Iodine-induced Transformation of [2,2]Metacyclophanes to 1,2,3,3a,4,5,-Hexahydropyrenes: A Highly Selective Cycloisomerization Reaction Involving Intermolecular Hydrogen Transfer

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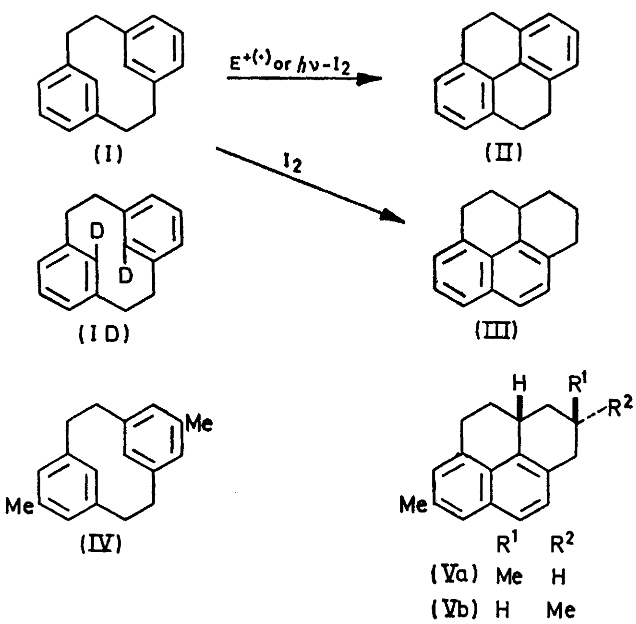
Summary An iodine-induced cycloisomerization reaction of [2,2]metacyclophanes to form 1,2,3,3a,4,5-hexahydropyrenes has been shown to occur with remarkable ease and with high selectivity and to involve an intermolecular hydrogen-transfer process as shown by experiments using a deuteriated precursor.

Transannular reactions between aryl rings in [2,2]metacyclophane (I) have been previously reported.[1] Electrophilic,[2-4] photolytic,[3,5] and some radical reactions† produce a dehydrogenation product, 4,5,9,10-tetrahydropyrene (II), as the initial product, which undergoes further substitution or dehydrogenation.

We have found an iodine-induced cycloisomerization reaction of (I) which occurs with remarkable ease and with high selectivity. When a benzene solution of (I) (0·32 M) containing 0·14 equiv. iodine was warmed at 60° for 20 h, 1,2,3,3a,4,5-hexahydropyrene (III),[6] m.p. 103—104° (picrate, m.p. 147·5—148°) was obtained in quantitative yield.

The reaction has been found to be general for this class of compounds. Under similar conditions, for example, 5,13-dimethyl[2,2]metacyclophane (IV)[7] gave 2,7-dimethyl-1,2,3,9,10,10a-hexahydropyrene (V) as a mixture of configurational isomers in 70% yield. By repeated chromatography on alumina axial and equatorial isomers, (Va) (m.p. 90—91°) and (Vb) (m.p. 163—164°) were separated. The ratio of (Va) to (Vb) was 54:46 as determined by n.m.r. The structures were confirmed by analysis, and mass, u.v., and n.m.r. spectra. From the u.v. spectra tetra-alkylnaphthalene structures were easily recognized: λ_{max} (C_6H_{12}), 230 (ϵ 54,500), 236 (95,400), 248 (3530), 268 (4170), 278 (6020), 284 (5650), 291 (5040), 299 (3030), 315 (1570), 324 (1420), 330 (2380), and 338 nm (903) [a mixture of (Va) and (Vb)].



Deuterium distribution (%)

Compound	Source	$^2H_0$	$^2H_1$	$^2H_2$	$^2H_3$	$^2H_4$	$^2H_5$
(ID)		1·7	21·3	77·0			
(IIID)	(ID)	21·5	34·6	26·4	12·5	4·0	1·0
(IIID)	(ID) + (IV)	39·0	38·0	17·2	4·9	0·9	
(VD)	(ID) + (IV)	52·3	34·7	10·7	2·1	0·2	

Each compound exhibited two methyl signals in $CDCl_3$, one as a singlet at δ 2·43 (the same for both, $ArCH_3$) and the other as a doublet at δ 1·11 (*J* 7·0) and at δ 1·13 (*J* 6·0) together with other signals expected from (V). The methyl doublet for (Vb) has a smaller *J* and is shifted upfield on addition of C_6D_6, in agreement with a quasi-equatorial configuration. The structure is further supported by chromatographic behaviour and physical properties, *e.g.* (Vb) has a higher m.p. and elutes from an alumina column more slowly than (Va).

Direct chemical evidence for the structure of (V) was derived by its conversion into 2,7-dimethylpyrene, m.p. 229—230°, by dehydrogenation over Pd–C. Other alkylated [2,2]metacyclophanes which underwent similar isomerization include the 4,14-dimethyl and 4,6,12,14-tetra-

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† Examples include reactions with benzoyl peroxide and di-isopropyl peroxydicarbonate.

methyl derivatives. No alkyl migration or skeletal changes were observed during the transformation.

The cycloisomerization proceeded satisfactorily in hexane, but no reaction occurred in EtOH, AcOH, CS_2, or DMF. No isomerization of (I) was observed in benzene solution when less than 0·06 equiv. iodine was used. Low concentration of the substrate ($< 0·013$ M) also retarded the reaction even when a sufficient amount of iodine was present. Except for $AlCl_3$,[8] Lewis acids such as $FeCl_3$, $CuCl_2$ and $CuBr_2$, and $NiCl_2$ were ineffective. Bromine gave a small amount of (III) although the major product was (II).

The marked effects of substrate and iodine concentration on the rate of cycloisomerization suggest an intermolecular hydrogen transfer process. To test this by a cross experiment an equimolar mixture of $[8,16\text{-}^2H_2]$-[2,2]metacyclophane (ID) (m.p. 132—133°) (for deuterium content see Table) and (IV) was similarly treated with iodine. By chromatography, deuteriated (III) and (V) were separated and subjected to mass spectrometry.[9] For comparison, deuterium distribution in (IIID) derived from (ID) is shown in the Table. The fact that a total of 47·7% of deuterium was transferred during the cross experiments clearly indicated that the reaction proceeded *via* an intermolecular mechanism.‡ Due to internal scrambling the position of labelling in (IIID) and (VD) could not be located by mass spectrometry.[10]

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‡ No deuterium transfer was observed in the control experiments in which a $[^2H_8]$toluene–*m*-xylene–iodine system was similarly treated and analysed.

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[8] Baker and his co-workers (W. Baker, J. F. W. McOmie, and J. M. Norman, *J. Chem. Soc.*, 1951, 1114) have noticed the formation of (III) among other products on treatment of (I) with $AlCl_3$ in CS_2. Re-examination of the reaction showed the presence of at least seven substances. The reaction involves fragmentation as well as alkyl disposition and a different mechanism from ours must be formulated.

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