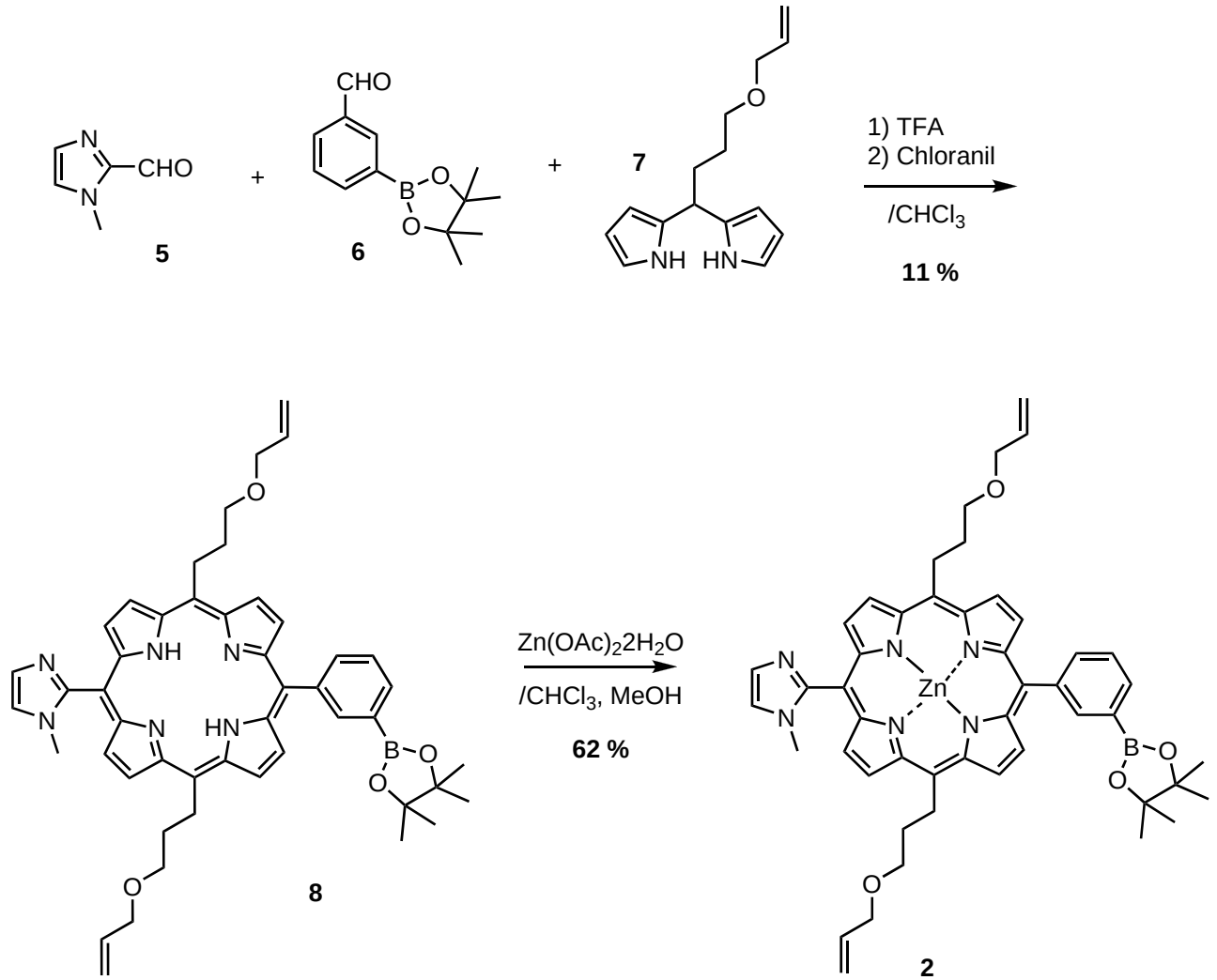
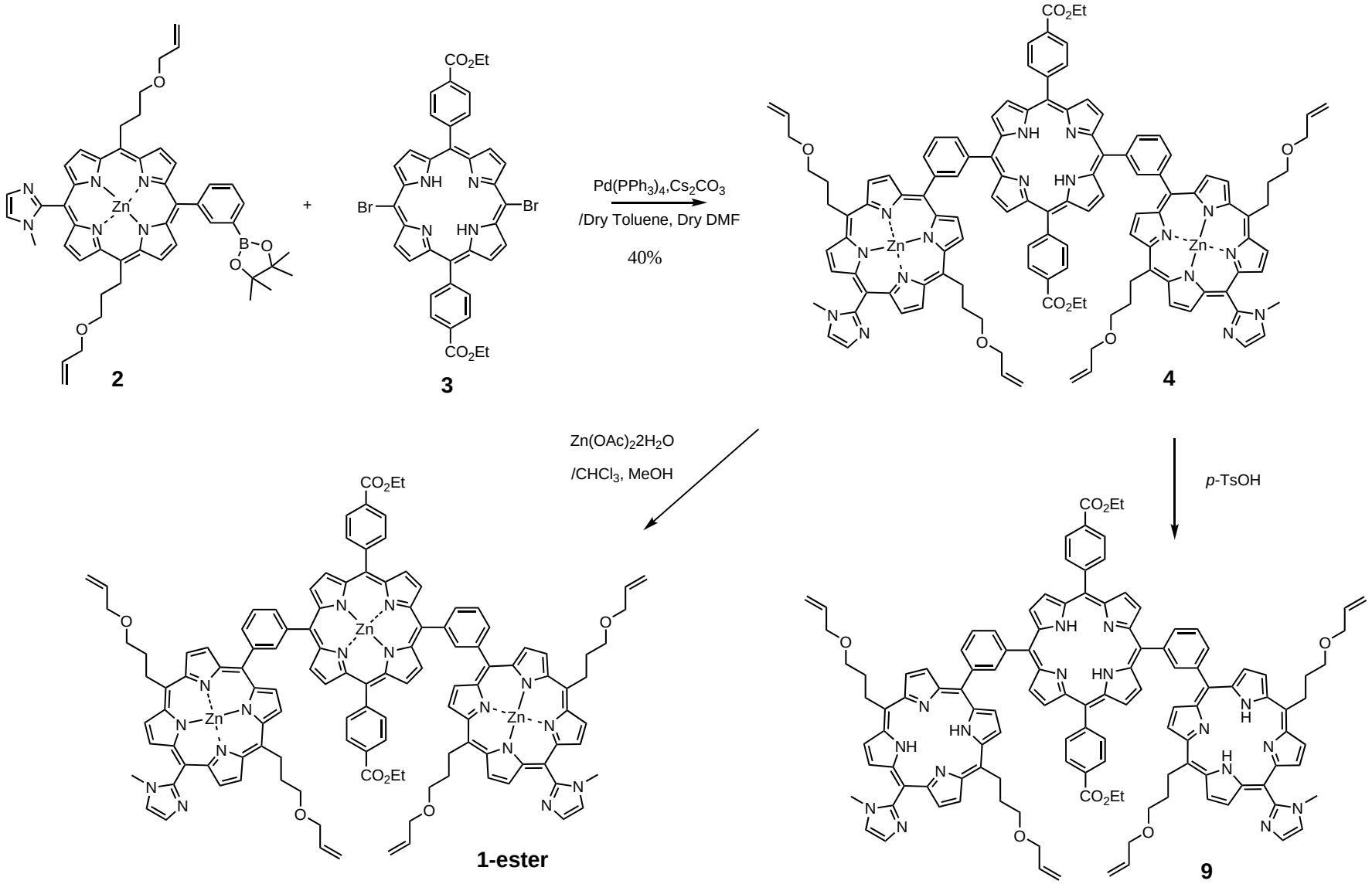
Supporting information

Transmembrane Nanopore from Porphyrin Supramolecule

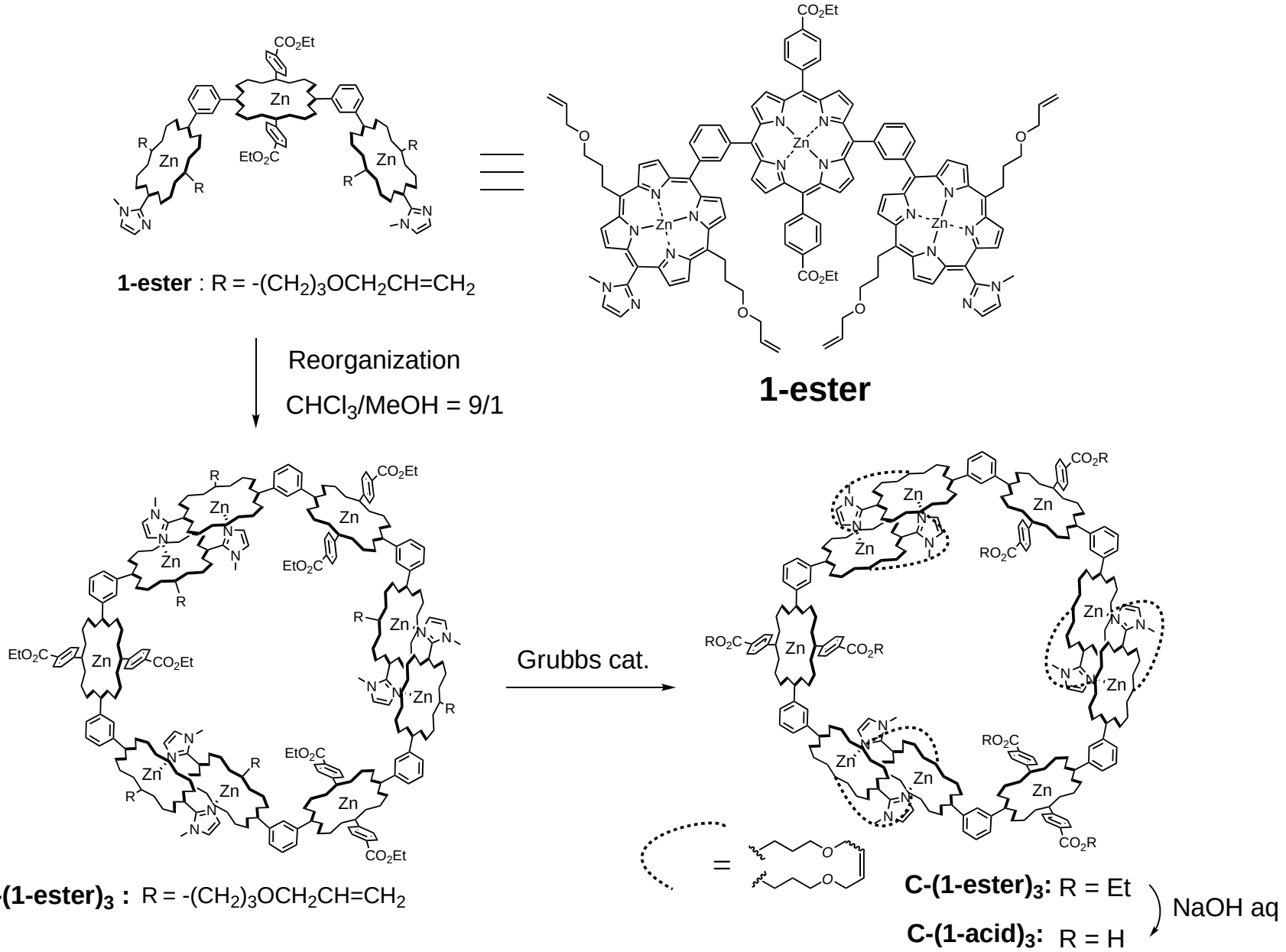
Akiharu Satake, Mika Yamamura, Masafumi Oda, and Yoshiaki Kobuke



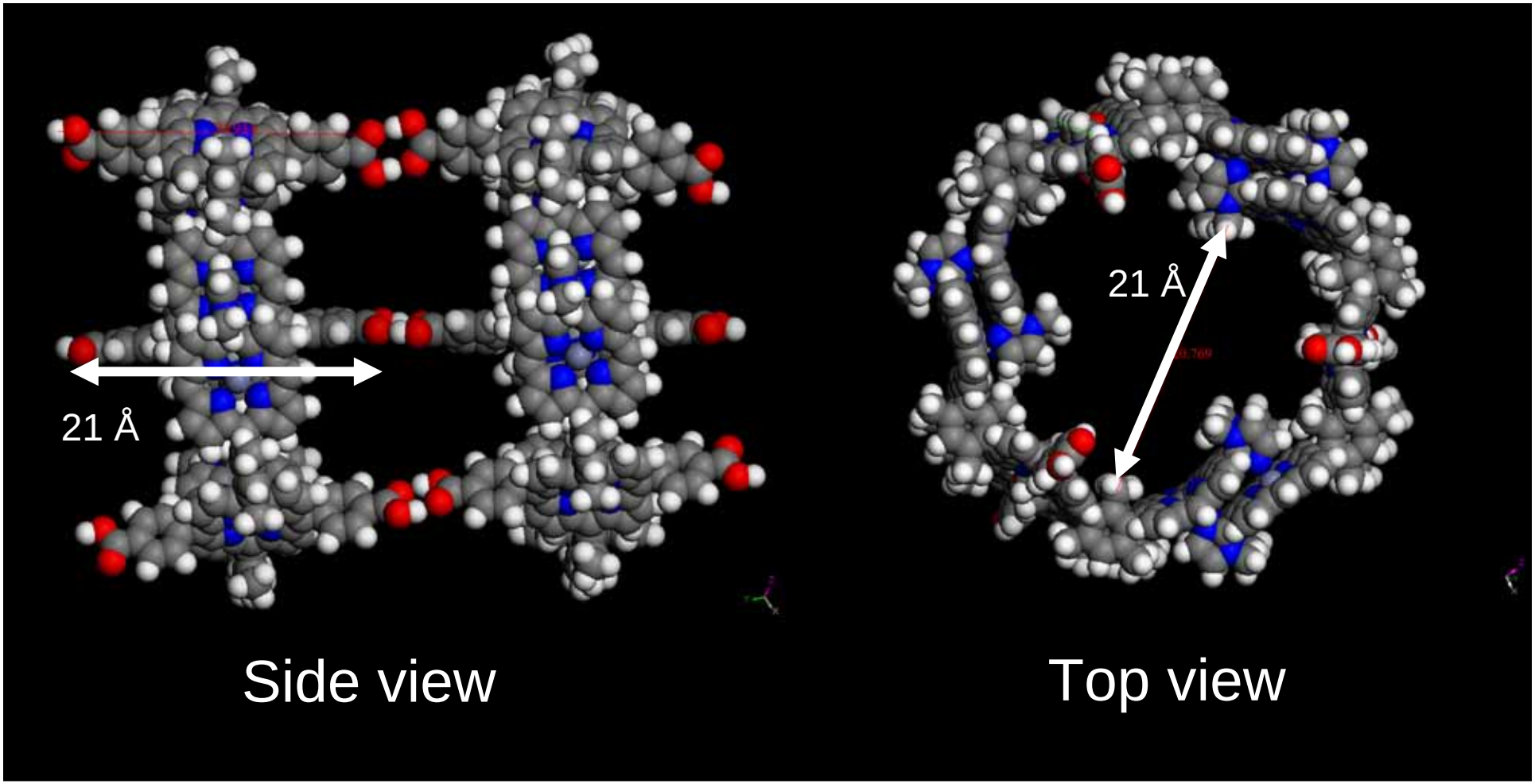
Scheme S1. Synthetic scheme of zinc porphyrin **2**



Scheme S2. Synthesis of **1-ester** and **9**



Scheme S3. Synthesis of **C-(1-acid)$_3$**



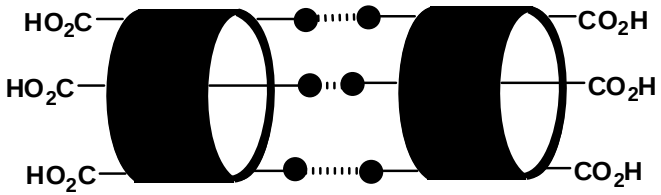


Figure S1. Molecular model of dimeric **C-(1-acid)$_3$** constructed by Material Studio (supplied from Accelrys), molecular mechanics calculation (Universal force field)

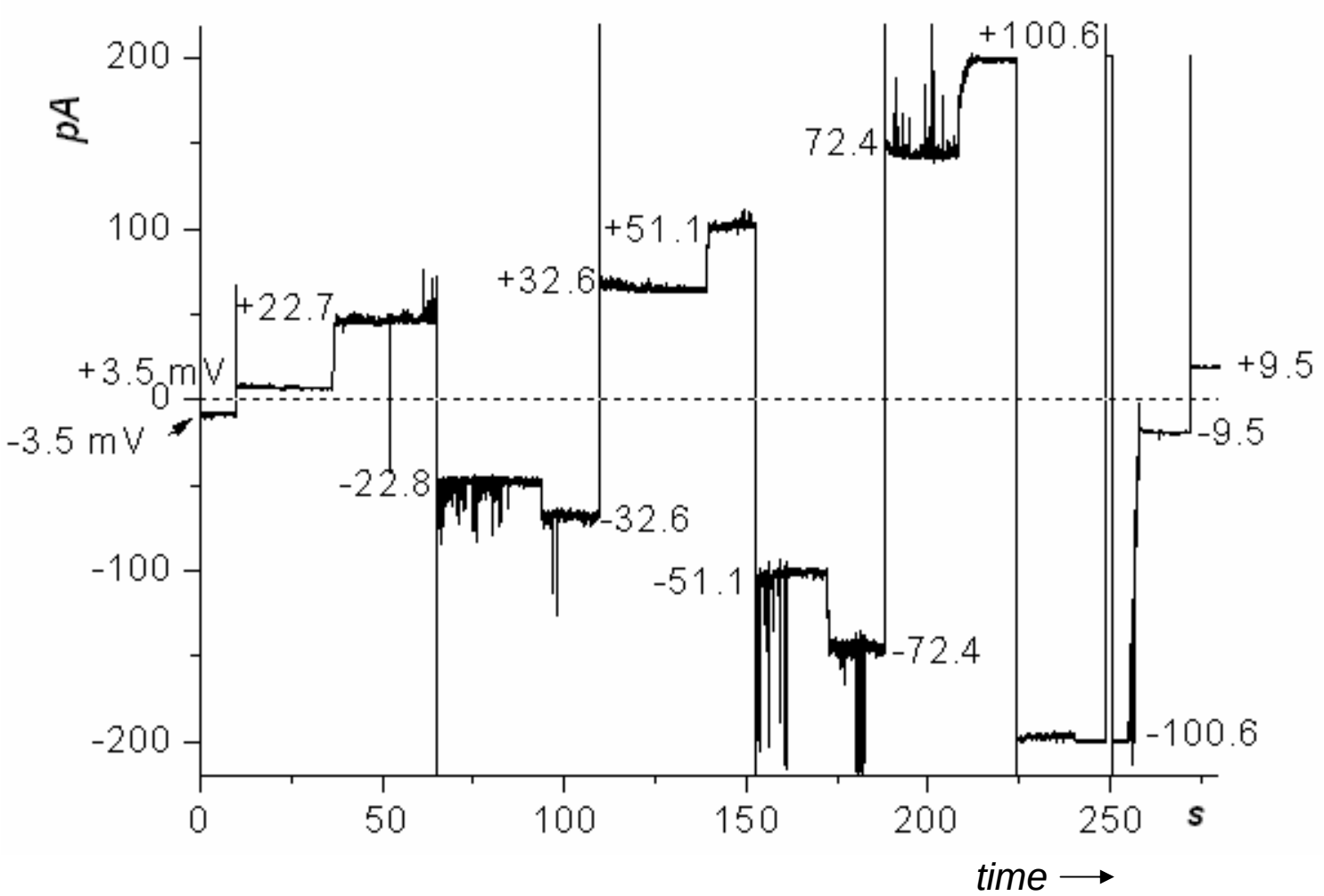
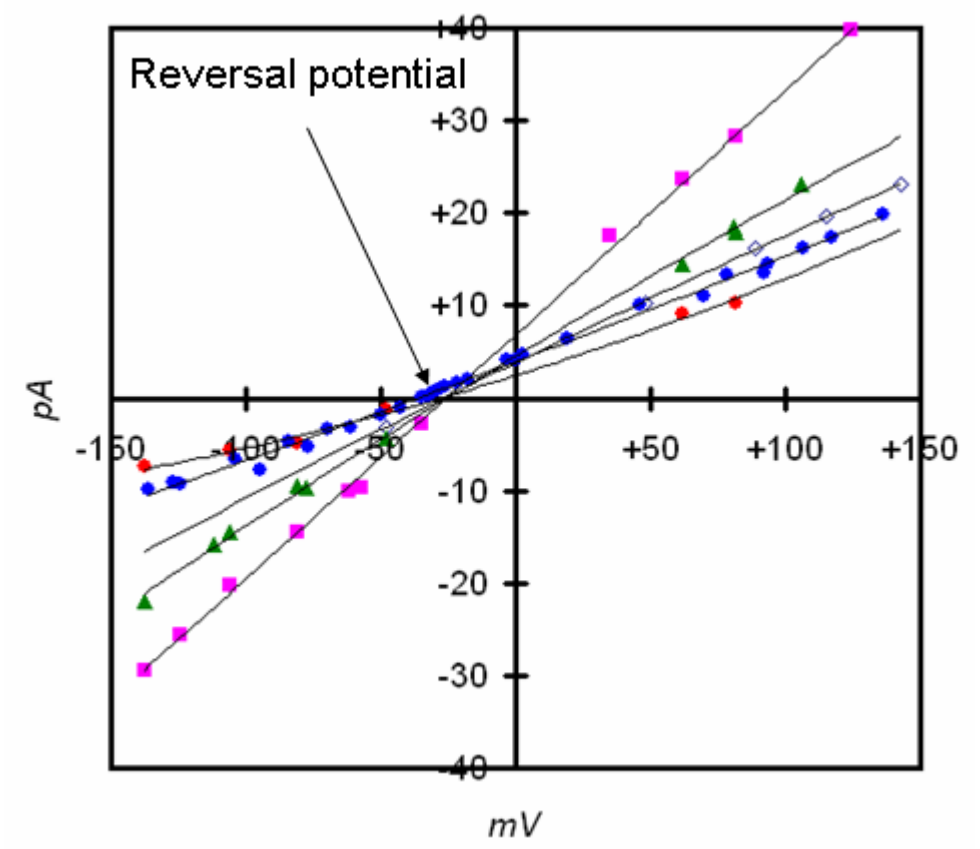


Figure S2. Time profile of ion-channel current observation (500 mM KCl symmetric conditions at pH 7.2), Y-axis: current (*pA*), dotted line: 0 *pA*, values indicated in the profile: applied voltage, The I-V plot is shown in Figure 1 in the main text.



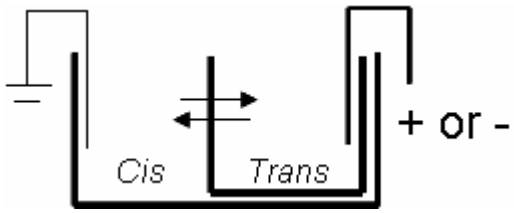


Figure S3. *I-V* plots of ion-channel current of **C-(1-acid)$_3$** , salt conditions: *cis* 10 mM / *trans* 100 mM tetramethylammonium chloride, pH 7.2,
V_{rev}: -28.2 ± 4.4 mV

Experimental

Materials

All the commercially available chemicals were used directly unless otherwise described. Grubbs catalyst (1st generation) and PAMAM dendrimer (generation 4, 10wt% MeOH solution) were purchased from Aldrich. Soybean lecithin (type-IIS) was purchased from Sigma Chemical Co. Ltd. 1-Methylimidazole-2-carboxyaldehyde (**5**)[1], boronic ester **6**[2], dipyrromethane 7[3], and 5,15-bis-(4'-eyhoxycarbonylphenyl)-porphyrin[4] were prepared according to the corresponding literatures. TLC was operated on glass plates coated with 60 F_{254} (Merck) silica gel. Column chromatography was undertaken using a column packed with silica gel 60 N (Kanto Chemical, spherical, neutral, 63-210 μm).

Instruments

^{1}H NMR spectra were measured on a JEOL JNM-ECP 600 spectrometer in $CDCl_3$. ^{1}H chemical shifts were referenced to tetramethysilane or the residual proton resonance ($(CHCl_2)_2$, 5.95 ppm) in the case of $(CDCl_2)_2$ as the internal standard. UV-vis spectra were measured by a Shimadzu UV-3000 PC spectrometer. Fluorescence spectra were recorded on a Hitachi F-4500 spectrometer. MALDI-TOF mass spectra were measured on a Perseptive Biosystems Voyager DE-STR or Bruker Daltonics autoflex II with dithranol as a matrix. High resolution mass spectra (FAB method, *m*-NBA as a matrix) were measured on a JEOL *M*Station.

For ion channel measurements, a patch/whole cell clamp amplifier (CEZ-2400, Nihon Kohden), an A/D converter (VR-10B, Instrutech Corp.), a video recorder (NV-HV1, Panasonic), a multifunction filter (3611, NF electronic), and a digitizer (DIGI DATA 1322A, Axon) were used. Data analysis was carried out on pCLAMP 8 (Axon) and Origin 7 (Origin Lab).

Synthesis

Free base porphyrin 8. Into a 3 L three-necked flask, 1-methylimidazole-2-carboxaldehyde **5** (0.61 g, 5.50 mmol), 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenylcarboxaldehyde **6** (1.28 g,

5.50 mmol), dipyrromethane **7** (2.68 g, 11.0 mmol), and degassed $CHCl_3$ (1.1 L) were added. After replacing by N_2, tifluoroacetic acid (1.27 mL, 16.5 mmol) was added slowly to the mixture over 30 seconds. The mixture was stirred at rt for 8 h. Triethylamine (2.30 mL, 16.5 mmol) was added to neutralize the mixture, and then, *p*-chloranil (4.06 g, 16.5 mmol) was added to the mixture for oxidative aromatization. After stirring for 8 h, the reaction mixture was passed through a column packed with Celite® 545 to remove precipitate. The filtrate was washed with saturated $NaHCO_3$ solution and brine, and dried over anhydrous Na_2SO_4. The mixture was concentrated under reduced pressure, and the residue was purified by SiO_2 column chromatography ($CHCl_3$/acetone = 6/1 to 3/1) to give a mixture of porphyrin **8** and aldehyde **6** (462.8 mg including 23% of **6**) as purple solid. The mixture was used for the next coupling reaction. Aldehyde **6** could be removed after the next reaction. TLC ($CHCl_3$/Acetone=4/1) R_f = 0.37, HRMS (FAB, *m*-NBA matrix) mass m/z ($[M+H]^+$) 789.4304, calcd for $C_{48}H_{54}BN_6O_4$ 789.4308. ^{1}H NMR (600 MHz, $CDCl_3$) of **8** δ 9.54 (d, *J* = 4.7 Hz, 2H, *β-pyrrole*), 9.47 (d, *J* = 4.7 Hz, 2H, *β-pyrrole*), 8.85-8.83 (m, 2H, *β-pyrrole*), 8.80-8.77 (m, 2H, *β-pyrrole*), 8.67* and 8.58* (s, 1H, *ph*), 8.29-8.26* and 8.19-8.16* (m, 1H, *ph*), 8.26-8.22 (m, 1H, *ph*), 7.77* and 7.75* (t, *J* = 7.4 Hz, 1H, *ph*), 7.70* and 7.69* (d, *J* = 1.6 Hz, 1H, *Im*), 7.49* and 7.48* (d, *J* = 1.6 Hz, 1H, *Im*), 6.08 (ddt, *J* = 17.0, 10.4, 5.7 Hz, 2H, -*CH*=), 5.42 (dq, *J* = 17.0, 1.6 Hz, 2H, =*CH*$_2$), 5.26 (dt, *J* = 10.4, 1.6 Hz, 2H, =*CH*$_2$), 5.10 (t, *J* = 7.7 Hz, 4H, CH_2), 4.11-4.04 (m, 4H, -*OCH*$_2$-), 3.66 (t, *J* = 5.7 Hz, 4H, CH_2), 3.43* and 3.39* (s, 3H, -*NMe*), 2.83-2.75 (m, 4H, CH_2), 1.41 and 1.40 (s, 12H, *4Me*), -2.68 (s, 2H, *Inner -NH*), and 23% of **6** δ 10.05 (s, CHO), 8.31 (s, Ar), 8.07-8.05 (m, Ar), 8.00-7.97 (m, Ar), 7.53 (t, *J* = 7.7 Hz, Ar), 1.37 (s, Me). (*: atropisomers)

Zinc porphyrin 2. Free base porphyrin **8** (441.5 mg, 559.7 μmol) was dissolved in $CHCl_3$ (72 mL). Saturated solution of $Zn(OAc)_2{\cdot}2H_2O$ in methanol (10.6 mL) was added to the solution, and stirred for 7 h. The mixture was washed with saturated $NaHCO_3$ solution and brine. The mixture was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was dissolved in $CHCl_3$ (200 mL). Saturated $NaHSO_3$ solution (pH 3) was adjusted to pH 8 with saturated $NaHCO_3$ solution, and the mixture (200 mL) was added to the chloroform solution to remove aldehyde **6**.[5]

After stirring for 3 h, the chloroform layer was washed with saturated $NaHCO_3$ solution and distilled water. The mixture was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was washed with hexane to give **2** (293.4 mg, 62%). TLC ($CHCl_3$/Acetone=20/1) *Rf*=0.49, HRMS (FAB, *m*-NBA matrix) mass m/z ($[M+H]^+$) 851.3429, calcd for $C_{48}H_{52}BN_6O_4Zn$ 850.3443, ^1H NMR of complementary coordination dimer of **2** (600 MHz, $CDCl_3$) δ 9.64-9.59 (m, 2H, *β-pyrrole*), 9.16* (s, 0.5H*, *ph*), 9.01-8.94 (m, 4H, *β -pyrrole*), 8.73* (d, *J* = 7.3 Hz, 0.3H*, *ph*), 8.63* (s, 0.4H, *ph*), 8.31 (d, *J* = 7.7 Hz, 0.8H*, *ph*), 8.18-8.15 (m, 0.5H*, *ph*), 7.94 (t, *J* = 7.7 Hz, 0.3H, *ph*), 7.76* (t, *J* = 7.7 Hz, 0.5H*, *ph*), 6.22-6.15 (m, 2H, -*CH*=), 5.57-5.55* (m, 0.5H*, *Im-5*), 5.54-5.52* (0.5H*, *Im-5*), 5.52 (d, 2H, J=17.0 Hz, =*CH*$_2$), 5.44-5.38 (m, 2H, *β-pyrrole*), 5.29-5.14 (m, 4H, CH_2), 4.26-4.19 (m, 4H, -*OCH*$_2$-), 3.97-3.88 (m, 4H, CH_2), 3.15-3.05 (m, 2H, CH_2), 3.04-2.95 (m, 2H), 2.20-2.18* (m, 0.5H*, *Im-4*), 2.14-2.11* (m, 0.5H*, *Im-4*), (1.72, 1.69, 1.68, and 1.65) (s, 3H, -*NMe*), 1.56 and 1.40 (s, 6H, Me). (*: atropisomers)

5,15-Bisbromo-10,20-Bis-(4'-ethoxycarbonylphenyl)-porphyrin (3). **5,15-Bis-(4-eyhoxycarbonylphenyl)-porphyrin**[4] (203.7 mg, 0.336 mmol) was dissolved in degassed $CHCl_3$ (102 mL), and the solution was cooled at 0 °C. Pyridine (0.774 mL, 9.5703 mmol) and *N*-bromosuccinimide (179.3 mg, 1.0074 mmol) were added to the solution successively. After stirring for 1 h at 0 °C, acetone (30 mL) was added to the mixture, and the mixture was warmed to rt. The mixture was concentrated under reduced pressure, and the residue was washed with methanol and dried under reduced pressure to give dibromoporphyrin **3** (177.8 mg, 69 %). TLC ($CHCl_3$) Rf=0.39, MALDI-TOF mass m/z ($[M]^+$) 764.0, calcd for $C_{38}H_{28}Br_2N_4O_4$ 764.05 (Average), ^1H NMR (600 MHz, $CDCl_3$) δ 9.63 (broad d, *J* = 4.4 Hz, 4H, *β -pyrrole*), 8.79 (br, 4H, *β-pyrrole*), 8.47 (d, *J* = 8.2 Hz, 4H, *β-pyrrole*), 8.24 (d, *J* = 8.2 Hz, 4H, *β-pyrrole*), 4.60 (q, *J* = 7.2 Hz, 4H, *CH*$_2$), 1.57 (t, *J* = 7.2 Hz, 6H, *CH*$_3$), -2.74 (s, 2H, *NH*).

(Zn)-(Free base)-(Zn) trisporphyrin 4. In the Schlenk flask (50 mL), boronate-porphyrin **2** (20.7 mg, 24.3 μmol) and dibromoporphyrin **3** (9.3 mg, 12.2 μmol) was placed. The atmosphere was

replaced with Ar. Dry toluene (6.1 mL) and dry DMF (3.05 mL) were added to the flask, and the mixture was degassed by freeze-pump-thaw processes three times. The mixture was heated at 80 °C. To the mixture, Cs_2CO_3 (11.9 mg, 36.6 μmol) dried in a microwave oven for 1 min and $Pd(PPh_3)_4$ (2.8 mg, 2.44 μmol) were added successively. The mixture was stirred at 80 °C for 20 h. The mixture was cooled to rt. Distilled water (30 mL) was added, and the mixture was stirred for 10 min. Precipitates were removed by filtration, and the filtrate was transferred to a separated funnel. Toluene was added to the mixture, and the mixture was washed with brine. The organic layer was extracted with $CHCl_3$ several times, and dried over anhydrous Na_2SO_4. The Na_2SO_4 was filtered out, and colored precipitates on the filter paper were eluted with a mixture of chloroform and methanol (9/1). The organic solution was concentrated under reduced pressure, and the residue was passed through short column chromatography (SiO_2, $CHCl_3$/acetone=4/1). The collected solution was divided into three equal parts. Each part was purified further by recycle gel permeation chromatography (Tosoh G2500H_{HR}, Pyridine, flow rate: 3 mL/min, detection: 430 nm, three recycle). Totally 10.0 mg of trisporphyrin **4** (40 %) was obtained as purple solid. TLC (benzene/THF = 10/1) *Rf* = 0.47, MALDI-TOF mass m/z ($[M+H]^+$) 2056.2, calcd for $C_{122}H_{106}N_{16}O_8Zn_2$ 2055.70 (Average), UV-vis (in pyridine) λ_{max} / nm (Abs.): 611 (0.018), 562 (0.029), 518 (0.019), 439 (0.423), 430 (0.417), 423 (0.406), 365 (0.031), Fluorescence (in pyridine, λ_{ex}=518 nm) λ_{max} / nm (intensity) 619 (42.8), 654 (83.2), 720 (60.4).

Tris(free base porphyrin) 9. For ^{1}H NMR spectral analysis of free base trisporphyrin, a part of **4** was demetalated to give tris(free base porphyrin). Biszinc-mono free base porphyrin **4** (27.4 μmol) was dissolved in $CHCl_3$ (110 mL) under Ar atmosphere. *p*-Toluenesulfonic acid monohydrate (208.5 mg, 1.1 mmol) was added to the solution, and the mixture was stirred for 1 h. The organic layer was washed with water, saturated $NaHCO_3$ solution, and water, successively. The organic layer was dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (eluent: benzene/THF from 1.5/1 to 1/1) and further reprecipitation from chloroform/hexane to give tris(free base porphyrin) **9** (13.4 mg, 25 %) as

purple solid. This sample was unstable as compared with **4**. On standing 5 days in air at rt, about 80% of sample was decomposed. TLC (benzene/THF = 1/1) Rf = 0.45, MALDI-TOF mass m/z ($[M+H]^+$) 1929.4, calcd for $C_{122}H_{110}N_{16}O_8$ 1927.87 (Average), ^1H NMR (as a mixture of atropisomers, 600 MHz, $CDCl_3$) δ 9.65-9.48 (m, 8H, *β-pyrrole*), 9.38-9.27 (m, 8H, *β-pyrrole*), [9.13, 9.11, 9.08, and 9.02]* (s, 1H, *ph*), 8.98 (m, 4H, *β-pyrrole*), 8.80-8.74 (m, 4H, *β-pyrrole*), 8.69-8.52 (m, 4H, *ph*), 8.48-8.12 (m, 10H, *ph*), 7.68-7.64 (m, 2H, *Im*), 6.12-6.00 (m, 4H, -*CH*=), 5.43-5.35 (m, 4H, =*CH*), 5.27-5.20 (m, 4H, =*CH*), 5.15-5.05 (m, 8H, CH_2), 4.62 (q, 4H, *J* = 7.1 Hz, $C\underline{H_2}CH_3$), 4.12-4.00 (m, 8H, CH_2), 3.68-3.60 (m, 8H, CH_2), [3.41, 3.38, 3.37, and 3.31]* (s, 6H, NCH_3), 2.81-2.75 (m, 8H), 1.65-1.45 (m, H_2O & $CH_2C\underline{H_3}$), -2.60 ~ -2.70* (m, 6H, *NH*). UV-vis ($CHCl_3$) λ_{max}/nm (Abs.): 648 (0.033), 592 (0.040), 553 (0.064), 517 (0.131), 433 (1.220), 414 (1.379), Fluorescence ($CHCl_3$, λ_{ex}=517 nm) λ_{max}/nm (intensity): 653 (316.8), 717 (92.7).

Tris(zinc porphyrin) (1-ester). Trisporphyrin **4** (1.7 mg, 0.88 μmol) was dissolved in $CHCl_3$ (0.7 mL). Saturated $Zn(OAc)_2{\cdot}2H_2O$ solution in methanol (0.1 mL) was added to the solution. The mixture was stirred for 3 h. The mixture was washed with saturated $NaHCO_3$ and brine, dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by reprecipitation from chloroform/hexane to give **1-ester** (1.9 mg, quant.) as purple solid. TLC (benzene/THF=10/1) R_f=0.47, HRMS (FAB, *m*-NBA matrix) mass m/z ($[M+H]^+$) 2119.6155, calcd for $C_{122}H_{105}N_{16}O_8Zn_3$ 2119.6162.

Reorganization of 1-ester to macroring *N*-(1-ester)$_3$.[6] Tris(zincporphyrin) **1-ester** (4.7 mg, 2.2 μmol) was dissolved in a mixture of $CHCl_3$/methnol (9/1 (v/v), 110 mL), and the mixture was left stand without stirring at 27 °C for 24 h. The mixture was concentrated under reduced pressure (30 °C from 250 to 150 hPa). Conversion into cyclic trimer *N*-**(1-ester)$_3$** was confirmed by analytical gel permeation chromatography (JAIGEL-3HA, Chloroform).

Covalent linked macroring C-(1-ester)$_3$. Macroring *N*-**(1-ester)$_3$** (7.0 mg, 1.1 μmol) was

dissolved in $CHCl_3$ (16 mL) under Ar atmosphere, and 1st generation of Grubbs catalyst (1.4 mg, 1.7 μmol) was added to the solution. The reaction progress was monitored by MALDI–TOF spectrometry, and continued until most of the peaks were converted to the corresponding trimer (for 9 h in this experiment). Distilled water (15 mL) was added to the mixture to quench the reaction. The organic layer was washed with water, dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography ($CHCl_3$/Acetone=20/1) to give covalently linked macroring **C-(1-ester)$_3$** (6.3 mg, 92 %) as purple solid. TLC ($CHCl_3$/Acetone=15/1) Rf=0.30, MALDI-TOF mass m/z ($[M+H]^+$) 6177, calcd for $C_{354}H_{288}N_{48}O_{24}Zn_9$ 6170 (monoisotopic) and 6188 (average), UV-vis (1,1,2,2-tetrachloroethane) λ_{max}/nm (Abs): 621 (0.028), 565 (0.049), 555 (0.049), 442 (0.6325), 412 (0.635), Fluorescence (1,1,2,2-tetrachloroethane, λ_{ex}=548 nm) λ_{max}/nm (Int): 665 (59.9), 625 (219.7).

Hydrolysis of C-(1-ester)$_3$ to give C-(1-acid)$_3$. Hexaester **C-(1-ester)$_3$** was dissolved in a mixture of THF/methanol (2/1(v/v), 10.0 mL). 8M NaOH solution (3.38 mL) was added to the mixture to hydrolyze the ester groups. The reaction progress was monitored by MALDI-TOF mass analysis of a small amount of sample neutralized with acetic acid. After 7h, most of ester groups were hydrolyzed. Distilled water (30 mL) and $CHCl_3$ were added to the mixture, successively. The mixture was cooled with ice bath, and acidified with 1M HCl to adjust pH 3. The organic layer was separated, and the solvent was evaporated. To the residue, ion-exchanged water was added, and the suspension was stirred vigorously. The sample was centrifuged, and the supernatant was removed. This washing process was repeated totally three times. After dryness under reduced pressure, similar washings with diethyl ether, hexane, and chloroform were carried out in sequence to give **C-(1-acid)$_3$** (6.5 mg, quant.) as purple solid. MALDI-TOF mass m/z ($[M+H]^+$) 6018, calcd for $C_{342}H_{264}N_{48}O_{24}Zn_9$ 6001 (monoisotopic) and 6018 (average), UV-vis (dry THF) λ_{max}/nm (Abs): 619 (0.013), 563 (0.027), 442 (0.282), 410 (0.228), Fluorescence (dry THF, λ_{ex}=563 nm) λ_{max}/nm (Int): 676 (157.1), 623 (516.9).

Measurements of ion channel currents

Ion channel currents were measured by the planar bilayer lipid membrane method. Details may refer to the previous papers.[7] A premix solution of **C-(1-acid)$_3$** (10 μg) and soybean lecithin (10 mg) in *n*-decane (250 μL) was prepared. The premix solution was applied to the *cis* side of a hole precoated with a concentrated lecithin solution in *n*-decane (80 mg/mL) in a partition separating two aqueous chambers. In advance, the two chambers were filled with ca. 1 mL of appropriate salt solution, such as 500 mM of KCl, LiCl, $CaCl_2$, or tetraalkylammonium chloride, and adjusted to pH 7.2 by Tris-HEPES buffer. Triangular voltage ramps were applied to form bilayer membranes. Then, data were collected at various applied potentials. The data storage and analysis were undertaken in a similar way as reported previously.[7]

Blocking pore

A stock solution of 4th generation of PAMAM dendrimer (**G4**, $1.1x10^{-5}$ M) was prepared by mixing 10wt% methanol solution of **G4** (0.8 mg) and 500 mM Me_4NCl solution (0.5 mL). Appropriate drops of the G4 stock solution (5 μL/drop) was added to the *trans* side with applying positive voltage when ion channel current was observed. Data were collected at positive and, then, negative applied voltage.

Deblocking pore

After diminishing of ion current by the above blocking, appropriate drops of 1 M of HEPES solution (5 μL/drop) were added to the both *cis* and *trans* sides with applying negative voltage. Data were collected at various applied voltages.

References

1. Milgrom, L. R.; Dempsey P. J. F. and Yahioglu D. *Tetrahedron* **1996,** *52*, 9877.

2. Vogels, C. M.; Nikolcheva, L. G.; Norman, D. W.; Spinney, H. A.; Decken, A.; Baerlocher, M. O.; Baerlocher, F. J.; Westcott, S. A. *Can. J. Chem.* **2001**, *79*, 1115.

3. Ohashi, A.; Satake, A.; Kobuke, Y. *Bull. Chem. Soc. Jpn.* **2004**, *77*, 365.

4. Ogawa, K.; Dy, J.; Kobuke, Y. *J. Porphyrins and Phthalocyanines*, **2005**, *9*, 735.

5. Fieser, M., *Fieser and Fieser's Reagents for Organic Synthesis*, vol. 11, p. 487, 1984, John Wiley & Sons, Canada.

6. Kuramochi, Y.; Satake, A.; Itou, M.; Ogawa, K.; Araki, Y.; Ito, O.; Kobuke, Y. *Chem. Eur. J.* **2008**, *14*, 2827-2841.

7. a) C. Goto, M. Yamamura, A. Satake, Y. Kobuke, *J. Am. Chem. Soc.* **2001**, *123*, 12152, b) Y. Kobuke, T. Nagatani, *J. Org. Chem*. **2001**, *66*, 5094.

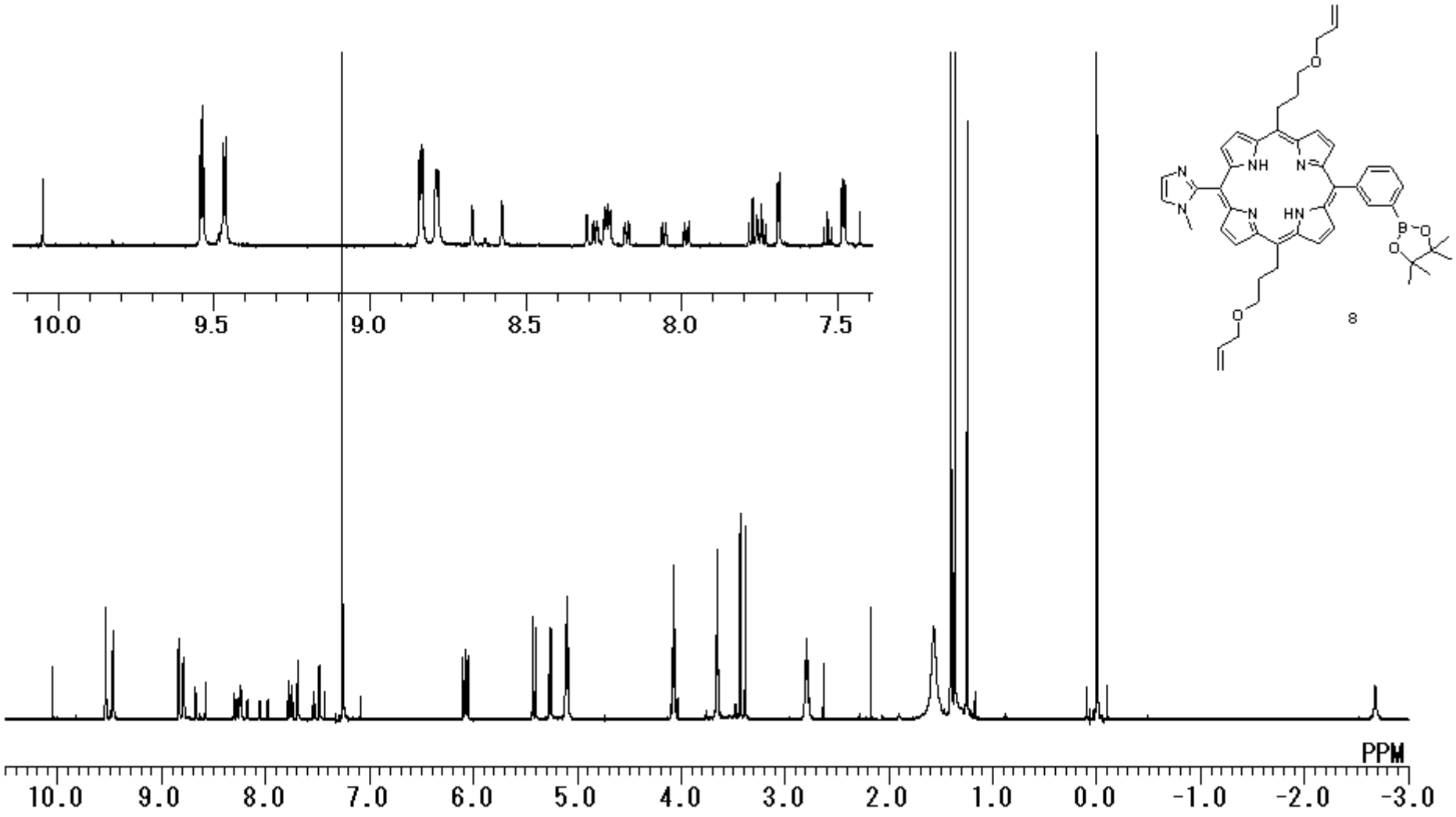


Figure S4. ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **8**

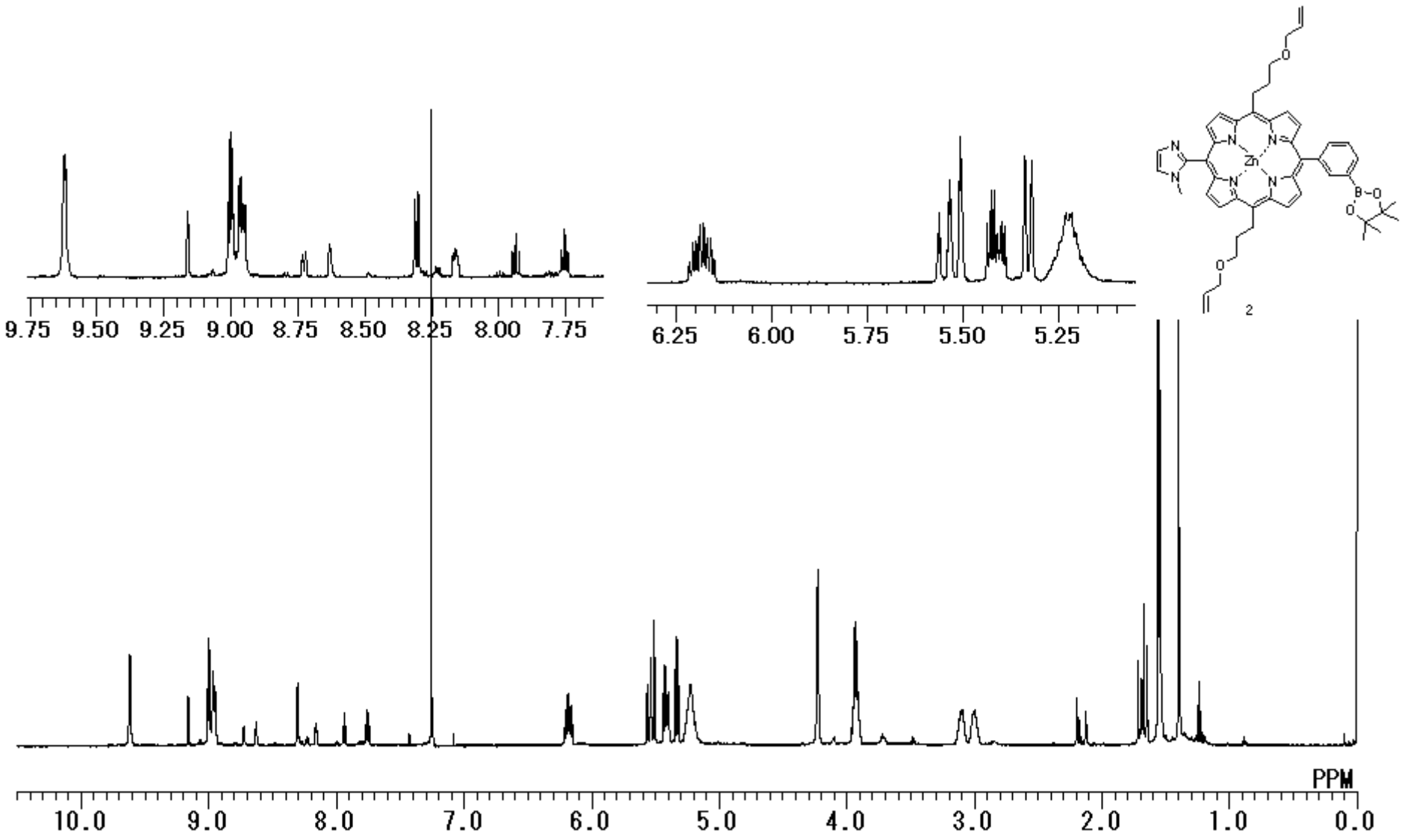


Figure S5. ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **2**

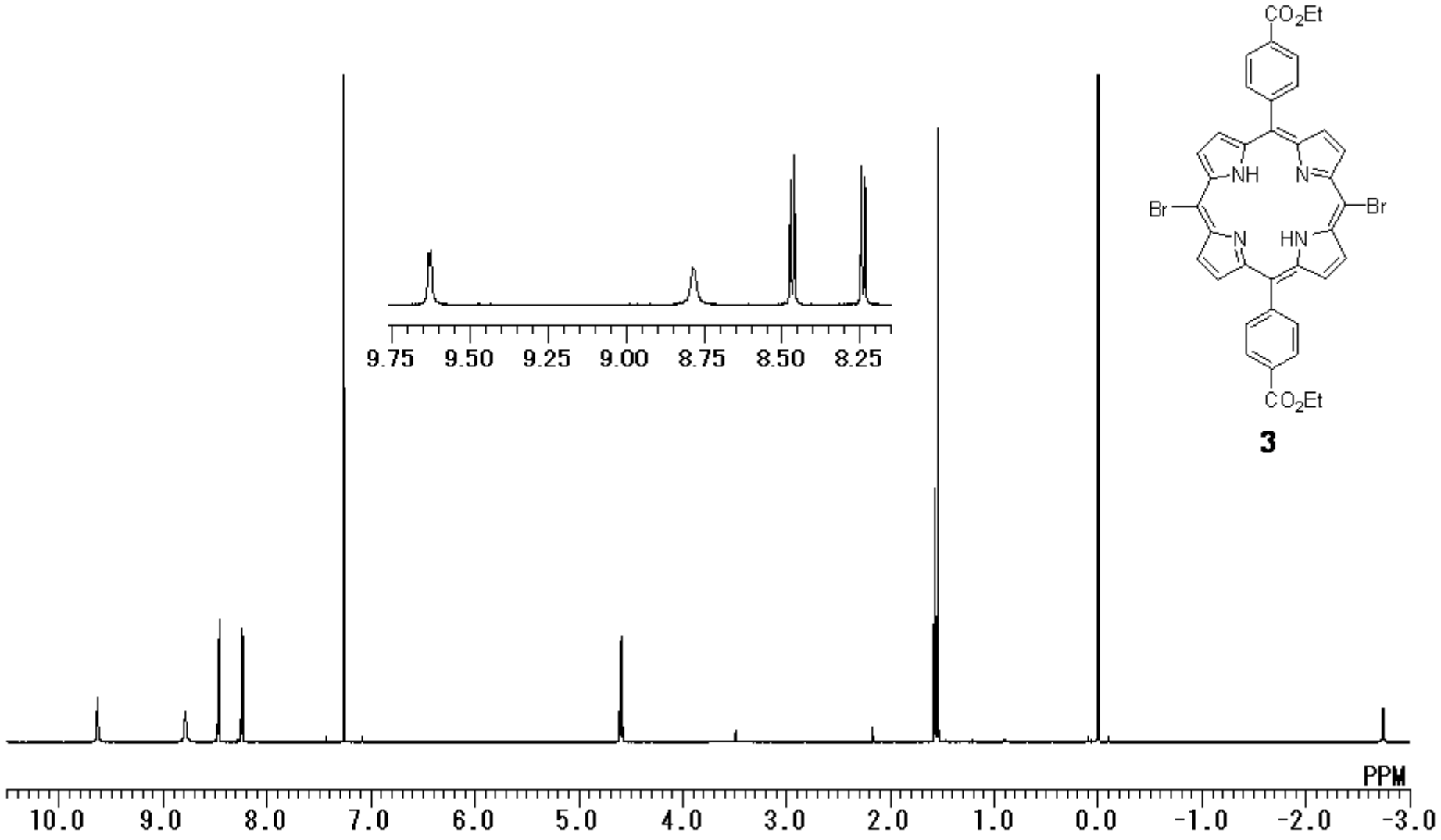


Figure S6. ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **3**

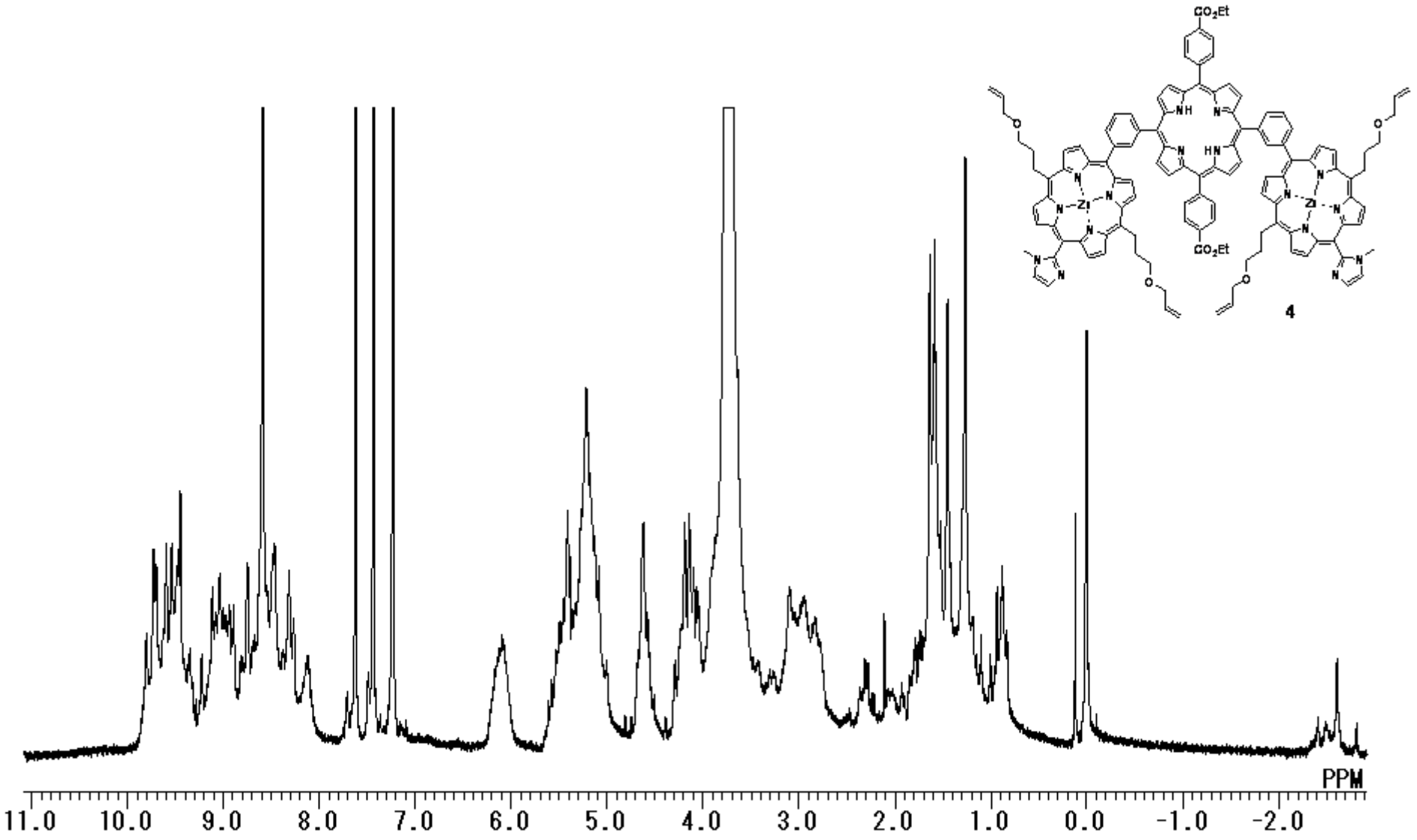


Figure S7. ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **4**

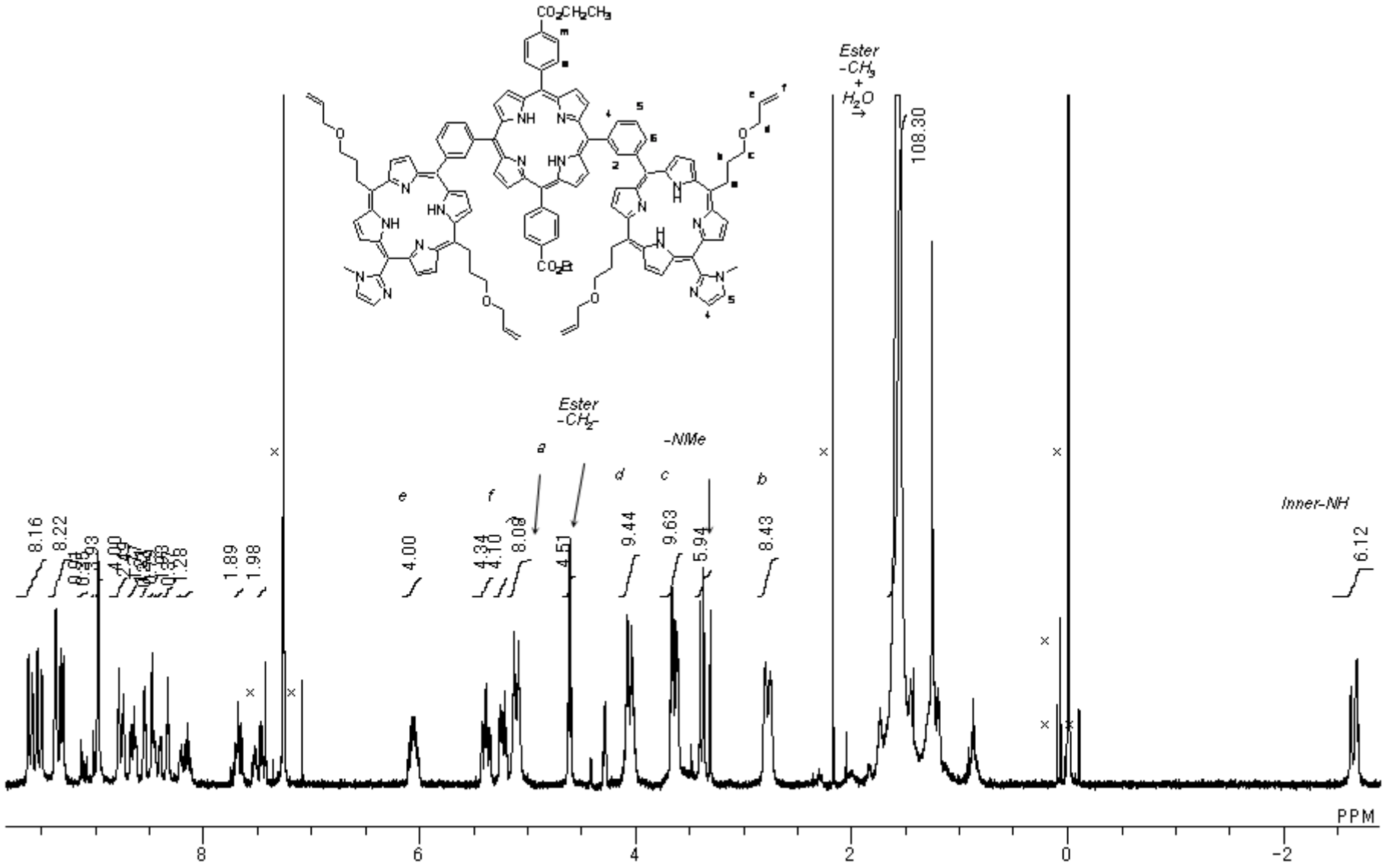


Figure S8. ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **9**

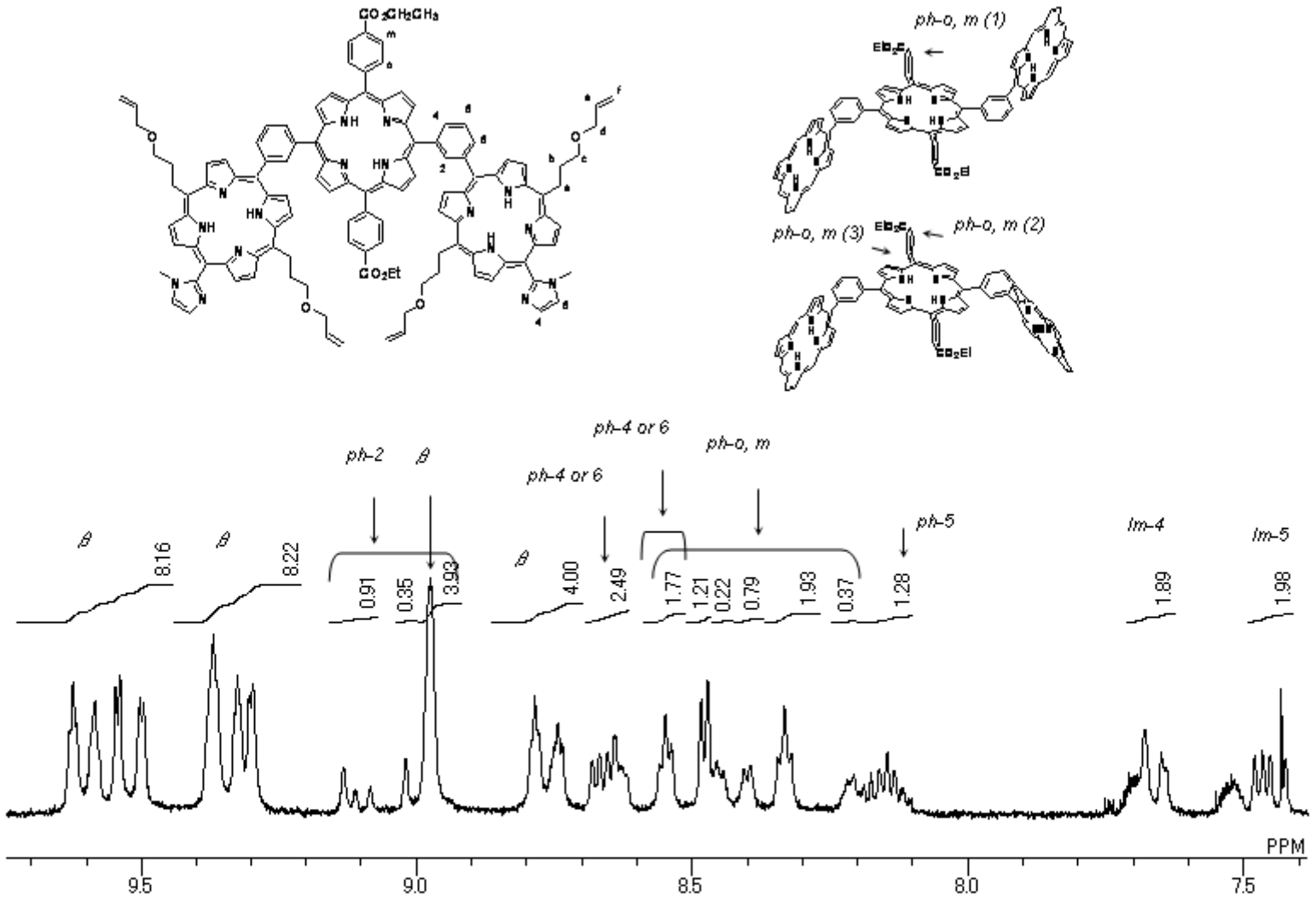


Figure S9. Magnified ^{1}H-NMR spectrum (600 MHz, $CDCl_3$) of **9**

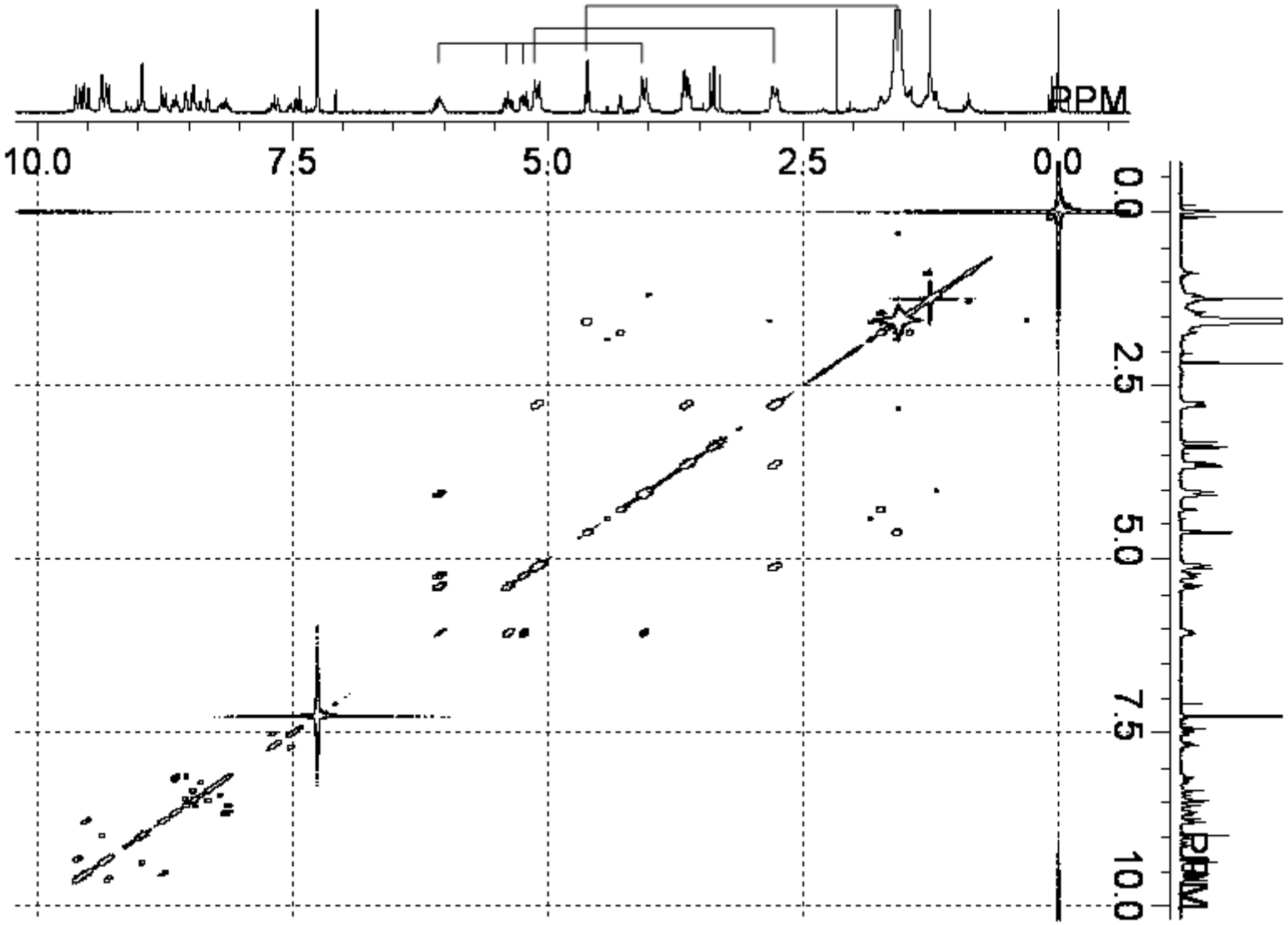


Figure S10. HH-COSY spectrum of **9** recorded at 600 MHz in $CDCl_3$

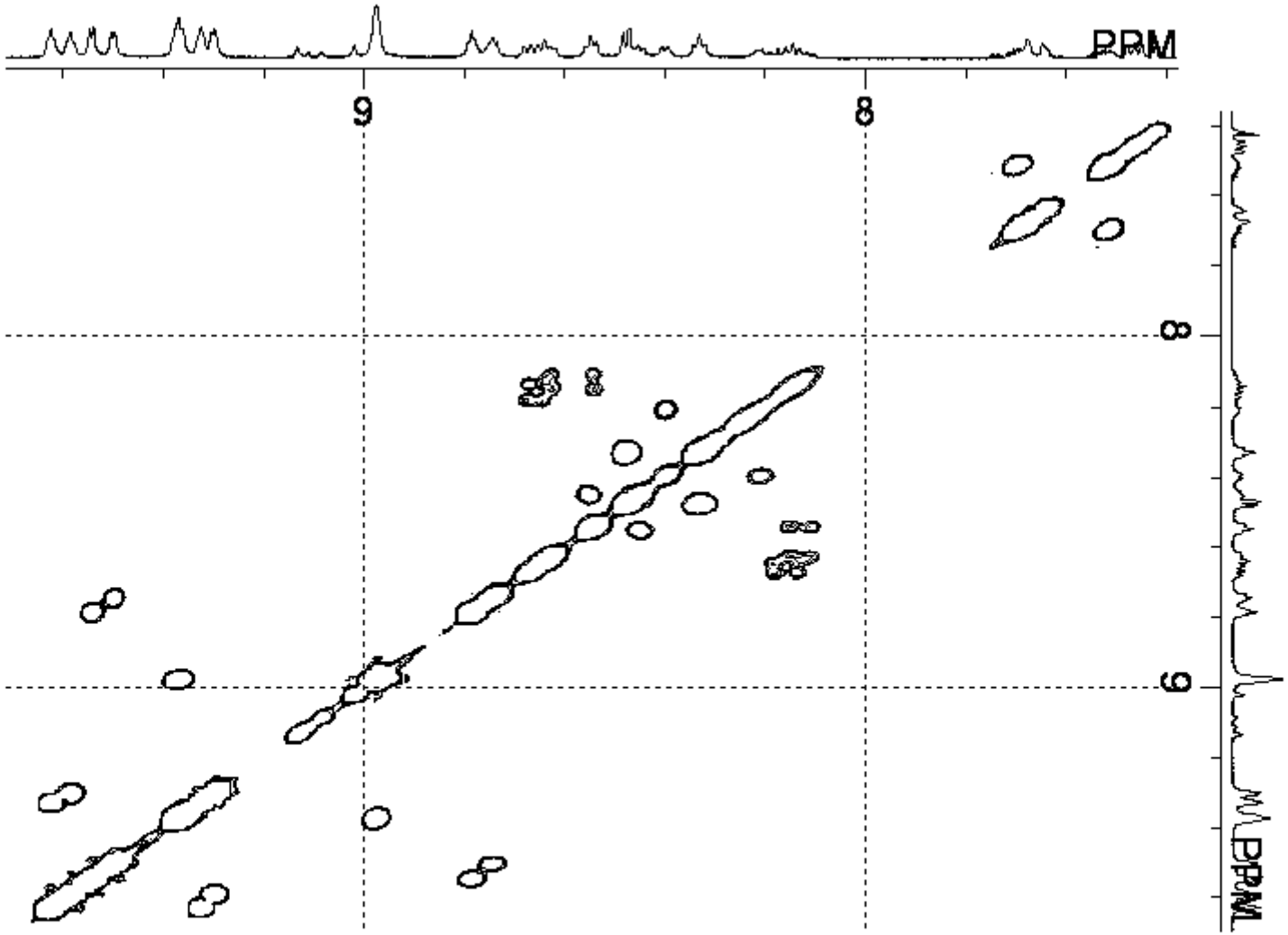


Figure S11. Magnified HH-COSY spectrum of **9** (600 MHz, $CDCl_3$)

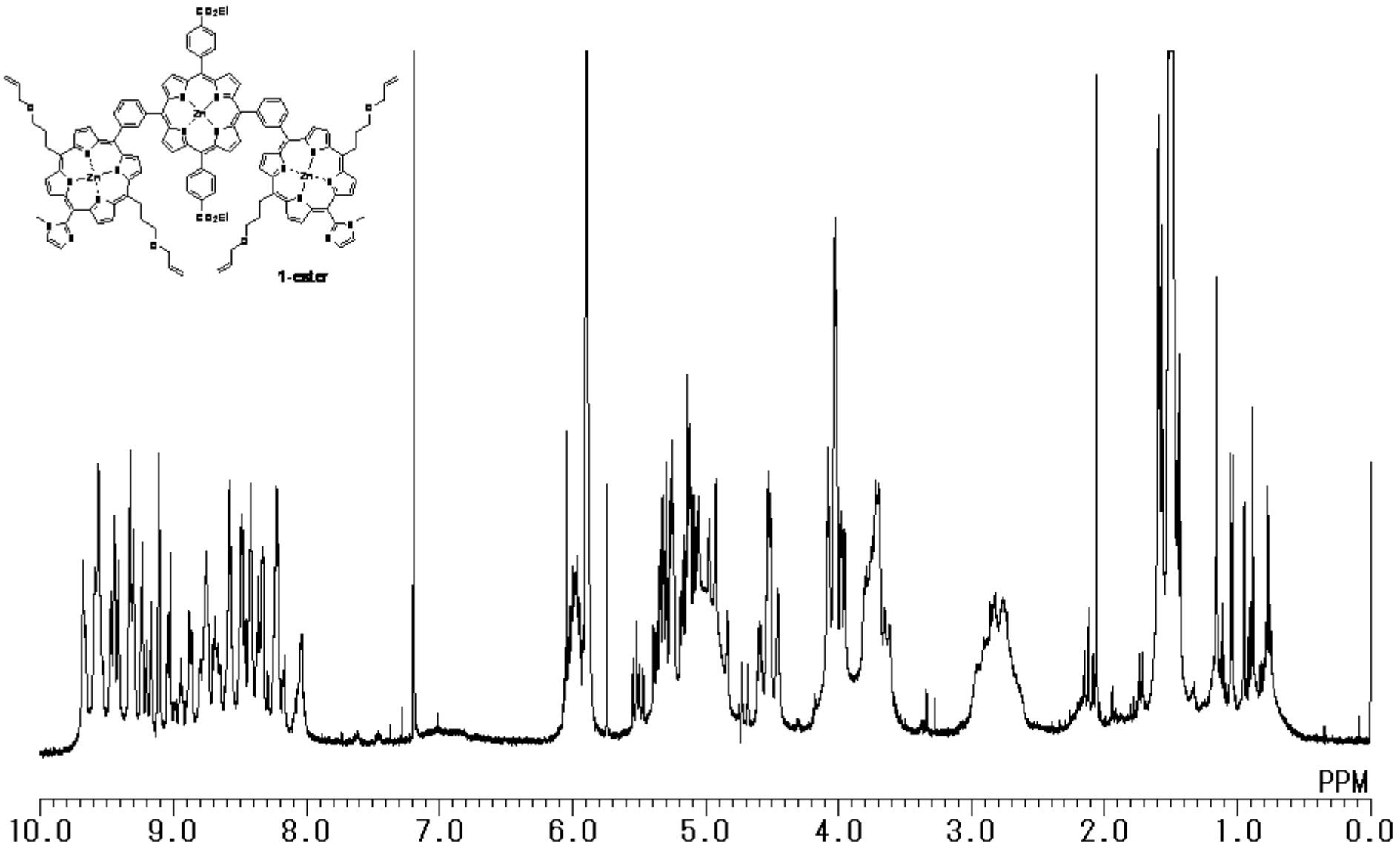


Figure S12. ^{1}H-NMR spectrum (600 MHz, $(CDCl_2)_2$) of ***N*-(1ester)$_3$**

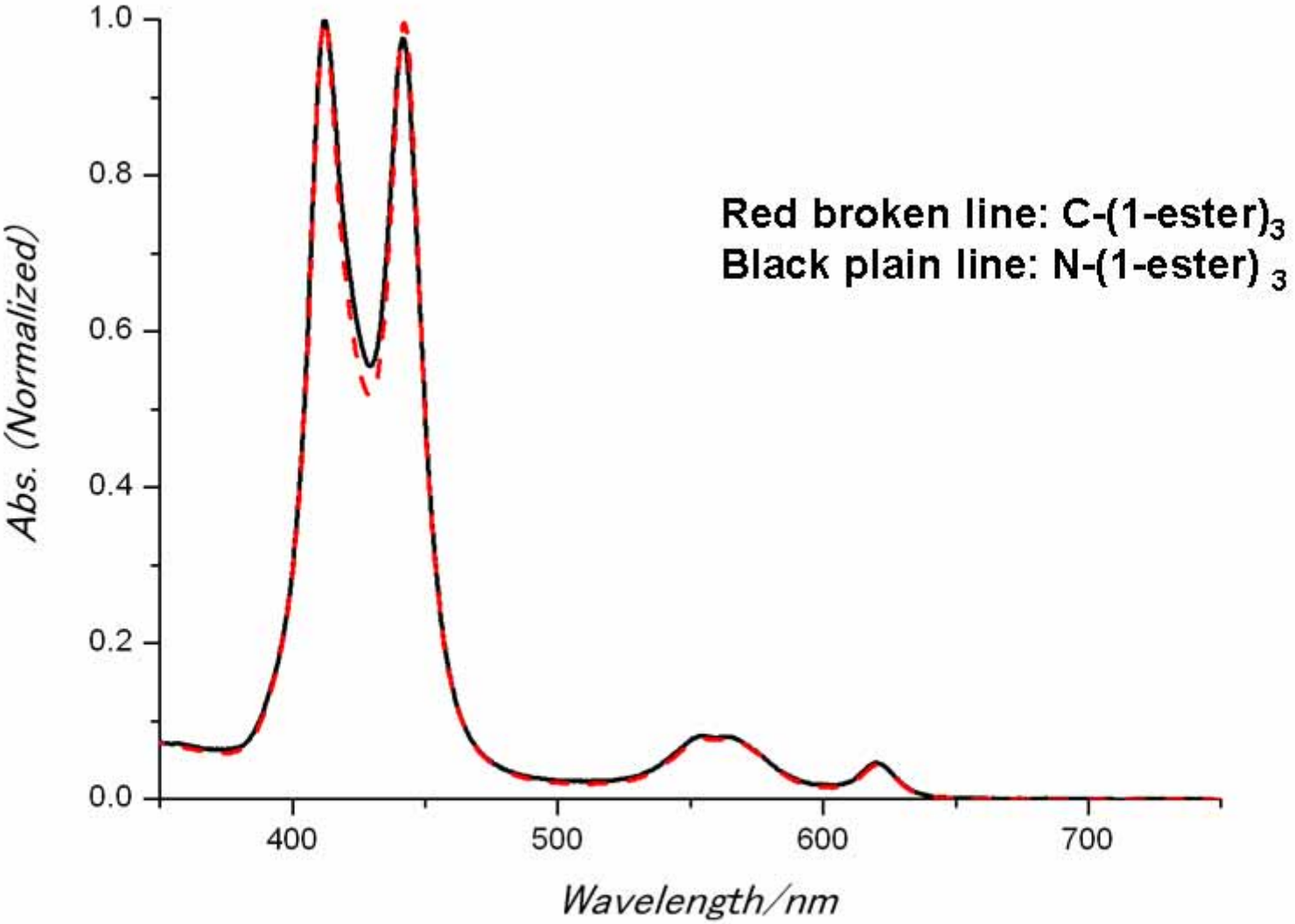


Figure S13. UV-vis spectra of N-(1-ester)$_3$ and C-(1-ester)$_3$ in 1,1,2,2-tetrachloroethane at 25 °C

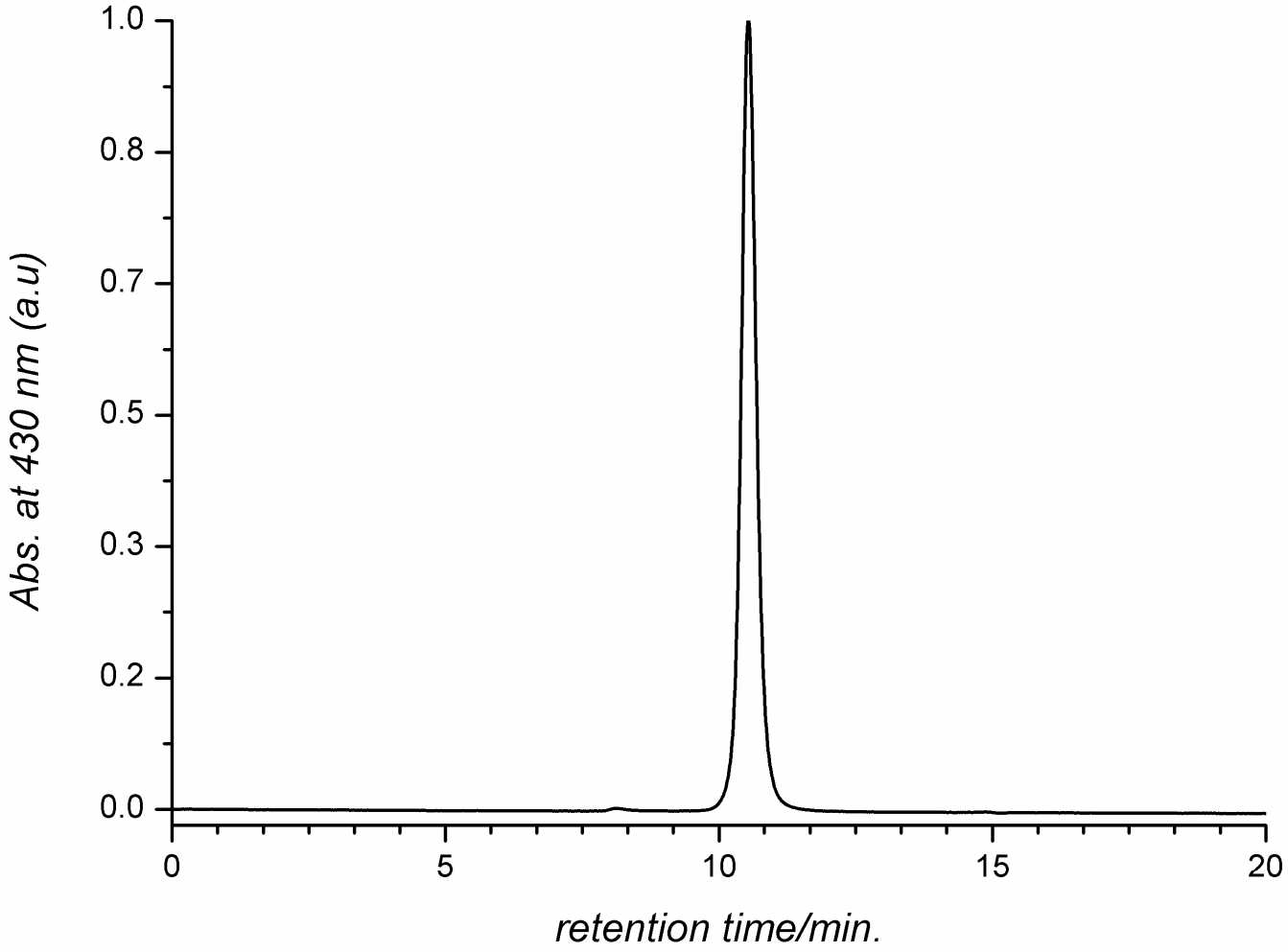


Figure S14. HPLC-GPC chart of C-(1-ester)$_3$
(conditions; column : Tosoh G2500H$_{HR}$, pyridine, 0.8 mL/min)

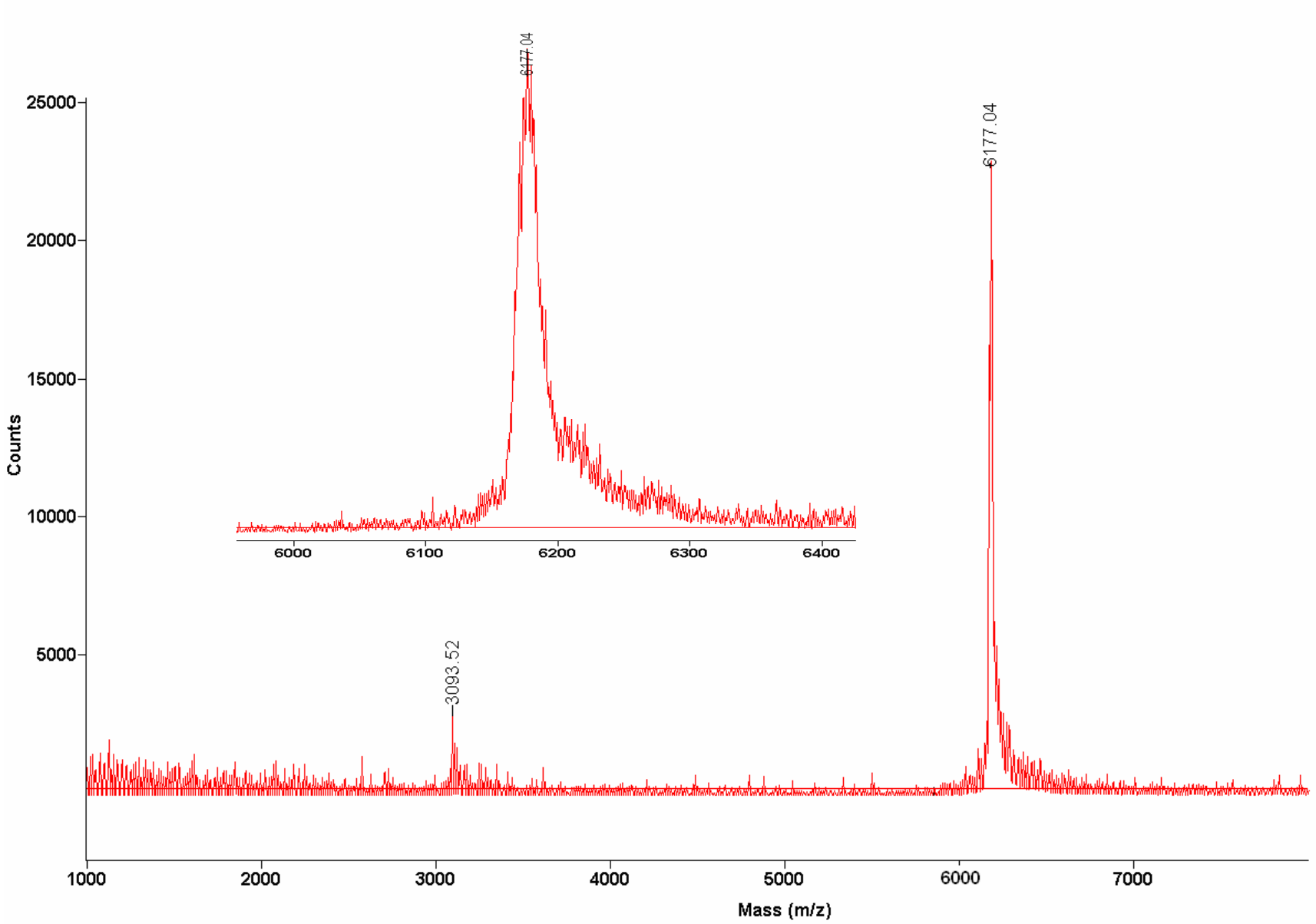


Figure S15. MALDI-TOF mass spectrum of C-(1-ester)$_3$ (matrix: dithranol)

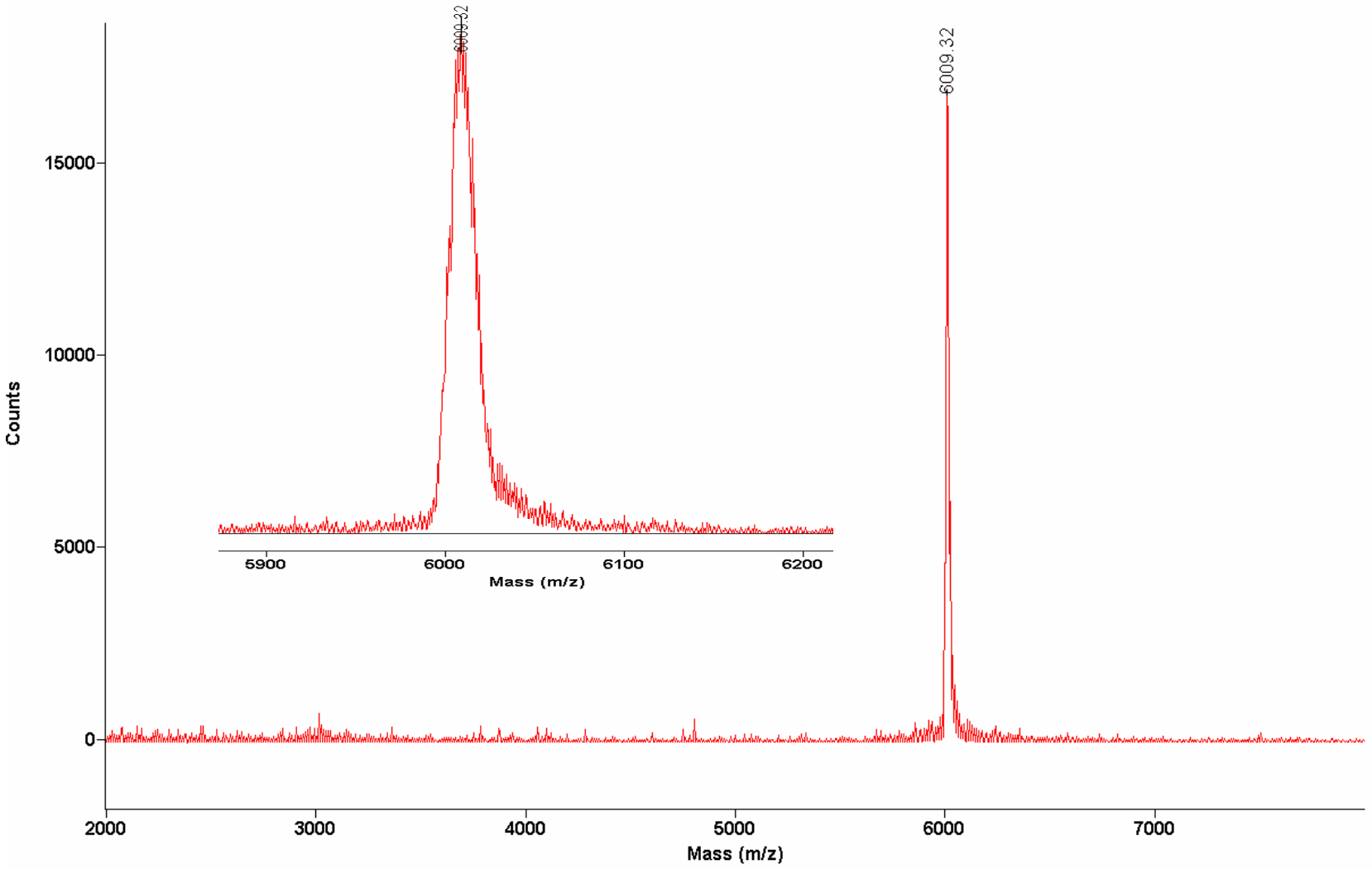


Figure S16. MALDI-TOF mass spectrum of C-(1-acid)$_3$ (matrix: dithranol)