Winter 2024 **Chemistry 2500 Midterm #2X** ____/60 marks

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam with (or in the presence of) any CHEM 2500 student who has yet to write it. I understand that breaking this agreement would constitute academic misconduct. The minimum penalty would be a mark of 0/60 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 9 pages of questions and a periodic table.
2) You have also been given a data sheet. It does not have a QR code, so nothing written on it will be graded. If you need scrap paper, use the back of any page of the test.
3) **DO NOT WRITE ON ANY QR CODE!!!** Work on pages without a QR code will not be graded.
4) You may use a molecular model kit. You may not have written materials in your model kit.
5) No electronic devices are allowed. This test does not require a calculator.
6) ALL structures must be drawn showing lone pairs, non-zero formal charges and reasonable bond angles – regardless of whether you are using line-bond notation. Marks will be deducted for poorly drawn structures.
7) 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. If delocalization of electrons is invoked, the relevant resonance structures must be drawn.
8) Marks will be deducted for incorrect information added to an otherwise correct answer.
9) You have 2 hours to complete this test.

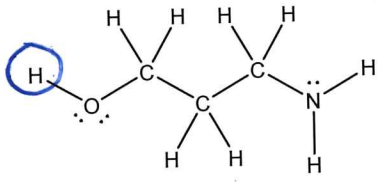
Question Breakdown

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10					Total
/ 4	/ 2	/ 3	/ 12	/ 8	/ 5	/ 8	/ 6	/ 6	/ 6					/ 60

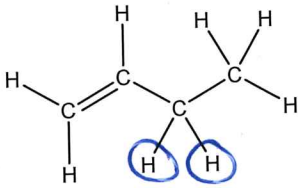
For all questions on this page, if more than one atom meets the description, you may either circle one of them or circle both/all of them.

1. Circle the most acidic hydrogen atom in each of the molecules below. **[4 marks]**

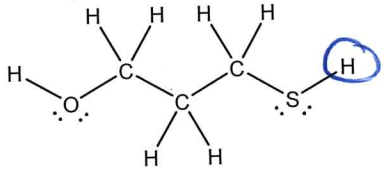
(a)



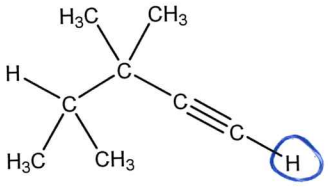
(b)



(c)

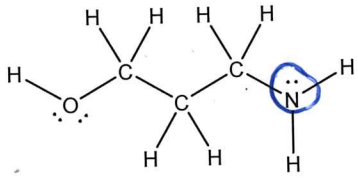


(d)

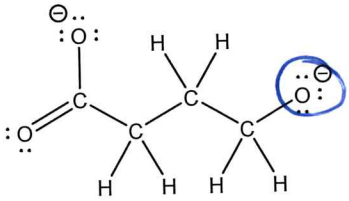


2. Circle the most basic atom in each of the molecules below. **[2 marks]**

(a)

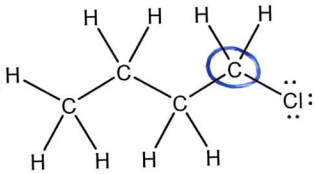


(b)

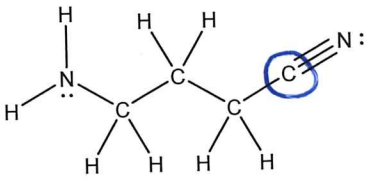


3. Circle the most electrophilic atom in each of the molecules below. **[3 marks]**

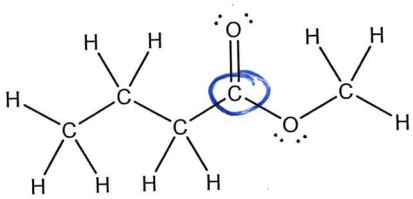
(a)



(b)

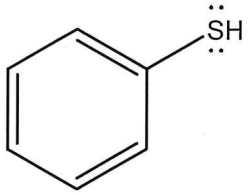
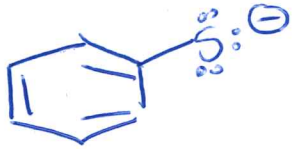
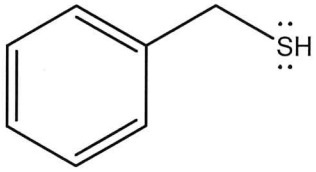
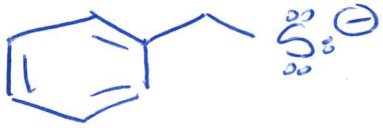
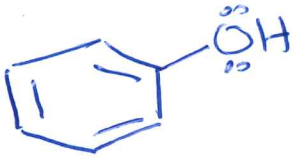
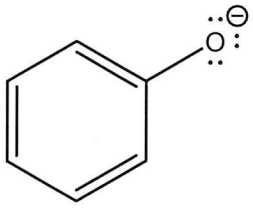
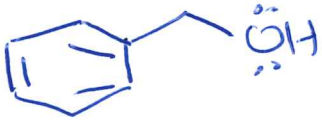
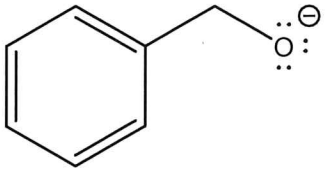


(c)

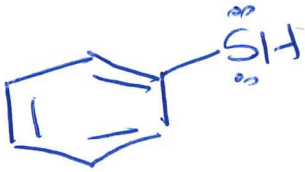


4. **[12 marks]**

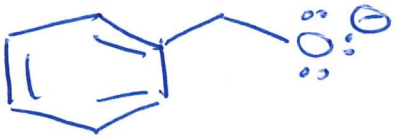
(a) Complete the table below. *[4 marks]*

pK_a	Conjugate Acid	Conjugate Base
6.6		
9.4		
10.0		
15.4		

(b) Based on the information in the table above, which of the four conjugate acids is the strongest acid? *[1 mark]*



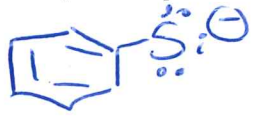
(c) Based on the information in the table above, which of the four conjugate bases is the strongest base? *[1 mark]*



continued on next page...

4. *....continued from previous page*

(d) Explain why your answer to part (b) is the strongest of the four conjugate acids **without reference to pK_a values**. For full marks, you must directly compare your answer to part (b) with each of the other three acids and, for each of them, provide at least one reason why it is the stronger acid. *[6 marks]*

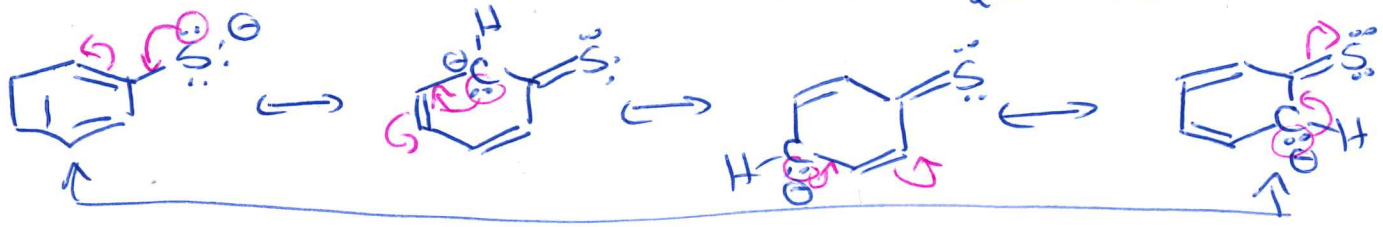
 is the strongest acid because  is the most stable (∴ weakest) conjugate base.

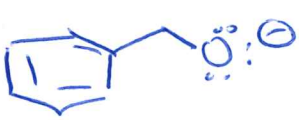
①  vs 

Sulfur is a larger atom than oxygen ∴ $S^{\ominus}$ has a lower charge density than $O^{\ominus}$

②  vs 

The negative charge in $PhS^{\ominus}$ is resonance-stabilized (delocalized over multiple atoms). The negative charge in $PhCH_2S^{\ominus}$ is not.



③  vs 

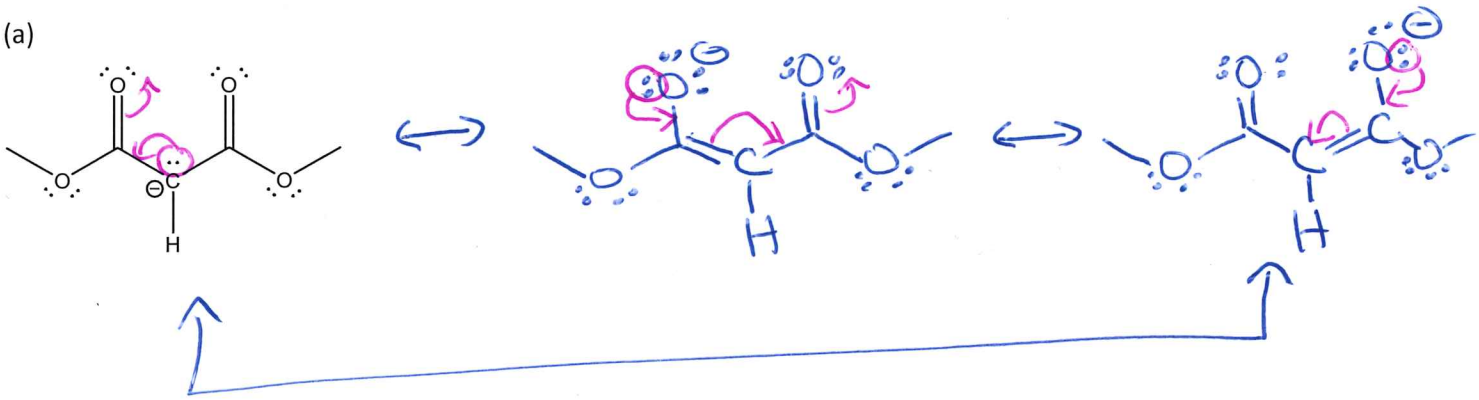
Sulfur is a larger atom than oxygen ∴ $S^{\ominus}$ has a lower charge density than $O^{\ominus}$

AND

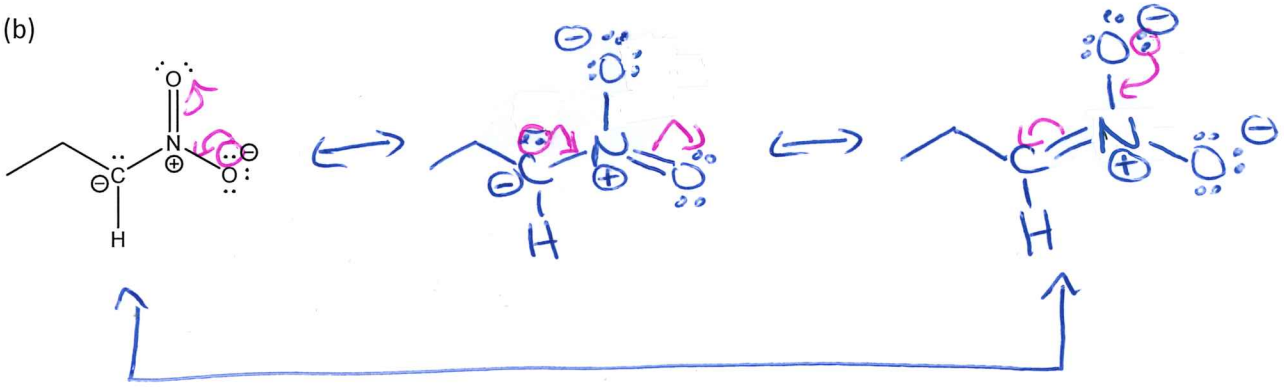
The negative charge in $PhS^{\ominus}$ is resonance-stabilized (delocalized over multiple atoms). The negative charge in $PhCH_2O^{\ominus}$ is not.

5. For each of the anions below, draw the other two valid resonance structures. Use curved arrows to show how electrons "move" from each resonance structure to the next (and the last back to the first). **[8 marks]**

(a)



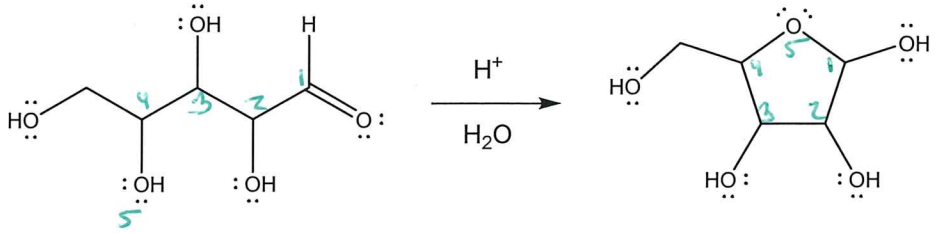
(b)



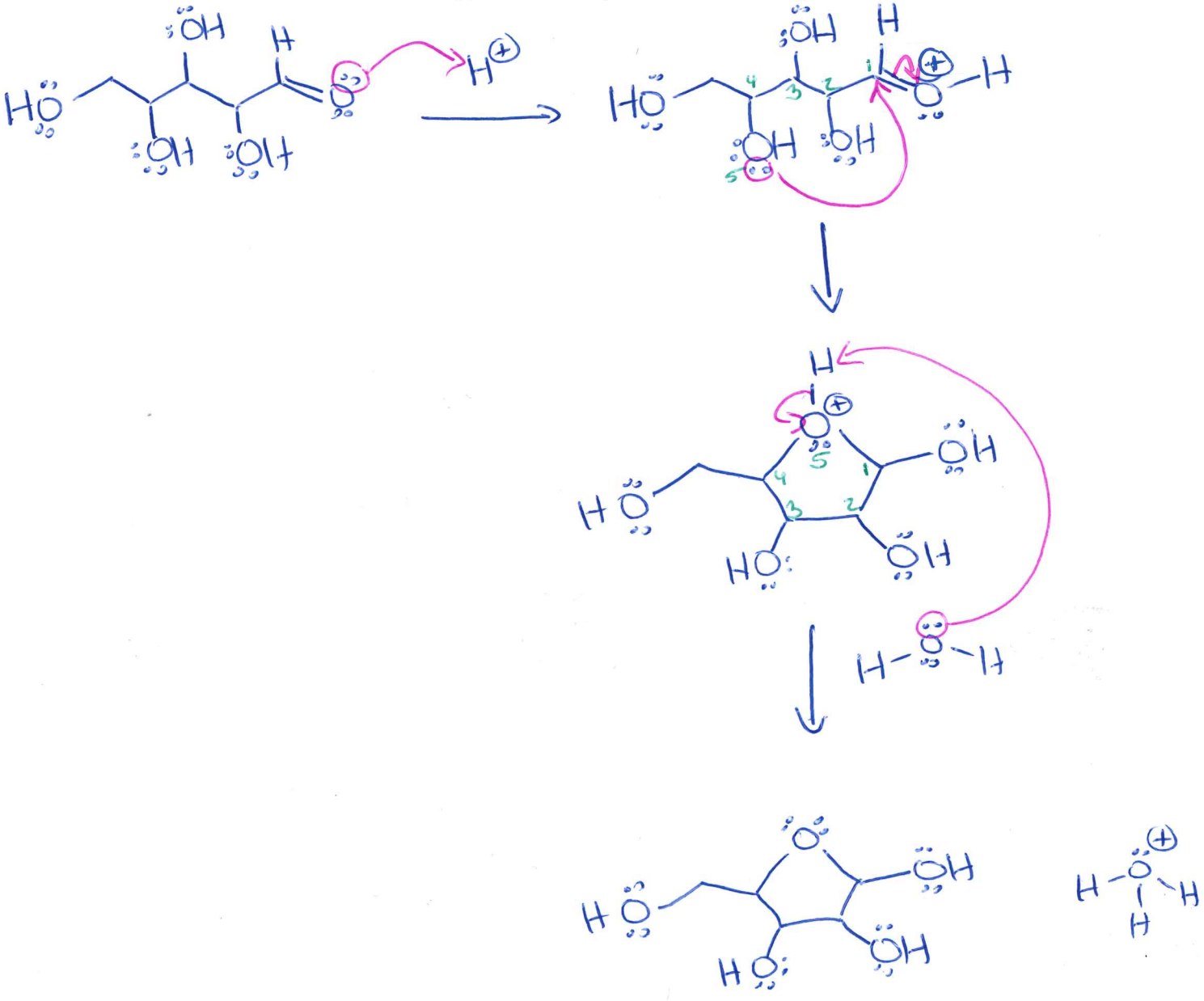
BONUS: Why did Susan put the word "move" in quotation marks when she wrote this question? *[1 mark]*

Resonance structures don't actually exist, so molecules don't "bounce" back and forth between them. The molecule (or ion) just exists as a weighted average.

6. Ribose ($C_5H_{10}O_5$) is a simple sugar, one enantiomer of which is an important component of the ribonucleotides which make up RNA. In aqueous environments, it exists primarily as a cyclic hemiacetal. The reaction equation below shows one of the two cyclic hemiacetals that can form from ribose in the presence of aqueous acid. For clarity, stereochemistry is not shown (and therefore you are not required to show it either). **[5 marks]**



Propose a valid mechanism for the acid-catalyzed reaction shown above. Use curved arrows to show the movement of electrons in each step, and draw all products of each step.

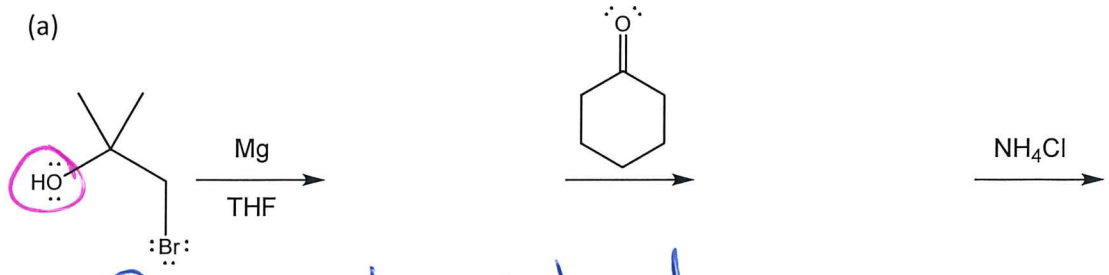


7. For each of the following sets of reagents, **[8 marks]**

- Indicate whether a Grignard reagent will be produced by:
  - Drawing the Grignard reagent if it is produced, or
  - Briefly explaining why no Grignard reagent is produced.
- If a Grignard reagent is produced, drawing the immediate product of its reaction with the electrophile provided and the final product after NH_4Cl is added.

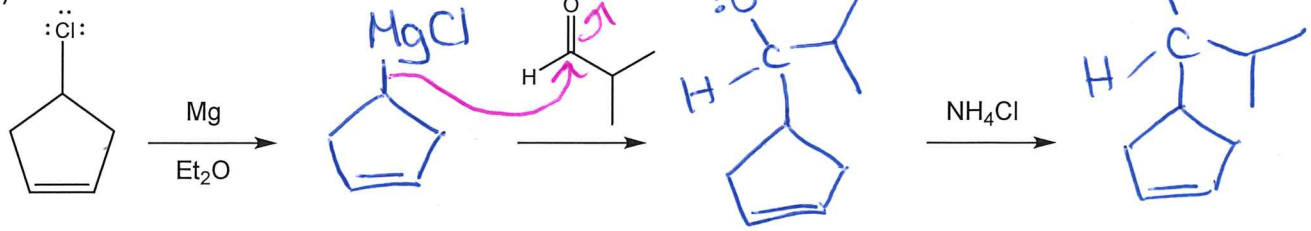
The reagents for each step have been provided on a separate arrow to help you stay organized. If no Grignard reagent can form, you do not need to draw anything after any arrow in that row! For row(s) in which that is the case, just provide a quick verbal explanation of why the Grignard reagent did not form.

(a)

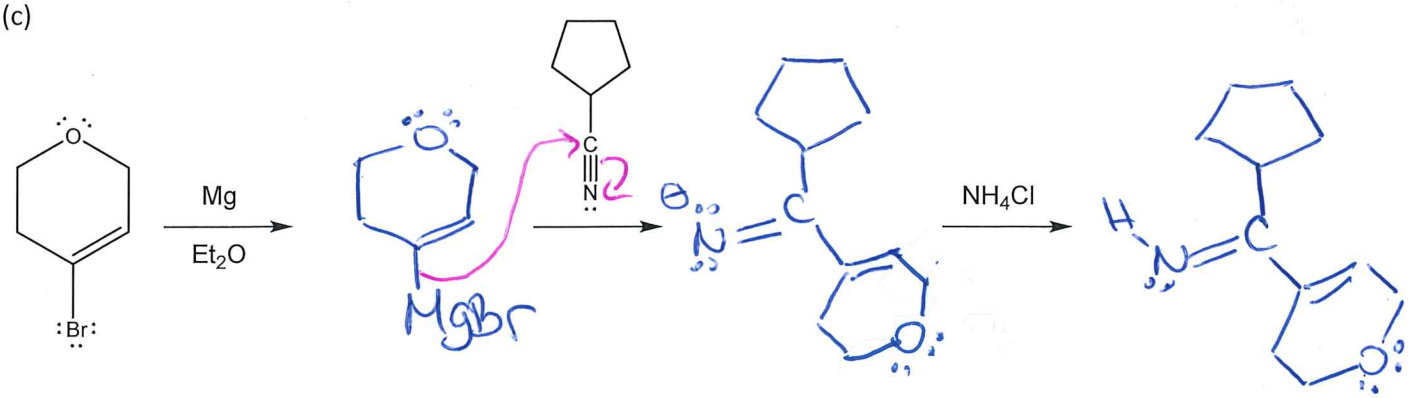


no Grignard produced due to the acidic hydrogen of the OH group

(b)



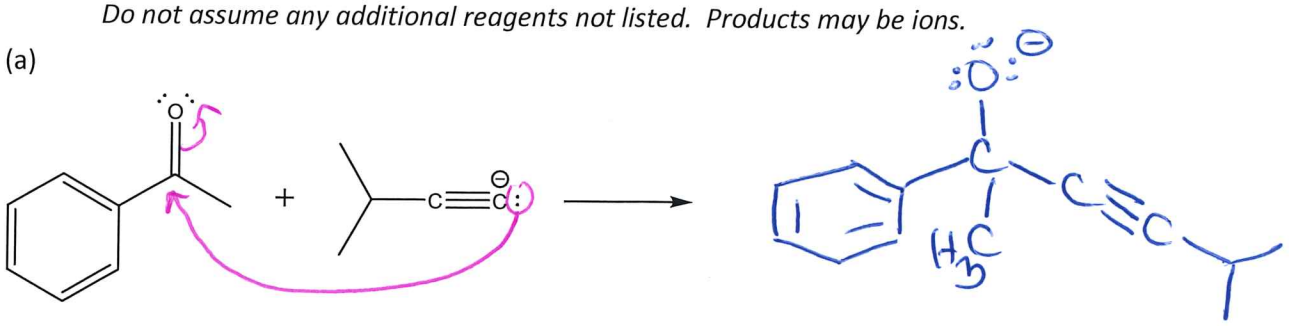
(c)



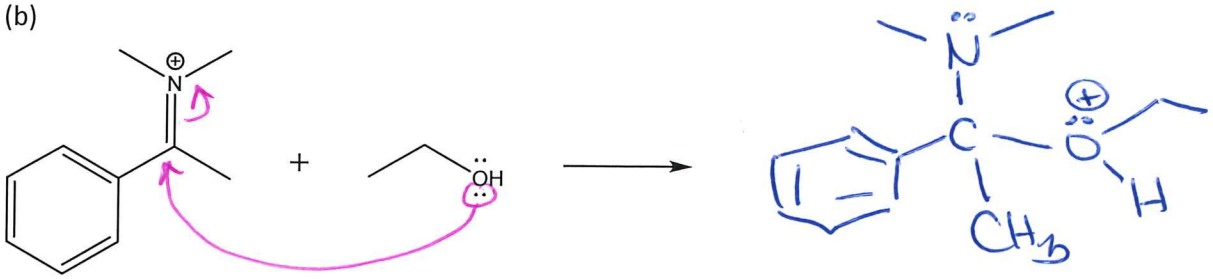
8. Draw the major organic product of each for the following reactions. **[6 marks]**

Do not assume any additional reagents not listed. Products may be ions.

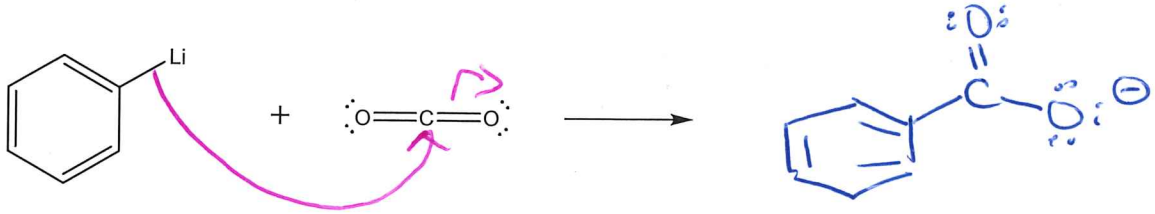
(a)



(b)

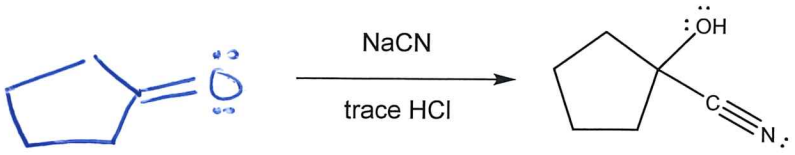


(c)

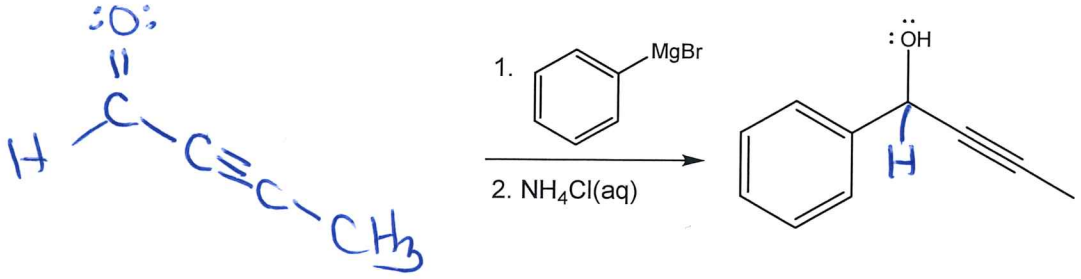


9. For each of the following reactions, identify the missing reactant. **[6 marks]**

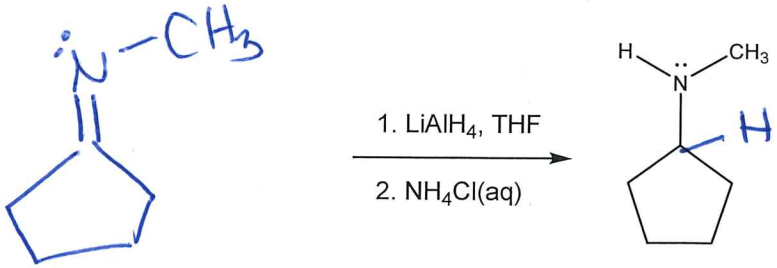
(a)



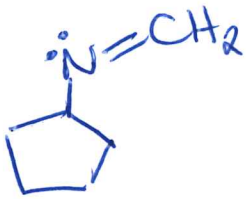
(b)



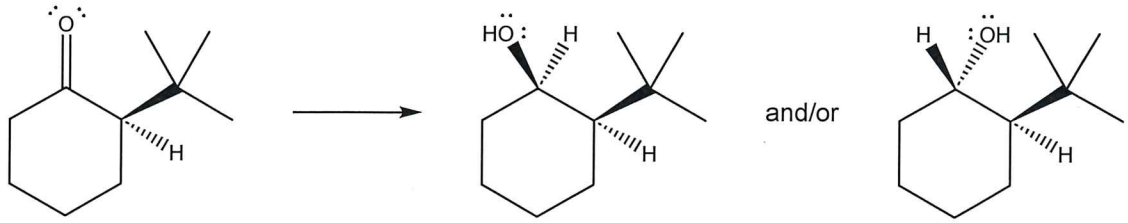
(c)



or



10. Consider the reaction below in which either **A** or **B** is produced from (*R*)-2-*tert*-butylcyclohexanone. **[6 marks]**



A **B**

(a) Give an example of reaction conditions you could use to effect this reaction. In other words, what do you need to add to (*R*)-2-*tert*-butylcyclohexanone to make either **A** or **B**? *[2 marks]*

Be specific. If a particular solvent is necessary, list it. If order of addition matters, number the steps.

1. $LiAlH_4$, THF
2. $NH_4Cl_{(aq)}$

or

$NaBH_4$, CH_3OH

(b) Which of the two products drawn will be the major product of this reaction? Explain your choice. For full marks, your explanation should include curved arrows showing electron movement in the relevant step of the mechanism. *[4 marks]*

A is the major product.

The nucleophile ("$H:^{\ominus}$" from either $LiAlH_4$ or $NaBH_4$) will attack from the more accessible side ∴ on the opposite side from the bulky *t*-Bu group):

