Bowl Shaped Cavitands Dimerize and Complex Certain Organic Guests in Organic Solvents which Themselves are Poor Guests

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The syntheses and binding properties of rigidly bowl-shaped polycyclic cavitands (**1–4**) are reported. Attached to the four aryl rim positions of the bowls are four benzenes substituted in their *para* positions with four CO_2Me, Br, OH or NO_2 groups, which deepen the bowls. Attached to the base of the bowls are four pentyl feet, which increase the solubilities of these hosts in organic solvents. Of the four hosts, only the one containing the CO_2Me groups dimerized both in the crystalline state and in solution in ten deuterated solvents which themselves are poor guests. In three other deuterated solvents, no dimerization was observed. A crystal structure of the dimer showed that one p-$MeO_2CC_6H_4$ group of each monomer occupied the cavity of its complexing partner in a reciprocating double host-guest arrangement. Such a structure is compatible with the ^1H-NMR spectra of the dimer in solution. The dimer was also detected in its FAB-MS. The tetrabromocavitand at low concentrations in CD_2Cl_2 complexed $MeCO_2CH_2Me$, $MeCO_2Me$, $PhCO_2Me$ and $MeCOCH_2CO_2Me$. Tetranitrocavitand **4** also complexed $MeCO_2CH_2Me$ in CD_2Cl_2 as solvent.

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* This paper is dedicated to Professor Vladimir Prelog on the occasion of his 90th birthday. His research and character have served as inspirations to me for half a century.

INTRODUCTION

Earlier studies in the host-guest complexation field[1] have contained examples of noncharged kite-shaped compounds that self-complex in deuterated organic solvents to form dimers strongly held together by multiple attractive forces involving neither hydrogen bonding nor ion pairing.[2] Each molecule contained a roughly planar, large surface complementary in shape to that of a second molecule rotated 90° with respect to the first. The two cavities in each monomer were only large enough to accommodate two methyl groups that protruded perpendicularly from the surface of each complexing partner. The cavities were too small to accommodate solvent. In the dimer, two methyl groups of each molecule inserted into the two cavities of the other molecule to provide a beautiful four-fold lock system.[2]

The current paper reports the syntheses of new extended bowl-shaped cavitands **1** and **4**, the dimerization of **1** in a variety of deuterated organic solvents, and a qualitative survey of the binding properties of **2**[3] and **4** toward various ester guests. Unlike the kite-shaped, small double-cavity hosts of the former investigation[2] the single cavities of **1–4** are shaped like rigid bowls, to whose four aryl positions on the rims of the bowls are respectively attached $4\text{-}C_6H_4CO_2Me$, $4\text{-}C_6H_4Br$, $4\text{-}C_6H_4OH$ or $4\text{-}C_6H_4NO_2$ groups. These groups greatly deepen the cavity, providing room for complexation of most simple solvents. They are also enough separated from one another for one C_6H_4X group of one host to insert reciprocally into the cavity of the second host at the same time the second host's C_6H_4X group inserts into the cavity of the first host (Corey-Pauling Koltun, CPK, model examination).
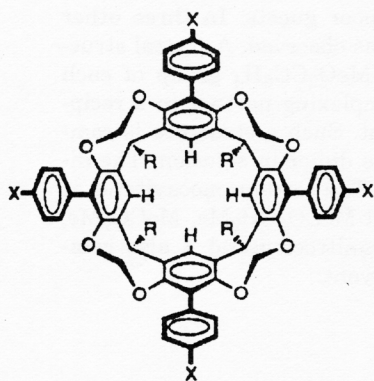
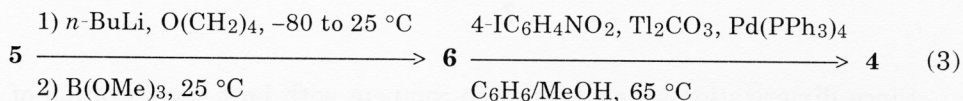R = (CH_2)_4Me
1, X = CO_2Me
2, X = Br
3, X = OH
4, X = NO_2
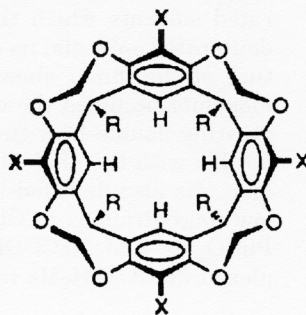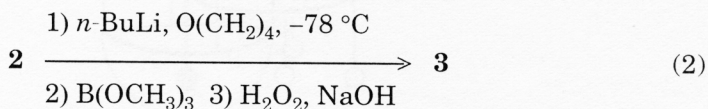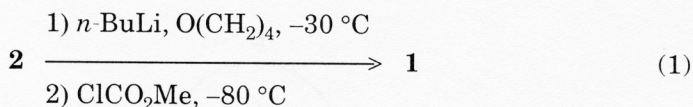
R = (CH_2)_4Me

5, X = Br
6, X = B(OMe)_2

RESULTS AND DISCUSSION

Syntheses

Tetraester host **1** was prepared (47% yield) from tetrabromide **2**[3] by the sequence shown in Eq. (1). Tetraphenolic compound **3** was synthesized (63%) from **2** by the method of Eq. (2). The synthesis of tetranitro host **4** employed as starting material the simpler tetrabromide **5**,[4] which was converted to the uncharacterized tetraboronic ester **6** (58%). This compound was arylated with 4-IC$_6$H$_4$NO$_2$ making use of the Suzuki reaction[5] to give **4** (13% overall), as shown in Eq. (3).

$$\text{2} \quad \xrightarrow[\text{2) ClCO}_2\text{Me, } -80\text{ °C}]{\text{1) } n\text{-BuLi, O(CH}_2)_4, -30\text{ °C}} \quad \text{1} \qquad (1)$$

$$\text{2} \quad \xrightarrow[\text{2) B(OCH}_3)_3 \text{ 3) H}_2\text{O}_2, \text{ NaOH}]{\text{1) } n\text{-BuLi, O(CH}_2)_4, -78\text{ °C}} \quad \text{3} \qquad (2)$$

$$\text{5} \quad \xrightarrow[\text{2) B(OMe)}_3, 25\text{ °C}]{\text{1) } n\text{-BuLi, O(CH}_2)_4, -80 \text{ to } 25\text{ °C}} \quad \text{6} \quad \xrightarrow[\text{C}_6\text{H}_6/\text{MeOH, }65\text{ °C}]{\text{4-IC}_6\text{H}_4\text{NO}_2, \text{ Tl}_2\text{CO}_3, \text{ Pd(PPh}_3)_4} \quad \text{4} \qquad (3)$$

Dimerization of 1

The 500 MHz ^{1}H-NMR spectrum of tetraester **1** at 0.050 M concentration in CDCl$_2$CDCl$_2$ at 22 °C provided two upfield-shifted CH_3O signals at δ of 0.5 and 0.6 ppm in a respective 1 : 2 integral ratio, as well as two normal CH_3O signals at δ = 3.6 and 3.7 ppm. The two sets of signals were demonstrated to be due to CH_3O protons by irradiation-decoupling experiments. When the solution was heated, both sets of signals decreased in intensity (disappearing at $\approx$ 50 °C) to produce a new broad peak at δ = 3.4, and the spectrum as a whole became simpler. Above 50 °C the spectrum showed little further sensitivity to temperature changes. When cooled to 22 °C, the sample exhibited the original spectrum. The spectrum of a 0.00010 M solution of **1** in CDCl$_2$CDCl$_2$ at 22 °C contained no CH_3O proton signals at δ = 3.6, 3.7, 0.5 or 0.6 ppm, and was very similar to the spectrum of the 500 times more concentrated original solution taken at 90 °C. Thus the spectrum of **1** was both concentration- and temperature-dependent.

These results are interpreted as reflecting the existence of the equilibrium $1 + 1 \rightleftarrows 1 \cup 1$, in which the rates of complexation and decomplexation

are slow on the ^{1}H-NMR time scale at 22 °C, but fast at > 50 °C. The symbol ∪ is used to denote nesting complexation. Molecular model (CPK) examination of two molecules of **1**, B and C of simplified diagram **7** (the 8 pentyl »feet« are omitted), indicated B and C to be mutually complementary to one another. The large upfield shifts of the CH_3O signals ($\Delta\delta$ > 3 ppm) are due to the strong shielding effect of the four aryl groups whose faces line the bottoms of the bowls into which the methoxyl groups fit in the dimer. The existence of two signals at 3.6 and 3.7 ppm is explained if one is attributed to the monomer and the other to the six CH_3O groups in the dimer that are not inserted into cavities. The existence of two signals for the inserted CH_3O protons in the dimer is discussed in a later section of this paper.

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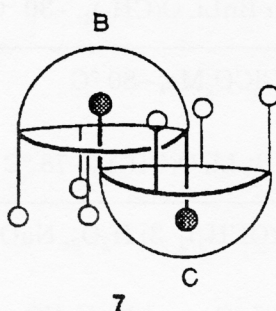
Since dimerization seemed likely to compete with host complexation of suitably structured solvent molecules, the ^{1}H-NMR spectra of 0.05 M **1** dissolved in 13 deuterated solvents were examined at 22 °C for the presence of the upfield-shifted familiar doublet CH_3O signals of dimer. These sets of signals with $\Delta\delta$ values of about 3.4 ppm and integral ratios of ≈ 1 : 2 were observed in CDCl$_3$, CDCl$_2$CDCl$_2$, CD$_2$Cl$_2$ (a temperature of 0 °C was needed), (CD$_3$)$_2$CO (broadened signals), (CD$_3$)$_2$NCDO, CDCl$_3$-(CD$_3$)$_2$NCOCD$_3$, and CDCl$_3$-(CD$_2$)$_4$O. Singlet CH_3O signals of dimer at 0.4–0.5 ppm were observed in CD$_3$C$_6$D$_5$, C$_6$D$_6$ and o-(CD$_3$)$_2$C$_6$D$_4$. These ten solvents, although present at much higher concentrations than **1**, did not completely eliminate dimerization. The spectra in CDCl$_3$-CD$_3$CN, CDCl$_3$-CD$_3$NO$_2$ and CDCl$_3$-CD$_3$CO$_2$CD$_2$CD$_3$ all gave sharp peaks and no upfield-shifted CH_3O signals, which indicated that CD$_3$CN, CD$_3$NO$_2$ and CD$_3$CO$_2$CD$_2$CD$_3$ complexed **1** well enough to eliminate dimerization. C$_6$D$_5$NO$_2$ neither produced sharp signals nor signals for dimer.

Further evidence for dimerization of tetraester host **1** was observed in its FAB-MS. The (M)$^+$ peak for **1** was 20% that for the most intense peak (100%) at m/z = (M-OMe)$^+$. A peak for (1∪1-2OMe)$^+$ was detected at 0.6% intensity. A second scan of the higher mass spectral region gave peaks for (2M-4OMe)$^+$ (100%), (2M-OMe)$^+$ (95%) and (2M)$^+$ (20%).

Crystal Structure

A crystal structure of **1** indicates that aside from the pentyl feet (omitted from drawings **7–11**), each host contains a pseudo C_4 axis perpendicular to and centered in the square defined by the appropriate parts of the four biaryls. The aryl-to-aryl dihedral angles in the biaryl groups vary from 62 to 80° and the ester-to-attached aryl planes are nearly coincident, with one of the four carbonyl groups oriented inward and three outward. Stereoviews **8**, **9** and **10** illustrate the three types of close intermolecular contacts between hosts (C···C ≤ 3.5 Å, O···C ≤ 3.3 Å). View **8** shows two host molecules (B and C), related by a center of symmetry, that reciprocally fit each other's cavities with p-phenylcarbomethoxy groups as guests. In **8** the two guest benzenes are nearly aligned head to tail in parallel planes with the nearest two symmetry-related carbons of each phenyl group separated by 3.3 Å in an edge-to-edge contact. The only other close contact between these two molecules is the 3.3 Å distance between the carbonyl oxygen of each of the two nesting CO2Me groups and the closest aryl carbon of phenyl groups composing the nests. Stereoviews **9** and **10** show additional close contacts between mole-
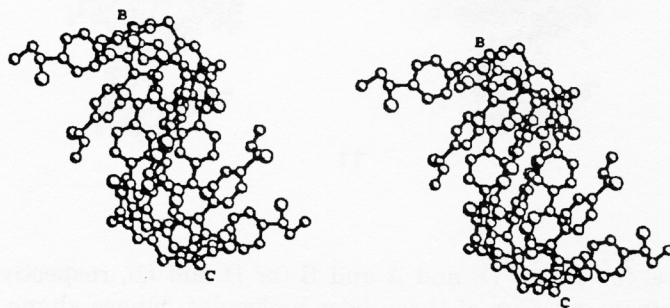
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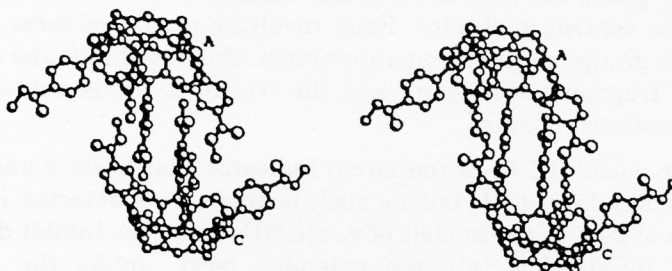
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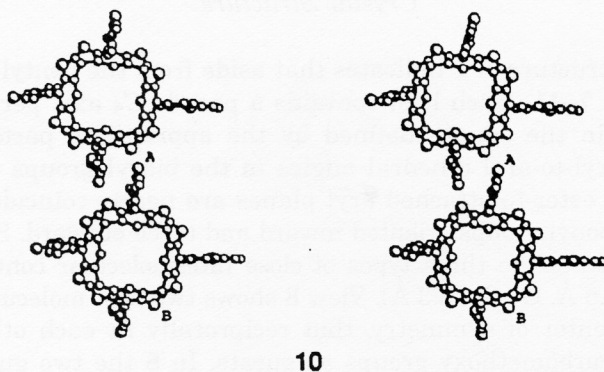
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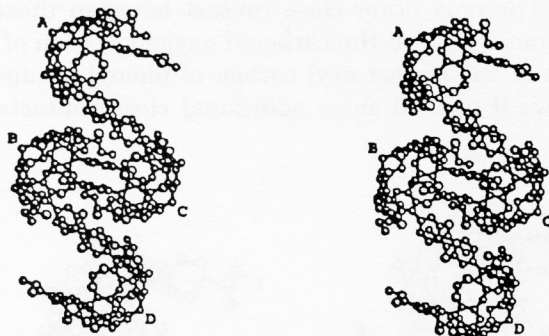
11

cules A and C (or B and D) and A and B (or D and C), respectively. Stere-
oview **11** portrays all four of these host molecules, whose shape resembles
that of a sea-horse. The two central molecules at 9 and 3 o'clock are fitted
together as in **8**. The molecules at 12 and 6 o'clock each insert a *p*-phenyl-
carbomethoxy group between two *p*-phenylcarbomethoxy units, one provided
by each of the central molecules. Each resulting packet of three *p*-phenyl-
carbomethoxy groups contains one interaction illustrated in **9** and one in **10**.
View **11** is a fragment of a chain, and the crystal contains paired, crystal-
lographically-related chains.

Molecular model (CPK) examination indicates that hosts **2** and **3** might
also dimerize similarly to **1**, but no such behavior was detected in the ^{1}H-
NMR spectra of **2–4**. In the models of **4**, the NO_2 branches inhibit deep pene-
tration of a *p*-$C_6H_4NO_2$ into the extended bowl, unlike the similarly-
branched *p*-$C_6H_4CO_2Me$ group of **1**, whose methyl beautifully contacts the
bottom of the cavity.

Complexation by Hosts 2 and 4 of Complementary Guest Compounds

The ability of tetrabromo cavitand **2** to act as a host for a series of ester guests dissolved in CD_2Cl_2 at ≈ 0.01 M concentration was surveyed. The ^{1}H-NMR spectrum of **2** alone in CD_2Cl_2 was consistent with only monomer being present even at temperatures as low as -88 °C. When $MeCO_2CH_2Me$ was added at 22 °C the averaged signal for the CH_3CO of free and complexed guest moved upfield by as much as ≈ 0.1 ppm as the overall concentration or the relative concentration of guest to **2** increased. When cooled to -70 °C, 0.01 M solutions of **2** and $MeCO_2CH_2Me$ in CD_2Cl_2 gave ^{1}H-NMR signals for CH_3CO of $MeCO_2CH_2Me$ which were moved upfield ($\Delta\delta \approx 3.4$ ppm) to $\delta \approx -1.7$ and ≈ -1.8, with a respective integral ratio of 1 : 2, again favoring the upfield signal. A similar solution of $MeCO_2Me$ when cooled to -80 °C gave an upfield shift of $\Delta\delta \approx 3.7$ ppm for both the CH_3CO and the OCH_3 proton signals, providing the now familiar doublet pattern for both kinds of protons. A similar solution of **2** and $PhCO_2Me$ when cooled to -80 °C gave a $\Delta\delta \approx 3.5$ ppm upfield shift for the OCH_3 signal, which again exhibited the doublet pattern. A similar solution of **2** and $MeCOCH_2CO_2Me$ when cooled to -80 °C provided a $\Delta\delta \approx 3.5$ ppm upfield shift with the usual doublet pattern, but only for the OCH_3 signal. The tetrabromo analogue compound **5** without the four bowl-deepening phenyl groups neither dimerized nor gave evidence of binding $MeCO_2CH_2Me$ in ^{1}H-NMR spectral experiments.

Tetranitro host **4** in CD_2Cl_2 containing $MeCO_2CH_2Me$ in solution at 25 °C provided an averaged CH_3CO signal for free and complexed $MeCO_2CH_2Me$. At -80 °C, this signal appeared as a singlet, 3.8 ppm upfield of the signal for uncomplexed ester, rather than in the doublet pattern observed with hosts **1** and **2**.

Origins of the Doublet Pattern Observed for CH_3CO and CH_3O Protons in the ^{1}H-NMR Spectra of Guests in Caviplexes of 1 and 2

Ordinarily, the energy barrier to rotation of methyl groups bonded to carbon or oxygen is only a few kcal mol^{-1}, and therefore rotations about these bonds ordinarily are much too fast to be frozen out at temperatures available to solution ^{1}H-NMR spectral measurements. However, the observed doublet patterns with integral ratios of 1 : 2 found in the spectra of a variety of ester guests in caviplexes of **1** and **2** in a variety of solvents suggest this energy barrier has been raised sufficiently to allow the chemical shift of one of the protons of the methyls to be differentiated from the other two. These protons are slightly acidified by the bonding of their methyl group to either end of an ester group, making each of the *three protons* available to hydrogen bond weakly to the *pi*-systems of *three of the four* aryl groups that compose the deepest part of the host's cavity. This leaves one

aryl non-hydrogen bonded. In such a model, three hydrogen bonded aryls provide two kinds of environments for their hydrogen bonded CH_3 protons, one being located midway between the two flanking aryls. This geometric arrangement provides a possible explanation for the integral ratio of 1 : 2 for the two far-upfield peaks observed in the 1H-NMR spectra of the many complexes reported here.

EXPERIMENTAL

General

Before use, anhydrous Me_2NCOMe (DMA), Me_2NCHO (DMF) and Me_2SO (DMSO) were degassed under high vacuum. Tetrahydrofuran (THF) was distilled from benzophenone ketyl immediately prior to use. Samples were dried at least 24 h at 110 °C/10^{-5} torr prior to elemental analyses. All ^{1}H-NMR spectra were obtained on Bruker AM 360 or AM 500 spectrometers and the chemical shifts were measured relative to residual non-deuterated solvent resonances; δ(CHCl$_3$) = 7.24, δ(Me$_2$CO) = 2.04 ppm. Melting points are uncorrected. Analytical thin-layer chromatography (tlc) was performed using Merck DC-Fertigplatten KIESELGEL 60 F-254 0.25 mm silica gel precoated glass plates. Column chromatography was performed using EM Silica Gel 60 (particle size 0.063–0.200 mm, 70–230 mesh ASTM or particle size 0.040–0.063 mm, 230–400 mesh ASTM). All reactions were carried out under a slightly positive pressure of dry argon; the glassware used was either oven-dried (2 h at 120 °C) or flame dried under vacuum.

4-Bromo-2',6'-dimethoxy-1,1'-biphenyl

To a solution of 1,3-dimethoxybenzene in 1 L of Et$_2$O was added over a 20 minute period 680 mL (1.70 mol) of n-BuLi in hexane. The mixture was stirred for 20 h at 25 °C, cooled to –78 °C, and 500 g (4.08 mol) of B(OMe)$_3$ was added. The mixture was stirred at –78 °C for 1 h, allowed to warm to 25 °C, and stirred an additional 2 h. One L of 2 N aqueous HCl solution was added, and the mixture filtered. The ether layer of the filtrate was extracted with three 150 mL portions of 3 N aqueous NaOH, and the combined extracts were acidified with aqueous HCl. The 2,6-dimethoxyboronic acid that separated was dried (high vacuum) to give 72 g (25%) of product. This material (24.0 g) was dissolved under argon in 100 mL of MeOH and 100 mL of MePh; 46.7 g of 1,4-Br$_2$C$_6$H$_4$, 43 g of Cs$_2$CO$_3$ and 3.00 g of Pd(PPh$_3$)$_4$ were added, and the mixture was refluxed for 24 h. The solids were filtered, and the filtrate was evaporated. The residue was chromatographed on silica gel-CH$_2$Cl$_2$-hexanes (3 : 2, v). The desired product gave R_f = 0.75. It was recrystallized from EtOH to give 19.8 g (50%) of the diether, m.p. 127–128 °C; ^{1}H-NMR (CDCl$_3$) δ/ppm: 7.52, 7.20 (two d, 4H, ArH), 7.27 (t, 1H, ArH), 6.64 (d 2H, ArH), 3.73 (s, 6H, OCH_3).

Anal. Calcd. for C$_{14}$H$_{13}$BrO$_2$: C 57.36, H 4.47, Br 27.26%; found C 57.39, H 4.34, Br 27.23%.

4-Bromo-2',6'-dihydroxy-1,1'-biphenyl

To a solution of 10.0 g of the above diether dissolved in 100 mL of CH$_2$Cl$_2$ held at 0 °C was added dropwise 5 mL of BBr$_3$. The mixture was stirred for 5 h at 25 °C,

150 mL of water was added, and the mixture was stirred for 2 h. The CH_2Cl_2 layer was separated, evaporated, and the residue, dissolved in 100 mL of Et_2O, was extracted with three 50 mL portions of aqueous 1 N NaOH. The combined basic extracts were acidified with concentrated HCl solution and extracted with four 100 mL portions of Et_2O. The combined ether phases were dried ($MgSO_4$), and the solvent was evaporated. The residue was recrystallized from $MeOH-H_2O$ to give 7.40 g (82%) of the desired diol, m.p. 142–143 °C; ^1H-NMR ($CDCl_3$) δ/ppm: 7.70, 7.30 (two d, 4H, ArH), 7.15 (t, 1H, ArH), 6.57 (d, 2H, ArH), 4.77 (s, 2H, OH).

Anal. Calcd. for $C_{12}H_9BrO_2$: C 54.37, H 3.42, Br 30.14%; found C 54.49, H 3.52, Br 30.10%.

*2,8,14,20-Tetrapentyl-5,11,17,23-tetrakis(4-bromophenyl)pentacyclo[19.3.1.1^{3,7}.
1^{9,13}.1^{15,19}]octacosa-1(25),3,5,7(28),9,11,13(27),15,17,19(26),21,23-dodeca-
en-4,6,10,12,16,18,22,24-octol*

To a solution of 36.8 g of 4-bromo-2,6-dihydroxy-1,1'-biphenyl in one L of n-propanol was added a mixture of 370 mL of concentrated aqueous HCl and 770 mL of n-propanol. To the resulting mixture stirred at 50 °C was added 13.9 g of hexanal, which caused the temperature to increase to 80 °C over a 25 minute period without external heating. The initially clear orange solution turned yellow and subsequently a white precipitate formed. The mixture was held at 80 °C for 6 days, cooled to 25 °C and filtered. The precipitate was washed with 250 mL of cold concentrated aqueous HCl/n-propanol (1 : 2, v) and dried for 6 days over drierite under vacuum to yield 29.5 g (61%) of the desired octol; ^1H-NMR ((CD_3)$_2$CO) δ/ppm: 7.81 (s, 4H, ArH), 7.47 (d, J = 8.3 Hz, 8H, ArH), 7.10 (d, J = 8.3 Hz, 8H, ArH), 4.43 (t, J = 7.9 Hz, 4H, CH methine), 2.45–2.42 (m, 8H, CHCH_2), 1.48–1.30 (m, 24H, CH_2), 0.94–0.86 (m, 12H, CHCH_3); MS (FAB), 1389 (M+H)$^+$.

Anal. Calcd. for $C_{72}H_{76}Br_4O_8$: C 62.26, H 5.51; found C 62.17, H 5.46.

*2,20:3,19-Dimetheno-1H,21H,23H,25H-bis[1,3]dioxocino[5,4-i:5',4'-i']benzo[1,2-d:
5,4-d']bis[1,3]benzodioxocin, 7,11,15,28-Tetrakis(4-bromophenyl)-
1,21,23,25-tetrapentyl-, Stereoisomer,* **2.**

To a suspension of 49.0 g of K_2CO_3 in 1 L of DMF (degassed) were added 27.3 g of the above octol and 27.9 g of $BrCH_2Cl$. The mixture was stirred at 65–75 °C, and after 60 h, 13.9 g of additional $BrCH_2Cl$ was added and stirred an additional 24 h. The solvent was evaporated under vacuum, and the residue was dried under vacuum prior to trituration under ultrasonification in $CHCl_3$ for 3 h. The mixture was filtered, the solvent was evaporated from the filtrate, and the residue was chromatographed (Alox, dry loaded, hexanes-EtOAc, 19 : 1, v). The product was recrystallized from hexanes-EtOAc and dried to give 17.8 g (63%) of **2**; ^1H-NMR ($CDCl_3$) δ/ppm: 7.40 (d, J = 8.2 Hz, 8H, ArH), 7.20 (s, 4H, ArH), 6.83 (d, J = 8.2 Hz, 8H, ArH), 5.18 (d, J = 7.0 Hz, 4H, OCH outer), 4.76 (t, J = 8.0 Hz, 4H, CH methine), 4.10 (d, J = 7.0 Hz, 4H, OCH inner), 2.32–2.19 (m, 8H, CHCH_2), 1.44–1.20 (m, 24H, CH_2), 0.88 (t, J = 7.1 Hz, 12H, CH_2CH_3); MS (FAB) 1437 (M+H)$^+$.

Anal. Calcd. for $C_{76}H_{76}Br_4O_8$: C 63.52, H 5.33; found C 63.69, H 5.34.

2,20:3,19-Dimetheno-1H,21H,23H,25H-bis[1,3]dioxocino[5,4-i:5',4'-i']benzo[1,2-d:
5,4-d']bis[1,3]benzodioxocin, 7,11,15,28-Tetrakis(4-carbomethoxyphenyl)-
1,21,23,25-tetrapentyl-, Stereoisomer, 1.

Tetrabromo bowl compound **2** (8.20 g) was dissolved in 1.5 L THF, and a solution of *n*-BuLi in hexane (2.5 m, 11.0 mL) was added slowly to the solution stirred at −78 °C under argon. After 30 minutes at −78 °C, 4.31 g of MeO_2CCl was added drop-wise, and the mixture was allowed to warm to ambient temperature over a 12 h period. Water (20 mL) was added, and most of the organic solvent was evaporated under vacuum. The residue was partitioned between added CH_2Cl_2 and the residual water, and the organic layer was washed with brine. The solution was dried ($MgSO_4$), the solvent was evaporated under vacuum, and the residue was chroma-tographed on silica gel-EtOAc/hexane, 1 : 25 to 2 : 1 (v) to yield 3.62 g (47%) of tetraester **1**; ^{1}H-NMR ($CDCl_2CDCl_2$) at 120 °C δ/ppm: 7.90 (d, J = 7.9 Hz, 8H, Ar*H*), 7.46 (s, 4H, Ar*H*), 7.10 (d, J = 8.1 Hz, 8H, Ar*H*), 5.14 (d, J = 6.9 Hz, 4H, OC*H* outer), 4.97 (t, J = 7.8 Hz, 4H, C*H* methine), 4.17 (d, J = 6.9 Hz, 4H, OC*H* inner), 3.58 (s, 12H, OC*H*3), 2.52–2.40 (m, 8H, CHC*H*2), 1.57–1.40 (m, 24H, C*H*2), 1.03 (t, J = 7.1 Hz, 12H, CH2C*H*3); MS (FAB) 1353 (M+H)$^+$.

Anal. Calcd. for $C_{84}H_{88}O_{16}$: C 74.54, H 6.55; found C 74.72, H 6.50.

2,20:3,19-Dimetheno-1H,21H,23H,25H-bis[1,3]dioxocino[5,4-i:5',4'-i']benzo[1,2-d:
5,4-d']bis[1,3]benzodioxocin, 7,11,15,28-Tetrakis(4-hydroxyphenyl)-
1,21,23,25-tetrapentyl-, Stereoisomer, 3.

Tetrabromo compound **2** (9.2 g in 800 mL of THF) was metallated with *n*-BuLi (2.5 m in hexane, 13.3 mL) at −78 °C for 10 minutes. Subsequently 15.8 mL of $B(OMe)_3$ was added at −78 °C, and the reaction mixture stirred under argon was then held at 25 °C for 2 h. To this stirred mixture cooled to −70 °C was added 100 mL of an aqueous 1.5 N NaOH-15% H_2O_2 solution. After 10 minutes at this temperature, the mixture was warmed to 25 °C, and after 3 h, it was cooled to 0 °C and 40 g of $Na_2S_2O_5$ was cautiously added in portions. The THF was evaporated from the re-sulting mixture, and the residue was mixed with water, filtered, and the solid crude product was washed with water. This material was chromatographed on silica gel – 76% CH_2Cl_2 – 20% Me_2CO – 4% EtOH (v) to yield 4.79 g (63%) of tetraphenolic host **3**; ^{1}H-NMR ($CDCl_3/(CD_3)_2CO$) δ/ppm: 7.88 (s, 4H, O*H*), 7.36 (s, 4H, Ar*H*), 6.79 (d, J = 8.5 Hz, 8H, Ar*H*), 6.73 (d, J = 8.5 Hz, 8H, Ar*H*), 5.16 (d, J = 7.0 Hz, 4H, OC*H* outer), 4.75 (t, J = 8.2 Hz, 4H, C*H* methine), 4.15 (d, J = 7.1 Hz, 4H, OC*H* inner), 2.29–2.25 (m, 8H, CHC*H*2), 1.36–1.27 (m, 24H, C*H*2), 0.84 (t, J = 7.1 Hz, 12H, CH2C*H*3); MS (FAB) 1185.5 (M+H)$^+$.

Anal. Calcd. for $C_{76}H_{80}O_{12}$: C 77.00, H 6.80; found C 77.06, H 6.68.

2,20:3,19-Dimetheno-1H,21H,23H,25H-bis[1,3]dioxocino[5,4-i:5',4'-i']benzo[1,2-d:
5,4-d']bis[1,3]benzodioxocin,7,11,15,28-Tetrakis(4-nitrophenyl)-
1,21,23,25-tetrapentyl-, Stereoisomer, 4.

To a solution of 4.6 g of tetrabromide **5** in 250 mL of THF stirred at −78 °C under argon was added 14 mL of a 2.2 M solution of *n*-BuLi-hexane in one minute. The mixture was stirred for 30 minutes at −78 °C and 20 mL of $B(OMe)_3$ was added over one minute. After the mixture had stirred at −78 °C for 30 min and 25 °C for 1 h, the solvent was evaporated under vacuum to 40 mL, and anhydrous MeOH (80 mL)

was added. The solution was again concentrated to 40 mL under vacuum. This addition-concentration procedure was repeated twice more. The boronic ester (**6**) that separated was filtered, washed and dried under vacuum at 25 °C to give 2.6 g of product (58%), used directly in the next step. A mixture of 2.6 g of **6**, 4.4 g of 4-IC$_6$H$_4$NO$_2$ and 12 g of Tl$_2$CO$_3$ in anhydrous MeOH (60 mL) and C$_6$H$_6$ (70 mL) under argon was heated to 65 °C (preheated oil bath). To this stirred suspension was added 1.1 g of Pd(PPh$_3$)$_4$ and the resulting mixture was heated for 18 h. A 20 mL portion of C$_6$H$_6$ and 0.2 g of Pd(PPh$_3$)$_4$ were added, and the mixture was heated for 24 h. The suspension was cooled to 25 °C, diluted with 400 mL portions each of CHCl$_3$ and 10% aqueous NaCl, and filtered. The CHCl$_3$ layer was dried (MgSO$_4$), concentrated under vacuum to 30 mL, and flash chromatographed on 125 g silica gel-CH$_2$Cl$_2$. Elution of the product with CH$_2$Cl$_2$-Et$_2$O (49 : 1, v) gave 686 mg (13% overall) of **4**, m.p. > 300 °C; ^{1}H-NMR (CDCl$_3$) δ/ppm: 8.20 (d, J = 8.6 Hz, 8H, ArH), 7.39 (s, 4H, ArH), 7.21 (d, J = 8.6 Hz, 8H, ArH), 5.26 (d, J = 6.9 Hz, 4H, OCH outer), 4.85 (t, J = 8.0 Hz, 4H, CH methine), 4.22 (d, J = 6.9 Hz, 4H, OCH inner), 2.34–2.38 (m, 8H, CHCH_2), 1.37–1.50 (m, 24H, CH_2), 0.96 (t, J = 7.2 Hz, 12H, CH$_2$CH_3); MS (FAB) 1301 (M+H)$^+$.

Anal. Calcd. for C$_{76}$H$_{76}$N$_4$O$_{16}$: C 70.14, H 5.89; found C 70.05, H 5.99.

Crystal Structure Determination

The crystal structure of **1**, crystallized from a Me$_2$NCHO and Me$_2$NCOMe mixture, determined at 25 °C, belongs to the monoclinic space group $P2_1/c$ and was refined to R = 0.156. Nonidentified and disordered solvent molecules are close to the disordered *n*-pentyl 'feet' of the host. Feet and solvent are omitted from **8–11**.

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SAŽETAK

Kupasti kavitandi dimeriziraju i kompleksiraju neke organske goste u organskim otapalima koja su inače loši gosti

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Izvješćuje se o sintezi i svojstvima vezanja krutih policikličkih kavitanada u obliku kupe (**1-4**). Četiri benzenska prstena smještena po rubu kupe supstituirana su u *para*-položaju skupinama CO_2Me, Br, OH ili NO_2, koje produbljuju kupu. Na osnovicu kupe vezane su četiri pentilne stope, koje povećavaju topljivost ovih domaćina u organskim otapalima. Od četiri domaćina, dimerizira samo onaj koji sadrži skupinu CO_2Me, i to kako u kristalnom stanju tako i u otopini, u deset deuteriranih otapala koja su inače loši gosti. U tri preostala deuterirana otapala, nije opažena dimerizacija. Kristalna struktura pokazuje da jedna skupina p-$MeO_2CC_6H_4$ svakog monomera zauzima šupljinu svojega kompleksirajućeg partnera u recipročnom aranžmanu gost-domaćin. Takova struktura u skladu je s ^{1}H-NMR spektrima dimera u otopini. Dimer je određen također putem spektroskopije FAB-MS. Tetrabromokavitand kompleksira pri niskim koncentracijama u CD_2Cl_2 $MeCO_2CH_2Me$, $MeCO_2Me$, $PhCO_2Me$ i $MeCOCH_2CO_2Me$. Tetranitrokavitand **4** također kompleksira $MeCO_2CH_2Me$ u CD_2Cl_2 kao otapalu.