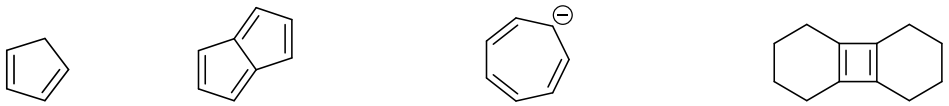
Multiple choice questions: Each question is worth 1 point. There is no penalty for wrong answers. ***Only answers transferred to the tables below will be graded.*** (20 points)

Question	A	B	C	D	E
1	X				
2			X		
3		X			
4				X	
5		X			
6					X
7		X			
8			X		
9	X				
10			X		

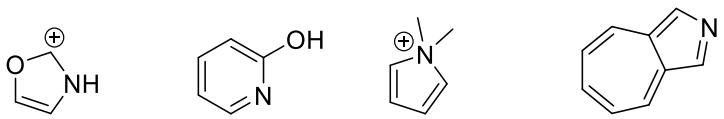
Question	A	B	C	D	E
11					X
12				X	
13				X	
14			X		
15		X			
16				X	
17	X				
18			X		
19	X				
20			X		

1) Which of the following molecules could NOT be classified as anti-aromatic? Assume planarity of all ring atoms.



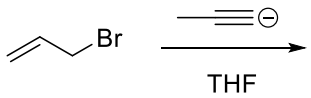
A B C D

2) Which of the following molecules could NOT be classified as aromatic?



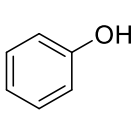
A B C D

3) Which mechanism will most likely take place under these conditions?

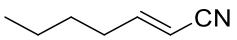


a. S_N1
b. S_N2
c. E1
d. E2

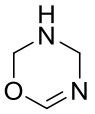
4) Which of the following compounds does NOT contain a conjugated system?



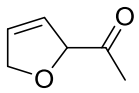
A



B

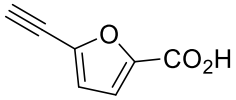


C



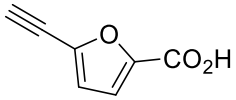
D

5) How many electron PAIRS are part of the conjugated system in the molecule below?



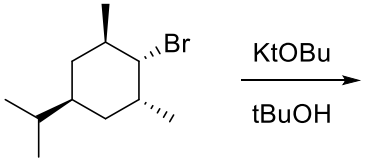
a. 4 b. 6 c. 8 d. 9 e. 10

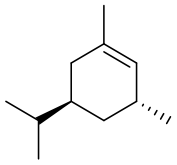
6) How many atoms are part of the conjugated system in the molecule below?



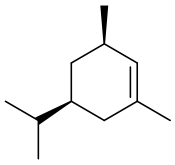
a. 6 b. 7 c. 8 d. 9 e. 10

7) What is the expected outcome of the following reaction?

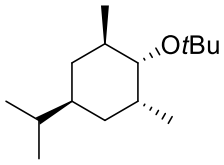




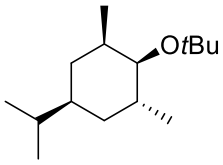
A



B



C



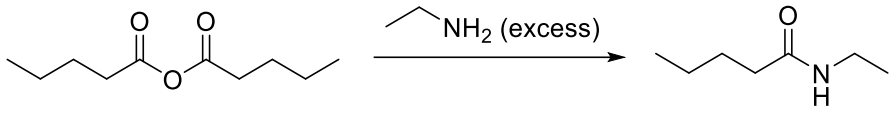
D

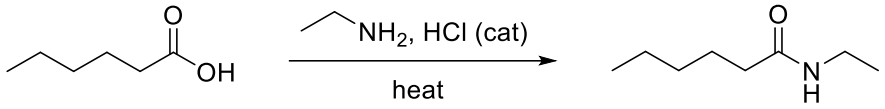
NO REACTION

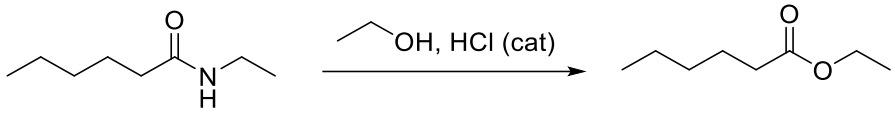
E

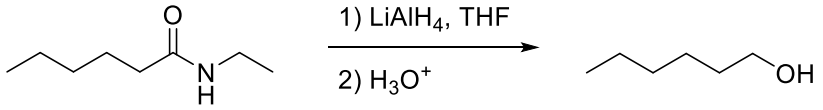
8) Select the INCORRECT statement:
   a. Soft nucleophiles tend to react with soft electrophiles.
   b. The *beta* carbon of an *alpha*, *beta*-unsaturated carbonyl is a softer electrophilic site than the carbonyl carbon.
   c. Enolates are classified as hard nucleophiles because they carry a negative charge.
   d. Conjugate addition products are generally more stable than direct addition products.

9) Which of the following reactions will work well *as written*?

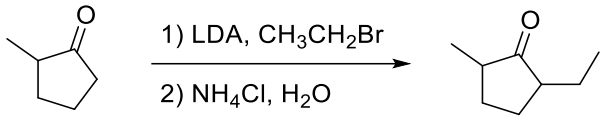
a. 

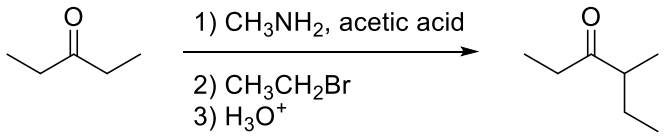
b. 

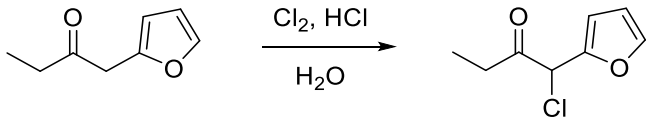
c. 

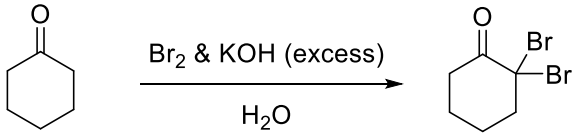
d. 

10) Which of the following reactions will work well *as written*?

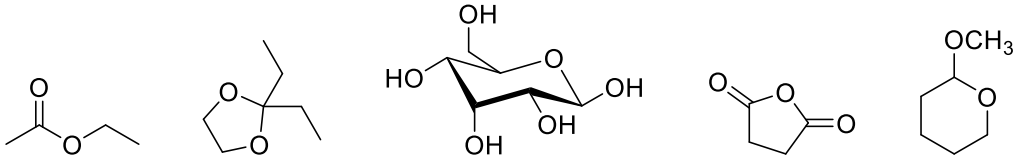
a. 

b. 

c. 

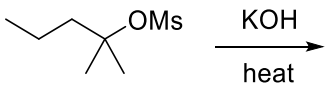
d. 

11) Which of the following structures is an acetal derived from an aldehyde?



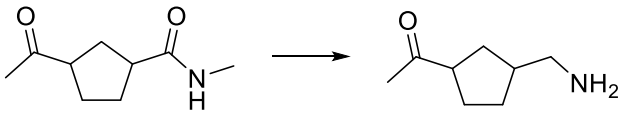
A **B** **C** **D** **E**

12) Which mechanism will most likely take place under these conditions?



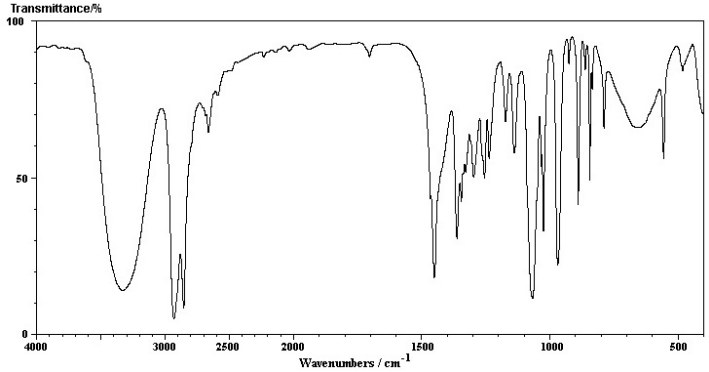
a. S_N1
b. S_N2
c. E1
d. E2

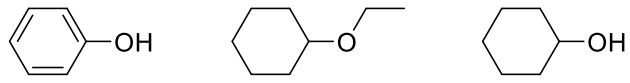
13) What conditions should be chosen to carry out the following transformation?



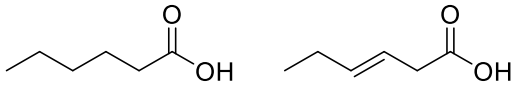
a. $NaBH_4$, EtOH
b. $LiAlH_4$ followed by HCl, H_2O
c. DIBAl, -78 ºC, followed by NH_4Cl, H_2O
d. BH_3•OEt_2, 20 ºC, followed by H_2O
e. none of the above

14) Select the most likely structure to give the IR spectrum below.



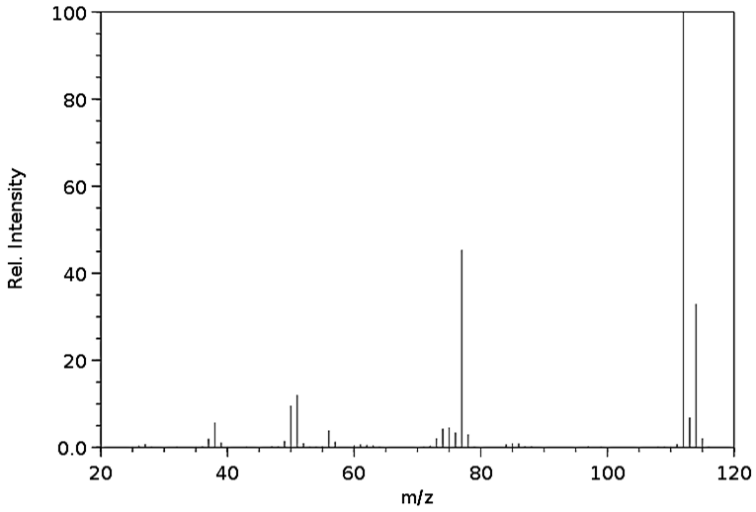


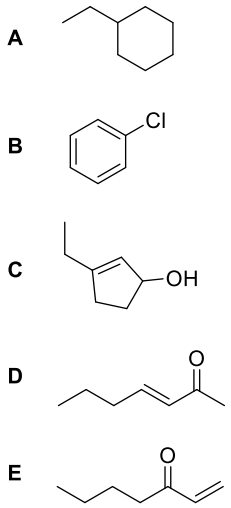
A **B** **C**



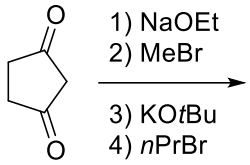
D **E**

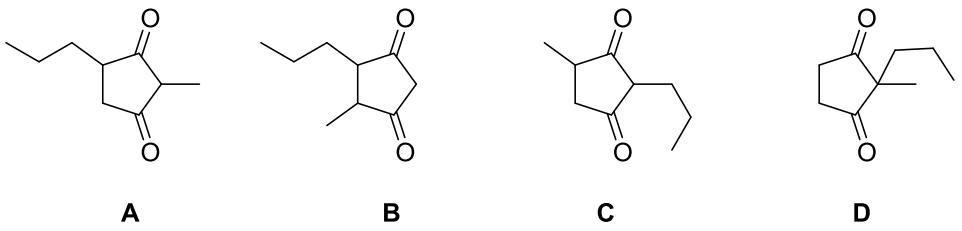
15) Select the most likely structure to give the LRMS below. Note that all compounds have a molar mass of 112.



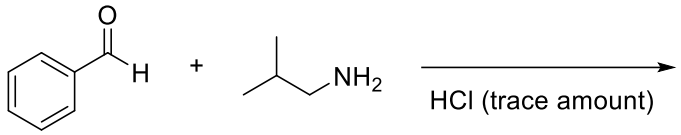


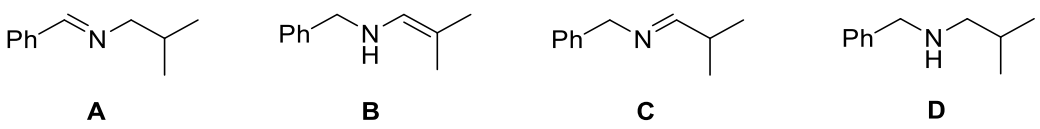
16) Predict the major product formed.



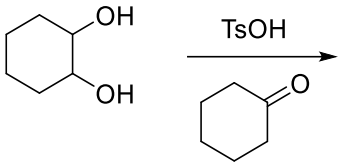


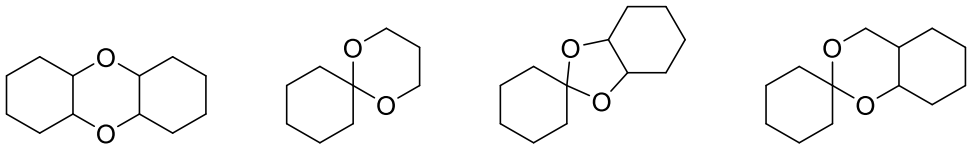
17) Predict the major product formed.





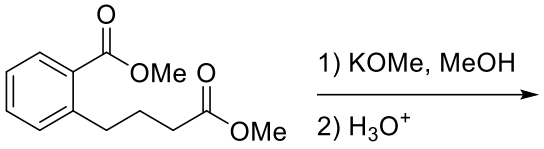
18) Predict the major product formed. Note: TsOH is an organic acid.

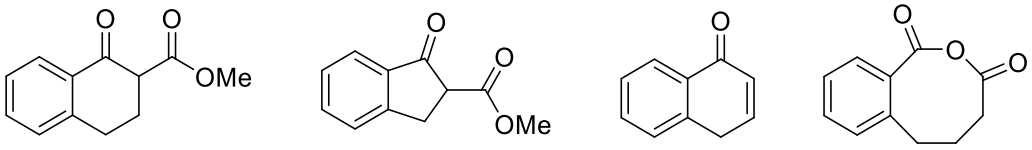




A **B** **C** **D**

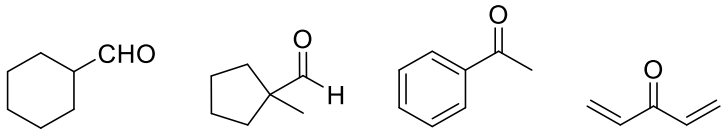
19) Predict the major product formed.





A **B** **C** **D**

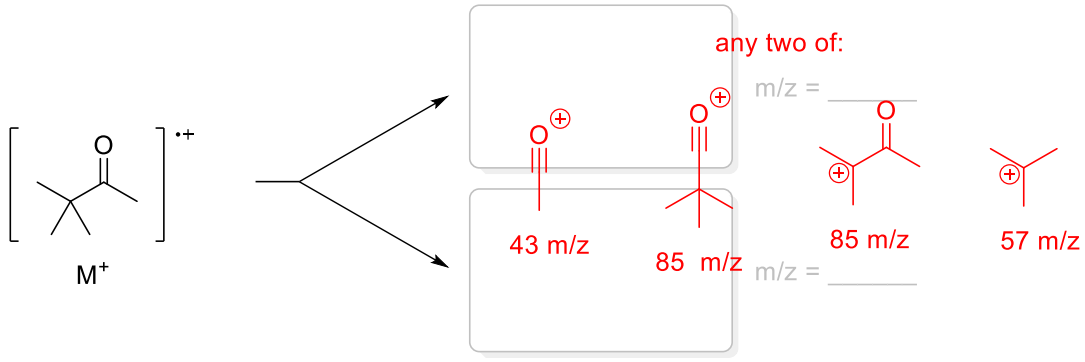
20) How many of the following compounds can undergo an aldol reaction?



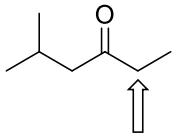
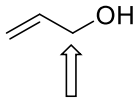
A) 0
B) 1
C) 2
D) 3
E) 4

Short answer questions: Answer in the spaces provided.

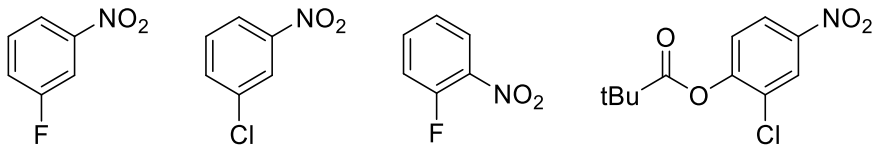
21) The compound below has a molecular ion peak (M+) at 100 *m/z* in its mass spectrum. Suggest structures for two other peaks which are likely to appear in the spectrum and include their expected m/z values. (4 points)



22) Fill in the chart for the compounds below, indicating the number of signals expected in the ^{1}H and ^{13}C NMR spectra, as well as the splitting pattern expected for the indicated hydrogen (the one with the arrow). (6 points)

	Number of H signals	5
	Number of C signals	6
	Splitting pattern of indicated H	q
	Number of H signals	5
	Number of C signals	3
	Splitting pattern of indicated H	d

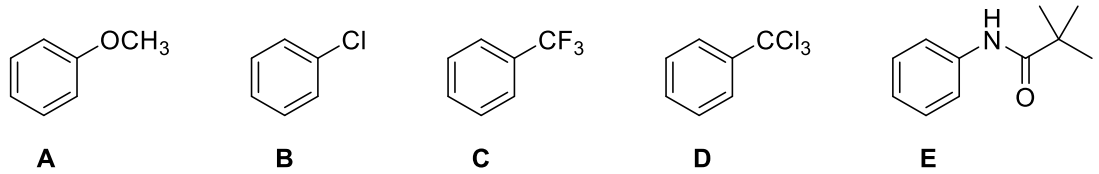
23) Rank the following compounds in order of increasing reaction rate for **nucleophilic aromatic substitution**. (2 points)



A **B** **C** **D**

(slowest reaction) D < B < A < C (fastest reaction)

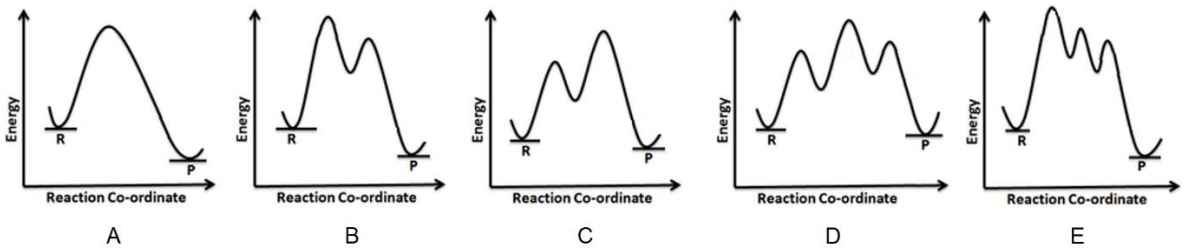
24) Rank the following structures in order of increasing reactivity towards an electrophile in an **electrophilic aromatic substitution** reaction. (2 points)



A **B** **C** **D** **E**

(least reactive) C < D < B < E < A (most reactive)

25) Assign the appropriate reaction coordinate diagram to each of the reactions below (circle the correct letter). Diagrams may be assigned to more than one reaction; not all diagrams need to be used. (5 points)



A B C D E

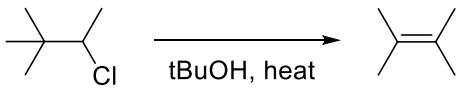


diagram: **A** **B** **C** **D** **E**

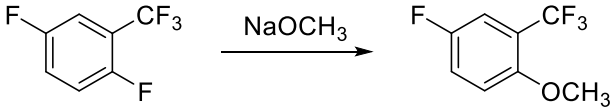


diagram: **A** **B** **C** **D** **E**

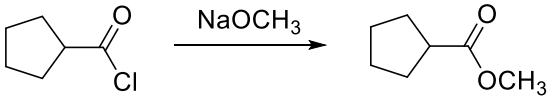


diagram: **A** **B** **C** **D** **E**

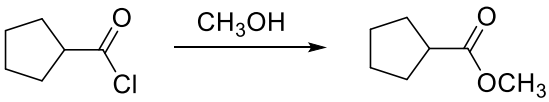


diagram: **A** **B** **C** **D** **E**

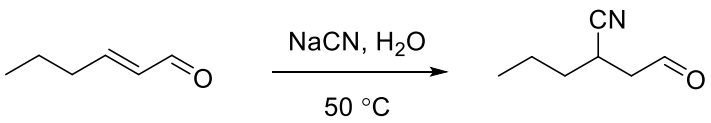
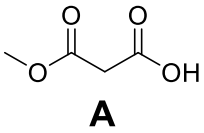
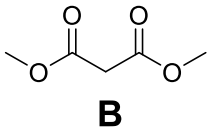


diagram: **A** **B** **C** **D** **E**

26) For each pair of compounds below, select the compound with the lowest pKa. (3 points)

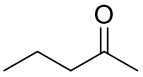


A

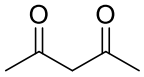


B

lowest pKa: **A**

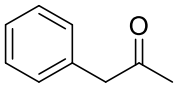


A

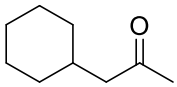


B

lowest pKa: **B**



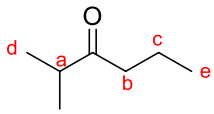
A

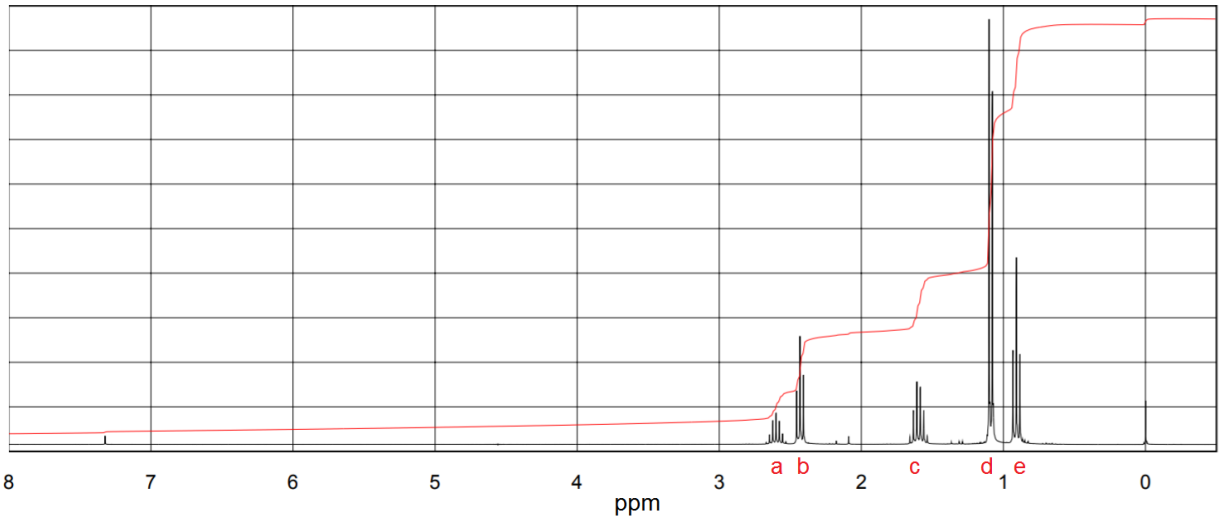


B

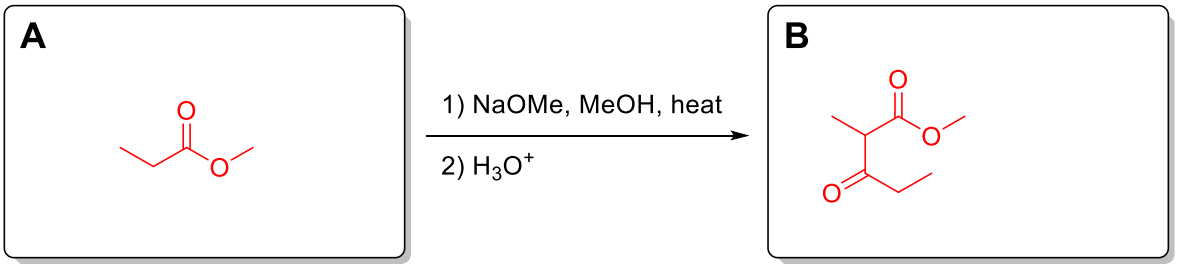
lowest pKa: **A**

27) Below is the structure and ^{1}H NMR for 2-methyl-3-hexanone. Assign the peaks in the spectrum to the appropriate set of hydrogens using the letters provided in the spectrum. (5 points)

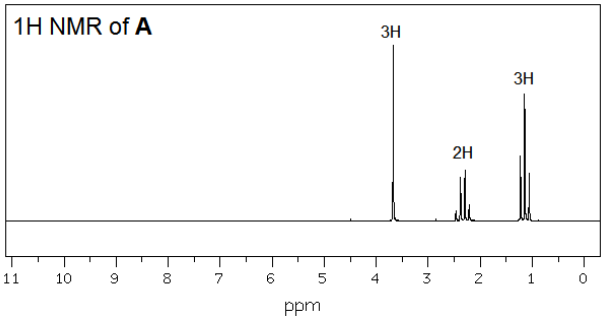


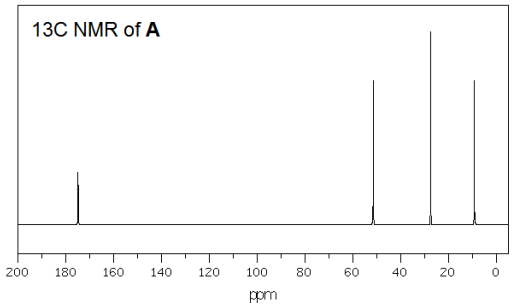


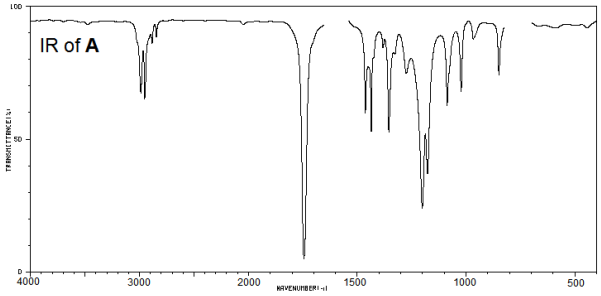
28) Compound **A** contains C, H and O atoms only. It is treated with a stoichiometric amount of sodium methoxide in methanol (i.e. 1 mole of NaOMe for every mole of compound **A**). After heating for 45 minutes, dilute aqueous acid is added and product **B** is isolated. Using the spectral data provided below, determine the structures of **A** and **B**. For full marks, you must adequately annotate your spectra to support the structures you provide. (10 points)



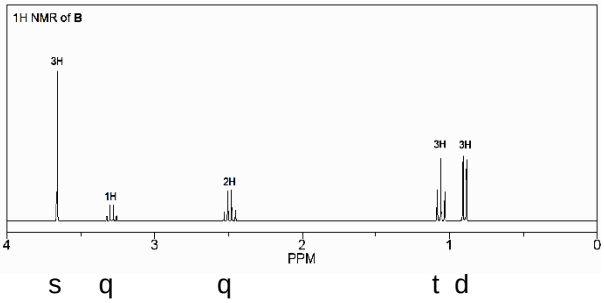
Spectral data for compound **A**:

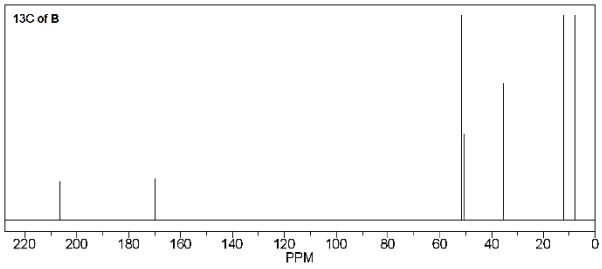






Spectral data for compound **B**:

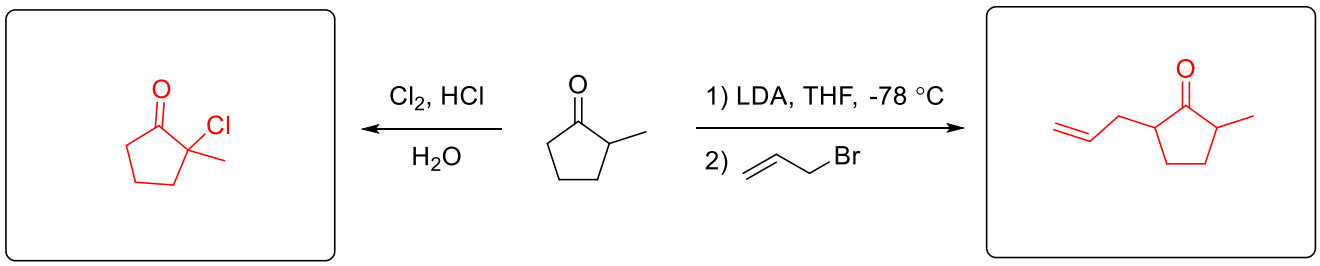


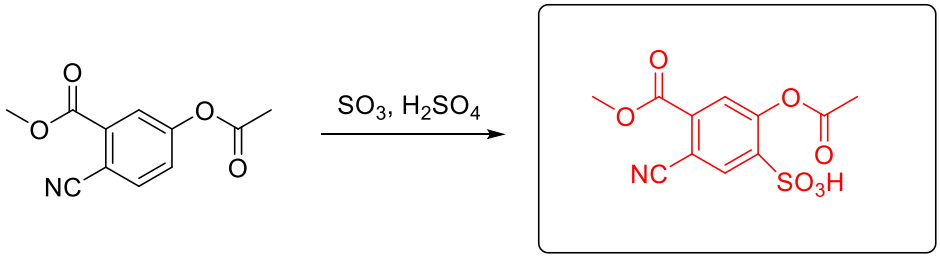


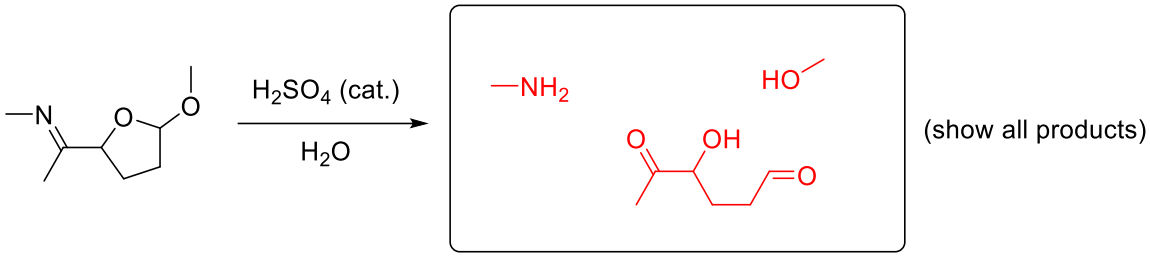
s q q t d

(letters indicate splitting patterns)

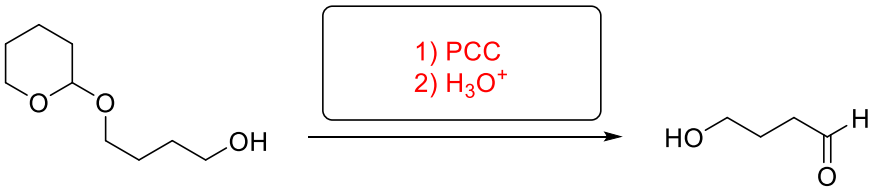
29) Fill in the missing reagents and/or structures for each of the following transformations. Unless otherwise indicated, show only the major product. (48 points, 2 points per box)

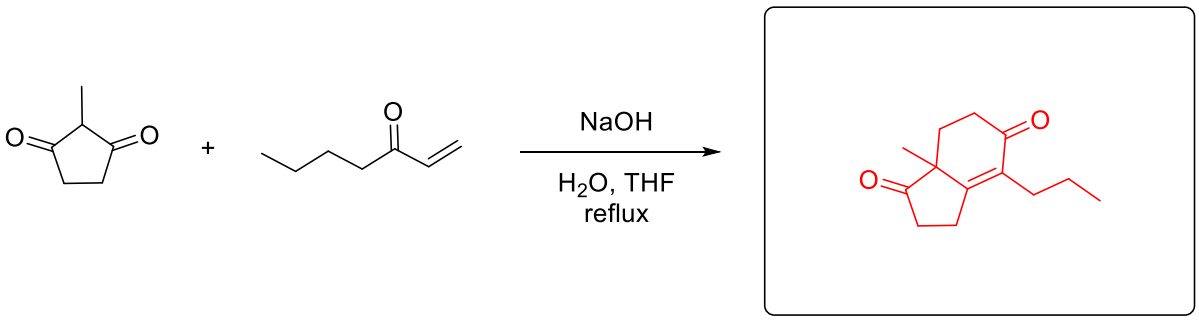




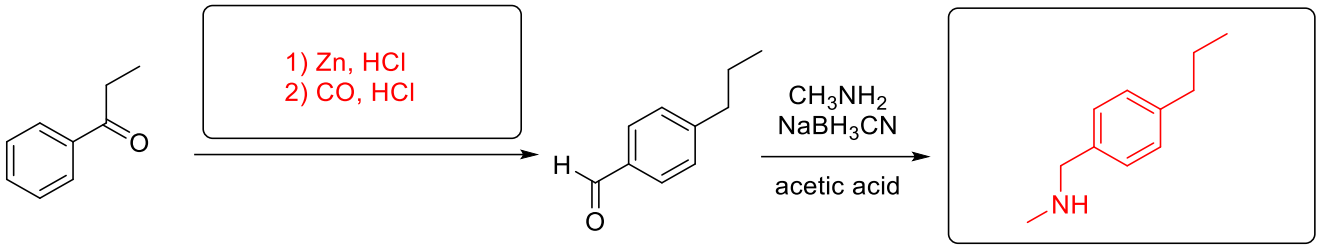


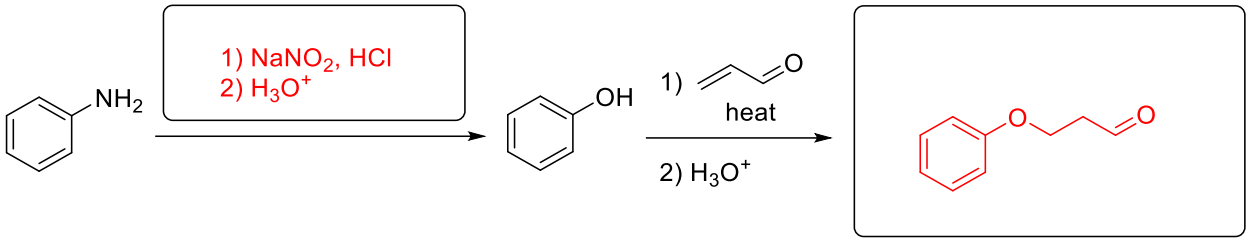
(show all products)

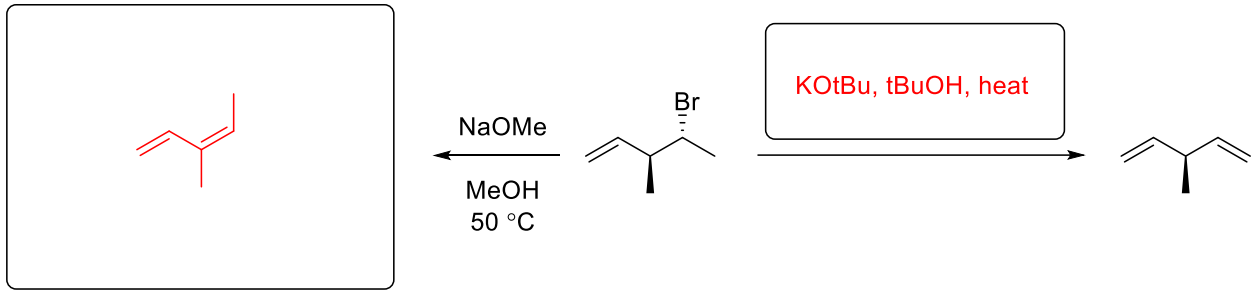


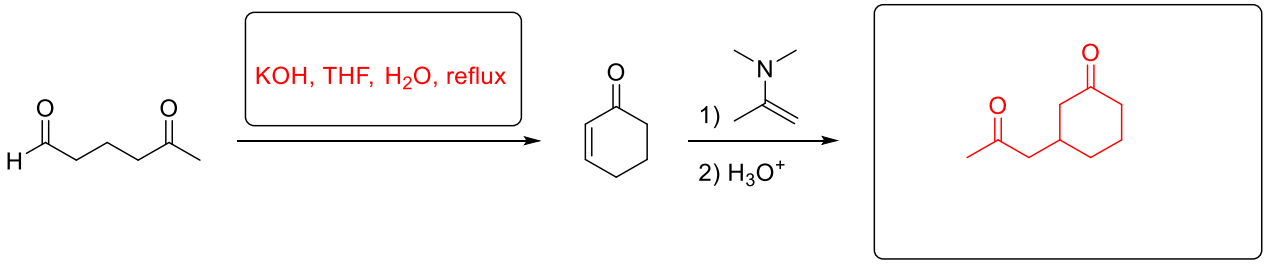


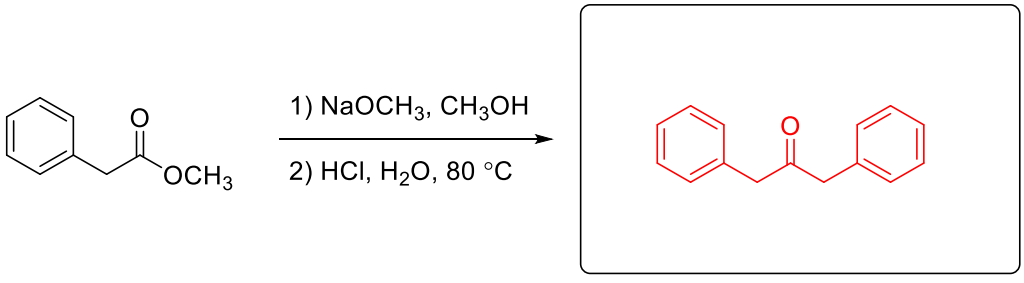
$C_{13}H_{18}O_2$

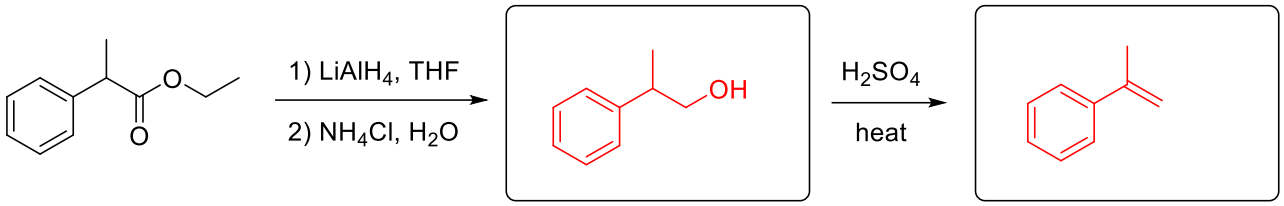

1) Zn, HCl
2) CO, HCl
O
H
O
CH_3NH_2
$NaBH_3CN$
acetic acid
NH

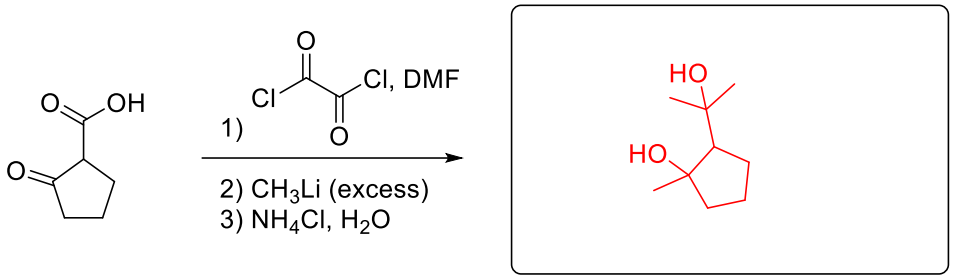

NH_2
1) $NaNO_2$, HCl
2) H_3O^+
OH
1)
O
heat
2) H_3O^+
O
O

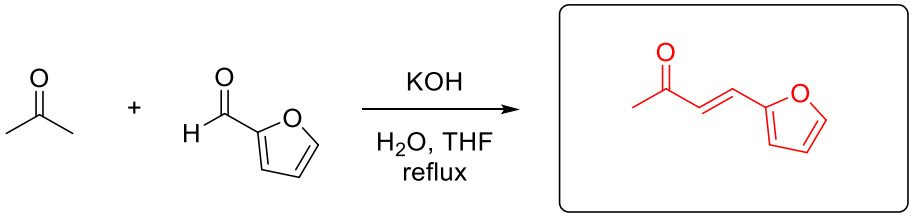

NaOMe
MeOH
50 °C
Br
KOtBu, tBuOH, heat

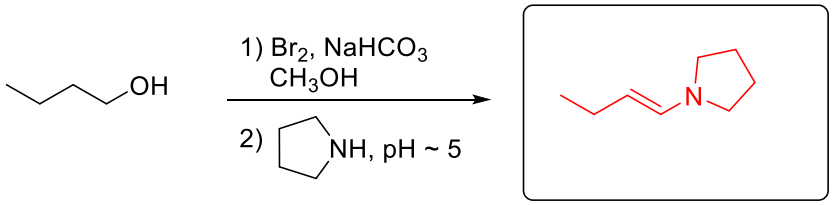

KOH, THF, H_2O, reflux
O
O
H
O
1)
N
2) H_3O^+
O
O

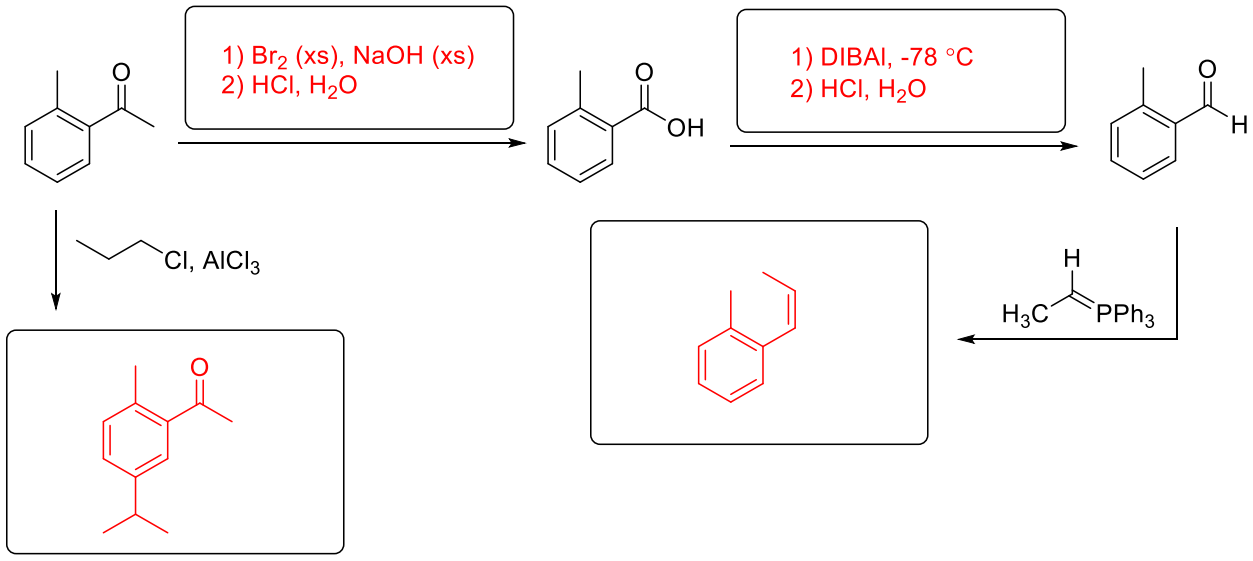

O
OCH_3
1) $NaOCH_3$, CH_3OH
2) HCl, H_2O, 80 °C
O


1) LiAlH4, THF
2) NH4Cl, H2O
OH
H2SO4
heat


OH
O
O
Cl
Cl, DMF
1)
2) CH3Li (excess)
3) NH4Cl, H2O
HO
HO

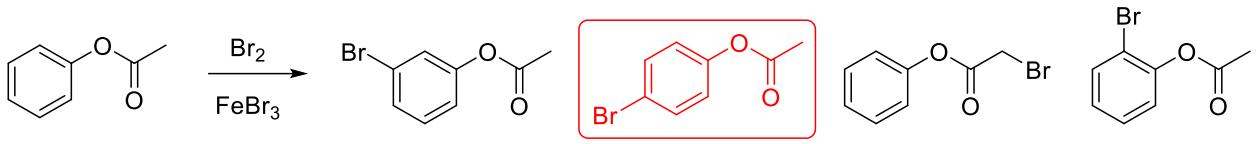

O
+
O
H
O
KOH
H2O, THF
reflux
O
O

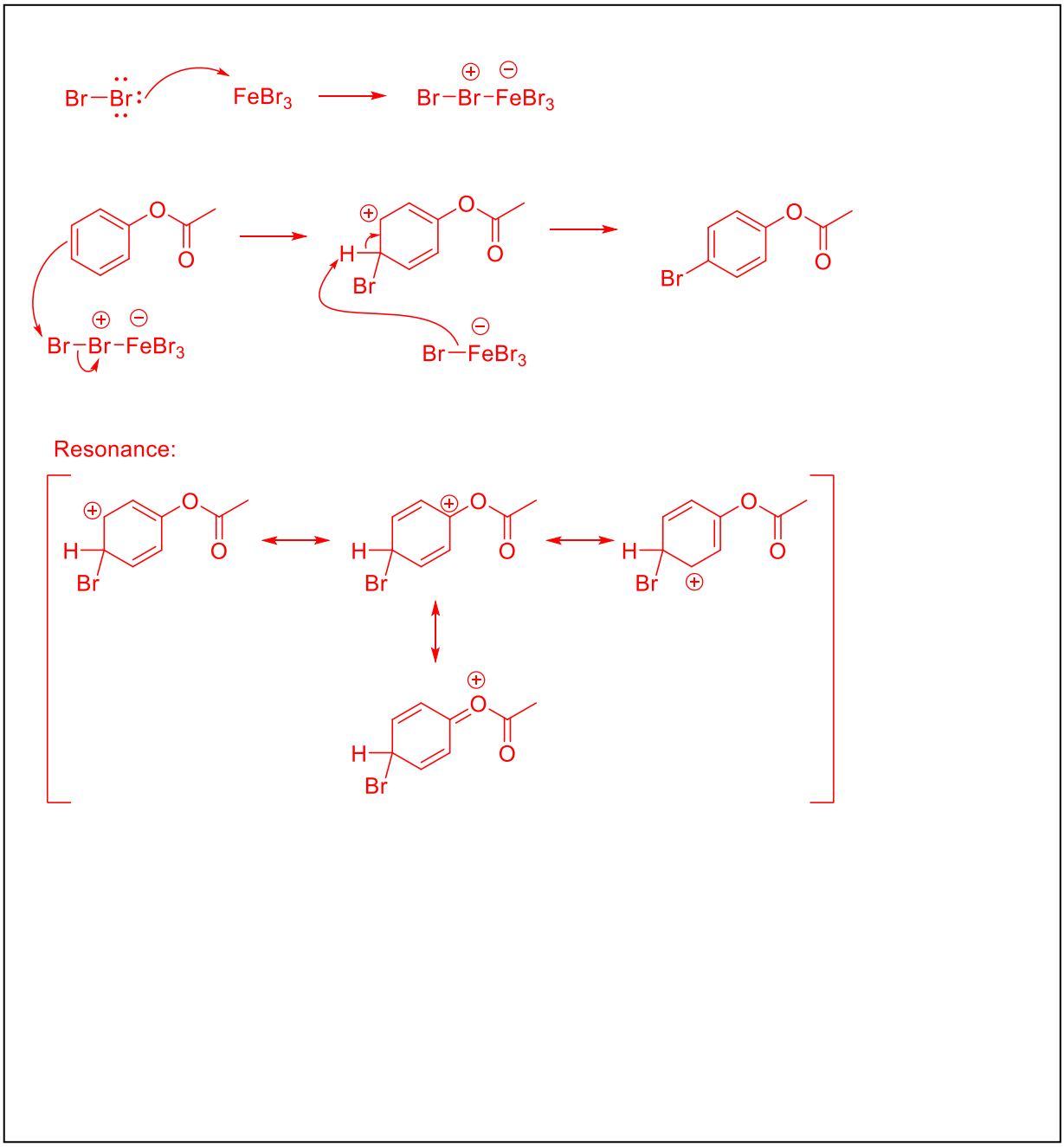

OH
1) Br2, NaHCO3
CH3OH
2)
NH, pH ~ 5
N


1) Br2 (xs), NaOH (xs)
2) HCl, H2O
OH
1) DIBAl, -78 °C
2) HCl, H2O
H
Cl, AlCl3
H
H3C
PPh3
O

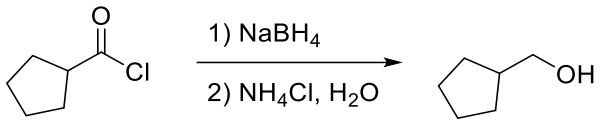
Long answer questions: Answer in the spaces provided.

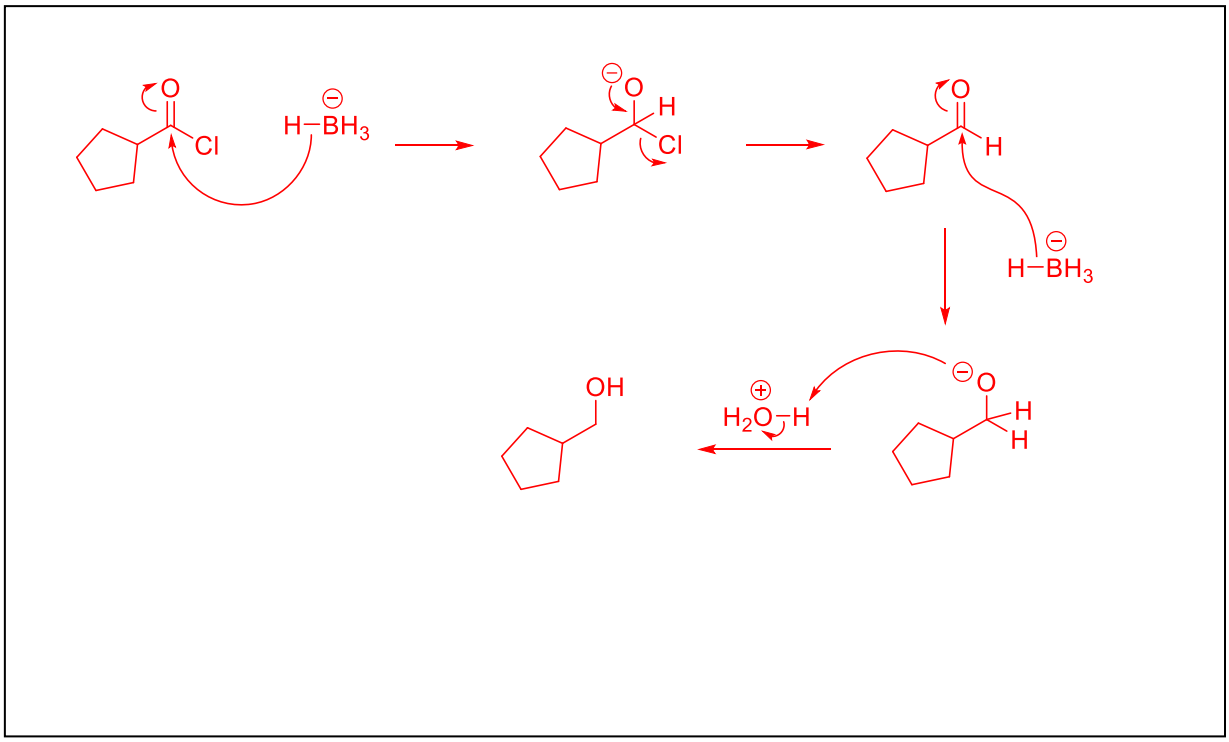
30) Circle the major product of the following reaction and draw a curved arrow mechanism for its formation. Be sure to include **resonance structures for any charged intermediates** and label the most stable resonance structure. (7 points)



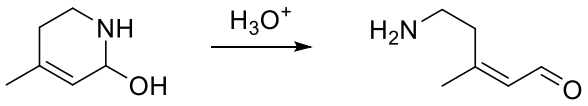


31) Provide a curved arrow mechanism for all steps of the following reaction. (7 points)

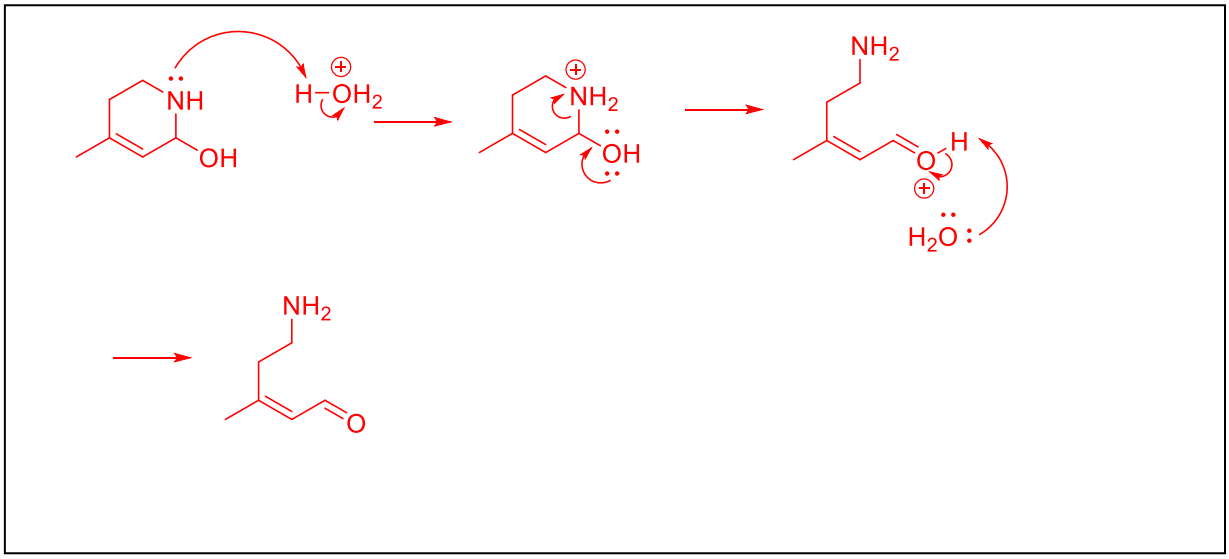




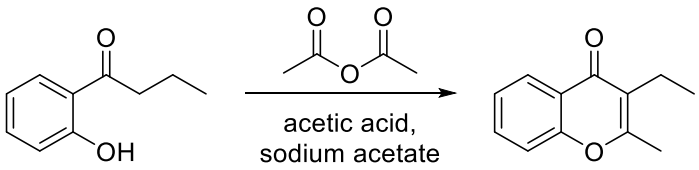
32) Provide a curved arrow mechanism for all steps of the following reaction. (5 points)



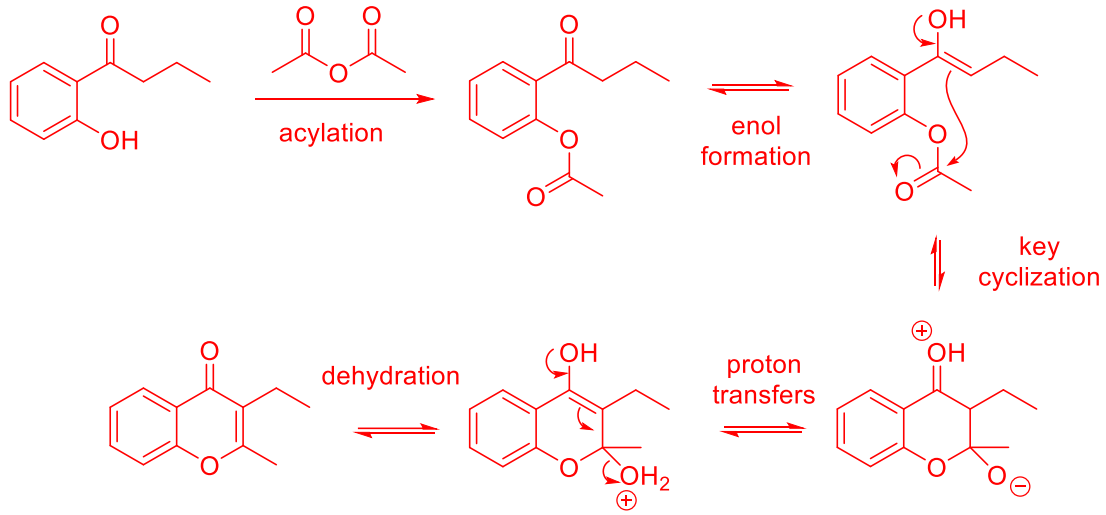
hemiaminal



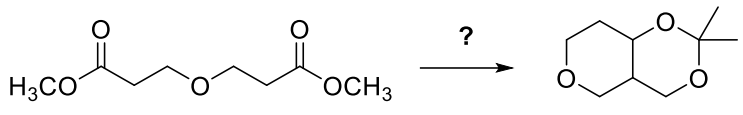
33) Below is a reaction you have never seen before. Propose a mechanism for this transformation using ideas learned in Chapters 15 and 17. **Note: I am not expecting you to come up with a perfect mechanism**; rather, I want to see evidence that you understand the inherent reactivity of these types of molecules. (9 points)



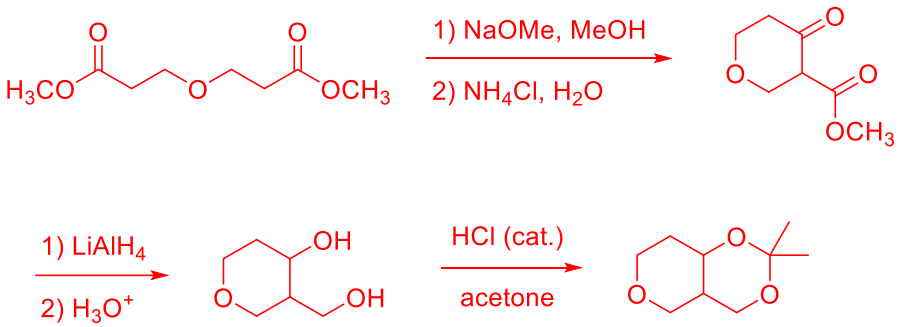
Lots of flexibility with answers; key intermediates and steps shown below:

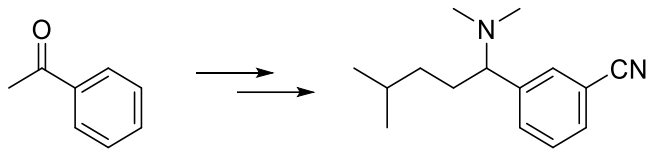


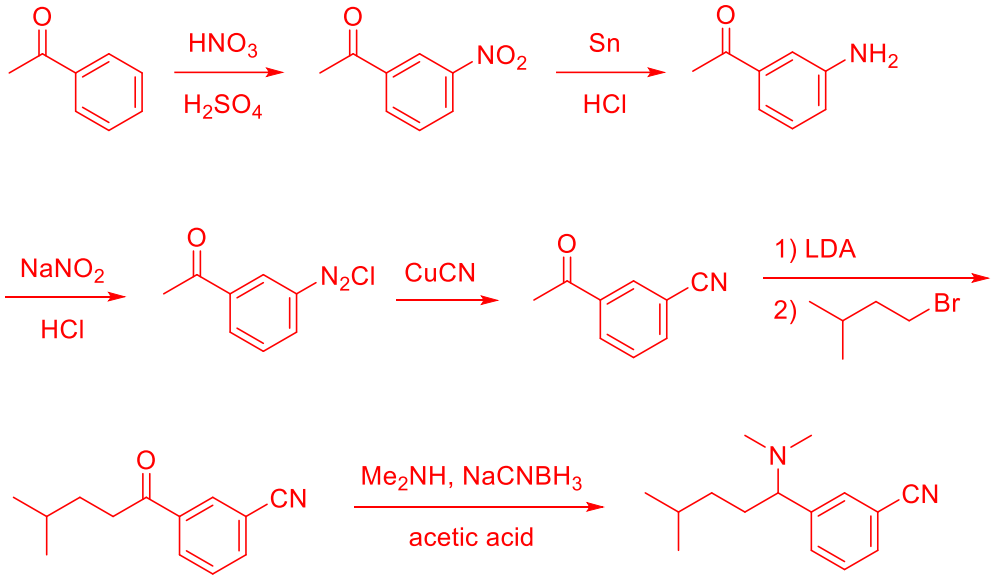
34) Propose a multistep synthesis for each of the following transformations. For full marks, be sure to show the products formed after each step in the synthesis. You do NOT need to show retrosynthetic planning or curved arrow mechanisms.

a. 

(3 points)



b. 
O
N
CN
(6 points)


O
HNO3
H2SO4
NO2
Sn
HCl
NH2
NaNO2
HCl
N2Cl
CuCN
CN
1) LDA
2)
Br
Me2NH, NaCNBH3
acetic acid