Exploring the Construction of Multicompartmental Micelles by Halogen Bonding of Complementary Macromolecules

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Electronic Supplementary Information

Contents

General

Reactions were carried out without effort to exclude air or moisture, unless otherwise indicated. Syringes with stainless steel needles were used to transfer air- and moisture-sensitive liquids.

Materials

Monomers 2-(dimethylamino)ethyl methacrylate (DMAEMA) and methyl methacrylate were filtered through basic alumina prior to use in polymerizations. Azobisisobutyronitrile (AIBN) was recrystallized from methanol. Copper (I) bromide was purified prior to use by stirring 2 g in 20 mL of acetic acid overnight, and isolated by vacuum filtration. The obtained CuBr was washed sequentially with ethanol and ether, dried in vacuo and transferred to a glove box for storage. Dry toluene, DCM, and acetonitrile (for polymer synthesis) were purified by passing through two columns of activated alumina under nitrogen (Innovative Technology, Inc.). Deuterated solvents were purchased from Cambridge Isotope Laboratories. All other starting materials were purchased from Sigma Aldrich.

Nuclear Magnetic Resonance / Infrared Spectroscopy

Nuclear Magnetic Resonance (NMR) spectra were recorded using the following spectrometers: Bruker Avance III 400, Varian NMR System 400 and Varian Mercury 400. The spectra were processed using MestReNova. ^{1}H NMR are reported in parts per million (ppm) relative to tetramethylsilane and referenced to residual protium in the solvent. Spectral features are tabulated in the following order: chemical shift (δ, ppm); multiplicity (s-singlet, d-doublet, t-triplet, q-quartet, quin-quintet, m-complex multiplet, app-apparent, br-broad); number of protons; coupling constants (*J*, Hz). ^{19}F NMR spectra were calibrated to an external standard of 2,2,2-trifluoroethanol (δ –78.22 ppm, C_6D_6). Infrared (IR) spectra were obtained on a Perkin-Elmer Spectrum 100 instrument equipped with a single-bounce diamond / ZnSe ATR accessory, either in the solid state or as neat liquids, as indicated. Spectral features are tabulated as follows: wavenumber (cm^{-1}); intensity (s-strong, m-medium, w-weak, br-broad).

Electron Microscopy

Carbon/formvar TEM grids were purchased from Ted Pella, Inc. (product number 01822-F). Grids were prepared by placing 2 µL of the solution to be analyzed on the grid, and wicking most of the solution using a Kimwipe® within seconds of the application. TEM micrographs were collected using a Hitachi H-7000 with an acceleration voltage of 75 or 100 kV. The EELS map was recorded using a LEO 912B with an acceleration voltage of 120 kV.

Dynamic Light Scattering

Dynamic light scattering (DLS) was carried out without dilution. Data were collected with a Malvern Nanoseries Zetasizer. Measurements were made at 25 °C with a HeNe laser (633 nm) and at a scattering angle of 173˚. Particle sizes were determined by distribution analysis using a non-negatively constrained least squares algorithm and by cumulants analysis.

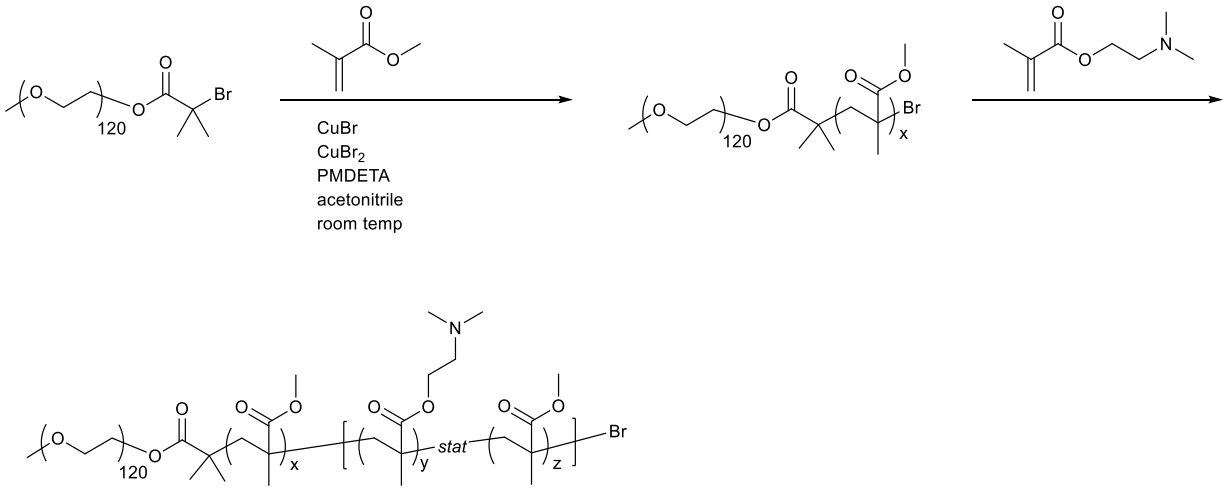
Gel Permeation Chromatography

Gel permeation chromatography (GPC) was conducted at 85 °C using a 1.0 g/L solution of lithium chloride in N-methylpyrrolidone (NMP) as eluent, at a flow rate of 1.0 mL/min through a guard column and two Agilent PLgel 5µm MIXED-C columns equipped with a refractive index detector. Poly(methyl methacrylate) (PMMA) standards were used for calibration.

Triblock Terpolymer Halogen Bond Acceptor Synthesis

ATRP macro-initiator methoxy poly(ethylene oxide) bromoisobutyrate (**11**) was synthesized as described in our previous report.[1]

12a (PEO_{120}-*b*-$PMMA_{90}$-*b*-$PDMAEMA_{40}$-*stat*-$PMMA_4$)



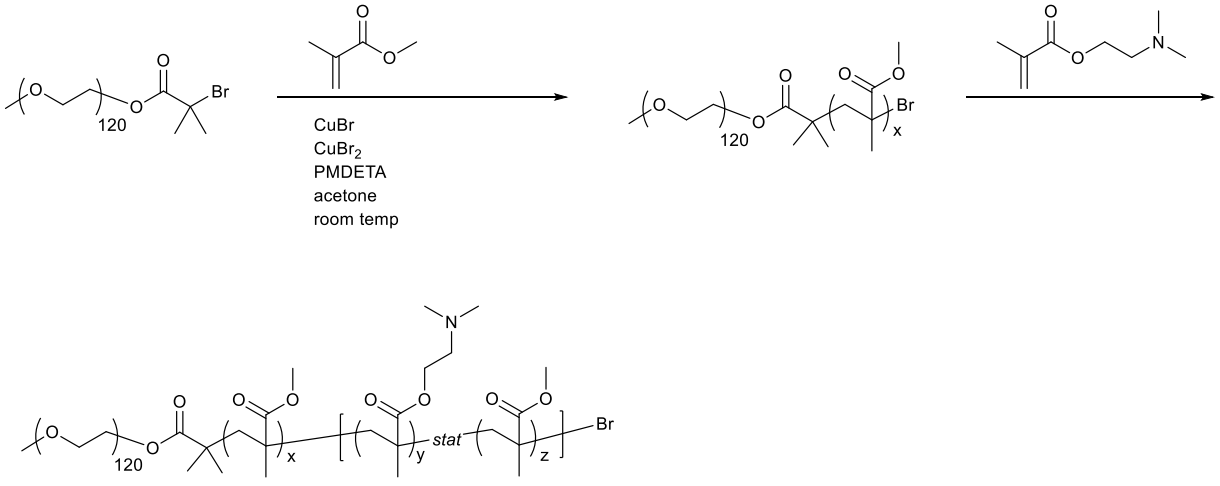
x ≈ 90, y ≈ 40, z ≈ 4, Đ = 1.26

In a Schlenk flask, methoxy poly(ethylene oxide) bromoisobutyrate (**11**) (190 mg, 35 µmol) was combined with methyl methacrylate (MMA) (0.4 mL, 3.7 mmol, 110 equiv), pentamethyldiethylenetriamine (PMDETA) (75 µL, 0.36 mmol, 10 equiv), and dry acetonitrile (0.75 mL). This Schlenk was degassed by three cycles of freeze–pump–thaw and refilled with argon. The polymerization was initiated by transferring this solution using a degassed syringe to another Schlenk flask containing CuBr (5 mg, 35 µmol, 1 equiv) and $CuBr_2$ (60 mg, 0.27 mmol, 7.7 equiv) which had been previously evacuated and refilled with an atmosphere of argon ten times. The heterogeneous reaction mixture was stirred at room temperature for 24 hours at which time a small aliquot was removed with a degassed syringe and analyzed by ^{1}H NMR to reveal approximately 80% conversion of the MMA monomer. Subsequently, 2-(dimethylamino)ethyl methacrylate (DMAEMA) (0.8 mL, 4.7 mmol, 130 equiv) which had been

degassed in a separate Schlenk flask by three cycles of freeze–pump–thaw and refilled with argon was added using a degassed syringe and the reaction was stirred at room temperature for a further 22.5 hours. The reaction was stopped by exposure to air. Analysis of an aliquot by ^{1}H NMR indicated approximately 25% conversion of DMAEMA and approximately 85% conversion of MMA. The reaction mixture was filtered through a pad of basic alumina using THF (~20 mL), followed by DCM/MeOH (20:1 ; ~15 mL), followed by more THF (~ 400 mL). The polymer solution was evaporated, redissolved in THF (10 mL) and precipitated into hexanes (450 mL), cooled to –20 °C, and isolated by decanting/filtering. The polymer was precipitated a second time from DCM (10 mL) into hexanes (450 mL), cooled to –20 °C, and isolated by decanting/filtering. The polymer was transferred to a vial using chloroform and evaporated. The product was collected as a white solid (0.521 g). ^{1}H NMR spectroscopy indicated between 90 and 100 units of MMA and 40 units of DMAEMA (M_n = 2.1 × 10^4 Da) based on the methyl signal of PMMA at 3.60 ppm, the methylene signal of PDMAEMA at 4.08 ppm and the terminal methoxy group of PEO at 3.38 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a $Đ$ of 1.26 and an M_n of 31,000 Da, relative to PMMA.

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 4.08 (br, ~84H), 3.64 (br, ~489H), 3.60 (br, ~282H), 3.38 (s, 3H), 2.59 (br, ~78H), 2.31 (br, ~254H), 0.85–1.94 (m, ~688H). FTIR (powder, cm^{-1}): 2948 (m), 2885 (m), 2821 (w), 2770 (w), 1724 (s), 1484 (m), 1450 (m), 1387 (w), 1359 (w), 1343 (w), 1271 (m), 1240 (m), 1189 (m), 1143 (s), 1105 (s), 1061 (m), 1042 (m), 1018 (m), 986 (m), 963 (m), 915 (m), 842 (m), 811 (w), 779 (w), 748 (m), 667 (w).

12b (PEO_{120}-*b*-$PMMA_{170}$-*b*-$PDMAEMA_{20}$-*stat*-$PMMA_5$)



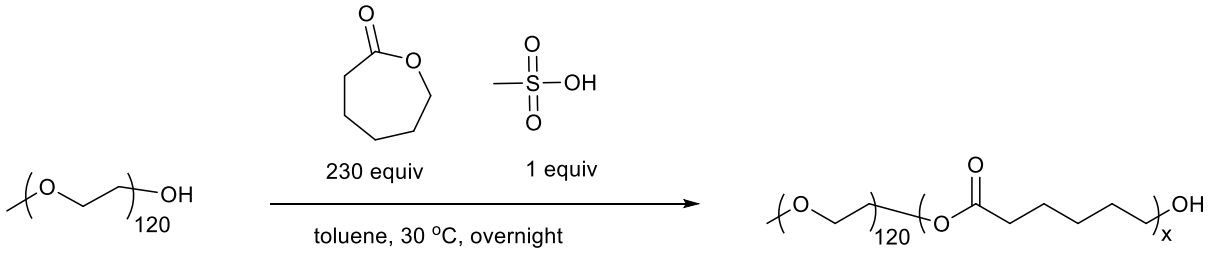
x ≈ 170, y ≈ 20, z ≈ 5, Đ = 1.43

In a Schlenk flask, methoxy poly(ethylene oxide) bromoisobutyrate (**11**) (272 mg, 49 µmol) was combined with methyl methacrylate (MMA) (1.1 mL, 10 mmol, 210 equiv), PMDETA (110 µL, 0.53 mmol, 11 equiv), and acetone (2.0 mL, dried over 3Å molecular sieves). This Schlenk was degassed by four cycles of freeze–pump–thaw, refilled with argon, and subsequently heated with a heat gun to dissolve all the macroinitiator. The polymerization was initiated by transferring this solution using a degassed syringe to another Schlenk flask containing CuBr (7 mg, 49 µmol, 1 equiv) and $CuBr_2$ (89 mg, 0.40 mmol, 8 equiv) which had been previously evacuated and refilled with an atmosphere of argon nine times. The reaction mixture was stirred at room temperature for 47 hours at which time a small aliquot was removed with a degassed syringe and analyzed by ^{1}H NMR to reveal approximately 80% conversion of the MMA monomer. Subsequently, DMAEMA (1.2 mL, 7.1 mmol, 150 equiv) which had been degassed in a separate Schlenk flask by three cycles of freeze–pump–thaw and refilled with argon was added using a degassed syringe and the reaction was stirred at room temperature for a further 24 hours. The reaction was stopped by exposure to air. Analysis of an aliquot by ^{1}H NMR indicated approximately 10–15% conversion of DMAEMA and approximately 80–85% conversion of MMA. The reaction mixture was filtered through a pad of neutral alumina using

THF (~50 mL), followed by a few milliliters of DCM/MeOH (20:1), followed by more THF (~ 500 mL). The polymer solution was evaporated, redissolved and precipitated twice from THF (10 mL) into hexanes (400 mL) and isolated by decanting/filtering. The product was collected as a white solid (1.151g). ^{1}H NMR spectroscopy indicated between 170 and 180 units of MMA and 20 units of DMAEMA (M_n = 2.6 × 10^4 Da) based on the methyl signal of PMMA at 3.59 ppm, the methylene signal of PDMAEMA at 4.08 ppm and the terminal methoxy group of PEO at 3.37 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a *Đ* of 1.43 and an M_n of 43,000 Da, relative to PMMA.

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 4.08 (br, ~42H), 3.63 (br, ~488H), 3.59 (br, ~527H), 3.37 (s, 3H), 2.60 (br, ~39H), 2.31 (br, ~125H), 0.84–2.06 (m, ~986H). FTIR (powder, cm^{-1}): 2993 (w), 2949 (m), 2878 (w), 2768 (w), 1724 (s), 1485 (m), 1448 (m), 1436 (m), 1386 (w), 1349 (w), 1272 (m), 1240 (m), 1191 (m), 1143 (s), 1063 (m), 986 (m), 965 (m), 911 (m), 842 (m), 827 (w), 811 (w), 748 (m), 666 (w).

PEO_{120}-*b*-PCL_{200}



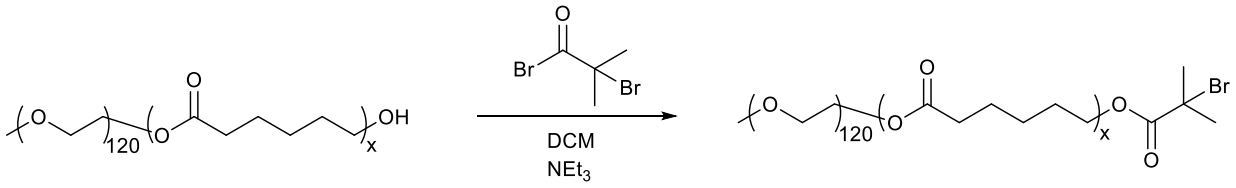
x ≈ 200

The synthesis of poly(ethylene oxide)-*block*-poly(caprolactone) (PEO-*b*-PCL) was guided by previously described procedures.[2,3] In a round bottom flask, methoxy poly(ethylene oxide) (M_n 5,000) (0.50 g, 0.1 mmol) was dissolved in dry toluene and evaporated three times to remove water. To this was added dry toluene (5.0 mL) and ε-caprolactone (2.5 mL, 23 mmol, 230 equiv) which had been stirred over calcium hydride and distilled under vacuum. The mixture was

stirred at 30 °C and methanesulfonic acid (6 µL, 90 µmol, 1 equiv) was injected to begin the polymerization. The reaction was stirred for 20.5 hours before an excess of triethylamine (150 µL) was added to neutralize the acid. Analysis of an aliquot by ^{1}H NMR indicated approximately 80% conversion of the monomer. The reaction mixture was precipitated in 450 mL of hexanes, cooled to –20 °C and the polymer was collected by decanting/filtering. The polymer was precipitated a second time from DCM (20 mL) into hexanes (450 mL), cooled to –20 °C and collected by decanting/filtering. The product was transferred to a vial using chloroform and evaporated to obtain a white solid (2.536 g). ^{1}H NMR spectroscopy indicated 200 units of the caprolactone monomer (M_n = 2.8 × 10^4 Da) based on the methylene signal at 4.06 ppm and the terminal methoxy group of PEO at 3.37 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a *Đ* of 1.19 and an M_n of 30,000 Da, relative to PMMA.

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 4.06 (t, *J* = 6.7 Hz, ~405H), 3.64 (br, ~480H), 3.37 (s, 3H), 2.30 (t, *J* = 7.5 Hz, ~409H), 1.60–1.69 (m, ~818H), 1.34–1.42 (m, ~414H). FTIR (powder, cm^{-1}): 2941 (m), 2895 (w), 2866 (m), 2676 (w), 1723 (s), 1469 (w), 1436 (w), 1419 (w), 1397 (w), 1366 (m), 1294 (m), 1240 (m), 1172 (s), 1103 (m), 1066 (w), 1044 (m), 960 (m), 934 (m), 841 (w), 731 (m), 710 (w).

PEO$_{120}$-*b*-PCL$_{190}$-Br

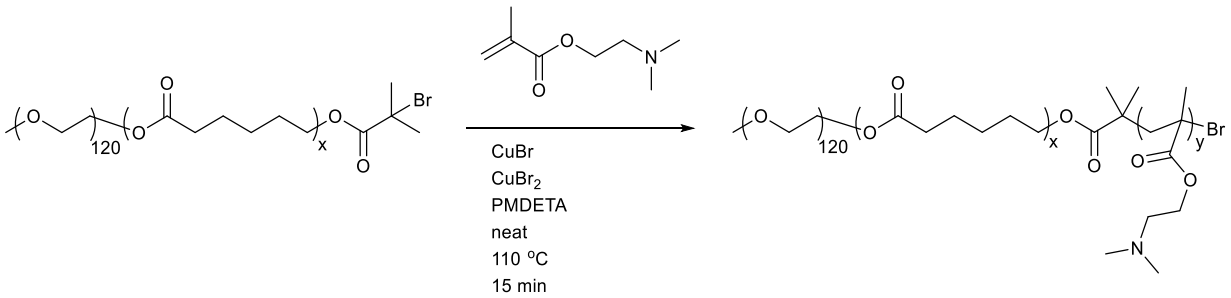


The synthesis of the macroinitiators from PEO-*b*-PCL was guided by a previous report.[4] To PEO$_{120}$-*b*-PCL$_{200}$ (1.009 g, 36 µmol) in a round bottom flask were added dry DCM (10 mL) and

triethylamine (0.8 mL, 5.7 mmol, 160 equiv). The solution was cooled in an ice bath and bromoisobutyryl bromide (0.4 mL, 3.2 mmol, 90 equiv) was added slowly. The solution was stirred and allowed to warm slowly to room temperature overnight. The polymer was precipitated by the addition of methanol (450 mL) and cooled to –20 °C before being collected by filtration over a frit. The polymer was precipitated twice more by dissolving in DCM (20 mL), adding methanol (450 mL), and cooling to –20 °C before filtration. The product was transferred to a vial using chloroform and collected as a white solid (0.78 g). GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a *Đ* of 1.13 and an M_n of 30,000 Da, relative to PMMA.

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 4.04 (t, *J* = 6.7 Hz, ~379H), 3.62 (br, ~482H), 3.35 (s, 3H), 2.28 (t, *J* = 7.5 Hz, ~381H), 1.90 (s, 6H), 1.58–1.67 (m, ~753H), 1.32–1.40 (m, ~370H). FTIR (powder, cm^{-1}): 2942 (m), 2895 (w), 2866 (m), 1724 (s), 1469 (w), 1438 (w), 1418 (w), 1397 (w), 1366 (m), 1294 (m), 1240 (m), 1173 (s), 1103 (m), 1066 (w), 1045 (m), 960 (m), 934 (m), 841 (w), 773 (w), 731 (m), 711 (w).

13a (PEO$_{120}$-*b*-PCL$_{190}$-*b*-PDMAEMA$_{150}$)



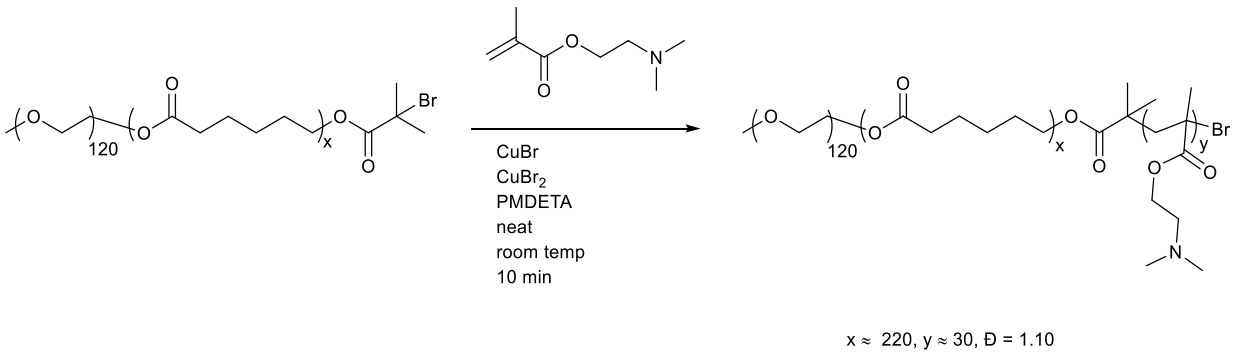
x ≈ 190, y ≈ 150, Đ = 1.24

The polymerization of DMAEMA from a PCL macroinitiator was guided by a previously described procedure.[5] In a Schlenk flask, macroinitiator PEO$_{120}$-*b*-PCL$_{190}$-Br (0.266 g, 10 µmol) was combined with CuBr (2 mg, 14 µmol, ~1 equiv) and $CuBr_2$ (2 mg, 9 µmol, ~1 equiv). The Schlenk was evacuated and refilled with an atmosphere of argon ten times before being stirred

and heated in an oil bath at 110 °C. A solution of DMAEMA (0.6 mL, 3.6 mmol, 360 equiv) and PMDETA (12 µL, 57 µmol, 6 equiv) which had been degassed in another Schlenk flask by four cycles of freeze–pump–thaw and refilled with argon, was added using a degassed syringe. After 15 minutes the reaction was stopped by submerging the flask in liquid nitrogen. Analysis of an aliquot by ^{1}H NMR indicated approximately 45% conversion of the monomer. The reaction mixture was filtered through a pad of neutral alumina using THF (50 mL) followed by DCM/MeOH (20:1 ; 15 mL) followed by more THF (150 mL). The solution was evaporated and then twice precipitated from DCM (10 mL) into hexanes (450 mL) and cooled to –20 °C before collecting the polymer by decanting/filtering. The product was transferred to a vial using chloroform and evaporated to obtain a white solid (0.452 g). ^{1}H NMR spectroscopy indicated 190 units of the caprolactone and 150 units of DMAEMA (M_n = 5.1 × 10^4 Da) based on the methylene signal of PDMAEMA at 2.58 ppm, the overlapping methylene signals near 4.0 ppm and the terminal methoxy group of PEO at 3.37 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a *Đ* of 1.24 and an M_n of 46,000 Da, relative to PMMA.

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 4.03–4.07 (m, ~684H), 3.63 (br, ~479H), 3.37 (s, 3H), 2.58 (br, ~305H), 2.25–2.37 (m, ~1325H), 1.81–1.96 (m, ~299H), 1.60–1.68 (m, ~751H), 1.33–1.41(m, ~389H), 0.90–1.23 (m, ~468H). FTIR (powder, cm^{-1}): 2944 (m), 2895 (w), 2866 (m), 2822 (w), 2770 (w), 1724 (s), 1459 (m), 1419 (w), 1396 (w), 1365(m), 1293 (m), 1269 (m), 1240 (m), 1153 (s), 1103 (m), 1064 (w), 1044 (m), 1017 (m), 990 (w), 960 (m), 935 (w), 882 (w), 849 (m), 779 (w), 749 (m), 732 (m), 711 (w).

13b (PEO_{120}-*b*-PCL_{220}-*b*-$PDMAEMA_{30}$)



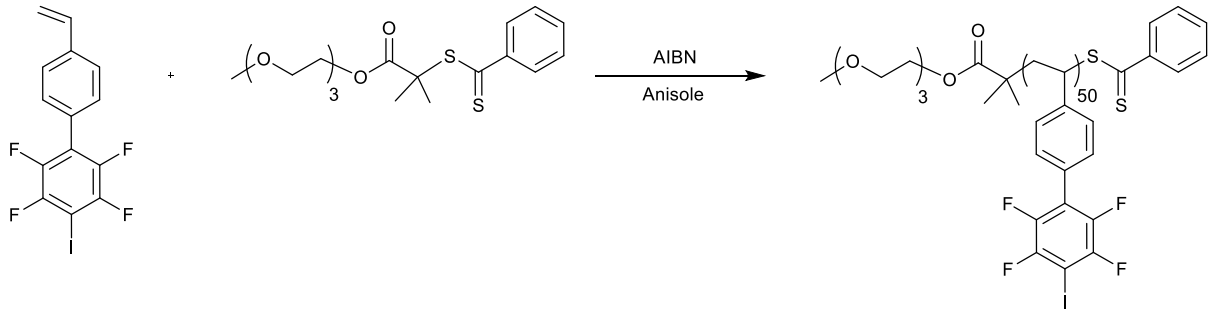
In a Schlenk flask, macroinitiator PEO_{120}-*b*-PCL_{210}-Br (232 mg, 8µmol) was combined with CuBr (3.6 mg, 25 µmol, ~3 equiv), $CuBr_2$ (18 mg, 81 µmol, 10 equiv), and DMAEMA (3.0 mL, 18 mmol, 2,300 equiv). The mixture was degassed by four cycles of freeze–pump–thaw and refilled with argon. The macroinitiator required gentle heating to dissolve. It was dissolved after the second and the fourth rounds of freeze–pump–thaw. The solution was stirred in a room temperature water bath and PMDETA (25µL, 120 µmol, 15 equiv) was injected to initiate the reaction. The reaction was stopped after 10 minutes by bubbling a stream of air through the solution. Analysis of an aliquot by ^{1}H NMR revealed a small amount of polymerization of DMAEMA. The reaction mixture was filtered through a pad of neutral alumina using THF (50 mL) followed by DCM/MeOH (20:1 ; 5mL) followed by more THF (200 mL). The solution was evaporated and then precipitated from THF (10 mL) into hexanes (500 mL) and cooled to –20 °C before collecting the polymer by decanting/filtering. The polymer was precipitated a second time from DCM (10 mL) into hexanes (500 mL) and cooled to –20 °C before collecting the polymer by decanting/filtering. The product was transferred to a vial using chloroform and evaporated to obtain a white solid (0.242 g). ^{1}H NMR spectroscopy indicated 220 units of the caprolactone and 30 units of DMAEMA (M_n = 3.5 × 10^4 Da) based on the methylene signal at 2.53 ppm, the overlapping methylene signals near 4.0 ppm and the terminal methoxy group of PEO at 3.33 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a *Đ* of 1.10 and an M_n of 36,000 Da, relative to PMMA.

^{1}H NMR (CD_2Cl_2, 400 MHz) δ = 4.01–4.05 (m, ~489H), 3.60 (br, ~498H), 3.33 (s, 3H), 2.53 (br, ~58H), 2.25–2.30 (m, ~616H), 1.76–1.98 (m, ~59H), 1.58–1.66 (m, ~907H), 1.33–1.41 (m, ~435H), 0.88–1.11 (m, ~88H). FTIR (powder, cm^{-1}): 2945 (m), 2896 (w), 2866 (m), 2826 (w), 2772 (w), 1722 (s), 1471(m), 1464 (m), 1419 (w), 1397 (w), 1366 (m), 1294 (m), 1240 (m), 1170 (m), 1107 (m), 1066 (w), 1045 (m), 960 (m), 934 (m), 841 (w), 776 (w), 732 (m), 710 (w).

Polymeric Halogen Bond Donor Synthesis

The synthesis of the substituted styrene monomers **2** and **4**, dithiobenzoate chain transfer agent , and control polymer **8a** are described in another of our reports on halogen bonding polymer self-assembly.[6]

6a



In a Schlenk flask, the dithiobenzoate chain transfer agent (4.5 mg, 12 µmol) was combined with monomer **2** (396 mg, 1.0 mmol, 83 equiv), azobisisobutyronitrile (0.4 mg, 2 µmol, 0.2 equiv) and anisole (0.5 mL). The mixture was degassed by four freeze–pump–thaw cycles and backfilled with argon. The reaction was initiated by submerging the flask in a 90 °C oil bath. After stirring for 6 hours the reaction was stopped by submerging the flask in liquid nitrogen. Analysis of an aliquot by ^{19}F NMR indicated approximately 55% conversion of the monomer. The polymer was precipitated twice from DCM (5–10 mL) into hexanes (400 mL) and cooled to –20 °C before being isolated by filtering/decanting. The product was transferred to a vial using chloroform and subsequently evaporated. The polymer was collected as a pink solid (0.221 mg).

This color is consistent with the polymer having the dithioester end group from the chain transfer agent. ^{1}H NMR spectroscopy indicated a degree of polymerization of 50 (M_n = 1.9 × 10^4 Da) based on integration of the signals corresponding to the aromatic protons of the repeat unit and the terminal methoxy signal at 3.33 ppm. GPC analysis using 1.0 g/L LiCl in N-methylpyrrolidone as eluent at 85 °C and calibrated to PMMA standards indicated a $Đ$ of 1.18 and an M_n of 19,000 Da, relative to PMMA. A second batch of **6a** with the same degree of polymerization as determined by ^{1}H NMR was also synthesized by a similar procedure and used in the assembly experiments (GPC: $Đ$ = 1.12 and an M_n = 16,000).[6]

^{1}H NMR ($CDCl_3$, 400 MHz) δ = 6.56–7.17 (m, ~209H), 3.41–3.81 (m, 12H), 3.33 (s, 3H), 0.88–2.26 (m, ~172H). ^{19}F NMR ($CDCl_3$, 376 MHz) δ = –122.44 to –121.93 (m, 2F), –143.20 (br, 2F). FTIR (powder, cm^{-1}): 2926 (w), 2854 (w), 1611 (w), 1566 (w), 1518 (w), 1470 (s), 1411 (m), 1397 (m), 1371 (w), 1355 (w), 1315 (w), 1290 (m), 1191 (w), 1153 (m), 1127 (w), 1112 (w), 1045 (w), 1020 (w), 965 (s), 947 (m), 907 (w), 833 (m), 788 (s), 759 (m), 734 (m), 714 (m), 667 (w).

Assembly Studies

Standard Conditions for Multicompartmental Assembly of Triblock Terpolymer Halogen Bond Acceptors with Halogen Bond Donor Homopolymer 6a.

In a typical experiment, triblock terpolymer halogen bond acceptors and halogen bond donor polymer **6a** were dissolved separately in acetone at a concentration of iodo and amine functional groups of 4.8 mM. The acceptor polymer solution was added to the donor polymer solution at a 1:1 volume ratio by one quick injection while stirring at 60 rpm (diluting acceptor and donor to 2.4 mM concentration of repeat units). These mixed solutions were then stirred overnight. Subsequently, 2 mL of the acetone solution was removed and stirred at 60 rpm while acetonitrile was added by syringe pump at a constant rate over 1 day so that the resulting composition was 4:1 (acetonitrile:acetone v/v). 2 mL of the resultant solution in acetonitrile/acetone was then stirred at 60 rpm while water was added by syringe pump at a constant rate over 1 day so that the resulting composition was 4:1 (water:organic v/v). This solution was then dialyzed against 1 L of water for 4–

5 hours using a regenerated cellulose dialysis membrane with molecular weight cut-off 6000–8000 Da. The external solution was replaced half way through dialysis.

The polymer assemblies were analyzed by TEM by preparing a grid minutes after mixing the acetone solutions. They were also analyzed after stirring in acetone overnight, post acetonitrile addition, and in their final aqueous condition.

Chain stretching calculation

Zhang and Eisenberg calculated the core chain stretching of polystyrene using the equations:[7,8]

$$S_c = \frac{R_{core}}{R_o}$$

and

$$R_o = (C \times N)^{0.5} l$$

"S_c" is the degree of core chain stretching, "R_{core}" is the radius of the micelle core, "R_o" is the the end-to-end distance of the polymer in the unperturbed state, "*C*" is the characteristic ratio (6.67), "*N*" is the degree of polymerization, and "*l*" is the monomer length (0.25 nm). Zhang and Eisenberg neither report a reference nor how they arrived at the characteristic ratio *C* = 6.76. Therefore, in order to use an appropriate value of "*C*" for PDMAEMA (C_b = 11.0), an analagous equation based on the number of C-C bonds (*n*) in the polymer backbone as explained by Linton[9] was employed to determine the unperturbed chain length. The value of 0.154 nm was used for the length (l_b) of the C-C bonds. The maximum chain stretching of Zhang and Eisenberg's micelle using this method ($C_{polystyrene}$ = 10.11) was S_c = 1.68 (versus 1.79 reported in Zhang and Eisenberg's paper).

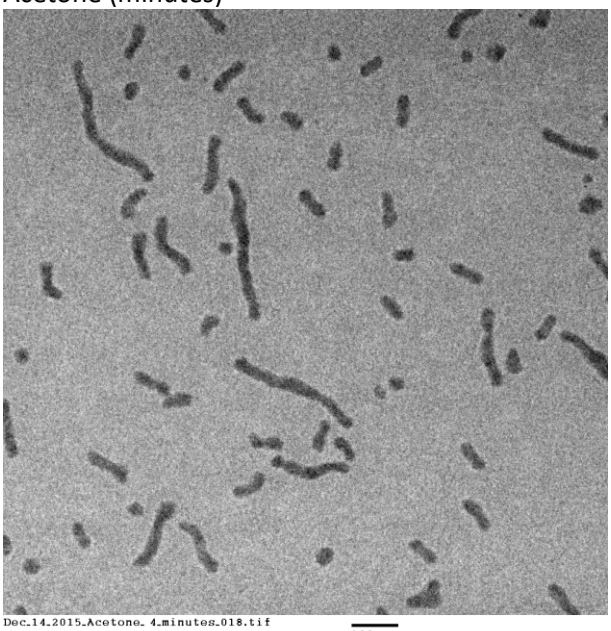
$$R_o = (C_b \times n)^{0.5} l_b$$

Assembly Results

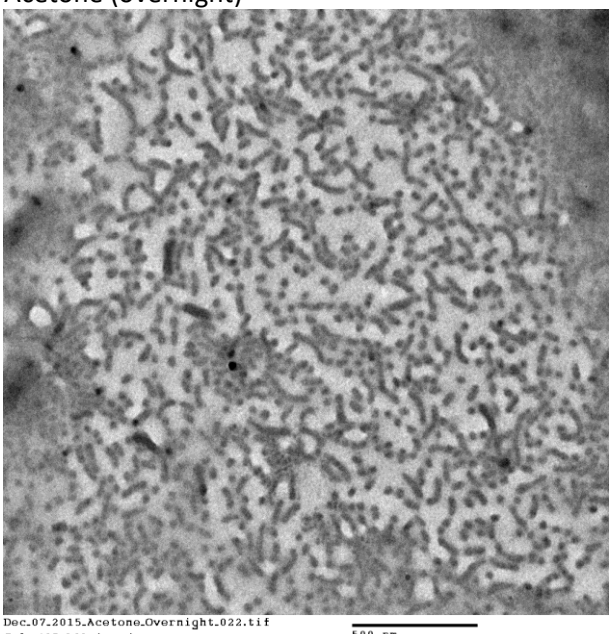
Standard Assembly Conditions

12a and **6a**: (acetone → acetonitrile → water)

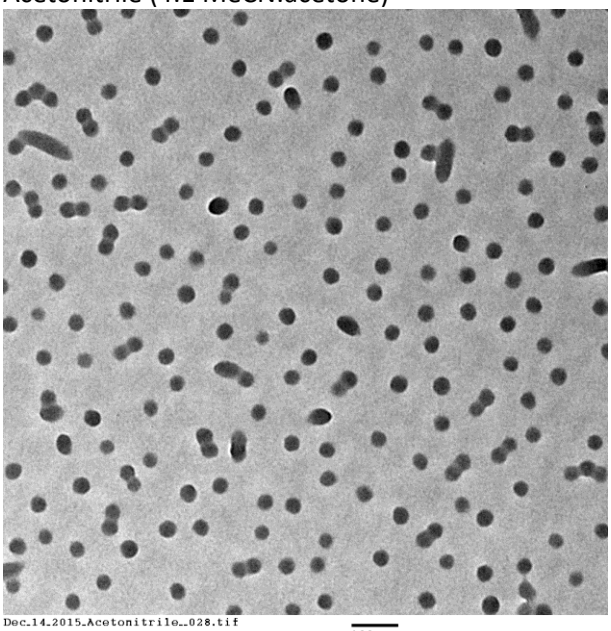
Acetone (minutes)



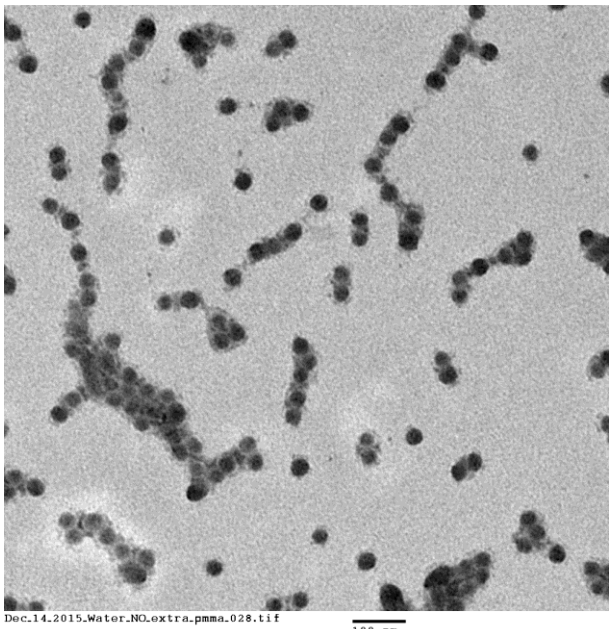
Acetone (overnight)



Acetonitrile (4:1 MeCN:acetone)



Water



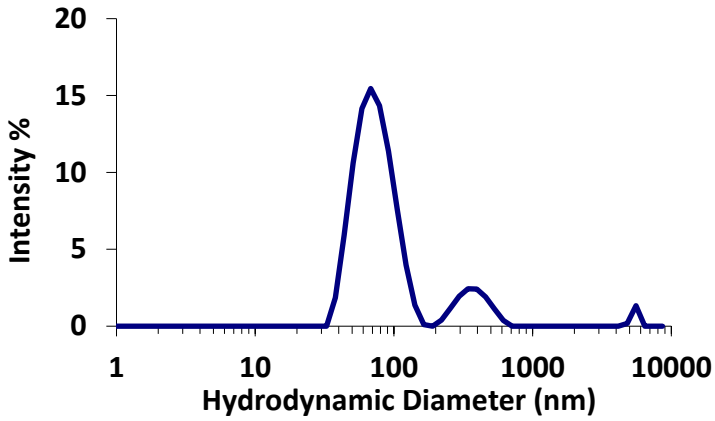
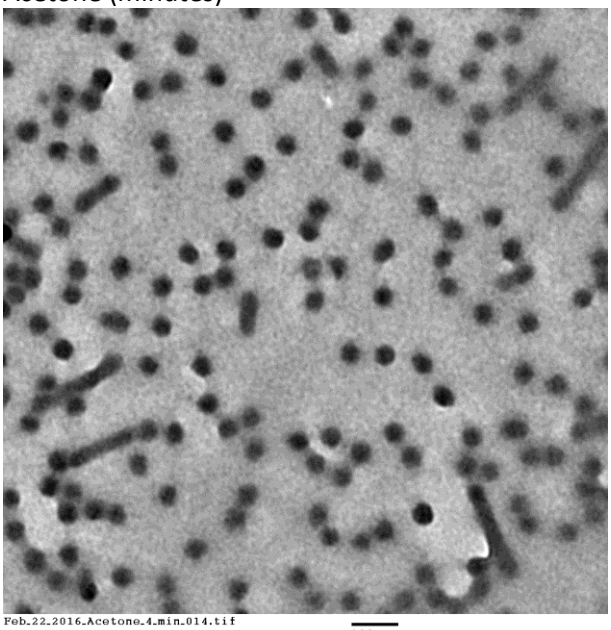


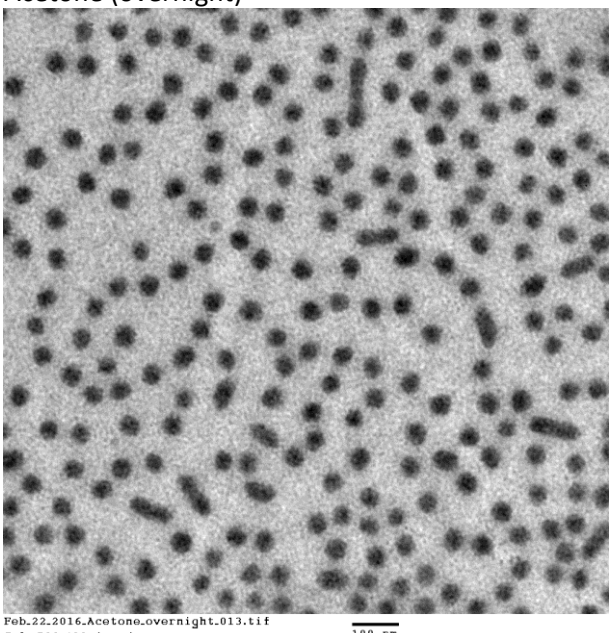
Figure S1:TEM micrographs and DLS data from assemblies formed from **12a** and **6a** using the standard conditions. TEM micrographs are shown for grids prepared from: a fresh acetone sample, a sample aged in acetone overnight, a sample post acetonitrile addition, and in the final aqueous state. The DLS curve is for the aqueous assemblies and was obtained by distribution analysis which gave average diameters of 70 and 540 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 100 nm (PdI = 0.307).

12b and **6a**: (acetone → acetonitrile → water)

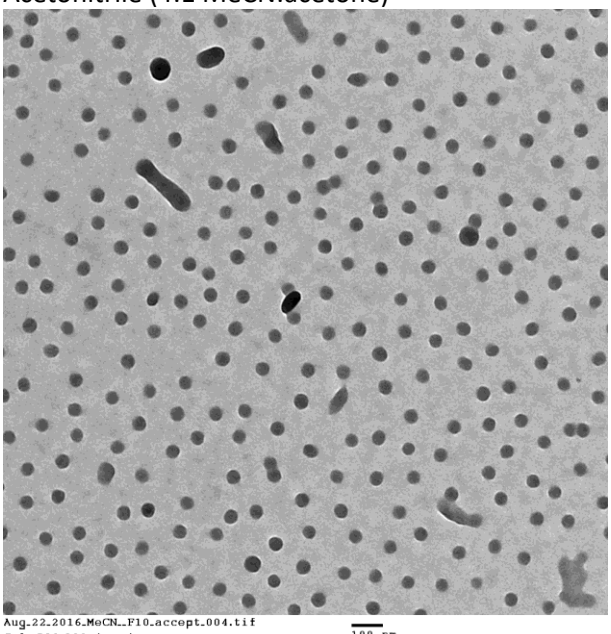
Acetone (minutes)



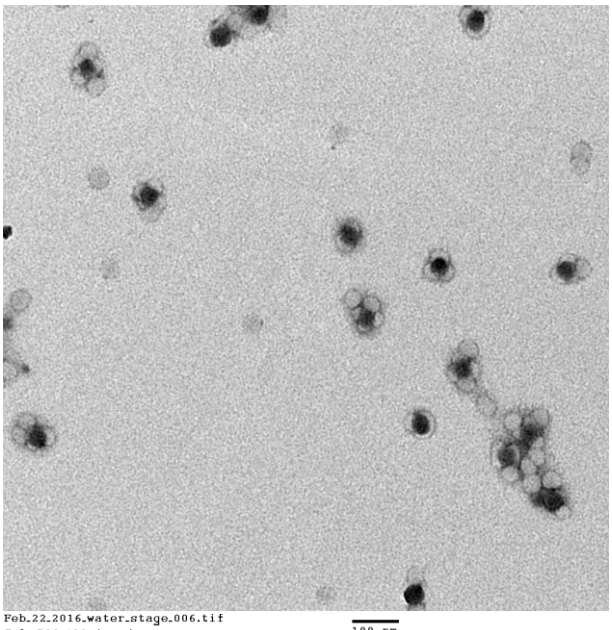
Acetone (overnight)



Acetonitrile (4:1 MeCN:acetone)



Water



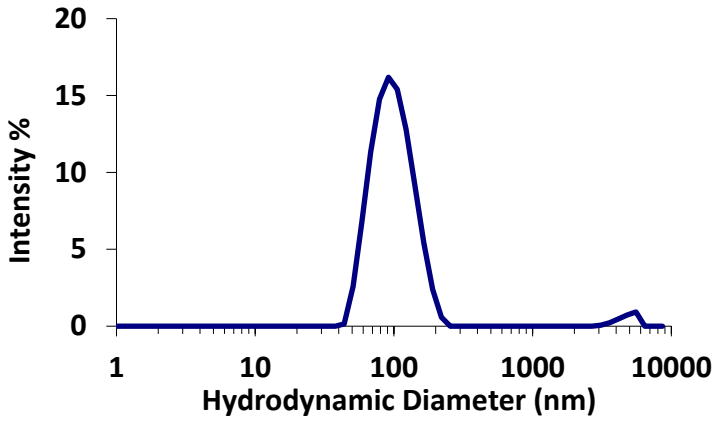
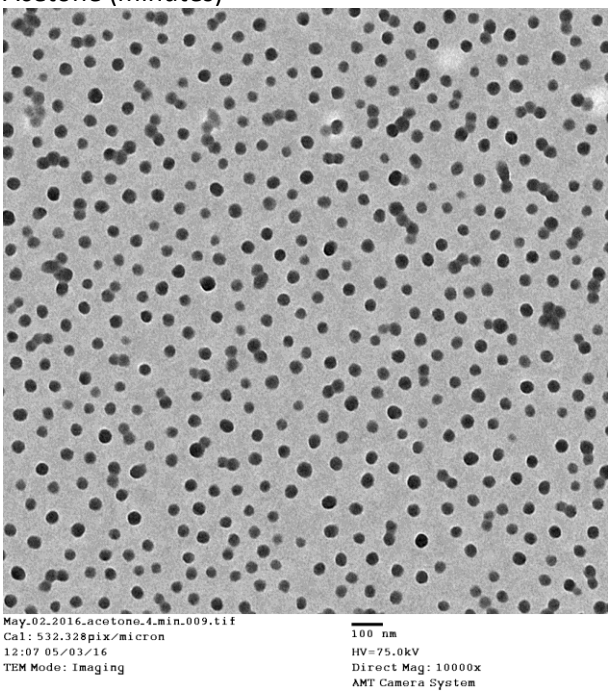


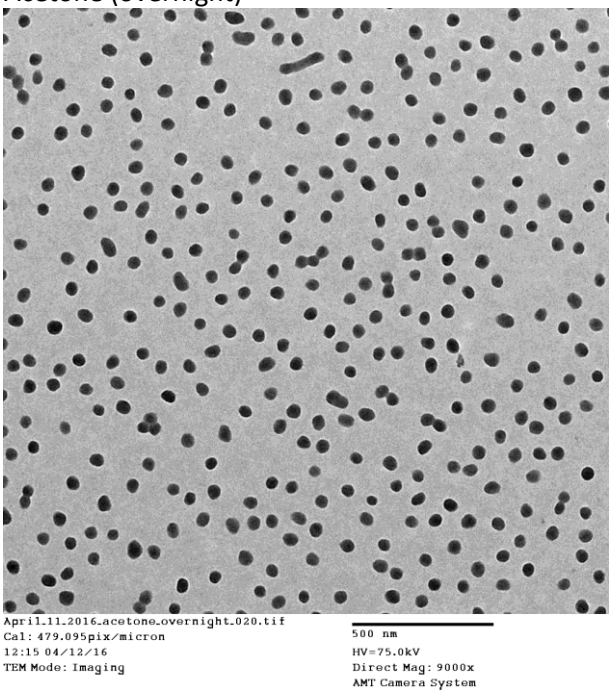
Figure S2:TEM micrographs and DLS data from assemblies formed from **12b** and **6a** using the standard conditions. TEM micrographs are shown for grids prepared from: a fresh acetone sample, sample aged in acetone overnight, sample post acetonitrile addition, and in the final aqueous state. The DLS curve is for the aqueous assemblies and was obtained by distribution analysis which gave an average diameter of 100 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 100 nm (PdI = 0.171).

13a and **6a**: (acetone → acetonitrile → water)

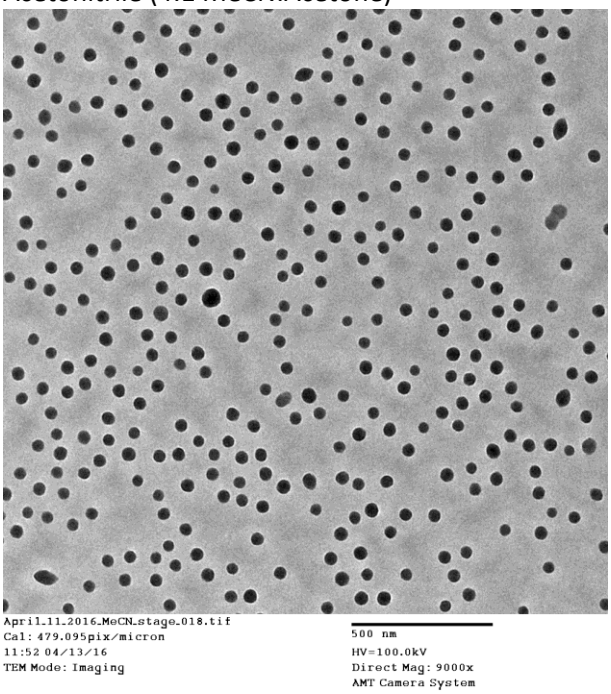
Acetone (minutes)



Acetone (overnight)



Acetonitrile (4:1 MeCN:Acetone)



Water

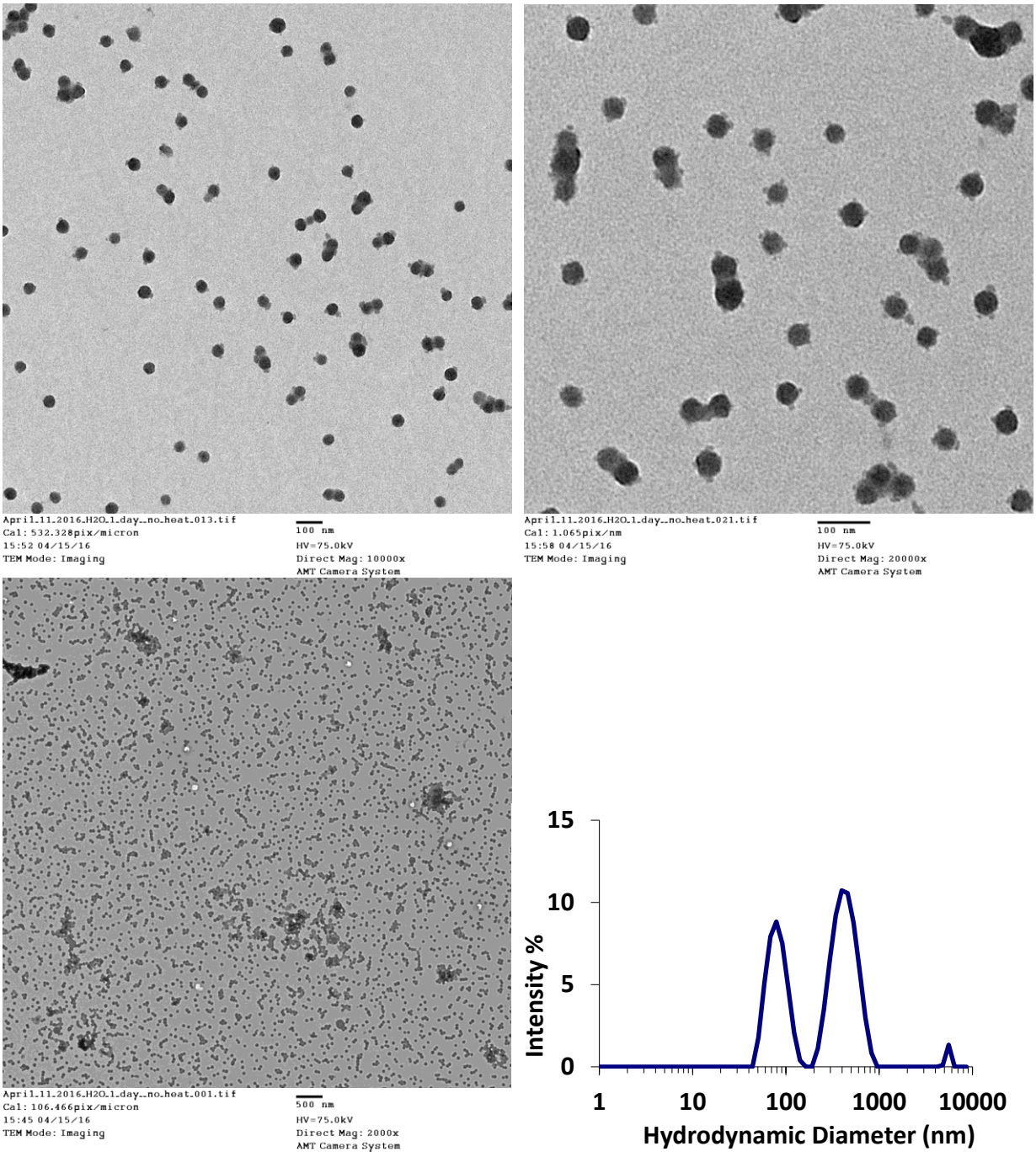
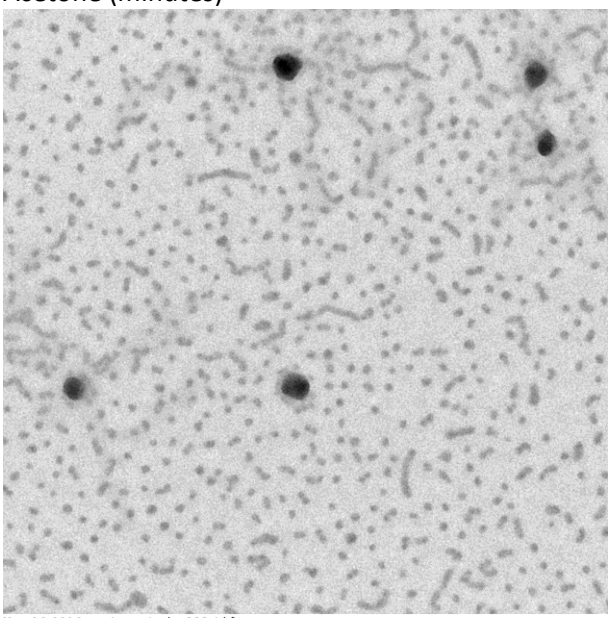


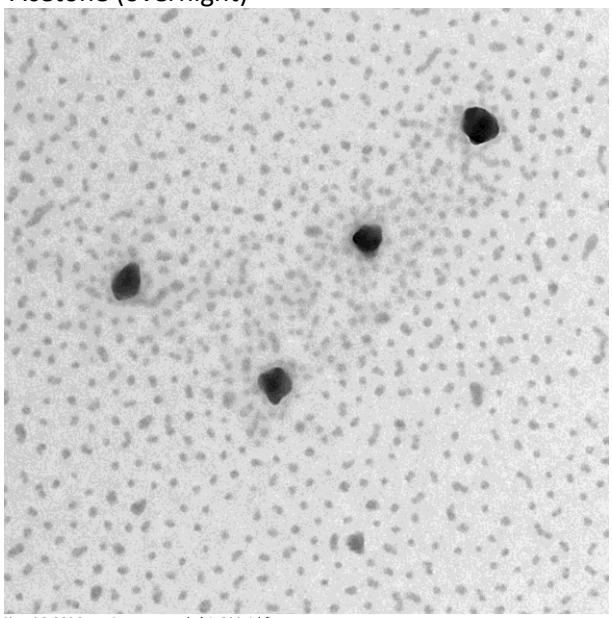
Figure S3: TEM micrographs and DLS data from assemblies formed from **13a** and **6a** using the standard conditions. TEM micrographs are shown for grids prepared from: a fresh acetone sample, a sample aged in acetone overnight, a sample post acetonitrile addition, and a sample in water. The DLS curve is for the aqueous assemblies and was obtained by distribution analysis which gave average diameters of 80 and 470 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 190 nm (PdI = 0.615).

13b and **6a**: (acetone → acetonitrile → water)

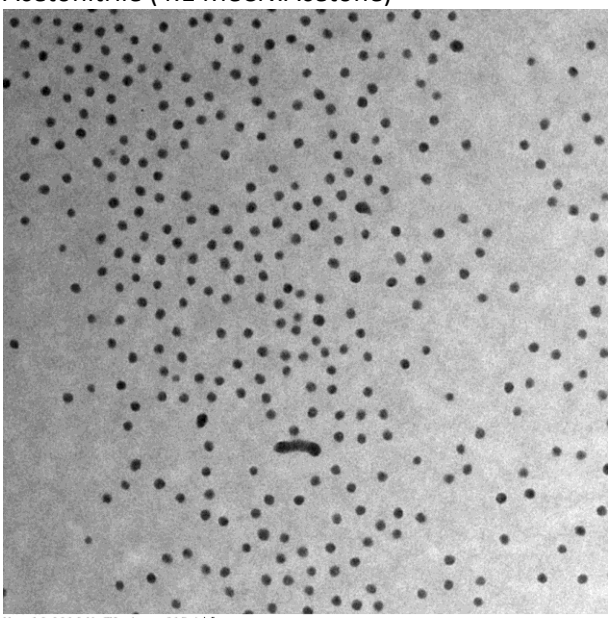
Acetone (minutes)



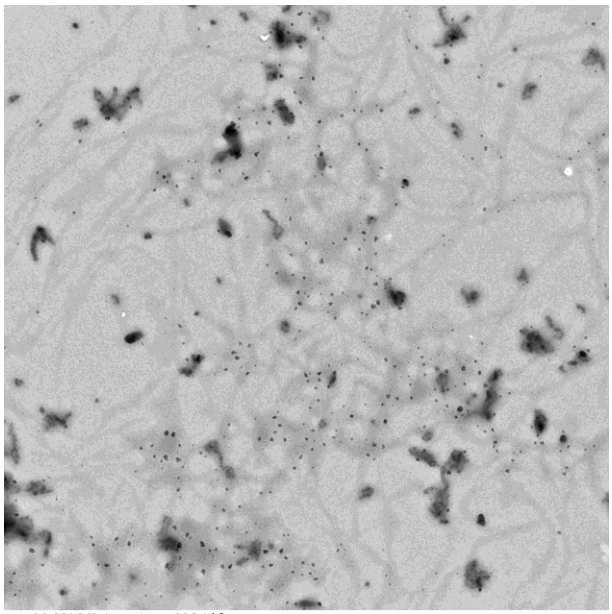
Acetone (overnight)



Acetonitrile (4:1 MeCN:Acetone)



Water



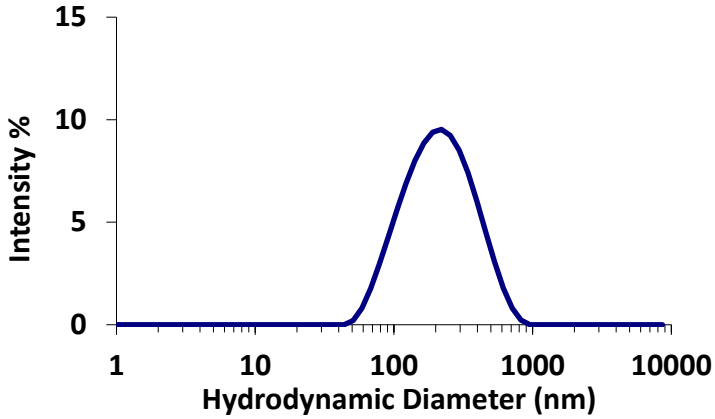
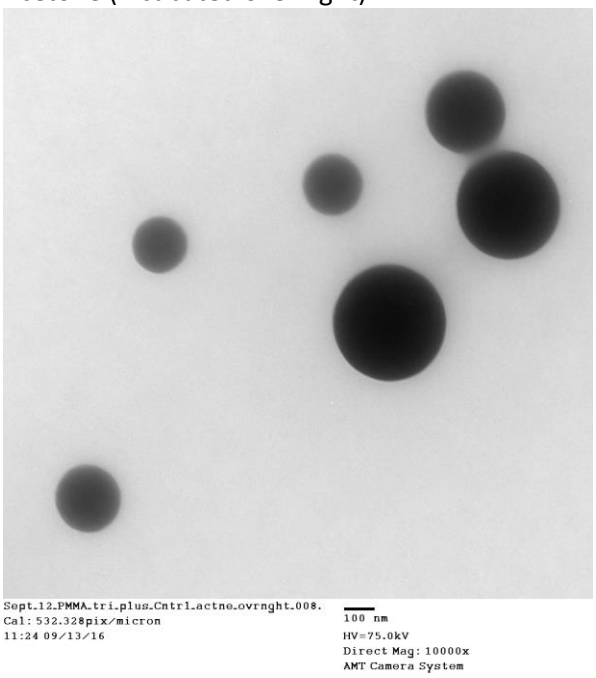


Figure S4:TEM micrographs and DLS data for particles formed from **13b** and **6a** using the standard conditions. TEM micrographs are shown for grids prepared from: a fresh acetone sample, a sample aged in acetone overnight, a sample post acetonitrile addition, and in the final aqueous state. The DLS curve is for the aqueous sample and was obtained by distribution analysis which gave an average diameter of 230 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 180 nm (PdI = 0.230).

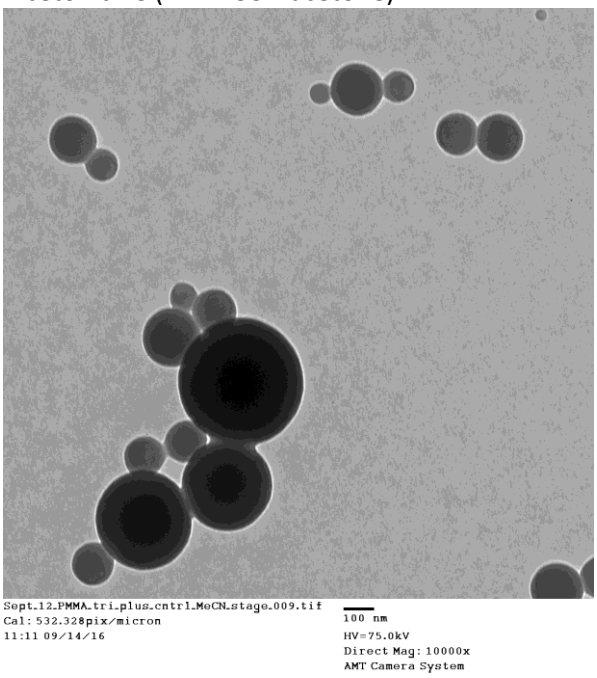
Control Experiments with 8a

12a and **8a**: (acetone → acetonitrile → water)

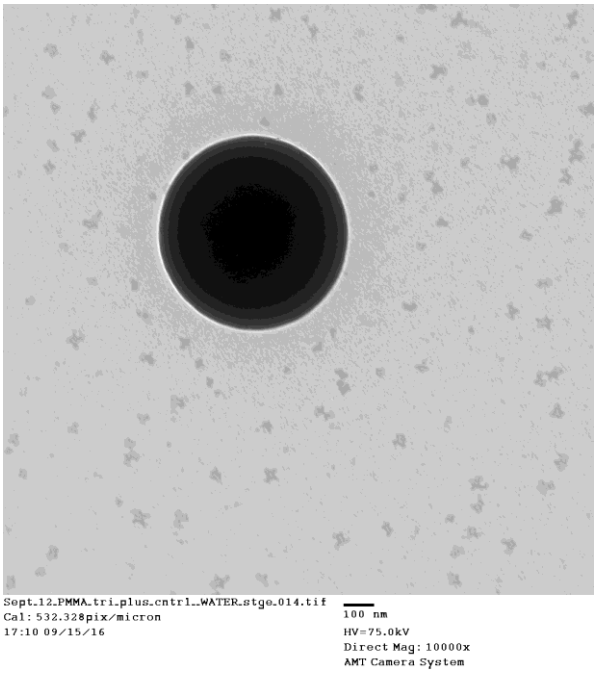
Acetone (incubated overnight)



Acetonitrile (4:1 MeCN:acetone)



Water



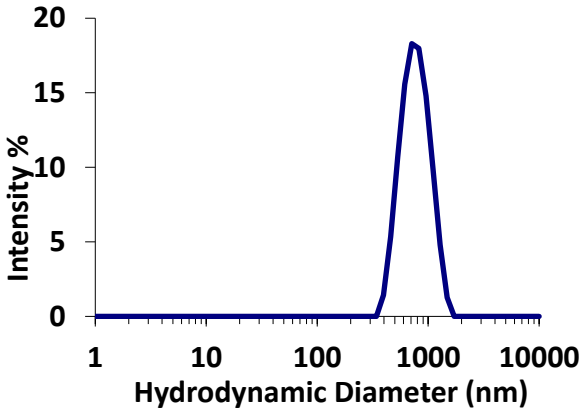
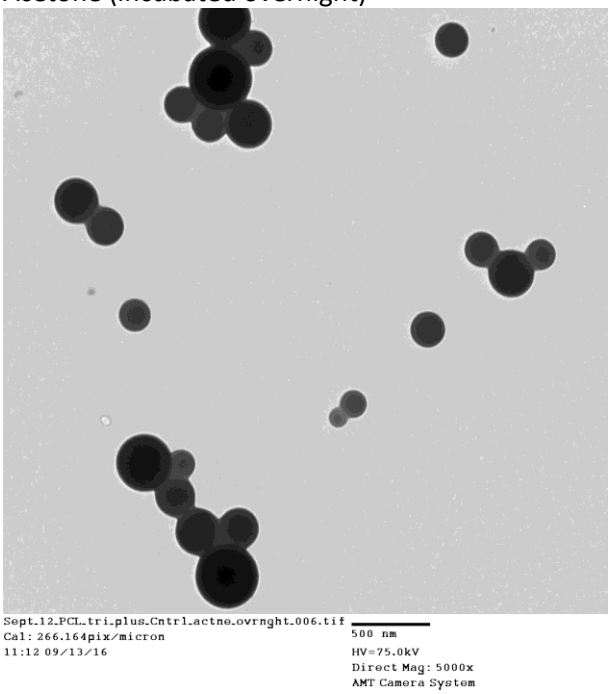


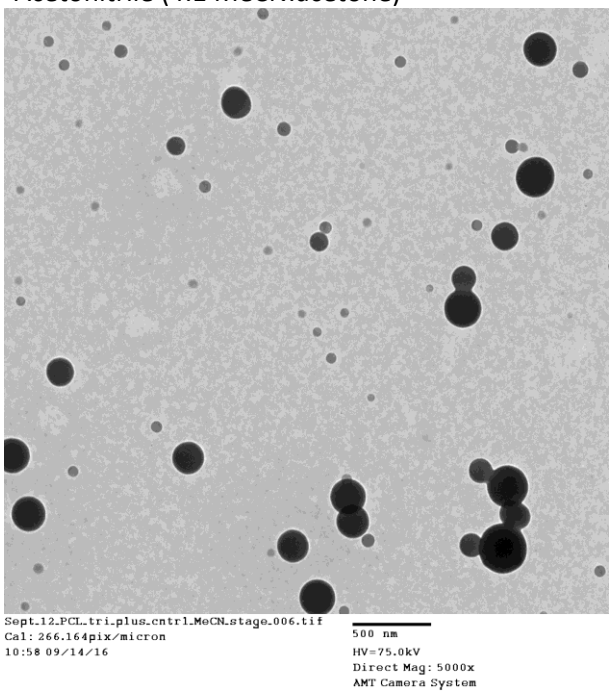
Figure S5: TEM and DLS data from a sample of **12a** and **8a** using the standard conditions. TEM micrographs are shown for grids prepared from: a sample aged in acetone overnight, a sample post acetonitrile addition, and in the final aqueous state. The DLS curve is for the aqueous sample and was obtained by distribution analysis which gave an average diameter of 790 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 690 nm (PdI = 0.180).

13a and **8a**: (acetone → acetonitrile → water)

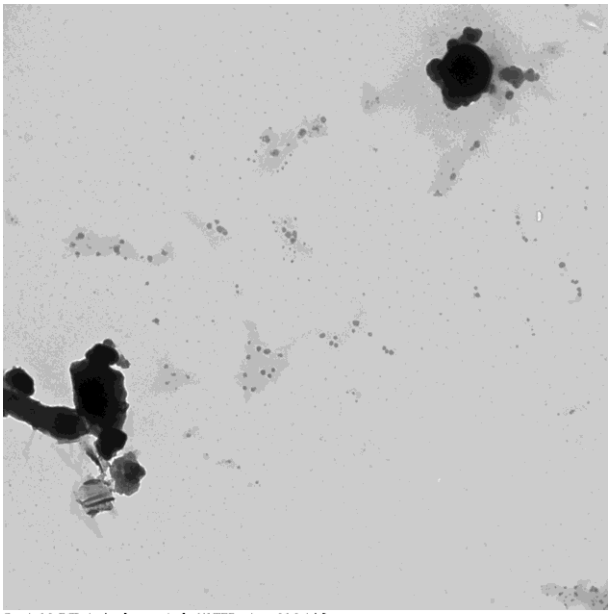
Acetone (incubated overnight)



Acetonitrile (4:1 MeCN:acetone)



Water



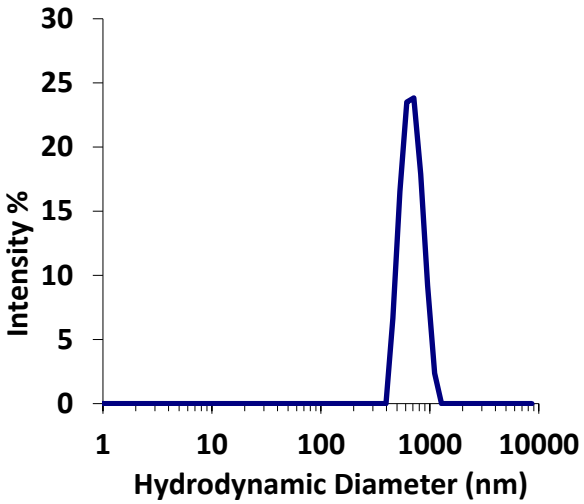


Figure S6:TEM micrographs and DLS data from a sample of **13a** and **8a** using the standard conditions. TEM micrographs are shown for grids prepared from: a sample aged in acetone overnight, a sample post acetonitrile addition, and in the final aqueous state. The DLS curve is for the aqueous sample and was obtained by distribution analysis which gave an average diameter of 710 nm. The apparent hydrodynamic diameter was also determined by cumulants analysis to be 700 nm (PdI = 0.232).

Variations of the Assembly Conditions

Influence of Additives on Multicompartmental Assembly

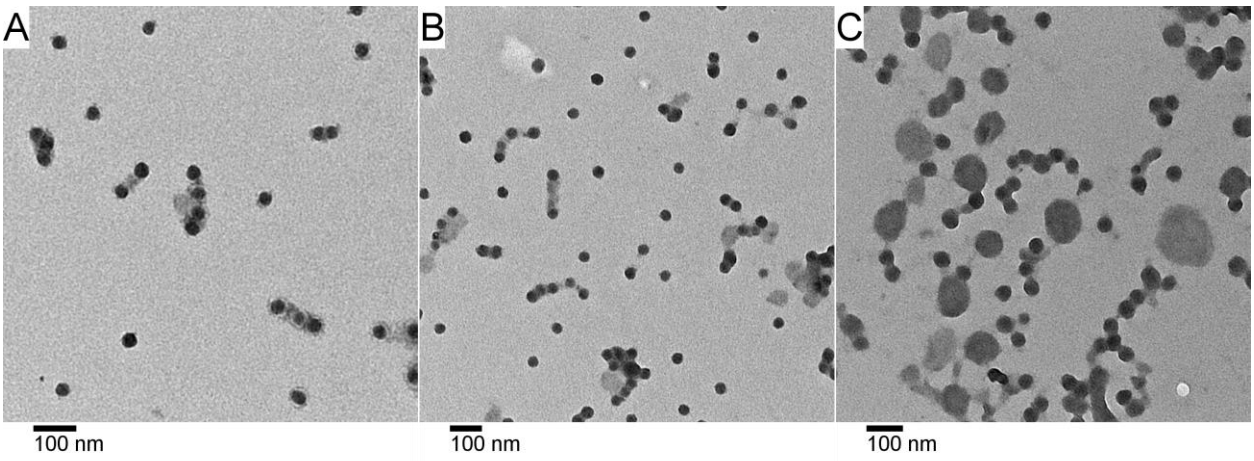


Figure S7: TEM micrographs of grids prepared from aqueous samples of **12a** and **6a** subjected to the standard assembly conditions with additives. (A) PMMA added to the MeCN/acetone (4:1) solution before the addition of water (0.1 mg/mL of PMMA with degree of polymerization of 80 added to the MeCN solution). (B) The fluorous additive perfluorohexane (C_6F_{14}) was included in the initial polymer mixture in acetone (50 mM). (C) The halogen bond donor 1-iodoperfluorohexane ($C_6F_{13}I$) was included in the initial polymer mixture in acetone (50 mM).

Solvent Switching Procedures without Acetonitrile as an Intermediate Solvent

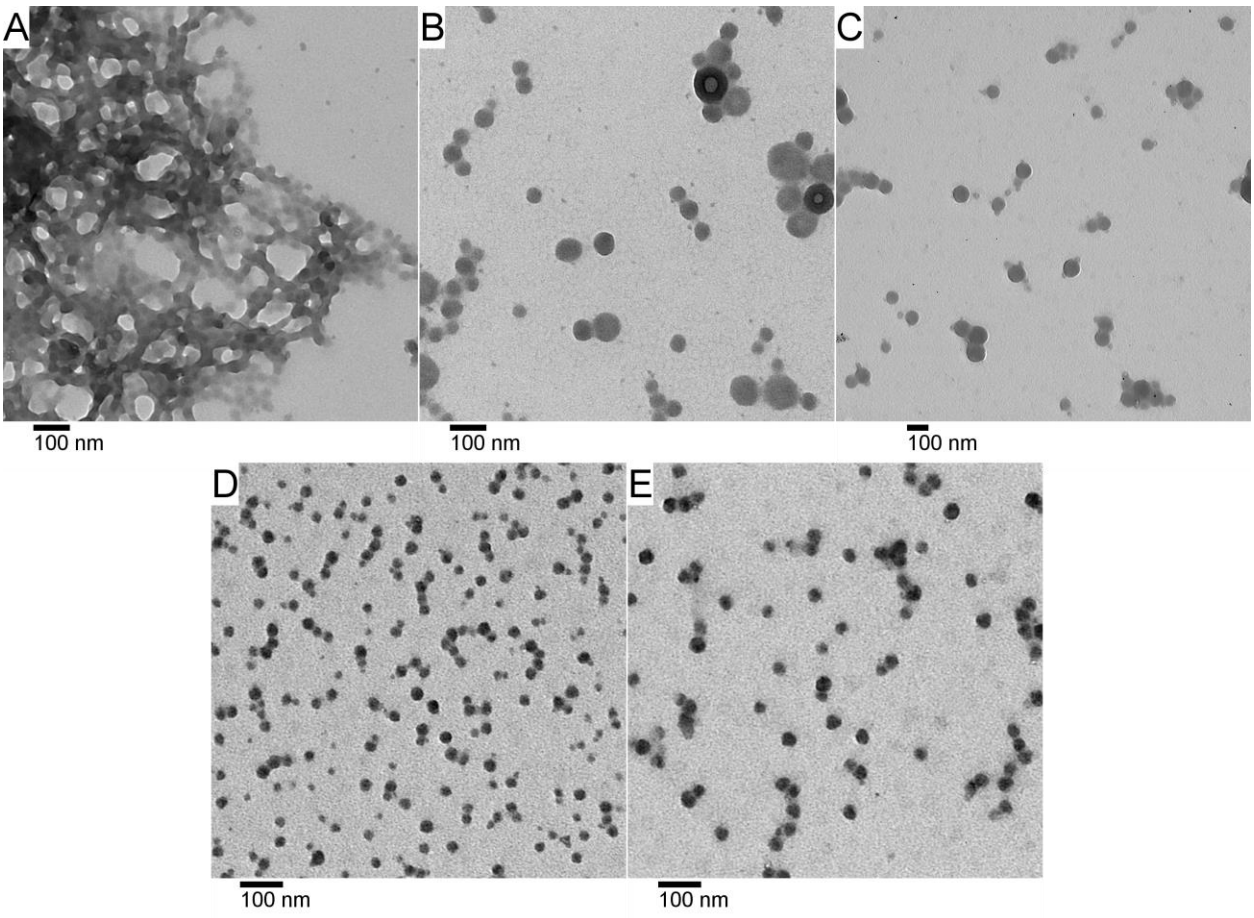


Figure S8: TEM micrographs of grids prepared from polymer mixtures transferred from organic solvent to water directly by syringe pump and dialysis, without acetonitrile as an intermediate solvent. (A) **12a** and **6a** transferred from DMSO to water. (B) **12a** and **6a** transferred from acetone to water. (C) **13a** and **6a** transferred from dioxane to water. (D) **12a** and a block copolymer of PEO and donor **6** transferred from acetone to water with 50 mM of perfluorohexane (C_6F_{14}) included in the initial acetone mixture. (E) **13a** and a block copolymer of PEO and donor **6** transferred from acetone to water with 50 mM of perfluorohexane (C_6F_{14}) included in the initial acetone mixture.

THF as initial solvent

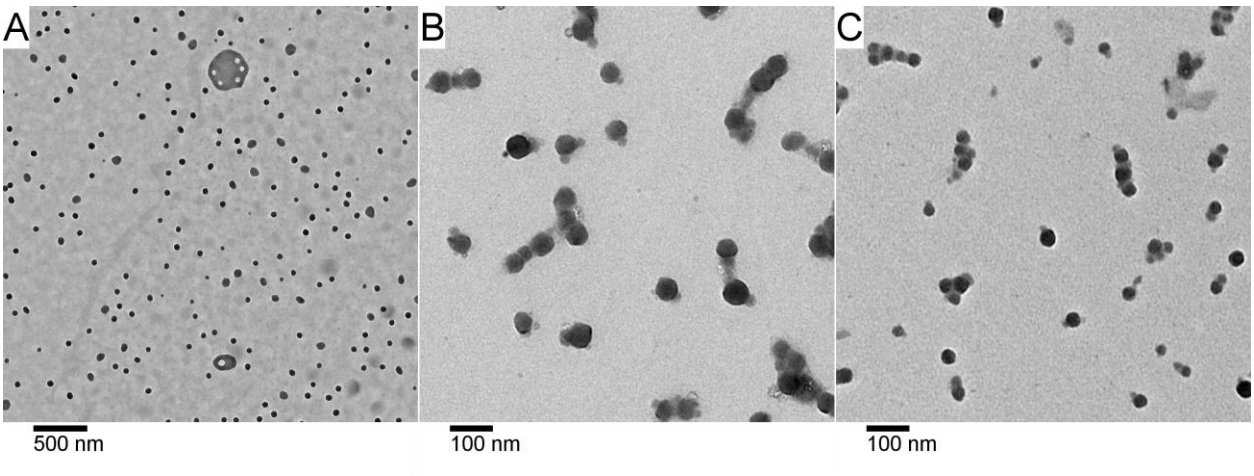


Figure S9: TEM micrographs of grids prepared from assemblies formed by replacing acetone with THF as the initial solvent in the standard assembly conditions. (A) Assemblies of **13a** and **6a** after addition of acetonitrile (MeCN/THF 4:1). (B) Assemblies of **13a** and **6a** after addition of MeCN followed by addition of water and dialysis. (C) Assemblies of **12a** and **6a** after addition of MeCN followed by addition of water and dialysis.

Worm formation by heating or by blending acceptors (samples in MeCN/THF 4:1)

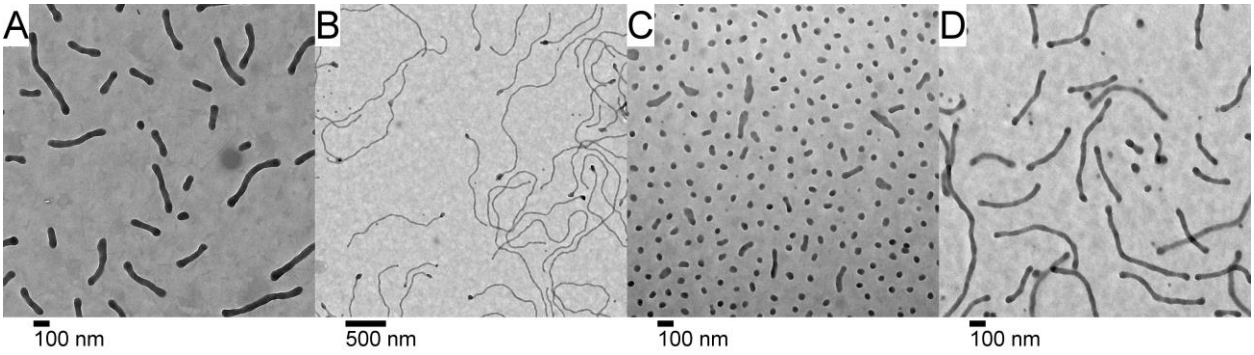


Figure S10: TEM micrographs of assemblies formed by either heating (A-C) samples obtained by slow addition of acetonitrile to THF (MeCN/THF 4:1) or by blending acceptors (D). (A) Worms formed from heating assemblies of **6a** and **13a** at 70 °C for an hour. (B) Worms formed from heating assemblies of **6a** and **13b** at 70 °C for an hour. (C) Mixture of structures formed from heating assemblies of **6a** and **12a** at 70 °C for an hour (D) Worms formed from **6a** and a blend of **13b** and **13a** without heating (3:1 blend based on amine concentration respectively).

Transfer of worms into water

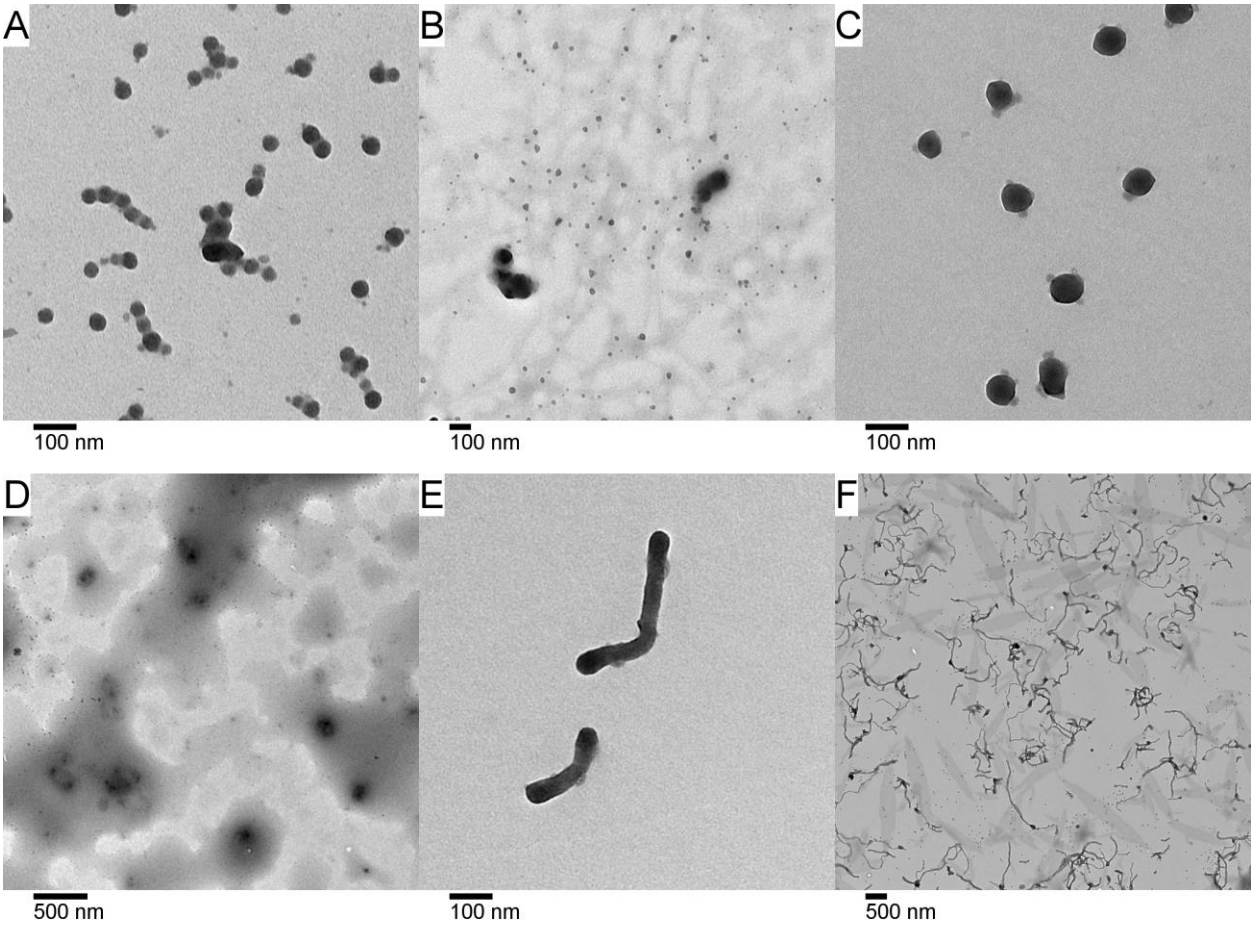
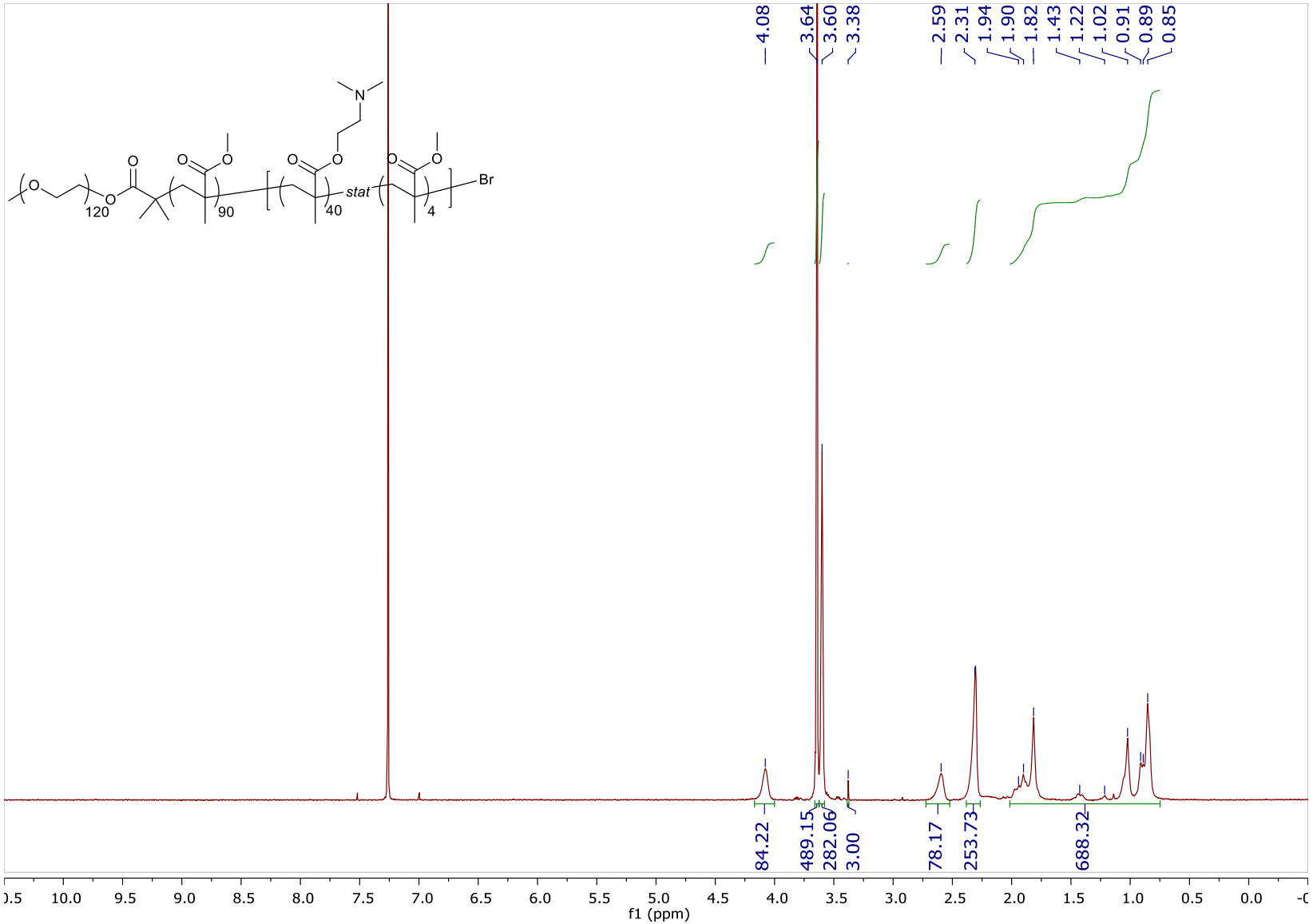


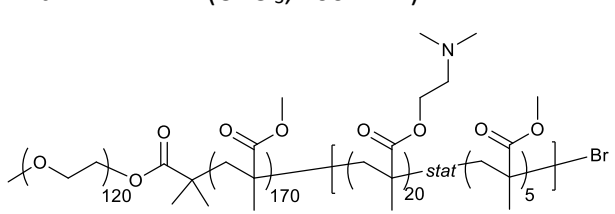
Figure S11: TEM micrographs of grids prepared from the resultant samples after transferring the worm-like assemblies from Figure S10 to water. (A) Sample of **12a** and **6a** transferred by syringe pump and dialysis. (B) Sample of **13b** and **6a** transferred by syringe pump and dialysis. (C) Sample of **13a** and **6a** transferred by syringe pump and dialysis. (D) Sample of **13a** and **6a** heated to 70 °C during the addition of water by syringe pump followed by dialysis. (E) Sample of **13a** and **6a** transferred to water by rapid addition of a ten-fold dilution, followed by dialysis and subsequently heated at 70 °C for 40 minutes. (F) Sample of **13b** and **6a** cooled to 0 °C during the addition of water by syringe pump followed by dialysis.

NMR Appendix

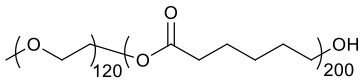
12a ^{1}H NMR ($CDCl_3$, 400 MHz)



12b ^{1}H NMR ($CDCl_3$, 400 MHz)

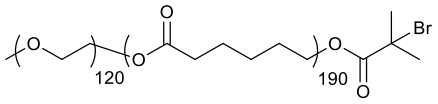


PEO_{120}-*b*-PCL_{200} ^1H NMR ($CDCl_3$, 400 MHz)

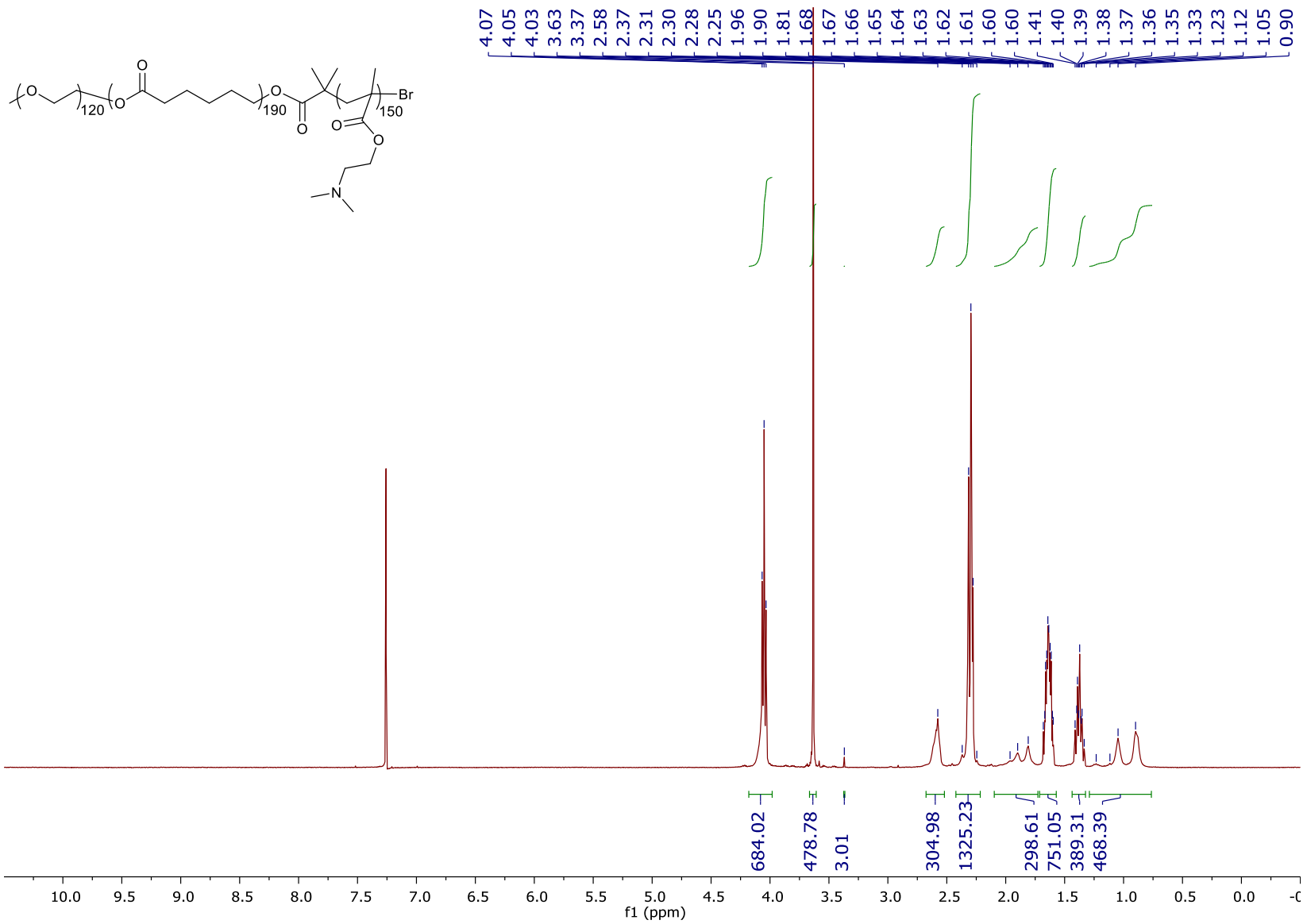


PEO_{120}-*b*-PCL_{190}-Br

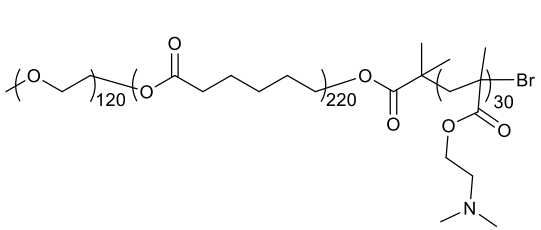
^1H NMR ($CDCl_3$, 400 MHz)



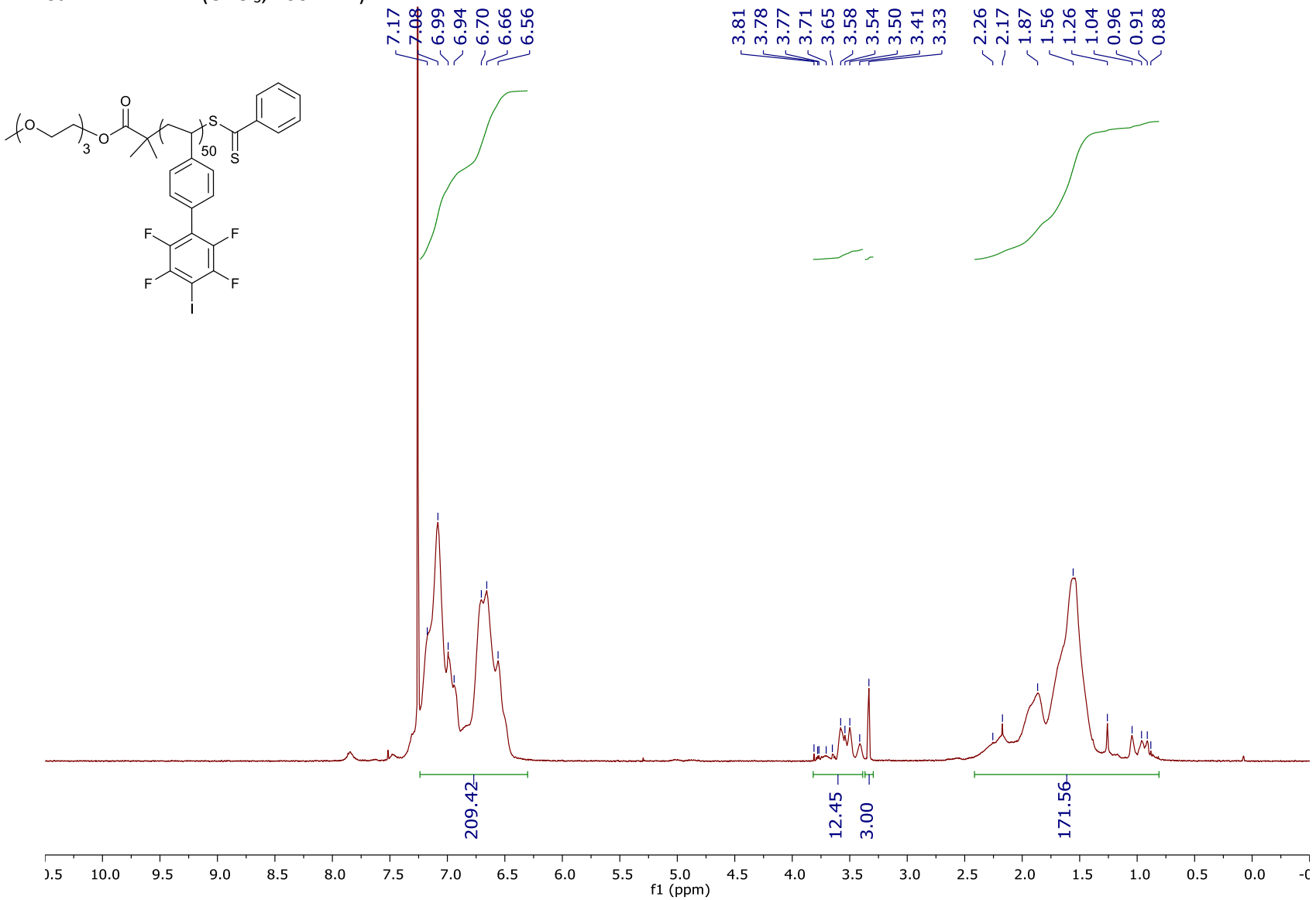
13a ^{1}H NMR ($CDCl_3$, 400 MHz)



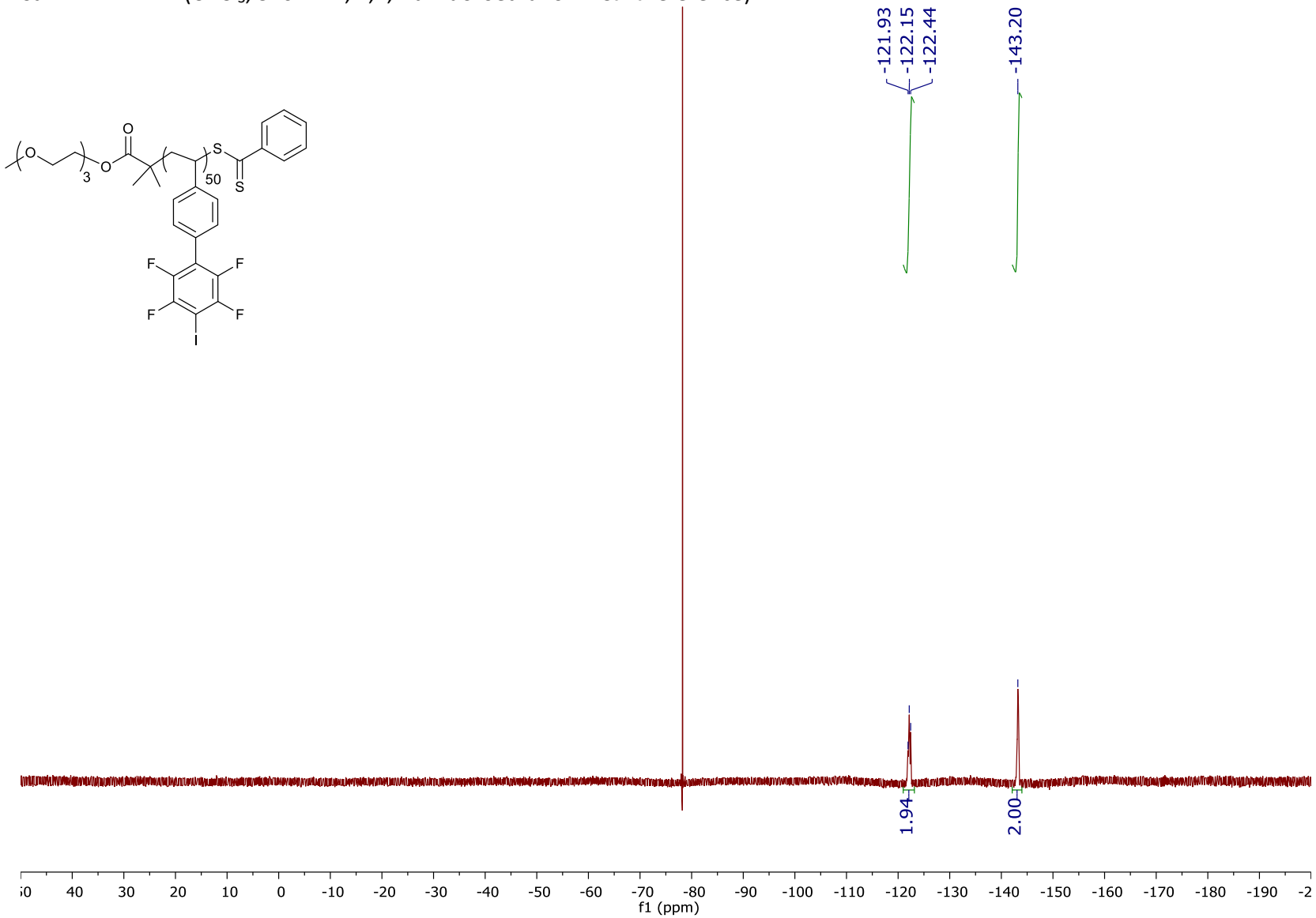
13b ^{1}H NMR (400 MHz, CD_2Cl_2)



6a ^{1}H NMR ($CDCl_3$, 400 MHz)

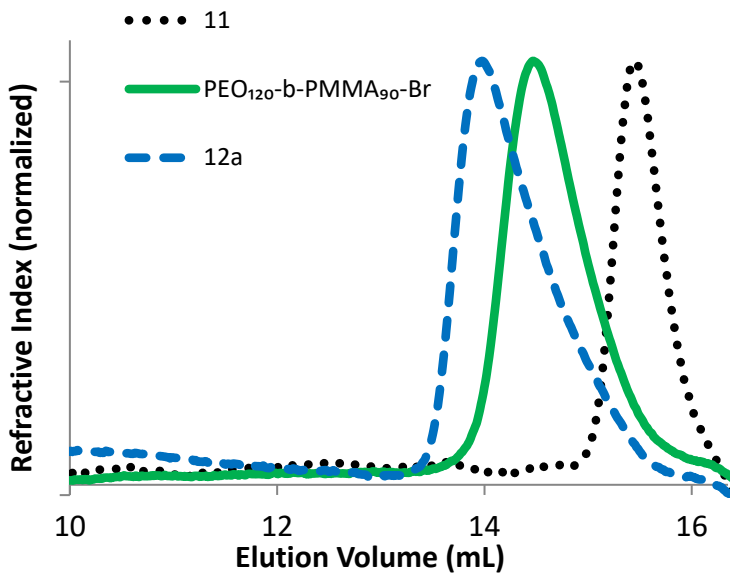


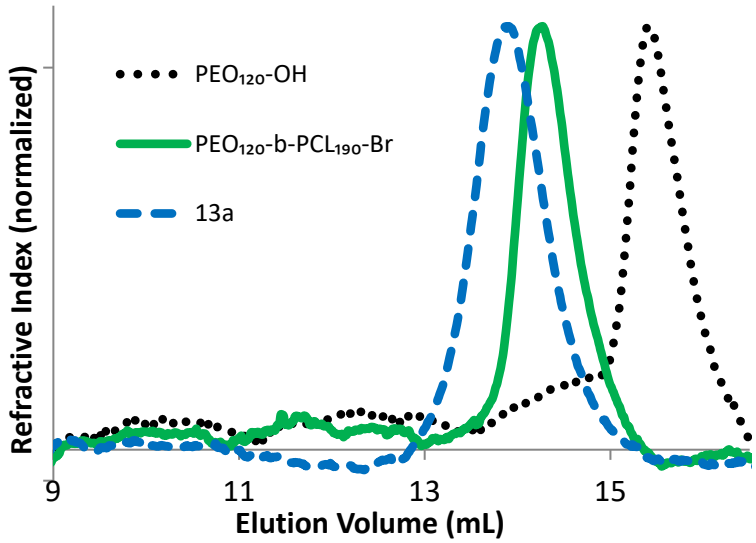
6a ^{19}F NMR ($CDCl_3$, 376 MHz, 2,2,2-trifluoroethanol in C_6D_6 reference)



GPC Appendix

Overlay of GPC traces from triblock syntheses

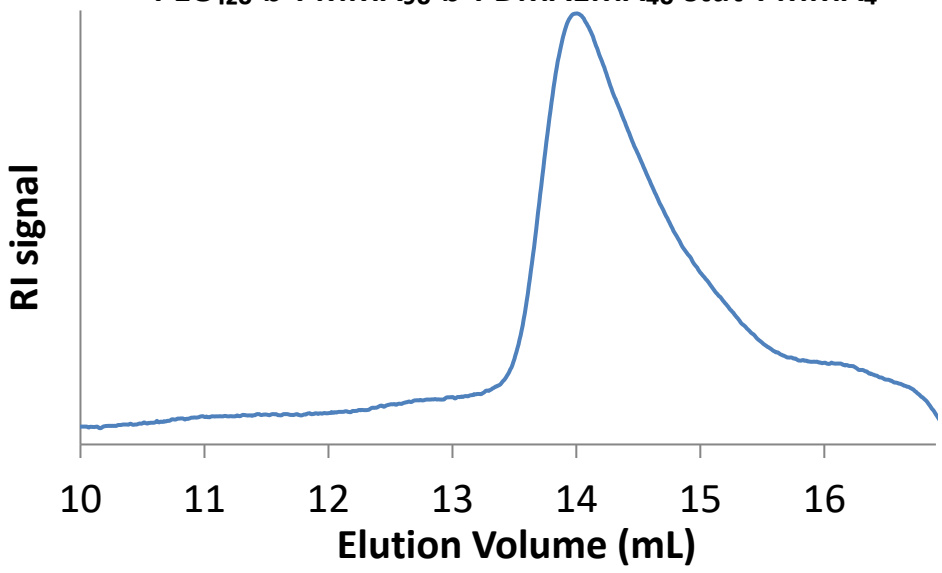




Individual Polymers

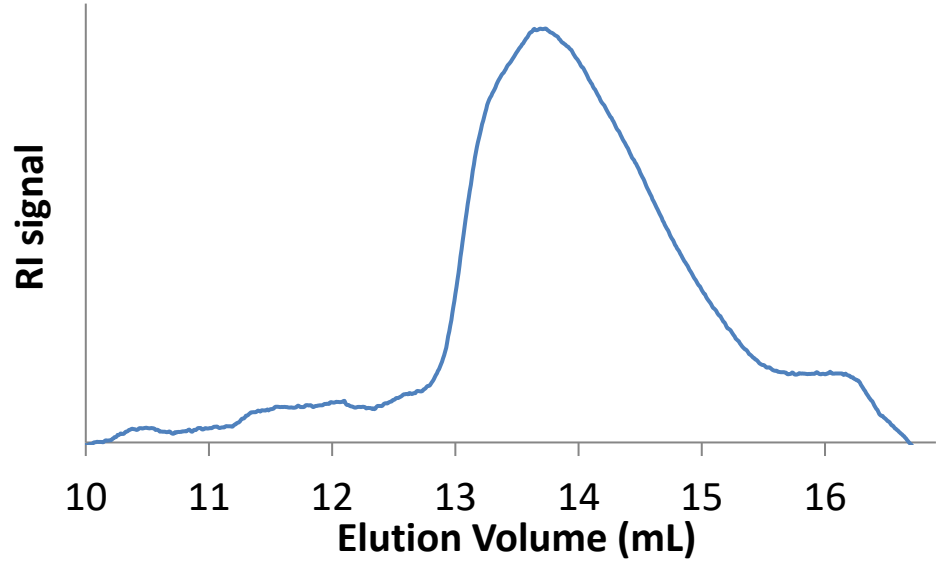
12a

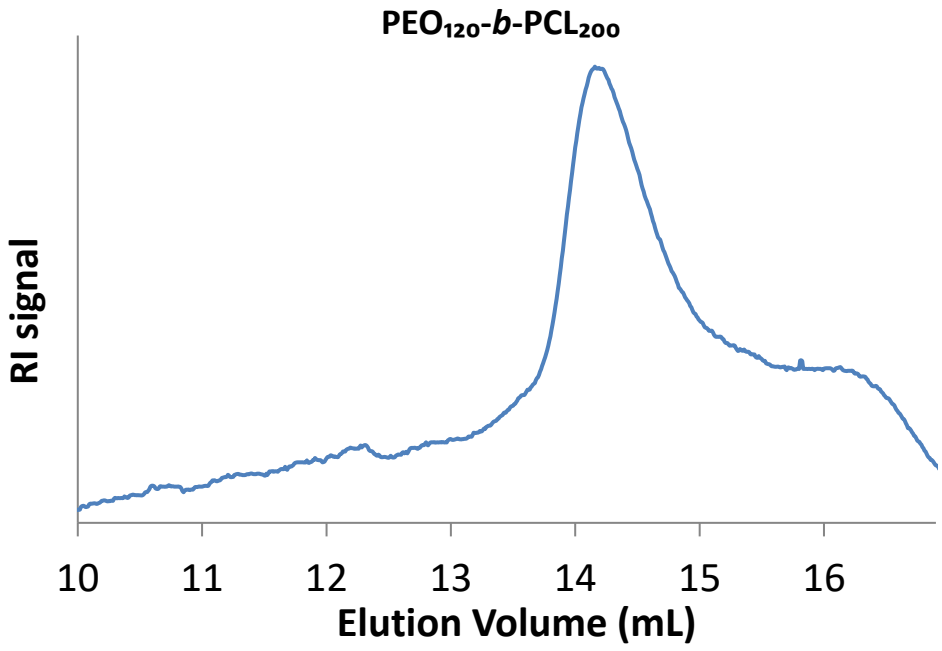
PEO_{120}-*b*-$PMMA_{90}$-*b*-$PDMAEMA_{40}$-*stat*-$PMMA_4$

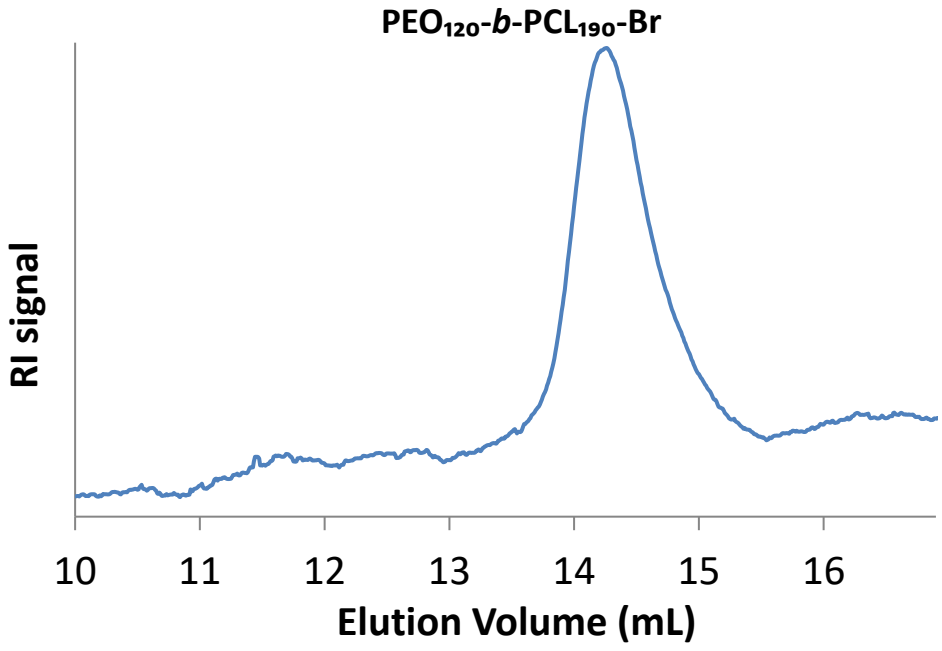


12b

PEO_{120}-*b*-$PMMA_{170}$-*b*-$PDMAEMA_{20}$-*stat*-$PMMA_5$

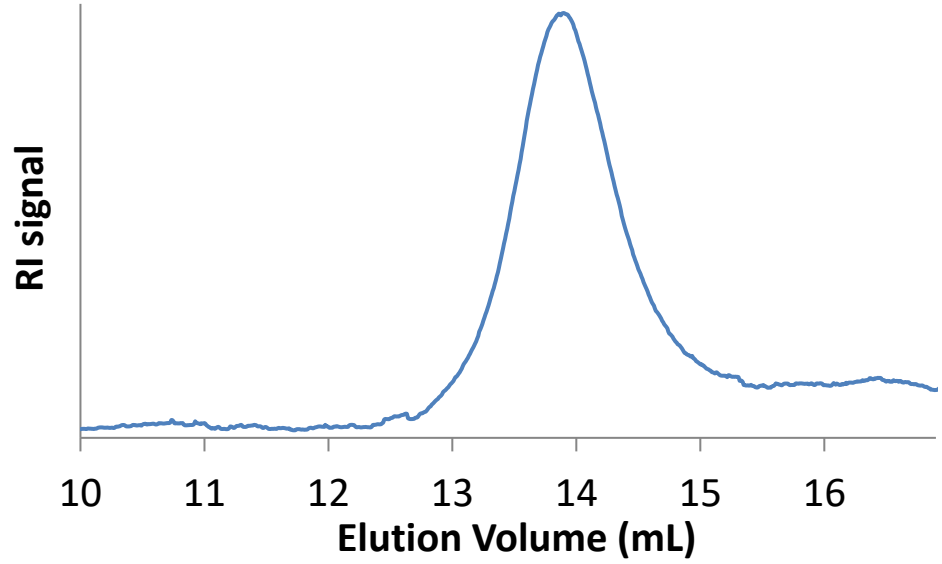



PEO120-b-PCL200
RI signal
10
11
12
13
14
15
16
Elution Volume (mL)


PEO120-b-PCL190-Br
RI signal
10
11
12
13
14
15
16
Elution Volume (mL)

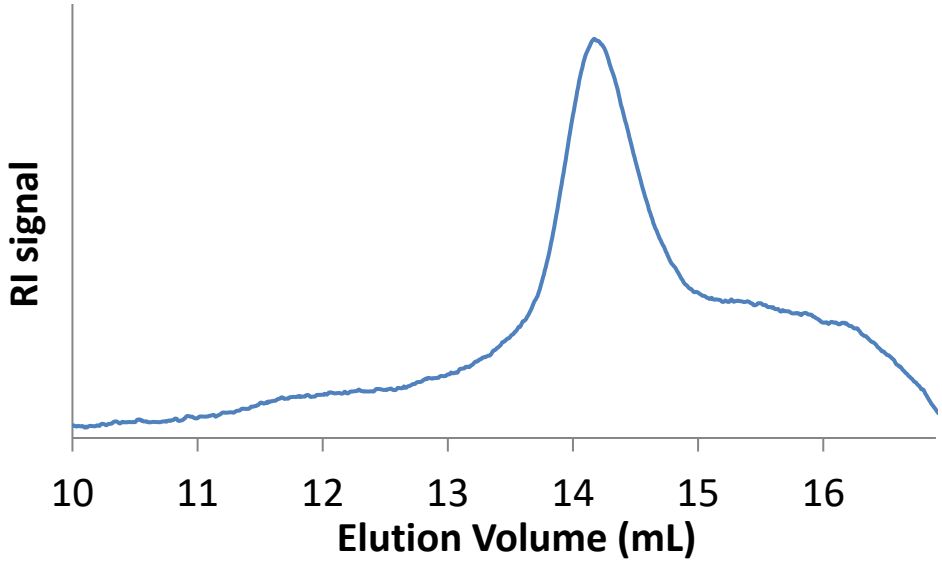
13a

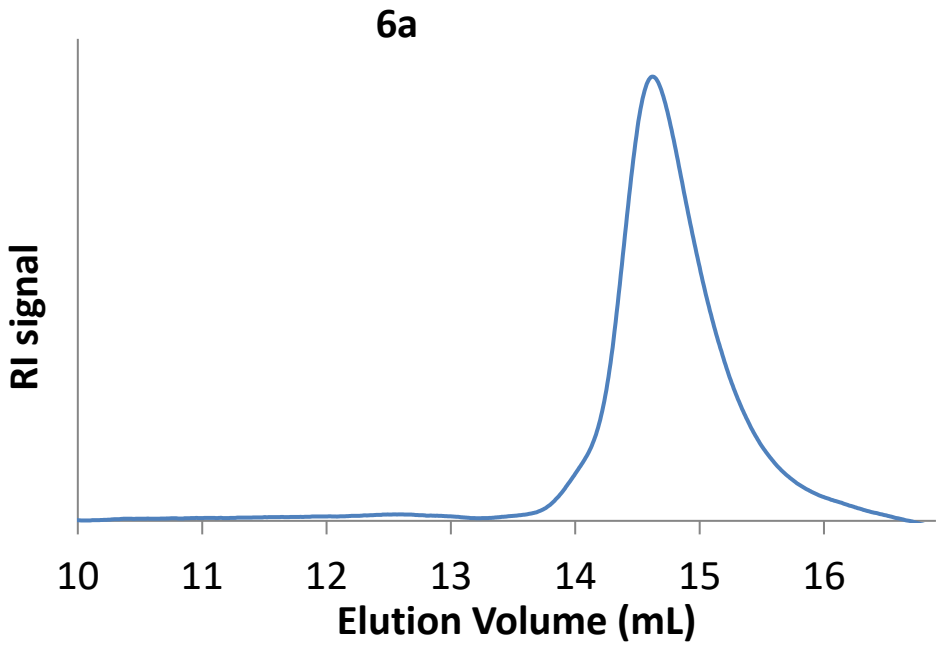
PEO_{120}-*b*-PCL_{190}-*b*-$PDMAEMA_{150}$



13b

PEO_{120}-*b*-PCL_{220}-*b*-$PDMAEMA_{30}$




6a
RI signal
10
11
12
13
14
15
16
Elution Volume (mL)

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