Synthesis and Properties of Calixarene Analogs Incorporating a Thiophene Unit in the Macrocyclic Ring

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Calixarene analogs containing a thiophene unit in the macrocyclic ring were prepared by a stepwise method. The macrocycles adopt a cone-like form as the preferred conformation in solution. The induced chemical shift change, nOe experiment, and ^{1}H relaxation time (T_1) measurement supported the fact that the macrocycle forms a complex with the *N*-methylpyridinium salt. In contrast, *O*-tetramethylated macrocycles and linear phenol-formaldehyde tetramer, could not efficiently include the *N*-methylpyridinium salt.

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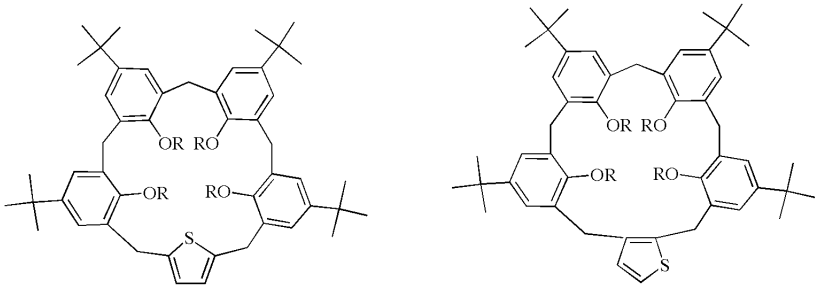
Introduction.

Calixarenes are macrocycles available in a variety of ring sizes and are of interest both as complexation hosts for ion and molecules and as a skeleton for producing more complex structures [1]. Although the chemistry of calixarenes has been extensively studied with respect to the modification of the frameworks at the lower (small) or upper (large) rims of the calixarene skeleton from the viewpoint of additional functionality, there has been relatively little research concerning the replacement of the phenol unit with other aromatic rings [2,3].

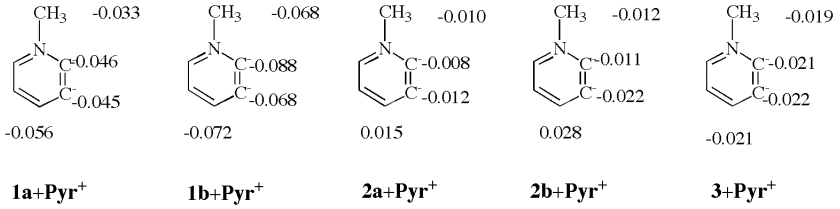
This situation inspired us to synthesize the calixarene analogs, which were constructed by changing from the phenol moiety to an other aromatic unit. Therefore, we synthesized the calixarene analogs containing a thiophene unit in the macrocyclic ring. The use of thiophene as a building block offers the possibility of interesting modifications on the thiophene ring due to its high reactivity [4]. Here we describe the syntheses of the calixarene analogs incorporating the thiophene unit and their complexation behavior with the *N*-methylpyridinium ion.



1a: R = H
2a: R = Me

1b: R = H
2b: R = Me

Figure 1



1a+**Pyr**$^+$ **1b**+**Pyr**$^+$ **2a**+**Pyr**$^+$ **2b**+**Pyr**$^+$ **3**+**Pyr**$^+$

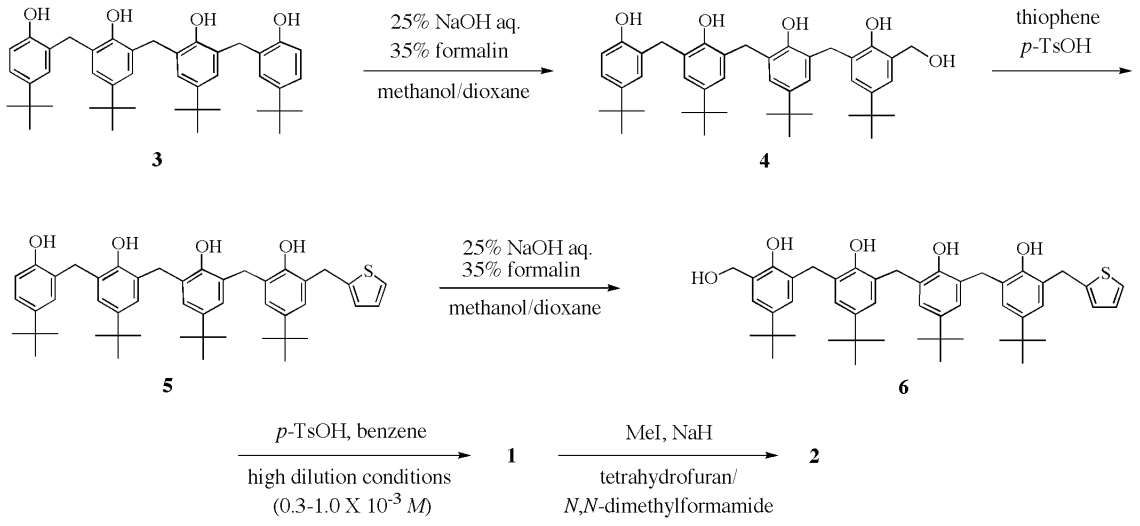
Figure 2. Chemical shift changes of the protons in *N*-methylpyridinium iodide (**Pyr**$^+$) induced by added calixarene analog (**1** or **2**) or phenol-formaldehyde tetramer **3** as a reference compound at 25° in deuteriochloroform:deuterioacetonitrile-d_3 10:1 (v/v) ([**1**] = [**2**] = [**3**] = [**Pyr**$^+$] = 1.0 X 10^{-2} *M*), denote the shift to higher magnetic field.

Results and Discussion.

Macrocycles **1** were prepared from the corresponding acyclic oligomers in a stepwise method as shown in Scheme 1. Hydroxymethylation of the phenol-formaldehyde tetramer **3** with 35% formalin in the presence of 25% aqueous sodium hydroxide solution led to the monohydroxymethyl tetramer **4** in 25% yield [5]. Condensation of **4** with an excess of thiophene in the presence of *p*-toluenesulfonic acid without solvent gave the linear oligomer **5** in 58% yield. Compound **5** was hydroxymethylated again, then followed by acid-catalyzed cyclization of the resulting alcohol **6** under high dilution conditions (0.3-1.0 x 10^{-3} *M*) to yield **1a** and **1b** in 50 and 40% yields, respectively. The *O*-tetramethylated macrocycles **2** were prepared from the reactions of **1** with an excess amount of methyl iodide in the presence of sodium hydride at 80° in 62% (**2a**) and 90% (**2b**) yields.

The spectroscopic properties such as nmr, ir, and FAB mass spectra of macrocycles **1** and **2** are in agreement with the assigned structures. Coupling constants for the protons of the thiophene rings in **1** and **2** indicated that **1a** and **2a** (J = 0.0 Hz) are the 2,5-disubstituted thiophene derivative and **1b** (J = 5.3 Hz) and **2b** (J = 5.0 Hz) are 2,3-disubstituted.

Scheme 1



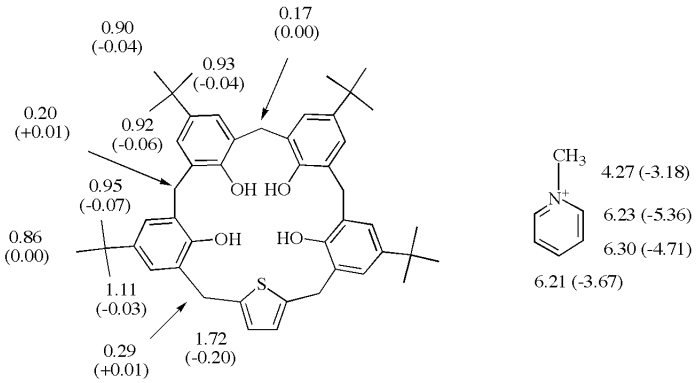
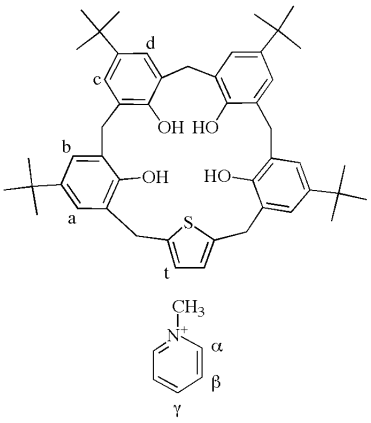


Figure 3. ^{1}H Nmr relaxation times T_1 [s] of calixarene analog **1a** in the absence of *N*-methylpyridinium iodide **Pyr**$^+$ at 25° in deuteriochloroform:-deuterioacetonitrile-d_3 =10:1 (v/v). The figures in the parentheses denote the changes in T_1 in the presence of **Pyr**$^+$.

Table 1

NOes in the Complex of **1a** with **Pyr**$^+$ at 25° in Deuteriochloroform:Deuterioacetonitrile-d_3 = 10:1 (v/v)



		Observed nOe, % *N*-methylpyridinium iodide (**Pyr**$^+$)			
Irradiated		*N*-CH_3	H-α	H-β	H-γ
phenol	H-a	5.6	8.7	11.0	9.5
	H-b	6.6	8.9	11.2	9.8
	H-d	6.7	8.5	10.0	10.9
thiophene	H-t	2.6	4.2	5.4	9.4

H-c proton was overlapped with the proton of cholorform.

In the ir spectra, the OH absorption of **1** was observed at 3357 cm^{-1} as a broad band in chloroform. In the ^{1}H nmr spectra of **1** in deuteriochloroform at 20°, the OH proton signals were observed in the range of δ 6.48-9.11 ppm. Comparing the ir and ^{1}H nmr spectra of the phenolic OH groups of **1** with those of calix[*n*]arene (ν_{OH} = 3138 (*n* = 4), 3280 (*n* = 5) cm^{-1}, δ_{OH} = 10.2 (*n* = 4), 8.0 (*n* = 5) ppm) [1a], the intramolecular hydrogen bonding in **1** is weaker than that of the calix[*n*]arene due to the introduction of the thiophene ring, which does not contribute to intramolecular hydrogen bonding.

The methylene protons of **1** and **2** in the ^{1}H nmr spectra appeared as singlets at room temperature, and are not split at -60° in deuteriochloroform, indicating that **1** is conformationally flexible. Therefore, the conformation of **1** and **2** was evaluated using the ^{13}C nmr chemical shift of the $ArCH_2Ar$ methylene carbon, which is used as a means for assessing calixarene conformations. It is known that the methylene carbon resonances for calixarenes appear at *ca*. δ 30-33 ppm when the adjacent aryl rings are *syn* and at *ca*. δ 36-38 ppm when they are *anti* [6]. Applying this to **1** and **2**, the chemical shifts of the methylene carbon atoms, which were observed in the range of δ 31.1-31.4 ppm, suggested that all the phenol units adopt a *syn* orientation. Thus, a cone-like form is the preferable conformation in this system.

It is known that calixarenes bind quaternary ammonium ions in solution [7]. We also investigated the host-guest complexation behavior of marcocycles **1** and **2** with

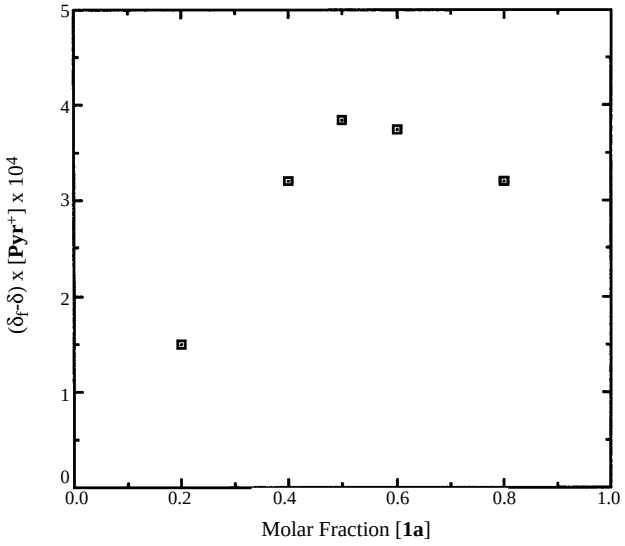


Figure 4. Job's plot. (δ_f-δ) is shift in ppm induced in the NCH_3 proton of **Pyr**$^+$, and the total concentration of **1a** plus **Pyr**$^+$ maintained at 10 m*M* in deuteriochloroform:deuterioacetonitrile-*d3* = 10:1 (v/v) at 20°.

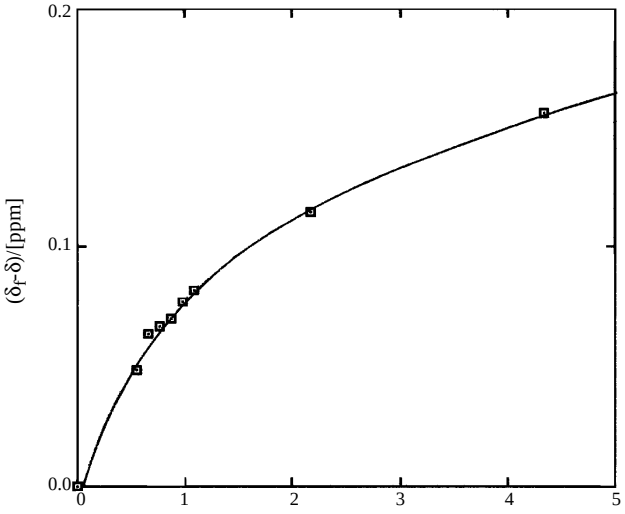


Figure 5. H^1 Nmr titration of **Pyr**$^+$ with **1a** in deuteriochloroform:-deuterioacetonitrile-d_3 = 10:1 (v/v) at 20°. (δ_f-δ) is change in chemical shift of NCH_3 proton of **Pyr**$^+$ as a result of added **1a**.

N-methylpyridinium iodide **Pyr**$^+$. In the presence of **1**, all resonance peaks of the salt moved to a higher magnetic field due to the ring current effect of the cyclophane core. Interestingly, for the *O*-tetramethylated compounds **2** a significant up-field shift due to induction was not observed. This discrepancy suggests the importance of intramolecular hydrogen bonding, which contributes to the

suppression of molecular motion. Analogously, for linear oligomer **3** an up-field shift of the guest proton was not observed, indicating the importance of the ring structure during the inclusion of the cationic guest molecules.

Further evidence for the inclusion of **Pyr**$^+$ in **1a** was obtained from nOe experiments [7b]. The nOe peak intensities with respect to the protons of **Pyr**$^+$ are shown in Table 1. The peak intensities are strong enough to support the inclusion of **Pyr**$^+$ into the cavity of **1a**.

The ^{1}H nmr relaxation time (T_1) measurement also supported the fact that **Pyr**$^+$ was included in the core [8]. The T_1 values for all protons of **Pyr**$^+$ drastically decreased when **1a** was complexed with **Pyr**$^+$, indicating that the formation of the complex suppressed the molecular motion of both **Pyr**$^+$ and **1a**. Interestingly, a larger decrease was observed at the β-proton in the thiophene ring of **1a** during the formation of the complex, implying that the thiophene ring also participated in the formation of the complex as a π-base as well as the phenol ring.

We estimated the stoichiometry of the complex using Job's plot method [9]. The 1:1 stoichiometry of the complex was confirmed by a plot that contains a maximum at the mole ratio of 0.5 in this case. The association constants (K_a) of the macrocycles **1** to **Pyr**$^+$ were determined by a nonlinear least-squares fitting method of a binding curve obtained from the ^{1}H nmr titration (**1a**: K_a = 104±10, **1b**: 80±10 M^{-1}) [10]. This value is quite similar to those of the calix[*n*]arenes (K_a = 52 M^{-1} (*n*=4), K_a = 190 M^{-1} (*n*=6), K_a = 132 M^{-1} (*n*=8)) [7b]. In contrast, the association constants of the *O*-tetramethylated macrocycles **2** are very small values (**2a**: K_a=10±2, **2b**: 6±1 M^{-1}).

In conclusion, we prepared the calixarene analogs containing a thiophene ring in the macrocyclic ring. We also elucidated that the macrocycles **1** have a binding ability for *N*-methylpyridinium iodide. The formation of the complex was supported by the induced chemical shifts, nOe experiments, and ^{1}H relaxation time (T_1) measurement. In contrast, the *O*-tetramethylated compounds **2** and linear oligomer **3** could not efficiently include the salt. This discrepancy suggests that suppression of molecular motion and the ring structure of the host molecule are important factors during the inclusion of a cationic guest.

EXPERIMENTAL

All melting points are uncorrected. The ^{1}H and ^{13}C NMR spectra were measured with Varian Mercury 200 and Varian 500 INOVA spectrometers using tetramethylsilane as internal standard. The IR and UV spectra were acquired on Horiba FT-200 and Hitachi 228A spectrophotometers, respectively. FAB-mass spectra were recorded on a JEOL JMS AX-505HA spectrometer, using *m*-nitrobenzyl alcohol as the matrix. Column chromatography was performed using silica gel (Kieselgel 60, 63-200 mm, 70-230 mesh, Merck). The ^{1}H relaxation time T_1 measuremets were made by the inversion recovery method at 25°; the deviation of the T_1 values is within 5%. All chemicals were reagent grade and were used without further purification. Compounds **3** and **4** were prepared according to methods reported in the literature [5].

Condensation Reaction of **4** with Thiophenes.

A mixture of **4** (8.3 g, 13 mmoles), thiophene (126 g, 1.5 moles), and *p*-toluenesulfonic acid (0.24 g, 1.3 mmoles) was refluxed for 4 hours under a nitrogen atmosphere. The reaction mixture was washed with 100 ml of water two times and dried over anhydrous sodium sulfate. Removal of thiophene under reduced pressure gave an oily residue that was subjected to column chromatography on silica gel using hexane:ethyl acetate 3:1 as the eluent to give **5** (5.3 g, 58 %) as colorless crystals.

4-*tert*-Butyl-2-((5-(*tert*-butyl)-3-((5-(*tert*-butyl)-2-hydroxyphenyl)methyl)-2-hydroxyphenyl)methyl-6-((5-*tert*-butyl)-2-hydroxy-3-(thienymethyl)phenyl)methyl)phenol (**5**).

Compound **5** has mp 107-110° (ethyl acetate-hexane); ^{1}H nmr (deuteriochloroform): δ 1.24 (s, 9H, *t*-Bu), 1.25 (s, 18H, *t*-Bu x 2), 1.26 (s, 9H, *t*-Bu), 3.75 (s, 2H, CH_2), 3.76 (s, 2H, CH_2), 3.77 (s, 2H, CH_2), 4.08 (s, 2H, CH_2), 6.62 (d, 1H, Ar-H, 8.0 Hz), 6.78 (dd, 1H, thiophene ring proton, *J* = 1.5, 3.5 Hz), 6.85 (dd, 1H, thiophene ring proton, *J* = 3.5, 5.5 Hz), 6.90 (d, 1H, Ar-H, *J* = 2.0 Hz), 6.95 (dd, 1H, Ar-H, *J* = 2.0, 8.0 Hz), 7.03-7.06 (m, 4H, Ar-H x 4), 7.08 (dd, 1H, thiophene ring proton, *J* = 1.5, 5.5 Hz), 7.09 (d, 1H, Ar-H, *J* = 2.0 Hz), 7.18 (d, 1H, Ar-H, *J* = 2.0 Hz), 8.80 (bs, 1H, OH), 8.85 (bs, 2H, OH x 2), 8.88 (bs, 1H, OH); ^{13}C nmr (deuteriochloroform): δ 31.4, 31.5, 31.8, 32.0, 32.2, 33.9, 34.0, 115.1, 124.2, 124.6, 125.2, 125.6, 125.7, 125.8, 125.9, 126.2, 126.4, 126.5, 126.9, 127.0, 127.1, 127.2, 127.3, 127.6, 143.3, 143.7, 144.1, 144.2, 144.3, 147.0, 147.2, 148.6, 149.7; (FAB) ms: m/z 733 $(M+1)^+$.

Anal. Calcd. for $C_{48}H_{60}O_4S$: C, 78.65; H, 8.25. Found: C, 78.82; H, 8.53.

Hydroxymethylation of **5**.

A mixture of **5** (5.3 g, 7.2 mmoles), 23 % sodium hydroxide aqueous solution (6.2 ml, 40 mmoles), 35 % formaldehyde aqueous solution (25 ml, 290 mmoles), and 50 ml of methanol was heated at 50° for 8 hours under a nitrogen atmosphere. After cooling to room temperature, the mixture was acidified by 10 % hydrochloride aqueous solution until pH 1, and then extracted with 100 ml of chloroform. The extract was washed with 100 ml of water three times and the organic layer was dried over anhydrous sodium sulfate. Removal of solvent gave oily residue, which was subjected to column chromatography on silica gel using hexane:ethyl acetate 4:1 as the eluent to give **6** (3.5 g, 64 %) as crystals.

4-(*tert*-Butyl)-2-((5-(*tert*-butyl)-3-((5-(*tert*-butyl)-2-hydroxy-3-(hydroxy-methyl)phenyl)methyl)-2-hydroxyphenyl)methyl)-6-((5-(*tert*-butyl)-2-hydroxy-3-(2-thienylmethyl)phenyl)-methyl)phenol (**6**).

Compound **6** has mp 105-108° (ethyl acetate-hexane); ^{1}H nmr (deuteriochloroform): δ 1.17 (s, 9H, *t*-Bu), 1.22 (s, 9H, *t*-Bu), 1.25 (s, 9H, *t*-Bu), 1.26 (s, 9H, *t*-Bu), 3.85 (s, 2H, CH_2), 3.86 (s, 4H, CH_2 x 2), 3.88 (s, 2H, CH_2), 4.59 (s, 2H, CH_2), 6.83 (dd, 1H, thiophene ring proton, *J* = 0.5, 3.5 Hz), 6.83 (d, 1H, Ar-H, *J* = 2.5 Hz), 6.85 (d, 1H, Ar-H, *J* = 2.5 Hz), 6.97 (dd, 1H,

thiophene ring proton, *J* = 3.5, 5.0 Hz), 7.10 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.13 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.16 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.17 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.18 (dd, 1H, thiophene ring proton, *J* = 0.5, 5.0 Hz), 7.19 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.20 (d, 1H, Ar-H, *J* = 2.5 Hz), 9.50 (bs, 4H, OH x 4); ^{13}C nmr (deuteriochloroform): δ 30.7, 31.3, 31.4, 31.5, 31.7, 32.2, 33.9, 34.0, 34.1, 65.0, 121.3, 122.5, 123.5, 124.2, 125.1, 125.3, 125.7, 125.8, 125.9, 126.0, 126.1, 126.6, 126.7, 126.8, 126.9, 127.1, 127.6, 128.6, 143.1, 143.6, 143.8, 144.0, 144.2, 146.9, 147.6, 148.4, 149.1; (FAB) ms: m/z 746 $(M\text{-}OH+1)^+$.

Anal. Calcd. for $C_{49}H_{62}O_5S$: C, 77.13; H, 8.19. Found: C, 77.32; H, 8.20.

Cyclization Reaction of **6**.

To a refluxing solution of dry benzene in the presence of *p*-toluenesulfonic acid (1.0 g, 0.6 mmole) was slowly added dropwised a solution of **5** (0.40 g, 0.54 mmole) in 100 ml of dry benzene over 8 hours. After the addition was complete, the mixture was further refluxed for 2 hours. After cooling to room temperature, the mixture was washed with 100 ml of water three times and the organic layer was dried over anhydrous sodium sulfate. Removal of solvent gave an oily residue, which was subjected to column chromatography on silica gel using chloroform as the eluent to give **1a** (0.20 g, 50 %) and **1b** (0.16 g, 40 %) as colorless crystals.

10,16,22,28-Tetrakis(*tert*-butyl)-31-thiahexacyclo-[24.3.1.1^{3,6}.1^{8,12}.1^{14,18}.1^{20,24}]tetratriaconta-1(29), 3(4), 5, 8 (9), 10, 12(32), 14(15), 16, 18(33), 20(21), 24(34), 26(30), 27-tetradecaene-30, 32, 33, 34-tetraol (**1a**).

The yield was 50 % as crystals, mp 141-144° (dichloromethane-hexane); ^{1}H nmr (deuteriochloroform): δ 1.25 (s, 18H, *t*-Bu x 2), 1.28 (s, 18H, *t*-Bu x 2), 3.76 (s, 6H, CH_2 x 3), 4.06 (s, 4H, CH_2 x 2), 6.60 (bs, 2H, OH x 2), 6.75 (s, 2H, thiophene ring protons), 7.00 (d, 2H, Ar-H x 2, *J* = 2.5 Hz), 7.19 (d, 2H, Ar-H x 2, *J* = 2.5 Hz), 7.21 (d, 2H, Ar-H x 2, *J* = 2.5 Hz), 7.24 (d, 2H, Ar-H x 2, *J* = 2.5 Hz), 7.43 (bs, 2H, OH); ^{13}C nmr (deuteriochloroform): δ 31.2, 31.3, 31.5, 33.0, 33.9, 125.3, 125.4, 125.8, 126.1, 126.2, 126.3, 126.4, 126.8, 142.4, 143.3, 143.9, 147.9, 149.4; (FAB) ms: m/z 745 $(M+1)^+$.

Anal. Calcd. for $C_{49}H_{60}O_4S$: C, 78.99; H, 8.12. Found: C, 78.76; H, 8.22.

5,11,17,19-Tetrakis(*tert*-butyl)-24-thiahexacyclo-[25.3.1.1^{3,7}.1^{9,13}.1^{15,19}. 0^{21,25}]tetratriaconta-1(31), 3(4), 5, 7(32), 9(10), 11, 13(33), 15(34), 16, 18, 21(25), 22, 27(28),29-tetradecaene-31,32,33,34-tetraol (**1b**).

The yield was 40 % as crystals, mp 168-173° (dichloromethane-hexane); ^{1}H nmr (deuteriochloroform): δ 1.22 (s, 9H, *t*-Bu), 1.23 (s, 9H, *t*-Bu), 1.25 (s, 9H, *t*-Bu), 1.30 (s, 9H, *t*-Bu), 3.80 (s, 2H, CH_2), 3.87 (s, 6H, CH_2 x 3), 4.00 (s, 2H, CH_2), 6.48 (bs, 1H, OH), 6.70 (d, 1H, thiophene ring proton, *J* = 5.3 Hz), 6.80 (bs, 1H, OH), 6.99 (d, 1H, thiophene ring proton, *J* = 5.3 Hz), 7.07 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.10 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.12 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.13 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.15 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.18 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.19 (d, 1H, Ar-H, *J* = 2.4 Hz), 7.20 (d, 1H, Ar-H, *J* = 2.4 Hz, 8.99 (bs, 1H, OH), 9.11 (bs, 1H, OH); ^{13}C nmr (deuteriochloroform): δ 29.5, 30.0, 31.4, 31.5, 32.1, 32.4, 33.9, 34.0, 122.9, 125.5, 125.8, 126.0, 126.2, 126.5, 126.6, 126.7, 126.9, 127.0, 127.1, 127.2, 129.1, 143.2, 143.5, 143.7, 144.2, 144.3, 147.2, 147.7, 148.7, 148.9, 149.5, 149.8; (FAB) ms: m/z 745 $(M+1)^+$.

Anal. Calcd. for $C_{49}H_{60}O_4S$: C, 78.99; H, 8.12. Found: C, 78.92; H, 8.09.

O-Tetramethylation of Macrocycles (**1**).

To a solution of **1** (0.40 mmole) in 6 ml of dry tetrahydrofuran and 2 ml of dry dimethylformamide was added sodium hydride (0.11 g, 4.6 mmoles) over 15 minutes. Methyl iodide (1.02 g, 7.2 mmole) was added and the resulting mixture was refluxed for 4 hours. After cooling to room temperature the reaction mixture was quenched by addition of methanol and 10 % aqueous hydrochloric acid solution. After removal of the solvent the organic residue was extracted two times with 20 ml of chloroform. Removal of the chloroform gave an oily residue, that was subjected to column chromatography on silica gel using 6:1 as the eluent to give *O*-tetramethylated compound (**2**) as a colorless oil.

30,32,33,34-Tetramethoxy-10,16,22,28-tetrakis(*tert*-butyl)-31-thiahexacyclo[24.3.1.1^{3,6}.1^{8,12}.1^{14,18}.1^{20,24}]tetratriaconta-1(29), 3(4), 5, 8(9), 10, 12(32), 14(15), 16, 18(33), 20(21), 24(34), 26(30), 27-tetradecaene (**2a**).

The yield was 62% as colorless oil; ^{1}H nmr (deuteriochloroform): δ 1.16 (s, 18H, *t*-Bu x 2), 1.21 (s, 18H, *t*-Bu x 2), 2.85 (s, 6H, OMe x 2), 3.25 (s, 6H, OMe x 2), 3.80 (s, 2H, CH_2), 3.85 (s, 4H, CH_2 x 2), 6.51 (s, 2H, thiophene ring protons), 6.94 (d, 2H, Ar-H x 2, *J* = 2.6 Hz), 7.07 (d, 2H, Ar-H x 2, *J* = 2.4 Hz), 7.12 (d, 2H, Ar-H x 2, *J* = 2.6 Hz), 7.15 (d, 2H, Ar-H x 2, *J* = 2.4 Hz); ^{13}C nmr (deuteriochloroform): δ 29.9, 30.6, 31.3, 31.4, 32.2, 34.0, 34.1, 60.2, 61.2, 123.4, 125.9, 126.0, 126.5, 126.9, 132.4, 133.5, 133.8, 134.1, 143.9, 145.2, 145.7, 153.5, 154.5; (FAB) ms: m/z 801 $(M+1)^+$.

Anal. Calcd. for $C_{53}H_{68}O_4S$: C, 79.46; H, 8.56. Found: C, 79.55; H, 8.61.

31,32,33,34-Tetramethoxy-5,11,17,19-tetrakis(*tert*-butyl)-24-thiahexacyclo-[25.3.1.1^{3,7}.1^{9,13}.1^{15,19}.0^{21,25}]tetratriaconta-1(31), 3(4), 5, 7(32), 9(10), 11, 13(33), 15(34), 16, 18, 21(25), 22, 27(28), 29-tetradecaene (**2b**).

The yield was 90% as colorless oil; ^{1}H nmr (deuteriochloroform): δ 1.11 (s, 9H, *t*-Bu), 1.13 (s, 9H, *t*-Bu), 1.22 (s, 9H, *t*-Bu), 1.24 (s, 9H, *t*-Bu), 2.54 (s, 6H, OMe x 2), 2.60 (s, 6H, OMe x 2), 3.53 (s, 2H, CH_2), 3.59 (s, 2H, CH_2), 3.66 (s, 2H, CH_2), 3.79 (s, 2H, CH_2), 3.83 (s, 2H, CH_2), 6.80 (d, 1H, Ar-H, *J* = 2.5 Hz), 6.83 (d, 1H, thiophene ring proton, *J* = 5.0 Hz), 6.89 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.02 (d, 1H, thiophene ring proton, *J* = 5.0 Hz), 7.04 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.06-7.09 (m, 2H, Ar-H x 2), 7.10 (d, 1H, Ar-H, *J* = 2.5 Hz), 7.15 (d, 1H, *J* = 2.5 Hz), 7.16. (d, 1H, *J* = 2.5 Hz); ^{13}C nmr (deuteriochloroform): δ 29.6, 30.8, 31.4, 33.9, 59.4, 59.5, 60.2, 60.3, 121.2, 124.4, 125.7, 125.8, 125.9, 126.2, 126.5, 130.6, 131.7, 132.1, 133.1, 133.2, 133.3, 133.9, 134.0, 135.7, 136.8, 144.9, 145.0, 145.3, 145.5, 154.0, 154.1; (FAB) ms: m/z 801 $(M+1)^+$.

Anal. Calcd. for $C_{53}H_{68}O_4S$: C, 79.46; H, 8.56. Found: C, 79.55; H, 8.61.

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