

NAME (Print): _____

EID _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
2nd Midterm
October 22, 2025

Please print the
first three letters
of your last name
in the three boxes

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Please Note: Please take your time. We are giving you three hours to take this exam even though it is really a one hour exam. The idea is to give you enough time to show us what you know, not how fast you can draw structures. Please take all the time you need to draw the best possible structures that you can! Do not be surprised if you are comfortable leaving the exam long before 9 PM. That is to be expected!

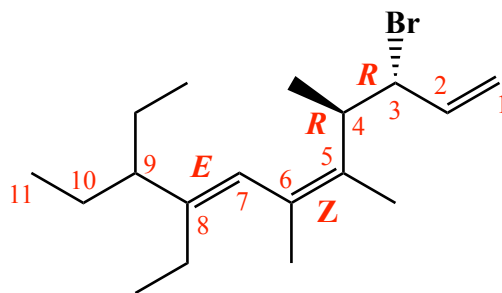
FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENTS YOU ARE NOT ALLOWED TO INTERACT WITH YOUR CELL PHONE IN ANY WAY. IF YOU TOUCH YOUR CELL PHONE DURING THE EXAM YOU WILL GET A "0" NO MATTER WHAT YOU ARE DOING WITH THE PHONE. PUT IT AWAY AND LEAVE IT THERE!!!

Compound		pK _a
Hydrochloric acid	$\text{H}-\text{Cl}$	-7
Protonated alcohol	$\text{RCH}_2\text{OH}_2^+$	-2
Hydronium ion	H_3O^+	-1.7
Carboxylic acids	$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$	3-5
Thiols	RCH_2SH	8-9
Ammonium ion	H_4N^+	9.2
β-Dicarbonyls	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{CR}'$	10
Primary ammonium	$\text{H}_3\text{N}^+\text{CH}_2\text{CH}_3$	10.5
β-Ketoesters	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	11
β-Diesters	$\text{ROC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	13
Water	HOH	15.7
Alcohols	RCH_2OH	15-19
Acid chlorides	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	16
Aldehydes	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	18-20
Ketones	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CR}'$	18-20
Esters	$\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$	23-25
Terminal alkynes	$\text{RC}\equiv\text{C}-\text{H}$	25
LDA	$\text{H}-\text{N}(\text{i}-\text{C}_3\text{H}_7)_2$	40
Terminal alkenes	$\text{R}_2\text{C}=\underset{\text{H}}{\text{C}}-\text{H}$	44
Alkanes	$\text{CH}_3\text{CH}_2-\text{H}$	51

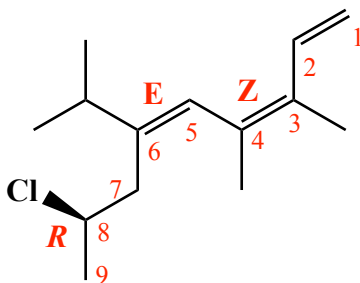
1. (5 pts) What is the most important question in organic chemistry?

Where are the electrons?

2. (12 pts) Write an acceptable IUPAC name for the following two molecules. Where appropriate, use E and Z or R and S.



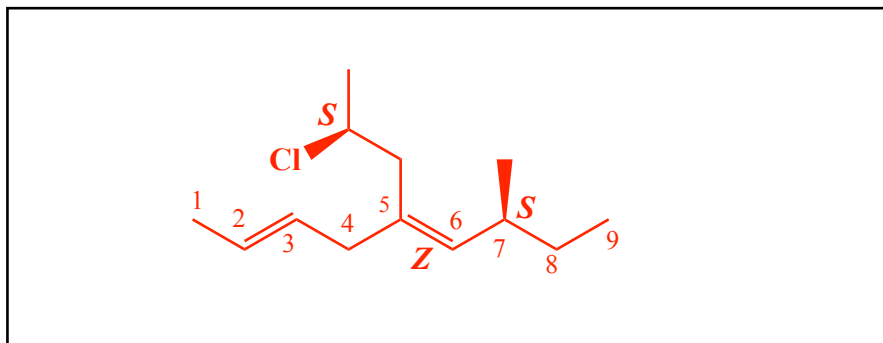
**(3R,4R,5Z,7E)-3-bromo-8,9-diethyl-4,5,6-trimethylundeca-1,5,7-triene or
(3R,4R,5Z,7E)-3-bromo-8,9-diethyl-4,5,6-trimethyl-1,5,7-undecatriene**



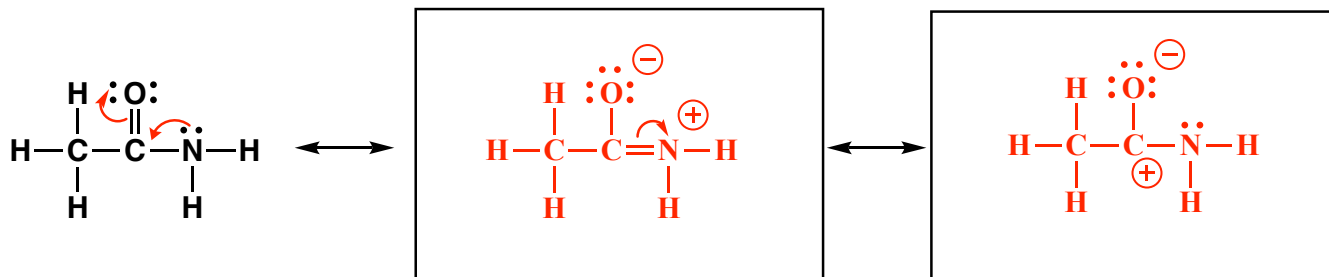
**(R,3Z,5E)-8-chloro-6-isopropyl-3,4-dimethylnona-1,3,5-triene or
(R,3Z,5E)-8-chloro-6-isopropyl-3,4-dimethyl-1,3,5-nonatriene**

3. (6 pts) Draw the structure that corresponds to the following name:

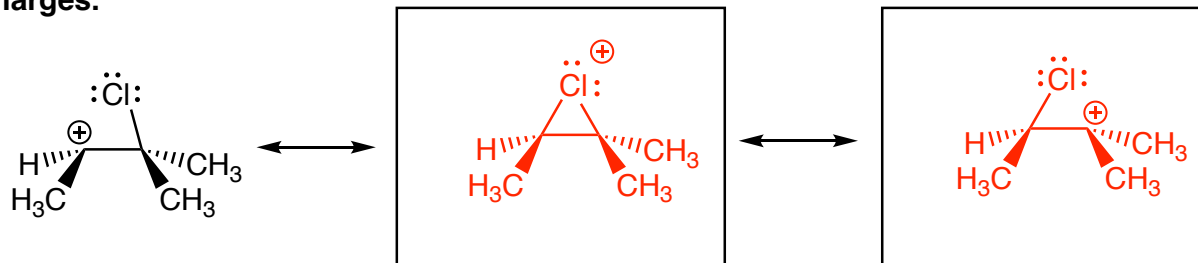
(7S,2E,5Z)-5-((S)-2-chloropropyl)-7-methyl-2,5-nonadiene



4. (9 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided, including all lone pairs and formal charges. For the two structures on the left, use arrows to indicate the movement of electrons to give the structures you drew. There is no need to draw any circles around any of these contributing structures. You might want to read these directions again to make sure you know what we want



5. (7 pts) Draw the two other most important contributing structures for the chloronium ion. Fill in the circle next to "Most important" under the contributing structure of the three that makes the largest contribution to the overall resonance hybrid. You do NOT need to draw arrows on any of the structures for this problem. **Because this is a mechanism type question, use wedges and dashes to indicate stereochemistry, write "racemic" if appropriate, draw all lone pairs and formal charges.**

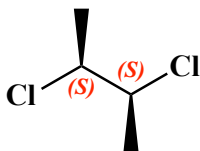
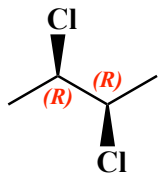

☐ Most important

☐ Most important

☒ Most important

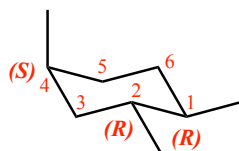
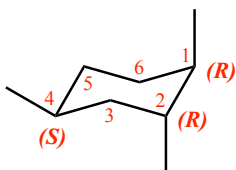
6. (6 pts) Fill in the circle to indicate the appropriate relationship between the following pairs of molecules.

A.



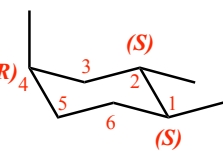
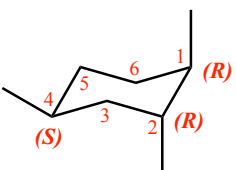
☒ Enantiomers ☐ Same Molecule
☐ Diastereomers ☐ Different constitutional isomers

B.



☐ Enantiomers ☒ Same Molecule
☐ Diastereomers ☐ Different constitutional isomers

C.

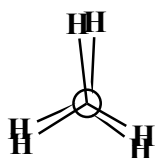
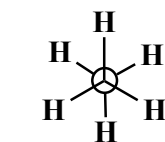
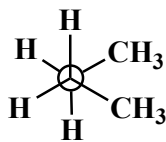
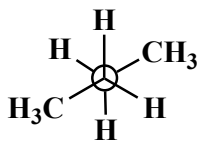
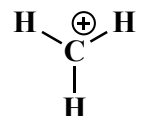
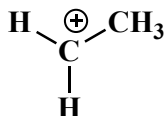
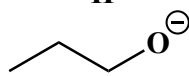
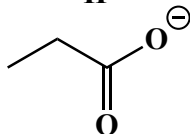
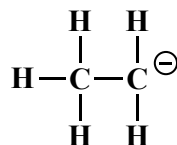
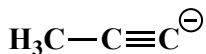
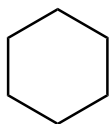
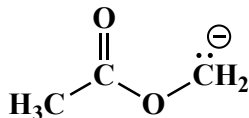
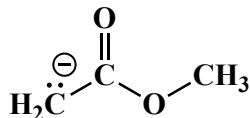
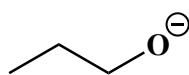
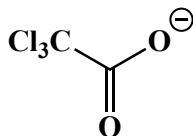


☒ Enantiomers ☐ Same Molecule
☐ Diastereomers ☐ Different constitutional isomers

7. (28 pts) For each pair of molecules, the one drawn on the left is more stable (lower in energy) because of one or more principles we have discussed. **In the boxes provided, write the letter corresponding to the principle or principles (yes there can be more than one!) that explain why the molecule on the left is more stable.**

A. Steric Strain**B.** Angle Strain**C.** Torsional Strain**D.** The inductive effect**E.** Hyperconjugation**F.** Delocalization of a charge**G.** Delocalization of pi electron density over more than two atoms (pi-way)**H.** Greater s-character of the orbital containing an electron pair on a negatively-charged atom**I.** The negative charge is on a more electronegative element**J.** The negative charge is on a larger atom**More stable****Less stable**

The molecule on the left is more stable primarily because of:

**C.****A.****D. E. (F. is OK)****F. G.****H.****B. C.****F. G.****D. F. G.**

8. (8 points) It is helpful to think of organic chemistry mechanisms in terms of distinct mechanistic elements. We have learned four of these so far. Fill in the circle that indicates the appropriate mechanistic element to choose if you see the following:

A. When the carbon containing piece is a base or there is a strong acid present

- ☐ Make a bond between a nucleophile and an electrophile
- ☐ Break a bond to give stable molecules or ions
- ☒ Add a proton
- ☐ Take a proton away

B. You see both a good nucleophile and electrophile present

- ☒ Make a bond between a nucleophile and an electrophile
- ☐ Break a bond to give stable molecules or ions
- ☐ Add a proton
- ☐ Take a proton away

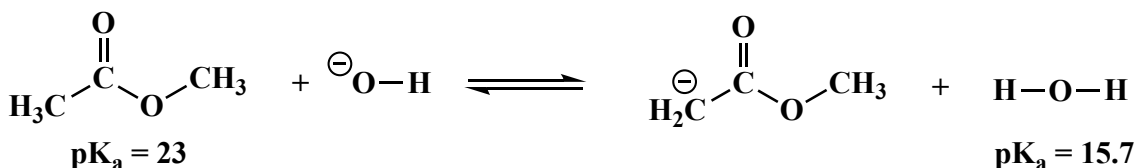
C. When the carbon containing piece is a strong acid or there is a base present

- ☐ Make a bond between a nucleophile and an electrophile
- ☐ Break a bond to give stable molecules or ions
- ☐ Add a proton
- ☒ Take a proton away

D. When none of the above are true and you can see how the carbon containing piece can fragment to create stable molecules or ions.

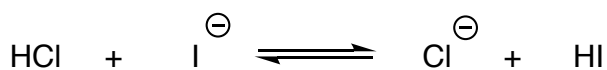
- ☐ Make a bond between a nucleophile and an electrophile
- ☒ Break a bond to give stable molecules or ions
- ☐ Add a proton
- ☐ Take a proton away

9. (2 pts each) For the following equilibria, fill in the circle that is appropriate.



☒ This side favored at equilibrium

☐ This side favored at equilibrium



☒ This side favored at equilibrium

☐ This side favored at equilibrium

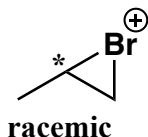
10. (3 pts each) For the following species we have seen in mechanisms, fill in the circle that is appropriate.



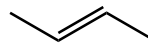
☐ nucleophile
☐ electrophile
☒ strong acid



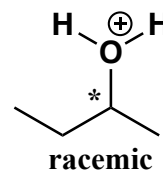
☐ nucleophile
☒ electrophile
☐ strong acid



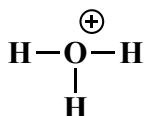
☐ nucleophile
☒ electrophile
☐ strong acid



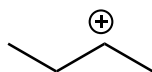
☒ nucleophile
☐ electrophile
☐ strong acid



☐ nucleophile
☐ electrophile
☒ strong acid



☐ nucleophile
☐ electrophile
☒ strong acid



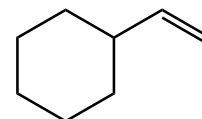
☐ nucleophile
☒ electrophile
☐ strong acid



☒ nucleophile
☐ electrophile
☐ strong acid

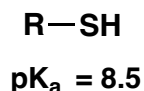
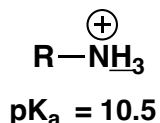
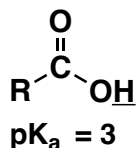


☒ nucleophile
☐ electrophile
☐ strong acid

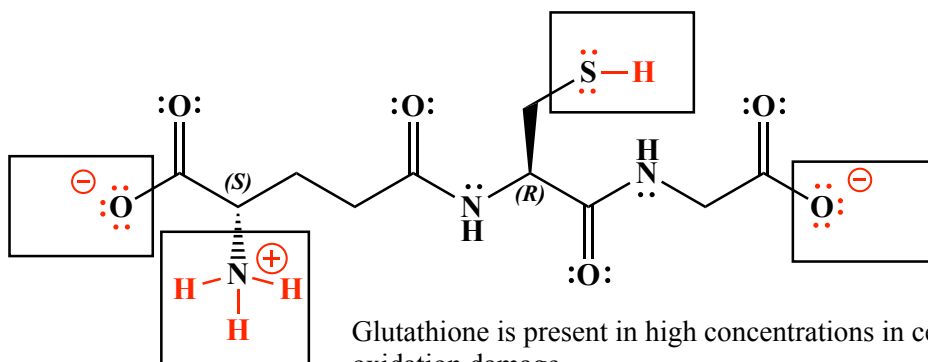


☒ nucleophile
☐ electrophile
☐ strong acid

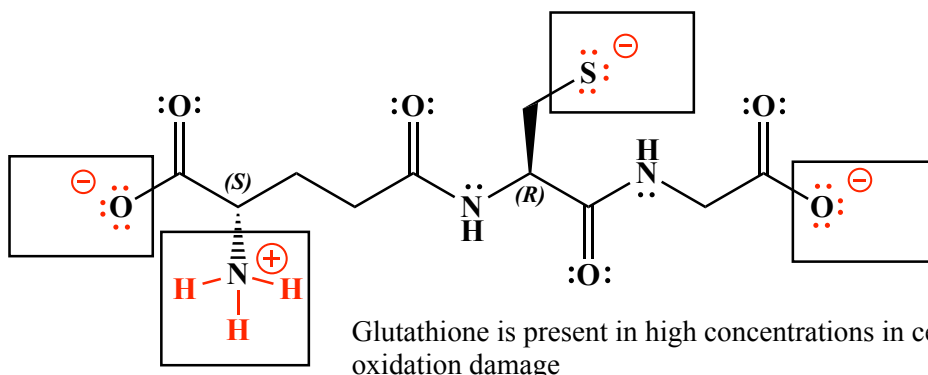
11. (20 pts) **Complete the following three structures by adding appropriate numbers of lone pair electrons, H atoms, and formal charges to the atoms in the boxes.** You must adjust your answers to indicate the predominant species at each indicated pH value. (You do not have to add anything such as H atoms to atoms not drawn in the boxes.) This problem is testing your understanding of the relationship of protonation state to pH to pK_a values for certain functional groups we have discussed. **Next, in the space provided, write the overall charge on each structure at the indicated pH.** For your reference, here are the relevant pK_a values:

**pH = 6**

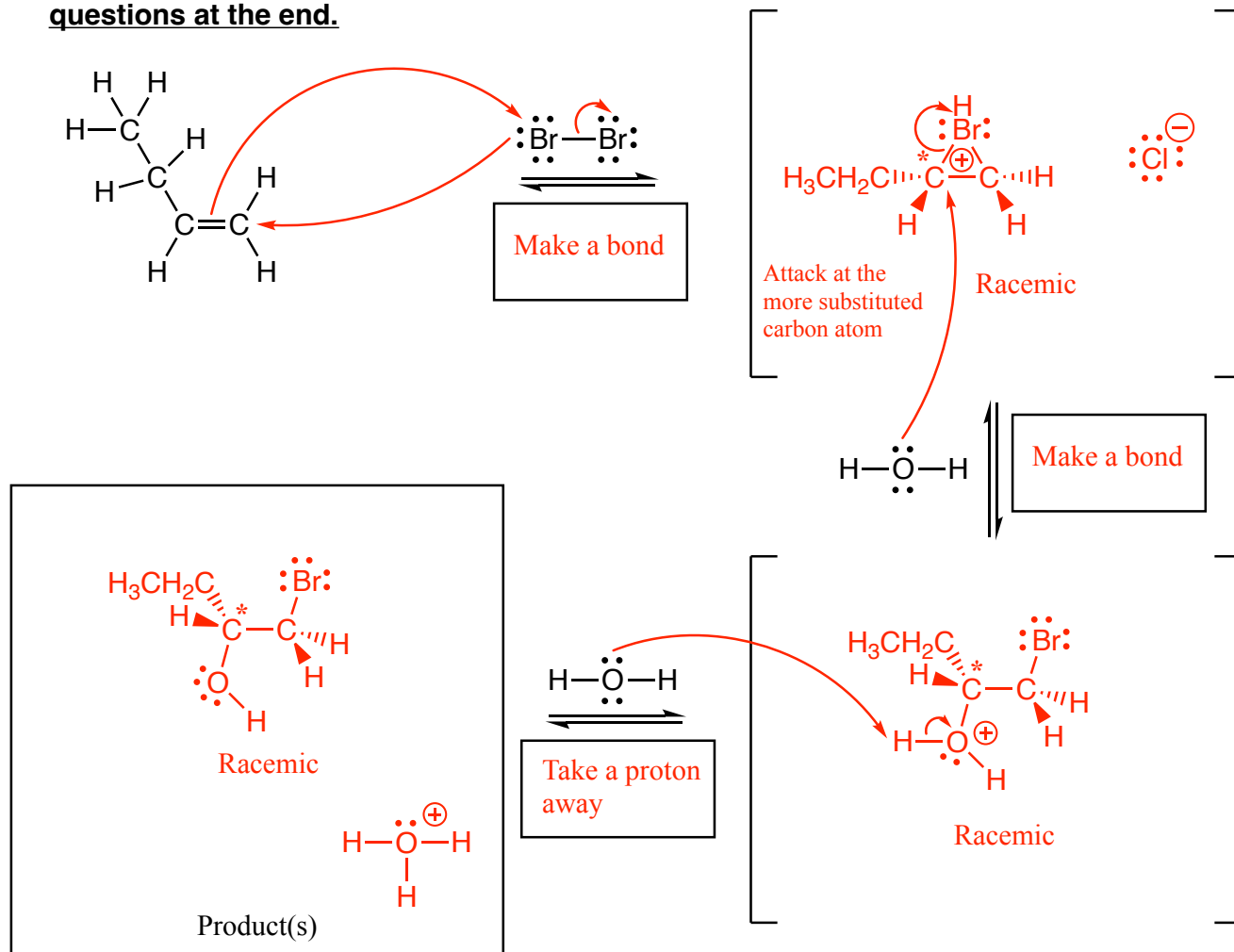
Total charge on molecule:

-1**pH = 9.5**

Total charge on molecule:

-2

13. (32 pts) Complete the mechanism for the following reaction of an alkene with Br_2 in the presence of H_2O . **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE.** In the boxes provided under/beside the arrows, write which of the 4 most common mechanistic elements describes each step (make a bond, break a bond, etc.). Be sure to notice the questions at the end.



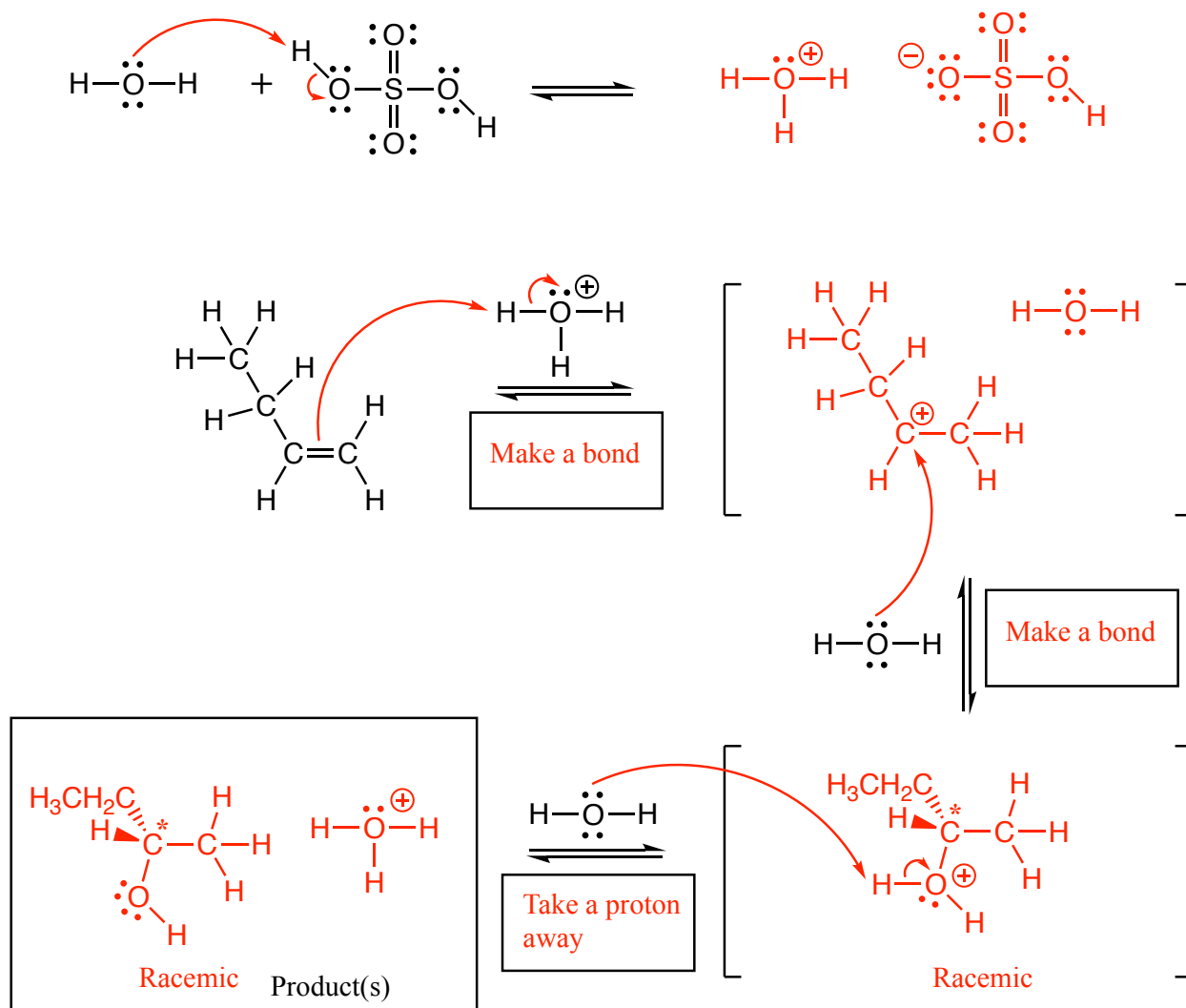
(2 pts) How many total stereoisomers are produced by this reaction? 2 (R and S)

(2 pts) As the reaction proceeds, does the pH of the solution increase, decrease, or stay the same? Decrease (H_3O^+ is produced)

Signature _____

Pg 8 _____ (32)

13. (32 pts) Complete the mechanism for the following reaction of an alkene with H_2O in the presence of catalytic amount of H_2SO_4 . **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE.** In the boxes provided under/beside the arrows, write which of the 4 most common mechanistic elements describes each step (make a bond, break a bond, etc.). Be sure to notice the questions at the end.



(2 pts) How many total stereoisomers are produced by this reaction? 2 (R and S)

(2 pts) As the reaction proceeds, does the pH of the solution increase, decrease, or stay the same? Stays the same

Signature _____

Pg 9 _____ (26)

14. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. **Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products)** and please remember that **you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate**. When a racemic mixture is formed, **you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES**.

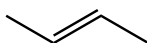
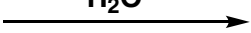
A.



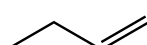
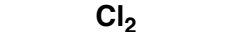
HBr



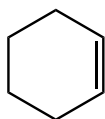
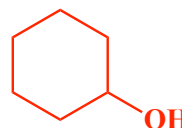
B.

 H_2O  H_2SO_4
(catalytic amount)

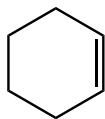
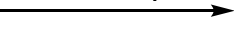
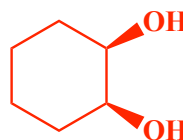
C.

 Cl_2  H_2O 

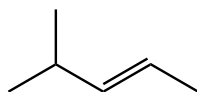
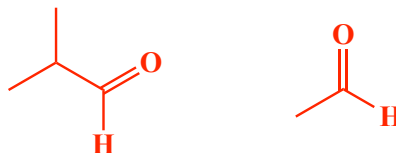
D.

1. BH_3 2. $\text{H}_2\text{O}_2 / \text{NaOH}$ 

E.

1. OsO_4 2. $\text{NaHSO}_3 / \text{H}_2\text{O}$ 

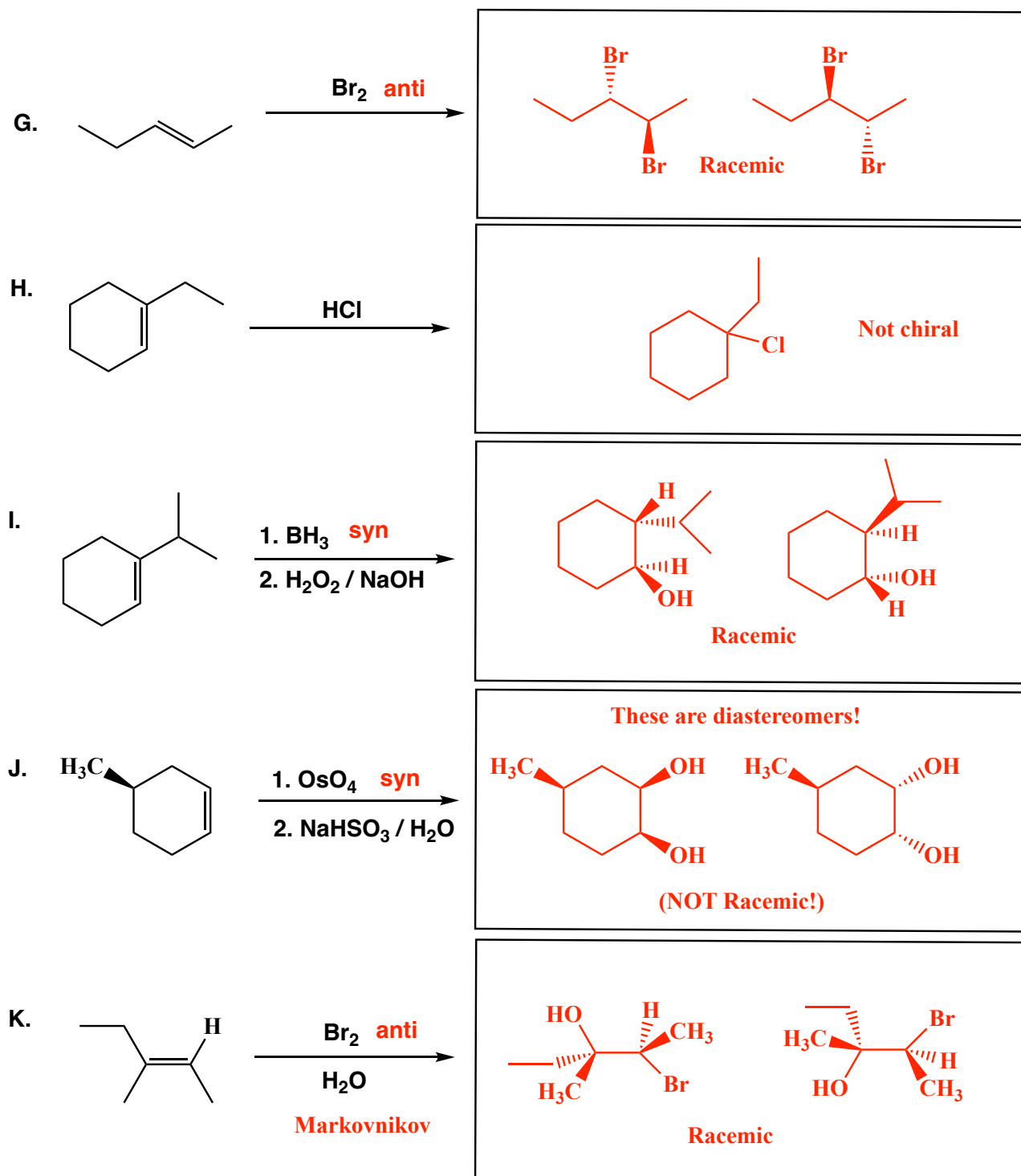
F.

1. O_3 2. $(\text{CH}_3)_2\text{S}$ 

Signature _____

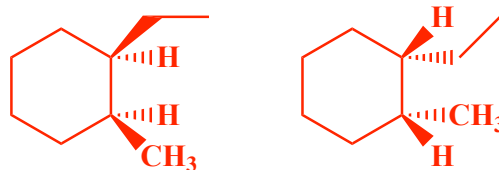
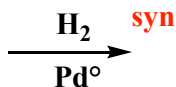
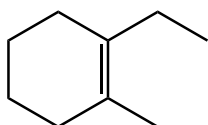
Pg 10 _____ (23)

14. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products) and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry when appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.



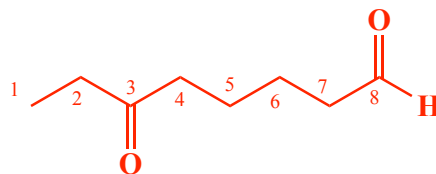
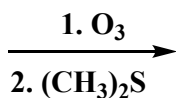
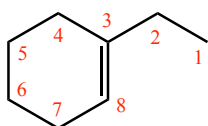
14. (5 or 9 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products (i.e. Markovnikov or non-Markovnikov products) and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.

L.

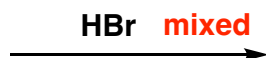
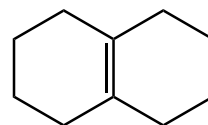


Racemic

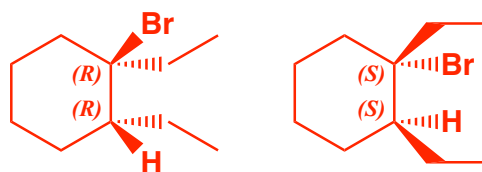
M.



N.

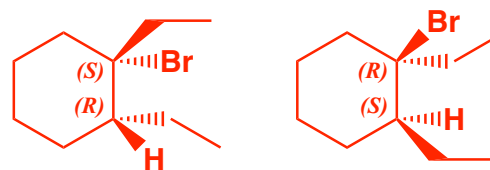


syn addition



Racemic

anti addition



Racemic

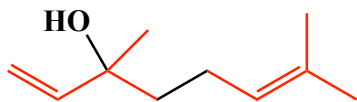
Signature _____

Pg 12 _____ (15)

15. (8 pts total) If you understand terpenes this one is not hard. Fill in the circle to designate how many isoprene units are present in each terpene molecule.

Linool

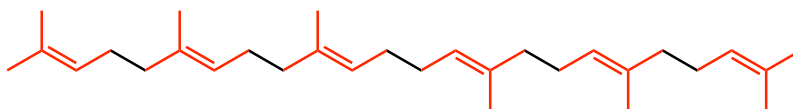
(major component of lavender)



- ☒ 2 Isoprene units
☐ 3 Isoprene units
☐ 4 Isoprene units
☐ 5 Isoprene units

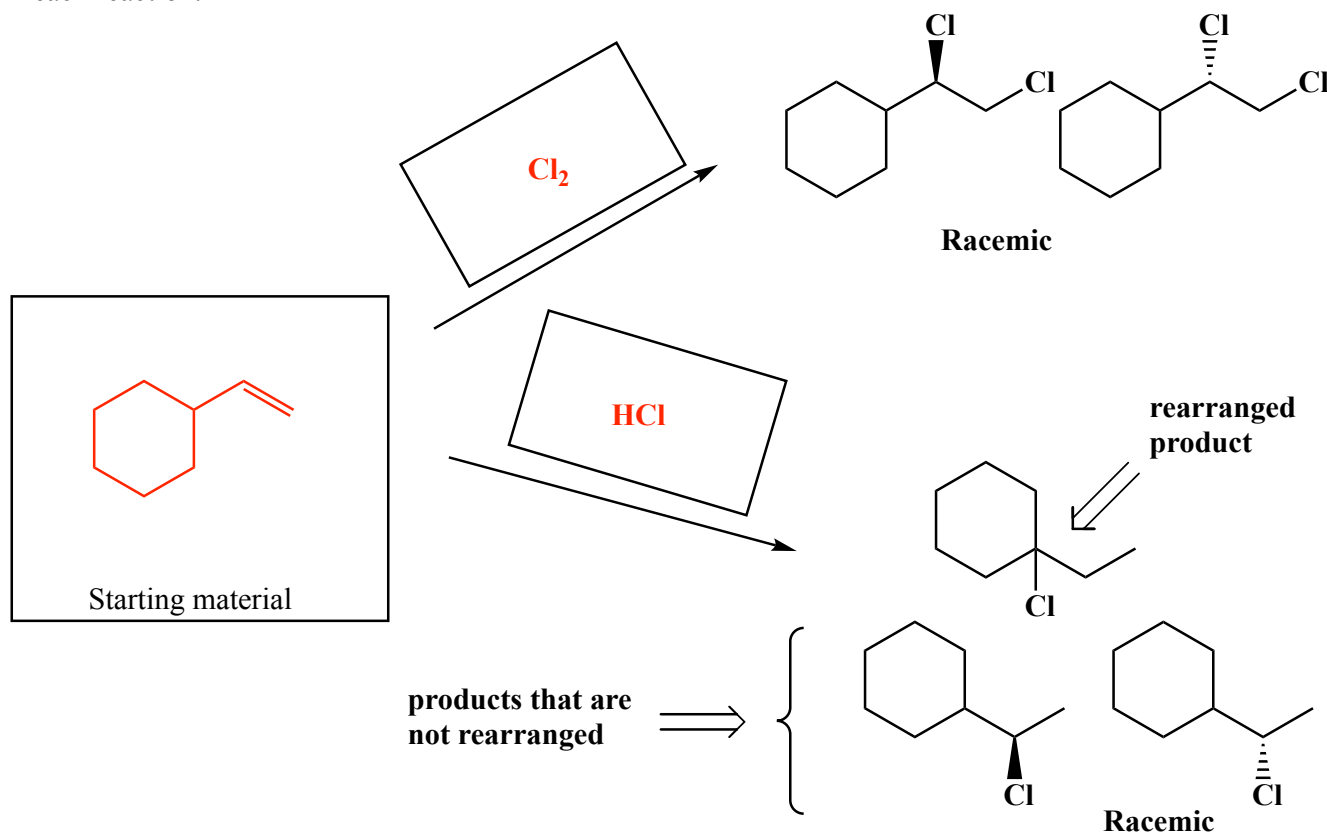
Squalene

(a very important molecule in the body that is converted into steroid)



- ☐ 3 Isoprene units
☐ 4 Isoprene units
☐ 5 Isoprene units
☒ 6 Isoprene units

16. (7 pts total) It is important to think about reactions in both directions. To solve synthesis questions you will need to work backwards from a target molecule. Both reactions shown below use the same starting material. **Write the structure of that starting material in the box provided on the left, then write the appropriate reagents in the boxes over each arrow.** All observed products are shown for each reaction.



17. (16 pts total) The point of organic chemistry is synthesis, the conversion of simpler molecules to more complicated ones with enhanced structure and function. Each reaction you are learning should be thought of as a "tool" that allows you to create a desired type of molecule. These tools can be used in an almost infinite number of combinations to create truly interesting molecules. In the boxes provided, draw the structures of the molecule or the required reagent indicated in this synthesis scheme. FOR THIS ONE, IF STEREOISOMERS ARE CREATED YOU MUST DRAW THEM ALL USING WEDGES AND DASHES. And you must write "racemic" when appropriate. You will not recognize all of this chemistry, but by the time you finish this semester you will!!

