

First name: \_\_\_\_\_ Last name: \_\_\_\_\_  
i.d. (last 4 digits only): \_\_\_\_\_

**Midterm 1**  
Version 1

**Organic Chemistry 2**

**CHEM222 and CHEM234**

**1 February 2013, 6:15-9:00 pm**

**INSTRUCTIONS:**

Please write your **Name and ID number** in the space provided above.

This is a Closed Book Examination. Multiple choice questions **1-8** are worth **2 points** each and **9-30** are worth **3 points** each. Short answer questions **31-36** are worth **3 points** each.

Answer multiple choice questions on the answer sheet provided (scantron) with a pen or pencil and short answer questions directly on the exam paper with ink.

Molecular models and pen/pencils are allowed.

Calculators, dictionaries or electronic devices are NOT allowed.

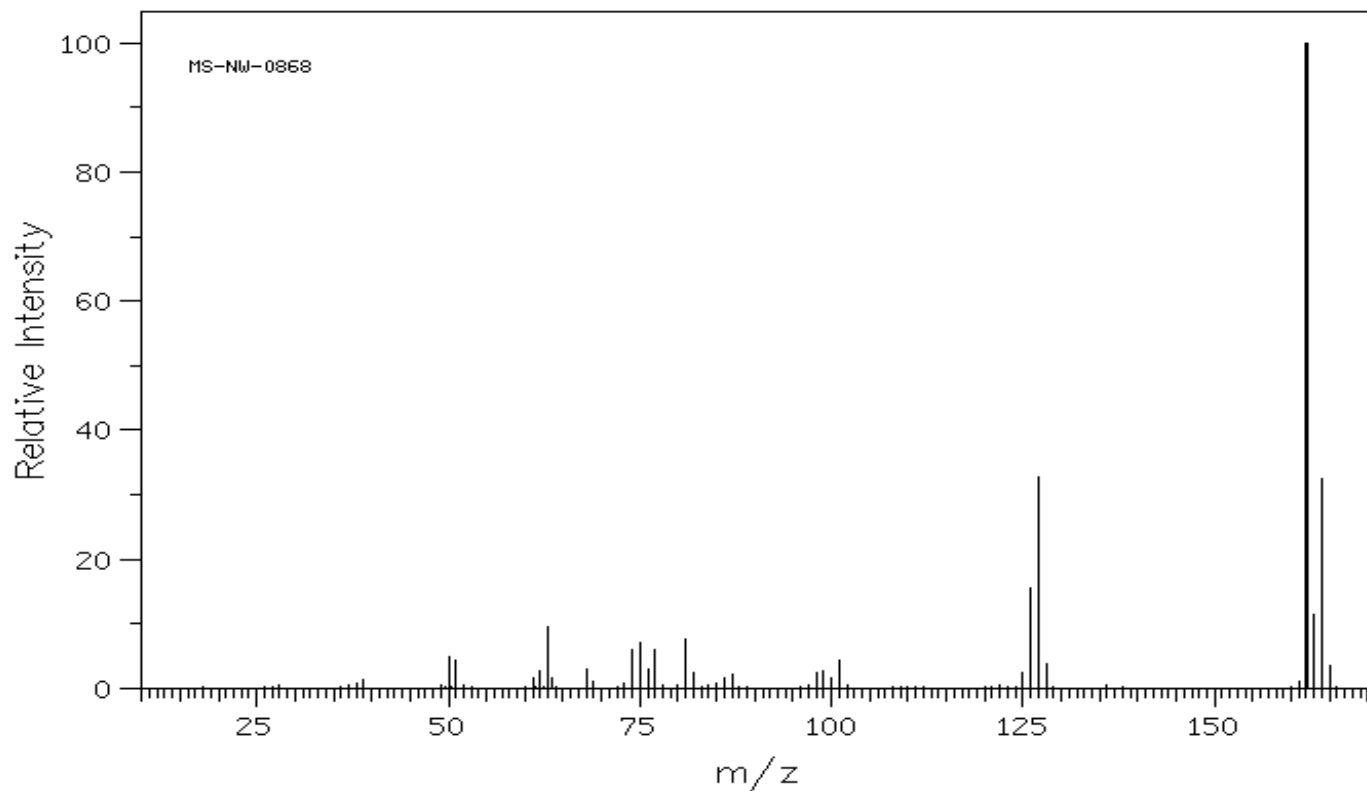
At the end you must **hand in ALL pages** of your exam.

*McGill University values academic integrity. Therefore all students must understand the meaning and consequences of cheating, plagiarism, and other academic offenses under the code of students conduct and disciplinary procedures.*

Good Luck!

**ANSWER QUESTION 1-30 ON THE SCANTRON (multiple answer sheet). Keep in mind that the scantron will NOT be returned to students.**

**Questions 1-3 refer to the MS spectrum below**



1-What can you conclude from this MS spectrum?

- a) this molecule contains Br
- b) this molecule contains Cl
- c) this molecule contains no F
- d) this molecule contains an odd number of N

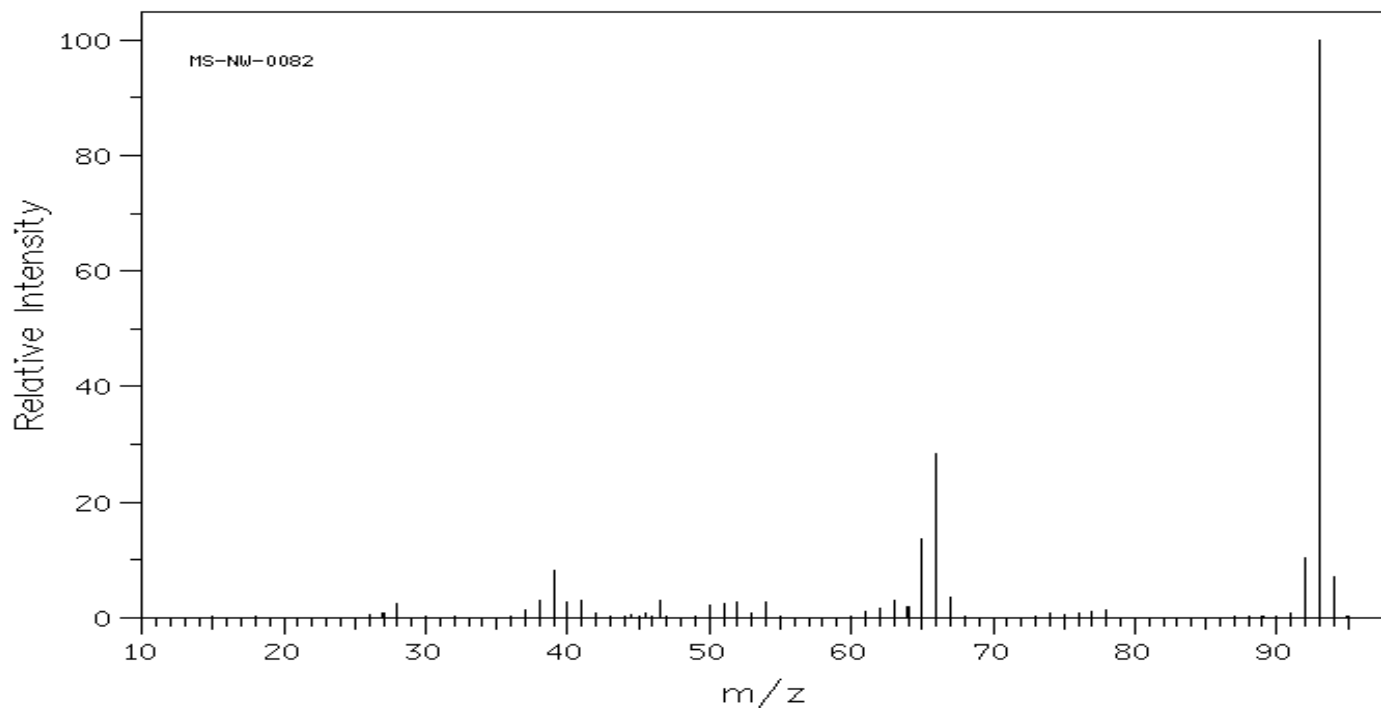
2-Which of the peaks of the above MS spectrum corresponds to the base peak?

- a) 162
- b) 165
- c) 127
- d) Does not show up

3- Which of the peaks of the above MS spectrum corresponds to the molecular ion?

- a) 162
- b) 165
- c) 127
- d) Does not show up

Questions 4, 5 and 6 refer to the MS spectrum below



4- In the MS spectrum above, what is the peak at 66?

- a) an impurity
- b) it is a fragment
- c) it is the base peak
- d) it is evidence for the presence of Cl

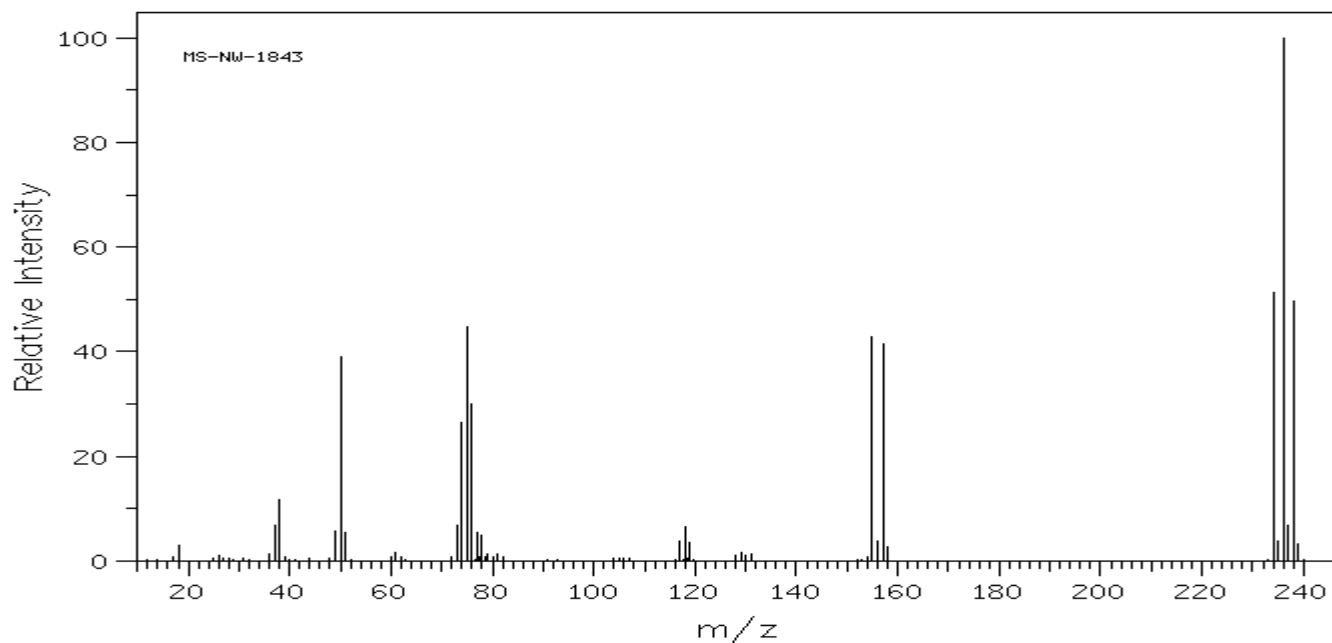
5- What can you say about the molecule that gives the MS spectrum above?

- a) it contains two chlorine atoms
- b) it contains bromine
- c) it contains nitrogen
- d) it has an even mass

6- In the MS spectrum above, what is the peak at 94?

- a) it is the molecular ion ( $M^+$ )
- b) it is caused by the presence of Cl
- c) it is caused by nitrogen
- d) it is caused by  $^{13}C$

7-What can you say about the molecule that gives the MS spectrum below?



- a) it contains one atom of Br
- b) it contains one atom of Cl
- c) it contains two atoms of Br
- d) it contains one atom of S

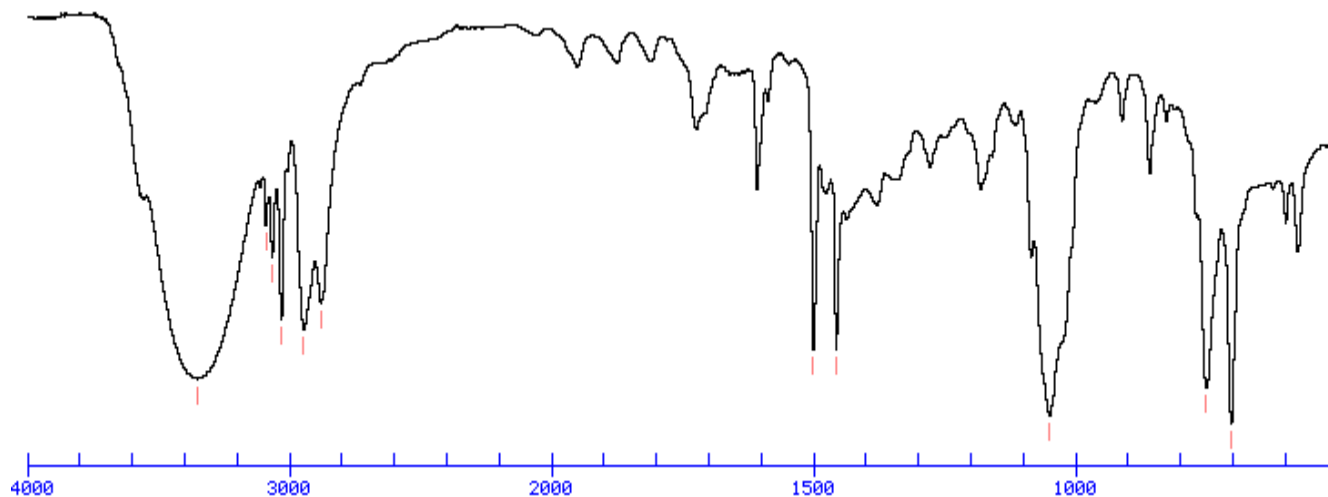
8- Which of the statements below is CORRECT about MS?

- a) MS is especially useful to verify for the presence of any halogen
- b) Not all isotopes can be detected by MS
- c) An odd molecular ion can only be observed when the molecule contains an odd number of N
- d) The molecular ion does not often show up with ketones

9- Which of the statements below is CORRECT about IR?

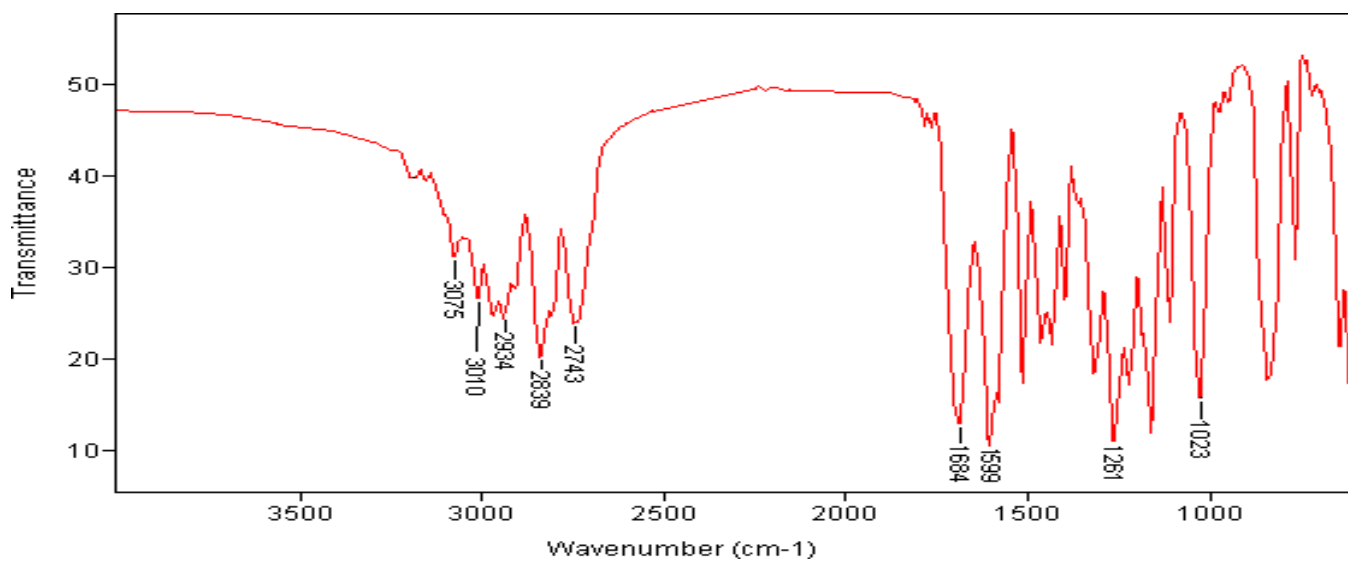
- a) IR allows easy detection of isotopes
- b) IR is very useful to detect the presence of halogens
- c) IR helps determine which functional group is adjacent to which
- d) IR allows easy detection of triple bonds

10- From the IR spectrum below, what can you conclude?



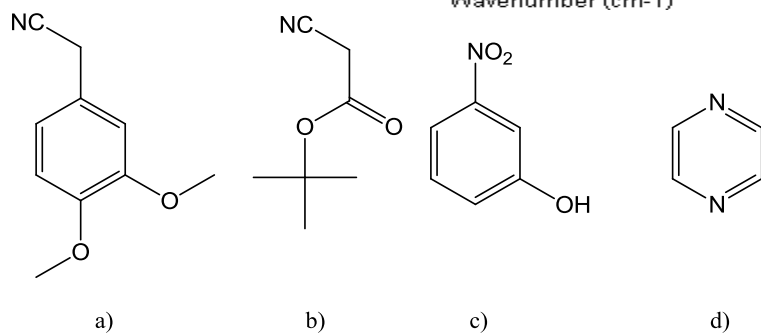
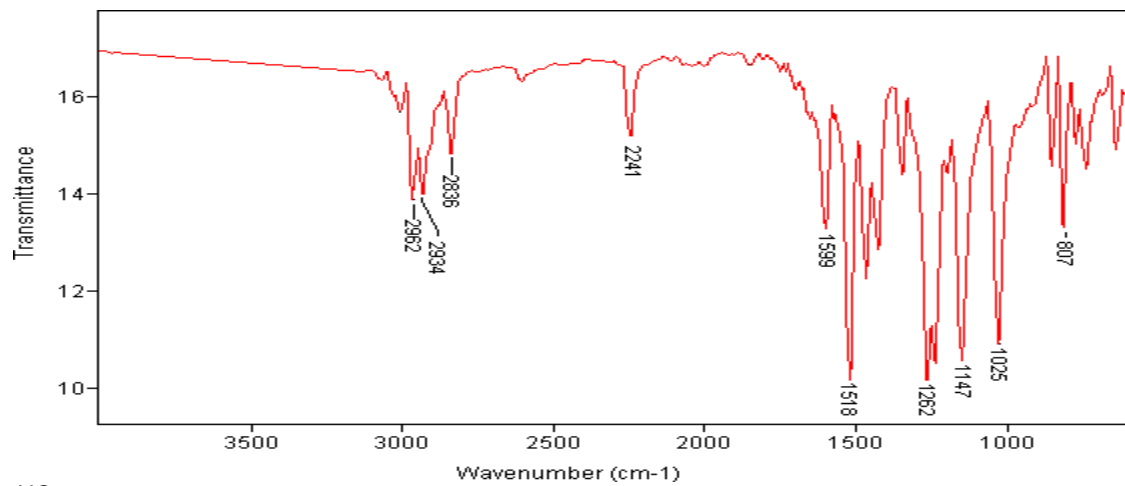
- a) presence of a carboxylic acid in the molecule
- b) presence of an alcohol and  $sp^2$  C-H bonds
- c) presence of a triple bond and an alcohol
- d) presence of an amide

11- From the IR spectrum below, what can you conclude?

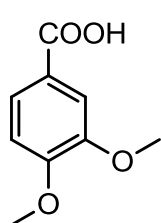
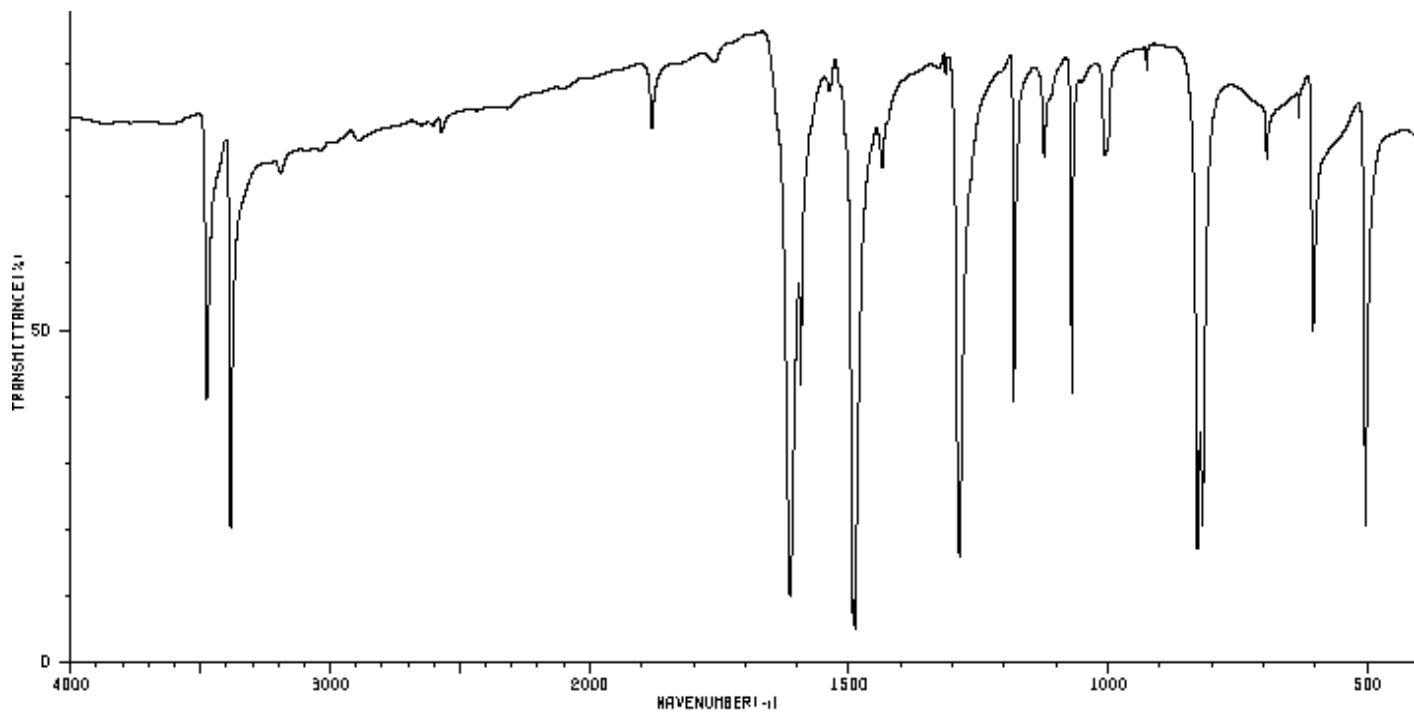


- a) presence of an alcohol in the molecule
- b) presence of a triple bond in the molecule
- c) presence of a ketone in the molecule
- d) presence of an aldehyde in the molecule

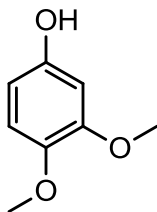
12- What is the most likely molecule giving rise to the IR spectrum below?



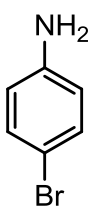
13- What is the most likely molecule giving rise to the IR spectrum below? (strong peaks are at ~3500, ~3400, ~1600, 1500, 1300, 800, and 500  $\text{cm}^{-1}$ )



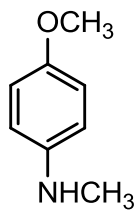
a)



b)

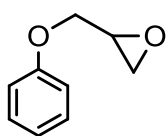
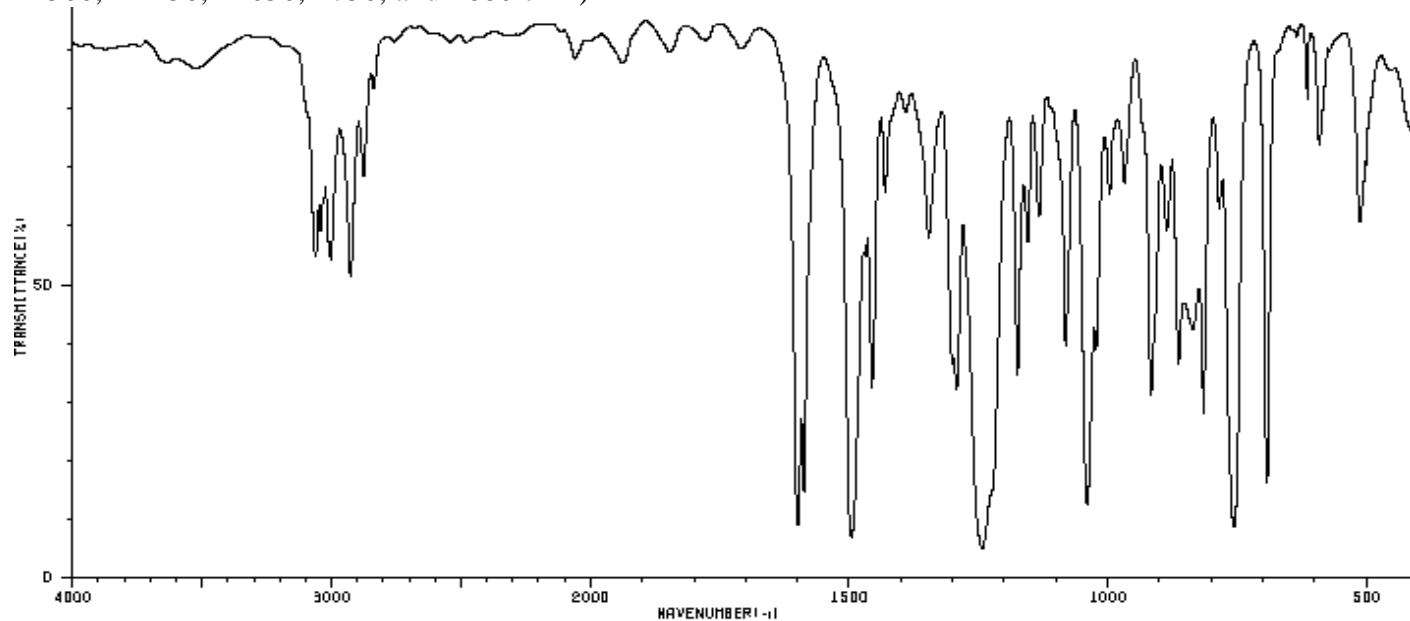


c)

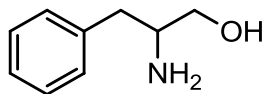


d)

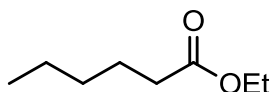
14-Which of the molecules below is more likely to give the IR spectrum below? (strong peaks are at ~1600, ~1500, ~1250, ~1050, ~750, and ~680  $\text{cm}^{-1}$ )



a)



b)

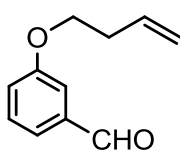
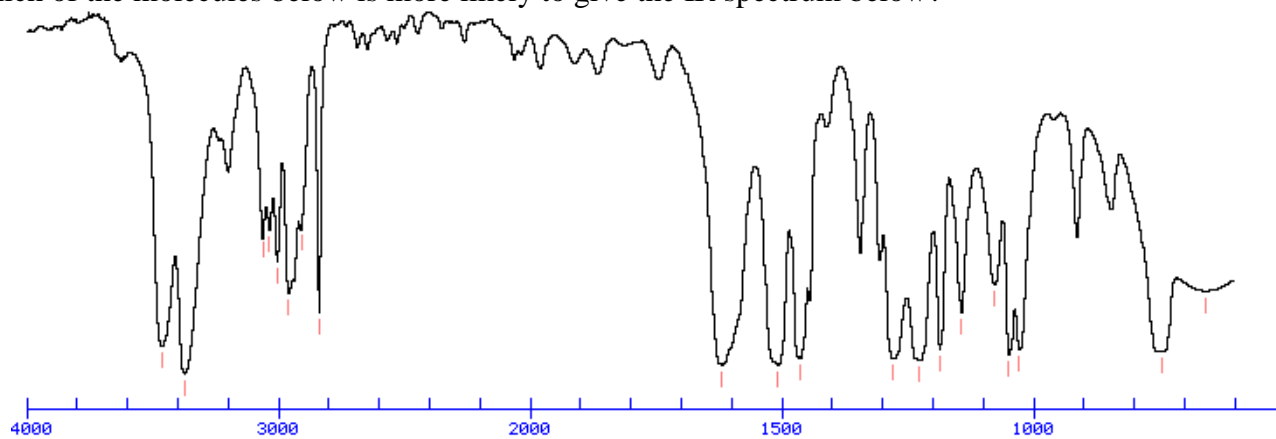


c)

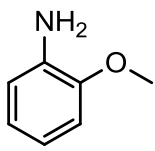


d)

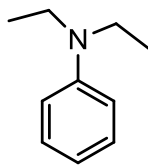
15-Which of the molecules below is more likely to give the IR spectrum below?



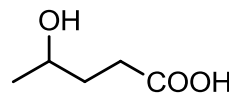
a)



b)

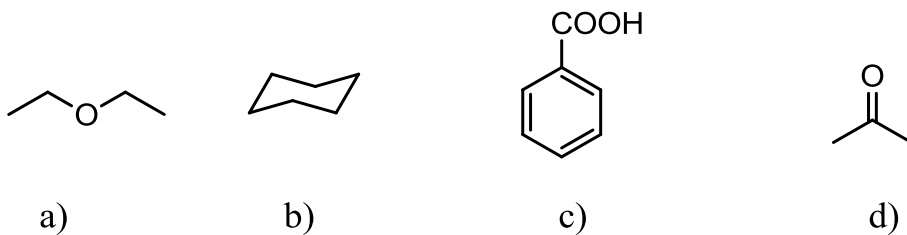
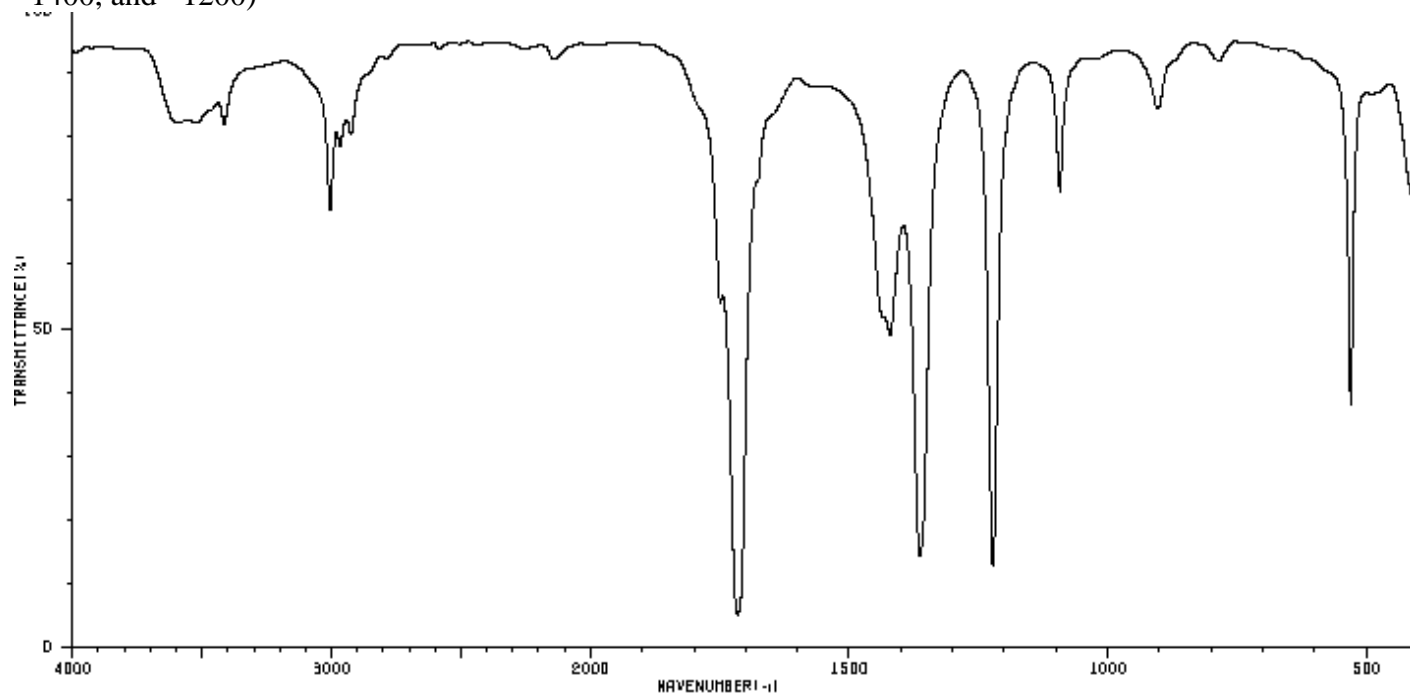


c)

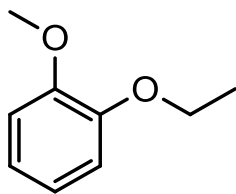


d)

16-Which of the molecules below is more likely to give the IR spectrum below? (strong peaks are at ~1700, ~1400, and ~1200)

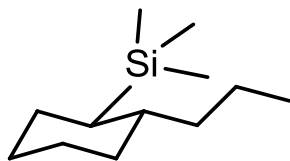


17- How many  $^1\text{H}$  NMR signals are theoretically expected for the molecule below?



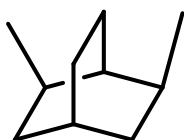
- a) 4
- b) 5
- c) 7
- d) 9

18- How many  $^1\text{H}$  NMR signals would you expect for the molecule below?



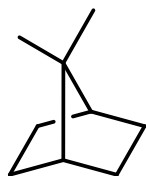
- a) 8
- b) 10
- c) 16
- d) 18

19- How many  $^1\text{H}$  NMR signals would you expect for the molecule below?



- a) 9
- b) 8
- c) 7
- d) 6

20- How many  $^{13}\text{C}$  NMR signals would you expect for the molecule below?



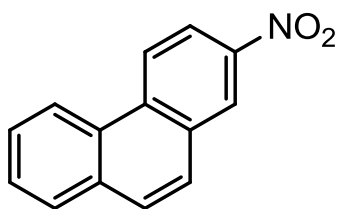
- a) 3
- b) 4
- c) 5
- d) 7

21- How many  $^{13}\text{C}$  NMR signals would you expect for the molecule below?



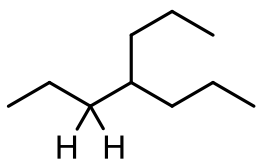
- a) 4
- b) 5
- c) 7
- d) 8

22- How many  $^{13}\text{C}$  NMR signals would you expect for the molecule below?



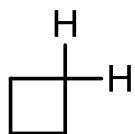
- a) 5
- b) 8
- c) 10
- d) 14

23-How do you qualify the two protons drawn out in the molecule below?



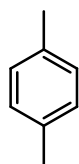
- a) homotopic
- b) enantiotopic
- c) diastereotopic

24-How can you qualify the two protons drawn out in the molecule below?

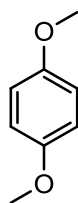


- a) homotopic
- b) enantiotopic
- c) diastereotopic

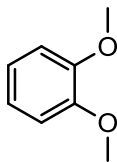
25- Which of the molecules below is more likely to have resulted in a  $^1\text{H}$  NMR spectrum with only 3 signals, located at 3.8, 6.8 and 6.9 ppm?



a)



b)



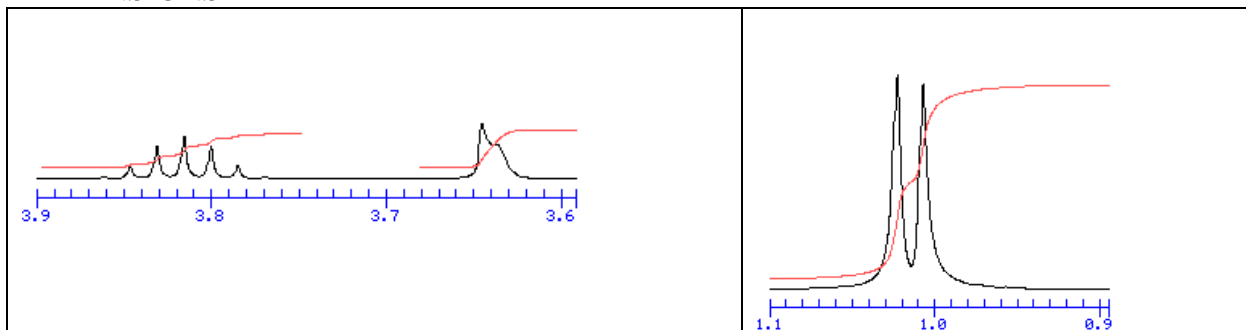
c)



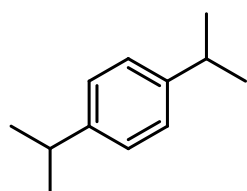
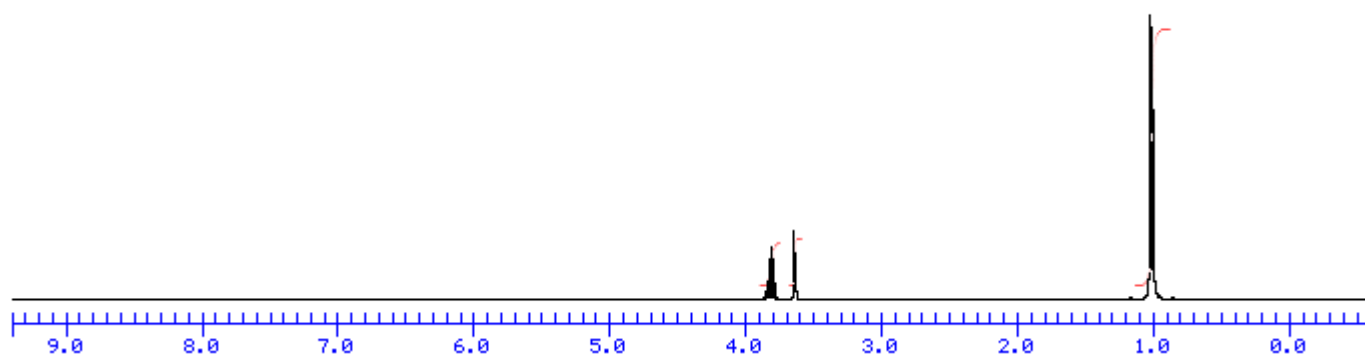
d)

26- Which of the molecules below is more likely to have resulted in the  $^1\text{H}$  NMR spectrum shown (expansions are shown and peak at 3.65 exchanges)?

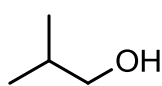
### EXPANSIONS



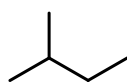
### FULL SPECTRUM



a)



b)



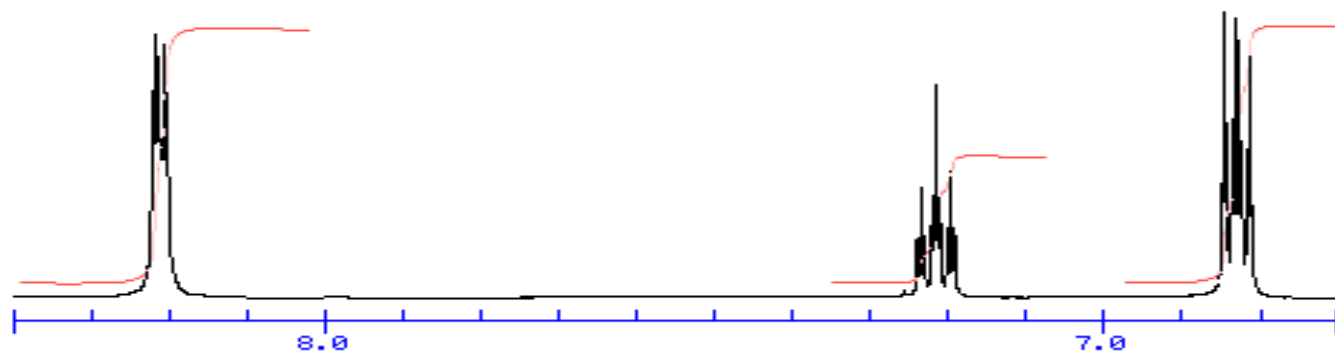
c)



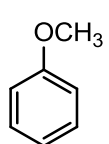
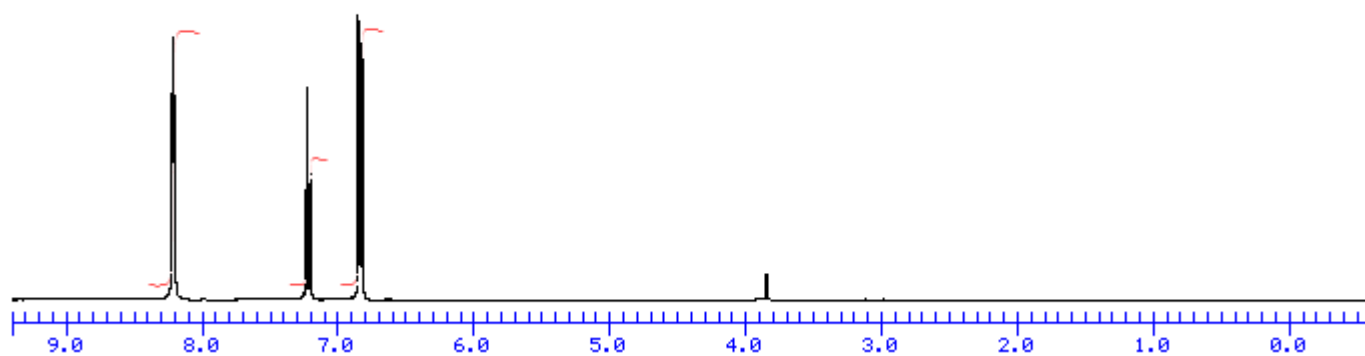
d)

27- Which of the molecules below is more likely to have resulted in the  $^1\text{H}$  NMR spectrum shown (expansions are shown)?

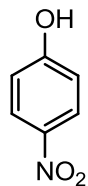
EXPANSION



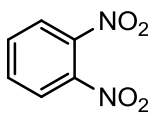
FULL SPECTRUM (signal at  $\sim 3.8$  ppm is caused by solvent)



a)



b)

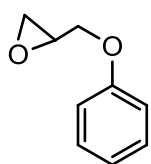
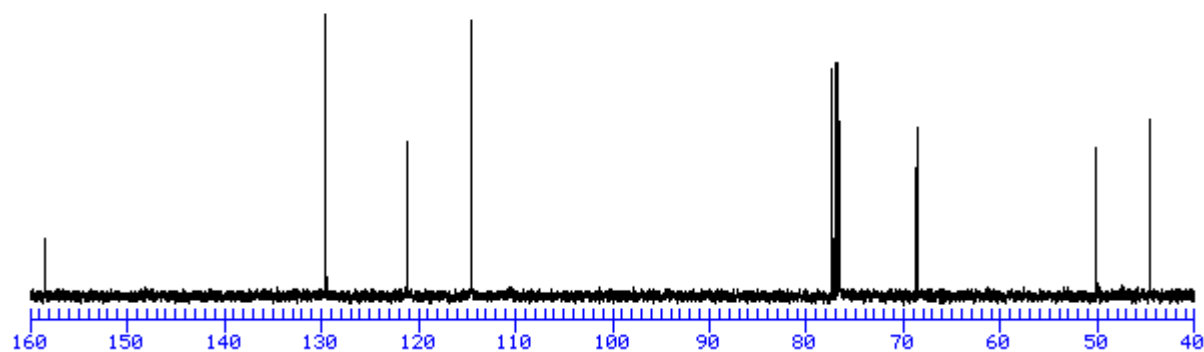


c)

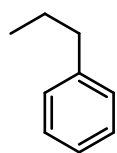


d)

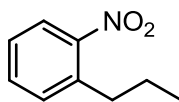
28- Which of the molecules below could best account for the  $^{13}\text{C}$  NMR spectrum shown?  
(only the section with signals is shown; triplet at  $\sim 77$  ppm is due to NMR solvent)



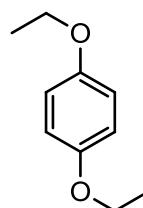
a)



b)

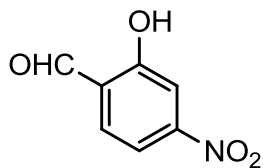
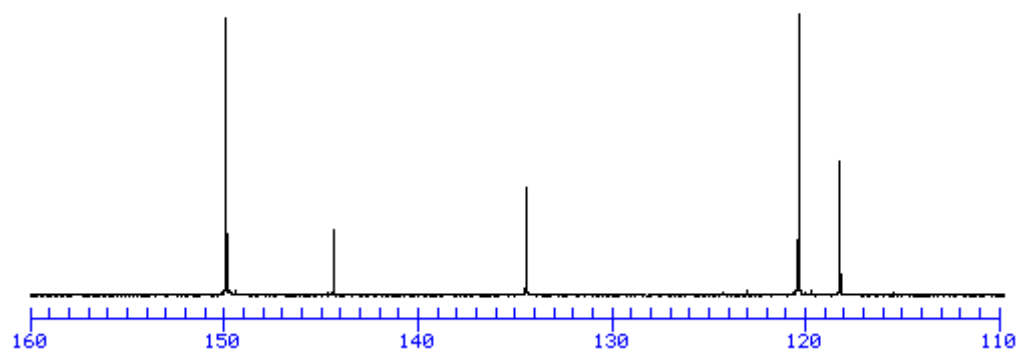


c)

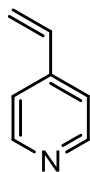


d)

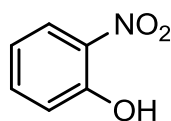
29- Which of the molecules below could best account for the  $^{13}\text{C}$  NMR spectrum shown?  
(only the section with signals is shown)



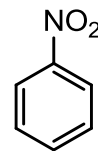
a)



b)



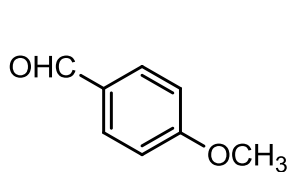
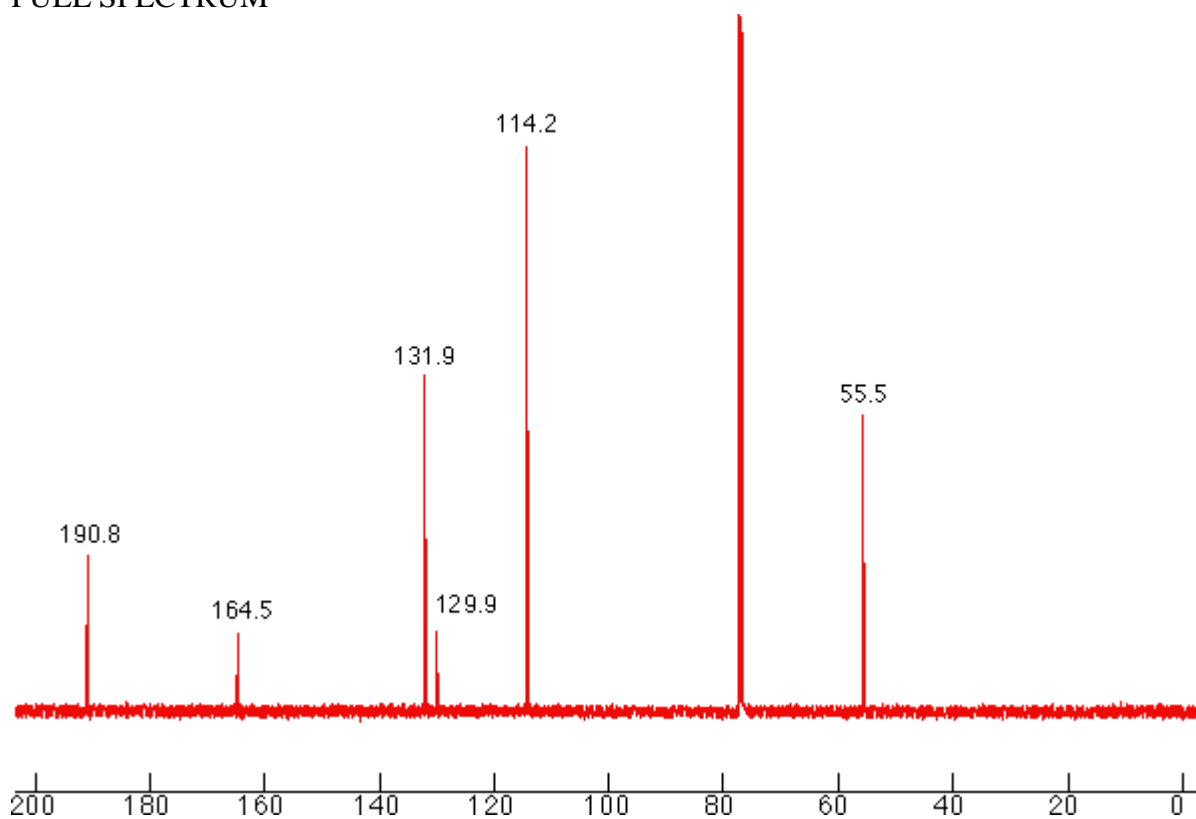
c)



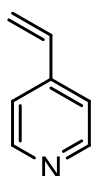
d)

30- Which of the molecules below could best account for the  $^{13}\text{C}$  NMR spectrum shown?  
(the signal at  $\sim 77$  ppm is due to the NMR solvent)

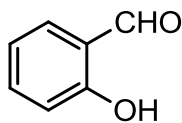
FULL SPECTRUM



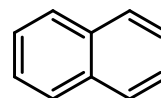
a)



b)



c)



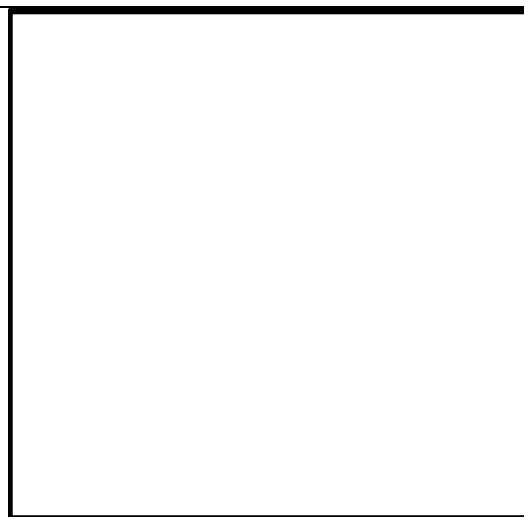
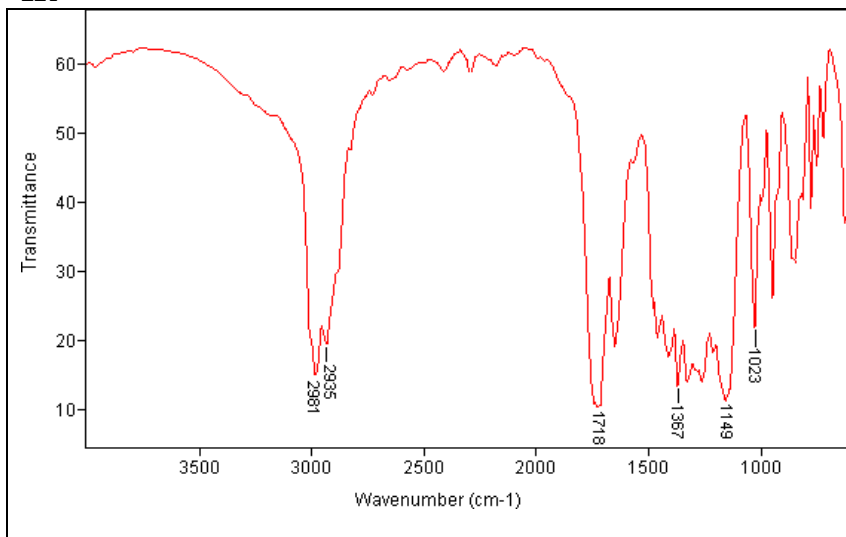
d)

**FOR QUESTIONS 30-36, ANSWER DIRECTLY IN THE BOX PROVIDED  
ANY STRUCTURES OUTSIDE THE BOX WILL NOT BE CONSIDERED BY THE GRADERS.**

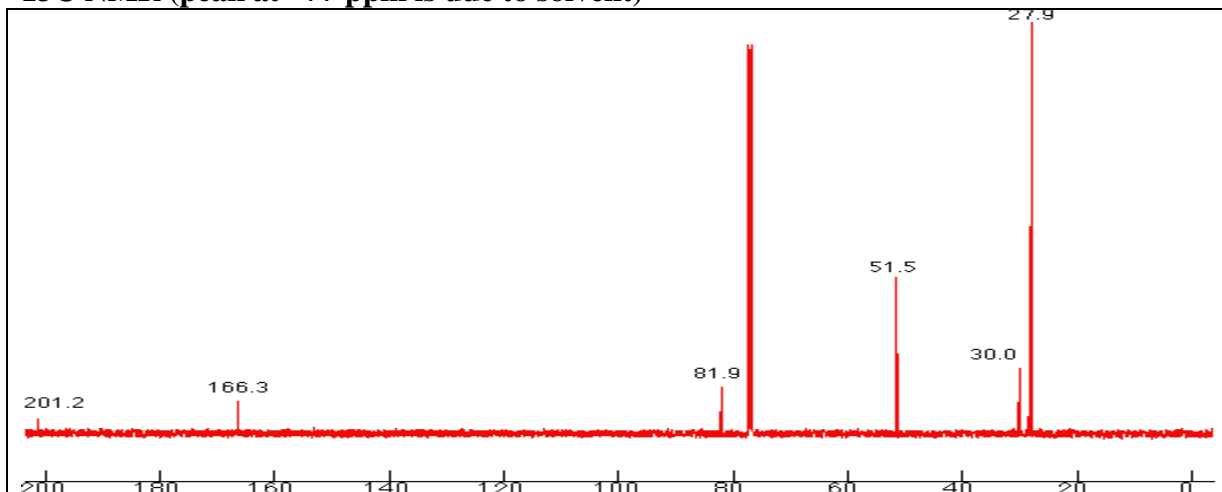
31- Spectra are shown for a molecule of formula  $C_8H_{14}O_3$ . Propose a structure (write final answer in the box).

**IR**

**ANSWER**

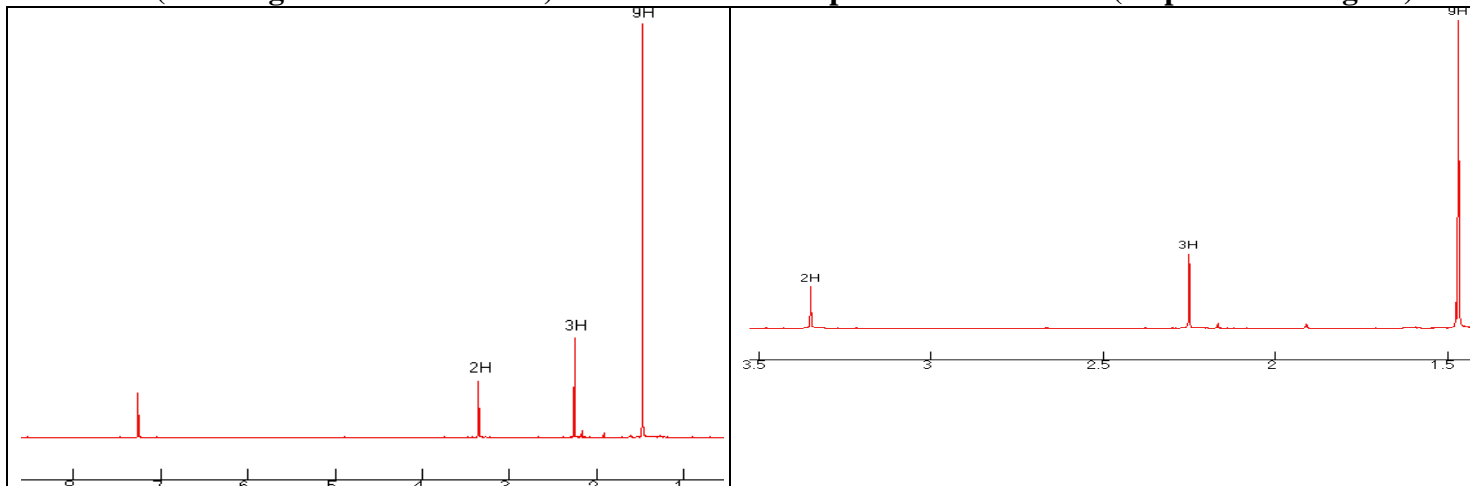


**$^{13}C$  NMR (peak at ~77 ppm is due to solvent)**



**$^1H$  NMR (7.26 singlet is due to solvent)**

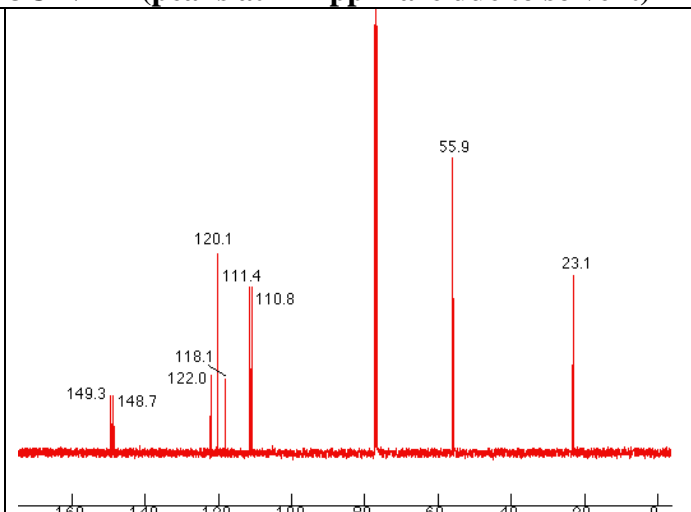
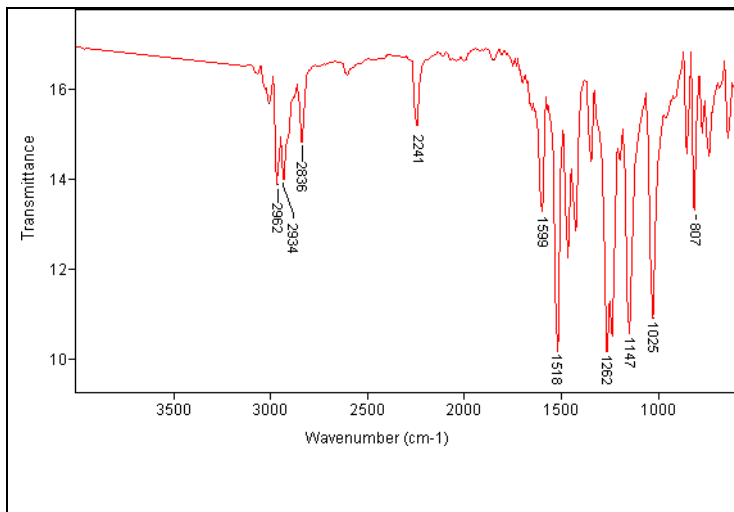
**Expansion of  $^1H$  NMR (all peaks are singlets)**



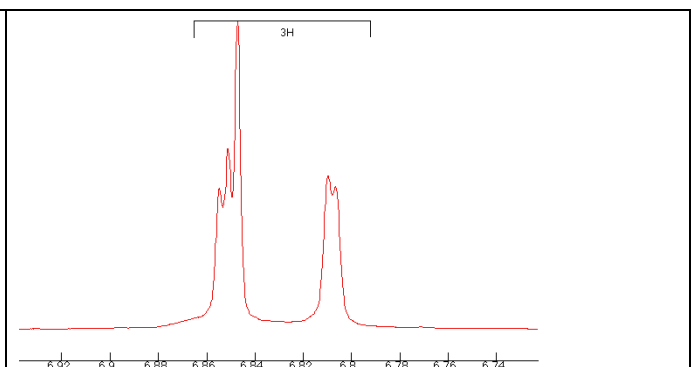
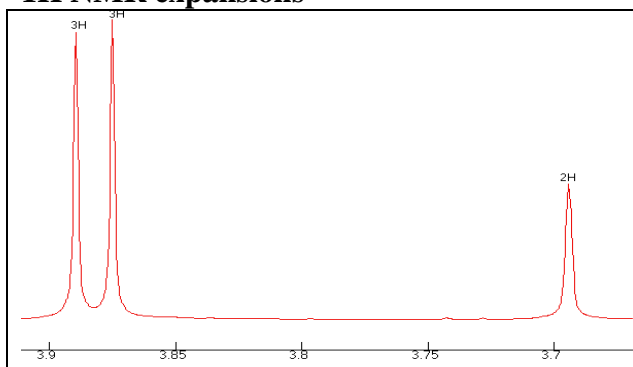
32- Spectra are shown for a molecule of formula  $C_{10}H_{11}NO_2$ . Propose a structure (write final answer in the box). No partial points given.

**IR**

**$^{13}C$  NMR (peaks at ~77 ppm are due to solvent)**

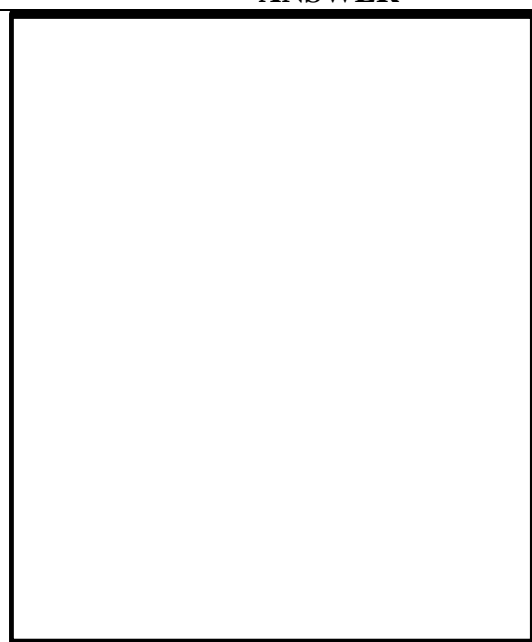
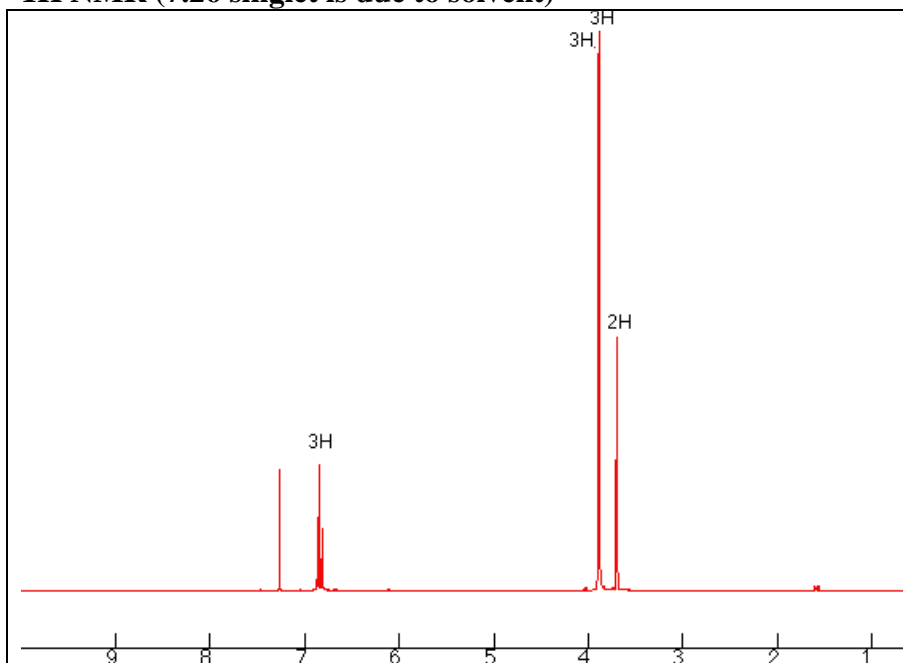


**$^1H$  NMR expansions**



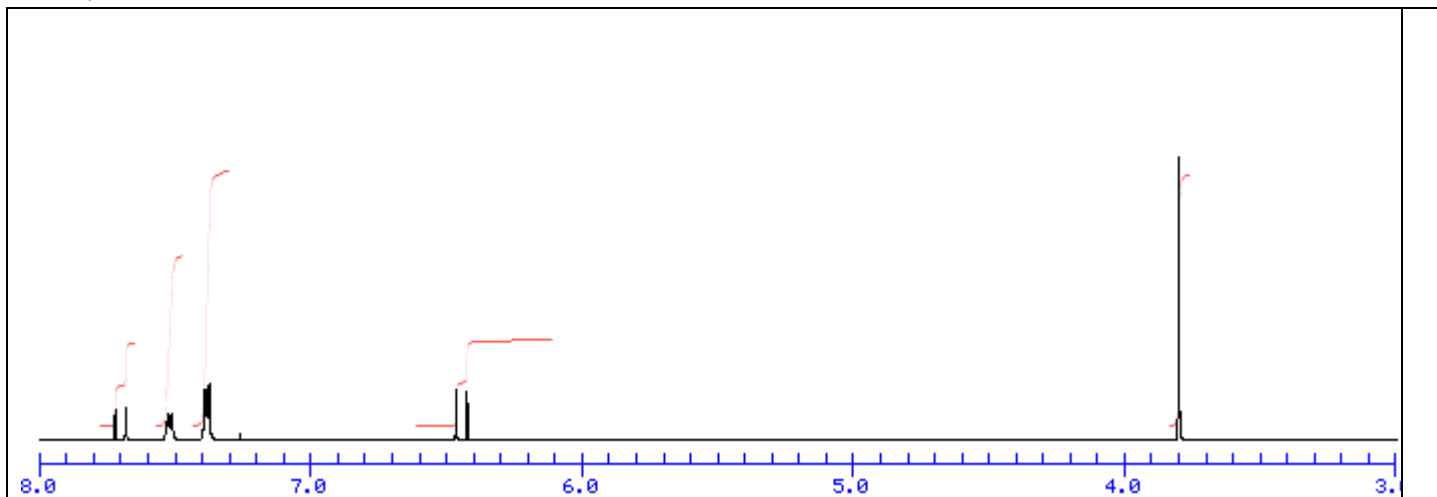
**$^1H$  NMR (7.26 singlet is due to solvent)**

**ANSWER**

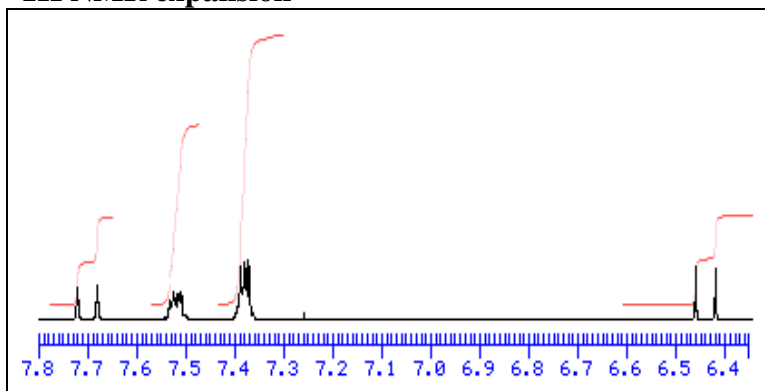


33- Spectra are shown for a molecule of formula  $C_{10}H_{10}O_2$ . Propose a structure (write final answer in the box). No partial points given.

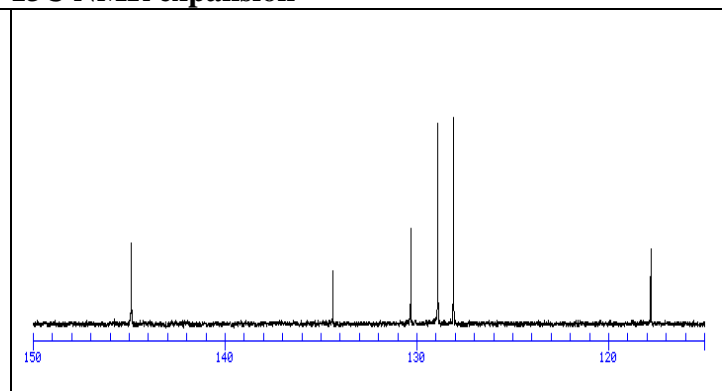
**$^1H$  NMR**



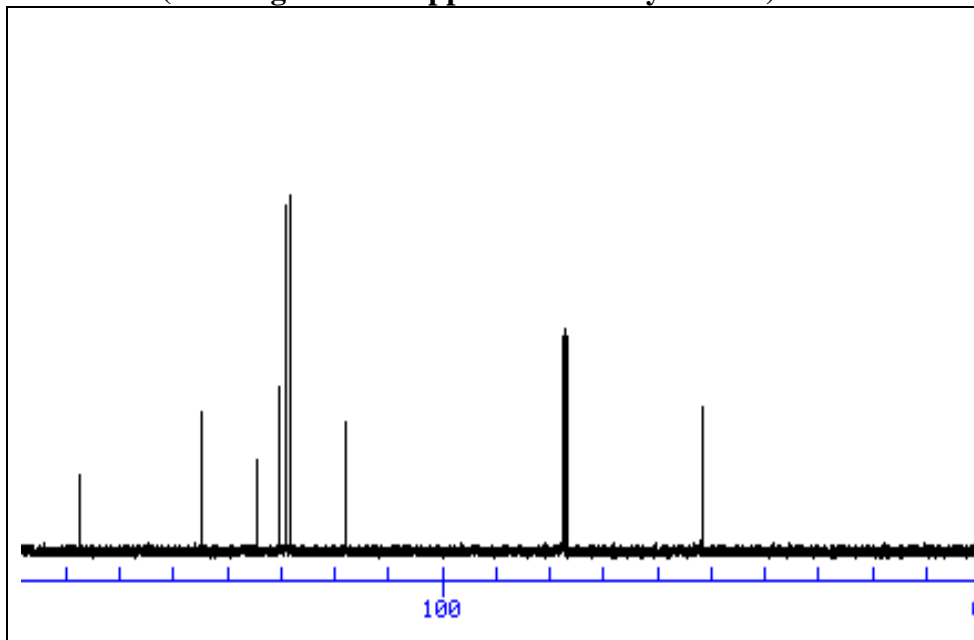
**$^1H$  NMR expansion**



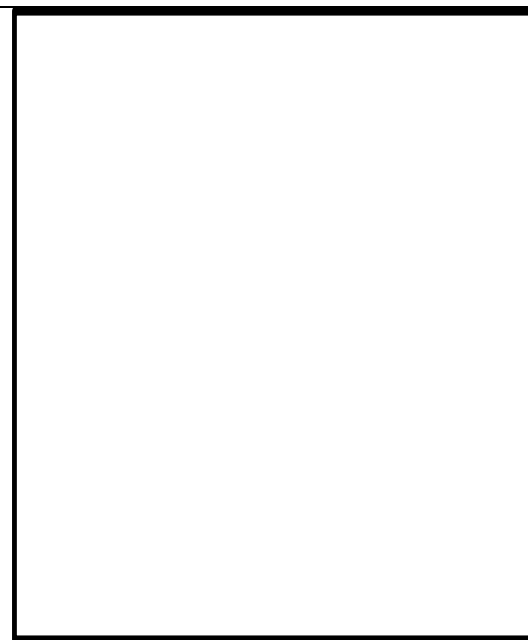
**$^{13}C$  NMR expansion**



**$^{13}C$  NMR (thick signal at ~77 ppm is caused by solvent)**



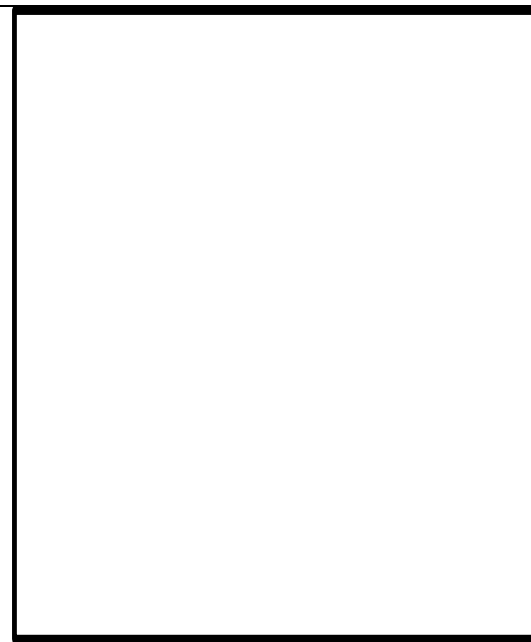
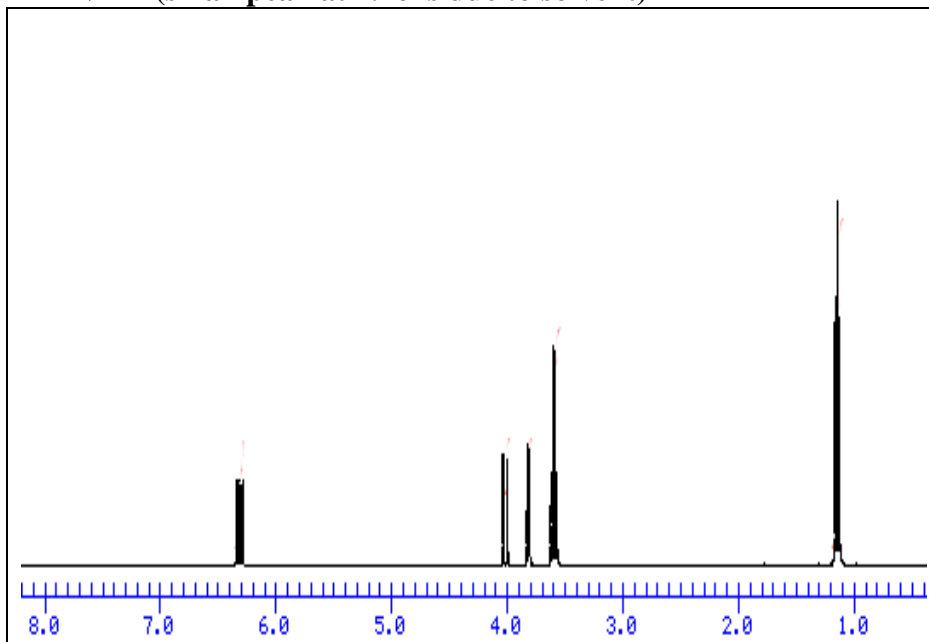
**ANSWER**



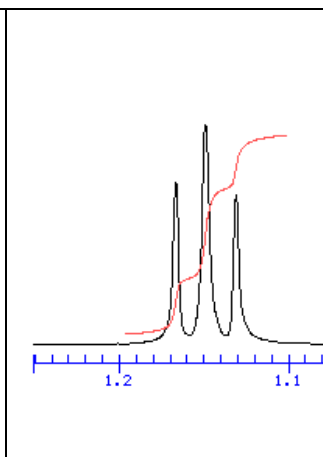
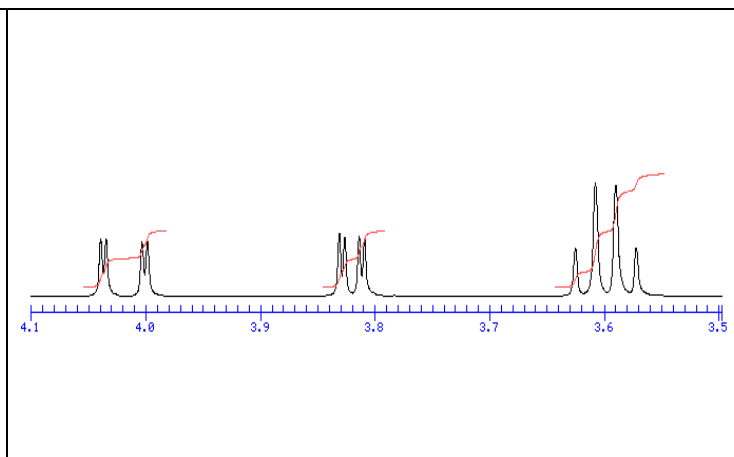
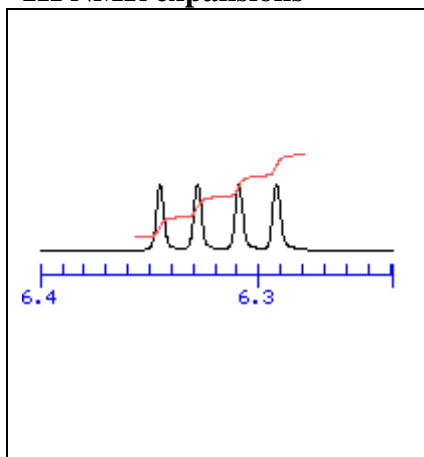
34- Spectra are shown for a molecule of formula  $C_4H_8O$ . Propose a structure (write final answer in the box).  
No partial points given.

$^1H$  NMR (small peak at 7.26 is due to solvent)

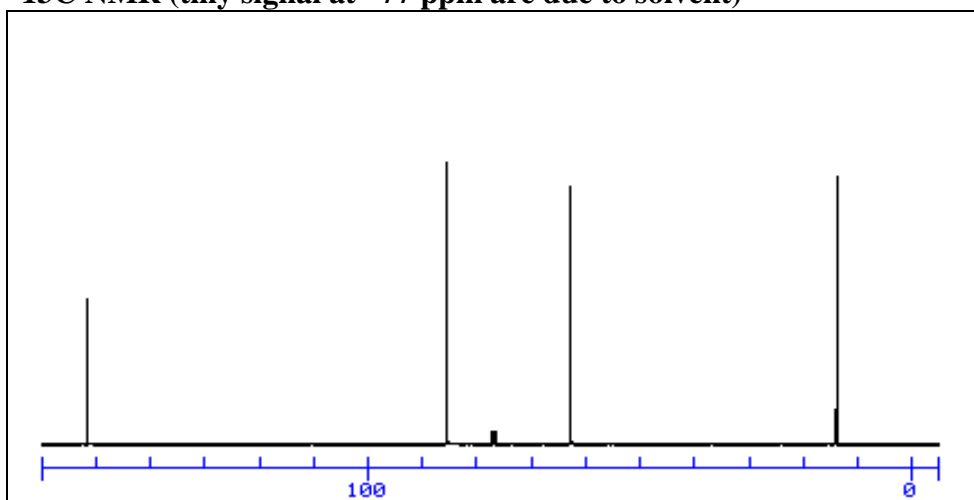
ANSWER



$^1H$  NMR expansions



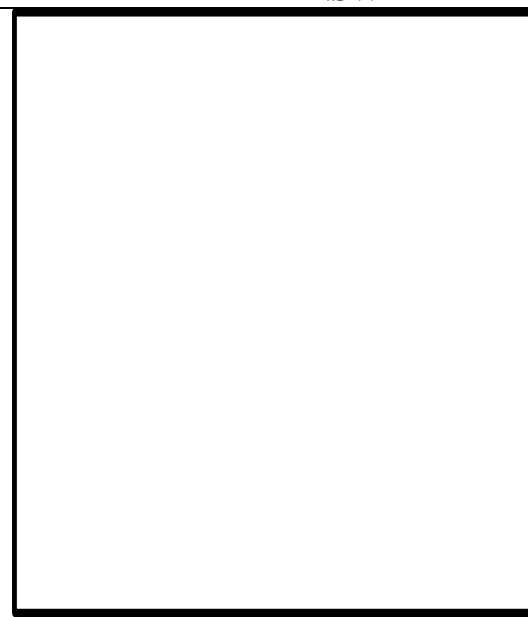
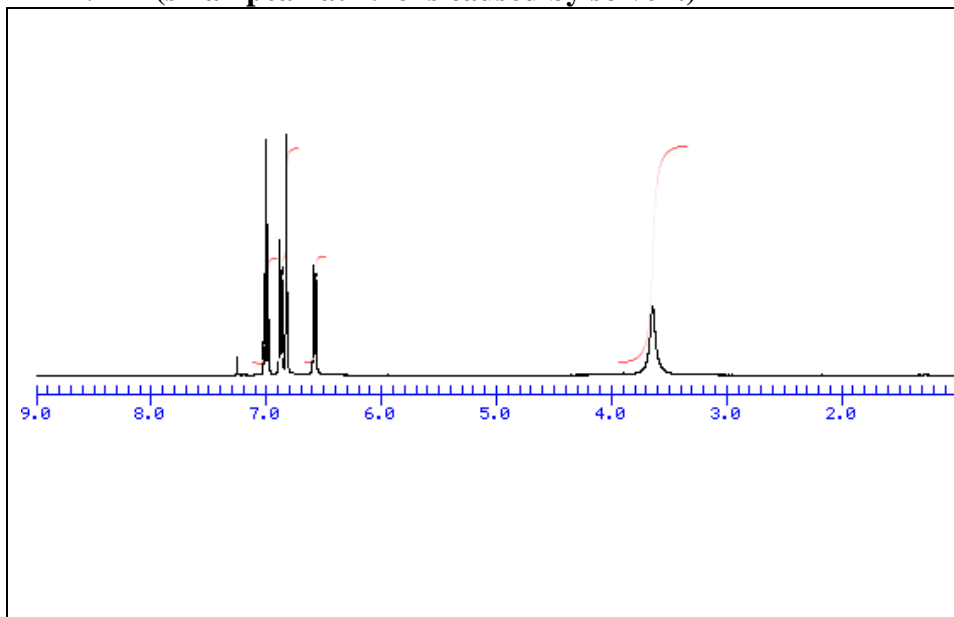
$^{13}C$  NMR (tiny signal at ~77 ppm are due to solvent)



35- Spectra are shown for a molecule of formula  $C_6H_6NBr$ . Propose a structure (write final answer in the box). No partial points given.

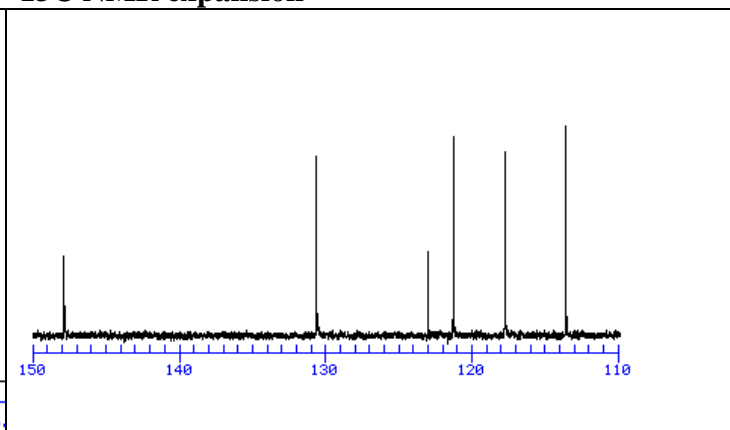
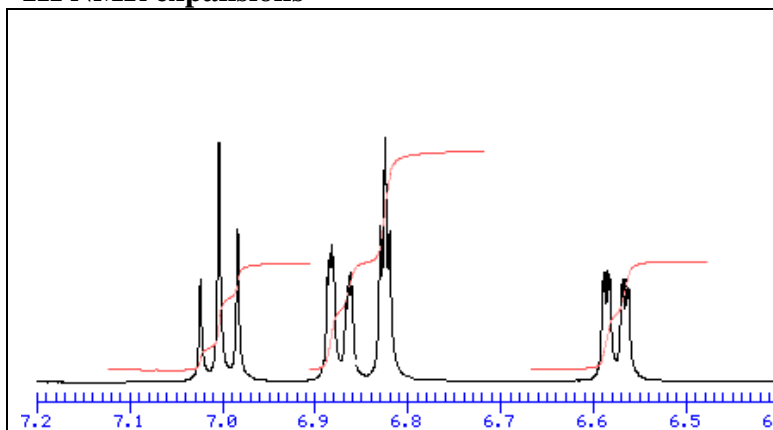
$^1H$  NMR (small peak at 7.26 is caused by solvent)

ANSWER



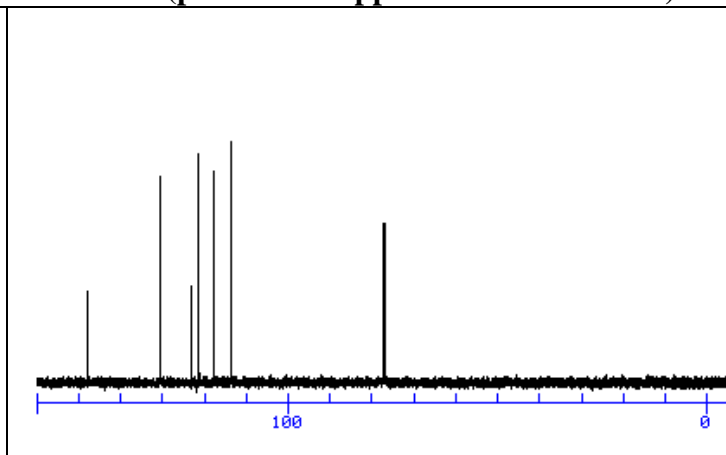
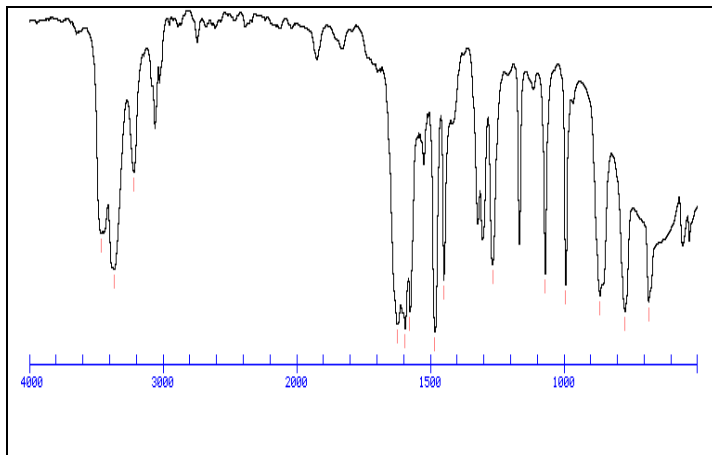
$^1H$  NMR expansions

$^{13}C$  NMR expansion



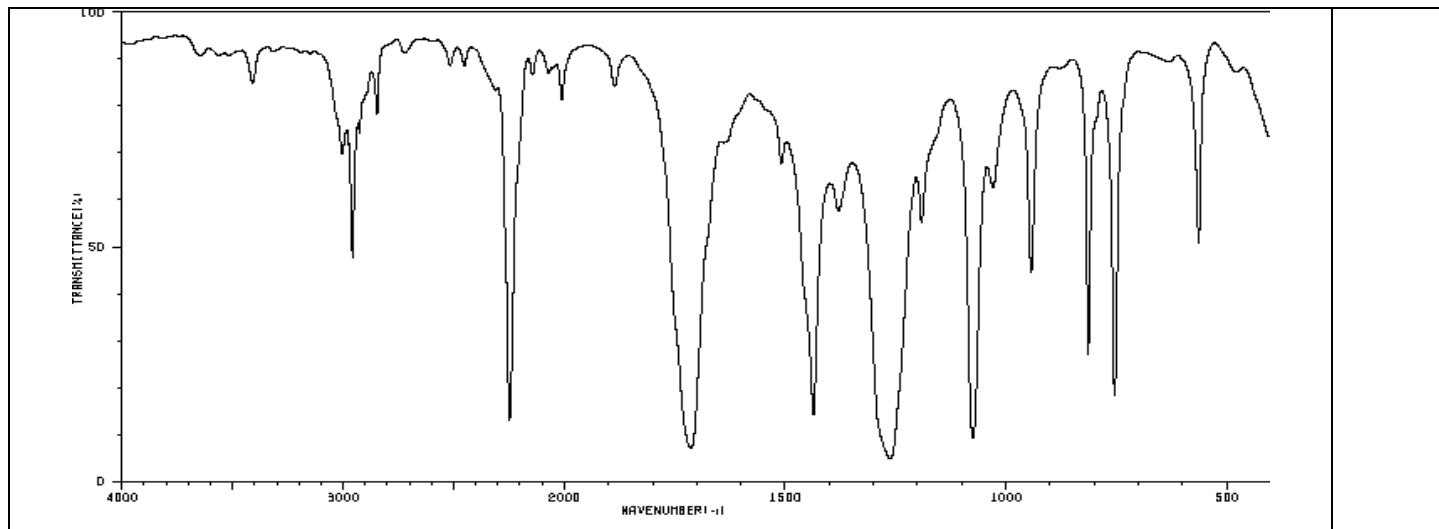
IR

$^{13}C$  NMR (peaks at ~77 ppm are due to solvent)

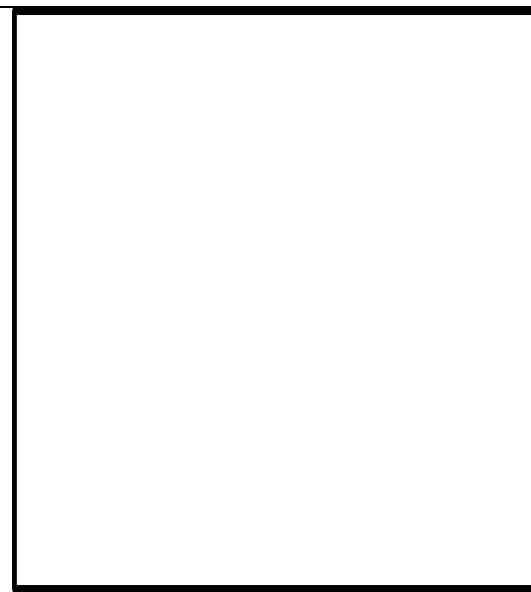
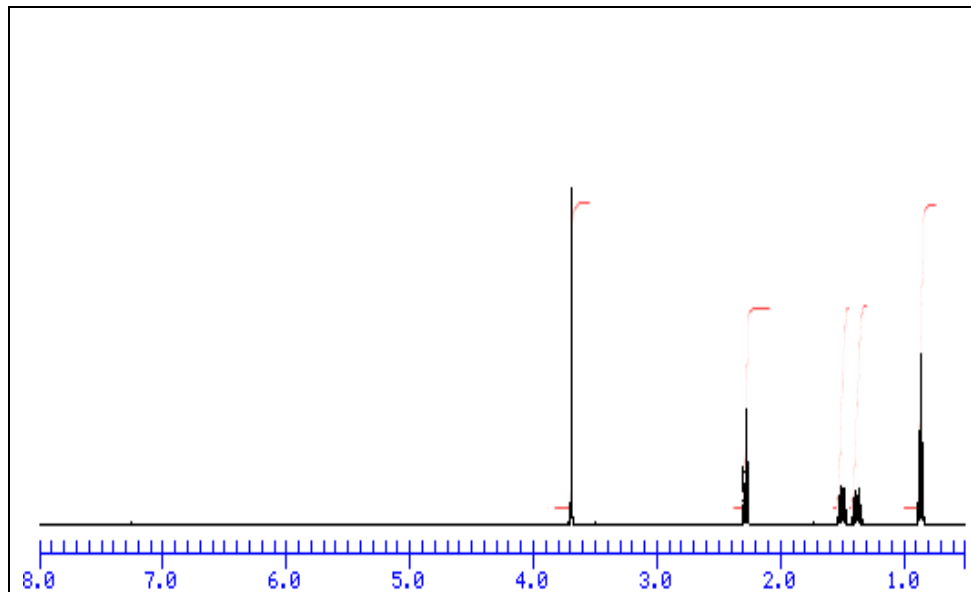


36- Spectra are shown for a molecule of formula  $C_8H_{12}O_2$ . Propose a structure (write final answer in the box). No partial points given.

**IR**

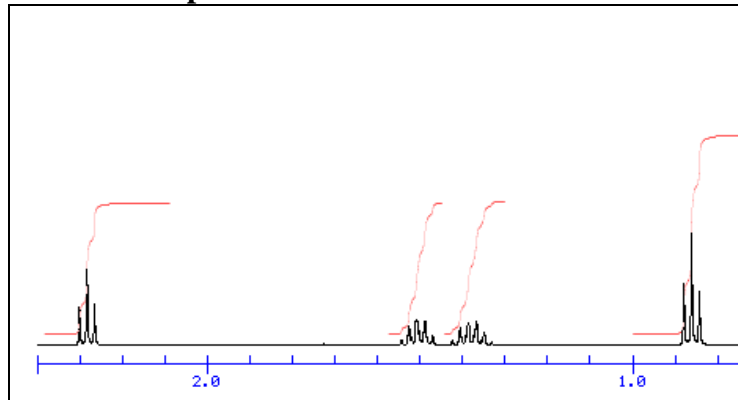


**$^1H$  NMR**

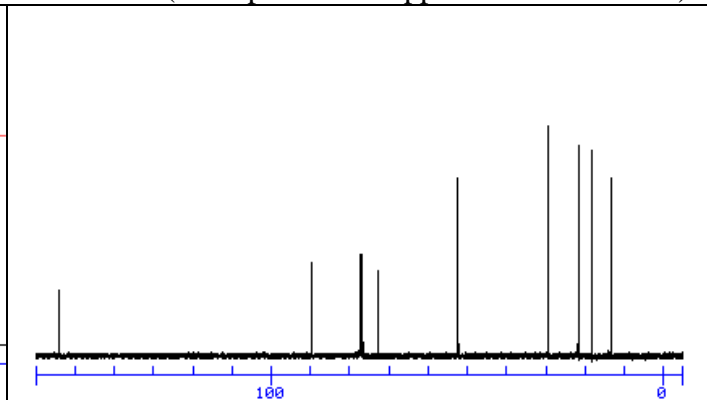


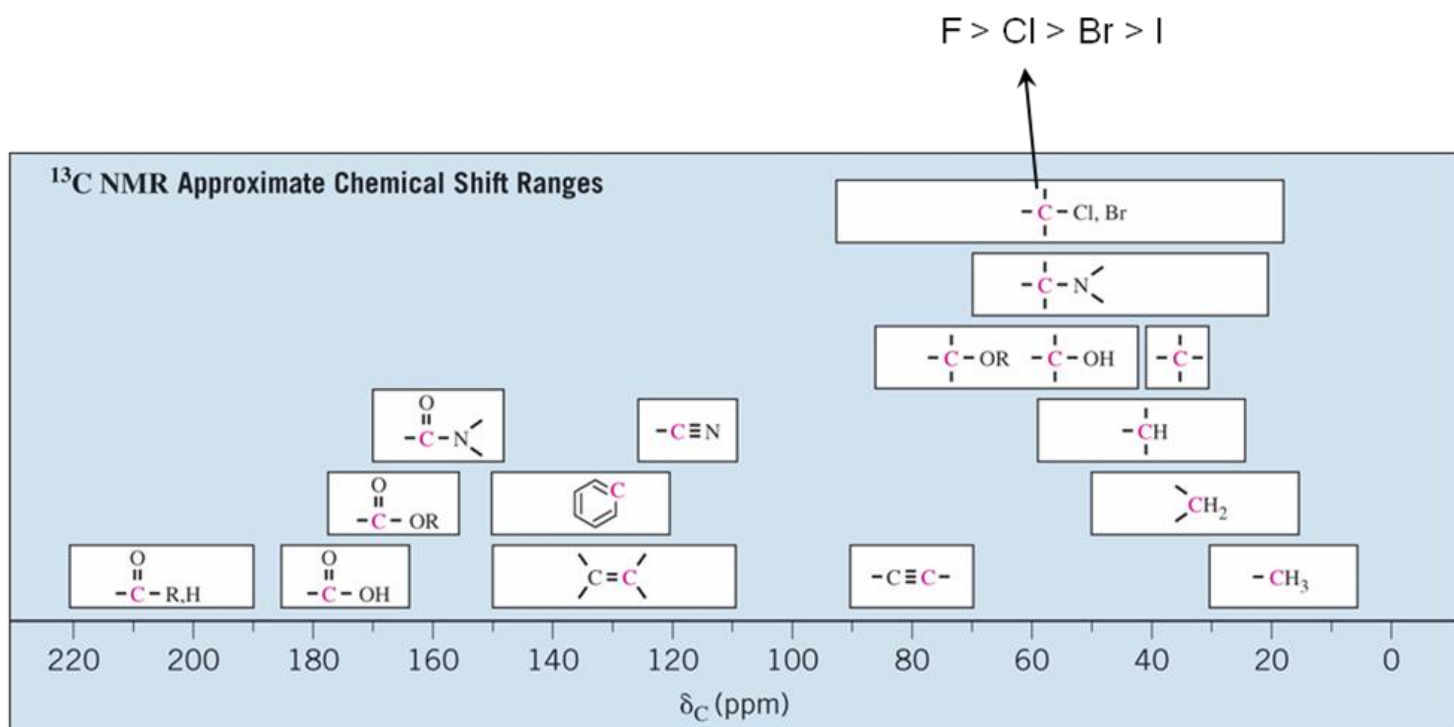
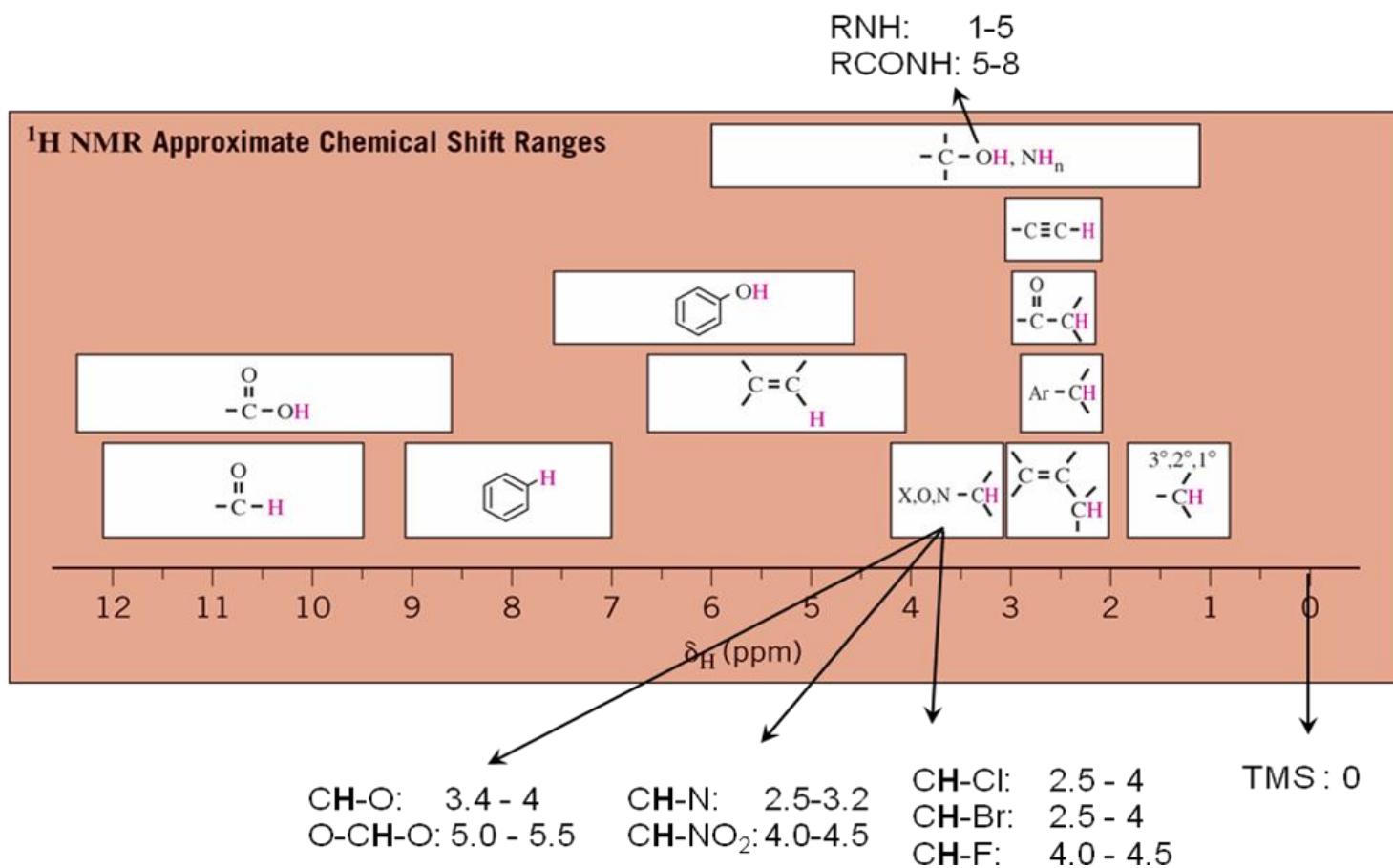
**ANSWER**

**$^1H$  NMR expansions**

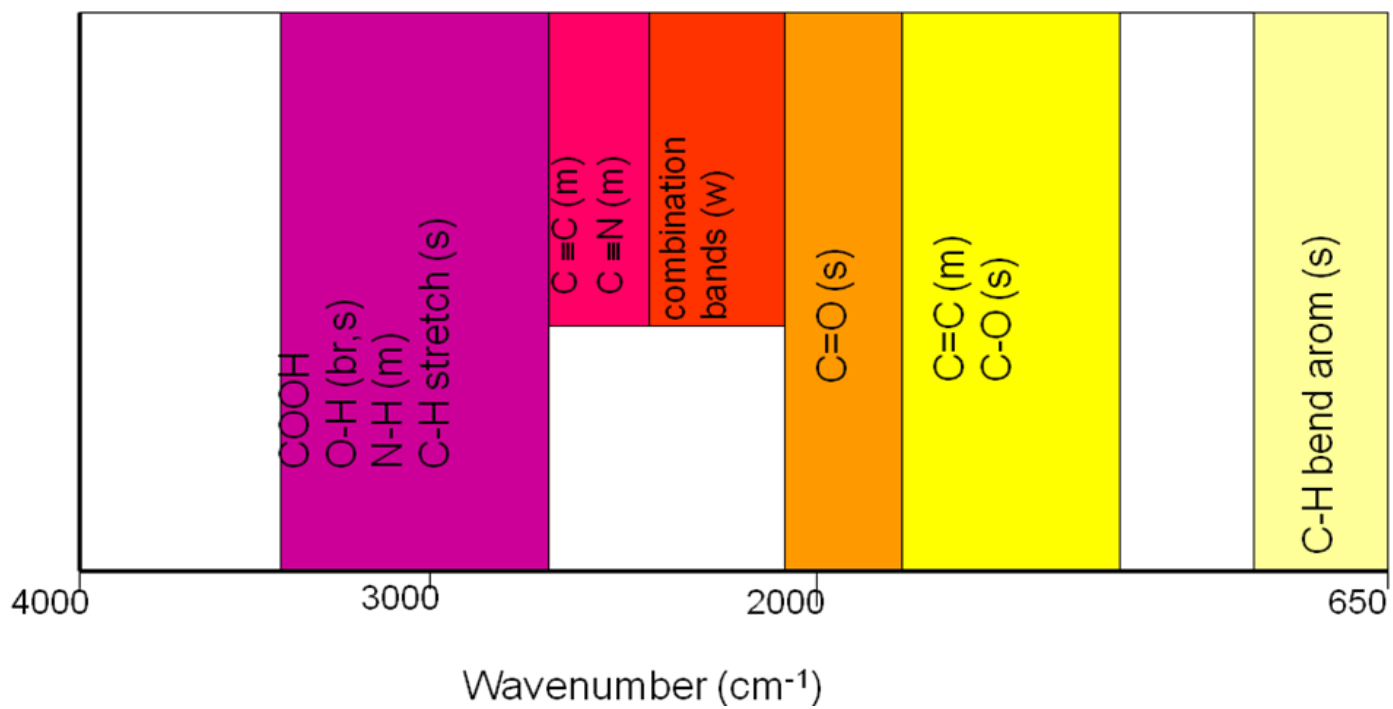


**$^{13}C$  NMR (thick peak at ~77 ppm is due to solvent)**





# IR Absorption Ranges



Group	Frequency Range (cm <sup>-1</sup> )	Intensity <sup>a</sup>
<b>A. Alkyl</b>		
C—H (stretching)	2853–2962	(m–s)
Isopropyl, —CH(CH <sub>3</sub> ) <sub>2</sub>	1380–1385	(s)
	and 1365–1370	(s)
<i>tert</i> -Butyl, —C(CH <sub>3</sub> ) <sub>3</sub>	1385–1395	(m)
	and ~ 1365	(s)
<b>B. Alkenyl</b>		
C—H (stretching)	3010–3095	(m)
C=C (stretching)	1620–1680	(v)
R—CH=CH <sub>2</sub>	985–1000	(s)
	and 905–920	(s)
R <sub>2</sub> C=CH <sub>2</sub>	880–900	(s)
		(s)
<i>cis</i> -RCH=CHR	675–730	(s)
<i>trans</i> -RCH=CHR	960–975	(s)
<b>C. Alkynyl</b>		
≡C—H (stretching)	~ 3300	(s)
C≡C (stretching)	2100–2260	(v)
<b>D. Aromatic</b>		
Ar—H (stretching)	~ 3030	(v)
Aromatic substitution type (C—H out-of-plane bendings)		
Monosubstituted	690–710	(very s)
<i>o</i> -Disubstituted	and 730–770	(very s)
<i>m</i> -Disubstituted	735–770	(s)
	680–725	(s)
	and 750–810	(very s)
<i>p</i> -Disubstituted	800–860	(very s)
<b>E. Alcohols, Phenols, and Carboxylic Acids</b>		
O—H (stretching)		
Alcohols, phenols (dilute solutions)	3590–3650	(sharp, v)
Alcohols, phenols (hydrogen bonded)	3200–3550	(broad, s)
Carboxylic acids (hydrogen bonded)	2500–3000	(broad, v)
<b>F. Aldehydes, Ketones, Esters, and Carboxylic Acids</b>		
C=O (stretching)	1630–1780	(s)
Aldehydes	1690–1740	(s)
Ketones	1680–1750	(s)
Esters	1735–1750	(s)
Carboxylic acids	1710–1780	(s)
Amides	1630–1690	(s)
<b>G. Amines</b>		
N—H	3300–3500	(m)
<b>H. Nitriles</b>		
C≡N	2220–2260	(m)

<sup>a</sup>Abbreviations: s = strong, m = medium, w = weak, v = variable, ~ = approximately.

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