

Supporting Information

of

One-pot ATRP synthesis of PEG-*b*-PNIPAAm-*b*-P(NIPAAm-co- 5 HEAAm) triblock copolymer with dual LCSTs and its thermo-induced association behavior

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1. Experimental details
2. Figure S1, S2 and S3

1. Experimental details

Materials

Poly(ethylene glycol) monomethyl ether (PEG₄₅-OH, $M_w=2000$ and the polydispersity index (PDI) = 1.05) was purchased from Fluka. The subscript refers to the average degree of polymerisation (DP) of the repeated ethylene oxide units as reported by the supplier. *N*-isopropylacrylamide (NIPAAm), 2-bromoisobutyryl bromide and tris(aminoethyl)amine (TREN) were purchased from Sigma and used as received. PEG₄₅-bromide (PEG₄₅-Br) macroinitiator was prepared according to reported procedure¹. Tris(2-(dimethylamino)ethyl)amine (Me₆TREN) was synthesized from TREN according to previous study by Ciampolini and Nardi.² *N*-hydroxyethyl acrylamide (HEAAm) obtained from Sigma and was used after distillation under reduced pressure to remove the inhibitor. Copper (I) chloride (CuCl, Sigma) was washed with acetic acid and ethanol in turn to remove Cu²⁺. Anhydrous toluene, anhydrous *N,N'*-dimethylformamide (DMF), anhydrous ethyl ether, tetrahydrofuran (THF), and all other chemicals were purchased from Sigma and used without further purification.

Preparation of PEG-*b*-PNIPAAm-*b*-P(NIPAAm-co-HEAAm) Triblock Copolymer

PEG-*b*-PNIPAAm-*b*-P(NIPAAm-co-HEAAm) triblock copolymer was synthesized by ATRP using PEG-Br as the macroinitiator and CuCl/Me₆TREN as the catalyst. Firstly, NIPAAm (1.13 g, 10 mmol), PEG₄₅-Br (0.025 g, 0.0125 mmol), Me₆TREN (6.88 μL, 0.025 mmol), a DMF (2.25 mL)/water (2.5 mL) mixed solution were introduced into a 25 mL Schlenk flask charged with a magnetic stirrer. The flask was deoxygenated by three freeze-pump-thaw cycles, back-filled with Ar, and then CuCl (0.0025 g, 0.025 mmol) was introduced into the flask under the protection of Ar flow. The reaction mixture was degassed with another three freeze-pump-thaw cycles, and then sealed followed by immersing the flask into an oil bath preheated at 30 °C to start the polymerization. After 15 min, a degassed DMF (1.5 mL)/water (1.5 mL) mixed solution containing NIPAAm (0.212 g, 1.875 mmol) and HEAAm (0.086 g, 0.75 mmol) was injected into the reaction mixture via a needle under the protection of Ar flow. This reaction further proceeded at 30 °C for 24 h. Thereafter, the flask was taken away from the bath and the reaction was stopped by exposure to air. The reaction mixture was diluted with THF (10 mL), and then passed through a short neutral Al₂O₃ column to remove the copper catalyst. The resulting solution was concentrated and poured into anhydrous ethyl ether to precipitate the product. The product was separated by filtration and further purified twice by

redissolving/precipitating with THF/ethyl ether, and finally dried in vacuum for 2 days.

¹H NMR Measurements

¹H NMR spectra of the synthesized polymers were recorded on a Bruker Ultra Shield Avance (400 MHz) spectrometer using CDCl₃ as the solvents.

SEC-MALLS Measurements.

Size-exclusion chromatography and multi-angle laser light scattering (SEC-MALLS) analysis were used to determine the molecular weights of the polymers. A dual-detector system, consisting of a MALLS device (DAWN EOS, Wyatt Technology) and an interferometric refractometer (Optilab DSP, Wyatt Technology) were used. The columns were styragel HR1 and HR4. The injected volume of polymer solution (10 mg/mL) was 100 μL. THF (chromatographic grade) was used as the eluent at a flow rate of 0.3 mL/min. The MALLS detector was operated at a laser wavelength of 690 nm.

15 LCST Behaviours

The turbidity of polymer aqueous solutions (1 g/L) at various temperatures was measured at 542 nm using a Lambda Bio40 UV–Vis spectrometer (Perkin-Elmer). Sample cells were thermostated in a circulator bath at different temperatures from 25 °C to 65 °C prior to the measurements. The LCST was defined as the temperature in which turbidity was half of the maximum value.

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Size Distribution Measurements

Nano ZS ZEN3600 (Malvern Instruments) was used to monitor the average size distribution of polymer and its self-assemblies in aqueous solution (1 g/L) at different temperatures. All data were averages of three independent determinations.

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Transmission Electron Microscopy (TEM) Observation

The TEM sample was prepared by dipping a Formvar film coated copper grid into the micelle or vesicle aqueous solutions preheated at different temperatures. After the deposition of particles the residue of aqueous solution was

blotted away with a strip of filter paper, the sample was stained with 1% phosphatetungstic acid aqueous solution, and dried in air. The TEM analysis was then carried out on a JEOL 1400 instrument operating at an acceleration voltage of 120 kV to examine the particle characteristics.

5 Static and Dynamic Laser Light Scattering (LLS) Measurements.

A modified commercial light scattering spectrometer (ALV/SP-125, ALV, Germany) equipped with an ALV-5000/E multi- τ digital time correlator, and a He-Ne laser (at $\lambda=632.8$ nm) was used. The details of the Laser Light Scattering (LLS) instrumentation and theory can be found in literatures.^{3,4} Briefly, in static LLS, the angular dependence of scattered light intensity, termed as the Rayleigh ratio (R_θ), of dilute polymer solution leads to the root-mean square z -average radius of gyration $\langle s^2 \rangle^{1/2}$ (or written as $\langle R_g \rangle$) via a Zimm plot. In dynamic LLS, the precisely measured intensity-intensity time correlation function $G^{(2)}(q, \tau)$ in the self-beating mode can be related to the linewidth distribution $G(\Gamma)$ by using the CONTIN Laplace inversion algorithm in the correlator. For a pure diffusive relaxation, $G(\Gamma)$ can be converted to a translational diffusion coefficient distribution $G(D)$ by $\Gamma=Dq^2$ or a hydrodynamic radius distribution $f(R_h)$ using the Stoke-Einstein equation $\langle R_h \rangle = k_B T / 6\pi\eta D$, where k_B is Boltzmann constant, T is the absolute temperature, η is the solvent viscosity and D is the translational diffusion coefficient.

References

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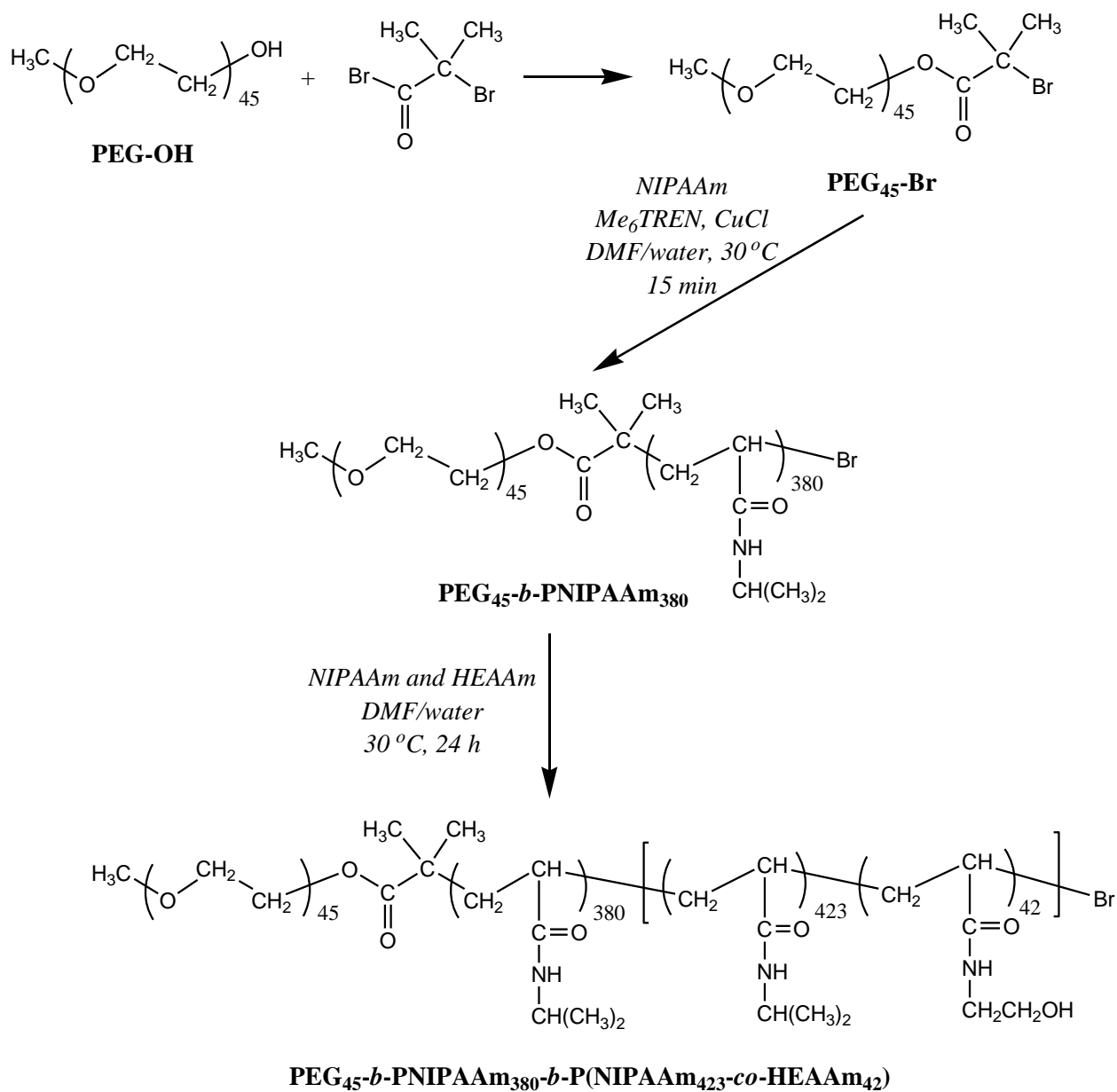


Fig. S1 Synthesis route of PEG₄₅-*b*-PNIPAAm₃₈₀-*b*-P(NIPAAm₄₂₃-*co*-HEAAm₄₂) tri-block copolymer by a one-pot ATRP technique.

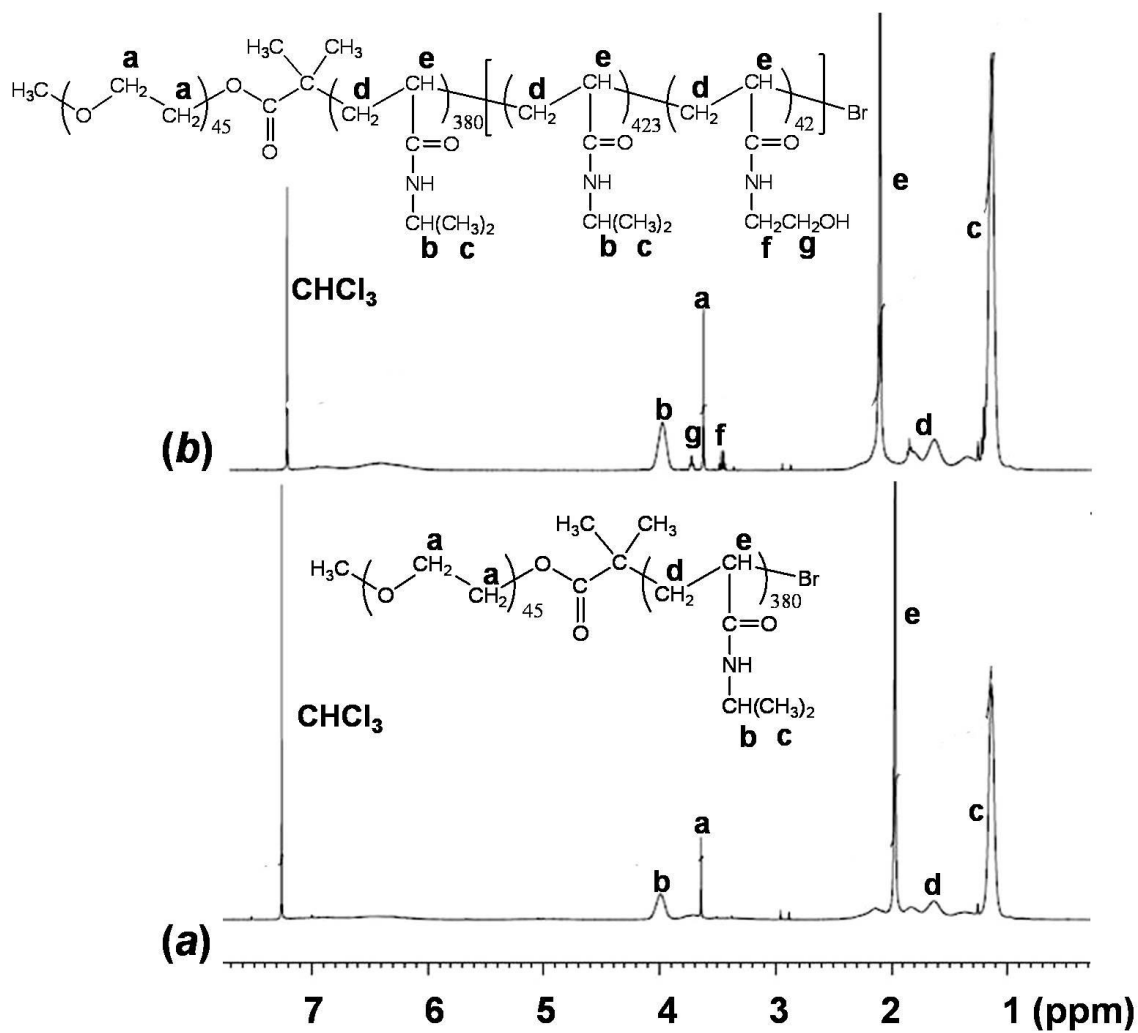


Fig. S2 ¹H NMR spectra of (a) PEG₄₅-*b*-PNIPAAm₃₈₀, and
(b) PEG₄₅-*b*-PNIPAAm₃₈₀-*b*-P(NIPAAm₄₂₃-*co*-HEAAm₄₂) in CDCl₃.

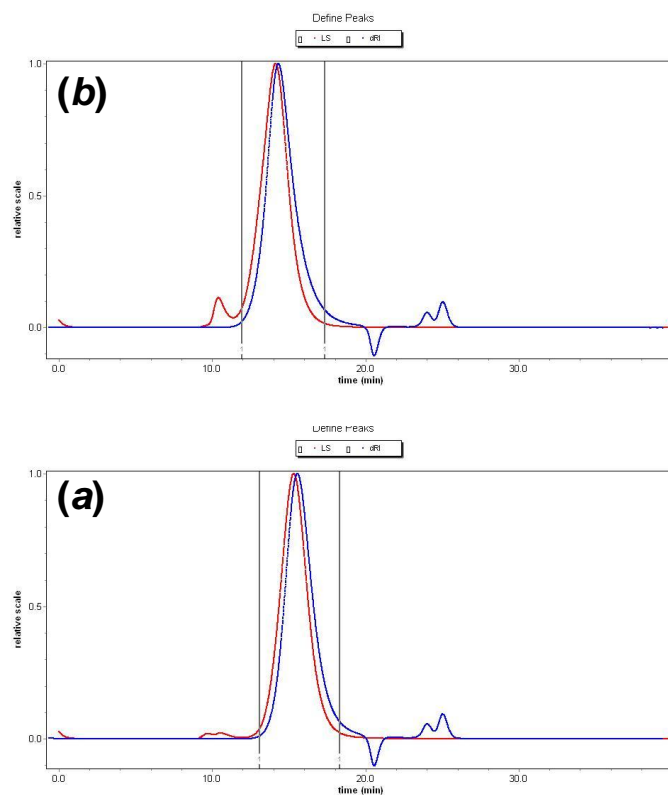


Fig. S3. SEC-MALLS traces of (a) PEG₄₅-*b*-PNIPAAm₃₈₀, $M_n = 43,500$, $M_w/M_n = 1.16$ and (b) PEG₄₅-*b*-PNIPAAm₃₈₀-*b*-P(NIPAAm₄₂₃-*co*-HEAAm₄₂), $M_n = 85,100$, $M_w/M_n = 1.24$.