Spring 2023 **Chemistry 2500 Final Exam** ____/97 marks

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam until after 7:30pm Mountain Time on Sunday, April 16th, 2023. I understand that breaking this agreement would constitute academic misconduct. The minimum penalty would be a mark of 0/97 on this exam.

Signature: _____ Date: _____

KEY

1) Please read the test carefully before starting. It has 14 pages of questions including this cover page and (almost) three blank pages.
2) The exam is worth a total of 97 marks. Most of these marks are for explanation/showing your work rather than for reaching the correct answer. Explain all your answers fully using diagrams where appropriate (a picture really is worth a thousand words!).
3) You may use a molecular model kit and ruler. You may not have written materials in your model kit.
4) No calculators allowed.
5) **DO NOT WRITE ON ANY QR CODE!!!** Work on pages without a QR code will not be graded.
6) If your work is not legible, it will be given a mark of zero. For full credit, explanations must be complete. In many cases, complete explanations include drawing relevant structures.
7) Marks will be deducted for incorrect information added to an otherwise correct answer.
8) You have 3 hours to complete this test.

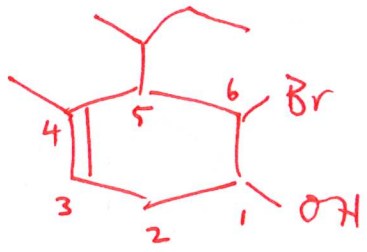
Question Breakdown

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Total
/4	/4	/10	/5	/8	/5	/4	/5	/8	/5	/3	/10	/6	/10	/5	/4	/1	/97

1. **[4 marks]**

(a) The following molecule has been named incorrectly; however, the structure of the molecule can still be deduced. Draw the structure of the molecule using proper line-bond format.

1-bromo-2-*sec*-butyl-3-methyl-6-hydroxycyclohex-3-ene

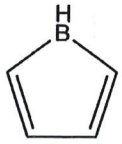


(b) Based on the structure above, give the correct name of this molecule according to IUPAC rules.

6-bromo-5-sec-butyl-4-methylcyclohex-3-enol.

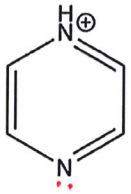
2. Predict whether the following molecules, as drawn, are aromatic, anti-aromatic, or non-aromatic. Hint: start by adding all missing lone pairs. **[4 marks]**

(a)



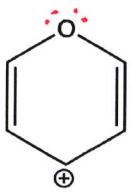
anti aromatic

(b)



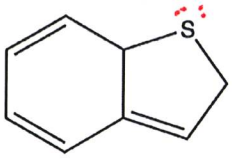
aromatic.

(c)



aromatic

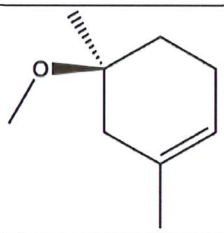
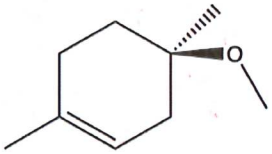
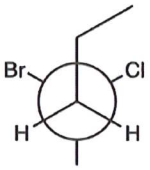
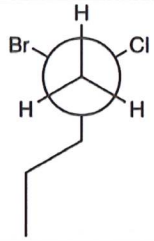
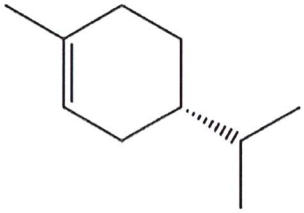
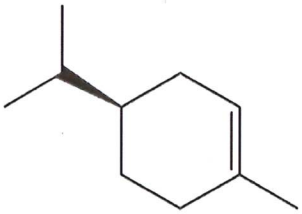
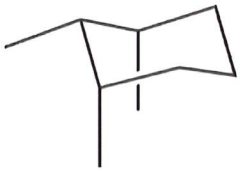
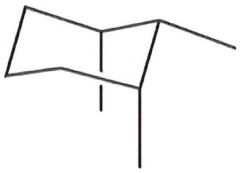
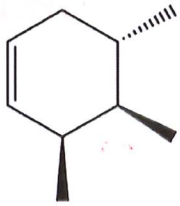
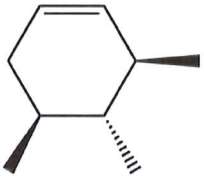
(d)



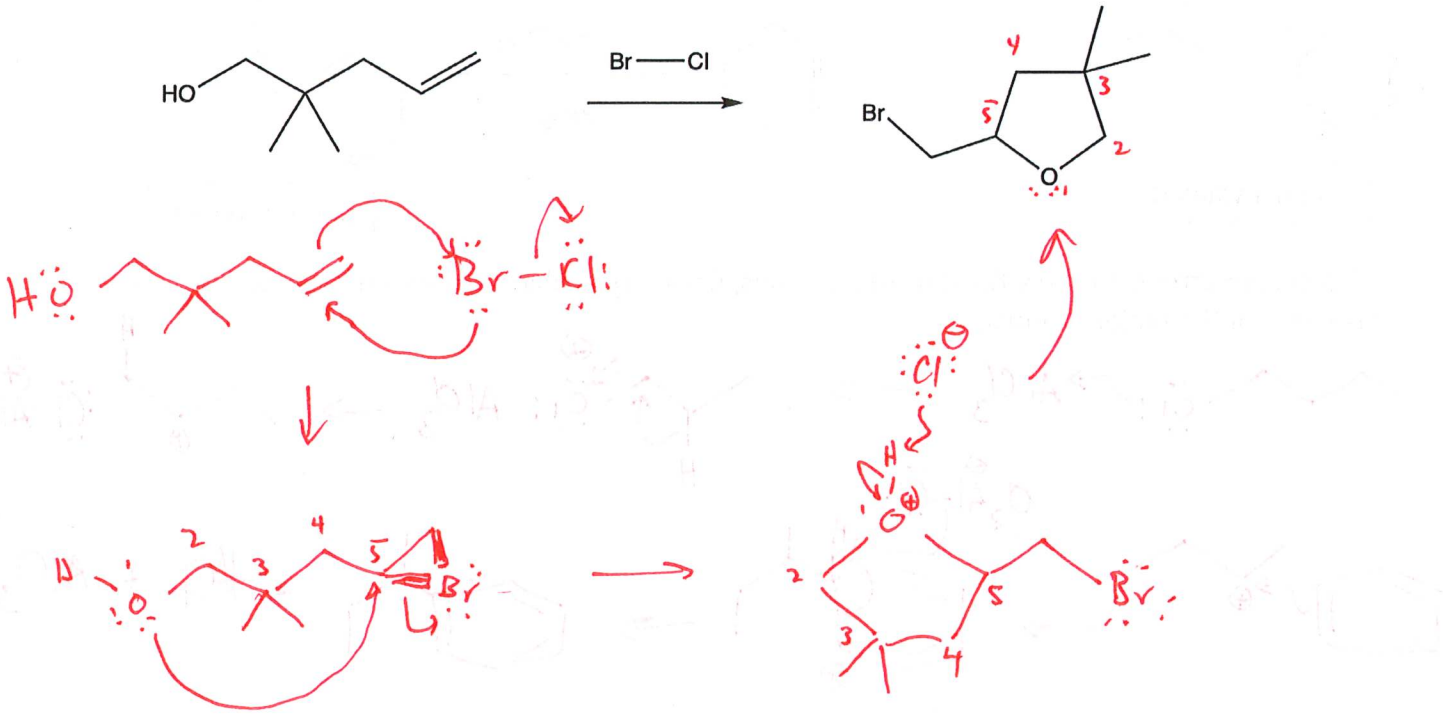
non-aromatic

3. Using the appropriate letter or letters, indicate the relationship(s) between the following pairs of molecules. If there is more than one relationship, provide all the letters that apply. *No explanation is necessary.* **[10 marks]**

A = stereoisomers
B = constitutional isomers
C = conformers
D = diastereomers
E = enantiomers
F = identical molecules
G = none of the above

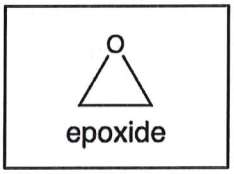
	relationship(s)
 and 	B
 and 	A, E
 and 	A, D
 and 	F
 and 	A, D

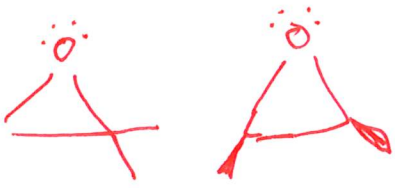
4. Using curved arrows to show the flow of electrons, draw a plausible mechanism for the following transformation. **[5 marks]**



5. (a) For the formula **C_4H_8O**, draw all possible *epoxide* isomers (constitutional isomers and stereoisomers). Epoxides are cyclic 3-membered ethers. All structures must be drawn in proper line-bond format and have 0 charges.

(b) Label each isomer as chiral or achiral. **[8 marks]**



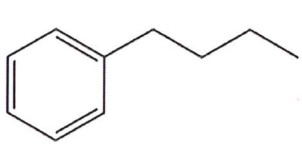


achiral.

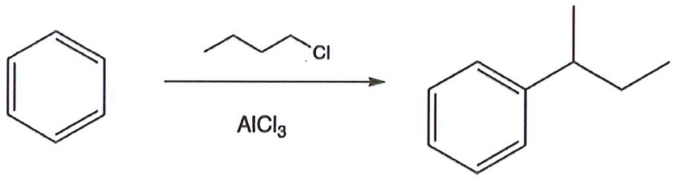


chiral

6. While working in the lab, Al Kane attempts to synthesize butylbenzene, however, he obtains a different compound as the major product: **[5 marks]**

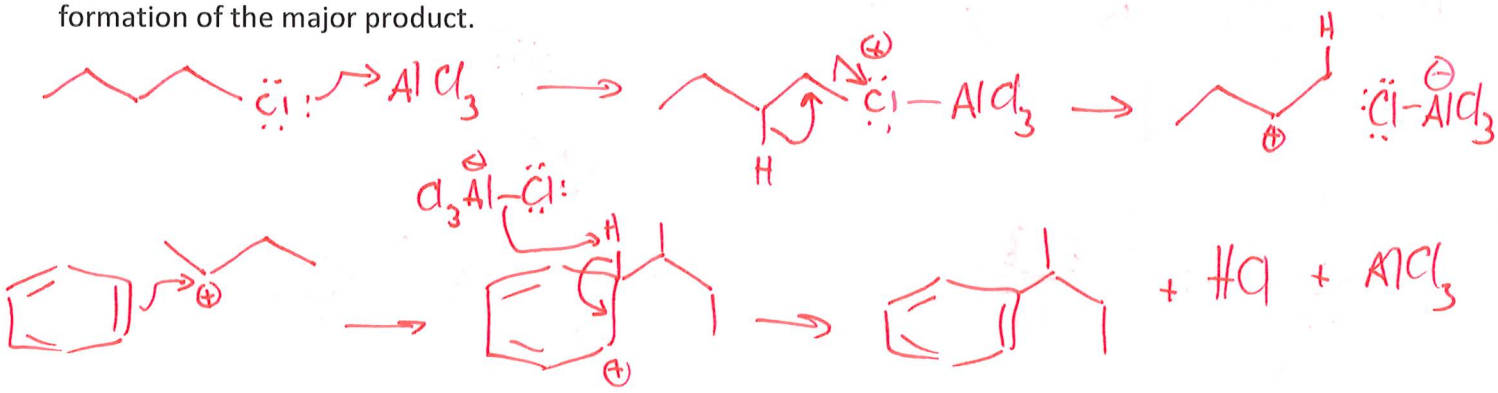


product wanted



major product

Using curved arrows to show the flow of electrons, draw a plausible mechanism that accounts for the formation of the major product.

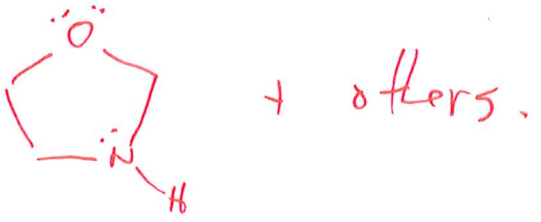


7. For the following question, your structures must be drawn in line-bond format, be valid Lewis structures, and contain NO charges. **[4 marks]**

(a) Draw an ***aromatic*** 5-membered ring. The ring must contain at least 1 nitrogen and 1 oxygen atom (the N and O atom must be part of the ring and not attached to it).

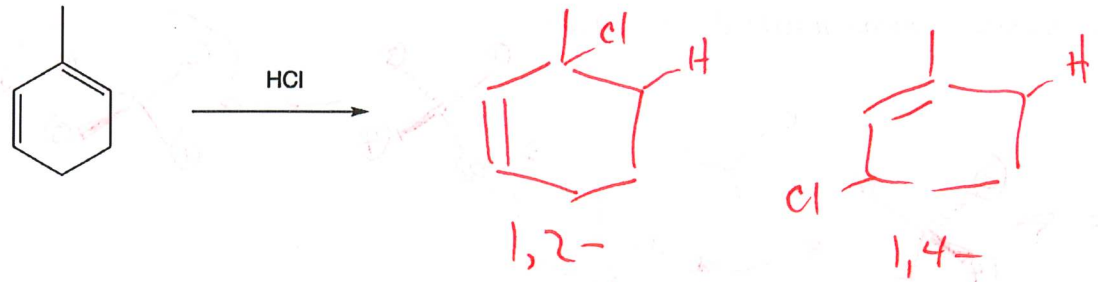


(b) Draw a ***non-aromatic*** 5-membered ring. The ring must contain 1 nitrogen and 1 oxygen atom (the N and O atom must be part of the ring and not attached to it).

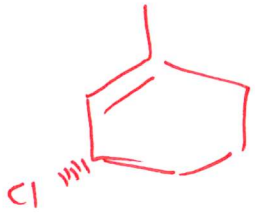


8. **[5 marks]**

(a) For the following reaction draw and label both the major 1,2- and 1,4- addition products:



(b) Draw the (*S*) enantiomer of the 1,4-addition product.



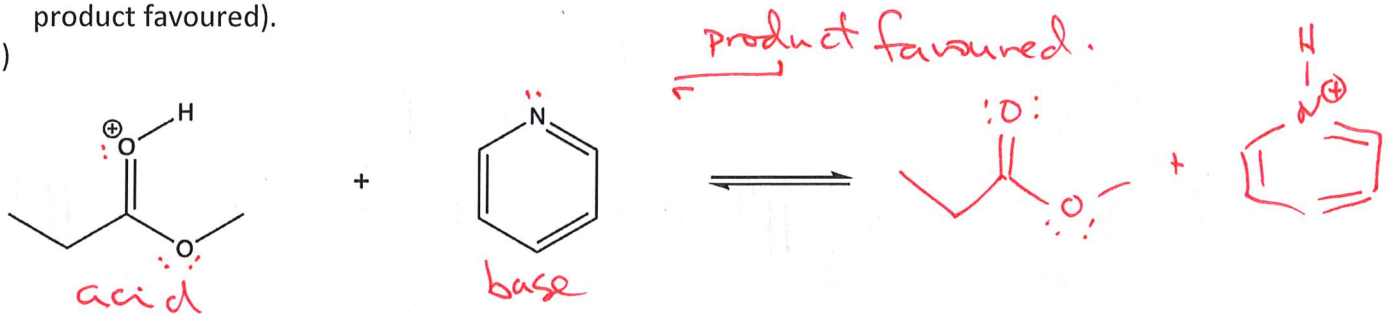
9. For each of the following proton transfer reactions: **[8 marks]**

(i) Add all missing lone pair electrons and identify the acid and base.

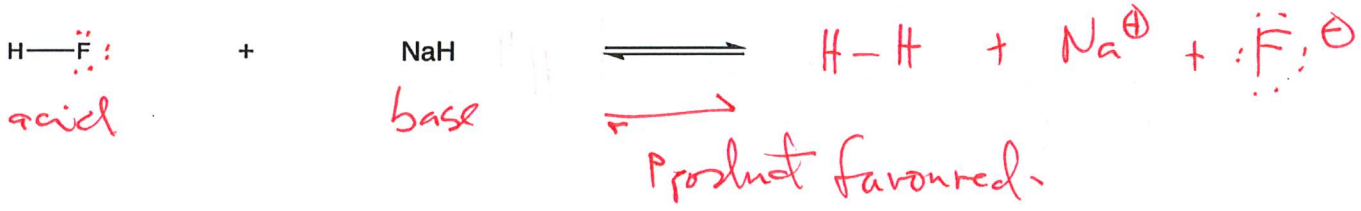
(ii) Draw the product(s) of each reaction in line-bond notation. Be sure to include all lone pairs and formal charges.

(iii) For each reaction, predict the position of the equilibrium (indicate whether the reaction is reactant or product favoured).

(a)

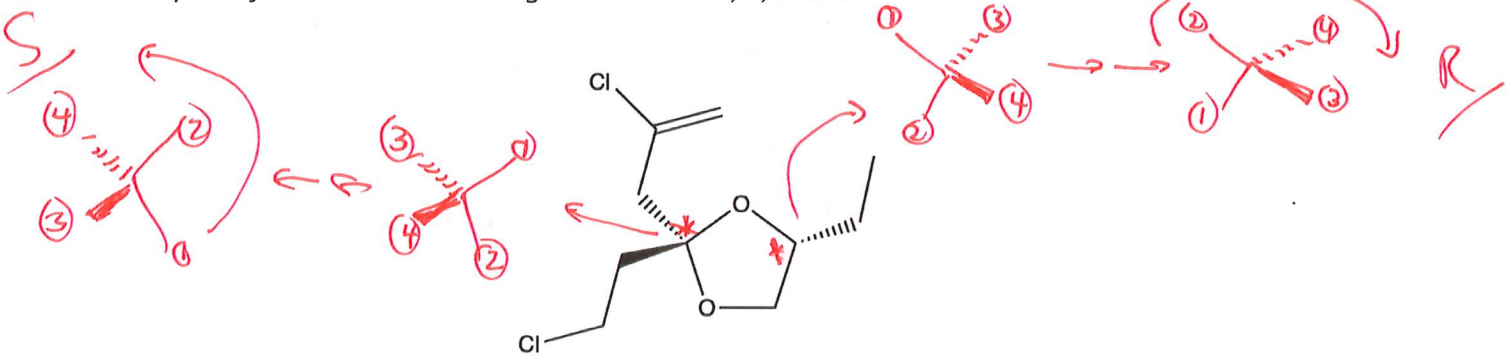


(b)

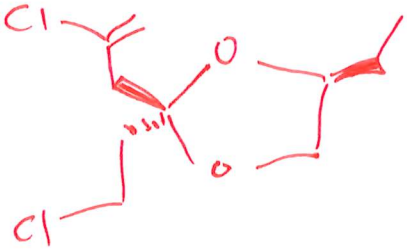


10. **[5 marks]**

(a) For the molecule below, where appropriate, assign the stereochemical configuration(s) as *E*, *Z*, *R* or *S*. *For full marks, you must show the priority numbers you used to assign each configuration and it must be clear what part of the molecule is being described as E, Z, R or S.*

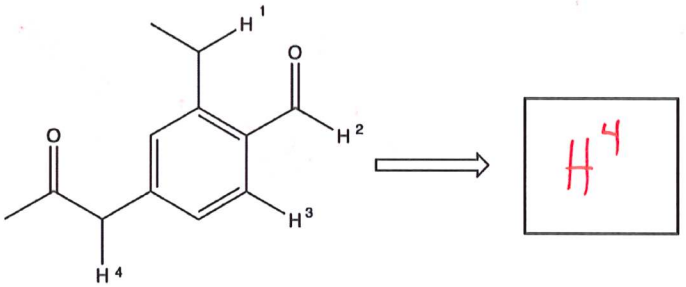


(b) Draw its enantiomer.

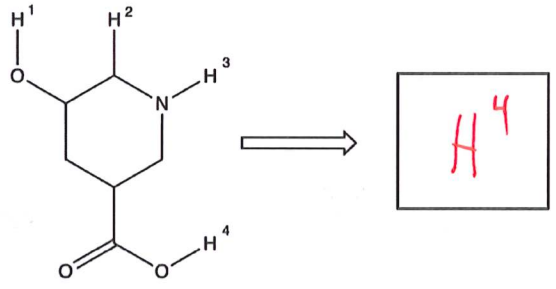


11. For each of the following molecules identify which of the highlighted H atoms (H^1, H^2, etc.) is most acidic in the box provided. **[3 marks]**

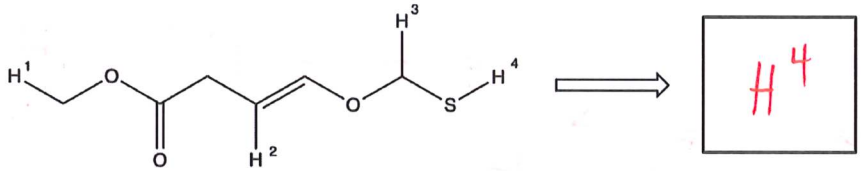
(a)



(b)

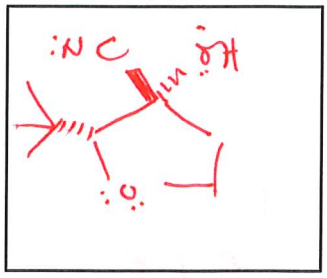


(c)

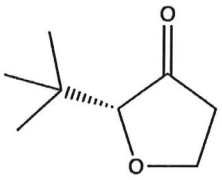


12. For the following reactions, fill in the missing starting materials, products, or reagents. Marks are given for correct connectivity, proper bond angles and, where appropriate, correct stereochemistry and regiochemistry. If more than one organic product is possible, draw only the major product. **[10 marks]**

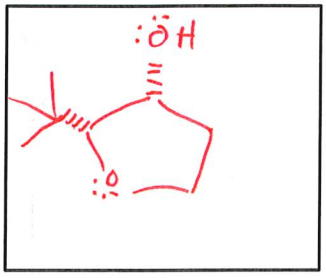
(a)



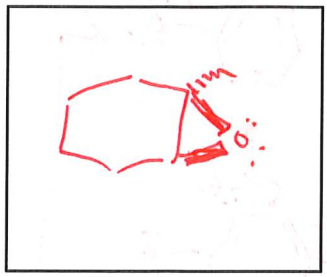
1. NaCN
2. HCl

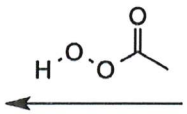


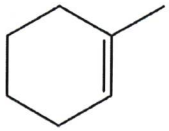
1. $LiAlH_4$
2. HCl, H_2O



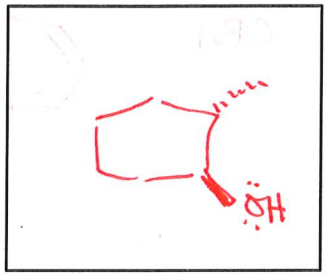
(b)



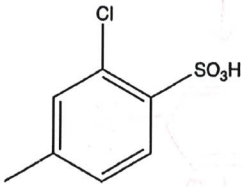




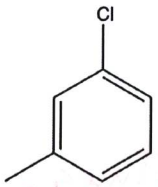
1. BH_3
2. H_2O_2, NaOH



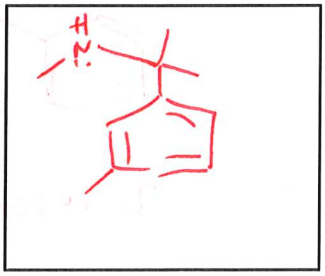
(c)



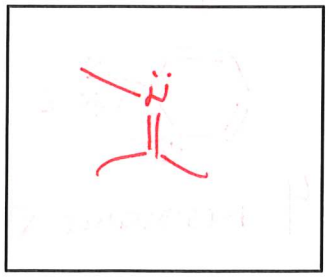
H_2SO_4 (aq)



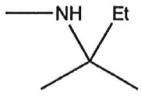
1. Mg, THF
2. 
3. H_3O^+



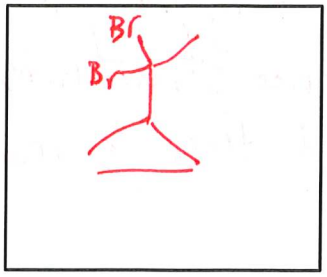
(d)



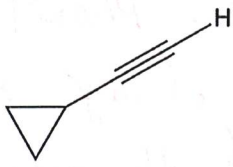
1.  Li, THF
2. H_3O^+



(e)

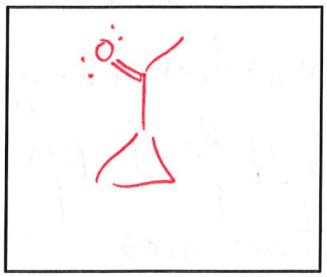


HBr, excess

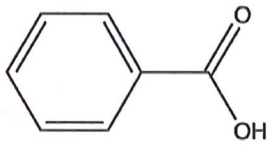


H_3O^+

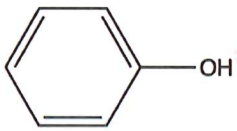
H_2O



13. Benzoic acid is much more acidic than phenol despite having ***less*** resonance stabilization. Draw the different resonance forms for each conjugate base and provide an explanation as to why benzoic acid is more acidic. **[6 marks]**

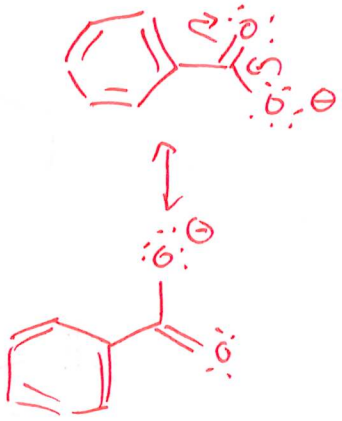


$pK_a = 4.2$



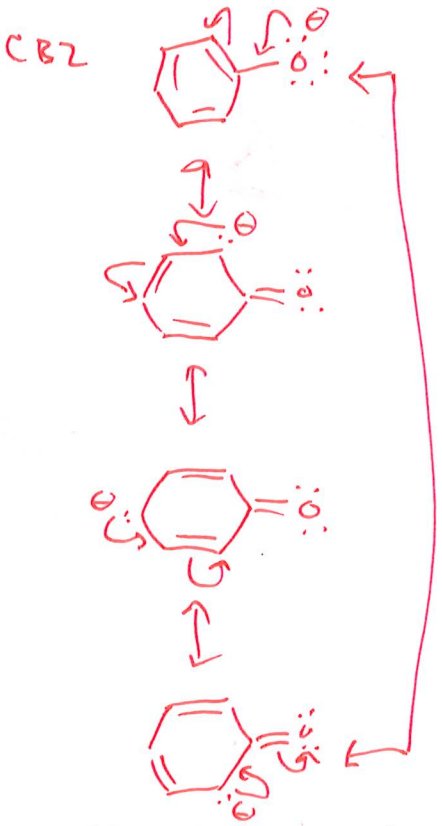
$pK_a = 10.0$

CB1



2 resonance structures.

CB2

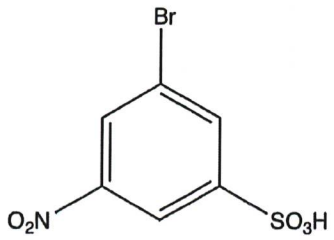


4 resonance structures.

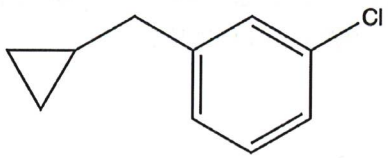
While benzoic acid only has 2 resonance structures, they both put negative charge on oxygen. Phenol has 4 resonance structures but 3 of the 4 put negative charge on carbon and these 3 resonance structures have to break the aromaticity.

14. Starting from benzene, propose a workable synthesis (mechanisms are not necessary) for **2** of the following molecules. You may use any other organic or inorganic reagents or solvents as needed. **[10 marks]**

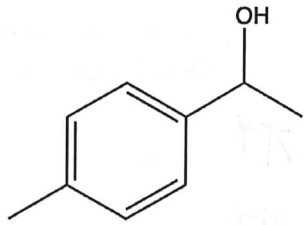
(a)



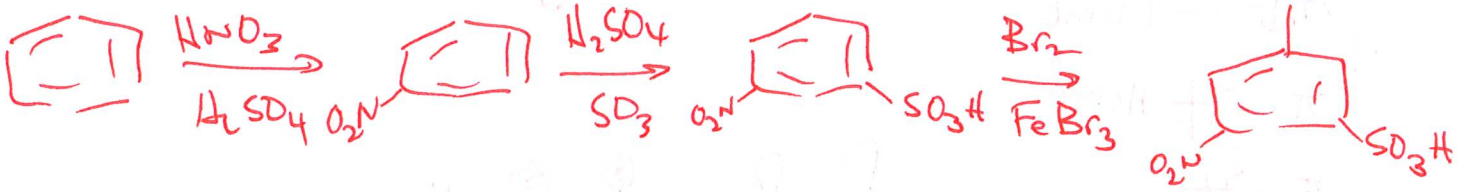
(b)



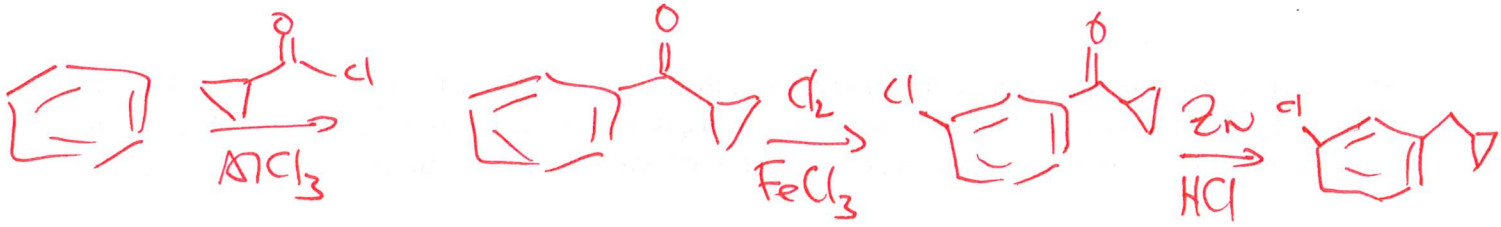
(c)



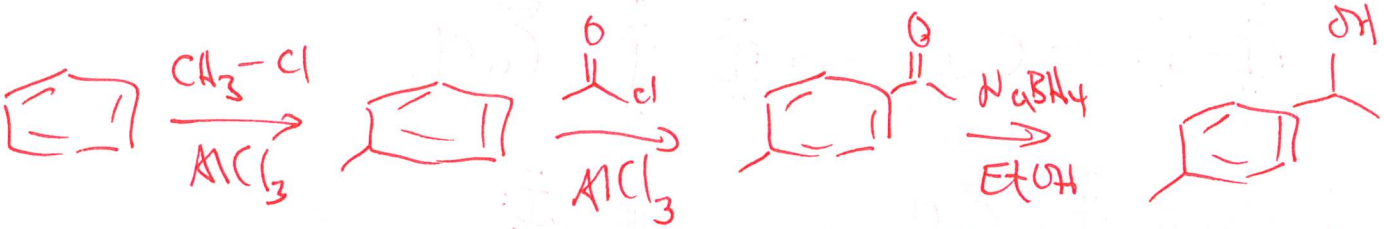
(a)



(b)



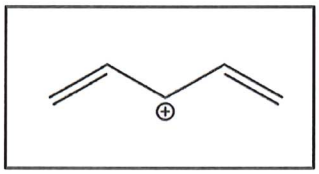
(c)

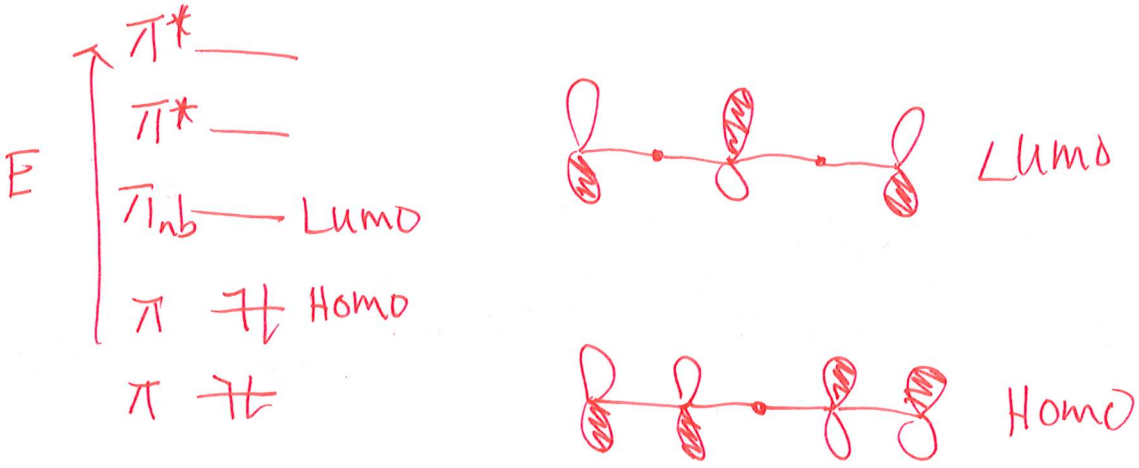


15. Sketch the π–MO energy level diagram for the following molecule. **[5 marks]**

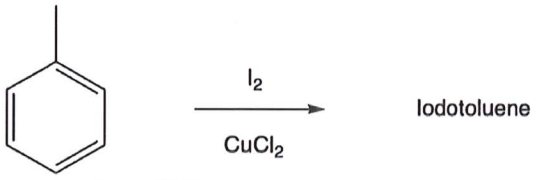
On your diagram:

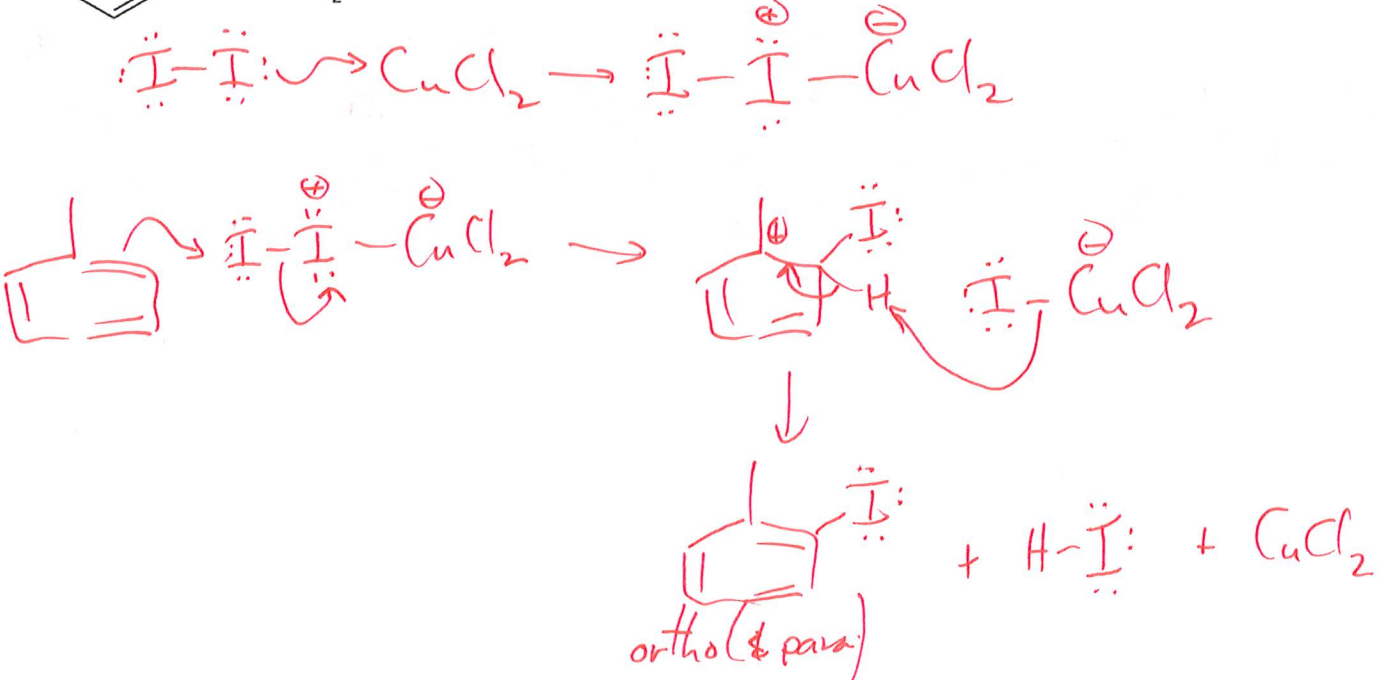
- Determine the relative energy levels of the orbitals.
- Include the appropriate number of π–electrons.
- Label each energy level as bonding, non-bonding, or antibonding.
- Sketch the π–MO for the HOMO and LUMO.





16. When iodine is used in Electrophilic Aromatic Substitution reactions, $CuCl_2$ is typically used as a catalyst. Using curved arrows to show the flow of electrons, draw a plausible mechanism for iodination of toluene. Be sure to consider the regiochemistry and stereochemistry where appropriate. **[4 marks]**





17. What was the most useful and/or interesting thing you learned in CHEM 2500? **[1 mark]**

Have a great summer!!

Extra space for: rough work, grocery list, poems, jokes, meaning of life, non-Euclidean proofs, cartoons, etc.