

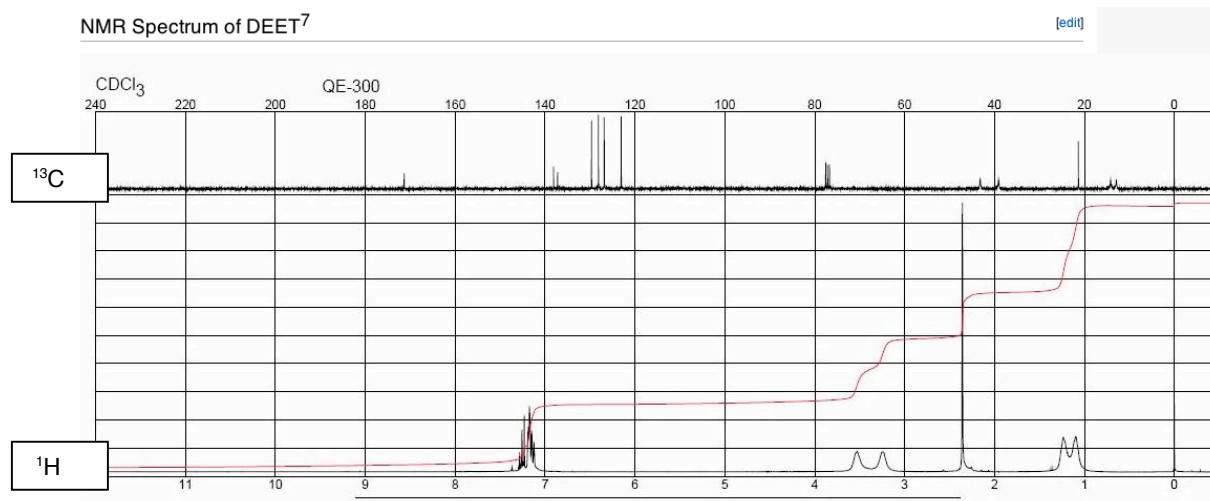
Name(s): _____
Chem 227/ Dr. Rusay

Sec. _____

DEET Postlab Questions

A) NMR: Resonance/ Rotations/ Conformations

Nuclear magnetic resonance occurs on a fairly slow time scale. Therefore, fast conformational/rotational changes are not discernable by NMR and the observed spectrum is the average spectrum of the interconverting molecules. In general, an averaged spectrum is observed when the rate of the process is 2π times the frequency difference, i.e. ($2\pi \times \Delta\nu$) between the peaks being observed. For example, consider a hypothetical molecule with two nonequivalent methyl groups with respective ^1H NMR chemical shifts of 3.0 and 3.5 ppm recorded on a 300 MHz instrument. The frequency difference between the two peaks is 150 Hz ($0.5 \text{ ppm} \times 300 \text{ Hz/ppm}$). If a bond rotation interconverted these methyl groups faster than 900 times per second (900 s^{-1}) as in the example, $2\pi \times 150 \text{ Hz} = 942 \text{ Hz} = 942 \text{ s}^{-1} = 942$ times per second), then these six protons would show up as a single peak at 3.25 ppm. In contrast, if the methyl groups interconverted much slower than 900 times per second, they appear as two distinct signals at 3.0 and 3.5 ppm. When the interconversion rate is greater or approximately equal to $2\pi \times \Delta\nu$, the six methyl protons appear as a single broad peak at the average chemical shift (3.25 ppm).

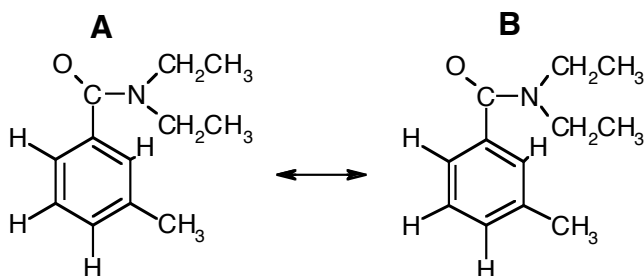


Therefore, at lower temperatures the change is slower and separate peaks are observed as in the DEET spectra above. At higher temperatures, one sharp peak at an average chemical shift value is observed. The ethyl groups in the ^1H spectrum above, which was recorded at 5°C , are very poorly resolved. It shows a pair of broad signals that appear to be singlets for each set of chemically equivalent protons in each ethyl group. These pairs represent two different rotational conformers, which can be related to their respective resonance structures.

The energy barrier to rotation about most carbon-carbon single bonds is usually on the order of 3-5 kcal/mol. This low barrier means that these bonds freely rotate. For instance, the C-C bond of ethane rotates approximately 10^{11} times per second at room temperature.

However, rotation about the C-N bond of an amide is constrained relative to the C-C bond. This can be explained by the amide's resonance structures, where the C-N bond has appreciable double bond character. In other words, rotation about the C-N bond disrupts the pi overlap between the carbonyl carbon and the nitrogen resulting in a much higher energy barrier (E_a) for bond rotation and hence additional NMR signals at low temperatures.

1. Refer to the DEET *NMRs* in the introduction. Complete the two DEET resonance structures shown below. Consider the ^1H *NMR* data and which protons are chemically equivalent and which are not. Number the chemically equivalent protons in the respective resonance structures, predict the theoretical signal splitting, and assign the peaks in the spectrum to their chemical shifts in the table below.



peak assignment #	peak splitting	peak assignment #	peak splitting

2. What are the relative percentages of **A** and **B** for the two respective resonance forms in the *NMR* mixture? Show your calculation and briefly explain your reasoning.

3. If the ^1H spectrum were recorded at room temperature, the two pairs of signals (4 total) collapse into two signals. Calculate the respective chemical shifts for the chemically equivalent protons of the ethyl groups at room temperature. (Note: the spectrum was recorded using a 300Mhz instrument.) Using *Acorn Nuts* process the ^1H *NMR* *fid* file for the experiment's composite DEET synthesis sample, which can be downloaded from the Chem 227 assignments page. Compare the chemical shifts of the ethyl group protons with your calculation. Attach a print out of the ^1H *NMR*.

- Using *Acorn Nuts* process the ^{13}C NMR *fid* file for the experiment's composite DEET synthesis sample, which can be downloaded from the Chem 227 assignments page. Attach a print out of the ^{13}C NMR. Compare the chemical shifts of the ethyl group protons with those in the introduction's ^{13}C NMR. Is the same conformational/rotational NMR phenomena observed as in the ^1H NMR? Provide a clear explanation citing chemical shift data.

B) Synthesis, Mode of Action & Toxicity of DEET

- Write an equation that describes the reaction of thionyl chloride with water.
- Write the reaction that would take place if the acid chloride of m-toluic acid were mixed with water.
- Why is the final reaction mixture extracted with saturated sodium chloride solution?
- If N,N-diethyl-m-toluamide distills at $165\text{ }^\circ\text{C}$ at 20 mm, what should its boiling point be at 760 mm?
- Write a mechanism for each step in the preparation of N,N-diethyl-m-toluamide.

10. Consult the following readings. Briefly describe how DEET works on a molecular level to repel mosquitoes. Include one drawing that best illustrates its mode of action.

Deet I: Science(2008) <http://chemconnections.org/organic/chem227/DEET-orig-Sci-08.pdf>

Deet II: Science(2008) <http://chemconnections.org/organic/chem227/DEET-sci-2008.pdf>

11. Advise Dr. R. if it would be wise for his two infant granddaughters to use DEET. Cite one or more reliable references to support your advice.