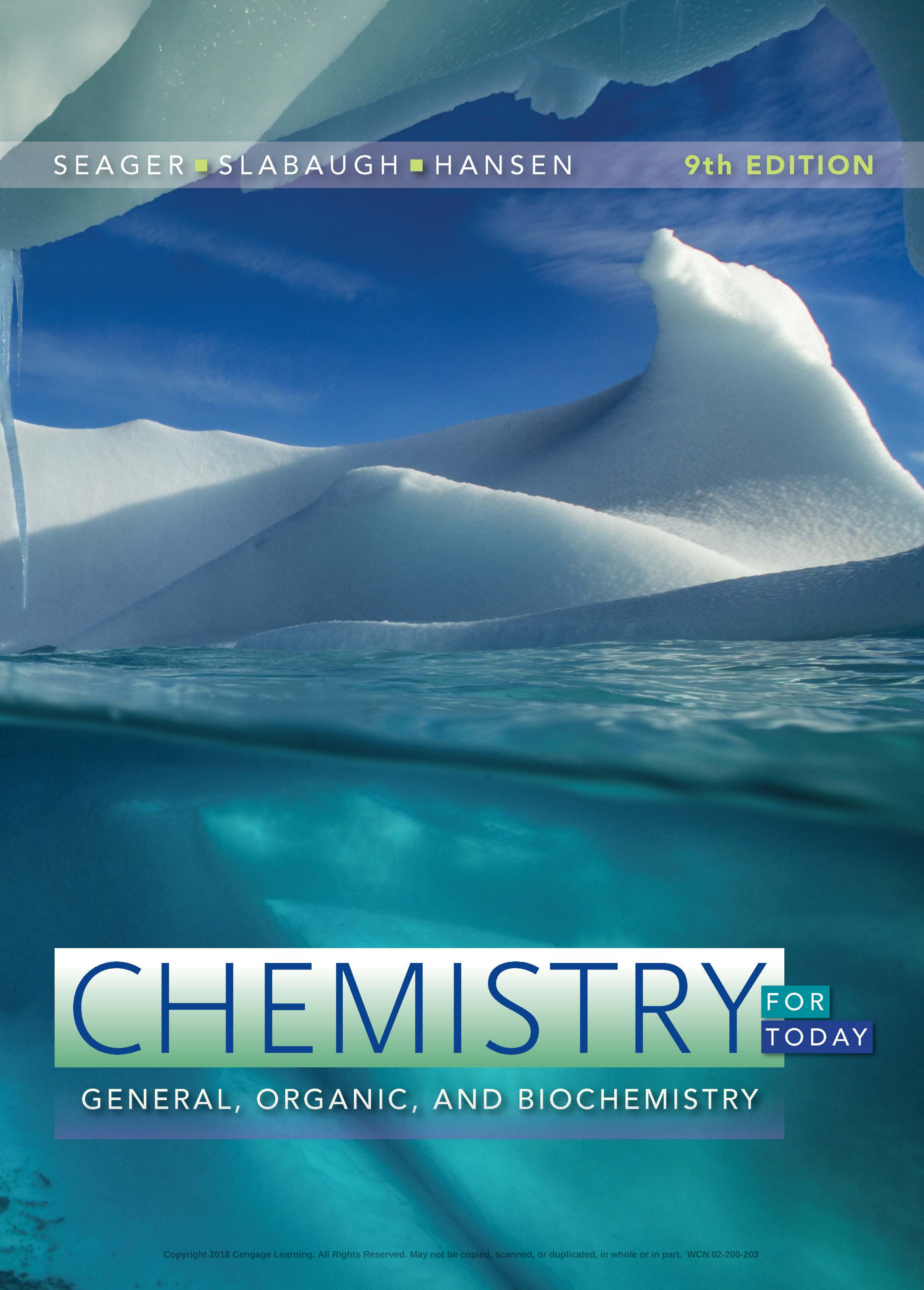

SEAGER ■ SLABAUGH ■ HANSEN

9th EDITION

CHEMISTRY FOR TODAY

GENERAL, ORGANIC, AND BIOCHEMISTRY

NINTH EDITION

Chemistry for Today

General, Organic, and Biochemistry

Spencer L. Seager

University of South Dakota

Weber State University

Michael R. Slabaugh

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Weber State University

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***Chemistry for Today: General, Organic, and Biochemistry*, Ninth Edition**
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Production Service: MPS Limited

Photo Researcher: Lumina Datamatics

Text Researcher: Lumina Datamatics

Copy Editor: MPS Limited

Text Designer: Hespenheide Design

Cover Designer: Delgado and Company

Cover Image: Paul Souders/Getty Images

Compositor: MPS Limited

Library of Congress Control Number: 2016952183

Student Edition:
ISBN: 978-1-305-96006-0

Loose-leaf Edition:
ISBN: 978-1-305-96870-7

Cengage Learning
20 Channel Center Street
Boston, MA 02210
USA

Printed in the United States of America
Print Number: 01 Print Year: 2016

To our grandchildren:

Nate and Braden Barlow, Megan and Bradley Seager, and Andrew Gardner

Alexander, Annie, Charlie, Christian, Elyse, Foster, Megan, and Mia Slabaugh, Addison, Hadyn, and Wyatt Hansen

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Brief Contents

Contents

Chapter 4

Forces between Particles 100

Chapter 5

Chemical Reactions 144

Chapter 6

The States of Matter 174

Chapter 7

Solutions and Colloids 210

Chapter 8

Reaction Rates and Equilibrium 250

Chapter 9

Acids, Bases, and Salts 276

Chapter 16

Amines and Amides 516

Chapter 17

Carbohydrates 548

Chapter 18

Lipids 582

Chapter 19

Proteins 610

Chapter 20

Enzymes 642

Chapter 21

Nucleic Acids and Protein Synthesis 668

Chapter 22

Nutrition and Energy for Life 702

Chapter 23

Carbohydrate Metabolism 732

Chapter 24

Lipid and Amino Acid Metabolism 760

Chapter 25

Body Fluids 788

Preface

The Image of Chemistry

We, as authors, are pleased that the acceptance of the previous eight editions of this textbook by students and their teachers has made it possible to publish this ninth edition. In the earlier editions, we expressed our concern about the negative image of chemistry held by many of our students, and their genuine fear of working with chemicals in the laboratory. Unfortunately, this negative image not only persists, but seems to be intensifying. Reports in the media related to chemicals or to chemistry continue to be primarily negative, and in many cases seem to be designed to increase the fear and concern of the general public. With this edition, we continue to hope that those who use this book will gain a more positive understanding and appreciation of the important contributions that chemistry makes in their lives.

Theme and Organization

This edition continues the theme of the positive and useful contributions made by chemistry in our world.

This text is designed to be used in either a two-semester or three-quarter course of study that provides an introduction to general chemistry, organic chemistry, and biochemistry. Most students who take such courses are majoring in nursing, other health professions, or the life sciences, and consider biochemistry to be the most relevant part of the course of study. However, an understanding of biochemistry depends upon a sound background in organic chemistry, which in turn depends upon a good foundation in general chemistry. We have attempted to present the general and organic chemistry in sufficient depth and breadth to make the biochemistry understandable.

The decisions about what to include and what to omit from the text were based on our combined 75-plus years of teaching, input from numerous reviewers and adopters, and our philosophy that a textbook functions as a personal tutor to each student. In the role of a personal tutor, a text must be more than just a collection of facts, data, and exercises. It should also help students relate to the material they are studying, carefully guide them through more difficult material, provide them with interesting and relevant examples of chemistry in their lives, and become a reference and a resource that they can use in other courses or their professions.

New to This Edition

In this ninth edition of the text, we have some exciting new features, including Ask a Pharmacist boxes written by Marvin Orrock and Chemistry Tips for Living Well. We have also retained features that received a positive reception from our own students, the students of other adopters, other teachers, and reviewers. The retained features are Case Studies, which begin each chapter, including 8 new to this edition; 45 Chemistry Around Us boxes, including 19 new to this edition; 23 Study Skills boxes; 4 How Reactions Occur boxes; and 10 Ask an Expert boxes. The 12 Ask a Pharmacist boxes reflect coverage of both prescription and nonprescription health-related products. The 25 Chemistry Tips for Living Well contain current chemistry-related health issues and suggestions. In addition, approximately 10% of the end-of-chapter exercises have been changed.

Also new to this edition are many new photographs and updated art to further enhance student comprehension of key concepts, processes, and preparation.

Revision Summary of Ninth Edition:

Chapter 1:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask an Expert: *Does Food Density Matter When You're Trying to Lose Weight?*
- New Chemistry Around Us: *Are Chemicals Getting a Bad Rap?*
- New Chemistry Tips for Living Well: *Choose Wisely for Health Information*
- 10% new Exercises

Chapter 2:

- Several revised figures
- New photography
- Updated element table
- New Chemistry Around Us: *Chemical Elements in the Human Body*
- New Ask a Pharmacist: *Uprooting Herbal Myths*
- New Chemistry Tips for Living Well: *Take Care of Your Bones*
- 10% new Exercises

Chapter 3:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Watch the Salt*
- New Chemistry Around Us: *A Solar Future*
- New Chemistry Around Us: *Transition and Inner-Transition Elements in Your Smart Phone*
- 10% new Exercises

Chapter 4:

- Several revised figures
- New photography
- New Ask a Pharmacist: *Are All Iron Preparations Created Equal?*
- New Chemistry Tips for Living Well: *Consider the Mediterranean Diet*
- New Chemistry Around Us: *Ozone: Good up High, Bad Nearby*
- 10% new Exercises

Chapter 5:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Add Color to Your Diet*
- New Chemistry Around Us: *Teeth Whitening*
- New Chemistry Around Us: *Electric Cars*
- 10% new Exercises

Chapter 6:

- Several revised figures
- New photography
- New Ask a Pharmacist: *Zinc for Colds?*
- New Chemistry Tips for Living Well: *Get an Accurate Blood Pressure Reading*
- New Chemistry Around Us: *Air Travel*
- 10% new Exercises

Chapter 7:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Around Us: *Health Drinks*
- New Chemistry Around Us: *CO_2 Emissions: A Blanket around the Earth*
- New Chemistry Tips for Living Well: *Stay Hydrated*
- 10% new Exercises

Chapter 8:

- Several revised figures
- New photography
- New Ask a Pharmacist: *Energy for Sale*
- New Chemistry Around Us: *Why "Cold" Does Not Exist*
- New Chemistry Tips for Living Well: *Use Your Phone to Help You Stay Healthy*
- 10% new Exercises

Chapter 9:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Beware of Heartburn*
- New Chemistry Around Us: *Sinkholes*
- 10% new Exercises

Chapter 10:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask a Pharmacist: *Medications to Avoid on Test Day*
- New Chemistry Tips for Living Well: *Check the Radon Level in Your Home*
- 10% new Exercises

Chapter 11:

- Several revised figures
- New photography
- New Chemistry Around Us: *Fracking Oil Wells*
- New Chemistry Around Us: *Reducing Your Carbon Footprint*
- New Chemistry Tips for Living Well: *Take Care of Dry Skin*
- 10% new Exercises

Chapter 12:

- Several revised figures
- New photography
- New Ask a Pharmacist: *Controlled Substances*
- New Chemistry Tips for Living Well: *Think before Getting Brown*
- New Chemistry Around Us: *Three-Dimensional Printers*
- New Chemistry Around Us: *Polycarbonate—The Lucky Polymer*
- New Chemistry Around Us: *Graphene*
- 10% new Exercises

Chapter 13:

- Several revised figures
- New photography

- New Ask a Pharmacist: Marijuana: *A Gateway Drug*
- New Chemistry Tips for Living Well: *Take Advantage of Hand Sanitizers*
- 10% new Exercises

Chapter 14:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Get the Right Dose of Exercise*
- 10% new Exercises

Chapter 15:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Consider Low-Dose Aspirin*
- 10% new Exercises

Chapter 16:

- Several revised figures
- New photography
- New Ask a Pharmacist: *A Wake-Up Call for Treating Insomnia*
- New Chemistry Tips for Living Well: *Try a Little Chocolate*
- 10% new Exercises

Chapter 17:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Put Fiber into Snacks and Meals*
- 10% new Exercises

Chapter 18:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Consider Olive Oil*
- New Chemistry Around Us: *Biofuels Move into the Kitchen*
- 10% new Exercises

Chapter 19:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Ask a Pharmacist: *Who Really Needs Gluten-Free Food?*
- New Chemistry Around Us: *A Milk Primer*
- New Chemistry Tips for Living Well: *Go for the Good Grains*
- 10% new Exercises

Chapter 20:

- Several revised figures
- New photography
- New Ask a Pharmacist: *Treatment Options for the Common Cold*
- New Chemistry Around Us: *No Milk Please*
- New Chemistry Tips for Living Well: *Cut Back on Processed Meat*
- 10% new Exercises

Chapter 21:

- New Case Study
- New Case Study Follow-up
- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Reduce Your Chances for Developing Cancer*
- 10% new Exercises

Chapter 22:

- Several revised figures
- New photography
- New Ask a Pharmacist: Sports Supplements: *Where Is My Edge?*
- New Chemistry Tips for Living Well: *Select a Heart-Healthful Diet*
- 10% new Exercises

Chapter 23:

- Several revised figures
- New photography
- New Chemistry Tips for Living Well: *Choose Complex Carbohydrates*
- 10% new Exercises

Chapter 24:

- New Case Study
- New Case Study Follow-up
- New photography
- New Chemistry Tips for Living Well: *Pick the Right Fats*
- 10% new Exercises

Chapter 25:

- New photography
- New Ask a Pharmacist: *Performance-Enhancing Drugs*
- New Chemistry Tips for Living Well: *Select the Right Pre-Exercise Foods*
- 10% new Exercises

Features

Each chapter has features especially designed to help students study effectively, as well as organize, understand, and enjoy the material in the course.

Case Studies. These scenarios introduce you the students to diverse situations a health care professional might encounter. The purpose of the case studies is to stimulate inquiry; for that reason, we've placed them at the beginning of each chapter of the book. Vocabulary and scenarios may be unfamiliar to you who are studying these course materials, but our intent is to raise questions and pique your curiosity. Medicine has long been described as an art. The questions raised by these case studies rarely have a single correct answer. With the knowledge that you gain from this text and your future training,

▶ Case Study

Purpose: The case study scenarios introduce diverse situations that a health care professional might encounter. Their purpose is to stimulate inquiry; for that reason, we've placed them at the beginning of each chapter. Vocabulary and scenarios may be unfamiliar, but our intention is to stimulate questions and to pique curiosity. Medicine has long been described as an art as well as a science. The questions raised by these case studies rarely have a single correct answer. With the knowledge that you gain from this text, and your future training, acceptable answers to the questions raised in our scenarios will become apparent.

Disclaimer: Some of the case studies are based on real-life situations. In such cases, names have been changed to protect the individual's anonymity.

acceptable answers to the questions raised in our scenarios will become apparent. A Case Study Follow-up to each Case Study can be found at the end of each chapter before the Concept Summary.

Chapter Outlines and Learning Objectives. At the beginning of each chapter, a list of learning objectives provides students with a convenient overview of what they should gain by studying the chapter. In order to help students navigate through each chapter and focus on key concepts, these objectives are repeated at the beginning of the section in which the applicable information is discussed. The objectives are referred to again in the concept summary at the end of each chapter along with one or two suggested end-of-chapter exercises. By working the suggested exercises, students get a quick indication of how well they have met the stated learning objectives. Thus, students begin each chapter with a set of objectives and end with an indication of how well they satisfied the objectives.

Key Terms. Identified within the text by the use of bold type, key terms are defined in the margin near the place where they are introduced. Students reviewing a chapter can quickly identify the important concepts on each page with this marginal glossary. A full glossary of key terms and concepts appears at the end of the text.

Ask a Pharmacist. These boxed features written by Marvin Orrock, Pharm.D., contain useful information about health-related products that are readily available to consumers with or without a prescription. The information in each box provides a connection between the chemical behavior of the product and its effect on the body.

ASK A PHARMACIST 12.1

Controlled Substances

So what are *controlled substance,* anyway, and why do we have them? Before we answer those questions, let's briefly review the major legislation that pertains to products used as medicines. Prior to the 1900s there were no governmental regulations on foods or drugs. As a result, some products were contaminated and some not labeled accurately. Consequently, the U.S. Congress passed the Pure Food and Drug Act of 1906. It proved to be helpful, but opiates and cocaine were not regulated. A significant percentage of the population became addicted, and many deaths were attributed to the use of products that were "pure" and "labeled" correctly but still contained addicting materials. In 1914 the Harrison Act was passed. It regulated heroin and cocaine sales. During the

United States, or a currently accepted medical use with severe restrictions. Abuse of the substance might lead to severe psychological or physical dependence (e.g., Percocet, Demerol, Ritalin).

Schedule III: The substance has a potential for abuse less than the compounds in Schedules I and II. The substance has a currently accepted medical use for treatment in the United States. Abuse of the substance might lead to moderate or low physical dependence or high psychological dependence (e.g.,Tylenol with codeine used for pain, anabolic steroids).

Schedule IV: The substance has a low potential for abuse relative to the compounds in Schedule III. The substance has a currently accepted medical use for treatment in the United States. Abuse of the substance might lead to limited physical dependence or psychological dependence relative to the sub-

Chemistry Around Us. These boxed features present everyday applications of chemistry that emphasize in a real way the important role of chemistry in our lives. Thirty percent of these are new to this edition and emphasize health-related applications of chemistry.

Chemistry Tips for Living Well. These boxed features contain current chemistry-related health issues such as "Add Color to Your Diet," and suggestions for maintaining good health such as "Consider the Mediterranean Diet," "Cut Back on Processed Meat," and "Try a Little Chocolate."

CHEMISTRY TIPS FOR LIVING WELL 14.1

Get the Right Dose of Exercise

Experts agree that exercise is one of the best preventative "medicines" available. It increases energy, stamina, and one's sense of well-being. In the long term it also reduces the risk of premature death from cardiovascular disease. Put simply, it makes you feel better and live longer. We expect medicines to make us feel better when we are ill. But exercise acts as a powerful medicine to prevent illness. How do you know what the proper dose is? Do you need to exercise on a daily basis or will a weekly dose provide the desired health benefits? Just how little can you get away with and stay healthy?

Researchers arrive at the proper dose by examining

times the recommended amount), health benefits are comparable to those achieved by people who merely meet the minimum requirements. In other words, many extra hours of exercise do not equate to huge gains in longevity. On the other hand, many times the recommended exercise level is not considered to be harmful. It is difficult to overdose on moderate exercise.

Intensity, as well as frequency, should be considered when calculating the ideal exercise dose. People who spend part of their daily exercise time in vigorous activity, rather than moderate activity alone (e.g., running instead of walking) reap additional health benefits. People who spent up to

Ask an Expert. These boxed features, written by Melina B. Jampolis, M.D., engage students by presenting questions and answers about nutrition and health, as related to chemistry, that are relevant and important in today's world.

Examples. To reinforce students in their problem-solving skill development, complete step-by-step solutions for numerous examples are included.

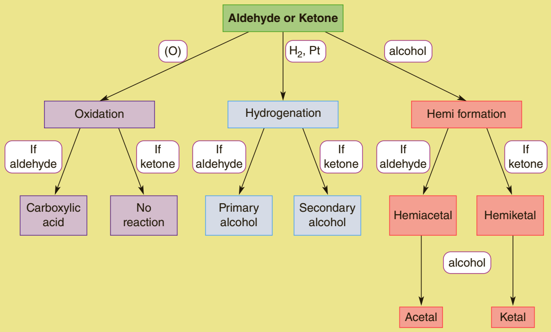
Learning Checks. Short self-check exercises follow examples and discussions of key or difficult concepts. A complete set of solutions is included in Appendix C. These allow students to measure immediately their understanding and progress.

Study Skills. Most chapters contain a *Study Skills* feature in which a challenging topic, skill, or concept of the chapter is addressed. Study suggestions, analogies, and approaches are provided to help students master these ideas.

STUDY SKILLS 14.1

A Reaction Map for Aldehydes and Ketones

This reaction map is designed to help you master organic reactions. Whenever you are trying to complete an organic reaction, use these two basic steps: (1) Identify the functional group that is to react, and (2) Identify the reagent that is to react with the functional group. If the reacting functional group is an aldehyde or a ketone, find the reagent in the summary diagram, and use the diagram to predict the correct products.



How Reactions Occur. The mechanisms of representative organic reactions are presented in four boxed inserts to help students dispel the mystery of how these reactions take place.

Concept Summary. Located at the end of each chapter, this feature provides a concise review of the concepts and includes suggested exercises to check achievement of the learning objectives related to the concepts.

Concept Summary

Symbols and Formulas Symbols based on names have been assigned to every element. Most consist of a single capital letter followed by a lowercase letter. A few consist of a single capital letter. Compounds are represented by formulas made up of elemental symbols. The number of atoms of each element in a molecule is shown by subscripts.
Objective 1 (Section 2.1), Exercise 2.4

Inside the Atom Atoms are made up of numerous smaller particles, of which the most important to chemical studies are the proton, neutron, and electron. Positively charged protons and neutral neutrons have a relative mass of 1 u each and are located in the nuclei of atoms. Negatively charged electrons with a mass of 1/1836 u are located outside the nuclei of atoms.
Objective 2 (Section 2.2), Exercises 2.10 and 2.12

Isotopes Most elements in their natural state are made up of more than one kind of atom. These different kinds of atoms of a specific element are called isotopes and differ from one another only in the number of neutrons in their nuclei. A symbol incorporating atomic number, mass number, and elemental symbol is used to represent a specific isotope.
Objective 3 (Section 2.3), Exercises 2.16 and 2.22

Key Terms and Concepts. These are listed at the end of the chapter for easy review, with a reference to the chapter section in which they are presented.

Key Equations. This feature provides a useful summary of general equations and reactions from the chapter. This feature is particularly helpful to students in the organic chemistry chapters.

Exercises. Nearly 1,700 end-of-chapter exercises are arranged by section. Approximately half of the exercises are answered in the back of the text. Complete solutions to these answered exercises are included in the Student Study Guide. Solutions and answers to the remaining exercises are provided in the Instructor's Manual. We have included a significant number of clinical and other familiar applications of chemistry in the exercises.

Chemistry for Thought. Included at the end of each chapter are special questions designed to encourage students to expand their reasoning skills. Some of these exercises are based on photographs found in the chapter, while others emphasize clinical or other useful applications of chemistry.

Allied Health Exam Connection. These examples of chemistry questions from typical entrance exams used to screen applicants to allied health professional programs help students focus their attention on the type of chemical concepts considered important in such programs.

Allied Health Exam Connection

The following questions are from these sources:

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- *McGraw-Hill's Nursing School Entrance Exams* by Thomas A. Evangelist, Tamara B. Orr, and Judy Unrein © 2009, The McGraw-Hill Companies, Inc.
- *NSEE Nursing School Entrance Exams,* 3rd edition © 2009, Kaplan Publishing.
- *Cliffs Test Prep: Nursing School Entrance Exams* by Fred N. Grayson © 2004, Wiley Publishing, Inc.
- *Peterson's Master the Nursing School and Allied Health Entrance Exams,* 18th edition by Marion F. Gooding © 2008, Peterson's, a Nelnet Company.

9.137 An acid is a substance that dissociates in water into one or more _______ ions and one or more _______.
a. hydrogen . . . anions
b. hydrogen . . . cations
c. hydroxide . . . anions
d. hydroxide . . . cations

9.138 A base is a substance that dissociates in water into one or more ________ ions and one or more _________.
a. hydrogen . . . anions
b. hydrogen . . . cations
c. hydroxide . . . anions

9.143 Dissolving H_2SO_4 in water creates an acid solution by increasing the:
a. sulfate ions.
b. water ions.
c. hydrogen ions.
d. oxygen ions.

9.144 When a solution has a pH of 7, it is:
a. a strong base.
b. a strong acid.
c. a weak base.
d. neutral.

Possible Course Outlines

This text may be used effectively in either a two-semester or three-quarter course of study:

First semester: Chapters 1–13 (general chemistry and three chapters of organic chemistry)

Second semester: Chapters 14–25 (organic chemistry and biochemistry)

First semester: Chapters 1–10 (general chemistry)

Second semester: Chapters 11–21 (organic chemistry and some biochemistry)

First quarter: Chapters 1–10 (general chemistry)

Second quarter: Chapters 11–18 (organic chemistry)

Third quarter: Chapters 19–25 (biochemistry)

Supporting Materials

Please visit **http://www.cengage.com/chemistry/seager/gob9e** for information about student and instructor resources for this text.

Acknowledgments

We express our sincere appreciation to the following reviewers, who helped us revise the many editions:

Hugh Akers
Lamar University–Beaumont

Johanne I. Artman
Del Mar College

Gabriele Backes
Portland Community College

Bruce Banks
University of North Carolina–Greensboro

David Boykin
Georgia State University

Deb Breiter
Rockford College

Lorraine C. Brewer
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John Vincent
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Scott White
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Grossmont College

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Hope College

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We also give special thanks to Dawn Giovanniello, Product Director, and Peter McGahey, Senior Content Developer for Cengage Learning, who guided and encouraged us in the preparation of this ninth edition. We would also like to thank Teresa Trego, Senior Content Project Manager; Elizabeth Woods, Content Developer and Ana Albinson, Associate Marketing Manager. All were essential to the team and contributed greatly to the success of the project. We are very grateful for the superb work of Prashant Kumar Das of MPS Limited for his outstanding coordination of production, and Erika Mugavin, IP Project Manager, for coordinating the excellent photos. We are especially pleased with the new feature Ask a Pharmacist and wish to thank Marvin Orrock for his excellent work. We appreciate the significant help of four associates: Monica Linford, who did an excellent job writing 8 new case studies, Mary Ann Francis, who helped with submitting the manuscript, Kimberly Francis, who helped write the Chemistry Around Us features, and David Shinn of the U.S. Merchant Marine Academy for assistance with accuracy checking.

Finally, we extend our love and heartfelt thanks to our families for their patience, support, encouragement, and understanding during a project that occupied much of our time and energy.

Spencer L. Seager

Michael R. Slabaugh
Maren S. Hansen

1

Matter, Measurements, and Calculations


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▶ Case Study

Purpose: The case study scenarios introduce diverse situations that a health care professional might encounter. Their purpose is to stimulate inquiry; for that reason, we've placed them at the beginning of each chapter. Vocabulary and scenarios may be unfamiliar, but our intention is to stimulate questions and to pique curiosity. Medicine has long been described as an art as well as a science. The questions raised by these case studies rarely have a single correct answer. With the knowledge that you gain from this text, and your future training, acceptable answers to the questions raised in our scenarios will become apparent.

Disclaimer: Some of the case studies are based on real-life situations. In such cases, names have been changed to protect the individual's anonymity.

Any resemblance to a particular person is purely coincidental. Models are used in all photos illustrating the cases. No photos of actual people experiencing particular medical scenarios are ever used in this text.

Case Study: Katie enjoyed well-child appointments at the military clinic. Because of the remote location, several doctors operated the clinic in turn. Katie liked the positive feedback at Norah's two-week checkup, where doctors praised Katie for her attentive mothering and congratulated her on Norah's impressive weight gain on what one doctor called "high-octane" milk. Today, at Norah's nine-month check, the nurse recorded important measurements of weight, length, temperature, and head circumference. Doctor Watson pondered these for a disconcertingly long time. He asked questions, including "Does she crawl?" and "Can she say ten words?" Dr. Watson admitted his concern about microcephaly and directed that Norah should be returned every two weeks for head measurements. Katie felt sure of her daughter's intelligence, but perhaps she was just a proud parent. Two months later, a different pediatrician examined Norah and reassured Katie that hats come in different sizes for a reason. Now, thirty years later, Norah's name is followed by Ph.D.

▶ **What other factors should the doctor consider when microcephaly is suspected? How important is it for medical professionals to consider the emotional impact of their diagnoses on family members (e.g., the mother's anxiety)?**

Follow-up to this Case Study appears at the end of the chapter before the *Concept Summary*.

Learning Objectives

When you have completed your study of this chapter, you should be able to:

1. Explain what matter is. **(Section 1.1)**
2. Explain the difference between the terms *physical* and *chemical* as applied to the properties of matter and changes in matter. **(Section 1.2)**
3. Describe matter in terms of the accepted scientific model. **(Section 1.3)**
4. On the basis of observation or information given to you, classify matter into the correct category of each of the following pairs: heterogeneous or homogeneous, solution or pure substance, and element or compound. **(Section 1.4)**
5. Recognize the use of measurement units in everyday activities. **(Section 1.5)**
6. Recognize units of the metric system, and convert measurements done using the metric system into related units. **(Section 1.6)**
7. Express numbers using scientific notation, and do calculations with numbers expressed in scientific notation. **(Section 1.7)**
8. Express the results of measurements and calculations using the correct number of significant figures. **(Section 1.8)**
9. Use the factor-unit method to solve numerical problems. **(Section 1.9)**
10. Do calculations involving percentages. **(Section 1.10)**
11. Do calculations involving densities. **(Section 1.11)**

Chemistry is often described as the scientific study of matter. In a way, almost any study is a study of matter, because matter is the substance of everything. Chemists, however, are especially interested in matter; they study it and attempt to understand it from nearly every possible point of view.

The chemical nature of all matter makes an understanding of chemistry useful and necessary for individuals who are studying in a wide variety of areas, including the health sciences, the natural sciences, home economics, education, environmental science, and law enforcement.

Matter comes in many shapes, sizes, and colors that are interesting to look at and describe. Early chemists did little more than describe what they observed, and their chemistry was a descriptive science that was severely limited in scope. It became a much more useful science when chemists began to make quantitative measurements, do calculations, and incorporate the results into their descriptions. Some fundamental ideas about matter are presented in this chapter, along with some ideas about quantitative measurement, the scientific measurement system, and calculations.

1.1 What Is Matter?

Learning Objective

1. Explain what matter is.

Definitions are useful in all areas of knowledge; they provide a common vocabulary for both presentations to students and discussions between professionals. You will be expected to learn a number of definitions as you study chemistry, and the first one is a definition of *matter*. Earlier, we said that matter is the substance of everything. That isn't very scientific, even though we think we know what it means. If you stop reading for a moment and look around, you will see a number of objects that might include people, potted plants, walls, furniture, books, windows, and a TV set or radio. The objects you see have at least two things in common: Each one has mass, and each one occupies space. These two common characteristics provide the basis for the scientific definition of matter. **Matter** is anything that has mass and occupies space. You probably understand what is meant by an object occupying space, especially if you have tried to occupy the same space as some other object. The resulting physical bruises leave a lasting mental impression.

matter Anything that has mass and occupies space.

You might not understand the meaning of the term *mass* quite as well, but it can also be illustrated "painfully." Imagine walking into a very dimly lit room and being able to just barely see two large objects of equal size on the floor. You know that one is a bowling ball and the other is an inflated plastic ball, but you can't visually identify which is which. However, a hard kick delivered to either object easily allows you to identify each one. The bowling ball resists being moved much more strongly than does the inflated ball. Resistance to movement depends on the amount of matter in an object, and **mass** is an actual measurement of the amount of matter present.

mass A measurement of the amount of matter in an object.

The term *weight* is probably more familiar to you than *mass*, but the two are related. All objects are attracted to each other by gravity, and the greater their mass, the stronger the attraction between them. The **weight** of an object on Earth is a measurement of the gravitational force pulling the object toward Earth. An object with twice the mass of a second object is attracted with twice the force, and therefore has twice the weight of the second object. The mass of an object is constant no matter where it is located (even if it is in a weightless condition in outer space). However, the weight of an object depends on the strength of the gravitational attraction to which it is subjected. For example, a rock that weighs 16 pounds on Earth would weigh about 2.7 pounds on the moon because the gravitational attraction is only about one-sixth that of Earth. However, the rock contains the same amount of matter and thus has the same mass whether it is located on Earth or on the moon.

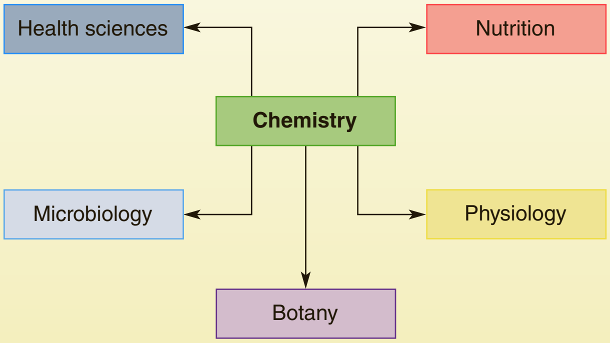
weight A measurement of the gravitational force acting on an object.

Despite the difference in meaning between mass and weight, the determination of mass is commonly called "weighing." We will follow that practice in this book, but we will use the correct term *mass* when referring to an amount of matter.

CHEMISTRY AROUND US 1.1

A Central Science

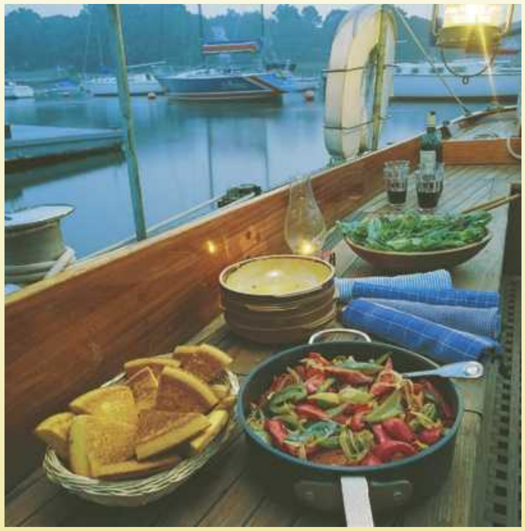
Chemistry is often referred to as the "central science" because it serves as a necessary foundation for many other scientific disciplines. Regardless of which scientific field you are interested in, every single substance you will discuss or work with is made up of chemicals. Also, many processes important to those fields will be based on an understanding of chemistry.



Chemistry is the foundation for many other scientific disciplines.

We also consider chemistry a central science because of its crucial role in responding to the needs of society. We use chemistry to discover new processes, develop new sources of energy, produce new products and materials, provide more food, and ensure better health.

As you read this text, you will encounter chapter opening photos dealing with applications of chemistry in the health-care professions. Within the chapters, other Chemistry Around Us boxes focus on specific substances that play essential roles in meeting the needs of society.



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Chemicals are present in everything we can touch, smell, or see. Chemistry is all around us.

1.2 Properties and Changes

Learning Objective

2. Explain the difference between the terms *physical* and *chemical* as applied to the properties of matter and changes in matter.

When you looked at your surroundings earlier, you didn't have much trouble identifying the various things you saw. For example, unless the decorator of your room had unusual tastes, you could easily tell the difference between a TV set and a potted plant by observing such characteristics as shape, color, and size. Our ability to identify objects or materials and discriminate between them depends on such characteristics. Scientists prefer to use the term *property* instead of *characteristic*, and they classify properties into two categories, physical and chemical.

Physical properties are those that can be observed or measured without changing or trying to change the composition of the matter in question—no original substances are destroyed, and no new substances appear. For example, you can observe the color or measure the size of a sheet of paper without attempting to change the paper into anything else. Color and size are physical properties of the paper. **Chemical properties** are the properties matter demonstrates when attempts are made to change it into other kinds of matter. For example, a sheet of paper can be burned; in the process, the paper is changed into new substances. On the other hand, attempts to burn a piece of glass under similar conditions fail. The ability of paper to burn is a chemical property, as is the inability of glass to burn.

physical properties Properties of matter that can be observed or measured without trying to change the composition of the matter being studied.

chemical properties Properties that matter demonstrates when attempts are made to change it into new substances.

CHEMISTRY AROUND US 1.2

Are Chemicals Getting a Bad Rap?

The following question was overheard in a grocery store when a customer approached a sales clerk and asked, “Are there any chemicals in this yogurt?” If the clerk had been a chemistry student, a correct answer would have been “Of course, the yogurt itself is made of chemicals.”

The reason for this correct answer is that all matter, including yogurt, is made up of atoms of the elements. This means that any sample of any kind of matter contains atoms, and therefore contains chemicals. What the customer really should have asked is a more specific question, such as “Does this yogurt contain any chemical preservative?” or, if the customer had a condition such as lactose intolerance, “Does this yogurt contain any lactose?”

However, unfortunately, in today’s world the word “chemical” is often used in a negative way, as illustrated by this conversation. Hopefully, students using this textbook will be taking a course that will eliminate the negative feeling toward chemistry and chemicals.

AP Images/DAWN VILLELLA

All matter, including yogurt, is comprised of chemicals.

physical changes Changes matter undergoes without changing composition.

chemical changes Changes matter undergoes that involve changes in composition.

You can easily change the size of a sheet of paper by cutting off a piece. The paper sheet is not converted into any new substance by this change, but it is simply made smaller. **Physical changes** can be carried out without changing the composition of a substance. However, there is no way you can burn a sheet of paper without changing it into new substances. Thus, the change that occurs when paper burns is called a **chemical change. Figure 1.1** shows an example of a chemical change, the burning of magnesium metal. The bright light produced by this chemical change led to the use of magnesium in the flash powder used in early photography. Magnesium is still used in fireworks to produce a brilliant white light.

Example 1.1 Classifying Changes as Physical or Chemical

Classify each of the following changes as physical or chemical: (a) a match is burned; (b) iron is melted; (c) limestone is crushed; (d) limestone is heated, producing lime and carbon dioxide; (e) an antacid seltzer tablet is dissolved in water; and (f) a rubber band is stretched.

Solution

Changes b, c, and f are physical changes because no composition changes occurred and no new substances were formed.

The others are chemical changes because new substances were formed. A match is burned—combustion gases are given off, and matchstick wood is converted to ashes. Limestone is heated—lime and carbon dioxide are the new substances. A seltzer tablet is dissolved in water—the fizzing that results is evidence that at least one new material (a gas) is produced.

✔ **LEARNING CHECK 1.1** Classify each of the following changes as physical or chemical, and, in the cases of chemical change, describe one observation or test that indicates new substances have been formed: (a) milk sours, (b) a wet handkerchief dries, (c) fruit ripens, (d) a stick of dynamite explodes, (e) air is compressed into a steel container, and (f) water boils.

1 A strip of magnesium metal.

2 After being ignited with a flame, the magnesium burns with a blinding white light.

3 The white ash of magnesium oxide from the burning of several magnesium strips.

Figure 1.1 A chemical change occurs when magnesium metal burns.

Among the most common physical changes are changes in state, such as the melting of solids to form liquids, the sublimation of solids to form gases, or the evaporation of liquids to form gases. These changes take place when heat is added to or removed from matter, as represented in **Figure 1.2**. We will discuss changes in state in more detail in Chapter 6.

A Solid iodine becomes gaseous iodine when heated.

B Liquid benzene becomes solid benzene when cooled.

Figure 1.2 Examples of physical change.

1.3 A Model of Matter

Learning Objective

3. Describe matter in terms of the accepted scientific model.

Model building is a common activity of scientists, but the results in many cases would not look appropriate on a fireplace mantle. **Scientific models** are explanations for observed behavior. Some, such as the well-known representation of the solar system, can easily be depicted in a physical way. Others are so abstract that they can be represented only by mathematical equations.

scientific models Explanations for observed behavior in nature.

Our present understanding of the nature of matter is a model that has been developed and refined over many years. Based on careful observations and measurements of the properties of matter, the model is still being modified as more is learned. In this book, we will concern ourselves with only some very basic concepts of this model, but even these basic ideas will provide a powerful tool for understanding the behavior of matter.

The study of the behavior of gases—such as air, oxygen, and carbon dioxide—by some of the earliest scientists led to a number of important ideas about matter. The volume of a gas kept at a constant temperature was found to change with pressure. An increase in pressure caused the gas volume to decrease, whereas a decrease in pressure permitted the gas volume to increase. It was also discovered that the volume of a gas maintained at constant pressure increased as the gas temperature was increased. Gases were also found to have mass and to mix rapidly with one another when brought together.

Alexandra Lande/Shutterstock.com

Figure 1.3 A hang glider soars far above the ground. How does this feat confirm that air is matter?

A simple model for matter was developed that explained these gaseous properties, as well as many properties of solids and liquids. Some details of the model are discussed in Chapter 6, but one conclusion is important to us now. All matter is made up of particles that are too small to see (see **Figure 1.3**). The early framers of this model called the small particles *molecules.* It is now known that molecules are the constituent particles of many, but not all, substances. In this chapter, we will limit our discussion to substances made up of molecules. Substances that are not made of molecules are discussed in Sections 4.3 and 4.11.

The results of some simple experiments will help us formally define the term *molecule.* Suppose you have a container filled with oxygen gas and you perform a number of experiments with it. You find that a glowing splinter of wood bursts into flames when placed in the gas. A piece of moist iron rusts much faster in the oxygen than it does in air. A mouse or other animal can safely breathe the gas.

Now suppose you divide another sample of oxygen the same size as the first into two smaller samples. The results of similar experiments done with these samples would be the same as before. Continued subdivision of an oxygen sample into smaller and smaller samples does not change the ability of the oxygen in the samples to behave just like the oxygen in the original sample. We conclude that the physical division of a sample of oxygen gas into smaller and smaller samples does not change the oxygen into anything else—it is still oxygen. Is there a limit to such divisions? What is the smallest sample of oxygen that will behave like the larger sample? We hope you have concluded that the smallest sample must be a single molecule. Although its very small size would make a one-molecule sample difficult to handle, it would nevertheless behave just as a larger sample would—it could be stored in a container, it would make wood burn rapidly, it would rust iron, and it could be breathed safely by a mouse.

molecule The smallest particle of a pure substance that has the properties of that substance and is capable of a stable independent existence. Alternatively, a molecule is the limit of physical subdivision for a pure substance.

We are now ready to formally define the term *molecule.* A **molecule** is the smallest particle of a pure substance that has the properties of that substance and is capable of a stable independent existence. Alternatively, a molecule is defined as the limit of physical subdivision for a pure substance.

In less formal terms, these definitions indicate that a sample of pure substance—such as oxygen, carbon monoxide, or carbon dioxide—can be physically separated into smaller and smaller samples only until there is a single molecule. Any further separation cannot be done physically, but if it were done (chemically), the resulting sample would no longer have the same properties as the larger samples.

The idea that it might be possible to chemically separate a molecule into smaller particles grew out of continued study and experimentation by early scientists. In modern terminology, the smaller particles that make up molecules are called atoms. John Dalton (1766–1844) is generally credited with developing the first atomic theory containing ideas that are still used today. The main points of his theory, which he proposed in 1808, can be summarized in the following five statements:

1. All matter is made up of tiny particles called atoms.
2. Substances called elements are made up of atoms that are all identical.
3. Substances called compounds are combinations of atoms of two or more elements.
4. Every molecule of a specific compound always contains the same number of atoms of each kind of element found in the compound.
5. In chemical reactions, atoms are rearranged, separated, or combined, but are never created nor destroyed.

Early scientists used graphic symbols such as circles and squares to represent the few different atoms that were known at the time. Instead of different shapes, we will use representations such as those in **Figure 1.4** for oxygen, carbon monoxide, and carbon dioxide molecules.

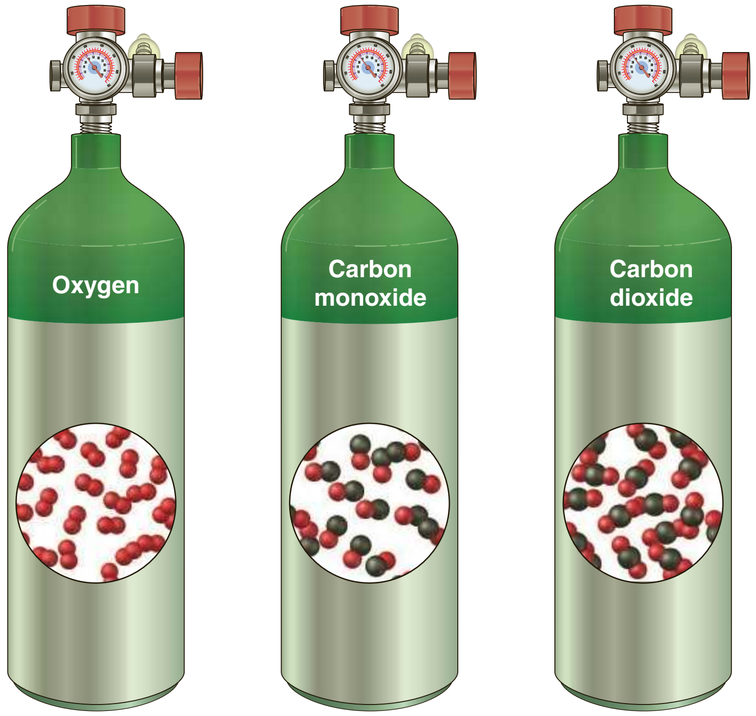


Figure 1.4 Symbolic representations of molecules.

The three pure substances just mentioned illustrate three types of molecules found in matter. Oxygen molecules consist of two oxygen atoms, and are called **diatomic molecules** to indicate that fact. Molecules such as oxygen that contain only one kind of atom are also called **homoatomic molecules** to indicate that the atoms are all of the same kind. Carbon monoxide molecules also contain two atoms and therefore are diatomic molecules. However, in this case the atoms are not identical, a fact indicated by the term **heteroatomic molecule**. Carbon dioxide molecules consist of three atoms that are not all identical, so carbon dioxide molecules are described by the terms **triatomic** and heteroatomic. The words *diatomic* and *triatomic* are commonly used to indicate two- or three-atom molecules, but the word **polyatomic** is usually used to describe molecules that contain more than three atoms.

diatomic molecules Molecules that contain two atoms.

homoatomic molecules Molecules that contain only one kind of atom.

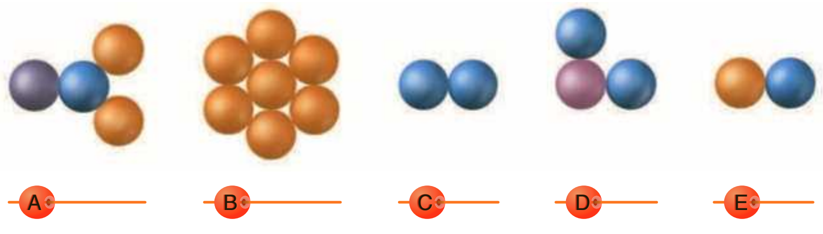
heteroatomic molecules Molecules that contain two or more kinds of atoms.

triatomic molecules Molecules that contain three atoms.

polyatomic molecules Molecules that contain more than three atoms.

Example 1.2 Classifying Molecules

Use the terms *diatomic, triatomic, polyatomic, homoatomic,* or *heteroatomic* to classify the following molecules correctly:



Solution

A. Polyatomic and heteroatomic (more than three atoms, and the atoms are not all identical)
B. Polyatomic and homoatomic (more than three atoms, and the atoms are identical)
C. Diatomic and homoatomic (two atoms, and the atoms are identical)
D. Triatomic and heteroatomic (three atoms, and the atoms are not identical)
E. Diatomic and heteroatomic (two atoms, and the atoms are not identical)