# Calixarenes. 32. Reactions of Calix[4]quinones

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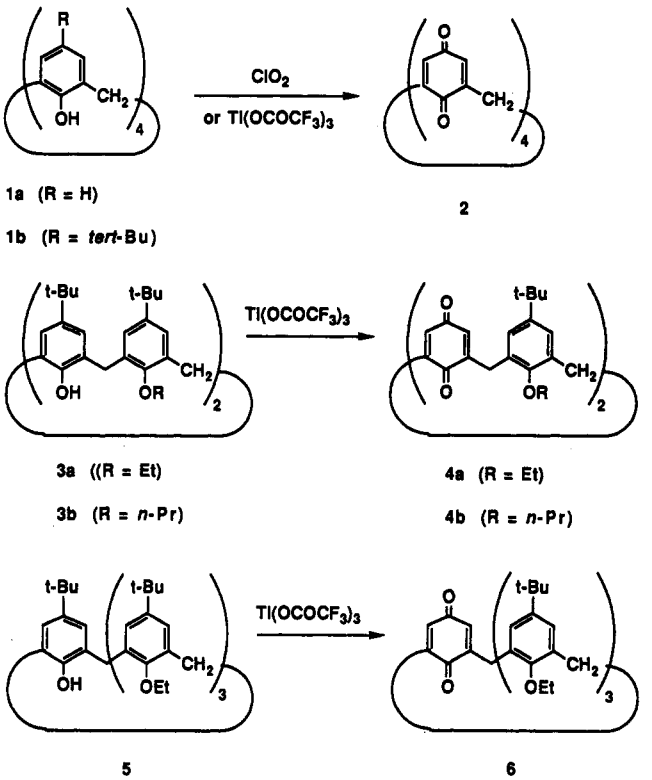
*Received January 26, 1993*

Calix[4]quinones are readily accessible by direct oxidation of *p-tert*-butylcalix[4]arenes as mono-, di-, tri- or tetraquinones depending on the number of free phenolic rings in the calixarene. The mono- and diquinones are shown to be useful synthesis intermediates in the following processes: (a) 1,2-carbonyl additions with malononitrile in the presence of secondary amines to yield *p*-[1-(dialkylamino)-2,2-dicyanovinyl]calixarenes (**11**) or with malononitrile in the absence of amines to yield *p*-(1,2,2-tricyanovinyl)calixarenes (**9**); (b) 1,2-carbonyl addition with pyrrolidine to yield a *p*-pyrrolidinocalix[4]arene (**14**); (c) 1,4-conjugate additions with a variety of nucleophiles, including sodio diethyl malonate, acetate, thiourea, *p*-thiocresol, and mercaptoacetic acid to give the chiral calixarenes **16–21**.

Calixarenes, easily prepared by base-induced condensation of certain *para*-substituted phenols with formaldehyde, are of interest because of their basket shape and their ability to be functionalized in various ways.[1] Among the functionalized calixarenes, the calixquinones are attractive because of their potential for use as redox systems, as participants in charge–transfer complexes,[2] and as useful synthesis intermediates. Calix[4]quinone (**2**) was first synthesized in 1986 by Rosik[3] who oxidized *p*-H-calix[4]arene (**1a**) with chlorine dioxide in a phosphate-buffered aqueous acetone solution at 0 °C. In 1989 Morita and co-workers[4] reported a multistep synthesis of **2** and provided conclusive X-ray crystallographic data for its structure. Subsequently, the Rosik procedure was investigated in greater detail by Reddy and co-workers[5] and extended to the preparation of calix[5]quinone and calix[6]quinone, the structure of which was confirmed by X-ray crystallography. In the course of that study it was found that $Tl(OCOCF_3)_3$, which was introduced a number years ago by Taylor and co-workers[6] for the oxidation of 2,6-disubstituted-4-*tert*-butylphenols to 2,6-disubstituted 1,4-benzoquinones, can also serve as a useful reagent for calixquinone formation. The advantage of this reagent is that is can be used directly on the *p-tert*-butylcalixarenes, obviating the necessity for removing the *tert*-butyl groups in a separate step. Although the yield of **2** from *p-tert*-butylcalix[4]arene (**1b**) is only *ca.* 15%, much better yields of calixquinones are obtained from the partially etherified or esterified *p-tert*-butylcalix[4]arenes. For example, the 1,3-diquinone **4a**, which has been described by Reinhoudt and co-workers,[7] is obtained in 64% yield from the diether **3a**; 1,3-diquinone **4b** is obtained in 56% yield from the diether **3b**; and the monoquinone **6** is obtained in 51% yield from the triether **5**. Because of the greater accessibility and solubility of the monoquinone **6** and the diquinones **4a** and **4b** as compared with the polyquinones, the present study concentrates on the synthesis possibilities using these compounds as starting materials.




**1,2-Carbonyl Additions: The Synthesis of Polyfunctional Calix[4]arenes.** Application of the $TiCl_4$/pyridine-catalyzed Knoevenagel condensation procedure of Lehnert,[8] which has been used for the preparation of a wide variety of TCNQ derivatives from quinones,[9] yielded only intractable materials from the diquinone **4b**. In the absence of $TiCl_4$, however, the tricyanovinylcalix[4]arene

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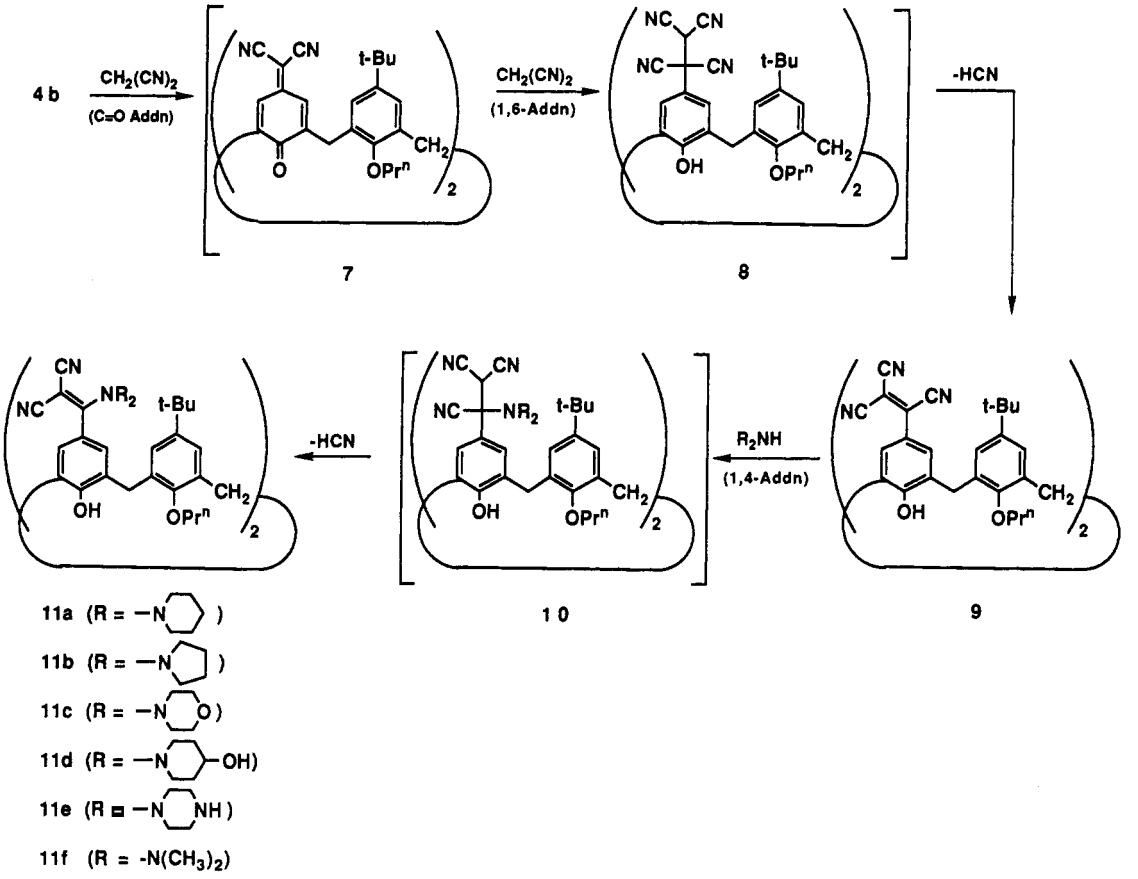


**Figure 1.** Reaction of calix[4]-1,3-diquinones with malononitrile and secondary amines.

**9** was isolated in 68% yield, a reaction that has been observed with various other quinones.[10] For example, 2,6-dimethyl-1,4-benzoquinone and 3,3-metacyclophanequinones react in comparable fashion either in the presence or absence of $TiCl_4$.[9e,10b] Application of the piperidine-catalyzed procedure of Rieker[10b] using malononitrile and **4b**, on the other hand, yielded a mixture of compounds containing only traces of **9**. When larger amounts of piperidine were used, the product proved to be the dicyanopiperidino compound **11a** in 79% yield, the formation of which is rationalized by the pathway outlined in Figure 1 involving 1,2-carbonyl addition of malononitrile to form **7**, 1,6-conjugate addition of a second molecule of malononitrile to form **8**, elimination of HCN to form **9**, 1,4-conjugate addition of the secondary amine to form **10**, and elimination of a second molecule of HCN. Comparable results were obtained when various other secondary amines were employed, as illustrated by products **11b–e**. Compounds **11a**, **11b**, and **11f** can also be obtained from **9**, isolable when pyridine is used as the catalyst, by treatment with the appropriate secondary amine. Although nucleophiles other than amines were not tested, it is likely that they will add to **9** in comparable fashion, providing a useful pathway to a variety of polyfunctionalized calixarenes in a process well documented for other substrates.[11]

In the absence of malononitrile **4b** reacted with the amines shown in Figure 1 to give mixtures which, in all but one case, resisted separation and characterization. The one exception is pyrrolidine which afforded the product of 1,2-carbonyl addition in 37% yield. This unexpected result is postulated to arise from a competition between 1,2-direct addition to give **12** and 1,4-conjugate addition to give **13**, followed by a redox reaction between these two products to give **14** and **15**, as shown in Figure 2. Only **14** was isolated and characterized, however, so this pathway remains conjectural. The $^1H$ and $^{13}C$ NMR spectra of **14** indicate that it is in a cone conformation.

**1,4-Conjugate Additions: The Synthesis of Chiral Calixarenes.** The majority of nucleophilic additions to quinones proceed in a 1,4-conjugate fashion to yield substituted hydroquinones as the initially-formed products.[12] Since reactions of this type with the diquinone **4b** have the potential for yielding regioisomers, the monoquinone **6** was chosen as the preferred substrate for the reactions shown in Figure 3. Of particular interest is the fact that the products of nucleophilic 1,4-addition to **6** possess molecular chirality, as shown by the doubling of $^1H$ NMR patterns of the products **16-21** in the presence of Pirkle's reagent {(*S*)-(+)-2,2,2-trifluoro-1-(9-anthryl)-ethanol},[13] thus providing a facile route to chiral calixarenes. Other routes that have been used to produce chiral calixarenes include asymmetric functionalization at the lower and/or upper rim[14] and the fragment condensation approach using *meta*-substituted phenolic units.[15]

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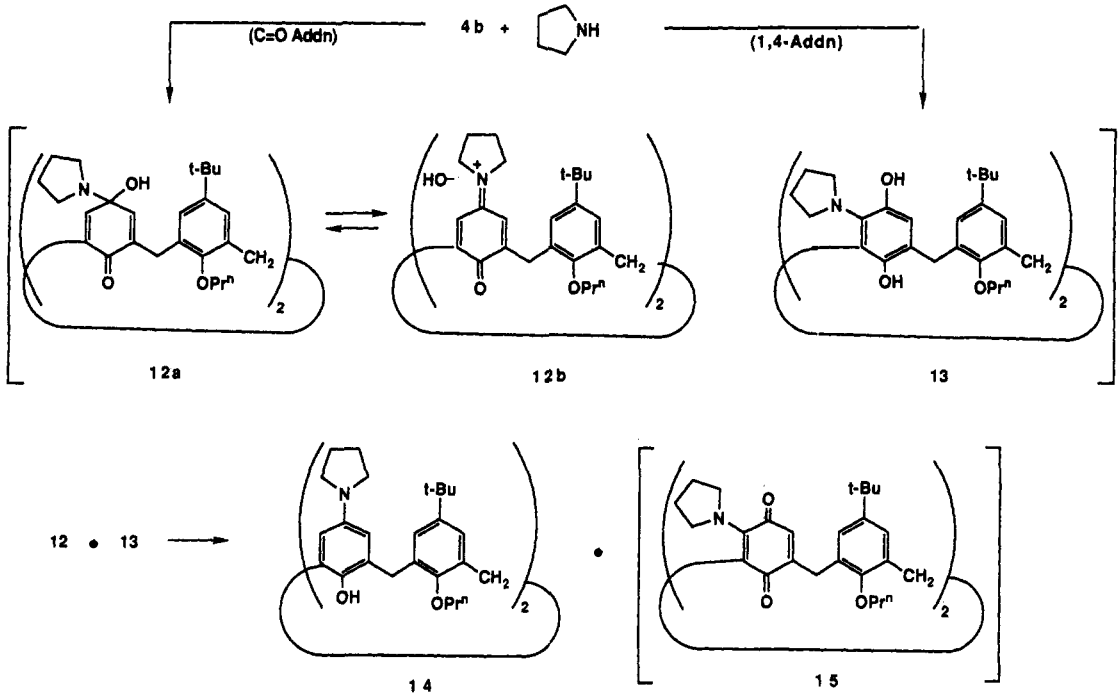


**Figure 2.** 1,2-Direct and 1,4-conjugate addition of pyrrolidine to a calix[4]-1,3-diquinone.

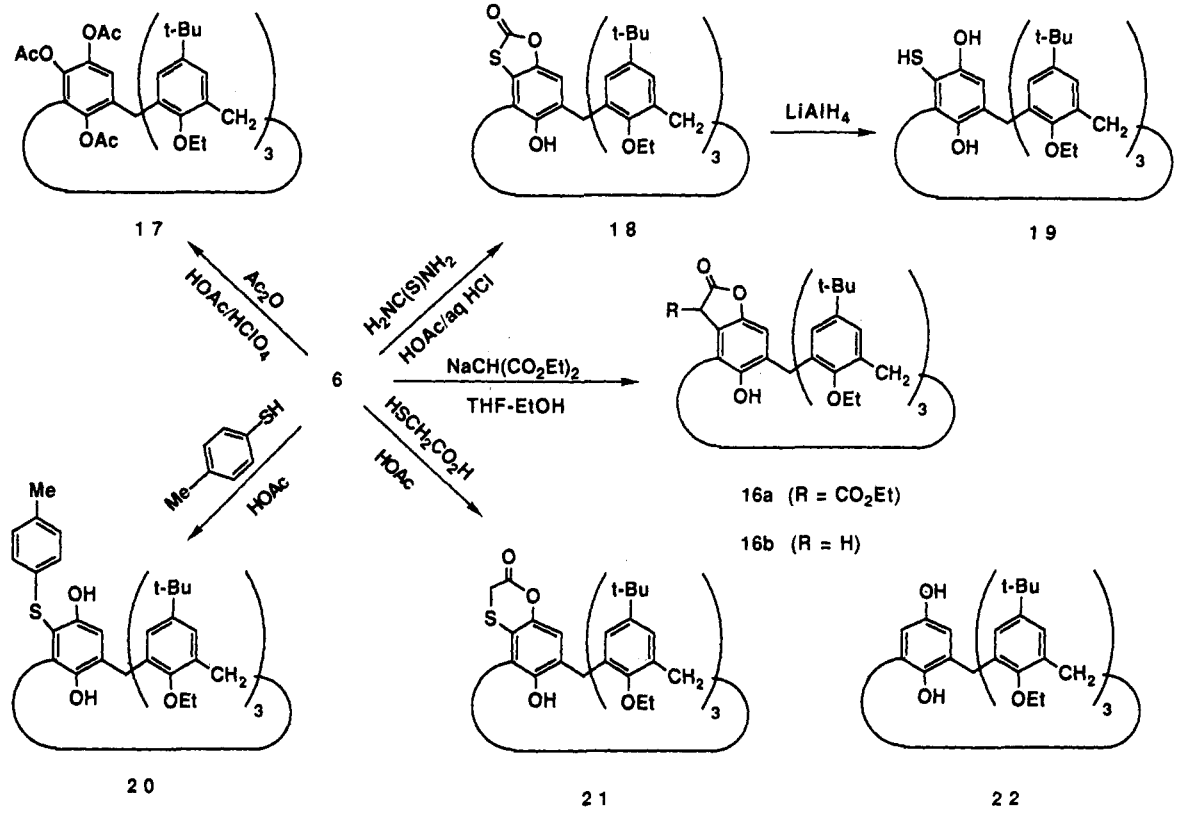


**Figure 3.** 1,4-Conjugate additions to a calix[4]monoquinone.

Following the procedures of Smith and co-workers for the Michael addition of active methylene compounds to quinones,[16] treatment of **6** with sodio diethyl malonate afforded a 67% yield of **16a** which underwent hydrolysis and decarboxylation to the lactone **16b**. Applying the Thiele–Winter acetoxylation procedure,[17] treatment of **6** with $Ac_2O$/HOAc in the presence of $HClO_4$ produced the triacetate **17** in 62% yield. Reaction of **6** with excess thiourea in HOAc/HCl solution[18] formed an *S*-arylthiouronium salt which, without isolation, produced the

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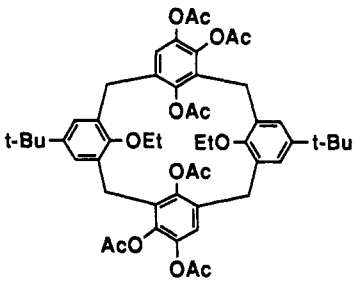
benzoxathiolone 18 in 80% yield upon heating. Comparable products have been reported with 2,6-dimethyl-1,4-benzoquinone, although in only 38% yield along with 33% of 4-chloro-2,6-dimethylphenol.[18b] Compound 18 was reduced with $LiAlH_4$ in THF to the mercaptohydroquinone 19 in 63% yield.

Additions of thiols to quinones have been extensively studied and can lead either to oxidized or reduced products, depending on the reaction conditions.[19] The reaction of 6 with *p*-thiocresol in HOAc at room temperature afforded an 80% yield of 20 with no cross-oxidation products being observed. The reaction of 6 with thioglycolic acid in HOAc at room temperature, on the other hand, yielded only 31% of the thiolactone 21 along with 26% of the calix[4]-hydroquinone 22, based on recovered starting material. However, when the reaction was conducted at 80 °C for 48 h, 21 was isolated as the only product in 81% yield. The structure of 22 was confirmed by its elemental analysis, $^1H$ NMR spectrum indicating that it exists in the cone conformation, and an independent synthesis by reduction of 6 with Zn/HOAc under sonication conditions.[20] The reduction of benzoquinone to hydroquinone by thioglycolic acid was observed many years ago by Bongartz.[21]

The diquinone 4a undergoes 1,4-nucleophilic additions comparable to those described above, but the reaction is complicated by the formation of regioisomeric mixtures. Whereas calix[4]monoquinones afforded a single product of 1,4-addition, calix[4]-1,3-diquinones produced a pair of regioisomers. Thus, from the acetylation of 4a, only 14% of the isomer with $C_2$ symmetry (23) was isolable from the reaction mixture.

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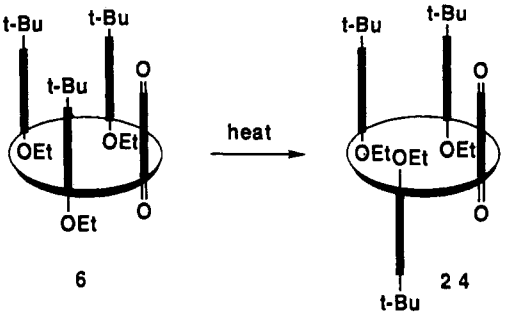
Attempts to effect 1,4-additions of amines to 6 were unsuccessful. Treatment of 6 with *n*-$BuNH_2$, $(n\text{-Bu})_2NH$, $Me_2NH$, and piperidine under a variety of conditions generally resulted in the complete recovery of starting material. Only with $Me_2NH$ in refluxing MeCN for 40 h did 6 undergo a change; however, not to yield a Michael product but an isomer of the starting material. The same conversion was effected in 94% yield simply by refluxing 6 in MeCN for 3 days. What appears to be occurring is the transformation of a cone to a partial cone conformer, *viz.* 6 to 24. This also explains the melting point behavior of 6; it melts at 169–171 °C, resolidifies at *ca.* 178 °C, and remelts at 236–238 °C, which is the same temperature at which 24 melts. *p*-Hexanoylcalix[4]arene has been shown to behave in a comparable fashion upon heating.[22]




6 24

**Conformational Assignments.** The diquinone 4b is shown by X-ray crystallography to exist in the 1,3-alternate conformation in the solid state.[23] In $CDCl_3$ solution, however, the $^1H$NMR spectrum shows a pair of doublets at $\delta$ 3.81 and 3.28 for the $ArCH_2Ar$ methylenes, compatible with a cone conformation. Also, the $^{13}C$ NMR spectrum shows a resonance at $\delta$ 33.17, which is closer to $\delta$ 31 (characteristic of a methylene carbon carrying adjacent aromatic moieties *syn* to one another, *i.e.* cone), rather than a resonance near $\delta$ 37 (characteristic of a methylene carbon carrying these groups *anti* to one another, *i.e.* 1,3-alternate).[24] Similarly, the piperidino compound 11a and the pyrrolidino compound 11b show a pair of doublets in the $^1H$ NMR spectrum at room temperature for the $ArCH_2Ar$ protons, again indicative of cone coformations. They differ, however, in the patterns arising from the OH, ArH, and amino moieties. At room temperature 11a shows a less complex spectrum than 11b which at −50 °C becomes quite similar to that of 11b, suggesting that 11a is more conformationally flexible around the amine moiety than is 11b. Possibly, the pyrrolidine ring, smaller than the piperidine ring, is able to reside more comfortably in the cavity of the calixarene to provide a self-complexation that reduces conformational flexibility.

The monoquinone 6, less symmetric than the diquinone 4b, shows an $^1H$ NMR spectrum containing two singlets (2:1 ratio) for the *tert*-butyl protons and pair of doublets and a singlet for the $ArCH_2Ar$ protons, commensurate with a conelike conformation in which the quinone ring is either fixed in the inverted position or is interchanging positions rapidly on the NMR time scale. The $^{13}C$ NMR spectrum shows resonances at $\delta$ 33.78 and 30.88 for the $ArCH_2Ar$ carbons, the downfield resonance possibly being a time-averaged signal for a quinone ring in the partial cone position (expected resonance *ca.* $\delta$ 37) and the cone position (expected resonance *ca.* $\delta$ 31). The Michael adducts from 6 possess even less symmetry and, accordingly, display the more complex spectra for the methylene hydrogens and methylene carbon shown in Table I.

## Experimental Section[25]

**5,17-Di-*tert*-butyl-11,23-bis(tricyanovinyl)-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (9).** A mixture of 0.162 g (0.25 mmol) of quinone 4b,[5,26a] 0.165 g (2.5 mmol) of malononitrile, and 0.395 g (5.0 mmol) of pyridine in 25 mL of $CHCl_3$ was stirred under reflux for 48 g in an argon atmosphere. The reaction mixture was cooled and poured into 50 mL of ice-water. The layers were separated, the aqueous layer was extracted with $CHCl_3$, and the combined organic layer was washed with water and brine and dried over anhydrous $MgSO_4$. Solvent was removed in vacuo, and the residue was chromatographed over silica gel

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Table I. $^1H$ and $^{13}C$ NMR Spectral Data for $ArCH_2Ar$ of the Compounds 6, 16b, and 17–21

| compd | $^1H$ NMR | | $^{13}C$ NMR |
|---|---|---|---|
| 6 | 4.12 (d, 2, J = 12.5 Hz) | 3.10 (d, 2, J = 12.5 Hz) | 33.78, 30.88 |
| | 3.51 (br s, 4) | | |
| 16b | 4.34 (d, 2, J = 12.5 Hz) | 3.19 (d, 2, J = 12.5 Hz) | 31.94, 31.28, 28.55 |
| | 4.33 (d, 1, J = 13.6 Hz) | 3.28 (d, 1, J = 13.6 Hz) | |
| | 4.28 (d, 1, J = 13.6 Hz) | 3.25 (d, 1, J = 13.6 Hz) | |
| 17 | 4.49 (d, 2, J = 12.4 Hz) | 3.19 (d, 2, J = 12.4 Hz) | 30.87, 30.61, 30.57, 24.17 |
| | 4.02 (d, 1, J = 13.3 Hz) | 3.46 (d, 1, J = 13.3 Hz) | |
| | 3.74 (d, 1, J = 13.2 Hz) | 3.17 (d, 1, J = 13.2 Hz) | |
| 18 | 4.40 (d, 1, J = 13.7 Hz) | 3.31 (d, 1, J = 13.7 Hz) | 31.70, 31.22, 30.68 |
| | 4.34 (d, 3, J = 12.8 Hz) | 3.19 (d, 3, J = 12.8 Hz) | |
| 19 | 4.36 (d, 1, J = 12.5 Hz) | 3.18 (d, 2, J = 12.5 Hz) | 31.48, 31.35, 28.25 |
| | 4.34 (d, 1, J = 12.5 Hz) | | |
| | 4.31 (d, 1, J = 13.3 Hz) | 3.21 (d, 1, J = 13.3 Hz) | |
| | 4.28 (d, 1, J = 13.5 Hz) | 4.18 (d, 1, J = 13.5 Hz) | |
| 20 | 4.42 (d, 1, J = 13.2 Hz) | 3.28 (d, 1, J = 13.2 Hz) | 31.58, 31.26(×2), 27.89 |
| | 4.36 (d, 1, J = 12.6 Hz) | 3.19 (d, 1, J = 12.6 Hz) | |
| | 4.34 (d, 1, J = 12.6 Hz) | 3.17 (d, 1, J = 12.6 Hz) | |
| | 4.18 (d, 1, J = 13.6 Hz) | 4.12 (d, 1, J = 13.6 Hz) | |
| 21 | 4.35 (d, 1, J = 12.5 Hz) | 3.19 (d, 2, J = 12.5 Hz) | 31.30(×2), 29.28, 27.99 |
| | 4.33 (d, 1, J = 12.5 Hz) | | |
| | 4.28 (d, 1, J = 14.0 Hz) | 3.69 (d, 1, J = 14.0 Hz) | |
| | 4.26 (d, 1, J = 13.5 Hz) | 3.26 (d, 1, J = 13.5 Hz) | |

using $CH_2Cl_2$ as eluant to give 0.16 g (68%) of **9** as a bright yellow powder after recrystallization from $CH_2Cl_2$–$Et_2O$: mp 251–253 °C; IR (KBr) $\nu_{max}$ 3405–3230 (OH), 2224 $cm^{-1}$ (CN); $^1H$ NMR ($CDCl_3$) $\delta$ 10.30 (s, 2, OH), 7.93 and 7.04 (2 s, 2 × 4, ArH), 4.28 and 3.51 (2 d, 2 × 4, $J$ = 13.2 Hz, $ArCH_2Ar$), 4.01 (t, 4, $J$ = 6.3 Hz, $OCH_2CH_2CH_3$), 2.10 (sextet, 4, $OCH_2CH_2CH_3$), 1.32 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 1.13 (s, 18, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) $\delta$ 162.07 ($C(CN)=C(CN)_2$), 149.38, 149.29, 139.74, 131.27, 130.99, 130.39, 126.61 and 120.44 (Ar), 114.09, 112.67, and 112.40 (CN), 84.77 ($C(CN)=C(CN)_2$), 79.01 ($OCH_2CH_2CH_3$), 34.40 ($C(CH_3)_3$), 31.67 ($ArCH_2Ar$), 31.16 ($C(CH_3)_3$), 23.38 ($OCH_2CH_2CH_3$), 10.89 ($OCH_2CH_2CH_3$); MS (FAB POS) $m/e$ 823 $(M+1)^+$. Anal. Calcd for $C_{52}H_{50}N_6O_4$: C, 75.89; H, 6.12; N, 10.21. Found: C, 75.95; H, 6.29; N, 10.22.

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-piperidino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11a). Method A.** To a solution of 0.162 g (0.25 mmol) of quinone **4b**[5,26a] and 0.083 g (1.25 mmol) of malononitrile in 15 mL of $CH_2Cl_2$ was added 0.213 g (2.5 mmol) of piperidine in 10 mL of $CH_2Cl_2$ at 0 °C with stirring in an argon atmosphere over a period of 30 min. The reaction mixture was stirred at rt for 18 h, poured into 50 mL of ice-water, and worked up as described above. Chromatography of the gummy product over silica gel using $CH_2Cl_2$–EtOAc (49:1, v/v) gave 0.20 g of a colorless powder. Recrystallization from $CHCl_3$–MeOH afforded 0.185 g (79%) of **11a** as colorless needles which powdered upon drying: mp >338 °C dec ($CH_2Cl_2$–$CH_3CN$); IR (KBr) $\nu_{max}$ 3237–3503 (OH), 2207, and 2191 $cm^{-1}$ (CN); $^1H$ NMR ($CDCl_3$) $\delta$ 8.65 (br s, 2, OH), 7.18 (s, 4, ArH), 6.76 (br s, 4, ArH), 4.28 and 3.40 (2 d, 2 × 4, $J$ = 13.4 Hz, $ArCH_2Ar$), 3.97 (t, 4, $J$ = 6.3 Hz, $OCH_2CH_2CH_3$), 3.89 and 3.20 (2 br s, 2 × 4, $NCH_2CH_2CH_2$), 2.02 (sextet, 4, $OCH_2CH_2CH_3$), 1.94–1.45 (m, 12, $NCH_2CH_2CH_3$), 1.28 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 0.95 (s, 18, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) $\delta$ 172.30 ($C=C(CN)_2$), 157.52, 149.91, 147.54, 131.50, 129.94, 129.27, 125.68, and 122.29 (Ar), 118.09 ($C=C(CN)_2$), 117.42 (CN), 78.20 ($OCH_2CH_2CH_3$), 53.00 ($NCH_2CH_2CH_2$), 34.03 ($C(CH_3)_3$), 31.43 ($ArCH_2Ar$), 31.04 ($C(CH_3)_3$), 26.70 ($NCH_2CH_2CH_2$), 23.78 ($NCH_2CH_2CH_2$), 23.45 ($OCH_2CH_2CH_3$), 10.81 ($OCH_2CH_2CH_3$); MS (FAB POS) $m/e$ 939 $(M+1)^+$. Anal. Calcd for $C_{60}H_{70}N_6O_4 \cdot {}^1/_4CH_3OH$: C, 76.40; H, 7.55; N, 8.87. Found: C, 76.25; H, 7.38; N, 8.80.

**Method B.** To a solution of 0.103 g (0.125 mmol) of **9** in 15 mL of $CH_2Cl_2$ was added 0.106 g (1.25 mmol) of piperidine in 5 mL of $CH_2Cl_2$ at 0 °C with stirring in a $N_2$ atmosphere over a 15-min period. After 10 h at rt the product was worked up as in method A to give 0.085 g (73%) of **11a**.

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-pyrrolidino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11b). Method A.** A reaction of 0.162 g (0.25 mmol) of quinone **4b**,[5,26a] 0.083 g (1.25 mmol) of malononitrile, and 0.178 g (2.5 mmol) of pyrrolidine in 25 mL of $CH_2Cl_2$ was carried out as described for **11a** to give 0.23 g of crude product. Recrystallization from $CH_2Cl_2$–MeOH produced 0.19 g (83%) of **11b** as colorless needles which powdered upon drying: mp >330 °C dec; IR (KBr) $\nu_{max}$ 3420 (OH), 2209 and 2193 $cm^{-1}$ (CN); $^1H$ NMR ($CDCl_3$) (at 60 °C) $\delta$ 8.09 (br s, 2, OH), 7.04 (s, 4, ArH), 6.69 (br s, 4, ArH), 4.30 and 3.35 (2 d, 2 × 4, $J$ = 13.4 Hz, $ArCH_2Ar$), 4.00 and 3.12 (2 br s, 2 × 4, $NCH_2CH_2$), 3.96 (t, 4, $J$ = 6.3 Hz, $OCH_2CH_2CH_3$), 2.01 (sextet, 4, $OCH_2CH_2CH_3$), 2.17–1.61 (br m, 8, $NCH_2CH_2$), 1.25 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 0.91 (s, 18, $C(CH_3)_3$); MS (FAB POS) $m/e$ 911 $(M+1)^+$. Anal. Calcd for $C_{58}H_{66}N_6O_4$: C, 76.45; H, 7.30; N, 9.22. Found: C, 76.08; H, 7.20; N, 9.04.

**Method B.** The reaction of 0.103 g (0.125 mmol) of **9** and 0.089 g (1.25 mmol) of pyrrolidine in 20 mL of $CH_2Cl_2$ as described in the preparation of **11a** afforded 0.09 g (79%) of **11b**.

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-morpholino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11c).** The reaction of 0.162 g (0.25 mmol) of quinone **4b**,[5,26a] 0.083 g (1.25 mmol) of malononitrile, and 0.218 g (2.5 mmol) of morpholine in 25 mL of $CH_2Cl_2$ for 18 h as described in the preparation of **11a** gave 0.18 g (76%) of **11c** as a colorless silky solid after recrystallization from $CH_2Cl_2$–MeOH: mp 321–323 °C; $^1H$ NMR ($CDCl_3$) $\delta$ 8.88 (br s, 2, OH), 7.19 (s, 4, ArH), 6.79 (br s, 4, ArH), 4.28 and 3.42 (2 d, 2 × 4, $J$ = 13.2 Hz, $ArCH_2Ar$), 3.97 (t, 4, $J$ = 6.2 Hz, $OCH_2CH_2CH_3$), 3.83 (br s, 16, $NCH_2CH_2O$), 2.03 (sextet, 4, $OCH_2CH_2CH_3$), 1.29 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 0.97 (s, 18, $C(CH_3)_3$); MS (FAB NEG) $m/e$ 941 $(M-1)^+$. Anal. Calcd for $C_{58}H_{66}N_6O_6$: C, 73.86; H, 7.05; N, 8.91. Found: C, 73.56; H, 7.04; N, 8.88.

(25) Unless otherwise noted, materials were obtained from commercial suppliers and used without further purification. Chloroform ($CHCl_3$) and dichloromethane ($CH_2Cl_2$) used for the reactions were stored over 4Å type molecular sieves. Tetrahydrofuran (THF) was distilled over sodium/benzophenone. The melting points of all compounds were taken in sealed and evacuated capillary tubes on a Mel-Temp apparatus (Laboratory devices, Cambridge, MA) using a Fluka 51 K/J digital thermometer with a K-type thermocouple. Column chromatography was carried out using Aldrich 70-230 mesh, 60 A silica gel. Flash chromatography was carried out using J. T. Baker silica gel with a 40-$\mu$m particle size. Thin-layer chromatography was carried out on 250-$\mu$m Analtech silica gel plates containing a fluorescent indicator. IR spectra were obtained with an Acer 915P FT-IR spectrometer, and NMR spectra were recorded on a Varian XL-300 spectrometer. Chemical shifts are reported as $\delta$ values in parts per million relative to tetramethylsilane ($\delta$ 0.00) as an internal standard. Microanalyses were carried out by Desert Laboratories, Tucson AZ. All analytical samples showed a single spot in the TLC and were dried at least 48 h at 111 °C and 1–2 mm pressure.

(26) (a) Compound **4b** has been reported[5] but without the following data: $^{13}C$ NMR ($CDCl_3$) $\delta$ 188.57 and 185.41 (C=O), 154.32, 147.67, 145.80, 132.52, 129.21, and 126.88 (Ar), 75.52 ($OCH_2CH_2CH_3$), 34.00 ($C(CH_3)_3$), 33.17 ($ArCH_2Ar$), 31.41 ($C(CH_3)_3$), 23.43 ($OCH_2CH_2CH_3$), 10.38 ($OCH_2CH_2CH_3$). (b) Compound **6** has been reported[5] but without the following data: $^{13}C$ NMR ($CDCl_3$) $\delta$ 189.34 and 186.32 (C=O), 153.92, 153.81, 146.78, 145.62, 144.97, 135.81, 133.54, 132.87, 127.51, 126.31, 126.06, and 125.52 (Ar), 69.61 and 68.94 ($OCH_2CH_3$), 35.45 and 34.12 ($C(CH_3)_3$), 33.78 and 30.88 ($ArCH_2Ar$), 31.67 and 31.33 ($C(CH_3)_3$), 15.84 and 15.22 ($OCH_2CH_3$).

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-hydroxypiperidino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11d).** The reaction of 0.162 g (0.25 mmol) of quinone **4b**,[5,26a] 0.083 g (1.25 mmol) of malononitrile, and 0.253 g (2.5 mmol) of 4-hydroxypiperidine in 25 mL of $CH_2Cl_2$ for 18 h as described in the preparation of **11a** gave 0.16 g (66%) of **11d** as a colorless powder: mp >325 °C dec ($CH_2Cl_2$–EtOH); $^1H$ NMR ($CDCl_3$) $\delta$ 8.74 (br s, 2, OH), 7.19 and 6.77 (2 br s, 2 × 4, ArH), 4.29 and 3.41 (2 d, 2 × 4, $J$ = 13.4 Hz, $ArCH_2Ar$), 3.97 (t, 4, $J$ = 6.4 Hz, $OCH_2CH_2CH_3$), 2.02 (sextet, 4, $OCH_2CH_2CH_3$), 1.28 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 0.96 (s, 18, $C(CH_3)_3$); the hydroxypiperidino protons appear as broad signals at $\delta$ 4.10, 3.91–2.99, and 2.26–1.48; MS (FAB NEG) $m/e$ 969 $(M-1)^+$. Anal. Calcd for $C_{60}H_{70}N_6O_6$: C, 74.20; H, 7.26; N, 8.65. Found: C, 74.57; H, 7.30; N, 8.87.

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-piperazino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11e).** The reaction of 0.162 g (0.25 mmol) of quinone **4b**,[5,26a] 0.083 g (1.25 mmol) of malononitrile, and 0.215 g (2.5 mmol) of piperazine in 25 mL of $CH_2Cl_2$ for 18 h as described in the preparation of **11a** gave 0.24 g of crude product. Recrystallization from $CH_2Cl_2$–MeOH gave 0.175 g (74%) of **11e** as a colorless solid: mp 220 °C (glass); $^1H$ NMR ($CDCl_3$) $\delta$ 8.75 (br s, 2, OH), 7.19 (s, 4, ArH), 6.77 (br s, 4, ArH), 4.28 and 3.41 (2 d, 2 × 4, $J$ = 13.3 Hz, $ArCH_2Ar$), 3.97 (t, 4, $J$ = 6.2 Hz, $OCH_2CH_2CH_3$), 3.33–2.66 (br m, 18, $NCH_2CH_2NH$), 2.02 (sextet, 4, $OCH_2CH_2CH_3$), 1.28 (t, 6, $J$ = 7.3 Hz, $OCH_2CH_2CH_3$), 0.96 (s, 18, $C(CH_3)_3$); MS (FAB NEG) $m/e$ 939 $(M-1)^+$. Anal. Calcd for $C_{58}H_{68}N_8O_4 \cdot {}^1/_2H_2O$: C, 73.31; H, 7.32; N, 11.79. Found: C, 73.11; H, 6.95; N, 11.45.

**5,17-Di-*tert*-butyl-11,23-bis[(2,2-dicyano-1-dimethylamino)vinyl]-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (11f).** The reaction of 0.103 g (0.125 mmol) of (tricyanovinyl)phenol **9** and 0.141 g (1.25 mmol) of dimethylamine (40% aqueous solution) in 20 mL of $CH_2Cl_2$ as described in the preparation of **11a** afforded 0.075 g (70%) of **11f** as a colorless powder after recrystallization from $CHCl_3$–MeOH: mp >210 °C dec; $^1H$ NMR ($CDCl_3$) $\delta$ 8.72 (s, 2, OH), 7.15 and 6.77 (2 br s, 2 × 4, ArH), 4.28 and 3.40 (2 d, 2 × 4, $J$ = 13.3 Hz, $ArCH_2Ar$), 3.97 (t, 4, $J$ = 6.1 Hz, $OCH_2CH_2CH_3$), 3.49 (br s, 6, $N(CH_3)_2$), 2.98–2.83 (br m, 6, $N(CH_3)_2$), 2.03 (sextet, 4, $OCH_2CH_2CH_3$), 1.29 (t, 6, $J$ = 7.4 Hz, $OCH_2CH_2CH_3$), 0.95 (s, 18, $C(CH_3)_3$). Anal. Calcd for $C_{54}H_{62}N_6O_4$: C, 75.49; H, 7.27; N, 9.78. Found: C, 75.65; H, 7.15; N, 9.66.

**5,17-Di*tert*-butyl-11,23-bis(pyrrolidino)-25,27-dihydroxy-26,28-bis(*n*-propoxy)calix[4]arene (14).** A mixture of 0.162 g (0.25 mmol) of quinone **4b**[5,26a] and 0.178 g (2.5 mmol) of pyrrolidine in 25 mL of $CH_2Cl_2$ was stirred at room temperature for 16 h. It was poured into 50 mL of ice-cooled water, and the layers were separated. The aqueous layer was extracted with $CH_2Cl_2$, and the combined organic layer was washed with water and brine and dried over anhydrous $MgSO_4$. Solvent was removed in vacuo, and the residue was flash chromatographed over silica gel using $CH_2Cl_2$–EtOAc (97:3, v/v) as eluant to give 0.07 g (37%) of **14** as a colorless solid: mp 226–231 °C; IR (KBr) $\nu_{max}$ 3329 $cm^{-1}$ (OH); $^1H$ NMR ($CDCl_3$) $\delta$ 7.80 (s, 2, OH), 7.06 and 6.24 (2 s, 2 × 4, ArH), 4.40 and 3.27 (2 d, 2 × 4, $J$ = 12.5 Hz, $ArCH_2Ar$), 3.98 (t, 4, $J$ = 7.1 Hz, $OCH_2CH_2CH_3$), 3.13 (t, 8, $J$ = 6.3 Hz, $NCH_2CH_2$), 2.15 (sextet, 4, $OCH_2CH_2CH_3$), 1.89 (t, 8, $J$ = 6.3 Hz, $NCH_2CH_2$), 1.21 (t, 6, $J$ = 7.3 Hz, $OCH_2CH_2CH_3$), 1.18 (s, 18, $C(CH_3)_3$; $^{13}C$ NMR ($CDCl_3$) $\delta$ 150.74, 146.71, 142.86, 142.23, 134.10, 130.24, 125.55, and 111.76 (Ar), 78.27 ($OCH_2CH_2CH_3$), 48.09 ($NCH_2CH_2$), 34.14 ($C(CH_3)_3$), 32.24 ($ArCH_2Ar$), 25.34 ($NCH_2CH_2$), 23.29 ($OCH_2CH_2CH_3$), 10.64 ($OCH_2CH_2CH_3$); MS (FAB POS) $m/e$ 759 $(M+1)^+$. Anal. Calcd for $C_{50}H_{66}N_2O_4$: C, 79.11; H, 8.76; N, 3.69. Found: C, 79.23; H, 8.65; N, 3.64.

**5,11,17-Tri-*tert*-butyl-22,23-[(methylcarbonyl)oxy]-25-hydroxy-26,27,28-tris(ethoxy)calix[4]arene (16b).** To sodio diethyl malonate (prepared from 0.5 mmol of NaOEt and 0.6 mmol of diethyl malonate in 2 mL of EtOH) in 1 mL of THF was added 0.173 g (0.25 mmol) of quinone **6**[5,26b] in 2 mL of THF with stirring at rt in an atmosphere of $N_2$. The resulting blue-colored solution was stirred at 65–70 °C for 16 h (becomes colorless after a few minutes of heating), cooled, and poured into 100 g of crushed ice. The compound was extracted into $CHCl_3$, and the $CHCl_3$ layer washed with water and brine and dried over $MgSO_4$. The solvent was removed in vacuo, and the residue was recrystallized twice from MeOH to give 0.135 g (67%) of the $\beta$-keto ester **16a** as a colorless crystalline solid: mp 212–216 °C ($CH_2Cl_2$–MeOH); IR (KBr) $\nu_{max}$ 3522–3385 (OH), 1809 (lactone C=O), 1738 $cm^{-1}$ (ester C=O); $^1H$ NMR ($CDCl_3$) $\delta$ 6.97 and 6.83 (2 s, 2, 1, ArH), 6.73 and 6.67 (2 d, 2 × 1, $J$ = 2.1 Hz, ArH), 6.62 and 6.45 (2 d, 2 × 1, $J$ = 2.2 Hz, ArH), 5.86 (s, 1, OH), 4.68 (s, 1, $CHCO_2Et$), 4.39–4.25 (m, 6, $ArCH_2Ar$ and $CO_2CH_2CH_3$), 4.00–3.87 (m, 6, $OCH_2CH_3$), 3.34 (d, 1, $J$ = 13.6 Hz, $ArCH_2Ar$), 3.27 (d, 1, $J$ = 13.4 Hz, $ArCH_2Ar$), 3.20 (d, 2, $J$ = 12.8 Hz, $ArCH_2Ar$), 1.69, 1.51, and 1.49 (3 t, 3 × 3, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.29 (t, 3, $J$ = 7.0 Hz, $CO_2CH_2CH_3$), 1.20, 0.96, and 0.91 (3 s, 3 × 9, $C(CH_3)_3$).

A mixture of 0.08 g (0.1 mmol) of **16a**, 2 mL of DMSO, and 4 $\mu$L (0.2 mmol) of water was stirred at 110–115 °C for 2 h in an atmosphere of $N_2$. After cooling to rt, the reaction mixture was poured into 50 g of crushed ice and the precipitate collected by filtration. The dark-colored material was purified by filtration through a short column of silica gel using $CH_2Cl_2$–hexanes (4:1, v/v) to give 0.05 g (68%) of the lactone **16b** as a colorless solid. An analytical sample was prepared by recrystallization from hexane (refrigerated) to give a colorless crystalline solid: mp 234–236 °C; IR (KBr) $\nu_{max}$ 3536–3404 (OH), 1811 (lactone C=O) $cm^{-1}$; $^1H$ NMR ($CDCl_3$) $\delta$ 7.06 and 6.83 (2 s, 2 × 1, ArH), 6.66 and 6.65 (2 d, 2 × 1, $J$ = 2.9 Hz, ArH), 6.59 and 6.42 (2 d, 2 × 1, $J$ = 2.3 Hz, ArH), 5.56 (s, 1, OH), 4.34 and 3.19 (2 d, 2 × 2, $J$ = 12.5 Hz, $ArCH_2Ar$), 4.33, 4.28, 3.28 and 3.25 (4 d, 4 × 1, $J$ = 13.6 Hz, $ArCH_2Ar$), 4.01–3.87 (m, 6, $OCH_2CH_3$), 3.83 and 3.74 (2 d, 2 × 1, $J$ = 22.7 Hz, $ArCH_2C{=}O$), 1.66, 1.50, and 1.49 (3 t, 3 × 3, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.27, 0.92 and 0.88 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) $\delta$ 175.06 (C=O), 153.61, 152.22, 151.78, 149.58, 147.21, 145.69, 145.44, 135.59, 133.35, 133.08, 131.29, 130.91, 130.61, 127.79, 125.78, 125.57, 125.41, 124.46, 123.65, 119.80, and 109.70 (Ar), 71.30, 71.27, and 69.62 ($OCH_2CH_3$), 34.08, 33.81, and 33.66 ($C(CH_3)_3$), 33.32 ($ArCH_2C{=}O$), 31.94, 31.28 and 28.55 ($ArCH_2Ar$), 31.19 and 31.16 ($C(CH_3)_3$), 15.70 and 15.66 ($OCH_2CH_3$); MS (EI) $m/e$ 732 $(M^+)$. Anal. Calcd for $C_{48}H_{60}O_6$: C, 78.65; H, 8.25. Found: C, 78.83; H, 8.36.

**5,11,17-Tri-*tert*-butyl-22,23,25-tris(acetoxy)-26,27,28-tris(ethoxy)calix[4]arene (17).** A 0.036-g (0.25 mmol) amount of $HClO_4$ (69–72%) was slowly added to a solution of 0.345 g (0.5 mmol) of quinone **6**[5,26b] in 10 mL of $Ac_2O$ cooled in an ice bath, and the resulting mixture was stirred at rt for 6 h. Then it was poured into 150 g of crushed ice, and the compound was extracted into $CH_2Cl_2$. The $CH_2Cl_2$ layer was washed with water and brine and dried over $MgSO_4$. the solvent was removed in vacuo, and the gummy residue was recrystallized from $CH_2Cl_2$–MeOH to give 0.26 g (62%) of **17** as colorless crystals: mp 237–239 °C; IR (KBr) $\nu_{max}$ 1777 and 1757 $cm^{-1}$ (C=O); $^1H$ NMR ($CDCl_3$) $\delta$ 7.18 and 7.06 (2 s, 2 × 1, ArH), 6.65 (d, 2, $J$ = 2.2 Hz, ArH), 6.49 and 6.47 (2 d, 2 × 1, $J$ = 2.3 Hz, ArH), 4.49 and 3.19 (2 d, 2 × 2, $J$ = 12.4 Hz, $ArCH_2Ar$), 4.17 (q, 2, $J$ = 7.0 Hz, $OCH_2CH_3$), 4.02 and 3.46 (2 d, 2 × 1, $J$ = 13.3 Hz, $ArCH_2Ar$), 3.80–3.68 (m, 4, $OCH_2CH_3$), 3.74 and 3.17 (2 d, 2 × 1, $J$ = 13.2 Hz, $ArCH_2Ar$), 2.86, 2.34, and 2.26 (3 s, 3 × 3, $OCOCH_3$), 1.46, 1.45, and 1.38 (3 t, 3 × 3, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.36, 0.87, and 0.86 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) $\delta$ 172.08, 167.84, and 167.76 (C=O), 154.08, 151.66, 151.56, 145.67, 145.31, 145.07, 144.96, 139.45, 138.48, 135.47, 135.44, 133.99, 132.39, 130.66, 130.53, 130.39, 125.47, 125.38, 125.16, 125.02, 124.70, and 121.51 (Ar), 71.12 and 70.59 ($OCH_2CH_3$), 34.08 and 33.71 ($C(CH_3)_3$), 31.79 and 31.13 ($C(CH_3)_3$), 30.87, 30.61, 30.57, and 24.17 ($ArCH_2Ar$), 22.24, 20.79, and 20.42 ($OCOCH_3$), 15.88 and 15.66 ($OCH_2CH_3$); MS (FAB POS) $m/e$ 835 $(M+1)^+$. Anal. Calcd for $C_{52}H_{66}O_9$: C, 74.79; H, 7.97. Found: C, 75.36; H, 8.12.

**5,11,17-Tri-*tert*-butyl-22,23-(thiocarbonyloxy)-25-hydroxy-26,27,28-tris(ethoxy)calix[4]arene (18).** A solution of 0.345 g (0.5 mmol) of quinone **6**[5,26b] in 5 mL of HOAc was treated with a solution of 0.057 g (0.75 mmol) of thiourea in 0.75 mL of 2 N HCl (1.5 mmol) while stirring at rt. After 30 min the solution became turbid, and at this stage 4 mL of 2 N HCl was added and the resulting suspension stirred at 80 °C for 3 h. The reaction mixture was cooled and poured into 100 g of crushed ice. The precipitate was collected by suction filtration and dried under vacuum to give 0.36 g of colorless powder. Recrystallization from $CH_2Cl_2$–MeOH afforded 0.30 g (80%) of **18** as a white silky solid: mp 234–236 °C; IR (KBr) $\nu_{max}$ 3542 (OH), 1769 and 1734 $cm^{-1}$ (C=O); $^1H$ NMR ($CDCl_3$) $\delta$ 7.06 and 7.05 (2 d, 2 × 1, $J$ = 2.7 Hz, ArH), 7.01 (s, 1, ArH), 6.67 and 6.66 (2 d, 2 × 1, $J$ = 2.5 Hz, ArH), 6.60 and 6.57 (2 d, 2 × 1, $J$ = 2.4 Hz, ArH), 5.91 (s, 1, OH), 4.40

and 3.31 (2 d, 2 × 1, $J$ = 13.7 Hz, $ArCH_2Ar$), 4.34 and 3.19 (2 d, 2 × 3, $J$ = 12.8 Hz, $ArCH_2Ar$), 4.01–3.87 (m, 6, $OCH_2CH_3$), 1.66, 1.51, and 1.50 (3 t, 3 × 3, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.27, 0.91, and 0.89 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) δ 169.58 (C=O), 153.57, 151.90, 151.62, 150.27, 145.80, 145.71, 140.97, 135.55, 135.51, 133.23, 133.18, 130.82, 130.03, 129.93, 125.98, 125.61, 125.56, 124.86, 124.36, 123.77, 120.73, and 110.89 (Ar), 71.39 and 69.56 ($OCH_2CH_3$), 34.07, 33.79, and 33.68 ($C(CH_3)_3$), 31.70, 31.22, and 30.68 ($ArCH_2Ar$), 31.54, 31.16, and 31.09 ($C(CH_3)_3$), 15.68 and 15.61 ($OCH_2CH_3$); MS (FAB POS) $m/e$ 751 $(M + 1)^+$. Anal. Calcd for $C_{47}H_{58}O_6S$: C, 75.17; H, 7.78. Found: C, 75.11; H, 7.82.

**5,11,17-Tri-*tert*-butyl-22-mercapto-23,25-dihydroxy-26,27,-28-tris(ethoxy)calix[4]arene (19).** A solution of 0.25 g (0.33 mmol) of benzoxathiolone **18** in 5 mL of THF was added dropwise (*ca.* 15 min) to a well-stirred slurry of 0.076 g (2.0 mmol) of $LiAlH_4$ in 10 mL of THF at 0 °C in an atmosphere of $N_2$. The resulting mixture was stirred at rt for 2 h and then at reflux for 30 min. It was then cooled in an ice-bath, treated with a few drops of EtOAc to decompose excess $LiAlH_4$, and acidified with concd HCl. Filtration and concentration produced a residue that was dissolved in 50 mL of $CH_2Cl_2$. The $CH_2Cl_2$ layer was washed with water and brine and dried over $MgSO_4$. The solvent was removed in vacuo, and the residue was dissolved in 5 mL of petroleum ether and kept in a freezer overnight to give 0.15 g (63%) of **19** which separated as a white powder: mp 185–190 °C (glass) ($CH_2Cl_2$–petroleum ether); IR (KBr) $\nu_{max}$ 3524 (OH), 2569 $cm^{-1}$ (SH); $^1H$ NMR ($CDCl_3$) δ 7.14 and 6.78 (2 s, 2, 1, ArH), 6.59 and 6.51 (2 d, 2 × 1, $J$ = 2.4 Hz, ArH), 6.55 and 6.53 (2 d, 2 × 1, $J$ = 3.0 Hz, ArH), 6.01 (br s, 1, OH), 5.14 (s, 1, OH), 4.36 and 4.34 (2 d, 2 × 1, $J$ = 12.5 Hz, $ArCH_2Ar$), 4.31 and 3.21 (2 d, 2 × 1, $J$ = 13.3 Hz, $ArCH_2Ar$), 4.28 and 4.18 (2 d, 2 × 1, $J$ = 13.5 Hz, $ArCH_2Ar$), 4.05–3.84 (m, 6, $OCH_2CH_3$), 3.18 (d, 2, $J$ = 12.5 Hz, $ArCH_2Ar$), 2.86 (s, 1, SH), 1.72 and 1.48 (2 t, 3, 6, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.34, 0.86, and 0.83 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) δ 153.76, 151.85, 151.50, 149.09, 147.13, 145.73, 145.44, 145.22, 136.17, 135.97, 134.51, 132.63, 132.45, 131.45, 130.96, 125.58, 125.14, 124.97, 124.45, 123.72, 113.64, and 108.91 (Ar), 71.33, 71.22, and 69.61 ($OCH_2CH_3$), 34.13, 33.74, and 33.61 ($C(CH_3)_3$), 31.66, 31.15, and 31.11 ($C(CH_3)_3$), 31.48, 31.35, and 28.25 ($ArCH_2Ar$), 15.76 and 15.63 ($OCH_2CH_3$); MS (FAB POS) $m/e$ 725 $(M + 1)^+$. Anal. Calcd for $C_{46}H_{60}O_5S \cdot {}^1/_{10}\ CH_2Cl_2$: C, 75.49; H, 8.27. Found: C, 75.44, H, 8.22.

**5,11,17-Tri-*tert*-butyl-23,25-dihydroxy-22[(*p*-methylphenyl)thio]-26,27,28-tris(ethoxy)calix[4]arene (20).** A mixture of 0.173 g (0.25 mmol) of quinone **6**[5,26b] and 0.068 g (0.55 mmol) of *p*-thiocresol in 5 mL of glacial HOAc was stirred at rt for 18 h and poured into 100 g of crushed ice. The precipitate was dried under vacuum to give 0.196 g of pale yellow powder. Column chromatography using $CH_2Cl_2$–hexane (1:1, v/v) afforded 0.162 g (80%) of **20** as a colorless powder: mp 130–135 °C ($CH_2Cl_2$–MeOH); $^1H$ NMR ($CDCl_3$) δ 7.15 (s, 2, ArH), 7.03 and 6.94 (2 d, 2 × 2, $J$ = 8.2 Hz, $p$-$CH_3ArH$), 6.92 and 6.54 (2 s, 1, 2, ArH), 6.54 and 6.38 (2 d, 2 × 1, $J$ = 2.4 Hz, ArH), 6.40 and 5.13 (2 s, 2 × 1, OH), 4.42 and 3.28 (2 d, 2 × 1, $J$ = 13.2 Hz, $ArCH_2Ar$), 4.36, 4.34, 3.19, and 3.17 (4 d, 4 × 1, $J$ = 12.6 Hz, $ArCH_2Ar$), 4.18 and 4.12 (2 d, 2 × 1, $J$ = 13.6 Hz, $ArCH_2Ar$), 4.00, 3.87, and 3.81 (3 q, 3 × 2, $J$ = 7.0 Hz, $OCH_2CH_3$), 2.28 (s, 3, $ArCH_3$), 1.75, 1.50, and 1.44 (3 t, 3 × 3, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.35, 0.85, and 0.77 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) δ 153.81, 151.80, 151.57, 150.74, 147.38, 145.77, 145.40, 145.26, 136.16, 135.62, 135.35, 132.44, 132.31, 130.97, 130.86, 129.98, 125.83, 125.57, 125.02, 124.92, 124.45, 124.28, 114.04, and 112.59 (Ar), 71.29, 71.21, and 69.61 ($OCH_2CH_3$), 34.14, 33.71, and 33.59 ($C(CH_3)_3$), 31.68, 31.14, and 31.02 ($C(CH_3)_3$), 31.58, 31.26, and 27.89 ($ArCH_2Ar$), 20.85 ($ArCH_3$), 15.77, 15.66, and 15.60 ($OCH_2CH_3$). Anal. Calcd for $C_{53}H_{66}O_5S$: C, 78.09; H, 8.16, S, 3.93. Found: C, 78.21; H, 8.14; S, 3.62.

**5,11,17-Tri-*tert*-butyl-22,23-(thiomethylcarbonyloxy)-25-hydroxy-26,27,28-tris(ethoxy)calix[4]arene (21).** A mixture of 0.173 g (0.25 mmol) of quinone **6**[5,26b] and 0.115 g (1.25 mmol) of mercaptoacetic acid in 5 mL of glacial HOAc was stirred at 80 °C for 48 h in an atmosphere of $N_2$ and poured into 100 g of crushed ice. Filtration yielded 0.195 g of a pale yellow powder which was flash chromatographed ($CH_2Cl_2$) to yield 0.155 g (81%) of **21** as a colorless powder: mp 258–260 °C (acetone–MeOH); IR (KBr) $\nu_{max}$ 3528 (OH), 1775 $cm^{-1}$ (C=O); $^1H$ NMR ($CDCl_3$) δ 7.13 and 6.91 (2 s, 2 × 1, ArH), 6.64 and 6.56 (2 d, 2 × 1, $J$ = 2.2 Hz, ArH), 6.53 (s, 2, ArH), 6.03 (s, 1, OH), 4.35 and 4.33 (2 d, 2 × 1, $J$ = 12.5 Hz, $ArCH_2Ar$), 4.28 and 3.69 (2 d, 2 × 1, $J$ = 14.0 Hz, $ArCH_2Ar$), 4.26 and 3.26 (2 d, 2 × 1, $J$ = 13.5 Hz, $ArCH_2$-Ar), 4.01–3.86 (m, 6, $OCH_2CH_3$), 3.50 and 3.42 (2 d, 2 × 1, $J$ = 14.3 Hz, $SCH_2$), 3.19 (d, 2, $J$ = 12.5 Hz, $ArCH_2Ar$), 1.70, 1.50, and 1.49 (3 t, 3 × 3, $J$ = 6.9 Hz, $OCH_2CH_3$), 1.32, 0.89, and 0.83 (3 s, 3 × 9, $C(CH_3)_3$); $^{13}C$ NMR ($CDCl_3$) δ 164.16 (C=O), 153.75, 151.97, 151.29, 150.39, 145.81, 145.77, 145.38, 143.82, 135.99, 135.74, 132.93, 132.70, 130.79, 130.55, 129.67, 128.85, 125.61, 125.55, 125.51, 125.35, 124.42, 123.60, and 117.23 (Ar), 71.55, 71.32, and 69.50 ($OCH_2CH_3$), 34.13, 33.79, and 33.64 ($C(CH_3)_3$), 31.65, 31.14, and 31.09 ($C(CH_3)_3$), 31.30, 29.28, and 27.99 ($ArCH_2Ar$), 15.77, and 15.65, and 15.61 ($OCH_2CH_3$). Anal. Calcd for $C_{48}H_{60}O_6S$: C, 75.36; H, 7.90. Found: C, 75.44; H, 8.05.

**5,11,17-Tri-*tert*-butyl-23,25-dihydroxy-26,27,28-tris(ethoxy)-calix[4]arene (22).** A mixture of 0.173 g (0.25 mmol) of quinone **6**[5,26b] and 0.065 g (1.0 mmol) of zinc dust in 5 mL of glacial HOAc was sonicated (Bransonic Model B 2200R-1) for 10 min and filtered, and the filtrate was poured into 100 g of crushed ice. The precipitate was collected by filtration and dried under vacuum to give 0.14 g (81%) of **22** as a colorless powder: mp 181–183 °C (acetone–MeOH); $^1H$ NMR ($CDCl_3$) δ 7.13 and 6.58 (2 s, 2 × 2, ArH), 6.57 and 6.54 (2 d, 2 × 2, $J$ = 2.3 Hz, ArH), 5.08 (s, 1, OH), 4.36 and 3.18 (2 d, 2 × 2, $J$ = 12.4 Hz, $ArCH_2Ar$), 4.32 and 3.17 (2 d, 2 × 2, $J$ = 13.3 Hz, $ArCH_2Ar$), 4.01 and 3.87 (2 q, 2, 4, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.72 and 1.48 (2 t, 3 × 6, $J$ = 7.0 Hz, $OCH_2CH_3$), 1.33 and 0.87 (2 s, 9 × 18, $C(CH_3)_3$); MS (EI) $m/e$ 692 $(M^+)$. Anal. Calcd for $C_{46}H_{60}O_5$: C, 79.73; H, 8.73. Found: C, 80.33; H, 8.67.

**5,17-Di-*tert*-butyl-10,11,22,23,25,27-hexaacetoxy-26,28-bis-(ethoxy)calix[4]arene (23).** To a solution of 0.10 g of quinone **4a**[5,7] in 5 mL of glacial HOAc and 5 mL of acetic anhydride cooled in an ice bath was slowly added 0.1 mL of $HClO_4$ (69–72%), and the resulting mixture was stirred at rt for 24 h. It was then poured into 150 g of crushed ice, and the compound was extracted into $CHCl_3$. The $CHCl_3$ layer was washed with water and brine and dried over $MgSO_4$. The solvent was removed in vacuo, and the gummy residue was recrystallized from $CH_2Cl_2$–MeOH to give 0.02 g (14%) of **23** as colorless crystals: mp 325–327 °C; IR (KBr) $\nu_{max}$ 1782, 1750, and 1736 $cm^{-1}$ (C=O); $^1H$ NMR ($CDCl_3$) δ 7.33 and 6.97 (2 d, 2 × 2, $J$ = 2.3 Hz, ArH), 7.03 (s, 2, ArH), 3.96 and 3.79 (2 d, 2 × 2, $J$ = 17.2 Hz, $ArCH_2Ar$), 3.72 and 3.42 (2 d, 2 × 2, $J$ = 13.1 Hz, $ArCH_2Ar$), 3.55 (q, 4, $J$ = 7.0 Hz, $OCH_2CH_3$), 2.44, 2.26, and 1.37 (3 s, 3 × 6, $OCOCH_3$), 1.28 (s, 18, $C(CH_3)_3$), 0.78 (t, 6, $J$ = 7.0 Hz, $OCH_2CH_3$); MS (FAB POS) $m/e$ 909 $(M + 1)^+$. Anal. Calcd for $C_{52}H_{60}O_{14} \cdot {}^1/_2CH_3OH$: C, 68.17; H, 6.76. Found: C, 68.10; H, 6.68.

**5,11,17-Tri-*tert*-butyl-26,27,28-tris(ethoxy)calix[4]-25-quinone (24).** A sample of 0.345 g (0.5 mmol) of quinone **6**[5,26b] in 20 mL of MeCN was stirred and refluxed for 72 h. The solvent was removed in vacuo, and the residue was triturated with MeOH to give 0.325 g (94%) of **24** as a yellow powder: mp 236–238 °C ($CH_2Cl_2$–$CH_3CN$); IR (KBr) $\nu_{max}$ 1655 $cm^{-1}$ (C=O); $^1H$ NMR ($CDCl_3$) δ 7.32, 7.19, 7.15, 7.05, 6.96, and 6.42 (6 d, 6 × 1, $J$ = 2.0 Hz, ArH), 6.38, and 5.90 (2 br s, 1 × 1, ArH), 4.12, 3.98, 3.15, and 2.73 (4 d, 4 × 1, $J$ = 13.4 Hz, $ArCH_2Ar$), 3.93–3.67 (m, 6, $OCH_2$-$CH_3$ and $ArCH_2Ar$), 3.65 and 3.45 (2 d, 2 × 1, $J$ = 13.0 Hz, $ArCH_2$-Ar), 3.41 and 3.18 (2 q, 2 × 1, $OCH_2CH_3$), 1.43–1.37 (m, 6, $OCH_2CH_3$), 1.35, 1.32, and 1.00 (3 s, 3 × 9, $C(CH_3)_3$), 0.83 (t, 3, $J$ = 7.1 Hz, $OCH_2CH_3$); $^{13}C$ NMR ($CDCl_3$) δ 188.30 and 185.86 (C=O), 155.63, 153.47, 152.17, 150.07, 145.76, 145.72, 144.61, 144.19, 136.32, 134.52, 133.68, 132.93, 132.68, 132.51, 131.32, 128.90, 128.55, 127.23, 127.01, 126.38, 125.33, and 125.15 (Ar), 69.32, 67.91, and 67.59 ($OCH_2CH_3$), 37.00, 34.61, 31.42, and 29.69 ($ArCH_2Ar$), 34.14 and 33.75 ($C(CH_3)_3$), 31.60 and 31.25 ($C(CH_3)_3$), 16.42, 16.07, and 14.86 ($OCH_2CH_3$). Anal. Calcd for $C_{46}H_{58}O_5$: C, 79.96; H, 8.46. Found: C, 79.73; H, 8.41.

**Acknowledgment.** We are indebted to the National Science Foundation and the Robert A. Welch Foundation for generous support of this work. For the mass spectral determinations we are indebted to the Washington University Mass Spectrometry Resource Center partially supported by NIH grant RR00954 and to Professor Clive A. Slaughter and Dr. Bikash C. Pramanik, University of Texas Southwestern Medical Center at Dallas.