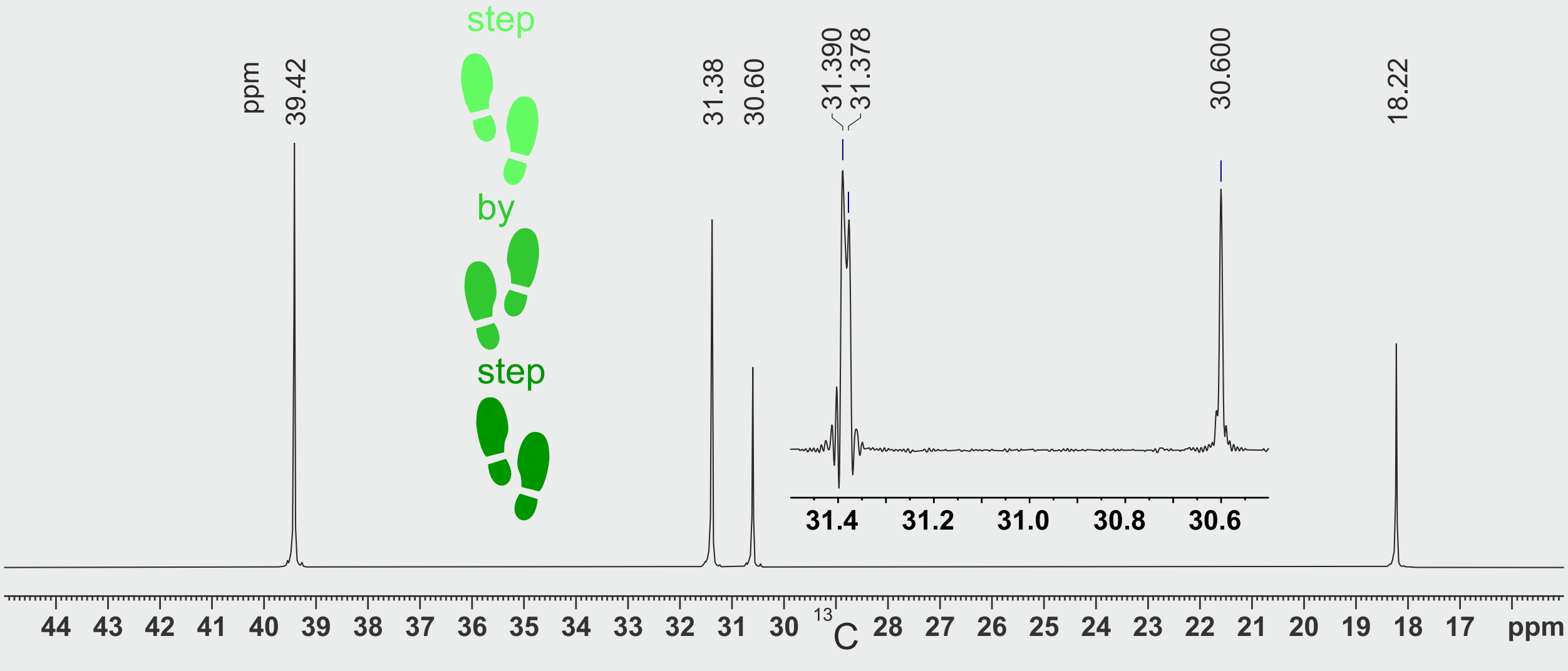
Exercise plus Solution – Quick overview

It is recommended to use this version only for a quick overview of the NMR challenge. All animations of the PowerPoint version are missing, under certain circumstances quality deficiencies may also occur.
The higher quality PowerPoint files are freely available for download at any time.



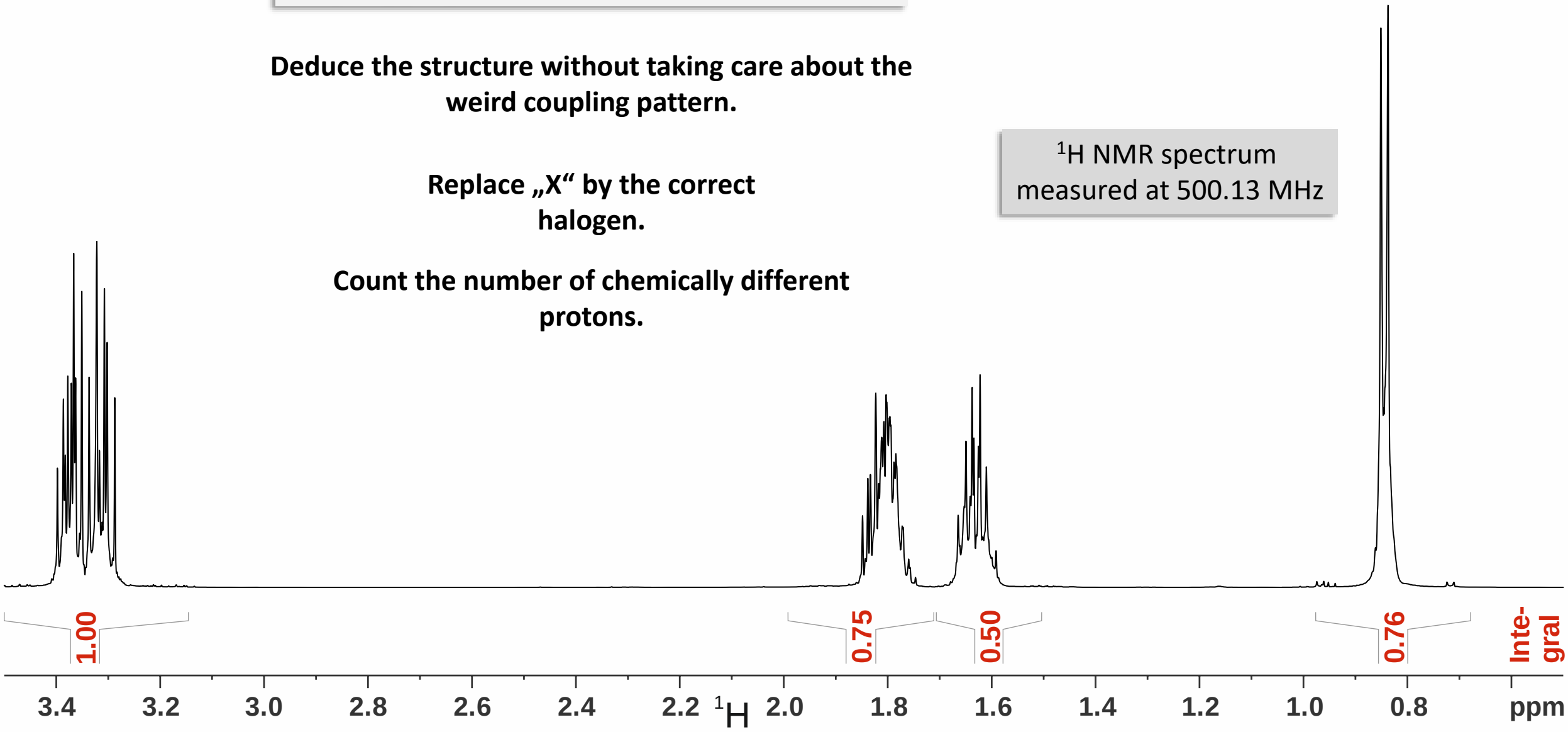
$C_6H_{12}X_2$ measured in $CDCl_3$

Deduce the structure without taking care about the weird coupling pattern.

Replace „X“ by the correct halogen.

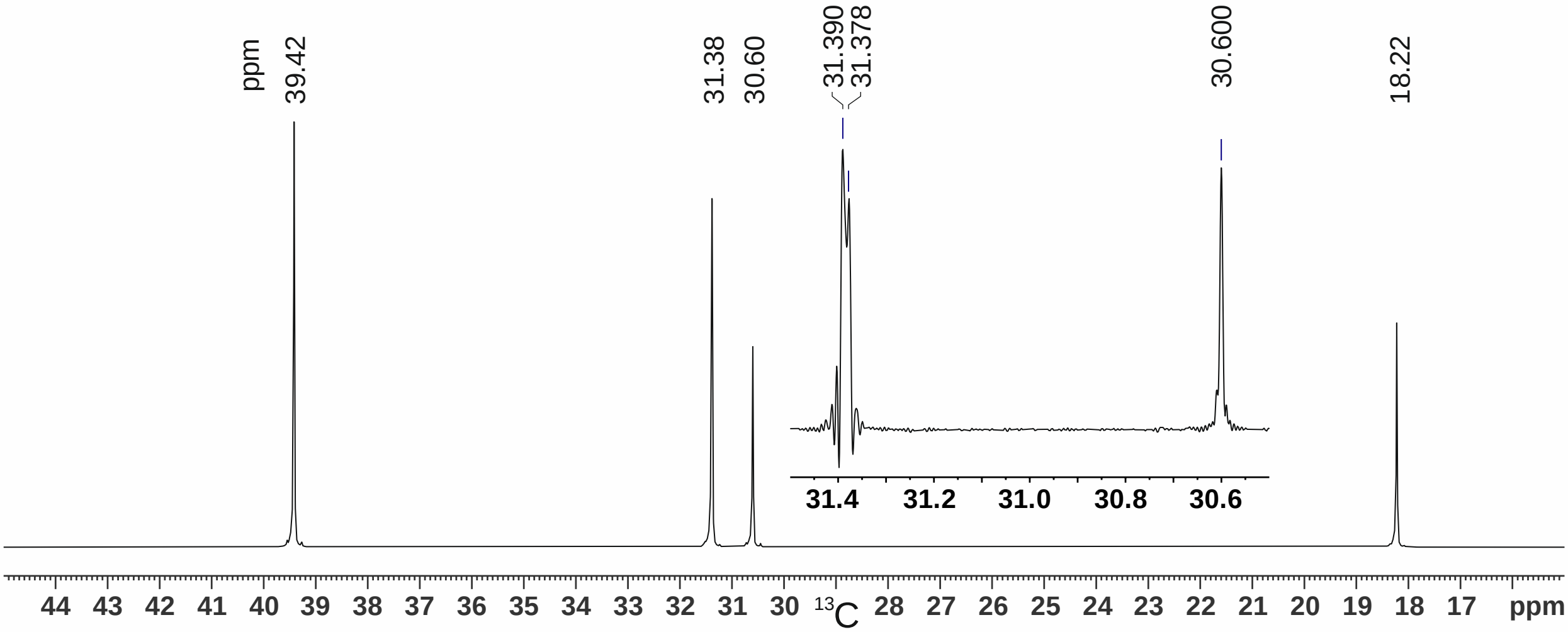
Count the number of chemically different protons.

^{1}H NMR spectrum measured at 500.13 MHz

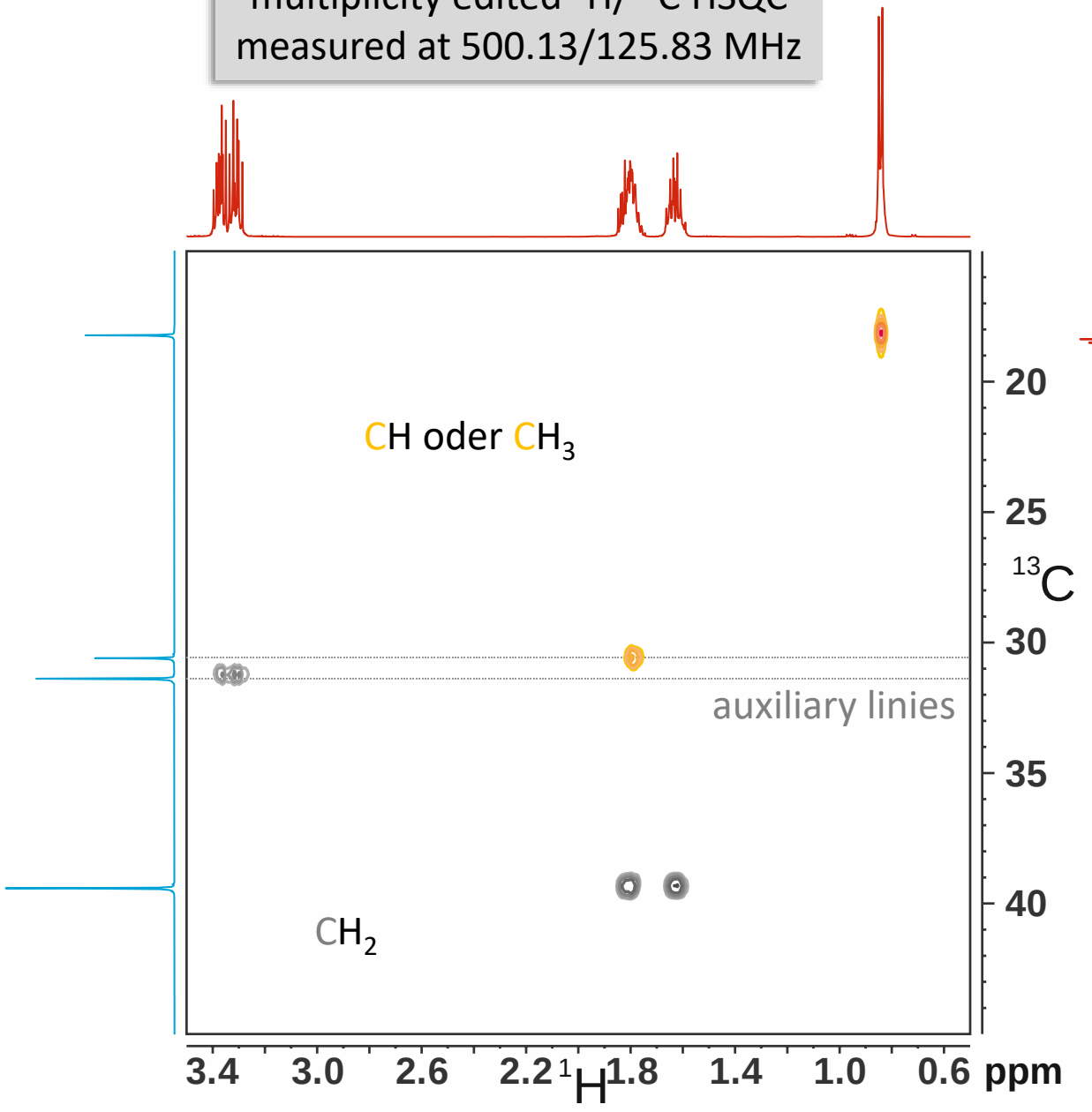


$^{13}C\{^{1}H\}$ NMR spectrum measured at 125.83{500.13} MHz

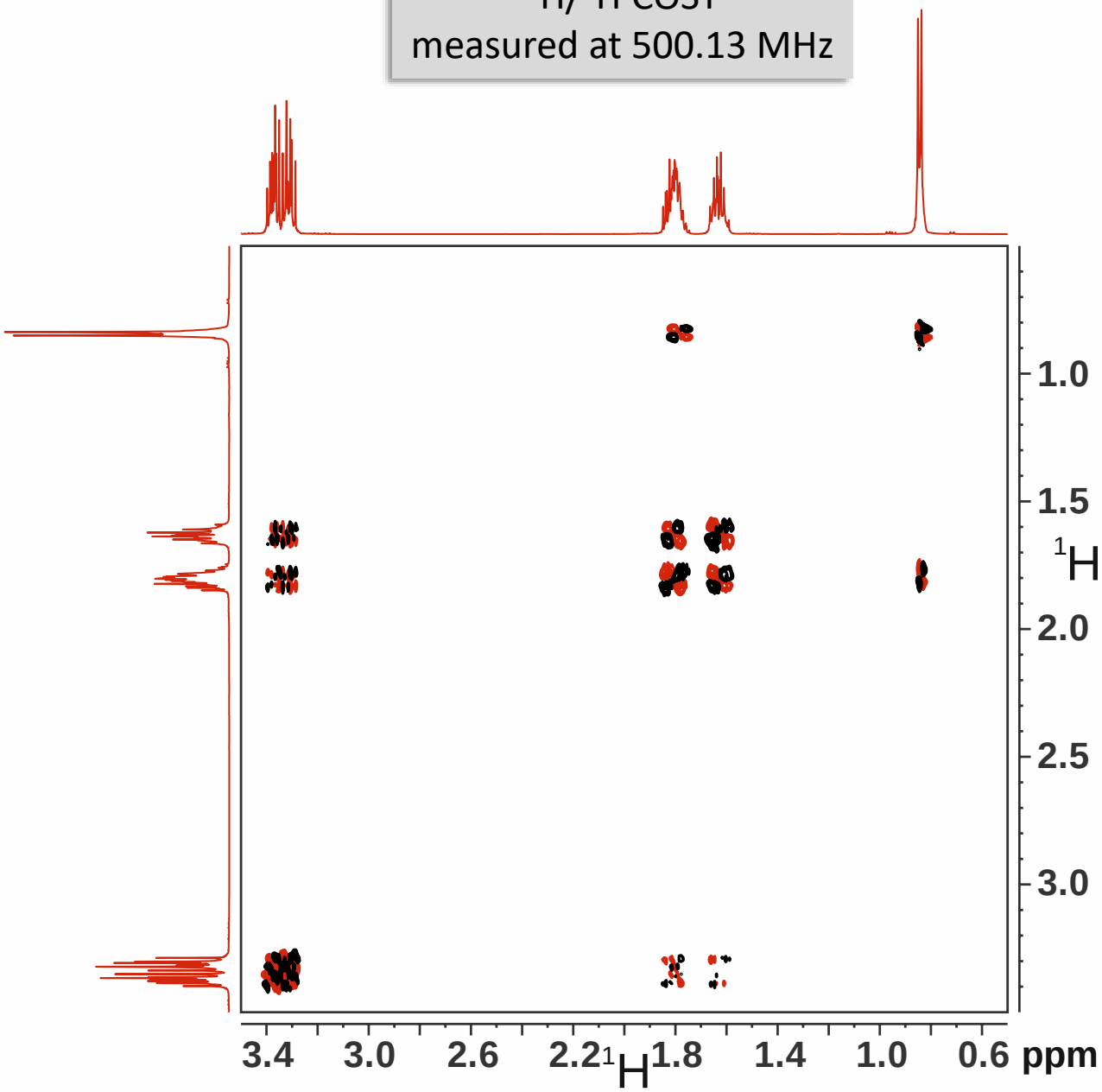
To process the area with two signals around 31 ppm some kind of „magic“ (the correct name is *reference deconvolution*) was used.
What might be the reason for the splitting visible at 31.8 ppm?



multiplicity edited $^{1}H/^{13}C$ HSQC
measured at 500.13/125.83 MHz

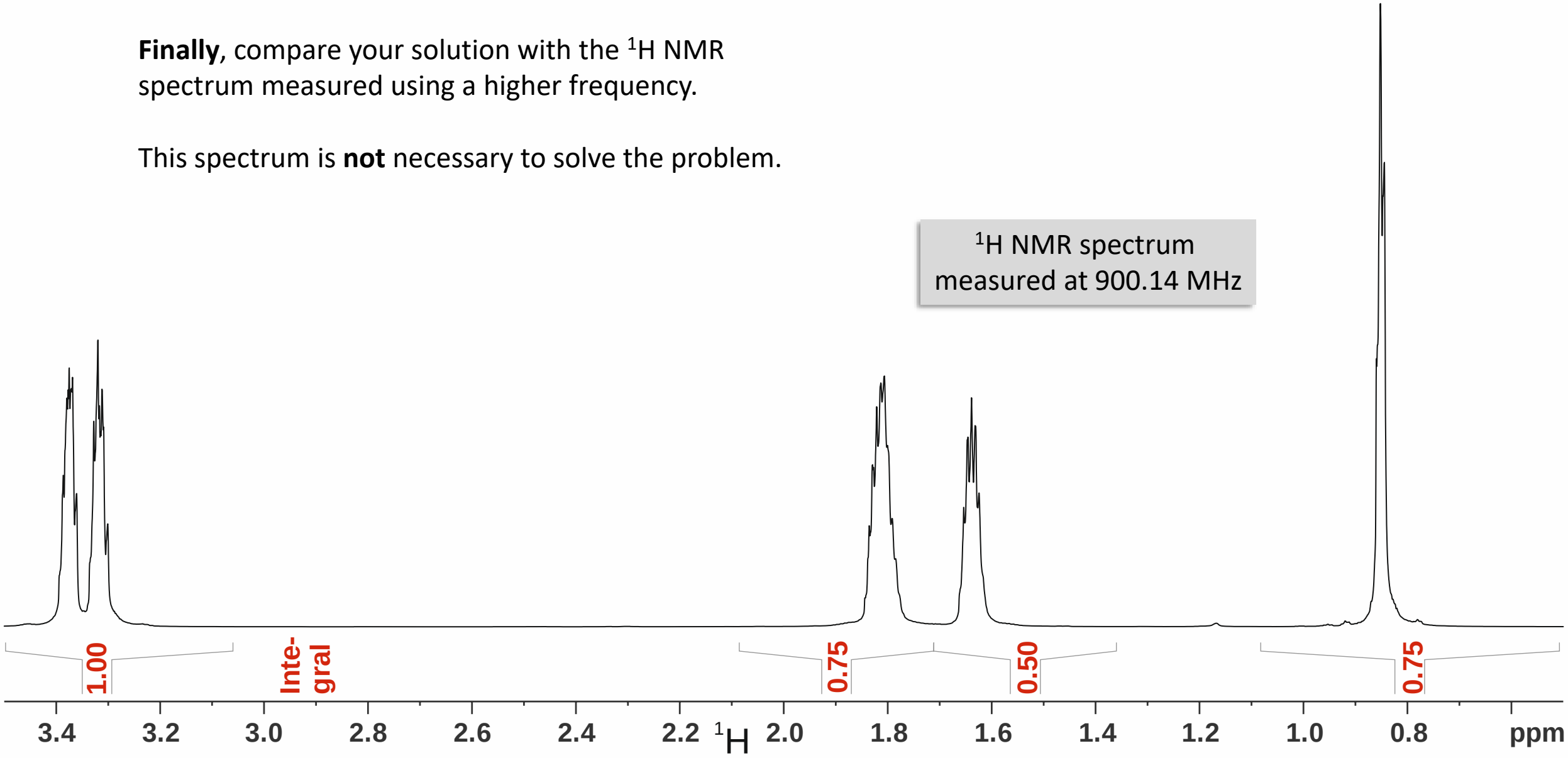


$^{1}H/^{1}H$ COSY
measured at 500.13 MHz



Finally, compare your solution with the ^{1}H NMR spectrum measured using a higher frequency.

This spectrum is **not** necessary to solve the problem.



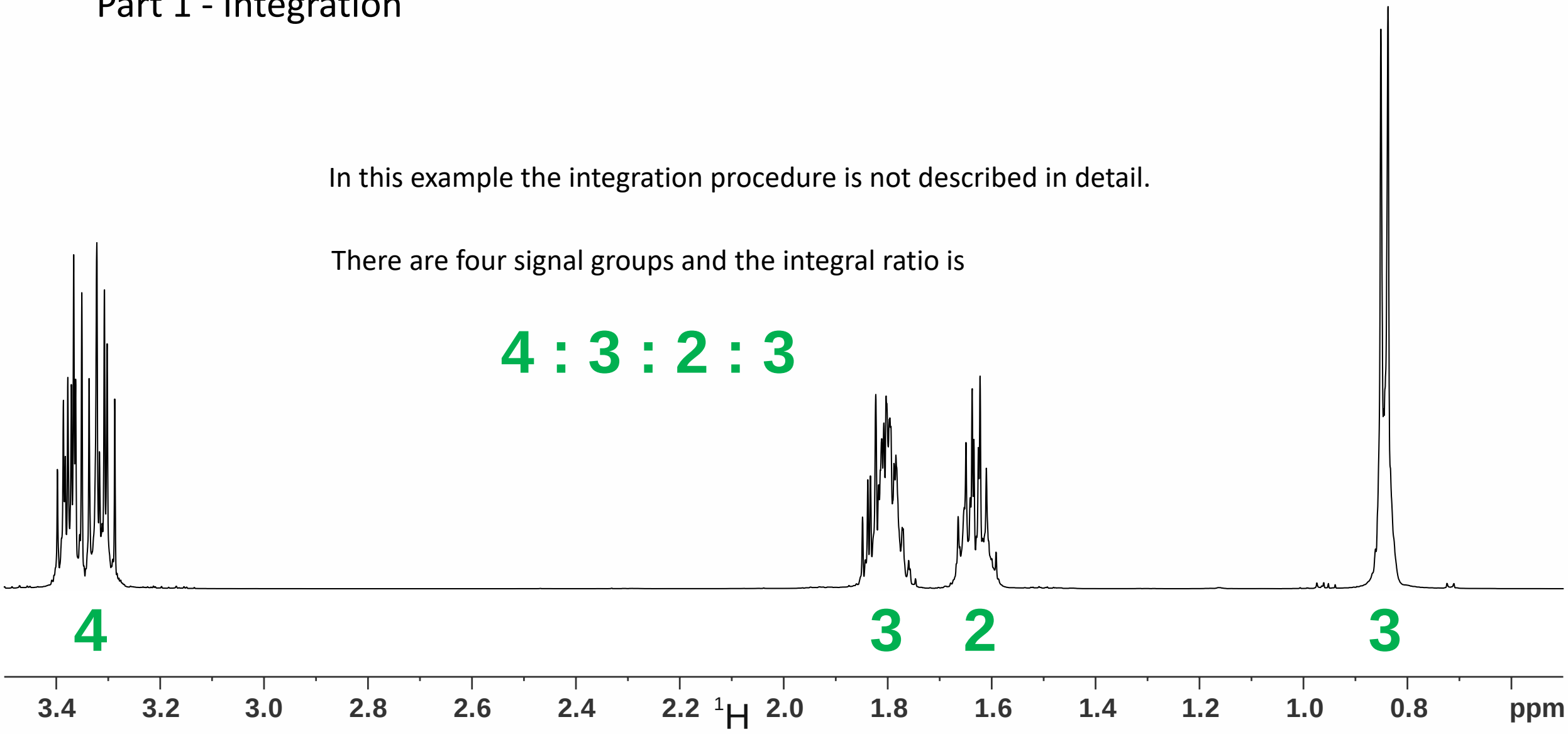
Solution

Part 1 - Integration

In this example the integration procedure is not described in detail.

There are four signal groups and the integral ratio is

4 : 3 : 2 : 3



Solution

Part 2 – Building blocks

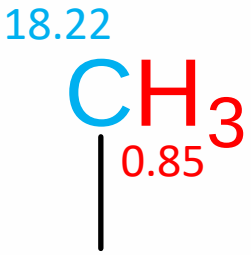
If available, the HSQC/HMQC is nearly always the best starting point to collect all or at least a large number of partial structures as an unordered pile of building blocks.

The integrals from the proton spectrum have just been determined, the chemical shifts of the carbon signals may be taken from the one-dimensional carbon spectrum.

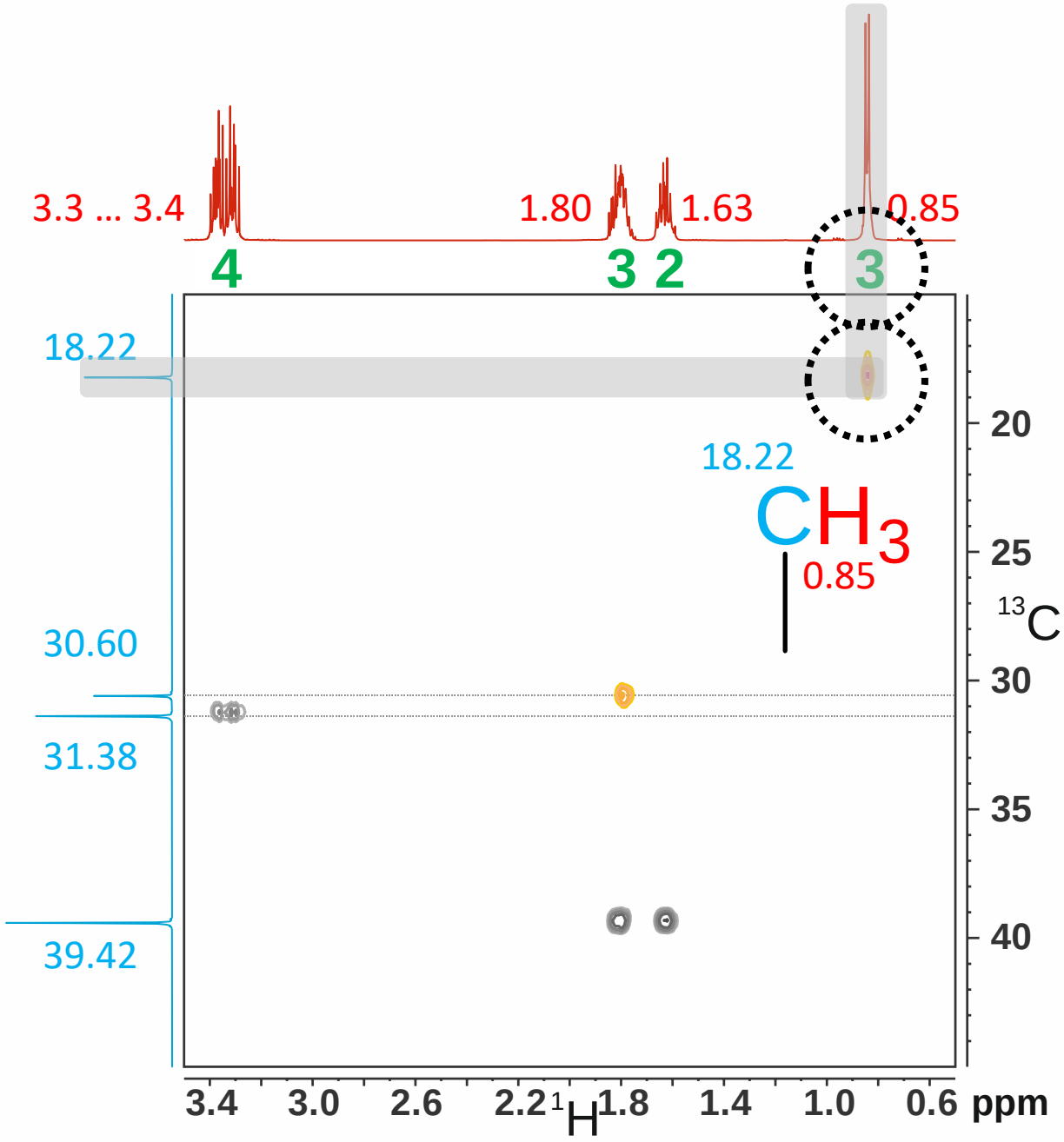
For the chemical shifts of the proton multiplets, only estimated values are possible due to the absence of peak labels.

Solution

Part 2 – Building blocks

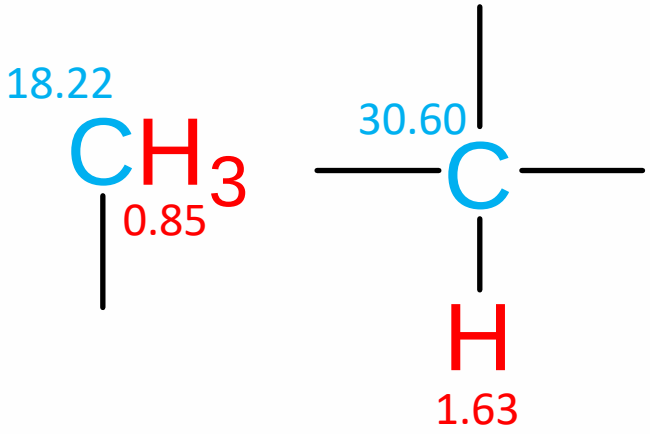


Undoubtedly, the first fragment to be taken from the HSQC is a methyl group.



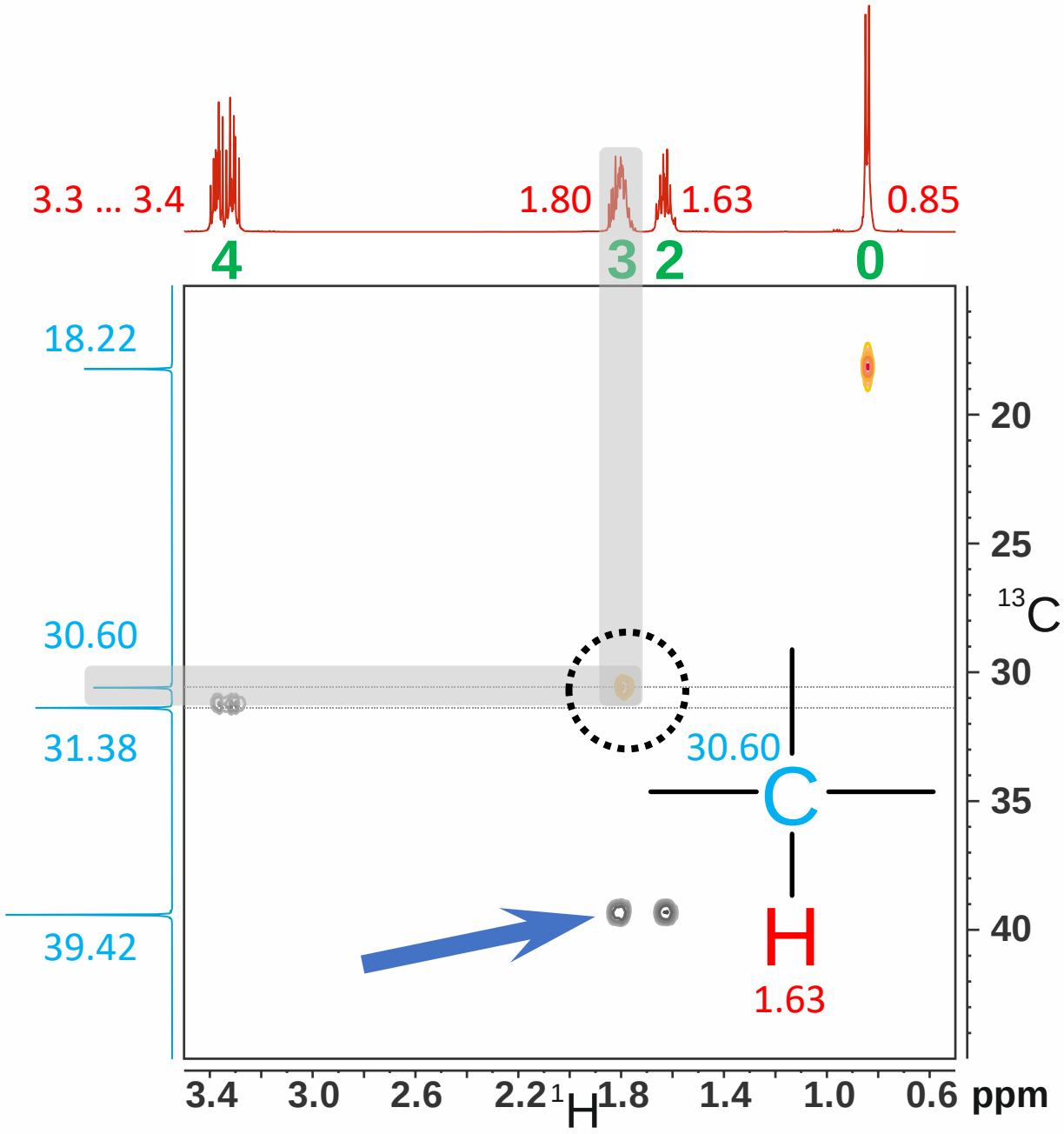
Solution

Part 2 – Building blocks



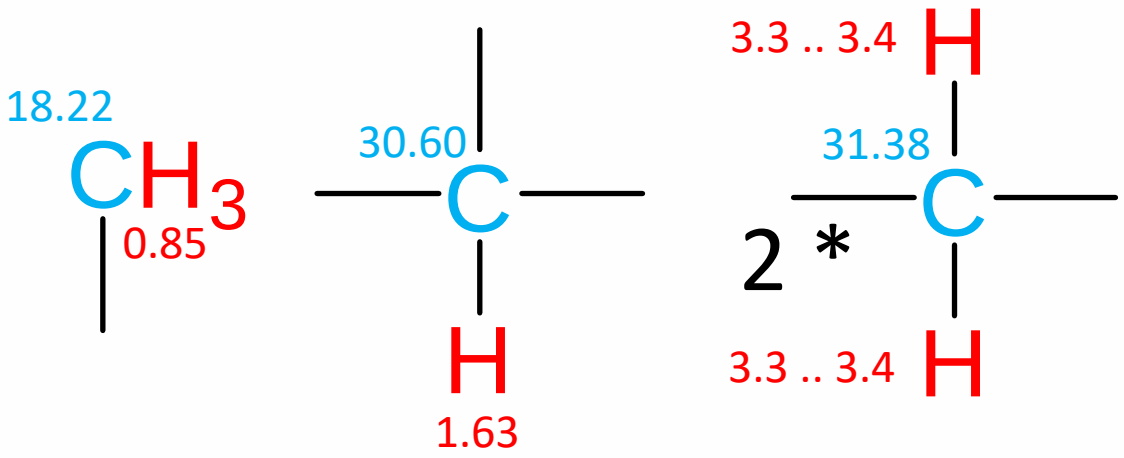
According to the sign of the cross peak, the next fragment could be both a methyl or a methine group.

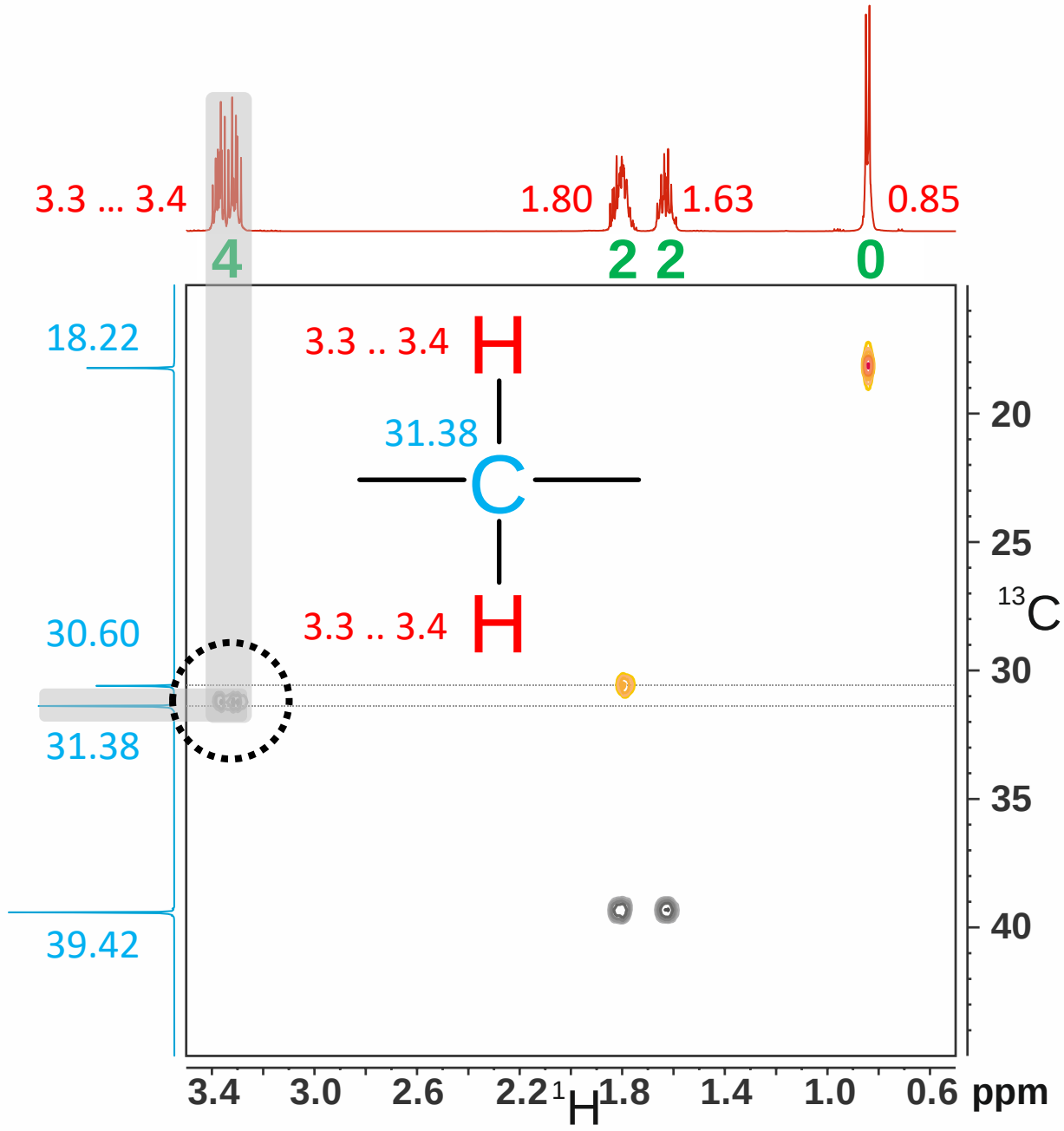
In the HSQC there is another cross peak with the same proton chemical shift visible. This means that less than 3 protons (which is the integral of the proton spectrum) are available for this cross peak. A methyl group is therefore excluded.



Solution

Part 2 – Building blocks



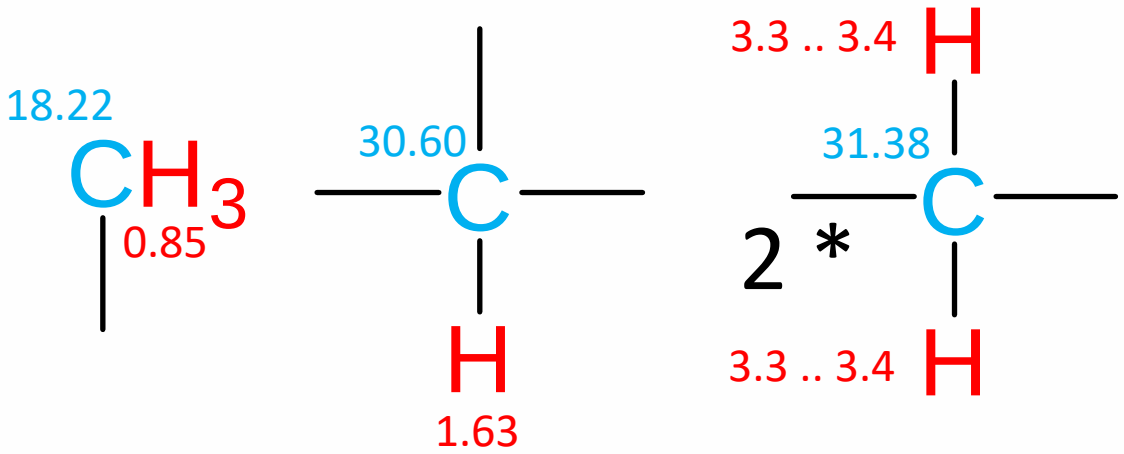


According to the sign of the cross peak in the edited HSQC, the complex proton signal at about 3.4 ppm can only belong to a CH_2 group.

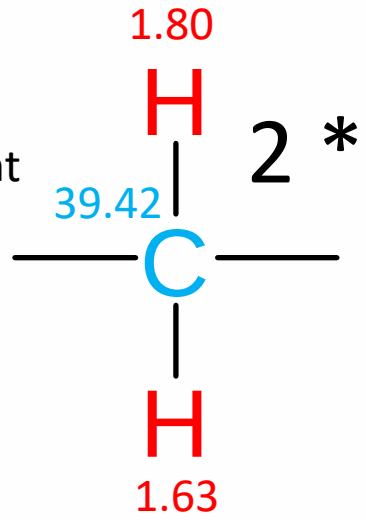
Four protons, but only one carbon signal?
There are two equivalent methylene groups in the molecule!

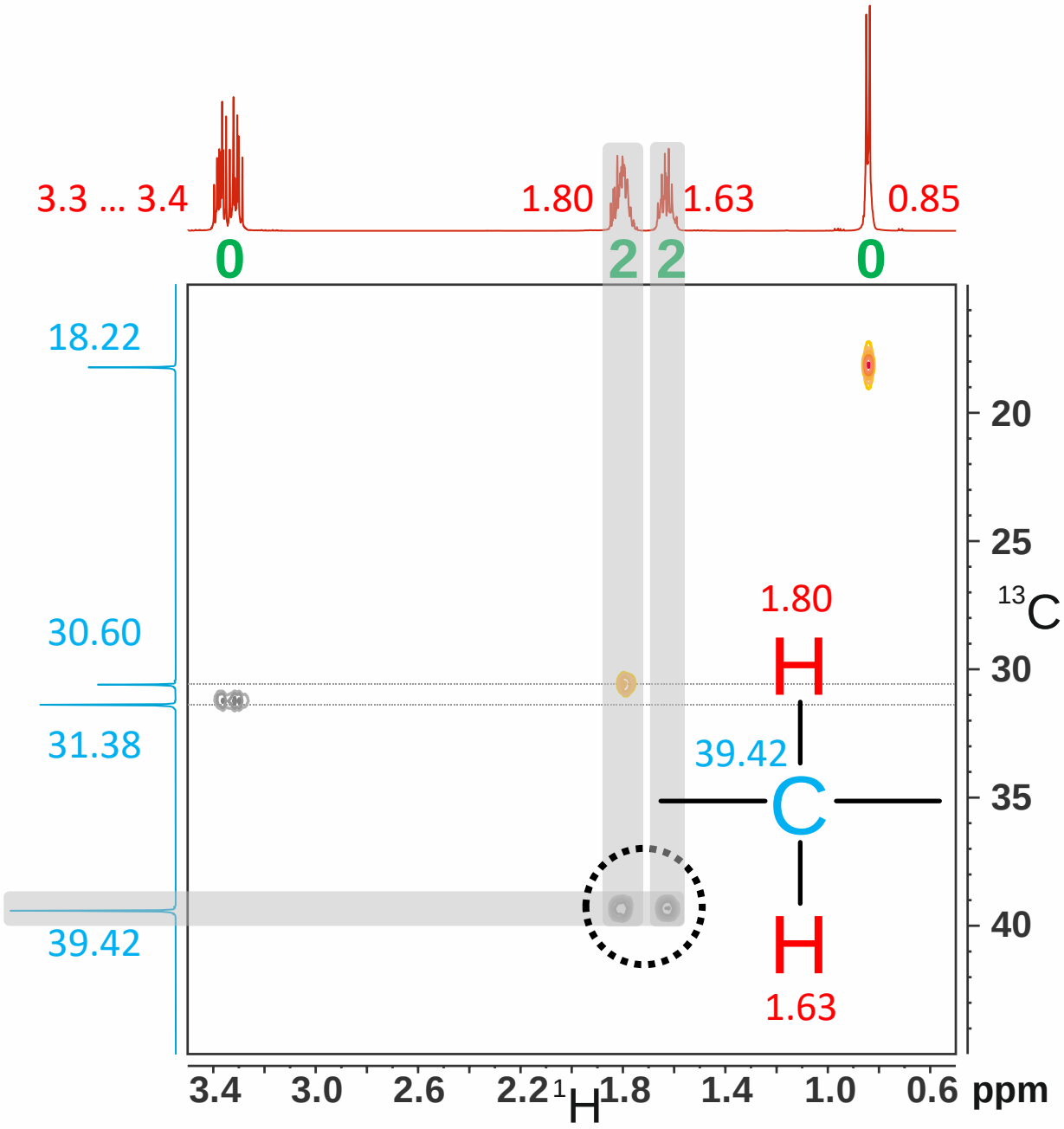
Solution

Part 2 – Building blocks



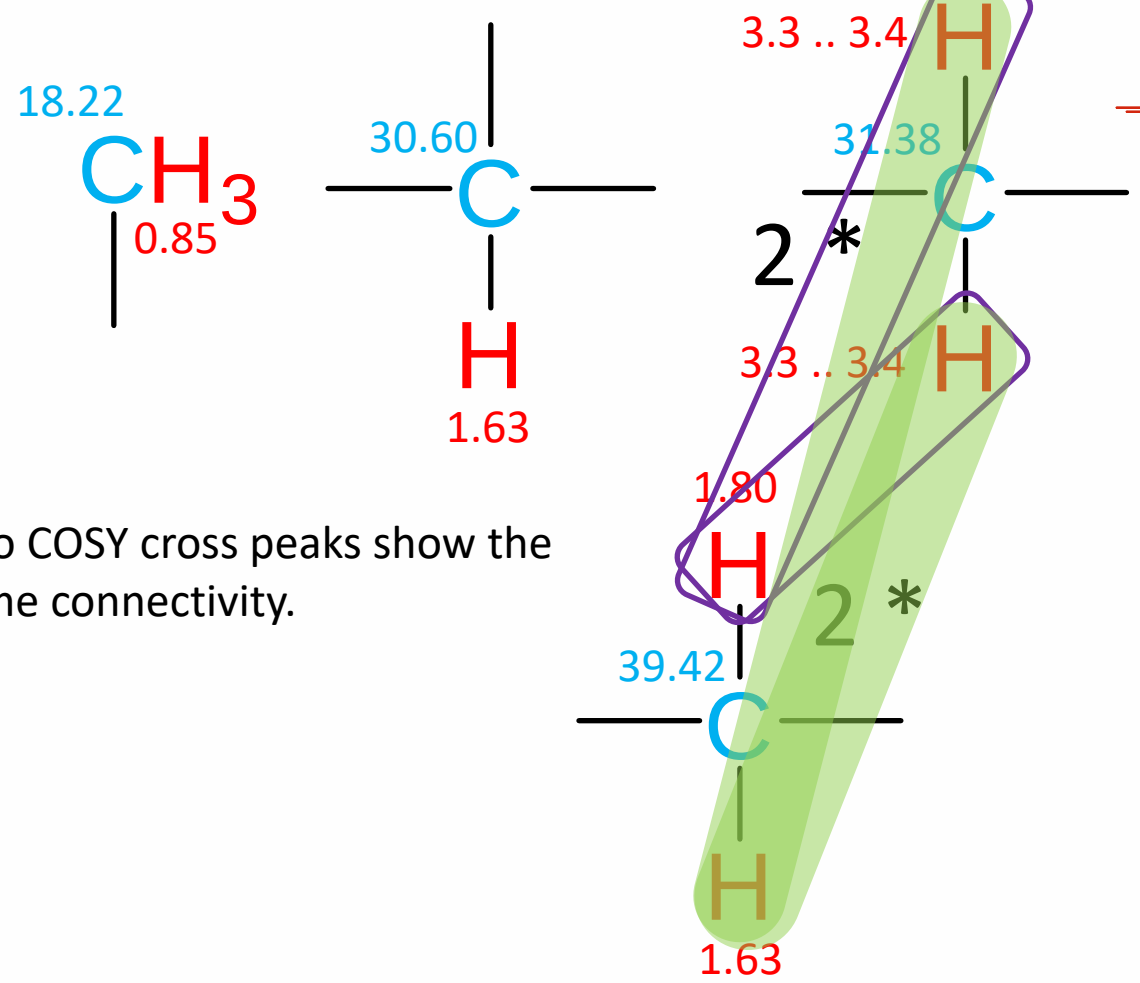
There are two further equivalent methylene groups.
This time the proton signals are clearly separated.



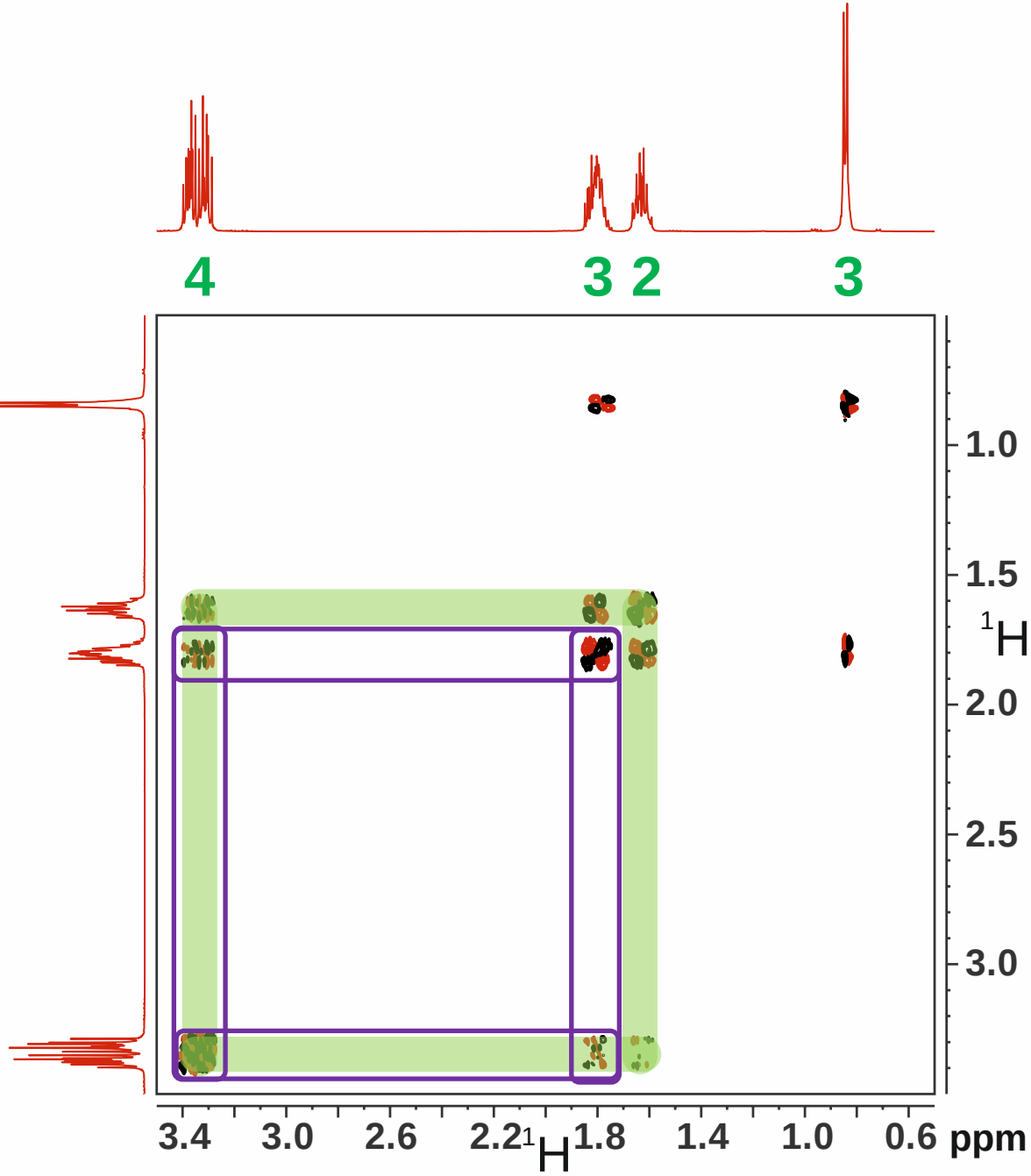


Solution

Part 3 – Connect the building blocks

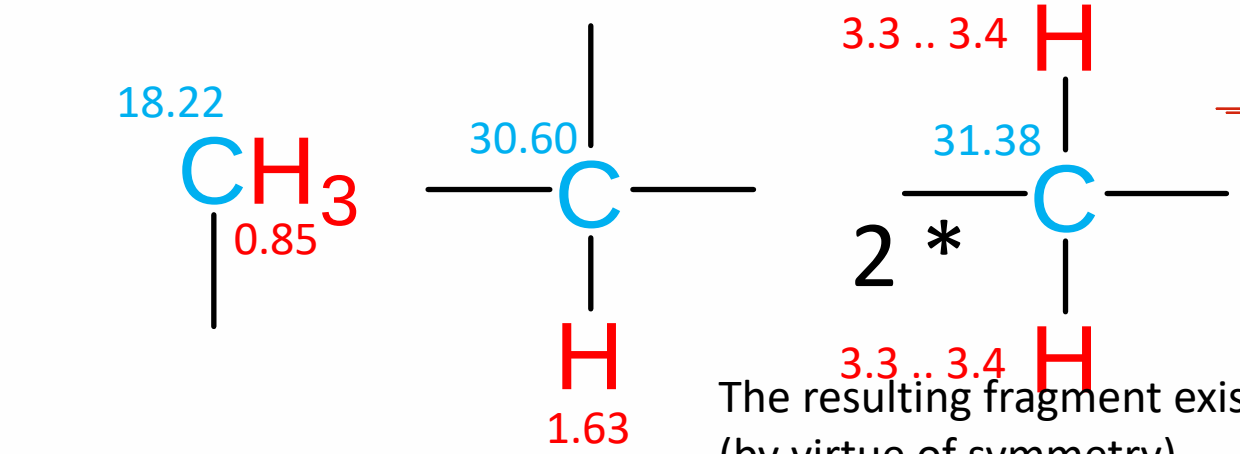


Two COSY cross peaks show the same connectivity.

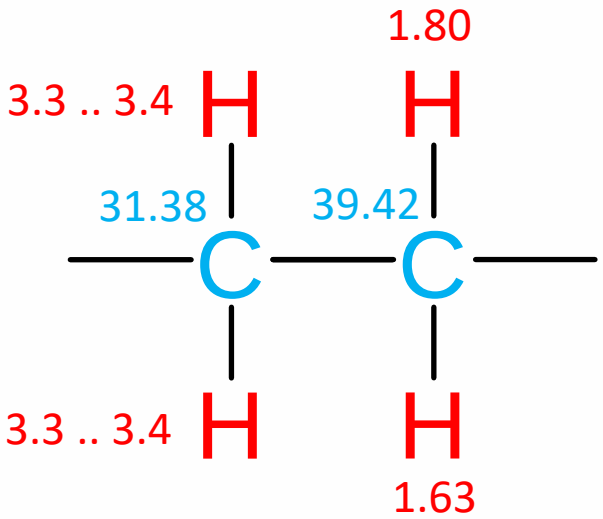


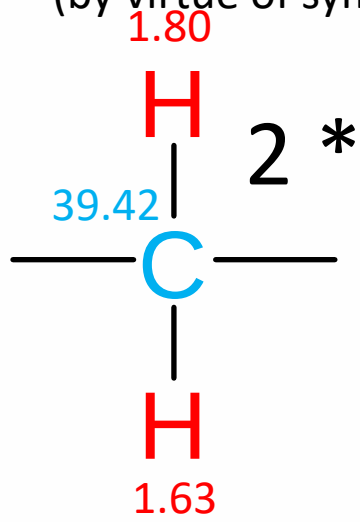
Solution

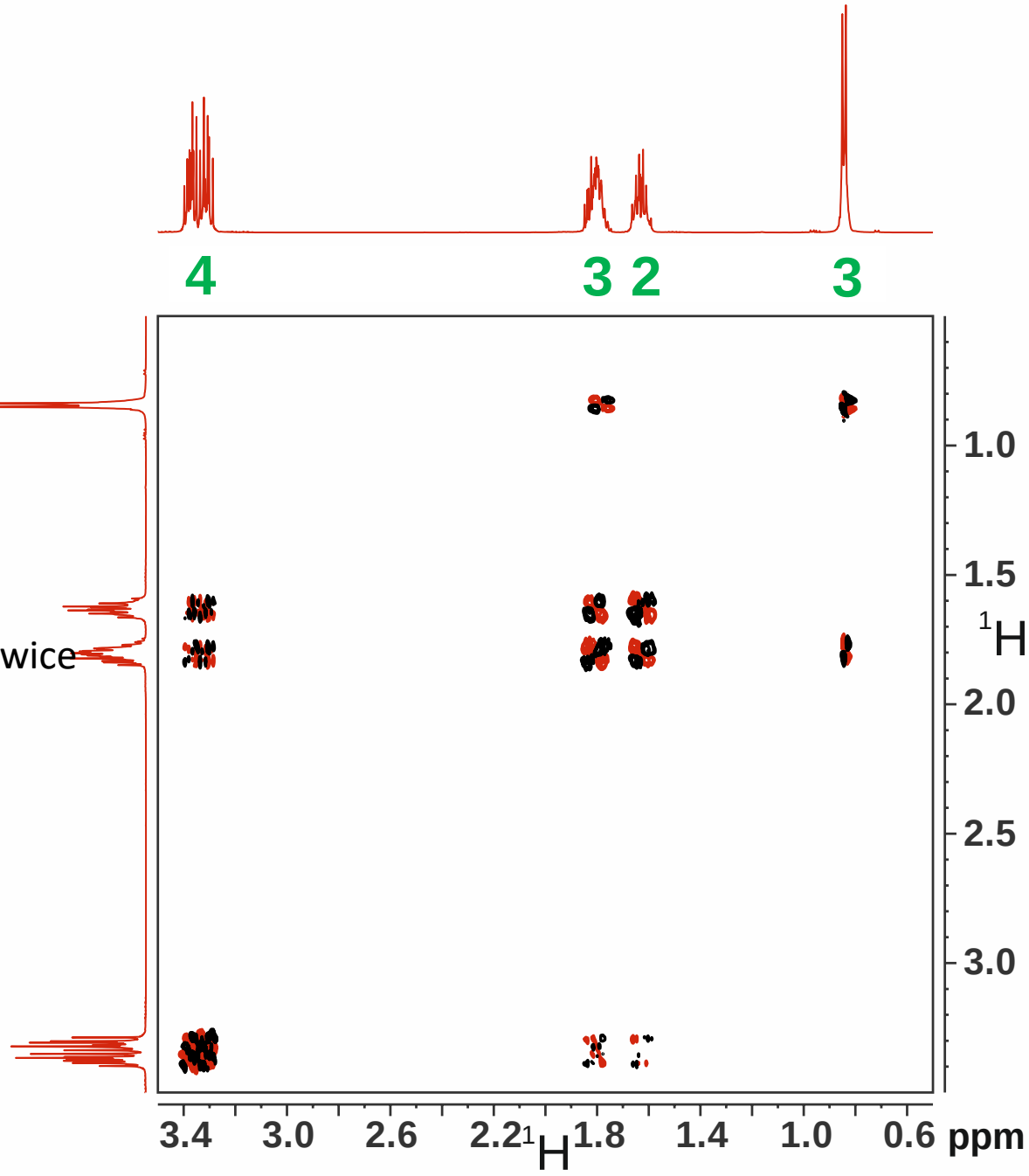
Part 3 – Connect the building blocks



The resulting fragment exists twice (by virtue of symmetry).

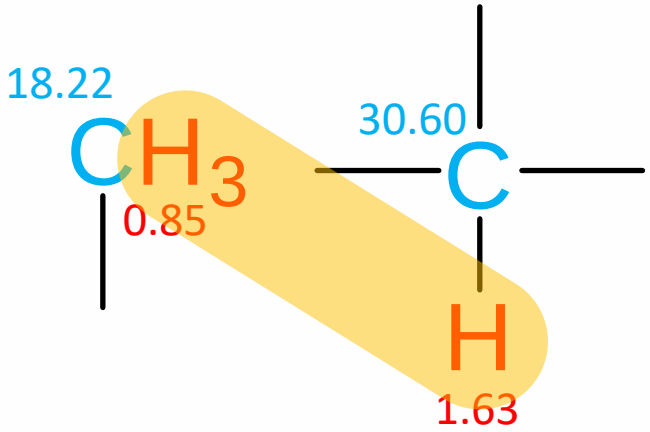


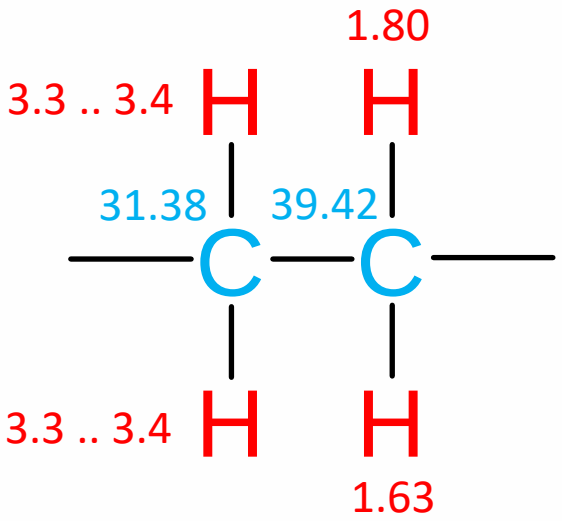




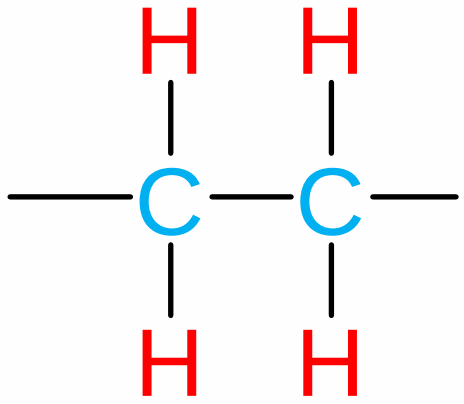
Solution

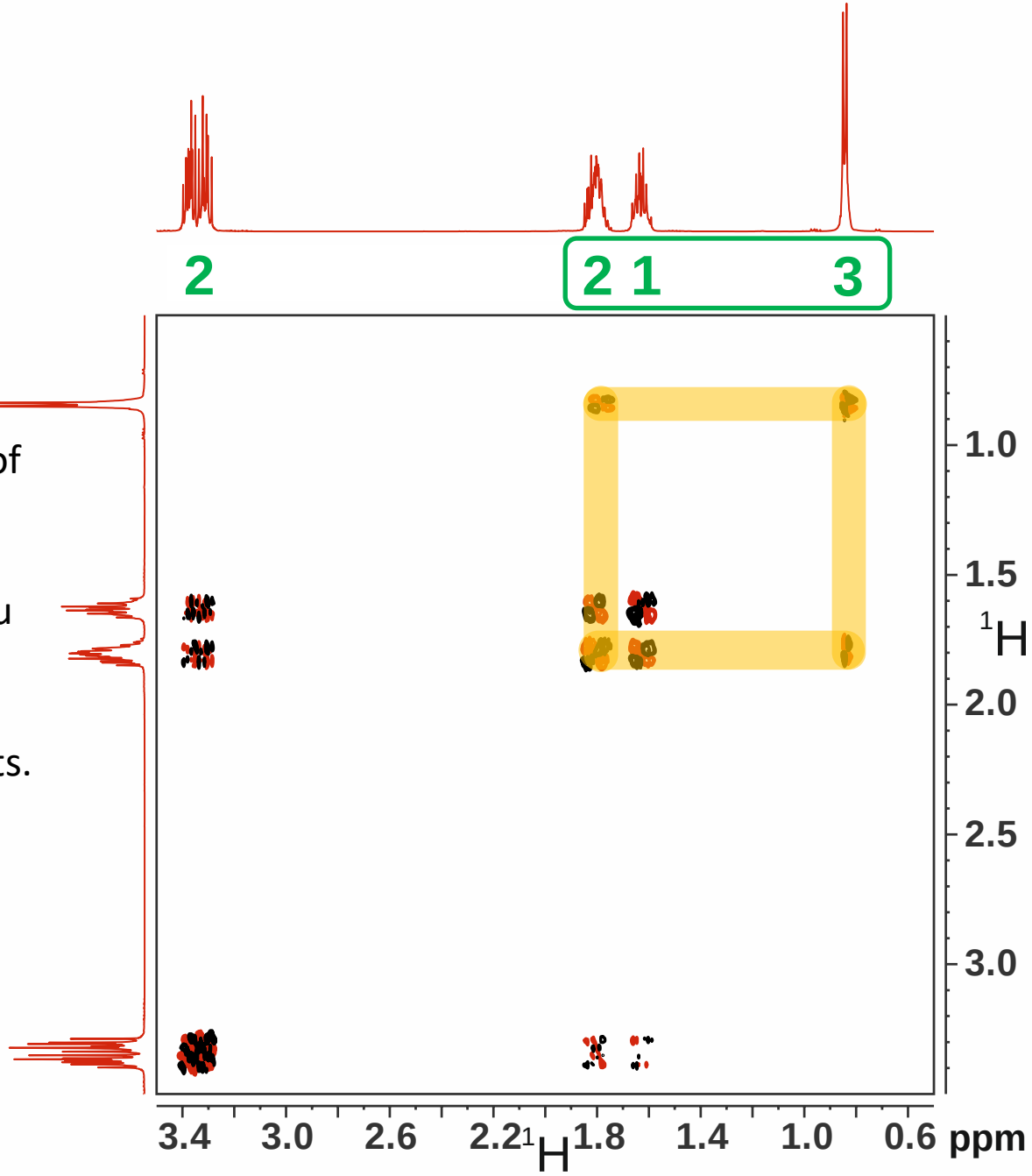
Part 3 – Connect the building blocks





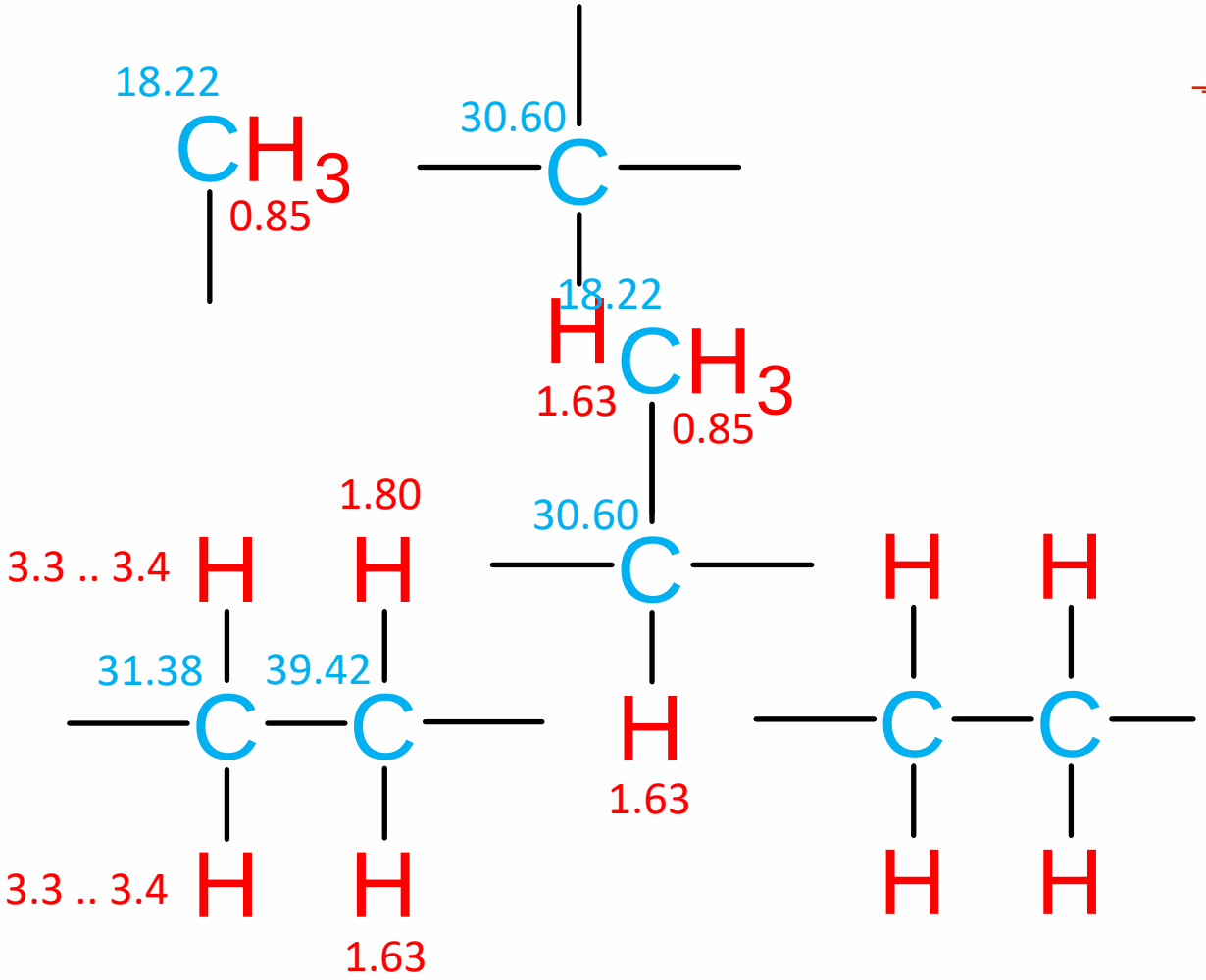
According to the number of remaining protons 1 + 3 protons have to be connected. In principle you don‘t need the COSY cross peak for this task, but of course the cross peak exists.

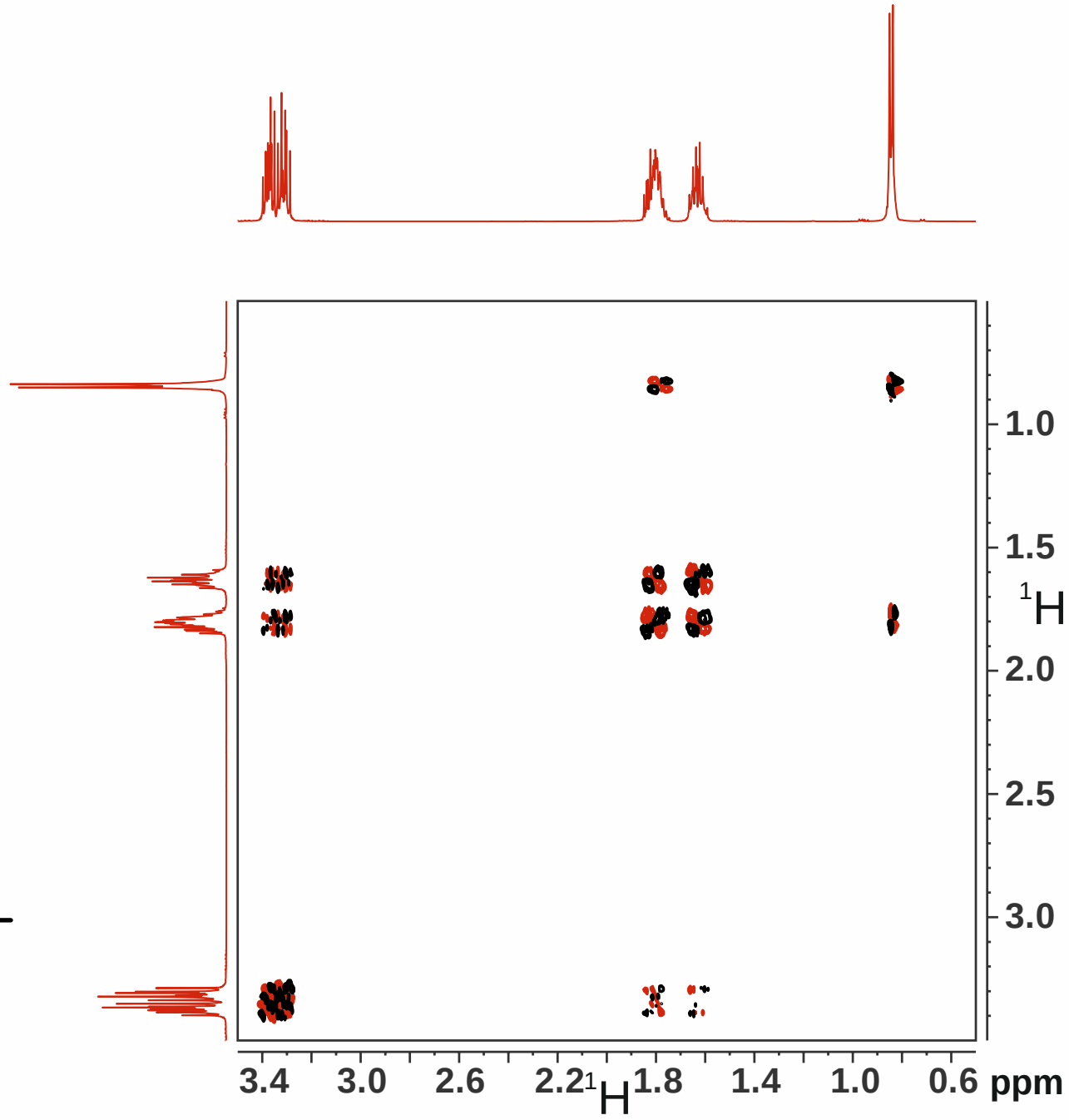




Solution

Part 3 – Connect the building blocks



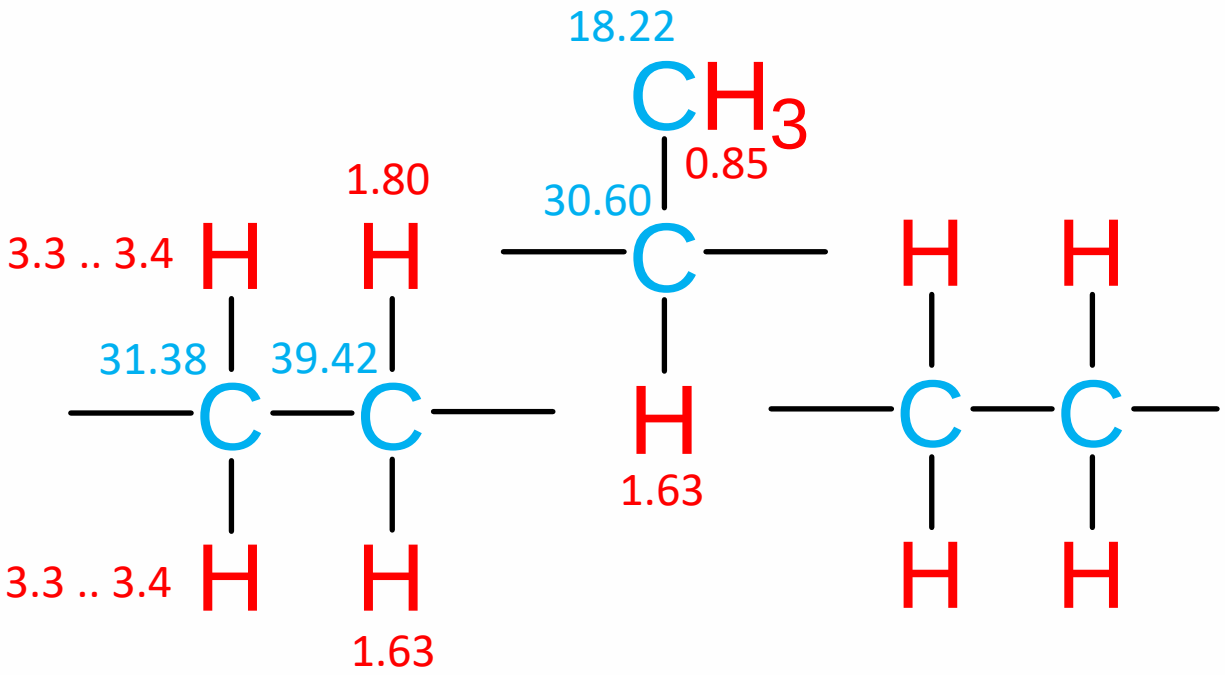


Solution

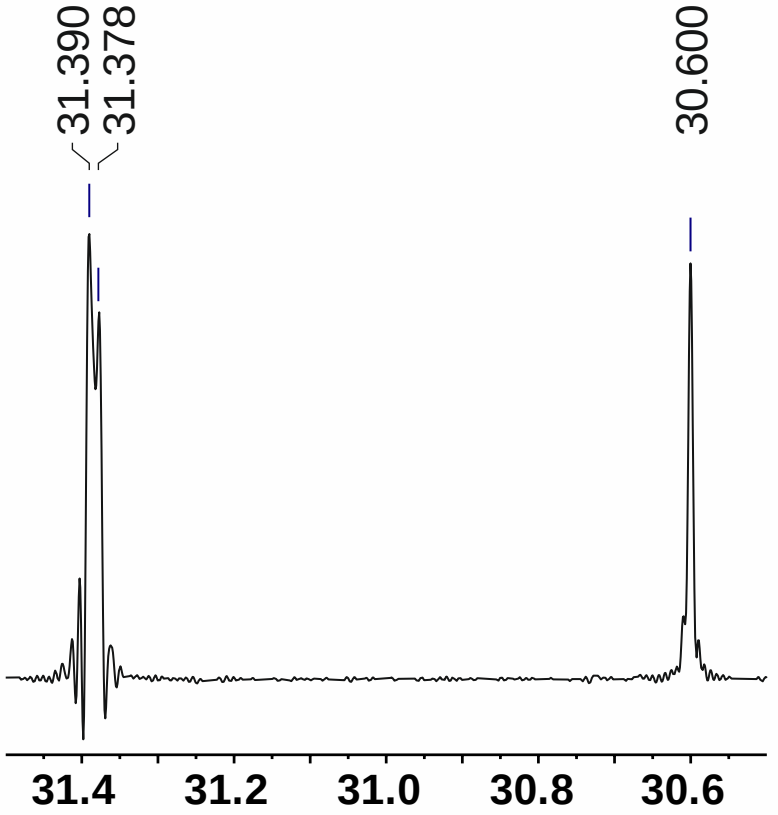
Part 4 – What is the halogene

Either a really carefully done measurement or sometimes an appropriate postprocessing shows an isotope pattern (1:1) at 31.38 ppm.

The natural isotopes of which halogene show the isotope ratio of about 1:1?



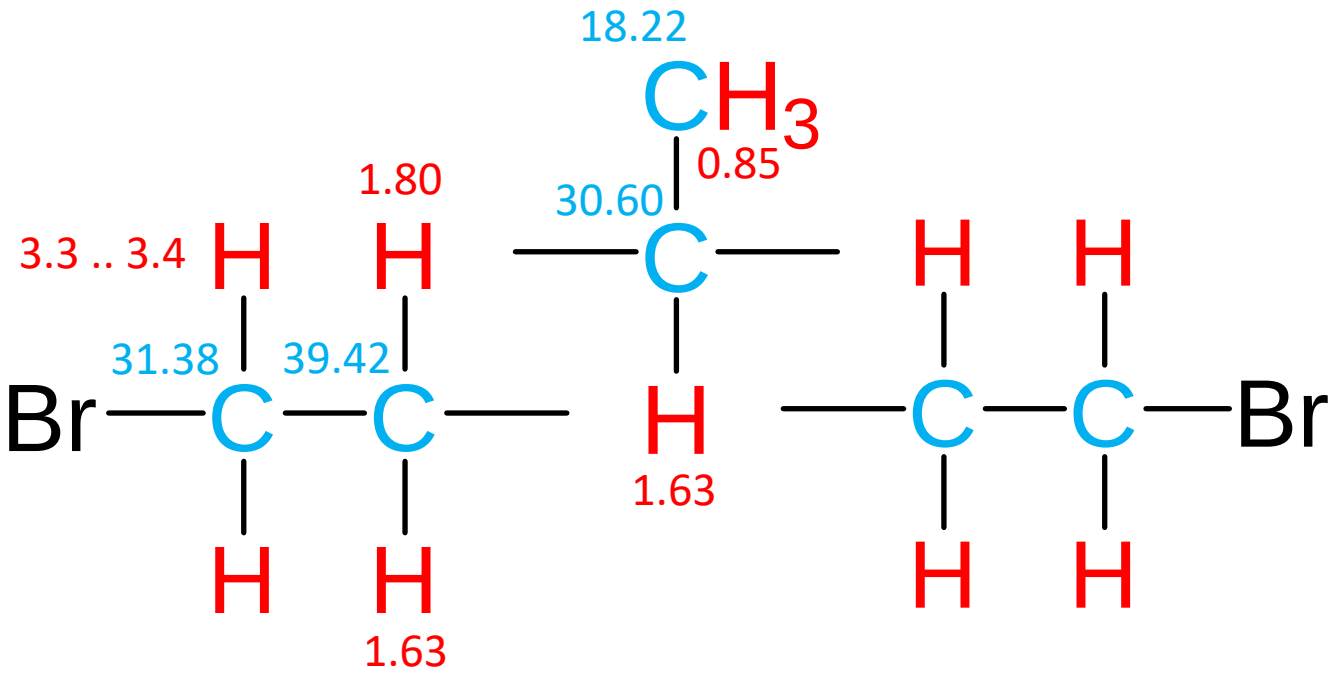
^{19}F	-	100 %
^{35}Cl / ^{37}Cl	-	76/24 %
^{79}Br / ^{81}Br	-	51/49%
^{127}I	-	100%



Solution

Part 5 – Nearly done

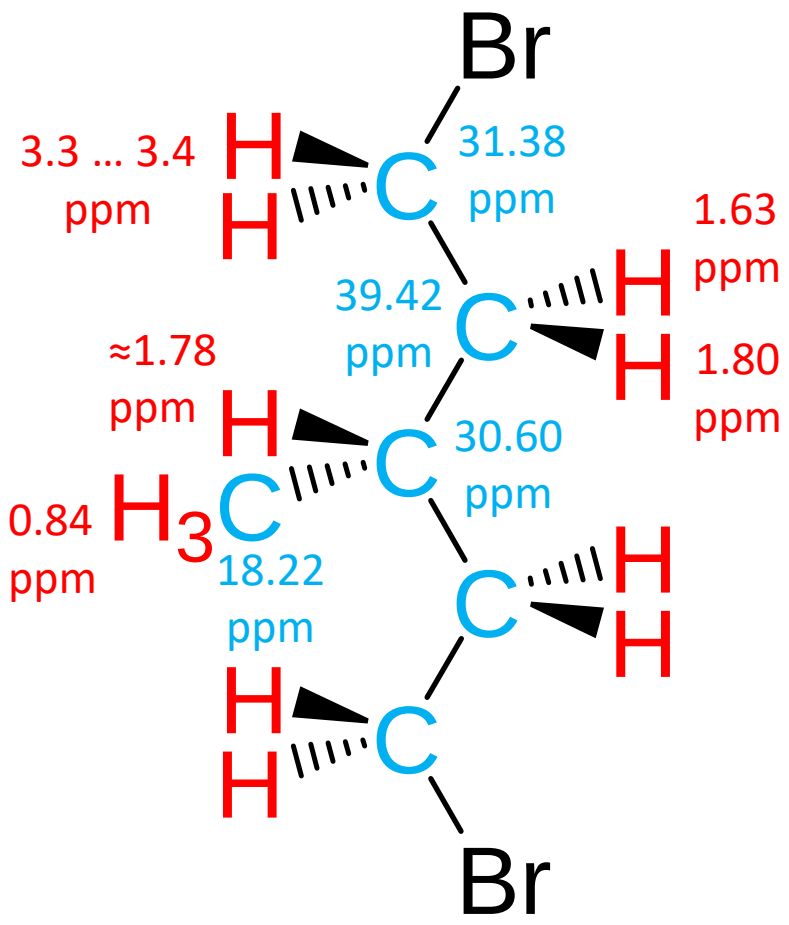
Even if it is impossible to evaluate the crowded region between 1.63 and 1.80 ppm in the COSY, there is only one final combination of all components possible.



Solution

Part 6 – Stereochemistry

But why are the methylene protons not equivalent?

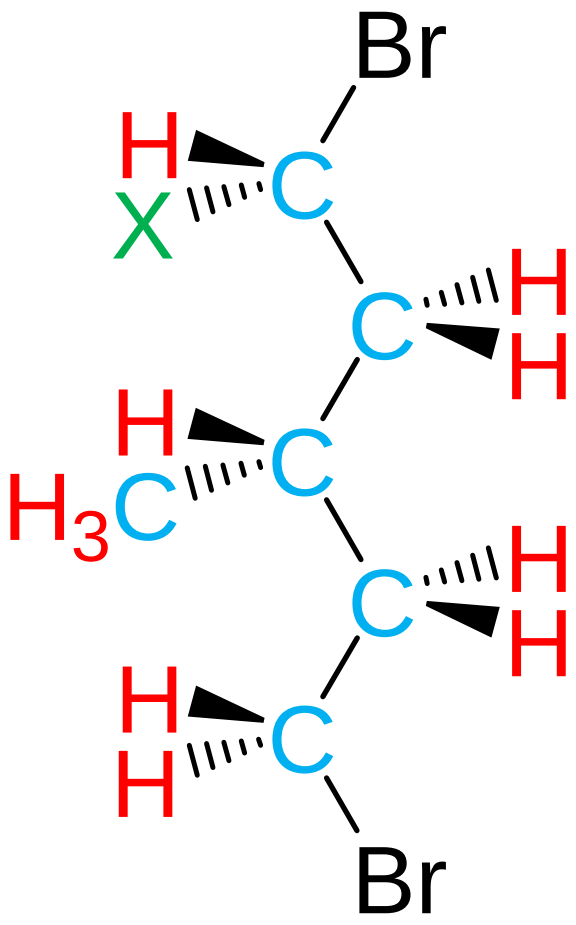


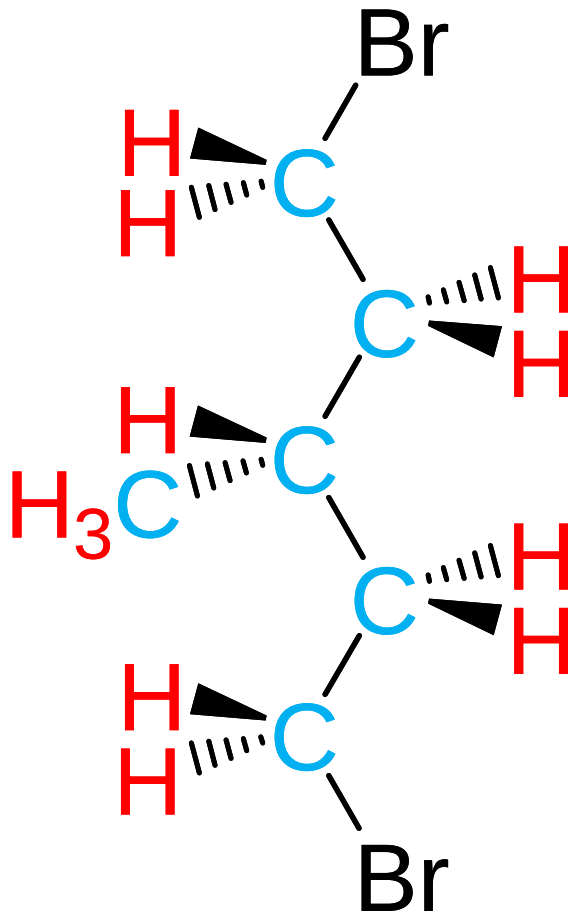
There is no center of chirality anywhere.

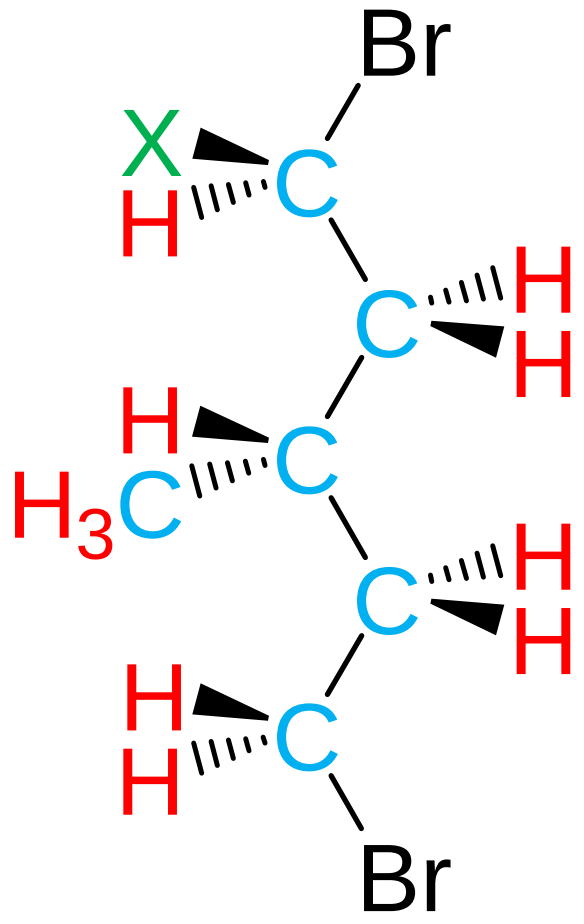
Solution

Part 6 – Stereochemistry

Let us tentatively exchange, one after the other, both protons of any methylene group using a fictive nucleus X.

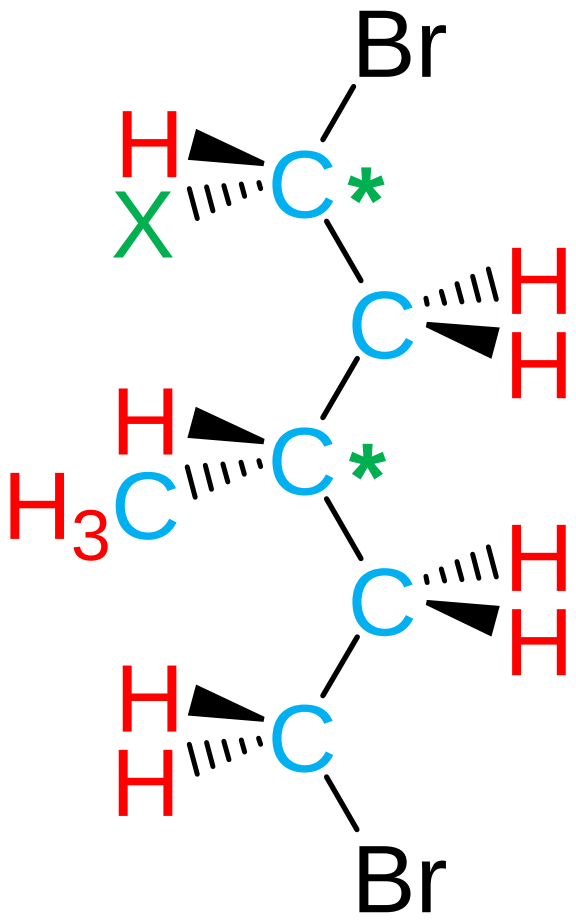




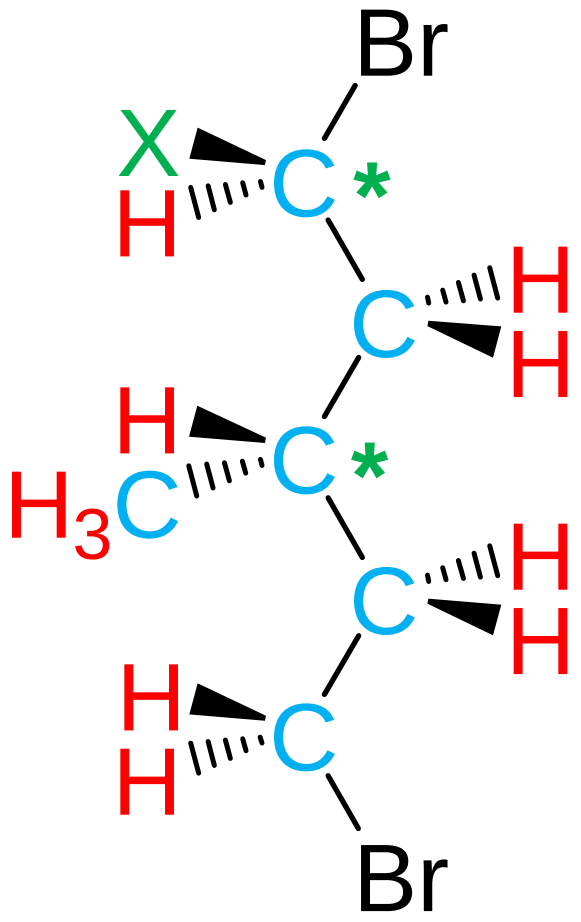


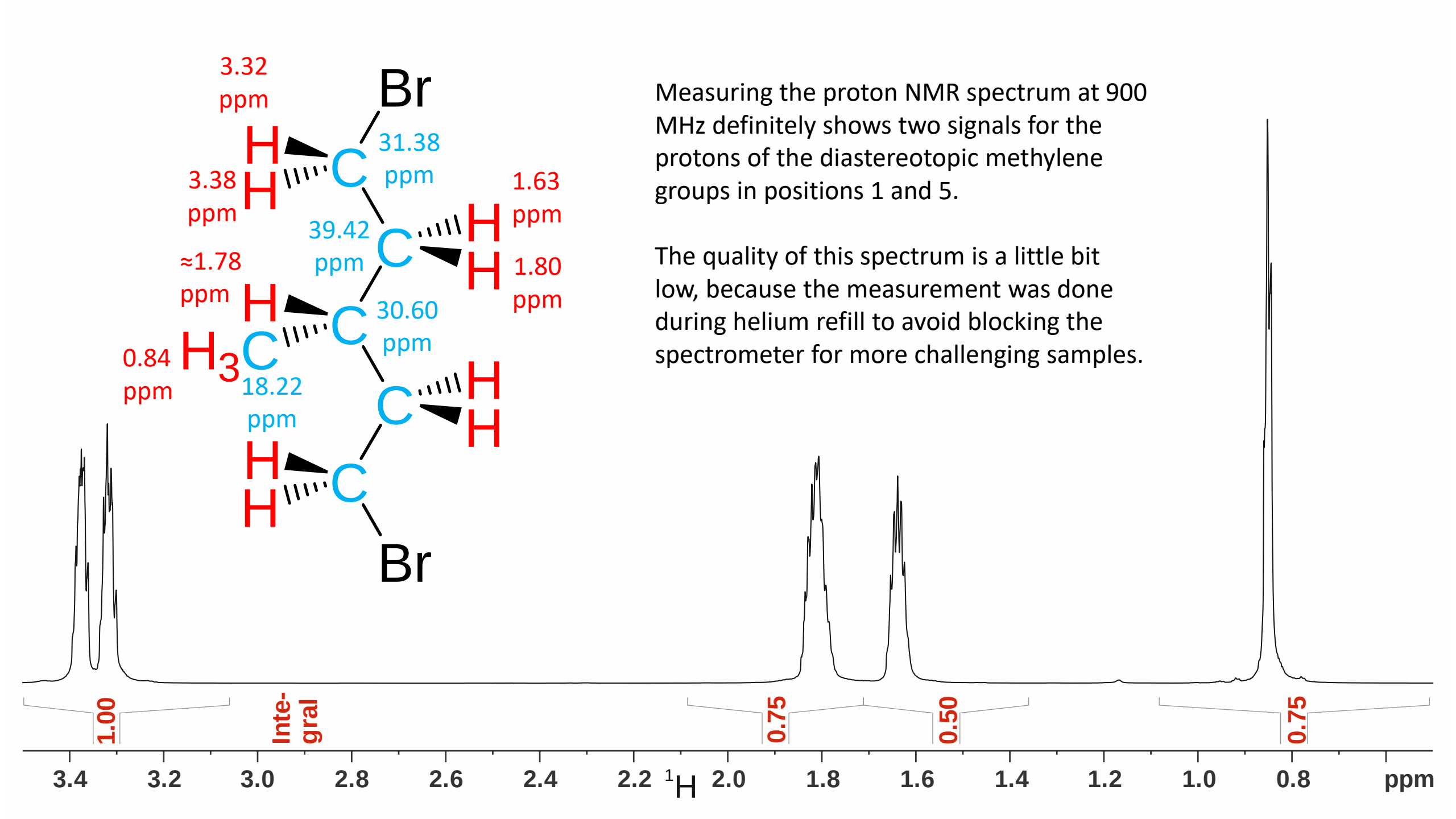
Solution

Part 6 – Stereochemistry



We create two centers of chirality at once. It is impossible to make both molecules coincide by any symmetry operation (including mirroring). The molecule on the left and the molecule on the right side are chemically different, which finally means, all four methylene group protons are diasterotopic.

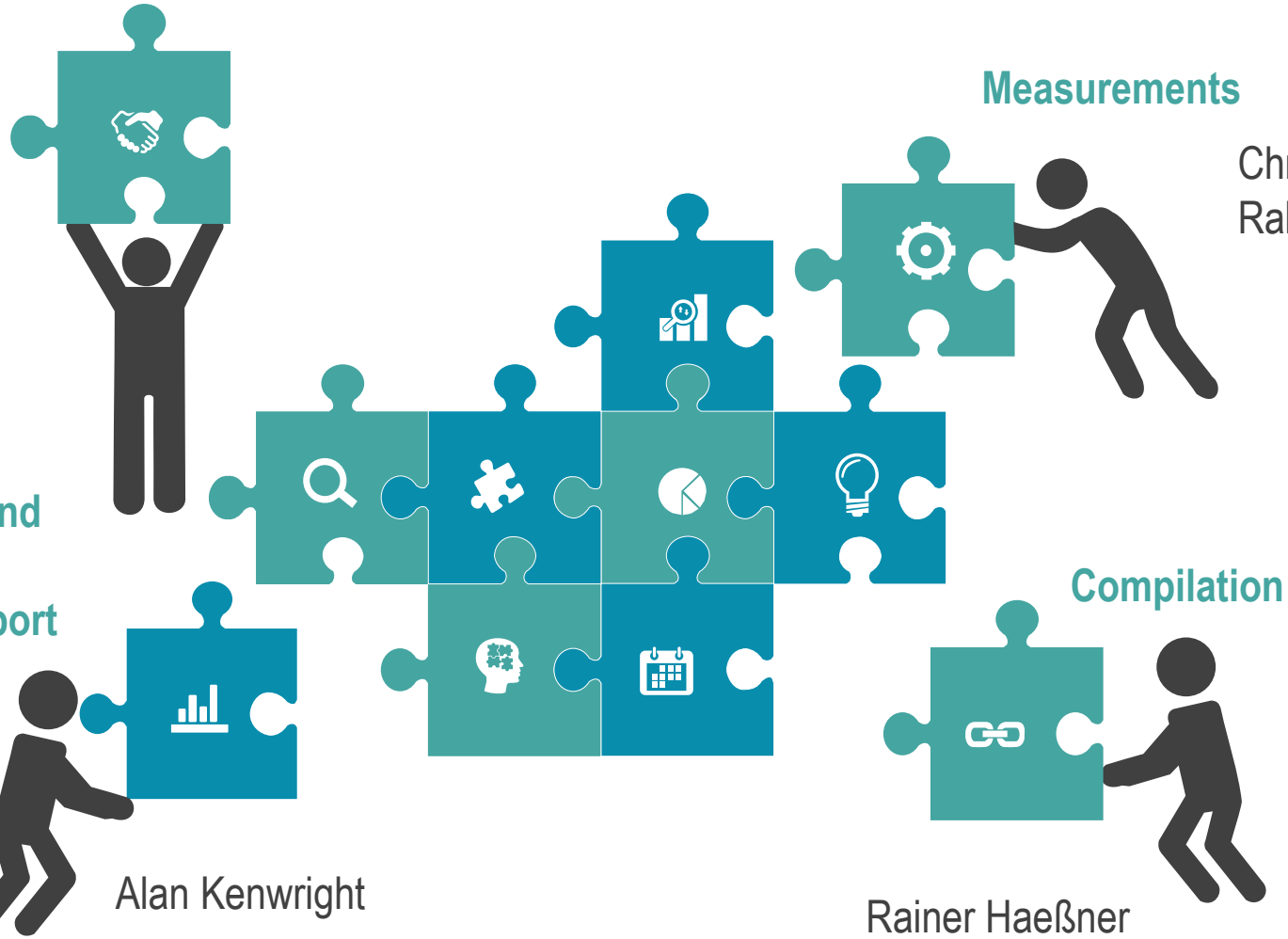



3.32 ppm
Br
31.38 ppm
3.38 ppm
1.63 ppm
39.42 ppm
≈1.78 ppm
1.80 ppm
30.60 ppm
0.84 ppm
18.22 ppm
Br
Measuring the proton NMR spectrum at 900 MHz definitely shows two signals for the protons of the diastereotopic methylene groups in positions 1 and 5.
The quality of this spectrum is a little bit low, because the measurement was done during helium refill to avoid blocking the spectrometer for more challenging samples.
1.00
Inte-gral
0.75
0.50
0.75
3.4
3.2
3.0
2.8
2.6
2.4
2.2
^{1}H
2.0
1.8
1.6
1.4
1.2
1.0
0.8
ppm

Contributions

Spectrometer time

TU Munich



Measurements

Christine Schwarz
Ralf Stehle

Discussions and native English language support

Alan Kenwright

Compilation

Rainer Haeßner

More exercises ...