C8953
NMR structural analysis seminar

Information about classes + 1D ^{1}H-NMR

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Information about classes

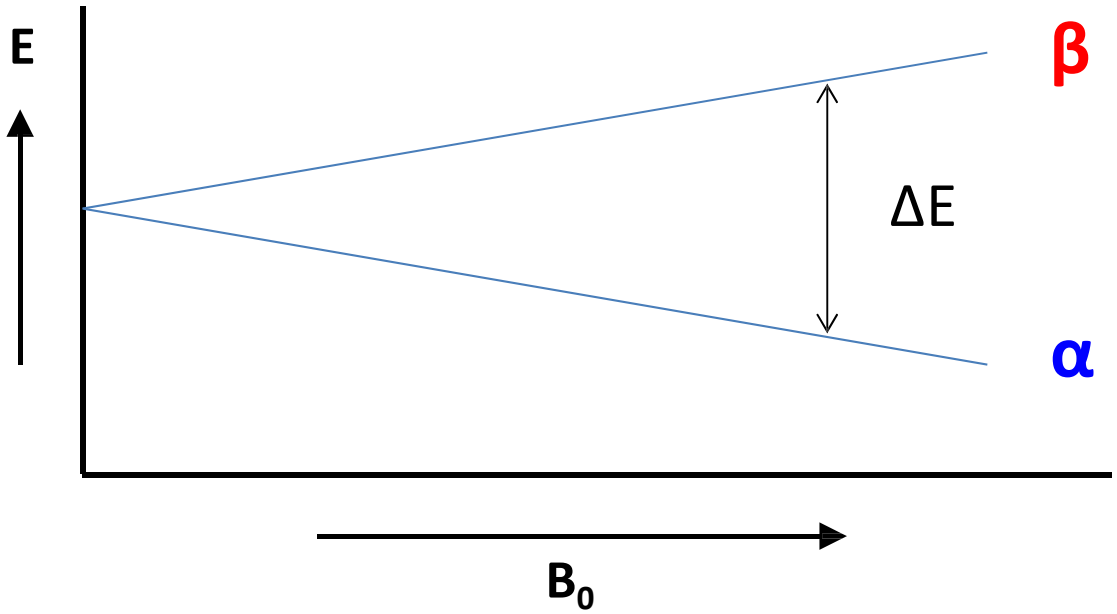
Credit:

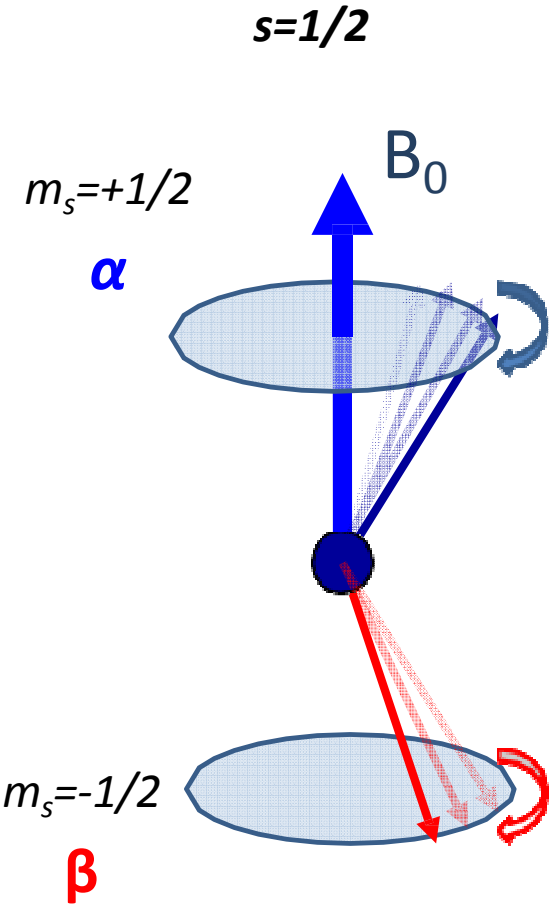
- 3 homework tests + final exercise

Study materials:
`https://is.muni.cz/auth/el/1431/jaro2021/C8953/um`

E-tests:
`https://is.muni.cz/auth/el/1431/jaro2021/C8953/odp`

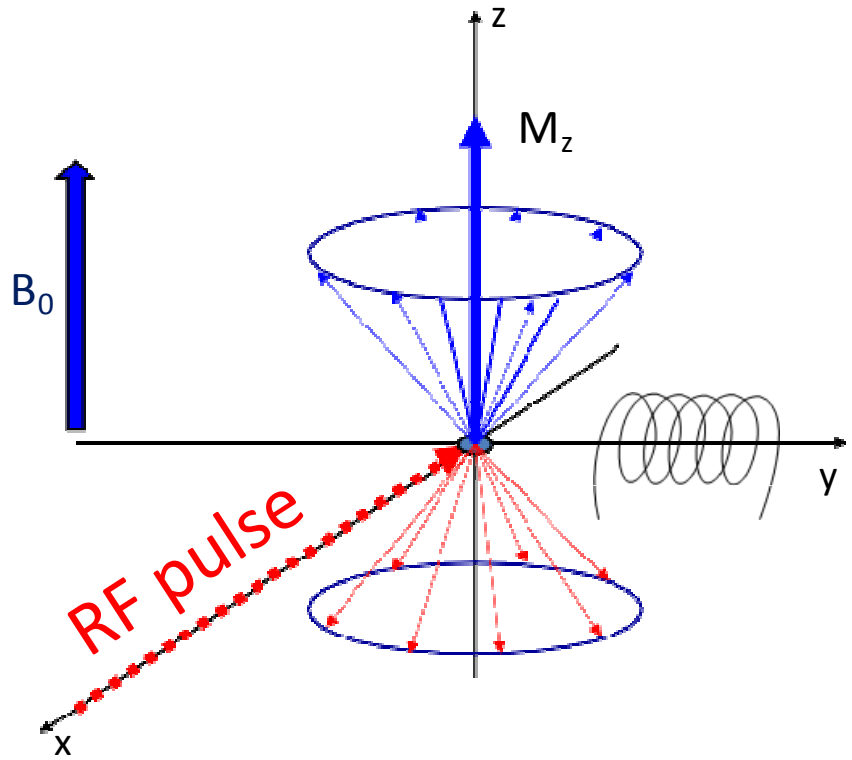
Energy levels splitting

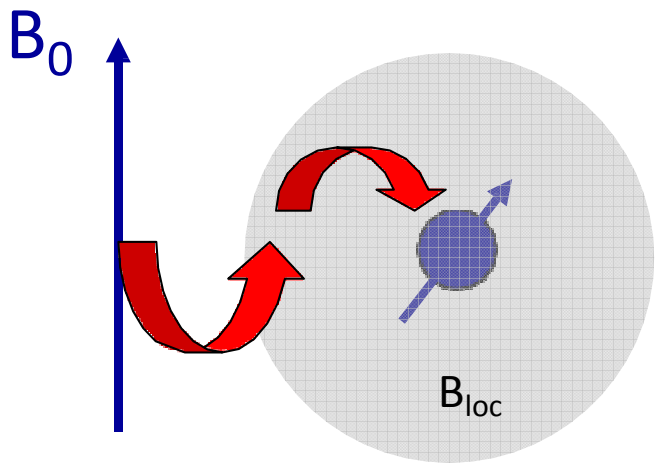




$N_{\alpha} > N_{\beta}$

Behavior of nuclear spin after irradiation by RF pulse





B_0 induces local mag. field B_{loc}, which affects against B_0

↓

Nuclear shielding

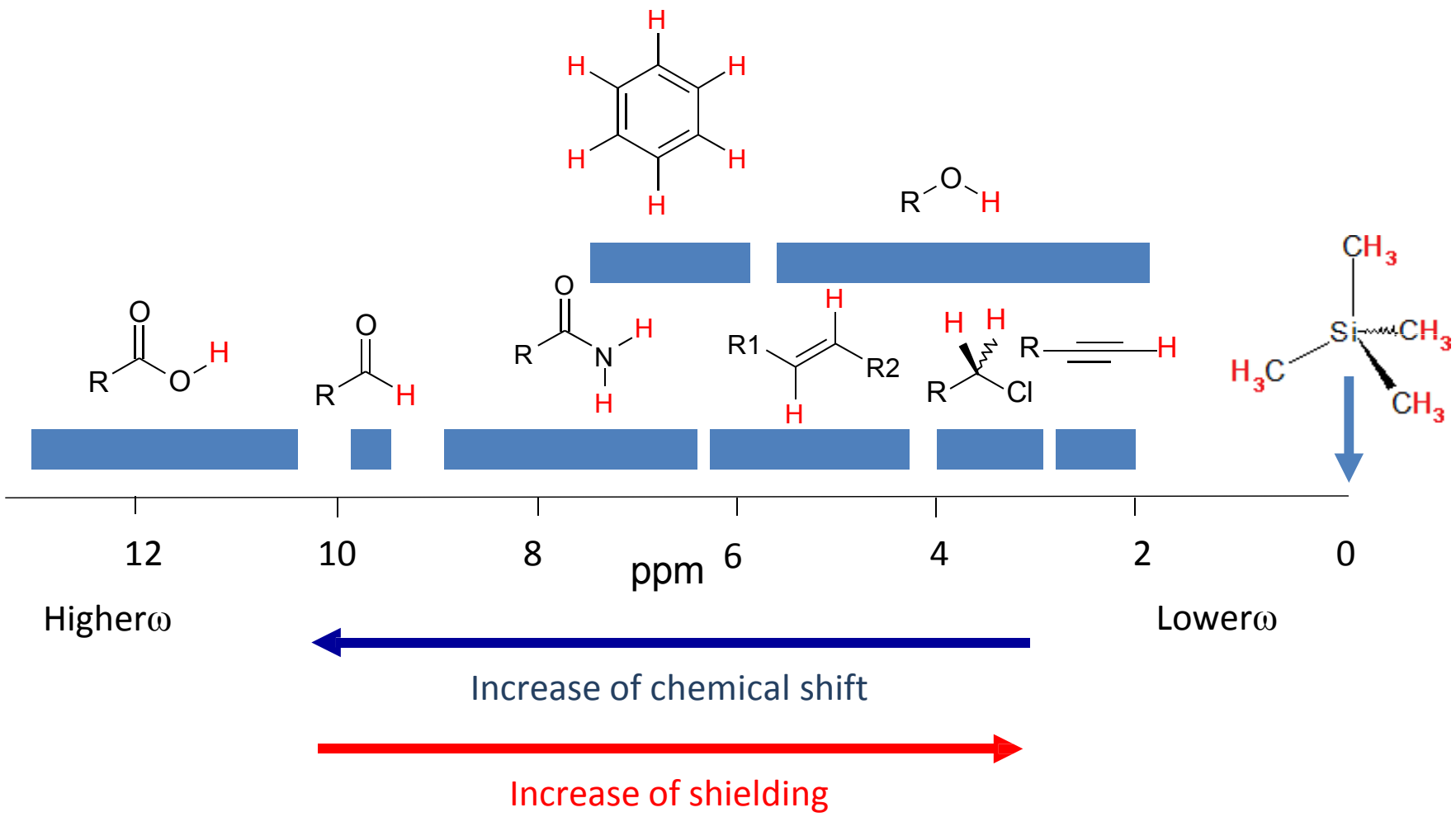
Precession frequency: $\omega = -\gamma B_0$

Precession frequency affected by nuclear shielding: $\omega = -(1+\sigma)B_0$

Chemical shift: $\delta = \omega - \omega_{ref}$

Definition of th relative scale of the chemical shift: $\delta = (\omega - \omega_{ref})/\omega_{ref}.10^6$ ppm

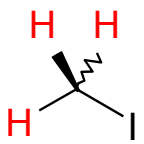
Characteristic intervals of chemical shifts values



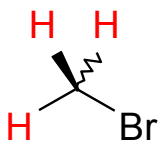
Trends in chemical shifts

- Electronegativity, inductive and mesomeric effects of substituents
- Hybridisation
- Relative position towards the ring, double bond

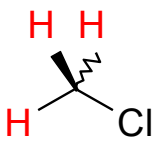
2,1 ppm



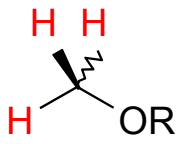
2,3 ppm



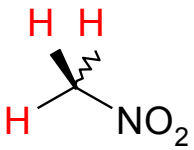
3 ppm



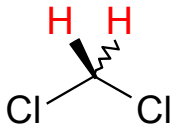
3,1 ppm



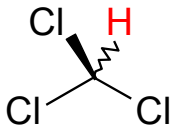
4,5 ppm



5,3 ppm



7,3 ppm



Substituents with -I effect

$=N^+R_2 > -N^+R_3 > -NO_2 > -NR_2$

$-SO_2R > -SO_3 > -SOR > -SR$

$-F > -OR > -NR_2 > -CR_3$

$-F > -Cl > -Br > -I$

$=N > =NR > -NR_2$

$-C^{=}CH > -CH{=}CH_2 > -CH_2-CH_3$

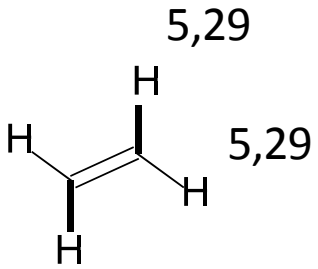
Substituents with +I effects

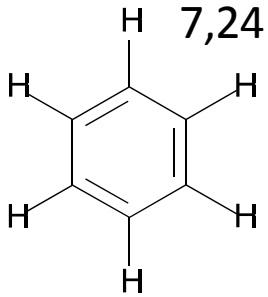
-N-R>-O->S-

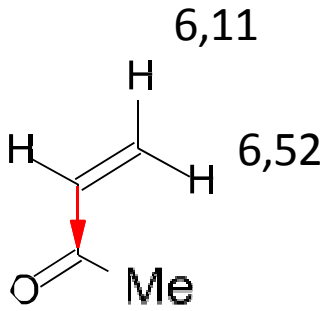
$-C(CH_3)_3 > -CH(CH_3)_2 > -CH_2CH_3 > -CH_3$

metals

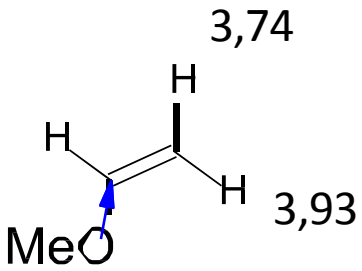
Mesomeric effect



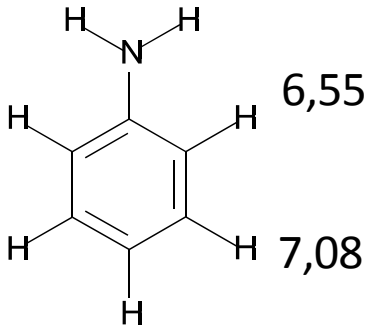




-M

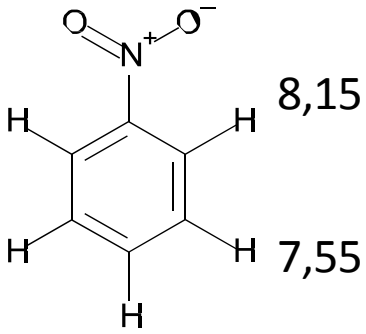


+M



6,70

+M



7,70

-M

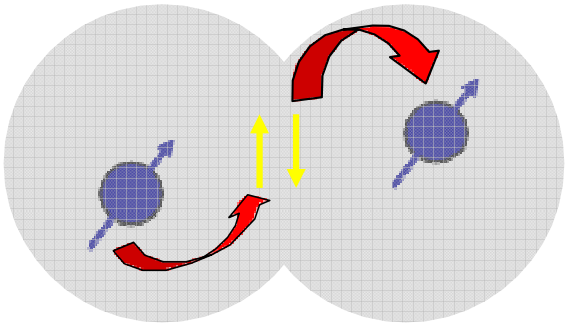
Substituents with -M effects

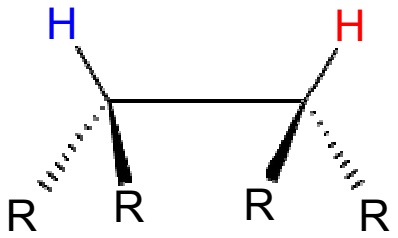
-F, -Cl, -Br, -I, -OH, -OR, -NH_2, -NHR, -NR_2, -SH, -SR

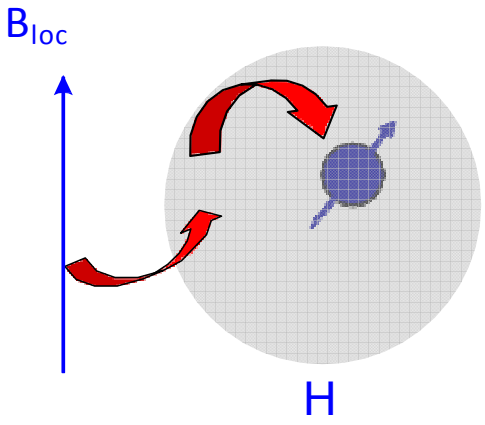
Substituents with +M effect

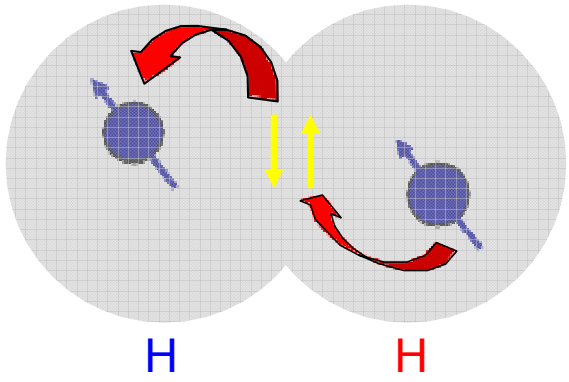
-CH=O, -RC=O, -C(OH)=O, -C(OR)=O, -C(NH_2)=O, -NO_2, -SO_3H, -C=N

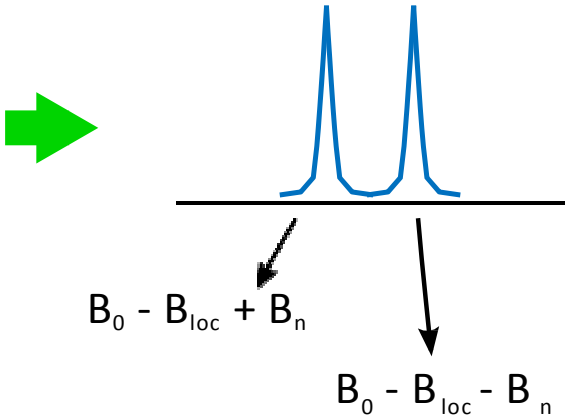
Spin-spin interaction, *J*-coupling









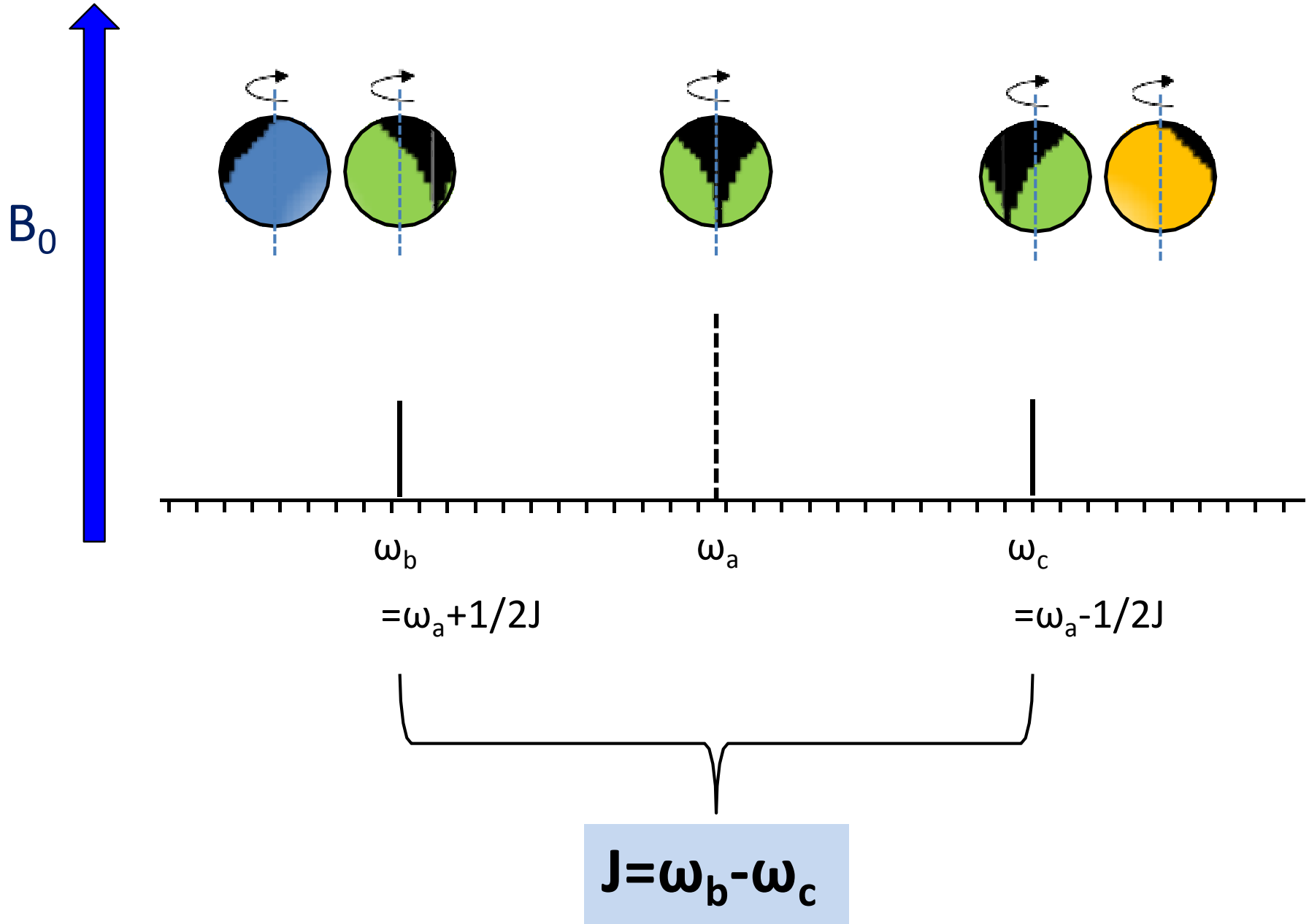


$B_0 - B_{loc}$

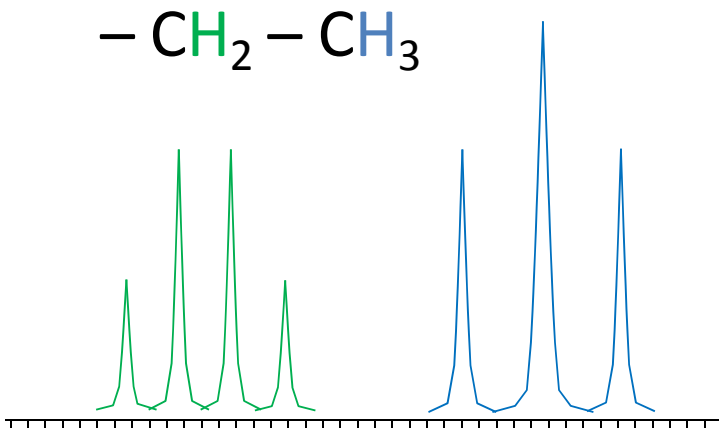
Nucleus H: spin $\alpha \rightarrow -B_n$

spin $\beta \rightarrow +B_n$

Interaction constant *J*



Interaction constant *J*



- Multiplicity of the nucleus I with the spin 1/2 is given by: m = n + 1, n = number of interacting nuclei with nucleus I
- Intensity of lines in multiplet follows Pascal's triangle

1

1 1

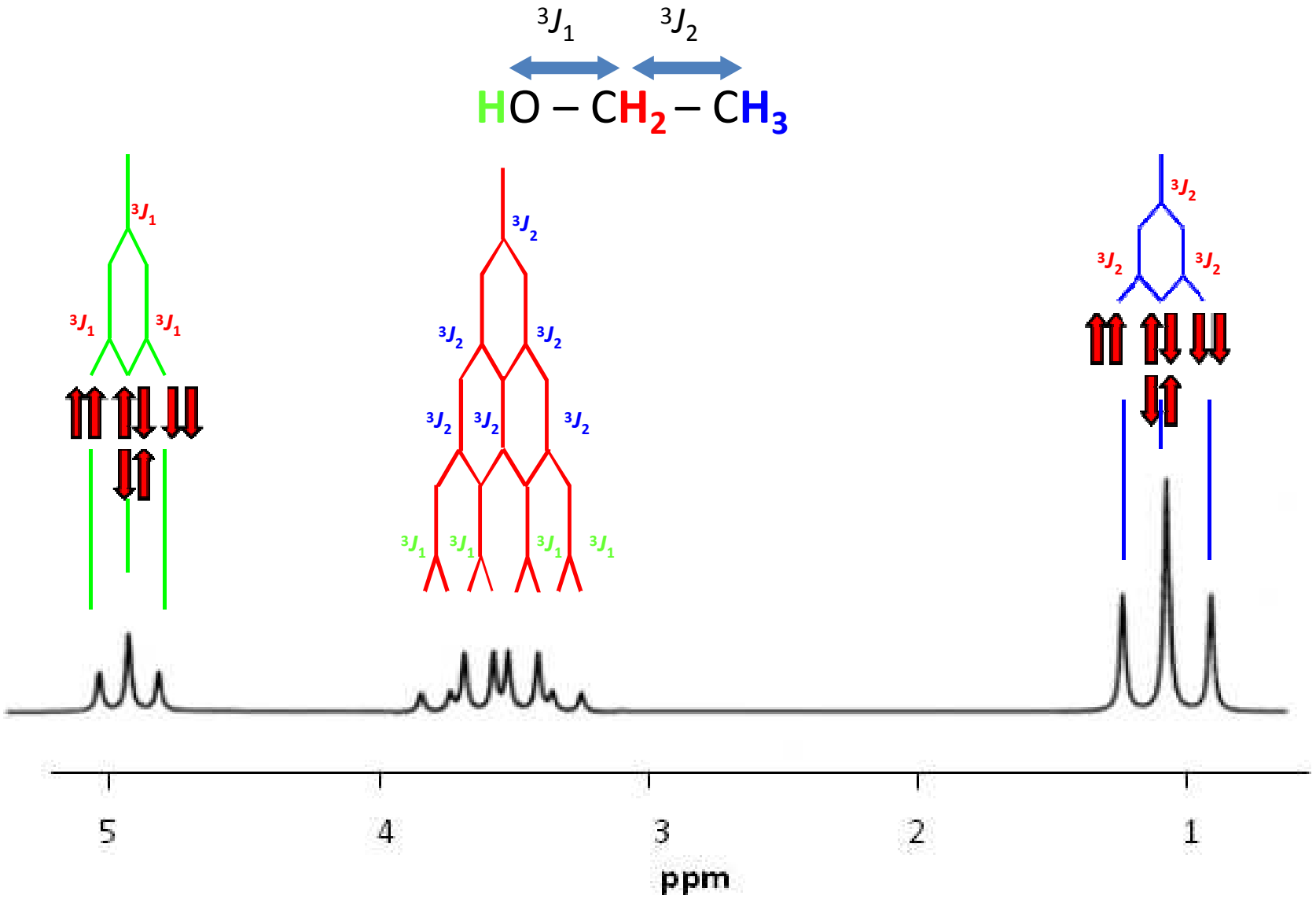
1 2 1

1 3 3 1

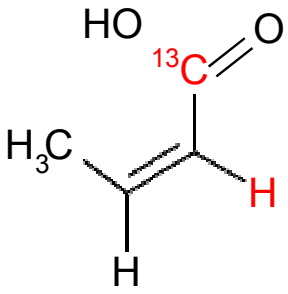
1 4 6 4 1

1 5 10 10 5 1

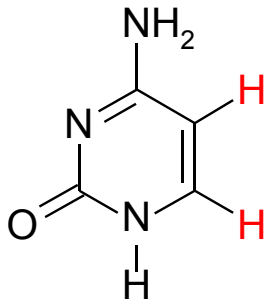
1D ^{1}H NMR spectrum



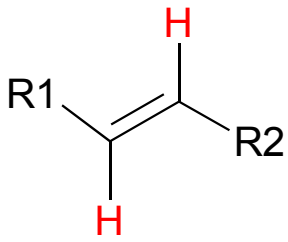
Values of *J*-constants - trends



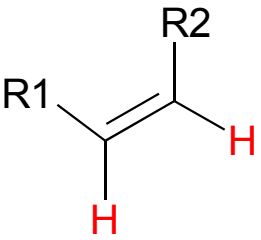
$^{2}J_{CH}$= 3.1 Hz



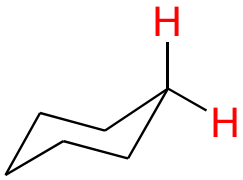
$^{3}J_{HH}$= 12 Hz



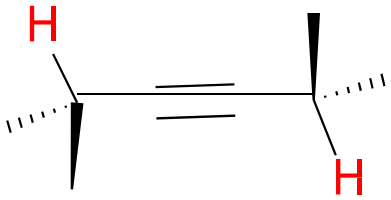
$^{3}J_{HH}$ = 13 - 18 Hz



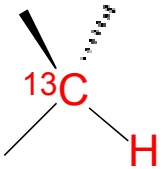
$^{5}J_{HH}$ = 7 - 12 Hz



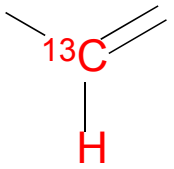
$^{2}J_{HH}$= -12,5 Hz



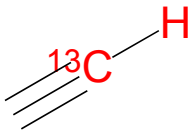
$^{5}J_{HH}$= 2 - 3 Hz



$^{1}J_{CH}$ = 125 Hz

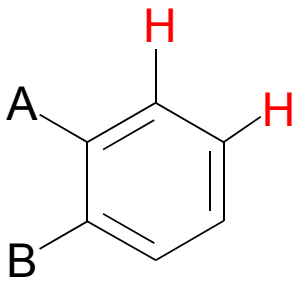


$^{1}J_{CH}$ = 160 Hz

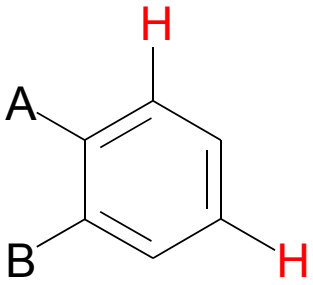


$^{1}J_{CH}$ = 250 Hz

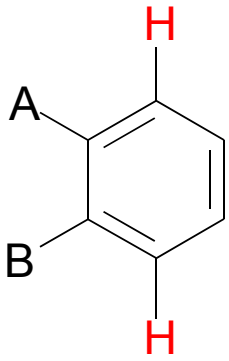
Values of *J*-constants - trends



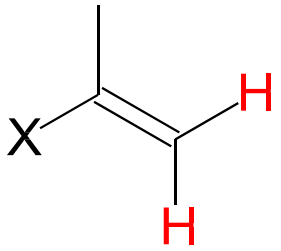
$^{3}J_{HH}$ = 7,5 Hz



$^{4}J_{HH}$ = 1,5 Hz



$^{5}J_{HH}$ = 0,7 Hz



X=	Li	H	Cl	OMe	F
$^{2}J_{HH}$ (Hz)	7,1	2,5	-1,4	-2,0	-3,2

1D ^{1}H NMR spectroscopy

- the fastest measuring, the highest sensitivity
- complicated interpretation in case of more complex systems

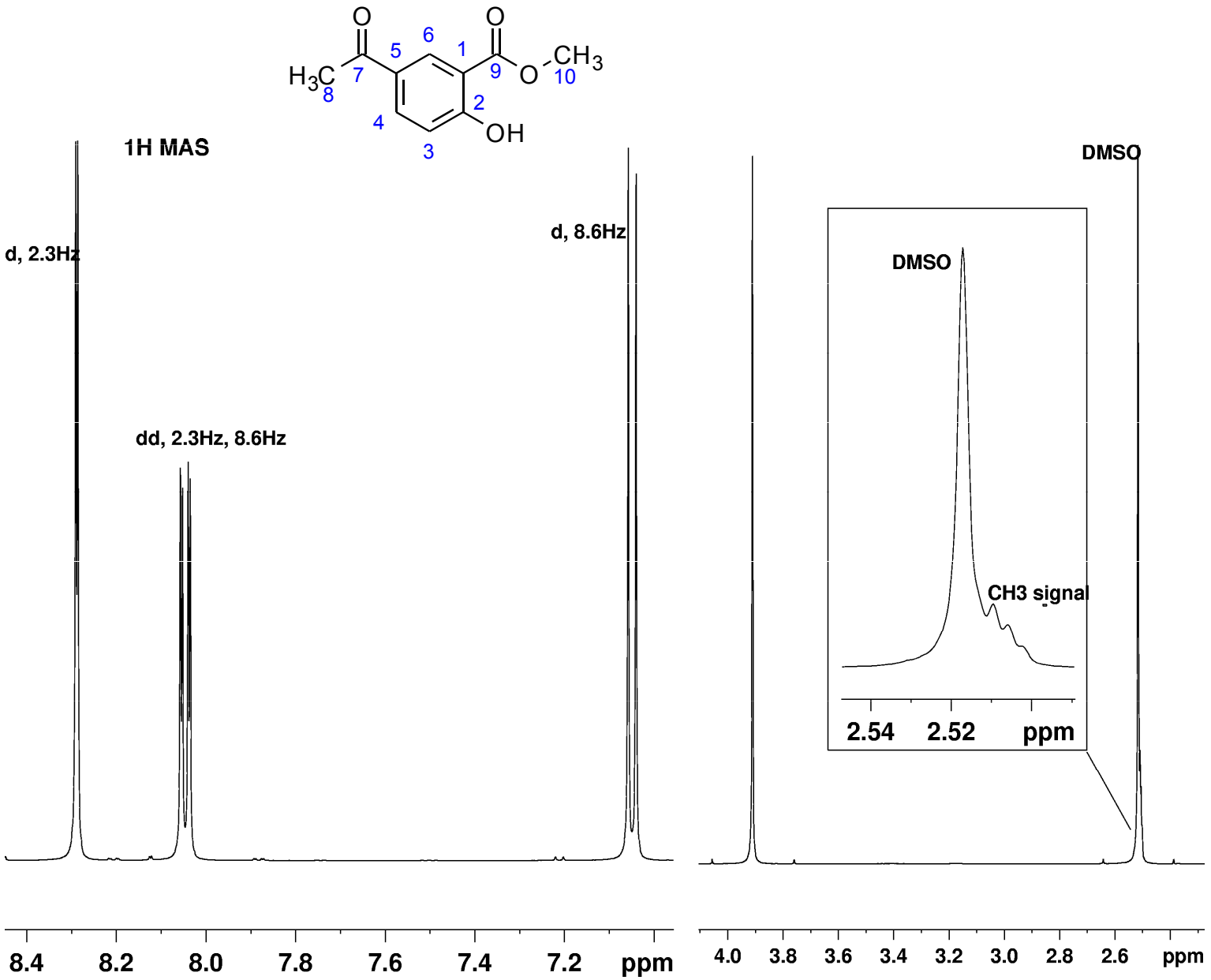
We are looking for:

- position of the signal (ppm)
- multiplicity (^{2}J, ^{3}J, ^{4}J)
- intensity (integral)
- halfwidth

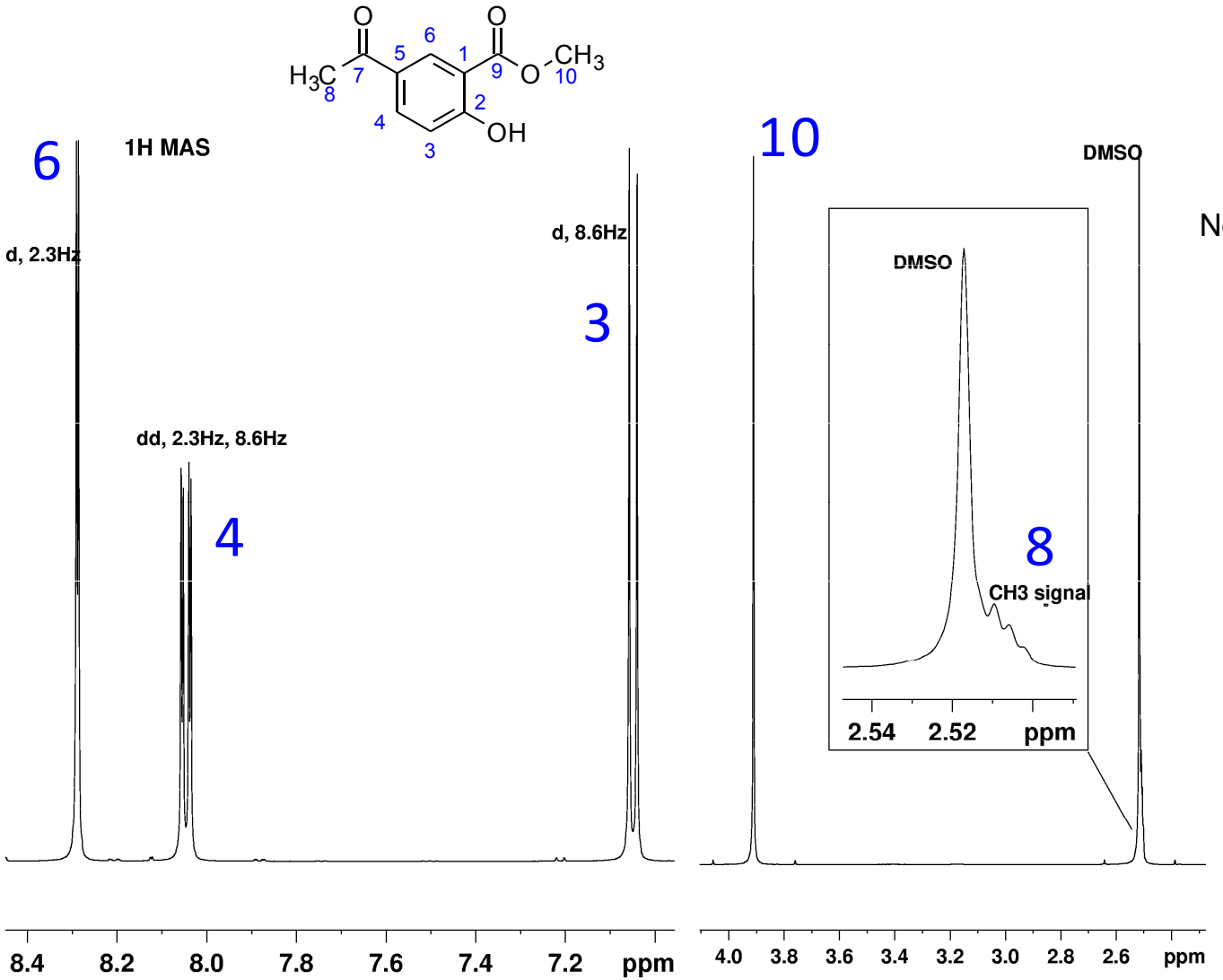
We are considering:

- chemical/magnetic equivalence
- enantiotopicity/diastereotopicity
- averaging of signals (dynamics, chemical exchange)

1D ^{1}H NMR spectrum of methyl-5-acetylsalicylate



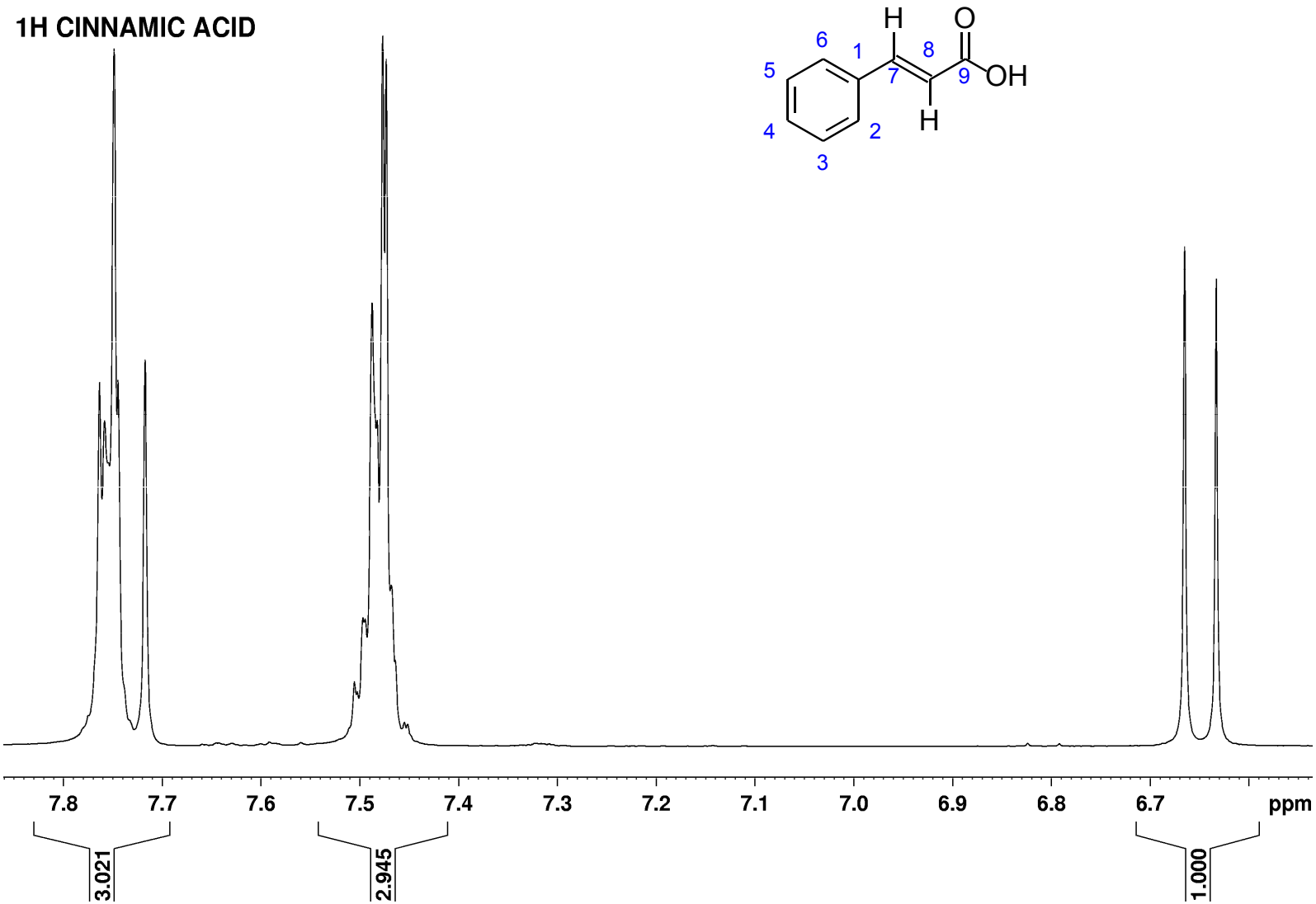
1D ^{1}H NMR spectrum of methyl-5-acetylsalicylate



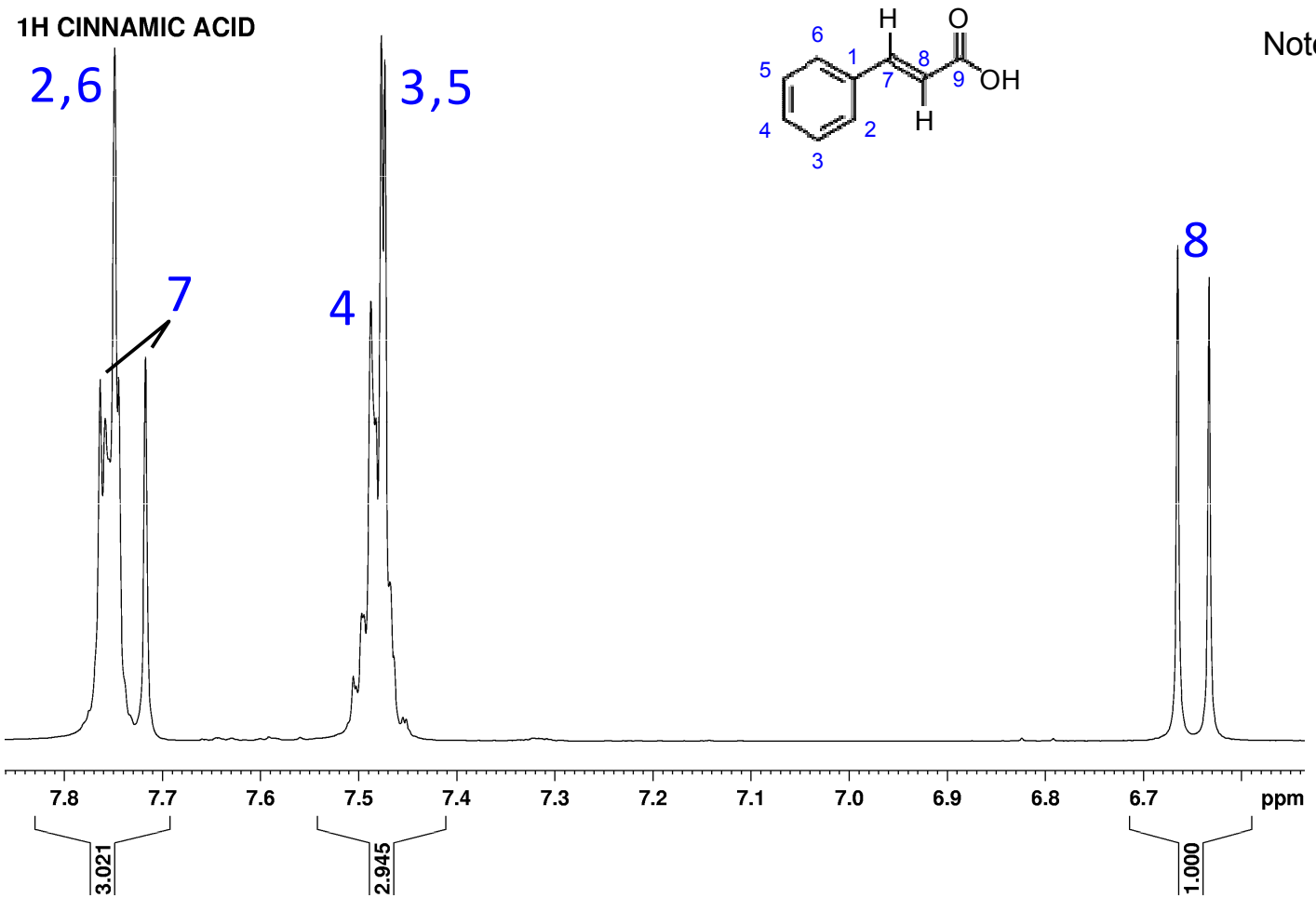
Notes:

- two singlets in the spectrum - two isolated groups in the structure - CH_3 groups; **Met-8** neighboring carbonyl has lowest shift than ester **Met-10**
- doublet of doublets (cca 8.0 ppm) - proton signal splitted by two neighbors - **H-4**
- two doublets in interaction with H-4 - based on the *J*-interaction: doublet with larger *J*-constant belongs to close proton - **H-3**, smaller *J*-constant - more distant proton - **H-6**

1D ^{1}H NMR spectrum of cinnamic acid



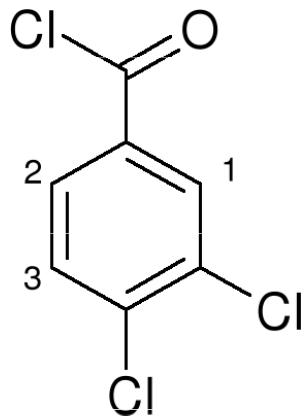
1D ^{1}H NMR spectrum of cinnamic acid



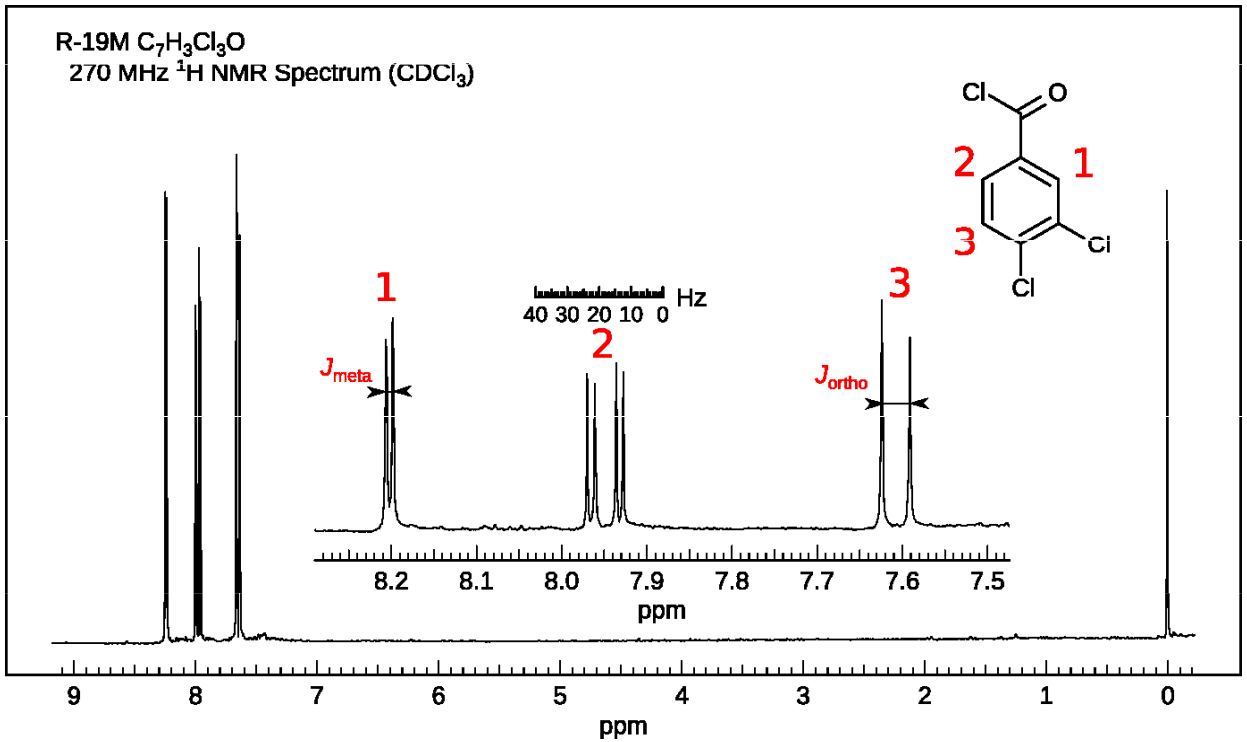
Notes:

- **H-8** - doublet with large coupling, in range of shifts of protons on double bond, integral = 1
- **H-7** - doublet with the same coupling like doublet H-8, deshielded due to -M effect of carboxyl and due to nearby aromatic ring
- more intensive signal between 7.7 and 7.8 ppm has integral: 3-1=2 protons - **H-2,6**, symmetrical, highest shift due to -M effect of substituent in *ortho* position on aromatic ring
- signal with integral = 3 around 7.5 ppm - less intensive signal - only one proton, highest shift due to -M effect of substituent in *para* position - **H-4**; more intensive signal with highest shift - **H-3,5**

Draw approximate 1D ^{1}H NMR spectrum of the following compound



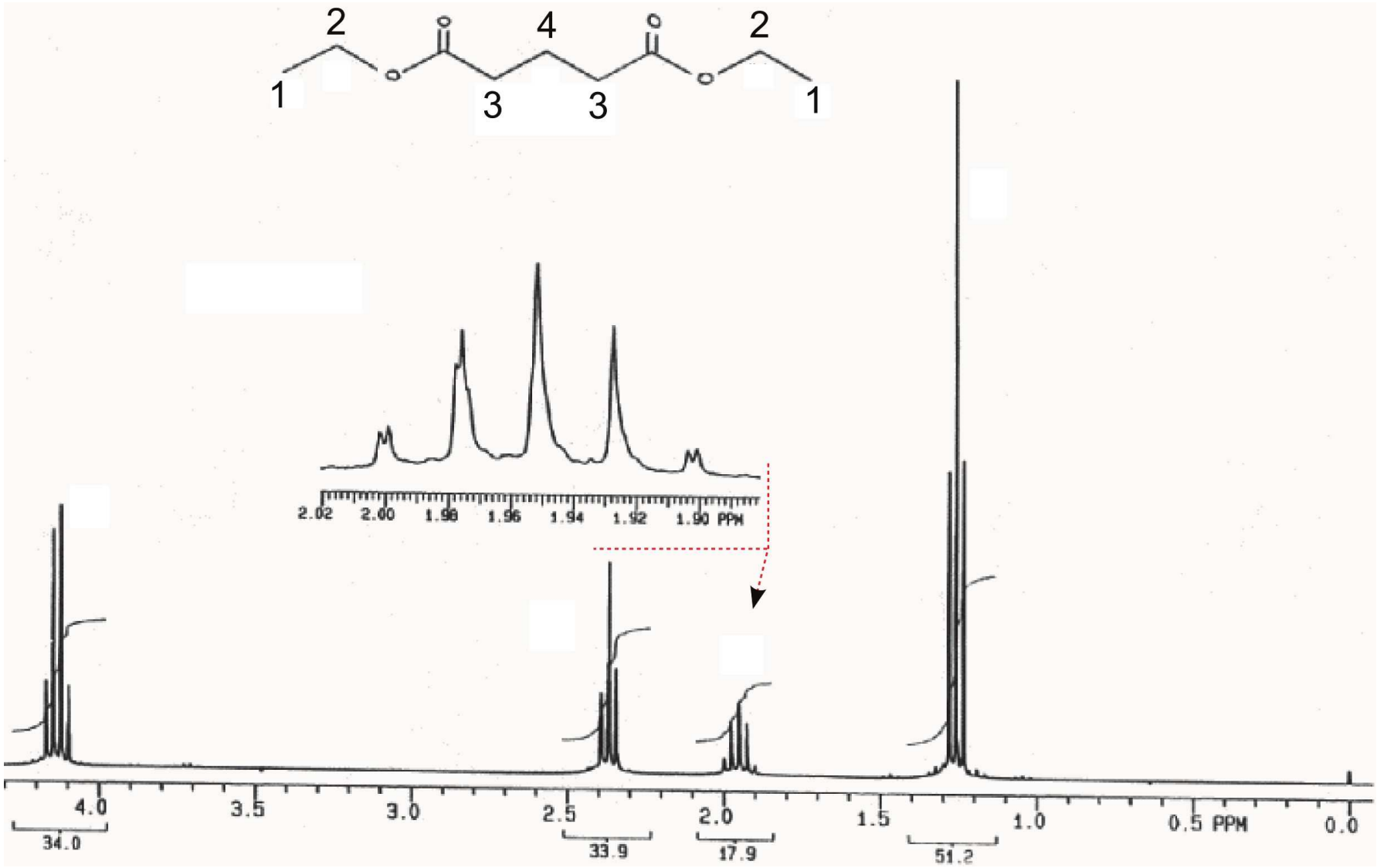
Draw approximate 1D ^{1}H NMR spectrum of the following compound



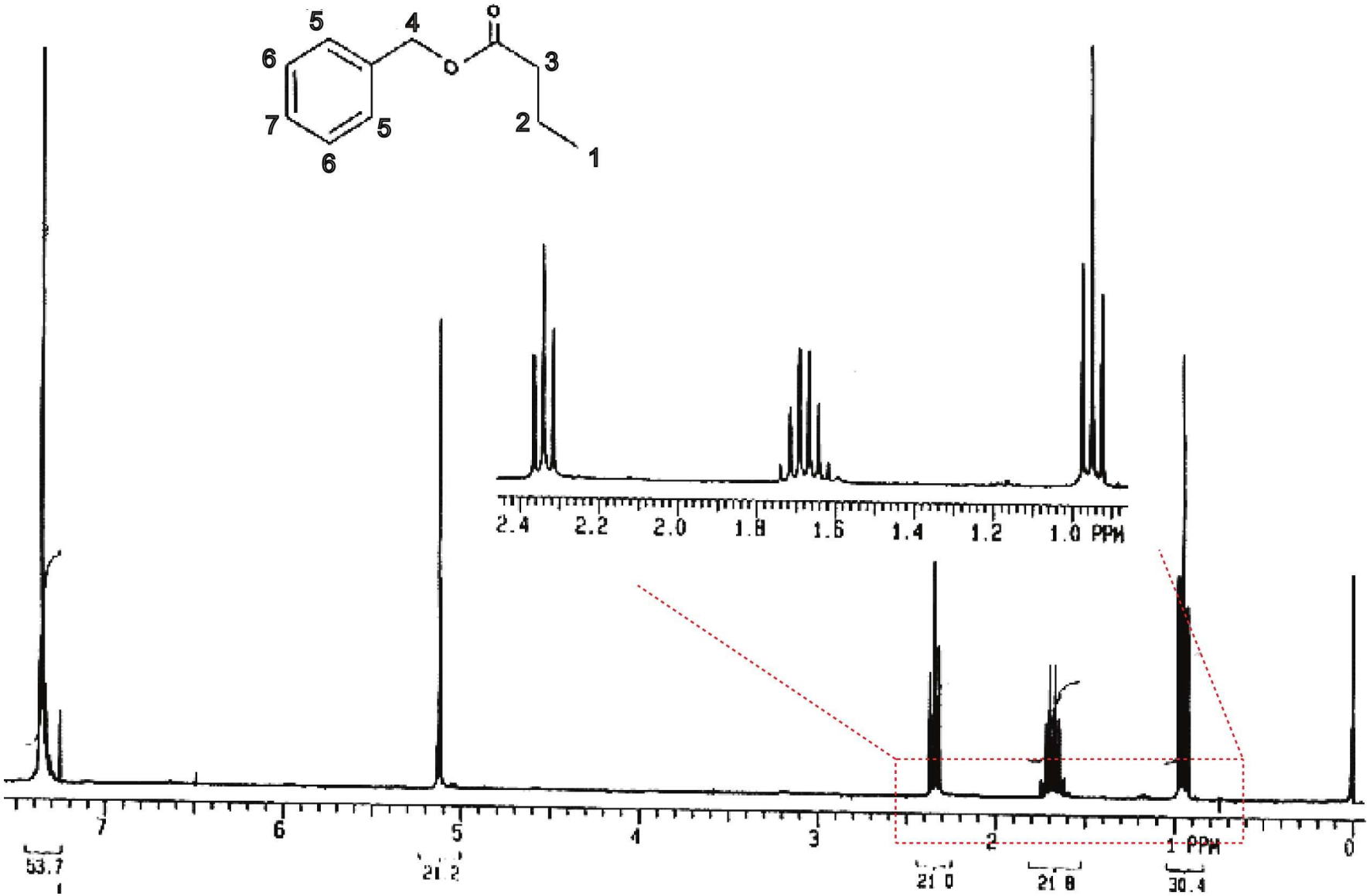
Notes:

- **H-2** - *meta*- and *ortho*- interaction with H-1 a H-3 - doublet of doublets
- **H-1** - only *meta*- interaction with H-2 - smaller coupling than **H-3** in *ortho*- interaction with H-2
- chemical shifts are result of overall effects of substituents on the aromatic ring

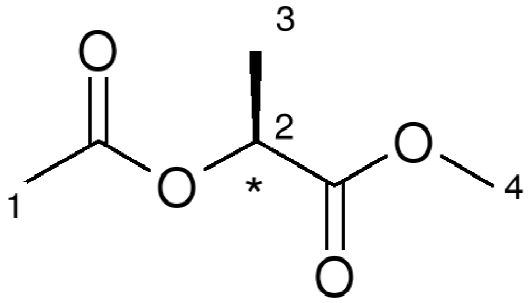
1D ^{1}H NMR spectrum of ethyl glutarate

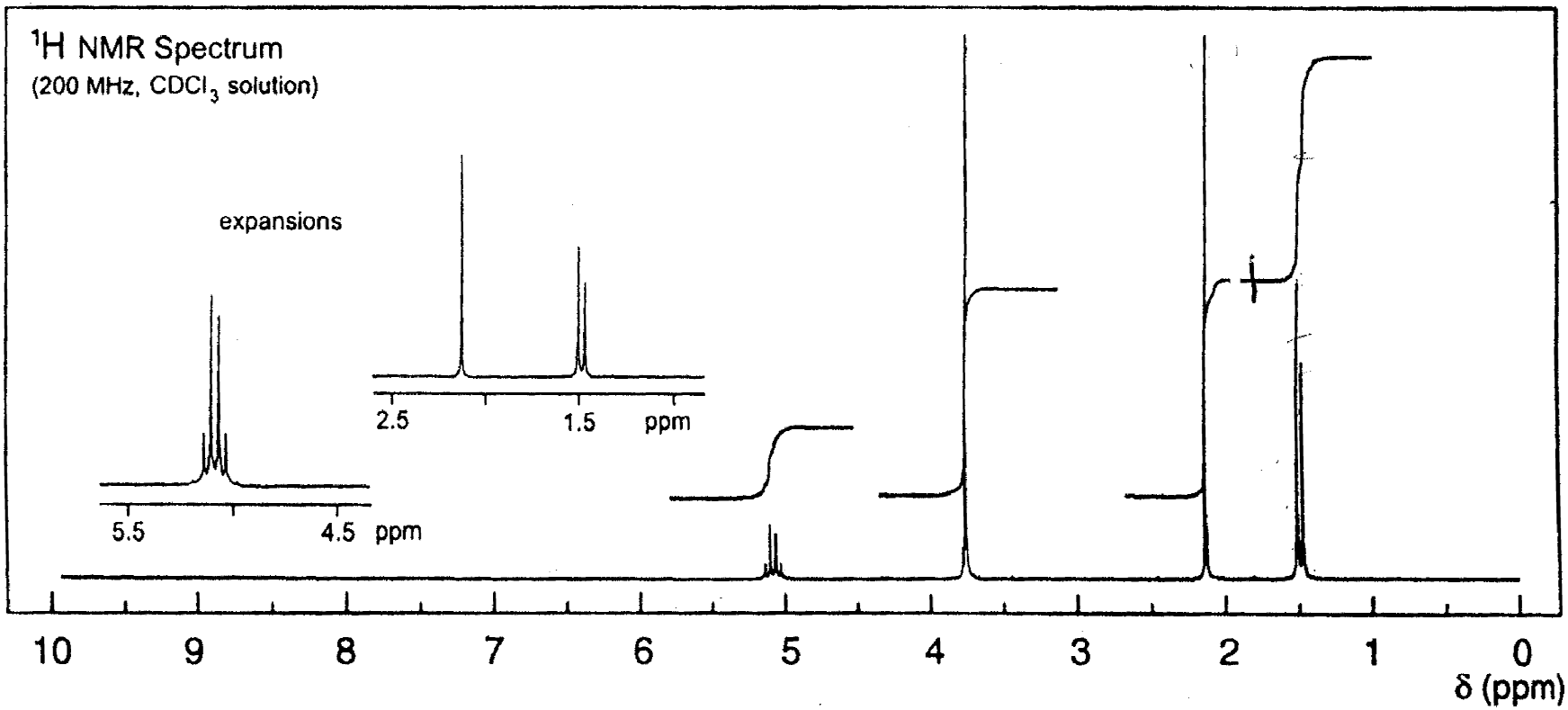


1D ^{1}H NMR spectrum of benzyl butyrate

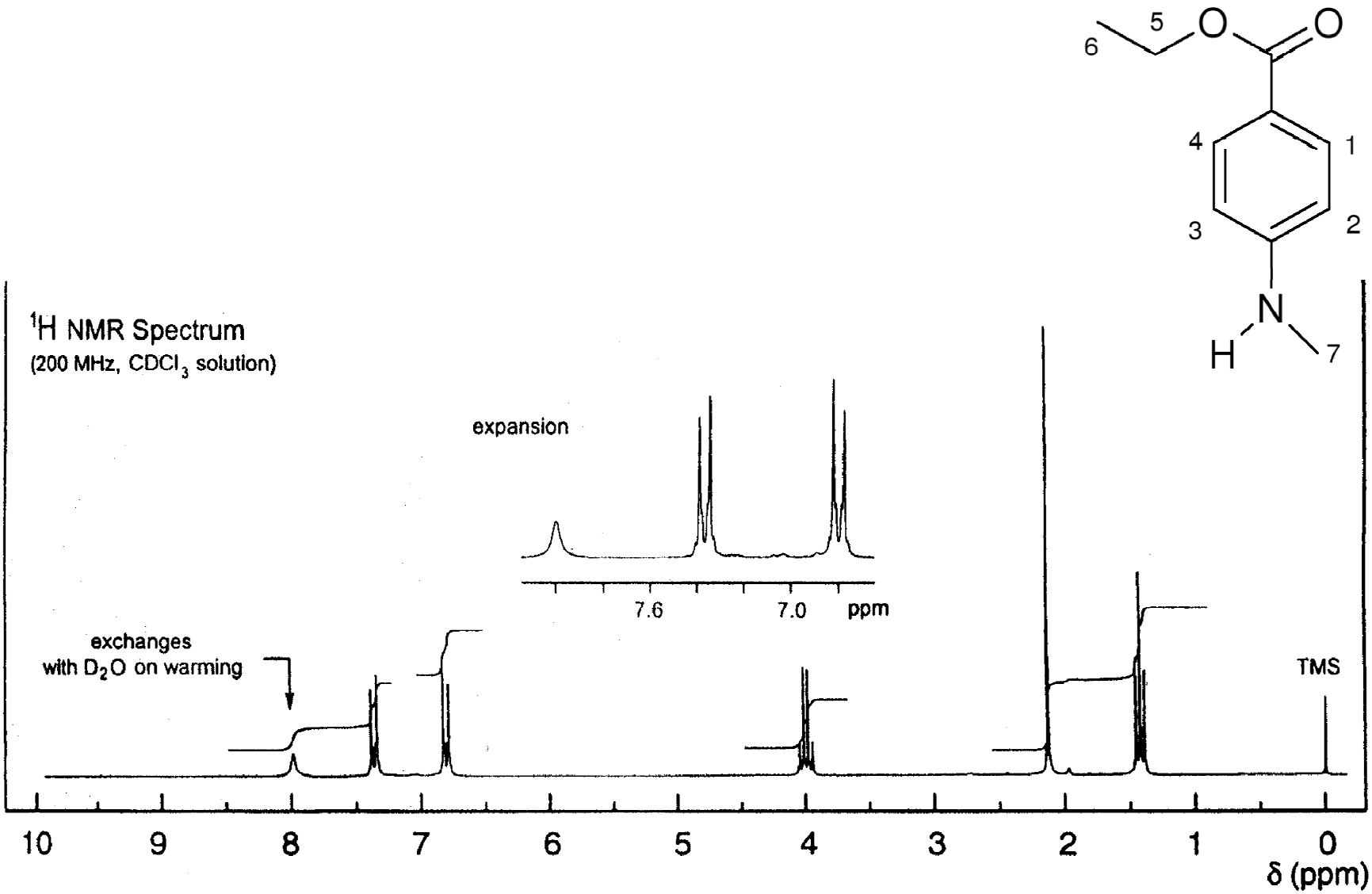


1D ^{1}H NMR spectrum of methyl 2-acetoxy propanoate

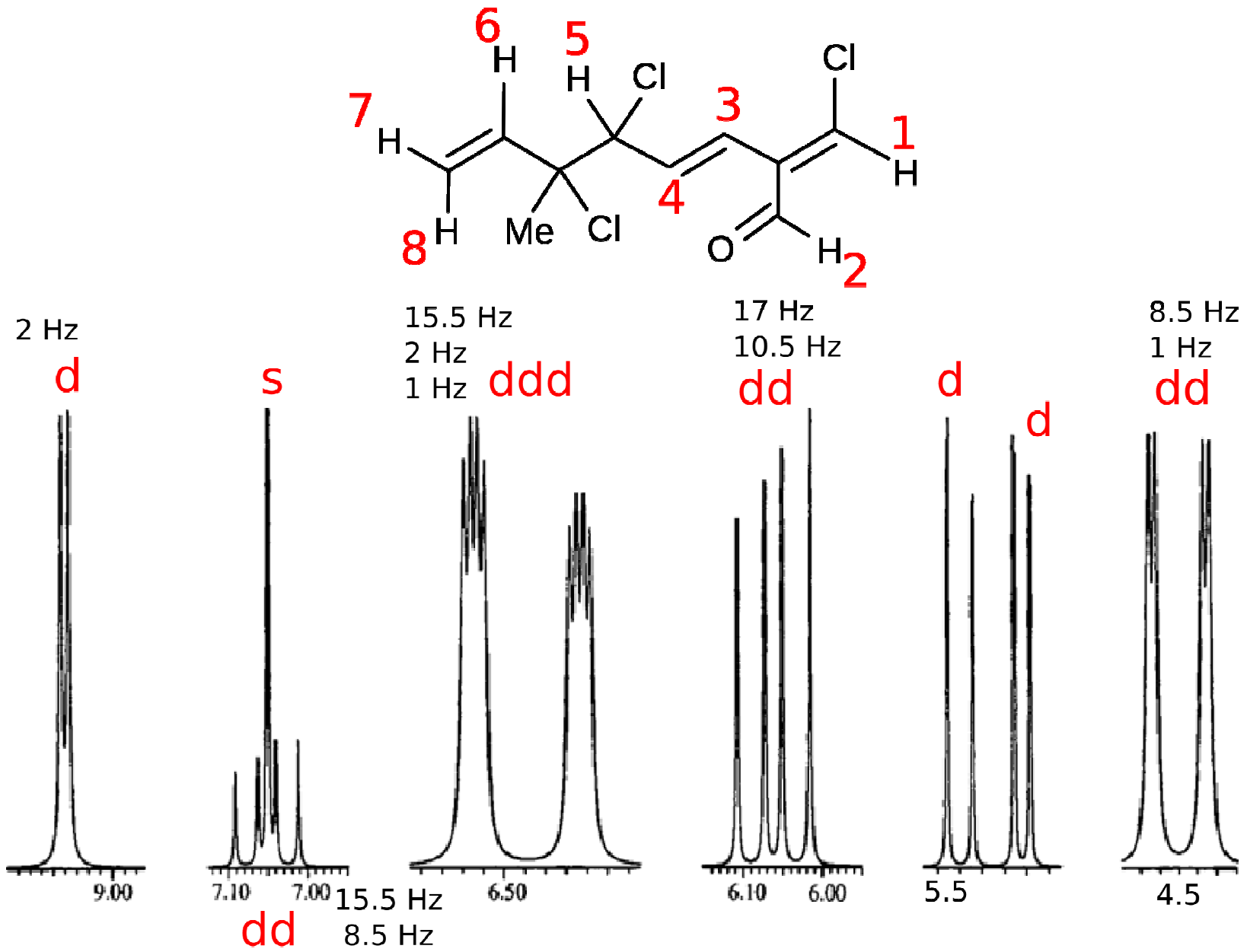




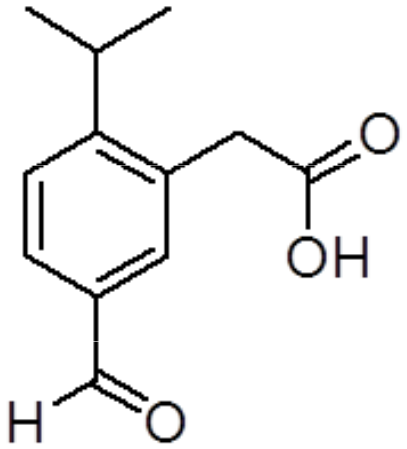
1D ^{1}H NMR spectrum of ethyl 4-(methylamino)benzoate

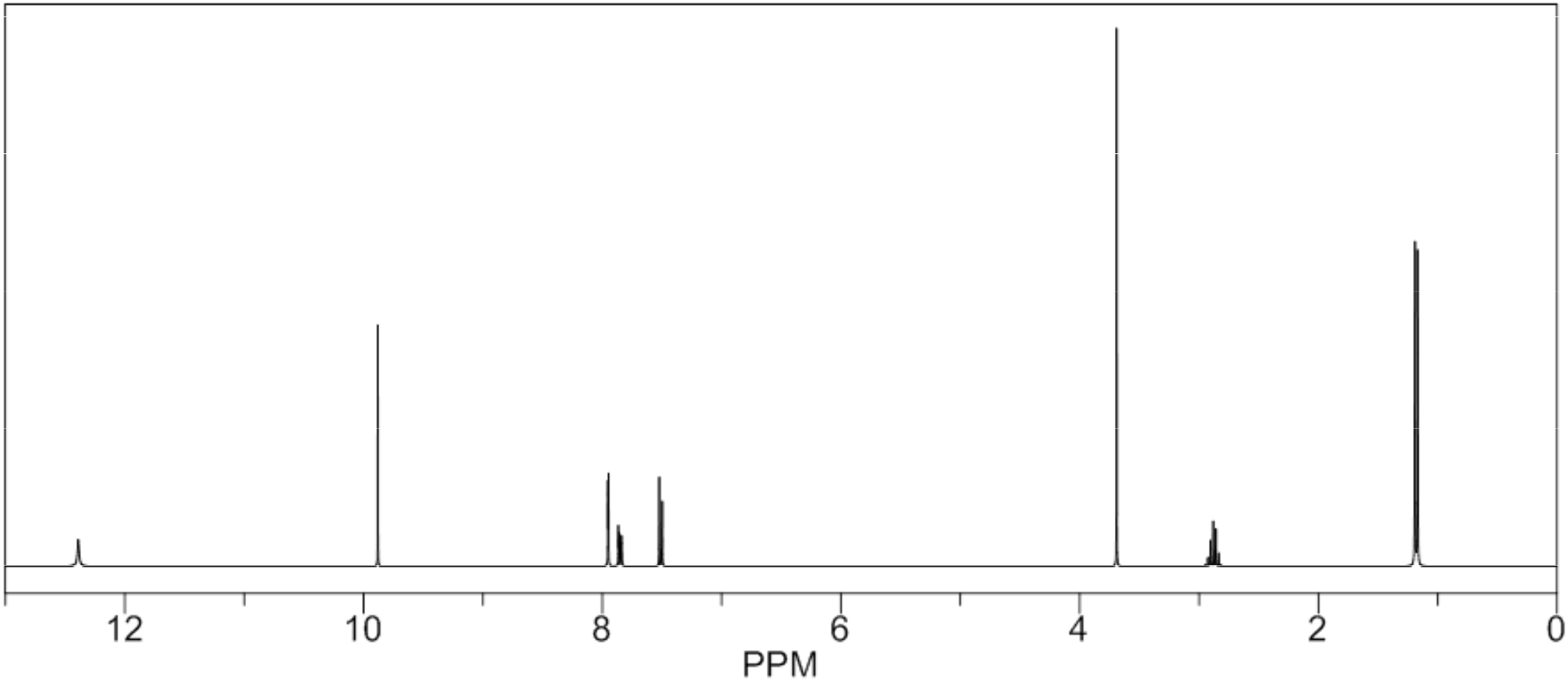


1D ^{1}H NMR spectrum of cartilagineal



1D ^{1}H NMR spectrum





Next session:

1D ^{13}C-NMR spectra