studyOrgo.com

## The StudyOrgo.com Organic Chemistry Rapid Review

# StudyGuide

### Learn Basic Organic Chemistry Fast!

## About the StudyOrgo.com Organic Chemistry Rapid Review Study Guide

The writers at StudyOrgo.com are dedicated to providing usefull study materials that are easy to understand. That's why we created the StudyOrgo.com Organic Chemistry Rapid Review Study Guide. We have taken all of the beginning topics of Organic Chemistry and have consolidated the important information into this concise, yet comprehensive Study Guide. This guide is infused with a tremendous amount of "highyield" information. This means that in addition to providing all of the necessary facts and notes on each topic, we reveal all of the frequently tested key points that are favorites among university classroom exams and standardized exams alike. These are candidly pointed out to guide your studying to focus on the most popular test topics. In addition, we alert you of common student traps and pitfalls. Perhaps the most valuable of gems studded throughout our Study Guide are the tips and shortcuts that help students hone in on how to solve and critically think about organic chemistry. This simply can not be obtained by attempting to sift through the abyss of what most organic chemistry textbooks present.

## TABLE OF CONTENTS

Topics Covered:

- Introduction to Organic Chemistry
- Carbon
- Valence Electrons
- Octet Rule

Topics Covered:

- How to Draw Bonds
- Condensed Formula
- Conventional Structural Drawing
- Line-Angle Formula

Topics Covered:

- Subshells
- Atomic Orbitals
- Hybridization
- Sigma and Pi bonds
- Geometry
- Bond Angles

Topics Covered:

- What is a Lewis Structure?
- How do I draw a Lewis Structure?
- How do I figure out an atom’s formal charge?
- What is resonance?
- How do I figure out resonance problems?
- Major resonance vs. minor resonance

Topics Covered:

- Introduction to the concept of nomenclature in Organic Chemistry
- Step-by-step process for naming alkanes

Topics Covered:

Introduction to functional groups
Basic images of each functional group presented

Topics Covered:

Arrhenius Acid and Base

Bronstead-Lowry Acid and Base
Lewis Acid and Base
pKa and pKb
Acid-Base Reactions
Effects on acidity
Effects on Basicity

Topics Covered:

Constitutional isomers
Conformational Isomers
Diastereomers
Geometric Isomers
Conformational Isomers Analysis
Newman Projections
Cyclohexane Chair Conformation

Topics Covered:

Chiral vs. Achiral
R and S Nomenclature of Enantiomers
Properties of Enantiomers
Racemic Mixtures
Meso Compound

Topics Covered:

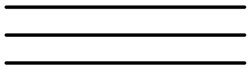
Reaction Format
Degree of Substitution in Alkanes
Degree of Substitution in Alkenes
Reaction Intermediates: Radical, Carbocation, Carbanion

## Chapter One: Intro to Orgo

1) What is Orgo?
    a. Organic chemistry, also known as "*Orgo*" or "*O-Chem*," is the study of molecular structure and reactions pertaining to living matter. It is commonly referred to as the study of compounds that contain carbon.
    b. Why spend an entire year learning about **carbon**?!?
        i. Carbon containing compounds are the gateway to life. By studying organic chemistry one can have an appreciation for *living organisms* and the basis for life. One can also gain an understanding for organic chemistry contributions to *health*, *medicine*, *pharmacology and industry.*
2) Carbon
    a. Organic Chemistry is the study of carbon. So let's review carbon.
    b. Atomic number = 6
    c. Electron configuration = $1s^2 2s^2 2p^2$
    d. **Valence Electrons**
        i. Definition: The electrons found in the **outermost shell** in the atom.
            1. They are the electrons that can participate in **bonding**.
            2. Note: **Lone pair** electrons are a subset of the valence electrons that *do not participate in bonding*.
        ii. $1s^2 2s^2 2p^2$
            1. The electrons in the second shell ($2s^2 2p^2$) represent carbon's **valence electrons**
            2. 2 +2 =4
               So carbon has four valence electrons
        iii. In order to complete its **octet** it needs to share four more electrons
    e. **Octet Rule**
        i. Definition: the sum of all bonding electrons and non-bonding electrons on a given atom in the 2nd row of the periodic table will *never be greater than 8*
        ii. Exceptions to the Octet Rule:
            1. Hydrogen and Lithium = 1 Valence Electron
            2. Beryllium = 2 Valence Electrons
            3. Elements in period 3 can occupy more than 8 valence electrons (e.g. Phosphorus and Sulfur)
    f. So if carbon has four electrons it may accommodate four more electrons
        i. How can it do so? It may gain four more bonds
            1. One bond = 2 electrons
            2. Carbon "takes on" one of those electrons from a given bond towards its octet

## Chapter Two: Drawing in Orgo

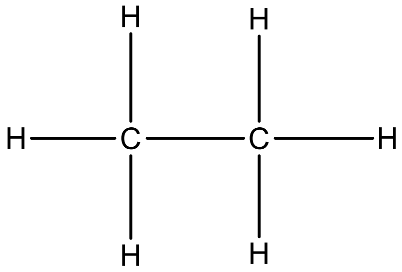
1) Learning organic chemistry is like learning a new language. With a new language comes a new way of speaking and a new way of writing. In organic chemistry we communicate with lines and letters.
2) How to draw bonds
    a. Bonds are represented by lines. One line is a single bond, two lines is a double bond and three lines is a triple bond

| Bond | Drawing |
|---|---|
| **Single** |  |
| **Double** |  |
| **Triple** |  |

    b. Bonds may be in a variety of *different planes*

| Drawing | Representation |
|---|---|
|  | Drawn to represent a bond **within same plane** as the computer screen or paper |
|  | Drawn to represent a bond **coming out** of the plane of the computer screen or paper. In essence this bond is **pointing toward you**. |
|  | Drawn to represent a bond **going into** the plane of the computer screen or paper. In essence this bond is **pointing away from you.** |

3) General rules of drawing in orgo using the *"Line-Angle Formula"*
    *a.* General Rule #1:
        i. Anytime there is a line drawn, the atom at each end is a carbon unless otherwise indicated.
        ii. The appropriate number of hydrogens are attached to it and implied even though they may not be drawn
        iii. For example, each of these three are equivalent depictions of the same compound:

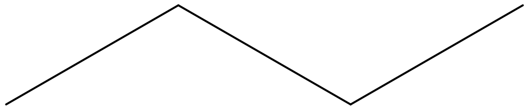
| Condensed Formula | Conventional Structure Drawing | Line-Angle Formula Drawing |
|---|---|---|
| **$CH_3CH_3$** |  |  |

Looking at this Line-Angle Formula drawing we see a line. Each end of the line has a carbon. Since the carbons are connected by a single bond, each carbon has three hydrogens attached to it.

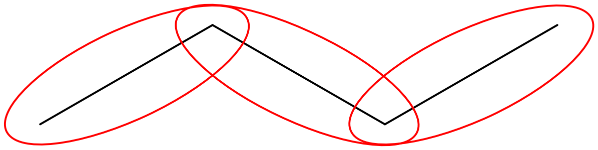
b. <u>General Rule #2:</u>

   i. Each carbon molecule may accommodate four "things" attached to it via a single bond. If there is a double bond that counts as "two things" if there is a triple bond that counts as "three things"

   ii. So what about this molecule:

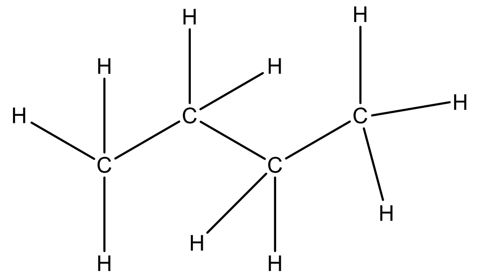
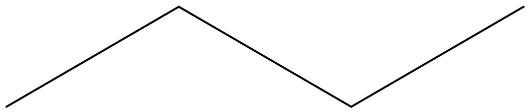


Let's start by circling all the lines:



Well, there are three lines, right? Each positioned at an angle to one another to indicate that there is a new carbon at that joint.

So the following two images are equivalent:

| Conventional Structure Drawing | Line-Angle Formula Drawing |
|---|---|
|  |  |

**Sign-Up for Full Access!**

For an interactive **Exercise Set** on **Drawing in Orgo**, **Sign Up and become a member** of StudyOrgo.com. We are so confident in our program that we offer a guarantee like no other. **We guarantee you will pass!** While many students are happy with just passing this course, most of the students that we have feedback from, have excelled to be in the top of their class.

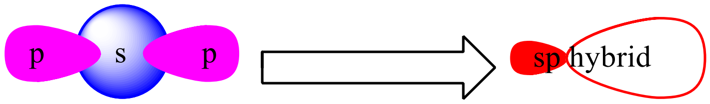
For more information and to Sign-Up visit:

https://www.studyorgo.com/signup.php

## Chapter Three: Molecular Orbitals, Hybridization and Geometry

1) Atomic orbitals
    - a. Remember these **subshells** from general chemistry?
        - i. s
        - ii. p
        - iii. d
        - iv. etc.
    - b. Each subshell has a certain number of **atomic orbitals** (represented by the lines below)
        - i. s ___ **one orbital**
        - ii. p ___ ___ ___ **three orbitals**
        - iii. d ___ ___ ___ ___ ___ **five orbitals**
    - c. Each atomic orbital can accommodate two electrons
2) **Hybridization**
    - a. A hybrid or a mix of atomic orbitals
    - b. An atom's orbitals can interact with other atoms and <u>overlap</u> to form a given *hybrid atomic orbital*

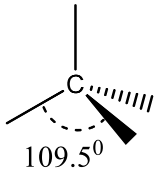
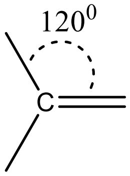
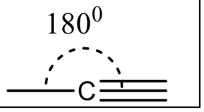
      For example- here the sp hybrid atomic orbital is formed:



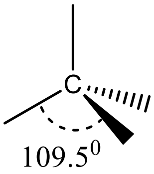
3) Molecular Orbitals
    - a. **Molecular orbital** = overlap of two atomic orbitals from different atoms
    - b. There are two types of bonds formed in molecular orbitals: sigma bonds and pi bonds.
    - c. **sigma bond** (σ)= overlap of hybridized orbitals **along the line** between nuclei
        - i. single bonds are sigma bonds
        - ii. double and triple bonds each have one sigma bond
    - d. **pi bond** (π) = **sideways overlap** between two p orbitals
        - i. double bonds have one pi bond
        - ii. triple bonds have two pi bonds
        - iii. there must be a sigma bond in order for a pi bond to occur
    - e. Summary Chart

| Bond | Sigma bonds | Pi bonds | Total |
|---|---|---|---|
| Single | 1 | 0 | 1 |
| Double | 1 | 1 | 2 |
| Triple | 1 | 2 | 3 |

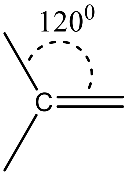
4) Geometry
    - a. An atom has a given hybridization depending on the number of bonds extending from it
    - b. There is also an implicit geometric shape associated with the hybridization
    - c. Furthermore, the bond angles formed are important
    - d. Here is a chart that sums this up:

| Bond | Hybridization | Geometry | Bond angle | Picture |
|---|---|---|---|---|
| Single | $sp^3$ | Tetrahedral | 109.5° |  |
| Double | $sp^2$ | Trigonal planar | 120° |  |
| Triple | sp | Linear | 180° |  |

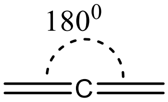
5) Ways carbon can bond to others
   a. Option #1: Carbon may accommodate four single bonds



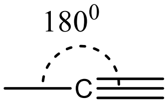
   b. Option #2: Carbon may accommodate one double bond and two single bonds



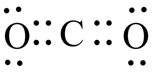
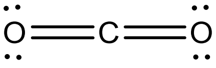
   c. Option #3: Carbon may accommodate two double bonds



   d. Option #4: Carbon may accommodate one triple bond and one single bond



## Chapter Four: Lewis Structures, Formal Charge and Resonance Structures

1) What is a **Lewis Structure**?
   a. A way to draw out electrons and bonding by using dots
2) How do I draw a Lewis Structure? Let's go step by step and demonstrate using $CO_2$ as an example.
   a. Step 1: Determine the number of valence electrons an atom has to participate in bonding.
      i. Remember: Valence electrons are the electrons in the *outermost shell of an atom.* Some valence electrons participate in bonding to another atom. Others, known as lone pairs, do not.
      ii. The number of valence electrons that *participate in bonding* for popular atoms are as follows:
         - C = 4
         - N = 3
         - O = 2
         - F = 1
         - H = 1
      ii. For example: In $CO_2$ we have C (draw 4 dots) and O (draw 2 dots per atom)
   b. Step 2: Place a dot around that atom for each valence electron that participates in bonding
      i. For example: O∶ ∶C∶ ∶O
   c. Step 3: Determine the lone pairs for a given atom:
      i. Remember: Lone pairs are a subset of the valence electrons that *do not participate in bonding* to another atom
      ii. Lone pairs for popular atoms are as follows:
         1. C = 0
         2. N = 1 pair = 2 electrons
         3. O = 2 pairs = 4 electrons
         4. F = 3 pairs = 6 electrons
         5. H = 0
      iii. For example, in $CO_2$ we have C (no lone pairs) and O (two lone pairs per atom)
   d. Step 4: Place the lone pairs around the atom using a pair of dots to depict each lone pair.
      i. For example: 
   e. Step 5: Wherever there is an atom bonding to another atom there are two dots between them, one from each atom. You may decide to convert this pair of electrons into a line to denote a bond.
      i. For example: 

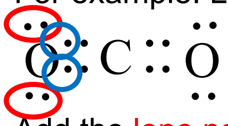
3) How do I figure out an atom's **formal charge**?
   *a.* Step 1: Count the atom's *lone pair electrons*

b. Step 2: Count *one from each pair of electrons that particular atom is using to bond* to another atom

c. Step 3: *Add the number you get from Step 1 to Step 2*

d. Step 4: The formal charge is *whatever you need to do to the number* you got from *step 3* to get to the atom's *group number* on the periodic table

e. For example: Let's use an O atom in $CO_2$ as an example



Add the lone pair electrons (4) to one from each pair of bonding electrons (2) = 6

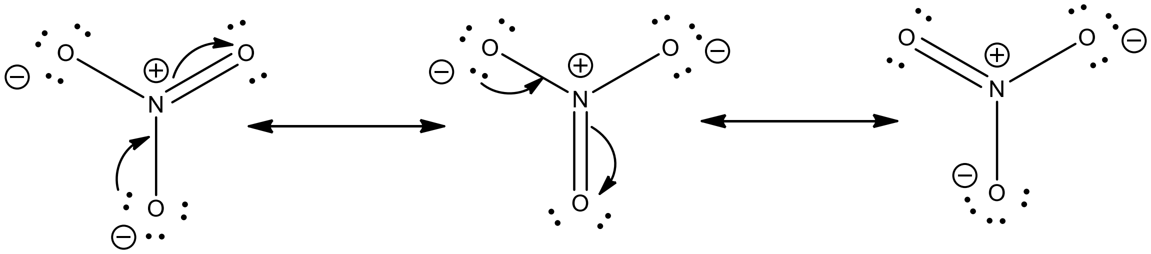
Since oxygen is in group 6 in the periodic table the formal charge is **0 (zero)**. (You do not need to do anything to the number you get from step 3 to get to the atom's group number on the periodic table)

4) What is **resonance**?
   a. A drawn structure with a double bond on its own does not completely represent the structure of a given molecule
      i. There can be more than one possible structure for the same molecule!
      ii. The actual structure is the average of all of the resonance structures
5) Why resonance?
   a. *Resonance spreads the charge* over two atoms which makes the structure more stable
6) How do I figure out resonance problems? Follow these simple rules:
   a. Rule #1: Try moving around electrons.
      i. When moving electrons use an arrow to demonstrate where the electrons are going.
      ii. **Electrons can be moved around in one of two ways:**
         1. **Move double bond electrons**
         2. **Move lone pair electrons**
   b. Rule #2: The number of unpaired electrons must remain the same
   c. Rule #3: Figure out which of your drawings represent the major and minor structures
      i. **Major resonance** = the resonance contributors that are **more** stable as they have the **least** energy. **Low** energy structures satisfy as many of the following as possible:
         1. There are as many octets as possible
         2. There are as many bonds as possible
         3. There are as few lone pairs as possible
         4. Any negative charges are placed on the most electronegative atoms
            a. Most electronegative F > O > Cl > N > C least electronegative
         5. There is the *least separation of charge* amongst the structures

        ii. **Minor resonance** = the resonance contributors that are **less** stable as they have the **most** energy. **High** energy structures **do not** satisfy as many of the above guidelines

  d. Example: $NO_3^-$

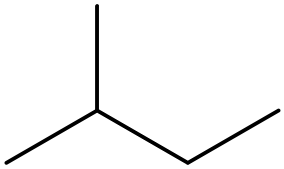
        i. In the following example $NO_3^-$ is drawn out showing three different resonance structures. Please remember that while electrons are moving around no atoms are moving.
        ii. The arrows show the movement of the electrons to show how to arrive at the next structure moving from the left to the right of the screen.
        iii. Since all three structures satisfy the same guidelines to the same extent as outlined above, all three are equal contributors. However this is often not the case and will be seen in the next exercise set.



## Chapter Five: Basic Naming in Orgo- Naming Alkanes

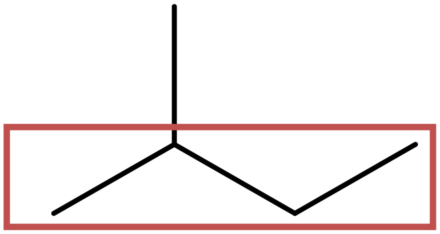
- Each structure in organic chemistry has its own name
- Alkanes are one of the first structures to learn about when starting to study Organic Chemistry
    - Alkanes are molecules that are composed entirely by single bonds.

- Follow these three simple steps to arrive at a name for a given molecule.
    - We will use this molecule as an example to demonstrate each step:

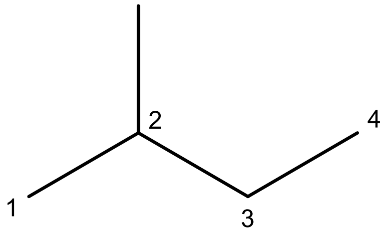


**Step #1:** Find the **longest chain of carbons in the molecule** and **number them** *starting with the carbon closest to a branch*.

- Note: If there is a branch at the same point at either end, start numbering at the end *closest to the largest branch*. If the branches are of equal size at the same point at either end, *start numbering at the end where the next branch is closer*.



**Step #2:** The **number of carbons** tells us the *main stem of the structure's name*

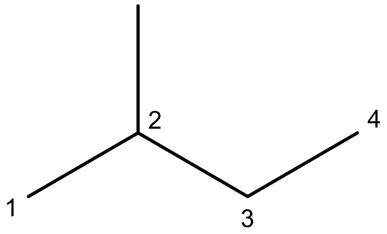


- So in total that's four carbons as part of the longest chain.

- This chart lists prefixes for structures based off the number of carbons in the longest chain. When naming alkanes, the three letter suffix "-ane" can be joined with the appropriate prefix to arrive at the main stem of the name.

| Number of carbons in the longest chain | Prefix | Main stem of name if structure is an alkane |
|---|---|---|
| **1** | Meth- | Methane |
| **2** | Eth- | Ethane |
| **3** | Prop- | Propane |
| **4** | But- | Butane |
| **5** | Pent- | Pentane |
| **6** | Hex- | Hexane |
| **7** | Hept- | Heptane |
| **8** | Oct- | Octane |
| **9** | Non- | Nonane |
| **10** | Dec- | Decane |
| **11** | Undec- | Undecane |
| **12** | Dodec- | Dodecane |
| **13** | Tridec- | Tridecane |
| **14** | Tetradec- | Tetradecane |

- OK- so back to our example:

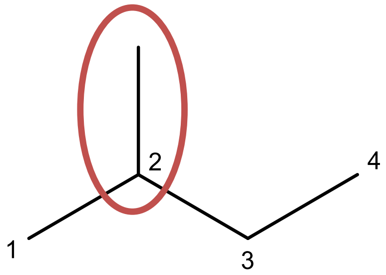


- In this case the prefix is **But-**
- Since it is made up of *all single bonds*, the structure is an alkane, and therefore the suffix is **–ane**
- Put together the prefix and the suffix and you have the main stem of the name.
- *Prefix + suffix = main stem of the name*
    - In this case **But- + -ane = Butane**

- Note: Other structure types will have different suffixes. For example, a structure with a double bond, is not an alkane, rather it is an alkene. Therefore the suffix would be "-ene." A structure with a triple bond would have the suffix "-yne."

| Bond | Suffix |
|---|---|
| **Single** | -ane |
| **Double** | -ene |
| **Triple** | -yne |

**<u>Step #3:</u>** Is there anything else on that chain? If so—add it to the main stem of the name.



- Here there is a $CH_3$ group. This is known as a *methyl group*. It is a type of *alkyl group*, which means a branch off a main molecule made up of carbons and hydrogen.
  - So you will need add that to the name.
    - Check and see what carbon it is attached to—OK so it is attached to carbon #2.
    - You need to add the numbered carbon, then a hyphen, then the substituent's name.

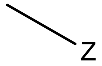
- So the full name of this structure is:
  **2-methylbutane**

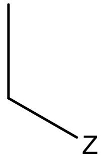
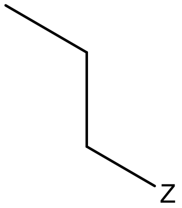
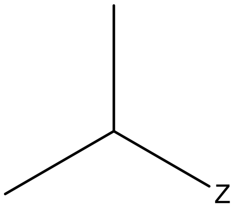
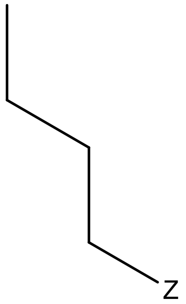
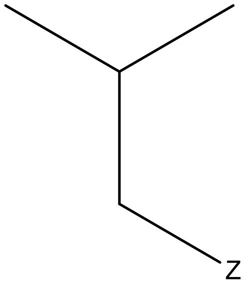
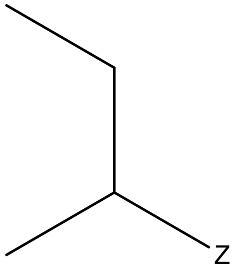
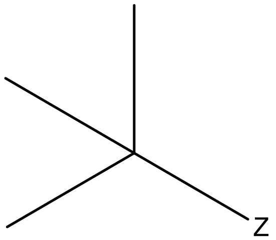
## Some Important Details:

1) If there is more than one structure attached to the same carbon, list them in alphabetical order
2) If there is more than one of the exact same structure in the compound, then use the following table of prefixes to annotate the substituent name in the final overall name

| Number of the exact same group | Prefix |
|---|---|
| **2** | di- |
| **3** | tri- |
| **4** | tetra- |
| **5** | penta- |

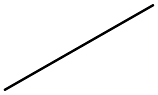
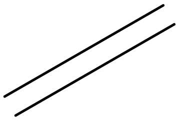
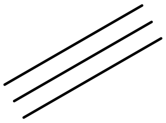
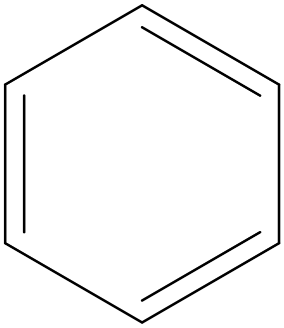
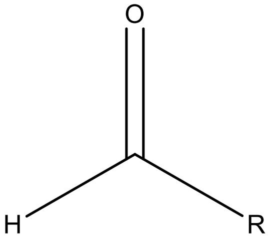
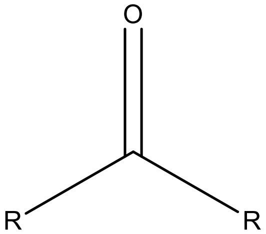
3) To make naming easier, commit the following common alkyl groups and their names to memory:

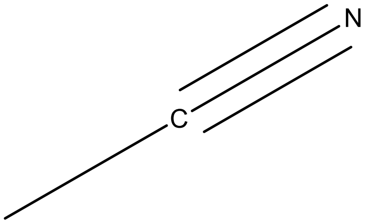
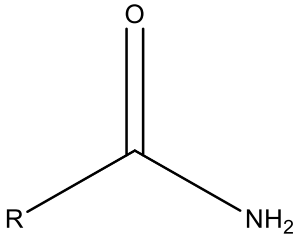
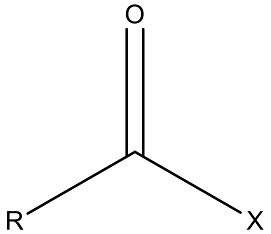
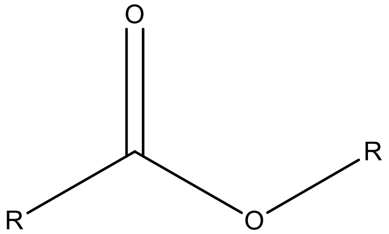
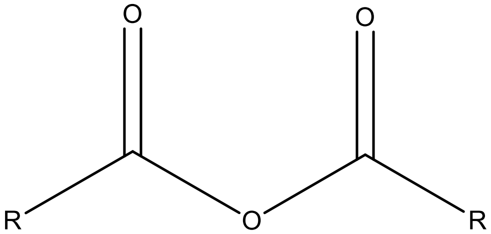
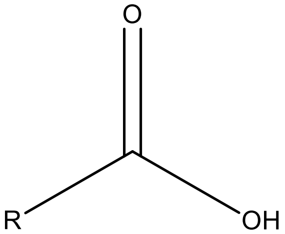
| Alkyl group | Name (The letter Z stands for "the rest of the compound") |
|---|---|
| **Methyl** |  |

| | |
|---|---|
| **Ethyl** |  |
| **Propyl** |  |
| **Isopropyl** |  |
| **Butyl** |  |
| **Isobutyl** |  |
| **Sec-butyl** |  |
| **Tert-butyl** |  |

## Chapter Six: Functional Groups

- There are many identifying structures within compounds known as functional groups. Here is a table of the main functional groups in organic chemistry.

| Functional Group | Structure |
|---|---|
| **Alkane** |  |
| **Alkene** |  |
| **Alkyne** |  |
| **Halide** | R-X |
| **Alcohol** | R-OH |
| **Ether** | R-O-R |
| **Aromatic** |  |
| **Amine** | R-$NH_2$<br>$R_2$-NH<br>$R_3$-N |
| **Aldehyde** |  |
| **Ketone** |  |

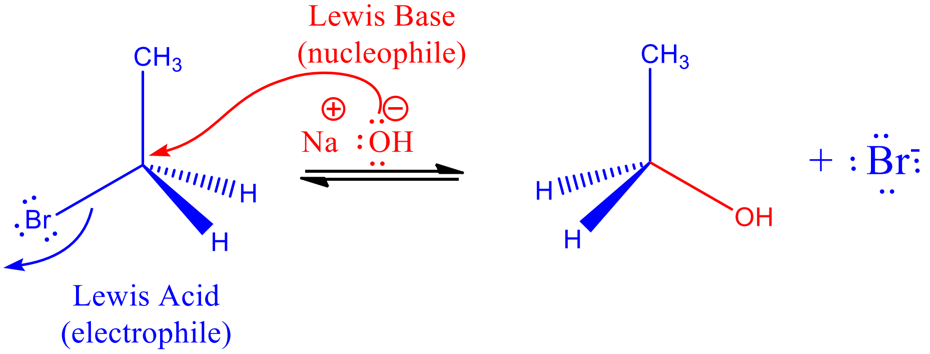
| | |
|---|---|
| **Nitrile** |  |
| **Amide** |  |
| **Acyl Halide** |  |
| **Ester** |  |
| **Acid Anhydride** |  |
| **Carboxylic Acid** |  |
| | |
| **Key** | **R**= represents an unspecified hydrocarbon chain attached to a given molecule (example: $CH_2CH_3$)<br>**X** = represents an unspecific halogen attached to a given molecule (examples: F, Cl, Br, I) |

# Chapter Seven: Acid-Base Chemistry

1) Acid-Base Definitions

| | Acid | Base |
|---|---|---|
| Arrhenius | Dissociation in water yields $H^+$ | Dissociation in water yields $^-OH$ |
| Bronstead-Lowry | Proton ($H^+$) donor | Proton ($H^+$) acceptor |
| Lewis | Electrophile (a compound that accepts electrons) | Nucleophile (a compound that donates electrons) |

2) pKa and pKb
    a. Equations:
        i. $(K_a) \times (K_b) = 1 \times 10^{-14}$
        ii. (pKa) + (pKb) = 14
        iii. $pKa = -\log_{10}[Ka]$
    b. **The lower the pKa, the stronger the acid**
    c. **The higher the Ka, the stronger the acid**
    d. Weaker acids (low Ka or high pKa) and weaker bases (low Kb or high pKb) are favored in acid-base reactions.
3) Acid-Base Reactions
    a. Depicted here is a sample acid-base reaction



- The arrows are used to demonstrate the movement of electrons. The *Lewis Base is donating electrons to the Lewis Acid*. The red arrow shows this. Once this occurs, the Br leaves the acid. The electrons that were originally shared with the rest of the acid leave to exist on the Br alone.

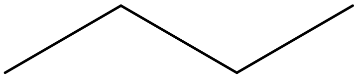
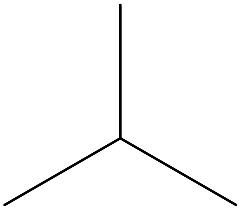
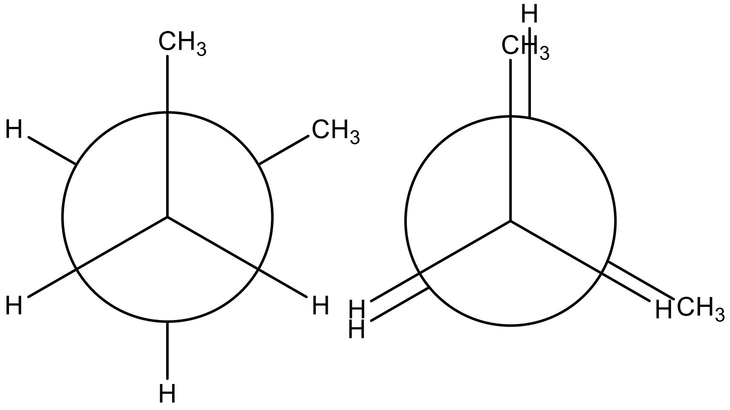
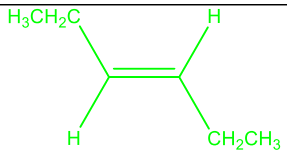
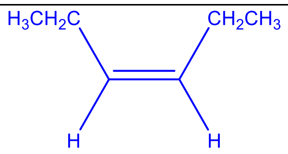
4) Effects on acidity
    a. **The more readily a compound can donate a proton, the more acidic it is.**
    b. Certain functional groups are more acidic that others. Here are some representative functional groups and compounds listed in order from most acidic to least acidic. See Chapter Six for review of functional groups.
        i. Carboxylic acid
        ii. Phenol (aromatic compound with OH attached to it)

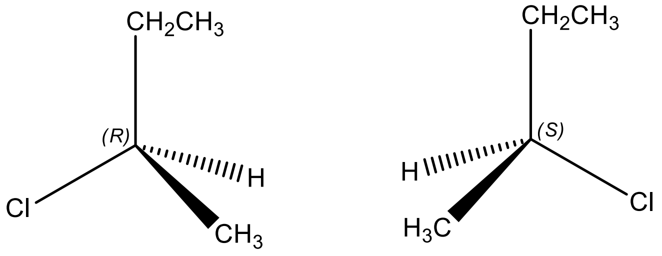
        - iii. Water
        - iv. Alcohol
        - v. Ketone
        - vi. Alkyne
        - vii. Alkene
        - viii. Alkane
    - c. The more stable a molecule is without a proton, the more easily it will give it up and become deprotanated.
        1. The more electronegative the atom connected to the carbon with an OH, the more electropositive the H is, the more acidic it is, and the more likely it will donate it.
    - d. Strong acids have weak, stable, conjugate bases.
        - i. The more the conjugate base is stabilized by resonance delocalization, the more stable the base is.
    - e. The higher the electronegativity of the atom in a compound, the higher the acidity
        - i. eg: HF is more acidic than $HCH_3$
    - f. The greater the acidity the more readily it will react with a base.
- 5) Effects on Basicity
    - a. **The more readily a compound donates electrons the more basic it is.**
        - i. The more lone pairs a base has, the more basic it is.
    - b. The weaker the conjugate acid the stronger the conjugate base.
    - c. The more stable the base the less basic
    - d. Effect of charge on basicity
        - i. No negative charge = more stable = least basic
        - ii. Negative charge on carbon is least stable → more basic
        - iii. Negative charge on electronegative atom → more stable → less basic

## Chapter Eight: Isomers

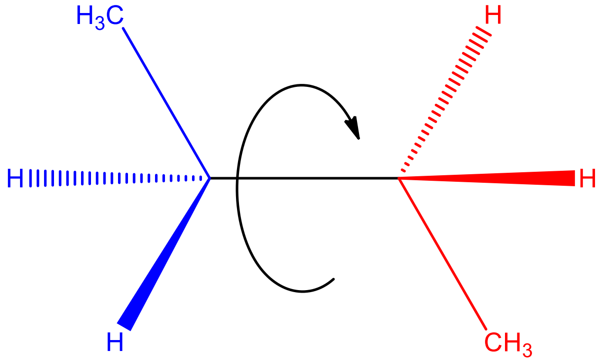
1) Isomers Overview

**Isomers** = compounds that are not the same but share the same molecular formula

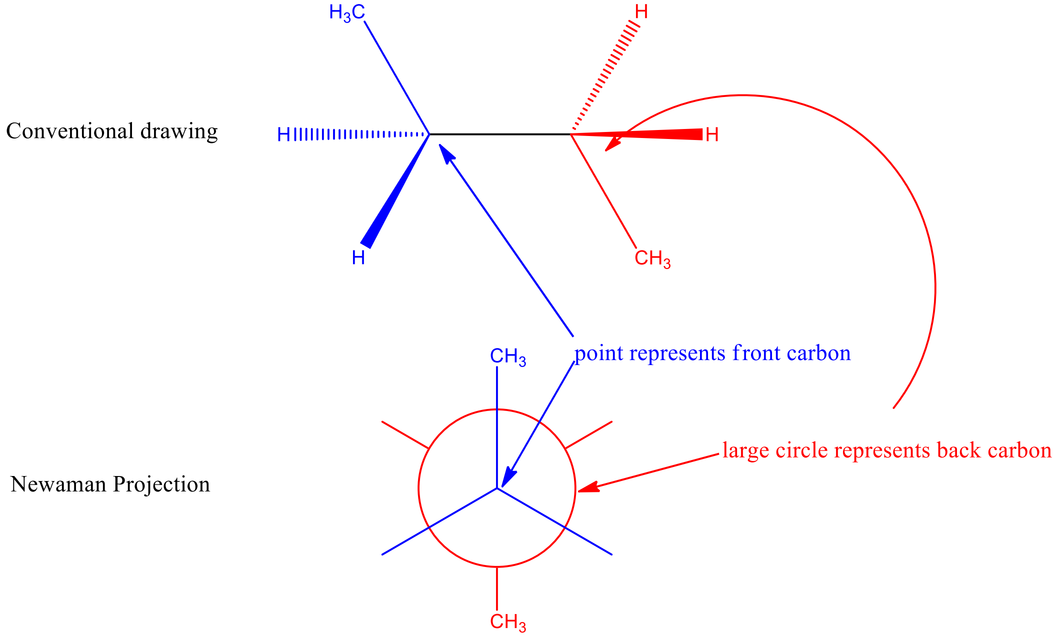
| Isomer Type | Example |
|---|---|
| **Structural Isomers = constitutional isomers**<br>Compounds that have a difference in the order in which the components are bonded | <br>butane<br><br>isobutane |
| **Conformational Isomers**<br>Compounds that differ in the rotation about a single bond |  |
| Stereoisomers<br>**Compounds that differ in the way they are oriented** | |
| **A** **Diastereomers**<br>Stereoisomers that are NOT mirror images | |
| **A-1** **Geometric Isomers**<br>Diastereomers that differ specifically regarding the orientation of the substituents of a double bond or ring in a *cis* or *trans* orientation |  <br>Trans<br>Trans isomers have the substituents on the opposite side of the double bond or ring<br> <br>Cis<br>Cis isomers have the substituents on the same side of the double bond or ring |

|  |  |  |
|---|---|---|
| **B** | **Enantiomers**<br>Stereoisomers that are *mirror images* |  |

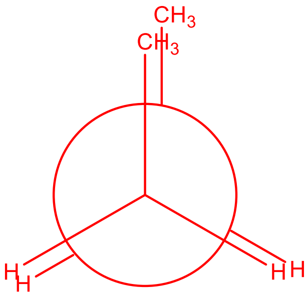
2) Conformational Isomers Analysis
   a. **Newman projections** = a way to depict the different arrangements formed by **rotation about the single bond** of a molecule
      1. For example, in this conventional drawing of butane, one can appreciate that the structure can be rotated about its single bond



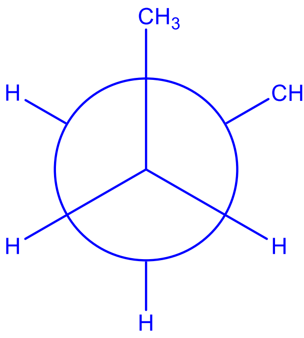
      2. Understanding Newman projections:
         The following images of the traditional structure drawing and corresponding Newman projection are color coordinated to demonstrate their relationship:



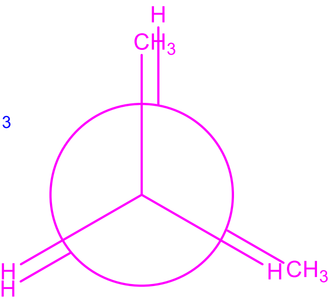
b. What are the different types of conformational isomers? Here we define them by using butane as an example. We will go through the conformers by starting in the totally eclipsed position and rotate about the single bond from there.



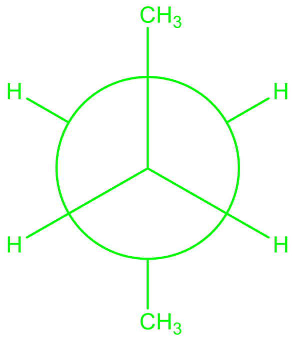
Totally Eclipsed



Gauche



Eclipsed

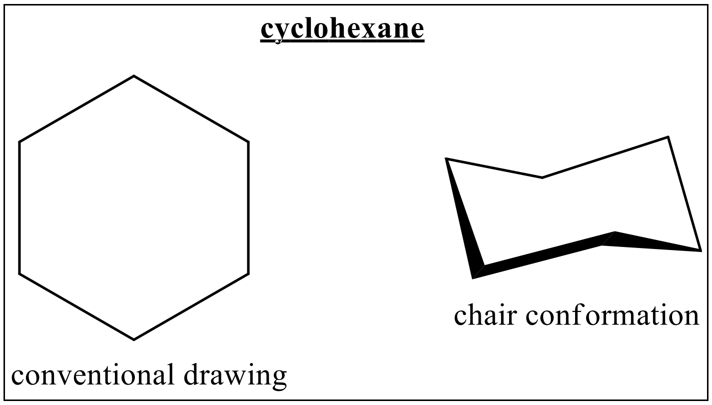


Anti

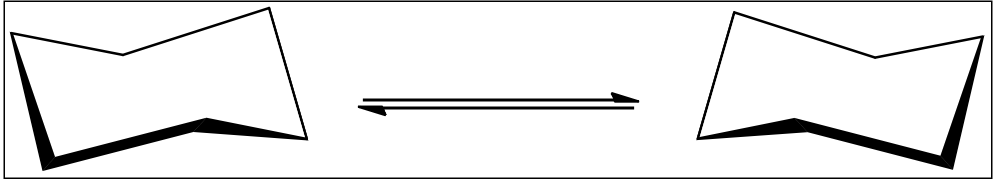
1. **Totally Eclipsed** – methyl groups are aligned with one another
    i. There is **torsional strain** between groups
        - Repulsion of electron clouds
    ii. There is **steric hindrance**
        - The interference between two bulky groups
    iii. These are the least stable of the conformations
    iv. They possess the highest potential energy of the conformations
2. **Gauche** – When the methyl groups are staggered to the left or right of one another at a $60^0$ angle
    i. More stable
    ii. Lower potential energy
3. **Eclipsed** – Eclipsed position, but methyl groups are not eclipsed and are at a $120^0$ angle to one another
    i. Less stable
    ii. Higher potential energy
4. **Anti** – When the methyl groups are staggered to be complete opposite on another and are at a $180^0$ angle
    i. Most stable
    ii. Least potential energy

c. **Chair conformations**

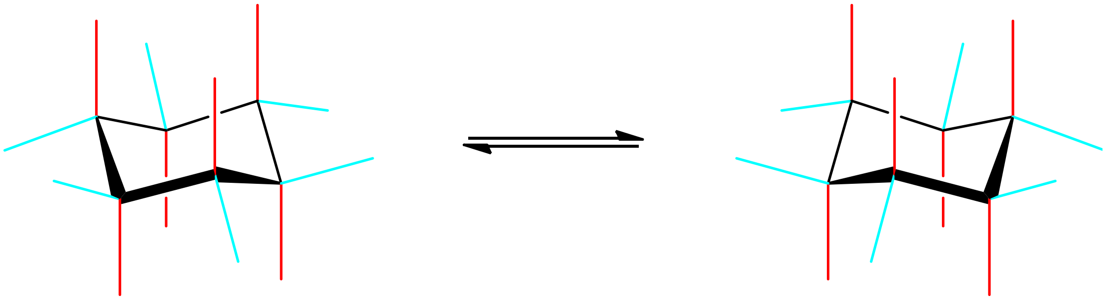
1. Cyclohexane can be drawn in its conventional form, or in a variety of 3-D like model drawings. An important such conformation is known as a **chair conformation**.



2. The chair conformation can flip between two different positions:

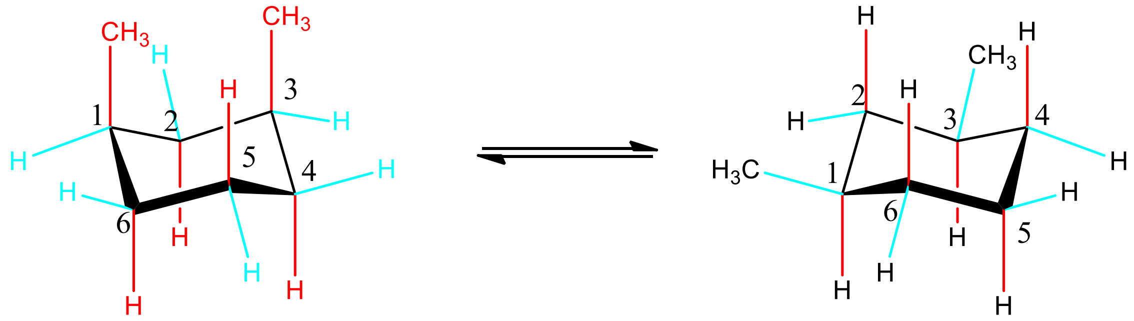


3. Positions on the chair conformation



Lines in blue indicate the equatorial positions
Lines in red indicate the axial positions

4. The chair conformations also demonstrate the importance of minimizing repulsion between groups to increase stability of a molecule
5. 1,3 di-axial versus 1,3 di-equatorial
   i. **1,3 di-axial** = very **unfavorable** due to **steric hindrance** between bulky groups
   ii. **1,3 di-equatorial** = much more **favorable** as steric hindrance is minimized and the structure is much more stable



Here the CH$_3$ groups are in the
1,3 di-axial position
This is unfavorable

Here the CH$_3$ groups are in the
1,3 di-equatorial position
This is favorable

**Sign-Up for Full Access!**

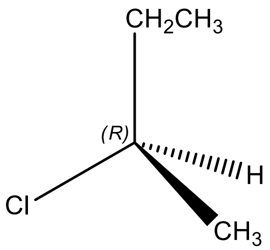
For an interactive **Exercise Set** on **Isomers**, **Sign Up and become a member** of StudyOrgo.com. We are so confident in our program that we offer a guarantee like no other. **We guarantee you will pass!** While many students are happy with just passing this course, most of the students that we have feedback from, have excelled to be in the top of their class.

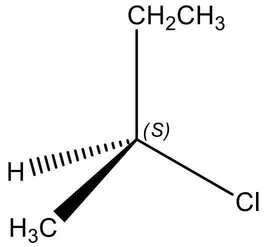
For more information and to Sign-Up visit:

https://www.studyorgo.com/signup.php

# Chapter Nine: Chirality and Enantiomers

1) **Chiral**
    a. Definition: a plane of symmetry does NOT exist in a given structure
    b. Two objects are **chiral** if they are **NOT superimposable** on one another
2) **Achiral**
    a. Definition: a plane of symmetry DOES exitst in a given structure
    b. Two objects are **achiral** if they **are superimposable** on one another
3) **Enantiomers**
    a. Definition: **Two isomers that are mirror images of one another**
    b. Enantiomers are chiral and they are NOT superimposable on one another
    c. **Chiral carbons**
        i. A chiral carbon has four different items attached to it.
        ii. A chiral carbon is also known as asymmetric carbon
        iii. The chiral carbon is the chirality center of the molecule
        iv. Enantiomers possess chiral carbons.
4) **R** and **S** nomenclature
    a. Used to assign an identifying label to each chiral carbon in a given enantiomer
        i.



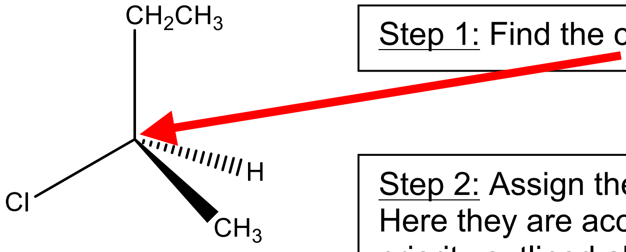


    b. How to determine R and S nomenclature
        i. Step 1: Find the chiral carbon
        ii. Step 2: Assign the numbers 1 through 4 to each item attached to that carbon.
            1. Assign 1 to the item that is of highest priority through 4 to the item of lowest priority
            2. Hierarchy of priority (in order from most important to least important)
                a. Halogens (I>Br>Cl>F)
                b. O
                c. N
                d. C
                e. H
            3. Some important notes:
                a. Often you will have a *tie*. In that case, go to the next item after that atom to break the tie and determine the priority.
                b. When encountering double or triple bonds, pretend they are single bonds and duplicate the items attached to that bond. Duplicate twice for triple bonds.
        iii. Step 3: Draw a circle from 1 to 2 to 3 to 4.

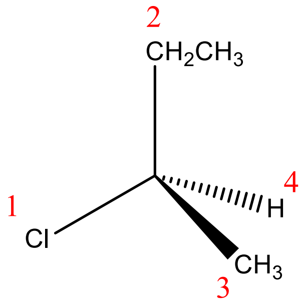
    1. Before starting look and see where item #4 is. If item #4 is within the plane of the screen or paper → redraw the image to have item #4 going into the plane of the screen or paper before continuing.
        a. If item #4 is going into the screen or paper or coming out of the screen or paper, continue as follows.
    2. Determine if the circle was drawn clockwise or counterclockwise.
    3. If the circle was drawn clockwise → assign the letter "R"
    4. If the circle was drawn counterclockwise → assign the letter "S"
    5.

iv. <u>Step 4:</u> Check and see where the item #4 is
    1. Usually this item is a hydrogen. If item #4 is in the plane positioned **behind** you or is going into the plane of the screen or paper then **leave the assigned letter as is.** However, if item #4 is position in front of you or is coming out of the place of the screen or paper, then **assign the opposite letter** from what you assigned in Step 3.
    2. If item #4 is going into the place of the screen or paper→ leave alone
    3. If item #4 is coming out of the plane of the screen or paper→ assign the opposite letter
        a. If R was chosen → new assignment is **S**
        b. If S was chosen → new assignment is **R**
    4. Remember, if item #4 is within the plane of the screen or paper → redraw the image to have item #4 going into the plane of the screen or paper before determining clockwise or counterclockwise (see step 3 above.

v. Example:



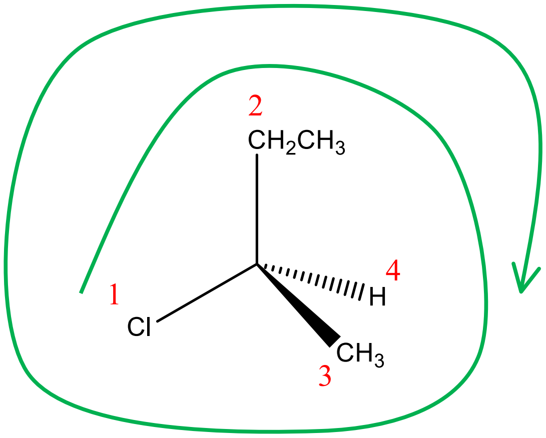
<u>Step 1:</u> Find the chiral carbon



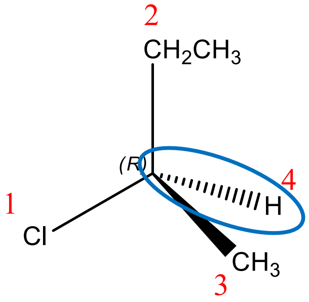
<u>Step 2:</u> Assign the numbers
Here they are according to the hierarchy of priority outlined above
#1: Cl
#2:$CH_2CH_3$

- There are two carbons directly attached to the chiral carbon. In order to break the tie, we look to see what is attached to those carbons. The $CH_2CH_3$ substituent has a further carbon attached, while the $CH_3$ substituent only has hydrogen attached therefore $CH_2CH_3$ wins.

#3: $CH_3$
#4: H



Step 3: Draw a circle from 1 to 2 to 3 to 4
In this case the circle drawn is clockwise.
Therefore the assignment is **R**



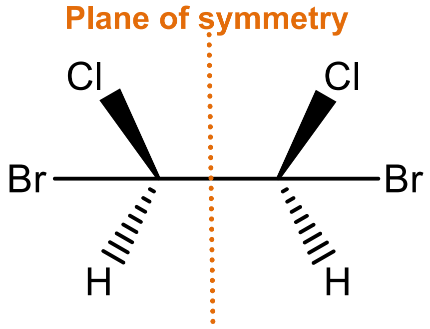
Step 4: Check and see where the item #4 is
Since item 4 is already in the back the assignment stays the way it is at **R**

5) Properties of Enantiomers
   a. A pair of **enantiomers almost have identical properties.** They differ in one aspect:
      i. **Two enantiomers rotate plane-polarized light in opposite directions**
         1. Plane polarized light are light waves that travel only in one plane
         2. This is referred to as **optical activity**
         3. **Clockwise** rotations are abbreviated by a **(+)** or the letter ***"d"***
         4. **Counterclockwise** rotations are abbreviated by a **(-)** or the letter ***"l"***

6) **Racemic mixture**
   a. Definition: When equal amounts of each enantiomer of a pair of mixed together

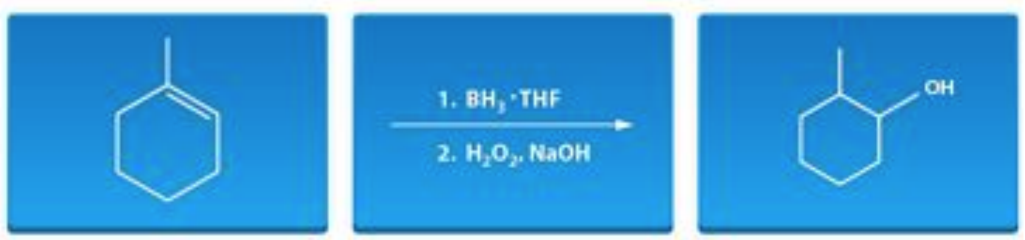
   b. While each individual enantiomer on its own it optically active, when the two equal amounts are mixed together, **the mixture is NOT optically active**

7) **Meso compound**
   a. Definition: A structure that possesses both a plane of symmetry and at least one asymmetric carbon. Meso compounds are **achiral**.
   b. Example:



# Chapter Ten: Introduction to the Study of Orgo Reactions

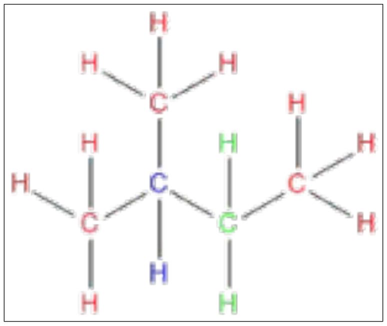
1) Reaction Format
    a. Organic chemistry reactions are typically presented in the following format:
        i. Reactants or reagents are mixed together to form product(s).
        ii. Reactants and reagents are placed to the left and on top of an arrow which point to the product(s).
        iii. If certain reagents are added separately from one another in a particular sequence, then numbers are used to indicate the order in which they are added.
        iv. Example:



    b. Reaction Mechanism and Intermediates
        i. Most reactions occur over a span of multiple steps. This is commonly known as the **reaction mechanism**. The mechanism is written in a step-wise fashion using arrows to demonstrate where the electrons are going from step to step.
        ii. Each compound created along the way is known as a **reaction intermediate.**

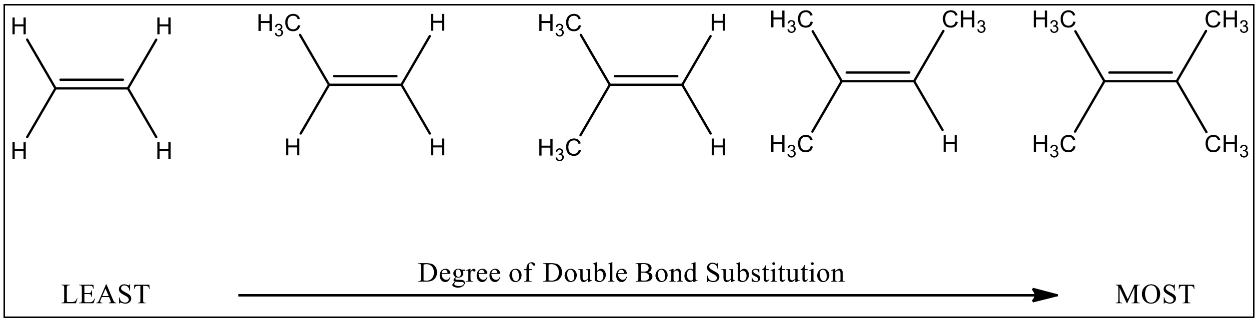
2) Degree of Substitution in Alkanes
    a. Carbon atoms in alkanes may be bonded to up to four other carbon atoms. We use the terms primary, secondary, and tertiary, and quaternary to refer to the *degree of substitution* level that a given carbon has in a molecule.
    b. This is important because the fate of how certain reactions proceed depends on these substitutions levels
    c. To figure out the substitution level of any given carbon, follow these three easy steps:
        i. Step #1: Pick a carbon
        ii. Step #2: Count how many carbons are directly attached to it. Other elements such as hydrogen, nitrogen, oxygen etc. don't count.
        iii. Step #3: Give it a label:
            1. **Primary** = a carbon attached to only **one** other carbon
            2. **Secondary** = a carbon attached to only **two** other carbons
            3. **Tertiary** = a carbon attached to only **three** other carbons
            4. **Quaternary** = a carbon attached to **four** other carbons
    d. In the following example, the carbons are color-coded to highlight their degree of substitution:
        i. Primary
        ii. Secondary

        iii. Tertiary



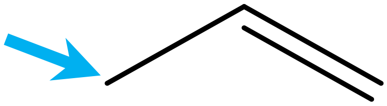
  e. Bear in mind that hydrogens attached to a given carbon also take on the labels as described in step #3 above:
      i. Primary = a hydrogen on a carbon attached to only **one** other carbon
      ii. Secondary = a hydrogen on a carbon attached to only **two** other carbons
      iii. Tertiary = a hydrogen on a carbon attached to **three** other carbons

3) Degree of Substitution in Alkenes
  a. Carbon atoms on either side of a double bond may each bond up to two other carbons
      i. The more carbons each of those carbons are attached to the more highly substituted the alkene is



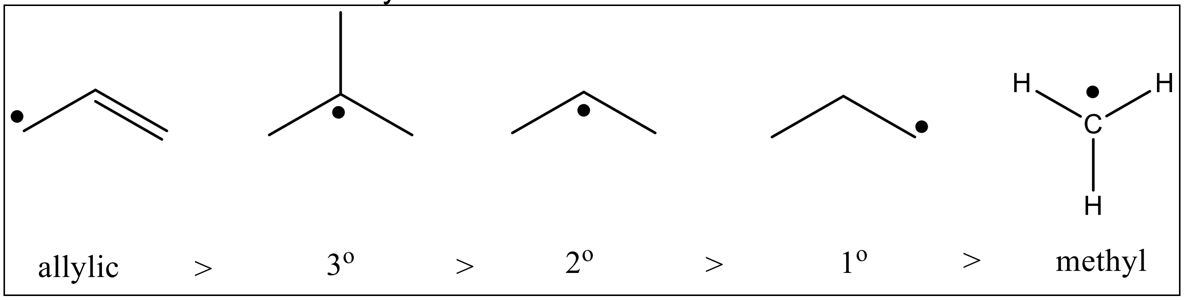
  b. This is important because the fate of how certain reactions proceed depends on these substitutions levels. Also a certain degree of substitution may be favored in certain reaction products.

4) Allylic position
  a. Definition: The position immediately next to a double bond

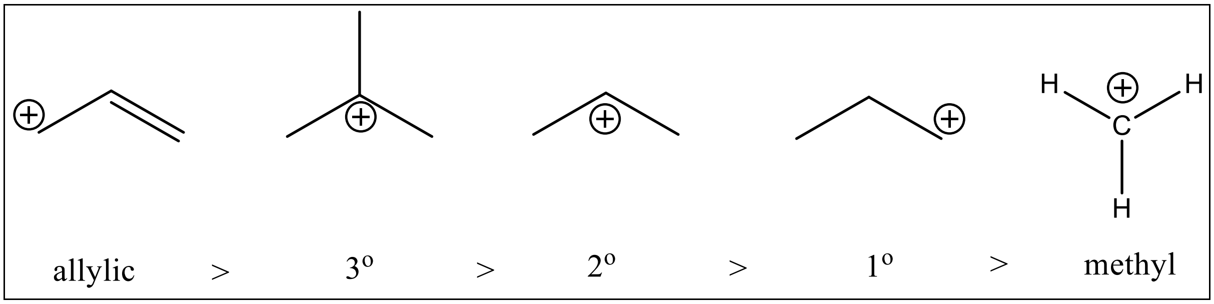


   b. This is important because this position is typically favored by certain reactive intermediates

5) Reaction Intermediates
   a. **Radical**
      i. Typically electrons come in pairs. However there are *unpaired electrons* known as *radical electrons*. These are usually just called *radicals*.
      ii. Radical stability
         1. Radicals prefer a **greater** degree of alkyl substitution. Even more so, radicals prefer to be in the **allylic** position. Therefore here is the hierarchy of radical intermediate stability:



   b. **Carbocation**
      i. Carbocations serve as electrophiles in reactions. They will attract electrons easily as the carbon is deficient in electrons.
      ii. Carbocation stability
         1. Carbocations prefer a **greater** degree of alkyl substitution. Even more so, carbocations prefer to be in the **allylic** position. Therefore here is the hierarchy of carbocation intermediate stability:



   c. **Carbanion**
      i. Carbanions serve as nucleophiles in reactions. They will donate electrons easily as the carbon has excess electrons.

ii. Carbanion stability

1. Carbanions prefer a **lesser** degree of alkyl substitution. Even more so, carbanions prefer to be in the **allylic** position. Therefore here is the hierarchy of carbanion intermediate stability: