Fall 2023 **Chemistry 2600 Midterm #1** ____/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 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 0/60 on this exam.

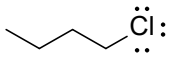
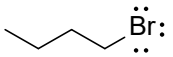
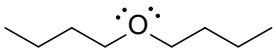
Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 7 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 may use a molecular model kit and ruler. You may not have written materials in your model kit.
4) You may use a calculator but only for calculation. No other electronic devices are 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. If delocalization of electrons is invoked, the relevant resonance structures must be drawn.
7) Marks will be deducted for incorrect information added to an otherwise correct answer.
8) You have 2 hours to complete this test.

Question Breakdown

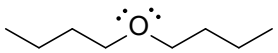
Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**									**Total**
/ 8	/ 4	/ 12	/ 4	/ 10	/ 22									/ 60

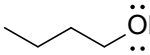
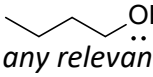
1. You find an unlabeled bottle in the back of the chemical cabinet. In order to decide how best to dispose of it, you analyze it by ^{1}H NMR and ^{13}C NMR. That convinces you that it is one of the following three compounds: **[8 marks]**

The lab next door offers to let you use their mass spectrometer to analyze your mystery compound since that should let you choose definitively between these three options.

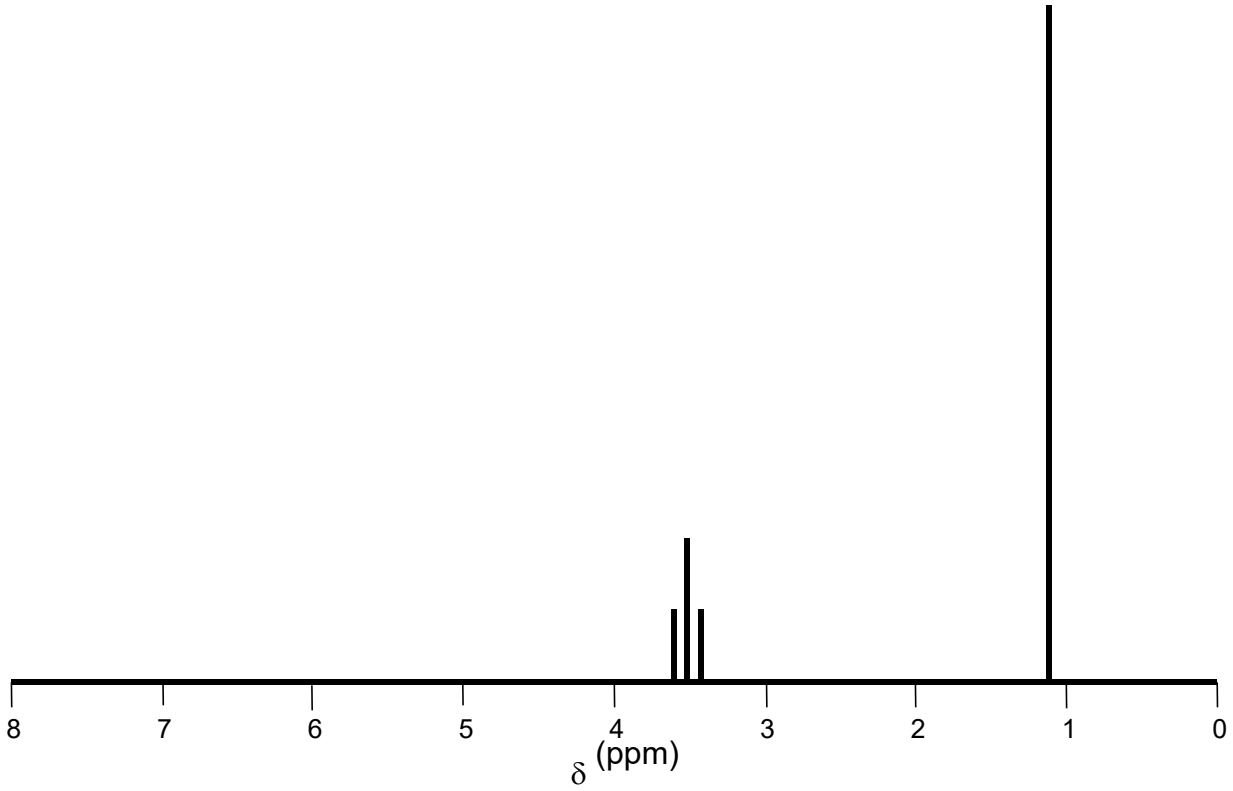
(a) Describe what you would expect to see in the molecular ion region of a mass spectrum for each of these three compounds. Be specific. Your answer should address two factors. *[5 marks]*

(b) Your friend points out that  contains a lot more hydrogen atoms than the other two options. Why can't you use the integrals on the ^{1}H NMR to distinguish between this option and the other two? *[1 mark]*

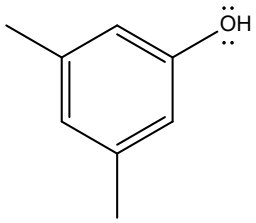
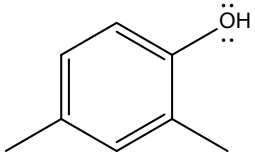
(c) Your friend also wonders why you haven't included  on your list of options. Which of the two types of NMR let you eliminate this compound as an option? How did it do that? *In other words, how would that spectrum for*  *be different from the spectrum for any of the three compounds in part (a). Describe any relevant peaks.* *[2 marks]*

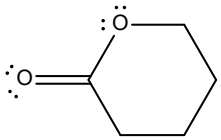
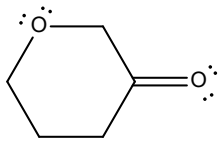
2. I had to draw the ^{1}H NMR spectrum below myself because it can't possibly correspond to any real compound. Why not? What's wrong with it? Explain. **[4 marks]**

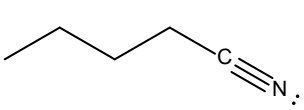
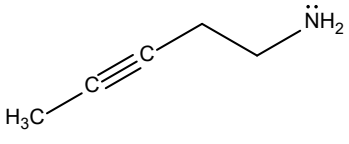
Since integrals are not provided, I will confirm that there are two peaks on this spectrum.



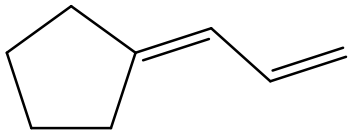
3. For each of the following pairs of molecules, explain how you would use **<u>two</u>** different spectroscopic methods to distinguish between them. Be specific. What peak(s) are you looking for? Where are they? Give numbers or ranges where possible. Unless the distinguishing feature of a spectrum is its lack of interesting peaks, mention at least one peak per molecule. **[12 marks]** *You may choose from ^{1}H NMR, ^{13}C NMR, IR and MS. You may choose different spectroscopic methods for each pair of molecules. It must be clear which methods you have chosen.*

(a)  vs. 

(b)  vs. 

(c)  vs. 

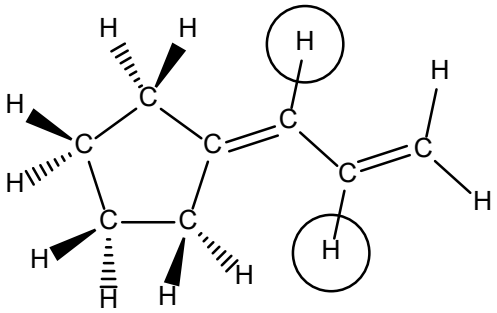
4. Consider the following molecule: **[4 marks]**



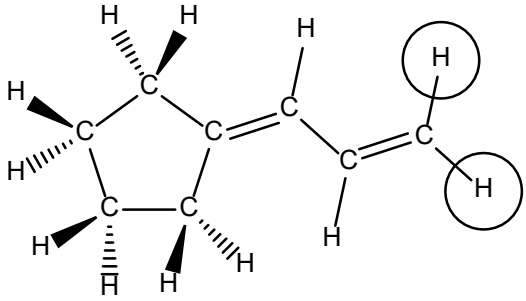
Below each drawing, write one of the following abbreviations (H, E, D or CD) to indicate the relationship between the circled hydrogen atoms:

- Homotopic (H)
- Enantiotopic (E)
- Diastereotopic (D)
- Constitutionally Different (CD)

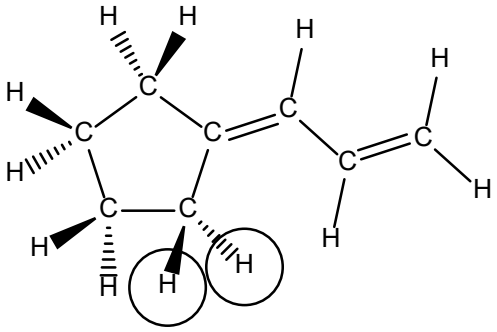
(a)



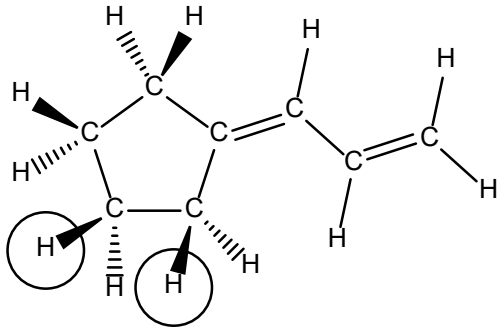
(b)



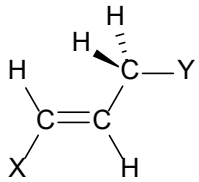
(c)



(d)

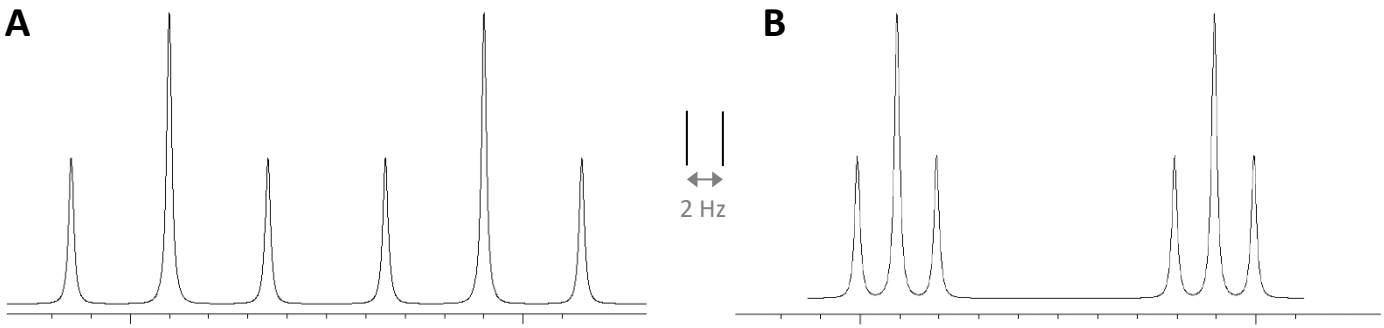


5. When the following molecule is analyzed by ^{1}H NMR, three signals are observed. **[10 marks]**



X and Y contain no hydrogen atoms.

Two of those signals are shown below (labeled "A" and "B"). The distance between adjacent "ticks" along the bottom of each spectrum is 2 Hz.



(a) Both signals have the same splitting pattern (with different coupling constants). *[2 marks]*
Name the splitting pattern.

(b) Measure or calculate the coupling constants for each signal. Label each diagram with the appropriate coupling constants, clearly indicating which lines were used to measure/calculate each coupling constant. *[4 marks]*

(c) Clearly identify which hydrogen atom(s) generated each of the two signals shown above. *[2 marks]*

(d) What does the third signal on the ^{1}H NMR look like? Sketch a picture and name the splitting pattern. *You are not expected to predict chemical shift since you do not know what "X" and "Y" are.* *[2 marks]*

6. The following page contains spectra for Unknown X ($C_5H_{14}N_2$). **[22 marks]**

(a) Identify Unknown X based on these spectra. Draw your answer in the box provided below.

(b) Use this page to explain your reasoning. **Calculation of integrals is required for full marks.**

(c) On both NMR spectra, assign as many peaks as you can by numbering the peaks from left to right, drawing Unknown X in the box provided, and labeling each carbon or hydrogen atom with the appropriate peak number. For atoms that cannot be assigned with certainty, list the signals to which they might reasonably correspond.

(d) Label any important peaks on the IR, clearly identifying which bond(s) correspond(s) to each peak. "Important peaks" are those for which a wavenumber has been listed.

Unknown X:

6. *…continued*

$C_5H_{14}N_2$

