Fall 2023 **Chemistry 2600 Final Exam** ____/95 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 2600 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 0/95 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 13 pages of questions and a periodic table.
2) You have been given a 6-page Spectroscopy Data Package. **PLEASE DO NOT WRITE ON THE SPECTROSCOPY DATA PACKAGE**! If you need scrap paper, use the back of any page of the test. On questions with spectra, you may also do rough work directly on the spectra.
3) You are allowed to bring one index card (maximum size 3"x5") into the exam with you as a "cheat sheet". This card must be submitted with your exam.
4) You may use a molecular model kit and ruler. You may not have written materials in your model kit.
5) You may use a calculator but only for calculation. No other electronic devices are allowed.
6) **DO NOT WRITE ON ANY QR CODE!!!** Work on pages without a QR code will not be graded.
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 3 hours to complete this test.

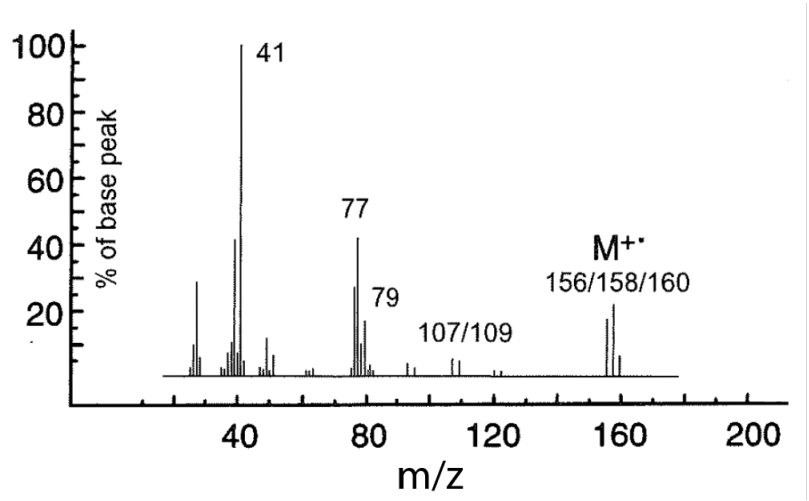
Question Breakdown

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8							Total
/ 15	/ 12	/ 15	/ 17	/ 11	/ 18	/ 6	/ 1							/ 95

1. **[15 marks]**

(a) The mass spectrum for Unknown **X** is shown below. The peak height ratio for the lines at m/z 156, m/z 158 and m/z 160 is 3: 4: 1. Unknown **X** contains only carbon, hydrogen and halogen atoms.

Determine the molecular formula for Unknown **X**. Show your work. *[4 marks]*



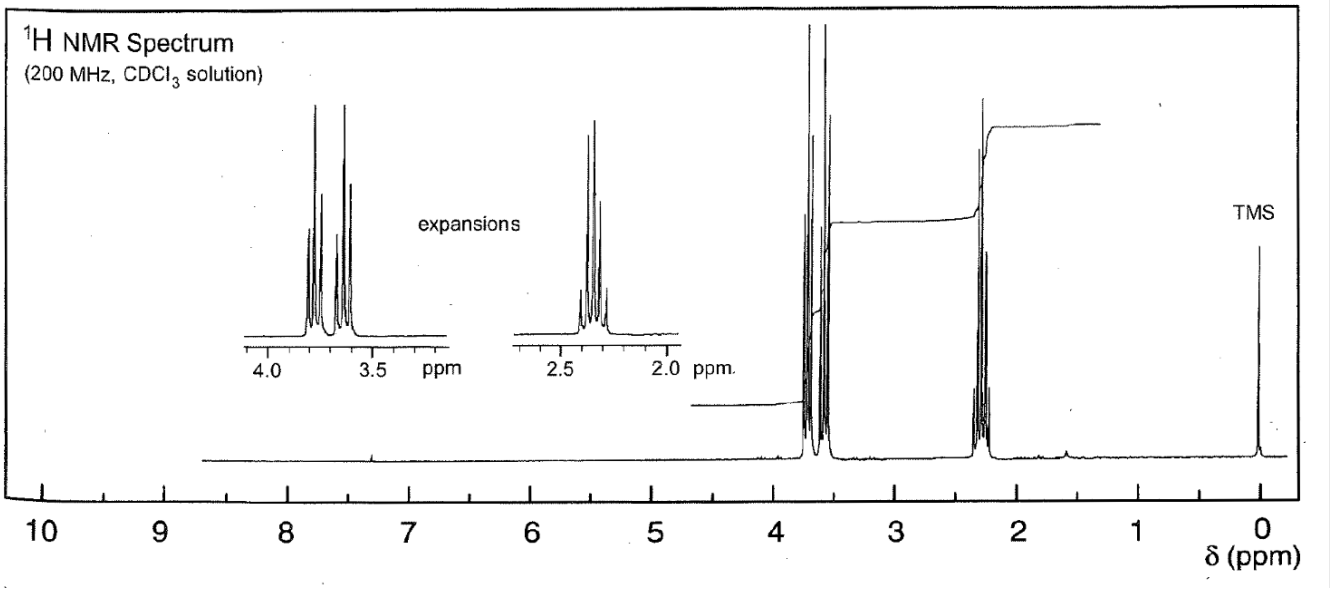
(b) There are five possible structural isomers for Unknown **X**'s molecular formula. Draw them all. *[5 marks]*

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1. *continued…*

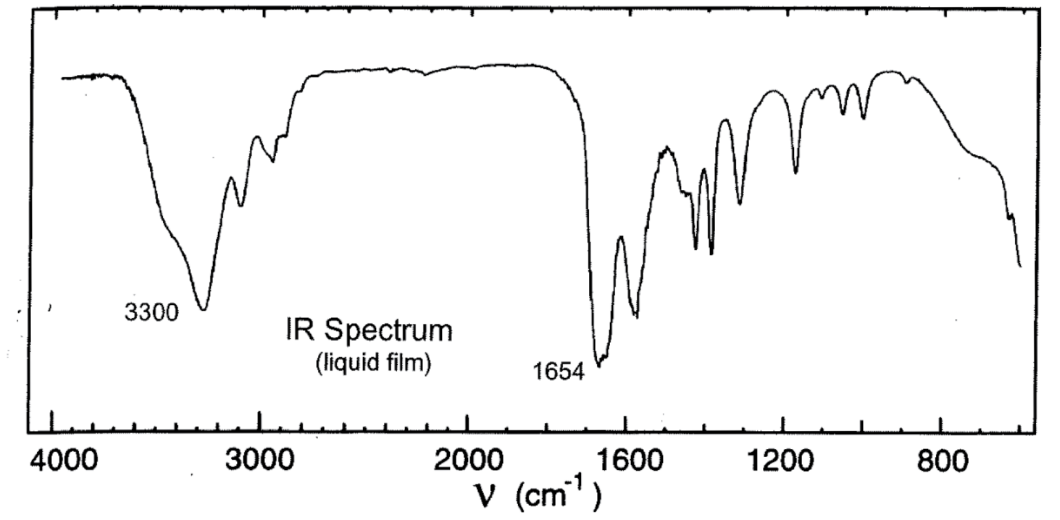
(c) The ^{1}H NMR spectrum for Unknown **X** is shown below. Use this spectrum to determine which of the five structural isomers drawn in part (b) must correspond to Unknown **X**. Clearly explain your reasoning. For full marks, your answer must address at least two different types of information provided by the spectrum.

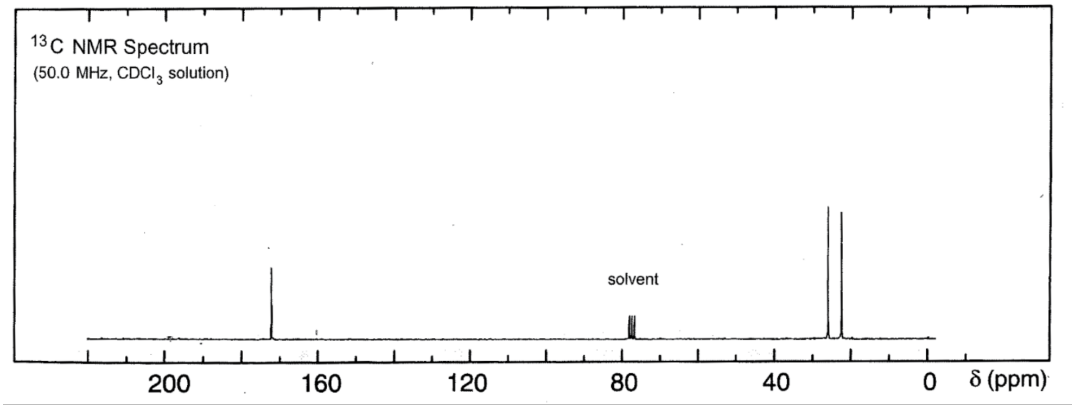
[6 marks]



2. The molecular formula of Unknown **Y** is C_3H_7NO. **[12 marks]**

(a) The infrared spectrum and ^{13}C NMR spectrum for Unknown **Y** are shown below. What can you conclude about Unknown **Y** based on these two spectra? Clearly explain your reasoning for each conclusion with direct reference to specific peaks on the relevant spectrum or spectra. *[6 marks]*





continued on next page…

2. *…continued*

(b) A ^{1}H NMR spectrum for Unknown **Y** shows three peaks with integral ratios of $1:3:3$. *[4 marks]*

- A broad singlet at 7.4 ppm (1H) which exchanges with D_2O upon warming
- A sharp singlet at 2.8 ppm (3H)
- A sharp singlet at 2.0 ppm (3H)

What can you conclude about Unknown **Y** based on this information? Clearly explain your reasoning for each conclusion with direct reference to the relevant feature(s) of the peaks being discussed.

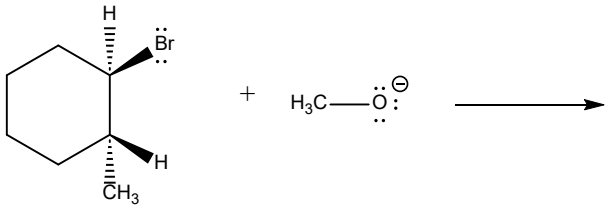
(c) Identify Unknown Y. *[2 marks]*

3. Indicate whether or not you would expect to see a significant amount of reaction according to each mechanism type by circling 'yes' or 'no'. In the bottom row of each table, justify your answer by: **[15 marks]**

- For each 'yes', drawing the organic product(s) that will be observed. If multiple regioisomers and/or stereoisomers can be produced via that mechanism, draw each of them.
- For each 'no', briefly explaining why you expect little-to-no reaction.

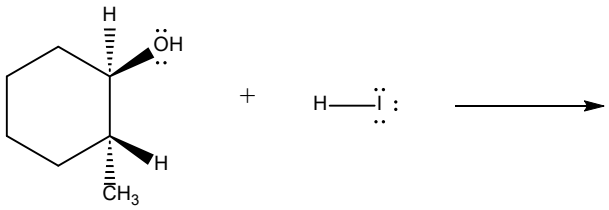
The marks are for the product(s) and/or explanations. The yes/no part is just to help you think.

(a)



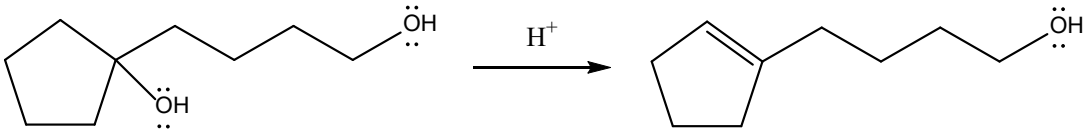
S_N1? yes / no	**S_N2?** yes / no	**E1?** yes / no	**E2?** yes / no

(b)



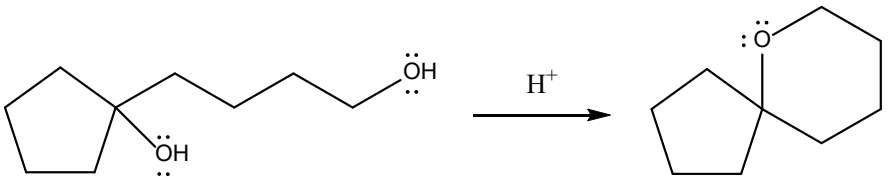
S_N1? yes / no	**S_N2?** yes / no	**E1?** yes / no	**E2?** yes / no

4. When I was a graduate student, I needed to prepare Compound **B** from Compound **A**: **[17 marks]**



A **B**

This was challenging because many acid catalysts would convert Compound **A** into Compound **C** instead:



A **C**

Fortunately, I was eventually able to find an acid/solvent combination that favoured the production of Compound **B** over Compound **C**.

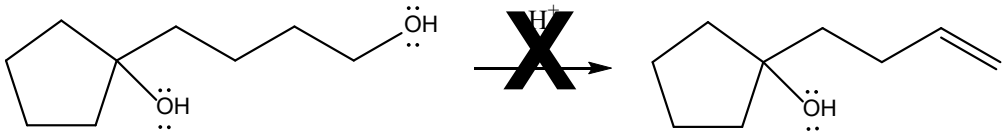
(a) Draw a reasonable mechanism for the formation of Compound **B** from Compound **A**. Clearly label your mechanism as either E1 or E2. *[6 marks]*

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4. *…continued*

(b) Why did I not need to worry about production of Compound **D** as a side reaction? *[2 marks]*

For full marks, your answer must include a relevant structure.

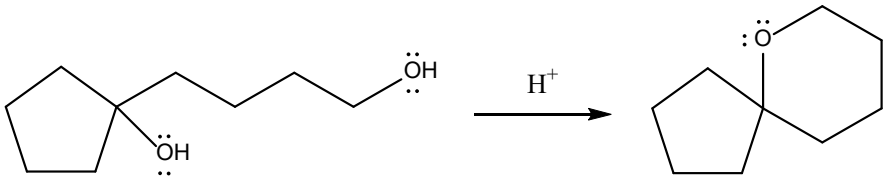


A **D**

(c) I did see one other elimination product when I reacted Compound **A** with acid. I was able to minimize its formation but never entirely eliminate it. What would you expect to be the other elimination product formed when Compound **A** is reacted with an acid catalyst? *[2 marks]*

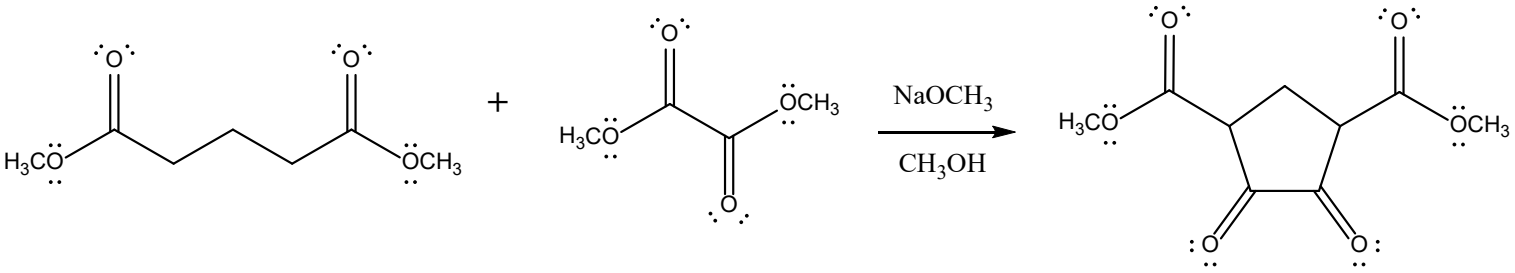
Just draw the structure of the product; I'm not looking for a mechanism.

(d) Draw a reasonable mechanism for the formation of Compound **C** from Compound **A**. *[7 marks]*

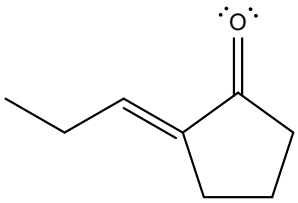


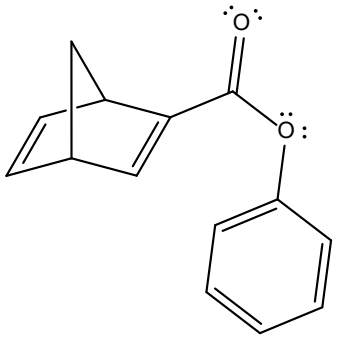
A **C**

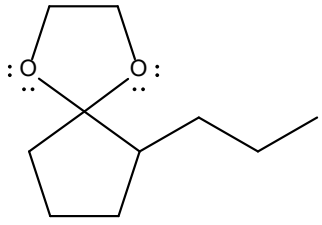
5. Propose a reasonable mechanism for the following reaction. **[11 marks]**

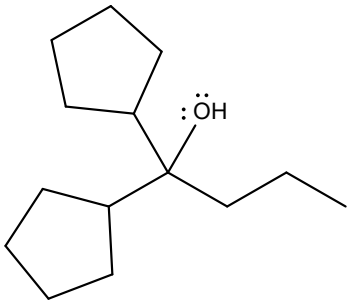


6. Choose any **three** of the molecules below and propose a synthesis for each one. **[18 marks]**
   - If your synthesis involves more than one step, write an equation for each step. Show all required reactants. Number steps within a reaction if order of addition is important.
   - All organic reactants must be stable compounds containing **no more than five carbon atoms**. They may be **hydrocarbons, alkyl halides or alcohols** and may contain C=C or C≡C bonds. The only exception to this rule is that you are **also allowed** to use **benzene, bromobenzene or phenol**.
   - If you wish to use an organic reactant (including Grignard reagent) that does not meet these requirements, you must show how to make it from starting materials that do.
   - You may use any inorganic reagents, acids, bases, catalysts, etc.
   - Acids, bases, catalysts, etc. do not need to meet the "organic reactant" requirements if the organic part will not be present in the final product.
   - Clearly indicate stereochemistry of reaction products where appropriate. Assume that all stereochemistry shown is relative and that you are to make racemic product.
   - You are **not** required to show mechanisms for this question.
   - There are three pages after this page. Use one of those pages for each synthesis and clearly identify the synthetic target at the top of the page. This page is scrap paper.
   - If you give more than three syntheses, I will only mark the first three (ignoring any that are crossed out).









6. *continued…* *[6 marks]*

Synthetic Target #1:

Synthesis:

6. *continued…* *[6 marks]*

Synthetic Target #2:

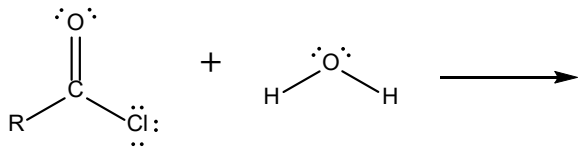
Synthesis:

6. *continued…* *[6 marks]*

Synthetic Target #3:

Synthesis:

7. A solvolysis is a reaction in which the solvent is one of the reactants. For example, if an acid chloride is added to a beaker of water, solvolysis of the acid chloride will occur: **[6 marks]**



(a) Draw the organic product of this reaction in the space provided above. *[2 marks]*

(b) This is a second order reaction. Write the rate law for this reaction. You do not need to provide a numerical value for k. *[2 marks]*

(c) Using kinetic data to prove that this is a second order reaction would be challenging. Briefly explain why having one of the reactants be the solvent makes it difficult to collect experimental data that clearly demonstrates reaction order. *[2 marks]*

8. What was the most useful and/or interesting thing you learned in CHEM 2600? **[1 mark]**

…AND THAT'S ALL FOR CHEM 2600.

HAPPY HOLIDAYS!