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LONG-RANGE SHIELDING EFFECTS OF THE OXIMIDO GROUP IN 4-tert-BUTYLCYCLOHEXANONE OXIME

W. F. Trager[a] and A. C. Huitric

College of Pharmacy, University
of Washington, Seattle, Washington

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In a recent communication (1) Saitô, Nukada and Ohno have reported observing a chemical shift difference between the C-2 and C-6 methylene hydrogens in the NMR spectrum of cyclohexanone oxime. Since Saitô et al. worked with a conformationally mobile compound, from which the chemical shifts of the observed signals are the time averaged positions of purely axial and equatorial environments for a given carbon atom, they were unable to detect any possible differences in the long-range effect of the oximido groups on an equatorial versus an axial hydrogen bonded to a specific carbon.

4-tert-Butylcyclohexanone oxime, with its absence of syn and anti isomers and its probable high degree of conformational homogeneity, presents an ideal system with which to study this effect.

The 60 mc NMR spectra of 4-tert-butylcyclohexanone oxime and 4-tert-butylcyclohexanone-3(axial),5,5-d_3 oxime in deuterochloroform are given in Figure 1. The lowest field signal at τ 6.61 is attributable to one hydrogen and must arise from one of the equatorial hydrogens adjacent to C-1 since

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[a] Public Health Service Predoctoral Fellow, Fellowship number 5-FI-18,507-03.

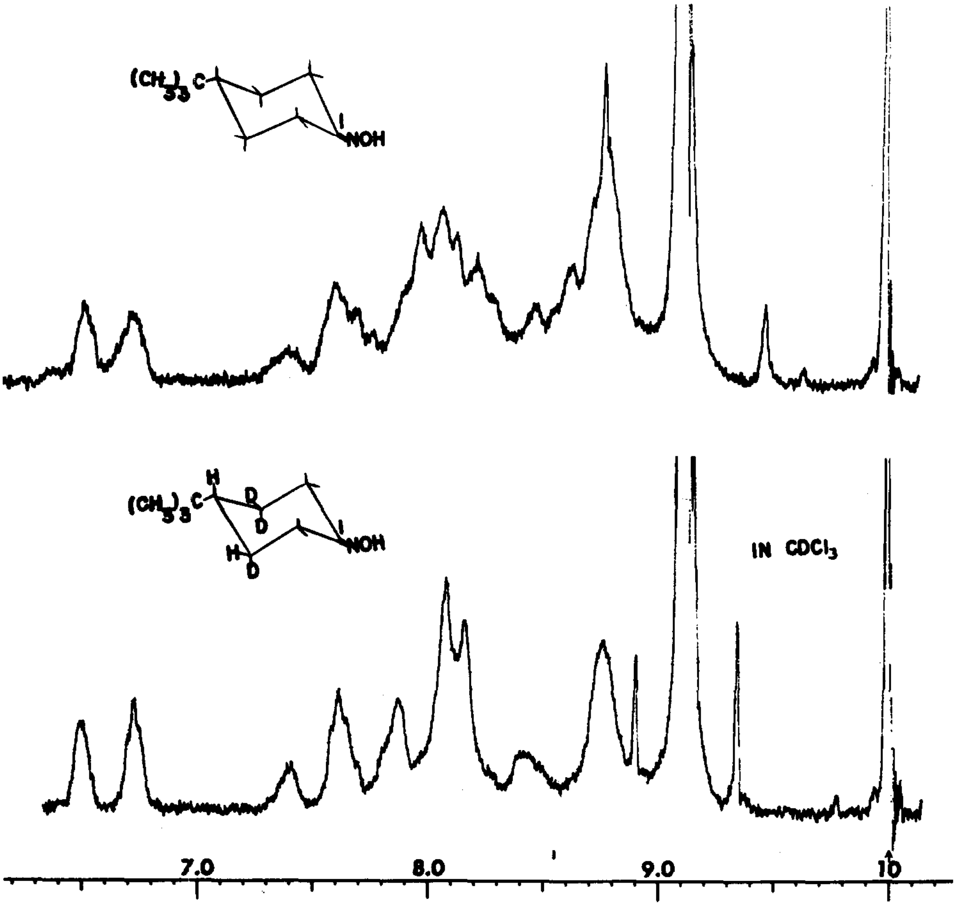

FIG. 1

NMR spectra of 4-tert-butylcyclohexanone oxime and 4-tert-butylcyclohexanone-3(axial),5,5-d_3 oxime in deuterochloroform at 60 mc and 37°. T.M.S. was used as internal reference.

it occurs basically as a doublet*, Jgem = 13.5 c.p.s. in the spectra of both

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* The smaller couplings Jae and Jee are not resolved and only the larger coupling, Jgem, governs the general appearance of the signal. If the signal were due to an axial hydrogen then it should appear as basically a triplet in the spectrum of the non-deuterated oxime due to the couplings Jgem$\simeq$Jaa.

the deuterated and non-deuterated oxime. The next signal upfield at τ 7.52 arises from the remaining equatorial hydrogen adjacent to C-1. The possibility of this signal being due to either of the axial hydrogens adjacent to C-1 is excluded as follows. In the non-deuterated compound an axial hydrogen at C-2 or C-6 would give essentially a triplet pattern due to Jaa and Jgem but the same signal of the deuterated compound would collapse to a doublet pattern. The chemical shift would not change and the doublet would be centered at the middle component of the triplet of the non-deuterated analog. A partially overlapped triplet for the signal of the non-deuterated compound is ruled out by the position of the doublet of the deuterated analog. Furthermore, the 100 mc spectra show discrete doublets for this signal in the non-deuterated and deuterated compounds. By comparison of the two spectra and from the spectrum of the deuterated compound at 100 mc[*] it is seen that the axial hydrogens adjacent to C-1 occur at approximately τ 7.95 and τ 8.29 but it is not possible to assign these signals to specific axial hydrogens from inspection alone.

Saitô and co-workers (1) found the chemical shift difference between the signals of the methylene hydrogens at C-2 and C-6 in cyclohexanone oxime to be 0.26 ppm in carbon tetrachloride with the lower field methylene signal occurring at τ 7.54 and the higher at τ 7.80. We have found τ 7.48 and 7.77 for these same signals in deuterochloroform. Since the chemical shift of each signal represents the time average position of an axial and an equatorial hydrogen of a given α-methylene group in the mobile system these same values

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[*] The 100 mc spectra were determined by Varian Associates in deutero-chloroform with T.M.S. as external reference and in pyridine using the α-hydrogen of pyridine as lock signal. At 100 mc in deuterochloroform the partially overlapped signal which appears at $\tau \simeq 8.29$ in Fig. 1 shows up as a distinct doublet about 1.68 ppm upfield from the signal shown at τ 6.61 in Fig. 1. The partially overlapped signal which appears at $\tau \simeq 7.95$ in Fig. 1 is not completely unmasked in deuterochloroform at 100 mc but its position can be measured as 0.43 ppm upfield from the signal at τ 7.52. At 100 mc in pyridine this signal is seen as a distinct doublet.

should be obtained by taking the average of the chemical shifts of the signals of the equatorial and axial hydrogens bonded to C-2 and to C-6 in 4-_tert_-butylcyclohexanone oxime, or its deuterated analog. The average of the chemical shifts of the equatorial hydrogen at τ 6.61 and the axial hydrogen at τ 8.29 is 7.45. The average of the signals at τ 7.52 and 7.95 is 7.74. These sets, therefore, comprise the two methylene groups at C-2 and C-6 in 4-_tert_-butylcyclohexanone oxime. On one of the methylene carbons adjacent to the oximido group the signals of the equatorial and axial hydrogens are about 1.68 ppm apart while on the other α-methylene group they are only 0.43 ppm apart. The large difference between the chemical shifts of hydrogens on a given α-methylene carbon in 4-_tert_-butylcyclohexanone oxime, contrasted to the equivalence of such chemical shifts in the mobile cyclohexanone oxime, indicates that contribution from flexible conformations must be minimal in the former. The structure of 4-_tert_-butylcyclohexanone oxime in solution in chloroform is probably best represented as a rigid chair conformation.

The large difference on the geometrical dependence of the deshielding effect on each side of the oximido group provides an explanation for the perplexing observation of almost identical chemical shifts for the two methyl groups in acetone oxime but a large difference in the chemical shifts of the two methine hydrogens in diisopropyl ketone oxime (5). This also explains the fact that in mixtures of _syn_ and _anti_ isomeric oximes of methyl ketones there is a significant difference in the chemical shifts of the α-methylene hydrogens but little difference, if any, for the chemical shifts of the α-methyl groups in the two isomers (5)*. Protons of freely rotating α-methyl groups pass

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* Oxime formation from 1-phenyl-2-propanone, in this laboratory, has yielded a mixture of two isomers in ratio of about 2 to 1. The NMR spectrum of the mixture in CCl_4 gives a single methyl peak at τ 8.26 and two signals in ratio of 2 to 1 at τ 6.55 and τ 6.30 attributed to the α-methylene hydrogens of the _syn_ and _anti_ isomers. The α-methylene hydrogens of the isomer in smallest amount are deshielded the most. Work is in progress to characterize the two oximes. In pyridine the signals of the methyl groups of the two isomers are separated by about 4 c.p.s.

through different limits of maximum and minimum deshielding when located on opposite sides of the oximido group but fortuitously the time average chemical shifts become almost identical for the two sides. The nonequivalences of the methine protons in diisopropyl ketone oxime and the α-methylene protons of isomeric oximes of certain methyl ketones must result from higher populations of preferred conformations, on a time average, because of restricted rotation. This will cause the differences on geometrical dependence of the deshielding effect on the two sides of the oximido group to come into play.

The geometry of the magnetic anisotropy of the oximido group is not known with certainty. Saitô and co-workers (1-4) have attributed the greatest deshielding effect to the proximity of the unshared pair of electrons on the nitrogen, but evidence is also found (5-9) which indicates that the largest deshielding effect is caused by the proximity of the hydroxyl group.

4-tert-Butylcyclohexanone-3(axial),5,5-d_3 oxime was prepared from 4-tert-butylcyclohexanone-3(axial),5,5-d_3 (10). The corresponding non-deuterated oxime is a known compound. (11).

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