalysis 96
- 3.12 Adsorption 97
Problems 106
References 112

CHAPTER 4**Basic Concepts from Equilibrium Chemistry 114**

- 4.1 Introduction 114
- 4.2 Limitations of Equilibrium Calculations 114
- 4.3 Ion Activity Coefficients 116
- 4.4 Solution to Equilibrium Problems 118
- 4.5 Acids and Bases 121
- 4.6 Buffers 160
- 4.7 Buffer Index 162
- 4.8 Complex Formation 164
- 4.9 Solubility of Salts 174
- 4.10 Oxidation-Reduction Reactions 190
- 4.11 Computer Methods for Solving Equilibrium Problems 198
Problems 199
References 211

CHAPTER 5**Basic Concepts from Organic Chemistry 212**

- 5.1 Introduction 212
Aliphatic Compounds
- 5.2 Hydrocarbons 216
- 5.3 Alcohols 222
- 5.4 Aldehydes and Ketones 227
- 5.5 Acids 231
- 5.6 Esters 235
- 5.7 Ethers 236
- 5.8 Alkyl Halides and Other Halogenated Aliphatic Compounds 237
- 5.9 Simple Compounds Containing Nitrogen 242
- 5.10 Cyclic Aliphatic Compounds 245
- 5.11 Mercaptans or Thioalcohols 245
Aromatic Compounds
- 5.12 Introduction 246
- 5.13 Hydrocarbons 247

- 5.14 Phenols 251
- 5.15 Alcohols, Aldehydes, Ketones, and Acids 254
- 5.16 Simple Compounds Containing Nitrogen 256
Heterocyclic Compounds
- 5.17 Heterocyclic Compounds 258
- 5.18 Dyes 260
The Common Foods and Related Compounds
- 5.19 General 260
- 5.20 Carbohydrates 260
- 5.21 Fats, Oils, and Waxes 266
- 5.22 Proteins and Amino Acids 269
Detergents
- 5.23 Detergents 275
- 5.24 Soaps 275
- 5.25 Synthetic Detergents 276
Pesticides
- 5.26 Pesticides 279
- 5.27 Chlorinated Pesticides 279
- 5.28 Organic Phosphorus Pesticides 281
- 5.29 Carbamate Pesticides 282
- 5.30 s-Triazines 283
- 5.31 Biological Properties of Pesticides 283
- 5.32 Pharmaceutically Active and Endocrine-Disrupting Chemicals 284
Behavior of Organics in the Environment and in Engineered Systems
- 5.33 Introduction 288
- 5.34 Fate of Organics 289
- 5.35 Structure- and Property-Activity Relationships 303
Problems 307
References 313

CHAPTER 6**Basic Concepts from Biochemistry 315**

- 6.1 Introduction 315
- 6.2 Enzymes 316

- 6.3 Cofactors 318
- 6.4 Temperature Relationships 318
- 6.5 pH 321
- 6.6 Major and Trace Elements 322
- 6.7 Biodegradation 322
- 6.8 Biochemistry of Carbohydrates 324
- 6.9 Biochemistry of Proteins 325
- 6.10 Biochemistry of Fats and Oils 326
- 6.11 General Biochemical Pathways 328
- 6.12 Energetics and Bacterial Growth 336
- 6.13 Novel Biotransformations 339
- 6.14 Molecular Biology and Genetic Engineering 345
- 6.15 Biochemistry of Humans 352
 - Problems 355
 - References 359

CHAPTER 7

Basic Concepts from Colloid Chemistry 360

- 7.1 Introduction 360
- 7.2 Colloidal Dispersions in Liquids 364
- 7.3 Colloidal Dispersions in Air 373
 - Problems 375
 - References 375

CHAPTER 8

Basic Concepts from Nuclear Chemistry 376

- 8.1 Introduction 376
- 8.2 Atomic Structure 377
- 8.3 Stable and Radioactive Nuclides 379
- 8.4 Atomic Transmutations and Artificial Radioactivity 385
- 8.5 Nuclear Reactions 387
- 8.6 Nuclear Fission 388
- 8.7 Nuclear Fusion 390
- 8.8 Use of Isotopes as Tracers 390

- 8.9 Effect of Radiation on Humans 394
 - Problems 396
 - References 397

PART 2

Water and Wastewater Analysis 399

CHAPTER 9

Introduction 401

- 9.1 Importance of Quantitative Measurements 401
- 9.2 Character of Environmental Engineering and Science Problems 402
- 9.3 Standard Methods of Analysis 402
- 9.4 Scope of a Course in Analysis of Environmental Samples 402
- 9.5 Expression of Results 403
- 9.6 Other Items 408
 - Problems 408

CHAPTER 10

Statistical Analysis of Analytical Data 410

- 10.1 Introduction 410
- 10.2 Rounding Numerical Data 411
- 10.3 Definitions 412
- 10.4 Distribution of Experimental Data 416
- 10.5 Errors 419
- 10.6 Hypothesis Testing 426
- 10.7 Detection Limits 430
- 10.8 Lognormal Distribution 433
- 10.9 Regression Analysis 437
- 10.10 Quality Assurance and Quality Control 446
 - Problems 446
 - References 451

CHAPTER 11**Basic Concepts from
Quantitative Chemistry 452**

- 11.1 General Operations 452
- 11.2 The Analytical Balance 455
- 11.3 Gravimetric Analysis 457
- 11.4 Volumetric Analysis 458
- 11.5 Colorimetry 466
- 11.6 Physical Methods of
Analysis 472
- 11.7 Precision, Accuracy,
and Statistical Treatment
of Data 474
Problems 474
References 475

CHAPTER 12**Instrumental Methods of
Analysis 477**

- 12.1 Introduction 477
- 12.2 Optical Methods of Analysis 478
- 12.3 Electrical Methods of
Analysis 490
- 12.4 Chromatographic Methods
of Analysis 503
- 12.5 Other Instrumental Methods 512
Problems 516
References 517

CHAPTER 13**Turbidity 518**

- 13.1 General Considerations 518
- 13.2 Environmental Significance 519
- 13.3 Standard Unit of Turbidity 520
- 13.4 Method of Determination 520
- 13.5 Application of Turbidity
Data 521
Problems 522
Reference 522

CHAPTER 14**Color 523**

- 14.1 General Considerations 523
- 14.2 Public Health Significance 524
- 14.3 Methods of Determination 524
- 14.4 Interpretation and Application of
Color Data 526
Problems 527
Reference 527

CHAPTER 15**Standard Solutions 528**

- 15.1 General Considerations 528
- 15.2 Preparation of 1.00 N
and 0.020 N H_2SO_4
Solutions 530
- 15.3 Preparation of 1.00 N
and 0.020 N NaOH
Solutions 532
Problems 534
Reference 535

CHAPTER 16**pH 536**

- 16.1 General Considerations 536
- 16.2 Theoretical Considerations 536
- 16.3 Measurement of pH 538
- 16.4 Interpretation of pH Data 540
Problems 540
References 541

CHAPTER 17**Acidity 542**

- 17.1 General Considerations 542
- 17.2 Sources and Nature
of Acidity 542
- 17.3 Significance of Carbon Dioxide
and Mineral Acidity 544

- 17.4** Methods of Measurement 544
- 17.5** Application of Acidity Data 547
Problems 547
Reference 548
- CHAPTER 18**
Alkalinity 549
- 18.1** General Considerations 549
- 18.2** Public Health Significance 550
- 18.3** Method of Determining Alkalinity 550
- 18.4** Methods of Expressing Alkalinity 551
- 18.5** Carbon Dioxide, Alkalinity, and pH Relationships in Natural Waters 557
- 18.6** Application of Alkalinity Data 558
- 18.7** Other Considerations 559
Problems 560
Reference 562
- CHAPTER 19**
Hardness 563
- 19.1** General Considerations 563
- 19.2** Cause and Source of Hardness 564
- 19.3** Public Health Significance 566
- 19.4** Methods of Determination 566
- 19.5** Types of Hardness 568
- 19.6** Application of Hardness Data 569
Problems 569
Reference 570
- CHAPTER 20**
Residual Chlorine and Chlorine Demand 571
- 20.1** General Considerations 571
- 20.2** Chemistry of Chlorination 574
- 20.3** Public Health Significance of Disinfection Residuals 578
- 20.4** Methods of Chlorine Residual Determination 580
- 20.5** Measurement of Chlorine Demand 583
- 20.6** Disinfection with Chlorine Dioxide 583
- 20.7** Disinfection with Ozone 584
- 20.8** Application of Disinfectant Demand and Disinfectant Residual Data 585
Problems 585
Reference 586
- CHAPTER 21**
Chloride 587
- 21.1** General Considerations 587
- 21.2** Significance of Chloride 588
- 21.3** Methods of Determination 588
- 21.4** Application of Chloride Data 590
Problems 591
References 592
- CHAPTER 22**
Dissolved Oxygen 593
- 22.1** General Considerations 593
- 22.2** Environmental Significance of Dissolved Oxygen 595
- 22.3** Collection of Samples for Determination of Dissolved Oxygen 596
- 22.4** Standard Reagent for Measuring Dissolved Oxygen 597
- 22.5** Methods of Determining Dissolved Oxygen 599
- 22.6** Dissolved-Oxygen Membrane Probes 601
- 22.7** Application of Dissolved-Oxygen Data 602
Problems 602
References 603
- CHAPTER 23**
Biochemical Oxygen Demand 604
- 23.1** General Considerations 604
- 23.2** The Nature of the BOD Reaction 605
- 23.3** Method of Measuring BOD 610
- 23.4** Rate of Biochemical Oxidations 616

- 23.5 Discrepancy between L_0 Values and Theoretical Oxygen Demand Values 620
- 23.6 Discrepancy between Observed Rates and First-Order Rates 621
- 23.7 Application of BOD Data 621
 - Problems 622
 - Reference 624

CHAPTER 24

Chemical Oxygen Demand 625

- 24.1 General Considerations 625
- 24.2 History of the COD Test 626
- 24.3 Chemical Oxygen Demand by Dichromate 626
- 24.4 Inorganic Interferences 629
- 24.5 Application of COD Data 629
 - Problems 630
 - References 630

CHAPTER 25

Nitrogen 631

- 25.1 General Considerations 631
- 25.2 Environmental Significance of Nitrogen Species 635
- 25.3 Methods of Analysis 640
- 25.4 Application of Nitrogen Data 646
 - Problems 647
 - References 648

CHAPTER 26

Solids 649

- 26.1 General Considerations 649
- 26.2 Environmental Significance of Solids Determinations 651
- 26.3 Determination of Solids in Water Supplies 652
- 26.4 Determinations Applicable to Polluted Waters and Domestic Wastewaters 653

- 26.5 Determinations Applicable to Industrial Wastewaters 655
- 26.6 Determination of Solids in Sludges 656
- 26.7 Applications of Solids Data in Environmental Engineering Practice 657
 - Problems 657
 - Reference 658

CHAPTER 27

Iron and Manganese 659

- 27.1 General Considerations 659
- 27.2 Environmental Significance of Iron and Manganese 661
- 27.3 Methods of Determining Iron 661
- 27.4 Methods of Determining Manganese 662
- 27.5 Applications of Iron and Manganese Data 663
 - Problems 664

CHAPTER 28

Fluoride 665

- 28.1 General Considerations 665
- 28.2 Chemistry of Fluorine and Its Compounds 667
- 28.3 Methods of Determining Fluoride 668
- 28.4 Application of Fluoride Data 669
 - Problems 669

CHAPTER 29

Sulfate 670

- 29.1 General Considerations 670
- 29.2 Methods of Analysis 674
- 29.3 Applications of Sulfate Data 675
 - Problems 676
 - Reference 676

CHAPTER 30**Phosphorus and Phosphate 677**

- 30.1** General Considerations 677
- 30.2** Phosphorus Compounds of Importance 679
- 30.3** Methods of Determining Phosphorus or Phosphate 679
- 30.4** Applications of Phosphorus Data 681
 - Problems 681
 - Reference 682

CHAPTER 31**Oil and Grease 683**

- 31.1** General Considerations 683
- 31.2** Oil and Grease and Their Measurement 684
- 31.3** Methods of Analysis 685
- 31.4** Applications of Oil and Grease Data 687
 - Problems 688
 - Reference 688

CHAPTER 32**Volatile Acids 689**

- 32.1** General Considerations 689
- 32.2** Theoretical Considerations 691
- 32.3** Methods of Determining Volatile Acids 694
- 32.4** Applications of Volatile-Acids Data 697
 - Problems 698
 - Reference 698

CHAPTER 33**Gas Analysis 699**

- 33.1** General Considerations 699
- 33.2** Methods of Analysis 700
- 33.3** Volumetric Analysis 701
- 33.4** Gas Chromatographic Analysis 705
- 33.5** Hydrogen Sulfide 706
- 33.6** Applications of Gas-Analysis Data 707
 - Problems 708
 - Reference 708

CHAPTER 34**Trace Contaminants 709**

- 34.1** General Considerations 709
- 34.2** The Safe Drinking Water Act 713
- 34.3** Drinking Water Standards 714
- 34.4** Trace Organic Contaminants 716
- 34.5** Trace Inorganic Contaminants 718
- 34.6** Secondary Standards and Guidelines 723
- 34.7** Trace Chemical Analyses 724
 - Problems 727
 - References 728

APPENDIX A**Thermodynamic Properties at 25 °C 729****APPENDIX B****Acronyms, Roman Symbols, and Greek Symbols 736****Index 742**