

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

Chemistry 320N  
Final Exam  
May 3, 2024

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 during your organic chemistry journey. 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!!!**

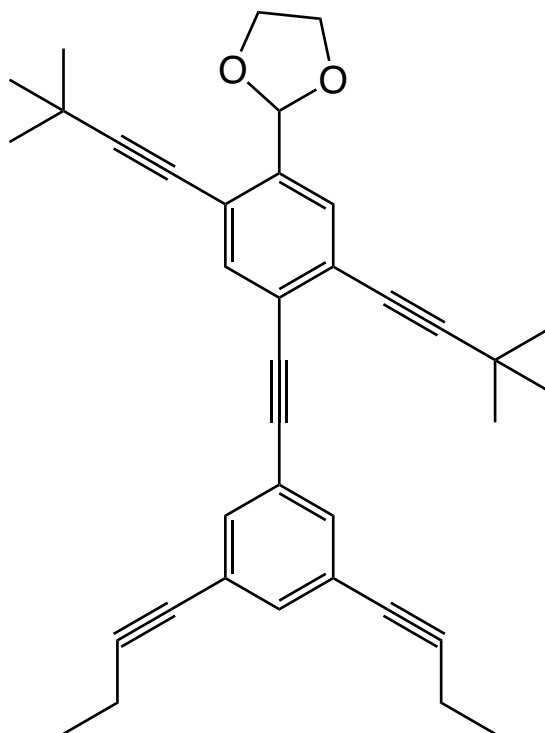


Compound		pK <sub>a</sub>
Hydrochloric acid	$\text{H-Cl}$	-7
Protonated alcohol	$\text{RCH}_2\text{OH}_2^+$	-2
Hydronium ion	$\text{H}_3\text{O}^+$	-1.7
Carboxylic acids	$\text{R}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$	3-5
Thiols	$\text{RCH}_2\text{SH}$	8-9
Ammonium ion	$\text{H}_4\text{N}^+$	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	$\text{ROC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{COR}'$	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	$\text{RCH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{CR}'$	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

## Golden Rules of Chemistry for your reference

**A. Predicting Structure and Bonding** 1. In most stable molecules, all the atoms will have filled valence shells. 2. Five- and six-membered rings are the most stable. 3. There are two possible arrangements of four different groups around a tetrahedral atom.

**B. Predicting Stability and Properties** 4. The most important question in organic chemistry is "Where are the electrons?" 5. Delocalization of charge over a larger area is stabilizing. 6. Delocalization of unpaired electron density over a larger area is stabilizing. 7. Delocalization of pi electron density over a larger area is stabilizing. **C. Predicting Reactions** 8. Reactions will occur if the products are more stable than the reactants and the energy barrier is low enough. 9. Functional groups react the same in different molecules. 10. A reaction mechanism describes the sequence of steps occurring during a reaction. 11. Most bond-making steps in reaction mechanisms involve nucleophiles reacting with electrophiles.



Hello everyone, my name is 2-(4-((3,5-di(but-1-yn-1-yl)phenyl)ethynyl)-2,5-bis(3,3-dimethylbut-1-yn-1-yl)phenyl)-1,3-dioxolane. I understand that your class absolutely crushed the 3.1 mile challenge so that there is no nomenclature on this final exam. That is awesome and I hope you noticed how exercise resets your brain chemistry for better mental health while providing a path toward better overall health and fitness!

We are here at the end of your OChem experience. ***I have been honored to be on this journey of learning and discovery with you.*** You started by learning about molecular structure and bonding in OChem 1 and now you can carry out sophisticated syntheses to make complex molecules from simpler ones. That technology, the ability to make and break specific chemical bonds, has created what we know as modern life. And now you understand how it works. But that is not all. You also have a solid foundation for understanding the structure and reactivity of the very molecules that are responsible for life on this planet.

And if you have gone through my previous finals you have seen this poem before, but I want you to read this on your own final exam. This is to you, my sincere wish, taken from the words of one of the great poets of the 20<sup>th</sup> Century, Bob Dylan.

*Here is my original first verse, written specifically for each of you:*

***“Every chance you get,  
You should go out for a run,  
That is the very best way  
For you to stay forever young.”***

*“May your wishes all come true  
May you always do for others  
And let others do for you  
May you build a ladder to the stars  
And climb on every rung  
May you stay forever young*

*May you always know the truth  
And see the light surrounding you  
May you always be courageous  
Stand upright and be strong  
May you stay forever young*

*May your hands always be busy  
May your feet always be swift  
May you have a strong foundation  
When the winds of changes shift  
May your heart always be joyful  
May your song always be sung  
And may you stay forever young”*

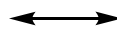
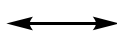
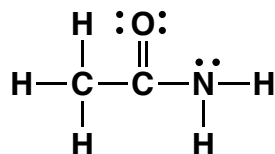
*Use this for scratch paper*

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

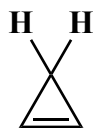
2. (1 pt each) Fill in each blank with the word that best completes the sentences. Yep, this is the MRI paragraph!

The popular medical 1. \_\_\_\_\_ technique of 2. \_\_\_\_\_  
 3. \_\_\_\_\_ imaging (MRI) is based on the same principles as  
 4. \_\_\_\_\_, namely the 5. \_\_\_\_\_ (i.e. 6. \_\_\_\_\_ )  
 of nuclear 7. \_\_\_\_\_ of H atoms by radio 8. \_\_\_\_\_  
 irradiation when a patient is placed in a strong 9. \_\_\_\_\_ field. Magnetic field  
 10. \_\_\_\_\_ are used to gain imaging information, and rotation of the  
 11. \_\_\_\_\_ 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 12. \_\_\_\_\_  
 that when stacked make up the three-dimensional image of 13. \_\_\_\_\_ amounts  
 of 14. \_\_\_\_\_ atoms, especially the 15. \_\_\_\_\_ atoms from  
 16. \_\_\_\_\_ and 17. \_\_\_\_\_, in the different tissues.

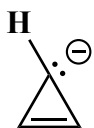
3. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided. You do **not** have to put arrows on any of the structures.



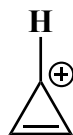
4. (1 pts each). Each of the following structures is either aromatic, not aromatic, or anti-aromatic. Fill in the circle that best describes each of the following structures. Note that on the following structures, some H atoms are drawn for the sake of clarity, while others are assumed to be present but are not drawn.



- Aromatic  
 Not aromatic  
 Anti-aromatic



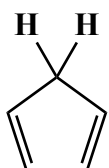
- Aromatic  
 Not aromatic  
 Anti-aromatic



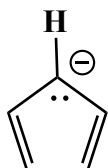
- Aromatic  
 Not aromatic  
 Anti-aromatic



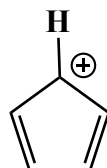
- Aromatic  
 Not aromatic  
 Anti-aromatic



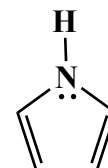
- Aromatic  
 Not aromatic  
 Anti-aromatic



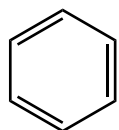
- Aromatic  
 Not aromatic  
 Anti-aromatic



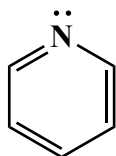
- Aromatic  
 Not aromatic  
 Anti-aromatic



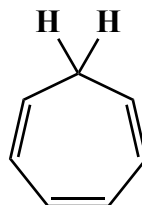
- Aromatic  
 Not aromatic  
 Anti-aromatic



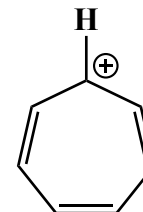
- Aromatic  
 Not aromatic  
 Anti-aromatic



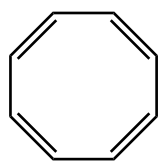
- Aromatic  
 Not aromatic  
 Anti-aromatic



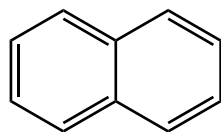
- Aromatic  
 Not aromatic  
 Anti-aromatic



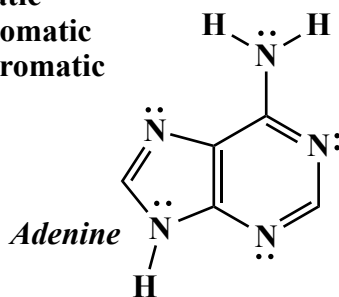
- Aromatic  
 Not aromatic  
 Anti-aromatic



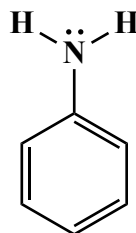
- Aromatic  
 Not aromatic  
 Anti-aromatic



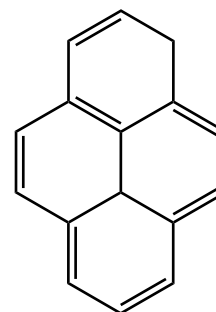
- Aromatic  
 Not aromatic  
 Anti-aromatic



- Aromatic  
 Not aromatic  
 Anti-aromatic



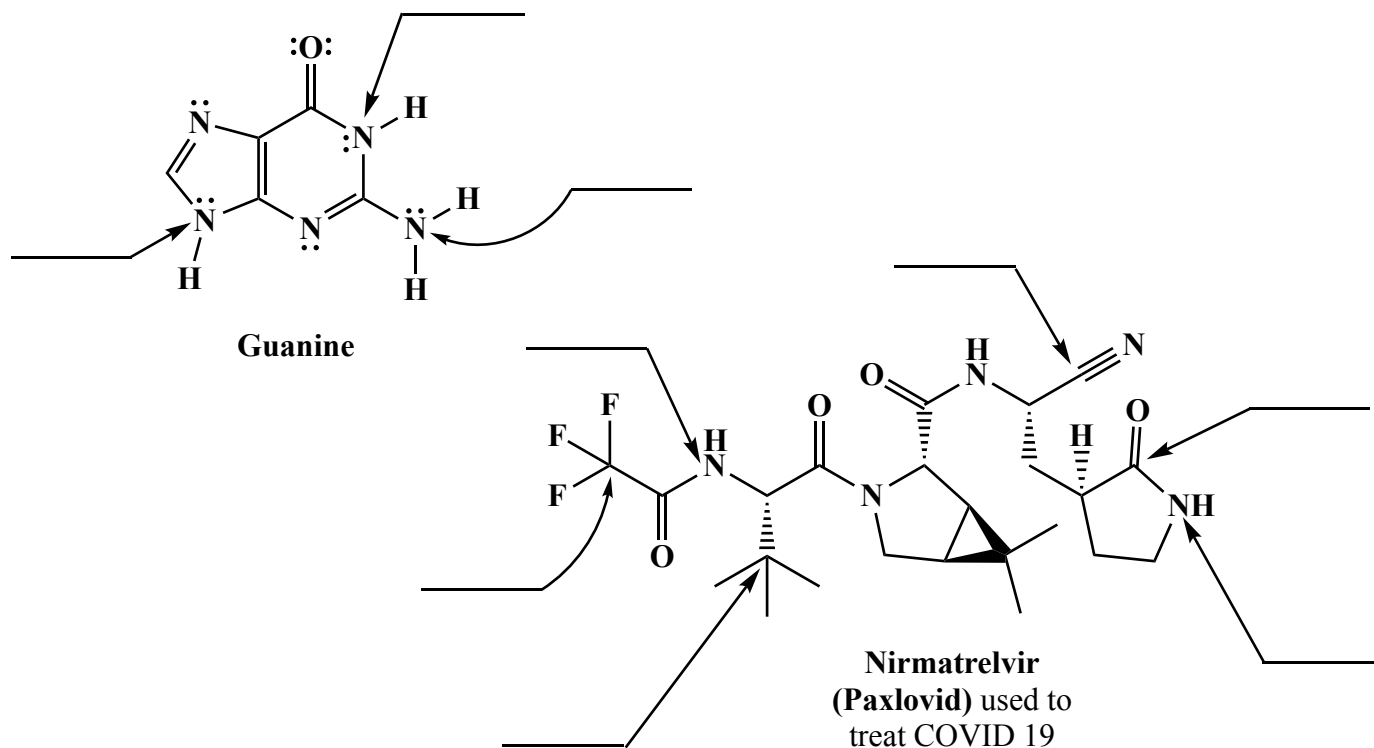
- Aromatic  
 Not aromatic  
 Anti-aromatic



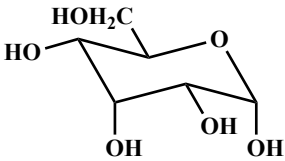
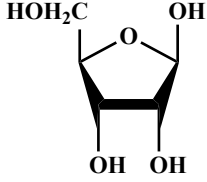
- Aromatic  
 Not aromatic  
 Anti-aromatic



5. (2 pts each) For each arrow, on the line provided write the hybridization state of the atom indicated. Appropriate answers might be  $sp$ ,  $sp^2$ , or  $sp^3$ .



6. (2 pts each) For each set of molecules, fill in the circles that correctly describe the situation.

<p><b>A)</b></p> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CHO} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_2\text{OH} \end{array}</math> <p>D-Glyceraldehyde</p> </div> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CHO} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_2\text{OH} \end{array}</math> </div> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CHO} \\   \\ \text{HO} - \text{C} - \text{H} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_2\text{OH} \end{array}</math> </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <input type="radio"/> D-Carbohydrate  <input type="radio"/> Not a D-Carbohydrate         </div> <div style="text-align: center;"> <input type="radio"/> D-Carbohydrate  <input type="radio"/> Not a D-Carbohydrate         </div> </div>	<p><b>B)</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CHO} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{H} - \text{C} - \text{OH} \\   \\ \text{CH}_2\text{OH} \end{array}</math> </div> <div style="text-align: center;"> <math display="block">\begin{array}{c} \text{CHO} \\   \\ \text{HO} - \text{C} - \text{H} \\   \\ \text{HO} - \text{C} - \text{H} \\   \\ \text{HO} - \text{C} - \text{H} \\   \\ \text{CH}_2\text{OH} \end{array}</math> </div> </div> <div style="text-align: center; margin-top: 10px;"> <input type="radio"/> Enantiomers  <input type="radio"/> Diastereomers         </div>	<p><b>C)</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <input type="radio"/> Furanose  <input type="radio"/> Pyranose         </div> <div style="text-align: center;"> <input type="radio"/> Furanose  <input type="radio"/> Pyranose         </div> </div>
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7. (2 pts each) For each set of molecules, fill in the circle corresponding to the answer that correctly describes the situation.

**A.**

$\oplus$   
 The  $pK_a$  of  $R-NH_3$  is about 10  
 The  $pK_a$  of  $R-CO_2H$  is about 3.5  
 The  $pK_a$  of  $R-CH_2OH$  is about 16

This is correct for pH 2.0   
  This is correct for pH 2.0   
  This is correct for pH 2.0   
  This is correct for pH 2.0  
 This is correct for pH 7.0   
  This is correct for pH 7.0   
  This is correct for pH 7.0   
  This is correct for pH 7.0  
 This is correct for pH 10.0   
  This is correct for pH 10.0   
  This is correct for pH 12.0   
  This is correct for pH 10.0  
 This is never correct   
  This is never correct   
  This is never correct   
  This is never correct

**B.**

Can be used as a base   
  Can be used as a base  
 Not a base   
  Not a base

**C.**

Lower  $pK_a$    
  Lower  $pK_a$   
 Higher  $pK_a$    
  Higher  $pK_a$

**D.**

Can be an electrophile in a Michael reaction   
  Can be an electrophile in a Michael reaction  
 Can be a nucleophile in a Michael reaction   
  Can be a nucleophile in a Michael reaction

**E.**

A conjugated diene   
  A conjugated diene  
 Not a conjugated diene   
  Not a conjugated diene

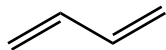
**F.**

Can make an enolate   
  Can make an enolate  
 Cannot make an enolate   
  Cannot make an enolate

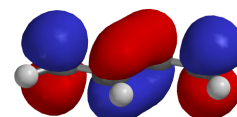
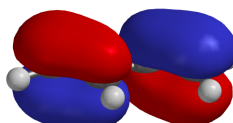
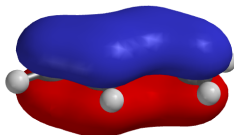
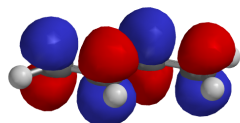
**G.**

Reactive conformation in a decarboxylation reaction   
  Reactive conformation in a decarboxylation reaction  
 Not a reactive conformation in a decarboxylation reaction   
  Not a reactive conformation in a decarboxylation reaction

8. (16 pts) Yep, this exact problem was on the 3rd midterm except this time we shuffled the locations of the different orbitals. We wanted to give you the opportunity to improve how you did on this! The following are the pi molecular orbitals for 1,3-butadiene. Under each one place a number corresponding to energy, with a "1" under the lowest energy (most stable) molecular orbital, a "4" under the highest energy (least stable) molecular orbital and a "2" and a "3" as appropriate.



1,3-Butadiene



\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

B) On the lines below, write "bonding" or "antibonding" as appropriate to describe the orbitals above:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

C) On the lines below, write how many electrons are in each orbital BEFORE a photon is absorbed:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

D) On the lines below, write how many electrons are in each orbital immediately AFTER a photon is absorbed (before the energy is lost as heat):

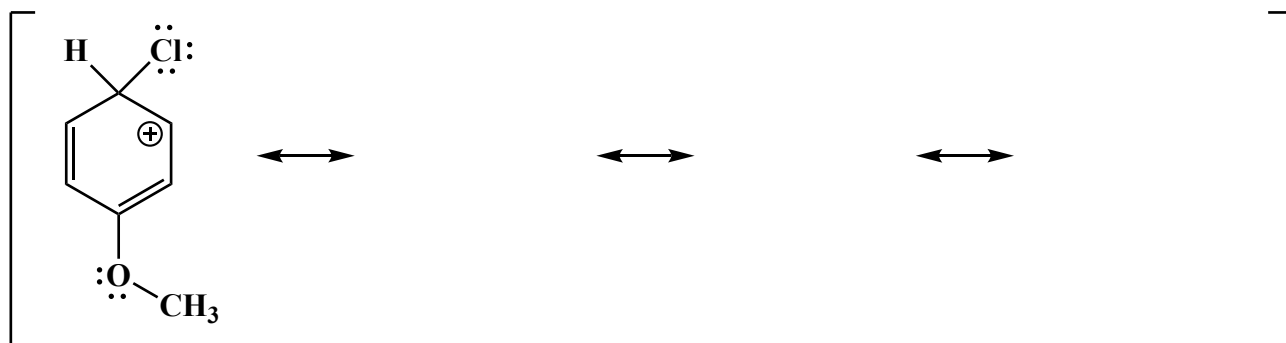
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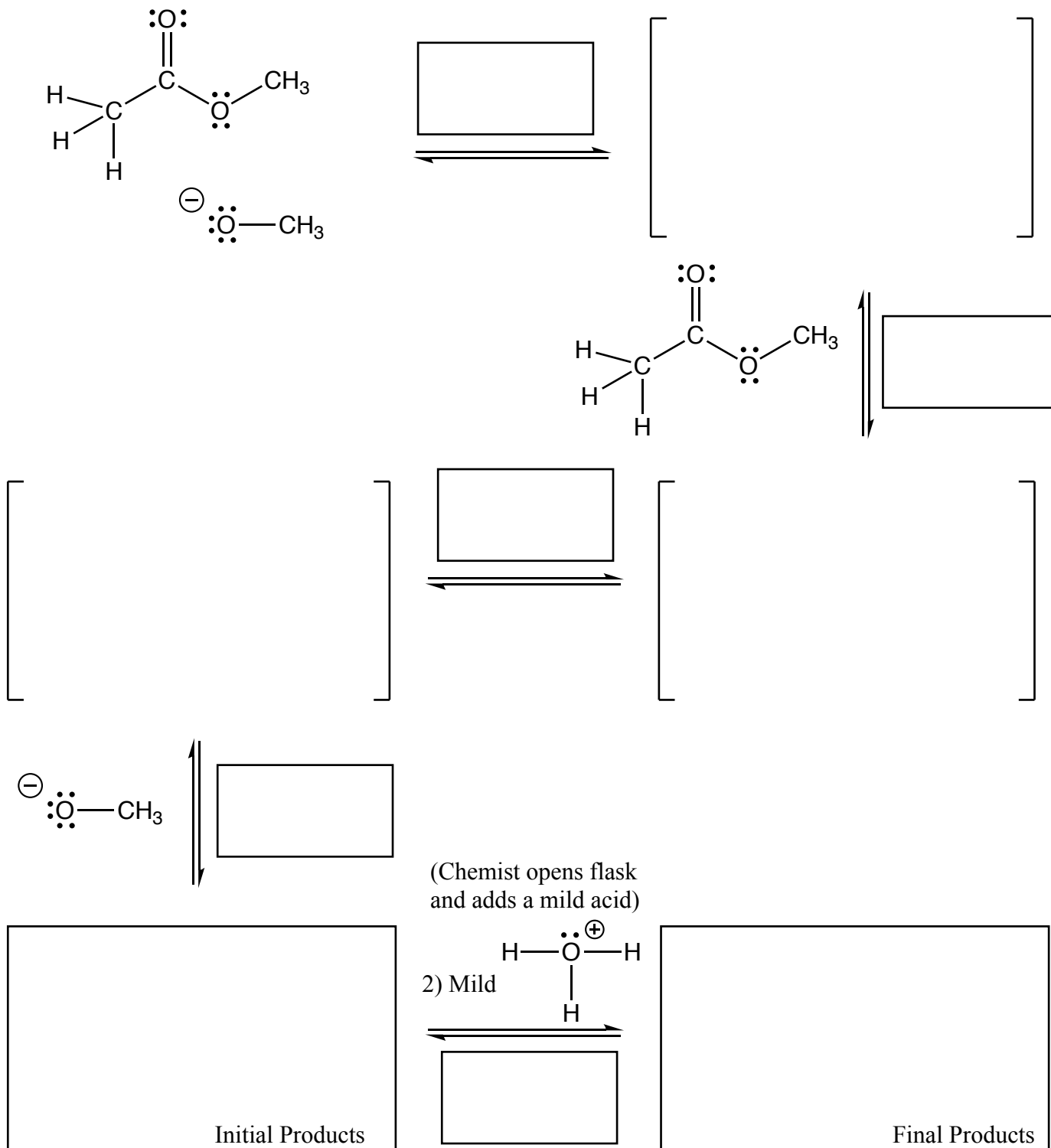
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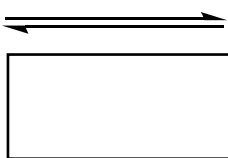
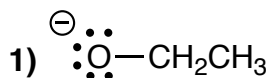
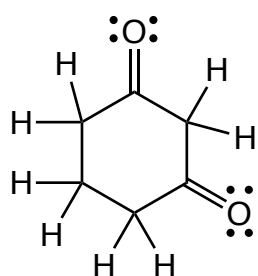
9. (9 pts) Draw all three of the other important contributing structures of the following arenium ion intermediate. Make sure to draw all lone pairs and formal charges. You do **not** have to put arrows on any of the structures.



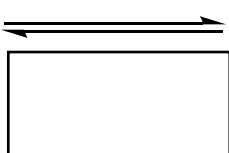
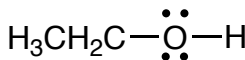
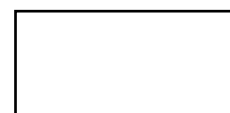
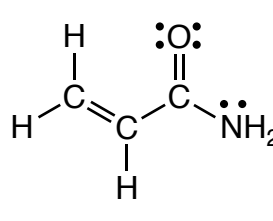
10. (30 pts) Complete the mechanism for the following Claisen reaction. **Be sure to show arrows to indicate movement of all electrons, write all lone pairs, all formal charges, and all the products for each step.** Remember, I said all the products for each step. **IF A NEW CHIRAL CENTER IS CREATED 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.).



11. (26 pts) Complete the mechanism for the following Michael reaction. **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. **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.).

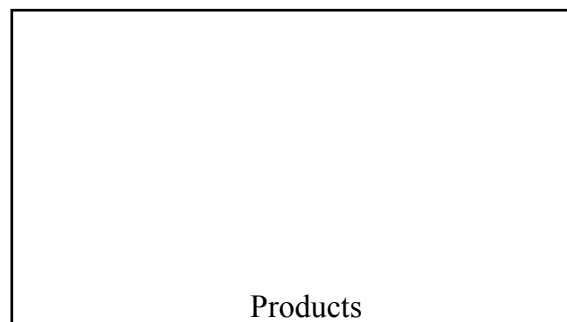
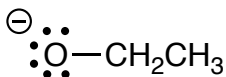


2)

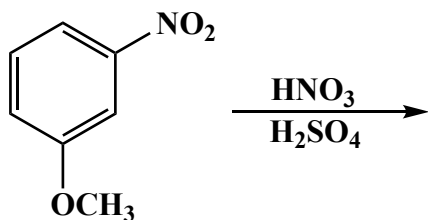
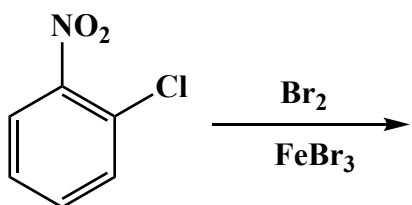
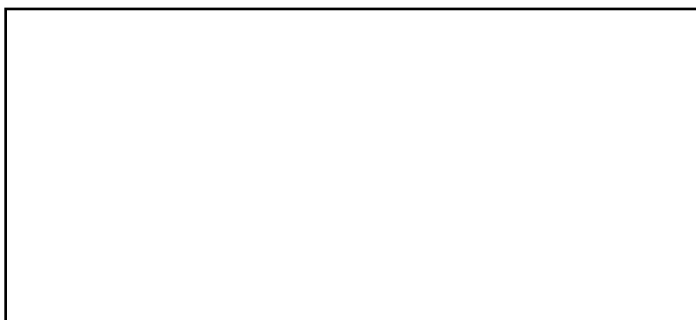
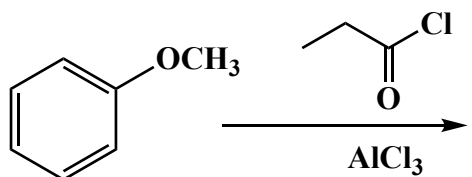
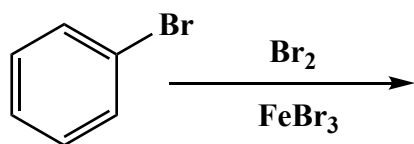
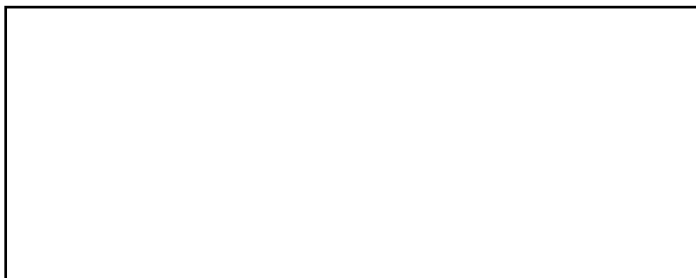
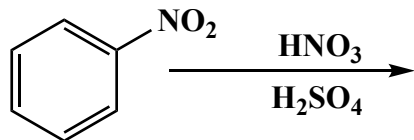


(No need to draw arrows on this structure)

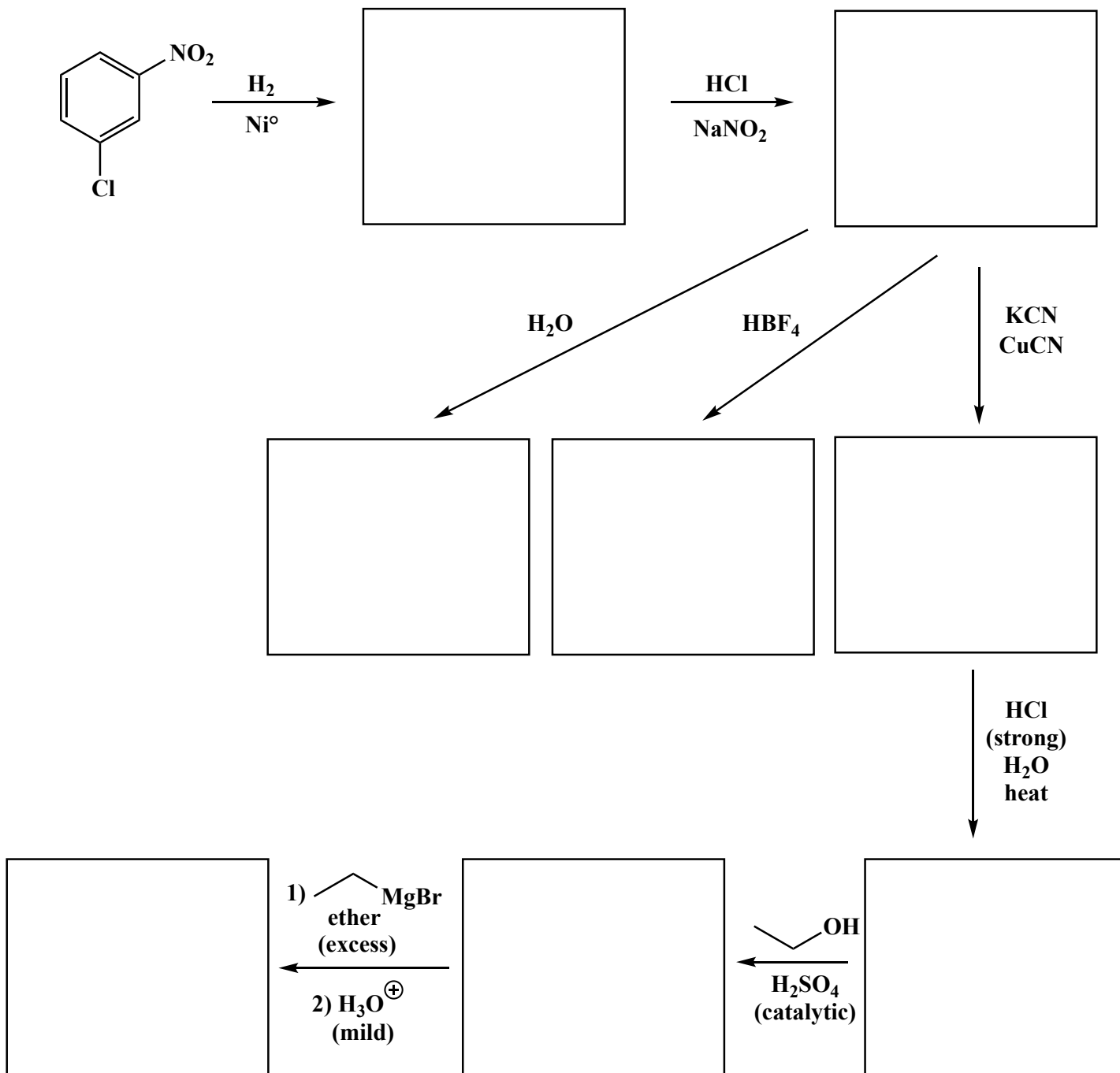
Tautomerization



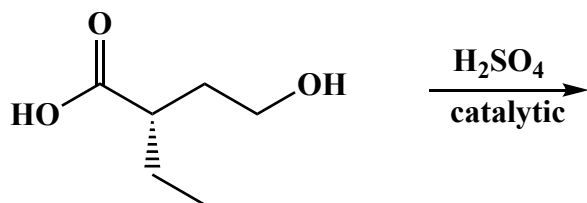
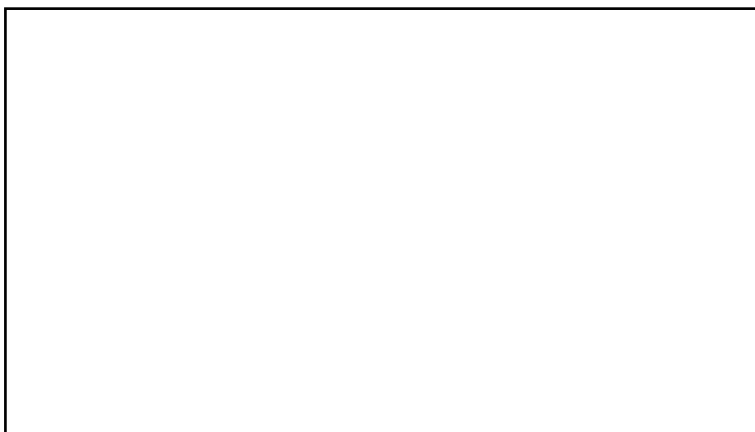
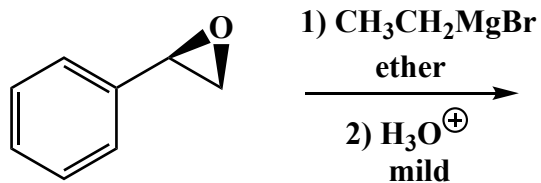
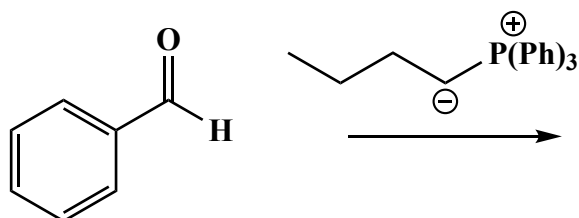
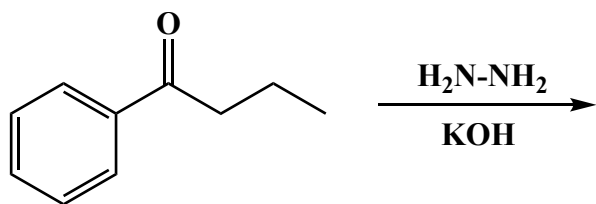
12. (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\dashv$  ) to indicate stereochemistry. For these, you do not have to worry about metal salts in the products. **For all aldol reactions, we only want you to draw the dehydrated products.**



**12 (cont.).** (3 or 5 pts.) Write the predominant 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 (  $\cdots\cdots\cdots$  ) to indicate stereochemistry. For these, you do not have to worry about metal salts in the products. **For all aldol reactions, we only want you to draw the dehydrated products.**

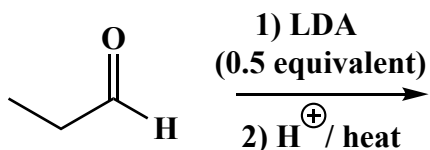
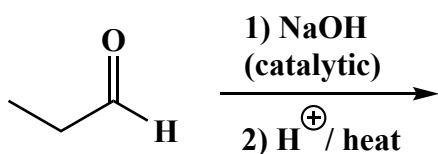
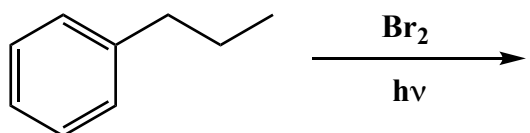
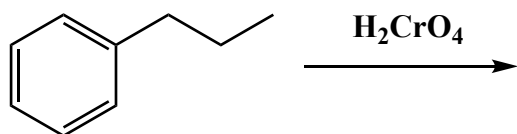


**12 cont.** (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. For these, you do not have to worry about metal salts in the products. **For all aldol reactions, we only want you to draw the dehydrated products.**

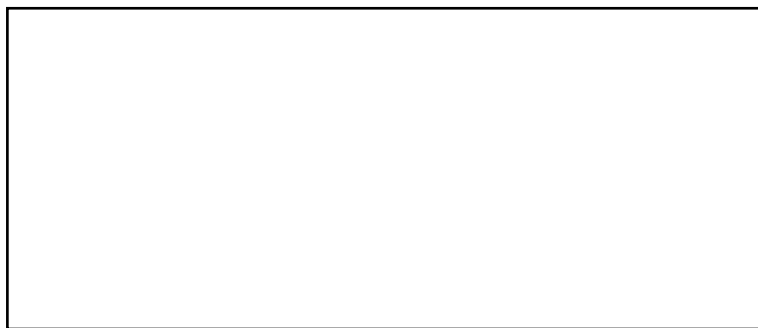
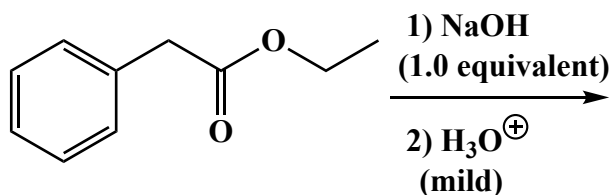
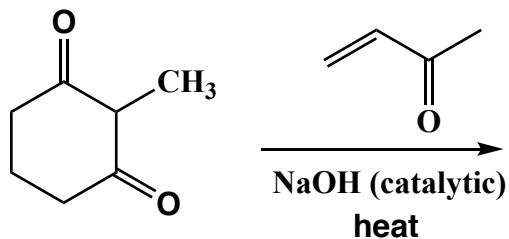
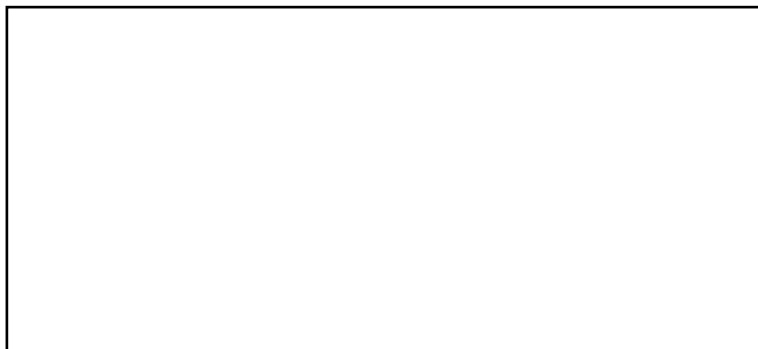
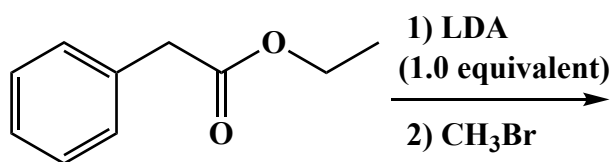
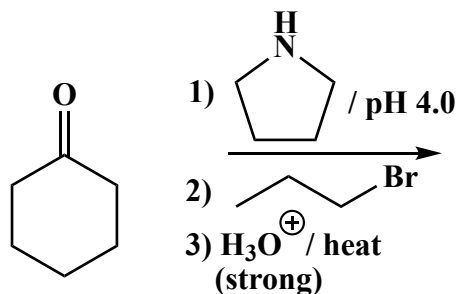




**12 cont.** (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\cdots$  ) to indicate stereochemistry. For these, you do not have to worry about metal salts in the products. **For all aldol reactions, we only want you to draw the dehydrated products.**

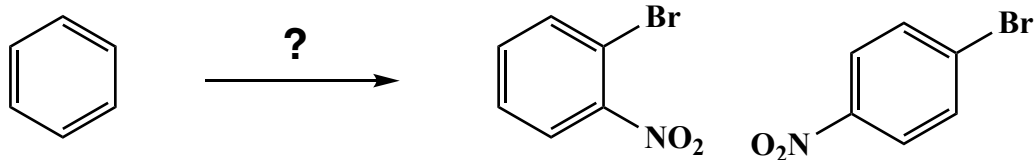


**12 cont.** (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (  $\blacktriangleleft$  ) and dashes (  $\dashv$  ) to indicate stereochemistry. For these, you do not have to worry about metal salts in the products. **For all aldol reactions, we only want you to draw the dehydrated products.**



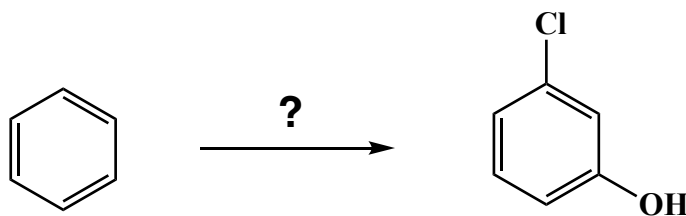
13. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized 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.**

A) (4 pts)



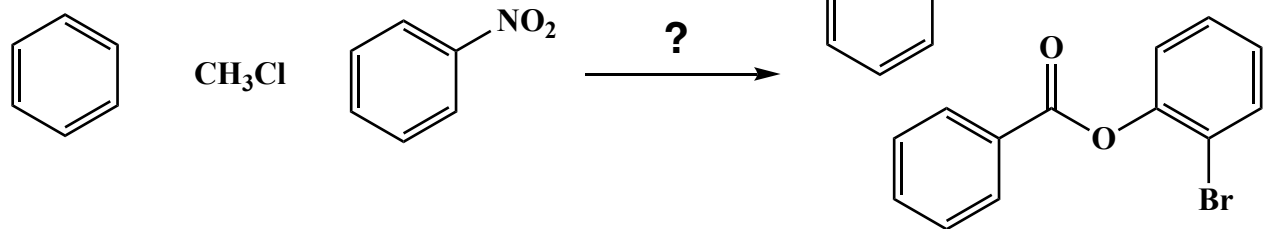
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B) (13 pts)



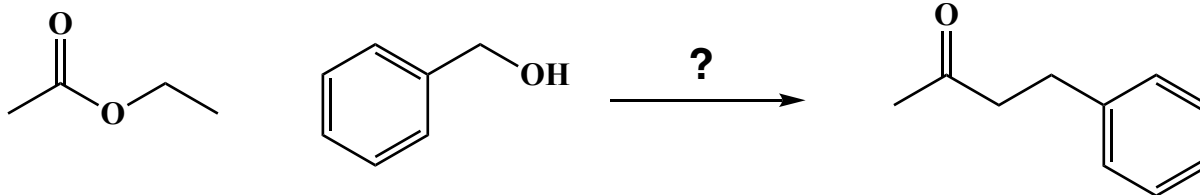
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C) (21 pts)



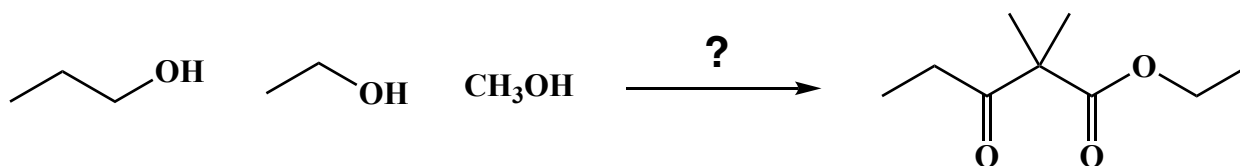
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D) (10 pts)

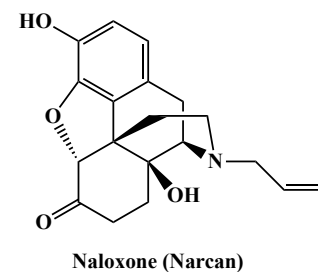
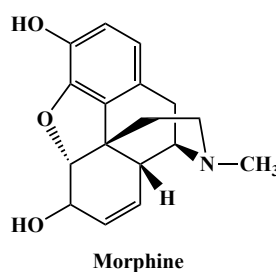
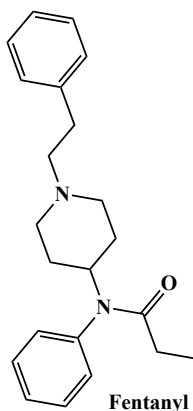


13. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized 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.**

E) (16 pts)



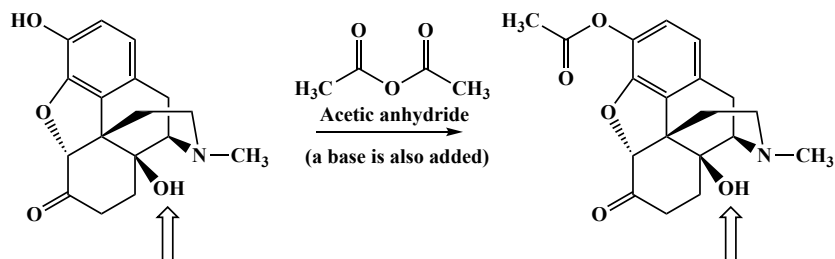
14. (8 pts) Here is an “apply what you know” problem with an important message. Monday, April 29<sup>th</sup>, 2024, KXAN News reported 30 overdoses in Austin, resulting in 4 deaths. The individuals who survived were saved by the use of Naloxone, also known as Narcan. The fentanyl opioid crisis is far deadlier than any other substance abuse problem we have ever faced because fentanyl is too easy to make and too potent. Two milligrams is the difference between life and death for people using fentanyl. The other difference is that fentanyl is being sold to young people as Xanax and other legitimate medications used to treat anxiety, complete with very realistic looking pills intended to look like authentic Xanax. **There is no such thing as black market authentic Xanax**, it is all some binding substance laced with a small amount of fentanyl. Too many doses will take unsuspecting consumers into full opioid addiction, leading to catastrophic personal consequences. And one dealer accidentally adding 0.5 mg too much to each pill could kill everyone taking them, unless someone nearby has Narcan, the spray bottle form of Naloxone. Two squirts of Narcan in each nostril will save the life of an unconscious person who had taken a fatal overdose of fentanyl. The reason this works is that Naloxone is an extremely potent derivative of morphine that binds very tightly to the same opioid receptor as morphine, heroin and fentanyl. Unlike the three opioids, Naloxone does **not** activate the receptor, it just binds and blocks morphine, heroin or fentanyl from binding and causing receptor activation. Naloxone is referred to as an *antagonist*, while morphine, heroin and fentanyl are *agonists*.



**Recall that a key principle behind organic chemistry is that functional groups react the same in complex molecules as they do in simpler ones.**

Naloxone is relatively inexpensive because it is made in few steps from morphine or other natural derivatives, an approach called “semi-synthesis”. You have not seen all of the steps involved in synthesizing Naloxone from morphine, but you have seen a couple of them.

1. An early step in the conversion of morphine to Naloxone involves making an ester on the OH group attached to the aromatic ring using acetic anhydride.

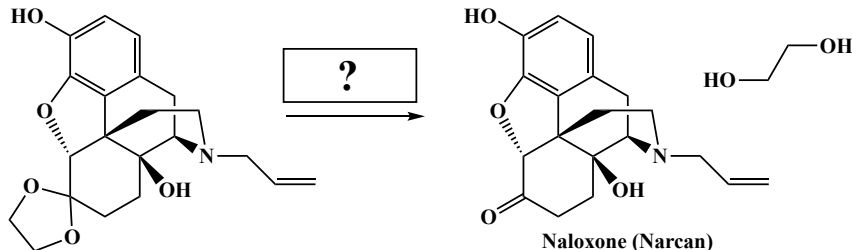


An interesting feature of this reaction is that only one of the two OH groups on the starting molecule reacts. The OH group indicated by the arrow does **not** react even though an excess of acetic anhydride is used. **Select the single answer that best explains why the OH group indicated by the arrow does not react with acetic anhydride in this reaction:**

- The tertiary alcohol (the OH indicated by the arrow) has too much steric hindrance around it.
- The aromatic OH group (the one that reacts) is just a better electrophile.
- The aromatic OH group (the one that reacts) has more steric hindrance around it.
- The N atom nearby makes the tertiary alcohol (the OH indicated by the arrow) too much of an electrophile.



2. In one published synthesis of Naloxone (Adv Synth. Catal. **2013**, 355, 1869 – 1973), this is the very last step:



Select from the following reaction conditions and indicate the one set of conditions that is the most appropriate for this step:

- 1) NaBH<sub>4</sub>, 2) H<sub>2</sub>O
- H<sub>2</sub>CrO<sub>4</sub>
- H<sub>2</sub>O (excess) HCl (catalytic) heat
- CH<sub>3</sub>OH (excess) HCl (catalytic) heat

Remember, you can get a dose of Narcan at the PCL circulation desk. It is free of charge and no questions will be asked. Please do this. **You could save a life.** A former student in the class took my advice and saved their brother's life because when it was needed, they happened to have the very same dose of Narcan I had told them how to obtain from PCL.