

second edition

1A

1  
H

3  
Li

11  
Na

19  
K

37  
Rb

55  
Cs

14  
Si

32  
Ge

50  
Sn



*Raymond Chang*  
***Essential Chemistry***

A Core Text for General Chemistry

# *Essential Chemistry*

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A Core Text for General Chemistry

second edition

*Raymond Chang*

Williams College

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ESSENTIAL CHEMISTRY:

A CORE TEXT FOR GENERAL CHEMISTRY, SECOND EDITION

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This book is printed on acid-free paper.

2 3 4 5 6 7 8 9 0 VNH/VNH 0 9 8 7 6 5 4 3 2 1 0

ISBN 0-07-290500-X

Vice president and editorial director: *Kevin T. Kane*

Publisher: *James M. Smith*

Sponsoring editor: *Kent A. Peterson*

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Compositor: *York Graphic Services, Inc.*

Typeface: *10/12 Times Roman*

Printer: *Von Hoffmann Press, Inc.*

Cover/interior designer: *Jamie O'Neal*

Cover image: *Photo Reseachers, Inc.*

Photo researcher: *Toni Michaels/PhotoFind*

The credits section for this book begins on page 763 and is considered an extension of the copyright page.

## Library of Congress Cataloging-in-Publication Data

Chang, Raymond.

Essential chemistry : a core text for general chemistry / Raymond

Chang. — 2<sup>nd</sup> ed.

p. cm.

Includes index.

ISBN 0-07-290500-X. — ISBN 0-07-117902-X ISE

1. Chemistry. I. Title.

QD33.C434 2000

540—dc21

99-29970

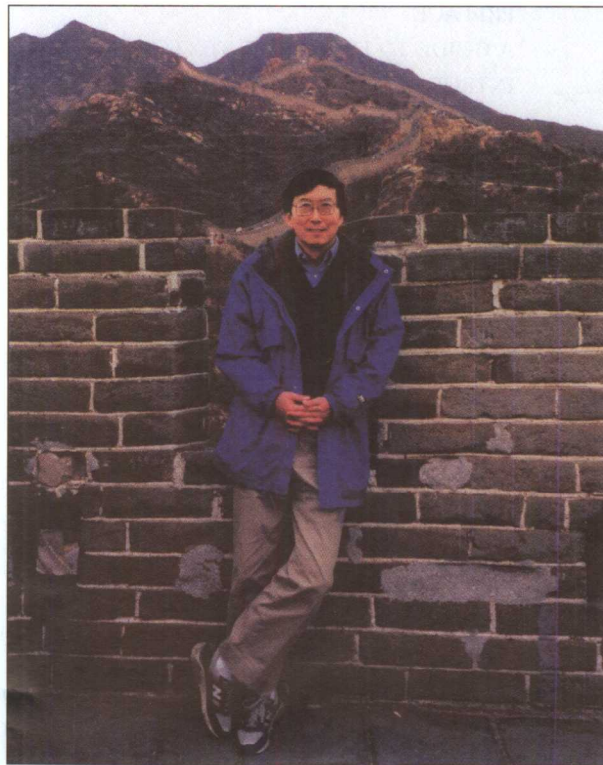
CIP

INTERNATIONAL EDITION ISBN 0-07-117902-X

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## *About the Author*



*At the Great Wall, near Beijing*

Raymond Chang was born in Hong Kong and grew up in Shanghai, China, and Hong Kong. He received his B.Sc. degree in chemistry from London University, England, and his Ph.D. in chemistry from Yale University. After doing postdoctoral research at Washington University and teaching for a year at Hunter College, he joined the chemistry department at Williams College, where he has taught since 1968. Professor Chang has written books on spectroscopy, physical chemistry, and industrial chemistry and has coauthored books on the Chinese language, a novel for juvenile readers, and children's picture books.

For relaxation, Professor Chang maintains a forest garden, plays tennis, and practices the violin.

12/27/03

# Preface

My goal in writing the second edition of this book has been the same as it was for the first edition: to present only the material that is essential for a one-year general chemistry course. I have included all the core topics that are necessary for a solid foundation in general chemistry without sacrificing depth, clarity, or comprehension.

*Essential Chemistry* covers these core topics in the same depth and at the same level as 1200-page texts. Therefore, this book is not a condensed version of a big text. Rather, I have written it so that an instructor can cover 95 percent of the content, instead of the two-thirds or three-quarters that in my experience is typical for the big books. My hope is that this concise-but-thorough approach will appeal to efficiency-minded instructors and will please value-conscious students.

## WHAT'S OUT, WHAT'S IN

Planning for this text involved a certain amount of selectivity. Each time I started a chapter, I asked myself, "What is essential for students to know about this area of chemistry?" and of course, "What is not?" In deciding what to include and what to omit, I relied on my experience as a classroom teacher, on my knowledge of how instructors have used the six editions of my full-length chemistry textbook, and on extensive interaction with fellow chemistry instructors. With this awareness, I chose the following:

### What's Out

- *Discrete chapters on descriptive chemistry.* Most instructors do not find the time to implement an extensive survey of the chemistry of the periodic groups. Therefore, with the exception of Chapter 18, "The Chemistry of Coordination Compounds," there are no chapters focusing on descriptive chemistry. However, descriptive chemistry is integrated throughout the text to show how chemical principles are applied to the real world.

- *Molecular Orbital Theory.* It is my observation that many instructors choose not to include molecular orbital theory in the general chemistry course. For this reason, I have omitted coverage of this topic.

- *Diversions.* Secondary readings and boxed features spotlighting current events or everyday phenomena, common in almost all full-length books, can be interesting and fun to read, but they are often skipped over by instructors and ignored by time-strapped students. So, in the interest of sticking to the essentials, I have for the most part left out tangential readings. However, because I believe that a foothold in the history and application of the science falls under the "essential" category, I open each chapter with a short historical vignette or contemporary story that orients students to the content of the chapter.

### What's In

Scanning the table of contents will verify my previous statement that this text covers all the core topics. Included is a complete chapter introducing organic chemistry (Chapter 13), as well as a chapter (Chapter 22) at the end covering organic polymers.

The organization of this text is fairly conventional and flexible. Chapters 1 to 12 follow a familiar sequence for easy coordination with lab work. Organic chemistry is placed in Chapter 13, allowing the use of organic compounds in examples and problems in subsequent chapters. This chapter can be covered later in the course without a break in continuity. Organic polymers are now covered in the final chapter, for instructors who choose to cover this topic.

As I mentioned earlier, there are no discrete chapters on descriptive chemistry. Instead I have integrated this topic in many parts of the text, especially in Chapters 2, 3, 4, and 8, as well as in many of the worked-out examples and end-of-chapter problems.

Each chapter opens with a short vignette, as I described. By emphasizing chemistry as a human endeavor,

the fruits of which are all around us, these introductions provide a real context for chemistry, and I hope they will stimulate the reader's interest.

## WHAT'S NEW (AND IMPROVED)

The response to this text's first edition leads me to believe that I am on the right track in offering a briefer book that benefits from the heritage of my big book. However, writing a text is an interactive process between author and user, and from this interaction a number of ideas for additions and improvement have arisen, leading to the following **new items for the second edition**:

- *Essential Concepts*. This distinctive rundown of key concepts now begins every chapter. More than just an outline, it is designed to introduce students to what they will need to master and to provide a gauge of their knowledge as they review the content of the chapter.

- *Essential Animations (with icons)*. Included with this edition is a set of top-quality animations that demonstrate the core concepts of general chemistry. Icons in the margins identify correlated animations so that students can readily turn to an animation online to view a concept in motion. Instructors can use the animations as an easy-to-use tool to help students understand the most abstract and important processes in chemistry.

- *Essential Notes*. To help students sharpen crucial problem-solving skills, I have added these new notes in the margins alongside selected worked-out examples. These notes appear at the exact part of the problem to which they apply.

- *Online Learning Center*. This comprehensive, exclusive web site provides a wealth of electronic resources for instructors and students alike. For students, it offers ChemQuest, Visual Chemistry, additional quizzes, and links to chemical databases, listings of professional opportunities, and banks of equations. Instructors will have password-protected access to the answers to ChemQuest and Visual Chemistry, as well as additional quiz questions to assign.

- *End-of-Chapter Problems*. I have added more than 200 new problems to this edition, mostly in the "Additional Problems" section at the end of each chapter. In this edition, I have also included a new category, "Special Problems," which draws on the student's ability to apply comprehensive knowledge of the chapter's content.

- *New Topic Coverage*. Based on comments from users of the book, I have added or expanded on my coverage of selected topics. Specifically, Chapter 11 now includes treatment of the Clausius-Clapeyron equation, and Chapter 14 covers second-order kinetics. Both of these topics were absent from the first edition. New chapter-opening essays have been added to Chapters 13 and 22, and molecular model drawings now accompany worked examples on chemical bonding in Chapter 9.

## THE PROBLEM-SOLVING STRATEGY

To a great extent, a student's understanding of chemistry depends on his or her ability to solve and analyze problems. I have structured this book with the idea of weaving the techniques of problem-solving throughout the content, so that the student is systematically guided and challenged to view chemistry as a series of solvable problems. The strategy employs a number of specific items within the chapters:

- *Examples with Solutions and Practice Exercises*. The text provides 163 example problems with full solutions, showing students how to approach a given type of problem. Their placement demonstrates problem-solving strategies in context. Some examples in this edition also offer "Essential Notes" in the margin, providing helpful pointers or additional information to further assist students. Each worked example is followed by a related practice exercise that lets students try their hand at the problem type just discussed. Students can turn to the end of the chapter to view solutions to these practice problems to complete their introduction to the methodology for solving a given type of problem.

- *End-of-Chapter Problems*. The text provides three types of end-of-chapter problems, which appear in the following order:

1. *Review Questions/Problems*. The questions explore the "why" of chemistry and check students' understanding of the conceptual side of it. Organized by chapter subject headings, review questions are followed by quantitative problems.

2. *Additional Problems*. These exercises further test students with more challenging problems that may involve two or more concepts. They give students experience in identifying concepts and techniques needed to solve real problems. Answers to the even-numbered problems appear at the end of the text.

3. **Special Problems.** These serve as challenges to summarize the chapter's content, testing students' comprehension of multiple concepts and themes.

In summary, I have attempted to provide a clear pathway by which students learn to be problem-solving strategists and in this way become active thinkers about chemistry and physical science in general.

## SUPPLEMENTS

A number of excellent electronic and printed resources are available with this text to aid the instructor in presenting and managing the course and to help the student in exploring and mastering the many facets of general chemistry.

### For the Instructor: Electronic Media

**The Chang Visual Resource Library (VRL) CD-ROM** is an outstanding multimedia product that combines several exceptional resources:

- **Essential Animations.** New with this edition is a set of top-quality animations, available at the Online Learning Center ([www.mhhe.com/essentialchemistry](http://www.mhhe.com/essentialchemistry)), that vividly demonstrate the core concepts and processes of chemistry. Icons correlate these animations to points in the text, and instructors can use them to augment lecture presentations.

- **Text Images.** More than 300 images from the text can be used for standalone classroom presentation or can be included in a PowerPoint presentation.

**Online Learning Center for the Instructor.** Also new with this edition is the Online Learning Center ([www.mhhe.com/essentialchemistry](http://www.mhhe.com/essentialchemistry)), a comprehensive and exclusive web site for both instructors and students. Resources on the site include ChemQuest exercises, Visual Chemistry, additional quizzes, and links to a wealth of data and information sites. For the instructor, the site offers password-protected access to the answers to ChemQuest and Visual Chemistry, as well as additional quiz questions to assign.

### For the Instructor: Print Supplements

**Instructor's Resource Manual with Solutions**, by Vicki Ellis (Gulf Coast Community College) and Raymond Chang, is a complete manual for teaching a general chem-

istry course based on *Essential Chemistry*. This unique guide includes demonstrations that can be done in any classroom or assigned for homework, accompanied by discussion questions and tips to ensure success; information on relevant applications; chapter overviews and outlines; and annotated cross-references to other elements of the text package. In addition, this manual provides complete solutions to all end-of-chapter problems in the text.

**Test Bank**, by Gary Wolf (Spokane Falls Community College), contains more than 2,000 multiple-choice, short-answer, and true-false exam questions. The questions, which are graded in difficulty, are comparable to problems in the text and include multistep problems that require conceptual analysis.

**Computerized Test Bank** contains all the questions in the print test bank and over 200 algorithm-based questions that instructors can edit to create their own test templates. This supplement is available in Windows and Mac formats.

**Overhead Transparencies** are a set of 200 full-color acetates of important illustrations from the text.

### For the Student: *Print and Media Supplements*

- **Problem-Solving Workbook with Solutions**, by Brandon Cruickshank (Northern Arizona University) and Raymond Chang, is a success guide written for use with *Essential Chemistry*. It aims to help students hone their analytical and problem-solving skills by presenting detailed approaches to solving chemical problems. Solutions for all of the text's even-numbered problems are included.

- **Online Learning Center** ([www.mhhe.com/essentialchemistry](http://www.mhhe.com/essentialchemistry)) is a comprehensive, exclusive web site that provides a wealth of electronic resources for instructors and students alike. The site features interactive quizzes for each topic area of the text, which students can use to test themselves. Other offerings on the site include ChemQuest, containing Internet search exercises; Visual Chemistry, with Internet exercises that require students to find and manipulate molecules that are discussed in the text; links to chemical databases; and listings of professional opportunities in chemistry.

## ACKNOWLEDGMENTS

I would like to thank the following individuals, whose reviews and comments were of great help to me in writing and revising *Essential Chemistry*.

### *Reviewers for the Second Edition*

Cathy Cobb, *Augusta State University*  
John Goodman, *Coastal Carolina University*  
Harriet Ades, *University of Kentucky*  
Susan Henderson, *Quinnipiac College*  
Bhairan Joshi, *SUNY Geneseo*  
Nancy Gordon, *University of Southern Maine*  
Lorraine Brewer, *University of Arkansas*  
Mitchel Fedak, *CCAC Boyce Campus*  
David Henderson, *Trinity College*  
Frank Palocsay, *James Madison University*  
Hong Xie, *Florida International University*  
Joe Sprague, *CUNY Cobleskill*  
David Hawkes, *Lambuth University*  
Dahong Lu, *Fitchburg State College*  
John Hartman, *Western Illinois University*  
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Diana Malone, *Clarke College*

Rene Rodriguez, *Idaho State University*  
Patricia Amateis, *Virginia Technical University*  
Dilip Paul, *Pittsburg State University*  
Douglas Cody, *Nassau Community College*

### *Reviewers for the First Edition*

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Wyatt R. Murphy, Jr., *Seton Hall University*  
Paul Poskozim, *Northeastern Illinois University*  
David P. Richardson, *Williams College*  
Chris D. Spindler, *North Harris College*  
James B. Wood, *Palm Beach Community College*

It is also a pleasure to acknowledge the support and assistance given to me by the following people at McGraw-Hill: Jennifer Bensink, Kevin Kane, Craig Marty, Tami Petsche, and James Smith. In particular, I would like to mention Gloria Schiesl for supervising the production, Stuart Paterson for the book design, and Terrence Stanton for coordinating the project. My appreciation goes to Marty Lange, the marketing manager, for his constant support and valuable feedback. Finally, my special thanks go to my editor, Kent Peterson, for his unending enthusiasm, encouragement, and supervision at every stage of the writing of this edition.

—Raymond Chang



# A Guide to Using This Text

*Essential Chemistry* seeks to present the core concepts of general chemistry directly and efficiently, through text and illustrations and with a selective array of features chosen to help the student to focus on the content and to practice problem-solving skills.

This illustrated guide walks you through each feature of the chapter, with an explanation of why it is included and how it can help you use the textbook to learn chemistry fully.

—Raymond Chang

## CHAPTER OPENER

The *Outline* provides a handy rundown of the numbered sections in the chapter and includes subheadings that indicate topics covered in the sections.

The new *Essential Concepts* feature is a succinct listing of the important concepts in the chapter. It can serve as a preview of the material you will be learning and as a review device to gauge your knowledge of the chapter content.

Chapter 3

Stoichiometry

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Average Atomic Mass
- 3.2 Molar Mass of an Element and Avogadro's Number 61
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Writing Chemical Equations • Balancing Chemical Equations
- 3.8 Amounts of Reactants and Products 77
- 3.9 Limiting Reagents and Yields of Reactions 81  
Yields of Reactions


**ESSENTIAL CONCEPTS**

<b>Atomic Mass and Molar Mass</b>	The mass of an atom, which is extremely small, is based on the carbon-12 isotope. An atom of the carbon-12 isotope is assigned a mass of exactly 12 atomic mass units (amu). To work with the more convenient scale of grams, chemists use the molar mass. The molar mass of carbon-12 is exactly 12 g and contains an Avogadro's number ( $6.022 \times 10^{23}$ ) of atoms. The molar masses of other elements are also expressed in grams and contain the same number of atoms. The molar mass of a molecule is the sum of the molar masses of its constituent atoms.	<b>Writing Chemical Equations</b>	An effective way to represent the outcome of a chemical reaction is to write a chemical equation, which uses chemical formulas to describe what happens. A chemical equation must be balanced so that we have the same number and type of atoms and the products, the substances formed at the end of the reaction.
<b>Percent Composition of a Compound</b>	The makeup of a compound is most conveniently expressed in terms of its percent composition, which is the percent by mass of each element the compound contains. A knowledge of its chemical formula allows us to calculate the percent composition. Experimental determination of percent composition and the molar mass of a compound enables us to determine its chemical formula.	<b>Mass Relationships of a Chemical Reaction</b>	A chemical equation allows us to predict the amount of product(s) formed, called the yield, knowing how much reactant(s) was (were) used. This information is of great importance for reactions run on the laboratory or industrial scale. In practice, the actual yield is almost always less than that predicted from the equation because of various complications.

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The chapter-opening *Essays* are written to orient you to the content of the chapter, with a short vignette to demonstrate that chemistry is a human endeavor with a rich history and a connection to all parts of our lives.

**W**hen wood, paper, and wax are burned, they appear to lose mass. The decrease in mass that results from these combustion reactions was once attributed to the release of "phlogiston" into the air. For most of the eighteenth century, scientists accepted the phlogiston theory. Then, in August 1774, the English chemist and clergyman Joseph Priestley isolated oxygen—which he called "dephlogisticated air"—as a product of the decomposition of mercuric oxide,  $\text{HgO}$ . The French chemist Antoine Lavoisier had noticed that nonmetals like phosphorus actually gain mass when they burn in air. He concluded that these nonmetals must combine with something in the air. This substance turned out to be Priestley's dephlogisticated air. Lavoisier named the new element "oxygen" (from the Greek word meaning "to form acid"), because he knew that it is also a constituent of all acids.



Lavoisier igniting a mixture of hydrogen and oxygen gases.

Born in 1743, Lavoisier is generally regarded as the father of modern chemistry. He was noted for his carefully controlled experiments and for the use of quantitative measurements. By carrying out chemical reactions, such as the decomposition of mercuric oxide in a closed container, he showed that the total mass of the products equals the total mass of the reactants. In other words, the quantity of matter is not changed by chemical reactions. This observation is the basis of the law of conservation of mass and the principle underlying stoichiometry.

Lavoisier determined the composition of water by igniting a mixture of hydrogen and oxygen gases with an electric spark. He also served on the commission that established the metric system on which SI is based. Unfortunately, his scientific career was cut short by the French Revolution. A member of the nobility, Lavoisier was also a tax collector. For these "crimes," he was sent to the guillotine in 1794.

10.3 Hybridization of Atomic Orbitals 311

**FIGURE 10.4** Change in potential energy of two H atoms with their distance of separation. At the point of minimum potential energy, the  $H_2$  molecule is in its most stable state and the bond length is 74 pm.

same and does not clearly explain why chemical bonds exist. For example, the Lewis theory describes the single bond between the H atoms in  $H_2$  and that between the F atoms in  $F_2$  in essentially the same way—as the pairing of two electrons. Yet these two molecules have quite different bond energies and bond lengths (436.4 kJ/mol and 74 pm for  $H_2$  and 150.6 kJ/mol and 142 pm for  $F_2$ ). These and many other facts cannot be satisfactorily explained by the Lewis theory. For a more complete explanation of chemical bond formation we must look to quantum mechanics. In fact, the quantum mechanical study of chemical bonding also provides a means for understanding molecular geometry.

In the 1930s *valence bond (VB) theory* was introduced to account for chemical bond formation. VB theory describes covalent bonding as the overlapping of atomic orbitals. This means that the orbitals share a common region in space. Thus the covalent bond in  $H_2$  is formed when the  $1s$  orbitals on the two H atoms overlap (Figure 10.4). The region of overlap is a favorable one for electrons to reside in, for they are simultaneously attracted to the two positively charged nuclei.

Similarly, a stable  $F_2$  molecule forms when the  $2p$  orbitals (containing the unpaired electrons) in the two F atoms overlap to form a covalent bond, and the formation of the  $HF$  molecule can be explained by the overlap of the  $1s$  orbital in H with the  $2p$  orbital in F. Because the orbitals involved are not the same kind in all cases, we can see why the bond energies and bond lengths in  $H_2$ ,  $F_2$ , and  $HF$  might be different.

The concept of atomic orbital overlap can also be applied to polyatomic molecules. However, a satisfactory bonding scheme must account for molecular geometry. We will discuss three examples of VB treatment of bonding in polyatomic molecules.

***sp* Hybridization**

The  $BeCl_2$  (beryllium chloride) molecule is predicted to be linear by VSEPR. The orbital diagram for the valence electrons in Be is

1s	2s	2p
↑↓	↑↓	↑   ↑   ↑

## INTEGRATED MEDIA/ANIMATIONS

New to this edition is *Essential Animations*, a set of top-quality animations that vividly demonstrates the important concepts and processes. An icon in the margin points to material that is captured in an animation.

Animation:  $\alpha$ -particle scattering

## ANIMATION TITLES:

- $\alpha$ -particle scattering
- Limiting reagent
- The hydration process
- Gas laws
- Emission spectra
- Atomic and ionic radius
- Hybridization
- Packing spheres
- Equilibrium vapor pressure
- Le Chatelier's principle
- Acid ionizations
- Buffer solutions
- Galvanic cells
- Activation energy
- Orientation of collision
- Radioactive decay

## THE PROBLEM-SOLVING APPROACH

The text is carefully designed to help you develop the skills to solve the many types of problems you will encounter in chemistry. The features shown here will help you apply an effective strategy for solving problems.

*Worked-Out Examples* appear throughout the text to demonstrate problem-solving methods for new material and concepts. Answers are thoroughly explained, and each example is followed by a sample problem for the student to solve. You can compare your work with solutions that appear at the end of the chapter.

*Essential Notes* accompany many of the Examples and provide helpful tips for working through problems.

14.1 The Rate of a Reaction 431

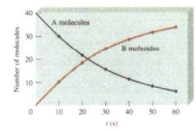


FIGURE 14.2 The rate of reaction  $A \rightarrow B$  is represented as the decrease of A molecules with time and as the increase of B molecules with time.

Two moles of A disappear for each mole of B that forms—that is, the rate of disappearance of A is twice as fast as the rate of appearance of B. We write the rate as either

$$\text{rate} = -\frac{1}{2} \frac{\Delta[A]}{\Delta t} \quad \text{or} \quad \text{rate} = \frac{\Delta[B]}{\Delta t}$$

For the reaction

$$aA + bB \rightarrow cC + dD$$

the rate is given by

$$\text{rate} = -\frac{1}{a} \frac{\Delta[A]}{\Delta t} = -\frac{1}{b} \frac{\Delta[B]}{\Delta t} = \frac{1}{c} \frac{\Delta[C]}{\Delta t} = \frac{1}{d} \frac{\Delta[D]}{\Delta t}$$

**EXAMPLE 14.1**  
**Writing Rate Expressions**  
 Write the rate expressions for the following reactions in terms of the disappearance of the reactants and the appearance of the products:  
 (a)  $\text{I}^-(\text{aq}) + \text{OCl}^-(\text{aq}) \rightarrow \text{Cl}^-(\text{aq}) + \text{OI}^-(\text{aq})$   
 (b)  $4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$

**Answer:** (a) Because each of the stoichiometric coefficients equals 1,

$$\text{rate} = -\frac{\Delta[\text{I}^-]}{\Delta t} = -\frac{\Delta[\text{OCl}^-]}{\Delta t} = \frac{\Delta[\text{Cl}^-]}{\Delta t} = \frac{\Delta[\text{OI}^-]}{\Delta t}$$

(b) In this reaction

$$\text{rate} = -\frac{1}{4} \frac{\Delta[\text{NH}_3]}{\Delta t} = -\frac{1}{5} \frac{\Delta[\text{O}_2]}{\Delta t} = \frac{1}{4} \frac{\Delta[\text{NO}]}{\Delta t} = \frac{1}{6} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t}$$

**PRACTICE EXERCISE**  
 Write the rate expression for the following reaction:  
 $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$

**ESSENTIAL NOTES**  
 What are the units for the rate of a reaction?

## REVIEW AND REINFORCEMENT

Chapters conclude with a *Summary* that restates the main concepts of the chapter.

Following the summary is a list of *Key Words* that includes the important terms discussed in the chapter. These terms are page referenced.

Key Words 323

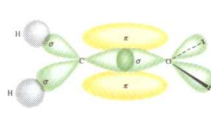


FIGURE 10.18 Bonding in the formaldehyde molecule. A sigma bond is formed by the overlap of the  $sp^2$  hybrid orbital of carbon and the  $sp^2$  hybrid orbital of oxygen; a pi bond is formed by the overlap of the  $2p_z$  orbitals of the carbon and oxygen atoms. The two lone pairs on oxygen are placed in the other two  $sp^2$  orbitals of oxygen.

**Summary**

The VSEPR model for predicting molecular geometry is based on the assumption that valence-shell electron pairs repel one another and tend to stay as far apart as possible. According to the VSEPR model, molecular geometry can be predicted from the number of bonding electron pairs and lone pairs. Lone pairs repel other pairs more strongly than bonding pairs do and thus distort bond angles from those of the ideal geometry.

The dipole moment is a measure of the charge separation in molecules containing atoms of different electronegativities. The dipole moment of a molecule is the resultant of whatever bond moments are present in a molecule. Information about molecular geometry can be obtained from dipole moment measurements.

In valence bond theory, hybridized atomic orbitals are formed by the combination and rearrangement of orbitals of the same atom. The hybridized orbitals are all of equal energy and electron density, and the number of hybridized orbitals is equal to the number of pure atomic orbitals that combine. Valence-shell expansion can be explained by assuming hybridization of  $s$ ,  $p$ , and  $d$  orbitals.

In  $sp$  hybridization, the two hybrid orbitals lie in a straight line; in  $sp^2$  hybridization, the three hybrid orbitals are directed toward the corners of a triangle; in  $sp^3$  hybridization, the four hybrid orbitals are directed toward the corners of a tetrahedron; in  $sp^3d$  hybridization, the five hybrid orbitals are directed toward the corners of a trigonal bipyramid; in  $sp^3d^2$  hybridization, the six hybrid orbitals are directed toward the corners of an octahedron.

In an  $sp^2$ -hybridized atom (for example, carbon), the one unhybridized  $p$  orbital can form a pi bond with another  $p$  orbital. A carbon-carbon double bond consists of a sigma bond and a pi bond. In an  $sp$ -hybridized carbon atom, the two unhybridized  $p$  orbitals can form two pi bonds with two  $p$  orbitals on another atom (or atoms). A carbon-carbon triple bond consists of one sigma bond and two pi bonds.

**Key Words**

Dipole moment ( $\mu$ ), 308	Pi bond ( $\pi$ bond), 320	Valence-shell electron-pair repulsion (VSEPR) model, 298
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## Questions and Problems

## SIMPLE GEOMETRIC SHAPES

## Review Questions

- 10.1 What is molecular geometry? Why is the study of molecular geometry important?
- 10.2 Sketch the shape of a linear triatomic molecule, a trigonal planar molecule containing four atoms, a tetrahedral molecule, a trigonal bipyramidal molecule, and an octahedral molecule. Give the bond angles in each case.
- 10.3 How many atoms are directly bonded to the central atom in a tetrahedral molecule, a trigonal bipyramidal molecule, and an octahedral molecule?

## VSEPR

## Review Questions

- 10.4 Discuss the basic features of the VSEPR model. Explain why the repulsion decreases in the following order: lone pair–lone pair > lone pair–bonding pair > bonding pair–bonding pair.
- 10.5 In the trigonal bipyramidal arrangement, why does a lone pair occupy an equatorial position rather than an axial position?
- 10.6 Another possible geometry for  $\text{CH}_4$  is square planar, with the four H atoms at the corners of a square and the C atom at the center of the square. Sketch this geometry and compare its stability with that of a tetrahedral  $\text{CH}_4$ .

## Problems

- 10.7 Predict the geometries of the following species using the VSEPR method: (a)  $\text{PCl}_3$ , (b)  $\text{CHCl}_3$ , (c)  $\text{SiH}_4$ , (d)  $\text{TeCl}_4$ .
- 10.8 What are the geometries of the following species? (a)  $\text{AlCl}_3$ , (b)  $\text{ZnCl}_2$ , (c)  $\text{ZnCl}_2^{2-}$ .
- 10.9 Predict the geometry of the following molecules using the VSEPR method: (a)  $\text{HgH}_2$ , (b)  $\text{N}_2\text{O}$  (arrangement of atoms is NNO), (c)  $\text{SCN}^-$  (arrangement of atoms is SCN).
- 10.10 What are the geometries of the following ions? (a)  $\text{NH}_2^-$ , (b)  $\text{NH}_2^+$ , (c)  $\text{CO}_3^{2-}$ , (d)  $\text{ICl}_2^-$ , (e)  $\text{ICl}_4^-$ , (f)  $\text{AH}_2^+$ , (g)  $\text{SnCl}_2$ , (h)  $\text{H}_3\text{O}^+$ , (i)  $\text{BeF}_2^{2-}$ .
- 10.11 Describe the geometry around each of the three central atoms in the  $\text{CH}_3\text{COOH}$  molecule.

- 10.12 Which of the following species are tetrahedral:  $\text{SiCl}_4$ ,  $\text{SeF}_6$ ,  $\text{XeF}_4$ ,  $\text{Cl}_4$ ,  $\text{COCl}_2$ ?

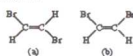
## DIPOLE MOMENTS AND MOLECULAR GEOMETRY

## Review Questions

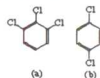
- 10.13 Define dipole moment. What are the units and symbol for dipole moment?
- 10.14 What is the relationship between the dipole moment and bond moment? How is it possible for a molecule to have bond moments and yet be nonpolar?
- 10.15 Explain why an atom cannot have a permanent dipole moment.
- 10.16 The bonds in beryllium hydride ( $\text{BeH}_2$ ) molecules are polar, yet the dipole moment of the molecule is zero. Explain.

## Problems

- 10.17 Arrange the following molecules in order of increasing dipole moment:  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{S}$ ,  $\text{H}_2\text{Te}$ ,  $\text{H}_2\text{Se}$ . (See Table 10.3.)
- 10.18 The dipole moments of the hydrogen halides decrease from HF to HI (see Table 10.3). Explain this trend.
- 10.19 List the following molecules in order of increasing dipole moment:  $\text{H}_2\text{O}$ ,  $\text{CB}_4$ ,  $\text{H}_2\text{S}$ ,  $\text{HF}$ ,  $\text{NH}_3$ ,  $\text{CO}_2$ .
- 10.20 Does the molecule  $\text{OCS}$  have a higher or lower dipole moment than  $\text{CS}_2$ ?
- 10.21 Which of the following molecules has a higher dipole moment?



- 10.22 Arrange the following compounds in order of increasing dipole moment:



## END-OF-CHAPTER-PROBLEMS

The problems section at the end of the chapter provides a complete opportunity to practice your skills.

Grouped by chapter section, two types of problems are offered:

*Review Questions* test your knowledge of factual and conceptual content.

*Problems* pose quantitative situations to be solved. Solutions to even-numbered problems appear at the end of the book.

either side, carbon and oxygen, have substantial positive electron affinities.

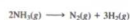
- 8.100 Little is known of the chemistry of astatine, the last member of Group 7A. Describe the physical characteristics that you would expect this halogen to have. Predict the products of the reaction between sodium astatide (NaAt) and sulfuric acid. (Hint: Sulfuric acid is an oxidizing agent.)
- 8.101 As discussed in the chapter, the atomic mass of argon is greater than that of potassium. This observation created a problem in the early development of the periodic table because it meant that argon should be placed after potassium. (a) How was this difficulty resolved? (b) From the following data, calculate the average atomic masses of argon and potassium: Ar-36 (35.9675 amu; 0.337 percent), Ar-38 (37.9627 amu; 0.063 percent), Ar-40 (39.9624 amu; 99.600 percent); K-39 (38.9637 amu; 93.258 percent), K-40 (39.9640 amu; 0.0117 percent), K-41 (40.9618 amu; 6.730 percent).

percent).

- 8.102 Calculate the maximum wavelength of light (in nanometers) required to ionize a single sodium atom.
- 8.103 The first four ionization energies of an element are approximately 738 kJ/mol, 1450 kJ/mol,  $7.7 \times 10^3$  kJ/mol, and  $1.1 \times 10^4$  kJ/mol. To which periodic group does this element belong? Why?
- 8.104 Match each of the elements on the right with its description on the left:
- |   |                           |
|---|---------------------------|
| (a) A greenish-yellow gas that reacts with water            | Nitrogen ( $\text{N}_2$ ) |
| (b) A soft metal that reacts with water to produce hydrogen | Boron (B)                 |
| (c) A metalloid that is hard and has a high melting point   | Aluminum (Al)             |
| (d) A colorless, odorless gas                               | Fluorine ( $\text{F}_2$ ) |
| (e) A more reactive metal than iron, which does not corrode | Sodium (Na)               |

## SPECIAL PROBLEM

8.105 In the late 1800s the British physicist Lord Rayleigh accurately determined the atomic masses of a number of elements, but he obtained a puzzling result with nitrogen. One of his methods of preparing nitrogen was by the thermal decomposition of ammonia:



Another method was to start with air and remove oxygen, carbon dioxide, and water vapor from it. Invariably, the nitrogen from air was a little denser (by about 0.5 percent) than the nitrogen from ammonia.

Later the English chemist Sir William Ramsay carried out an experiment in which he passed nitrogen, which he had obtained from air by Rayleigh's procedure, over red-hot magnesium to convert it to magnesium nitride:



in air

## Answers to Practice Exercises

- 8.1 (a)  $[\text{Ar}]4s^2$ ; (b) representative element; (c) diamagnetic. 8.2  $\text{Li} > \text{Be} > \text{C}$ . 8.3  $\text{Li}^+$ , (b)  $\text{Au}^{3+}$ , (c)  $\text{N}^{3-}$ . 8.4 (a) N, (b) Mg, 8.5 No.

*Additional Problems*, which follow the section-grouped set, further test you with more challenging problems that may involve two or more concepts.

The chapters conclude with one or two *Special Problems*, which call on students to demonstrate their comprehension of multiple concepts and themes.

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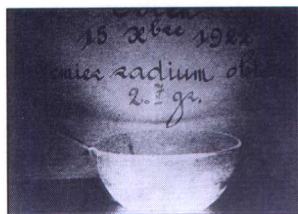


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