Organic Chemistry Peer Tutoring Department
University of California, Irvine
Sebastian Zolog (szolog@uci.edu)
Isaac Mora (moraji@uci.edu)
Jisoo Kim (jisok13@uci.edu)

Chem 51A
Professor Weiss
https://sites.uci.edu/ochemtutors/

Midterm 2 Review Worksheet KEY

Learning Objectives:

Chapter 4

- Name simple and complex alkanes using **IUPAC nomenclature**
- Draw **Newman projections** in both **staggered** and **eclipsed** configurations
  - Determine which projections are either high or low energy and explain why in terms of **anti-** and **gauche-** interactions
- Draw **chair conformations** and properly label the substituents in **equatorial** or **axial** positions
  - Perform a **chair flip** and explain why one chair conformation may be higher in energy than the other
- Differentiate between **oxidation** and **reduction** reactions

Chapter 5

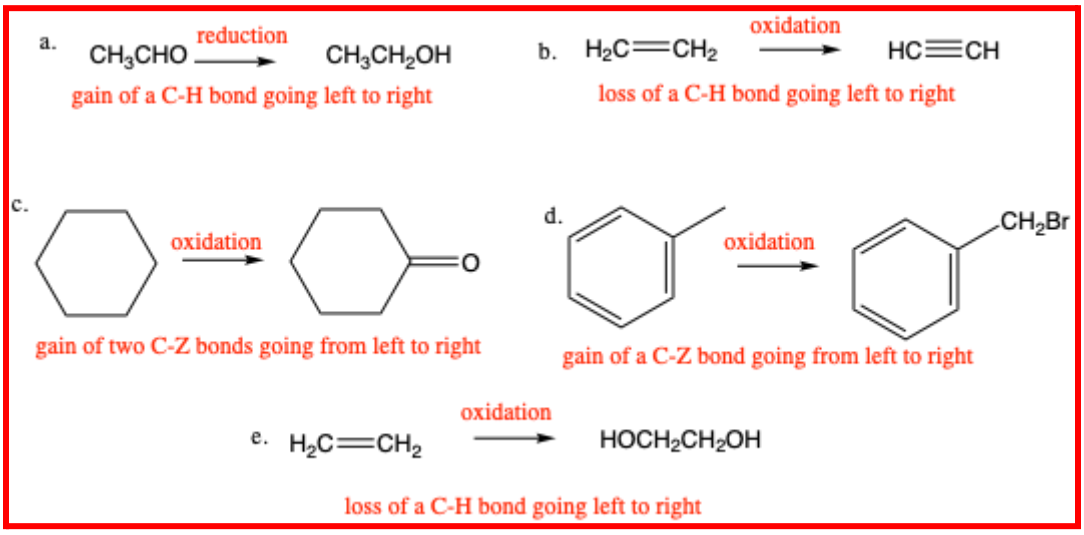
- Identify similarities and differences between **constitutional isomers** and **stereoisomers**
  - Define and differentiate between **enantiomers** and **diastereomers**
- Determine the location of **stereogenic centers** and explain how they contribute to a molecule's **chirality**
- Differentiate between a **chiral**, **achiral**, and **meso** compound
- Identify under which conditions a solution can rotate polarized light
  - Differentiate between an **optically active** and **optically inactive** solution
- Utilize **R** and **S** in IUPAC nomenclature when naming compounds with stereogenic centers
- Compare and contrast the physical properties of isomers

Problem Set:

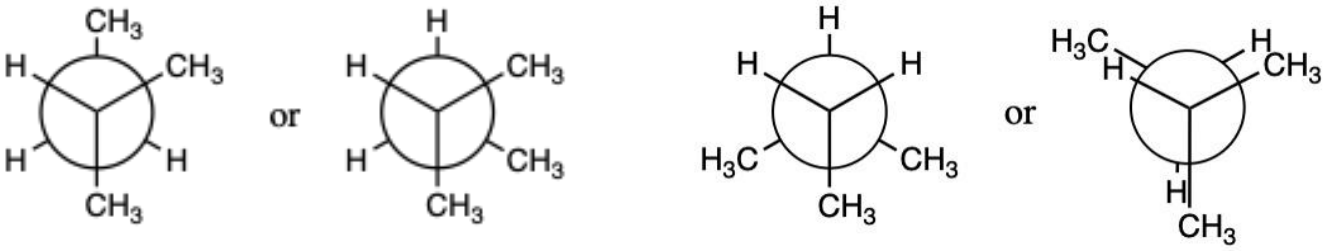
1. Classify each reaction as oxidation, reduction, or neither.

Oxidation results in an **increase in the number of C-Z bonds** or **a decrease in the number of C-H bonds.**

Reduction results **in a decrease in the number of C-Z bonds** or **an increase in the number of C-H bonds.**



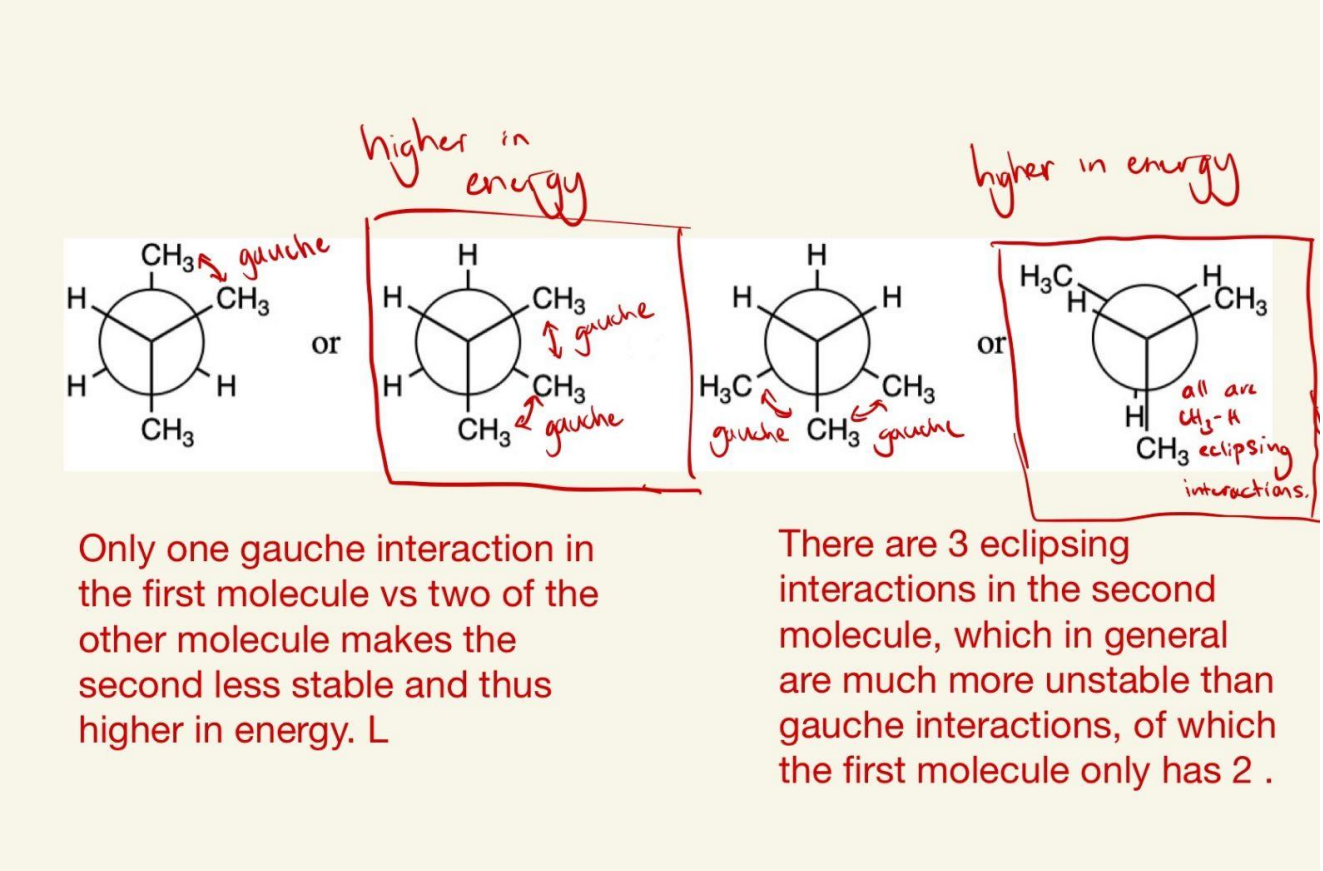
2. (4.45) Which conformation in each pair is higher in energy?



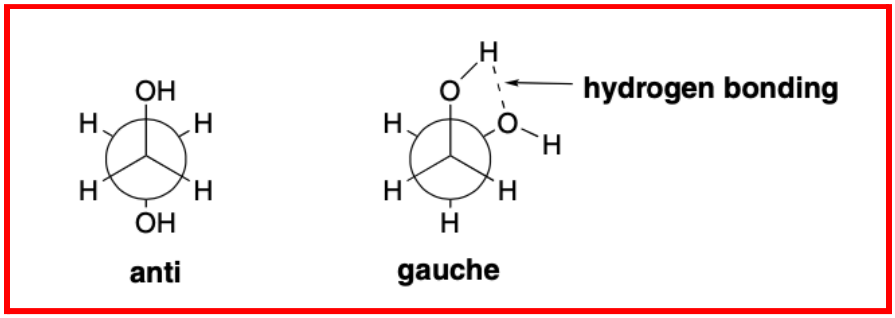
Electron–electron repulsion between the bonds in the eclipsed conformation increases its energy compared to the staggered conformation, where the bonding electrons are farther apart. This produces Torsional strain, which is an increase in energy caused by eclipsing interactions.

A staggered conformation with two larger groups 60° from each other is called gauche.

An anti-conformation is lower in energy than a gauche conformation because of the steric strain that results from the proximity of the large groups in gauche creating **electron–electron repulsion.**

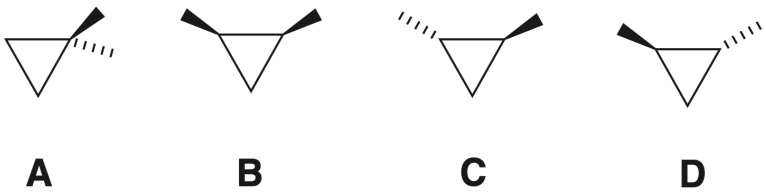


3. (4.52) (a) Draw the anti and gauche conformations for ethylene glycol ($HOCH_2CH_2OH$). (b) Ethylene glycol is unusual in that the gauche conformation is more stable than the anti conformation. Offer an explanation.



The gauche conformation allows ethylene glycol to intramolecularly hydrogen bond which is a stabilizing interaction, while the anti conformation prevents this. Thus in this rare case the gauche conformation is much more stable and lower in energy than the anti conformation.

4. (5.64) Consider Compounds A-D below.



a. How are the compounds in each pair related (enantiomers, diastereomers, constitutional isomers): A and B; A and C; B and C; C and D? A and B are constitutional isomers. A and C are constitutional isomers. B and C are diastereomers (cis versus trans). C and D are enantiomers.

b. Label each compound as chiral or achiral. A and B are both achiral since their mirror images are superimposable, whereas C and D are both chiral since their mirror images are NOT superimposable.

c. Which compounds, alone, would be optically active? Alone, C and D would be optically active, given that they are chiral.

d. Which compounds have a plane of symmetry? A and B have a plane of symmetry. A plane of symmetry in one conformation makes a compound achiral, thus molecules A and B are the ones we listed as achiral in part A.

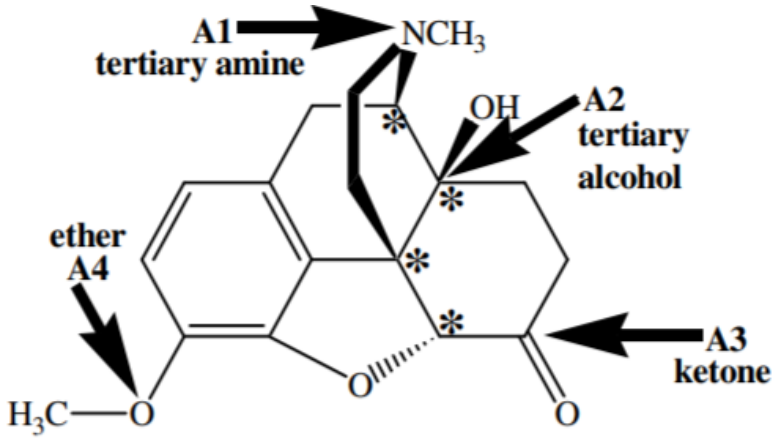
e. How do the boiling points of the compounds in each pair compare: A and B; B and C; C and D? A and B have different boiling points; B and C have different boiling points; C and D have the same boiling point. This is because constitutional isomers and diastereomers have different physical properties than their respective isomer

counterparts. Whereas enantiomers will have the same physical properties except for the rotation of plane polarized light.

f. Which of the compounds are meso compounds? B is a meso compound, since it is an achiral compound with two or more stereogenic centers.

g. Would an equal mixture of compounds C and D be optically active? What about an equal mixture of B and C? An equal mixture of C and D is optically inactive because it is a racemic mixture. An equal mixture of B and C would be optically active.

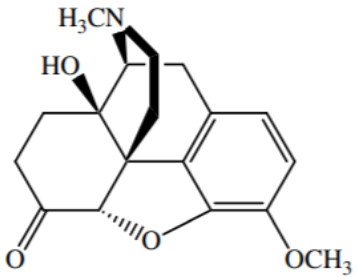
5. One of the most widely prescribed painkillers in the United States, at present, for the relief of moderate to heavy pain contains the following codeine derivative, Oxycodone. Consider its structure below: (http://sunny.moorparkcollege.edu/~bgopal/OLD_EXAMS/SPRING2011_ANSWERS/exam_four_answers_spring_2011_11.pdf)



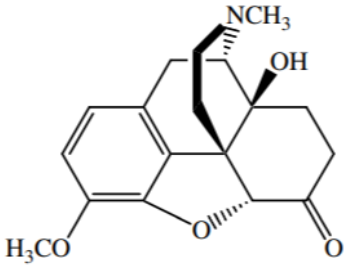
Oxycodone

a. Identify the functional groups labeled with arrows A1 - A4 by labeling the structure above. If any alcohols or amines are present, determine if they are primary, secondary, or tertiary.
b. How many total stereocenters (if any) are present in Oxycodone? Clearly label them in the structure above with an asterisk (*). 4; definition by the textbook of a stereogenic center is a carbon atom with four different groups. Professor Weiss defines a stereogenic center as a carbon atom with four different groups in the absence of a line of symmetry. It must NOT have a mirror image symmetry to make it a stereocenter. For instance, a meso compound can have stereo carbons (4 different groups) but no stereocenters due to a mirror plane that cuts a molecule in half.
c. What is the maximum number of possible stereoisomers for this molecule? $2^4 = 16$; The maximum number of stereoisomers = 2^n where n = the number of stereogenic centers.

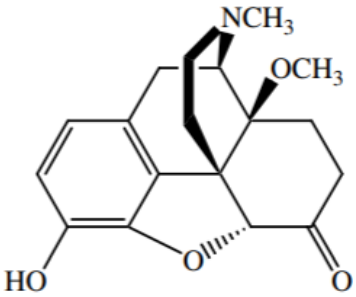
d. Compare each molecule below with Oxycodone (above). In the box below each molecule, write “identical”, “enantiomer”, “diastereomer”, or “none of these”.

A) 

Enantiomer- mirror images, not superimposable

B) 

Diastereomer- one different configuration

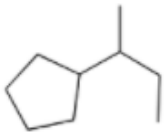
C) 

none of these (constitutional isomer)- different connectivity

6. (4.42-4.44, 5.46-5.47)

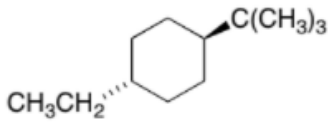
Draw the structure corresponding to each IUPAC name.

a. *Sec*-butylcyclopentane



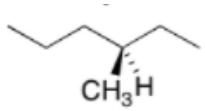
In cyclic compounds, the ring is usually considered the parent chain, unless it is attached to a longer chain of carbons.

b. Trans-1-*tert*-butyl-4-ethylcyclohexane



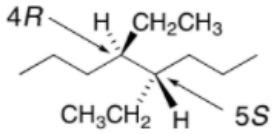
The two substituent groups are ethyl and tert-butyl and can be opposite or across from each other in which case it is called the "trans" isomer. If the two groups are adjacent to each other, or all wedges or dashes, the isomer is called " cis".

c. (3R)-3-methylhexane



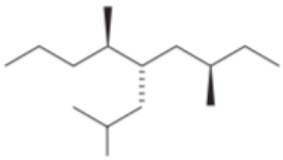
To assign R or S to the molecule, first rank the groups. The lowest priority group must be oriented behind the page. If tracing a circle from (1) (2) (3) proceeds in the clockwise direction, the stereogenic center is labeled R; if the circle is counterclockwise, it is labeled S.

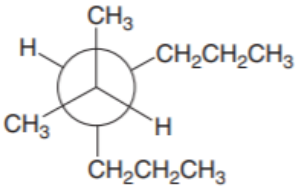
d. (4R,5S)-4,5-diethyloctane *meso compound



Use the rules in 6c to assign R or S to each stereogenic center. Switch R/S configuration if the lowest priority (4) is in front.

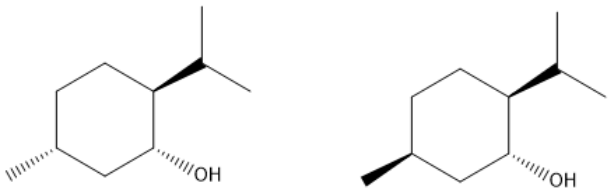
Give the IUPAC name for each compound

a.  (3R,5S,6R)-5-isobutyl-3,6-dimethylnonane

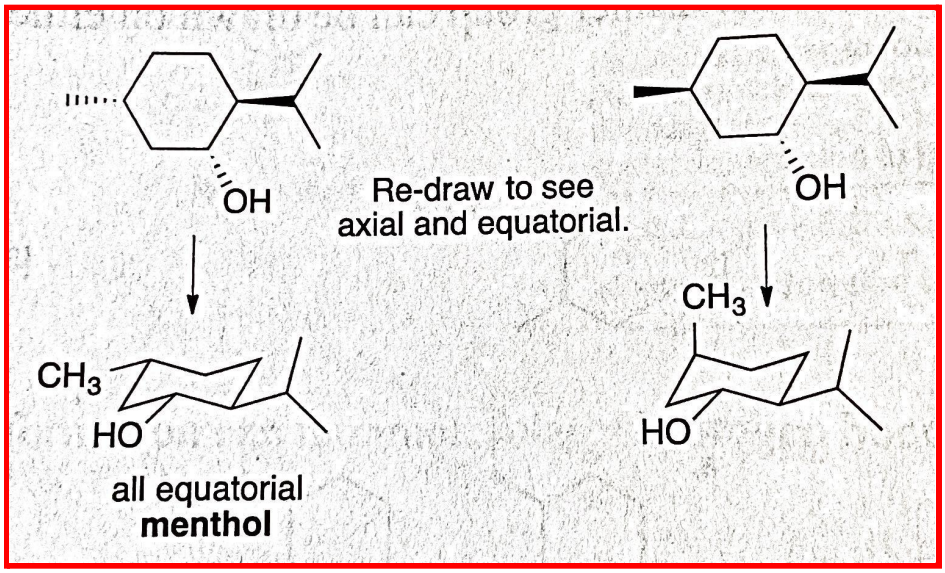
b. 

4-isopropylheptane

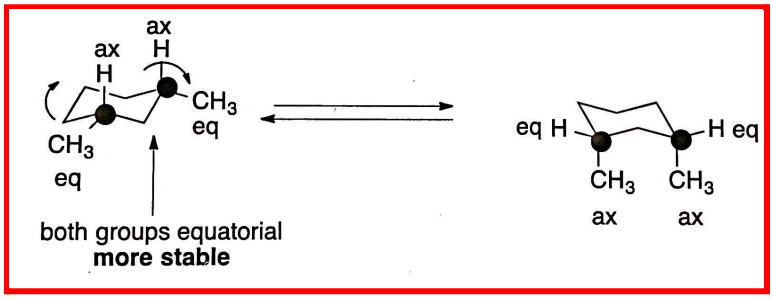
7. (4.56) Convert each of the following structures into its more stable chair form. One structure represents menthol and one represents isomenthol. Menthol, the more stable isomer, is used in lip balms and mouthwash. Which structure corresponds to menthol?



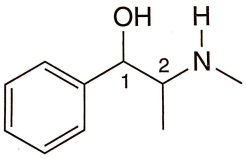
When drawing the chair conformations for the two compounds pictured above, the one with all non-hydrogen substituents being in the equatorial position will be much more stable than the other in which some substituents are axial. Recall that **low energy chair conformations have substituents in equatorial positions**, largely due to a decrease in steric strain and a decrease in electron cloud "clashing".



8. (4.54) Draw the two possible chair conformations for *cis*-1,3-dimethylcyclohexane. Which conformation, if either, is more stable?

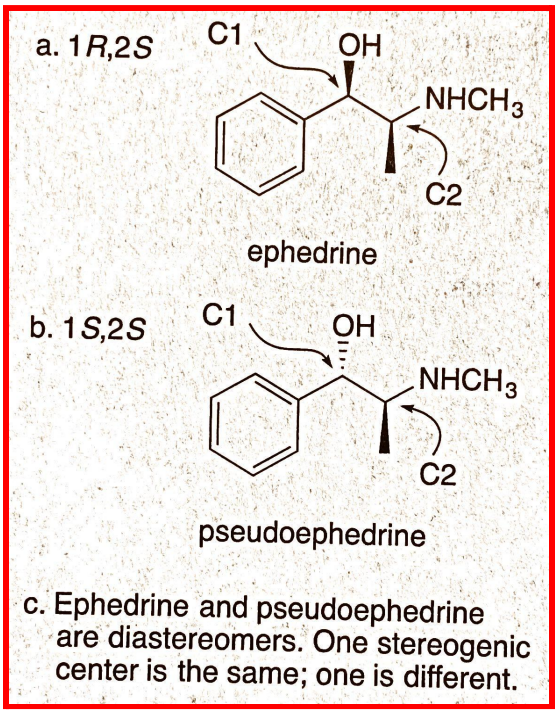


9. (5.55) The shrub *ma huang* contains two biologically active stereoisomers- ephedrine and pseudoephedrine- with two stereogenic centers as shown in the given structure.



isolated from ma huang

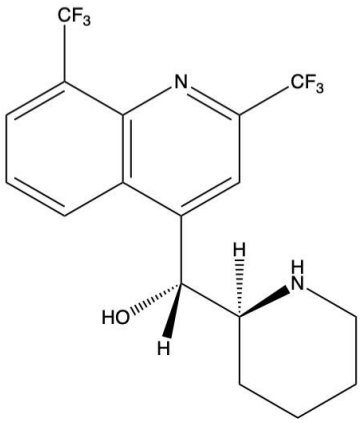
a. Draw the structure of naturally occurring (-)-ephedrine, which has the (1R, 2S) configuration.
b. Draw the structure of naturally occurring (+)-pseudoephedrine, which has the (1S, 2S) configuration.
c. How are ephedrine and pseudoephedrine related?



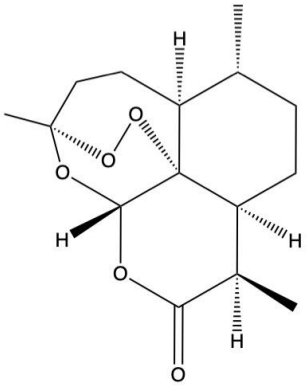
The key to recognizing relationships between two stereoisomers, from their IUPAC name, is by looking at their R/S configurations. If all configurations are switched in one compound versus the other, they must be **enantiomers**. If any one of the stereocenters remains untouched, while others are switched, then the compounds are **diastereomers**. Finally, if none of the stereocenters have switched, they are **identical compounds**.

Extra Practice:

1. (4.69) For the compounds presented below:



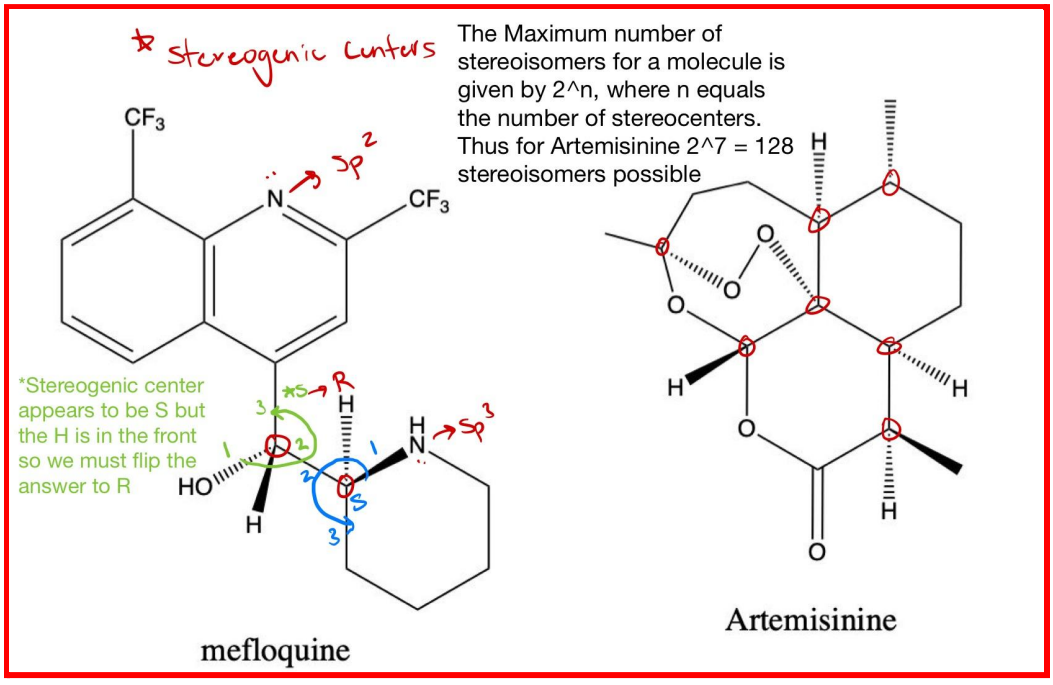
mefloquine



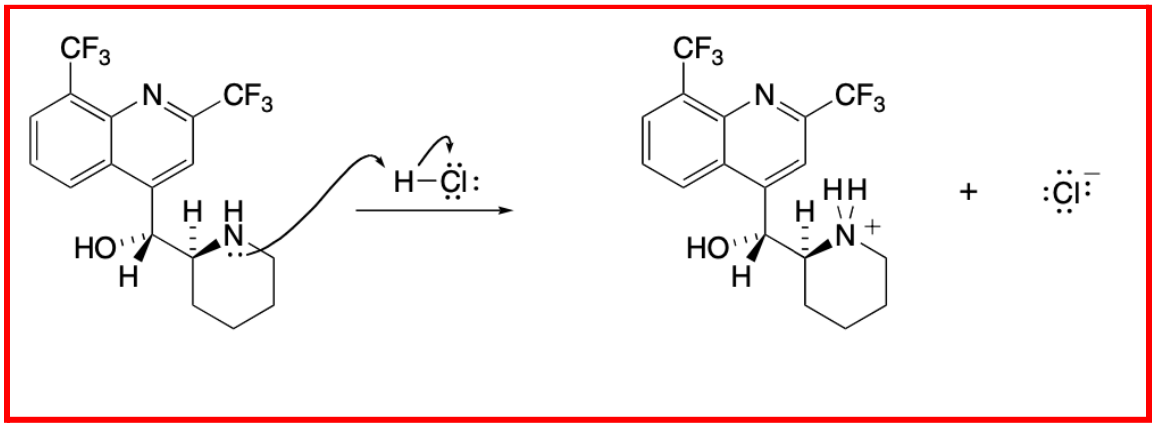
Artemisinine

a. Locate the stereogenic centers in both drugs.
b. Label each stereogenic center in mefloquine as *R* or *S.*
c. What is the maximum number of stereoisomers possible for artemisinin?
d. How are the N atoms in mefloquine hybridized?
e. What product is formed when mefloquine is treated with HCl?

a.-d.

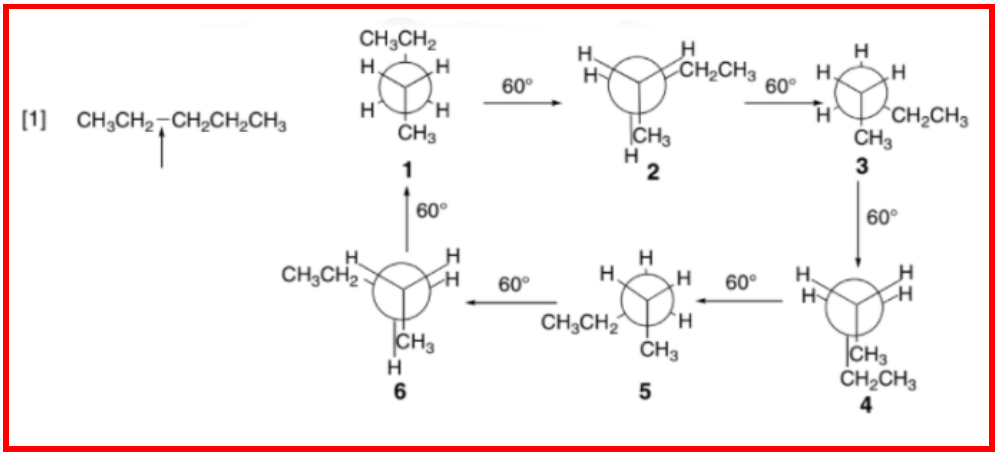


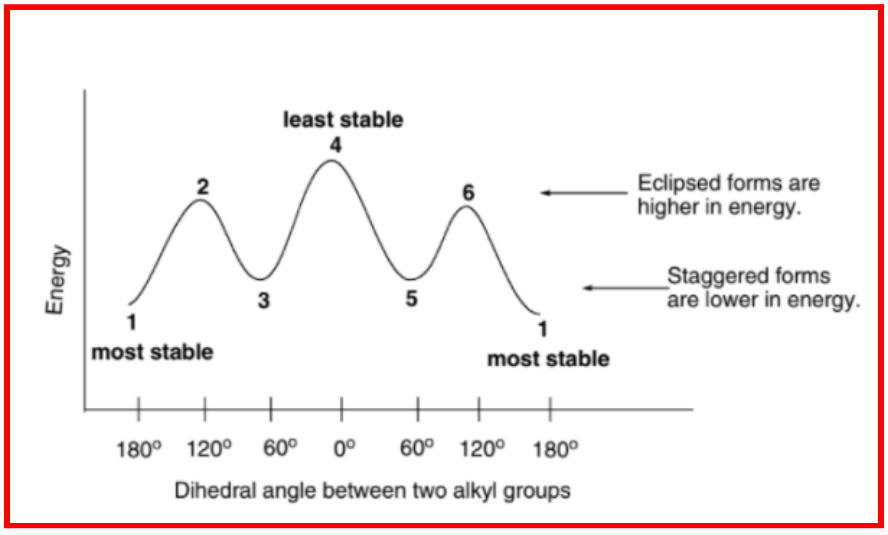
e.



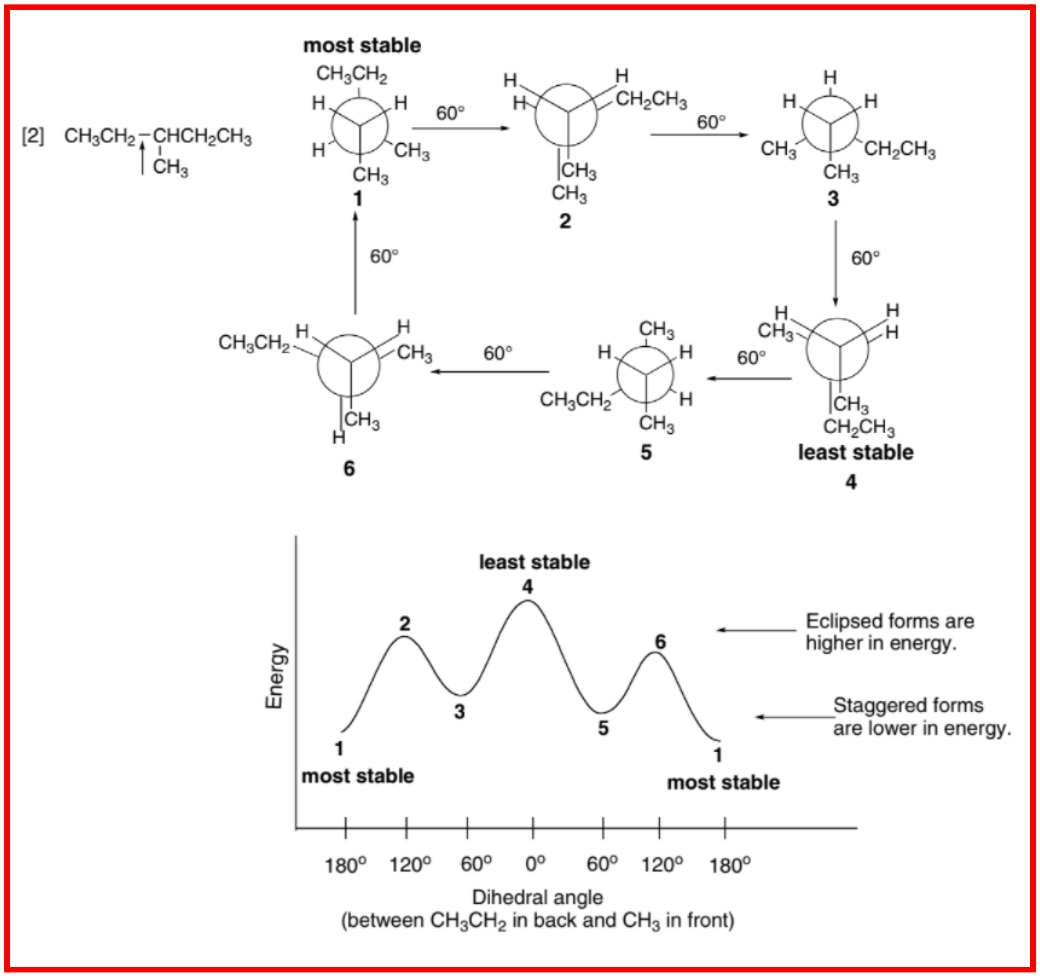
2. (4.52) (a) Using Newman projections, draw all staggered and eclipsed conformations that result from rotation around the indicated bond in each molecule; (b) Draw a graph of energy versus dihedral angle for rotation around this bond.

(a)



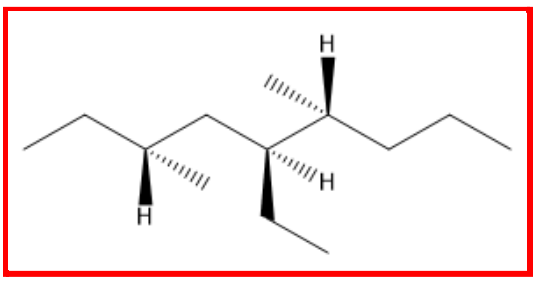


(b)

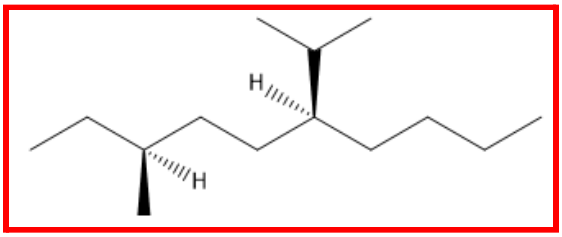


3. (5.51) Draw the structure for each compound.

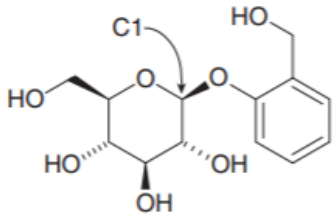
a. (3R,5S,6R)-5-ethyl-3,6-dimethylnonane



b. (3S,6S)-6-isopropyl-3-methyldecane

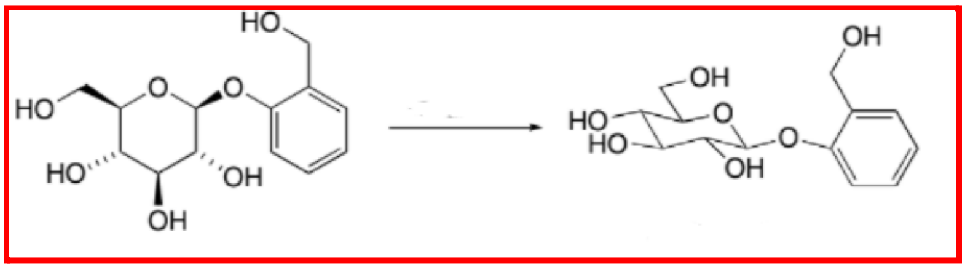


4. (5.68) Salicin is an analgesic isolated from willow bark.

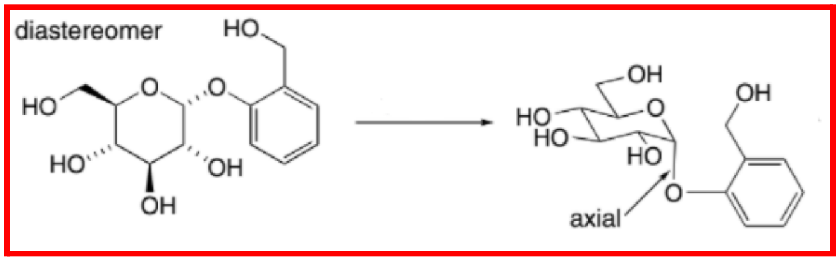


salicin

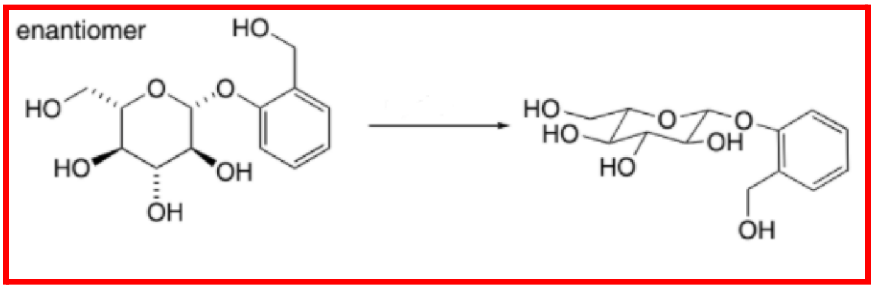
a. Convert the given skeletal structure to a representation that shows the more stable chair form of the six-membered ring.



b. Draw a diastereomer of salicin at C1 and label each substituent on the six-membered ring as axial or equatorial.



c. Draw the enantiomer of salicin.



5. (4.56) Go back to question 7 of the problem set. Using IUPAC nomenclature, name menthol and isomenthol (include R/S stereochemistry).

Menthol: (1R, 2S, 5R)-2-isopropyl-5-methylcyclohexanol

Isomenthol: (1R, 2S, 5S)-2-isopropyl-5-methylcyclohexanol

*DISCLAIMER: all images from Problem Set Questions 7-9 were obtained from Janice Gorzynski Smith's Organic Chemistry 5th Ed. Solutions Manual.