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STRUCTURAL SPECIFICITY IN ASYMMETRIC CHARGE-TRANSFER COMPLEXATION OF HELICENES

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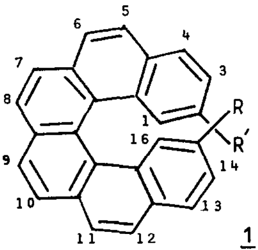
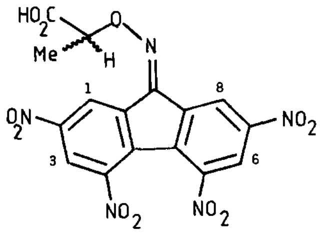
Abstract The diastereomeric charge-transfer complexes formed between the two enantiomers of 2,15-dimethoxy[6]helicene and R(-)2-(2,4,5,7-tetranitro-9-fluorenyloximino)propanoic acid have quite distinct geometries, revealed by NMR.

The original resolution[1] of [6] helicene (1) was carried out by repeated fractional crystallisation of the racemate from solutions containing the optically active π-acid R(-)2-(2,4,5,7-tetranitro-9-fluorenyloximino)propanoic acid (2). Preferential *association between the S (+) isomer of (2) and the M(-)enantiomer of (1) was subsequently* demonstrated by circular dichroism, but selectivity was rather small.[2] Resolution of helicenes has been effected on silica HPLC columns modified by covalent bonding of (2) to the silica surface via an amidopropylsiloxane linkage, enantiomer separation increasing with the degree of annelation.[3] Other chiral supports have been similarly utilised in the separation of helicene enantiomers with varying success. The charge-transfer complex formed is sufficiently simple that we have investigated its solution structure by NMR in an attempt to elucidate the origin of asymmetric induction.



1 R=R^1=H
3 R=H; R=OMe
4 R=R^1=OMe



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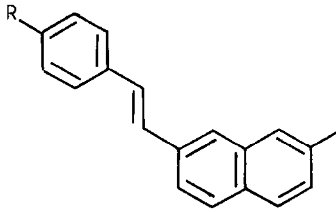
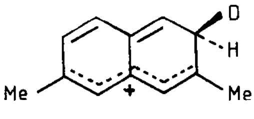
Compounds [6]-helicene (1), 2-methoxy[6]-helicene (3) and 2,15-dimethoxy [6] helicene (4) were readily synthesised by photocyclisation (C_7H_8, medium-pressure 450 W lamp) of the appropriate 2,7, bis(E-2-phenylethenyl)naphthalenes (5) prepared by Siegrist reaction.[5] Preliminary NMR experiments indicated that the 7- and 8-positions of (1), which are near-isochronous in the absence of (±)(2) were strongly differentiated in its presence, and thus a deuterated analogue was prepared to avoid ambiguity. In CF_3CO_2D at 70^{o}, 2,7-dimethylnaphthalene was observed to incorporate deuterium rapidly at the 1- and 8-positions, less rapidly at the 3- and 6-positions (via cation (6)) and considerably more slowly at the 4- and 5-positions. This permitted the preparation of a partially deuterated sample of (5a) which was converted into (1) selectively labelled at the 7-position.[6]



5a R=R^1=H
5b R=H; R^1=OMe
5c R=R^1=OMe



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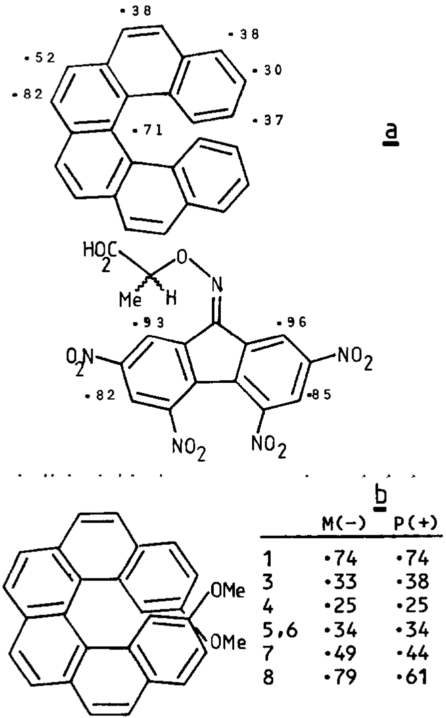
Quantitative measurements were carried out in 50:50 v/v $(CD_3)_2CO:CD_2Cl_2$ on solutions containing a fixed quantity of (1) and varying concentrations of (±) (2). The chemical-shift data analysed well for 1:1 complexation[7] and gave the limiting-shifts displayed in Figure 1a. All ring sites in the acceptor (2) are similarly affected but those of the helicene are differentially shifted with diamagnetic shielding outweighing the deshielding effect of



	M(-)	P(+)
1	·74	·74
3	·33	·38
4	·25	·25
5,6	·34	·34
7	·49	·44
8	·79	·61

Figure 1 a Limiting shifts for (1) complexed to (±) 2, 230 K and b for (4) complexed to R(-)(2) 248 K

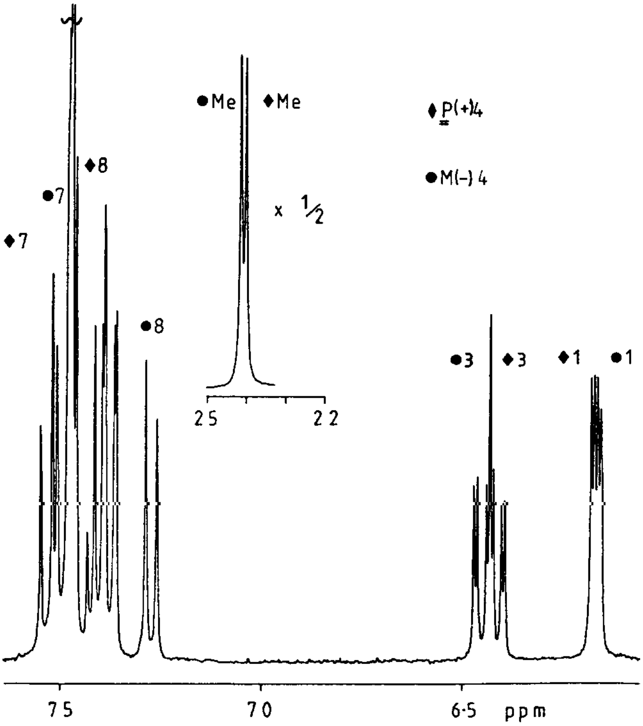


Figure 2 ^{1}H NMR spectrum of a solution 0.0155 M in (4) and 0.086 M in R(-)(2), 248 K. The region 6-8 ppm is displayed with OMe resonances inset.

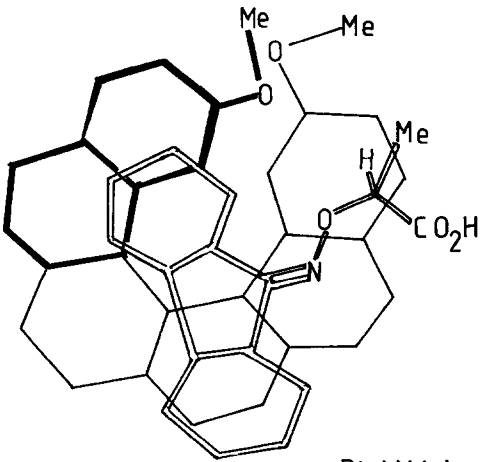
charge-transfer, as anticipated.[8] The protons most strongly affected in (1) are the 1- and 8-sites, with the periphery of the A- and B rings evidently more remote from the π-system of the acceptor. Experiments were conducted with R(-)(2) in admixture with (1) and it was noted that the 8-protons showed the largest diastereomeric splittings.[9]

A more detailed study of stereoselectivity was carried out using (4), following on from the observation that complexation of acceptor (2) occurs preferentially to the methoxyl-substituted face of helicene (3). X-ray structural studies indicate that substituents at the 2- (and 15-) positions of [6]-helicenes cause little skeletal distortion.[10] Limiting shifts for the association of acceptor R(-)(2) in solutions containing 0.015 M(4) at 248 K are shown in Figure 1b, and a typical spectrum of the helicene moiety is displayed in Figure 2. This clearly demonstrates that the sample contains two diastereomeric complexes in rapid equilibration with the respective enantiomeric helicenes:

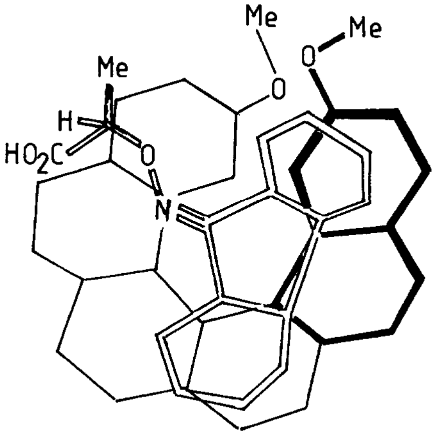
$$[\underline{\underline{P}}(+)(4)\underline{\underline{R}}(-)(2)] \overset{K_+}{\rightleftharpoons} \underline{\underline{P}}(+)(4);\ M(-)(4) \overset{K_-}{\rightleftharpoons} [M(-)(4)\underline{\underline{R}}(-)(2)]$$

The chirality of diastereomeric complexes was defined by similar spectral studies on partially resolved (4), prepared by flash chromatography of racemic material on silica gel to which R(-)(2) had previously been adsorbed.[11] The initial eluate was 20% enriched in M(-) isomer, and tail fractions similarly enriched in P(+) isomer. A striking feature of the spectra is the strong chiral splitting of 8-protons (corresponding to a 54 Hz shift separation at 300 MHz for an average complexation shift of 210 Hz). Equilibrium constants are rather similar, with $K_- = 53 \pm 3$ and $K_+ = 57 \pm 3$, and it is the less well-complexed M(-) enantiomer which shows the greater 8- proton shift. The other pronounced chiral splitting is of the 3-protons and here it is the P(+) isomer which experiences the greater effect.

For the parent compound (1) the data are consistent with formation of a charge-transfer complex with an intermolecular spacing of ca. 3.3Å [12] for which 1- and 8-protons are most strongly exposed to ring current of (2) whose chiral side-chain is associated with the groove of the helix. Dimethoxyhelicene (4) forms complexes with R(-)(2) whose detailed structure depends on which enantiomer is involved, with the side-chain more deeply entrained in the P(+): R(-) diastereomer (Figure 3). In the M(-): R(-) diastereomer the preferred



$\underline{\underline{R}}(-)\underline{\underline{M}}(-)$



$\underline{\underline{R}}(-)\ \underline{\underline{P}}(+)$

conformation of the side-chain[13] engenders greater steric hindrance and causes a pronounced displacement. Despite the close similarity of complexation constant, the structures of the two diastereomeric complexes are significantly different, more so than in previously observed cases.[9] The sites most strongly affected are those most remote from the region of arene ring overlap responsible for molecular asymmetry.

Refinement of the model is in progress.[14,15]

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