

ChemActivity 6: Alkanes and Alkenes

BUILD MODELS: CH_3CH_3 AND $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

While you wait for class to begin, make a model of each molecule in the "BUILD MODELS" section.

PART A: CONFORMERS OF ALKANES

(What is the lowest-energy conformation of butane?)

Model 1: Lowest P.E. Conformation of Ethane (CH_3CH_3)

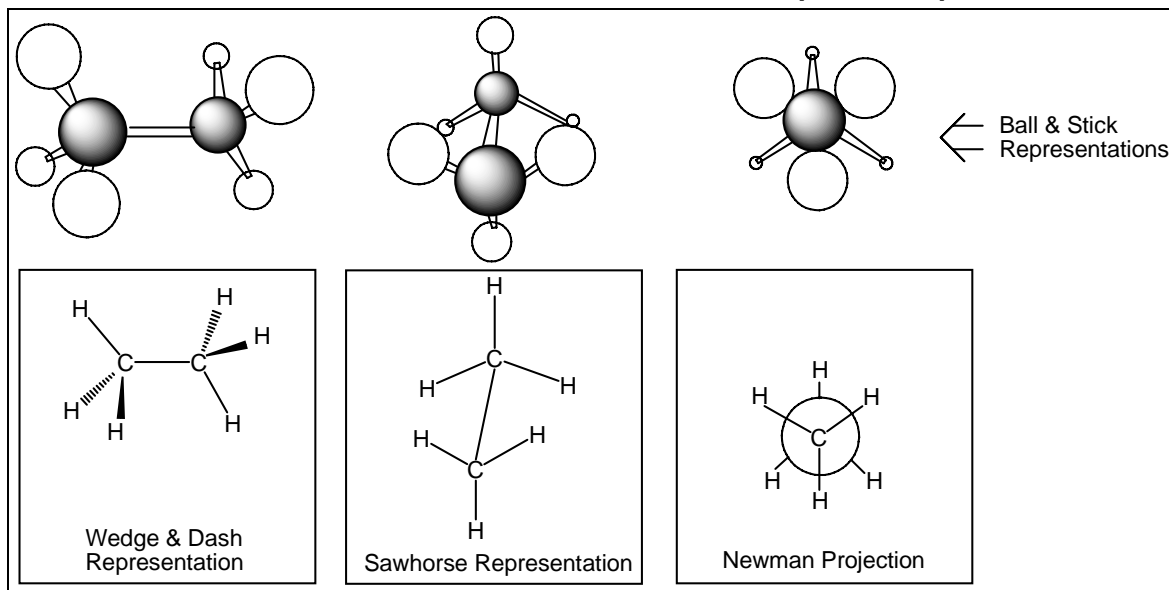
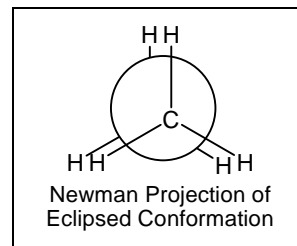


Figure 6.1: Ethane in the Staggered Conformation

Each representation above shows ethane (CH_3CH_3) in its lowest P.E. (most favorable) **conformation**.

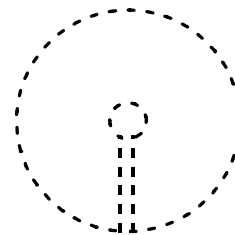
Critical Thinking Questions

- (E) Make a model of ethane. Each time you move atoms by rotating a single bond you are changing the **conformation** of the molecule. Rotate the C—C single bond of butane to put it in its most favorable conformation (as shown in Model 1). This conformation is called **staggered**.
- The conformation at right is called **eclipsed**. It is the least favorable (highest P.E.) conformation of ethane.
 - (E) Explain the names **staggered** and **eclipsed**.



- Construct an explanation for why the staggered conformation is more favorable than the eclipsed conformation. (Both are "**conformers**" or "**conformational stereoisomers**" of ethane.)

3. Newman projections are confusing partly because an imaginary disc is inserted in the drawing to create the illusion of near and far.
 - a. Tear or cut out a piece of paper the shape of this object →
 - b. Hold your eye up to your model of ethane to simulate the perspective shown by the Newman projection in Figure. 6.1.
 - c. Hang your cut-out shape on the C—C bond of your model of ethane to serve as the disc shown in every **Newman projection**.
 - d. Identify the single atom of ethane that is hidden from view behind this disc in the drawing (and now in your model).



Model 2: Potential Energy (P.E.) Revisited

Recall our analogy between chemical **potential energy** and gravitational potential energy.

In the diagram below a marble moves from high to low P.E.. As in most chemical systems, the **spontaneous** change from high to low P.E. is accompanied by the release of heat.

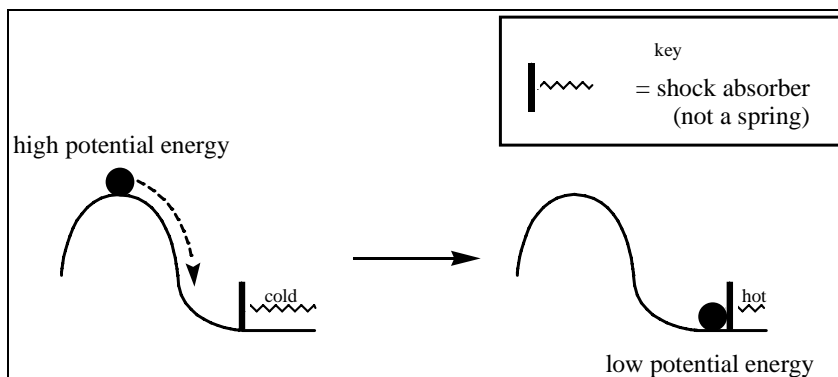
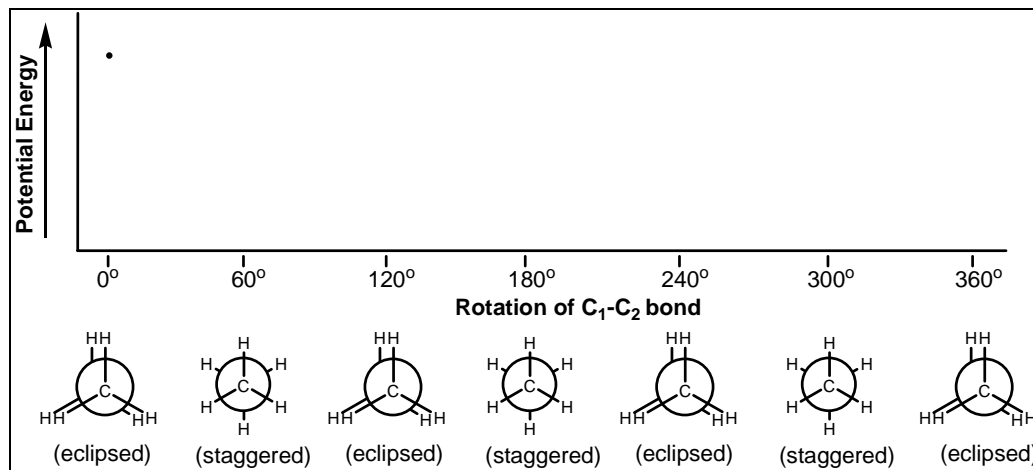


Figure 6.2: High and Low Potential Energy Marble

Critical Thinking Questions

4. (E) In which location is the marble more stable (unlikely to change position)?
5. In general, **high potential energy** systems are **unstable** and **likely to change if they have a way to change**. Because single bonds can rotate freely, ethane in the eclipsed (highest P.E.) conformation is not stable (see Newman Projection in CTQ 2).
 - a. (E) What conformation of ethane is “downhill” in terms of potential energy from the eclipsed conformation?
 - b. What repulsive force(s) will cause ethane in the eclipsed conformation to quickly adopt the conformation you cited above?

6. Complete this graph of *relative potential energy* vs. **rotation of the C₁-C₂ bond** of ethane. The point drawn for you indicates the P.E. at 0° (eclipsed).



Model 3: Ethane in Motion

At room temperature, the C₁-C₂ bond of ethane is spinning rapidly. If you could observe this spinning closely you would see that the molecule zips past the high-energy eclipsed conformations and slows down to take advantage of the low-energy staggered conformations. Chemists explain this phenomenon by saying that the molecule gets stuck in the **potential energy wells** of the staggered conformations. (These wells are the valleys on your diagram above.)

Critical Thinking Question

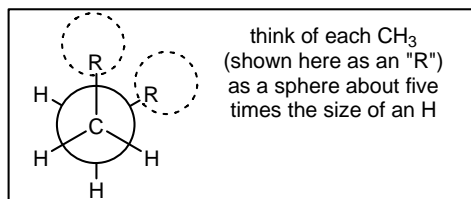
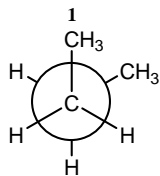
7. If you could devise a way to take an instantaneous snapshot of ethane, in what conformation would you be most likely to “catch ethane?” Explain your reasoning.

Model 4: Newman Projections of Butane (CH₃CH₂CH₂CH₃)

A **Newman projection** of a molecule focuses on rotation of one bond. In the example below it is C₂-C₃, so we ignore the rotation of all other bonds.

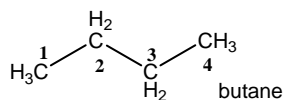
For simplicity, we treat groups attached to C₂ or C₃ as R groups.

staggered conformation
with methyl groups **gauche**
to one another



Critical Thinking Questions

8. Make a model of butane and put it in the conformation shown in Model 4.
- Locate C₂, C₃ and C₄ in Model 4.




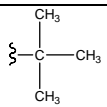
- b. Have each member of your group sight down the C₂—C₃ bond of a model to simulate the perspective shown by the Newman projection in Model 4.
9. The conformation shown in Model 4 is a special type of **staggered conformation** in which the two methyl groups are neighbors (60° apart). This is called the **staggered-gauche** conformation. It is NOT the most favorable conformation (nor the least favorable conformation).
- a. Draw a Newman Projection of butane showing the C₂-C₃ bond in its most favorable conformation. (Show CH₃ groups as “R”)
- b. This most favorable (lowest potential energy) conformation which you drew in part a is called **staggered-anti**. Construct an explanation for both parts of this name.

Model 5: Alkyl Groups (R groups)

Butane is a straight four-carbon chain. For drawing a Newman projection it was convenient for us to think of the CH₃ at either end of the chain as an R group. This same strategy can be used to simplify Newman projections of more complicated molecules.

alkyl group = group consisting of C and H connected by single bonds and designated by “R”

Memorization Task 6.1: Memorize the names and structures of common alkyl (R) groups

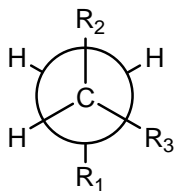
Condensed Structure	Structure (if branched)	Name of R Group (abbreviations)
-CH ₃		methyl group (Me)
-CH ₂ CH ₃		ethyl group (Et)
-CH ₂ CH ₂ CH ₃		propyl group (Pr or <i>n</i> -Pr) <i>n</i> = “normal”
-CH(CH ₃) ₂		isopropyl group (<i>i</i> -propyl, or <i>i</i> -Pr)
-CH ₂ CH ₂ CH ₂ CH ₃		butyl group (Bu or <i>n</i> -Bu) <i>n</i> = “normal”
-C(CH ₃) ₃		<i>tertiary</i> -butyl group (<i>tert</i> -butyl or <i>t</i> -butyl)

Memorization of the parent names, meth, eth, prop, but, etc., is the starting point for learning the rules for naming all organic molecules. These rules can be found in Nomenclature Worksheet 1 (NW1).

Critical Thinking Questions

10. Consider the Newman projection below.

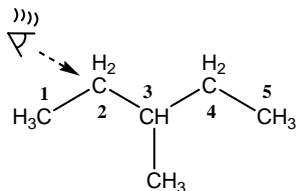
- a. Draw a full Lewis structure of this molecule with $R_1 = \text{Me}$, $R_2 = \text{Et}$, and $R_3 = i\text{-Pr}$.



- b. Given the sizes of these R groups ($R_3 > R_2 > R_1$), does the Newman projection above show the lowest potential energy conformation of this bond? If not, draw a Newman projection showing the lowest P.E. conformation (sighting down this same bond).

- c. To draw a Newman projection in the lowest P.E. conformation, the following rule of thumb usually applies: *Place the largest group on the front carbon **anti** to the largest group on the back carbon.* Is your answer to the previous question consistent with this rule of thumb?

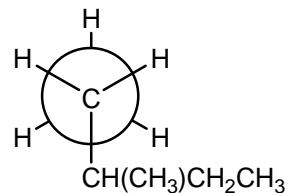
11. Draw a Newman projection showing the lowest P.E. conformation of the following molecule sighting down the $\text{C}_2\text{—C}_3$ bond (as indicated below). Show methyl and ethyl groups as Me and Et.



Only the carbons in the longest chain receive a number.

12. An R group that is not common enough to have an abbreviation should be represented on a Newman projection using its **condensed structure**, as in the following example:

- a. Confirm that the Newman projection at right is a representation of the molecule in the previous question.
- b. Label carbons 1-5 on the Newman projection at right (being sure to indicate which C is hidden behind the imaginary “disk”).
- c. Add to the Lewis structure in the previous question a drawing of an eye and a dotted arrow indicating the sight line represented by the Newman projection at right.



BUILD MODELS: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ **PART B: CONSTITUTIONAL ISOMERS**(Are two molecules with the same molecular formula the same/conformers or **constitutional isomers**?)**Model 6: Representations of Carbon Structures**

Skeletal	Bond-Line	Wedge & Dash	Ball & Stick	Condensed
				CH_3CH_3
				$\text{CH}_3\text{CH}_2\text{CH}_3$
				$(\text{CH}_2)_4$
				$\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)\text{CH}=\text{CH}_2$
				$\text{CH}_3\text{CH}_2\text{O}^-$




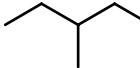
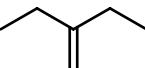
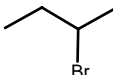
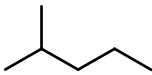
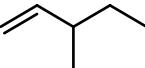

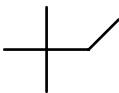
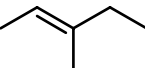
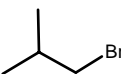
Critical Thinking Questions

13. (E) Draw a bond-line representation of the molecule shown below as a skeletal representation.



14. In skeletal representations the hydrogens are not shown. Is it still possible to tell how many hydrogens there are on a particular carbon? If so, explain how.
15. (E) If you know the formal charge of an atom in a structure, you can tell how many lone pairs are on that atom. If you know how many lone pairs are on the atom, you can determine its formal charge. Up to this point, both have been shown. However, by convention **only one is required**. Based on Model 6, which is required to be shown, an atom's formal charge or its lone pairs?

Model 7: Constitutional Isomers

Column 1		Column 2		Column 3	
structure	molecular formula	structure	molecular formula	structure	molecular formula
	C_6H_{14}		C_6H_{12}		$C_6H_{13}Br$
	C_6H_{14}		C_6H_{12}		
	C_6H_{14}				
					

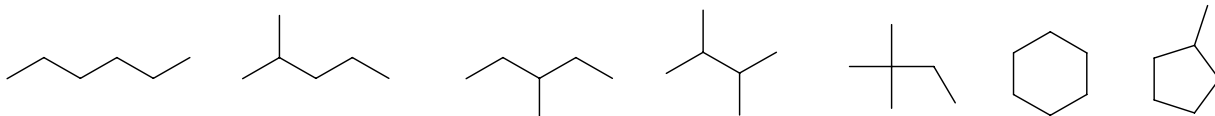
Critical Thinking Questions

- (E) Complete the table in Model 7 by writing in the missing molecular formulas.
- What do the molecules in a given column (1 or 2 or 3, above) have in common with the other molecules in that same column?
- Describe the differences among the four molecules in a given column.
- All the structures in a given column are **constitutional isomers** of one another, but the structures in column 1 are not constitutional isomers of structures in other columns. Based on this information, write a definition for the term **constitutional isomers** that starts: *“Two molecules are constitutional isomers if...”*
- Without breaking bonds, change your model of hexane from the conformation shown in Model 7 to the one shown in the bottom left corner of this page.
- Each structure below is an alternate representation of a structure in Model 7. Under each structure, draw the structure from Model 7 that represents the same molecule. Recall that: **Two molecules are the same if models of each can be interconverted without breaking bonds** (i.e., they are conformers).

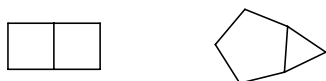


22. Draw five constitutional isomers missing from Column 2 in Model 7. (There are more than five.)

23. Shown below are a handful of the possible six-carbon backbones (i.e., the ways six carbons can be arranged). If the previous question asked you to draw ALL missing constitutional isomers, a good way to start would be to draw all possible “backbones,” then add double bonds as needed.



- Circle the backbones above that need a double bond to become a constitutional isomer of the molecules in **Column 2** of Model 7.
- Explain why the following arrangements of six carbons CANNOT form the backbone of a constitutional isomer of the molecules in Column 2 of Model 7.



- T or F: All constitutional isomers of the molecules in Column 2 will have exactly one double bond or one ring.

Memorization Task 6.2: Molecular formula of a *saturated* alkane = C_nH_{2n+2} (where n = no. C's)

alkane = molecule with only C/H, and no π bonds or rings, e.g., pentane $[CH_3-CH_2-CH_2-CH_2-CH_3]$

(Note: pentane has two H's for each C, plus one extra H on each end C, thus no. H's = $2 \times$ no. C's + 2.)

Critical Thinking Questions

- Draw a constitutional isomer of pentane, and explain why branching does not change the ratio of C to H (the molecular formula remains C_5H_{12}).
- How many H's are lost from the molecular formula of pentane if a double bond is introduced? (This changes the parent name of the molecule to **pentene**, as described in Model 1 of NW2.)
- How many H's are lost from the molecular formula of pentane if the ends are joined into a ring (changing the parent name of the molecule to **cyclopentane**)?

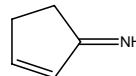
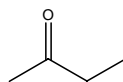
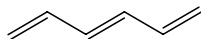
Model 8: Degree of Unsaturation

Because π bonds and rings have the same effect on the molecular formula of a molecule (lose two H's), the total number of π bonds and rings in a molecule is given a name...

degree of unsaturation = [no. of π bonds] + [no. of rings]

Critical Thinking Questions

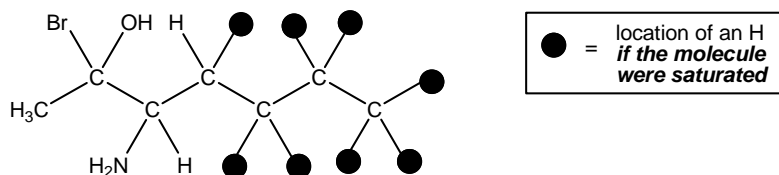
27. Write the degree of unsaturation below each structure.



Memorization Task 6.3: Determining Degree of Unsaturation from Molecular Formula

If you are given only the molecular formula of an unknown molecule (e.g., $\text{C}_7\text{H}_8\text{NOBr}$) and asked to find the molecule's **degree of unsaturation** (or to draw a possible structure of the molecule)...

- I. Draw **any** straight-chain structure containing all the atoms but with no π bonds or rings.
(It doesn't matter where you put the groups as long as each atom has the correct number of bonds.)

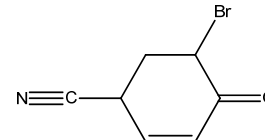
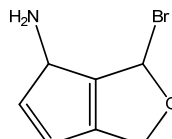
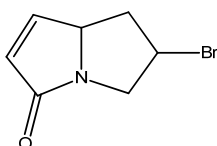
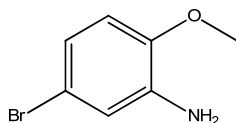


- II. Count the number of H's it would take to "saturate" the molecule with H's. (This always will be an even number—if it is an odd number you have made an error.)

$$\text{degree of unsaturation} = \frac{\text{No. of "missing" H's}}{2}$$

Critical Thinking Questions

28. What is the degree of unsaturation for the example molecular formula $\text{C}_7\text{H}_8\text{NOBr}$?
29. **Without counting hydrogens**, determine which one of the following CANNOT be the unknown molecule with molecular formula $\text{C}_7\text{H}_8\text{NOBr}$, and explain your reasoning.



30. Determine the degree of unsaturation (and draw a possible structure) for a molecule with molecular formula $\text{C}_6\text{H}_4\text{O}_2$

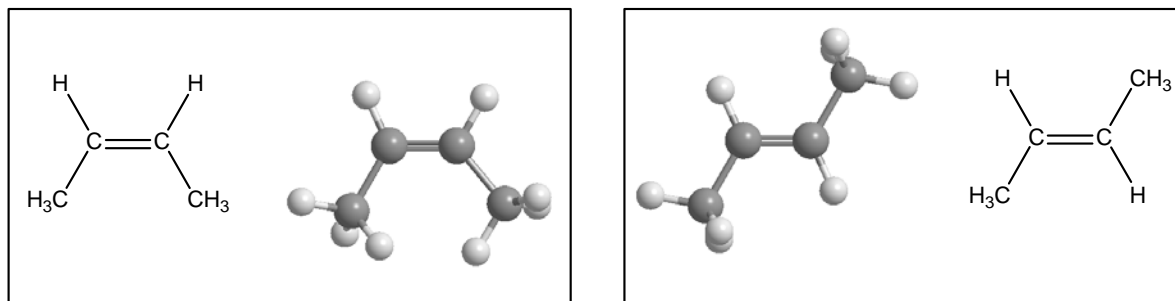
BUILD MODELS: $H_3C-CH=CH-CH_3$ **PART C: ALKENE STEREOISOMERS (*E/Z* AND *trans/cis*)**(How can you tell which **stereoisomer** of an *E/Z* pair is *E* and which is *Z*?)**Model 9: But-2-ene (or 2-Butene)**

Figure 6.3: Representations of but-2-ene molecules

Critical Thinking Questions

31. Make a model of each molecule shown above: Is the molecule in the left box the **same molecule** as the molecule in the right box? Use your models to answer the question, and recall that...

Two molecules are the same if models of each can be interconverted without breaking bonds.

Model 10: *E, Z*, or Neither?

The π portion of a double bond prevents rotation. As a result, many double bonds have two different orientations that give rise to two different molecules.

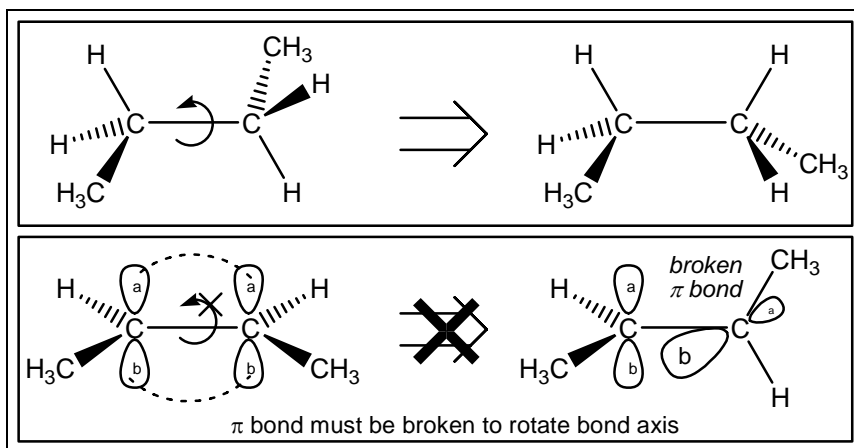


Figure 6.4: Single bonds rotate freely, but double bonds do not.

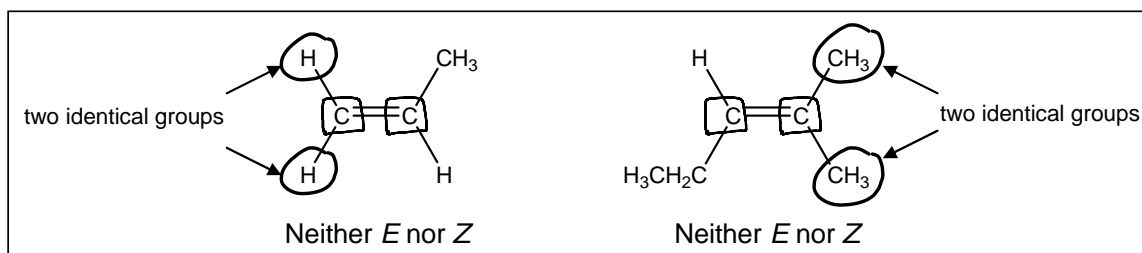
The letters *E* and *Z* (or the terms *trans* and *cis*) are used to name the two possibilities that result.

Rules for determining *E* and *Z* are on the next page.

Memorization Task 6.4: Memorize the definitions of *E* and *Z* (and *trans* and *cis*)

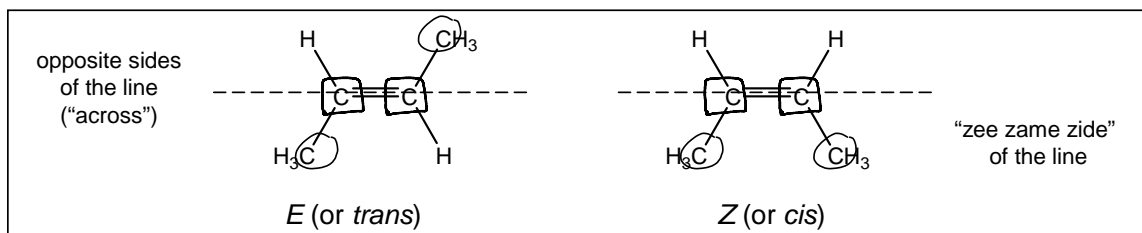
To determine if a double bond is **E**, **Z**, or **neither**...

- I. Put a box around each carbon involved in the double bond (as shown below)
- II. Are there two identical groups on *either* boxed C? → If **YES** double bond is neither *E* nor *Z*
(If a double bond is **neither** there is only one way to draw the molecule, and its name will not include either letter.)



STOP here if neither *E* nor *Z*

- III. Otherwise, draw a dotted line along the double bond, and **circle the atom with the highest atomic number on each boxed C**. (Atomic numbers from the periodic table: $H = 1$, $C = 6$, $N = 7$, $O = 8$, etc.)



- If circled groups are on opposite sides of this line → double bond is **E**
E stands for *entgegen*, which is German for “opposite.”
- If circled groups are on the same side of this line → double bond is **Z**
Z stand for *zusammen*, German for “together.” (Say it in a German accent “zee zame zide”)

Trans and *Cis*: alternates for *E* and *Z*

The two circled groups in the *E* molecule above are said to be *trans* to each other. (*trans* = “across”)

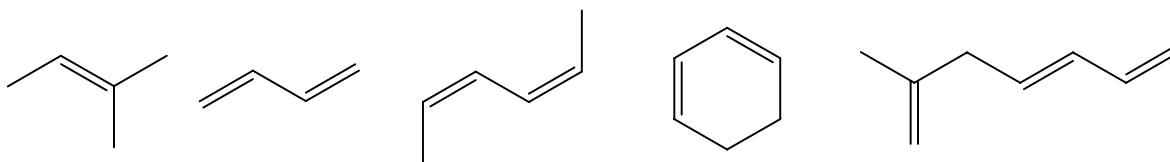
The two circled groups in the *Z* molecule are *cis* to each other. (Say *cis* with a German accent: “**Zis**”)

trans and *cis* are often used in place of *E* or *Z* when the groups that are *trans* or *cis* to each other are identical (as in each example above in which both circled groups are methyl groups).

Critical Thinking Questions

32. Label each but-2-ene molecule (also called 2-butene) in Model 9 with the appropriate two names. Choose from: *Z*-but-2-ene, *E*-but-2-ene, *cis*-but-2-ene, and *trans*-but-2-ene.
33. Draw skeletal representations (see Model 6) of *Z*-hex-3-ene and *E*-hex-3-ene.
(The “3” tells you the π bond starts on the 3rd carbon, i.e. $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_3$)

34. Label each double bond *E*, *Z*, or neither. (It may help to draw in some missing H's.)



Model 11: CAHN-INGOLD-PRELOG RULES for Assigning *E/Z* Priorities

The rules for assigning priority outlined in this activity are called the Cahn-Ingold-Prelog rules after their three co-inventors.

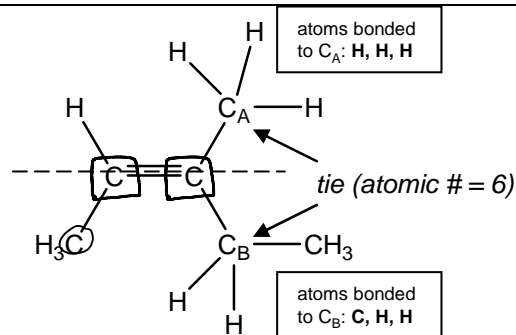
In the structure at right, carbons C_A and C_B are tied.

To determine which gets circled, look at the 3 atoms (other than the boxed carbon) that are bonded to each.

Think of these atoms as “cards.”

- C_A 's “cards” = H H H
- C_B 's “cards” = H H C

High card wins, so C_B beats C_A , and the molecule is *Z*.



Additional Rules:

isotopes → the heavier atom wins (D beats H)

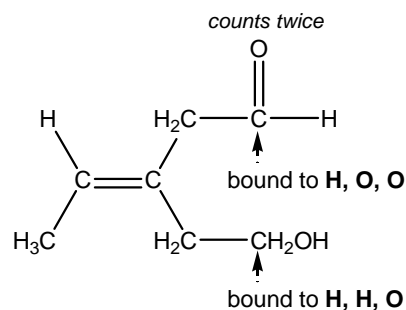
multiple bonds → double bond (e.g., C=O) counts the same as two single bonds to that atom (O-C-O)

If a tie results after the first round of the card game, play a 2nd round using the highest card from each hand.

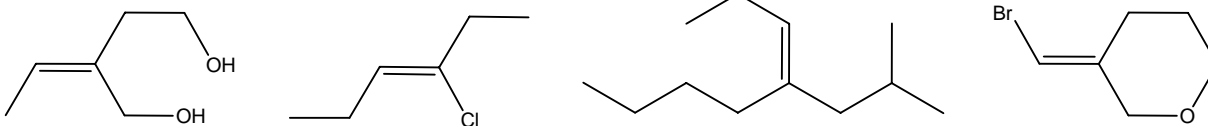
Keep playing until an assignment of *E* or *Z* is made.

Critical Thinking Questions

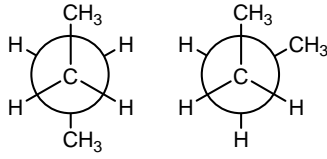
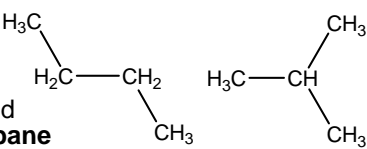
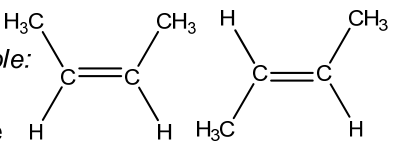
35. Explain why the molecule at right is *E*.



36. Label each molecule below *E*, *Z*, or neither.



Model 12: Configurational Stereoisomers

<p>*Conformers (conformational stereoisomers) can be interconverted via single bond rotation (that is, without breaking bonds).</p> <p>Conformers are alternate representations of the same molecule.</p>	<p>For example:</p> <p>anti and gauche butane</p> 
<p>Constitutional Isomers have the same molecular formula but different atom connectivity</p>	<p>For example:</p> <p>butane and 2-methylpropane</p> 
<p>**Configurational Stereoisomers (some books call these “stereoisomers” for short) have the same molecular formula AND the same atom connectivity, but CANNOT be interconverted via single bond rotation.</p>	<p>For example:</p> <p>Z and E-but-2-ene</p> 

You cannot buy a bottle of “anti” butane or “gauche” butane because in any sample of butane at normal temperatures the molecules are rapidly interconverting among all possible conformations. You can buy a bottle of E-butene or Z-butene.

*To avoid confusion between conformational and configurational stereoisomers we will call the former “conformers.”

** Many books erroneously drop the term “configurational” and call configurational stereoisomers simply “stereoisomers” for short. **WATCH OUT:** The term stereoisomer is often used in place of “configurational stereoisomer.”

Critical Thinking Questions

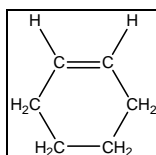
37. Indicate the relationship between each pair. Choose from: **configurational stereoisomers**, **conformers or identical**, **constitutional isomers**, or **different formulas** (use *each* at least twice).

Model 13: ALKENE NOMENCLATURE

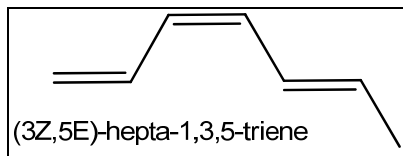
Naming can be a great way to figure out the relationship between two molecules. For example: If two molecules have the same name, they are the same or conformers. If two names differ only in the prefixes *Z* vs. *E*, the molecules are configurational stereoisomers.

Memorization Task 6.5: Rules and Conventions for Naming Alkenes

- A molecule with a carbon-carbon double bond has a parent name ending in “ene” (instead of “ane”), and when there is more than one possible location for this double bond a number is used to designate where the double bond is located. For example, but-1-ene versus but-2-ene (shown in the first box in the previous question).
- To properly name a molecule with one *Z* or *E* double bond you must include the appropriate prefix before the name (omitting the prefix implies a mixture of *Z* and *E*).
 - An exception to the above: A double bond in a ring is assumed to be *Z*. e.g., “**cyclohexene**” is used, not *Z*-cyclohexene.
- If there is more than one double bond that is *Z* or *E*, use multiple prefixes and numbers to designate which bonds are *Z* and which are *E*.
 - Molecules with two, three, or four double bonds have the base names “diene,” “triene,” and “tetraene,” respectively.



It is understood that the double bond is *cis* because placing a *trans* double bond in a ring puts tremendous strain on the molecule.

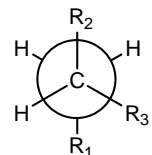


Critical Thinking Questions

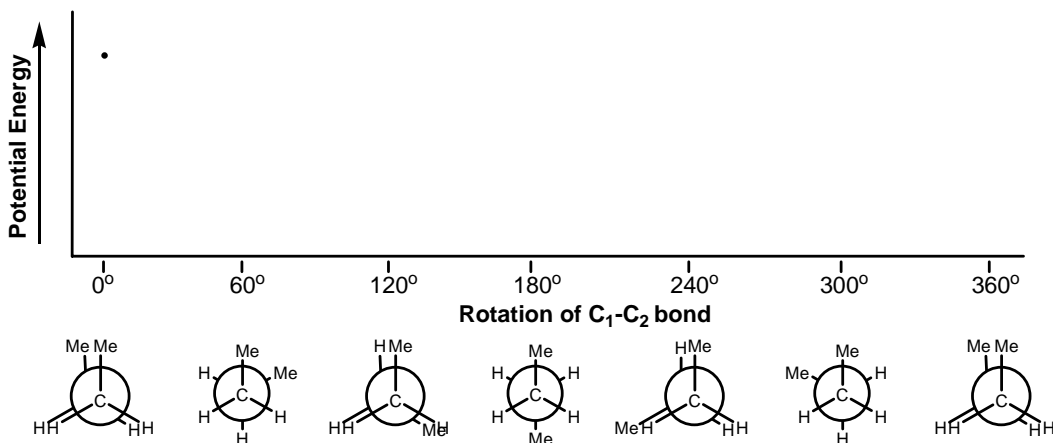
38. Name each molecule on the previous page using information found in Model 13 and Nomenclature Worksheet 1.

Exercises for Part A

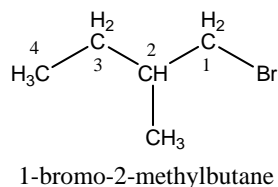
- The staggered-gauche conformation shown in Model 4 is not the most favorable or the least favorable conformation of butane. Draw a Newman Projection of butane in its least favorable (highest potential energy) conformation.
- The words **anti** and **gauche** can describe a molecule's conformation, or the relative positions of two groups. For example, R_1 and R_2 are **anti** to one another.
 - Label the H that is **anti** to R_3 , and label the H that is **gauche** to R_3 .
 - Which word (**anti**, **gauche**, or **neither term**) describes the relationship between R_1 and R_3 ? ... R_2 and R_3 ?



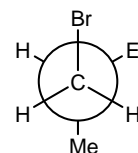
3. Using your model of butane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$), complete the following graph of the **angle between the two Me groups** vs. potential energy.



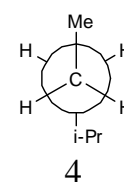
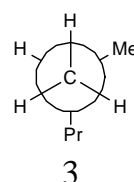
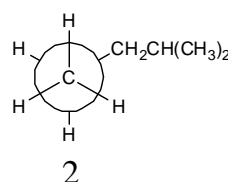
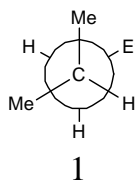
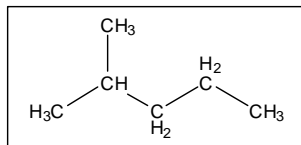
- Label each Newman projection of butane on the graph with the words staggered, eclipsed, gauche, and anti, as appropriate. (Note that some structures will have more than one label.)
 - Draw a wedge and dash bond representation of butane in its lowest P.E. conformation.
4. Consider the molecule 1-bromo-2-methylbutane. C_3 and C_4 should be drawn as Et as in the example. This group is called an **ethyl group** and can be considered a sphere about twice the size of a methyl group. Draw the following Newman projections **sighting down the C_1 — C_2 bond**...



example Newman Projection



- The lowest potential energy conformation.
 - The highest potential energy staggered conformation.
5. Which is a Newman projection of the molecule in the box?



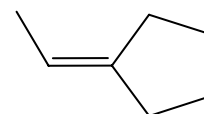
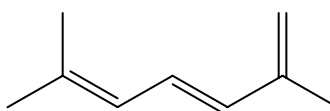
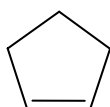
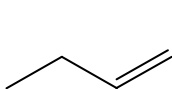
6. **Complete Nomenclature Worksheet 1.** By next class you must memorize the rules for naming alkanes and alkenes.
7. Read the assigned sections in your text, and do the assigned problems.

Exercises for Part B

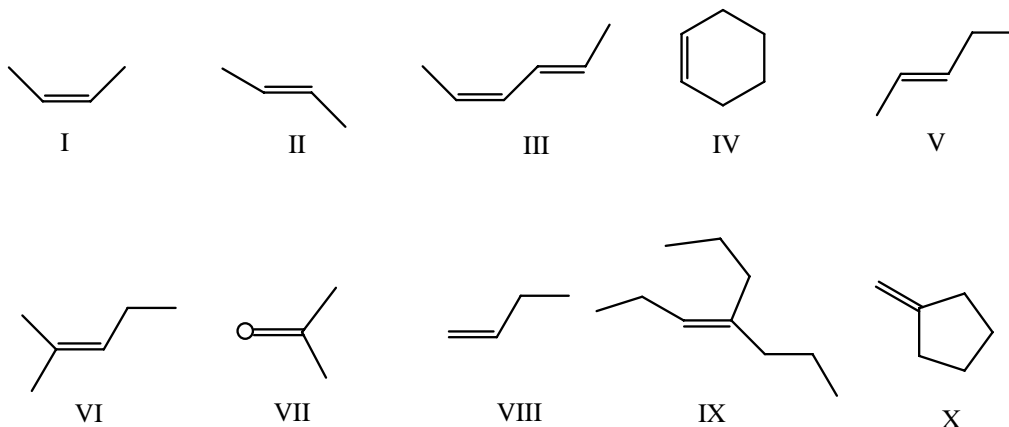
8. Draw the one constitutional isomer that is missing from column 1 of Model 7.
9. Draw skeletal representations of as many constitutional isomers missing from column 2 in Model 7 as you can. (Hint: Other than cyclohexane, there are 11 ways to draw a six-carbon backbone that contains a ring. Plus there are isomers of cyclohexane that do not contain a ring.)
10. Are any constitutional isomers missing from Column 3 in Model 7? (A good way to answer this and similar questions is to start by drawing all possible carbon backbones. Then figure out how many different ways you can add the Br atom, or double bond—as in the previous question—or fluorine—as in the next question.)
11. Draw as many constitutional isomers as you can with the formula $C_5H_{11}F$.
12. Draw the structure of a six-carbon alkene (containing only C and H) with one ring and one double bond.
 - a. Draw a constitutional isomer of the structure you drew above with no rings.
 - b. Explain the following statement found in many text books: “In terms of molecular formula, a ring is equivalent to a double bond.”
13. What is the purpose of CTQ 21? What concept distinction or common misconception is it designed to highlight?
14. Read the assigned sections in your text, and do the assigned problems.

Exercises for Part C

15. Draw a skeletal representation of *Z*-2-hexene and *E*-2-hexene.
16. Draw but-1-ene. Why does it not make sense to specify either *Z*- or *E*-but-1-ene while you must specify *Z*- or *E*-but-2-ene to draw the correct molecule?
17. Label each double bond *E* (*trans*), *Z* (*cis*), or neither. (It may help to draw in critical H's.)



18. Label each double bond *Z*, *E*, or neither.

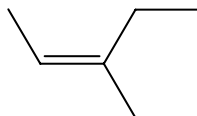


- For each structure draw one constitutional isomer and all possible configurational stereoisomers.
- A “terminal” double bond is a double bond found at the end of a carbon chain (e.g., VIII and X). What generalization can you make about all “terminal” double bonds in terms of *Z/E* (or neither)?
- What is the relationship between Compounds III and IV above?

19. Draw a skeletal structure of *E*-3,4-dimethyl-3-heptene.

- Following the algorithm in Memorization Task 6.4 results in two circled groups attached to the carbons involved in the double bond that are not identical. Nevertheless, the molecule still qualifies as *trans* (having two identical groups *trans* to one another). Explain.
- Draw and name the configurational stereoisomer of *E*-3,4-dimethyl-3-heptene

20. Name this molecule, draw and name its configurational stereoisomer, and construct an explanation for why naming this molecule using *cis* or *trans* (instead of *E* or *Z*) could lead to ambiguity.



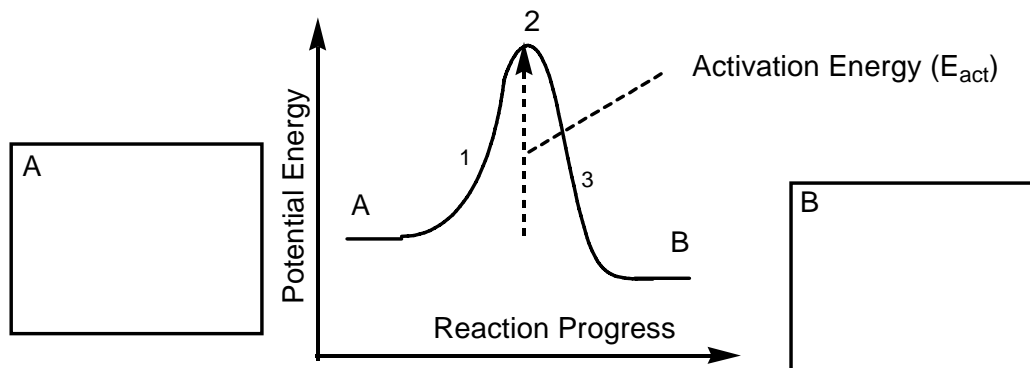
- Draw another example of an alkene that cannot be named using the *cis/trans* nomenclature. (Such a molecule is not *cis*, *trans* or neither, but instead requires the *E/Z* nomenclature.)
- Draw the configurational stereoisomer of the molecule you drew above. (If it has no configurational stereoisomer, your original structure is not correct.)
- Describe the characteristics of a molecule that falls outside the *cis*, *trans* or neither naming scheme and requires the *E/Z* naming scheme.

22. Double bonds do not rotate freely under normal conditions. The change from Z to E requires a reaction. This can occur in the presence of a catalyst or with the addition of a large amount of energy (e.g., at high temperature).

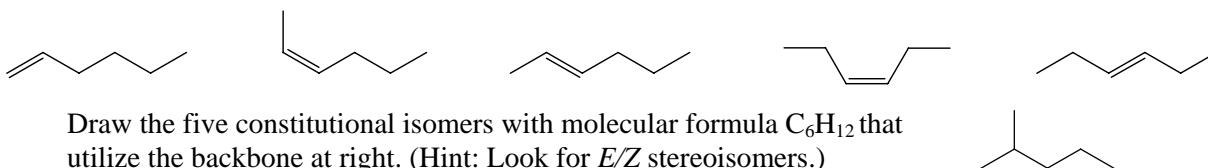
One such reaction is diagramed below:

- (1) Add enough potential energy to break the double bond (E_{act}),
- (2) free rotation occurs at high energy transition state, then
- (3) reforming the double bond as a mixture of Z and E.

Draw *E*-but-2-ene in one box and *Z*-but-2-ene in the other box, and explain your reasoning.



23. Make up an example (not appearing in this ChemActivity) of a pair of molecules that are a) constitutional isomers, b) conformers, c) configurational stereoisomers.
24. Explain why, in the question at the start of Part B of this ChemActivity there is a slash (/) between the words conformers/same.
25. Exercise 9 in Part B asks you to draw all possible isomers (constitutional isomers and configurational stereoisomers) with molecular formula C_6H_{12} . A good way to go about answering such a problem is to start by drawing all possible six-carbon backbones that can accommodate either a ring or a double bond. Then for each unique backbone without a ring, draw all possible ways to accommodate a double bond. For example, a six-carbon straight chain can accommodate a double bond in the five ways shown below.



26. Read the assigned pages in the text, and do the assigned problems.

The Big Picture

The main purpose of Part A is to begin improving your ability to think in three dimensions. 3D thinking is a central skill in organic chemistry. Some people are instantly good at it, but everyone can get good at it with practice (so don't get too frustrated if your group mates seem much faster than you at first).

THE KEY IS WORKING WITH YOUR MODEL SET! You must train your brain to see the representations on the page as 3D objects.

Parts B and C are designed to start you thinking about same and different. This course will require you to recognize subtle differences between molecules, especially in the context of multiple-choice questions. To understand the topics around the corner you have to train yourself in this skill.

In a subsequent activity we will break down the term configurational stereoisomers into finer categories, so it is critical that you are comfortable with the distinction between conformers, constitutional isomers, and configurational stereoisomers before you move on.

The terms *Z/cis* and *E/trans* can be mystifying until you work with some models. These terms **cis** and **trans** will be applied to a totally new context in the next activity. Watch for this.

If you do not have a model set, you must borrow or purchase one immediately. Next week it will be too late. This activity and the next one are two of several key activities that absolutely require a model set.

Common Points of Confusion

- Each semester a few students come to my office ready to throw in the towel on account of Newman projections. There are a few truly hard concepts in this course, but Newman projections are NOT among them. If you are frustrated by Newman projections you need to sit down with a model set and have someone show you where to put your eye up to a model. In my experience, with this type of coaching **IN THE PRESENCE OF A MODEL SET** everyone eventually “gets” Newman projections.
- **MODELS MODELS MODELS.** In my class I spend lots of energy trying to get students to make models. You might wonder, if they are so helpful, why students need so much encouragement to make them. From talking to students, it seems that many think they can picture a molecule without making the model. Others think models are useful, but not useful enough to justify the five minutes it takes to put a model together. BOTH are WRONG. I have been doing this for a long time, and building a model usually helps *me* see the answer more accurately and *more quickly*. Get in the habit of making a model whenever you are stuck, especially if it has to do with **stereochemistry** (“stereo” meaning “requiring two channels” or “3D”).
- The terms **conformational stereoisomer**, **conformer**, **same molecule**, and **identical** are often used synonymously. When chemists say two compounds are the same, picture going to the stockroom, pulling a bottle of each from the shelf, and confirming that the contents of each bottle are the same. Every possible conformation is represented simultaneously in any large sample of a molecule. Only if you freeze the sample toward absolute zero will you begin to see one or a handful of conformations (those at the bottom of the potential energy wells you drew in CTQ 6). Occasionally you will encounter a molecule with groups that are so large that they hinder free rotation of a single bond at room temperature. The bottom line is that, for most molecules, different conformers are just different representations of the same molecule.
- Watch out for “**stereoisomer.**” It is often used in place of “**configurational stereoisomer.**”
- Like Newman projections, *Z/E* configurational stereoisomers drive a few students toward the exit door each semester. And like Newman projections, a few minutes with a model always brings them back. If you are having trouble recognizing *Z* and *E*, **make some models.**