

Synthesis and unimolecular micellar behavior of amphiphilic star-shaped block copolymers obtained via the Passerini three component reaction

S. Oelmann and M. A. R. Meier*

Karlsruhe Institute of Technology (KIT), Institute of Organic Chemistry (IOC),
Straße am Forum 7, 76131 Karlsruhe, Germany
E-mail: m.a.r.meier@kit.edu

SUPPORTING INFORMATION

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1. Materials

The following chemicals were used as received: 10-undecenal ($\geq 90\%$, Aldrich), 3-mercaptopropionic acid ($\geq 99\%$, Aldrich), 2,2-dimethoxy-2-phenylacetophenone (DMPA, 99%, Aldrich), *tert*-butyl isocyanide (98%, Aldrich), benzyl isocyanide (98%, Aldrich), *tert*-butyl 2-isocyanoacetate (98%, Aldrich), trimesic acid (95%, Aldrich), O-Methyl-O-[2-(6-oxocaproylamino)ethyl]polyethylene glycol 2000, (PEG aldehyde 2000, Aldrich), 11-aminoundecanoic acid (97%, Aldrich), methanol (99%, Aldrich), thionyl chloride (97%, Aldrich), trimethyl orthoformate (99%, Aldrich), diisopropyl amine (99%, Aldrich), phosphorus(V) oxychloride (99%, Aldrich), 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD, 98%, Aldrich), poly(ethylene glycol) methyl ether 750 (Methoxy PEG 750, Aldrich), poly(ethylene glycol) methyl ether thiol 800 (PEG thiol 800, Aldrich), Orange II sodium salt (85% dye content, Aldrich), para red (95% dye content, Aldrich), silica gel 60 (0.035–0.070, Aldrich), chloroform-*d* (CDCl_3 , 99.8 atom-% D, euriso-top), methanol-*d*₄ (99.8 atom-% D, euriso-top). All solvents used were of technical grade.

2. Characterization

Thin-layer chromatography (TLC) identification of reactants and products was performed on silica-gel-coated aluminum foil (Aldrich, silica gel 60, F 254 with fluorescence indicator). Compounds were visualized by Seebach reagent (mixture of phosphomolybdic acid, cerium(IV) sulfate, water and sulfuric acid).

NMR spectra were recorded on a Bruker AVANCE DPX spectrometer (measuring frequency: ^1H NMR = 300 MHz, ^{13}C NMR = 75 MHz) or a Bruker AMX R 500 spectrometer (measuring frequency: ^1H -NMR = 500 MHz, ^{13}C NMR = 126 MHz). NMR spectra were obtained using CDCl_3 . All ^1H NMR spectra are reported in ppm relative to the solvent signal for CDCl_3 at 7.26 ppm, ^{13}C NMR spectra are reported relative to the solvent signal for CDCl_3 at 77.16 ppm.

Polymers were characterized on a SEC System LC-20A (Shimadzu) equipped with a SIL-20A autosampler and a RID-10A refractive index detector using THF (flow rate 1 mL/min) at 50 °C. The analysis was performed on the following column system: analytical main-column PSS SDV (5 μ m, 300 mm \times 8.0 mm, 10,000 Å) with a PSS SDV analytical precolumn (5 μ m, 50 mm \times 8.0 mm). For the calibration, narrow linear poly(methyl methacrylate) standards (Polymer Standards Service PPS, Germany) ranging from 1.1 to 981 kDa were used. FAB (fast atom bombardment) mass spectra were recorded on a MAT95 (Finnigan) instrument. Infrared (IR) spectra were recorded on a Bruker alpha-p instrument applying KBr- as well as ATR-technology.

Particle size (d_{DLS}) was obtained using a dynamic light scattering (DLS) instrument (Malvern Instruments, Zeta Sizer Nano S) with a scattering angle of 176.1°. The reported diameter is an intensity-weighted average particle size (z -average), comprised of five to nine measurements analyzed in ten to 20 runs. The reported polydispersity index values (PD_{DLS}) are those given by the instrument and are not conventional PDI values. These PD_{DLS} values are referred to as Malvern polydispersity.

A UV/VIS spectrometer of the type Cary 60 from Agilent Technologies was used to record UV/VIS spectra.

3. Synthetic procedures

Synthesis of AB-type monomer **3** via thiol-ene reaction^{S1}

1.68 g 10-undecenal **1** (10.0 mmol, 1.00 equiv.) and 130 mg DMPA (0.50 mmol, 5.00 mol%) were dissolved in 4.00 mL THF. After purging with argon for 10 minutes, the solution was exposed to UV light (365 nm) for 30 s. Subsequently, 1.17 g 3-mercaptopropionic acid **2** (11.0 mmol, 1.10 equiv.) were slowly added and the reaction mixture was stirred for 2 h under UV irradiation. After evaporating the solvent under reduced pressure, the crude product was purified by silica gel column chromatography (*n*-hexane/ethyl acetate = 3:1 – 1:1) to yield a white solid (2.10 g, 77%). $R_f = 0.30$ (dichloromethane/methanol = 20:1); ^1H NMR (CDCl_3 , 300 MHz): δ (ppm) = 1.21–1.41 (m, 12 H, 6 CH_2), 1.51–1.69 (m, 4 H, 2 CH_2), 2.42 (td, $J = 7.3, 1.7$ Hz, 2 H, CH_2CHO), 2.53 (t, $J = 7.3$ Hz, 2 H, CH_2S), 2.61–2.70 (m, 2 H, CH_2COOH), 2.73–2.82 (m, 2 H, SCH_2), 9.76 (t, $J = 1.8$ Hz, 1 H, CHO); ^{13}C NMR (CDCl_3 , 75 MHz): δ (ppm) = 22.13, 26.67, 28.88, 29.20, 29.22, 29.37, 29.39, 29.47, 29.56, 32.25, 34.78, 178.12, 203.31; FAB of $[\text{C}_{14}\text{H}_{26}\text{O}_3\text{S}]^+ = 275.1$; HRMS (FAB) of $[\text{C}_{14}\text{H}_{26}\text{O}_3\text{S}]^+$ calc. 275.1681, found 275.1680; IR (KBr) $\nu = 2914.7, 2847.2, 2742.6, 1708.0, 1684.7, 1466.7, 1407.2, 1338.2, 1263.9, 1197.5, 1064.0, 915.4, 894.3, 761.7, 737.7, 721.1, 696.0, 660.8, 490.5\text{ cm}^{-1}$.

Synthesis of star-shaped homopolymers **P1**, **P2** and **P3** via Passerini reaction^{S1}

General procedure: To a vigorously stirred solution of trimesic acid **4** (1.00 equiv.) and *tert*-butyl isocyanide **5** (75.0 equiv., 150 equiv) in 1.50 mol/L THF, AB-type monomer **3** (15.0 equiv., 30.0 equiv.) in 0.50 mL DCM was added slowly. After stirring for 24 hours at room temperature, the polymer was precipitated from ice-cold diethyl ether.

Following the aforementioned procedure, **P1** was obtained as white solid (93 %). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.22–1.30 (m, 840 H, 420 CH₂), 1.32–1.36 (m, 540 H, *t*-Bu), 1.53–1.61 (m, 120 H, 60 CH₂CH₂S), 1.75–1.87 (m, 120 H, 60 CHCH₂), 2.53 (t, *J* = 7.5 Hz, 120 H, 60 CH₂S), 2.66–2.72 (m, 120 H, 60 SCH₂), 2.77–2.85 (m, 120 H, 60 CH₂COO), 5.04–5.11 (m, 60 H, OCH(CO)), 6.06–6.16 (m, 60 H, NH), 8.89–8.91 (m, 3 H, Ar-H).

Following the aforementioned procedure, **P2** was obtained as white solid (93%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.22–1.30 (m, 420 H, 210 CH₂), 1.32–1.36 (m, 270 H, *t*-Bu), 1.53–1.61 (m, 60 H, 30 CH₂CH₂S), 1.75–1.87 (m, 60 H, 30 CHCH₂), 2.53 (t, *J* = 7.5 Hz, 60 H, 30 CH₂S), 2.66–2.72 (m, 60 H, 30 SCH₂), 2.77–2.85 (m, 60 H, 30 CH₂COO), 5.04–5.11 (m, 30 H, OCH(CO)), 6.06–6.16 (m, 30 H, NH), 8.89–8.91 (m, 3 H, Ar-H).

Following the aforementioned procedure, **P3** was obtained as white solid (95%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.20–1.33 (m, 210 H, 105 CH₂), 1.31–1.36 (m, 135 H, *t*-Bu), 1.55–1.64 (m, 30 H, 15 CH₂CH₂S), 1.71–1.83 (m, 30 H, 15 CHCH₂), 2.53 (t, *J* = 7.4 Hz, 30 H, 15 CH₂S), 2.65–2.72 (m, 30 H, 15 SCH₂), 2.77–2.86 (m, 30 H, 15 CH₂COO), 5.00–5.09 (m, 15 H, OCH(CO)), 6.05–6.16 (m, 15 H, NH), 8.88–8.91 (m, 3 H, Ar-H).

Synthesis of PEG isocyanide **9**

11-Methoxy-11-oxoundecan-1-aminium chloride **13**^{S2}

10.0 g 11-aminoundecanoic acid **11** (50.0 mmol, 1.00 equiv.) were suspended in 75.0 mL methanol **12** (1.875 mol, 37.5 equiv.), acting as solvent and reactant. The suspension was cooled in an ice bath and subsequently 11.2 mL thionyl chloride (18.4 g, 0.155 mol, 3.10 equiv.) were added dropwise at 0 °C. After addition of the thionyl chloride, the solution was warmed to room temperature and stirred overnight. The yellow solution was then poured into 350 mL diethyl ether and stored in the freezer overnight. The product was then filtered off and dried under high

vacuum. 11-(Methoxy)-11-oxoundecan-1-aminium chloride **13** was obtained as a white solid (10.0 g, 80%). ^1H NMR (CD_3OD , 300 MHz) δ (ppm) = 1,21–1,45 (m, 12 H, 6 CH_2), 1,47–1,71 (m, 4 H, 2 CH_2), 2,30 (t, J = 7,4 Hz, 2 H, CH_2), 2,90 (t, J = 7,5 Hz, 2 H, CH_2), 3,56–3,63 (m, 3 H, CH_3); ^{13}C NMR (CD_3OD , 75 MHz) δ (ppm): 26.0, 27.4, 28.5, 30.1, 30.2, 30.3, 30.4, 30.4, 34.8, 40.8, 52.0, 176.0; FAB of $[\text{C}_{12}\text{H}_{26}\text{NO}_2]^+$ = 216.2; HRMS (FAB) of $[\text{C}_{12}\text{H}_{26}\text{NO}_2]^+$ calc. 216.1958, found 216.1956; IR (KBr) ν = 2918.6, 2848.1, 1722.4, 1561.0, 1510.4, 1467.9, 1443.6, 1375.6, 1334.0, 1306.1, 1276.8, 1245.0, 1210.6, 1174.5, 1097.3, 1001.1, 970.7, 938.2, 885.7, 723.3, 425.6 cm^{-1} .

Methyl 11-formamidoundecanoate **15^{S2}**

9.80 g 11-(methoxy)-11-oxoundecan-1-aminium chloride **13** (0.039 mol, 1.00 equiv.) were dissolved in 43.0 ml trimethyl orthoformate **14** (41.4 g, 0.39 mol, 10.0 eq.), which is used as solvent and reactant and heated to 100 °C for 12 hours. Trimethyl orthoformate was removed under reduced pressure and the product was used without further purification. Methyl 11-formamidoundecanoate **15** was obtained as a white solid (9.55 g, quant.). ^1H NMR (CDCl_3 , 300 MHz) δ (ppm) = 1,16–1,40 (m, 12 H, 6 CH_2), 1,42–1,70 (m, 4 H, 2 CH_2), 2,28 (t, J = 7,5 Hz, 2 H, CH_2), 3,16–3,35 (m, 2 H, CH_2), 3,66 (s, 3 H, CH_3), 5,71 (s, 1 H, NH), 8,01–8,28 (m, 1 H, OCH); ^{13}C NMR (CDCl_3 , 75 MHz) δ (ppm): 25.0, 26.5, 26.9, 29.2, 29.3, 29.4, 29.5, 29.6, 34.2, 38.3, 51.6, 161.3, 174.5; FAB of $[\text{C}_{13}\text{H}_{26}\text{NO}_3]^+$ = 244.2; HRMS (FAB) of $[\text{C}_{13}\text{H}_{26}\text{NO}_3]^+$ calc. 244.1907, found 244.1906; IR (KBr) ν = 3255.9, 2914.8, 2848.0, 1734.9, 1682.5, 1637.3, 1534.4, 1462.8, 1435.5, 1378.3, 1334.1, 1300.6, 1268.2, 1226.0, 1203.7, 1168.0, 1113.0, 1070.0, 1002.0, 980.5, 883.3, 720.7, 518.7, 449.4, 380.1 cm^{-1} .

Methyl 11-isocyanoundecanoate **17^{S2}**

9.55 g methyl 11-formamidoundecanoate **15** (0.039 mol, 1.00 equiv.) were dissolved in 120 mL dichloromethane (0.33 M), 17.2 mL diisopropylamine **16** (12.4 g, 0.122 mol, 3.10 equiv.) were

added and the reaction mixture was cooled to 0 °C. Subsequently, 4.77 mL phosphorous oxy chloride (7.82 g, 0.051 mmol, 1.30 equiv.) were added dropwise and the reaction mixture was stirred at room temperature for two hours. The reaction was quenched by addition of sodium carbonate solution (20 %, 75.0 mL) at 0 °C. After stirring this mixture for 30 minutes, 50.0 mL water and 50.0 mL dichloromethane were added. The aqueous phase was separated and the organic layer was washed with brine (4 × 80.0 mL). The combined organic layers were dried over sodium sulfate and the solvent was evaporated under reduced pressure. The crude product was then purified by column chromatography (hexane / ethyl acetate 19:1 – 8:1). Methyl 11-isocyanoundecanoate **17** was obtained as slightly yellow oil (4.30g, 52%). $R_f = 0.49$ (hexane/ethylacetate = 5:1); ^1H NMR (CDCl_3 , 300 MHz) δ (ppm) = 1,18–1,50 (m, 12 H, 6 CH_2), 1,52–1,75 (m, 4 H, 2 CH_2), 2,29 (t, $J = 7,5$ Hz, 2 H, CH_2), 3,30–3.43 (m, 2 H, CH_2), 3,66 (s, 3 H, CH_3); ^{13}C NMR (CDCl_3 , 75 MHz) δ (ppm): 24.9, 26.3, 28.6, 29.1, 29.1, 29.2, 34.0, 41.4, 41.5, 41.5, 51.4, 155.7, 174.2; FAB of $[\text{C}_{13}\text{H}_{22}\text{NO}_2]^- = 224.2$; HRMS (FAB) of $[\text{C}_{13}\text{H}_{22}\text{NO}_2]^-$ calc. 224.1645, found 224.1644; IR (KBr) $\nu = 2925.0, 2854.2, 2146.0$ (isocyanide), 1735.0, 1435.6, 1352.7, 1194.4, 1169.1, 1103.9, 1010.8, 850.2, 722.1 cm^{-1} .

PEG isocyanide **9**

3.00 g poly(ethylene glycol) methyl ether **18** (4.00 mmol, 1.00 equiv., 750 g/mol) and 4.50 g methyl 11-isocyanoundecanoate **17** (20.0 mmol, 5.00 equiv.) were placed and 28.0 mg TBD (0.20 mmol, 5.00 mol%) were added and the reaction mixture was distilled at 100 °C for 3 days (a continuous air flow was bubbled through the solution to remove the resulting methanol from the reaction mixture). Afterwards, the polymer was precipitated from ice-cold diethyl ether to obtain a yellow solid (1.85 g 50 %). ^1H NMR (CDCl_3 , 300 MHz) δ (ppm) = 1,19–1,47 (m, 12 H, 6 CH_2), 1,49–1,71 (m, 4 H, 2 CH_2), 2,29 (t, $J = 7,5$ Hz, 2 H, CH_2), 3,27–3.41 (m, 5 H, CH_2 , CH_3), 3,49–3.67 (m, 66 H, 33 PEG- CH_2), 4.18 (t, $J = 4,8$ Hz, 2 H, OCOCH_2).

Synthesis of PEG aldehyde **10**

316 mg 10-undecenal **1** (1.875 mmol, 2.00 equiv.) and 12.0 mg DMPA (0.047 mmol, 5.00 mol%) were placed in a quartz tube and dissolved in 0.50 mL THF. Then, the tube was purged with argon for 10 min and afterwards the solution was exposed to UV light (365 nm) for 30 s. Subsequently, 750 mg PEG thiol **19** (0.9375 mmol, 1.00 equiv., 800 g/mol) dissolved in 0.40 mL THF were added. The reaction mixture was stirred for 24 h under UV irradiation. Afterwards, the product was precipitated from ice-cold diethyl ether to obtain a white solid (610 mg, 70%). ¹H NMR (CDCl₃, 300 MHz) δ (ppm) = 1,17–1,41 (m, 12 H, 6 CH₂), 1,47–1,68 (m, 4 H, 2 CH₂), 2,34–2,46 (m, 2 H, CH₂), 2,47–2,58 (m, 2 H, CH₂), 2,63–2,78 (m, 2 H, CH₂), 3,37 (s, 3 H, CH₃), 3,48–3,57 (m, 2 H, CH₂), 3,58–3,71 (m, 60 H, 30 PEG-CH₂), 9,75 (s, 1 H, OCH).

Synthesis of functionalized star-shaped polymers

Star-shaped polymer **P4**, **P5** and **P6** (10 repeating units, 1 PEG 2000 g/mol) using different isocyanides

General procedure: To a vigorously stirred solution of star-shaped polymer **P2** (1.00 equiv.) and PEG aldehyde (2000 g/mol) **8** (3.00 equiv.) in 0.05 mol/L DCM, *tert*-butyl isocyanide **5**, benzyl isocyanide **6** or *tert*-butyl 2-isocynoacetate **7** (15.0 equiv.) were added slowly. After stirring for 72 hours at room temperature, the polymer was precipitated from diethyl ether.

Following the aforementioned procedure, **P4** was obtained as white solid (94%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.12–1.31 (m, 420 H, 210 CH₂), 1.32–1.41 (m, 297 H, *t*-Bu), 1.46–1.66 (m, 72 H, 30 CH₂CH₂S, 3 CH₂CH₂CONH, 3 CH₂CH₂CHO), 1.72–1.90 (m, 60 H, 30 CHCH₂), 1.93–2.01 (m, 6 H, 3 CH₂CONH), 2.13–2.21 (m, 6 H, 3 CH₂CHO), 2.53 (t, *J* = 7.4 Hz, 60 H, 30 CH₂S), 2.65–2.75 (m, 60 H, 30 SCH₂), 2.77–2.86 (m, 60 H, 30 CH₂COO), 3.36 (s, 3 H, CH₃), 3.46–3.50 (m, 12 H, 3 OCH₂, 3 NHCH₂), 3.59–3.69 (m, 492 H, 246 PEG-CH₂), 5.03–5.25 (m, 33 H, OCH(CO)), 5.81–6.10 (m, 33 H, NH), 8.88–8.92 (m, 3 H, Ar-H).

Following the aforementioned procedure, **P5** was obtained as yellow solid (89%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.17–1.30 (m, 420 H, 210 CH₂), 1.31–1.36 (m, 270 H, *t*-Bu), 1.47–1.67 (m, 72 H, 30 CH₂CH₂S, 3 CH₂CH₂CONH, 3 CH₂CH₂CHO), 1.68–1.90 (m, 60 H, 30 CHCH₂), 1.92–2.01 (m, 6 H, 3 CH₂CONH), 2.10–2.23 (m, 6 H, 3 CH₂CHO), 2.53 (t, *J* = 7.4 Hz, 60 H, 30 CH₂S), 2.65–2.75 (m, 60 H, 30 SCH₂), 2.76–2.88 (m, 60 H, 30 CH₂COO), 3.37 (s, 3 H, CH₃), 3.45–3.49 (m, 12 H, 3 OCH₂, 3 NHCH₂), 3.58–2.68 (m, 492 H, 246 PEG-CH₂), 5.03–5.26 (m, 33 H, OCH(CO)), 5.80–6.13 (m, 33 H, NH), 7.21–7.43 (m, 15 H, Ar_{benzyl}-H), 8.88–8.92 (m, 3 H, Ar-H).

Following the aforementioned procedure, **P6** was obtained as white solid (91%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.17–1.31 (m, 420 H, 210 CH₂), 1.32–1.37 (m, 297 H, *t*-Bu), 1.53–1.64 (m, 72 H, 30 CH₂CH₂S, 3 CH₂CH₂CONH, 3 CH₂CH₂CHO), 1.74–1.90 (m, 60 H, 30 CHCH₂), 1.92–2.04 (m, 12 H, 3 CH₂CONH, 3 NHCH₂CO), 2.14–2.22 (m, 6 H, 3 CH₂CHO), 2.54 (t, *J* = 7.4 Hz, 60 H, 30 CH₂S), 2.66–2.74 (m, 60 H, 30 SCH₂), 2.78–2.87 (m, 60 H, 30 CH₂COO), 3.38 (s, 3 H, CH₃), 3.45–3.51 (m, 12 H, 3 OCH₂, 3 NHCH₂), 3.56–3.73 (m, 492 H, 246 PEG-CH₂), 5.04–5.23 (m, 33 H, OCH(CO)), 5.82–6.14 (m, 33 H, NH), 8.89–8.92 (m, 3 H, Ar-H).

Star-shaped polymer **P7** (5 repeating units, 1 PEG 2000 g/mol)

General procedure: To a vigorously stirred solution of star-shaped polymer **P3** (1.00 equiv.) and PEG aldehyde (2000 g/mol) **8** (3.00 equiv.) in 0.05 mol/l DCM, *tert*-butyl isocyanide **5**, (15.0 equiv.) was added slowly. After stirring for 72 hours at room temperature, the polymer was precipitated from diethyl ether.

Following the aforementioned procedure, **P7** was obtained as white solid (85%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.17–1.31 (m, 210 H, 105 CH₂), 1.32–1.41 (m, 162 H, *t*-Bu), 1.49–1.66 (m, 42 H, 15 CH₂CH₂S, 3 CH₂CH₂CONH, 3 CH₂CH₂CHO), 1.72–1.88 (m, 30 H, 15 CHCH₂), 1.93–2.00 (m, 6 H, 3 CH₂CONH), 2.12–2.21 (m, 6 H, 3 CH₂CHO), 2.52 (t, *J* = 7.4 Hz, 30 H, 15 CH₂S), 2.63–2.74 (m, 30 H, 15 SCH₂), 2.76–2.85 (m, 30 H, 15 CH₂COO), 3.37 (s, 3 H, CH₃), 3.50–3.56 (m, 12 H, 3 OCH₂, 3 NHCH₂), 3.58–3.68 (m, 492 H, 246 PEG-CH₂), 5.02–5.23 (m, 18 H, OCH(CO)), 5.78–6.13 (m, 18 H, NH), 8.87–8.92 (m, 3 H, Ar-H).

Star-shaped polymer P8 (5 repeating units, 1 PEG 950 g/mol)

General procedure: To a vigorously stirred solution of star-shaped polymer **P3** (1.00 equiv.) and PEG aldehyde (950 g/mol) **10** (3.00 equiv.) in 0.05 mol/l DCM, *tert*-butyl isocyanide **5**, (15.0 equiv.) was added slowly. After stirring for 72 hours at room temperature, the polymer was precipitated from diethyl ether.

Following the aforementioned procedure, **P8** was obtained as white solid (74%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.14–1.31 (m, 252 H, 126 CH₂), 1.32–1.40 (m, 162 H, *t*-Bu), 1.48–1.61 (m, 36 H, 18 CH₂CH₂S), 1.68–1.90 (m, 36 H, 18 CHCH₂), 2.52 (t, *J* = 7.4 Hz, 36 H, 18 CH₂S), 2.63–2.74 (m, 36 H, 18 SCH₂), 2.76–2.88 (m, 36 H, 15 CH₂COO, 3 CH₂O), 3.37 (s, 3 H, CH₃), 3.59–3.70 (m, 180 H, 90 PEG-CH₂), 5.02–5.23 (m, 18 H, OCH(CO)), 5.78–6.13 (m, 18 H, NH), 8.88–8.91 (m, 3 H, Ar-H).

Star-shaped polymer P9 (5 repeating units, 2 PEG a 950 g/mol)

General procedure: Star-shaped polymer **P3** (1.00 equiv.), PEG aldehyde (950 g/mol) **10** (3.00 equiv.) and PEG isocyanide **9** (950 g/mol) X (3.00 equiv.) were dissolved in 0.05 mol/l DCM. After 24 hours at room temperature PEG aldehyde (950 g/mol) **10** (3.00 equiv.) and PEG

isocyanide **9** (950 g/mol) X (3.00 equiv.) were added again and precipitated from diethyl ether after 72 hours.

Following the aforementioned procedure, **P9** was obtained as slightly yellow solid (78%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.16–1.29 (m, 300 H, 150 CH₂), 1.30–1.42 (m, 135 H, *t*-Bu), 1.46–1.66 (m, 36 H, 18 CH₂CH₂S), 1.67–1.90 (m, 36 H, 18 CHCH₂), 2.27–2.32 (m, 6 H, 3 CH₂COO), 2.51 (m, *J* = 7.4 Hz, 36 H, 18 CH₂S), 2.60–2.73 (m, 36 H, 18 SCH₂), 2.74–2.86 (m, 36 H, 15 CH₂COO, 3 CH₂O), 3.35 (s, 3 H, CH₃), 3.54–3.77 (m, 378 H, 189 PEG-CH₂), 4.13–4.24 (m, 6 H, 3 NHCH₂), 4.97–5.26 (m, 18 H, OCH(CO)), 5.75–6.16 (m, 18 H, NH), 8.83–8.92 (m, 3 H, Ar-H).

Star-shaped polymer P10 (10 repeating units, 2 PEG a 950 g/mol)

General procedure: Star-shaped polymer **P2** (1.00 equiv.), PEG aldehyde (950 g/mol) **10** (3.00 equiv.) and PEG isocyanide **9** (950 g/mol) X (3.00 equiv.) were dissolved in 0.05 mol/l DCM. After 24 hours at room temperature PEG aldehyde (950 g/mol) **10** (3.00 equiv.) and PEG isocyanide **9** (950 g/mol) X (3.00 equiv.) were added again and precipitated from diethyl ether after 72 hours.

Following the aforementioned procedure, **P10** was obtained as slightly yellow solid (80%). ¹H NMR (CDCl₃, 300 MHz): δ (ppm) = 1.17–1.30 (m, 510 H, 255 CH₂), 1.31–1.41 (m, 270 H, *t*-Bu), 1.47–1.66 (m, 66 H, 33 CH₂CH₂S), 1.74–1.93 (m, 66 H, 33 CHCH₂), 2.24–2.36 (m, 6 H, 3 CH₂COO), 2.52 (m, *J* = 7.4 Hz, 66 H, 33 CH₂S), 2.63–2.73 (m, 66 H, 33 SCH₂), 2.74–2.85 (m, 66 H, 30 CH₂COO, 3 CH₂O), 3.36 (s, 3 H, CH₃), 3.58–3.66 (m, 378 H, 189 PEG-CH₂), 4.14–4.24 (m, 6 H, 3 NHCH₂), 5.01–5.26 (m, 18 H, OCH(CO)), 5.78–6.16 (m, 18 H, NH), 8.88–8.92 (m, 3 H, Ar-H).

4. Relevant ^1H NMR spectra

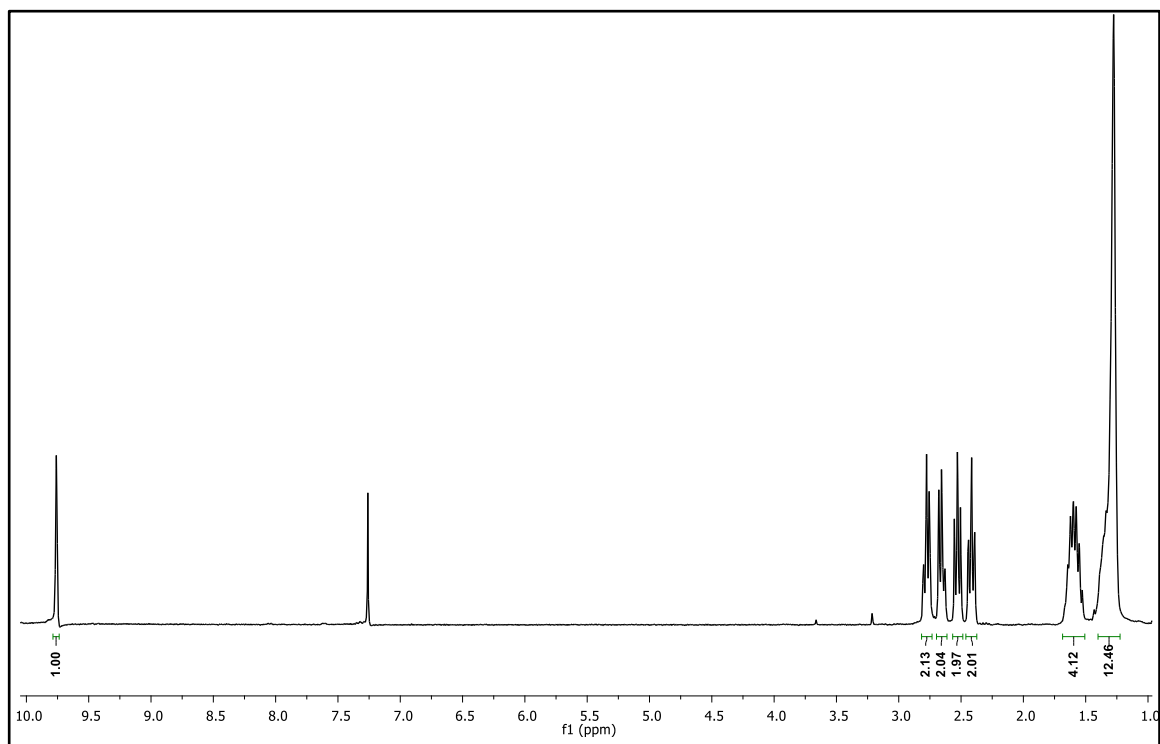


Figure S1: Integrated ^1H NMR spectrum of AB-type monomer **3**.

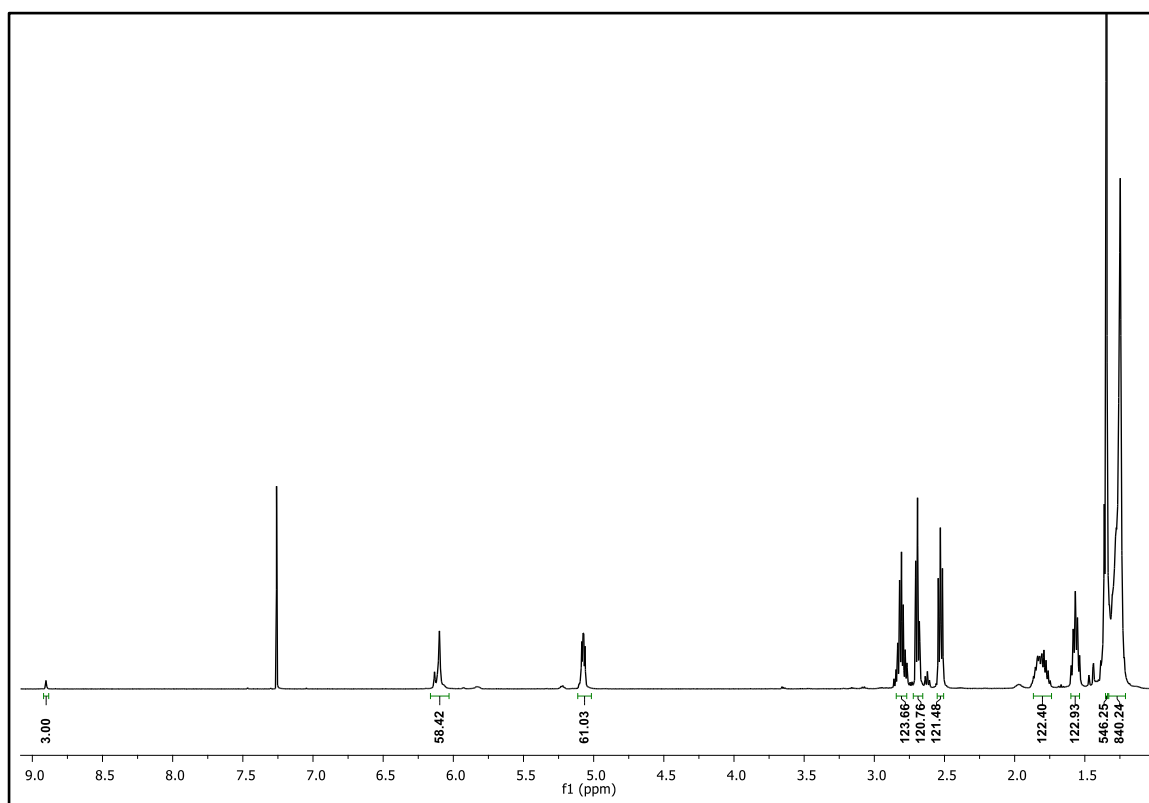


Figure S2: Integrated ^1H NMR spectrum of star-shaped polymer **P1** (20 repeating units).

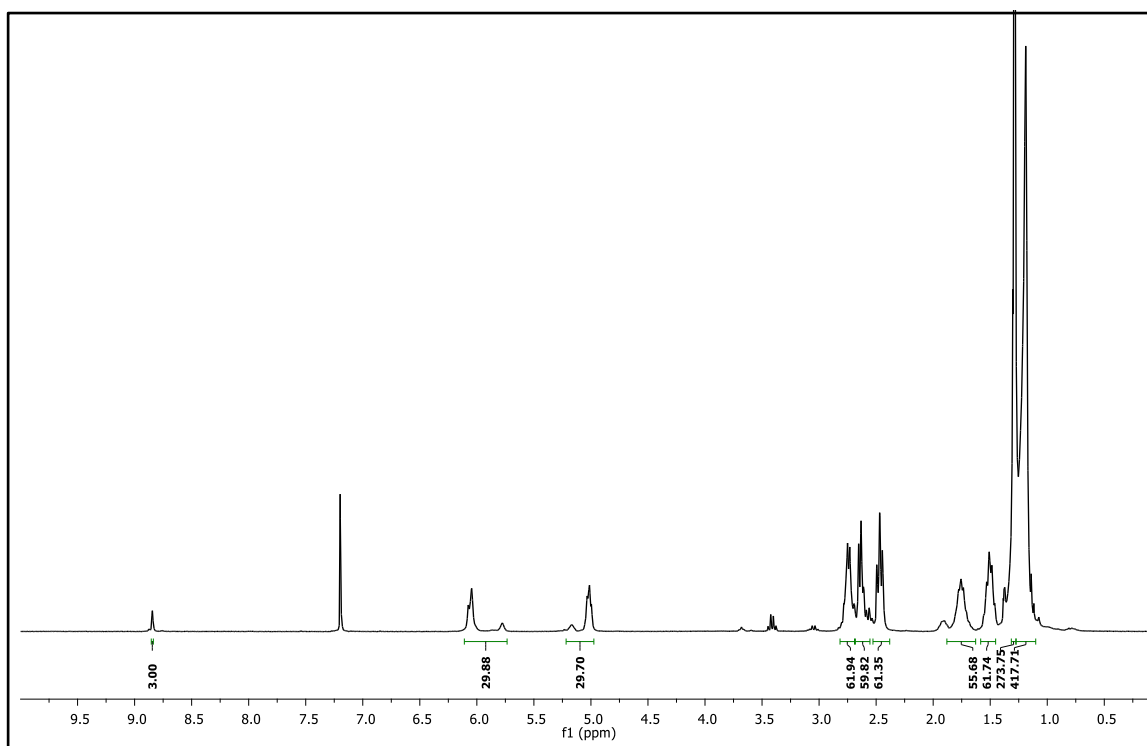


Figure S3: Integrated ^1H NMR spectrum of star-shaped polymer **P2** (10 repeating units).

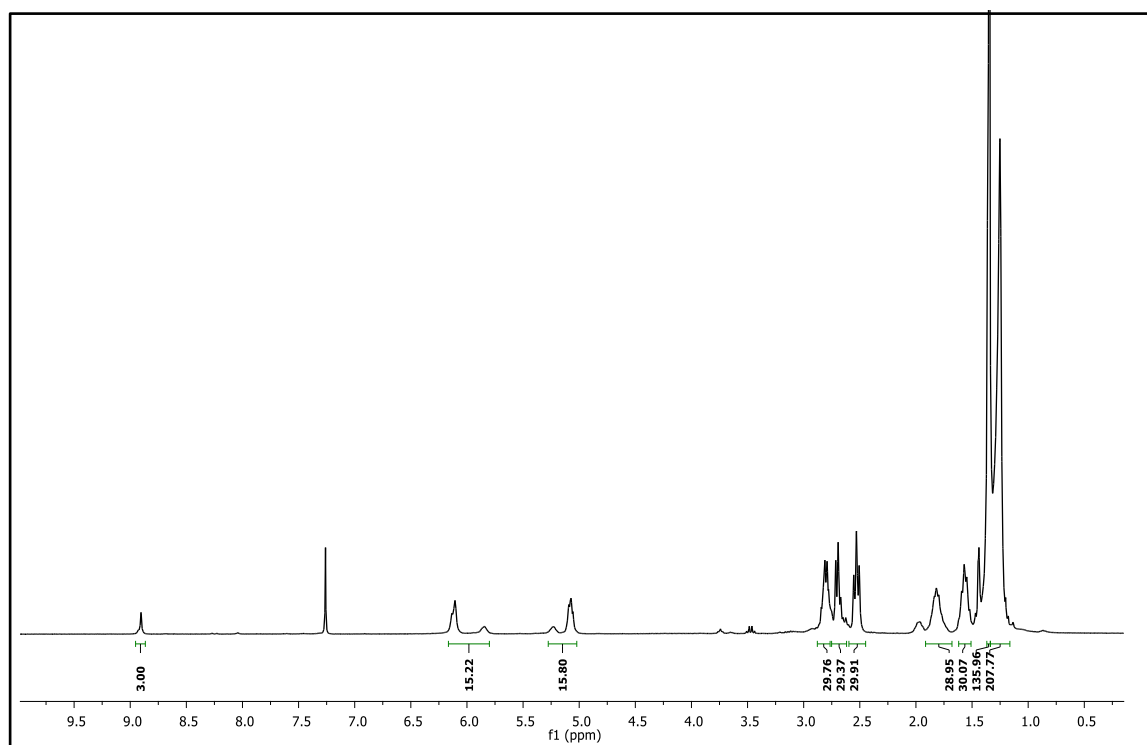


Figure S4: Integrated ^1H NMR spectrum of star-shaped polymer **P3** (5 repeating units).

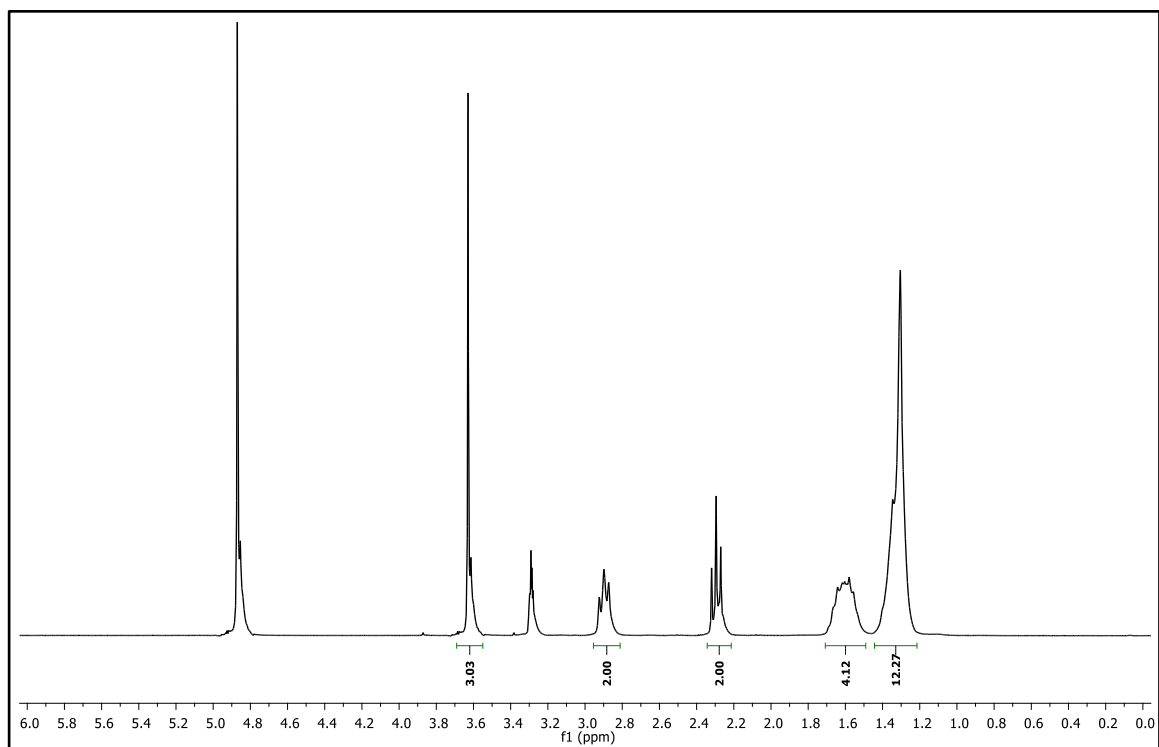


Figure S5: Integrated ^1H NMR spectrum of 11-Methoxy-11-oxoundecan-1-aminium chloride **13**.

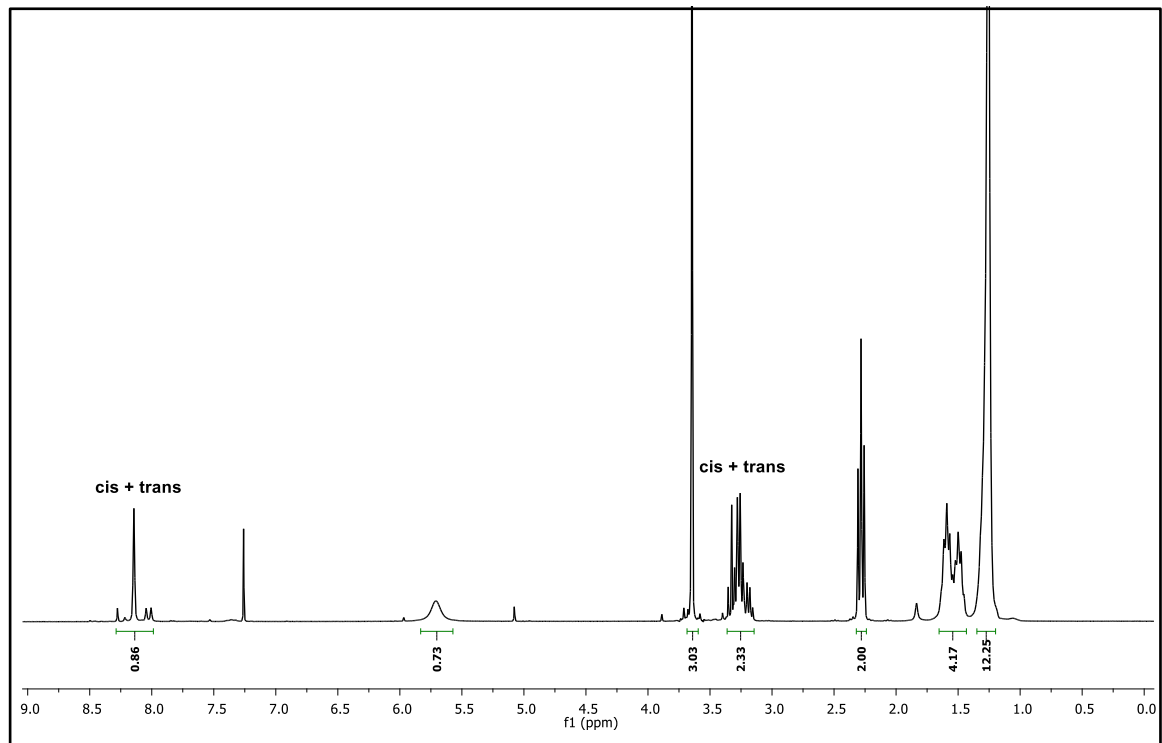


Figure S6: Integrated ^1H NMR spectrum of Methyl 11-formamidoundecanoate **15**.

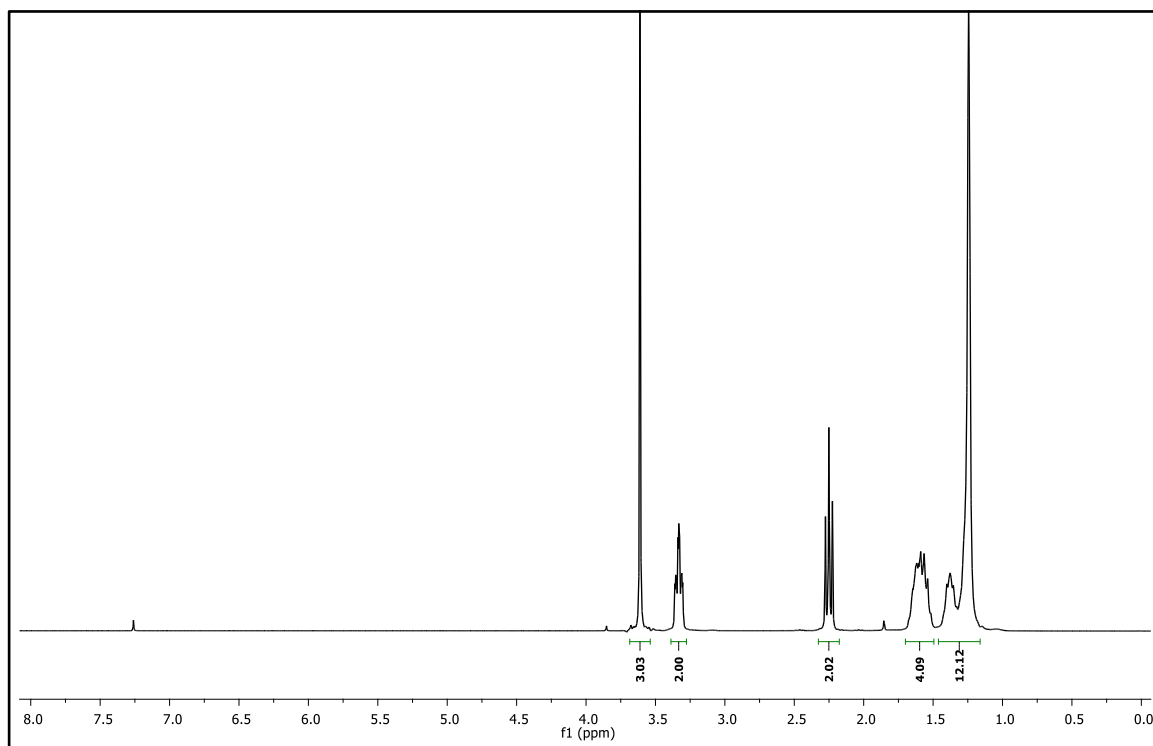


Figure S7: Integrated ^1H NMR spectrum of Methyl 11-isocyanoundecanoate **17**.

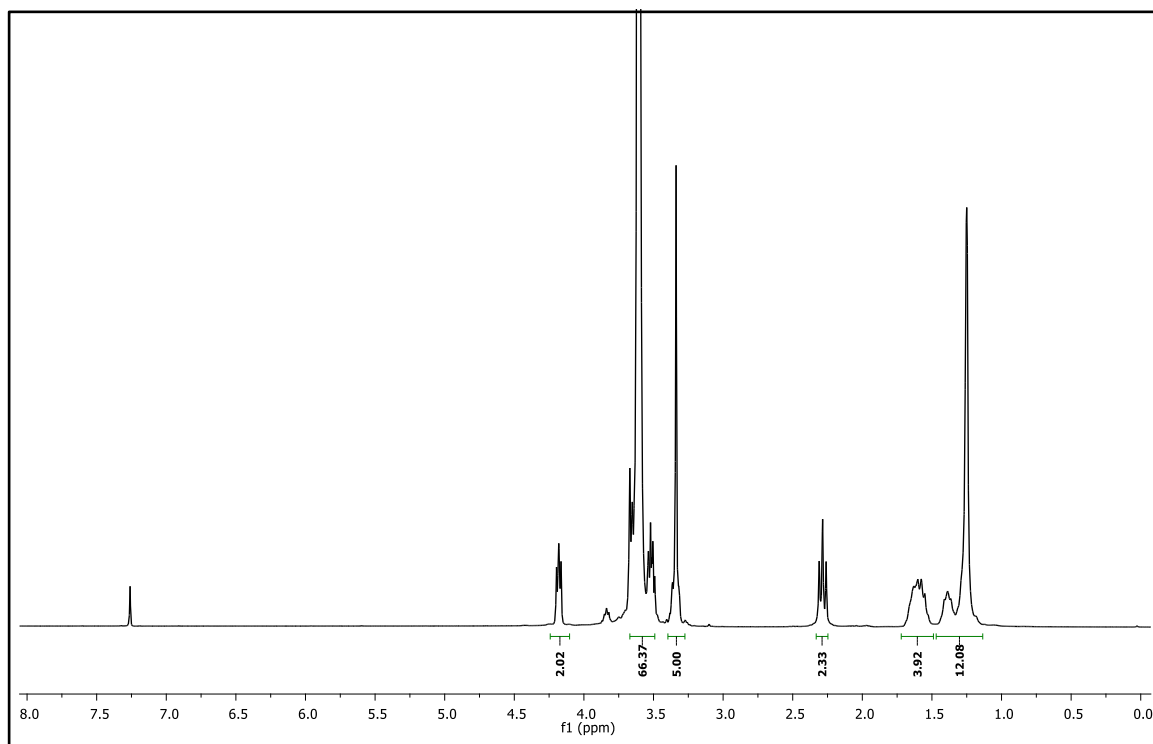


Figure S8: Integrated ^1H NMR spectrum of PEG isocyanide **9** (950 g/mol).

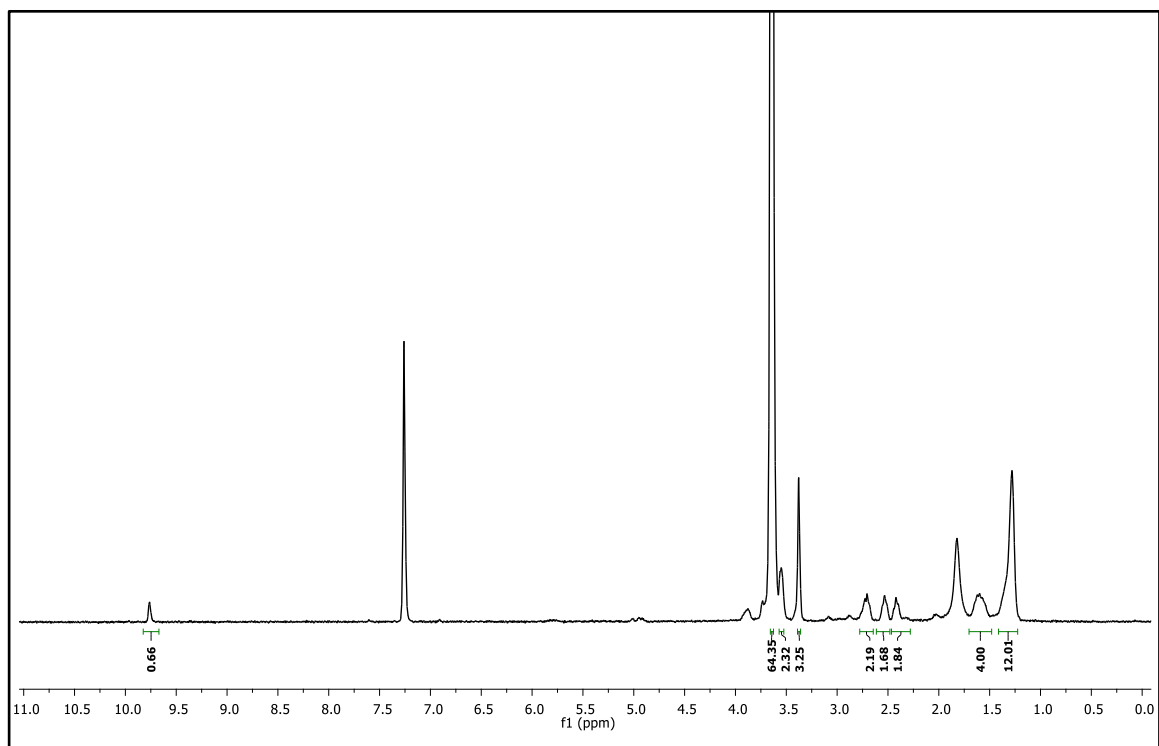


Figure S9: Integrated ^1H NMR spectrum of PEG aldehyde **10** (950 g/mol).

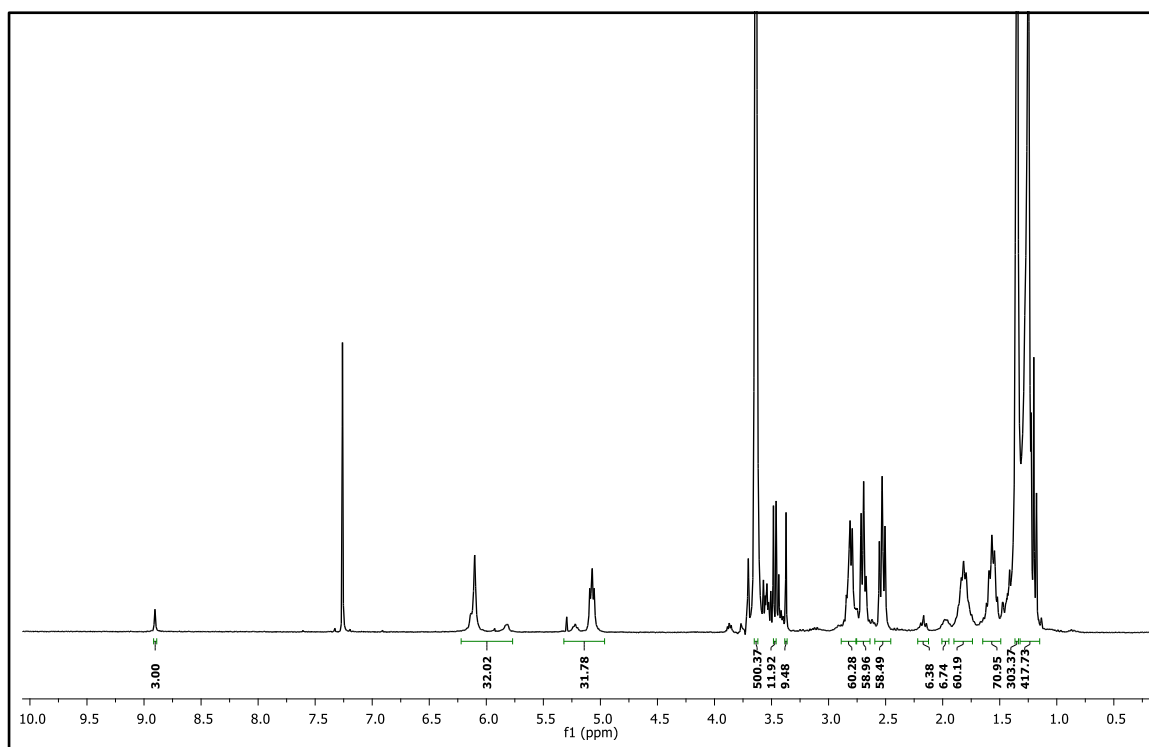


Figure S10: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P4** (10 repeating units, 1 PEG 2000 g/mol).

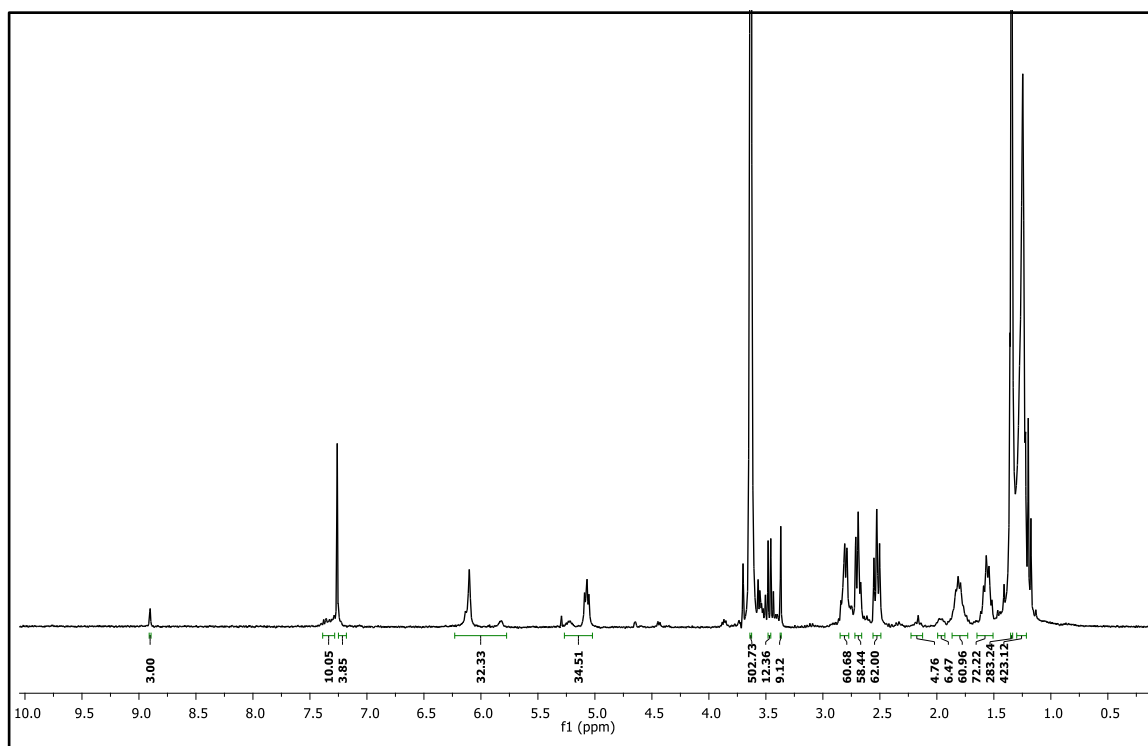


Figure S11: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P5** (10 repeating units, 1 PEG 2000 g/mol).

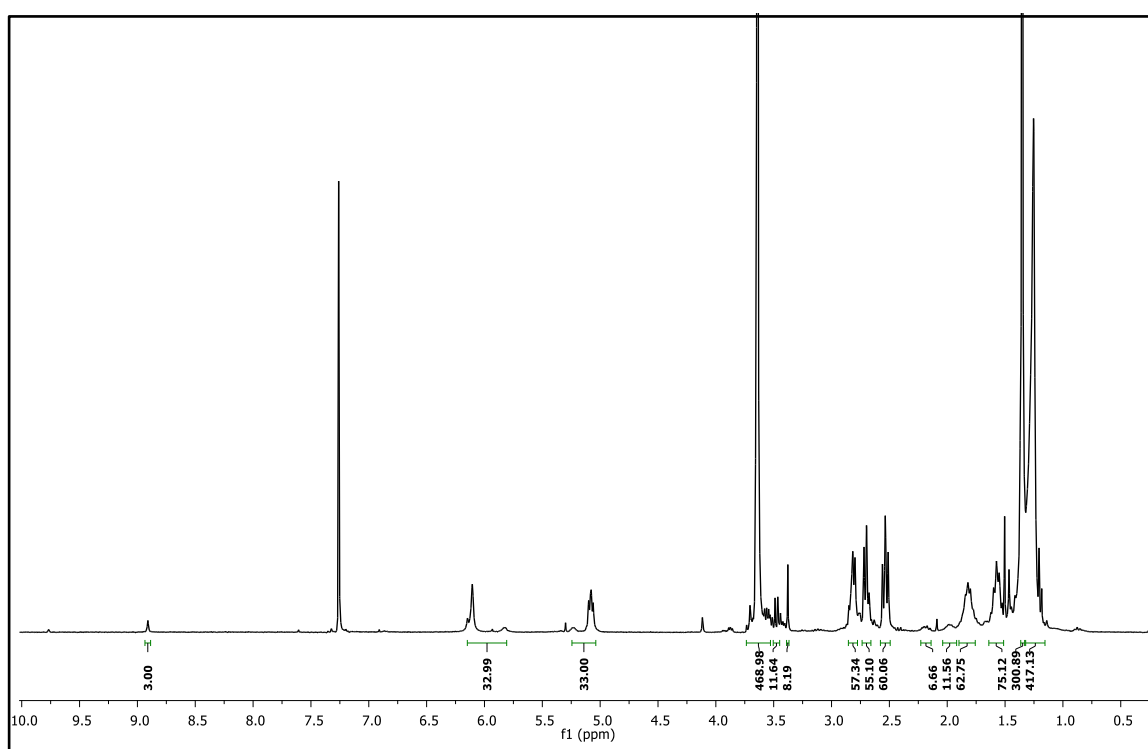


Figure S12: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P6** (10 repeating units, 1 PEG 2000 g/mol).

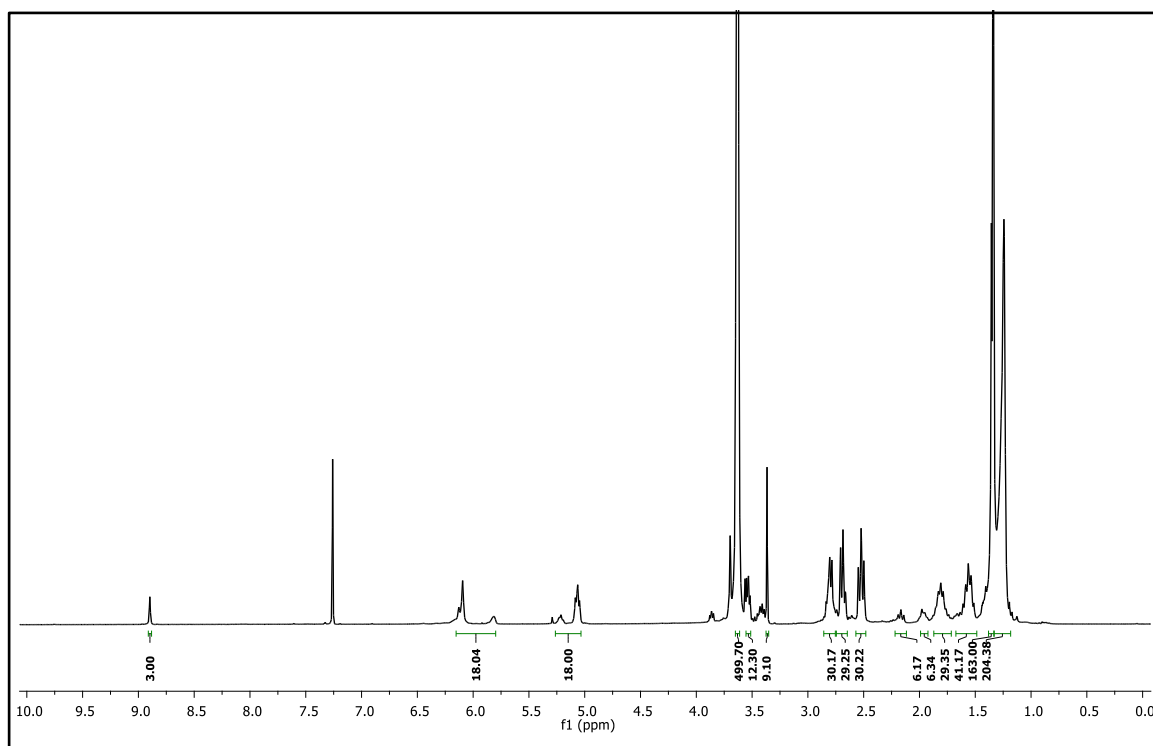


Figure S13: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P7** (5 repeating units, 1 PEG 2000 g/mol).

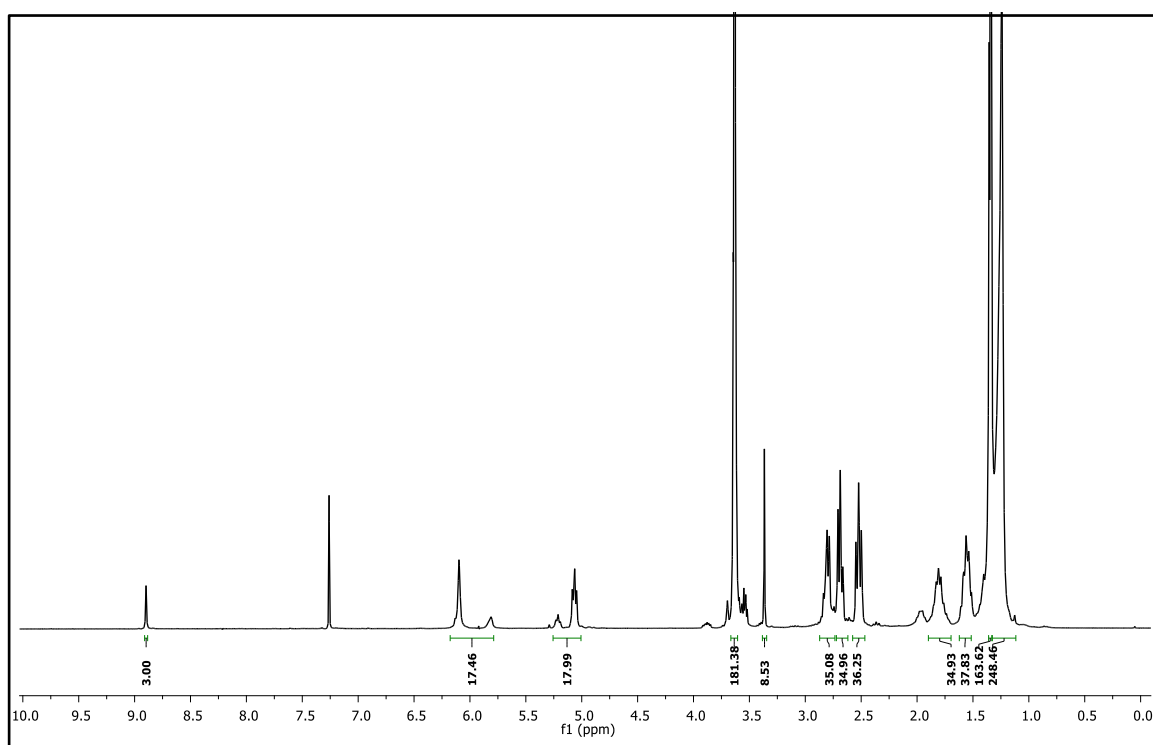


Figure S14: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P8** (5 repeating units, 1 PEG 950 g/mol).

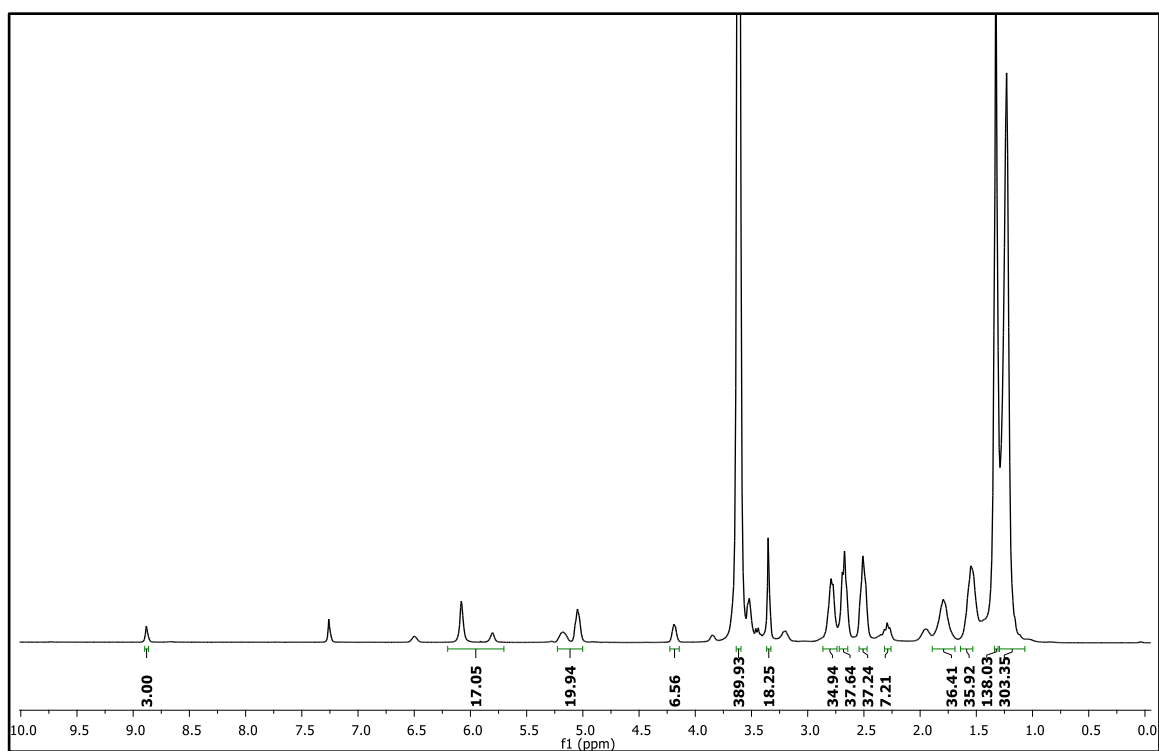


Figure S15: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P9** (5 repeating units, 2 PEG 950 g/mol).

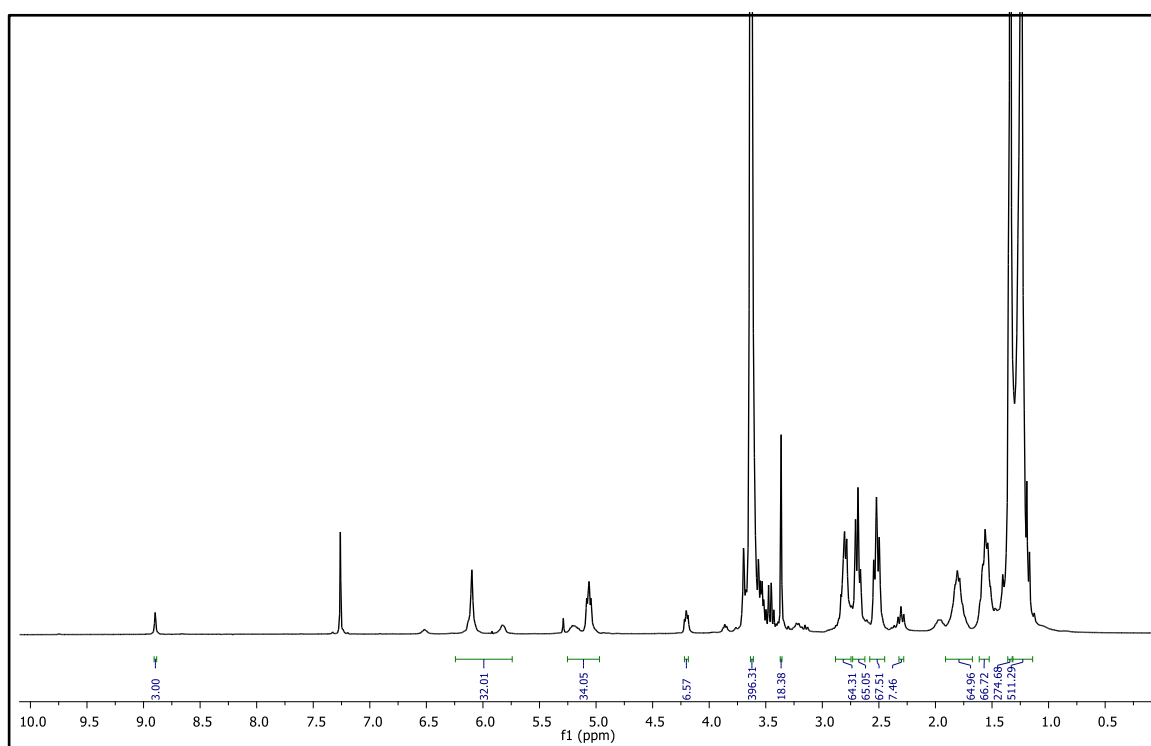
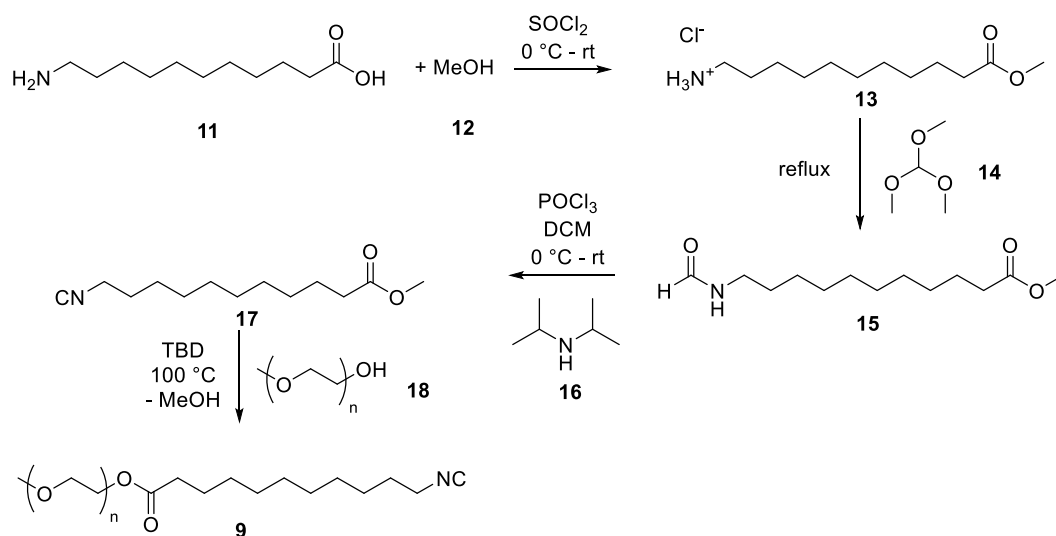
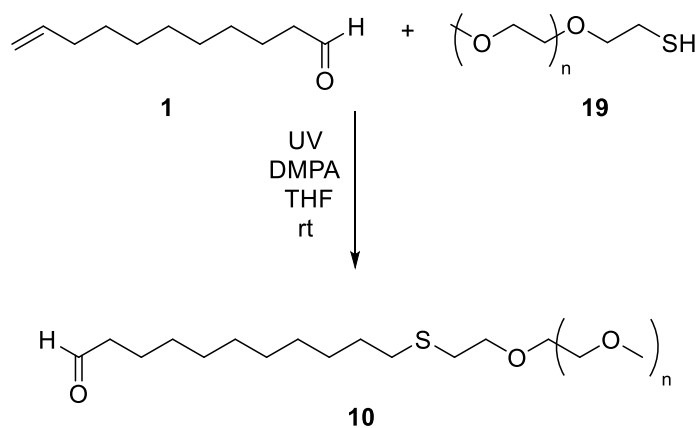


Figure S16: Integrated ^1H NMR spectrum of functionalized star-shaped polymer **P10** (10 repeating units, 2 PEG 950 g/mol).

5. Reaction schemes



Scheme S1: Synthesis route of PEG isocyanide **9**.



Scheme S2: Synthesis of PEG aldehyde **10**.

6. SEC figures

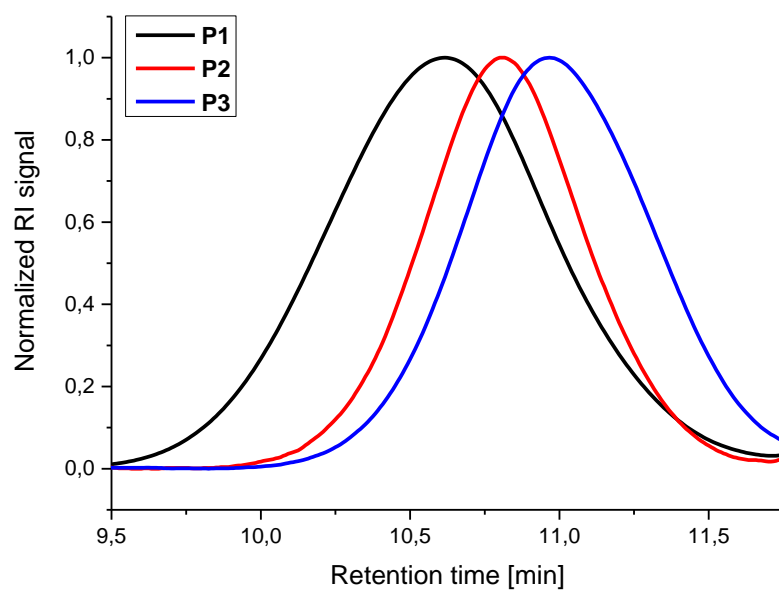


Figure S17: SEC results of star-shaped homopolymers **P1**, **P2** and **P3** with varying ratio of AB-type monomer **3** and trimesic acid **4** (**P1** = 20:1, **P2** = 10:1, **P3** = 5:1 per arm).

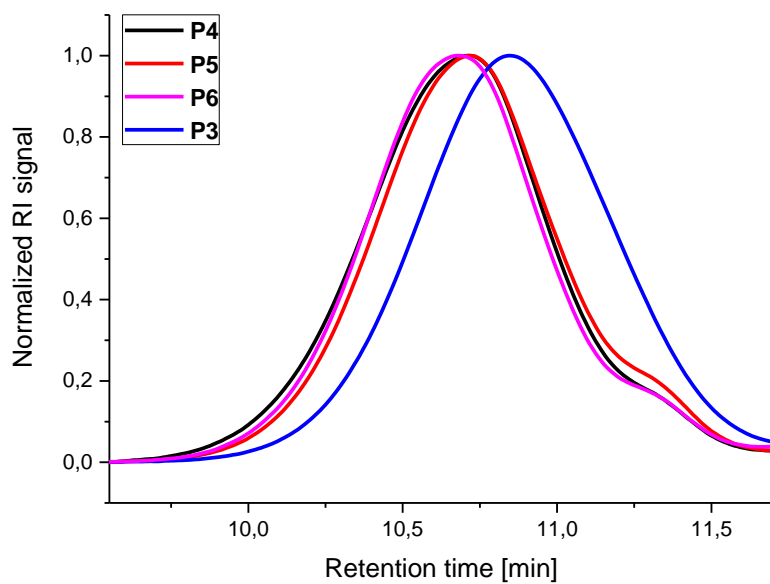


Figure S18: SEC results of the functionalization of **P2** using one PEG-aldehyde (2000 g/mol) and different isocyanides.

7. UV/VIS results

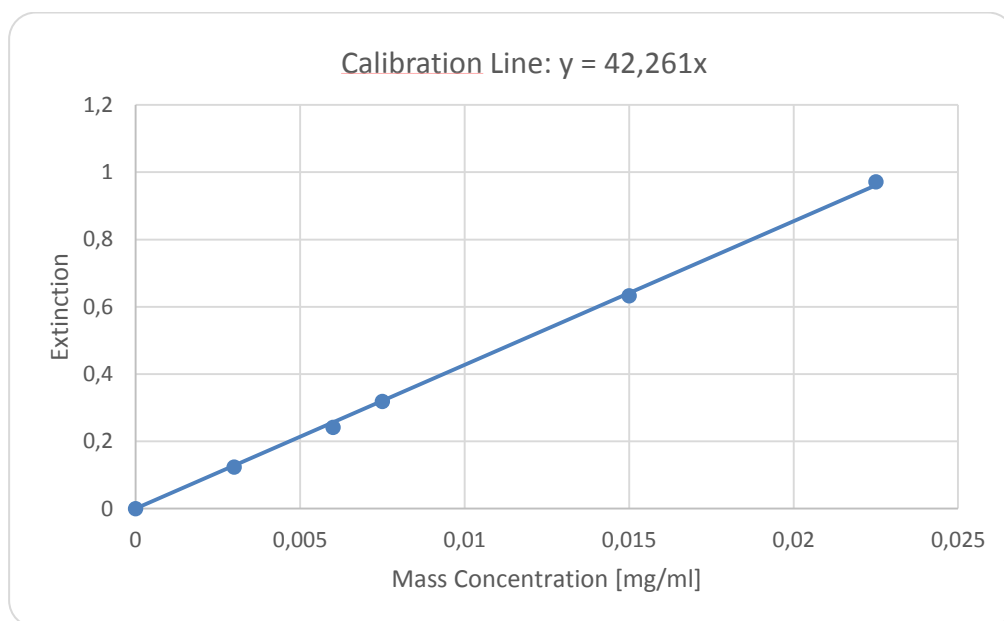


Figure S19: UV/VIS calibration line of Orange II in water.

8. DLS figures

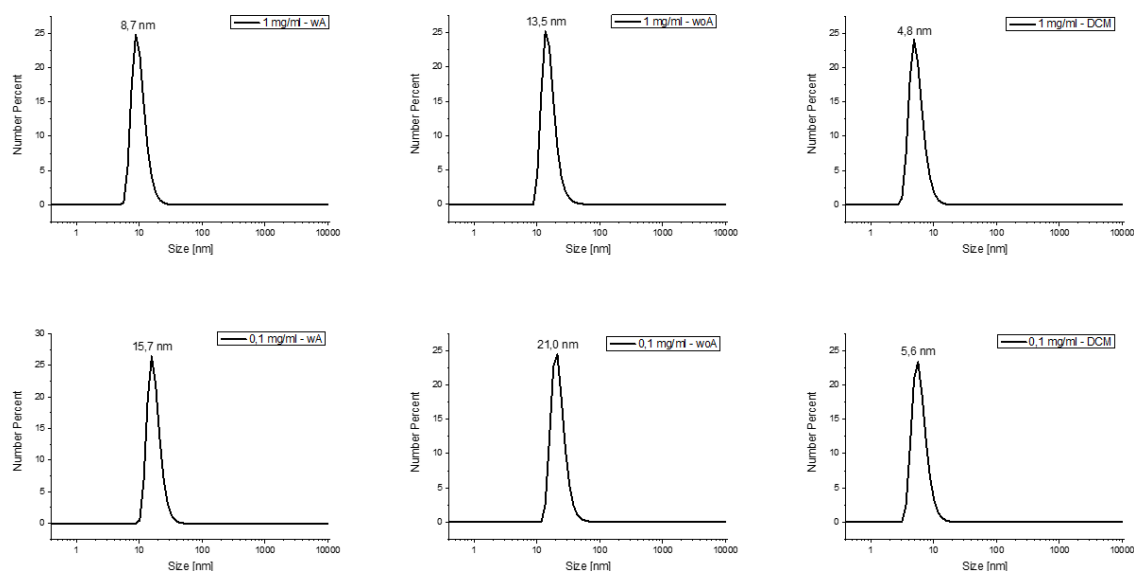


Figure S20: DLS results of functionalized star-shaped polymer **P10** (10 repeating units and 2 PEG (950 g/mol)): first row 1 mg/mL of **P10**, second row 0.1 mg/mL of **P10**, left in water with acetone (wA), middle in water without acetone (woA), right in dichloromethane (DCM).

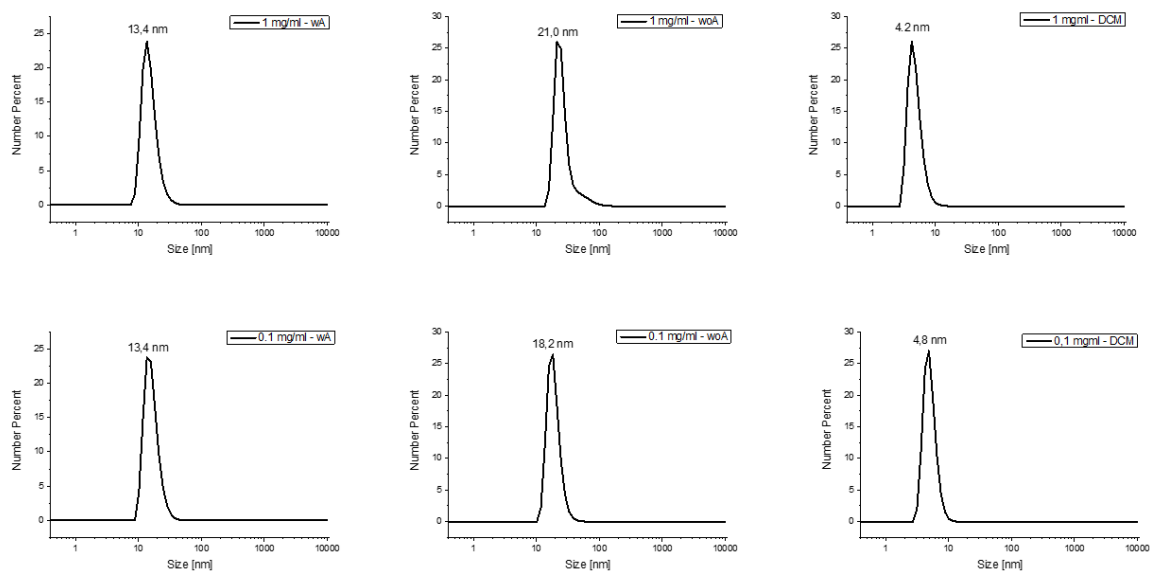


Figure S21: DLS results of functionalized star-shaped polymer **P8** (5 repeating units and 1 PEG (950 g/mol)): first row 1 mg/mL of **P8**, second row 0.1 mg/mL of **P8**, left in water with acetone (wA), middle in water without acetone (woA), right in dichloromethane (DCM).

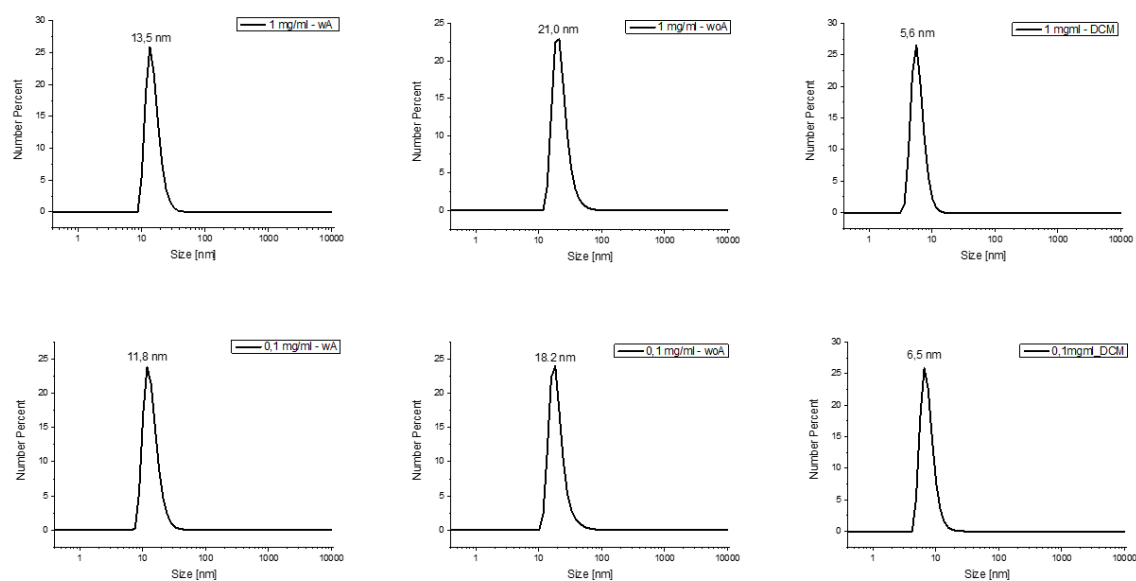


Figure S22: DLS results of functionalized star-shaped polymer **P7** (5 repeating units and 1 PEG (2000 g/mol)): first row 1 mg/mL of **P7**, second row 0.1 mg/mL of **P7**, left in water with acetone (wA), middle in water without acetone (woA), right in dichloromethane (DCM).

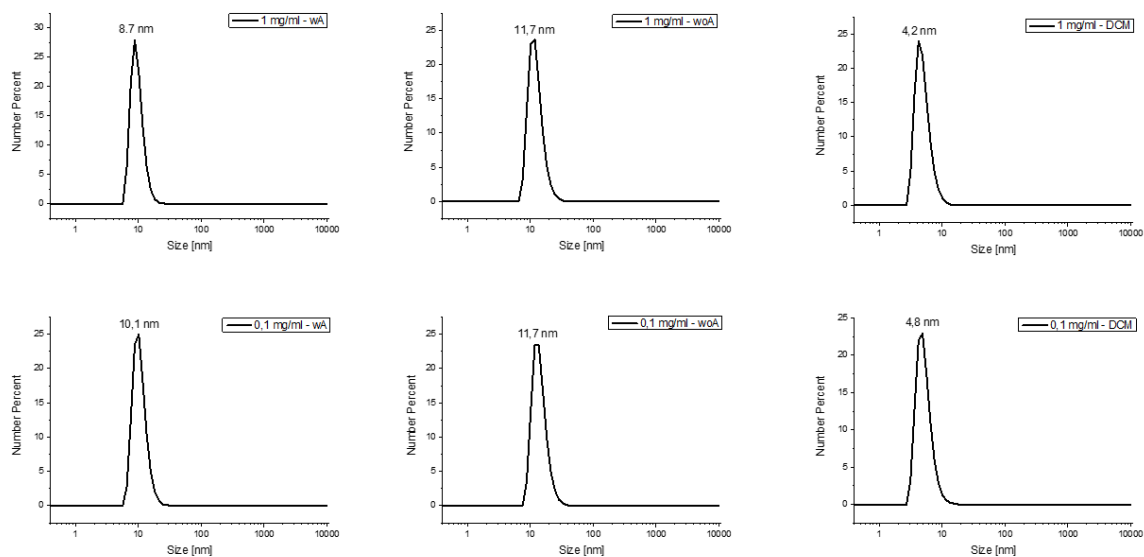


Figure S23: DLS results of functionalized star-shaped polymer **P9** (5 repeating units and 2 PEG (950 g/mol)): first row 1 mg/mL of **P9**, second row 0.1 mg/mL of **P9**, left in water with acetone (wA), middle in water without acetone (woA), right in dichloromethane (DCM).

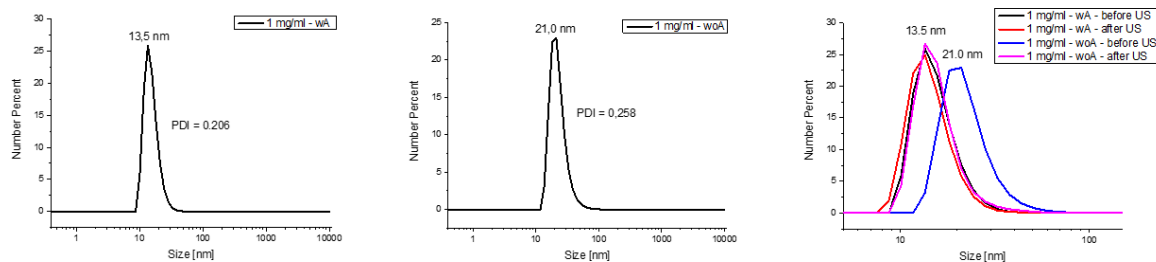


Figure S24: DLS results of functionalized star-shaped polymer **P7** (5 repeating units and 1 PEG (2000 g/mol)): comparison of 1 mg/ml **P7** with and without acetone after and before ultrasonication (US).

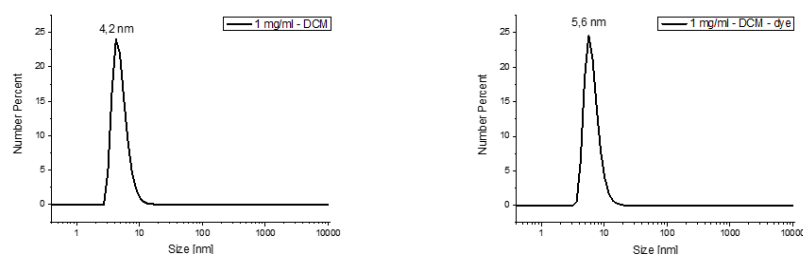


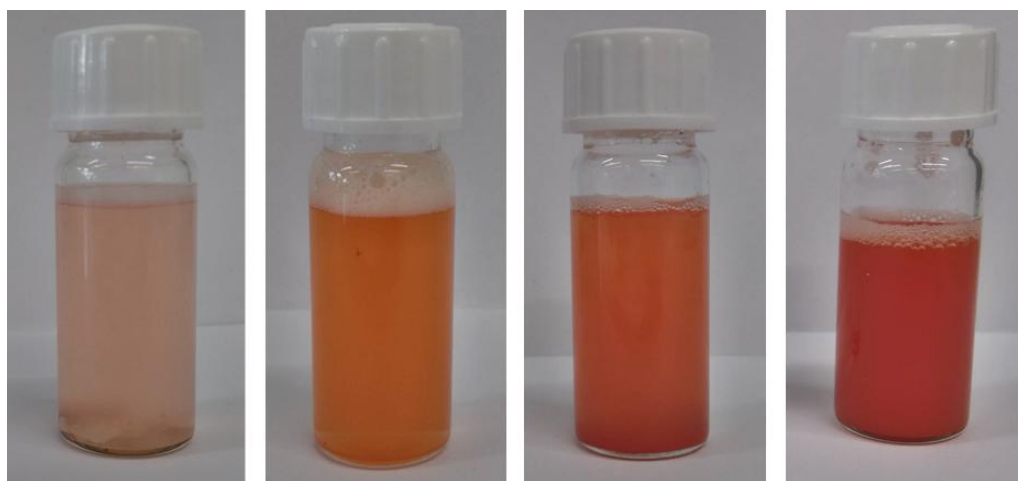
Figure S25: DLS results of functionalized star-shaped polymer **P9** (5 repeating units and 2 PEG (950 g/mol)): comparison of 1 mg/ml **P9** in dichloromethane (DCM) without encapsulated dye (left) and with encapsulated dye (right).

9. Tables

Table S1: Molecular weights of polyesters **P1**, **P2** and **P3** synthesized with different ratios of AB-type monomer **3** and trimesic acid **4**.

polymer	ratio	M_n	M_n	M_n	\bar{D} M_w/M_n
	[3]:[4]	calc.	NMR	SEC	
	per arm	[g/mol]	[g/mol]	[g/mol]	
P1	20:1	21663	22031	13500	1.40
P2	10:1	10937	10829	10200	1.23
P3	5:1	5573	5859	6500	1.40

10. Pictures of encapsulation and phase transfer experiments



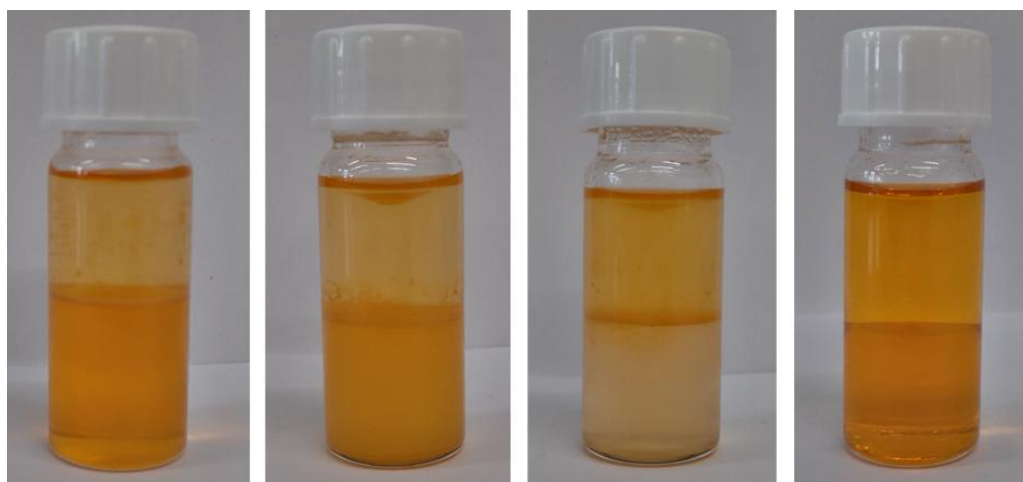
**5 repeating units
1 PEG (950 g/mol)**

**5 repeating units
1 PEG (2000 g/mol)**

**10 repeating units
2 PEG (950 g/mol)**

**5 repeating units
2 PEG (950 g/mol)**

Figure S26: Pictures of the encapsulation of water-insoluble para red in water of four different polymers.



**5 repeating units
2 PEG (950 g/mol)**

**5 repeating units
1 PEG (2000 g/mol)**

**5 repeating units
1 PEG (950 g/mol)**

**10 repeating units
2 PEG (950 g/mol)**

Figure S27: Pictures of the encapsulation and the phase transfer of Orange II from water (top phase) to dichloromethane (bottom phase) of four different polymers.

11. Notes and references

$$M_n = M_n(\text{Monomer } \mathbf{3} + \text{tert} - \text{butyl isocyanide } \mathbf{5}) * n * m + M_n(\text{ITCA } \mathbf{4})$$

Formula S1: Formula to calculate the molecular weight of the star-shaped homopolymers by the number of monomer units n and the number of arms m.

Representative example with **P1**:

$$M_n = \left(274.42 \frac{\text{g}}{\text{mol}} + 83.13 \frac{\text{g}}{\text{mol}} \right) * 20 * 3 + 210.14 \frac{\text{g}}{\text{mol}} = 21663 \frac{\text{g}}{\text{mol}}$$

S1 S. Oelmann, S. C. Solleder and M. A. R. Meier, *Polym. Chem.*, 2016, **7**, 1857.

S2 S. C. Solleder, D. Zengel, K. S. Wetzels and M. A. R. Meier, *Angew. Chem. Int. Ed.*, 2016, **55**, 1204.