THE THERMAL RACEMIZATION OF METHYL-SUBSTITUTED HEXAHELICENES

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Abstract—Rates of racemization of several Me-substituted hexahelicenes have been measured. It appeared that Me groups at the positions 3, 4, 13 and 14 have no influence; at the positions 2 and 15 the effect is small; Me-substitution at C(1) and C(16) leads, however, to a large increase of the free energy of activation. From an analysis of the data the suggestion is made that the conformation of highest energy during racemisation of 1-methyl- and 1,16-dimethylhexahelicene (and possibly also of hepta and octahelicene) is that with the terminal rings in orthogonal position.

In a previous paper¹ we reported that Me-substituents at the positions 1 and 16 of hexahelicene have a rather large influence on the helical conformation. The deformations of the benzene rings are more regularly spread over the whole helix and the overlap of the terminal rings becomes larger.

In Martin's investigation² of the racemization of helicenes it has been shown that the addition of a benzo group to hexahelicene leads to a substantial increase of the free energy of activation in going from hexahelicene to heptahelicene (ΔG_{rac}^{-} 36.2 and 41.7 kcal/mol at 27°, respectively); the effect of further annelation of benzo groups is much smaller, however (ΔG_{rac}^{-} of octahelicene 42.4 kcal/mol, nonahelicene 43.5 kcal/mol). The racemization of these compounds is thought to occur via an achiral intermediate state in which deformations have been spread over many degrees of freedom in the molecules. In connection with these results it seemed interesting to investigate the influence of Me-substituents at the terminal rings of hexahelicene on the rate of racemization.

RESULTS AND DISCUSSION

Several Me-substituted hexahelicenes were partly resolved by column chromatography over silicagel, impregnated with *ca.* 3% (-)TAPA.³ Dilute[†] solutions of the compounds (*ca.* 10^{-3} mol/l) in dibenzylether (naph-thalene for experiments at higher temperatures²) were heated in a carius oven at temperatures between 200 and

†At higher concentrations 1,16-dimethyl- and 1,3,14,16tetramethylhexahelicene undergo a remarkable rearrangement, even at temperatures lower than necessary for racemization (see the next paper).

> (1) R = H (5) $R_1 = R_3 = R_{14} = R_{18} = Me$ (2) $R_1 = Me$ (6) $R_2 = R_{15} = Me$ (3) $R_1 = R_{14} = Me$ (7) $R_4 = R_{13} = Me$ (4) $R_1 = R_{16} = Me$

300°, and the racemization process was followed by measuring the optical rotation ($[\alpha]_D$) at intervals. In control experiments it was established that the solvent had no influence on the results.

The decrease of $[\alpha]_D$ with time, expressed as $\ln [\alpha]_0/[\alpha]_t$, appeared to be linear over a period of at least 2 hr. Rate constants (k_{rac}) and free energies of activation (ΔG_{rac}) of the racemizations were calculated from the eqns (1) and (2), respectively. T in (2) is the absolute temperature at which k_{rac} was measured.

$$\mathbf{k}_{\rm rac} = 1/2\mathbf{t} \cdot \ln\left[\alpha\right]_0 / \left[\alpha\right]_{\rm t} \tag{1}$$

$$\Delta G_{rac}^{\neq} = 4.574 \,\mathrm{T} \,(10.319 - \log k_{rac}/\mathrm{T}). \tag{2}^4$$

From determinations of ΔG_{rac} at different temperatures the enthalpy (ΔH_{rac}) and entropy of activation (ΔS_{rac}) were obtained by application of the eqn (3). The results are given in the Table together with

$$\Delta G_{rac}^{\neq} = \Delta H_{rac}^{\neq} - T\Delta S_{rac}^{\neq}$$
(3)

data from the literature for hexahelicene and some benzologues.

Comparison of the data for the compounds 1 and 7, 2 and 3, 4 and 5 (Fig. 1) show that the introduction of Me-substituents at C(3), C(4), C(13) and C(14) which do not change the helical conformation, has no influence on the racemization parameters. Me-substitution at C(2) and C(15) in 6 causes a significant but small increase of ΔG_{rac}^{+} (2.3 kcal/mol at 240°). A large effect is observed on introduction of a Me group at C(1) (see 2 and 3), but it is only slightly enhanced when a second Me substituent is present at C(16) as in 4. The effect of the 1-Me substiTable 1. Kinetic and thermodynamic data of the racemization of methyl substituted hexahelicenes and some related compounds.

6	punoduc	10 ⁵ k	rac ^{(°} C)	∆G [‡] ac 1	n kJ/mol	°c	ΔH [*] rac ir	kJ/mol	ΔS [*] ac i	n J/mol.deg
		in se		(kcal/m	01)		(kcal/m	51)	(cal/mo	l.deg)
-17	hexahelicene	5.6	(194)	154.0	(36.8)	194				
	hexahelicene ^a			154.3	(36.9)	194	146.2	(35.0)	-17.6	(-4.2)
20	l-methylhexahelicene	2.5	(569)	183.2	(43.8)	269	161+2	(38.5)	-41+2	(8.6-)
m?	1,14-dimethylhexahelicene	2.4	(269)	183.2	(43.8)	269				
4	1,16-dimethylhexahelicene	1.3	(270)	186.5	(44.0)	270				
ŝ	1,3,14,16-tetramethyl-									
	hexahelicene	1.3	(270)	186.5	(44.0)	270	158+2	(37.7)	-54+2	(-12.9)
ŝ	2,15-dimethylhexahelicene	2.6	(240)	165.2	(39.5)	240			1	
~ ?	4,13-dimethylhexahelicene	6.6	(961)	153.9	(36.8)	196				
80 }	heptahelicene ^a			178.1	(42.6)	269	169.4	(40.5)	-16.9	(-3.9)
ov.	octahelicene ^a			181.9	(43.5)	270	171.5	(41.0)	-19.2	(-4.6)
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 a $\Delta {
m H}^{\pm}_{
m rac}$ and $\Delta {
m S}^{\pm}_{
m rac}$ -values given by Martin $^{-}$, from measurements in naphthalene; $\Delta {
m G}^{\pm}_{
m rac}$ has been calculated from these values.

^b The accuracy of δG_{rac}^{\dagger} is better than 0.4 kJ/mol (0.1 kcal/mol); that of $\Delta H_{rac}^{\ddagger}$ and $\delta S_{rac}^{\ddagger}$ ca. 2 kJ/mol (0.5 kcal/mol) and 2 J/mol.deg (0.5 cal/mol.deg), respectively.

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tuent on ΔG_{rec}^{*} appears significantly larger than the influence of the additional benzo group in 8, and a similar difference is found between 4 and 9. This is apparently due to a much larger loss of entropy during the race-mization of 2 and 4 than of 8 and 9; ΔS_{rec}^{*} of the latter compounds is rather equal to that of hexabelicene.

The racemization of unsubstituted hexahelicene is supposed to occur via a symmetrical intermediate state in which the terminal rings are parallel to each other, and this conformation has been identified with the transition state of the racemisation.⁵ The effect of Me-substituents on this conformation should, however, be small, and in 1-methyl- and 1,16-dimethylhexahelicene certainly be smaller than in the normal helical form of these molecules. So, it seems that the conformation with the highest energy content during the racemization of these connounds is not that with parallel but with orthogonal terminal rings; a conformation which is passed twice during racemization. From molecular models it might be supposed that the same is true for benzologues of hexahelicene. The large loss of entropy during racemization of 2 and 4 points to a right transition state in which the rotation of the Me group's) is grossly hindered. In & Jand 9) the additional energy is apparently found in additional deformations of the entire π -system; including the new ring(s); 25"rac does not differ much from that of nexahelicene, but ΔH_{rac} is largely increased.

EXPERIMENTAL

UV spectra were recorded with a Cary 15 spectrophotometer. Optical rotations were measured with a Perkin-Elmer 241 polarimeter.

The syntheses of the compounds 2, 3, 4 and 7 have been described previously.¹ The novel compounds 5 and 6 were prepared analogously from 2.7-dimethylaphthalane. Bromination, with two equivalents of N-bromosuccinimide in CCL gave 2,7di(bromomethyl)naphthalene (m.p. 147°). It was dissolved in DMF, and the solution was supplied with two equivalents of triphenylphosphine. After stirring for 16 hr the diphosphonium salts were precipitated by addition of xylene, and filtered (yield 75%).

The phosphonium salts were used in Wittig reactions with 3,5-dimethylbenzaldehyde and with p-tolualdehyde for the preparation of 5 and 6 respectively. In both cases EtOH was used as the solvent and sodium methoxide as the base. After 16 hr the solvent was evaporated, the residue taken up in toluene and water, the taluene layer dried aver $MgSQ_4$, and then evaporated to dryness.

The residue was extracted with hexane to remove triphenylphosphine oxide, and the extract was chromatographed over silicagel with hexane-CCl₄ as the eluent. The eluted mixture of *cis-trans* isomers was dissolved in benzene (10^{-3} molar) and subjected to photodehydrocyclization by irradiation for 6 hr at 360 nm in the presence of 15 mol% of iodine. The solvent was then evaporated and the residue chromatographed on silicagel.

1,3,14,16-Tetramethylhexahelicene (5) was isolated in 80% yield; m.p. 237-238.5° (from EtOH); m/e 384; UV (CH₂Cl₂), λ_{max} (log ϵ) 425 (2.37), 406 (sh, 2.65), 366 (sh, 4.01), 330 (4.32), 271 (sh, 4.68), 263 (4.78), 243 (4.59); NMR(CDCl₃), δ : 0.60 (s, 6H, 2CH₃), 2.26 (s, 6H, 2CH₂), 6.23 (s, 2H, H₂ and H₁₅), 7.40 (s, 2H, H₄ and H₁₃), 7.76 (s, 4H, H₅, H₆, H₁₁ and H₁₂), 7.93 and 8.01 (AB, 4H, H₇, H₁₀ and H₈ and H₉, J_{AB} = 8.1 Hz). Mass. Calc. for C₃₉H₂₄: 384:1878, Funntl. 384:1877.

The partial resolution of the helicenes was achieved by slow solution with hexane from a silicage! column impregnated with 3% TAPA.³

Most racemization experiments were carried out with dilute solutions in dibenzylether under nitrogen. Experiments at 300° or higher were done in sealed evacuated tubes with naphthalene as the solvent. Concentrations were determined spectroscopically in dibenzylether or dichloromethane. Optical rotations were measured every 30 minutes during 2 or 3 hr.

REFERENCES

¹W. H. Laarhoven and Th. J. H. M. Cuppen, Tetrahedron 30, 1101 (1974).

²R. H. Martin and M. J. Marchant, *Tetrahedron Letters* 3707 (1973); *Tetrahedron* 30, 347 (1974).

³L. H. Klemm, K. B. Desai andf J. R. Spooner, J. Chromatogr. 14, 300 (1964).

⁴F. W. Cagle and H. Eyring, J. Am. Chem. Soc. 73, 5628 (1951).

⁵H. J. Lindner, Tetrahedron 31, 281 (1975).