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HINDERED ROTATION IN PARACYCLOPHANES WITH SUBSTITUENTS[1] ON THE AROMATIC RINGS.

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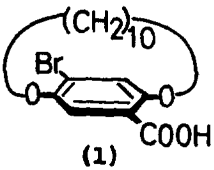
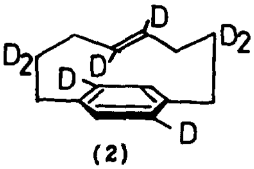
Hindered rotation of the aromatic ring in paracyclophanes with suitable length of bridge was first demonstrated by the successful optical resolution of the oxygen-containing paracyclophane (1) by Lüttringhaus and co-workers[2]. Of the available spectroscopic techniques, n.m.r. spectroscopy has proved to be the best suited for the direct examination of this sort of internal rotation, and Cope[3] made the elegant kinetic analysis of spin-coupled nmr spectra of (2) to obtain the rates and activation parameters describing the interconversion of enantiomers of (2).

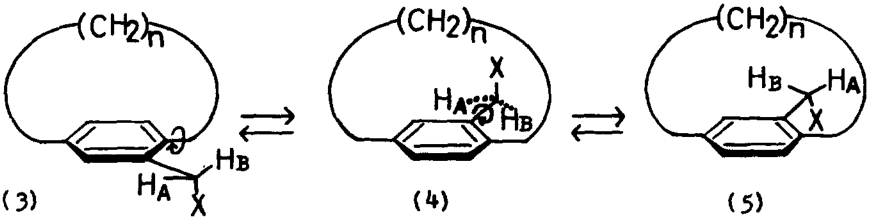


(1)



(2)

In this communication, we report examination of the rates of interconversion (3)⇄(4)⇄(5), between the enantiomers of each of five inherently chiral paracyclophanes (3a)~(3e) with the diastereotopic methylene protons which become indistinguishable on rapid interconversion.[4]



(3) (4) (5)

a, $n = 10$, $X = Br$

b, $n = 11$, $X = Br$ d, $n = 12$, $X = CO_2C_2H_5$

c, $n = 12$, $X = Br$ e, $n = 12$, $X = OH$

Bromomethylation of [n] paracyclophanes (n=10, 11, 12)[5] afforded the corresponding bromomethyl derivatives: 12-bromomethyl[10]paracyclophane (3a), b.p.131-132°/0.1 Torr, n_D^{23}1.5591; 13-bromomethyl[11]paracyclophane (3b), b.p. 134-135°/0.1 Torr, n_D^{22}1.5587; 14-bromomethyl[12]paracyclophane (3c), b.p.141-142°/0.1 Torr, n_D^{23}1.5561.

14-Carboethoxymethyl[12]paracyclophane (3d), b.p.152-153°/0.6 Torr, n_D^{29} 1.5148, was prepared from the bromide (3c), Via the nitril, and the alkaline hydrolysis of (3c) gave 14-hydroxymethyl[12]paracyclophane (3e), b.p. 172-173°/2.0 Torr, n_D^{21}1.5346.*

The nmr spectra[6] of the methylene protons of the bromides (3a) and (3b) in hexachloro-1,3-butadiene show typical AB spectra whose shapes didn't show much change on heating up to 160°, indicating considerably high barriers of rotation in these cases.

If it is assumed that the bromomethyl group and carboxyl group exhibit similar steric effect on the racemization, the upper limit of optical resolvability of [n] paracyclophane carboxylic acids could be extended to 13-carboxy[11]paracyclophane from the lower homolog 12-carboxy[10]paracyclophane which has been successfully resolved by Blomquist and co-workers[2].

Each of the AB spectra of the compounds (3c), (3d) and (3e) at room temperature, collapsed to a single sharp line on warming.

Determination of the rate of interchange of protons leading to this collapse was carried out using density matrix procedure[7].

Typical observed and calculated spectra are compared in Fig.1 and the coupling constants and chemical shifts used in this variable temperature analysis, together with the coalescence temperature (Tc) and Arrhenius activation energy (Ea) are given in Table I.

It seems pertinent here to mention that the Arrhenius parameters given in Table I are for the whole interconversion $(3)\rightleftarrows(4)\rightleftarrows(5)$, and not just for the internal rotation of the benzene ring through the loop of the bridging chain.

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* New compounds and their derivatives prepared in this work have been characterized satisfactorily by elemental analysis and various spectroscopies.

The considerable substituent effect, OH > Br > $CO_2C_2H_5$ probably reflects the order of their steric hinderances in the (4)⇄(5) process.

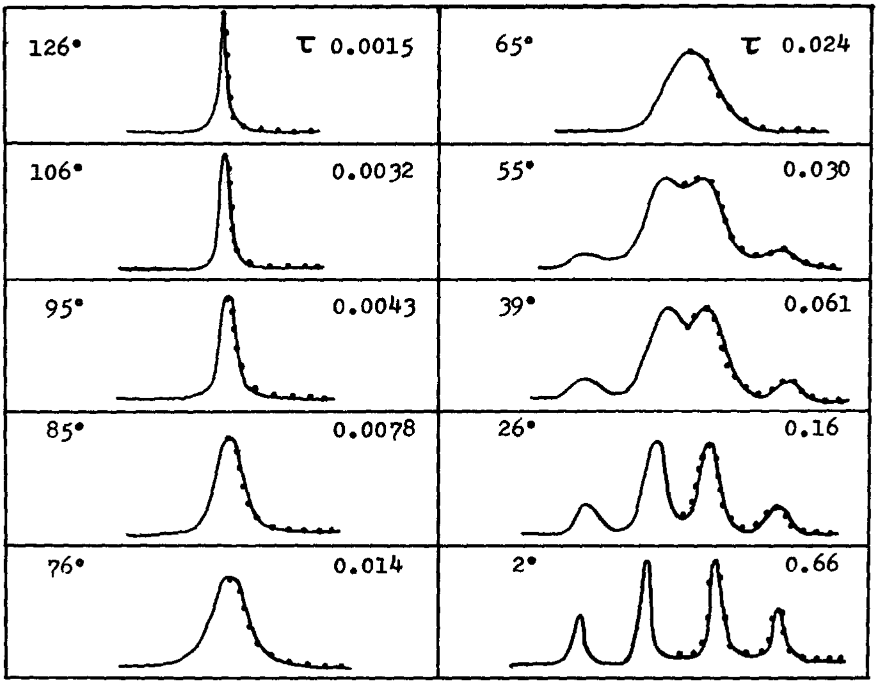

Fig.1. Observed (——) and calculated (••••) spectra for the $-CH_2Br$ protons of 14-bromomethyl[12]paracyclophane (3c) as a function of temperature. (τ : lifetime in second)

Table I.

Coupling Constants and Chemical Shifts used in Variable-Temperature Analysis. Tc: Coalescence Temperature; Ea: Arrhenius Activation Energy.

Compd.	Solvent	Temp. range (°C)	δ_{AB} (cps)	J_{AB} (cps)	Tc (°C)	Ea (kcal/mole)
(3a)	a	23 ~ 161	18.5	10.1	161	
(3b)	a	23 ~ 162	18.4	10.0	162	
(3c)	a	0 ~ 126	15.0	10.1	65	11.3 ± 0.4
	b	12 ~ 143	15.3	10.3	61	11.7 ± 0.5
(3d)	b	11 ~ 151	8.9	15.5	60	6.5 ± 0.6
(3e)	a	9 ~ 163	19.5	13.5	74	13.3 ± 0.6

Solvent: a, hexachloro-1,3-butadiene; b, nitrobenzene.

REFERENCES

1) Presented at the 21st Annual Meeting of the Chemical Society of Japan, Osaka, March 31, 1968.

2) A. Lüttringhaus and H. Gralheer, Ann., **550**, 67 (1940); **537**, 108, 112 (1945); A. Lüttringhaus and G. Eyring, ibid., **604**, 111 (1957).
The carbocyclic analogue, 12-carboxy[10]paracyclophane also has been optically resolved. A. T. Blomquist and B. H. Smith, J. Am. Chem. Soc., **82**, 2073 (1960); A. T. Blomquist, R. E. Stahl, Y. C. Meinwald and B. H. Smith, J. Org. Chem., **26**, 1687 (1961).

3) G. M. Whitesides, B. A. Pawson and A. C. Cope, J. Am. Chem. Soc., **90**, 639 (1968).

4) For the first and pertinent example applying the kinetic analysis of the spin-coupled nmr spectra of diastereotopic methylene protons to internal rotation study, see W. L. Meyer and R. B. Meyer, ibid., **85**, 2170 (1963).

5) D. J. Cram and H. Daenicker, ibid., **76**, 2743 (1954); D. J. Cram, N. L. Allinger and H. Steinberg, ibid., **76**, 6132 (1954).

6) Nmr spectra are taken on a Nucleomagnetic Resonance Spectrometer JNM-4H-100, Japan Electron-Optics Laboratory Co., Ltd.

7) (a) S. Alexander, J. Chem. Phys., **37**, 967 (1962); **38**, 1787 (1963). (b) J. Heidberg, J. A. Weil, G. A. Janusonis and J. K. Anderson, ibid., **41**, 1033 (1963). (c) C. S. Johson, Jr., Advan. Magnetic Resonance, **1**, 33 (1965).
These calculated spectra were made up with the aid of a program written for a NEAC-2200 Computer, Osaka University Computation Center.