1,2-Bridged Calix[4]arene Monocrowns and Biscrowns in the 1,2-Alternate Conformation†

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The condensation of 1,2-di[(2-pyridylmethyl)oxy]calix[4]arenes **1** (R = ^{t}Bu, H) with glycol ditosylates **2a**−**e** in anhydrous toluene in the presence of ^{t}BuOK has led to a mixture of 1,2-alternate and cone 1,2-calix[4]arene crown conformers **3** and **4**, respectively. Similarly, the reaction of 1,2-bridged calix[4]arene crown-4 **5** with tri- to pentaethylene glycol ditosylates **2a**−**c** has produced 1,2-alternate and cone calix[4]arene biscrown conformers **6** and **7**, respectively. The distribution of conformers depends on the para-substituent at the upper rim and the length and bulkiness of the ditosylates. The best yields of the 1,2-alternate conformer (up to 51%) are observed in the absence of ^{t}Bu groups and with the longer polyether chain. The conformational features of **3** and **6** have been deduced by NMR spectroscopy and by X-ray crystallography. X-ray analysis of 25,26-27,28-biscrown-4-calix-[4]arene (**6a**) shows that there are two independent molecules in the asymmetric unit, both in the 1,2-alternate conformation.

Introduction

Calix[4]arenes are commonly used as three-dimensional building blocks for the construction of more elaborate host molecules with desired properties.[1] Owing to their nonplanar structure, calix[4]arenes can be locked in one of the four extreme conformations, i.e., cone, partial cone, 1,3-alternate, and 1,2-alternate. However, despite the undeniable advances in the stereocontrolled functionalization of calix[4]arenes, direct methods for the attainment of calix[4]arenes in the 1,2-alternate conformation are still lacking.[2] Except for some specific cases,[3,4] the 1,2-alternate conformation appears to be precluded by the inability to get in situ the ideal anti-distal dialkylated precursors,[2b] the isomeric syn-proximal[5] or syn-distal[6] intermediates being generally observed, according to the nature and strength of the base used.

In the frame of a general project aimed at the comparative evaluation of the complexation properties of regioisomers and conformational isomers of di[(2-pyridylmethyl)oxy]-*p-tert*-butylcalix[4]arene crown ethers,[7] we have tackled the synthesis of 1,2-alternate calix[4]arene crowns. This conformation provides a potentially useful binding geometry, in which the soft character of two adjacent aromatic nuclei could act cooperatively with the facing crown moiety in metal ion recognition.

Earlier we have shown that readily available syn-proximal di[(2-pyridylmethyl)oxy]calixarenes **1** (R = ^{t}Bu, H) represent useful starting materials for the attainment of calix[4]arene crown ethers in this particular conformation.[8] In this paper, we report full details of the reaction of **1** with ditosylates **2** for the synthesis of the relevant 1,2-calix[4]arene crown ethers in the 1,2-alternate conformation. In the course of this work, Arduini et al. have reported the synthesis of 1,2-bridged *p-tert*-butylcalix[4]-arene biscrowns in the 1,2-alternate conformation, emphasizing the necessity of ^{t}Bu substituents in the stereocontrol of the reaction.[9] Since these observations were not in agreement with our previous findings,[8] we were

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(1) For full reviews on calixarene chemistry, cf.: (a) Gutsche, C. D. Calixarenes. In *Monographs in Supramolecular Chemistry*; Stoddart, J. F., Ed.; Royal Society of Chemistry: Cambridge, U.K., 1989. (b) *Calixarenes, A Versatile Class of Macrocyclic Compounds*; Vicens, J., Böhmer, V., Eds.; Kluwer: Dordrecht, The Netherlands, 1991. (c) Böhmer, V. *Angew. Chem., Int. Ed. Engl.* **1995**, *34*, 713. (d) Ikeda, A.; Shinkai, S. *Chem. Rev.* **1997**, *97*, 1713.

(2) For the stepwise synthesis of 1,2-alternate calix[4]arenes by protection−deprotection methods, see: (a) Groenen, L. C.; van Loon, J.-D.; Verboom, W.; Harkema, S.; Casnati, A.; Ungaro, R.; Pochini, A.; Ugozzoli, F.; Reinhoudt, D. N. *J. Am. Chem. Soc.* **1991**, *113*, 2385. (b) Iwamoto, K.; Araki, K.; Shinkai, S. *J. Chem. Soc., Perkin Trans. 1* **1991**, 1611. (c) Iwamoto, K.; Araki, K.; Shinkai, S. *J. Org. Chem.* **1991**, *56*, 4955. (d) Iwamoto, K.; Shinkai, S. *J. Org. Chem.* **1992**, *57*, 7066.

(3) Gibbs, C. G.; Gutsche, C. D. *J. Am. Chem. Soc.* **1993**, *115*, 5338. Gibbs, C. G.; Sujieeth, P. K.; Rogers, J. S.; Stanley, G. G.; Krawiec, M.; Watson, W. H.; Gutsche, C. D. *J. Org. Chem.* **1995**, *60*, 8394.

(4) Minute amounts of 1,2-alternate calix[4]arenes have been sporadically observed in the exhaustive alkylation or acylation of the parent calix[4]arenes: (a) Jaime, C.; de Mendoza, J.; Prados, P.; Nieto, P. M.; Sánchez, C. *J. Org. Chem.* **1991**, *56*, 3372. (b) Iwamoto, K.; Araki, K.; Shinkai, S. *J. Org. Chem.* **1991**, *56*, 4955. (c) Pappalardo, S.; Ferguson, G.; Neri, P.; Rocco, C. *J. Org. Chem.* **1995**, *60*, 4576. (d) Akabori, S.; Sannohe, H.; Habata, Y.; Mukoyama, Y.; Ishii, T. *Chem. Commun.* **1996**, 1467. (e) Neri, P.; Bottino, A.; Geraci, C.; Piattelli, M. *Tetrahedron: Asymmetry* **1996**, *7*, 17.

(5) Bottino, F.; Giunta, L.; Pappalardo, S. *J. Org. Chem.* **1989**, *54*, 5407. Groenen, L. C.; Ruel, B. H. M.; Casnati, A.; Timmerman, P.; Verboom, W.; Harkema, S.; Pochini, A.; Ungaro, R. *Tetrahedron Lett.* **1991**, *32*, 2675.

(6) Collins, E. M.; McKervey, M. A.; Harris, S. J. *J. Chem. Soc., Perkin Trans. 1* **1989**, 372. van Loon, J.-D.; Arduini, A.; Verboom, W.; Ungaro, R.; van Hummel, G. J.; Harkema, S.; Reinhoudt, D. N. *Tetrahedron Lett.* **1989**, *30*, 2681.

(7) Arnaud-Neu, F.; Ferguson, G.; Fuangswasdi, S.; Notti, A.; Pappalardo, S.; Parisi, M. F.; Petringa, A. *J. Org. Chem.* **1998**, *63*, 7770.

(8) For a preliminary communication, see: Pappalardo, S.; Petringa, A.; Parisi, M. F.; Ferguson, G. *Tetrahedron Lett.* **1996**, *37*, 3907.

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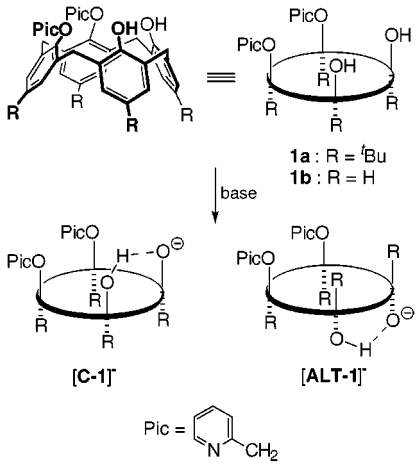
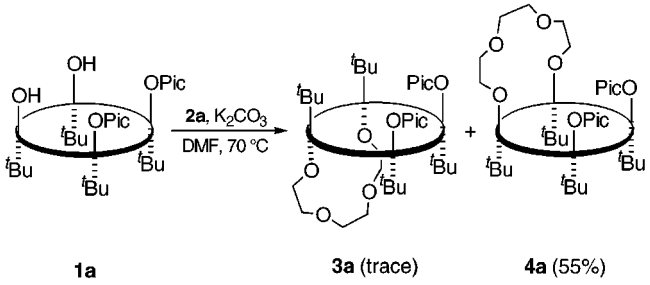
Scheme 1



Scheme 2



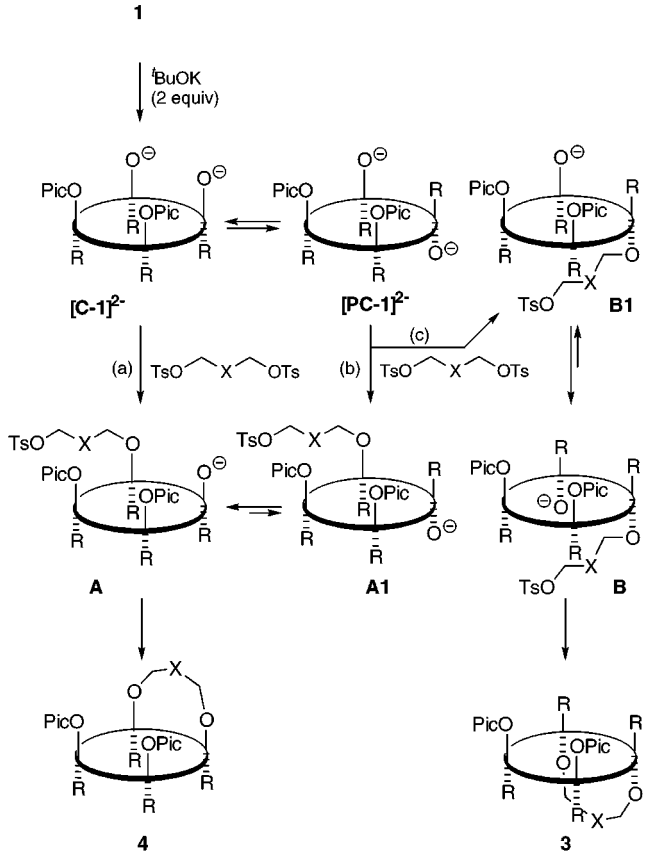
prompted to extend our studies to the synthesis of 1,2-alternate calix[4]arene biscrowns devoid of ^{t}Bu groups at the upper rim.

Results and Discussion

Preliminary Remarks. Previous studies have established that the exhaustive alkylation of calix[4]arenes with weak bases, such as metal carbonates, proceeds through a sequence of mono-deprotonation/alkylation steps.[10] MM2 calculations have shown that the mono-anion generated from 1,2-alkylated calix[4]arenes **1** can assume both cone [**C-1**]$^-$ and 1,2-alternate [**ALT-1**]$^-$ conformations, which are preferred over other conformations by favorable hydrogen bonding of the phenolate moiety with the adjacent OH group (Scheme 1).[11] Although the 1,2-alternate conformer is only 1−2 kcal mol^{-1} less stable than the cone, initial reaction of 5,11,17,23-tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)-oxy]-27,28-dihydroxycalix[4]arene (**1a**) with triethylene glycol ditosylate (**2a**, 1.1 equiv) and K_2CO_3 (excess) in dry DMF at 70 °C has produced only a trace amount of the 1,2-alternate *p-tert*-butylcalix[4]arene crown-4 **3a**, the main compound being the cone conformer **4a** (Scheme 2).

On the other hand, deprotonation of **1** with 2 equiv of a stronger base affords two dianionic conformers, cone [**C-1**]$^{2-}$ and partial cone [**PC-1**]$^{2-}$, in equilibrium. In this case, MM2 calculations have shown a negligible energy

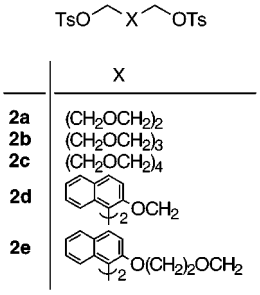
Scheme 3



difference between these conformers,[11] which may eventually lead to better yields of the 1,2-alternate derivatives by reaction with bifunctional electrophiles, in the light of the plausible reaction pathways depicted in Scheme 3. Upon cyclization with glycol ditosylates, [**C-1**]$^{2-}$ can only afford, via intermediate **A**, the cone conformers **4** (path a). [**PC-1**]$^{2-}$, on the other hand, can yield both **4** and the 1,2-alternate conformers **3** (paths b and c, respectively), after inversion of the residual phenoxide group on the initial tosylated intermediate (**A1** → **A** or **B1** → **B**, Scheme 3).

Whereas the use of hard bases (NaH) in DMF did not succeed for the production of 1,2-alternate calix[4]arene crowns, satisfactory results were obtained with softer bases (^{t}BuOK) and low polarity solvents such as toluene.

Synthesis of 1,2-Alternate 1,2-Di[(2-pyridylmethyl)-oxy]calix[4]arene Crown Ethers. When calixarenes **1** were subjected to ditosylates **2a**−**e** (1.1 equiv) in toluene at 70 °C in the presence of ^{t}BuOK (2.2 equiv), a mixture of 1,2-alternate and cone calix[4]arene crown ethers **3** and **4**, respectively, was formed in most cases (Table 1). Due to the different polarity of the two

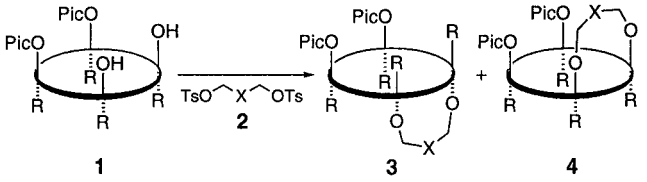


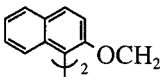
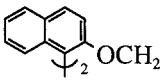
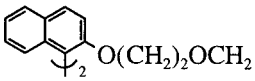
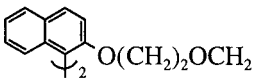
(9) Arduini, A.; Domiano, L.; Pochini, A.; Secchi, A.; Ungaro, R.; Ugozzoli, F.; Struck, O.; Verboom, W.; Reinhoudt, D. N. *Tetrahedron* **1997**, *53*, 3767.

(10) van Loon, J.-D.; Verboom, W.; Reinhoudt, D. N. *Org. Prep. Proc. Intl.* **1992**, *24*, 437.

(11) Pappalardo, S.; Giunta, L.; Foti, M.; Ferguson, G.; Gallagher, J. F.; Kaitner, B. *J. Org. Chem.* **1992**, *57*, 2611.

Table 1. Isolated Yields of 1,2-Alternate and Cone Monocrown Conformers in the Reaction of 1 with 2 and ^{t}BuOK in Toluene at 70 °C

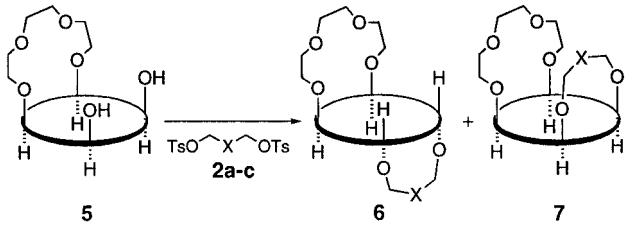


Entry	R	X	1,2-ALT (%)	CONE (%)
1	^{t}Bu	$(CH_2OCH_2)_2$	**3a** (37)	**4a** (3)
2	H	$(CH_2OCH_2)_2$	**3b** (40)	**4b** (3)
3	^{t}Bu	$(CH_2OCH_2)_3$	**3c** (27)	**4c** (45)
4	H	$(CH_2OCH_2)_3$	**3d** (32)	**4d** (28)
5	^{t}Bu	$(CH_2OCH_2)_4$	**3e** (21)	**4e** (35)
6	H	$(CH_2OCH_2)_4$	**3f** (51)	**4f** (12)
7	^{t}Bu		-	**4g** (45)
8	H		**3h** (36)	**4h** (21)
9	^{t}Bu		**3i** (6)	**4i** (43)
10	H		**3j** (28)	**4j** (12)

conformers, their separation was easily achieved by column chromatography, the 1,2-alternate conformers **3** generally being less polar than cone **4**. In the case of crown ethers that incorporate the binaphthyl moiety and are devoid of ^{t}Bu substituents at the upper rim of the calixarene skeleton, the chromatographic behavior is reversed, the cone conformers **4h** and **4j** representing the fastest moving components.

The yield of isolated product is shown in Table 1. In the reactions of **1** with ditosylates **2a**,**b** (Table 1, entries 1−4), the 1,2-alternate/cone ratio is ca. 12:1 with the shorter polyether chain (crown-4), and roughly 1:1 with the chain of intermediate length (crown-5), irrespective of the para-substituent. Conversely, with the longer ditosylate **2c** (Table 1, entries 5 and 6) the para-substituent has an effect, the 1,2-alternate crown-6 conformer clearly prevailing over cone (ratio 4:1) in the absence of ^{t}Bu groups at the upper rim. Interestingly, when **1a** (R = ^{t}Bu) was treated with the binaphthyl-containing ditosylates **2d**,**e** (Table 1, entries 7 and 9) the yield of 1,2-alternate crown-6 conformer **3i** dropped to 6%, while the smaller crown-4 derivative **3g** was not even detected in the reaction mixture. Inspection of molecular models suggests that the approach of the bulky binaphthyl-containing ditosylates to the inverted phenolate group in [**PC-1**]$^{2-}$, leading to intermediate **B1** (Scheme 3), is difficult with **2e** and prevented with **2d**, having a

Table 2. Isolated Yields of 1,2-Alternate and Cone Biscrown Conformers in the Reaction of 5 with 2a−c and ^{t}BuOK in Toluene at 70 °C



Entry	X	1,2-ALT (%)	CONE (%)
1	$(CH_2OCH_2)_2$	**6a** (25)	**7a** (35)
2	$(CH_2OCH_2)_3$	**6b** (30)	**7b**(55)
3	$(CH_2OCH_2)_4$	**6c** (45)	**7c** (22)

shorter glycolic chain, due to severe steric interactions with the upper rim ^{t}Bu groups. In agreement with this interpretation, the reaction of **1b** (R = H) with **2d** restored the usual mixture of conformers (Table 1, entry 8).

These findings clearly indicate that both the length and steric encumbrance of the ditosylate, as well as the bulkiness of the para-substituent at the upper rim, play a role in the conformational outcome of this reaction. The distribution of conformers is determined by the ratio of the relative rates of the first alkylation step of the phenolate groups in different chemical environments (syn or anti to picolyl groups). The stabilization of the relevant transition states likely results from a balance between steric interactions and a possible template effect of the potassium ion.

Synthesis of 1,2-Bridged Calix[4]arene Biscrowns in the 1,2-Alternate Conformation. In all cases discussed above, comparatively higher yields of the 1,2-alternate conformers are *always* observed in the absence of ^{t}Bu groups at the upper rim of the starting 1,2-di-*O*-alkylated calix[4]arene (Table 1). This contradicts recently published findings which suggest that the ^{t}Bu substituents at the upper rim of the parent calix[4]arene are necessary to ensure stereochemical control in the direct synthesis of the structurally related 1,2-bridged calix[4]arene biscrowns in the 1,2-alternate conformation.[9] More specifically, the 1,2-bridged *p*-H-calix[4]arene biscrown-4 in the cone conformation (compound **7a**) was reported to be the only product isolated, whatever the starting material (*p*-H-calix[4]arene or 1,2-bridged *p*-H-calix[4]arene crown-4 **5**) and the conditions applied (**2a**, NaH in DMF, ^{t}BuOK or ^{t}BuOCs in toluene).[9]

To throw light on this controversial point, we have revisited the reaction of **5** with **2a** and ^{t}BuOK in toluene and extended it to the longer ditosylates **2b**,**c** (see Table 2). In our hands, the reaction has invariably produced the expected mixtures of 1,2-alternate and cone biscrown derivatives **6** and **7**, respectively, confirming our earlier observations[8] and the general applicability of the present procedure.

The yield of isolated product in the reactions of **5** with **2a−c** is shown in Table 2. The yield of the 1,2-alternate conformers **6** is in the range 25−45% and increases with increasing length of the polyether chain. The relatively

high yield of mixed crown-4-crown-5 derivative **7b** (55%) could be explained by a very favorable template effect of the potassium ion, in the light of the known ability of 1,2-bridged calix[4]arene biscrowns (cone conformers) to strongly bind alkali-metal ions.[12,13]

NMR Characterization Studies. Structures and conformations of all new compounds were established by FAB (+) MS, ^{1}H and ^{13}C NMR spectroscopies, and single-crystal X-ray analyses (for **3c** and **6a**). The NMR probes are especially useful for establishing calix[4]arene conformations, taking advantage of the well-documented patterns of the ^{1}H NMR resonances (particularly those arising from $ArCH_2Ar$[1a] and OCH_2Py groups[14]) and the position of the ^{13}C NMR resonances associated with the same groups.[4a]

The ^{1}H NMR spectra of 1,2-alternate monocrowns **3** and mixed biscrowns **6b**,**c** display two AX systems (J = 12.4 ± 0.3 Hz) and an AB quartet (J = 17.1 ± 0.5 Hz) in the ratio 1:1:2 for the $ArCH_2Ar$ groups (one AX system and one singlet in the ratio 1:1 in the case of the highly symmetrical biscrown **6a**). Compounds **3** show an additional AB system for the diastereotopic OCH_2Py protons (two AB systems for binaphthyl-containing derivatives **3h**−**j**, owing to the axial chirality of this subunit). The ^{13}C NMR spectra of 1,2-alternate structures exhibit two resonances in the range 28−30 ppm (one resonance for **6a**) and one resonance of double intensity at 37−39 ppm (two distinct resonances in the case of racemic **3h**−**j**) for the bridging methylene carbons, and a very diagnostic[14] resonance at 74.5 ± 0.1 ppm for OCH_2Py groups (two distinct resonances for **3h**−**j**). The uniformity of the spectra of **3a**−**f** clearly indicates that these compounds in solution adopt a similar conformation.

1,2-Bridged monocrown and mixed biscrown cone conformers **4a**−**f** and **7b**,**c** show the expected proton and carbon NMR spectral patterns for a mixed bis-syn-proximal functionalization at the lower rim of calix[4]-arenes [in particular, a set of three AX systems (J = 12.9 ± 0.6 Hz) for $ArCH_2Ar$ in the ratio 1:2:1 and three resonances for the pertinent carbons at δ 29−31 ppm].[11,15] Obviously, binaphthyl-containing derivatives **4g**−**j** display four AX systems (ratio 1:1:1:1) for $ArCH_2Ar$ protons and four resonances for the relevant carbons.

A comparison of the ^{1}H NMR spectra of **3** and **4** reveals strong upfield shifts for a pair of symmetrical oxyethylene protons and for the pyridyl protons of the 1,2-alternate structures **3**, which are respectively exposed to the diamagnetic shielding effect of two pairs of aryl rings (one above and one below the mean methylene-containing plane). The conspicuous upfield shift experienced by H3 ($\Delta\delta$ ca. 1.7 ppm) and to a lesser extent by H4 ($\Delta\delta$ ca. 0.8 ppm) picolyl protons further suggests that (a) the hetero-aromatic pendant groups alternate in filling the pocket created by the two facing aryl rings and (b) the ring nitrogen is exo to the calix cup and anti oriented with respect to the phenolic oxygen.

The 1,2-alternate conformation of **3c** was further proven by single-crystal X-ray analysis.[8] In the crystal,

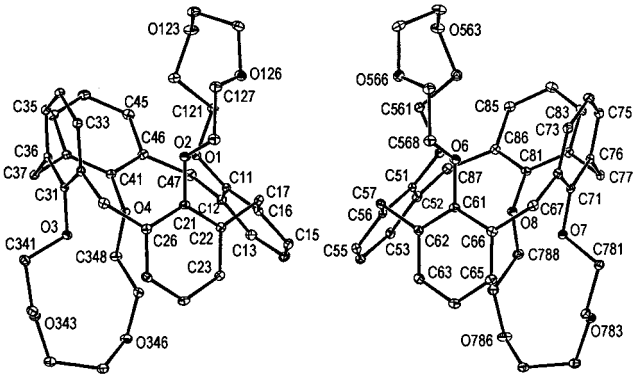


Figure 1. Views of the two molecules of **6a** at 123 K with our numbering scheme. For clarity, H atoms are omitted and displacement ellipsoids are drawn at the 10% probability level.

one of the two picolyl groups is leaning toward the hemicavity. In the attempt to freeze in solution this transient chiral conformation, a VT-NMR study on **3c** in CD_2Cl_2 was conducted. Unfortunately, the motion of the picolyl groups is still fast even at −90 °C. It is interesting to note, however, that sterically congested binaphthyl derivatives **3h**,**i** assume in solution a conformation in which only one of the two picolyl groups resides in the hemicavity, as suggested by the presence of a single high-field resonance for the H3 (5.62 ppm in **3h** and 5.93 ppm in **3i**) integrating for one proton. In contrast, the more flexible **3j** displays two distinct signals for the relevant pyridyl protons at 6.11 and 6.18 ppm.

X-ray Analysis of 6a. X-ray analysis[16] of **6a** shows that there are two independent molecules in the crystal asymmetric unit and that both molecules have very similar conformations. The molecules are inherently chiral, and the asymmetric unit of the centrosymmetric crystal system was chosen so that it contained one molecule of each chirality. Views of the two molecules are in Figure 1. The torsion angles ϕ and χ describing the conformations[19] (Table 3) correspond with the symbolic representation +−, ++, −+, −−, and are entirely in accord with the 1,2-alternate conformation. An exactly comparable conformation was recently noted for the corresponding ^{t}Bu derivative.[9] The conformation of the **6a** molecules is also defined by the interplanar angles which the aromatic rings make with the best plane through the four methylene carbons which link them; these data are shown in Table 4.

(12) Arduini, A.; Casnati, A.; Dodi, L.; Pochini, A.; Ungaro, R. *J. Chem. Soc., Chem. Commun.* **1990**, 1597. Arduini, A.; Casnati, A.; Fabbi, M.; Minari, P.; Pochini, A.; Sicuri, A. R.; Ungaro, R. *Supramol. Chem*. **1993**, *1*, 235.

(13) Asfari, Z.; Astier, J.-P.; Bressot, C.; Estienne, J.; Pepe, G.; Vicens, J. *J. Inclusion Phenom*. **1994**, *19*, 291.

(14) Bottino, F.; Pappalardo, S. *J. Inclusion Phenom*. **1994**, *19*, 85.

(15) Brunink, J. A. J.; Verboom, W.; Engbersen, J. F. J.; Harkema, S.; Reinhoudt, D. N. *Recl. Trav. Chim. Pays-Bas* **1992**, *111*, 511.

(16) Crystals of **6a**, $C_{40}H_{44}O_8$, are orthorhombic, space group *Pbca*, with cell data (at 123 K): a = 16.3267(4), b = 19.8109(4), and c = 41.4114(10) Å, V = 13394.4(5) Å^3, Z = 16, D_x = 1.295 g cm^{-3}, F(000) = 5568. A crystal of dimensions 0.25 × 0.20 × 0.08 mm was used for the data collection with a Nonius KappaCCD system at 123 K and using graphite-monochromated Mo Kα radiation to a maximum θ value of 24.71°. In all, some 54999 reflections were measured; these reduced to 11334 unique reflections of which 6196 had $I > 2\sigma(I)$. The structure was solved by direct methods using SHELXLS-97[17] and refined using all available data with SHELXL-97.[18] Hydrogen atoms were visible in difference maps and allowed for as riding atoms. All non-H atoms were allowed anisotropic displacement parameters. Final R-factors are 0.0540 for R(obs) and 0.1349 for Rw (all F^2 data). Final difference maps were featureless. Full details of the crystallographic results have been deposited in CIF format and are also available from the authors.

(17) Sheldrick, G. M. SHELXS97. Program for the solution of crystal structures; University of Göttingen, Germany, 1997.

(18) Sheldrick, G. M. SHELXL97. Program for the refinement of crystal structures; University of Göttingen, Germany, 1997.

(19) Ugozzoli, F.; Andreetti, G. D. *J. Inclusion Phenom*. **1992**, *13*, 337.

Table 3. Torsion Angles ϕ and χ (deg) for the Two Molecules of 6a

	ϕ		χ
	molecule 1		
C16−C17−C22−C23	58.4(3)	C15−C16−C17−C22	−95.5(3)
C46−C47−C12−C13	149.4(3)	C45−C46−C47−C12	148.0(3)
C36−C37−C42−C43	−95.5(3)	C35−C36−C37−C42	61.0(3)
C26−C27−C32−C33	−119.9(3)	C25−C26−C27−C32	−118.6(3)
	molecule 2		
C56−C57−C62−C63	−61.8(3)	C55−C56−C57−C62	91.2(3)
C86−C87−C52−C53	−144.5(3)	C85−C86−C87−C52	−146.5(3)
C76−C77−C82−C83	87.7(3)	C75−C76−C77−C82	−67.4(3)
C66−C67−C72−C73	131.1(3)	C65−C66−C67−C72	119.7(3)

Table 4. Interplanar Angles for 6a Which the Aromatic Rings Make with the Plane of the Methylene C Atoms Linking Them

	ring atoms	angle (deg)
molecule 1	C11−C16	135.05(5)
	C21−C26	96.71(4)
	C31−C36	98.19(5)
	C41−C46	134.46(5)
molecule 2	C51−C56	130.74(5)
	C61−C66	99.98(4)
	C71−C76	106.58(5)
	C81−C86	130.83(5)

Conclusions

We have developed a general procedure for the preparation of 1,2-bridged calix[4]arene monocrowns and biscrowns in the 1,2-alternate conformation and discussed the various factors affecting the conformational outcome in the reaction of 1,2-functionalized calix[4]arenes with glycol ditosylates and ^{t}BuOK in toluene. This synthetic strategy is currently being employed for the design of new enlarged hydrophobic cavities, based on 1,2-alternate calix[4]arene substructures, potentially useful for the selective inclusion of organic guests.

Experimental Section

General. All chemicals were reagent grade and were used without further purification. Anhydrous toluene was obtained commercially. Melting points were determined on a Kofler or Electrothermal melting point apparatus and are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ at 300 and 75 MHz, respectively, with TMS as the internal standard. The multiplicity of the ^{13}C signals was determined with the APT technique. Where present, peak assignments followed from COSY and HETCOR experiments. For FAB (+) mass spectra, 3-nitrobenzyl alcohol was used as the matrix. 1,2-Di[(2-pyridylmethyl)oxy]calix[4]arenes **1a**,**b**,[11] ditosylates **2a**−**c**,[20] (±)-**2d** (mp 129−130 °C from cyclohexane−CH_2Cl_2 (lit.,[21] viscous oil)), (±)-**2e**,[22] and 1,2-bridged calix[4]arene crown-4 **5**[23] were prepared according to reported procedures or slight modifications thereof. All reactions were carried out under nitrogen atmosphere.

Reaction of 1 with Glycol Ditosylates 2. General Procedure. A stirred mixture of **1** (0.5 mmol) and ^{t}BuOK (0.12 g, 1.1 mmol) in dry toluene (50 mL) was heated at 70 °C for 1 h. Then a solution of the appropriate ditosylate (0.55 mmol) in dry toluene (30 mL) was added dropwise over 3 h. The stirred mixture was kept at 70 °C for a further 24−36 h. Progress of the reaction could be monitored by following the disappearance of **1** (TLC analysis). After evaporation of the solvent, the residue was partitioned between water and CH_2Cl_2. The organic layer was dried over $MgSO_4$ and concentrated. The crude product was separated into the pure conformers **3** and **4** by column chromatography (SiO_2, a gradient of AcOEt in cyclohexane or CH_2Cl_2 as an eluent), followed by recrystallization from an appropriate solvent system. Further details are given for the individual compounds.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis-[(2-pyridylmethyl)oxy]-27,28-crown-4-calix[4]arene, 1,2-Alternate Conformer (3a): 37% yield, mp 259−262 °C (MeOH−CH_2Cl_2); ^{1}H NMR δ 1.09, 1.39 (s, 18 H each), 2.61 (ddd, J = 10.2, 5.9, 4.4 Hz, 2 H), 3.21, 3.23 (d, J = 12.3 Hz, 1 H each), 3.26−3.69 (m, 10 H), 3.81 and 3.87 (ABq, J = 17.4 Hz, 4 H), 4.17, 4.40 (d, J = 12.3 Hz, 1 H each), 4.57 and 4.65 (ABq, J = 14.2 Hz, 4 H), 6.26 (dt, J = 7.6, 0.9 Hz, 2 H), 6.71 (td, J = 7.6, 1.8 Hz, 2 H), 6.75 and 7.21 (AX, J = 2.5 Hz, 4 H), 6.89 (ddd, J = 7.6, 4.8, 1.2 Hz, 2 H), 7.08 and 7.42 (AX, J = 2.5 Hz, 4 H), 8.32 (ddd, J = 4.8, 1.8, 0.9 Hz, 2 H); ^{13}C NMR δ 28.5, 29.7, 38.6 (×2) (t, $ArCH_2Ar$), 31.5, 31.8 (q, $C(CH_3)_3$), 33.9, 34.1 (s, $C(CH_3)_3$), 67.3, 69.3, 70.7 (t, OCH_2CH_2O), 74.5 (t, OCH_2-Py), 121.0, 121.2 (d, 3,5-Py), 125.1, 125.7 (×2), 125.9 (d, Ar), 132.49, 132.53, 133.8, 134.5 (s, bridgehead-C), 136.4 (d, 4-Py), 144.6, 145.2 (s, C_{sp^2}−$C(CH_3)_3$), 147.9 (d, 6-Py), 153.3, 153.8 (s, C_{sp^2}−O), 158.2 (s, 2-Py); MS, m/z 945 (MH^+). Anal. Calcd for $C_{62}H_{76}N_2O_6$: C, 78.78; H, 8.10; N, 2.96. Found: C, 78.57; H, 8.18; N, 2.84.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-crown-4-calix[4]arene, Cone Conformer (4a): 3% yield; mp 190−191 °C; ^{1}H NMR δ 1.08, 1.09 (s, 18 H each), 3.07, 3.10 (d, J = 12.5 Hz, ratio 1:3, 4 H), 3.60−3.67 (m, 2 H), 3.73−3.85 (m, 6 H), 4.07−4.24 (m, 4 H), 4.33, 4.41, 4.77 (d, J = 12.5 Hz, ratio 2:1:1, 4 H), 5.02 and 5.12 (ABq, J = 12.7 Hz, 4 H), 6.79 and 6.81 (ABq, J = 2.6 Hz, 4 H), 6.88 (s, 4 H), 7.18 (ddd, J = 7.5, 4.9, 1.2 Hz, 2 H), 7.60 (td, J = 7.5, 1.8 Hz, 2 H), 7.78 (dt, J = 7.5, 0.9 Hz, 2 H), 8.55 (ddd, J = 4.9, 1.8, 0.9 Hz, 2 H); ^{13}C NMR δ 30.1, 30.6, 31.1 (×2) (t, $ArCH_2Ar$), 31.4 (q, $C(CH_3)_3$), 33.82, 33.85 (s, $C(CH_3)_3$), 70.3, 70.5, 73.2 (t, OCH_2CH_2O), 78.1 (t, OCH_2Py), 122.3, 123.3 (d, 3,5-Py), 124.9, 125.1, 125.2, 125.4 (d, Ar), 133.3, 133.5, 133.6, 134.4 (s, bridgehead-C), 136.5 (d, 4-Py), 144.69, 144.74 (s, C_{sp^2}−$C(CH_3)_3$), 148.7 (d, 6-Py), 152.8, 152.9 (s, C_{sp^2}−O), 158.3 (s, 2-Py); MS, m/z 945 (MH^+). Anal. Calcd for $C_{62}H_{76}N_2O_6$: C, 78.78; H, 8.10; N, 2.96. Found: C, 78.95; H, 8.27; N. 2.88.

Cone **4a** was prepared more conveniently (55% yield) by reacting **1a** with **2a** (1.1 equiv) and K_2CO_3 (10 equiv) in dry DMF at 70 °C for 36 h.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-4-calix[4]-arene, 1,2-Alternate Conformer (3b): 40% yield, mp 230−233 °C (hexane−CH_2Cl_2); ^{1}H NMR δ 2.60 (ddd, J = 10.3, 6.0, 4.3 Hz, 2 H), 3.23 (m, 2 H), 3.24 and 4.37 (AX, J = 12.7 Hz, 2 H), 3.31 and 4.28 (AX, J = 12.5 Hz, 2 H), 3.41−3.76 (m, 8 H), 3.81 and 3.87 (ABq, J = 17.4 Hz, 4 H), 4.61 and 4.66 (ABq, J = 13.8 Hz, 4 H), 6.10 (ddd, J = 7.5, 1.4, 0.9 Hz, 2 H), 6.60−6.72 (m, 4 H), 6.88 (td, J = 7.5, 1.9 Hz, 2 H), 6.94 (ddd, J = 7.5, 4.7, 1.4 Hz, 2 H), 7.04 (t, J = 7.5 Hz, 2 H), 7.15 (dd, J = 7.5, 1.7 Hz, 2 H), 7.20 (dd, J = 6.3, 3.0 Hz, 2 H), 7.38 (dd, J = 7.5, 1.7 Hz, 2 H), 8.33 (ddd, J = 4.7, 1.9, 0.9 Hz, 2 H); ^{13}C NMR δ 28.0, 28.8, 37.8 (×2) (t, $ArCH_2Ar$), 68.0, 69.9, 70.7 (t, OCH_2CH_2O), 74.5 (t, OCH_2Py), 121.0, 121.4 (d, 3,5-Py), 122.6, 123.1, 128.5, 129.3 (×2), 129.6 (d, Ar), 133.29, 133.32, 134.5, 135.3 (s, bridgehead-C), 136.0 (d, 4-Py), 147.9 (d, 6-Py), 155.2, 156.0 (s, C_{sp^2}−O), 157.6 (s, 2-Py); MS, m/z 721 (MH^+). Anal. Calcd for $C_{46}H_{44}N_2O_6$: C, 76.64; H, 6.15; N, 3.89. Found: C, 76.52; H, 6.04; N, 3.97.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-4-calix[4]-arene, Cone Conformer (4b): 3% yield, mp 184−185 °C (hexanes−Et_2O); ^{1}H NMR δ 3.05 and 4.32 (AX, J = 13.5 Hz, 2 H), 3.11 and 4.99 (AX, J = 13.2 Hz, 4 H), 3.14 and 4.39 (AX, J = 13.6 Hz, 2 H), 3.64−3.73 (m, 4 H), 3.80−3.90 (m, 4 H), 4.16 (ddd, J = 11.0, 8.3, 2.7 Hz, 2 H), 4.28 (ddd, J = 11.0, 3.8, 2.7 Hz, 2 H), 5.07 and 5.19 (ABq, J = 12.6 Hz, 4 H), 6.56−6.68 (m, 12 H), 7.19 (ddd, J = 7.4, 4.9, 1.3 Hz, 2 H), 7.58 (td, J = 7.4, 1.8 Hz, 2 H), 7.66 (dt, J = 7.4, 1.0 Hz, 2 H), 8.54 (ddd,

(20) Ouchi, M.; Inoue, Y.; Kanzaki, T.; Hakushi T. *J. Org. Chem.* **1984**, *49*, 1408.
(21) Widhalm, M.; Kalchhauser, H.; Kählig, H. *Helv. Chim. Acta* **1994**, *77*, 409.
(22) Kyba, E. P.; Gokel, G. W.; de Jong, F.; Koga, K.; Sousa, L. R.; Siegel, M. G.; Kaplan, L.; Dotsevi, G.; Sogah, Y.; Cram D. J. *J. Org. Chem.* **1977**, *42*, 4173.
(23) Yamamoto, H.; Sakaki, T.; Shinkai, S. *Chem. Lett.* **1994**, 469.

J = 4.9, 1.8, 1.0 Hz, 2 H); ^{13}C NMR δ 30.0, 30.9, 31.1 (×2) (t, $ArCH_2Ar$), 70.0, 70.6, 73.3 (t, OCH_2CH_2O), 77.5 (t, OCH_2Py), 122.2, 122.4, 122.5, 123.3, 128.18, 128.25, 128.34, 128.4 (d, 3,5-Py and ArH), 134.4, 134.5, 134.7, 135.9 (s, bridgehead-C), 136.2 (d, 4-Py), 148.9 (d, 6-Py), 155.5, 156.0 (s, C_{sp^2}−O), 157.9 (s, 2-Py); MS, *m*/*z* 721 (MH^+). Anal. Calcd for $C_{46}H_{44}N_2O_6$: C, 76.64; H, 6.15; N, 3.89. Found: C, 76.81; H, 6.38; N, 3.68.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-crown-5-calix[4]arene, 1,2-Alternate and Cone Conformers (3c) and (4c). Reaction of **1b** with **2b** and ^{t}BuOK under standard conditions gave after chromatography crown-5 conformers **3c** (27% yield) and **4c** (45% yield).[7]

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-5-calix[4]arene, 1,2-Alternate Conformer (3d): 32% yield, mp 180−181 °C (cyclohexane−CH_2Cl_2); ^{1}H NMR δ 2.56 (dt, J = 9.5, 6.5 Hz, 2 H), 3.24, 3.32 (d, J = 12.5 Hz, 1 H each), 3.19−3.24 (m, 2 H), 3.47−3.75 (m, 12 H), 3.85 and 3.91 (ABq, J = 16.7 Hz, 4 H), 4.26, 4.28 (d, J = 12.5 Hz, 1 H each), 4.62 and 4.68 (ABq, J = 14.0 Hz, 4 H), 6.17 (ddd, J = 7.5, 1.4, 0.9 Hz, 2 H), 6.67 (t, J = 7.3 Hz, 2 H), 6.71 (dd, J = 7.3, 2.2 Hz, 2 H), 6.88 (td, J = 7.5, 1.9 Hz, 2 H), 6.96 (ddd, J = 7.5, 4.8, 1.4 Hz, 2 H), 7.00 (t, J = 7.5 Hz, 2 H), 7.17 (dd, J = 7.3, 2.2 Hz, 2 H), 7.23 (dd, J = 7.5, 1.7 Hz, 2 H), 7.36 (dd, J = 7.5, 1.7 Hz, 2 H), 8.34 (ddd, J = 4.8, 1.9, 0.9 Hz, 2 H); ^{13}C NMR δ 28.2, 29.7, 37.7 (×2) (t, $ArCH_2Ar$), 69.3, 70.4, 70.6, 71.8 (t, OCH_2CH_2O), 74.6 (t, OCH_2Py), 121.1, 121.5 (d, 3,5-Py), 122.5, 123.2, 128.5, 129.0, 129.6, 129.7 (d, Ar), 133.1, 133.3, 134.3, 135.1 (s, bridgehead-C), 136.0 (d, 4-Py), 147.9 (d, 6-Py), 155.6, 156.0 (s, C_{sp^2}−O), 157.6 (s, 2-Py); MS, *m*/*z* 765 (MH^+). Anal. Calcd for $C_{48}H_{48}N_2O_7$: C, 75.37; H, 6.33; N, 3.66. Found: C, 75.18; H, 6.11; N, 3.81.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-5-calix[4]arene, Cone Conformer (4d): 28% yield, mp 150−151 °C (hexanes−Et_2O); ^{1}H NMR δ 3.02, 3.14, 3.15 (d, J = 13.5 Hz, ratio 1:2:1, 4 H), 3.60−3.67 (m, 8 H), 3.95−4.03 (m, 6 H), 4.19−4.23 (m, 2 H), 4.28, 4.41, 4.61 (d, J = 13.5 Hz, ratio 1:2:1, 4 H), 5.08 and 5.15 (ABq, J = 12.7 Hz, 4 H), 6.56−6.66 (m, 12 H), 7.18 (ddd, J = 7.5, 4.9, 1.2 Hz, 2 H), 7.60 (td, J = 7.5, 1.8 Hz, 2 H), 7.81 (dt, J = 7.5, 0.9 Hz, 2 H), 8.51 (ddd, J = 4.9, 1.8, 0.9 Hz, 2 H); ^{13}C NMR δ 29.7, 30.9, 31.1 (t, $ArCH_2Ar$), 70.2, 70.3, 71.1, 73.3 (t, OCH_2CH_2O), 77.5 (t, OCH_2Py), 122.3, 122.4 (×2), 123.3, 128.2, 128.37, 128.41, 128.44 (d, 3,5-Py and Ar), 134.6, 134.7, 134.8, 135.5 (s, bridgehead-C), 136.4 (d, 4-Py), 148.7 (d, 6-Py), 155.6, 156.1 (s, C_{sp^2}−O), 158.1 (s, 2-Py); MS, *m*/*z* 765 (MH^+). Anal. Calcd for $C_{48}H_{48}N_2O_7$: C, 75.37; H, 6.33; N, 3.66. Found: C, 75.58; H, 6.54; N, 3.85.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-crown-6-calix[4]arene, 1,2-Alternate Conformer (3e): 21% yield; mp 134−137 °C (cyclohexane−CH_2Cl_2); ^{1}H NMR δ 1.11, 1.37 (s, 18 H each), 2.55 (dt, J = 9.7, 7.1 Hz, 2 H), 3.09−3.16 (m, 2 H), 3.16, 3.21 (d, J = 12.2 Hz, 1 H each), 3.39−3.63 (m, 16 H), 3.84 and 3.90 (ABq, J = 17.2 Hz, 4 H), 4.17, 4.46 (d, J = 12.2 Hz, 1 H each), 4.54 and 4.59 (ABq, J = 13.9 Hz, 4 H), 6.14 (dt, J = 7.6, 0.9 Hz, 2 H), 6.76 and 7.19 (AX, J = 2.5 Hz, 4 H), 6.78 (td, J = 7.6, 1.9 Hz, 2 H), 6.87 (ddd, J = 7.6, 4.8, 1.3 Hz, 2 H), 7.12 and 7.37 (AX, J = 2.5 Hz, 4 H), 8.28 (ddd, J = 4.8, 1.9, 0.9 Hz, 2 H); ^{13}C NMR δ 28.8, 29.7, 38.8 (×2) (t, $ArCH_2Ar$), 31.4, 31.7 (q, $C(CH_3)_3$), 33.9, 34.1 (s, $C(CH_3)_3$), 68.1, 70.1, 70.3, 70.5, 70.9 (t, OCH_2CH_2O), 74.4 (t, OCH_2Py), 121.11, 121.15 (d, 3,5-Py), 124.6, 125.6, 125.7, 126.0 (d, Ar), 132.0, 132.5, 133.6, 134.8 (s, bridgehead-C), 136.3 (d, 4-Py), 144.5, 145.1 (s, C_{sp^2}−$C(CH_3)_3$), 147.8 (d, 6-Py), 153.1, 153.6 (s, C_{sp^2}−O), 158.0 (s, 2-Py); MS, *m*/*z* 1033 (MH^+). Anal. Calcd for $C_{66}H_{84}N_2O_8$: C, 76.71; H, 8.19; N, 2.71. Found: C, 76.95; H, 8.30; N, 2.61.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-crown-6-calix[4]arene, Cone Conformer (4e): 35% yield; mp 270−271 °C (cyclohexane−CH_2Cl_2); ^{1}H NMR δ 1.08, 1.09 (s, 18 H each), 3.10, 3.12 (d, J = 12.5 Hz, ratio 3:1, 4 H), 3.48−4.08 (m, 20 H), 4.34, 4.43, 4.51 (d, J = 12.5 Hz, ratio 2:1:1, 4 H), 5.01 (pseudo-s, 4 H), 6.80−6.83 (m, 8 H), 7.17 (ddd, J = 7.5, 4.9, 1.2 Hz, 2 H), 7.59 (td, J = 7.5, 1.8 Hz, 2 H), 7.85 (dt, J = 7.5, 0.9 Hz, 2 H), 8.53 (ddd, J = 4.9, 1,8, 0.9 Hz, 2 H); ^{13}C NMR δ 30.7, 30.8 (×2), 30.9 (t, $ArCH_2Ar$), 31.4 (q, $C(CH_3)_3$), 33.0, 33.8 (s, $C(CH_3)_3$), 69.7, 70.4, 70.5, 70.8, 73.1 (t, OCH_2CH_2O), 78.1 (t, OCH_2Py), 122.3, 123.2 (d, 3,5-Py), 125.0, 125.1, 125.2, 125.3 (d, Ar), 133.5 (×2), 133.6, 134.0, (s, bridgehead-C), 136.5 (d, 4-Py), 144.7, 144.8 (s, C_{sp^2}−$C(CH_3)_3$), 148.6 (d, 6-Py), 152.7, 153.1 (s, C_{sp^2}−O), 158.3 (s, 2-Py); MS, *m*/*z* 1033 (MH^+). Anal. Calcd for $C_{66}H_{84}N_2O_8$: C, 76.71; H, 8.19; N, 2.71. Found: C, 76.53; H, 8.24; N, 2.66.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-6-calix[4]arene, 1,2-Alternate Conformer (3f): 51% yield, thick oil; ^{1}H NMR δ 2.40−2.48 (m, 2 H), 3.08−3.15 (m, 2 H), 3.22, 3.32 (d, J = 12.7 Hz, 1 H each), 3.46−3.71 (m, 16 H), 3.88 (pseudo-s, 4 H), 4.28, 4.32 (d, J = 12.7 Hz, 1 H each), 4.61 and 4.67 (ABq, J = 13.7 Hz, 4 H), 6.14 (dt, J = 7.5, 0.9 Hz, 2 H), 6.67 (t, J = 7.5 Hz, 2 H), 6.72 (dd, J = 7.5, 2.3 Hz, 2 H), 6.89 (td, J = 7.5, 1.9 Hz, 2 H), 6.95 (ddd, J = 7.5, 4.8, 1.3 Hz, 2 H), 7.17 (dd, J = 7.5, 2.3 Hz, 2H), 7.18 (dd, J = 7.5, 1.7 Hz, 2 H), 7.34 (dd, J = 7.5, 1.7 Hz, 2 H), 8.33 (ddd, J = 4.8, 1.9, 0.9 Hz, 2 H); ^{13}C NMR δ 29.2, 29.7, 37.8 (×2) (t, $ArCH_2Ar$), 68.8, 70.3, 70.7, 70.9 (×2), (t, OCH_2CH_2O), 74.6 (t, OCH_2Py), 121.1, 121.5, 122.5, 123.2, 128.4, 129.1, 129.5, 129.6 (d, 3,5-Py and Ar), 133.1, 133.2, 134.4, 135.3 (s, bridgehead-C), 136.0 (d, 4-Py), 147.9 (d, 6-Py), 155.4, 156.1 (s, C_{sp^2}−O), 157.5 (s, 2-Py); MS, *m*/*z* 809 (MH^+). Anal. Calcd for $C_{50}H_{52}N_2O_8$: C, 74.24; H, 6.48; N, 3.46. Found: C, 73.95; H, 6.76; N, 3.35.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-crown-6-calix[4]arene, Cone Conformer (4f): 12%, thick oil; ^{1}H NMR δ 3.05 and 4.58 (AX, J = 13.5 Hz, 2 H), 3.12 and 4.39 (AX, J = 13.3 Hz, 4 H), 3.17 and 4.34 (AX, J = 13.5 Hz, 2 H), 3.5−3.7 (m, 12 H), 3.82−3.89 (m, 4 H), 4.13 (t, J = 6.4 Hz, 4 H), 5.03 and 5.12 (ABq, J = 13.5 Hz, 4 H), 6.56−6.66 (m, 12 H), 7.19 (ddd, J = 7.5, 4.9, 1.2 Hz, 2 H), 7.61 (td, J = 7.5, 1.8 Hz, 2 H), 7.75 (dt, J = 7.5, 0.9 Hz, 2 H), 8.53 (ddd, J = 4.9, 1.8, 0.9 Hz, 2 H); ^{13}C NMR δ 30.9, 31.0 (t, $ArCH_2Ar$), 70.1, 70.5, 70.7, 70.8, 72.9 (t, OCH_2CH_2O), 77.6 (t, OCH_2Py), 122.2, 122.46, 122.53, 123.5, 128.21, 128.24, 128.4 (d, 3,5-Py and Ar), 134.7, 134.8, 134.9, 135.2 (s, bridgehead-C), 136.3 (d, 4-Py), 148.8 (d, 6-Py), 155.5, 156.1 (s, C_{sp^2}−O), 158.1 (s, 2-Py); MS, *m*/*z* 809 (MH^+). Anal. Calcd for $C_{50}H_{52}N_2O_8$: C, 74.24; H, 6.48; N, 3.46. Found: C, 74.43; H, 6.67; N, 3.41.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthyl-crown-4-calix-[4]arene, Cone Conformer (4g): 45% yield, mp 280−282 °C (MeOH−Et_2O); ^{1}H NMR δ 0.98, 1.00, 1.14 and 1.15 (s, $C(CH_3)_3$, 9 H each), 2.87 and 3.85 (AX, J = 12.4 Hz, $ArCH_2Ar$, 2 H), 2.90 and 4.37 (AX, J = 12.4 Hz, $ArCH_2Ar$, 2 H), 3.17 and 4.39 (AX, J = 12.7 Hz, $ArCH_2Ar$, 2 H), 3.22 and 4.54 (AX, J = 12.6 Hz, $ArCH_2Ar$, 2 H), 3.74 (m, OCH_2CH_2O, 1 H), 4.03 (t, J = 6.7 Hz, OCH_2CH_2O, 2 H), 4.20 (m, OCH_2CH_2O, 2 H), 4.4−4.5 (m, OCH_2CH_2O, 3 H), 4.75 and 5.11 (ABq, J = 12.7 Hz, OCH_2Py, 2 H), 4.93 and 4.98 (ABq, J = 12.0 Hz, OCH_2-Py′, 2 H), 6.63 (td, J = 7.5, 1.9 Hz, 4-Py′H, 1 H), 6.64 (d, J = 2.4 Hz, ArH, 1 H), 6.69 (d, J = 2.4 Hz, ArH, 2 H), 6.73 (ddd, J = 7.5, 4.9, 1.3 Hz, 5-Py′H, 1 H), 6.74, 6.81, 6.84, 6.92, 6.96 (d, J = 2.4 Hz, ArH, 1 H each), 7.00 (d, J = 8.9 Hz, BinaphH, 1 H), 7.08−7.36 (m, 5-PyH, 3-Py′H, and BinaphH, 10 H), 7.47 (td, J = 7.5, 1.9 Hz, 4-PyH, 1 H), 7.61 (d, J = 8.9 Hz, BinaphH, 1 H), 7.73 (dt, J = 8.0, 0.6 Hz, BinaphH, 1 H), 7.84 (ddd, J = 7.5, 1.9, 0.9 Hz, 3-PyH, 1 H), 7.92 (d, J = 8.9 Hz, BinaphH, 1 H), 8.29 (ddd, J = 4.9, 1.9, 0.9 Hz, 6-PyH, 1 H), 8.69 (ddd, J = 4.9, 1.9, 0.9 Hz, 6-Py′H, 1 H); ^{13}C NMR δ 30.8, 30.9, 31.0, 31.2 (t, $ArCH_2Ar$), 31.3 (×2), 31.46, 31.51 (q, ($C(CH_3)_3$), 33.74, 33.77, 33.88, 33.91 (s, ($C(CH_3)_3$), 68.7, 69.3, 71.8, 72.8 (t, OCH_2CH_2), 78.0, 78.5 (t, OCH_2Py), 114.8, 117.7 (d), 119.0, 121.7 (s), 122.0, 122.7, 123.3, 123.4, 123.68, 123.73, 124.8, 125.06, 125.10, 125.15 (×2), 125.2 (×3), 125.4, 125.8, 126.27, 126.32, 127.8, 127.9, 129.11 (d), 129.15 (s), 129.2 (d), 129.8, 132.8, 132.9, 133.0, 133.1, 133.8, 134.2, 134.3 (×2), 134.4, 134.6 (s), 136.2, 136.7 (d, 4-Py), 144.6, 144.8, 144.9, 145.1 (s, C_{sp^2}−$C(CH_3)_3$), 147.9, 149.1 (d, 6-Py), 152.5, 152.6, 153.24, 153.26, 154.0, 155.0 (s, C_{sp^2}−O), 157.9 and 158.0 (s, 2-Py); MS, *m*/*z* 1169 (MH^+). Anal. Calcd for $C_{80}H_{84}N_2O_6$: C, 82.16; H, 7.24; N, 2.40. Found: C, 82.40; H, 7.11; N, 2.35.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthylcrown-4)-calix[4]arene, 1,2-Alternate Conformer (3h):

36% yield, mp 277−279 °C (MeOH); ^{1}H NMR δ 2.24 (ddd, J = 10.2, 7.7, 6.1 Hz, OCH_2CH_2O, 1 H), 2.91 (ddd, J = 10.7, 7.7, 4.3 Hz, OCH_2CH_2O, 1 H), 3.10 (dt, J = 11.6, 5.8 Hz, OCH_2-CH_2O, 1 H), 3.26−3.33 (m, OCH_2CH_2O, 1 H), 3.29 and 4.41 (AX, J = 12.4 Hz, $ArCH_2Ar$, 2 H), 3.36 and 4.30 (AX, J = 12.8 Hz, $ArCH_2Ar$, 2 H), 3.68−3.96 (m, $ArCH_2Ar$ and OCH_2CH_2O, 6 H), 4.14−4.22 (m, OCH_2CH_2O, 1 H), 4.31−4.39 (m, OCH_2-CH_2O, 1 H), 4.43 and 4.70 (ABq, J = 14.6 Hz, OCH_2Py, 2 H), 4.56 and 4.77 (ABq, J = 12.9 Hz, OCH_2Py', 2 H), 5.62 (dt, J = 7.5, 0.9 Hz, 3-PyH, 1 H), 6.50−6.59 (m, 5 H), 6.75 (t, J = 7.5 Hz, ArH, 1 H), 6.84−7.25 (m, 17 H), 7.30 (d, J = 9.0 Hz, 1 H), 7.39 (ddd, J = 8.1, 6.8, 1.3 Hz, 1 H), 7.45 (dd, J = 7.8, 1.4 Hz, 1 H), 7.60 (dt, J = 7.5, 1.2 Hz, 1 H), 7.78 (dt, J = 8.2, 0.8 Hz, 1 H), 7.85 (d, J = 9.4 Hz, 1 H), 7.99 (d, J = 8.0 Hz, 1 H), 8.10 (d, J = 8.5 Hz, 1 H), 8.30 (ddd, J = 4.8, 1.8, 0.9 Hz, 6-Py′H, 1 H), 8.33 (dt, J = 4.8, 1.4 Hz, 6-PyH, 1 H); ^{13}C NMR δ 28.1, 29.7 37.7, 38.2 (t, $ArCH_2Ar$), 68.3, 68.5, 69.2, 72.5 (t, OCH_2-CH_2O), 73.4, 75.8 (t, OCH_2Py), 113.7 (d), 119.2 (s), 120.1, 120.6, 121.0 (d), 121.5 (s), 121.7, 121.9, 122.1, 123.1, 123.3, 123.4, 123.8, 124.0, 125.6, 125.9, 126.3, 127.7, 128.0, 128.1, 128.4, 128.76, 128.80, 128.93 (d), 128.96 (s), 129.0, 129.10, 129.16, 129.21 (d), 130.0 (s), 130.3 (d), 131.9, 132.3, 133.4, 133.6, 133.8, 134.16, 134.24, 135.0 (s), 135.57, 135.61 (d), 136.0 (s), 136.2, 147.4, 148.3 (d), 153.7, 154.8, 155.4, 155. 5, 156.7, 157.01, 157.03, 158.0 (s, C_{sp^2}−O, 2-Py and 2-Py′); MS, m/z 945 (MH^+). Anal. Calcd for $C_{64}H_{52}N_2O_6$: C, 81.32; H, 5.55; N, 2.97. Found: C, 81.23; H, 5.40; N, 2.88.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthylcrown-4)-calix[4]arene, Cone Conformer (4h): 21% yield, mp 268−269 °C (MeOH−Et_2O); ^{1}H NMR δ 2.78, 2.93, 3.19, 3.21 (d, J = 13.4 Hz, 1 H each), 3.92−4.55 (m, 8 H), 3.72, 4.18, 4.46, 4.51 (d, J = 13.4 Hz, 1 H each), 4.79 and 4.97 (ABq, J = 12.1 Hz, 2 H), 4.98 and 5.01 (ABq, J = 11.6 Hz, 2 H), 6.42−6.85 (m, 13 H), 7.01 (ddd, J = 7.6, 1.8, 0.9 Hz, 2 H), 7.09 (d, J = 9.0 Hz, 1 H), 7.15 (d, J = 9.1 Hz, 2 H), 7.11−7.31 (m, 6 H), 7.54 (d, J = 9.0 Hz, 1 H), 7.56−7.71 (m, 3 H), 7.84 (d, J = 8.0 Hz, 1 H), 7.91 (d, J = 9.0 Hz, 1 H), 8.27 (ddd, J = 4.9, 1.8, 0.9 Hz, 1 H), 8.63 (ddd, J = 4.9, 1.8, 0.9 Hz, 1 H); ^{13}C NMR δ 30.8 (×2), 31.1, 31.2 (t, $ArCH_2Ar$), 69.1, 69.3, 71.9, 72.1 (t, OCH_2CH_2O), 77.5, 78.2 (t, OCH_2Py), 115.2, 117.8 (d,), 119.0 (s), 122.1, 122.2 (d), 122.4 (s), 122.51, 122.54, 122.6, 122.8, 123.3, 123.6, 123.9, 124.1, 124.9, 125.26, 125.34, 126.4, 127.8, 127.87, 127.90, 128.0, 128.2, 128.3, 128.4, 128.5, 128.6, 129.0 (d), 129.2 (s), 129.3, 129.4, (d), 130.0, 133.9, 134.1, 134.2, 134.27, 134.32, 135.0, 135.2, 135.5, 135.6 (s), 136.0, 136.5 (d, 4-Py and 4-Py′), 147.9, 149.3 (d, 6-Py and 6-Py′), 153.7, 154.9, 155.3, 155.4, 155.7, 156.0 (s, C_{sp^2}−O), 157.0 and 157.5 (s, 2-Py and 2-Py′); MS, m/z 945 (MH^+). Anal. Calcd for $C_{64}H_{52}N_2O_6$: C, 81.32; H, 5.55; N, 2.97. Found: 81.48; H, 5.31; N, 2.92.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthyl-crown-6)calix-[4]arene, 1,2-Alternate Conformer (3i): 6% yield after chromatographic purification on preparative TLC plates ($CHCl_3$−AcOEt, 7:1; three elutions); mp 138−140 °C (MeOH−CH_2Cl_2); ^{1}H NMR δ 1.06, 1.17, 1.29, 1.36 (s, 9 H each), 2.55−2.64, 2.79−2.87, 2.95−3.02 (m, 1 H each), 3.05−3.48 (m, 10 H), 3.70−4.16 (m, 9 H), 4.18 (d, J = 12.3 Hz, 1 H), 4.44 and 4.66 (ABq, J = 14.7 Hz, 2 H), 4.46 (d, J = 12.5 Hz, 1 H), 4.51 and 4.77 (ABq, J = 13.6 Hz, 2 H), 5.93 (dt, J = 7.9, 0.9 Hz, 1 H), 6.48−6.54 (m, 2 H), 6.67 (d, J = 2.4 Hz, 1 H), 6.81−7.35 (m, 18 H), 7.55 (d, J = 8.7 Hz, 1 H), 7.66 (dd, J = 8.4, 0.8 Hz, 1 H), 7.85 (d, J = 7.7 Hz, 1 H), 7.93 (d, J = 8.7 Hz, 1 H), 8.31 (dt, J = 4.7, 0.9 Hz, 2 H); ^{13}C NMR δ 28.9, 30.4 (t, $ArCH_2Ar$), 31.4, 31.58, 31.64, 31.66 (q, $C(CH_3)_3$), 33.89, 33.93, 34.07, 34.14 (s, $C(CH_3)_3$), 38.6, 38.8 (t, $ArCH_2Ar$), 67.2, 67.9, 68.8, 68.9, 69.0, 69.2, 69.3, 71.3 (t, OCH_2CH_2O), 73.7, 74.9 (t, OCH_2Py), 114.4, 116.7 (d), 119.8, 120.5, (s), 120.9, 121.4, 121.6 (d, 3,5-Py and 3,5-Py′), 123.4, 124.6, 125.3, 125.4, 125.5, 125.7, 125.8, 125.90, 125.94, 126.0, 126.3, 126.4, 127.8 (d), 129.0 (s), 129.1, 129.2 (d), 129.4, 131.4, 131.8, 132.8, 133.18, 133.25, 133.87, 133.90, 134.06, 134.14, 135.5(s), 136.3, 137.1 (d, 4-Py and 4-Py′), 144.3, 144.9, 145.0, 145.3 (s), 147.2, 147.9 (d, 6-Py and 6-Py′), 153.1, 153.2, 153.76, 153.83, 154.3, 154.5 (s), 157.6 and 158.3 (s, 2-Py and 2-Py′); MS, m/z 1257 (MH^+). Anal. Calcd for $C_{84}H_{92}N_2O_8$: C, 80.22; H, 7.37; N, 2.23. Found: C, 80.54; H, 7.65; N, 2.12.

5,11,17,23-Tetrakis(1,1-dimethylethyl)-25,26-bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthylcrown-6)calix-[4]arene, Cone Conformer (4i): 43% yield; mp 156−157 °C ($CHCl_3$−MeOH); ^{1}H NMR δ 1.06, 1.08, 1.09, 1.12 (s, 9 H each), 3.05, 3.07, 3.11, 3.13 (d, J = 12.5 Hz, 1 H each), 3.24−4.14 (m, 16 H), 4.27, 4.41, 4.44, 4.47 (d, J = 12.5 Hz, 1 H each), 4.93 and 5.01 (ABq, J = 12.9 Hz, 2 H), 4.99 and 5.19 (ABq, J = 12.6 Hz, 2 H), 6.77−6.83 (m, 8 H), 6.92 (ddd, J = 7.5, 4.8, 1.2 Hz, 1 H), 7.03−7.13 (m, 3 H), 7.17 (ddd, J = 8.4, 6.7, 1.4 Hz, 1 H), 7.21 (ddd, J = 8.4, 6.7, 1.4 Hz, 1 H), 7.24 (d, J = 9.0 Hz, 1 H), 7.29 (ddd, J = 8.1, 6.7, 1.3 Hz, 1 H), 7.32 (ddd, J = 8.1, 6.7, 1.3 Hz, 1 H), 7.39 (td, J = 7.5, 1.8 Hz, 1 H), 7.43 (td, J = 7.5, 1.8 Hz, 1 H), 7.45 (d, J = 9.0 Hz, 1 H), 7.68 (dt, J = 7.5, 0.9 Hz, 1 H), 7.82 (bd, J = 8.8 Hz, 1 H), 7.84 (d, J = 8.8 Hz, 1 H), 7.85 (d, J = 8.5 Hz, 1 H), 7.88 (dt, J = 7.5, 0.9 Hz, 1 H), 7.89 (d, J = 8.8 Hz, 1 H), 8.46 (ddd, J = 4.8, 1.8, 0.9 Hz, 1 H), 8.48 (ddd, J = 4.8, 1.8, 0.9 Hz, 1 H); ^{13}C NMR δ 30.7, 30.8, 30.96, 31.05, 31.41 (×2), 31.43, 31.45, 33.80, 33.83, 33.85, 33.87, 68.9, 69.2, 69.3, 69.4, 69.9, 70.0, 73.07, 73.12 77.97, 78.02, 115.4, 116.3, 120.1, 120.3, 122.2, 122.3, 123.1, 123.5, 123.6, 124.89, 124.94, 125.0, 125.16, 125.20, 125.24, 125.27, 125.38, 125.40, 125.48, 126.1, 126.2, 127.82, 127.84, 129.1, 129.2, 129.3, 129.4, 133.40, 133.44, 133.50, 133.7, 133.89, 133.95, 134.0, 134.1, 136.2, 136.6, 144.67, 144.74, 144.79, 144.84, 148.5, 148.6, 152.6, 152.77, 152.80, 153.3, 154.4, 154.6, 158.3, 158.4; MS, m/z 1257 (MH^+). Anal. Calcd for $C_{84}H_{92}N_2O_8$: C, 80.22; H, 7.37; N, 2.23. Found: C, 80.46; H, 7.48; N, 2.16.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthylcrown-6)-calix[4]arene, 1,2-Alternate Conformer (3j): 28% yield, mp 145−147 °C (hexane−CH_2Cl_2); ^{1}H NMR δ 2.08−2.16 (m, 1 H), 2.26−2.34 (m, 1 H), 2.88−3.00 (m, 2 H), 3.18−3.55 (m, 10 H), 3.83 (bs, 4 H), 3.99−4.10 (m, 3 H), 4.259, 4.264 (d, J = 12.5 and 12.8 Hz, respectively, 1 H each), 4.22−4.29 (m, 1 H), 4.60 and 4.66 (ABq, J = 14.2 Hz, 2 H), 4.63 and 4.64 (ABq, J = 13.1 Hz, 2 H), 6.11, 6.18 (dt, J = 7.7, 0.9 Hz, 1 H each), 6.66−6.98 (m, 10 H), 7.06−7.35 (m, 12 H), 7.36, 7.52 (d, J = 9.0 Hz, 1 H each), 7.74 (dd, J = 7.6, 1.0 Hz, 1 H), 7.76 (d, J = 9.3 Hz, 1H), 7.89 (dt, J = 8.0, 0.7 Hz, 1 H), 8.01 (d, J = 9.3 Hz, 1 H), 8.34 (ddd, J = 4.8, 1.9, 0.9 Hz, 2 H); ^{13}C NMR δ 28.2, 29.3, 37.6, 37.8 (t, $ArCH_2Ar$), 68.4, 68.6, 68.9, 69.0, 69.4, 69.5, 70.5, 71.2 (t, OCH_2CH_2O), 74.5, 74.7 (t, OCH_2Py), 115.2, 116.4 (d), 120.2 (s), 121.0, 121.1, 121.4, 121.5, 122.6 (×2), 123.0, 123.3, 123.5, 123.6, 125.36, 125.44, 126.1, 126.3, 127.8, 127.9, 128.4, 128.5, 129.0, 129.23, 129.26 (×2), 129.30 (d), 129.4 (s), 129.5, 129.6, 129.8 (d), 133.06, 133.14, 133.20, 133.3, 133.9, 134.1, 134.2, 134.5, 135.3 (×2) (s), 135.92, 135.97 (d, 4-Py and 4-Py′), 147.86, 147.95 (d, 6-Py and 6-Py′), 154.2, 154.6, 155.2, 155.4, 156.06, 156.14 (C_{sp^2}−O), 157.5 and 157.6 (2-Py and 2-Py′); MS, m/z 1033 (MH^+). Anal. Calcd for $C_{68}H_{60}N_2O_8$: C, 79.04; H, 5.86; N, 2.71. Found: C, 79.13; H, 6.01; N, 2.58.

25,26-Bis[(2-pyridylmethyl)oxy]-27,28-(2,2′-binaphthylcrown-6)-calix[4]arene, Cone Conformer (4j): 12% yield, mp 113−115 °C (EtOH); ^{1}H NMR δ 3.02, 3.08, 3.14, 3.17 (d, J = 13.5 Hz, 1 H each), 3.37−3.57 (m, 4 H), 3.74 (bt, J = 5.7 Hz, 2 H), 3.84−4.15 (m, 10 H), 4.30, 4.33, 4.46, 4.54 (d, J = 13.5 Hz, 1 H each), 5.00 and 5.07 (ABq, J = 12.6 Hz, 2 H), 5.10 and 5.21 (ABq, J = 12.3 Hz, 2 H), 6.55−6.71 (m, 12 H), 7.03 (ddd, J = 7.5, 4.9, 1.2 Hz, 1 H), 7.06−7.34 (m, 7 H), 7.17 (d, J = 9.0 Hz, 1 H), 7.37 (td, J = 7.5, 1.8 Hz, 1 H), 7.43 (d, J = 9.0 Hz, 1 H), 7.49 (td, J = 7.5, 1.8 Hz, 1 H), 7.67 (ddd, J = 7.5, 1.8, 0.9 Hz, 2 H), 7.74 (d, J = 8.8 Hz, 1 H), 7.79−7.83 (m, 2 H), 7.89 (d, J = 8.8 Hz, 1 H), 8.47 (ddd, J = 4.9, 1.8, 0.9 Hz, 1 H), 8.49 (ddd, J = 4.9, 1.8, 0.9 Hz, 1 H); ^{13}C NMR δ 30.9 (×3), 31.1 (t, $ArCH_2Ar$), 69.1, 69.2, 69.4, 69.5, 70.1, 70.4, 72.9, 73.0 (t, OCH_2CH_2O), 77.4, 77.5 (t, OCH_2Py), 115.4, 116.0 (d), 120.2 (s), 122.3 122.41, 122.45, 122.48, 122.53, 123.2, 123.5, 123.7, 125.3, 125.5, 126.16, 126.23, 127.80, 127.84, 128.13, 128.18, 128.3, 128.39, 128.41, 128.5, 129.1, 129.28 (d), 129.21, 129.33, 134.01, 134.06, 134.57, 134.65, 134.71, 134.85, 134.94, 134.96, 135.28 (s), 136.2, 136.3 (d, 4-Py and 4-Py′), 148.8, 148.9 (d, 6-Py and 6-Py′), 154.3, 154.4, 155.38, 155.43, 156.0 (×2) (C_{sp^2}−O), 157.88 and 157.93 (2-Py and 2-Py′); MS, m/z 1033 (MH^+). Anal. Calcd for $C_{68}H_{60}N_2O_8$: C, 79.04; H, 5.86; N, 2.71. Found: C, 78.84; H, 5.96; N, 2.77.

Reaction of 5 with 2a−c. Diol **5** (0.269 g, 0.5 mmol) was reacted with tri- to pentaethylene glycol ditosylate (1.1 equiv) and ^{t}BuOK (0.123 g, 1.1 mmol) in dry toluene, by following the general procedure. Usual workup, followed by column chromatography (SiO_2, hexane−AcOEt, 75:25 to 0:100, v/v) gave in order the relevant 1,2-alternate and cone biscrown conformers. Further details are given for the individual compounds.

25,26−27,28-Biscrown-4-calix[4]arene, 1,2-Alternate Conformer (6a): 25% yield; mp 245−247 °C (MeOH), ^{1}H NMR δ 2.80 (ddd, J = 10.5, 5.6, 4.7 Hz, OCH_2CH_2O, 4 H), 3.19 and 4.34 (AX, J = 12.3 Hz, $ArCH_2Ar$, 4 H), 3.21 (ddd, J = 10.5, 7.2, 5.6 Hz, OCH_2CH_2O, 4 H), 3.41−3.62 (m, OCH_2CH_2O, 12 H), 3.71 (ddd, J = 8.7, 7.2, 5.6 Hz, OCH_2CH_2O, 4 H), 3.90 (s, $ArCH_2Ar$, 4 H), 6.94 (t, J = 7.5 Hz, ArH, 4 H), 7.08 and 7.20 (2dd, J = 7.5, 1.8 Hz, ArH, 8 H); ^{13}C NMR δ 28.4 and 38.1 (t, $ArCH_2Ar$), 68.6, 70.1, 70.4 (t, OCH_2), 122.5, 128.9, 129.1 (d), 133.0, 135.0 (s, bridgehead-C), 155.5 (s, C_{sp^2}−O); MS, m/z 653 (MH^+). Anal. Calcd for $C_{40}H_{44}O_8$: C, 73.60; H, 6.79. Found: C, 73.42; H, 6.70.

25,26−27,28-Biscrown-4-calix[4]arene, Cone Conformer (7a): 35% yield; mp 233−235 °C (MeCN) (lit.[9] mp 234−236 °C); ^{1}H NMR δ 3.11 and 4.97 (AX, J = 12.9 Hz, 4 H), 3.22 and 4.35 (AX, J = 13.3 Hz, 4 H), 3.7−3.9 (m, 20 H), 4.20 (ddd, J = 10.7, 8.1, 2.9 Hz, 2 H), 4.36 (m, 2 H), 6.59 (dd, J = 8.2, 6.4 Hz, 4 H), 6.67 (m, 8 H).

25,26-Crown-4-27,28-crown-5-calix[4]arene, 1,2-Alternate Conformer (6b): 30% yield; mp 189−191 °C (MeOH), ^{1}H NMR δ 2.74−2.85 (m, 4 H), 3.19 (d, J = 12.5 Hz, 2 H), 3.22−3.31 (m, 4 H), 3.46−3.74 (m, 20 H), 3.86 and 3.95 (ABq, J = 16.6 Hz, 4 H), 4.22 and 4.34 (2d, J = 12.5 Hz, 2 H), 6.91 and 6.93 (2t, J = 7.5 Hz, 4 H), 7.09 (dd, J = 7.5, 1.9 Hz, 2 H), 7.16 (d, J = 7.5 Hz, 4 H), 7.17 (dd, J = 7.5, 1.9 Hz, 2 H); ^{13}C NMR δ 28.5, 28.8 and 37.9 (×2) (t, $ArCH_2Ar$), 68.6, 69.7, 70.0, 70.4, 70.5, 70.6, 71.4 (t, OCH_2), 122.4, 122.6, 128.7, 128.9, 129.3, 129.4 (d, Ar), 132.9, 133.0, 134.8, 135.0 (s, bridgehead-C), 155.5 and 155.9 (s, C_{sp^2}−O); MS, m/z 697 (MH^+). Anal. Calcd for $C_{42}H_{48}O_9$: C, 72.39; H, 6.94. Found: C, 72.12; H, 6.78.

25,26-Crown-4-27,28-crown-5-calix[4]arene, Cone Conformer (7b): 55% yield; mp 208−210 °C (MeOH), ^{1}H NMR δ 3.11 and 4.99, 3.13 and 4.54, 3.20 and 4.38 (3AX, J = 13.0−13.3 Hz, ratio 1:1:2, 8 H), 3.67−4.36 (m, 28 H), and 6.56−6.68 (m, 12 H); ^{13}C NMR δ 29.8, 30.5, 31.0 (×2) (t, $ArCH_2Ar$), 70.3, 70.5, 70.8, 71.4, 73.37, 73.40 (t, OCH_2), 122.2, 122.3, 128.07, 128.13, 128.26, 128.33 (d, Ar), 134.5, 134.7, 135.1, 135.7 (s, bridgehead-C), 156.0 and 156.2 (s, C_{sp^2}−O); MS, m/z 697 (MH^+). Anal. Calcd for $C_{42}H_{48}O_9$: C, 72.39; H, 6.94. Found: C, 72.16; H, 7.15.

25,26-Crown-4-27,28-crown-6-calix[4]arene, 1,2-Alternate Conformer (6c): 45% yield, thick oil; ^{1}H NMR δ 2.62 (dt, J = 10.0, 7.0 Hz, 2 H), 2.80 (ddd, J = 10.4, 5.7, 4.6 Hz, 2 H), 3.12−3.28 (m, 4 H), 3.18, 3.19 (d, J = 12.5 Hz, 1 H each), 3.43−3.75 (m, 24 H), 3.87 and 3.94 (ABq, J = 16.6 Hz, 4 H), 4.27, 4.34 (d, J = 12.5 Hz, 1 H each), 6.90, 6.93 (t, J = 7.5 Hz, 2 H each), 7.08, 7.11, 7.16, 7.17 (dd, J = 7.5, 1.7 Hz, 2 H each); ^{13}C NMR δ 28.5, 28.7 and 37.9 (×2) (t, $ArCH_2Ar$), 68.5, 69.2, 70.0, 70.4, 70.48, 70.53, 70.7, 70.8 (t, OCH_2), 122.4, 122.6, 128.8 (×2), 129.0, 129.4 (d, Ar), 132.9 (×2), 134.9, 135.0 (s, bridgehead-C), 155.5 and 155.7 (s, C_{sp^2}−O); MS, m/z 741 (MH^+). Anal. Calcd for $C_{44}H_{52}O_{10}$: C, 71.32; H, 7.08. Found: C, 71.06; H, 7.24.

25,26-Crown-4-27,28-crown-6-calix[4]arene, Cone Conformer (7c): 22% yield, thick oil; ^{1}H NMR δ 3.11 and 5.00, 3.16 and 4.54, 3.18 and 4.38 (3AX, J = 13.2 Hz, ratio 1:1:2, 8 H), 3.64−4.35 (m, 30 H), 6.56−6.69 (m, 12 H); ^{13}C NMR δ 29.8, 29.9 and 31.0 (×2) (t, $ArCH_2Ar$), 70.2, 70.3, 70.6, 70.86, 70.94, 70.96, 73.1, 73.4 (t, OCH_2), 122.23, 122.26, 128.13, 128.16, 128.24, 128.29 (d, Ar), 134.6, 134.9, 135.0, 135.7 (s, bridgehead-C), 156.0 and 156.3 (s, C_{sp^2}−O); MS, m/z 741 (MH^+). Anal. Calcd for $C_{44}H_{52}O_{10}$: C, 71.32; H, 7.08. Found: C, 70.94; H, 7.36.

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Supporting Information Available: Atomic coordinates, displacement parameters, and molecular geometry for **6a** (11 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of this journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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