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Organic Chemistry II

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- Observe from a macro-scopic and micro-scopic view
- Grasp chemical and organic reactions
- Follow along and ace your Organic Chemistry II course

John T. Moore, EdD
Richard H. Langley, PhD
Professors of Chemistry and coauthors of
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by John T. Moore, EdD, and Richard H. Langley, PhD

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About the Authors

John T. Moore, EdD, grew up in the foothills of western North Carolina. He attended the University of North Carolina–Asheville where he received his bachelor's degree in chemistry. He earned his master's degree in chemistry from Furman University in Greenville, South Carolina. After a stint in the United States Army, he decided to try his hand at teaching. In 1971 he joined the chemistry faculty of Stephen F. Austin State University in Nacogdoches, Texas, where he still teaches chemistry. In 1985 he went back to school part time and in 1991 received his doctorate in education from Texas A&M University. For the past several years he has been the co-editor (along with one of his former students) of the "Chemistry for Kids" feature of *The Journal of Chemical Education.* In 2003 his first book, *Chemistry For Dummies,* was published by Wiley, soon to be followed by *Chemistry Made Simple* (Broadway) and *Chemistry Essentials For Dummies* (Wiley). John enjoys cooking and making custom knife handles from exotic woods.

Richard H. Langley, PhD, grew up in southwestern Ohio. He attended Miami University in Oxford, Ohio, where he received bachelor's degrees in chemistry and in mineralogy and a master's degree in chemistry. His next stop was the University of Nebraska in Lincoln, Nebraska, where he received his doctorate in chemistry. Afterwards he took a postdoctoral position at Arizona State University in Tempe, Arizona, followed by a visiting assistant professor position at the University of Wisconsin–River Falls. In 1982 he moved to Stephen F. Austin State University. For the past several years he and John have been graders for the free-response portion of the AP Chemistry Exam. He and John have collaborated on several writing projects, including *5 Steps to a Five AP Chemistry* and *Chemistry for the Utterly Confused* (both published by McGraw-Hill). Rich enjoys jewelry making and science fiction.

Dedication

John: I dedicate this book to my wife, Robin; sons, Matthew and Jason; my wonderful daughter-in-law, Sara; and the two most wonderful grandkids in the world, Zane and Sadie. I love you guys.

Rich: I dedicate this book to my mother.

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Contents at a Glance

Table of Contents

Introduction

Welcome to *Organic Chemistry II For Dummies.* We're certainly happy you decided to delve further into the fascinating world of organic chemistry. It's a complex area of chemistry, but understanding organic chemistry isn't really that difficult. It simply takes hard work, attention to detail, some imagination, and the desire to know. Organic chemistry, like any area of chemistry, is not a spectator sport. You need to interact with the material, try different study techniques, and ask yourself why things happen the way they do.

Organic Chemistry II is a more intricate course than the typical freshman introductory chemistry course, and you may find that it's also more involved than Organic I. You may actually need to use those things you learned (and study habits you developed) in Organic I to be successful in Organic II. But if you work hard, you can get through your Organic II course. More importantly, you may grow to appreciate the myriad chemical reactions that take place in the diverse world of organic chemistry.

About This Book

Organic Chemistry II For Dummies is an overview of the material covered in the second half of a typical college-level organic chemistry course. We have made every attempt to keep the material as current as possible, but the field of chemistry is changing ever so quickly as new reactions are developed and the fields of biochemistry and biotechnology inspire new avenues of research. The basics, however, stay the same, and they are where we concentrate our attention.

As you flip through this book, you see a lot of chemical structures and reactions. Much of organic chemistry involves knowing the structures of the molecules involved in organic reactions. If you're in an Organic Chemistry II course, you made it through the first semester of organic chemistry, so you recognize many of the structures, or at least the functional groups, from your previous semester's study.

If you bought this book just to gain general knowledge about a fascinating subject, try not to get bogged down in the details. Skim the chapters. If you find a topic that interests you, stop and dive in. Have fun learning something new.

If you're taking an organic chemistry course, you can use this rather inexpensive book to supplement that very expensive organic textbook.

Conventions Used in This Book

We have organized this book in a logical progression of topics; your second semester organic chemistry course may progress similarly. In addition, we set up the following conventions to make navigating this book easier:

- *Italics* introduce new terms that you need to know.
- **Bold** text highlights keywords within a bulleted list.
- We make extensive use of illustrations of structures and reactions. While reading, try to follow along in the associated figures, whether they be structures or reactions.

What You're Not to Read

You don't have a whole lot of money invested in this book, so don't feel obliged to read what you don't need. Concentrate on the topic(s) in which you need help. Feel free to skip over any text in a gray shaded box (which we refer to as sidebars). Although interesting, they aren't required reading.

Foolish Assumptions

We assume — and we all know about the perils of assumptions — that you are one of the following:

- A student taking a college-level organic chemistry course.
- A student reviewing organic chemistry for some type of standardized exam (the MCAT, for example).
- An individual who just wants to know something about organic chemistry.

If you fall into a different category, you're special and we hope you enjoy this book anyway.

How This Book Is Organized

The topics in this book are divided into six parts. Use the following descriptions and the table of contents to map out your strategy of study.

Part I: Brushing Up on Important Organic Chemistry I Concepts

Part I is really a rapid review of many of the concepts found in an Organic Chemistry I course. It's designed to review the topics that you need in Organic II. We set the stage by giving you an overview of Organic Chemistry II, and then review mechanisms. Next we cover alcohols and ethers, their properties, synthesis, and reactions; followed by an overview of conjugated unsaturated systems. We end this review section with a discussion of spectroscopy, including IR, UV-visible, mass spec, and, of course, NMR. A whirlwind tour of Organic I!

Part II: Discovering Aromatic (And Not So Aromatic) Compounds

In Part II we concentrate on aromatic systems, starting with the basics of structure and properties of benzene and then moving on to related aromatic compounds. We even throw in a section of spectroscopy of aromatic compounds. Chapters 7 and 8 finish up this part by going into detail about substitution reactions of aromatic compounds. You find out all you ever wanted to know (and maybe more) about electrophilic and nucleophilic substitutions, along with a little about elimination reactions.

Part III: Carbonyls: Good Alcohols Gone Bad

In Part III we cover that broad category of organic compounds called the carbonyls. First we give you an overview of carbonyl basics, including structure, reactivity, and spectroscopy. Then we go into more detail on aldehydes and ketones, enols and enolates, and carboxylic acids and their derivatives.

Part IV: Advanced Topics (Every Student's Nightmare)

In Part IV we start by taking a closer look at nitrogen compounds and their structure, reactivity, and reactions. Then we move on to organometallic compounds, where we meet the infamous Grignard reaction. We then finish up this part by addressing some more-involved reactions of the carbonyls and biomolecules. You pick up some good hints for synthesis and roadmaps here.

Part V: Pulling It All Together

In Part V we show you how to pull all the previous information together and use it to develop strategies for designing synthesis reactions. We talk about both one-step and multistep synthesis as well as retrosynthetic analysis. Then we tackle the dreaded organic roadmaps. (We all wish we had an organic chemistry GPS here.)

Part VI: The Part of Tens

In this final part of the book we discuss ten surefire ways to flunk your organic chemistry class (so you know what to avoid) along with ten ways to increase your grade on those organic chemistry exams.

Icons Used in This Book

If you have ever read other *For Dummies* books (such as the wonderful *Chemistry For Dummies* or *Biochemistry For Dummies,* written by yours truly and published by Wiley), you recognize the icons used in this book. The following four icons can guide you to certain kinds of information:

This icon is a flag for those really important things that you shouldn't forget as you go deeper into the world of organic chemistry.

We use this icon to alert you to a tip on the easiest or quickest way to learn a concept. Between the two of us, we have almost 70 years of teaching experience. We've learned a few tricks along the way and we don't mind sharing.

The warning icon points to a procedure or potential outcome that can be dangerous. We call it our Don't-Try-This-At-Home icon.

We try to avoid getting too technical throughout this book (believe it or not), but every now and then we can't help but throw something in that is a little more in-depth than you might need. You won't hurt your education by skipping it.

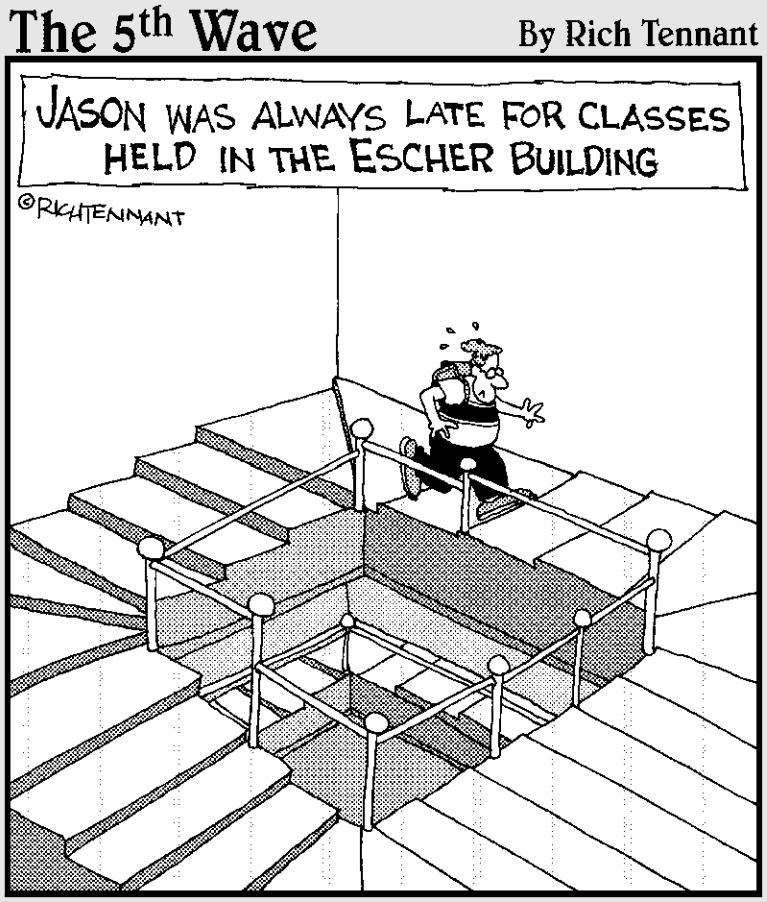
Where to Go from Here

The answer to this question really depends of your prior knowledge and goals. As with all *For Dummies* books, this one attempts to make all the chapters independent so that you can dive right into the material that's causing you trouble without having to read other chapters first. If you feel comfortable with the topics covered in Organic Chemistry I, feel free to skip Part I. If you want a general overview of organic chemistry, skim the remainder of the book. Take a deeper plunge into a chapter when you find a topic that interests you or one in which you really need help.

And for all of you, no matter who you are or why you're reading this book, we hope you have fun reading it and that it helps you to understand and appreciate organic chemistry.

Part I

Brushing Up on Important Organic Chemistry I Concepts



In this part . . .

Part I is a review of some general chemistry and Organic Chemistry I topics you need a firm grounding in before moving on to Organic Chemistry II. Different books and different instructors break Organic I and Organic II material at different places. We use the most common break, but some Part I material may, in fact, be new to you. Even if you covered these concepts last semester, some of them have a high vapor pressure and may have escaped between semesters.

We begin by bringing you up to speed on mechanisms and reminding you how to push electrons around with those curved arrows. We jog your memory with a discussion of substitution and elimination reactions and their mechanisms, in addition to free radical reactions. Next you review the structure, nomenclature, synthesis, and reactions of alcohols and ethers, and then you get to tackle conjugated unsaturated systems. Finally, we remind you of spectroscopic techniques, from the IR fingerprints to NMR shifts. The review in this part moves at a pretty fast pace, but we're sure you can keep up.

Chapter 1

Organic Chemistry II: Here We Go Again!

In This Chapter

- Reviewing the material you learned in Organic I
- Previewing what you find out in Organic II

If you're looking at this chapter, it's probably because you're getting ready to take the second half of organic chemistry, are in the midst of Organic II, or you're trying to figure out what Organic II covers in time to change your major from pre-med to art history. In any respect, you probably successfully completed Organic Chemistry I. Many of the study techniques (and coping mechanisms) you learned that helped you do well in Organic I are helpful in Organic II. The two primary things to remember are

- *Never* get behind.
- Carbon has four bonds.

In this book we use larger, more complex molecules than you may have encountered in Organic I. We chose to do this because, firstly, that's the nature of Organic II — larger and more complex molecules. Secondly, many of you will be taking biochemistry at some point, and to succeed in that subject you need to become comfortable with large, involved molecules. (If you do take biochemistry, be sure to check out *Biochemistry For Dummies* by John T. Moore and Richard H. Langley [Wiley]. We understand the authors are really great guys.)

To get you started, this chapter does a quick review of the topics commonly found in Organic I, and then gives an overview of what we cover in Organic II.

Recapping Organic Chemistry I

In Organic I you learned that organic chemistry is the study of carbon compounds. Until the mid-1800s, people believed that all carbon compounds were the result of biological processes requiring a living organism. This was called the *vital force theory.* The synthesis (or formation) of urea from inorganic materials showed that other paths to the production of carbon compounds are possible. Many millions of organic compounds exist because carbon atoms form stable bonds to other carbon atoms. The process of one type of atom bonding to identical atoms is *catenation*. Many elements can catenate, but carbon is the most effective, with apparently no limit to how many carbon atoms can link together. These linkages may be in chains, branched chains, or rings, providing a vast combination of compounds.

Carbon is also capable of forming stable bonds to a number of other elements, including the biochemically important elements hydrogen, nitrogen, oxygen, and sulfur. The latter three elements form the foundation of many of the functional groups you studied in Organic I.

Intermolecular forces

You also learned about intermolecular forces in Organic I. Intermolecular forces (forces between chemical species) are extremely important in explaining the interaction between molecules. Intermolecular forces that you saw in Organic I and see again in Organic II include dipole-dipole interactions, London, hydrogen bonding, and sometimes ionic interactions.

Dipole-dipole forces exist between polar regions of different molecules. The presence of a dipole means that the molecule has a partially positive ($\delta+$) end and a partially negative ($\delta-$) end. Opposite partial charges attract each other, whereas like partial charges repel.

Hydrogen bonding, as the name implies, involves hydrogen. This hydrogen atom must be bonded to either an oxygen atom or a nitrogen atom. (In non-biological situations, hydrogen bonding also occurs when a hydrogen atom bonds to a fluorine atom.) Hydrogen bonding is significantly stronger than a normal dipole-dipole force, and is stronger than London dispersion forces, the forces between nonpolar molecules due to the fluctuations of the electron clouds of atoms or molecules. The hydrogen bonded to either a nitrogen or oxygen atom is strongly attracted to a different nitrogen or oxygen atom. Hydrogen bonding may be either intramolecular or intermolecular.