Electronic Supplementary Information

Interlaced capsules by self-assembly of cavitands substituted with tripeptides and tetrapeptides

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# General procedures

**General coupling procedure**

An amine substrate and an acid substrate (1 eq. each) were dissolved in DMF and the mixture was cooled to 0 °C. Then, OXYMA (1 eq.) was added, after 5 min Et3N (1 eq.) and after 15 min EDCI∙HCl (1 eq.) were added. The reaction mixture was allowed to warm to r.t. and stirred for 20 h. Then, the reaction mixture was evaporated under reduced pressure and ethyl acetate was added. The mixture was washed with H2O, saturated NaHCO3, H2O, citric acid (5 % in H2O) and H2O. The organic phase was dried with MgSO4, evaporated and vacuum dried.

**General Boc deprotection procedure**

Substrate (1 eq.) was dissolved in TFA (10 eq., 10 % in CH2Cl2) and the reaction mixture was stirred at r.t. for 5 h. Then, 1 M NaOH (10 eq.) was added. The product precipitated from the mixture and was washed with CH2Cl2 and H2O, and vacuum dried.

**General Cbz deprotection procedure**

To a suspension of substrate in MeOH and H2O under argon, palladium on activated charcoal was added (10 % Pd basis, 50 mg for 1 mmol). Hydrogen from a balloon was bubbled through the solution at r.t. to complete the conversion. The catalyst was removed by filtration through celite, the filtrate was concentrated under reduced pressure and dried.

# Synthesis and spectra of substrates

**Tetraformylresorcin[4]arene 1**

Obtained by the literature procedure.[[1]](#endnote-1) Analytical data in agreement with literature data.

**H-Phe-NH-NH-Cbz**

Obtained by a general coupling procedure from Boc-Phe-OH (25 mmol) and H2N-NH-Cbz (25 mmol), and next by a general Boc deprotection procedure. Yield 85%.

1H NMR (400 MHz, DMSO) δ 10.40 (b, 1H); 9.53 (b, 1H); 8.22 (b, 2H); 7.37 (bs, 5H); 7.31 (bs, 5H); 5.12 (s, 2H); 4.03 (m, 1H); 3.14 (m, 1H); 2.98 (m, 1H).

**H-Gly-Phe-NH-NH-Cbz**

Obtained by a general coupling procedure from Boc-Gly-OH (10 mmol) and H-Phe-NH-NH-Cbz (10 mmol), and next by a general Boc deprotection procedure. Yield 40%.

1H NMR (400 MHz, DMSO) δ 8.02 (b, 1H); 7.45 – 7.15 (m, 10H); 5.10 (s, 2H); 4.60 (m, 1H); 3.01 (m, 2H+1H); 2.83 (m, 1H).

**Ac-Phe-Gly-Phe-NH-NH2 2**

Obtained by a general coupling procedure from Ac-Phe-OH (2 mmol) and H-Gly-Phe-NH-NH-Cbz (2 mmol), and next by a general Cbz deprotection procedure. Yield 73%.

1H NMR (400 MHz, DMSO) δ 9.15 (s, 1H); 8.16 (m, 2H); 8.03 (d, 1H); 7.30 – 7.13 (m, 11H); 4.44 (m, 1H); 3.78 (dd, J = 16.7, 6.2 Hz, 1H); 3.53 (dd, J = 16.7, 5.3 Hz, 1H); 3.00 (dd, J = 9.4, 4.6 Hz, 1H); 2.97 (dd, J = 9.3, 4.6 Hz, 1H); 2.79 (dd, J = 11.3, 7.0 Hz, 1H); 2.74 (dd, J = 11.4, 7.6 Hz, 1H); 1.76 (s, 3H).

13C NMR (100 MHz, DMSO) δ 171.6; 170.0; 169.4; 168.3; 138.0; 137.8; 129.1; 128.06; 128.01; 126.24; 126.18; 54.3; 52.8; 41.8; 37.8; 37.3; 22.4.

HR – MS (ESI – TOF): m/z calculated for (C22H27N5O4Na)+ [M + Na]+: 448.1961, obtained: 448.1950.

**Ac-Gly-Phe-OH**

Obtained by a general coupling procedure from from Ac-Gly-OH (5 mmol) and H-Phe-OBn∙TsOH (5 mmol) and 2 eq. Et3N, and next by a benzyl removal using a general Cbz deprotection procedure. Yield 77%.

1H NMR (400 MHz, DMSO) δ 8.07 (d, J = 8.0 Hz, 1H); 8.00 (t, J = 5.7 Hz, 1H); 7.30 – 7.17 (m, 5H); 4.43 (ddd, J = 8.5, 5.1 Hz, 1H); 3.70 (dd, J = 16.7, 5.9 Hz, 1H); 3.61 (dd, J = 16.7, 5.8 Hz, 1H); 3.04 (dd, J = 13.7, 5.0 Hz, 1H); 2.88 (dd, J = 13.8, 8.8 Hz, 1H); 1.82 (s, 3H).

**Ac-Gly-Phe-Gly-Phe-NH-NH2 3**

Obtained by a general coupling procedure from Ac-Gly-Phe-OH (2 mmol) and H-Gly-Phe-NH-NH-Cbz (2 mmol), and next by a general Cbz deprotection procedure. Yield 64%.

1H NMR (400 MHz, DMSO) δ 9.17 (bs, 1H); 8.20 (bs, 1H); 8.06 (m, 1H+1H); 7.99 (bs, 1H); 7.30 – 7.13 (m, 10H); 4.46 (m, 1H+1H); 3.75 (m, 1H+1H); 3.58 (m, 1H+1H); 2.98 (m, 1H+1H); 2.79 (m, 1H+1H); 1.81 (s, 3H).

13C NMR (100 MHz, DMSO) δ 171.2; 170.0; 169.6; 169.0; 168.3; 137.82; 137.74; 129.14; 129.10; 128.09; 128.05; 126.3; 54.1; 52.8; 41.93; 41.84; 37.9; 37.4; 22.4.

HR – MS (ESI – TOF): m/z calculated for (C24H30N6O5Na)+ [M + Na]+: 505.2175, obtained: 505.2175.

# 4

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **2** (0.2 mmol) were dissolved in CHCl3 (2 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 99%.

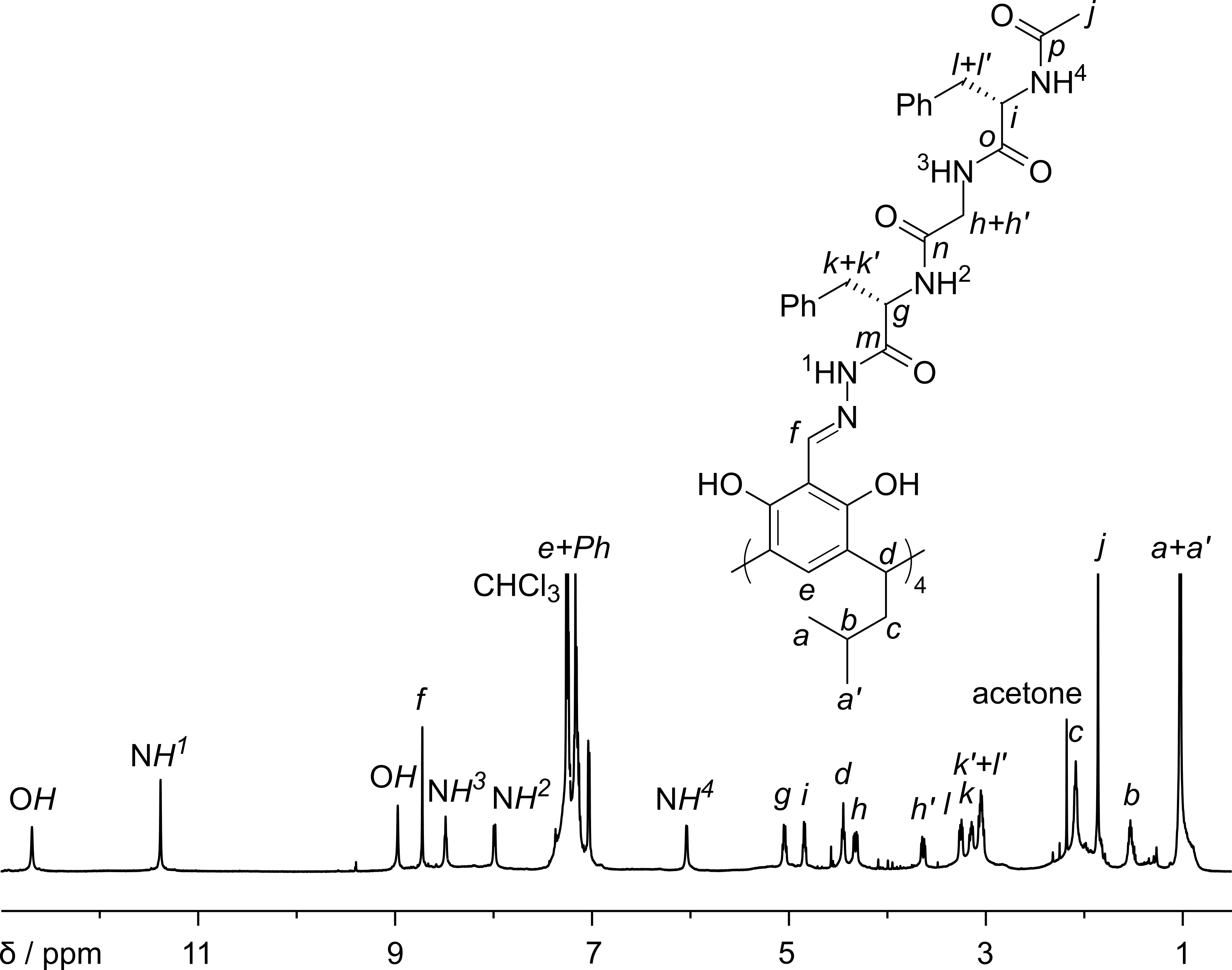


Fig. S1. 1H NMR spectrum of **4** (600 MHz, CDCl3).

1H NMR (600 MHz, CDCl3) δ 12.68 (s, 1H); 11.37 (s, 1H); 8.96 (s, 1H); 8.71 (s, 1H); 8.47 (bdd, 1H); 7.98 (bd, 1H); 7.28 – 6.99 (m, 11H); 6.02 (bd, 1H); 5.03 (dd, J = 16.4, 7.1 Hz, 1H); 4.83 (dd, J = 12.6, 6.5 Hz, 1H); 4.43 (t, J = 7.7 Hz, 1H); 4.31 (dd, J = 17.3, 6.0 Hz, 1H); 3.62 (dd, J = 17.1, 5.3 Hz, 1H); 3.24 (dd, J = 13.8, 6.3 Hz, 1H); 3.13 (dd, J = 13.3, 7.2 Hz, 1H); 3.03 (m, 1H+1H); 2.07 (m, 2H); 1.84 (s, 3H); 1.51 (m, 1H); 1.01 (bd, 6H).

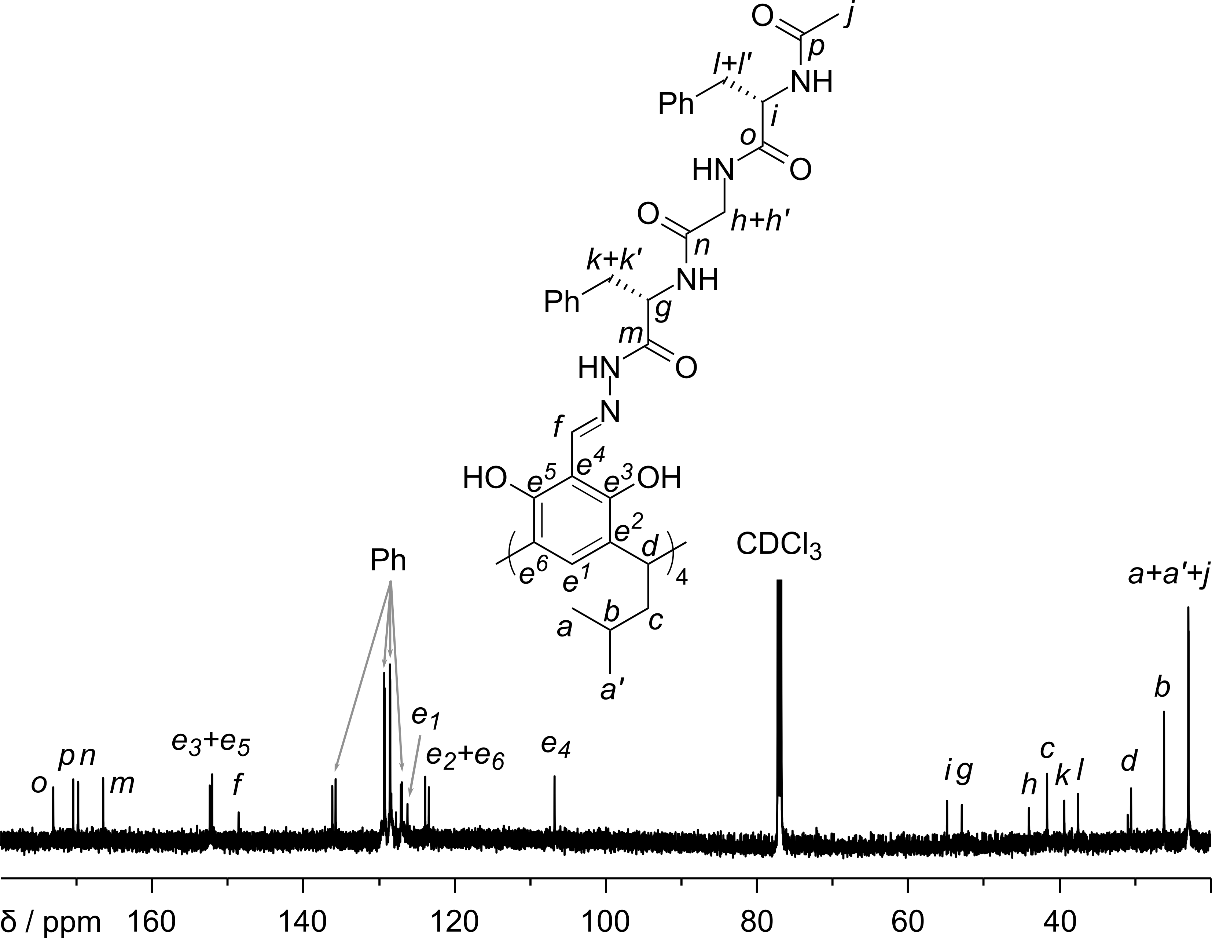


Fig. S2. 13C NMR spectrum of **4** (150 MHz, CDCl3).

13C NMR (150 MHz, CDCl3) δ 173.3; 170.6; 170.0; 166.7; 152.6; 152.3; 148.7; 136.4; 135.9; 129.48; 129.41; 128.72; 128.69; 127.28; 127.15; 126.4, 124.1; 123.6; 106.9; 55.0; 53.0; 44.2; 41.8; 39.5; 37.7; 30.6; 26.3; 23.05; 23.04; 23.0.

HR – MS (ESI – TOF): m/z calculated for (C136H156N20O24Na2)+ [M + 2Na]+: 1249.5693, obtained: 1249.5654.

# (4)2⊃C60

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **2** (0.2 mmol) and fullerene C60 (0.025 mmol) were suspended in CHCl3 (2 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 96%.

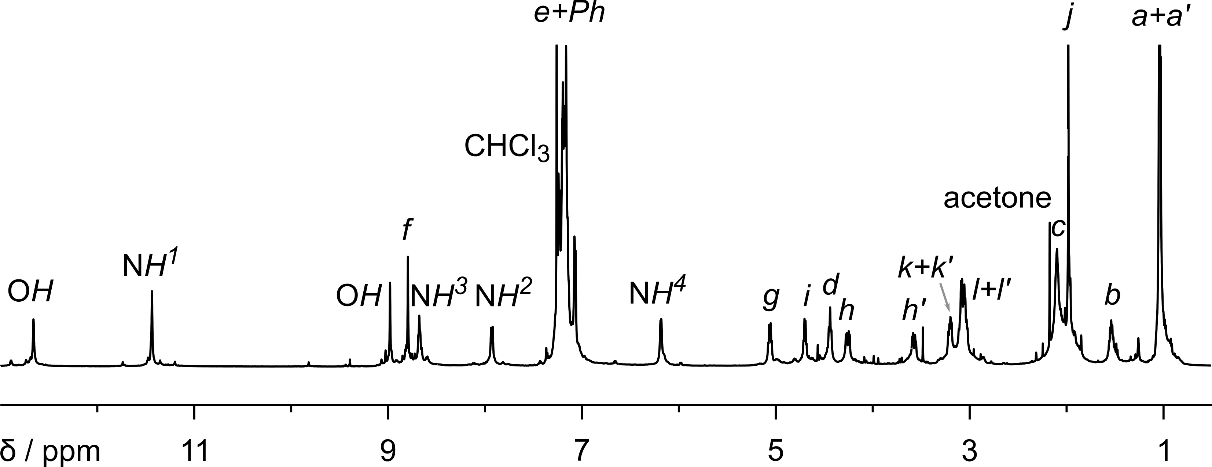


Fig. S3. 1H NMR spectrum of **(4)2⊃C60** (600 MHz, CDCl3).

1H NMR (600 MHz, CDCl3) δ 12.66 (s, 2H); 11.44 (s, 2H); 8.98 (s, 2H); 8.80 (s, 2H); 8.68 (bdd, 2H); 7.93 (bd, 2H); 7.25 – 7.04 (m, 22H); 6.18 (bd, 2H); 5.06 (dd, J = 16.2, 6.7 Hz, 2H); 4.70 (dd, J = 12.6, 6.5z Hz, 2H); 4.44 (t, J = 7.9 Hz, 2H); 4.25 (dd, J = 17.2, 5.7 Hz, 2H); 3.57 (dd, J = 17.2, 5.8 Hz, 2H); 3.20 (dd, J = 13.4, 6.8 Hz, 2H); 3.11 – 3.00 (m, 2H+2H+2H); 2.09 (m, 4H); 1.53 (m, 2H); 1.04 (d, J = 4.7 Hz, 6H); 1.03 (d, J = 4.7 Hz, 6H).

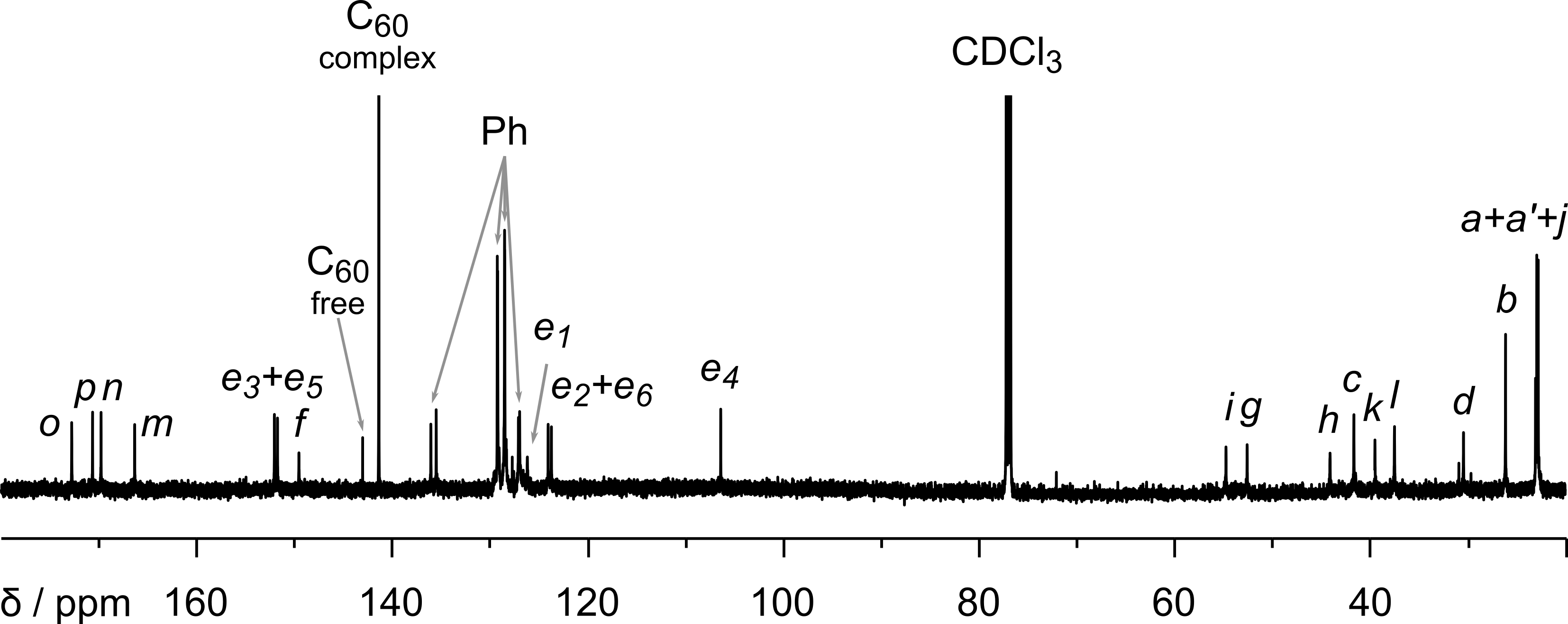


Fig. S4. 13C NMR spectrum of **(4)2⊃C60** (150 MHz, CDCl3).

13C NMR (150 MHz, CDCl3) δ 173.0; 170.9; 170.0; 166.6; 152.3; 151.9; 149.7; 141.6, 136.2; 135.7; 129.45; 129.41; 128.71; 128.69; 127.28; 127.17; 126.4; 124.3; 123.9; 106.6; 54.9; 52.7; 44.3; 41.8; 39.7; 37.7; 30.6; 26.3; 23.24; 23.11; 22.96.

HR – MS (ESI – TOF): m/z calculated for (C332H309N40O48)3- [M – 3H]3-: 1874.4317, obtained: 1874.4310.

# (4)2⊃C70

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **2** (0.2 mmol) and fullerene C70 (0.025 mmol) were dissolved/suspended in CHCl3 (2 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 96%.

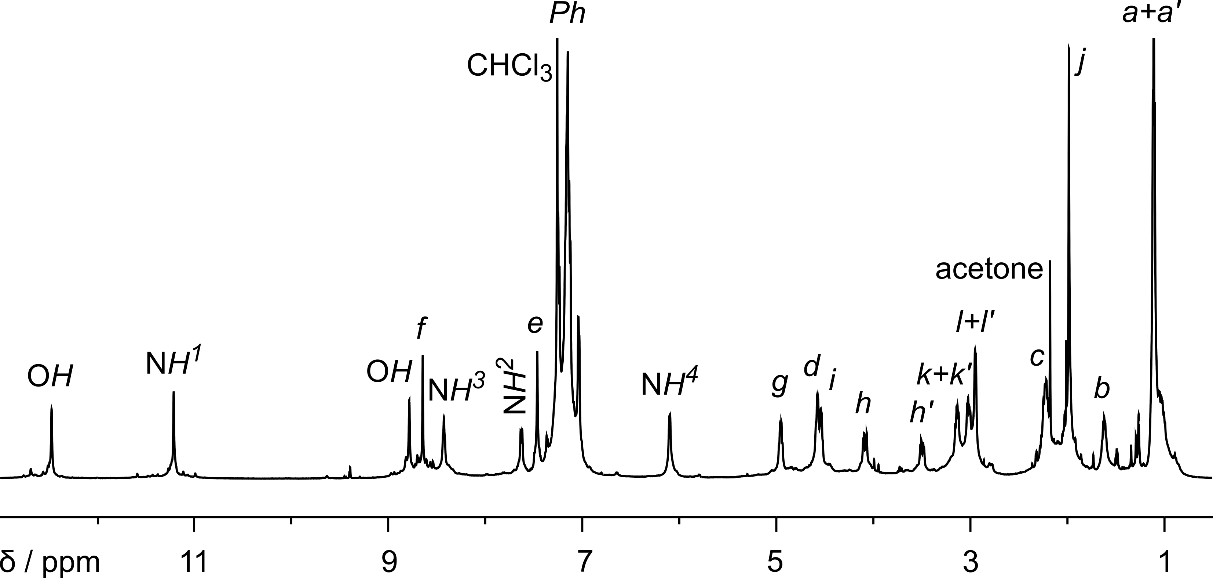


Fig. S5. 1H NMR spectrum of **(4)2⊃C70** (600 MHz, CDCl3).

1H NMR (600 MHz, CDCl3) δ 12.48 (s, 2H); 11.22 (s, 2H); 8.79 (s, 2H); 8.65 (s, 2H); 8.43 (bt, 2H); 7.63 (bd, 2H); 7.46 (s, 2H); 7.26 – 6.98 (m, 20H); 6.10 (bd, 2H); 4.95 (dd, J = 15.9, 6.3 Hz, 2H); 4.57 (dd, J = 12.3, 6.2 Hz, 2H); 4.53 (dd, J = 7.3, 5.6 Hz, 2H); 4.08 (dd, J = 16.7, 5.4 Hz, 2H); 3.49 (dd, J = 16.8, 5.8 Hz, 2H); 3.13 (dd, J = 13.2, 7.3 Hz, 2H); 3.01 (dd, J = 13.2, 5.7 Hz, 2H); 2.94 (m, 4H); 2.22 (m, 2H+2H); 1.61 (m, 2H); 1.11 (d, J = 6.1, 6H); 1.10 (d, J = 6.2, 6H).

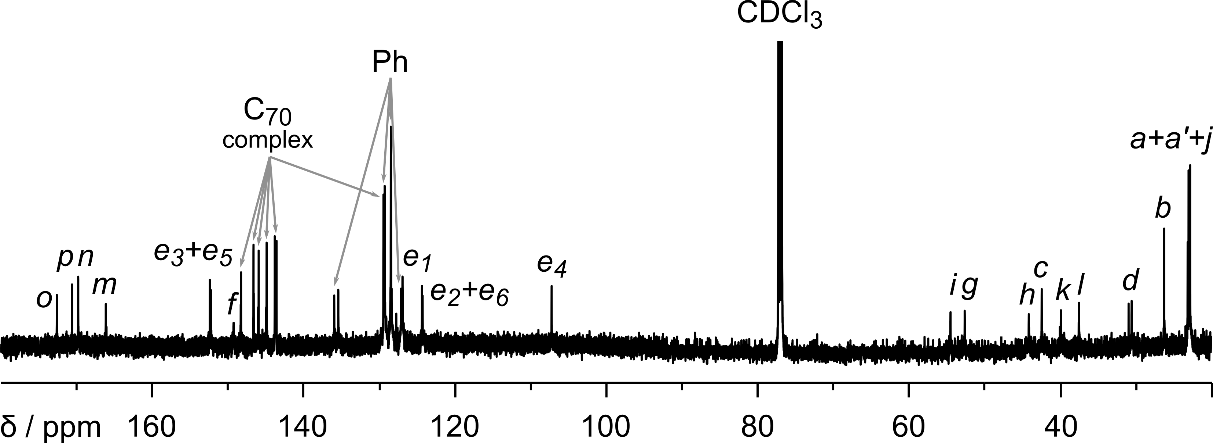


Fig. S6. 13C NMR spectrum of **(4)2⊃C70** (150 MHz, CDCl3).

13C NMR (150 MHz, CDCl3) δ 172.8; 170.8; 170.0; 166.3; 152.58; 152.44; 149.4; 148.5; 146.8; 146.1; 145.1; 143.99; 143.76; 136.1; 135.6; 129.63; 129.62; 129.56; 129.46; 128.64; 128.63; 127.3; 127.1; 124.52; 124.44; 107.4; 54.6; 52.8; 44.3; 42.6; 40.0; 37.6; 30.7; 26.4; 23.27; 23.14; 22.94.

HR – MS (ESI – TOF): m/z calculated for (C342H312N40O48Na3)3+ [M + 3Na]3+: 1938.4293, obtained: 1938.4363.

# 5

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **3** (0.2 mmol) were dissolved in CHCl3 : MeOH (1.9 ml : 0.1 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 99%.

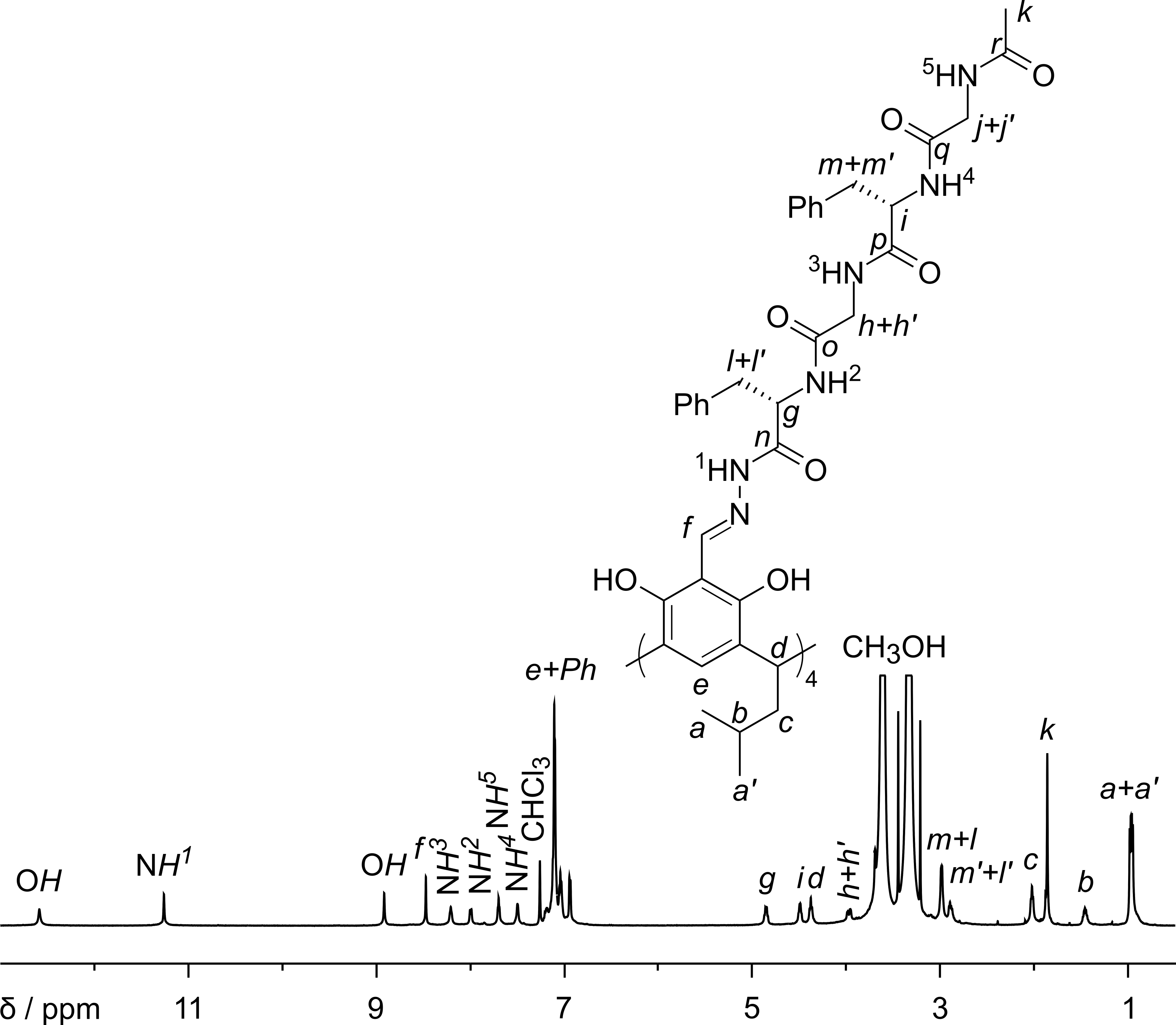


Fig. S7. 1H NMR spectrum of **5** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

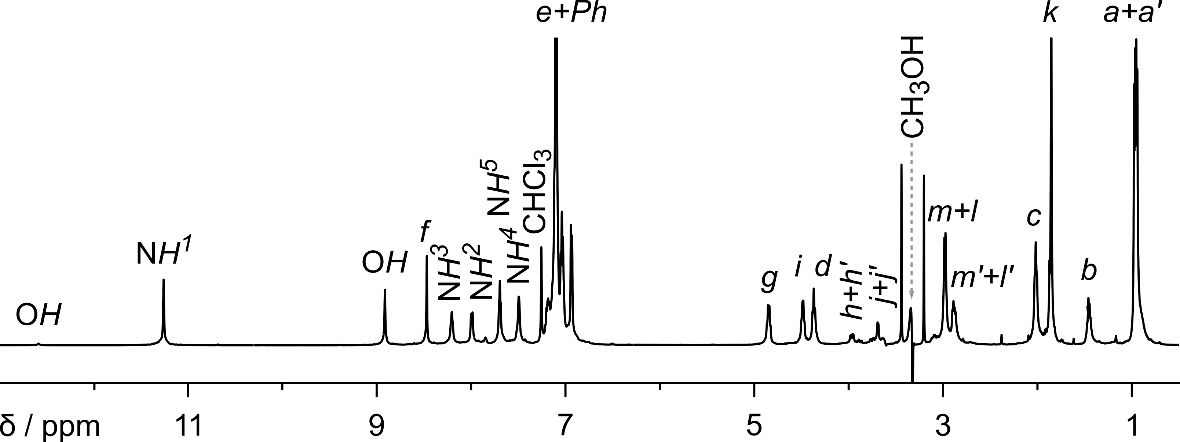


Fig. S8. 1H NMR spectrum of **5** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*, solvent suppression).

1H NMR (600 MHz, CDCl3 : CH3OH, 95 : 5, *v* : *v*) δ 12.59 (s, 2H); 11.26 (s, 2H); 8.92 (s, 2H); 8.47 (s, 2H); 8.21 (bt, 2H); 8.00 (bd, 2H); 7.70 (bt, 2H); 7.50 (bd, 2H); 7.23 – 6.85 (m, 22H); 4.85 (dd, J = 15.6, 6.9 Hz, 2H); 4.49 (dd, J = 11.8, 6.9 Hz, 2H); 4.38 (t, J = 7.7 Hz, 2H); 4.00 - 3.86 (m, 2H+2H); 3.78 - 3.63 (m, 2H+2H); 2.98 (m, 2H+2H); 2.89 (m, 2H+2H); 2.02 (m, 4H); 1.46 (m, 2H); 0.97 (d, J = 6.5 Hz, 6H); 0.95 (d, J = 6.6 Hz, 6H).

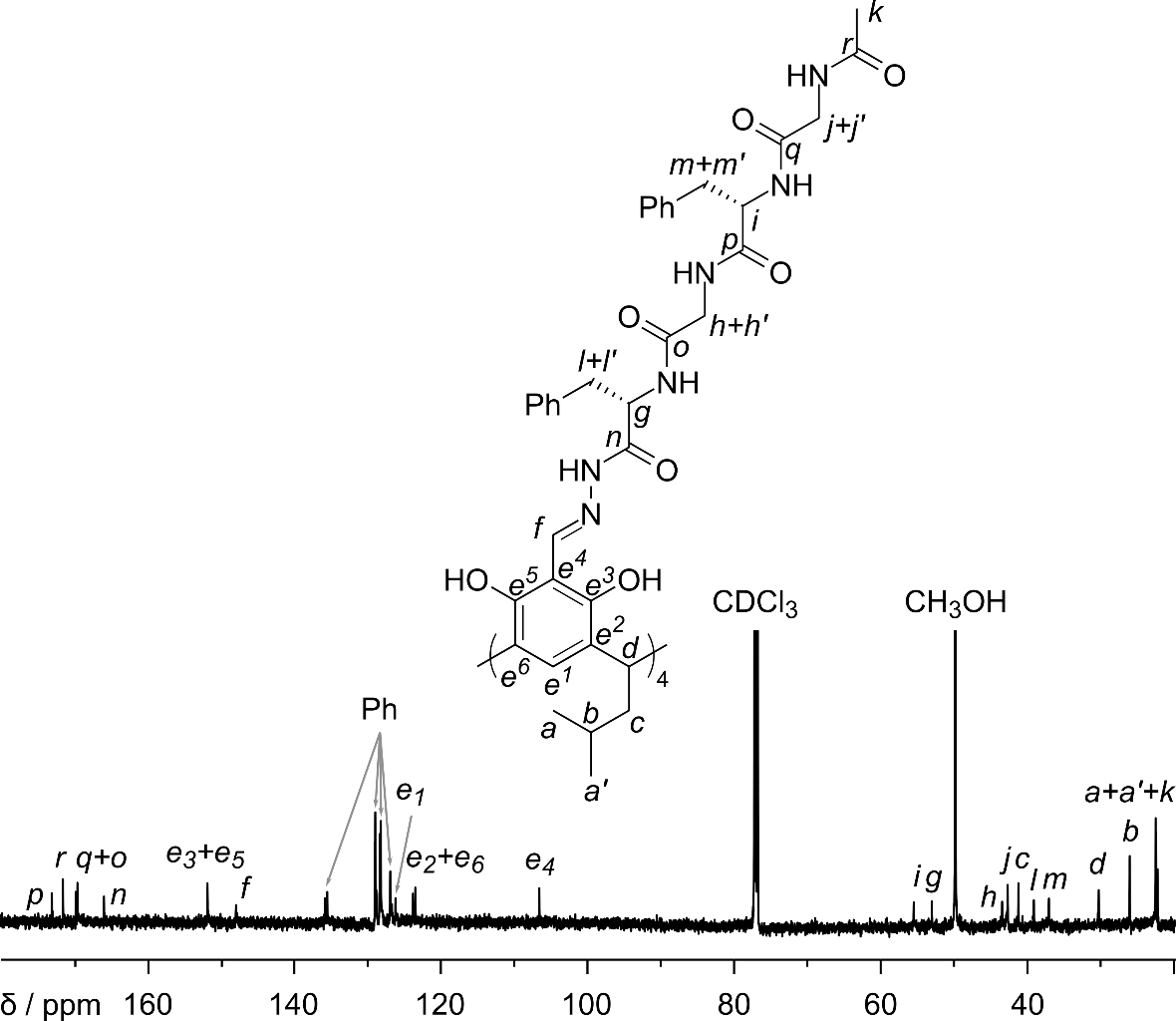


Fig. S9. 13C NMR spectrum of **5** (150 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

13C NMR (150 MHz, CDCl3 : CH3OH, 95 : 5, *v* : *v*) δ 173.3; 171.8; 170.1; 169.8; 166.2; 152.09; 152.05; 148.2; 136.0; 135.7; 129.20; 129.15; 128.53; 128.40; 127.1; 126.4; 124.0; 123.7; 106.8; 55.7; 53.3; 43.6; 42.9; 41.4; 39.2; 37.2; 30.4; 26.1; 22.68; 22.61; 22.43.

HR – MS (ESI – TOF): m/z calculated for (C144H168N24O28Na2)2+ [M + 2Na]2+: 1363.6122, obtained: 1363.6128.

# (5)2⊃C60

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **3** (0.2 mmol) and fullerene C60 (0.025 mmol) were suspended in CHCl3 : MeOH (1.9 ml : 0.1 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 96%.

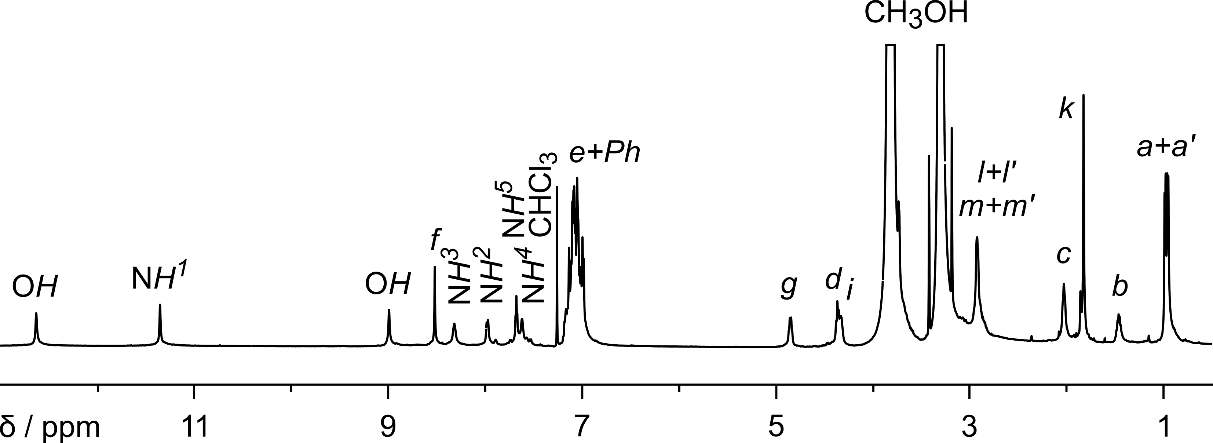


Fig. S10. 1H NMR spectrum of **(5)2⊃C60** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

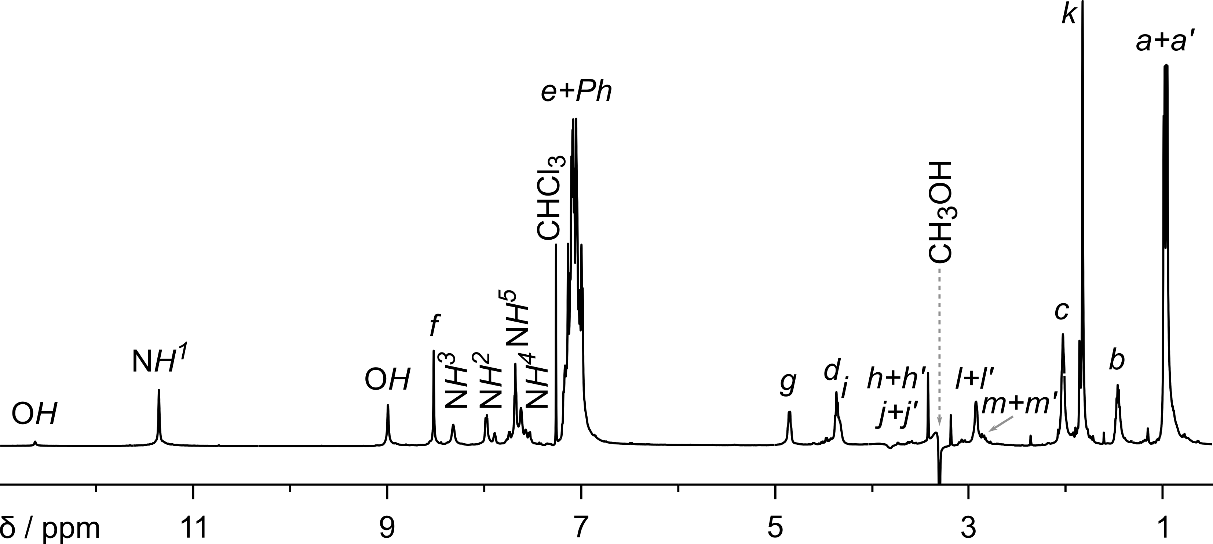


Fig. S11. 1H NMR spectrum of **(5)2⊃C60** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*, solvent suppression).

1H NMR (600 MHz, CDCl3 : CH3OH, 95 : 5, *v* : *v*) δ 12.64 (s, 2H); 11.36 (s, 2H); 8.99 (s, 2H); 8.52 (s, 2H); 8.32 (s, 2H); 7.98 (bd, 2H); 7.68 (bt, 2H); 7.62 (s, 2H); 7.20 – 6.96 (m, 22H); 4.85 (dd, J = 14.6, 6.2 Hz, 2H); 4.41 – 4.28 (m, 2H+2H); 3.67 – 3.51 (m, 2H+2H+2H+2H); 2.99 – 2.80 (m, 2H+2H+2H+2H); 2.03 (m, 4H); 1.82 (s, 6H); 1.46 (m, 2H); 0.98 (d, J = 6.5 Hz, 6H); 0.95 (d, J = 6.5 Hz, 6H).

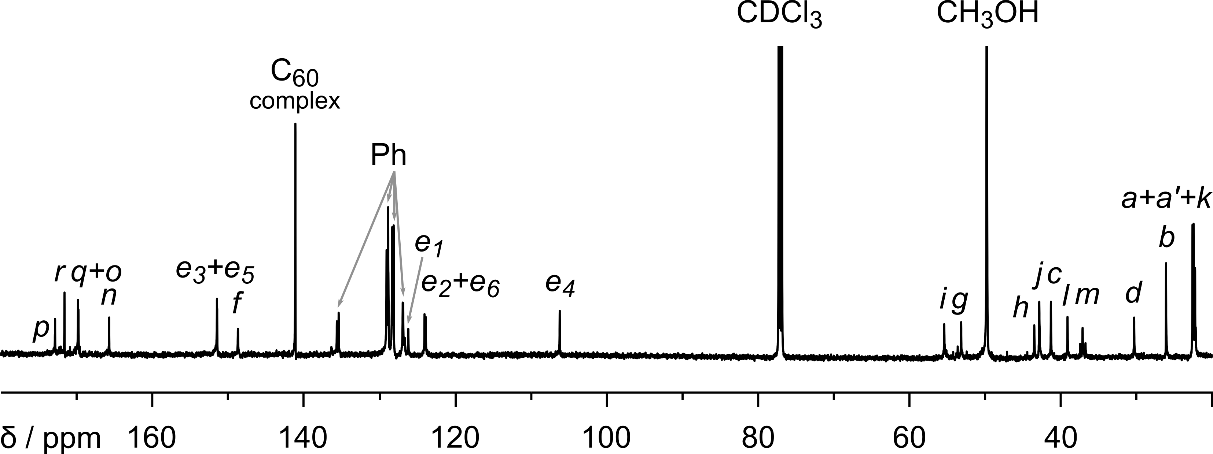


Fig. S12. 13C NMR spectrum of **(5)2⊃C60** (150 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

13C NMR (150 MHz, CDCl3 : CH3OH, 95 : 5, *v* : *v*) δ 173.1; 171.8; 170.05; 170.00; 165.9; 151.67; 151.64; 148.9; 141.3; 135.8; 135.6; 129.2; 129.0; 128.5; 128.3; 127.10; 127.04; 126.4; 124.22; 124.05; 106.3; 55.5; 53.3; 43.6; 42.9; 41.4; 39.2; 37.2; 30.4; 26.2; 22.7; 22.5; 22.3.

HR – MS (ESI – TOF): m/z calculated for (C348H333N48O56)3- [M – 3H]3-: 2026.4890, obtained: 2026.4865.

# (5)2⊃C70

Tetraformylresorcin[4]arene **1** (0.05 mmol) and hydrazide **3** (0.2 mmol) and fullerene C70 (0.025 mmol) were suspended in CHCl3 : MeOH (1.9 ml : 0.1 ml) in a sealed pressure vial. The mixture was heated at 70 °C for 20 h. Then the reaction mixture was cooled down. The solution was evaporated under reduced pressure and vacuum dried. Yield 96%.

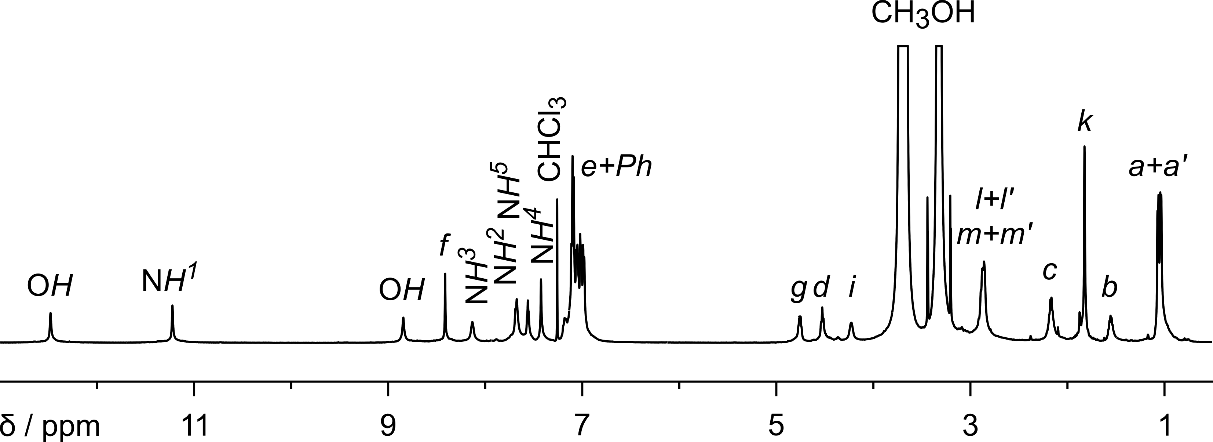


Fig. S13. 1H NMR spectrum of **(5)2⊃C70** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

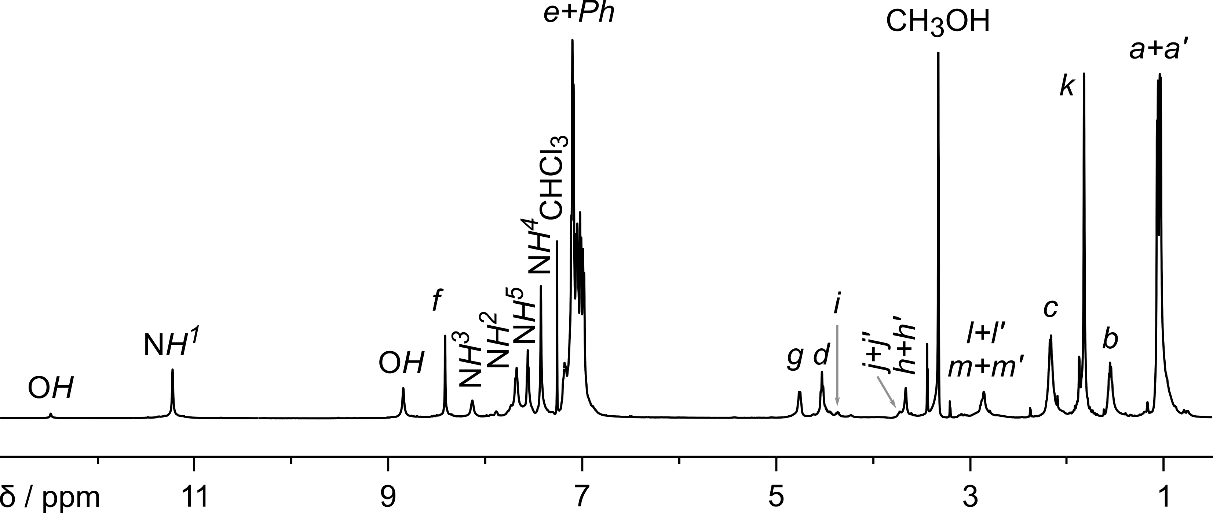


Fig. S14. 1H NMR spectrum of **(5)2⊃C70** (600 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*, solvent suppression).

1H NMR (600 MHz, CDCl3 : CH3OH, 95 : 5, *v* : *v*) δ 12.49 (s, 2H); 11.23 (s, 2H); 8.85 (s, 2H); 8.42 (s, 2H); 8.14 (s, 2H); 7.68 (bd, 2H); 7.56 (bd, 2H); 7.43 (s, 2H); 7.21 – 6.96 (m, 22H); 4.76 (bdd, 2H); 4.53 (t, J = 7.7 Hz, 2H); 4.36 (bdd, 2H); 3.70 (m, 2H+2H); 3.66 (m, 2H+2H); 2.87 (m, 2H+2H+2H+2H); 2.16 (m, 4H); 1.82 (s, 6H); 1.55 (m, 2H); 1.06 (d, J = 6.5 Hz, 6H); 1.03 (d, J = 6.5 Hz, 6H).

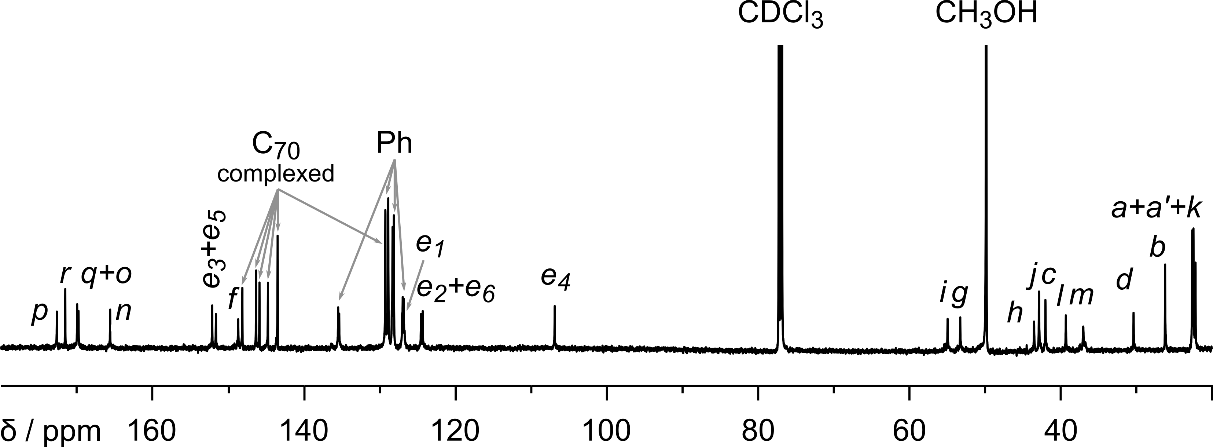


Fig. S15. 13C NMR spectrum of **(5)2⊃C70** (150 MHz, CDCl3 : MeOH, 95 : 5, *v* : *v*).

13C NMR (150 MHz, CDCl3: CH3OH, 95 : 5, *v* : *v*) δ 172.9; 171.7; 170.17; 170.00; 165.8; 152.3; 151.8; 148.9; 148.3; 146.5; 146.1; 144.9; 143.66; 143.64; 135.65; 135.51; 129.4; 129.0; 128.5; 128.3; 127.18; 127.11; 126.99; 124.7; 124.5; 107.0; 55.1; 53.4; 43.6; 43.0; 42.1; 39.4; 37.1; 30.5; 26.3; 22.7; 22.5; 22.3.

HR – MS (ESI – TOF): m/z calculated for (C358H333N48O56)3- [M – 3H]3-: 2066.4890, obtained: 2066.4880.

1. Grajda, M.; Wierzbicki, M.; Cmoch, P.; Szumna, A. *J. Org. Chem.* **2013**, *78*, 11597-11601. [↑](#endnote-ref-1)