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A SIMPLE H^1 NMR APPROACH TO THE CONFORMATIONS OF α,β-DIARYLACRYLONITRILES[1]

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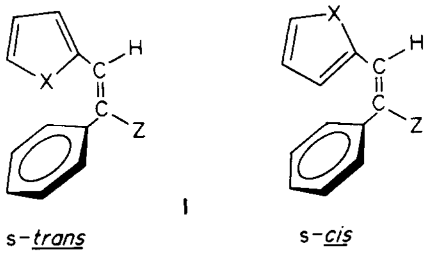
Abstract—Room temperature 60 MHz NMR data of α,β-diarylacrylonitriles were interpreted in a search for a method for routine stereochemical assignments and to establish the conformational preferences of the β-heterocyclic ring. The conformation of the α-phenyl group differs from that of diaryl ethylenes previously investigated. Solvent effect on the conformations is observed only for pyrrole derivatives.

Our previous work was related to the stereochemical and conformational study of (*E*)-α,β-diaryl-ethylenes **1** containing a -COOH or a $-NO_2$ group in α position, and a five-membered heterocyclic nucleus in β position.[2–4]



1

X=O, S, N−CH_3
Z=−COOH, $-NO_2$

Scheme 1.

These molecules may exist in both s-*trans* and s-*cis* conformations. We pointed out that the interaction between the heteroatom and the π orbital of the orthogonal phenyl ring may strongly affect the stability of the favoured s-*trans* conformation giving a relevant contribution to the conformational behaviour of the molecules **1**.

In connection with these studies, we now report the results for some α,β-diaryl-acrylonitriles **2**, where the -COOH or the NO_2 group is replaced by -CN group, which we have observed to give rise to quite different stereochemical features.

RESULTS AND DISCUSSION

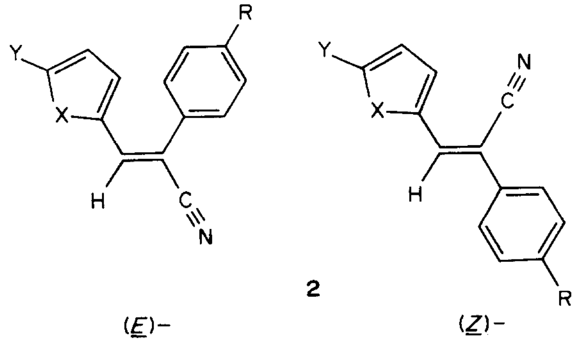
Different synthetic routes have been used (see Experimental) to prepare the (*E*)- or (*Z*)-isomers **2**.

The assignment of stereochemistry was confirmed by ^{1}H-NMR data. In contrast with what was observed for α,β-diaryl-acrylic acids,[4–6] no remarkable differences appear in chemical shift values of the ethylene proton between the (*E*) or (*Z*)-isomers **2** (Table 1). This approach therefore cannot be used for the assignment of configuration.

However the ^{1}H-NMR spectrum of the (*E*)-α-phenyl-β-(*p*-methoxyphenyl) acrylonitrile (Fig. 1) shows the AA'BB' pattern of the β-*p*-substituted nucleus, where AA' resonate at higher fields, and a singlet corresponding to five protons that should be attributed to the α-phenyl. On the other hand the PMR spectrum of the corresponding (*Z*)-isomer (Fig. 1) shows that: (a) the BB' protons are strongly deshielded, whereas the AA' ones remain substantially at the same field; (b) the singlet of the α-phenyl is changed into a complex system that absorbs from 7.2 to 7.7 δ (ppm).

The paramagnetic shift of BB' protons should be ascribed to a deshielding effect of the electronic current of the near cyano group. The same behaviour is observed (Table 1) for the other pairs of the (*E*) and (*Z*) isomers **2** which contain a phenyl ring in the β position. The position of the BB' protons in the ^{1}H-NMR spectrum and the shape of the signal of the α-unsubstituted phenyl may then allow the configurational assignment to similar diaryl-acrylonitriles.

For **2** in β-furyl or β-thienyl series only the shape of

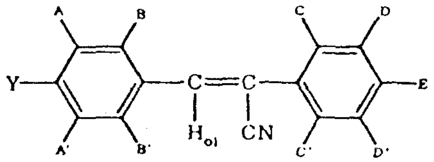


2

X=−CH=CH−   Y=H, O−CH_3, NO_2 R=H
X=O, S, N−H, N−CH_3 Y=H   R=H, CH_3

Scheme 2.

Table 1. Chemical shifts (δ, ppm) of the protons of some (E)- and (Z)-α,β-diaryl-acrylonitriles



	(Z)-				(E)-			
	H_{ol}	$H_{AA'}$	$H_{BB'}$	$H_{CC'DD'E}$	H_{ol}	$H_{AA'}$	$H_{BB'}$	$H_{CC'DD'E}$
Y = H	7,52	(7,33-8,00) (m)			7,33	7,18		7,33 (s)
Y = O-CH_3	7,43	6,93	7,87	(7,20-7,70) (m)	7,26	6,71	7,11	7,37 (s)
Y = NO_2	7,60	8,33	8,01	(7,40-7,82) (m)	7,35	8,08	7,30	7,35 (s)

s= singlet m= multiplet

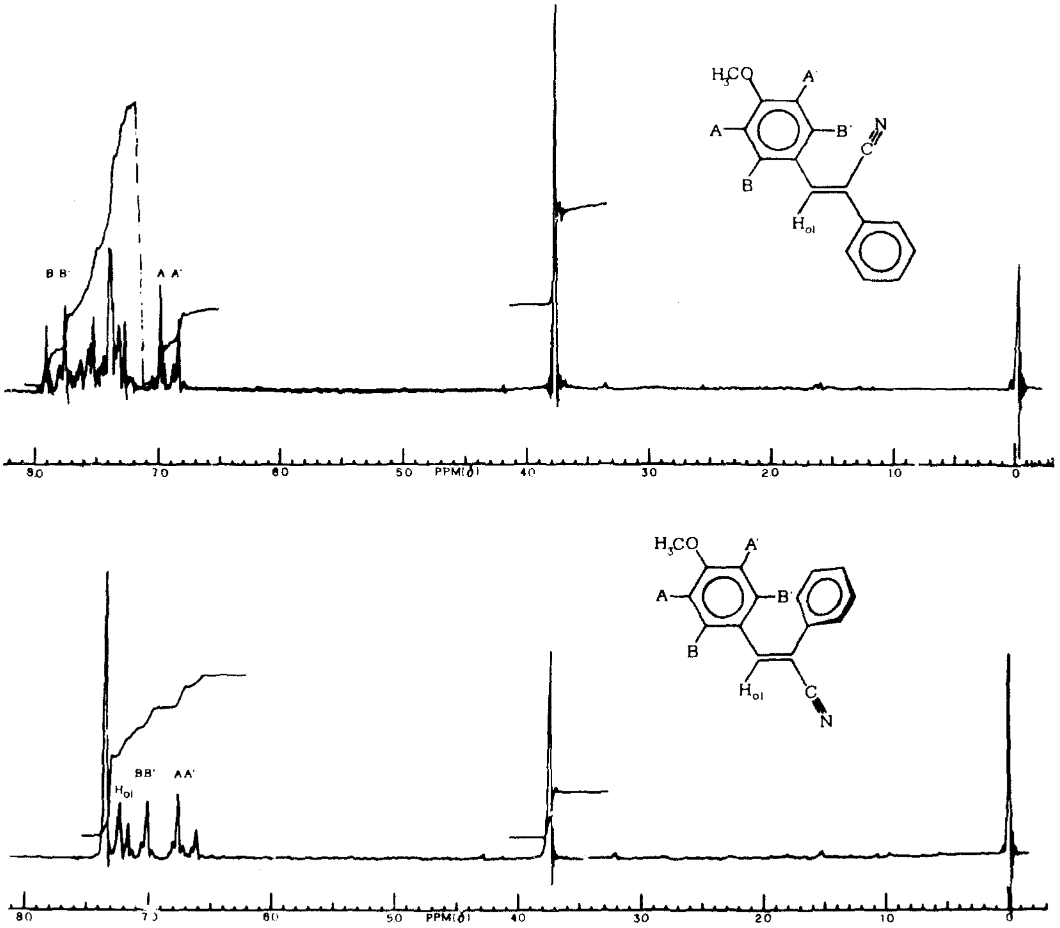
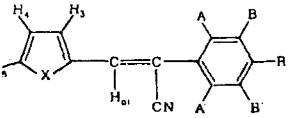


Fig. 1. PMR spectra of the (E)- and (Z) - α - phenyl - β - (p - methoxy - phenyl)acrylonitriles.

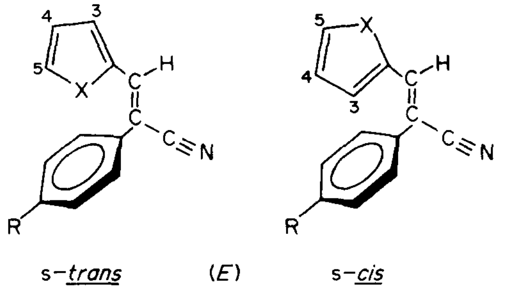
the phenyl signal can be used for the configurational assignment. As expected, ^{1}H-NMR data (Table 2) exhibited a singlet in the (E)-structure that changed into a complex pattern in the (Z)-isomer. In the case of **2** (X = N-H, N-CH_3, Y = H, R = H, CH_3) only the (Z)-isomers have been synthesized, whose ^{1}H-NMR data are here reported below.

Because of poor solubility at low temperature we could not accomplish low temperature ^{1}H-NMR spectra to provide insight on the population of s-*trans* and s-*cis* rotamers of the acrylonitriles **2** containing a β-heterocyclic nucleus. However, from PMR room temperature data it is possible to establish whether s-*trans* or s-*cis* is the preferred conformation.

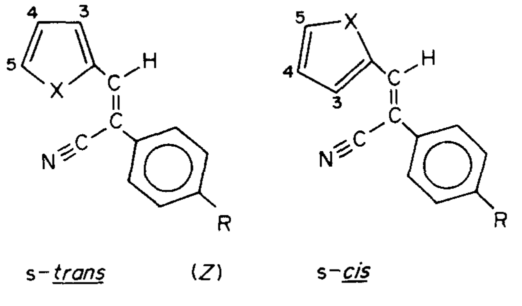
Table 2. Chemical shifts (δ, ppm) of the protons of some (E)- and (Z)-α,β-diaryl-acrylonitriles 2 in CDCl$_3$



X=	R=		H_{ol}	H_3	H_4	H_5	$H_{AA'}$	$H_{BB'}$
S	H	($\underline{E}$)-	7.40	7.08	6.88	7.20	7.40	
S	H	($\underline{Z}$)-	(7.21-7.95)	(7.21-7.95)	(7.21-7.95)	(7.21-7.95)	(7.21-7.95)	
S	CH_3	($\underline{Z}$)-	7.55	7.50	7.10	7.60	7.48	7.20
O	H	($\underline{E}$)-	7.05	6.30	6.30	7.30	7.38	
O	H	($\underline{Z}$)-	(7.15-7.70)	(7.15-7.70)	6.35	(7.15-7.70)	(7.15-7.70)	
O	CH_3	($\underline{Z}$)-	7.30	7.16	6.53	7.30	7.50	7.20



Scheme 3.



X=O, S, N-H, N-CH$_3$;
R=H, CH$_3$.

Scheme 4.

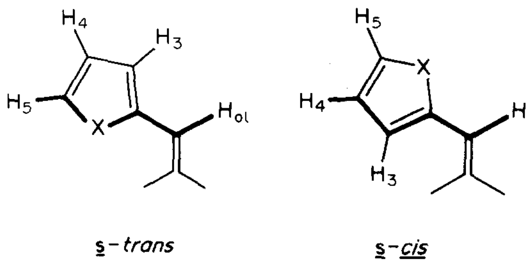
The signal of H-5 of the (E)- and (Z)-thiophene derivatives 2 (X = S, Y = H) exhibits a noticeable stereospecific long-range spin–spin coupling (0.7 Hz) with the ethylene proton. A multiplicity of eight lines (first order) appears because of the couplings with H$_3$, H$_4$ and ethylene proton. As previously observed,[3–4,7–10] a *trans* coplanar disposition (dihedral angle 0°) is necessary for the $^5J_{H,H}$ (W-plan) coupling. No coupling is observed between H-4 and the olefinic proton, the H-4 signal appearing as a clean first order quartet (doublet of doublets) because of the spin-spin couplings with H-3 and H-5. The s-*trans* conformation seems to be preferred.

On the contrary, in the case of the (Z) - α - phenyl - β - (2 - furyl)acrylonitrile 2 (X = O, Y = H, R = CH$_3$), a ^5J_W of 0.7 Hz between H$_4$ and H$_{ol}$ is observed, whereas no coupling occurs H$_5$–H$_{ol}$. Moreover a marked deshielding is noticed (Table 2) on H$_3$ because of the cyano magnetic anisotropy. This effect is better shown by comparison with H-3 chemical shift of the corresponding (E)-isomer, where because of the distance of cyano group the H-3 signal remains at usual field values. No differences are observed in both H$_4$ and H$_5$ chemical shifts between the (E) and the (Z) structure, this indicating that the H$_3$ paramagnetic shift of the (Z)-isomer is due exclusively to a conformational factor. Clear evidence of the s-*cis* conformation preference is then given. This behaviour could be ascribed to the destabilization of the thermodynamically favoured s-*trans* conformation[11] owing to electrostatic interaction between the negative charged oxygen and the cloud of the cyano group. This interaction appears to be similar to that previously observed for furyl derivatives 1.[2,3,11]

In the case of the (E) - 2 - furyl derivative 2 it is impossible to detect the H-4 multiplicity owing to the equivalence in chemical shift of H-3 and H-4, that persist in spite of the change of several solvents. The H-5 signal is however a clean quartet (doublet of doublet). Also in this case it may be suggested that the s-*cis* is the preferred conformation.

No solvent effect on the conformations of the thiophene or furan derivatives 2 is revealed by DMSO, acetonitrile, pyridine and methanol.

On the contrary to that observed for all (E)-α,β-diaryl - ethylenes existing in the s-*cis* conformation,[2–4] any diamagnetic shift is noticed on H-3 of the (E) - 2 -



Scheme 5.

furyl - derivative **2**. No shielding is observed also for BB′ protons of the (*E*)- molecules **2** containing a β-phenyl nucleus (Table 1). This result reveals that the α-phenyl ring is not perpendicular to the molecular plane,[12] but distorted from the planar conformation of the minimum angle which is permitted by steric hindrance. Therefore the H-3 and BB′ protons are not located in the shielding zone of the α-benzene and thus they resonate at usual values. This α-phenyl conformation is favoured providing the minimum interaction between the π orbitals of both the phenyl and the cyano group, whereas the perpendicular conformation would provide maximum π-interaction owing to the cylindrical symmetry of the cyano group.

The (*Z*) - (N-methyl) - pyrrolyl - derivatives **2** (X = N-CH_3, Y = H, R = H, CH_3) assume the s-*cis* conformation because of steric hindrance between the bulky N-CH_3 and cyano group. It is possible then to verify: (a) the deshielding effect on H-3, owing to the magnetic anisotropy of the cyano group; (b) the sterospecific coupling H_{ol}–H_4 due to their *trans*- coplanar disposition; no coupling should be observed H_{ol}–H_5.

As expected, $CDCl_3$ PMR spectrum of (*Z*) - α - (*p* - tolyl) - β - (N - methyl - 2 - pyrrolyl)acrylonitrile (Fig. 2) shows that H_3 resonates at lowest fields among the heterocyclic protons (the attribution is made on the basis of the typical spin–spin coupling constants). A marked deshielding was displayed by H-3 (about 1 ppm). The stereospecific couplings are in agreement to what was expected.

No difference in spectral behaviour was noticed in DMSO-d_6.

On the other hand, in the case of the corresponding (*Z*) - 2 - pyrrolyl - derivative (Fig. 3), $CDCl_3$ PMR spectrum reveals that (a) the N–H proton is strongly deshielded (about 3 ppm); (b) the H_3 proton resonates between H_4 and H_5 at the usual fields.

To detect the stereospecific couplings we have reduced the multiplicity of the heterocyclic protons by N–H deuteration.

The $CDCl_3$ spectrum of the deuterated compound (Fig. 4) exhibits a $^5J_{H_{ol}-H_5} = 0.6$ Hz and $^5J_{H_{ol}-H_4} = 0.0$. Thus, differently from the N-methyl derivatives, in $CDCl_3$ the s-*trans* is the preferred conformation. The same behaviour is observed in CCl_4.

If the DMSO-d_6 spectrum is compared, it is noticed (Fig. 4) (a) a strong paramagnetic shift of H_3, but no significant shift of H-4 and H-5. It is impossible to observe N–H proton because of chemical exchange with the solvent; (b) a multiplet of eight lines for H_4 ($^5J_{H_{ol}-H_4} = 0.7$ Hz). Hence in DMSO the conformation behaviour is identical to the corresponding N-methyl-compounds. A conformational inversion due to the solvent is thus indicated.

In acetonitrile, pyridine, methanol (Table 3) the behaviour is identical to DMSO. The s-*cis* is then the preferred rotamer in the basic solvents, probably owing to the formation of an adduct between the basic centre of the solvent and the N–H proton.

The chemical shifts of the compounds (*Z*)-**2** (X = N-CH_3, N–H; R = H) in $CDCl_3$ and in DMSO-d_6 are reported in Table 4. The stereospecific $^5J_{H,H}$ values are identical to those observed for *p*-CH_3 derivatives **2** above reported.

The investigation in mixed solvents reveals that gradual additions of a basic solvent to a $CDCl_3$ solution of the pyrrolyl-derivatives **2** (X = N–H) cause gradual increases of the s-*cis* population. This is supported by: (a) the progressive paramagnetic shift of H-3; (b) the gradual collapse of H_5–H_{ol} coupling and the gradual increase of H_4–H_{ol} coupling.

The curves of the H_3 chemical shift vs solvent/solute ratio are reported in the Fig. 5 for various basic solvents. Pure starting $CDCl_3$ solutions were all at 5%.

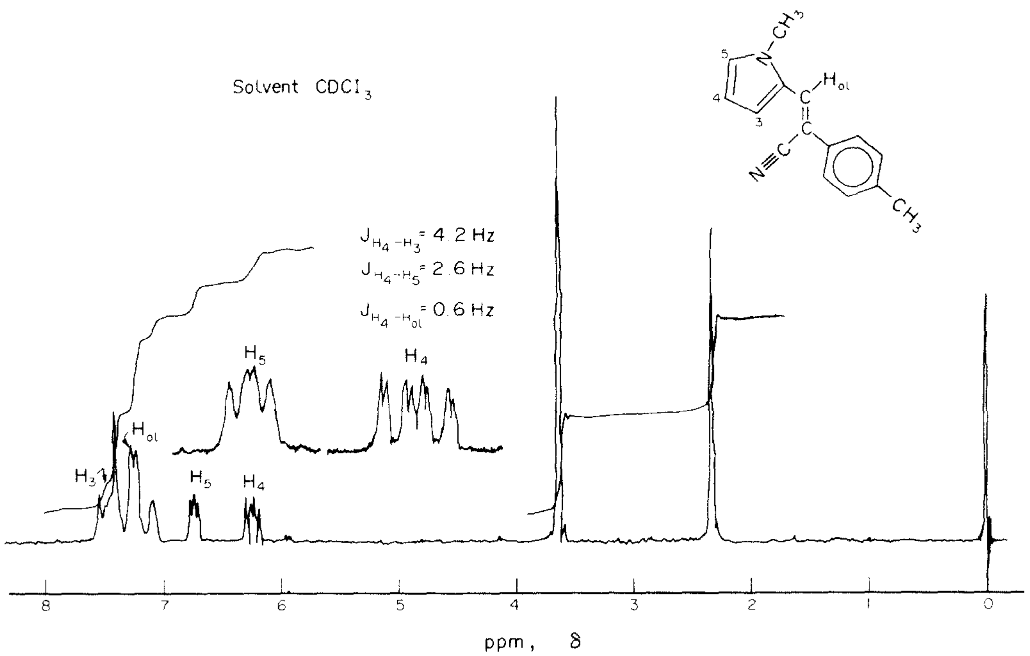


Fig. 2. PMR spectrum of (*Z*) - α - (*p* - tolyl) - β - (N - methyl - 2 - pyrrolyl) - acrylonitrile.

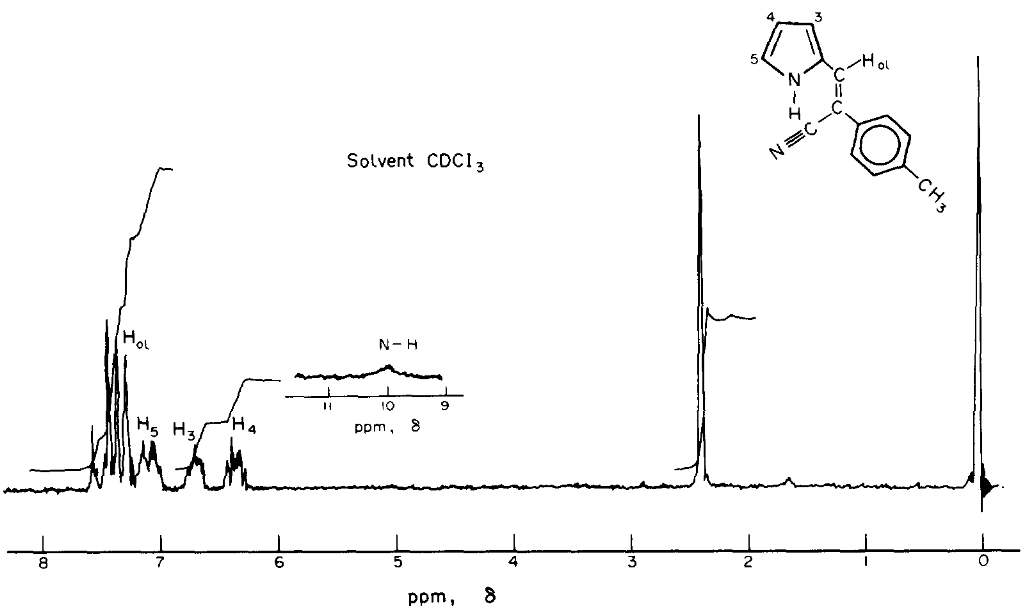


Fig. 3. PMR spectrum of (Z) - α - (p - tolyl) - β - (2 - pyrrolyl)acrylonitrile.

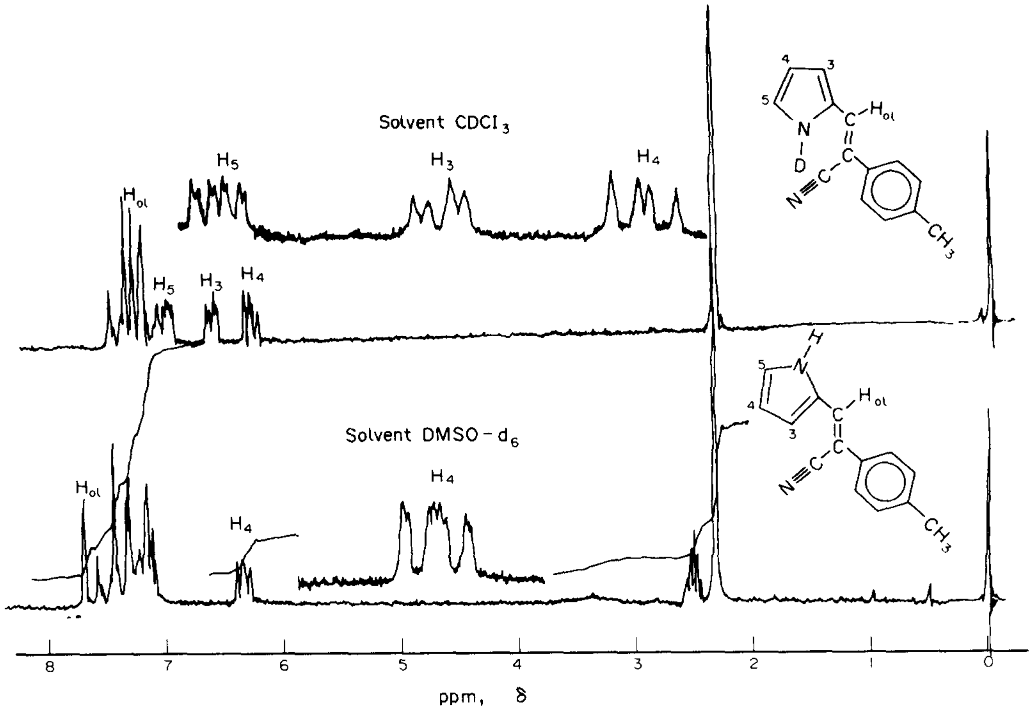


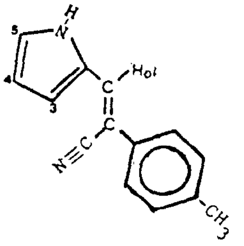
Fig. 4. PMR spectrum of (Z) - α - (p - tolyl) - β - (2 - pyrrolyl)acrylonitrile in $CDCl_3$ and DMSO-d_6.

At fixed solvent–solute ratios, typical for each solvent, the slope becomes very close to zero, indicating that the complete conformational inversion has occurred and the final conformational equilibrium has reached, where the s-*cis* rotamer is strongly favoured. In the initial range of the curves a conformational mixture is certainly present. If we assume that the s-*cis* and the s-*trans* conformers are the only existing rotamer respectively in the basic pure solvents and in the $CDCl_3$, then an approximate evaluation of population ratio in a given mixture is possible by H-3 chemical shift values:

$$\%\text{s-}cis = \frac{\nu_{obs} - \nu_{CDCl_3}}{\nu_{solv} - \nu_{CDCl_3}} \cdot 100$$

where ν_{obs} = the observed H_3 chemical shift (Hz) in a given mixture; ν_{CDCl_3} = the H_3 chemical shift in $CDCl_3$ at the same concentration of the product in the given

Table 3. Chemical shift (δ, ppm) and stereospecific coupling constants (Hz) of the protons of (*Z*)-α-phenyl-β-(2-pyrrolyl)acrylonitriles in various solvents



		H_3	H_4	H_5	$J_{H_{ol}-H_4}$
acetone-d_6	R=H	6.95	6.35	6.95	0.60
	R=CH_3	6.98	6.35	6.98	0.60
acetonitrile	R=H	6.90	6.30	7.10	0.55
	R=CH_3	(6.95-7.10)	6.33	(6.95-7.10)	0.60
CD_3OD	R=H	7.10	6.35	7.00	0.55
	R=CH_3	7.13	6.31	7.00	0.60
pyridine-d_6	R=H	(7.40-7.60)	6.40	(7.40-7.60)	0.60
	R=CH_3	(7.43-7.60)	6.47	(7.43-7.60)	0.60

[a] In all cases $J_{H_{ol}-H_5}$ = 0.0 Hz.

Table 4. Chemical shift (δ, ppm) of the protons of the compounds 2, (*Z*)- (X = N-CH_3, N-H; Y = H; R = H) in $CDCl_3$ and DMSO-d_6

X	R		H_{ol}	H_3	H_4	H_5	Phenyl	N-H or N-CH_3
N-H	H	$CDCl_3$	(7.20-7.58)	6.68	6.30(dd)[a]	7.00(ddd)[a]	(7.20-7.58)	9.95
		DMSO-d_6	7.95	(7.11-7.66)	6.38(ddd)	(7.11-7.66)	(7.11-7.66)	-
N-CH_3	H	$CDCl_3$	(7.26-7.53)	(7.26-7.53)	6.24(ddd)	6.75(dd)	(7.26-7.53)	3.63
		DMSO-d_6	7.69	7.28	6.27(ddd)	7.09(dd)	(7.31-7.58)	3.76

dd = doublet of doublet; ddd = doublet of doublet of doublet.

[a] N-H deuterated compound.

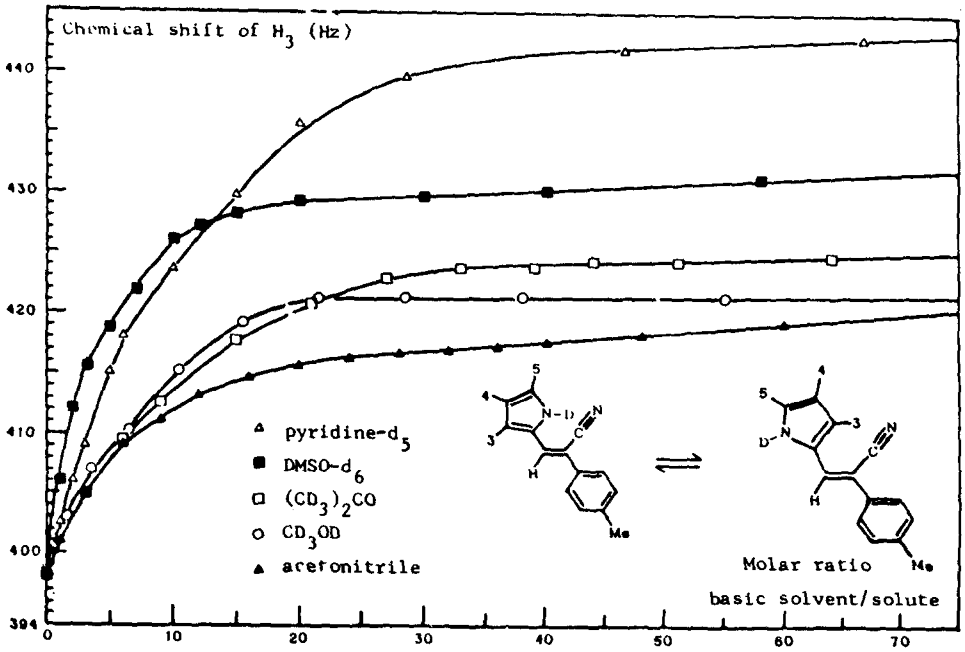


Fig. 5. Dependence of H_3 chemical shift on the molar ratio basic solvent–solute.

mixture; ν_{solv} = the H_3 chemical shift in the basic solvent at the same concentration.

The values obtained by the above formula are obviously approximate because ν_{obs} is affected not only by the conformational ratio variations, but also by other factors such as the change of the solvation. But if we assume that these latter effects are very small with respect to conformational ones, then these values may be considered quite close to the real values.

EXPERIMENTAL

All (*Z*) - α,β - diarylacrylonitriles were prepared by condensations of the suitable arylacetonitrile and arylcarboxaldehyde in EtOH with EtONa, as previously reported.[13–16] Melting points (°C) of unknown products (crystallization solvent: EtOH) are here reported: (*Z*) - α - (*p* - tolyl) - β - (2 - pyrrolyl)acrylonitrile (**2**: X = NH, Y = H, R = CH_3) 105; (*Z*) - α - (*p* - tolyl) - β - (2 - furyl)acrylonitrile (**2**: X = 0, Y = H, R = CH_3) 79; (*Z*) - α - (*p* - tolyl) - β - (N - methyl - 2 - pyrrolyl)acrylonitrile (**2**: X = N–CH_3, Y = H, R = CH_3) 100. Satisfactory combustion analytical data for C, H and N were found for these new compounds.

The (*E*) - α,β - diarylacrylonitriles were obtained following the method of Codington and Mosettig,[17] as already described.[18]

^{1}H NMR spectra were performed on 5% soln with *ca.* 1% of TMS as internal standard. A Varian A-60D spectrometer was used.

In all cases solvents of commercial quality were employed. The J values were measured directly from the spectra run at maximum scale width.

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REFERENCES

[1] Part of this work has been presented at the IXth International Symposium on Organic Sulphur Chemistry (June 1980, Riga).
[2] S. Fisichella, G. Mineri, G. Scarlata and D. Sciotto, *Tetrahedron* **31**, 2445 (1975).
[3] A. Arcoria, F. A. Bottino and D. Sciotto, *J. Heterocyclic Chem.* **14**, 1353 (1977).
[4] F. A. Bottino, G. Mineri and D. Sciotto, *Tetrahedron* **34**, 1557 (1978).
[5] S. Fisichella, G. Scarlata and D. Sciotto, *Ann. Chim.* (*Rome*) **63**, 55 (1973).
[6] S. Fisichella, G. Mineri, G. Scarlata and D. Sciotto, *Ibid.* **63**, 779 (1973).
[7] S. Forsen and B. Akermark, *Acta Chem. Scand.* **17**, 1712 (1963); and refs cited.
[8] G. J. Karabatsos and F. M. Vane, *J. Am. Chem. Soc.* **85**, 3886 (1963); and refs cited.
[9] M. Farnier and T. Drakenberg, *Tetrahedron Letters* 429 (1973); and refs cited.
[10] F. A. Bottino, M. L. Longo, D. Sciotto and M. Torre *Can. J. Chem.* **59**, 1205 (1981).
[11] B. Roques, S. Combrisson, C. Riche and C. Pascard-Billy, *Tetrahedron* **26**, 3555 (1970); B. Roques and M. L. Fournie-Zaluski, *Org. Magnetic Resonance* **3**, 305 (1971).
[12] H. E. Zimmermann and L. Ahramjian, *J. Am. Chem. Soc.* **81**, 2806 (1959).
[13] S. Wawzonek and E. Smolin, *Organic Synth. Coll. Vol. III*, p. 75. Wiley, New York (1955).
[14] W. Herz and J. Brosch, *J. Org. Chem.* **23**, 711 (1958).
[15] R. N. McDonald and D. G. Hill, *Ibid* **35**, 2942 (1970).
[16] E. Maccarone, A. Mamo, G. Scarlata and M. Torre, *Ibid.* **44**, 2896 (1979).
[17] J. F. Codington and E. Mosettig, *Ibid.* **17**, 1027 (1952).
[18] E. Maccarone, A. Mamo, G. Scarlata and M. Torre, *Tetrahedron* **34**, 3531 (1978).