Nuclear Spin–Spin Interactions. Effect of Nitrogen Lone-pair Orientation on Geminal ^{15}N–^{1}H Spin–Spin Coupling†

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IT has been reported recently that electronic "lone pairs" on nitrogen or oxygen atoms may affect geminal or vicinal proton–proton coupling constants in adjacent CH_2 or CH–CH fragments.[1–3] We report here a very striking effect of nitrogen lone-pair orientation on ^{15}N–^{1}H coupling constants in N=CH fragments.

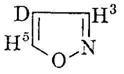
Using hydroxylamine hydrochloride 57% enriched in ^{15}N (spin $\frac{1}{2}$), we prepared the oximes (I—IV) as well as isoxazole (V). The ^{15}N=CH coupling constants measured for these compounds are reported in the Table. In the monodeuterated isoxazole (V) a 15 c./sec. coupling is observed in Me_2SO solution. This compound may be considered as an oxime locked in the *anti*-configuration.

The n.m.r. spectra of the oximes from propionaldehyde and from phenylacetaldehyde contain the signals from both *syn*- and *anti*-isomers. The measured ^{15}N=CH couplings are *ca.* 3 c./sec. for one form and *ca.* 16 c./sec. for the other. Comparing these values with the coupling observed in compound (V), it follows that the 16 c./sec. splitting is to be attributed to the *anti*-forms (Ib) and (IIb); the 3 c./sec. coupling arises from the *syn*-forms (Ia) and (IIa). Steric hindrance in the oximes from pivalaldehyde and from benzaldehyde should favour the *syn*- over the *anti*-form. Indeed only one form is present in the spectra of these compounds, showing a ^{15}N=CH coupling of *ca.* 3 c./sec. It follows that, as expected, these oximes exist in the *syn*-forms (IIIa) and (IVa).

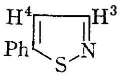
These results show a very strong dependence of the ^{15}N=CH coupling on the oxime configuration. The question then arises whether this is mainly due to the effect of the nitrogen lone-pair or of the substituent on nitrogen. 5-Phenylisothiazole, 95% ^{15}N-enriched (VI), shows a coupling of *ca.* 14 c./sec. between ^{15}N and H-3.[4] [$^{15}N_2$]-2,4-Dichloropyrimidine shows a 12·5 c./sec. ^{15}N=CH coupling.[5] [$^{15}N_5$]-Adenosine triphosphate presents a 10 and a 15 c./sec. ^{15}N=CH coupling.[6] Furthermore, compounds (VII)[7] and (VIII)[8] show a *ca.* 4 c./sec. coupling. Comparing these values with those obtained from the oximes, it is apparent that the *main factor* affecting the ^{15}N=CH coupling constants is the orientation of the nitrogen lone-pair with respect to the C–H bond. A *cis*-relationship (*anti*-form) leads to a 10—16 c./sec. coupling. A *trans*-relationship (*syn*-form) leads to a 2—4 c./sec. coupling.

a (*syn*) b (*anti*)

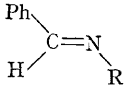
(I) R=Et; (II) R=CH_2Ph; (III) R=Bu^t; (IV) R=Ph



(V)



(VI)



(VII) R=Me
(VIII) R=Ph

[^{15}N throughout]

Removing the lone pair by protonation should then give similar N=CH couplings for the protonated *syn*- and *anti*-forms. Protonation greatly reduces the ^{15}N-H-3 coupling in compound (VI): the n.m.r. spectrum of (VI) in conc. H_2SO_4 shows a 4·2 c./sec. splitting. On the other hand, the spectrum of the *syn*-oxime (IIIa) in conc. H_2SO_4 displays a 3·5 c./sec. ^{15}N=CH coupling. These results again indicate that the nitrogen lone-pair orientation is the main factor influencing ^{15}N=CH coupling constants, and that a lone pair *cis* to the C–H bond strongly enhances the absolute value of the coupling.

The vicinal $\overset{+}{H}N$=CH coupling constants of 14·4 and 4·2 c./sec. measured respectively for compounds (IIIa) and (VI) in conc. H_2SO_4 correspond to a *trans*- and a *cis*-H–H coupling as expected for vinylic protons (see footnotes b, c of the Table).

Several corollaries may be drawn from the above results:

(1) It should be easy (although expensive!) to determine in an unambiguous way, the

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† Previous Paper in this series: J. M. Lehn and R. Seher, *Chem. Comm.*, 1966, 847.
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TABLE

$^{15}N{=}CH$ *Coupling constants.*[a]

Compound	Solvent	$J(^{15}N{=}CH)$ in c./sec.	Chemical shift of H of the N=CH fragment, in p.p.m.
(I)	Pentane	3·0	—
	CH_2Cl_2	2·95	7·50
(Ib)	Pentane	15·45	—
	CH_2Cl_2	16·25	6·75
(IIa)	$CDCl_3$	2·9	7·50
	Me_2SO	2·9	—
(IIb)	$CDCl_3$	15·8	6·85
	Me_2SO	16·0	—
(IIIa)	Pentane	3·0	—
	CH_2Cl_2	2·8	7·35
	Me_2SO	2·8	7·20
	H_2SO_4	3·5[b]	—
(IVa)	$CDCl_3$	2·6	8·15
(V)	Me_2SO	15·0	8·60
(VI)	$CDCl_3$	14·2	8·40
	H_2SO_4	4·2[c]	—
(VII)	Me_2SO	3·9 (see ref. 7)	
(VIII)	$CDCl_3$	3·8 (see ref. 8)	

[a] Measured on a Varian A-60 spectrometer using side-band modulation for calibration. The various other couplings will be reported in the final Paper. Couplings are ± 0·1 c./sec.; Shifts are ±0·02 p.p.m., from internal Me_4Si.

[b] $J(H\overset{+}{N}{=}CH) = 14\cdot4$ c./sec., *trans*-H–H coupling.

[c] $J(H\overset{+}{N}{=}CH) = 4\cdot2$ c./sec., *cis*-H–H coupling.

configuration of the double bond in compounds of the type $XCH{=}NY$ from $^{15}N{=}CH$ coupling constants. The present results on oximes are in agreement with the former assignments.[9]

(2) Protonation (or in general quaternisation) of the nitrogen in the *anti*-form leads to a decrease in the N=CH coupling parallel to the disappearance of the nitrogen lone-pair.

(3) From the dependence of the $^{15}N{=}CH$ couplings on lone-pair orientation (and also on N–C–H angle[10]) indications on lone-pair delocalization (*e.g.*, into C–H bonds) may be obtained. Recent calculations on $CH_2{=}NH$ show such delocalization.[11]

(4) The broadening of the n.m.r. signals of the protons α to nitrogen in ^{14}N-containing heterocycles arises from incomplete washing out of the large $^{14}N{=}CH$ coupling by quadrupolar relaxation of the nitrogen nucleus.

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[10] Unpubished results.

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