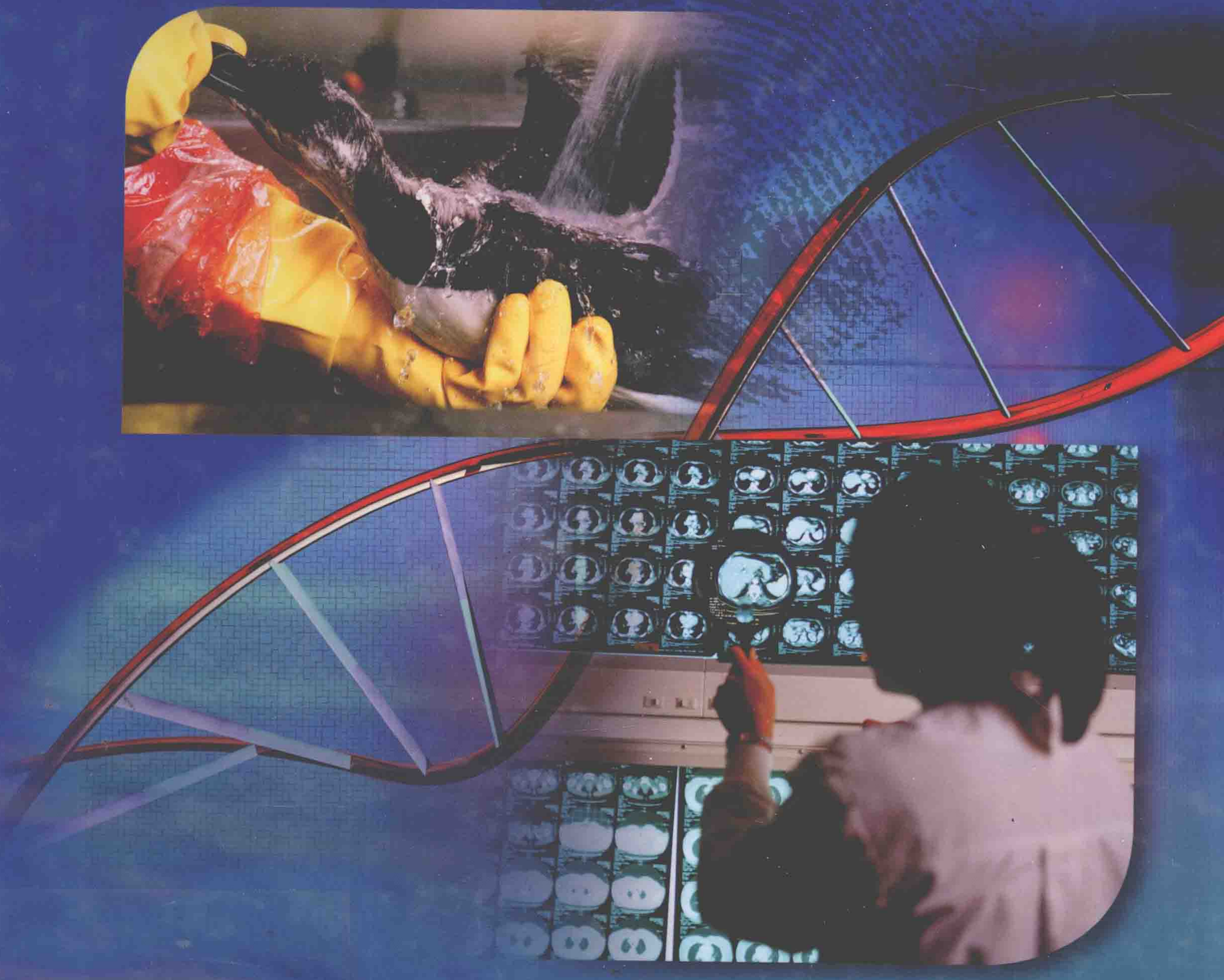
Foundations of

General, Organic, and Biochemistry



Katherine J. Denniston   Joseph J. Topping

Foundations *of* General, Organic, 原版 *and* Biochemistry

Katherine J. Denniston
Towson University

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We are thankful to our families, whose patience and support made it possible for us to embark on this new adventure.

—Katherine J. Denniston

—Joseph J. Topping

About the Authors

Katherine J. Denniston is the Associate Dean of the Jess and Mildred Fisher College of Science and Mathematics, Director of Premedical and Predental Programs, and Professor in the Department of Biological Sciences.

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From 2002–2004, Dr. Denniston served as a Program Officer in the Division of Undergraduate Education at the National Science Foundation, working with a number of programs, including the Course, Curriculum, and Laboratory Improvement; Science, Technology, Engineering, and Mathematics Talent Expansion; Advanced Technological Education Teacher Preparation; and the Robert Noyce Scholarship Programs.

Before coming to Towson University in 1985, Denniston earned her Ph.D. in Microbiology from the Pennsylvania State University. She was a post-doctoral fellow in the Department of Genetics at the University of Wisconsin, Madison, a Senior Staff Fellow at the National Cancer Institute, and a Research Assistant Professor at the Division of Molecular Virology and Immunology, Georgetown University. At Towson, Dr. Denniston has taught a wide variety of courses from the introductory to the graduate level.

Dr. Denniston has published extensively on various aspects of molecular biology and virology. She has also published articles and presented workshops on science education and was co-editor of *Recombinant DNA*, published by Dowden, Hutchinson, and Ross, Inc.

Joseph Topping was born in Amsterdam, New York. He received his B.S. degree in chemistry from Le Moyne College in Syracuse, and his M.S. and Ph.D. from the University of New Hampshire. After doing postdoctoral research at the Ames Laboratory of Iowa State University, he joined the chemistry department at Towson University, where he has taught since 1970.

Professor Topping has been involved with a number of initiatives designed to improve the quality of middle and secondary school instruction, most notably the NSF-sponsored Maryland Collaborative for Teacher Preparation. He has a number of papers and presentations in the literature, including baseline studies of contamination of the Chesapeake Bay and its tributaries. He is actively involved with the Maryland Section of the American Chemical Society and is a member of the Board of Governors of the Eastern Analytical Symposium.

Professor Topping's hobbies include golf, fly fishing, softball, and collecting vintage baseball cards. He is an avid reader of history, particularly, the history of baseball.

Preface

This first edition of *Foundations of General, Organic, and Biochemistry* is the answer to a long-standing dream of ours to write a text that would condense the critical topics of chemistry into a book that could serve a one-semester, as well as a two-semester, chemistry course. The key to doing this well is to put the "general" back into general chemistry, providing students with a view of chemistry as an integrated discipline. Our strategy to accomplish this goal has been to tighten the inorganic chapters to emphasize those topics essential to understanding basic concepts in organic chemistry and biochemistry, as well as to highlight critical applications in related careers. This approach allows us to provide sufficient opportunity for students to develop an understanding of organic and biochemistry, areas often neglected for lack of time.

Reaching the Student Audience

Like two-semester books, this text is designed for majors in health-related fields. However, our target audience for this book is somewhat broader. We recognize the increased need for two-year programs to teach biotechnologists, medical technicians, forensic technologists, and agriculture and environmental managers, in addition to the nursing programs that are the typical target audience for such texts. Our response to this expanded set of needs has been to write a book fostering student understanding of key concepts in chemistry that are needed to successfully pursue these varied career paths.

With this target audience in mind, we have used a writing style and level intended to stimulate student interest and maintain that interest throughout the course. We have also integrated concepts and applications to produce scientifically literate students—those who are able to recognize the connections between the chemistry they are studying and the world in which they live. Such students are better able to make well-informed decisions on the scientific and technological issues facing the world today. Both practical understanding and scientific literacy are promoted through inclusion of special boxed topics connecting chemistry to medical, environmental, and forensic applications, and the often open-ended "For Further Understanding" questions that follow, which require students to think "beyond the box."

Key Features of *Foundations of General, Organic, and Biochemistry*

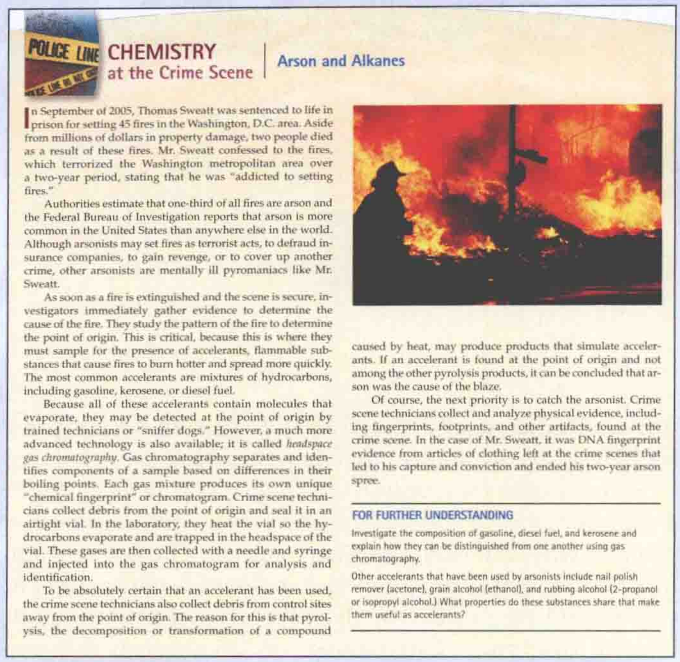
Throughout the project, we have been true to one goal: to write a book that is student-oriented and readable. The ultimate goal is to promote student learning and to facilitate teaching. We want to engage students, appeal to visual learners, and provide a variety of pedagogical tools to support the needs of different types of learners. We have utilized a variety of strategies to accomplish these goals.

Engaging Students

Students learn better when they can see a clear relationship between the subject material they are studying and real life. We have written the text to help students make connections between the principles of chemistry and their life experiences, as well as their future professional experiences. This is accomplished through the inclusion of numerous boxed topics called *Connections*. These short stories present real-world situations involving one or more topics that students will encounter in the chapter.

- *Medical Connections* relate chemistry to a health concern or a diagnostic application.
- *Environmental Perspectives* deal with issues, including the impact of chemistry on the ecosystem and the way in which these environmental changes affect human health.
- *Lifestyle Connections* delve into chemistry and society, and include such topics as gender issues in science and historical viewpoints.

- *Chemistry at the Crime Scene* essays explore the chemistry behind the emergent field of forensic science.



CHEMISTRY at the Crime Scene | **Arson and Alkanes**

In September of 2005, Thomas Sweatt was sentenced to life in prison for setting 45 fires in the Washington, D.C. area. Aside from millions of dollars in property damage, two people died as a result of these fires. Mr. Sweatt confessed to the fires, which terrorized the Washington metropolitan area over a two-year period, stating that he was "addicted to setting fires."

Authorities estimate that one-third of all fires are arson and the Federal Bureau of Investigation reports that arson is more common in the United States than anywhere else in the world. Although arsonists may set fires as terrorist acts, to defraud insurance companies, to gain revenge, or to cover up another crime, other arsonists are mentally ill pyromaniacs like Mr. Sweatt.

As soon as a fire is extinguished and the scene is secure, investigators immediately gather evidence to determine the cause of the fire. They study the pattern of the fire to determine the point of origin. This is critical, because this is where they must sample for the presence of accelerants, flammable substances that cause fires to burn hotter and spread more quickly. The most common accelerants are mixtures of hydrocarbons, including gasoline, kerosene, or diesel fuel.

Because all of these accelerants contain molecules that evaporate, they may be detected at the point of origin by trained technicians or "sniffer dogs." However, a much more advanced technology is also available; it is called *headspace gas chromatography*. Gas chromatography separates and identifies components of a sample based on differences in their boiling points. Each gas mixture produces its own unique "chemical fingerprint" or chromatogram. Crime scene technicians collect debris from the point of origin and seal it in an airtight vial. In the laboratory, they heat the vial so the hydrocarbons evaporate and are trapped in the headspace of the vial. These gases are then collected with a needle and syringe and injected into the gas chromatogram for analysis and identification.

To be absolutely certain that an accelerant has been used, the crime scene technicians also collect debris from control sites away from the point of origin. The reason for this is that pyrolysis, the decomposition or transformation of a compound caused by heat, may produce products that simulate accelerants. If an accelerant is found at the point of origin and not among the other pyrolysis products, it can be concluded that arson was the cause of the blaze.

Of course, the next priority is to catch the arsonist. Crime scene technicians collect and analyze physical evidence, including fingerprints, footprints, and other artifacts, found at the crime scene. In the case of Mr. Sweatt, it was DNA fingerprint evidence from articles of clothing left at the crime scenes that led to his capture and conviction and ended his two-year arson spree.

FOR FURTHER UNDERSTANDING

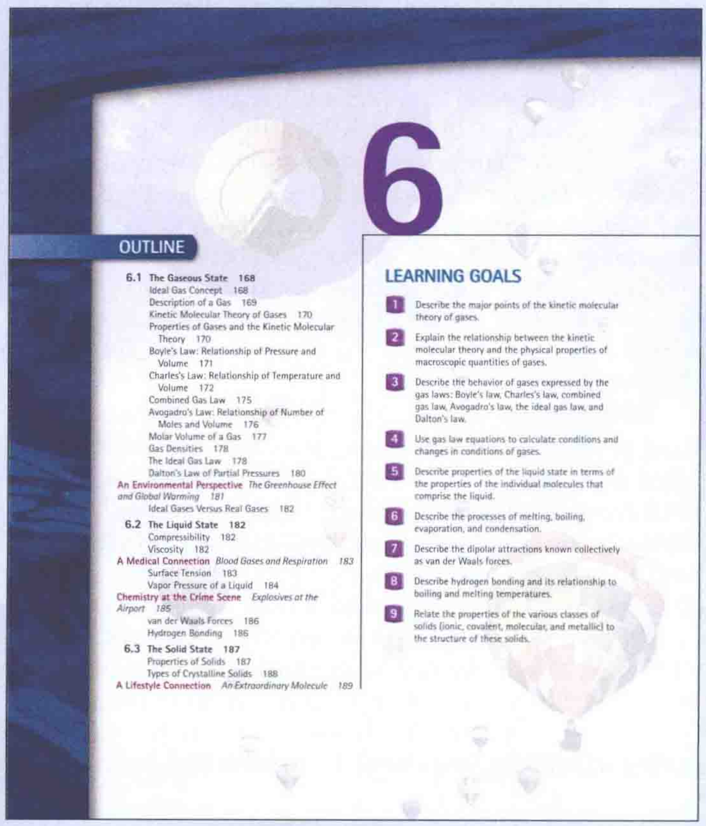
Investigate the composition of gasoline, diesel fuel, and kerosene and explain how they can be distinguished from one another using gas chromatography.

Other accelerants that have been used by arsonists include nail polish remover (acetone), grain alcohol (ethanol), and rubbing alcohol (2-propanol or isopropyl alcohol.) What properties do these substances share that make them useful as accelerants?

Learning Tools

In designing the original learning system, we asked ourselves the question: "If we were students, what would help us organize and understand the material covered in this chapter?" With valuable suggestions from reviewers, we have established a set of pedagogical tools to support student learning:

- **Learning Goals:** A set of objectives at the beginning of each chapter previews concepts that will be covered in the chapter. Icons within the margin locate text material that supports the learning goals.
- **Detailed Chapter Outline:** A listing of topic headings is provided for each chapter. Topics are arranged in outline form to help students organize the material in their own minds.
- **Chapter Cross-References:** To help students locate the pertinent background material, references to previous chapters, sections, and perspectives are noted in the margins of the text. These marginal cross references also alert students to upcoming topics related to the information currently being studied.



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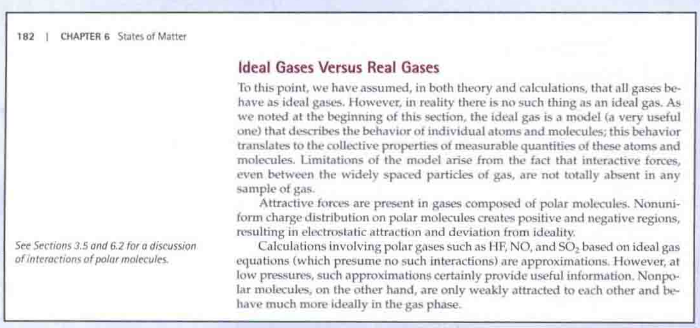
LEARNING GOALS

1. Describe the major points of the kinetic molecular theory of gases.
2. Explain the relationship between the kinetic molecular theory and the physical properties of macroscopic quantities of gases.
3. Describe the behavior of gases expressed by the gas laws: Boyle's law, Charles's law, combined gas law, Avogadro's law, the ideal gas law, and Dalton's law.
4. Use gas law equations to calculate conditions and changes in conditions of gases.
5. Describe properties of the liquid state in terms of the properties of the individual molecules that comprise the liquid.
6. Describe the processes of melting, boiling, evaporation, and condensation.
7. Describe the dipolar attractions known collectively as van der Waals forces.
8. Describe hydrogen bonding and its relationship to boiling and melting temperatures.
9. Relate the properties of the various classes of solids (ionic, covalent, molecular, and metallic) to the structure of these solids.



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Ideal Gases Versus Real Gases

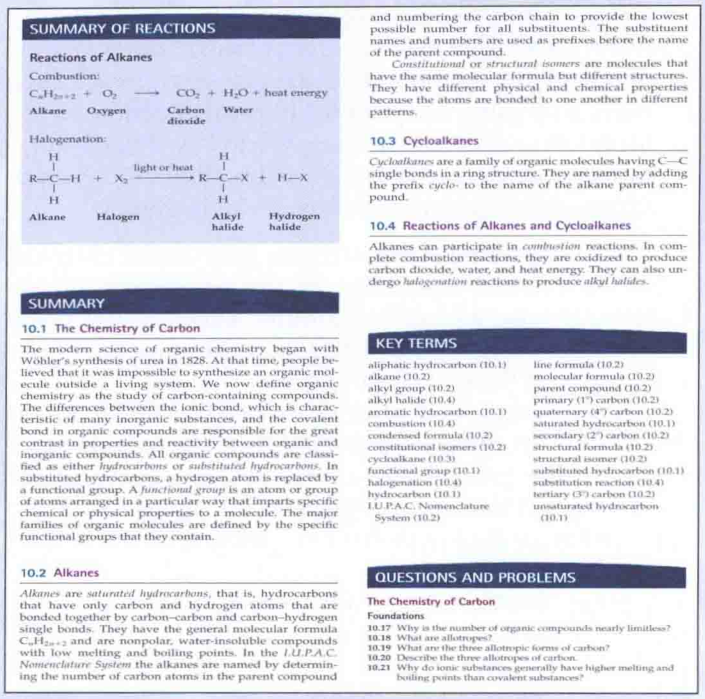
To this point, we have assumed, in both theory and calculations, that all gases behave as ideal gases. However, in reality there is no such thing as an ideal gas. As we noted at the beginning of this section, the ideal gas is a model (a very useful one) that describes the behavior of individual atoms and molecules; this behavior translates to the collective properties of measurable quantities of these atoms and molecules. Limitations of the model arise from the fact that interactive forces, even between the widely spaced particles of gas, are not totally absent in any sample of gas.

Attractive forces are present in gases composed of polar molecules. Nonuniform charge distribution on polar molecules creates positive and negative regions, resulting in electrostatic attraction and deviation from ideality.

See Sections 3.5 and 6.2 for a discussion of interactions of polar molecules.

Calculations involving polar gases such as HF, NO, and SO_2 based on ideal gas equations (which presume no such interactions) are approximations. However, at low pressures, such approximations certainly provide useful information. Nonpolar molecules, on the other hand, are only weakly attracted to each other and behave much more ideally in the gas phase.

- **Summary of Key Reactions:** In the organic chemistry chapters, each major reaction type is highlighted on a blue background. Major equations are summarized at the end of the chapter, facilitating review.
- **Chapter Summary:** Each major topic of the chapter is briefly reviewed in paragraph form in the end-of-chapter summary. These summaries serve as a mini-study guide, covering the major concepts in the chapter.
- **Key Terms:** Key terms are printed in boldface in the text and defined immediately. Each key term is also listed at the end of the chapter and is accompanied by a section number for easy reference.
- **Glossary of Key Terms:** In addition to being listed at the end of the chapter, each key term from the text is defined in the alphabetical glossary at the end of the book.
- **Further Information Online:** The ARIS website for this textbook provides important readings, equations, and tables of formula weights, mathematics reviews, among numerous other topics, and can be accessed at www.mhhe.com/denniston.
- **Online Animations:** An animation icon alerts the reader to animations that are available online to help bring chemistry to life.



SUMMARY OF REACTIONS

Reactions of Alkanes

Combustion:

$C_nH_{2n+2} + O_2 \longrightarrow CO_2 + H_2O$ + heat energy

Alkane Oxygen Carbon dioxide Water

Halogenation:

R—CH₃-type: $R{-}CH_2{-}H + X_2 \xrightarrow{\text{light or heat}} R{-}CH_2{-}X + H{-}X$

Alkane Halogen Alkyl halide Hydrogen halide

SUMMARY

10.1 The Chemistry of Carbon

The modern science of organic chemistry began with Wöhler's synthesis of urea in 1828. At that time, people believed that it was impossible to synthesize an organic molecule outside a living system. We now define organic chemistry as the study of carbon-containing compounds. The differences between the ionic bond, which is characteristic of many inorganic substances, and the covalent bond in organic compounds are responsible for the great contrast in properties and reactivity between organic and inorganic compounds. All organic compounds are classified as either *hydrocarbons* or *substituted hydrocarbons*. In substituted hydrocarbons, a hydrogen atom is replaced by a functional group. A *functional group* is an atom or group of atoms arranged in a particular way that imparts specific chemical or physical properties to a molecule. The major families of organic molecules are defined by the specific functional groups that they contain.

10.2 Alkanes

Alkanes are *saturated hydrocarbons*, that is, hydrocarbons that have only carbon and hydrogen atoms that are bonded together by carbon–carbon and carbon–hydrogen single bonds. They have the general molecular formula C_nH_{2n+2} and are nonpolar, water-insoluble compounds with low melting and boiling points. In the *I.U.P.A.C. Nomenclature System* the alkanes are named by determining the number of carbon atoms in the parent compound and numbering the carbon chain to provide the lowest possible number for all substituents. The substituent names and numbers are used as prefixes before the name of the parent compound.

Constitutional or *structural isomers* are molecules that have the same molecular formula but different structures. They have different physical and chemical properties because the atoms are bonded to one another in different patterns.

10.3 Cycloalkanes

Cycloalkanes are a family of organic molecules having C—C single bonds in a ring structure. They are named by adding the prefix *cyclo-* to the name of the alkane parent compound.

10.4 Reactions of Alkanes and Cycloalkanes

Alkanes can participate in *combustion* reactions. In complete combustion reactions, they are oxidized to produce carbon dioxide, water, and heat energy. They can also undergo *halogenation* reactions to produce *alkyl halides*.

KEY TERMS

aliphatic hydrocarbon (10.1)	line formula (10.2)
alkane (10.2)	molecular formula (10.2)
alkyl group (10.2)	parent compound (10.2)
alkyl halide (10.4)	primary (1°) carbon (10.2)
aromatic hydrocarbon (10.1)	quaternary (4°) carbon (10.2)
combustion (10.4)	saturated hydrocarbon (10.1)
condensed formula (10.2)	secondary (2°) carbon (10.2)
constitutional isomers (10.2)	structural formula (10.2)
cycloalkane (10.3)	structural isomer (10.2)
functional group (10.1)	substituted hydrocarbon (10.1)
halogenation (10.4)	substitution reaction (10.4)
hydrocarbon (10.1)	tertiary (3°) carbon (10.2)
I.U.P.A.C. Nomenclature System (10.2)	unsaturated hydrocarbon (10.1)

QUESTIONS AND PROBLEMS

The Chemistry of Carbon

Foundations

10.17 Why is the number of organic compounds nearly limitless?
10.18 What are allotropes?
10.19 What are the three allotropic forms of carbon?
10.20 Describe the three allotropes of carbon.
10.21 Why do ionic substances generally have higher melting and boiling points than covalent substances?

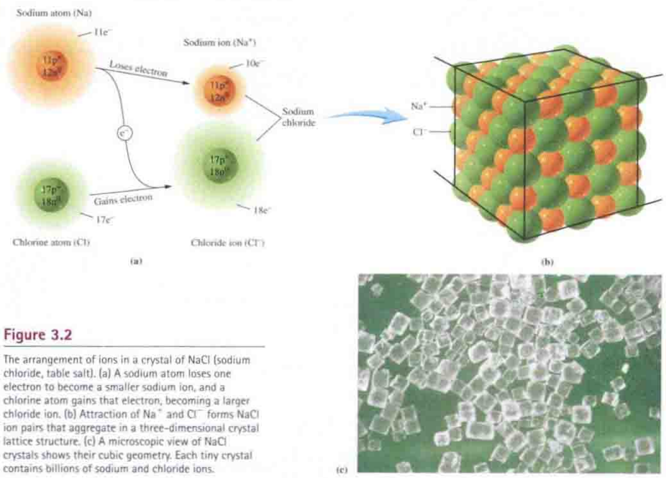


Figure 3.2

The arrangement of ions in a crystal of NaCl (sodium chloride, table salt). (a) A sodium atom loses one electron to become a smaller sodium ion, and a chlorine atom gains that electron, becoming a larger chloride ion. (b) Attraction of Na^+ and Cl^- forms NaCl ion pairs that aggregate in a three-dimensional crystal lattice structure. (c) A microscopic view of NaCl crystals shows their cubic geometry. Each tiny crystal contains billions of sodium and chloride ions.

The Art Program

Today's students are much more visually oriented than students of any previous generation. Television and the computer represent alternate modes of learning. We have built upon this observation through use of color, figures, and three-dimensional computer-generated models. This art program enhances the readability of the text and provides alternative pathways to learning.

- **Dynamic Illustrations:** Each chapter is amply illustrated using figures, tables, and chemical formulas. All of these illustrations are carefully annotated for clarity.

124 | CHAPTER 4 Calculations and the Chemical Equation

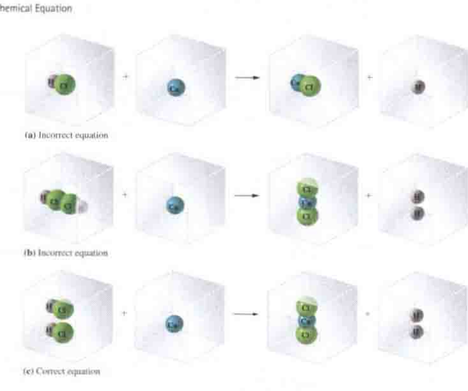


Figure 4.6

Balancing the equation HCl + Ca → $CaCl_2 + H_2$. (a) Neither product is the correct chemical species. (b) The reactant, HCl, is incorrectly represented as H_2Cl_2. (c) This equation is correct; all species are correct, and the law of conservation of mass is obeyed.

- **Color-Coding Scheme:** We have color-coded the reactions so that chemical groups being added or removed in a reaction can be quickly recognized. This is done by using red print in chemical equations or formulas to draw the reader's eye to key elements or properties in a reaction or structure. Blue print is used when additional features must be highlighted.

Blue background screens denote generalized chemical and mathematical equations. In the organic chemistry chapters, we use a blue background screen to designate key reactions within the text and in the Summary of Reactions section at the end of the chapter.

Yellow background screens are used to illustrate energy—either as energy stored in electrons or groups of atoms—in the general and biochemistry sections of the text. In the organic chemistry section of the text, we use yellow background screens to show the parent chain of organic compounds.

Certain situations make it necessary to adopt a unique color convention tailored to the material in a particular chapter. For example, in Chapter 16, the structures of amino acids require three colors to draw students' attention to key features of these molecules. For consistency, red is used to denote the acid portion of an amino acid, and blue is used to denote the basic portion of an amino acid. Green print is used to denote the R groups, and a yellow background screen directs the eye to the α-carbon.

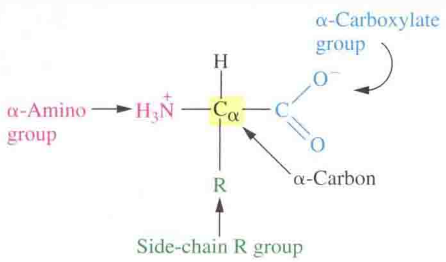


Figure 16.1

General structure of an α-amino acid. All amino acids isolated from proteins, with the exception of proline, have this general structure.

- **Computer-Generated Models:** The students' ability to understand the geometry and three-dimensional structure of molecules is essential to the understanding of organic and biochemical reactions. Computer generated models are used throughout the text because they are both accurate and easily visualized.

Problem Solving and Critical Thinking

The best way to learn chemistry and apply it to practical situations is to develop problem-solving and critical thinking skills. To help students accomplish this, we have created a variety of problems that require recall, fundamental calculations, and complex reasoning.

- **In-Chapter Examples, Solutions, and Problems:** Each chapter includes a number of examples that show the student, step-by-step, how to properly reach the correct solution to model problems. Whenever possible, they are followed by in-text problems that allow the students to test their mastery of information and to build self-confidence.

EXAMPLE 5.2 Calculating Energy Involved in Calorimeter Reactions

3 Learning Goal
Describe experiments that yield thermochemical information and calculate fuel values based on experimental data.

If 0.050 mol of hydrochloric acid (HCl) is mixed with 0.050 mol of sodium hydroxide (NaOH) in a "coffee cup" calorimeter, the temperature of 1.00×10^2 g of the resulting solution increases from 25.0°C to 31.5°C. If the specific heat of the solution is 1.00 cal/g solution °C, calculate the quantity of energy involved in the reaction. Also, is the reaction endothermic or exothermic?

SOLUTION

The change in temperature is

$$\Delta T_s = T_{s\,\text{final}} - T_{s\,\text{initial}}$$
$$= 31.5°\text{C} - 25.0°\text{C} = 6.5°\text{C}$$
$$Q = m_s \times \Delta T_s \times SH_s$$
$$Q = 1.00 \times 10^2 \cancel{\text{g solution}} \times 6.5\cancel{°\text{C}} \times \frac{1.00 \text{ cal}}{\cancel{\text{g solution °C}}}$$
$$= 6.5 \times 10^2 \text{ cal}$$

6.5×10^2 cal (or 0.65 kcal) of heat energy were released by this acid-base reaction to the surroundings, the solution; the reaction is exothermic.

EXAMPLE 5.3 Calculating Energy Involved in Calorimeter Reactions

If 0.10 mol of ammonium chloride (NH_4Cl) is dissolved in water producing 1.00×10^2 g solution, the water temperature decreases from 25.0°C to 18.0°C. If the specific heat of the resulting solution is 1.00 cal/g-°C, calculate the quantity of energy involved in the process. Also, is the dissolution of ammonium chloride endothermic or exothermic?

SOLUTION

The change in temperature is

$$\Delta T = T_{s\,\text{final}} - T_{s\,\text{initial}}$$
$$= 18.0°\text{C} - 25.0°\text{C} = -7.0°\text{C}$$
$$Q = m_s \times \Delta T_s \times SH_s$$
$$Q = 1.00 \times 10^2 \cancel{\text{g solution}} \times (-7.0\cancel{°\text{C}}) \times \frac{1.00 \text{ cal}}{\cancel{\text{g solution °C}}}$$
$$= -7.0 \times 10^2 \text{ cal}$$

7.0×10^2 cal (or 0.70 kcal) of heat energy were absorbed by the dissolution process because the solution lost (– sign) 7.0×10^2 cal of heat energy to the system. The reaction is endothermic.

QUESTION 5.11

Refer to Example 5.2 and calculate the temperature change that would have been observed if 50.0 g solution were in the calorimeter instead of 1.00×10^2 g solution.

- **End-of-Chapter Problems:** We have created a wide variety of paired concept problems. The answers to the odd-numbered questions are found in the back of the book as reinforcement for the students as they develop problem-solving skills. The students must then apply the same principles to the related even-numbered problems.

Questions and Problems | 191

volume of any ideal gas is 22.4 L. STP conditions are defined as 273 K (or 0°C) and 1 atm pressure.

Boyle's law, Charles's law, and Avogadro's law may be combined into a single expression relating all four terms, the *ideal gas law*: $PV = nRT$. R is the ideal gas constant (0.0821 L-atm K^{-1} mol^{-1}) if the units P (atmospheres), V (liters), n (number of moles), and T (Kelvin) are used.

The *combined gas law* provides a convenient expression for gas law calculations involving the most common variables: pressure, volume, and temperature.

Dalton's law of partial pressures states that a mixture of gases exerts a pressure that is the sum of the pressures that each gas would exert if it were present alone under similar conditions ($P_t = p_1 + p_2 + p_3 + \cdots$).

6.2 The Liquid State

Liquids are practically incompressible because of the closeness of the molecules. The *viscosity* of a liquid is a measure of its resistance to flow. Viscosity generally decreases with increasing temperature. The *surface tension* of a liquid is a measure of the attractive forces at the surface of a liquid. *Surfactants* decrease surface tension.

The conversion of liquid to vapor at a temperature below the boiling point of the liquid is *evaporation*. Conversion of the gas to the liquid state is *condensation*. The *vapor pressure of the liquid* is defined as the pressure exerted by the vapor at equilibrium at a specified temperature. The *normal boiling point* of a liquid is the temperature at which the vapor pressure of the liquid is equal to 1 atm.

Molecules in which a hydrogen atom is bonded to a small, highly electronegative atom such as nitrogen, oxygen, or fluorine exhibit *hydrogen bonding*. Hydrogen bonding in liquids is responsible for lower than expected vapor pressures and higher than expected boiling points. The presence of *van der Waals forces* and hydrogen bonds significantly affects the boiling points of liquids as well as the melting points of solids.

6.3 The Solid State

Solids have fixed shapes and volumes. They are *incompressible*, owing to the closeness of the particles. Solids may be *crystalline*, having a regular, repeating structure, or *amorphous*, having no organized structure.

Crystalline solids may exist as *ionic solids*, *covalent solids*, *molecular solids*, or *metallic solids*. Electrons in metallic solids are extremely mobile, resulting in the high *conductivity* (ability to carry electrical current) exhibited by many metallic solids.

KEY TERMS

amorphous solid (6.3)
Avogadro's law (6.1)
barometer (6.1)
Boyle's law (6.1)
Charles's law (6.1)
combined gas law (6.1)
condensation (6.2)
covalent solid (6.3)
crystalline solid (6.3)
Dalton's law (6.1)
dipole–dipole interactions (6.2)
evaporation (6.2)
hydrogen bonding (6.2)
ideal gas (6.1)
ideal gas law (6.1)
ionic solid (6.3)
kinetic molecular theory (6.1)
London forces (6.2)
melting point (6.3)
metallic bond (6.3)
metallic solid (6.3)
molar volume (6.1)
molecular solid (6.3)
normal boiling point (6.2)
partial pressure (6.1)
pressure (6.1)
standard temperature and pressure (STP) (6.1)
surface tension (6.2)
surfactant (6.2)
van der Waals forces (6.2)
vapor pressure of a liquid (6.2)
viscosity (6.2)

QUESTIONS AND PROBLEMS

Kinetic Molecular Theory

Foundations

6.21 Compare and contrast the gas, liquid, and solid states with regard to the average distance of particle separation.
6.22 Compare and contrast the gas, liquid, and solid states with regard to the nature of the interactions among the particles.
6.23 Describe the molecular/atomic basis of gas pressure.
6.24 Describe the measurement of gas pressure.

Applications

6.25 Why are gases easily compressible?
6.26 Why are gas densities much lower than those of liquids or solids?
6.27 Do gases exhibit more ideal behavior at low or high pressures? Why?
6.28 Do gases exhibit more ideal behavior at low or high temperatures? Why?
6.29 Use the kinetic molecular theory to explain why dissimilar gases mix more rapidly at high temperatures than at low temperatures.
6.30 Use the kinetic molecular theory to explain why aerosol cans carry instructions warning against heating or disposing of the container in a fire.
6.31 Predict and explain any observed changes taking place when an inflated balloon is cooled (perhaps refrigerated).
6.32 Predict and explain any observed changes taking place when an inflated balloon is heated (perhaps microwaved).

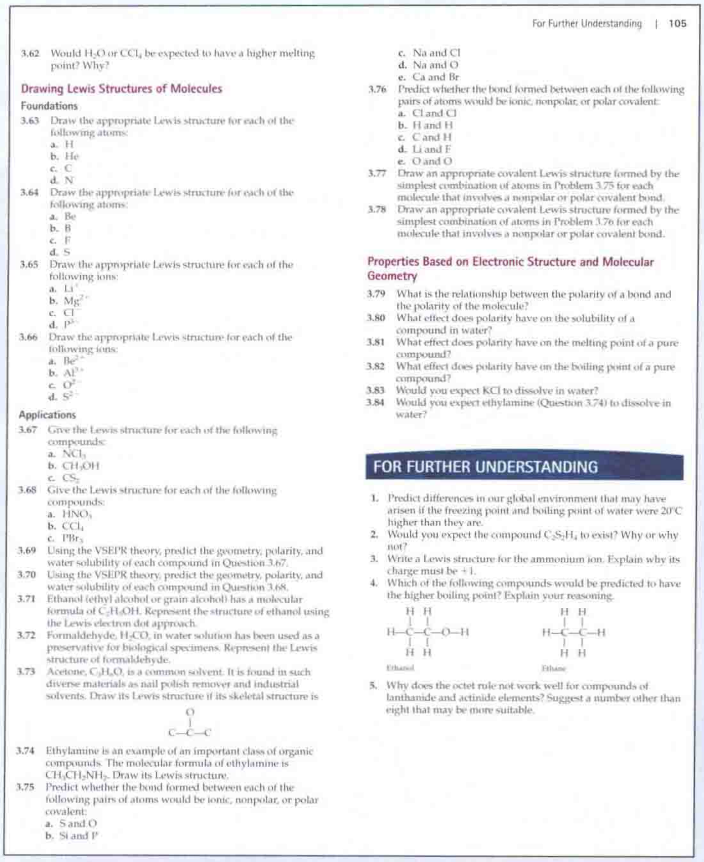
Gas Laws

Foundations

6.33 The pressure on a fixed mass of a gas is tripled at constant temperature. Will the volume increase, decrease, or remain the same?
6.34 By what factor will the volume of the gas in Question 6.33 change?

Applications

6.35 Explain why the Kelvin scale is used for gas law calculations.
6.36 The temperature on a summer day may be 90°F. Convert this value to Kelvins.



For Further Understanding | 105

3.62 Would H_2O or CCl_4 be expected to have a higher melting point? Why?

Drawing Lewis Structures of Molecules

Foundations

3.63 Draw the appropriate Lewis structure for each of the following atoms:
a. H
b. He
c. C
d. N
3.64 Draw the appropriate Lewis structure for each of the following atoms:
a. Be
b. B
c. F
d. S
3.65 Draw the appropriate Lewis structure for each of the following ions:
a. Li^+
b. Mg^{2+}
c. Cl^-
d. P^{3-}
3.66 Draw the appropriate Lewis structure for each of the following ions:
a. Be^{2+}
b. Al^{3+}
c. O^{2-}
d. S^{2-}

Applications

3.67 Give the Lewis structure for each of the following compounds:
a. NCl_3
b. CH_3OH
c. CS_2
3.68 Give the Lewis structure for each of the following compounds:
a. HNO_3
b. CCl_4
c. PBr_3
3.69 Using the VSEPR theory, predict the geometry, polarity, and water solubility of each compound in Question 3.67.
3.70 Using the VSEPR theory, predict the geometry, polarity, and water solubility of each compound in Question 3.68.
3.71 Ethanol (ethyl alcohol or grain alcohol) has a molecular formula of C_2H_5OH. Represent the structure of ethanol using the Lewis electron dot approach.
3.72 Formaldehyde, H_2CO, in water solution has been used as a preservative for biological specimens. Represent the Lewis structure of formaldehyde.
3.73 Acetone, C_3H_6O, is a common solvent. It is found in such diverse materials as nail polish remover and industrial solvents. Draw its Lewis structure if its skeletal structure is
C—C(=O)—C
3.74 Ethylamine is an example of an important class of organic compounds. The molecular formula of ethylamine is $CH_3CH_2NH_2$. Draw its Lewis structure.
3.75 Predict whether the bond formed between each of the following pairs of atoms would be ionic, nonpolar, or polar covalent:
a. S and O
b. Si and P
c. Na and Cl
d. Na and O
e. Ca and Br
3.76 Predict whether the bond formed between each of the following pairs of atoms would be ionic, nonpolar, or polar covalent:
a. Cl and Cl
b. H and H
c. C and H
d. Li and F
e. O and O
3.77 Draw an appropriate covalent Lewis structure formed by the simplest combination of atoms in Problem 3.75 for each molecule that involves a nonpolar or polar covalent bond.
3.78 Draw an appropriate covalent Lewis structure formed by the simplest combination of atoms in Problem 3.76 for each molecule that involves a nonpolar or polar covalent bond.

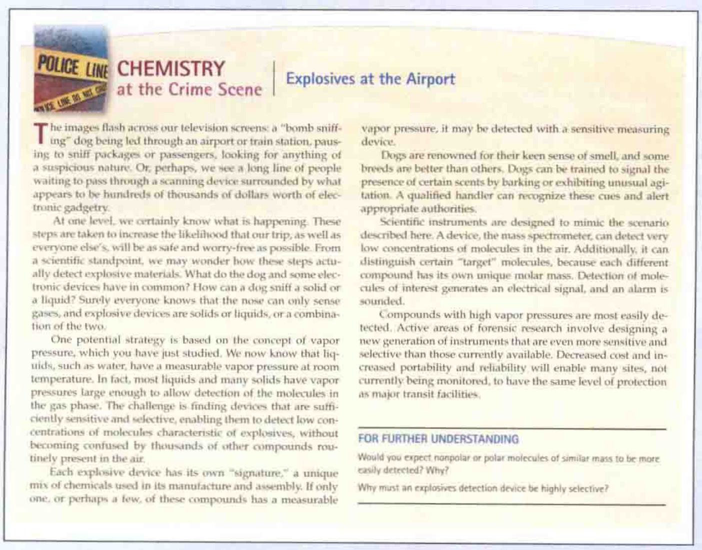
Properties Based on Electronic Structure and Molecular Geometry

3.79 What is the relationship between the polarity of a bond and the polarity of the molecule?
3.80 What effect does polarity have on the solubility of a compound in water?
3.81 What effect does polarity have on the melting point of a pure compound?
3.82 What effect does polarity have on the boiling point of a pure compound?
3.83 Would you expect KCl to dissolve in water?
3.84 Would you expect ethylamine (Question 3.74) to dissolve in water?

FOR FURTHER UNDERSTANDING

1. Predict differences in our global environment that may have arisen if the freezing point and boiling point of water were 20°C higher than they are.
2. Would you expect the compound $C_2S_2H_4$ to exist? Why or why not?
3. Write a Lewis structure for the ammonium ion. Explain why its charge must be +1.
4. Which of the following compounds would be predicted to have the higher boiling point? Explain your reasoning.
H—C(H)(H)—C(H)(H)—O—H (Ethanol)   H—C(H)(H)—C(H)(H)—H (Ethane)
5. Why does the octet rule not work well for compounds of lanthanide and actinide elements? Suggest a number other than eight that may be more suitable.

- **For Further Understanding Problems:** Each end-of-chapter Questions and Problems section includes a set of critical thinking problems referred to as "For Further Understanding." These problems are intended to challenge students to integrate concepts to solve more complex problems. They make a perfect complement to the classroom lecture because they provide an opportunity for in-class discussion of complex problems dealing with daily life and the health care sciences. Each of the boxed essays in the text also includes open-ended For Further Understanding problems that challenge the student to investigate the topic further.



CHEMISTRY at the Crime Scene | Explosives at the Airport

The images flash across our television screens: a "bomb sniffing" dog being led through an airport or train station, pausing to sniff packages or passengers, looking for anything of a suspicious nature. Or, perhaps, we see a long line of people waiting to pass through a scanning device surrounded by what appears to be hundreds of thousands of dollars worth of electronic gadgetry.

At one level, we certainly know what is happening. These steps are taken to increase the likelihood that our trip, as well as everyone else's, will be as safe and worry-free as possible. From a scientific standpoint, we may wonder how these steps actually detect explosive materials. What do the dog and some electronic devices have in common? How can a dog sniff a solid or a liquid? Surely everyone knows that the nose can only sense gases, and explosive devices are solids or liquids, or a combination of the two.

One potential strategy is based on the concept of vapor pressure, which you have just studied. We now know that liquids, such as water, have a measurable vapor pressure at room temperature. In fact, most liquids and many solids have vapor pressures large enough to allow detection of the molecules in the gas phase. The challenge is finding devices that are sufficiently sensitive and selective, enabling them to detect low concentrations of molecules characteristic of explosives, without becoming confused by thousands of other compounds routinely present in the air.

Each explosive device has its own "signature," a unique mix of chemicals used in its manufacture and assembly. If only one, or perhaps a few, of these compounds has a measurable vapor pressure, it may be detected with a sensitive measuring device.

Dogs are renowned for their keen sense of smell, and some breeds are better than others. Dogs can be trained to signal the presence of certain scents by barking or exhibiting unusual agitation. A qualified handler can recognize these cues and alert appropriate authorities.

Scientific instruments are designed to mimic the scenario described here. A device, the mass spectrometer, can detect very low concentrations of molecules in the air. Additionally, it can distinguish certain "target" molecules, because each different compound has its own unique molar mass. Detection of molecules of interest generates an electrical signal, and an alarm is sounded.

Compounds with high vapor pressures are most easily detected. Active areas of forensic research involve designing a new generation of instruments that are even more sensitive and selective than those currently available. Decreased cost and increased portability and reliability will enable many sites, not currently being monitored, to have the same level of protection as major transit facilities.

FOR FURTHER UNDERSTANDING

Would you expect nonpolar or polar molecules of similar mass to be more easily detected? Why?

Why must an explosives detection device be highly selective?

Supplements for the Instructor

The following items may accompany this text. Please consult your McGraw-Hill representative for policies, prices, and availability as some restrictions may apply.

- McGraw-Hill's *Foundations of General, Organic, and Biochemistry* ARIS website (Assessment, Review, and Instruction System) makes homework meaningful—and manageable—for instructors and students. Instructors can assign and grade chapter-specific homework within the industry's most robust and versatile homework management system. These homework questions can be imported into a variety of course management solutions such as WebCT, Blackboard, and WebAssign. These course cartridges also provide online testing and powerful student tracking features. From the ARIS website, students can access these chapter-specific self-study tools:
    - Self-quizzes
    - Animations
    - Key Terms

Go to www.aris.mhhe.com to learn more, or go directly to this book's ARIS site at www.mhhe.com/denniston.

- An *Instructor's Testing and Resource CD-ROM* includes the Instructor's Solutions Manual, prepared by the authors and by Timothy Dwyer of Villa Julie College. The Instructor's Solutions Manual contains suggestions for organizing lectures, instructional objectives, perspectives on boxed readings from the text, a list of each chapter's key problems and concepts, and contains all answers for the textbook's even-numbered end-of-chapter problems. A Computerized Test Bank of questions for each chapter, prepared by Ann T. Eakes, is also included on this cross-platform CD-ROM.
- Laboratory Resource Guide: Written by Charles H. Henrickson, Larry C. Byrd, and Norman W. Hunter of Western Kentucky University, this helpful prep guide contains the hints that the authors have learned over the years to ensure students' success in the laboratory. This Resource Guide is available through the ARIS course website for this text.
- Over 300 animations are available within McGraw-Hill's *Chemistry Animations DVD*. Instructors can easily view the animations and import them into PowerPoint to create multimedia presentations.
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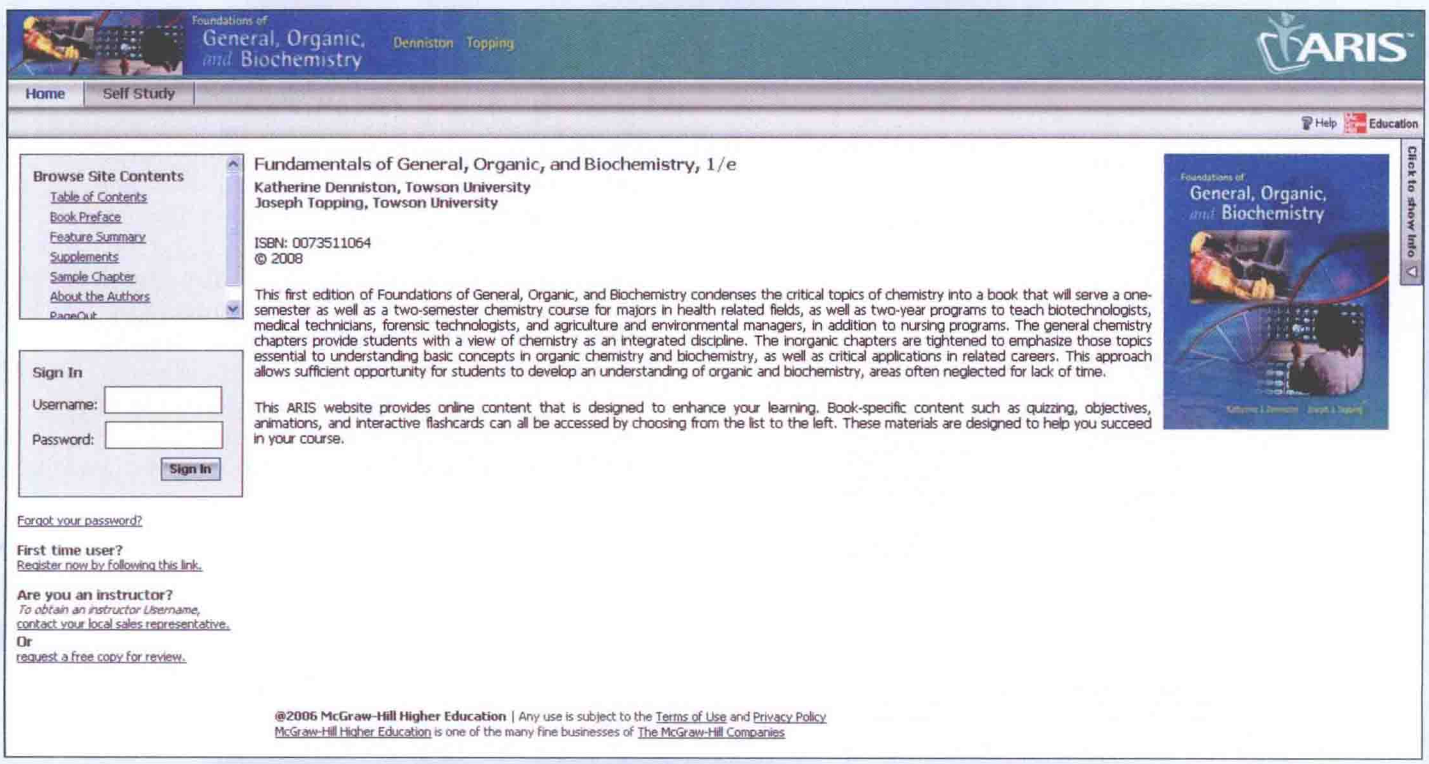

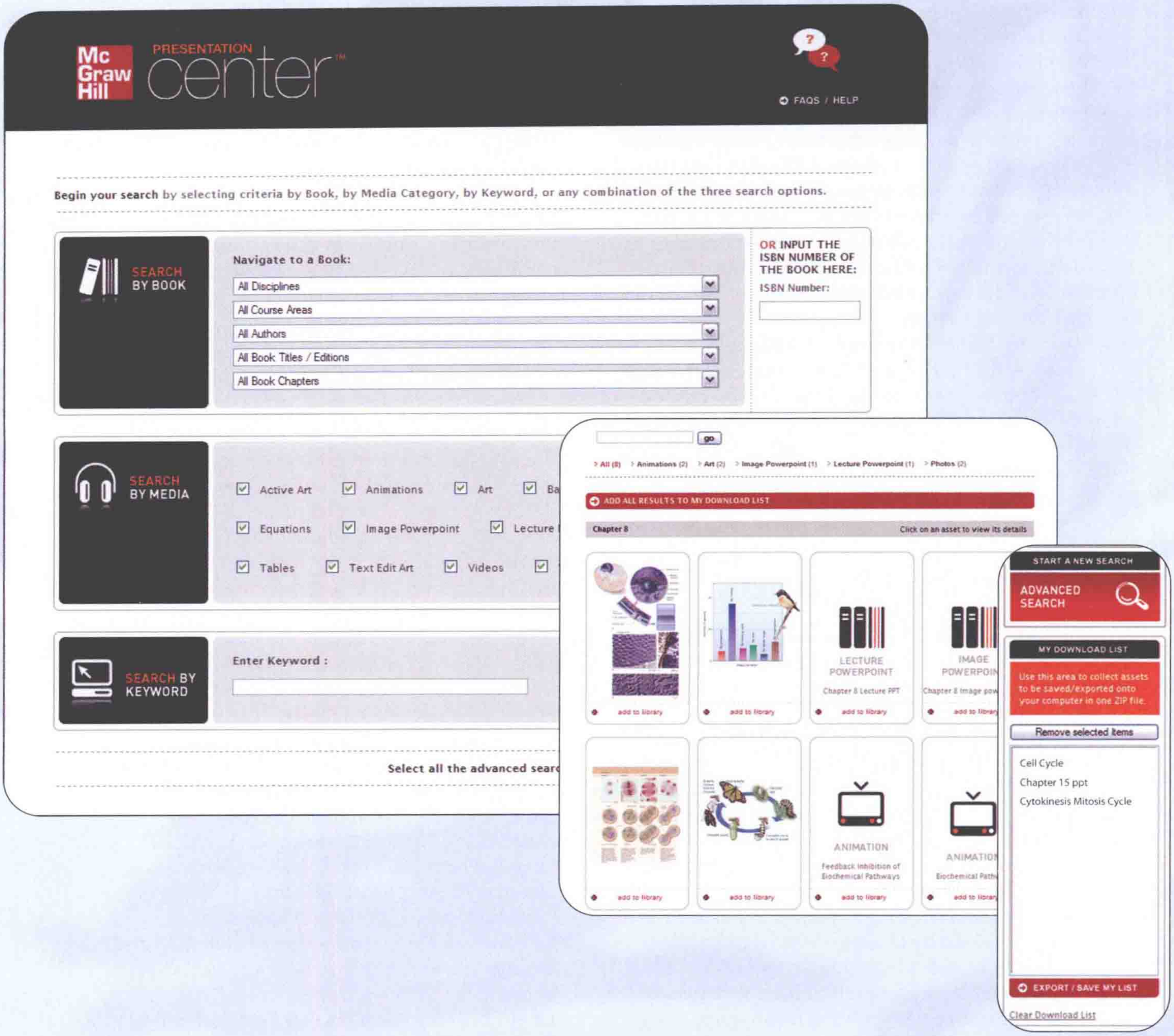

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- *A Laboratory Manual for General, Organic, and Biochemistry* by Henrickson/Byrd/Hunter provides clear and concise laboratory experiments to reinforce students' understanding of concepts. Prelaboratory exercises, questions, and report sheets are coordinated with each experiment to ensure active student involvement and comprehension.

Supplements for the Student

- The *Student Solutions Manual*, prepared by Timothy Dwyer of Villa Julie College, contains chapter-sorted, detailed solutions and explanations for all odd-numbered problems in the text.
- McGraw-Hill's *Foundations of General, Organic, and Biochemistry* ARIS Website (www.mhhe.com/denniston) contains useful study and review tools for students, including chapter-specific quizzing and animations specific to the content in each chapter. Animations have quiz questions associated with them, to check your comprehension of the material.
- *Schaum's Outline of General, Organic, and Biological Chemistry* is written by George Odian and Ira Blei. This supplement provides students with over 1400 solved problems with complete solutions. It also teaches effective problem-solving techniques.

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