EMISTI

Structure and Function Fifth Edition

VOLLHARDT

SCHORE

CONTENTS.

Prefac	ee: A User's Guide to Organic Chemistry: Structure and Function	XX
	Structure and Bonding in Organic Molecules	1
1-1	The Scope of Organic Chemistry: An Overview	2
Chen	nical Highlight 1-1 Saccharin: One of the Oldest Synthetic Organic Compounds in Commercial Use	4
1-2	Coulomb Forces: A Simplified View of Bonding	5
1-3	Ionic and Covalent Bonds: The Octet Rule	7
1-4	Electron-Dot Model of Bonding: Lewis Structures	14
1-5	Resonance Forms	19
1-6	Atomic Orbitals: A Quantum Mechanical Description	
	of Electrons Around the Nucleus	23
1-7	Molecular Orbitals and Covalent Bonding	29
1-8	Hybrid Orbitals: Bonding in Complex Molecules	32
1-9	Structures and Formulas of Organic Molecules	38
	Chapter Integration Problems	41
	Important Concepts	45
	Problems	46
	Structure and Reactivity: Acids and Bases,	
	Polar and Nonpolar Molecules	51
2-1	Kinetics and Thermodynamics of Simple Chemical Processes	52
2-2	Acids and Bases; Electrophiles and Nucleophiles	58
Chen	nical Highlight 2-1 Stomach Acid	
	and Food Digestion	59
2-3	Functional Groups: Centers of Reactivity	66
2-4	Straight-Chain and Branched Alkanes	69
2-5	Naming the Alkanes	71
2-6	Structural and Physical Properties of Alkanes	76
2-7	Rotation about Single Bonds: Conformations	79
Cnen	nical Highlight 2-2 "Sexual Swindle" by Means of Chemical Mimicry	79
2-8	Rotation in Substituted Ethanes	83
	Chapter Integration Problems	87
	Important Concepts	89
	Problems	90

3	Reactions of Alkanes: Bond-Dissociation Energies,	0.5
	Radical Halogenation, and Relative Reactivity	96
3-1	Strength of Alkane Bonds: Radicals	97
3-2	Structure of Alkyl Radicals: Hyperconjugation	100
3-3	Conversion of Petroleum: Pyrolysis	101
Chemi	ical Highlight 3-1 Petroleum and Gasoline: Our Main Energy Sources	104
3-4	Chlorination of Methane: The Radical	
	Chain Mechanism	105
3-5	Other Radical Halogenations of Methane	110
3-6	Chlorination of Higher Alkanes: Relative Reactivity	
	and Selectivity	112
3-7	Selectivity in Radical Halogenation with Fluorine	
	and Bromine	116
3-8	Synthetic Radical Halogenation	118
3-9	Synthetic Chlorine Compounds and the	
	Stratospheric Ozone Layer	119
Chem	ical Highlight 3-2 Chlorination, Chloral, and DDT	119
3-10	Combustion and the Relative Stabilities	
	of Alkanes	122
	Chapter Integration Problems	124
	Important Concepts	126
	Problems	127
4	Cycloalkanes	131
4-1	Names and Physical Properties of Cycloalkanes	132
4-2	Ring Strain and the Structure of Cycloalkanes	134
4-3	Cyclohexane: A Strain-Free Cycloalkane	139
4-4	Substituted Cyclohexanes	144
4-5	Larger Cycloalkanes	148
4-6	Polycyclic Alkanes	149
4-7	Carbocyclic Products in Nature	151
Chem	ical Highlight 4-1 Cubane Derivatives with Potential as Explosives: Octanitrocubane	151
Chem	ical Highlight 4-2 Cholesterol: How Is It Bad and How Bad Is It?	155
Chem	ical Highlight 4-3 Controlling Fertility: From "the Pill" to RU-486	156
	Chapter Integration Problems	158
	Important Concepts	161
	Problems	162

i.

5	Stereoisomers	168
5-1	Chiral Molecules	170
Chen	nical Highlight 5-1 Chiral Substances in Nature	173
5-2	Optical Activity	174
5-3	Absolute Configuration: R-S Sequence Rules	177
Chen	nical Highlight 5-2 Absolute Configuration:	
	A Historical Note	181
5-4	Fischer Projections	182
5-5	Molecules Incorporating Several Stereocenters: Diastereomers	186
Chen	nical Highlight 5-3 Stereoisomers of Tartaric Acid	189
5-6	Meso Compounds	190
5-7	Stereochemistry in Chemical Reactions	192
Chen	nical Highlight 5-4 Chiral Drugs: Racemic or	
	Enantiomerically Pure?	194
	nical Highlight 5-5 Why Is Nature "Handed"?	198
5-8	Resolution: Separation of Enantiomers	201
	Chapter Integration Problems	204
	Important Concepts	206
	Problems	207
6	Properties and Reactions of Haloalkanes: Bimolecular	
0	Nucleophilic Substitution	215
6-1	Physical Properties of Haloalkanes	215
	·	213
Chen	nical Highlight 6-1 Halogenated Steroids as Anti-Inflammatory and Anti-Asthmatic Agents	217
6-2	Nucleophilic Substitution	218
6-3	Reaction Mechanisms Involving Polar Functional Groups:	210
0.5	Using "Electron-Pushing" Arrows	221
6-4	A Closer Look at the Nucleophilic Substitution	441
· ·	Mechanism: Kinetics	223
6-5	Frontside or Backside Attack? Stereochemistry of	223
0-5	•	226
6-6	the S _N 2 Reaction	226
6-7	Consequences of Inversion in $S_N 2$ Reactions	228
6-8	Structure and S _N 2 Reactivity: The Leaving Group	231
0-8 6-9	Structure and S _N 2 Reactivity: The Nucleophile	232
	Structure and S _N 2 Reactivity: The Substrate	239
unen	nical Highlight 6-2 The Dilemma of Bromomethane: Highly Useful but Also Highly Toxic	240
	Chapter Integration Problems	243
	Important Concepts	245
	Problems	245

1	Further Reactions of Haloalkanes: Unimolecular	
	Substitution and Pathways of Elimination	250
7-1	Solvolysis of Tertiary and Secondary Haloalkanes	250
7-2	Unimolecular Nucleophilic Substitution	252
7-3	Stereochemical Consequences of S _N 1 Reactions	255
7-4	Effects of Solvent, Leaving Group, and Nucleophile on	
	Unimolecular Substitution	256
7-5	Effect of the Alkyl Group on the S _N 1 Reaction:	
	Carbocation Stability	258
Chemi	cal Highlight 7-1 Unusually Stereoselective S _N 1 Displacement in Anticancer Drug Synthesis	t 261
7-6	Unimolecular Elimination: E1	262
7-7	Bimolecular Elimination: E2	265
7-8	Competition Between Substitution and Elimination:	
	Structure Determines Function	268
7-9	Summary of Reactivity of Haloalkanes	271
	Chapter Integration Problems	273
	New Reactions	275
	Important Concepts	276
	Problems	276
۸	Hydroxy Functional Group: Alcohols: Properties, Preparation,	
8	and Strategy of Synthesis	285
8-1	Naming the Alcohols	286
8-2	Structural and Physical Properties of Alcohols	287
8-3	Alcohols as Acids and Bases	290
8-4	Industrial Sources of Alcohols: Carbon Monoxide and Ethene	293
8-5	Synthesis of Alcohols by Nucleophilic Substitution	294
8-6	Synthesis of Alcohols: Oxidation–Reduction Relation	
	Between Alcohols and Carbonyl Compounds	295
	cal Highlight 8-1 Biological Oxidation and Reduction	298
Chemi	cal Highlight 8-2 The Breath Analyzer Test	301
8-7	Organometallic Reagents: Sources of Nucleophilic	
	Carbon for Alcohol Synthesis	303
8-8	Organometallic Reagents in the Synthesis of Alcohols	306
Chemi	cal Highlight 8-3 Transition Metal-Catalyzed Cross-Coupling Reactions	308
8-9	Complex Alcohols: An Introduction to Synthetic Strategy	309
		318
	Chapter Integration Problems	310
	Chapter Integration Problems New Reactions	321
	•	

9	Further Reactions of Alcohols and the Chemistry of Ethers	332
9-1	Reactions of Alcohols with Base: Preparation of Alkoxides	333
9-2	Reactions of Alcohols with Strong Acids: Alkyloxonium	
	Ions in Substitution and Elimination Reactions	
	of Alcohols	334
9-3	Carbocation Rearrangements	337
9-4	Organic and Inorganic Esters from Alcohols	342
9-5	Names and Physical Properties of Ethers	346
9-6	Williamson Ether Synthesis	349
Chem	ical Highlight 9-1 Chemiluminescence of 1,2-Dioxacyclobutanes	350
9-7	Synthesis of Ethers: Alcohols and Mineral Acids	354
9-8	Reactions of Ethers	355
Chem	ical Highlight 9-2 Protecting Groups in Synthesis	357
9-9	Reactions of Oxacyclopropanes	358
Chem	ical Highlight 9-3 Hydrolytic Kinetic Resolution of	
	Oxacyclopropanes	360
9-10	Sulfur Analogs of Alcohols and Ethers	364
9-11	Physiological Properties and Uses of Alcohols and Ethers	367
Chem	ical Highlight 9-4 Garlic and Sulfur	370
	Chapter Integration Problems	371
	New Reactions	374
	Important Concepts	376
	Problems	377
	Using Nuclear Magnetic Resonance Spectroscopy	
10	to Deduce Structure	387
10-1	Physical and Chemical Tests	388
10-2	Defining Spectroscopy	388
10-3	Hydrogen Nuclear Magnetic Resonance	391
Chem	ical Highlight 10-1 Recording an NMR Spectrum	394
10-4	Using NMR Spectra to Analyze Molecular Structure:	
	The Proton Chemical Shift	396
10-5	Tests for Chemical Equivalence	401
Chem	ical Highlight 10-2 Magnetic Resonance Imaging in Medicine	404
10-6	Integration	405
10-7	Spin-Spin Splitting: The Effect of Nonequivalent	
	Neighboring Hydrogens	407
10-8	Spin-Spin Splitting: Some Complications	415
Chem	ical Highlight 10-3 The Nonequivalence of Diastereotopic	
10 -	Hydrogens	418
10-9	Carbon-13 Nuclear Magnetic Resonance	422

Chemi	cal Highlight 10-4 Correlated NMR Spectra; COSY and HETCOR	428
Chemi	cal Highlight 10-5 Structural Characterization of Natural Products: Antioxidants from Grape Seeds	430
	Chapter Integration Problems	432
	Important Concepts	435
	Problems	436
H	Alkenes, Intrared Spectroscopy and Mass Spectrometry	446
11-1	Naming the Alkenes	447
11-2	Structure and Bonding in Ethene: The Pi Bond	450
11-3	Physical Properties of Alkenes	453
11-4	Nuclear Magnetic Resonance of Alkenes	454
Chemi	cal Highlight 11-1 Prostaglandins	459
11-5	Infrared Spectroscopy	460
11-6	Measuring the Molecular Mass of Organic Compounds:	
	Mass Spectrometry	464
11-7	Fragmentation Patterns of Organic Molecules	468
11-8	Degree of Unsaturation: Another Aid to Identifying	
	Molecular Structure	473
11-9	Catalytic Hydrogenation of Alkenes: Relative Stability	
	of Double Bonds	475
11-10	Preparation of Alkenes from Haloalkanes and Alkyl	
	Sulfonates: Bimolecular Elimination Revisited	477
11-11	Preparation of Alkenes by Dehydration of Alcohols	481
Chemi	cal Highlight 11-2 Acid-Catalyzed Dehydration of α -Terpineol	483
	Chapter Integration Problems	484
	New Reactions	486
	Important Concepts	487
	Problems	488
12	Reactions of Alkenes	500
12-1	Why Addition Reactions Proceed: Thermodynamic Feasibility	501
12-2	Catalytic Hydrogenation	5 01
12-3	Nucleophilic Character of the Pi Bond: Electrophilic	
	Addition of Hydrogen Halides	504
12-4	Alcohol Synthesis by Electrophilic Hydration:	
	Thermodynamic Control	508
12-5	Electrophilic Addition of Halogens to Alkenes	510
12-6	The Generality of Electrophilic Addition	513

12-7	Oxymercuration–Demercuration: A Special	
	Electrophilic Addition	516
Chemi	cal Highlight 12-1 Juvenile Hormone Analogs in the Battle against Insect-Borne Diseases	517
12-8	Hydroboration-Oxidation: A Stereospecific	
	Anti-Markovnikov Hydration	520
12-9	Diazomethane, Carbenes, and Cyclopropane Synthesis	522
12-10	Oxacyclopropane (Epoxide) Synthesis: Epoxidation by	
	Peroxycarboxylic Acids	524
12-11	Vicinal Syn Dihydroxylation with Osmium Tetroxide	526
Chemi	cal Highlight 12-2 Enantioselective Dihydroxylation in the Synthesis of Antitumor Drugs	528
12-12	Oxidative Cleavage: Ozonolysis	529
12-13	Radical Additions: Anti-Markovnikov Product Formation	531
12-14	Dimerization, Oligomerization, and Polymerization of Alkenes	533
12-15	Synthesis of Polymers	535
Chemi	cal Highlight 12-3 Polymers in the Clean-Up of Oil Spills	536
Chemi	cal Highlight 12-4 Polymer-Supported Synthesis of Chemical Libraries	538
12-16	Ethene: An Important Industrial Feedstock	540
12-17	Alkenes in Nature: Insect Pheromones	541
Chemi	cal Highlight 12-5 Metal-Catalyzed Alkene Metathesis for Constructing Medium and Large Rings	542
	Chapter Integration Problems	544
	New Reactions	546
	Important Concepts	549
	Problems	550
13	Alkynes: The Carbon-Carbon Triple Bond	561
13-1	Naming the Alkynes	562
13-2	Properties and Bonding in the Alkynes	563
13-3	Spectroscopy of the Alkynes	565
13-4	Preparation of Alkynes by Double Elimination	570
13-5	Preparation of Alkynes from Alkynyl Anions	571
13-6	Reduction of Alkynes: The Relative Reactivity of the	• , ,
10 0	Two Pi Bonds	572
13-7	Electrophilic Addition Reactions of Alkynes	576
13-8	Anti-Markovnikov Additions to Triple Bonds	579
13-9	Chemistry of Alkenyl Halides	580
13-10	Ethyne as an Industrial Starting Material	582
	ical Highlight 13-1 Metal-Catalyzed Stille, Suzuki, and Sonogashira Coupling Reactions	582

13-11	Naturally Occurring and Physiologically Active Alkynes	585
	Chapter Integration Problems	588
	New Reactions	589
	Important Concepts	593
	Problems	593
14	Delocalized Pi Systems: Investigation by Ultraviolet and	
14	Visible Spectroscopy	602
14-1	Overlap of Three Adjacent p Orbitals: Electron	
	Delocalization in the 2-Propenyl (Allyl) System	603
14-2	Radical Allylic Halogenation	606
14-3	Nucleophilic Substitution of Allylic Halides: S _N 1 and S _N 2	607
14-4	Allylic Organometallic Reagents: Useful Three-Carbon	
	Nucleophiles	609
14-5	Two Neighboring Double Bonds: Conjugated Dienes	610
14-6	Electrophilic Attack on Conjugated Dienes:	
	Kinetic and Thermodynamic Control	614
Chemi	cal Highlight 14-1 Use of a Fungicidal Diene in Making Wine: Sorbic Acid	615
14-7	Delocalization among More than Two Pi Bonds: Extended	
	Conjugation and Benzene	618
14-8	A Special Transformation of Conjugated Dienes: Diels-Alder	r
	Cycloaddition	620
Chemi	cal Highlight 14-2 Conducting Organic Polymers: Materials for the Future?	622
Chemi	cal Highlight 14-3 The Dicls-Alder Reaction is "Green"	628
14-9	Electrocyclic Reactions	632
Chemi	cal Highlight 14-4 An Extraordinary Electrocyclic Reaction of Anticancer Agents	636
14-10	Polymerization of Conjugated Dienes: Rubber	638
14-11	Electronic Spectra: Ultraviolet and Visible Spectroscopy	642
Chemi	cal Highlight 14-5 The Contributions of IR, MS, and UV	
	to the Characterization of Viniferone	647
	Chapter Integration Problems	648
	New Reactions	651
	Important Concepts	653
	Problems	653
INTEI	RLUDE: A Summary of Organic Reaction Mechanisms	660
15	Benzene and Aromaticity: Electrophilic Aromatic Substitution	665
15-1	Naming the Benzenes	667
15-2	Structure and Resonance Energy of Benzene: A First	
	Look at Aromaticity	669

15-3	Pi Molecular Orbitals of Benzene	672
15-4	Spectral Characteristics of the Benzene Ring	674
15-5	Polycyclic Aromatic Hydrocarbons	679
Chemi	cal Highlight 15-1 The Allotropes of Carbon: Graphite,	
	Diamond, and Fullerenes	680
15-6	Other Cyclic Polyenes: Hückel's Rule	685
Chemi	cal Highlight 15-2 Juxtaposing Aromatic and Antiaromatic Rings in Fused Hydrocarbons	686
15-7	Hückel's Rule and Charged Molecules	690
15-8	Synthesis of Benzene Derivatives: Electrophilic	
	Aromatic Substitution	692
15-9	Halogenation of Benzene: The Need for a Catalyst	695
15-10	Nitration and Sulfonation of Benzene	696
15-11	Friedel-Crafts Alkylation	699
15-12	Limitations of Friedel-Crafts Alkylations	702
15-13	Friedel-Crafts Alkanoylation (Acylation)	704
	Chapter Integration Problems	708
	New Reactions	711
	Important Concepts	713
	Problems	713
16	Electrophilic Attack on Derivatives of Benzene: Substituents Control Regioselectivity	721
16-1	Activation or Deactivation by Substituents on a	
	Benzene Ring	722
16-2		722
	Directing Inductive Effects of Alkyl Groups	724
16-3	Directing Inductive Effects of Alkyl Groups Directing Effects of Substituents in Conjugation with	
16-3		
	Directing Effects of Substituents in Conjugation with	724
Chemi	Directing Effects of Substituents in Conjugation with the Benzene Ring	724 728
Chemi	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid	724 728 731
Chemi 16-4	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes	724 728 731 735
Chemi 16-4 16-5	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes	724 728 731 735 738 744 748
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons	724 728 731 735 738 744
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer	724 728 731 735 738 744 748 750 753
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer Chapter Integration Problems New Reactions Important Concepts	724 728 731 735 738 744 748 750 753 754
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer Chapter Integration Problems New Reactions	724 728 731 735 738 744 748 750 753
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer Chapter Integration Problems New Reactions Important Concepts	724 728 731 735 738 744 748 750 753 754
Chemi 16-4 16-5 16-6	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer Chapter Integration Problems New Reactions Important Concepts Problems	724 728 731 735 738 744 748 750 753 754 755
Chemi 16-4 16-5 16-6 16-7	Directing Effects of Substituents in Conjugation with the Benzene Ring cal Highlight 16-1 Explosive Nitroarenes: TNT and Picric Acid Electrophilic Attack on Disubstituted Benzenes Synthetic Strategies Toward Substituted Benzenes Reactivity of Polycyclic Benzenoid Hydrocarbons Polycyclic Aromatic Hydrocarbons and Cancer Chapter Integration Problems New Reactions Important Concepts Problems Aldehydes and Ketones. The Carbonyl Group	724 728 731 735 738 744 748 750 753 754 755

17-4	Preparation of Aldehydes and Ketones	773
17-5	Reactivity of the Carbonyl Group:	
	Mechanisms of Addition	775
17-6	Addition of Water to Form Hydrates	778
17-7	Addition of Alcohols to Form Hemiacetals and Acetals	<i>7</i> 79
17-8	Acetals as Protecting Groups	782
17-9	Nucleophilic Addition of Ammonia and Its Derivatives	784
Chemi	cal Highlight 17-1 Imines in Biological Transformations	786
17-10	Deoxygenation of the Carbonyl Group	789
17-11	Addition of Hydrogen Cyanide to Give Cyanohydrins	791
17-12	Addition of Phosphorus Ylides: The Wittig Reaction	792
Chemi	cal Highlight 17-2 The Wittig Reaction in Synthesis	794
17-13	Oxidation by Peroxycarboxylic Acids:	
	The Baeyer-Villiger Oxidation	795
17-14	Oxidative Chemical Tests for Aldehydes	796
	Chapter Integration Problems	<i>798</i>
	New Reactions	800
	Important Concepts	803
	Problems	803
	Enols, Enolates, and the Aldol Condensation:	
10		
18	α, β -Unsaturated Aldehydes and Ketones	814
1 8 18-1		814 815
	$lpha,oldsymbol{eta}$ -Unsaturated Aldehydes and Ketones	
18-1	α, β · Unsaturated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions	815
18-1 18-2	α, β. Unsalutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria	815 816
18-1 18-2 18-3	α, β. Unsaturated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones	815 816 819
18-1 18-2 18-3 18-4	α β. Unsatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones	815 816 819
18-1 18-2 18-3 18-4	α β. Unsaturated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function:	815 816 819 821
18-1 18-2 18-3 18-4 18-5	α β Unsatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation	815 816 819 821
18-1 18-2 18-3 18-4 18-5	α β Unsaturated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective	815 816 819 821 824 828
18-1 18-2 18-3 18-4 18-5 18-6 Chemi	α β Unsatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature	815 816 819 821 824 828
18-1 18-2 18-3 18-4 18-5 18-6 Chemi	α β Insatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation	815 816 819 821 824 828
18-1 18-2 18-3 18-4 18-5 18-6 Chemi	α β Insatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective	815 816 819 821 824 828 829 830
18-1 18-2 18-3 18-4 18-5 18-6 Chemi 18-7 Chemi	α β Unsatutated Aldehydes and Ketones Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective Crossed Aldol Condensations	815 816 819 821 824 828 829 830
18-1 18-2 18-3 18-4 18-5 18-6 Chemi 18-7 Chemi	Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Altack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective Crossed Aldol Condensations Properties of α,β-Unsaturated Aldehydes and Ketones cal Highlight 18-3 Reactions of Unsaturated Aldehydes	815 816 819 821 824 828 829 830 830 832
18-1 18-2 18-3 18-4 18-5 18-6 Chemi 18-7 Chemi	Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective Crossed Aldol Condensations Properties of α,β-Unsaturated Aldehydes and Ketones cal Highlight 18-3 Reactions of Unsaturated Aldehydes in Nature: The Chemistry of Vision	815 816 819 821 824 828 829 830 830 832
18-1 18-2 18-3 18-4 18-5 18-6 Chemi 18-7 Chemi	Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Altack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective Crossed Aldol Condensations Properties of α,β-Unsaturated Aldehydes and Ketones cal Highlight 18-3 Reactions of Unsaturated Aldehydes in Nature: The Chemistry of Vision Conjugate Additions to α,β-Unsaturated Aldehydes	815 816 819 821 824 828 829 830 830 832
18-1 18-2 18-3 18-4 18-5 18-6 Chemi 18-7 Chemi 18-8 Chemi	Acidity of Aldehydes and Ketones: Enolate Ions Keto-Enol Equilibria Halogenation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Alkylation of Aldehydes and Ketones Attack by Enolates on the Carbonyl Function: Aldol Condensation Crossed Aldol Condensation cal Highlight 18-1 Enzyme-Catalyzed Stereoselective Aldol Condensations in Nature Intramolecular Aldol Condensation cal Highlight 18-2 Enzymes in Synthesis: Stereoselective Crossed Aldol Condensations Properties of α,β-Unsaturated Aldehydes and Ketones cal Highlight 18-3 Reactions of Unsaturated Aldehydes in Nature: The Chemistry of Vision Conjugate Additions to α,β-Unsaturated Aldehydes and Ketones	815 816 819 821 824 828 829 830 830 832 832

	in Synthesis	
	Chapter Integration Problems	841
	New Reactions	844
	Important Concepts	847
	Problems	847
19	Carboxylic Acids	856
19-1	Naming the Carboxylic Acids	857
19-2	Structural and Physical Properties of Carboxylic Acids	859
Chemi	ical Highlight 19-1 Toxicity of Oxalic Acid	859
19-3	Spectroscopy and Mass Spectrometry of	
	Carboxylic Acids	861
19-4	Acidic and Basic Character of Carboxylic Acids	864
19-5	Carboxylic Acid Synthesis in Industry	867
19-6	Methods for Introducing the Carboxy Functional Group	867
19-7	Substitution at the Carboxy Carbon:	
	The Addition-Elimination Mechanism	870
19-8	Carboxylic Acid Derivatives: Alkanoyl (Acyl) Halides	
	and Anhydrides	873
19-9	Carboxylic Acid Derivatives: Esters	876
19-10	Carboxylic Acid Derivatives: Amides	880
19-11	Reduction of Carboxylic Acids by Lithium	
	Aluminum Hydride	882
19-12	Bromination Next to the Carboxy Group:	
	The Hell-Volhard-Zelinsky Reaction	· 882
19-13	Biological Activity of Carboxylic Acids	884
Chemi	ical Highlight 19-2 Soaps from Long-Chain Carboxylates	885
Chemi	ical Highlight 19-3 Trans Fatty Acids and Your Health	887
	ical Highlight 19-4 Biodegradable Polyester Plastics	889
	Chapter Integration Problems	89.
	New Reactions	894
	Important Concepts	89
	Problems	892
20	Carboxylic Acid Derivatives	909
20-1	Relative Reactivities, Structures, and Spectra of	
	Carboxylic Acid Derivatives	91
20-2	Chemistry of Alkanoyl Halides	91
20-3	Chemistry of Carboxylic Anhydrides	918
	·	919
20-4	Chemistry of Esters	917

Chemi	ical Highlight 20-1 Alternatives to Petroleum: Fuels from Vegetable Oil	926
20-6	Amides: The Least Reactive Carboxylic Acid Derivatives	928
	ical Highlight 20-2 Battling the Bugs: Antibiotic Wars	930
20-7	Amidates and Their Halogenation: The Hofmann	200
	Rearrangement	933
Chemi	ical Highlight 20-3 Methyl Isocyanate, Carbamate-based Insecticides, and Safety in the Chemical	,
	Industry	936
20-8	Alkanenitriles: A Special Class of Carboxylic	
	Acid Derivatives	937
	Chapter Integration Problems	941
	New Reactions	944
	Important Concepts	948
	Problems	948
21	Amines and Their Derivatives: Functional Groups Containing Nitrogen	956
21-1	Naming the Amines	957
21-2	Structural and Physical Properties of Amines	958
Chemi	ical Highlight 21-1 Physiologically Active Amines	070
21.2	and Weight Control	960
21-3 21-4	Spectroscopy of the Amine Group	962
	Acidity and Basicity of Amines	965
Спепп	ical Highlight 21-2 Separation of Amines from Other Organic Compounds by Aqueous Extraction Techniques	968
21-5	Synthesis of Amines by Alkylation	969
21-6	Synthesis of Amines by Reductive Amination	972
21-7	Synthesis of Amines from Carboxylic Amides	975
21-8	Quaternary Ammonium Salts: Hofmann Elimination	975
21-9	Mannich Reaction: Alkylation of Enols by Iminium Ions	977
21-10	Nitrosation of Amines	979
Chemi	ical Highlight 21-3 N-Nitrosodialkanamines and Cancer	980
Chem	ical Highlight 21-4 Amines in Industry: Nylon	982
	Chapter Integration Problems	985
	New Reactions	988
	Important Concepts	993
	Problems	993
22	Chemistry of Benzene Substituents: Alkylbenzenes, Phenols,	
L L	and Benzenamines	1001
22-1	Reactivity at the Phenylmethyl (Benzyl) Carbon: Benzylic	
	Resonance Stabilization	1002

22-2	Benzylic Oxidations and Reductions	1006	
22-3	Names and Properties of Phenols	1009	
Chemi	cal Highlight 22-1 Two Phenols in the News:		
	Bisphenol A and Resveratrol	1012	
22-4	Preparation of Phenols: Nucleophilic Aromatic Substitution	1013	
22-5	Alcohol Chemistry of Phenols	1022	
	cal Highlight 22-2 Aspirin: A Phenyl Alkanoate Drug	1023	
22-6	Electrophilic Substitution of Phenols	1024	
22-7	An Electrocyclic Reaction of the Benzene Ring:		
	The Claisen Rearrangement	1028	
22-8	Oxidation of Phenols: Benzoquinones	1030	
Chemi	cal Highlight 22-3 Chemical Warfare in Nature: The Bombardier Beetle	1032	
22-9	Oxidation-Reduction Processes in Nature	1033	
22-10	Arenediazonium Salts	1038	
22-11	Electrophilic Substitution with Arenediazonium Salts:		
	Diazo Coupling	1041	
Chemi	cal Highlight 22-4 William Perkin and the Origins of		
	Industrial and Medicinal Chemistry	1042	
	Chapter Integration Problems	1044	
	New Reactions	1046	
	Important Concepts	1052	
	Problems	1052	
23	Ester Englates and the Claisen Condensation: Synthesis of		
45	B Dicarbonyl Compounds; Acyl Anion Equivalents	1061	
23-1	β -Dicarbonyl Compounds: Claisen Condensations	1062	
Chemi	cal Highlight 23-1 Claisen Condensations in Biochemistry	1066	
23-2	β -Dicarbonyl Compounds as Synthetic Intermediates	1069	
23-3	β-Dicarbonyl Anion Chemistry: Michael Additions	1074	
23-4	Alkanoyl (Acyl) Anion Equivalents: Preparation of		
	α -Hydroxyketones	1076	
Chemical Highlight 23-2 Thiamine: A Natural, Metabolically Active Thiazolium Salt 1080			
	Chapter Integration Problems	1083	
	New Reactions	1087	
	Important Concepts	1088	
	Problems	1089	
24	1096		
24-1	Names and Structures of Carbohydrates	1097	
24-2	Conformations and Cyclic Forms of Sugars	1101	
24-3	Anomers of Simple Sugars: Mutarotation of Glucose	1105	

24-4	Polyfunctional Chemistry of Sugars: Oxidation to	
	Carboxylic Acids	1107
24-5	Oxidative Cleavage of Sugars	1109
24-6	Reduction of Monosaccharides to Alditols	1110
24-7	Carbonyl Condensations with Amine Derivatives	1111
24-8	Ester and Ether Formation: Glycosides	1112
Chemi	cal Highlight 24-1 ¹⁸ F-Labeled Glucose as a Radiotracer: Imaging the Human Brain	1113
Chemi	cal Highlight 24-2 Protecting Groups in Vitamin C Synthesis	1115
24-9	Step-by-Step Buildup and Degradation of Sugars	1116
Chemi	cal Highlight 24-3 Sugar Biochemistry	1118
24-10	Relative Configurations of the Aldoses: An Exercise in	
	Structure Determination	1120
24-11	Complex Sugars in Nature: Disaccharides	1122
Chemi	cal Highlight 24-4 Carbohydrate-Derived Sugar Substitutes	1124
24-12	Polysaccharides and Other Sugars in Nature	1127
	Chapter Integration Problem	1133
	New Reactions	1135
	Important Concepts	1138
	Problems	1139
25	Heterocycles: Heteroatoms in Cyclic Organic Compounds	1145
25 25-1	Heterocycles: Heteroatoms in Cyclic Organic Compounds Naming the Heterocycles	1145 1148
27021 W. 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		
25-1 25-2	Naming the Heterocycles	1148
25-1 25-2 Chemi	Naming the Heterocycles Nonaromatic Heterocycles	1148 1149
25-1 25-2 Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics	1148 1149 1150
25-1 25-2 Chemi Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer	1148 1149 1150 1152
25-1 25-2 Chemi Chemi 25-3	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes	1148 1149 1150 1152 1153
25-1 25-2 Chemi Chemi 25-3 25-4	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes	1148 1149 1150 1152 1153 1156
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature:	1148 1149 1150 1152 1153 1156 1160
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide	1148 1149 1150 1152 1153 1156 1160 1164
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines	1148 1149 1150 1152 1153 1156 1160 1164 1166 1167
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature	1148 1149 1150 1152 1153 1156 1160 1164
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles	1148 1149 1150 1152 1153 1156 1160 1164 1166 1167 1168
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature	1148 1149 1150 1152 1153 1156 1160 1164 1166 1167
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature cal Highlight 25-5 Nature Is Not Always Green:	1148 1149 1150 1152 1153 1156 1160 1164 1166 1167 1168
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature cal Highlight 25-5 Nature Is Not Always Green: Natural Pesticides	1148 1149 1150 1152 1153 1156 1160 1164 1167 1168 1170
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature cal Highlight 25-5 Nature Is Not Always Green: Natural Pesticides Chapter Integration Problems	1148 1149 1150 1152 1153 1156 1160 1164 1167 1168 1170 1172
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature cal Highlight 25-5 Nature Is Not Always Green: Natural Pesticides Chapter Integration Problems New Reactions	1148 1149 1150 1152 1153 1156 1160 1164 1167 1168 1170 1172 1174 1178
25-1 25-2 Chemi Chemi 25-3 25-4 25-5 25-6 Chemi 25-7 Chemi 25-8	Naming the Heterocycles Nonaromatic Heterocycles cal Highlight 25-1 Azacyclopropene Antibiotics cal Highlight 25-2 Smoking, Nicotine, and Cancer Structure and Properties of Aromatic Heterocyclopentadienes Reactions of the Aromatic Heterocyclopentadienes Structure and Preparation of Pyridine: An Azabenzene Reactions of Pyridine cal Highlight 25-3 Pyridinium Salts in Nature: Nicotinamide Adenine Dinucleotide Quinoline and Isoquinoline: The Benzopyridines cal Highlight 25-4 Azanaphthalenes in Nature Alkaloids: Physiologically Potent Nitrogen Heterocycles in Nature cal Highlight 25-5 Nature Is Not Always Green: Natural Pesticides Chapter Integration Problems	1148 1149 1150 1152 1153 1156 1160 1164 1167 1168 1170 1172

26	Amino Acids, Peptides, Proteins, and Nucleic Acids: Nitrogen Containing Polymers in Nature	1191
ac 1	enterestration and the second content content of the transfer of the second sec	1192
26-1	Structure and Properties of Amino Acids	1192
Chemi	cal Highlight 26-1 Arginine and Nitric Oxide in Biochemistry and Medicine	1197
26-2	Synthesis of Amino Acids: A Combination of Amine and	
	Carboxylic Acid Chemistry	1198
26-3	Synthesis of Enantiomerically Pure Amino Acids	1201
Chemi	cal Highlight 26-2 Synthesis of Optically Pure Amino Ac Phase-Transfer Catalysis	eids: 1202
26-4	Peptides and Proteins: Amino Acid Oligomers	
	and Polymers	1203
26-5	Determination of Primary Structure:	
	Amino Acid Sequencing	1211
26-6	Synthesis of Polypeptides: A Challenge in the	
	Application of Protecting Groups	1216
26-7	Merrifield Solid-Phase Peptide Synthesis	1219
26-8	Polypeptides in Nature: Oxygen Transport by the	
	Proteins Myoglobin and Hemoglobin	1221
26-9	Biosynthesis of Proteins: Nucleic Acids	1223
Chemi	ical Highlight 26-3 Synthetic Nucleic Acid Bases and	1005
	Nucleosides in Medicine	1225
26-10	Protein Synthesis Through RNA	1228
26-11	DNA Sequencing and Synthesis: Cornerstones of	
	Gene Technology	1231
Chemi	ical Highlight 26-4 DNA Fingerprinting	1238
	Chapter Integration Problems	1243
	New Reactions	1246
	Important Concepts	1247
	Problems	1248
MCAT® Questions		MCAT®-1
Answe	ers to Exercises	A-1
Photograph Credits		C-1
Index		I-1