STEREOCHEMICAL PECULIARITIES OF THE CATALYTIC REDUCTION OF sym-OCTAHYDROTHIOXANTHYLIUM SALTS

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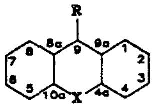
The three-dimensional structures of the products of catalytic hydrogenation of sym-octahydrothioxanthylium salts in the presence of palladium on carbon were studied by ^{13}C NMR spectroscopy. It was shown that the reaction proceeds stereoselectively with the formation of cis-syn-cis isomers. The stereochemistry of the reduction products is in agreement with the previously proposed reaction mechanism.

The synthesis of substituted perhydrothioxanthenes by the catalytic reduction of the corresponding sym-octahydrothioxanthylium salts in the presence of Pd/C was described in [1]. Considering the difference in the position of the double bonds in the probable intermediates with a 2H- or 4H-thiopyran heteroring in the molecular structure, in the catalytic reduction of sym-octahydrothioxanthylium salts one might have expected the formation of perhydrothiozanthenes only with cis, trans or cis, cis fusion of the hetero- and carbocycles, respectively.

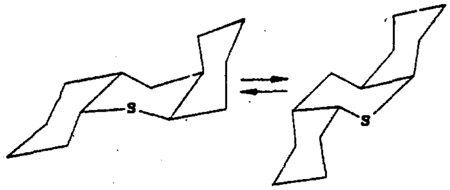
To establish the three-dimensional structures of the reaction products and to confirm the previously proposed mechanism of the catalytic reduction of thiopyrylium salts and their condensed analogs [1] we used ^{13}C NMR spectroscopy to investigate sulfides I-III, as well as the corresponding sulfones IV-VI. The latter are formed by oxidation of sulfides I-III with hydrogen peroxide in acetic acid.



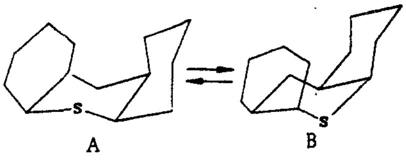
I–VI

I R=H, X=S; II R=CH_3, X=S; III R=C_6H_5, X=S; IV R=H, X=SO_2; V R=CH_3, X=SO_2; VI R=C_6H_5; X=SO_2

An analysis of the data obtained shows that the catalytic reduction of sym-octahydrothioxanthylium salts is stereoselective: sulfides I-III are individual isomers. Broadening of the signals in the spectrum of I and the presence of strong-field signals in the spectra of II and III indicate the cis character of the fusion of the tetrahydrothiopyran and cyclohexane rings (Table 1). Only the cis-anti-cis and cis-syn-cis isomers of perhydrothioxanthene have such properties. Like the carbon analogs of perhydroanthracene [2], these isomers will be conformationally labile. In analogy with cis-thiadecalins, the conformers of cis-syn-cis-perhydrothioxanthene can be designated as A and B [3]:



cis-anti-cis-Perhydrothioxanthene



cis-syn-cis-Perhydrothioxanthene

The broadening of the signals in the spectrum of I makes it impossible to arrive at an unambiguous assignment to one of these configurations. However, the conformational lability

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TABLE 1. ^{13}C NMR Spectra of cis-syn-cis-Perhydrothiozanthenes I-III, Sulfones IV-VI, and cis-syn-cis-Perhydroanthracene (VII)*

Compound	δ, ppm						
	$C_{(1,8)}$	$C_{(2,7)}$	$C_{(3,6)}$	$C_{(4,5)}$	$C_{(9)}$	$C_{(4a,10a)}$	$C_{(8a,9a)}$
I**	32,10	24,88	23,41	33,03	31,88	43,11	37,69
II***	23,63	27,52	22,34	32,51	41,18	42,88	47,88
III	24,86	27,45	22,09	32,72	53,67	41,46	48,12
IV	32,15	20,43	26,10	23,49	25,59	62,65	34,16
V***	22,27	26,60	21,92	23,42	39,08	60,13	44,84
VI	23,28	26,60	21,65	23,70	51,39	60,71	43,86
VII4*	31,97	24,99	24,99	31,97	32,93	37,20	37,20
VII5*	30,54	28,03	22,00	33,10	38,37	37,94	36,14

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*The assignment of the resonance signals was made by comparison with the low-temperature spectrum of the carbon analog with recourse to the off-resonance spectra, as well as with allowance for the shielding effect of the sulfonyl group [10, 11].

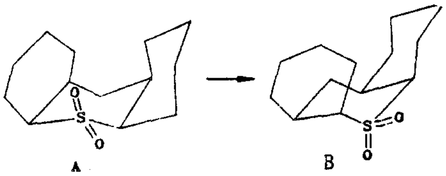
**The unambiguous assignment of the $C_{(1)}$–$C_{(8)}$ signals is difficult because of the lack of data on the conformational equilibrium.

***δ_{CH_3} for II is 17.11 ppm; for V it is 16.79 ppm.

4*$\delta_{(10)}$ 32.93 ppm.

5*At –32°C [4]; $\delta_{C(10)}$ 26.94 ppm.

of the isomers may change for some of its derivatives. Thus the sulfone obtained on the basis of cis-syn-cis-perhydrothioxanthene I will be stabilized in the B form, since in conformer A 1,3-diaxial interactions arise between the axial oxygen atom of the sulfo group and the axial C–C bonds of the cyclohexane rings. Thus a configurational assignment for sulfide I becomes possible when one examines the spectrum of the corresponding sulfone IV. Seven narrow resonance signals are recorded in the spectrum of this compound; one of them (δ 25.59 ppm) has an intensity that is half the intensities of the others, on the basis of which it can be assigned to the signal of the $C_{(9)}$ atom. The presence in the spectrum of IV of two strong-field signals at δ 20.43 and 23.49 ppm constitutes evidence for cis-syn-cis configuration of the investigated suflone:



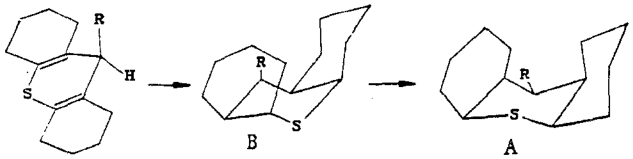
In the low-temperature ^{13}C NMR spectrum of cis-syn-cis-perhydroanthracene, in which the rate of the conformational transition is low, the positions of the signals of the $C_{(3)}$ and $C_{(10)}$ atoms differ by 11.43 ppm [4]. This fact can be used to solve the problem of the conformational state of such heterocyclic systmes. In our case the position of the signal of the $C_{(9)}$ atom at 25.59 ppm confirms the existence of sulfone IV, obtained from cis-syn-cis-perhydrothioxanthene I, in the B form.

The conformation equilibrium of cis-fused perhydrothioxanthenes will also change when a substituent is introduced into the 9 position. An axial orientation of the substituting group leads to the development of unfavorable 1,3-diaxial interactions; this is the reason for stabilization of one conformer for the cis-anti-cis isomer and two conformers A and B for the cis-syn-cis isomers.

The number of signals in the spectra of sulfides II and III, as well as sulfones V and VI, makes it possible to classify these compounds as cis-syn-cis-perhydrothioxanthenes. The equatorial orientation of the substituent attached to $C_{(9)}$ is confirmed by the chemical shift of the carbon atom of the methyl group in II and V. In the case of trimethylcyclohexanes it has been shown [5] that the carbon atoms of the methyl group located between the other two substituents is characterized by resonance signals of ~15-19 ppm, as compared with 5-7 ppm for the axial group.

The conformational state of II, III, V, and VI is determined from the position of the resonance signal of the $C_{(9)}$ atom. It is known that the introduction of an equatorial CH_3 group into the 1 position of trans- and cis-thiadecalins [6] or into the 4 position of trans-thiadecalins [3] leads to deshielding of these carbon atoms. A $\Delta\delta$ value of 13.49 ppm was obtained on comparing the resonance signals of the $C_{(9)}$ atoms of sulfones IV [without a substituent attached to $C_{(9)}$] and V [with a CH_3 group attached to $C_{(9)}$]; this constitutes evidence for different conformational states of these compounds, i.e., sulfones V and VI and, consequently, the corresponding sulfides II and III are stabilized in the form of conformer A of cis-syn-cis-perhydrothioxanthene.

The three-dimensional structures of perhydrothioxanthenes I-III are in agreement with the assumption [1] that the hydrogenation of thiopyrylium salts and their condensed analogs proceeds through the formation of the corresponding 4H-thiopyrans. In a study of the structure of sym-octahydrothioxanthenes by x-ray diffraction analysis it was shown [7] that the substituent attached to $C_{(9)}$ occupies a pseudoaxial position. This orientation of the substituent should introduce certain corrections into the possibility of coordination of the substrate on the catalyst, and cis addition of hydrogen in this case will lead to form B of the cis-syn-cis-perhydrothioxanthene with an axial orientation of R. However, we have already noted that this form is unstable and is probably converted to stable conformer A with an equatorial orientation of the substituent:



Thus a study of the products of the catalytic reduction of sym-octahydrothioxanthylium salts by ^{13}C NMR spectroscopy makes it possible to draw a conclusion regarding the high stereoselectivity of the reaction and regarding the formation during it of intermediates with a 4H-thiopyran ring in the structure, similar to the catalytic hydrogenation of thiopyrylium salts [1].

EXPERIMENTAL

The ^{13}C NMR spectra were recorded with a Varian FT-80A spectrometer (20 MHz) under conditions of complete and partial proton decoupling. The samples were prepared in the form of solutions in deuterochloroform (0.5 mole/liter). Tetramethylsilane (TMS) was used as the internal standard.

9-R-sym-Octahydrothioxanthylium Tetrafluoroborates (R = H, CH_3). These compounds were synthesized by the method in [8]. In connection with the difficulties involved in obtaining 9-phenyl-sym-octahydrothioxanthylium tetrafluoroborate, we used the corresponding hexachloroantimonate as the substrate for the preparation of 9-phenylperhydrothioxanthene by catalytic reduction of the salt.

9-Phenyl-sym-octahydrothioxanthylium Hexachloroantimonate. A solution of 11.96 g of $SbCl_5$ in 12 ml of concentrated HCl was added slowly dropwise with stirring and cooling to a solution of 2.82 g of 9-phenyl-sym-octahydrothioxanthene in 36 ml of acetic anhydride. The resulting brick-red precipitate was washed successively with acetic acid and ether and dried. The yield of the salt, which had mp 118-119°C, was 4.5 g (83%). Found: C 37.2; H 3.5; S 5.1%. $C_{19}H_{21}Cl_6SSb$. Calculated: C 37.0; H 3.4; S 5.2%.

Perhydrothioxanthenes I-III. These compounds were obtained by the method in [1] by hydrogenation of the sym-octahydrothioxanthylium tetrafluoroborates at a substrate:palladium ratio of 10:2 (10:3.5 in the case of 9-phenyl-sym-octahydrothioxanthylium hexachloroantimonate). Compound I, with mp 68-68.5°C (from ethanol), was obtained in 72% yield. Found: C 74.1; H 10.8; S 15.3%. $C_{13}H_{22}S$. Calculated: C 74.3; H 10.5; S 15.2%. Compound II, with mp 121-123°C (from ethanol), was obtained in 65% yield. Found: C 74.8; H 10.7; S 14.4%. $C_{14}H_{24}S$. Calculated: C 75.0; H 10.7; S 14.3%. Compound III, with mp 143-143.5°C [from benzene–ethanol (1:1)], was obtained in 86% yield. Found: C 79.8; H 9.1; S 11.1%. $C_{19}H_{26}S$. Calculated: C 79.7; H 9.1; S 11.2%.

Perhydrothioxanthene Dioxides IV-VI. These compounds were obtained by oxidation of sulfides I-III with 30% hydrogen peroxide in glacial acetic acid as in the method described in [9]. Sulfone IV, with mp 166-167°C (from ethanol), was obtained in 86% yield. Found: C

64.4; H 8.9; S 13.3%. $C_{13}H_{22}O_2S$. Calculated: C 64.5; H 9.1; S 13.2%. Sulfone V, with mp 243-245°C (from ethanol), was obtained in 81% yield. Found: C 65.6; H 9.0; S 12.3%. $C_{14}H_{24}O_2S$. Calculated: C 65.5; H 9.4; S 12.5%. Compound VI, with mp 196-198°C (from ethanol), was obtained in 94% yield. Found: C 71.5; H 8.0; S 10.5%. $C_{19}H_{26}O_2S$. Calculated: C 71.7; H 8.2; S 10.1%.

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