Pergamon

Tetrahedron 54 (1998) 10053–10068

TETRAHEDRON

Covalently Linked Multi-Calixarenes

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Received 20 April 1998; accepted 12 June 1998

Abstract: *ipso*-Nitration of *t*-butyl calix[4]arene tetraethers and subsequent hydrogenation provides an easy access to monoamino calix[4]arenes. Reaction with di- and triacid chlorides leads to various double- and triple-calix[4]arenes. With tetra-acid chlorides derived from calix[4]arenes in the *cone*- or *1,3-alternate*-conformations penta-calix[4]arenes are available as molecularly uniform species, which may be regarded as the first generation of calix[4]arene based dendrimers. The structure of the mononitro tetraester derivative, which may serve as a general building block has been confirmed by single crystal X-ray analysis. © 1998 Elsevier Science Ltd. All rights reserved.

Introduction

Calixarenes are well defined macrocyclic molecules which are readily available in large quantities and easily modified by chemical reactions.[1] Suitable calixarene derivatives may be used as building blocks for the construction of larger molecules or molecular assemblies. The most elegant approach, the self assembly of complementary[2] or self complementary[3] calixarene derivatives has led to well defined molecular boxes or capsules which are able to include suitable guest molecules. However, due to their reversible formation[4], self assembled systems may be sensitive to competitive solvents or concentration changes. Hydrogen bonded dimers of tetraurea calix[4]arenes, for instance, which are quantitatively formed in benzene are quantitatively destroyed by the addition of 1 % DMSO.[5]

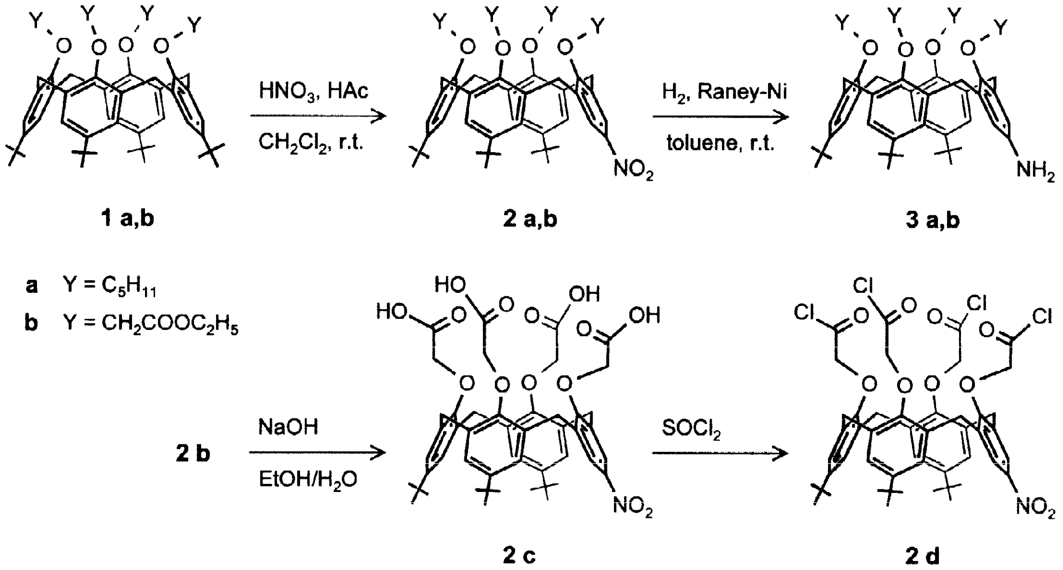
PII: S0040-4020(98)00594-8

These problems do not exist in covalently linked systems and numerous double-calixarenes linked via one, two or four bridges at the wide or narrow rim have been described.[1] In recent years also larger molecules consisting of three[6,7] or more[8,9] calix[4]arene substructures have been synthesised. This covalent connection may involve the narrow (lower) or wider (upper) rim, may consist of one or more bridges between the calixarene units and may lead to linear, branched or macrocyclic structures. For example a rather rigid macrocyclic combination of two calix[4]arenes in the *cone* conformation and two resorcarene derived cavitands, a "holand"[10] has been prepared. A "linear" combination of three calix[4]arenes fixed in the *1,3-alternate* conformation[11] also shows the structural diversity and potential variety.

In comparison to self assembly strategies, where the main difficulty lies in the synthesis of suitably functionalized building block(s), the most difficult step in the connection of calixarenes via covalent links is the final "connecting" step itself, which is prone to "irreversible" side reactions. It requires a clean, definite (clear-cut) reaction which should be possible under mild conditions. This is especially important if macrocyclic compounds should be synthesised under "high dilution". We have chosen the formation of amide bonds, since *p*-amino calixarenes are easily available via *ipso*-nitration and subsequent reduction.[12] While the first rotaxanes with calix[4]arene stoppers have been recently obtained in this way[13], we describe in the following our first steps towards amide linked[14], calix[4]arene based dendrimers.

Results and Discussion

Syntheses

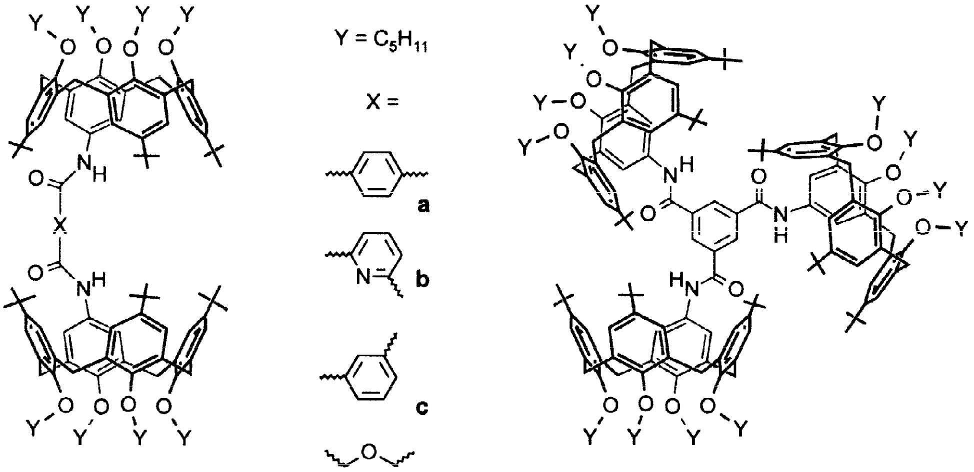


Scheme 1

ipso-Nitration of *t*-butyl calix[4]arene tetraethers has been used to synthesise the corresponding tetranitro compounds[12] in yields of 85%. Under less drastic conditions (treatment of a solution of **1** in CH_2Cl_2

with a mixture of concentrated nitric acid and glacial acetic acid at room temperature) the reaction can be restricted to one phenolic unit and the mononitro compounds **2** are formed more or less exclusively.[15] They can be isolated and purified simply by filtration of the crude reaction mixture over silica gel. Subsequent reduction of the nitro group by catalytic hydrogenation (Raney-Ni, r.t., normal pressure) yields the pure amino derivatives **3**, which can be used in further steps usually without additional purification. (Scheme 1).

Of particular interest is **2b** (for its X-ray structure see later), an ideal building block for the construction of branched dendritic oligo calix[4]arenes, since independently it may be "activated" also on the narrow rim by hydrolysis of the ester groups and reaction with $SOCl_2$.



4 a-d **5**

Scheme 2

The reaction of various diacid chlorides with monoamine **3a** was chosen as a model. Double calixarenes **4a-d** were obtained directly as analytically pure products (see Scheme 2) in yields of 85% and the triple- (or tri-) calixarene **5** (74%) was prepared in an analogous way from trimesoyl chloride, thus demonstrating that the amino group in **3** can be easily acylated without any indication of sterical hindrance. Compounds of type **4** or **5**, in which two (or three) cavities point towards each other, may be useful as host molecules especially if additional ligating groups are introduced through the acid[16] or attached to the *p*-positions of the calixarenes.

Compounds **4** and **5** can be thoroughly characterised by ^1H and ^{13}C NMR which is illustrated for **4b** as an example (Fig. 1). The ^1H NMR spectrum shows in the aromatic region a doublet (8.25 ppm) and a triplet (7.99 ppm) for the protons of the bridging pyridine and a singlet (8.59 ppm) for the amide protons. The aromatic protons of the calixarene appear as two doublets (7.05 and 6.98 ppm) and two singlets (6.9 and 6.31 ppm) as expected for calixarenes of the AAAB-type. Moreover in the methylene region (4.6 - 3 ppm) two pairs of doublets can be found for the protons of the bridging methylene groups as well as two triplets for the

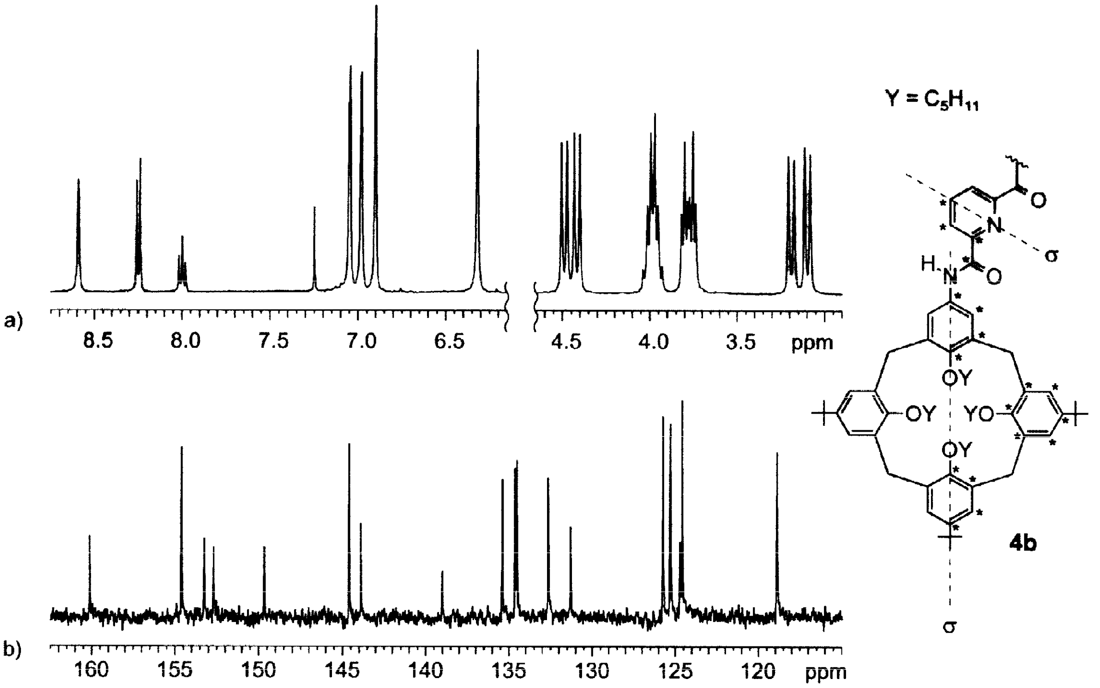
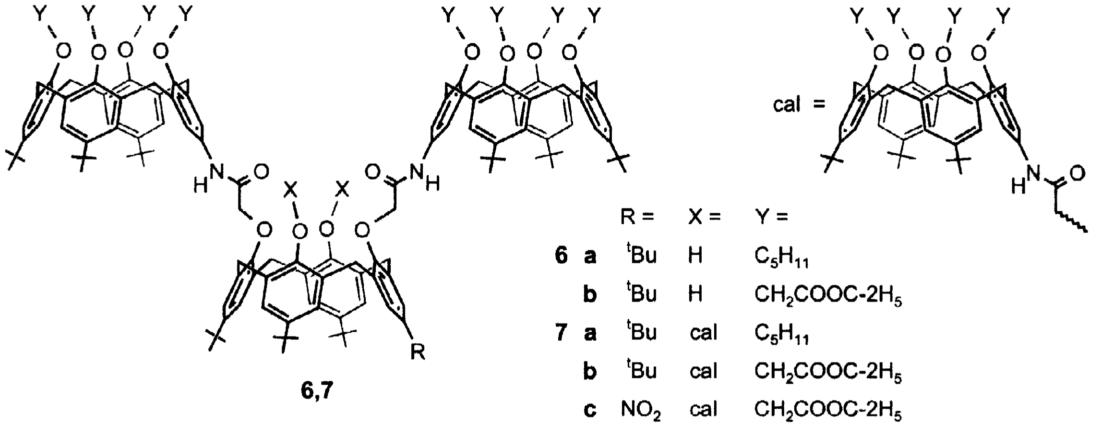


Fig. 1: Sections of the 400 MHz ^{1}H NMR spectrum ($CDCl_3$) (a) and section of the 100 MHz ^{13}C NMR spectrum (b) of **4b**.

protons of the OCH_2-groups lying on the symmetry plane. The diastereotopic protons of the other OCH_2-groups appear as a multiplet (~4 ppm). In the ^{13}C NMR spectrum 17 signals for the aromatic carbon atoms (155 - 115 ppm) and the signal for the carbonyl carbon atom (160.1 ppm) can be distinguished.

Similarly the ^{1}H NMR spectrum of the triple-calix[4]arene **5** is in agreement with a molecule with time-averaged C_{3v}-symmetry showing no indication of rotational barriers.



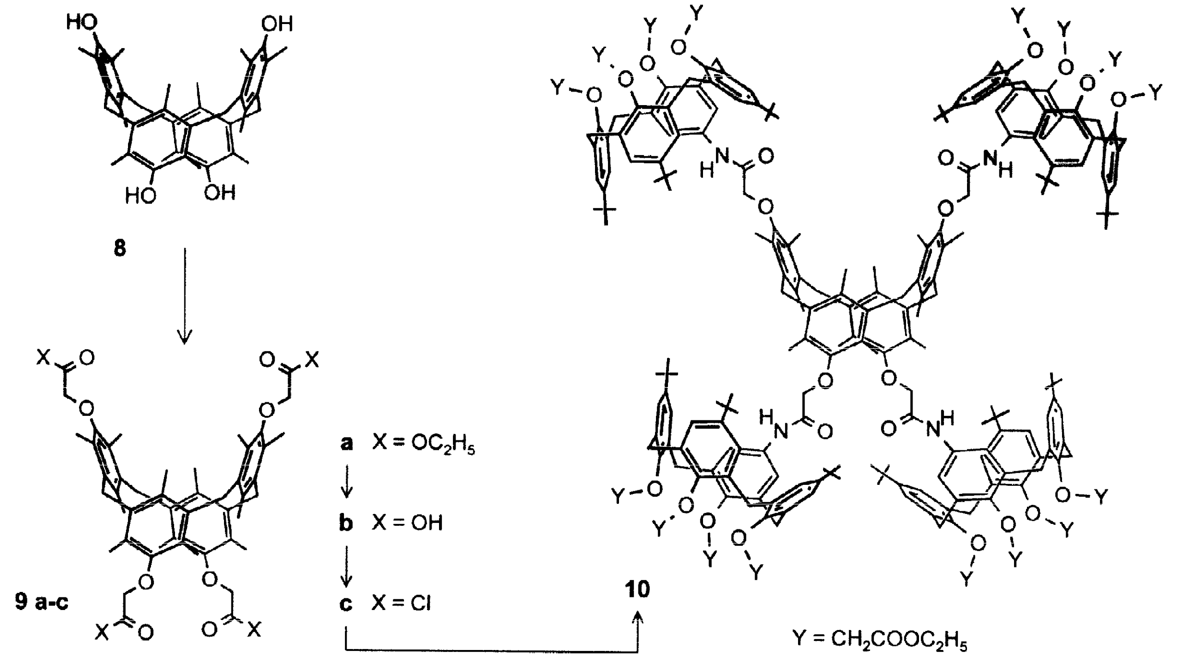
6,7

		R =	X =	Y =
6	**a**	^{t}Bu	H	C_5H_{11}
	b	^{t}Bu	H	$CH_2COOC\text{-}2H_5$
7	**a**	^{t}Bu	cal	C_5H_{11}
	b	^{t}Bu	cal	$CH_2COOC\text{-}2H_5$
	c	NO_2	cal	$CH_2COOC\text{-}2H_5$

Scheme 3

1,3-Diacid chlorides (*syn* isomer) and tetraacid chlorides (*cone* isomer) can be easily prepared from *t*-butyl calix[4]arene (compare the synthesis of **2d**, outlined in Scheme 1). Their reaction with monoamines

3a,b leads to triple-calix[4]arenes **6a,b** and to penta-calix[4]arenes **7a-c** in yields of up to 70% in spectroscopically pure form. Similarly, the exo-calix[4]arene **8** derived from 2,4,6-trimethylphenol[17] can be converted in three steps into the tetraacid chloride **9c**, from which the penta-calix[4]arene **10** can be obtained (Scheme 3). All penta-calix[4]arenes can be completely analysed by ^{1}H NMR spectra and have been confirmed also by FD- or MALDI-TOF mass spectra.



Scheme 4

Fig. 2a shows, as an example, two sections of the ^{1}H NMR spectrum of **10**, which is in entire agreement with the proposed structure. A more or less unambiguous assignment of all signals is possible in analogy to especially **9a** and **6b**. For the central calixarene unit in the 1,3-alternate conformation we find two singlets for the methyl groups at 2.24 and 1.06 ppm (ratio 2:1) and a broader singlet for the methylene protons (3.89 ppm). The attached O-CH_2-CO-NH group gives a sharp singlet for NH and a somewhat broader singlet for the CH_2 protons (7.99 and 4.04 ppm). The outer calix[4]arenes fixed in the cone conformation have in principle four different aromatic protons which appear as three singlets (ratio 2:1:1) at 7.03, 6.81 and 6.33 ppm. Similarly, the attached O-CH_2-CO arms give rise to three singlets (ratio 2:1:1) at 4.94, 4.61 and 4.57 ppm and the diastereotopicity at two methylene groups (per calix) becomes not evident. As usual two pairs of doublets are found for the axial (4.92 and 4.84 ppm) and equatorial (3.22 and 3.19 ppm) protons of Ar-CH_2-Ar-groups, while the *t*-butyl groups give two sharp singlets (ratio 2:1) at 1.27 and 0.95 ppm. Finally the ethyl groups show three partly superimposed quartets (ratio 1:1:2) between 4.26-4.17 ppm and a multiplet at 1.33-1.24 ppm.

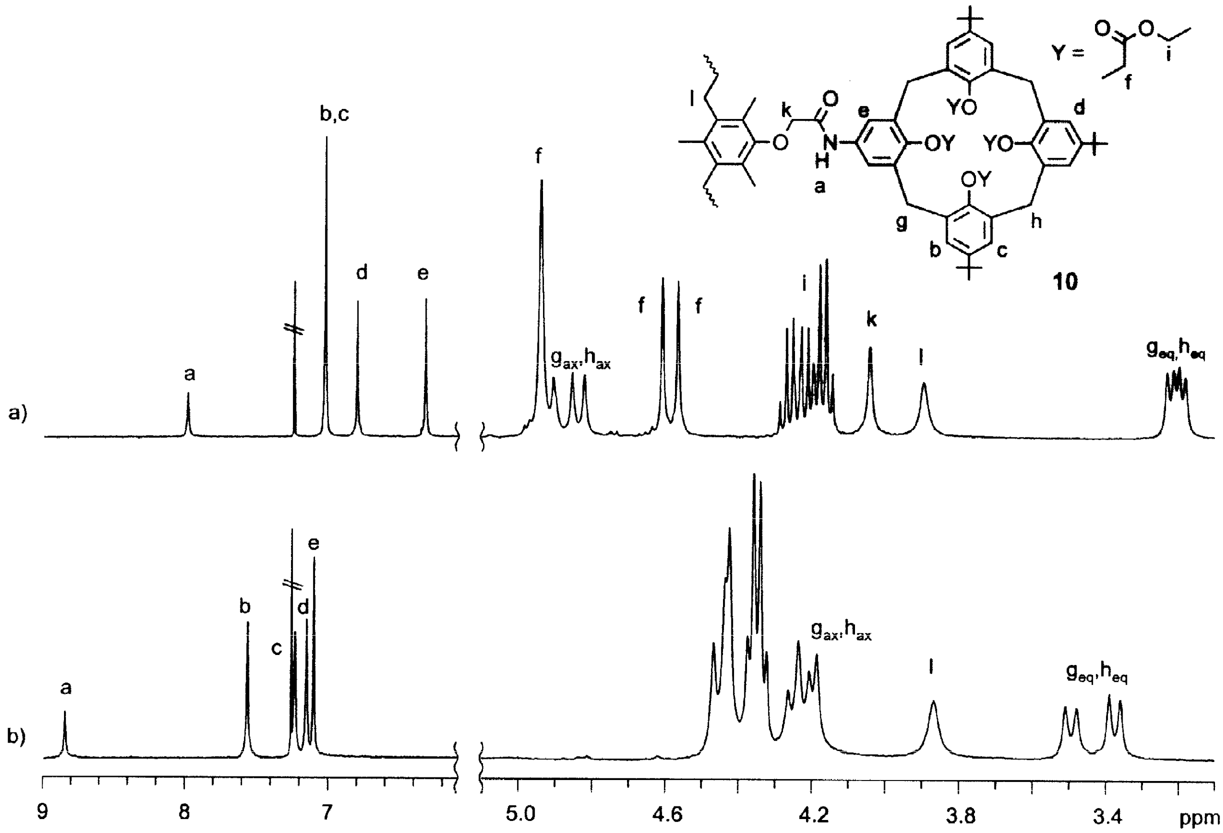


Fig 2.: Section of the 400 MHz ^1H NMR Spectrum ($CDCl_3$) of **10** (a) and after shaking with NaSCN (b). (The aromatic and the methylene region are shown on different scale.)

Complexation of Sodium Cations

Tetraester derivatives like **1b** are strong and selective ligands for sodium cations.[18] These complexes are usually kinetically stable on the NMR time scale and show characteristic spectroscopic changes with respect to the free ligand.[19] Most important are downfield shifts for the aromatic (+0.34 ppm) and the equatorial methylene protons (+0.61 ppm) and upfield shifts for the $-CH_2-CO-$ (-0.33 ppm) and the axial methylene protons (-0.20 ppm). Fig. 2b shows the ^1H NMR spectrum obtained after shaking a solution of **10** with excess NaSCN. The complexation of Na^+ is indicated again by strong up- and downfield shifts. All aromatic protons show now chemical shifts > 7.0 ppm, and all $O-CH_2-CO$-protons of the ester arms appear between 4.4 and 4.5 ppm. The axial methylene protons are downfield shifted to ~4.2 ppm while the equatorial ones are upfield shifted to 3.35 and 3.5 ppm. Finally all quartets of the ethyl groups coincide at ~3.5 ppm.

The entire spectrum again is compatible with a S_4-symmetrical structure, indicated for instance by a single singlet for NH protons at 8.84 ppm (downfield shifted by 0.85 ppm with respect to free **10**). This suggests that all four tetraester units have complexed a Na^+-cation, unless rapid exchanges average their signals.

Addition of free ligand **10** leads to a spectrum roughly identical with a superposition of the spectra of **10** (Fig. 2a) and its Na^+-complex (Fig. 2b).[20] This clearly demonstrates that the exchange of Na^+ is, as expected, slow on the NMR time scale.

Single Crystal X-Ray Analysis

Single crystals of **2b** were obtained from chloroform/methanol. Due to the severe disorder and weak scattering power, the R-value and the e.s.d.'s for the bond lengths, bond angles etc. are rather poor, but the conclusions below are entirely justified. All the *t*-butyl groups are rotationally disordered over two positions and were refined isotropically with a population parameter of 0.5. Also one of the ethyl residues (C39 - C40) of the ester moieties is disordered. However, C39 had to be refined isotropically as one atom to obtain a reasonable model for the ester group (thus the resulting temperature factor for C39 is very large). An additional peak in the crystal lattice was treated as a fractional water molecule (occupancy 0.25, H-atoms were not located). Four geometrical restrains were used to keep some parts of the molecule chemically reasonable.

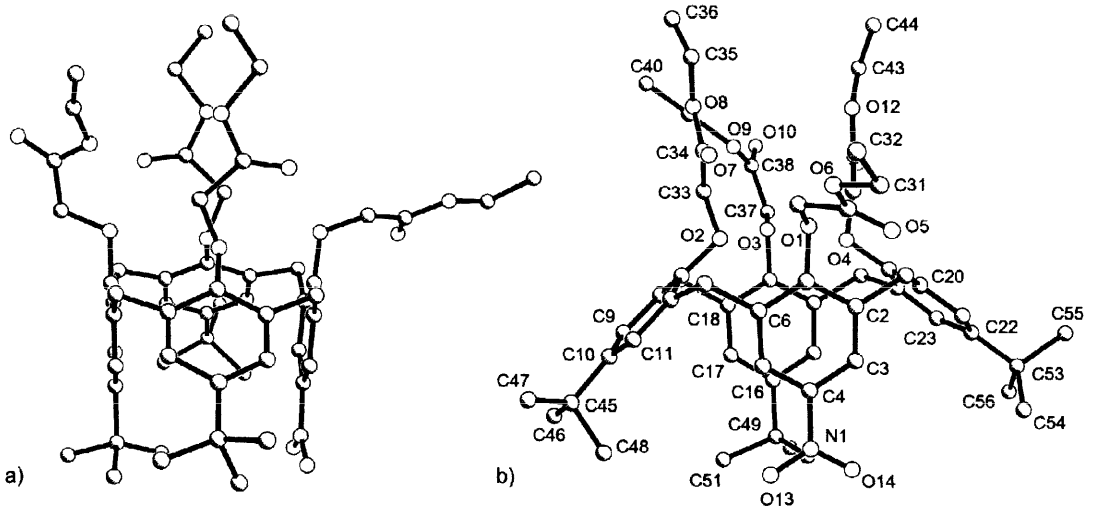


Fig. 3: X-ray structure of compound **2b** (two different directions); hydrogen atoms are omitted for clarity.

The molecular structure, the conformation and the numbering scheme of **2b** are shown in Fig. 3. The molecule adopts a pinched cone conformation usually found for tetraethers of calix[4]arenes. The *p*-nitrophenyl ring and its opposite ring are nearly parallel (interplanar angle -7.4°, distance O1 - O3 = 5.58 Å) while the other two rings are nearly perpendicular (interplanar angle 96.1°, distance O2 - O4 = 3.41 Å). The inclinations of the aromatic rings with respect to the best plane through the methylene carbons C25 to C28 (r.m.s. = 0.019 Å) are (in the order O1 to O4): 84.6°, 134.6°, 92.1°, and 141.5°. The X-ray structure, a rare example for tetra-O-alkyl calix[4]arene (*cone* isomer) with the substitution pattern AAAB on the wider rim, confirms the constitution of **2b**, while it reveals a conformation known from many other tetraether derivatives.

Conclusions and Outlook

ipso-Nitration of tetraethers of *t*-butyl calix[4]arenes and subsequent hydrogenation represents a simple route to monoamino calix[4]arenes, which have been successfully used to synthesise a variety of covalently linked oligo-calix[4]arenes. The penta-calixarenes **7a** or **10** may be regarded as a first step towards dendritic structures[21] with calix[4]arenes as "branching points". Hydrolysis of the 16 ester functions should allow in principle, the attachment of a second generation of 16 calix[4]arenes of type **3** via amide bonds. This connection between the narrow and the wide rim contrasts Shinkai's approach in which calix[4]arenes were linked between their oxygen functions at the narrow rim.

The quantitative transformation of a hexadecaacid into the acid chloride and subsequently into the corresponding amide without side reactions (e.g. hydrolysis) may be difficult as well as difficult to control analytically. An alternative strategy consists in the reduction of **7c** which should lead to a stable, analytically characterizable monoamine. Its reaction with tetraacid chlorides like **2d** or **9a** should yield the desired heneicosa-calix[4]arenes. However, up to now, the hydrogenation of **7c** failed for yet unknown reasons and modified reaction conditions (solvent, catalyst) have to be elaborated. As in the preparation of rotaxanes, the controlled synthesis of larger covalently linked systems may be facilitated by the introduction of (flexible) spacer groups between the calixarene units.

Experimental Part

^{1}H NMR spectra were recorded on a Bruker AC 200 (200 MHz) or AC 400 (400 MHz) spectrometer. Chemical shifts are reported as δ values in ppm relative to $(CH_3)_4Si$ as internal standard. FD-mass spectra were recorded on a Finnigan MAT 8230; MALDI-TOF spectra were measured in the reflectron mode with a Tof Spec E (Micromass) using dithranol (1,8,9-trihydroxyanthracene) as matrix. Melting points reported are uncorrected. Solvents were purified by standard procedures. Compounds **1a** and **1b** were prepared according to procedures described in the literature.[1,12]

11,17,23-Tri-*t*-butyl-5-nitro-25,26,27,28-tetrapentyloxycalix[4]arene (2a)

To a vigorously stirred solution of compound **1a** (6.4 g, 6.89 mmol) in CH_2Cl_2 (400 mL) a mixture of concentrated nitric acid (10 mL, 140 mmol) and glacial acetic acid (10 mL, 180 mmol) was added. The colour of the reaction mixture immediately turned to dark purple and then to black. Over a period of time (18-24h) the colour of the mixture changed to yellow at which point it was diluted with water. The organic layer was washed with water (3 x 150 mL), dried (Na_2SO_4) and the solvent removed under reduced pressure. The residue is dissolved and filtered over silica (CCl_4 or $CHCl_3$/n-hexane (1:1)). After removal of the solvent the recrystallization of the residue from $CHCl_3$/MeOH yields the pure compound **2a** as a white solid (4.81 g, 76 %).

mp 139-140°C; R_f: 0.85 $CHCl_3$/n-hexane 1:1. ^1H NMR 400 MHz ($CDCl_3$) δ (ppm) 7.25 (s, 2H, ArH), 7.15 (d, 2H, ArH, *J* 2.1 Hz), 7.12 (d, 2H, ArH, *J* 2.1 Hz), 6.19 (s, 2H, ArH), 4.46 (d, 2H, $ArCH_2Ar$, *ax*, *J* 12.9 Hz), 4.39 (d, 2H, $ArCH_2Ar$, *ax*, *J* 12.9 Hz), 4.13-4.06 (m, 2H, OCH_2), 4.01-3.87 (m, 2H, OCH_2), 3.74 (t, 2H, OCH_2, *J* 6.8 Hz), 3.69 (t, 2H, OCH_2, *J* 6.6 Hz), 3.16 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13.2 Hz), 3.12 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13.2 Hz), 2.09-1.95 (m, 4H, CH_2), 1.92-1.83 (m, 4H, CH_2), 1.57-1.47 (m, 4H, CH_2), 1.45-1.34 (m, 8H, CH_2), 1.37 (s, 18H, CH_3), 1.29-1.21 (m, 4H, CH_2), 0.95 (t, 12H, CH_3, *J* 7.2 Hz), 0.63 (s, 9H, CH_3); ^{13}C-NMR 100 MHz ($CDCl_3$) δ (ppm) 160.8, 154.7, 152.8, 145.4, 144.5, 142.6, 136.3, 135.2, 134.2, 131.9, 126.7, 125.2, 124.5, 123.1, 76.1, 75.5, 75.0, 34.2, 33.2, 31.7, 31.3, 31.2, 30.7, 30.3, 30.1, 29.8, 28.7, 28.5, 28.2, 22.9, 22.7, 22.6, 14.3, 14.0, 13.9. MS (FD), m/z 918.3 (M^+, calc. for $C_{60}H_{87}NO_6$: 918.4).

11,17,23-Tri-*t*-butyl-5-nitro-25,26,27,28-tetrakis(ethoxycarbonylmethoxy)calix[4]arene (2b)

A vigorously stirred solution of compound **1b** (5.96 g, 6.0 mmol) in CH_2Cl_2 (300 mL) was cooled in an ice bath to 10°C and fuming nitric acid (1.4 mL, 19.6 mmol) was added. The ice bath was then removed and the reaction mixture allowed to warm to room temperature. The reaction was followed by TLC (acetone/$CHCl_3$ 2:5) and stopped by the addition of water when compound **1b** completely disappeared (~30 min). (Usually the reaction was complete when the mixture reached room temperature). The organic layer was washed several times with water, dried ($NaSO_4$) and evaporated under reduced pressure. The residue was purified column chromatography (ethyl acetate/n-hexane 1:3). After removal of the solvents the addition of MeOH yields the pure compound **2b** as white crystals (2.79 g, 47 %).

mp 145-146°C; ^1H NMR 200 MHz ($CDCl_3$) δ (ppm) 7.32 (s, 2H, ArH), 7.08 (bs, 4H, ArH), 6.24 (s, 2H, ArH), 5.06 (d, 2H, $ArCH_2Ar$, *ax*, *J* 13.4 Hz), 5.03 (d, 2H, OCH_2CO, *J* 19.2 Hz), 4.80 (d, 2H, OCH_2CO, *J* 19.2 Hz), 4.70 (d, 2H, $ArCH_2Ar$, *ax*, *J* 13.2 Hz), 4.67 (s, 2H, OCH_2CO), 4.51 (s, 2H, OCH_2CO), 4.28-4.10 (m, 8H, $COCH_2$), 3.23 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13.2 Hz), 3.21 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13.4 Hz), 1.31 (s, 18H, $(CH_3)_3$), 1.4-1.15 (m, 12H, CH_3), 0.65 (s, 9H, $(CH_3)_3$). MS (FD) m/z 982.4 (M^+, calc. for $C_{56}H_{71}NO_{14}$: 982.18).

11,17,23-Tri-*t*-butyl-5-nitro-25,26,27,28-tetrakis(hydroxycarbonylmethoxy)calix[4]arene (2c)

A mixture of compound **2b** (0.5g, 0.51 mmol) and NaOH (0. 5g, 12.5 mmol) was refluxed for 12h in ethanol (7 mL) and water (5 mL) and then concentrated to dryness. The residue was dissolved in ethyl acetate washed with 50% H_2SO_4 (2 x 25 mL) and water (4 x 25 mL). The organic layer was dried over $MgSO_4$ and concentrated to yield 0.44g (98 %) of **2c** as a yellow solid.

mp 232-234°C; ^1H NMR 200 MHz ($CDCl_3$) δ (ppm) 7.52 (s, 2H, ArH), 7.13 (s_b, 4H, ArH), 6.54 (s, 2H, ArH), 4.91-4.40 (m, 12H, OCH_2CO and $ArCH_2Ar$), 3.34 (d, 2H, $ArCH_2Ar$, *eq*, *J* 14 Hz), 3.27 (d, 2H, $ArCH_2Ar$, *eq*, *J* 14 Hz), 1.28 (s, 18H, $(CH_3)_3$), 1.31 (s, 9H, $(CH_3)_3$). MS (FD) m/z 870.3 (M^+, calc. for $C_{48}H_{55}NO_{14}$: 869.9).

11,17,23-Tri-*t*-butyl-5-nitro-25,26,27,28-tetrakis(chlorocarbonylmethoxy)calix[4]arene (2d)

A solution of compound **2c** (0.1g, 0.115 mmol) was heated under reflux in $SOCl_2$ (1 mL) for 3h and then evaporated to dryness under reduced pressure yielding quantitatively **2d** as a pale yellow solid. Due to the sensitivity of this compound it was just characterised by ^{1}H NMR 200 MHz (**$CDCl_3$**) δ (ppm) 7.30 (s, 2H, ArH), 7.13 (s_b, 4H, ArH), 6.26 (s, 2H, ArH), 5.38 (d, 2 H, OCH_2CO, *J* 18.8 Hz).

5-Amino-11,17,23-tri-*t*-butyl-25,26,27,28-tetrapentyloxycalix[4]arene (3a)

Compound **2a** (4 g, 4.35 mmol) was dissolved in toluene (300 mL), Raney-Nickel was added (~ 0.5-1 cm^3) and the resulting suspension then vigorously stirred under a hydrogen atmosphere at room temperature. When the hydrogen uptake was finished the suspension was rapidly filtered over sand, washed with warm toluene (100 mL) and the combined organic layers dried over Na_2SO_4. After removal of the solvent under reduced pressure the pure compound **3a** (3.59 g, 93 %) was obtained as a white solid and stored under argon.

mp 113°C; ^{1}H NMR 200 MHz (**$CDCl_3$**) δ (ppm) 7.09 (d, 2H, ArH, *J* 1.9 Hz), 7.0 (d, 2H, ArH, *J* 2 Hz), 6.27 (s, 2H, ArH), 5.68 (s, 2H, ArH), 4.44 (d, 2H, $ArCH_2Ar$, *ax*, *J* 12.9 Hz), 4.36 (d, 2H, $ArCH_2Ar$, *ax*, *J* 12.7 Hz), 4,01 (t, 4H, OCH_2, *J* 8.3 Hz), 3.73 (t, 2H, OCH_2, *J* 6.6 Hz), 3.61 (t, 2H, OCH_2, *J* 6.8 Hz), 3.11 (d, 2H, $ArCH_2Ar$, *eq*, *J* 12.9 Hz), 2.99 (d, 2H, $ArCH_2Ar$, *eq*, *J* 12.7 Hz), 2.68 (s_{br}, 2H, NH_2), 2.03 (p, 4H, CH_2, *J* 7.9 Hz), 1.85 (p, 4H, CH_2, *J* 7.1 Hz), 1.33 (s, 18H, CH_3), 0.95 (t, 12H, CH_3, *J* 7 Hz), 0.78 (s, 9H, CH_3); ^{13}C-NMR 50 MHz (**$CDCl_3$**) δ (ppm) 155.1, 153.1, 148.8, 144.3, 143.8, 139.8, 136.1, 135.5, 133.9, 132.3, 125.8, 125.3, 124.6, 114.8, 75.7, 75.5, 75.1, 34.1, 33.5, 31.8, 31.3, 31.2, 31.1, 30.4, 30.3, 29.9, 28.8, 23.1, 22.8, 14.5, 14.1. MS (FD) m/z 887.9 (M^+, calc. for $C_{60}H_{89}NO_4$: 888.3).

5-Amino-11,17,23-tri-*t*-butyl-25,26,27,28-tetrakis(ethoxycarbonylmethoxy)calix[4]arene (3b)

In analogy to the procedure described for compound **2a**, the reduction of compound **2b** (2 g, 2.04 mmol) yielded compound **3b** (1.83g, 94%) as a yellow oil. This compound was just characterised by ^{1}H NMR 200 MHz (**DMSO-d_6**) δ (ppm) 6.89 (bs, 2H, ArH), 6.80 (bs, 2H, ArH), 6.59 (bs, 4H, ArH), 5.90 (s, 2H, ArH), 4.87-4.48 (m, 12H, OCH_2 and $ArCH_2Ar$ ax), 4.25-4.04 (m, 8H, $COCH_2CO$), 3.20 (d, 2H, $ArCH_2Ar$, *eq*, *J* 14. Hz), 2.99 (d, 2H, $ArCH_2Ar$, *eq*, *J* 14 Hz), 1.35-1.2 (m, 12H, CH_3), 1.14 (s, 18H, $(CH_3)_3$), 0.97 (s, 9H, $(CH_3)_3$).

General procedure for the preparation of compounds 4a-d, 5, 6a,b, 7a-c:

In a typical experiment to a stirred solution of compounds **3a,b** (5% excess with respect to the functional groups) in dry dioxane (20 mL) a solution of the corresponding acid chloride in dry dioxane (10 mL) was added. No additional base has to be added in these experiments. Stirring was continued for 6-12 h and then water was added. The solid thus formed was separated by filtration, dissolved in CH_2Cl_2 (50 mL) washed with water (2 x 50 mL) and the organic layer then evaporated. Finally cold methanol was added to precipitate a product which was recrystallized from $CHCl_3$/MeOH, if necessary, to yield the desired compounds **4a-d**, **5**, **6a,b**, **7a-c**.

Double-calixarene 4a: White solid (87 %), mp 290-291°C. ^{1}H NMR 400 MHz **(CDCl$_3$)** δ (ppm) 7.65 (s, 4H, ArH), 7,09 (d, 2H, ArH, *J* 2.3 Hz), 7.07 (d, 2H, ArH, *J* 2.2 Hz), 6.97 (s, 2H, NH), 6.6 (s, 4H, ArH), 6.21 (s, 4H, ArH), 4.42 (d, 8H, ArCH$_2$Ar, *ax*, *J* 12.9 Hz), 4.07-3.97 (m, 8H, OCH$_2$), 3.71 (t, 4H, OCH$_2$, *J* 6.7 Hz), 3.67 (t, 4H, OCH$_2$, *J* 6.9 Hz), 3.12 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.7 Hz), 3.10 (d, 4H, ArCH$_2$Ar, *eq*, *J* 13 Hz), 2.11-1.95 (m, 8H, CH$_2$), 1.91-1.83 (m, 8H, CH$_2$), 1.55-1.17 (m, 32H, CH$_2$), 1.33 (s, 36H, CH$_3$), 0.97-0.91 (m, 24H, CH$_3$), 0.67 (s, 18H, CH$_3$); ^{13}C-NMR 100 MHz **(CDCl$_3$)** δ (ppm) 163.7, 154.9, 153.2, 152.8, 144.7, 143.6, 138.1, 136.1, 135.1, 134.3, 132.3, 131.3, 126.9, 126.0, 125.4, 124.5, 119.8, 75.7, 75.5, 75.0, 34.1, 33.4, 31.8, 31.3, 31.2, 30.9, 30.3, 30.1, 29.8, 28.7, 28.6, 28.3, 22.9, 22.7, 14.3, 14.1, 14.0. MS (FD), m/z 1907.5 (M$^+$, calc. for C$_{128}$H$_{180}$N$_2$O$_{10}$: 1906.8).

Double-calixarene 4b: White solid (85 %), mp 301-302°C. ^{1}H NMR 400 MHz **(CDCl$_3$)** δ (ppm) 8.6 (s, 2H, NH), 8.25 (d, 2H, ArH, *J* 7.8 Hz), 7.99 (t, 1H, ArH, *J* 7.8 Hz), 7.06 (s, 4H, ArH), 6.99 (s, 4H, ArH), 6.91 (s, 4H, ArH), 6.32 (s, 4H, ArH), 4.49 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.7 Hz), 4.42 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.7 Hz), 4.04 - 3.93 (m, 8H, OCH$_2$), 3.81 (t, 4H, OCH$_2$, *J* 7 Hz), 3.76 (t, 4H, OCH$_2$, *J* 6.9 Hz), 3.19 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.8 Hz), 3.1 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 2.11-1.99 (m, 8H, CH$_2$), 1.98-1.89 (m, 8H, CH$_2$), 1.57-1.21 (m, 32H, CH$_2$), 1.24 (s, 36H, CH$_3$), 0.99-0.95 (m, 24H, CH$_3$), 0.59 (s, 18H, CH$_3$). ^{13}C-NMR 400 MHz **(CDCl$_3$)** δ (ppm) 160.2, 154.6, 153.3, 152.7, 149.7, 144.6, 143.9, 139.0, 135.4, 134.7, 134.5, 132.7, 131.3, 125.8, 125.3, 124.7, 124.6, 118.9, 75.6, 75.4, 75.2, 33.9, 33.3, 31.7, 31.4, 31.2, 30.8, 30.3, 30.0, 29.9, 28.6, 28.5, 28.3, 22.9, 22.8, 14.3, 14.1. E.A. calc. for C$_{127}$H$_{180}$O$_{10}$N$_3$: C,79.94; H,8.39; N, 2.2. found C, 79.84; H, 9.04; N, 2.04. MS (FD) m/z 1908.5 (M$^+$, calc. for C$_{127}$H$_{179}$N$_3$O$_{10}$: 1907.8).

Double-calixarene 4c: White solid (83 %), mp 264-265°C; ^{1}H NMR 400 MHz **(CDCl$_3$)** δ (ppm) 7.99 (s, 1H, ArH), 7.68 (d, 2H, ArH, *J* 7.7 Hz), 7.46 (t, 1H, ArH, *J* 7.7 Hz), 7.11 (s, 2H, NH), 7.07 (d, 4H, ArH, *J* 2.3 Hz), 7.05 (d, 4H, ArH, *J* 2.2 Hz), 6.67 (s, 4H, ArH), 6.23 (s, 4H, ArH), 4.43 (d, 8H, ArCH$_2$Ar, *ax*, *J* 12.8 Hz), 4,05-3.95 (m$_{br}$, 8H, OCH$_2$), 3.73 (t, 4H, OCH$_2$, *J* 6.7 Hz), 3.68 (t, 4H, OCH$_2$, *J* 7 Hz), 3.13 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.8 Hz), 3.11 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 2.1-1.96 (m, 8H, CH$_2$), 1.9-1.84 (m, 8H, CH$_2$), 1.56-1.21 (m, 32H, CH$_2$), 1.32 (s, 36H, CH$_3$), 0.97-0.91 (m, 24H, CH$_3$), 0.69 (s, 18H, CH$_3$). E.A. calc. for C$_{128}$H$_{180}$O$_{10}$N$_2$: C, 80.63; H, 9.51; N, 1.47. found: C, 79.33; H, 9.19; N, 1.26. MS (FD), m/z 1908.9 (M$^+$, calc. for C$_{128}$H$_{180}$N$_2$O$_{10}$: 1906.8).

Double-calixarene 4d: White solid (69 %), mp 137-139°C. ^{1}H NMR 400 MHz **(CDCl$_3$)** δ (ppm) 7.22 (s, 2H, NH), 7.06 (d, 4H, ArH, *J* 2.1 Hz), 7.03 (s$_b$, 4H, ArH), 6.55 (s, 4H, ArH), 6.25 (s, 4H, ArH), 4.42 (d, 8H, ArCH$_2$Ar, ax, *J* 12.8 Hz), 4.03-3.98 (m, 8H, OCH$_2$), 3.89 (s, 4H, OCH$_2$), 3.73 (t, 4H, OCH$_2$, *J* 6.9 Hz), 3,69 (t, 4H, OCH$_2$, *J* 7.1 Hz), 3.11 (d, 8H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 2.07-1.98 (m, 8H, CH$_2$), 1.93-1.85 (m, 8H, CH$_2$), 1.56-1.47 (m, 8H, CH$_2$), 1.46-1.38 (m, 16H, CH$_2$), 1.29 (s, 36H, CH$_3$), 1.32-1.227(m, 8H, CH$_2$), 0.95 (t, 24H, CH$_3$, *J* 7.2 Hz), 0.74 (s, 18H, CH$_3$); ^{13}C-NMR 100 MHz **(CDCl$_3$)** δ (ppm) 164.7, 154.8, 153.2, 152.7, 144.7, 143.6, 135.8, 134.9, 134.4, 132.4, 130.5, 125.9, 125.3, 124.5, 119.3, 75.7, 75.4, 75.0, 71.6, 34.0, 33.4, 31.7, 31.3, 31.2, 30.9, 30.3, 30.1, 29.8, 28.7, 28.6, 28.3, 22.9, 22.7, 14.3, 14.1, 14.0. MS (FD) m/z 1875.7 (M$^+$, calc. for C$_{124}$H$_{180}$N$_2$O$_{11}$: 1874.8).

Triple-calixarene 5: White solid (74 %), mp 206-207°C. ^{1}H NMR 400 MHz (CDCl$_3$) δ (ppm) 8.1 (s, 3H, ArH or NH), 7.47 (s$_{br}$, 3H, ArH or NH), 7.02 (d$_{br}$, 12H, ArH, *J* 7.4 Hz), 6.79 (s, 6H, ArH), 6.29 (s, 6H, ArH), 4.44 (d, 12H, ArCH$_2$Ar, *ax*, *J* 12.8 Hz), 4.4-3.95 (m$_{br}$, 12H, OCH$_2$), 3.69 (t, 6H, OCH$_2$, *J* 6.9 Hz), 3.49 (t, 6H, OCH$_2$, *J* 6.9 Hz), 3.13 (d$_{br}$, 12H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 2.04-1.98 (m, 12H, CH$_2$), 1.95-1.88 (m, 12H, CH$_2$), 1.55-1.16 (m, 48H, CH$_2$), 1.29 (s, 54H, CH$_3$), 0.979-0.937 (m, 36H, CH$_3$), 0.762 (s, 27H, CH$_3$); ^{13}C-NMR 100 MHz (CDCl$_3$) δ (ppm) 163.2, 154.7, 153.3, 153.1, 144.6, 143.9, 136.6, 135.6, 134.7, 134.4, 132.7, 131.5, 125.9, 125.1, 124.6, 119.7, 75.6, 75.3, 75.1, 34.0, 33.5, 31.8, 31.4, 31.0, 30.3, 30.0, 29.8, 28.7, 28.6, 28.3, 22.9, 22.8, 14.3, 14.1, 14.0. MS (FD) m/z 2822.4 (M$^+$, calc. for $C_{189}H_{267}N_3O_{15}$: 2821.1).

Triple-calixarene 6a: White solid (78 %), mp 212-214°C. ^{1}H NMR 400 MHz (CDCl$_3$) δ (ppm) 9.43 (s, 2H, NH or OH), 8.34 (s, 2H, NH or OH), 7.05-6.98 (broad signals, 12H, ArH), 6.68 (s, 4H, ArH), 6.63 (s, 4H, ArH), 6.59 (s, 4H, ArH), 4.52 (s, 4H, OCH$_2$), 4.41 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.5 Hz), 4.39 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.3 Hz), 4.19 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.9 Hz), 3.92-3.77 (m, 16H, OCH$_2$), 3.40 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 3.07 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.7 Hz), 2.99 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.5 Hz), 2.15-2.04 (m, 4H, CH$_2$), 2.03-1.92 (m, 12H, CH$_2$), 1.49-1.32 (m, 32H, CH$_2$), 1.22 (s, 18H, CH$_3$), 1.12 (s, 18H, CH$_3$), 0.98 (s, 18H, CH$_3$), 0.94 (t, 24H, CH$_3$, *J* 6.9 Hz), 0.85 (s, 36H, CH$_3$). MS (FD) m/z 2502.1 (M$^+$, calc. for $C_{168}H_{234}N_2O_{14}$: 2505.6).

Triple-calixarene 6b: White solid (81 %), mp 318-320°C. ^{1}H NMR 400 MHz (CDCl$_3$) δ (ppm) 9.57 (s, 2H, NH or OH), 8.41 (s, 2H, NH or OH), 7.03 (s, 8H, HAr), 6.99 (s, 4H, HAr), 6.68 (s, 4H, HAr), 6.65 (s, 4H, HAr), 6.57 (s, 4H, HAr), 4.9-4.6 (m, 28H, ArCH$_2$Ar ax and OCH$_2$), 4.51(s, 4H, OCH$_2$), 4.25-4.12 (m, 16H, COCH$_2$), 3.41 (d, 4H, ArCH$_2$Ar, *eq*, *J* 13.5 Hz), 3.14 (d, 4H, ArCH$_2$Ar, *eq*, *J* 13.3 Hz), 3.04 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.99 Hz), 1.33-1.22 (m, 24H, CH$_3$), 1.21 (s, 18H, CH$_3$), 1.12 (s, 18H, CH$_3$), 0.96 (s, 18H, CH$_3$), 0.85 (s, 36H, CH$_3$). MS (MALDI TOF) m/z 2633.2 (M$^+$, calc. for $C_{160}H_{202}N_2O_{30}$: 2633.36).

Penta-calixarene 7a: White solid (67 %), mp 201-202°C. ^{1}H NMR 400 MHz (CDCl$_3$) δ (ppm) 8.06 (s$_{br}$, 4H, NH), 7.02 (s$_{br}$, 8H, ArH), 6.75 (s$_{br}$, 8H, ArH), 6.72 (s$_{br}$, 8H, ArH), 6.69 (s$_{br}$, 8H, ArH), 6.59 (s$_{br}$, 8H, ArH), 4.67 (d, 4H, ArCH$_2$Ar, *ax*, *J* 12.5 Hz), 4.6 (s, 8H, OCH$_2$), 4.39 (d, 8H, ArCH$_2$Ar, *ax*, *J* 12.6 Hz), 4.29 (d, 8H, ArCH$_2$Ar, *ax*, *J* 12.7 Hz), 3.89-3.69 (m, 32H, OCH$_2$), 3.19 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.6 Hz), 3.07 (d, 8H, ArCH$_2$Ar, *eq*, *J* 12.9 Hz), 2.96 (d, 8H, ArCH$_2$Ar, *eq*, *J* 12.8 Hz), 2.07-1.82 (m, 32H, CH$_2$), 1.51-1.21 (m, 64H, CH$_2$), 1.07 (s, 36H, CH$_3$), 1.05 (s, 72H, CH$_3$), 0.96-0.89 (m, 48H, CH$_3$), 0.92 (s, 36H, CH$_3$); ^{13}C-NMR 100 MHz (CDCl$_3$) δ (ppm) 167.4, 153.9, 153.8, 153.1, 144.9, 144.2, 144.1, 135.2, 133.9, 133.4, 132.8, 125.6, 125.2, 125.0, 124.9, 119.9, 75.3, 75.1, 33.8, 33.6, 31.6, 31.4, 31.2, 30.0, 29.9, 28.5, 28.4, 28.3, 22.8, 14.2, 14.1. MS (FD) m/z 4359.4 (M$^+$, calc. for $C_{292}H_{412}N_4O_{24}$: 4362.3).

Penta-calixarene 7b: White solid (60 %), mp 191-193 °C. ^{1}H NMR 400 MHz (CDCl$_3$) δ (ppm) 8.00 (s, 4H, NH), 6.99 (s, 8H, HAr), 6.74 (s, 24H, HAr), 6.52 (s, 8H, HAr), 4.87-4.42 (m, 60H, OCH$_2$ and ArCH$_2$Ar *ax*), 4.22-4.05 (m, 32H, COCH$_2$), 3.22 (d, 4H, ArCH$_2$Ar, *eq*, *J* 12.3 Hz), 3.14 (d, 8H, ArCH$_2$Ar, *eq*, *J* 13.2 Hz), 3.05 (d, 8H, ArCH$_2$Ar, *eq*, *J* 13.2 Hz), 1.31-1.17 (m, 48H, CH$_3$), 1.05 (s, 144H, CH$_3$), 0.82 (s, 36H, CH$_3$). MS (MALDI TOF) m/z 4618.06 (M$^+$, calc. for $C_{276}\,H_{348}N_4O_{56}$: 4617.79).

Penta-calixarene 7c: White solid (75 %), mp 179-180°C. ^{1}H NMR 400 MHz (**$CDCl_3$**) δ (ppm) 9.03 (s, 4H, NH), 7.21-7.12 (m, 12H, HAr), 6.97 (s, 10H, HAr), 6.79 (s, 6H, HAr), 6.56 (s, 6H, HAr), 6.14-6.09 (m, 6H, HAr), 5.07-3.98 (m, 92H, $ArCH_2Ar$ *ax* and OCH_2 and $COCH_2$), 3.45 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13Hz), 3.38 (d, 2H, $ArCH_2Ar$, *eq*, *J* 13.5 Hz), 3.2-2.93 (m, 16H, $ArCH_2Ar$, *eq*), 1.39 (s, 27H, CH_3), 1.35-1.16 (m, 48H, CH_3), 1.27 (s, 81H, CH_3), 1.05 (s, 18H, CH_3), 0.88 (s, 27H, CH_3), 0.6 (s, 9H, CH_3), 0.43 (s, 9H, CH_3), 0.37 (s, 9H, CH_3). MS (MALDI TOF) m/z 4607 (M^+, calc. for $C_{272}H_{339}N_5O_{58}$: 4606.68).

3,5,7,10,12,14,17,19,21,24,26,28-Dodecamethyl[1.1.1.1]metacyclophane -4,11,18,25-tetrol (8)

A stirred solution of 3-bromomethyl-2,4,6-trimethylphenol (6.87g, 30 mmol) in $EtNO_2$ (100ml) containing a few drops of anhydrous $SnCl_4$ was heated in an oil bath at 60 °C for 6 h under vigorous N_2 stream. The mixture was allowed to stir overnight at room temperature. The solid was collected by filtration and washed with small portions of cold $EtNO_2$. Crude product was recrystallized from aqueous DMF. Yield 1.94g (44%). Spectroscopic data were in agreement with those of the literature.[17]

4,11,18,25-Tetrakis(ethoxycarbonylmethoxy)-3,5,7,10,12,14,17,19,21,24,26,28-dodecamethyl[1.1.1.1]-metacyclophane (9a)

A mixture of compound **8** (0.8 g, 1.35 mmol), potassium carbonate (1.12g, 8.1 mmol) and ethyl bromoacetate (1.2 mL, 10.8 mmol) was refluxed in dry acetone for 5 days. The cooled reaction mixture was filtered and the remaining inorganic salts were washed with CH_2Cl_2. The combined organic layers were evaporated to dryness and the residue recrystallized from CH_2Cl_2/MeOH to yield 0.93 g (74 %) of compound **9a**.

mp 230-231°C. ^{1}H NMR 200 MHz (**$CDCl_3$**) δ (ppm) 4.3 (q, 8H, OCH_2CH_3, *J* 7.2 Hz) 4.26 (s, 8H, OCH_2CO), 3.87 (s, 8H, $ArCH_2Ar$), 2.31 (s, 24 H, $ArCH_3$), 1.33 (t, 12H, CH_3, *J* 7.1 Hz), 1.03 (s, 12H, $ArCH_3$). MS (FD) m/z 937.7 (M^+, calc. for $C_{56}H_{72}O_{12}$: 937.18).

4,11,18,25-Tetrakis(hydroxycarbonylmethoxy)-3,5,7,10,12,14,17,19,21,24,26,28-dodecamethyl[1.1.1.1]-metacyclophane (9b)

A mixture of compound **9a** (0.8g, 0.86 mmol) and NaOH (0.85g, 21.3 mmol) was refluxed for 12h in ethanol (13 mL) and water (8.5 mL) and then concentrated to dryness. The residue was dissolved in ethyl acetate washed with 50% H_2SO_4 (2 x 25 mL) and water (4 x 25 mL). The organic layer was dried over $MgSO_4$ and concentrated to yield 0.67g (94 %) of **9b** as a white solid. Spectroscopic data were in agreement with those of the literature.[17]

4,11,18,25-Tetrakis(chlorocarbonylmethoxy)-3,5,7,10,12,14,17,19,21,24,26,28-dodecamethyl[1.1.1.1]-metacyclophane (9c)

A mixture of compound **9b** (0.1g, 0.121 mmol) and $SOCl_2$ (1 mL) in dry toluene (3 mL) was heated under reflux with stirring for 3 hours. The reaction mixture was concentrated to dryness under reduced pressure yielding a white solid which has been used for further reactions without characterisation.

Penta-calixarene 10: To a stirred solution of compound **9c** (0.58g, 0.6 mmol) and triethylamine (0.075 mL, 0.53 mmol) in dry THF (20 mL) was added a solution of compound **9d** (0.117g, 0.121 mmol) in dry THF (10 mL). Stirring was continued for 48h and the reaction mixture then filtered. The filtrate was evaporated under reduced pressure to dryness. The residue was dissolved in CH_2Cl_2 (50 mL) washed with water (2 x 50 mL) and the organic layer then evaporated and finally cold methanol was added to precipitate a crude product which was recrystallized from $CHCl_3$/MeOH to yield 0.36g (64 %) of compound **10**.

mp 196-198°C. ^{1}H NMR 400 MHz (**$CDCl_3$**) δ (ppm) 7.99 (s, 4H, NH), 7.03 (s, 16H, ArH), 6.81 (s, 8H, ArH), 6.33 (s, 8H, ArH), 4.94 (s, 16H, OCH_2CO), 4.92 (d, 8H, $ArCH_2Ar$, ax, *J* 13.9 Hz), 4.84 (d, 8H, $ArCH_2Ar$, ax, *J* 13.3 Hz), 4.61 (s, 8H, OCH_2CO), 4.57 (s, 8H, OCH_2CO), 4.26 (q, 8H, $COCH_2$, *J* 7.2 Hz), 4.22 (q, 8H, $COCH_2$, *J* 7.2 Hz), 4.17 (q, 8H, $COCH_2$, *J* 7.1 Hz), 4.04 (s_b, 8H, OCH_2CONH), 3.89 (s_b, 8H, $ArCH_2Ar$), 3.22 (d, 8H, $ArCH_2Ar$, *eq*, *J* 13.3 Hz), 3.19 (d, 8H, $ArCH_2Ar$, *eq*, *J* 13 Hz), 2.24 (s, 24H, $ArCH_3$), 1.33-1.24 (m, 48H, CH_3), 1.27 (s, 72H, $(CH_3)_3$), 1.06 (s, 12H, $ArCH_3$), 0.95 (s, 36H, $(CH_3)_3$). MS (MALDI TOF) m/z 4559.8 (M^+, calc. for $C_{272}H_{340}N_4O_{56}$: 4561.8).

X-Ray Crystal Structure Analysis

By recrystallization of **2b** from chloroform/methanol, single crystals of the empirical formula $C_{56}H_{71}NO_{14}$ x 0.25 H_2O were obtained: M_r = 986.14, triclinic, space group *P*-1 (no. 2), a = 14.142(5), b = 14.311(4), c = 15.675(5) Å, α = 75.80(2)°, β = 88.05(3)°, γ = 70.11(3)°, V = 2888(2) Å^3, Z = 2, D_C = 1.134 g cm^{-3}, *F(000)* = 1056, T = 293±1 K. The data were collected from a colourless crystal (0.20 x 0.20 x 0.30 mm) in a capillary tube and recorded with an Enraf-Nonius CAD4 diffractometer using graphite monochromatized MoK_α radiation [$\lambda(MoK_\alpha)$ = 0.71073 Å] and a ω/2θ scan mode to θ = 25° (0 → h → 16, -15 → k → 16, -18 → l → 18). Of 10582 collected reflections 10136 were unique (R_{int} = 0.04), 10129 reflections [seven excluded as bad reflections, 2809 reflections with $I > 2\sigma(I)$] were used for refinement. *Lp* correction, $\mu(MoK_\alpha)$ = 0.081 mm^{-1}, no absorption correction was applied. The structure was solved by direct methods (SHELXS-97)[22] and refined on F^2 (SHELXL-97)[23] The hydrogen atoms were calculated to their idealised positions with isotropic temperature factors (1.2 or 1.5 times the C temp. factor) and were refined as riding atoms. The final *R*-values were R = 0.1004, wR^2 = 0.2524 [$I > 2\sigma(I)$], R = 0.2724, wR^2 = 0.3051 [all data] for 643 parameters: $w = 1 / [\sigma^2(F_o^2) + (0.1358 * P)^2]$, where $P = [\max(F_o^2, 0) + 2F_c^2] / 3$ and GoF = 0.866. A final difference map displayed no electron density higher than 0.63 e.Å^{-3}.

The atomic co-ordinates for the structure, as well as bond lengths, bond angles and thermal parameters are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this publication.

Acknowledgement

These studies were supported by the Deutsche Forschungsgemeinschaft, the Scientific & Technological Co-operation between Germany and Poland and the Finnish Academy (project no. 37435).

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20. An exact summation of the spectra in Figs. 2a and 2b cannot be expected, since in addition to **10** and its tetra sodium complex all kinds of partial complexes should exist in a solution which is not „saturated“ with Na^+. This is evidenced for instance by amide signals in the range of 8.92-8.72 ppm in addition to the signal at 8.84 ppm found for **10**.

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