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TETRAHEDRON

Synthesis and Conformational Analysis of *p-tert*-Butyldihomooxacalix[4]arene Derivatives Containing the Carbonyl Group

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***Abstract*:** Three novel tetraketones (methyl, adamantyl and *tert*-butyl) and the first tetraamide (diethylamide) derived from *p-tert*-butyldihomooxacalix[4]arene were obtained and their conformations established by NMR studies. Tetramethylketone was isolated in two different conformations, partial cones A and B, respectively, and the other derivatives were all obtained in the cone conformation. The conformational behaviour of the tetramethylketone conformers was studied by means of temperature dependent ^{1}H-NMR. © 1999 Elsevier Science Ltd. All rights reserved.

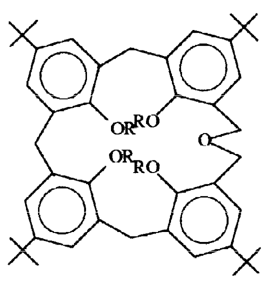
INTRODUCTION

Due to the variety of properties that calixarenes can assume by appropriate functionalization in the upper or in the lower rim, these compounds are currently a subject of great interest.[1-3] Their inclusion properties towards metal cations, in particular, have been widely explored in the last decade, especially the calix[4]arene derivatives,[2-8] but also within some calix[5]-,[4] calix[6]-[2, 4-7, 9] and calix[8]arenes.[2, 4-6]

The substituent group, the conformation adopted and the size of the cavity of the derivative are very important factors in its efficiency as host or carrier for a certain guest.[4,10]

Dihomooxacalix[4]arenes are cyclic tetramers where a -CH_2OCH_2- group replaces one of the methylene bridges.[1a] They have a cavity size that stands between the respective calix[4]- and calix[5]arenes and a conformational mobility somewhat higher than that of conventional tetramers.[1b] These characteristics make these molecules suitable for inclusion studies. With appropriate lower rim substitution, dihomooxacalix[4]arenes with binding properties can be obtained.[11]

This work reports the synthesis and conformational analysis of four novel carbonyl-containing derivatives obtained from *p-tert*-butyldihomooxacalix[4]arene (**1**).



1 R = H
2 R = CH_2COCH_3
3 R = CH_2COAd
4 R = CH_2COt-Bu
5 R = $CH_2CON(CH_2CH_3)_2$

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RESULTS AND DISCUSSION

Synthesis and conformation

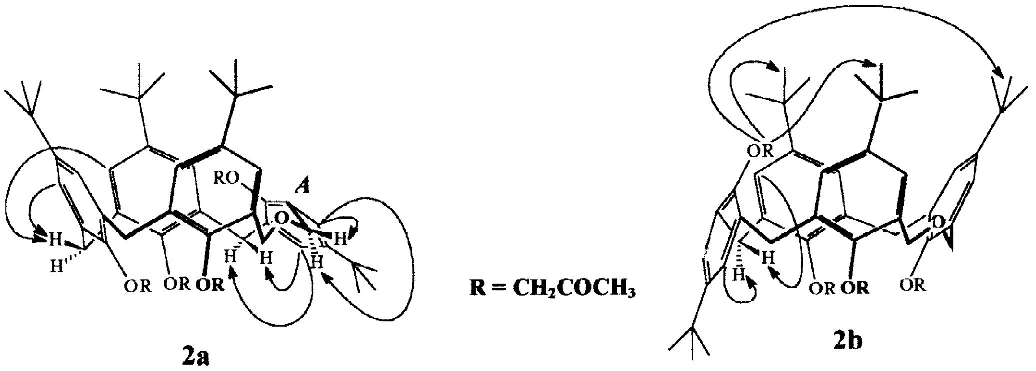
The parent *p-tert*-butyldihomooxacalix[4]arene (**1**) was synthesised in 25 % yield by the optimised procedure.[12] Compounds **2**, **3**, **4** and **5** were prepared according to the literature methods used to synthesise the analogous *p-tert*-butylcalix[4]arene ketones[5, 8a] and amide[13] with some adaptations.

Conformational analysis was performed by NMR. Due to the presence of the dimethyleneoxa bridge in the macrocycle ring, dihomooxacalix[4]arenes can exist in six basic conformations. The ^{1}H NMR spectrum is not sufficient to distinguish each one of them,[14b] but this is possible from the analysis of the ^{13}C NMR spectrum, in particular from the ArCH$_2$Ar resonances.[15] A combination of techniques, involving conventional proton and carbon spectra and ^{1}H-^{1}H and ^{1}H-^{13}C bidimensional spectra, was used to probe the structures and the conformations of the novel derivatives, as it was done before for the dihomooxacalix[4]arenes previously synthesised.[11,14]

Tetramethylketone

The reaction of **1** with 1-chloroacetone / sodium iodide, in the presence of potassium carbonate in refluxing acetone, furnished a white solid which proton NMR spectrum suggested to be a mixture of conformations of **2**. This was confirmed by elemental analysis, that was in agreement with the tetramethylketone **2** composition. It was possible to isolate these two different conformers by selective precipitation followed by preparative TLC.

In both cases, the proton spectrum displays five AB quartets for the protons of the ring bridges and eight doublets for the aromatic protons, as confirmed by gCOSY experiments. This means that in these conformers the molecule has no symmetry elements. In the carbon-13 spectra, there are significant differences between the ArCH$_2$Ar resonances of the two conformers; in one case, there are two peaks around 30 ppm and one peak around 39 ppm, and in the other case there is one peak around 30 ppm and two peaks around 39 ppm. These results indicate, respectively, the conformations partial cone A (**2a**) and partial cone B (**2b**), for the conformers isolated,[15] in chloroform at room temperature. This was confirmed in both cases by NOESY experiments.



2a R = CH$_2$COCH$_3$ **2b**

Figure 1. Relevant NOE assignments for derivatives **2a** and **2b**

However, for **2a** this experiment showed that ring *A* is not completely inverted, as shown in figure 1, so it has a partial cone A flattened conformation. An HSQC experiment was also performed with the partial cone B conformer.

For both conformers, a series of variable temperature ^{1}H NMR spectra was performed, in 1,1,2,2-tetrachloroethane. As can be seen in figure 2, the spectrum of isomer **2b** broadens much faster with temperature than that of isomer **2a**, which retains its main features at 120 °C. However, the presence of minor resonances in the spectra of **2a** at high temperature may indicate that a new conformer, different from **2a** and **2b**, has been formed. These studies also show that the rigidity of these conformers is still high enough to prevent the coalescence proton spectrum from being observed, even at 120 °C.

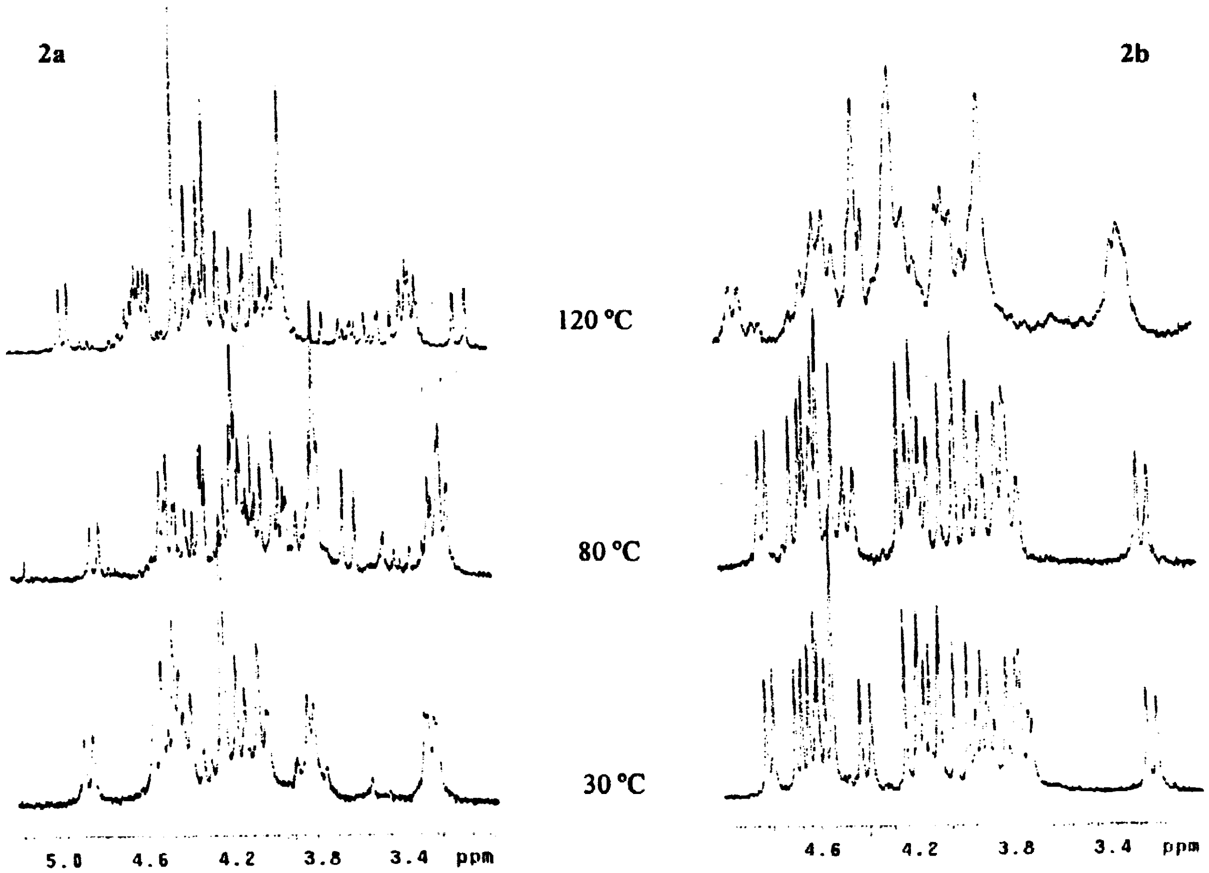


Figure 2. Variable temperature ^{1}H NMR spectra ($Cl_2CDCDCl_2$, 300 MHz) of derivatives **2a** and **2b**

Tetra adamantyl and *tert*-butyl ketones

Both ketones were obtained from **1**, using potassium carbonate as the base, in refluxing acetone.

In the case of compound **3**, the reaction with 1-adamantyl bromomethyl ketone furnished the complex ketone•KBr, as probed by elemental analysis. ^{1}H, ^{13}C, DEPT, COSY, NOESY and HMQC NMR spectra confirmed the tetraketone structure and showed that the complexed molecule is in the cone conformation in chloroform at room temperature. After refluxing the complex in water / ethanol (4:1) for three days,[16] the free ketone was obtained.

For compound **4**, using 1-bromopinacolone as reagent, an unworkable mixture was obtained. Using this reagent together with potassium iodide to promote *in situ* halogen exchange, a mixture containing mostly the di but also the tetra derivative was obtained, as shown by the proton NMR spectrum. Adopting the procedure used for compound **2**, using 1-chloropinacolone together with sodium iodide, the reaction furnished the tetraketone, without traces of the difunctionalised derivative.

For both tetra adamantyl and *tert*-butyl ketones, the ^{1}H-NMR spectrum displays three AB quartets of relative intensities 2:2:1, for the protons of the CH_2 bridges, and four doublets of equal intensities for the aromatic protons, as confirmed by the gCOSY spectra. This means that the molecules have a symmetry plane. The carbon-13 resonances of the $ArCH_2Ar$ bridges indicate that all the adjacent aryl rings are in a *syn* position,[15] which is consistent with the cone conformation. The most relevant NOE cross peaks, between the CH_2 groups and the aromatic protons in the calixarene ring of compound **4** are shown in figure 3. The same pattern of NOE correlations were obtained for derivative **3**.

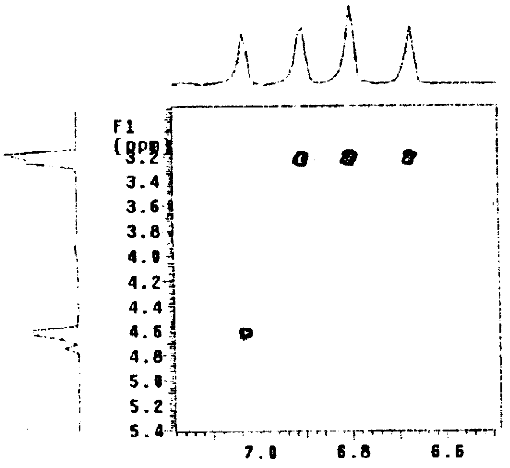


Figure 3. Partial NOESY spectrum of 4, showing the cross peaks that correlate aromatic and methylenic protons, at 24 °C ($CDCl_3$, 300 MHz)

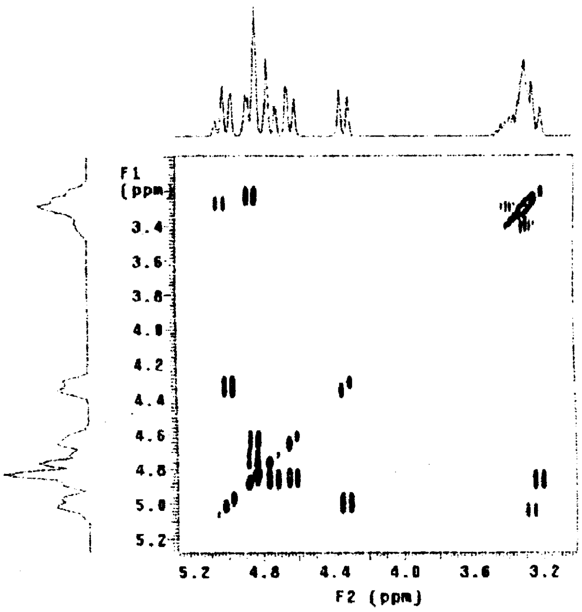


Figure 4. Partial COSY spectrum of derivative 5, showing the methylenic protons coupling at 24 °C ($CDCl_3$, 300 MHz)

Tetrakis diethylamide

Compound **5** was synthesised by reaction of **1** with 1-chloro-N,N-diethylacetamide in refluxing THF / DMF, using sodium hydride as the base.

The ^{1}H NMR spectrum of this compound displays the same methylene and aromatic patterns as obtained for ketones **3** and **4**, showing that the molecule has a symmetry plane. Proton couplings were established from the COSY spectrum (figure 4). The ^{13}C NMR spectrum shows two signals around 31-32 ppm for the CH_2 bridges. This indicates that the derivative is, in chloroform at room temperature, in the cone conformation.[15] This was confirmed by a series of 1D-NOE experiments.

CONCLUSIONS

Four novel *p-tert*-butyldihomooxacalix[4]arene tetraderivatives were synthesised and their conformations studied by NMR, in $CDCl_3$ solution at room temperature. Three of them: the adamantyl and *tert*-butyl ketones and the diethylamide, were obtained in the cone conformation, as for the *p-tert*-butylcalix[4]arene analogues. The methylketone **2** was isolated in two different conformations, partial cone A and partial cone B, while the respective *p-tert*-butylcalix[4]arene ketone had been obtained in the cone conformation. Temperature dependent proton NMR experiments in 1,1,2,2-tetrachloroethane showed that, although the isomer in partial cone B is less rigid than the isomer in partial cone A, no conformational interconversion was observed at high temperatures.

Meanwhile, extraction of alcali, alcaline-hearth and transition metal cation picrates from aqueous medium is being performed with derivatives **2b**, **3**, **4** and **5**. Preliminary results show that the three compounds isolated in the cone conformation are, in general, good extractants, while derivative **2b** exhibits small percentages of extraction.

EXPERIMENTAL

All chemicals used were reagent grade. Sodium sulphate was used as drying agent. Analytical and preparative TLC were carried out on Merck silica-gel 60 F_{254} plates. Melting points were measured in an Electrothermal 9200 apparatus. The ^1H and ^{13}C NMR spectra were recorded on a Varian Unity 300 spectrometer and on a Varian Inova 300 spectrometer, with TMS as internal reference at 24 °C. The 1D-NOE difference spectra were acquired with a saturation delay of 5s and 256 transients. The phase sensitive NOESY experiments were collected as a 256x2K complex points and a mixing time of 1s. The COSY and the phase sensitive HSQC experiments were run with gradients to achieve a much higher sensitivity over the classical experiments. The COSY was acquired with 4 transients, a delay of 1s and as 512x2K complex points. The indirect HSQC experiments were run with 4 transients, a delay of 1.5s and as 128x1K complex points. In both cases zero filling to 1K in f1 was done prior to Fourier transformation. Elemental analyses were carried out on a Fisons EA 1108 apparatus.

7,13,19,25-Tetra-*tert*-butyl-2,3-dihomo-3-oxacalix[4]arene-27,28,29,30-tetramethylketone (2). 1.26 mL (15 mmol) of chloroacetone was stirred with 2.33 g (15 mmol) of sodium iodide in 20 mL of dry acetone, under N_2. After 30min., a suspension of 2.20 g (15 mmol) of potassium carbonate and 1.36 g (2 mmol) of *p-tert*-butyldihomooxacalix[4]arene in 100 mL of dry acetone was added. The reaction mixture was refluxed and stirred under N_2 for 6h. After cooling, it was filtered through a bed of celite and the filtrate concentrated to a residue that was suspended in water at *ca.* 60 °C, for 2h. The product was extracted into dichloromethane, washed with 0.1 M sodium thiosulfate and water and dried. Evaporation of the solvent left a yellow solid, that was recrystallized from acetone, furnishing a white solid that was the mixture of two conformations of **2**. Anal. Calcd. for $C_{57}H_{74}O_9$: C 75.80, H 8.26. Found: C 75.60, H 8.46.

Conformer **2b** was isolated by selective precipitation from acetone and twice recrystallized from the same solvent, to furnish 520 mg (29 %) of the pure conformer as white crystals. From the remaining solution, the mixture of the two conformers was precipitated and filtered (330 mg) and **2a** was isolated by preparative TLC (ethyl acetate / n-heptane 1:2). **2a**: ^{1}H NMR ($CDCl_3$, 300 MHz) δ -0.01, 1.75, 2.08, 2.09 (s, 3H each, $COCH_3$); 1.16 (s, 18H, $C(CH_3)_3$); 1.32, 1.35 (s, 9H each, $C(CH_3)_3$); 2.08, 2.82 (J_{AB}=17.9 Hz), 4.27, 4.38 (J_{AB}=16.6 Hz), 4.36, 4.56 (J_{AB}=16.9 Hz), 4.48, 4.60 (J_{AB}=16.1 Hz) (d, 1H each, $ArOCH_2$); 3.34, 4.61 (J_{AB}=13.3 Hz), 3.38, 4.70 (J_{AB}=13.1 Hz), 3.89, 4.00 (J_{AB}=16.3 Hz) (d, 1H each, $ArCH_2Ar$); 4.11, 4.35 (J_{AB}=11.3 Hz), 4.16, 4.92 (J_{AB}=12.2 Hz) (d, 1H each, CH_2OCH_2); 7.05, 7.06, 7.19, 7.23, 7.25, 7.26, 7.28, 7.39 (d, 1H each, Ar). ^{13}C NMR ($CDCl_3$, 75.4 MHz) δ 24.22, 26.19, 26.29 (*p*, $COCH_3$); 29.07, 30.41, 38.99 (*s*, $ArCH_2Ar$); 31.13, 31.50 (*p*, $C(CH_3)_3$); 34.14, 34.23 (*q*, $C(CH_3)_3$); 65.38, 67.47 (*s*, CH_2OCH_2); 75.99, 77.70, 78.24, 78.56 (*s*, $ArOCH_2$); 126.09, 126.50, 126.51, 126.95, 127.02, 127.34, 127.92, 128.12 (*t*, Ar); 129.50, 130.83, 132.73, 132.98, 133.23, 133.39, 133.99, 134.76, 146.20, 146.46, 146.56, 147.18, 152.03, 153.15, 153.24, 153.41 (*q*, Ar); 203.05, 203.36, 204.94, 208.37 (*q*, C=O). **2b**: mp 190-191 °C. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 0.095, 1.77, 2.10, 2.13 (s, 3H each, $COCH_3$); 1.08, 1.16, 1.25, 1.35 (s, 9H each, $C(CH_3)_3$); 1.86, 2.28 (J_{AB}=18.5 Hz), 4.01, 4.74 (J_{AB}=16.8 Hz), 4.20, 4.74 (J_{AB}=16.8 Hz), 4.34, 4.66 (J_{AB}=16.8 Hz) (d, 1H each, $ArOCH_2$); 3.30, 4.54 (J_{AB}=12.7 Hz), 3.82, 3.94 (J_{AB}=15.0 Hz), 3.84, 4.02 (J_{AB}=15.0 Hz) (d, 1H each, $ArCH_2Ar$); 4.23, 4.68 (J_{AB}=9.6 Hz), 4.28, 4.94 (J_{AB}=9.5 Hz) (d, 1H each, CH_2OCH_2); 6.99, 7.02, 7.06, 7.09, 7.16, 7.30 (d, 1H each, Ar); 7.19 (d, 2H, Ar). ^{13}C NMR ($CDCl_3$, 75.4 MHz) δ 24.02, 26.28, 26.63 (*p*, $COCH_3$); 30.53, 39.25, 39.94 (*s*, $ArCH_2Ar$); 31.05, 31.12, 31.49, 31.56 (*p*, $C(CH_3)_3$); , 34.22 (*q*, $C(CH_3)_3$); 68.15, 68.65 (*s*, CH_2OCH_2); 76.84, 77.46, 77.88, 78.03 (*s*, $ArOCH_2$); 125.90, 127.08, 127.26, 127.27, 127.56, 128.14, 128.24, 129.65 (*t*, Ar); 130.44, 130.80, 133.03, 133.13, 133.50, 134.01, 134.91, 146.02, 146.67, 146.80, 147.33, 152.23, 153.52, 154.22, 154.59 (*q*, Ar); 202.37, 202.53, 203.15, 208.65 (*q*, C=O).

7,13,19,25-Tetra-*tert*-butyl-2,3-dihomo-3-oxacalix[4]arene-27,28,29,30-tetraadamantylketone (3).
A mixture of 1.02 g (1.5 mmol) of *p*-*tert*-butyldihomooxacalix[4]arene and 1.04 g (7.5 mmol) of potassium carbonate in 80 mL of dry acetone was refluxed and stirred under N_2. After 15min., a solution of 1.94 g of 1-adamantyl bromomethyl ketone (7.5 mmol) in 40 mL of dry acetone was added through a rubber septum with a syringe and the reaction mixture was refluxed for nearly 40h, stirring under N_2. After cooling, the mixture was filtered and the filtrate concentrated to a residue that was treated with cold ethanol, forming a white precipitate (complexed ketone) that was filtered. The solid was refluxed and stirred in water / ethanol 4:1 for 3 days under N_2, releasing 0.590 g (34 %) of the free ketone that was recrystallized from chloroform / ethanol as white crystals. mp 232-233 °C. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 0.96, 1.16 (s, 18H each, $C(CH_3)_3$); 1.75-2.04 (m, 60H, Ad); 3.27, 4.63 (J_{AB}=13.7 Hz), 3.27, 4.73 (J_{AB}=13.3 Hz) (d, 2H each, $ArCH_2Ar$); 4.64, 5.15 (J_{AB}=17.7 Hz), 4.85, 5.16 (J_{AB}=18.7 Hz) (d, 2H each, $ArOCH_2$); 4.69, 4.86 (J_{AB}=12.9 Hz) (d, 2H each, CH_2OCH_2); 6.72, 6.85, 6.94, 7.08 (d, 2H each, Ar). ^{13}C NMR ($CDCl_3$, 75.4 MHz) δ 27.96, 28.06 (*t*, Ad); 31.43 (*p*, $C(CH_3)_3$); 32.06,

32.69 (*s*, Ar*C*H$_2$Ar); 33.88, 33.98 (*q*, *C*(CH$_3$)$_3$); 36.64, 37.87, 38.02 (*s*, Ad); 45.12, 45.22 (*q*, Ad); 67.35 (*s*, CH$_2$OCH$_2$); 73.14, 74.56 (*s*, ArO*C*H$_2$); 123.75, 125.77, 125.85, 126.15 (*t*, Ar); 131.26, 131.45, 132.49, 134.00, 144.25, 145.22, 152.74, 153.06 (*q*, Ar); 209.72, 210.78 (*q*, C=O). Anal. Calcd. for $C_{93}H_{122}O_9$: C 80.71, H 8.88. Found: C 80.47, H 8.95.

7,13,19,25-Tetra-*tert*-butyl-2,3-dihomo-3-oxacalix[4]arene-27,28,29,30-tetra-*tert*-butylketone (4).

Prepared following the procedure described for compound **2**, using 2.1 mL (15 mmol) of 1-chloro-pinacolone and refluxing the reaction mixture for 48h. After cooling, the mixture was filtered through glass-fibre filter paper. Evaporation of the solvent furnished a dark-red residue that was suspended in water at *ca.* 60 °C for 2h. The product was extracted into dichloromethane, washed with 3% sulphuric acid, 0.1 M sodium thiosulfate and water and dried. The solution was concentrated to a residue that was treated with cold ethanol, giving a yellow solid that was filtered and washed several times with the solvent. Recrystallization from dichloroethane / acetone afforded 0.380 g (18 %) of tetraketone as white crystals. mp 225-226 °C. ^{1}H NMR (CDCl$_3$, 300 MHz) δ 0.94, 1.15 (s, 18H each, ArC(C*H*$_3$)$_3$); 1.14, 1.15 (s, 18H each, COC(CH$_3$)$_3$); 3.27, 4.62 (J_{AB}=14.1 Hz), 3.27, 4.71 (J_{AB}=13.3 Hz) (d, 2H each, ArC*H*$_2$Ar); 4.61, 5.20 (J_{AB}=17.7 Hz), 4.85, 5.16 (J_{AB}=18.3 Hz) (d, 2H each, ArOC*H*$_2$); 4.67, 4.83 (J_{AB}=13.2 Hz) (d, 2H each, CH$_2$OCH$_2$); 6.71, 6.85, 6.95, 7.07 (d, 2H each, Ar). ^{13}C NMR (CDCl$_3$, 75.4 MHz) δ 26.34, 26.41 (*p*, COC(*C*H$_3$)$_3$); 31.44 (*p*, ArC(*C*H$_3$)$_3$); 31.92, 32.60 (*s*, Ar*C*H$_2$Ar); 33.91, 34.00 (*q*, Ar*C*(CH$_3$)$_3$); 42.71, 42.78 (*q*, CO*C*(CH$_3$)$_3$); 67.29 (*s*, CH$_2$OCH$_2$); 73.24, 74.64 (*s*, ArO*C*H$_2$); 123.86, 125.84, 125.93, 126.18 (*t*, Ar); 131.05, 131.37, 132.55, 133.91, 144.37, 145.36, 152.75, 152.97 (*q*, Ar); 210.15, 211.37 (*q*, C=O). Anal. Calcd. for $C_{69}H_{95}O_9 \cdot H_2O$: C 76.28, H 9.00. Found: C 76.40, H 9.26.

7,13,19,25-Tetra-*tert*-butyl-2,3-dihomo-3-oxacalix[4]arene-27,28,29,30-tetrakisdiethylamide (5).

A suspension of 1.36 g (2 mmol) of *p-tert*-butyldihomooxacalix[4]arene and 0.80 g (20 mmol) of sodium hydride (60 % oil dispersion) in 50 mL of THF / DMF 10:1 was stirred in N$_2$ atmosphere for nearly 15min. A solution of 2.4 mL (16 mmol) of 1-chloro-N,N-diethylacetamide in 10 mL of THF was then added through a rubber septum, with a syringe, and the reaction mixture was refluxed and stirred under N$_2$ for 3h. After cooling, the solvent was evaporated, leading to a brown oily residue that was poured into acidified water, forming a beige precipitate. This precipitate was filtered, washed several times with water and dried overnight at 60 °C. The solid was taken up in the minimum amount of diethylether, forming a white precipitate that was filtered and dried under vacuum. Recrystallization from methanol released 0.624 g (30 %) of purum **5** as little white needles. mp 231-232 °C. ^{1}H NMR (CDCl$_3$, 300 MHz) δ 0.92, 1.14 (s, 18H each, C(CH$_3$)$_3$); 1.06, 1.10 (t, 12H each, NCH$_2$C*H*$_3$); 3.25-3.40 (m, 16H, NC*H*$_2$CH$_3$); 3.22, 4.86 (J_{AB}=13.7 Hz), 3.27, 5.03 (J_{AB}=13.2 Hz) (d, 2H each, ArC*H*$_2$Ar); 4.33, 4.99 (J_{AB}=14.0 Hz), 4.74, 4.86 (J_{AB}=15.0 Hz) (d, 2H each, ArOC*H*$_2$); 4.63, 4.85 (J_{AB}=13.3 Hz) (d, 2H each, CH$_2$OCH$_2$); 6.68, 6.86, 6.98, 7.02 (d, 2H each, Ar). ^{13}C NMR (CDCl$_3$, 75.4 MHz) δ 13.07, 13.16, 14.36 (*p*, NCH$_2$*C*H$_3$); 31.44 (*p*, C(*C*H$_3$)$_3$); 31.60, 32.06 (*s*, Ar*C*H$_2$Ar); 33.93, 33.98 (*q*, *C*(CH$_3$)$_3$);

39.95, 41.03 (*s*, NCH_2CH_3); 68.33 (*s*, CH_2OCH_2); 71.55, 72.23 (*s*, $ArOCH_2$); 124.01, 125.94, 126.44 (*t*, Ar); 131.18, 132.48, 132.75, 133.59, 144.54, 145.24, 153.24, 153.82 (*q*, Ar); 168.26, 168.87 (*q*, C=O). Anal. Calcd. for $C_{69}H_{102}O_9N_4$: C 73.24, H 9.08, N 4.96. Found: C 73.11, H 9.11, N 4.86.

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REFERENCES

1. Gutsche, C. D. *Calixarenes*, Royal Society of Chemistry, Cambridge, 1989. **a)** Pgs. 61-62. **b)** Pgs. 99-101.
2. Vicens, J.; Bohmer, V. (Eds.) *Calixarenes: a Versatile Class of Macrocyclic Compounds*, Kluwer Academic Publishers, Dordrecht, 1991.
3. Vicens, J.; Asfari, Z.; Harrowfield, J. (Eds.) *Calixarenes 50th anniversary: Commemorative Issue*, Kluwer Academic Publishers, Dordrecht, 1995.
4. Schwing-Weill, M. J.; Arnaud-Neu, F.; McKervey, M. A. *J. Phys. Org. Chem.* **1992**, *5*, 496.
5. Arnaud-Neu, F.; Collins, E. M.; Deasy, M.; Ferguson, G.; Harris, S. J.; Kaitner, B.; Lough, A. J.; McKervey, M. A.; Marques, E.; Ruhl, B. L.; Schwing-Weill, M.; Seward, E. M. *J. Am. Chem. Soc.* **1989**, *111*, 8681.
6. Chang, S. K.; Cho, I. *J. Chem. Soc., Perkin Trans. 1* **1986**, 211.
7. Ohto, K.; Murakami, E.; Shinihara, T.; Shiratsuchi, K.; Inoue, K.; Iwasaki, M. *Anal. Chim. Acta* **1997**, 341, 275.
8. a) Ferguson, G.; Kaitner, B.; McKervey, M. A.; Seward, E. M. *J. Chem. Soc., Chem. Commun.* **1987**, 584. b) Arnaud-Neu, F.; Cremin, D.; Cunningham, D.; Harris, S. J.; McArdle, P.; McKervey, M. A.; McManus, M.; Schwing-Weill, M. J.; Ziat, K. *J. Inc. Phenom. Molec. Recogn. Chem.* **1991**, *10*, 329. c) Zhong, Z. L.; Tang, C. P.; Wu, C. Y.; Chen, Y. Y. *J. Chem. Soc., Chem. Commun.* **1995**, 1737. d) Arnaud-Neu, F.; Asfari, Z.; Souley, B.; Vicens, J. *New J. Chem.* **1996**, *20*, 453. e) Ohto, K.; Yamaga, H.; Murakami, E.; Inoue, K. *Talanta* **1997**, *44*, 1123.
9. Han, S. Y.; Kang, M. H.; Jung, Y. E.; Chang, S. K. *J. Chem. Soc., Perkin Trans. 2* **1994**, 835.
10. Ikeda, A.; Shinkai, S. *Chem. Rev.* **1997**, *97*, 1713.
11. a) Marcos, P. M., PhD Thesis, Universidade de Lisboa, 1997. b) Félix, S.; Ascenso, J. R.; Lamartine, R.; Pereira, J. L. C. *Synth. Commun.* **1998**, *28*(10), 1793.
12. Bavoux, C.; Vocanson, F.; Perrin, M.; Lamartine, R. *J. Inc. Phenom. Mol. Recogn. Chem.* **1995**, *22*, 119.
13. Arduini, A.; Ghidini, E.; Pochini, A.; Ungaro, R.; Andreeti, G. D.; Calestani, G.; Ugozzoli, F. *J. Inc. Phenom.* **1988**, *6*, 119.
14. a) Marcos, P. M.; Ascenso, J. R.; Lamartine, R.; Pereira, J. L. C. *Supramol. Chem.* **1996**, *6*, 303. b) Marcos, P. M.; Ascenso, J. R.; Lamartine, R.; Pereira, J. L. C. *Tetrahedron* **1997**, *53*(34), 11791. c) Marcos, P. M.; Ascenso, J. R.; Lamartine, R.; Pereira, J. L. C. *J. Org. Chem.* **1998**, *63*(1), 69.
15. Jaime, C.; de Mendoza, J.; Prados, P.; Nieto, P.; Sanchez, C. *J. Org. Chem.* **1991**, *56*, 3372.
16. Dijkstra, P. J.; Brunink, J. A. J.; Bugge, K. E.; Reinhoudt, D. N.; Harkema, S.; Ungaro, R.; Ugozzoli, F.; Ghidini, E. *J. Am. Chem. Soc.* **1989**, *111*, 7567.