Synthesis of Calix[4]arenes with Four Different "Lower Rim" Substituents

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Calix[4]arenes with four different "lower rim" substituents were synthesized following six-step sequences. The first alkyl group (R_1) was introduced using R_1X and CH_3ONa, and then reaction with R_2X and K_2CO_3 led to the introduction of a second alkyl group (R_2) at the 3-position. Benzoate was introduced as a protecting group at the 1,3-O-disubstituent stage and was removed under basic conditions after the incorporation of the third alkyl group (R_3) with R_3X and NaH. The final alkyl group (R_4) was introduced with R_4X and NaH to give the chiral title compounds.

Introduction

Calixarenes, which are cyclic oligomers of phenol−formaldehyde condensed compounds, are not planar and possess an inner cavity. This unique structure has attracted considerable attention in the research area of enzyme mimics.[1] A good enzyme-mimic model requires not only an appropriate functional group positioned to display the reactivity and selectivity of the real enzyme but also the chirality to effect their high stereoselectivity. To incorporate an appropriate functional group, properly positioned, onto the calixarene framework was a major goal of early calixarenes research, and a wide range of calixarene derivatives were reported.[1] However, the preparation of calixarenes with chirality has been accomplished only recently.[2]

In the literature, several strategies, including fragment condensation,[3] introduction of chiral substituents,[4] and "lower rim" functionalization,[5] have been used for the preparation of inherently chiral calix[4]arenes. In our previous work on the synthesis of trialkoxycalix[4]arenes,[6] we demonstrated that alkyl ether linkages can be introduced at various synthetic stages. We report here a general synthetic strategy comprised a six-step sequence, in which monoalkoxycalix[4]arenes are treated with different alkyl halides at various alkylation stages, for the synthesis of calix[4]arenes that are chiral by virtue of the four different substituents on their "lower rim".

Results and Discussion

Monoalkoxycalix[4]arenes. According to the literature, monoalkoxycalix[4]arenes have usually been prepared either by a multistep process[7] or by a one-step procedure employing a careful separation technique.[8] During the synthesis of a series of calix[4]arene allyl ethers, we were surprised to find that $NaOCH_3$ in CH_3CN would mediate the conversion of calix[4]arene into monoallyloxycalix[4]arene in good yield.[9] Further investigation proved that calix[4]arene would react with most of the simple primary alkyl halides in CH_3CN in the presence of $NaOCH_3$ to yield the corresponding monoalkoxycalix[4]arenes (**2a**−**f**) in roughly 75% yield (Figure 1). This result was quite unexpected, seeming to violate the notion that more severe reaction conditions should lead to multiply-substituted products, given that weaker bases such as Na_2CO_3 or K_2CO_3 produced the 1,3-

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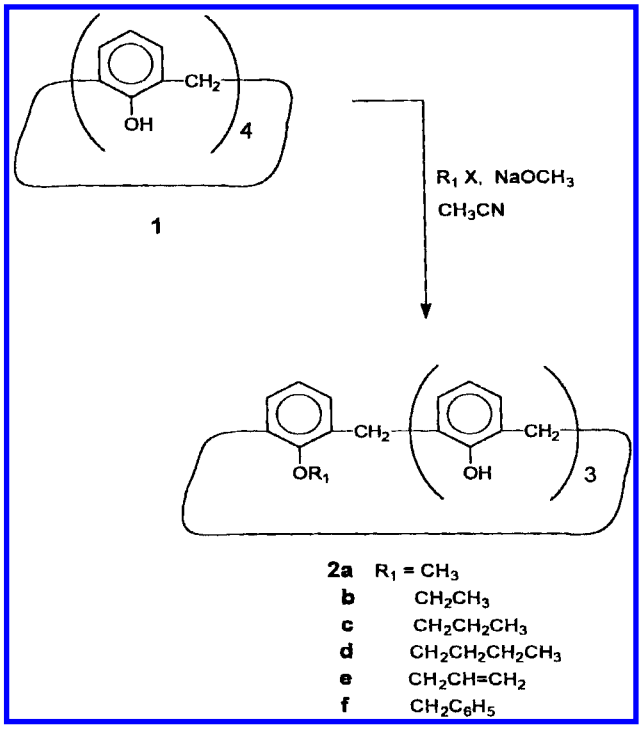

Figure 1. Monoalkoxycalix[4]arenes.

dialkoxy products under the same reaction conditions. Even after extensive studies, we are still not able to propose a reasonable explanation for the strange behavior of $NaOCH_3$ in this monoalkylation reaction. Other bases such as NaOH or KOH also produced monoalkylated calix[4]arene, but the composition of the products is sensitive to the reaction conditions and erratically reproducible.[10]

1,3-Dialkoxycalix[4]arenes. When monobenzyloxycalix[4]arene (**2f**) was refluxed with a second alkyl halide in CH_3CN in the presence of K_2CO_3 by a literature procedure for synthesis of 1,3-dialkoxycalix[4]arenes,[11] corresponding 25-alkoxy-27-benzyloxy-calix[4]arenes (**3a**−**e**) were formed in 88−94% yields (Figure 2). Compound **3e**, 25-allyloxy-27-benzyloxy-26,28-dihydroxycalix[4]arene, could also be prepared by refluxing monoallyloxycalix[4]arene (**2e**) with benzyl bromide in the presence of K_2CO_3. It is suspected that all calix[4]arenes with two different alkoxy substituents at their 1,3-positions can be synthesized stepwise in either order.

1,2,3-Trialkoxycalix[4]arenes. Treatment of 1,3-dialkoxy compounds **3c**−**e** with benzoyl chloride in pyridine at room temperature gave the corresponding monobenzoates **4a**−**c** quantitatively. In compounds **4a**−**c**, the three substituents on the "lower rim" are all larger than an ethoxy group. Therefore, the "through-the-annulus" free rotation (i.e., calix[4]arene ring inversion) is restricted.[12] The restriction of the calix[4]arene ring inversion yields a pair of enantiomers during the benzoylation of compounds **3c**−**e**; in other word, a chiral element[13] is created in this benzoylation reaction and compounds **4a**−**c** were produced as racemic mixtures. Due to the lack of any symmetry in compounds **4a**−**c**, all of the methylene hydrogens (four calix[4]arene methylenes, benzyloxy methylene, and alkoxy methylene) reside in different magnetic environments, and consequently, a total of six sets of AB quartets were observed in the range of δ 3.50−5.00 in the proton NMR spectra. By comparing the spectra of **4a**−**c** and monobenzoated diallyloxycalix[4]arene,[6] the benzoyloxy moiety of **4a**−**c** was assigned as *anti* to the two alkoxy groups.

Compounds **4a**−**c** were further alkylated by treatment with NaH and large primary alkyl halides in CH_3CN to give 25,26,27-trialkoxy-28-monobenzoyloxycalix[4]arenes (**5a**−**d**). The ^{1}H NMR spectra of **5a**−**d** displayed pairs of multiplets corresponding to the newly introduced alkoxy methylene hydrogens, which indicated that these alkoxy methylene hydrogens are also located in a distinct magnetic environment. This phenomena is believed to be caused by these alkoxy moieties being *syn* to the two existing alkoxy moieties, whereas an *anti* orientation would result in a set of triplets for the same methylene hydrogens. The *syn* orientation of three alkoxy groups in compounds **5a**−**d** is consistent with our earlier observation in trialkoxycalix[4]arenes cases,[6] and compounds **5a**−**d** are assigned an "up-up-up-down" conformation.

The protecting benzoate moieties were readily removed under basic hydrolysis to liberate the fourth hydroxy group for the final alkylation. Basic hydrolysis of compounds **5a**−**d** following a literature procedure[6,7a] produced the corresponding hydrolyzed products **6a**−**d**, 25,26,27-trialkoxy-28-hydroxycalix[4]arenes, in 81−87% yields.

1,2,3,4-Tetraalkoxycalix[4]arenes. The last alkyl group was introduced by heating compounds **6a**−**d**, NaH, and a fourth primary alkyl iodide in refluxing CH_3CN to yield the final product 25,26,27,28-tetraalkoxycalix[4]arenes (**7a**−**c**), with four different "lower rim" substituents. The last alkoxy group can in principle be introduced into compounds **6a**−**d** either in *syn* or in *anti* orientation to the other three alkoxy groups, thus producing products **7a**−**c** in either the "cone" or "partial cone" conformations. However, the ^{1}H NMR spectra of **7a**−**c**, which were similar to those of the *syn*-1,3-dialkoxycalix[4]arenes, revealed that the four different "lower rim" substituents were all oriented in the same direction and the products existed only in "cone" conformation. It is noteworthy that compound **7b**, 25-allyloxy-26-benzyloxy-27-butoxy-28-propoxycalix[4]arene, was prepared either by allylation of compound **6b** or by introduction of a propoxy group onto compound **6c**. In other words, the allyloxy (the third alkoxy) and *n*-propoxy (the fourth alkoxy) groups can be introduced into products **3d** in either order, which is similar to the previous observation with 1,3-dialkoxycalix[4]arenes (**3a**−**e**).

The products **5a**−**d**, **6a**−**d**, and **7a**−**c** all inherit the chirality of compounds **4a**−**d**, and all exist in a racemic mixture. The optical resolution and X-ray structure

(10) Unpublished results, Chinese Culture University.

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(13) Compounds **4**−**7** are asymmetric molecules and belong to the C_1 point group. The chiral element of compounds **4**−**7** can be visualized either as a chiral axis that goes through the center of the calix[4]arene's cavity or as a chiral plane that contains the cavity main axis. Even though the calixarenes can be classified as *meta*-cyclophanes, the chirality of the calix[4]arenes is different from cyclophane systems. For an excellent review on the specification of molecular chirality, see: Cahn, R. S.; Ingold, C.; Prelog, V. *Angew. Chem., Int. Ed. Engl.* **1966**, *5*, 385.

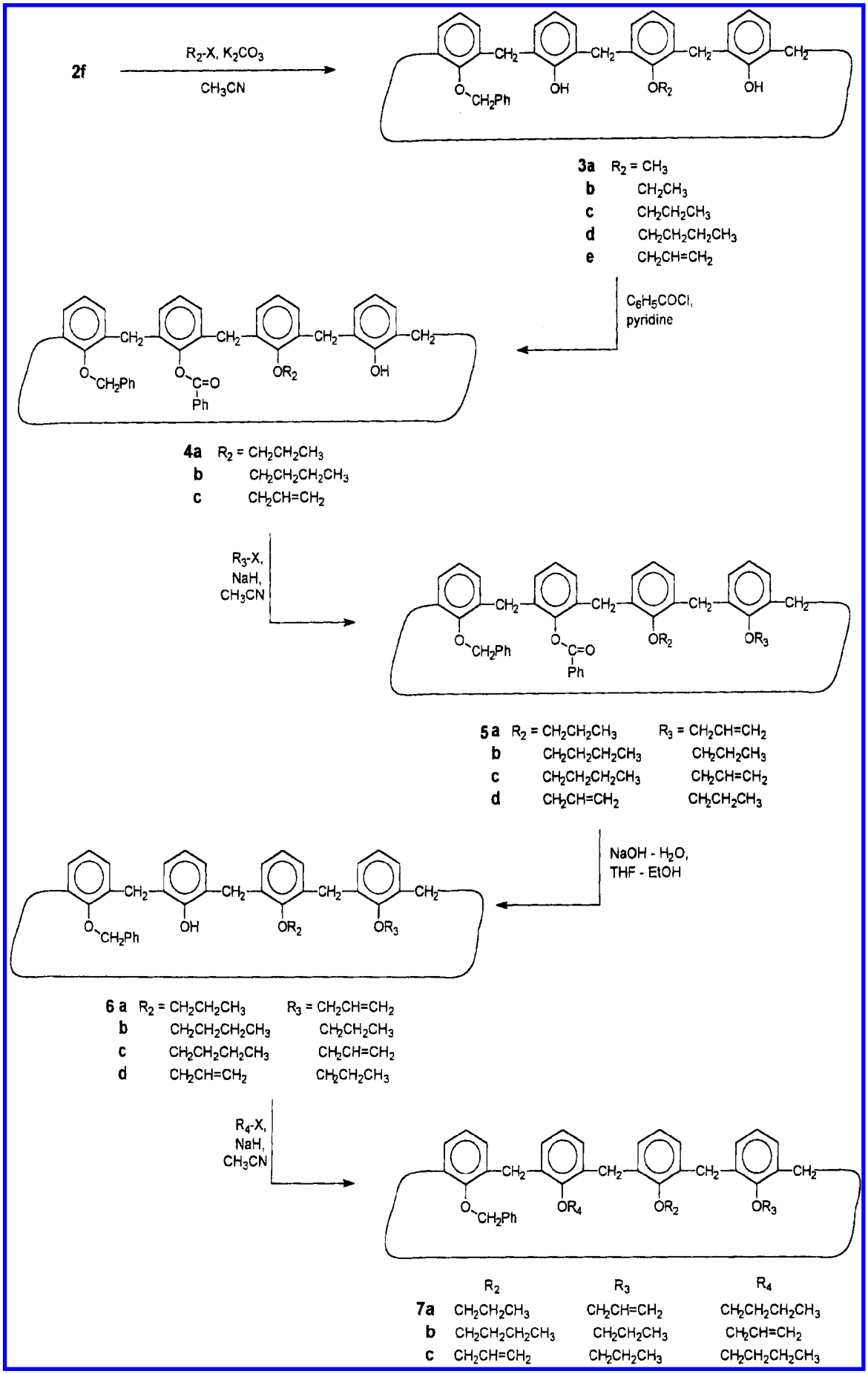

Figure 2. Synthesis of calix[4]arenes with four different "lower rim" substituents.

determination of these compounds (**4a**−**d**, **5a**−**d**, **6a**−**d**, and **7a**−**c**) is under investigation at present.[14]

Experimental Section[15]

General Procedure for 25-Alkoxycalix[4]arenes 2a−**f.** A sample of 2.12 g (5.00 mmol) of calix[4]arene (**1**) and 0.32 g (5.9 mmol) of $NaOCH_3$ was refluxed in 150 mL of CH_3CN for 30 min to monodeprotonate the calix[4]arene completely. An excess amount of alkyl halides was added, and the reaction mixture was further refluxed for 8 h (24 h for less reactive alkyl halides). The reaction mixture was neutralized with a few drops of acetic acid, and solvent was removed to leave an off-white residue. The residue was recrystallized from $CHCl_3$ with a slow addition of CH_3OH to yield the corresponding monoalkylated calix[4]arene **2a**−**f**.

25-Methoxy-26,27,28-trihydroxycalix[4]arene (2a). The reaction mixture was refluxed with 0.80 mL (1.82 g, 12.8 mmol) of methyl iodide for 8 h to afford 1.60 g (73%) of colorless crystals: mp 273−274 °C; ^{1}H NMR ($CDCl_3$) δ 9.69 (s, 1 H), 9.34 (s, 2 H), 6.67−7.10 (m, 12 H), 4.35 (d, 2 H, J = 13.0 Hz), 4.26 (d, 2 H, J = 13.0 Hz), 4.13 (s, 3 H), 3.46 (2d, 4 H, J = 13.0 Hz); ^{13}C NMR ($CDCl_3$) δ 152.54 (C_q), 150.65 (C_q), 149.22 (C_q), 134.04 (C_q), 129.38 (CH), 128.82 (CH), 128.72 (CH), 128.55 (CH), 128.43 (CH), 126.20 (CH), 121.90 (CH), 120.98 (CH), 63.43 (CH_3), 31.88 (CH_2), 31.30 (CH_2); FAB-MS m/z 437 ($M^+ - 1$). Anal. Calcd for $C_{29}H_{26}O_4$: C, 79.43; H, 5.98. Found: C, 79.38; H, 6.03.

25-Ethoxy-26,27,28-trihydroxycalix[4]arene (2b). The reaction mixture was refluxed with 1.00 mL (1.95 g, 12.5 mmol) of ethyl iodide for 8 h to afford 1.74 g (77%) of colorless crystals: mp 292−293 °C; ^{1}H NMR ($CDCl_3$) δ 9.86 (s, 1 H), 9.52 (s, 2 H), 6.68−7.14 (m, 12 H), 4.22−4.42 (m, 6 H), 3.50 (2d, 4 H, J = 13.4 Hz), 1.77 (t, 3 H, J = 7.1 Hz); ^{13}C NMR ($CDCl_3$) δ 151.28 (C_q), 150.62 (C_q), 149.33 (C_q), 134.39 (C_q), 129.56 (CH), 129.22 (CH), 128.76 (CH), 128.69 (CH), 128.56 (CH), 128.50 (CH), 128.41 (CH), 126.10 (CH), 121.85 (CH), 120.98 (CH), 72.60 (CH_2), 31.88 (CH_2), 31.46 (CH_2), 15.17 (CH_3); FAB-MS m/z 451 ($M^+ - 1$). Anal. Calcd for $C_{30}H_{28}O_4$: C, 79.62; H, 6.24. Found: C, 79.60; H, 6.23.

25-Propoxy-26,27,28-trihydroxycalix[4]arene (2c). The reaction mixture was refluxed with 1.20 mL (2.09 g, 12.3 mmol) of *n*-propyl iodide for 10 h to afford 1.63 g (70%) of colorless crystals: mp 262−263 °C; ^{1}H NMR ($CDCl_3$) δ 9.62 (s, 1 H), 9.31 (s, 2 H,), 6.52−6.97 (m, 12 H), 4.24 (d, 2 H, J = 13.3 Hz), 4.16 (d, 2 H, J = 13.3 Hz), 3.99 (t, 2 H, J = 6.9 Hz), 3.42 (2d, 4 H, J = 13.3 Hz), 2.03−2.11 (m, 2 H), 1.15 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 151.40 (C_q), 150.77 (C_q), 149.17 (C_q), 134.19 (C_q), 129.28 (CH), 128.79 (CH), 128.76 (CH), 128.70 (CH), 128.41(CH), 128.38 (CH), 126.02 (CH), 121.91 (CH), 120.87 (CH), 78.96 (CH_2), 31.87 (CH_2), 31.41 (CH_2), 23.22 (CH_2), 10.56 (CH_3); FAB-MS m/z 465 ($M^+ - 1$). Anal. Calcd for $C_{31}H_{30}O_4$: C, 79.80; H, 6.48. Anal. Calcd for $C_{31}H_{30}O_4 \cdot H_2O$: C, 76.84; H, 6.66. Found: C, 76.91; H, 6.31.

25-Butoxy-26,27,28-trihydroxycalix[4]arene (2d). The reaction mixture was refluxed with 1.40 mL (2.26 g, 12.3 mmol) of *n*-butyl iodide for 24 h to afford 1.73 g (72%) of colorless crystals: mp 240−241 °C; ^{1}H NMR ($CDCl_3$) δ 9.73 (s, 1 H), 9.41 (s, 2 H), 6.64−7.08 (m, 12 H), 4.36 (d, 2 H, J = 13.2 Hz), 4.28 (d, 2 H, J = 13.2 Hz), 4.14 (t, 2H, J = 3.5 Hz), 3.46 (2d, 4 H, J = 13.2 Hz), 2.13−2.20 (m, 2 H), 1.68−1.76 (m, 2 H), 1.12 (t, 3 H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$) δ 151.50 (C_q), 150.80 (C_q), 149.22 (C_q), 134.23 (C_q), 129.31 (CH), 128.84 (CH), 128.80 (CH), 128.75 (CH), 128.41 (CH), 126.05 (CH), 121.95 (CH), 120.90 (CH), 77.32 (CH_2), 77.22 (CH_2), 31.96 (CH_2), 31.91 (CH_2), 31.45 (CH_2), 19.26 (CH_2), 14.01 (CH_3); FAB-MS m/z 479 ($M^+ - 1$). Anal. Calcd for $C_{32}H_{32}O_4$: C, 79.97; H, 6.71. Anal. Calcd for $C_{32}H_{32}O_4 \cdot {}^1/_4H_2O$: C, 79.23; H, 6.75. Found: C, 78.97; H, 6.70.

25-Allyloxy-26,27,28-trihydroxycalix[4]arene (2e). The reaction mixture was refluxed with 1.00 mL (1.40 g, 11.6 mmol) of allyl bromide for 8 h to afford 1.74 g (75%) of colorless needlelike crystals: mp 201−202 °C; ^{1}H NMR ($CDCl_3$) δ 9.71 (s, 1 H), 9.31 (s, 2 H), 6.66−7.12 (m, 12 H), 6.42−6.47 (m, 1 H), 5.53−5.65 (m, 2 H), 4.65−4.68 (m, 2 H), 4.37 (d, 2 H, J = 13.2 Hz), 4.27 (d, 2 H, J = 13.2 Hz), 3.46 (2d, 4 H, J = 13.2 Hz); ^{13}C NMR ($CDCl_3$) δ 151.24 (C_q), 150.78 (C_q), 149.30 (C_q), 134.35 (C_q), 132.28 (CH), 129.40 (CH), 128.87 (CH), 128.79 (CH), 128.50 (CH), 128.46 (CH), 128.43 (CH), 126.28 (CH), 121.96 (CH), 120.99 (CH), 120.34 (CH_2), 77.75 (CH_2), 31.94 (CH_2), 31.63 (CH_2); FAB-MS m/z 463 ($M^+ - 1$). Anal. Calcd for $C_{31}H_{28}O_4$: C, 80.15; H, 6.08. Anal. Calcd for $C_{31}H_{28}O_4 \cdot {}^1/_6CHCl_3$: C, 77.27; H, 5.86. Found: C, 77.22; H, 5.91%.

25-Benzyloxy-26,27,28-trihydroxycalix[4]arene (2f). The reaction mixture was refluxed with 1.50 mL (2.16 g, 12.6 mmol) of benzyl bromide for 9 h to afford 2.06 g (80%) of colorless crystals: mp 234−235 °C; ^{1}H NMR ($CDCl_3$) δ 9.56 (s, 1 H), 9.21 (s, 2 H), 6.66−7.71 (m, 17 H), 5.19 (s, 2 H), 4.34 (d, 2 H, J = 13.4 Hz), 4.22 (d, 2 H, J = 13.4 Hz), 3.43 (2d, 4 H, J = 13.4 Hz); ^{13}C NMR ($CDCl_3$) δ 151.22 (C_q), 150.79 (C_q), 149.10 (C_q), 135.47 (C_q), 134.29 (C_q), 129.49 (CH), 129.02 (CH), 128.94 (CH), 128.90 (CH), 128.77 (CH), 128.72 (CH), 128.37 (CH), 128.30 (CH), 126.26 (CH), 121.90 (CH), 120.84 (CH), 79.26 (CH_2), 31.84(CH_2), 31.59(CH_2); FAB-MS m/z 513 ($M^+ - 1$). Anal. Calcd for $C_{35}H_{30}O_4$: C, 81.69; H, 5.88. Anal. Calcd for $C_{35}H_{30}O_4 \cdot {}^1/_4H_2O$: C, 80.98; H, 5.92. Found: C, 81.08; H, 5.90.

General Procedure for 25,27-Dialkoxycalix[4]arenes 3a−**e.** A sample of 2.57 g (5.00 mmol) of 25-benzyloxy-26,27,-28-trihydroxycalix[4]arene (**2f**), 0.82 g (5.9 mmol) of K_2O_3, and an excess amount of alkyl halides was refluxed in 50 mL of CH_3CN. The solvent was removed, and the residue was recrystallized from $CHCl_3$ with a slow addition of CH_3OH to yield the corresponding dialkylated products **3a**−**e**.

25-Benzyloxy-27-methoxy-26,28-dihydroxycalix[4]-arene (3a). The reaction mixture was refluxed with 1.20 mL (2.74 g, 19.3 mmol) of methyl iodide for 4 h to afford 2.32 g (88%) of colorless crystals: mp 245−246 °C; ^{1}H NMR ($CDCl_3$) δ 7.75 (s, 2H), 7.59−7.61 (m, 2 H), 7.39−7.41 (m, 3 H), 6.65−7.06 (m, 12 H), 5.07 (s, 2 H), 4.24−4.31 (2d, 4 H, J = 13.1 Hz), 3.93 (s, 3 H), 3.35 (d, 2 H, J = 13.0 Hz), 3.28 (d, 2 H, J = 13.1 Hz); ^{13}C NMR ($CDCl_3$) δ 153.11 (C_q), 151.69 (C_q), 136.41 (C_q), 133.37 (C_q), 133.01 (C_q), 128.95 (CH), 128.91 (CH), 128.53 (CH), 128.44 (CH), 128.41 (CH), 128.27 (CH), 128.05 (CH), 125.33 (CH), 125.27 (CH), 119.02 (CH), 78.04 (CH_2), 63.44 (CH_3), 31.34 (CH_2), 31.16 (CH_2); FAB-MS m/z 529 ($M^+ + 1$). Anal. Calcd for $C_{36}H_{32}O_4$: C, 81.79; H, 6.10. Found: C, 81.53; H, 6.01.

25-Benzyloxy-27-ethoxy-26,28-dihydroxycalix[4]-arene (3b). The reaction mixture was refluxed with 1.50 mL (2.93 g, 18.8 mmol) of ethyl iodide for 4 h to afford 2.41 g (89%) of colorless crystals: mp 258−259 °C; ^{1}H NMR ($CDCl_3$) δ 8.19 (s, 2 H), 7.74−7.76 (m, 2 H), 7.43−7.45 (m, 3 H), 6.61−7.05 (m, 12 H), 5.08 (s, 2 H), 4.34 (d, 2 H, J = 12.9 Hz), 4.28 (d, 2 H, J = 12.9 Hz), 4.09 (q, 2 H, J = 7.0 Hz), 3.37 (2d, 4 H, J = 12.9 Hz), 1.65 (t, 3 H, J = 7.0 Hz); ^{13}C NMR ($CDCl_3$) δ 153.25 (C_q), 151.79 (C_q), 151.59 (C_q), 136.75 (C_q), 133.54 (C_q), 133.50 (C_q), 129.02 (CH), 128.86 (CH), 128.53 (CH), 128.44 (CH), 128.37 (CH), 128.12 (CH), 128.08 (CH), 127.51 (CH), 125.58

(14) Single-crystal X-ray crystallography of the tetraalkoxy calix-[4]arenes indicated that it is in a "cone" conformation. The author has deposited atomic coordinates for **7c** with the Cambridge Crystallographic Data Center. The coordinates can be obtained, on request, from the Director, Cambridge Crystallographic Data Center, 12 Union Road, Cambridge, CB2 1EZ, U.K. We are indebted to Mr. J.-H. Lee (NTU) and Prof. S.-M. Peng for the single-crystal X-ray analyses.

(15) All reagents were obtained from Merck Chemical Co. and used without further purification. Melting points were taken in capillary tubes on a Mel-Temp apparatus (Laboratory Devices Cambridge, MA) and are uncorrected. ^{1}H NMR spectra were recorded on either a Varian Gemini 200 or Unity-300 spectrometer. Chemical shifts are reported as δ values in ppm relative to TMS (δ = 0.0) as an internal standard. DEPT program of the ^{13}C NMR was used to determine the C_q, CH, CH_2, and CH_3 of each carbon. FAB-MS spectra were taken on a JEOL JMS-HX 110 spectrometer, and elemental analyses were taken on a Perkin-Elmer 240C analyzer. MMCALC program in ChemWindow 3 computer software package was used to calculate the theoretical EA values. Chromatographic separations were performed with Merck silica gel (230−400 mesh ASTM) on columns of 25 mm diameter filled to a height of 150 mm. TLC analyses were carried out on Merck aluminum sheets silica gel 60 F_{254} plates (absorbant thickness 0.2 mm).

(CH), 125.29 (CH), 119.01 (CH), 78.18 (CH_2), 72.11 (CH_2), 31.51 (CH_2), 31.43 (CH_2), 15.29 (CH_3); FAB-MS *m*/*z* 541 ($M^+ - 1$). Anal. Calcd for $C_{37}H_{34}O_4$: C, 81.89; H, 6.32. Found: C, 81.75; H, 6.35.

25-Benzyloxy-27-propoxy-26,28-dihydroxycalix[4]-arene (3c). The reaction mixture was refluxed with 1.50 mL (2.61 g, 15.4 mmol) of *n*-propyl iodide for 3 h to afford 2.61 g (94%) of colorless needlelike crystals: mp 234−235 °C; ^{1}H NMR ($CDCl_3$) δ 8.14 (s, 2 H), 7.74−7.76 (m, 2 H), 7.43−7.45 (m, 3 H), 6.62−7.06 (m, 12 H), 5.07 (s, 2 H), 4.36 (d, 2 H, J = 13.0 Hz), 4.29 (d, 2 H, J = 13.0 Hz), 3.95 (t, 2 H, J = 6.1 Hz), 3.37 (2d, 4 H, J = 13.0 Hz), 2.03−2.06 (m, 2 H), 1.24 (t, 3 H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$) δ 153.37 (C_q), 151.82 (C_q), 151.65 (C_q), 136.77 (C_q), 133.38 (C_q), 133.33 (C_q), 129.04 (CH), 128.91 (CH), 128.54 (CH), 128.49 (CH), 128.42 (CH), 128.05 (CH), 128.02 (CH), 127.47 (CH), 125.56 (CH), 125.26 (CH), 118.94 (CH), 78.33 (CH_2), 78.25 (CH_2), 31.43 (CH_2), 23.47 (CH_2), 11.02 (CH_3); FAB-MS *m*/*z* 555 ($M^+ - 1$). Anal. Calcd for $C_{38}H_{36}O_4$: C, 81.99; H, 6.52. Found: C, 82.01; H, 6.55.

25-Benzyloxy-27-butoxy-26,28-dihydroxycalix[4]-arene (3d). The reaction mixture was refluxed with 1.70 mL (2.75 g, 14.9 mmol) of *n*-butyl iodide for 4 h to afford 2.59 g (91%) of colorless needlelike crystals: mp 196−197 °C; ^{1}H NMR ($CDCl_3$) δ 8.06 (s, 2 H), 7.73−7.74 (m, 2 H), 7.43−7.46 (m, 3 H), 6.60−7.06 (m, 12 H), 5.07 (s, 2 H), 4.34 (d, 2 H, J = 13.0 Hz), 4.29 (d, 2 H, J = 13.0 Hz), 3.96 (t, 2 H, J = 6.1 Hz), 3.36 (2d, 4 H, J = 13.0 Hz), 1.92−2.02 (m, 2 H), 1.60−1.70 (m, 2 H), 1.06 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 153.33 (C_q), 151.92 (C_q), 151.69 (C_q), 136.74 (C_q), 133.30 (C_q), 133.23 (C_q), 129.56 (CH), 128.99 (CH), 128.86 (CH), 128.53 (CH), 128.45 (CH), 128.40 (CH), 128.00 (CH), 127.46 (CH), 125.48 (CH), 125.18 (CH), 118.89 (CH), 78.26 (CH_2), 76.45 (CH_2), 32.05 (CH_2), 31.40 (CH_2), 19.23 (CH_2), 14.03 (CH_3); FAB-MS *m*/*z* 569 ($M^+ - 1$). Anal. Calcd for $C_{39}H_{38}O_4$: C, 82.08; H, 6.71. Found: C, 82.06; H, 6.74.

25-Allyloxy-27-benzyloxy-26,28-dihydroxycalix[4]-arene (3e). Method A. From 25-Benzyloxycalix[4]arene (2f). A sample of 2.57 g (5.00 mmol) of 25-benzyloxy-26,27,-28-trihydroxycalix[4]arene (**2f**), 0.82 g (5.9 mmol) of K_2CO_3, and 1.30 mL (1.82 g, 15.0 mmol) of allyl bromide was refluxed in 50 mL of CH_3CN for 4 h. The solvent was removed, and the residue was recrystallized from $CHCl_3$ and CH_3OH to yield 2.55 g (92%) of colorless crystals: mp 213-214 °C; ^{1}H NMR ($CDCl_3$) δ 7.98 (s, 2 H), 7.70−7.72 (m, 2 H), 7.31−7.46 (m, 3 H), 6.63−7.06 (m, 12 H), 6.10−6.25 (m, 1 H), 5.69−5.75 (d, 1 H, J = 18.5 Hz), 5.30 (d, 1 H, J = 10.3 Hz), 5.07 (s, 2 H), 4.53 (s, 2 H), 4.26−4.37 (2d, 4 H, J = 12.9 Hz), 3.37 (2d, 4 H, J = 12.9 Hz); ^{13}C NMR ($CDCl_3$) δ 153.28 (C_q), 151.59 (C_q), 136.60 (C_q), 133.19 (C_q), 133.13 (CH), 132.62 (CH), 129.50 (CH), 128.98 (CH), 128.88 (CH), 128.55 (CH), 128.46 (CH), 128.44 (CH), 128.03 (CH), 127.92 (CH), 127.90 (CH), 127.58 (CH), 125.48 (CH), 125.36 (CH), 118.90 (CH), 117.54 (CH_2), 78.26 (CH_2), 76.66 (CH_2), 31.38 (CH_2); FAB-MS *m*/*z* 553 ($M^+ - 1$). Anal. Calcd for $C_{38}H_{34}O_4$: C, 82.28; H, 6.18. Anal. Calcd for $C_{38}H_{34}O_4 \cdot {}^1/_4H_2O$: C, 81.62; H, 6.22. Found: C, 81.80; H, 6.20.

Method B. From 25-Allyloxycalix[4]arene (2e). A sample of 2.32 g (5.00 mmol) of 25-allyloxy-26,27,28-trihydroxy-calix[4]arene (**2e**), 0.82 g (5.9 mmol) of K_2CO_3, and 1.50 mL (2.16 g, 12.6 mmol) of benzyl bromide was refluxed in 50 mL of CH_3CN for 4 h. The solvent was removed, and the residue was recrystallized from $CHCl_3$ and CH_3OH to yield 2.50 g (90%) of colorless crystals that were identical in physical and spectral properties with compound **3e** obtained by method A.

General Procedure for 25,27-Dialkoxy-26-benzoyl-oxycalix[4]arenes 4a−c. A sample of 1.00 mmol of 25,27-dialkoxycalix[4]arenes (**3c**−**e**) was dissolved in 10 mL of pyridine, and 2.00 mL (3.14 g, 17.0 mmol) of benzoyl chloride was added. The mixture was stirred at room temperature for 48 h and was then treated with 100 mL of diluted HCl to induce a white solid. The white solid was recrystallized from $CHCl_3$ with a slow addition of CH_3OH to yield the corresponding benzoate products **4a**−**c**.

25-Benzyloxy-26-benzoyloxy-28-hydroxy-27-pro-poxycalix[4]arene (4a). A sample of 0.56 g (1.0 mmol) of 25-benzyloxy-27-propoxy-26,28-dihydroxycalix[4]arene (**3c**) was benzoated and yielded 0.63 g (95%) of colorless needlelike crystals: mp 179−181 °C; ^{1}H NMR ($CDCl_3$) δ 7.80 (s, 1 H), 6.12−7.33 (m, 22 H), 5.05, 4.83 (AB, 2 H, J = 12.1 Hz), 4.26 (d, 1 H, J = 13.0 Hz), 4.12 (d, 1 H, J = 13.0 Hz), 3.72−4.05 (m, 6 H), 3.38 (d, 1 H, J = 13.0 Hz), 3.24 (d, 1 H, J = 13.0 Hz), 1.77−1.83 (m, 2 H), 1.04 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 163.46 (C_q), 154.47 (C_q), 153.43 (C_q), 153.21 (C_q), 147.96 (C_q), 137.61 (C_q), 133.14 (C_q), 133.04 (C_q), 132.49 (C_q), 132.39 (CH), 130.10 (CH), 129.73 (CH), 129.55 (CH), 129.17 (CH), 128.83 (CH), 128.16 (CH), 128.03 (CH), 127.90 (CH), 127.46 (CH), 127.14 (CH), 127.07 (CH), 126.75 (CH), 123.57 (CH), 118.75 (CH), 75.20 (CH_2), 74.50 (CH_2), 37.94 (CH_2), 31.37 (CH_2), 30.91 (CH_2), 23.03 (CH_2), 10.61 (CH_3); FAB-MS *m*/*z* 661 ($M^+ + 1$). Anal. Calcd for $C_{45}H_{40}O_5$: C, 81.79; H, 6.10. Anal. Calcd for $C_{45}H_{40}O_5 \cdot {}^1/_4H_2O$: C, 81.24; H, 6.14. Found: C, 81.31; H, 6.13.

25-Benzyloxy-26-benzoyloxy-27-butoxy-28-hydroxy-calix[4]arene (4b). A sample of 0.57 g (1.0 mmol) of 25-benzyloxy-27-butoxy-26,28-dihydroxy-calix[4]arene (**3d**) was benzoated and yielded 0.62 g (93%) of colorless crystals: mp 161−162 °C; ^{1}H NMR ($CDCl_3$) δ 7.63 (s, 2 H), 6.01−7.23 (m, 17 H), 4.94, 4.74 (AB, 2 H, J = 12.1 Hz), 3.61−4.17 (m, 8 H), 3.28 (d, 1 H, J = 12.7 Hz), 3.24 (d, 1 H, J = 12.7 Hz), 1.39−1.80 (m, 4 H), 0.92 (t, 3 H, J = 7.3 Hz); ^{13}C NMR ($CDCl_3$) δ 163.60 (C_q), 154.60 (C_q), 153.59 (C_q), 153.28 (C_q), 148.04 (C_q), 137.70 (C_q), 133.24 (C_q), 132.55 (C_q), 132.46 (CH), 130.23 (CH), 129.89 (CH), 129.36 (CH), 129.29 (CH), 129.25 (CH), 128.93 (CH), 128.24 (CH), 128.09 (CH), 128.02 (CH), 127.53 (CH), 127.24 (CH), 127.16 (CH), 126.86 (CH), 125.08 (CH), 118.79 (CH), 74.68 (CH_2), 73.63 (CH_2), 37.98 (CH_2), 37.92 (CH_2), 31.73 (CH_2), 31.44 (CH_2), 30.98 (CH_2), 19.09 (CH_2), 14.15(CH_3); FAB-MS *m*/*z* 675 ($M^+ + 1$). Anal. Calcd for $C_{46}H_{42}O_5$: C, 81.87; H, 6.27. Anal. Calcd for $C_{46}H_{42}O_5 \cdot {}^1/_4H_2O$: C, 81.33; H, 6.31. Found: C, 81.24; H, 6.26.

25-Allyloxy-26-benzoyloxy-27-benzyloxy-28-hydroxy-calix[4]arene (4c). A sample of 0.55 g (1.0 mmol) of 25-allyloxy-27-benzyloxy-26,28-dihydroxycalix[4]arene (**3e**) was benzoated and yielded 0.64 g (98%) of colorless needlelike crystals: mp 162−163 °C; ^{1}H NMR ($CDCl_3$) δ 7.57 (s, 1 H), 6.18−7.36 (m, 22 H), 5.95−6.10 (m, 1 H), 5.34−5.37 (m, 2 H), 5.08, 4.84 (AB, 2 H, J = 11.9 Hz), 4.60−4.68 (m, 1 H), 4.26−4.36 (m, 1 H), 4.17 (d, 1 H, J = 13.1 Hz), 4.11 (d, 1 H, J = 13.1 Hz), 3.62−4.17 (m, 4 H), 3.37 (d, 1 H, J = 13.1 Hz), 3.27 (d, 1 H, J = 13.1 Hz); ^{13}C NMR ($CDCl_3$) δ 163.60 (C_q), 154.20 (C_q), 153.49 (C_q), 153.18 (C_q), 147.95 (C_q), 137.25 (C_q), 133.59 (C_q), 133.32 (C_q), 132.65 (C_q), 132.62 (C_q), 132.56 (C_q), 132.53 (CH), 132.35 (CH), 130.27 (CH), 129.41 (CH), 128.21 (CH), 128.18 (CH), 128.10 (CH), 127.81 (CH), 127.42 (CH), 127.19 (CH), 127.11 (CH), 125.16 (CH), 118.77 (CH), 117.27(CH_2), 74.87 (CH_2), 73.87 (CH_2), 37.89 (CH_2), 37.86 (CH_2), 31.22 (CH_2), 31.02 (CH_2); FAB-MS *m*/*z* 659 ($M^+ + 1$). Anal. Calcd for $C_{45}H_{38}O_5$: C, 82.04; H, 5.81. Anal. Calcd for $C_{46}H_{38}O_5 \cdot {}^1/_4H_2O$: C, 81.49; H, 5.85. Found: C, 81.30; H, 5.80.

General Procedure for 25,26,27-Trialkoxy-28-ben-zoyloxycalix[4]arenes 5a−d. A sample of 1.0 mmol of 25,-27-dialkoxy-26-benzoyloxycalix[4]arene (**4a**−**c**), 0.12 g (5.0 mmol) of NaH, and an excess amount of alkyl halides was refluxed in 50 mL of CH_3CN for 1 h. The solvent was removed, and the crude product was recrystallized from $CHCl_3$ with a slow addition of CH_3OH to yield the corresponding trialkoxy products **5a**−**d**.

25-Allyloxy-26-benzyloxy-27-benzoyloxy-28-pro-poxycalix[4]arene (5a). A sample of 0.66 g (1.0 mmol) of 25-benzyloxy-26-benzoyloxy-28-hydroxy-27-propoxycalix[4]-arene (**4a**) was alkylated with 0.43 mL (0.60 g, 5.0 mmol) of allyl bromide and yielded 0.60 g (86%) of colorless crystals: mp 155−156 °C; ^{1}H NMR ($CDCl_3$) δ 6.39−7.74 (m, 22 H), 5.48−5.62 (m, 1 H), 4.71−4.89 (m, 4 H), 4.03−4.20 (m, 4 H), 3.47−3.85 (m, 6 H), 3.17 (d, 1 H, J = 13.2 Hz), 2.99 (d, 1 H, J = 13.2 Hz), 1.84−1.91 (m, 2 H), 1.04 (t, 3 H, J = 7.5 Hz); ^{13}C NMR ($CDCl_3$) δ 166.12 (C_q), 157.70 (C_q), 157.45 (C_q), 157.21 (C_q), 150.07 (C_q), 139.60 (CH), 139.11 (C_q), 138.60 (C_q), 135.57 (C_q), 135.27 (CH), 134.88 (C_q), 133.80 (CH), 133.55 (CH), 133.42 (CH), 132.34 (CH), 130.63 (CH), 130.58 (CH), 130.49 (CH), 130.39 (CH), 129.89 (CH), 129.55 (CH), 129.41 (CH), 124.54 (CH), 123.42 (CH), 114.91 (CH_2), 78.29 (CH_2), 75.36 (CH_2),

38.65 (CH_2), 32.73 (CH_2), 32.65 (CH_2), 25.28 (CH_2), 12.42 (CH_3); FAB-MS *m/z* 701 ($M^+ + 1$). Anal. Calcd for $C_{48}H_{44}O_5$: C, 82.26; H, 6.33. Anal. Calcd for $C_{48}H_{44}O_5 \cdot {}^1/_2H_2O$: C, 81.21; H, 6.39. Found: C, 81.40; H, 6.29.

25-Benzyloxy-26-benzoyloxy-27-butoxy-28-propoxycalix[4]arene (5b). A sample of 0.67 g (1.0 mmol) of 25-benzyloxy-26-benzoyloxy-27-butoxy-28-hydroxy-calix[4]arene (**4b**) was alkylated with 0.48 mL (0.84 g, 4.9 mmol) of *n*-propyl iodide and yielded 0.58 g (82%) of colorless crystals: mp 158−159 °C; ^{1}H NMR ($CDCl_3$) δ 6.40−7.80 (m, 22 H), 4.84, 4.66 (AB, 2 H, J = 10.9 Hz), 4.12−4.19 (m, 2 H), 3.82 (bd, 3 H, J = 12.3 Hz), 3.25−3.58 (m, 5 H), 3.10 (t, 2 H, J = 13.5 Hz), 1.74−1.84 (m, 2 H), 1.51−1.56 (m, 2 H), 1.10−1.45 (m, 2 H), 1.02 (t, 3 H, J = 7.3 Hz), 0.53 (t, 3 H, J = 7.6 Hz); ^{13}C NMR ($CDCl_3$) δ 164.52 (C_q), 156.72 (C_q), 155.85 (C_q), 155.51 (C_q), 148.47 (C_q), 137.39 (C_q), 136.78 (C_q), 136.69 (C_q), 133.94 (C_q), 133.72 (C_q), 133.41(CH), 133.31 (C_q), 133.21 (C_q), 132.03 (CH), 131.86 (CH), 130.69 (CH), 130.08 (CH), 129.94 (CH), 129.04 (CH), 128.92 (CH), 128.82 (CH), 128.75 (CH), 128.36 (CH), 127.97 (CH), 127.75 (CH), 124.28 (CH), 122.65 (CH), 122.04 (CH), 121.66 (CH), 76.73 (CH_2), 75.37 (CH_2), 74.28 (CH_2), 36.96 (CH_2), 32.55 (CH_2), 30.50 (CH_2), 30.35 (CH_2), 21.56 (CH_2), 19.50 (CH_2), 14.04 (CH_3), 8.98(CH_3); FAB-Ms *m/z* 717 ($M^+ + 1$). Anal. Calcd for $C_{49}H_{48}O_5$: C, 82.09; H, 6.75. Anal. Calcd for $C_{49}H_{48}O_5 \cdot {}^1/_4H_2O$: C, 81.58; H, 6.78. Found: C, 81.70; H, 6.67.

25-Allyloxy-26-benzyloxy-27-benzoyloxy-28-butoxycalix[4]arene (5c). A sample of 0.67 g (1.0 mmol) of 25-benzyloxy-26-benzoyloxy-27-butoxy-28-hydroxy-calix[4]arene (**4b**) was alkylated with 0.43 mL (0.60 g, 5.0 mmol) of allyl bromide and yielded 0.61 g (86%) of colorless crystals: mp 152−153 °C; ^{1}H NMR ($CDCl_3$) δ 6.37−7.72 (m, 17 H), 5.42−5.58 (m, 1 H), 4.69−4.88 (m, 4 H), 4.00−4.17 (m, 4 H), 3.71−3.87 (m, 3 H), 3.56−3.62 (m, 1H), 3.38−3.49 (m, 2 H), 3.14 (d, 1 H, J = 13.2 Hz), 2.98 (d, 1 H, J = 13.2 Hz), 1.79−1.81 (m, 2 H), 1.46−1.56 (m, 2 H), 0.99 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 164.52 (C_q), 156.11 (C_q), 155.82 (C_q), 155.58 (C_q), 148.42 (C_q), 137.97 (C_q), 137.49 (CH), 136.98 (C_q), 133.94 (C_q), 133.65 (C_q), 133.38 (C_q), 133.24 (CH), 132.17 (C_q), 131.93 (CH), 131.78 (CH), 130.76 (CH), 130.69 (CH), 129.89 (CH), 129.82 (CH), 128.99 (CH), 128.87 (CH), 128.77 (CH), 128.26 (CH), 127.92 (CH), 127.78 (CH), 124.13 (CH), 122.87 (CH), 122.12 (CH), 121.75 (CH), 113.23 (CH_2), 76.25 (CH_2), 74.35 (CH_2), 73.72 (CH_2), 37.01 (CH_2), 32.51 (CH_2), 31.11 (CH_2), 31.01 (CH_2), 29.70 (CH_2), 19.47 (CH_2), 14.01(CH_3); FAB-MS *m/z* 715 ($M^+ + 1$). Anal. Calcd for $C_{49}H_{46}O_5$: C, 82.32; H, 6.49. Anal. Calcd for $C_{49}H_{46}O_5 \cdot {}^1/_4H_2O$: C, 81.81; H, 6.51. Found: C, 81.82; H, 6.54.

25-Allyloxy-26-benzoyloxy-27-benzyloxy-28-propoxycalix[4]arene (5d). A sample of 0.66 g (1.0 mmol) of 25-allyloxy-26-benzoyloxy-27-benzyloxy-28-hydroxycalix[4]arene (**4c**) was alkylated with 0.48 mL (0.84 g, 4.9 mmol) of *n*-propyl iodide and yielded 0.59 g (84%) of colorless crystals: mp 156−158 °C; ^{1}H NMR ($CDCl_3$) δ 6.40−7.76 (m, 22 H), 6.08−6.20 (m, 1 H), 5.29−5.39 (m, 2 H), 4.84, 4.66 (AB, 2 H, J = 10.9 Hz), 4.19−4.21 (m, 1 H), 4.13−4.17 (3d, 3 H), 3.81 (bd, 2 H, J = 14.1 Hz), 3.45 (bd, 2 H, J = 13.8 Hz), 3.31−3.33 (m, 2 H), 3.04−3.14 (m, 2 H), 1.26−1.30 (m, 2 H), 0.52 (t, 3H, J = 7.6 Hz); ^{13}C NMR ($CDCl_3$) δ 164.29 (C_q), 156.44 (C_q), 155.24 (C_q), 154.98 (C_q), 148.15 (C_q), 137.13 (C_q), 136.42 (C_q), 134.23 (CH), 133.69 (C_q), 133.57 (CH), 133.18 (C_q), 132.92 (C_q), 131.81 (C_q), 131.56 (CH), 128.79 (CH), 128.71 (CH), 128.52 (CH), 128.44 (CH), 128.09 (CH), 127.71 (CH), 127.52 (CH), 122.39 (CH), 121.76 (CH), 116.99 (CH_2), 76.43 (CH_2), 75.06 (CH_2), 75.01 (CH_2), 36.70 (CH_2), 30.30 (CH_2), 30.27 (CH_2), 21.34 (CH_2), 8.81 (CH_3); FAB-MS *m/z* 701 ($M^+ + 1$). Anal. Calcd for $C_{48}H_{44}O_5$: C, 82.26; H, 6.33. Anal. Calcd for $C_{48}H_{44}O_5 \cdot {}^1/_4H_2O$: C, 81.73; H, 6.36. Found: C, 81.87; H, 6.36.

General Procedure for 25,26,27-Trialkoxy-28-hydroxycalix[4]arenes 6a−d. A solution of 0.71 mmol of 25,26,27-trialkoxy-28-benzoyloxycalix[4]arene (**5a**−**d**) in 10 mL of THF was added to a solution of 1.25 g of KOH in 5 mL of H_2O and 10 mL of EtOH, and the mixture was then refluxed for 4 h. The solvent was removed, and the residue was treated with CH_3OH to induce an off-white solid. Further recrystallization from $CHCl_3$ and CH_3OH afforded the corresponding hydrolysis products **6a**−**d**.

25-Allyloxy-26-benzyloxy-27-hydroxy-28-propoxycalix[4]arene (6a). A sample of 0.50 g (0.71 mmol) of 25-allyloxy-26-benzyloxy-27-benzoyloxy-28-propoxycalix[4]arene (**5a**) was subjected to hydrolysis and yielded 0.35 g (81%) of colorless crystals: mp 106−107 °C; ^{1}H NMR ($CDCl_3$) δ 7.45−7.48 (m, 2 H), 7.32−7.38 (m, 3 H), 6.38−7.30 (m, 12 H), 5.09 (s, 1 H), 4.78−4.99 (m, 4 H), 4.54−4.58 (m, 2 H), 4.31−4.44 (m, 4 H), 3.72−3.78 (m, 2 H), 3.07−3.33 (m, 4 H), 1.83−1.91 (m, 2 H), 1.18 (t, 3 H, J = 7.5 Hz); ^{13}C NMR ($CDCl_3$) δ 155.85 (C_q), 154.20 (C_q), 154.07 (C_q), 153.27 (C_q), 137.29 (C_q), 137.15 (C_q), 136.23 (CH), 133.43 (C_q), 133.34 (C_q), 132.87 (C_q), 132.49 (C_q), 131.01 (C_q), 130.67 (C_q), 129.01 (CH), 128.58 (CH), 128.41 (CH), 128.31 (CH), 127.92 (CH), 127.85 (CH), 123.26 (CH), 123.21 (CH), 123.09 (CH), 119.20 (CH), 116.12 (CH_2), 77.44 (CH_2), 75.11 (CH_2), 31.35 (CH_2), 31.18 (CH_2), 30.86 (CH_2), 23.31 (CH_2), 10.76 (CH_3); FAB-MS *m/z* 597 ($M^+ + 1$). Anal. Calcd for $C_{41}H_{40}O_4$: C, 82.52; H, 6.76. Anal. Calcd for $C_{41}H_{40}O_4 \cdot {}^1/_4H_2O$: C, 81.90; H, 6.79. Found: C, 82.08; H, 6.79.

25-Benzyloxy-27-butoxy-26-hydroxy-28-propoxycalix[4]arene (6b). A sample of 0.40 g (0.56 mmol) of 25-benzyloxy-26-benzoyloxy-27-butoxy-28-propoxycalix[4]arene (**5b**) was subjected to hydrolysis and yielded 0.29 g (85%) of colorless crystals: mp 117−118 °C; ^{1}H NMR ($CDCl_3$) δ 7.50−7.52 (m, 2 H), 7.35−7.38 (m, 2 H), 6.36−7.17 (m, 12 H), 4.86, 4.74 (AB, 2 H, J = 10.9 Hz), 4.71 (s, 1 H), 4.32−4.45 (m, 4 H), 3.72−3.75 (m, 4 H), 3.17−3.30 (m, 4 H), 1.78−1.81 (m, 2 H), 1.52−1.63 (m, 2H), 1.41−1.49 (m, 2 H), 0.98 (t, 3 H, J = 7.3 Hz), 0.64 (t, 3 H, J = 7.5 Hz); ^{13}C NMR ($CDCl_3$) δ 156.83 (C_q), 154.18 (C_q), 154.08 (C_q), 153.24 (C_q), 137.08 (C_q), 137.07 (C_q), 133.48 (C_q), 132.88 (C_q), 132.46 (C_q), 131.26 (C_q), 130.99 (C_q), 129.14 (C_q), 129.12 (C_q), 128.60 (CH), 128.43 (CH), 128.37 (CH), 128.00 (CH), 127.95 (CH), 127.89 (CH), 127.83 (CH), 127.80 (CH), 122.94 (CH), 119.31 (CH), 77.76 (CH_2), 76.59 (CH_2), 75.69 (CH_2), 32.35 (CH_2), 30.87 (CH_2), 30.79 (CH_2), 30.68 (CH_2), 22.31 (CH_2), 19.59 (CH_2), 14.04 (CH_3), 9.39 (CH_3); FAB-MS *m/z* 613 ($M^+ + 1$). Anal. Calcd for $C_{42}H_{44}O_4$: C, 82.32; H, 7.24. Found: C, 82.00; H, 7.44.

25-Allyloxy-26-benzyloxy-28-butoxy-27-hydroxycalix[4]arene (6c). A sample of 0.30 g (0.42 mmol) of 25-allyloxy-26-benzyloxy-27-benzoyloxy-28-butoxycalix[4]arene (**5c**) was subjected to hydrolysis and yielded 0.21 g (81%) of colorless crystals: mp 114−116 °C; ^{1}H NMR ($CDCl_3$) δ 4.46−7.48 (m, 2 H), 7.34−7.39 (m, 3 H), 6.39−7.25 (m, 13 H), 5.05 (s, 1 H), 4.95−4.99 (m 2 H), 4.88, 4.82 (AB, 2 H, J = 11.3 Hz), 4.54−4.60 (m, 2 H), 4.32−4.44 (m, 4 H), 3.77−3.79 (m, 2 H), 3.08−3.33 (m, 4 H), 1.92−2.02 (m, 2 H), 1.52−1.54 (m, 2 H), 0.98 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 155.89 (C_q), 154.25 (C_q), 154.07 (C_q), 153.29 (C_q), 137.31 (CH), 137.28 (C_q), 137.16 (C_q), 136.29 (C_q), 133.43 (C_q), 133.35 (C_q), 132.89 (C_q), 132.51 (C_q), 131.01 (C_q), 130.65 (C_q), 129.03 (CH), 129.00 (CH), 128.60 (CH), 128.34 (CH), 127.95 (CH), 127.89 (CH), 127.87 (CH), 127.84 (CH), 123.12 (CH), 119.22 (CH), 116.02 (CH_2), 77.59 (CH_2), 75.84 (CH_2), 75.13 (CH_2), 32.22 (CH_2), 31.34 (CH_2), 31.16 (CH_2), 30.86 (CH_2), 19.50 (CH_2), 14.03 (CH_3); FAB-MS *m/z* 611 ($M^+ + 1$). Anal. Calcd for $C_{42}H_{42}O_4$: C, 82.59; H, 6.93. Found: C, 82.27; H, 6.93.

25-Allyloxy-27-benzyloxy-26-hydroxy-28-propoxycalix[4]arene (6d). A sample of 0.61 g (0.87 mmol) of 25-allyloxy-26-benzoyloxy-27-benzyloxy-28-propoxycalix[4]arene (**5d**) was subjected to hydrolysis and yielded 0.45 g (87%) of colorless crystals: mp 142−143 °C; ^{1}H NMR ($CDCl_3$) δ 7.52−7.54 (m, 2 H), 7.38−7.40 (m, 3 H), 6.41−7.18 (m, 12 H), 6.08−6.22 (m, 1 H), 5.20−5.46 (m, 2 H), 4.87 (s, 1 H), 4.86, 4.76 (AB, 2 H, J = 14.1 Hz), 4.32−4.45 (m, 6 H), 3.75 (t, 2 H, J = 8.5 Hz), 3.20−3.34 (m, 4 H), 1.86−2.14 (m, 2 H), 0.64 (t, 3 H, J = 7.5 Hz); ^{13}C NMR ($CDCl_3$) δ 156.82 (C_q), 154.03 (C_q), 153.83 (C_q), 153.25 (C_q), 137.27 (C_q), 137.00 (C_q), 136.95 (C_q), 133.97 (CH), 133.53 (C_q), 132.83 (C_q), 132.66 (C_q), 131.10 (C_q), 130.88 (C_q), 129.11 (CH), 128.60 (CH), 128.43 (CH), 128.24 (CH), 128.02 (CH), 127.97 (CH), 127.90 (CH), 127.85 (CH), 123.33 (CH), 122.92 (CH), 119.30 (CH), 117.72 (CH_2), 77.44 (CH_2), 76.59 (CH_2), 76.39 (CH_2), 30.98 (CH_2), 30.84 (CH_2), 22.32 (CH_2), 9.42 (CH_3); FAB-MS *m/z* 597 ($M^+ + 1$). Anal. Calcd for $C_{41}H_{40}O_4$: C, 82.52; H, 6.76. Found: C, 82.57; H, 6.92.

General Procedure for 25,26,27,28-Tetraalkoxycalix[4]arenes 7a−c. A sample of 0.65 mmol of 25,26,27-trialkoxycalix[4]arene (**6a**−**c**), 0.06 g (2.5 mmol) of NaH, and an excess amount of alkyl halides was refluxed in 30 mL of CH_3CN for 1 h. The solvent was removed, and the crude product was recrystallized from $CHCl_3$ with a slow addition of CH_3OH or *n*-hexane to yield the corresponding tetraalkoxy products **7a**−**c**.

25-Allyloxy-26-benzyloxy-27-butoxy-28-propoxycalix[4]arene (7a). A sample of 0.19 g (0.32 mmol) of 25-allyloxy-26-benzyloxy-27-hydroxy-28-propoxycalix[4]arene (**6a**) was alkylated with 0.18 mL (0.29 g, 1.6 mmol) of *n*-butyl iodide and yielded 0.16 g (76%) of colorless crystals: mp 90−91 °C; ^{1}H NMR ($CDCl_3$) δ 7.38−7.39 (m, 2 H), 7.24−7.26 (m, 3 H), 6.26−6.82 (m, 13 H), 4.93−5.02 (m, 2 H), 4.75 (s, 2 H), 4.26, 4.44 (m, 6 H), 3.86 (t, 2 H, J = 8.0 Hz), 3.68 (t, 2 H, J = 7.1 Hz), 2.99−3.09 (m, 4 H), 1.74−1.87 (m, 4 H), 1.15−1.18 (m, 2 H), 0.97 (t, 3 H, J = 7.4 Hz), 0.79 (t, 3 H, J = 7.3 Hz); ^{13}C NMR ($CDCl_3$) δ 157.28 (C_q), 156.50 (C_q), 155.70 (C_q), 154.90 (C_q), 137.79 (C_q), 136.50 (C_q), 136.45 (C_q), 136.23 (C_q), 136.12 (CH), 134.20 (C_q), 134.09 (C_q), 133.92 (C_q), 129.09 (CH), 128.53 (CH), 128.41 (CH), 128.12 (CH), 127.84 (CH), 127.75 (CH), 127.72 (CH), 127.64 (CH), 127.61 (CH), 122.15 (CH), 121.82 (CH), 116.31 (CH_2), 76.79 (CH_2), 75.58 (CH_2), 74.73 (CH_2), 31.93 (CH_2), 31.21 (CH_2), 31.16 (CH_2), 31.05 (CH_2), 30.94 (CH_2), 23.44 (CH_2), 19.01 (CH_2), 14.03 (CH_3), 10.70 (CH_3); FAB-MS *m*/*z* 653 ($M^+ + 1$). Anal. Calcd for $C_{45}H_{48}O_4$: C, 82.79; H, 7.41. Anal. Calcd for $C_{45}H_{48}O_4 \cdot {}^1/_2H_2O$: C, 81.66; H, 7.46. Found: C, 81.34; H, 7.56.

25-Allyloxy-26-benzyloxy-28-butoxy-27-propoxycalix[4]arene (7b). Method A. From 25-Benzyloxy-27-butoxy-26-hydroxy-28-propoxycalix[4]arene (6b). A sample of 0.40 g (0.65 mmol) of 25-benzyloxy-27-butoxy-26-hydroxy-28-propoxycalix[4]arene (**6b**) was alkylated with 0.17 mL (0.24 g, 2.0 mmol) of allyl bromide and yielded 0.29 g (67%) of colorless crystals: mp 62−63 °C; ^{1}H NMR ($CDCl_3$) δ 7.45−7.46 (m, 2 H), 7.34−7.37 (m, 3 H), 6.31−6.89 (m, 13 H), 4.96−5.08 (m, 2 H), 4.83 (bd, 2 H), 4.32−4.45 (m, 6 H), 3.78−3.92 (m, 4 H), 3.10−3.17 (m, 4 H), 1.81−1.88 (m, 4 H), 1.49−1.51 (m, 2 H), 0.98 (t, 3 H, J = 7.4 Hz), 0.81 (t, 3 H, J = 7.4 Hz); ^{13}C NMR ($CDCl_3$) δ 156.97 (C_q), 156.28 (C_q), 155.51 (C_q), 154.58 (C_q), 137.49 (CH), 136.19 (C_q), 136.14 (C_q), 135.93 (C_q), 135.87 (C_q), 134.02 (C_q), 133.90 (C_q), 133.73 (C_q), 128.92 (CH), 128.28 (CH), 128.22 (CH), 128.15 (CH), 127.84 (CH), 127.59 (CH), 127.52 (CH), 127.45 (CH), 127.40 (CH), 121.90 (CH), 121.67 (CH), 116.05 (CH_2), 76.32 (CH_2), 76.20 (CH_2), 75.37 (CH_2), 74.62 (CH_2), 32.10 (CH_2), 30.93 (CH_2), 30.87 (CH_2), 30.81 (CH_2), 30.68 (CH_2), 22.77 (CH_2), 19.17 (CH_2), 13.79 (CH_3), 9.65 (CH_3); FAB-MS *m*/*z* 653 ($M^+ + 1$). Anal. Calcd for $C_{45}H_{48}O_4$: C, 82.79; H, 7.41. Anal. Calcd for $C_{45}H_{48}O_4 \cdot {}^1/_4CH_3OH$: C, 82.27; H, 7.42. Found: C, 82.46; H, 7.53.

If the recrystallization of compound **7b** was carried out in $CHCl_3$ and *n*-hexane, the resulting crystals melted at 88−89 °C and the elemental analysis had a value of C, 82.78 and H, 7.81. (Anal. Calcd for $C_{45}H_{48}O_4 \cdot {}^1/_4C_6H_{14}$: C, 82.81; H, 7.70.)[16]

Method B. From 25-allyloxy-26-benzyloxy-28-butoxy-27-hydroxycalix[4]arene (6c). A sample of 0.10 g (0.16 mmol) of 25-allyloxy-26-benzyloxy-28-butoxy-27-hydroxy-calix[4]arene (**6c**) was alkylated with 0.11 mL (0.20 g, 1.6 mmol) of *n*-propyl iodide and yielded 0.06 g (54%) of colorless crystals, which were identical in physical and spectral properties with the product **7b** afforded in method A.

25-Allyloxy-27-benzyloxy-26-butoxy-28-propoxycalix[4]arene (7c).[14] A sample of 0.30 g (0.50 mmol) of 25-allyloxy-27-benzyloxy-26-hydroxy-28-propoxycalix[4]arene (**6d**) was alkylated with 0.28 mL (0.49 g, 2.9 mmol) of *n*-propyl iodide and yielded 0.28 g (85%) of colorless crystals: mp 82−83 °C; ^{1}H NMR ($CDCl_3$) δ 7.37−7.39 (m, 2 H), 7.33−7.34 (m, 3 H), 6.32−6.70 (m, 13 H), 5.12−5.24 (m, 2 H), 4.99 (s, 2 H), 4.30, 4.53 (m, 6 H), 3.74−3.79 (m, 4 H), 3.06−3.18 (m, 4 H), 1.81−1.84 (m, 4 H), 1.32−1.40 (m, 2 H), 0.90−0.96 (m, 6 H); ^{13}C NMR ($CDCl_3$) δ 156.87 (C_q), 156.81 (C_q), 156.44 (C_q), 155.96 (C_q), 138.39 (C_q), 136.38 (C_q), 136.19 (CH), 136.15 (C_q), 136.12 (C_q), 135.31 (C_q), 135.13 (C_q), 130.12 (CH), 128.77 (CH), 128.66 (CH), 128.46 (CH), 128.43 (CH), 128.40 (CH), 128.38 (CH), 128.36 (CH), 128.27 (CH), 122.66 (CH), 122.62 (CH), 122.38 (CH), 117.04 (CH_2), 77.17 (CH_2), 76.89 (CH_2), 76.10 (CH_2), 75.39 (CH_2), 32.51 (CH_2), 31.67 (CH_2), 31.54 (CH_2), 23.60 (CH_2), 19.69 (CH_2), 14.51 (CH_3), 10.73 (CH_3); FAB-MS *m*/*z* 653 ($M^+ + 1$). Anal. Calcd for $C_{45}H_{48}O_4$: C, 82.79; H, 7.41. Found: C, 82.77; H, 7.59.

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Supporting Information Available: NMR spectra for **2f**, **3e**, **4c**, **5d**, **6d**, and **7c** and an ORTEP diagram. This material is available free of charge via the Internet at http://pubs.acs.org.

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(16) A different crystal structure was formed when compound **7b** was crystallized from different solvent-pair systems (e.g., $CHCl_3$ and CH_3OH, or $CHCl_3$ and *n*-hexane); consequently, a different melting point was also observed. We speculated that the different crystal structures of compound **7b** was caused by the inclusion of different solvent molecules such as CH_3OH or *n*-hexane into the same cavity.