

## Supporting Information

### **Aqueous Radical Addition-Coupling Polymerization for Synthesis of Hydrophilic Periodic Polymer**

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## 1 Experimental Section

### 1.1 Materials

PEG600, PEG1000 and PEG2000 were all purchased from Aldrich and were dried by azeotropic distillation using toluene prior to use. 2-methyl-2-nitroso propyl 2-hydroxyl acetate (MNPHA) was synthesized according to procedures previously reported in our literature.<sup>[1]</sup> N-(2-hydroxyl ethoxyethyl) 2-pyridyl methanimine (HEEPMI) was synthesized according to previously literature procedures.<sup>[2]</sup> Copper powder (3.25-4.75  $\mu\text{m}$ , 99.9%, Alfa Aesar), Copper bromide (CuBr, 98%, Aldrich) was purified according to literature method.<sup>[3]</sup> 2-amino-2-methyl-1-propanol (>97%, Fluka). 2-bromo-2-methylpropionyl bromide (98%, Aldrich), *m*-chloroperoxybenzoic acid (*m*-CPBA, 70–75%, Alfa Aesar), 2,2'-bipyridyl (bpy, 99.0%, aladdin), *N,N,N',N'',N''*-pentamethyldiethylenetriamine (PMDETA, 98%, Alfa Aesar), Pyridine-2-carboxaldehyde (99%, Aldrich), 2-(2-aminoethoxy)ethanol (98%, Alfa Aesar) and EPHP (95%, Aldrich) were used as received. The water used in all experiments was deionized and doubly distilled prior to use.

### 1.2 Characterization

Number average molecular weight ( $M_n$ ) and molecular weight distributions (MWDs) were determined by gel permeation chromatograph (GPC) on a PL GPC220 equipped with two PLgel 5  $\mu\text{m}$  MIXED-C columns using polystyrene standards and THF as the eluent at a flow rate of 1.0 mL/min at 40 °C. <sup>1</sup>H NMR spectra were recorded at room temperature by a Bruker (400 MHz) spectrometer using tetramethylsilane as the internal standard and CDCl<sub>3</sub> (or D<sub>2</sub>O) as the solvent.

### 1.3 Synthesis of dibromo poly (ethylene glycol)

#### 1.3.1 Synthesis of Br-PEG2000-Br

In a three-neck flask, PEG2000 (5.0 g, 25 mmol) and pyridine (0.401 mL, 50 mmol) were mixed in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (50 mL) at 0 °C. A 30 mL CH<sub>2</sub>Cl<sub>2</sub> solution of 2-bromo-2-methylpropionyl bromide (0.927 mL, 75 mmol) was added dropwise over a

period of 2 h. Then the reaction solution was allowed to warm to room temperature and was stirred for another 24 h. The reaction mixture was washed with 1M HCl (3×50 mL), 5% aqueous solution of NaHCO<sub>3</sub> (3×50 mL) and saturated aqueous solution of NaCl (2× 100 mL). Then the organic layers were combined and dried over magnesium sulfate. The solvent was removed by evaporation, and the product was precipitated by diethyl ether for three times. It was finally dried under vacuum at 40 °C to yield pale yellow solid. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ (ppm): 4.33 (t, CH<sub>2</sub>-O-C=O), 3.74 (t, CH<sub>2</sub>-CH<sub>2</sub>-O-C=O), 3.64 (m, O-CH<sub>2</sub>CH<sub>2</sub>-O), 1.94 (s, O=C-C(CH<sub>3</sub>)<sub>2</sub>-).

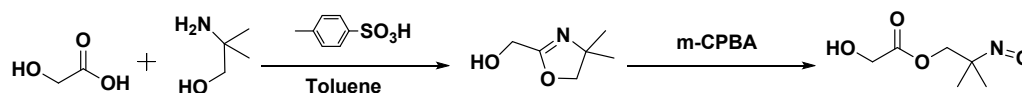
### 1.3.2 Synthesis of Br-PEG1000-Br

Br-PEG1000-Br was prepared from PEG1000 by the same method for Br-PEG2000-Br. The product was precipitated by n-hexane to afford pure product as sticky liquid. <sup>1</sup>H NMR (400 MHz, D<sub>2</sub>O) δ (ppm): 4.26 (t, CH<sub>2</sub>-O-C=O), 3.71(t, CH<sub>2</sub>-CH<sub>2</sub>-O-C=O), 3.58 (m, O-CH<sub>2</sub>CH<sub>2</sub>-O), 1.84 (s, O=C-C(CH<sub>3</sub>)<sub>2</sub>-).

### 1.3.3 Synthesis of Br-PEG600-Br

Br-PEG600-Br was prepared from PEG600 by the same method for Br-PEG2000-Br. The product was precipitated by n-hexane to afford pure product as light yellow liquid. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ (ppm): 4.33 (t, CH<sub>2</sub>-O-C=O), 3.74 (t, CH<sub>2</sub>-CH<sub>2</sub>-O-C=O), 3.65(m, O-CH<sub>2</sub>CH<sub>2</sub>-O), 1.94 (s, O=C-C(CH<sub>3</sub>)<sub>2</sub>-).

## 1.4 Synthesis of 2-methyl-2-nitrosopropyl 2-hydroxyl acetate (MNPHA)



Scheme 1

### 1.4.1 Synthesis of 2-hydroxymethyl-4,4-dimethyl 2-oxazoline

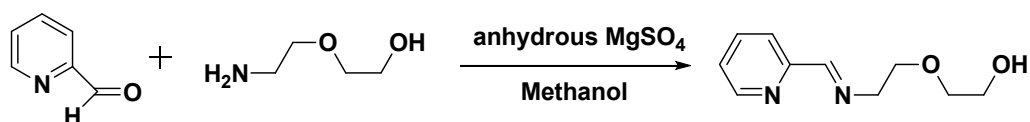
Glycolic acid (4.56 g, 60 mmol), *p*-toluenesulfonic acid monohydrate (114.1 mg, 0.66 mmol) and 2-amino-2-methyl-1-propanol (5.34 g, 60 mmol) were dissolved together in 28 mL of toluene and refluxed for 48 h. After it was cooled to room temperature, the solvent was removed under vacuum. The residue was slowly distilled under reduced pressure to yield white crystalline solid. Yield:3.26 g (42.3%).

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ (ppm): 5.19 (b, -OH), 4.22 (s, C-CH<sub>2</sub>-OH), 4.01 (s, C(CH<sub>3</sub>)<sub>2</sub>-CH<sub>2</sub>-O-), 1.30 (s, CH<sub>3</sub>-C-CH<sub>3</sub>).

#### 1.4.2 Synthesis of 2-methyl-2-nitroso propyl 2-hydroxyl acetate (MNPHA)

A solution of m-CPBA (11.83 g, 48 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) was added dropwise to an ice cooled solution of 2-hydroxymethyl-4,4-dimethyl 2-oxazoline (3.1 g, 24 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) with stirring under N<sub>2</sub> over 2 h. The mixture was allowed to gradually warm to 25 °C with stirring for another 14 h. The white precipitation was removed by filtration, then the resulting blue CH<sub>2</sub>Cl<sub>2</sub> solution was washed with aqueous solution of Na<sub>2</sub>CO<sub>3</sub> (10wt%, 3×50 mL), then with saturated aqueous solution of NaCl (3×100 mL), and dried over anhydrous magnesium sulfate. Evaporation of the solvent and purification by flash column chromatography (petroleum ether : ethyl acetate = 2:1) gave dark blue oil, which was distilled under vacuum to yield final product as light green crystalline solid (19%). <sup>1</sup>H NMR (monomer, 400 MHz, CDCl<sub>3</sub>) δ (ppm): 4.92 (s, C-CH<sub>2</sub>-O), 4.06 (s, O=C-CH<sub>2</sub>-OH), 2.25 (b, -OH), 1.16 (s, CH<sub>3</sub>-C-CH<sub>3</sub>). <sup>1</sup>H NMR (dimer, 400 MHz, CDCl<sub>3</sub>) δ (ppm): 4.70 (s, C-CH<sub>2</sub>-O), 4.17 (s, O=C-CH<sub>2</sub>-OH), 1.60 (s, CH<sub>3</sub>-C-CH<sub>3</sub>).

#### 1.5 Synthesis of N-(2-hydroxyl ethoxyethyl) 2-pyridyl methanimine (HEEPMI)



Scheme 2

N-(2-hydroxyl ethoxyethyl) 2-pyridyl methanimine (HEEPMI) was synthesized according to literature method <sup>[3]</sup> and stored under anhydrous conditions prior to use. 2-(2-aminoethoxy)ethanol (6.08 g, 0.21 mol) was added dropwise to a stirred solution of pyridine-2-carboxaldehyde (6.14 g, 0.21 mol) in methanol (80 mL) which was cooled in an ice bath, The color changed from colourless to pale yellow. After complete addition of the 2-(2-aminoethoxy)ethanol, anhydrous magnesium sulfate (0.4 g) was added and the mixture was then stirred at room temperature over 2 h under nitrogen atmosphere. The solution was filtered, and then methanol was removed in vacuum to give an orange yellow oil. Yield: 10.7 g (97%). <sup>1</sup>H NMR (400

MHz, D<sub>2</sub>O)  $\delta$  (ppm): 7.42-8.47 (m, C<sub>5</sub>H<sub>5</sub>N), 3.78 (s, CH<sub>2</sub>-O-CH<sub>2</sub>), 3.61 (m, O-CH<sub>2</sub>CH<sub>2</sub>-OH), 3.55 (m, N-CH<sub>2</sub>CH<sub>2</sub>-O).

### 1.6 Aqueous Radical Addition Coupling Polymerization

In a typical procedure of aqueous RACP, Br-PEG-Br ( $5.0 \times 10^{-5}$  mol) and MNPHA ( $5.5 \times 10^{-5}$  mol) were dissolved in 0.5 mL of doubly deionized water in a 10 mL Schlenk flask which was equipped with a stirring bar. The mixture was stirred at a given temperature for 15 min to form a blue homogeneous solution. Then HEEPMI ( $2 \times 10^{-4}$  mol) was added. After four freeze-pump-thaw cycles, CuBr ( $1.1 \times 10^{-4}$  mol) was added under nitrogen to start the polymerization. The reaction solution became dark brown immediately and gradually became viscous. After 4 h, the mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub>/CH<sub>3</sub>OH (v:v =20:1) and purified by passing through a neutral alumina column. The polymer solution was concentrated and dried under vacuum at 40 °C to yield crude product as a colorless tacky gum, and the crude product was analyzed by GPC.

### 1.7 Quaternization reaction between Br-PEG600-Br and ligands

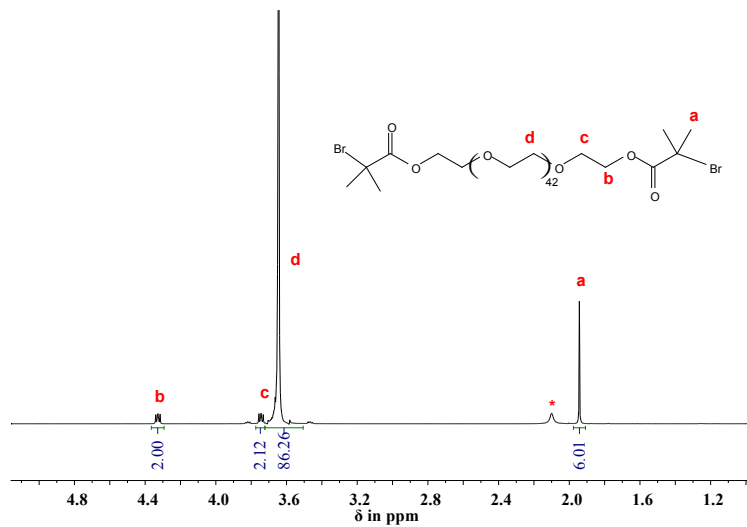
Br-PEG600-Br (8.9 mg,  $1.0 \times 10^{-5}$  mol) and HEEPMI (7.8 mg,  $4.0 \times 10^{-5}$  mol) were dissolved in 0.5 mL of D<sub>2</sub>O or CDCl<sub>3</sub> in a NMR tube equipped with a tiny stirring bar. The mixture was stirred at 50°C for 1h. Quaternization between Br-PEG600-Br and PMDETA was carried out as the same procedures described above and the molar ratio of Br-PEG600-Br/PMDETA was 1/2. The products were determined by <sup>1</sup>H NMR immediately after the reaction had stopped.

### 1.8 Thermal fragmentation of polymer in the presence of 1-ethylpiperidinehypophosphite (EHP)

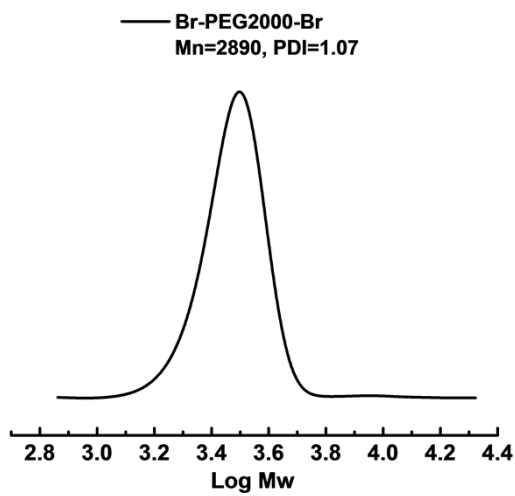
The polymer (30 mg), EHP (946 mg) were charged to a 10 mL Schlenk flask which was equipped with a stir bar, and they were dissolved in anisole (1.5 mL). After three freeze-pump-thaw cycles, the Schlenk tube was placed in an oil bath thermostated at 125 °C, after 60 h the product was diluted with 80 mL CH<sub>2</sub>Cl<sub>2</sub> and washed with

deionized water for three times. The polymer solution was concentrated. It was finally dried under vacuum at 40 °C, the resulting product was analyzed by GPC.

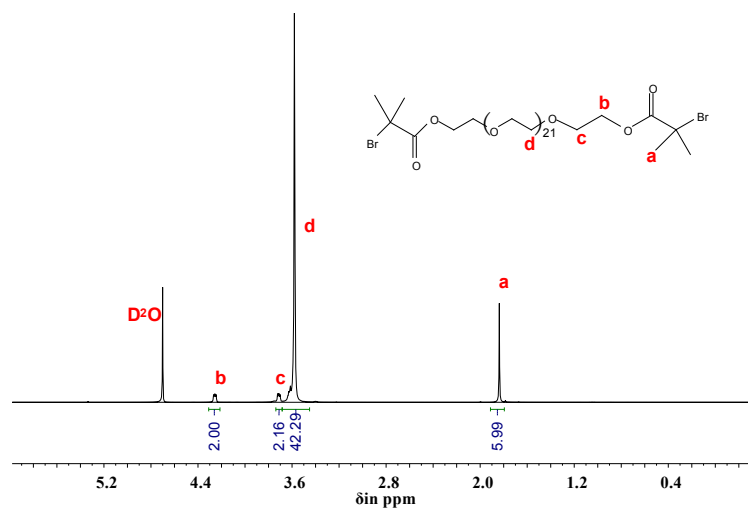
## 2. Figures of $^1\text{H}$ -NMR and GPC



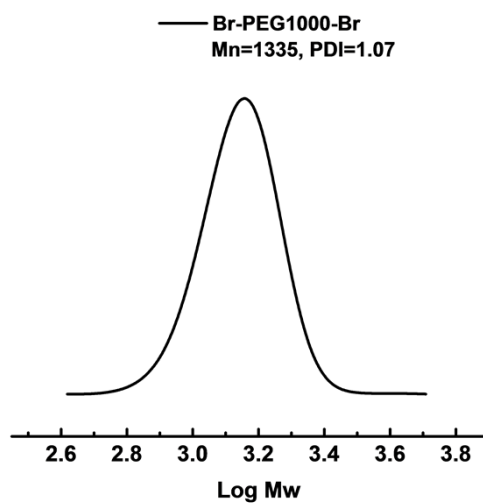
**Fig.S1**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400MHz) spectrum of Br-PEG2000-Br. (\*:impurity)



**Fig.S2** GPC curve of Br-PEG2000-Br.

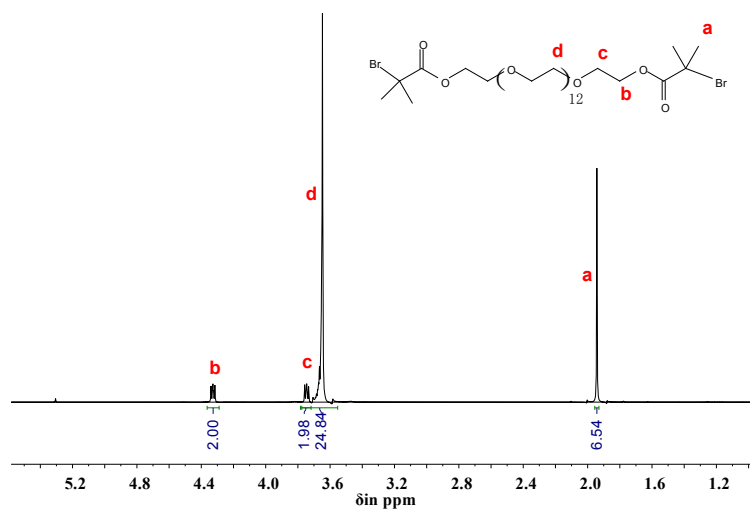


**Fig.S3**  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ , 400MHz) spectrum of Br-PEG1000-Br.

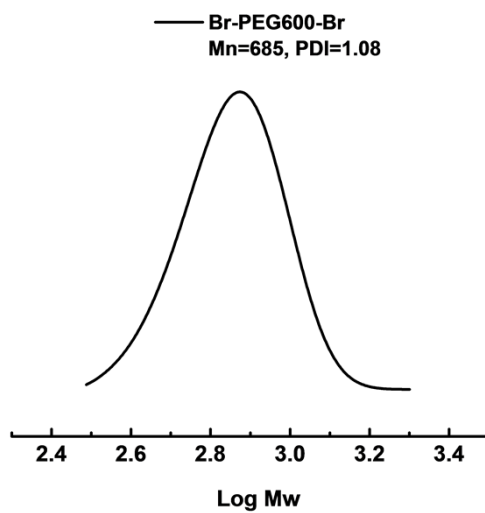


**Fig.S4** GPC curve of Br-PEG1000-Br.

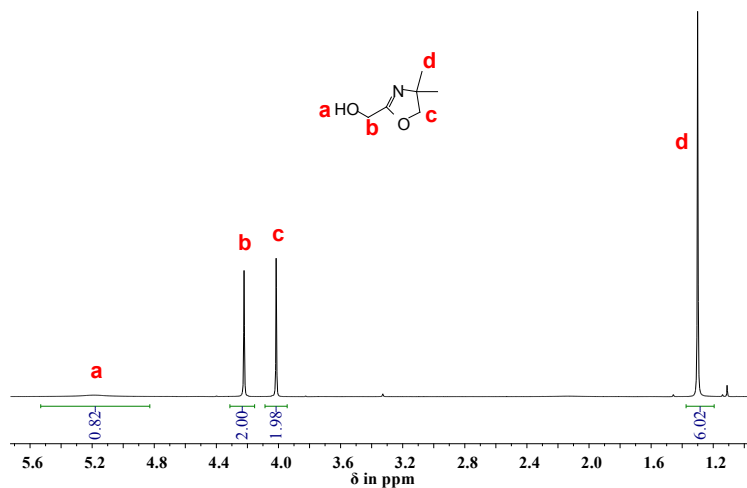




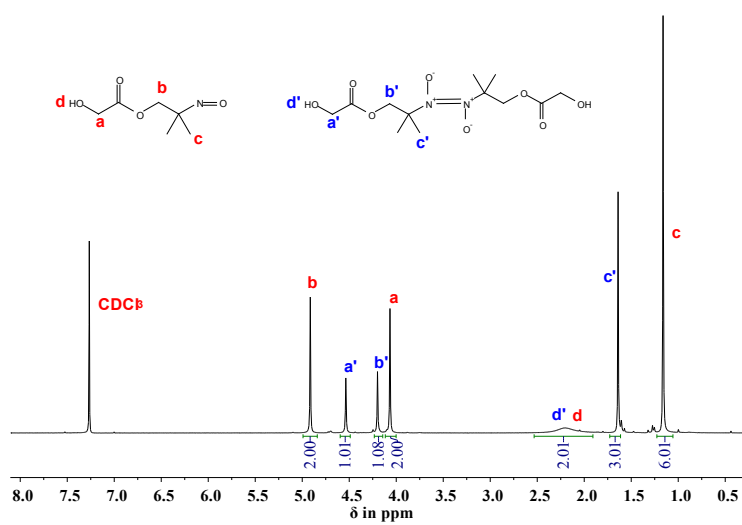
**Fig.S5** <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400MHz) spectrum of Br-PEG600-Br.



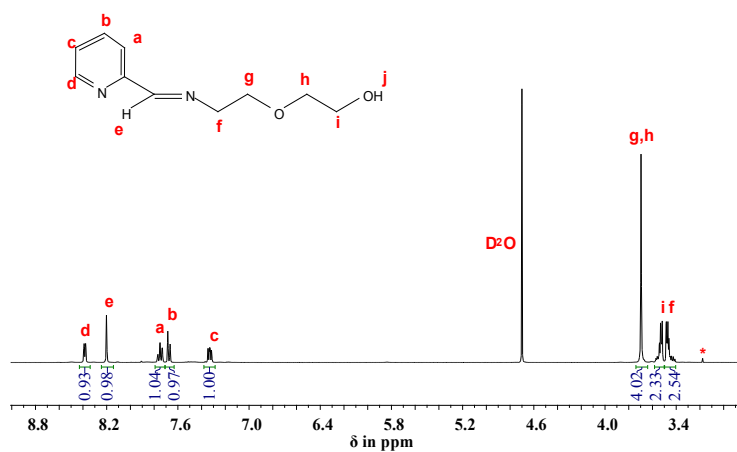
**Fig.S6** GPC curve of Br-PEG600-Br.



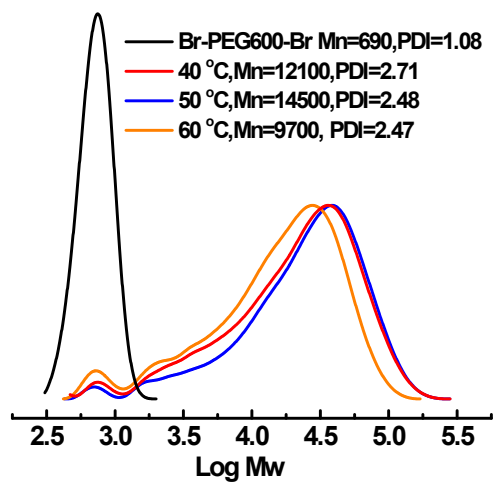
**Fig.S7**  $^1\text{H}$  NMR spectrum ( $\text{CDCl}_3$ , 400MHz) of 2-hydroxymethyl-4,4-dimethyl 2-oxazoline.



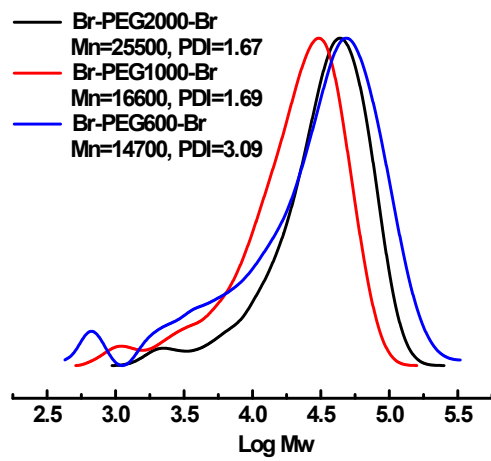
**Fig.S8**  $^1\text{H}$  NMR ( $\text{CDCl}_3$ , 400MHz) spectrum of 2-methyl-2-nitrosopropyl hexanoate (MNPHA).



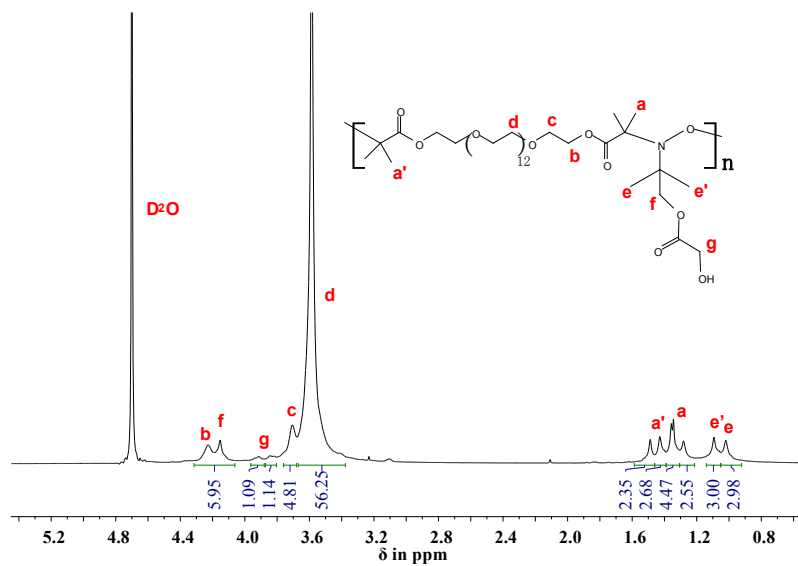
**Fig.S9** <sup>1</sup>H NMR (D<sub>2</sub>O, 400MHz) spectrum of N-(2-hydroxyethyl ethoxyethyl) 2-pyridyl methanimine (HEEPMI).



**Fig. S10** GPC curves of polymers by aqueous RACP under different temperatures.



**Fig. S11** GPC curves of polymers prepared by aqueous RACP with different Br-PEG-Br.

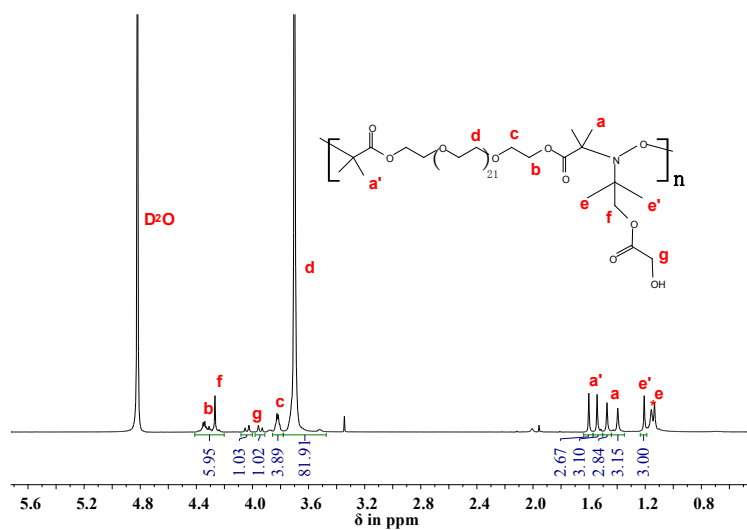


**Fig.S12**  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ , 400MHz) spectrum of polymer prepared by aqueous RACP between Br-PEG600-Br and MNPHA using CuBr/HEEPMI.

Let  $n_{\text{Br-PEG600-Br}} = x$ ,  $n_{\text{MNPHA}} = y$ , then

$$S_{\text{Ha} + \text{Ha}'} = 12x = 12.05 \text{ and } S_{\text{He}'} = 3y = 3,$$

We got  $[\text{Br-PEG600-Br}]/[\text{MNPHA}] = x/y = 1.00$ .

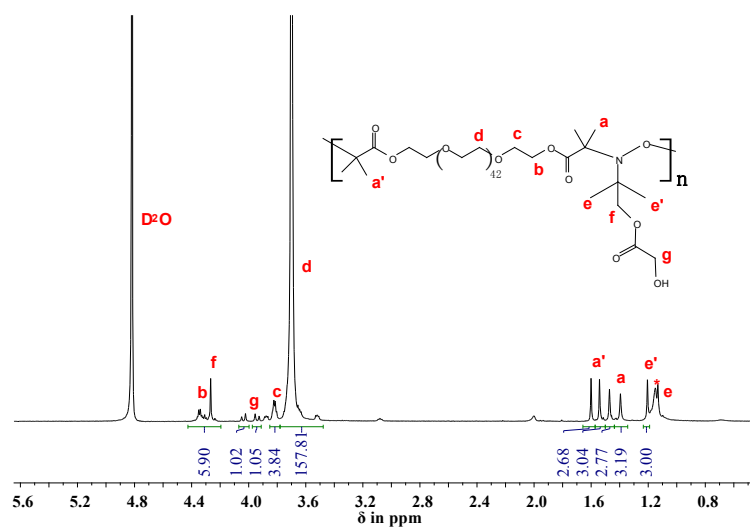


**Fig.S13**  $^1\text{H}$ NMR ( $\text{D}_2\text{O}$ , 400MHz) spectrum of polymer prepared by aqueous RACP between Br-PEG1000-Br and MNPHA using CuBr/HEEPMI. (\* impurity)

Let  $n_{\text{Br-PEG1000-Br}} = x$ ,  $n_{\text{MNPHA}} = y$ , then

$$S_{\text{Ha} + \text{Ha}'} = 12x = 11.76 \text{ and } S_{\text{He}'} = 3y = 3,$$

We got  $[\text{Br-PEG1000-Br}]/[\text{MNPHA}] = x/y = 0.98$ .



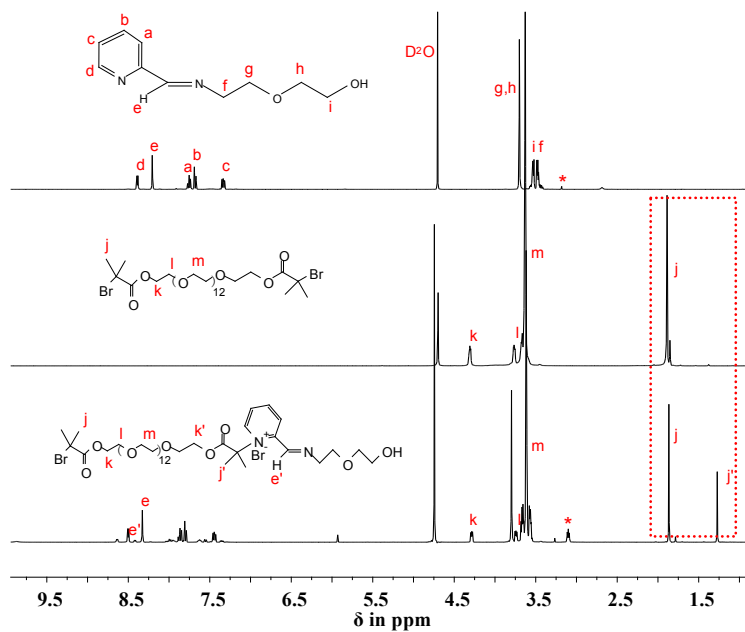
**Fig.S14**  $^1\text{H}$ NMR ( $\text{D}_2\text{O}$ , 400MHz) spectrum of polymer prepared by aqueous RACP between Br-PEG2000-Br and MNPHA using CuBr/HEEPMI. (\* impurity)

Let  $n_{\text{Br-PEG2000-Br}} = x$ ,  $n_{\text{MNPHA}} = y$ , then

$S_{\text{Ha} + \text{Ha}'} = 12x = 11.68$  and  $S_{\text{He}'} = 3y = 3$ ,

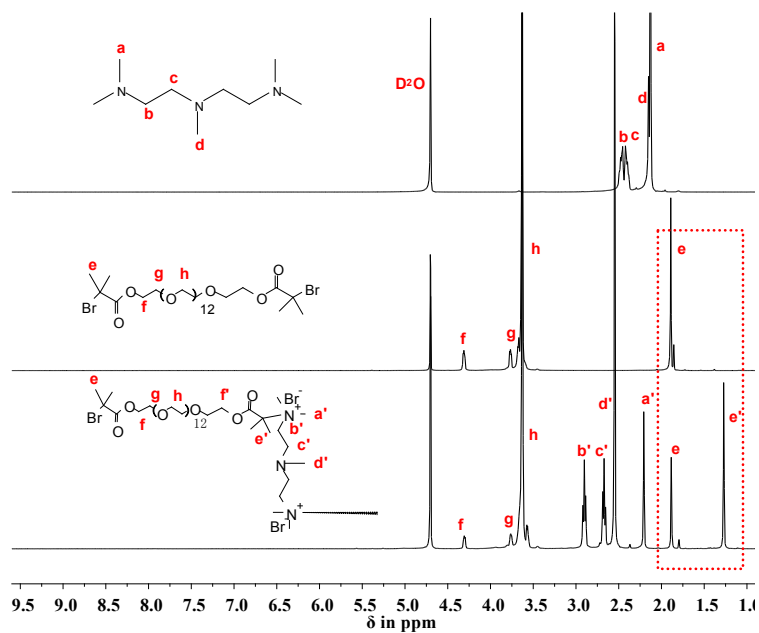
We got  $[\text{Br-PEG1000-Br}]/[\text{MNPHA}] = x/y = 0.97$ .





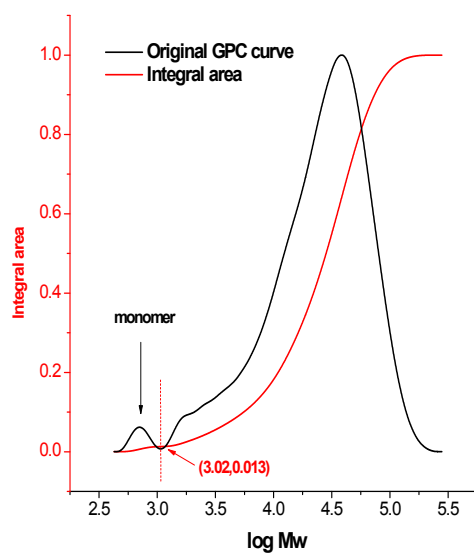
**Fig.S15** <sup>1</sup>H NMR (D<sub>2</sub>O, 400 MHz) spectrum of product of reaction between Br-PEG600-Br and HEEPMI in D<sub>2</sub>O.

Degree of quaternization is  $S_n / (S_n + S_{n'}) = 31\%$ .



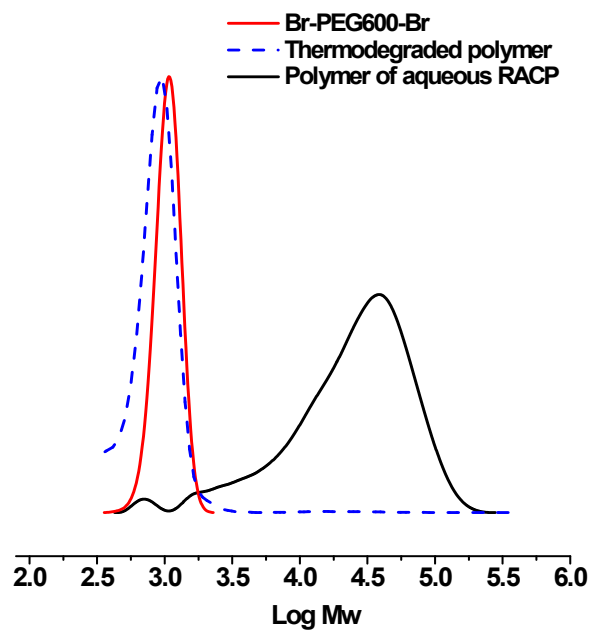
**Fig.S16** <sup>1</sup>H NMR (D<sub>2</sub>O, 400 MHz) spectrum of product of quaternization between Br-PEG600-Br and PMDETA in D<sub>2</sub>O.

Degree of quaternization is  $S_{i'} / (S_i + S_{i'}) = 48\%$ .



**Fig.S17** GPC curve of polymer prepared by aqueous RACP between Br-PEG600-Br and MNPHA using CuBr/HEEPMI and its integral area curve.

The weight fraction of monomer is about 1.3%, So the polymer yield is about 98.7%.



**Fig.S18** GPC curves of Br-PEG600-Br and periodic polymer prepared by aqueous RACP before and after thermodegradation.

## References

- [1] Li, J. J.; Wang, Q. J. *Polym. Sci., Part A: Polym. Chem.* **2014**, 52, 810-815.
- [2] David, M. H.; Martin, C. C. *Macromolecules.* **1999**, 32, 2110-2119.
- [3] Acar, M. H.; Matyjaszewski, K. *Macromol. Chem. Phys.* **1999**, 200, 1094-1100.