Preparation of [2.2]*meta*- and *ortho*-Paracyclophanes Containing the Cyclohexano Group

J. Chem. Research (S), 1999, 608–609
J. Chem. Research (M), 1999, 2626–2636

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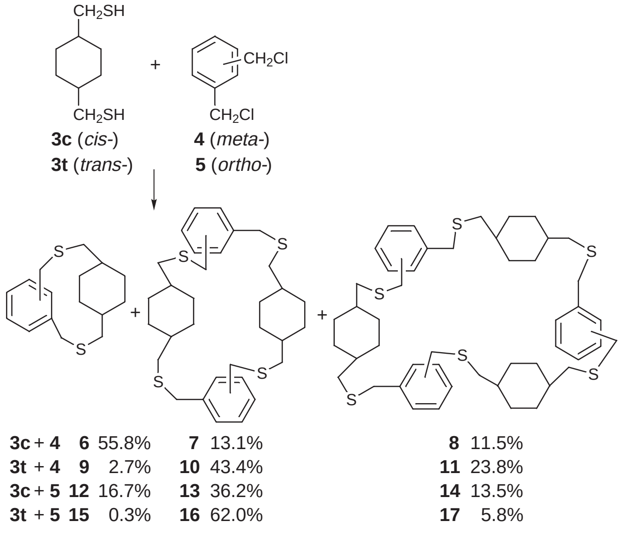
[2.2]Metaparacyclophane (**20**, *cis*-tricyclo[9.2.2.1^{4,8}]octadeca-4,6,8(16)-triene) and [2.2]orthoparacyclophane (**22**, *cis*-tricyclo[10.2.2.0^{4,9}]octadeca-4,6,8-triene) containing a 1,4-cyclohexano group bridged with two carbons are prepared through a coupling reaction to form the dithiacyclophanes, oxidation yields the sulfones followed by pyrolysis.

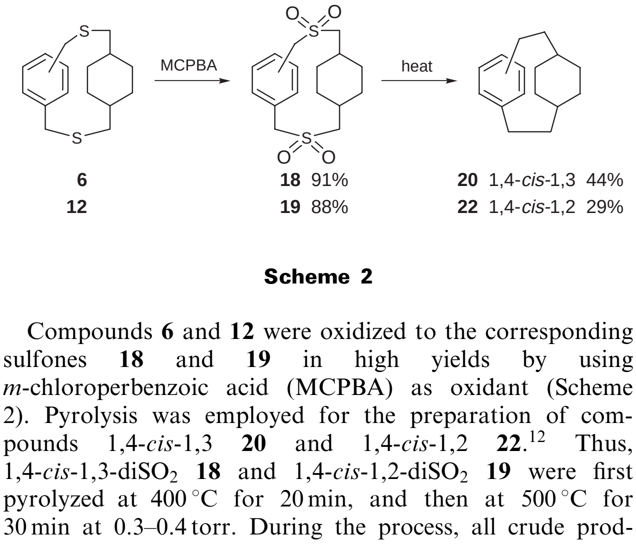
The majority of pure hydrocarbon cyclophanes which have been reported contain two arene rings.[1] In a previous work, we prepared paracyclophanes bearing a benzene ring and a *cis*- or *trans*-cyclohexane ring bridged with two carbons, *i.e.* 3*a*,4,5,6*e*,7,8-hexahydro[2.2]paracyclophane (1,4-*cis*-1,4 monomer) (**1**)[2] and 3*e*,4,5,6*e*,7,8-hexahydro-[2.2]paracyclophane (1,4-*trans*-1,4 monomer) (**2**).[3] Compound **1** was reduced using Li/NH$_3$ to form a diene,[2] which is different from that obtained by the catalytic hydrogenation of [2.2]paracyclophane.[4] The bridgehead methine hydrogen in the rigid structure of compound **2** appears at the high field resonance (δ −2.36) because of its placement over the π-cloud of the benzene ring. In this work we will describe their *meta*- and *ortho*-counterparts, prepared from the reaction of 1,4-bis(mercaptomethyl)cyclohexanes and 1,3- or 1,2-α,α'-dichloroxylene followed by oxidation and pyrolysis, for comparison.



Scheme 1

Results and discussion

The coupling reaction of α,α'-dichloroxylenes (**4**, **5**) and *cis*-, *trans*-1,4-bis(mercaptomethyl)cyclohexane (**3c**, **3t**) was carried out in an alcoholic NaOH solution, using the high dilution technique described by Davis.[6] The resultant solution was concentrated and then separated chromatographically to give the corresponding monomer, dimer, and trimer as shown in Scheme 1. The ratios of monomer : dimer were quite different when the *cis*-, and *trans*-isomer of mercaptanes and dichloroxylenes were used. The variations of the product distribution are due to possible ring strain in the products (Scheme 1). Too low yields of the resultant monomers 1,4-*trans*-1,3-diS **9** and 1,4-*trans*-1,2-diS **15** from the coupling of *trans*-bis(mercaptomethyl)cyclohexane **3t** and 1,3-$\alpha\,\alpha'$-dichloroxylene **4** and 1,2-α, α'-dichloroxylene **5** did not allow us to carry out further reactions. None of the isomers in this study showed the internal strain observed in the *cis* form of the corresponding paracyclophane which resulted in a non-planar benzene ring.[7] However, the conformation of the cyclohexane ring in the 1,4-*trans*-1,3-diS monomer **9** is a twist boat according to the X-ray crystallographic analysis.[7]



Scheme 2

Compounds **6** and **12** were oxidized to the corresponding sulfones **18** and **19** in high yields by using *m*-chloroperbenzoic acid (MCPBA) as oxidant (Scheme 2). Pyrolysis was employed for the preparation of compounds 1,4-*cis*-1,3 **20** and 1,4-*cis*-1,2 **22**.[12] Thus, 1,4-*cis*-1,3-diSO$_2$ **18** and 1,4-*cis*-1,2-diSO$_2$ **19** were first pyrolyzed at 400 °C for 20 min, and then at 500 °C for 30 min at 0.3–0.4 torr. During the process, all crude products were collected in a cold trap at −196 °C. After column chromatography the 1,4-*cis*-1,3 monomer **20** and 1,4-*cis*-1,2 monomer **22** were obtained, respectively, without any ring-opened compound as in the case of the *para*-counterpart. However, an intermediate, 1,4-*cis*-1,3-SO$_2$ monomer **21**, was obtained from pyrolysis of compound **18**.

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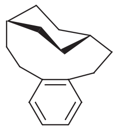

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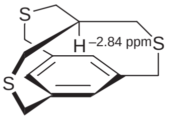

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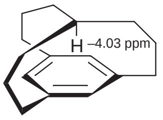

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Cyclophane series always contain bridges located at the benzene ring current cone resulting in an up-field shift in the ^{1}H NMR as well as in the ^{13}C NMR spectra. Therefore, NMR analysis will give some information about the conformation of the bridge chain in the liquid state.[13,14] However, ^{1}H NMR spectra for compounds **20** and **22** display relatively low-field resonances at $\delta \approx 0.25$ and $\delta \approx 0.85$, respectively. This is attributed to the lower ring strain in these compounds placing the bridging proton

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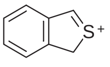
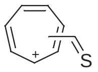
far away from the benzene ring current cone. The fragmentation of monomers in this series of compounds displays a characteristic fragment of 135 amu which corresponds to C_6H_7S. This fragment ion is a base peak for the coupling products **12**, **15** from *ortho*-dichloroxylene and 1,4-bis(mercaptomethyl)cyclohexane and relatively small intensities resulted from their *meta*-counterparts (**6**, **9**). However, there is no observation of their *para*-counterpart. Apparently, the fragment C_8H_7S can be a ring structure with a five-membered ring (**A**) or a tropylium ion (**B**) and ion **B** may form the *ortho*-, and *meta*-product.



A



B

Experimental

General.—^{1}H NMR spectra were recorded at 250 MHz, and ^{13}C NMR at 62.86 MHz at ambient temperature. Chemical shifts for the samples in deuteriochloroform solution are reported in δ units relative to tetramethylsilane. EI mass spectra were obtained on a JEOL JMS DX-300 double-focusing mass spectrometer at an ionization potential of 70 eV. Samples were introduced *via* a direct insertion probe. FAB-MS spectra were obtained on the same spectrometer with *m*-nitrobenzyl alcohol as matrix.

Typical Procedure for the Coupling Reaction.—A solution of compound **3c** (1.24 g, 0.7 mmol) and α,α'-dichloro-*m*-xylene (1.21 g, 0.7 mmol) was added over a period of 70 h to a solution of NaOH (0.6 g, 1.5 mmol) in 95% ethanol (200 ml), using a high dilution technique. The solution was refluxed for an additional 2 h and then concentrated *in vacuo* to give a viscous residue. The residue was extracted with CCl_4 (3 × 20 ml), dried over $MgSO_4$, filtered, and evaporated to give a waxy residue. The residue was separated chromatographically on silica gel with CH_2Cl_2–*n*-hexane (2/3: v/v) as an eluent to yield 1,4-*cis*-1,3-diS monomer **6**, 1,4-*cis*-1,3-tetraS-dimer **7**, 1,4-*cis*-1,3-hexaS trimer **8**.

Typical Procedure to Oxidize the Dithials to Sulfoxide.—A mixture of **6** (1.0 g, 3.48 mmol), MCPBA (70% purity, 3.52 g, 14.3 mmol) and 20 ml of $CHCl_3$ was refluxed for 16 h. The solvent was removed by evaporation. The remaining solid was stirred with saturated aqueous $Na_2S_2O_3$ (50 ml) for 10 min to quench the excess of MCPBA. The solid was collected by filtration and washed with water (30 ml × 3 and ether (30 ml × 3) to give 1.11 g (91.4% yield) of compound **18** as a white powder.

Typical Procedure to Pyrolyze the Extraction of Sulfur Dioxide.—Compound **18** (0.5 g, 1.5 mmol) was placed in a quartz tube (2.5 cm outer diameter × 120 cm length) with a cold trap for pyrolysis. The pyrolysis system was pre-evacuated to a pressure of 0.30–0.4 torr for 20 min and then the cold trap was cooled by means of liquid nitrogen. During pyrolysis, the temperature was held at 400 °C for 20 min, and then at 500 °C for 30 min. After the trap was warmed to room temperature, the residue was dissolved in CH_2Cl_2 (30 ml × 3). A waxy material obtained from the CH_2Cl_2 solution was subjected to chromatographic separation on 20% $AgNO_3$ on Al_2O_3 (1.5 cm outer diameter × 30 cm length) with hexane as eluent to give the 1,4-*cis*-1,3 monomer **20** and the 1,4-*cis*-1,3-monoSO_2 monomer **21**.

Techniques used: ^{1}H NMR, ^{13}C NMR, IR, MS, elemental analysis, mp

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Received, 8th June 1999; Accepted, 15th July 1999
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