Abnormal Reaction of an Aryl Azide confined in a Calix[6]arene Skeleton

Norihiro Tokitoh, Toshiyuki Saiki and Renji Okazaki*

Department of Chemistry, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

Photolysis of an aryl azide embedded in a *m*-phenylene-bridged *p-tert*-butylcalix[6]arene **2** results in the formation of unusual reaction products **3** and **4** *via* the transannular addition reaction of an initially formed nitrene intermediate; the molecular structure of **4** was determined by X-ray crystallographic analysis.

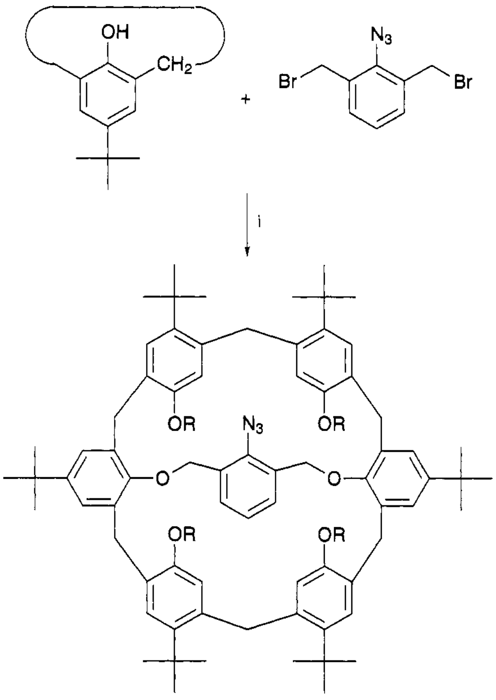
The bowl shapes of the cone conformation of calixarenes and their large cavities formed by aryl moieties in the macrocyclic array make this family of compounds fascinating substrates for studies on molecular materials and supramolecular chemistry.[1] In contrast to the wide chemistry of calix[4]arenes, that of calix[6]arenes has been less explored because of the difficulty in functionalizing their six phenolic hydroxy groups and their inherent higher conformational flexibility.

In continuation of our study on sterically congested molecules we became interested in the reaction behaviour of a functional group embedded in a concave space of calix[6]arene skeleton. We report here on the synthesis of an aryl azide confined in a calix[6]arene skeleton and its abnormal behaviour on photolysis.

Azide **2** was readily prepared by the reaction of *p-tert*-butylcalix[6]arene[2] with 2-azido-1,3-bis(bromomethyl)benzene† under basic conditions leading to a bridged calix[6]arene **1**[4] followed by methylation of the remaining four phenolic hydroxy groups (Scheme 1).

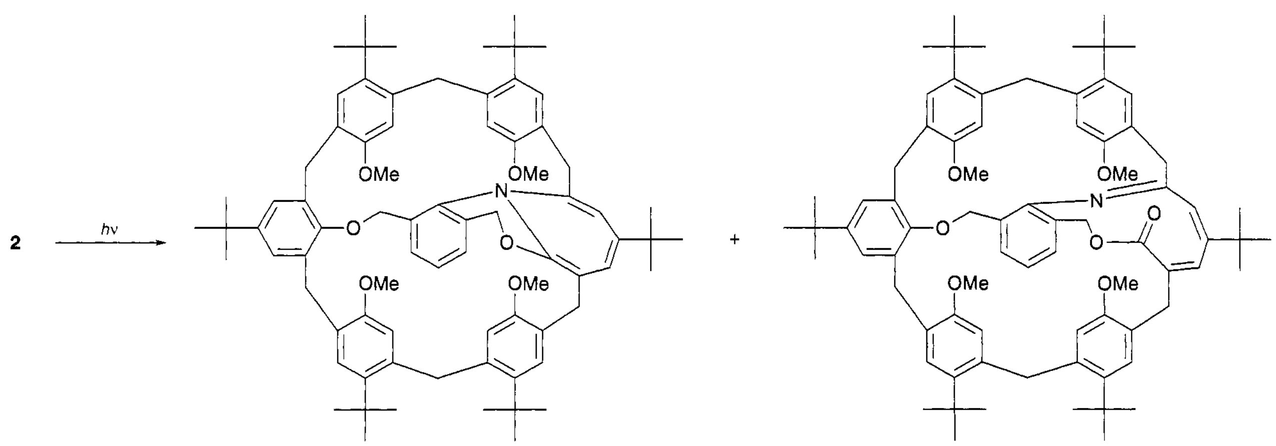
In the hope of elucidating the behaviour of a nitrene embedded in the concave position of a bridged calixarene, a THF solution of azide **2** was irradiated by a high pressure mercury lamp (400 W) under argon for 13 h at −78 °C. After usual chromatographic separation, two interesting products, *i.e.* a fused azepine **3** (yellow solid, 41%) and a cyclic imine **4** (colourless crystals, 11%), were isolated along with a small amount of recovered azide **2** (10%) (Scheme 2).

Compounds 3 and 4 were identified by spectral and analytical data. Azepine **3** in hexane showed characteristic absorption maxima at 272 nm (ε 10000 $dm^3\ mol^{-1}\ cm^{-1}$), 279 (10000) and 308 (sh, 4000) in its UV/VIS spectrum[5] as well as a clearly distinguishable ^{13}C NMR signal of a quaternary carbon at δ 100.6 ($CDCl_3$) attributable to the sp^2 carbon situated in β-position to both oxygen and nitrogen. The molecular structure of **4** was unequivocally determined by X-ray crystallographic analysis and is shown in Fig. 1,‡ where one can recognize an interesting eleven-membered cyclic imine moiety. Both the short distance C(1)–N(1) [1.290(7) Å] and the completely trigonal-planar geometry around the C(1) atom [sum of bond angles = 359.9°] are consistent with the cyclic imine structure suggested by the ^{13}C NMR spectrum (δ 163.4 and 169.3 for the ester and imine units, respectively) and the IR spectrum (1637 and 1738 cm^{-1} for $\nu_{C=N}$ and $\nu_{C=O}$, respectively).



1 R = H (86%)
2 R = Me (77%)

Scheme 1 *Reagents and conditions*: i, NaH/THF–DMF, reflux 1 h; ii, NaH, CH_3I–THF–DMF, reflux 2 h



3

4

Scheme 2

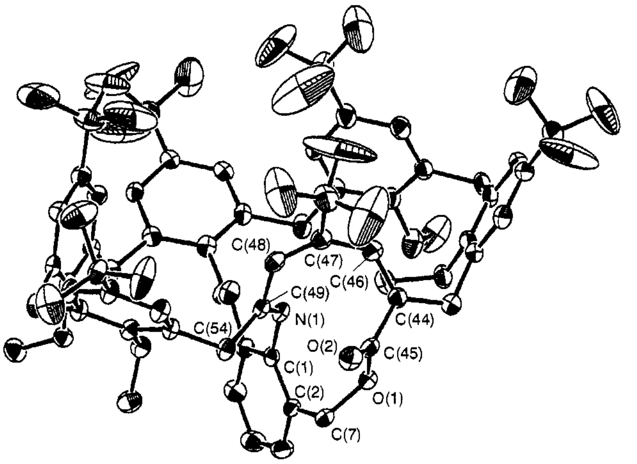


Fig. 1 ORTEP drawing of cyclic imine **4** with thermal ellipsoids at 20% probability. Selected bond lengths (Å) and angles (°): O(1)–C(7) 1.449(8), O(1)–C(45) 1.357(8), O(2)–C(45) 1.201(8), N(1)–C(1) 1.414(7), N(1)–C(49) 1.292(7), C(1)–C(2) 1.417(8), C(2)–C(7) 1.486(9), C(44)–C(45) 1.479(9), C(44)–C(46) 1.328(8), C(46)–C(47) 1.479(9), C(47)–C(48) 1.325(9), C(48)–C(49) 1.468(9), C(49)–C(54) 1.534(9), N(1)–C(1)–C(2) 122.8(6), C(1)–C(2)–C(7) 122.1(6), O(1)–C(7)–C(2) 109.1(5), O(1)–C(45)–O(2) 123.7(7), O(1)–C(45)–C(44) 109.3(6), O(2)–C(45)–C(44) 127.0(7), C(45)–C(44)–C(46) 119.5(6), C(44)–C(46)–C(47) 129.0(7), C(47)–C(48)–C(49) 130.6(6), N(1)–C(49)–C(48) 121.1(6), C(1)–N(1)–C(49) 121.9(5), N(1)–C(49)–C(54) 125.8(6).

Azepine **3** is most likely formed by addition of an intermediary nitrene generated from the azide to the bridgehead benzene ring, followed by isomerization. Since a separate experiment showed that exposure of azepine **3** to open air led to the formation of the cyclic imine **4** readily in solution or slowly in the solid state, **4** is thought to be a secondary reaction product by oxidation of **3** during work-up. It is known that singlet phenylnitrene undergoes ring expansion to give 1,2,4,6-azacycloheptatetraene, which is efficiently trapped by diethylamine.[7] Photolysis of **2** in the presence of diethylamine, however, did not afford any trapped product. It is noteworthy that, in the present bridged calixarene, the addition of the nitrene to the benzene ring in the calixarene framework is more favourable than the ring expansion which is common for arylnitrenes.

This unusual reaction mode of the intermediary nitrene can be interpreted in terms of poor flexibility of an arylnitrene unit confined in a rigid bridged calix[6]arene skeleton. The formation of cyclic imine **4** by oxidation of azepine **3** is also worthy of mention as a new reaction mode of a fused α-alkoxyazepine derivative, which is among an almost unexplored class of conjugated systems.[8]

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Footnotes

† 2-Azido-1,3-bis(bromomethyl)benzene was synthesized from 2-azido-1,3-dimethylbenzene[3a] using the literature method of the bromination of azidotoluenes.[3b]

‡ *Crystal data* for **4**: $C_{78}H_{97}NO_7$, M = 1160.63, monoclinic, space group $P2_1/c$, a = 15.781(9), b = 21.709(5), c = 21.169(4) Å, β = 98.85°, V = 7166(3) Å^3, Z = 4, D_c = 1.076 g cm^{-3}, μ = 0.63 cm^{-1}. The intensity data were collected on a Rigaku AFC5R diffractometer with graphite-monochromated Mo-Kα radiation (λ = 0.71069 Å), and the structure was solved by direct methods with SHELXS-86.[7] All non-hydrogen atoms were refined anisotropically. The final cycle of full-matrix least-squares refinement was based on 4631 observed reflections [$I > 3\sigma(I)$] and 775 variable parameters with $R(R_w)$ = 0.067(0.064).

Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Information for Authors, Issue No. 1.

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