NAME:_____   Section:_____   Student Number:_____

Fall 2019   **Chemistry 2600 Midterm**   ____/ 65 marks

INSTRUCTIONS: 1) Please read over the test carefully before beginning. You should have 8 pages
                     of questions in addition to this cover page and a periodic table.
                  2) You have also 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 any papers
                     or other written materials in your model kit.
                  4) You may use a calculator. It may not have wireless capability. You may not
                     have any other electronic devices (phone, iPod, etc.) with you when you write
                     the exam.
                  5) If your work is not legible, it will be given a mark of zero.
                  6) Marks will be deducted for incorrect information added to an otherwise
                     correct answer.
                  7) You have 2 hours to complete this test.

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam until after 8:00pm Mountain
Time on Tuesday, October 8th, 2019. I understand that breaking this agreement would constitute
academic misconduct, a serious offense with serious consequences. The minimum punishment would
be a mark of 0/65 on this exam and removal of the "overwrite midterm mark with final exam mark"
option for my grade in this course; the maximum punishment would include expulsion from this
university.

Signature: _____   Date: _____
Course: CHEM 2600 (Organic Chemistry II)
Semester: Fall 2019
The University of Lethbridge

Question Breakdown

Q1	/ 12
Q2	/ 6
Q3	/ 8
Q4	/ 19
Q5	/ 20

Total	/ 65

1.   For each of the following pairs of molecules, explain how you would use **two** spectroscopic methods to distinguish between them. Be specific. What peak(s) are you looking for? Where are they? Give numbers or ranges where possible.   **[12 marks]**
    You may choose from ^1H 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.
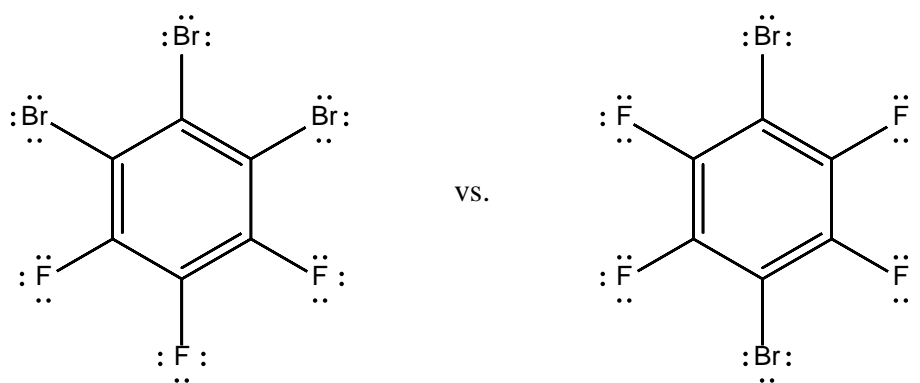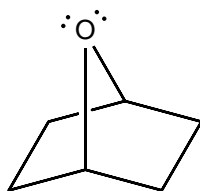
(a)

vs.

(b)

vs.

(c)

vs.
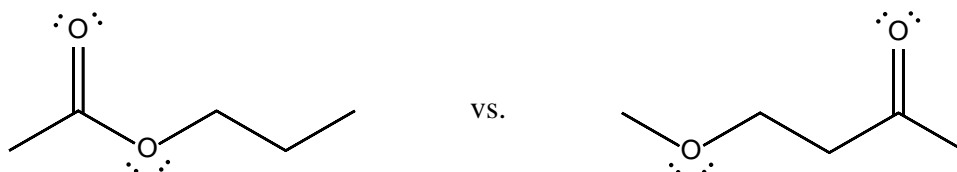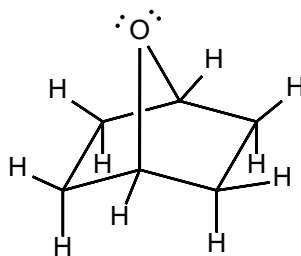
2.   Consider the following molecule: **[6 marks]**
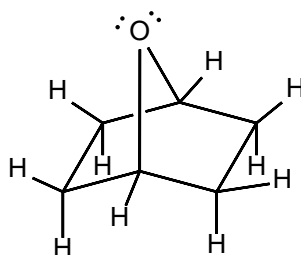

(a)   On the picture below, circle two hydrogen atoms which are enantiotopic: *[2 marks]*
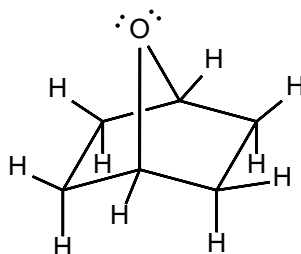

(b)   On the picture below, circle two hydrogen atoms which are diastereotopic: *[2 marks]*

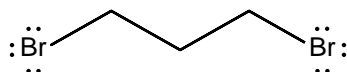(c)   On the picture below, circle two hydrogen atoms which are constitutionally different:

[2 marks]

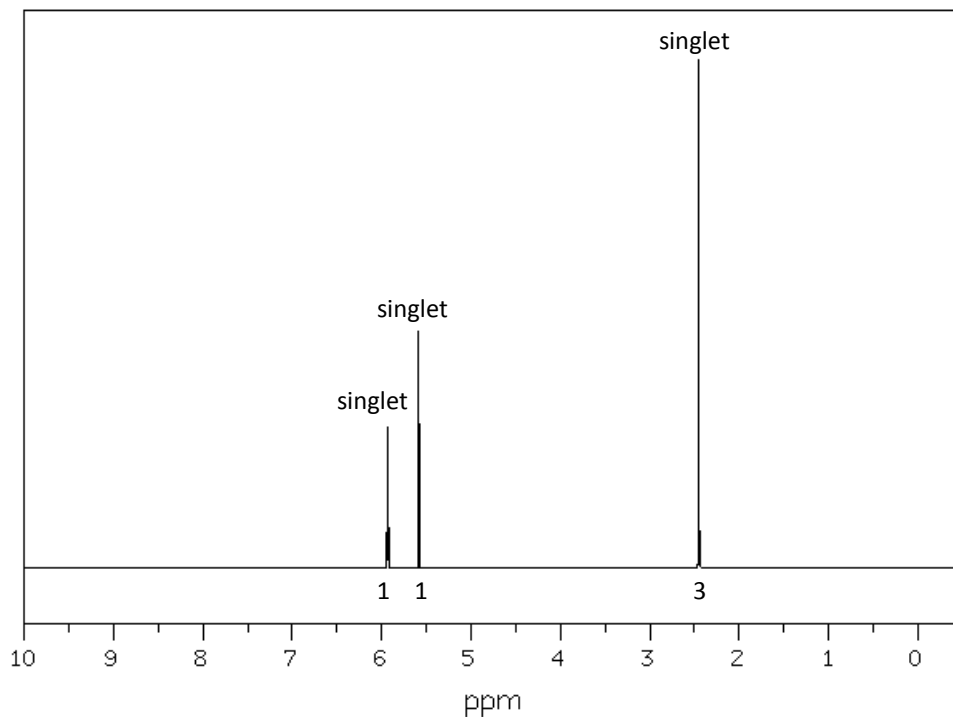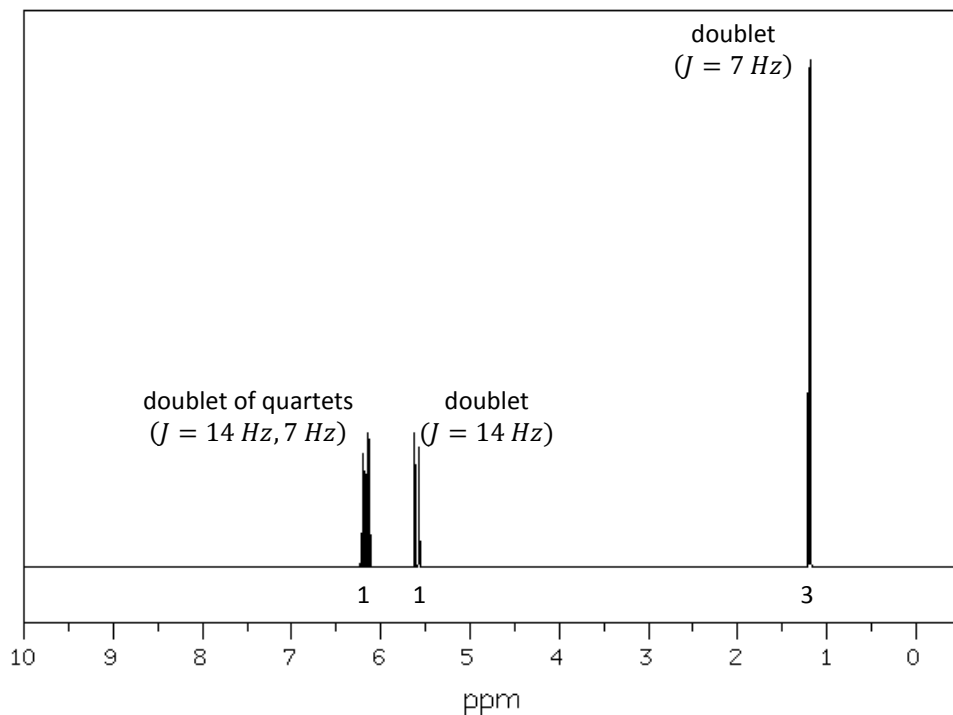3.   Consider the following molecule: **[8 marks]**

:Br Br:

(a)   If you were to analyze this molecule by mass spectrometry, what would you expect to see **in the molecular ion region**? Your answer should address both the value(s) at which you would see peaks and the ratio of those peaks.   *[4 marks]*
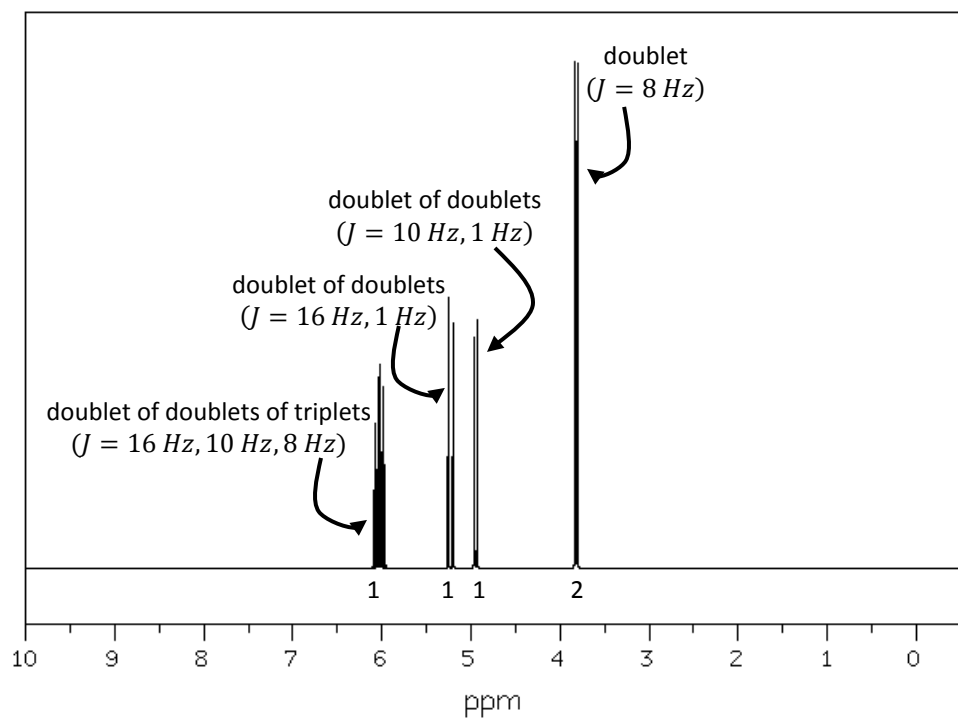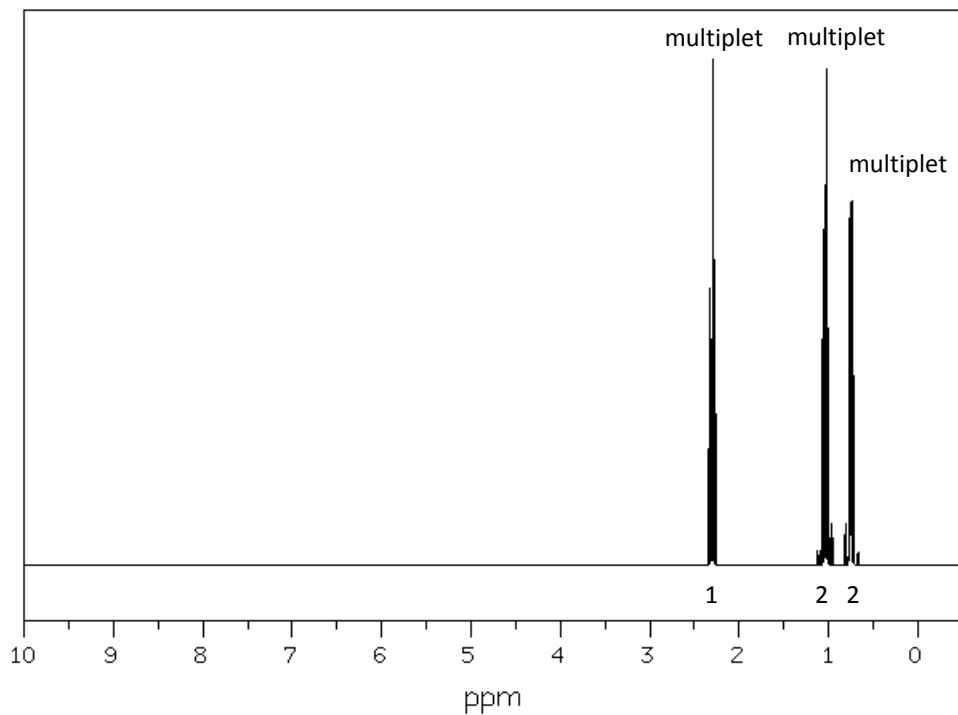*You do not need to explain your answer.*

(b)   Identify two fragments you would also expect to see on the mass spectrum. For each, identify both the value for the peak and the chemical formula for the fragment (or draw it).   *[4 marks]*
You do not need to explain your answer.

4.   Including stereoisomers, five isomers are possible for C_3H_5I. ^{1}H NMR spectra for these five
isomers are shown on the next three pages. Multiplicity and coupling constants (where
applicable) are listed above each peak; integration is listed below.
Next to each spectrum, draw the isomer to which it corresponds. Label each hydrogen (or set of
shift equivalent hydrogens) with a unique number or letter. Use these labels to identify the ^{1}H
NMR peak corresponding to each hydrogen. In cases where it is not possible to know which of
two hydrogen atoms made each of two peaks, label both peaks with both options.   **[19 marks]**

doublet
$(J = 7\ Hz)$

doublet of quartets   doublet
$(J = 14\ Hz, 7\ Hz)$ $(J = 14\ Hz)$

1   1   3

10   9   8   7   6   5   4   3   2   1   0
ppm

singlet

singlet

singlet

1   1   3

10   9   8   7   6   5   4   3   2   1   0
ppm

4.   *…continued…*

4.   *…continued*

doublet
$(J = 6.5\ Hz)$

doublet
$(J = 7.3\ Hz)$

doublet of quartets
$(J = 7.3\ Hz, 6.5\ Hz)$

1   1

3

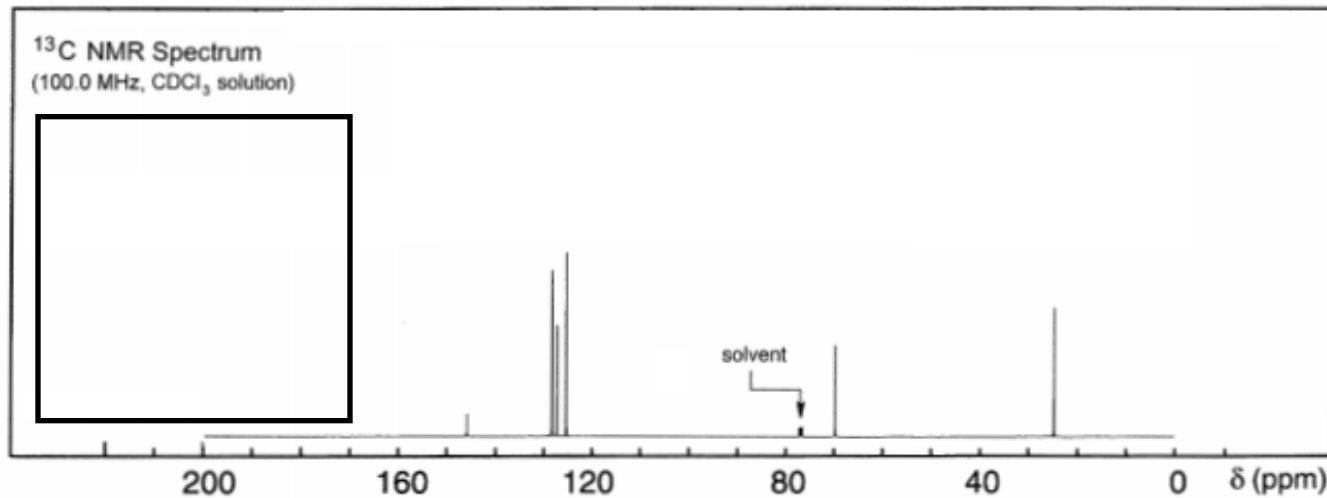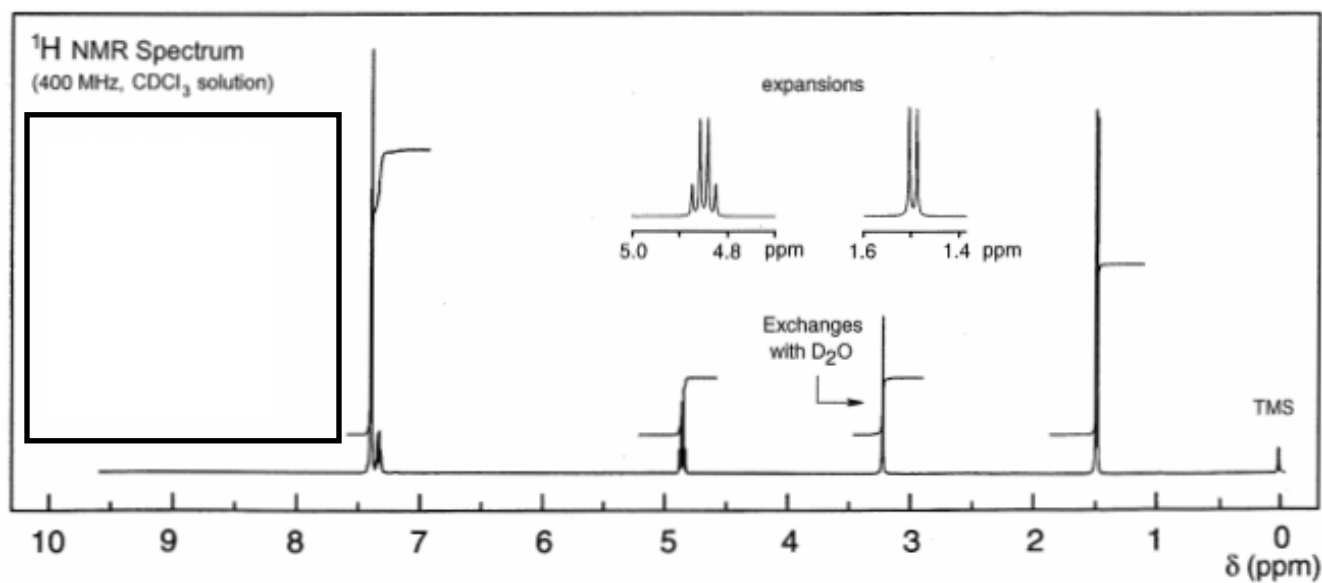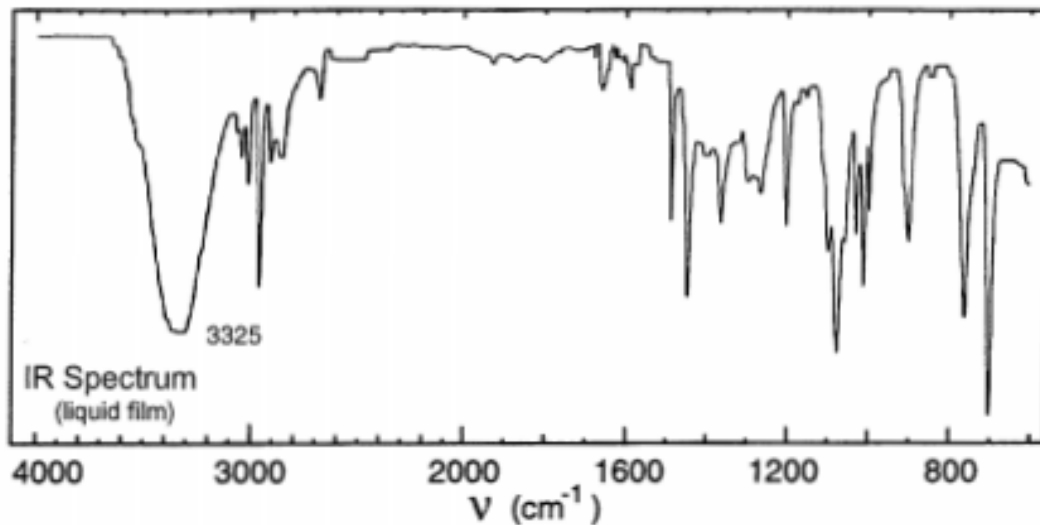10   9   8   7   6   5   4   3   2   1   0

ppm
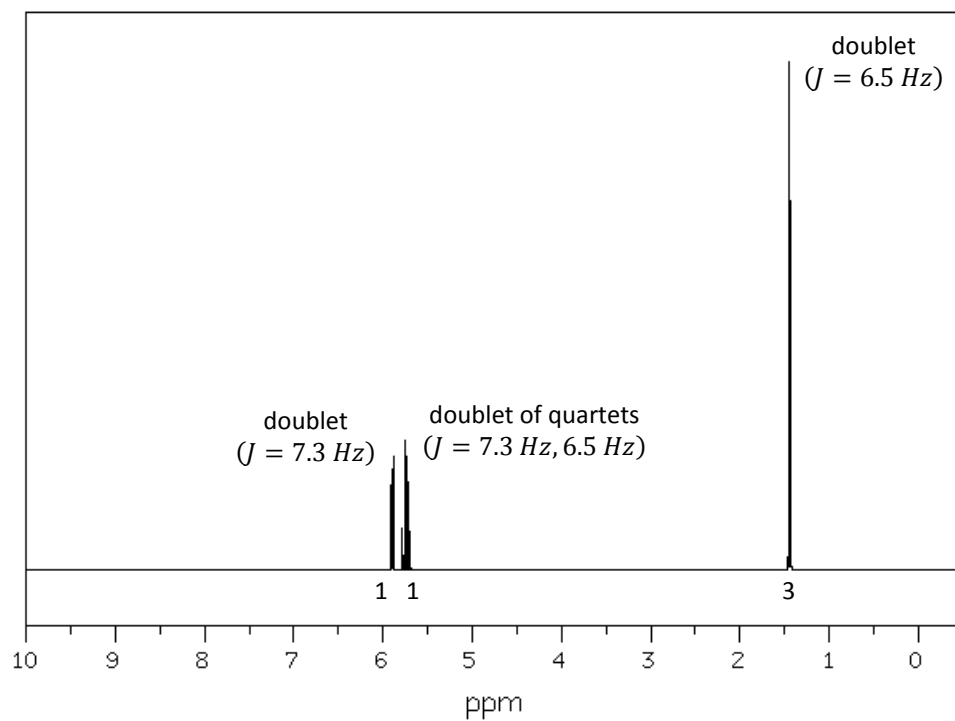
5.   The following page contains spectra for Unknown X ($C_8H_{10}O$).   **[20 marks]**
(a)   Identify Unknown X based on these spectra. Draw your answer in the box provided below.
(b)   Use this page to explain your reasoning.
(c)   On both NMR spectra, assign as many peaks as you can by numbering the 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.

Unknown X:

5.   ...*continued*

C₈H₁₀O

3325

IR Spectrum
(liquid film)

4000   3000   2000   1600   1200   800

V (cm⁻¹)

¹H NMR Spectrum
(400 MHz, CDCl₃ solution)

expansions

5.0   4.8 ppm   1.6   1.4 ppm

Exchanges
with D₂O

TMS

10   9   8   7   6   5   4   3   2   1   0

δ (ppm)

¹³C NMR Spectrum
(100.0 MHz, CDCl₃ solution)

solvent

200   160   120   80   40   0   δ (ppm)

CHEM 1000 Standard Periodic Table

1																		18
1.0079 **H** 1	**2**												**13**	**14**	**15**	**16**	**17**	4.0026 **He** 2
6.941 **Li** 3	9.0122 **Be** 4												10.811 **B** 5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	20.1797 **Ne** 10
22.9898 **Na** 11	24.3050 **Mg** 12	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**		26.9815 **Al** 13	28.0855 **Si** 14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	39.948 **Ar** 18
39.0983 **K** 19	40.078 **Ca** 20	44.9559 **Sc** 21	47.88 **Ti** 22	50.9415 **V** 23	51.9961 **Cr** 24	54.9380 **Mn** 25	55.847 **Fe** 26	58.9332 **Co** 27	58.693 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30		69.723 **Ga** 31	72.61 **Ge** 32	74.9216 **As** 33	78.96 **Se** 34	79.904 **Br** 35	83.80 **Kr** 36
85.4678 **Rb** 37	87.62 **Sr** 38	88.9059 **Y** 39	91.224 **Zr** 40	92.9064 **Nb** 41	95.94 **Mo** 42	(98) **Tc** 43	101.07 **Ru** 44	102.906 **Rh** 45	106.42 **Pd** 46	107.868 **Ag** 47	112.411 **Cd** 48		114.82 **In** 49	118.710 **Sn** 50	121.757 **Sb** 51	127.60 **Te** 52	126.905 **I** 53	131.29 **Xe** 54
132.905 **Cs** 55	137.327 **Ba** 56	**La-Lu**	178.49 **Hf** 72	180.948 **Ta** 73	183.85 **W** 74	186.207 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.967 **Au** 79	200.59 **Hg** 80		204.383 **Tl** 81	207.19 **Pb** 82	208.980 **Bi** 83	(210) **Po** 84	(210) **At** 85	(222) **Rn** 86
(223) **Fr** 87	226.025 **Ra** 88	**Ac-Lr**	(265) **Rf** 104	(268) **Db** 105	(271) **Sg** 106	(270) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112		(284) **Nh** 113	(289) **Fl** 114	(288) **Mc** 115	(293) **Lv** 116	(294) **Ts** 117	(294) **Og** 118

138.906 **La** 57	140.115 **Ce** 58	140.908 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.965 **Eu** 63	157.25 **Gd** 64	158.925 **Tb** 65	162.50 **Dy** 66	164.930 **Ho** 67	167.26 **Er** 68	168.934 **Tm** 69	173.04 **Yb** 70	174.967 **Lu** 71
227.028 **Ac** 89	232.038 **Th** 90	231.036 **Pa** 91	238.029 **U** 92	237.048 **Np** 93	(240) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(262) **Lr** 103

Developed by Prof. R. T. Boeré (updated 2016)