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| 18 Ar Argon 39.948 | | 18 Ar Argon 39.948 | | 26 Fe Iron 55.845 | | 34 Se Selenium 78.96 | | 42 Mo Molybdenum 95.94 | | 50 Sn Tin 118.71 | | 58 Ce Cerium 140.12 | | 66 Dy Dysprosium 162.50 | | 74 W Tungsten 183.84 | | 82 Pb Lead 207.2 | | 90 Th Thorium 232.04 | | 94 Pu Plutonium (244) | | | |
| 19 K Potassium 39.098 | | 19 K Potassium 39.098 | | 27 Co Cobalt 58.933 | | 35 Br Bromine 79.904 | | 43 Tc Technetium (98) | | 51 Sb Antimony 121.76 | | 59 Pr Praseodymium 140.91 | | 67 Ho Holmium 164.93 | | 75 Re Rhenium 186.21 | | 83 Bi Bismuth 208.98 | | 91 Pa Protactinium 231.04 | | 93 Np Neptunium (237) | | | |
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| 21 Sc Scandium 44.956 | | 21 Sc Scandium 44.956 | | 29 Cu Copper 63.546 | | 37 Rb Rubidium 85.468 | | 46 Pd Palladium 106.42 | | 54 Xe Xeno 131.29 | | 62 Sm Samarium 150.36 | | 70 Yb Ytterbium 173.04 | | 78 Pt Platinum 195.08 | | 86 Rn Radon (222) | | 93 Np Neptunium (237) | | 95 Am Americium (243) | | | |
| 22 Ti Titanium 47.867 | | 22 Ti Titanium 47.867 | | 30 Zn Zinc 65.409 | | 38 Sr Strontium 87.62 | | 47 Ag Silver 107.87 | | 55 Cs Caesium 132.91 | | 63 Eu Europium 151.96 | | 71 Lu Lutetium 174.97 | | 80 Hg Mercury 200.59 | | 88 #Ac Actinium (227) | | 94 Pu Plutonium (244) | | 96 Cm Curium (247) | | | |
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| 24 Cr Chromium 51.996 | | 24 Cr Chromium 51.996 | | 32 Ge Germanium 72.64 | | 40 Zr Zirconium 91.224 | | 49 In Indium 114.82 | | 57 La Lanthanum (139) | | 65 Tb Terbium 158.93 | | 73 U Uranium (238) | | 82 Pb Lead 207.2 | | 90 Th Thorium 232.04 | | 96 Cm Curium (247) | | 98 Cf Californium (251) | | | |
| 25 Mn Manganese 54.938 | | 25 Mn Manganese 54.938 | | 33 As Arsenic 74.922 | | 41 Nb Niobium 92.906 | | 50 Sn Tin 118.71 | | 58 Ce Cerium 140.12 | | 66 Dy Dysprosium 162.50 | | 74 W Tungsten 183.84 | | 83 Bi Bismuth 208.98 | | 91 Pa Protactinium 231.04 | | 97 Bk Berkelium (247) | | 99 Es Einsteinium (252) | | | |
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| 27 Co Cobalt 58.933 | | 27 Co Cobalt 58.933 | | 35 Br Bromine 79.904 | | 43 Tc Technetium (98) | | 52 Te Tellurium 127.60 | | 60 Nd Neodymium 144.24 | | 68 Er Erbium 167.26 | | 76 Os Osmium 190.23 | | 85 At Astatine (210) | | 93 Np Neptunium (237) | | 99 Es Einsteinium (252) | | 101 Md Mendelevium (258) | | | |
| 28 Ni Nickel 58.693 | | 28 Ni Nickel 58.693 | | 36 Kr Krypton 83.798 | | 44 Ru Ruthenium 101.07 | | 53 I Iodine 126.90 | | 61 Pm Promethium (145) | | 69 Tm Thulium 168.93 | | 77 Ir Iridium 192.22 | | 86 Rn Radon (222) | | 94 Pu Plutonium (244) | | 100 Fm Fermium (257) | | 102 No Nobelium (259) | | | |
| 29 Cu Copper 63.546 | | 29 Cu Copper 63.546 | | 37 Rb Rubidium 85.468 | | 45 Rh Rhodium 102.91 | | 54 Xe Xeno 131.29 | | 62 Sm Samarium 150.36 | | 70 Yb Ytterbium 173.04 | | 78 Pt Platinum 195.08 | | 87 Fr Francium (223) | | 95 Am Americium (243) | | 101 Md Mendelevium (258) | | 103 Lr Lawrencium (262) | | | |
| 30 Zn Zinc 65.409 | | 30 Zn Zinc 65.409 | | 38 Sr Strontium 87.62 | | 46 Pd Palladium 106.42 | | 55 Cs Caesium 132.91 | | 63 Eu Europium 151.96 | | 71 Lu Lutetium 174.97 | | 80 Hg Mercury 200.59 | | 88 #Ac Actinium (227) | | 96 Cm Curium (247) | | 102 No Nobelium (259) | | 104 Rf Rutherfordium (261) | | | |
| 31 Ga Gallium 69.723 | | 31 Ga Gallium 69.723 | | 39 Y Yttrium 88.906 | | 47 Ag Silver 107.87 | | 56 Ba Barium 137.33 | | 64 Gd Gadolinium 157.25 | | 72 Hf Hafnium 178.49 | | 81 Tl Thallium 204.38 | | 89 *La Lanthanum (139) | | 97 Bk Berkelium (247) | | 103 Lr Lawrencium (262) | | 105 Db Dubnium (262) | | | |
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| 36 Kr Krypton 83.798 | | 36 Kr Krypton 83.798 | | 44 Ru Ruthenium 101.07 | | 52 Te Tellurium 127.60 | | 53 I Iodine 126.90 | | 69 Tm Thulium 168.93 | | 77 Ir Iridium 192.22 | | 86 Rn Radon (222) | | 94 Pu Plutonium (244) | | 102 No Nobelium (259) | | 108 Hs Hassium (277) | | 110 Dn Darmstadtium (281) | | | |
| 37 Rb Rubidium 85.468 | | 37 Rb Rubidium 85.468 | | 45 Rh Rhodium 102.91 | | 53 I Iodine 126.90 | | 54 Xe Xeno 131.29 | | 70 Yb Ytterbium 173.04 | | 78 Pt Platinum 195.08 | | 87 Fr Francium (223) | | 95 Am Americium (243) | | 103 Lr Lawrencium (262) | | 109 Mt Meitnerium (268) | | 111 Rg Roentgenium (282) | | | |
| 38 Sr Strontium 87.62 | | 38 Sr Strontium 87.62 | | 46 Pd Palladium 106.42 | | 54 Xe Xeno 131.29 | | 55 Cs Caesium 132.91 | | 71 Lu Lutetium 174.97 | | 79 Au Gold 196.97 | | 88 #Ac Actinium (227) | | 96 Cm Curium (247) | | 104 Rf Rutherfordium (261) | | 110 Dn Darmstadtium (281) | | 112 Uub Ununbium (285) | | | |
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| 40 Zr Zirconium 91.224 | | 40 Zr Zirconium 91.224 | | 48 Cd Cadmium 112.41 | | 56 Ba Barium 137.33 | | 57 La Lanthanum (139) | | 73 U Uranium (238) | | | | | | | | | | | | | | | |

TABLE 3.1

Relative Strength of Selected Acids and Their Conjugate Bases

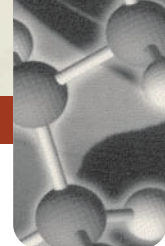
| | Acid | Approximate pK_a | Conjugate Base | |
|----------------|---|--------------------|-------------------------------------|----------------|
| Strongest acid | HSbF_6 | < -12 | SbF_6^- | Weakest base |
| | HI | -10 | I^- | |
| | H_2SO_4 | -9 | HSO_4^- | |
| | HBr | -9 | Br^- | |
| | HCl | -7 | Cl^- | |
| | $\text{C}_6\text{H}_5\text{SO}_3\text{H}$ | -6.5 | $\text{C}_6\text{H}_5\text{SO}_3^-$ | |
| | $(\text{CH}_3)_2\text{OH}^+$ | -3.8 | $(\text{CH}_3)_2\text{O}$ | |
| | $(\text{CH}_3)_2\text{C}=\text{OH}^+$ | -2.9 | $(\text{CH}_3)_2\text{C}=\text{O}$ | |
| | CH_3OH_2^+ | -2.5 | CH_3OH | |
| | H_3O^+ | -1.74 | H_2O | |
| | HNO_3 | -1.4 | NO_3^- | |
| | $\text{CF}_3\text{CO}_2\text{H}$ | 0.18 | CF_3CO_2^- | |
| | HF | 3.2 | F^- | |
| | $\text{C}_6\text{H}_5\text{CO}_2\text{H}$ | 4.21 | $\text{C}_6\text{H}_5\text{CO}_2^-$ | |
| | $\text{C}_6\text{H}_5\text{NH}_3^+$ | 4.63 | $\text{C}_6\text{H}_5\text{NH}_2$ | |
| | $\text{CH}_3\text{CO}_2\text{H}$ | 4.75 | CH_3CO_2^- | |
| | H_2CO_3 | 6.35 | HCO_3^- | |
| | $\text{CH}_3\text{COCH}_2\text{COCH}_3$ | 9.0 | $\text{CH}_3\text{COHCOCH}_3$ | |
| | NH_4^+ | 9.2 | NH_3 | |
| | $\text{C}_6\text{H}_5\text{OH}$ | 9.9 | $\text{C}_6\text{H}_5\text{O}^-$ | |
| | HCO_3^- | 10.2 | CO_3^{2-} | |
| | CH_3NH_3^+ | 10.6 | CH_3NH_2 | |
| | H_2O | 15.7 | OH^- | |
| | $\text{CH}_3\text{CH}_2\text{OH}$ | 16 | $\text{CH}_3\text{CH}_2\text{O}^-$ | |
| | $(\text{CH}_3)_3\text{COH}$ | 18 | $(\text{CH}_3)_3\text{CO}^-$ | |
| | CH_3COCH_3 | 19.2 | $^-\text{CH}_2\text{COCH}_3$ | |
| | $\text{HC}\equiv\text{CH}$ | 25 | $\text{HC}\equiv\text{C}^-$ | |
| | H_2 | 35 | H^- | |
| | NH_3 | 38 | NH_2^- | |
| | $\text{CH}_2=\text{CH}_2$ | 44 | $\text{CH}_2=\text{CH}^-$ | |
| Weakest acid | CH_3CH_3 | 50 | CH_3CH_2^- | Strongest base |

Increasing acid strength

Increasing base strength

TENTH EDITION

Organic Chemistry



TENTH EDITION

Organic Chemistry

T.W. GRAHAM SOLOMONS

University of South Florida

CRAIG B. FRYHLE

Pacific Lutheran University



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*In memory of my beloved son, John Allen Solomons, TWGS
To Deanna, in the year of our 25th anniversary. CBF*

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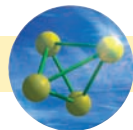
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"Capturing the Powerful and Exciting Subject of Organic Chemistry"

We want our students to learn organic chemistry as well and as easily as possible. We also want students to enjoy this exciting subject and to learn about the relevance of organic chemistry to their lives. At the same time, we want to help students develop the skills of critical thinking, problem solving, and analysis that are so important in today's world, no matter what career paths they choose. The richness of organic chemistry lends itself to solutions for our time, from the fields of health care, to energy, sustainability, and the environment.

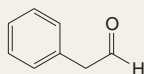
Guided by these goals, and by wanting to make our book even more **accessible to students** than it has ever been before, we have brought many changes to this edition.

New To This Edition

- **Solved Problems.** We have greatly increased the number of Solved Problems. Now over 150 **Solved Problems** guide students in their strategies for problem solving. Solved Problems are **usually paired with a related Review Problem**.
- **Review Problems.** In-text **Review Problems**, over 10% of them new, provide students with opportunities to check their progress as they study. If they can work the review problem, they should move on. If not, they should review the preceding presentation.

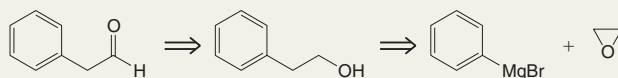
Solved Problem 12.6

ILLUSTRATING A MULTISTEP SYNTHESIS Starting with bromobenzene and any other needed reagents, outline a synthesis of the following aldehyde:

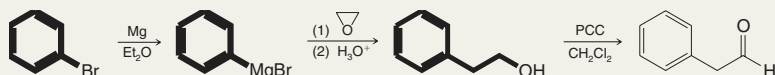


ANSWER Working backward, we remember that we can synthesize the aldehyde from the corresponding alcohol by oxidation with PCC (Section 12.4A). The alcohol can be made by treating phenylmagnesium bromide with oxirane. [Adding oxirane to a Grignard reagent is a very useful method for adding a $-\text{CH}_2\text{CH}_2\text{OH}$ unit to an organic group (Section 12.7B).] Phenylmagnesium bromide can be made in the usual way, by treating bromobenzene with magnesium in an ether solvent.

Retrosynthetic Analysis

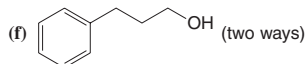
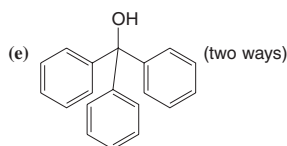
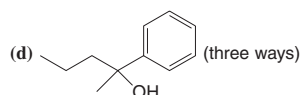
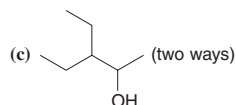
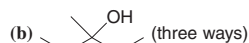
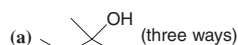


Synthesis



Provide retrosynthetic analyses and syntheses for each of the following alcohols, starting with appropriate alkyl or aryl halides.

Review Problem 12.8





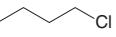
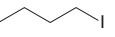
- End-of-chapter problems have been grouped and labeled by topic. Students and instructors can more easily select problems for specific purposes.


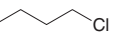
- **End-of-Chapter Problems.** Over 15% of the end-of-chapter problems are new, and others have been revised.


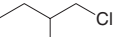
RELATIVE RATES OF NUCLEOPHILIC SUBSTITUTION

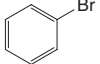
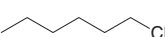
6.20 Which alkyl halide would you expect to react more rapidly by an S_N2 mechanism? Explain your answer.

(a) -Br or -Br





(b) -Cl or -I

(c) -Cl or -Cl

(d) -Cl or -Cl

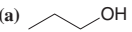
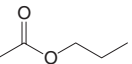
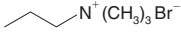
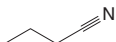
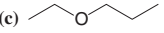
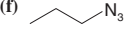
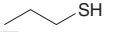
(e) -Br or -Cl

6.21 Which S_N2 reaction of each pair would you expect to take place more rapidly in a protic solvent?

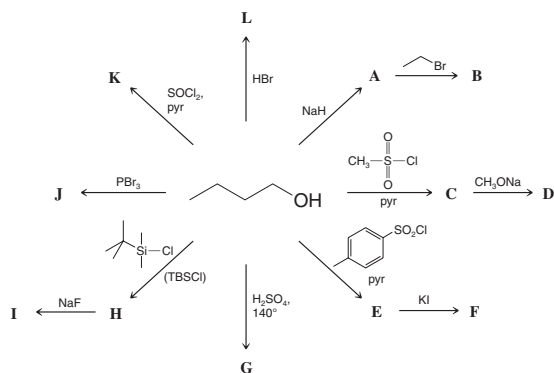
(a) (1)  + $\text{EtO}^- \rightarrow$  + Cl^-
or
(2)  + $\text{EtOH} \rightarrow$  + HCl

SYNTHESIS

6.23 Show how you might use a nucleophilic substitution reaction of 1-bromopropane to synthesize each of the following compounds. (You may use any other compounds that are necessary.)

(a)  (e)  (g) 
 (b) 1-Iodopropane (h) 
 (c)  (f) 
 (d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{-S-CH}_3$ (i) 

- 11.34** Considering A–L to represent the major products formed in each of the following reactions, provide a structure for each of A through L. If more than one product can reasonably be conceived from a given reaction, include those as well.



- Throughout the book, more problems are cast in a visual format using structures, equations, and schemes. In addition, we still provide **Challenge Problems** and **Learning Group Problems** to serve additional teaching goals.
- Key ideas in every section have been rewritten and emphasized as **bullet points** to help students focus on the most essential topics.

3.2A Brønsted–Lowry Acids and Bases

Two classes of acid–base reactions are fundamental in organic chemistry: Brønsted–Lowry and Lewis acid–base reactions. We start our discussion with Brønsted–Lowry acid–base reactions.

- Brønsted–Lowry acid–base reactions involve the transfer of protons.
- A **Brønsted–Lowry acid** is a substance that can donate (or lose) a proton.
- A **Brønsted–Lowry base** is a substance that can accept (or remove) a proton.

- “How to” Sections give step-by-step instructions to guide students in performing important tasks, such as using curved arrows, drawing chair conformations, planning a Grignard synthesis, determining formal charges, writing Lewis structures, and using ^{13}C and ^1H NMR spectra to determine structure.

3.5 How to Use Curved Arrows in Illustrating Reactions

Up to this point we have not indicated how bonding changes occur in the reactions we have presented, but this can easily be done using curved-arrow notation.

Curved arrows

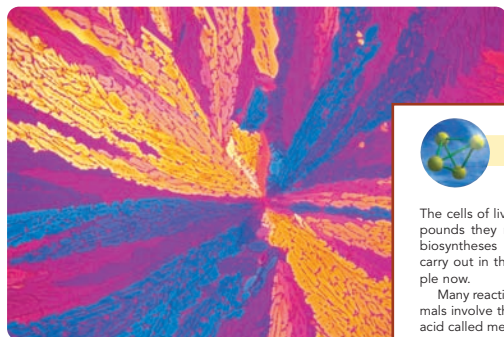
- show the direction of electron flow in a reaction mechanism.
- point from the source of an electron pair to the atom receiving the pair. (Curved arrows can also show the movement of single electrons. We shall discuss reactions of this type in a later chapter.)
- always show the flow of electrons from a site of higher electron density to a site of lower electron density.
- **never** show the movement of atoms. Atoms are assumed to follow the flow of the electrons.

- New and updated **chapter-opening vignettes** and **The Chemistry of . . .** boxes bring organic chemistry home to everyday life experiences. **More photos are included** to help students relate organic chemistry to the world around them.

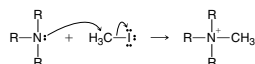
6

Ionic Reactions

Nucleophilic Substitution and Elimination Reactions of Alkyl Halides



Organic syntheses, whether they take place in the glassware of the laboratory or in the cells of living organisms, often involve fairly simple processes, such as the installation of a methyl group on the nitrogen atom of a tertiary amine. For example, we may want to install a methyl group on the nitrogen atom of a tertiary amine. To do this we often employ a reaction with an important counterpart in biochemistry. To do this we often employ a reaction



If we wanted to describe this reaction to an organic chemist we would describe it as a **methyl iodide reaction**, a kind of reaction we describe in detail in this chapter.

On the other hand, if we wanted to describe this reaction to a biochemist we would describe it as a **methyl transfer reaction**. Biochemists have described many similar reactions this way, for example, the reaction in which

S-adenosylmethionine (SAM) to a tertiary amine to make choline. Choline is incorporated into the phospholipids of our cell membranes, and it is the hydrolysis product of acetylcholine, an important neurotransmitter. (Crystals of acetylcholine are shown in the polarized light microscopy image above.)

Now, the biological reaction may seem more complicated, but its essence is similar to many nucleophilic substitution reactions we shall study in this chapter. First we consider alkyl halides, one of the most important types of reactants in nucleophilic substitution reactions.

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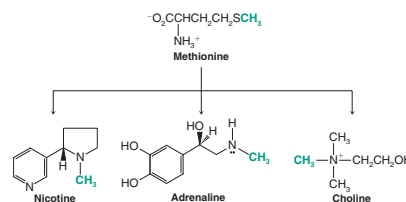
THE CHEMISTRY OF . . .

Biological Methylation: A Biological Nucleophilic Substitution Reaction

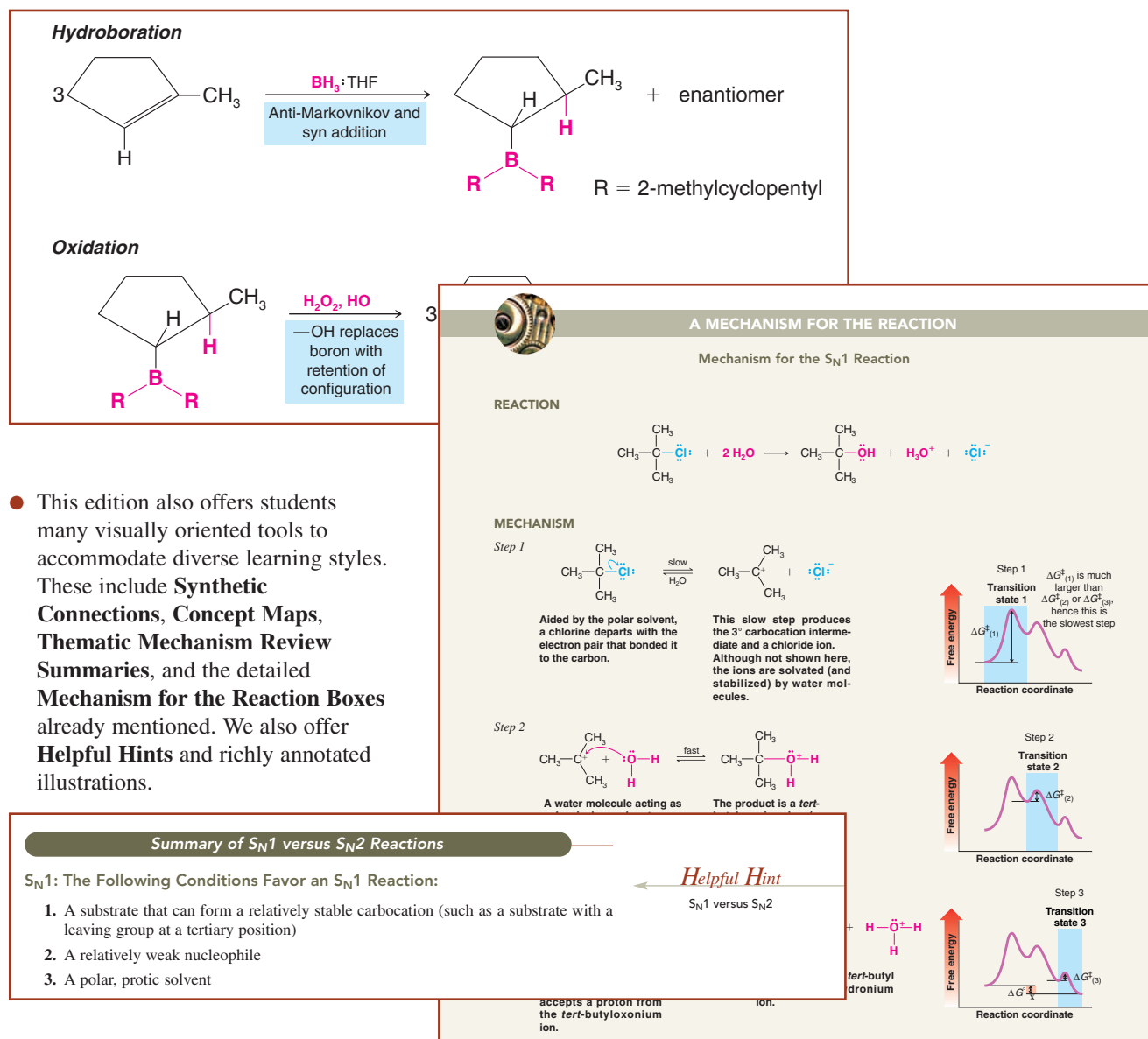
The cells of living organisms synthesize many of the compounds they need from smaller molecules. Often these biosyntheses resemble the syntheses organic chemists carry out in their laboratories. Let us examine one example now.

Many reactions taking place in the cells of plants and animals involve the transfer of a methyl group from an amino acid called methionine to some other compound. That this

transfer takes place can be demonstrated experimentally by feeding a plant or animal methionine containing an isotopically labeled carbon atom (e.g., ^{13}C or ^{14}C) in its methyl group. Later, other compounds containing the “labeled” methyl group can be isolated from the organism. Some of the compounds that get their methyl groups from methionine are the following. The isotopically labeled carbon atom is shown in green.



- **Bond-line formulas** replace almost all dash and condensed structural formulas after Chapter One where they are introduced and explained. Bond-line formulas are cleaner, simpler, and faster for students to interpret, and they are the format most often used by chemists to depict organic molecules.



- Chapters on **carbonyl chemistry** have been reorganized to emphasize mechanistic themes of nucleophilic addition, acyl substitution, and reactivity at the α -carbon.
- The important modern synthetic methods of the **Grubbs**, **Heck**, **Sonogashira**, **Stille**, and **Suzuki** transition metal catalyzed carbon-carbon bond-forming reactions are presented in a practical and student-oriented way that includes review problems and mechanistic context (Special Topic G).
- Throughout the book, we have **streamlined or reduced content** to match the modern practice of organic chemistry, and we have provided new coverage of current reactions. We have made our book more accessible to students than ever before. While maintaining our commitment to an appropriate level and breadth of coverage.

Organization - An Emphasis on the Fundamentals

So much of organic chemistry makes sense and can be generalized if students master and apply a few fundamental concepts. Therein lays the beauty of organic chemistry. If students learn the essential principles, they will see that memorization is not needed to succeed in organic chemistry.

Most important is for students to have a solid understanding of structure—of hybridization and geometry, steric hindrance, electronegativity, polarity, formal charges, and resonance — so that they can make intuitive sense of mechanisms. It is with these topics that we begin in Chapter 1. In Chapter 2 we introduce the families of functional groups – so that students have a platform on which to apply these concepts. We also introduce intermolecular forces, and infrared (IR) spectroscopy – a key tool for identifying functional groups. Throughout the book we include calculated models of molecular orbitals, electron density surfaces, and maps of electrostatic potential. These models enhance students' appreciation for the role of structure in properties and reactivity.

We begin our study of mechanisms in the context of acid-base chemistry in Chapter 3. Acid-base reactions are fundamental to organic reactions, and they lend themselves to introducing several important topics that students need early in the course: (1) curved arrow notation for illustrating mechanisms, (2) the relationship between free-energy changes and equilibrium constants, and (3) the importance of inductive and resonance effects and of solvent effects.

In Chapter 3 we present the first of many “Mechanism for the Reaction” boxes, using an example that embodies both Bronsted-Lowry and Lewis acid-base principles. All throughout the book, we use boxes like these to show the details of key reaction mechanisms. All of the Mechanism for the Reaction boxes are listed in the Table of Contents so that students can easily refer to them when desired.

A central theme of our approach is to emphasize the *relationship between structure and reactivity*. This is why we choose an organization that combines the most useful features of a functional group approach with one based on reaction mechanisms. Our philosophy is to emphasize mechanisms and fundamental principles, while giving students the anchor points of functional groups to apply their mechanistic knowledge and intuition. The structural aspects of our approach show students **what organic chemistry is**. Mechanistic aspects of our approach show students **how it works**. And wherever an opportunity arises, we show them **what it does** in living systems and the physical world around us.

In summary, our work on the 10th edition reflects the commitment we have as teachers to do the best we can to help students learn organic chemistry and to see how they can apply their knowledge to improve our world. The enduring features of our book have proven over the years to help students learn organic chemistry. The changes in our 10th edition make organic chemistry even more accessible and relevant. Students who use the in-text learning aids, work the problems, and take advantage of the resources and practice available in *WileyPLUS* (our online teaching and learning solution) will be assured of success in organic chemistry.



This online teaching and learning environment integrates the **entire digital textbook** with the most effective instructor and student resources to fit every learning style. With *WileyPLUS* (www.wileyplus.com):

- Students achieve concept mastery in a rich, structured environment that's available 24/7
- Instructors personalize and manage their course more effectively with assessment, assignments, grade tracking, and more.

WileyPLUS can complement your current textbook or replace the printed text altogether. The problem types and resources in *WileyPLUS* are designed to enable and support problem-solving skill development and conceptual understanding. **Three unique repositories of assessment are offered which provides breadth, depth and flexibility:**

1. **End of chapter exercises**, many of which are algorithmic, feature structure drawing/assessment functionality using MarvinSketch, and provide immediate answer feedback. A subset of these end of chapter questions are linked to **Guided Online Tutorials** which are stepped-out problem-solving tutorials that walk the student through the problem, offering individualized feedback at each step.

2-butanol

CCC(O)C $\xrightarrow[\text{heat}]{\text{H}_2\text{SO}_4}$?

Click on the drawing box above to activate the MarvinSketch drawing tool and then draw your answer to this question. If there is no reaction, then check the "no reaction" box below.

no reaction

2. **Test Bank questions** consisting of over 3,000 questions.

3. **Prebuilt concept mastery assignments**, organized by topic and concept, featuring robust answer feedback.

✓ Your answer is correct!

C=C(c1ccccc1)c2ccccc2 $\xrightarrow[2) \text{NaHSO}_3, \text{H}_2\text{O}]{1) \text{OsO}_4}$?

Click on the drawing box above to activate the MarvinSketch drawing tool and then draw your answer to this question. If there is no reaction, then check the "no reaction" box below.

no reaction

Show Answer

WileyPLUS For Students

Different learning styles, different levels of proficiency, different levels of preparation—each of your students is unique. *WileyPLUS* offers a myriad of rich multimedia resources for students to facilitate learning. These include:

- **Office Hour Videos:** The solved problems from the book are presented by an organic chemistry professor, using audio and a whiteboard. It emulates the experience that a student would get if she or he were to attend office hours and ask for assistance in working a problem. The goal is to illustrate good problem solving strategies.

03 Skill Building Exercise

- MO Bases of nucleophiles and electrophiles
 - Problem 1
 - Problem 2
 - Problem 3
 - Problem 4
 - Problem 5
 - Problem 6

Nucleophiles and Electrophiles: Problem #2

Click on all of the nucleophilic centers in the following compound, and then hit the submit button:

CC1=CCCC(S)C1

- **SkillBuilding Exercises:** Animated exercises, with instant feedback, reinforce the key skills required to succeed in organic chemistry.
- **Core Concept Animations:** Concepts are thoroughly explained using audio and whiteboard.

WileyPLUS For Instructors

WileyPLUS empowers you with the tools and resources you need to make your teaching even more effective:

- You can customize your classroom presentation with a wealth of resources and functionality from PowerPoint slides to a database of rich visuals. You can even add your own materials to your *WileyPLUS* course.
- *WileyPLUS* allows you to help students who might fall behind, by tracking their progress and offering assistance easily, even before they come to office hours.
- *WileyPLUS* simplifies and automates such tasks as student performance assessment, creating assignments, scoring student work, keeping grades, and more.

Supplements

Study Guide and Solutions Manual (ISBN 978-0-470-47839-4)

The Study Guide and Solutions Manual for *Organic Chemistry, Tenth Edition*, authored by Robert Johnson, of Xavier University, Craig Fryhle, Graham Solomons, with contributions from Christopher Callam, of The Ohio State University, **contains explained solutions to all of the problems in the text.** The Study Guide also contains:

- An introductory essay “Solving the Puzzle—or—Structure is Everything” that serves as a bridge from general to organic chemistry
- Summary tables of reactions by mechanistic type and functional group
- A review quiz for each chapter
- A set of hands-on molecular model exercises
- Solutions to the problems in the Special Topics sections (many of the Special Topics are only available within *WileyPLUS*)

Organic Chemistry as a Second Language™, Volumes I & II By David Klein (Johns Hopkins University)

David Klein's series of course companions has been an enormous success with students and instructors (Organic Chemistry as a Second Language, Part I, ISBN: 978-0-470-12929-6; Organic Chemistry as a Second Language, Part II, ISBN: 978-0-471-73808-5). Presenting fundamental principles, problem-solving strategies, and skill-building exercise in relaxed, student-friendly language, these books have been cited by many students as integral to their success in organic chemistry.

Molecular Visions™ Model Kits

We believe that the tactile experience of manipulating physical models is key to students' understanding that organic molecules have shape and occupy space. To support our pedagogy, we have arranged with the Darling Company to bundle a special ensemble of Molecular Visions™ model kits with our book (for those who choose that option). We use Helpful Hint icons and margin notes to frequently encourage students to use hand-held models to investigate the three-dimensional shape of molecules we are discussing in the book.

Instructor Resources

All Instructor Resources are available within *WileyPLUS* or they can be accessed by contacting your local Wiley Sales Representative.

Test Bank. Authored by Robert Rossi, of Gloucester County College, Justin Wyatt, of the College of Charleston, and Maged Henary, of Georgia State University, the Test Bank for this edition has been completely revised and updated to include over 3,000 short answer, multiple choice, and essay/drawing questions. It is available in both a printed and computerized version.

PowerPoint Lecture slides. A set of PowerPoint Lecture Slides have been prepared by Professor William Tam, of the University of Guelph and his wife, Dr. Phillis Chang. This new set of PowerPoint slides includes additional examples, illustrations, and presentations that help reinforce and test students' grasp of organic chemistry concepts. An additional set of PowerPoint slides features the illustrations, figures, and tables from the text. All PowerPoint slide presentations are customizable to fit your course.

Personal Response System (“Clicker”) Questions. A bank of questions is available for anyone using personal response system technology in their classroom. The clicker questions are also available in a separate set of PowerPoint slides.

Digital Image Library. Images from the text are available online in JPEG format. Instructors may use these to customize their presentations and to provide additional visual support for quizzes and exams.

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About the Authors

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Craig Barton Fryhle **Craig Barton Fryhle** is Chair and Professor of Chemistry at Pacific Lutheran University. He earned his B.A. degree from Gettysburg College and Ph.D. from Brown University. His experiences at these institutions shaped his dedication to mentoring undergraduate students in chemistry and the liberal arts, which is a passion that burns strongly for him. His research interests have been in areas relating to the shikimic acid pathway, including molecular modeling and NMR spectrometry of substrates and analogues, as well as structure and reactivity studies of shikimate pathway enzymes using isotopic labeling and mass spectrometry. He has mentored many students in undergraduate research, a number of whom have later earned their Ph.D. degrees and gone on to academic or industrial positions. He has participated in workshops on fostering undergraduate participation in research, and has been an invited participant in efforts by the National Science Foundation to enhance undergraduate research in chemistry. He has received research and instrumentation grants from the National Science Foundation, the M J. Murdock Charitable Trust, and other private foundations. His work in chemical education, in addition to textbook co-authorship, involves incorporation of student-led teaching in the classroom and technology-based strategies in organic chemistry. He has also developed experiments for undergraduate students in organic laboratory and instrumental analysis courses. He has been a volunteer with the hands-on science program in Seattle public schools, and Chair of the Puget Sound Section of the American Chemical Society. He lives in Seattle with his wife and two daughters.

Contrary to what you may have heard, organic chemistry does not have to be a difficult course. It will be a rigorous course, and it will offer a challenge. But you will learn more in it than in almost any course you will take—and what you learn will have a special relevance to life and the world around you. However, because organic chemistry can be approached in a logical and systematic way, you will find that with the right study habits, mastering organic chemistry can be a deeply satisfying experience. Here, then, are some suggestions about how to study:

1. Keep up with your work from day to day—never let yourself get behind. Organic chemistry is a course in which one idea almost always builds on another that has gone before. It is essential, therefore, that you keep up with, or better yet, be a little ahead of your instructor. Ideally, you should try to stay one day ahead of your instructor's lectures in your own class preparations. The lecture, then, will be much more helpful because you will already have some understanding of the assigned material. Your time in class will clarify and expand ideas that are already familiar ones.

2. Study material in small units, and be sure that you understand each new section before you go on to the next. Again, because of the cumulative nature of organic chemistry, your studying will be much more effective if you take each new idea as it comes and try to understand it completely before you move on to the next concept.

3. Work all of the in-chapter and assigned problems. One way to check your progress is to work each of the in-chapter problems when you come to it. These problems have been written just for this purpose and are designed to help you decide whether or not you understand the material that has just been explained. You should also carefully study the Solved Problems. If you understand a Solved Problem and can work the related in-chapter problem, then you should go on; if you cannot, then you should go back and study the preceding material again. Work all of the problems assigned by your instructor from the end of the chapter, as well. Do all of your problems in a notebook and bring this book with you when you go to see your instructor for extra help.

4. Write when you study. Write the reactions, mechanisms, structures, and so on, over and over again. Organic chemistry is best assimilated through the fingertips by writing, and not through the eyes by simply looking, or by highlighting material in the text, or by referring to flash cards. There is a good reason for this. Organic structures,

mechanisms, and reactions are complex. If you simply examine them, you may think you understand them thoroughly, but that will be a misperception. The reaction mechanism may make sense to you in a certain way, but you need a deeper understanding than this. You need to know the material so thoroughly that you can explain it to someone else. This level of understanding comes to most of us (those of us without photographic memories) through writing. Only by writing the reaction mechanisms do we pay sufficient attention to their details, such as which atoms are connected to which atoms, which bonds break in a reaction and which bonds form, and the three-dimensional aspects of the structures. When we write reactions and mechanisms, connections are made in our brains that provide the long-term memory needed for success in organic chemistry. We virtually guarantee that your grade in the course will be directly proportional to the number of pages of paper that your fill with your own writing in studying during the term.

5. Learn by teaching and explaining. Study with your student peers and practice explaining concepts and mechanisms to each other. Use the *Learning Group Problems* and other exercises your instructor may assign as vehicles for teaching and learning interactively with your peers.

6. Use the answers to the problems in the *Study Guide* in the proper way. Refer to the answers only in two circumstances: (1) When you have finished a problem, use the *Study Guide* to check your answer. (2) When, after making a real effort to solve the problem, you find that you are completely stuck, then look at the answer for a clue and go back to work out the problem on your own. The value of a problem is in solving it. If you simply read the problem and look up the answer, you will deprive yourself of an important way to learn.

7. Use molecular models when you study. Because of the three-dimensional nature of most organic molecules, molecular models can be an invaluable aid to your understanding of them. When you need to see the three-dimensional aspect of a particular topic, use the Molecular Visions™ model set that may have been packaged with your textbook, or buy a set of models separately. An appendix to the *Study Guide* that accompanies this text provides a set of highly useful molecular model exercises.

8. Make use of the rich online teaching resources in *WileyPLUS* and do any online exercises that may be assigned by your instructor.

