

NAME (Print): _____

Chemistry 320N

Final Exam

May 1, 2023

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 _a
Hydrochloric acid	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	RCH_2SH	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	HOH	15.7
Alcohols	RCH_2OH	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

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.

We have all been through a lot these past three years. But here we are, your final exam for second semester We have all been through a lot these past three years. But here we are, your final exam for second semester OChem. You have proven you are resilient and strong. I have really enjoyed getting to know all of you this past semester, and for many of you, the past two semesters. I no longer take for granted that we can be together in person, but we have been all year and I enjoyed every minute! 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. Here is my sincere wish for each of you, taken from the words of one of the great poets of the 20th Century, Bob Dylan.

*“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”*

And here are my own extra lines:

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

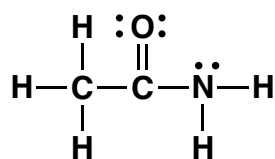
Use this for scratch paper but do not detach this page from your exam,

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

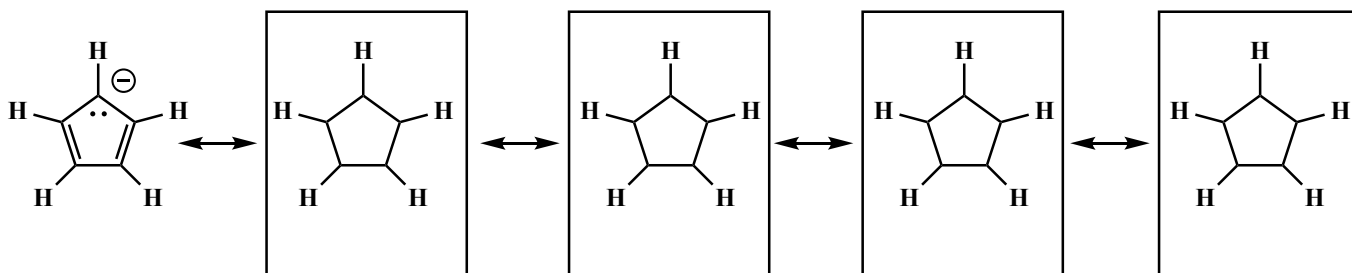
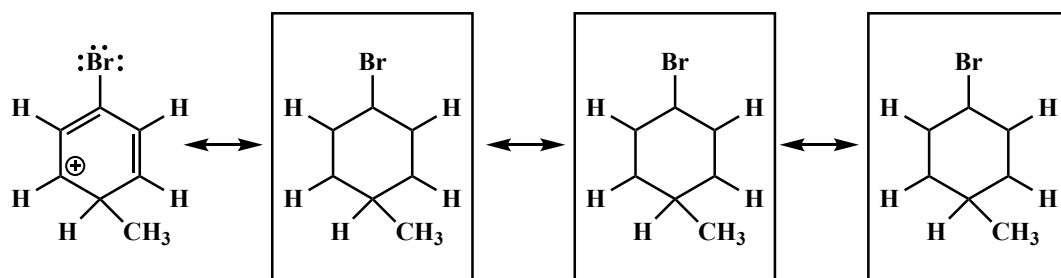
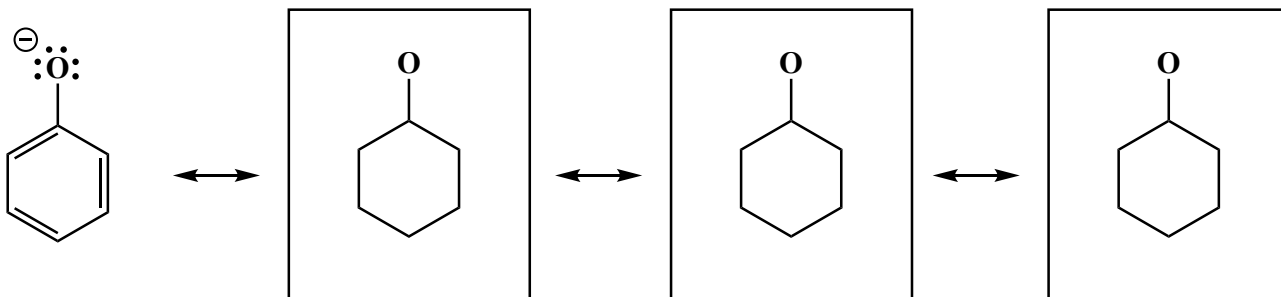
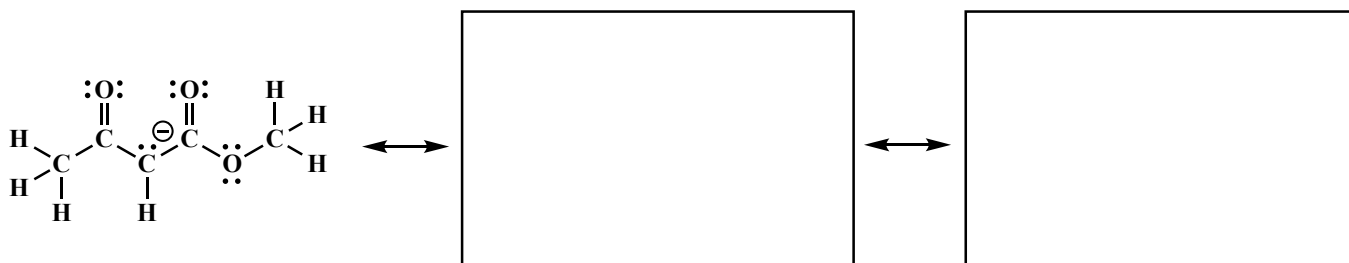
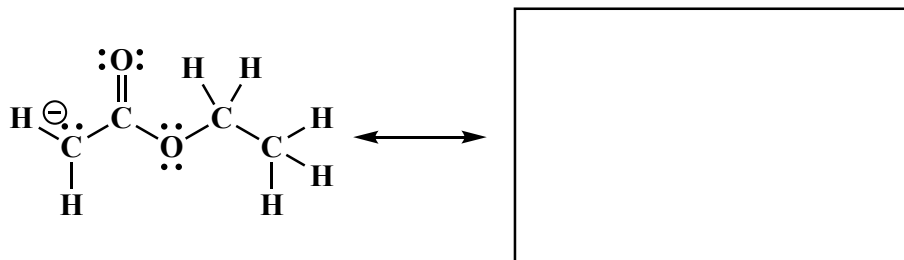
2. (1 pt each) Fill in each blank with the word that best completes the sentences. Yep, this is the MRI paragraph!

The popular 1. _____ diagnostic technique of magnetic 2. _____
 3. _____ (MRI) is based on the same principles as
 4. _____, namely the 5. _____ (i.e. 6. _____)
 of 7. _____ spins of 8. _____ atoms by 9. _____
 frequency 10. _____ when a patient is placed in a strong magnetic
 11. _____. Magnetic 12. _____ gradients
 are used to gain 13. _____ information, and 14. _____
 of the 15. _____ 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 16. _____
 that when stacked make up the three-dimensional image of relative amounts
 of H atoms, especially the H atoms from 17. _____ and 18. _____, in
 the different tissues.

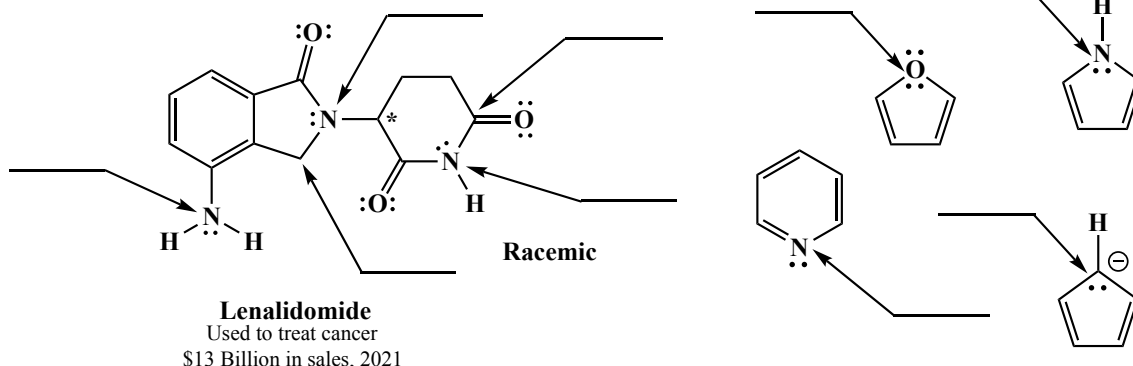
3. (10 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided.



4. (2 pts each) Throughout the past two semesters, resonance contributing structures help you understand a variety of situations in which electron density and charges are delocalized. For the following molecules, draw the indicated number of important contributing structures. Make sure to indicate all lone pairs and formal charges. There is no need to draw arrows on any structures here. We added some ring templates at the bottom to save you time. **Remember to write all lone pairs!**



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.

A)

$$\begin{array}{c} \text{CHO} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

D-Glyceraldehyde

$$\begin{array}{c} \text{CHO} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

D-Carbohydrate D-Carbohydrate
 Not a D-Carbohydrate Not a D-Carbohydrate

B)

β -1,3-Glycosidic Bond
 β -1,4-Glycosidic Bond
 α -1,3-Glycosidic Bond
 α -1,4-Glycosidic Bond

C)

Furanose
 Pyranose

Furanose
 Pyranose

D)

Cellulose
 Starch

E)

Cellulose
 Starch

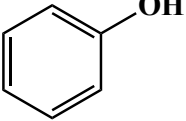
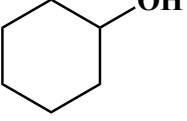
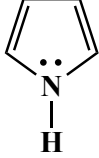
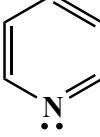

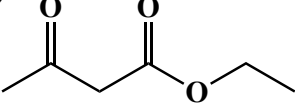
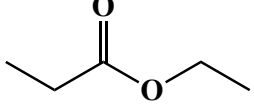
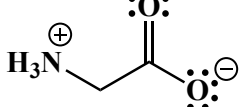
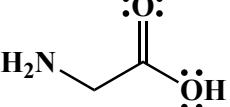
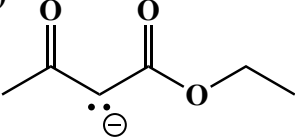
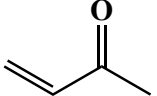
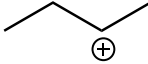
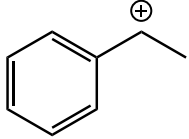
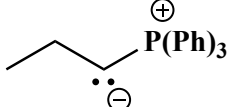
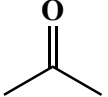
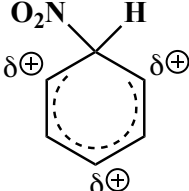
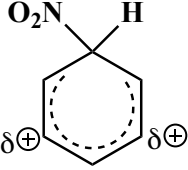
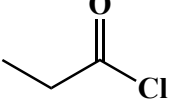
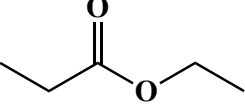
F)

$$\begin{array}{c} \text{CHO} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

$$\begin{array}{c} \text{CHO} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{HO} - \text{C} - \text{H} \\ | \\ \text{H} - \text{C} - \text{OH} \\ | \\ \text{CH}_2\text{OH} \end{array}$$

Enantiomers
 Diastereomers

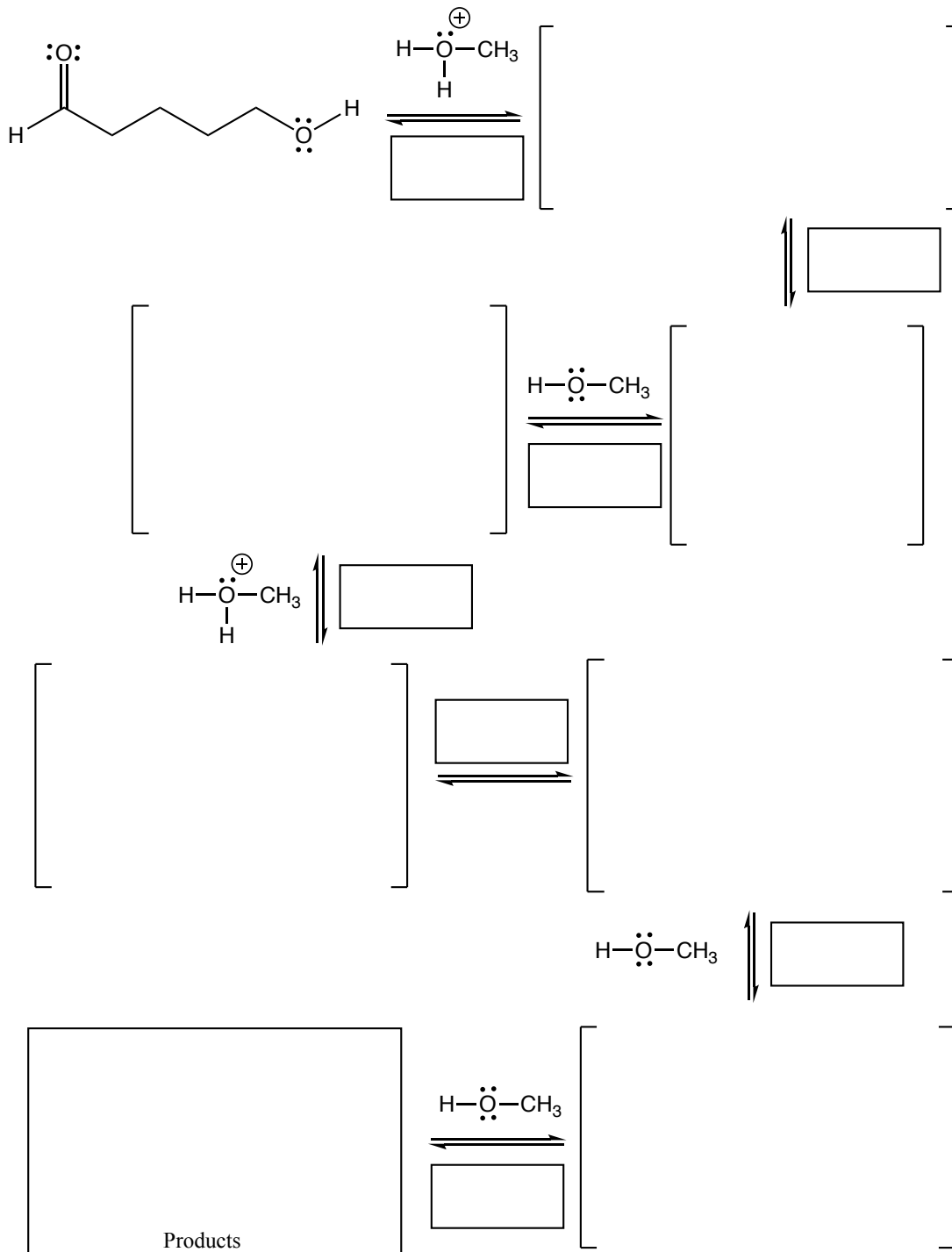
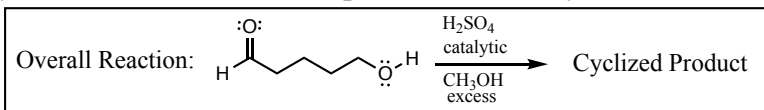
6 cont. (2 pts each) For each set of molecules, fill in all the circles that correctly describe the situation.

<p>A)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Stronger acid <input type="radio"/> Weaker acid</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Stronger acid <input type="radio"/> Weaker acid</p> </div> </div>	<p>F)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Aromatic <input type="radio"/> Not aromatic</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Aromatic <input type="radio"/> Not aromatic</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Aromatic <input type="radio"/> Not aromatic</p> </div> </div>
<p>B)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Stronger acid <input type="radio"/> Weaker acid</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Stronger acid <input type="radio"/> Weaker acid</p> </div> </div>	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> The appropriate structure at pH = 7 <input type="radio"/> Not the appropriate structure at pH = 7</p> </div> <div style="text-align: center;">  <p><input type="radio"/> The appropriate structure at pH = 7 <input type="radio"/> Not the appropriate structure at pH = 7</p> </div> </div>
<p>C)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Nucleophile <input type="radio"/> Electrophile</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Nucleophile <input type="radio"/> Electrophile</p> </div> </div>	<p>F)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> More stable <input type="radio"/> Less stable</p> </div> <div style="text-align: center;">  <p><input type="radio"/> More stable <input type="radio"/> Less stable</p> </div> </div>
<p>D)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Nucleophile <input type="radio"/> Electrophile</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Nucleophile <input type="radio"/> Electrophile</p> </div> </div>	<p>G)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> Appropriate distribution of charge for an arenium ion intermediate <input type="radio"/> Not an appropriate distribution of charge for an arenium ion intermediate</p> </div> <div style="text-align: center;">  <p><input type="radio"/> Appropriate distribution of charge for an arenium ion intermediate <input type="radio"/> Not an appropriate distribution of charge for an arenium ion intermediate</p> </div> </div>
<p>E)</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><input type="radio"/> More reactive with nucleophiles <input type="radio"/> Less reactive with nucleophiles</p> </div> <div style="text-align: center;">  <p><input type="radio"/> More reactive with nucleophiles <input type="radio"/> Less reactive with nucleophiles</p> </div> </div>	

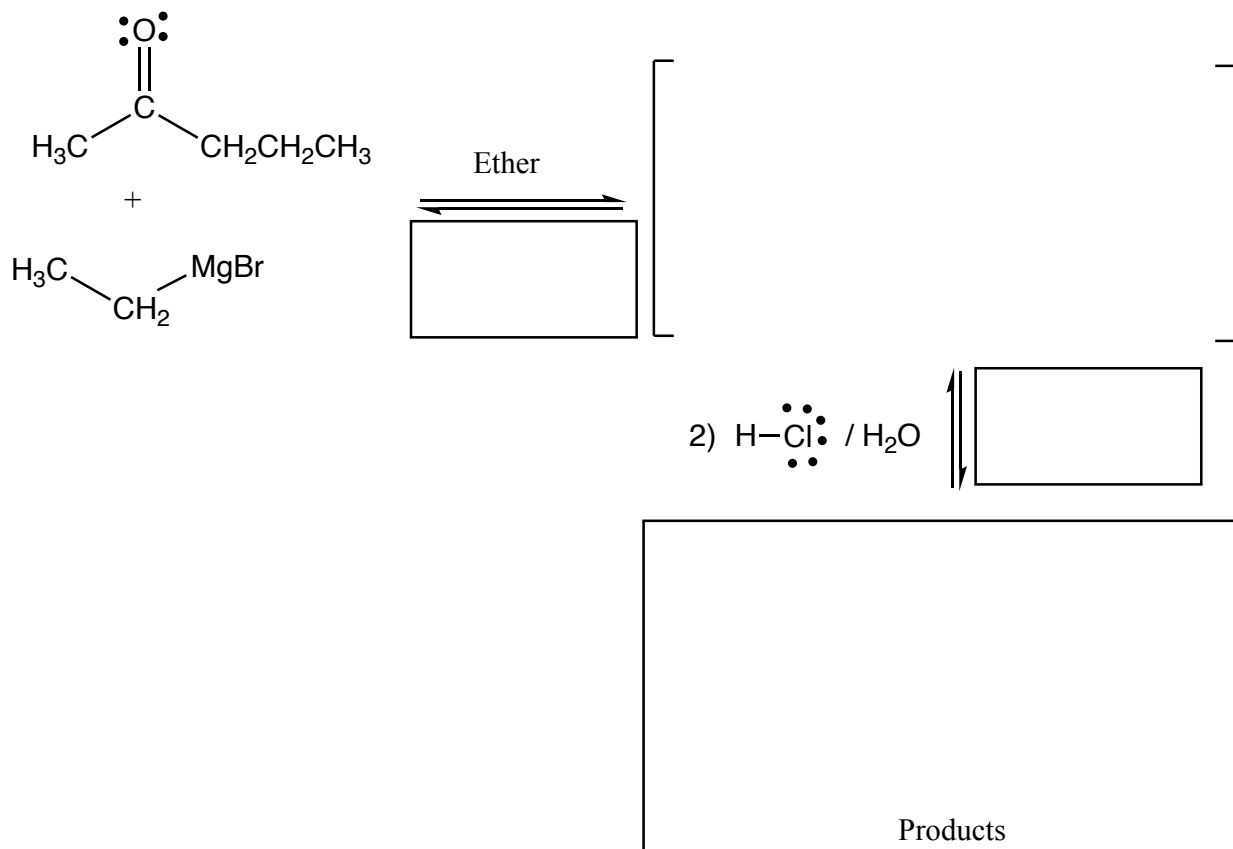
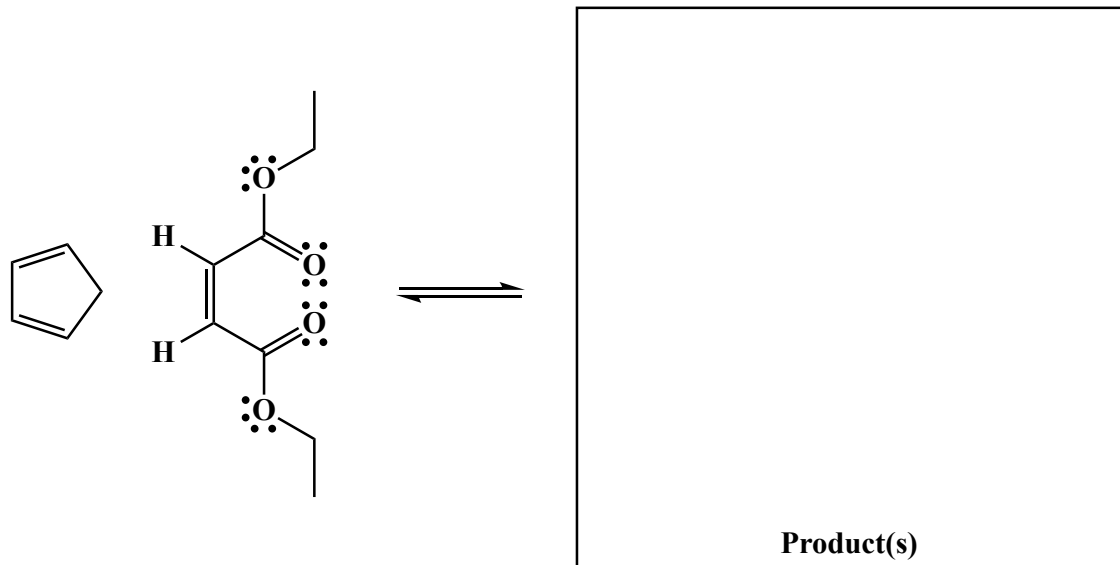
Signature _____

Pg 6 _____ (44)

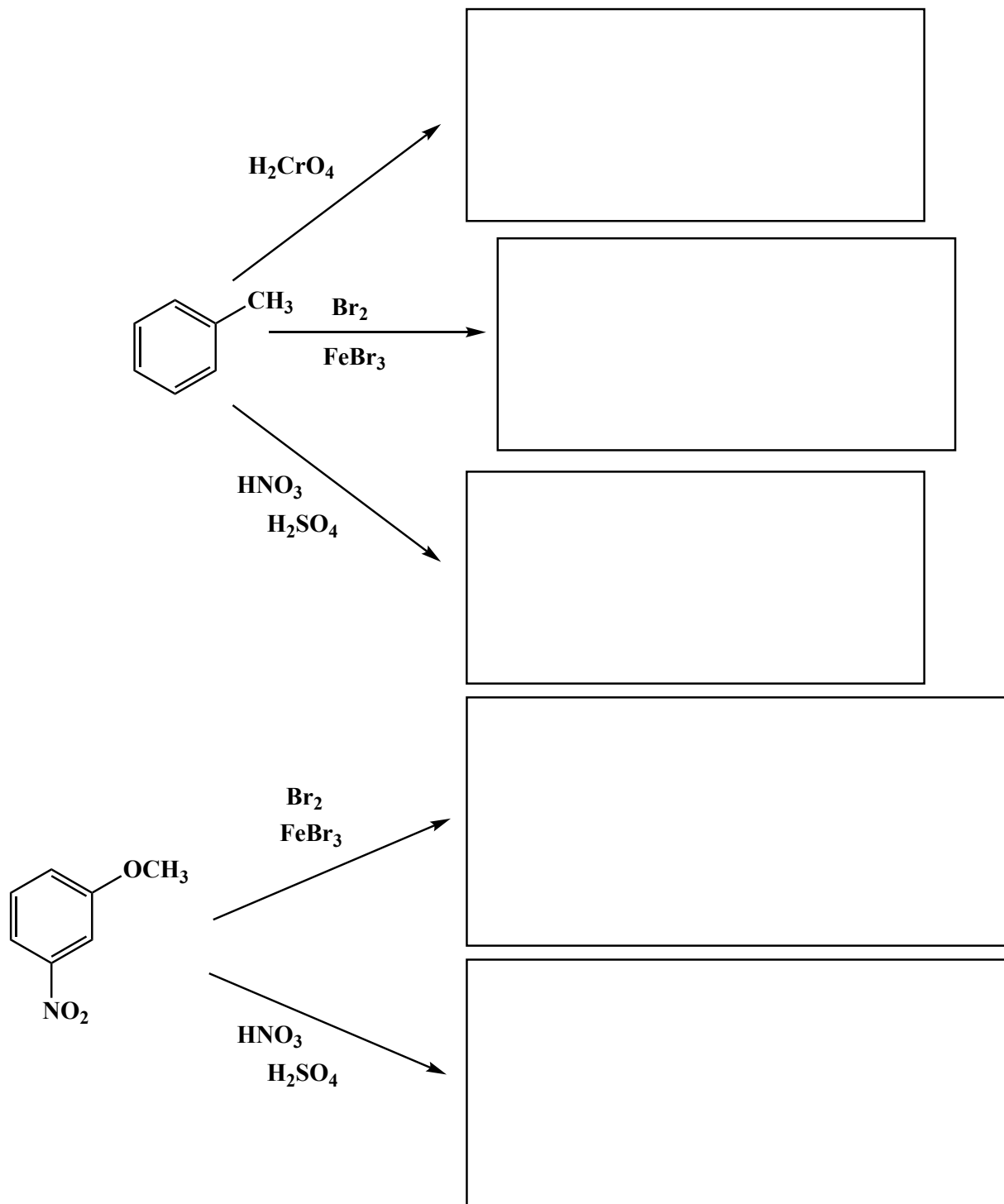
8. (44 pts) Complete this mechanism for the following acid-catalyzed acetal formation reaction. The directions are the same as for the mechanism on the previous page. To be clear, this reaction is run with methanol and the aldehyde-alcohol shown in the presence of catalytic H_2SO_4 . Hint: Assume cyclization takes place.



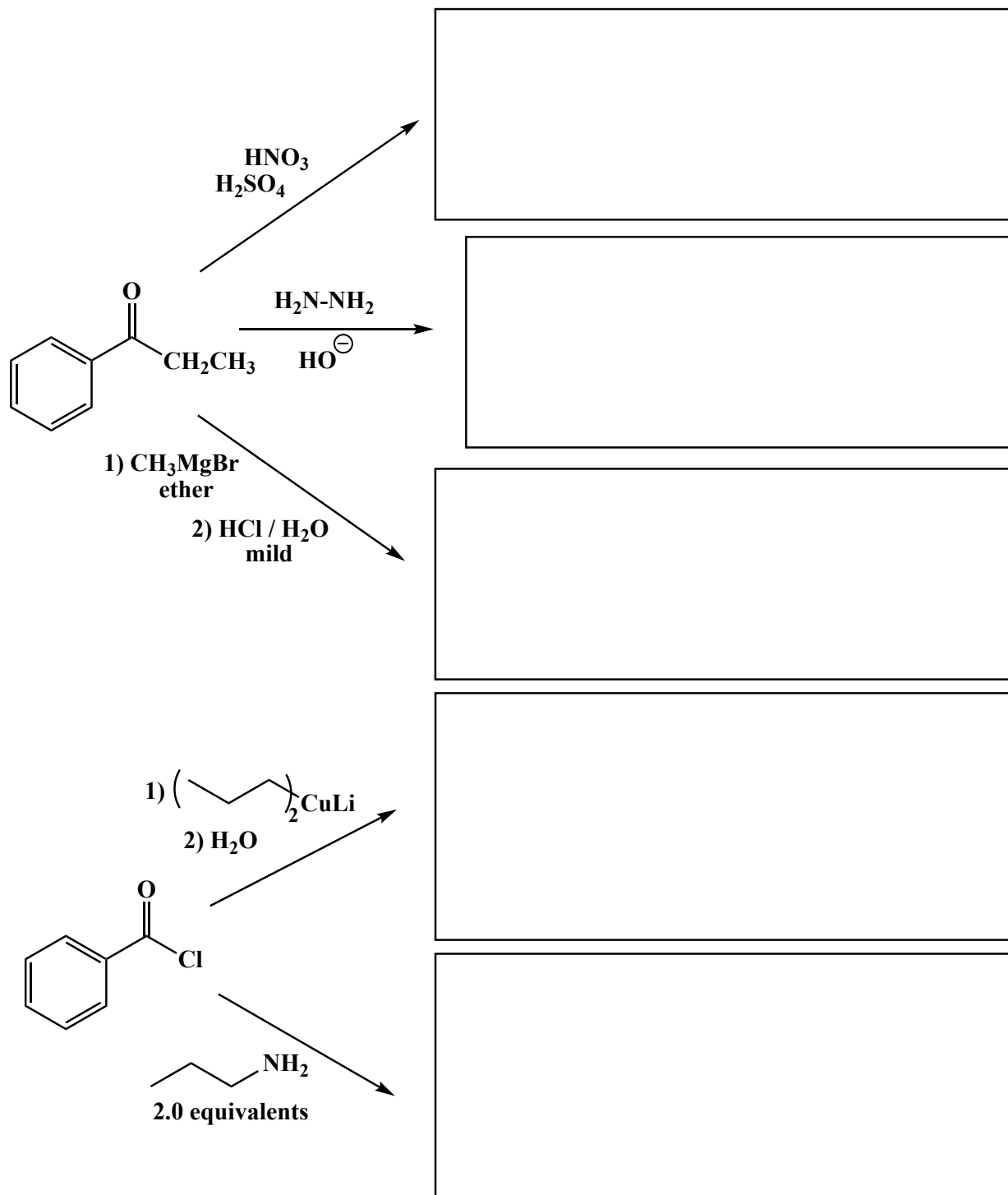
9. (17 pts) Complete the following two mechanisms. Use the same directions as for problem 7. The first reaction is from the last midterm. Make sure to add arrows to the starting materials of this Diels-Alder reaction!



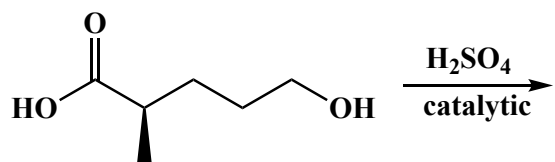
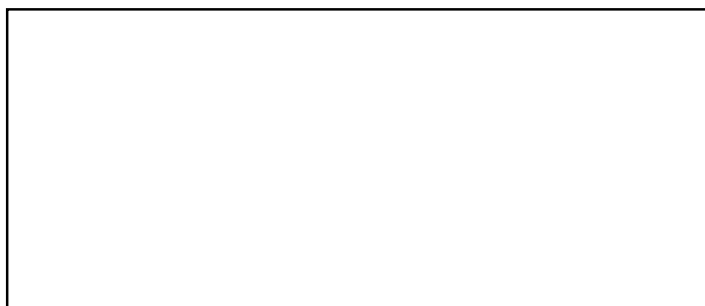
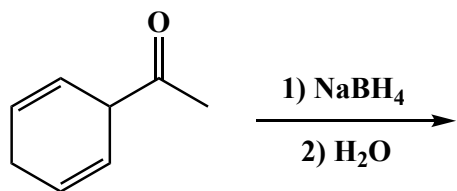
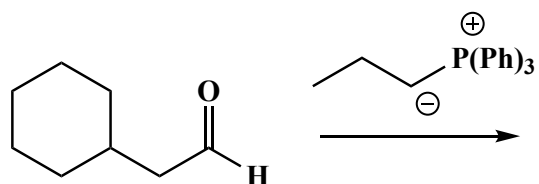
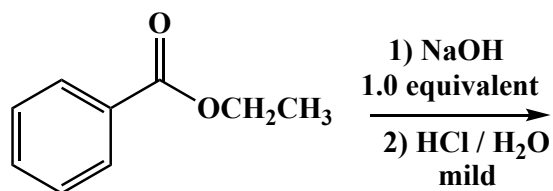
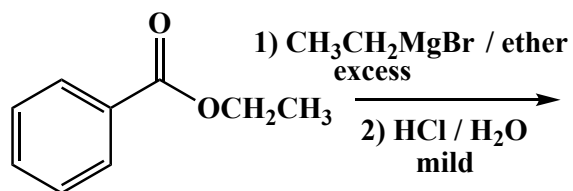
10. (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (\blacktriangleleft) and dashes (\cdots) to indicate stereochemistry. 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.**



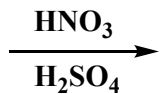
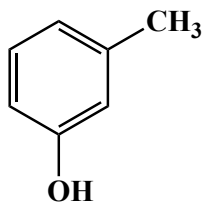
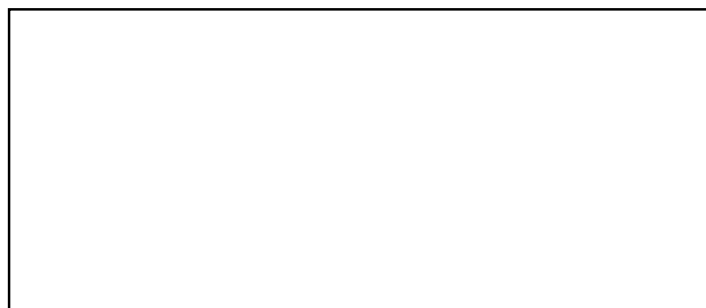
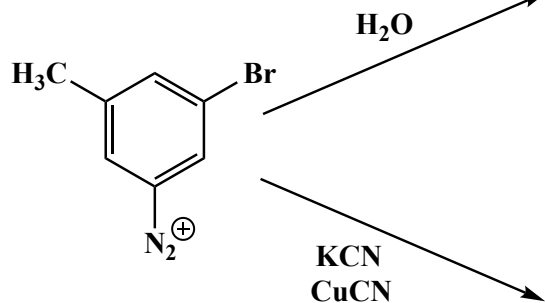
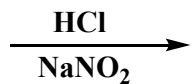
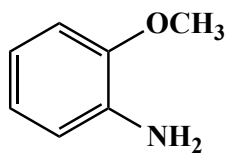
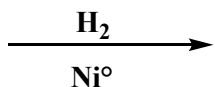
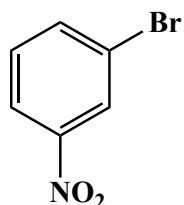
10 cont. (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (\blacktriangleleft) and dashes (\cdots) to indicate stereochemistry. 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.**



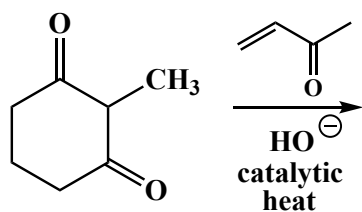
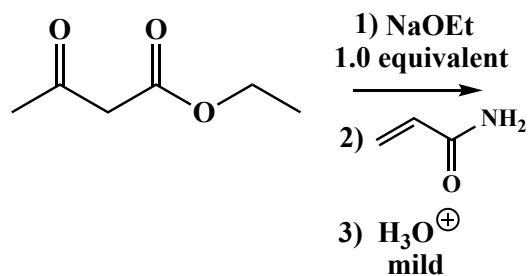
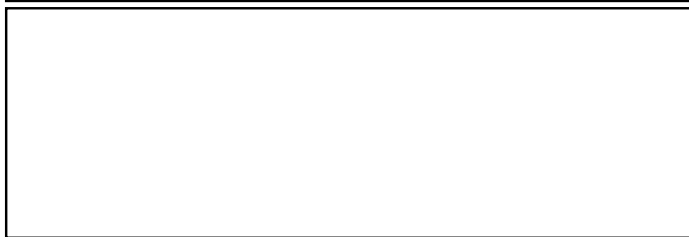
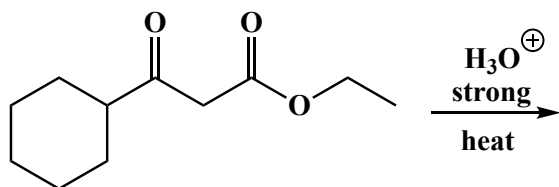
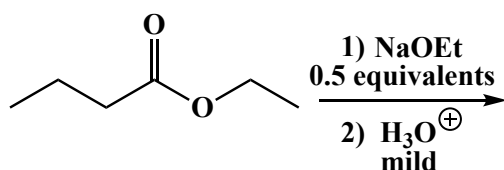
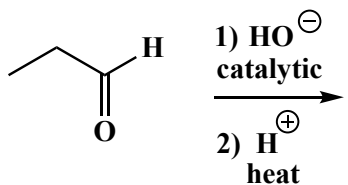
10 cont. (3 or 5 pts.) Write the predominant product(s) that will occur for each transformation. If a new chiral center is created and a racemic mixture is formed, you must draw both enantiomers and write "racemic" under the structure. Use wedges (\blacktriangleleft) and dashes (\dashv) to indicate stereochemistry. 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.**



10 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.**



10 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.**

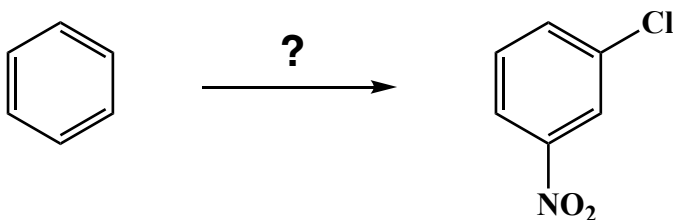


Signature _____

Pg 13 _____ (4)

11. 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)

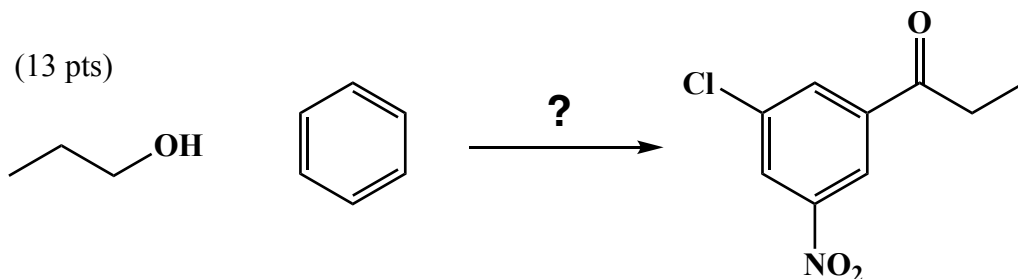


Signature _____

Pg 14 _____(13)

11. 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)

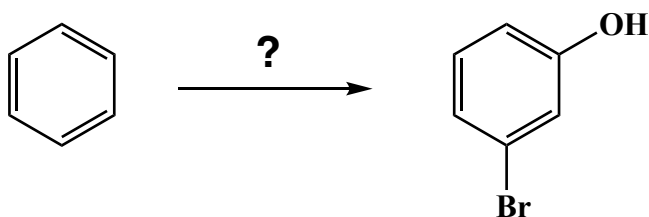


Signature _____

Pg 15 _____(13)

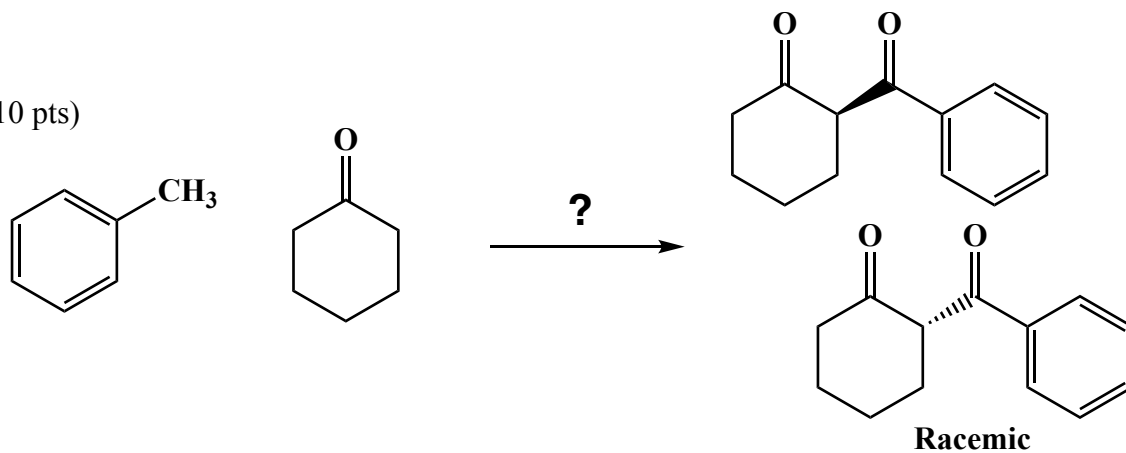
11. These are synthesis questions. You need to show how the starting material can be converted into the product(s) shown. You may use any reactions we have learned provided that the product(s) you draw for each step is/are the predominant one(s). Show all the reagents you need. Show each molecule synthesized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

C) (13 pts)



11. 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.**

D) (10 pts)



Signature _____

Pg 17 _____ (16)

11. 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)

