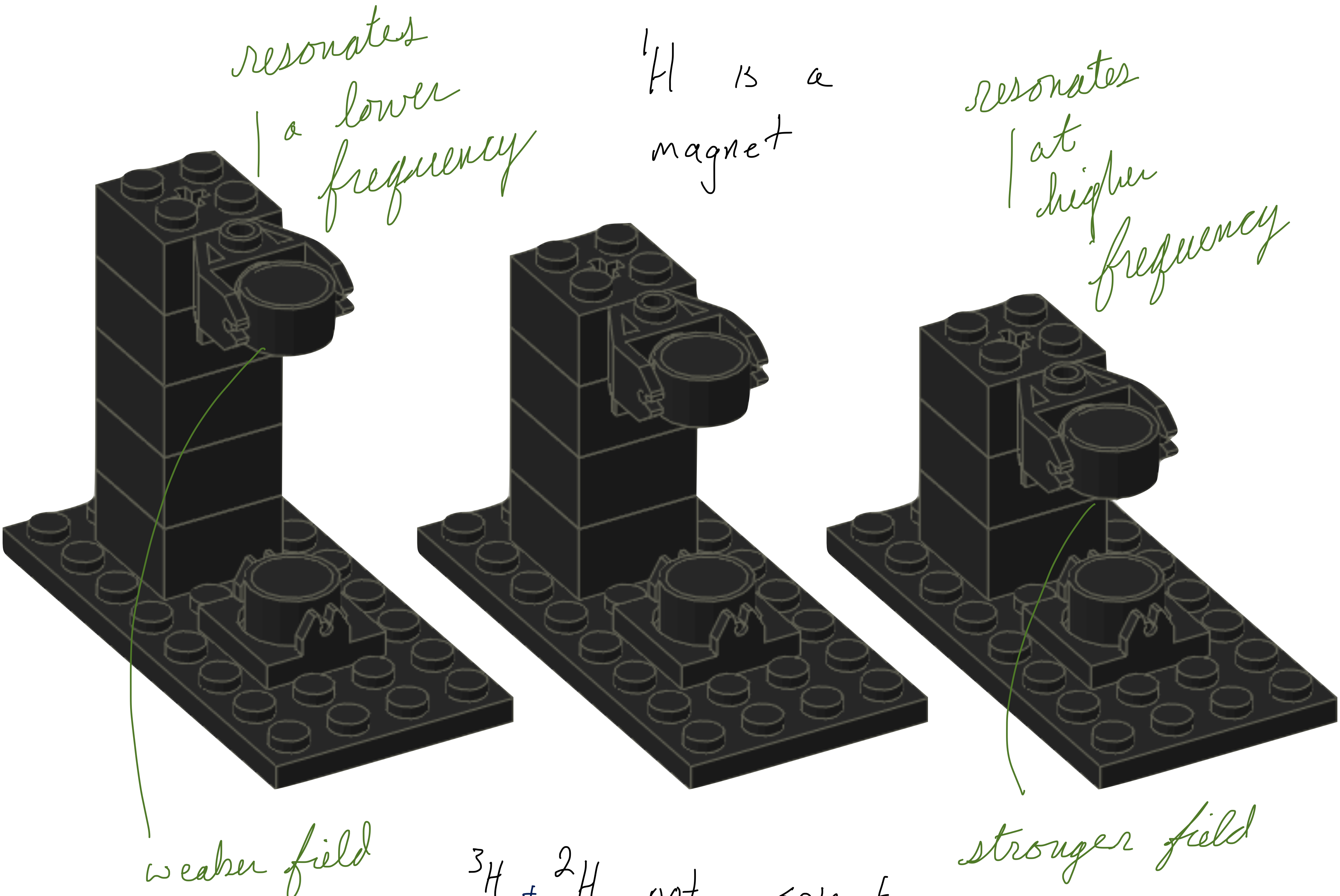
Magnets placed in a magnetic field align with the magnetic field.

When perturbed the magnets will "resonate".

The frequency of the resonance depends on the strength of the magnetic fields

^1H is a magnet



^3H & ^2H not magnets

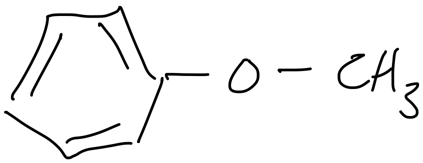
spin $\frac{1}{2}$

a super conducting wire with e^- going round and round

~1.4 T magnet will cause ^1H to align + resonate at ~60,000,000 Hz

900 MHz, (21.2 T) NMR Magnet at HWB-NMR, Birmingham, UK
https://en.wikipedia.org/wiki/Nuclear_magnetic_resonance#/media/File:HWB-NMR_-_900MHz_-_21.2_Tesla.jpg

sample experiences a uniform magnetic field

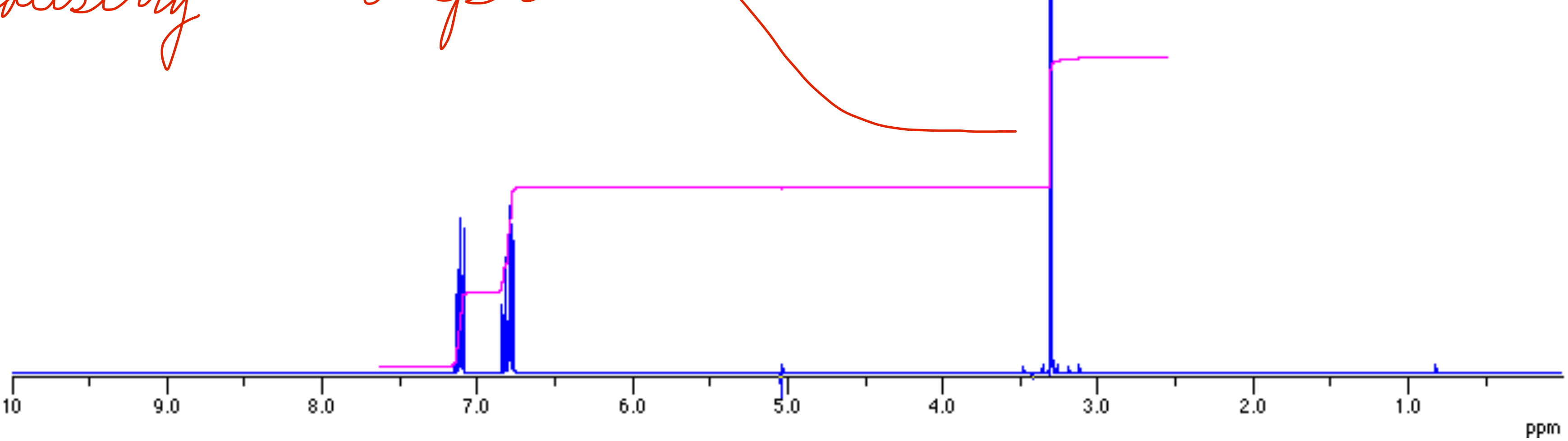


The # of peaks is related to the number of different H's in our molecule.

The chemical environment

The # of H atoms on neighboring C, N, or O atoms

relative #'s of ¹H atoms causing the peak



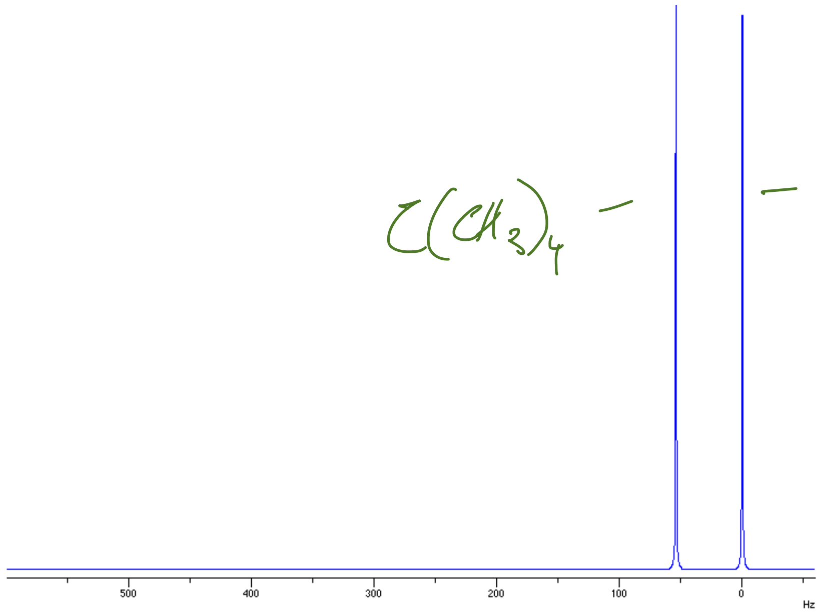
magnetic field varies based on position

www.radiologyinfo.org

Magnetic Resonance Imaging H_2O

Maps the varying concentrations of water molecules in tissues to create an image.

Resonance frequencies depend on magnetic strength

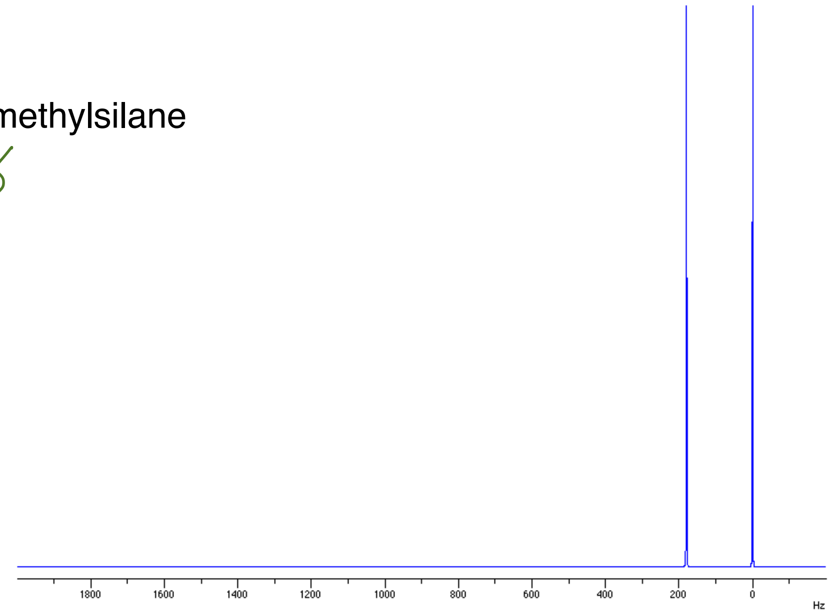


C(CH3)4 – – TMS

tetramethylsilane

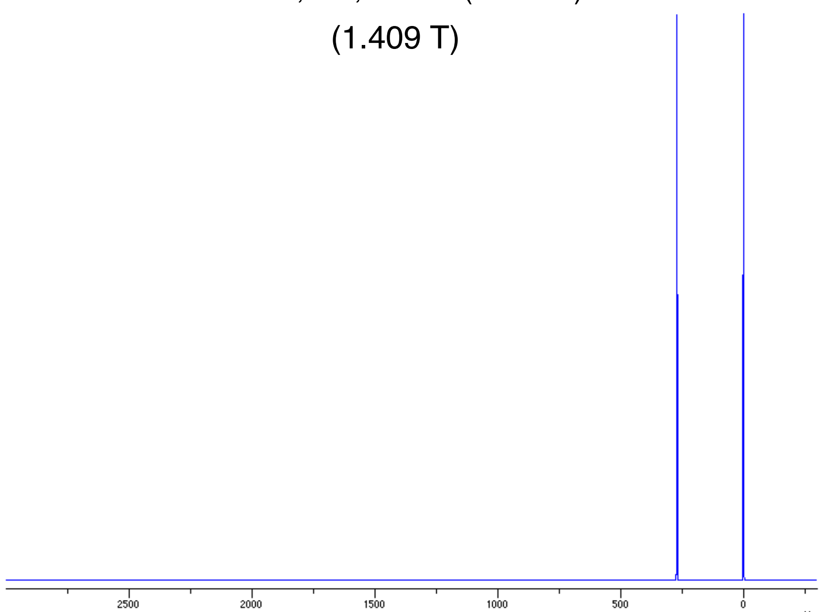
+ 60,000,000 Hz (60 MHz)

(1.409 T)



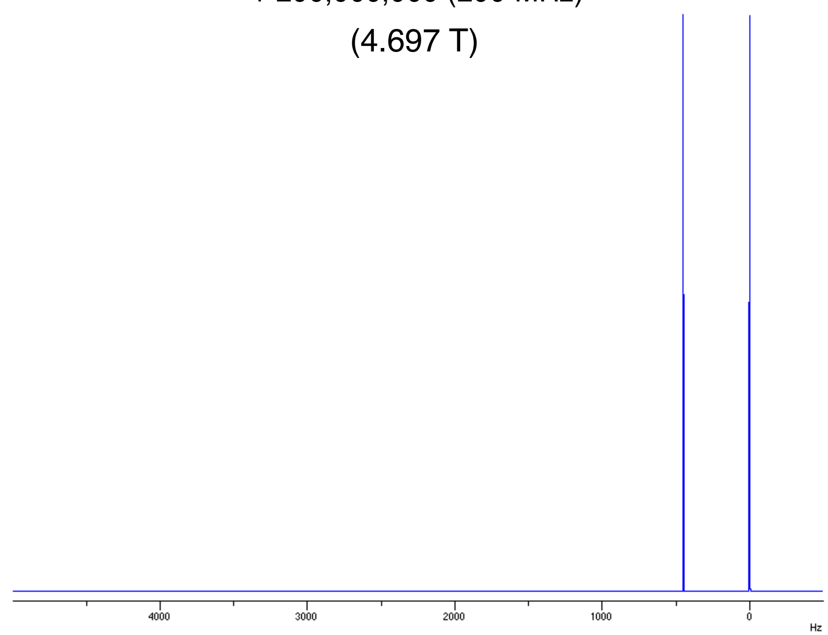
+ 200,000,000 (200 MHz)

(4.697 T)



+300,000,000 Hz (300 MHz)

(7.046 T)



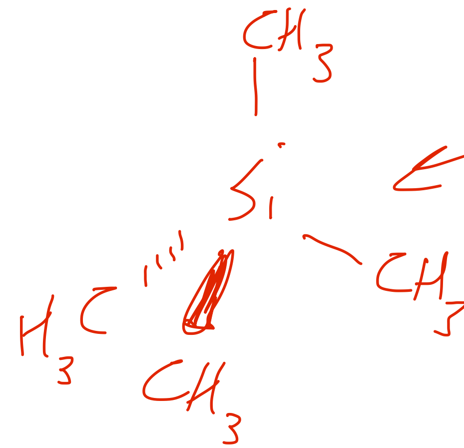
+ 500,000,000 Hz (500 MHz)

(11.743 T)

$$\delta \text{ ppm} = \frac{\nu_{(peak)}\text{Hz} - \nu_{(TMS)}\text{Hz}}{\nu_{(TMS)}\text{MHz}}$$

← reference molecule

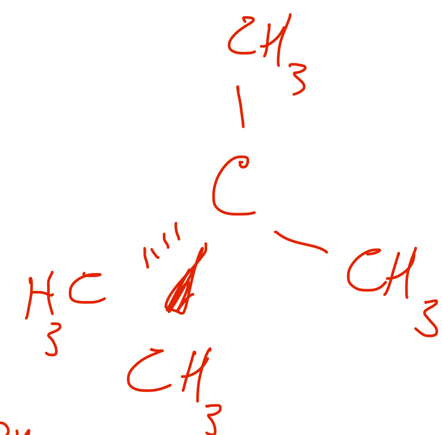
TMS = tetramethyl silane



← 0 ppm

1.409 T magnet TMS resonates at 60,000,000 Hz

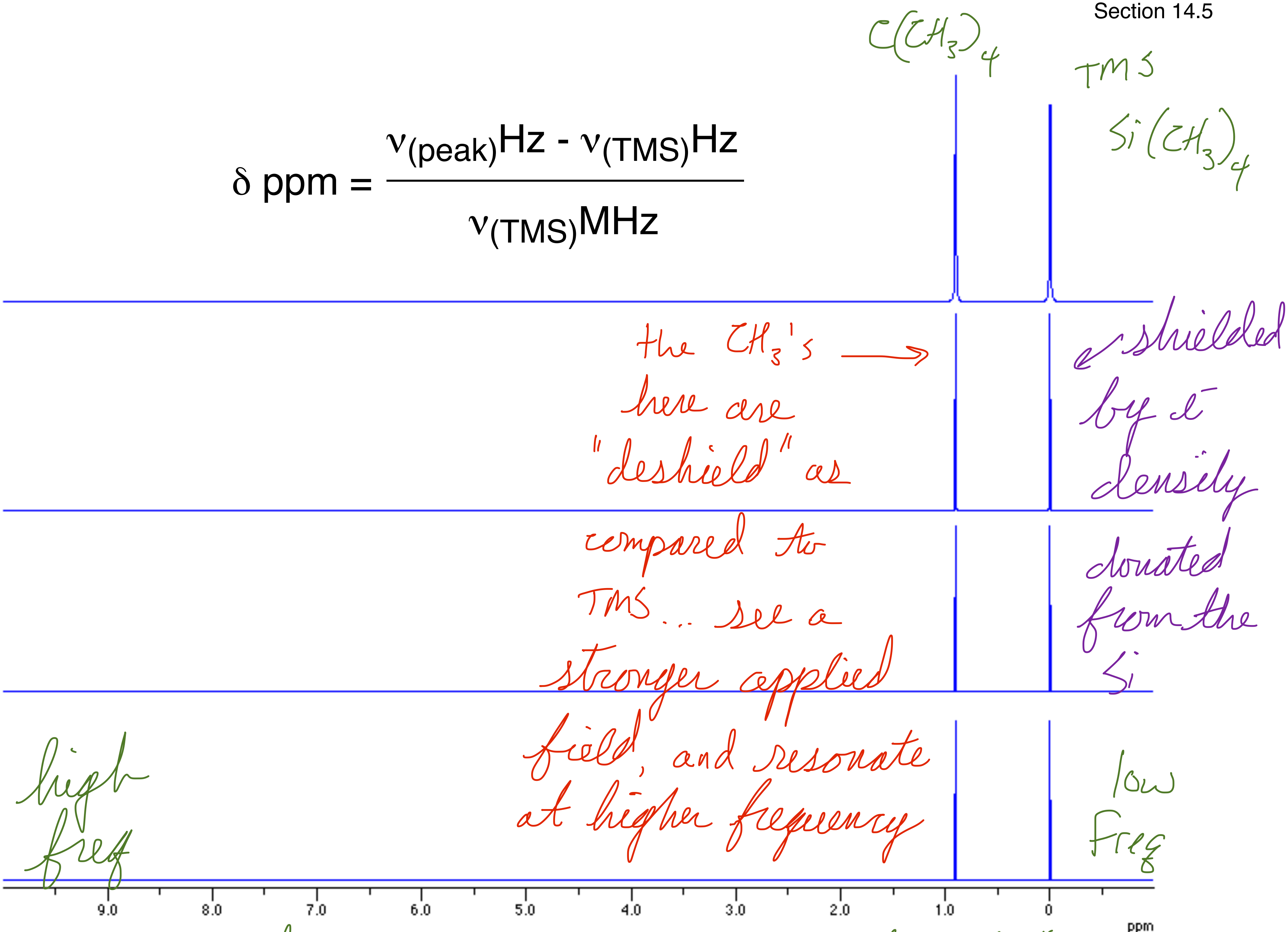
neopentane resonates at 60,000,054 Hz



0.9 ppm

$$\frac{(60{,}000{,}054 - 60{,}000{,}000)\text{ Hz}}{60 \text{ MHz}} = 0.9 \text{ ppm}$$

$$\delta \text{ ppm} = \frac{\nu_{(peak)}\text{Hz} - \nu_{(TMS)}\text{Hz}}{\nu_{(TMS)}\text{MHz}}$$



for historical reasons its "backwards"

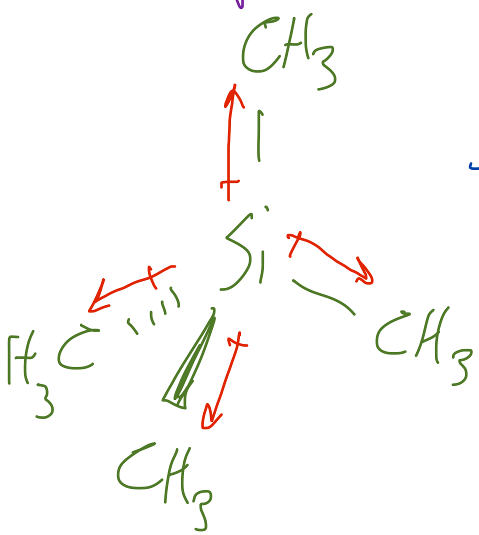
shielding causes these H's to "see" a weaker field & thus resonate at a lower freq

What gives rise to differences in chemical shift?

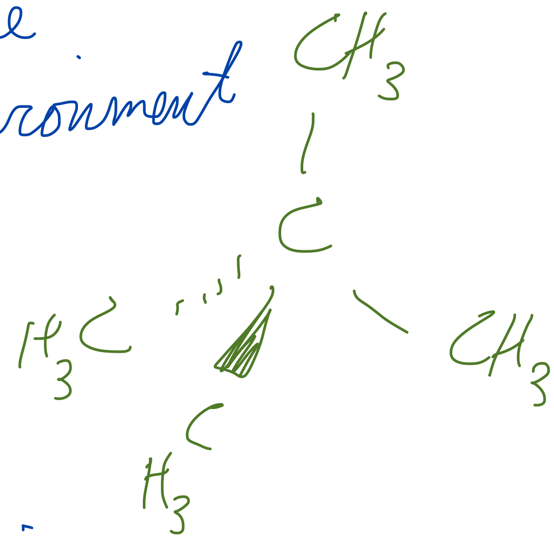
position in NMR spectrum

Why do the H's of tetramethylsilane resonate at a different frequency than 2,2-dimethylpropane?

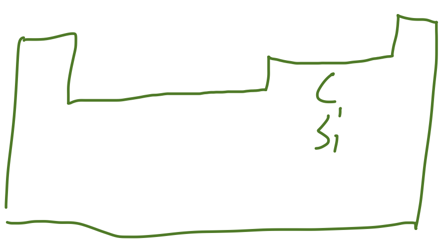
these H are in a more e^- rich environment



vs

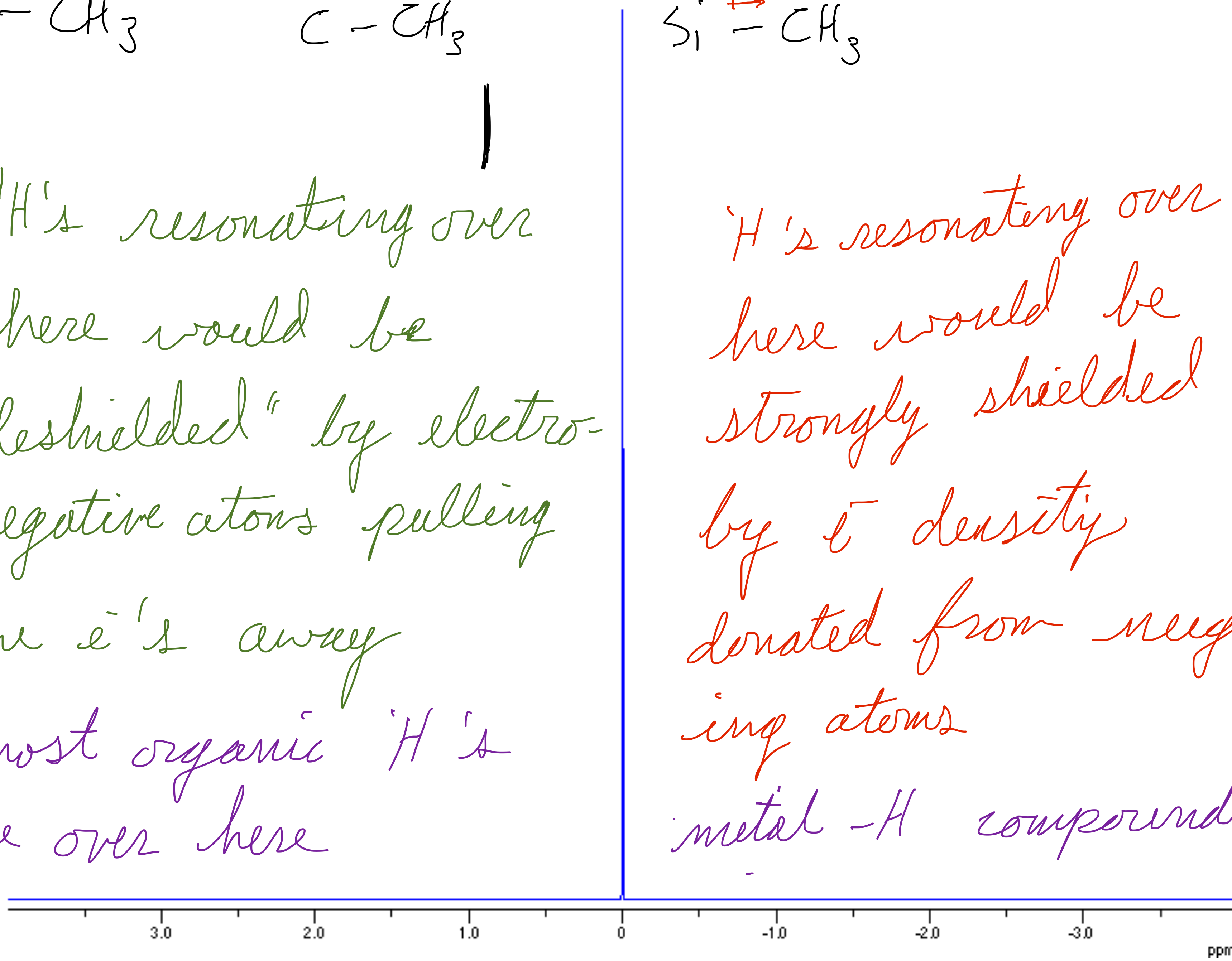


these moving e^-'s are creating a magnetic field which shields the H's from the applied field



TMS

$O \leftarrow CH_3$ $C - CH_3$ $Si \rightarrow CH_3$



^{1}H's resonating over here would be "deshielded" by electro-negative atoms pulling the e^-'s away

most organic ^{1}H's are over here

^{1}H's resonating over here would be strongly shielded by e^- density donated from neighbor-ing atoms

metal-H compounds