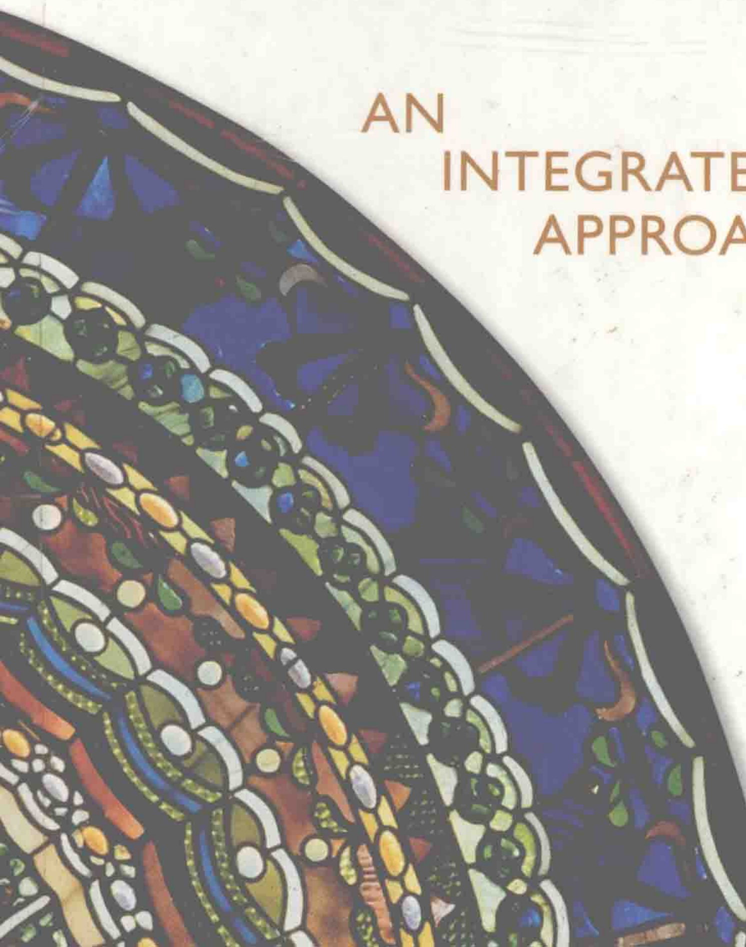
SECOND EDITION

General Chemistry

AN INTEGRATED APPROACH



Hill

Petrucci

General Chemistry

An Integrated Approach

Second Edition

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Library of Congress Cataloging-in-Publication Data

Hill, John William,
General chemistry / John W. Hill, Ralph H. Petrucci. -- 2nd ed.
p. cm.
Includes index.
ISBN 0-13-918673-5
1. Chemistry. I. Petrucci, Ralph H. II. Title.
QD33.H654 1999
540--dc21 98-37642
CIP

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John LaFarge, "Peacocks and Peonies I," 1982. Stained glass, $105^{3/4} \times 45$ inches (268.6×114.3 cm).
Gift of Henry LaFarge. National Museum of American Art, Washington DC, USA. / Art Resource, NY. (*Detail*)

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-918673-5

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

Preface

Students come to a general chemistry course with a variety of backgrounds and interests. Most plan to become scientists, engineers, or professionals in medicine or other areas of the life sciences. Part of the task of the chemistry instructor is convincing students that knowledge of chemistry is essential to a true understanding of fields that range from cell biology to medicine to materials science. Indeed, the chemical properties and principles students learn in this course will pervade almost every aspect of their personal and professional lives. In this text, we have tried to provide students with both the core principles and interesting applications of chemistry, with the belief that such knowledge will both help them in their professions and enrich their everyday lives.

This New Edition: Achieving Balance

In addition to establishing the relevance of chemistry to broader concerns, a textbook can enhance students' success in the study of chemistry by satisfying other needs: the need for background reading and a second voice for students to hear; help in visualizing chemical phenomena, both what students can see with their eyes and what they must learn to see with their minds' eyes; and help in formulating strategies for solving problems, the basis on which their knowledge will so often be tested. In crafting the second edition of this text, we have striven to strike a necessary balance in meeting these basic needs. Following are some of the ways we have revised the previous edition:

- In response to reviewer suggestions, we have expanded coverage of a number of topics while at the same time being sensitive to the common desire for leaner books. In particular, **we have added many more problems**, both mid-level and those of a more challenging nature.
- We have **rewritten explanations of difficult topics to be carefully paced** and appropriate to the background of the typical student. In some instances we have approached the topic in a nontraditional manner, but we have always been careful to adhere to current views, such as in the treatment of expanded valence shells in Lewis structures, the rationalization of Raoult's law, and the use of electrochemical conventions.
- We have **added many new chemical applications** throughout this edition. These include in-text discussions, new boxes, and a new feature called Application Notes. In-text discussions include those of the Alkali Metals and Living Matter (Section 20.7) and the Group 2A Metals and Living Matter (Section 20.11). As in the first edition, our box features focus on applications. New box features introduce topics such as Electron Probabilities and a Close-Up Look at Atoms (p. 308) and NO: A Messenger Molecule (p. 899). Application Notes are marginal notes that highlight interesting applications of key topics. For example, an Application Note in Chapter 5 (Gases, p. 213) describes how methyl mercaptan enables us to detect natural gas leaks. These notes help the student see that we can apply our knowledge of chemistry to solve real-life problems. Another Application Note in Chapter 24 (Chemistry of Materials) explains that the Titanic sank partly because the steel rivets that held the ship together were weakened by the presence of too much slag.
- We have **expanded the teaching of all problem-solving skills** by adding flowcharts for quantitative problem-solving, more Conceptual Examples and

Exercises, and more Estimation Examples and Exercises (which encourage students to develop the habit of asking, "Is this answer reasonable?").

In summary, we have tried to combine our collective experience in teaching and writing for various audiences to produce a textbook that strikes a balance between the principles that give meaning to chemistry and the applications that make it come alive.

Organization

The first 18 chapters of the text emphasize chemical principles, but the principles are illustrated throughout with significant applications and concrete examples from descriptive chemistry. Chapter 20 (The *s*-Block Elements), Chapter 21 (The *p*-Block Elements), and Chapter 22 (The *d*-Block Elements and Coordination Chemistry) provide a systematic treatment of descriptive chemistry, but with an emphasis on how the properties of substances relate to the principles learned earlier in the text. Chapter 19 (Nuclear Chemistry), Chapter 23 (Chemistry and Life), Chapter 24 (Chemistry of Materials), and Chapter 25 (Environmental Chemistry) are fairly independent, free-standing chapters. These chapters can serve as capstones to a general chemistry course, for each revisits the basic principles of earlier chapters to cover topics in which students generally have a strong interest. These chapters can be studied, in whole or in part, in just about any order.

Integrating Organic and Biological Chemistry

A major goal of ours in writing this text has been **to provide a truly general course that integrates all the major areas of chemistry**. Physical principles, inorganic compounds, and analytical techniques are addressed repeatedly. As in the previous edition, organic chemistry is incorporated throughout the text, as students may be ill-served by being sheltered from organic compounds until very late in their study of general chemistry. Thus, some simple organic chemistry is introduced in Chapter 2 and used thereafter to describe physical properties of substances, aspects of chemical bonding, acid-base chemistry, and oxidation-reduction reactions. Biochemistry is introduced in Chapter 6 in a discussion of carbohydrates and fats as fuels for our bodies; it is used frequently in following chapters where appropriate.

New to this edition is Chapter 23, titled "Chemistry and Life: More On Organic, Biological, and Medicinal Chemistry." This chapter brings together the core organic chemistry concepts introduced in earlier chapters, expands on them in those cases where the earlier introduction was necessarily brief, and then discusses the chemistry of selected biomolecules and medicinal compounds. In this way, we have tried to provide a useful set of core material to those who will never take an organic chemistry course, while also offering a broader-than-usual preparation for students who will enroll in organic chemistry courses.

A Balanced Approach to Problem Solving

Problem-solving skills and the ability to think critically are essential for success in today's world. We provide ample opportunities for practicing these skills. For every type of problem we provide *Examples* that are carefully worked out, step-by-step, to guide students in solving similar problems.

Two new problem-solving tools accompany the Examples. *Problem-Solving Notes* provide ready reference and help for students as they study specific Examples:

The notes highlight relevant problem-solving techniques, help students understand and test the assumptions used to solve a worked Example, provide helpful hints, and encourage students to check their answers. Also, in the early chapters, particularly Chapter 3 (Stoichiometry), **the various terms in a series of related calculations may be annotated**. These annotations present a brief rationale for each calculation; we hope they will help students focus on "why" as well as "how."

The Examples are followed by *Exercises* that students can use to practice their understanding of the methods illustrated. In most cases, **two Exercises are given**, labeled *A* and *B*. The goal in an *A* Exercise is to apply to a similar situation the method outlined in the Example. In a *B* Exercise, students often must combine that method with other ideas previously learned. Many of the *B* Exercises provide a context closer to that in which chemical knowledge is applied, and they thus serve as a bridge between the worked Examples and the more challenging problems at the end of the chapter.

The ability to plug numbers into an equation and get an answer, in itself, is seldom enough to attain mastery of a concept. For example, **students should generally be able to judge whether an answer is reasonable**, and in some cases, to obtain a reasonable estimate of an answer without doing a detailed calculation. To assist in the acquisition of these skills, we offer worked-out *Estimation Examples* followed by *Estimation Exercises*. Examples and Exercises of this type are found throughout the text.

Students also need to **develop insights into chemical concepts** that are often best demonstrated by an ability to solve problems of a qualitative nature. To emphasize this aspect of problem-solving, we provide guided *Conceptual Examples* followed by *Conceptual Exercises*.

Through the different types of Examples and Exercises described, students of this text should gain a balanced set of skills in chemical problem-solving. As additional reinforcement, the text offers three kinds of end-of-chapter exercises:

- *Review Questions* are intended to provide a qualitative measure of student understanding of the main ideas introduced in the chapter. Answers to a few of the Review Questions are given in Appendix F (Answers to Selected Problems).
- *Problems* are arranged by topic; they test mastery of the problem-solving techniques discussed in the chapter. The Problems are arranged in matched pairs, with answers to odd-numbered problems given in Appendix F.
- *Additional Problems* are not grouped by type. Some are more challenging than the Problems, often requiring a synthesis of ideas from more than one chapter. Others pursue an idea further than is done in the text, or introduce new ideas. Answers to the odd-numbered Additional Problems are given in Appendix F.

Some of the Problems and Additional Problems are of an estimation or conceptual type, mirroring similar types of exercises within each chapter. We did not specifically label these questions, however; we want to give students experience in recognizing different types of problems as well as solving them.

Improving Students' Visualization Skills

Difficulty seeing the unseeable and imagining things in three dimensions is cited among the top three barriers confronting students in a general chemistry course. (The other two are poor study habits and poor math skills, both of which are addressed by specific print supplements to this text; see p. xvi.) In this book, we use drawings, computer graphics, and photographs to help students visualize chemical phenomena at both the microscopic (molecular) and macroscopic (visible) levels. Users of this text also have available ChemCDX, which includes nearly 70 animations and videos, and a link to the Companion Website that presents almost all the molecules in the book as three-dimensional images that students can examine in detail on their computers.

Supplements

For the Instructor

Annotated Instructor's Edition (0-13-010318-7), with annotations by Leslie Kinsland, University of Southwestern Louisiana. This special edition of the text includes the entire student text plus marginal icons and annotations to aid instructors in preparing their lectures. Included are suggestions for lecture demonstrations, teaching tips, common student misconceptions, and indications of which graphics in the textbook are available as overhead transparencies. The AIE also includes cross-references to all figures, demonstrations, and animations available in electronic form on the *Matter '99* CD-ROM.

Instructor's Resource Manual (0-13-918947-5), prepared by Robert K. Wismer of Millersville University. This book provides chapter-by-chapter lectures outlines, teaching tips, common student misconceptions, background references, and suggested lecture demonstrations for in-class use.

Solutions Manual (0-13-918724-3) by C. Alton Hassell of Baylor University contains worked-out solutions to all in-chapter, end-of-chapter, review, conceptual, and estimation exercises and problems.

Transparencies (0-13-918913-0) Over 200 full-color transparencies chosen from the text put principles into visual perspective and save you time while you are preparing your lectures.

Test Item File (0-13-919051-1), revised and expanded by Michael Mosher, University of Nebraska, Kearney. This printed test bank includes over 1300 questions written exclusively for the Hill & Petrucci text, with all answers section-referenced to the text.

Prentice Hall Custom Test. The computerized version of the Test Item File is available in both a Windows version (0-13-919069-4) and a Mac version (0-13-919077-5). The software available with this database allows you to create and tailor exams to your specific needs.

Matter '99 Visual Presentation Manager CD-ROM is available for Windows (0-13-012503-2) and Macintosh (0-13-012504-0) and contains over 400 pieces of art from the text (in electronic format), 20 lab demonstration video segments, and 50 animations of core concepts. This CD also includes Presentation Manager 3.0, Prentice Hall's software designed specifically for classroom presentation, and Presentation Manager '99, our new PowerPoint-based image and animation gallery. Instructors can select one or the other to display material using a classroom projection system. Instructors can also access a special Website for updated graphics and new images related to their courses.

For the Student

ChemCDX (0-13-012505-9). A free copy of the ChemCDX CD-ROM accompanies each new copy of the textbook. This CD-ROM features 50 chapter-based modules containing 70 animations and videos that allow students to explore, extend, experiment, and expand their understanding of chemistry. Each module includes a brief introduction and is followed by questions that test student understanding of the material. References to relevant reading in the text are provided for students who need additional review to answer questions correctly. ChemCDX also serves as a launching point to the Companion Website for this textbook. ChemCDX and the Companion Website are easy-to-use and offer many ways to integrate media into your course, if you desire.

Study Guide (0-13-918765-0) by D. J. Goss of Hunter College. This book is keyed to the main text and provides further learning material for students: chapter-by-chapter overviews, learning goals, numerous examples and exercises, parallel text material, worked-out solutions, and practice tests with answers. This book serves as an excellent diagnostic tool and also helps sharpen students' skills in test-taking.

Selected Solutions Manual (0-13-918740-5) by C. Alton Hassell of Baylor University, contains worked-out solutions to over half of the text's problems. The answers to these problems also appear in the text as Appendix F, Answers to Selected Problems.

Math Review Toolkit (0-13-919184-4) by Gary Long of Virginia Polytechnic Institute. This brief paperback is engineered for students who find math a significant challenge in this course. The book provides a chapter-by-chapter review of the mathematics used throughout the text; a guide to preparing for a career in chemistry; and a review of some of the special writing requirements often needed in the general chemistry course, focusing particularly on the laboratory notebook. This supplement is free to qualified adopters; please speak with your local Prentice Hall representative.

Interactive Chemistry Journey CD-ROM (0-13-548116-3) by Steven Gammon, University of Idaho, Lynn R. Hunsberger, University of Louisville, and Sharon Hutchison, University of Idaho. This student tutorial CD-ROM is an interactive study tool that fosters understanding of a number of core chemical concepts. In this dynamic, simulation-based environment, students interact with and visualize chemical concepts in ways that are not possible with static learning programs.

Companion Website for *General Chemistry, Second Edition*. This innovative on-line resource center is designed specifically to support and enhance the Hill & Petrucci text. The Website features the following:

- a visualization gallery that includes hundreds of pre-built molecules. Students can manipulate these models in real-time on their computers using Chime or Rasmol.
- an interactive problem-solving center with nearly 1300 unique quiz problems referenced to the text. All quizzes feature hints, scrambled answer choices, and are graded on-line. Student feedback includes readings from the textbook.
- constantly updated links to recently-published articles and other chemistry-related Websites;
- chatrooms and bulletin boards, where students can communicate with you, TAs, or classmates.

Chemistry on the Internet: A Guide for Students (0-13-083977-9) by Thomas Gardner, Tennessee State University. This brief, paperback booklet helps students gain a greater understanding of the Internet while showing them how to access chemical information and learn about chemistry. It includes an overview of the Web and introduces students to search techniques for navigation. This supplement is free to qualified adopters; please speak with your local Prentice Hall representative.

The New York Times/Prentice Hall Themes of the Times. This newspaper-format resource brings together current chemistry-related articles from the award-winning science pages of *The New York Times*. This supplement is free to qualified adopters; please speak with your local Prentice Hall representative.

Acknowledgments

JWH would like to thank his colleagues at the University of Wisconsin-River Falls for so many ideas that made their way into this text, and to Kathy Sumter, Program Aide in the Department of Chemistry. He is especially indebted to Ina Hill and Cynthia Hill for library research, typing, and unfailing support throughout this project, and to Mike Davis for his encouragement and for sharing his love of learning.

RHP would like to thank his colleagues at California State University, San Bernardino for the interest they have shown and the helpful suggestions they have contributed to his textbooks over the years. His greatest debt is to his wife, Ruth, for her love, encouragement, and continuing support of a husband who has been preoccupied and neglectful for so long.

Both of us would like to thank Robert K. Wismer of Millersville University, who is ever ready to offer his excellent advice on the broad range of issues that crop up in the preparation of a new text. We are especially indebted to our students, who have challenged us to be better teachers, and the reviewers of this and our other books, who have challenged us to write more clearly and accurately. We also owe a debt of gratitude to the many creative people at Prentice Hall who have contributed their talents to this edition: John Challice, our chemistry editor, for imaginative guidance throughout the project; Amanda Griffith, editorial assistant, for diligence and patience in managing a myriad of reviews and other correspondence; Shana Ederer, our marvelous development editor, for her innumerable creative contributions; Yvonne Gerin, photo researcher, for her aesthetic contributions to the photographic illustrations; and to the production staff for their diligence and patience in bringing all the parts together to yield a finished work.

This edition has benefited from the thoughtful and careful input of users of the previous edition and reviewers of the new manuscript. To these colleagues we convey our sincere appreciation; we are pleased to acknowledge them below:

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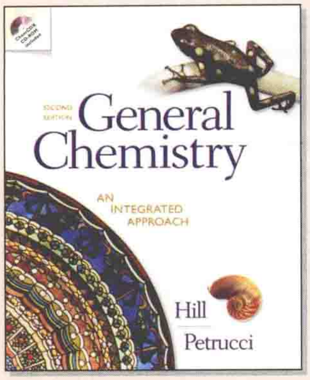


A Guide to Using this Text

You and your classmates come to this course with a variety of backgrounds and interests. Most of you plan to be scientists, engineers, or professionals in medicine or another life science. Knowledge of chemistry is essential to a true understanding of everything from DNA replication to drug discovery to computer chip design and manufacturing. Indeed, the chemical properties and principles you learn in this course will pervade almost every aspect of your private and professional lives. In this text, we provide you with both the principles and applications of chemistry that will help you in your professional practice and enrich your everyday life as well.

This text is rich in pedagogical aids, both within and at the ends of the chapters. We present this "user's guide" to the text to help you get the most out of this book and your course.

3.3 More on the Mole **89**

EXAMPLE 3.4

Calculate (**a**) the mass of a sodium atom, in grams; and (**b**) the number of Cl^- ions present in 1.38 g $MgCl_2$.

SOLUTION

a. The answer must have the unit "grams per sodium atom," that is, "g/Na atom." Thus, if we knew the mass of a certain number of Na atoms, our answer would simply be the mass divided by that number. But we do know these quantities: One mole of Na has a mass of 22.99 g and consists of 6.022×10^{23} Na atoms. As shown, the division (22.99 g/6.022×10^{23} Na atoms) is represented as the product of two factors, one involving the molar mass and the other, Avogadro's number.

$$? \text{ g/Na atom} = \frac{22.99 \text{ g}}{\text{1 mol Na}} \times \frac{\text{1 mol Na}}{6.022 \times 10^{23} \text{ Na atoms}} = 3.818 \times 10^{-23} \text{ g/Na atom}$$

Because there is only one naturally-occurring type of sodium atom (^{23}Na), what we have just calculated is truly the mass of a sodium atom. For elements that have two or more isotopes, our calculation would be a *weighted average* mass and not the mass of an atom of any particular isotope.

b. First we need the formula mass of $MgCl_2$ and then the molar mass. Once we have established the amount of $MgCl_2$ in moles, we can use Avogadro's number to determine the number of formula units (f.u.) of $MgCl_2$. Finally, we can use a factor (shown in red) that establishes the number of Cl^- ions per formula unit (f.u.).

$$? \text{ Cl}^- \text{ ions} = 1.38 \text{ g MgCl}_2 \times \frac{1 \text{ mol MgCl}_2}{95.21 \text{ g MgCl}_2} \times \frac{6.022 \times 10^{23} \text{ f.u.}}{1 \text{ mol MgCl}_2} \times \frac{2 \text{ Cl}^- \text{ ion}}{1 \text{ f.u.}} = 1.75 \times 10^{22} \text{ Cl}^- \text{ ions}$$

PROBLEM-SOLVING NOTE

The mass of a single atom is tiny—very much less than 1 g. Keep this fact in mind to avoid mistakenly multiplying by Avogadro's number when you should divide.

PROBLEM-SOLVING NOTE

Example 3.4(b) illustrates the common practice of expressing molar mass and Avogadro's number with one more significant figure than the least precisely known quantity (1.38 g $MgCl_2$). This ensures that the precision of the calculated result is limited only by the least precisely known quantity.

EXERCISE 3.4A

Calculate (**a**) the weighted average mass, in grams, of a bismuth atom; (**b**) the weighted average mass, in grams, of a glycerol molecule, $CH_2OHCHOHCH_2OH$; (**c**) the number of molecules in 0.0100 g of nitrogen gas; and (**d**) the total number of atoms in 215 g of sucrose, $C_{12}H_{22}O_{11}$.

EXERCISE 3.4B

Calculate (**a**) the number of Br_2 molecules in 125 mL of liquid bromine ($d = 3.12$ g/mL); and (**b**) the number of liters of liquid ethanol ($d = 0.789$ g/mL) required to obtain a sample containing 1.00×10^{25} CH_3CH_2OH molecules.

◀ Examples

These worked problems help you build your problem-solving skills by showing you how to solve various types of problems. Study the Examples carefully to make sure you understand the model solution. Then start to master the problem-solving process by working the Exercises that follow.

◀ Problem-Solving Notes

These marginal notes highlight good problem-solving practices and warn you of common student misconceptions. These tips and techniques can help you avoid common pitfalls.

◀ Exercise A

Exercise A asks a question similar to that in the Example. By drawing on the model solution in the Example and your growing knowledge of chemistry, you will be able to create a strategy and solve the A Exercise.

▲ Exercise B

To solve Exercise B, you will need all the skills and knowledge derived from the Example and Exercise A. You may also need to apply a problem-solving technique or an idea you learned earlier. These Exercises help prepare you for solving more complex problems, such as those you might face on an exam.

EXAMPLE 11.4—A Conceptual Example

To keep track of how much gas remains in a cylinder, we can weigh the cylinder when it is empty, when it is filled, and after each use. In some cases, though, we can equip the cylinder with a pressure gauge and simply relate the amount of gas to the measured gas pressure. Which method should we use to keep track of the bottled propane, C_3H_8, in a gas barbecue?

SOLUTION

The propane is at a temperature below its T_c (369.8 K) and exists in the cylinder as a mixture of a liquid and vapor. As the fuel is consumed, the volume of liquid in the cylinder decreases, and that of the vapor increases. However, the vapor pressure of the liquid propane does not depend on the amounts of liquid and vapor present. The pressure will remain constant (assuming a constant temperature) as long as some liquid remains. Only after the last of the liquid has vaporized, will the pressure drop. Measuring the pressure doesn't tell us how much propane is left in the cylinder until it's almost gone. We would have to monitor the contents of the cylinder by weighing.

EXERCISE 11.4

Which of the two methods described above could you use if the fuel in the cylinder were methane, CH_4? Explain.

◀ Conceptual Examples and Exercises

Conceptual Examples help you understand the most important ideas in your chemistry course. You will find that they focus on concepts rather than calculations, but they still require careful thought and study. Test your mastery of the material by examining the Conceptual Example and solving the Conceptual Exercise that follows it.

Estimation Examples and Exercises ▶

Have you ever made a mistake using a calculator and come up with the wrong answer? Estimation Examples and Exercises help you learn to estimate the answer to a problem before you perform detailed calculations. This lets you determine at a glance if your calculated answer is a reasonable one.

EXAMPLE 6.10—An Estimation Example

Without doing detailed calculations, determine which of the following is a likely approximate final temperature when 100 g of iron at 100 °C is added to 100 g of water in a Styrofoam® cup calorimeter at 20 °C:

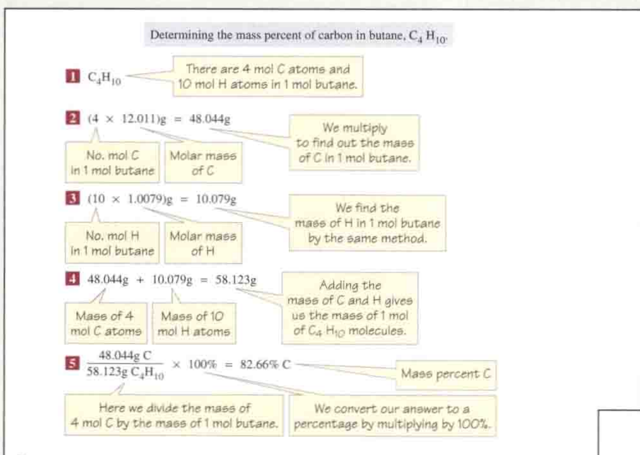
20 °C   30 °C   60 °C   70 °C

SOLUTION

Because we have the same mass of each substance, *if* the water and iron had the same specific heat, the rise in temperature of the water would be the same as the drop in temperature of the iron. The final temperature would be the average of 20 °C and 100 °C, or 60 °C. However, from Table 6.1 we see that the specific heat of water (4.18 J g^{-1} $°C^{-1}$) is much greater than that of iron (0.45 J g^{-1} $°C^{-1}$). It takes more heat to change the temperature of a given mass of water than of the same mass of iron. The final water temperature must be below 60 °C, but also it has to be above 20 °C, the initial temperature. The only possible approximate temperature of those given is 30 °C.

EXERCISE 6.10

Without doing detailed calculations, determine the final temperature if 200.0 mL of water at 80 °C is added to 100.0 mL of water at 20 °C.

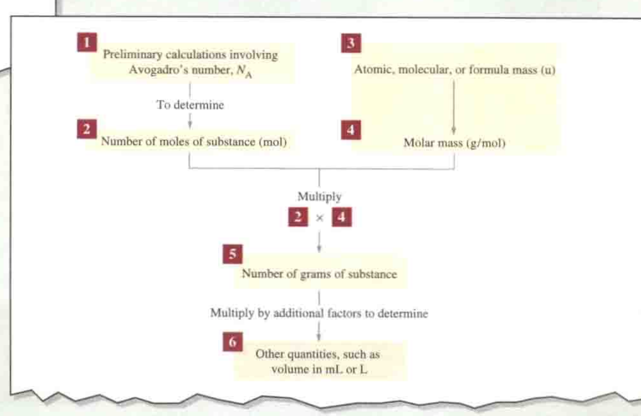


◀ Voice Balloons

Voice balloons help you understand each step in the solution to a problem, as well as why each step is necessary. Make sure you understand each step; don't just memorize them.

Flow Charts ▶

Flow charts provide a visual outline of the problem-solving process. Use them to plan how to solve a related problem, to check your progress as you solve a problem, or to review your solution after it is complete.



monoxide, and dinitrogen *tetr*oxide, not dinitrogen *tetra*oxide. However, PI_3 is phosphorus *tri*iodide, not phosphorus *tri*odide.

- The names are further altered by adding prefixes such as *mono*, *di*, *tri*, and so on to denote the numbers of atoms of each element in the molecule (see Table 2.3). Thus, P_4S_3 is called *tetra*phosphorus *tri*sulf*ide*. Note that in these examples the prefix *mono*- is treated in a special way. We do not use it for the first-named element, but we do for the second. For example, the name for CO is carbon monoxide, *not* monocarbon monoxide.

EXAMPLE 2.6

Write the formula and name of a compound that has six oxygen atoms and four phosphorus atoms in its molecules.

APPLICATION NOTE

Is P_4S_3 just a curiosity chemical with a tongue twister name? No, indeed. It is the chemical on the head of a strike-anywhere match that is ignited through frictional heat. P_4S_3 does not spontaneously ignite at temperatures below 100 °C.

Application Notes

Application Notes highlight the intriguing ways in which we can put our knowledge of chemistry to work, touching on fields as diverse as medicine, engineering, and agriculture.

Essays

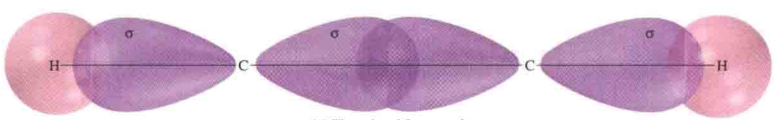
Essays focus on how we apply our chemical knowledge to solve real-life problems, and on historical topics of interest. These readings will help you see how chemistry affects everyday life and how we arrived at our current understanding of chemistry.

What Is a Low-Sodium Diet?

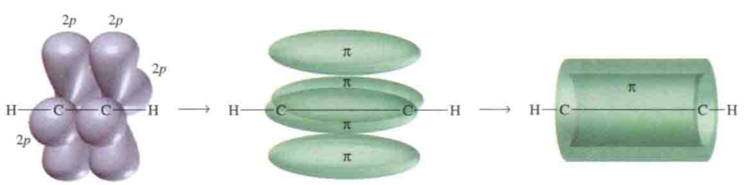
There are about 27.5 million people with hypertension (high blood pressure) in the United States. Physicians usually advise them to follow a low-sodium diet. Just what does that mean? Surely they are not being advised to reduce their consumption of sodium itself. Sodium is an extremely reactive metal that reacts violently with moisture. Sodium metal is not a part of anyone's diet. The concern is really with sodium *ion*, Na^+, but sodium ion taken alone is not a substance. It enters our diet in combination with anions in the form of ionic compounds, the principal one being sodium chloride—common table salt. Some people eat 6 or 7 grams of sodium chloride a day, most of it in prepared foods. Many snack foods, such as potato chips, pretzels, and corn chips, are especially high in salt. Most physicians recommend that people with hypertension restrict their salt intake. Some, but not all, physicians suggest that even people with normal blood pressure should eat less salt.

Ions differ greatly from the atoms from which they are formed. Sodium atoms make up an element that, although quite reactive, can exist by itself. Sodium *ions* are generally unreactive, but they come only in combination with anions. A metal atom and its cation are as different as a whole peach (atom) and a peach pit (ion). Unfortunately, the situation is confused when people talk about diets with too much "sodium" or of taking "calcium" for healthy teeth and bones. They really mean sodium *ions* and calcium *ions*. As scientists, we try to be more precise in our terminology.

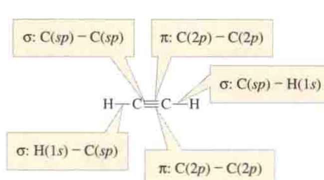
Some familiar foods with high Na^+ content.



(a) The σ-bond framework



(b) Formation of π-bonds by the overlap of half-filled 2p orbitals



(c) Hybridization and bonding scheme

▲ **Figure 10.22 Bonding in acetylene, C_2H_2, by the valence bond theory**
The σ-bond framework joins the atoms in a linear structure through the overlap of 1*s* orbitals of the H atoms and *sp* orbitals of the C atoms. Each π bond can be thought of as two parallel cigar-shaped segments. In fact, however, when two π bonds are present, the segments merge into a hollow and symmetric cylindrical shell with the carbon-to-carbon σ bond as its axis.

Art

Study the art carefully; this will help you to visualize atoms, molecules, and chemical processes that cannot be seen with the unaided (and sometimes even with the aided) eye.

Review Questions

1. Describe what a gas is like at the molecular level.
2. Why don't the molecules of a gas settle to the bottom of their container?
3. Give a kinetic-molecular explanation of the origin of gas pressure.
4. What does a mercury barometer measure? How does it work?
5. Why is mercury (rather than water or another liquid) used as the fluid in barometers?
6. How does a manometer differ from a barometer? How does an open-end manometer differ from a closed-end manometer?

(a) an increase in temperature at constant volume

(b) a decrease in volume at constant temperature

(c) an increase in temperature coupled with a decrease in volume

16. According to the kinetic-molecular theory, **(a)** what change in temperature occurs as the molecules of a gas begin to move more slowly, on average? **(b)** What change in pressure occurs when the walls of the container are struck less often by molecules of the gas?
17. Container A has twice the volume but holds twice as many gas molecules as container B at the same temperature.

◀ Review Questions

These end-of-chapter questions help you to review definitions and key concepts in the chapter without performing detailed calculations. You will find them useful in building your knowledge of chemistry and solidifying your understanding of key ideas.

Problems ▶

Problems test your mastery of the problem-solving techniques presented in the chapter. They are arranged by topic and come in matched pairs (each odd- and even-numbered pair test the same concept). Problems may emphasize estimation skills or conceptual understanding. You can check your answers to odd-numbered problems in Appendix F. Work many of the Problems to develop the strong problem-solving skills that will help you succeed.

Mixtures of Gases

93. Only one of the accompanying sketches is a reasonable molecular view of a mixture of 1.0 g H_2 and 1.0 g He. Which is the correct view, and what is wrong with the other two?

(a)

(b)

(c)

94. With reference to Problem 93, draw a molecular-level sk... of the ...seous mix... ...ter the ad... ...7.5 g

Torr? [*Hint:* Recall that volume percent is the same as mole percent for ideal gas mixtures.]

97. Mixtures of helium and oxygen are used in scuba diving. What are **(a)** the mole fractions of the two gases, **(b)** their partial pressures, and **(c)** the total pressure in a mixture of 1.96 g He and 60.8 g O_2 confined in a 5.00-L tank at 25.0 °C?
98. A 267-mL sample of a mixture of noble gases at 25.0 °C contains 0.354 g Ar, 0.0521 g Ne, and 0.0049 g Kr. What are **(a)** the mole fractions of the three gases, **(b)** their partial pressures, and **(c)** the total gas pressure?
99. Oxygen is collected over water at 30 °C and a barometric pressure of 742 Torr. What is the partial pressure and mole fraction of $O_2(g)$ in the container?
100. An oxygen-helium gas sample, collected over water at 23 °C, exerts a total pressure of 758 Torr. Calculate the mole fraction of water vapor in the sample.
101. *Elodea* is a green plant that carries out photosynthesis under water.

$$6\,CO_2(g) + 6\,H_2O(l) \longrightarrow C_6H_{12}O_6(aq) + 6\,O_2(g)$$

In an experiment, some *Elodea* produce 122 mL of $O_2(g)$, collected over water at 743 Torr and 21 °C. What mass of oxygen is produced? What mass of glucose ($C_6H_{12}O_6$) is produced concurrently?

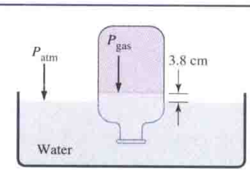
102. A 2.02-g sample of aluminum reacts with an excess of HCl(aq), and the liberated hydrogen is collected over water at a temperature of 24 °C. What is the *total* volume of the gas collected?

$$2\,Al(s) + 6\,H^+(aq) \longrightarrow 2\,Al^{3+}(aq) + 3\,H_2(g)$$

103. The reaction between carbon dioxide gas and sodium peroxide, $Na_2O_2(s)$, to produce solid sodium carbonate and oxygen gas, is used in submarines to replace expired

Additional Problems

111. In terms of pressure (P), volume (V), Kelvin temperature (T), and amount of gas (n), and in the manner of Figures 5.6 and 5.8, sketch a graph of each of the following.
    (a) V as a function of P, with T and n held constant
    (b) n as a function of P, with T and V held constant
    (c) T as a function of P, with V and n held constant
    (d) n as a function of T, with P and V held constant
112. Stephen Malaker of Cryodynamics, Inc. has developed a refrigerator that uses compressed helium as a refrigerant gas. A typical system uses 5.00 in^3 of He compressed to 195 psi at 20 °C. What mass of helium, in grams, is needed for one refrigerator?
113. In an attempt to verify Avogadro's hypothesis, small quantities of several different gases were weighed in 100.0-mL syringes. Masses were determined on an analytical balance. The following masses were obtained: 0.0080 g



115. A 2.135-g sample of a gaseous chlorofluorocarbon (a type of gas implicated in the depletion of stratospheric ozone) occupies a volume of 315.5 mL at 739.2 mmHg and 26.1 °C. Analysis of the compound shows it to be 14.05% C, 41.48% Cl, and 44.46% F, by mass. What is the molecular formula of this compound?
116. The gaseous hydrocarbon 1,3-butadiene is used to make synthetic rubber. The following measurements were mad...

◀ Additional Problems

Some of the Additional Problems are more challenging than the Problems, requiring a synthesis of concepts from multiple chapters. Others will help you to attain a stronger mastery of key concepts in this chapter. Additional Problems may also emphasize estimation skills or conceptual understanding. Answers to odd-numbered Additional Problems are given in Appendix F.

EXPLAIN • EXPLORE • EXPAND • EXAMINE

Tools to Help You Succeed in this Course

Explore, Expand, Experiment—The Multimedia Program

ChemCDX

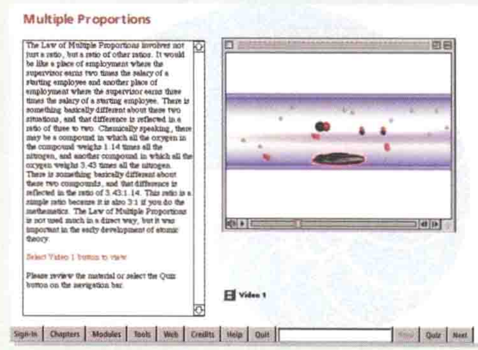
The ChemCDX CD-ROM that accompanies the text includes animations of 50 key concepts (processes that are more easily understood in an animation than in a picture), each of which has an introduction and is followed by multiple-choice questions designed to gauge your understanding of the concepts presented. Icons in the margin of the text will refer you to ChemCDX when there is a relevant module for you to study.

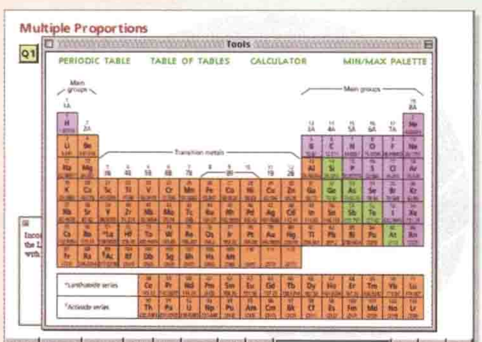
● **ChemCDX** Changes of State

its partial pressure. But the ice and liquid water are under atmospheric pressure (760 mmHg). Moreover, at the normal melting point liquid water contains some dissolved air and this affects the equilibrium temperature slightly. To have a true triple point, a system must consist of a *pure* substance existing *only under the pressure of its own vapor*. There can be no extraneous substances present (such as the gases in air).

Module Opening Screen ▶

Every chapter contains modules you can access, each corresponding to a key topic in the text chapter. When reading about a topic, you will always be able to find a related video or figure to help clarify.



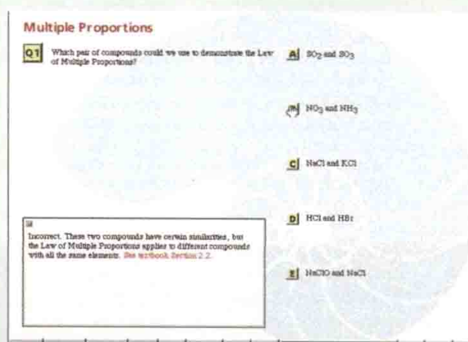


◀ Tools

At any time, you can access one of several tools, including the Periodic Table, a Table of Tables, and a calculator. Each can be used to work through the content and problems on ChemCDX.

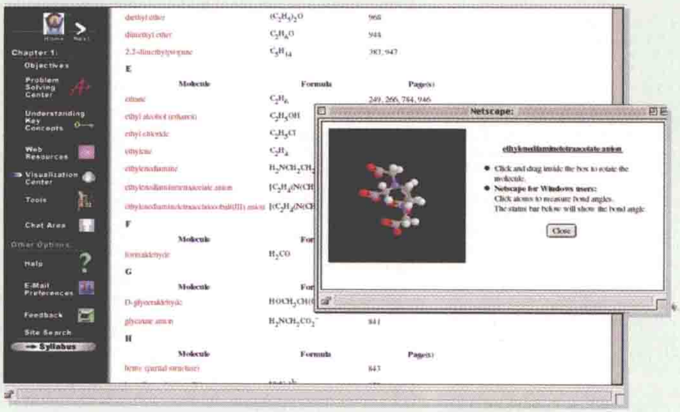
Quiz ▶

Each module contains several quiz questions. If your answer is incorrect, you'll receive an explanation and a prompt pointing you to the corresponding section in the text.

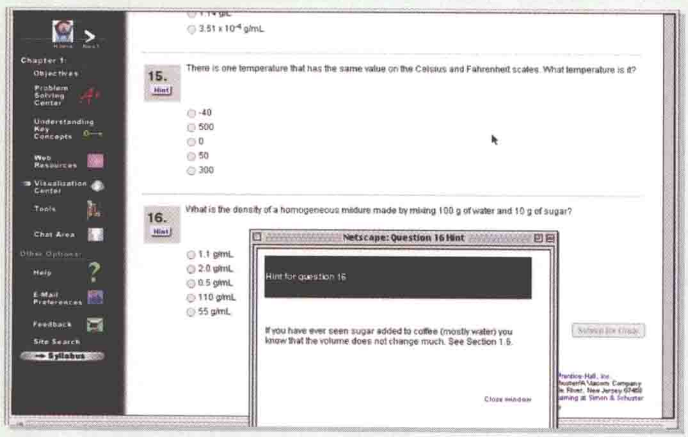


Companion Website

The interactive student Website that accompanies this text enables you to take multiple-choice quizzes (three different levels) and view a gallery of three-dimensional molecules. Feedback from quizzes includes detailed reading lists from the textbook. Icons in the textbook refer to the student Website and ChemCDX CD-ROM at appropriate points. You can enter the Companion Website directly at www.prenhall.com/~chem or through the ChemCDX CD-ROM.



◀ **Visualization Center**
Engage in tutorials and access an archive of animations tied to the text. Click on a molecule and watch it become "live"; you can re-size and rotate the three-dimensional molecules. All molecules are organized alphabetically and by chapter.



Problem Solving Center ▶
Several quizzes and tests are tied to each chapter in the Problem Solving Center. As you work through these, you can access hints, get immediate feedback, and e-mail results to your instructor or TA.

Other study aids available with Hill/Petrucci's General Chemistry, second edition

Study Guide (0-13-918765-0)

For each chapter, the Study Guide includes a summary of key topics, an overview, worked examples, and expanded self-tests with answers.

Selected Solutions Manual (0-13-918740-5)

The Selected Solutions Manual contains solutions to all in-chapter problems, all conceptual exercises, and selected end-of-chapter problems.

Molecular Model Kit for General and Organic Chemistry (0-13-955444-0)

This model kit comes with a detailed set of instructions that will show you how to build hundreds of ball-and-stick models. You can also use this kit in your organic chemistry course.

If you are interested in purchasing any of these supplements, check with your bookstore to see if these items are in stock. If not, ask if they can be special ordered for you or call Prentice Hall at 1-800-947-7700.

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