Week (7) Worksheet #4

1. (Klein 4th Ed. 15.35)
   a. All six methyl groups are equivalent (giving rise to one signal), while all four aromatic protons are also equivalent (giving rise to another signal). In total, we expect two signals.
   b. This molecule has no symmetry, so all four aromatic protons are in unique environments. Therefore, we expect four signals.
   c. This molecule has no symmetry, so all four aromatic protons are in unique environments. Therefore, we expect four signals.
   d. This compound has two different kinds of protons (highlighted below), giving rise to two signals.

   ![Chemical Structure]

   e. The methine (CH) proton gives one signal, while the two methyl groups collectively give one signal (with an integration of 6). In total, we expect two signals.

2. (Klein 4th Ed. 15.37)
   The first compound exhibits symmetry that causes some of the carbon atoms to be equivalent. As such, the first compound will have five signals in its 13C NMR spectrum. In contrast, the second compound lacks this symmetry. Each carbon atom occupies a unique environment, so the second compound is expected to produce seven signals in its 13C NMR spectrum.
3. (Klein 4th Ed. 15.80)

\[ N,N\text{-dimethylformamide (DMF)} \] has three resonance structures:

Consider the third resonance structure, in which the C-N bond is a double bond. This indicates that this bond is expected to have some double bond character. As such, there is an energy barrier associated with rotation about this bond, such that rotation of this bond occurs at a rate that is slower than the timescale of the NMR spectrometer. Therefore, the two methyl groups will appear as distinct signals in a 1H NMR spectrum and in a 13C NMR spectrum. At high temperature, more molecules will have the requisite energy to undergo free rotation about the C-N bond, so the process can occur on a timescale that is faster than the timescale of the NMR spectrometer. For this reason, the signals are expected to collapse into one signal at high temperature.

4. (Klein 4th Ed. 15.83)

The methyl group on the right side is located in the shielding region of the \( \pi \) bond, so the signal for this proton is moved upfield to 0.8 ppm.
5. The more electronegative atoms are bonded to a carbon, the greater the inductive effect will be. This results in a greater deshielding effect, so the chloroform carbon will appear most downfield (77.16 ppm in CDCl₃).

6. To determine the ratio of peak heights, count the number of lines that meet to make the line below it. For a simple triplet, the ratio of peak heights will be 1:2:1.