hydroxybenzoic acid with the observed labeling pattern. The alternative proposal of Hornemann,[3a] involving transamination at the acyclic heptulosonic acid stage to form 4-amino-3,4-dideoxy-D-*arabino*-heptulosonic acid 7-phosphate (4-amino-4-deoxy DAHP), followed by cyclization, also remains a viable possibility. A distinction among these and other possible intermediates must await labeling results with those intermediates.

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Registry No. 2, 30562-34-6; phosphoenol pyruvate, 138-08-9; erythrose 4-phosphate, 19234-99-2; [$^{13}C_6$]glucose, 19030-38-7; glucose, 50-99-7.

Calixarenes. 6. Synthesis of a Functionalizable Calix[4]arene in a Conformationally Rigid Cone Conformation

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The calixarenes[1] when in the "cone" conformation, are members of a small group of organic compounds that are basketlike in shape and possess the potential for forming guest-host complexes in which the guest resides in a cavity completely within a single host molecule. Calixarenes have been synthesized by two fundamentally different methods. One is a rather lengthy multistep process originally devised by Hayes and Hunter[2] and recently improved and exploited by Kämmerer and co-workers[3]; the other is a simple, one-flask, base-catalyzed condensation of a *p*-substituted phenol with formaldehyde. The latter method was first reported by Zinke and co-workers[4] and subsequently, with modifications, by Cornforth and co-workers,[5] Buriks, Fauke, and Munch,[6] Gutsche and co-workers[7] and Patrick and Egan.[8] As our recent work[1] has shown, however, this procedure affords mixtures of cyclic oligomers that are difficult to separate; to date, good yields of pure products have been obtained *only* from the *p-tert*-butylphenol condensation in which, by appropriate choice of reaction conditions, it is possible to prepare *p-tert*-butylcalix[4]arene (**1a**), *p-tert*-butylcalix[6]arene (**1b**), and *p*-tert-butylcalix[8]arene (**1c**). This communication describes the conversion of **1a** to a calixarene that is conformationally fixed in the "cone" conformation and which carries the potentially functionalizable allyl group in the para positions.

p-tert-Butylcalix[4]arene (**1a**) was obtained in ca. 35% yield, mp 344-346 °C, by using the Zinke method[4] as modified by Cornforth,[5] and the *tert*-butyl groups were then removed by an aluminum chloride catalyzed alkyl group transfer.[9] From 5.00 g of the toluene complex of **1a** calix[4]arene (**2**) was obtained in 66% yield as opaque, trapezoidal plates after recrystallization first from $CHCl_3/CH_3OH$ and then from acetone: mp 315-318 °C; IR (KBr) 3120 cm^{-1} (OH stretching); ^1H NMR (Me_4Si, $CDCl_3$) δ 10.19 (s, 4, OH), 7.22-6.64 (m, 12, ArH), 3.63-3.48 (br d, 8, CH_2); ^{13}C NMR (Me_4Si, $CDCl_3$) δ 148.4 (25%, Ar), 129.0 (100%, Ar), 128.2 (53%, Ar), 122.2 (60%, Ar), 31.7 (42%, CH_2); osmometric M_r ($CHCl_3$, 37 °C), 452 (calcd for **2** with $^1/_4$ mol of acetone, 439); mass spectrum M_r, 424 (calcd 424). Anal. Calcd for $C_{28}H_{24}O_4 \cdot {}^1/_4C_3H_6O$: C, 78.67; H, 5.81. Found: C, 78.68; H, 5.88.

The allyl ether **3** was prepared by the method of Stoochnoff and Benoiton[10] and obtained in 74% yield as colorless needles after recrystallization from 95% ethanol: mp 183-184 °C; IR (KBr) 1645 and 930 cm^{-1} (vinyl group); ^1H NMR (Me_4Si, $CDCl_3$) δ 7.4-5.9 (m, 16, ArH and HC=), 5.5-4.8 (m, 8, H_2C=), 4.5-2.9 (m, 16, $ArCH_2Ar$ and OCH_2CH=CH_2); mass spectrum M_r, 584 (calcd, 584). Anal. Calcd for $C_{40}H_{40}O_4$: C, 82.16; H, 6.90. Found: C, 82.43; H, 6.97.

A Claisen rearrangement of **3** was effected[11] by refluxing a solution of 1.66 g (2.84 mmol) of **3** in 25 mL of *N,N*-diethylaniline in an atmosphere of N_2 for 4 h. The crude product was recrystallized from isopropyl alcohol to yield 1.22 g (74%) of off-white needles, mp 245-248 °C. An analytical sample was obtained by a second recrystallization as colorless needles: mp 250.5-252 °C; IR (KBr) 3150 (OH stretching), 1635, and 905 cm^{-1} (vinyl group); ^1H NMR (Me_4Si, $CDCl_3$) δ 10.1 (s, 4, OH), 6.8 (s, 8, ArH), 6.1-5.5 (m, 4, vinyl H), 5.2-5.0 (m, 4, vinyl H), 5.0-4.8 (m, 4, vinyl H), 4.1-3.3 (br d, 8, $ArCH_2Ar$), 3.17 (d, 8, CH_2CH=CH_2); ^{13}C NMR (Me_4Si, $CDCl_3$) δ 137.5 (46%, vinyl), 133.4 (37%, Ar), 128.9 (100%, Ar), 128.2 (65%, Ar), 115.5 (50% vinyl), 39.3 (49%, CH_2CH=CH_2), 31.7 (34%, $ArCH_2Ar$); osmometric M_r ($CHCl_3$, 37 °C), 590 (calcd, 585). Anal. Cacld for $C_{40}H_{40}O_4$: C, 82.16; H, 6.90. Found: C, 82.25; H, 7.02.

All of the analytical and spectral data for **4** support the fact that the macrocyclic ring survives the Claisen rearrangement intact. Of particular significance in this respect is the temperature-dependent ^1H NMR spectrum, which displays a singlet resonance for the $ArCH_2Ar$ methylene hydrogens at temperatures above 60 °C and a pair of doublets at temperatures below 20 °C. This behavior is best interpreted in terms of a "cone" conformation that is interconverting rapidly on the NMR time scale above room temperature and slowly below room temperature.[12-14] Among the four possible conformations ("cone", "partial cone", "1,2-alternate", "1,3-alternate"), the "cone" is favored (especially in nonpolar solvents[14]) because of the very strong intramolecular hydrogen bonding between the four OH groups at the "bottom" of the calix. Thus, in spite of this conformational mobility, appropriately functionalized calixarenes may have the capacity to serve as catalysts via host-guest complexation that requires the "cone" conformation. Nevertheless, it is of interest to prepare a conformationally rigid calixarene that exists at all times in the "cone" conformation. This has been accomplished by conversion to the tetrakis(trimethylsilyl) derivative (**5**). The ^1H NMR pattern for each of the four conformations is distinctive, allowing a definitive characterization of the conformation on this basis. For example, the pattern that would be expected for the tetrakis-(trimethylsilyl) ether of *p-tert*-butylcalix[4]arene (**5a**) in the "cone"

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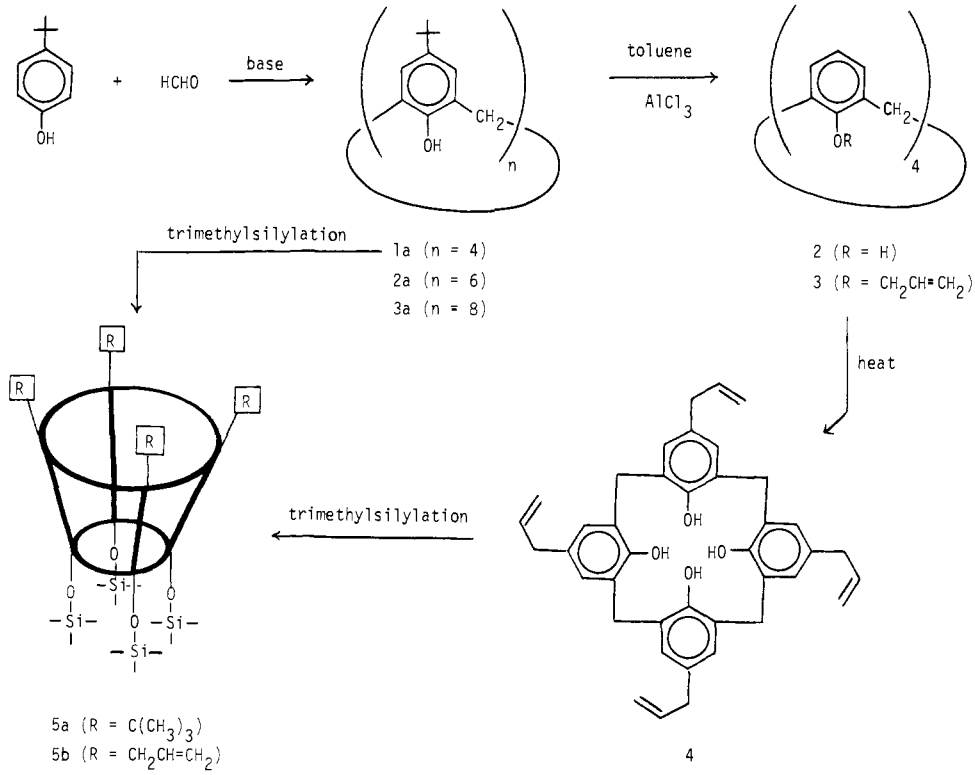
Scheme I



conformation is a downfield singlet for the aryl hydrogens, a pair of doublets at midfield for the methylene hydrogens, and two upfield singlets from the *tert*-butyl and trimethylsilyl hydrogens, respectively. We have prepared compound **5a** by the action of *N,O*-bis(trimethylsilyl)acetamide[15] on **1a** in CH_3CN solution. After being heated for 16 h in an atmosphere of N_2, it was obtained in 92% yield as colorless, long blades: mp 338 °C (softening at 315–320 °C); ^1H NMR (Me_4Si, $CDCl_3$) δ 6.76 (s, 8, ArH), 4.37 (d, 4, J = 12 Hz, CH_2), 2.97 (d, 4, J = 12 Hz, CH_2), 1.00 (s, 36, $C(CH_3)_3$), 0.26 (s, 36, $Si(CH_3)_3$). Anal. Calcd for $C_{56}H_{88}O_4Si_4$: C, 71.79, H, 9.40. Found: C, 71.51; H, 9.47. The ^1H NMR of **5a** accords exactly with that predicted for a "cone" conformation, indicating that it is a conformationally rigid molecule possessing what has been called an "enforced cavity".[16] In comparable fashion, **4** was converted to the tetrakis(trimethylsilyl) ether (**5b**) and obtained as colorless, fine needles: mp 173–181 °C; ^1H NMR (Me_4Si, $CDCl_3$) δ, 6.43 (s, 8, ArH), 6.03–5.43 (m, 4, vinyl H), 5.13 (br s, 4, vinyl H), 4.93–4.63 (m, 4, vinyl H), 4.31 (d, 4, J = 12 Hz, $ArCH_2Ar$), 3.12 (br, s, 8, $CH_2CH{=}CH_2$), 3.02 (d, 4, J = 12 Hz, $ArCH_2Ar$), 0.26 (s, 36, $Si(CH_3)_3$). Anal. Calcd for $C_{52}H_{72}O_4Si_4$: C, 71.50; H, 8.31. Found: C, 71.49; H, 8.45. The downfield singlet for the aryl hydrogens and the upfield singlet for the trimethylsilyl hydrogens are both in complete accord with the "cone" conformation. Although the resonances from the methylene hydrogens of the allyl groups overlay some of those arising from the $ArCH_2Ar$ methylene hydrogens, the downfield doublet arising from the latter is cleanly displayed at δ 4.38 and the upfield doublet is clearly discernible in the pattern near δ 3.0.

Compound **5b** represents what may be the closest current approach to a *synthetic* molecule that has an architecture comparable to that of the cyclodextrins. Since *p-tert*-butylcalix[6]arene and *p-tert*-butylcalix[8]arene are also readily available starting materials and since the allyl group is amenable to conversion to a variety of functional groups, this synthetic approach has the promise of providing a variegated collection of molecules with large cavities.

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Registry No. 1a, 60705-62-6; **2**, 74568-07-3; **3**, 81294-22-6; **4**, 81294-23-7; **5a**, 81294-24-8; **5b**, 81315-60-8; *p*-(*tert*-butyl)phenol, 98-54-4; formaldehyde, 50-00-0.

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Abnormally High Nucleophilicity of Micellar-Bound Azide Ion

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Rate enhancements of bimolecular reactions in aqueous micelles are typically caused by concentration of both reactants into the small volume of the micellar pseudophase. For both nonfunctional and functional micelles, second-order rate constants in the micellar pseudophase are similar to or smaller than those in water.[2-11]

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