

Chemistry 605 (Reich)

SECOND HOUR EXAM

Tue. April 13, 2010

Practice Exam 2 answer

Question/Points

R-09G_____/25

R-09H_____/10

R-09I_____/15

R-09J_____/15

R-09K_____/16

R-09LM_____/18

Total ____/100

Average	65
Hi	86
Mode	72
Median	65
AB	75
BC	50

Name _____ **Grading**

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-09G ($C_{12}H_{16}O_2$). Determine the structure (or part structure) of **R-09G** from the 1H NMR, ^{13}C NMR provided. The IR spectrum shows no strong peaks in the region from 1650 to 1800 cm^{-1} .

1 (a) DBE 5

(b) Interpret the ^{13}C NMR spectrum. Identify what kind of carbon each signal corresponds to, and write possible part structures (e.g. sp^3 OCH_3 , Aromatic C-H, ketone $C=O$, $N-CH_2$).

5	1	142.6	<u>sp² aromatic/alkene Quat</u>	6	126.3	<u>aromatic/alkene sp² CH 2x (o/m)</u>
	2	138.7	<u>aromatic/alkene sp² CH (<u>C</u>H=C)</u>	7	75.6	<u>sp³ <u>C</u>H-O (possible H<u>C</u>=C-O)</u>
	3	129.7	<u>aromatic/alkene sp² CH (<u>C</u>H=C)</u>	8	71.9	<u>sp³ C-O (quat)</u>
	4	128.3	<u>aromatic/alkene sp² CH 2x (o/m)</u>	9	30.4	<u>CH₃</u>
	5	127.5	<u>aromatic/alkene sp² CH (p)</u>	10	29.4	<u>CH₃</u>

(c) Do a mathematically accurate analysis of the expansion below, and report your results. If there are two solutions, report them both. Show a coupling tree.

Solution 1=2

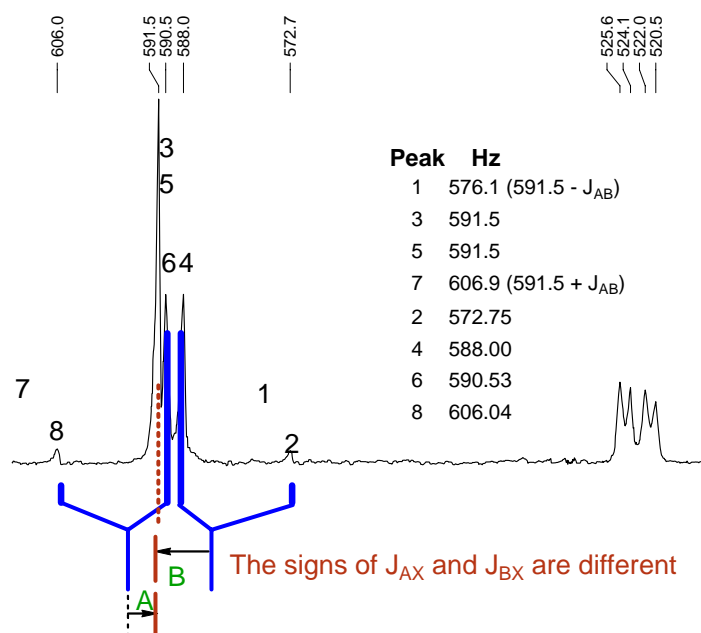
$c_- = (3+5)/2 = 591.5$	J_{AB}	15.4
$\Delta v_{ab-} = \delta_- = \sqrt{(7-1)(5-3)} = 0$	J_{AX}	-2.4
$c_{\pm} \pm \Delta\delta/2 = 591.5 \quad 591.5$	J_{BX}	+6.8
$c_+ = (6+4)/2 = 598.27$	ν_A	592.7
$\Delta v_{ab+} = \delta_+ = \sqrt{(8-2)(6-4)} = 9.18$	ν_B	588.1
$c_{\pm} \pm \Delta\delta_+/2 = 593.9 \quad 584.7$	$\Delta\nu_{AB}$	4.6
Intensity Calculation	δ_A	5.93
Solution 1=2	δ_B	5.88

$$\Phi_{1+} = 0.5 \arcsin(J_{AB}/2D+) = 29.4$$

$$\Phi_{1-} = 0.5 \arcsin(J_{AB}/2D-) = 45$$

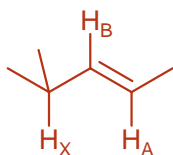
$$i_{10} = i_{11} = 0.929$$

This is the special ABX pattern with Solution 1 = Solution 2 (one of the ab quartets has collapsed to a singlet), To use the normal method for ABX solution, put in calculated frequencies for the - ab quartet - both central lines superimposed, the outer lines $+J$ (although the position of the outer lines does not affect the calculation - ν_{ab-} will always be 0 if the central lines are identical)

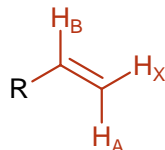


(d) What part structure is suggested by the shifts and couplings of this part of the spectrum?

3



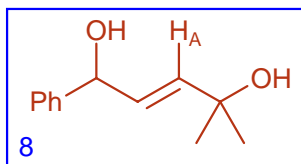
Also possible:



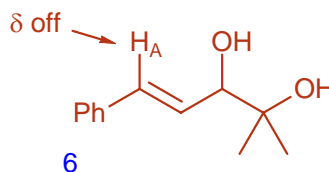
However, both J_{AX} and J_{BX} would be positive for structures of this type, unless $R = O$. In this case, the chemical shifts are way off. J_{BX} is also too small

(e) Determine the structure of **R-09G**. If more than one structure is possible, show them, and circle your best choice.

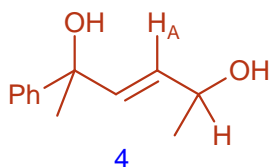
8



Base:	5.25
CH ₂ OH gem	0.64
CH ₂ OH cis	-0.01
Calc	5.88
Obs.	5.93



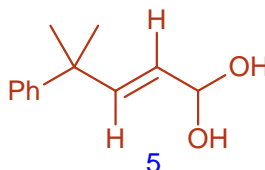
Base:	5.25
Ph-gem	1.38
CH ₂ OH cis	-0.01
Calc	6.62
Obs.	5.93



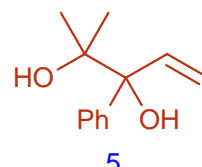
4



5



5



5

¹H

6.46 (14.4, 6.9)
3.86
3.74
1.27
4.17 (14.4, -1.9)

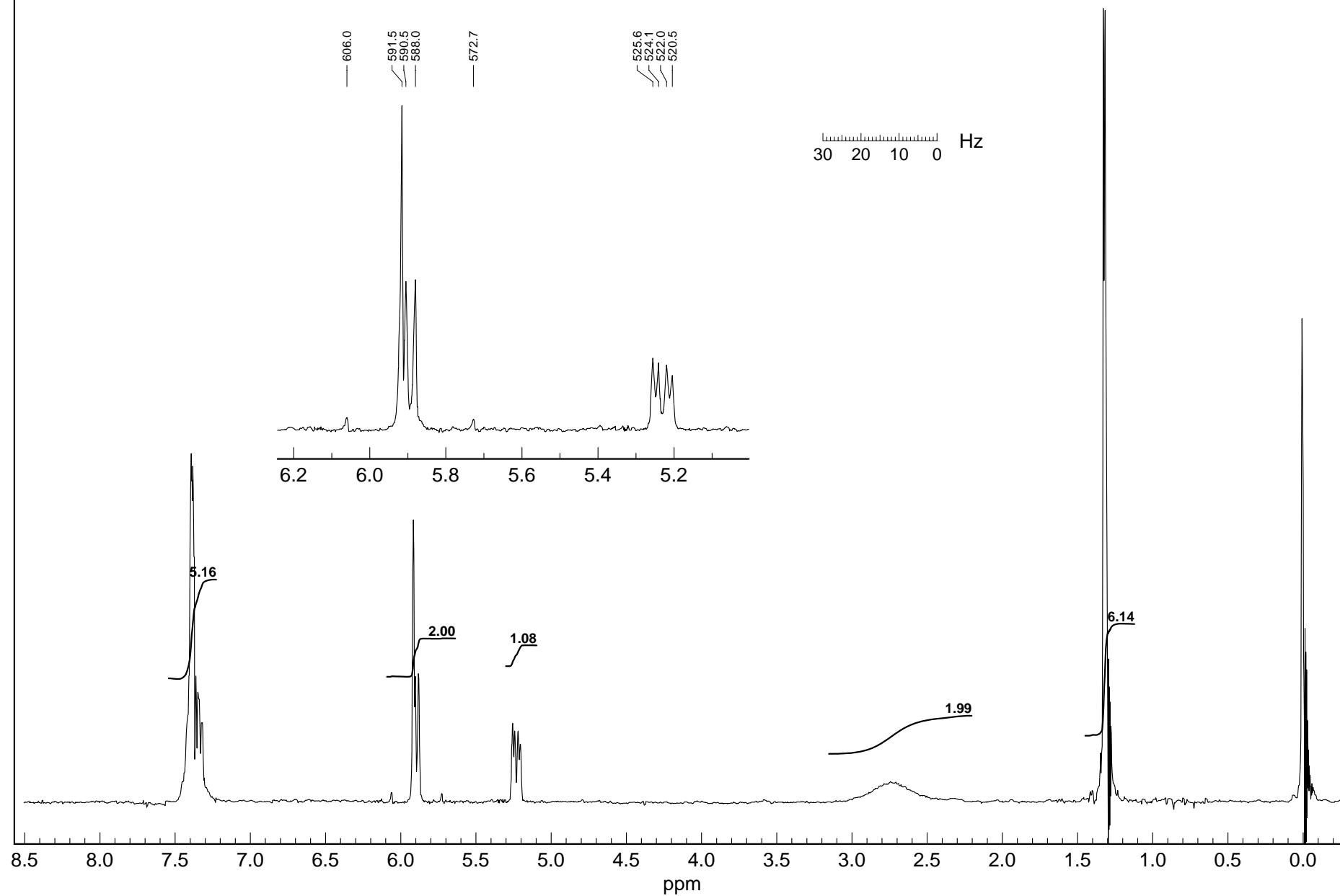
¹³C

12.5
147.5
54.9
96.0
*TET-78-425

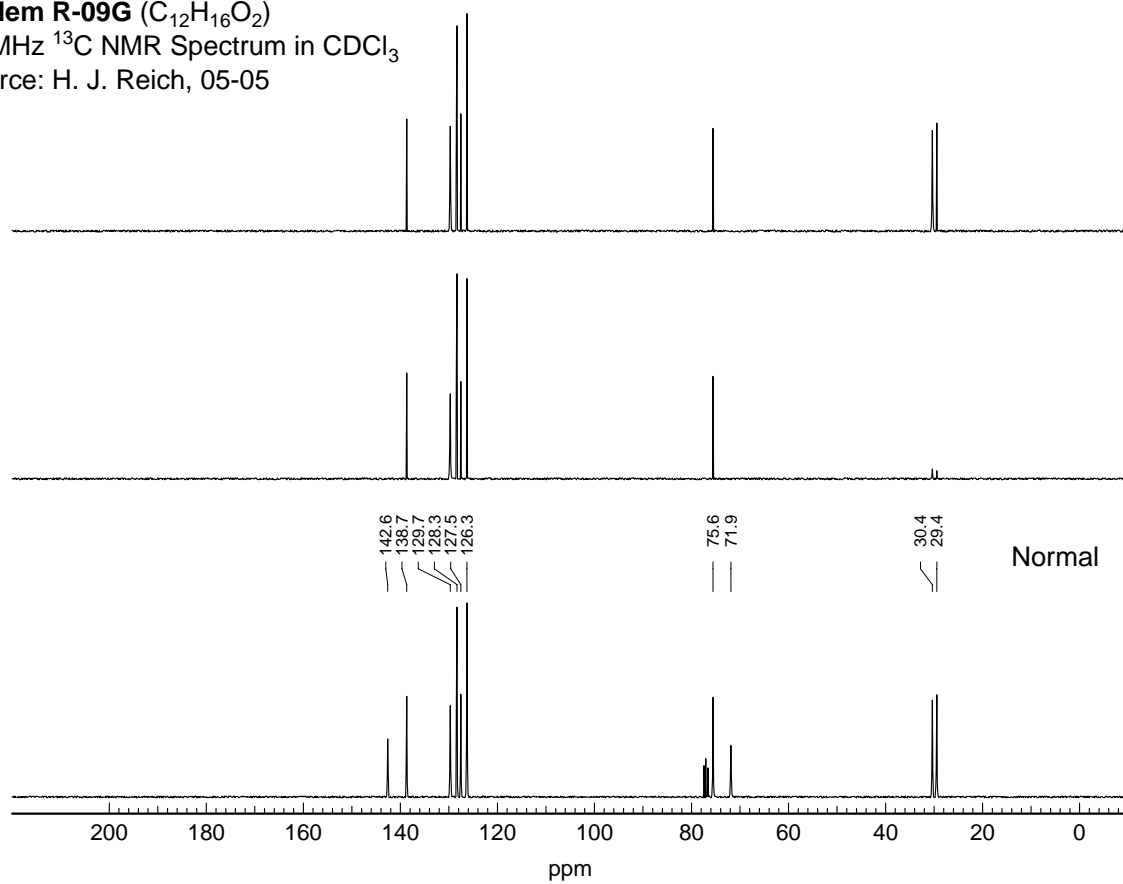
Problem R-09G ($C_{12}H_{16}O_2$)

100 MHz 1H NMR Spectrum in $CDCl_3$

Source: H. J. Reich, 1975



Problem R-09G ($C_{12}H_{16}O_2$)
 25 MHz ^{13}C NMR Spectrum in $CDCl_3$
 Source: H. J. Reich, 05-05



10 Problem R-09H. The two simulated spectra below differ *only* in the relative chemical shift of the protons ν_5 and ν_6 .

$J_{12} = 0.00$, $J_{13} = 3.00$, $J_{14} = 0.00$, $J_{15} = 14.0$, $J_{16} = 6.00$

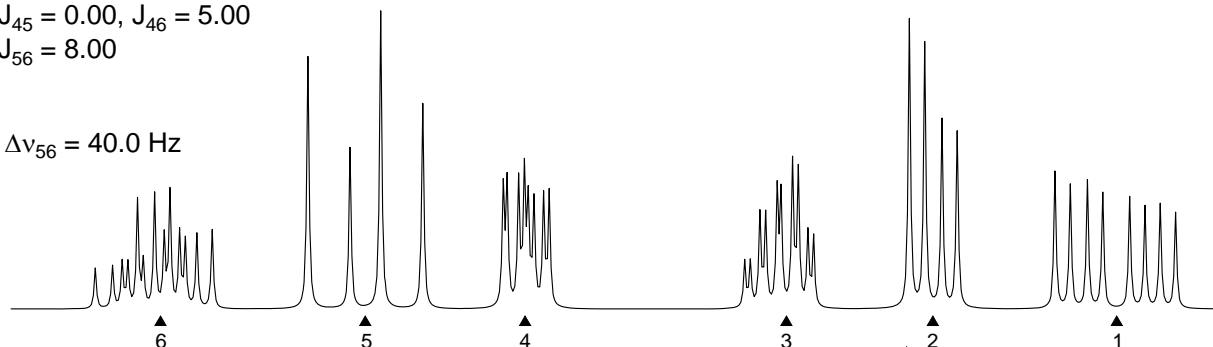
$J_{23} = 6.00$, $J_{24} = 3.00$, $J_{25} = 0.00$, $J_{26} = 0.00$

$J_{34} = 1.00$, $J_{35} = 0.00$, $J_{36} = 3.00$

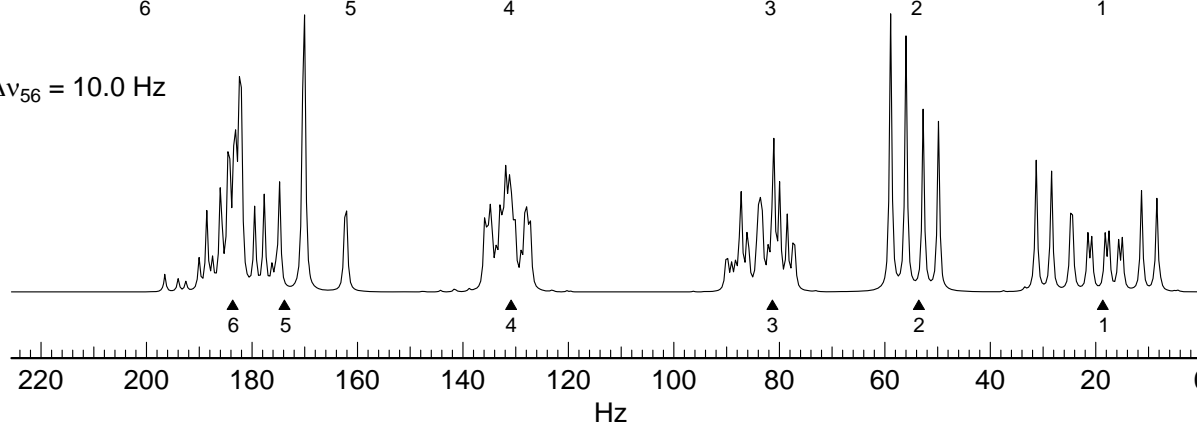
$J_{45} = 0.00$, $J_{46} = 5.00$

$J_{56} = 8.00$

$\Delta\nu_{56} = 40.0$ Hz



$\Delta\nu_{56} = 10.0$ Hz



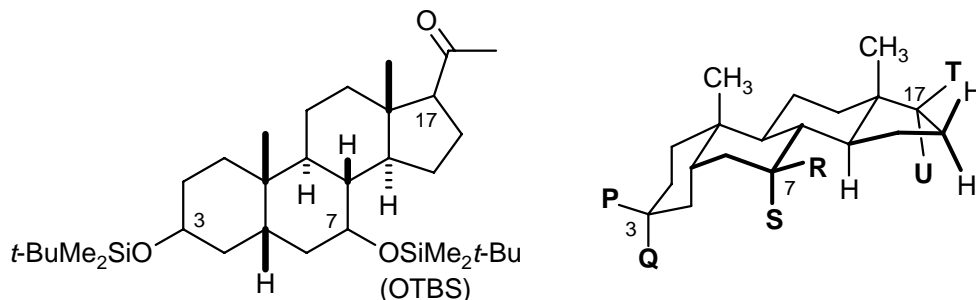
(a) Explain why most of the multiplets look so different in the two spectra. What phenomenon is this?

H_5 and H_6 are coupled to each other. When the chemical shift between H_5 and H_6 are small (comparable to or smaller than J_{56}) then we see the effects of "virtual coupling" - this causes second order effects (additional lines and false coupling) in the signals for H_5 and H_6 , as well as for all protons coupled to them (H_1 , H_3 and H_4).

(b) Specifically explain why *only* H_2 is unchanged in the second spectrum.

H_2 is the only proton which is NOT coupled to either H_5 or H_6 - so it remains perfectly first order

Problem R-09I This problem requires you to analyze the ^1H NMR spectrum of a steroid, and determine the stereochemistry at three centers. A planar projection and conformational drawing is shown below.



(a) Assign the signal at C-3 (δ 3.4). Explain how you identified the signal, and make a stereochemical assignment: P = H, Q = OTBS (H or OTBS).

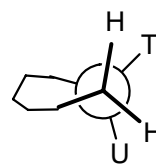
The multiplet at δ 3.4 is a tt, $J = 11, 4$ Hz. This must correspond to two J_{aa} and two J_{ae} couplings, and can only be H-3. H-7 has only 3 neighbors, and H-17 only two. Since there are two large axial couplings, H-3 must be axial, and the OTBS group equatorial.

(b) Assign the signal at C-7 (δ 3.81). Explain how you identified the signal, and make a stereochemical assignment: R = H, S = OTBS (H or OTBS).

This signal is probably a broad quartet, with $J = 3$ Hz, thus at least 3 nearest neighbors. None of couplings are axial-axial, thus the proton must be equatorial.

(c) Assign the signal at C-17 (δ 2.52). Explain how you identified the signal, and make a stereochemical assignment: T = Ac, U = H (H or $\text{CH}_3\text{C}(=\text{O})$).

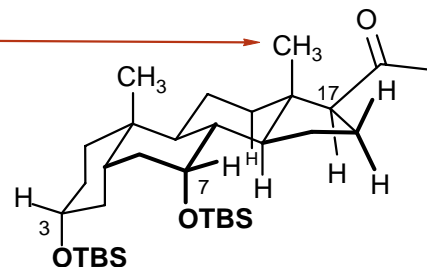
This is the only other downfield signal (no other protons are adjacent to a carbonyl group). The signal is a triplet, $J = 9$ Hz. Examination of the conformation shows that if T = H then one of the couplings should be very small, since Θ is likely to be near 90° . On the other hand, if U = H then both couplings will be fairly large, since one has Θ near 0° , the other with Θ near 180° .



(d) Why is the methyl group at δ 2.1 so much taller (i.e. sharper) than the one at δ 0.6?

The ring Me group has small W-couplings to the trans-diaxial protons, the Me-C(=O) group is essentially uncoupled

We don't, however, know which of the bridgehead methyl groups we are looking at, the other one is under the t-butyl signals

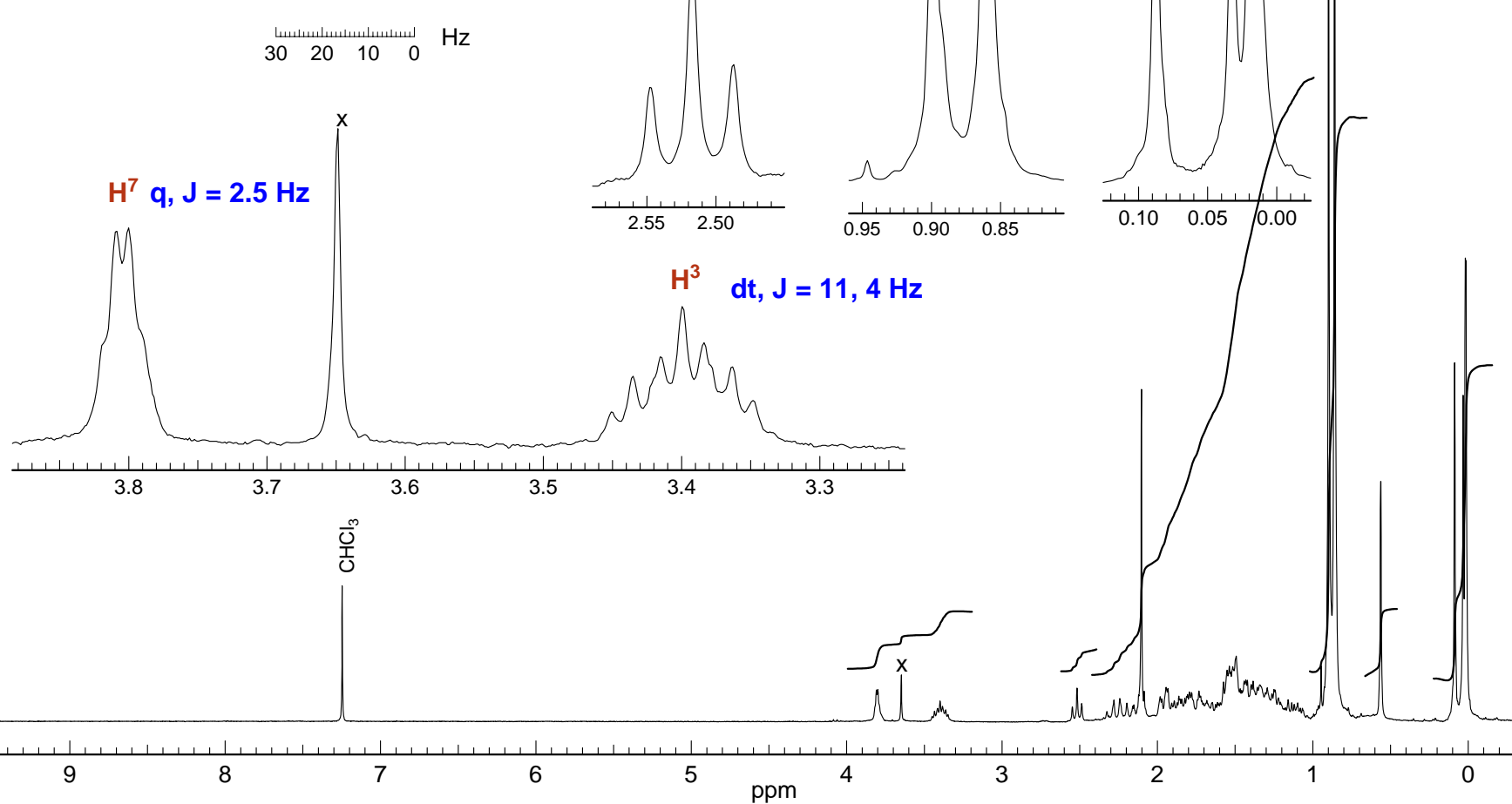
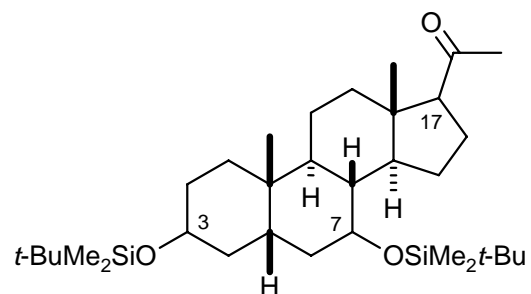


(e) Assign and explain the signals at δ 0.00 to 0.10

The SiMe_2 groups are each diastereotopic, so we see four Me signals

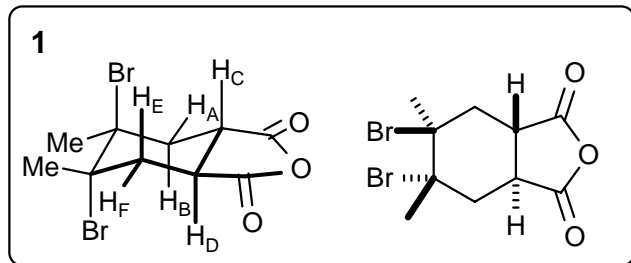
Problem R-09I ($C_{33}H_{62}O_2Si_2$)300 MHz ^{13}C NMR Spectrum in $CDCl_3$

Source: I. L. Reich, K. Plessel/Reich 040-04

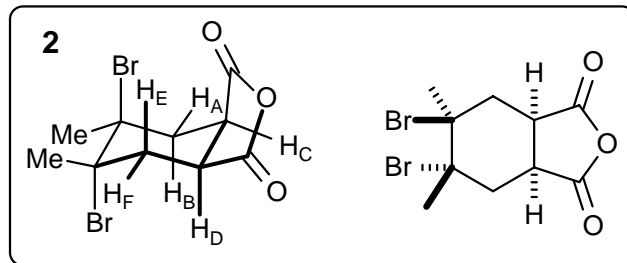


Problem R-09J. You are asked to determine which of two possible isomers of a dibromo anhydride is the correct one, and assign the protons. The complete spectrum is shown on the next page.

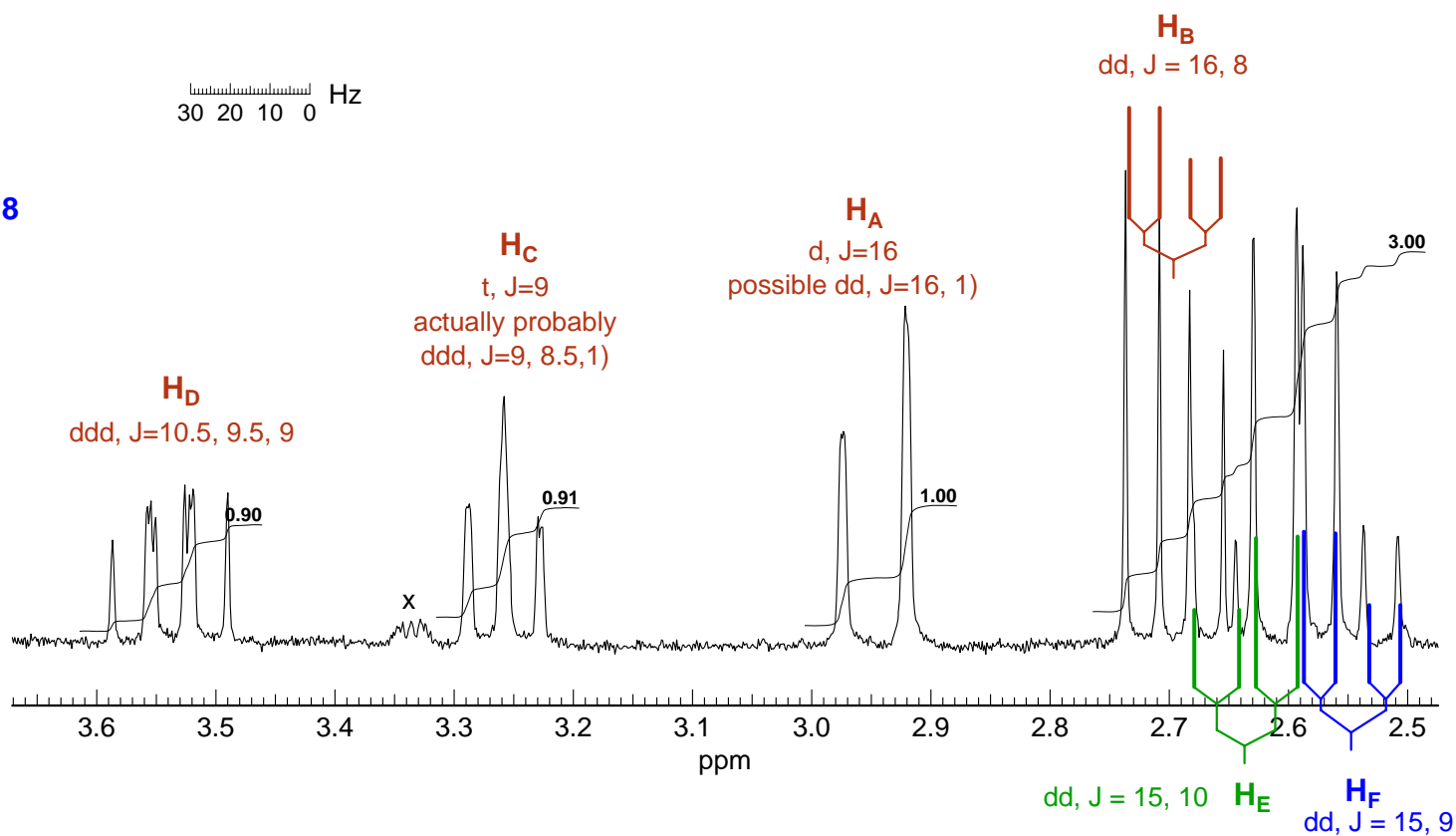
(a) Assign the protons, draw appropriate coupling trees on the spectrum below, and label each one with a proton assignment (H_A , H_B , etc). It is not necessary to report couplings, although you might wish to measure them to aid in your analysis.



or



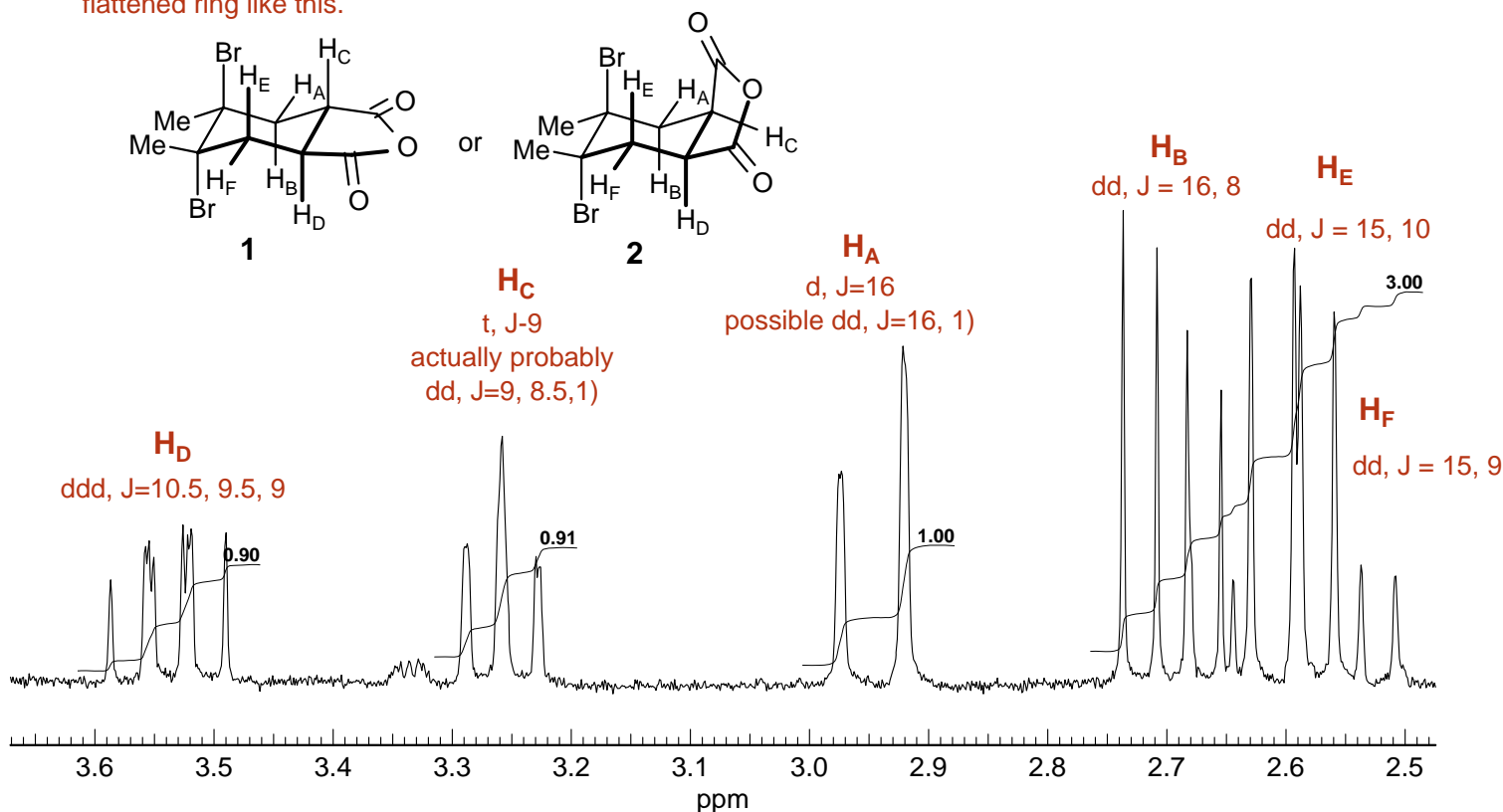
8



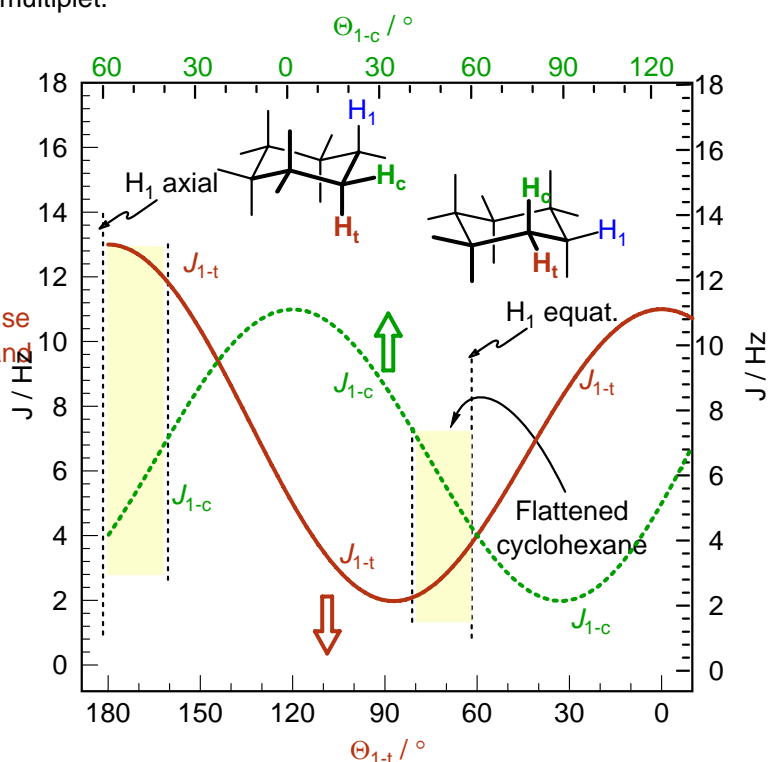
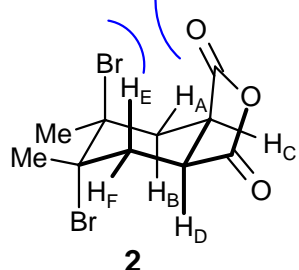
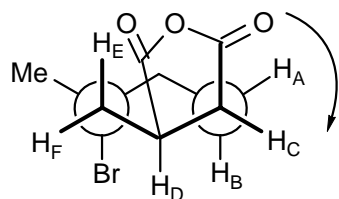
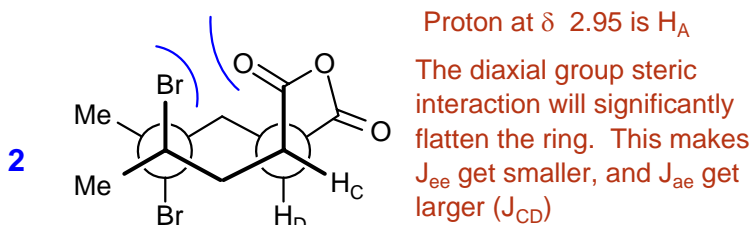
(b) Which isomer 2 (1 or 2) is correct? Explain briefly how you decided which was correct.

Isomer 1 has an axis of symmetry, $H_C = H_D$, $H_A = H_F$ and $H_B = H_E$, so spectrum would be much simpler (only 3 chemical shifts, rather than 6)

5 Can also make arguments based on the individual coupling constants: in isomer 1, H_C should be coupled to H_A and H_D with large couplings (aa), and H_A with a small one (ae), we see only two medium sized couplings. On the other hand, for isomer 2, H_C might be coupled to H_A by only a very small J , since the ee coupling should be near 0 for a flattened ring like this.



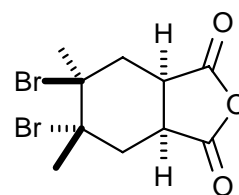
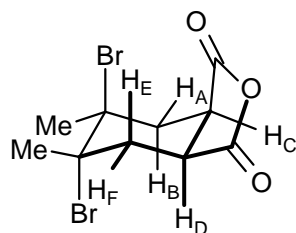
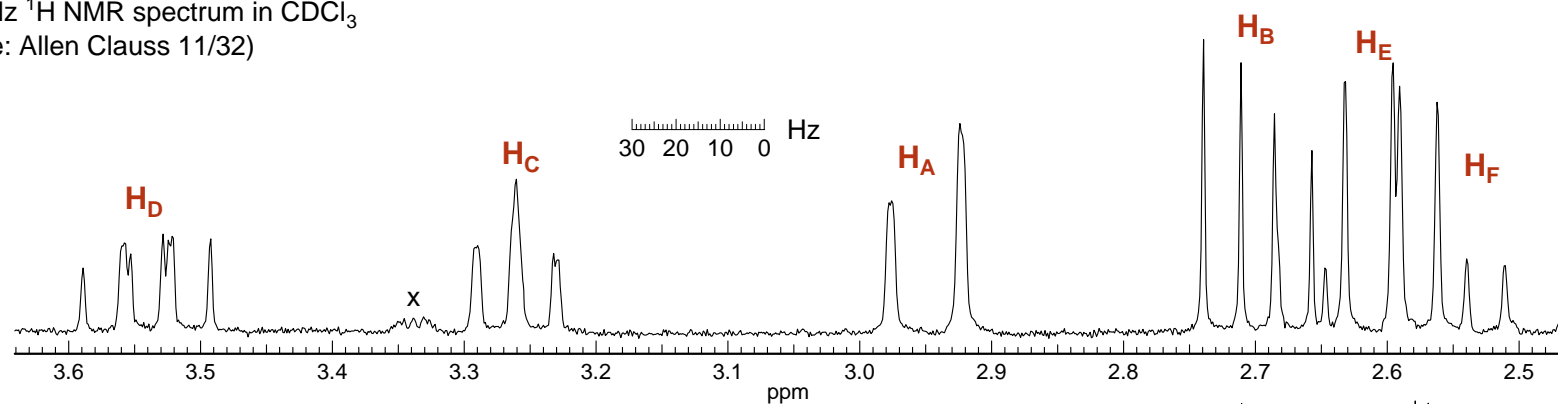
(c) Explain why the proton at δ 2.95 shows such a simple multiplet.



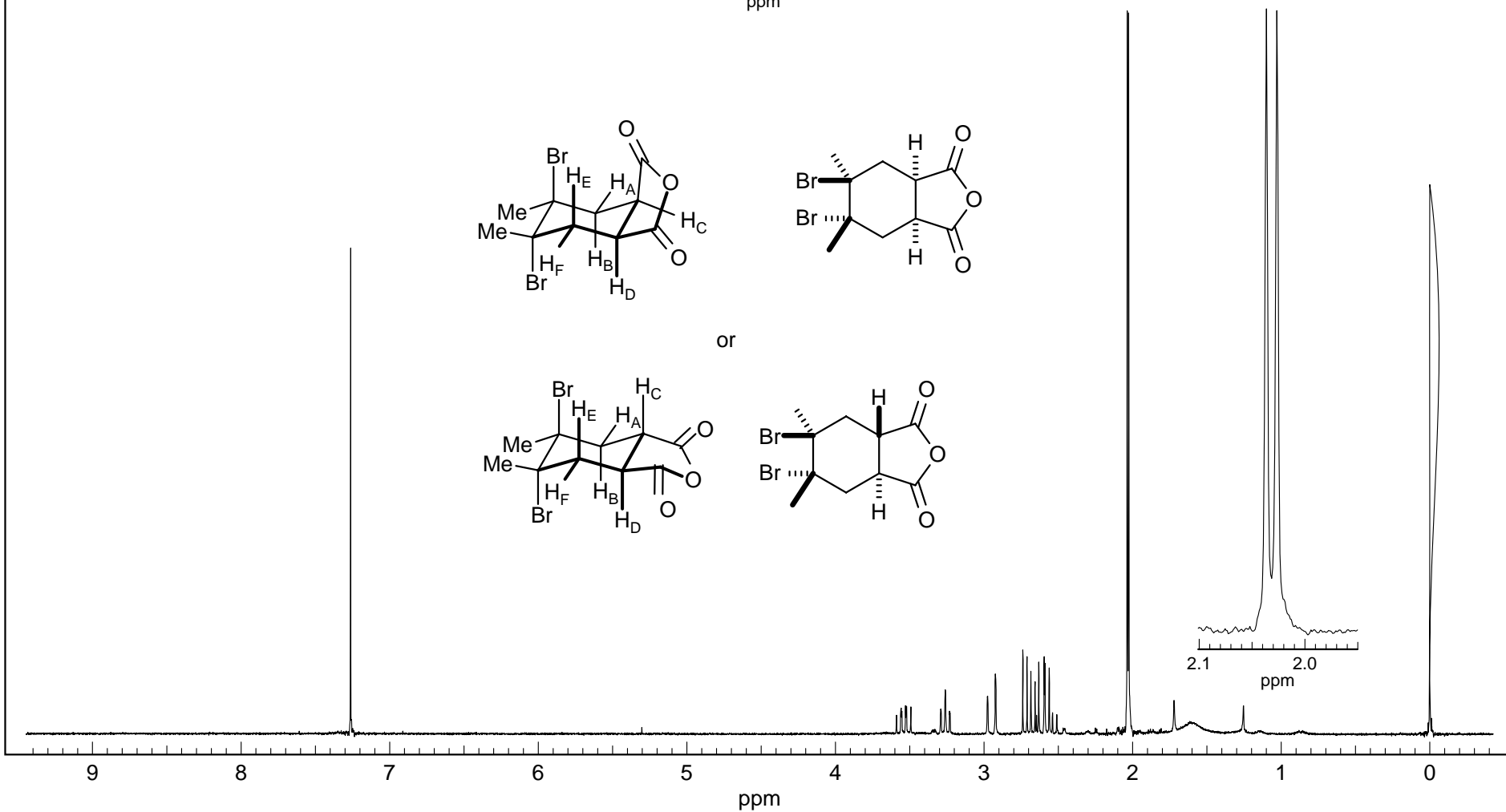
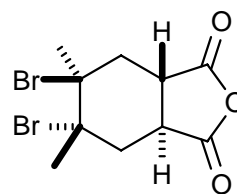
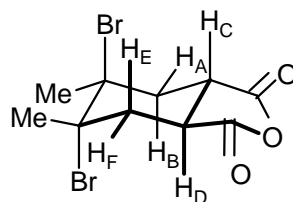
Problem R-09J ($C_{10}H_{12}Br_2O_3$)

300 MHz 1H NMR spectrum in $CDCl_3$

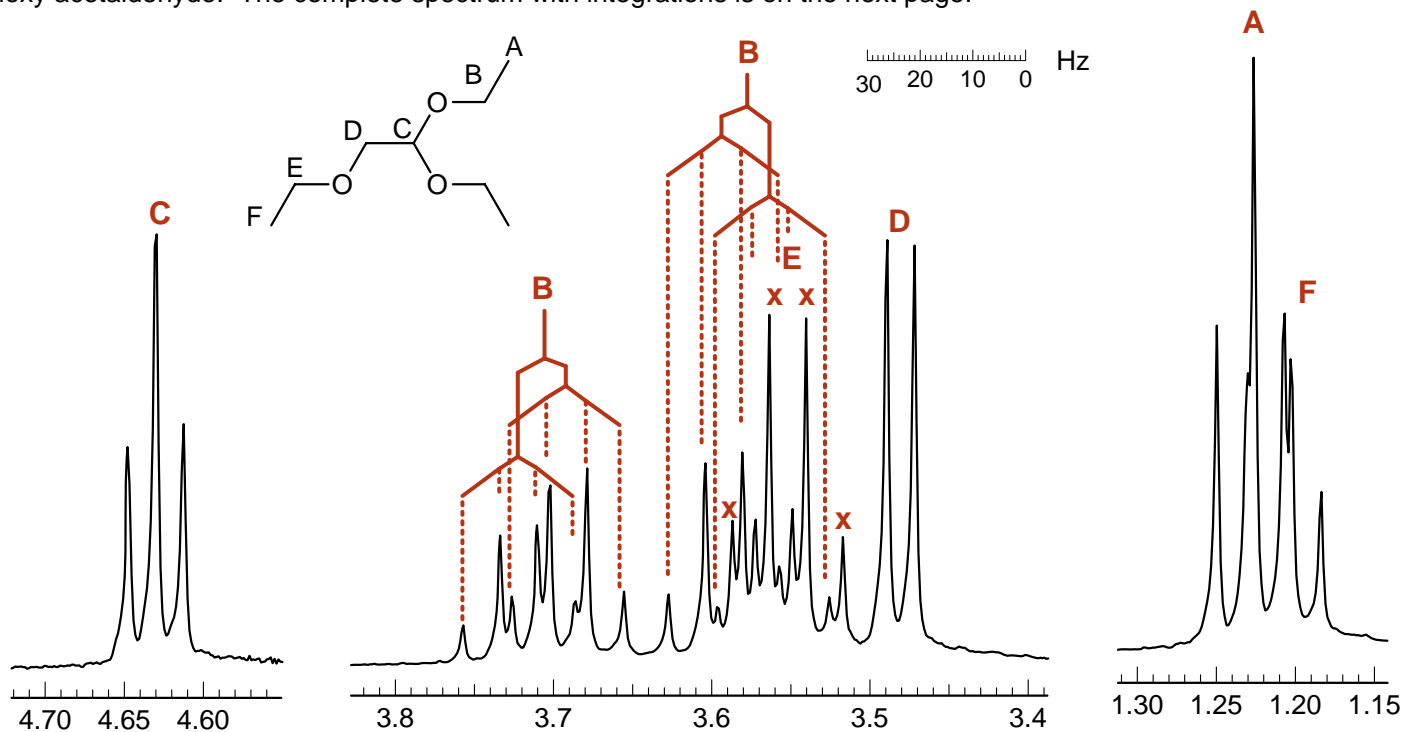
(Source: Allen Clauss 11/32)



or



Problem R-09K $C_8H_{18}O_3$. This problem requires you to analyze the 1H NMR spectrum of the diethyl acetal of ethoxy acetaldehyde. The complete spectrum with integrations is on the next page.



(a) Give the chemical shift(s), multiplicity and couplings (δ 3.23, dt, $J = 8, 2$ Hz) of each unique proton in the spectrum. You may use first order analysis.

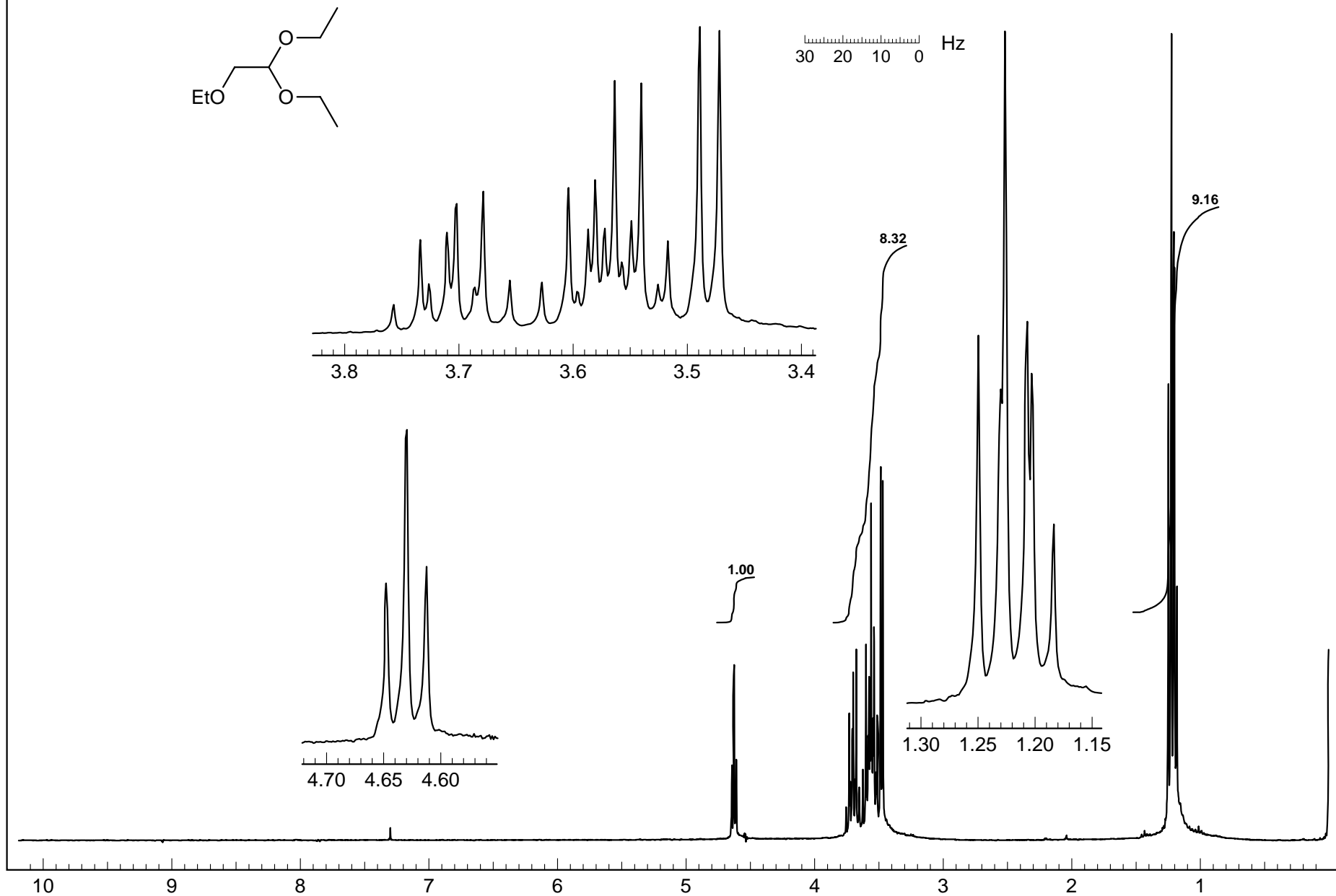
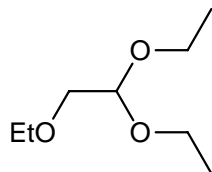
- 2 A δ 1.23, t, $J = 7$ Hz
- 6 B δ 3.71, dq, $J = 10, 7$ Hz, δ 3.58, dq, $J = 10, 7$ Hz (B protons are diastereotopic)
- 1 C δ 4.63, t, $J = 5$ Hz
- 1 D δ 3.48, d, $J = 5$ Hz
- 2 E δ 3.55, q, $J = 7$ Hz
- 2 F δ 1.20, t, $J = 7$ Hz

- 2 (b) To show you understand the pattern, put a marker (x) over each peak corresponding to proton E.

Problem R-09K: C₈H₁₈O₃

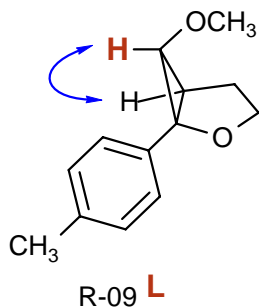
300 MHz ¹H NMR spectrum in CDCl₃

Source: Aldrich Spectra Viewer/Reich

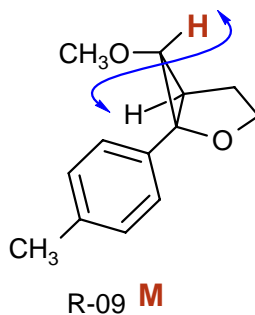


Problem R-09L and R-09M ($C_{13}H_{16}O_2$). The 270 MHz 1H spectra are of the isomers below:

cis coupling
should be larger
($\Theta = 0^\circ$): $J = 7.5$
Hz



trans coupling
should be
smaller: $J = 3$
Hz



(a) Identify a key feature of the spectra which allows confident assignment of the stereochemistry. Explain and label the structures above appropriately. It is not necessary to analyze the spectra completely.

The most reliable stereochemical feature is the 3J coupling cis and trans in the cyclopropane, with the expectation that $J_{cis} > J_{trans}$. Each isomer has an isolated doublet at ca δ 3.3 corresponding to the CH-OMe proton

8

R-09L has a d, $J = 7.5$ Hz at δ 3.36, thus the two Hs are cis

R-09M has a d, $J = 3$ Hz at δ 3.22, the two H s are trans

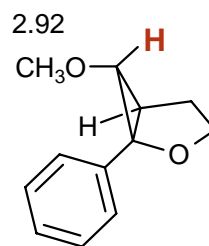
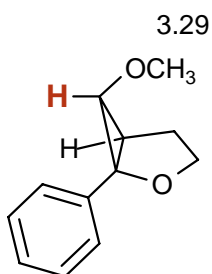
4 for chemical shift arguments

1-2 for others

(b) Explain the differences in the chemical shift of the sharp singlet at δ 3.25 in **R-09L** and δ 2.9 in **R-09M**.

Apparently, in R-09M the MeO group is over the shielding portion of the aromatic ring, so shifted upfield to δ 2.9 from its "normal" position - alkyl ethers like Me_2O are typically at δ 3.4-3.5.

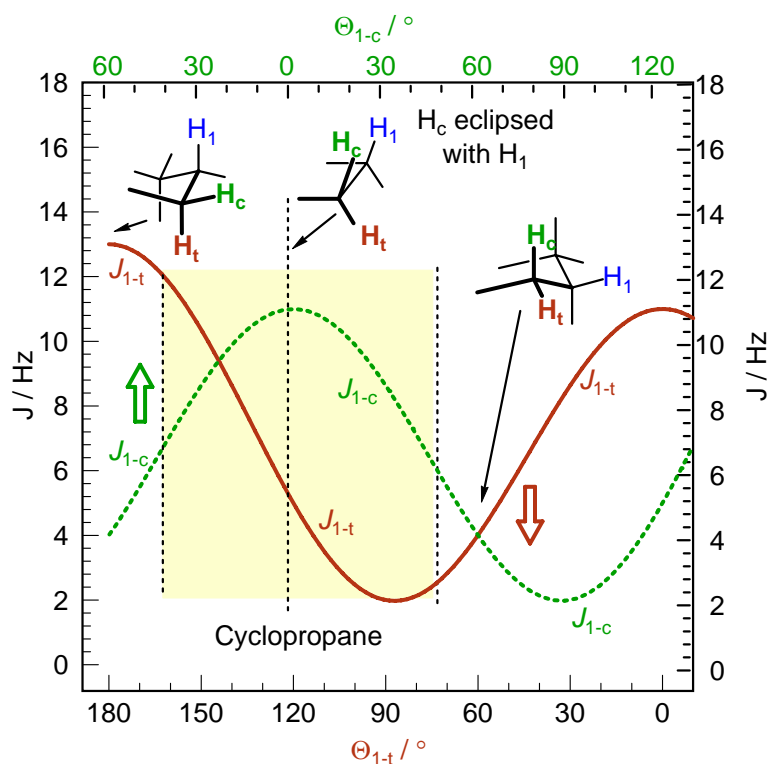
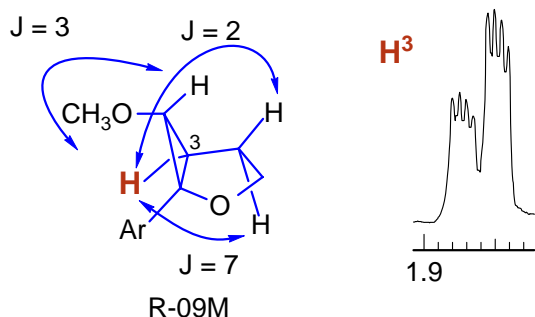
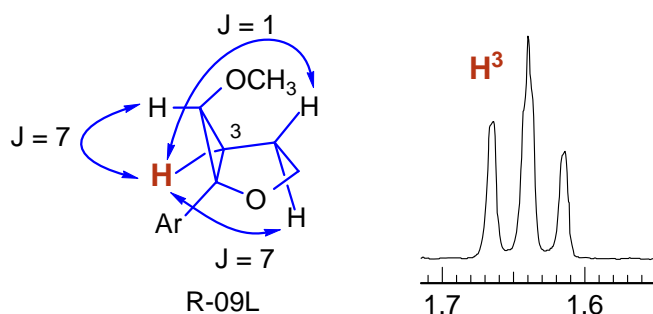
4



- 6 (c) Assign and interpret the signal at δ 1.65 (explain the coupling) in the spectrum of **R-09L**. Give the chemical shift of the corresponding signal in the spectrum of **R-09M** 1.86 . 2

This is roughly a t, $J = 7$ Hz, although actually almost a ddd, $J = 7, 6, 1$, which can be assigned from its chemical shift (upfield of the other cyclopentane protons) and coupling. It must have a dihedral angle near 90° to one of the vicinal CH_2 protons

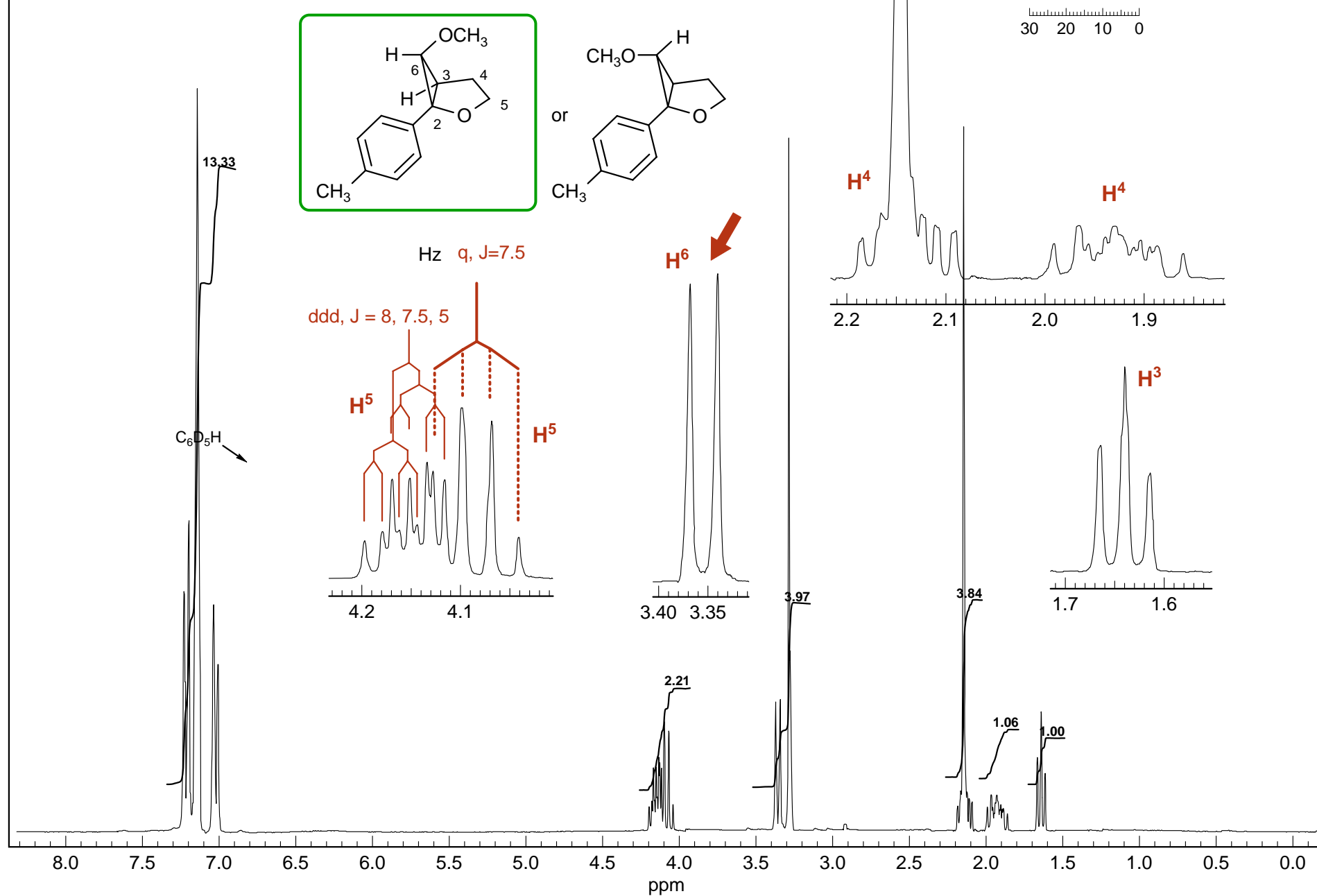
The corresponding proton in R-09M is at δ 1.86, ddd, $J = 7.5, 3, 1.5$ Hz 4



Problem R-09L ($C_{13}H_{16}O_2$)

270 MHz 1H NMR Spectrum in C_6D_6

(Source: Nora Hornung/Casey 11/16)



Problem R-09M (C₁₃H₁₆O₂)

270 MHz ¹H NMR Spectrum in C₆D₆

(Source: Nora Hornung/Casey 11/16)

