Contents

	Pref	ace	v
I	INT	TRODUCTION TO CHEMISTRY	3
1	Elen	nents and Compounds	7
	1-1	Introduction	7
	1-2	Some Quantitative Properties of Matter	14
	1-3	The Masses of Atoms	21
		Dalton's atoms and their relative masses / 21	
		The modern atomic weight scale; the mole / 25	
	1-4	Compounds	30
		The composition of chemical compounds; molecular weights / 30	
		Water, a familiar chemical compound / 33	
	1-5	Isotopes and Masses of Isotopic Molecular Species	38
	Biog	graphical Notes	45
	Prob	olems and Questions	46
2	Che	mical Reactions	51
	2-1	Introduction	51
		Balanced Chemical Equations	53

x			Calculations Involving Chemical Reactions	57
Contents			Chemical Reactions of Unstable Compounds	63
			Other Aspects of Chemical Reactions	65
		_	raphical Notes	66
		Probl	ems and Questions	67
	3	Chen	nistry and Energy	71
		3-1	Introduction	71
		3–2	Energy, Heat, and Work Potential and kinetic energy; some definitions and units / 73	72
			Electrical energy; some definitions and units / 77 The first law of thermodynamics / 80	
			Internal energy and enthalpy / 84	
		3-3	Energy Changes in Chemical Reactions	86
		0 0	Calorimetric measurements of ΔU and $\Delta H / 87$	
			Standard enthalpies of formation of chemical	
			substances; thermochemical calculations / 91	
			The dependence of ΔH on temperature / 97	
			The second law of thermodynamics; the concept of	
			entropy / 99	
			A Summary of Thermodynamic Functions	111
		3–5	Chemistry and Energy: Some Practical Aspects The gasification of coal / 113	112
			Hydrogen as a fuel / 114	
		Biogr	raphical Notes	116
		Prob	lems and Questions	116
	II	STA	TES OF MATTER; SOLUTIONS	121
	4	The	Gaseous State	123
		4-1	Introduction	123
		4–2	The Ideal Gas Law; The Absolute Temperature Scale Boyle's law / 125	125
			Charles' law; the absolute temperature scale / 129	
			The ideal gas law / 132	
			Mixtures of gases / 138	
		4-3	The Kinetic Molecular Theory	141
			Kinetic energy of gas molecules and absolute temperature / 141	
			Heat capacities of gases / 150	
			Distribution of kinetic energies of gas molecules / 155	
		4-4		156
	•		Empirical representation of gas nonideality / 157	
			The van der Waals equation of state / 158	

	The potential energy of intermolecular interaction / 162	
	4–5 Thermal Effects in the Expansion of Gases	166
	Biographical Notes	176
	Problems and Questions	177
•	The Solid State	182
	5–1 Introduction	182
	5-2 Some Polyhedra and Their Geometrical Properties	185
	5–3 X-Ray Diffraction	187
	5-4 Solids Containing Identical Atoms	190
	Closest-packed structures / 191	
	The body-centered cubic structure / 196	
	Some solid elements with directional bonds / 199	
	Some solid elements consisting of discrete	
	molecules / 201	000
	5–5 The Thermal Properties of Solids	202
	Molar heat capacities of solids / 202	
	Entropy of crystalline solids; the third law of	
	thermodynamics / 208	213
	Biographical Notes Problems and Questions	213
	Problems and Questions	214
;	The Liquid State; Changes of State	217
	6–1 Introduction	217
	6–2 The Structure of Liquids	218
	6-3 Thermodynamic Relationships for Liquid-Vapor Interconversion	221
	Equilibrium between a liquid and its vapor / 221	
	Boiling; the normal boiling point / 232	
	The entropy of vaporization; Trouton's rule / 234 The critical state / 236	
	6-4 Phase Equilibria Involving Solid, Liquid, and Vapor	240
	Biographical Notes	246
	Problems and Questions	246
,	Solutions	249
	7–1 Introduction	249
	7–2 The Composition of Solutions	250
	The mole-fraction unit / 250	
	The molal unit / 251	
	The weight-percentage unit / 252	
	The parts-per-million unit / 253	
	The molarity unit / 253	

Contents

xii Contents	7–3	Calculations involving concentrations of solutions / 254 The interconversion of concentration units / 258 The Thermodynamics of Liquid Solutions	260
	7–4	Dilute Solutions Solutions of volatile solutes; Henry's law / 266 The effect of a solute on the solvent's vapor pressure / 271 Osmosis, reverse osmosis, and osmotic pressure / 278	266
	7–5	Liquid Solutions and Solid Solutions Liquid solutions of volatile components / 283 Separating a solution's volatile components by distillation / 290 The freezing of solutions / 295	283
	Biog	graphical Notes	300
	Prob	olems and Questions	300
III	AT	OMIC AND MOLECULAR STRUCTURE	305
8	Ator	nic Structure and the Periodic Table	307
	8-1	Introduction	307
	8-2	The Electron, the Proton, and the Neutron	308
	8–3	The Old Quantum Theory and the Bohr Atom Radiant energy / 312	312
		The spectrum of atomic hydrogen / 315 The Bohr atom / 317	
	8–4	The Quantum-Mechanical Theory of the Atom The wave nature of the electron / 323	322
		The quantum-mechanical theory of the one-electron atom / 324	
		Atoms with more than one electron / 332	
		Ionization energies / 339 Electron affinities / 341	
		Excited electronic states of atoms / 343 The characteristic x rays from elements / 345	
	8–5	The Periodic Table and Trends in the Elements' Properties	347
		The periodic table / 347	311
		Trends in properties of elements / 351	
	Biog	graphical Notes	352
	Prol	olems and Questions	354
9	Bin	ary Ionic Compounds	357
	9–1	Introduction	357
	9–2	The Ionic Crystal Lattice Coordination numbers in ionic lattices / 361	361

9-3 The Stability of Ionic Compounds The Born-Haber cycle / 372 Trends in certain properties of metal halides / 381 9-4 The Defect Solid State Imperfect crystals / 384 Nonstoichiometric crystals / 385 9-5 Ionic Compounds in Other States Molten salts / 387 Gaseous ionic compounds / 388 Solutions of ionic compounds in water / 392 Biographical Notes Problems and Questions 401 10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecules of the Nonmetals 10-4 Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 449 11-1 Introduction 449 11-1 Introduction 449 11-1 Introduction 449 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	metal halides / 381 384 387 387 380 an water / 392 400 401 404 404 404 407 410 415 415 416 415 416 416 416 417 418 418 419 419 419 419 419 419 419 419 419 419					
The Born–Haber cycle / 372 Trends in certain properties of metal halides / 381 9-4 The Defect Solid State	metal halides / 381 384 387 387 388 an water / 392 400 401 404 404 404 406 so of Diatomic Molecules 415 and helium / 416 second-row Demetry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 449 449 449 449			The lattice energy / 369	250	xiii
Trends in certain properties of metal halides / 381 9-4 The Defect Solid State	tes 387 tes 387 an water / 392 400 401 404 404 404 407 410 s of Diatomic Molecules 415 and helium / 416 second-row ometry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and			•	372	Contents
9-4 The Defect Solid State	tes 387 tes 387 an water / 392 400 401 404 404 404 407 410 s of Diatomic Molecules 415 and helium / 416 second-row ometry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and			,		
Imperfect crystals / 384 Nonstoichiometric crystals / 385 9-5 Ionic Compounds in Other States Molten salts / 387 Gaseous ionic compounds / 388 Solutions of ionic compounds in water / 392 Biographical Notes Problems and Questions 10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row clements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 449 11-1 Introduction 449 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	tes 387 tes 387 an water / 392 400 401 404 404 404 407 410 415 and helium / 416 second-row ometry of Polyatomic tions of some simple in repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and				994	
Nonstoichiometric crystals / 385 9-5 Ionic Compounds in Other States Molten salts / 387 Gaseous ionic compounds / 388 Solutions of ionic compounds in water / 392 Biographical Notes Problems and Questions 400 10 Covalent Bonding 404 10-1 Introduction 40-2 Bond Energies in Diatomic Molecules 407 10-3 Molecules of the Nonmetals 410 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 437 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 449 11-1 Introduction 449 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	n water / 392 400 401 404 404 404 405 60lecules 410 410 415 410 415 416 416 424 424 424 437 448 446 446 446 449 449 4anic Species 400 401 404 404 404 404 405 407 410 415 415 416 427 428 429 437 440 446 446 446 446 446 447 449 449 449 449 449 449 449 449 449				304	
9–5 Ionic Compounds in Other States Molten salts / 387 Gaseous ionic compounds / 388 Solutions of ionic compounds in water / 392 Biographical Notes Problems and Questions 10 Covalent Bonding 10–1 Introduction 10–2 Bond Energies in Diatomic Molecules 10–3 Molecules of the Nonmetals 10–4 Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 10–7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 449 11–1 Introduction 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	n water / 392 400 401 404 404 404 405 60lecules 410 410 415 410 415 416 416 424 424 424 437 448 446 446 446 449 449 4anic Species 400 401 404 404 404 404 405 407 410 415 415 416 427 428 429 437 440 446 446 446 446 446 447 449 449 449 449 449 449 449 449 449			• ,		
Molten salts / 387 Gaseous ionic compounds / 388 Solutions of ionic compounds in water / 392 Biographical Notes	n water / 392 400 401 404 404 404 405 60lecules 410 410 415 416 415 416 424 424 427 437 440 446 446 446 446 446 449 4anic Species 407 410 415 424 415 427 424 427 437 440 446 446 446 446 446 446 446 447 449 449 449 449 449 449 449 449 44			•	907	
Gaseous ionic compounds / 388	400 401 404 404 404 407 410 415 and helium / 416 second-row Dimetry of Polyatomic 424 tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 449 4anic Species 450 hydrogen, oxygen, and			-	367	
Biographical Notes Problems and Questions 10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 11 Structures of Simple Carbon Compounds 11-1 Introduction 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	400 401 404 404 404 407 410 415 and helium / 416 second-row Dimetry of Polyatomic 424 tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 449 4anic Species 450 hydrogen, oxygen, and					
Biographical Notes Problems and Questions 10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11-1 Introduction 449 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	400 401 404 404 404 407 410 415 415 416 415 416 424 tions of some simple fir repulsion model / 427 s; Electronegativity 437 440 446 446 446 anic Species 449 449 449 449 449 449 449 449 449 4					
Problems and Questions 10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 11 Structures of Simple Carbon Compounds 11-1 Introduction 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	401 404 404 407 410 415 and helium / 416 second-row ometry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity and Bond Lengths 446 446 446 449 449 449 449 449 450 Anic Species 407 410 415 415 415 415 424 424 424 424 427 437 437 440 446 446 446 446 446 446 447 449 449 449 449 449 449 449 449 449			•	400	
10 Covalent Bonding 10-1 Introduction 10-2 Bond Energies in Diatomic Molecules 10-3 Molecules of the Nonmetals 10-4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10-5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10-6 Polarity of Covalent Molecules; Electronegativity 10-7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 11 Structures of Simple Carbon Compounds 11-1 Introduction 11-2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	dolecules dolecules dolecules 407 410 dolecules and helium / 416 second-row cometry of Polyatomic dometry of some simple dir repulsion model / 427 st; Electronegativity and Bond Lengths 437 446 446 446 449 449 449 449 Anic Species 450 hydrogen, oxygen, and		_	-		
10–1 Introduction 404 10–2 Bond Energies in Diatomic Molecules 407 10–3 Molecules of the Nonmetals 410 10–4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 425 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	folecules folecules 407 410 410 415 and helium / 416 second-row cometry of Polyatomic 424 tions of some simple for repulsion model / 427 s; Electronegativity find Bond Lengths 446 446 446 449 449 449 449 449 4hydrogen, oxygen, and		110010	enis and Questions	401	
10–1 Introduction 404 10–2 Bond Energies in Diatomic Molecules 407 10–3 Molecules of the Nonmetals 410 10–4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 425 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	folecules folecules 404 407 410 415 and helium / 416 second-row cometry of Polyatomic 424 tions of some simple for repulsion model / 427 s; Electronegativity find Bond Lengths 446 446 446 449 449 449 449 449 4hydrogen, oxygen, and	10	Cova	lent Ronding	404	
10–2 Bond Energies in Diatomic Molecules 407 10–3 Molecules of the Nonmetals 410 10–4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 425 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	solecules 407 410 410 415 and helium / 416 second-row cometry of Polyatomic 424 tions of some simple for repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 counds 449 449 449 449 4hydrogen, oxygen, and	10		O Company of the comp		
10–3 Molecules of the Nonmetals 10–4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	as of Diatomic Molecules and helium / 416 second-row ometry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity and Bond Lengths 440 446 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and					
10–4 Molecular-Orbital Descriptions of Diatomic Molecules Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 10–7 More About Bond Energies and Bond Lengths Biographical Notes Problems and Questions 446 Problems and Questions 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	and helium / 416 second-row ometry of Polyatomic tions of some simple ir repulsion model / 427 s; Electronegativity and Bond Lengths 440 446 446 bounds 449 449 449 4hydrogen, oxygen, and					
Molecules involving hydrogen and helium / 416 Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 425 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	a and helium / 416 second-row ometry of Polyatomic 424 tions of some simple ir repulsion model / 427 s; Electronegativity 437 nd Bond Lengths 446 446 446 oounds 449 anic Species 450 hydrogen, oxygen, and					
Diatomic molecules involving second-row elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 424 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	second-row metry of Polyatomic 424 tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 449 449 449 449 Annic Species hydrogen, oxygen, and		10–4	•	415	
elements / 420 10–5 Electronic Structures and Geometry of Polyatomic Molecules 424 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	ometry of Polyatomic 424 tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 anic Species 449 449 449 449 4hydrogen, oxygen, and					
10–5 Electronic Structures and Geometry of Polyatomic Molecules 424 Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and			*		
Molecules Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 446 bounds 449 anic Species 450 hydrogen, oxygen, and					
Lewis electron-dot representations of some simple molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	tions of some simple ir repulsion model / 427 s; Electronegativity 437 and Bond Lengths 440 446 446 449 449 449 449 4hydrogen, oxygen, and		10–5	· · · · · · · · · · · · · · · · · · ·	40.4	
molecules / 425 The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	s; Electronegativity 437 and Bond Lengths 440 446 446 446 449 449 449 449 4hydrogen, oxygen, and				424	
The valence-shell electron-pair repulsion model / 427 Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	s; Electronegativity 137 140 1446 1446 1446 1449 1449 1449 1450 1449 1450 1449 1450 1449 1450					
Resonance / 433 Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	s; Electronegativity 137 140 1446 1446 1446 1449 1449 1449 1450 1449 1450 1449 1450 1449 1450					
Hybrid atomic orbitals / 435 10–6 Polarity of Covalent Molecules; Electronegativity 437 10–7 More About Bond Energies and Bond Lengths 440 Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	nd Bond Lengths 440 446 446 449 449 449 449 450 Anic Species 450			• • •		
10–6 Polarity of Covalent Molecules; Electronegativity 10–7 More About Bond Energies and Bond Lengths Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	nd Bond Lengths 440 446 446 449 449 449 449 450 Anic Species 450					
10–7 More About Bond Energies and Bond Lengths Biographical Notes 446 Problems and Questions 446 11 Structures of Simple Carbon Compounds 449 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	nd Bond Lengths 440 446 446 449 449 449 449 450 Anic Species 450		10.6	·	497	
Biographical Notes Problems and Questions 446 11 Structures of Simple Carbon Compounds 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	446 446 bounds 449 449 449 450 hydrogen, oxygen, and			,		
Problems and Questions 446 11 Structures of Simple Carbon Compounds 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and			*		
11 Structures of Simple Carbon Compounds 11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and		-	-		
11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and		Proble	enis and Questions	440	
11–1 Introduction 449 11–2 Carbon and Its Simple Inorganic Species 450 Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and	11	Struc	tures of Simple Carbon Compounds	449	
11–2 Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and					
Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455	hydrogen, oxygen, and					
Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455			11-2		430	
Simple species of carbon with hydrogen, oxygen, and nitrogen / 455				~ -		
nitrogen / 455						
	457					
II-3 Hydrocarbons 457	737		11 2		457	
			11-3		737	
	ed hydrocarbons / 461			Saturated Hydrocarbons / 437		
The conformations of saturated hydrocarbons / 4hl	/ 463			The conformations of saturated hydrocarbons / 461		
11–3 Hydrocarbons 457 Saturated hydrocarbons / 457		11	11–1 11–2	Introduction Carbon and Its Simple Inorganic Species Diamond and graphite / 450 Oxides of carbon / 454 Simple species of carbon with hydrogen, oxygen, and nitrogen / 455 Hydrocarbons	449 450	

11

xiv			Derivatives of Hydrocarbons	470
Contents			Oxygen-containing derivatives / 472	
			Nitrogen-containing derivatives / 481	400
			phical Notes	483
		Problei	ns and Questions	483
	IV	PRIN	CIPLES OF CHEMICAL REACTIONS	487
	12	$Hydro_{\delta}$	gen, Equilibrium, and Acid–Base Chemistry	489
		12-1	Introduction	489
		12-2	Chemical Equilibrium in the Gas Phase	490
			The ammonia-synthesis reaction / 493	
			The general reaction / 499	
			The dependence of equilibrium constants on	
			temperature / 501	
			Nonideality in the ammonia-synthesis reaction / 503	
			The hydrogen halides / 505 The standard Gibbs free energy of formation / 508	
		12-3	The Proton, a Very Special Chemical Species	509
		12 0	Gas-phase proton-association reactions / 509	000
			Brønsted acids and bases / 512	
		12-4	The Hydrogen Bond	522
			Hydrogen-Bridged Electron-Deficient Molecules	527
		Biogra	phical Notes	530
		Proble	ms and Questions	531
	13	Acid-A	Base Reactions in Solution	534
		13-1	Introduction; Equilibrium in Solution	534
		13-2	Strong Acids and Bases	536
			The self-dissociation of water / 536	
			Dilute solutions of strong acids and bases; the pH	
			scale / 539	
			The neutralization of a strong acid by a strong base / 543	
		13 - 3	Weak Acids and Bases	547
			Equilibrium in aqueous solutions of weak acids / 548	
			The neutralization of a weak acid by a strong base / 562	
			Buffer solutions / 569	
			Indicators and their use / 572	
			Concentration of hydrogen ion; base-neutralizing capacity / 575	
			Dibasic acids; general derivations / 576	
			Dibasic acids; specific examples / 588	
			Polybasic acids / 594	

		Acids in Very Concentrated Aqueous Solution aphical Notes	596 599
	0	ems and Questions	599
14	Solub	ility and Complex-Ion Equilibria	603
	14-1	Introduction	603
	14-2	Solubility Equilibria	604
		Thermodynamics of dissolution reactions / 607	
		Solubility-product calculations / 610	
	14–3	Metal-Ligand Complexes	620
		Hydrated metal ions / 620	
	14 4	Complex-ion equilibria / 623	
	14–4	The Influence of Other Equilibria on Solubility Equilibria	630
		The influence of iodide ion on the solubility of	000
		iodine / 630	
		The influence of ammonium ion on the solubility of magnesium hydroxide / 632	
		The influence of ammonia, thiosulfate ion, and excess	
		chloride ion on the solubility of silver(I)	
		chloride / 633	
		The influence of acidity and sulfide ion on the solubility of metal sulfides / 639	
		The influence of hydroxide ion on the solubility of an amphoteric metal hydroxide / 642	
	14-5	Distribution Equilibria	644
	Proble	ems and Questions	646
15	Rates	and Mechanisms of Chemical Reactions	649
	15-1	Introduction	649
	15-2	Rates of Chemical Reactions	651
		The integrated rate laws for first-order and	
		second-order reactions / 655	
		The temperature coefficient of reaction velocity	
		(empirical) / 663	
	15 9	Some complex empirical rate laws / 666 Mechanisms of Chemical Reactions	670
	15–3	The meaning of an empirical rate law / 671	070
		The steady-state derivation of rate law / 674	
		Rate laws and mechanisms for reversible	
		reactions / 676	
		Catalysis; mechanisms of catalyzed reactions / 681	
		Chain reactions / 687	
	15–4	Theoretical Aspects of Reaction Kinetics	688
		The temperature coefficient of reaction velocity	
		(theoretical) / 689	

xv Contents

•	•
777	

Contents

		The elementary reactions of molecules with specific	
	15-5	energies; molecular beams / 694 Fast Reactions in Solution	696
		aphical Notes	700
	_	ems and Questions	700
		2	, 00
16	Oxida	tion-Reduction Reactions and Electrochemistry	704
	16–1	Introduction	704
	16–2		705
		Oxidation states / 706	
		Half-reactions / 709	
		Balancing oxidation-reduction equations / 710	
	16–3	,	718
		Electrolysis of molten sodium chloride / 718	
		Stoichiometric relationships in electrochemistry / 721	
		Electrolysis of aqueous sodium chloride / 722	
	16.4	Electrolytic production of aluminum / 724	705
	16–4	Galvanic Cells	725
		Construction of galvanic cells; ion migration / 726	
		Emf of galvanic cells; standard emf values for half-reactions / 729	
		The thermodynamics of galvanic cells / 738	
		The dependence of $\mathscr E$ on concentration; the Nernst	
		equation / 739	
		The silver(I)–silver couple / 740	
		The dependence of emf on acidity; the pH meter / 744	
	16-5	Some Practical Batteries; Fuel Cells	754
		The dry cell / 755	
		The lead storage battery / 755	
		Fuel cells / 757	
	16-6		757
	16–7	7	763
	_	aphical Notes	767
	Proble	ems and Questions	767
\mathbf{v}	CHE	MISTRY OF THE ELEMENTS	771
•	OII	,	•••
17	The N	Nonmetals	773
	17-1		773
	17-2		778
	17 - 3	0	782
		The elements / 782	
		Oxidation states and oxidation-reduction chemistry / 785	

	1 . 1 1 . 1 . 1 . 1 . 700	
	Interhalogen molecules and ions / 790	
	Other nonmetal fluorides, including xenon	
17 4	fluorides / 792	
17-4	Oxygen and Oxygen-Containing Compounds of Nonmetals	704
		794
	Oxides and oxoacids / 796	
	Oxidation-reduction chemistry of oxygen; superoxides and peroxides / 801	
17-5	Nitrogen and Its Compounds	809
	Compounds of nitrogen with hydrogen and oxygen / 810	
	Reactions of nitrogen; the fixation of atmospheric nitrogen / 813	
	Oxidation–reduction chemistry / 817	
17-6	Sulfur and Phosphorus	820
	Oxidation–reduction chemistry / 822	
	Oxides and oxoacids / 826	
	Phosphate esters / 830	
Biogra	aphical Notes	833
Proble	ems and Questions	833
	-	
The N	Metals	836
18-1	Introduction	836
	Electronic Structures of Metal Atoms	838
	The Metallic State	846
	The Occurrence of Metals in Nature	848
	The Nontransition Metals	849
10-3	The alkali and alkaline-earth metals / 851	010
	Aluminum and silicon; silicates and	
	aluminosilicates / 863	
	Tin and lead / 866	
	Zinc, cadmium, and mercury / 867	
Biogra	aphical Notes	873
_	ems and Questions	873
	2	
Trans	ition Metals and Coordination Chemistry	876
19-1	Introduction	876
19-2	Compounds of the Transition Metals	877
	Oxidation states of 3d transition metals in aqueous solution / 880	
	The acidity and basicity of oxides and hydroxides of 3d transition metals / 881	
	Oxidation–reduction chemistry of some transition metals / 885	
	The metallurgy of iron / 892	

xviiContents

xviii			Coordination Chemistry of the Transition Metals	895
Contents		19–4	Bonding in Transition-Metal Coordination	000
		10 5	Compounds Motel Corb and a	906
			Metal Carbonyls	912 915
		_	phical Notes ms and Questions	916
	VI	ОТН	ER ASPECTS OF CHEMISTRY	919
	20	Macro	molecules and Biopolymers	921
		20-1	Introduction	921
		20-2	Polymerization Reactions	921
			Addition polymerization; hydrocarbon polymers / 922 Polymerization through ester and amide linkages; synthetic fibers / 926	
		20-3	Proteins	929
			The primary structure of proteins / 930	
			The secondary and tertiary structures of proteins / 936	
			The acid-base properties of proteins / 941	
			Fats and Fatty-Acid Metabolism	944
			Carbohydrates	949
			Nucleotides and Molecular Biology	954
		-	phical Notes	959
		Proble	ms and Questions	960
	21	Chemi	stry and Light	962
		21-1	Introduction	962
			The nature of light / 963	
			The energy associated with transitions of different types / 964	
		21-2	Energy Levels in Molecules	965
			The rotational energy states of molecules / 968	
			The vibrational energy states of molecules / 972	
			The electronic energy states of molecules / 976	
		21–3	The Absorption of Light by Atoms and Molecules	977
			The Beer-Lambert law / 978	
			The fate of electronically excited molecules / 982	
			The dissociation of molecules by light absorption / 983	
		91 4	Ozone in the atmosphere / 990 The Spectra of Inorganic Species	992
		21-4 21-5	The Spectra of Inorganic Species Ouantitative Study of Complex-Ion Equilibria by	992

Spectrophotometry Biographical Notes

Problems and Questions

996 999

1000

22	Chemi	istry and the Atomic Nucleus	1002	xix
	22-1	Introduction	1002	Contents
	22-2		1003	
		Nuclides, Stable and Unstable	1005	
		Stable nuclides / 1006		
		Unstable nuclides / 1009		
		The rate of disintegration of an unstable nuclide / 1017		
	22-4	Naturally Occurring Radioactive Nuclides	1019	
	22-5	Man-Made Nuclear Transmutations	1022	
		Nuclear reactions / 1022		
		The transuranium elements / 1026		
		Nuclear fission / 1028		
		Nuclear fusion / 1030		
		Neutron-activation analysis / 1031		
	22-6	The Uses of Isotopes in Chemistry and Allied Fields	1033	
		Tracer studies / 1033		
		Radiocarbon dating / 1035		
		Isotope effects / 1037		
		Radiation Chemistry	1038	
	0	aphical Notes	1040	
	Proble	ems and Questions	1040	
	APP	ENDIXES	1043	
1	Physic	cal Quantities, Units, and Conversion Factors	1044	
_	•			
		al Quantities	1044	
	SI Un		1045	
	-	ssion of Physical Quantities	1046	
	Value	s of Some Physical Constants	1048	
2	Some	Aspects of Mathematics	1049	
	Expor	nential Notation and Logarithms	1049	
	•	acy, Precision, and Significant Figures	1052	
		nical Presentation of Data	1056	
	Some	Elementary Aspects of Calculus	1058	
3	Some	Aspects of Chemistry	1062	•
		equivalent, a Unit of Amount; Normality, a Unit of		
		ncentration	1062	
	Nome	nclature of Inorganic Chemistry	1064	
		Simple binary compounds / 1064		
		Simple monatomic ions / 1064		
		Polyatomic ions / 1065		

xx		Acids / 1065
Contents		Coordination compounds / 1066
		The Sign Between Reactants and Products in a Chemical
		Equation
		Selected Thermodynamic Data
	4	Answers to Selected Problems and Questions
		INDEX

uestions