Supplementary Information

An Oxo-Bacteriochlorin Derivative for Long-Wavelength Fluorescence Ratiometric Alcohol Sensing

Kosuke Takano, Shin-ichi Sasaki, Daniel Citterio, Hitoshi Tamiaki and Koji Suzuki

Synthesis and spectral characterization of the fluororeceptor docosyl 3-trifluoroacetyl-8-oxo-bacteriochlorin (BC-1)

General

^{1}H-, ^{13}C- and ^{19}F-NMR spectra were recorded on a JEOL JNM-600HR spectrometer in $CDCl_3$. Chemical shifts are reported relative to the residual solvent peak or the external standard: δ = 7.26 ppm ($CHCl_3$) for ^{1}H-NMR, δ = 77.0 ppm ($^{13}CDCl_3$) for ^{13}C-NMR, and –77.0 ppm (CF_3COOD) for ^{19}F-NMR. Proton peaks were assigned by ^{1}H-^{1}H COSY and NOESY or ROESY spectra, and carbon signals except for quaternary peaks were assigned by DEPT and ^{13}C-^{1}H COSY spectra. Electronic absorption and fluorescence emission spectra were measured on Hitachi U-3500 and F-4500 spectrophotometers, respectively. Fluorescent emission quantum yield was determined at room temperature using a Hamamatsu Photonics absolute PL quantum yield measurement system C9920-02. FT-IR spectra in CH_2Cl_2 were measured with a Jasco FT/IR 6200 spectrometer. Atmospheric pressure chemical ionization (APCI) quadrupole mass spectra (MS) and high resolution (HR) fast atomic bombardment (FAB) MS were measured by a Shimadzu LCMS-2010 EV apparatus and a JEOL GCmate II

spectrometer, respectively. APCI-MS samples were injected as MeOH solutions. A FAB-MS sample for HRMS measurement was dissolved in CH_2Cl_2, *m*-nitrobenzyl alcohol and glycerol were used as the matrix, and PEG1000 was added as an external reference. GPC was performed with recycling preparative high-performance liquid chromatography LC-908 (Japan Analytical Industry) with a connected polystyrene packed column (Jaigel 1H) using $CHCl_3$ as an eluent.

1,3-Dichlorotetrabutyl distannoxane [$(Bu_2ClSn)_2O$] was purchased from Aldrich. 1-Docosanol and osmium tetraoxide were purchased from Tokyo Chemical Industry and Nacalai Tesque, respectively. Methyl 3-trifluoroacetyl-3-devinyl-pyropheophorbide-*a* (**1**) was prepared as previously reported.[S1]

Docosyl 3-trifluoroacetyl-8-oxo-bacteriochlorin BC-1 (3)

The synthesis route for the fluororeceptor **BC-1** is outlined in Scheme S1. According to the reported procedure,[S2] 3-trifluoroacetyl-chlorin **1** (278 mg, 0.45 mmol) was reacted with OsO_4 (ca. 200 mg) in CH_2Cl_2 and pyridine, then the resulting osmium ester was cleaved by H_2S. The crude product was roughly purified by a short column of silica gel column (MeOH-CH_2Cl_2, 1:19) to give the corresponding 7,8-*cis*-dihydroxy-bacteriochlorin (180 mg, 61%) as a stereoisomeric mixture, which was used without further purification. VIS (CH_2Cl_2) λ_{max} 762 (relative intensity, 73%), 549 (28), 356 nm (100); MS (APCI) *m/z* 653 ($M+H^+$), 685 ($M+MeOH+H^+$).

The above *cis*-diol (163 mg, 0.25 mmol) was dissolved in CF_3COOH (20 ml), and the mixture was stirred for 30 min at room temperature. The mixture was poured into water and extracted with CH_2Cl_2. The extract was washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated. The crude product was purified by silica gel chromatography (Et_2O-CH_2Cl_2, 1:9) to give **2** (75 mg, 47%) as a 7-epimeric mixture.

VIS (CH_2Cl_2) λ_{max} 736 (relative intensity, 70%), 556 (17), 397 nm (100); VIS (EtOH) λ_{max} 685 (relative intensity, 47%), 626 (16), 532 (13), 502 (13), 384 nm (100); ^{1}H-NMR δ = 9.42/9.41 (1H, s, 10-H), 8.96 (1H, s, 5-H), 8.69 (1H, s, 20-H), 5.17, 5.02 (each 1H, d, J = 20 Hz, 13^1-CH_2), 4.42 (1H, q, J = 7 Hz, 18-H), 4.23 (1H, d, J = 9 Hz 17-H), 3.65/3.64 (3H, s, 12-CH_3), 3.58 (3H, s, $COOCH_3$), 3.56 (3H, s, 2-CH_3), 2.66, 2.58, 2.33, 2.23 (1H+3H+1H+1H, m, 7-CH_2 and 17-CH_2CH_2), 1.89/1.87 (3H, s, 7-CH_3), 1.79 (3H, d, J = 7 Hz, 18-CH_3), 0.48/0.47 (3H, t, J = 7 Hz, 7^1-CH_3), 0.13, -1.08 (each 1H, br-s, NH); MS (APCI) *m/z* 635 ($M+H^+$), 667 ($M+MeOH+H^+$).

According to the reported procedure,[S3] transesterification of **2** (30 mg, 0.047 mmol) was performed with 1-docosanol (164 mg, 0.50 mmol) and [$(Bu_2ClSn)_2O$] (13 mg, 0.02 mmol) in toluene (20 ml). The crude product was purified by silica gel chromatography (Et_2O-CH_2Cl_2, 1:49) followed by GPC to give **3** (35 mg, 82%) as a 7-epimeric mixture. VIS (EtOH) λ_{max} 685 (relative intensity, 46%), 625 (16), 532 (13), 502 (13), 384 nm (100); λ_{flu}(EtOH) 696 nm; Φ_{EtOH} = 0.12; ^{1}H-NMR δ = 9.423/9.419 (1H, s, 10-H), 8.96 (1H, s, 5-H), 8.68 (1H, s, 20-H), 5.18, 5.02 (each 1H, d, J = 20 Hz, 13^1-CH_2), 4.43 (1H, dq, J = 2, 7 Hz, 18-H), 4.23 (1H, br-d, J = 9 Hz 17-H), 4.41 (2H, m, 17^2-$COOCH_2$), 3.58 (3H, s, 2-CH_3), 3.56 (3H, s, 12-CH_3), 2.66, 2.59, 2.32, 2.24 (1H+3H+1H+1H, m, 7-CH_2 and 17-CH_2CH_2), 1.89/1.87 (3H, s, 7-CH_3), 1.78 (3H, d, J = 7 Hz, 18-CH_3), 1.51 (2H, m, 17^2-$COOCCH_2$), 1.23-1.19 (38H, m, 17^2-$COOC_2(CH_2)_{19}$), 0.87 (3H, t, J = 7 Hz, 17^2-$COOC_{21}CH_3$), 0.48/0.47 (3H, t, J = 7 Hz, 7^1-CH_3), 0.12, -1.09 (each 1H, br-s, NH); ^{13}C-NMR δ = 208.8 (C13^1), 195.0 (C8), 182.2 (q, $^2J_{C\text{-}F}$ = 38 Hz, C3^1), 172.9, 170.6, 167.3, 160.7, 148.4, 145.5, 140.1, 138.2, 138.1, 136.4, 131.6, 128.8, 126.8 (C1, 2, 3, 4, 6, 9, 11, 12, 13, 14, 16, 17^3, 19), 116.4 (q, $^1J_{C\text{-}F}$ = 289 Hz, C3^2), 110.3 (C15), 100.3 (C10), 97.3 (C20), 95.0 (C5), 64.9 (C17^5), 55.84/55.81 (C7), 51.5 (C17), 49.7 (C18), 47.7 (C13^2), 31.9, 31.5, 31.4, 31.0, 29.71,

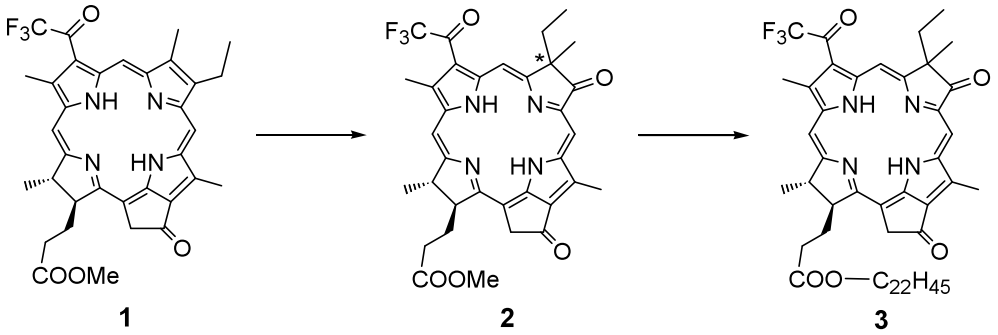
29.66, 29.63, 29.58, 29.5, 29.4, 29.3, 29.2, 28.52, 28.50, 25.8, 23.07, 23.06, 22.7, 22.63, 22.57 (7-*C*H_2, 7-*C*H_3, $C17^1$, $C17^2$, $C17^6$-$C17^{25}$, several peaks appear to overlap at 29.6 ppm), 14.1 ($C17^{26}$), 12.9 (q, $^5J_{C\text{-}F}$ = 3 Hz, $C2^1$), 11.8 ($C12^1$), 8.8 ($C7^2$); ^{19}F-NMR δ = -79.66 (s, 3^1-CF_3); IR (CH_2Cl_2) ν 1711, 1697, 1622 cm^{-1}; MS (APCI) *m/z* 930 ($M+H^+$), 962 ($M+MeOH+H^+$); HRMS (FAB) *m/z* 929.5762 (MH^+), calcd for $C_{55}H_{75}F_3N_4O_5$ 929.5768.

References

S1 S. Sasaki and H. Tamiaki, *Tetrahedron Lett.,* 2006, **47**, 4849-4852.

S2 S. Sasaki, M. Omoda, and H. Tamiaki, *J. Photochem. Photobiol. A: Chem.,* 2004, **162**, 307-315.

S3 S. Sasaki and H. Tamiaki, *Tetrahedron Lett.,* 2006, **47**, 4965-4968.



Scheme S1. Synthesis route for the fluororeceptor **BC-1** (**3**).

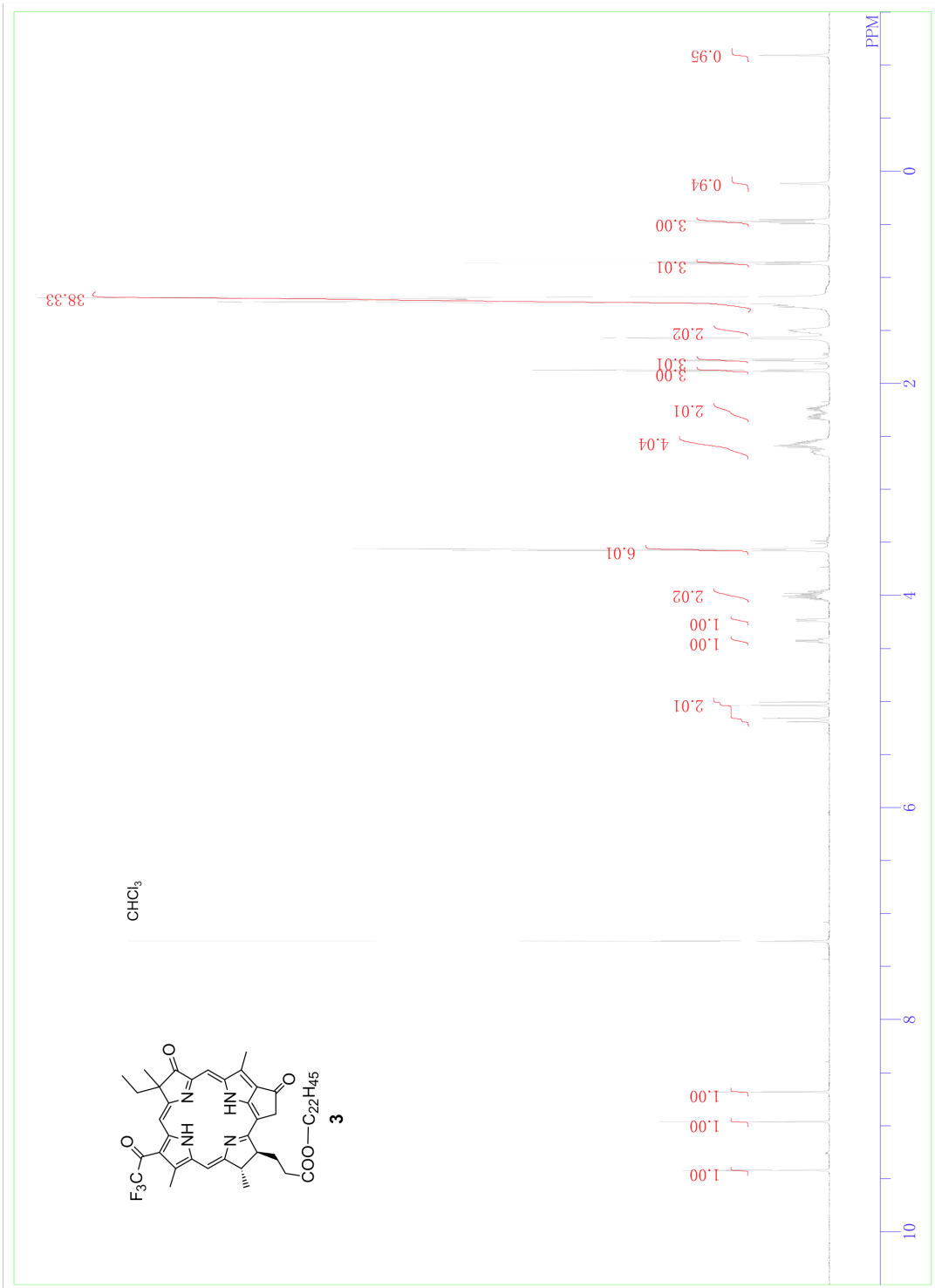


Figure S1. ^{1}H-NMR spectrum of bacteriochlorin **3** in $CDCl_3$.

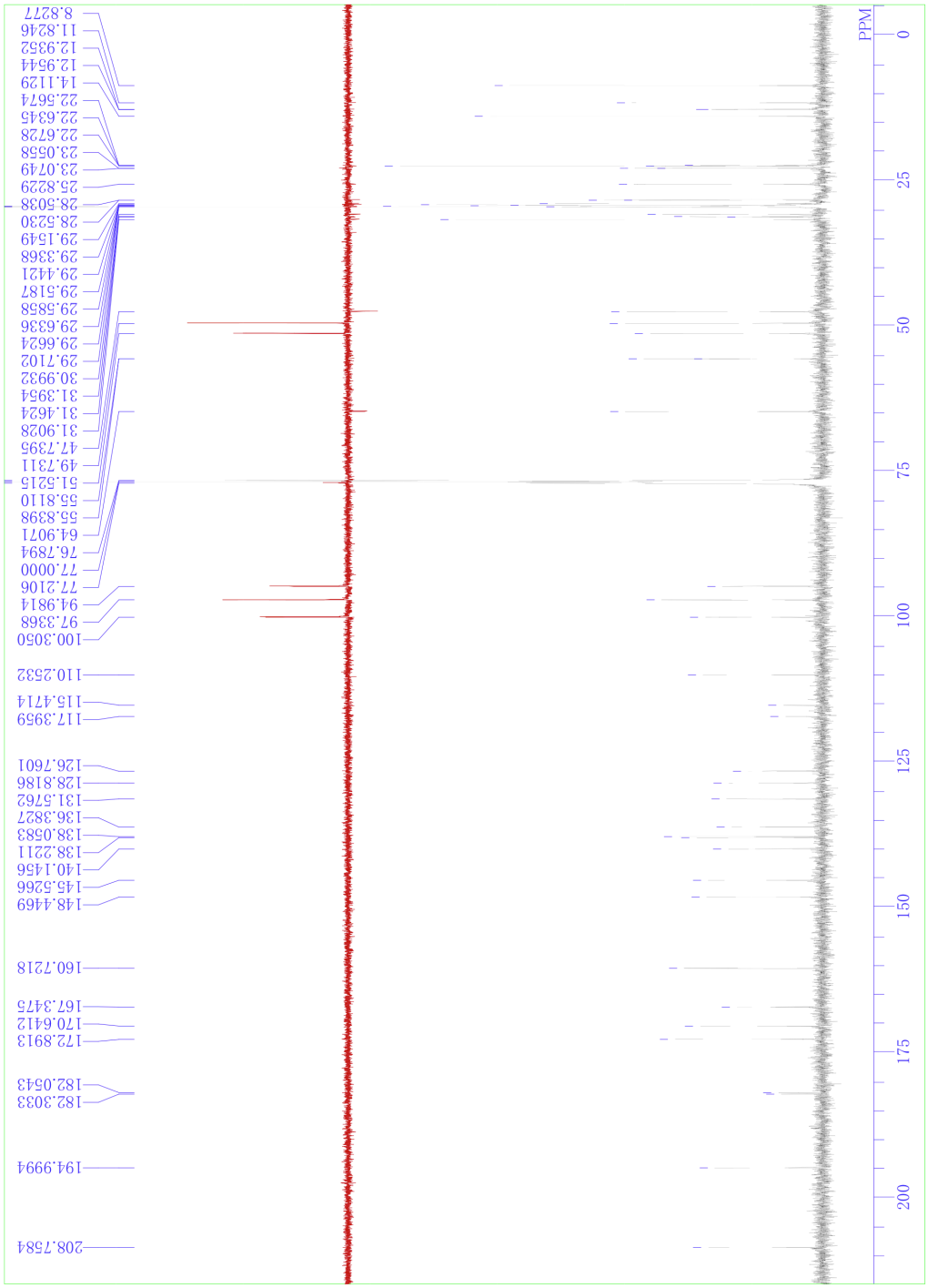


Figure S2. ^{13}C-NMR spectra of bacteriochlorin **3** in $CDCl_3$ (lower, black). Primary and tertiary carbon signals are shown upwards while secondary ones appear downwards in the DEPT spectrum (upper, red).

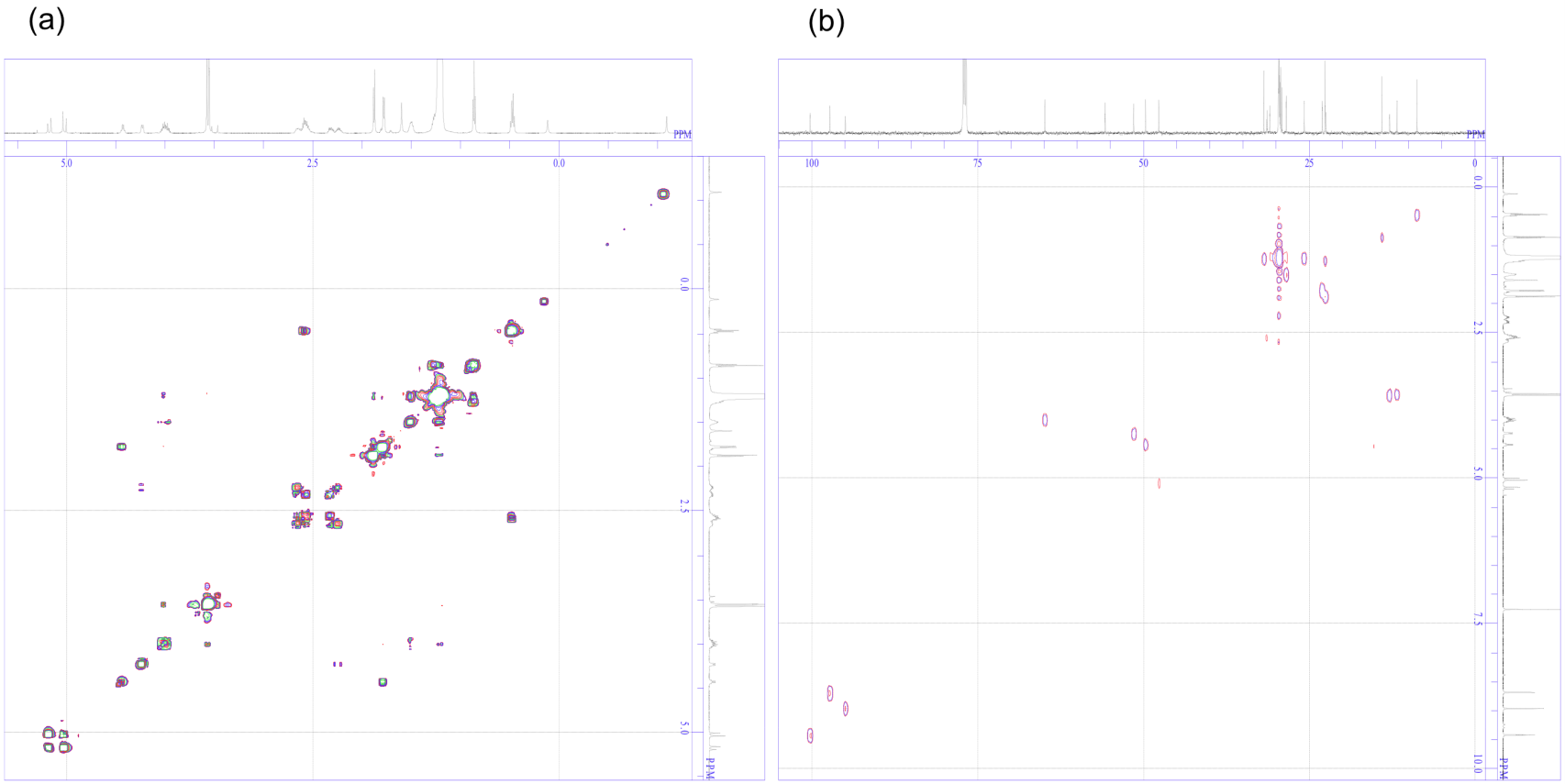


Figure S3. Selected region of (a) ^{1}H-^{1}H and (b) ^{1}H-^{13}C COSY spectra of bacteriochlorin **3** in $CDCl_3$.

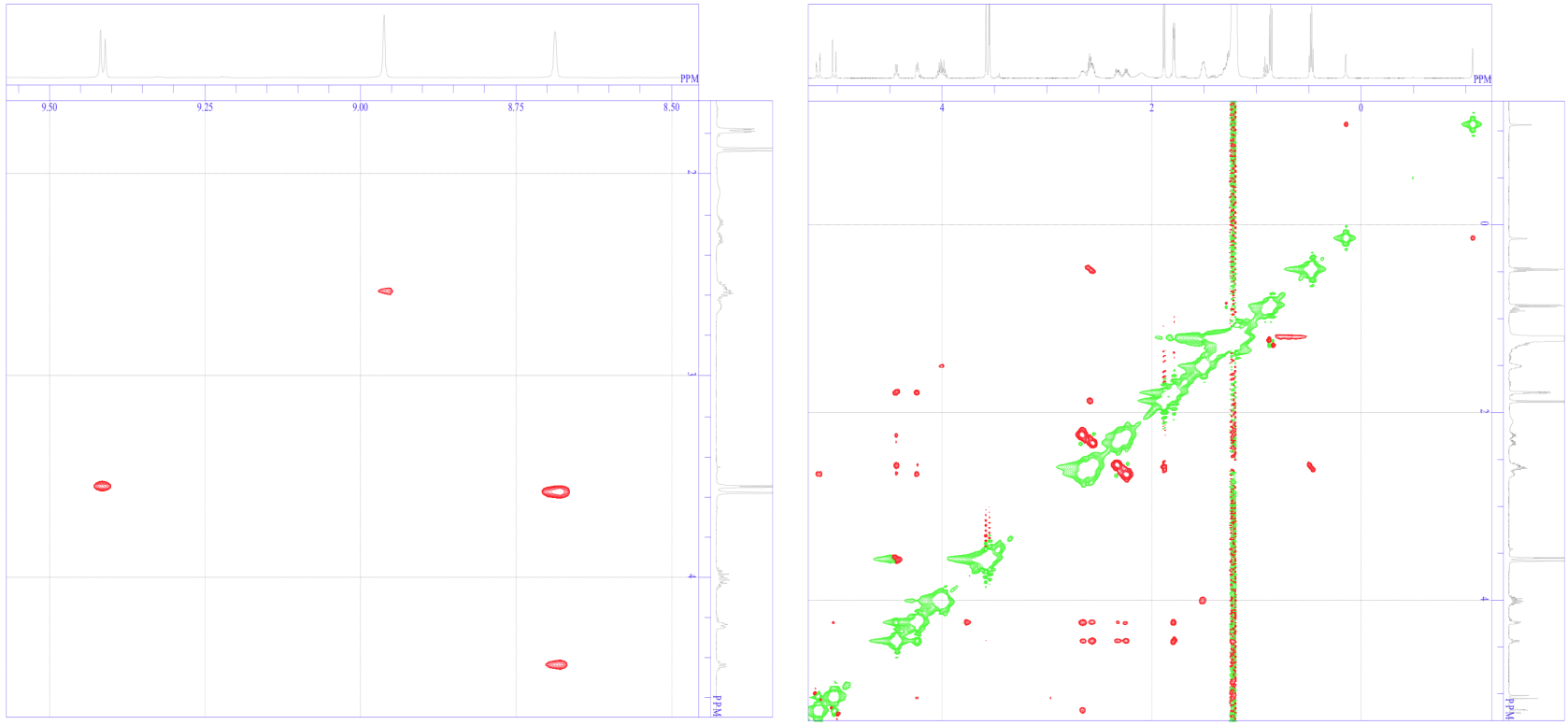


Figure S4. Selected region of ROESY spectra of bacteriochlorin **3** in $CDCl_3$.

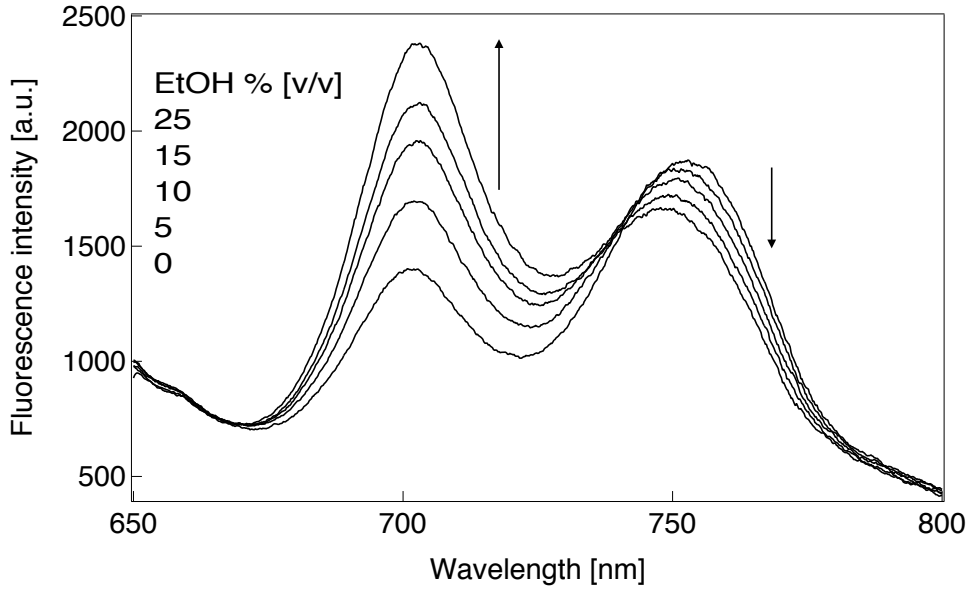


Figure S5a. Fluorescence emission spectra of an ethanol sensing membrane of composition M2 (35 mol% TDMACl) upon continuous flow (0.5 ml/min) exposure to phosphate-buffered (pH 6.8) aqueous ethanol solutions (exc. 631 nm).

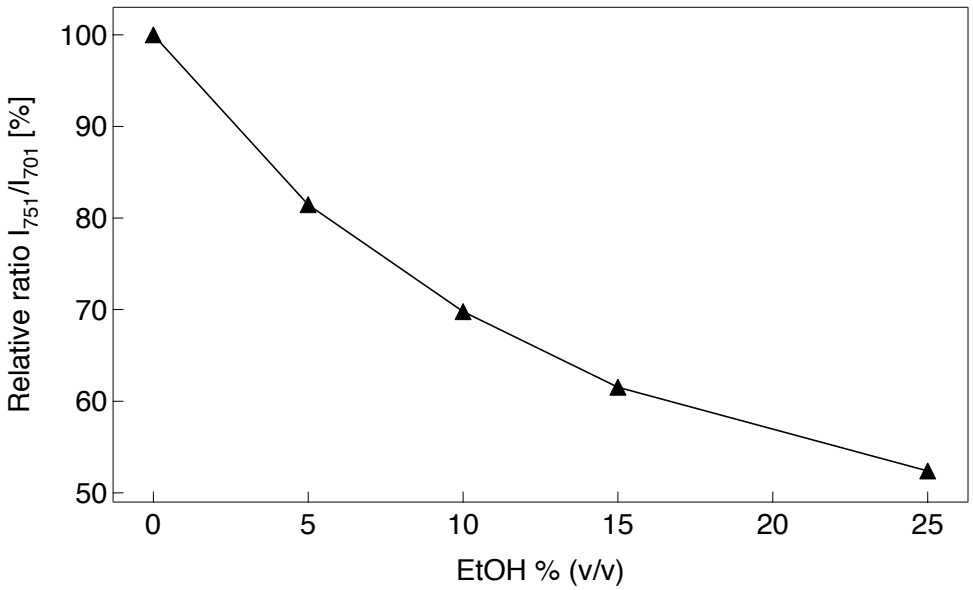


Figure S5b. Relative changes of the ratiometric emission signal ($I_{751\ nm}$ / $I_{701\ nm}$) for a membrane of composition M2 excited at 631 nm in response to aqueous ethanol solutions (phosphate buffer at pH 6.8); based on data from Fig. S5a.

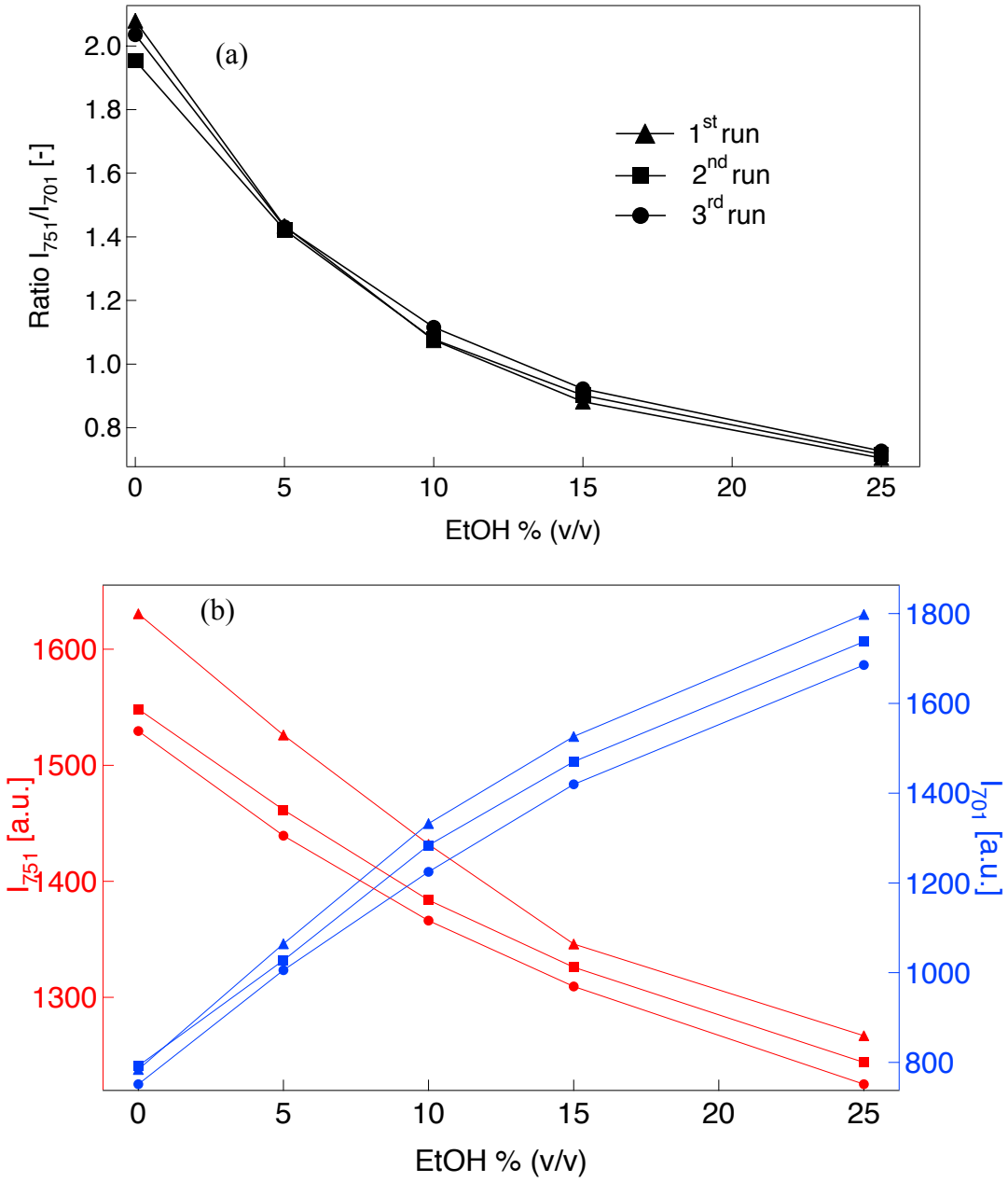


Figure S6. (a) Absolute changes in the ratiometric signal ($I_{751\ nm}$ / $I_{701\ nm}$), and (b) in the emission signal at 701 nm and at 751 nm for a membrane of composition M2 excited at 431 nm upon repeated and continuous exposure (0.5 ml/min flow) to aqueous ethanol solutions (phosphate buffer at pH 6.8): ▲ 1st run (0 – 190 min), ■ 2nd run (240 – 400 min), ● 3rd run (450 – 600 min); the sensor membrane was continuously flushed with ethanol-free buffer solution between the single runs.