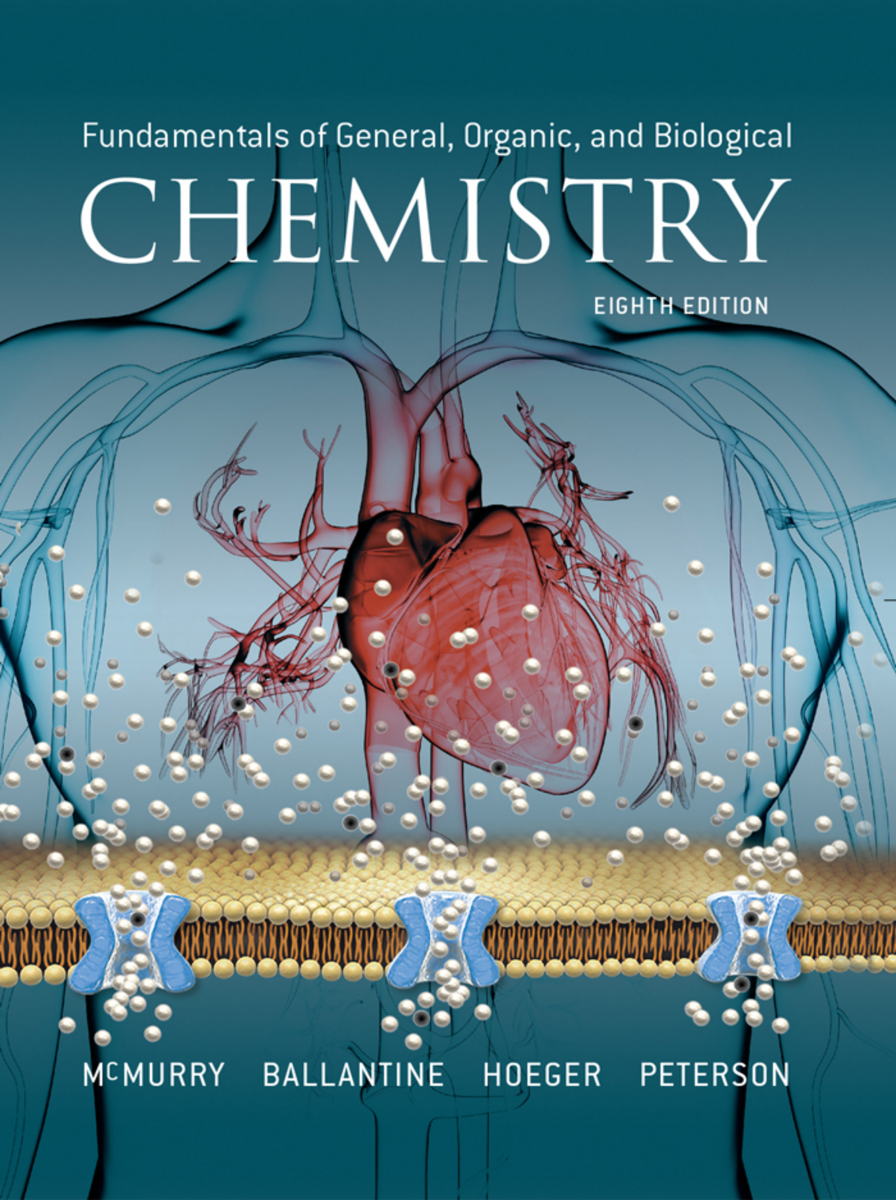
Fundamentals of General, Organic, and Biological

CHEMISTRY

EIGHTH EDITION



McMURRY BALLANTINE HOEGER PETERSON

Periodic Table of the Elements

Main groups: 1A (1), 2A (2), 3A (13)–8A (18)

Transition metal groups: 3B (3) – 2B (12)

Period	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8	8B 9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 **H** 1.00794																	2 **He** 4.00260
2	3 **Li** 6.941	4 **Be** 9.01218											5 **B** 10.81	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.1797
3	11 **Na** 22.98977	12 **Mg** 24.305											13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.9738	16 **S** 32.066	17 **Cl** 35.4527	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.996	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.710	51 **Sb** 121.757	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
6	55 **Cs** 132.9054	56 **Ba** 137.33	57 ***La** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0254	89 **†Ac** 227.0278	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)	112 **Cn** (285)	113 (284)	114 (289)	115 (288)	116 (292)	117 (293)	118 (294)

Lanthanides	58 **Ce** 140.12	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.965	64 **Gd** 157.25	65 **Tb** 158.9254	66 **Dy** 162.50	67 **Ho** 164.9304	68 **Er** 167.26	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
Actinides	90 **Th** 232.0381	91 **Pa** 231.0399	92 **U** 238.0289	93 **Np** 237.048	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Metals Metalloids Nonmetals

List of the Elements with Their Atomic Symbols and Atomic Weights

Name	Symbol	Atomic Number	Atomic Weight	Name	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	227.028	Meitnerium	Mt	109	(268)
Aluminum	Al	13	26.9815	Mendelevium	Md	101	(258)
Americium	Am	95	(243)	Mercury	Hg	80	200.59
Antimony	Sb	51	121.757	Molybdenum	Mo	42	95.94
Argon	Ar	18	39.948	Neodymium	Nd	60	144.24
Arsenic	As	33	74.9216	Neon	Ne	10	20.1797
Astatine	At	85	(210)	Neptunium	Np	93	237.048
Barium	Ba	56	137.33	Nickel	Ni	28	58.69
Berkelium	Bk	97	(247)	Niobium	Nb	41	92.9064
Beryllium	Be	4	9.01218	Nitrogen	N	7	14.0067
Bismuth	Bi	83	208.9804	Nobelium	No	102	(259)
Bohrium	Bh	107	(264)	Osmium	Os	76	190.2
Boron	B	5	10.81	Oxygen	O	8	15.9994
Bromine	Br	35	79.904	Palladium	Pd	46	106.42
Cadmium	Cd	48	112.41	Phosphorus	P	15	30.9738
Calcium	Ca	20	40.078	Platinum	Pt	78	195.08
Californium	Cf	98	(251)	Plutonium	Pu	94	(244)
Carbon	C	6	12.011	Polonium	Po	84	(209)
Cerium	Ce	58	140.12	Potassium	K	19	39.0983
Cesium	Cs	55	132.905	Praseodymium	Pr	59	140.9077
Chlorine	Cl	17	35.4527	Promethium	Pm	61	(145)
Chromium	Cr	24	51.996	Protactinium	Pa	91	231.0399
Cobalt	Co	27	58.9332	Radium	Ra	88	226.0254
Copernicium	Cn	112	(285)	Radon	Rn	86	(222)
Copper	Cu	29	63.546	Rhenium	Re	75	186.207
Curium	Cm	96	(247)	Rhodium	Rh	45	102.9055
Darmstadtium	Ds	110	(271)	Roentgenium	Rg	111	(272)
Dubnium	Db	105	(262)	Rubidium	Rb	37	85.4678
Dysprosium	Dy	66	162.50	Ruthenium	Ru	44	101.07
Einsteinium	Es	99	(252)	Rutherfordium	Rf	104	(261)
Erbium	Er	68	167.26	Samarium	Sm	62	150.36
Europium	Eu	63	151.965	Scandium	Sc	21	44.9559
Fermium	Fm	100	(257)	Seaborgium	Sg	106	(266)
Fluorine	F	9	18.9984	Selenium	Se	34	78.96
Francium	Fr	87	(223)	Silicon	Si	14	28.0855
Gadolinium	Gd	64	157.25	Silver	Ag	47	107.8682
Gallium	Ga	31	69.72	Sodium	Na	11	22.98977
Germanium	Ge	32	72.61	Strontium	Sr	38	87.62
Gold	Au	79	196.9665	Sulfur	S	16	32.066
Hafnium	Hf	72	178.49	Tantalum	Ta	73	180.9479
Hassium	Hs	108	(269)	Technetium	Tc	43	(98)
Helium	He	2	4.00260	Tellurium	Te	52	127.60
Holmium	Ho	67	164.9304	Terbium	Tb	65	158.9254
Hydrogen	H	1	1.00794	Thallium	Tl	81	204.383
Indium	In	49	114.82	Thorium	Th	90	232.0381
Iodine	I	53	126.9045	Thulium	Tm	69	168.9342
Iridium	Ir	77	192.22	Tin	Sn	50	118.710
Iron	Fe	26	55.847	Titanium	Ti	22	47.88
Krypton	Kr	36	83.80	Tungsten	W	74	183.85
Lanthanum	La	57	138.9055	Uranium	U	92	238.0289
Lawrencium	Lr	103	(262)	Vanadium	V	23	50.9415
Lead	Pb	82	207.2	Xenon	Xe	54	131.29
Lithium	Li	3	6.941	Ytterbium	Yb	70	173.04
Lutetium	Lu	71	174.967	Yttrium	Y	39	88.9059
Magnesium	Mg	12	24.305	Zinc	Zn	30	65.39
Manganese	Mn	25	54.9380	Zirconium	Zr	40	91.224

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CHEMISTRY

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CHEMISTRY

Eighth Edition

John McMurry
Cornell University

David S. Ballantine
Northern Illinois University

Carl A. Hoeger
University of California, San Diego

Virginia E. Peterson
University of Missouri, Columbia

with contributions by

Sara Madsen

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About the Authors

John McMurry, educated at Harvard and Columbia, has taught approximately 17,000 students in general and organic chemistry over a 30-year period. A professor of chemistry at Cornell University since 1980, Dr. McMurry previously spent 13 years on the faculty at the University of California at Santa Cruz. He has received numerous awards, including the Alfred P. Sloan Fellowship (1969–1971), the National Institute of Health Career Development Award (1975–1980), the Alexander von Humboldt Senior Scientist Award (1986–1987), and the Max Planck Research Award (1991).

David S. Ballantine received his B.S. in Chemistry in 1977 from the College of William and Mary in Williamsburg, VA, and his Ph.D. in Chemistry in 1983 from the University of Maryland at College Park. After several years as a researcher at the Naval Research Labs in Washington, DC, he joined the faculty in the Department of Chemistry and Biochemistry of Northern Illinois University, where he has been a professor since 1989. He was awarded the Excellence in Undergraduate Teaching Award in 1998. Since then, he has served as the coordinator for the Introductory and General Chemistry programs, with responsibilities for supervision of supervising the laboratory teaching assistants. He served as the departmental director of undergraduate studies from 2008 to 2014 and is currently the associate dean for undergraduate affairs in the College of Liberal Arts and Sciences. He continues to teach in the Department of Chemistry and Biochemistry.

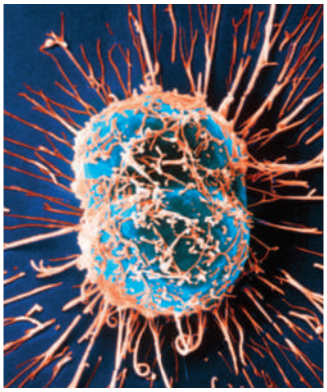
Carl A. Hoeger received his B.S. in Chemistry from San Diego State University and his Ph.D. in Organic Chemistry from the University of Wisconsin–Madison in 1983. After a postdoctoral stint at the University of California–Riverside, he joined the Peptide Biology Laboratory at the Salk Institute in 1985, where he supervised the NIH Peptide Facility while doing basic research in the development of peptide agonists and antagonists. During this time, he also taught general, organic, and biochemistry at San Diego City College, Palomar College, and Miramar College. He joined the teaching faculty at University of California–San Diego (UCSD) in 1998. Dr. Hoeger has been teaching chemistry to undergraduates for 30 years, where he continues to explore the use of technology in the classroom; his current project involves the use of video podcasts as adjuncts to live lectures, along with the use of tablets to deliver real-time lectures with slide annotations. In 2004, he won the Barbara and Paul Saltman Distinguished Teaching Award from UCSD. He is deeply involved with both the general and organic chemistry programs at UCSD and has shared partial responsibility for the training and guidance of teaching assistants and new instructors in the Chemistry and Biochemistry department.

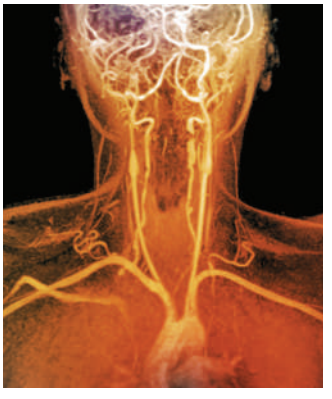
Virginia E. Peterson received her B.S. in Chemistry in 1967 from the University of Washington in Seattle and her Ph.D. in Biochemistry in 1980 from the University of Maryland at College Park. Between her undergraduate and graduate years, she worked in lipid, diabetes, and heart disease research at Stanford University. Following her Ph.D., she took a position in the Biochemistry Department at the University of Missouri in Columbia and is now professor emerita. When she retired in 2011, she had been the director of undergraduate advising for the department for 8 years and had taught both senior capstone classes and biochemistry classes for nonscience majors. Although retired, Dr. Peterson continues to advise undergraduates and teach classes. Awards include both the college-level and the university-wide Excellence in Teaching Award and, in 2006, the University's Outstanding Advisor Award and the State of Missouri Outstanding University Advisor Award. Dr. Peterson believes in public service and in 2003 received the Silver Beaver Award for service from the Boy Scouts of America. In retirement, she continues her public service activities by participating in a first-year medical student mentoring program and her more than 25-year commitment to the Boy Scouts of America as an active adult volunteer.

Sara K. Madsen received her B.S. in Chemistry at Central Washington University in Ellensburg, Washington, in 1988 and her Ph.D in Inorganic Chemistry at the University of Wyoming in 1998. She has been teaching since 2001. The beginning of her teaching career started with a one-semester survey course and moved from there to courses in general, organic, and biochemistry, general chemistry, organic and inorganic chemistry for undergraduates, and inorganic chemistry for graduate students. She loves helping students develop the connections between ideas and concepts and, above all, exposing their realization about how chemistry is involved in their program of study or professional path.

Brief Contents

Contents





Features

CHEMISTRY IN ACTION

MASTERING REACTIONS

HANDS-ON CHEMISTRY

Preface

This textbook and its related digital resources provide students in the allied health sciences with a needed background in chemistry and biochemistry while offering a general context for chemical concepts to ensure that students in other disciplines gain an appreciation of the importance of chemistry in everyday life.

To teach chemistry all the way from “What is an atom?” to “How do we get energy from glucose?” is a challenge. Throughout our general chemistry and organic chemistry coverage, the focus is on concepts fundamental to the chemistry of living things and everyday life. In our biochemistry coverage, we strive to meet the further challenge of providing a context for the application of those concepts in biological systems. Our goal is to provide enough detail for thorough understanding while avoiding so much detail that students are overwhelmed. Many practical and relevant examples are included to illustrate the concepts and enhance student learning.

The material covered is ample for a two-term introduction to general, organic, and biological chemistry. While the general and early organic chapters contain concepts that are fundamental to understanding the material in biochemistry, the later chapters can be covered individually and in an order that can be adjusted to meet the needs of the students and the duration of the course.

The writing style is clear and concise and punctuated with practical and familiar examples from students’ personal experience. Art work, diagrams, and molecular models are used extensively to provide graphical illustration of concepts to enhance student understanding. Since the true test of knowledge is the ability to apply that knowledge appropriately, we include numerous worked examples that incorporate consistent problem-solving strategies.

Regardless of their career paths, all students will be citizens in an increasingly technological society. When they recognize the principles of chemistry at work not just in their careers but in their daily lives, they are prepared to make informed decisions on scientific issues based on a firm understanding of the underlying concepts.

New to This Edition

The major themes of this revision are active learning, an increased focus on clinical examples, updates based on current teaching and research findings, and digital innovations designed to engage and personalize the experience for students, all of which are accomplished in a variety of ways:

- **NEW! Chapter opening photos and vignettes** with an increased clinical focus have been added to provide a theme for each chapter and to strengthen connections between the concepts and applications in Chemistry in Action features in the chapter.
- **NEW! Chapters now have a more focused roadmap** that begins with specific learning objectives and ends with a summary study guide that addresses these initial goals and offers students targeted problems designed to help them assess their ability to understand those topics.
- **NEW! Hands-On Chemistry** boxes offer students an opportunity to solidify their understanding of chemistry through elementary experiments that can be safely done in their living spaces with household items. Many students strongly benefit from kinesthetic activities, and regardless of whether this is their “preferred” style, the evidence suggests that variety in exposure to concepts is by itself tremendously valuable.
- **NEW! Interactive Worked Examples** have been developed and are identified in the text with special icons, with video tutorials linked to the problem to help students master key concepts.
- **NEW! In-chapter questions have been added to the Chemistry in Action and Mastering Reactions** features to reinforce the connection between the chapter content and practical applications.

- **NEW! Concept Maps** have been added to most chapters, and others have been modified to draw connections between general, organic, and biological chemistry.
- **Updated Concept Links** offer visual reminders for students that indicate when new material builds on concepts from previous chapters or foreshadow related material that will be explained in more detail in future chapters.
- **Updated questions in the end-of-chapter section build on Concept Links** and require students to recall information learned in previous chapters.
- **Chemistry in Action** features (many with a clinical focus) extend the discussion of major chapter topics in new ways, providing students with enhanced perspective on core concepts relevant to their future careers.
- **All Learning Objectives tied to EOC problem sets:** Chapter summaries include a list of EOC problems that correspond to the learning objectives for a greater connection between problems and concepts.
- **NEW! Group Problems** at the end of every chapter are ideally used in class to get students to carefully think about higher level problems, such as how concepts fit together, or to put the concepts they have learned to use in a clinical application.
- **Chapters 1 and 2** have been restructured: Chapter 1 focuses on building math skills, while Chapter 2 focuses on matter, atomic structure, and the periodic table.
- **An expanded discussion of stereochemistry and chirality** has been moved to Chapter 14 to allow instructors and students more time to get used to this challenging topic before coming across it again in biochemistry. The concept of symmetry has also been introduced in this section.
- **Chapter 16 is now the chapter on amines**, allowing the discussion of organic bases and acids (Chapter 17) to flow together, whereas in the seventh edition, they were separated by the ketone and aldehyde chapter, which is now Chapter 15.
- **Chapter 20 is now the chapter on carbohydrates**, preceding the discussion of energy generation (now Chapter 21) and carbohydrate metabolism.
- **Chapter 25 is now the chapter on protein metabolism**, completing the discussions of metabolism before addressing DNA (Chapter 26) and Genomics (Chapter 27).

Organization

General Chemistry: Chapters 1–11 The introduction to elements, atoms, the periodic table, and the quantitative nature of chemistry (Chapters 1 and 2) is followed by chapters that individually highlight the nature of ionic and molecular compounds (Chapters 3 and 4). The next three chapters discuss chemical reactions and their stoichiometry, energies, rates, and equilibria (Chapters 5, 6, and 7). Topics relevant to the chemistry of life follow: Gases, Liquids, and Solids (Chapter 8); Solutions (Chapter 9); and Acids and Bases (Chapter 10). Nuclear Chemistry (Chapter 11) closes the general chemistry sequence.

Organic Chemistry: Chapters 12–17 These chapters concisely focus on what students must know in order to understand biochemistry. The introduction to hydrocarbons (Chapters 12 and 13) includes the basics of nomenclature, which is thereafter kept to a minimum. Discussion of functional groups with single bonds to oxygen, sulfur, or a halogen (Chapter 14) is followed by introducing aldehydes and ketones (Chapter 15), where a double bond between carbon and oxygen plays a key role in their chemistry. A short chapter on organic bases, the amines, which are so important to the chemistry of living things and drugs (Chapter 16) follows. Finally, the chemistry of carboxylic acids and their derivatives (esters and amides) is covered (Chapter 17), with a focus on similarities among the derivatives. Attention to the mechanisms by which organic reactions occur and the vernacular used to describe them has been retained in this edition. Stereochemistry, which is key to the understanding of how biological molecules function as they do, has been moved to Chapter 14 in this edition, allowing students more exposure to this complicated topic before reaching the biological chemistry section of this text.

Biological Chemistry: Chapters 18–29 Rather than proceeding through the complexities of protein, carbohydrate, lipid, and nucleic acid structure before getting to the roles of these compounds in the body, structure and function are integrated in this text. Protein structure (Chapter 18) is followed by enzyme and coenzyme chemistry (Chapter 19). Next, the structure and functions of common carbohydrates are introduced (Chapter 20). With enzymes and carbohydrates introduced, the central pathways and themes of biochemical energy production can be described (Chapter 21). If the time you have available to cover biochemistry is limited, stop with Chapter 21 and your students will have an excellent preparation in the essentials of metabolism. The following chapters cover more carbohydrate chemistry (Chapter 22), then lipid chemistry (Chapters 23 and 24), followed by protein and amino acid metabolism (Chapter 25). Next, we discuss nucleic acids and protein synthesis (Chapter 26) and genomics (Chapter 27). The last two chapters cover the function of hormones and neurotransmitters and the action of drugs (Chapter 28) and provide an overview of the chemistry of body fluids (Chapter 29).

Chapter-by-Chapter Changes

Coverage of General Chemistry

The major revisions in this section involve reorganization or revision of content to strengthen the connections between concepts and to provide a more focused coverage of specific concepts. Concept Maps, included in all general chemistry chapters, reinforce the relationship between topics.

Specific changes to chapters are provided below:

Chapter 1

- Content related to elements and the periodic table was moved to Chapter 2.
- Information on shape-memory alloys was added to the Chemistry in Action "Temperature Sensitive Materials" and the clinical information in the Chemistry in Action "Aspirin" and "A Measurement Example: Obesity and Body Fat" was updated.

Chapter 2

- Content from Chapter 1 on matter and the periodic table was moved to Chapter 2 to provide a more comprehensive and concentrated focus in the chapter.
- Information on the periodic table has been updated to reflect recent discoveries.
- A new Chemistry in Action, "Essential Elements and Group Chemistry," has been added. One Chemistry in Action was eliminated and "Are Atoms Real?" and "Atoms and Light" were revised to strengthen the connections between chapter content and clinical applications.

Chapter 3

- Sections have been reorganized to provide a more logical progression from ions and ion formation to the naming of ions and ionic compounds and finishing with the properties of ionic compounds. Coverage on the octet rule was also expanded and moved to earlier in the chapter.
- The Chemistry in Action "Salt" was streamlined to enhance clarity and relevancy to the student, and clinical information added.

Chapter 4

- Additional tables and text have been added, including a new Worked Example on coordinate covalent bonds, and some figures have been modified to enhance student learning of molecular models and molecular shape.
- Both the Chemistry in Action "VERY Big Molecules" and "Damascenone by Any Other Name Would Smell as Sweet" were updated with new clinical applications and photos.

Chapter 5

- Content from Section 5.3 from the seventh edition (Classes of Chemical Reactions) has been distributed to the individual sections dealing with the types of reactions: 5.3 (Precipitation Reactions), 5.4 (Neutralization Reactions), and 5.5 (Redox Reactions).
- Both Chemistry in Action were streamlined, and the Chemistry in Action "Batteries" was updated with relevant, new clinical applications.

Chapter 6

- The limiting reactant and percent yield discussion was expanded and clarified with new, specific examples to enhance student understanding.
- One Chemistry in Action was eliminated, and others were revised to strengthen the connections between chapter content and practical applications.

Chapter 7

- The quantitative aspects of spontaneity, entropy, enthalpy discussions (including the Worked Example) were revised to enhance clarity, and the Worked Example on drawing energy diagrams was simplified.
- One Chemistry in Action was eliminated, and the Chemistry in Action "Regulation of Body Temperature" was updated with new, practical applications.

Chapter 8

- The qualitative discussions on enthalpy and entropy in Section 8.1 were significantly streamlined.
- Section 8.13 from the seventh edition (Water: A Unique Liquid) has been deleted, and the content has been distributed to other sections to provide relevant examples for key concepts.
- The title to the last section (Section 8.14) was changed to "Change of State Calculations" to more clearly identify the focus for this section and to distinguish the content from the more general discussion on the changes of state of matter in Section 8.1.
- The Chemistry in Action "CO_2 as an Environmentally Friendly Solvent" was updated with new, cutting-edge information on supercritical fluids as they relate to allied health.

Chapter 9

- Section 9.3 (Solid Hydrates) was modified and converted into a new Chemistry in Action, "Solid Hydrates—Salt + Water."
- Section 9.10 from the seventh edition (Electrolytes in Body Fluids) has been modified in the eighth edition and combined with Section 9.9 (Ions in Solution: Electrolytes). References to gram-equivalents have been removed.
- The Chemistry in Action "Time-Release Drug Delivery Systems" was updated with new, clinical content.

Chapter 10

- Sections 10.1 (Acids and Bases in Aqueous Solution) and 10.3 (The Bronsted-Lowry Definition of Acids and Bases) have been combined to highlight the relationship between the various definitions of acids and bases.
- The information in Section 10.2 (Some Common Acids and Bases) has been condensed into Table 10.1.
- Section 10.7 (Measuring Acidity in Aqueous Solution: pH) and Section 10.9 (Laboratory Determinations of Acidity) have been combined to strengthen the connection between these concepts.
- Section 10.12 (Some Common Acid-Base Reactions) has been moved forward in the chapter, and Sections 10.10 (Buffer Solutions), 10.14 (Acidity and Basicity of

Salt Solutions), and 10.13 (Titrations) have been rearranged to improve the logical progression of these concepts.

- The Chemistry in Action "Acid Rain" was updated with new statistics, maps, and bar graphs.

Chapter 11

- Section 11.6 (Radioactive Decay Series) was abbreviated and combined with Section 11.5 (Radioactive Half-Life). A new, additional Worked Example on half-lives was added as metadata indicated students struggled with this concept.
- Sections 11.8 (Detecting Radiation) and 11.9 (Measuring Radiation) were condensed and combined.

Coverage of Organic Chemistry

Since organic and biological chemistry are so tightly allied with one another, a major emphasis has been placed on the introduction of biologically significant molecules throughout the organic chapters in this edition. Emphasis on making the fundamental reactions that organic molecules undergo much clearer to the reader, with particular attention on those reactions encountered again in biochemical transformations has been retained in the Mastering Reactions feature boxes. This boxed feature discusses in relative depth the "how" behind a number of organic reactions. Mastering Reactions has been designed so that they may be integrated into an instructor's lecture or simply left out with no detriment to the material in the text itself, to accommodate those that do not wish to discuss the mechanisms of organic reactions. More emphasis on the use and evaluation of line-angle structure for organic molecules has been added, as this is incredibly important when discussing biomolecules. New to this edition is the inclusion of a more detailed examination of stereochemistry and chirality; its new placement at the end of Chapter 14 will allow students more time to grasp these concepts, but will also allow instructors who do not wish to discuss it to easily omit them. New and updated application features (Chemistry in Action) have been included in almost all the organic chapters, stressing the clinical aspects of the different classes of organic molecules and reflecting current understanding and research into the topics covered. Additionally, each chapter includes a new supplementary feature known as Integrated Worked Examples, which will provide students with tutor-like walkthroughs of topics and reactions they need to be familiar with before heading into the biological chemistry sections of this text.

Other specific changes to chapters are provided below:

Chapter 12

- Several figures were revised and/or simplified for clarity and to enhance understanding. Art was added to help students synthesize complex topics where visuals were previously lacking.
- Table 12.1 has been reworked to highlight the atoms responsible for each functional group.
- Table 12.2 (Common Abbreviations in Organic Chemistry) has been added.
- A three-step mechanism (initiation, propagation, and termination) was added to the halogenation section along with a new Worked Example on drawing halogenated isomers; this Worked Example will be useful throughout the organic chapters in learning to draw isomers of other organic molecules.
- A new Chemistry in Action discussing biological methylation, "How Important Can a Methyl Group Really Be?," has been added, and the Chemistry in Action "Surprising Uses of Petroleum" was updated with new clinical information.
- There is an expanded functional group concept map that will aid in classifying functional groups; this will be included at the end of each of the organic chapters, with coloring added as each functional group family is discussed.

Chapter 13

- Expanded use and discussion of line structures has been added throughout.
- A new Chemistry in Action discussing biologically active alkynes, "Enediyne Antibiotics: A Newly Emerging Class of Antitumor Agents," has been added.

Chapter 14

- Table 14.1 (Common Alcohols and Their Uses) has been added, replacing and expanding on what was previously Section 14.3, making it easier for students to digest.
- A new and expanded discussion of stereochemistry and chirality has been added (Section 14.10), moving the introduction of these topics from Chapter 18 to a more appropriate location in the text.
- Two new Worked Examples, one on drawing alcohols, have been added.
- A new Chemistry in Action discussing the harm ethanol has on fetuses, "Fetal Alcohol Syndrome: Ethyl Alcohol as a Toxin," has been added.

Chapter 15

- Chapter 15, known previously as the amine chapter, now covers aldehydes and ketones.
- The section on common aldehydes and ketones has been shortened by the inclusion of Table15.2 (Common Aldehydes and Ketones and Their Uses) making it easier for students to read.
- The Addition of Alcohols to Aldehydes and Ketones section was revised to clarify the distinction between hemiketals and hemiacetals.
- Worked Examples and problems have been modified to include the early introduction of carbohydrates.
- A new Chemistry in Action discussing anticancer drugs, "When Is Toxicity Beneficial?," has been added.

Chapter 16

- This is now the amine chapter, which was Chapter 15 in the seventh edition.
- The section on alkaloids has been simplified by the inclusion of Table16.2 (Some Alkaloids and Their Properties) making it easier for students to digest the material.
- A new Worked Example on ammonium ions as acids has been included.
- A new Chemistry in Action discussing antidepressants, "Calming a Stormy Mind: Amines as Anti-Anxiety Medications," has been added.

Chapter 17

- The concept of pKa is discussed in Section 17.2; in addition, Table 17.2 now contains pKa values for the acids listed.
- Section 17.3 in the seventh edition has been expanded and converted into a new Chemistry in Action, "Medicinally Important Carboxylic Acids and Derivatives."
- The Worked Example on acid anhydrides has been removed and their coverage is limited in this edition.
- The Chemistry in Action "Medications, Body Fluids, and the 'Solubility Switch'" that was in Chapter 15 in the seventh edition has been updated and moved to the end of this chapter.

Coverage of Biological Chemistry

Biological chemistry, or biochemistry as professionals refer to the subject, is the chemistry of organisms and particularly chemistry at the cellular level—both inside and outside the cell. The foundations of biological chemistry are found in inorganic and organic chemistry, the first two major topics of this textbook. Biological chemistry integrates inorganic and organic chemistry in the study of biological molecules, many of which are large organic molecules with specific cellular roles. As you will see in the following chapters, biological molecules undergo the same reactions studied in the organic chemistry part of this book, and the fundamentals of inorganic chemistry are also important in cells.

Chapter 18

- The chapter was reorganized for a smoother flow that is more pedagogically sound. We now present an overview of proteins first, then discuss amino acids, peptides and peptide bonds, followed by protein structure and chemical properties. The one letter code for each amino acid was added to Table 18.3.
- The chirality discussion is limited to amino acids (the rest of this discussion moved to Chapter 14).
- Diagrams of the specific examples of the forces involved in tertiary protein structure were added.

Chapter 19

- Two new tables and a revised discussion enhance the "Enzyme Cofactors" section.
- The enzyme classification section has a new table describing each classification.
- The vitamins, minerals, and antioxidants section was streamlined for clarity.
- A Mastering Reactions on how to read biochemical reactions has been added.
- The Chemistry in Action "Enzymes in Medical Diagnosis" was updated to reflect current blood chemistry tests used in diagnosis of a heart attack.

Chapter 20

- This is now the carbohydrates chapter.
- Two new tables, one on important monosaccharides and another on disaccharides, make this content easy for students to digest. Both polysaccharides sections were streamlined and combined into one section.

Chapter 21

- This is now the generation of biological energy chapter.
- The first two sections were streamlined by reducing much of the review material from Chapter 7 (a Concept to Review link was added in place of lengthy narrative, directing students back to where they can review the material if necessary) and combined into one section.
- The citric acid cycle is now explained equation by equation with the description of each step directly above the equation for better student understanding.
- The section on reactive oxygen species has been converted into a new Chemistry in Action, "Reactive Oxygen Species and Antioxidant Vitamins."
- The discussion of "uncouplers" has been integrated into a new Chemistry in Action, "Metabolic Poisons."

Chapter 22

- The discussion of the steps in glycolysis was improved by explicitly splitting the descriptions of the reactions into individual steps.
- Most of the discussion of glucose metabolism in diabetes has been moved to a revised and now comprehensive Chemistry in Action "Diagnosis and Monitoring of Diabetes."

Chapter 23

- The Phospholipids and Glycolipids section was reorganized to ensure a smoother, more logical presentation of concepts.
- The Chemistry in Action "Lipids in the Diet" was updated to include some information from the deleted Chemistry in Action "Butter and Its Substitutes" as well as updated dietary and obesity statistics.

- The text discussion of eicosanoids was converted into a new Chemistry in Action, "Eicosanoids: Prostaglandins and Leucotrienes."

Chapter 24

- A clearer explanation of fatty acid activation and beta-oxidation is presented step-by-step with the appropriate biochemical reaction shown with each step's description.
- The discussion of energy yields from fat metabolism was converted into two sequential Worked Examples.
- The Chemistry in Action "Lipids and Atherosclerosis" was combined with information from the deleted Chemistry in Action "Fat Storage: A Good Thing or Not?" and updated to give a new Chemistry in Action, "Fat Storage, Lipids, and Atherosclerosis."

Chapter 25

- This chapter, Protein and Amino Acid Metabolism, was Chapter 27 in the seventh edition.
- The Chemistry in Action "The Importance of Essential Amino Acids and Effects of Deficiencies" on essential amino acids has been updated with new clinical information and streamlined.

Chapter 26

- Changes were made to the figure showing DNA replication to clarify copying of the opposite strands.
- The Chemistry in Action "Influenza: Variations on a Theme" now focuses on the nature of the common influenza viruses, primarily type A, and zoonotic pools for the mutating virus.

Chapter 27

- This chapter, "Genomics," was Chapter 26 in the seventh edition.
- The Chemistry in Action on the polymerase chain reaction has been shortened and streamlined.
- The Chemistry in Action "DNA Fingerprinting" has been updated to include PCR fingerprinting.

Chapter 28

- This chapter is now focused only on the messenger aspect of these peptides, amino acid derivatives, and steroids.
- Table 28.2, "Acetylcholine Drug Family" (therapeutic or poisonous), has been added to clarify this section for students.
- The steroid-abuse section was condensed to increase relevance for the student.

Chapter 29

- A new Chemistry in Action on common blood tests, "What's in Your Blood Test?," has been added and the Chemistry in Action "Blood–Brain Barrier" was updated with new clinical information.

Acknowledgments

Although this text is now in its eighth edition, each revision has aspired to improve the quality and accuracy of the content and emphasize its relevance to the student users. Achieving this goal requires the coordinated efforts of a dedicated team of editors and media experts. Without them, this textbook would not be possible.

On behalf of all my coauthors, I would like to thank Jeanne Zalesky (Editor in Chief), Chris Hess (Senior Acquisitions Editor) and Scott Dustan (Senior Acquisitions Editor) for building an excellent team for this project. Thanks also to Andrea Stefanowicz (Production Manager), Eric Schrader (Photo Researcher), Sarah Shefveland (Program Manager), and Lindsey Pruett (Editorial Assistant) for their attention to detail as we moved forward. Coleen Morrison, our developmental editor, deserves special recognition for providing invaluable feedback—her painstaking perusal of each chapter and her eye for details have contributed greatly to the accessibility and relevance of the text. Very special thanks also to Beth Sweeten, Senior Project Manager, who patiently guided the process and worked closely with us—thank you for your flexibility and dedication to the success of this project.

The value of this text has also been enhanced by the many individuals who have worked to improve the ancillary materials. Particular thanks to Emily Halvorson for her efforts to ensure the accuracy of the answers to problems provided in the text and Susan McMurry for her revisions to the solutions manual. Thanks to Kyle Doctor, Jackie Jakob, Sara Madsen and Dario Wong for their work on the media supplements. Thanks also to Margaret Trombley, Kristin Mayo, and Jayne Sportelli for their efforts to expand and improve MasteringChemistry™.

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John Sullivan, *Highland Community College*
Deborah E. Swain, *North Carolina Central University*
Susan T. Thomas, *University of Texas–San Antonio*
Richard Triplett, *Des Moines Area Community College*
Yakov Woldman, *Valdosta State University*

The authors are committed to maintaining the highest quality and accuracy and look forward to comments from students and instructors regarding any aspect of this text and supporting materials. Questions or comments should be directed to the lead coauthor.

David S. Ballantine
dballant@niu.edu

Increased Focus on Clinical Relevancy

Active learning, an increased focus on clinical examples, updates based on current teaching and research findings, and digital innovations designed to engage and personalize students' experiences make the eighth edition of *Fundamentals of General, Organic, and Biological Chemistry* simply the best choice for students with a future in allied health.

NEW! Chapter-opening stories and visuals throughout the text have a greater clinical focus, providing even more relevance to allied health majors. Throughout the chapters, Learning Objectives follow each section head, and each chapter ends with a summary study guide offering students targeted problems designed to help them assess their ability to understand those topics.

13

Alkenes, Alkynes, and Aromatic Compounds

CONTENTS

13.1 Alkenes and Alkynes
13.2 Naming Alkenes and Alkynes
13.3 The Structure of Alkenes: Cis–Trans Isomerism
13.4 Properties of Alkenes and Alkynes
13.5 Types of Organic Reactions
13.6 Addition Reactions of Alkenes
13.7 Alkene Polymers
13.8 Aromatic Compounds and the Structure of Benzene
13.9 Naming Aromatic Compounds
13.10 Reactions of Aromatic Compounds

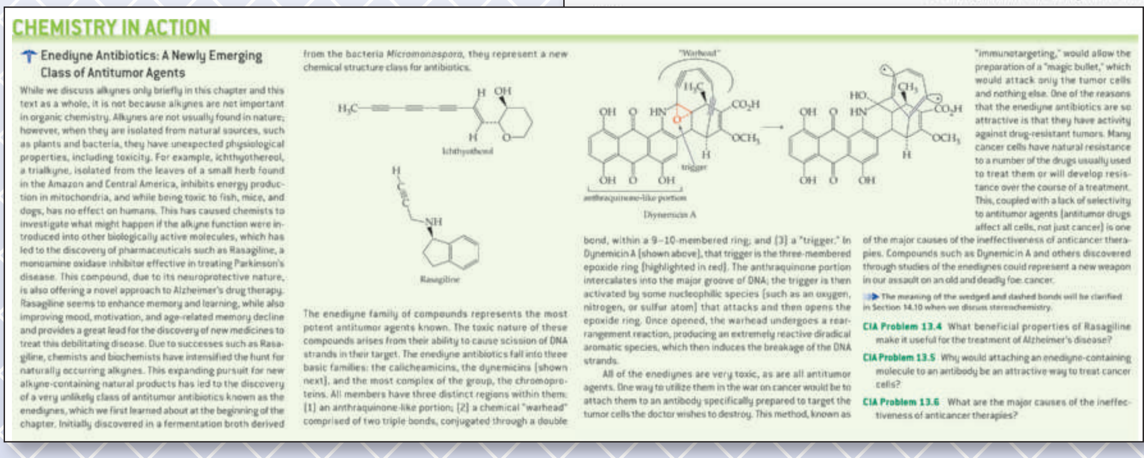
CONCEPTS TO REVIEW

A. VSEPR and Molecular Shapes (Section 4.8)
B. Families of Organic Molecules: Functional Groups (Section 12.2)
C. Drawing Organic Structures (Section 12.4)
D. The Shapes of Organic Molecules (Section 12.5)
E. Naming Alkanes (Section 12.6)

▲ In the war on cancer, potent new drugs containing carbon–carbon triple bonds are providing hope for the treatment of diseases such as cervical cancer.

Functional groups give organic molecules their characteristic physical, chemical, and biological properties. In Chapter 12, we examined the simplest hydrocarbons, alkanes, which provide the scaffolding upon which the complicated molecules responsible for life are built. Now we will look at the chemistry of molecules that contain carbon–carbon multiple bonds, or *unsaturated hydrocarbons*. While alkenes and aromatic systems are found in many naturally occurring biomolecules, alkynes are not as commonly observed. However, when

CHEMISTRY IN ACTION boxes (many with a clinical focus) extend the discussion of major chapter topics in new ways, providing students with an enhanced perspective on core concepts relevant to their future careers. The final Chemistry in Action box in each chapter ties back to the chapter-opening topic, ensuring the clinical relevancy is woven throughout the chapter from beginning to end.



CHEMISTRY IN ACTION

Enediyne Antibiotics: A Newly Emerging Class of Antitumor Agents

While we discuss alkynes only briefly in this chapter and this text as a whole, it is not because alkynes are not important in organic chemistry. Alkynes are not usually found in nature; however, when they are isolated from natural sources, such as plants and bacteria, they have unexpected physiological properties, including toxicity. For example, ichthyothereol, a trialkyne, isolated from the leaves of a small herb found in the Amazon and Central America, inhibits energy production in mitochondria, and while being toxic to fish, mice, and dogs, has no effect on humans. This has caused chemists to investigate what might happen if the alkyne function were introduced into other biologically active molecules, which has led to the discovery of pharmaceuticals such as Rasagiline, a monoamine oxidase inhibitor effective in treating Parkinson's disease. This compound, due to its neuroprotective nature, is also offering a novel approach to Alzheimer's drug therapy. Rasagiline seems to enhance memory and learning, while also improving mood, motivation, and age-related memory decline and provides a great lead for the discovery of new medicines to treat this debilitating disease. Due to successes such as Rasagiline, chemists and biochemists have intensified the hunt for naturally occurring alkynes. This expanding pursuit for new alkyne-containing natural products has led to the discovery of a very unlikely class of antitumor antibiotics known as the enediynes, which we first learned about at the beginning of the chapter. Initially discovered in a fermentation broth derived from the bacteria *Micromonospora*, they represent a new chemical structure class for antibiotics.

Ichthyothereol

Rasagiline

The enediyne family of compounds represents the most potent antitumor agents known. The toxic nature of these compounds arises from their ability to cause scission of DNA strands in their target. The enediyne antibiotics fall into three basic families: the calicheamicins, the dynemicins (shown next), and the most complex of the group, the chromoproteins. All members have three distinct regions within them: (1) an anthraquinone-like portion; (2) a chemical "warhead" comprised of two triple bonds, conjugated through a double bond, within a 9–10-membered ring; and (3) a "trigger." In Dynemicin A (shown above), that trigger is the three-membered epoxide ring (highlighted in red). The anthraquinone portion intercalates into the major groove of DNA; the trigger is then activated by some nucleophilic species (such as an oxygen, nitrogen, or sulfur atom) that attacks and then opens the epoxide ring. Once opened, the warhead undergoes a rearrangement reaction, producing an extremely reactive diradical aromatic species, which then induces the breakage of the DNA strands.

Dynemicin A

All of the enediynes are very toxic, as are all antitumor agents. One way to utilize them in the war on cancer would be to attach them to an antibody specifically prepared to target the tumor cells the doctor wishes to destroy. This method, known as "immunotargeting," would allow the preparation of a "magic bullet," which would attack only the tumor cells and nothing else. One of the reasons that the enediyne antibiotics are so attractive is that they have activity against drug-resistant tumors. Many cancer cells have natural resistance to a number of the drugs usually used to treat them or will develop resistance over the course of a treatment. This, coupled with a lack of selectivity to antitumor agents (antitumor drugs affect all cells, not just cancer) is one of the major causes of the ineffectiveness of anticancer therapies. Compounds such as Dynemicin A and others discovered through studies of the enediynes could represent a new weapon in our assault on an old and deadly foe: cancer.

The meaning of the wedged and dashed bonds will be clarified in Section 14.10 when we discuss stereochemistry.

CIA Problem 13.4 What beneficial properties of Rasagiline make it useful for the treatment of Alzheimer's disease?

CIA Problem 13.5 Why would attaching an enediyne-containing molecule to an antibody be an attractive way to treat cancer cells?

CIA Problem 13.6 What are the major causes of the ineffectiveness of anticancer therapies?

NEW! These boxes now include questions at the end of the narrative, designed specifically as engaging checkpoints to help students asses their understanding.

Active Learning Leads to Conceptual Understanding

Fundamentals of General, Organic, and Biological Chemistry has always provided a remarkably clear introduction to the broad subject of allied health chemistry in an appealing, applied, and precise manner. In the eighth edition, the authors make learning chemistry more active through features designed to get students doing chemistry.

HANDS-ON CHEMISTRY 3.1

Obtain a set of Lego building blocks and separate them into groups that are one, two, and three units long (if you do not have access to a physical set of blocks, visit www.buildwithchrome.com/builder). The blocks will represent anions and cations that have charges of 1, 2, and 3, respectively. If possible, try to have multiple colors within each group. Label the blocks in each group as follows:

–*One unit long:* Label as Na^+, K^+, Cl^-, and NO_3^-.
–*Two units long:* Label as Mg^{2+}, Ca^{2+}, Fe^{2+}, O^{2-}, and SO_4^{2-}.
–*Three units long:* Label as Al^{3+}, Fe^{3+}, N^{3-}, and PO_4^{3-}.

Try to have at least three blocks for each ion in a given group and, if possible, keep the colors consistent for a given ion; for example, let all Na^+ ions be black, all Cl^- ions be yellow, all O^{2-} ions be blue, and so on.

Using the blocks, assemble the following compound matching anion and cation blocks. Starting with the ca block, connect an anion on top of it. If the anion layer is not long enough for the two layers to match up exactly, add another anion of the same type beside it on top of the cation layer. If the anion layer extends over the end of the cation layer, add another cation to the bottom layer. When the cation and anion layers match exactly in length, count how many of the cation and anion blocks were necessary to determine the formula of the ionic compound.

Try building the compounds suggested next, or make up your own combinations. Just be sure that each compound has a cation and an anion!

a) Cation = Na^+ Anion = SO_4^{2-}
b) Cation = Fe^{2+} Anion = NO_3^-
c) Cation = Mg^{2+} Anion = PO_4^{3-}

HANDS-ON CHEMISTRY 19.1

Do food items contain active catalase? You can test this at home with samples of raw meat and vegetables. You will need clear (not colored), transparent glasses, 3% hydrogen peroxide (from a drugstore or grocery store), and a few 1 cm cubes of raw meat such as chicken liver or a bit of hamburger. Also cube some raw potato. Drop some of the raw meat in a glass with an inch or two of hydrogen peroxide in it. Using a different glass of hydrogen peroxide, do the same thing with potato cubes. What happened with the meat? With the potato? Does the amount of meat or potato used matter? Repeat your experiment with cooked meat and cooked potato. What happened?

Evolution of bubbles means catalase present in the sample was converting hydrogen peroxide to water and oxygen; the enzyme was active, in its native state and not denatured. If no significant amount of bubbles appeared, catalase was either absent or inactive. Based on the results of the trials with raw samples, was catalase absent or inactive? If inactive, why?

NEW! **HANDS-ON CHEMISTRY** boxes offer students an opportunity to solidify their understanding of chemistry through elementary experiments that can be safely done in their home with household items. Many students strongly benefit from kinesthetic activities, and regardless of whether this is their preferred style, evidence suggests that variety in exposure to concepts is tremendously valuable.

GROUP PROBLEMS

2.95 Look up one of the experiments by the scientists discussed in the Chemistry in Action on page 44, and explain how it contributed to our understanding of atomic structure.

2.96 Do a web search to identify each of the following elements/isotopes and indicate the number of neutrons, protons, and electrons in an atom of the element/isotope:

(a) A radioactive isotope used in cancer treatments? (There may be more than one answer!)

(b) The element having the greatest density.

(c) An element with $Z < 90$ that is *not* found in nature.

2.97 Tellurium $(Z = 52)$ has a *lower* atomic number than iodine $(Z = 53)$, yet it has a *higher* atomic weight (127.60 amu for Te vs. 126.90 amu for I). How is this possible? Can you find any other instances in the periodic table where two adjacent elements exhibit a similar behavior, that is, the element with the lower atomic number has a higher atomic mass?

2.98 Look again at the trends illustrated in Figures 2.3 and 2.4.

(a) How do the peaks/valleys correlate with locations in the periodic table?

(b) Are there other chemical properties that also exhibit periodic trends? What are they?

NEW! **GROUP PROBLEMS** at the end of every chapter are ideally used in class to get students to carefully think about higher level problems, such as how concepts fit together, or to put the concepts they have learned to use in a clinical application.