The intensity of the signal is proportional to the number of hydrogens that make the signal. Sometimes, NMR machines display signal intensity as an automatic display above the regular spectrum. (The exact number of hydrogens giving rise to each signal is sometimes also explicitly written above each peak, making our job a lot easier.) The intensity of the signal allows us to conclude that the more hydrogens there are in the same chemical environment, the more intense the signal will be.

### Introduction

We can get the following information from a $^1$H Nuclear Magnetic Resonance (NMR) structure:

1. **The number of signals** gives the number of non-equivalent hydrogens
2. **Chemical shifts** show differences in the hydrogens’ chemical environments
3. **Splitting** presents the number of neighboring hydrogens (N+1 rule)
4. **Integration** gives the relative number of hydrogens present at each signal

The integrated intensity of a signal in a $^1$H NMR spectrum (does not apply to $^{13}$C NMR) gives a ratio for the number of hydrogens that give rise to the signal, thereby helping calculate the total number of hydrogens present in a sample. NMR machines can be used to measure signal intensity, a plot of which is sometimes automatically displayed above the regular spectrum. To show these integrations, a recorder pen marks a vertical line with a length that is proportional to the integrated area under a signal (sometimes referred to as a peak)-- a value that is proportional to the number of hydrogens that are accountable for the signal. The pen then moves horizontally until another signal is reached, at which point, another vertical marking is made. We can manually measure the lengths by which the horizontal line is displaced at each peak to attain a ratio of hydrogens from the various signals. We can use this technique to figure out the hydrogen ratio when the number of hydrogens responsible for each signal is not written directly above the peak (look in the links section for an animation on how to manually find the ratio of hydrogens as described here).

Now that we’ve seen how the signal intensity is directly proportionate to the number of hydrogens that give rise to that signal, it makes sense to conclude that the more hydrogens of one kind there are in a molecule (equivalent hydrogens, so in the same chemical environment), the more intense the corresponding NMR signal will be. **Here’s a model that may help clear up some of the uncertainties. [NMR model]**

### Study tips

1. When trying to build a structure for an unknown molecule from NMR data, find a common divisor that reduces the integrated areas of all signals to small whole numbers when the exact number of hydrogens responsible of each peak is NOT given.
2. If, for example, the total number of hydrogens you count from your NMR spectrum is 5, but you know that there are supposed to be 10 hydrogens in the molecular formula, then it is a sure sign that the your molecule is symmetrical. You only find half the hydrogens in your NMR spectrum because the symmetry places hydrogens in the same chemical environment-- giving rise to the same peaks. (Again, the spectrum simply gives you a ratio.)
3. A peak with 3 hydrogens commonly belongs to a -CH$_3$ group.
4. More instructions on how to approach an NMR problem are given in the links below.
Outside Links

- Animation: how to manually find the ratio of hydrogens in a spectrum
  - http://www.wfu.edu/~ylwong/chem/nmr/h1/integration.html
- Clear cut instructions on how to approach a \textsuperscript{1}H NMR spectrum problem
  - http://www.chemhelper.com/nmrspechelp2.html

References

2. UC Davis 118A Supplementary Booklet for the Laboratory/Discussion (Fall quarter 2008)_ Page 39

Problems

1.) True or False? The number of hydrogens determines the intensity of a signal.
2.) Give the number of signals, the chemical shift value for each signal, and the number of integrating hydrogens for CH\textsubscript{3}OCH\textsubscript{2}CH\textsubscript{2}OCH\textsubscript{3}?

3.)

4.)
Answers

1. False. The *relative* number of hydrogens determines the intensity of a signal. The signal given by the three hydrogens in CH₃CH₂CHCl₂ will not have the same intensity as the three hydrogens in ClCH₂OCH₃.

2. There are 2 signals. One is at 3.3 ppm (6 hydrogens); the other at 3.5 ppm (4 hydrogens).

3. a and d

4. c

5. d