

LEARNING MADE EASY

2nd Edition



Organic Chemistry I

WORKBOOK

for
dummies[®]
A Wiley Brand

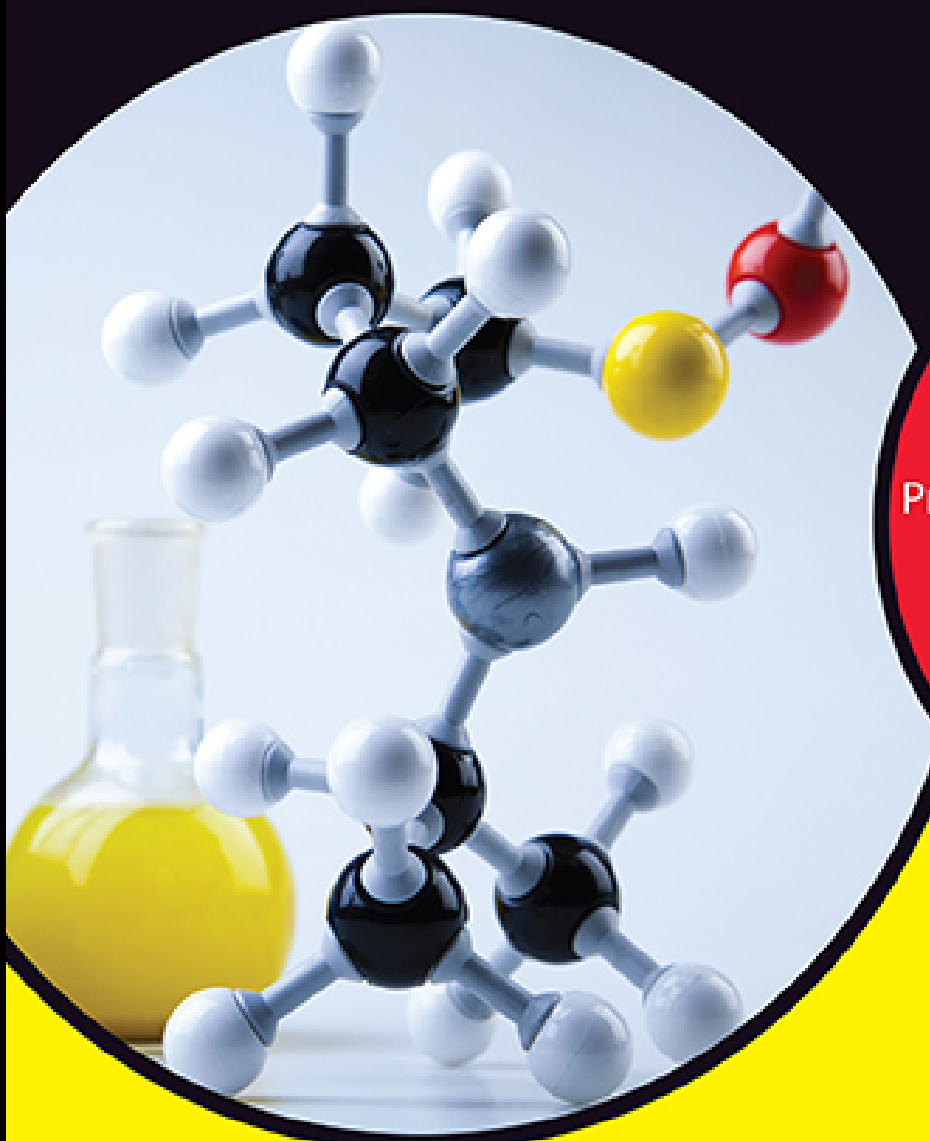
Review key organic
chemistry concepts

Practice solving organic chemistry
problems and structures

Get complete answer
explanations

Arthur Winter, PhD

Chemistry Professor





Organic Chemistry I Workbook

2nd Edition

by Arthur Winter, PhD

**for
dummies**[®]
A Wiley Brand

Organic Chemistry I Workbook For Dummies,® 2nd Edition

Published by: **John Wiley & Sons, Inc.**, 111 River Street, Hoboken, NJ 07030-5774, www.wiley.com

Copyright © 2022 by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the Publisher. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permissions>.

Trademarks: Wiley, For Dummies, the Dummies Man logo, Dummies.com, Making Everything Easier, and related trade dress are trademarks or registered trademarks of John Wiley & Sons, Inc. and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

<p>LIMIT OF LIABILITY/DISCLAIMER OF WARRANTY: WHILE THE PUBLISHER AND AUTHORS HAVE USED THEIR BEST EFFORTS IN PREPARING THIS WORK, THEY MAKE NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS WORK AND SPECIFICALLY DISCLAIM ALL WARRANTIES,</p>

INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. NO WARRANTY MAY BE CREATED OR EXTENDED BY SALES REPRESENTATIVES, WRITTEN SALES MATERIALS OR PROMOTIONAL STATEMENTS FOR THIS WORK. THE FACT THAT AN ORGANIZATION, WEBSITE, OR PRODUCT IS REFERRED TO IN THIS WORK AS A CITATION AND/OR POTENTIAL SOURCE OF FURTHER INFORMATION DOES NOT MEAN THAT THE PUBLISHER AND AUTHORS ENDORSE THE INFORMATION OR SERVICES THE ORGANIZATION, WEBSITE, OR PRODUCT MAY PROVIDE OR RECOMMENDATIONS IT MAY MAKE. THIS WORK IS SOLD WITH THE UNDERSTANDING THAT THE PUBLISHER IS NOT ENGAGED IN RENDERING PROFESSIONAL SERVICES. THE ADVICE AND STRATEGIES CONTAINED HEREIN MAY NOT BE SUITABLE FOR YOUR SITUATION. YOU SHOULD CONSULT WITH A SPECIALIST WHERE APPROPRIATE. FURTHER, READERS SHOULD BE AWARE THAT WEBSITES LISTED IN THIS WORK MAY HAVE CHANGED OR DISAPPEARED BETWEEN WHEN THIS WORK WAS WRITTEN AND WHEN IT IS READ. NEITHER THE PUBLISHER NOR AUTHORS SHALL BE LIABLE FOR ANY LOSS OF PROFIT OR ANY OTHER COMMERCIAL DAMAGES, INCLUDING BUT NOT LIMITED TO SPECIAL, INCIDENTAL, CONSEQUENTIAL, OR OTHER DAMAGES.

For general information on our other products and services, please contact our Customer Care Department within the U.S. at 877-762-2974, outside the U.S. at 317-572-3993, or fax 317-572-4002. For technical support, please visit <https://hub.wiley.com/community/support/dummies>.

Wiley publishes in a variety of print and electronic formats and by print-on-demand. Some material included with standard print versions of this book may not be included in e-books or in print-on-demand. If this book refers to media such as a CD or DVD that is not included in the version you purchased, you may download this material at <http://booksupport.wiley.com>. For more information about Wiley products, visit www.wiley.com.

Library of Congress Control Number: 2021950191

ISBN 978-1-119-85577-4 (pbk); ISBN 978-1-119-85578-1 (ebk); ISBN 978-1-119-85579-8 (ebk)

Organic Chemistry I Workbook For Dummies®

To view this book's Cheat Sheet, simply go to www.dummies.com and search for “Organic Chemistry I Workbook For Dummies Cheat Sheet” in the Search box.

Table of Contents

[Cover](#)

[Title Page](#)

[Copyright](#)

[Introduction](#)

[About This Book](#)

[Foolish Assumptions](#)

[Icons Used in This Book](#)

[Beyond the Book](#)

[Where to Go from Here](#)

[**Part 1: The Fundamentals of Organic Chemistry**](#)

[**Chapter 1: Working with Models and Molecules**](#)

[Constructing Lewis Structures](#)

[Predicting Bond Types](#)

[Determining Bond Dipoles](#)

[Determining Dipole Moments for Molecules](#)

[Predicting Atom Hybridizations and Geometries](#)

[Making Orbital Diagrams](#)

[Answer Key](#)

Chapter 2: Speaking Organic Chemistry: Drawing and Abbreviating Lewis Structures

[Assigning Formal Charges](#)

[Determining Lone Pairs on Atoms](#)

[Abbreviating Lewis Structures with Condensed Structures](#)

[Drawing Line-Bond Structures](#)

[Determining Hydrogens on Line-Bond Structures](#)

[Answer Key](#)

Chapter 3: Drawing Resonance Structures

[Seeing Cations Next to a Double Bond, Triple Bond, or Lone Pair](#)

[Pushing Lone Pairs Next to a Double or Triple Bond](#)

[Pushing Double or Triple Bonds Containing an Electronegative Atom](#)

[Alternating Double Bonds around a Ring](#)

[Drawing Multiple Resonance Structures](#)

[Assigning Importance to Resonance Structures](#)

[Answer Key](#)

Chapter 4: Working with Acids and Bases

[Defining Acids and Bases](#)

[Comparing Acidities of Organic Molecules](#)

[Predicting Acid-Base Equilibria Using pKa Values](#)

[Answer Key](#)

Part 2: The Bones of Organic Molecules: The Hydrocarbons

Chapter 5: Seeing Molecules in 3-D: Stereochemistry

[Identifying Chiral Centers and Assigning Substituent Priorities](#)

[Assigning R & S Configurations to Chiral Centers](#)

[Working with Fischer Projections](#)

[Comparing Relationships between Stereoisomers and Meso Compounds](#)

[Answer Key](#)

Chapter 6: The Skeletons of Organic Molecules: The Alkanes

[Understanding How to Name Alkanes](#)

[Drawing a Structure from a Name](#)

[Answer Key](#)

Chapter 7: Shaping Up with Bond Calisthenics and Conformation

[Setting Your Sights on Newman Projections](#)

[Comparing Conformational Stability](#)

[Choosing Sides: The Cis-Trans Stereochemistry of Cycloalkanes](#)

[Getting a Ringside Seat with Cyclohexane Chair Conformations](#)

[Predicting Cyclohexane Chair Stabilities](#)

[Answer Key](#)

Chapter 8: Doubling Down: The Alkenes

[Giving Alkenes a Good Name](#)

[Markovnikov Mixers: Adding Hydrohalic Acids to Alkenes](#)

[Adding Halogens and Hydrogen to Alkenes](#)

[Just Add Water: Adding H₂O to Alkenes](#)

[Seeing Carbocation Rearrangements](#)

[Answer Key](#)

Chapter 9: Tripling the Fun: Alkyne Reactions and Nomenclature

[Playing the Name Game with Alkynes](#)

[Adding Hydrogen and Reducing Alkynes](#)

[Adding Halogens and Hydrohalic Acids to Alkynes](#)

[Adding Water to Alkynes](#)

[Creating Alkynes](#)

[Back to the Beginning: Working Multistep Synthesis Problems](#)

[Answer Key](#)

Part 3: Functional Groups and Their Reactions

Chapter 10: The Leaving Group Boogie: Substitution and Elimination of Alkyl Halides

[The Replacements: Comparing \$S_N1\$ and \$S_N2\$ Reactions](#)

[Kicking Out Leaving Groups with Elimination Reactions](#)

[Putting It All Together: Substitution and Elimination](#)

[Answer Key](#)

Chapter 11: Not as Thunk as You Drink I Am: The Alcohols

[Name Your Poison: Alcohol Nomenclature](#)

[Beyond Homebrew: Making Alcohols](#)

[Transforming Alcohols \(without Committing a Party Foul\)](#)

[Answer Key](#)

Chapter 12: Conjugated Dienes and the Diels-Alder Reaction

[Seeing 1,2- and 1,4-Addition Reactions to Conjugated Dienes](#)

[Dienes and Their Lovers: Working Forward in the Diels-Alder Reaction](#)

[Reverse Engineering: Working Backward in the Diels-Alder Reaction](#)

[Answer Key](#)

Chapter 13: The Power of the Ring: Aromatic Compounds

[Determining Aromaticity, Anti-aromaticity, or Nonaromaticity of Rings](#)

[Figuring Out a Ring System's MO Diagram](#)

[Dealing with Directors: Reactions of Aromatic Compounds](#)

[Order! Tackling Multistep Synthesis of Polysubstituted Aromatic Compounds](#)

[Answer Key](#)

Part 4: Detective Work: Spectroscopy and Spectrometry

Chapter 14: Breaking Up (Isn't Hard to Do): Mass Spectrometry

[Identifying Fragments in the Mass Spectrum](#)

[Predicting a Structure Given a Mass Spectrum](#)

[Answer Key](#)

Chapter 15: Cool Vibrations: IR Spectroscopy

[Distinguishing between Molecules Using IR Spectroscopy](#)

[Identifying Functional Groups from an IR Spectrum](#)

[Answer Key](#)

Chapter 16: Putting Molecules under the Magnet: NMR Spectroscopy

[Seeing Molecular Symmetry](#)

[Working with Chemical Shifts, Integration, and Coupling](#)

[Putting It All Together: Solving for Unknown Structures Using Spectroscopy](#)

[Answer Key](#)

Part 5: The Part of Tens

Chapter 17: The Ten Commandments of Organic Chemistry

[Thou Shalt Work the Practice Problems before Reading the Answers](#)

[Thou Shalt Memorize Only What Thou Must](#)

[Thou Shalt Understand Thy Mechanisms](#)

[Thou Shalt Sleep at Night and Not in Class](#)

[Thou Shalt Read Ahead Before Class](#)

[Thou Shalt Not Fall Behind](#)

[Thou Shalt Know How Thou Learnest Best](#)

[Thou Shalt Not Skip Class](#)

[Thou Shalt Ask Questions](#)

[Thou Shalt Keep a Positive Outlook](#)

Chapter 18: Ten Tips for Acing Orgo Exams

[Scan and Answer the Easy Questions First](#)

[Read All of Every Question](#)

[Set Aside Time Each Day to Study](#)

[Form a Study Group](#)

[Get Old Exams](#)

[Make Your Answers Clear by Using Structures](#)

[Don't Try to Memorize Your Way Through](#)

[Work a Lot of Problems](#)

[Get Some Sleep the Night Before](#)

[Recognize Red Herrings](#)

Chapter 19: Ten Cool Natural Products

[Maitotoxin](#)

[Penicillin](#)

[Nicotine](#)

[THC](#)

[Morphine](#)

[Taxol](#)

[Bombykol](#)

[The Green Fluorescent Protein Fluorophore](#)

[Ladderanes](#)

[Caffeine](#)

[Index](#)

[About the Author](#)

[Advertisement Page](#)

[Connect with Dummies](#)

[End User License Agreement](#)

List of Tables

Chapter 1

[Table 1-1 The Hybridization of an Atom](#)

Chapter 6

[Table 6-1 Parent and Substituent Names](#)

Chapter 8

[Table 8-1 Naming the Parent Chains](#)

Chapter 10

[Table 10-1 Structural Preferences for Replacements](#)

[Table 10-2 Reaction Conditions for Elimination Mechanisms](#)

Chapter 15

[Table 15-1 IR Absorption of Common Functional Groups](#)

Chapter 16

[Table 16-1 Common Fragments](#)

List of Illustrations

Chapter 1

[FIGURE 1-1: Electronegativity values for common atoms.](#)

Chapter 2

[FIGURE 2-1: Charge patterns for common atoms.](#)

Chapter 4

[FIGURE 4-1: Bronsted-Lowry acids and bases reacting.](#)

[FIGURE 4-2: Lewis acids and bases.](#)

Chapter 5

[FIGURE 5-1: Breaking ties when prioritizing substituents.](#)

[FIGURE 5-2: Double and triple bonds using the Cahn-Ingold-Prelog rules.](#)

[FIGURE 5-3: Using wedges and dashes.](#)

[FIGURE 5-4: Converting a 3-D representation to a Fischer projection.](#)

Chapter 6

[FIGURE 6-1: Common names for complex substituents.](#)

Chapter 7

[FIGURE 7-1: Newman projection of ethane.](#)

[FIGURE 7-2: Building the Newman projection of ethane.](#)

[FIGURE 7-3: Eclipsed and staggered conformations.](#)

[FIGURE 7-4: Anti, gauche, eclipsed, and totally eclipsed conformations.](#)

[FIGURE 7-5: *Cis* and *trans* configurations.](#)

[FIGURE 7-6: A chair cyclohexane with axial and equatorial hydrogens.](#)

[FIGURE 7-7: Performing a chair ring flip.](#)

Chapter 8

[FIGURE 8-1: Mechanism of hydrohalic addition to alkenes.](#)

[FIGURE 8-2: \$H_2\$ and \$X_2\$ addition reactions to alkenes.](#)

[FIGURE 8-3: Markovnikov addition of water to an alkene via the oxymercuration/d...](#)

[FIGURE 8-4: Anti-Markovnikov addition of water to an alkene via the hydroborati...](#)

[FIGURE 8-5: Hydride and alkyl shifts.](#)

[FIGURE 8-6: A carbocation ring expansion of a five-membered ring.](#)

Chapter 9

[FIGURE 9-1: Halogen-ation and hydrohalic acid addition reactions of alkynes.](#)

[FIGURE 9-2: Markovnikov and anti-Markovnikov addition of water to alkynes.](#)

[FIGURE 9-3: Making alkynes by double dehydrohalogenation.](#)

[FIGURE 9-4: Making alkynes using acetylide chemistry.](#)

Chapter 10

[FIGURE 10-1: The mechanisms of the \$S_N1\$ and \$S_N2\$ reactions, in which a nucleophil...](#)

[FIGURE 10-2: The mechanisms of the E1 and E2 reactions, in which a base \(\$B:^-...\$](#)

[FIGURE 10-3: A reaction tree for distinguishing among the four substitution and...](#)

Chapter 11

[FIGURE 11-1: Making alcohols by reduction reactions.](#)

[FIGURE 11-2: Grignard reactions.](#)

[FIGURE 11-3: Comparing PCC and Jones' oxidations of primary alcohols.](#)

[FIGURE 11-4: The Williamson ether synthesis.](#)

Chapter 12

[FIGURE 12-1: The 1,2- and 1,4-addition reactions of a hydrogen halide \(H-X\) to ...](#)

[FIGURE 12-2: Reaction coordinate diagram showing kinetic and thermodynamic prod...](#)

[FIGURE 12-3: The Diels-Alder reaction.](#)

[FIGURE 12-4: Dienes in rings lead to bicyclic products.](#)

Chapter 13

[FIGURE 13-1: The three possible orientations of a disubstituted benzene.](#)

[FIGURE 13-2: Reagents for preparing substituted benzenes.](#)

[FIGURE 13-3: Three additional aromatic reactions you should know.](#)

Chapter 14

[FIGURE 14-1: How molecules break apart in a mass spectrometer.](#)

[FIGURE 14-2: The McLafferty rearrangement.](#)

Introduction

Organic chemistry is a subject that blends basic chemistry, logic problems, 3-D puzzles, and stick-figure art that looks like something out of a prehistoric cave. If you thirst for knowledge, taking organic chemistry will feel like drinking from a firehose.

Indeed, I've heard some students complain that the weight of their organic chemistry textbook is comparable to that of a small elephant. Rest assured, though, that these complaints represent shameless exaggerations: I have yet to find an ochem text that weighs even two-thirds as much.

Nevertheless, organic chemistry does cover so much material that you can't possibly hope to memorize it all. But good news! You don't need to memorize the vast majority of the material if you understand the basic concepts at a fundamental level, and indeed, memorization beyond the basic rules and conventions is even frowned upon. The catch is that to really understand the concepts, you have to practice at it by working problems. Lots of problems. Lots. Did I mention the whole working problems thing? Mastering organic chemistry without working problems is impossible — kind of like trying to become a chef by reading recipes and never practicing chopping up veggies.

This workbook is for getting hands-on experience. Organic chemistry exams are a lot like a gunfight. You act with discipline only if you've drilled the material. Classmates who haven't worked the problems will see the problems gunning at them on an exam and spook. They'll come down with a bad case of exam-block, let their nerves get the better of them, and get blown to

smithereens. You, on the other hand, having been to boot camp and practiced by drilling the problems, will stare the exam down like you were Wyatt Earp or Annie Oakley. When the smoke clears, you'll emerge without a nick, and it'll be the exam that's carted away on a stretcher.

About This Book

Ideally, you should use this book in conjunction with some other reference book, such as a good introductory organic textbook or *Organic Chemistry I For Dummies*. This book doesn't cover the material in great detail; for each section, I give a brief overview of the topic followed by problems that apply the material.

The organization of this book follows the *For Dummies* text, which in turn is organized to follow most organic texts fairly closely. The basic layout of this workbook is to give you straightforward problems for each section to really drill the concepts and build your confidence — before spicing things up with a mischievous humdinger or two at the end of each section to make you don the old thinking cap.

For added convenience, the book is modular, meaning you can jump around to different chapters without having to have read or worked problems in other chapters. If you need to know some other concepts to get you up to speed, just follow the cross-references.

As with all *For Dummies* books, I try to write the answers in a simple conversational style, just as if you and I were having a one-on-one tutoring session, coffee in hand. Here are some other conventions I follow concerning the problems:

- » At the beginning of each section, I present one or two example problems to show you the thought process involved in working that problem type before you take a stab at similar problems. You can refer back to the example while you're working the other problems in that section if you get stuck.
- » Short answers appear in bold in the Answer Key, followed by a detailed breakdown of how I solved each problem. This includes my personal thought process of how to solve a particular problem type, such as where to start and how to proceed. Although other thought processes may lead to the same answer, my explanation can at least give you a guide for problems on which you get stuck.
- » Sometimes, I discuss common mistakes that people make with a certain problem type. My basic philosophy is that I'd rather over-explain than give too little explanation.
- » In naming molecules, I use official nomenclature of the International Union of Pure and Applied Chemistry (IUPAC).

Foolish Assumptions

When writing this book, I made a few general assumptions about you, the reader. You probably meet at least one of these assumptions:

- » You have a background in general chemistry, and ideally, you've taken a one- or two-semester course in introductory chemistry.
- » You're in the midst of or are getting ready to enter your organic chemistry I class in college, and you need some extra help practicing the concepts.

» You took organic chemistry a few years ago, and you want to review what you know.

No matter where you stand, this book provides multiple chances to practice organic chemistry problems in an easy-to-understand (and dare I say fun) way.

Icons Used in This Book

This book uses icons to direct you to important information. Here's your key to these icons:



TIP

The Tip icon highlights information that can save you time and cut down on the frustration factor.



REMEMBER

This symbol points out especially important concepts that you need to keep in mind as you work problems.



WARNING

The Warning icon helps you steer clear of organic chemistry pitfalls.



EXAMPLE

This icon directs you to the examples at the beginning of each set of problems.

Beyond the Book

In addition to what you're reading right now, this book comes with a free access-anywhere Cheat Sheet that includes handy information on the basics of organic chemistry and the periodic table of elements. To get this Cheat Sheet, simply go to www.dummies.com and type **Organic Chemistry I Workbook For Dummies Cheat Sheet** in the Search box.

Where to Go from Here

Organic chemistry builds on the concepts you picked up in general chemistry, so I strongly suggest starting with [Chapter 1](#). I know, I know, you've already taken a class in introductory chemistry and have stuffed yourself silly with all that basic general-chemistry goodness — and that's all in the past, man, and you're now looking to move on to bigger and better things. However, winter breaks and days spent at the beach during summer vacations have a cruel tendency to swish the eraser around the old bean, particularly across the places that contain your vast, vast stores of chemistry knowledge. That's why I suggest you start with [Chapter 1](#) for a quick refresher and that you at least breeze through the rest of [Part 1](#). In a sense, [Part 1](#) is the most important part of the book, because if you can get the hang of drawing structures and interpreting what they mean, you've reached the first major milestone. Getting versed in these fundamental skills can keep you out of organic purgatory.

Of course, this book is designed to be modular, so you're free to jump to whatever section you're having trouble with, without having to have done the problems in a previous chapter as reference. Feel free to flip through the Table of Contents or the Index to find the topic that most interests you.

Part 1

The Fundamentals of Organic Chemistry

IN THIS PART ...

You discover the words of the organic chemist — chemical structures. You start with drawing structures using the various drawing conventions and then see how you can assign charges, draw lone pairs, and predict the geometries around any atom in an organic molecule. With these basic tools under your belt, you get to resonance structures, which are patches chemists use to fix a few leaks in the Lewis structures of certain molecules. You also get to acid and base chemistry, the simplest organic reactions, and begin your mastery of depicting how reactions occur by drawing arrows to indicate the movement of electrons in a reaction.

Chapter 1

Working with Models and Molecules

IN THIS CHAPTER

- » **Diagramming Lewis structures**
 - » **Predicting bond dipoles and dipole moments of molecules**
 - » **Seeing atom hybridizations and geometries**
 - » **Discovering orbital diagrams**
-

Organic chemists use models to describe molecules because atoms are tiny creatures with some very unusual behaviors, and models are a convenient way to describe on paper how the atoms in a molecule are bonded to each other, and where the electrons in an atom are located. Models are also convenient for helping you understand how reactions occur.

In this chapter, you use the Lewis structure, the most commonly used model for representing molecules in organic chemistry. You also practice applying the concept of atom hybridizations to construct orbital diagrams of molecules, explaining where electrons are distributed in simple organic structures. Along the way, you see how to determine dipoles for bonds and for molecules — an extremely useful tool for predicting solubility and reactivity of organic molecules.

Constructing Lewis Structures

The *Lewis structure* is the basic word of the organic chemist; these structures show which atoms in a molecule are bonded to each other and also show how many electrons are shared in each bond. You need to become a whiz at working with these structures so you can begin speaking the language of organic chemistry.

To draw a Lewis structure, follow four basic steps:

1. Determine the connectivity of the atoms in the molecule.



REMEMBER Figure out how the atoms are attached to each other. Here are some guidelines:

- In general, the central atom in the molecule is the least electronegative element. (Electronegativity decreases as you go down and to the left on the periodic table.)
- Hydrogen atoms and halide atoms (such as F, Cl, Br, and I) are almost always peripheral atoms (not the central atom) because these atoms usually form only one bond.

2. Determine the total number of valence electrons (electrons in the outermost shell).

Add the valence electrons for each of the individual atoms in the molecule to obtain the total number of valence electrons in the molecule. If the molecule is charged, add one electron to this total for each

negative charge or subtract one electron for each positive charge.

3. **Add the valence electrons to the molecule.**

Follow these guidelines:

- Start adding the electrons by making a bond between the central atom and each peripheral atom; subtract two valence electrons from your total for each bond you form.
- Assign the remaining electrons by giving lone pairs of electrons to the peripheral atoms until each peripheral atom has a filled octet of electrons.
- If electrons are left over after filling the octets of all peripheral atoms, then assign them to the central atom.

4. **Attempt to fill each atom's octet.**

If you've completed Step 3 and the central atom doesn't have a full octet of electrons, you can share the electrons from one or more of the peripheral atoms with the central atom by forming double or triple bonds.



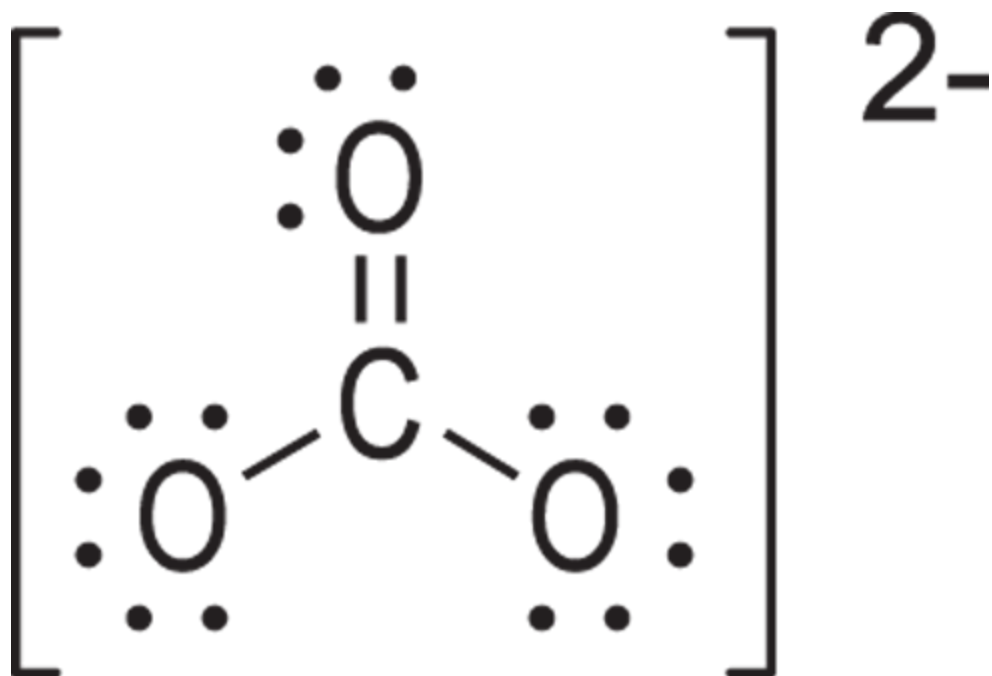
WARNING You can't break the octet rule for second-row atoms; in other words, the sum of the bonds plus lone pairs around a second-row atom (like carbon) can't exceed four.



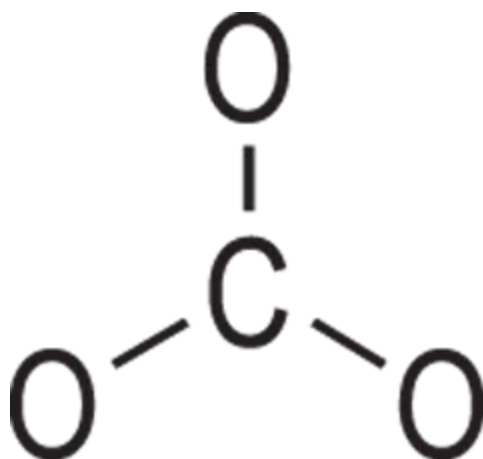
EXAMPLE

Q. Draw the Lewis structure of CO_3^{2-} .

A.



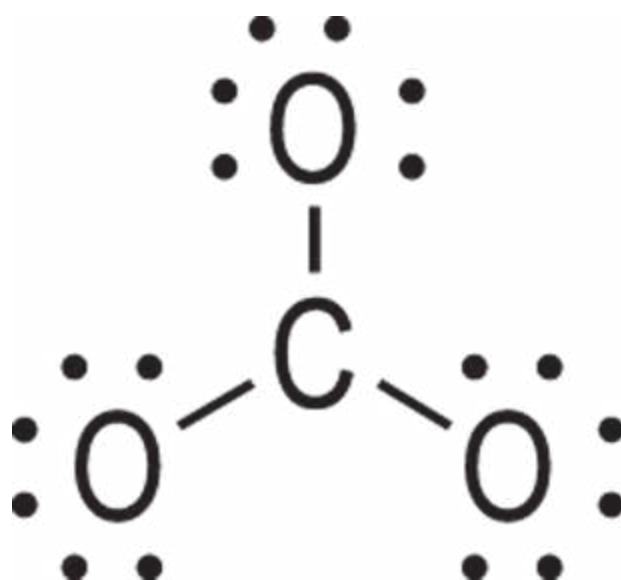
Most often, the *least* electronegative atom is the central atom. In this case, carbon is less electronegative than oxygen, so carbon is the central atom and the connectivity is the following:



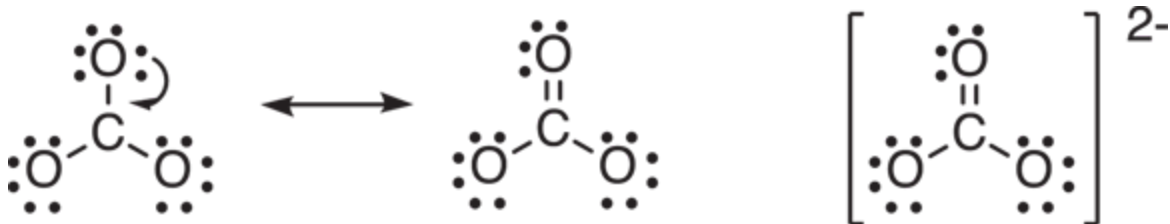
Carbon has four valence electrons because it's an atom in the fourth column of the periodic table, and oxygen has six valence electrons because it's in the sixth column. Therefore, the total number of valence electrons in the molecule is $4 + 6(3) + 2 = 24$ valence electrons. You add the additional two electrons because

the molecule has a charge of -2 (if the molecule were to have a charge of -3, you'd add three electrons; if -4, you'd add four; and so forth).

Start by forming a bond between the central carbon atom and each of the three peripheral oxygen atoms. This accounts for six of the electrons (two per bond). Then assign the remaining 18 electrons to the oxygens as lone pairs until their octets are filled. This gives you the following configuration:



The result of the preceding step leaves all the oxygen atoms happy because they each have a full octet of electrons, but the central carbon atom remains unsatisfied because this atom is still two electrons short of completing its octet. To remedy this situation, you move a lone pair from one of the oxygens toward the carbon to form a carbon-oxygen double bond. Because the oxygens are identical, which oxygen you take the lone pair from doesn't matter. In the final structure, the charge is also shown:



- 1 Draw the Lewis structure of BF_4^- .
- 2 Draw the Lewis structure of H_2CO .
- 3 Draw the Lewis structure of NO_2^- .

Predicting Bond Types

Bonds can form between a number of different atoms in organic molecules, but chemists like to broadly classify these bonds so they can get a rough feel for the reactivity of that bond. These bond types represent the extremes in bonding.

In chemistry, a bond is typically classified as one of three types:

- » **Purely covalent:** The bonding electrons are shared equally between the two bonding atoms.
- » **Polar covalent:** The electrons are shared between the two bonding atoms, but unequally, with the electrons spending more time around the more electronegative atom.
- » **Ionic:** The electrons aren't shared. Instead, the more electronegative atom of the two bonding atoms selfishly grabs the two electrons for itself, giving this more electronegative atom a formally negative charge and leaving the other atom with a formal positive charge. The bond in an ionic bond is an attraction of opposite charges.



REMEMBER You can often determine whether a bond is ionic or covalent by looking at the difference in electronegativity between the two atoms. The general rules are as follows:

- » If the electronegativity difference between the two atoms is 0.0, the bond is purely covalent.
- » If the electronegativity difference is between 0.0 and 2.0, the bond is considered polar covalent.
- » If the electronegativity difference is greater than 2.0, the bond is considered ionic.



WARNING Ionic and covalent bonding are extreme ends of a continuum of possibilities for how much the electrons are shared, so these numbers are just guidelines (some texts even give slightly different numbers as the cutoffs between covalent and ionic). For example, there is not a huge difference in the bonding situation arising between atoms having an electronegativity difference of 1.9 or between atoms having an electronegativity difference of 2.0, even though the first bond would be classified as polar covalent and the second one ionic. The bond with a 1.9 electronegativity difference would just have slightly more shared bonding electrons than the bond with a 2.0 difference, but in both cases the electrons would spend most of their time around the more electronegative element.

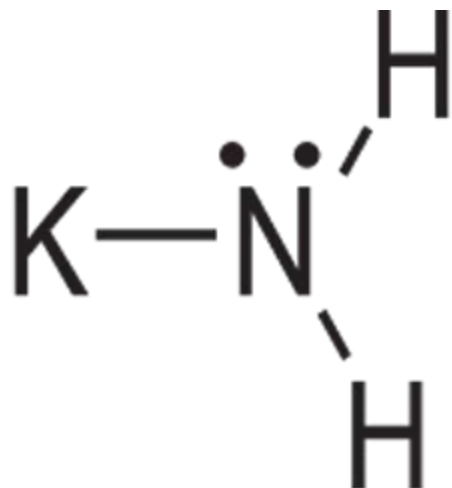
[Figure 1-1](#) shows the electronegativity values.

H 2.1					
Li 1.0	Be 1.5				
Na 0.9	Mg 1.2				
K 0.8	Ca 1.0				
		B 2.0	C 2.5	N 3.0	O 3.5
		Al 1.5	Si 1.8	P 2.1	S 2.5
					Cl 3.0
					Br 2.8
					I 2.5

FIGURE 1-1: Electronegativity values for common atoms.



EXAMPLE Q. Using the following figure, classify the bonds in potassium amide as purely covalent, polar covalent, or ionic.



potassium amide

A. You classify the N-H bonds as polar covalent and the N-K bond as ionic. To determine the bond type, take the electronegativity difference between the two atoms in each bond. For the nitrogen-potassium (N-K) bond, the electronegativity value is 3.0 for nitrogen and 0.8 for potassium, giving an electronegativity difference of 2.2. Therefore, this bond is considered ionic. For the N-H bonds, the nitrogen has an electronegativity value of 3.0 and hydrogen has an electronegativity value of 2.2, so the electronegativity difference is 0.8. Therefore, the N-H bonds are classified as polar covalent.

- 4 Classify the bond in NaF as purely covalent, polar covalent, or ionic.
- 5 Using the following figure, classify the bonds in hexachloroethane as purely covalent, polar covalent, or ionic.