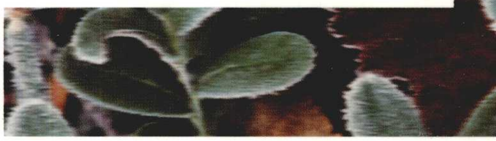
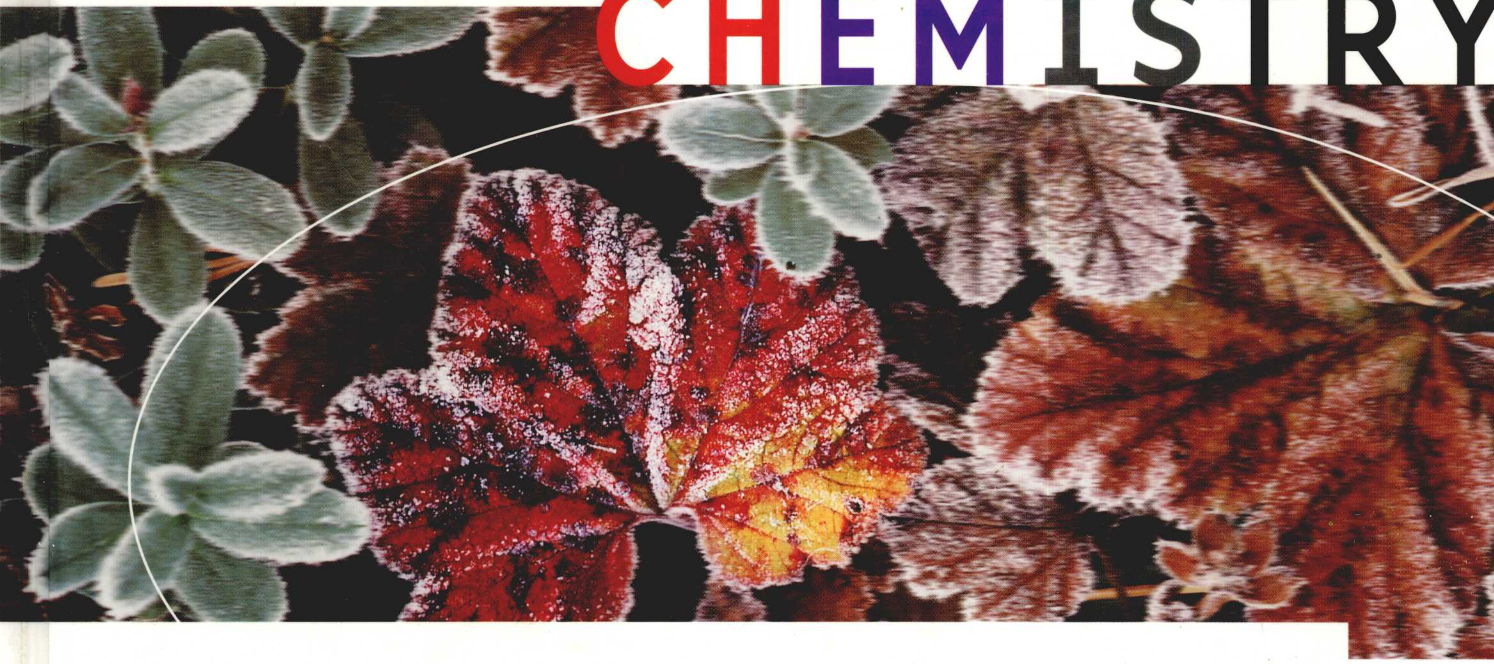
INTRODUCTORY CHEMISTRY





SECOND EDITION

EBBING | WENTWORTH

Introductory Chemistry

Second Edition

Darrell D. Ebbing
Wayne State University

R. A. D. Wentworth
Indiana University

Houghton Mifflin Company
Boston New York

Senior Sponsoring Editor *Richard Stratton*
Senior Associate Sponsor *Sue Warne*
Assistant Editor *Marianne Stepanian*
Senior Production/Design Coordinator *Jill Haber*
Senior Manufacturing Coordinator *Priscilla J. Abreu*
Marketing Manager *Penny Hoblyn*

Warning: This book contains text descriptions of chemical reactions and photographs of experiments that are potentially dangerous and harmful if undertaken without proper supervision, equipment, and safety precautions. DO NOT attempt to perform these experiments relying solely on the information presented in this text.

Credits: A list of credits precedes the index.

Cover Design: Stoltze Design
Cover Photograph: Frosted Fallen Fall Leaves, © J. Jamsen/Natural Selection.

Printed in the U.S.A.

Library of Congress Catalog Card Number: 97-72467
ISBN: 0-395-87118-2

3456789-VH-01 00 99

Preface

In writing *Introductory Chemistry,* we have had two types of students in mind. One includes those with no previous background in chemistry, who need an understanding of the basic principles of chemistry to pursue their particular career goals and interests. The second type of student includes those who, while perhaps having had a previous chemistry course, require a thorough review of the basic principles as preparation for taking a general chemistry course.

Though this is a diverse group of students, their requirements seem clear. They want to learn the *skills* needed to advance in their studies. They want to be shown how chemistry is *relevant* to their particular interests and careers. And they are looking for a text that is not only informative but *engaging* and *up to date.* In summarizing what we have done to satisfy these requirements, four areas of the book stand out.

■ **Problem-Solving Skills.** Traditionally, textbooks for these courses have relied heavily on problem solving. While we agree with the importance of problem solving to understanding chemistry, we believe it is most important that students acquire *problem-solving skills.* They need explicit help in seeing how to approach a problem. We feel that this requires an approach in which both the text and the worked-out examples help develop these skills. Therefore, every example problem statement is followed by a *problem analysis,* which walks students through the thinking process involved in solving the problem. Only after this problem analysis do we present the full solution to the problem.

■ **Conceptual Understanding.** Most instructors agree that problem solving is an important element in chemistry, but the manner in which many textbooks deal with problem solving frequently leads students to see it as a rote process. They memorize specific methods and apply them uncritically to problems. Students need to acquire a vivid feel for the underlying concepts of chemistry so that they can properly place a particular problem in its context. We have directed the text and illustration programs to promote this type of understanding. For instance, the idea of the molecule is central to a chemist's thinking. Early in the book, we introduce molecular models, and we continue to build on the molecular concept. So, before we talk about the gas laws, we describe the kinetic-molecular theory of gases. This gives the student a vivid picture of a gas, which the student can use when approaching gas-law problems.

■ **Applications of Chemistry.** We answer students' need to see how chemistry is relevant by introducing everyday applications of chemistry throughout the text, in illustrations, and in boxed essays. We have chosen these applications for student interest and have tried to use an engaging style to capture students' attention. The number of boxed essays *(Chemical Perspectives)* has been nearly doubled with this edition, and the topics are up-to-date and range over many fields, such as nitric oxide as a biochemical messenger (biochemistry, medicine); digital X-ray photography (technology); the greenhouse effect (environment); carbon monoxide and hemoglobin (toxicology); and dinosaurs, human origins, and ancient molecules (archaeology).

■ **Multimedia Package.** We are pleased to be the first introductory chemistry book to offer a CD-ROM directly tied to it. *Chemistry: Interactive 3.0 for Introductory Chemistry* contains electronically generated problem sets modeled after examples from the text, as well as many tools—such as tutorials, animations, videos, and molecular models—to help the student learn problem solving and deepen conceptual understanding. For instance, a student can work through a tutorial on ionic formulas, view an animation of an ionic solid dissolving in water, generate problems involving precipitation reactions, or view the hydronium ion from various angles. The instructors' version of the CD provides many lecture aids, including selected artwork and tables from the text, and an easy-to-use classroom presentation tool. Together, these electronic multimedia supplements provide students and instructors with the most up-to-date learning and teaching environment.

OUTSTANDING FEATURES OF THE BOOK

We have been gratified by the positive comments from users of the first edition, and we have worked hard to retain and strengthen the features of *Introductory Chemistry* that help students develop problem-solving skills, understand fundamental chemical concepts, and appreciate the applications of chemistry to their everyday life. The following features have all been designed to contribute to achieving these goals.

Writing Style

Because many students view chemistry as a challenging subject, we have adopted a friendly, direct writing style that will appeal to students. To aid students in their reading, we have consciously erected verbal signposts that remind them where they have been and where they are going. To show students that chemistry is indeed a subject that is useful and relevant to them, we have worked in as much everyday chemistry as possible. Finally, we have tried to make it clear through organization and illustration that in chemistry, concepts build one on another and each topic introduced has a purpose in developing the subject.

Problem Solving

Problem-solving skills are important because many everyday questions require them; they are also important to an understanding of chemical concepts. Developing these skills requires the student to understand how to approach problems, and it requires practice in solving problems. We have directed much of our effort to helping students gain these problem-solving skills.

When faced with a problem, many beginning students ask, "How do I begin?" To help these students, we included the **Problem Analysis** section with the **Examples** in the text. This problem analysis follows each problem statement, and its purpose is to show the student how to think the problem through, using the information given in the problem and using relevant principles from the text. The **Solution** applies this problem analysis to the specific problem statement. As students work through the problem analysis and solution of many problems, they will begin to see that problem solving is not a matter of grasping thoughts from thin air, but that it involves a process that can be learned.

Learning problem solving involves more than simply reading about how some problems are solved. Students have to solve numerous problems on their own. We have helped by following each worked-out example with a similar **Exercise** and then directing students to similar problems at the end of the chapter **(Try problems . . .).** The end-of-chapter **Practice Problems** are similar to the problems solved in the examples, though some practice problems provide a variation or extension of the problem-solving skill used in the examples. The **Additional Problems** provide more practice and in many cases more difficult problems. All of these problems are in matched pairs; every odd-numbered problem is answered at the back of the book and is followed by a similar even-numbered problem (unanswered).

With this edition, we have added **Practice in Problem Analysis** and **Practice Exam** sections to the end-of-chapter problems. In the Practice in Problem Analysis, we ask students to describe the thinking, or problem analysis, involved in a problem, rather than to solve the problem. Our aim is to get students to focus on this problem analysis and take them away from rote thinking. The purpose of the Practice Exam is to provide students with practice in taking multiple-choice exams.

Study Aids

The job of the textbook is to help students see the connections among ideas and the significance of what they have read. We have done our best to guide students through a chapter by designing a system of *study aids* that they can adapt to their own study program.

Each chapter begins with an **Outline** that shows the structure of the chapter. Note that chapters are divided into *parts,* which are divided into *sections* and *subsections.* This outline can help students, both as they read the chapter for the first time and as they review, to see how topics are related. Each section of a chapter begins with learning **Objectives.** These objectives list concepts and problem-solving skills introduced in the section, and so provide an overview of the significant points in the section.

Throughout the text, **marginal notes** give students additional historical and descriptive information to help engage them in the topic. These notes also provide cross-references to other sections of the text for students to use in reviewing background information.

Chemistry requires that students learn a special vocabulary for expressing ideas. Every time we introduce a **key word,** we note the word by setting it in **boldface type** and following it with an explicit definition of the word in *italic type,* so that students do not have to guess the exact meaning of key words. These key words and some others are gathered in a **Glossary** at the end of the book.

An extensive **Chapter Review** appears at the end of each chapter. **Key Words** are listed, as well as the **Key Equations** appearing in the chapter. Following these lists is a **Summary,** a condensation of the important points covered in the chapter. **Problem-Solving Skills** is a summary list of the different problem-solving skills introduced in the chapter. Each skill is keyed to the worked-out *Examples* in the text that use that problem-solving skill.

Chapter questions follow these review features. Students should be able to answer these **Questions to Test Your Reading** after reading (and perhaps rereading) the chapter. The questions are followed by the end-of-chapter problems described above.

Applications to Chemistry

While our aim is to cover the basic principles of chemistry, we strongly believe that students need to see how these principles relate to the world around them. The principles must appear in the context of everyday chemistry. We have brought applications of chemistry into the book in several ways. First, we have woven applications into the discussion of principles. Where possible, we have used a chemical application as a thread for our discussion, both for interest and to help the students see relationships among principles. Also, we have introduced applications into the examples and problems to give them significance.

The **Chemical Perspectives** are a special feature of the book. These consist of short essays appearing in boxes in the chapter. Each Chemical Perspective deals with a topic of everyday interest—perhaps an environmental concern or chemistry applied to medicine. A Chemical Perspective uses one or more principles in the chapter to illustrate the application of those principles. We have adopted an informal writing style that will serve to engage the students' interest and make for enjoyable reading.

Illustration Program

Chemistry is about three-dimensional objects, and chemical concepts are often best taught with images to reinforce the words. We have gone to great lengths to ensure that the illustration program meets our twofold goal of appropriateness to the topic and of visual interest. The style of many of the figures is, we believe, fresh and modern. For example, zoom-sequence photos are used in some cases to allow students to compare the macroscopic aspects of a piece of matter to its submicroscopic structure. Pictures of a mineral are inset into a photograph of the country where the mineral is mined. Molecular models are generally computer-generated color images. Atoms in these images have been color-coded so that an atom will have the same color throughout the book. In short, much of the photography and artwork is designed to help the student learn from it, as well as enjoy it.

Alternate Edition

This text is also available in a paperback edition, *Fundamentals of Introductory Chemistry,* which contains the first thirteen chapters, covering basic concepts, chemical substances and reactions, atomic structure and bonding, and states of matter.

COMPLETE INSTRUCTIONAL PACKAGE

This text is accompanied by a complete package of instructional materials designed to help instructors and students alike.

For the Student

A **CD-ROM,** *Chemistry: Interactive 3.0 for Introductory Chemistry,* supports the goals of the second edition by helping students visualize molecular behavior and manipulate molecules in three dimensions. Tutorials, animations, videos, molecular models, and problem sets are included. The problem sets will also be available on floppy disk. See your Houghton Mifflin sales representative for more information.

The **Study Guide,** by Susan M. Schelble of the University of Southern Colorado, provides discussion of all key concepts and topics, with worked-out examples incorporated. Important terms and algebra/calculator review are included for each chapter, and additional practice problems are given for all problem-solving skills. Chapters conclude with a practice exam.

The **Lab Manual,** by R. A. D. Wentworth and Karen Pressprich, Indiana University, contains 22 experiments class-tested by hundreds of students. At least one experiment is included for each text chapter, and safety is emphasized throughout.

The **Partial Solutions Manual,** by David Bookin of Mt. San Jacinto College, contains worked-out solutions to all in-chapter exercises and half of the end-of-chapter problems, using strategies emphasized in the text. To ensure the accuracy of the solutions, this supplement and the *Complete Solutions Manual* were checked independently by several instructors.

For the Instructor

A **CD-ROM** product contains the animations, videos, and molecular models that appear on the student version of the CD-ROM. In addition, transparency acetates from the text are included in electronic form, along with a simple-to-use classroom presentation program. The disc is specifically designed to allow instructors to facilitate active learning and to enhance multimedia classroom presentations. The classroom presentation program and electronic versions of the transparencies are also available on floppy disk. See your Houghton Mifflin sales representative for additional information.

The **Complete Solutions Manual,** by David Bookin, contains worked-out solutions to all in-chapter exercises and end-of-chapter problems. Complete answers are also provided for the Questions to Test Your Reading. This is for the convenience of faculty and staff involved in instruction and for instructors who want their students to have solutions for all of the exercises. Departmental approval is required for the sale of the *Complete Solutions Manual* to students.

The **Instructor's Resource Manual with Test Bank,** by Darrell D. Ebbing, R. A. D. Wentworth, Richard S. Perkins, and Leslie N. Kinsland (the latter two of the University of Southwestern Louisiana), is a comprehensive teaching aid that includes chapter descriptions, lecture demonstration sources, and a 1600-item multiple-choice test bank.

The **Computerized Test Bank** is an electronic version of the 1600-item test bank, available in DOS, Windows, and Macintosh versions.

The **Instructor's Resource Manual to Accompany the Lab Manual,** by Karen Pressprich, includes suggested equipment and materials, time requirements, answers to pre-lab and post-lab questions, and sample student data for all experiments.

The **Transparency Package** contains 100 two- and four-color acetates from images and line art used in the text.

Houghton Mifflin Chemistry Videodisc contains video clips of lecture demonstrations and animations of important chemical processes and concepts that can be used in classroom presentations. The disc is available free to adopters of the second edition.

Houghton Mifflin Videotape Series A, B, C, and D provide over 100 lecture demonstrations performed by John Luoma, Cleveland State University; John J. Fortman and Rubin Battino, Wright State University; Patricia L. Samuel, Boston University; and Paul Kelter, University of Nebraska—Lincoln. Series C demonstrations appear on the Houghton Mifflin videodisc as well.

ACKNOWLEDGMENTS

The preparation of an introductory book requires the work of many people. Reviewers have read and commented at various stages of the manuscript, and their work has been

indelibly etched in the final text. We owe these people a debt beyond measure. Following is a list of these contributors in alphabetical order:

David W. Ball
Cleveland State University

Hal Bender
Clackamas Community College

Kyle A. Beran
Mesa State College

Michael J. Brabec
Eastern Michigan University

Helen Chichester
College of Alameda

Darwin B. Dahl
Western Kentucky University

Chhabil Dass
The University of Memphis

James E. Hardcastle
Texas Women's University

Kathleen Harter
Community College of Philadelphia

James N. Jacob
University of Rhode Island

Charles Keilin
Larncy College

Leslie N. Kinsland
The University of Southwestern Louisiana

Susanne M. Mathews
Joliet Junior College

Hugh McLean
Florida A&M University

David Nachman
Phoenix College

Barbara Rainard
Community College of Allegheny County

David E. Saleeby
Florence Darlington Technical College

Susan M. Schelble
University of Southern Colorado

Jeffrey A. Schneider
State University of New York at Oswego

Joel Shelton
Bakersfield College

Linda K. Thomas-Glover
Guilford Technical Community College

Vivek Utgikar
The University of Dayton

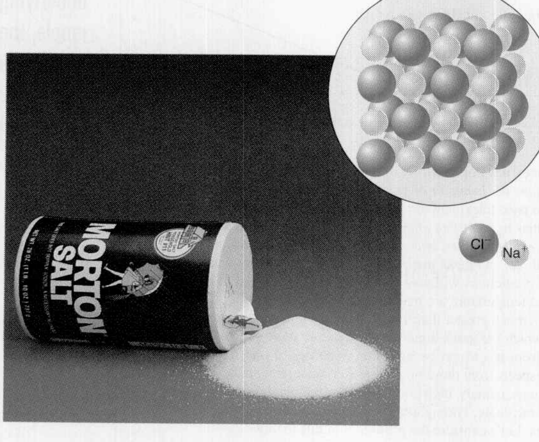
Robert O. Wiley
Arizona State University

The technical accuracy of the book owes much to Beverly Foote; Catherine Keenan, Chaffey College; John Nash, Purdue University; and David Treichel, Nebraska Wesleyan University, who read all or parts of the book.

Our special thanks go to Richard Stratton, Senior Sponsoring Editor, and Sue Warne, Senior Associate Sponsor, who worked with us from our first planning session in Boston to the final stages of production. Richard and Sue provided us with many creative ideas and the enthusiasm that made this revision possible. Marjorie Anderson was our Developmental Editor for this revision. Her comments and suggestions were most important to us as we produced the manuscript; we are most grateful for her efforts. We also wish to thank Marianne Stepanian, Assistant Editor. Marianne was instrumental in overseeing the development of the ancillary package. When authors sign off on copyedited manuscript, the rigors of production begin. We were very pleased to have Peggy J. Flanagan again as Production Editor. Her attention to the details of turning manuscript to book pages was unflagging, and we are most grateful to her. Douglas Sawyer of Scottsdale Community College did the setup photography for this revision, as he had for the first edition. We thank him for turning our rough ideas into actual photographs. We also thank Jessyca Broekman, Art Editor, Sharon Donahue, Photo Researcher, Jill Haber, Senior Production/Design Coordinator, and Janet Theurer, Designer, for their contributions to the "look" of the finished book.

Finally, we wish to dedicate this book to our wives, Jean Ebbing and Anne Fraker, who by their wit and good humor managed to keep us on an even keel through the inevitable windless days and stormy periods of the writing process.

FIGURE 12.16
The structure of sodium chloride, an ionic solid. Every chloride ion is surrounded by six smaller sodium ions. The chloride ions are approximately close-packed with the much smaller sodium ions in the cavities between the chloride ions.



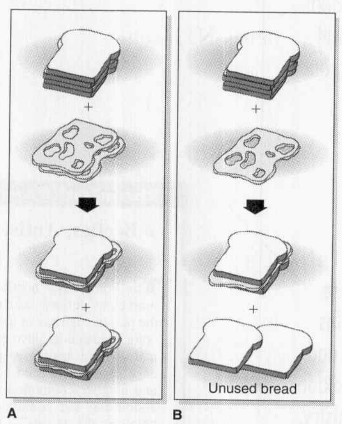
Wherever possible, artwork links the macroscopic everyday world with microscopic and atomic level illustrations to help students understand what atoms and molecules are and how they behave.

ordered array of molecules together in a molecular solid always include dispersion
forces, but dipole-
the melting points
ing points of liqui
often liquids (such
ture.

Ionic Solids

Ionic solids such a
exist between op
between the part
dipole–dipole for
higher than the m
Unlike molecular
Ionic forces are
can be surrounded
chloride is a good
eral other solids,
However, other ar
The next two e
in them affect thei

FIGURE 8.9
Cheese sandwiches, stoichiometric amounts, and limiting reactants. Making cheese sandwiches provides an analogy for reactions with *(A)* stoichiometric amounts and *(B)* a limiting reactant (here, the cheese).



Artwork also helps students get an intuitive feel for the concepts underlying the chemistry.

reactants in stoichiometric amounts, both will be consumed at the completion of the reaction. You can calculate the mass of product obtained from either reactant. On the other hand, if the reactants are not in stoichiometric amounts, there is a limiting reactant. It will be used up and the other reactant will be left over when the reaction is complete. You calculate the amount of any product from the amount of the limiting reactant present at the start of the reaction.

How can you tell if 2.0 mol $Mg(OH)_2$ and 5.0 mol HCl are stoichiometric amounts of reactants? One way is to use the amount of one reactant, say, $Mg(OH)_2$, to calculate the amount of the other reactant (HCl) that would be needed to react with it. If the amount of HCl that you calculate is exactly equal to the amount actually added at the start, the two reactants are present in stoichiometric amounts. Let's do the calculation.

You need to make the following conversion:

2.0 mol $Mg(OH)_2$ —Converts to→ mol HCl

Here is the calculation:

$$2.0\ \text{mol Mg(OH)}_2 \times \frac{2\ \text{mol HCl}}{1\ \text{mol Mg(OH)}_2} = 4.0\ \text{mol HCl}$$

In other word… 0 mol $Mg(OH)_2$ react… with 4.0 mol HCl. Sinc… u actually added 5.0 mol HCl … add stoichi… nts of react…

the gas and the atmosphere. For example, suppose the atmospheric pressure is 751 mmHg and the height of mercury in the arm open to the gas is 63 mm greater than in the end open to the atmosphere. The gas pressure must be 63 mmHg *less* than atmospheric pressure, or

$$P = 751 \text{ mmHg} - 63 \text{ mmHg} = 688 \text{ mmHg}$$

11.3 The Kinetic Molecular Theory of Gases

OBJECTIVE

- Name the theory that explains the behavior of real gases under moderate conditions, and list its four postulates.

Animations: Kinetic molecular theory and heat transfer; Visualizing molecular motion (single molecule); Visualizing molecular motion (many molecules).

The **kinetic molecular theory of gases,** developed during the eighteenth and nineteenth centuries by several scientists, *explains the behavior of gases.* As we will see in Chapter 12, part of this theory can also be used to explain the behavior of liquids and solids.

The kinetic molecular theory applies to *a gas that obeys a simple mathematical relationship between its pressure, volume, temperature, and amount.* ● This gas is called an **ideal gas** and it does not really exist. We can make mathematical predictions about the behavior of an ideal gas, and these predictions will also apply to a real gas as long as moderate conditions of pressure and temperature are maintained. Moderate conditions are pressures that are less than or not much greater than 1 atm and temperatures that are considerably greater than those at which the gases liquefy. We cannot be more specific about these conditions; they vary from gas to gas because the properties of one substance will always differ in many respects from those of another substance. If a real gas is subjected to more extreme conditions, namely, high pressure or low temperature, then deviations from ideal behavior are noticeable. Throughout this chapter, we assume ideal behavior due to moderate conditions. Let's consider the postulates in this theory.

● This relationship, called the *ideal gas law,* is introduced in Section 11.8.

The text promotes an understanding of the underlying concepts of chemistry. For example, the kinetic-molecular theory of gases is discussed before gas law calculations are introduced, to give students a conceptual understanding of gases that will help them understand the gas laws.

Icons in the margin point students to multimedia resources on the CD-ROM that will help deepen conceptual understanding and strengthen problem-solving skills.

he *-ite* ending to *-ous,* and substitute the word *acid* for the word *ion.*

Solution

The formula for the sulfate ion is SO_4^{2-}. Since its charge is −2, the subscript to H in the oxyacid formula is 2. The result is H_2SO_4. To name this compound, change the *-ate* ending in the name of the oxyanion to *-ic* and then substitute the word *acid* for the word *ion.* Thus, the name is sulfuric acid, as shown in Table 5.5.

Exercise 5.10

Give the formula and name of the oxyacid corresponding to the sulfite ion.

(Try Problems 5.45, 5.46, 5.47, and 5.48.)

The number of Chemical Perspective boxes has been nearly doubled with this edition, and the topics are up-to-date and cover many fields: for instance nitric oxide as a biochemical messenger (biochemistry, medicine), digital X-ray photography (technology), the greenhouse effect (environment), carbon monoxide and hemoglobin (toxicology), dinosaurs, human origins, and ancient molecules (archaeology).

Chemical Perspective

Beetles, Antiseptics, and Bleaches

The bombardier beetle ensures its survival with a marvelous defense mechanism (Figure 5.10). Unlike the passive defense of the chameleon, who changes its color to match its surroundings, this insect uses chemical warfare against its predators. When it is threatened, it forces a fluid containing hydrogen peroxide and another compound called hydroquinone into an abdominal sac containing enzymes. (Enzymes are "biological catalysts"—that is, biological substances that cause a chemical reaction to speed up without being consumed in the reaction.) The enzymes cause a vigorous and quick reaction between hydrogen peroxide and hydroquinone with the release of a great deal of heat—so much heat that the liquid boils. The beetle discharges the hot liquid and vapor as a fine mist toward the soon-to-be-surprised predator.

Hydrogen peroxide, one of the substances used by the beetle, is a very reactive compound. We use it as an antiseptic because it kills harmful microorganisms. We also use it to bleach hair because it reacts with natural pigments and destroys them. Although it is toxic, it is produced in our bodies through biological processes involving oxygen from the air we breathe. Fortunately, we have a biological safeguard that prevents the internal buildup of this substance. Once again, enzymes play an important role. This time they speed up the natural decomposition of hydrogen peroxide, producing water and oxygen gas. One of these enzymes is *catalase.* The effect of catalase from beef liver on hydrogen peroxide is shown in Figure 5.11. The froth you see is caused by bubbles of oxygen from the decomposing hydrogen peroxide.

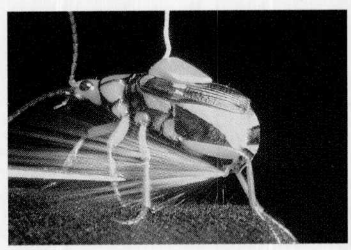
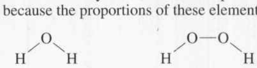


FIGURE 5.10
A bombardier beetle defending itself. The reaction between hydrogen peroxide and hydroquinone in the presence of a catalyst generates enough heat to boil the reaction liquid. The beetle expels this steaming liquid toward a foe.

Water, the other product of the reaction in Figure 5.11, and hydrogen peroxide happen to share one feature: Both are binary molecular compounds of the same elements. They are different compounds, however, because the proportions of these elements differ.



H_2O Water H_2O_2 Hydrogen peroxide

An extensive **Chapter Review** consists of **Key Words, Key Equations,** and a **Summary. Problem-Solving Skills** is a summary list of the different problem-solving skills introduced in the chapter, each keyed to worked-out *Examples* in the chapter. **Questions to Test Your Reading** provide a basic review of the key concepts of the chapter.

Chapter Review **213**

Summary

A *molecular weight* is the sum of the atomic weights of all the atoms in the formula for a molecule of a compound. A *formula weight* is the sum of the atomic weights of all the atoms in the formula unit of a compound. If the formula unit is the formula for a molecule, then the formula weight is identical to the molecular weight.

A *mole* of any element or compound contains *Avogadro's number* (6.022×10^{23}) of atoms, molecules, or formula units. The molar mass of a substance equals the mass of 1 mole of that substance. For an element with a nonmolecular structure, this molar mass equals the atomic weight of that element expressed in grams. If the element occurs as molecules, the molar mass is the molecular weight in grams. For a molecular compound, the molar mass is the compound's molecular weight in grams; for an ionic compound, the molar mass is the compound's formula weight in grams.

The *empirical formula* of a compound is the simplest formula for that substance. It is obtained from the *percentage composition* of the compound, which is expressed as *mass percentages* of the elements that make up the compound. These mass percentages can be determined by chemical analysis in a laboratory, or they can be calculated from the chemical formula if it is known. When you calculate an empirical formula, you convert the mass percentages to ratios of moles that lead you to the subscripts in the formula. A *molecular formula* is a multiple of the empirical formula. An experimental measurement of the molecular weight is required to obtain this multiple.

Problem-Solving Skills

1. **Computing a Molecular Weight from a Formula:** Given a compound's molecular formula, calculate the molecular weight (Example 7.1).
2. **Computing a Formula Weight from a Formula:** Given an ionic compound's formula, calculate the formula weight (Example 7.2).
3. **Determining the Number of Molecules a[...] from the Moles of Substance:** Given the a[...] substance in moles, calculate the number of [...] and atoms in the sample (Example 7.3).
4. **Obtaining the Molar Mass of an Element:** [...] element, calculate its molar mass (Example 7.4[...]
5. **Calculating the Molar Mass of a Compoun[...]** compound, calculate its molar mass (Example [...]
6. **Converting Grams to Moles:** Given a substa[...] in grams, calculate the amount of that substanc[...] (Example 7.6).
7. **Converting Moles to Grams:** Given the qu[...] substance in moles, calculate the mass in gram[...] 7.7).
8. **Calculating Mass Percentages from a Formula:** Given the formula of a compound, calculate the mass percentage of each element in the compound (Example 7.8).
9. **Comparing Mass Percentages:** Given two compounds containing a common element, determine which one contains the greater amount of the element per gram of compound (Example 7.9).

Questions to Test Your Reading

7.1 What is the difference between a formula w[...] molecular weight? Define each one.

7.2 Could one substance have both a formula w[...] molecular weight? Explain.

7.3 What is Avogadro's number? What is Avoga[...] ber of chlorine atoms? What is Avogadro's[...] diatomic chlorine molecules?

7.4 What is a mole? What is the molar mass[...]

12.6 The Solid State **385**

EXAMPLE 12.9 Identifying Types of Solids

Sulfur dioxide (SO_2) is an air pollutant; potassium iodide (KI) is added to common table salt by the distributor to provide iodine in our diets. Identify the type of solid you expect for each substance.

Problem Analysis

Notice that both substances are compounds. Distinguish between ionic and covalent compounds.

Solution

Sulfur dioxide is a molecular substance (both sulfur and oxygen are nonmetals); therefore, it freezes as a molecular solid. Potassium iodide is an ionic substance (potassium is a metal, and iodine is a nonmetal); it exists as an ionic solid.

Exercise 12.9

Classify each of the following solids according to its type: zinc (Zn), sodium bromide (NaBr), and methane (CH_4).

(Try Problems 12.53, 12.54, 12.55, and 12.56.)

EXAMPLE 12.10 Determining Relative Melting Points

Does sulfur dioxide or potassium iodide have a higher melting point? Explain your reasoning.

Problem Analysis

Identify the type of solid expected for each substance (see Example 12.9). Determine the types of attractions in each solid and which one has the stronger forces. The compound with stronger attractions between the molecules has a higher melting point.

Solution

As you saw in Example 12.9, sulfur dioxide is a molecular solid, so it is held together by dispersion forces. Potassium iodide is an ionic compound, so it is held together by electrical attractions between oppositely charged ions. Because ionic attractions are stronger than dispersion forces, potassium iodide will have a higher melting point than sulfur dioxide.

Exercise 12.10

Name the type of solid that is formed for each of the following substances: $MgCl_2$, CH_3OH, and Ar. On the basis of the type of solid that you expect, arrange these substances in order of increasing melting point.

(Try Problems 12.57, 12.58, 12.59, and 12.60.)

In-text worked **Examples** guide students through the steps of solving problems

A **Problem Analysis** section shows students how to think the problem through using the information given in the problem and the relevant principles from the text.

The **Solution** applies this problem analysis to the specific problem statement.

Each worked-out Example is followed by a similar **Exercise** and a reference to similar matched-pair problems at the ends of the chapters (**Try Problems** . . .) to give students lots of practice in solving these problems.

The end-of-chapter **Practice Problems** are similar to the problems solved in the Examples, and in some cases provide a variation or extension of the problem-solving skill used in the Examples.

Additional Problems are not keyed to specific topics and are more difficult to solve.

All of these problems are in **matched pairs;** every odd-numbered problem is answered at the back of the book and is followed by a similar even-numbered problem (unanswered).

7.7 If hydrogen peroxide has an empirical formula of HO and a molecular weight of 34 amu, what is the molecular formula?

7.8 A compound's molecular formula is $C_6H_{12}O_6$. What is the empirical formula?

Practice Problems

Molecular Weight and Formula Weight (Section 7.1)

7.9 Calculate the molecular weight of each of the following substances.
(a) F_2 (b) PF_5 (c) SO_3
(d) $HC_2H_3O_2$ (e) $C_6H_6O_6$ (f) $C_{12}H_{22}O_{11}$

7.10 Calculate the molecular weight of each of the following substances.
(a) Br_2 (b) SF_6 (c) P_4O_{10}
(d) $H_2C_2O_4$ (e) $C_2H_4Cl_2$ (f) C_3H_7SH

7.11 As grapes ripen, the exceptionally sour taste caused by tartaric acid ($C_4H_6O_2$) disappears as this acid is converted to the sugar glucose ($C_6H_{12}O_6$). Calculate the molecular weight of each of these compounds.

7.12 Indigo ($C_{16}H_{10}N_2O_2$), the dye used to color blue jeans, is derived from a compound known as indoxyl (C_8H_7ON). Calculate the molecular weight of each of these compounds.

7.13 Calculate the formula weight of each of the following compounds.
(a) ZnI_2 (b) $AlBr_3$ (c) C_2H_6
(d) NH_4NO_3 (e) Fe_2O_3 (f) Na_2CrO_4

7.14 Calculate the formula weight of each of the following compounds.
(a) K_2SO_4 (b) $K_2Cr_2O_7$ (c) $Ca_3(PO_4)_2$
(d) $C_{18}H_{36}O_{18}$ (e) Al_2O_3 (f) $CaCO_3$

7.15 Identify the substance that has a formula weight of 125.84 amu.
(a) BCl_3 (b) $MgCl_2$ (c) IF_7
(d) $MnCl_2$ (e) H_3PO_4 (f) $TiCl_4$

7.16 Identify the substance that has a formula weight of 100.46 amu.
(a) $HClO_3$ (b) $BeSO_4$ (c) $PtCl_2$
(d) SF_6 (e) H_2SO_4 (f) $HClO_4$

The Mole and Molar Mass (Sections 7.2 to 7.5)

7.17 How many atoms of each element are in 2.33 mol ethyl mercaptan (C_2H_5SH)?

7.19 How many magnesium ions are in 0.234 mole o nesium nitride?

7.21 What are the molar masses of hydrogen and heli

7.23 What are the molar masses of iron and of sulfur

7.25 What are the molar masses of the following pounds?
(a) CH_3OH (b) PF_5 (c) SO_3
(d) $HC_2H_3O_2$ (e) $C_6H_{12}O_6$ (f) $C_{12}H_{22}O$

7.27 What are the molar masses of the following pounds?
(a) LiH (b) $Mg(ClO_4)_2$ (c) $VOCl_3$
(d) $Ba_3(PO_4)_2$ (e) C_3H_7Br (f) K_2SO

7.29 How many moles are in 1.00 g of each of the foll elements?
(a) hydrogen (b) lithium (c) sodium
(d) potassium (e) rubidium (f) cesium

Practice in Problem Analysis

For each problem, describe the thinking you would use (the problem analysis) before doing the actual solution, but do not solve the problem.

1. Write a chemical equation that describes how you would prepare barium sulfate from potassium sulfate and another reactant by a precipitation reaction.

2. Write a chemical equation that describes how you would prepare sodium hydroxide from calcium hydroxide and another reactant by a precipitation reaction.

PRACTICE EXAM

1. Consider the chemical equation

$$2H_2O_2(aq) \xrightarrow{Br^-} 2H_2O(l) + O_2(g)$$

Which of the following statements best fits the description given by this equation?
(a) Hydrogen peroxide liquid decomposes to water and oxygen gas.
(b) Hydrogen peroxide solution decomposes with a bromide ion catalyst to give liquid water and oxygen gas.
(c) Hydrogen peroxide liquid decomposes with a bromide ion catalyst to liquid water and oxygen gas.
(d) Hydrogen peroxide solution reacts with bromide ion to give liquid water and oxygen gas.
(e) Hydrogen peroxide decomposes to water and oxygen.

2. Consider the following chemical equation.

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

Which of the following statements is not true?
(a) Solid sodium reacts with water.
(b) Sodium hydroxide is a product.
(c) The coefficient of hydrogen is one.
(d) As indicated by the (*aq*) on the right, water is a product.
(e) The products are a solution and a gas.

3. Which of the following equations is not balanced?
(a) $NO(g) + O_2(g) \longrightarrow NO_2(g)$
(b) $2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$
(c) $HBr + KOH \longrightarrow KBr + H_2O$
(d) $Zn(s) + 2HBr(aq) \longrightarrow ZnBr_2(aq) + H_2(g)$
(e) None of the above

4. Nickel metal reacts with hydrochloric acid to produce hydrogen and a solution of nickel chloride. Which of the following is a balanced equation for this reaction?
(a) $Ni(s) + 2HCl(g) \longrightarrow NiCl_2(aq) + H_2(g)$
(b) $Ni(s) + 2HCl(aq) \longrightarrow NiCl_2(s) + H_2(g)$
(c) $Ni(s) + 2HCl(aq) \longrightarrow NiCl_2(aq) + H_2(g)$
(d) $2Ni(s) + 2HCl(aq) \longrightarrow 2NiCl_2(aq) + H_2(g)$
(e) None of the above

5. Which of the following is a combination reaction?
(a) $Zn(s) + CuBr_2(aq) \longrightarrow ZnBr_2(aq) + Cu(s)$
(b) $2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$
(c) $PbO_2(s) \longrightarrow Pb(s) + O_2(g)$
(d) $2HI(aq) + Na_2S(aq) \longrightarrow H_2S(g) + 2NaI(aq)$
(e) None of the above

6. Which of the following is a decomposition reaction?
(a) $Zn(s) + CuBr_2(aq) \longrightarrow ZnBr_2(aq) + Cu(s)$
(b) $SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$
(c) $PbO_2(s) \longrightarrow Pb(s) + O_2(g)$
(d) $2HI(aq) + Na_2S(aq) \longrightarrow H_2S(g) + 2NaI(aq)$
(e) None of the above

7. Which of the following is a single-replacement reaction?
(a) $Zn(s) + CuBr_2(aq) \longrightarrow ZnBr_2(aq) + Cu(s)$
(b) $SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$
(c) $PbO_2(s) \longrightarrow Pb(s) + O_2(g)$
(d) $2HI(aq) + Na_2S(aq) \longrightarrow H_2S(g) + 2NaI(aq)$
(e) None of the above

Practice in Problem Analysis asks students to describe the thinking involved in a problem, rather than solving the problem. The goal is to get students to focus on problem analysis and take them away from rote thinking.

Practice Exams appear at the end of every chapter and provide students with practice in taking multiple-choice exams.

Contents in Brief

Contents