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LARGE MOLECULAR CAVITIES BEARING SIDEROPHORE TYPE FUNCTIONS

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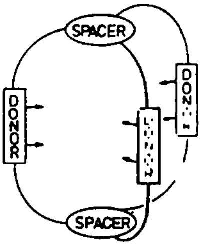
Abstract. Novel host skeletons (1), (2) and (3) of type I spacered by triphenylbenzene or trityl- or benzene units and bearing three catechol functions, have been synthesized. They constitute the largest molecular host cavities known so far. The very strong $Fe^{3\oplus}$ binding of the new cyclic and acyclic ligands and their capability to enclose organic guest molecules was investigated by spectroscopic methods and by competition experiments.

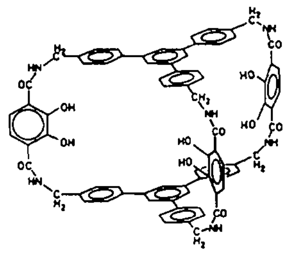
1. INTRODUCTION

The macrobicyclic ligand **4b** forms a tailor-shaped molecular cavity with six catechol oxygen atoms allowing the insertion of small matching cations like $Fe^{3\oplus}$.[1] The complex constant of the **4b**·$Fe^{3\oplus}$ complex is 10^{59}, the highest ever reported for a complex of this type.[2] In contrast to **4b**, the vastly enhanced cavity inside hitherto unknown skeletons like **1b** is spacered by six additional p-phenylene units and should rather be suited to recognize and enclose large organic molecules of complementary size and shape as guest particles than to bind $Fe^{3\oplus}$ intramolecularly.



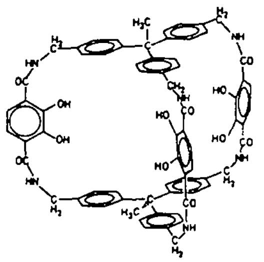
I

In this contribution we describe the first syntheses of the largest molecular cavities of type I known so far.



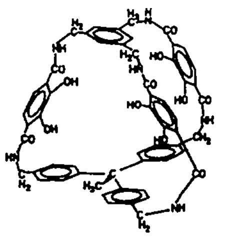
1b

(42 ring members)



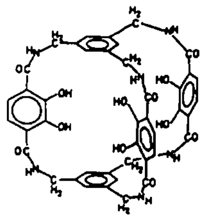
2b

(38 ring members)



3b

(32 ring members)

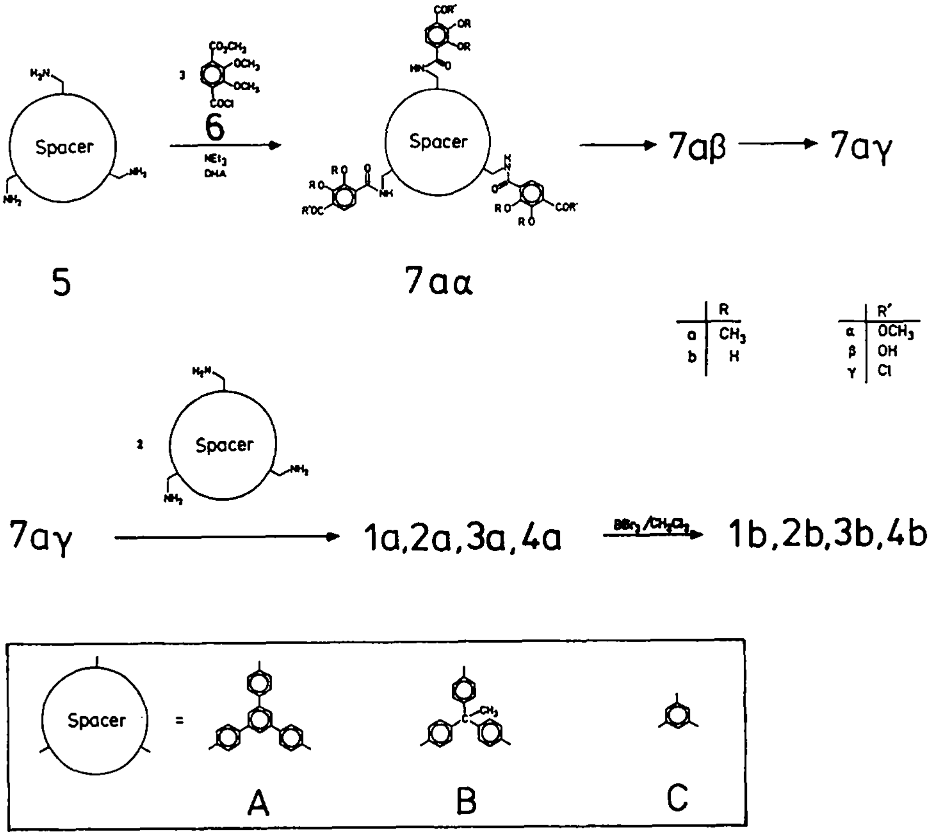


4b

(26 ring members)

2. SYNTHESES

The synthetic steps yielding the novel skeletons **1**, **2**, **3** and in particular the siderophore type ligands **1b**, **2b**, **3b** (cyclic) and **7Abβ**, **7Bbβ** (acyclic) are outlined below.



	R
a	CH$_3$
b	H

	R'
α	OCH$_3$
β	OH
γ	Cl

The critical cyclization steps **7Caγ** + **5B** → **3a**, **7Baγ** + **5B** → **2a** and **7Aaγ** + **5A** → **1a** were carried out under dilution conditions in chlorobenzene as solvent at 132°C. A step-by-step synthesis of the macrobicyclic ligands using the triamines **5(A,B, C)** and 2,3-dimethoxy-4-methoxycarbonylbenzoylchloride (**6**) [3] leads to yields of 5%, 12% and 3%, respectively. Splitting the OCH_3 bonds was achieved by use of BBr_3 and yielded **3b**, **2b** and **1b**. The general procedures are described in the experimental section.

3. UV/VIS SPECTROSCOPIC INVESTIGATION OF $Fe^{3\oplus}$ COMPLEXATION

CPK models (Figure 1) show that **2b** should be conformationally flexible enough to form octahedral $Fe^{3\oplus}$ complexes inside the cavity. On the other hand, the more spacered cavity of **1b** is definitely too large for one $Fe^{3\oplus}$ ion being enclosed in its centre.

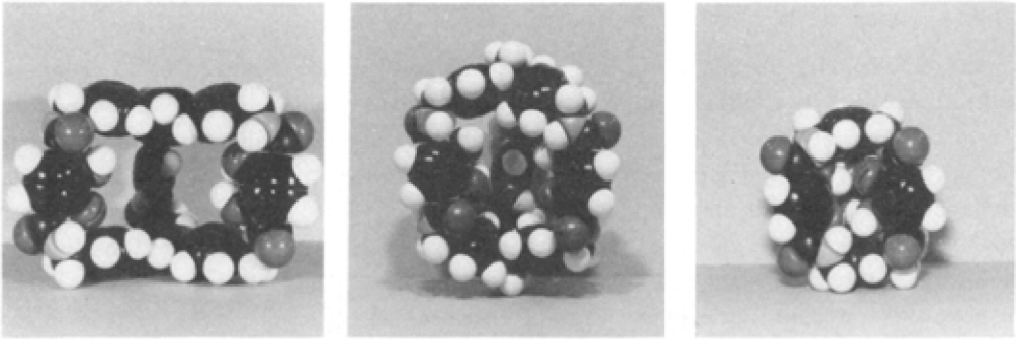


Figure 1. A comparison of the space filling and cavity sizes of **1b**, **2b** and **4b** (from left to right)

According to molecular models the six OH groups of **1b** can be easily directed towards the cavities' centre all at once without significant steric hindrance. The space filling of **1b**, shown in Figure 1, gives an idea of the size and shape of the cavities' interior. The formal transition from a small cavity like **4** to a cavity like **1** using analogous structural principles and synthetic strategies, only differing by the application of larger spacer units, can be used as a concept to construct or even to tailor-shape functionalized molecular cavities of type I and similar ones bearing modified donor systems.

As UV spectra show, **3b**, **2b** and **1b** as well as **4b** form complexes with $Fe^{3\oplus}$ ions [λ_{max}= 600, 598 and 581 nm, resp.; in DMSO (**4b**:λ_{max}= 538 nm)]. Competition experiments between the ligands and $Fe^{3\oplus}$ (equal amounts of **4b** and **3b**, **4b** and **2b**, **4b** and **1b** and the open chained ligands **7Abβ**, **7Cbβ** are added to solutions of $FeCl_3$ in DMSO) show the following results: At room temperature there is no significant equilibration between the complexes, which are all formed to a certain extent. Even the open chained ligand **7Abβ** under these conditions competes successfully with the macrobicyclic ligand **4b** in the complexation of $Fe^{3\oplus}$. The situation is changed drastically by heating the solutions. The UV spectra of all mixtures mentioned now in all cases are identical with that of the **4b**·$Fe^{3\oplus}$ complex, showing that this specific complex as the strongest one is formed exclusively.[2] All other ligands mentioned cannot compete under these conditions.[4]

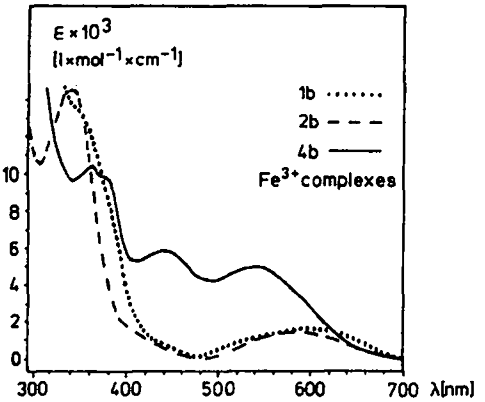
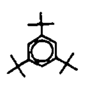


Figure 2. UV spectra of the **1b**, **2b** and **4b**·$Fe^{3\oplus}$ complexes (in DMSO)

4. ^{1}H-NMR STUDIES OF HOST/GUEST INCLUSION

In contrast to **4b**, **3b** and **2b** which may be used for photometric $Fe^{3\oplus}$ detection and determination, **1b** should also form complexes with larger guest particles, e.g. organic molecules of complementary size and shape, as has been revealed for hosts bearing cavities fitted with similar ionizable functions.[5] Neither 1,3,5-tri-tert-butylbenzene (**8**) as an uncharged guest leads to highfield shifted ^{1}H-n.m.r. signals (in DMSO-d_6) compared to the isolated components, nor do molecules of complementary functionality like 1,3,5-benzenetriyl-tris(methaneamine) (**9**) (after protonation by the hosts' OH groups) effect highfield chemical shifts. Only the proton transfer from the OH groups to the NH_2 groups can be detected: The failure of an encapsulation of a sterically fitting tris-cation by an anionic macrobicyclic large cavity is in accord with previous findings.[5] We conclude that the binding of a morefold charged guest inside a morefold opposite charged host with matching cavity size rises the problem of a sincere electrostatic barrier.[6] Similar electrostatic barriers may be relevant to some extent to transport processes at biological membranes.



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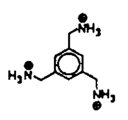

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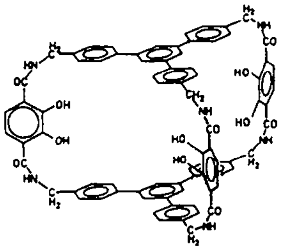


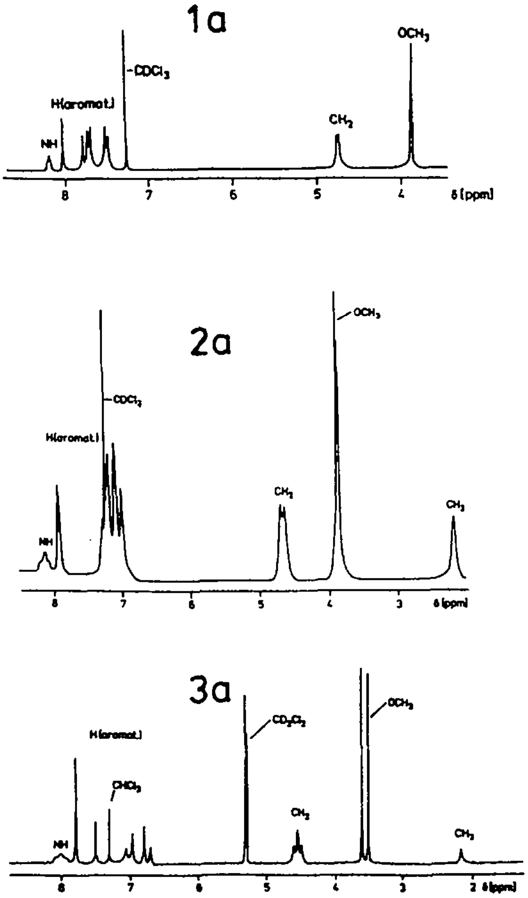
1b

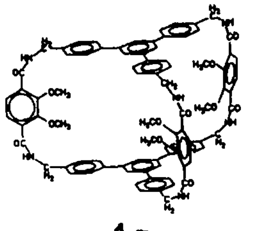
Whereas space filling models indicate toluene, benzene and 1,2-dichloroethane to be matching guests for the cavity of **3b**, experiments using this potential host/guest combination in D_2O as the solvent did not result in high field shifts for host or guest protons. We suppose that the three catechol units do not form favourable walls for the inclusion of a guest molecule, because their aromatic hydrogen atoms project into the interior of the cavity. The OH groups must likely being turned outward in an appropriate hydrophilic solvent.

Therefrom we conclude that in the future design of host cavities it might be reasonable to build up walls facing the cavity sphere rather than partly projecting into it perpendicular to the potential guest.

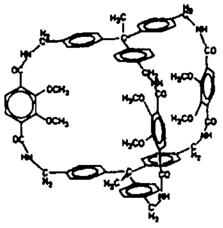
As can be seen from the ^{1}H-n.m.r. spectrum, **3a** forms a clathrate with 1 mol crystal-chloroform. The latter can be removed by heating for 5 d at 80°C/0.05

Torr (6.6 Pa). These findings are according to the elemental analysis values.

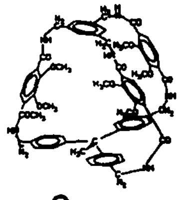




1a



2a

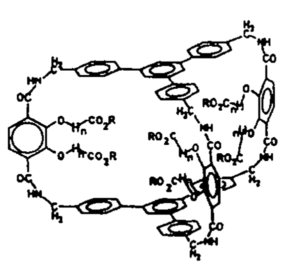


3a

Figure 3. ^{1}H-n.m.r. spectra of **1a** (400 MHz), **2a** (90 MHz) (in $CDCl_3$) and of the **3a** clathrate with chloroform (90 MHz, in CD_2Cl_2)

Host systems of the types **1b** and **2b** [7] are of additional interest beyond their receptor model properties, not only because these spacer units can be intramolecularly combined (cf. **3a**, **3b**; see experimental section), but also as they allow further functionalization utilizing their OH groups.

The hexaoxa acetic acid **10b**, e.g. (from **1b** and ethyl-α-bromoacetate) should be capable of forming a smaller cavity compared to **1b** and therefore again be able to coordinate metal cations. A novel family of acidic, EDTA type "concave complexes" should evoke through alternation of the $(CH_2)_n$ chain.



10 a: $R=C_2H_5$ b: $R=H$

EXPERIMENTAL SECTION

Physical Measurements. Melting points are taken on a Reichert microscope melting point apparatus and are uncorrected. ^{1}H-n.m.r. spectra were recorded on a Bruker WH-90 and WM-400 instrument. Ultraviolet-visible spectra were recorded on a Cary model 219 spectrophotometer with quartz cuvettes. Mass spectra were recorded on MS-30 and MS-50 A.E.I., Manchester, U.K. FAB mass spectra were performed at the Institut für Physikalische Chemie, Universität Bonn, by Prof. Dr. F. Röllgen and Dipl.-Chem. K.P.Wirth and at the Institut für Physiologische Chemie, Bonn, by Mrs. Dr.J.Peter-Katalinić. TLC and column chromatography were performed on silica gel coated AL sheets and silica gel (0.063-0.1 mm) from E.Merck, Darmstadt.

*Trimethyl-2,2',2",3,3',3"-hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris-(4,1-phenylenmethyleniminocarbonyl)]tris benzoate (**7Aaα**); Trimethyl-2,2',2",3,3',3"-hexamethoxy-4,4',4"-[1,1,1-ethantriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoate (**7Baα**); Trimethyl-2,2',2",3,3',3"-hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris(methyleniminocarbonyl)]tris benzoate (**7Caα**):* Triethylamine (8.3 mL, 60.0 mmol, dried with KOH and distilled after addition of 2% phenylisocyanate) and triamine **5A** (**5B**, **5C**) (13.05 mmol) are dissolved in 100 mL of N,N-dimethylacetamide (Janssen Nr. 18588-4), methyl 2,3-dimethoxyterephthaloyl chloride (**6**) (10.13 g, 39.16 mmol) is added dropwise to the stirred solution. Colourless ammonium salts precipitate. After 4 hrs stirring in the closed flask the precipitated salts are filtered by suction. The solvent is evaporated. The residue is dissolved in chloroform, washed with 2% NaOH, 2% HCl and water, dried with Na_2SO_4 and again evaporated. To remove the solvent completely, the crude product is melted at 150°C and evacuated (0.05 torr, 6.6 Pa) for 1 hr. After cooling to room temperature the material is purified by column chromatography on silica gel with $CHCl_3$/EtOH:

7Aaα (chloroform/ethanol 93:7, v/v): $\underline{R}_F = 0.50$
7Baα (chloroform/ethanol 97:3, v/v): $\underline{R}_F = 0.50$
7Caα (chloroform/ethanol 25:2, v/v): $\underline{R}_F = 0.57$.

The solvent is evaporated and the residue dried at 100°C/0.05 torr.- The m.p. are 138-140°C, 146-148°C and 44-48°C, respectively. ^{1}H-n.m.r. and MS data see Table 1. Anal. calcd for **7Aaα**, $C_{60}H_{57}N_3O_{15}$ (1060.12): C 67,98, H 5.42, N 3.96; found: C 67.90, H 5.70, N 3.89.- Anal. calcd for **7Baα**, $C_{56}H_{57}N_3O_{15}$ (1012.08): C 66.46, H 5.68, N 4.15, found: C 66.45, H 5.87, N 4.39. **7Caα**: $C_{42}H_{45}N_3O_{15}$ (831.83).

*2,2',2",3,3',3"-Hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris-(4,1-phenylenmethyleniminocarbonyl)]tris benzoic acid (**7Aaβ**); 2,2',2",3,3',3"-Hexamethoxy-4,4',4"-[1,1,1-ethantriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoic acid (**7Baβ**):* To a solution of **7Aaα** (**7Baα**) (6.06 mmol) dissolved in 180 mL of diglycol dimethylether and 70 mL of water sodium hydroxide (0.84 g, 20.98 mmol, p.a.) is added. The mixture is stirred until the sodium hydroxide is dissolved completely and refluxed for 5 hrs. After cooling the solvents are distilled off. The residue is dissolved in water. The solution is acidified using diluted HCl. The flocky precipitate is filtered by suction, washed with water and finally dried at 100°C/0.05 torr (6.6 Pa); the yield is nearly quantitative. ^{1}H-n.m.r. data see Table 1.
Anal. calcd for **7Aaβ**, $C_{57}H_{51}N_3O_{15}$ (1018.05): C 67.25, H 5.05, N 4.13; found C 67.10, H 5.17, N 4.12.- Anal. calcd for **7Baβ**, $C_{53}H_{51}N_3O_{15}$ (970.00): C 65.63, H 5.30, N 4.33; found C 65.87, H 5.44, N 4.51.

*Trisodium-2,2',2",3,3',3"-hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris(methyleniminocarbonyl)]tris benzoate (sodium salt of **7Caβ**):* To a solution of **7Caα** (7.64 g, 9.18 mmol) dissolved in 150 mL of methanol (distilled) and 3 mL of water sodium hydroxide (1.15 g, 27.7 mmol, p.a.) is added. The mixture is stirred until the sodium hydroxide is dissolved completely and refluxed over night. After cooling the solvents are distilled off. The foam produced is dried in vacuo, pulverized and dried at 100°C/0.05 torr (6.6 Pa). The substance decomposes at 245°C, the yield is nearly quantitative. ^{1}H-n.m.r. data see Table 1. $C_{39}H_{36}N_3Na_3O_{15}$ (855.69).

*2,2',2",3,3',3"-Hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoyl chloride (**7Aaγ**); 2,2',2",3,3',3"-Hexamethoxy-4,4',4"-[1,1,1-ethantriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoyl chloride (**7Baγ**):* A 100 mL flask fitted with 50 mL of thionyl chloride (colourless, otherwise distilled) is cooled with liquid nitrogen until the thionyl chloride begins to solidify. After that, 3.90 mmol of the tris benzoic acid **7Aaβ** (**7Baβ**) are added. The mixture is stirred, while the flask is warmed to room temperature by the surrounding air. Stirring is continued at 20°C for additional 0.5 hr. The thionyl chloride is distilled off in vacuo from the yellow solution at a temperature <25°C. A pale yellow foam is formed, from which the thionyl chloride is completely removed in vacuo (0.05 torr, 6.6 Pa). After some hrs the material changes to a pale solid. The yield is quantitative. ^{1}H-n.m.r. data see Table 1. **7Aaγ**: $C_{57}H_{48}Cl_3N_3O_{12}$ (1073.38), **7Baγ**: $C_{53}H_{48}Cl_3N_3O_{12}$ (1025.33).

*2,2',2",3,3',3"-Hexamethoxy-4,4',4"-[1,3,5-benzenetriyltris(methyleniminocarbonyl)]-tris benzoyl chloride (**7Caγ**):* A 100 mL flask fitted with 50 mL of thionyl chloride is cooled with liquid nitrogen until the thionyl chloride begins to solidify. After that, 5.00 g (ca. 5.8 mmol) of the trisodium salt of **7Caβ** are added. The mixture is stirred, while the flask is warmed to room temperature by the surrounding air. Stirring is continued at 20°C for an additional 0.5 hr; after this, no educt should swim on the thionyl chloride surface. The mixture is filtered by suction through a glass frit. Usually, NaCl is easily filtered off in this way. The thionyl chloride is distilled off in vacuo from the yellow filtrate at a temperature <25°C. A pale yellow foam is formed, from which the thionyl chloride is completely removed in vacuo (0.05 torr, 6.6 Pa). After some hrs the material changes to a pale solid with m.p. 130-132°C. The yield is quantitative. ^{1}H-n.m.r. data see Table 1. $C_{39}H_{36}Cl_3N_3O_{12}$ (845.08).

*2,2',2",3,3',3"-Hexahydroxy-4,4',4"-[1,3,5-benzenetriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoic acid (**7Abβ**); 2,2',2",3,3',3"-Hexahydroxy-4,4',4"-[1,1,1-ethantriyltris(4,1-phenylenmethyleniminocarbonyl)]tris benzoic acid (**7Bbβ**); 2,2',2",3,3',3"-Hexahydroxy-4,4',4"-[1,3,5-benzenetriyltris(methyleniminocarbonyl)] tris benzoic acid (**7Cbβ**):* To 1 1M solution of BBr_3 in dichloromethane (7.5 mL, 7.5 mmol) under cooling with ice a solution of **7Aaα** (**7Baα**, **7Caα**) (0.22 mmol) in 20 mL of dichloromethane (distilled from P_4O_{10}) is added dropwise. After completed addition the mixture is stirred at room temperature for 24 hrs. Under cooling with ice 20 mL of water are added dropwise. The mixture is stirred intensively at room temperature for 4 hrs, afterwards filtered by suction (frit) and washed several times with water and dichloromethane. The residue is dissolved in some mL of water and the pH set to 11 using NaOH. The nearly clear solution is filtered, the filtrate is acidified using diluted HCl. The fine flocky precipitate is filtered by suction, washed five times with water and finally dried at 100°C/0.05 torr (6.6 Pa). The yields are **7Abβ**: 81%, **7Bbβ**: 78% and in the case of **7Cbβ**: 73% colourless powder, insensitive to air, thermal decomposition at 330, 250 and 205°C, respectively. ^{1}H-n.m.r. and MS data see Table 1. **7Abβ**: $C_{51}H_{39}N_3O_{15}$ (933.88), **7Bbβ**: $C_{47}H_{39}N_3O_{15}$ (885.85), **7Cbβ**: $C_{33}H_{27}N_3O_{15}$ (705.57).

*12,13,35,36,55,56-Hexamethoxy-9,16,32,39,52,59-hexaazatridecacyclo[22.22.18.$2^{4,7}$.$2^{11,14}$.$2^{18,21}$.$2^{27,30}$.$2^{34,37}$.$2^{41,44}$.$2^{47,50}$.$2^{54,57}$.$2^{61,64}$.$1^{3,45}$.$1^{22,26}$]tetraoctaconta-1,3(71),4,6,11,13,18,20,22,24,26(78),27,29,34,36,41,43,45,47,49,54,56,61,63,65,67,69,72,74,76,79,81,83-tritriacontaene-10,15,33,38,53,58-hexone (**1a**); 1,20-Dimethyl-10,11,29,30,47,48-hexamethoxy-7,14,26,33,44,51-hexaazaundecacyclo[20.20.16.$2^{2,5}$.$2^{9,12}$.$2^{16,19}$.$2^{21,24}$.$2^{28,31}$.$2^{35,38}$.$2^{39,42}$.$2^{46,49}$.$2^{53,56}$]tetraheptaconta-2,4,9,11,16,18,21,23,28,30,35,37,39,41,46,48,53,55,57,59,61,63,65,67,69,71,73-heptacosaene-8,13,27,32,45,50-hexone (**2a**); 1-Methyl-10,11,25,26,43,44-hexamethoxy-7,14,22,29,40,47-hexaazanonacyclo[16.16.12.$2^{2,5}$.$2^{9,12}$.$2^{24,27}$.$2^{31,34}$.$2^{35,38}$.$2^{42,45}$.$1^{16,20}$]henhexa-2,4,9,11,16,18,20(57),24,26,31,33,35,37,42,44,49,51,53,55,58,60-heneicosaene-8,13,23,28,41,46-hexone (**3a**); 8,9,23,24,35,36-Hexamethoxy-5,12,20,27,32,39-hexaazaheptacyclo[14.14.10.$2^{7,10}$.$2^{22,25}$.$2^{34,37}$.$1^{3,29}$.$1^{14,18}$]octatetraconta-1,3(43),7,9,14,16,18(46),22,24,29,34,36,41,44,47-pentadecaene-6,11,21,26,33,38-hexone (**4a**):*

The following components are used for the cyclization reactions:

macrobicyclic system	trichloride	triamine	solvent
1a	**7Aaγ** (3.50 g, 3.26 mmol) in 250 mL of chlorobenzene	**5A** (2.55 g, 6.52 mmol) in 250 mL of chlorobenzene	chlorobenzene
2a	**7Baγ** (3.68 g, 3.69 mmol) in 245 mL of chlorobenzene and 5 mL of N,N-dimethylacetamide	**5B** (2.48 g, 7.19 mmol) in 250 mL of chlorobenzene	chlorobenzene
3a	**7Caγ** (1.60 g, 1.89 mmol) in 245 mL of chlorobenzene and 5 mL of N,N-dimethylacetamide	**5B** (1.31 g, 3.78 mmol) in 250 mL of chlorobenzene	chlorobenzene
4a	**7Caγ** (5.60 g, 6.63 mmol) in 235 mL of benzene and 15 mL of N,N-dimethylacetamide	**5C** (2.18 g, 13.2 mmol) in 250 mL of benzene	benzene

In a high dilution apparatus (according to Vögtle, NORMAG) a solution of the trichloride and a solution of the triamine are added dropwise and synchronously within 8 hrs in a argon atmosphere to 2.2 L of vigorously stirred solvent. During this addition colourless fluffy precipitates are formed. After cooling to room temperature the suspension is filtered and the residue is washed well with the solvent. The solvents of the filtrate are distilled off, the residue stirred with little methanol, the resulting solid collected on a glass frit. The residue is dissolved in 100 mL of chloroform and the solution is washed with 2% HCl, 2% NaOH and water, dried with Na_2SO_4 and evaporated. The residue is chromatographed on a silica gel column (35 x 500 mm): **1a** (chloroform/ethanol 93:7, v/v): R_F= 0.41; **2a** (chloroform/ethanol 93:7, v/v): R_F= 0.41; **3a** (dichloromethane/acetone/ethanol 80:15:5, v/v/v): R_F= 0.45; **4a** (chloroform/ethanol 9:1, v/v): R_F= 0.48.- The solvent is evaporated and the residue dried at 100°C/0.05 torr. ^{1}H-n.m.r. and MS data see Table 1. **1a**: $C_{84}H_{72}N_6O_{12}$ (1357.53); **2a**: $C_{76}H_{72}N_6O_{12}$ (1261.45); **3a**: $C_{62}H_{60}N_6O_{12}$ (1081.20);

4a: $C_{48}H_{48}N_6O_{12}$ (900.93).

12,13,35,36,55,56-Hexahydroxy-9,16,32,39,52,59-hexaazatridecacyclo[22.22.18.$2^{4,7}.2^{11,14}.2^{18,21}.2^{27,30}.2^{34,37}.2^{41,44}.2^{47,50}.2^{54,57}.2^{61,64}.1^{3,45}.1^{22,26}$*]tetraoctaconta-1,3(71),4,6,11,13,18,20,22,24,26(78),27,29,34,36,41,43,45,47,49,54,56,61,63,65,67,69,72,74,76,79,81,83-tritriacontaene-10,15,33,38,53,58-hexone (**1b**); 1,20-Dimethyl-10,11,29,30,47,48-hexahydroxy-7,14,26,33,44,51-hexaazaundecacyclo[20.20.16.*$2^{2,5}.2^{9,12}.2^{16,19}.2^{21,24}.2^{28,31}.2^{35,38}.2^{39,42}.2^{46,49}.2^{53,56}$*]tetraheptaconta-2,4,9,11,16,18,21,23,28,30,35,37,39,41,46,48,53,55,57,59,61,63,65,67,69,71,73-heptacosaene-8,13,27,32,45,50-hexone (**2b**); 1-Methyl-10,11,25,26,43,44-hexahydroxy-7,14,22,29,40,47-hexaazanonacyclo[16.16.12.*$2^{2,5}.2^{9,12}.2^{24,27}.2^{31,34}.2^{35,38}.2^{42,45}.2^{16,20}$*]henhexa-2,4,9,11,16,18,20(57),24,26,31,33,35,37,42,44,49,51,53,55,58,60-heneicosaene-8,13,23,28,41,46-hexone (**3b**); 8,9,23,24,35,36-Hexahydroxy-5,12,20,27,32,39-hexaazaheptacyclo[14.14.10.*$2^{7,10}.2^{22,25}.2^{34,37}.1^{3,29}.1^{14,18}$*]octatetraconta-1,3(43),7,9,14,16,18(46),22,24,29,34,36,41,44,47-pentadecaene-6,11,21,26,33,38-hexone (**4b**):* To a 1 M solution of BBr_3 in dichloromethane (7.5 mL, 7.5 mmol) under cooling with ice a solution of **1a** (**2a**, **3a**, **4a**) (0.22 mmol) in 20 mL of dichloromethane (distilled from P_4O_{10}) is added dropwise. After completed addition the mixture is stirred at room temperature for 24 hrs. Under cooling with ice 20 mL of water are added dropwise. The mixture is stirred intensively at room temperature for 4 hrs, afterwards filtered by suction (frit) and washed several times with water and dichloromethane. The residue is dried at 100°C/0.05 torr (6.6 Pa). The yields are **1b**: 79%, **2b**: 82%, **3b**: 72% and **4b**: 78% colourless powder, insensitive to air, thermal decomposition at 248, 280, 285 and 250°C, respectively.- ^1H-n.m.r. and MS data see Table 1.- **1b**: $C_{78}H_{60}N_6O_{12}$ (1273.38); **2b**: $C_{70}H_{60}N_6O_{12}$ (1177.29); **3b**: $C_{56}H_{48}N_6O_{12}$ (997.04); **4b**: $C_{42}H_{36}N_6O_{12}$ (816.73).

Table 1. ^1H-n.m.r. and MS data

Compound	^1H-n.m.r. data δ [ppm]	MS [*]
5A	[a] 1.5 (s, 6H, NH_2), 3.83 (s, 6H, CH_2), 7.31, 7.61 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.68 (s, 3H, Ar-H)	EI: 393 ($M^{\oplus}$)
5B	[a] 1.47 (s, 6H, NH_2), 2.13 (s, 3H, CH_3), 3.83 (s, 6H, CH_2), 7.26, 7.32 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz)	EI: 345 ($M^{\oplus}$)
5C	[a] 1.6 (s, 6H, NH_2), 3.90 (s, 6H, CH_2), 7.15 (s, 3H, Ar-H)	EI: 165 ($M^{\oplus}$)
7Aaα	[a] 3.93 (3s, 27H, OCH_3), 4.75 (d, 6H, CH_2), 7.50, 7.70 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.77 (s, 3H, Ar-H), 7.62, 7.97 (AB, 6H, Ar-H, J_{AB}= 8.5 Hz), 8.35 (t, 3H, NH, J= 6 Hz)	-
7Baα	[a] 2.17 (s, 3H, CH_3), 3.7-3.9 (3s, 27H, OCH_3), 4.64 (d, 6H, CH_2, J= 6 Hz), 7.07, 7.27 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.58, 7.91 (AB, 6H, Ar-H, J_{AB}= 8.5 Hz), 8.27 (t, 3H, NH, J= 6 Hz)	EI: 1011 ($M^{\oplus}$)
7Caα	[a] 3.9-4.0 (2s, 27H, OCH_3), 4.70 (d, 6H, CH_2, J= 6 Hz), 7.35 (s, 3H, Ar-H), 7.56, 7.86 (AB, 6H, Ar-H, J_{AB}= 8 Hz), 8.40 (t, 3H, NH, J= 6 Hz)	EI: 831 ($M^{\oplus}$)
7Aaß	[b] 3.93 (s, 9H, OCH_3), 3.94 (s, 9H, OCH_3), 4.63 (d, 6H, CH_2, J= 5.2 Hz), 7.40, 7.51 (AB, 6H, Ar-H, J_{AB}= 8 Hz), 7.58, 7.94 (AA'BB', 12H, Ar-H, J= 8 Hz), 7.97 (s, 3H, Ar-H), 9.01 (t, 3H, NH, J= 5.2 Hz)	FAB-MS in tetraethylene glycol matrix: 1018 $M+H^{\oplus}$
7Baß	[b] 2.18 (s, 3H, CH_3), 3.8, 3.9 (2s, 18H, OCH_3), 4.54 (d, 6H, CH_2, J= 5 Hz), 7.12, 7.28 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.38, 7.51 (AB, 6H, Ar-H, J_{AB}= 9 Hz), 8.89 (t, 3H, NH, J= 5 Hz)	-
7Caß-Na salt	[b] 3.85 (s, 9H, OCH_3), 3.90 (s, 9H, OCH_3), 4.60 (s, 6H, CH_2), 7.21, 7.47 (AB, 6H, Ar-H, J_{AB}= 8 Hz), 7.34 (s, 3H, Ar-H)	
7Aaγ	[a] 3.95 (s, 18H, OCH_3), 4.76 (d, 6H, CH_2, J= 5 Hz), 7.50, 7.70 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.77 (s, 3H, Ar-H), 7.80, 8.01 (AB, 6H, Ar-H, J= 8.5 Hz), 8.28 (t, 3H, NH, J= 5 Hz)	
7Baγ	[a] 2.13 (s, 3H, CH_3), 3.91 (s, 18H, OCH_3), 4.64 (d, 6H, CH_2, J= 6 Hz), 7.04, 7.22 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.87, 7.98 (AB, 6H, Ar-H, J_{AB}= 9 Hz), 8.16 (t, 3H, NH, J= 6 Hz)	

Table 1, Contd.

Compound	^{1}H-n.m.r. data δ [ppm]	MS [*]
7Caγ	[a] 3.95 (s, 18H, OCH_3), 4.70 (d, 6H, Ar-H, J_{AB}= 8 Hz), 7.30 (s, 3H, Ar-H), 7.74, 7.90 (AB, 6H, Ar-H, J_{AB}= 8 Hz), 8.30 (t, broad, 3H, NH, J= 6 Hz)	-
7Abβ	[b] 4.57 (s, broad, 6H, CH_2), 7.20-7.82 (m, 21H, Ar-H), 9.69 (s, broad, 3H, NH)	-
7Bbβ	[b] 2.07 (s, broad, 3H, CH_3), 4.49 (s, broad, 6H, CH_2), 6.98-7.47 (m, 18H, Ar-H), 9.42 (s, broad, 3H, NH)	-
7Cbβ	[b] 4.59 (d, 6H, CH_2, J= 6 Hz), 7.20-7.45 (m, 9H, Ar-H), 9.57 (m, 3H, NH)	FAB-MS in glycerol matrix: 706 $[M+H]^{\oplus}$
1a	[a] 3.86 (s, 18H, OCH_3), 4.76 (d, 12H, CH_2, J= 5.5 Hz), 7.49, 7.69 (AA'BB', 24H, Ar-H, J_{AB}= 8 Hz), 7.78 (s, 6H, Ar-H), 8.03 (s, 6H, Ar-H), 8.18 (t, 6H, NH, J= 5.5 Hz)	FAB-MS in m-nitrobenzyl alcohol matrix: 1358 $[M+H]^{\oplus}$
2a	[a] 2.18 (s, 6H, CH_3), 3.84, 3.88 (2s, 18H, OCH_3), 4.69 (d, 12H, CH_2, J= 6 Hz), 7.09, 7.29 (AA'BB', 24H, Ar-H, J_{AB}= 8.5 Hz), 7.97, 8.02 (2s, 6H, Ar-H), 8.19 (t, 6H, NH, J= 6 Hz)	FAB-MS in m-nitrobenzyl alcohol matrix: 1261 $[M+H]^{\oplus}$
3a	[c] 2.16 (s, 3H, CH_3), 3.51 (s, 9H, OCH_3), 3.61 (s, 9H, OCH_3), 4.52-4.61 (m, 12H, CH_2, J= 6 Hz), 6.73, 7.01 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.50 (s, 3H, Ar-H), 7.78 (s, 6H, Ar-H), 8.01 (t, 6H, NH, J= 6 Hz)	FAB-MS in thioglycerol matrix: 1358 $[M+H]^{\oplus}$
4a	[a] 2.82 (s, 18H, OCH_3), 4.55 (d, 12H, CH_2, J= 6 Hz), 7.41 (s, 6H, Ar-H), 7.90 (s, 6H, Ar-H), 7.93 (t, 6H, NH, J= 6 Hz)	EI: 900 $[M^{\oplus}]$
1b	[b] 4.66 (s, broad, 12H, CH_2), 7.1-8.0 (m, 36H, Ar-H), 9.58 (s, broad, 6H, NH)	FAB-MS in m-nitrobenzyl alcohol matrix: 1271 $[(M-2H)+H]^{\oplus}$
2b	[b] 2.18 (s, broad, 6H, CH_3), 4.57 (s, broad, 12H, CH_2), 7.07, 7.24 (AA'BB', 24H, Ar-H, J_{AB}= 8.5 Hz), 7.42 (s, 6H, Ar-H), 9.46 (s, broad, 6H, NH)	FAB-MS in m-nitrobenzyl alcohol matrix: 1177 $[M+H]^{\oplus}$
3b	[b] 2.09 (s, broad, 3H, CH_3), 4.47 (s, broad, 12H, CH_2), 6.82, 6.98 (AA'BB', 12H, Ar-H, J_{AB}= 8 Hz), 7.20 (s, 6H, Ar-H), 7.42 (s, 3H, Ar-H), 9.16 (s, broad, 6H, NH)	FAB-MS in thioglycerol matrix: 997 $[M+H]^{\oplus}$
4b	[b] 4.35 (s, broad, 12H, CH_2), 6.92 (s, 6H, Ar-H), 7.31 (s, 6H, Ar-H), 8.63 (s, broad, 6H, NH)	FAB-MS in glycerol matrix: 817 $[M+H]^{\oplus}$

[a] $CDCl_3$.- [b] DMSO-d_6.- [c] CD_2Cl_2.-

[*] For the new macrobicyclic pyrocatechols **1b-3b** and their methylethers no electron induced mass spectra could be obtained. Fast atom bombardment mass spectrometry supplied intensive molecular peaks using thioglycerol- and m-nitrobenzyl alcohol matrices.

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4. As to the preparation of ^{252}Cf-plasma desorption mass spectra of the Pb(II)- and Bi(III)-complexes of **4b** and metal exchange studies with radioisotopes see: *M.Magerstädt*, *O.Gansow*, *L.K.Pannell*, *F.Vögtle*, *W.Kiggen*, *P.Stutte*, J.Labld.Cpds. and Radiopharmaceut., in press.
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7. In concord with the systematization of the names of ligands (ending 'and') and complexes (ending 'plex') by *Cram*[8] we propose the family name 'siderands' for the iron binding ligands **1b-4b** and **7Abβ**, **7Bbβ**, **7Cbβ** and 'sideroplexes' to their complexes. The natural siderophores then are a subclass of the siderands.
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