

NAME (Print): \_\_\_\_\_

Chemistry 320N  
2nd Midterm Exam  
March 12, 2026

EID \_\_\_\_\_

SIGNATURE: \_\_\_\_\_

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

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**Please Note:** Please take your time. You have three hours to take this exam. Please do not rush, we want you to show us everything you have learned this semester so far! Making careless mistakes is not good for anyone! If you find yourself getting anxious because of a problem, skip it and come back. Please do not second guess yourself! Keep track of the questions worth a lot of points. (This does not mean they are hard, it just means we think they cover important material.)

One last thing: I recommend you close your eyes for a moment, then take some nice deep breaths before you begin. **YOU GOT THIS!**

**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!!!**

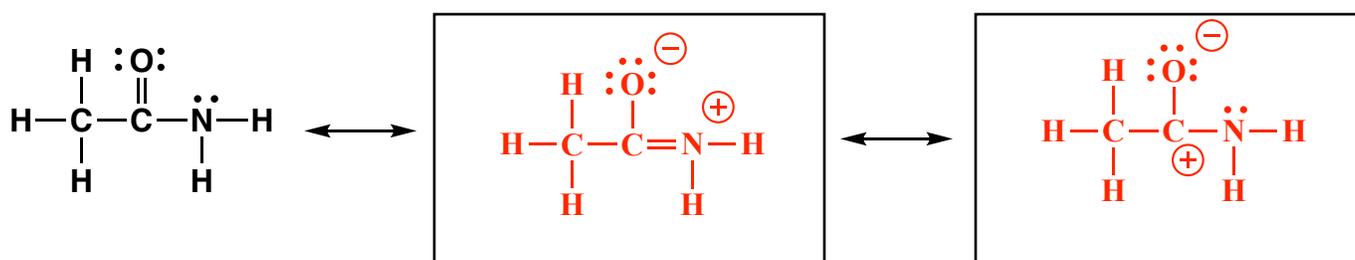


| Compound           |   | pK <sub>a</sub> |
|--------------------|---|-----------------|
| Hydrochloric acid  | $\text{H-Cl}$   | -7              |
| Protonated alcohol | $\text{RCH}_2\text{OH}_2^{\oplus}$  | -2              |
| Hydronium ion      | $\text{H}_3\text{O}^{\oplus}$   | -1.7            |
| Carboxylic acids   | $\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$   | 3-5             |
| Thiols             | $\text{RCH}_2\text{SH}$   | 8-9             |
| Ammonium ion       | $\text{H}_4\text{N}^{\oplus}$   | 9.2             |
| β-Dicarbonyls      | $\text{RC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$   | 10              |
| Primary ammonium   | $\text{H}_3\text{N}^{\oplus}\text{CH}_2\text{CH}_3$   | 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              | $\text{HOH}$  | 15.7            |
| Alcohols           | $\text{RCH}_2\text{OH}$   | 15-19           |
| Acid chlorides     | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{Cl}$  | 16              |
| Aldehydes          | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$   | 18-20           |
| Ketones            | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{R}'$  | 18-20           |
| Esters             | $\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OR}'$   | 23-25           |
| Terminal alkynes   | $\text{RC}\equiv\text{C}-\text{H}$  | 25              |
| LDA                | $\text{H}-\text{N}(\text{i-C}_3\text{H}_7)_2$   | 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              |

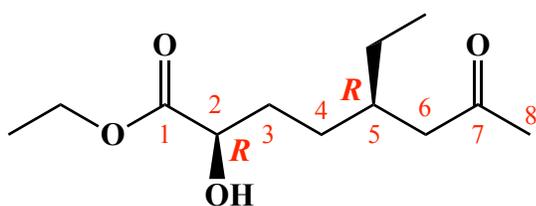
1. (5 pts) What is the most important question in organic chemistry?

**Where are the electrons?**

2. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided. (No need to draw any arrows for this.)



3. (6 pts) Write an acceptable IUPAC name or draw a structural formula for the following molecules:



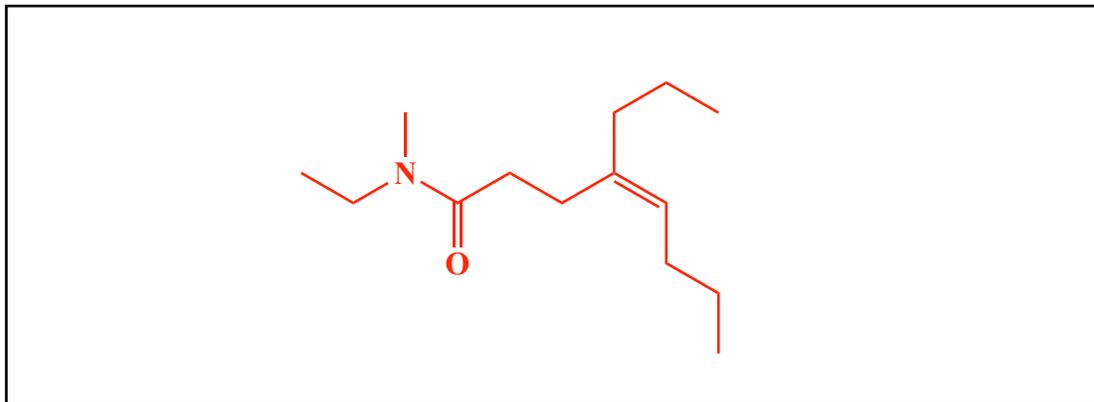
**Ethyl (2R,5R)-5-ethyl-2-hydroxy-7-oxooctanoate**

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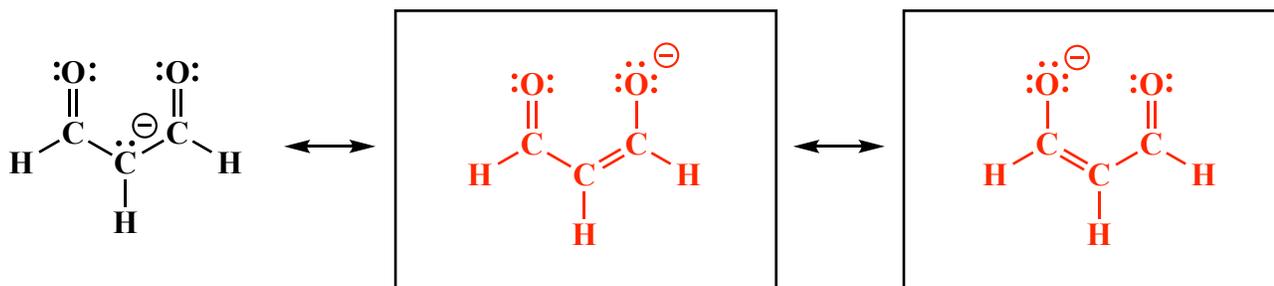
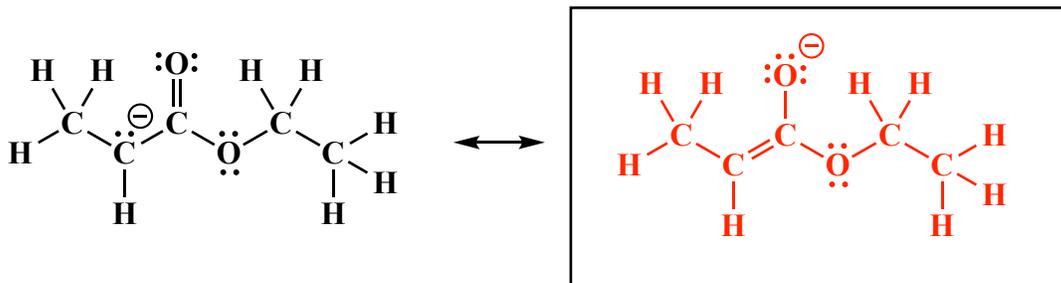
4. (6 pts each) Write an acceptable IUPAC name or draw a structural formula for the following molecules:

In the box, draw the structure corresponding to the following IUPAC name.

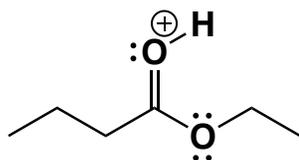
**(Z)-N-ethyl-N-methyl-4-propyloct-4-enamide**  
or  
**(Z)-N-ethyl-N-methyl-4-propyl-4-octenamide**



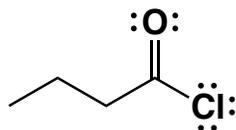
5. (10 pts) For the two different enolates shown below, draw the other important contributing structures. Make sure to show all electrons and formal charges. No arrows are required for this one.



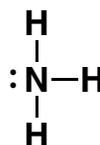
6. (11 pts) This is the nucleophile and electrophile question. You have encountered each of these species in mechanisms this semester. Each was seen to act as an electrophile or nucleophile in a mechanism. Fill in the circle to indicate whether the given species is an electrophile or nucleophile in one or more mechanisms we have seen. **Note: these same species can sometimes act as acids or bases in some mechanisms, but we are ignoring these acid or base activities for this problem.**



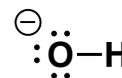
Nucleophile  
 Electrophile



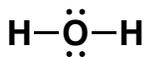
Nucleophile  
 Electrophile



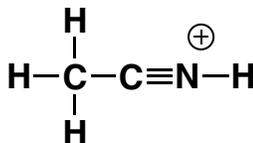
Nucleophile  
 Electrophile



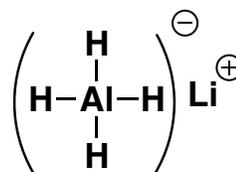
Nucleophile  
 Electrophile



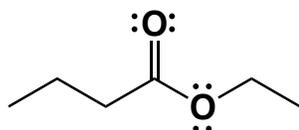
Nucleophile  
 Electrophile



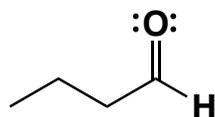
Nucleophile  
 Electrophile



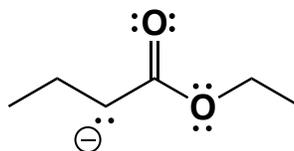
Nucleophile  
 Electrophile



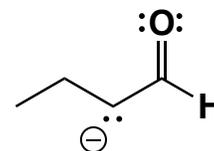
Nucleophile  
 Electrophile



Nucleophile  
 Electrophile

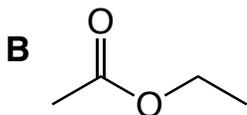
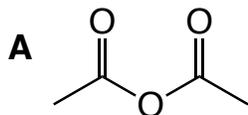


Nucleophile  
 Electrophile

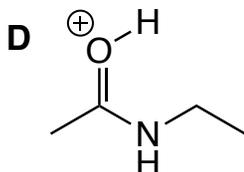
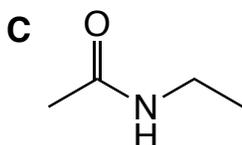


Nucleophile  
 Electrophile

7. (4 pts) For each pair of molecules, fill in the circles to indicate which in each pair is **more or less reactive with nucleophiles.**



**A** is more reactive than **B**  
 **B** is more reactive than **A**



**C** is more reactive than **D**  
 **D** is more reactive than **C**

Signature \_\_\_\_\_

Pg 4 \_\_\_\_\_ (22)

8. (2 pts each) Fill in the blank with the word or words that best complete the statements. You should recognize these as Rules of the Day.

A. Esters require acid catalysis or base promotion to hydrolyze. The acid catalyzed ester hydrolysis mechanism is the functional reverse of the Fischer esterification mechanism, illustrating the concept of microscopic reversibility.

B. Nitriles are hydrolyzed in strong acid to give carboxylic acids, according to a mechanism that involves formation of amides.

C. Anhydrides react with water to produce two molecules of carboxylic acid and this process is catalyzed by acid.

D. A special reagent called DIBALH (diisobutyl aluminum hydride) can be used to reduce esters that stops at the aldehyde stage due to steric hindrance caused by the two isobutyl "antlers".

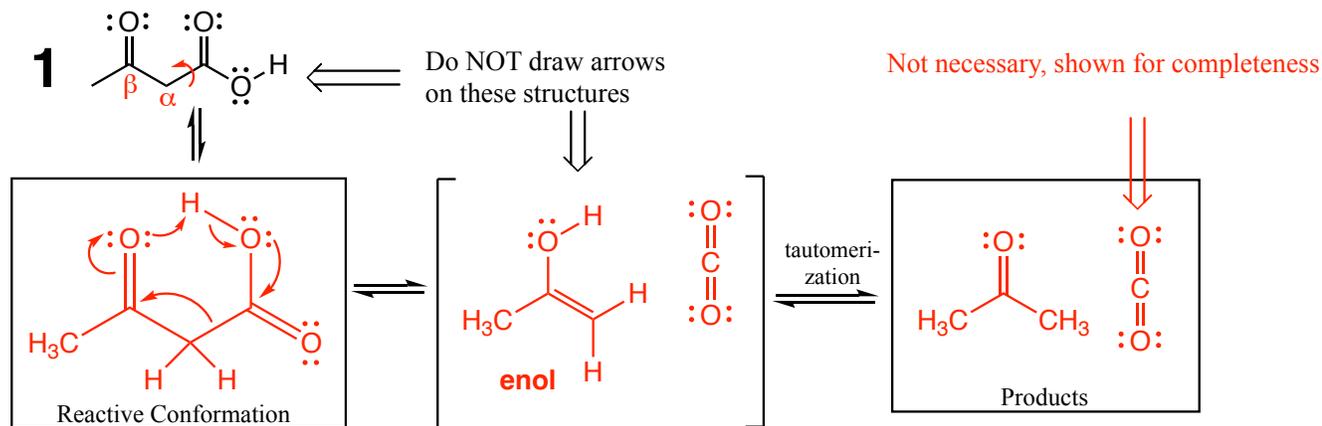
E. Aldols between two different carbonyl compounds can be run in high yield if one of the carbonyl compounds is a ketone and the other is an aldehyde that cannot make an enolate. This is generally only relevant to formaldehyde and benzaldehyde.

F. The C atom next to a carbonyl is called the alpha ( $\alpha$ ) carbon, and a carbon atom two carbon atoms away is called the beta ( $\beta$ ) carbon.

G. Enolates are stabilized by a combination of delocalization of charge and formation of a pi-bond. By far the most important reactions of enolates are with carbonyl groups to make carbon-carbon bonds.

H. Reactions follow the mechanisms according to the paths of lowest energy (greatest opportunity), that is why I always emphasize when a charged species is stabilized by resonance delocalization.

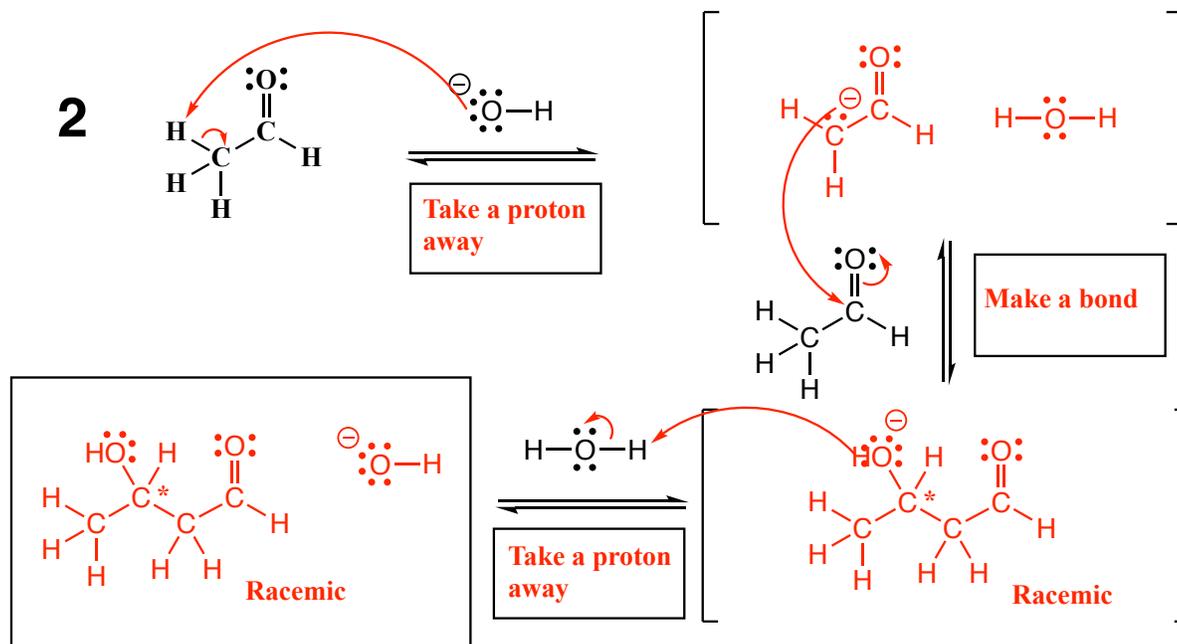
9. (12 pts) Complete the mechanism for the following decarboxylation reaction. **Be sure to show arrows to indicate movement of all electrons on the “Reactive Conformation”, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **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.**



Draw arrows on this structure

**Note you will have to write a balanced equation for the above mechanism on page 10**

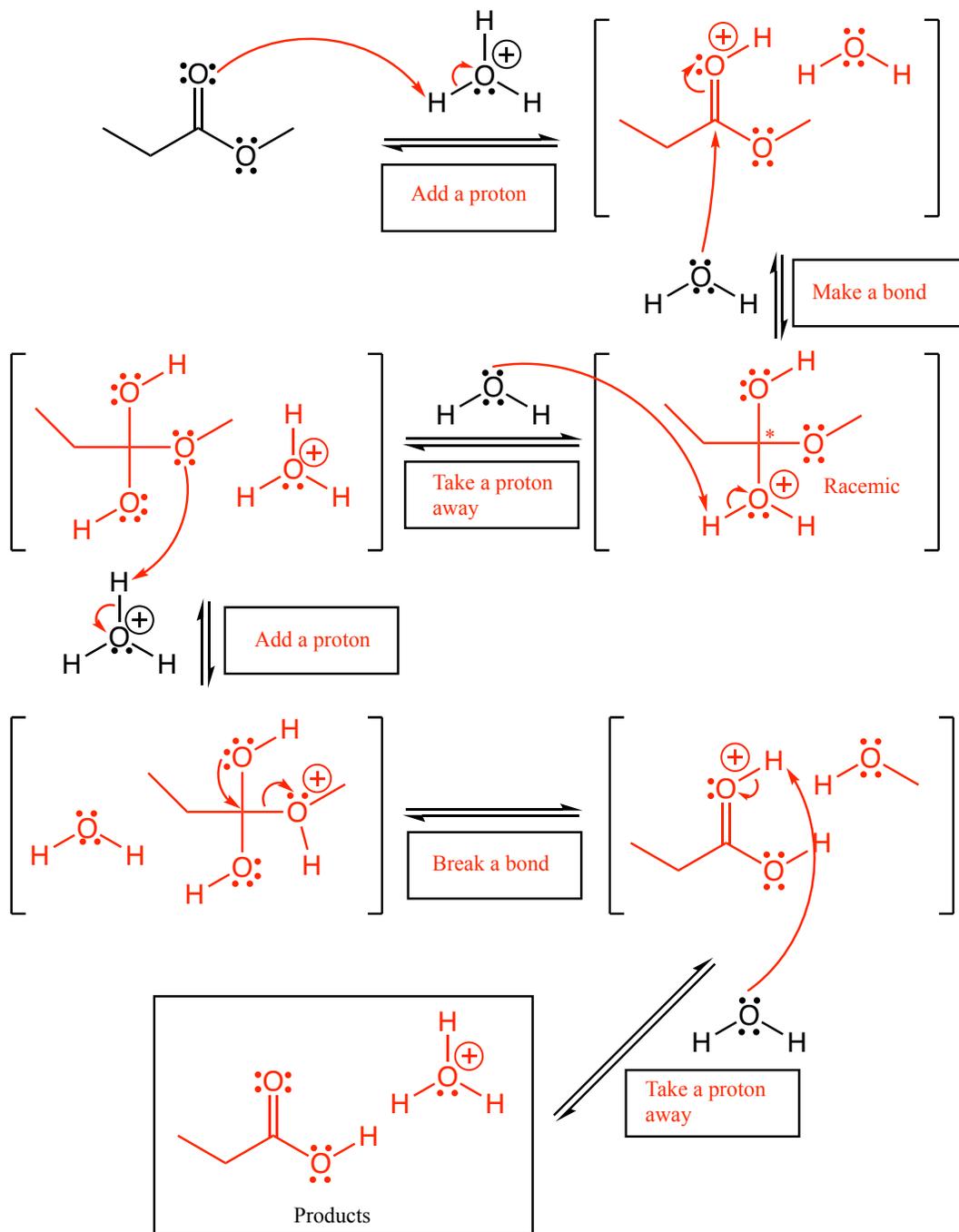
10. (21 pts) Complete the mechanism for the following aldol reaction of an aldehyde and hydroxide. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** **IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS “RACEMIC” IF APPROPRIATE.** **FOR ALL CHIRAL PRODUCTS YOU MUST DRAW ALL ENANTIOMERS WITH WEDGES AND DASHES AND WRITE “RACEMIC” IF APPROPRIATE.** In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).



**Note you will have to write a balanced equation for the above mechanism on the page 9**

11. (36 pts) Complete the mechanism for the following hydrolysis reaction of an ester in aqueous acid. **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. IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. FOR ALL CHIRAL PRODUCTS YOU MUST DRAW ALL ENANTIOMERS WITH WEDGES AND DASHES AND WRITE "RACEMIC" IF APPROPRIATE.** In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).

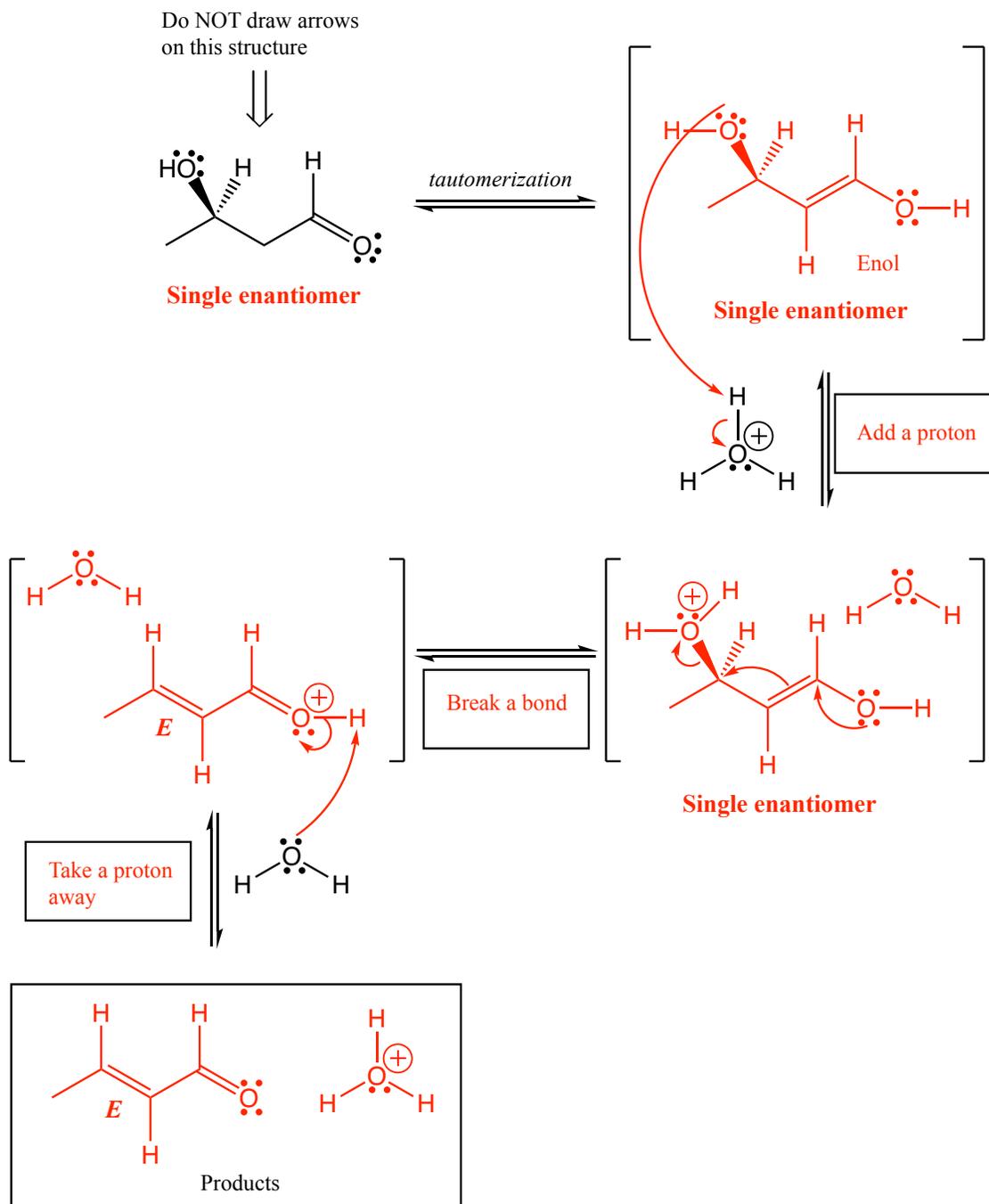
3



Note you will have to write a balanced equation for the above mechanism on PAGE 9

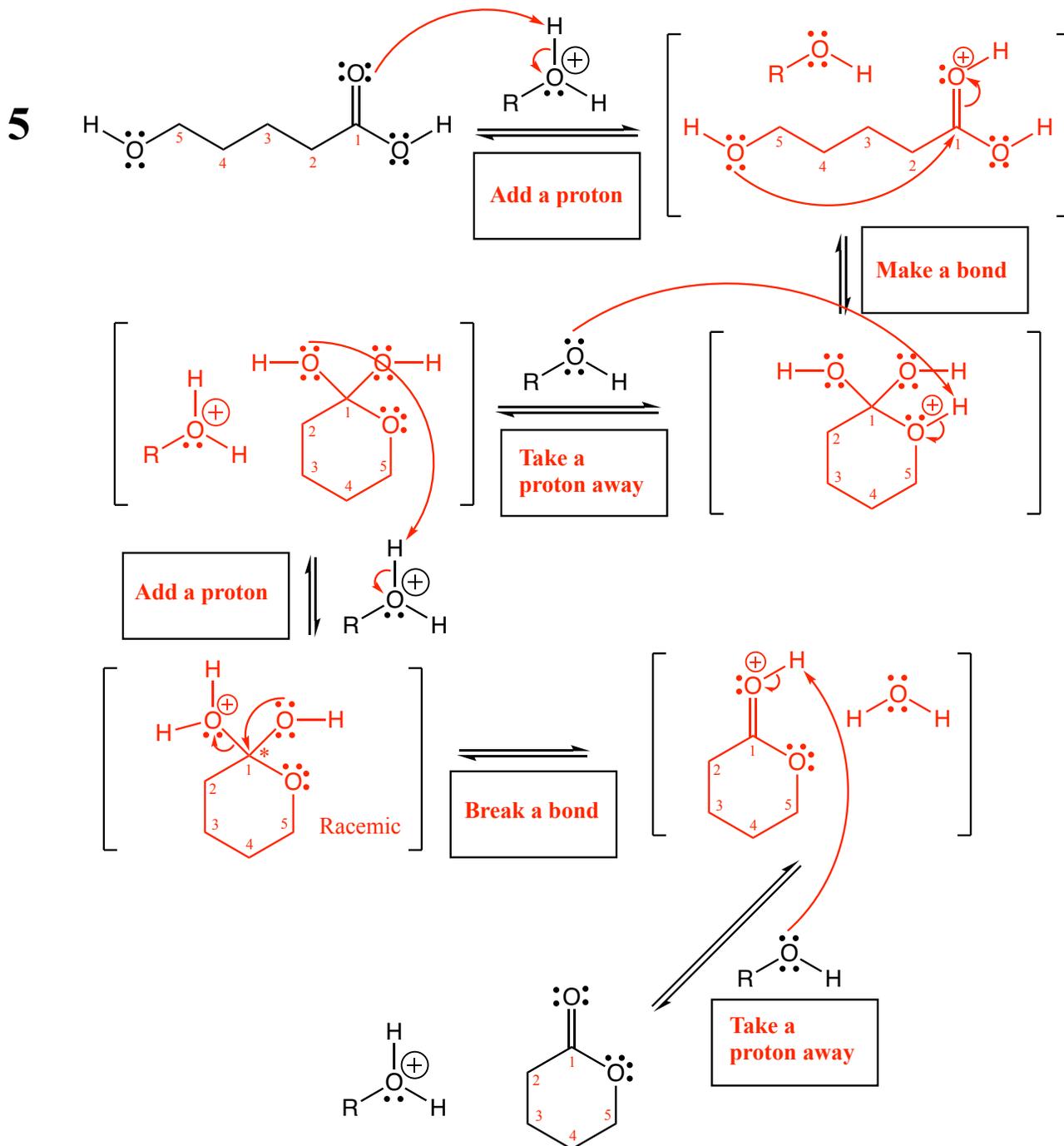
12. (21 pts) Complete the mechanism for the following dehydration of a  $\beta$ -hydroxy aldehyde in acid. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step. IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. FOR ALL CHIRAL PRODUCTS YOU MUST DRAW ALL ENANTIOMERS WITH WEDGES AND DASHES AND WRITE "RACEMIC" IF APPROPRIATE. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.). In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).**

4



Note you will have to write a balanced equation for the above mechanism on PAGE 9

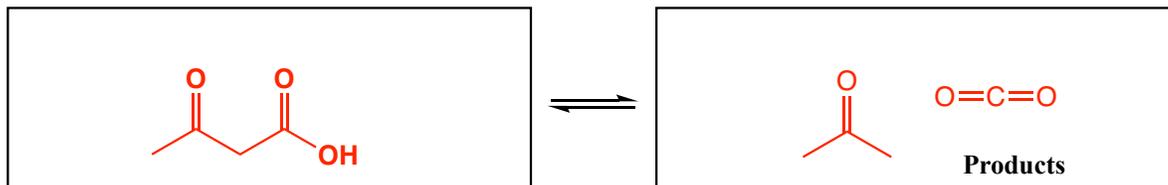
13. (32 pts) Complete the mechanism for the following lactone formation in acid. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step. IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. FOR ALL CHIRAL PRODUCTS YOU MUST DRAW ALL ENANTIOMERS WITH WEDGES AND DASHES AND WRITE "RACEMIC" IF APPROPRIATE.** In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).



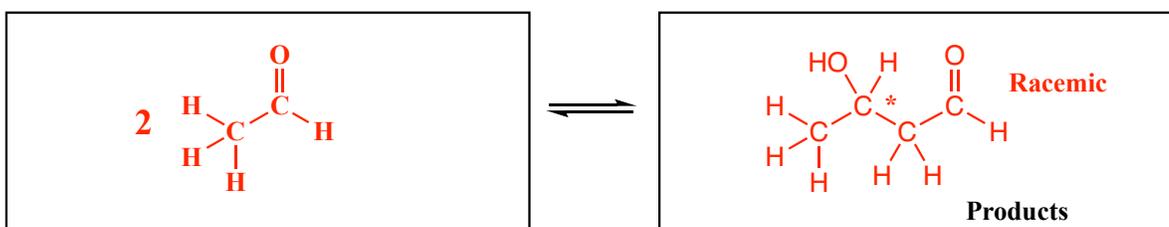
Note you will have to write a balanced equation for the above mechanism on PAGE 9

14. (26 pts) Write BALANCED equations for the four mechanisms, 1-4, that you drew on the last three pages. Only include molecules consumed or created during the reactions. In addition, you must use whole numbers when designating stoichiometries, not fractions or decimals. This is not asking to give equivalents, but rather balanced equations for each reaction.

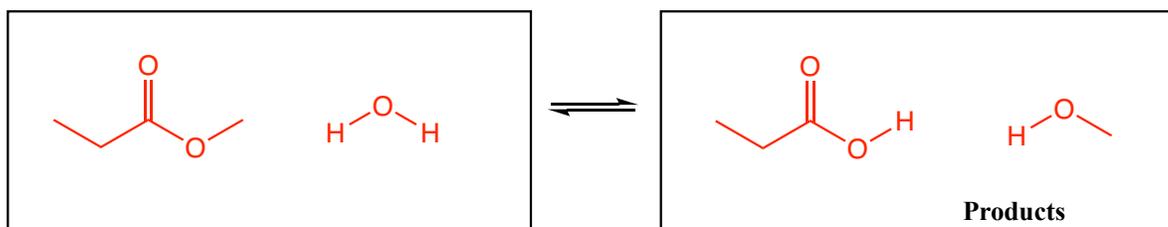
Write a balanced equation for the overall process described by mechanism 1 from page 5



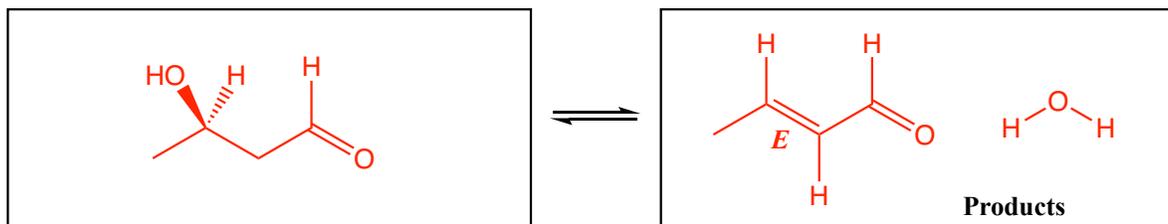
Write a balanced equation for the overall process described by mechanism 2 from page 5



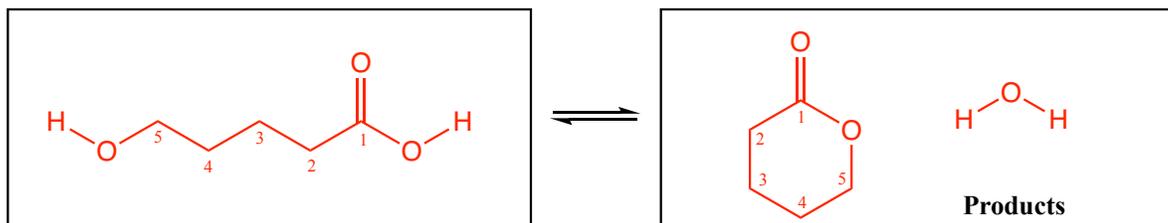
Write a balanced equation for the overall process described by mechanism 3 from page 6



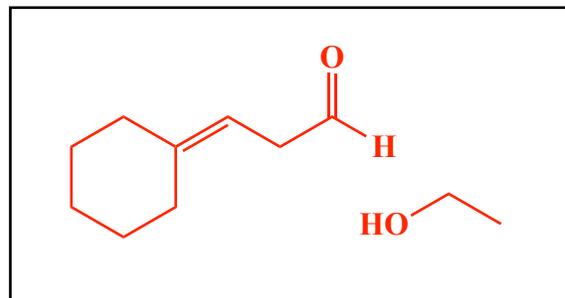
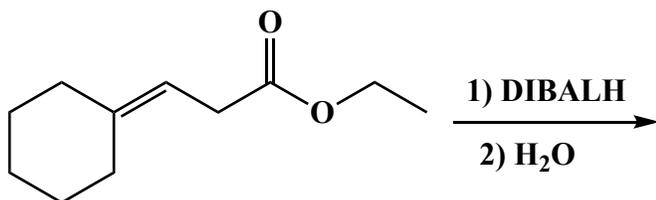
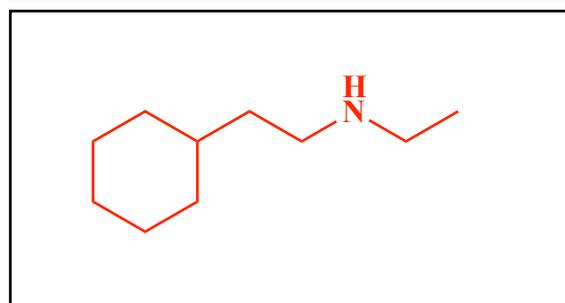
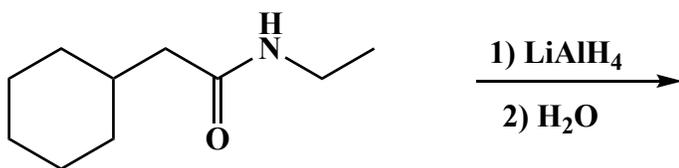
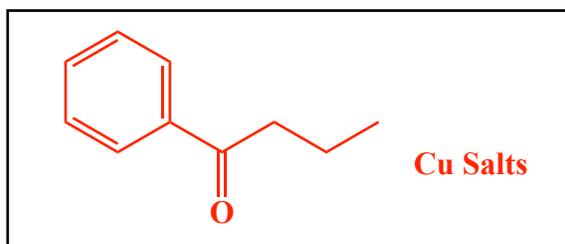
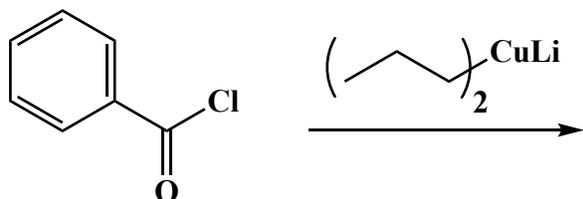
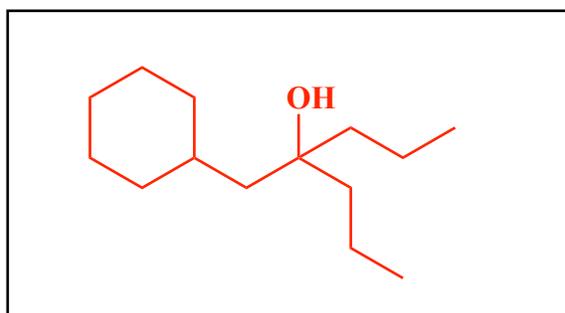
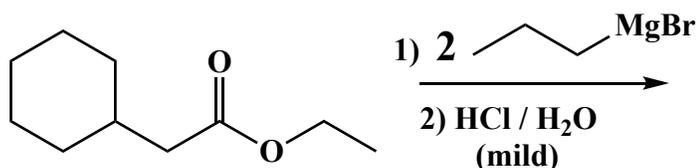
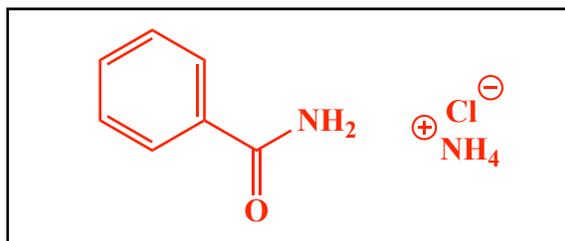
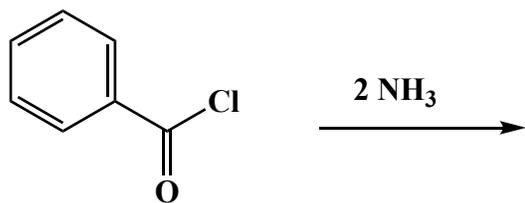
Write a balanced equation for the overall process described by mechanism 4 from page 7



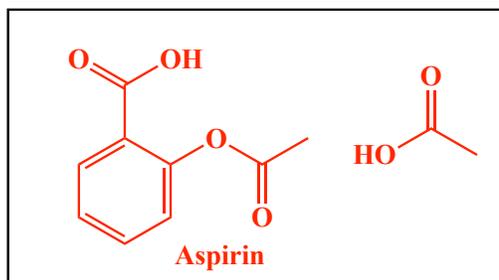
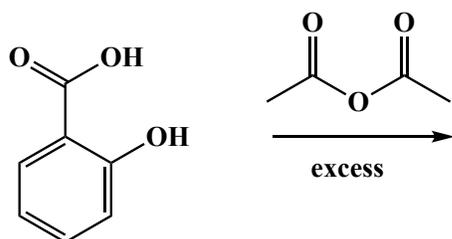
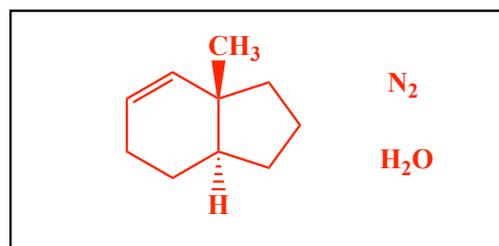
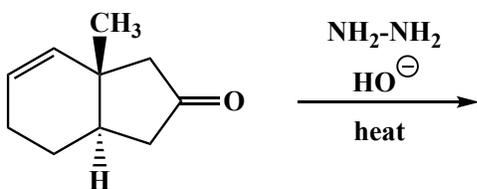
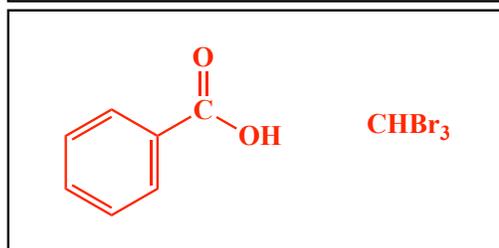
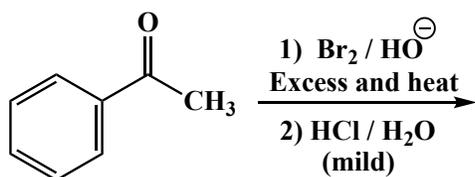
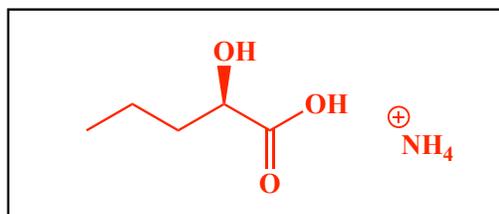
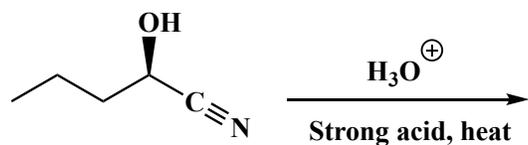
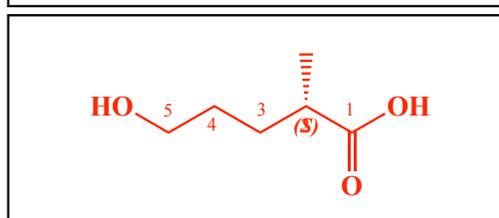
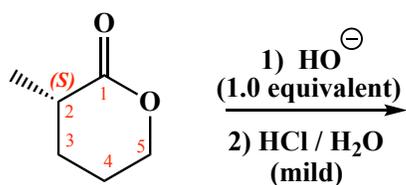
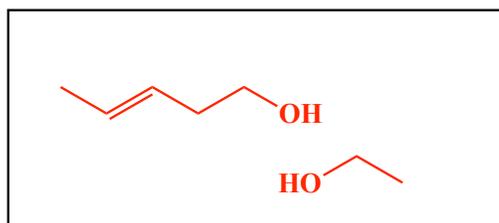
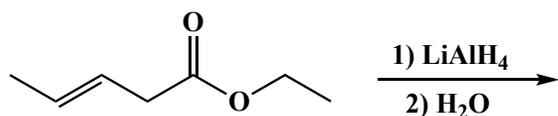
Write a balanced equation for the overall process described by mechanism 5 from page 8



15. (3 or 5 pts.) Write all of the organic product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. **For these, you need to write all of the products of the reactions except for the products containing metals.**

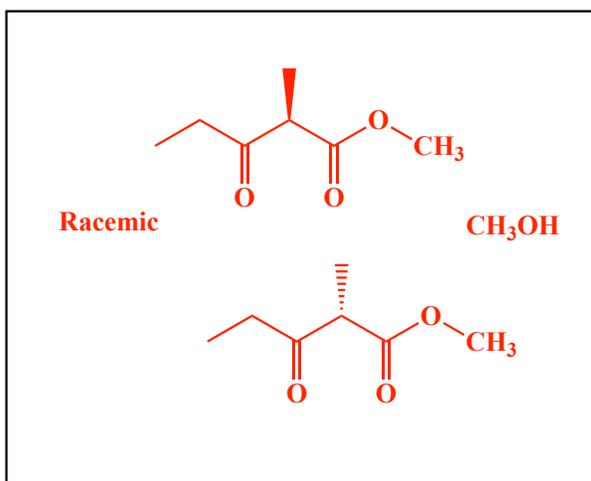
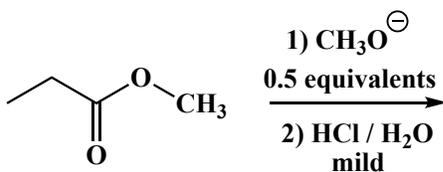
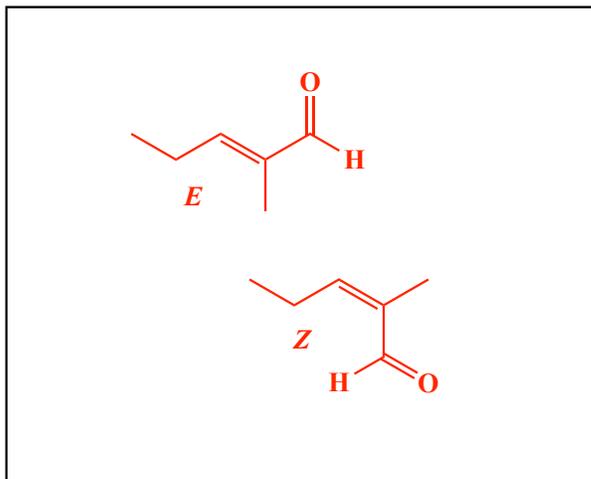
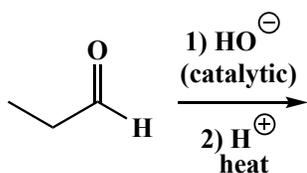


16. (3 or 5 pts.) Write all of the organic product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\cdots\text{|||||}$  ) to indicate stereochemistry. **For these, you need to write all of the products of the reactions except for the products containing metals.**

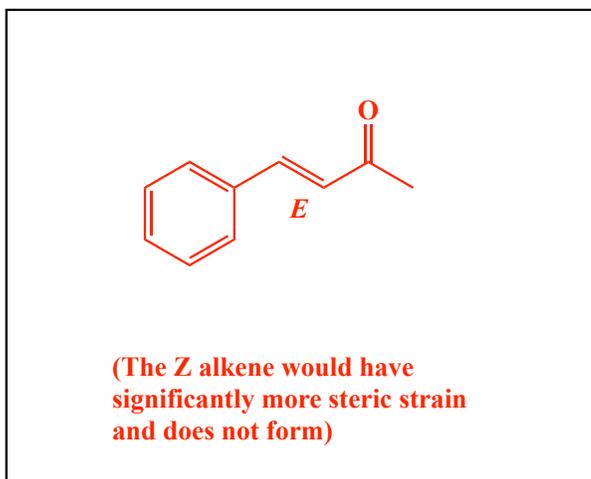
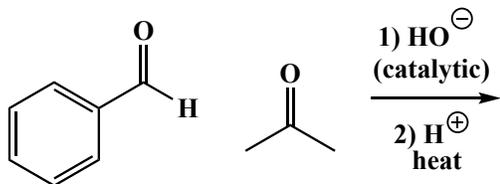


17. (4 or 6 pts.) Write the predominant product that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. **For these, you need to write all of the products of the reactions except for the products containing metals.**

ASSUME THIS DEHYDRATES.



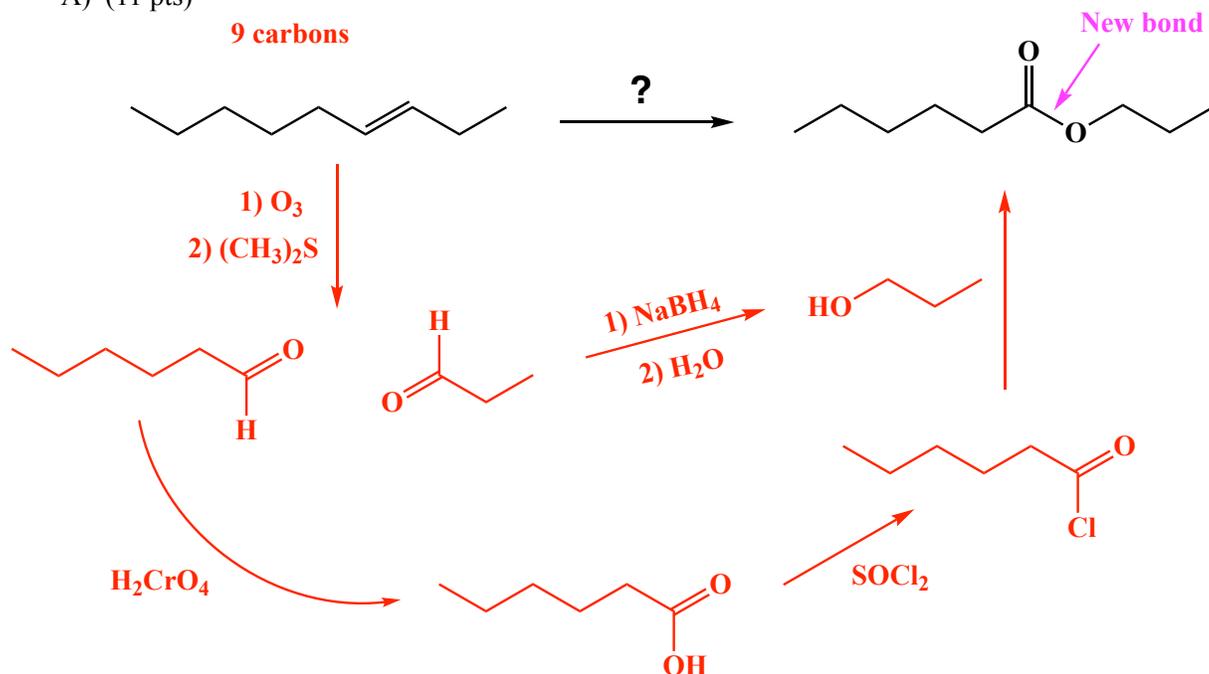
ASSUME THIS DEHYDRATES.



18. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

9 carbons

A) (11 pts)



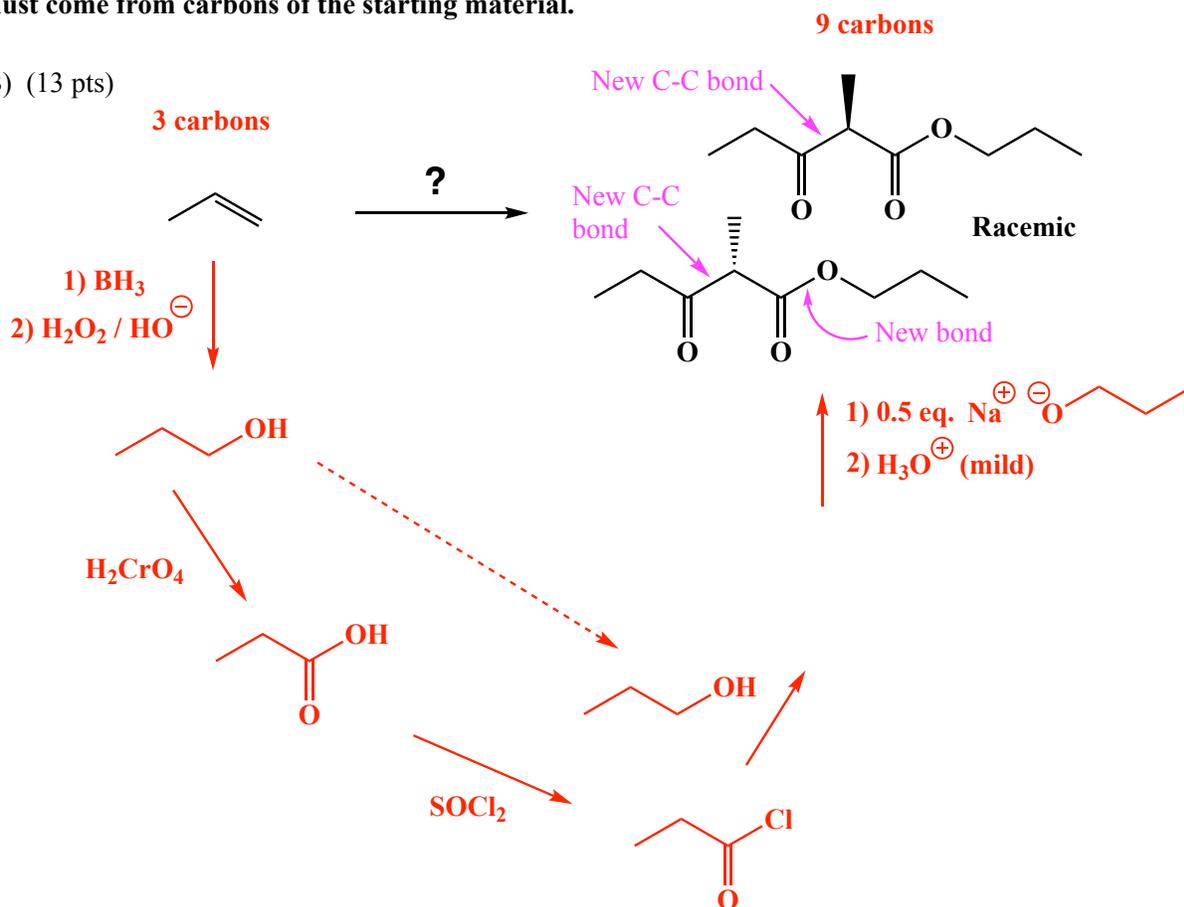
**Recognize** that both the starting material and product have 9 carbons. Therefore predict that all of the carbons of the starting material will end up in the product. **Recognize** further that the product is an ester. The bond between the carbonyl carbon and the oxygen indicated by the arrow is therefore the new bond. Propose the last step is a reaction between hexanoyl chloride and 1-propanol as shown. **Recognize** that the acid chloride can be made from the hexanoic acid using  $\text{SOCl}_2$ . **Recognize** that the starting alkene can be reacted with ozone followed by  $(\text{CH}_3)_2\text{S}$  to give hexanal and propanal. Those can be converted to the required hexanoic using  $\text{H}_2\text{CrO}_4$  and the required 1-propanol using 1)  $\text{NaBH}_4$  and 2)  $\text{H}_2\text{O}$  as shown.

Note that the Fischer esterification between the same 1-propanol and hexanoic acid would also give the product ester in one less step. That is a great way to go and will get full credit.



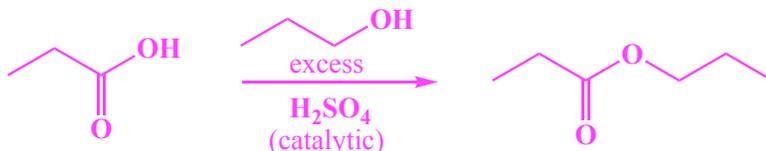
18. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized along the way and be sure to pay attention to the regiochemistry and stereochemistry preferences for each reaction. You must draw all stereoisomers formed, and use wedges and dashes to indicate chirality at each chiral center. Write racemic when appropriate. **All the carbons of the product must come from carbons of the starting material.**

B) (13 pts)



**Recognize** that the starting alkene has 3 carbons, while the product has 9 carbons. Therefore predict three molecules of the starting material are contained within the product. **Recognize** further that the product is a  $\beta$ -keto ester, the KRE of a Claisen reaction. Therefore predict the last step is a Claisen reaction using propyl propanoate as shown. **Recognize** that propyl propanoate can be synthesized from propanoyl chloride and 1-propanol as shown. Propanoyl chloride can be made from propanoic acid with  $\text{SOCl}_2$ . **Recognize** that propanoic acid can be made from 1-propanol, which in turn can be made from the starting propene using 1)  $\text{BH}_3$  and 2)  $\text{H}_2\text{O}_2/\text{HO}^\ominus$ .

Note that the Fischer esterification between the 1-propanol and propanoic acid would also give the product ester in one less step. That is a great way to go and will get full credit.



Yay, SPRING BREAK IS HERE. Do something you really enjoy next week. Promise me you will do that! YOU DESERVE IT, after all, you are in OChem II! And, PLEASE EXERCISE EVERY CHANCE YOU GET. Our 3.1 mile challenge is coming up in April!