Electronic Supplementary Information

Morphological control and molecular recognition by bis-urea hydrogen bonding in micelles of amphiphilic tri-block copolymers.

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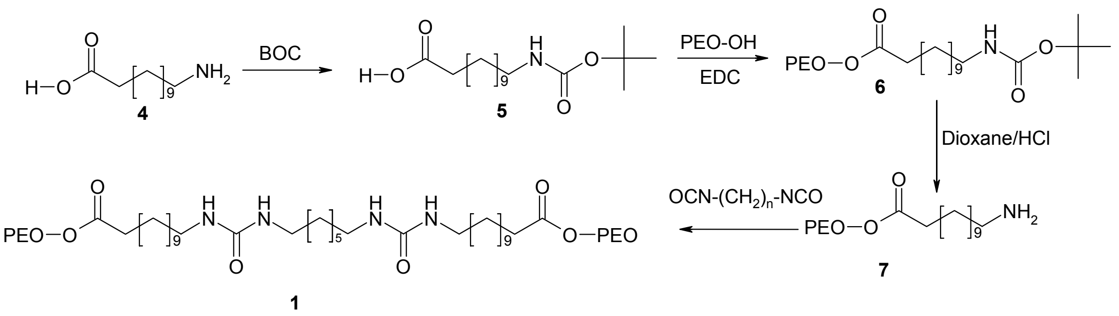
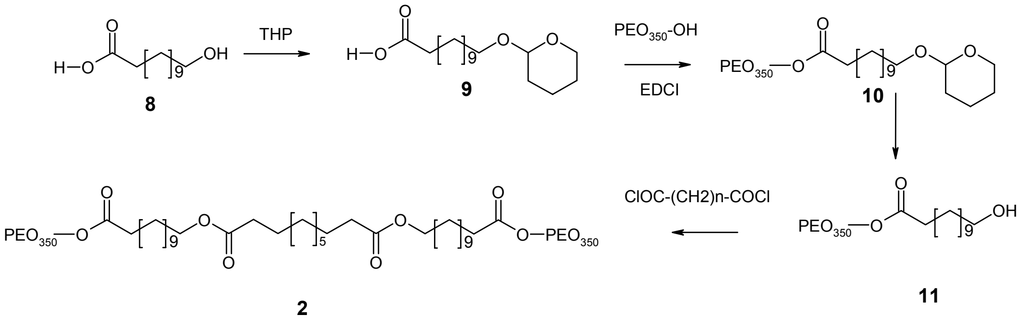
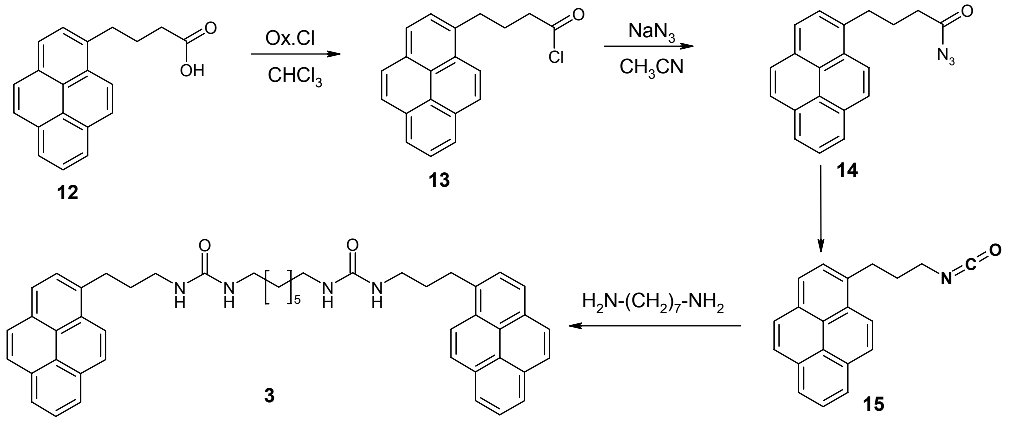


Scheme 1. *Synthesis of compound **1**.*



Scheme 2. *Synthesis of compound **2**.*



Scheme 3. *Synthesis of compound **3**.*

Experimental section:

Materials: Solvents used in the synthesis were reagent grade. THF and toluene were freshly distilled from Na metal. CH_2Cl_2, $CHCl_3$, DMF, Et_3N and Pyridine were distilled from CaH_2. All PEO derivatives were dried in vacuum over P_2O_5 during at least 12h. Reagents were purchased from Aldrich, Fluka, or Acros and were used without additional purification.

N-(*ter*t-butyloxycarbonyl)-12-aminododecanoic acid[1] (5), 12-(tetrahydropyranyloxy)-dodecanoic acid[2] (9) and di-*tert*-butyl tricarbonate[3] were prepared according to literature procedures.

Methods: ^1H and ^{13}C NMR spectra were acquired on either a Bruker 400 MHz or Varian Gemini 300 MHz spectrometer. Infrared spectra were measured on a Perkin Elmer 1600 FT-IR. Size exclusion chromatography (SEC) was performed on a Shimadzu LC10-AT, using a Polymer Laboratories Plgel 5μm Mixed-D column, a Shimadzu RID-6A detector and THF as an eluent. Molecular weights were calculated relative to polystyrene standards. Matrix assisted laser desorption ionization time-of-flight mass spectroscopy (MALDI-TOF) was performed on a Perseptive DE PRO Voyager MALDI-TOF mass spectrometer using a dithranol as a matrix. Sample for cryogenic transmission electron microscopy (cryo-TEM) were prepared in a 'Vitrobot' instrument[4] (PC controlled vitrification robot, patent applied, Frederik et al 2002, patent licensed to FEI) at room temperature and a relative humidity >95%. In the preparation chamber of the 'Vitrobot' a 3μl sample was applied on a Quantifoil grid (R 2/2, Quantifoil Micro Tools GmbH; freshly glow discharged just prior to use), excess liquid was blotted away and the thin film thus formed was shot (acceleration about 3 g) into liquid ethane. The vitrified film was transferred to a cryoholder (Gatan 626) and observed at -170°C in a Philips CM12 microscope operating at 120kV. Micrographs were taken at low dose conditions.

N-(*ter*t-butyloxycarbonyl)-12-aminododecanoyl-(poly(ethyleneglycol)-monomethylether)-ester (6). In a 50 ml two-neck round-bottom flask 3.6 g (11.4 mmol) of N-(*ter*t-butyloxycarbonyl)-12-aminododecanoic acid (**5**), 2.19 g (11.4 mmol) of N-(3-dimethylaminopropyl)-N-ethylcarbodiimide hydrochloride and 1.39 g (11.4 mmol) of dimethylaminopyridine were stirred in 5 ml of dry dichloromethane under argon for 20 min. To the resulting solution was added 2 g (5.7 mmol) of poly(ethylene glycol)-monomethyl ether (M_n ca. 350) and the reaction mixture was stirred overnight. Purification of the product using column chromatography (silica gel, CH_2Cl_2/Methanol 9:1 v/v) yielded 3.5 g (92%) of a transparent oil.

^1H-NMR (300 MHz, $CDCl_3$, T=295K): δ = 4.51 (bs, 1H, NH), 4.20 (t, 2H, ^3J(H,H)=4.36Hz, $C\underline{H_2}OCO$), 3.7-3.5 (m, 30H, $O C\underline{H_2}$), 3.36 (s, 3H, $OC\underline{H_3}$), 3.08 (q, 2H, ^3J(H,H)= 6.55Hz, $C\underline{H_2}N$), 2.31 (t, 2H, ^3J(H,H)=7.5Hz, $C\underline{H_2}CO$), 1.59 (p, 2H, ^3J(H,H)=7.1Hz, $C\underline{H_2}CH_2CO$), 1.42 (s, 9H, $CC\underline{H_3}$), 1.24 (m, 16H, $C\underline{H_2}$).

MALDI-TOF[$M+Na^+$] = 704.47 ± n*44, (calcd: 704.91 ± n*44).

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1) I.T. Dorn, K.R. Neumaier, R. Tampe, *J. Am. Chem. Soc.* 1998, **120**, 2753-2763.

2) A. Sadownik, J. Stefely, S.L. Regen, *J. Am. Chem. Soc.* 1986, **108**, 7789-7791.

3) C.S. Dean, D.S. Tarbell, A.W. Friederang, *J. Org. Chem.* 1970, **35**, 3393-3397.

4) P.M. Frederik, D. H. W. Hubert, *Methods Enzymol.*, 2005, **391**, 431-448.

FT-IR (cm^{-1}): 3365.69 (NH), 2924.93, 2856.04 (CH_2), 1735.62(CO), 1712.81(CO), 1520.59(CN), 1455.12, 1390.52, 1365.06, 1248.53, 1170.93, 1105.27. 1040.59, 951.32, 861.89, 781.17.

12-Aminododecanoyl-(poly(ethylene glycol)-monomethylether)-ester (7). To 30 ml of a 4 M HCl solution in dioxane was added 3 g (4.4 mmol) of N-(*tert*-butyloxycarbonyl)-12-aminododecanoyl-(poly(ethyleneglycol)-monomethylether)-ester (**6**) and the solution was stirred at 0°C for 1 h and subsequently at room temperature for 2 h. The solvent was evaporated to yield 2.7 g (100%) of the product as its hydrochloric salt, which was used without further purification.
^{1}H-NMR (300 MHz, $CDCl_3$, T=295K): δ = 8.17 (bs, 3H, $N\underline{H}_3^+$), 4.19 (t, 2H, ^3J(H,H)=4.26Hz, $C\underline{H}_2OCO$), 3.7-3.5 (m, 30H, $OC\underline{H}_2$), 3.36 (s, 3H, $OC\underline{H}_3$), 2.94 (bs, 2H, $C\underline{H}_2N$), 2.29 (t, 2H, ^3J(H,H)=7.4Hz, $C\underline{H}_2CO$), 1.73 (p, 2H, ^3J(H,H)=6.5 Hz, $C\underline{H}_2CH_2N$) 1.58 (p, 2H, ^3J(H,H)=7.2Hz, $C\underline{H}_2CH_2CO$), 1.23 (m, 14H, $C\underline{H}_2$).
FT-IR (cm^{-1}): 2915.54, 2848.31 (CH_2), 1736.93(CO), 1712.81(CO-BOC), 1577.82, 1518.6, 1464.6, 1390.30, 1348.14, 1325.6, 1294.19, 1266.58, 1237.63, 1182.33, 1103.947. 1044.32, 960.77, 857.86, 777.03, 730.53, 721.73.

Bis-1,7-{12-[Polyethyleneglycol(monomethylether)-carbonyl)-undecyl] -ureido}-heptane (1). To a solution of 0.216 g (1.65 mmol) of 1,7-diaminoheptane in 1 ml of dichloromethane, a solution of di-*tert*-butyl tricarbonate (0.977 g, 3.74 mmol) in dichloromethane (1 ml) was injected. The reaction mixture was stirred for 30 min. A drop of pyridine was added to quench the excess of di-*tert*-butyl tricarbonate and the reaction mixture was stirred for another 10 min. A solution of 12-aminododecanoyl-(poly(ethylene glycol)-monomethylether)-ester **7** (2 g, 3.4 mmol) and triethylamine (0.94 ml, 6.8 mmol) in 2 ml dichloromethane was added and stirred overnight. The solution was concentrated and purified by precipitation from diethyl ether to give 0.5 g (20%) of the product as a white solid.
^{1}H-NMR (300 MHz, $CDCl_3$, T=295K): δ = 4.94 (bs, 4H, $N\underline{H}$), 4.2 (t, 4H, ^3J(H,H)=4.6Hz, $C\underline{H}_2OCO$), 3.7-3.5 (m, 60H, $OC\underline{H}_2$), 3.36 (s, 6H, $OC\underline{H}_3$), 3.12 (m, 8H, $C\underline{H}_2N$), 2.32 (t, 4H, ^3J(H,H)=7.5Hz, $C\underline{H}_2CO$), 1.59 (p, 4H, ^3J(H,H)=6.6 Hz, $C\underline{H}_2CH_2N$) 1.44 (m, 8H, $C\underline{H}_2$), 1.3 (m, 34H, $C\underline{H}_2$).
^{13}C-NMR (400 MHz, $CDCl_3$, T=295K): δ = 173.94, 159.3, 99.91, 94.47, 71.97, 70.65, 70.61, 70.54, 69.25, 63.42, 59.07, 40.52, 40.08, 34.25, 30.42, 29.9, 29.63, 29.59, 29.49, 29.47, 29.32, 29.17, 27.04, 26.36, 24.95
FT-IR (cm^{-1}): 3335.96 (NH), 2921.89, 2850.17 (CH_2), 1731.88(CO), 1610.78 (C=O stratching), 1572.35, 1476.44, 1464.08, 1349.28, 1318.59, 1264.22, 1232.4, 1211.71, 1101.94, 1038.09, 950.53, 852.78, 769.73, 724.47.
GPC (THF; PS standards): Mn = 1200 g/mol, PDI = 1.04.
MALDI-TOF[$M+Na^+$] = 1279.8 ± n*44 (calcd: 1280 ± n*44).

12-(Tetrahydropyranyloxy)-dodecanoyl-(Poly(ethyleneglycol)-monomethyl ether)-ester (10). In a 50 ml two-neck round-bottom flask 2.9 g (9.65 mmol) of 12-(tetrahydropyranyloxy)-dodecanoic-acid (**9**), 1.83 g (9.65 mmol) of N-(3-dimethylaminopropyl)-N-ethylcarbodiimide hydrochloride and 1.17 g (9.65 mmol) of dimethylaminopyridine were stirred in 7 ml of dry dichloromethane under argon for 20 min. To the resulting solution was added 6.75 g (19.3 mmol) of poly(ethyleneglycol)-monomethyl ether (M_n ca. 350) and the solution was stirred overnight. The product was purified using column chromatography (silica gel, CH_2Cl_2/Methanol 9.5 : 0.5 v/v) to give 5.3 g (88.1%) of the product as a transparent oil.

^{1}H-NMR (400 MHz, $CDCl_3$, T=295K): δ = 4.56 (t, 1H, $C\underline{H}$), 4.21 (t, 2H, ^3J(H,H)=4.87Hz, $C\underline{H}_2OCO$), 3.87-3.38 (m, 41H, $OC\underline{H}_2$, $OC\underline{H}_3$, $C\underline{H}_{2THP}$), 2.31 (t, 2H, ^3J(H,H)=7.16Hz, $C\underline{H}_2CO$), 1.83-1.25 (m, 24H, $C\underline{H}_2$).

^{13}C-NMR (400 MHz, $CDCl_3$, T=295K): δ = 174.06, 149.74, 99.06, 72.15, 70.84, 70.82, 70.79, 70.73, 69.42, 67.91, 63.57, 62.55, 59.24, 34.42, 31.01, 29.97, 29.78, 29.75, 29.7, 29.66, 29.49, 29.35, 26.45, 25.72, 25.12, 22.21, 19.92.

FT-IR (cm^{-1}): 2924.48, 2855.98, 1735.5, 14.55.75, 1350.21, 1323.06, 1285.05, 1250.73, 1200.01, 1104.3, 1032.15, 987.82, 950.81, 906.06, 868.0, 814.37, 753.73, 723.24.

12-Hydroxydodecanoyl-(poly(ethyleneglycol)-monomethylether)-ester (11). To a solution of 3 g (4.61 mmol) of 12-(tetrahydropyranyloxy)-dodecanoyl-(poly(ethyleneglycol)-monomethylether)-ester (**10**) in ethanol (45 ml) warmed up to 45 °C, 0.2 g of pyridinium *p*-toluenesulfonate and 0.17 g of *p*-toluene sulfonic acid were added. The reaction mixture was stirred for 2 h at 45 °C. The solvent was evaporated and the residue was redissolved in chloroform, washed with sodium bicarbonate solution (1M) and dried over magnesium sulfate. Yield: 2.38 g (96%) of a transparent oil.

^{1}H-NMR (400 MHz, $CDCl_3$, T=295K): δ = 4.21 (t, 2H, ^3J(H,H)=4.26Hz, $C\underline{H}_2OCO$), 3.7-3.53.38 (m, 32H, $OC\underline{H}_2$), 2.31 (t, 2H, ^3J(H,H)=7.73Hz, $C\underline{H}_2CO$), 1.2-1.52 (m, 4H, $C\underline{H}_2$), 1.3-1.19 (m, 14H, $C\underline{H}_2$).

^{13}C-NMR (400 MHz, $CDCl_3$, T=295K): δ = 174.07, 72.15, 70.79, 70.73, 69.43, 63.58, 62.25, 59.25, 34.42, 33.01, 31.01, 29.97, 29.75, 29.68, 29.61, 29.44, 29.31, 25.95, 25.01, 19.92.

FT-IR (cm^{-1}): 3502.14, 2924.51, 2855.61, 1734.43, 1456.13, 1349.59, 1285.05, 1249.19, 1102.72, 949.36, 852.29.

GPC (THF; PS standards): Mn = 390 g/mol, PDI = 1.04.

MALDI-TOF [M+Na$^+$] = 605.26 ± n*44 (calcd: 605.73 ± n*44)

Undecanedioic acid-bis-[11-{(poly(ethylene glycol-oxicarbonyl}-undecyl] ester (2).
To a solution of 2 g (3.7 mmol) 12-hydroxydodecanoyl-(poly(ethyleneglycol)-monomethylether)-ester (**11**) and 0.52 g (4.25 mmol) of 4-dimethylaminopyridine in 5 ml of dichloromethane was added 0.47 g (1.85 mmol) of freshly prepared undecanedioyl dichloride in 1 ml of dichloromethane and the mixture was stirred overnight. Purification by column chromatography (silica gel, CH_2Cl_2/Methanol 9:1 v/v, R_f=0.5 yielded 1.5 g (64%) of the product as a waxy solid.

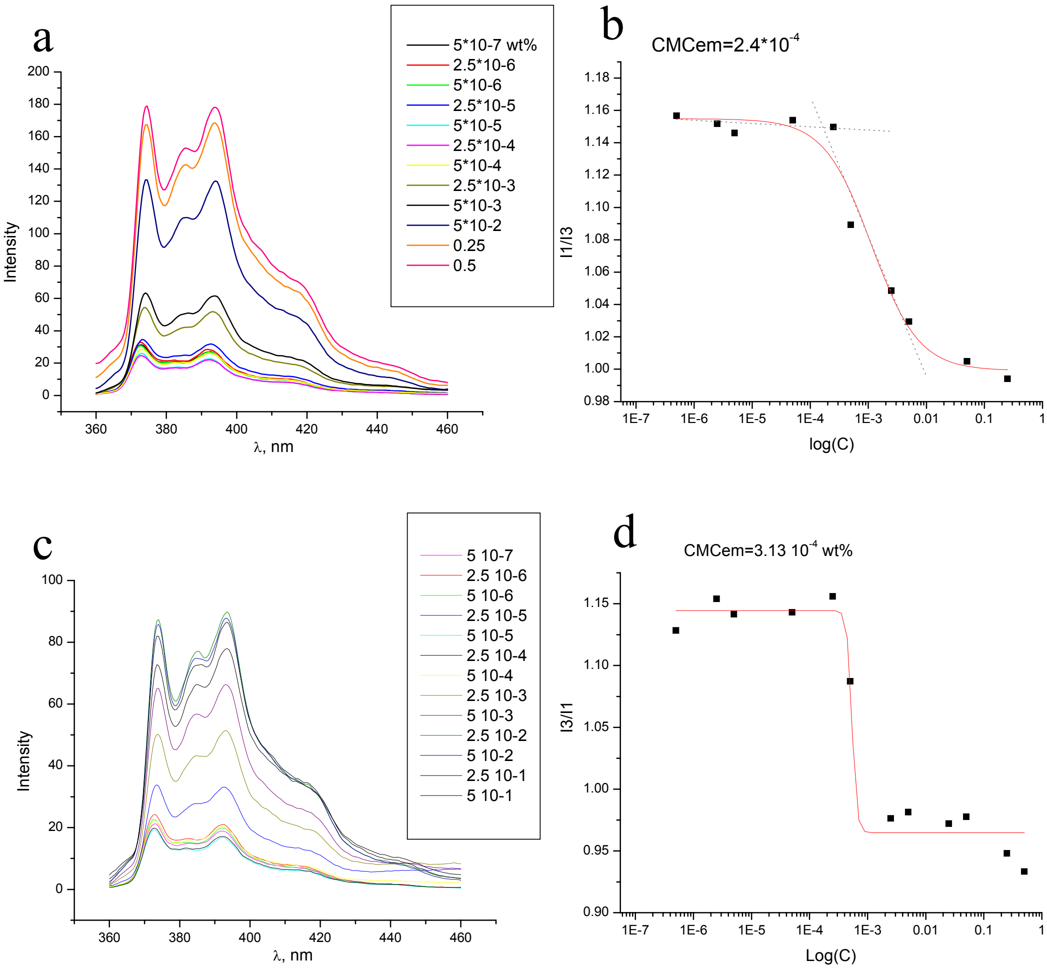
^{1}H-NMR (400 MHz, $CDCl_3$, T=295K): δ = 4.20 (t, 4H, ^3J(H,H)=4.47Hz, $C\underline{H}_2OCO$), 4.03 (t, 4H, ^3J(H,H)=6.72Hz, $C\underline{H}_2OCO$), 3.68-3.52 (m, 60H, $OC\underline{H}_2$), 3.36 (s, 6H, $OC\underline{H}_3$)2.30 (m, 4H, $C\underline{H}_2CO$), 1.59 (m, 8H, $C\underline{H}_2$), 1.25 (m, 42H, $C\underline{H}_2$).

^{13}C-NMR (400 MHz, $CDCl_3$, T=295K): δ = 174.01, 173.85, 99.9, 71.99, 70.67, 70.63, 70.57, 69.25, 64.43, 63.4, 59.08, 34.42, 34.24, 29.55, 29.47, 29.31, 29.3, 29.25, 29.17, 28.71, 25.97, 25.04, 24.94.

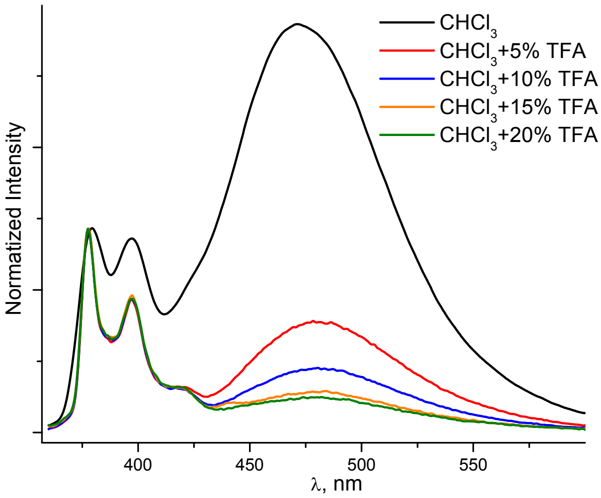
FT-IR (cm^{-1}): 2924.75, 2856.26, 1733.52, 1460.42, 1349.93, 1249.97, 1106.79, 949.29, 853.93.

GPC (THF; PS standards): Mn = 900 g/mol, PDI = 1.05.
MALDI-TOF [M+Na$^+$] = 1279.71 ± n*44 (calcd: 1280.7 ± n*44).

Bis-1,7-{3-pyrenyl)-propane-ureido}-heptane (3). To a suspension of 1-pyrene butyric acid (1 g, 3.4 mmol) and oxalyl chloride (0.44 ml) in chloroform, 50 µl of dry DMF was added and the mixture was stirred for 10 min. After evaporation of solvent, acetonitrile (5 ml) was added and the reaction mixture was heated up to 85 °C, followed by addition of NaN_3 (0.243 g). To complete the conversion of azide to isocyanide, the reaction mixture was stirred for 5h at 85 °C. 1,7-diaminoheptane was added and the reaction mixture was stirred for another 50 h at 50 °C. The product was filtered off and washed with chloroform and methanol and finally reprecipitated from a CHCl3/MeOH (7:3 v/v) mixture.
^{1}H-NMR (400 MHz, $CDCl_3$:TFA, T=295K): δ = 8.21-7.81 (m, 18H, Ar-H), 3.42 (t, 4H, ^3J(H,H)=7.13Hz, C$\underline{H}_2$N), 3.3(t, 4H, ^3J(H,H)=6.57Hz, C$\underline{H}_2$N), 2,4 (bs, 4H, C$\underline{H}_2$-Ar), 2.18 (p, 4H, ^3J(H,H)=7.03Hz, C$\underline{H}_2$), 0.99 (p, 4H, ^3J(H,H)=7.09Hz, C$\underline{H}_2$), 0.76 (m, 6H, C$\underline{H}_2$).
^{13}C-NMR (400 MHz, $CDCl_3$:TFA, T=295K): δ = 160.81, 134.16, 131.33, 130.69, 130.28, 128.5, 127.99, 127.27, 127.17, 126.19, 125.33, 125.08, 124.95, 124.74, 122.69, 122.46, 115.88, 113.04, 41.12, 40.87, 30.48, 29.3, 27.62, 25.44.
MALDI-TOF[M$^+$] = 701.36 (calcd. for $C_{47}H_{48}N_4O_2$: 700.93)



SI1. Determination of critical micelle concentration of compounds **1** and **2** using pyrene as a fluorescence probe. a) Pyrene emission spectra of aqueous solutions containing different concentrations of **1**. b) Ratio of intensities of peak 1 and peak 3 I1/I3 in the spectra from (a) versus concentration; The cmc is taken as the concentration at which the ratio starts to decrease. c) Pyrene emission spectra of aqueous solutions containing different concentrations of **2**. d) Ratio of intensities of peak 1 and peak 3 I1/I3 in the spectra from (c) versus concentration. The cmc is taken as the concentration at which the ratio starts to decrease;



SI 2. Normalized fluorescence spectra of 10^{-6}M of **3** in $CHCl_3$ at various concentrations of TFA.