

### Fundamentals of Organic and Biological Chemistry



### John McMurry

Cornell University

### Mary E. Castellion

Norwalk, Connecticut



E9464436



Library of Congress Cataloging-in-Publication Data

McMurry, John

Fundamentals of organic and biological chemistry / John

McMurry. Mary E. Castellion.

p. cm. Includes index. ISBN 0-13-293085-4

1. Chemistry. 2. Chemistry, Organic. 3. Biochemistry. I. Castellion, Mary E. II. Title. QD31.2.M3878 1994

547—dc20

93-39094

CIP

Editor-in-Chief: Tim Bozik Acquisitions Editor: Paul Banks Marketing Manager: Kelly McDonald Design Director: Florence Dara Silverman

Cover and Interior Designer: Bruce Kensellaer, Meryl Poweski

Manufacturing Buyer: Trudy Pisciotti Supplements Editor: Mary Hornby Production Editor: Susan Fisher Illustrations by Vantage Art

Photo Research Coordinator: Lorinda Morris-Nantz

Photo Researcher: Tobi Zausner

Cover photo by Dr. R. Clark & M. Goff/Photo Researchers

COVER PHOTO is an infrared photo, or thermogram, of hands demonstrating blood flow as reflected in heat given off. Areas of normal blood flow are red and yellow, while cooler areas of diminished blood flow are blue.

Photo credits and acknowledgments appear on pages A-48 and A-49, which constitute a continuation of the copyright page.



© 1994 by Prentice-Hall, Inc. A Paramount Communications Company Englewood Cliffs, New Jersey 07632

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Printed in the United States of America 10 9 8 7 6 5 4 3 2 1

12BN 0-13-293085-4

Prentice-Hall International (UK) Limited, London Prentice-Hall of Australia Pty. Limited, Sydney Prentice-Hall Canada Inc., Toronto Prentice-Hall Hispanoamericana, S.A., Mexico Prentice-Hall of India Private Limited, New Delhi Prentice-Hall of Japan, Inc., Tokyo Simon & Schuster Asia Pte. Ltd., Singapore Editora Prentice-Hall do Brasil, Ltda., Rio de Janeiro

## PERIODIC CHART OF THE ELEMENTS

	_								Jak .							
8A	18	2 Helium	He 4.0026	10 Neon	Ne 20.183	18 Argon	Ar 39.944	36	Kr 82 80	54	Xenon	Xe 131.29	86 Radon	Rn (222)		
			7A 17	9 Fluorine	F 18.9984	17 Chlorine	CI 35.453	35	Br	53	Iodine	I 126.905	85 Astatine	At (210)		
			6A 16	8 Oxygen	0 15.9994	16 Sulfur	S 32.06	34	Seemum	52	Tellurium	<b>Te</b> 127.60	84 Polonium	Po (209)		
			5A 15	7 Nitrogen	N 14.0067	15 Phos- phorus	P 30.9738	33	Arsenic	14.922	Antimony	Sb 121.75	83 Bismuth	<b>Bi</b> 208.980		
			4A 14	6 Carbon	C 12.011	Silicon	Si 28.086	32 Germa-	Ge Ge	50	Tin	Sn 118.91	82 Lead	<b>Pb</b> 207.2		
			3A 13	5 Boron	B 10.81	13 Aluminum	AI 26.9815	31	Gallium	49	Indium	In 114.82	81 Thallium	TI 204.383		
							12	30	Zn	48	Cadmium	Cd 112.41	80 Mercury	Hg 200.59		
							11	29	Copper	03.340	Silver	Ag 107.868	79 Gold	Au 196.967		
							10	28	Nickel Nickel	28.09	Palladium	Pd 106.4	78 Platinum	Pt 195.08		
							6	27	Cobalt	38.933	Rhodium	Rh 102.906	77 Tridium	Ir 192.22	109 Unnil-	Une (266)
						n Metals	00	26	Fe	25.84/	Ruthenium	Ru 101.07	76 Osminm	0s 190.2	108 Unnil-	Uno (265)
	mhor	in in	veighta			Transition Metals	7	25	Maganese	54.938	Tech-	Tc (98)	75 Rhenium	Re 186.207	107 Unnil-	Uns (262)
	Z Oimot L	Name	Symbol Atomic weight <sup>a</sup>				9	24	Chromium	51.996	Molyb-	Mo 95.94	74 Tunosten	W 183.85	106 Unnil- hexium	Unh (263)
	,	Carbon	C 12.011				w	23	Vanadium	50.942	Niobium	Nb 92.906	73 Tantalum	<b>Ta</b> 180.948	105 Unnil-	Unp (262)
							4		Titanium	47.88	Zirconium	<b>Zr</b> 91.22	72 Hafnium	Hf 178.49	104 Unnil-	Unq (261)
							6	21	Scandium		n	¥ 88.906	* 57 Lantha-	La 138.91	† 89 Actinium	Ac 227.028
			2A 2	4 Rervllium	Be 9.0122	Magne-	Mg 24.305	20	Calcium	38	Strontium	Sr 87.62	56 Rarium	<b>Ba</b> 137.33	88 Radium	Ra 226.025
Group 1A	-	l Hydrogen	H 1.00797	3 Lithium	<b>Li</b> 6.941	11 Sodium	Na 22.9898	19	Potassium	39.098	Rubidium	Rb 85.468	55 Cesium	Cs 132.905	87 Francium	Fr (223)
	Period	,	_		7	,	0		4			n		9	-	
	Impel															

	58	59	09	19	62	63	64	65	99	19	89	. 69	70	71
* I anthanida sarias	Cerium	Praseo- dymium	Neo- dymium	Prome- thium	Samarium	Europium	Gadolin- ium	Terbium	Dys- prosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium
Lammand School	Ce 140.12	Pr 140.908	Nd 144.24	Pm (147)	Sm 150.36	Eu 151.96	<b>Gd</b> 157.25	Tb 158.924	Dy 162.50	Ho 164.930	Er 167.26	Tm 168.934	Yb 173.04	Lu 174.97
	06	91	92	93	94	95	96	76	86	66	100	101	102	103
+ Actinido corios	Thorium	Protac-	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Califor- nium	Einstei- nium	Fermium	Mende- levium	Nobelium	Lawren- cium
Actimide series	Th	Pa	n	dN	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No.	L
	232.038	231.036	238.029	(237)	(244)	(243)	(247)	(247)	(251)	(254)	(257)	(258)	(259)	(260)

<sup>a</sup> Numbers in parentheses are mass numbers of the most stable or best-known isotope of radioactive elements.

# LIST OF ELEMENTS WITH THEIR SYMBOLS AND ATOMIC WEIGHTS

Helium	Hafnium	Gold	Germanium	Gallium	Gadolinium	Francium	Fluorine	Fermium	Europium	Erbium	Einsteinium	Cyclocodin	Dyenrosium	Curium	Copper	Cobalt Copper Curium	Chromium Cobalt Copper Curium	Chlorine Chromium Cobalt Copper Curium	Cesium Chlorine Chromium Cobalt Copper Curium	Cerium Cesium Chlorine Chromium Cobalt Copper Curium Dysprosiur	Carbon Cerium Cesium Chlorine Chromium Cobalt Copper Curium Dysprosium	Californium Carbon Cerium Cesium Chlorine Chromium Cobalt Copper Curium	Calcium Californium Carbon Cerium Cesium Chorine Chromium Cobalt Copper Curium	Cadmium Calcium Californium Carbon Cerium Cesium Chlorine Chromium Cobalt Copper Curium Dysprosiur	Bromine Cadmium Calcium Californium Carbon Cerium Cerium Cesium Chlorine Chromium Cobalt Copper Curium	Boron Bromine Cadmium Calcium Californium Cathon Cerium Cerium Cesium Chlorine Chromium Cobalt Copper Curium	Bismuth Boron Bromine Cadmium Calcium Californium Carbon Cerium Cesium Chlorine Chromium Cobalt Copper Curium	Beryllium Bismuth Boron Bromine Cadmium Calcium Californium Carbon Cerium Cesium Chlorine Chromium Cobalt Copper Curium	Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Californium Carbon Cerium Cerium Chlorine Choronium Cobalt Copper Curium	Barium Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Californium Carbon Cerium Cerium Chlorine Chormium Cobalt Copper Curium Cosiur	Astatine Barium Berkelium Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Californium Californium Carbon Cerium Chlorine Chromium Cobalt Copper Curium	Arsenic Astatine Barium Berkelium Berkelium Beryllium Bismuth Boron Bromine Caddmium Californium Californium Californium Carbon Cerium Cerium Cobalt Copper Curium Cobalt Copper	Argon Arsenic Astatine Barium Berkelium Berkelium Beryllium Bismuth Boron Bromine Calcium Calcium Californium Californium Carbon Cerium Cerium Cobalt Coppper Curium Cobalt Coppper Curium	Antimony Argon Arsenic Astatine Barium Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Calcium Calcium Calcium Californium Carbon Cerium Cobalt Copper Curium Cobalt Copper	Americium Antimony Argon Arsenic Astatine Barium Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Calcium Calcium Calcium Calcium Carbon Cerium Cerium Cobalt Copper Curium Cobalt Copper	Aluminum Americium Antimony Argon Arsenic Astatine Barium Berkelium Berkelium Beryllium Bismuth Boron Bromine Cadmium Calcium Calcium Calcium Calcium Carbon Cerium Cerium Cobalt Copper Curium Cobalt Copper
He	エ	Au	n Ge	Ga	n Gd	Fr	П	Fm	Eu	щ																										
2	72	79	32	31	64	87	9	100	63	68	99	00	00	96	96	27 29 96	24 27 29 86	17 24 27 29 96	55 17 24 27 29 96	58 17 24 27 29 96	55 55 17 24 27 29 96	98 55 55 17 27 27 29 96	20 98 98 96 96	3 6 6 8 9 2 2 4 4 8 9 8 9 8 9 8 9 8 9 8 9 8 9 8 9 8 9	3 6 6 9 2 2 4 4 7 5 5 6 6 8 8 2 3 5 6 6 8 6 8 6 8 6 6 6 6 6 6 6 6 6 6 6 6	5 6 6 8 8 9 2 2 4 4 3 5 6 8 8 9 2 2 4 4 3 5 6 8 8 9 2 2 4 4 7 5 8 8 6 8 8 9 2 2 4 8 5 5 6 8 8 9 2 2 4 8 5 6 8 8 9 2 2 4 8 5 6 8 8 9 2 2 4 8 5 6 6 8 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 8 9 2 2 4 8 5 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 4 8 6 6 6 8 9 2 2 2 4 8 6 6 6 8 9 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	83 5 5 8 6 8 8 9 2 2 4 4 3 5 5 8 6 6 8 8 9 2 2 7 4 4 7 5 5 8 6 6 8 8 9 2 2 7 4 4 7 7 5 5 8 6 6 6 8 8 9 2 2 7 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7	55 5 6 6 8 8 2 2 4 4 3 5 5 8 6 6 6 8 8 9 2 2 7 4 4 7 5 5 8 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	97 55 6 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	56 6 6 6 7 7 7 8 7 8 7 8 7 8 7 8 7 8 7 8	3 5 6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	3 6 6 8 6 8 8 6 8 8 6 8 8 6 8 8 6 8 8 6 8	3 6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	50 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	6 6 6 8 6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	3 6 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
4.00260	178.49	196,9665	72.61	69.72	157.25	(223)	18.998403	(257)	151.96	167.26	(254)	162.50		(247)	63.546 (247)	58.9332 63.546 (247)	51.996 58.9332 63.546 (247)	35.453 51.996 58.9332 63.546 (247)	132.9054 35.453 51.996 58.9332 63.546 (247)	140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	(251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	(247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	(210) (217) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	74.9216 (210) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	39.948 74.9216 (210) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	121.75 39.948 74.9216 (210) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	(243) 121.75 39.948 74.9216 (210) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)	26.98154 (243) 121.75 39.948 74.9216 (210) 137.33 (247) 9.01218 208.9804 10.81 79.904 112.41 40.078 (251) 12.011 140.12 132.9054 35.453 51.996 58.9332 63.546 (247)
Radon	Radium	Protactinium	Promethium	Praseodymium	Potassium	Polonium	Plutonium	Platinum	Phosphorus	Palladium	Oxygen	Osmium		Nobelium	Nitrogen Nobelium	Niobium Nitrogen Nobelium	Nickel Niobium Nitrogen Nobelium	Neptunium Nickel Niobium Nitrogen Nobelium	Neon Neptunium Nickel Niobium Nitrogen Nobelium	Neodymium Neon Neptunium Nickel Niobium Nitrogen Nobelium	Molybdenum Neodymium Neon Neptunium Nickel Niobium Nitrogen Nobelium	Mercury Molybdenur Neodymium Neptunium Nickel Niobium Nitrogen Nobelium	Mendelevium Mercury Molybdenum Neodymium Neon Neptunium Nickel Nicbium Nitrogen Nobelium	Manganese Mendeleviur Mercury Molybdenun Neodymium Neon Neptunium Nickel Niobium Nitrogen	Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neptunium Nickel Nickel Niobium Nobelium	Lutetium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neptunium Nickel Nickel Niobium Nobelium	Lithium Lutetium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neptunium Nickel Niobium Nitrogen Nobelium	Lead Lithium Lutetium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neptunium Nickel Niobium Nitrogen	Lawrencium Lithium Lutetium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neodymium Nickel Niobium Nitrogen Nobelium	Lanthanum Lawrencium Lead Lithium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Meodymium Neon Neptunium Nickel Niobium Nitrogen	Krypton Lawrencium Lawrencium Lead Lithium Lutetium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neptunium Nickel Niobium Nitrogen	Iron Krypton Lanthanum Lead Lithium Lead Lithium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neodymium Nickel Niobium Nitrogen	Iridium Iron Krypton Lanthanum Lawrencium Lead Lithium Lutetium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neon Neotunium Nickel Niobium Nitrogen	lodine Iridium Iron Krypton Lanthanum Lead Lithium Lutetium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neodymium Neon Neon Nickel Niobium Nitrogen	Indium Iodine Iridium Iron Krypton Lanthanum Lawrencium Lead Lithium Lutetium Magnesium Magnesium Manganese Mendeleviu Mercury Molybdenur Neoon Neptunium Nickel Niobium Nitrogen Nobelium	Hydrogen Indium Iodine Iridium Iron Krypton Lanthanum Lawrencium Lead Lithium Magnessium Manganese Mendeleviu Mercury Molybdenur Neoon Neptunium Nickel Niobium Nitrogen
Rn	Ra		n Pm		_	Po	Pu	Pt	P	Pd	0	Os		No	Z Z	Z Z Z	N N N N	Z Z Z Z Z	Z Z Z Z Z &																- 3	- 3
86	88	91	61	59	19	84	94	78	15	46	00	76		102	7 102	41 7	28 41 7	93 28 41 7	10 93 28 41 7	60 10 93 93 28 41 7	42 60 10 93 93 28 41 7	80 42 60 10 93 93 41 7	101 80 42 60 10 93 93 28 28	25 101 80 80 42 60 10 93 93 93 7	12 25 101 101 80 42 60 60 10 93 93 93 7	71 12 101 101 80 42 80 10 10 28 28 28	3 71 12 101 101 80 80 60 60 42 83 93 93 93 7	82 3 3 42 101 102 7 7 4 42 80 80 80 80 80 80 7 7	103 3 3 3 3 103 101 12 12 12 12 12 12 12 12 12 12 12 12 12	103 3 3 3 7 101 101 102 102 102	36 103 103 103 103 103 104 101 102 102 103	26 103 36 82 82 103 101 102 103 103 103 103 104 105 107 107	77 103 82 82 101 102 103 103 104 104 105 107 107	53 77 103 82 82 103 101 112 102 80 80 80 80 80 80 80 80 80 80 80 80 80	49 53 77 53 60 60 60 60 60 60 60 60 60 60 60 60 60	53 54 54 54 57 57 57 57 57 60 60 60 60 60 60 60 60 60 60 60 60 60
(222)	226.0254	231.0359	(145)	140.9077	39.0983	(209)	(244)	195.08	30.97376	106.42	15.9994	190.2		(259)	14.0067 (259)	92.9064 14.0067 (259)	58.69 92.9064 14.0067 (259)	237.0482 58.69 92.9064 14.0067 (259)	20.179 237.0482 58.69 92.9064 14.0067 (259)	144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	200.59 95.94 144.24 20.1.79 237.0482 58.69 92.9064 14.0067 (259)	(258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	(260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	55.847 83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	192.22 55.847 83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	126.9045 192.22 55.847 83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	114.82 126.9045 192.22 55.847 83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)	1.0079 114.82 112.22 126.9045 192.22 55.847 83.80 138.9055 (260) 207.2 6.941 174.967 24.305 54.9380 (258) 200.59 95.94 144.24 20.179 237.0482 58.69 92.9064 14.0067 (259)
	Zirconium	Zinc	Yttrium	Ytterbium	Xenon	Vanadium	Uranium	Unnilseptium <sup>b</sup>	Unnilquadium	Unnilpentium	Unniloctiumb	Unnilhexiumb	1	Unnilennium <sup>t</sup>	Tungsten Unnilennium <sup>t</sup>	Titanium Tungsten Unnilennium	Tin Titanium Tungsten Unnilennium <sup>b</sup>	Thulium Tin Titanium Tungsten Unnilennium	Thorium Thulium Tin Titanium Tungsten Unnilennium	Thallium Thorium Thulium Tin Tin Titanium Trungsten Unnilennium	Terbium Thallium Thorium Thulium Tin Titanium Tungsten Unnilennium	Tellurium Terbium Thallium Thallium Thulium Thulium Tin Tianium Titanium Tungsten Unnilennium	Technetium Tellurium Terbium Thallium Thallium Thulium Tin Tianium Tianjum Tianjum Tianjum Tianjum	Tantalum Technetium Tellurium Terbium Thallium Thallium Thulium Tin Tianium Tiungsten Unnilennium	Sulfur Tantalum Technetium Tellurium Tellium Thallium Thorium Thulium Tin Tianium Tiungsten Unnilennium	Strontium Sulfur Tantalum Technetium Terbium Terbium Thallium Thorium Thulium Thulium Tin Tin Titanium Tiungsten Unnilennium	Sodium Strontium Sulfur Tantalum Technetium Tellurium Terbium Thallium Thulium Thulium Thulium Thulium Tin Titanium Tungsten Unnilennium	Silver Sodium Strontium Suffur Tantalum Technetium Tellurium Terbium Thallium Thorium Thulium Titanium Titanium Tingsten Unnilennium	Silicon Silver Sodium Strontium Strontium Sulfur Tantalum Technetium Tellurium Trorium Thallium Thulium Titanium Tiungsten Unnilennium	Selenium Silicon Silicer Sodium Strontium Strontium Sulfur Tantalum Technetium Tellurium Thallium Thorium Thulium Tin Titanium Tungsten Unnilennium	Scandium Selenium Silicon Silicon Silicon Sodium Strontium Strontium Strontium Tantalum Technetium Terbium Trabilium Thallium Thulium Tin Titanium Tungsten Unnilennium	Samarium Scandium Scandium Silicon Silver Sodium Strontium Strontium Strontium Tantalum Technetium Tellurium Trabilium Thulium Thulium Tin Titanium Tungsten Unnilennium	Rutherfordium <sup>b</sup> Samarium Scandium Scandium Scalenium Silicon Silver Sodium Strontium Strontium Strontium Tantalum Technetium Tellurium Terbium Thallium Thulium Thulium Tin Titanium Tiungsten Unnilennium b	Ruthenium Rutherfordium Samarium Scandium Scelenium Scelenium Silicon Silver Sodium Strontium Strontium Strontium Trantalum Technetium Terbium Thallium Thulium Thulium Tin Tin Titanium Tungsten Unnilennium	Rubidium Rutheriordiun Rutherfordium Samarium Scandium Sclenium Silicon Silver Sodium Strontium Strontium Tantalum Technetium Terbium Trahiium Thorium Thulium Trugsten Unnilennium Tungsten	Rhodium Ruthenium Rutherfordiun Rutherfordiun Samarium Scandium Scandium Scilicon Silicon Silicon Silicon Silicon Tentalium Technetium Terbium Thorium Thorium Thorium Thulium Titanium
	Zr	Zn	~	Υb	Xe	<																														Une Note that the control of the co
	40	30	39	70	54	23	92	107	104	105	108	106		109	74 109	22 74 109	50 22 74	69 50 22 74	90 69 50 22 74	81 90 69 50 22 74	65 81 90 69 50 22 74	52 65 81 90 69 50 22 74	43 52 65 81 90 69 50 50 74	73 52 65 81 90 69 50 50 74	16 73 52 65 81 90 50 50 74	38 16 52 52 65 81 81 90 90 74	11 38 43 73 65 81 65 81 74 74	11 47 11 16 38 17 16 52 52 52 52 52 52 52 52 52 52 52 52 52	14 14 14 16 16 16 16 17 10 10 10	147 147 147 147 147 147 147 147 147 147	21 14 14 14 16 16 17 18 10 10 10 10 10 10 10 10 10 10	62 21 21 14 14 14 14 16 65 52 65 65 65 65 65 65 65 65 65 65	104 62 62 114 147 147 147 147 147 147 147 147 147	104 104 104 104 109 109	37 44 44 47 47 47 47 47 47 47 47 47 47 47	109 109 109 109 109 109
	91.22	65.39	88.9059	173.04	131.29	50.941	238.028	(262)	(261)	(262)	(265)	(263)	1	(266)	183.85	47.88 183.85 (266)	118.71 47.88 183.85 (266)	168.9342 118.71 47.88 183.85 (266)	232.0381 168.9342 118.71 47.88 183.85 (266)	204.383 232.038 168.934; 118.71 47.88 183.85 (266)	158.9254 204.383 232.0381 168.9342 118.71 47.88 183.85 (266)	127.60 158.925- 204.383 232.038- 168.934: 118.71 47.88 183.85 (266)	(98) 127.60 158.9254 204.383 232.0381 168.9342 118.71 47.88 183.85 (266)	180.947( (98) 127.60 158.925- 204.383 230.0381 168.9341 118.71 47.88 183.85 (266)	32.06 180.947(98) 127.60 158.925 204.383 232.038 168.934; 118.71 47.88 183.85 (266)	87.62 32.06 180.947(98) 127.60 158.925 204.383 232.0383 232.0383 168.934; 118.71 47.88 183.85 (266)	22.9897 87.62 32.06 180.947( (98) 127.60 158.925- 204.383 232.038 168.934, 118.71 47.88 183.85	107.868; 22.9897 87.62 32.06 180.947; (98) 127.60 158.925- 204.383 232.038 168.934; 118.71 47.88 183.85	28.0855 107.868, 22.9897 87.62 32.06 32.06 180.947 (98) 127.60 158.925- 204.383 232.038 168.934; 118.71 47.88 183.85 (266)	78.96 28.0855 107.868. 22.9893 22.9893 87.62 32.06 180.947 (98) 127.60 158.925 204.383 232.038 168.934; 118.71 47.88	44.9554 78.96 28.065 107.868; 107.868; 22.989 87.62 32.06 180.947; (98) 127.60 158.925- 204.383 232.038 168.934; 118.71 47.88 183.85	150.36 44.9554 78.96 28.096 22.989 107.868; 22.989 22.989 22.989 180.947; (98) 127.60 158.925- 204.383 232.038 168.934; 118.71 47.88	(261) 150.36 44.9554 78.96 28.086 107.868 22.9891 87.62 32.06 180.947 (98) 127.60 158.925- 204.383 232.038 168.934; 118.71 47.88	101.07 (261) 150.36 44.9554 78.96 28.0855 107.8682 22.98977 87.62 32.06 180.9479 (98) 127.60 158.9254 204.383 232.0381 168.9342 118.71 47.88 183.85 (266)	85.4678 101.07 (261) 150.36 44.9554 78.96 28.0855 107.868; 222.9897 87.62 32.086 180.947( (98) 127.60 158.925, 204.383 232.038 168.934, 118.71 47.88	102.9055 85.4678 101.07 (261) 150.36 44.9554 78.96 28.0855 107.8682 22.98977 87.62 32.06 180.9479 (98) 127.60 158.9254 204.383 232.0381 168.9342 118.71 47.88 183.85 (266)

<sup>&</sup>lt;sup>a</sup> Numbers in parentheses are mass numbers of the most stable or best-known isotope of radioactive elements.

<sup>b</sup> The official name and symbol have not been agreed to. The names for elements 106, 107, 108, and 109 represent their atomic numbers, as in un (1) nil (0). hex (6) = unnilhexium (Unh) for element 106.

### **Preface**

To provide an introduction to organic chemistry and to the chemistry of living things—that is the goal of this textbook. The writing style, content, and organization are directed toward students with career goals in the allied health sciences and toward students seeking to know something about chemistry's role in our complex society.

Teaching chemistry is a challenging activity, just as learning chemistry is challenging. Teaching chemistry all the way from What is an atom? to How do we get energy from glucose? is especially difficult. Conversations with many teachers who face this challenge show that there are just about as many approaches to it as there are teachers. This textbook is designed for the one-semester course in organic and biological chemistry for students who have already had an introduction to general chemistry.

The chapters here are drawn from the organic and biological chemistry portions of Fundamentals of General, Organic, and Biological Chemistry, our textbook for the two-semester course. By varying the topics covered and the time devoted to them, each teacher can change the focus of the one-semester course to meet their students individual needs. Our unique biochemistry sequence, described below, allows for an unusual degree of flexibility with this material.

Because an understanding of bonding and acid-base chemistry is so important to success with this material, we have provided appendices on these subjects (Appendix A, Chemical Bonds; Appendix B, Acids and Bases). Marginal notes direct students to the appendices for independent review. The two appendices are written in such a manner that, as an alternative, they can be the basis for class lectures on these topics.

In addition, about 50 new marginal notes have been added to this one-semester text. The purpose of these notes is to provide support for students who may need reminders of essential concepts from their introduction to chemistry.

Most students in this course have their sights set well beyond academic concerns and the laboratory bench. They want to know why: Why must I study organic chemistry?

Why are molecular shapes important for me as a nurse, a farmer, or an informed citizen? We have therefore endeavored at every step along the way to place chemistry in the context of applications and everyday life. To meet this challenge, we have written about these matters in the mainstream of the text as well as in the Application and Interlude sections. With the intent of gaining student confidence, our writing style is relaxed and friendly, and we have included many visual and verbal study aids.

### **ORGANIZATION**

The six *organic chemistry* chapters provide a concise overview of the subject and focus on what students must know in order to get on with the study of biochemistry. Nomenclature rules are included with the introduction to hydrocarbons (Chapters 1 and 2) and thereafter are kept to a minimum. The functional group chapters (Chapters 3–6) emphasize the structures and properties relevant to biomolecules and profile commonly encountered compounds. The chapter on amines presents their numerous biological roles and, by preceding the carboxylic acids chapter, allows amide chemistry to be covered with that of related carboxylic acid derivatives.

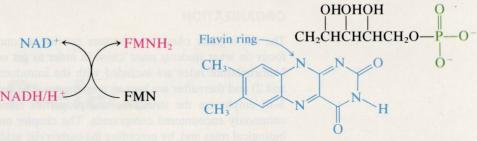
Our effort to allow for flexibility is especially evident in the *biological chemistry* chapters, where *structure and function are integrated*. Protein structure (Chapter 7) is followed by enzyme chemistry and biochemical energy (Chapters 8 and 9). Then come carbohydrates and their metabolism, lipids and their metabolism, and protein metabolism. If your time for biochemistry is limited, stop with Chapter 9 on biochemical energy, and your students will have an excellent preparation in the essentials of metabolism. To carry the metabolism story further, cover the next two chapters on carbohydrates and their metabolism (Chapters 10 and 11). And if you want to cover all classes of biomolecules and their metabolism, you will find a thorough, integrated treatment in Chapters 7–14. Nutrition is not treated as yet another separate subject, but is integrated with the discussion of each type of biomolecule. In the last two chapters, we cover subjects that we've found are an essential part of the course to many of you, but optional to others—Nucleic Acids and Protein Synthesis in Chapter 15 and Body Fluids in Chapter 16. Throughout, we have made every effort to provide up-to-date coverage, recognizing that biological chemistry is a most rapidly advancing area of science.

### **KEY FEATURES**

Applications and Interludes A wide variety of special topics are covered in over 50 Application and Interlude sections. These sections provide thorough coverage—whether the topics are just assigned for additional reading or incorporated in the course, students can gain a reasonable understanding of each topic. Representative subjects (a complete list precedes the Preface) include everyday chemistry (Detergents; Sweetness; The Biochemistry of Running), environmental and societal issues (Chlorofluorocarbons and the Ozone Layer; Is It Poisonous or Isn't It?), health and medical applications (Barbiturates; Ethyl Alcohol as a Drug and Poison; Glucose Tolerance Test), and modern applied chemistry (Magnetic Resonance Imaging; Antioxidants; Prodrugs). Questions on the Applications and Interludes are provided in a separate section at the end of each chapter.

**Color Photos** Each chapter opens with a photo chosen to generate curiosity about the chapter subject. Then, throughout each chapter, photos are used to enhance understanding and appreciation for the subject matter.

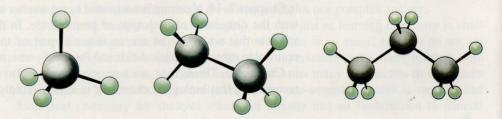
**Graphics** Molecular structures, chemical equations, and charts and diagrams have been highlighted with color to emphasize their meaning. Many topics in organic and biological chemistry become much clearer when the reacting parts of molecules are color coded. For example, color has been used consistently to highlight phosphate groups in biomolecules and to distinguish energy-rich forms of such molecules as ATP and reduced coenzymes (red) from their lower energy counterparts, ADP and oxidized coenzymes (blue).



Flavin mononucleotide (FMN)

Nowhere are graphics more important than in clarifying the complexities of biochemical pathways and we believe our graphics are the best ever offered to students in this course. Our overall metabolism diagram has been adapted as a logo and is repeated as appropriate with the topic under discussion highlighted.

**Computer-Generated Structures** Computer-generated molecular models are used extensively in the organic and biological chapters, both for their accuracy in portraying the three-dimensional structures of molecules and for their visual appeal.



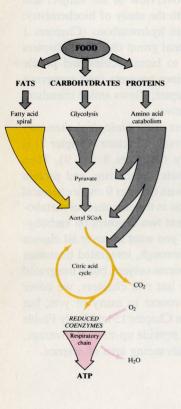
**Problem Solving** The problem solving skills essential to this course are illustrated with clearly explained and worked out Solved Problems. Solved Problems are all followed by related Practice Problems, and most text sections include additional practice problems to provide an immediate test of understanding. Practice Problems are answered at the back of the book.

### **PEDAGOGY**

**Introduction and Goals** Each chapter begins with a brief introductory overview, followed by a list of goals for the student to keep in mind while studying.

**Marginal Definitions** Key terms are boldfaced in the text on their first use, and the definition of each term is provided in the margin nearby for easy review.

Marginal Notes Brief marginal notes provide reminders of essential concepts from introductory chemistry.



**Glossary** The definitions of all key terms are collected in alphabetical order in the Glossary at the back of the book.

**Summaries** Certain complex topics are summarized immediately after their presentation in bulleted statement lists. Each chapter ends with a clear, concise summary that reviews key points, with essential terms highlighted in boldface type.

**Review Problems** The end-of-chapter Review Problems provide approximately 1000 questions and problems: 400 on organic chemistry, and 600 on biological chemistry.

Appendices and Reference Tables The first two appendices provide review of essential topics from introductory chemistry: Chemical Bonds, and Acids and Bases. Other Appendices provide a review of exponential notation and useful conversion factors. The reference tables inside the cover display for easy reference the periodic table, an alphabetical list of elements, the structural features of important families of organic molecules, and a list of important tables and diagrams in the text.

**Index** The index is designed to be especially useful by including both general and specific citations and by the absence of cross reference entries without page numbers.

### SUPPLEMENTS

**Study Guide and Solutions Manual,** by Susan McMurry. This companion volume answers all in-text and end-of-chapter problems and explains in detail how the answers are obtained. The solutions and data have been carefully prepared and reviewed for accuracy and coordination with the textbook. Chapter summaries, study hints, and self-test materials for each chapter are included.

**Instructor's Resource Manual**, by Theodore Sakano, and **Prentice Hall Test Manager** The *Manual* includes chapter overviews, lecture outlines, learning objectives, suggested readings, and 1500 multiple choice test questions. The *Test Manager* provides these questions on disk in either IBM® or MacIntosh® format and includes an editing feature that allows questions to be added or changed.

**Laboratory Manual and Instructor's Manual to Laboratory Manual**, by Scott Mohr and Susan Griffin The *Laboratory Manual* provides 24 laboratory experiments adaptable to either two- or three-hour laboratory periods. The *Instructor's Manual* includes detailed descriptions of all necessary chemicals, supplies, and equipment, as well as answers to pre-lab questions, typical student results, and completed report forms.

**How to Study Chemistry,** by Vernon Burger This free supplement contains problem-solving strategies, helpful hints for learning and achieving success in chemistry, and a mathematics review.

**Transparencies** A set of 100 two-color and four-color transparencies from this and other Prentice Hall chemistry texts is available.

**Additional resources** A collection of timely news stories from *The New York Times*, described elsewhere in the opening pages of this book, and several video packages are available upon adoption. For further information please contact your local Prentice Hall sales representative.

### **ACKNOWLEDGMENTS**

It is a pleasure to thank the many people whose help and suggestions were so valuable in preparing Fundamentals of General, Organic, and Biological Chemistry, on which this book is based. We especially thank Leslie Kinsland, University of Southwestern Louisiana, for her assistance with questions and problems. The persons listed below provided many excellent suggestions after reviewing all or part of the manuscript. In particular, John M. Daly, Leland Harris, Larry Jackson, Gloria G. Lyle, and Les Wynston travelled across the country to make significant contributions for which we are very grateful, and Larry Jackson helped out with the special topic boxes for Chapter 16.

James N. Beck

McNeese State University

Richard E. Beitzel

Bemidji State University

Rodney Buyer

Hope College

John M. Daly

Bellarmine College

Lindsley Foote (Retired)

Western Michigan State University

Leland Harris

University of Arizona

Kenneth I. Hardcastle

California State University, Northridge

Merrill Hugo

Shasta College

Larry L. Jackson

Montana State University

Gloria G. Lyle

University of Texas, San Antonio

Frank R. Milio

Towson State University

Danny V. White

American River College

Karen Wiechelman

University of Southwestern Louisiana

Donald W. Williams

Hope College

Leslie Wynston

California State University, Long

Beach

In addition, the book benefited from the careful reading of galley proofs by Clyde Metz, College of Charleston, and by Leland Harris, University of Arizona. During production, the persistence and professionalism of John Morgan, Production Editor, Prentice Hall; Tobi Zausner, Photo Researcher; and Diane Koromhas, Layout Artist were greatly appreciated. We further extend our thanks to Susan Fisher, Production Editor for this book, and to everyone on the capable staff of Prentice Hall, both those named on the copyright page and the many others who worked and continue to work for the success of our books.

### A Note to the Student

Here you are, about to study organic and biological chemistry, perhaps for the first time. The topics you are about to study will be useful in all health-related professions and in many business endeavors. The chemistry you are introduced to in this book will also be useful in exercising judgment in everyday life. Newspapers and magazines are filled with chemistry-related stories about protecting the environment, about new materials designed to improve the quality of life, and about drugs that promise to revolutionize medical care. The better you understand such matters, the better you will be able to function in today's society.

The following suggestions should prove helpful in your study:

**Don't read the text immediately.** As you begin each new chapter, look it over first. Read the introductory paragraphs and familiarize yourself with the chapter goals. Find out what topics are covered, and take a look at the illustrations—to get a feel for the topics at hand. Then turn to the end of the chapter and read the summary. You'll be in a much better position to learn new material if you first have a general idea of where you're going.

Work the problems. The problems are designed to give you practice in the skills necessary to understand and use chemistry. There are no shortcuts here. The sample problems illustrate the skills, the in-chapter practice problems provide immediate practice, and the end-of-chapter problems provide additional drill. Brief answers to inchapter practice problems and most even-numbered review problems are given at the end of this book.

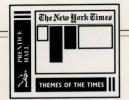
Use the study guide. Complete answers and explanations for all problems, along with chapter outlines, additional study hints, and self-tests, are given in the *Study Guide* and *Solutions Manual* that accompanies this text. The *Study Guide* can be extremely

useful when you're working problems and when you're studying for an exam. Investigate what's there now so you'll know where to find help when you need it.

**Ask questions.** Faculty members and teaching assistants are there to help you learn. Don't hesitate because you think a question might be stupid or silly. If it's something you need to know to get on with understanding chemistry, it's always a good question.

Many of the words and symbols that lie ahead in this book may at first seem strange to you. We urge you not to let their unfamiliarity cause you to lose sight of your goals: to learn about the amazing kinds of chemistry that keep us all alive and well, and to understand the impact of chemistry on everyday life.

John McMurry Mary E. Castellion



### The New York Times Program

The New York Times and Prentice Hall are sponsoring a THEMES OF THE TIMES, a program designed to enhance student access to current information of relevance in the classroom.

Through this program, the core subject matter provided in the text is supplemented by a collection of time-sensitive articles from one of the world's most distinguished newspapers, *The New York Times*. These articles demonstrate the vital, ongoing connection between what is learned in the classroom and what is happening in the world around us.

To enjoy the wealth of information of *The New York Times* daily, a reduced subscription rate is available in deliverable areas. For information, call toll-free: 1-800-631-1222.

Prentice Hall and *The New York Times* are proud to co-sponsor THEMES OF THE TIMES. We hope it will make the reading of both textbooks and newspapers a more dynamic, involving process.

### SOME IMPORTANT FAMILIES OF ORGANIC MOLECULES

Family Name	Functional Group Structure <sup>a</sup>	Simple Example	Name Ending
Alkane	(contains only C—H and C—C single bonds)	CH <sub>3</sub> CH <sub>3</sub> ethane	-ane
Alkene	C=C'	$H_2C=CH_2$ ethylene	-ene
Alkyne	-C≡C-	H—C≡C—H acetylene (ethyne)  H H	-yne
Arene		C=C H-C C-H benzene	none
Alkyl halide <sup>b</sup>	-c-x	H H CH <sub>3</sub> —Cl methyl chloride	none
Alcohol	-С-О-Н	CH <sub>3</sub> —OH methyl alcohol (methanol)	-ol
Ether	-c-o-c-	CH <sub>3</sub> —O—CH <sub>3</sub> dimethyl ether	none
Amine	_N_H, _N_H, _N_   	CH <sub>3</sub> —NH <sub>2</sub> methylamine	-amine
	0	O	
Aldehyde	H	CH <sub>3</sub> —C—H acetaldehyde (ethanal)	-al
Ketone	-C-C-C-	CH <sub>3</sub> —C—CH <sub>3</sub> acetone	-one
Carboxylic acid	О    СОН	O    CH <sub>3</sub> —C—OH acetic acid	-ic acid
Anhydride	0 0 	O O O O O O O O O O O O O O O O O O O	none
Ester	0  -  - 	CH <sub>3</sub> —C—O—CH <sub>3</sub> methyl acetate	-ate
Amide	$\begin{matrix} O & O & O \\ \parallel & \parallel & \parallel \\ -C-NH_2, -C-N-H, -C-N- \end{matrix}$	CH <sub>3</sub> —C—NH <sub>2</sub> acetamide	-amide

<sup>&</sup>quot;The bonds whose connections aren't specified are assumed to be attached to carbon or hydrogen atoms in the rest of the molecule.  ${}^{b}X = F$ , Cl, Br, or I.

学 \$41.24 P \*\* \*\*

### ELEMENTS ESSENTIAL FOR HUMAN LIFE

Element	Symbol	Function
Carbon	c )	
Hydrogen	Н	These four elements are present throughout all living
Oxygen	0	organisms.
Nitrogen	N	
Calcium	Ca	Necessary for growth of teeth and bones
Chlorine	Cl	Necessary for maintaining salt balance in body fluids
Chromium	Cr	Aids in carbohydrate metabolism
Cobalt	Co	Component of vitamin B-12
Copper	Cu	Necessary to maintain blood chemistry
Fluorine	F	Aids in development of teeth and bones
Iodine	I	Necessary for thyroid function
Iron	Fe	Necessary for oxygen-carrying ability of blood
Magnesium	Mg	Necessary for bones, teeth, and muscle and nerve action
Manganese	Mn	Necessary for carbohydrate metabolism and bone formation
Molybdenum	Mo	Component of enzymes necessary for metabolism
Phosphorus	P	Necessary for growth of bones and teeth; present in DNA/RNA
Potassium	K	Component of body fluids; necessary for nerve action
Selenium	Se	Aids in vitamin E action and fat metabolism
Sodium	Na	Component of body fluids; necessary for nerve and muscle action
Sulfur	S	Component of proteins; necessary for blood clotting
Zinc	Zn	Necessary for growth, healing, and overall health

### TABLES AND FIGURES USEFUL FOR REFERENCE

Description	Table or Figure	Description	Table or Figure
Common alkyl groups	Table 1.5	Triacylglycerol metabolism	Figure 13.6
Amino acids	Table 7.1	Fatty acid spiral	Figure 13.8
Catabolism overview	Figure 9.6	Fatty acid biosynthesis	Figure 13.10
Citric acid cycle	Figure 9.11	Protein digestion	Figure 14.1
p-Glucose structure	Figure 10.4	Protein and amino acid metabolism	Figure 14.3
Carbohydrate digestion	Figure 11.2	Urea cycle	Figure 14.7
Glucose metabolism	Figure 11.4	DNA replication	Figure 15.6
Glycolysis	Figure 11.5	Protein synthesis	Figure 15.11
Families of lipids	Figure 12.2	Cations and anions in body fluids	Figure 16.2
Cell membrane	Figure 12.9	Composition of whole blood	Figure 16.5
Triacylglycerol digestion	Figure 13.1	•	

### Contents

Applications and Interludes xi

Preface xii

A Note to the Student xvii



### CHAPTER 1 Introduction to Organic Chemistry: Alkanes 2

- 1.1 The Nature of Organic Molecules 3
- 1.2 Families of Organic Molecules: Functional Groups 6
- 1.3 The Structure of Organic Molecules: Alkanes and Their Isomers 9
  An Application: Natural vs. Synthetic 12
- 1.4 Drawing Organic Structures 12
- 1.5 The Shapes of Organic Molecules 14
  An Application: Displaying Molecular Shapes 16
- 1.6 Naming Alkanes 17
- 1.7 Properties of Alkanes 22
- 1.8 Chemical Reactions of Alkanes 23
- 1.9 Cycloalkanes 25
- 1.10 Drawing and Naming Cycloalkanes 26
  Interlude: Petroleum 28
  Summary 28
  Review Problems 29



### CHAPTER 2 Alkenes, Alkynes, and Aromatic Compounds 33

- 2.1 Saturated and Unsaturated Hydrocarbons 35
- 2.2 Alkenes 35
- 2.3 Naming Alkenes and Alkynes 35
- 2.4 The Structure of Alkenes: Cis-trans Isomerism 38
- 2.5 Properties of Alkenes 41
  An Application: The Chemistry of Vision 42
- 2.6 Chemical Reactions of Alkenes and Alkynes 43
- 2.7 How an Alkene Addition Reaction Occurs 48
- 2.8 Alkene Polymers 49
  An Application: Isoprene, Terpenes, and Natural Rubber 50
- 2.9 Alkynes 53
- 2.10 Aromatic Compounds and the Structure of Benzene 54
- 2.11 Naming Aromatic Compounds 54
- 2.12 Chemical Reactions of Aromatic Compounds 58
- 2.13 Polycyclic Aromatic Compounds and Cancer 59
  Interlude: Color in Unsaturated Compounds 60
  Summary 61

Review Problems 62

### CHAPTER 3 Some Compounds with Oxygen, Sulfur, or Halogens 66

- 3.1 Alcohols, Phenols, and Ethers 68
- 3.2 Some Common Alcohols 69
- 3.3 Naming Alcohols 71
- 3.4 Properties of Alcohols 74
- 3.5 Chemical Reactions of Alcohols 75
- 3.6 Phenols 79
  An Application: Ethyl Alcohol as a Drug and Poison 80
- 3.7 Acidity of Alcohols and Phenols 81
  An Application: Antioxidants 83
- 3.8 Names and Properties of Ethers 84
- 3.9 Some Common Ethers 85
- 3.10 Sulfur-containing Compounds: Thiols and Disulfides 86
- 3.11 Halogen-containing Compounds 88

  Interlude: Chlorofluorocarbons and the Ozone Layer 90

  Summary 91

  Review Problems 91

### CHAPTER 4 Amines 95

- 4.1 Amines *96*
- 4.2 Naming Amines 97
- 4.3 Heterocyclic Nitrogen Compounds 98
- 4.4 Properties of Amines 99
  An Application: Chemical Information 101



	An Application: Organic Compounds in Body Fluids 108 4.8 Amines in Plants 109 4.9 Amines in Drugs 111 Interlude: Prodrugs 114 Summary 114 Review Problems 115
WAY.	CHAPTER 5 Aldehydes and Ketones 119
	<ul> <li>5.1 Kinds of Carbonyl Compounds 120</li> <li>5.2 Naming Aldehydes and Ketones 122</li> <li>5.3 Properties of Aldehydes and Ketones 123</li> <li>5.4 Some Common Aldehydes and Ketones 125 An Application: Is It Poisonous or Isn't It? 128</li> </ul>
	<ul> <li>5.5 Oxidation of Aldehydes 128</li> <li>5.6 Reduction of Aldehydes and Ketones 131</li> <li>5.7 Reaction With Alcohols: Hemiacetals and Acetals 133</li> <li>5.8 Aldol Reaction of Aldehydes and Ketones 138         <ul> <li>An Application: A Biological Aldol Reaction 139</li> <li>Interlude: Chemical Warfare in Nature 141</li> <li>Summary 142</li> <li>Review Problems 142</li> </ul> </li> </ul>
	CHAPTER 6 Carboxylic Acids and Their Derivatives 146
CARLES LA CONTROL OF THE PARTY	<ul> <li>6.1 Properties of Carboxylic Acids and Their Derivatives 148</li> <li>6.2 Naming Carboxylic Acids and Their Derivatives 150</li> <li>6.3 Some Common Carboxylic Acids 155</li> <li>6.4 Acidity of Carboxylic Acids 156</li> </ul>
Control 233	An Application: Acid Salts as Food Additives 158 6.5 Reactions of Carboxylic Acids: Ester Formation 159 6.6 Some Common Esters 161 An Application: Thiol Esters—Biological Carboxylic Acid Derivatives 162
	6.7 Reactions of Esters: Hydrolysis 164 6.8 Reactions of Esters: Claisen Condensation 165 6.9 Reactions of Carboxylic Acids: Amide Formation 167 6.10 Reactions of Amides: Hydrolysis 169
	6.11 Acid Anhydrides 171 6.12 Phosphate Esters and Anhydrides 171 6.13 Organic Reactions 174 Interlude: Polyamides and Polyesters 176 Summary 177 Review Problems 177

4.5 Basicity of Amines 103 4.6 Ammonium Salts 105

4.7 Amines in Biomolecules 107

