Fall 2022 **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 8pm Mountain Time on Friday, December 16th, 2022. 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: _____

Solution

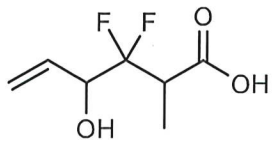
1) Read the test carefully. It has 14 pages of questions, including this cover page and 1½ blank pages with QR codes. Functional group priorities, a periodic table, and a pK_a table are found on a separate sheet.
2) The exam is worth a total of 97 marks. Many of these marks are for explanation/showing 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!). **Unless stated otherwise, provide your answers as line structures.**
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 *(+2 bonus questions)*

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Total
/ 4	/ 4	/ 3	/ 2	/ 5	/ 4	/ 2	/ 5	/ 3	/ 6	/ 4	/ 4	/ 5	/ 5	/ 4	/ 10	/ 7	/ 5	/ 5	/ 10	/ 97

- EXTRA ROOM TO WRITE YOUR ANSWERS -

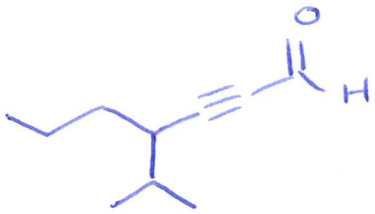
1. Name the following molecule according to IUPAC rules. **[4 marks]**



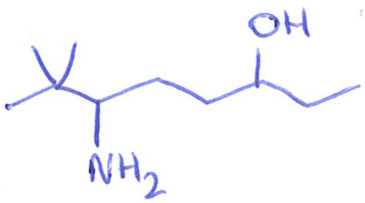
3,3-difluoro-4-hydroxy-2-methylhex-5-enoic acid.

2. Draw line structures for the following compounds. **[4 marks]**

(a) 4-isopropylhept-2-ynal



(b) 6-amino-7,7-dimethyloctan-3-ol



3. Specify the number of π electrons for each of the following molecules. Predict whether they are aromatic, anti-aromatic, or non-aromatic. Assume that all three molecules are planar. **[3 marks]**
Hint: Start by adding missing lone pairs.

(a)



number of π electrons

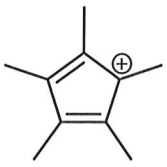
6

aromatic

anti-aromatic

non-aromatic

(b)



number of π electrons

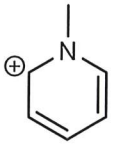
4

aromatic

anti-aromatic

non-aromatic

(c)



number of π electrons

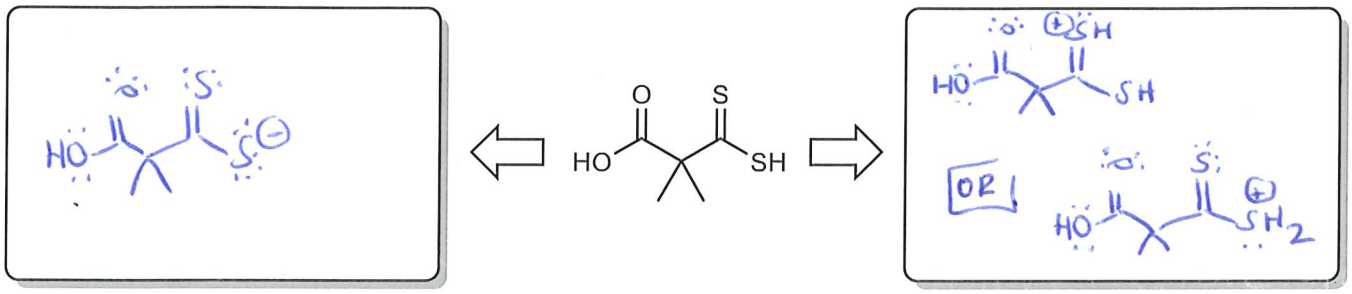
6

aromatic

anti-aromatic

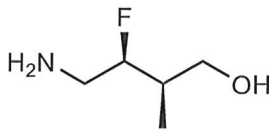
non-aromatic

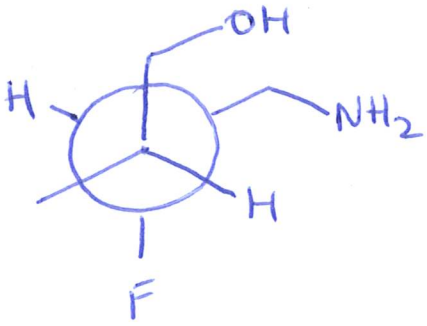
4. Draw the conjugate base (CB) and conjugate acid (CA) for the following molecule. **[2 marks]**



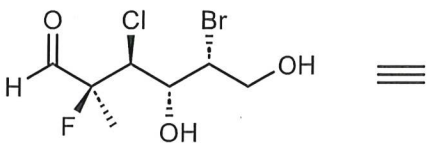
Conjugate base (CB) ***Conjugate acid (CA)***

5. For the following molecule, draw the Newman projection of the lowest energy conformer looking down the C2-C3 bond, where the carbon chain is numbered according to IUPAC nomenclature. Be sure that the correct stereochemistry is reflected in your Newman projection where appropriate. **[5 marks]**

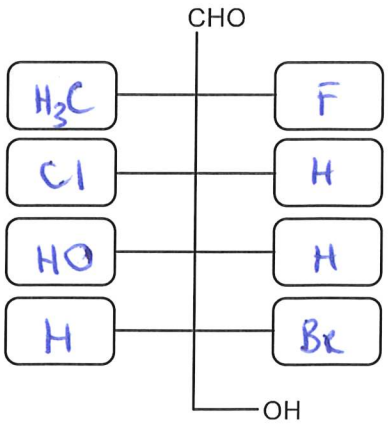




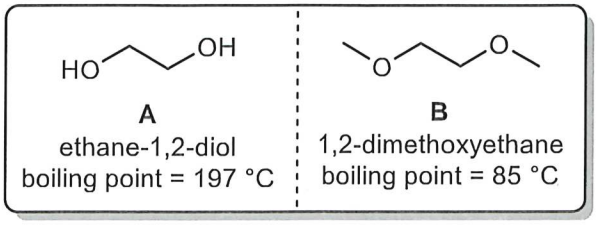
6. Convert the following line structure to its corresponding Fischer projection. Fill in the boxes with the correct atoms or groups. **[4 marks]**



≡



7. Ethane-1,2-diol (**A**) has a higher boiling point than 1,2-dimethoxyethane (**B**), despite being significantly heavier. Briefly explain why that is the case. **[2 marks]**



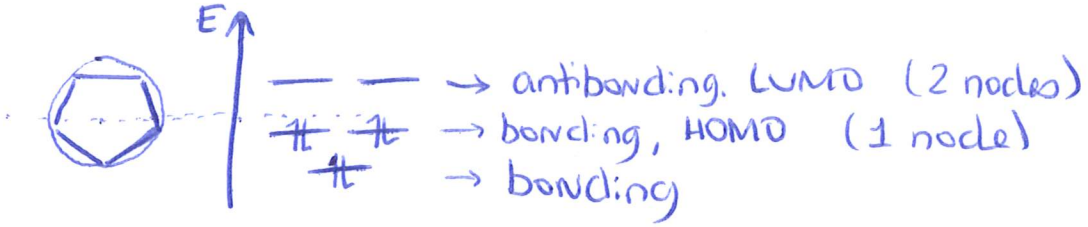
A has stronger intermolecular forces than B. While both can engage in London dispersion forces and dipole-dipole interactions, A is also capable of hydrogen bonding.

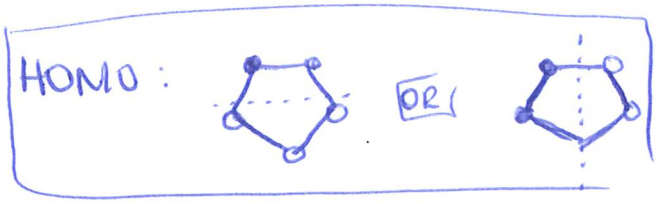
8. Sketch the π–MO energy level diagram for furan. **Hint:** Start with a Frost Circle. **[5 marks]**

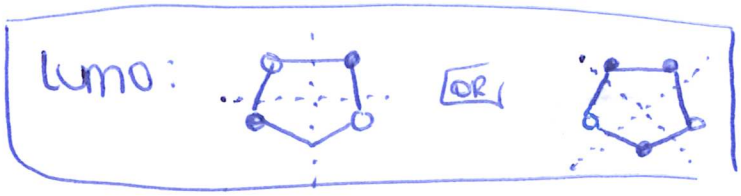


On your diagram:

- 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 1 HOMO **and** 1 LUMO.

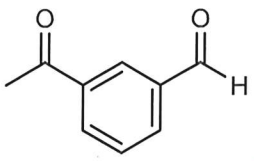






9. For each of the following aromatic molecules, name the functional group attached to the benzene ring and identify their relative position (ortho, meta, para). **[3 marks]**

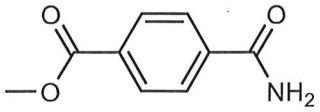
(a)



Ketone _____ aldehyde _____
name name

ortho **meta** **para**

(b)

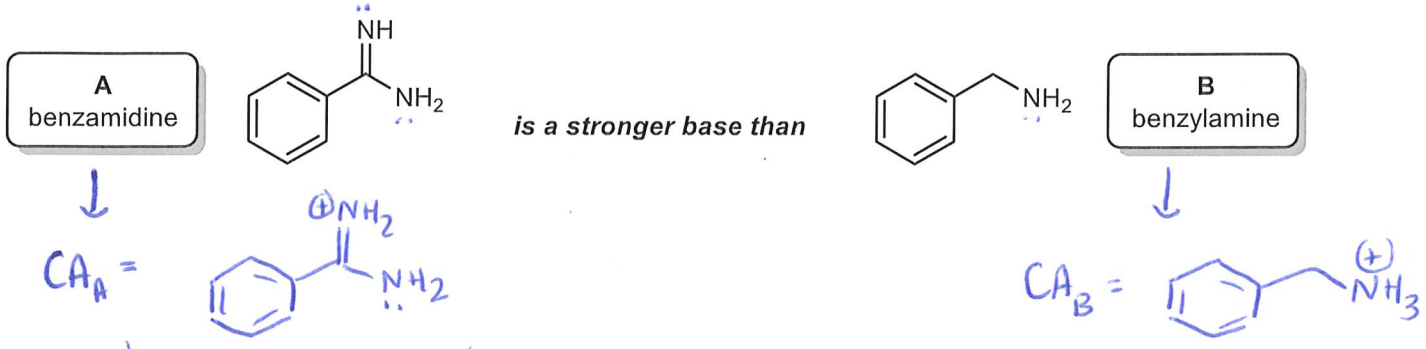


ester _____ Amide _____
name name

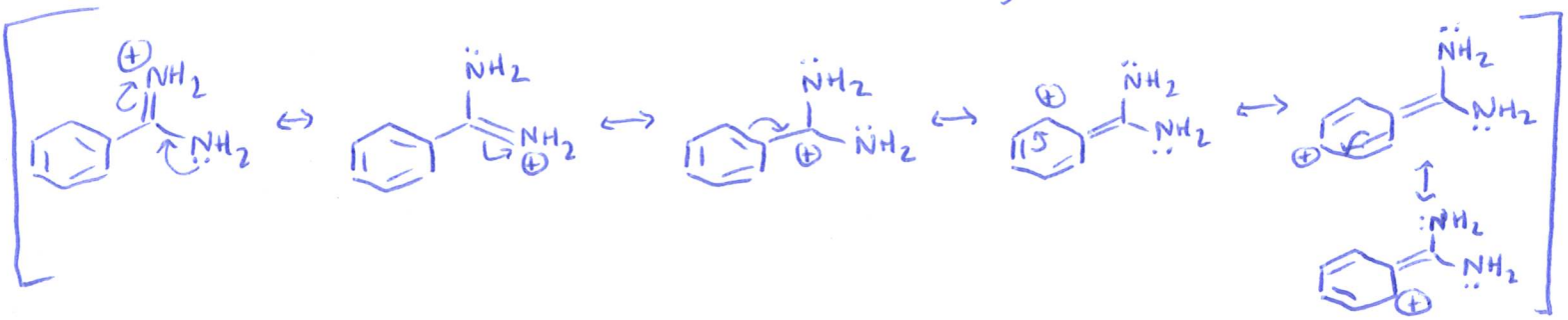
ortho **meta** **para**

10. Your lab partner found on a website that benzamidine (**A**) is a stronger base than benzylamine (**B**), but they don't understand why. Explain why that is the case. **[6 marks]**

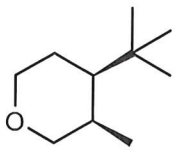
Hint: Start by drawing the conjugate acid of each molecule. A picture is worth a thousand words!! If your answer makes reference to a structure, a resonance form, a reaction, etc., DRAW it! Do not just use words to describe these. An entire language has been developed to represent these species with pictures and we are partly testing you on your ability to use this language.

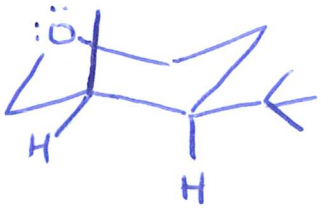


stabilized by RESONANCE
= more stable = less reactive
= weaker conjugate acid → consequently, A has to be a stronger base than B

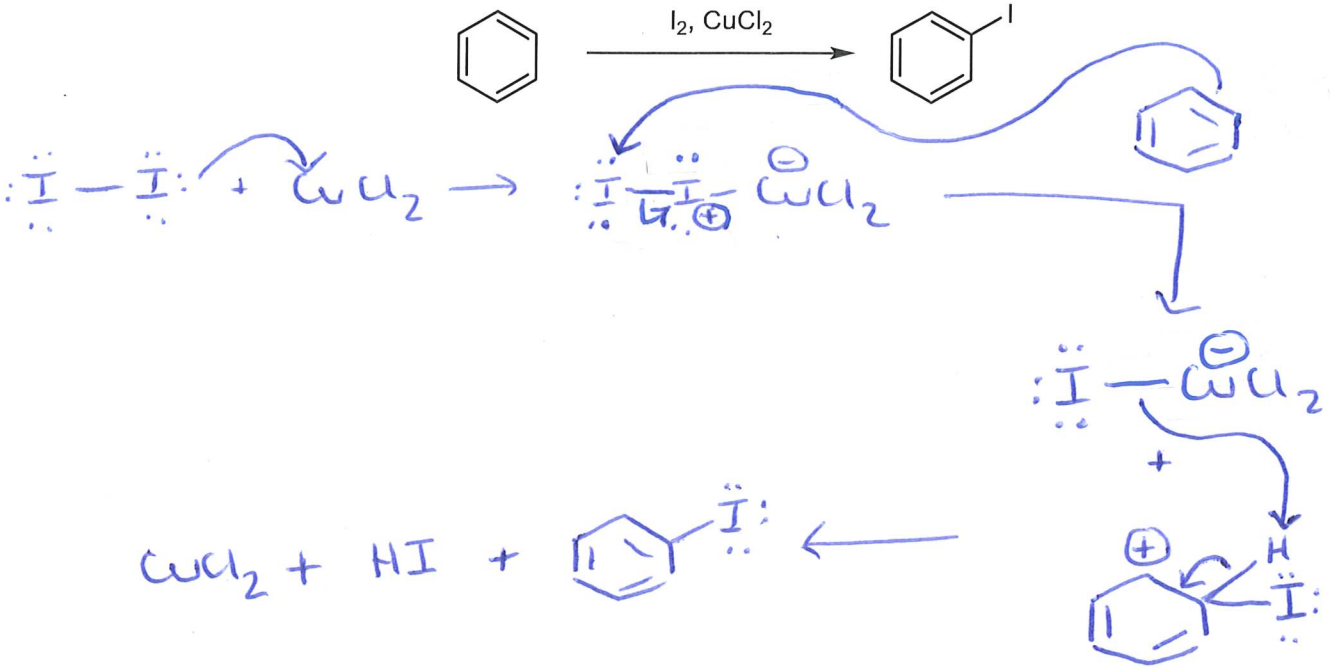


11. For the following molecule, draw its most stable chair conformer. Include all bonds (i.e. axial and equatorial bonds, and what is attached to them) only where substituents are attached to the ring. Bond angle/placement will be evaluated. **[4 marks]**

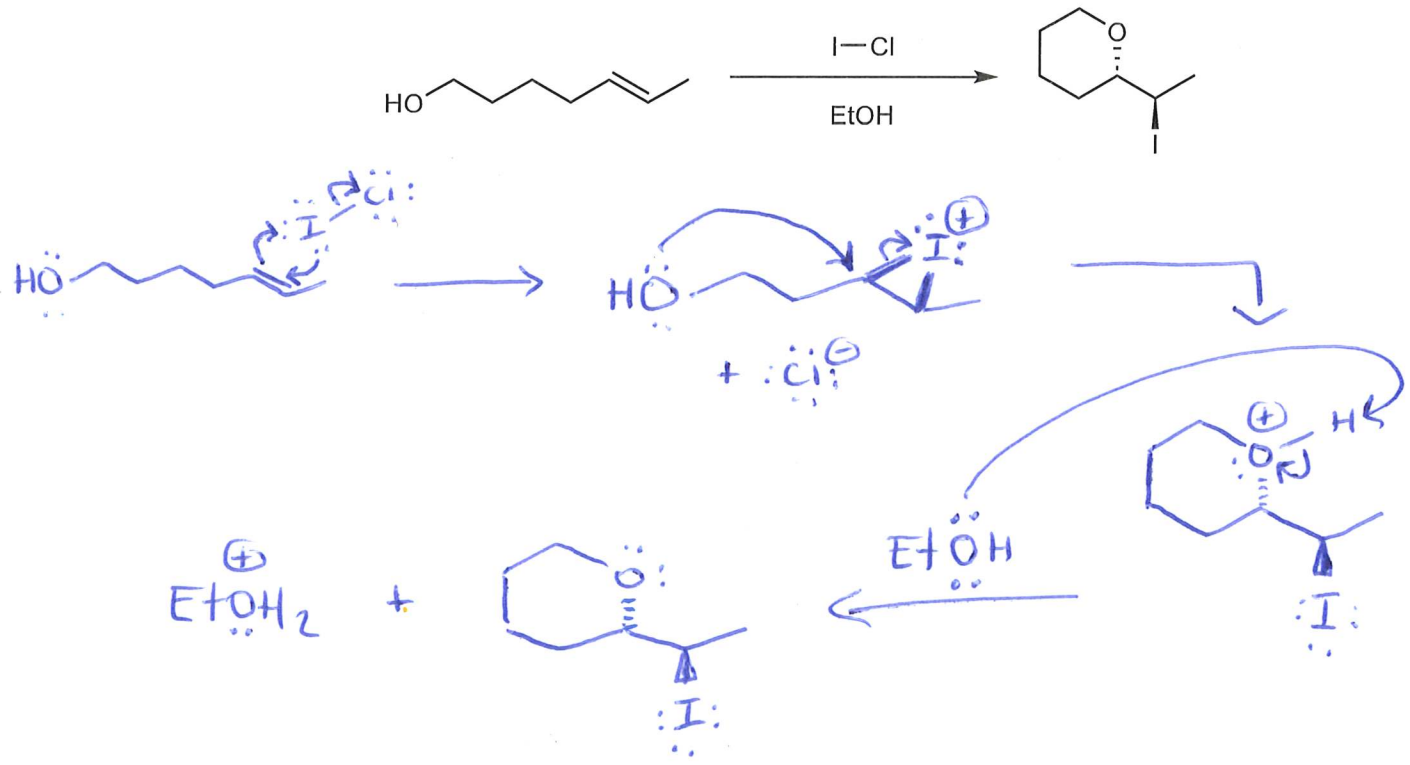




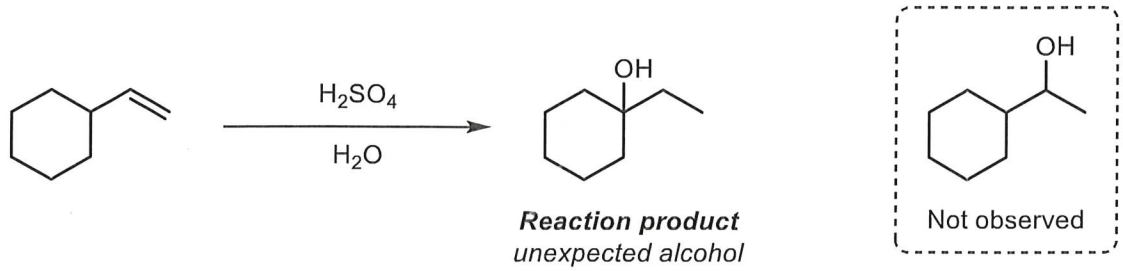
12. When I_2 is used in electrophilic aromatic substitution reactions, $CuCl_2$ is the usual Lewis acid catalyst. Using curved arrows to show the flow of electrons, draw a plausible mechanism for iodination of benzene. **[4 marks]**



13. Iodine monochloride, ICl, is a reagent whose reactivity mirrors that of other dihalogens (X_2) with nucleophilic π bonds. Using curved arrows to show the flow of electrons, draw a plausible mechanism for the following transformation. Make sure that your mechanism accounts for the correct stereoselectivity. **[5 marks]**



14. Hydration under acidic conditions of the alkene below led to an unexpected alcohol. **[5 marks]**



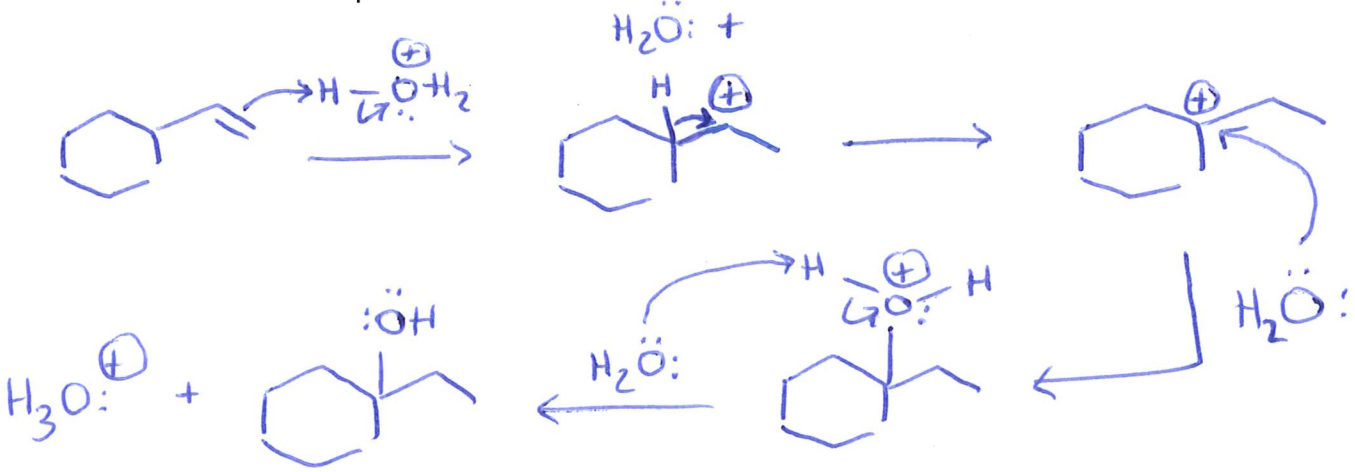
Reaction product
unexpected alcohol

Not observed

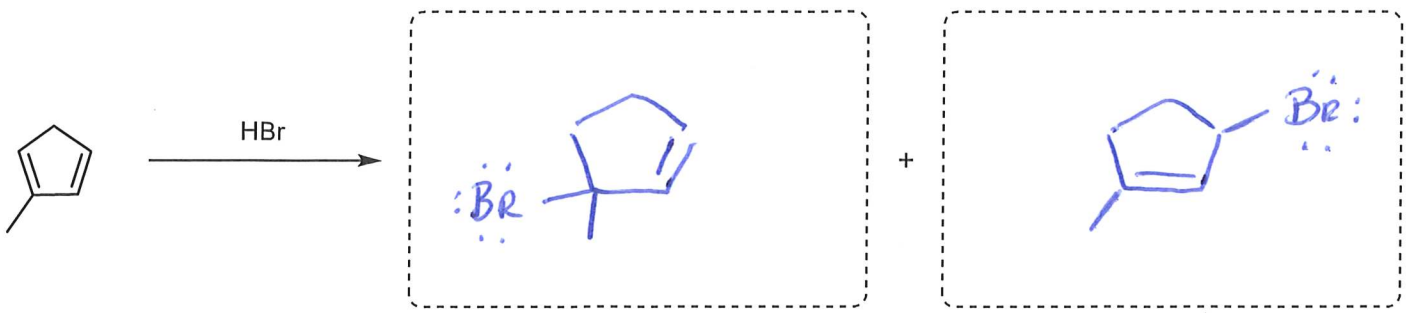
(a) In a few words, explain <u>why</u> this was the case.

CARBOCATION REARRANGEMENT

(b) Using curved arrows to show the flow of electrons, <u>draw</u> the complete curved arrow mechanism that explains the formation of the unexpected alcohol.



15. For the following reaction, draw both the major 1,2- and 1,4-addition products. **[4 marks]**

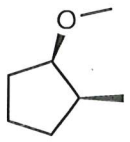
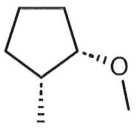
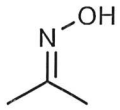
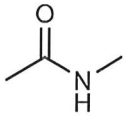
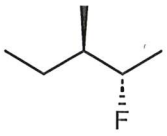
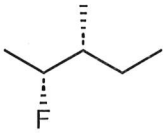
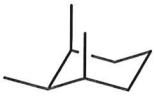
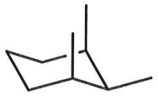
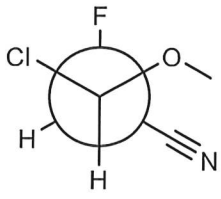
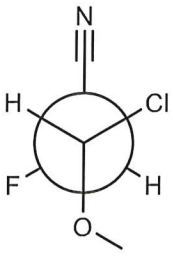


Product of 1,2-addition

Product of 1,4-addition

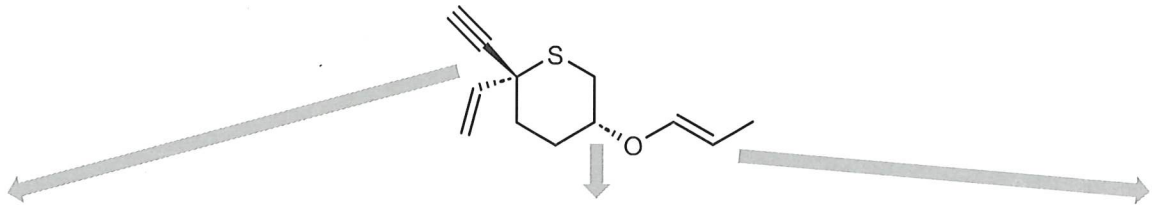
16. Using the appropriate letter or letters, indicate the relationship(s) between the following pairs of molecules. If there is more than one relationship, provide all the letters that apply. *No explanation is necessary.* **[10 marks]**

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

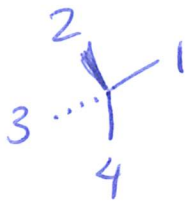
		relationship(s)
	and 	A, E
	and 	B
	and 	A, D
	and 	F
	and 	C

17. Consider the molecule below: **[7 marks]**

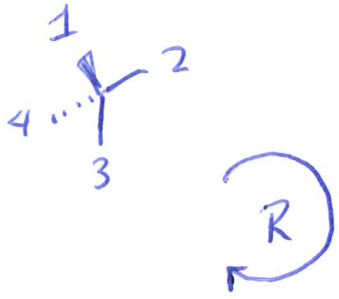
(a) Assign the stereochemical configuration(s) as *E*, *Z*, *R* or *S*. *For full marks, <u>you must show the priority numbers</u> you used to assign each configuration and it must be clear what part of the molecule is being described as E, Z, R or S. The assignment must be consistent with the priorities that you established to deem the answer correct.*



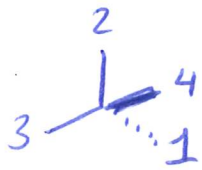
Chiral center #1



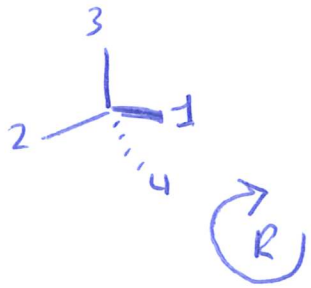
two switcher: 3→4, 1→2



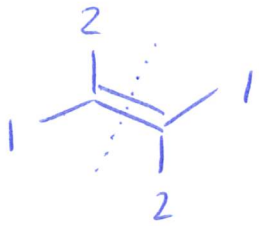
Chiral center #2



two switches: 1→4, 2→3



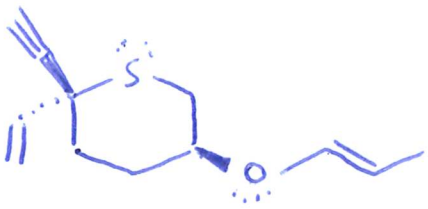
Alkene



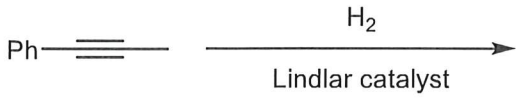
E

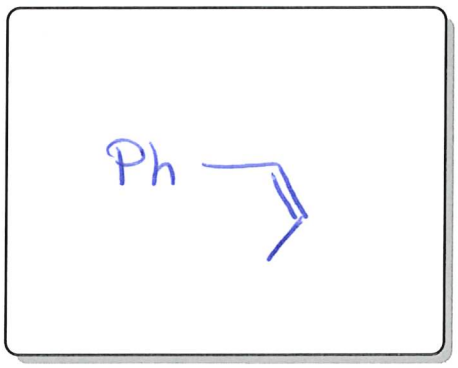
(b) Draw a diastereomer of the molecule.

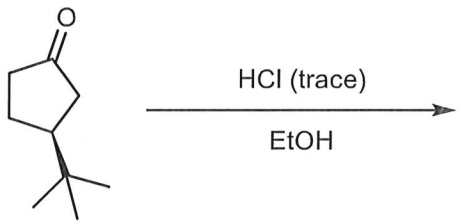
For example:

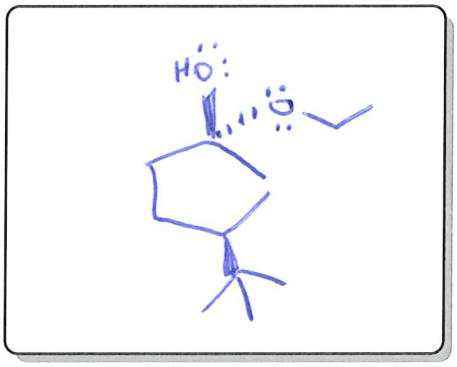


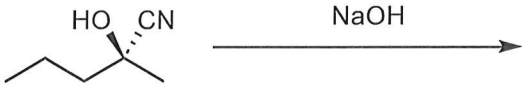
18. For the following reactions, fill in the missing products. If more than one product is formed, only draw the major one. Indicate stereochemistry where appropriate. **[5 marks]**

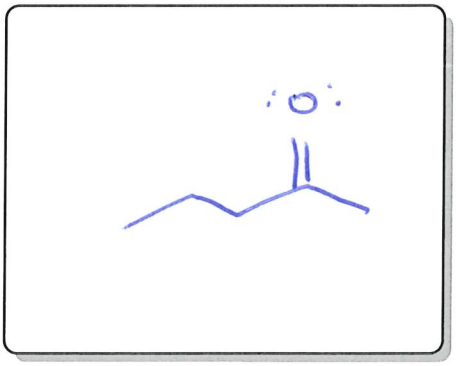


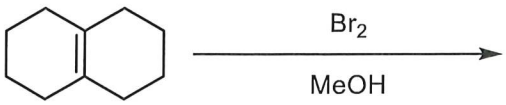


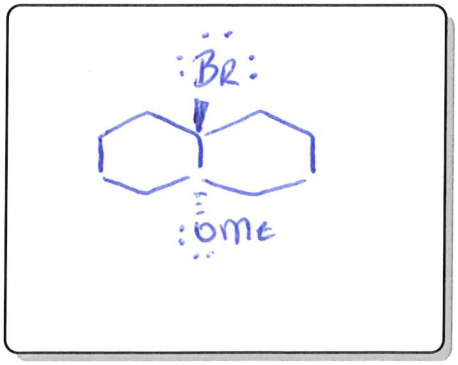




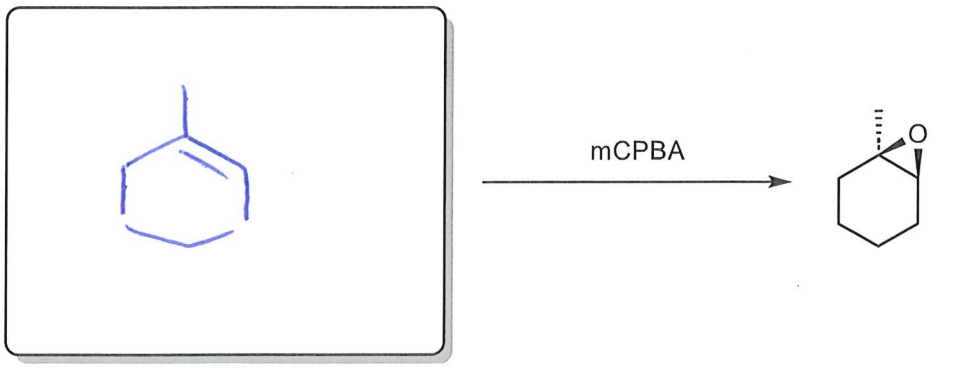


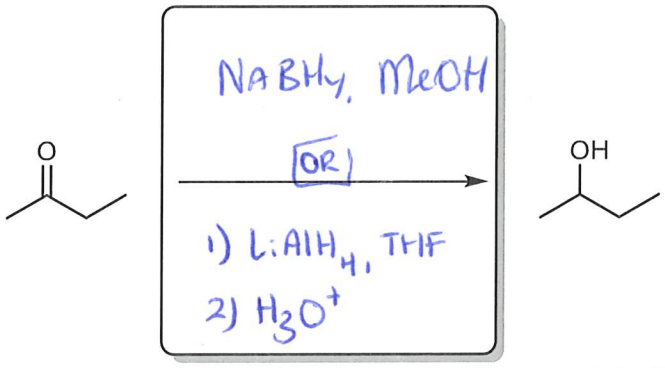


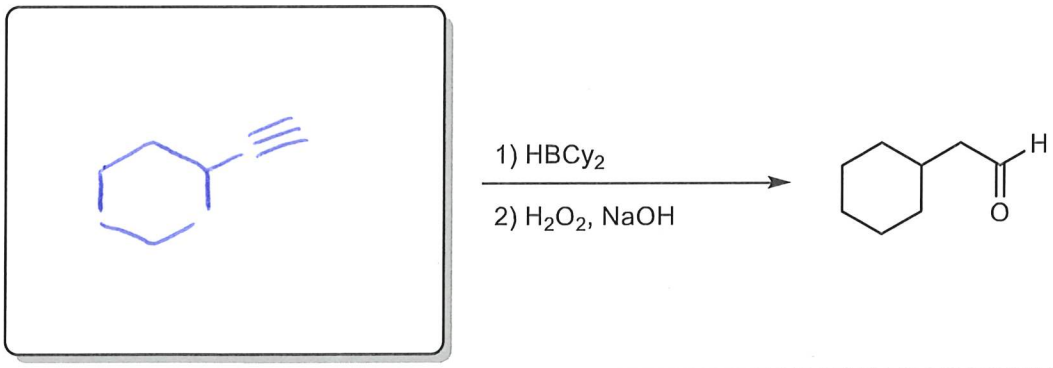


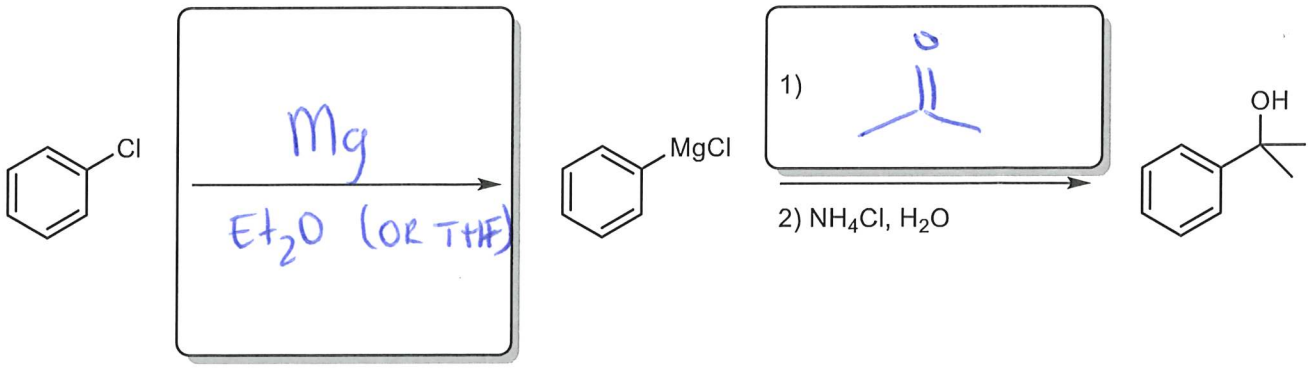


19. For the following reactions, fill in the missing reagents or starting materials. **[5 marks]**







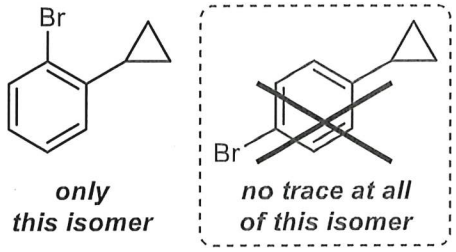


20. Starting from benzene, propose a workable synthesis for **TWO** of the following molecules. You may use any other organic or inorganic reagents or solvents as needed. **[10 marks]**

Hint #1: Each of those molecules can be made in 3 or 4 steps. In each case, the first step is an electrophilic aromatic substitution reaction.

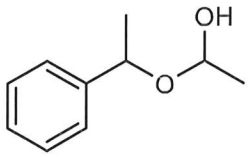
Hint #2: See this as a puzzle. Start by identifying which reactions need to happen to install each group. Then, figure out which reaction sequence will allow each group to fall in the right spot.

(a)

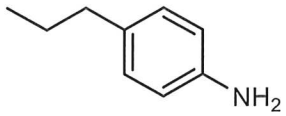


only this isomer ***no trace at all of this isomer***

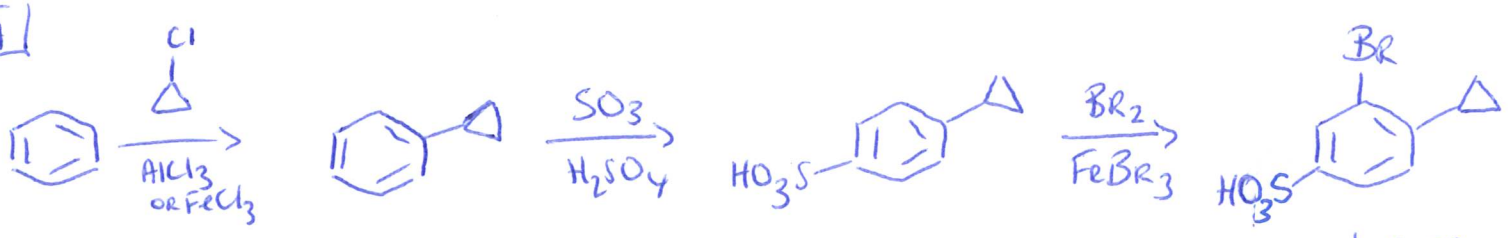
(b)



(c)

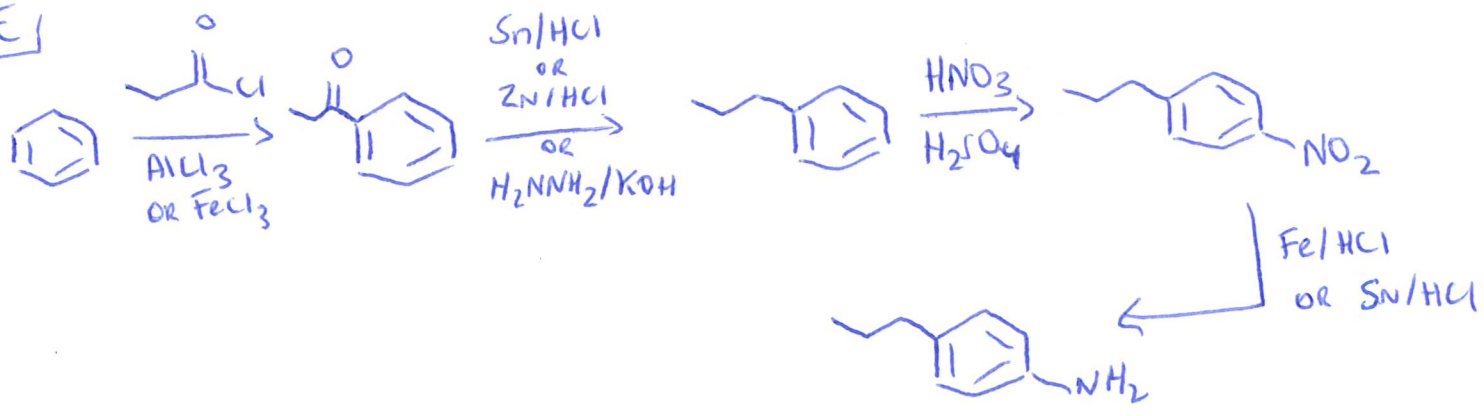


A

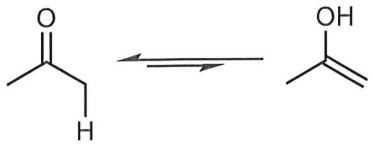


B see next page.

C



BONUS #1.
[1 mark]
What is the fancy name of this equilibrium?



tautomerization

BONUS #2.
[1 mark]
What is one thing you liked from Chem 2500?

END OF THE EXAM

- EXTRA ROOM TO WRITE YOUR ANSWERS -

B) many options!

