Synthesis and conformational analysis of extended calix[4]arenes and a doubly bridged bis-calix[4]arene

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Calix[4]arenes extended at the 5 and 17 upper rim positions with arylamide substituents have been prepared *via* a tetrapropoxycalixarene-5,17-dicarboxylic acid. Also, a surprisingly facile cyclooligomerization leading to the dimeric and tetrameric calix[4]arenes 1 and 2 with arylamide bridges has been developed. NMR investigations including NOE difference measurements showed that *N*,*N*′-bis(4-nitrophenyl)tetrapropoxycalix[4]arene-5,17-dicarboxamide 5 exists in two different pinched cone conformations: 5a in [$^2H_6$]-DMSO and 5b in $CDCl_3$. With this background, the conformation of the dimer 1 could be inferred. Finally, binding studies with 1 and 5 as hosts and benzene, naphthalene, anthracene and pyrene as guests have been investigated and related to the solvent-dependent conformations.

Introduction

Large molecules with an internal cavity capable of including guest molecules are of great interest to workers in supramolecular chemistry. Of such compounds calixarenes have received special attention because both of their ease of preparation and their ability to undergo further synthetic elaboration.[1] Simple calix[4]arene ethers with the cone geometry are beaker-shaped molecules with a rather open and small cavity the ability of which to bind guest molecules is limited. Much work has been done to modify either the lower rim with the phenolic hydroxy functions,[2] or the upper rim positions[3] to create host molecules mainly for the attraction of simple cations,[4] anions[5] and small molecules.[6]

The creation of hosts for small molecules is an especially important challenge since they can be used as novel sensors if groups are added that signal the presence of an analyte molecule, *e.g.* photometrically. This goal requires larger cavities to hold the molecules and the possibility of arranging multiple contacts to functional groups of the analyte.

Several possibilities exist for enlarging the cavity to enhance binding of molecular guests. Calixarenes with six or eight phenolic units are easily prepared and have correspondingly larger internal holes. Unfortunately, they cannot be made conformational rigid by simple etherification although progress has been made in this direction.[7] Alternatively, one can extend the calix[4]arenes at the upper rim positions with flat aryl groups, or even combine two or more calixarene units. Examples of the latter strategy are the cacerands made by Cram *et al.*,[8] a double calixarene joined by two bis-ethynyl bridges made by Arduini *et al.*[9] and the so-called 'holand' with four calixarene/rescorcinane units prepared by the group of Reinhoudt.[10] Two calixarene units have also been elegantly joined by self-assembly and shown to include guest molecules.[11] The present work is an extension of this strategy. Monomeric and dimeric calixarenes extended at the upper rim have been prepared, with the aim of producing large host molecules suitable for inclusion of flat aromatic-type guest molecules.

Results and discussion

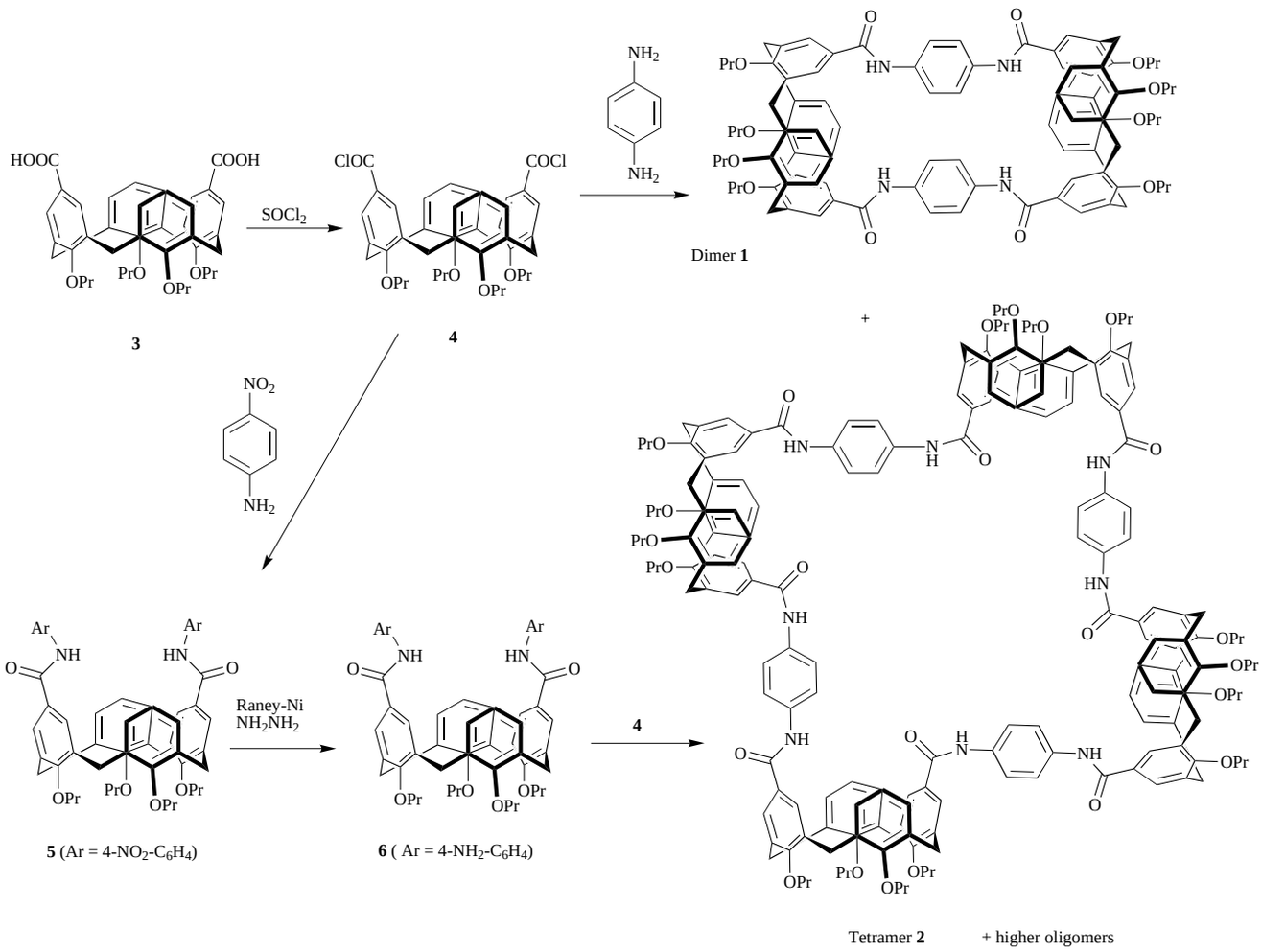
In the present work extended calix[4]arenes, suitable for including flat aromatic guests, were prepared building on previous experience in selective upper rim functionalization.[12] We report a cyclo-oligomerization that surprisingly yields the dimeric calix[4]arene **1** with two bridges as the dominant product. A cyclic tetrameric calixarene species **2** can also be obtained from the reaction mixture, although in very low yield. The synthesis is outlined in Scheme 1. 25,26,27,28-Tetrapropoxycalix[4]arene-5,17-dicarboxylic acid **3** was prepared from the corresponding 5,17-dibromo derivative through halogen to lithium exchange and quenching of the intermediate with gaseous carbon dioxide, as described previously.[12] The diacid **3** was then treated with thionyl chloride to produce the 25,26,27,28-tetrapropoxycalix[4]arene-5,17-dicarboxoyl chloride **4**. Cyclo-oligomerization to the dimer **1** was then carried out by condensing **4** with 1,4-diaminobenzene in the presence of pyridine. The raw product was analyzed by matrix-assisted laser desorbtion ionization time-of-flight mass spectrometry (MALDI-TOF MS) and size exclusion chromatography (SEC). Mass spectrometry indicated that the major product was the dimer but higher oligomers with *n* calixarene and *n* diaminobenzene units (n = 3, 4, 5, 6, 7 and 8) were also observed (see Fig. 1). Interestingly, no linear oligomers could be detected which should have 18 mass unit higher than the cyclic species and thus be clearly identifiable. The molecular mass in all cases corresponded to cyclic oligomers with amide bonds connecting calixarene and diaminobenzene units. Size-exclusion chromatography was then applied to estimate the proportions of each oligomer, which showed that the dimer **1** was the dominant species (*ca*. 50%) followed by the tetramer **2** (<10%). The surprisingly high yields of cyclic oligomers must be due to a pre-organization of the reactants. The oligomerization can be viewed as a simple condensation polymerization which is terminated by exceptionally favoured end-group condensations.

Alternatively, the dimer **1** was built up stepwise. The diacyl dichloride **4** was treated with 4-nitroaniline in the presence of pyridine to give the 25,26,27,28-tetrapropoxy-*N*,*N*′-bis(4-nitrophenyl)calix[4]arene-5,17-dicarboxamide **5**. The nitro groups in compound **5** could then, in turn, be reduced with Raney nickel and hydrazine in ethanol to produce the 25,26,27,28-tetrapropoxy-*N*,*N*′-bis(4-aminophenyl)calix[4]arene-5,17-dicarboxamide **6** (see Scheme 1). Reaction of **6** with the diacyl dichloride **4** again gave a mixture of oligomers, but in this case the yield of

Table 1 ^{1}H Chemical shifts (ppm) for compound **5** in two solvents [a]

Solvent	NH	H-1	H-2	H-3	H-4	H-5	H_{ax}	H_{eq}	Propyl-1 [b]			Propyl-2 [b]		
$CDCl_3$	7.65	6.74	7.01	6.85	7.33	7.84	4.43	3.16	3.96	1.90	0.87	3.70	1.82	1.02
[$^2H_6$]-DMSO	10.59	7.75	6.31	6.31	8.04	8.25	4.42	3.33	4.08	1.95	0.93	3.69	1.87	1.09
Δ		1.01	−0.70	−0.54	0.71	0.41								

[a] 0.01 M. [b] The propyl group signals are not assigned to specific positions on the calixarene skeleton.



Scheme 1

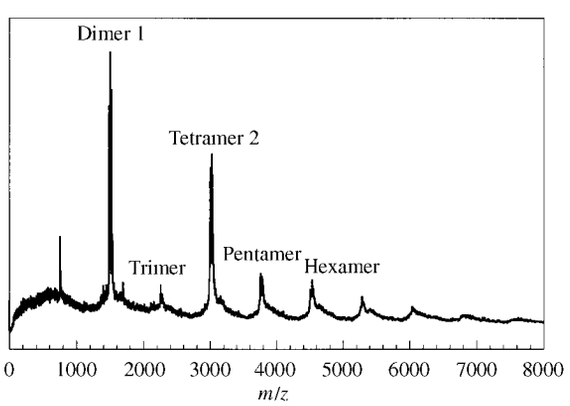
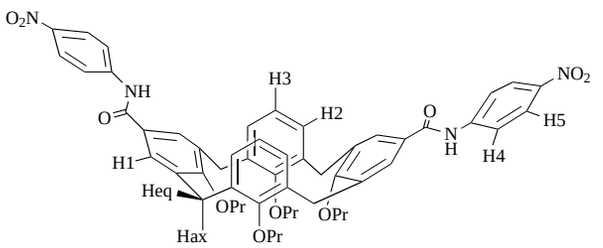


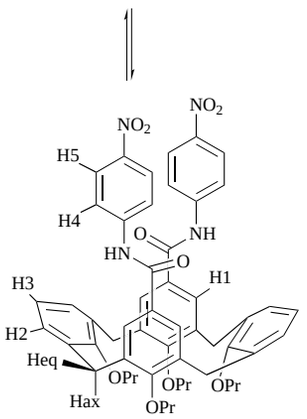
Fig. 1 MALDI-TOF MS of the unpurified reaction product of **4** and 1,4-diaminobenzene. Each oligomer gives rise to three peaks: M + H^+, M + Na^+ and M + K^+.

dimer **1** was increased to 74% as shown by SEC. It was found that the dimer **1** could be purified by first extracting the higher oligomers with hot acetic acid and then precipitating it from hot benzene–acetic acid; finally it was recrystallized from dioxane.

An analysis of the ^{1}H NMR data of compound **5** shows that there exists an equilibrium between two conformers that can be shifted dramatically by choice of solvent. Since this has implications both in regard to binding studies and for the structure of dimer **1** in solution, it is described below. The assigned ^{1}H chemical shift values for **5** in $CDCl_3$ and [$^2H_6$]-DMSO are given in Table 1. The assignments follow directly from the COSY spectra except for the non-equivalent methylene protons H_{ax} and H_{eq}. These are assigned from information obtained in the NOESY spectra. Thus, the lowfield methylene signal, assigned as H_{ax}, shows cross peaks to the protons of the propyl groups, while the highfield signal, assigned H_{eq}, has cross peaks to the aromatic part of **5**. Large shift differences are observed for the aromatic signals of **5** in [$^2H_6$]-DMSO compared to $CDCl_3$ solution (see Table 1). Not surprisingly the amide proton signal moves from 7.65 ppm in $CDCl_3$ to 10.59 ppm in [$^2H_6$]-DMSO because of hydrogen bonding between the [$^2H_6$]-DMSO oxygen and the amide protons. More interesting are the changes observed for the aromatic protons. The A_2B pattern (H-2 and H-3) at *ca*. 7.0 ppm in $CDCl_3$ moves to a singlet at 6.31 ppm in [$^2H_6$]-DMSO while the singlet at 6.74 ppm in $CDCl_3$ due to the H-1 protons *ortho* to the amide group shifts more than 1 ppm downfield to 7.75 ppm in [$^2H_6$]-DMSO solution. The signals H-



5a favoured in [$^2H_6$]-DMSO



5b favoured in $CDCl_3$

Fig. 2 Schematic representation of the two pinched cone conformers of compound **5** present in [$^2H_6$]-DMSO and $CDCl_3$

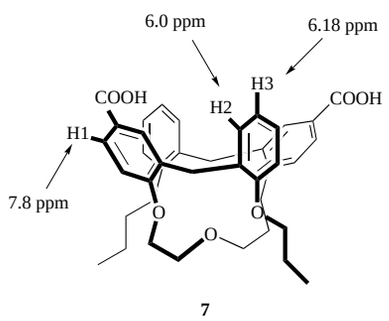


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Fig. 3 ^{1}H NMR ($CDCl_3$) assignments of aromatic protons in 11,23-dicarboxy-26,28-dipropoxycalix[4]arene-25,27-crown-3 according to ref. 13

4 and H-5 from the *p*-nitroaryl groups show shift changes of the same size as H-2 and H-3, although in the reverse direction. In the highfield portion of the spectrum the signals arising from the propyl groups are split into two sets with equal intensity and with similar chemical shifts in both solvents. However, when small amounts of [$^2H_6$]-DMSO gradually are added to **5** in $CDCl_3$ these propyl signals first move towards each other to become almost identical (addition of *ca*. 3% [$^2H_6$]-DMSO) and then move apart again as the [$^2H_6$]-DMSO concentration is increased. The signals for the bridging methylene protons are insensitive to these solvents changes. In the lowfield region a gradual change from the $CDCl_3$ pattern to the [$^2H_6$]-DMSO pattern is observed by this addition of [$^2H_6$]-DMSO. All this can be related to changes in the detailed geometry of the cone conformation. Simple calix[4]arene ethers have been shown by temperature-dependent ^{1}H NMR measurements to exist in two rapidly interconverting equivalent pinched cone conformations with C_{2v} symmetry[13] (see Fig. 2). One pinched cone conformer can be stabilized by introducing, for example, carboxylic acid groups on two opposing aryl groups, that hold together the parallel arrangement by hydrogen bonding.[14] More conclusively, Arduini *et al.*[13] have prepared 11,23-dicarboxy-26,28-dipropoxycalix[4]arene-25,27-crown-3 **7** (see Fig. 3) where two opposite phenolic groups have been connected with a 2,2′-diethyl ether linkage, fixing the conformation to one type of pinched cone. The chemical shift values of **7** (see Fig. 3) are similar to those obtained for compound **5** in DMSO. This suggests that the pinched cone conformation with the aryl amide groups flattened outward (**5a** in Fig. 2) is preferred in [$^2H_6$]-DMSO solution while the other pinched cone conformer (**5b** in Fig. 2) dominates in $CDCl_3$ solution. This could be explained, because in [$^2H_6$]-DMSO the amide and nitro groups are well solvated and force the aryl amide groups apart while in $CDCl_3$ these groups are held together by π-π interactions or positive van der Waals interactions. This interpretation is supported by difference NOE experiments. In $CDCl_3$ solution the correlation times for **5** are within the extreme narrowing limit at 400 MHz and positive NOEs are observed. This also applies when small amounts of [$^2H_6$]-DMSO are added as described above. In pure [$^2H_6$]-DMSO solution, no NOEs were observed for **5** even in experiments at 250 MHz. The reported NOEs are measured at the equatorial proton of the bridging methylene group. In $CDCl_3$ solution, separate irradiation at the frequencies for H-1 and H-2 resulted in different NOEs at H_{eq}. An enhancement ratio of 1.7 is measured for irradiation of the H-2 chemical shift relative to H-1. This ratio gradually decreases by addition of [$^2H_6$]-DMSO. When the chemical shift of the propyl group signals almost coincide the ratio becomes 1. Further addition of [$^2H_6$]-DMSO reduces the ratio further. Table 2 gives the measured NOE ratio for four different [$^2H_6$]-DMSO additions, together with the corresponding chemical shift values for H-1 and H-2. In **5a**, H_{eq} is closer to H-1 than to H-2 and this is reversed in **5b** (see Fig. 2). Therefore the NOE results are in agreement with solution structures of **5** being **5a** and **5b**. The latter is the dominant species in $CDCl_3$ and by addition of [$^2H_6$]-DMSO the equilibrium between **5a** and **5b** is gradually shifted in favour of **5a**. We have estimated the distances from H_{eq} to H-1 and H-2 in **5a** and **5b** by a Force Field calculation† and used the NOE enhancement ratios to derive approximate population ratios. Since **5a** and **5b** are in fast exchange, averaging of NOEs does not occur over the enhancements themselves but instead over the various cross-relaxation and relaxation rate terms. Using the formulae derived in ref. 15 for fast exchange, we notice that the conformer population ratio becomes independent of the relaxation rate terms when measuring different NOEs to the same proton. Thus, if indirect contributions to the NOEs and corrections for small variations between specific correlation times of the two conformers are neglected,[15] approximate ratios of **5a** to **5b** can be calculated. The values obtained are included in Table 2 and show a ratio of 0.2 : 1 between **5a** and **5b** in $CDCl_3$ solution. According to this, only a small energy difference is found between the two pinched cone conformers (ΔG ~1 kcal). The calculated conformer ratios are correlated with the measured chemical shifts of H-1 ($R = 0.987$) and H-2 ($R = 0.980$). This correlation provides

Table 2 Results of ^{1}H NOE difference experiments[a] on **5** in $CDCl_3$[b] with varying amounts of [$^2H_6$]-DMSO added

% [$^2H_6$]-DMSO added	δ(H-1)/ ppm	δ(H-2)/ ppm	NOE ratio[c]	**5a** : **5b** approx. ratio
0	6.80	7.10	1.7	0.2
2.5	7.12	6.72	1.1	0.8
3.8	7.17	6.69	0.9	1
6.3	7.42	6.48	0.7	3

[a] Obtained at 250 MHz at 300 K. [b] 0.03 M. [c] Measured at H_{eq} for irradiation at H-2 relative to H-1.

† Distances in **5a**: *r*[H(1)-H_{eq}] = *ca*. 2.77 Å; *r*[H-2-H_{eq}] = *ca*. 2.40 Å. Distances in **5b**: *r*[H(1)-H_{eq}] = *ca*. 2.40 Å; *r*[H-2-H_{eq}] = *ca*. 2.77 Å. Computational results were obtained using software programs from Molecular Simulations; dynamics calculations were done with the Discover® program, using the CVFF forcefield.

Table 3 ^{1}H chemical shift changes in ppm of calixarene **5** (35 mM) in $CDCl_3$ on addition of different arenes (130 mM)

	Benzene	Naphthalene	Anthracene	Pyrene
NH	+0.064	*a*	−0.144	−0.156
H-1	−0.002	−0.007	−0.010	−0.047
H-2	+0.013	+0.004	−0.036	−0.056
H-3		+0.004	−0.024	−0.031
H-4	0	−0.010	−0.025	−0.164
H-5	−0.005	−0.009	−0.012	−0.115

[a] NH signal obscured by naphthalene signals.

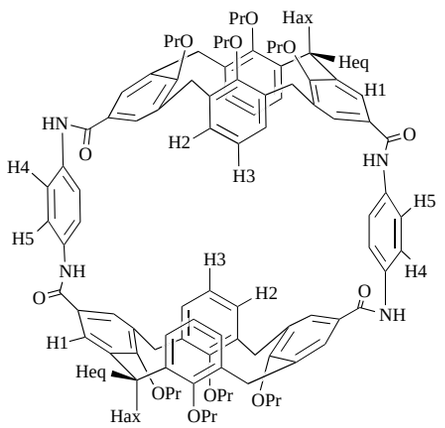

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Fig. 4 Schematic representation of the conformation of dimer **1** derived from the ^{1}H NMR spectrum

estimates of chemical shifts for H-1 of 7.7 and 6.6 ppm and H-2 of 6.1 and 7.2 ppm for the conformers **5a** and **5b**, respectively. The values for H-2 agree well with the low-temperature chemical shifts of 6.15 and 7.10 ppm assigned to specific pinched cone conformers of a simple calix[4]arene ether.[13]

Dimer **1** could only be dissolved in a mixture of [$^2H_6$]-DMSO and $CDCl_3$ and the ^{1}H NMR spectrum can easily be interpreted in light of the DMSO spectrum of **5**. The aromatic protons of **1** occur at 6.24 ppm (presumably H-2 and H-3), 7.77 and 7.80 (presumably H-1 and H-4) indicating a major contribution of a pinched cone conformer with the H(2)–H(3) rings parallel and the H(1)-rings flattened outward (as in **5b**). The resulting geometry is schematically shown in Fig. 4. Clearly, the 1,4-diaminobenzene groups are forced out of planarity with the H(1)-rings inducing some strain. This conformation is somewhat counter-intuitive as one would expect a periplanar arrangement of the H(1)-rings, amide groups and bridging benzenes to maximize π–π overlap. The hydrogen bonding interactions between DMSO and the amide groups obviously offsets the strain and loss of π–π overlap to make the overall ball-like shape more stable.

Both compounds **1** and **5** were tested (by ^{1}H NMR) for their ability to include the aromatic guest molecules: benzene, naphthalene, anthracene and pyrene. Chemical-shift changes were observed at relatively high guest concentrations for **5** in $CDCl_3$ while in DMSO no significant chemical shift changes of **5** occurred on addition of aromatic guests. A summary of the results in $CDCl_3$ are shown in Table 3. Only the larger aromatic compounds anthracene and pyrene showed significant chemical-shift changes. NMR titration studies with pyrene as guest gave a linear response of $\Delta\delta$ for all protons *versus* concentration, even up to 0.75 M guest. It was not possible to obtain the saturation part of the binding isotherm and calculation of binding constants were not carried out. The change of conformation due to DMSO could account for the lack of binding in this solvent, but it is also possible that solvent molecules compete more effectively for the binding site. The dimer **1** showed no significant chemical-shift changes on addition of any aromatic guest molecules, which can also be ascribed to the effect of DMSO on conformation and occlusion of the binding site.

Experimental

Materials and methods

Melting points are uncorrected. NMR spectra were recorded either with an Avance 250 DPX, an AC 250, or a Unity 400 NMR instrument with internal TMS as standard. NOE difference measurements were performed with a pre-irradiation time of 2.0 s (8–10 × T_1 for H_{eq}). The enhancements were between 1.9 and 3.4% and obtained by weighted subtraction of the control spectrum from the irradiated spectrum until a null signal resulted for H_{eq}. All NOE experiments were performed at least twice. MALDI-TOF spectra were recorded on a G2025A LD-TOF System with a 2,5-dihydroxybenzoic acid matrix. SEC chromatograms were obtained with a system equipped with a Polygen Jordi-Gel DVB 500 A column (500 × 22 mm) and a PYE UNICAM UV-RI detector, using unstabilized THF as eluent.

25,26,27,28-Tetrapropoxycalix[4]arene-5,17-dicarboxoyl dichloride 4

The diacid **3** (2.00 g, 2.94 mmol) was refluxed in $SOCl_2$ (20 cm^3) for 2 h, after which excess of $SOCl_2$ was removed *in vacuo*. The remaining solid was washed with light petrol (2 × 10 cm^3) and dried *in vacuo* to give **4** (1.31 g, 62.2%); mp 181–183 °C (Found: C, 69.75; H, 6.5. $C_{42}H_{46}Cl_2O_6$ requires C, 70.28; H, 6.46%); δ_H(250.1 MHz, $CDCl_3$) 1.01 (12H, double triplet, *J* 8), 1.91 (m, 8H), 3.25 (4H, d, *J* 14), 3.82 (4H, t, *J* 7), 4.02 (4H, t, *J* 8), 4.47 (4H, d, *J* 14), 6.52 (6H, m) and 7.54 (4H, s); δ_C(62.9 MHz, $CDCl_3$) 10.9, 11.1, 77.8, 123.5, 127.4, 129.2, 132.8, 134.2, 137.2, 156.6, 164.2 and 168.1.

N,*N*′-Bis(4-nitrophenyl)-25,26,27,28-tetrapropoxycalix[4]arene-5,17-dicarboxamide 5

A solution of the diacyl dichloride **4** (1.43 g, 2.00 mmol) in methylene dichloride (50 cm^3) and pyridine (3 cm^3) was treated with 4-nitroaniline (0.80 g, 5.8 mmol) in methylene dichloride (50 cm^3). The mixture was stirred at ambient temperature for 2 h and then washed with 6 M aq. HCl (50 cm^3). After concentration of the mixture by solvent removal on a rotary evaporator the residual solid was recrystallized from ethanol. The solid was then triturated with hot methanol and cooled before being filtered off and dried *in vacuo* to give **5** as a light-yellow crystalline powder (1.45 g, 78.7%); mp 236–238 °C (from acetic acid) [Found: C, 64.4; H, 6.4; N, 4.8. $C_{62}H_{72}N_4O_{18}$ **5**·4 (acetic acid) requires C, 64.13; H, 6.25; N, 4.82%]; δ_H(250.1 MHz, $CDCl_3$) 0.87 (6H, t, *J* 7), 1.02 (6H, t, *J* 7), 1.82 (4H, m), 1.90 (4H, m), 3.16 (4H, d, *J* 14), 3.70 (4H, t, *J* 7), 3.96 (4H, t, *J* 8), 4.43 (4H, d, *J* 14), 6.74 (2H, s), 6.85 (2H, t, *J* 8), 7.01 (2H, d, *J* 8), 7.33 (4H, d, *J* 9), 7.65 (2H, s) and 7.85 (4H, d, *J* 9), see also Table 1; δ_C(62.9 MHz, $CDCl_3$) 10.6, 11.3, 24.1, 23.7, 31.8, 77.4, 78.1, 120.0, 123.3, 125.1, 127.5, 128.2, 130.0, 135.6, 136.9, 143.8, 144.4, 158.1, 160.2 and 166.5.

Dimer 1

From the diacyl dichloride 4 and 1,4-diaminobenzene. A solution of the diacyl dichloride **4** (1.42 g, 2 mmol) in $CHCl_3$ (100 cm^3) was treated with a mixture of 1,4-diaminobenzene (0.220 g, 2 mmol) and pyridine (5 cm^3) in $CHCl_3$ (100 cm^3). The reaction mixture was stirred overnight at ambient temperature and then evaporated to dryness on a rotary evaporator. The residue was treated with 6 M aq. HCl (50 cm^3) and then filtered off, washed with water, ethanol and diethyl ether (50 cm^3 each) and dried. MALDI-TOF spectrometry of a sample in a CH_2Cl_2 and dihydroxybenzoic acid matrix (1:1) showed a series of peaks at regular intervals, dominated by peaks at *m/z* 1487.4

($M^+ - OH$), 1504.2 (M^+) and 1526.4 ($M^+ + Na$). The next highest peaks occur at 3009.0 and 3030.7 corresponding to a tetramer. SEC with THF as eluent, with both refractive index and UV detectors, show that the area under the dimer **1** peak corresponds to *ca*. 50% of the total. The raw product was triturated with boiling acetic acid (100 cm^3) and filtered whilst hot to remove higher oligomers. The residue was dissolved in hot benzene–acetic acid (5:1) and precipitated with four volumes of acetic acid. The product was filtered off and washed with ethanol and diethyl ether to give **1** (0.293 g, 19.5%) as a powder; mp >300 °C (decomp.) (from dioxane) [Found: C, 74.7; H, 7.0; N, 3.6. $C_{104}H_{120}N_4O_{16}$ **1**·2(dioxane) requires C, 74.26; H, 7.19; N, 3.33%]; δ_H(250.1 MHz, $CDCl_3$–[$^2H_6$]-DMSO, 1:1, 330 K) 0.94 (12H, t, *J* 7), 1.12 (12H, t, *J* 7), 1.89 (16H, m), 3.28 (8H, d, *J* 13), 3.72 (8H, unresolved t), 4.12 (16H, unresolved t), 4.48 (8H, d, *J* 13), 6.24 (12H, s), 7.77 and 7.80 (14H, s + s) and 9.81 (4H, s); δ_C(62.9 MHz, $CDCl_3$–[$^2H_6$]-DMSO, 1:1, 330 K) 9.3, 10.1, 22.7, 22.3, 30.2, 75.7, 76.4, 120.3, 121.5, 127.2, 128.0, 128.1, 131.9, 134.7, 135.8, 154.5, 159.9 and 164.0.

Dimer 1

From the diacyl dichloride 4 and the diamine 6. The calixarene **5** (1.0 g, 1.09 mmol) was dissolved in ethanol (50 cm^3) at reflux with Raney nickel (*ca*. 50 mg) (decanted twice from ethanol). Hydrazine hydrate (1.0 cm^3) was added dropwise over 5 min to the mixture which was then refluxed for a further 1 h. After this, the reaction mixture was cooled to ambient temperature, filtered to remove the catalyst and evaporated on a rotary evaporator. The residue was taken up in methylene dichloride (50 cm^3) and the solution washed with water (50 cm^3), dried (Na_2SO_4) and evaporated to dryness to give **6** as a semi-solid; δ_H(250.1 MHz, [$^2H_6$]-DMSO) 1.01 (t, 6H, *J* 7), 1.20 (t, 6H, *J* 7), 2.01 (m, 8H), 3.37 (d, 4H, *J* 13, partly obscured by H_2O in solvent), 3.76 (unresolved triplet, 4H), 4.50 (d, 4H, *J* 13), 4.98 (s, 4H), 6.33 (s, 6H), 6.66 (d, 4H, *J* 8), 7.48 (d, 4H, *J* 8), 7.85 (s, 4H) and 9.81 (s, 2H). The diamine **6** (476 mg, 0.553 mmol), used without further purification, was dissolved in ethyl acetate (50 cm^3) with pyridine (3 cm^3) and treated with the diacyl dichloride **4** (410 mg, 0.572 mmol). The mixture was stirred at ambient temperature for 2 h after which it was evaporated *in vacuo*. The residue taken up in chloroform (50 cm^3) and the solution washed with water (50 cm^3) and evaporated *in vacuo*. The residue was triturated with hot ethanol (25 cm^3) and then filtered off and dried *in vacuo* (0.41 g). SEC indicated that 74% of this material was the dimer **1**.

Tetramer 2

Several preparative SEC runs of the crude product, obtained from diacyl dichloride **4** and 1,4-diaminobenzene, yielded *ca*. 1 mg of the tetramer **2**. MALDI-TOF and analytical SEC indicated that it was almost free of other oligomers. FAB-MS showed a small peak at *m/z* 3035.6, which can be attributed to the $M + Na^+$ species (largest isotope peak expected at 3034.52). The largest peaks in the FAB-MS was the dimer at 1505 (M^+) and 1528 ($M + Na^+$) even though this was a minor component as shown by the other analytical techniques.

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