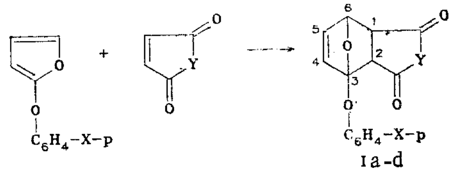
INVESTIGATION OF THE STEREOCHEMISTRY OF ADDUCTS OF ARYLOXYFURANS WITH MALEIC ACID DERIVATIVES BY PMR SPECTROSCOPY

N. P. Solov'eva, Yu. N. Sheinker,
A. F. Oleinik, and E. V. Adamskaya

UDC 547.759.3'745'723:542.944.1:
541.63:543.422.25

The stereochemistry of adducts of aryloxyfurans with maleic acid derivatives was studied by PMR spectroscopy. It was shown that adducts with maleic anhydride are produced only in the form of exo isomers, whereas adducts with N-phenylmaleinimide are isolated from the reaction in the form of mixtures of endo and exo forms. Bromination of the adducts was realized. The orientation of the bromine atoms in the bromination products was established by PMR spectroscopy: The bromine atoms in the dibromo derivative of the adduct with maleic anhydride are cis-oriented (endo-4-Br, endo-5-Br), whereas the bromine atoms have a trans configuration (endo-4-Br, exo-5-Br) in the dibromo derivative of the adduct with N-phenylmaleinimide.

In our continuing research in the aryloxyfuran series we have previously [1] accomplished the diene synthesis of aryloxyfurans with maleic anhydride and with N-phenylmaleinimide. The present research is devoted to a study by means of PMR spectroscopy of the stereochemistry of these adducts (Ia-d) and the structures of the compounds that were subsequently obtained by bromination of adducts I.



Ia-d

I a X=H, Y=O; b X=CH_3, Y=O;
c X=H, Y=N-C_6H_5; d X=CH_3, Y=N-C_6H_5

Two configurations, viz., endo and exo,* are possible for adducts Ia-d. It follows from an analysis of the literature data [2, 3] and an examination of molecular models that dihedral $\angle H_6C_6C_1H_1 \sim 90°$ for the exo form and, in accordance with the Karplus curve [4], the spin–spin coupling constant (SSCC) of the H_1H_6 protons should be close to zero. For the endo isomer, $\angle H_6C_6C_1H_1 \sim 30°$, which should correspond to SSCC $^3J_{H_1H_6} \sim 6$ Hz. In addition to this, one should expect that the signals of the H_1 and H_2 protons in the endo isomer, inasmuch as they are close in space to the bridge oxygen atom, will be observed at weaker field in the PMR spectra than the signals of these protons in the exo isomer. Data from the PMR spectra of adducts Ia-d are presented in Table 1. An analysis of these data makes it possible to establish that the adducts (Ia, b) with maleic anhydride are produced only in the form of exo isomers ($^3J_{H_1H_6} \sim 0$ Hz). This result is in agreement with the literature data relative to the stereochemistry of adducts of unsubstituted furans with maleic anhydride [2, 3].

The adducts (Ic, d) with N-phenylmaleinimide were isolated from the reaction in the form of two geometrical isomers, viz., endo ($^3J_{H_1H_6} = 5.5$ Hz) and exo ($^3J_{H_1H_6} \sim 0$ Hz). We

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*The endo configuration is the configuration of the adduct in which the bridge oxygen atom and the substituent (the five-membered ring) are located on different sides of the plane of the molecule. In the exo configuration the bridge oxygen atom and the five-membered ring are located on the same side of the plane of the molecule.

S. Ordzhonikidze All-Union Scientific-Research Institute of Pharmaceutical Chemistry, Moscow 119815. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 5, pp. 613-615, May, 1984. Original article submitted March 29, 1983.

0009-3122/84/2005-0489$08.50

TABLE 1. Data from the PMR Spectra of I and II

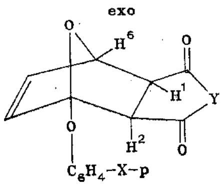
Compound	Type of isomer	δ, ppm						$^3J_{HH}$, Hz				$^4J_{HH}$, Hz			Solvent
		1-H	2-H	4-H	5-H	6-H	CH_3	12	16	45	56	46	24	26	
Ia	exo	3,39[a]		6,38	6,62	5,34	—	7,0	~0	6,0		2,0[b]	~0	~0	$CDCl_3$
Ib	exo	3,38[a]		6,39	6,62	5,35	2,28	7,5	~0	5,8		2,0[b]	~0	~0	same
Ic	exo	3,19[a]		6,38	6,60	5,34	—	6,5	~0	5,8		2,0[b]	~0	~0	" "
	endo	3,88	3,69	6,46	6,58	5,33	—	7,2	5,5	5,9	2,0	0	~0	~0,5	" "
Id	exo	3,20[a]		6,38	6,57	5,30	2,27	6,5	~0	5,8		1,9[b]	~0	~0	" "
	endo	3,85	3,65	6,44	6,55	5,30	2,29	7,6	5,5	5,9	1,9	0	~0	~0,5	" "
IIa	exo	4,24[a]		4,44	4,89	5,17	—	7,0	~0	9,9	5,0	0,6	~0	~0	$(CD_3)_2CO$
IIb	exo	4,25[a]		4,45	4,91	5,16	2,32	7,5	~0	9,0	5,1	0,6	~0	~0	same
IIc	endo	4,16—3,75		4,49[c]		5,12	—	10,6	6,95	c	0,5	0,5	0,9	0,7	" "

[a] The signals of the 1-H and 2-H protons form a degenerate AB system.

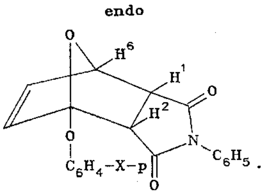
[b] Determined from $\Sigma J = {}^3J_{56} + {}^4J_{46}$.

[c] The signals of the 4-H and 5-H protons coincided completely; $^3J_{56}$ could not be determined (replacement of the solvent did not lead to separation of the 4-H and 5-H signals).

have established that the ratios of the endo and exo forms for adducts Ic,d depend on the reaction temperature and time. Conditions for the preparation of the individual isomers of the adducts with N-phenylmaleinimide were found.



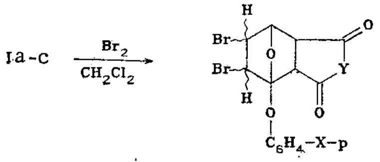
Ia-d



Ic,d

The regularity in the change in the chemical shifts of the 1-H and 2-H protons predicted above is observed in the PMR spectra of adducts Ic,d (see Table 1). Thus, for example, in the spectrum of exo isomer Ic, δ 1-H and δ 2-H = 3.19 ppm, whereas for endo isomer Ic, δ 1-H = 3.88 ppm, and δ 2-H = 3.69 ppm.

We then accomplished the bromination of adducts Ia-c.* Bromination was carried out in a solvent with low polarity. Under these conditions, according to the literature data, the cis-dibromide is formed in the case of the adduct of unsubstituted furan with maleic anhydride [6].



IIa-c

As in the case of the adducts themselves, the configurations of the dibromo derivatives (IIa-c) of the adducts were established on the basis of data on the $^3J_{H_1H_6}$ SSCC. It was shown that adducts IIa,b are exo isomers ($^3J_{H_1H_6} \sim 0$ Hz), whereas IIc is the endo isomer ($^3J_{H_1H_6} = 6.95$ Hz).

It followed from an examination of molecular models of dibromo derivatives IIa-c that four relative orientations of the bromine atoms in each of the geometrical isomers are possible. One can choose among these variants on the basis of an analysis of the vicinal $^3J_{H_5H_6}$ and $^3J_{H_4H_5}$ SSCC [7]. Thus $^3J_{H_6H_5} = 5.0$-5.1 Hz in isomers IIa,b which corresponds to an exo orientation of the 5-H protons, and the bromine atom in the 5 position is consequently endo-oriented. In addition, $^3J_{H_4H_5} = 9.9$ (IIa) and 9.0 Hz (IIb), which corresponds to a cisoid orientation of the coupling 4-H and 5-H protons.

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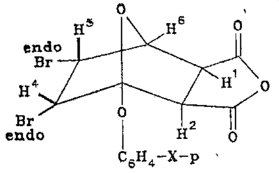
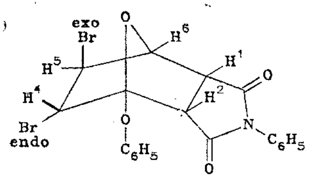
*The bromination of adducts Ia,b was mentioned briefly in [5].

It hence follows that, first, the bromine atoms are cis-oriented relative to one another and, second, the bromine atom in the 4 position is endo-oriented relative to the bridge oxygen atom. Thus both bromine atoms in IIa,b have a cis endo orientation.



IIa,b



IIc

In the case of dibromo derivative IIc, because of superimposition of the signals of the 4-H and 5-H protons in the PMR spectra, we were unable to use the $^3J_{H_4H_5}$ SSCC to determine the orientation of the bromine atoms. We found that $^3J_{H_5H_6}$ = 0.5 Hz for IIc, which corresponds to an endo orientation of the 5-H proton, and the bromine atom in the 5 position consequently has an exo orientation. The orientation of the 4-H proton was determined by means of the long-range $^4J_{HH}$ SSCC. It is known that the long-range SSCC of the protons are manifested only in the case of a planar "W" orientation of the bonds [8, 9]. In the investigated two-ring system this can occur for the 6-H and 2-H, 6-H and 4-H, and 2-H and 4-H protons; the latter two couplings can give a measurable $^4J_{HH}$ constant only if the 4-H proton has an exo orientation.

The existence of three long-range $^4J_{HH}$ SSCC for IIc ($^4J_{H_2H_6}$ = 0.7, $^4J_{H_2H_4}$ = 0.9, and $^4J_{H_4H_6}$ = 0.5 Hz) was established by means of double resonance. The existence of three long-range SSCC makes it possible to assert that the bromine atom in the 4 position has an endo orientation. Thus the two bromine atoms in the adduct have a trans configuration (endo-4-Br, exo-5-Br).

It should be pointed out that $^4J_{H_6H_4}$ = 0.6 Hz was observed for dibromo derivatives IIa,b, whereas the two other possible long-range SSCC were close to zero. This fact is in good agreement with the established structures of IIa,b.

EXPERIMENTAL

The PMR spectra were recorded with a Varian XL-100 spectrometer with tetramethylsilane as the internal standard.

3-Phenoxy-3,6-endoxo-4,5-dibromohexahydrophthalic Acid N-Phenylmaleinimide (IIc). A solution of 0.9 g (6 mmole) of bromine in 4 ml of methylene chloride was added dropwise with stirring to a cooled (to −20°C) suspension of 2 g (6 mmole) of adduct Ic [1] in 10 ml of methylene chloride, and the mixture was stirred at −20°C for 3 h. Hexane was then added to the resulting solution until precipitation ceased. The resulting crystals were removed by filtration, the mother liquor was evaporated, and the residue was recrystallized from carbon tetrachloride to give 0.5 g (15%) of a product with mp 131-132°C. Found: C 49.2; H 3.4; Br 32.3%. $C_{20}H_{15}Br_2NO_4$. Calculated: C 48.7; H 3.0; Br 32.4%.

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