

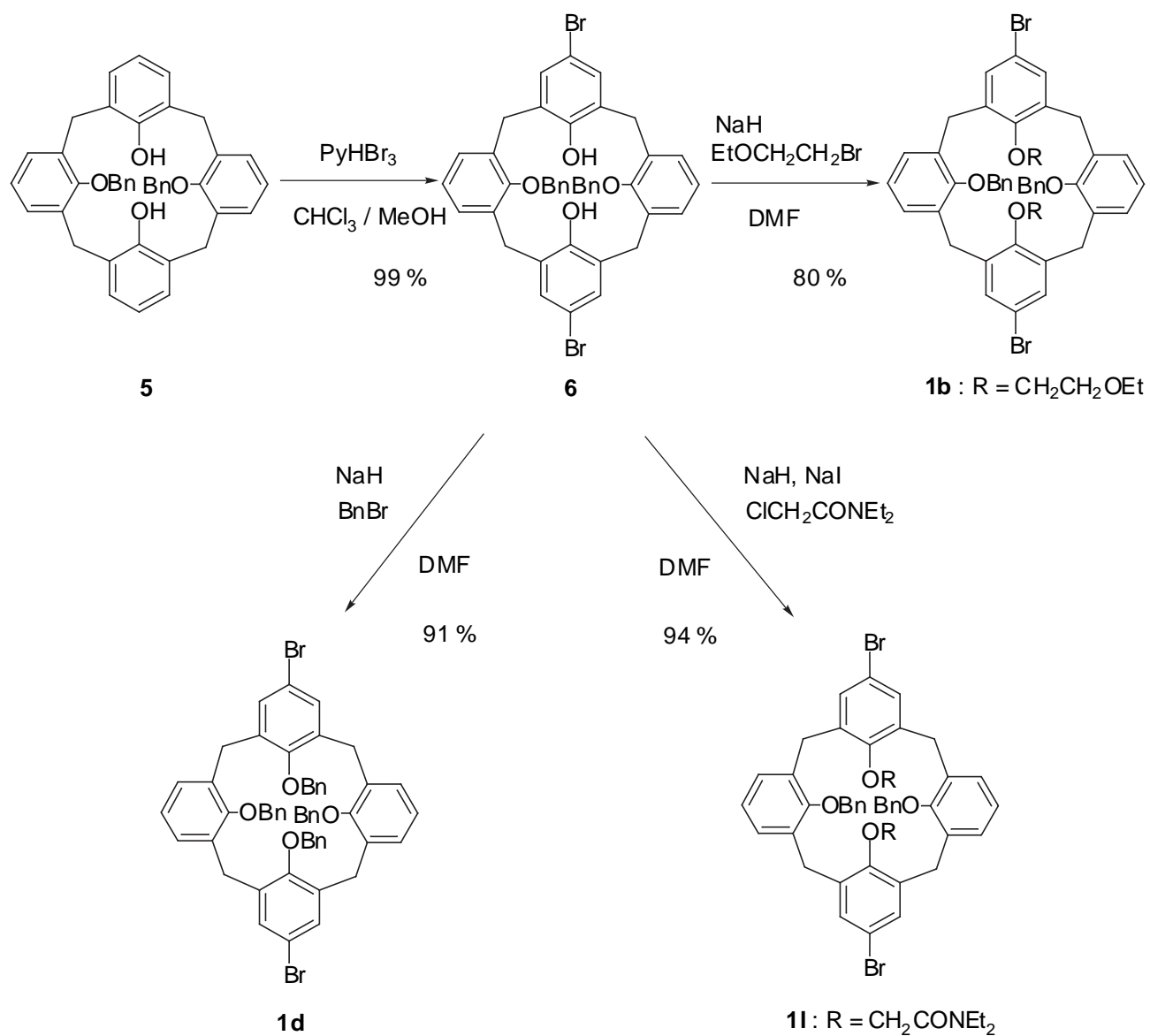
Electronic Supplementary Information

Palladium Catalyzed Cyanation of Bromocalix[4]arenes at the Upper Rim

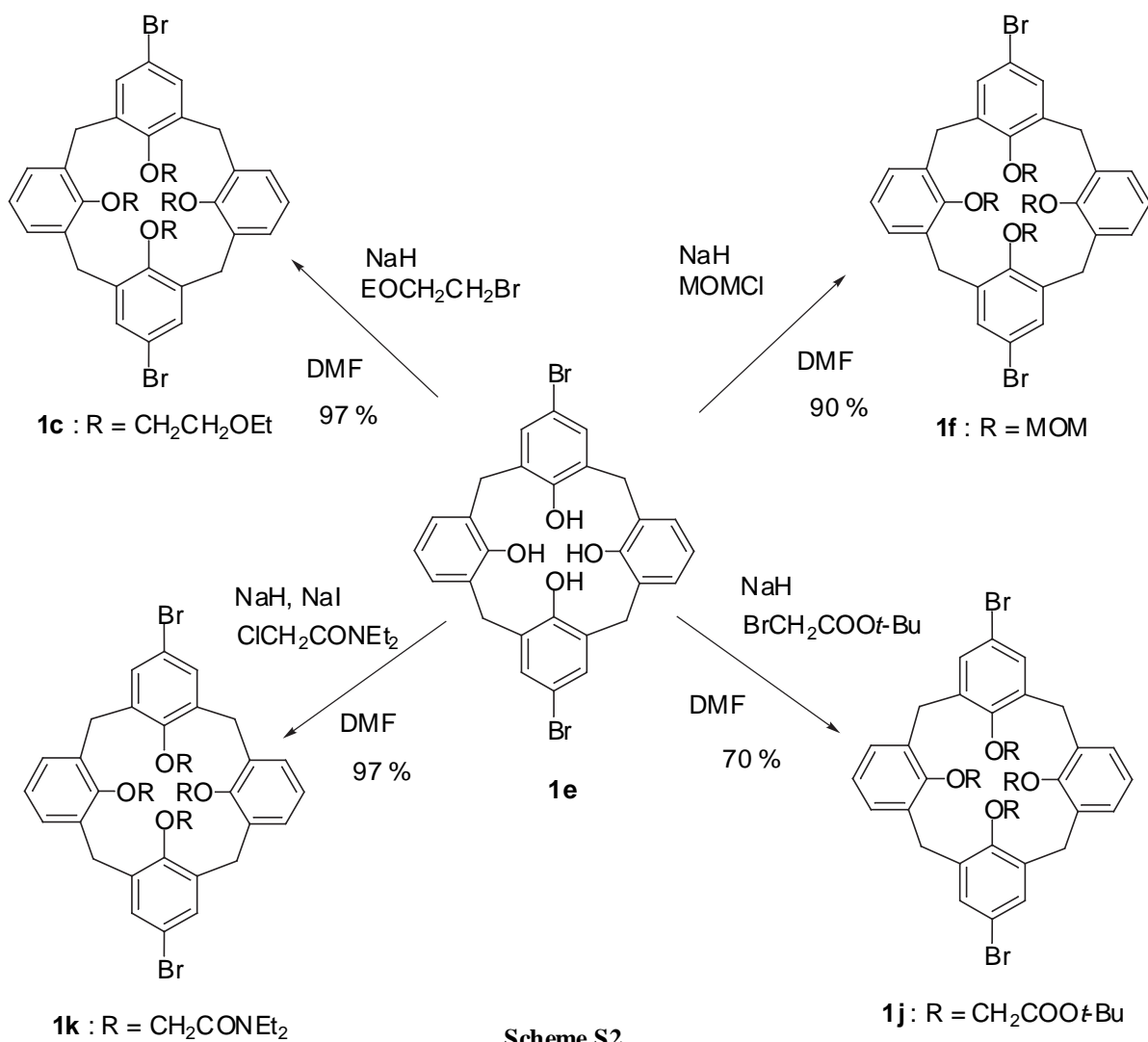
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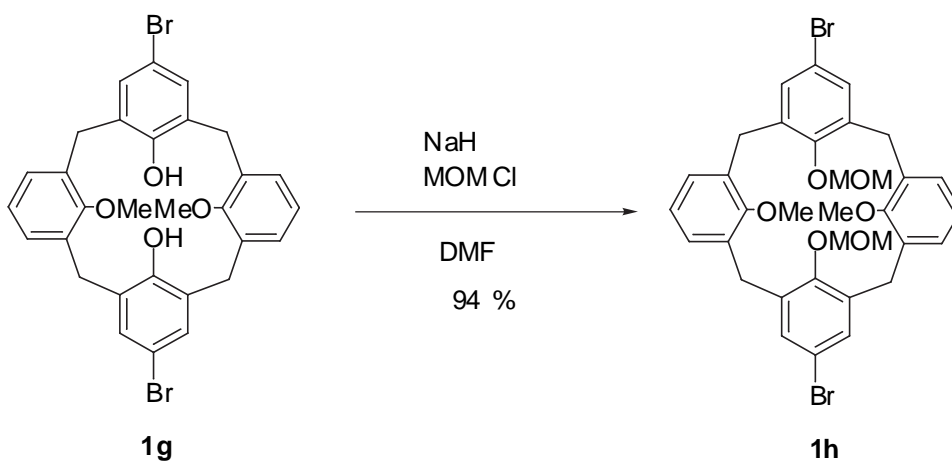
Preparation of Substrates



Scheme S1



Scheme S2



Scheme S3

Experimental

1a¹, **1e**¹, **1g**² and **3**³ were synthesized following literature.

5,17-Dibromo-25,27-dibenzyloxycalix[4]arene (6). Pyridinium tribromide (12.52 g, 39.1 mmol) was added portionwise to a solution of 25,27-dibenzyloxycalix[4]arene **5**² (10.58 g, 17.5 mmol) in 530 mL of CHCl₃ and MeOH (50 : 3) at 0 °C. After stirring for 2 h, 300 mL of 1 M HCl was added and the mixture was extracted with CHCl₃ (300 mL × 3). The combined organic layers were dried (Na₂SO₄) and evaporated. The crude product was recrystallized from CHCl₃/MeOH to give 13.3 g (17.5 mmol, 99 %) of **6**. colorless needles: mp >300 °C; IR (KBr) 3393, 1468, 1198, 739 cm⁻¹; ¹H (200 MHz, CDCl₃) δ 3.27 (4 H, d, *J* = 13.2 Hz), 4.24 (4 H, d, *J* = 13.2 Hz), 5.03 (4 H, s), 6.80 (2 H, dd, *J* = 5.9, 8.8 Hz), 6.90 (4 H, m), 7.17 (4 H, m), 7.36 - 7.40 (6 H, m), 7.59 – 7.63 (4 H, m), 7.86 (2 H, s); ¹³C NMR (50 MHz, CDCl₃) δ 31.3 (t), 78.5 (t), 110.4 (s), 125.6 (d), 127.5 (d), 128.2 (d), 128.8 (d), 129.3 (d), 129.8 (s), 130.7 (d), 132.5 (s), 136.3 (s), 151.8 (s), 152.5 (s); MS (EI) *m/z* 91 (base), 672, 760 (M⁺), 762, 764; Anal Calcd for C₄₂H₃₄Br₂O₄: C, 66.16; H, 4.49. Found: C, 66.03; H, 4.49.

5,17-Dibromo-25,27-dibenzyloxy-26,28-bis(2-ethoxyethoxy)calix[4]arene (1b). To a suspension of **6** (2.00 g, 2.62 mmol) and NaH (60 % in oil, 436 mg, 10.9 mmol) in DMF (25 mL) was added dropwise 2-bromoethyl ethyl ether (1.63 g, 1.2 mL, 10.6 mmol). After stirring for 19 h, the reaction mixture was cooled, quenched with saturated NH₄Cl solution (5 mL). After the addition of saturated NH₄Cl solution (100 mL), the mixture was extracted with EtOAc (100 mL × 3). The combined organic layers were dried (Na₂SO₄) and evaporated. The residue was purified by column chromatography on silica gel (EtOAc:hexane = 1:15 → 1:5) to yield **1b** (1.91 g, 4.17 mmol, 80 %) as a colorless solid. mp 172.0 – 172.5 °C; IR (KBr) 1455, 1195, 758 cm⁻¹; ¹H NMR (200 MHz, CDCl₃) δ 1.84 (6 H, t, *J* = 7.0 Hz), 3.00 (4 H, d, *J* = 13.6 Hz), 3.23 (4 H, q, *J* = 7.0 Hz), 3.60 (4 H, t, *J* = 5.9 Hz), 4.02 (4 H, t, *J* = 5.9 Hz), 4.32 (4 H, d, *J* = 13.6 Hz), 4.90 (4 H, s), 6.40 - 6.56 (6 H, m), 6.94 (4 H, s), 7.33 – 7.43 (10 H, m); ¹³C NMR (50 MHz, CDCl₃) δ 15.1 (q), 30.7 (t), 66.3 (t), 69.5 (t), 73.5. (t), 77.0 (t), 105.7 (s), 119.2 (s), 123.2 (d), 128.3 (d), 128.5 (d), 129.7 (d), 132.3 (d), 134.0 (s), 137.0 (s), 137.1 (s), 154.8 (s), 160.8 (s); MS (EI) *m/z* 91 (base), 815, 902 (M⁺), 904, 906; Anal Calcd for C₅₀H₅₀Br₂O₆: C, 66.23; H, 5.56, Found: C, 66.27; H, 5.56.

5,17-Dibromo-25,26,27,28-tetrabenzoyloxycalix[4]arene (1d). Compound **1d** was obtained as a colorless solid from **6** and BnBr as described above for the synthesis of **1b**. mp 189 - 191 °C; IR

(KBr) 1456, 1188 cm^{-1} ; ^1H (200 MHz, CDCl_3) δ 2.84 (4 H, d, $J = 13.6$ Hz), 4.10 (4 H, d, $J = 13.6$ Hz), 4.90 (4 H, s), 4.91 (4 H, s), 6.49 – 6.63 (6 H, m), 6.74 (4 H, s), 7.16 – 7.31 (20 H, m); ^{13}C NMR (50 MHz, CDCl_3) δ 31.1 (t), 76.4 (t), 115.0 (s), 122.8 (d), 128.0 (s), 128.1 (d), 128.4 (d), 129.7 (d), 129.8 (d), 130.8 (d), 134.4 (s), 137.4 (s), 137.7 (s), 154.6 (s), 155.1 (s); MS (EI) m/z 91 (base); Anal Calcd for $\text{C}_{56}\text{H}_{46}\text{Br}_2\text{O}_4$: C, 71.34; H, 4.92, Found: C, 71.38; H, 4.93.

5,17-Dibromo-25,27-dibenzyloxy-26,28-bis(diethylcarbamoylmethoxy)calix[4]arene

(11). Compound **11** was obtained as a colorless solid from **6** and $\text{ClCH}_2\text{CONEt}_2$ as described above for the synthesis of **1b**. mp 251 – 252 $^\circ\text{C}$; IR (KBr) 1669, 1454, 1196 cm^{-1} ; ^1H NMR (200 MHz, CDCl_3) δ 0.89 (6 H, t, $J = 6.9$ Hz), 1.11 (6 H, t, $J = 6.9$ Hz), 2.88 (4 H, q, $J = 6.9$ Hz), 3.08 (4 H, d, $J = 13.7$ Hz), 3.36 (4 H, q, $J = 6.9$ Hz), 4.43 (4 H, s), 4.55 (4 H, d, $J = 13.7$ Hz), 5.10 (4 H, s), 6.58 - 6.65 (6 H, m), 6.75 (4 H, s), 7.25 – 7.27 (6 H, m), 7.46 – 7.49 (4 H, m); ^{13}C NMR (50 MHz, CDCl_3) δ 13.1 (q), 14.1 (q), 31.4 (t), 39.8 (t), 40.5 (t), 70.9 (t), 77.0 (t), 115.0 (s), 122.9 (d), 127.7 (d), 127.9 (d), 128.4 (d), 130.1 (d), 131.0 (d), 134.7 (s), 136.9 (s), 137.8 (s), 155.1 (s), 155.3 (s), 167.4 (s); MS (FAB) m/z 92 (base), 1009 (M^+Na), 1011($\text{M}^+\text{Na}+2$), 1013($\text{M}^+\text{Na}+4$); Anal Calcd for $\text{C}_{54}\text{H}_{56}\text{Br}_2\text{N}_2\text{O}_6$: C, 65.59; H, 5.71. Found: : C, 65.57; H, 5.75.

5,17-Dibromo-25,26,27,28-tetrakis(2-ethoxyethoxy)calix[4]arene (1c). To a suspension of **1e**¹ (447 mg, 0.77 mmol) and NaH (60 % in oil, 261 mg 6.5 mmol) in DMF (35 mL) was added dropwise 2-bromoethyl ethyl ether (0.95 g, 0.7 mL, 6.2 mmol). After stirring for 3 days, the reaction mixture was cooled, quenched with saturated NH_4Cl solution (30 mL). The mixture was extracted with CHCl_3 (50 mL \times 3). The combined organic layers were washed with brine, dried over Na_2SO_4 , and then evaporated. The residue was purified by column chromatography on silica gel (EtOAc:hexane =1:3) to yield **1c** (652 mg, 0.75 mmol, 97 %) as a colorless solid. mp 99 $^\circ\text{C}$; IR (KBr) 1451, 1451. 1122 cm^{-1} ; ^1H (200 MHz, CDCl_3) δ 1.19 (12 H, t, $J = 6.9$ Hz), 3.10 (4 H, d, $J = 13.5$ Hz), 3.52 (8 H, q, $J = 6.9$ Hz), (6 H, s), 3.80 (8 H, t, $J = 5.5$ Hz), 3.81 (8 H, t, $J = 5.5$ Hz), 4.08 (8 H, t, $J = 5.5$ Hz), 4.11 (8 H, t, $J = 5.5$ Hz), 4.46 (4 H, d, $J = 13.5$ Hz), 6.60 (6 H, s), 6.82 (4 H, s); ^{13}C NMR (50 MHz, CDCl_3) δ 15.2 (q), 30.6 (t), 66.3 (t), 69.5 (t), 69.6 (t), 73.2 (t), 114.9 (s), 122.7 (d), 128.4 (d), 130.8 (d), 134.1 (s), 137.4 (s), 155.7 (s), 156.0(d); MS (EI) m/z 73 (base), 868 (M^+), 870, 872; Anal Calcd for $\text{C}_{44}\text{H}_{54}\text{Br}_2\text{O}_8$: C, 60.69; H, 6.25, Found: C, 60.76; H, 6.29.

5,17-Dibromo-25,26,27,28-tetrakis(methoxymethoxy)calix[4]arene (1f). Compound **1f** was obtained as a colorless solid from **1e**¹ and MOMCl as described above for the synthesis of **1c**. mp 218 - 219 °C; IR (KBr) 1456, 1155. 1065 cm⁻¹; ¹H (200 MHz, CDCl₃) δ 3.19 (4 H, d, *J* = 13.8 Hz), 3.57 (6 H, s), 3.59 (6 H, s), 4.45 (4 H, d, *J* = 13.8 Hz), 5.07 (4 H, s), 5.08 (4 H, s), 6.69 (6 H, s), 6.82 (4 H, s); ¹³C NMR (50 MHz, CDCl₃) δ 31.4 (t), 58.0 (q), 100.4 (t), 123.5 (d), 128.6 (d), 131.0 (d), 134.2 (s), 137.0 (s), 153.7 (s), 154.4 (s); MS (EI) *m/z* 604, 608 (base), 610; Anal Calcd for C₃₆H₃₈Br₂O₈: C, 57.01; H, 5.05, Found: C, 57.01; H, 5.10.

5,17-Dibromo-25,26,27,28-tetrakis(1,1-dimethylethoxycarbonylmethoxy)calix[4]arene (1j). Compound **1j** was obtained as a colorless solid from **1e**¹ and BrCH₂COO*t*-Bu as described above for the synthesis of **1c**. mp 264 – 265 °C; IR (KBr) 1747, 1460. 1157 cm⁻¹; ¹H (200 MHz, CDCl₃) δ 1.46 (18 H, s), 1.46 (18 H, s), 3.18 (4 H, d, *J* = 13.8 Hz), 4.58 (4 H, s), 4.63 (4 H, s), 4.88 (4 H, d, *J* = 13.8 Hz), 6.60 (6 H, s), 6.85 (4 H, s); ¹³C NMR (50 MHz, CDCl₃) δ 28.1 (q), 31.4 (t), 71.8 (t), 72.0 (t), 81.1 (s), 81.2 (s), 115.3 (s), 123.1 (d), 128.6 (d), 131.1 (d), 133.7 (s), 137.1 (s), 155.4 (s), 155.8 (d), 169.0 (s); MS (FAB) *m/z* 1061 (base, M⁺+2+Na); Anal Calcd for C₅₂H₆₂Br₂O₁₂: C, 60.12; H, 6.02, Found: C, 59.80; H, 6.08.

5,17-Dibromo-25,26,27,28-tetrakis(diethylcarbamoylmethoxy)calix[4]arene (1k). Compound **1k** was obtained as a colorless solid from **1e**¹ and ClCH₂CONEt₂ as described above for the synthesis of **1c**. mp 241 – 243 °C; IR (KBr) 1657, 1432, 1198, 1052 cm⁻¹; ¹H (200 MHz, CDCl₃) δ 1.18 – 1.23 (24 H, m), 3.12 – 3.22 (8 H, m), 3.37 (4 H, d, *J* = 12.1 Hz), 3.43 (8 H, m), 4.45 (4 H, d, *J* = 12.1 Hz), 4.51 (4 H, m), 4.52 (4 H, m), 6.95 (2 H, t, *J* = 7.7 Hz), 7.15 (4 H, d, *J* = 7.7 Hz), 7.26 (4 H, s); ¹³C NMR (50 MHz, CDCl₃) δ 13.0 (q), 14.1 (q), 29.7 (t), 40.3 (t), 40.7 (t), 74.3 (t), 118.2 (s), 126.2 (d), 129.3 (d), 131.8 (d), 134.8 (s), 137.7 (s), 153.0 (s), 153.8 (s), 167.6 (s), 167.8 (s); MS (FAB) *m/z* 1055 (M⁺+Na), 1057 (base, M⁺+2+Na), 1059 (base, M⁺+4+Na); HRMS (FAB) *m/z* calcd for C₅₂H₆₆Br₂N₄O₈ 1055.3145, found 1055.3214.

5,17-Dibromo-25,27-dimethoxy-26,28-bis(methoxymethoxy)calix[4]arene (1h). Compound **1h** was obtained as a colorless solid from **1g**² and MOMCl as described above for the synthesis of **1b**. mp 227 – 228.5 °C; IR (KBr) 1468, 1152, 991 cm⁻¹; ¹H (200 MHz, CDCl₃) δ 3.00 –

4.98 (24 H, m), 6.45 – 7.82 (10 H, m); MS (EI) m/z 620, 622(base), 624, 696 (M^+), 698 (M^{+2}), 700 (M^{+4}); Anal Calcd for $C_{34}H_{34}Br_2O_6$: C, 58.47; H, 4.91, Found: 58.75; H, 4.94.

5,17-Dibromo-25,27-bis(1,1-dimethyl-ethoxycarbonylmethoxy)calix[4]arene (1i)

Compound **1i** was obtained as a colorless solid from **7**⁴ and pyridinium tetrabromide as described above for the synthesis of **6**. mp 245 °C; IR (KBr) 3314, 1470, 1119, 1122 cm^{-1} ; ¹H (200 MHz, $CDCl_3$) δ 1.27 (6 H, t, $J = 7.0$ Hz), 3.30 (4 H, d, $J = 13.2$ Hz), 3.69 (4 H, q, $J = 7.0$ Hz), 3.91 (4 H, m), 4.15 (4 H, m), 4.39 (4 H, d, $J = 13.2$ Hz), 6.78 (2 H, dd, $J = 6.4, 8.1$ Hz), 6.90 (2 H, d, $J = 6.4$ Hz), 6.90 (2 H, d, $J = 7.4$ Hz), 7.17 (4 H, s), 7.81 (2 H, s); ¹³C NMR (50 MHz, $CDCl_3$) δ 15.2 (q), 30.9 (t), 66.9 (t), 69.1 (t), 75.5 (t), 110.3 (s), 125.4 (d), 129.2 (d), 130.1 (s), 130.7 (d), 132.8 (s), 152.0 (s), 152.5 (s); MS (EI) m/z 654, 726 (base, M^{+2}); Anal Calcd for $C_{36}H_{38}Br_2O_6$: C, 59.52; H, 5.27, Found: C, 59.34; H, 5.36.

References

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