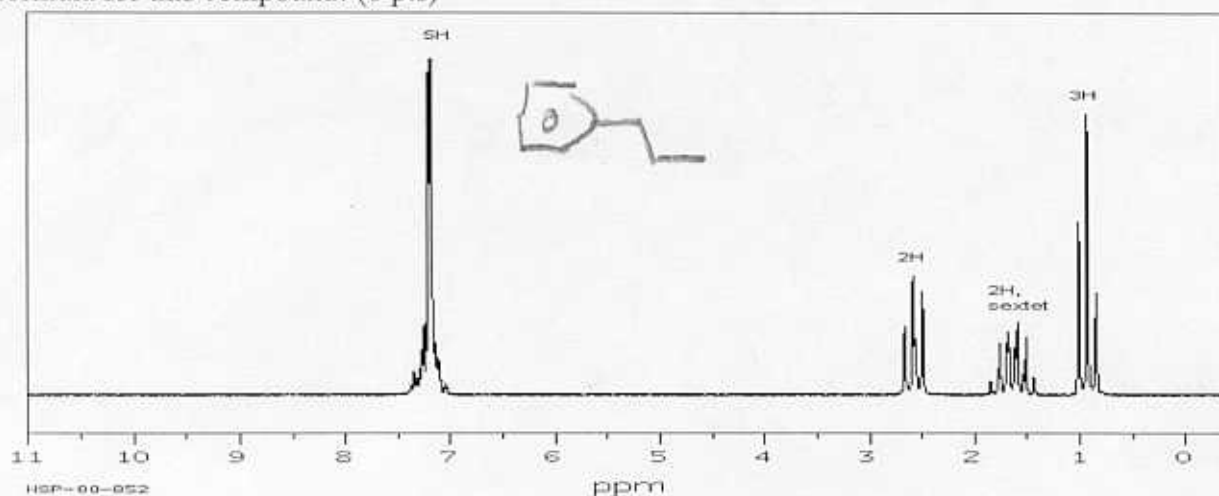


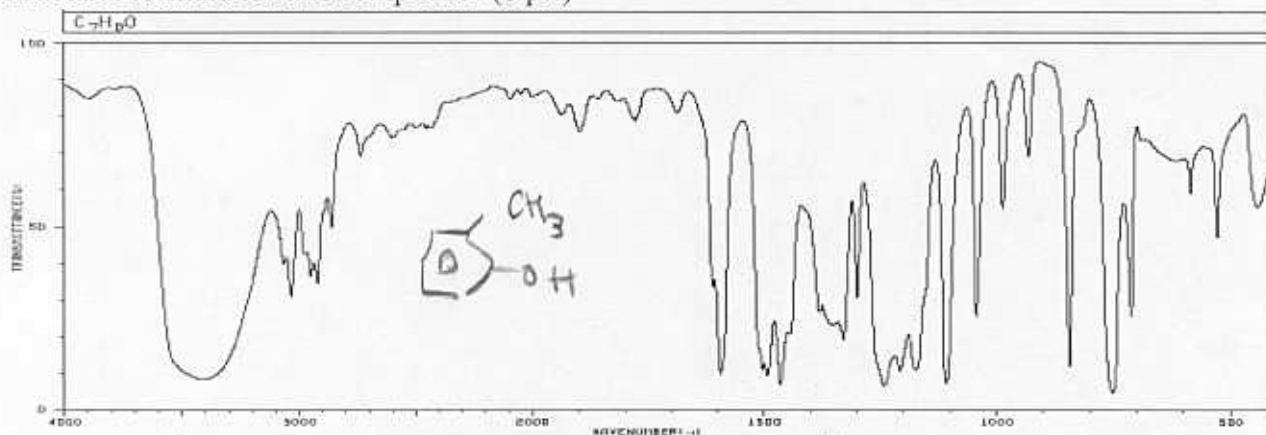
1. How are chemical shifts on the δ scale in NMR spectroscopy defined? Show a formula! (4 pts)

$$\delta = \frac{\text{observed freq (away from TMS) in Hz}}{\text{operating frequency in Hz}} \times 10^6$$

2. The NMR spectrum belongs to a compound with sum formula C_9H_{12} . Suggest a structural formula for this compound! (8 pts)



3. The IR spectrum below belongs to a compound with sum formula C_7H_8O . In addition, seven peaks were found in a ^{13}C NMR spectrum (their chemical shifts are shown below). Suggest a structural formula for this compound! (8 pts)



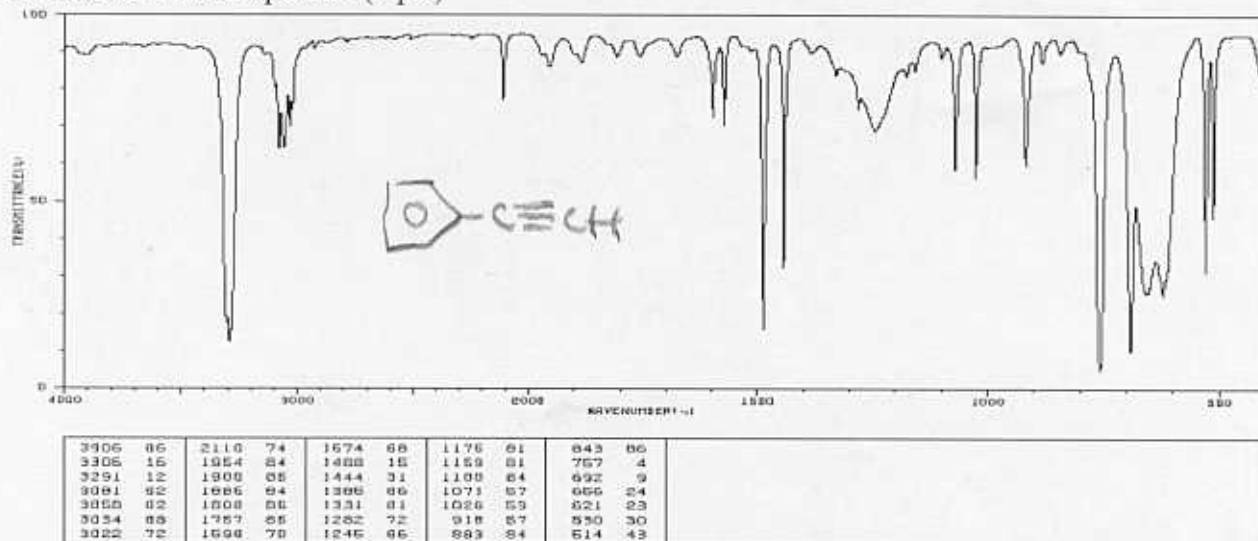
3408	6	2900	72	1694	9	1300	30	931	66
3063	38	2497	74	1503	10	1241	6	844	12
3055	30	2434	74	1494	9	1208	10	782	4
2960	36	1936	77	1466	7	1174	10	712	26
2920	34	1897	74	1381	26	1109	7	585	67
2861	49	1778	77	1342	23	1044	26	520	46
2736	66	1611	39	1329	18	986	69	442	63

^{13}C NMR resonances in ppm (seven in total)

153.58	120.94
131.14	115.12
127.12	15.72
124.15	

(m-isomer acceptable)

4. The IR spectrum below belongs to a compound with sum formula C_8H_6 . Suggest a structural formula for this compound! (8 pts)



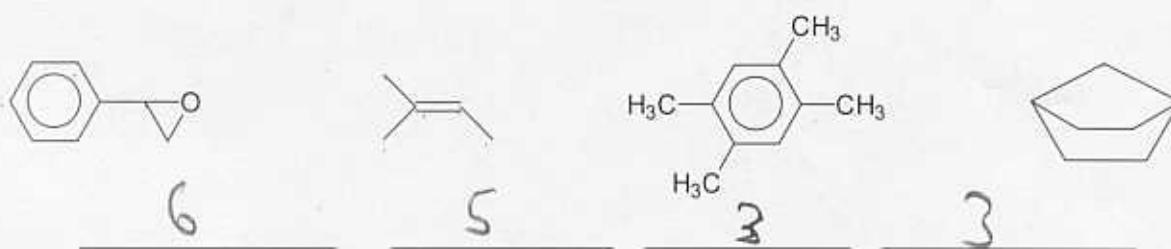
5. Indicate what you would expect the proton NMR spectrum of 2,2-dichlorobutane expect to look like (e.g. triplet, 2H; quintet, 1H) (4 pts)

single, 3H; quartet, 2H; triplet, 3H

6. Indicate what you would expect the proton NMR spectrum of diethyl ether expect to look like (e.g. triplet, 2H; quintet, 1H) (4 pts)

triplet, 6H; quartet, 4H

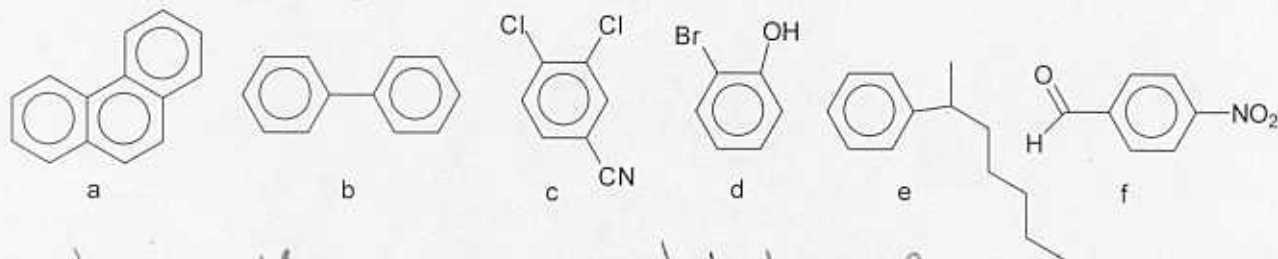
7. How many signals will the following compounds generate in ^{13}C NMR spectra? Show numbers! (8 pts)



8. How many non-equivalent kinds of protons (protons that can be distinguished by NMR) do the compounds from the previous question contain? Show numbers! (8 pts)

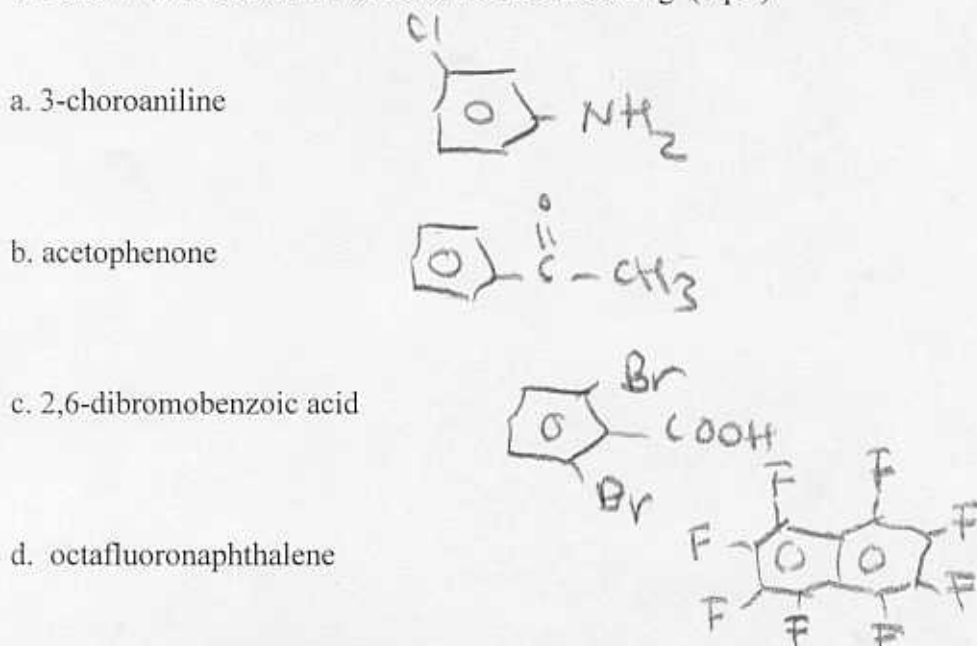
6 4 2 3

9. Name the following. (12 pts)

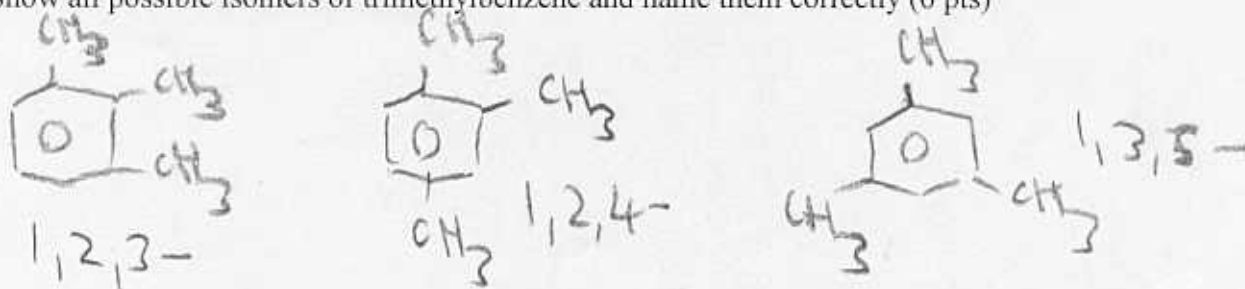


a phenanthrene b biphenyl
 c 3,4-dichlorobenzonitrile d 2-bromophenol
 e 2-phenylheptane f 4-nitrobenzaldehyde

10. Show valid structural formulas for the following (8 pts)

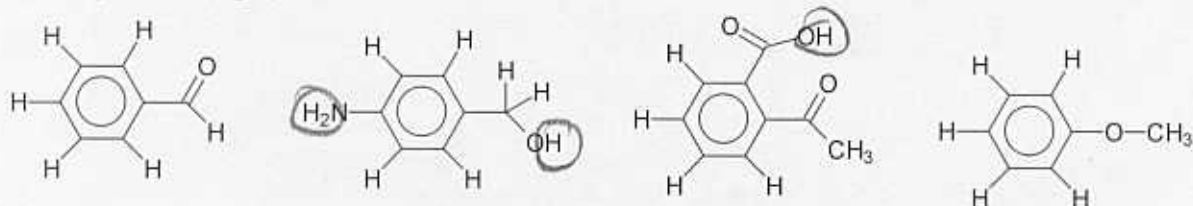


11. Show all possible isomers of trimethylbenzene and name them correctly (6 pts)

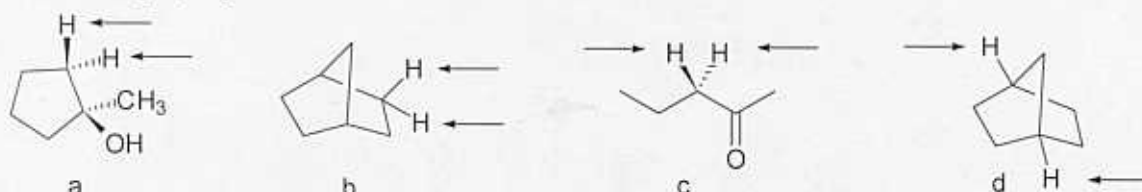


1,2,3 - trimethyl benzene
 1,2,4 - trimethyl benzene
 1,3,5 - trimethyl benzene

12. Several of the molecules below contain exchangeable protons. Circle all protons that are exchangeable! (5 pts)

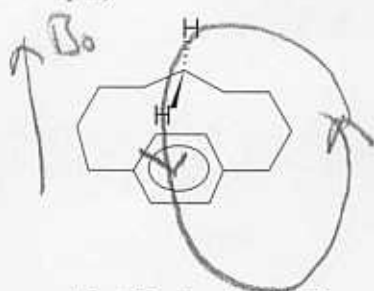


13. What are the relationships of the following protons (state homotopic, heterotopic, enantiotopic or diastereotopic) (8 pts)



a dia-stereotopic b dia-stereotopic c enantio-topic d homotopic

14. It has been noted that protons located directly over benzene rings, such as the ones in the molecule below, are extremely shielded and actually have negative shifts on the δ scale. Why? (5 pts)



Ring current shields protons right above rings.

15. Circle all TRUE statements: (4 pts)

- a) Only carbon and hydrogen atoms can be observed by NMR
- b) Chemical shifts increase with increasing field strength of the NMR's magnet.
- c) Coupling constants are reported in units of cm^{-1}
- d) Homotopic protons don't split each other's signals.