NAME (Print): ______________________________

SIGNATURE: ______________________________

Chemistry 320N
Dr. Brent Iverson
2nd Midterm
March 24, 2016

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

Please Note: This test may be a bit long, but there is a reason. I would like to give you a lot of little questions, so you can find ones you can answer and show me what you know, rather than just a few questions that may be testing the one thing you forgot. **I recommend you look the exam over and answer the questions you are sure of first**, then go back and try to figure out the rest. Also make sure to **look at the point totals** on the questions as a guide to help budget your time.

You must have your answers written in PERMANENT ink if you want a regrade!!!! This means no test written in pencil or ERASABLE INK will be regraded.

Please note: We routinely xerox a number of exams following initial grading to guard against receiving altered answers during the regrading process.

FINALLY, DUE TO SOME UNFORTUNATE RECENT INCIDENCTS 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!!!

Page	Points	
1		(63)
6		(30)
7		(12)
8		(35)
9		(19)
10		(12)
11		(12)
12		(17)
13		(23)
14		(21)
15		(10)
16		(16)
17		(4)
18		(10)
Total		(284)

Student Honor Code

"As a student of The University of Texas at Austin, I shall abide by the core values of the University and uphold academic integrity."

____

(Your signature)

Compound		pK_a
Hydrochloric acid	$\underline{H}$-Cl	**-7**
Protonated alcohol	$RCH_2O\underline{H}_2^{\oplus}$	**-2**
Hydronium ion	$\underline{H}_3O^{\oplus}$	**-1.7**
Carboxylic acids	$R-C(=O)O-\underline{H}$	**3-5**
Ammonium ion	$\underline{H}_4N^{\oplus}$	**9.2**
β-Dicarbonyls	$RC(=O)-C\underline{H}_2-C(=O)R'$	**10**
Primary ammonium	$\underline{H}_3\overset{\oplus}{N}CH_2CH_3$	**10.5**
β-Ketoesters	$RC(=O)-C\underline{H}_2-C(=O)OR'$	**11**
β-Diesters	$ROC(=O)-C\underline{H}_2-C(=O)OR'$	**13**
Water	$HO\underline{H}$	**15.7**
Alcohols	$RCH_2O\underline{H}$	**15-19**
Acid chlorides	$RC\underline{H}_2-C(=O)Cl$	**16**
Aldehydes	$RC\underline{H}_2-C(=O)H$	**18-20**
Ketones	$RC\underline{H}_2-C(=O)R'$	**18-20**
Esters	$RC\underline{H}_2-C(=O)OR'$	**23-25**
Terminal alkynes	$RC\equiv C-\underline{H}$	**25**
LDA	$\underline{H}$-N(i-C_3H_7)$_2$	**40**
Terminal alkenes	$R_2C=C(H)-\underline{H}$	**44**
Alkanes	$CH_3CH_2-\underline{H}$	**51**

DO NOT TEAR OUT THIS PAGE!!

You must write the answers for the questions on the next four pages on this single sheet.

Question 1, page 2 (5 pts) Write the correct letter, A), B), C), D) or E) corresponding to the order of acidity of the molecules, listed from most to least acidic.

C)

Question 2, page 2 (5 pts) Write the correct letter, A), B), C), D) or E) corresponding to the order of anion stability, listed from most to least stable.

D)

Question 3, page 3 (5 pts) Write the correct letter, A), B), C), D) or E) corresponding to the order of reactivty with nucleophiles, listed from most to least reactive.

B)

Question 4, page 3 (5 pts) Write the hybridization state of the atoms indicated by the arrows.

a) ***sp^3*** b) ***sp^3*** c) ***sp^2*** d) ***sp^2*** e) ***sp^2***

Question 5, page 4 (5 pts) Write""yes" or "no" corresponding to whether the bond indicated by the arrows does ("yes") or does not ("no") rotate freely at room temperature.

a) **yes** b) **no** c) **yes** d) **no** e) **yes**

Question 6, page 4 (5 pts) What pH (2.0, 7.0, or 11.0) corresponds to the stucture from question 5?

7.0

Question 7, page 4 (5 pts) Write the correct letter, A), B), C), D) or E) corresponding to the order of acidity, listed from most to least acidic.

A)

Question 8, page 5 (2 pts each word) Fill in the appropriate two words on the lines provided.

microscopic reversibility

Question 9, page 5 (4 pts each) Write "Make a Bond", "Break a Bond", "Add a Proton" or "Take a Proton Away"

9.1 Add a proton

9.2 Make a Bond

9.3 Take a Proton Away

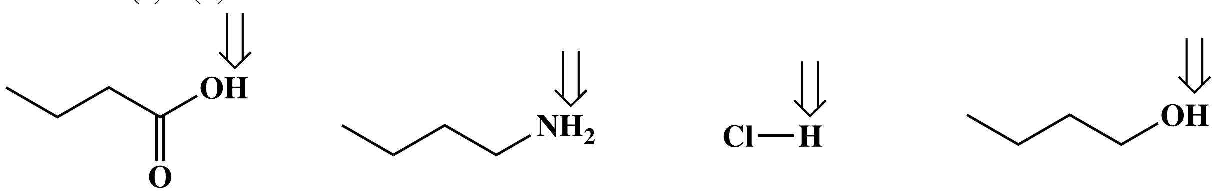
9.4 Break a Bond

9.5 Make a Bond

9.6 Make a Bond

Write the answers to these questions on the answer sheet on page 1

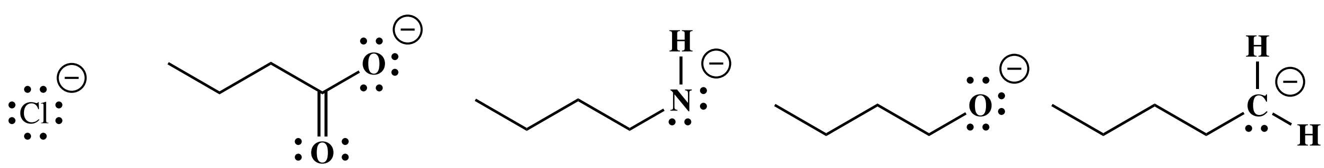
1. (5 pts) Rank order all of the following with respect to relative acidity. The acidic H atom in question is indicated with the arrow for each molecule. **On the answer sheet on page 1 write the letter corresponding to the correct order of acidity,** ranked from most to least acidic for the molecules labeled as (a) - (d).



(a) **(b)** **(c)** **(d)**

	most acidic			least acidic
A)	**(a)**	**(b)**	**(c)**	**(d)**
B)	**(b)**	**(a)**	**(d)**	**(c)**
C)	**(c)**	**(a)**	**(d)**	**(b)**
D)	**(c)**	**(b)**	**(a)**	**(d)**
E)	**(c)**	**(d)**	**(b)**	**(a)**

2. (5 pts.) Rank order the following in terms of anion stability. **On the answer sheet on page 1 write the letter corresponding to the correct order of anion stability,** ranked from most to least stable for the molecules labeled as (a) - (e).

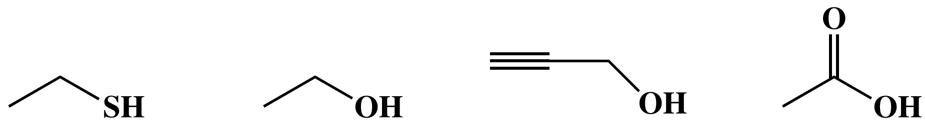


(a) **(b)** **(c)** **(d)** **(e)**

	most stable				least stable
A)	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**
B)	**(e)**	**(a)**	**(b)**	**(d)**	**(c)**
C)	**(a)**	**(e)**	**(b)**	**(d)**	**(c)**
D)	**(a)**	**(b)**	**(d)**	**(c)**	**(e)**
E)	**(b)**	**(a)**	**(e)**	**(d)**	**(c)**

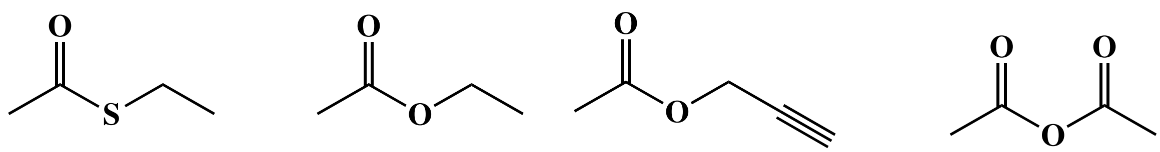
Write the answers to these questions on the answer sheet on page 1

3. (5 pts) You are going to have to think about this one! The following pK_a values will help in your analysis:



pK_a **= 10.61** pK_a **= 15.50** pK_a **= 13.60** pK_a **= 4.75**

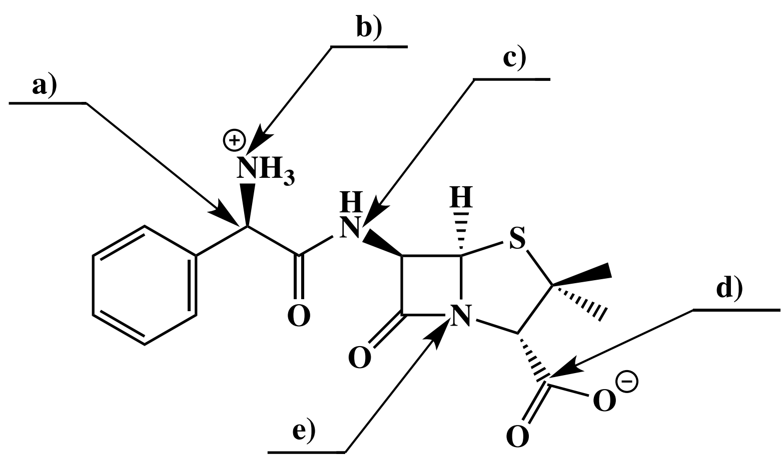
Rank order all of the following with respect to relative reactivity with a nucleophile such as NH_3. **On the answer sheet on page 1 write the letter corresponding to the predicted order of reactivity,** ranked from most to least reactive for the molecules labeled as (a) - (d).



(a) **(b)** **(c)** **(d)**

	most reactive			least reactive
A)	**(b)**	**(c)**	**(a)**	**(d)**
B)	**(d)**	**(a)**	**(c)**	**(b)**
C)	**(c)**	**(a)**	**(d)**	**(b)**
D)	**(c)**	**(b)**	**(a)**	**(d)**
E)	**(d)**	**(a)**	**(b)**	**(c)**

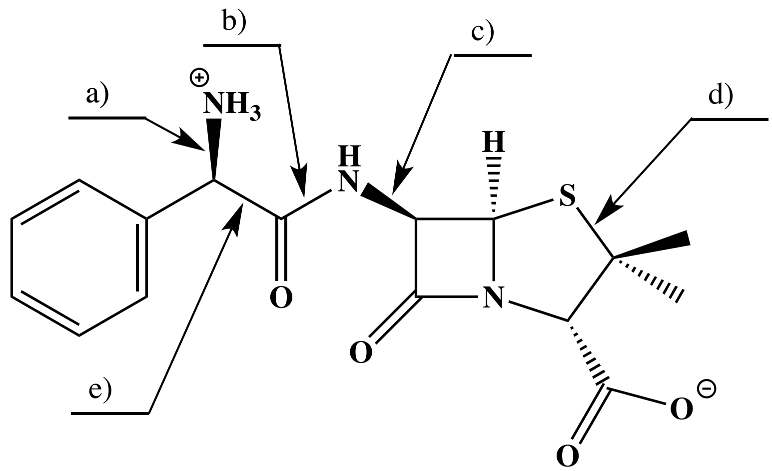
4. (5 points) On the answer sheet on page 1, indicate the hybridization state of each atom identified by the arrows.



Ampicillin - a common antibiotic used often in research

Write the answers to these questions on the answer sheet on page 1

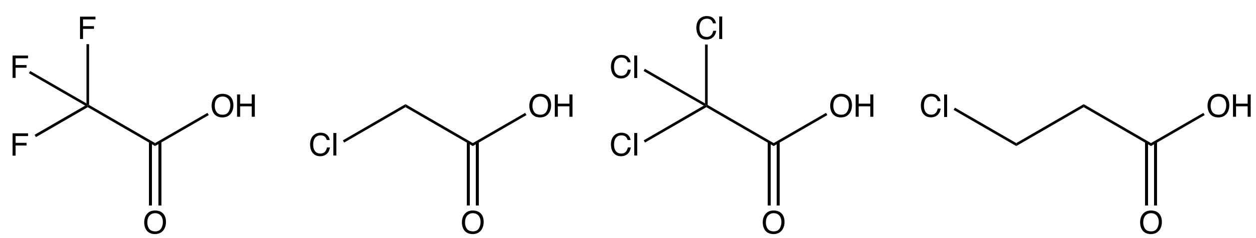
5. (5 pts) **On the answer sheet on page 1 write "yes" or "no" to indicate whether the bond identified by the arrow does (yes) or does not (no) rotate freely at room temperature.**



Ampicillin - a common antibiotic used often in research

6. (4 pts) For the above structure (problem 5), is the molecule drawn in the correct protonation state for pH 2.0, 7.0, or 11.0? Write 2.0, 7.0 or 11.0 on the answer sheet on page 1.

7. (5 pts) Rank the following molecules with respect to overall acidity. **On the answer sheet on page 1, write the letter corresponding to the correct order of acidity,** ranked from most to least acidic for the molecules labeled as (a) - (d).



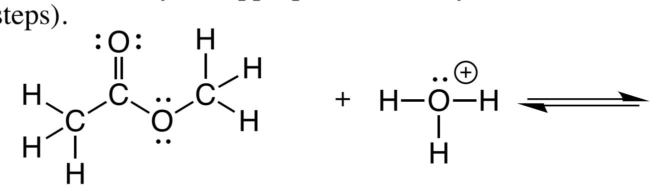
(a) **(b)** **(c)** **(d)**

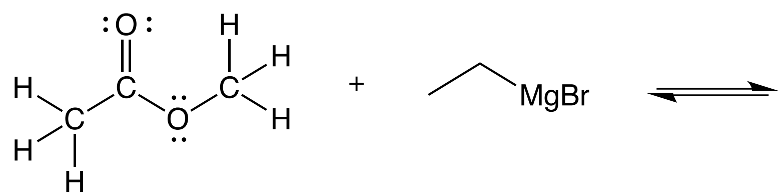
	most acidic			least acidic
A)	**(a)**	**(c)**	**(b)**	**(d)**
B)	**(a)**	**(b)**	**(d)**	**(c)**
C)	**(c)**	**(a)**	**(b)**	**(d)**
D)	**(c)**	**(d)**	**(b)**	**(a)**
E)	**(d)**	**(b)**	**(c)**	**(a)**

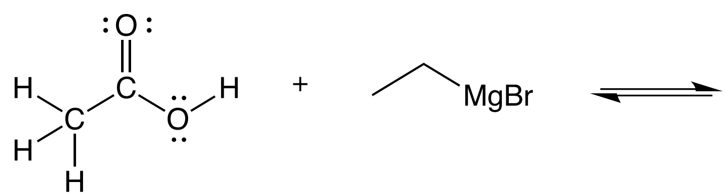
Write the answers to these questions on the answer sheet on page 1

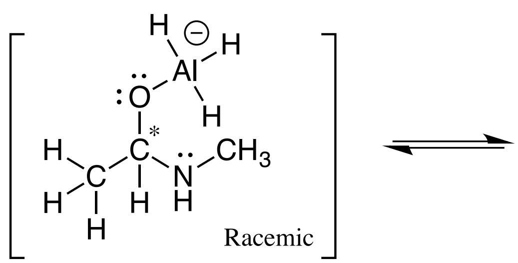
8. (2 pts each word) The mechanisms of reversible reactions are the same in either direction, meaning the same intermediates are encountered in either direction. A great illustration of this principle involves the mechanisms we have encountered for the Fischer esterification and acid catalyzed ester hydrolysis. The principle that indicates reaction mechanisms are the same in both directions of a reversible reaction is known as the principle of ____________________ ______________________. (write the two appropriate words on the answer sheet of page 1.

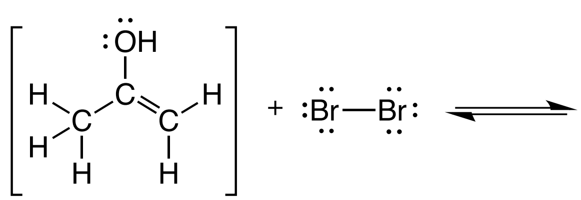
9. (4 pts each) Predict which of the four mechanistic elements describe the **next mechanism step** indicated by the following reagent or reagents. On page 1 write "Make a Bond", "Break a Bond", "Add a Proton" or "Take a Proton Away" as appropriate. (Note you do NOT need to draw any arrows or products for these steps).

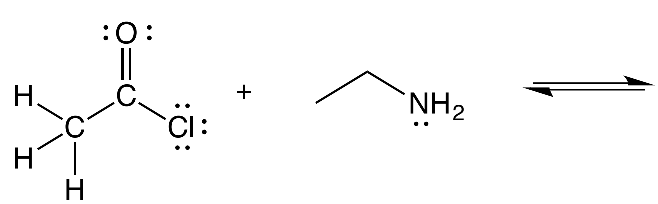
9.1 

9.2 

9.3 

9.4 

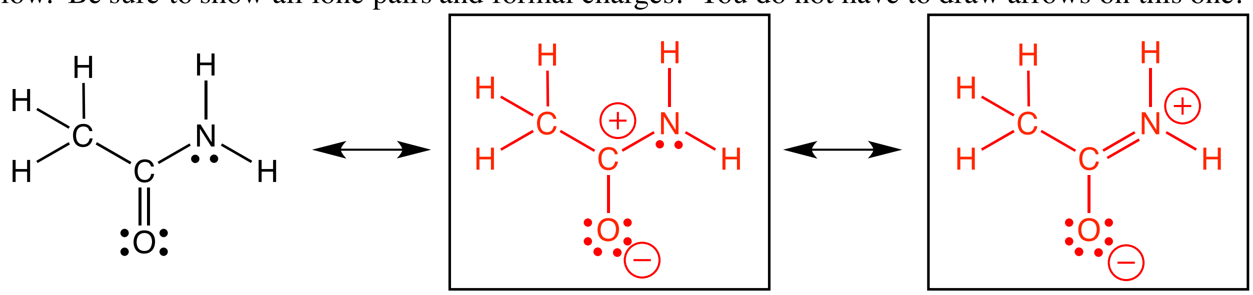
9.5 

9.6 

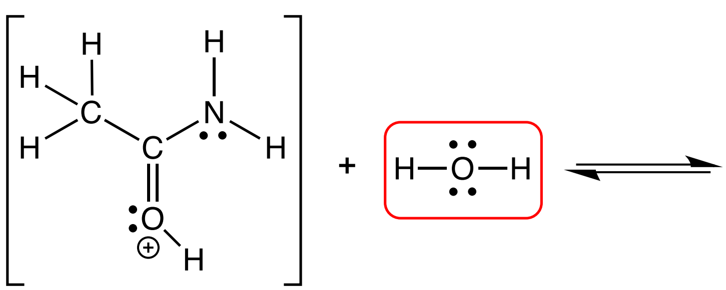
10. (14 points) Suppose a relative of yours is having an MRI. In no more than four sentences, explain to them what is happening when they have the MRI scan. We wil be looking for a minimum of 7 key points here.

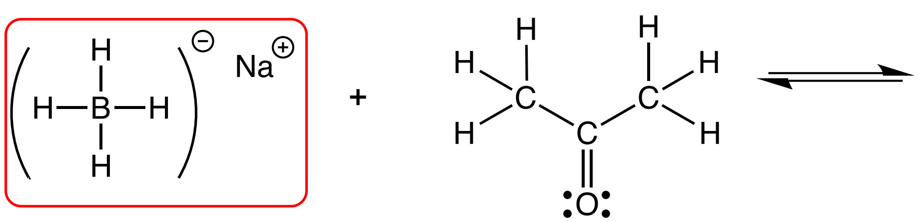
The popular medical diagnostic technique of **magnetic resonance imaging (MRI)** is based on the same principles as NMR, namely the **flipping (i.e. resonance) of nuclear spins of protons** by **radio frequency irradiation** when a patient is placed in a **strong magnetic field**. Magnetic field gradients are used to gain imaging information, and **rotation of the gradient around the center of the object** gives imaging in an entire plane (**i.e. slice inside patient**). In an MRI image, you are looking at **individual slices** that **when stacked make up the three-dimensional image** of **relative amounts of protons**, **especially the protons from water and fat, in the different tissues**.

11. (8 points) Draw the two most important resonance contributing structures of the amide shown below. Be sure to show all lone pairs and formal charges. You do not have to draw arrows on this one.

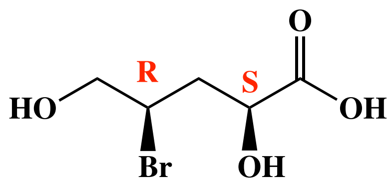


12. (4 pts each) For the following two pairs of reagents, **circle** the nucleophile.



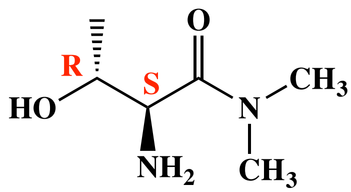


13. (4 pts each) In the space provided, write the IUPAC name (including stereochemistry where appropriate) for the following two molecules:



(2*S*,4*R*)-4-bromo-2,5-dihydroxypentanoic acid

____

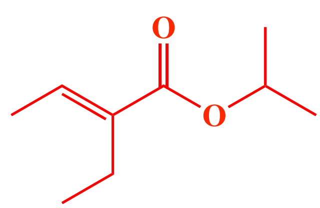


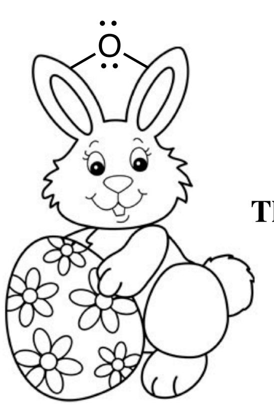
(2*S*,3*R*)-2-amino-3-hydroxy-*N*,*N*-dimethylbutanamide

____

14. (4 pts) In the space provided, draw the following molecule:

Isopropyl (*E*)-2-ethyl-2-butenoate

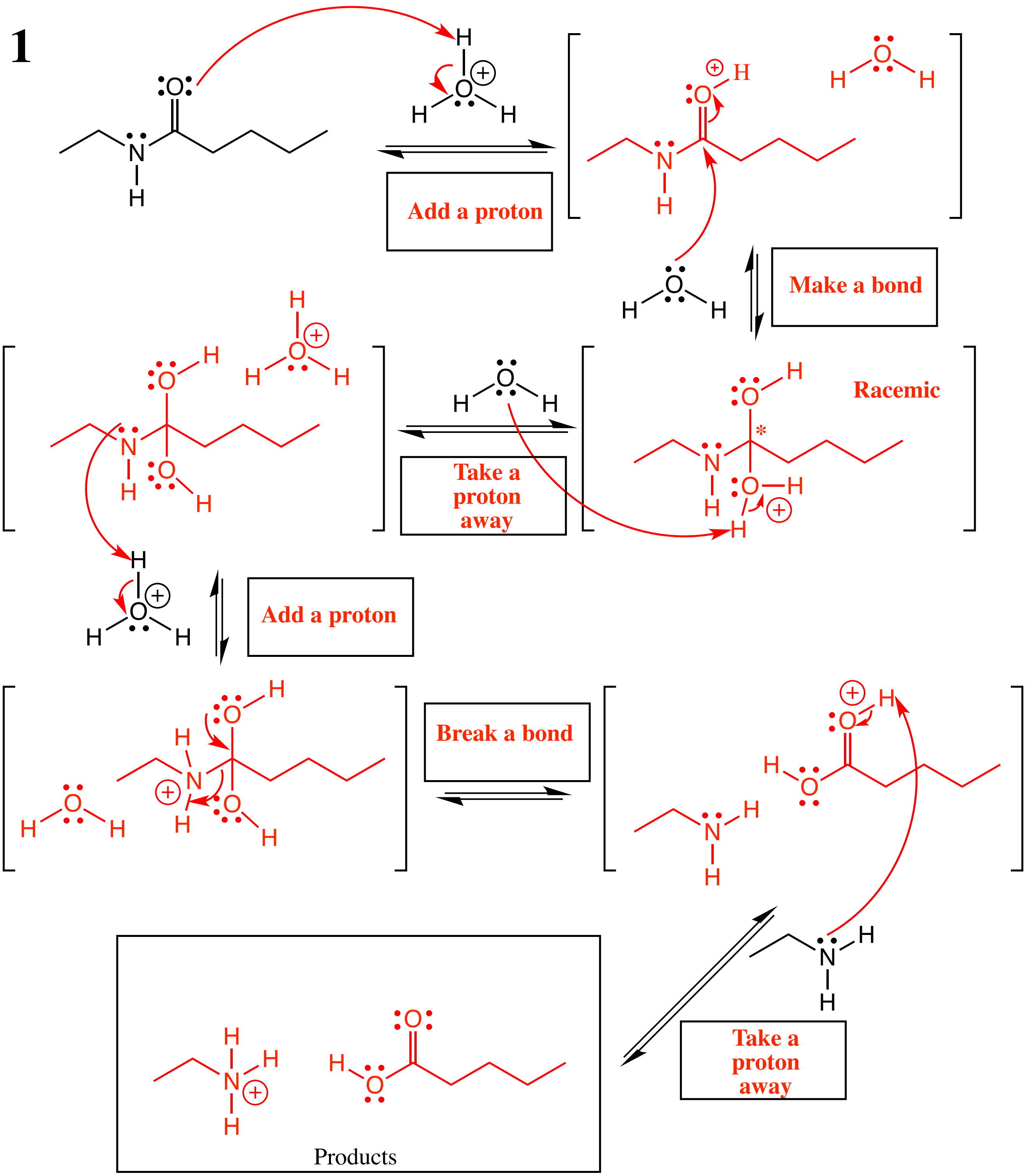




The Ether Bunny

The Ester Bunny

15. (35 pts) Complete the mechanism for the following amide hydrolysis reaction. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> 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. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).**

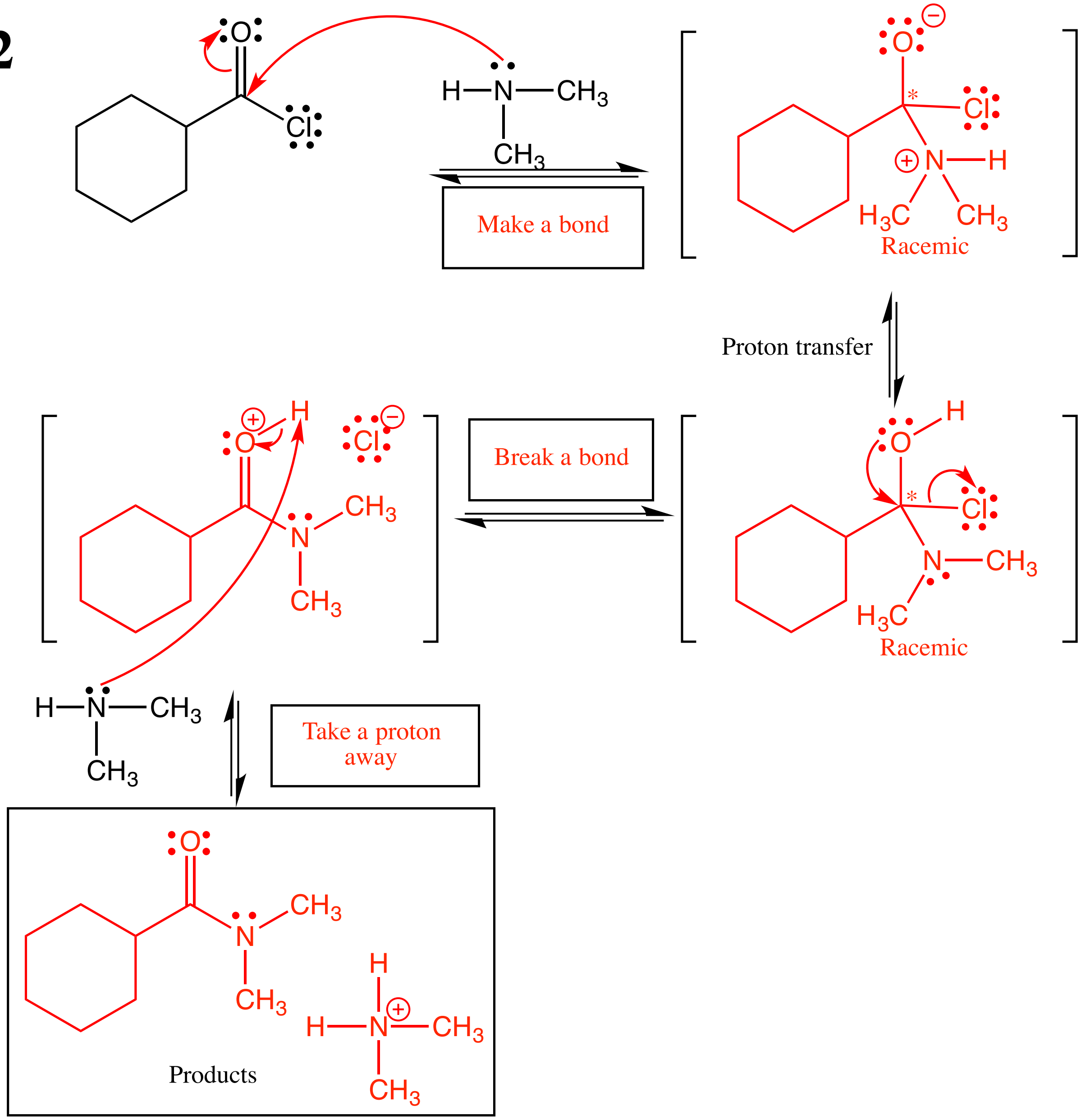


Note you will have to write a balanced equation for the above mechanism on PAGE 11

Signature__________________________ Pg 9 _____________ (19)

16. (19 pts) Complete the mechanism for the following reaction of an acid chloride with an amine. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> 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. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).**

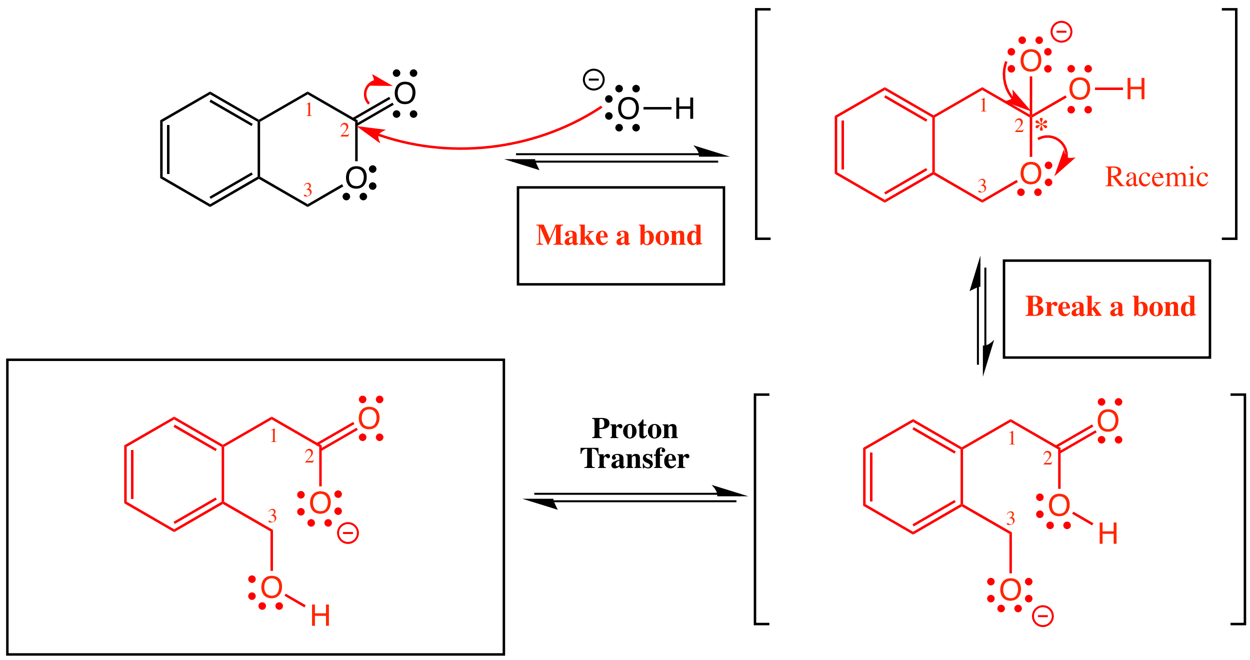
2



Note you will have to write a balanced equation for the above mechanism on PAGE 11

17. (12 pts) Complete the mechanism for the following reaction a lactone and hydroxide. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> 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. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).**

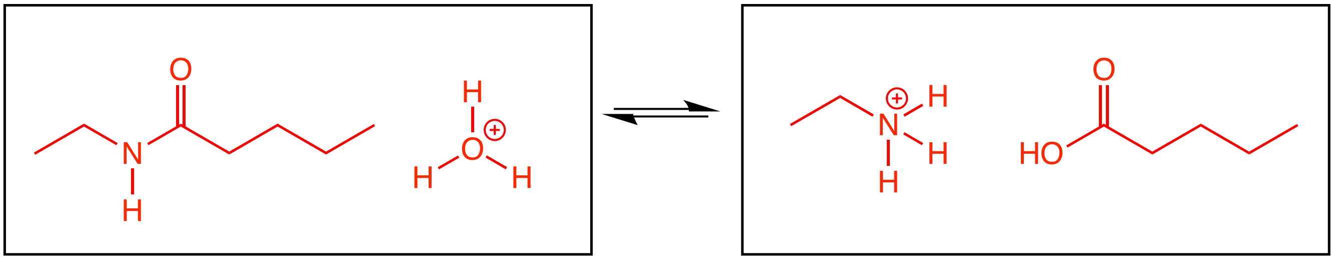
3



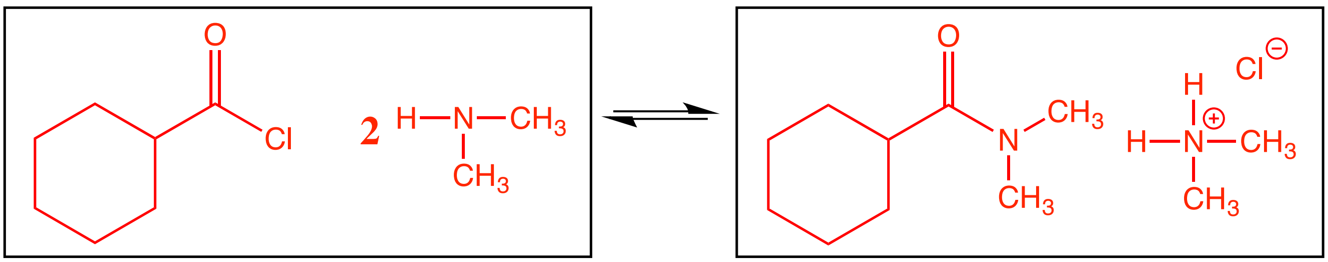
Note you will have to write a balanced equation for the above mechanism on the NEXT page

18. (12 pts) Write BALANCED equations for the three mechanisms, 1-3, that you drew on the last three pages.

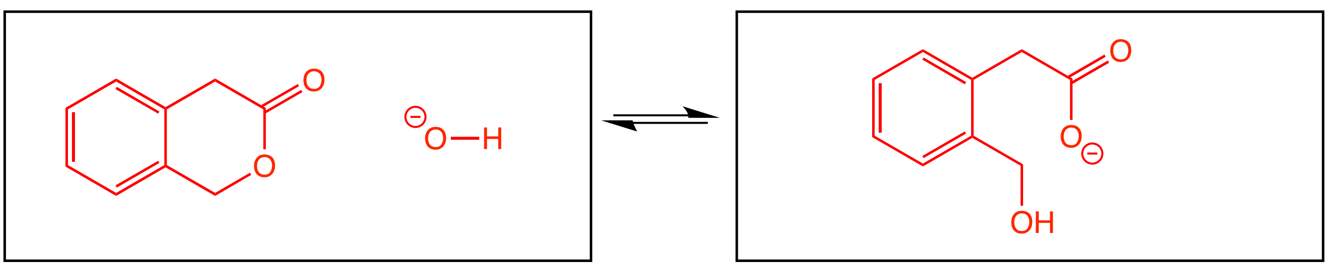
Write a balanced equation for the overall process described by mechanism 1 from page 8



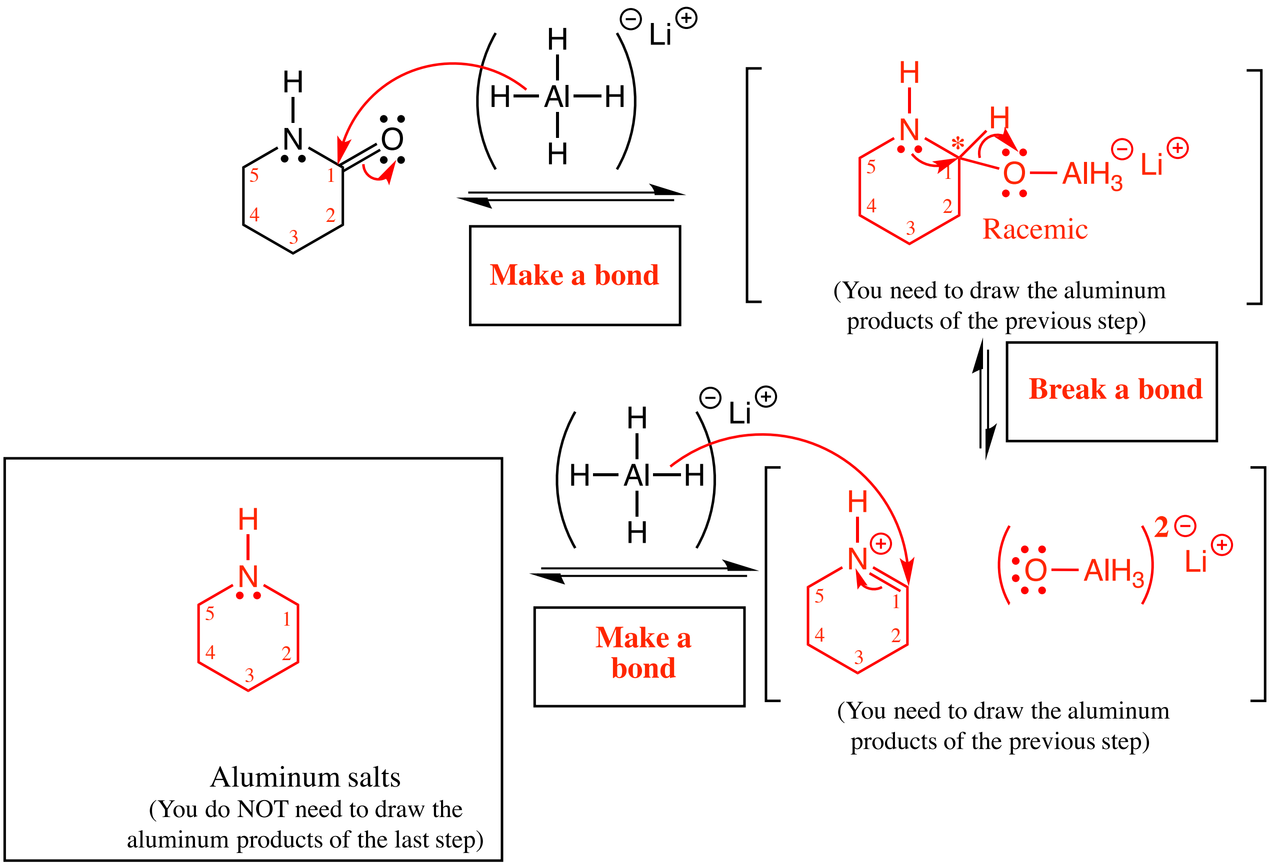
Write a balanced equation for the overall process described by mechanism 2 from page 9



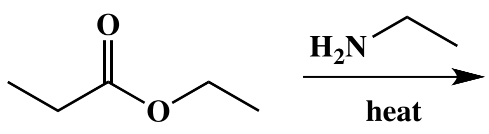
Write a balanced equation for the overall process described by mechanism 3 from page 10

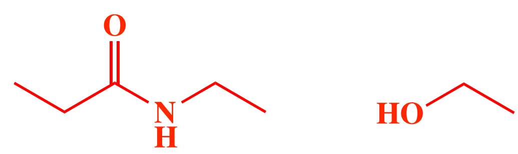


19. (17 pts) Complete the mechanism for the reduction of the following lactam. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the carbon containing products for each step.** Remember, I said all the carbon containing products for each 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. In the boxes provided, write which of the 4 mechanistic elements describes each step (make a bond, break a bond, etc.).**

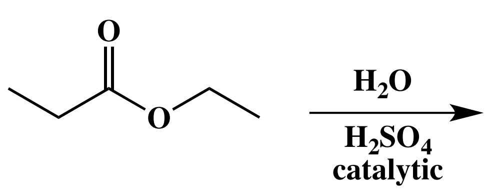


20. (3 or 5 pts.) Write the predominant **carbon containing** product or products that will occur for each transformation. **If there are two carbon containing products, WRITE THEM BOTH. If a new chiral center is created and a racemic mixture is formed, label the chiral center with an asterisk (*) and write racemic. No need for wedges and dashes. Also, do not worry about balancing these equations, you just need to show us the major carbon-containing products of these transformations.**

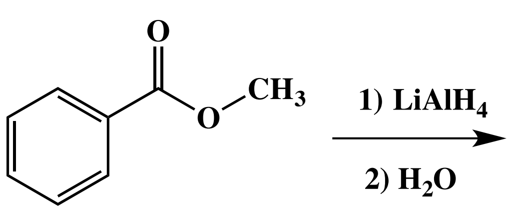


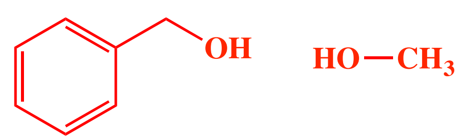


Draw all the organic products made from the ester starting material

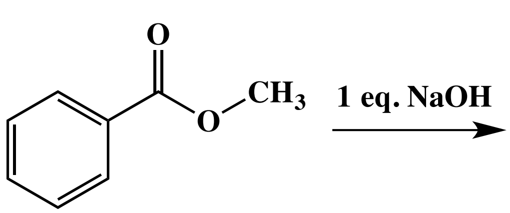


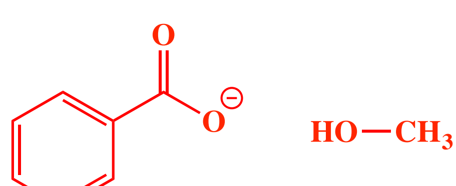
Draw all the organic products made from the ester starting material



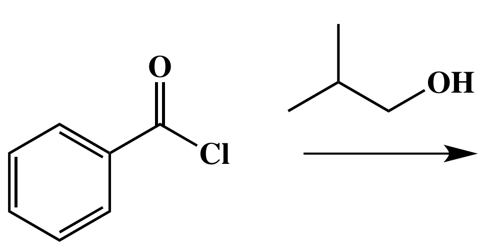


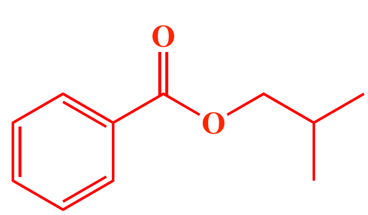
Draw all the organic products made from the ester starting material



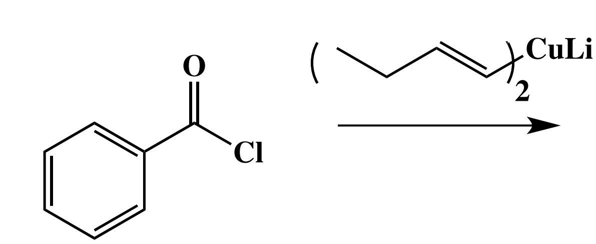


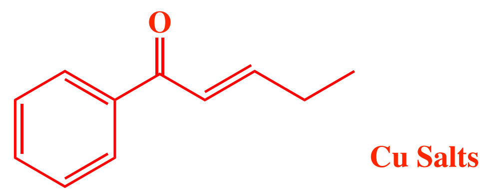
Draw all the organic products made from the ester starting material

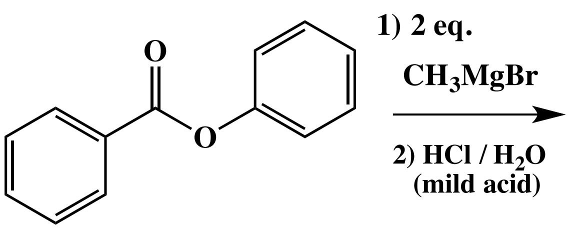


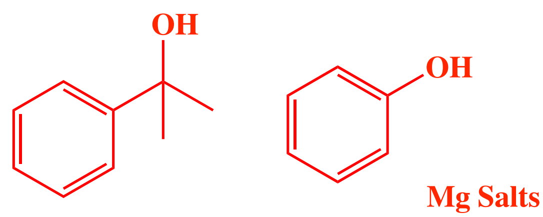


22. (3 or 5 pts.) Write the predominant **carbon containing** product or products that will occur for each transformation. **If there are two carbon containing products, WRITE THEM BOTH. If a new chiral center is created and a racemic mixture is formed, label the chiral center with an asterisk (*) and write racemic. No need for wedges and dashes. Also, do not worry about balancing these equations, you just need to show us the major organic products of these transformations.**

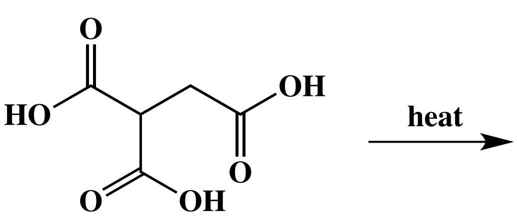


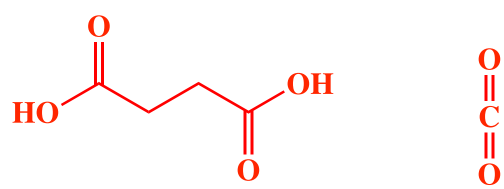




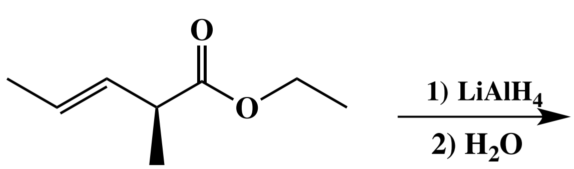


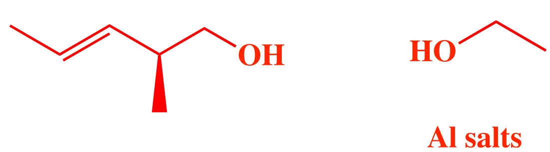
Draw all the carbon containing products made from the ester starting material



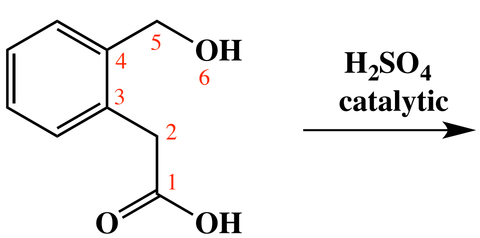


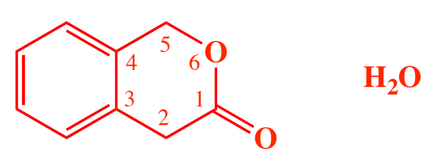
Draw all the carbon containing products made from the triacid starting material





Draw all the carbon containing products made from the ester starting material

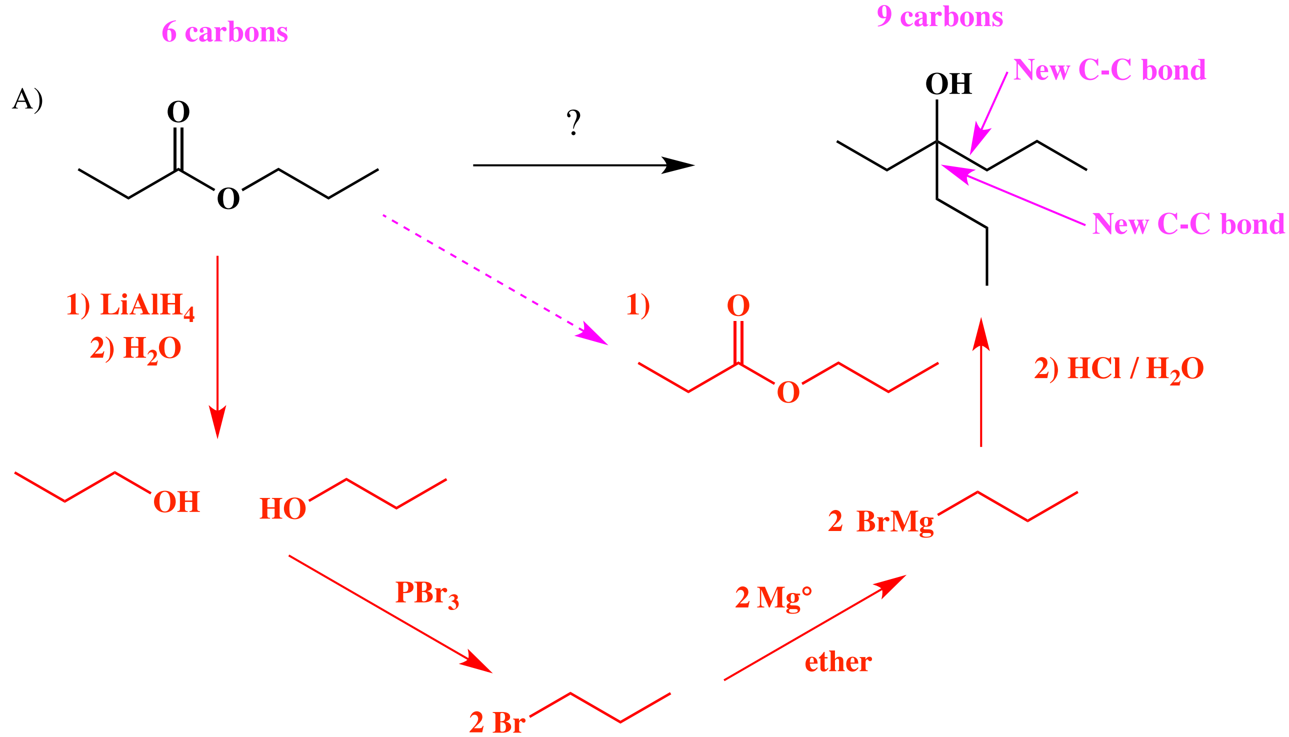




23. Using any reagents turn the starting material into the indicated product. All carbon atoms inthe product must come from the starting material. Draw all molecules synthesized along the way. When in doubt, draw the molecule! Label all chiral centers with an asterisk (*) and make sure to right "Racemic" where appropriate. Hint: this should look familiar as a homework problem.

Remember, all of the carbons of the product must come from the given starting material.
(10 pts)

A)



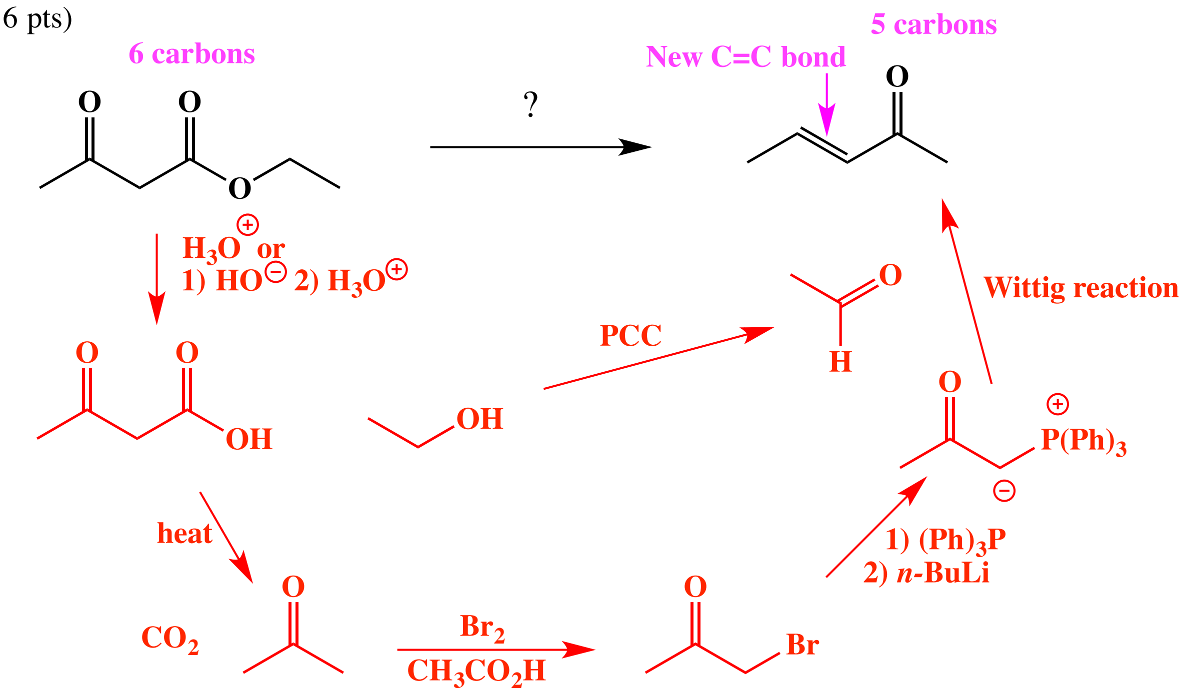
Recognize there are 9 carbons in the product, but 6 carbons in the starting material and that two new carbon-carbon bonds will need to be made. **Recognize** further the final product as a tertiary alcohol with two identical new groups attached, the KRE for an ester reacting with 2 equivalents of a Grignard. **Recognize** the ester used for this Grignard reaction is actually the ester starting material. **Recognize** the required alcohol as coming from 1-proponal (after a PBr_3 reaction), which can be easily derived via reduction of the starting ester with $LiAlH_4$. This answer is only one of several possible correct answers. Other approaches could include hydrolyzing the starting ester in acid or base to get the required 1-propanol. Other approaches include possible conversion of the ester into an acid chloride (after hydrolysis and reaction with $SOCl_2$) then reaction of this with a Gilman reagent made from 1-propanol. A final Grignard completes the synthesis.

23. You might want to save this until last. I consider it to be challenging. Using any reagents turn the starting material into the indicated product. All carbon atoms inthe product must come from the starting material. Draw all molecules synthesized along the way. When in doubt, draw the molecule! Label all chiral centers with an asterisk (*) and make sure to right "Racemic" where appropriate. Hint: this should look familiar as a homework problem.

Remember, all of the carbons of the product must come from the given starting material.

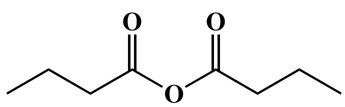
(16 pts)

B)

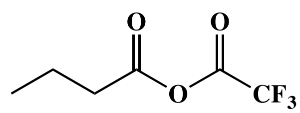


Recognize This is a challenge! The starting material has 6 carbons but the product has 5 carbons. The odd number of carbons means you probably have to lose one, and the best way you know to do that is through a decarboxylation of a β-keto acid. **Recognize** further that the product is an E alkene, with the new C=C bond adjacent to a carbonyl, the KRE of a Wittig reaction between a Wittig reagent with a carbonyl adjacent to the negatively charged atom and acetaldehyde. The required acetaldehyde can come from PCC oxidation of ethanol, easily derived from hydrolyzing the ester starting material in acid or base. **Recognize** the Wittig reagent can be derived from bromoacetone, which can be made from halogenation in acid of acetone. Perhaps the most difficult part of this synthesis is **recognizing** that acetone can be made from decarboxylating the same β-keto acid made from hydrolyzing the starting ester.

24. Here is an MCAT style "Passage" question. Read the passage then answer the multiple choice questions. The anhydrides you have seen thus far are symmetrical, meaning both halves are derived from the same carboxylic acid. It is possible to make unsymmetrical anhydrides. They are produced by reacting acid chlorides derived from one carboxylic acid with the carboxylate of a different carboxylic acid.

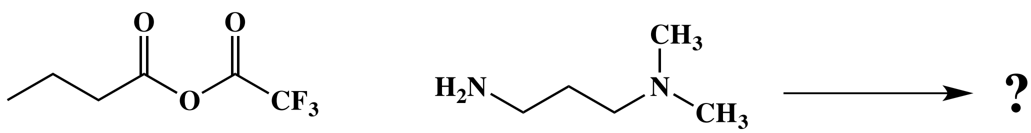


Symmetrical anhydride



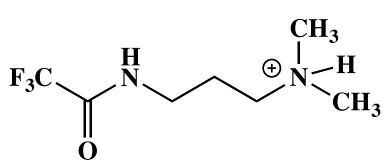
Unsymmetrical anhydride

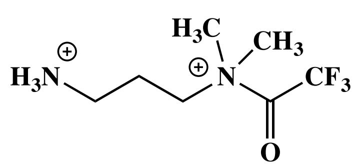
Unsymmetrical anhydrides react with nucleophiles according to mechanism B. Based on what you know about reactivity, predict the product of the following reaction of an unsymmetrical anhydride with a diamine.

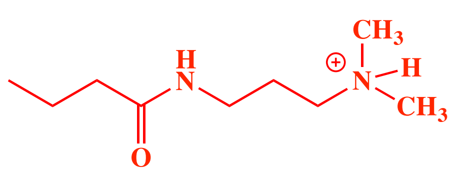


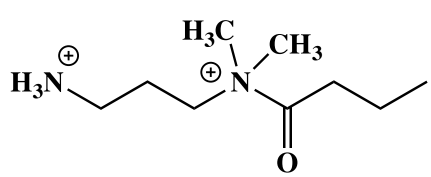
Unsymmetrical anhydride ***N,N*-dimethylpropane-1,3-diamine**

Question 1 (4 pts) Circle the predominant product of the above reaction:

A) 

B) 

C) 

D) 

Question 2 (6 pts) For the following question, you can only circle ONE answer. Let us consider the answer you chose for the first part (Question 1) of this problem. Select which of the following arguments supported your selection of the major reaction product you chose.

A) The three fluorine atoms stabilize an anion via the inductive effect so $CF_3CO_2^{\ominus}$ is the better leaving group.

B) The three fluorine atoms destabilize an anion via the inductive effect so $CH_3CH_2CH_2CO_2^{\ominus}$ is the better leaving group.

C) The primary amine is the better nucleophile because there is less steric hindrance and the product amide is neutral.

D) The tertiary amine is the better nucleophile because there is more steric hindrance and product amide has a positive charge.

E) Both A) and C)

F) Both B) and D)

Question 3 (4 pts) Think through the reaction mechanism. Select the MINIMUM number of equivalents of the *N*,*N*-dimethylpropane-1,3-diamine you would need to complete the reaction if we assume 1.0 equivalent of unsymmetrical anhydride is used as starting material.

A) 1.0 Equivalent

B) 2.0 Equivalents

C) 3.0 Equivalents

D) 4.0 Equivalents