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CYCLOPHANES, 33 1)

2,11-DITHIA-[3.3](5,6)INDANO-ORTHOCYCLOPHANE AND 2,11-DITHIA-[3.3](5,6)INDANOCYCLOPHANE: SYNTHESIS, DNMR AND X-RAY STRUCTURE ANALYSIS

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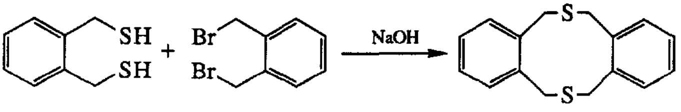
Abstract: The title compounds 11 and 10 have been prepared and studied by dynamic ^{1}H NMR spectroscopy. In solution, their preferred conformation is the same (probably anti) as for the nonanellated parent compound. In the solid state, 11 is anti according to an X-ray structure analysis.

2,11-Dithia-[3.3]orthocyclophane (3) was first reported in 1979 by Au et al.[2], who claimed that the dithiol-dibromide coupling of 1 and 2, in contrast to such couplings in the meta- and paracyclophane series, did not require high dilution conditions. This claim was recently challenged by Lai and Nakamura[3], who prepared 3 in order to determine the preferred conformation in solution. These authors concluded that the syn-conformer was of the lowest energy and that a syn/syn'-interconversion accounted for the observed coalescence of the bridge proton signals in the NMR spectrum at low temperature. More recently Fukazawa and coworkers presented results that suggest that the anti-conformer is preferred and that the dynamic process is in fact an anti/anti'-interconversion[4]:



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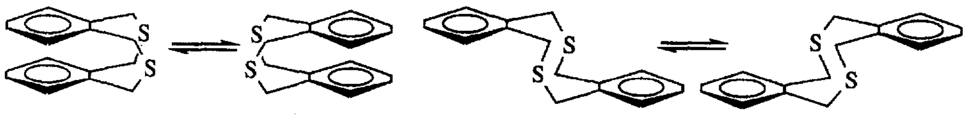
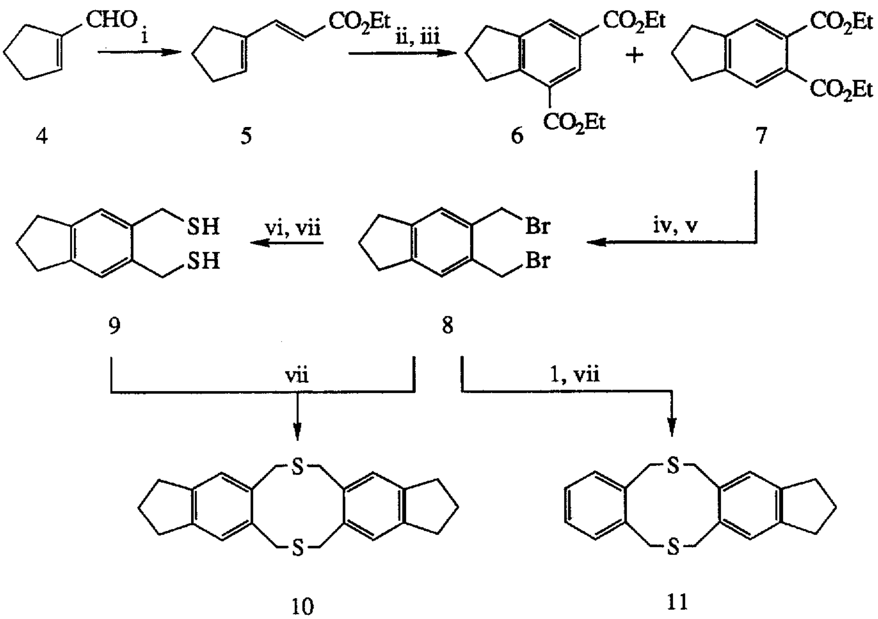


syn-3 syn'-3 anti-3 anti'-3

As part of our continuing study of indenocyclophanes[5] we have prepared 10 and 11, i.e. derivatives of 3, whose structural properties may shed light on the conformational properties of dithia-orthocyclophanes. The synthesis of these model systems is described in Scheme 1.

The Wittig reaction of 4[6] gave the diene 5[7] in 98% yield, exclusively as the trans-isomer. The Diels-Alder reaction of 5 with ethyl propiolate, followed by treatment of the crude mixture with DDQ, gave a mixture of the diesters 6 and 7, which were separated by column



Scheme 1. i) $(EtO)_2POCH_2CO_2Et$, NaH; ii) $HCCCO_2Et$; iii) DDQ; iv) $LiAlH_4$; v) PBr_3; vi) $(H_2N)_2CS$; vii) NaOH.

chromatography (SiO_2, CH_2Cl_2). The ratio of 6:7 lay between 1:2.5 and 1:6 and the total yield between 54 and 67%, depending on the reaction conditions[8)]. Reduction of 7 with $LiAlH_4$ in THF proceeded in 94% yield and subsequent bromination with PBr_3 in CH_2Cl_2 afforded 94% of the dibromide 8. The coupling of 1 with 8 under high dilution finally provided 87% of the cyclophane 11. Treatment of 8 with thiourea and then sodium hydroxide quantitatively furnished the dithiol 9 necessary for the synthesis of 10, which was obtained in 90% yield[8)].

In the low-temperature ^1H NMR spectra, the methylene protons of the CH_2SCH_2 bridges give rise to one coupled AB system in 10 and to two interleaved coupled AB systems in 11. The rate constants, k_c, at the coalescence temperatures, T_c, were evaluated by the method of Friebolin et al.[9)], which takes into account the line widths in the absence of chemical exchange. The resulting free energies of activation at the coalescence temperature, ΔG_c^*, for the conformational processes in 10 and 11 are listed in Table 1 and are compared with the literature value for 3. These data indicate an increase of ΔG_c^* with the number of anellated five-membered rings.

The chemical shifts of the protons of the non-anellated benzene ring in 11 and of the methylene protons in both 10 and 11 are very similar to those in 3 (Table 2). Hence in solution, the most stable conformer of 10 and of 11 is analogous to that of 3, which, according to the arguments of Fukazawa and co-workers[4)], is the anti-conformer.

To determine the preferred geometry of a dithia-indanophane in the solid state, a single-

Table 1. Parameters in the variable-temperature 400 MHz ^1H NMR spectra of the CH_2 groups in 3, 10 and 11.

Compound	$3^{a)}$	$11^{b,c)}$		$10^{c)}$
$\Delta\nu_{AB}$ [Hz]	96.0	106.6	94.3	107.4
J_{AB} [Hz]	14.7	15.0	15.0	15.0
$\nu_{1/2}$ [Hz]		≈3.5	≈3.5	3.3
T_c [K]	(225)	247±8	247±8	258±4
ΔG_c^* [kJ/mol]	46.0	48.9±1.9	48.9±1.9	51.1±0.8

a) From ref. 2; $\Delta\nu_{AB}$ converted from 90 to 400 MHz observation frequency; T_c not comparable to that of 10 and 11.

b) The larger error in T_c is caused by the overlap of the two AB spectra.

c) Solvent: $CD_2Cl_2/CDCl_3$ (3/1, v/v).

Table 2. ^1H NMR chemical shifts in 3, 10 and 11 ($CDCl_3$, ca. 25°C).

Compound	$3^{a)}$	11	10
$\delta[(CH_2)_3]$	-	2.91, 2.08	2.90, 2.07
$\delta(CH_2S)$	3.44	3.46, 3.41	3.43
$\delta(H_{Ar}$, <u>ortho</u>)	7.61	7.60	-
$\delta(H_{Ar}$, <u>meta</u>)	7.27	7.27	-
$\delta(H_{Ar}$, isol.)	-	7.45	7.45

a) From ref. 3.

crystal X-ray structure analysis was carried out with 11. As shown in Fig. 1, this orthocyclophane - like its parent compound 2,11-dithia[3.3]paracyclophane[4] - is anti-configurated. Provided, therefore, that there are no special geometric effects (such as bulky substituents in the molecular bridges) we conclude that this spatial arrangement is generally preferred by phanes of the type 3.

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10) Crystal data for 11: monoclinic, $P2_1/\underline{n}$, $\underline{a}$ = 990.3(4), $\underline{b}$ = 1133.7(5), $\underline{c}$ = 1421.2(7) pm, β = 95.49(3)°, $\underline{R}$ = 0.041 for 2142 unique observed reflections. Full details of the structure determination have been deposited at the Fachinformationszentrum Energie Physik Mathematik, D-7514 Eggenstein-Leopoldshafen 2, FRG; any request for this material should quote the full literature citation and the reference number CSD - 54057.

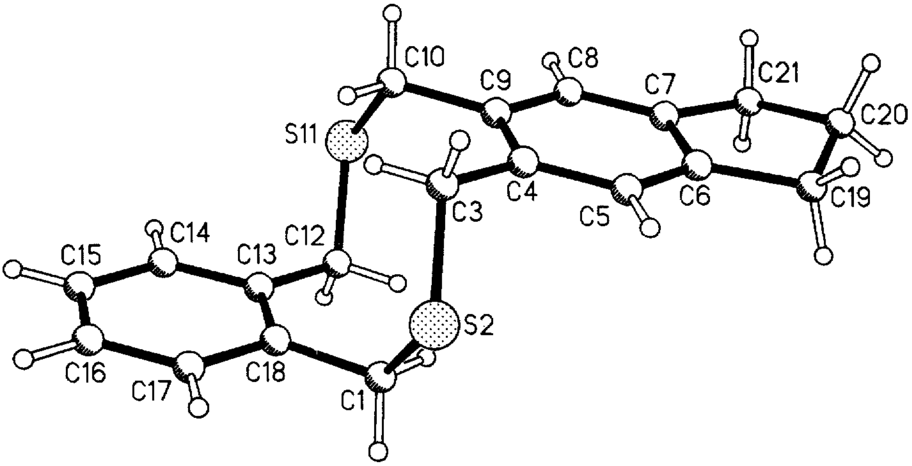

Fig. 1. X-ray structure analysis of 11 10)

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