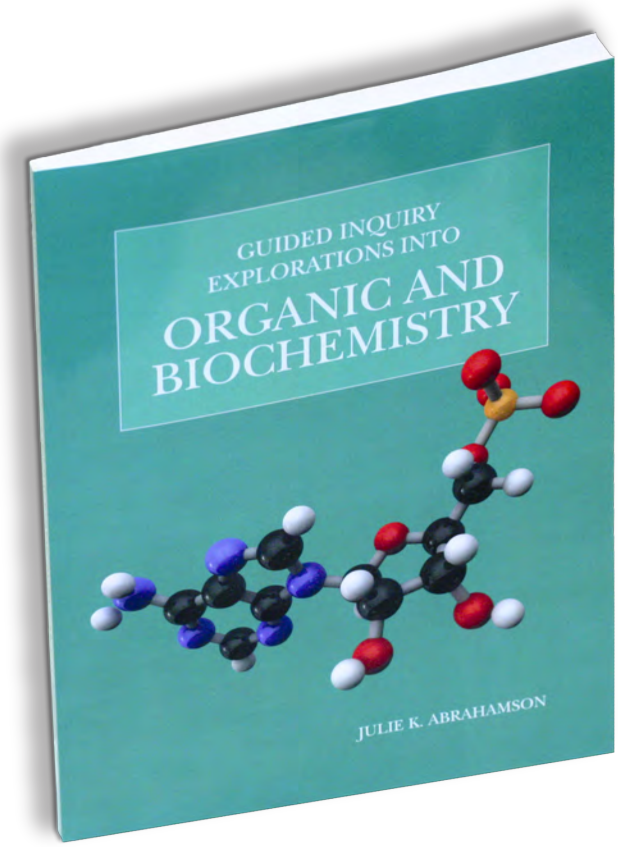

GUIDED INQUIRY EXPLORATIONS INTO ORGANIC AND BIOCHEMISTRY

By Julie K. Abrahamson

Included in this preview:

- Copyright Page
- Table of Contents
- Excerpt of Chapter 1

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Guided Inquiry Explorations Into Organic and Biochemistry

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Contents

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Thanks to the students with whom I have had the pleasure to share the interesting aspects of chemistry that can make the learning fun.

Thanks to the editors at Cognella, especially Marissa Waggoner and Jessica Knott, for their kind patience as the manuscript was prepared.

Thanks to my husband, Harmon, for his encouragement and patience with me during the various stages of this project. Without support at home, such endeavors would be more difficult to complete.

Dedication

To all the students who work hard to wrestle with and eventually master the challenging topics in organic and biochemistry. I wish the best of luck to all of you!

Why Use Guided Inquiry?

The approach of this text is based on education and cognitive theory research showing that students experience improved learning when they are actively engaged during class time. The learning styles of many undergraduates favor more active learning styles. The Activities in this text follow the learning cycle that begins with an exploration phase, continues with concept invention, and is followed by an application stage.

The Activities are inspired by the POGIL (*Process Oriented Guided Inquiry Learning*) classroom and laboratory technique that seeks to simultaneously teach content and key process skills such as the ability to think analytically and work effectively as part of a collaborative team. POGIL is based on research indicating that (a) teaching by telling does not work for most students, (b) students who are part of an interactive community are more likely to be successful, and (c) knowledge is personal: Students enjoy themselves more and develop greater ownership over the material when they are given an opportunity to construct their own understanding. For more information about POGIL, go to *www.pogil.org*.

Group Roles for Activities

A ***Manager*** will be designated by the instructor each day to assign roles in the group and keep everyone on task. The Manager aims to have all group members participate and understand the concepts discussed. The Manager raises a hand if the group has a question.

The ***Recorder*** records on the report form the names of each of the group members at the beginning of each day. The Recorder also keeps track of important observations, insights, group answers when requested, and other comments.

The ***Presenter*** presents the work of the group to the class when called upon. Presenters may be asked to go to the board to write out and explain answers, or to discuss their answers in comparison to those of other groups.

The ***Strategy Analyst*** or ***Reflector*** observes and comments on the group dynamics and behavior regarding the learning process. The analysis may include insights about how well the group worked together to the benefit of all and their learning.

Advice for success

Be sure you understand the answers to the ***Critical Thinking Questions*** (CTQ) and ***Exercises*** in each activity. Listen to the ideas of others in your group to clarify your own. *Ask more questions* until you are confident of your answers. Always read the corresponding sections and work the suggested problems in the textbook.

1 Structures and Names of Alkanes

How are simple organic molecules named and drawn?

Learning Objectives

- Recognize the condensed and structural formulas of alkanes.
- Learn the names for alkanes of up to 10 carbon atoms.
- Recognize alkyl groups and learn their names.
- Define and explain constitutional isomers.

Prerequisite Concepts

- Molecular formulas
- Lewis structures

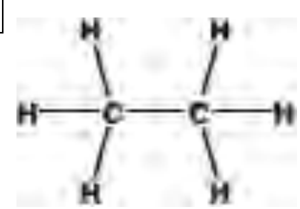
Information, Part I

Organic molecules are based on carbon structures. **Hydrocarbons**, compounds containing only carbon and hydrogen, include **alkanes**, the simplest of many functional groups. **Functional groups** are the parts of a larger molecule that have characteristic chemical behaviors, and that are used to determine (i) names, (ii) properties, and (iii) reactions for organic molecules.

Table 1. Names and Structures of the First Ten Alkanes

Molecular formula	Name of alkane	Condensed structure	Number of carbons
CH_4	methane	CH_4	1
C_2H_6	ethane	CH_3CH_3	2
C_3H_8	propane	$CH_3CH_2CH_3$	3
C_4H_{10}	butane	$CH_3CH_2CH_2CH_3$	4
C_5H_{12}	pentane	$CH_3(CH_2)_3CH_3$	5
C_6H_{14}	hexane	$CH_3(CH_2)_4CH_3$	6
C_7H_{16}	heptane	$CH_3(CH_2)_5CH_3$	7
C_8H_{18}	octane	$CH_3(CH_2)_6CH_3$	8
C_9H_{20}	nonane	$CH_3(CH_2)_7CH_3$	9
$C_{10}H_{22}$	decane	$CH_3(CH_2)_8CH_3$	10

The structures for the compounds in Table 1 are at times represented using complete **Lewis structures**, where each atom and its bonds in the molecule are shown. The Lewis structure for ethane is shown.



CRITICAL THINKING QUESTIONS . . .

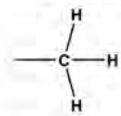
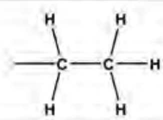
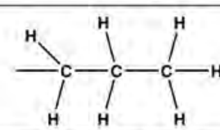
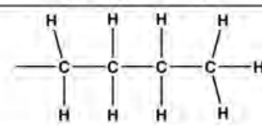
1. Look at the molecular formulas for the alkanes. In alkanes with more than two carbons, how could you describe the relationship between the *number* of *hydrogens* and *carbons*? Compare answers *among your group members*.

2. Draw complete Lewis structures for (a) propane, (b) butane, and (c) heptane.

Information, Part II

When alkanes occur in structures that do not have the carbons connected in a continuous chain, they are described as **branched**. A compound is branched if you cannot trace through all of its carbons without retracing a section or lifting your finger or pencil from the structure. The shorter branching segments of carbons in a compound are **substituents** and are given specific names determined by (a) the number of carbons and (b) in what arrangements they occur.

Table 2. Alkyl Groups

Alkyl Group Name	Condensed Structure	Detailed (Lewis) Structure	Number of Carbons
methyl	$-CH_3$		1
ethyl	$-CH_2CH_3$		2
propyl	$-CH_2CH_2CH_3$		3
butyl	$-CH_2CH_2CH_2CH_3$		4

CRITICAL THINKING QUESTION . . .

3. *As a group*, determine how the alkyl group names and structures in Table 2 are related to those of alkanes in Table 1. How are they alike or different?

Names of alkanes using the **IUPAC system of nomenclature** are designed for unambiguous naming of compounds and follow these guidelines.

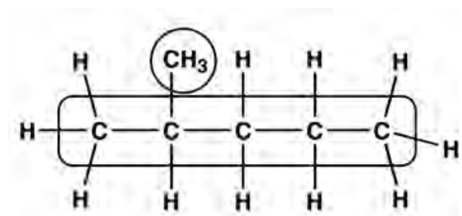
Step 1 Find the longest *continuous* chain of carbons to name the *parent compound* using an alkane name. (*Note:* It is helpful to draw a loop around or highlight the longest continuous or "main chain" in the compound, then circle any branching substituents.)

Step 2 Number the carbons in the main chain; give *lowest possible numbers* to substituents (branches) or other groups.

Step 3 Locate the carbon with each branching substituent and determine its number. If there is more than one of a certain type of substituent, use prefixes (di-, tri-, etc.) to describe how many are present. Arrange the substituents' names alphabetically; ignore prefixes in determining alphabetical order.

Step 4 Write the name as a single word, listing a number before each substituent with the name of the main chain as the last name. When multiple substituents of one type are present, there must be a number to indicate the location of each. Use *commas* between substituent numbers, and *hyphens* between numbers and prefixes.

Example 1. Naming a Simple Branched Alkane



1. The longest continuous carbon chain has 5 carbons, so the parent compound is ***pentane***. Make a ***loop*** around the main chain and ***circle*** any branching substituents.

2. ***Number*** the carbons in the main chain. Start at the end that gives the branch a lowest number. ***Determine*** the number of the carbon for the branch, e.g. number 2 in this case.

3. The branch in this compound has only one carbon so it is called a ***methyl*** group (*see* Table 2). There is only one substituent, so there is no need for ordering any.

4. The IUPAC name is *2-methylpentane*, written as one word.

CRITICAL THINKING QUESTIONS . . .

4. What is the molecular formula for the molecule in Example 1?

   C ____________ H ____________

5. What other compound in Table 1 has this molecular formula?

6. Are these two compounds the *same* or *different*? (*Circle one*.) Discuss this *as a group*. Come to a conclusion and explain why or why not.

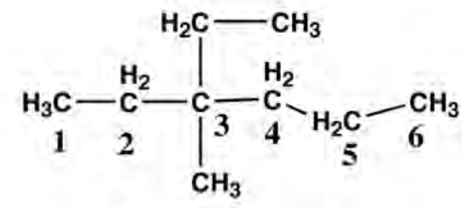
Information, Part III

Compounds that have the same molecular formula but different connections between their atoms are called **constitutional isomers**. These compounds will have unique IUPAC names because they have unique structures. Isomers often have distinguishable physical or chemical properties.

More Examples of Structures and Names

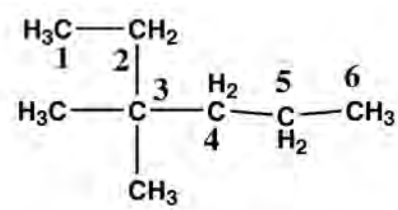
Example 2. 3-ethyl-3-methylhexane

6 carbons in the longest chain, with a methyl and an ethyl substituent, both on carbon 3



Example 3. 3,3-dimethylhexane

6 carbons in the longest chain, two methyl group branches on carbon 3



CRITICAL THINKING QUESTIONS . . .

7. What is the molecular formula for the molecule in Example 2?

C ____ H ____

8. What other compound in Table 1 has the same molecular formula?

9. What is the molecular formula for the molecule in Example 3?

C ____ H ____

10. What other compound in Table 1 has the same molecular formula?

11. Are the compounds in Example 2 and CTQ 8 the *same* or *different*? (*Circle one.*)

12. Are the compounds in Example 3 and CTQ 10 the *same* or *different*? (*Circle one.*)

CRITICAL THINKING QUESTIONS . . .

13. Are the compounds in Examples 2 and 3 the *same* or *different*? (*Circle one.*)

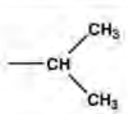
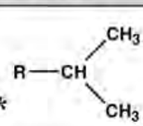
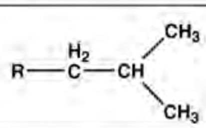
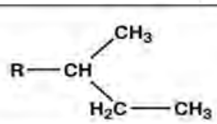
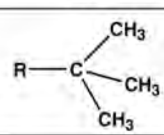
14. *As a group*, determine what is one (or more) simple way(s) to tell whether compounds are the same or different.

15. Which of the compounds in Example 2, Example 3, CTQ 8, and CTQ 10 are isomers of each other? Be sure to list any set of isomers. (*Hint:* There may be more than one set of isomers.)

Information, Part IV

There are other substituents that contain *branched* carbon fragments or non-carbon atoms. For convenience in naming, they are given specific names, too. Remember, substituents are *not* part of the longest continuous carbon chain.

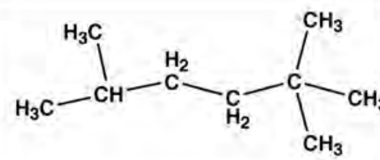
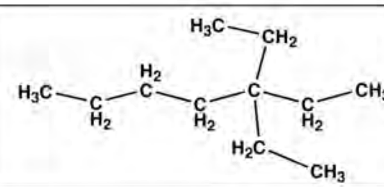
Table 3. Branched and Halogen Substituent Names

Branched Substituent	Name	Non-Carbon Substituent	Name
 *or* * 	isopropyl	–F	fluoro
	isobutyl	–Cl	chloro
	*sec*-butyl	–Br	bromo
	*tert*-butyl	–I	iodo

*On a substituent, **R** indicates where the substituent is attached to the rest (**R** for “rest”) of the molecule, the main chain.

EXERCISES

1. Complete the table.

Name	Lewis Structure	Condensed formula	Molecular Formula
2-bromo-butane			
			
3-isopropyl-pentane			
			

2. a. *Draw* and *name* as many isomers with the formula C_6H_{14} as you can.

b. How many isomers are there?

3. a. *Draw* and *name* as many isomers with the formula $C_4H_8Cl_2$ as you can.

b. How many isomers are there?

4. Be sure you *understand* the answers to the ***Critical Thinking Questions*** and ***Exercises*** in this activity. *Ask more questions* until you are confident of your answers.

5. Read the corresponding sections and work the suggested problems in the textbook.

2 Structures and Reactions of Alkenes

How are alkenes different from alkanes in structures and reactions?

Learning Objectives

- Recognize the geometric isomers of alkenes.
- Predict the products for alkene addition reactions.
- Learn and apply Markovnikov's Rule.
- Explain the differences in reaction types.

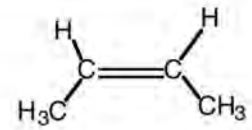
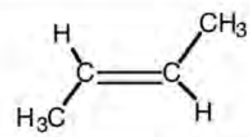
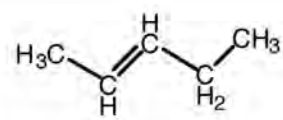
Prerequisite Concepts

- Simple alkene nomenclature
- Constitutional isomers
- Alkane halogenation reactions
- Functional group identification

Supplies

- Molecular model kit

Model 1. Names and Structures of Some Simple Alkenes

Molecular Formula	Name	Condensed Structure	Structural Formula
C___H___	*cis*-2-butene	$CH_3CH{=}CHCH_3$	
	trans-2-butene		
	cis-2-pentene	$CH_3CH{=}CHCH_2CH_3$	
	trans-2-pentene		

CRITICAL THINKING QUESTIONS . . .

1. Fill in the missing parts in Model 1.

2. Look at the information for Model 1.

a. How are *cis*-2-butene and *trans*-2-butene related? (*Circle one.*)

same compound isomers unrelated

b. How are *cis*-2-pentene and *trans*-2-pentene related? (*Circle one.*)

same compound isomers unrelated

CRITICAL THINKING QUESTIONS . . .

3. a. Draw a loop around the *longest continuous carbon chain* in the *structural* formulas for each compound in Model 1.

   b. How could the shape *around the double bond* in the longest carbon chains be described for *trans*-2-butene and *trans*-2-pentene?

4. How could the shapes *around the double bond* in the longest carbon chains be described for *cis*-2-butene and *cis*-2-pentene?

5. *As a group*, describe in *general* terms what distinguishes *cis*- from *trans*- isomers.

6. a. *As a group*, use a **molecular model kit** to make models of (a) *cis*- and *trans*-2-butene or (2) *cis*- and *trans*-2 pentene.

   b. Describe how the model of a *cis*- isomer could be converted to a *trans*-isomer.

Information, Part I

Alkenes that have the same connections between atoms, but are different in the geometry around the double bond are called **geometric isomers.** The two forms are called *cis-* and *trans-* isomers.

Model 2. More Alkene Structures

Molecular Formula	Name	Structural Formula
C__H__	1-butene	
	2-methyl-2-butene	
	3-methyl-2-pentene	

CRITICAL THINKING QUESTIONS . . .

7. Fill in the missing parts of Model 2.

8. a. What is the definition for constitutional isomers? (*see* Information Part III, Activity 1, *Structures and Names of Alkanes*.)

   b. Which compound in Model 2 is a constitutional isomer of 2-butene? (*see* Model 1.)

   c. Which compound in Model 2 is a constitutional isomer of 2-pentene?

CRITICAL THINKING QUESTIONS . . .

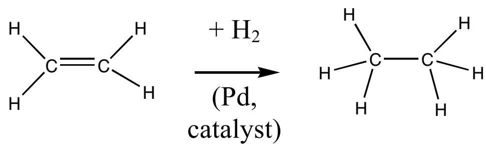
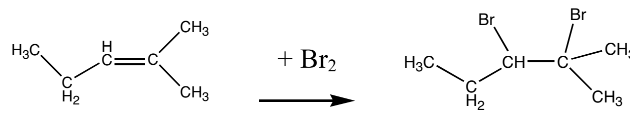
9. a. For each compound in Model 2, draw a loop around the longest continuous carbon chain in the structural formulas.

b. *As a group,* determine which compound(s) *could* have a loop containing the largest group (number) of carbons drawn more than one way.

10. Which of the compounds in Model 2 could be found as *cis*- and *trans*- isomers? (refer to CTQ 6.)

11. *As a group,* describe in general terms, how can you tell whether a compound *is able to* exhibit *cis*—*trans* isomerism.

Model 3. Reactions of Alkenes with Hydrogen or Halogens

	
Ethene + hydrogen → ethane	2-methyl-2-pentene + bromine → 2,3-dibromo-2-methylpentane

CRITICAL THINKING QUESTIONS . . .

12. What functional group is present in the *organic* compounds used as reactants in Model 3?

13. a. Make an "X" through the bonds that are broken in the reactants. Use an *arrow* to mark where atoms are added in the reactants forming new bonds.

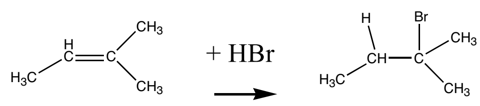
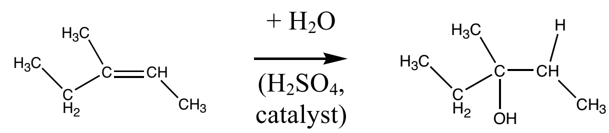
b. Describe what happens in these reactions, including which bonds are broken or formed.

14. To what general type of reaction do these reactions belong? (*Circle one.*)

addition elimination rearrangement substitution

15. *As a group*, list the distinguishing characteristics of the reaction type circled in CTQ 14.

Model 4. Reactions to Alkenes with Hydrogen Halides (HX) or Water

	
2-methyl-2-butene + HBr ⟶ 2-bromo-2-methylbutane	3-methyl-2-pentene + water ⟶ 3- methyl-3-pentanol

CRITICAL THINKING QUESTIONS . . .

16. To what general type of reaction do the reactions of Model 4 belong? Circle one.

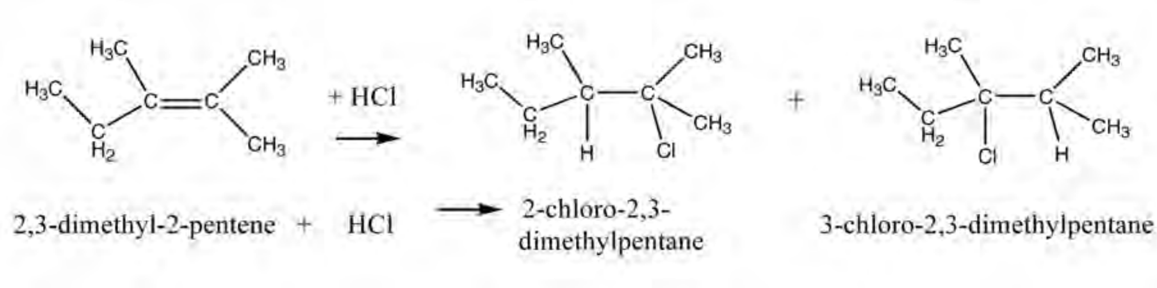
addition elimination rearrangement substitution

17. What do the reactions in Model 4 have in common? Note particularly the location of the added H in the products.

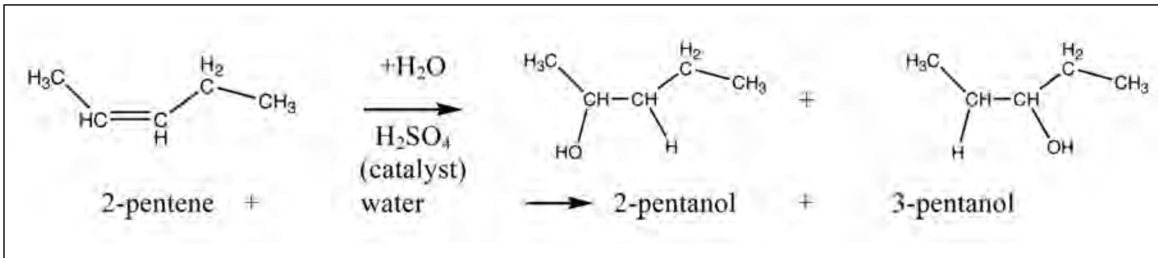
18. What do the non-organic reactants have in common with those from Model 3?

19. *As a group,* generalize what determines where the H is added in the reactions of Model 4.

Model 5A. More Reactions of Alkenes with Hydrogen Halides (HX)



Model 5B. More Reactions of Alkenes with Water



CRITICAL THINKING QUESTIONS . . .

20. The reactions in Model 5 are similar yet different from those in Model 4. How are they similar and different?

Alike: Different:

21. *As a group,* generalize how alkenes add hydrogen plus a halogen or –OH group as shown in Models 4 and 5.

Information, Part II

The reactions of Model 4 show only the major products. The reactions of Model 5 have more than one equally possible product. Those in Model 4 follow **Markovnikov's Rule** governing the addition of hydrogen to alkenes from reagents with the formula HX, where X is a halogen or –OH. The rule states that the *major* product results when ***H adds** to the double-bond carbon which has the **most H** atoms directly bonded to it*. The reactions of Model 5 have double-bond carbons with equal numbers of hydrogens bonded, so the rule does not apply, and two possible products result.

Exercises ——

1. Draw the structural formula for 2-hexene. Does it have *cis-* and *trans-* isomers? Yes / No

   Draw and label any cis or trans isomers for 2-hexene.

2. Draw and name one *isomer* of 2-hexene that ***does not*** have *cis-* and *trans-* isomers. (*Hint:* There is more than one.)

3. Draw and name an isomer of 2-hexene that <u>does</u> have *cis-* and *trans-* isomers. (*Hint:* There is more than one.)

4. Write out these reactions. Assume the appropriate catalysts are present. How many possible products result for each? Name any products you can.

   a. 2-hexene + Cl_2

   b. 2-hexene + H_2

   c. 2-hexene + HCl

   d. 2-hexene + H_2O

   e. 2-methyl-2-hexene + HI

   f. 2-methyl-2-hexene + H_2O

5. Be sure you *understand* the answers to the ***Critical Thinking Questions*** and ***Exercises*** in this activity. *Ask more questions* until you are confident of your answers.

6. Read the corresponding sections and work the suggested problems in the textbook.