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Biomimetic dendrimers for mineralization: Rare fibrous amorphous calcium carbonate (ACC) and branch-and-bud ACC-vaterite polymorphs

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The electronic supplementary information (ESI) includes 1 figure, and full details of dendrimer synthesis.

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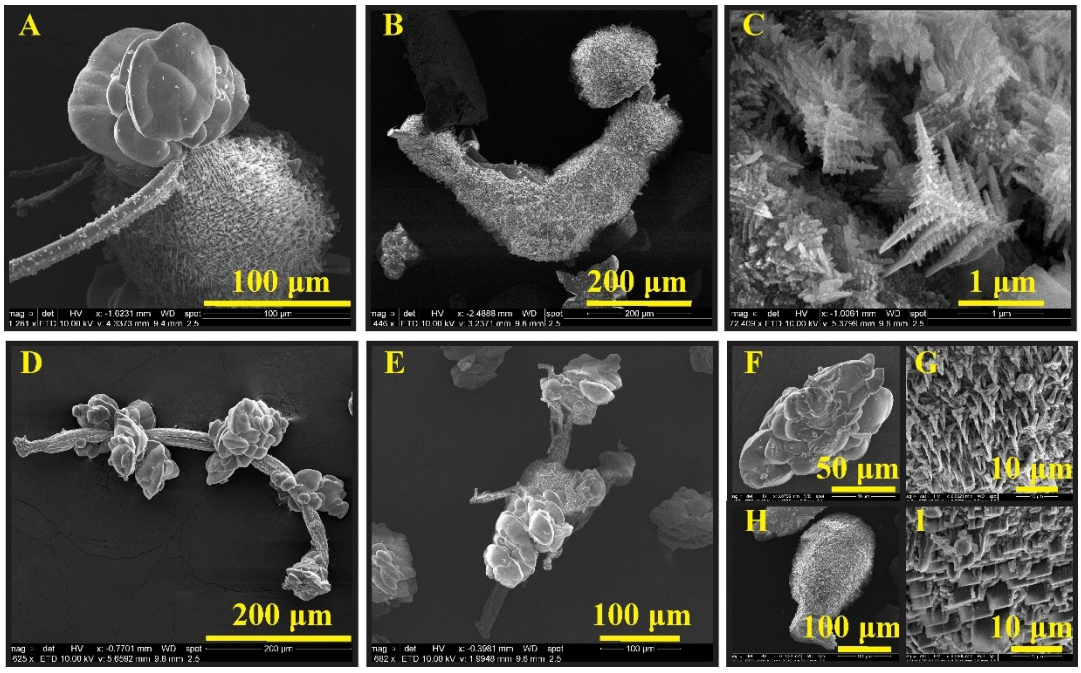
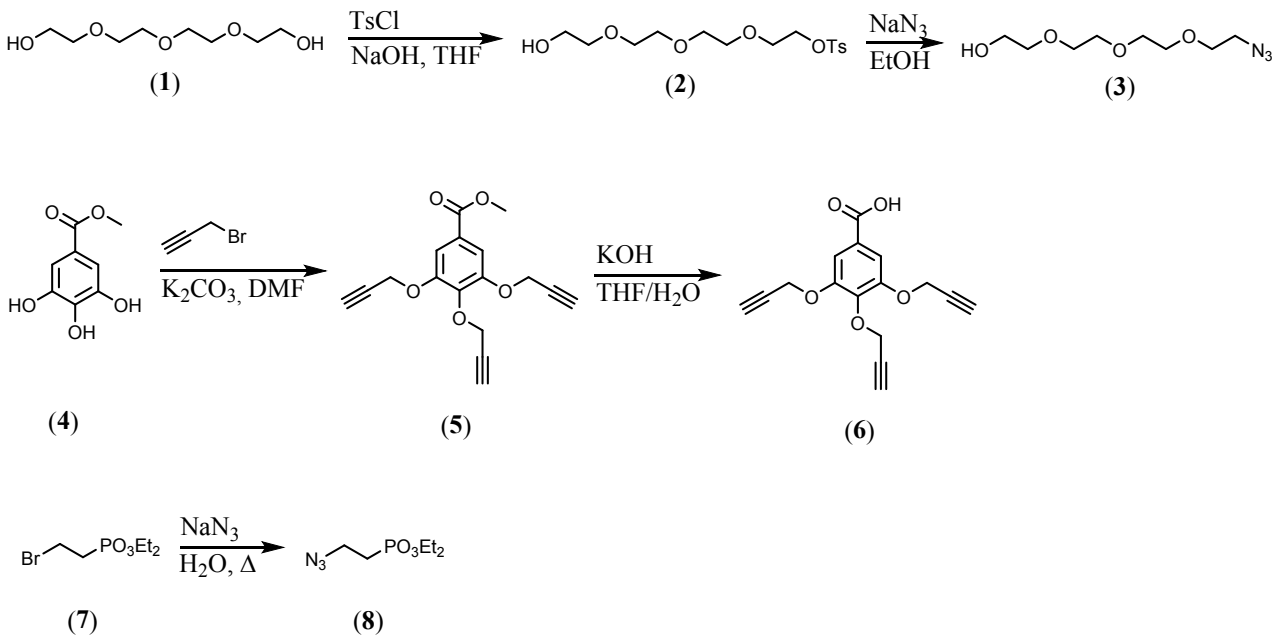


Figure S1. Long time (~ 25 days) biomimetic mineralization of calcium carbonate with 10 mM $CaCl_2$, 10 mM $NaHCO_3$, and 13.3 ppm TEG-G2 (A-C) or TEG-G0 (D-I) dendrimers results in similar features as for TEG-G1: elongated ACC structures with the decorations of nacre-like vaterite (A, D, E, F), calcite spikes (A, B, G-I), and dendritic features (C).

Dendrimer synthesis:



Scheme 1. Structure and synthesis of the building blocks used for the synthesis of TEG-based dendrimers.

The branching TEG entity was prepared *via* mono-tosylation and azide substitution of TEG to yield compound (**3**) (Scheme **1**). The branching monomer with terminal acetylene units (**6)** was synthesized from easily available starting materials in a two-step high-yield synthesis, and without the need for column chromatography. For coupling using a click chemistry approach, a small molecule containing both an azido group and a phosphonate diester group was prepared (**8**).

2-(2-(2-(2-Hydroxyethoxy)ethoxy)ethoxy)ethyl 4-methylbenzenesulfonate, OH-TEG-Ts (2)

This compound was prepared by adapting the procedure described in literature:[1] To a solution of tetraethylene glycol (TEG) (**1**) (101.88 g; 524.53 mmol) in THF (200 mL), a solution of NaOH (1.26 g; 52.45 mmol) was added in H_2O (10 mL), and the mixture was cooled to 0°C on an ice

bath. A solution of TsCl (10.00 g; 52.45 mmol) in THF (20 mL) was added dropwise over a period of 30 min. The mixture was left to stir for additional 2 h. The THF was removed under reduced pressure and DCM (50 mL) was added. The DCM phase was washed with water (3 × 25 mL) and brine (25 mL), dried ($MgSO_4$), and the crude product concentrated *in vacuo*. The product was purified using flash chromatography using EtOAc as the eluent to give 6.79 g (37%) of the product as a colorless transparent oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.79 (d, J = 8.3, 2H), 7.34 (d, J = 8.3, 2H), 4.21 – 4.11 (m, 2H), 3.75 – 3.51 (m, 14H), 2.44 (s, 3H).

2-(2-(2-(2-Azidoethoxy)ethoxy)ethoxy)ethanol, HO-TEG-N_3 (3)

This compound was prepared as described in the literature[1] with slight modifications to temperature and the purification procedure: A mixture of **2** (6.79 g; 19.49 mmol) and NaN_3 (3.20 g; 49.22 mmol) in EtOH (95%, 100 mL) was heated to 77 °C (oil bath temperature) for 20 h. The solvent was removed under reduced pressure, and H_2O (50 mL) was added. The product was extracted with $CHCl_3$ (3 × 50 mL). The collected organic phases were dried (K_2CO_3), filtered, and the product was concentrated *in vacuo* to give 4.10 g (96%) of the final product as a colorless oil. ^{1}H NMR (200 MHz, $CDCl_3$) δ 3.79 – 3.56 (m, 14H), 3.39 (t, 2H), 2.39 (s, 1H).

Methyl 3,4,5-tris(prop-2-ynyloxy)benzoate (5)

A mixture of methyl 3,4,5-trihydroxybenzoate (**4**) (12.82 g; 69.62 mmol), K_2CO_3 (38.55 g; 278.92 mmol) and propargyl bromide (80% in toluene; 29.85 g reactant; 37.28 g sample; 27.80 mL; 250.46 mmol) in DMF (100 mL) was stirred for 20 h. H_2O (250 mL) was added, and the product was extracted with EtOAc (4 × 150 mL). The collected organic phases were washed with H_2O (3

× 150 mL) and brine (3 × 150 mL), dried (K_2CO_3), and concentrated under reduced pressure to give 19.05 g (92%) of the final product as a white solid material. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.47 (s, 2H), 4.81 (2×d, *J* = 2.4, 2.4, 6H), 3.91 (s, 3H), 2.53 (t, *J* = 2.4, 2H), 2.46 (t, *J* = 2.4, 1H). NMR data are consistent with literature.[2]

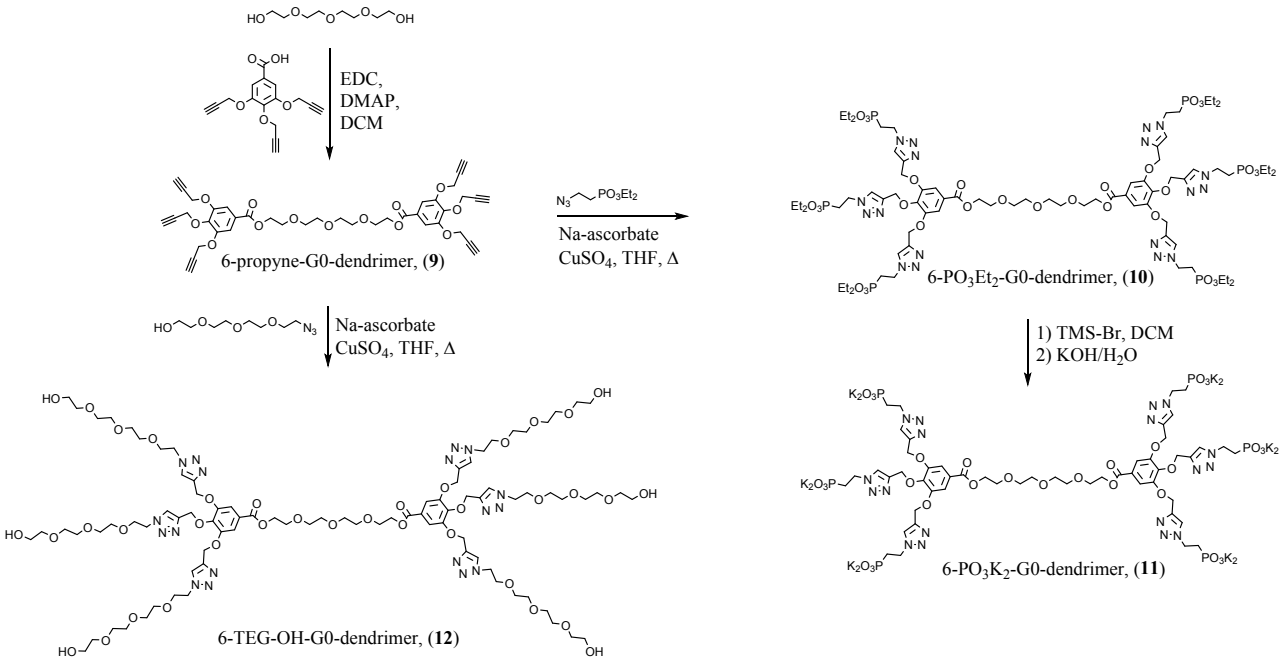
3,4,5-Tris(prop-2-ynyloxy)benzoic acid (6)

A mixture of **5** (4.53 g; 15.18 mmol) in THF (10 mL) was vigorously stirred with $KOH_{(aq)}$ (4 M, 20 mL) over night. The aqueous phase was made acidic (pH ~ 3) with $HCl_{(aq)}$, and the product was extracted with THF (3 × 20 mL). The collected organic phases were washed with brine (2 × 10 mL), dried ($MgSO_4$), filtered, and the product was concentrated *in vacuo* to give 3.65 g (84%) of the final product as a white solid material. ^{1}H NMR (200 MHz, DMSO) δ 13.06 (s, 1H), 7.38 (s, 2H), 4.89 (d, *J* = 2.4, 4H), 4.71 (d, *J* = 2.4, 2H), 3.62 (t, *J* = 2.4, 2H), 3.48 (t, *J* = 2.4, 1H). NMR data are consistent with literature.[3]

Diethyl (2-azidoethyl)phosphonate (8):

Sodium azide (10.60 g, 163.05 mmol) was added to a solution of 2-bromoethylphosphonate **(7)** (10.40 g, 42.44 mmol) in water (50 mL), and the reaction mixture was stirred for 24 h at 65°C. An extraction was performed with dichloromethane, the organic phase was dried with $MgSO_4$, filtered, and the residue obtained was a yellow oil (8.03 g, 0.0387 mol, 92% yield). ^{1}H NMR (400MHz, $CDCl_3$): δ = 1.18 (t, 6H), 1.91 (m, 2H), 3.38 (m, 2H), 3.97 (m, 4H) ppm. ^{13}C{^{1}H} NMR (300MHz, $CDCl_3$) δ = 16.27 (d, P-CH_2-$\underline{C}H_3$), 25.8 (d, P-$\underline{C}H_2$-CH_3), 45.2 (d, P-$\underline{C}H_2$-CH_2-), 61.7 (d, P-CH_2-

$\underline{C}H_2$-) ppm. $^{31}P\{^1H\}$ NMR (200MHz, $CDCl_3$) δ = 26.65 (-P-Et) ppm. NMR data are consistent with literature.[4]



Scheme 2. Synthesis of TEG-based dendrimers of generation 0, and the synthesis of 6-TEG-OH-G0-dendrimer (**12**).

Synthesis of dendrimers was conducted divergently starting from the TEG core (**1**) based on copper catalyzed Huisgen cycloaddition, yielding a triazole moiety, and coupling reactions between an alcohol on the TEG monomer and the carboxylic acid moiety on the AB_3 branching unit. For the latter reaction, 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC) was used as the catalyst, and neither protection nor de-protection steps were necessary. The synthesis of the TEG-type dendrimers starts with an esterification reaction involving TEG and compound **6**, yielding (**9**) with six terminal alkynyl groups. This functional group can be used either for the

functionalization of dendrimer or for its expansion to higher generation. The functionalization is achieved by a "click" reaction with compound **8** to yield the generation 0 dendrimer with six diethyl ester phosphonic acid groups at the terminus (6-PO_3Et_2-G0-dendrimer, **10**). The synthesis of the next generation dendrimer is done by reacting all the six triple bonds with six equivalents of monomer **3** yielding (**12**), which in turn can be coupled with six equivalents of monomer **6**, yielding a G1 dendrimer with 18 alkynyl surface groups (**13**).

6-propyne-G0-Dendrimer (9)

To a mixture of TEG (0.81 g; 4.17 mmol) in DCM (30 mL) was in success added **2** (2.61 g; 9.18 mmol), DMAP (1.18 g; 9.66 mmol), and EDC•HCl (2.43 g; 12.68 mmol). The reaction was stirred for two days, and the solvent was removed under reduced pressure. The product was purified using flash chromatography with a mixture of EtOAc/hexanes/MeOH (1.2:1.0:0.4) to give, after removal of solvents and drying *in vacuo*, 2.47 g (66%) of the product as a solid, white material. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48 (s, 4H), 4.81 (dd, J = 2.4, 12H), 4.50 – 4.37 (m, 4H), 3.87 – 3.74 (m, 4H), 3.73 – 3.57 (m, 8H), 2.56 (t, J = 2.4, 4H), 2.46 (t, J = 2.4, 2H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.09, 151.37, 140.10, 126.70, 79.53, 78.80, 59.92, 56.90. ESI MS Calculated $C_{40}H_{38}O_{13}$: 726.73. Found: 749.22 (M^-Na^+).

6-PO_3Et_2-G0-Dendrimer (10)

A solution of **9** (0.75 g; 1.035 mmol), Na-ascorbate (0.245 g; 1.24 mmol) and **8** (1.55 g; 7.48 mmol) in THF (9 mL) was added to a solution of $CuSO_4$ ($CuSO_4$•$5H_2O$; 0.16 g; 0.64 mmol) in water (2.5 mL) and stirred for two days at 40°C. The THF was removed under reduced pressure, the product was dissolved in DCM (10 mL), and $EDTA_{(aq)}$ (0.20 M; 10 mL) was added and stirred

for 1 h followed by the extraction of product with DCM (4 × 10 mL). The solvent was removed under reduced pressure, and the product was re-dissolved in a small amount of DCM. Et_2O was dropwise added to the solution until the product came out of solution as a thick sticky brown oil. The Et_2O was decanted, and the precipitation procedure was repeated two additional times. All volatile components were removed *in vacuo* to give 1.24 g (61%) of the product as a sticky brown syrup. ^{1}H NMR (200 MHz, $CDCl_3$) δ 7.94 (s,s, 6H), 7.42 (s, 4H), 5.10 (s,s, 12H), 4.75 – 4.49 (m, 12H), 4.49 – 4.36 (m, 4H), 4.20 – 3.97 (m, 24H), 3.87 – 3.75 (m, 4H), 3.73 (bs, 8H), 2.59 – 2.28 (m, 12H), 1.30 (t, J = 7.1, 36H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.72, 151.89, 144.14, 143.39, 141.54, 125.69, 124.27, 123.73, 109.22, 70.64, 70.59, 69.12, 66.20, 64.33, 63.04, 62.16 (d, J_{CP} = 6.5 Hz), 62.07, 44.65, 44.51, 27.08 (d, J_{CP} = 141.1 Hz), 16.37 (d, J_{CP} = 6.0 Hz). ^{31}P NMR (81 MHz, $CDCl_3$) δ 25.63. MALDI-TOF MS Calculated $C_{76}H_{122}N_{18}O_{31}P_6$: 1968.69. Found: 1991.0 (M^-Na^+).

6-PO_3K_2-G0-Dendrimer (11)

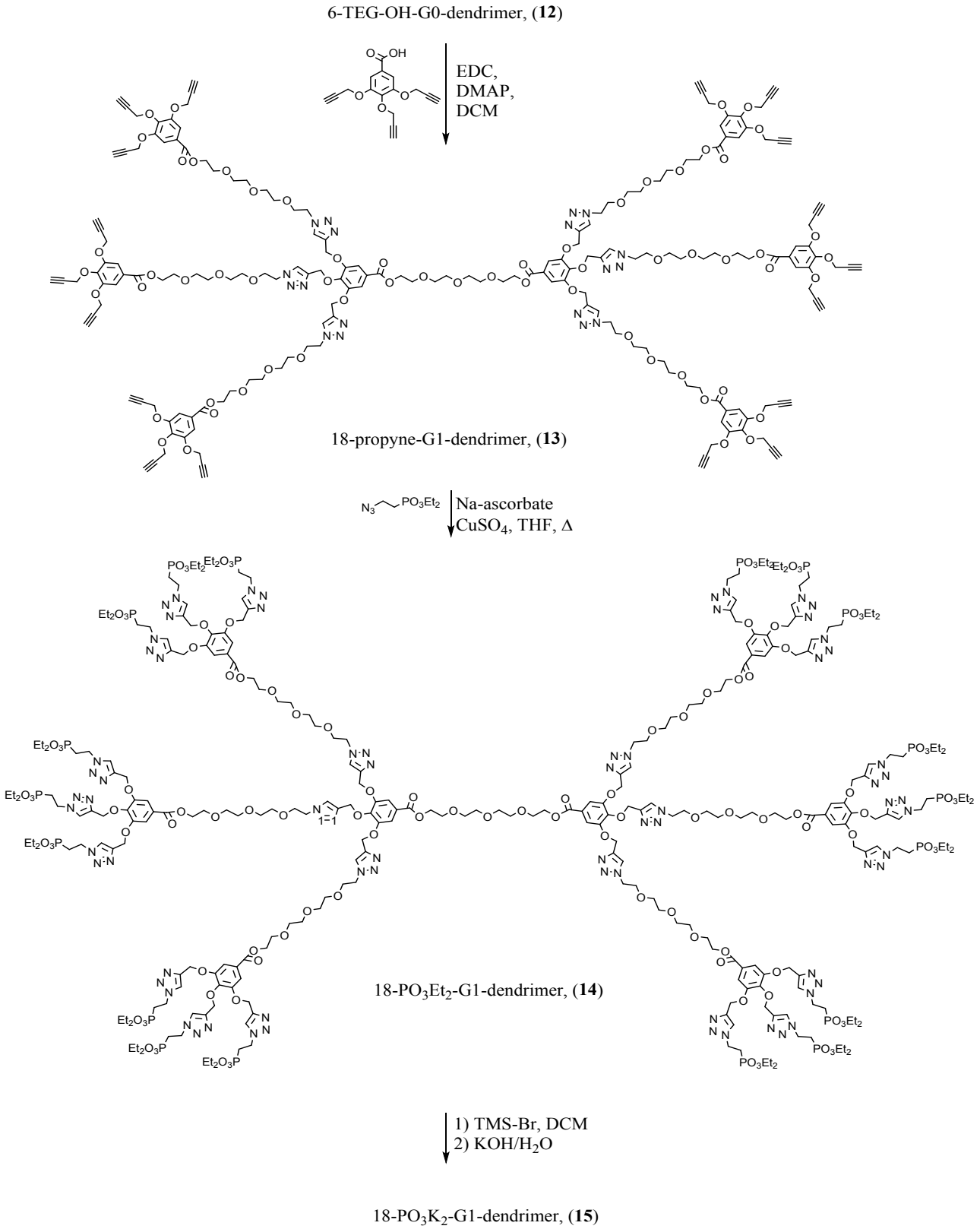
A solution of **10** (1.24 g; 0.63 mmol) and TMS-Br (2.20 mL; 2.54 g; 16.14 mmol) in DCM (10 mL) was stirred for 48 h. The volatile components were removed *in vacuo* and the residue was taken up in DCM. $KOH_{(aq)}$ (1M; 5 mL) was added, the DCM was removed gradually under reduced pressure, and the aqueous solution was stirred for 2 h. The pH was adjusted to 8-9. The volatile components were removed under reduced pressure to give 1.70 g (130%) of the product as a brown solid material. Yield > 100% due to residual H_2O. ^{1}H-NMR confirmed that all ethyl groups had been removed and gave very broad signals. ^{13}C NMR (126 MHz, D_2O) δ 166.94, 151.28, 142.82, 142.63, 139.84, 125.34, 125.07, 124.80, 108.88, 69.86, 69.65, 68.46, 64.92, 64.79, 61.94, 46.26, 46.05, 29.46 (d, J_{CP} = 129.8 Hz). ^{31}P NMR (81 MHz, D_2O) δ 18.09. MALDI-TOF MS Calculated $C_{52}H_{62}K_{12}N_{18}O_{31}P_6$, 2087.89. Found, 2052 $C_{52}H_{62}K_{12}N_{18}O_{31}P_6$ (- $1K^+$ + $1H^+$).

6-TEG-OH-G0-Dendrimer (12)

A solution of $CuSO_4$•$5H_2O$ (0.28 g; 1.12 mmol) in H_2O (4 mL) was added to a mixture of **9** (1.34 g; 1.84 mmol), **3** (2.93 g; 13.36 mmol), and Na-ascorbate (0.44 g; 2.22 mmol) in THF (40 mL), and the mixture was allowed to stir at 40°C (oil bath) for 24 h. All the volatile components were removed under reduced pressure, and the residue was taken up in CH_2Cl_2 (50 mL), stirred with Na-EDTA for 2 h, and filtered. Most of the CH_2Cl_2 was removed under reduced pressure and Et_2O was added dropwise to precipitate the product, yielding a brown sticky syrup. The Et_2O was decanted, the residue was re-dissolved in CH_2Cl_2, and the precipitation procedure repeated twice. The product was left *in vacuo* overnight to give 2.98 g (80%) of the product as a brown sticky syrup. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.98 (s, 4H), 7.87 (s, 2H), 7.42 (s, 4H), 5.12 (s, 12H), 4.62 – 4.34 (m, 16H), 3.95 – 3.74 (m, 16H), 3.73 – 3.46 (m, 80H). MALDI-TOF MS Calculated $C_{88}H_{140}N_{18}O_{37}$: 2042.18. Found: 2064.50 (M^-Na^+).

18-propyne-G1-Dendrimer (13)

A mixture of **12** (1.63 g; 0.798 mmol), **6** (1.63 g; 5.73 mmol), DMAP (0.64 g; 5.24 mmol), and EDC•HCl (1.38 g; 5.22 mmol) in DCM (15 mL) was stirred for 24 h. The reaction mixture was filtered through a plug of silica (twice) and concentrated under reduced pressure (the material may initially form a sticky foam with a (surprisingly) large volume) to give 2.21 g (76%) of the product as a brown sticky thick syrup. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (s, 4H), 7.83 (s, 2H), 7.48 (s,s, 16H), 5.18 (s, 12H), 4.77 (d,d, J = 2.4, 36H), 4.56 – 4.34 (m, 28H), 3.88 – 3.70 (m, 28H), 3.70 – 3.45 (m, 60H), 2.59 (s, 12H), 2.48 (s, 6H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.76, 151.23, 143.97, 143.14, 141.68, 141.08, 125.53, 109.97, 70.53, 69.34, 66.41, 63.12, 57.10, 50.19, 59.92, 56.90. MALDI-TOF MS Calculated $C_{184}H_{200}N_{18}O_{61}$: 3639.69. Found: 3638.66.



Scheme 3. Synthesis of TEG dendrimers: 6-TEG-OH-G1 and 18-PO_3K_2-G1.

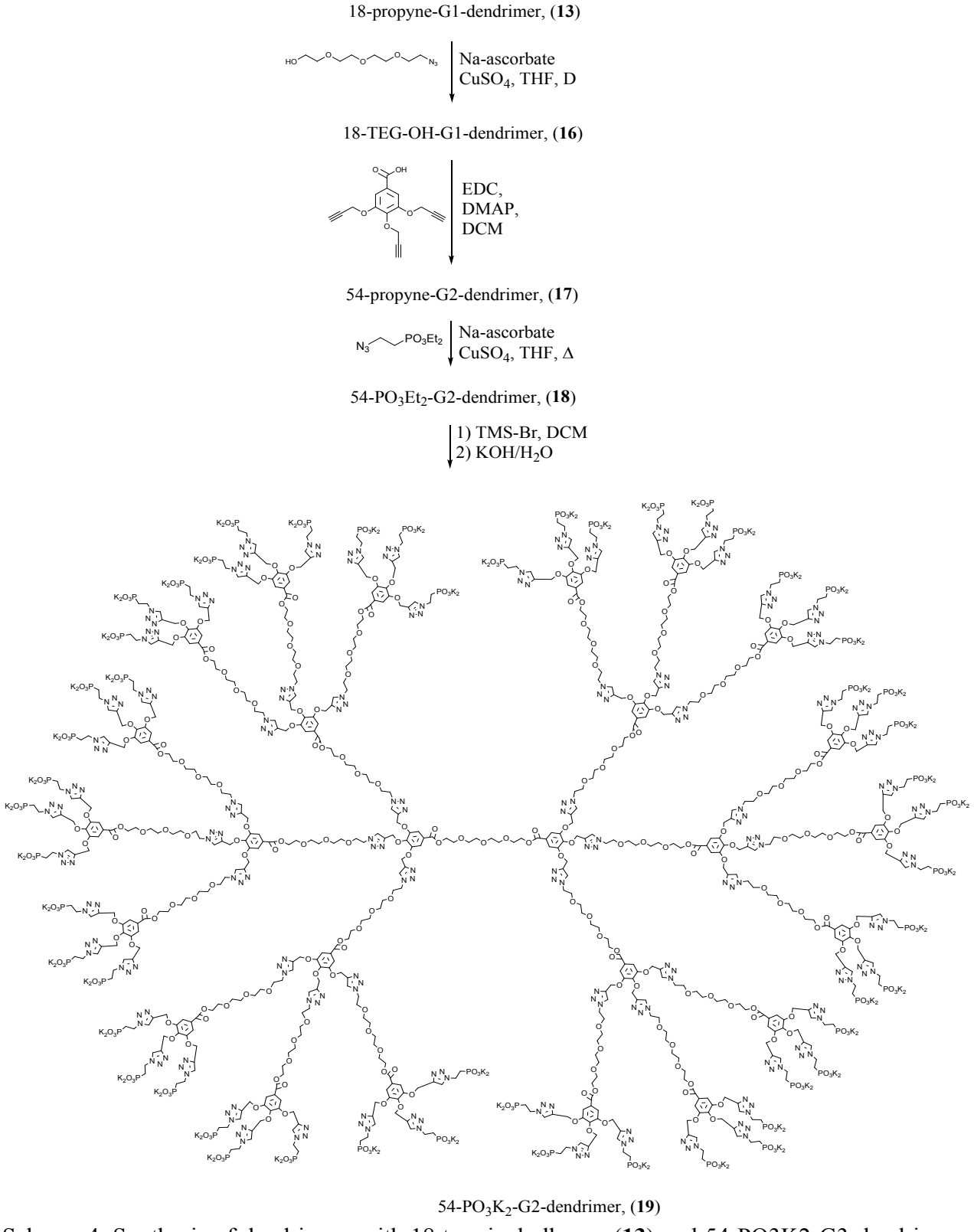
As with the G0 dendrimer, compound **13** can be either functionalized with phosphonate ester to give (**14**) or used as the starting material for the synthesis of the G2 dendrimer with another round of "click" reaction/esterification reactions. Note that for each generation, the number of end-groups triples from 6 to 18 to 54. The diethyl esters phosphonates are first deprotected to form the free phosphonic acid by reacting with TMS-Br, before being turned into phosphonate dipotassium salt by an aqueous KOH treatment.

18-PO_3Et_2-G1-Dendrimer (14)

A solution of $CuSO_4$•$5H_2O$ (0.05 g; 0.20 mmol) in H_2O (0.3 mL) was added to a mixture of **13** (0.34 g; 0.09 mmol), Na-ascorbate (0.07 g; 0.35 mmol), and **8** (0.47 g; 2.27 mmol) in THF (5 mL), and the mixture was stirred for 48 h at 40°C. All volatile components were removed *in vacuo* (including water), and the residue was re-dissolved in DCM (5mL) and stirred with Na-EDTA (about 0.15 g) for 1 h, stirred with Na_2SO_4 for ten minutes, filtered, and most of the DCM was removed using a stream of N_2. Et_2O (about 25 mL) was dropwise added to this solution until the product precipitated as a sticky brown syrup. The Et_2O was decanted, the residue was dissolved in DCM, and the precipitation repeated one additional time. The Et_2O was decanted, and the product was dried under reduced pressure to give 0.31 g (45%) of the product as a sticky, foamy brown material. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (s,s, 24H), 7.39 (s, 16H), 5.20 (s, 48H), 4.71 – 4.38 (m, 62H), 4.15 – 4.01 (m, 72H), 3.90 – 3.47 (m, 86H), 2.59 – 2.26 (m, 36H), 1.39 (t, J = 7.0, 108H). All signals were broad. ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.85, 152.10, 152.03, 144.23, 143.53, 141.63, 125.80, 125.68, 124.53, 124.01, 109.31, 70.57, 69.39, 69.20, 66.30, 64.41, 63.13, 62.35 (d, J_{CP} = 6.5 Hz), 50.34, 44.78, 44.64, 27.14 (d, J_{CP} = 141.7 Hz), 17.27 (d, J_{CP} = 6.0 Hz). ^{31}P NMR (81 MHz, $CDCl_3$) δ 25.64.

18-PO_3K_2-G1-Dendrimer (15)

TMS-Br (0.70 g; 0.6 mL; 4.57 mmol) was added to a solution of **14** (0.30 g; 0.04 mmol) in DCM (7 mL), and the mixture was stirred for 48 h. All the volatile components were removed under reduced pressure, and the residue was re-dissolved in DCM (2 mL). H_2O (2 mL) and $KOH_{(aq)}$ (1.40 mL; 1M) were added and the mixture was stirred for 3 h. The DMC was removed under reduced pressure. The pH was adjusted to 8-9 by the dropwise addition of $KOH_{(aq)}$ (1 M; only a few drops) and the mixture was stirred for additional 1 h. All the volatiles were removed *in vacuo* to give 0.41 g (130%) of the product as a light brown, solid material. Yield was above 100% due to residual water in product. ^{13}C NMR (126 MHz, D_2O) δ 166.63, 151.26, 142.88, 142.74, 142.53, 139.92, 125.28, 124.94, 124.74, 108.64, 72.71, 72.24, 69.69, 69.60, 69.38, 68.50, 68.40, 65.02, 64.51, 62.80, 61.92, 50.03, 46.84, 46.61, 30.07 (d, J_{CP} = 127.0 Hz). ^{31}P NMR (81 MHz, D_2O) δ 16.79. MALDI-TOF MS Calculated $C_{220}H_{272}K_{36}N_{72}O_{115}P_{18}$: 7721.99. Found: 7718.24 (M^-Na^+).



Scheme 4. Synthesis of dendrimers with 18 terminal alkynes (**13**) and 54-PO3K2-G3-dendrimer (**19**).

18-TEG-OH-G1-Dendrimer (16)

A solution of $CuSO_4$•$5H_2O$ (0.13 g; 0.52 mmol) in H_2O (2 mL) was added to a solution of **13** (0.96 g; 0.26 mmol), **3** (1.35 g; 6.16 mmol) and Na-ascorbate (0.20 g; 1.01 mmol) in THF (10 mL), and the mixture was allowed to stir at 40°C (oil bath) for 24 h. Na-EDTA (about 0.50 g) was added and left to stir for 2 h. All the volatile components were removed under reduced pressure (including the water), and the residue was taken up in CH_2Cl_2 (50 mL) and filtered. Most of the CH_2Cl_2 was removed under reduced pressure, and Et_2O was added dropwise to precipitate the product, yielding a brown sticky syrup. The Et_2O was decanted, the residue re-dissolved in CH_2Cl_2, and the precipitation procedure repeated. The product was left *in vacuo* for two days to give 1.69 g (85%) of the product as a brown sticky syrup. ^{1}H NMR (300 MHz, CD_3OD) δ 8.16 (s, 16H), 8.03 (bs, 8H), 7.46 (s,s, 16H), 5.17 (s, ~ 48H), 4.61 – 4.30 (m, ~ 60H), 3.92 – 3.43 (m, ~ 340H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.59, 152.05, 148.42, 130.50, 109.45, 70.49, 69.31, 69.23, 61.49, 56.35, 53.43, 50.45, 50.26. MALDI-TOF MS Calculated $C_{328}H_{506}N_{72}O_{133}$: 7586.03. Found: 7648.08 (M^{2-} K^+/Na^+).

54-propyn-G2-Dendrimer (17)

A mixture of **16** (1.45 g; 0.19 mmol), **6** (1.17 g; 4.12 mmol), DMAP (0.64 g; 5.24 mmol), and EDC•HCl (1.01 g; 5.27 mmol) in DCM (30 mL) was stirred overnight. The reaction mixture was filtered through a plug of silica, and the plug was washed with additional DCM. The product was concentrated under reduced pressure and left *in vacuo* overnight to give 1.69 g (72%) of a sticky, brown foam. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.29 – 7.77 (m, 24H), 7.61 (s, 52H), 5.44 (s, J = 28.5, 48H), 4.61 (s, ~ 108H), 4.60 – 3.36 (m, ~ 400H), 2.64 (s,s, 54H). Very broad peaks. ^{13}C NMR

(126 MHz, $CDCl_3$) δ 165.92, 165.76, 152.14, 151.39, 141.24, 125.81, 125.68, 110.14, 109.45, 78.82, 78.16, 76.59, 75.90, 72.64, 70.82, 70.68, 70.61, 70.47, 70.33, 69.43, 69.26, 64.57, 64.43, 63.30, 61.64, 60.44, 57.27, 50.36.

54-PO_3Et_2-G2-Dendrimer (18)

A solution of $CuSO_4$•$5H_2O$ (0.18 g; 0.72 mmol) in H_2O (2 mL) was added to a mixture of **17** (1.60 g; 0.13 mmol), **8** (1.97 g; 9.51 mmol), and Na-ascorbate (0.28 g; 1.41 mmol) in THF (50 mL) and stirred at 40°C overnight. Na-EDTA (ca 0.5 g) was added and left to stir for 2 h. All solvents were removed under reduced pressure, and the residue left under reduced pressure for 7 h. The residue was taken up in DCM (50 mL) and filtered through a plug of celite with suction. The plug was washed with additional DCM. Most of the DCM was evaporated under reduced pressure, and Et_2O was added dropwise to precipitate the product. The Et_2O was decanted, the product taken up in a small amount of DCM, and the precipitation repeated twice. Following the third decantation, the product was left under reduced pressure overnight to give 1.8 g (59%) of the product as a crispy, brown foam (the product becomes very large under reduced pressure). ^{1}H-NMR confirmed that there were no triple bonds left, and there were very broad peaks. ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.71, 151.96, 125.70, 109.27, 70.51, 69.13, 64.33, 62.20, 44.76, 27.03 (d, J_{CP} = 138.1 Hz), 16.42 (d, J_{CP} = 5.0 Hz). ^{31}P NMR (81 MHz, $CDCl_3$) δ 25.62.

54-PO_3K_2-G2-Dendrimer (19)

TMS-Br (2.32 g; 2.00 mL; 14.67 mmol) was added to a solution of **18** (1.60 g; 0.07 mmol) in DCM (30 mL), and the mixture was stirred overnight. All the volatile components were removed

under reduced pressure, and the residue was re-dissolved in DCM (20 mL). H_2O (10 mL) and $KOH_{(aq)}$ (7 mL, 1 M) were added, and the mixture was stirred for 2 h. The DMC was removed under reduced pressure. The pH was adjusted to 8-9 by the dropwise addition of $KOH_{(aq)}$ (1 M), and the mixture allowed to stirrer for additional 2 h. All the volatiles were removed *in vacuo* to give 2.26 g (135%) of the product as a brown, solid material. Yield was above 100% due to residual water in product. ^{1}H-NMR confirmed that all ethyl groups were removed. ^{13}C NMR (126 MHz, D_2O) δ 166.45, 166.23, 151.24, 150.98, 142.96, 142.68, 142.56, 139.99, 125.42, 124.98, 124.81, 108.70, 108.48, 104.99, 72.71, 72.34, 71.58, 69.76, 69.60, 69.49, 69.34, 69.26, 68.47, 65.06, 64.50, 62.80, 62.32, 61.91, 60.21, 50.06, 46.47, 46.29, 29.65 (d, J_{CP} = 129.6 Hz). ^{31}P NMR (81 MHz, D_2O) δ 17.54. MALDI-TOF MS Calculated $C_{724}H_{902}K_{108}N_{234}O_{367}P_{54}$: 24624.57. Found: 12696.36 (M^{2+})

References

1 M. K. Strulson, D. M. Johnson and J. A. Maurer, *Langmuir*, 2012, **28**, 4318–4324.

2 J. Camponovo, J. Ruiz, E. Cloutet and D. Astruc, *Chem. – A Eur. J.*, 2009, **15**, 2990–3002.

3 M. Bedard, P. K. Avti, T. Lam, L. Rouleau, J.-C. Tardif, E. Rheaume, F. Lesage and A. Kakkar, *J. Mater. Chem. B*, 2015, **3**, 1788–1800.

4 S. H. Yang, D. J. Lee and M. A. Brimble, *Org. Lett.*, 2011, **13**, 5604–5607.