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COMPARATIVE CONTRIBUTIONS OF CARBONYL AND THIOCARBONYL GROUPS TO MAGNETIC ASYMMETRY. CREATION OF A CHEMICAL SHIFT DIFFERENCE OF 2 PPM BETWEEN GEMINAL PROTONS OF A BENZYL GROUP.*

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It has frequently been observed that the two geminal hydrogens of a substituted methyl group, $-CH_2X$, may differ in chemical shift and appear as a pair of doublets of the AB type in the nuclear magnetic resonance spectra of molecules which have no plane of symmetry incorporating the bond joining the group $-CH_2X$ to the rest of the structure (1-7). In discussing magnetic effects in such systems it is useful to regard the molecule as composed of two parts, the monosubstituted methyl group and the unsymmetrical structural unit (unsymmetrical with respect to any plane passed through $-CH_2X$) which represents the rest of the molecule. It follows from symmetry considerations that a shift difference would not be

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observed between protons in an unsubstituted methyl group attached to an unsymmetrical unit unless the methyl rotation were "frozen out" (6). The substituent X in $-CH_2X$ makes the shift difference possible by a direct contribution to the magnetic asymmetry affecting the two protons and/or by the introduction of steric effects which create inequalities among conformer populations (1-7).

We have found a system in which a shift difference of nearly 2 ppm is established between the methylene protons of a benzyl group attached to an unsymmetrical unit. The n.m.r. spectrum of trans-1-benzyl-4-methyl-5-phenyl-2-imidazolidinone (I) contains pairs of doublets with equal coupling constants (J_{ab} = 15 cps) which must be assigned to the methylene protons (at (a) and (b)) of the N-benzyl group. (See Table I; all spectra were taken at room temperature in deuterochloroform at 60 Mc with tetramethylsilane as the internal reference.) These protons differ in chemical shift by 1.3 ppm. The shift difference approaches that (1.75 ppm) reported by Lewin, Lipowitz and Cohen in the accompanying communication (8) for hydrogens having a similar location (at (a) and (b)) in the phthalimidine derivative VI. The already exceptional shift difference becomes 1.85 to 1.99 ppm when the carbonyl oxygen of I is replaced by sulfur as in the trans and cis-1-benzyl-4-methyl-5-phenyl-2-imidazolidinethiones (II) and (III). Any uncertainty regarding the assignment of the widely spaced doublets to the geminal protons of the N-benzyl group in II and III was removed by comparison of the n.m.r. spectra of II and III with those of the N-methyl analogues IV and V. The pairs of doublets were absent from the

TABLE I

Nuclear Magnetic Resonance Data

Compound	Proton Position	Line Positions (cps separation from TMS)	Chemical Shift, τ-scale	Chemical Shift Difference, ppm
I	a	303, 288	5.08	1.30
	b	222, 207	6.38	
	c	237, 230	6.12	
	d	216*	6.40	
	e	74, 68	8.82	
II	a	344, 329	4.40	1.85
	b	233, 218	6.25	
	c	252, 244	5.87	
	d	228*	6.20	
	e	77.8, 71.1	8.75	
III	a	351, 336	4.27	1.99
	b	232, 217	6.26	
	c	287, 277.5	5.30	
	d	261*	5.65	
	e	53, 47	9.17	
IV	a	181	6.98	
	c	298, 288	5.13	
	d	288*	6.20	
	e	53, 46	9.17	
V	a	174	7.10	
	c	262, 253	5.71	
	d	228*	6.20	
	e	84, 78	8.65	

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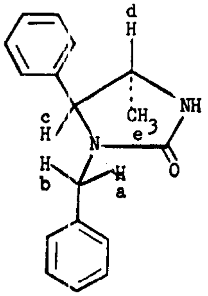
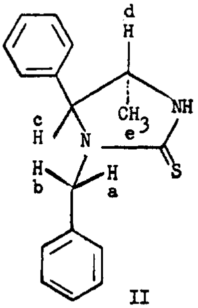
* Approximate center of multiplet.



I



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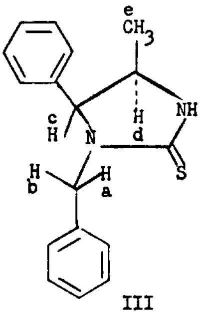

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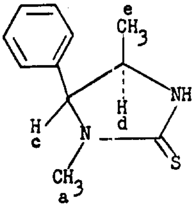

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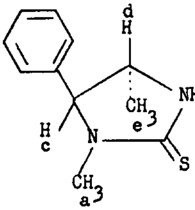

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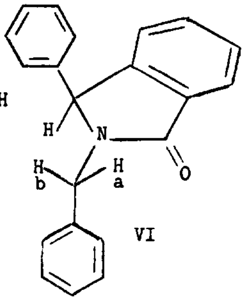

VI

spectra of the latter substances, and were replaced by a single line corresponding to the N-methyl group.

Comparison of the shifts of the individual geminal protons of the N-benzyl group in compound I with those observed for compounds II and III shows that the signals from the proton appearing at higher field have been moved downfield in the thio compounds by only 0.12 to 0.13 ppm, whereas the signals from the proton appearing at lower field are moved farther downfield by 0.55 to 0.69 ppm. Thus, the change from a carbonyl group to a thiocarbonyl group has resulted in a deshielding effect confined largely to one proton of the geminal pair. These observations are consistent with the hypothesis that the preferred conformation of compounds I, II and III approximates that represented in the formulas given. In such a conformation the proton at position (a) in compound I would reside in the deshielding region close to the plane of the carbonyl group (9), whereas the proton at (b) would be properly located to experience a shielding effect from the phenyl group (see ref. 8) at position 5 of the imidazolidine ring. The change from carbonyl to thiocarbonyl would presumably have little influence on the field affecting a proton residing mainly at (b), but it should have a pronounced influence on the magnitude of the field affecting a proton at (a). Although the virtually unchanged chemical shift of the upfield proton might be consistent with a change in conformational preferences if there chanced to be a compensation of resulting changes in shielding and deshielding influences, it seems more likely that the absence of any marked conformational change is indicated. It thus appears likely that the large effect on the downfield proton of replacing oxygen by sulfur is largely the result of altering the magnetic field gradients associated with the unsymmetrical structural unit, and provides a rough comparison of the magnetic anisotropies of the carbonyl and thiocarbonyl groups. That the anisotropy of the thiocarbonyl group should be greater than that of the carbonyl group is consistent with the fact that replacement of a carbonyl group by a thiocarbonyl group normally has a bathochromic effect (10). The electron circulations giving rise to magnetic anisotropy are associated with the possibility of n $\longrightarrow \pi^*$ electronic transitions, which are evidently of lower energy in the thiocarbonyl group.[†]

No other instance in which a shift difference as large as 1.99 ppm has been observed between diastereomeric[‡] geminal protons on a carbon capable of undergoing rotation has come to our attention, although separation of geminal protons approaching this magnitude has been observed very recently in a ferrocene derivative (1.66 ppm separation) obtained by Slocum, Smith and McLeskey (11), as well as in the phthalimidine VI (8). Larger shift differences (up to 5.8 ppm) have, however, been seen between geminal protons of a ring methylene group fixed in orientation and unsymmetrically placed with respect to the plane of a structure exhibiting electronic ring currents (13).

The cis or trans relationships of the phenyl and methyl substituents in compounds I-V were assigned on the basis of the chemical shift of the doublet arising from the 4-methyl group (labeled (e)). The upfield position of this doublet in compounds III and IV as compared to its

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[†] We are indebted to Professor John A. Pople for pointing out this relationship.

[‡] It has been proposed by Mislow and his associates (12) that geminal protons having non-equivalent environments be termed "diastereomeric" protons.

position in the spectra of II and V can be attributed to long-range shielding by a cis-5-phenyl group, which would be close to the 4-methyl group and would tend to be held in a position such that the methyl group would lie in the shielding region above the face of the benzene ring. Hyne (14) has correlated this effect with configuration in analogous oxazolidine derivatives. The magnitude of the shielding observed is consistent with calculations based on the work of Johnson and Bovey (15). Compounds I-V were prepared by the action of diethyl carbonate or carbon disulfide on 1,2-diamines, and all were easily characterized crystalline substances which showed the expected compositions and infrared spectra.

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