

### Lab Questions (20 points total)

- 1) Define carcinogenic in 5 words or less. (1 point)

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- 2) Define inflammable in 5 words or less. (1 point)

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- 3) Compound **X** has the following solubility data. Use this data to answer the questions which follow. (3 points)

- Highly soluble in water at all temperatures.
- Soluble in methanol at high temperatures; insoluble in methanol at cold temperatures.
- Insoluble in isopropanol at all temperatures.
- Insoluble in hexanes at all temperatures.

Which solvent(s) could be used for a single-solvent recrystallization?

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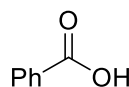
Which solvent combination(s) could be used for a two-solvent recrystallization?

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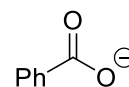
- 4) In the haloform reaction carried out in Experiment 5, acetophenone is first mixed with bleach. After 40 minutes, sodium sulfite is added, followed by diethyl ether. At this point in the experiment, a two-phase solution forms in the vial. Below is a sketch of the vial with two phases shown, along with a number of chemical species. Indicate which species are present in which layer by writing the corresponding letters in the correct space on the vial. Note that not all letters will be used. (4 points)



**A**



**B**



**C**



**D**



**E**



**F**

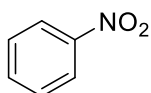


**G**

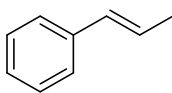
- 5) In the dehydration of *tert*-amyl alcohol (Experiment #1), the final products are in equilibrium with the starting materials. Which of the following statements correctly explains how the reaction is driven in the forward direction? (1 point)
- An excess of the starting material is used.
  - The reaction is carried out at an elevated temperature.
  - Water is distilled from the solution as it forms.
  - The alkenes are distilled from the solution as they form.
  - An acid catalyst is used to facilitate the desired reaction.
- 6) Two chemical tests were used in Experiment 1 to help determine the functional groups present in some unknown compounds. Below are some sample test results for an unknown compound, **X**. Use these test results to determine which of the structures below could be compound **X**. (5 points)

	5% Br in CH <sub>2</sub> Cl <sub>2</sub>	0.1 M KMnO <sub>4</sub>
Observations	<ul style="list-style-type: none"> <li>1 drop: no colour change</li> <li>2 drops: no colour change</li> <li>3 drops: solution goes yellow initially, then fades to colourless</li> <li>4 drops: solution turns yellow and colour persists</li> </ul>	<ul style="list-style-type: none"> <li>1 drop: persistent purple colour</li> <li>2 drops: persistent purple colour</li> <li>No further changes with additional drops or over time</li> </ul>

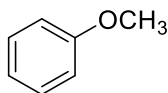
Possible structures (circle 'yes' or 'no'; 'yes' = the structure fits with the test results)



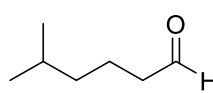
yes / no



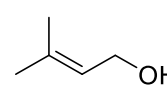
yes / no



yes / no



yes / no



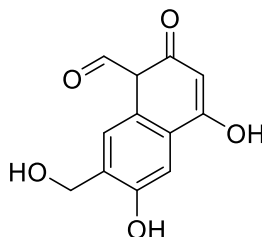
yes / no

- 7) Indicate whether the following statements are TRUE or FALSE: (5 points)

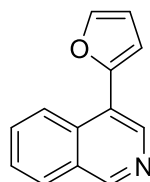
TRUE / FALSE	The refractive index of a vacuum is 1.0.
TRUE / FALSE	Refractive indices increase with increasing temperature.
TRUE / FALSE	Lidocaine, the final product made in Experiment 4, is water soluble. Hint: Consider the reaction/purification procedures to evaluate this statement.
TRUE / FALSE	Sodium acetate is used in Experiment 4 to trap the HCl produced during the amide-forming step.
TRUE / FALSE	In Experiment 4, excess diethylamine is removed from the reaction mixture by washing the organic layer with water.

**Short Answer Questions: (21 points total)**

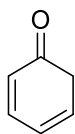
- 8) The structure below contains five carbon-oxygen bonds. Place a star next to the longest CO bond and circle the shortest CO bond. (2 points)



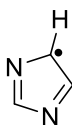
- 9) The structure below contains three aromatic rings. Place a star inside the ring which is most reactive toward electrophiles, and circle the ring which is most reactive toward nucleophiles. (2 points)



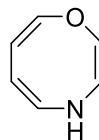
- 10) Indicate whether the following compounds are aromatic (A), anti-aromatic (AA) or non-aromatic (NA). Assume all atoms in the rings are planar. (4 points)



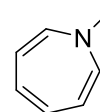
A / AA / NA



A / AA / NA

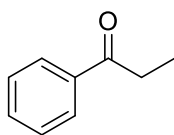


A / AA / NA

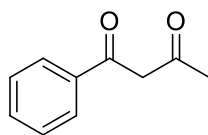


A / AA / NA

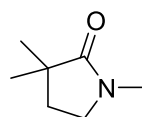
- 11) Below are five carbonyl compounds with varying reactivity. Consider their structures and answer the questions which follow. (4 points)



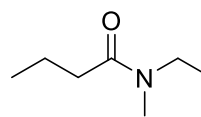
**A**



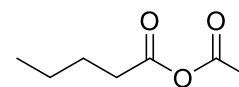
**B**



**C**



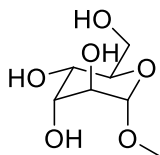
**D**



**E**

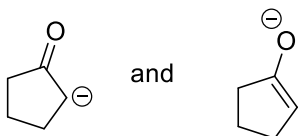
- Which compound has the lowest pKa? \_\_\_\_\_
- Which compound has the highest pKa? \_\_\_\_\_
- Which compound is the most reactive towards nucleophiles? \_\_\_\_\_
- Which compound is the least reactive towards nucleophiles? \_\_\_\_\_

- 12) Circle the anomeric carbon in the structure below and indicate whether it is in the alpha or beta configuration. (2 points)



- 13) Select a term from the list below to describe the relationship between the pairs of compounds which follow. If more than one term is possible, choose the one that is the most informative. For example, a pair of stereoisomers could also be described as isomers, but calling them stereoisomers says more about their relationship and is therefore a more informative term. (3 points)

Terms: *anomers*, *epimers*, *redox pair*, *resonance structures*, *stereoisomers*, *structural isomers*, *tautomers*



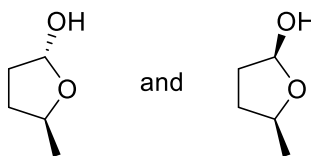
and



and

\_\_\_\_\_

\_\_\_\_\_



and

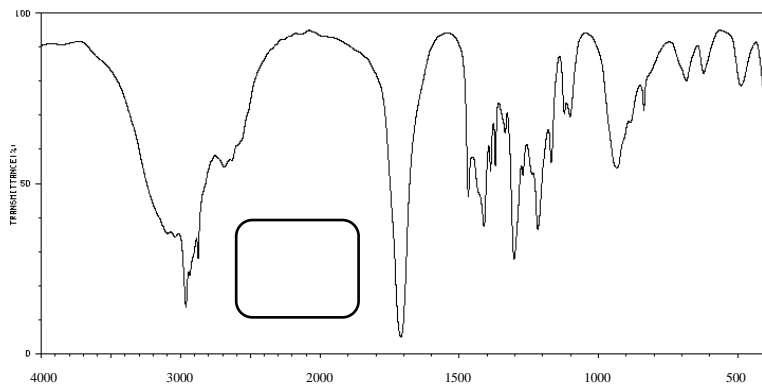
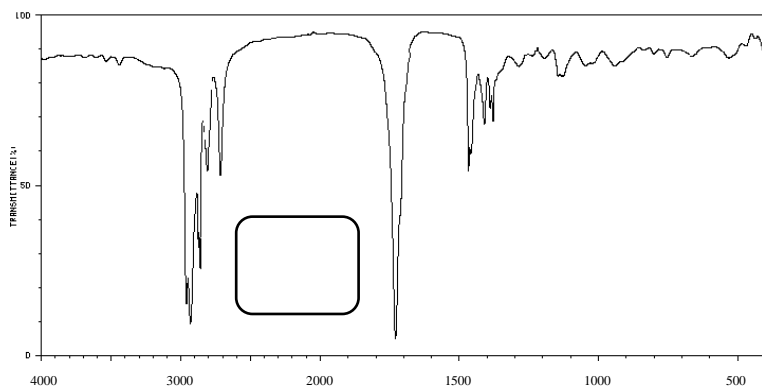
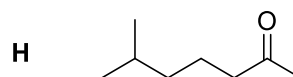
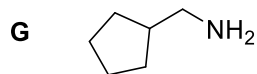
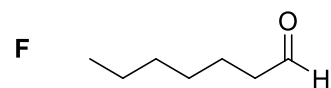
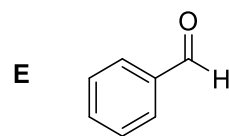
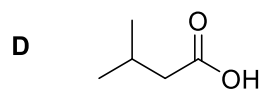
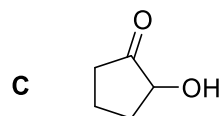
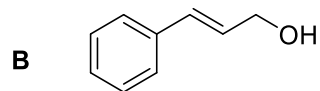
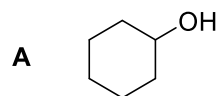
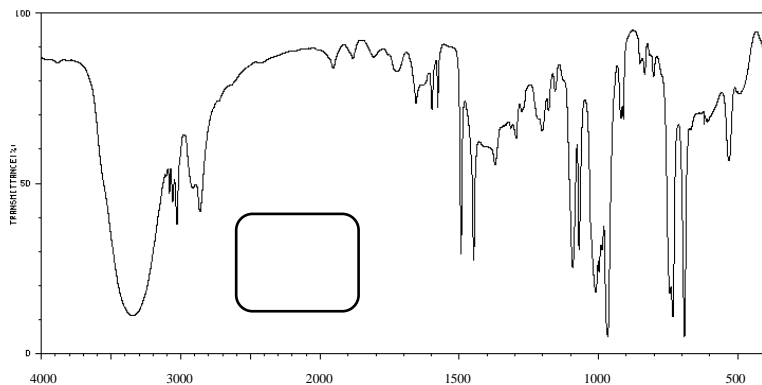
\_\_\_\_\_

- 14) Classify the following nucleophiles as either hard (H), soft (S), or intermediate (I). (4 points)

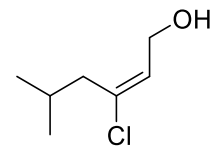
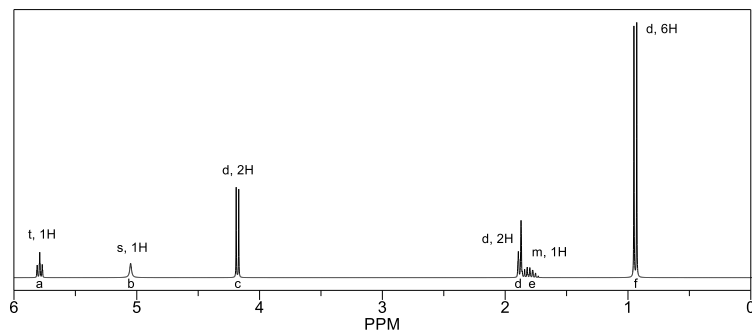
		KI	Ph <sub>3</sub> P
H / S / I	H / S / I	H / S / I	H / S / I

### Spectroscopy Questions (26 points total)

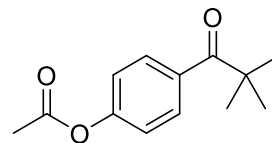
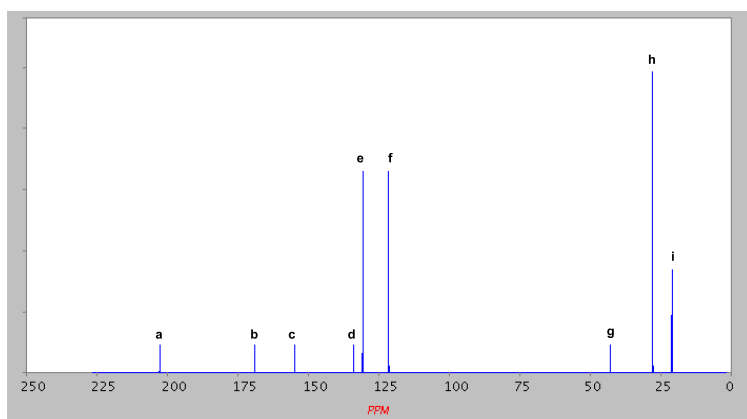
15) Assign a structure (A-H) to each IR spectrum by placing the correct letter in the provided boxes. (3 points)



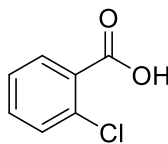
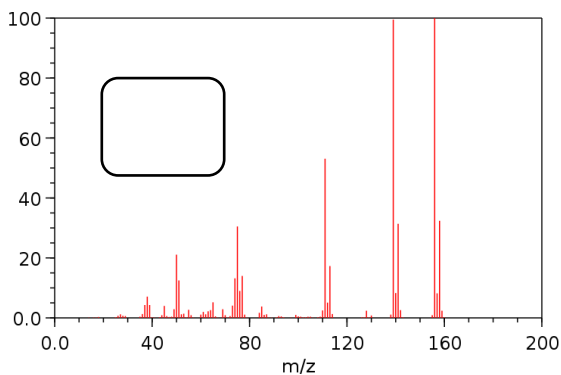
- 16) Assign the signals in the  $^1\text{H}$  NMR spectrum to the structure using the letters under the peaks. The splitting pattern and the relative integration are provided above each signal. (6 points)



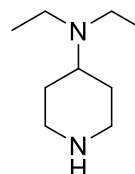
- 17) A compound and its  $^{13}\text{C}$  NMR spectrum are shown below. Use the letters above each signal to assign the peaks in the NMR to the carbon atoms in the compound. (9 points)



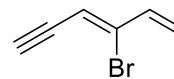
- 18) Assign the correct structure (A-C) to the structure below by placing the correct letter in the box. Note that all three compounds give a molecular ion peak at  $156\text{ m/z}$ . (3 points)



**A**



**B**



**C**

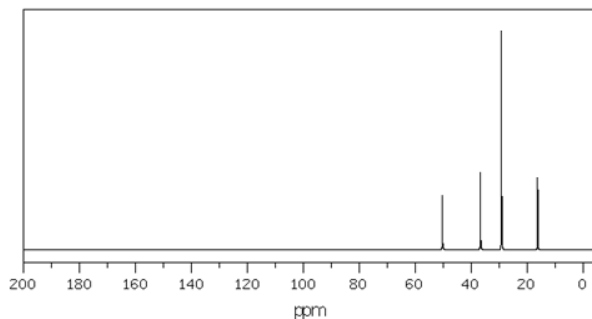
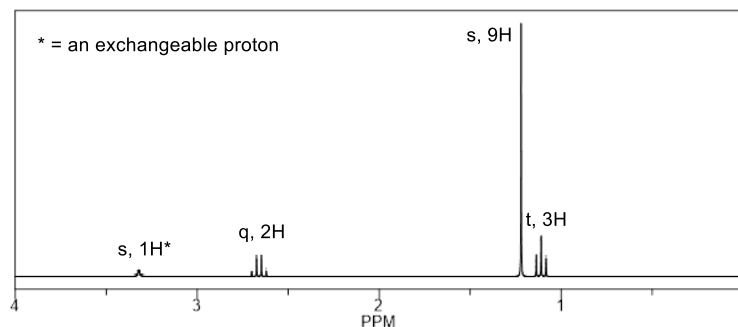
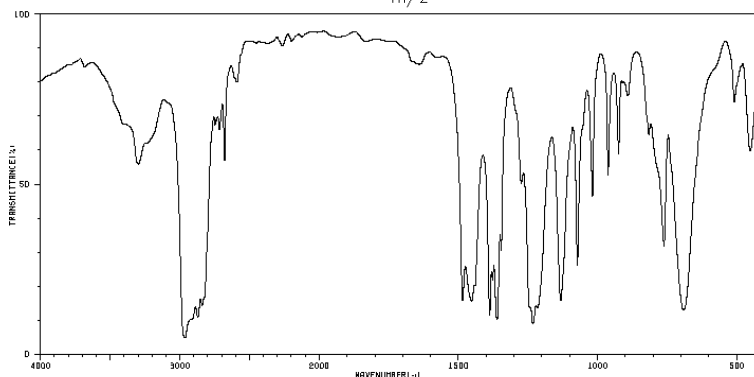
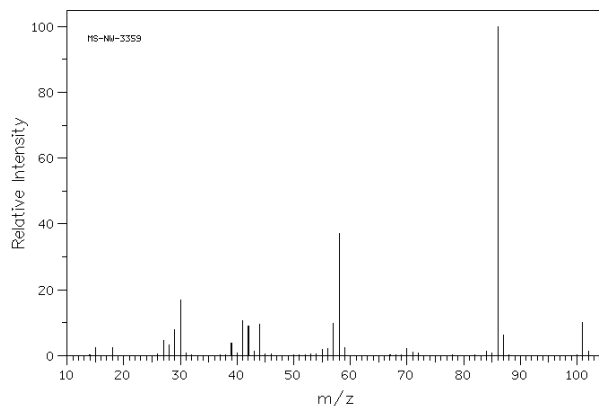
Explanation for selection (20 words or less – anything more will not be read!)

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- 19) A chemist finds an unlabelled vial in the lab containing a pale yellow liquid. In order to identify the liquid, the chemist collects the following spectral data. Use the data provided to suggest a reasonable structure for the unknown substance. You do not need to annotate the spectra – although you are welcome to do so for part marks in case your final structure is incorrect. (5 points)

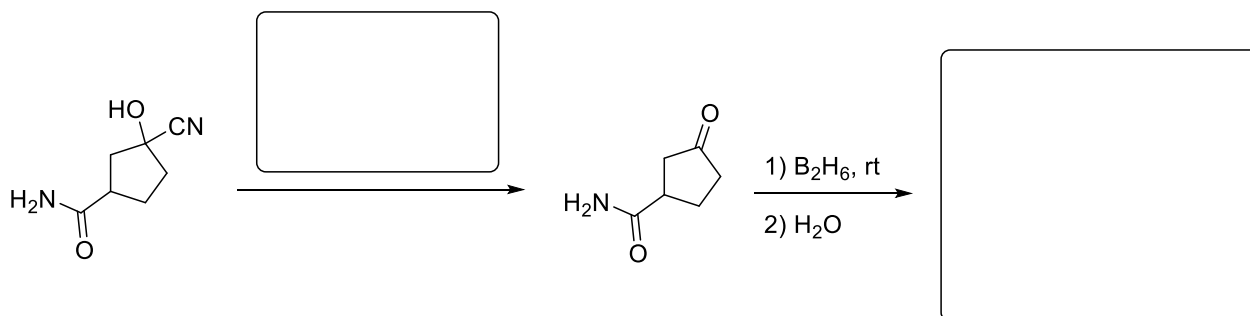
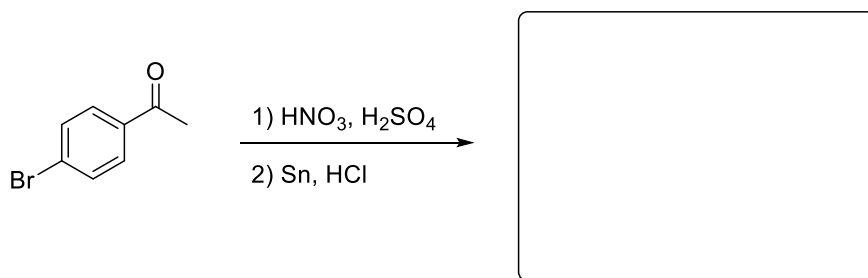
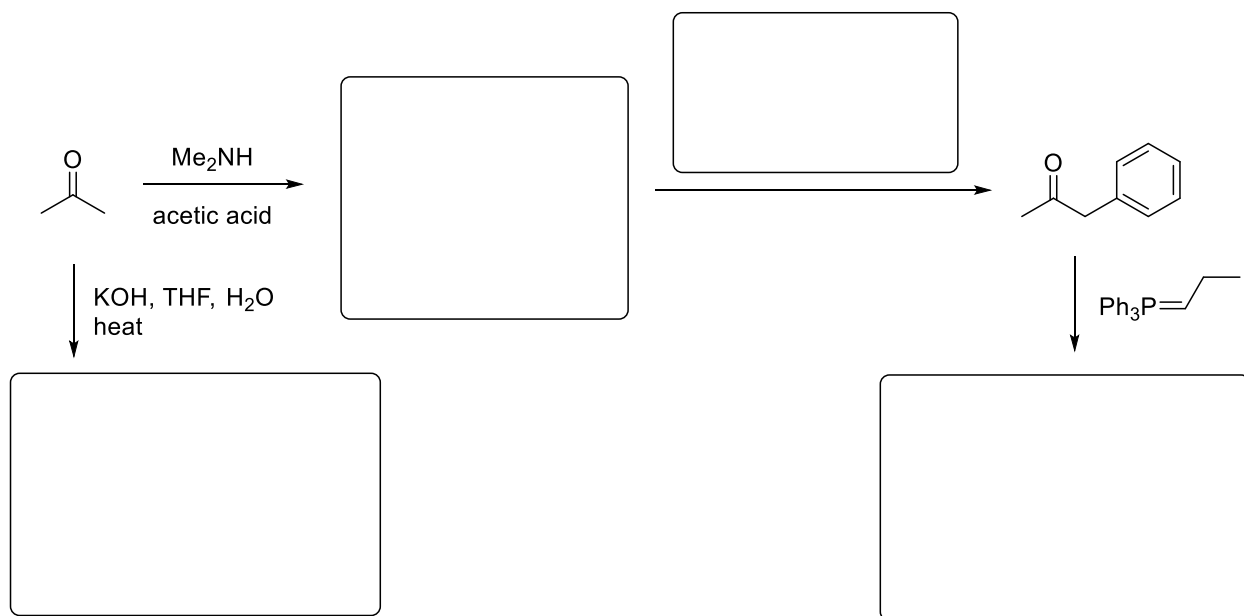


Proposed Structure:

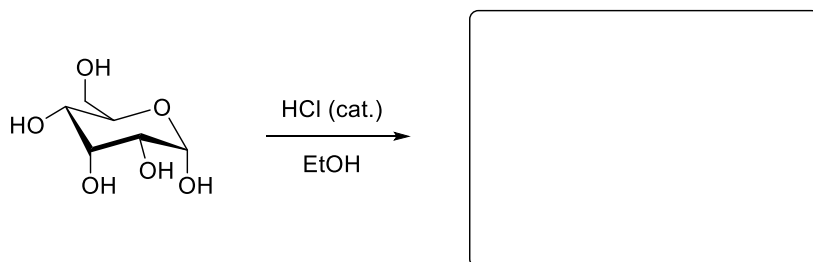
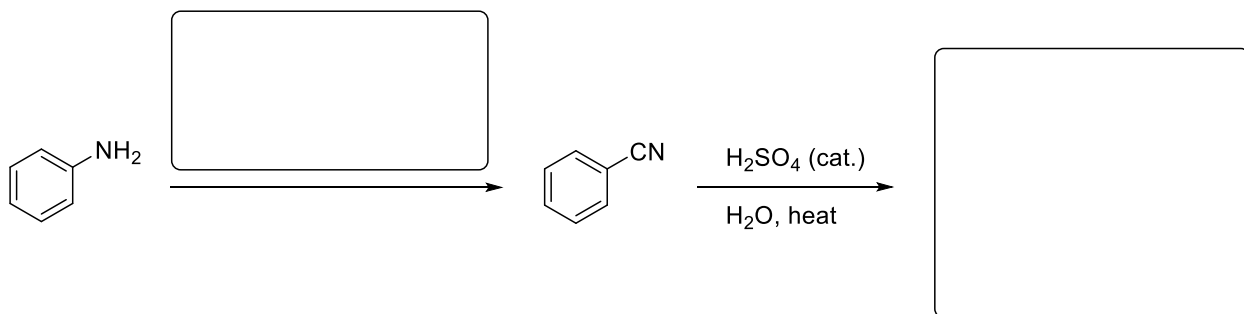
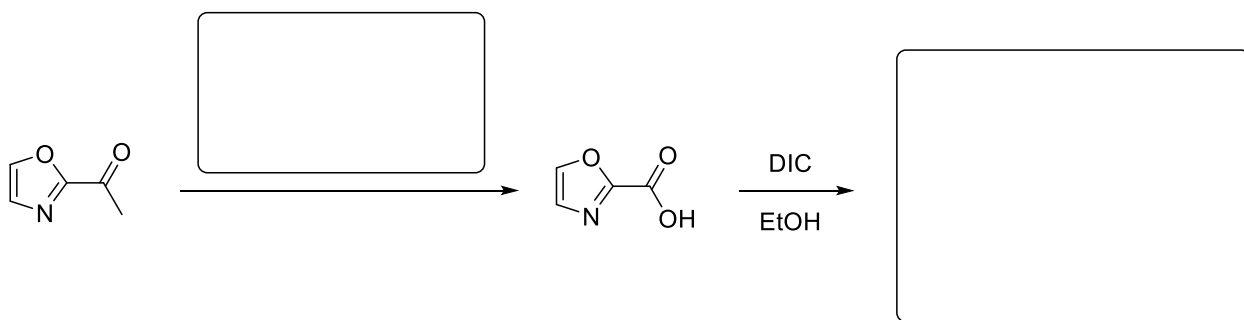
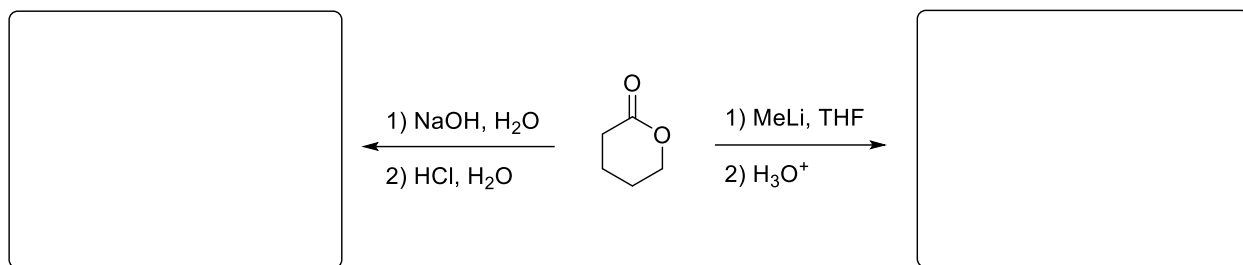


**Products and Reagents (45 points total)**

20) Provide the missing reagents and/or products for the reactions below. Note that unless otherwise indicated, only the major product is required. Most boxes are worth 2 points; however, some are worth either 1 or 3 points.



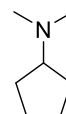
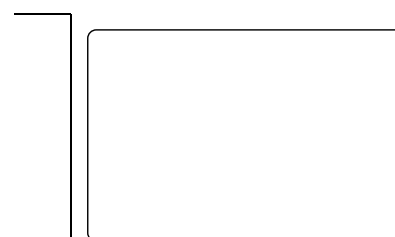
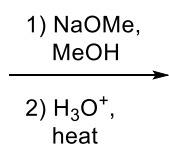
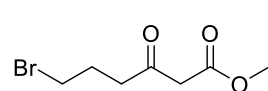
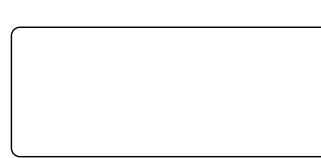
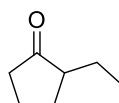
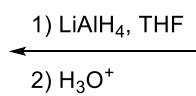


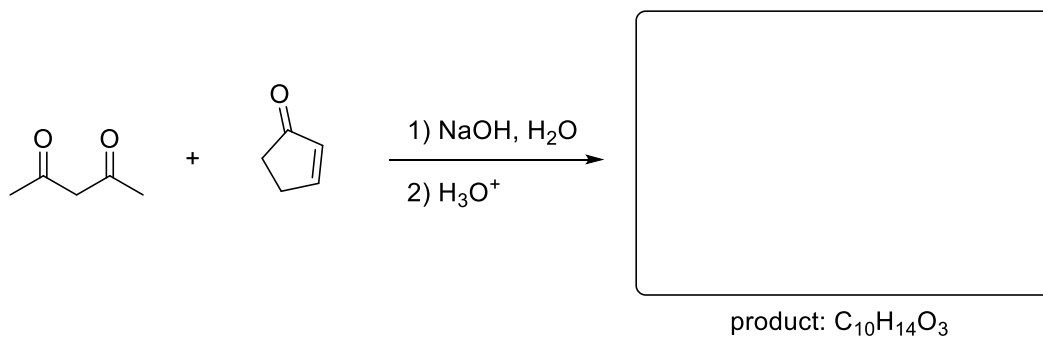
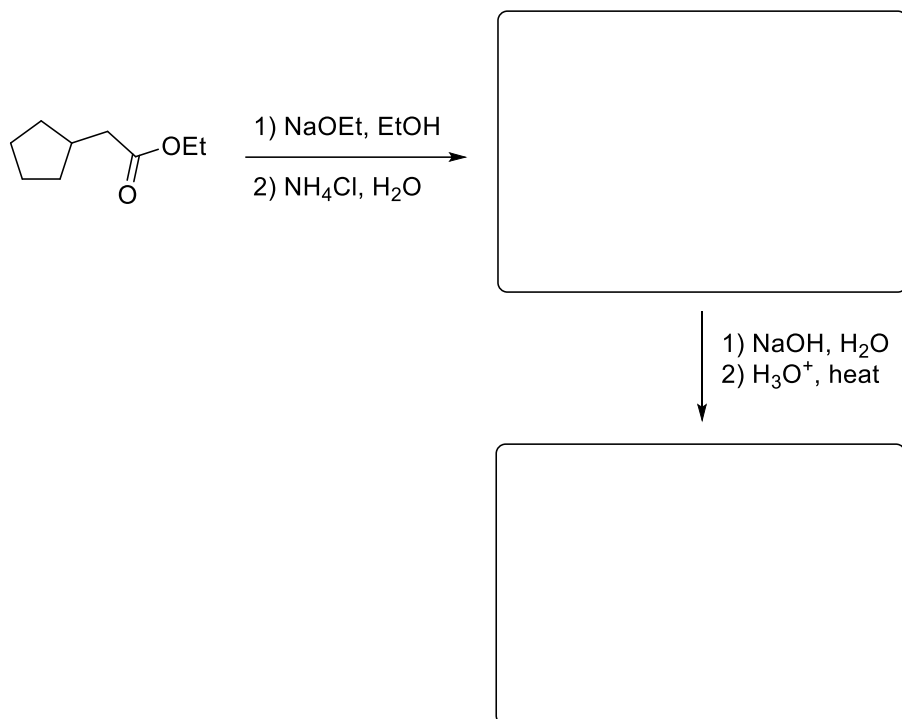
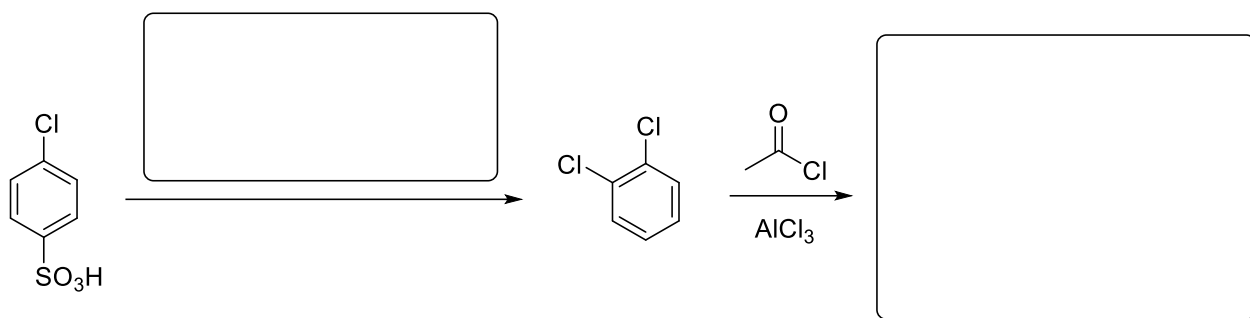




(draw all three products formed)

+

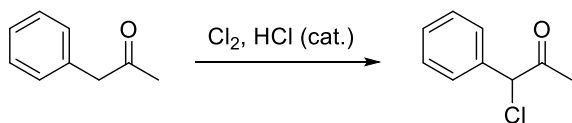




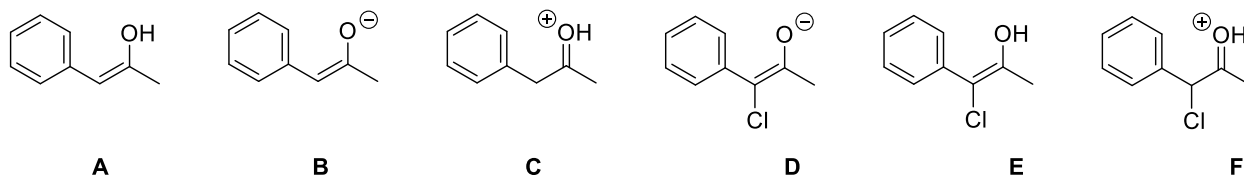
## Reaction Mechanisms (23 points total)

21) For each of the reactions below, decide which intermediates are involved in the reaction mechanism and place them in the correct order using the boxes provided (6 points)

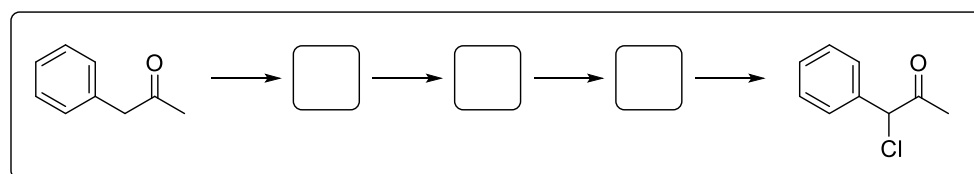
Reaction A:



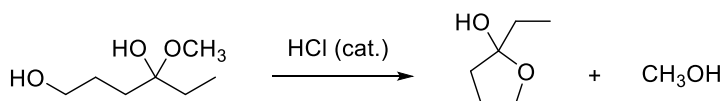
Possible Intermediates:



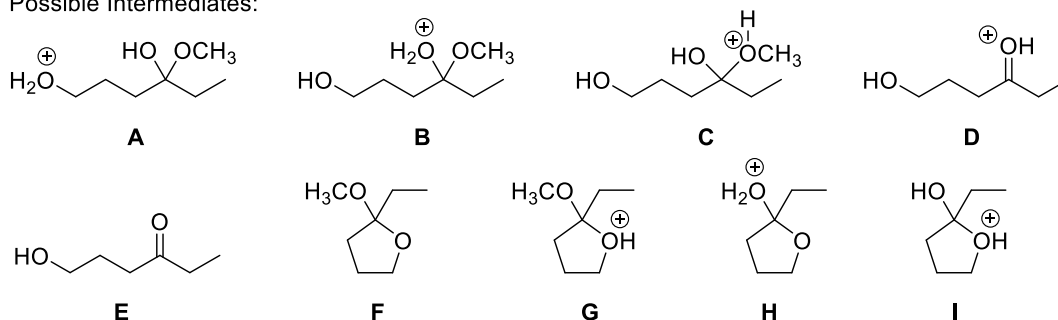
Mechanism:



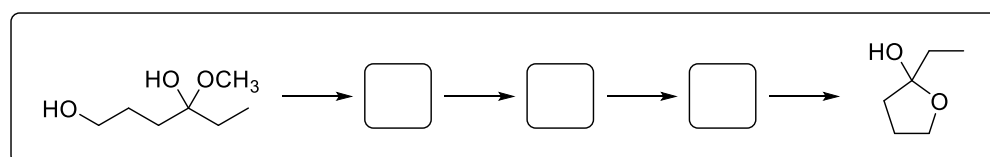
Reaction B:



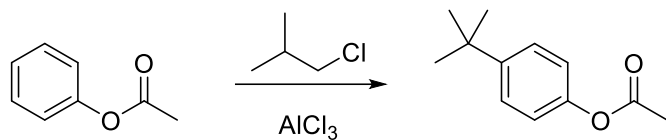
Possible Intermediates:



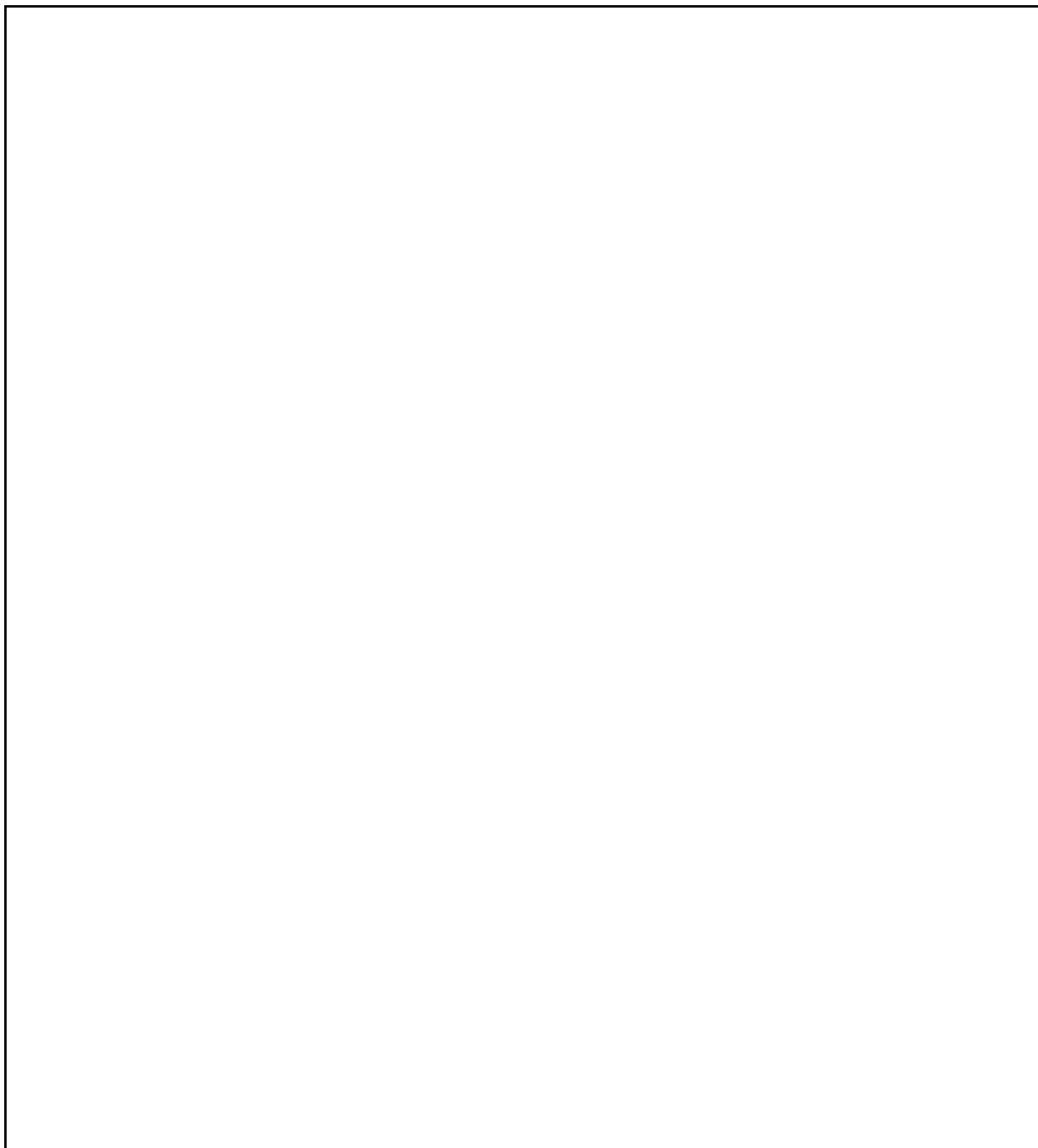
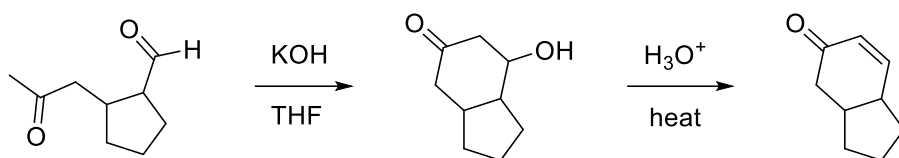
Mechanism:



22) Provide a detailed stepwise mechanism for all steps of the following reaction. Note that you do NOT need to show resonance contributors for any of the intermediates. (7 points)

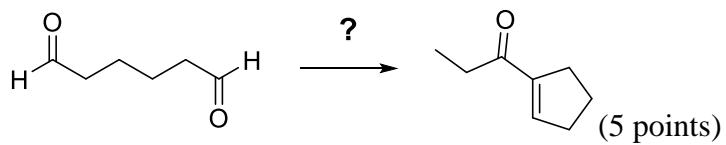
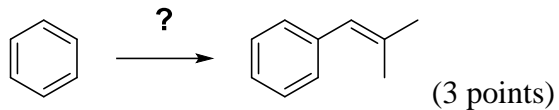


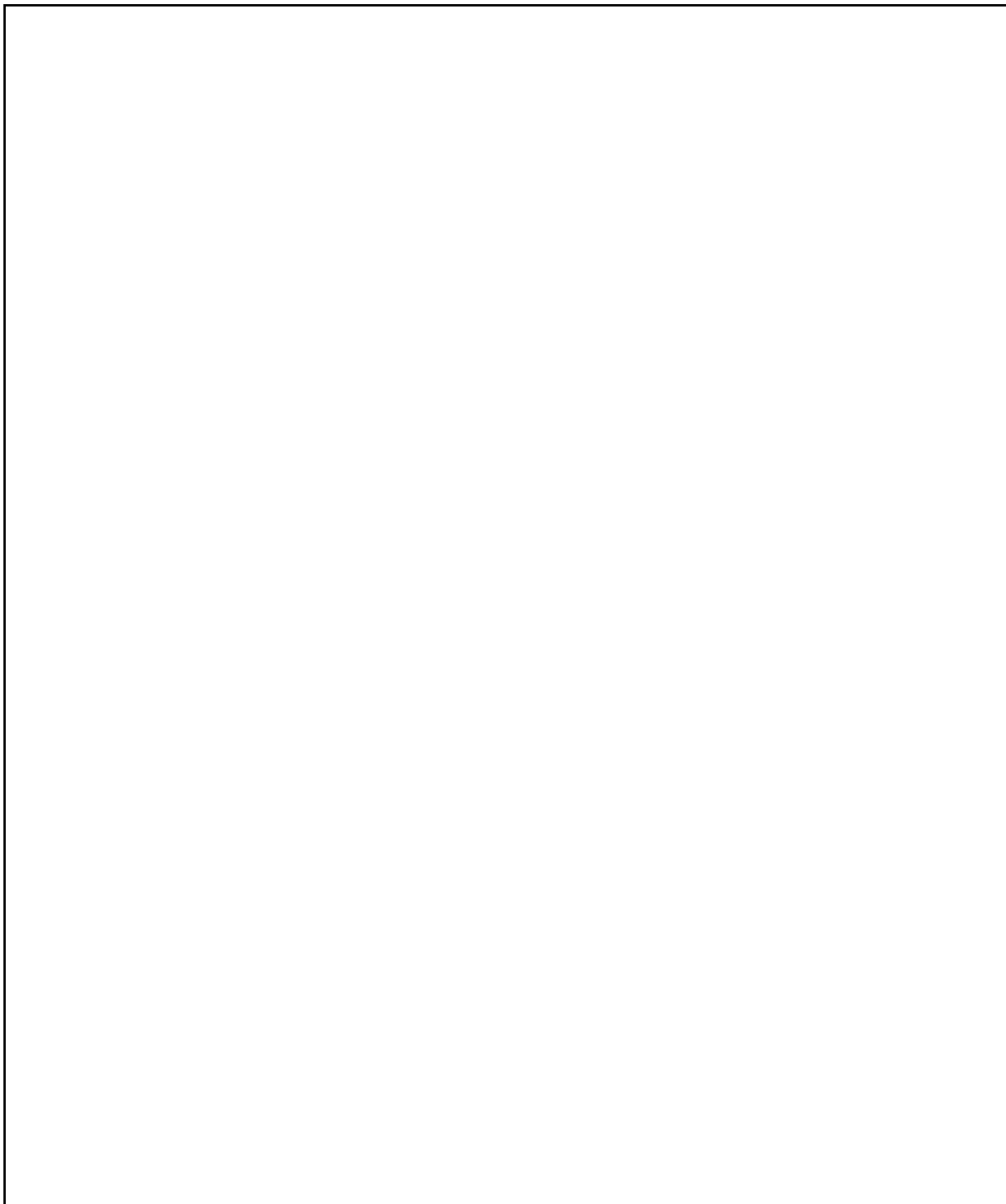
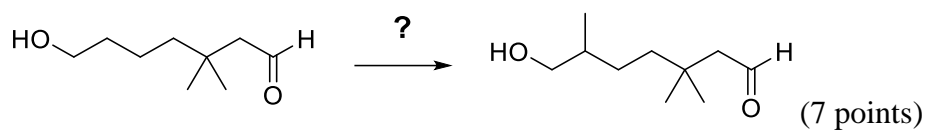
- 23) Provide a detailed stepwise mechanism for both steps of the following reaction sequence. Note that you do NOT need to show resonance contributors for any of the intermediates. (10 points)



**Multistep syntheses (15 points total)**

- 24) Suggest a series of reagents that could be used to carry out the following transformations. You do NOT need to include any curved arrow mechanisms or retrosynthetic planning; however, you must show the intermediate products formed between reaction steps.





END OF EXAM!!