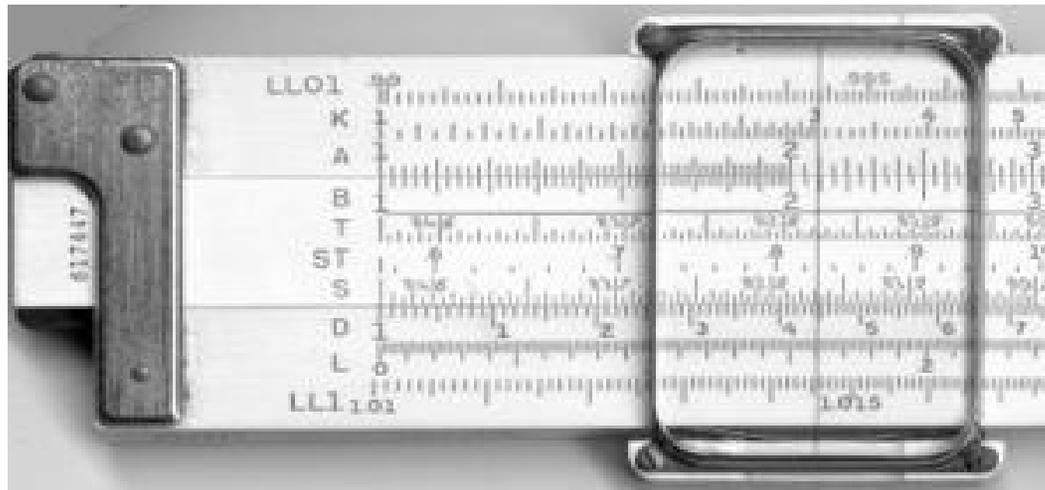


Information Content Available Through NMR



We need to measure the NMR signals...

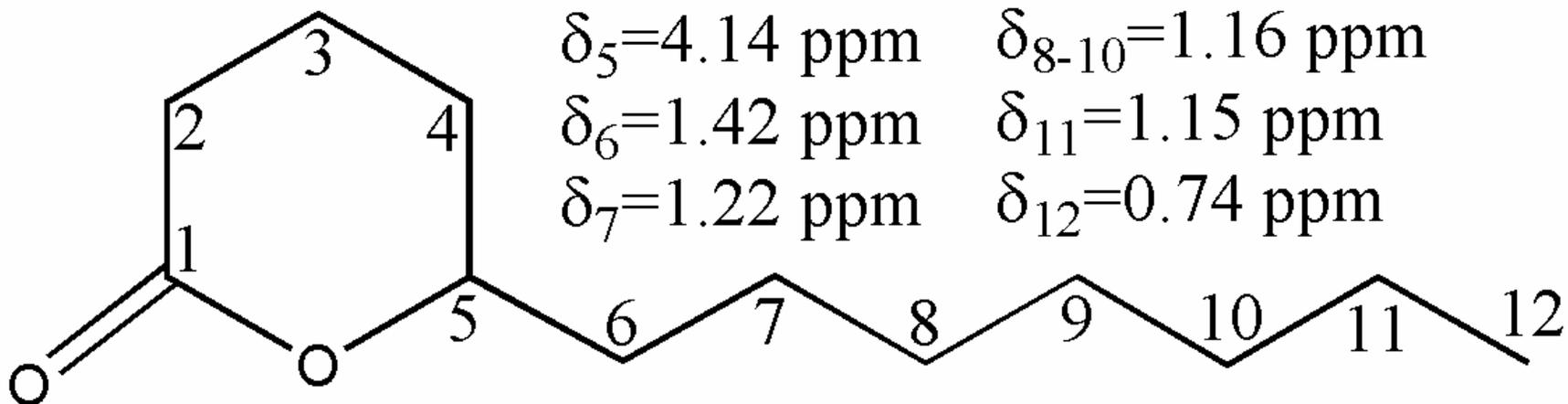


Tetramethylsilane (TMS) is our reference for ^1H , ^{13}C and ^{29}Si . The chemical shift (denoted δ) varies in different chemical environments.

$$\delta = [(v_{\text{obs}} - v_{\text{TMS}}) / v_{\text{TMS}}] \times 10^6$$

Chemical shifts depend on the electronegativities of nearby atoms

5-Hydroxydodecanoic acid δ -lactone



Having $2n+2 \pi$ electrons in a ring allows for charge circulation

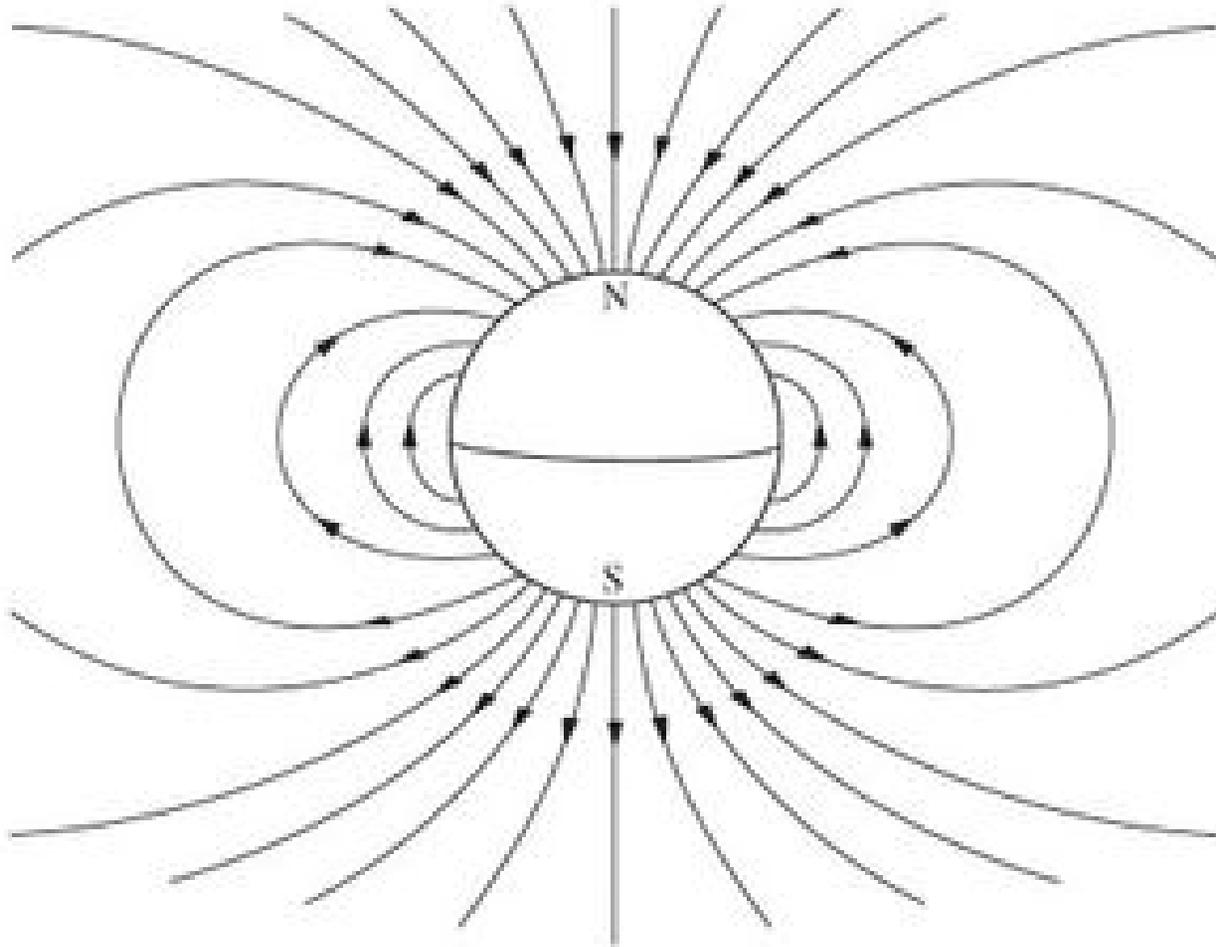
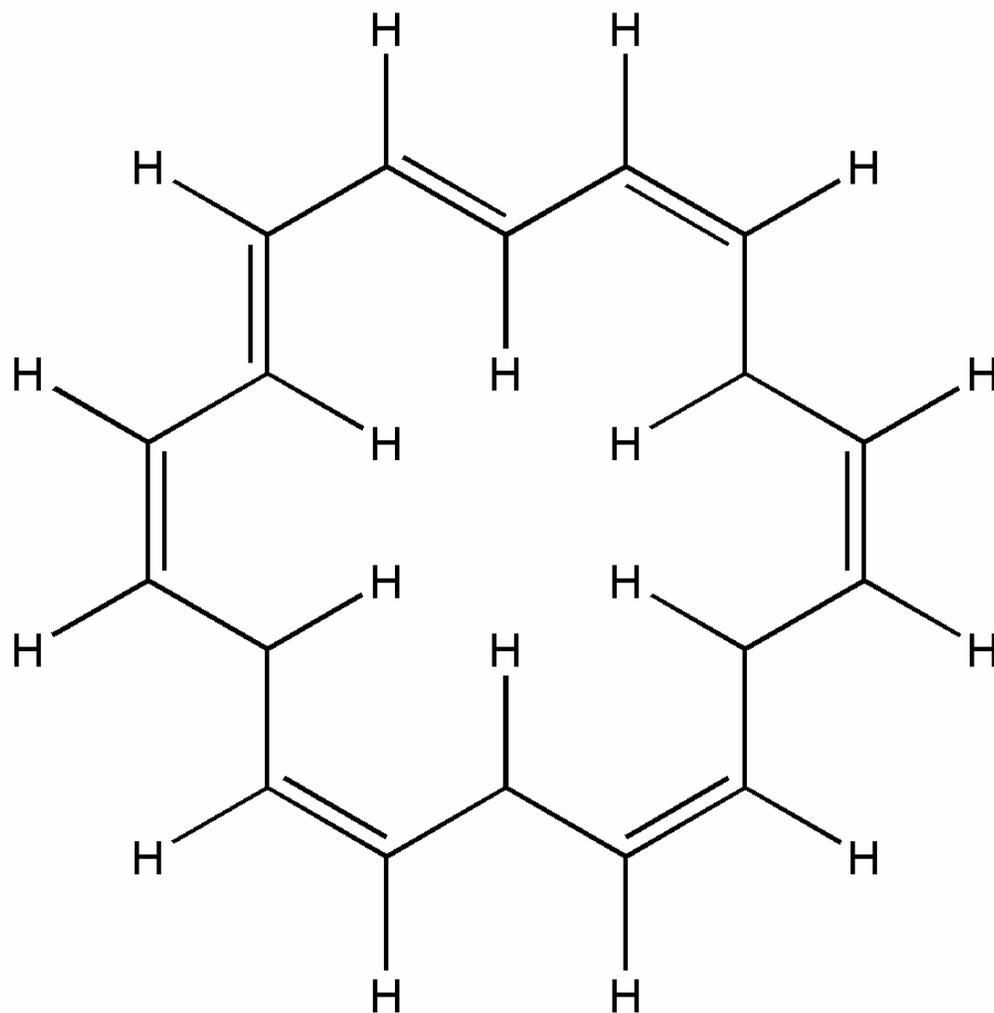


Image courtesy of the U.S. Geological Survey

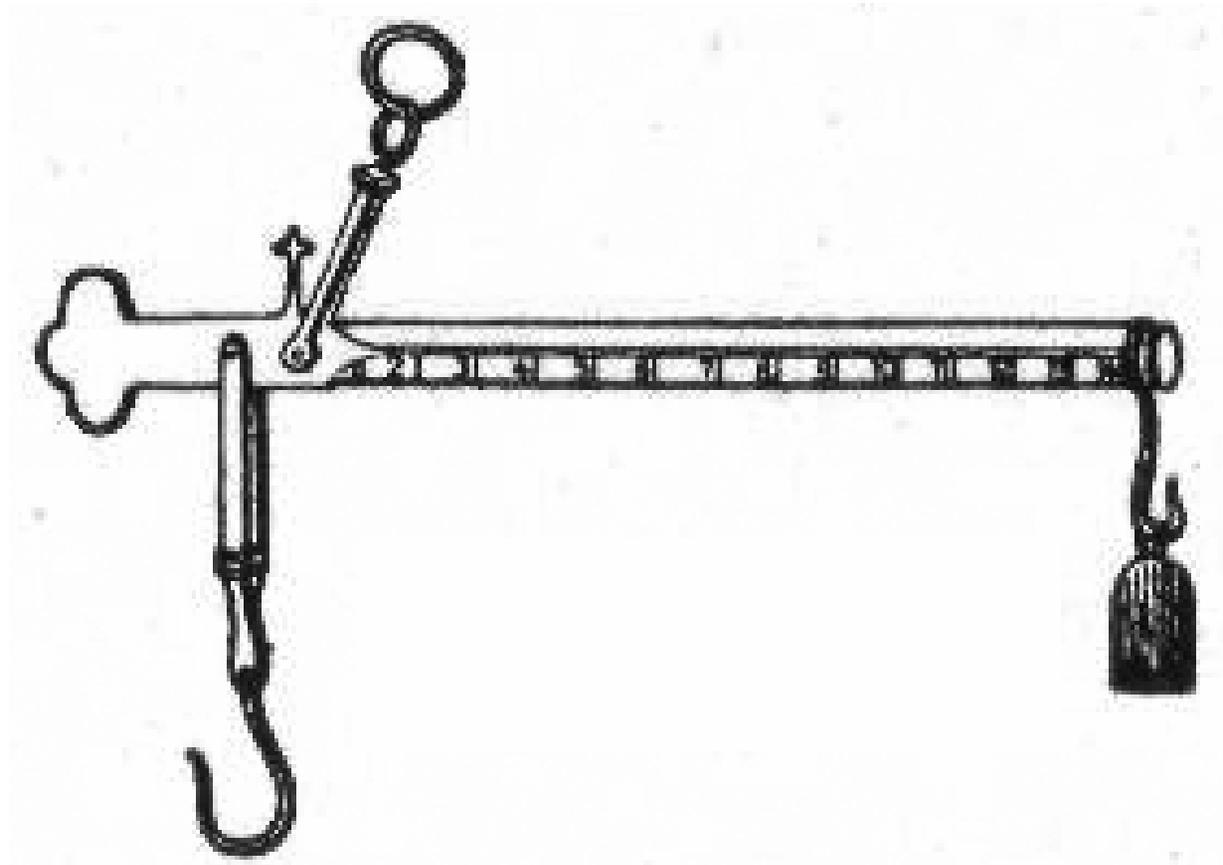
[18]-annulene

$$\delta_{\text{H}}(\text{outer}) = 8.9 \text{ ppm}$$

$$\delta_{\text{H}}(\text{inner}) = -1.8 \text{ ppm}$$



We also want to know how much of each signal we have



NMR provides information on
the relative amounts of
chemically distinct molecular
sites (integrals and intensities)

Quantitation requires...

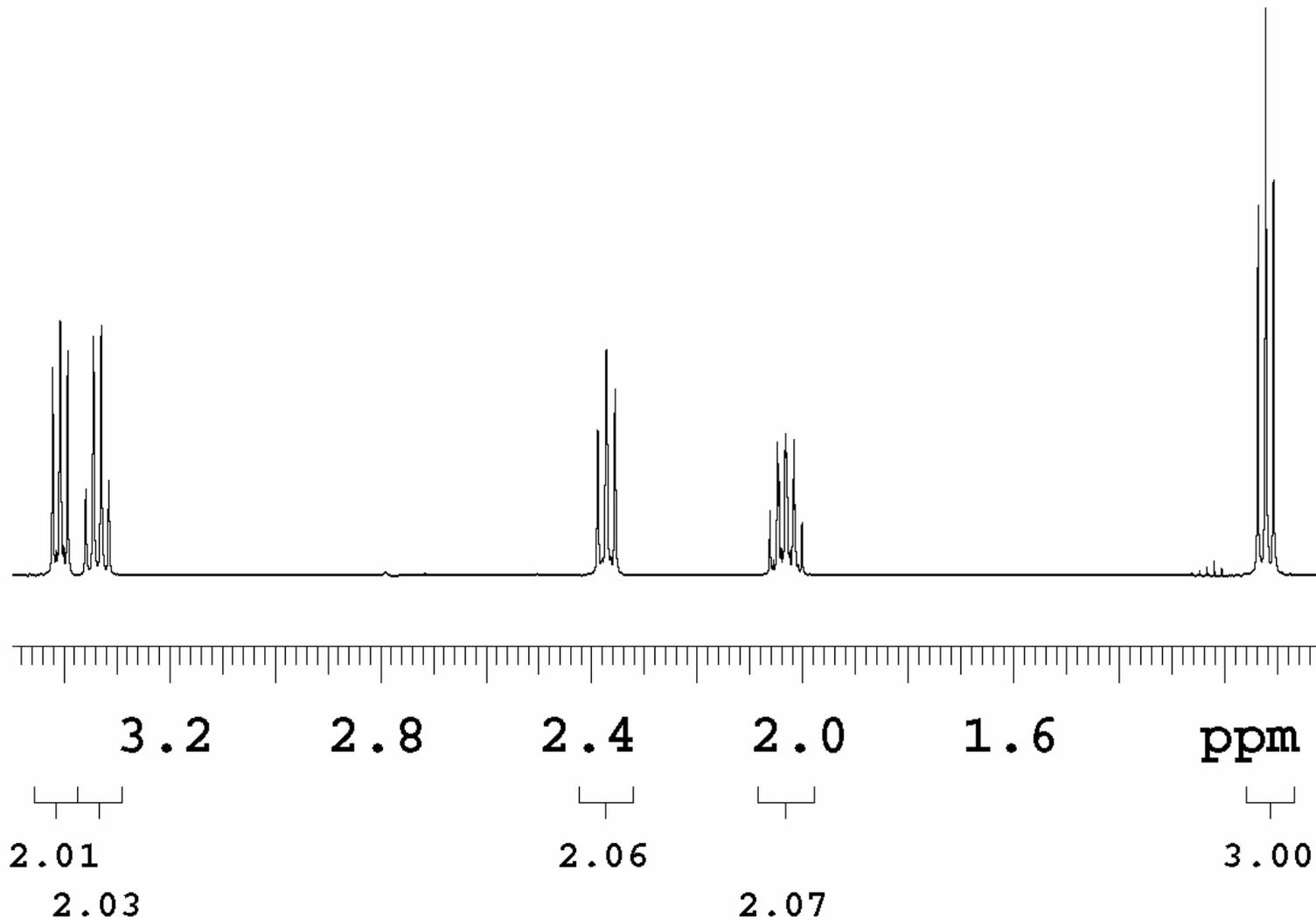
- Waiting five times the longest spin-lattice relaxation time T_1

$$\mathbf{M}_z(t) = \mathbf{M}_0 [1 - \exp(-t / T_1)]$$

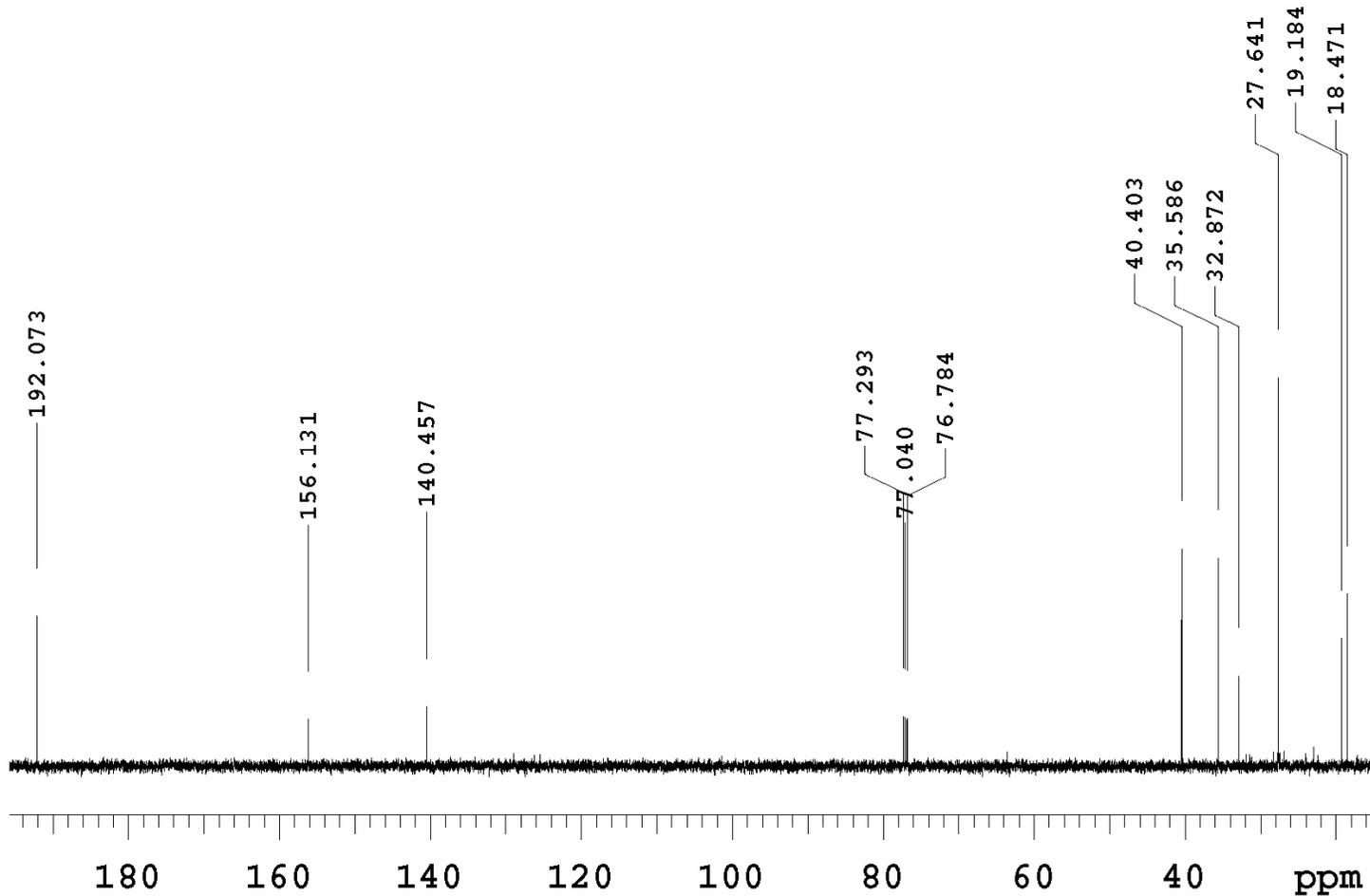
- The absence of any enhancement, such as that arising from decoupling

$$\eta = \gamma_X / (2 \gamma_A)$$

^1H 1-D integration



^{13}C spectra provide useful intensity information



How do spins talk to each other?



Image courtesy of U.S. Air Force

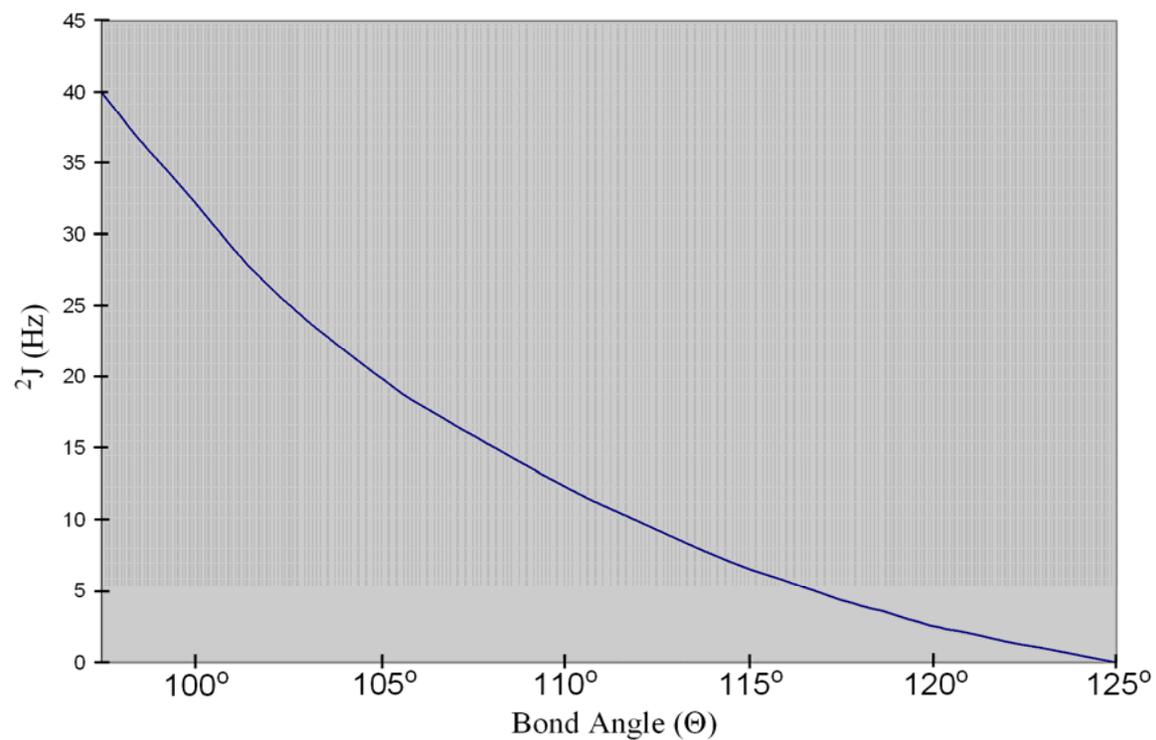
Through-bond connectivity
is revealed
through J-couplings

The magnitude of J

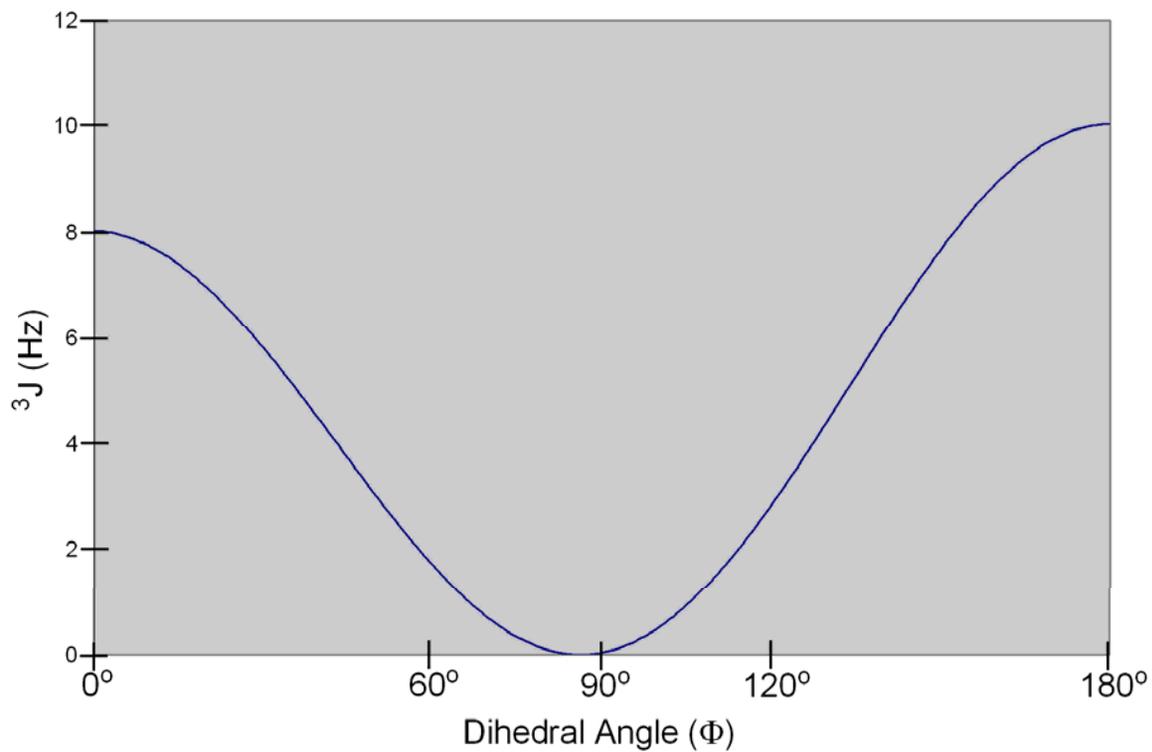
- 1J 's (ca. 125-160 Hz for ^1H - ^{13}C , sometimes more, used in HMQC, HSQC, and INADEQUATE)
- 2J 's (geminal couplings, 2-15 Hz)
- 3J 's (vicinal couplings, 0-15 Hz) ,
- sometimes 4J 's (0-4 Hz)
- and even 5J 's (0-2 Hz)

Geometry controlling magnitude
of 2J 's and 3J 's is well
understood and expressed
through the Karplus relationship

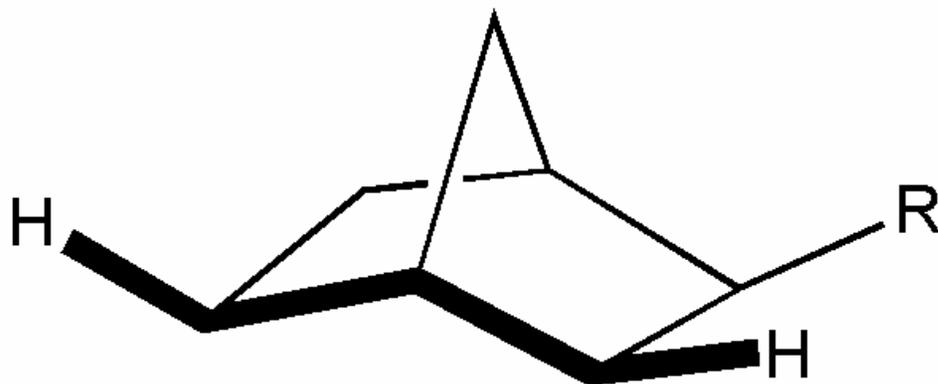
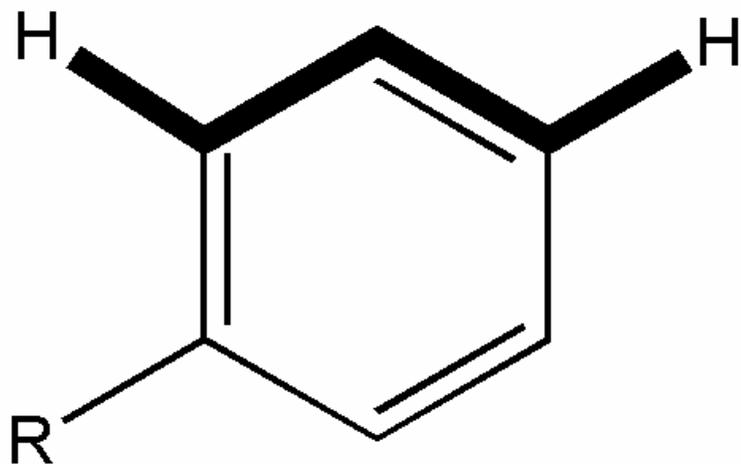
2J Karplus relationship



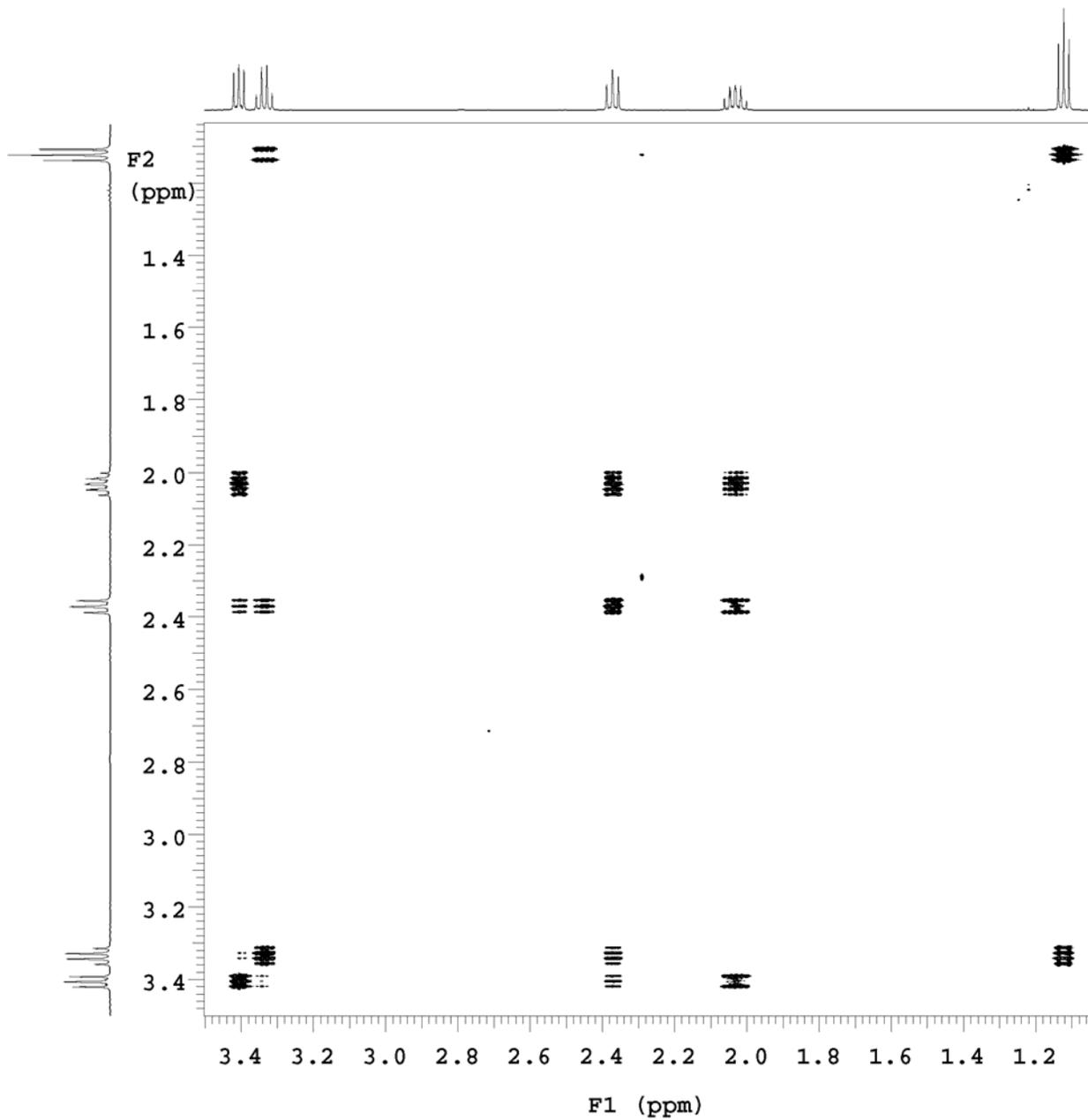
3J Karplus relationship



Measurable 4J 's are found in rigid molecules

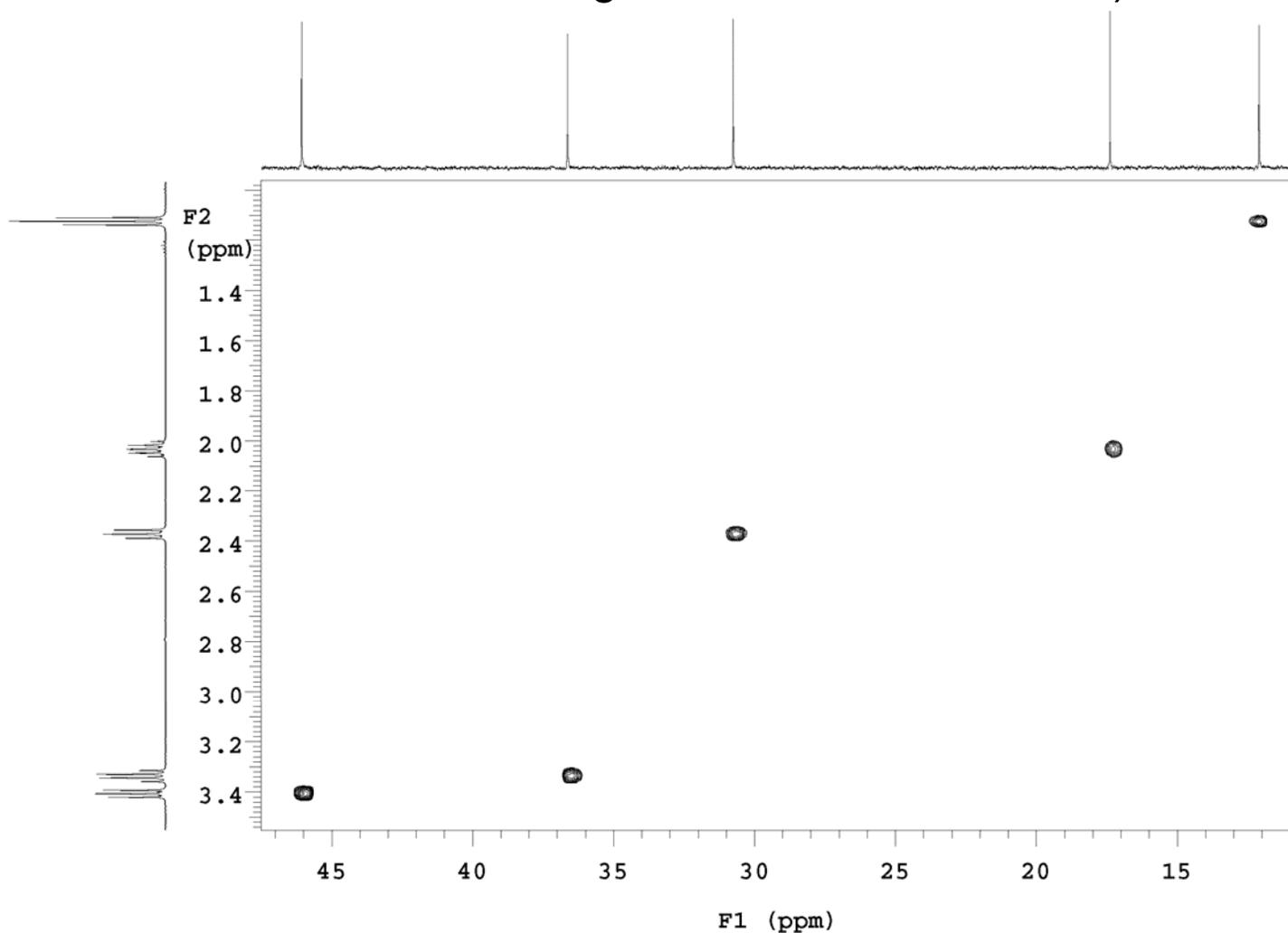


$^1\text{H}-^1\text{H}$
gCOSY
(gradient
COrrrelation
SpectroscopY)

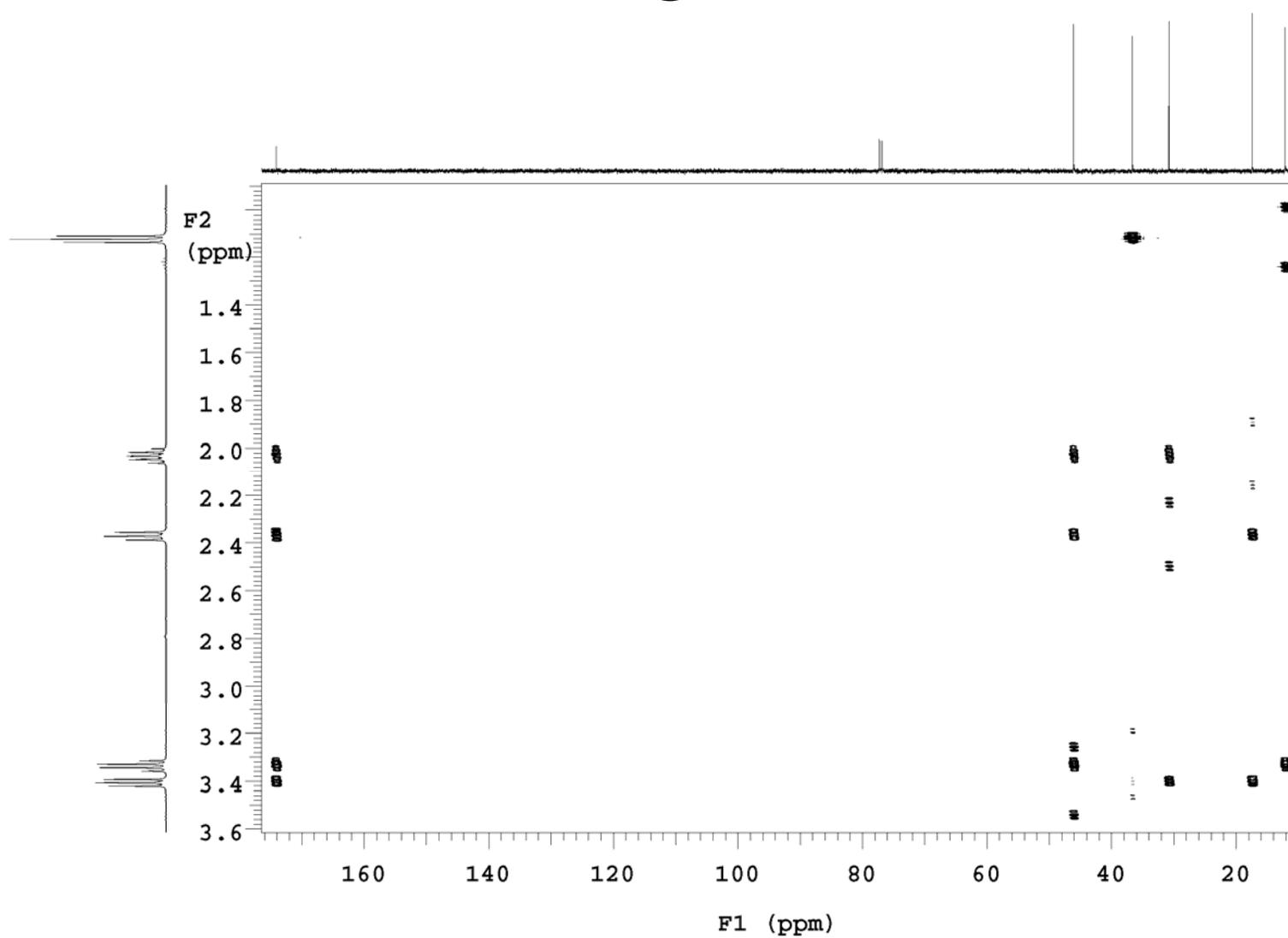


^1H - ^{13}C HMQC and HSQC

(Heteronuclear Multiple Quantum Correlation & Heteronuclear Single Quantum Correlation)



^1H - ^{13}C gHMBC



Other important through-bond
experiments:

^1H - ^1H DQFCOSY

(Double Quantum Filtered COrrrelation Spectroscopy)

and

^{13}C - ^{13}C INADEQUATE

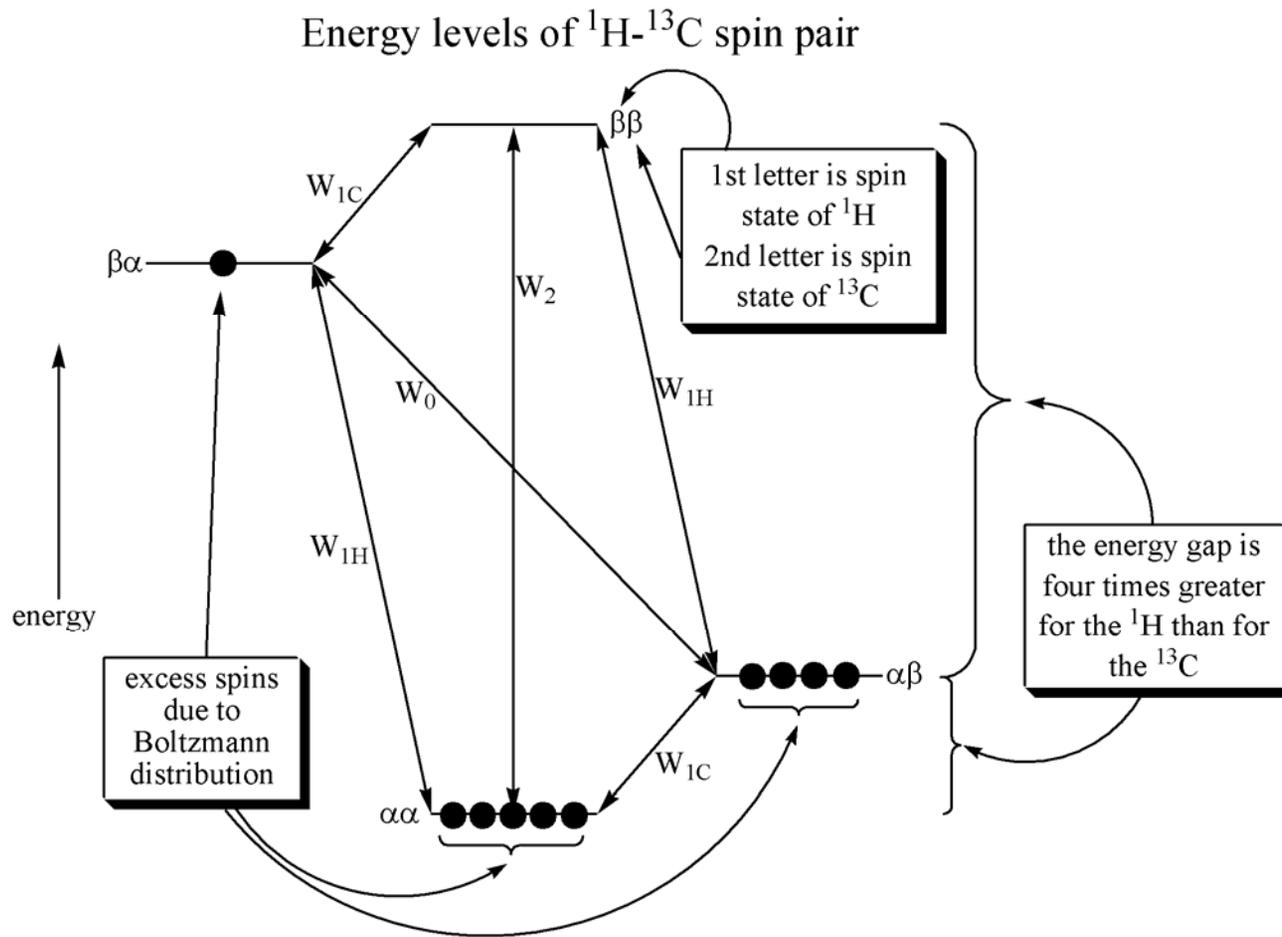
(Incredible Natural Abundance DEtection blah blah blah)

We can also detect interactions...

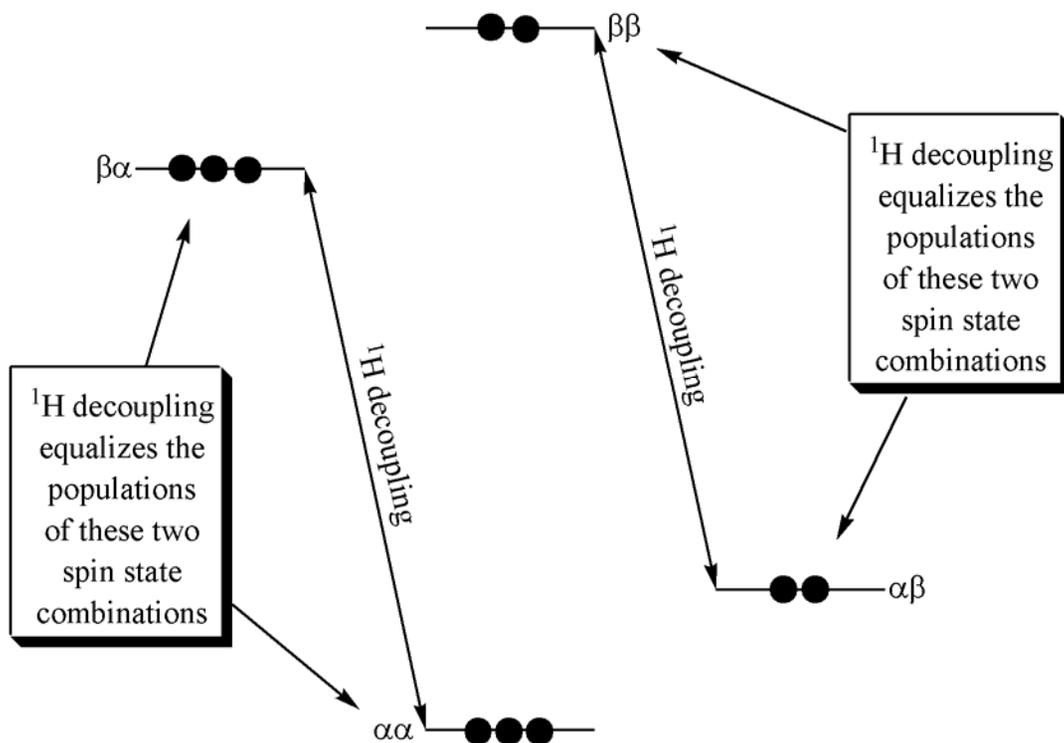
**THROUGH
SPACE**

Through-space effects: the dipolar interaction gives us the nuclear Overhauser effect (NOE)

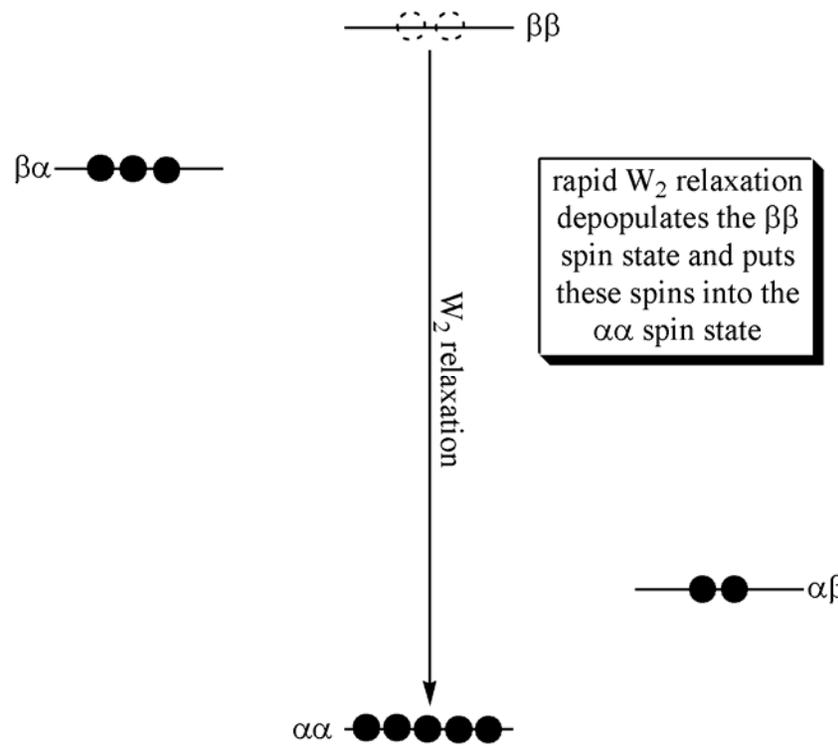
Consider a ^1H - ^{13}C spin pair at equilibrium



Now we irradiate (decouple) the ^1H transitions

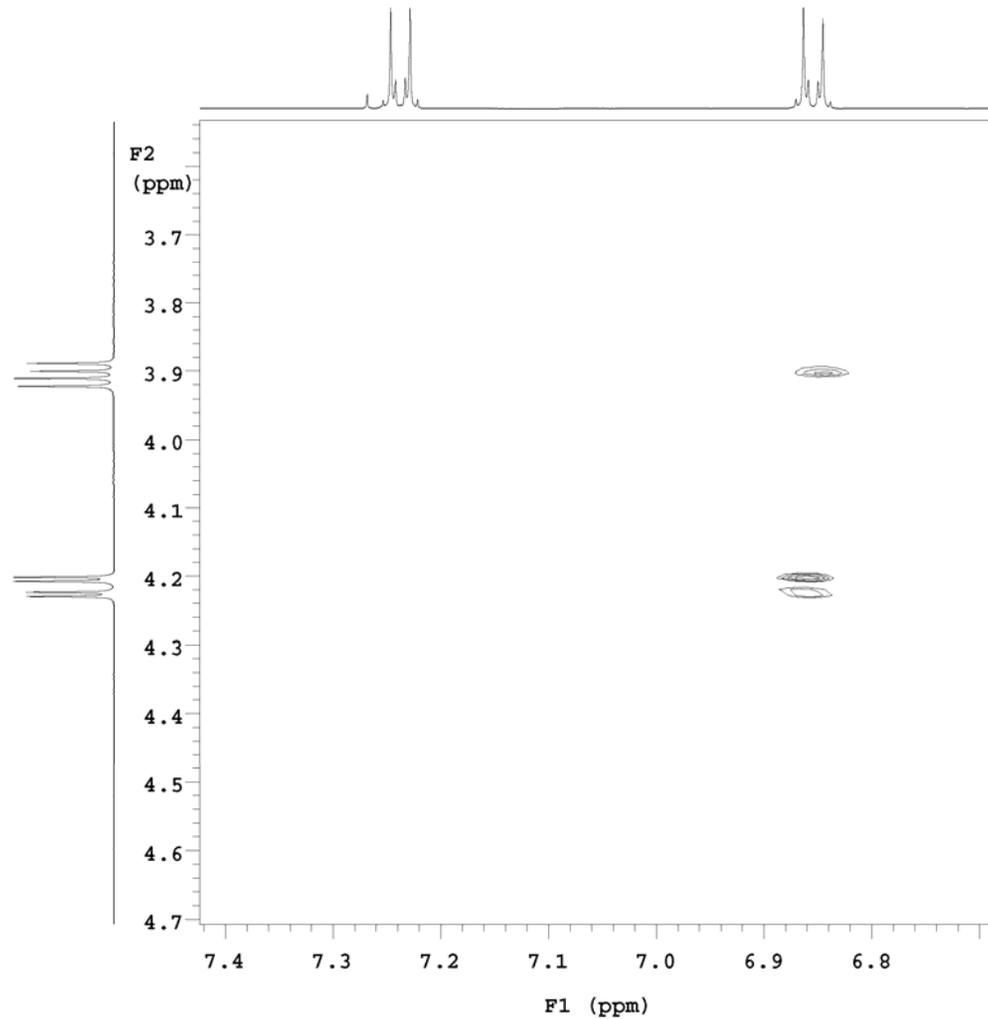


The double quantum transition relaxes the fastest (sometimes)



^1H - ^1H NOESY

(Nuclear Overhauser Effect Spectroscopy)

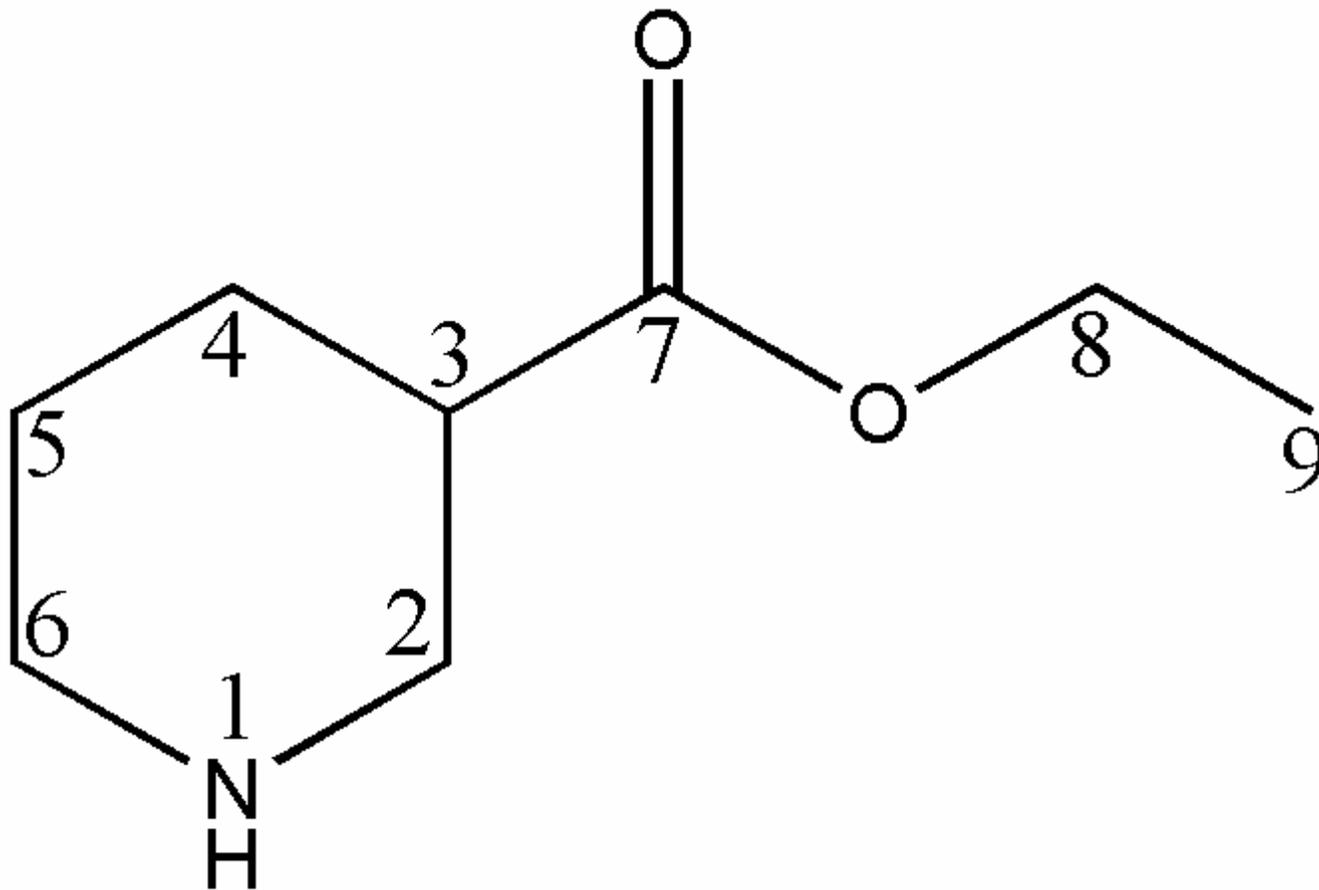


Those are the basic tools from
which we choose



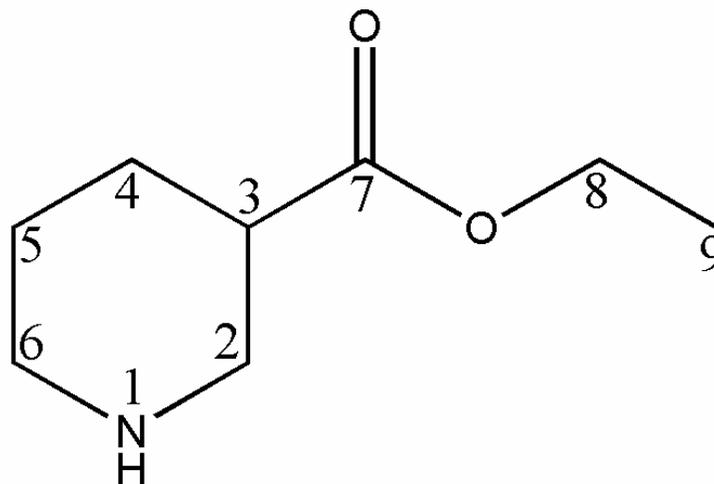
(Photo courtesy of JM, <http://www.logodesignweb.com/stockphoto>)

We start with assigning a molecule of known structure: ethyl nipecotate



Entry points

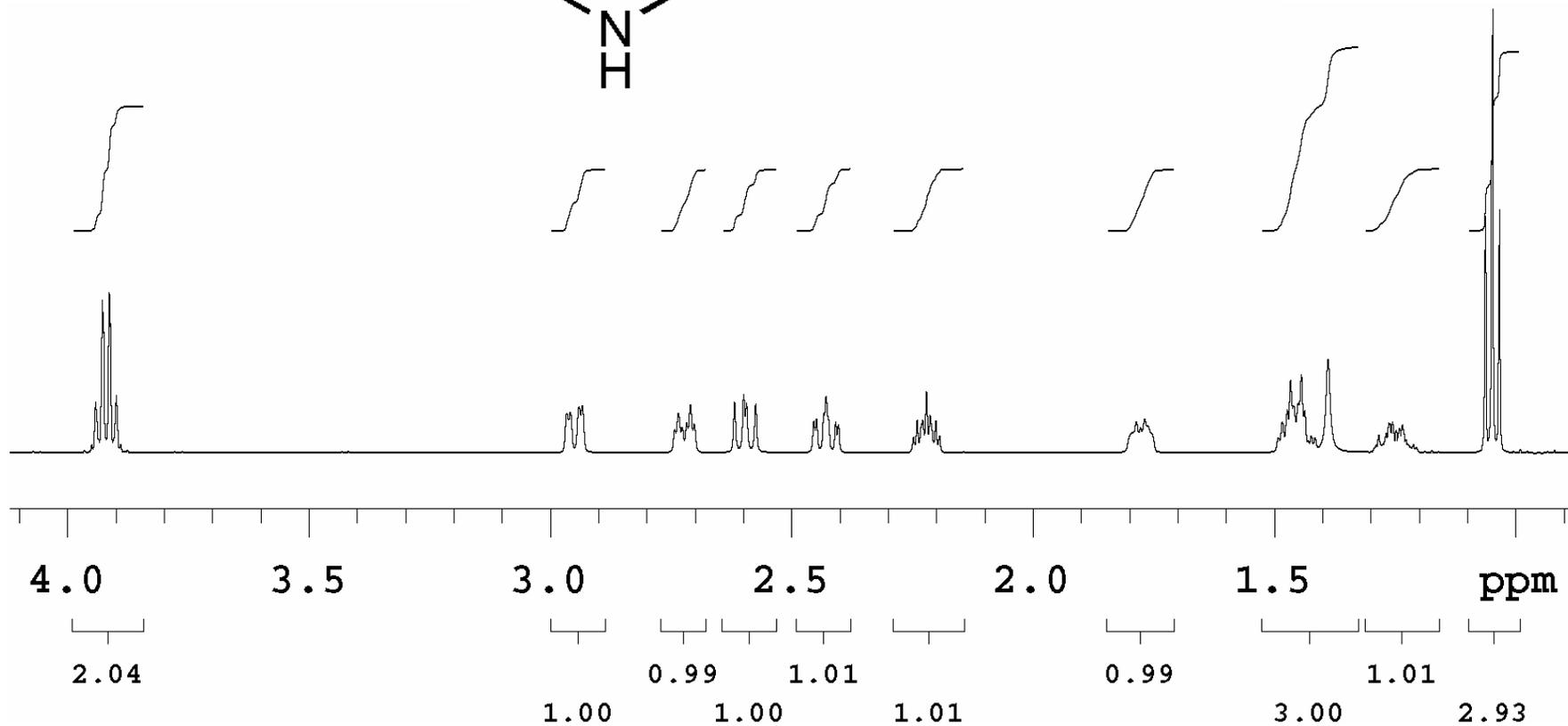
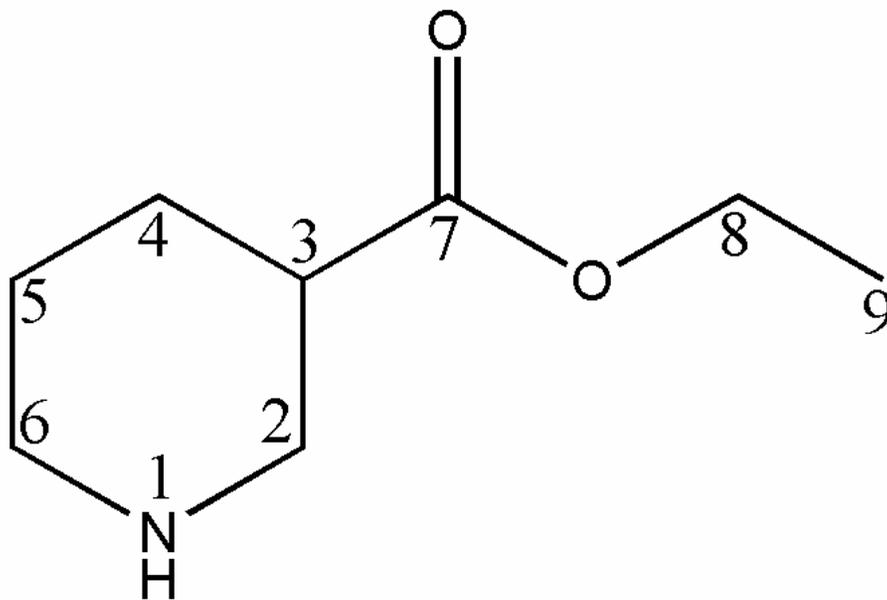
- Ethyl group
- Carbonyl carbon
- Methylenes α to N
- Lone methine @ 3



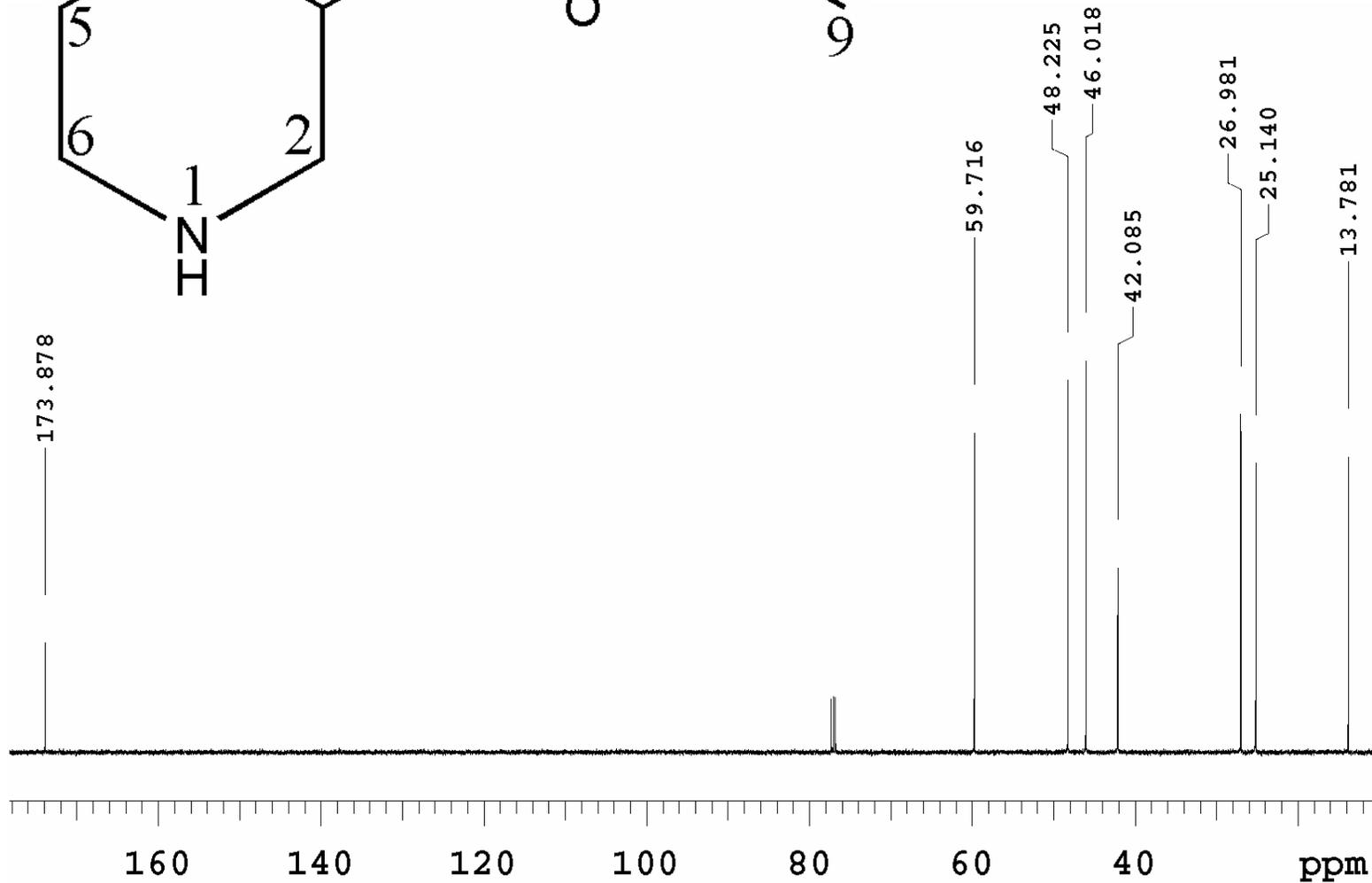
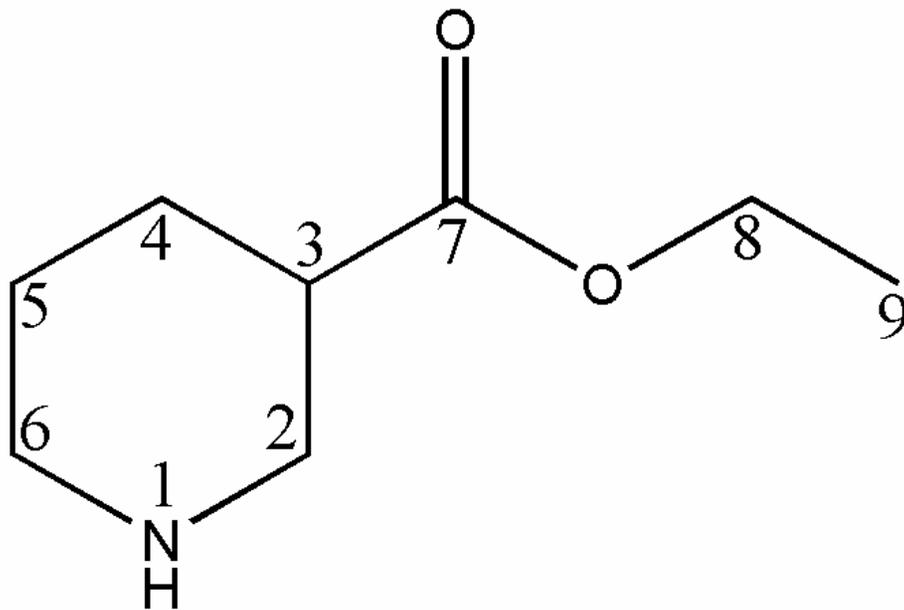
In simple problems:
Following the identification of
entry points, we use ${}^3J_{HH}$'s to
assign 1H 's adjacent to those
we already know using the
gCOSY

In complex problems:
Following the identification of
entry points, we use ${}^{3-5}J_{HH}$'s and
 ${}^{2-5}J_{HC}$'s to assign spins

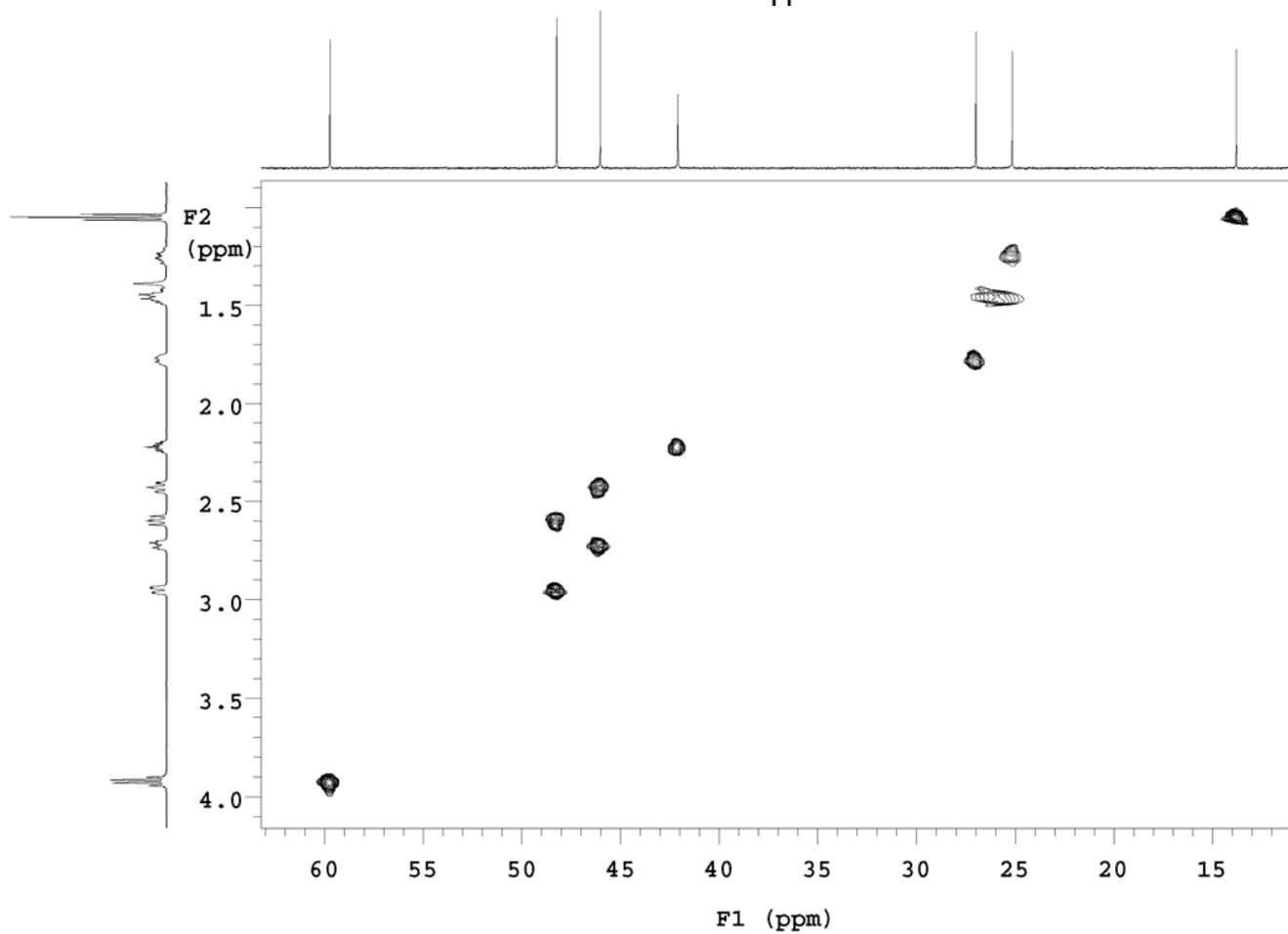
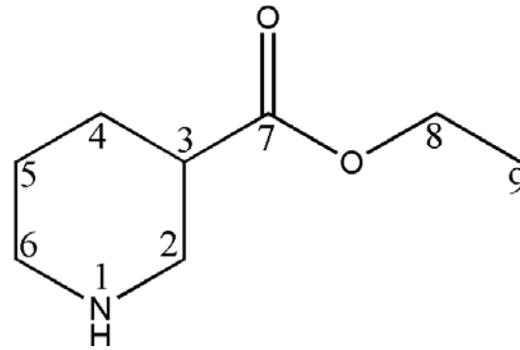
^1H 1-D



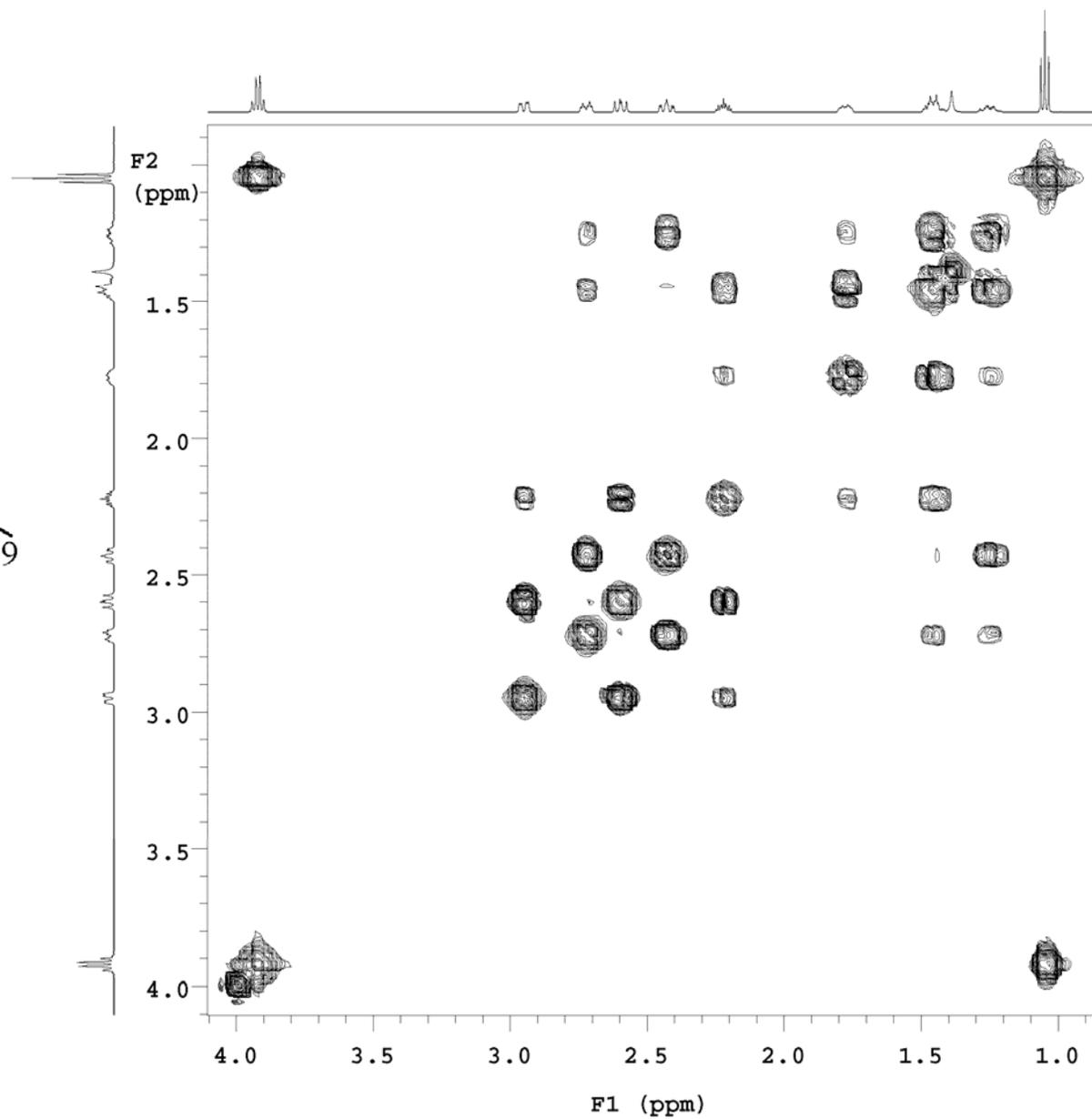
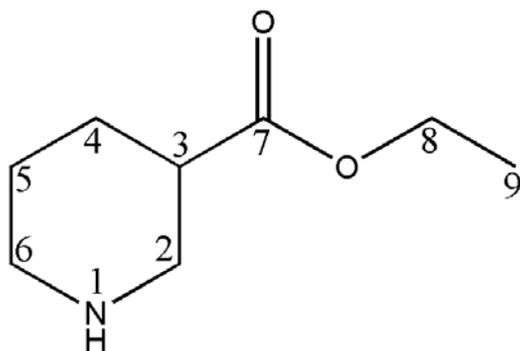
^{13}C 1-D



^1H - ^{13}C HMQC



^1H - ^1H gCOSY



For six-membered rings, we normally assume a chair conformation, and so the dihedrals are either *trans* or *gauche*

