FROST
DEAL

GENERAL, ORGANIC, AND BIOLOGICAL CHEMISTRY

CONCISE, PRACTICAL, INTEGRATED

THIRD EDITION

Periodic Table of Elements

Main-group elements

Alkali metals → Group 1A (1); Alkaline earth metals → Group 2A (2); Halogens → Group 7A (17); Noble gases → Group 8A (18)

Transition elements: 3B (3), 4B (4), 5B (5), 6B (6), 7B (7), 8B (8) (9) (10), 1B (11), 2B (12)

Period number	Group 1A (1)	Group 2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	Group 3A (13)	Group 4A (14)	Group 5A (15)	Group 6A (16)	Group 7A (17)	Group 8A (18)
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57* La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 208.9	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89† Ac (227)	104 Rf (267)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 — (284)	114 Fl (289)	115 — (288)	116 Lv (293)	117 — (294)	118 — (294)

*Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.26	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	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   Unknown

Atomic Masses of the Elements

Name	Symbol	Atomic Number	Atomic Mass[a]	Name	Symbol	Atomic Number	Atomic Mass[a]
Actinium	Ac	89	(227)	Mendelevium	Md	101	(258)
Aluminum	Al	13	26.98	Mercury	Hg	80	200.6
Americium	Am	95	(243)	Molybdenum	Mo	42	95.94
Antimony	Sb	51	121.8	Neodymium	Nd	60	144.2
Argon	Ar	18	39.95	Neon	Ne	10	20.18
Arsenic	As	33	74.92	Neptunium	Np	93	(237)
Astatine	At	85	(210)	Nickel	Ni	28	58.69
Barium	Ba	56	137.3	Niobium	Nb	41	92.91
Berkelium	Bk	97	(247)	Nitrogen	N	7	14.01
Beryllium	Be	4	9.012	Nobelium	No	102	(259)
Bismuth	Bi	83	208.9	Osmium	Os	76	190.2
Bohrium	Bh	107	(264)	Oxygen	O	8	16.00
Boron	B	5	10.81	Palladium	Pd	46	106.4
Bromine	Br	35	79.90	Phosphorus	P	15	30.97
Cadmium	Cd	48	112.4	Platinum	Pt	78	195.1
Calcium	Ca	20	40.08	Plutonium	Pu	94	(244)
Californium	Cf	98	(251)	Polonium	Po	84	(209)
Carbon	C	6	12.01	Potassium	K	19	39.10
Cerium	Ce	58	140.1	Praseodymium	Pr	59	140.9
Cesium	Cs	55	132.9	Promethium	Pm	61	(145)
Chlorine	Cl	17	35.45	Protactinium	Pa	91	231.0
Chromium	Cr	24	52.00	Radium	Ra	88	(226)
Cobalt	Co	27	58.93	Radon	Rn	86	(222)
Copernicium	Cn	112	(285)	Rhenium	Re	75	186.2
Copper	Cu	29	63.55	Rhodium	Rh	45	102.9
Curium	Cm	96	(247)	Roentgenium	Rg	111	(272)
Darmstadtium	Ds	110	(281)	Rubidium	Rb	37	85.47
Dubnium	Db	105	(262)	Ruthenium	Ru	44	101.1
Dysprosium	Dy	66	162.5	Rutherfordium	Rf	104	(267)
Einsteinium	Es	99	(252)	Samarium	Sm	62	150.4
Erbium	Er	68	167.26	Scandium	Sc	21	44.96
Europium	Eu	63	152.0	Seaborgium	Sg	106	(266)
Fermium	Fm	100	(257)	Selenium	Se	34	78.96
Flerovium	Fl	114	(289)	Silicon	Si	14	28.09
Fluorine	F	9	19.00	Silver	Ag	47	107.9
Francium	Fr	87	(223)	Sodium	Na	11	22.99
Gadolinium	Gd	64	157.3	Strontium	Sr	38	87.62
Gallium	Ga	31	69.72	Sulfur	S	16	32.07
Germanium	Ge	32	72.63	Tantalum	Ta	73	180.9
Gold	Au	79	197.0	Technetium	Tc	43	(98)
Hafnium	Hf	72	178.5	Tellurium	Te	52	127.6
Hassium	Hs	108	(277)	Terbium	Tb	65	158.9
Helium	He	2	4.003	Thallium	Tl	81	204.4
Holmium	Ho	67	164.9	Thorium	Th	90	232.0
Hydrogen	H	1	1.008	Thulium	Tm	69	168.9
Indium	In	49	114.8	Tin	Sn	50	118.7
Iodine	I	53	126.9	Titanium	Ti	22	47.87
Iridium	Ir	77	192.2	Tungsten	W	74	183.8
Iron	Fe	26	55.85	Uranium	U	92	238.0
Krypton	Kr	36	83.80	Vanadium	V	23	50.94
Lanthanum	La	57	138.9	Xenon	Xe	54	131.3
Lawrencium	Lr	103	(262)	Ytterbium	Yb	70	173.0
Lead	Pb	82	207.2	Yttrium	Y	39	88.91
Lithium	Li	3	6.941	Zinc	Zn	30	65.38
Livermorium	Lv	116	(293)	Zirconium	Zr	40	91.22
Lutetium	Lu	71	175.0	—	—	113	(284)
Magnesium	Mg	12	24.31	—	—	115	(288)
Manganese	Mn	25	54.94	—	—	117	(294)
Meitnerium	Mt	109	(268)	—	—	118	(294)

[a]Values in parentheses are the mass number of the most stable isotope.

CONCISE | PRACTICAL | INTEGRATED

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THIRD EDITION

Laura Frost
Florida Gulf Coast University

Todd Deal
Georgia Southern University

PEARSON

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About the **Authors**

LAURA FROST is a Professor of Chemistry at Florida Gulf Coast University and Director of the Whitaker Center for Science, Technology, Engineering, and Mathematics (STEM) Education. She received a bachelor's degree in chemistry from Kutztown University and her Ph.D. in chemistry with a biophysical focus from the University of Pennsylvania. She has been teaching chemistry in higher education for 20 years and has taught chemistry to allied health students since 2000.

Professor Frost is actively engaged in the teaching and learning in all STEM subjects, particularly chemistry, and uses a guided inquiry approach in her classes. She is very involved in the scholarship of teaching and learning and has demonstrated that the use of inquiry-based activities increases student learning in her one-semester allied health chemistry course.

Dr. Frost is a member of the American Chemical Society and its Chemical Education division. A member of the University System of Georgia faculty Hall of Fame, Dr. Frost has been honored on more than one occasion for her teaching excellence. Her writing has also been recognized, and in 2014, she was elected to the governing council of the Text and Academic Authors Association.

Dr. Frost is engaged in STEM education reform through evidence-based teaching and learning at all levels (K–16), as well as through community outreach. She is also principal investigator of an NSF-WIDER grant that provides professional development for faculty in evidence-based practices in STEM. She has spoken and attended numerous conferences and workshops on this topic.

DEDICATION

This book is dedicated to the students and faculty who continue to inspire me and to my ever-supportive family, Baxter, Iris, and Baxter. **—Laura Frost**

TODD DEAL received his B.S. degree in chemistry in 1986 from Georgia Southern College (now University) in Statesboro, Georgia, and his Ph.D. in chemistry in 1990 from The Ohio State University. He joined the faculty of his undergraduate alma mater in 1992 where he currently serves as Executive Director of the Office of Leadership and Community Engagement. During his tenure at Georgia Southern, Professor Deal has also served as Associate Dean of the Allen E. Paulson College of Science and Technology.

Professor Deal has taught chemistry to allied health and preprofessional students for more than 25 years. An award-winning educator, Dr. Deal has received numerous awards for excellence in teaching and in service and was named Professor of the Year by the students of Georgia Southern. Prof. Deal has also been recognized by Project Kaleidoscope for his innovative teaching in the sciences.

Professor Deal is a member of American Chemical Society and its Chemical Education division. He is also a member of the Omicron Delta Kappa National Leadership Honor Society, the International Leadership Association, and the Association of Leadership Educators. Dr. Deal's teaching interests span from chemistry and the hard sciences to the soft, human sciences of leadership and leadership development.

DEDICATION

I dedicate this book to my loving wife, Karen, and to our daughters, Abbie and Anna. Thank you for believing in me. And to my students who inspired me to help them learn; this book is written for you.

—Todd Deal

Brief Contents

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Preface

To the Student

Why have trans fats been so controversial? What are calories and how are they measured for food? How does kidney dialysis remove waste from the body? And if you look again at the image of the coconut on the cover, just why is there renewed interest in the health benefits of coconut oil? The key to understanding the answers to these questions starts with chemistry.

General, Organic, and Biological Chemistry was written especially for students interested in pursuing a health-science career like nursing, nutrition, dental hygiene, or respiratory therapy. Yet this textbook has applications for all students interested in discovering the concepts of chemistry in everyday situations. Throughout the text, you will find that we have integrated the concepts of general, organic, and biological chemistry to create a seamless framework to help you relate chemistry to your life.

One of our goals in writing this book is to help you become better problem solvers so that you can critically assess situations at your workplace, in the news, and in your world. In this edition, we have kept the problem-solving strategies while increasing their depth to encourage greater understanding.

As you explore the pages of this book, you will encounter materials that

- apply chemistry to your life
- apply chemistry to health careers that interest you
- encourage you to develop problem-solving skills
- help you to work with and learn from your fellow students
- demonstrate how to be successful in this chemistry course and other courses.

As you read this book, you will notice the language is less formal. Wherever possible, we relate the chemical concepts to objects in everyday life to help you understand chemistry. We also provide several study strategies with this edition including materials for you to engage with before, during, and after class. Cognitive research in learning tells us that new ideas stick with us better if they are related to things that we already know and we practice retrieving this information from our memories.

New to This Edition

The Third Edition continues to strengthen our strategy of integrating concepts from general, organic, and biological chemistry to give students a focused introduction to the fundamental and relevant connections between chemistry and life. Emphasizing the development of problem-solving skills with distinct Inquiry Questions and Activities and a clear exposition of strategies, this text empowers students to solve problems in different and applied contexts relating to health and biochemistry.

- The broader learning targets on the chapter openers now work in tandem with the more specific learning outcomes supported by Try-It references in the end-of-chapter study guide.
- We reorganized the Chapter Review to make it easier for students to consult and use. The Study Guide and Chapter Guide now run alongside each other. We positioned the Study Guide in the left column because it is the element that students want most. The learning outcomes in the Study Guide now have cross-references to sample problems and practice problems to help students master chapter skills. The Chapter Guide is a narrative summary with illustrative visuals. To enhance visual learning, the Chapter Guide now includes complete visuals rather than small insets.
- Each Integrating Chemistry feature now has a high-interest teaser (the "find out" header). The teaser appears with the standing header for the feature. We wrote these to spark interest and to encourage use of the feature and synthesis of ideas.
- We sought more realism in the biochemical applications and in biochemistry vocabulary. These applications judiciously increase the depth of the book even as they serve the needs of the student audience, which values seeing biochemistry in action.
- We used the health icon to highlight even more applied/health uses in the practice problems due to requests from reviewers for more evident "career" content and biochemistry, which are two a main interests of nursing and allied-health students.
- The figures now are more accessible to students. Our goal was to simplify, get concepts across, and use molecular representations that are in line with what is seen across the disciplines. In Chapter 3, we placed more stress on wedge/dash representation. Chapter 4 makes much more use of skeletal structures, even as we retired many of the Lewis structures. In Chapter 10, our many adjustments promote a more consistent presentation of the stereocenters in the amino acids. Many of the corrections in Chapter 10 and Chapter 11 reorient the portrayal of the two-dimensional structures.
- We created 13 new Practicing the Concepts videos to support the content of each chapter. (Chapter 1 has two supporting videos.) The videos, which run from 3 to 5 minutes, are narrated by author Todd Deal. In the videos, he reviews a big idea or concept from the chapter, then helps students deepen their knowledge and develop their skills. Carefully developed visuals portray concepts vividly, and a pause-and-predict stopping point gives the student a chance for a meaningful concept check.
- Every chapter has been renewed, including the sample problems and practice problems. To support areas of chapters with expanded coverage, we added new practice problems.

Chapter Organization and Revision

Throughout the text, we integrated general, organic, and biological chemistry topics using relevant examples and applications to solidify concepts. This text intentionally contains only 12 chapters, allowing all chapters to be covered in a single semester. Each chapter builds upon conceptual understanding and skills learned from previous chapters, providing students with an efficient path through the content and a clear context for how all of the topics connect to one another.

In this edition, we made extensive chapter revisions as discussed below.

1 Chemistry Basics—Matter and Measurement

- New Integrating Chemistry feature on minerals as micronutrients
- New Solving a Problem feature on dosage calculations
- New sample problem (1.23) and coverage of drop factors
- Upgraded, more precise molecular art

2 Atoms and Radioactivity

- New coverage of radiation exposure and radiation sickness
- Highlighted distinction between physical and effective half-life relates better to medical applications of radiation
- Upgraded art in radiation section, including Becquerel's original image (Figure 2.4)
- Twelve new practice problems

3 Compounds—How Elements Combine

- New chapter title adds clarity
- New Sample Problems 3.11 and 3.12 add depth by incorporating more conversion factors
- New wedge/dash structures in this chapter provide an earlier introduction to the three-dimensional nature of molecules for VSEPR discussion
- Twenty new practice problems

4 Introduction to Organic Compounds

- Earlier introduction of skeletal structures in Section 4.1
- To enhance the clarity of presentation, the description of chiral objects and the handedness of molecules has been rewritten
- New Integrating Chemistry feature on alkanes and biodiesel fuels and revised Integrating Chemistry feature on fatty acids and coconut oil
- Twenty new practice problems

5 Chemical Reactions

- Expanded thermodynamics coverage in Section 5.1 with new supporting figures
- New Integrating Chemistry on trans fats expands coverage
- Earlier introduction of biochemical reactions

6 Carbohydrates—Life's Sweet Molecules

- New Integrating Chemistry on glucose metabolism and diabetes
- More stress on functional-group nomenclature
- Eleven new practice problems

7 What's the Attraction? Gas Laws, State Changes, Solubility, and Lipids

- Revised chapter title highlights new conceptual balance
- Gas laws moved to Section 7.2
- New coverage of Gay-Lussac's law, combined gas law, and the ideal gas law
- New coverage of vapor pressure
- New Integrating Chemistry on solubility of drugs
- Twenty-five new practice problems
- The problem-solving models for Boyle's law and Charles's law now include a check step to teach good habits

8 Solution Chemistry—How Sweet Is Your Coffee?

- New description of water and its unique properties in Section 8.1
- New subsection on dilution factors in Section 8.5
- Eighteen new practice problems

9 Acids, Bases, and Buffers in the Body

- New coverage on naming strong acids
- New discussion of predominant form of weak acid based on pKa and pH
- New Integrating Chemistry on tissue pH and drug delivery
- New sample problems throughout chapter
- Twenty-one new practice problems

10 Proteins—Workers of the Cell

- New coverage of one-letter amino acid abbreviations
- New Integrating Chemistry feature on secondary structures and Alzheimer's disease
- Seventeen new practice problems

11 Nucleic Acids—Big Molecules with a Big Role

- Updated art on nucleic acid representations
- New Integrating Chemistry on use of fluorescent proteins as markers of DNA recombination
- Revised and updated discussion of HIV/AIDS drugs
- Fifteen new practice problems

12 Food as Fuel—An Overview of Metabolism

- New chapter title more directly points to the main event, metabolism
- New Discovering the Concepts on metabolism
- Updated art clarifies metabolic pathways
- New Integrating Chemistry on fructose metabolism

Resources in Print and Online

Supplement	Available in Print	Available Online	Instructor or Student Supplement	Description
Mastering Chemistry (ISBN: 0134019202)		X	Instructor and Student Supplement	The Mastering platform delivers engaging, dynamic learning opportunities—focused on your course objectives and responsive to each student's progress—that are proven to help students absorb course material and understand difficult concepts. **NEW! Practicing the Concepts Videos with Pause and Predict Quizzes in MasteringChemistry** bring chemistry to life. These 3- to 5-minute videos feature coauthor Todd Deal introducing key topics in general, organic, and biological chemistry that students find difficult. Students are asked to solve a problem while they watch the video content. Mastering also offers LearningCatalytics questions that directly relate to the content of the text. Learning Catalytics is a "bring your own device" student engagement, assessment, and classroom intelligence system.
Instructor Solutions Manual (ISBN: 0134162137)		X	Instructor Supplement	This Solutions Manual provides detailed solutions to all in-chapter as well as the end-of-chapter exercises in the text.
Test Bank (ISBN: 0134161882)		X	Instructor Supplement	This test bank contains over 600 multiple-choice, true/false, and matching questions. It is available in the TestGen program, in Word format, and included in the item library of MasteringChemistry.
Instructor Resources (ISBN: 0134162145)		X	Instructor Supplement	This provides an integrated collection of online resources to help instructors make efficient and effective use of their time. Includes all artwork from the text, including figures and tables in PDF format for high-resolution printing, as well as four pre-built PowerPoint™ presentations. The first presentation contains the images embedded within PowerPoint slides. The second includes a complete lecture outline that is modifiable by the user. Also available are PowerPoint slides of the parent text "in chapter" sample exercises. Also includes electronic files of the Instructor's Resource Manual, as well as the Test Bank. Access resources through http://www.pearsonhighered.com/.
Study Guide (ISBN: 0134160517)	X		Student Supplement	This manual for students contains complete solutions to the selected odd-numbered end-of-chapter problems in the text.
Laboratory Manual (ISBN: 032181925X)	X		Student Supplement	Written by one of the text's authors (Deal), the lab manual continues the strategy of integration of concepts to help students understand chemistry. Several of the experiments included in the lab manual are original works developed by Professor Deal and his students in support of the integrated strategy. Most experiments are designed around a question, which is intended to engage students and to demonstrate the applicability of chemistry concepts to real-world problems. Many of the experiments highlight concepts from multiple chapters of the text, once again building on the strategy of integration.
Guided Inquiry Activities (ISBN: 0134162056)	X		Instructor and Student Supplement	Guided Inquiry Activities authored by L. Frost are available through the Pearson Custom Library (pearsoncustomlibrary.com). These activities are designed for in-class use by groups of students with facilitation by instructor. Students explore information, develop chemical concepts, and apply the concepts to further examples.

Acknowledgments

We have learned much since the first edition was published. Faculty and reviewer feedback has allowed us to enhance the third edition with some much-needed coverage while keeping the book length reasonable for a one-semester course. The expertise and professionalism of Karen Timberlake in editing and developing the textbook cannot be understated. She has been an inspiration and mentor and we are deeply indebted.

The editorial staff at Pearson has been exceptional. We are extremely grateful for the assistance of Don Gecewicz, developmental editor, whose fresh look at the content allowed for better streamlining. His years of textbook development were apparent. We also want to acknowledge the enthusiasm of Terry Haugen, executive editor in chemistry, who convinced Pearson that, during a time of textbook consolidation, the third edition of this textbook would be worth the investment. We also greatly appreciate the project organizers, Lisa Pierce and Elisa Mandelbaum, who have gone through much of the material with a fine-tooth comb, making sure that author comments were interpreted correctly by production. We want to thank other members of the production team including Mary Tindle and Maya Gomez. They have been very patient with us as we embarked on the production process.

Laura Frost would like to also thank Adam Jaworski, VP, Science Editorial, for his continued support of this project, his shared vision that an actively engaged classroom can enhance student understanding of chemistry, and his support for the inclusion of the inquiry activities. She would also like to thank Jeanne Zalesky, editor-in-chief, whose strong effort on the second edition warranted a third edition. She also recognizes the continued mentorship and experience of Karen Timberlake in the area of GOB chemistry writing and publishing.

Todd Deal would like, once again, to express a special appreciation to Jim Smith, our original editor, whose enthusiasm for the integrated strategy used in this project and belief in us as authors provided the foundation upon which this text is built.

This text reflects the contributions of many professors who took the time to review and edit the manuscript and provided outstanding comments, help, and suggestions. We are grateful for your contributions.

In addition, this project could not have been completed without the support of several exceptional colleagues in the Department of Chemistry at Georgia Southern University, who have taught using the first and second editions and offered many comments and corrections.

If you would like to share your experience using this textbook, either as a student or faculty member, or if you have questions regarding its content, we would love to hear from you.

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Third Edition

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Concise. Practical. Integrated.

The **Third Edition** of ***General, Organic, and Biological Chemistry*** deepens its strategy of integrating concepts from general, organic, and biological chemistry, providing a focused introduction to the fundamental and relevant connections between chemistry and life. Frost and Deal's streamlined approach offers students a clear path through the content. Emphasizing the development of problem-solving skills with distinct Inquiry Questions and Activities and a clear exposition of strategies, this text empowers students to solve relevant problems in applied contexts relating to health and biochemistry. The third edition encourages students to engage with the material before, during, and after class.

"The Frost text is well written with great real-world applications for the students. It has a clear writing style that is great for incoming freshmen, nontraditional students, and those who have not taken a chemistry course and may be overwhelmed by 'chemistry' itself."

—Tanea Reed
Eastern Kentucky University

"The 3 greatest strengths of this textbook are (1) examples and problems that pertain to real-life situations, (2) problem-solving guides, (3) clear and easy-to-read figures. All of these are important in teaching and choosing a textbook. Problem solving is one of the most important concepts for a student to learn and all of the above make it easy to teach and help students with problem solving."

—Lisa Sharpe Elles
Washburn University

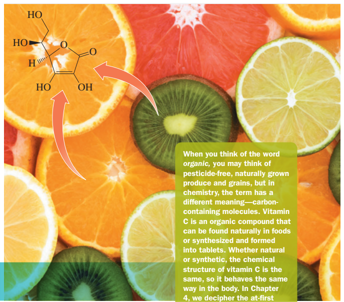
"This is the most student-friendly, yet rigorous, integrated GOB text out there!"

—Jim Zubricky
University of Toledo, OH

Concise coverage of important concepts and skills

The introduction and integration of biochemistry into the general and organic chapters of the text create a more direct and efficient path through topics needed in the course. **This text contains only 12 chapters, allowing all chapters to be covered in a single semester.**

Brief Contents



When you think of the word organic, you may think of pesticide-free, naturally grown produce and grains, but in chemistry, the term has a different meaning—carbon-containing molecules. Vitamin C is an organic compound that can be found naturally in foods or synthesized and formed into tablets. Whether natural or synthetic, the chemical structure of vitamin C is the same, so it behaves the same way in the body. In Chapter 4, we decipher the at-first strange-looking stick drawings used to represent organic compounds and investigate some unique properties of carbon-containing compounds.

4

Introduction to Organic Compounds

"ORGANIC" CAN DESCRIBE a set of environmentally friendly farming practices or imply that a product is in some way more natural, but chemists use the word *organic* to identify covalent compounds containing carbon. **Organic compounds** are composed mainly of carbon and hydrogen but may also include oxygen, nitrogen, sulfur, phosphorus, and other elements. The molecules of life, or **biomolecules,** such as proteins, carbohydrates, lipids, and DNA, are all organic compounds. This chapter combines the information about nonmetal elements from Chapter 2, and how they merge to form molecules from Chapter 3, to begin the study of the organic compounds that make up living things and the chemistry of life. Organic compounds, whether naturally occurring or synthesized in the laboratory, are found in familiar substances such as gasoline, cotton, plastics, vitamins, medicines, and cosmetics.

Why carbon? Carbon is unique in its ability to form bonds with other atoms of carbon and can create chains and rings of various sizes and shapes. In fact, most of the over 60 million known chemical compounds are organic.

Carbon's ability to form such a tremendous variety of compounds and our ability to manipulate and react these compounds in the laboratory contribute to an ever-increasing interest in the chemistry subdiscipline called **organic chemistry.** Organic chemistry is dedicated to the study of the structure,

A **Visual Framework for Studying** includes both chapter-opening pedagogy and aligned end-of-chapter study and chapter guides, all of which work together to introduce students to the main concepts of each chapter. It assesses student understanding through practice problems and gives students a practical way to study the most important concepts and skills.

NEW!

Updated Chapter Reviews at the end of each chapter include a visual **Study Guide and Chapter Guide** that work side by side to highlight the main concepts of each chapter and help students study more effectively. Among the end-of-chapter materials, the Study Guide now runs at left, elevating its importance to the students. This new layout gives students a practical way to pinpoint and focus on the most important concepts in each chapter and then assess their own proficiency. The Study Guide now has suggested "try-it" problems to point students toward practice that will help them master chapter content.

CHAPTER REVIEW

CHAPTER 2

The study guide will help you check your understanding of the main concepts in Chapter 2. You should be able to answer problems for each learning outcome in this list. To check your mastery, try the practice problem listed after each.

STUDY GUIDE

2.1 Atoms and Their Components

Characterize the subatomic particles that make up the atom.

- Name the kind of subatomic particles that make up an atom. (See Sample Problem 2.1. Try 2.45)
- Locate the subatomic particles in an atom. (Try 2.1, 2.46b)

2.2 Atom Number and Mass Number

Relate the atomic number and mass number to the parts of an atom.

- Distinguish atomic number and mass number. (Try 2.5)
- Predict the mass number of an atom given the subatomic particles. (Try 2.9, 2.51)
- Determine the number of protons, neutrons, and electrons for an element given the mass number or symbolic notation. (Try 2.11, 2.15, 2.47, 2.57)
- Write symbolic notation for atoms when the number of protons and neutrons is given. (Try 2.13, 2.55)

2.3 Isotopes and Atomic Mass

Distinguish mass number of an isotope and atomic mass of an element.

- Define isotope. (See key terms on page 72)
- Distinguish between mass number and atomic mass. (Try 2.17, 2.51, 2.57)
- Predict the most common isotope based on the atomic mass of an element. (See Sample Problem 2.4. Try 2.19)

CHAPTER GUIDE

Inquiry Question

What are the subatomic particles that make up an atom and where are they located?

An atom consists of three subatomic particles: protons, neutrons, and electrons. Protons have a positive charge, neutrons have no charge, and electrons have a negative charge. Most of the mass of an atom comes from the protons and neutrons located in the center, or nucleus, of an atom. The unit for the mass of an atom is the atomic mass unit (amu); each proton and neutron present in an atom weighs approximately 1 amu.

Properties of Particles in an Atom

Subatomic Particle	Symbol	Electrical Charge	Relative Mass	Location in Atom
Electron	e^-	1–	0.0005 (1/2000)	Outside nucleus
Proton	p or p^+	1+	1	Nucleus
Neutron	n or n^0	0	1	Nucleus

Inquiry Question

What do the atomic number and mass number indicate?

The atomic number of an atom indicates the number of protons present in an atom. All atoms of a given element have the same number of protons. The mass number of an atom is the total number of protons and neutrons present in a given atom of an element.

Mass number ⟶ $^{12}_{6}C$ ⟵ Atomic symbol
Atomic number ⟶

Inquiry Question

What is the difference between the mass number for an isotope and the atomic mass of an element?

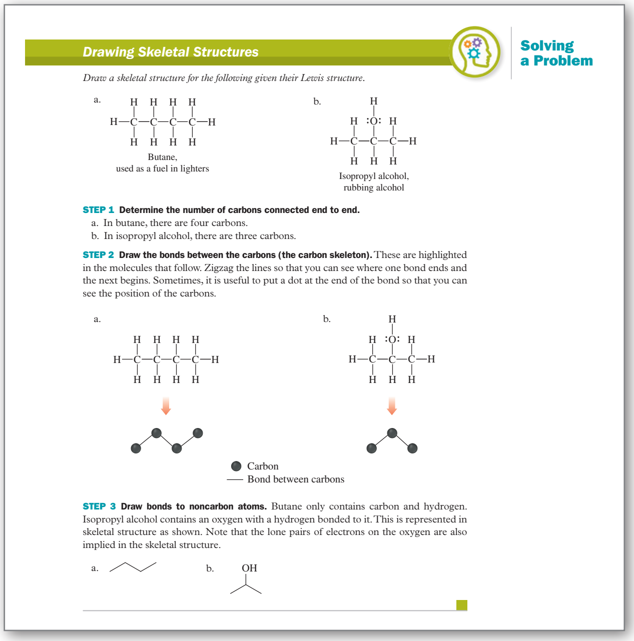
The mass number is the sum of protons and neutrons for a *given* isotope. For example, nitrogen-14 has seven protons and seven neutrons. The atomic mass is the average atomic mass for *all* the isotopes of an element found in nature. This number is found on the periodic table, often below the element symbol.

6	⟵ Number of protons
C	⟵ Symbol for carbon
12.01	⟵ Average atomic mass of all carbon atoms

Practical approaches and applications engage students

Practical connections between the chemistry being discussed and students' daily lives and future careers are made throughout each chapter to help engage students and reinforce their understanding.

Solving a Problem features are back and renewed. Located at strategic points within each chapter, these provide students with a step-by-step approach to solving the more challenging topics in chemistry.



Drawing Skeletal Structures — Solving a Problem

Draw a skeletal structure for the following given their Lewis structure.

a. Butane, used as a fuel in lighters

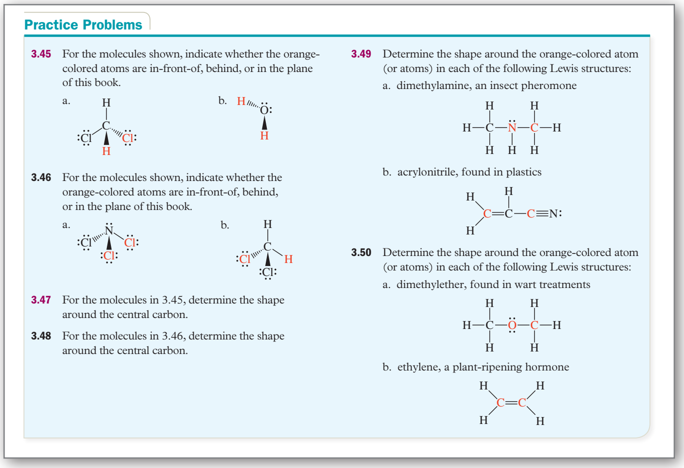
b. Isopropyl alcohol, rubbing alcohol

STEP 1 Determine the number of carbons connected end to end.
a. In butane, there are four carbons.
b. In isopropyl alcohol, there are three carbons.

STEP 2 Draw the bonds between the carbons (the carbon skeleton). These are highlighted in the molecules that follow. Zigzag the lines so that you can see where one bond ends and the next begins. Sometimes, it is useful to put a dot at the end of the bond so that you can see the position of the carbons.

● Carbon
— Bond between carbons

STEP 3 Draw bonds to noncarbon atoms. Butane only contains carbon and hydrogen. Isopropyl alcohol contains an oxygen with a hydrogen bonded to it. This is represented in skeletal structure as shown. Note that the lone pairs of electrons on the oxygen are also implied in the skeletal structure.



Practice Problems

3.45 For the molecules shown, indicate whether the orange-colored atoms are in-front-of, behind, or in the plane of this book.

3.46 For the molecules shown, indicate whether the orange-colored atoms are in-front-of, behind, or in the plane of this book.

3.47 For the molecules in 3.45, determine the shape around the central carbon.

3.48 For the molecules in 3.46, determine the shape around the central carbon.

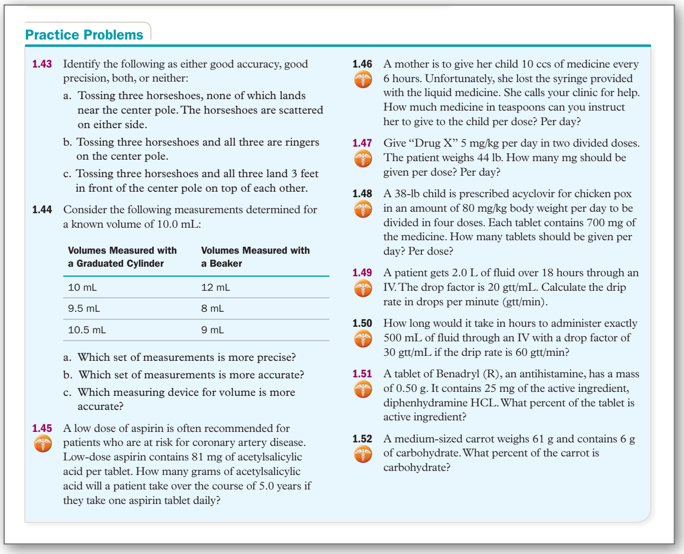
3.49 Determine the shape around the orange-colored atom (or atoms) in each of the following Lewis structures:
a. dimethylamine, an insect pheromone
b. acrylonitrile, found in plastics

3.50 Determine the shape around the orange-colored atom (or atoms) in each of the following Lewis structures:
a. dimethylether, found in wart treatments
b. ethylene, a plant-ripening hormone

NEW!
More challenging problems (both end-of-chapter and in-chapter) that integrate concepts from earlier chapters and build upon them.

Updated! Health-related Problems integrated throughout the chapter.
New end-of-chapter problems and in-chapter problems tied to real-life applications from allied health fields promote critical thinking and help students connect the chemistry learned with their future professions.

Health Icons are included next to specific problems with application to health careers and everyday products—a main interest of nursing and allied health students.



Practice Problems

1.43 Identify the following as either good accuracy, good precision, both, or neither:
a. Tossing three horseshoes, none of which lands near the center pole. The horseshoes are scattered on either side.
b. Tossing three horseshoes and all three are ringers on the center pole.
c. Tossing three horseshoes and all three land 3 feet in front of the center pole on top of each other.

1.44 Consider the following measurements determined for a known volume of 10.0 mL:

Volumes Measured with a Graduated Cylinder	Volumes Measured with a Beaker
10 mL	12 mL
9.5 mL	8 mL
10.5 mL	9 mL

a. Which set of measurements is more precise?
b. Which set of measurements is more accurate?
c. Which measuring device for volume is more accurate?

1.45 A low dose of aspirin is often recommended for patients who are at risk for coronary artery disease. Low-dose aspirin contains 81 mg of acetylsalicylic acid per tablet. How many grams of acetylsalicylic acid will a patient take over the course of 5.0 years if they take one aspirin tablet daily?

1.46 A mother is to give her child 10 ccs of medicine every 6 hours. Unfortunately, she lost the syringe provided with the liquid medicine. She calls your clinic for help. How much medicine in teaspoons can you instruct her to give to the child per dose? Per day?

1.47 Give "Drug X" 5 mg/kg per day in two divided doses. The patient weighs 44 lb. How many mg should be given per dose? Per day?

1.48 A 38-lb child is prescribed acyclovir for chicken pox in an amount of 80 mg/kg body weight per day to be divided in four doses. Each tablet contains 700 mg of the medicine. How many tablets should be given per day? Per dose?

1.49 A patient gets 2.0 L of fluid over 18 hours through an IV. The drop factor is 20 gtt/mL. Calculate the drip rate in drops per minute (gtt/min).

1.50 How long would it take in hours to administer exactly 500 mL of fluid through an IV with a drop factor of 30 gtt/mL if the drip rate is 60 gtt/min?

1.51 A tablet of Benadryl (R), an antihistamine, has a mass of 0.50 g. It contains 25 mg of the active ingredient, diphenhydramine HCL. What percent of the tablet is active ingredient?

1.52 A medium-sized carrot weighs 61 g and contains 6 g of carbohydrate. What percent of the carrot is carbohydrate?

Integrated chemistry connects organic and biochemistry

The **Integrating Chemistry** feature brings biochemical relevance to each chapter. These features now have a teaser prompt ("find out") appearing beneath the Integrating Chemistry icon to interest the student in the biochemistry application and encourage use of the feature to synthesize the concepts.

INTEGRATING Chemistry

Find out how the fatty acids in coconut oil are different from other oils.

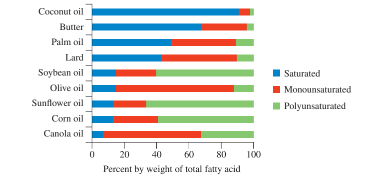
Coconut oil has high amounts of saturated fats, but it has other beneficial properties.

Fatty Acids in Our Diets

Fats are important in a balanced diet because they play important roles as insulators and protective coverings for internal organs and nerve fibers. Mono- and polyunsaturated fats are part of a healthy diet. The Food and Drug Administration (FDA) recommends that a maximum of 30% of the calories in a normal diet come from such fatty acid-containing compounds. The FDA also recommends that the majority of our fat intake come from foods containing a higher percentage of mono- and polyunsaturated fatty acids. **TABLE 4.6** shows the fatty acid composition of some common fats. Highly saturated oils like coconut and palm oils have found uses as natural substitutes for hydrogenated oils, which are chemically saturated. More about hydrogenated oils is found in Chapter 5.

Coconut oil has become increasingly popular in recent years due to some of its health benefits. Although the fatty acids in coconut oil are more than 90% saturated, most of the fatty acid chains are between 8 and 12 carbons, much shorter than most dietary sources. The medium-chain fatty acids found in coconut oil (predominantly the 12-carbon lauric acid) are more easily absorbed and digested by the body, a benefit for older adults and those with digestive tract disorders such as irritable bowel syndrome. Because most of the fatty acids do not contain double bonds, they are not very reactive, so coconut oil has a longer shelf life than other common oils, butter, or lard. Because it is a fatty acid, however, care should be taken not to consume large amounts due to its high calorie content.

TABLE 4.6 Fatty Acid Composition of Common Dietary Fats



Important Ions in the Body

A number of ions found in the fluids and cells of the human body perform important functions. The main cations found in the body include Na^+, K^+, Ca^{2+}, and Mg^{2+}, which are important in maintaining solution concentrations inside and outside cells. The main anions are Cl^-, HCO_3^-, and HPO_4^{2-}. These ions help maintain the charge neutrality between the blood and fluids inside cells. These ions are often referred to as electrolytes, with sodium being the main electrolyte. During periods of extreme exercise (three or more hours of continuous exercise), it is important to consume electrolytes in addition to rehydrating with water.

Another important ion in the body is the phosphate ion, also called inorganic phosphate and abbreviated P_i. It is involved in cellular energy transfer during chemical reactions.

In contrast to ions in fluids, ions can also form hard minerals. Tooth enamel contains the mineral hydroxyapatite, consisting of calcium (Ca^{2+}), phosphate (PO_4^{3-}), and hydroxide (OH^-) ions. **TABLE 3.3** lists some of the main ions in bodily fluids and their functions.

TABLE 3.3 Biologically Important Ions

Ion	Function	Sources
Cations		
Na^+	Regulates fluids outside cells	Table salt, seafood
K^+	Maintains ion concentration in cells; induces heartbeat	Dairy, bananas, meat
Ca^{2+}	Found outside cells; involved in muscle contraction, formation of bones and teeth; regulates heartbeat	Dairy, whole grains, leafy vegetables
Mg^{2+}	Found inside cells; involved in transmission of nerve impulses	Nuts, seafood, leafy vegetables
Fe^{2+}	Found in the protein hemoglobin, which is responsible for oxygen transport from lungs to tissue	Liver, red meat, leafy vegetables
Anions		
Cl^-	Found in gastric juice and outside cells; involved in fluid balance in cells	Table salt, seafood
HCO_3^-	Controls acid–base balance in blood	Body produces own supply through breathing and breakdown of foods
HPO_4^{2-}	Controls acid–base balance in cells	Fish, poultry, dairy

INTEGRATING Chemistry

Find out which cations and anions are important in your body.

Sports drinks contain water and important ions called electrolytes necessary during prolonged exercise.

Inquiry Questions are designed to focus student reading on the main concepts by section. An Inquiry Question appears at the beginning of each section, piquing interest and functioning as learning targets while prompting student interactivity. Inquiry Questions are repeated as reinforcement in the Chapter Guide at the end of every chapter.

FIGURE 2.1 Carbon atoms. Photographs of (a) a half-carat diamond ring and (b) carbon in the form of graphite. These are both forms of pure carbon. (c) Atoms in graphite, a form of pure carbon, taken with a scanning tunneling microscope.

(a) (b) (c)

What's an Inquiry Question?

Inquiry Questions are designed to focus your reading on the main concepts by section. An Inquiry Question appears at the beginning of each section.

2.1 Inquiry Question

What are the subatomic particles that make up an atom, and where are they located?

Subatomic Particles

If we could crush our half-carat diamond into particles even smaller than the atoms themselves, the atoms would no longer be recognizable as carbon. Instead, we would have a collection of small parts called **subatomic particles** that organize to form all atoms. The three basic subatomic particles are the proton, neutron, and electron. **Protons** and **electrons** are charged particles; that is, they have electrical properties. **Neutrons,** as their name implies, are neutral or uncharged. Protons have a positive (+) charge, and electrons have an opposite negative (−) charge. Overall, atoms have *no charge* because the number of protons is *equal* to the number of electrons (see **TABLE 2.1**).

CHAPTER REVIEW

CHAPTER 2

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STUDY GUIDE | **CHAPTER GUIDE**

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Properties of Particles in an Atom

Subatomic Particle	Symbol	Electrical Charge	Relative Mass	Location in Atom
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Relate the atomic number and mass number to the parts of an atom.

- Distinguish atomic number and mass number. (Try 2.5)
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Mass number $\longrightarrow$ ${}^{12}_{6}C$ $\longleftarrow$ Atomic symbol
Atomic number $\longrightarrow$

2.3 Isotopes and Atomic Mass

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- Define isotope. (See key terms on page 72)
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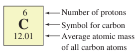
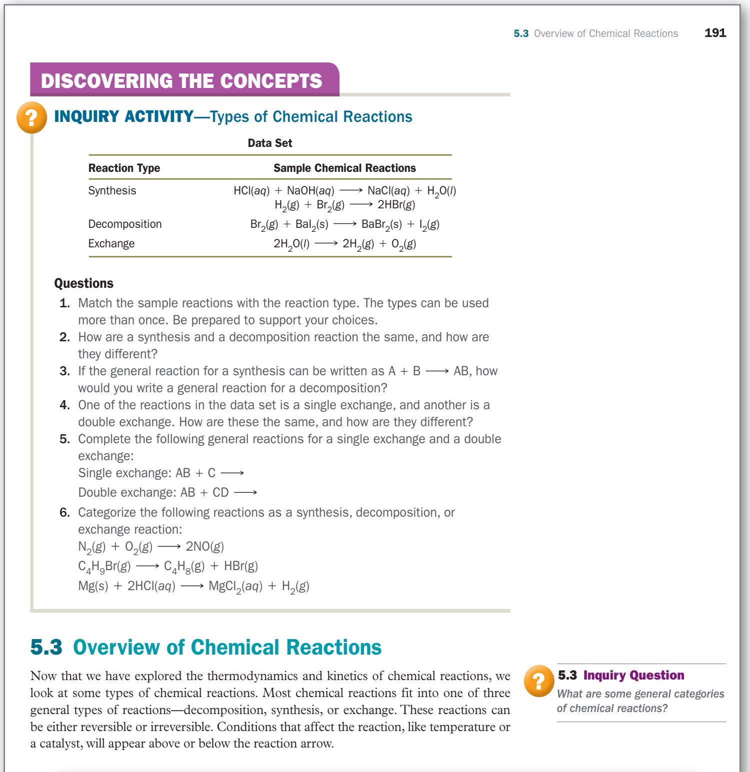


Special features promote mastery of concepts

Discovering the Concepts

Discovering the Concepts guides students through inquiry and exploration to develop chemical concepts. The activities can be used during class as an alternate way to introduce material to students as they work in groups.


5.3 Overview of Chemical Reactions 191

DISCOVERING THE CONCEPTS

INQUIRY ACTIVITY—Types of Chemical Reactions

Data Set

Reaction Type	Sample Chemical Reactions
Synthesis	$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$ $H_2(g) + Br_2(g) \longrightarrow 2HBr(g)$
Decomposition	$Br_2(g) + BaI_2(s) \longrightarrow BaBr_2(s) + I_2(g)$
Exchange	$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$

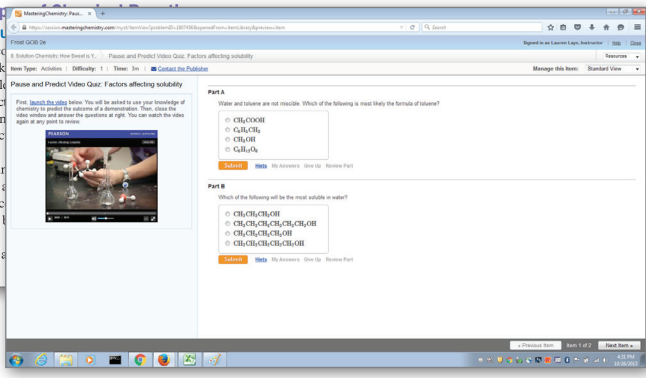
Questions

1. Match the sample reactions with the reaction type. The types can be used more than once. Be prepared to support your choices.
2. How are a synthesis and a decomposition reaction the same, and how are they different?
3. If the general reaction for a synthesis can be written as A + B ⟶ AB, how would you write a general reaction for a decomposition?
4. One of the reactions in the data set is a single exchange, and another is a double exchange. How are these the same, and how are they different?
5. Complete the following general reactions for a single exchange and a double exchange:
   Single exchange: AB + C ⟶
   Double exchange: AB + CD ⟶
6. Categorize the following reactions as a synthesis, decomposition, or exchange reaction:
   $N_2(g) + O_2(g) \longrightarrow 2NO(g)$
   $C_4H_9Br(g) \longrightarrow C_4H_8(g) + HBr(g)$
   $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

5.3 Overview of Chemical Reactions

Now that we have explored the thermodynamics and kinetics of chemical reactions, we look at some types of chemical reactions. Most chemical reactions fit into one of three general types of reactions—decomposition, synthesis, or exchange. These reactions can be either reversible or irreversible. Conditions that affect the reaction, like temperature or a catalyst, will appear above or below the reaction arrow.

5.3 Inquiry Question
What are some general categories of chemical reactions?



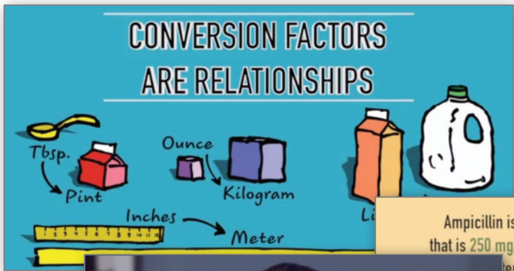
Guided Inquiry Activities

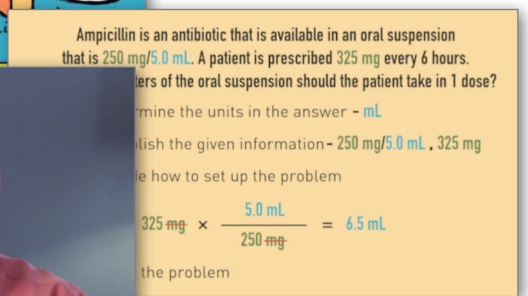
A full complement of Guided Inquiry Activities by Laura Frost are available through the Pearson Custom Library (http://www.pearsonlearningsolutions.com/custom-library/) and align with chapter topics. These activities are designed for in-class use by student groups with instructor facilitation allowing faculty to effectively incorporate more active learning or flip their classroom. Students gain exposure to chemistry through a learning cycle that starts with exploration of concrete models, allowing development of chemical concepts, and leads to applying concepts to further examples.

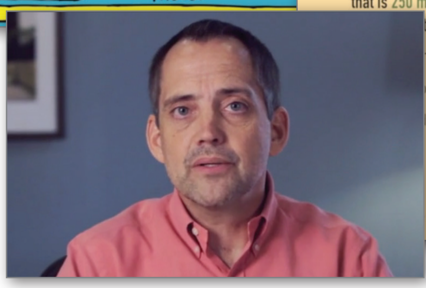
NEW!

Practicing the Concepts Videos

Practicing the Concepts Videos in MasteringChemistry bring chemistry to life. These 3- to 5-minute videos feature coauthor Todd Deal introducing key topics in general, organic, and biological chemistry that students find challenging. Students are asked to solve a problem while they watch the video content. Multiple-choice questions challenge students to apply the concepts from the video to related scenarios. These videos are designed to be used before, during, or after lectures.







Learning before, during, and after class

MasteringChemistry®

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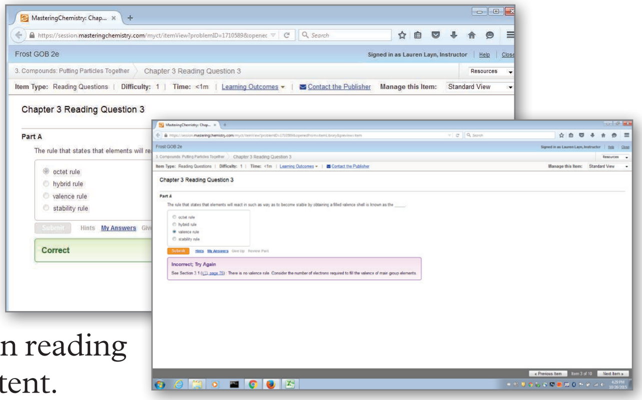
MasteringChemistry® from Pearson is the leading online teaching and learning system designed to improve results by engaging students before, during, and after class with powerful content. Ensure that students arrive ready to learn by assigning educationally effective content before class, and encourage critical thinking and retention with in-class resources such as Learning Catalytics. Students can further master concepts after class through traditional homework assignments that provide hints and answer-specific feedback. The Mastering gradebook records scores for all automatically graded assignments while diagnostic tools give instructors access to rich data to assess student understanding and misconceptions. Mastering brings learning full circle by continuously adapting to each student and making learning more personal than ever—before, during, and after class.

Before Class

Dynamic Study Modules

Help students quickly learn chemistry! Now assignable, Dynamic Study Modules enable your students to study on their own and be better prepared with the basic math and chemistry skills needed to succeed in the GOB course. The mobile app is available for iOS and Android devices for study on the go, and results can be tracked in the MasteringChemistry gradebook.



Reading Quizzes

Reading Quizzes give instructors the opportunity to assign reading and test students on their comprehension of chapter content.

During Class

NEW!

Learning Catalytics Questions

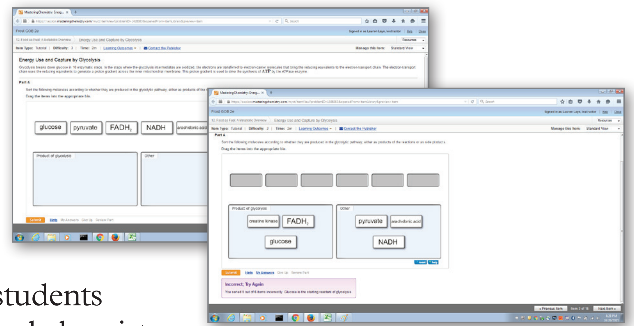
Learning Catalytics questions directly relate to the content of the text and also engage students with real-life applications. Learning Catalytics is a “bring your own device” student engagement, assessment, and classroom intelligence system. With Learning Catalytics, you can:

- Assess students in real time, using open-ended tasks to probe student understanding.
- Understand immediately where students are and adjust your lecture accordingly.
- Manage student interactions with intelligent grouping and timing.

After Class

Tutorials and Coaching

Integrated Tutorials in MasteringChemistry reinforce connections between general chemistry, organic chemistry, and biochemistry principles while helping students develop their problem-solving skills. Tutorials, featuring specific wrong-answer feedback, hints, and a wide variety of educationally effective content, guide your students through the toughest topics in general, organic, and biological chemistry.



1

Medications must be exactly measured before a dose can be given. We constantly measure things from doses to body weight to recipe ingredients. Chemists measure matter and its changes. To introduce you to the study of chemistry and measurements, we begin with Chapter 1.

Chemistry Basics—Matter and Measurement

DID YOU KNOW that everything you do every day involves chemistry? Yes, everything. From the water and shampoo in your shower, to the food you ate for breakfast, to the electronics that power your cell phone, to the therapeutic drugs for treating diseases, to the sunscreen lotion that protects your skin, and even the clothes that you wear—all of these somehow involve chemistry. Learning chemistry is really learning about how chemistry impacts our everyday lives and even provides life itself. Chemistry helps us understand concepts as diverse as how our bodies function and the wide variety of conveniences that make our lives easier. So, come explore with us. It will be challenging, but fun. We promise!

All of the "stuff" that we just mentioned is composed of something that chemists call matter. **Matter** can be defined as anything that takes up space (scientists call this volume) and weighs something (scientists call this mass). From the smallest tablet dispensed by a pharmacist to the shampoo in a bottle to the air in a balloon, each of these takes up some amount of space and is a form of matter.

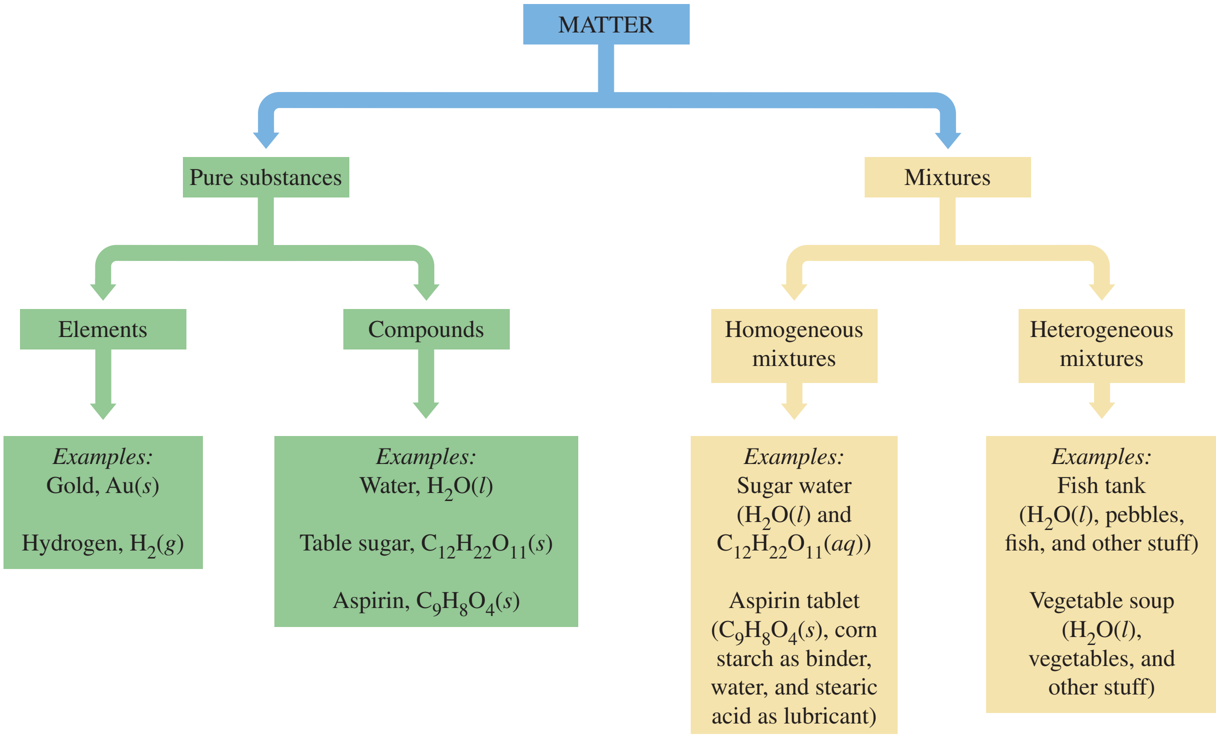
DISCOVERING THE CONCEPTS

INQUIRY ACTIVITY—Classifying Matter

Information

Chemistry is the study of matter and its changes. There are two main types of matter: *pure substances* and *mixtures* of substances. A mixture that is mostly water is called an *aqueous solution.* Matter can exist in several different *states,* the three most common being solid, liquid, or gas.

Types of Matter Flow Chart with Examples, Their Formulas, and States



Elements can exist as individual *atoms* (neon, Ne), in combination with other atoms, or as pairs (hydrogen, H_2) forming *molecules*.

Questions

1. Consider the examples on the flow chart. How does the formula of an element differ from that of a compound?
2. Can an element be a pure substance? Can a compound be a pure substance?
3. Using the information given, how might you define a pure substance? How does a pure substance differ from a mixture?
4. Based on the information in the data set, complete the table shown for the matter given.

Matter	Element or Compound	Atom or Molecule
He		
O_2		
CH_2O (formaldehyde)		
CH_3COOH (vinegar)		

5. As a group, devise a definition for a compound.
6. Describe the difference between a homogeneous and heterogeneous mixture.
7. Would you classify the following matter as element, compound, or mixture? If you classify it as a mixture, classify it as homogeneous or heterogeneous.
   a. table salt (NaCl) b. nickel (Ni)
   c. chocolate chip cookie dough d. air
8. What do you think the labels (s), (*l*), (*g*), and (*aq*) on the formulas in the figure mean?

1.1 Classifying Matter: Mixture or Pure Substance

In biology, organisms are classified by their genus and species name for identification purposes. For example, the genus and species name for humans is *Homo sapiens*. In chemistry, we classify matter to assign characteristics to different types of matter.

The flow chart shown in **FIGURE 1.1** gives you an idea of how we classify matter. This flow chart is your guide to classifying matter as chemists do.

As two examples of matter, consider blood and a diamond. If you are a blood donor, you may have heard blood discussed in terms of whole blood, plasma, white cells, and red cells. These terms give you a hint that blood is a mixture containing many components. In contrast, if you have ever bought a diamond, you know that one of the measures used to grade these gemstones is clarity, which is a measure of purity. The clearer (more pure) a diamond is, the more it costs. So, how do the complexity of a sample of blood and the purity of a diamond contribute to how they are classified?

Looking at the flow chart in Figure 1.1 from the top, we see that all matter is divided into two large categories or classifications—mixtures and pure substances. Let's consider these one at a time.

What's an Inquiry Question?

Inquiry Questions are designed to focus your reading on the main concepts by section. An Inquiry Question appears at the beginning of each section.

1.1 Inquiry Question

How is matter classified?

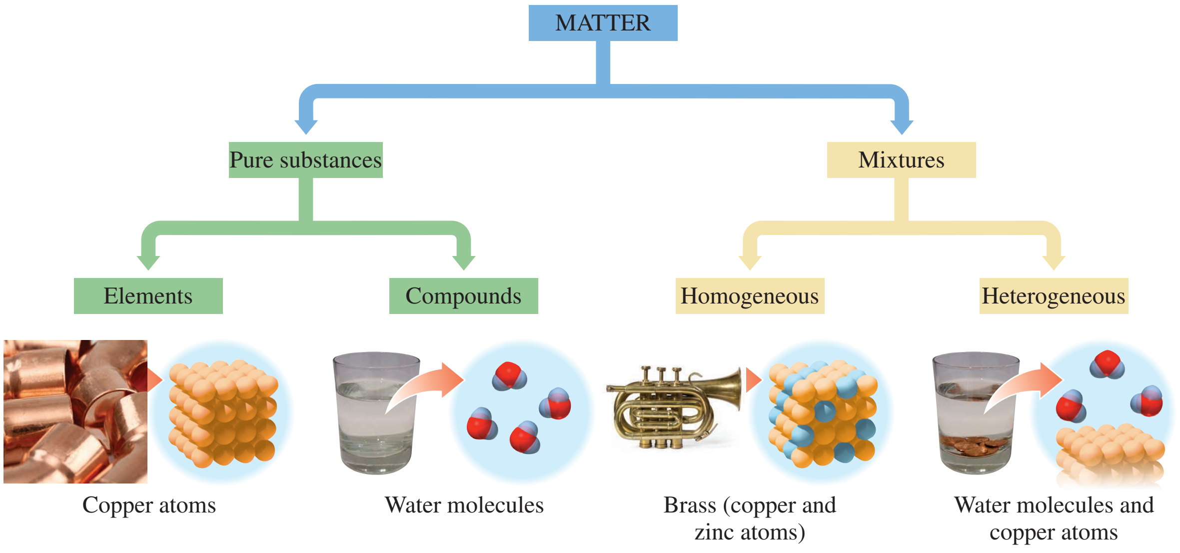


FIGURE 1.1 Flow chart used for classifying matter. Matter can be broadly classified as a mixture or a pure substance. Mixtures are classified as homogeneous or heterogeneous, and pure substances are classed as elements or compounds. The red balls on the water molecules represent oxygen, the gray balls hydrogen.

Blood is a mixture of many components, whereas a diamond is a single component of the element carbon. A specialist in blood banking separates and stores blood.

Mixtures

As we noted, blood contains red blood cells, white blood cells, plasma (which is mostly water), and several other components. Blood is an example of a **mixture,** a combination of two or more substances. One of the defining characteristics of a mixture is that it can be separated into its different components. A specialist in blood banking (SBB) is trained to separate blood into red cells and plasma for storage and use in different medical procedures at a blood bank.

Next, we consider different types of mixtures. Air contains nitrogen, oxygen, carbon dioxide, argon, and other gases. Every time you take a breath, you get the same substances in the same amount as another person breathing the same air. Air is classifed as a **homogeneous mixture** because its composition is the same throughout. In contrast, grandma's chunky spaghetti sauce is a **heterogeneous mixture** because its composition is not uniform, but varies throughout. One spoonful of spaghetti sauce may contain onions, mushrooms, and large chunks of tomato, while another spoonful contains celery, onions, and large chunks of green pepper. No two samples contain the same substances in the same amount.

Sample Problem 1.1 Classifying Mixtures

Classify each of the following mixtures as homogeneous or heterogeneous. Briefly justify your answer.

a. olive oil
b. rocky road ice cream

Solution

a. Olive oil is a homogeneous mixture. It has the same composition throughout.
b. Rocky road ice cream is a heterogeneous mixture. Each spoonful contains different amounts of nuts, marshmallow, and ice cream.

Pure Substances

From the air we breathe to the food we eat to the concrete we walk on, all are mixtures. Most matter we encounter everyday is a mixture. However, because of their varied composition, mixtures are difficult to study. While chemists routinely work with and study mixtures, pure substances are easier to characterize.

Diamonds are composed only of carbon. Because a diamond is composed of a single substance, it is not a mixture but a pure substance. A **pure substance** is matter that is made up of only one type of substance.

Note from the flow chart that pure substances can be one of two types—elements or compounds. Substances like diamond containing only one type of atom, carbon, are elements. An **element** is the simplest type of matter because it is made up of only one type of atom. An **atom** is the smallest unit of matter that can exist and keep its chemically unique characteristics. Substances like water that contain more than one type of atom, but contain these elements in a fixed composition, are also pure substances. Pure water contains only water and has the chemical formula H_2O. Because pure water has more than one type of atom, it is not an element but is a compound. A **compound** is a pure substance that is made of two or more elements that are chemically joined together.

Sample Problem 1.2 Mixture Versus Pure Substance

Classify each of the following substances as a mixture or a pure substance:

a. cake batter
b. helium gas inside a balloon

Solution

a. Cake batter is a mixture of flour, butter, sugar, and other ingredients.
b. The helium gas in the balloon is a pure substance.

Practice Problems

1.1 Classify each of the following mixtures as homogeneous or heterogeneous. Briefly justify your answer.
a. a bowl of vegetable soup b. mouthwash
c. an unopened can of cola d. a dinner salad

1.2 Classify each of the following mixtures as homogeneous or heterogeneous. Briefly justify your answer.
a. a bottle of sports drink b. a blueberry pancake
c. gasoline d. a box of raisin bran

1.3 Classify each of the following substances as a pure substance or a mixture:
a. copper b. ice cream
c. salt

1.4 Classify each of the following substances as a pure substance or a mixture:
a. saltwater b. tap water
c. concrete

DISCOVERING THE CONCEPTS

INQUIRY ACTIVITY—The Periodic Table

All *elements* are listed individually on the *periodic table of the elements.* There is a periodic table on the inside front cover of your textbook and an alphabetical listing of all the elements on the facing page. Refer to this as you answer the questions in this activity.

The rows on the periodic table are referred to as *periods*, and the columns are referred to as *groups.* The groups are numbered across the top of the periodic table, and the periods are numbered down the left side of the table. The table is organized with metals on the left and nonmetals on the right, with a staircase dividing line between the two. Find this staircase on the periodic table in your textbook.

Water's chemical formula is H_2O, meaning that it contains two hydrogen atoms and one oxygen atom. Chemical formulas show the type and number of each element present in a compound.

Questions

1. In which group on the periodic table are the following elements found?
   a. sodium b. oxygen c. calcium d. carbon
2. In which period are the following elements found?
   a. hydrogen b. nitrogen c. sulfur d. phosphorus
3. Provide names for the following elements and identify them as metals or nonmetals:
   a. Cu b. Na c. Cl d. C e. K f. P
4. Look at the periodic table of the elements. About how many elements are there?
5. Identify the number and name of each element in the chemical formulas given:
   a. $C_6H_{12}O_6$ (dextrose)
   b. NaOH (lye, found in drain cleaners)
   c. $NaHCO_3$ (baking soda)
   d. $C_{15}H_{21}NO_2$ (Demerol, a painkiller)
6. Are most of the elements on the periodic table metals or nonmetals? The Earth's biomass is made up mostly of carbon, hydrogen, and oxygen. Are these metals or nonmetals?

1.2 Elements, Compounds, and the Periodic Table

1.2 Inquiry Question

How is the periodic table organized?

If a pure substance can be an element or a compound, how do we distinguish which is which? We have a tool to guide us: the **periodic table of the elements.** At its most basic level, the periodic table is a listing of all the elements found on Earth.

You may have previously encountered the periodic table, most likely hanging on the wall in a science classroom. But have you ever tried to decipher it? This strangely shaped chart contains an amazing collection of data, both in the way that it is organized and in the actual information listed. We will make extensive use of the periodic table and the information it contains. Take a look at the periodic table in **FIGURE 1.2**.

The periodic table consists of many small blocks in a simple layout. Each has a letter or two in its center and numbers above and below these letters. The letters are known as the **chemical symbol** and represent the name of each element. For many of the elements, the symbols are derived directly from the name of the element—for example, lithium = Li, carbon = C, hydrogen = H, oxygen = O, and so on. A few of the elements have symbols that do not match the first few letters of their name—for example, sodium = Na, gold = Au. These elemental symbols are derived from the Latin names for the element, natrium and aurum respectively. Because the elements form the basic vocabulary of

Periodic Table of the Elements

Main-group elements: Group 1A (Alkali metals), Group 2A (Alkaline earth metals), Groups 3A–7A, Group 7A (Halogens), Group 8A (Noble gases)

Transition elements: Groups 3B–2B

Period number	Group 1A (1)	Group 2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	Group 3A (13)	Group 4A (14)	Group 5A (15)	Group 6A (16)	Group 7A (17)	Group 8A (18)
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57* La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 208.9	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89† Ac (227)	104 Rf (267)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 — (284)	114 Fl (289)	115 — (288)	116 Lv (293)	117 — (294)	118 — (294)

*Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.26	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
†Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	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 Unknown

FIGURE 1.2 The periodic table of the elements.

chemistry, it is important to know the names and symbols of the more common elements, especially those that are found in living things (carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur).

The blocks on the periodic table are organized in specific arrangements. Each block holds a different element. A vertical column of blocks is known as a **group** of elements. The elements in a group have similar chemical behaviors. Each group has a number and letter designation. The groups with A designations (1A–8A) are known as the main-group elements, and the groups with B designations are the transition elements. This system of numbering the groups is most common in North America and will be used throughout this textbook. The system using the numbers 1 through 18 for the columns has been recommended by the International Union of Pure and Applied Chemistry (IUPAC) and is also used. Several of the groups have special names to designate the members of the group as shown at the top of Figure 1.2.

A horizontal row of blocks is known as a **period.** The periods are numbered from 1 to 7 with sections of Periods 6 and 7 set apart at the bottom of the periodic table. The bold, descending staircase beginning at the element boron (#5) and running diagonally down and to the right separates the metals from the nonmetals. Elements bordered by the line, with the exception of aluminum (Al), are metalloids.

Metals and nonmetals show different properties. Aluminum can be made into sheets or blocks and is a metal. Carbon is more brittle, and we find it as a powder or as the "lead" in a pencil. Carbon is a nonmetal.

Elements in Nutrition

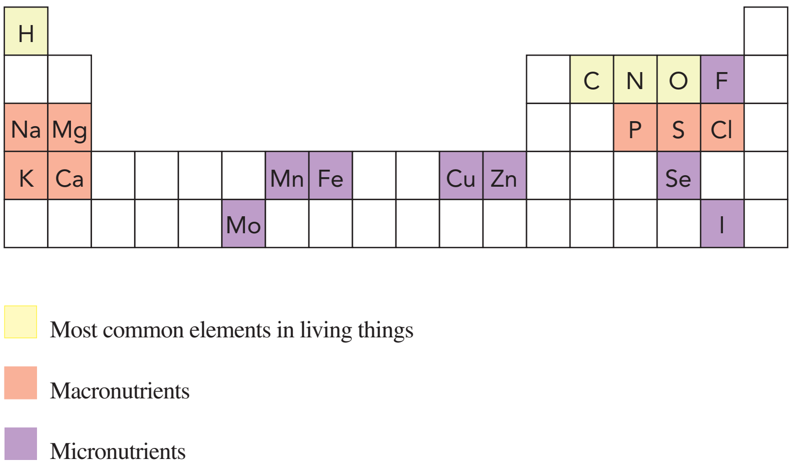
INTEGRATING Chemistry

Find out which elements the body uses.

Several elements on the periodic table have been identified as being essential for human health by the U.S. Food and Nutrition Board at the National Academies. These are in addition to the nonmetals found in great quantities in food, carbon, hydrogen, oxygen, and nitrogen, or the CHON elements, which make up most of the biological molecules on the Earth. Other elements essential for human health are further classified as macronutrients if required in quantities greater than 100 milligrams per day or as micronutrients if required in trace quantities less than 100 milligrams per day.

The macronutrients include several elements, sodium, magnesium, potassium, calcium, and chlorine, that are found in the body as charged particles and are essential for the transport of electrical signals through cells. The micronutrients are often found concentrated in particular organs. For example, iodine is found in the thyroid, fluorine in the teeth, and zinc mainly in muscle and bone. Red blood cells contain the protein hemoglobin, which contains iron. **TABLE 1.1** summarizes the uses and locations of the micronutrients.

Chromium, once considered a micronutrient, has recently been suggested to be nonessential because removal of this element from the diet has been shown to have no adverse health effects and no known molecule in the body uses chromium.



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Continued—

TABLE 1.1 Micronutrients

Element	Use in Body	Main Location in Body
Copper (Cu)	Used in several enzymes that are essential for human health and development.	Liver
Fluorine (F)	Mineralizes teeth and bones.	Teeth and bone
Iodine (I)	Found in thyroid hormones.	Thyroid
Iron (Fe)	Found in hemoglobin, a protein that transfers oxygen from lungs to tissues.	Red blood cells
Manganese (Mn)	Found in enzymes that act as antioxidants, enzymes involved in bone development and wound healing.	Pituitary gland, bones, and connective tissue
Molybdenum (Mo)	Used with enzymes that control oxidation processes.	Liver and kidney
Selenium (Se)	Used in proteins that regulate reproduction, thyroid, DNA synthesis, and oxidative damage.	Skeletal muscle, thyroid, immune system
Zinc (Zn)	Cell growth and division, also immune system. In males, also vital in fertility.	Bones and muscle

Sample Problem 1.3 Using the Periodic Table

Use the periodic table to answer the following questions:

a. What is the elemental symbol for oxygen?
b. To what group does oxygen belong?
c. What period is oxygen in?

Solution

a. Oxygen's symbol is O.
b. Oxygen is located in Group 6A.
c. Oxygen is in Period 2.

Compounds

How do we classify substances like water (H_2O) or table salt (NaCl) that contain more than one element from the periodic table? Remember that we said a pure substance containing two or more elements chemically combined is classified as a compound. Therefore, both water and table salt are compounds. Compounds combine elements in specific ratios. How and why elements combine in these ratios are discussed in Chapter 3.

Sample Problem 1.4 Classifying Pure Substances

Classify each of the following as an element or compound and explain your classification:

a. carbon dioxide (the gas we breathe out)
b. xenon (a gas sometimes used as an anesthetic)

Solution

a. Carbon dioxide is a compound. From its name, you can tell that this substance contains carbon and "something else" (even if you did not know that oxide is a name often used for oxygen when it is in compounds). Because carbon dioxide contains two different elements, it is a compound.

b. Xenon is an element. Look for xenon on the periodic table. You will find it in group 8A (18). This gas is becoming more common as an anesthetic agent due to its minimal effects on the environment.

Before we continue, let's take a quick look at the representations we use for compounds. Why does the representation for water contain the subscript 2 after hydrogen, but the one we use for table salt does not have a subscript? These representations, known as **chemical formulas,** show that water is composed of two atoms of hydrogen and one atom of oxygen and table salt is composed of one sodium and one chlorine. The subscript tells us how many of the preceding element are present in the compound. The absence of a subscript on oxygen, sodium, and chlorine is understood to mean *one* of each element. A compound's chemical formula identifies both the type and number of each of the elements in a compound.

Sample Problem 1.5 Elements in Compounds

Identify and give the number of atoms of each element in the following compounds:

a. $C_2H_4O_2$, acetic acid, a component of vinegar

b. H_3PO_4, phosphoric acid

Solution

a. Acetic acid contains 2 atoms of carbon, 4 atoms of hydrogen, and 2 atoms of oxygen.

b. Phosphoric acid contains 3 atoms of hydrogen, 1 atom of phosphorus, and 4 atoms of oxygen.

Practice Problems

1.5 Classify each of the following as an element or compound and explain your classification:

a. aluminum, used in soft drink cans and foil

b. sodium hypochlorite, found in bleach

c. hydrogen, fuel of the sun

d. potassium chloride, a table-salt substitute

1.6 Classify each of the following as an element or a compound:

a. Fe b. $CaCl_2$ c. Si d. KI

1.7 Use the periodic table to supply the missing information in the following chart:

Name	Elemental Symbol	Group	Period	Metal or Nonmetal
Fluorine				
		1A	2	
	Cl			
		4A	2	Nonmetal

—*Continued next page*