Supporting Information for

Pyranine-induced Micellization of Poly(ethylene glycol)-block-poly(4-vinylpyridine) and pH-triggered Release of Pyranine from the Complex Micelles

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Synthesis and Characterization of the Block Copolymer PEG\textsubscript{114}-b-P4VP\textsubscript{61}.

Synthesis of the macroinitiator PEG\textsubscript{114}-Br. The macroinitiator PEG\textsubscript{114}-Br was synthesized according to ref.\textsuperscript{1-2} The typical procedure to synthesize PEG\textsubscript{114}-Br can be introduced as follow. About 650 mL of toluene was first refluxed over sodium-benzophenone for about 8 h to remove water. Secondly, 30.0 g of CH$_3$O-PEG\textsubscript{114}-OH was dissolved in 500 mL of dried toluene in a 1000 mL three-neck flask at elevated temperature. Then about 60 mL of toluene was vacuum distilled from the polymer solution to remove the traces of water and the solution mixture was thermostatted to 25°C. Subsequently, 2.0 mL of triethylamine, which was dried over CaH$_2$ and vacuum distilled, was added into the flask. Finally, 2.0 mL of 2-bromoisobutyryl bromide was dissolved in about 80 mL of dried toluene and the solution was added into the reaction flask via a constant pressure-drop funnel over 1 h. The reaction mixture was magnetically stirred for 48 h. After the end of reaction, the reaction mixture was filtrated to remove the resultant salts. Then most of the toluene was removed from the filtrate by rotary evaporation prior to precipitation into a 10-fold excess of cold ether. The crude polymer was dried
under vacuum before being dissolved in water at pH 8-9. The aqueous solution was extracted with CH₂Cl₂ and the organic layer was collected. The dichloromethane solution was dried over CaSO₄ and filtrated. The filtrate was condensed by rotary evaporation and poured into 10-fold excess of cold ether. The precipitate was dried under vacuum and purified PEG₁₁₄-Br was obtained.

**Synthesis of PEG₁₁₄-b-P₄VP₆₁.** Tris-(2-dimethylaminoethyl) amine (Me₆TREN) as an atom transfer radical polymerization (ATRP) ligand used in this study was synthesized from tris(2-aminoethyl)amine (TREN) according to ref.³ PEG₁₁₄-b-P₄VP₆₁ was synthesized by ATRP of 4-vinylpyridine with PEG₁₁₄-Br as the macroinitiator and CuCl complexed by Me₆TREN as the catalyst.⁴⁻⁵ The typical polymerization procedure to synthesize PEG₁₁₄-b-P₄VP₆₁ can be introduced as follow. 4.0 g of PEG₁₁₄-Br, 0.10 g of CuCl and 0.25 g of Me₆TREN were added to a reaction flask followed by addition of 8 ml of solvent mixture of butanone and 2-propanol (7:3, v:v). The solution mixture was first stirred with ultrasonic and then degassed under nitrogen purge. Subsequently, 5.0 g 4-vinyl pyridine was added into the flask. The reaction mixture was degassed by three freeze-thaw cycles and flame-sealed under vacuum. Polymerization was performed at 40⁰C for 10 hours. After the end of the polymerization, the reaction mixture was dissolved in dichloromethane followed by passing through an Al₂O₃ column to remove the copper catalyst. The dichloromethane solution was condensed by rotary evaporation and poured into 10-fold excess of cold ether. The precipitate of PEG₁₁₄-b-P₄VP₆₁ was filtered under vacuum and dried in vacuum at room temperature.

**¹H NMR characterization.** The ¹H NMR spectra of the polymers in CDCl₃ were recorded using a Varian UNITY-plus 400 spectrometer and chemical shifts were
given in ppm relative to TMS. The $^1$HNMR spectrum of PEG$_{114}$-Br is shown in Figure S1. The area of peak c approximates to the twice of that of peak a indicating that the end hydroxyl groups in CH$_3$O-PEG$_{114}$-OH are fully esterified.

![1H NMR Spectrum of PEG$_{114}$-Br in CDCl$_3$ at the room temperature.](image1)

Figure S1. $^1$H NMR Spectrum of PEG$_{114}$-Br in CDCl$_3$ at the room temperature.

The $^1$H NMR spectrum of the block copolymer PEG$_{114}$-$b$-P4VP$_{61}$ is shown in Figure S2. The composition of PEG$_{114}$-$b$-P4VP$_{61}$ is determined by the ratio of the area of peak a to that of peak d.

![1H NMR Spectrum of PEG$_{114}$-$b$-P4VP$_{61}$ in CDCl$_3$ at the room temperature.](image2)

Figure S1. $^1$H NMR Spectrum of PEG$_{114}$-$b$-P4VP$_{61}$ in CDCl$_3$ at the room temperature.
**Gel permeation chromatography (GPC) analysis.** PEG$_{114}$-Br and PEG$_{114}$-$b$-P4VP$_{61}$ were characterized by a Waters 600E gel permeation chromatography (GPC) analysis system, where $N,N$-dimethylformamide (DMF) was used as the eluent and narrowly distributed poly(methyl methacrylate) was used as the calibration standard. The GPC traces for PEG$_{114}$-Br and PEG$_{114}$-$b$-P4VP$_{61}$ are shown in Figure S3. The polydispersity indices (PDIs) of PEG$_{114}$-Br and PEG$_{114}$-$b$-P4VP$_{61}$ are 1.06 and 1.15 respectively.

![Figure S3. GPC traces for PEG$_{114}$-Br and PEG$_{114}$-$b$-P4VP$_{61}$ in DMF at the room temperature.](image)

**Initial block copolymer concentration dependence of the structural characteristics of the complex micelles.**

Complex micelle solutions with the same final polymer and pyranine concentration of 0.40 and 0.50 g/L respectively were prepared by using block copolymer solutions with different concentrations, i.e. 0.60, 1.0, 2.0, 3.0 and 4.0 g/L respectively. Light scattering measurements indicated that the initial block
copolymers.

The copolymer concentration, $C_{ip}$, can influence the structural characteristics of the complex micelles, but mainly when the initial polymer concentrations are higher than 2.0 g/L. When polymer solutions with the $C_{ip}$ in the range of 0.60 to 2.0 g/L are used, the $R_h^0$, $R_g^0$, and $R_g^0/R_h^0$ of the resultant complex micelles change very little with the variation of $C_{ip}$. But when $C_{ip}$ is higher than 2.0 g/L, a progressive increase of the $R_h^0$, $R_g^0$, and $R_g^0/R_h^0$ of the resultant complex micelles with the increasing of $C_{ip}$ is observed, which suggests that higher initial block copolymer concentration favor the formation of complex micelles and/or large compound micelles with larger size and lower compactness.

Figure S4. The dependence of the hydrodynamic radius $R_h^0$, the apparent radius of gyration $R_g^0$, and the value of $R_g^0/R_h^0$ (the inset) of the PEG$_{114}$-b-P4VP$_{61}$/Pyranine complex micelles on the initial block copolymer concentrations, where all of the complex micelle solutions have the final polymer concentration of 0.40 g/L and the pyranine concentration of 0.50 g/L.
The influence of the order of addition of pyranine and polymer solutions on the structural characteristics of the resultant complex micelles.

The order of addition of block copolymer solution and pyranine solution has important influence on the structural characteristics of the complex micelles. In this study, 4.0 mL of polymer solution (1.0 g/L) was added into 2.5 mL of pyranine solution (2.0 g/L) under stirring followed by addition of 3.5 mL of water (pH 2) to prepare micelle solution with a block copolymer concentration of 0.40 g/L and a pyranine concentration of 0.50 g/L. The measured $R_0^h$ and $R_0^g$ for the reversely prepared complex micelles are 47.5 nm and 40.3 nm respectively, much larger than those of the micellar solution (with the polymer of 0.40 g/L and pyranine concentration of 0.50 g/L) prepared by adding pyranine solution into a block copolymer solution. The $R_0^g/R_0^h$ value is calculated to be 0.85, which indicates that the reversely prepared micelles are relatively incompact. A relatively broader size distribution was also observed during the DLS measurement.

The influence of the initial pyranine concentration on the release curves.

Controlled release of pyranine was also carried out with the complex micelle system with the polymer and pyranine concentrations of 0.40 and 0.25 g/L at pH 2, 4 and 7 respectively. The results suggested that the relative amounts of pyranine that could be released from the complex micelles at different pH values decreased when the initial pyranine concentration in the complex micelle solutions was reduced from 0.50 to 0.25 g/L as shown in Figure S5. After about 24 hours, the release of pyranine at pH 2, 4 and 7 ultimately ceased and only about 3, 8 and 26% of the incorporated pyranine were released out. It is evident that the relative
amounts of pyranine released from the complex micelles at different pH values decreases with the decreasing of the initial pyranine concentration in the complex micelle solutions. A possible reason is that the strong interaction between the pyranine and the pyridyl units prevents the continuous release of pyranine from the complex micelles. While at pH 7, though the strong electrostatic interaction between pyranine and pyridyl units could be destroyed, the formation of a hydrophobic P4VP layer around the P4VP before the disintegration of the complex micelles may also prevent the release of pyranine from the inner P4VP core.

Figure S5. Cumulative release of the pyranine from the complex micelles at different pH values at 25°C, where the concentrations of PEG$_{114}$-b-P4VP$_{61}$ and pyranine were 0.40 g/L and 0.25 g/L respectively.

References
