TAUTOMERIC PROTOTROPIC EQUILIBRIUM IN PENTAFLUOROPHENYL-SUBSTITUTED LEUCOVERDAZYLS

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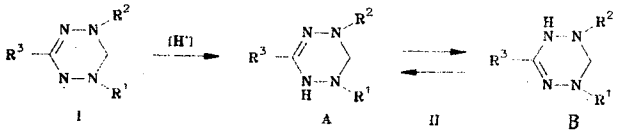
UDC 543.422.25:547.883'221.07:541.623

It was shown by NMR spectroscopy that unsymmetrically substituted pentafluorophenylleucoverdazyls exist in two stable tautomeric forms. The assignment of the signals in the PMR spectra to the individual tautomeric forms was made with the aid of a ^{15}N-labeled leucoverdazyl. The free energy of activation of the proton transfer was determined.

Pentafluorophenyl-containing verdazyl radicals I detach a hydrogen atom (from ascorbic acid, thiophenol, hydrazine, and hydrazobenzene) to give the corresponding 2,4,6-triaryl-1,2,3,4-tetrahydro-1,2,4,5-tetrazines (leucoverdazyls II), which, in contrast to the leuco compound of the triphenylverdazyl radical, are resistant to oxidation by air oxygen [1-3].



I A II B

a $R^1=R^3=C_6H_5$, $R^2=C_6F_5$; b $R^1=R^2=C_6H_5$, $R^3=C_6F_5$; c $R^1=C_6H_5$, $R^2=R^3=C_6F_5$; d $R^1=R^2=C_6F_5$, $R^3=C_6H_5$; e $R^1=R^2=R^3=C_6F_5$

Virtually no oxidation of solutions of leucoverdazyls IId,e by air oxygen occurs in the course of a week. It was found that 10^{-3} N solutions of IIa-c are less stable and undergo 5-7% oxidation after 24 h. The present paper is devoted to a study of the structures of pentafluorophenyl-containing leucoverdazyls by NMR spectroscopy.

Signals of three types of protons, viz., a singlet of methylene protons at 4.77 ppm (2H), a broad singlet of an NH proton at 6.05 ppm (1H), and a multiplet of aromatic ring protons at 6.8-7.3 ppm (10H), are observed in the PMR spectrum (in $CDCl_3$) of IIb, which contains identical substituents attached to the $N_{(2)}$ and $N_{(4)}$ atoms. A similar pattern of the PMR spectra is also observed for IId,e, which are symmetrically substituted at the $N_{(2)}$ and $N_{(4)}$ atoms (Table 1).

Splitting of the signals of the CH_2 and NH groups due to the existence of the IIA $\rightleftarrows$ IIB equilibrium [4-6] is observed in the PMR spectra of leucoverdazyls IIa,c, which contain nonidentical substituents attached to the $N_{(2)}$ and $N_{(4)}$ atoms. The addition of heavy water leads to disappearance of the NH signal. When small amounts of acetic acid are used, the NH signal is broadened and shifted to weak field. The addition of trifluoroacetic acid leads to rapid exchange of the protons attached to the $N_{(1)}$ and $N_{(5)}$ atoms and to disappearance of the corresponding signal in the spectra, whereas the signal of the CH_2 group is converted to a singlet. These data constitute unequivocal evidence in favor of a prototropic equilibrium and exclude the possibility of the conformational equilibrium examined in [7].

The position of the NH signals depends substantially on the ability of these protons to form intermolecular hydrogen bonds. In deuterobenzene the NH doublet is located at 5.5 ppm, whereas in the relatively inert solvent deuterochloroform it is shifted ~0.5 ppm to weak field, and, in addition, the mutual orientation of the NH signals of the two prototropic forms changes. In a solvent such as d_6-DMSO, which is capable of forming strong hydrogen bonds with the NH protons, their signals appear at ~8.5 ppm. The signals of the protons of the CH_2 group are

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Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 10, pp. 1425-1427, October, 1985. Original article submitted July 13, 1984; revision submitted November 15, 1984.

0009-3122/85/2110-1175$09.50

TABLE 1. Parameters of the PMR Spectra of Pentafluorophenyl-Substituted Leucoverdazyls

Compound	Solvent	CH_2, ppm		NH, ppm		C_6H_5, ppm	A, %	B, %
		A	B	A	B			
IIa	$CDCl_3$	4,70	4,60	6,12	6,19	6,8—7,7	65	35
	$CDCl_3$	4,69	4,60	6,15*	6,22	6,8—7,7	60	40
	C_6D_6	4,42	4,30	5,47	5,35	7,0—7,6	65	35
	C_6D_6	4,24	4,13	5,35*	5,25	7,0—7,6	65	35
	d_6-DMSO	4,82	4,58	8,65	8,71	7,0—7,5	65	35
	CD_3CN	5,09	4,90	Not obs.		7,2—8,3	70	30
	$(CD_3)_2CO$	4,88	4,68	Not obs.		6,9—8,0	55	45
	Dimethylacetamine	5,10	4,88	8,08	8,03	7,1—7,6	55	45
IIb	$CDCl_3$	4,77		6,05		6,8—7,3	—	
IIc	$CDCl_3$	4,69	4,55	Not obs.		7,0—7,3	65	35
	$(CD_3)_2CO$	4,90	4,68	8,15		7,0—7,5	65	35
IId	$(CD_3)_2CO$	4,48		Not obs.		7,2—7,7	—	
IIe	$CDCl_3$	4,48		6,34		—	—	

*These are the values for the ^{15}N-labeled compound, for which splitting of the proton with a spin-spin coupling constant (SSCC) of 90 Hz is observed; the spectrum was recorded with a spectrometer with an operating frequency of 200 MHz.

considerably less susceptible to the effect of the solvent and do not change their positions relative to one another.

For the assignment of the signals of the NH protons to individual prototropic forms A and B we synthesized ^{15}N-labeled [in the $N_{(1)}$ position] IIa. A characteristic feature of this label is doublet splitting of the signal bonded to the ^{15}N nucleus.*

In the PMR spectrum of labeled leucoverdazyl IIa the signal of the NH protons of tautomer A is split into a doublet with components with equal intensities and a SSCC of 90 Hz, which corresponds to the ^{15}NH coupling constant in labeled amines and formazans [8]. On the basis of the ratio of the integral intensities the signal in the doublet of the CH_2 group, which is located at weaker field, was also assigned to form A. As noted above, the mutual orientation of these signals is not subject to a solvent effect.

The solvent affects both the positions of the signals of the individual forms and the distances between the signals (the $\Delta\delta$ values). The greatest separation of the signals of the CH_2 protons is observed in acetone, dimethylacetamide (DMA), and dimethyl sulfoxide (DMSO). The ratio of the A and B isomers changes only slightly on passing from one solvent to another. Somewhat greater stability of the A form is observed in CD_3CN.

No change in the ratio of the isomeric forms is observed when a sample of IIa in deuterochloroform is cooled to −50°C; this constitutes evidence for a low value of the free energy of the tautomeric equilibrium. In fact, the ΔG^0 value of the reaction IIA $\rightleftarrows$ IIB calculated from the formula $\Delta G^0 = -RT \ln K$ is only ~1.5 kJ/mole and depends only slightly on the temperature and the nature of the solvent.

We also attempted to determine the free energy of activation of conversion of the tautomeric forms. Heating a solution of IIa in DMSO leads to gradual broadening of the CH_2 signals and to merging of them at 105-110°C. Because of decomposition of IIa under these conditions, it is difficult to accurately determine the coalescence temperature. The calculations show that the free energy of activation of proton exchange ranges from 75 to 84 kJ/mole.

EXPERIMENTAL

The PMR spectra of the compounds were recorded with Tesla BS 467 (60 MHz) and Bruker WP-200 (200 MHz) spectrometers with hexamethyldisiloxane as the internal standard. The deuterated solvents were used without prior purification.

*A similar method was used to determine the position of the proton in an unsymmetrical formazan and 2-(4-nitrophenyl)-4-phenyl-6-methyl-1,2,3,4-tetrahydro-sym-tetrazine. In the latter case the tautomeric equilibrium is shifted completely to favor the form in which the hydrogen is attached to the $N_{(5)}$ atom [6].

^{15}N-Labeled 1,3-diphenyl-5-pentafluorophenylformazan and 2,6-diphenyl-4-pentafluorophenylverdazyl radicals Ia were synthesized in accordance with I in the same way as the unlabeled compounds using $Na^{15}NO_2$ for diazotization.

2,6-Diphenyl-4-pentafluorophenyl-1,2,3,4-tetrahydro-[1-^{15}N]-sym-tetrazine (IIa). A solution of 0.132 g (0.75 mmole) of ascorbic acid in 30 ml of ethanol was added dropwise to a solution of 0.605 g (1.5 mmole) of 2,6-diphenyl-4-pentafluorophenyl[1-^{15}N]verdazyl radical (Ia) in 150 ml of ethanol. After a few minutes, the solution became colorless. The reaction mixture was evaporated in vacuo to ~30 ml, the same amount of water was added, and the precipitated leucoverdazyl IIa was removed by filtration to give 0.56 g (93%) of product. Crystallization from methanol gave a product with mp 140-141°C (in a sealed capillary).

LITERATURE CITED

1. O. M. Polumbrik, I. G. Ryabokon', and L. N. Markovskii, Khem. Geterotsikl. Soedin., No. 2, 266 (1978).
2. O. M. Polumbrik, I. G. Ryabokon', and L. N. Markovskii, Khim. Geterotsikl. Soedin., No. 8, 1130 (1980).
3. O. M. Polumbrik, I. G. Ryabokon', and L. N. Markovskii, Zh. Org. Khim., 18, 1060 (1982).
4. V. P. Shchipanov, E. O. Sidorov, L. S. Podenko, and G. D. Kadochnikova, Khim. Geterotsikl. Soedin., No. 7, 991 (1978).
5. V. P. Shchipanov and G. D. Kadochnikova, Khim. Geterotsikl. Soedin., No. 8, 1137 (1978).
6. F. A. Neugebauer and M. Jenne, Tetrahedron Lett., No. 10, 791 (1969).
7. F. A. Neugebauer and A. Mannschreck, Tetrahedron, 28, 2533 (1972).
8. P. B. Fischer, B. L. Kaul, and H. Zollinger, Helv. Chim. Acta, 51,1449 (1968).