

Chemistry 605 (Reich)

SECOND HOUR EXAM

Sat. April 19, 2014

Question/Points

R-13A____/20

R-13B____/15

R-13C____/20

R-13D____/15

R-13E____/20

R-13F____/10

Total ____/100

Average 61

Hi 92

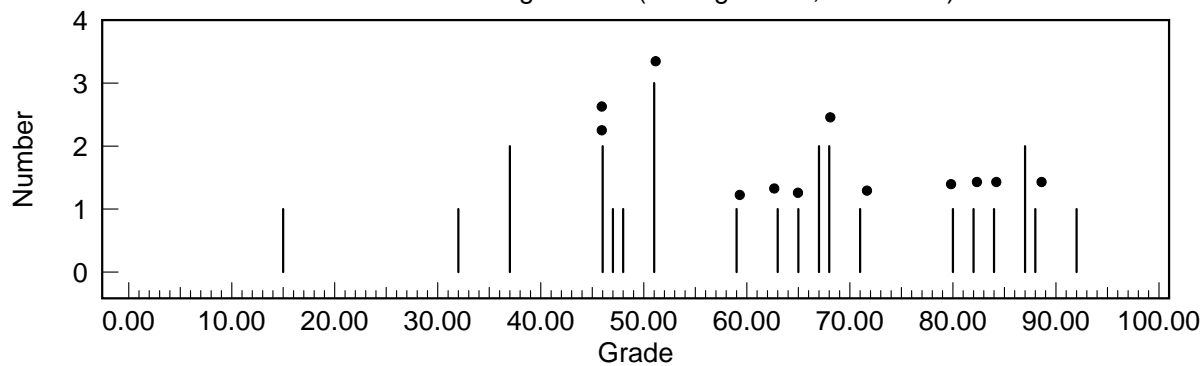
Mode 51

Median 64

AB 75

BC 45

Distribution from grade list (average: 61.1; count: 26)



Answer Key

Name_____

If you place answers anywhere else except in the spaces provided, (e.g. on the spectra or on extra pages) clearly indicate this on the answer sheets.

Problem R-13A. Assign several of the protons and analyze multiplets of a steroid.

(a) Assign and analyze the following signals (report multiplicity and J values). Use the steroid numbering on the structure:

δ 3.55 H^3 , tdd, $J = 11, 7, 6$ Hz

δ 4.55 H^{15} , ddd, $J = 7, 5, 2$ Hz

δ 5.40 H^6 , dt, $J = 5, 2$ Hz

(b) Assign the 2-proton signal between δ 2.4 and δ 2.7. Briefly provide a rationale for this assignment. What kind of multiplet is this? **AB of ABX**

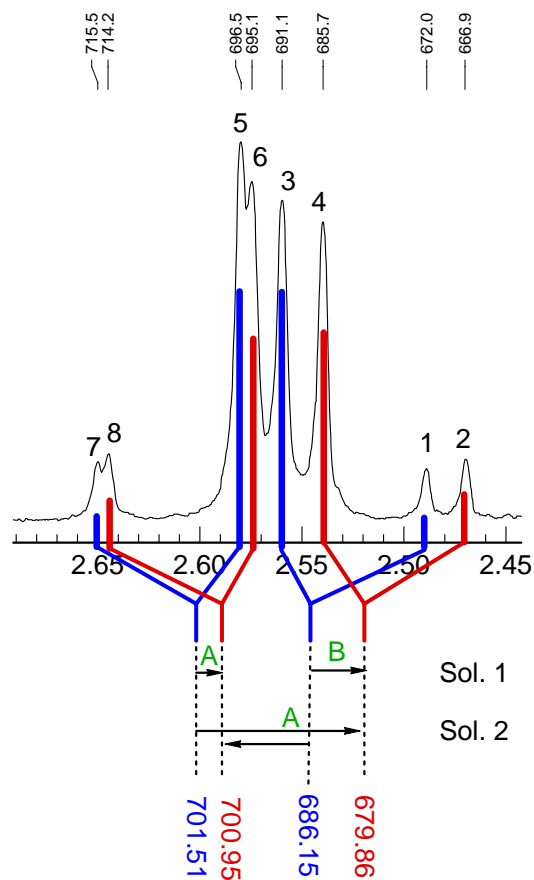
Apart from H^3 , H^{15} and H^6 , the H^{16} protons will be the most downfield. The large 2J (19 Hz) also means the protons must be next to the keto group

(c) Analyze this multiplet in a mathematically correct fashion (also show a coupling tree), using the frequencies given. Report coupling constants and chemical shifts. If two solutions are possible present them, and provide a rationale for choosing one of them.

$$\begin{aligned} c_- &= 693.8 & \Delta\nu_{ab-} &= 15.3 & c_- \pm \Delta\nu_{ab-}/2 &= 701.51, 686.15 \\ c_+ &= 690.4 & \Delta\nu_{ab+} &= 21.2 & c_+ \pm \Delta\nu_{ab+}/2 &= 700.95, 679.86 \end{aligned}$$

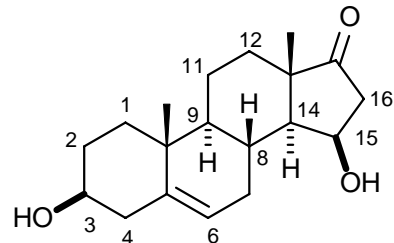
	Solution 1	Solution 2		
			1	671.99
			2	666.91
J_{AB}	19.1	19.1	3	691.12
J_{AX}	0.6	-14.8	4	685.71
J_{BX}	6.3	21.6	5	696.54
ν_A	701.2	693.5	6	695.1
ν_B	683.0	690.7	7	715.5
ν_{AB}	18.2	2.9	8	714.25
$i14=i15$	0.0074	0.47		
δ_A	2.60	2.57		
δ_B	2.53	2.56		

Solution 1 is correct - can't have a negative 3J , as in Sol. 2. Also the Sol. 2 couplings are unreasonably large

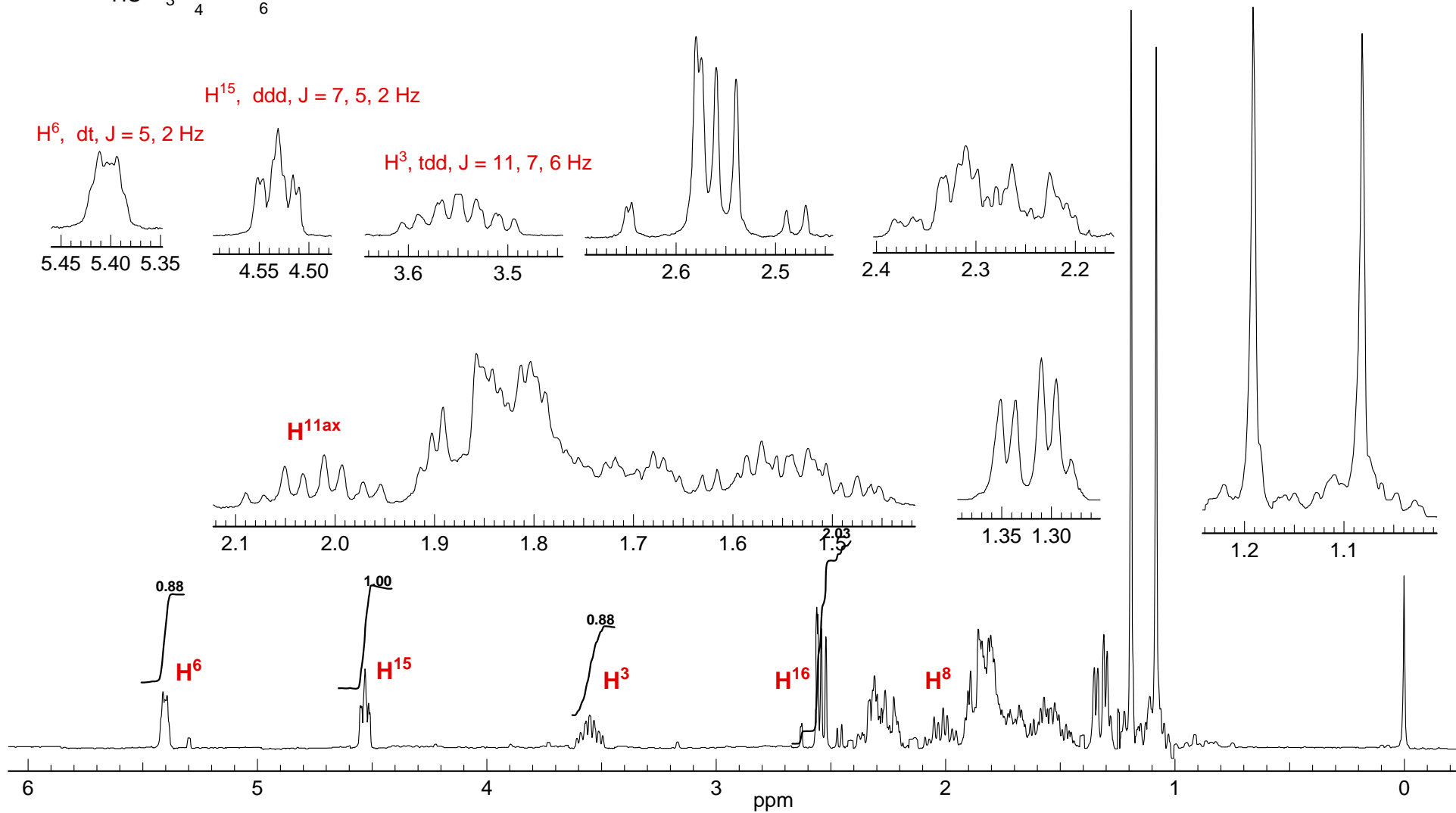


Problem R-13A270 MHz ^1H NMR Spectrum in CDCl_3

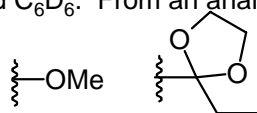
Source: Ieva Reich (3/27)



30 20 10 0 Hz



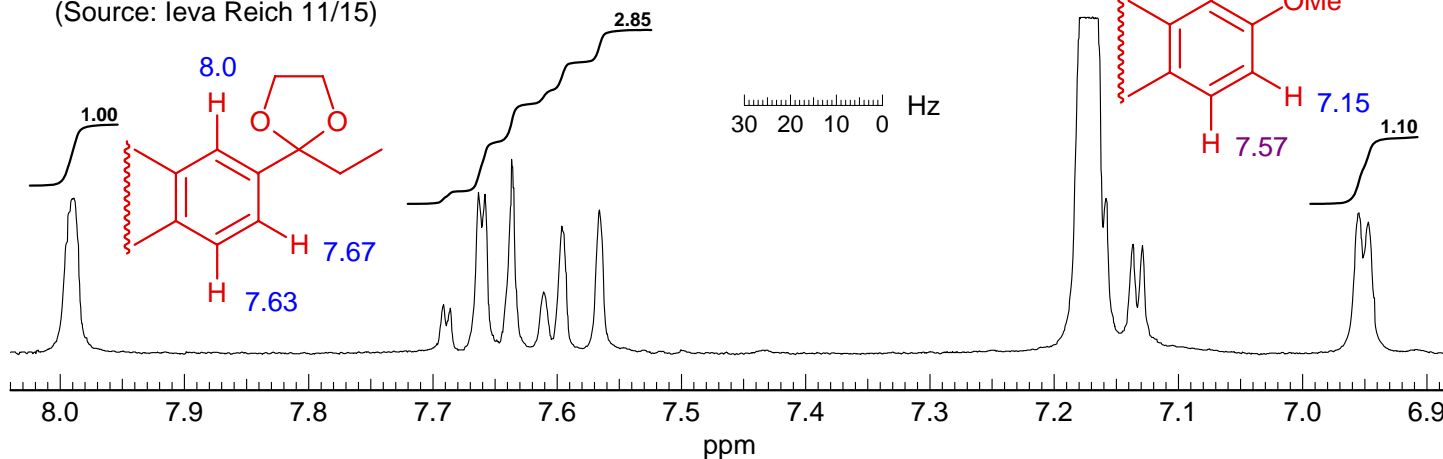
Problem R-13B. Compound **R-13B** is a disubstituted naphthalene. Spectra of just the aromatic region are provided in two different mixtures of CDCl_3 and C_6D_6 . From an analysis of the spectra, determine the positions of substitution. The substituents are:



Problem R-13B ($\text{C}_{16}\text{H}_{18}\text{O}_3$)

270 MHz ^1H NMR Spectrum in $\text{C}_6\text{D}_6/\text{CDCl}_3$ (4/1)

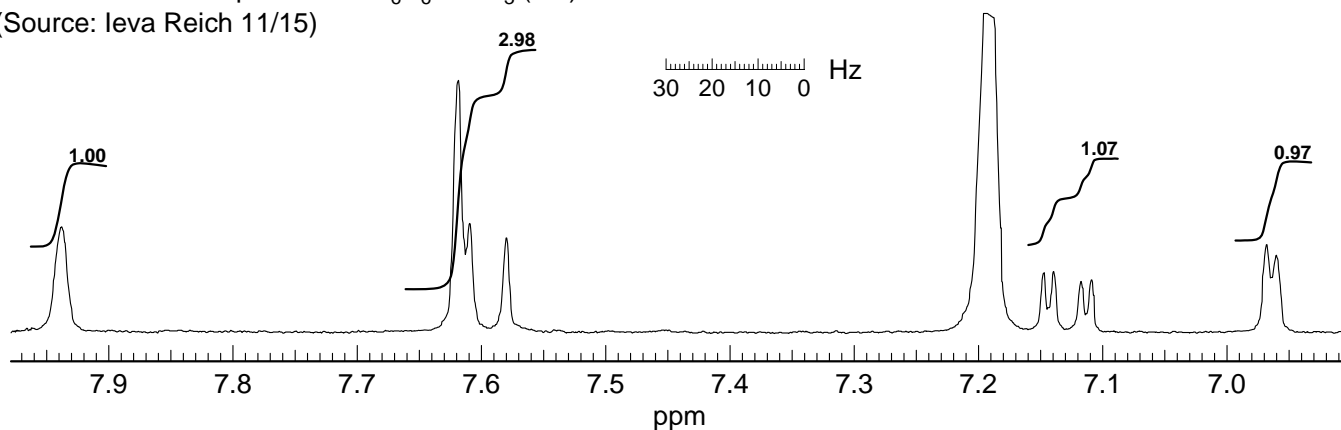
(Source: Ieva Reich 11/15)



Problem R-13B ($\text{C}_{16}\text{H}_{18}\text{O}_3$)

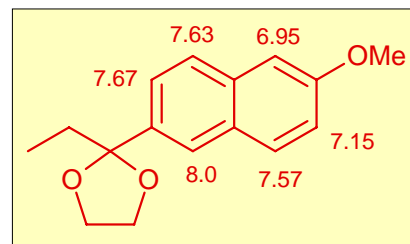
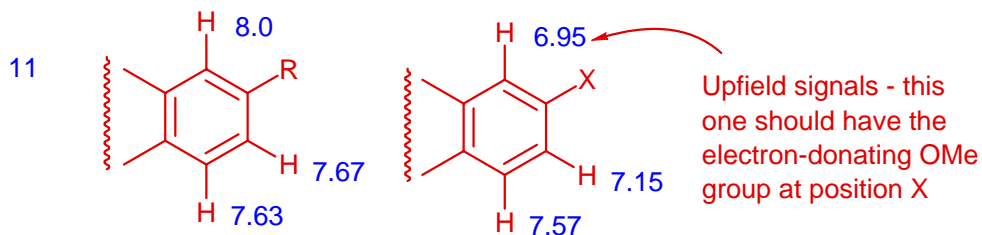
270 MHz ^1H NMR Spectrum in $\text{C}_6\text{D}_6/\text{CDCl}_3$ (5/2)

(Source: Ieva Reich 11/15)



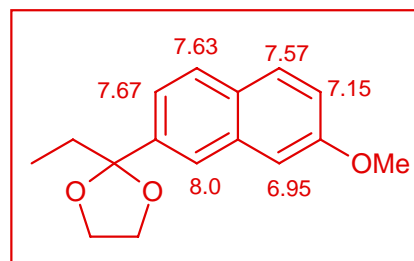
(a) Draw a possible structure, and label it with chemical shifts. Use the top spectrum for this, please.

There are two patterns of 1,2,4-hydrogens



(b) Is another substitution pattern consistent with the spectra? Explain.

There is no way to determine the relative position of the substituents on the two rings with the information at hand



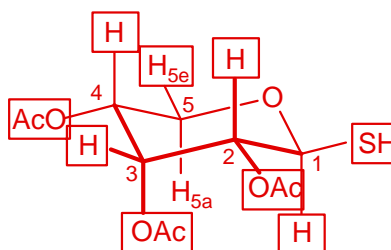
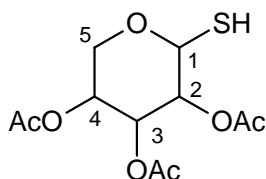
Problem R-13C. You are given the structure of a pentose thiol triacetate and asked to determine the relative stereochemistry and conformation from the 270 MHz ^1H NMR spectrum presented on the next page.

(a) Analyze the sets of signals and show coupling constants in the standard format. When you have completed the analysis, assign the individual protons (e.g., $\text{H}_{5\text{ax}}$). Use the numbering system given on the structure in part (b).

- | | | |
|---|---|---|
| 2 | δ 3.75 dd, $J = 12, 9$ Hz | This must be $\text{H}^{5\text{a}}$ from the chemical shift - coupled gem and ax-ax. Thus H^4 must be axial. |
| 2 | δ 4.05 ddd, $J = 11.5, 4.5, 1$ Hz | This must be $\text{H}^{5\text{e}}$ - coupled gem and eq-ax. There is also a W-coupling to the equatorial H^3 |
| 4 | δ 4.95 dd, 8, 2.5 - H^2
br d, 8 - H^1 | This is an AB pattern, one half is coupled to an X proton by ca 2.5 Hz, the other half is broadened. These must be the H^1 and H^2 protons, the H^1 is broadened by exchange of the SH (which is a broad singlet at δ 2.17). The 8 Hz coupling between H^1 and H^2 means both protons are axial. The small coupling (2.5 Hz) of H^2 to H^3 means H^3 is equatorial |
| 2 | δ 5.07 ddd, $J = 8.5, 4.5, 3$ | This is the proton at H^4 , coupled to the axial proton at C^5 (9 Hz) and to the eq protons at C^5 and C^3 . Thus H^3 must be equatorial. |
| 2 | δ 5.55 td, 2.5, 1 | This is the equatorial H^3 proton, coupled twice eq-ax (2.5 Hz) to H^4 and H^2 . There is a small W coupling to $\text{H}^{5\text{e}}$. |

(b) Determine the stereochemistry of **R-05K**. Place the appropriate substituents in each of the boxes on the structure below.

5



(c) Briefly describe how you made the assignment at C-4.

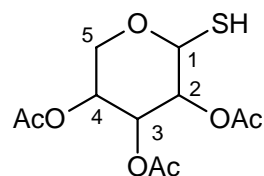
3

$\text{H}^{5\text{a}}$ and $\text{H}^{5\text{e}}$ can be assigned from their chemical shifts (most upfield of the ring protons) and coupling patterns. $\text{H}^{5\text{a}}$ shows, in addition to the 12 Hz gem coupling, a 9 Hz vicinal coupling, which means H^4 must be axial. H^4 can be assigned from the three couplings, two of which are to the H^5 protons.

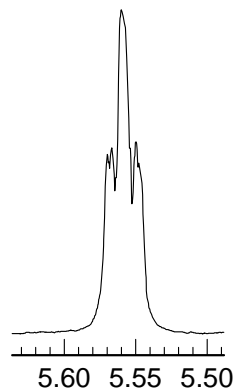
Problem R-13C (C₁₁H₁₆O₇S)

270 MHz ¹H NMR spectrum in CDCl₃

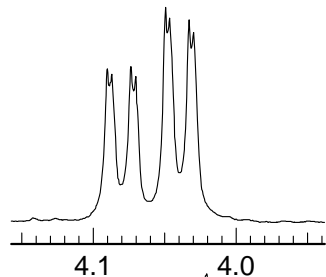
(Source: Paul Savage/Gellman 11/32)



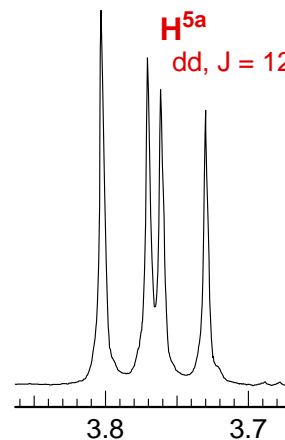
H³
dt, 2.5, 1



H^{5e}
dd, J = 11.5, 4.5, 1 Hz



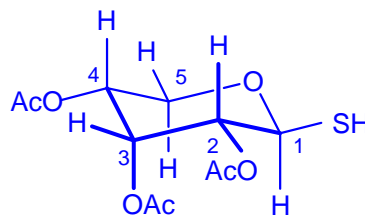
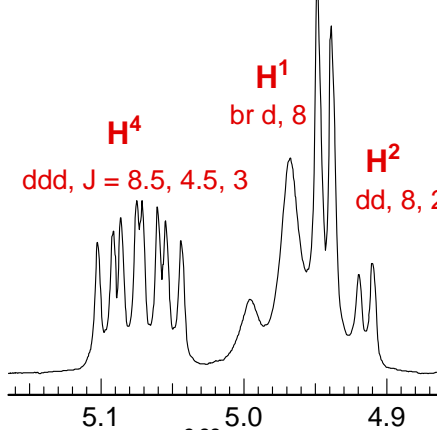
H^{5a}
dd, J = 12, 9 Hz



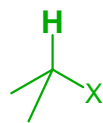
H⁴
ddd, J = 8.5, 4.5, 3

H¹
br d, 8

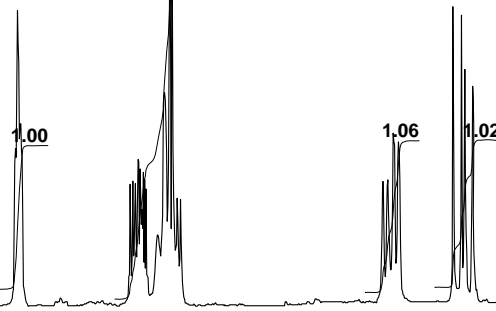
H²
dd, 8, 2.5



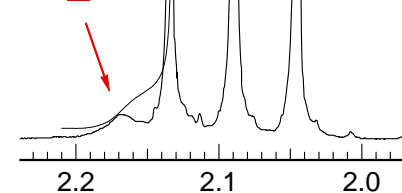
Curphy-Morrison:



SH	1.3
O-Alkyl	2.10
O-Ac	3.45



SH

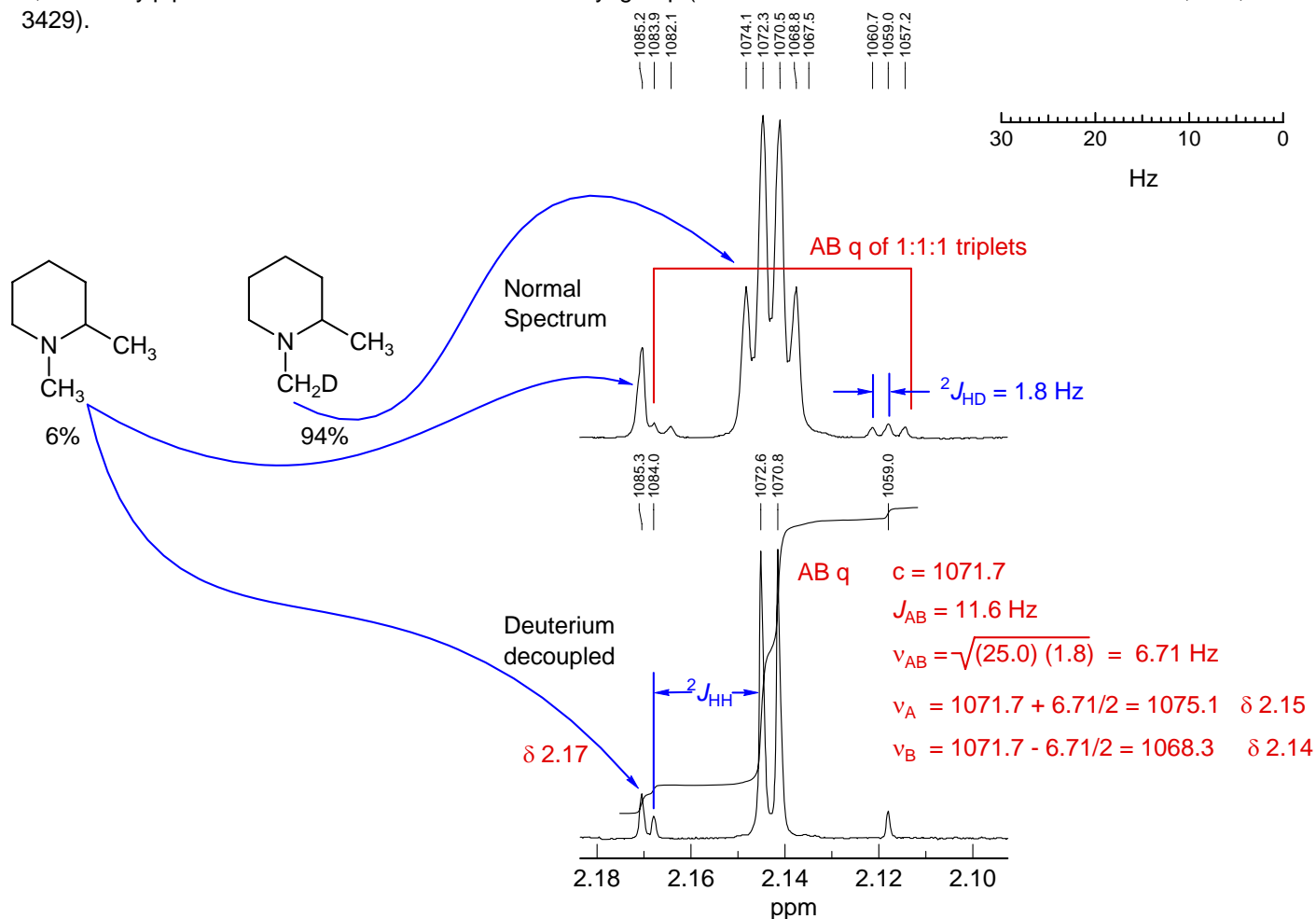


10.00

8.61

ppm

Problem R-13D. This problem requires you to interpret the partial 500 MHz ^1H NMR spectrum of a 1,2-dimethylpiperidine deuterated 94% on the N-methyl group (source: F. A. L. Anet *J. Am. Chem. Soc.* **1989**, 111, 3429).



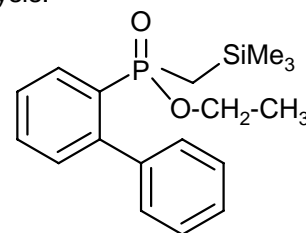
Identify all of the peaks in both the top and bottom spectra. Briefly explain the pattern, extract all coupling constants and determine exact chemical shifts, and report them in the standard format (e.g., $\delta 3.44$, t, $^nJ_{\text{xy}} = 3.5 \text{ Hz}$).

- 3 • The signals we are looking at are the N-CH₃ protons ($\delta 2.17$) and the N-CH₂-D protons (2.11-2.17)
- 3 • In the deuterium decoupled spectrum the singlet at $\delta 2.17$ is N-CH₃
- 9 • In D-decoupled the AB quartet centered at $\delta 2.14$ is the N-CH₂-D group. The CH₂ group is diastereotopic (there is an asymmetric center at C-2) and so forms an AB quartet.

$$^2J_{\text{AB}} = 11.7 \text{ Hz}, \delta_{\text{A}} = 2.15, \delta_{\text{B}} = 2.13$$

- Normal spectrum: each peak of the AB quartet is split into a 1:1:1 triplet by coupling to D. $^2J_{\text{HD}} = 1.7 \text{ Hz}$

Problem R-13E ($C_{18}H_{25}O_2PSi$). In this problem you are given the structure of a phosphorus compound and asked to interpret parts of the NMR spectrum. For each multiplet or set of multiplets report the pattern in the standard format: δ 0.00, triplet of pentets, $^1J_{XY} = 0.0$ Hz. You may use first order analysis.



- (a) Assign and interpret the three signals centered at δ -0.05.

Me_3Si signal

The two small peaks are ^{29}Si satellites

$$^2J_{H-Si} = 7 \text{ Hz}$$

- (b) Assign and interpret the multiplet at δ 0.75. Draw and label a coupling tree.

This is the $P-CH_2-SiMe_3$ group - the protons are diastereotopic (P is an asymmetric center), so this is an ABX pattern $X = ^{31}P$

$$J_{AB} = 14 \text{ Hz } (^2J_{HH})$$

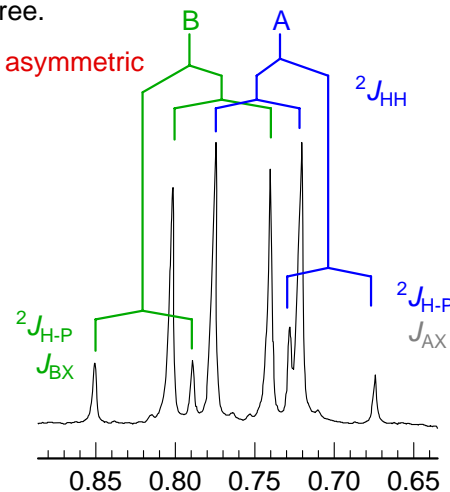
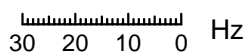
$$\delta_A = 0.73$$

$$J_{AX} = 16 \text{ Hz } (^2J_{H-P})$$

$$\delta_B = 0.78$$

$$J_{BX} = 18 \text{ Hz } (^2J_{H-P})$$

(this is "AMX" treatment which always corresponds to Solution1, not a proper ABX analysis, so if this happens to be a Solution 2 situation, then the J's would be very wrong - they do look OK though, and so Solution 1 is probably fine)



- (c) Assign and interpret the multiplets at δ 3.7 - 4.2. Draw and label a coupling tree.

ABM₃X

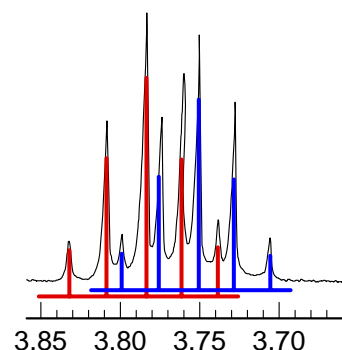
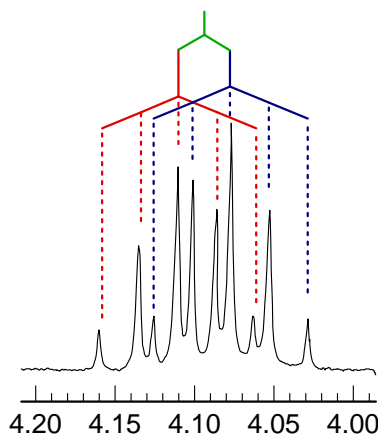
Each pattern is a doublet of pentets, $J = 10, 7$ Hz for the diastereotopic $O-CH_2-CH_3$ group. The pentet arises because $^3J_{HH}$ to the CH_3 group and $^3J_{HP}$ are nearly the same

$$^3J_{HH} = 7 \text{ Hz}$$

$$^3J_{HP} = 7 \text{ Hz}$$

$$^2J_{HH} = 10 \text{ Hz}$$

We know the 10 Hz coupling is the gem J_{HH} because of the size, and leaning effects.



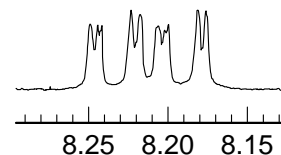
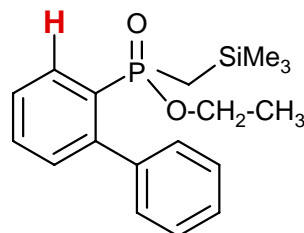
- (d) Assign and interpret the multiplet at δ 8.2.

This must be the proton ortho to the phosphonate group - approximately a ddd, $J = 12, 6, 2$ Hz. There are some second-order effects, so couplings are suspect

$$^3J_{HH} = 8 \text{ Hz (ortho coupling)}$$

$$^4J_{HH} = 2 \text{ Hz (meta coupling)}$$

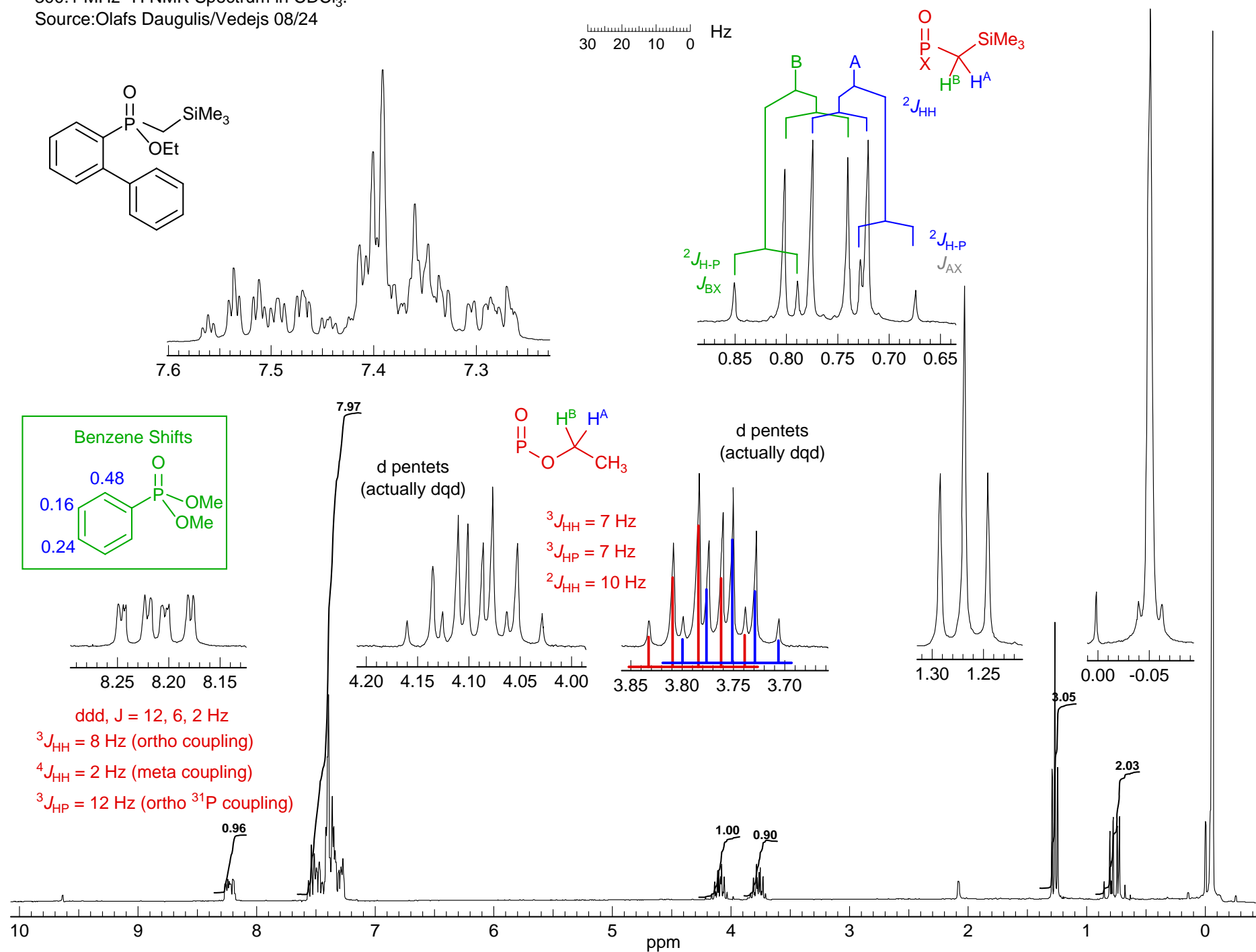
$$^3J_{HP} = 12 \text{ Hz (ortho } ^{31}P \text{ coupling)}$$



Problem R-13E ($\text{C}_{18}\text{H}_{25}\text{O}_2\text{PSi}$)

300.1 MHz ^1H NMR Spectrum in CDCl_3 .

Source:Olafs Daugulis/Vedejs 08/24

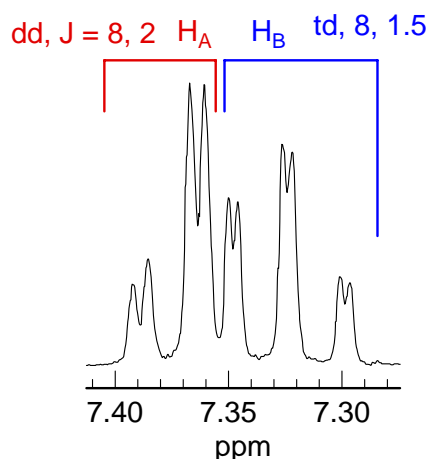


Problem R-13F. Here are the two parts of quiz 217 we didn't get to finish during my first lecture. Put your analysis (δ , J, multiplicity) in the space provide, and suggest some possible structures from the quiz answer sheet.

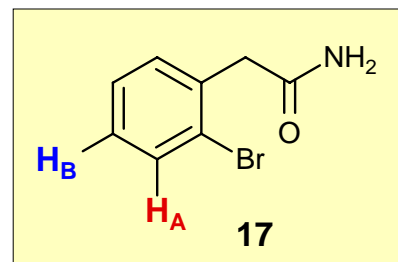
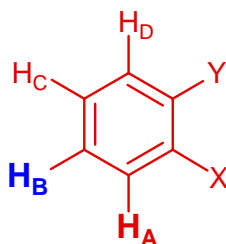
Below are proton multiplets in different molecules. Analyze the pattern and extract the coupling constants. From the chemical shift given, what kind of protons are these likely to be? What part structures are suggested by this pattern? Find one or more molecules on the "NMR Quiz Answers" sheet that fit the chemical shift and coupling pattern.

5

(b) Integration: 2H



These are two aromatic protons (H_A and H_B), coupled to each other with $J = 8$ Hz (ortho). The upfield proton H_B has a second ortho coupling to H_C . Both protons are meta-coupled also, H_A to H_C , and H_B to H_D

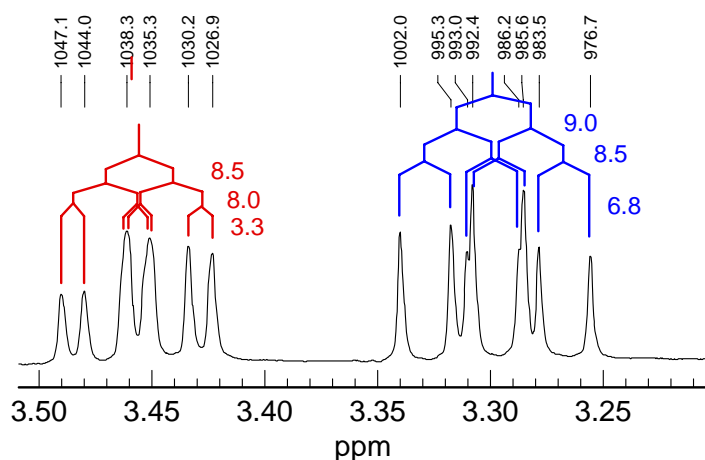


8 9 10 25 also fit

22 less well because J in pyridine are more varied

5

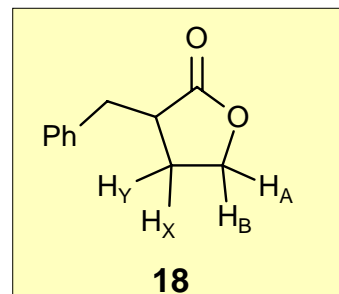
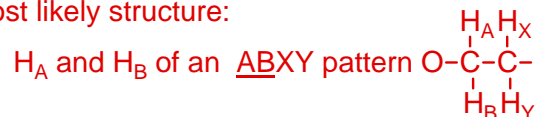
(c) Integration: 2H



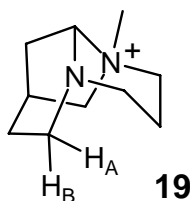
ddd, δ 3.45, $J = 8.5, 8, 3.3$ (almost a dt)

ddd, δ 3.30, $J = 9.0, 8.5, 6.8$

Most likely structure:



Coupling constants are consistent for those in a five-membered ring. They don't fit very well for chair cyclohexane



NMR Quiz Answers

Hans Reich
Chem 605

