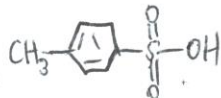
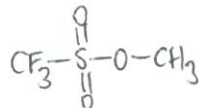


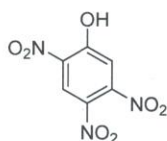
1. a) Draw the structure of *p*-toluenesulfonic acid (1 point)



- b) Draw the structure of methyl trifluoromethanesulfonate (1 point)



- c) Name the following compound. (1 point)



2,4,5-trinitrophenol

- d) Name the following compound. (1 point)



2-chlorobuta-1,3-diene

2. For each anion/cation, indicate if the charge can be delocalized and stabilized by resonance. If it can, write "Yes" below the structure; if not, write "No" below the structure. (14 points)

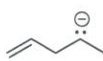
①  
each



No



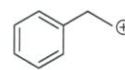
Yes



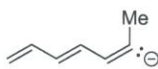
No



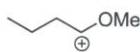
No



No



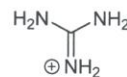
No



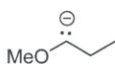
Yes



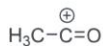
Yes



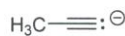
Yes



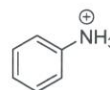
No



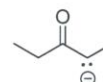
Yes



No

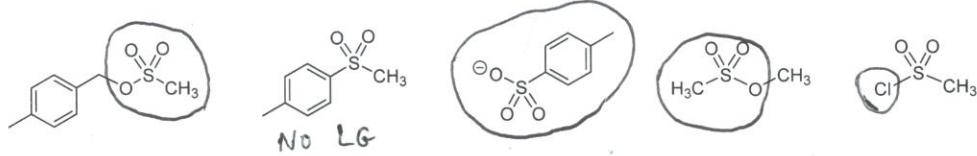


No

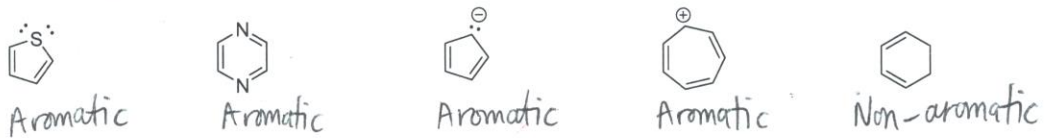


Yes

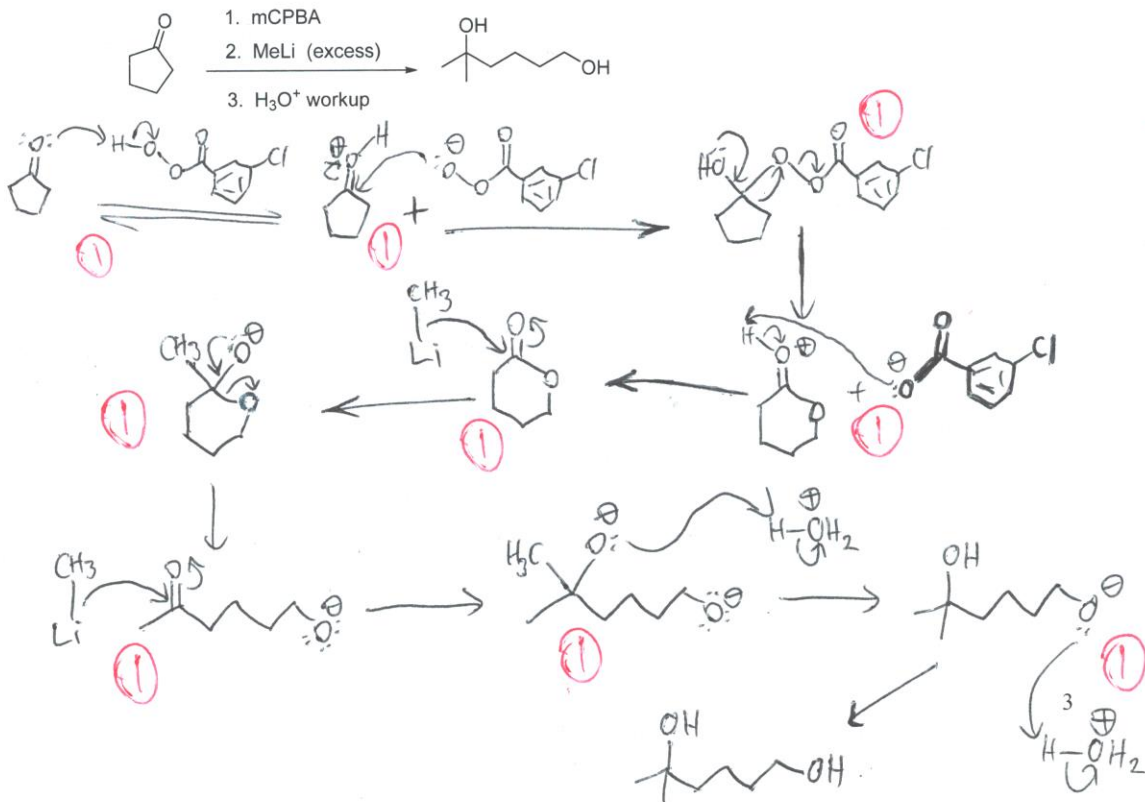
3. For each structure, circle the leaving group (LG). The LG can be part of the structure or the entire structure. If the structure is not a LG or does not contain a LG, write "No LG" below it. (9 points) ① each



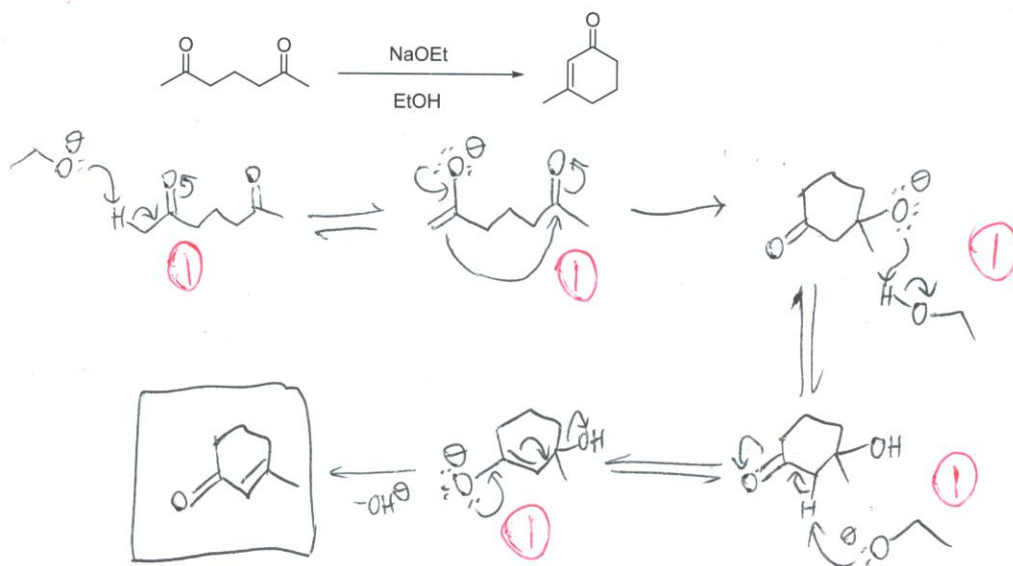
4. Indicate whether each of the following is: aromatic, anti-aromatic, or non-aromatic. (5 points) ① each



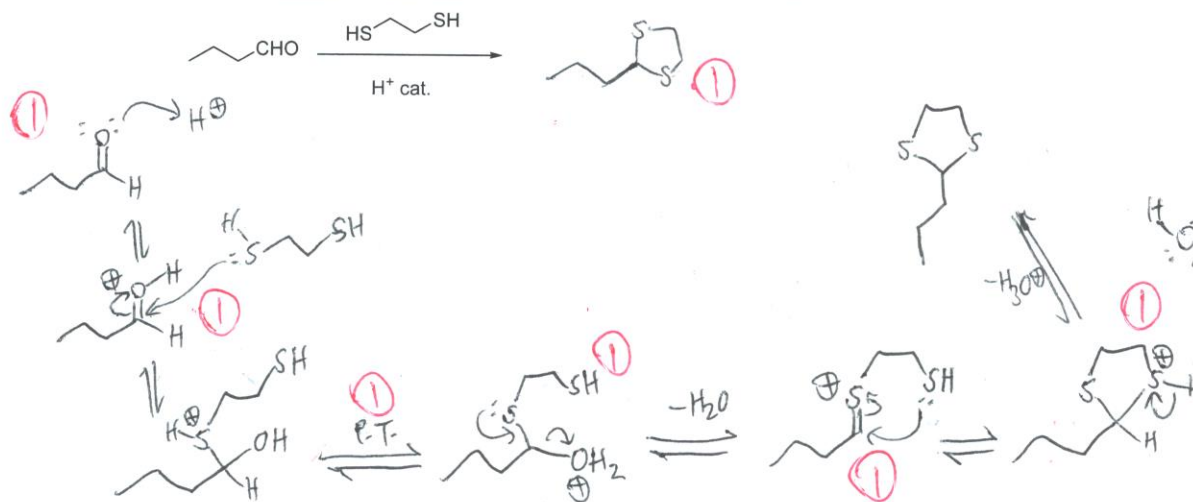
5. Give a mechanism for every step in the following reaction sequence: (9 points)



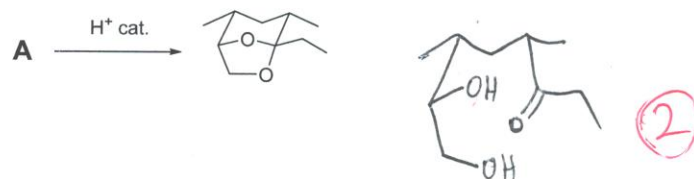
6. Provide a mechanism for the following reaction: (5 points)



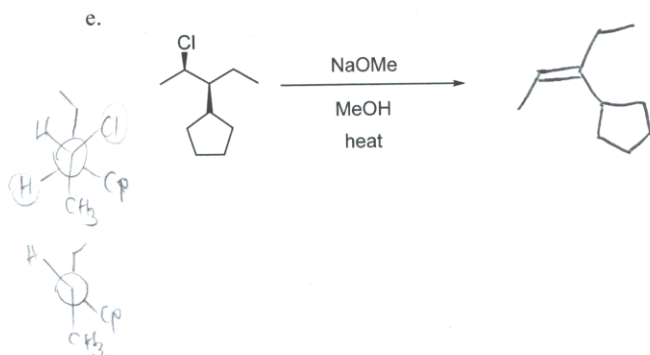
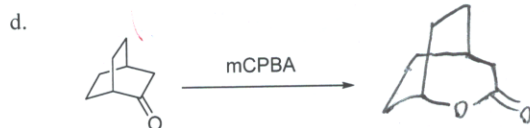
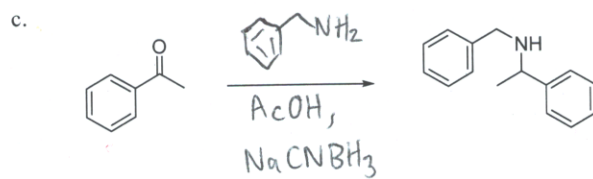
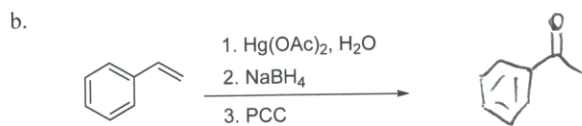
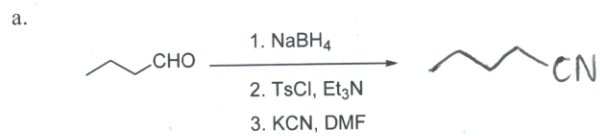
7. Provide a mechanism and product for the following reaction: (7 points)



8. Draw the structure of Compound A: (2 points)



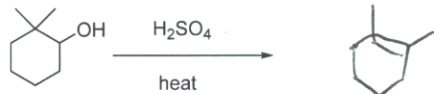
9. Give the missing reagents or the major product of the following reactions: (10 points – 2 each)



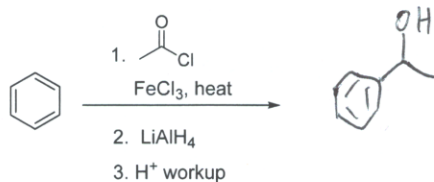


12. Give the missing reagents or the major product of the following reactions: (10 points – 2 each)

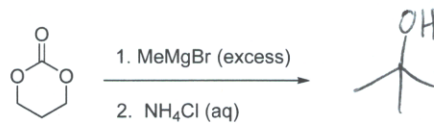
a.



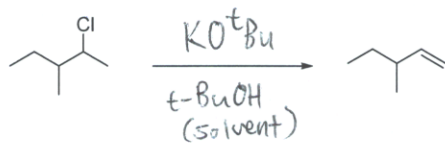
b.



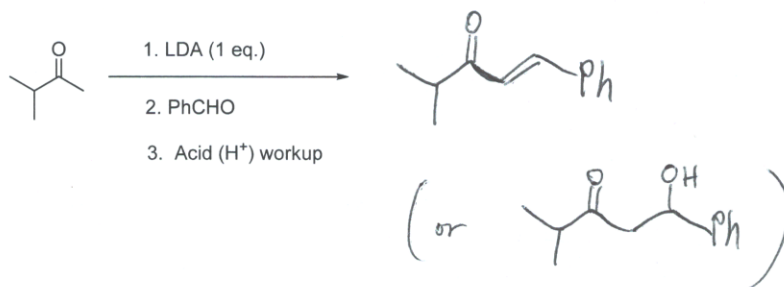
c.



d.



e.



13. How many unique proton signals would be expected in the  $^1\text{H}$  NMR spectrum of the following molecules? (3 points) - ① each

a.



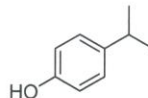
1

b.



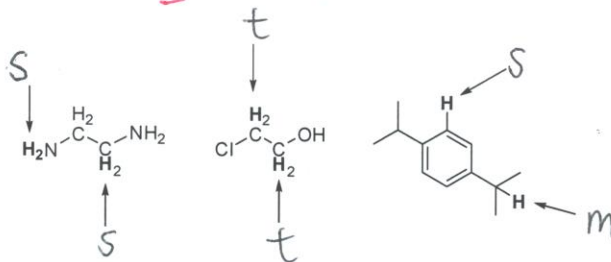
4

c.

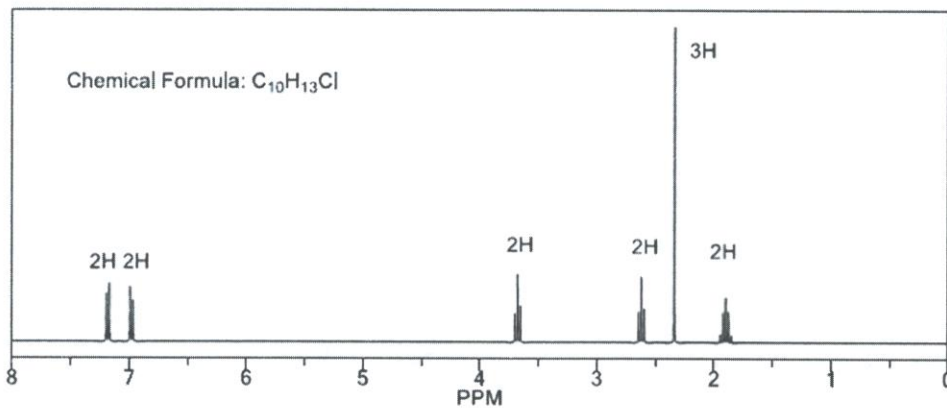


5

14. Indicate **s**, **d**, **t**, **q**, or **m** (i.e. singlet, doublet, triplet, quartet, multiplet) expected on the  $^1\text{H}$  NMR spectrum for the protons below: (6 points) - ① each



15. A compound  $\text{C}_{10}\text{H}_{13}\text{Cl}$  has the following  $^1\text{H}$  NMR spectrum. Write down the pertinent comments / ideas about each NMR signal and provide the structure of the unknown.



Calculate the degree of unsaturation (2 points):

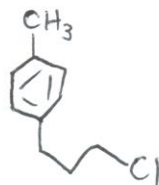
$$\text{DU} = \frac{2(10) + 2 + 0 - 13 - 1}{2} \quad \text{①}$$

$$= \underline{\underline{4}} \quad \text{①}$$

| Signal | $\delta$ | Integration | Multiplicity | Comments / ideas   |
|--------|----------|-------------|--------------|--|
| A      | 7.2      | 2H          | d            | - Next to one non-equiv. H<br>- Aromatic H   |
| B      | 7.0      | 2H          | d            | - Next to one non-equiv. H<br>- Aromatic H   |
| C      | 3.7      | 2H          | t            | - Next to two non-equiv. H's<br>- Next to electronegative atom (Cl)                    |
| D      | 2.6      | 2H          | t            | - Next to two non-equiv. H's<br>- CH <sub>2</sub> next to benzene ring (i.e. benzylic) |
| E      | 2.4      | 3H          | s            | - CH <sub>3</sub> without non-equiv. H neighbors<br>- Benzylic H's                     |
| F      | 1.9      | 2H          | m            | CH <sub>2</sub> next to many non-equiv. H's (i.e. 4)                                   |

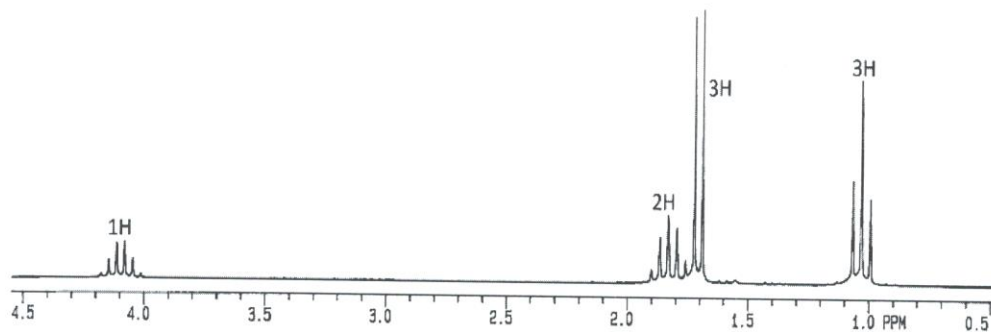
Structure of unknown:  
(2 points)

(2)

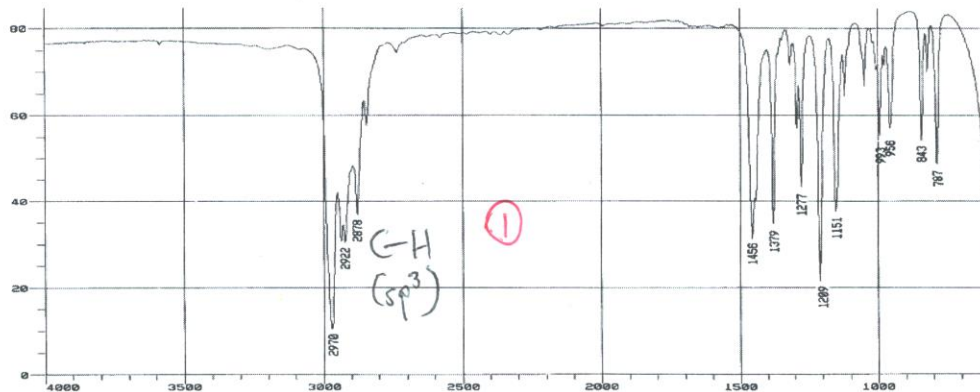


(11 points)

16. A compound has the formula  $C_4H_9Br$ . Its  $^1H$  NMR and IR spectra are shown below:



(9)



a. Calculate the degree of unsaturation for the compound. (2 points)

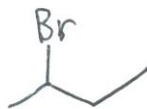
$$DU = \frac{2(4) + 2 - 9 - 1}{2} = 0 \quad (2)$$

b. Identify the key absorbance(s) in the IR spectrum. Write the functional group or bond next to the relevant peak on the spectrum above. (1 point)

c. Write down the pertinent comments / ideas about each NMR signal. (5 points)

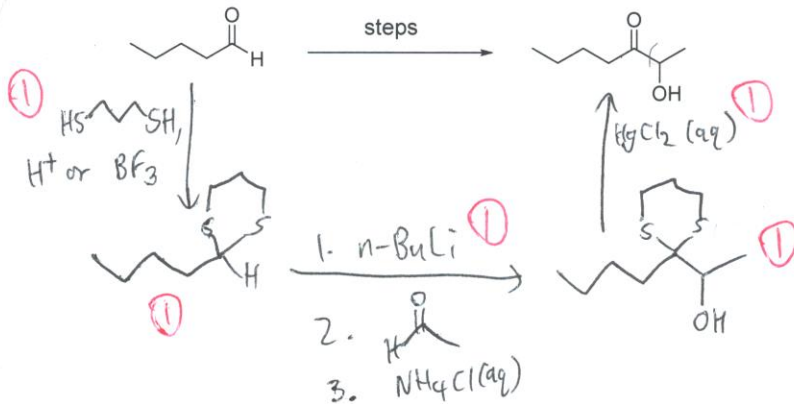
| Signal | $\delta$ | Integration | Multiplicity | Comments / ideas   |
|--------|----------|-------------|--------------|--|
| A      | 4.1      | 1H          | m            | - CH next to many non-equiv. H's (1)<br>- CH next to electronegative atom. (1) |
| B      | 1.8      | 2H          | m            | - CH <sub>2</sub> next to many non-equiv. H's (1)                              |
| C      | 1.7      | 3H          | d            | - CH <sub>3</sub> group next to a -CH (1)                                      |
| D      | 1.0      | 3H          | t            | - CH <sub>3</sub> next to two non-equiv. H's (1)                               |

d. Using the info above (formula, IR, NMR), draw the structure of the unknown. (2 points)

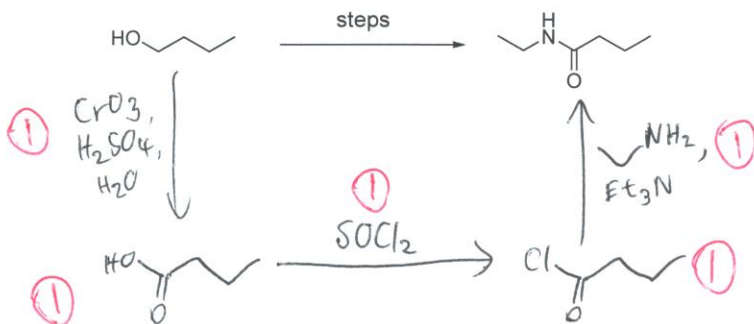


17. Propose a synthesis of the following compounds. Show all required reagents/solvents and intermediates. Retrosynthesis and mechanisms need not be shown. (15 points – 5 each)

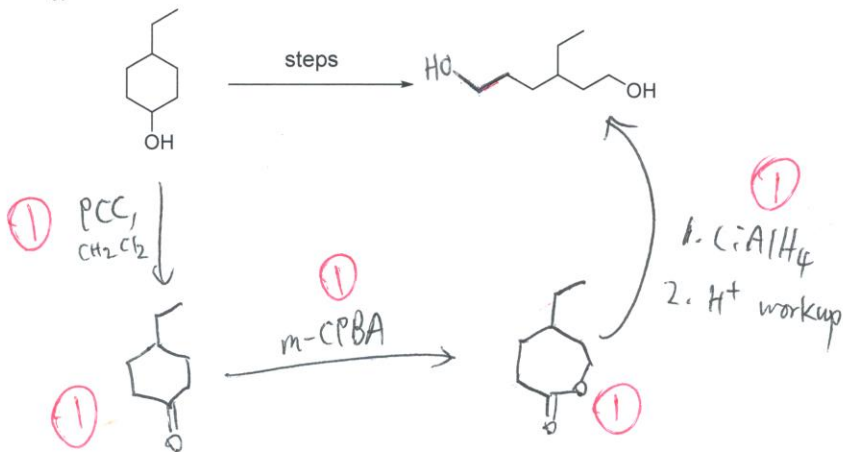
a.



b.



c.



End of exam