CONTENTS

PREFACE		XIII	
AU	AUTHOR		
1.	INTRODUCTION TO CHEMISTRY AND		
	GREEN CHEMISTRY	1	
1.1.	IF WE DO NOT CHANGE DIRECTION	1	
1.2.	THE ESSENTIAL ROLE OF CHEMISTRY		
1.3.	ENVIRONMENTAL CHEMISTRY AND GREEN CHEMISTRY	2 3	
1.4.	A MINI-COURSE IN CHEMISTRY	5	
1.5.	THE BUILDING BLOCKS OF MATTER	5	
	Subatomic Particles and Atoms	5	
	Atoms and Elements	6	
	The Periodic Table	7	
1.6.	CHEMICAL BONDS AND COMPOUNDS	8	
	Chemical Compounds	9	
	Ionic Bonds	10	
	Summary of Chemical Compounds and the Chemical Bond	11	
	Molecular Mass	11	
1.7.	CHEMICAL REACTIONS AND EQUATIONS	12	
1.8.	NUMBERS IN CHEMISTRY: EXPONENTIAL NOTATION	12	
	Addition and Subtraction of Exponential Numbers	13	
	Multiplication and Division of Exponential Numbers	14	
1.9.	SIGNIFICANT FIGURES AND UNCERTAINTIES IN NUMBERS	15	
	Significant Figures in Calculations	15	
	Rounding Numbers	17	
	Use of Three Significant Digits	17	
1.10.	MEASUREMENTS AND SYSTEMS OF MEASUREMENT	18	
	SI Units of Measurement	18	
	Multiples of Units	18	
	Metric and English Systems of Measurement	18	
	UNITS OF MASS	20	
1.12.		21	
1.13.	UNITS OF VOLUME	22	

vi Contents

1.14.	TEMPERATURE, HEAT, AND ENERGY	23	
	Temperature Scales	23	
	Melting Point and Boiling Point	26	
	Heat and Energy	27	
1.15.	PRESSURE	27	
	UNITS AND THEIR USE IN CALCULATIONS	28	
	Unit Conversion Factors	28	
СНА	PTER SUMMARY	31	
	Answers to Chapter Summary	33	
LITE	RATURE CITED	36	
	QUESTIONS AND PROBLEMS		
_			
2.	MATTER AND MATERIALS	45	
2.1.	WHAT IS MATTER AND WHY DOES IT MATTER		
	FOR SUSTAINABILITY AND GREEN CHEMISTRY?	45	
2.2.	CLASSIFICATION OF MATTER	46	
	Some General Types of Matter	47	
	Mixtures and Pure Substances	48	
	Summary of the Classification of Matter	49	
2.3.	QUANTITY OF MATTER: THE MOLE	49	
	The Mole and Avogadro's Number	50	
2.4.	PHYSICAL PROPERTIES OF MATTER	50	
	Density	51	
	Specific Gravity	52	
	Color	53	
	Electromagnetic Radiation and Green Chemistry	54	
2.5.	STATES OF MATTER	55	
2.6.	GASES	56 57	
	The Gas Laws	57 50	
	Gas Law Calculations	59	
2.7.	LIQUIDS AND SOLUTIONS	62	
	Evaporation and Condensation of Liquids	62	
	Vapor Pressure	63	
	Solutions	63	
2.8.	SOLIDS	65	
2.9.	THERMAL PROPERTIES	66 66	
	Melting Point	66	
	Boiling Point	66	
	Specific Heat	68	
	Heat of Vaporization	69	
	Heat of Fusion	69 69	
	Phase Change Materials in Green Technology	70	
2.10.		7 0 70	
	Distillation	70 71	
	Separation in Waste Treatment	71 74	
	THE GREEN CHEMISTRY OF MATTER	74 75	
CHAPTER SUMMARY		75 81	
QUE	STIONS AND PROBLEMS	01	

	Conten	nts vii
3.	ATOMS AND ELEMENTS	87
3.1.	ATOMS AND ELEMENTS	87
3.2.	THE ATOMIC THEORY	87 87
0.2.	Laws That Are Explained by Dalton's Atomic Theory	87
	Small Size of Atoms	89
	Atomic Mass	90
3.3.	SUBATOMIC PARTICLES	90
3.4.	THE BASIC STRUCTURE OF THE ATOM	91
	Atomic Number, Isotopes, and Mass Number of Isotopes	91
	Electrons in Atoms	92
3.5.	DEVELOPMENT OF THE PERIODIC TABLE	93
3.6.	HYDROGEN, THE SIMPLEST ATOM	93
	Designation of Hydrogen in the Periodic Table	94
	Showing Electrons in Hydrogen Atoms and Molecules	94
	Properties of Elemental Hydrogen	94
	Production and Uses of Elemental Hydrogen	95
3.7.	HELIUM, THE FIRST ATOM WITH A FILLED ELECTRON SHELL	95
	Occurrence and Uses of Helium	96
3.8.	LITHIUM, THE FIRST ATOM WITH BOTH INNER	, ,
	AND OUTER ELECTRONS	97
	Uses of Lithium	97
	Lithium, a Key Material in Green Technology	99
3.9.	THE SECOND PERIOD, ELEMENTS 4–10	99
	Beryllium, Atomic Number 4	99
	Boron, Atomic Number 5	100
	Carbon, Atomic Number 6	101
	Nitrogen, Atomic Number 7	101
	Oxygen, Atomic Number 8	102
	Fluorine, Atomic Number 9	103
	Neon, Atomic Number 10	103
3.10.	ELEMENTS 11–20, AND BEYOND	104
	The Elements Beyond Calcium	106
3.11.	A MORE DETAILED LOOK AT ATOMIC STRUCTURE	107
	Electromagnetic Radiation	107
3.12.	QUANTUM AND WAVE MECHANICAL MODELS OF	
	ELECTRONS IN ATOMS	108
	The Wave Mechanical Model of Atomic Structure	109
	Multielectron Atoms and Quantum Numbers	111
3.13.		113
	Hund's Rule of Maximum Multiplicity	115
3.14.		116
3.15.	ELECTRON CONFIGURATION	117
3.16.		118
	Electron Configuration of Hydrogen	118
	Electron Configuration of Helium	119
	Electron Configurations of Elements 2–20	119
	Lithium	119
	Valence Electrons	119

viii Contents 120 Beryllium Filling the 2p Orbitals 120 121 Filling the 3s, 3p, and 4s Orbitals ELECTRON CONFIGURATIONS AND THE PERIODIC TABLE 122 3.17. 126 **CHAPTER SUMMARY** 128 **Answers to Chapter Summary** 131 **OUESTIONS AND PROBLEMS** CHEMICAL BONDS, MOLECULES, 4. AND COMPOUNDS 139 139 CHEMICAL BONDS AND COMPOUND FORMATION 4.1. 140 Chemical Bonds and Valence Electrons CHEMICAL BONDING AND THE OCTET RULE 141 4.2. 141 The Octet Rule for Some Diatomic Gases 141 The Octet Rule for Chemical Compounds 142 IONIC BONDING 4.3. 142 Electron Configurations of Ions from a Single Atom 143 Sodium Chloride as an Ionic Compound 145 **Energetics in Ionic Bonding** 146 **Energy of Ion Attraction** 147 Lattice Energy 147 Ion Size 149 Formation of Some Example Ionic Compounds 150 FUNDAMENTALS OF COVALENT BONDING 4.4. 150 Chemical Bonds and Energy 150 **Covalent Bonding** 152 4.5. COVALENT BONDS IN COMPOUNDS 154 4.6. SOME OTHER ASPECTS OF COVALENT BONDING 154 Multiple Bonds and Bond Order 155 Lengths and Strengths of Multiple Bonds 156 **Electronegativity and Covalent Bonding** 157 Sharing Electrons—Unequally 158 **Coordinate Covalent Bonds** 159 Compounds That Do Not Conform to the Octet Rule 160 Resonance Structures 161 4.7. CHEMICAL FORMULAS OF COMPOUNDS 161 What a Chemical Formula States 162 Percentage Composition from Chemical Formulas 163 Calculation of Chemical Formulas 164 **Empirical Formula from Percentage Composition** 167 4.8. THE NAMES OF CHEMICAL COMPOUNDS 167 **Binary Molecular Compounds** 168 Names of Ionic Compounds 170 4.9. ACIDS, BASES, AND SALTS 170 Acids 171 Bases 171 Salts 172 CHAPTER SUMMARY 173 Answers to Chapter Summary 175

QUESTIONS AND PROBLEMS

5.	CHEMICAL REACTIONS, EQUATIONS,	
	AND STOICHIOMETRY	181
5.1.	THE SENTENCES OF CHEMISTRY	181
	Chemical Reactions and Equations: The Sentences of the Chemical Language	181
	Quantitative Calculations from Chemical Equations	182
5.2.	THE INFORMATION IN A CHEMICAL EQUATION	182
	Chemical Reactions	182
	Expressing a Chemical Reaction as a Chemical Equation	182
	Symbols Used in Chemical Equations	183
5.3.	BALANCING CHEMICAL EQUATIONS	184
	Balancing the Equation for the Reaction of Hydrogen Sulfide	
	with Sulfur Dioxide	184
	Some Other Examples of Balancing Equations	185
	Summary of Steps in Balancing an Equation	187
5.4.	WILL A REACTION OCCUR?	188
5.5.	HOW FAST DOES A REACTION GO?	190
5.6.	CLASSIFICATION OF CHEMICAL REACTIONS	190
5.7.	QUANTITATIVE INFORMATION FROM CHEMICAL REACTIONS	193
	Review of Quantitative Chemical Terms	193
5 0	Calcination of Limestone	194
5.8.	WHAT IS STOICHIOMETRY AND WHY IS IT IMPORTANT?	195
CIT	The Mole Ratio Method of Stoichiometric Calculations	196
CHA	APTER SUMMARY	200
OH	Answers to Chapter Summary ESTIONS AND PROBLEMS	202
QUI	SHONS AND FROBLEMS	203
6.	ACIDS, BASES, AND SALTS	209
6.1.	THE IMPORTANCE OF ACIDS, BASES, AND SALTS	209
6.2.	THE NATURE OF ACIDS, BASES, AND SALTS	210
	Hydrogen Ion and Hydroxide Ion	210
	Acids	210
	Bases	211
	Salts	211
	Amphoteric Substances	212
	Metal Ions as Acids	212
	Salts That Act as Bases	213
	Salts That Act as Acids	213
6.3.	CONDUCTANCE OF ELECTRICITY BY ACIDS, BASES,	
	AND SALTS IN SOLUTION	214
	Electrolytes	215
6.4.	DISSOCIATION OF ACIDS AND BASES IN WATER	216
6.5.	THE HYDROGEN ION CONCENTRATION AND BUFFERS	218
	Buffers	219
6.6.	PH AND THE RELATIONSHIP BETWEEN HYDROGEN ION	
	AND HYDROXIDE ION CONCENTRATIONS	219
<i>-</i> -	Acid-Base Equilibria	221
6.7.	PREPARATION OF ACIDS	222
6.8.	PREPARATION OF BASES	223
6.9.	PREPARATION OF SALTS	225

x Contents

ACID SALTS AND BASIC SALTS	227
	227
	227
	227
	228
	228
	228
— — — — — — — — — — — — — — — — — — —	229
	232
	233
	236
SOLUTIONS AND SOLVENTS	243
WHAT ARE SOLUTIONS? WHY ARE THEY IMPORTANT?	243
	244
	245
· · · · · · · · · · · · · · · · · · ·	245
	246
——————————————————————————————————————	246
 	247
	249
SOLUTION CONCENTRATIONS	251
Molar Concentration	252
	254
•	255
_	256
STANDARD SOLUTIONS AND TITRATIONS	257
PHYSICAL PROPERTIES OF SOLUTIONS	259
Freezing Point Depression	259
Boiling Point Elevation	259
Osmosis	259
SOLUTION EQUILIBRIA	261
Solution Equilibria	261
Solubilities of Gases	263
COLLOIDAL SUSPENSIONS	265
Kinds of Colloidal Particles	265
Colloid Stability	266
Coagulation and Flocculation of Colloidal Particles	268
	268
	270
STIONS AND PROBLEMS	272
CHEMISTRY AND ELECTRICITY	275
CHEMISTRY AND ELECTRICITY	275
OXIDATION AND REDUCTION	276
OXIDATION-REDUCTION IN SOLUTION	279
THE DRY CELL	281
	283
	WHAT ARE SOLUTIONS? WHY ARE THEY IMPORTANT? Reactions in Solution Solutions in Living Systems Solutions in the Environment Industrial Uses of Solutions SOLVENTS WATER—A UNIQUE SOLVENT THE SOLUTION PROCESS AND SOLUBILITY SOLUTION CONCENTRATIONS Molar Concentration Diluting Solutions Molar Concentration of H+ Ion and pH Solubility STANDARD SOLUTIONS AND TITRATIONS PHYSICAL PROPERTIES OF SOLUTIONS Freezing Point Depression Boiling Point Elevation Osmosis SOLUTION EQUILIBRIA Solution Equilibria Solubilities of Gases COLLOIDAL SUSPENSIONS Kinds of Colloidal Particles Colloid Stability Coagulation and Flocculation of Colloidal Particles APTER SUMMARY Answers to Chapter Summary STIONS AND PROBLEMS CHEMISTRY AND ELECTRICITY CHEMISTRY AND REDUCTION IN SOLUTION

•	٦		nte	
•	<i>- (</i>)T	116	nic	

хi

8.6.	USING ELECTRICITY TO MAKE CHEMICAL REACTIONS OCCUR	286
	Electrolysis of Water: A Green Technology	286
	Electrolytic Manufacture of Chemicals	288
8.7.	ELECTROPLATING	289
8.8.	FUEL CELLS	290
8.9.	SOLAR CELLS	291
8.10.	REACTION TENDENCY	292
	Measurement of E^0	293
	E ⁰ Values and Reaction Tendency	294
8.11.	EFFECT OF CONCENTRATION: NERNST EQUATION	296
	POTENTIOMETRY	297
	CORROSION	299
CHA	PTER SUMMARY	300
	Answers to Chapter Summary	302
QUE	STIONS AND PROBLEMS	304
9.	ORGANIC CHEMISTRY	307
9.1.	ORGANIC CHEMISTRY	307
	Molecular Geometry in Organic Chemistry	307
9.2.	HYDROCARBONS	308
	Alkanes	308
	Alkenes and Alkynes	314
	Alkenes and Cis-Trans Isomerism	315
	Condensed Structural Formulas	315
	Aromatic Hydrocarbons	316
9.3.	ORGANIC FUNCTIONAL GROUPS AND CLASSES	
	OF ORGANIC COMPOUNDS	318
	Organo-Oxygen Compounds	319
	Organonitrogen Compounds	321
	Organohalide Compounds	322
	Organosulfur Compounds	326
	Organophosphorus Compounds	328
9.4.	SYNTHETIC POLYMERS	330
CHA	PTER SUMMARY	332
	Answers to Chapter Summary	334
	LEMENTARY REFERENCES	335
QUE	STIONS AND PROBLEMS	336
10.	BIOLOGICAL CHEMISTRY	339
10.1.	BIOCHEMISTRY	339
	Biomolecules	340
10.2.	BIOCHEMISTRY AND THE CELL	340
	Major Cell Features	340
10.3.	PROTEINS	342
	Protein Structure	344
	Denaturation of Proteins	346
10.4.	CARBOHYDRATES	347
10.5.	LIPIDS	349

xii Contents

10.6.	ENZYMES	351
10.7.		355
10.7.	Nucleic Acids in Protein Synthesis	358
	Modified DNA	359
10.8.	RECOMBINANT DNA AND GENETIC ENGINEERING	359
10.9.	METABOLIC PROCESSES	360
1000	Energy-Yielding Processes	360
CHAPTER SUMMARY		361
	Answers to Chapter Summary	362
LITE	ERATURE CITED	363
	PLEMENTARY REFERENCES	364
	STIONS AND PROBLEMS	364
INI	DEX	367