2,2′-Bipyridine Lariat Calixcrowns: A New Class of Encapsulating Ligands Forming Highly Luminescent Eu^{3+} and Tb^{3+} Complexes

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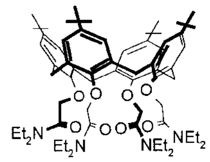
Abstract: A new class of calix[4]arene crown ethers with one or two bipyridines appended to the polyether ring (*lariat* calixcrowns) have been designed and synthesized; the luminescence properties of their Eu^{3+} and Tb^{3+} complexes have been studied in acetonitrile. In this solvent, long lifetimes for the metal emitting states and high metal-luminescence intensities obtained upon ligand excitation have been observed in both Eu^{3+} and Tb^{3+} complexes. The association constants in methanol have been determined for some of the complexes studied.

Keywords: calixarenes · conformation analysis · crown compounds · lanthanides · luminescence

Introduction

Eu^{3+} and Tb^{3+} complexes of encapsulating ligands are widely studied because of their potential use as labels in bioaffinity assays, which is based on time-resolved measurements of the metal luminescence obtained upon ligand excitation followed by ligand-to-metal energy transfer.[1–3] The sensitivity of this type of assay strongly depends on the metal luminescence intensity, which is determined by the product of the molar absorption coefficient of the ligand in the complex at the excitation wavelength and the metal luminescence quantum yield.[4] Therefore, research in this field aims at obtaining complexes characterized by high molar absorption coefficients of the ligands and high metal-luminescence quantum yields upon ligand excitation. Functionalized calixarenes are one of the classes of encapsulating ligands able to form Eu^{3+} and Tb^{3+} complexes that exhibit metal luminescence upon ligand excitation. The study of the complexes of the calix[4]arene tetramide ligand **1**[5] with the Eu^{3+} and Tb^{3+} ions demonstrated the stability and solubility of these complexes in water, as well a remarkably high metal-luminescence quantum yield upon ligand excitation for $[Tb \subset \mathbf{1}]^{3+}$.[≠] However, for this complex the metal luminescence intensity was rather low because of the low molar absorption coefficients of the ligand.



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In order to increase the intensity of the metal luminescence, we introduced two 6-methyl-2,2′-bipyridine or two 2,9-dimethyl-1,10-phenanthroline chromophores at the lower rim of the calix[4]arene 1,3-bisamide, which gave a podand-like structure with two types of chelating chains. Interestingly, some of the Tb^{3+} complexes of these ligands showed intense metal luminescence upon ligand excitation.[6] The luminescence properties of some Eu^{3+} and Tb^{3+} complexes of functionalized calixarenes containing chromophoric units have also been studied by other authors.[6–9]

More recently, we decided to synthesize a new class of calix[4]arene receptors incorporating the 2,2′-bipyridine (bpy) chromophore, in order to examine the effects of the relative orientations of the chromophore and the calixarene moiety on the thermodynamic stability and the luminescence properties of the Eu^{3+} and Tb^{3+} complexes. Note that in the complexes studied previously, the bpy chromophore is directly linked to the calix[4]arene oxygen atom and is nearly perpendicular to the macrocyclic ring.

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[≠] Following the widely accepted notation (J.-M. Lehn, *Struct. Bonding (Berlin)* **1973**, *16*, 1), we will indicate the formation of the inclusion complexes of the ligands (**L**) with different lanthanide ions (Ln^{3+}) as $[Ln \subset \mathbf{L}]^{3+}$.

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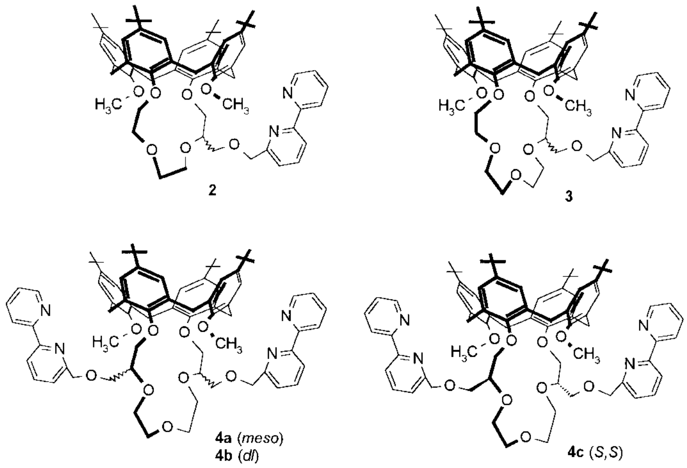
A different orientation of the chromophore could, in principle, give rise to a more efficient ligand–metal interaction, thus increasing the stability of the complexes and the intensity of the metal luminescence upon ligand excitation. To this end, we started with a class of ionophores, the calix[4]-arene crown ethers (calixcrowns), which exhibit exceptional efficiency in the complexation of metal ions.[10–12] Some of these ligands have been used for lanthanide complexation, but their Eu^{3+} and Tb^{3+} complexes showed poor luminescence properties.[13] We subsequently designed the new lariat[14] calixcrowns **2**–**4** ligands, in which one or two bipyridines

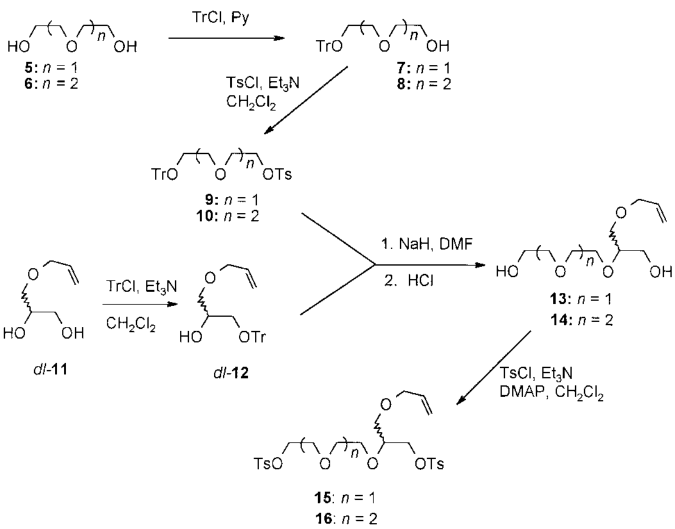


are attached to the crown ether units. This ligand structure would yield a complex with the desired orientation of the chromophore parallel to the calix[4]arene ring. Moreover, the conformational flexibility of the chromophore linked to the crown ether should contribute to optimization of the metal–ligand interaction.

In this paper we report the synthesis, the conformational and binding properties of ligands **2**–**4**, and the luminescence properties of their complexes with the Eu^{3+} and Tb^{3+} ions in acetonitrile.

Results and Discussion

Synthesis of oligoethylene glycols: Synthesis of the racemic lariat mono-bipyridine calixcrown-4 (**2**) or calixcrown-5 (**3**) requires the use of a tri- or tetraethylene glycol, respectively. Appropriate glycols such as compounds **13** and **14** bear a protected hydroxymethyl group on the second carbon atom of the ethylene chain. Very little is known about the general synthesis of such oligoethylene glycols and the few examples reported in literature are fragmentary or incomplete. Ikeda et al.[15] reported the synthesis of compound **14** by condensation of the commercially available glycidyl ether and triethylene glycol. However the reaction is not very regioselective and the glycol can react with either the primary or the secondary carbon atom of the epoxy group to afford a mixture of structural isomers that is very difficult to separate. A more promising approach has been proposed by Krakowiak et al.,[16] who reported the use of 1-allyloxy glycerol for the synthesis of some allyloxymethyl oligoethylene glycols. This approach also seemed particularly attractive to us because of the possibility of direct access to one of the two enantiomers of compound **11**, which can be easily prepared from the well-known and useful chiral synthon (*R*)- or (*S*)-2,3-*O*-isopropylideneglyceraldehyde.[17] Ditosylates **15** and **16** of 2-allyloxymethyl tri- and tetraethylene glycols were prepared through the reaction sequence depicted in Scheme 1.



Scheme 1. Preparation of the ditosylates **15** and **16**.

First, 1-*O*-allyl-glycerol [(*dl*)-**11**] was protected on the primary hydroxyl by reaction with trityl chloride and triethyl amine in dichloromethane.[16] The monotrityl monotosyl oligoethylene glycols **9** and **10** were prepared by reaction of trityl chloride in pyridine with a large excess of di- or triethylene glycols[18,19] followed by the reaction of the resulting monotrityl ethers (**7** and **8**) with tosyl chloride in dichloromethane. The resulting monotrityl monotosyl glycols **9** and **10** were allowed to react with the 1-*O*-allyl-3-*O*-trityl glycerol [(*dl*)-**12**] in basic conditions (NaH, DMF); the products thus formed were deprotected with HCl (36%) to give glycols **13** and **14** in high yields (75 and 71%, respectively). Compounds **13** and **14** were subsequently tosylated with tosyl chloride, triethylamine, and a catalytical amount of dimethylaminopyridine (DMAP) in dichloromethane to yield **15** and **16**.

In order to prepare a lariat bis-bipyridine calixcrown-5 derivative, we also needed a glycol with two protected

Abstract in Italian: *È stata progettata e sintetizzata una nuova classe di eteri a corona a base calix[4]arenica recanti uno o due bipiridili legati all'anello polietereo, e perciò chiamati calix-crown-lariati. Le proprietà di luminescenza dei corrispondenti complessi di* Eu^{3+} *e* Tb^{3+} *sono state studiate in acetonitrile. In questo solvente, sia i complessi di* Eu^{3+} *che quelli di* Tb^{3+} *presentano elevati tempi di vita degli stati emittenti del metallo e alte intensità di luminescenza per eccitazione nel legante. Per alcuni dei complessi studiati sono state determinate le costanti di associazione in metanolo.*

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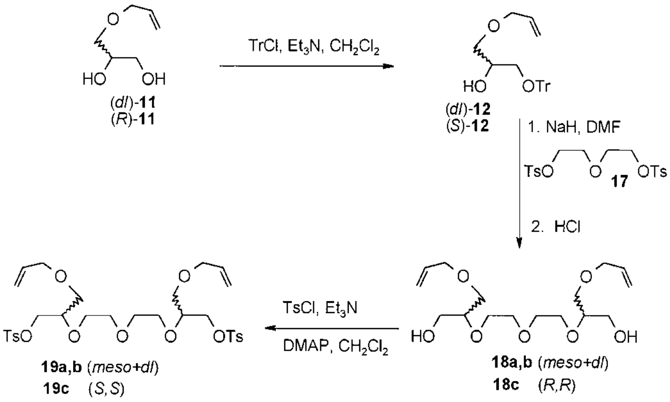
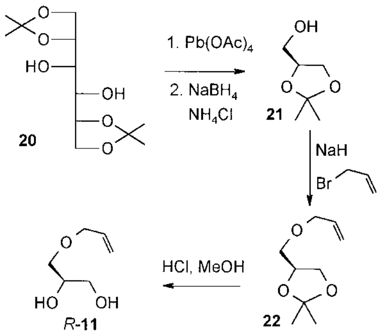
hydroxymethyl groups symmetrically located on the second and seventh carbon atom of tetraethylene glycol (**18**). We synthesized compound **18** by following the reactions reported in Scheme 2.



Scheme 2. Synthesis of the tetraethylene glycol **18**.

Since compound **18** is formed from two glycerol units and contains two chiral centers, the synthetic route that starts from the racemic glycerol (*dl*)-**11** yields a 1:1 mixture of the *meso* compound (**18a**) and the pair of enantiomers (**18b**); starting from the enantiomerically pure (*R*)-**11** produces only the *R*,*R*-stereoisomer **18c**. This allows us to study the effect of the stereochemical disposition of the side arms on the binding and luminescence properties of the lariat bis-bipyridine calix-crown-5 derivatives. Enantiomerically pure (*R*)-**11** was obtained as depicted in Scheme 3.

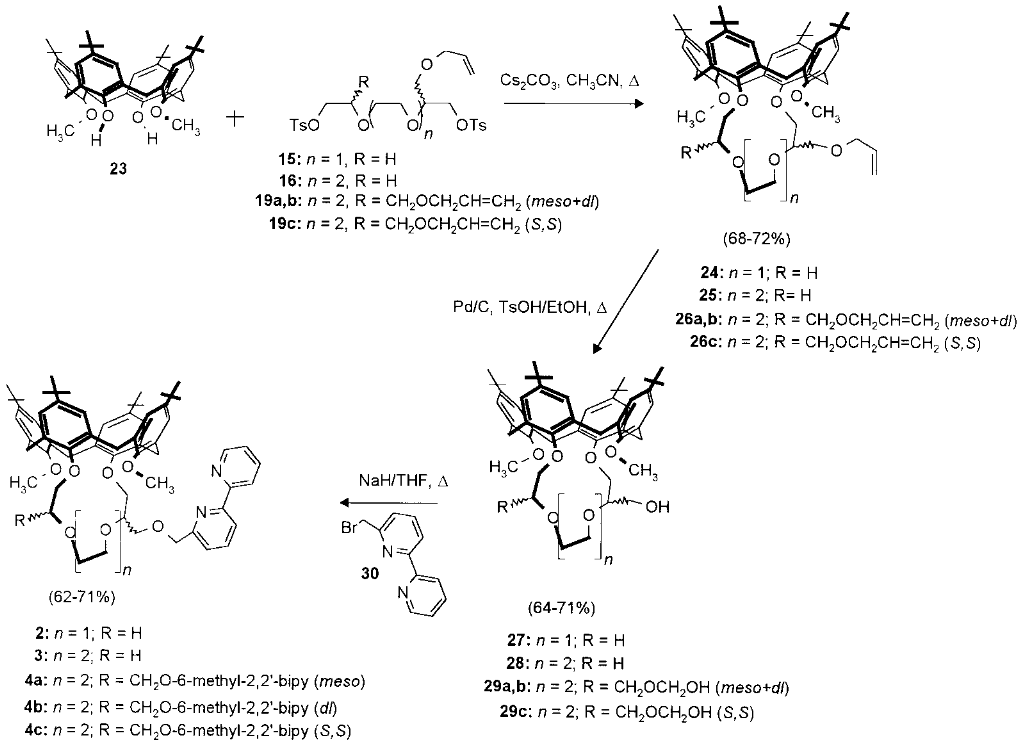
Among the several methods available for the oxidative cleavage of mannitol-1,2,5,6-diacetonide (**20**),[17] we chose to



Scheme 3. Preparation of enantiomerically pure (*R*)-**11**.

use $[Pb(OAc)_4]$ because it has been reported to give the best enantiomeric purity in the synthesis of (*R*)-2,3-isopropylideneglyceraldehyde.[20] The latter compound was directly reduced in situ with $NaBH_4$ to afford compound **21**, which was then alkylated with allyl bromide to give compound **22**.[21,22] Deprotection in acidic media to (*R*)-**11** followed by tritylation gives compound (*S*)-**12** (Scheme 2). Two equivalents of (*S*)-1-*O*-allyl-3-*O*-trityl glycerol, (*S*)-**12**, were treated with diethylene glycol ditosylate (**17**); subsequent detritylation in situ with concentrated HCl gave compound **18c** in 76% yield. Tosylation under the usual conditions (TsCl, Et_3N) affords the ditosylates **19c**.

Synthesis and conformational properties of the lariat calixcrowns: The 1,3-dimethoxy-*p*-*tert*-butylcalix[4]arene (**23**) was allowed to react with the appropriate oligoethylene glycol ditosylate (**15**, **16**, or **19**) and Cs_2CO_3 as a base in CH_3CN (Scheme 4)—the well-known conditions for high yields of the calixcrown-5, -6, and -7 derivatives.[11,12] The yields of the compounds **24**, **25**, and **26** are quite high (about 70%), which



Scheme 4. Synthesis of the calixcrowns **2**–**4**.

indicates that the steric hindrance of the allyloxymethyl side arm does not affect the cyclization reaction. Interestingly, the cyclization of the calixcrown-4 (**24**) proceeds with the same efficiency as for the calixcrowns-5, -6, and -7.

Subsequent removal of the allyl groups with *p*-toluenesulfonic acid (TsOH) and a catalytic amount of palladium on charcoal in refluxing ethanol afforded the lariat alcohols **27**, **28**, and **29** in good yields. Interestingly the calixcrown-4 derivative **27** could be isolated from the reaction mixture as a 1:1 complex with TsOH, which could only be removed from the organic phase after several washings with basic water. This indicates that compound **27** is able to form a strong complex with the hydronium ion. Subsequent reactions of the dialcohols **27**, **28**, or **29** with NaH and 6-bromomethyl-2,2′-bipyridine (**30**) in dry DMF yielded the calix[4]arene–bipyridine lariat ethers **2**, **3**, **4a**, **4b**, and **4c**. From the reaction that yielded the *meso* compound **4a** and the mixture of *dl* stereoisomers **4b**, it was possible to separate **4a** from the mixture **4b** by preparative thin-layer chromatography on Al_2O_3 with CH_2Cl_2 as eluent. The assignment of the structure of compounds **4a** and **4b** was made on the basis of their NMR spectra, which were consistent with a compound possessing a plane of symmetry (**4a**) and a binary axis (**4b**), respectively. The introduction of the bipyridine groups can be easily proven by analysis of the ^1H NMR spectra of compounds **2**, **3**, and **4**; these always indicate the presence of an AB system for the diastereotopic methylene groups of the CH_2(bpy) moiety and of the typical absorptions of the bipyridine nuclei between $\delta = 7.30$ and 8.70.

Whereas the lariat calixcrown-5 derivatives **3** and **4** are conformationally mobile, as are most of the 1,3-dimethoxy-calix[4]arene-crowns-5,[11] calixcrown-4 (**2**) is present in solution as a mixture of *cone*, *partial cone*, and *1,3-alternate* conformations, which, at room temperature, are in slow exchange on the 300 MHz NMR timescale. This is clearly indicated not only by the presence of two singlets at $\delta = 2.91$ and 2.81 for the methoxy groups of the inverted anisole nuclei of the *partial cone* and *1,3-alternate* structure inside the cavity of the calix[4]arene, but also by the presence of several signals for the $ArCH_2Ar$ carbons in the ^{13}C NMR spectrum (see Experimental Section). Because of the high asymmetry of the molecule and the presence of different conformations besides the *cone*, the NMR spectrum of the free ligand is not easily analyzed in terms of the purity of the compound. The sodium complex of **2** shows a much simpler ^1H NMR spectrum (see Experimental Section). Here the methoxy groups resonate at $\delta = 3.99$ and 4.03, indicating that the calix is mainly in the *cone* conformation.

Complexation and luminescence properties: The complexation of the Eu^{3+} and Tb^{3+} ions by ligands **2**–**4** was studied in methanol and acetonitrile. Spectrophotometric titrations of the ligands **2**, **3**, and **4c** with salts of the Eu^{3+} and Tb^{3+} ions were performed in dry acetonitrile by following the procedure indicated in the Experimental Section. All the ligands show a strong bathochromic shift of the absorption maxima upon complexation of Eu^{3+} or Tb^{3+}. Figure 1 reports the results obtained for ligand **3**. The absorption spectra show two isosbestic points at ≈260 and ≈295 nm. The plots of the

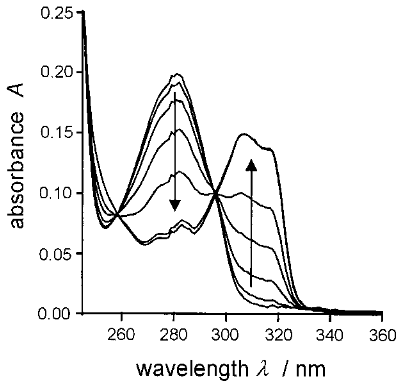


Figure 1. Absorption spectra of a solution (1.1×10^{-5} M) of ligand **3** in the presence of increasing amounts of $Eu(ClO_4)_3$ in acetonitrile. The europium/ligand ratio ranges from 0 to 20.

absorbance at 280 and 305 nm versus the metal/ligand ratio (Figure 2) indicate the formation of a complex with a 1:1 stoichiometry. The association constants in acetonitrile are

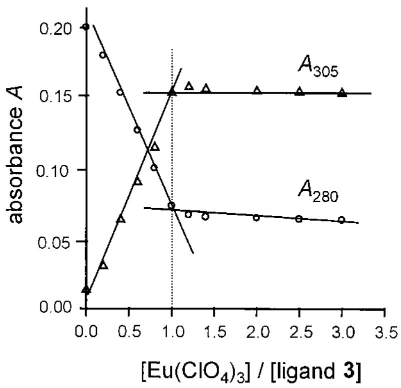


Figure 2. Spectrophotometric titration of ligand **3** with $Eu(ClO_4)_3$ in acetonitrile at 22 °C ($I = 0.001$ M Et_4NClO_4). Absorbances at 280 nm (○) and 305 nm (△) are reported in function of the salt/ligand ratio.

too high ($\log K > 7$) to be determined accurately, and therefore the same titrations were performed in methanol, in which the $\log K$ values are, as expected,[23a] smaller. In general, the association constants of the Eu^{3+} complexes with ligands **2** and **3** (Table 1) are at least two orders of magnitude higher than that found with a simple 18-crown-6,[23b] but lower than those with cryptands.[23c]

The photophysical properties of the complexes of ligands **2**–**4** with Eu^{3+} and Tb^3 were studied in acetonitrile. The molar absorption coefficients are quite high and, as expected, the values for the free ligands and the complexes are proportional to the number of bipyridine units (Table 2). As in previous

Table 1. Association constants ($\log K$) of perchlorate complexes as determined by spectrophotometric titration at 22 °C in methanol ($I = 0.001$ M Et_4NClO_4).

	Log*K*
$[Eu \subset \mathbf{2}]^{3+}$	3.68 ± 0.03
$[Tb \subset \mathbf{2}]^{3+}$	3.87 ± 0.02
$[Eu \subset \mathbf{3}]^{3+}$	3.76 ± 0.04
$[Tb \subset \mathbf{3}]^{3+}$	3.74 ± 0.07

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Table 2. Absorption and luminescence data.[a]

	Absorption		Lifetime[b]	Luminescence quantum
	λ_{max} [nm]	ε [$M^{-1}cm^{-1}$]	τ [ms]	yield[c] Φ
2	282	16000		
[Eu ⊂ **2**]$^{3+}$	305	13200	0.95	0.18
[Tb ⊂ **2**]$^{3+}$	305	13000	1.85	0.32
3	282	18000		
[Eu ⊂ **3**]$^{3+}$	305	14200	1.38	0.32
[Tb ⊂ **3**]$^{3+}$	305	13000	1.88	0.35
4a	282	25400		
[Eu ⊂ **4a**]$^{3+}$	305	22700	1.24	0.23
[Tb ⊂ **4a**]$^{3+}$	305	23400	1.86	0.39
4b	282	24000		
[Eu ⊂ **4b**]$^{3+}$	305	21000	1.29	0.28
[Tb ⊂ **4b**]$^{3+}$	305	22700	1.83	0.37
4c	282	23900		
[Eu ⊂ **4c**]$^{3+}$	305	21000	1.26	0.23
[Tb ⊂ **4c**]$^{3+}$	305	22200	1.93	0.39

[a] In aerated acetonitrile solution at 300 K. [b] Measured in correspondence with the most intense metal emission bands ($^5D_0 \rightarrow {}^7F_2$ for the Eu^{3+} ion and $^5D_4 \rightarrow {}^7F_6$ for the Tb^{3+} ion); experimental error ≤10%. [c] Excitation in the ligand absorption; $[Ru(bpy)_3]^{2+}$ ($\Phi = 0.028$ in water) and quinine sulfate ($\Phi = 0.546$ in 1N H_2SO_4) were used as standards for the Eu^{3+} and Tb^{3+} complexes, respectively; experimental error ~30%.

studies,[6,24] complex formation was proven by the red shift of the ligand absorption bands upon addition of the chloride salts of Eu^{3+} and Tb^{3+}, and by the analogy between the absorption spectra and the metal-luminescence excitation spectra upon ligand excitation. This analogy indicates that ligand-to-metal energy transfer occurs upon excitation in the ligand-centered absorption bands and that, in the case of the complexes of ligands **4a–c**, both bipyridines are involved in the ligand-to-metal energy transfer.

Interestingly, the values of the lifetimes of the metal emitting states and of the metal-luminescence quantum yields upon ligand excitation are high for both the Tb^{3+} and Eu^{3+} complexes. This behavior indicates that the nonradiative decay processes commonly observed in Tb^{3+} and Eu^{3+} complexes are not very efficient.[1–3] In particular, in the case of the Tb^{3+} complexes of ligands **2–4**, thermally activated metal-to-ligand back energy transfer may be inhibited because the energy of the lowest ligand triplet excited state (obtained from the ligand phosphorescence in the Gd^{3+} complexes) is rather high, ranging from 22400 to 24000 cm^{-1}. Most interestingly, in the case of the Eu^{3+} complexes nonradiative deactivation of the metal-emitting states by ligand-to-metal charge-transfer states seems to be negligible. For the Eu^{3+} complex of ligand **2**, the lower value of the quantum yield compared with those of the other two Eu^{3+} complexes may be due to a more efficient nonradiative deactivation by ligand-to-metal charge-transfer states, because the smaller polyether ring may lead to major involvement of the oxygen atoms of the calix[4]arene in the binding process. The smaller polyether ring may be also responsible for a less efficient shielding of the metal ion towards water molecules present in the lanthanide salts, which, as is known,[1–3] quench the Eu^{3+} and Tb^{3+} luminescence.

Conclusion

The introduction of one or two bipyridines as pendant arms in calixcrowns led to the synthesis of new ligands that form complexes with excellent photophysical properties. Compared with the Eu^{3+} and Tb^{3+} complexes of more classical 1,3-dialkoxycalixcrowns, the molar absorption coefficients increase significantly because of the presence of the bipyridines; the metal-luminescence quantum yields are in addition very high, not only for the Tb^{3+} but also for the Eu^{3+} complexes. The values of the metal-luminescence intensities are among the highest obtained for Eu^{3+} and Tb^{3+} complexes with encapsulating ligands. We are currently studying the possibility of synthesizing water-soluble lariat calixcrowns in order to apply these results to the development of efficient labels for bioaffinity assays.

Experimental Section

General: Most of the solvents and all the reagents were obtained from commercial suppliers and were used without further purification. DMF was freshly distilled and stored over molecular sieves (4 Å); the acetonitrile used for synthesis was also dried over sieves (3 Å). ^1H and ^{13}C NMR spectra were recorded on Bruker AC100, Bruker AC300, or Bruker AMX400 spectrometers. Chemical shifts are reported as δ values in ppm from tetramethylsilane ($\delta = 0.0$) as an internal standard. Analytical thin-layer chromatography was carried out on silica gel plates (SiO_2, Merck 60 F_{254}). Mass spectra were measured with a FINNIGAN MAT SSQ 710 instrument (CI, CH_4). Infrared spectra were recorded with Perkin–Elmer 298 spectrometer. The optical rotations were measured on a Autopol III Rudolph Research Polimeter. Melting points were obtained for compounds sealed in capillaries under nitrogen on an Electrothermal Apparatus. 25,27-Dimethoxy-*p*-*tert*-butylcalix[4]arene (**23**) was synthesized according to the literature method.[25] The UV/Vis absorption spectra were measured with a Perkin–Elmer Lambda 6 spectrophotometer. The luminescence spectra were obtained with a Perkin–Elmer LS50 spectrofluorimeter. The luminescence decays were acquired on a Perkin–Elmer LS50 spectrofluorimeter and analyzed with a least-squares fitting program. The luminescence quantum yields were obtained by the method described by Haas and Stein;[26] standards were $[Ru(bpy)_3]^{2+}$ ($\Phi = 0.028$ in aerated water)[27] for the Eu^{3+} complex, and quinine sulphate ($\Phi = 0.546$ in H_2SO_4 1N)[28] for the Tb^{3+} complex. The solvent used for the photophysical measurement was CH_3CN (Uvasol, Merck).

(*S*)-1-*O*-Allyl-2,3-*O*-isopropylideneglycerol (22):[21] The alcohol **21** (19.2 g, 145.2 mmol) was slowly added to a suspension of NaH (3.83 g, 159.7 mmol) and allyl bromide (15.1 mL, 174.2 mmol) in dry benzene (80 mL). The reaction mixture was refluxed for 2 h, cooled, and then quenched (CAUTION!) with MeOH. Water was added to this mixture, and the organic phase was separated and dried over $MgSO_4$. The pure allyl ether **22** was obtained after distillation under reduced pressure (20.6 g, 83%). B.p. 100 °C (100 mmHg); $[\alpha]^{25}_{546} = +19.5$ ($c = 0.011$, $CHCl_3$) (ref. [22]: $[\alpha]^{25}_{546} = +19.7$ ($c = 0.026$, $CHCl_3$)); ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 1.32$ (s, 3H; CH_3), 1.38 (s, 3H; CH_3), 3.38–3.48 (m, 2H; C^1HHO or C^3HHO), 3.67–3.71 (m, 1H; $C^1H\mathit{H}O$ or $C^3H\mathit{H}O$), 4.00 (m, 3H; $OC\mathit{H}_2CH{=}CH_2$, $C^1H\mathit{H}O$ or $C^3H\mathit{H}O$), 4.22 (m, 1H; $C^2\mathit{H}O$), 5.20 (m, 1H; $CH{=}C\mathit{H}H$), 5.26 (m, 1H; $CH{=}CH\mathit{H}$), 5.85 (m, 1H; $C\mathit{H}{=}CH_2$); MS (CI, CH_4): *m*/*z* (%): 172.3 (10) $[M]^+$; $C_9H_{16}O_3$ (172.22): calcd C 62.77, H 9.36; found C 62.69, H 9.42.

(*R*)-3-*O*-Allylglycerol [(*R*)-11]:[22] A solution of compound **22** (20.6 g, 119.7 mmol) in a mixture of methanol (140 mL) and HCl (1N, 5 mL) was refluxed for 1 h. After cooling, the reaction mixture was slowly neutralized with aqueous $NaHCO_3$ and then evaporated to dryness. The residue was dried by azeotropic distillation of benzene. The pure deprotected glycerol (*R*)-**11** was obtained by distillation under reduced pressure (12.3 g, 78%). B.p. 104–106 °C (0.1 mmHg); $[\alpha]^{25}_{589} = +0.6$ ($c = 0.026$, pyridine), (ref. [22]: $[\alpha]^{25}_{589} = +0.6$ ($c = 0.017$, pyridine)); ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 3.40$–3.96 (m, 7H; $C^1\mathit{H}_2OH$, $C^2\mathit{H}O\mathit{H}$, $C^3\mathit{H}_2O$), 4.07 (m, 2H;

$OCH_2CH{=}CH_2$), 5.13 (dd, $^3J = 10.5$ Hz, $^2J = 1.5$ Hz, 1H; CH=CHH), 5.21 (dd, $^3J = 17.2$ Hz, $^2J = 1.5$ Hz, 1H; CH=CHH), 5.84 (ddt, $^3J = 17.2$ Hz, $^3J = 10.5$ Hz, $^3J = 5.5$ Hz, 1H; $CH{=}CH_2$); $C_6H_{12}O_3$ (132.16): calcd C 54.53, H 9.15; found C 54.57, H 9.08.

(*S*)-1-*O*-Trityl-3-*O*-allyl-glycerol [(*S*)-12]: Tritylchloride (18.56 g, 66.6 mmol) and triethylamine (9.26 mL, 66.6 mmol) were added to a solution of (*R*)-**11** (8.8 g, 66.6 mmol) in CH_2Cl_2 (140 mL). The reaction mixture was refluxed for 1 h, cooled, and then quenched with diisopropyl ether (70 mL) and water (70 mL). The organic phase was separated, and the aqueous one extracted with diisopropyl ether (2 × 70 mL). After the combined ethereal extracts had been dried over Na_2SO_4, the solvent was distilled off and the residue was chromatographed (SiO_2: *n*-hexane/diethyl ether, 9:1 to 8:2). The product was crystallized from *n*-hexane (21.2 g, 85%). M.p. 58–59 °C (ref. [22]: 58 °C); $[\alpha]^{25}_{546} = -5$ ($c = 0.014$, $CHCl_3$) (ref. [22]: $[\alpha]^{25}_{546} = -5$ ($c = 0.013$, $CHCl_3$)).

1-*O*-Trityl-3-*O*-allyl-glycerol [(*dl*)-12]: The synthesis was carried out as for compound (*R*)-**12** by starting from the commercially available alcohol (*dl*)-**11**. M.p. 76–77 °C (ref. [16]: 75 °C); ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 2.50$ (d, $^3J = 4.7$ Hz, 1H; OH), 3.15–3.25 (m, 2H; C^1H_2O or C^3H_2O), 3.47–3.60 (m, 2H; C^1H_2O or C^3H_2O), 3.92–4.05 (m, 3H; $OCH_2CH{=}CH_2$, C^2H), 5.18 (dd, $^3J = 10.4$ Hz, $^2J = 1.6$ Hz, 1H; CH=CHH), 5.25 (dd, $^3J = 17.2$ Hz, $^2J = 1.8$ Hz, 1H; CH=CHH), 5.89 (ddt, $^3J = 17.1$ Hz, $^3J = 10.4$ Hz, $^3J = 6.7$ Hz, 1H; $CH{=}CH_2$), 7.15–7.55 (m, 15H; ArH); MS (CI, CH_4): *m*/*z* (%): 374.4 (5) $[M]^+$, 243.4 (100) $[Tr]^+$; $C_{25}H_{26}O_3$ (374.48): calcd C 80.18, H 6.99; found C 80.09, H 7.02.

General procedure for the synthesis of oligoethylene glycol monotrityl ethers 7 and 8: Trityl chloride (50.5 g, 0.18 mol) was added to a solution of glycol (diethylene glycol **5**: 260 mL, 2.7 mol; or triethylene glycol **6**: 363 mL, 2.7 mol) and pyridine (22 mL, 0.27 mol), which was then heated at 40 °C under nitrogen. The reaction mixture was stirred for 16 h and then extracted with toluene (3 × 250 mL). The combined organic solution was washed with H_2O (5 × 100 mL) and dried over Na_2SO_4. The toluene was removed under reduced pressure to give a residue which was purified as described below.

7,7,7-Triphenyl-3,6-dioxaheptanol (7): Pure compound **7** (46.9 g; 75%) was obtained by crystallization first from CH_2Cl_2 and then from a mixture of ethyl acetate and hexane. M.p. 113–114 °C (ref. [18]: 112.7–114.5 °C); ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 2.43$ (brs, 1H; OH), 3.31 (t, $^3J = 5.3$ Hz, 2H; CH_2OTr), 3.60–3.76 (m, 6H; $HOCH_2CH_2OCH_2$), 7.15–7.35 (m, 9H; Ar-H), 7.42–7.53 (m, 6H; Ar-H); MS (CI, CH_4): *m*/*z* (%): 348.6 (4) $[M]^+$, 243.4 (100) $[Tr]^+$; $C_{23}H_{24}O_3$ (348.44): calcd C 79.28, H 6.94; found C 79.23, H 7.00.

10,10,10-Triphenyl-3,6,9-trioxadecanol (8): The product **8** was obtained as a yellowish oil (58.3 g, 82%) and used without further purification in the subsequent reaction. Distillation of this oil at 0.3 mmHg brings about partial decomposition of the product. An analytically pure sample was therefore obtained by preparative thin-layer chromatography (SiO_2: $CHCl_3$/MeOH, 95:5). ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 1.68$ (brs, 1H; OH), 3.26 (t, $^3J = 5.1$ Hz, 2H; CH_2OTr), 3.60–3.74 (m, 10H; $HOCH_2CH_2OCH_2CH_2OCH_2$), 7.18–7.33 (m, 9H; Ar-H), 7.43–7.48 (m, 6H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 61.3$, 63.0 (t, CH_2OH; CH_2OTr), 70.1, 70.32, 70.45, 72.30 (t, $CH_2OCH_2CH_2OCH_2$), 86.3 (s, CPh_3), 126.6, 127.4, 128.4 (d, Ar), 143.8 (s, Ar); MS (CI, CH_4): *m*/*z* (%): 392.7 (2) $[M]^+$, 243.4 (100) $[Tr]^+$; $C_{25}H_{28}O_4$ (392.49): calcd C 76.50, H 7.19; found C 76.44, H 7.24.

General procedure for the synthesis of the oligoethylene glycol monotrityl ether monotosylates 9 and 10: A solution of tosyl chloride (2.10 g, 11.0 mmol) in dry CH_2Cl_2 (20 mL) was slowly added over 30 min to a solution of monotrityl glycol (compound **7**: 3.66 g, 10.5 mmol; compound **8**: 4.12 g, 10.5 mmol) in dry CH_2Cl_2 (20 mL) and triethylamine (5 mL) at 0 °C. The reaction mixture was stirred overnight at RT and then extracted with a saturated aqueous solution of K_2CO_3 (2 × 50 mL) and H_2O (2 × 50 mL). After the organic phase had been dried over Na_2SO_4, the dichloromethane was distilled off, and the residue was purified by column chromatography.

7,7,7-Triphenyl-3,6-dioxaheptyl-*p*-toluenesulfonate (9): After purification by chromatography (SiO_2: *n*-hexane/diethyl ether, 2:1), compound **9** was crystallized from diethyl ether (4.12 g, 78%). M.p. 90–91 °C; ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 2.41$ (s, 3H; CH_3-Ar), 3.20 (t, $^3J = 5.2$ Hz, 2H; CH_2OTr), 3.60 (t, $^3J = 4.7$ Hz, 2H; $TsOCH_2CH_2$), 3.73 (t, $^3J = 5.2$ Hz, 2H; CH_2CH_2OTr), 4.20 (t, $^3J = 4.7$ Hz, 2H; $TsOCH_2$), 7.23–7.31 (m, 11H; Ar-H), 7.43–7.47 (m, 6H; Ar-H), 7.80 (d, $^3J = 8.4$ Hz, 2H; Ar-H); MS (CI, CH_4): *m*/*z* (%): 502.9 (5) $[M]^+$, 243.4 (100) $[Tr]^+$; $C_{30}H_{30}O_5S$ (502.63): calcd C 71.69, H 6.02; found C 71.60, H 6.09.

10,10,10-Triphenyl-3,6,9-trioxadecyl-*p*-toluenesulfonate (10): Pure compound **10** (4.58 g, 80%) was obtained by chromatography (SiO_2 gradient elution: diethyl ether/*n*-hexane 1:9, 1:1, and then pure diethyl ether). M.p. 75–76 °C; ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 2.41$ (s, 3H; CH_3-Ar), 3.27 (t, $^3J = 5.1$ Hz, 2H; CH_2OTr), 3.63 (s, 4H; OCH_2CH_2O), 3.67 (t, $^3J = 5.1$ Hz, 2H; CH_2CH_2OTr or $TsOCH_2CH_2$), 3.73 (t, $^3J = 5.1$ Hz, 2H; CH_2CH_2OTr or $TsOCH_2CH_2$), 4.18 (t, $^3J = 5.1$ Hz, 2H; CH_2OTs), 7.23–7.34 (m, 11H; Ar-H), 7.47–7.52 (m, 6H; Ar-H), 7.80 (d, $^3J = 8.4$ Hz, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 21.5$ (q, CH_3), 63.2, 68.6, 69.2, 70.6, 70.7 (t, OCH_2CH_2O), 86.4 (s, CPh_3), 126.8 (d, Tr-Ar), 127.6 (d, Tr-Ar), 127.8 (d, Ts-Ar), 128.6 (d, Tr-Ar), 129.7 (d, Ts-Ar), 132.9 (s, Ts-Ar), 144.0 (s, Tr-Ar), 144.6 (s, Ts-Ar); MS (CI, CH_4): *m*/*z* (%): 546.8 (1) $[M]^+$, 243.4 (100) $[Tr]^+$; $C_{32}H_{34}O_6S$ (546.68): calcd C 70.31, H 6.27; found C 70.25, H 6.31.

General procedure for the synthesis of 2-allyloxymethyl-3,6-dioxa-1,8-octanediol (13) and 2-allyloxymethyl-3,6,9-trioxa-1,11-undecanediol (14): NaH (50% in mineral oil, 2.14 g, 44.8 mmol) was added to a stirred solution of (*dl*)-**12** (13.95 g, 37.3 mmol) in dry DMF (100 mL). After 30 min, the oligoethylene glycol monotrityl ether monotosylate **9** or **10** (37.3 mmol) was also added, and the reaction mixture was stirred for 17 h at RT. The solvent was removed under vacuum, and the residue quenched (CAUTION!) with water (100 mL). The aqueous phase was subsequently extracted with CH_2Cl_2 (2 × 100 mL), and the combined organic layers were dried over Na_2SO_4. The solution was concentrated to about 100 mL, and then methanol (100 mL) and HCl (36%, 20 mL) were added. The mixture was stirred at RT for 17 h and then neutralized (CAUTION!) with solid $KHCO_3$. The solvents were removed under reduced pressure, after which H_2O (200 mL) added to the residue. Methyltrityl ether was filtered off, and the water was removed from the filtrate under reduced pressure. The residue was treated with CH_2Cl_2 (200 mL), and the inorganic salts were filtered off. The product was obtained as an oil after removal of the solvent under vacuum.

2-Allyloxymethyl-3,6-dioxa-1,8-octanediol (13): The oily residue (6.16 g, 75%) was used directly in the subsequent reaction. ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 3.35$–3.72 (m, 12H; CH_2O-allyl, $HOCH_2CHROCH_2CH_2OCH_2CH_2OH$), 3.72–3.85 (m, 1H; $CHCH_2O$-allyl), 3.86–3.98 (m, 2H; $OCH_2CH{=}CH_2$), 5.05–5.27 (m, 2H; $CH{=}CH_2$), 5.72–5.90 (m, 1H; $CH{=}CH_2$); MS (CI, CH_4): *m*/*z* (%): 221.4 (100) $[M+H]^+$; $C_{10}H_{20}O_5$ (220.27): calcd C 54.53, H 9.15; found C 54.46, H 9.20.

2-Allyloxymethyl-3,6,9-trioxa-1,11-undecanediol (14): Pure product **14** (6.98 g, 71%) was obtained after distillation under reduced pressure. B.p. 176–178 °C (0.8 mmHg); ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 3.38$–3.75 (m, 16H; CH_2O-allyl, $HOCH_2CHRO(CH_2CH_2O)_3H$), 3.86–3.97 (m, 3H; $OCH_2CH{=}CH_2$, $CHCH_2O$-allyl), 4.05 (brs, 1H; OH), 4.22 (brs, 1H; OH), 5.15, 5.24 (m, 2H; $CH{=}CH_2$), 5.86 (m, 1H; $CH{=}CH_2$); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 61.6$, 62.4 (t, CH_2OH), 69.5, 69.9, 70.2, 70.5, 70.7, 72.3, 73.2 (t, $(OCH_2CH_2)_2OCH_2$, $CHCH_2OCH_2CH{=}$), 80.5 (d, $CHCH_2O$-allyl), 117.1 (t, $CH{=}CH_2$), 134.5 (d, $CH{=}CH_2$); MS (CI, CH_4): *m*/*z* (%): 265.5 (100) $[M+H]^+$; $C_{12}H_{24}O_6$ (264.32): calcd C 54.53, H 9.15; found C 54.48, H 9.22.

General procedure for the synthesis of 2-allyloxymethyl-1,8-bis(tosyloxy)-3,6-dioxaoctane (15) and 2-allyloxymethyl-1,11-bis(tosyloxy)-3,6,9-trioxa-undecane (16): A solution of TsCl (7.8 g, 41 mmol) in dry CH_2Cl_2 (100 mL) was added dropwise over a period of 30 min to a stirred solution of compound **13** or **14** (20.4 mmol), NEt_3 (14.2 mL, 102 mmol), and a catalytic amount of DMAP in dry CH_2Cl_2 (150 mL) at 0 °C. After one night of stirring at RT, the reaction was quenched with H_2O (200 mL) and the organic phase was washed to the point of neutrality. The dichloromethane solution was dried over Na_2SO_4, and the solvent was removed under vacuum.

2-Allyloxymethyl-1,8-bis(tosyloxy)-3,6-dioxaoctane (15): Pure compound **15** was obtained (8.86 g, 82%) as a colorless oil after column chromatography (SiO_2: gradient CH_2Cl_2 to CH_2Cl_2/MeOH, 98:2). ^1H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 2.41$ (s, 6H; CH_3-Ar), 3.38–3.70 (m, 9H; $OCH_2CH_2OCH_2$, $CHCH_2O$-allyl), 3.88 (m, 2H; OCH_2CH_2OTs), 4.01 (dd, $^2J = 10.4$ Hz, $^3J = 6.1$ Hz, 1H; $TsOCHHCHCH_2O$-allyl), 4.11 (dd, $^2J = 10.2$ Hz, $^3J = 6.0$ Hz, 1H; $TsOCHHCHCH_2O$-allyl), 4.12 (m, 2H; $OCH_2CH{=}CH_2$), 5.09–5.21 (m, 2H; $CH{=}CH_2$), 5.71–5.84 (m, 1H;

$CH{=}CH_2$), 7.31 (d, $^3J = 8.3$ Hz, 4H; Ar-H), 7.75 (d, $^3J = 8.4$ Hz, 2H; Ar-H), 7.76 (d, $^3J = 8.3$ Hz, 2H; Ar-H); MS (CI, CH_4): m/z (%): 529.0 (40) $[M]^+$; $C_{24}H_{32}O_9S_2$ (528.64): calcd C 54.53, H 6.10; found C 54.45, H 6.16.

2-Allyloxymethyl-1,11-bis(tosyloxy)-3,6,9-trioxaundecane (16): Pure compound **16** was obtained (10.18 g, 87%) as a colorless oil after column chromatography (SiO_2: $CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$, 300 K): $\delta =$ 3.30–3.72 (m, 13H; $(OCH_2CH_2)_2OCH_2$, $CH(CH_2O)$allyl), 3.88 (d, $^3J =$ 6 Hz, 2H; $TsOCH_2$), 4.02 (dd, $^2J = 10.0$ Hz, $^3J = 6.0$ Hz, 1H; TsOCH*H*CH-CH_2O-allyl), 4.12 (dd, $^2J = 10.0$ Hz, $^3J = 6.0$ Hz, 1H; TsOC*H*HCHCH_2O-allyl), 4.13 (m, 2H; $OCH_2CH{=}CH_2$), 5.12–5.20 (m, 2H; $CH{=}CH_2$), 5.72–5.83 (m, 1H; $CH{=}CH_2$), 7.31 (d, $^3J = 8.1$ Hz, 4H; Ar-H), 7.75 (d, $^3J = 8.4$ Hz, 2H; Ar-H), 7.76 (d, $^3J = 8.1$ Hz, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 21.4$ (q, CH_3Ar), 68.6, 69.2, 69.5, 70.0, 70.5, 70.7, 72.3 (t, $CHCH_2OCH_2CH{=}$, $CH_2CHR(OCH_2CH_2)_3$), 76.7 (d, $CHCH_2O$-allyl), 117.1 (t, $CH{=}CH_2$), 127.9, 129.8 (d, Ar), 132.8, 133.0 (s, Ar), 134.3 (d, $CH{=}CH_2$), 144.8 (s, Ar); MS (CI, CH_4): m/z (%): 573.1 (10) $[M+H]^+$; $C_{26}H_{36}O_{10}S_2$ (572.69): calcd C 54.53, H 6.34; found C 54.44, H 6.41.

Synthesis of 2,10-bis(allyloxymethyl)-3,6,9-trioxa-1,11-undecanediols (18a,b): A solution of (dl)-**12** (5.42 g, 14.5 mmol) and NaH (50% in mineral oil, 1.39 g, 30 mmol) in dry DMF (50 mL) was stirred for 30 min at RT, after which time the ditosylate **17** (3 g, 7.1 mmol) was added. The mixture was stirred for 48 h and the solvent was then distilled under reduced pressure. The residue was treated (CAUTION!) with H_2O (50 mL) and CH_2Cl_2 (50 mL). The organic layer was separated, and the water phase was extracted with CH_2Cl_2 (50 mL). After the combined organic phases had been dried over Na_2SO_4, the solvent was distilled off. This crude product was dissolved in a mixture of CH_2Cl_2/MeOH (1:1, 60 mL), and HCl (36%, 5 mL) was then added. This solution was stirred for 48 h at RT and subsequently neutralized (CAUTION!) with solid $KHCO_3$. After removal of the solvents under vacuum, the residue was treated with H_2O (50 mL), and the resulting precipitate was filtered off. After the water had been removed from the aqueous filtrate, and the residue had been taken up with CH_2Cl_2 (50 mL), the white precipitate was filtered off. After removal of dichloromethane from the filtrate, a yellowish oil (1.83 g, 76%) was obtained. ^{1}H NMR (100 MHz, $CDCl_3$, 300 K): $\delta = 3.35$–4.11 (m, 24H; $HOCH_2CHR(OCH_2CH_2)_2OCHRCH_2OH$; $CHCH_2O$-allyl, $OCH_2CH{=}CH_2$), 5.00–5.26 (m, 4H; $CH{=}CH_2$), 5.62–6.00 (m, 2H; $CH{=}CH_2$); MS (CI, CH_4): m/z (%): 335.3 (100) $[M+H]^+$; $C_{16}H_{30}O_7$ (334.41): calcd C 57.47, H 9.04; found C 57.40, H 9.12.

2*R*-10*R*-Bis(allyloxymethyl)-3,6,9-trioxa-1,11-undecanediol (18c): The synthetic route is analogous to that for compounds **18a,b**, but starts from alcohol (S)-**12**. The product **18c** shows the same physical and spectroscopic properties as **18a,b**. $[\alpha]^{25}_{589} = +28.4$ ($c = 0.0183$, $CHCl_3$).

2,10-Bis(allyloxymethyl)-1,11-bis(tosyloxy)-3,6,9-trioxaundecanes (19a,b): A solution of TsCl (2.09 g, 10.9 mmol) in CH_2Cl_2 (30 mL) was added dropwise over a period of 30 min to a solution of the dialcohol **18a,b** (1.83 g, 5.5 mmol), NEt_3 (4.6 mL, 32.8 mmol), and DMAP in dry CH_2Cl_2 (30 mL) at 0°C. The reaction mixture was stirred at RT for 24 h. The dichloromethane solution was then extracted with water (2 × 30 mL) and dried over $MgSO_4$. The solvent was then removed, and pure ditosylate **19a,b** (3.10 g, 88%) was obtained after column chromatography (SiO_2: elution gradient CH_2Cl_2–CH_2Cl_2/MeOH, 99:1). ^{1}H NMR (100 MHz, $CDCl_3$, 300 K): $\delta = 2.39$ (s, 6H; CH_3-Ar), 3.31–4.15 (m, 22H; $TsOCH_2$-$CHR(OCH_2CH_2)_2OCHRCH_2O$, $CHCH_2O$-allyl, $OCH_2CH{=}CH_2$), 5.03–5.26 (m, 4H; $CH{=}CH_2$), 5.55–6.95 (m, 2H; $CH{=}CH_2$), 7.30 (d, $^3J =$ 8.0 Hz, 4H; Ar-H), 7.74 (d, $^3J = 8.2$ Hz, 4H; Ar-H); MS (CI, CH_4): m/z (%): 643.2 (20) $[M+H]^+$, 489 (100) $[(M-Ts)]^+$; $C_{30}H_{42}O_{11}S_2$ (642.78): calcd C 56.06, H 6.59; found C 56.11, H 6.53.

2*S*-10*S*-Bis(allyloxymethyl)-1,11-bis(tosyloxy)-3,6,9-trioxaundecane (19c): The synthesis was carried out in the same way as for ditosylate **19a,b** by starting from the dialcohol **18c**. The product shows the same physical and spectroscopic properties as the racemic **19a,b**. $[\alpha]^{25}_{589} = +6.8$ ($c = 0.0147$, $CHCl_3$).

General procedure for the synthesis of 25,27-dimethoxy-*p*-*tert*-butylcalix[4]arene-26,28-allyloxymethyl-crown-4 (24) and -crown-5 (25), (26a,b), (26c): A solution of dimethoxy-*p*-*tert*-butylcalix[4]arene **23** (1.28 g, 1.9 mmol), Cs_2CO_3 (2.46 g, 7.6 mmol), and ditosylate **15**, **16**, **19a,b**, or **19c** (2.0 mmol) in CH_3CN (350 mL) was refluxed for 3 days. The acetonitrile was then removed under reduced pressure and the residue was taken up in CH_2Cl_2 (100 mL) and HCl (10%, 100 mL). The organic phase was separated and washed with water. After removal of dichloromethane, the residue was crystallized from MeOH to give compounds **24**, **25**, **26a,b**, or **26c** as white solids.

25,27-Dimethoxy-*p*-*tert*-butylcalix[4]arene-26,28-(2-allyloxymethyl)-crown-4 (24): Yield = 1.11 g (68%); m.p. 192–193°C; ^{1}H NMR (300 MHz, $CDCl_3$, 300 K, mixture of *partial cone*, *1,3-alternate* and *cone* conformers): $\delta = 0.81$, 0.84, 1.00, 1.03, 1.09, 1.13, 1.28, 1.29, 1.30, 1.31, 1.33, 1.34, 1.37 (s, 9H; $C(CH_3)_3$), 2.92, 2.82 (s, 3H; OCH_3), 4.05–3.10 (m, 26H; H_{ax}, OCH_3, $CH_2OCH_2CH{=}$, $ArOCH_2CHRO(CH_2CH_2O)_2Ar$, H_{eq}), 5.10–5.35 (m, 2H; $CH{=}CH_2$), 5.80–5.98 (m, 1H; $CH{=}CH_2$), 6.90–7.16 (m, 8H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 30.4$ (t, $ArCH_2Ar$, *cone*), 30.6, 31.0, 31.1, 31.3, 31.4, 31.5, 31.6 (q, $C(CH_3)_3$), 33.7, 34.0 (s, $C(CH_3)_3$), 38.3, 38.6, 38.8, 39.7 (t, $ArCH_2Ar$, *pc*, *1,3-alt*), 57.7, 58.1, 58.5 (q, OCH_3, *pc*, *1,3-alt*), 62.2 (q, OCH_3; *cone*), 68.0, 68.7, 69.1, 69.3, 69.5, 70.0, 71.2, 72.1, 72.3, 73.0, 75.9 (t, $CH_2CHRO(CH_2CH_2O)_2$, $CHCH_2OCH_2CH{=}$), 79.5 (d, CH_2CHRO), 116.3, 116.8 (t, $CH{=}CH_2$), 124.6, 125.3, 125.5, 125.6, 125.9, 126.0, 126.2, 126.4, 127.2 (d, *m*-Ar), 133.0, 133.2, 133.4, 133.8 (s, *o*-Ar), 134.2 (d, $CH{=}CH_2$), 144.1, 144.2, 144.5 (s, *p*-Ar), 154.1, 155.4, 155.5 (s, *i*-Ar); MS (CI, CH_4): m/z (%): 861.3 (100) $[M+H]^+$; $C_{56}H_{76}O_7$ (861.22): calcd C 78.10, H 8.89; found C 78.01, H 8.96.

25,27-Dimethoxy-*p*-*tert*-butylcalix[4]arene-26,28-(2-allyloxymethyl)-crown-5 (25): Yield = 71%; m.p. 250–254°C (MeOH); ^{1}H NMR (300 MHz, $CDCl_3$, 300 K): $\delta = 0.86$ (s, 9H; $C(CH_3)_3$), 0.89 (s, 9H; $C(CH_3)_3$), 1.36 (s, 9H; $C(CH_3)_3$), 1.37 (s, 9H; $C(CH_3)_3$), 3.17, 3.18 (d, $^2J =$ 12.0 Hz, 4H; H_{eq}), 3.45–4.50 (m, 29H; H_{ax}, OCH_3, $CH_2OCH_2CH{=}$, $ArOCH_2CHR(OCH_2CH_2)_3OAr$), 5.19, 5.27 (m, 2H; $CH{=}CH_2$), 5.89 (m, 1H; $CH{=}CH_2$), 6.53 (s, 2H; Ar-H), 6.58 (s, 2H; Ar-H), 7.13 (s, 2H; Ar-H), 7.15 (s, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 31.1$ (q, $C(CH_3)_3$), 31.5 (t, $ArCH_2Ar$), 31.7 (q, $C(CH_3)_3$), 33.5, 34.1 (s, $C(CH_3)_3$), 60.8, 61.2 (q, OCH_3), 69.2, 69.7, 70.9, 71.1, 71.2, 71.4, 72.4, 72.9, 75.7 (t, $CH_2CHR(OCH_2CH_2)_3$, $CHCH_2OCH_2CH{=}$), 79.1 (d, CH_2CHRO), 117.2 (t, $CH{=}CH_2$), 124.4, 124.8, 124.9 (d, *m*-Ar), 132.1, 132.5, 132.6 (s, *o*-Ar), 134.5 ($CH{=}CH_2$), 135.7, 135.9 (s, *o*-Ar), 144.1, 144.2, 144.6, 144.8 (s, *p*-Ar), 153.0, 153.4, 156.4, 157.0 (*i*-Ar); MS (CI, CH_4): m/z (%): 905.3 (100) $[M+H]^+$; $C_{58}H_{80}O_8$ (905.27): calcd C 76.95, H 8.91; found C 76.85, H 8.88.

25,27-Dimethoxy-*p*-*tert*-butylcalix[4]arene-26,28-[2,10-bis(allyloxymethyl)]-crown-5 (26):

(26a,b): Yield = 72%; m.p. 201–204°C (MeOH); ^{1}H NMR (400 MHz, $CDCl_3$, 300 K): $\delta = 0.85$ (s, 18H; $C(CH_3)_3$), 1.36, 1.38 (s, 9H; $C(CH_3)_3$), 3.12–3.25 (m, 4H; H_{eq}), 3.45–4.18 (m, 28H; OCH_3, $ArOCH_2$-$CHROCH_2CH_2$, $CH_2OCH_2CH{=}$), 3.20–4.51 (m, 4H; H_{ax}), 5.17–5.30 (m, 4H; $CH{=}CH_2$), 5.84–5.95 (m, 2H; $CH{=}CH_2$), 6.53 (brs, 4H; CH_3OAr-H), 7.12, 7.13, 7.14, 7.15 (s, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 31.1$ (q, $C(CH_3)_3$), 31.6 (t, $ArCH_2Ar$), 31.7 (q, $C(CH_3)_3$), 33.5, 34.1 (s, $C(CH_3)_3$), 61.2, 61.4 (q, OCH_3), 69.0, 69.1, 69.5, 70.2, 70.5, 71.3, 72.4, 75.7, 75.8 (t, $CH_2CHROCH_2CH_2$, $CHCH_2OCH_2CH{=}$), 78.6, 79.5 (d, CHRO), 117.18, 117.23 (t, $CH{=}CH_2$), 124.5, 124.8, 125.0, 125.1 (d, *m*-Ar), 132.0, 132.2, 132.5, 132.8 (s, *o*-Ar), 134.6 ($CH{=}CH_2$), 135.7, 135.9 (s, *o*-Ar), 144.2, 144.5, 144.8 (*p*-Ar), 153.5, 156.1, 156.2 (*i*-Ar); MS (CI, CH_4): m/z (%): 974.5 (100) $[M]^+$; $C_{62}H_{86}O_9$ (975.37): calcd C 76.35, H 8.89; found C 76.28, H 8.95.

(26c): Yield = 70%; m.p. 169–171°C (MeOH); $[\alpha]^{25}_{589} = +12.7$ ($c = 0.0126$, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$, 300 K): $\delta = 0.83$ (s, 18H; $C(CH_3)_3$), 1.35 (s, 18H; $C(CH_3)_3$), 3.15 (d, $^2J = 12.4$ Hz, 2H; H_{eq}), 3.17 (d, $^2J = 12.5$ Hz, 2H; H_{eq}), 3.14–4.50 (m, 28H; $OCH_2CHROCH_2CH_2$, $CHCH_2OCH_2CH{=}$, OCH_3), 4.33 (d, $^2J = 12.4$ Hz, 2H; H_{ax}), 4.40 (d, $^2J = 12.7$ Hz, 2H; H_{ax}), 5.18 (d, $^3J = 10.3$ Hz, 2H; CH=C*H*H), 5.25 (d, $^3J = 17.2$ Hz, 2H; CH=CH*H*), 5.88 (ddt, $^3J = 17.2$ Hz, $^3J = 10.3$ Hz, $^3J = 5.5$ Hz, 2H; $CH{=}CH_2$), 6.55 (s, 4H; Ar-H), 7.15 (s, 4H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta =$ 31.0, 31.1, 31.4, 31.6, 31.7 (t, $ArCH_2Ar$, q, $C(CH_3)_3$), 33.5, 34.1 (s, $C(CH_3)_3$), 61.2, 61.4 (q, OCH_3), 69.0, 69.5, 69.6, 69.7, 70.5, 72.4, 75.6 ($CH_2CHROCH_2CH_2$, $CHCH_2OCH_2CH{=}$), 78.6 (d, CHRO), 117.2 (t, $CH{=}CH_2$), 124.4, 124.5, 124.7, 124.9, 125.1, 125.4 (d, *m*-Ar), 132.2, 132.5 (s, *o*-Ar), 134.6 (d, $CH{=}CH_2$), 135.9 (s, *o*-Ar), 144.2, 144.5 (s, *p*-Ar), 153.4, 156.2 (s, *i*-Ar); MS (CI, CH_4): m/z (%): 974.5 (100) $[M]^+$; $C_{62}H_{86}O_9$ (975.37): calcd C 76.35, H 8.89; found C 76.30, H 8.93.

General procedure for the synthesis of 25,27-dimethoxy-*p*-*tert*-butylcalix[4]arene-26,28-hydroxymethyl-crown-4 (27) and -crown-5 (28), (29a,b), (29c): A suspension of the appropriate allyloxymethyl derivative **24**, **25**, **26a,b**, or **26c** (1.4 mmol), Pd/C (100 mg), and TsOH (240 mg, 1.4 mmol) in a mixture of ethanol/H_2O (20:1, 60 mL) was heated to reflux. After 15–18 h, the solvent was removed under reduced pressure.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-(2-hydroxymethyl)-crown-4 (27): The residue was treated with CH_2Cl_2/MeOH (10:1, 100 mL) and filtered on celite. The solvents were distilled under vacuum to give a white solid of the 1:1 complex between compound **27** and TsOH. Yield = 70%; ^1H NMR (400 MHz, $CDCl_3$, 300 K): δ = 1.06 (s, 18H; $C(CH_3)_3$), 1.18, 1.19 (s, 9H; $C(CH_3)_3$), 2.04 (brs, 1H; OH), 2.30 (s, 3H; CH_3Ar), 3.37 (d, ^2J = 12.8 Hz, 1H; H_{eq}), 3.39 (d, ^2J = 12.2 Hz, 1H; H_{eq}), 3.41 (d, ^2J = 12.7 Hz, 2H; H_{eq}), 3.68–4.70 (m, 17H; ArOC*H*$_2$C*H*R(OC*H*$_2$C*H*$_2$)OAr, C*H*$_2$OH; H_{ax}), 6.92–7.25 (m, 10H; Ar-H), 7.81 (d, ^3J = 8.0 Hz, 2H; TsH); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 21.2 (q, Ts*C*H$_3$), 30.0, 30.3, 30.4, 31.1, 31.3, 31.4 (q, C(*C*H$_3$)$_3$; t, ArCH$_2$Ar), 34.0, 34.1, 34.2 (s, *C*(CH$_3$)$_3$), 59.7, 64.0, 64.1 (q, OCH$_3$), 67.8, 70.0, 71.0, 73.7, 76.4 (t, *C*H$_2$CHR(O*C*H$_2$*C*H$_2$)$_2$), 80.0 (d, *C*HRO), 125.7, 125.8, 126.1, 126.2 (d, *m*-Ar), 128.6 (d, Ts) 133.7, 133.8, 134.0, 134.3, 134.4, 134.5 (s, *o*-Ar), 138.7 (s, Ts), 147.9, 148.1, 148.4 (s, *p*-Ar), 149.6, 149.7, 155.0 (s, *i*-Ar); MS (CI, CH_4): *m*/*z* (%): 821.3 (100) $[M+H]^+$; $C_{53}H_{72}O_7 \cdot C_7H_8O_3S$ (993.35): calcd C 72.55, H 8.12; found C 72.40, H 7.99.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-(2-hydroxymethyl)-crown-5 (28): Pure compound **28** was obtained by column chromatography (SiO_2, $CHCl_3$/MeOH, 95:5). Yield = 71%; m.p. 277–279 °C; ^1H NMR (300 MHz, $CDCl_3$, 300 K): δ = 0.88 (s, 9H; $C(CH_3)_3$), 0.92 (s, 9H; $C(CH_3)_3$), 1.25 (s, 9H; $C(CH_3)_3$), 1.26 (s, 9H; $C(CH_3)_3$), 2.00 (brs, 1H; OH), 3.14, 3.17 (d, ^2J = 11.0 Hz, 2H; H_{eq}), 3.53–4.37 (m, 27H; ArOC*H*$_2$-C*H*R(OC*H*$_2$C*H*$_2$)$_3$OAr, OCH$_3$, C*H*$_2$OH; H_{ax}), 6.58 (s, 2H; Ar-H), 6.63 (s, 2H; Ar-H), 7.01 (s, 2H; Ar-H), 7.02 (s, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 31.2, 31.7 (q, C(*C*H$_3$)$_3$; t, ArCH$_2$Ar), 33.6, 34.1 (s, *C*(CH$_3$)$_3$), 60.9, 61.3 (q, OCH$_3$), 61.9 (t, CH$_2$OH), 69.4, 71.2, 71.3, 72.9, 75.2 (t, *C*H$_2$CHRO(*C*H$_2$*C*H$_2$O)$_3$), 80.2 (*C*HRO), 124.7, 125.0 (d, *m*-Ar), 132.4, 132.9, 135.2 (s, *o*-Ar), 144.5, 144.7 (s, *p*-Ar), 153.4, 155.6, 155.8 (s, *i*-Ar); MS (CI, CH_4): *m*/*z* (%): 865.1 (100) $[M+H]^+$; $C_{55}H_{76}O_8$ (865.21): calcd C 76.35, H 8.85; found C 76.24, H 8.97.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-]2,10-bis(hydroxymethyl)]-crown-5 (29a,b): Pure compounds **29a,b** were obtained by column chromatography on SiO_2 with $CHCl_3$/MeOH (10:1) as eluent. Yield = 64%; m.p. > 300 °C; ^1H NMR (400 MHz, $CDCl_3$, 300 K): δ = 0.91 (s, 9H; $C(CH_3)_3$), 1.00 (s, 9H; $C(CH_3)_3$), 1.22 (s, 9H; $C(CH_3)_3$), 1.32, 1.33 (s, 9H; $C(CH_3)_3$), 2.07, 2.28 (brs, 2H; OH), 3.18–3.27 (m, 4H; H_{eq}), 3.59–4.52 (m, 28H; ArC*H*$_2$C*H*ROC*H*$_2$C*H*$_2$, CHC*H*$_2$OH, OCH$_3$, H_{ax}), 6.59 (brs, 2H; CH$_3$OAr-*H*), 6.72 (s, 2H; Ar-H), 6.97, 6.98 (s, 2H; Ar-H), 7.09, 7.10 (s, 2H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 31.1, 31.2, 31.6 (q, C(*C*H$_3$)$_3$; t, ArCH$_2$Ar), 33.6, 33.7, 34.0, 34.1 (s, *C*(CH$_3$)$_3$), 61.1, 61.6 (q, OCH$_3$), 61.5, 62.2 (t, CH$_2$OH), 68.7, 69.7, 70.8, 71.2, 75.0, 75.2 (t, ArO*C*H$_2$CHRO*C*H$_2$*C*H$_2$), 79.9, 80.4 (d, CHRO), 124.7, 124.9, 125.0, 125.2, 125.4 (d, *m*-Ar), 132.1, 132.8, 133.1, 134.4, 134.5, 135.3 (s, *o*-Ar), 144.4, 144.5, 144.8 (s, *p*-Ar), 153.4, 153.5, 155.2, 155.6, 156.1 (s, *i*-Ar); MS (CI, CH_4): *m*/*z* (%): 895.6 (100) $[M+H]^+$; $C_{56}H_{78}O_9$ (895.23): calcd C 75.13, H 8.78; found C 75.04, H 8.85.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-[2,10-bis(hydroxymethyl)]-crown-5 (29c): Pure compound **29c** was obtained by column chromatography on SiO_2 with $CHCl_3$/MeOH (10:1) as eluent. Yield = 65%; m.p. 290–292 °C; $[\alpha]^{25}_{589} = -5.0$ (c = 0.0140, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$, 300 K): δ = 0.96 (s, 18H; $C(CH_3)_3$), 1.21 (s, 18H; $C(CH_3)_3$), 3.20 (d, ^2J = 12.7 Hz, 2H; H_{eq}), 3.23 (d, ^2J = 12.7 Hz, 2H; H_{eq}), 4.29 (d, ^2J = 13.0 Hz, 2H; H_{ax}), 4.34 (d, ^2J = 13.0, 2H; H_{ax}), 3.61–4.36 (m, 24H; ArOC*H*$_2$-C*H*ROC*H*$_2$C*H*$_2$, CHC*H*$_2$OH; OCH$_3$), 6.70 (s, 4H; Ar-H), 6.96 (s, 4H; Ar-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 31.2 and 31.6 (q, C(*C*H$_3$)$_3$); t, ArCH$_2$Ar), 33.7, 34.0 (s, *C*(CH$_3$)$_3$), 61.6, 62.2 (q, OCH$_3$), 68.7, 70.8, 75.0 (O*C*H$_2$CHRO*C*H$_2$*C*H$_2$, CH*C*H$_2$OH), 79.8 (*C*HRO), 124.9, 125.0, 125.2 (d, *m*-Ar), 132.8, 133.1, 134.1, 134.4 (s, *o*-Ar), 144.5, 144.8 (s, *p*-Ar), 153.5, 155.2 (s, *i*-Ar); $C_{56}H_{78}O_9$ (895.23): calcd C 75.13, H 8.78; found C 75.01, H 8.71.

General procedure for the synthesis of 25,27-dimethoxy-*p-tert*-butylcalix[4]arene-26,28-[(2,2′-bipyridine-6-methyl)oxymethyl]crown-4 (2) and -crown-5 (3), (4a,b), (4c): NaH (50% in mineral oil, 18 mg, 0.36 mmol for compounds **27** and **28**; or 36 mg, 0.66 mmol for compounds **29a**,**b** and **29c**) was added at RT to a stirred solution of calix[4]arene-hydromethyl-crown **27**, **28**, **29a**,**b**, or **29c** (0.12 mmol) in dry THF (20 mL). After 15 min, 6-bromomethylbipyridine **30** (30.3 mg, 0.12 mmol for compounds **27** and **28**; or 61 mg, 0.24 mmol for compounds **29a**,**b** and **29c**) was also added, and the reaction mixture was heated at reflux temperature for 12 h. After removal of the solvent under vacuum, the residue was treated with CH_2Cl_2 (50 mL) and washed with H_2O (2 × 50 mL). The organic phase was separated, and the solvent was distilled under vacuum.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-[2-(2,2′-bipyridine-6-methyl)oxy-methyl]crown-4 (2): Reverse-phase (C18) column chromatography (elution gradient CH_3OH/H_2O, 15:1 – CH_3OH – CH_3OH/CH_2Cl_2, 20:1). Yield = 66%; m.p. 113–115 °C; ^1H NMR ($CDCl_3$, 300 MHz, 300 K): the spectrum was quite complex and demonstrated the presence of a mixture of conformations. The following signals were assigned: bpy multiplets at δ = 8.67, 8.36, 8.25, 7.77, 7.45, 7.30; OCH$_2$(bpy) at δ = 4.77 (brs), 4.71(s); and the two singlets of the OCH$_3$ protons at δ = 2.91 and 2.81; ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 29.6 (t, ArCH$_2$Ar c), 31.0, 31.2, 31.3, 31.4, 31.5, 31.6 (q, C(*C*H$_3$)$_3$), 33.8, 34.1 (s, *C*(CH$_3$)$_3$), 38.4, 38.8 (t, ArCH$_2$Ar pc, 1,3-alt), 57.7, 58.0, 58.5 (q, OCH$_3$), 62.2 (q, OCH$_3$), 68.2, 68.6, 69.4, 70.0, 70.3, 71.0, 71.2, 72.1, 73.0, 74.3, 74.5, 75.8 (t, *C*H$_2$CHRO(*C*H$_2$-*C*H$_2$O)$_2$, CH*C*H$_2$O*C*H$_2$bpy), 77.4 (d, CHRO), 119.5, 119.7, 120.9 and 121.2 (d, bpy-3, bpy-3′), 123.6, 123.7, 124.7, 125.7, 125.9, 126.1, 126.2, 127.3 (d, *m*-Ar, bpy-5, bpy-5′), 133.1, 133.3, 133.4, 133.5, 133.8, 133.9 (s, *o*-Ar), 136.9, 137.4 (d, bpy4, bpy-4′), 144.1, 144.4, 144.6 (s, *p*-Ar), 149.1, 149.2 (d, bpy-6′), 154.1, 154.2, 155.3, 155.4, 155.5 (s, *i*-Ar, bpy-2, bpy-2′, bpy-6); MS (CI, CH_4): *m*/*z* (%): 990.2 (100) $[M+H]^+$; $C_{64}H_{80}N_2O_7$ (989.35): calcd C 77.70, H 8.15, N 2.83; found C 77.83, H 8.25, N 2.76. A simpler ^1H NMR spectrum can be obtained by converting compound **2** into its 1:1 NaSCN complex (mainly in the cone structure), by stirring a solution of **2** in $CDCl_3$ with solid NaSCN for 1 night. **2**-NaSCN: ^1H NMR (300 MHz, $CDCl_3$, 300 K, NaSCN complex): δ = 1.04, 1.13, 1.19, 1.20 (s, 9H; $C(CH_3)_3$), 3.35–3.85, 4.15–4.80 (m, 21H; H_{eq}, ArOC*H*$_2$C*H*RO(C*H*$_2$C*H*$_2$O)$_2$, CHC*H*$_2$, H_{ax}), 3.99, 4.03 (s, 3H; OCH$_3$), 4.79 (s, 2H; OCH$_2$bpy), 6.98–7.24 (m, 8H; Ar-H), 7.27 (m, 1H; bpy-5′-H), 7.43 (d, ^3J = 7.7 Hz, 1H; bpy-5-H), 7.75 (ddd, ^3J = 7.5 Hz, ^3J = 7.5 Hz, ^4J = 1.8 Hz, 1H; bpy-4′-H), 7.85 (dd, ^3J = 7.7 Hz, ^3J = 7.7 Hz, 1H; bpy-4-H), 8.28 (d, ^3J = 7.5 Hz, 1H; bpy-3′-H), 8.37 (d, ^3J = 7.7 Hz, 1H; bpy-3-H), 8.65 (d, ^3J = 4.8 Hz, 1H; bpy-6′-H).

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-[2-(2,2′-bipyridine-6-methyl)oxy-methyl]crown-5 (3): Preparative layer chromatography on Al_2O_3 with CH_2Cl_2 as eluent gave compound **3** in a yield of 71%. An analytically pure sample can be obtained by crystallization from CH_3CN. M.p. 182–184 °C; ^1H NMR (300 MHz, $CDCl_3$, 300 K): δ = 0.83, 0.86 (s, 9H; $C(CH_3)_3$), 1.33 (s, 18H; $C(CH_3)_3$), 3.13 (d, ^2J = 13.2 Hz, 2H; H_{eq}), 3.15 (d, ^2J = 13.4 Hz, 2H; H_{eq}), 3.48–4.42 (m, 27H; ArOC*H*$_2$C*H*RO(C*H*$_2$C*H*$_2$O)$_3$, CHC*H*$_2$, OCH$_3$, H_{ax}), 4.70 (d, ^2J = 13.5 Hz, 1H; OC*H*Hbpy), 4.76 (d, ^2J = 13.5 Hz, 1H; OCH*H*bpy), 6.50–6.54 (m, 4H; Ar-H), 7.09 (s, 2H; Ar-H), 7.10 (s, 2H; Ar-H), 7.27 (ddd, ^3J = 7.5 Hz, ^3J = 4.5 Hz, ^4J = 1.2 Hz, 1H; bpy-5′-H), 7.42 (d, ^3J = 7.7 Hz, 1H; bpy-5-H), 7.74 (td, ^3J = 7.5 Hz, ^4J = 1.7 Hz, 1H; bpy-4′-H), 7.80 (dd, ^3J = 7.7 Hz, ^3J = 7.7 Hz, 1H; bpy-4-H), 8.27 (d, ^3J = 7.8 Hz, 1H; bpy-3′-H), 8.37 (d, ^3J = 7.8 Hz, 1H; bpy-3-H), 8.66 (d, ^3J = 4.5 Hz, 1H; bpy-6′-H); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): δ = 31.0 (t, ArCH$_2$Ar), 31.1, 31.7 (q, C(*C*H$_3$)$_3$), 33.6, 34.1 (s, *C*(CH$_3$)$_3$), 60.9, 61.3 (q, OCH$_3$), 69.8, 70.1, 70.9, 71.1, 71.2, 71.4, 72.9, 74.5, 75.6, 76.6 (t, Ar*C*H$_2$-CHR(O*C*H$_2$*C*H$_2$)$_3$), 77.4 (d, CHRO), 79.2 (t, CH$_2$bpy), 119.7 (d, bpy-3), 121.2 (d, bpy-3′), 123.6, 124.5, 124.9, 125.0 (d, *m*-Ar, bpy-5, bpy-5′), 132.2, 132.6, 132.7, 132.9, 135.7, 135.8 (s, *o*-Ar), 136.8 (d, bpy-4′), 137.5 (d, bpy-4), 144.2, 144.3, 144.7 (s, *p*-Ar), 149.2 (d, bpy-6′), 155.5 (s, bpy-2’), 156.0, 156.2 (s, *i*-Ar, bpy-6), 157.9 (s, bpy-2); MS (CI, CH_4): *m*/*z* (%): 1033.5 (100) $[M+H]^+$; $C_{66}H_{84}N_2O_8$ (1033.40): calcd C 76.71, H 8.19, N 2.71; found C 76.81, H 8.24, N 2.75.

25,27-Dimethoxy-*p-tert*-butylcalix[4]arene-26,28-[2,10-bis(2,2′-bipyridine-6-methyl)oxy-methyl]crown-4 (4):
Compounds **4a**,**b** can be obtained from **29a**,**b** in 62% yield after preparative layer chromatography on Al_2O_3 with CH_2Cl_2/MeOH (99:1) as eluent. The *meso* compound (**4a**) (R_f = 0.26) can be separated from the *dl* mixture (**4b**) (R_f = 0.24) by preparative layer chromatography on Al_2O_3 with CH_2Cl_2 as eluent.

meso-**4a**: ^1H NMR (400 MHz, $CDCl_3$, 253 K, *cone*): δ = 0.79 (s, 18H; $C(CH_3)_3$), 1.33 (s, 18H; $C(CH_3)_3$), 3.13 (d, ^2J = 12.1 Hz, 2H; H_{eq}), 3.16 (d, ^2J = 12.0 Hz, 2H; H_{eq}), 3.46–3.78 (m, 16H; ArOCH$_2$CHROC*H*$_2$C*H*$_2$, CHC*H*$_2$O), 4.02 (s, 3H; OCH$_3$), 4.19 (s, 3H; OCH$_3$), 4.22–4.35 (m, 2H; CHRO), 4.31 (d, ^2J = 11.8 Hz, 2H; H_{ax}), 4.41 (d, ^2J = 12.3 Hz, 2H; H_{ax}), 4.69 (d, ^2J = 13.8 Hz, 2H; OC*H*Hbpy), 4.83 (d, ^2J = 13.8 Hz, 2H; OCH*H*bpy), 6.46 (s, 2H; Ar-H), 6.47 (s, 2H; Ar-H), 7.14 (s, 2H; Ar-H), 7.15 (s, 2H; Ar-H), 7.34 (dd, ^3J = 8.6 Hz, ^3J = 4.7 Hz, 2H; bpy-5′-H), 7.43 (d, ^3J = 7.8 Hz, 2H; bpy-5-H), 7.82 (dd, $^3J = 8.6$ Hz, $^3J = 8.0$ Hz, 2H; bpy-4′-H), 7.86 (dd, $^3J = 7.8$ Hz, $^3J = 7.8$ Hz, 2H; bpy-4-H), 8.21 (d, $^3J = 7.8$ Hz, 2H; bpy-3-H), 8.32 (d, $^3J = 8.0$ Hz, 2H; bpy-3′-H), 8.69 (d, $^3J = 4.7$ Hz, 2H; bpy-6′-H); MS (CI, CH_4): m/z (%): 1231.7 (100) $[M+H]^+$; $C_{78}H_{94}N_4O_9$ (1231.63): calcd C 76.07, H 7.69; found C 75.96, H 7.61.

*(dl)-**4b***: ^1H NMR (400 MHz, $CDCl_3$, 253 K, *cone*): $\delta = 0.79$ (s, 18H; $C(CH_3)_3$), 1.22, 1.33 (s, 9H; $C(CH_3)_3$), 3.15 (d, $^2J = 11.8$ Hz, 2H; H_{eq}), 3.17 (d, $^2J = 11.7$ Hz, 2H; H_{eq}), 3.47–4.30 (m, 22H; $ArOCH_2CHROCH_2CH_2$, $CHCH_2O$, H_{ax}), 4.10 (s, 6H; OCH_3), 4.71 (d, $^2J = 13.7$ Hz, 2H; OC*H*Hbpy), 4.80 (d, $^2J = 13.8$ Hz, 2H; OCH*H*bpy), 6.48 (s, 4H; Ar-H), 7.13, 7.14 (s, 2H; Ar-H), 7.34 (ddd, $^3J = 7.5$ Hz, $^3J = 4.8$ Hz, $^4J = 1.0$ Hz, 2H; bpy-5′-H), 7.44 (d, $^3J = 7.7$ Hz, 2H; bpy-5-H), 7.82 (ddd, $^3J = 7.8$ Hz, $^3J = 7.7$ Hz, $^4J = 1.6$ Hz, 2H; bpy-4′-H), 7.85 (dd, $^3J = 7.8$ Hz, $^3J = 7.8$ Hz, 2H; bpy-4-H), 8.21 (d, $^3J = 7.9$ Hz, 2H; bpy-3′-H), 8.33 (d, $^3J = 7.9$ Hz, 2H; bpy-3-H), 8.69 (d, $^3J = 4.7$ Hz, 2H; bpy-6′-H); MS (CI, CH_4): m/z (%): 1231.7 (100) $[M+H]^+$; $C_{78}H_{94}N_4O_9$ (1231.63): calcd C 76.07, H 7.69; found C 75.99, H 7.59.

*(S,S)-**4c***: Compound (**4c**) was prepared from the enantiomerically pure compound (**29c**), and was purified by preparative layer chromatography (elution gradient CH_2Cl_2/CH_3OH, 100:1 – CH_2Cl_2). M.p. 80–82 °C; $[\alpha]^{25}_{589} = +9.04$ ($c = 0.0188$, $CHCl_3$); ^{13}C NMR (75.5 MHz, $CDCl_3$, 300 K): $\delta = 31.1$, 31.7 (q, $C(CH_3)_3$), 31.9 (t, $ArCH_2Ar$), 33.5, 34.1 (s, $C(CH_3)_3$), 61.4 (q, OCH_3), 69.0, 70.3, 70.5, 74.5, 75.5 (t, $OCH_2CHROCH_2CH_2$, $CHCH_2O$, OCH_2bpy), 78.6 (d, CHRO), 119.7 (d, bpy-3′), 121.2 (d, bpy-3), 123.4 (d, bpy-5′), 124.5 (d, bpy-5), 124.5, 125.0, 125.1, 125.2 (d, *m*-Ar), 132.2, 132.5, 135.6, 135.8 (s, *o*-Ar), 136.8 (d, bpy-4′), 137.5 (d, bpy-4), 144.2, 144.8 (s, *p*-Ar), 149.1 (d, bpy-6′), 153.4, 155.4 (s, *i*-Ar, bpy-2′), 156.0 (s, bpy-6), 157.8 (s, bpy-2); MS (CI, CH_4): m/z (%): 1231.7 (100) $[M+H]^+$; $C_{78}H_{94}N_4O_9$ (1231.63): calcd C 76.07, H 7.69; found C 75.99, H 7.60.

Spectrophotometric titration: Spectrophotometric titrations in dry acetonitrile or methanol (containing ≈5% H_2O) were performed on a spectrophotometer Kontron 860. Gradually larger amounts of a solution (1×10^{-3} M) of $Tb(ClO_4)_3$ or $Eu(ClO_4)_3$ were added to a solution (1×10^{-5} M, 2.5 mL) of ligands **2**, **3**, or **4c** (containing 5.7 mg of Et_4NClO_4) in order to produce a metal-to-ligand ratio in the range from 0.4 to 20. After each addition the corresponding UV/Vis spectrum was recorded between 240 and 360 nm. These spectra, together with the analytical concentrations of the ligand and the metal ion, were entered into the program SIRKO[29] for evaluation of the 1:1 association constants, K, between the ligands and the lanthanide ions.

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