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SYNTHESES AND PROPERTIES OF ARENEDIAZONIUM AND ANILINIUM CATION LARIAT ETHER COMPLEXES: AN "OSTRICH MOLECULE" COMPLEX AND EVIDENCE FOR INTRAMOLECULAR SIDEARM - MACRORING INTERACTION

JAMES R. BEADLE, DENNIS M. DISHONG,
RAJ K. KHANNA, AND GEORGE W. GOKEL*

Department of Chemistry, University of Maryland,
College Park, Maryland 20742 U.S.A.

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Abstract - The preparation of several novel lariat ethers (macrocyclic crown polyethers having sidearms bearing pendant donor groups) is reported. These compounds are ethers derived from known 2-hydroxymethyl-15-crown-5 or -21-crown-7. The sidearms include 2-aminophenyl, 2,4-diaminophenyl, 2-nitrophenyl, 2-(3'-nitrobiphenyl), and 2-(3'-aminobiphenyl). In several cases, the amino groups were converted into ammonium salts which showed substantial stabilization by intramolecular hydrogen bonding. Likewise, an $-NH_2^+ \cdot BF_3^-$ complex showed evidence of intramolecular hydrogen bonding. Diazotization of the aminobiphenyl residue produced an arenediazonium cation which underwent intramolecular crown complexation, as judged by infrared spectroscopic studies to form what we call an "ostrich molecule" complex. Addition of N,N-dimethylaniline to the intramolecular arenediazonium cation complex afforded an azo compound, but europium shift reagent studies showed clearly that the diazonium cation reacted outside the macroring.

INTRODUCTION

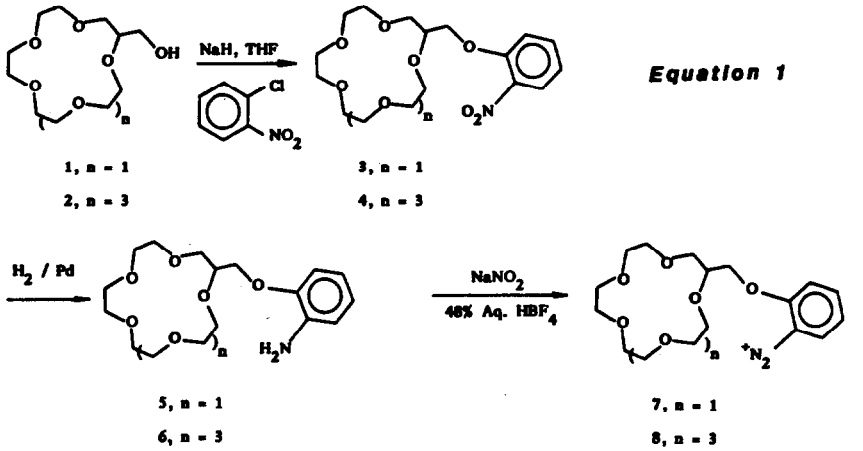
Complexes between macrocyclic polyethers and organic cations have proved intriguing to workers in this field since Pedersen first reported metallic cation binding by crown ethers.[1] Ammonium and substituted ammonium ions,[2] guanidinium ions,[3] arenediazonium,[4] and even nitrosyl cations[5] have all been studied in this connection. Indeed, the structures of several neutral complexes have been reported quite recently and others have been known for some time.[6] Our interest in crown complexation has led us to study binding stabilities and selectivities, especially those concerned with intramolecular interactions between macroring, cation and sidearm.[7]

In the first report of arenediazonium cation complexation it was noted that attempts to synthesize an azoarene threaded through the crown hole had failed.[4a] Only non-encircled coupling products were obtained. Apparently intermolecular arenediazonium cation complexes are highly dynamic in solution, and stable only in the solid phase. A further difficulty attending the synthesis of these rotaxanes is that crown complexation diminishes the reactivity of the ring-bound arenediazonium cation in several reactions[8] including azo-coupling.[9] At the outset of this effort, we thought that intramolecular arenediazonium complexation might be stronger than intermolecular complexation and this might permit coupling reactions leading to a rotaxane or molecular knot. Similar tethering strategies have been successfully employed in recent rotaxane[10] syntheses.[11] An important purpose of this study was therefore to prepare the first intramolecular arenediazonium-crown ether complex and to attempt formation of a molecular knot from it. In addition, it was anticipated that quite interesting intramolecular hydrogen bonding interactions would be observed between the protonated amines which serve as synthetic intermediates and the macrorings to which they are tethered.

RESULTS AND DISCUSSION

Intramolecular Complexation. An examination of C-P-K molecular models suggested that 2-(2-diazoniophenoxy)methyl-21-crown-7 (8) was a suitable target. The 21-crown-7 macroring was chosen because 18-crown-6 appeared to be too crowded (as judged by models) to form an intramolecular complex in this case. Further, of all the simple crown ether compounds, the 21-membered ring systems form the most stable intermolecular complexes with arenediazonium cations.[4,12]

The synthesis of 1 was accomplished as described previously for the 15-membered (3) and 18-membered ring homologs of 2-(2-nitrophenoxy)methyl-21-crown-7, 4.[13] Hydroxymethyl-15-crown-5 (1)[7a] or hydroxymethyl-21-crown-7 (2)[14] was converted into the corresponding alkoxide by treatment with NaH in THF solution. Reaction with 1-chloro-2-nitrobenzene afforded 3 and 4 respectively. Reduction (H_2, Pd/C) of the nitro groups afforded aminocrowns 5 and 6 which were, in turn, diazotized with $NaNO_2$ in 48% HBF_4 to yield diazonio-crowns 7 and 8. Extraction (CH_2Cl_2) of the aqueous solutions afforded stable, dark red oils which would not crystallize. They exhibited N=N IR absorptions characteristic of diazonium cations.



Equation 1

The IR and UV spectra of 7 and 8 were examined to determine if the observed spectral properties were those expected for an intramolecular complex. 2-Methoxybenzenediazonium BF_4 (9) was also prepared for use in spectral comparisons.

The IR spectra of 9 alone (mull), in the presence of 18-crown-6 and 21-crown-7 ($CHCl_3$) showed strong, relatively sharp absorptions at 2268 cm^{-1}, 2277 cm^{-1}, and 2276 cm^{-1} respectively. These bands are similar in shape to those previously reported.[4d,g] The UV spectra for the corresponding solutions ($CHCl_3$) showed maxima at 267 nm, 263 nm and 252 nm. Note that these results are somewhat different from the trends observed when 4-substituted diazonium ions are complexed by crowns.[4]

The shift in triple bond stretch for 9 (+9 cm^{-1}) in the presence of 18-crown-6 is less than observed for other salts, and the UV spectrum shows no change when this crown is added. 21-Crown-7, on the other hand, imparts a strong shift to the UV absorption and a typical IR shift.

The IR and UV spectra of 7 agreed well (λmax = 267 nm, $\nu_{N\equiv N}$ = 2262 cm^{-1}) with the values obtained for noncomplexed 9. The 15-crown-5 ring is too small to accommodate the arenediazonium cation,[4] so these values were anticipated. Compound 8, which should be intramolecularly complexed, i.e., exhibited IR and UV maxima at 2265 cm^{-1} and 267 nm respectively. Addition of one equivalent of 18-crown-6 did not alter the spectra.

When 18-crown-6 addition also failed to alter the IR and UV spectra of 7, it was presumed that the 2-methoxy group so crowds the diazonium ion, that insertion of $-N_2^+$ was sterically impossible. Work on these compounds as potential rotaxane precursors was thus abandoned.

TABLE: IR AND UV SPECTRAL PROPERTIES OF ARENEDIAZONIUM CATIONS

Compound Number	Added Crown	λ_{max}	$\nu_{N\equiv N}$	Compound Number	Added Crown	λ_{max}	$\nu_{N\equiv N}$
7	none	266	2262	22	none	253	2272
7	18-Crown-6	nd	2260	22	18-Crown-6	254	2302
8	none	267	2265	23	none	267	2290
8	18-Crown-6	nd	2264	23	18-Crown-6	nd	2290
9	none	265	2268	25	none	258	2278
9	18-Crown-6	263	2277	25	18-Crown-6	251	2307
9	21-Crown-7	252	2276	25	21-Crown-7	250	2289

Notes for table: Nd = not determined. IR data in reciprocal cm. UV data in nm. All spectra recorded in chloroform unless otherwise noted. One equiv of crown added unless otherwise noted; Compounds 9 and 25 were recorded in Nujol in the absence of crown. Crown to salt ratio for 9 with 18-crown-6 was ca. 10:1 and with 21-crown-7 was 2:1. Crown to salt ratio for 25 with 18-crown-6 was ca. 2:1.

Intramolecular Anilinium Complexes. When amine 5 was dissolved in EtOH and 48% HBF_2 added, a white solid (mp 183-184°C) precipitated. After treatment with isoamyl nitrite, which usually results in the immediate diazotization of amine groups, the white solid was recovered unchanged. We attribute this compound's inertness to the formation of intramolecular anilinium-crown complex 10 (see figure 1).[15] Models of this complex suggest that two of the three N-H bonds participate in hydrogen bonds to macroring oxygens. Stabilization of the protonated amine by hydrogen bonding to the crown ring reduces the likelihood of nitrosylation just as Barrett and coworkers have shown that non-complexed secondary amines acylate more readily than do crown-complexed primary amines.[16]

A related complex (11) was formed by similar treatment of 6. That such a complex should form while our attempts to form intramolecular diazonium-crown complexes apparently failed, is not surprising since the interaction between anilinium cations and crown ethers is less sensitive to the presence of ortho substituents.[17] Note (equation 1) that conversion of 5 to diazonium compound 7 was successful when performed in 48% HBF_4 solvent. The more polar medium must compete with the anilinium cation for macroring oxygens. IR spectral evidence (see below) suggests that intramolecular complexation by the 15-membered ring compounds is significant, although weaker than observed with larger macrorings. The related 2,4-diaminophenyl lariat ether, 14, was also prepared (see equation 3) in the hope that the IR spectrum for the ortho and para amino groups would be clearly distinguishable. These and other results are shown in figure 2 and are discussed below. A similar crystalline complex, 12, was formed when 5 was treated with BF_3 in diethyl ether. A likely structure for complex 12 is shown in equation 2.

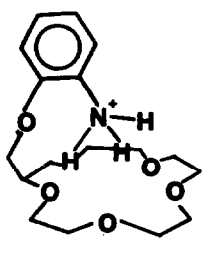


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Figure 1 (above)

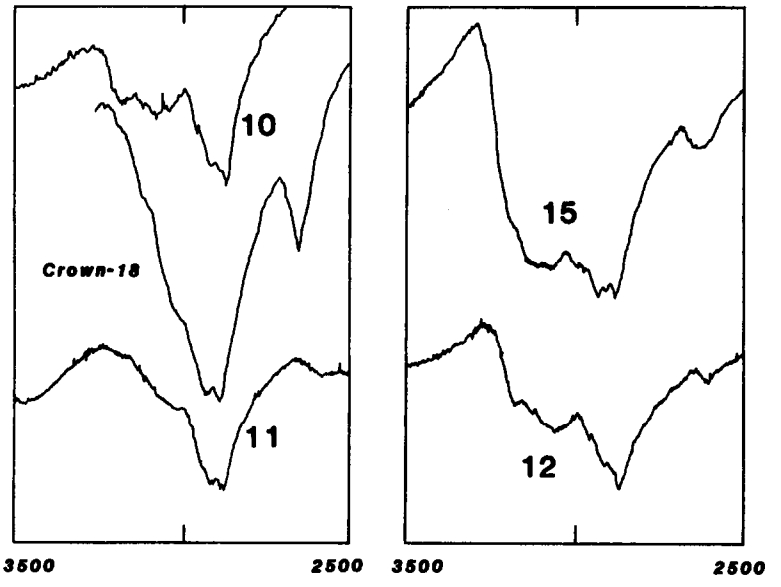
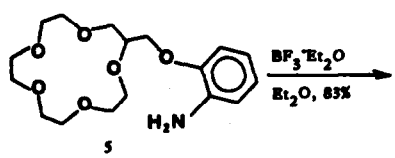


Figure 2: IR spectra for numbered compounds. "Crown-18" refers to the 18-membered ring analogs of crowns 10 and 11.

The IR spectrum of 10 (figure 2) shows peaks centered at ca. 3180, 3120 and 3080 cm^{-1} (fig 2a). These peaks are rather broad (halfwidth 40-60 cm^{-1}) and characteristic of N-H···O hydrogen bonds similar to those in amino acids.[18] Of course, N-H···F hydrogen bonding with the neighboring BF_4 groups cannot be ignored. Nevertheless, the extent of hydrogen bonding is small. With the 18-crown-6 analog of 10, the N-H···O frequencies are shifted downward to ca. 2850 cm^{-1} (overlapping with CH stretches) and ca. 2600 cm^{-1} (fig. 2b). The spectrum of 11 (21-membered ring) shows a similar downward shift (fig. 2c). The N-H vibrations are shifted to lower wavenumber due to an interaction with proximate oxygen atoms and the BF_4 group. Five-oxygen ring compounds interact more weakly than either the six- or seven-heteroatom rings, the N-H vibration remains separated from the C-H vibration, with which it is merged when larger rings are present (see figure 2a, b). The similarity in the spectra of 10 and 15 is quite striking. In 15, two $-NH_3^+$ groups are present, only one of which can interact with an intramolecular macroring. This suggests that both $-NH_3^+$ groups are hydrogen-bonded to a similar extent. Likewise, the BF_3 complex (12, Fig. 2e) shows spectral features which are similar to those of 10 and 15. It is interesting that the $-NH^+$ groups of 15 (see eq. 3) are less differentiated by IR spectra than expected since the ortho-amino groups in 5 and 6 appear to readily form intramolecular anilinium complexes.



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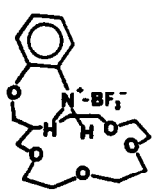

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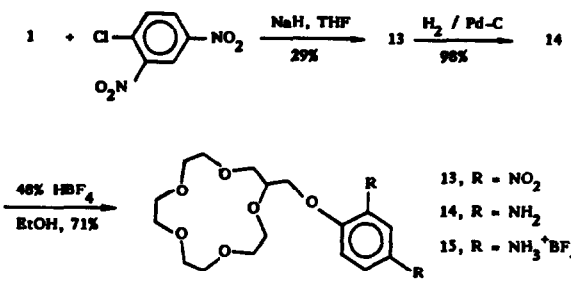
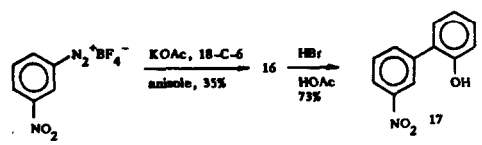
Equation 2

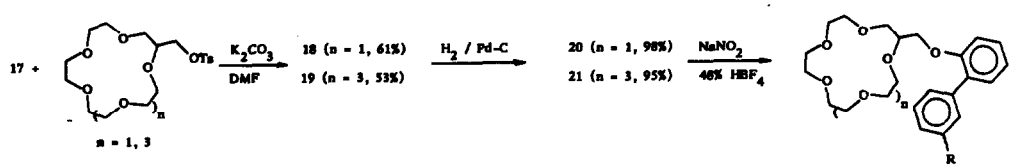


Equation 3

Synthesis of 3-[2'-(21-Crown-7-methoxy)phenyl]benzenediazonium BF_4. Since we believe the failure of 8 to form the desired intramolecular complex is due to steric hindrance at the ortho position, an obvious remedy is to attach the macroring elsewhere. It is clear from C-P-K molecular models that a longer bridge is required for intramolecular complexation to occur. For example, a 3-substituted phenethyl group, coupled to 1 or 2, appeared the appropriate. The 2,3'-biphenyl system appeared even better. It is more rigid than the phenethyl unit, potentially increasing complex stability, but still flexible enough to permit synthesis. The synthesis of 23, was accomplished as shown in equation 4. As before, the 15-membered homolog was prepared for comparative purposes.



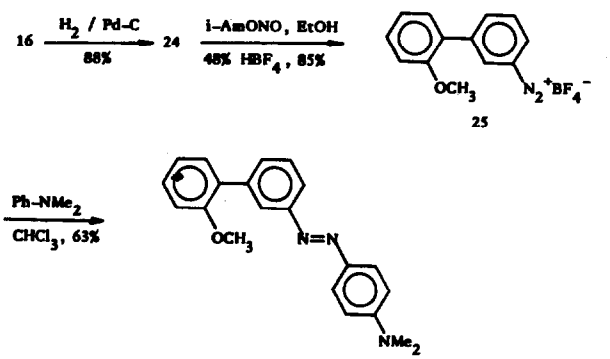
Equation 4



The desired compounds were accessible from 1 and 2 via their tosylates and 2-hydroxy-3'-nitrobiphenyl, 17. The latter was prepared by phase transfer Gomberg-Bachmann coupling of 3-nitrobenzenediazonium BF_4 with anisole.[19] Demethylation[20] (HBr, HOAc) gave 17 which was allowed to react with (15-crown-5)- or (21-crown-7)methyl 4-toluenesulfonate (K_2CO_3, DMF). Reduction of nitro crowns 18 and 19 (H_2, Pd/C) gave amino crowns 20 and 21 which were diazotized as before ($NaNO_2$, 48% HBF_4). Compound 23 was obtained as a colorless foam which undergoes a glass transition at 45-50°C and decomposes from 70-73°C. Compound 22 was isolated as a red gummy material.

A model compound was required for comparison with 23. Amine 24, obtained by reduction of nitro compound 16, was converted into 3-(2-methoxyphenyl)benzenediazonium BF_4, 25 which was coupled with N,N-dimethylaniline to provide model azo compound 26.

The UV spectra of 25 alone, in the presence of 18-crown-6, or 21-crown-7 showed maxima at 258 nm, 251 nm and 250 nm respectively. The infrared spectra for the corresponding solutions showed N=N bond absorptions at 2278 cm^{-1}, 2307 cm^{-1} and 2289 cm^{-1}. As expected, the values observed for 15-membered ring 22 ($\nu_{N=N}$ = 2272 cm^{-1} and λ_{max} = 253 nm) were similar to noncomplexed 25. The UV maximum for 23 was observed at 254 nm and the triple bond absorbed at 2290 cm^{-1}. The latter accords nicely with the value observed for 21-crown-7-complexed 25. Note also that this was a single, sharp peak indicating that the intramolecular complex is not dynamic, at least on the infrared timescale.



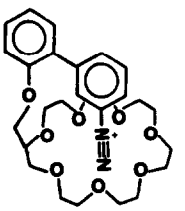


Figure 3 (above): Representation of "ostrich complex" presumed to form from compound **23**.

Equation 5 (left)

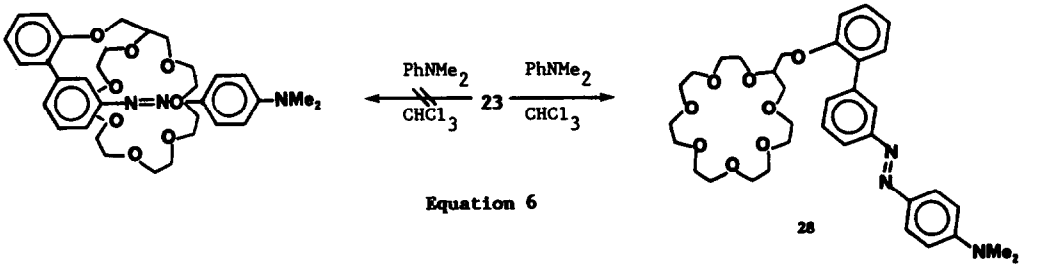
The UV maximum differs somewhat from what might have been expected based on a comparison with 25. That there should be some variation is not surprising since the UV spectrum is sensitive to the inter-ring dihedral angle which no doubt differs in systems having a crown sidechain rather than a simple methoxy substituent.

An interesting feature of intramolecular complex 23 was the appearance of its ^{1}H-NMR spectrum. The absorptions for the macroring protons of noncomplexed 22 and complexed 23 differed considerably. Compound 22 showed a single broad resonance in the 3-4 ppm region. In the 3-4 ppm region of 23, at least 5 distinct peaks comprise a broad multiplet. This reflects the different environments of the ring protons when they are held in the complexed conformation.

A further corroboration of intramolecular complex formation by 23 is that addition of 18-crown-6 has no effect on the IR spectrum. Addition of the latter macrocycle to 22 caused the N=N stretch to shift from 2272 cm^{-1} to 2302 cm^{-1}. Neither is 23's IR spectrum altered by dilution as expected for an intermolecular complex. We call this new type of intramolecular complex[21] an "ostrich" compound. The name is based on the popular myth that this bird hides its head when pursued and believes itself to be unseen.

Attempted Through-Hole azo-Coupling Reaction. With the desired ostrich complex in hand, we attempted the azo-coupling reaction in the hope of obtaining a rotaxane. N,N-dimethylaniline was added (25°C) to a stirred, $CHCl_3$ solution of 23. The azo dye formed readily and was then purified by flash chromatography. TLC analysis of the resulting red oil indicated that it was a single compound. The IR and ^{1}H-NMR spectra were consistent with the azo structure and the UV spectrum was essentially identical to that of azo compound 26.

If this azo-crown had threaded structure 27, its cavity should be unavailable for complexation. When $Eu(fod)_3$ was added to an equimolar mixture of 21-crown-7 and azo compound 26 ($CDCl_3$) the complexation of Eu(III) by the free macrocycle was easily detected by a large downfield shift of the ^{1}H-NMR crown resonance. The absorption before and after the addition was observed at 3.65 PPM (singlet) and 7.05-7.15 PPM (broad singlet). Addition of $Eu(fod)_3$ had a similar effect on the spectrum of the azo-crown demonstrating that the cavity was not filled by the desired azo compound. The macroring resonance appeared as a multiplet at 3.60 before the addition. After the europium reagent was added, the peak disappeared from this region and appeared as a very broad signal at 7 ppm. Based on these observations we assigned structure 28 to the azo-crown.



Equation 6

28

SUMMARY

We report here the preparation of several new lariat ether compounds having nitro and amino donors groups on the sidearms. These have been converted into anilinium salts by protonation or arenediazonium cations by diazotization. Intramolecular complexation of the anilinium salts leads to much reduced reactivity. Further, we have designed and prepared the first example of an intramolecular arenediazonium cation-crown ether complex. Our attempts to form a threaded azo-arene led instead to nonthreaded structure 28. Even in this case, where the crown-diazonium complex is strengthened by an intramolecular bridge, the cation comes out of the hole to react with the nucleophile.

EXPERIMENTAL SECTION

Uncorrected melting points were obtained in open capillaries and are reported in °C. NMR spectra (proton unless otherwise noted, $CDCl_3$, Varian EM-360) and C-13 NMR spectra are reported in ppm downfield from internal Me_4Si. Routine IR spectra (Perkin-Elmer 281, neat films, NaCl plates unless otherwise specified) are calibrated against the 1601.8 cm^{-1} band of polystyrene.

Tetrahydrofuran (THF) was distilled from $LiAlH_4$. $CHCl_3$ (AR grade) was washed with concentrated H_2SO_4, H_2O, dried over Na_2SO_4, distilled and stored over 3A molecular sieves. All reactions were conducted under dry N_2, and dried in work up using Na_2SO_4. Molecular distillations were conducted in a Kugelrohr apparatus; bp's are oven temperatures. 15-Crown-5, 18-crown-6, and 21-crown-7 were obtained as previously described.[18]

Preparation of Arenediazonium Cations. Arenediazonium BF_4 salts were prepared by the method of Roe,[22] dissolved in Me_2CO and precipitated by addition of Et_2O, and then air dried immediately prior to use.

IR Studies. The 1:1 complexes were mulled in Nujol and the 2400-2200 cm^{-1} region of their IR spectra recorded on a Perkin-Elmer Model 225 IR spectrophotometer using an expanded scale and calibrated as before. Solution spectra were obtained by stirring the arenediazonium salt (0.2 mmol) and the of crown ether in $CHCl_3$ (0.5 mL) until solution occurred. The homogeneous sample was placed in a solution IR cell (NaCl, 0.025 mm path length) and recorded as above.

UV Studies. The absorbance spectra of $CHCl_3$ solutions of the diazonium salts (2.2×10^{-4} M) and crown ethers (3.13×10^{-3} M) were recorded on a Hitachi 100-80A UV-Vis spectrophotometer.

C-13 NMR Studies. Samples were prepared by stirring the arenediazonium salt (0-0.5 mmol) with crown ether in $CDCl_3$ until solution occurred. C-13 NMR spectra were recorded on a Varian XL-100 NMR spectrophotometer in the proton fully. decoupled mode. $CDCl_3$ provided an internal deuterium lock.

(15-Crown-5)methyl 4-toluenesulfonate. A mixture of 4-toluenesulfonyl chloride (0.76 g, 4.0 mmol) and pyridine (1.0 mL) was added (dropwise, 0°) to 2-hydroxymethyl-15-crown-5[18a] (4, 1.0 g, 4.0 mmol) in pyridine (1 mL) (5 min.), stirred 1h, H_2O (10 mL) was added and the mixture was extracted with CH_2Cl_2 (3 x 15 mL). The extracts were washed with ice-cold 6N HCl (3 x 10 mL),

brine (10 mL) and dried. (15-Crown-5)methyl 4-toluenesulfonate (1.4 g, 87%) was isolated as a pale yellow oil: NMR 2.45 (s, 3H), 3.64 (m, 19H), 4.15 (m, 2H), 7.7 (q, 4H); C-13 NMR 21.57, 69.86, 70.30, 70.68, 71.03, 77.00, 127.74, 129.57, 132.87, 144.46; IR 2850, 1360, 1120, 700. Anal. Calcd for $C_{18}H_{28}O_8S$: C, 53.45; H, 6.98. Found: C, 53.59; H, 7.11.

2-Hydroxymethyl-21-crown-7, 2. Ethylene glycol monobenzyl ether (30 g, 0.20 mol) and NaH (10.4 g, 0.20 mol), suspended in THF (150 mL) were heated at reflux (5 h). After standing 0.5h, tetraethylene glycol ditosylate (50.2 g, 0.10 mol) in THF (100 mL) was added during 1h. The mixture was heated at reflux (24h), cooled, filtered and the THF evaporated. The residue (in CH_2Cl_2 150 mL) was washed with H_2O, brine, and then dried. The crude hexaethylene glycol dibenzyl ether was Kugelrohr distilled, affording 2 (31.6 g, 69%), a pale yellow oil: bp 198-250° (0.03 torr); NMR 3.66 (s, 24H), 4.54 (s, 4H), 7.32 (s, 10H); IR 2860, 1600, 1490, 1450, 1350, 1290, 1120, 700. Anal. Calcd for $C_{26}H_{38}O_7$: C, 67.51; H, 8.28. Found: C, 67.80; H, 8.59.

The dibenzyl ether (31.0 g, 0.067 mol) was cleared [H_2, 60 psi in the presence of 10% Pd/C, (100 mg) EtOH, concd HCl (1 mL)] to afford hexaethylene glycol (17.3 g, 91%): bp 164-168° (0.05 torr); NMR 3.0 (broad s, 2H), 3.67 (s, 24H).

The ditosylate prepared by standard methods (39 g, 0.066 mol) was stirred with 3-benzyloxy-1,2-propanediol (12.0 g, 0.066 mol) and of NaH (6.97 g, 0.145 mol) in THF (500 mL). Chromatography (alumina, 0-2% 2-propanol/hexane) afforded a yellow oil (8.1 g) which was purified by distillation, to give benzyloxymethyl-21-crown-7 (4.8 g, 17%) as a pale yellow oil: bp 186-188° (0.04 torr); NMR 3.34 (m, 29H), 4.51 (s, 2H), 7.40 (s, 5H); IR 2860, 1450, 1120, 735. Anal. Calcd for $C_{22}H_{26}O_8$: C, 61.66; H, 8.47. Found: C, 61.84; H, 8.63.

Hydrogenolysis of benzyloxymethyl 21-crown-7 [4.77 g, 0.011 mol, 10% Pd/C (100 mg), EtOH] gave 2-hydroxymethyl-21-crown-7 (3.52 g, 94%) as a colorless oil[14b] after distillation: bp 148-152° (0.03 torr); NMR 62.17, 69.54, 70.38, 70.76, 71.26, 79.39; IR 2860, 1450, 1110, 840. Anal. Calcd for $C_{15}H_{30}O_8$: C, 53.24; H, 8.94. Found: C, 53.27; H, 9.20.

(21-Crown-7)methyl 4-toluenesulfonate. 2-Hydroxymethyl-21-crown-7 (2.00 g, 5.9 mmol) in pyridine (5 mL) was added dropwise to 4-toluenesulfonyl chloride (1.25 g, 6.6 mmol) in pyridine (5 mL) at ca. 0°. After stirring 1h, H_2O (10 mL) was added, then CH_2Cl_2 (30 mL). The organic phase was washed [cold 6N HCl (15 mL)], dried and evaporated to give the tosylate (2.45 g, 84%) as a nearly colorless oil: NMR 2.37 (s, 3H), 3.54 (m, 27H), 4.00 (m, 2H), 7.60 (q, 4H); C-13 NMR 21.48, 69.51, 69.83, 69.98, 70.53, 70.79, 76.59, 127.65, 129.49, 132.75, 144.40; IR 2870, 1360, 1175, 1120, 785. Anal. Calcd for $C_{22}H_{36}O_{10}S$: C, 53.64; H, 7.37. Found: C, 53.51; H, 7.41.

2-(2-Nitrophenoxy)methyl-15-crown-5, 3. A solution of 2-hydroxymethyl-15-crown-5 (1.25 g, 5 mmol) in THF (10 mL) was added dropwise (3 min) to NaH (0.12 g, 5 mmol) in THF (25mL). After stirring 15 min, 1-chloro-2-nitrobenzene (0.79 g, 5 mmol) in THF (10 mL) was added in a stream. The mixture was stirred 1h at room temperature, at reflux 4h, cooled, filtered, evaporated, and chromatographed (alumina, 5% Et_2O/hexane followed by 5% 2-propanol/hexane) to yield 3 as a viscous pale yellow oil: 1.02 g (55%); NMR 3.70 (s, 19H), 4.17 (s, 2H), 6.93-8.12 (m, 4H); IR (neat) 1610, 1525, 1355, 1125 (br), 745. Anal. Calcd for $C_{17}H_{25}NO_8$: C, 54.98, H, 6.78; N, 3.77. Found: C, 55.26; H, 7.02; N, 3.74.

2-(2-Nitrophenoxy)methyl-21-crown-7, 4. 2-Hydroxymethyl-21-crown-7[14] (0.46 g, 1.4 mmol) in THF (10 mL) was stirred with NaH (34 mg, 1.4mmol) in THF (25 mL) until H_2 evolution ceased. 1-Chloro-2-nitrobenzene (0.22 g, 1.4 mmol) in THF (10 mL) was added in a stream. The mixture was stirred 16h, 25°, filtered, the solvent evaporated, and the remaining oil chromatographed (alumina, 5% Et_2O/hexane followed by 5% 2-propanol/hexane) to give 4 as a pale yellow oil: 0.26 g (40%); NMR 3.37-4.37 (m, 29H, sharp at 3.73), 6.93-7.96 (m, 4H); IR (neat) 1605, 1525, 1350 1110 (br), 745. Anal. Calcd for $C_{21}H_{33}NO_{10}$: C, 54.89; H, 7.24; N, 3.05. Found: C, 54,85; H, 7.50; N, 3.05.

2-(2-Aminophenoxy)methyl-15-crown-5, 5. An EtOH (25 mL) of 3 (1.25 g, 3.5 mmol) was hydrogenated (50 psi, 5h, 10% Pd/C), filtered, evaporated and distillated (160-180°/0.5 torr) to give 5 as a translucent, colorless oil: 1.03 g (90%); NMR 3.73 (s, 19H), 4.07 (s, 2H), 6.73 (s, 4H); IR (neat) 3320, 1505, 1120, 740. Anal. Calcd. for $C_{17}H_{27}NO_6$: C, 59.81; H, 7.97; N, 4.10. Found: C, 60.10; H, 8.20; N, 4.15.

2-(2-Aminophenoxy)methyl-21-crown-7, 6. An EtOH soln. of 4 (100 mg, 0.2 mmol) was hydrogenated (50 psi, 8h, 10% Pd/C), filtered, and evaporated to give an oil (93 mg, 98%) which was converted directly into crystalline 10.

2-(15-Crown-5-methoxy)benzenediazonium BF_4, 7. Aminocrown 5 (319 mg, 0.93 mmol) was dissolved in 48% HBF_4 (5 mL) and cooled to ca. 0°, and cold aq. $NaNO_2$ (69 mg, 1 mmol) was added dropwise. The soln became dark red. After 5 min, the mixture was extracted with CH_2Cl_2 (10 mL). The organic phase washed with cold 10% HBF_4, dried over Na_2SO_4, and evaporated to give 7 as a dark red oil, characterized only by IR: 2250 cm^{-1}.

2-(21-Crown-7-methoxy)benzenediazonium BF_4, 8. Compound 6 (30 mg, 0.06 mmol) was dissolved in 48% HBF_4 (0.2 mL), and cooled to ca. 0°. Cold aq. soln of $NaNO_2$ was added and, after an additional 5 min, was extracted with CH_2Cl_2 (5 mL). Evaporation left a dark red oil: IR (neat) 2250 (br).

2-Methoxybenzenediazonium BF_4, 9. The title compound was prepared as previously described.[17c]

2-(2-Aminophenoxy)methyl-15-crown-5 HBF_4, 10. Aqueous 48% HBF_4 (1 mL) was added to a solution of 5 (250 mg, 0.7 mmol) in EtOH (3 mL). After stirring, briefly, white precipitate 10 was collected and dried (high vacuum): 260 mg (87%); mp 183-184°; NMR (DMSO-d_6) 3.43-4.33 (m, 21H), 7.53-6.90 (m, 4H), 9.23 (br s, 3H); IR (mull) 1450, 1115-1000, 755. Anal. Calcd for $C_{17}H_{28}BF_4NO_6$: C, 47.57; H, 6.57; N, 3.26. Found: C, 47.37; H, 6.62; N, 3.14.

2-(2-Aminophenoxy)methyl-21-crown-7 HBF_4, 11. Aminocrown 6 (93 mg, 0.22 mmol) was dissolved in EtOH and 48% HBF_4 (0.25 mL) added, stirred until crystallization began, and cooled for 1h before the white powder was collected by filtration: 88 mg (77%); mp 183-184°; IR (mull) 1455, 1050 (br), 755. Anal. Calcd for $C_{21}H_{36}BF_4NO_8$: C, 48.76; H, 7.01; N, 2.71. Found: C, 48.74; H, 7.17; N, 2.66.

2-(2-Aminophenoxy)methyl-21-crown-7 boron trifluoride crystalline complex, 12. To aminocrown 5 (55 mg, 0.16 mmol) in Et_2O (3 mL) was added $BF_3{\cdot}Et_2O$ (57 mg, 0.40 mmol) and the mixture stirred until the white complex precipitated. The product was collected by filtration: 54 mg (83%); mp 218-220°; IR (mull) 1380, 1150-1000, 760. Anal. Calcd for $C_{17}H_{27}BF_3NO_6$: C, 49.88; H, 6.65; N, 3.42. Found: C, 47.60; H, 6.37; N, 3.27.

2-(2,4-Dinitrophenoxy)methyl-15-crown-5, 13. NaH (0.48 g, 20 mmol) in THF (30 mL) and a THF (20 mL) solution of 2-hydroxymethyl-15-crown-5 (5.00 g, 20 mmol) were stirred until H_2 evolution ceased. 1-Chloro-2,4-dinitrobenzene (4.05 g, 40 mmol) in THF (10 mL) was added in a stream. The mixture was stirred overnight (25°), filtered, the solvent evaporated and the residue chromatographed (alumina, 0-10% i-PrOH/hexane) to afford 13 as a viscous, pale yellow oil: 2.41 g (29%); NMR 3.56-4.43 (m, 21H, tall singlet at 3.67), 7.40 (d, 1H, J = 10 Hz), 8.53 (dd, 1H, J = 10.2 Hz), 8.87 (d, 1H, J = 2 Hz); IR (neat) 1605, 1525, 1345, 1125 (br), 830. Anal. Calcd for $C_{17}H_{24}N_2O_{10}$: C, 49.04; H, 5.81; N, 6.73. Found: C, 49.22; H, 5.94; N, 6.69.

2-(2,4-Diaminophenoxy)methyl-15-crown-5, 14. Compound 13 (1.25 g, 3 mmol) was hydrogenated (EtOH, 30 mL, 60 psi, 10% Pd/C) gave 14 as a very viscous oil that started out colorless but turned red after a few minutes exposure to air: 1.04 g (98%); NMR: 3.57 (brs, 4H), 3.49-4.07 (m, 21H), 6.00 (d, 0.5 H, J = 2 Hz) 6.23 (s, 1.5 H), 6.77 (d, 1 H, J = 8 Hz), addition of D_2O caused the 3.57 signal to disappear; IR (neat) 3400-3200, 1510, 1115 (br). Anal. Calcd for $C_{17}H_{28}N_2O_6$: C, 57.29; H, 7.92; N, 7.96. Found: C, 57.39; H, 8.70; N, 7.91.

2-(2,4-Diaminophenoxy)methyl-15-crown-5 bis-(hydrogen tetrafluoroborate), 15. Diaminocrown 14 (1.00 g, 2.8 mmol) in ethanol (6 mL) was treated with 48% HBF_4 (2 mL). A white precipitate was collected by filtration: 1.05 g (71%); mp 238-240° dec; IR (mull) 3220 (br), 1130-1120. Anal. Calcd for $C_{17}H_{30}B_2F_8N_2O_6$: C, 38.38; 5.68; N, 5.27. Found: C, 36.63, H, 5.26; N, 5.29.

2-Methoxy-3'-nitrobiphenyl, 16. To anisole (400 mL) and 3-nitrobenzenediazonium BF_4 (54.5 g, 0.23 mol) was added potassium acetate (49.0 g, 0.5 mol) in one portion. The mixture turned red and warmed slightly, was stirred for 12h, was filtered, and the anisole evaporated in vacuo. Column chromatography of the residue (alumina, 0-10% Et_2O/hexane, first yellow band) and recrystallization (95% EtOH) provided pure 13: 18 g (35%); mp 68-69° (lit.[23] mp 68.5-69.0°).

2-Hydroxy-3'-nitrobiphenyl, 17. Biphenyl 13 (9.00 g, 3.9 mmol) was refluxed with HOAc (50 mL) and 48% HBr (50 mL) for 8h. The solution was then concentrated, poured into ice-cold H_2O (300 mL), extracted with CH_2Cl_2, dried, evaporated and recrystallized (50% aq MeOH) to afford 17 as yellow needles: 6.12 g (73%); mp 99.5-100° (lit.[20] 99.5-100°).

2-[2-(3-Nitrophenyl)phenoxymethyl]-15-crown-5, 18. Anhydrous K_2CO_3 (0.54 g, 2.9 mmol), (15-crown-5)methyl 4-toluenesulfonate (1.28 g, 2.6 mmol) and 2-hydroxy-3'-nitrobiphenyl (0.56 g, 2.6 mmol) in DMF (15 mL) were stirred and at 50° overnight. After cooling, the solution was poured into H_2O (50 mL), extracted with Et_2O (2 x 25 mL), dried, and the residue was chromatographed (alumina, 0-5% 2-propanol/hexane) to afford 9 as a viscous yellow oil: 0.71 g (61%); NMR 3.50-4.23 (m, 21H, tall singlet at 3.73), 6.90-8.57 (m, 8H); C-13 NMR 69.04, 70.35, 77.81, 112.32, 121.00, 121.38, 124.41, 127.96, 128.49, 129.65, 130.30, 135.43, 139.99, 147.73, 155.44; IR 1520, 1345, 1110 (br), 720. Anal. Calcd for $C_{23}H_{29}NO_8$: C, 61.80; H, 6.43; N, 3.13. found: C, 61.44; H, 6.77; N, 3.11.

2-[2-(3-Nitrophenyl)phenoxymethyl]-21-crown-7, 19. (21-Crown-7)methyl 4-toluenesulfonate (0.96 g, 1.9 mmol), 2-hydroxy-3'-nitrobiphenyl (0.42 g, 1.9 mmol) in DMF (10 mL) and K_2CO_3 (0.41 g, 3 mmol) were stirred 8h at 50° then poured into H_2O (30 mL), extracted with Et_2O and dried. Column chromatography of the oil left after evaporation (alumina, 0-5% 2-propanol/hexane) provided 10 as a thick yellow oil: 0.54 g (53%); NMR 3.66-4.23 (m, 29H, tall peak at 3.70), 6.90-8.53 (m, 8H); C-13 NMR 68.75, 70.79, 77.99, 112.53, 121.18, 121.53, 124.53, 128.12, 128.61, 129.77, 130.42, 135.57, 140.11, 147.87, 155.50; IR 1530, 1350, 1105 (br), 730. Anal. Calcd for $C_{27}H_{37}NO_{10}$; C, 60.55, H, 6.96, N, 2.61. Found: C, 60.32; H, 6.89; N, 2.72.

2-[2-(3-Aminophenyl)phenoxymethyl]-15-crown-5, 20. Nitro compound 9 (0.35 g, 0.78 mmol) in 30 mL EtOH was treated with H_2 (60 psi) and 10% Pd/C (0.01 g) for 12h. The solution was then filtered (Celite) and evaporated to afford 11 as a very viscous oil: 0.32 g (98%); NMR 3.33-4.10 (m, 32H, tall singlet at 3.70), 6.57-7.50 (m, 8H); C-13 NMR 69.08, 70.39, 77.53, 112.67, 114.13, 117.13, 120.60, 120.89, 128.32, 128.41, 130.48, 131.06, 129.42, 144.73, 155.63; IR (neat) 3320 (br), 1110 (br), 750. Anal. Calcd for $C_{23}H_{31}NO_6$: C, 66.17; H, 7.48; N, 3.35. found: C, 66.17; H, 7.48; N, 3.35.

2-[2-(3-Aminophenyl)phenoxymethyl]-21-crown-7, 21. Nitrocrown 10 (0.78 g, 1.4 mmol) was treated with H_2 (60 psi) and 10% Pd/C (0.02 g) for 12h. The solution was filtered (Celite) and evaporated to provide 12 as a viscous, hygroscopic oil: 0.67 g (95%); NMR 3.63-4.13 (m, 31H, tall singlet at 3.70), 6.40-7.47 (m, 8H); C-13 NMR 69.13, 70.45, 77.97, 112.67, 113.52, 116.55, 119.93, 120.89, 128.26, 130.51, 131.17, 139.42, 145.78, 155.66; IR (neat) 3600-3100, 1100 (br), 755. Anal. Calcd for $C_{27}H_{39}NO_8$: C, 64.14; H, 7.77; N, 2.77. Found: C, 64.02; H, 7.63; N, 2.47.

3-[2-(15-Crown-5-methoxy)phenyl]benzenediazonium tetrafluoroborate, 22. Amino crown 11 (250 mg, 0.6 mmol) and 48% HBF_4 (1.5 mL) were magnetically stirred and heated gently until solution occurred. This solution was cooled (25°) and a solution of $NaNO_2$ (48 mg, 0.7 mmol) in H_2O (0.5 mL) was added dropwise. The mixture was stirred 10 min, extracted with CH_2Cl_2 (10 mL), washed with 10% HBF_4, with water, dried, and evaporated to give a residue which was taken up in CH_2Cl_2 (5 mL) then separated by addition of diethyl ether. After decanting the solvent, the remainder of the volatiles were removed under high vacuum. The red gummy material was used without further purification: IR ($CHCl_3$) 2272.

3-[2'-(21-Crown-7-methoxy)phenyl]benzenediazonium tetrafluoroborate, 23. Amino crown 12 (110 mg, 0.2 mmol) was dissolved in warm 48% HBF_4 and then cooled (25°) before dropwise addition of an aqueous $NaNO_2$ (30 mg, 0.4 mmol). The mixture was stirred 10 min, extracted with CH_2Cl_2 (25 mL), washed with 10% HBF_4 and H_2O, dried and evaporated. The residue was dissolved in CH_2Cl_2 (5 mL), then separated by addition of Et_2O. The solvent was decanted and the remaining oil was placed under high vacuum (0.1 torr) where it foamed. The colorless foam, when heated in a capillary, underwent a glass transition at 45-50° and decomposed from 70-73°: NMR 2.53, (broad s, impurity); 3.27-4.20 (m, 29H, sharp peaks at 3.30, 3.53 and 3.67), 6.80-7.60 (m, 4H), 7.97-8.67 (m, 3H), 9.70 (s, 1H); IR ($CHCl_3$) 2290. Anal. Calcd for $C_{27}H_{37}BF_4N_2O_8$: C, 53.65; H, 6.16. Found: C, 51.59; H, 6.51.

3'-Amino-2-methoxybiphenyl, 24. 2-Methoxy-3'-nitrobiphenyl (5.00 g, 25 mmol) was hydrogenated (50 psi) over 10% Pd/C catalyst for 3h to yield 14: mp 70-71° (lit.[20] mp 70.5-71°).

3-(2-Methoxyphenyl)benzenediazonium tetrafluoroborate, 25. 3'-Amino-2-methoxybiphenyl (2.30 g, 0.012 mol) and 48% HBF_4 (9 g) in EtOH (15 mL) was cooled to ca. 0° followed by dropwise addition of isoamyl nitrite (1.40 g, 0.014 mol). After 20 min Et_2O (100 mL) was added to precipitate 15. Reprecipitation from Me_2CO by addition of Et_2O yielded yellow needles: 3.04 g (85%); mp 80-81.5°; NMR (acetone-d_6) 3.92 (s, 3H), 6.98-7.68 (m, 4H), 8.18 (d, 1H, J = 8Hz), 8.45-9.15 (m, 3H); IR (mull) 2268, 1060 (br), 770. Anal. Calcd for $C_{13}H_{11}BF_4N_2O$: C, 52.39; H, 3.72; N, 9.40. Found: C, 52.47; H, 3.71; N, 9.70.

3-(2-Methoxyphenyl)-4'-N,N-dimethylaminoazobenzene, 26. To diazonium salt 15 (298 mg, 1 mmol) in Me_2CO (5 mL) was added N,N-dimethylaniline (133 mg, 1.1 mmol) while stirring. The mixture turned red immediately. Solid Na_2CO_3 (0.5 g) was added and stirred 15 min before the mixture was filtered then chromatographed (alumina, 0-50% Et_2O/hexane) to give a red solid, which after recrystallization (petroleum ether) afforded 16 as red plates: 208 mg (63%); mp 113-115°; NMR 3.10 (s, 6H), 3.83 (s, 3H), 6.67-8.03 (m, 12H); IR (neat) 1600, 1370, 1145, 760. Anal. Calcd for $C_{21}H_{21}N_3O$: C, 76.11; H, 6.38; N, 12.68. Found: C, 75.95; H, 6.42; N, 12.72.

3-[2-(21-Crown-7-methoxy)phenyl]-4'-N,N'-dimethylaminoazobenzene, 27. To Compound 23 (ca. 30 mg) in $CHCl_3$ (5 mL) was added a $CHCl_3$ (1 mL) a solution of N,N-dimethylaniline (ca. 30 mg). The mixture turned red immediately. After stirring 15 min, solid Na_2CO_3 was added and stirring continued 15 min. Evaporation and chromatography (alumina, hexane) yielded azocrown 27 as a red oil: NMR 3.10 (s, 6H), 3.57-4.10 (m, 29H, sharp peaks at 3.60, 3.67 and 3.70) 6.83-8.70 (m, 8H); IR 1600, 1370, 1120 (br), 760.

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