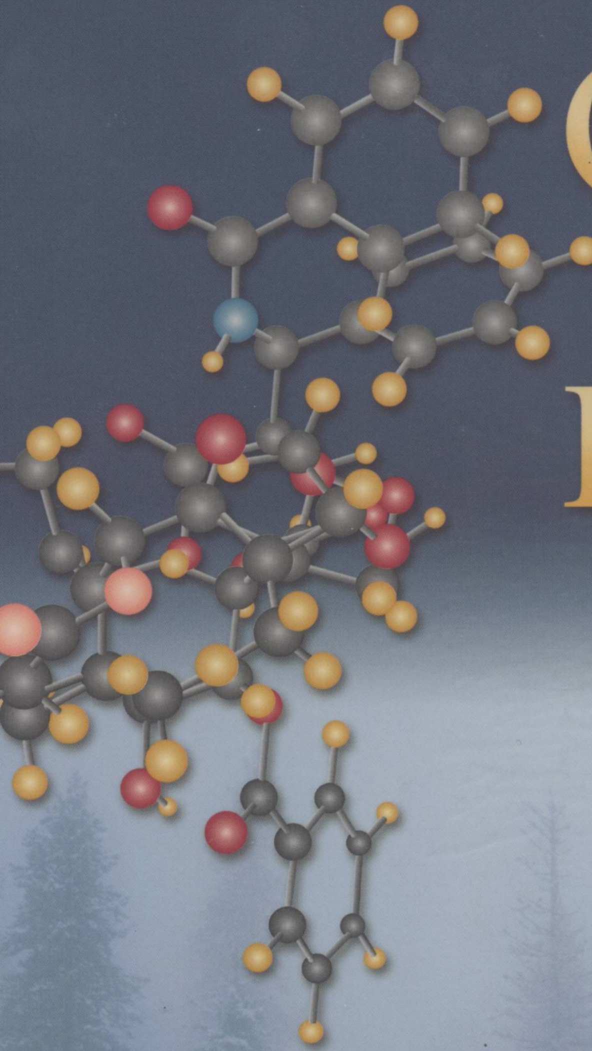
General, Organic, *and* Biochemistry

Fourth Edition



Denniston • Topping • Caret

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General, Organic, and Biochemistry

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Fourth Edition

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Preface

The fourth edition of *General, Organic, and Biochemistry*, like our earlier editions, has been designed to help undergraduate majors in health-related fields understand key concepts and appreciate the significant connections between chemistry, health, and the treatment of disease. We have tried to strike a balance between theoretical and practical chemistry, while emphasizing material that is unique to health-related studies. We have written at a level intended for students whose professional goals do not include a mastery of chemistry, but for whom an understanding of the principles and practice of chemistry is a necessity.

While we have stressed the importance of chemistry to the health-related professions, this book was written for all students that need a one or two semester introduction to chemistry. Our focus on the relationship between chemistry, the environment, medicine, and the function of the human body is an approach that can engage students in a variety of majors.

In this text we treat the individual disciplines of inorganic, organic, and biological chemistry. Moreover, we have tried to integrate these areas to show the interrelatedness of these topics. This approach provides a sound foundation in chemistry and teaches students that life is not a magical property, but rather is the result of a set of chemical reactions that obey the scientific laws.

Key Features of the Fourth Edition

In the preparation of the fourth edition, we have been guided by the collective wisdom of over fifty reviewers who are experts in one of the three subdisciplines covered in the book and who represent a diversity of experience, including community colleges, and four-year colleges and universities. We have retained the core approach of our successful earlier editions, modernized material where necessary, and expanded or removed material consistent with retention of the original focus and mission of the book. Throughout the project, we have been careful to ensure that the final product is as student-oriented and readable as its predecessors.

Specifically, new features of the fourth edition include:

- Chapters 1 and 2 have been rearranged to more smoothly facilitate students' transition from descriptive to quantitative chemistry.
- Twenty new boxed elements, particularly in the Organic and Biochemistry parts, give students insight into the modern-day application of various topics.
- Approximately 200 new end-of-chapter questions will allow instructors greater flexibility in assigning problems and will give students more opportunity to test themselves.
- The website and other media supplements, as described later in this Preface, have been enhanced. Specifically, the Digital Content Manager, a CD-ROM, contains electronic files of text figures and tables as well as PowerPoint lecture slides.

We designed the fourth edition to promote student learning and facilitate teaching. It is important to engage students, to appeal to visual learners, and to provide a variety of pedagogical tools to help them organize and summarize information. We have utilized a variety of strategies to accomplish our goals.

Engaging Students

Students learn better when they can see a clear relationship between the subject material they are studying and real life. We wrote the text to help students make connections between the principles of chemistry and their previous life experiences and/or their future professional experiences. Our strategy to accomplish this integration includes the following:

- **Boxed Readings—"Chemistry Connection":** We have crafted introductory vignettes to allow the student to see the significance of chemistry in their daily lives and in their future professions.
- **Boxed Perspectives:** These short stories present real-world situations that involve one or more topics that students will encounter in the chapter. The "Medical Perspectives" and "Clinical Perspectives" relate the chemistry to a health concern or a diagnostic application. The "Environmental Perspectives" deal with issues, including the impact of chemistry on the ecosystem and the way in which these environmental changes affect human health. "Human Perspectives" delve into chemistry and society and include such topics as gender issues in science and historical viewpoints.

In the fourth edition, we have added 20 new boxed topics and have updated many of the earlier ones. We have tried to include topics, such as self-tanning lotions and sugar substitutes, which are of interest to students today. We have included the most recent strategies for treatment of AIDS and new information on the use of genetic engineering to treat a variety of genetic diseases.

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 our reviewers, we have made some modifications to improve the learning system. However, with the blessings of those reviewers, we have retained all of the elements of the previous edition, which have been shown to support student learning:

- **Learning Goals:** A set of chapter objectives at the beginning of each chapter previews concepts that will be covered in the chapter. Icons 1 locate text material that supports the learning goals.
- **Detailed Chapter Outline:** A detailed listing of topic headings is provided for each chapter. Topics are divided and subdivided 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 that require an understanding of the information currently being studied.
- **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, defined immediately, and listed at the end of the chapter. Each end-of-chapter key term is accompanied by a section number for rapid reference.
- **Summary of Key Reactions:** In the organic chemistry chapters, each major reaction type is highlighted on a green background. These major reactions are summarized at the end of the chapter, facilitating review.
- **Glossary of Key Terms:** In addition to being listed at the end of the chapter, each key term from the text is also defined in the alphabetical glossary at the end of the book.
- **Appendix Material:** Each Appendix accomplishes one of two goals: remediation or expansion of information introduced in the chapter.

The Art Program

Today's students are much more visually oriented than any previous generation. Television and the computer represent alternate modes of learning. We have built upon this observation through expanded 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.
- **Color-Coding Scheme:** We have color-coded the reactions so that chemical groups being added or removed in a reaction can be quickly recognized. Each major organic reaction type is highlighted on a green background. The color-coding scheme is illustrated in the "Guided Tour" section of this book.
- **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

Perhaps the best preparation for a successful and productive career is the development of problem-solving and critical thinking skills. To this end, we created a variety of problems that require recall, fundamental calculations, and complex reasoning. In this edition, we have used suggestions from our reviewers, as well as from our own experience, to enhance the problem sets to include more practice problems for difficult concepts and further integration of the subject areas.

- **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.
- **In-Chapter and 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. However, the students must then be able to apply the same principles to the related even-numbered problems.
- **Critical Thinking Problems:** Each chapter includes a set of critical thinking problems. These problems are intended to challenge the 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.

Over the course of the last three editions, hundreds of reviewers have shared their knowledge and wisdom with us, as well as the reaction of their students to elements of this book. Their contributions, as well as our own continuing experience in the area of teaching and learning science, have resulted in a text that we are confident will provide a strong foundation in chemistry, while enhancing the learning experience of the students.

Supplementary Materials

This text has a complete support package for instructors and students. Several print and media supplements have been prepared to accompany the text and make learning as meaningful and up-to-date as possible.

For the Instructor

- **Digital Content Manager:** This is the primary instructor supplement and offers over 300 text images and nearly 300 PowerPoint lecture slides prepared by Kim Woodrum at the University of Kentucky. The text images are full color and can be readily incorporated into lecture presentations, exams, or classroom materials. The sets of PowerPoint slides cover all 24 chapters. These slides can be modified according to instructor preference.
- **Instructor's Manual:** Written by the authors and updated by Patricia DePra, this ancillary contains suggestions for organizing lectures, additional "Perspectives," and a list of each chapter's key problems and concepts. The Instructor's Manual also contains the test item file and solutions to the even-numbered problems.
- **Transparencies:** A set of 100 transparencies is available to help the instructor coordinate the lecture with key illustrations from the text.
- **Brownstone Diploma computerized classroom management system:** This service includes a database of test questions, reproducible student self-quizzes, and a grade-recording program.
- **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.
- **Online Learning Center:** A book-specific website is available to students and instructors using this text. The website will offer quizzes, key definitions, and interesting links for the students. The instructor will find a downloadable version of the Instructor's Manual. Also available for the instructor is PageOut, which allows the instructor to create his or her own personal course website. The address for the book-specific website is www.mhhe.com/denniston.

For the Students

- **Student Study Guide/Solutions Manual:** A separate Student Study Guide/Solutions Manual, prepared by the authors and updated by Patricia DePra, is available. It contains the answers and complete solutions for the odd-numbered problems. It also offers students a variety of exercises and keys for testing their comprehension of basic, as well as difficult, concepts.
- **Laboratory Manual:** Written by Charles H. Henrickson, Larry C. Byrd, and Norman W. Hunter, all of Western Kentucky University, *Experiments in General, Organic, and Biochemistry* carefully and safely guides students through the process of scientific inquiry. The manual features self-contained experiments that can easily be reorganized to suit individual course needs.
- **Schaum's Outline of General, Organic, and Biological Chemistry:** 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.
- **How to Study Science:** Written by Fred Drewes of Suffolk County Community College, this excellent workbook offers students helpful suggestions for meeting the considerable challenges of a science course. It offers tips on how to take notes and how to overcome science anxiety. The book's unique design helps to stir critical thinking skills, while facilitating careful note taking on the part of the student.
- **Online Learning Center:** A book-specific website is available to students and instructors using this text. The website offers quizzes, key definitions, and interesting links for the students. The address for the book-specific website is www.mhhe.com/denniston.

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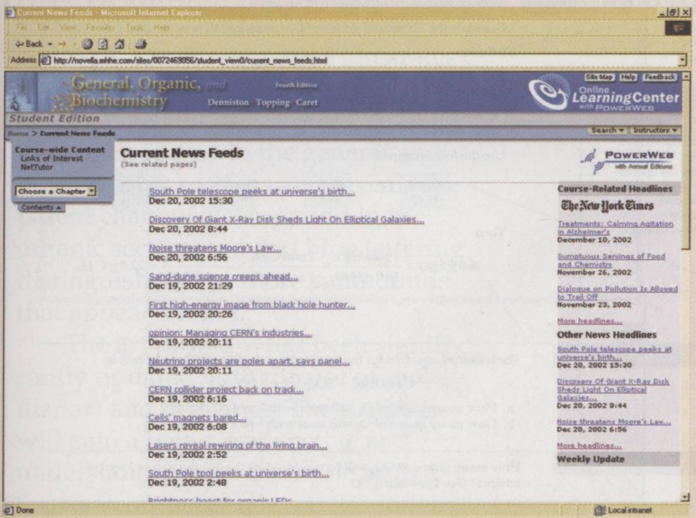
The *General Organic, and Biochemistry* Media System provides both instructors and students with a variety of tools to augment teaching and learning.



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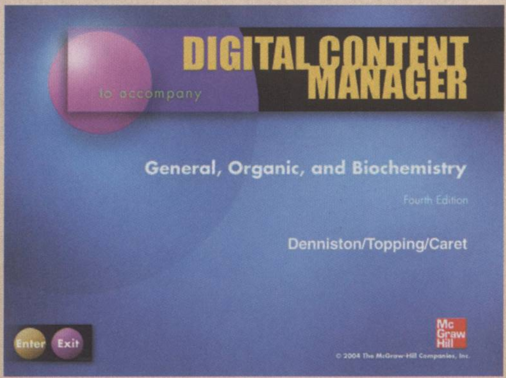

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The *General, Organic, and Biochemistry* Learning System

The *General, Organic, and Biochemistry* Learning System is easy to follow, and will allow the student to excel in this course. The materials are presented in such a way that the student will effectively learn and retain the important information.

Clear Approach to Solving Problems

Because problem solving is most efficiently learned by a combination of studying examples and practicing, problems with step-by-step solutions are provided wherever appropriate. Examples are followed by a question requiring the student to integrate the newly learned material.

EXAMPLE 5.17 ***Relating Masses of Reactants and Products***

Calculate the number of grams of C_3H_8 required to produce 36.0 g of H_2O.

Solution

It is necessary to convert

1. grams of H_2O to moles of H_2O,
2. moles of H_2O to moles of C_3H_8, and
3. moles of C_3H_8 to grams of C_3H_8.

Use the following path:

grams H_2O ⟶ moles H_2O ⟶ moles C_3H_8 ⟶ grams C_3H_8

Then

$$36.0\ \text{g}\ H_2O \times \frac{1\ \text{mol}\ H_2O}{18.0\ \text{g}\ H_2O} \times \frac{1\ \text{mol}\ C_3H_8}{4\ \text{mol}\ H_2O} \times \frac{44.0\ \text{g}\ C_3H_8}{1\ \text{mol}\ C_3H_8} = 22.0\ \text{g}\ C_3H_8$$

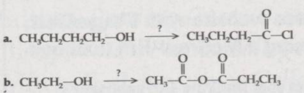
Question 5.13 The balanced equation for the combustion of ethanol (ethyl alcohol) is:

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

a. How many moles of O_2 will react with 1 mol of ethanol?
b. How many grams of O_2 will react with 1 mol of ethanol?

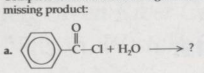
Question 5.14 How many grams of CO_2 will be produced by the combustion of 1 mol of ethanol? (See Question 5.13.)

Let's consider an example that requires us to write and balance the chemical equation, use conversion factors, and calculate the amount of a reactant consumed in the chemical reaction.

a. b.


c. Ethanol $\xrightarrow{?}$ ethanoic anhydride

15.53 Complete each of the following reactions by supplying the missing product:

a.


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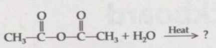


15.54 Use the I.U.P.A.C. Nomenclature System to name the products and reactants in Problem 15.53.

15.55 Write the condensed formula for each of the following compounds:
a. Decanoic anhydride
b. Acetic anhydride
c. Valeric anhydride
d. Benzoyl chloride

15.56 Write a condensed formula for each of the following compounds:
a. Propanoyl chloride
b. Heptanoyl chloride
c. Pentanoyl chloride

15.57 Describe the physical properties of acid chlorides.

15.58 Describe the physical properties of acid anhydrides.

15.59 Write an equation for the reaction of each of the following acid anhydrides with ethanol.
a. Propanoic anhydride
b. Ethanoic anhydride
c. Methanoic anhydride

15.60 Write an equation for the reaction of each of the following acid anhydrides with propanol. Name each of the products using the I.U.P.A.C. Nomenclature System.
a. Butanoic anhydride
b. Pentanoic anhydride
c. Methanoic anhydride

Phosphoesters and Thioesters

15.61 By reacting phosphoric acid with an excess of ethanol, it is possible to obtain the mono-, di-, and triesters of phosphoric acid. Draw all three of these products.

15.62 What is meant by a phosphoric anhydride bond?

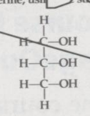
15.63 We have described the molecule ATP as the body's energy storehouse. What do we mean by this designation? How does ATP actually store energy and provide it to the body as needed?

15.64 Write an equation for each of the following reactions:
a. Ribose + phosphoric acid
b. Methanol + phosphoric acid
c. Adenosine diphosphate + phosphoric acid

15.65 Draw the thioester bond between the acetyl group and coenzyme A.

15.66 Explain the significance of thioester formation in the metabolic pathways involved in fatty acid and carbohydrate breakdown.

15.67 It is also possible to form esters as sulfuric acid and nitric acid. product is nitroglycerine, whic (explosive) and widely used in condition known as angina, a c usually resulting from coronar case its function is to alleviate angina. Nitroglycerine may be (usually placed just beneath th salve or paste that can be appli skin. Nitroglycerine is the trini structure of nitroglycerine, usi

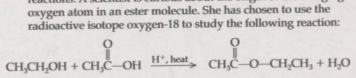


Glycerol

15.68 Show the structure of the thioester that would be formed between coenzyme A and stearic acid.

Critical Thinking Problems

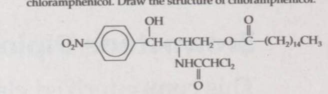
1. Radioactive isotopes of an element behave chemically in exactly the same manner as the nonradioactive isotopes. As a result, they can be used as tracers to investigate the details of chemical reactions. A scientist is curious about the origin of the bridging oxygen atom in an ester molecule. She has chosen to use the radioactive isotope oxygen-18 to study the following reaction:



Design experiments using oxygen-18 that will demonstrate whether the oxygen in the water molecule came from the —OH of the alcohol or the —OH of the carboxylic acid.

2. Triglycerides are the major lipid storage form in the human body. They are formed in an esterification reaction between glycerol (1,2,3-propanetriol) and three fatty acids (long chain carboxylic acids). Write a balanced equation for the formation of a triglyceride formed in a reaction between glycerol and three molecules of decanoic acid.

3. Chloramphenicol is a very potent, broad-spectrum antibiotic. It is reserved for life-threatening bacterial infections because it is quite toxic. It is also a very bitter tasting chemical. As a result, children had great difficulty taking the antibiotic. A clever chemist found that the taste could be improved considerably by producing the palmitate ester. Intestinal enzymes hydrolyze the ester, producing chloramphenicol, which can then be absorbed. The following structure is the palmitate ester of chloramphenicol. Draw the structure of chloramphenicol.



Chloramphenicol palmitate

A variety of questions and problems that range in level of difficulty help students measure their mastery of the chapter material. The odd-numbered questions are answered in the back of the text.

At the end of the chapter, the student will find several problems that require thought-provoking answers dealing with daily life and the health care sciences.

Dynamic Visuals

Many of the equations and reactions are color coded to help the student understand the chemical changes that occur in complex reactions. The student can easily recognize the chemical groups being added or removed in a reaction by the color coding. Green background illustrates an important equation or key reaction; yellow background illustrates energy in the general and biochemistry sections and reveals the parent chain of a compound in the organic section; red and blue lettering distinguish two or more compounds that appear similar.

The art program has been significantly updated with the use of molecular art and drawings. The students will gain a better perspective and understanding of a molecule with a Spartan computer-generated model.

7.6 Concentration-Dependent Solution Properties 187

We have already worked with one mole-based unit, *molarity*, and this concentration unit can be used to calculate either the freezing point depression or the boiling point elevation.

A second mole-based concentration unit, molality, is more commonly used in these types of situations. **Molality** (symbolized *m*) is defined as the number of moles of solute per kilogram of solvent in a solution:

$$m = \frac{\text{moles solute}}{\text{kg solvent}}$$

Molality does not vary with temperature, whereas molarity is temperature dependent. For this reason, molality is the preferred concentration unit for studies such as freezing point depression and boiling point elevation, in which measurement of *change* in temperature is critical.

Practical applications that take advantage of freezing point depression of solutions by solutes include the following:

Molarity is temperature dependent simply because it is expressed as mole/volume. Volume is temperature dependent—most liquids expand measurably when heated and contract when cooled. Molality is moles/mass; both moles and mass are temperature independent.

measurement of heat change in chemical reactions. The concentric Styrofoam cups insulate the system from its surroundings. Heat released by the chemical reaction enters the water, raising its temperature, which is measured by using a thermometer.

and the change in temperature (ΔT_s) of the solution as the reaction proceeds from the initial to final state.

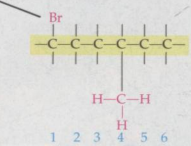
The heat is calculated by using the following equation:

$$Q = m_s \times \Delta T_s \times SH_s$$

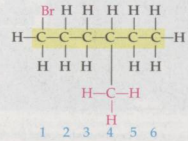
with units

$$\text{calories} = \text{gram} \times {}^\circ\text{C} \times \frac{\text{calories}}{\text{gram-}{}^\circ\text{C}}$$

Now add the substituents. In this example a bromine atom is bonded to carbon-1, and a methyl group is bonded to carbon-4:



Finally, add the correct number of hydrogen atoms so that each carbon has four covalent bonds:



As a final check of your accuracy, use the I.U.P.A.C. system to name the compound that you have just drawn, and compare the name with that in

24.2 The Structure of DNA and RNA 731

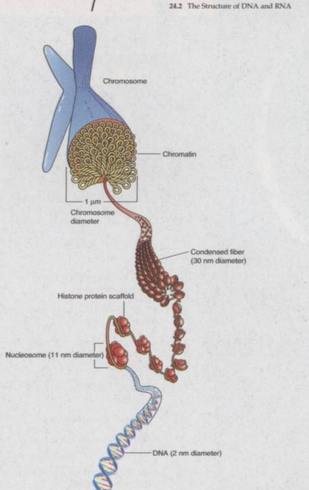


Figure 24.7
The eukaryotic chromosome has many levels of structure.

All animals, plants, and fungi are eukaryotes. The number and size of the chromosomes of eukaryotes vary from one species to the next. For instance, humans have 23 pairs of chromosomes, while the Adder's Tongue fern has 631 pairs of chromosomes. But the chromosome structure is the same for all those organisms that have been studied.

Eukaryotic chromosomes are very complex structures (Figure 24.7). The first level of structure is the **nucleosome,** which consists of a strand of DNA wrapped around a small disk made up of histone proteins. At this level the DNA looks like beads along a string. The string of beads then coils into a larger structure called the

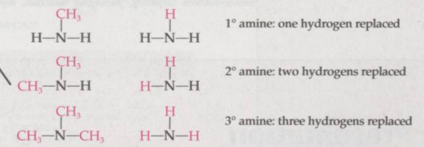
24-11

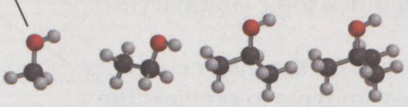
EXAMPLE 16.1 *Classifying Amines as Primary, Secondary, or Tertiary*

Classify each of the following compounds as a primary, secondary, or tertiary amine.

Solution

Compare the structure of the amine with that of ammonia.

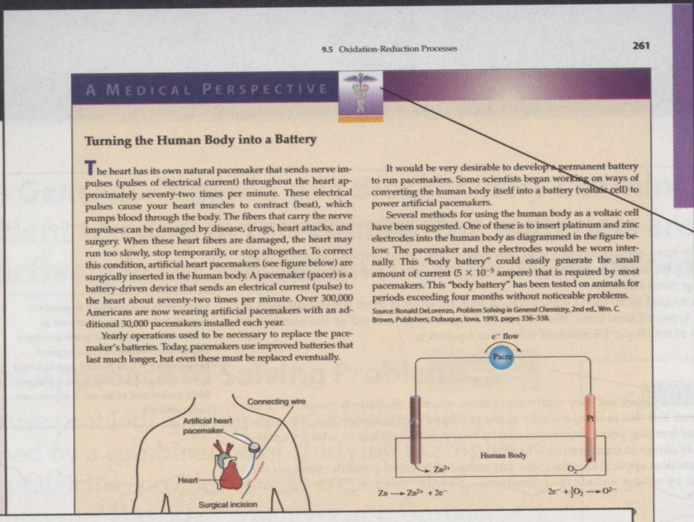




Classifying Alcohols **EXAMPLE 13.3**

Classify each of the following alcohols as primary, secondary, or tertiary. Learning Goal

Solution



9.5 Oxidation-Reduction Processes 261

A MEDICAL PERSPECTIVE

Turning the Human Body into a Battery

The heart has its own natural pacemaker that sends nerve impulses (pulses of electrical current) throughout the heart approximately seventy-two times per minute. These electrical pulses cause your heart muscles to contract (beat), which pumps blood through the body. The fibers that carry the nerve impulses can be damaged by disease, drugs, heart attacks, and surgery. When these heart fibers are damaged, the heart may run too slowly, stop temporarily, or stop altogether. To correct this condition, artificial heart pacemakers (see figure below) are surgically inserted in the human body. A pacemaker (pacer) is a battery-driven device that sends an electrical current (pulse) to the heart about seventy-two times per minute. Over 300,000 Americans are now wearing artificial pacemakers with an additional 30,000 pacemakers installed each year.

Yearly operations used to be necessary to replace the pacemaker's batteries. Today, pacemakers use improved batteries that last much longer, but even these must be replaced eventually.

It would be very desirable to develop a permanent battery to run pacemakers. Some scientists began working on ways of converting the human body itself into a battery (voltaic cell) to power artificial pacemakers.

Several methods for using the human body as a voltaic cell have been suggested. One of these is to insert platinum and zinc electrodes into the human body as diagrammed in the figure below. The pacemaker and the electrodes would be worn internally. This "body battery" could easily generate the small amount of current (5×10^{-5} ampere) that is required by most pacemakers. This "body battery" has been tested on animals for periods exceeding four months without noticeable problems.

Source: Ronald DeLorenzo, *Problem Solving in General Chemistry*, 2nd ed., Wm. C. Brown, Publishers, Dubuque, Iowa, 1993, pages 336–338.

348 Chapter 12 The Unsaturated Hydrocarbons: Alkenes, Alkynes, and Aromatics

AN ENVIRONMENTAL PERSPECTIVE

Plastic Recycling

Plastics, first developed by British inventor Alexander Parkes in 1862, are amazing substances. Some serve as containers for many of our foods and drinks, keeping them fresh for long periods of time. Other plastics serve as containers for detergents and cleansers or are formed into pipes for our plumbing systems. We have learned to make strong, clear sheets of plastic that can be used as windows, and feather-light plastics that can be used as packaging materials. In the United States alone, seventy-five billion pounds of plastics are produced each year.

But plastics, amazing in their versatility, are a mixed blessing. One characteristic that makes them so useful, their stability, has created an environmental problem. It may take forty to fifty years for plastics discarded into landfill sites to degrade. Concern that we could soon be knee-deep in plastic worldwide has resulted in a creative new industry: plastic recycling.

Since there are so many types of plastics, it is necessary to identify, sort, and recycle them separately. To help with this sorting process, manufacturers place recycling symbols on their plastic wares. As you can see in the accompanying table, each symbol corresponds to a different type of plastic.

Polyethylene terephthalate, also known as PETE or simply #1, is a form of polyester often used to make bottles and jars to contain food. When collected, it is ground up into flakes and formed into pellets. The most common use for recycled PETE is the manufacture of polyester carpets. But it may also be spun into a cotton-candy-like form that can be used as a fiber filling for pillows or sleeping bags. It may also be rolled into thin sheets or ribbons and used as tapes for VCRs or tape decks. Reuse to produce bottles and jars is also common.

HDPE, or #2, is high-density polyethylene. Originally used for milk and detergent bottles, recycled HDPE is used to produce pipes, plastic lumber, trash cans, or bottles for storage of materials other than food. LDPE, #4, is identical to HDPE chemically, but it is produced in a less-dense, more flexible form. Originally used to produce plastic bags, recycled LDPE is also used to make trash bags, grocery bags, and plastic tubing and lumber.

PVC, or #3, is one of the less commonly recycled plastics in the United States, although it is actively recycled in Europe. The recycled material is used to make non-food-bearing containers, shoe soles, flooring, sweaters, and pipes. Polypropylene, PP or

Polyethylene is a polymer made from the monomer ethylene (ethene):

$$n\,CH_2{=}CH_2 \longrightarrow \sim\!\!\sim\!\![CH_2{-}CH_2]_n\!\!\sim\!\!\sim$$

Ethene (ethylene) — Polyethylene

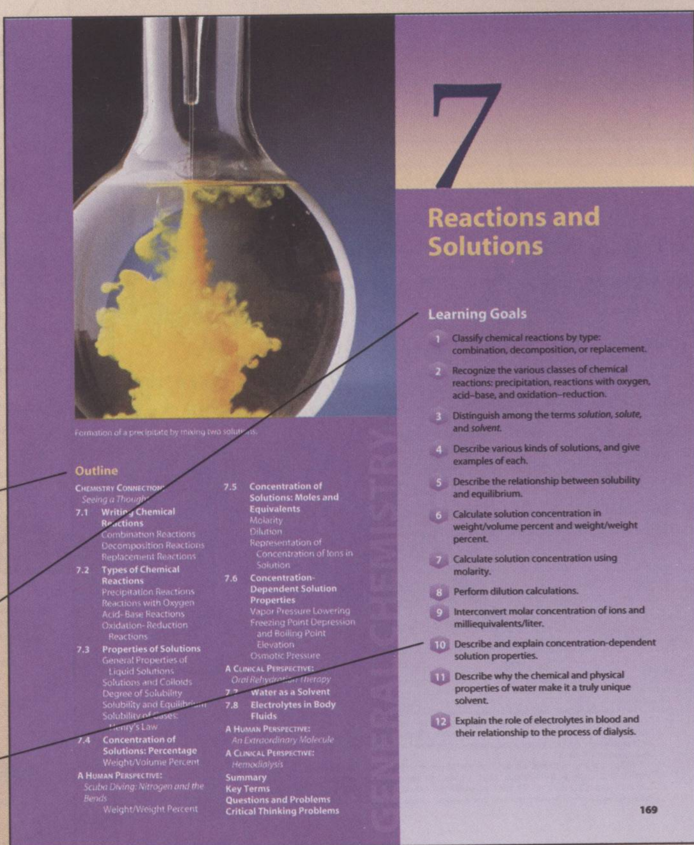
It is used to make bottles, injection-molded toys and housewares, and wire coverings.

Polypropylene is a plastic made from propylene (propene). It is used to make indoor-outdoor carpeting, packaging materials, toys, and housewares. When

12-24

Health/Life Related Applications

There are four different Perspective boxes in the text. Chemistry Connections provide an introductory scenario for the chapter; Medical Perspectives and Clinical Perspectives demonstrate use of the chapter material in an allied health field; Environmental Perspectives demonstrate chapter concepts in ecological problems; and Human Perspectives demonstrate how important chemistry is in our day-to-day lives.



7

Reactions and Solutions

Formation of a precipitate by mixing two solutions.

Outline

Learning Goals

1. Classify chemical reactions by type: combination, decomposition, or replacement.
2. Recognize the various classes of chemical reactions: precipitation, reactions with oxygen, acid–base, and oxidation–reduction.
3. Distinguish among the terms *solution*, *solute*, and *solvent*.
4. Describe various kinds of solutions, and give examples of each.
5. Describe the relationship between solubility and equilibrium.
6. Calculate solution concentration in weight/volume percent and weight/weight percent.
7. Calculate solution concentration using molarity.
8. Perform dilution calculations.
9. Interconvert molar concentration of ions and milliequivalents/liter.
10. Describe and explain concentration-dependent solution properties.
11. Describe why the chemical and physical properties of water make it a truly unique solvent.
12. Explain the role of electrolytes in blood and their relationship to the process of dialysis.

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Clear Presentation

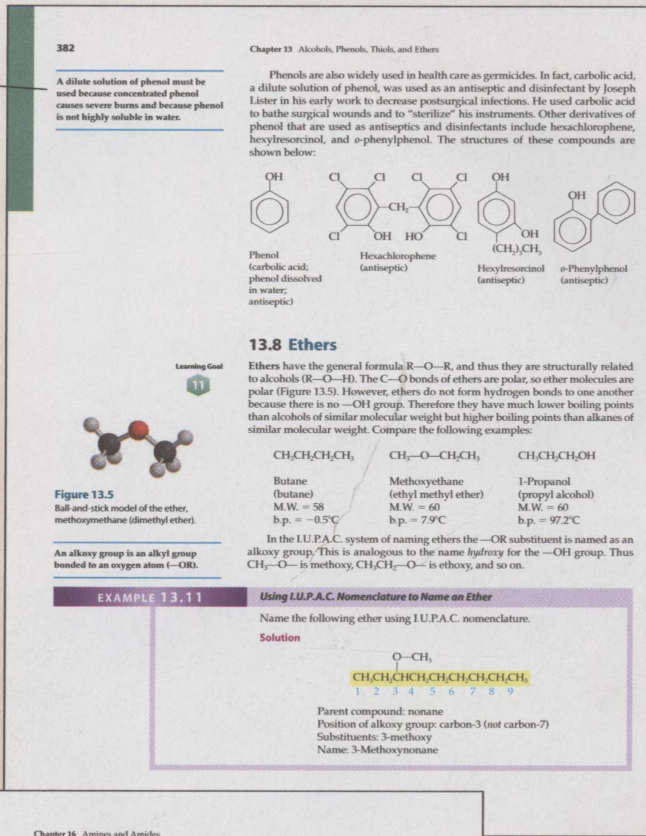
Each chapter begins with an outline that introduces students to the topics to be presented. This outline also provides the instructor with a quick topic summary to organize lecture material.

A list of learning goals, based on the major concepts covered in the chapter, enables students to preview the material and become aware of the topics they are expected to master.

This icon is found within the chapters wherever the associated learning goal is first presented, allowing the student to focus attention on the major concepts.

Additional Pedagogical Elements

Margin notes direct the student to a reference in the book for further material or review.



A dilute solution of phenol must be used because concentrated phenol causes severe burns and because phenol is not highly soluble in water.

Phenols are also widely used in health care as germicides. In fact, carbolic acid, a dilute solution of phenol, was used as an antiseptic and disinfectant by Joseph Lister in his early work to decrease postsurgical infections. He used carbolic acid to bathe surgical wounds and to "sterilize" his instruments. Other derivatives of phenol that are used as antiseptics and disinfectants include hexachlorophene, hexylresorcinol, and *o*-phenylphenol. The structures of these compounds are shown below:

Phenol (carbolic acid; phenol dissolved in water; antiseptic) — Hexachlorophene (antiseptic) — Hexylresorcinol (antiseptic) — *o*-Phenylphenol (antiseptic)

13.8 Ethers

Learning Goal 11

Ethers have the general formula R—O—R, and thus they are structurally related to alcohols (R—O—H). The C—O bonds of ethers are polar, so ether molecules are polar (Figure 13.5). However, ethers do not form hydrogen bonds to one another because there is no —OH group. Therefore they have much lower boiling points than alcohols of similar molecular weight but higher boiling points than alkanes of similar molecular weight. Compare the following examples:

$CH_3CH_2CH_2CH_3$	$CH_3—O—CH_2CH_3$	$CH_3CH_2CH_2OH$
Butane (butane)	Methoxyethane (ethyl methyl ether)	1-Propanol (propyl alcohol)
M.W. = 58	M.W. = 60	M.W. = 60
b.p. = −0.5°C	b.p. = 7.9°C	b.p. = 97.2°C

Figure 13.5 Ball-and-stick model of the ether, methoxymethane (dimethyl ether).

In the I.U.P.A.C. system of naming ethers the —OR substituent is named as an alkoxy group. This is analogous to the name *hydroxy* for the —OH group. Thus $CH_3—O—$ is methoxy, $CH_3CH_2—O—$ is ethoxy, and so on.

An alkoxy group is an alkyl group bonded to an oxygen atom (—OR).

EXAMPLE 13.11 ***Using I.U.P.A.C. Nomenclature to Name an Ether***

Name the following ether using I.U.P.A.C. nomenclature.

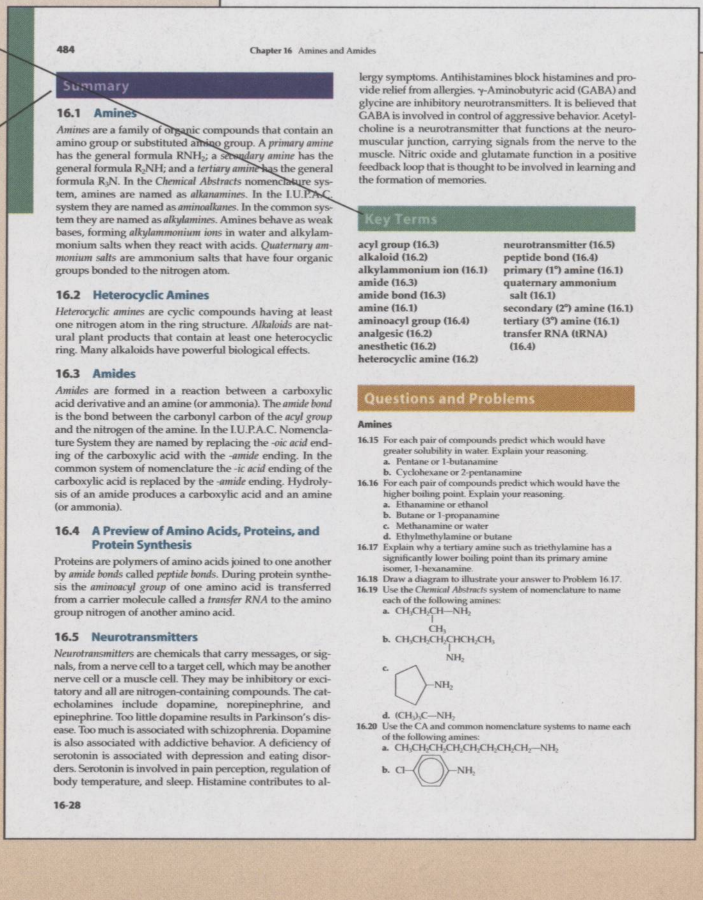
Solution

$CH_3CH_2CH(OCH_3)CH_2CH_2CH_2CH_2CH_2CH_3$ (carbons numbered 1–9)

Parent compound: nonane
Position of alkoxy group: carbon-3 (*not* carbon-7)
Substituents: 3-methoxy
Name: 3-Methoxynonane

All bold-faced terms in the chapter are listed at the end of each chapter and defined in the Glossary at the end of the text. The student can easily find important terms when reading and studying.

At the end of each chapter is a summary designed to help students more easily identify important concepts and help them review for quizzes and tests.



Summary

16.1 Amines

Amines are a family of organic compounds that contain an amino group or substituted amino group. A *primary amine* has the general formula RNH_2; a *secondary amine* has the general formula R_2NH; and a *tertiary amine* has the general formula R_3N. In the *Chemical Abstracts* nomenclature system, amines are named as *alkanamines*. In the I.U.P.A.C. system they are named as *aminoalkanes*. In the common system they are named as *alkylamines*. Amines behave as weak bases, forming *alkylammonium ions* in water and alkylammonium salts when they react with acids. *Quaternary ammonium salts* are ammonium salts that have four organic groups bonded to the nitrogen atom.

16.2 Heterocyclic Amines

Heterocyclic amines are cyclic compounds having at least one nitrogen atom in the ring structure. *Alkaloids* are natural plant products that contain at least one heterocyclic ring. Many alkaloids have powerful biological effects.

16.3 Amides

Amides are formed in a reaction between a carboxylic acid derivative and an amine (or ammonia). The *amide bond* is the bond between the carbonyl carbon of the *acyl group* and the nitrogen of the amine. In the I.U.P.A.C. Nomenclature System they are named by replacing the *-oic acid* ending of the carboxylic acid with the *-amide* ending. In the common system of nomenclature the *-ic acid* ending of the carboxylic acid is replaced by the *-amide* ending. Hydrolysis of an amide produces a carboxylic acid and an amine (or ammonia).

16.4 A Preview of Amino Acids, Proteins, and Protein Synthesis

Proteins are polymers of amino acids joined to one another by *amide bonds* called *peptide bonds*. During protein synthesis the *aminoacyl group* of one amino acid is transferred from a carrier molecule called a *transfer RNA* to the amino group nitrogen of another amino acid.

16.5 Neurotransmitters

Neurotransmitters are chemicals that carry messages, or signals, from a nerve cell to a target cell, which may be another nerve cell or a muscle cell. They may be inhibitory or excitatory and all are nitrogen-containing compounds. The catecholamines include dopamine, norepinephrine, and epinephrine. Too little dopamine results in Parkinson's disease. Too much is associated with schizophrenia. Dopamine is also associated with addictive behavior. A deficiency of serotonin is associated with depression and eating disorders. Serotonin is involved in pain perception, regulation of body temperature, and sleep. Histamine contributes to allergy symptoms. Antihistamines block histamines and provide relief from allergies. γ-Aminobutyric acid (GABA) and glycine are inhibitory neurotransmitters. It is believed that GABA is involved in control of aggressive behavior. Acetylcholine is a neurotransmitter that functions at the neuromuscular junction, carrying signals from the nerve to the muscle. Nitric oxide and glutamate function in a positive feedback loop that is thought to be involved in learning and the formation of memories.

Key Terms

acyl group (16.3)
alkaloid (16.2)
alkylammonium ion (16.1)
amide (16.3)
amide bond (16.3)
amine (16.1)
aminoacyl group (16.4)
analgesic (16.2)
anesthetic (16.2)
heterocyclic amine (16.2)
neurotransmitter (16.5)
peptide bond (16.4)
primary (1°) amine (16.1)
quaternary ammonium salt (16.1)
secondary (2°) amine (16.1)
tertiary (3°) amine (16.1)
transfer RNA (tRNA) (16.4)

Questions and Problems

Amines

16.15 For each pair of compounds predict which would have greater solubility in water. Explain your reasoning.
a. Pentane or 1-butanamine
b. Cyclohexane or 2-pentanamine

16.16 For each pair of compounds predict which would have the higher boiling point. Explain your reasoning.
a. Ethanamine or ethanol
b. Butane or 1-propanamine
c. Methanamine or water
d. Ethylmethylamine or butane

16.17 Explain why a tertiary amine such as triethylamine has a significantly lower boiling point than its primary amine isomer, 1-hexanamine.

16.18 Draw a diagram to illustrate your answer to Problem 16.17.

16.19 Use the *Chemical Abstracts* system of nomenclature to name each of the following amines:
a. $CH_3CH_2CH(CH_3)—NH_2$
b. $CH_3CH_2CH_2CH(NH_2)CH_2CH_3$
c. cyclopentyl—NH_2
d. $(CH_3)_3C—NH_2$

16.20 Use the CA and common nomenclature systems to name each of the following amines:
a. $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2—NH_2$
b. Cl—C_6H_4—NH_2