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Layered Compounds. III. Synthesis and Configuration of Some Layered Cyclophanes

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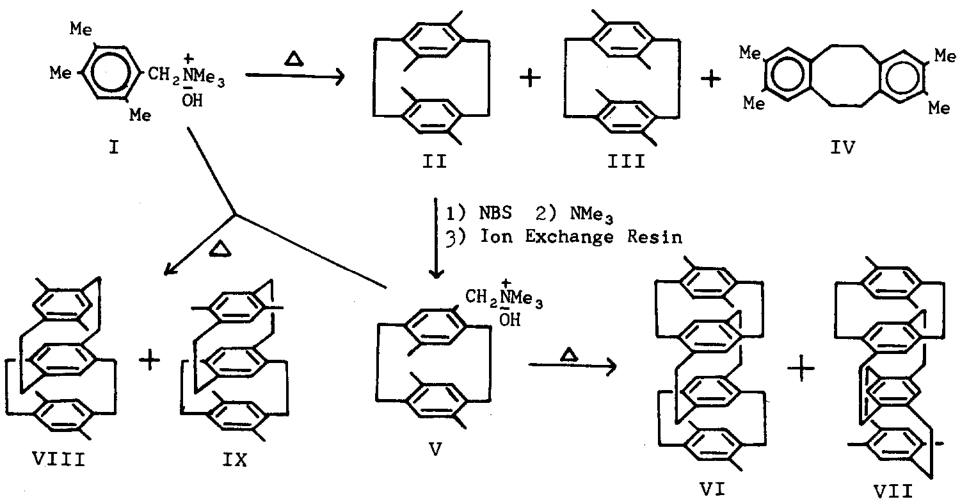
In the previous communications of this series, we have reported the synthesis of benzenoid triple-layered compounds, VIII, IX, and XVII(1), and triple-layered heterophanes(2) and observed a remarkable transannular interaction in those compounds. The present communication will report on separation and configuration of isomers producible on the Hofmann elimination reaction, i.e. double-layered compounds, II : III, and quadruple-layered compound, VI : VII and XIV : XV, together with the synthesis of a non-substituted, triple-layered compound XVI.

Longone reported that the structure of tetramethyl [2.2]paracyclophane was assigned to dissymmetric form II on the basis of optical resolution and that the other isomer III (eclipsed form) could not be afforded owing to mutual overcrowding of four methyl groups(3,4). On the pyrolysis of I in boiling xylene, however, we have observed the inclusion of a small amount of eclipsed form III in a mixture of main product II and by-product IV. The minor isomer III was separated from the readily soluble, staggered form II by treatment with a small amount of n-pentane.

The synthesis of a quarternary ammonium hydroxide V was carried out according to the procedure of Longone(3). Pyrolysis of V in boiling xylene afforded a mixture of quadruple-layered cyclophanes, VI and VII. After column chromatography the readily soluble isomer VII was separated from the sparingly soluble one VI by treatment with carbon tetrachloride-acetone (1 : 3). The structure of major isomer VII and minor isomer VI was determined by comparison of product ratio, solubility, and electronic spectra with non-methyl substituted quadruple-layered compounds, XIV and XV, which structures were established as described below.

Dimethyl [2.2]paracyclophane XI(5), obtained by the cross-breeding reaction of ammonium hydroxides I and X, was derived to an ammonium hydroxide XIII in the usual way. Pyrolysis of XIII in boiling xylene afforded a mixture of non-substituted quadruple-layered compounds, XIV and XV. Just as described in the case of methyl substituted quadruple-layered compounds, the

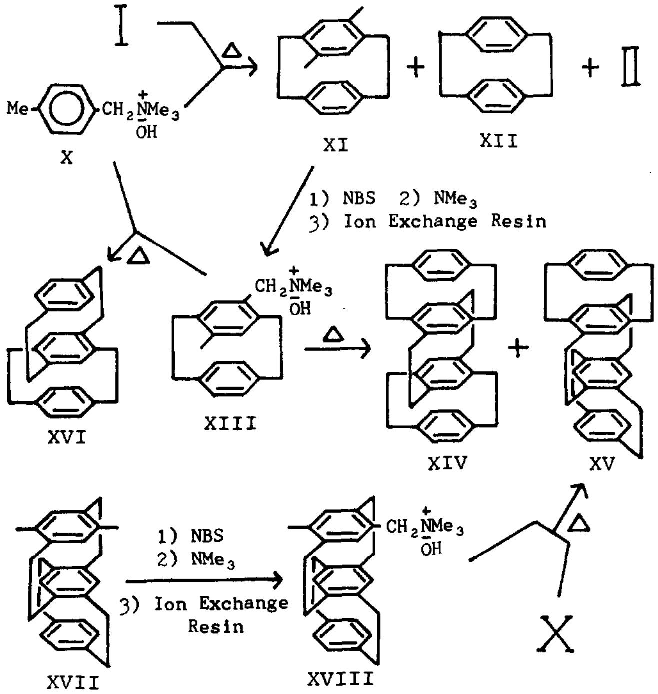


readily soluble isomer was separated from the sparingly soluble one by treatment with the same solvent mixture. The former was assigned to the structure XV by direct comparison with an independently synthesized sample. Thus, dimethyl triple-layered compound XVII1), obtained by the cross-breeding reaction of V and X, was derived to an ammonium hydroxide XVIII in the usual way. Following cross-breeding reaction of XVIII with X gave, together with [2.2]paracyclophane XII, only the dissymmetric compound XV, which was proved to be identical with the readily soluble isomer obtained by pyrolysis of XIII. Consequently, the sparingly soluble isomer was assigned to the isomeric structure XIV.

Also, non-substituted triple-layered compound XVI was prepared by the cross-breeding reaction of ammonium hydroxides X and XIII. The yield and properties of multilayered cyclophanes stated above were summarized in Table 1. All of new cyclophanes were characterized by NMR, IR, and Mass spectra and elemental analysis.

The mass spectra of each pair of double-layered compounds II-III, quadrupled-layered ones VI-VII and XIV-XV show entirely identical molecular ion peak and fragment pattern, supporting an isomeric relationship between each pair of the layered compounds.

The NMR spectra of these multilayered cyclophanes together with those of reference compounds are summarized in Table 2. The aromatic protons were assigned on the basis of integral strength and solvent effect. Thus, the protons which gave a smaller difference ($\Delta\tau$: 0.03∼0.06 ppm) between chemical shifts in carbon tetrachloride and deuteriochloroform were assigned to inner protons (inn.H), and the protons displaying larger difference ($\Delta\tau$: 0.10∼0.16



ppm) to outer ones (out.H). The fact that the aromatic protons in II are more deshielded (τ : 0.18 ppm) than the corresponding protons in III is due to steric compression effect6) of methyl group at pseudo-gem position+ to the very aromatic protons. A remarkable case of such the steric compression effect is of dimethyl [2.2]paracyclophane XI, in which the aromatic protons (τ 3.32) at pseudo-gem position to the methyl groups are in much lower field than the pseudo-ortho protons (τ 3.74). The differences in the chemical shifts of inn.H are also found to be ca. 0.4 τ for each pair of XVI-XVII and XVII-VIII. Of particular interest is the chemical shift of the inner protons in VIII, which are sandwiched in between two methyl groups. They appear in lower field by two times of value above-stated, i.e. ca. 0.8 ppm, than inn.H of XVI.

Table 1. Yield and Properties of Cyclophanes

Compound	Yield (%)	Crystal Form	M.P. (C°)
II	20	colorless plates1)	106~107
III	0.1	colorless plates2)	230~231 5)
VI	1.6	colorless prisms4)	265 (dec.)6)
VII	3.2	powdered crystals3)	265 (dec.)6)
XI	5.6	colorless plates1)	154~155
XIV	0.75	colorless prisms4)	220 (dec.)
XV	1.1	colorless plates2)	220 (dec.)
XVI	1.3	colorless plates2)	230 5),7)

recrystallized solvent: 1) petroleum ether, 2) carbon tetrachloride-acetone, 3) chloroform-ether-petroleum ether (1:1:1), 4) toluene.
5) sealed tube, 6) shock heating, 7) melt with decomposition

Table 2. NMR Spectra of Layered Compounds

Compound	Aromatic Proton		$\Delta\tau^{a}$	Benzylic Proton		Methyl Proton	
	CCl_4	$CDCl_3$		CCl_4	$CDCl_3$	CCl_4	$CDCl_3$
durene	3.26 (s)	3.10 (s)	0.16			7.88 (s)	7.85 (s)
XII	3.65 (s)	3.53 (s)	0.12	6.99 (s)	6.94 (s)		
XI pseudo-gem	3.32 (A_2B_2)	3.22 (A_2B_2)	0.10	6.5$\sim$7.7 (m)		7.95 (s)	7.90 (s)
pseudo-ortho	3.74 (A_2B_2)	3.64 (A_2B_2)	0.10				
ortho	4.12 (s)	4.00 (s)	0.12				
II (stagger)	3.75 (s)	3.64 (s)	0.11	6.8$\sim$7.6 (A_2B_2)		8.04 (s)	7.98 (s)
III (eclipse)	3.93 (s)	3.81 (s)	0.12	6.5$\sim$7.4 (A_2B_2)		7.85 (s)	7.78 (s)
XVI out.H (8H)	3.92 (s)	3.84 (s)	0.08	6.8$\sim$7.7 (m)			
inn.H (2H)	4.65 (s)	4.61 (s)	0.04				
XVII out.H (4H)	3.88 (s)	3.77 (s)	0.11	6.8$\sim$8.1 (m)		8.17 (s)	8.11 (s)
inn.H (2H)	4.30 (s)	4.25 (s)	0.05				
out.H (2H)	4.36 (s)		0.11				
VIII out.H (4H)	4.33 (s)	4.21 (s)	0.12	6.7$\sim$7.7 (m)		8.11 (s)	8.07 (s)
inn.H (2H)	3.94 (s)	3.88 (s)	0.06				
XIV out.H (8H)	4.02 (s)	3.88 (s)	0.14	6.7$\sim$7.9 (m)			
inn.H (4H)	4.90 (s)	4.87 (s)	0.03				
XV out.H (8H)	4.02 (s)	3.91 (s)	0.11	6.7$\sim$7.9 (m)			
inn.H (4H)	4.88 (s)	4.85 (s)	0.03				
VI out.H (4H)	4.45 (s)	4.32 (s)	0.13	6.8$\sim$8.1 (m)		8.20 (s)	8.16 (s)
inn.H (4H)	4.52 (s)	4.48 (s)	0.04				
VII out.H (4H)	4.43 (s)	4.31 (s)	0.12	6.8$\sim$8.1 (m)		8.19 (s)	8.16 (s)
inn.H (4H)	4.53 (s)	4.48 (s)	0.05				

a. $\Delta\tau = \tau\ (CCl_4) - \tau\ (CDCl_3)$

In addition to the steric compression effect of pseudo-gem methyl groups, Table 2 also reveals that the more the number of layer increases, the more the shielding effect (especially remarkable to aromatic protons) due to the anisotropy of benzene rings increases.

† Nomenclature of pseudo-gem and pseudo-ortho was taken according to D. J. Cram, J. Am. Chem. Soc., 91, 3505 (1969).

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