Organocatalytic domino Michael strategy: construction of bispiro[oxindole-thiazolidinone-hexahydroxanthone]s with five contiguous stereocenters

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Supporting Information

Contents

1. General information

Commercially available compounds were used without further purification. Solvents were dried according to standard procedures. Column chromatography was performed with silica gel (200–300 mesh). Melting points were determined with an XT-4 melting-point apparatus and are uncorrected. ^{1}H NMR spectra were measured with Bruker Ascend 400 MHz spectrometer, chemical shifts were reported in δ (ppm) units relative to tetramethylsilane (TMS) as internal standard. ^{13}C NMR spectra were measured at 100 MHz with 400 MHz spectrometer, chemical shifts are reported in ppm relative to tetramethylsilane and referenced to solvent peak ($CDCl_3$, δ C = 77.00). High resolution mass spectra (Electron spray ionization) were measured with an Agilent 6520 Accurate-Mass Q-TOF MS system equipped with an electrospray ionization (ESI) source. Optical rotations were measured with a Krüss P8000 polarimeter. Optical rotations were measured with a polarimeter at the indicated concentration with the units of g/100 mL. Enantiomeric excesses were determined by chiral HPLC analysis using an Agilent 1200 LC instrument with a Daicel Chiralpak IB or IC column.

2. Materials

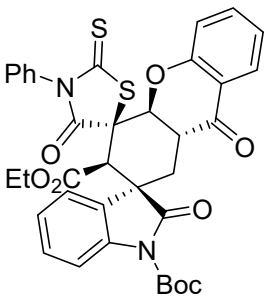
1a–**1k** were prepared according to literature reported by Liu and co-workers.[1] **2a**–**2n** were prepared according to the literature.[2] The chiral organocatalysts were prepared by following the reported procedures.[3]

3. Procedure for the synthesis of racemates of 3

To a dried small bottle were added **2** (0.05 mmol), Et_3N (1.0 mg, 0.01 mmol, 0.2 equiv) and DCE (0.5 mL). The mixture was stirred at room temperature for 5 min, and **1** (0.06 mmol) was then added. After stirring at room temperature for 48 h, the reaction mixture was concentrated and directly purified by silica gel column chromatography to afford the racemates of **3**.

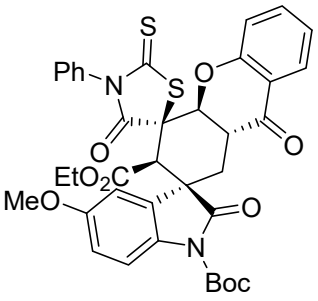
4. Procedure for the synthesis of chiral compounds 3

To a dried small bottle were added **2** (0.10 mmol), chiral organocatalyst **C6** (3.2 mg, 0.005 mmol, 0.05 equiv) and DCE (1.0 mL). The mixture was stirred at room temperature for 5 min, and **1** (0.12 mmol) was then added. After stirring at room temperature for 48 h, the reaction mixture was concentrated and directly purified by silica gel column chromatography to afford the desired products **3**.



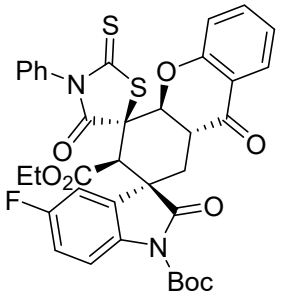
3a

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3a). From **1a** (47.0 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 62.3 mg (91% yield) compound **3a** as a white solid, m.p. 189–191 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/2-propanol = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 25.9 min (minor), t_R = 29.9 min (major); >99% ee. $[\alpha]_D^{25}$ = +17.1° (*c* = 2.15, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.0 Hz, 1H, ArH), 7.83 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.60–7.50 (m, 4H, ArH), 7.37–7.32 (m, 3H, ArH), 7.20–7.15 (m, 2H, ArH), 7.06 (t, J = 8.0 Hz, 1H, ArH), 6.95 (d, J = 8.0 Hz, 1H, ArH), 4.94 (d, J = 14.0 Hz, 1H, CH), 4.17 (s, 1H, CH), 4.09–3.97 (m, 2H, CH_2), 3.77–3.70 (m, 1H, CH), 2.63 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.80 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.0, 190.3, 177.3, 176.1, 166.8, 159.5, 148.9, 139.4, 136.5, 135.4, 130.8, 129.7, 129.6, 129.0, 128.0, 127.1, 124.7, 122.5, 121.0, 120.0, 117.7, 115.4, 84.9, 82.7, 65.6, 62.7, 53.1, 47.0, 39.6, 33.7, 28.1, 13.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{33}N_2O_8S_2$ $[M + H]^+$ 685.1673, found 685.1689.



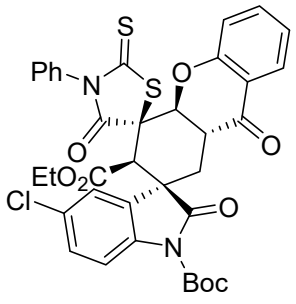
3d

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 5-methoxy-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3d). From **1d** (50.6 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 58.6 mg (82% yield) compound **3d** as a white solid, m.p. 192–194 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 19.8 min (minor), t_R = 22.5 min (major); 97% ee. $[\alpha]_D^{25}$ = +40.2° (*c* = 1.66, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.78 (d, *J* = 9.2 Hz, 1H, ArH), 7.60–7.56 (m, 2H, ArH), 7.54–7.50 (m, 2H, ArH), 7.33 (d, *J* = 7.2 Hz, 2H, ArH), 7.07 (t, *J* = 7.8 Hz, 1H, ArH), 6.95 (d, *J* = 8.0 Hz, 1H, ArH), 6.85 (dd, J_1 = 9.0 Hz, J_2 = 2.6 Hz, 1H, ArH), 6.73 (d, *J* =2.4 Hz, 1H, ArH), 4.94 (d, *J* = 14.0 Hz, 1H, CH), 4.13 (s, 1H, CH), 4.12–4.01 (m, 2H, CH_2), 3.80 (s, 3H, OCH_3), 3.76–3.69 (m, 1H, CH), 2.63 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.77 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 1.08 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.1, 190.4, 177.4, 176.1, 166.8, 159.5, 157.1, 148.9, 136.6, 135.4, 132.7, 132.1, 129.7, 129.6, 128.1, 127.1, 122.5, 120.0, 117.7, 116.4, 113.4, 107.7, 84.7, 82.7, 65.6, 62.8, 55.7, 53.1, 47.3, 39.6, 33.8, 28.1, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{37}H_{35}N_2O_9S_2$ $[M + H]^+$ 715.1786, found 715.1778.



3e

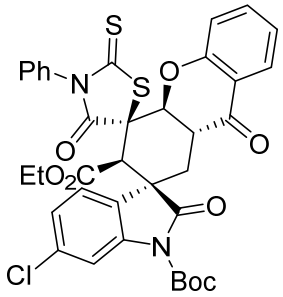
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 5-fluoro-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3e). From **1e** (49.1 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 60.4 mg (86% yield) compound **3e** as a white solid, m.p. 191−192 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 12.3 min (minor), t_R = 14.6 min (major); 94% ee. $[\alpha]_D^{25}$ = +11.3° (*c* = 2.10, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (dd, J_1 = 8.8 Hz, J_2 = 4.4 Hz, 1H, ArH), 7.82 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.59−7.55 (m, 2H, ArH), 7.51−7.45 (m, 2H, ArH), 7.30 (d, *J* = 7.2 Hz, 2H, ArH), 7.07−7.00 (m, 2H, ArH), 6.92 (dd, J_1 = 7.4 Hz, J_2 = 2.6 Hz, 1H, ArH), 6.87 (d, *J* = 8.4 Hz, 1H, ArH), 4.93 (d, *J* = 13.6 Hz, 1H, CH), 4.19 (s, 1H, CH), 4.15−4.02 (m, 2H, CH_2), 3.72−3.65 (m, 1H, CH), 2.56 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.74 (dd, J_1 = 15.0 Hz, J_2 = 11.8 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 1.10 (t, *J* = 7.0 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.8, 190.1, 177.4, 175.7, 166.8, 159.9 (d, $^1J_{C-F}$ = −243.0 Hz), 159.3, 148.8, 136.6, 135.3, 132.6 (d, $^3J_{C-F}$ = 7.5 Hz), 129.74, 129.67, 128.0, 127.1, 122.5, 119.8, 117.6, 121.0, 116.8 (d, $^3J_{C-F}$ = 7.7 Hz), 115.4 (d, $^2J_{C-F}$ = 22.5 Hz), 109.1 (d, $^2J_{C-F}$ = 24.7 Hz), 85.1, 82.5, 65.6, 62.9, 52.8, 47.4, 39.4, 33.4, 28.1, 13.6 ppm. ^{19}F NMR (376 MHz, $CDCl_3$): δ −116.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}FN_2O_8S_2$ $[M + H]^+$ 703.1579, found 703.1578.



3f

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 5-chloro-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3f). From **1f** (51.1 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 66.2 mg (92% yield) compound **3f** as a light yellow solid, m.p.

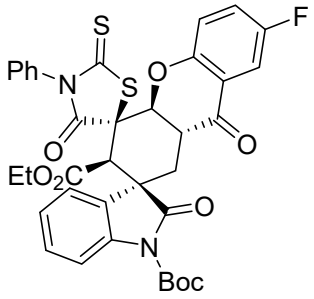
194–196 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 11.1 min (minor), t_R = 12.7 min (major); 93% ee. $[\alpha]_D^{25}$ = +40.9° (*c* = 2.33, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.84–7.81 (m, 2H, ArH), 7.60–7.56 (m, 2H, ArH), 7.52–7.46 (m, 2H, ArH), 7.33–7.30 (m, 3H, ArH), 7.17 (d, *J* = 2.0 Hz, 1H, ArH), 7.05 (t, *J* = 8.0 Hz, 1H, ArH), 6.89 (d, *J* = 8.0 Hz, 1H, ArH), 4.92 (d, *J* = 13.6 Hz, 1H, CH), 4.19 (s, 1H, CH), 4.15–4.02 (m, 2H, CH_2), 3.71–3.64 (m, 1H, CH), 2.57 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.74 (dd, J_1 = 15.0 Hz, J_2 = 11.8 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 1.10 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.8, 190.1, 177.3, 175.4, 166.7, 159.3, 148.7, 138.0, 136.6, 135.3, 132.6, 130.1, 129.73, 129.67, 129.0, 128.0, 127.1, 122.5, 121.7, 119.8, 117.6, 116.6, 85.2, 82.4, 65.6, 62.9, 52.9, 47.2, 39.4, 33.4, 28.0, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}ClN_2O_8S_2$ $[M + H]^+$ 719.1283, found 719.1298.



3g

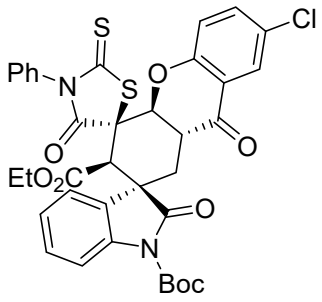
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 6-chloro-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3g). From **1g** (51.1 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 67.6 mg (94% yield) compound **3g** as a light yellow solid, m.p. 193–195 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 14.2 min (minor), t_R = 19.8 min (major); 86% ee. $[\alpha]_D^{25}$ = +14.3° (*c* = 2.35, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.95 (d, *J* = 2.0 Hz, 1H, ArH), 7.82 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.60–7.56 (m, 2H, ArH), 7.54–7.50 (m, 2H, ArH), 7.32 (d, *J* = 7.2 Hz, 2H, ArH), 7.16 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H, ArH), 7.12–7.05 (m, 2H, ArH), 6.95 (d, *J* = 8.4 Hz, 1H, ArH), 4.92 (d, *J* = 13.6 Hz, 1H, CH), 4.14 (s, 1H, CH), 4.11–4.02 (m, 2H, CH_2), 3.73–3.66 (m, 1H, CH), 2.61 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.77 (dd, J_1 = 15.0 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.09 (t, *J* = 7.2 Hz,

3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.7, 190.2, 177.2, 175.5, 166.7, 159.4, 148.6, 140.4, 136.6, 135.3, 134.8, 129.7, 129.6, 129.2, 128.0, 127.1, 124.7, 122.5, 122.0, 119.9, 117.7, 116.2, 85.4, 82.5, 65.5, 62.9, 53.0, 46.9, 39.5, 33.5, 28.0, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}ClN_2O_8S_2$ $[M + H]^+$ 719.1283, found 719.1285.



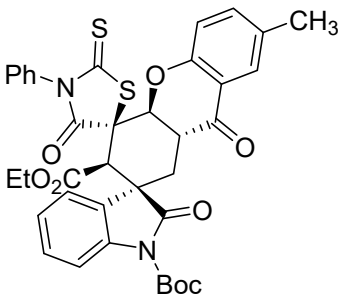
3h

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 7'-fluoro-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3h). From **1h** (49.1 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 66.1 mg (94% yield) compound **3h** as a light yellow solid, m.p. 185–187 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 14.1 min (minor), t_R = 24.1 min (major); 85% ee. $[\alpha]_D^{25}$ = +19.0° (*c* = 2.21, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.4 Hz, 1H, ArH), 7.60–7.56 (m, 2H, ArH), 7.54–7.51 (m, 1H, ArH), 7.48 (dd, J_1 = 8.0 Hz, J_2 = 3.2 Hz, 1H, ArH), 7.37–7.31 (m, 3H, ArH), 7.27–7.22 (m, 1H, ArH), 7.18 (d, *J* = 4.4 Hz, 2H, ArH), 6.95 (dd, J_1 = 9.2 Hz, J_2 = 4.0 Hz, 1H, ArH), 4.93 (d, *J* = 14.0 Hz, 1H, CH), 4.17 (s, 1H, CH), 4.09–3.99 (m, 2H, CH_2), 3.76–3.69 (m, 1H, CH), 2.62 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.79 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.8, 189.7, 177.2, 176.1, 166.8, 157.7 (d, $^1J_{C–F}$ = –242.5 Hz), 155.7, 148.8, 139.4, 135.3, 130.6, 129.7, 129.6, 129.1, 128.0, 124.8, 124.1 (d, $^2J_{C–F}$ = 24.5 Hz), 121.1, 120.4 (d, $^3J_{C–F}$ = 6.6 Hz), 119.5 (d, $^3J_{C–F}$ = 7.3 Hz), 115.4, 112.2 (d, $^2J_{C–F}$ = 23.4 Hz), 85.0, 82.9, 65.5, 62.8, 53.2, 47.0, 39.5, 33.6, 28.1, 13.5 ppm. ^{19}F NMR (376 MHz, $CDCl_3$): δ –119.4 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}FN_2O_8S_2$ $[M + H]^+$ 703.1579, found 703.1587.



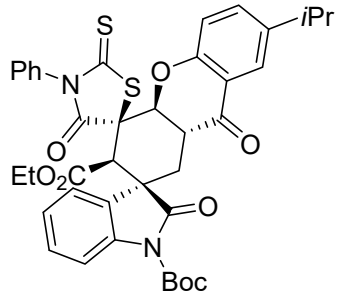
3i

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 7'-chloro-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3i). From **1i** (51.1 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 69.0 mg (96% yield) compound **3i** as a light yellow solid, m.p. 195–197 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 14.4 min (minor), t_R = 22.6 min (major); 81% ee. $[\alpha]_D^{25}$ = +24.8° (*c* = 2.37, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.0 Hz, 1H, ArH), 7.78 (d, *J* = 2.8 Hz, 1H, ArH), 7.59–7.55 (m, 2H, ArH), 7.53–7.49 (m, 1H, ArH), 7.45 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H, ArH), 7.37–7.30 (m, 3H, ArH), 7.17 (d, *J* = 4.4 Hz, 2H, ArH), 6.91 (d, *J* = 8.8 Hz, 1H, ArH), 4.94 (d, *J* = 14.0 Hz, 1H, CH), 4.17 (s, 1H, CH), 4.08–3.99 (m, 2H, CH_2), 3.76–3.69 (m, 1H, CH), 2.61 (dd, J_1 = 15.2 Hz, J_2 = 3.2 Hz, 1H, CH_2), 1.79 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.7, 189.3, 177.2, 176.1, 166.8, 157.9, 148.8, 139.4, 136.4, 135.3, 130.6, 129.7, 129.6, 129.1, 128.1, 128.0, 126.4, 124.8, 121.1, 120.7, 119.4, 115.4, 85.0, 82.8, 65.5, 62.8, 53.2, 47.0, 39.5, 33.5, 28.1, 13.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}ClN_2O_8S_2$ $[M + H]^+$ 719.1283, found 719.1300.



3j

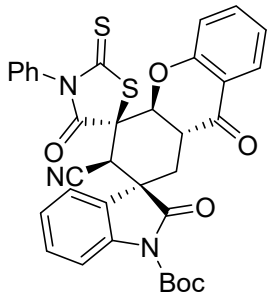
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 7'-methyl-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3j). From **1j** (48.6 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 65.0 mg (93% yield) compound **3j** as a light yellow solid, m.p. 184–186 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 15.7 min (minor), t_R = 21.2 min (major); 87% ee. $[\alpha]_D^{25}$ = +21.7° (*c* = 2.09, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.4 Hz, 1H, ArH), 7.62–7.56 (m, 3H, ArH), 7.54–7.51 (m, 1H, ArH), 7.36–7.31 (m, 4H, ArH), 7.20–7.17 (m, 2H, ArH), 6.85 (d, *J* = 8.4 Hz, 1H, ArH), 4.90 (d, *J* = 13.6 Hz, 1H, CH), 4.16 (s, 1H, CH), 4.09–3.98 (m, 2H, CH_2), 3.74–3.67 (m, 1H, CH), 2.63 (dd, J_1 = 15.2 Hz, J_2 = 3.2 Hz, 1H, CH_2), 2.30 (s, 3H, CH_3), 1.78 (dd, J_1 = 15.2 Hz, J_2 = 11.6 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.1, 190.6, 177.3, 176.1, 166.9, 157.6, 148.9, 139.4, 137.6, 135.4, 132.0, 130.8, 129.7, 129.6, 129.0, 128.1, 126.7, 124.7, 121.0, 119.6, 117.5, 115.4, 84.9, 82.7, 65.6, 62.7, 53.1, 47.1, 39.6, 33.8, 28.1, 20.4, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{37}H_{35}N_2O_8S_2$ $[M + H]^+$ 699.1829, found 699.1837.



3k

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 7'-isopropyl-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3k). From **1k** (52.0 mg, 0.12 mmol) and **2a** (29.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 71.0 mg (98% yield) compound **3k** as a light yellow solid, m.p. 200–202 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 8.5 min (minor), t_R = 14.0 min

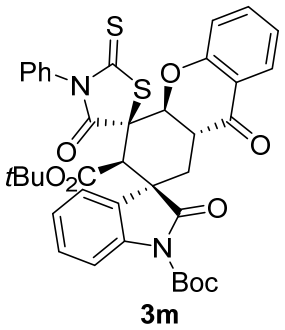
(major); 88% ee. $[\alpha]_D^{25}$ = +24.4° (*c* = 2.45, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.0 Hz, 1H, ArH), 7.69 (d, *J* = 2.4 Hz, 1H, ArH), 7.60–7.56 (m, 2H, ArH), 7.54–7.50 (m, 1H, ArH), 7.41 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H, ArH), 7.37–7.32 (m, 3H, ArH), 7.19–7.18 (m, 2H, ArH), 6.91 (d, *J* = 8.8 Hz, 1H, ArH), 4.91 (d, *J* = 13.6 Hz, 1H, CH), 4.16 (s, 1H, CH), 4.10–3.98 (m, 2H, CH_2), 3.75–3.68 (m, 1H, CH), 2.92–2.85 (m, 1H, CH), 2.65 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.78 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.22 (d, *J* = 6.8 Hz, 6H, CH_3), 1.06 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.1, 190.6, 177.3, 176.1, 166.9, 157.8, 148.9, 143.1, 139.4, 135.4, 135.3, 130.8, 129.7, 129.5, 129.0, 128.1, 124.7, 124.1, 121.0, 119.7 117.6, 115.4, 84.9, 82.7, 65.6, 62.7, 53.1, 47.1, 39.6, 33.8, 33.3, 28.1, 23.81, 23.77, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{39}H_{39}N_2O_8S_2$ $[M + H]^+$ 727.2142, found 727.2157.



3l

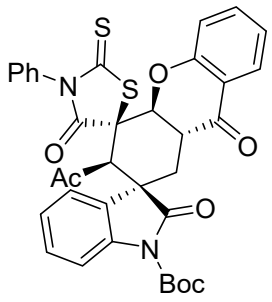
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-*tert*-Butyl 3'-cyano-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1-carboxylate (3l). From **1a** (47.0 mg, 0.12 mmol) and **2b** (24.6 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 52.3 mg (82% yield) compound **3l** as a light yellow solid, m.p. 247–249 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 12.8 min (minor), t_R = 25.2 min (major); 92% ee. $[\alpha]_D^{25}$ = +36.9° (*c* = 0.85, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.93 (d, *J* = 8.0 Hz, 1H, ArH), 7.86 (dd, J_1 = 7.8 Hz, J_2 = 1.4 Hz, 1H, ArH), 7.59–7.53 (m, 4H, ArH), 7.48–7.43 (m, 1H, ArH), 7.30–7.25 (m, 4H, ArH), 7.11 (t, *J* = 8.0 Hz, 1H, ArH), 6.99 (d, *J* = 8.0 Hz, 1H, ArH), 4.89 (d, *J* = 13.6 Hz, 1H, CH), 4.03 (s, 1H, CH), 3.94–3.87 (m, 1H, CH), 2.78 (dd, J_1 = 15.4 Hz, J_2 = 3.8 Hz, 1H, CH_2), 1.90 (dd, J_1 = 15.4 Hz, J_2 = 11.8 Hz, 1H, CH_2), 1.68 (s, 9H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 199.8, 189.8, 175.6, 173.7, 159.2, 148.2, 139.5, 136.9, 134.8, 130.8, 130.1, 129.8,

128.2, 127.3, 126.8, 125.7, 122.9, 122.1, 120.0, 117.8, 116.1, 113.2, 85.9, 81.4, 65.4, 47.9, 42.3, 40.0, 32.3, 28.1 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{34}H_{28}N_3O_6S_2$ $[M + H]^+$ 638.1414, found 638.1420.



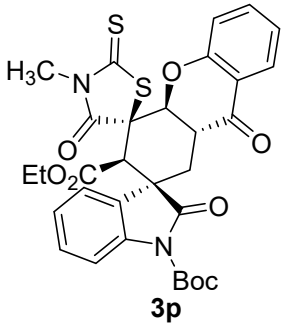
3m

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-Di-*tert*-butyl 2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3m). From **1a** (47.0 mg, 0.12 mmol) and **2c** (32.1 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 70.1 mg (98% yield) compound **3m** as a light yellow solid, m.p. 154–156 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 11.1 min (minor), t_R = 15.5 min (major); 86% ee. $[\alpha]_D^{25}$ = +13.6° (*c* = 2.59, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, J = 8.0 Hz, 1H, ArH), 7.84 (dd, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 1H, ArH), 7.59–7.49 (m, 4H, ArH), 7.38–7.33 (m, 3H, ArH), 7.21–7.17 (m, 2H, ArH), 7.06 (t, J = 7.6 Hz, 1H, ArH), 6.97 (d, J = 8.4 Hz, 1H, ArH), 4.97 (d, J = 14.0 Hz, 1H, CH), 4.03 (s, 1H, CH), 3.79–3.72 (m, 1H, CH), 2.63 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.78 (dd, J_1 = 15.0 Hz, J_2 = 11.8 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 1.17 (s, 9H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.2, 190.6, 177.4, 175.7, 165.9, 159.6, 149.0, 139.3, 136.5, 135.6, 130.8, 129.6, 129.5, 129.0, 128.2, 127.1, 124.8, 122.4, 121.1, 120.0, 117.8, 115.2, 85.0, 84.8, 82.4, 66.0, 54.3, 46.9, 39.8, 33.7, 28.1, 27.2 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{38}H_{37}N_2O_8S_2$ $[M + H]^+$ 713.1986, found 713.1992.



3n

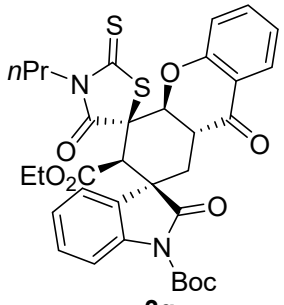
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-*tert*-Butyl 3'-acetyl-2,4'',9'-trioxo-3''-phenyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1-carboxylate (3n). From **1a** (47.0 mg, 0.12 mmol) and **2d** (26.2 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 53.7 mg (82% yield) compound **3n** as a light yellow solid, m.p. 198–199 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 18.7 min (minor), t_R = 24.5 min (major); 99% ee. $[\alpha]_D^{25}$ = +22.5° (*c* = 1.38, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89–7.84 (m, 2H, ArH), 7.62–7.53 (m, 4H, ArH), 7.36–7.32 (m, 1H, ArH), 7.27–7.25 (m, 2H, ArH), 7.19–7.15 (m, 2H, ArH), 7.09 (t, *J* = 8.0 Hz, 1H, ArH), 6.98 (d, *J* = 8.0 Hz, 1H, ArH), 4.96 (d, *J* = 14.0 Hz, 1H, CH), 4.21 (s, 1H, CH), 3.84–3.78 (m, 1H, CH), 2.61 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 2.00 (s, 3H, CH_3), 1.80 (dd, J_1 = 15.2 Hz, J_2 = 11.6 Hz, 1H, CH_2), 1.68 (s, 9H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.4, 200.3, 190.4, 177.7, 176.3, 159.4, 148.9, 139.5, 136.6, 135.1, 130.2, 130.0, 129.8, 129.3, 128.0, 127.2, 124.7, 122.6, 120.8, 120.0, 117.7, 115.8, 84.9, 83.5, 64.9, 60.0, 46.8, 39.7, 33.5, 29.9, 28.1 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{35}H_{30}N_2O_7S_2Na$ $[M + Na]^+$ 677.1387, found 677.1398.



3p

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-methyl-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylat

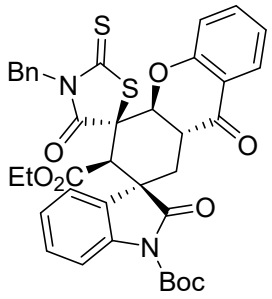
e (3p). From **1a** (47.0 mg, 0.12 mmol) and **2f** (23.1 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 58.2 mg (93% yield) compound **3p** as a white solid, m.p. 150–152 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 10.2 min (minor), t_R = 13.7 min (major); 95% ee. $[\alpha]_D^{25}$ = –27.1° (*c* = 2.44, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, *J* = 8.0 Hz, 1H, ArH), 7.81 (dd, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 1H, ArH), 7.50–7.46 (m, 1H, ArH), 7.36–7.32 (m, 1H, ArH), 7.20–7.15 (m, 2H, ArH), 7.04 (t, *J* = 8.0 Hz, 1H, ArH), 6.86 (d, *J* = 7.6 Hz, 1H, ArH), 4.87 (d, *J* = 13.6 Hz, 1H, CH), 4.09 (s, 1H, CH), 4.04–3.96 (m, 1H, CH_2), 3.86–3.78 (m, 1H, CH_2), 3.71–3.63 (m, 1H, CH), 3.53 (s, 3H, CH_3), 2.62 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.78 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 0.98 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.1, 190.4, 177.6, 176.1, 166.5, 159.4, 148.8, 139.5, 136.4, 130.7, 129.0, 127.0, 124.7, 122.4, 121.0, 119.9, 117.9, 115.5, 84.8, 82.2, 65.1, 62.4, 53.2, 47.0, 39.6, 33.6, 31.6, 28.1, 13.4 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{31}H_{31}N_2O_8S_2$ $[M + H]^+$ 623.1516, found 623.1538.



3q

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 2,4'',9'-trioxo-3''-propyl-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3q). From **1a** (47.0 mg, 0.12 mmol) and **2g** (25.9 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 61.2 mg (94% yield) compound **3q** as a white solid, m.p. 147–149 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 7.5 min (minor), t_R = 11.2 min (major); 92% ee. $[\alpha]_D^{25}$ = –37.4° (*c* = 2.54, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, *J* = 8.4 Hz, 1H, ArH), 7.82 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.50–7.46 (m, 1H, ArH), 7.36–7.31 (m, 1H, ArH), 7.20–7.15 (m, 2H, ArH),

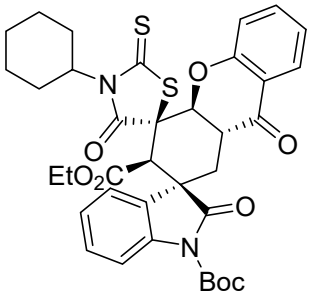
7.05 (t, J = 8.0 Hz, 1H, ArH), 6.82 (d, J = 8.4 Hz, 1H, ArH), 4.87 (d, J = 14.0 Hz, 1H, CH), 4.24–4.17 (m, 1H, CH_2), 4.08 (s, 1H, CH), 4.02–3.96 (m, 2H, CH_2), 3.88–3.80 (m, 1H, CH_2), 3.71–3.63 (m, 1H, CH), 2.62 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 1.86–1.74 (m, 3H, CH_2), 1.66 (s, 9H, CH_3), 1.06 (t, J = 7.4 Hz, 3H, CH_3), 0.98 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.2, 190.5, 177.6, 176.1, 166.6, 159.5, 148.8, 139.5, 136.5, 130.7, 129.0, 127.1, 124.6, 122.3, 121.0, 119.9, 117.6, 115.4, 84.8, 82.4, 64.5, 62.5, 53.1, 47.0, 46.4, 39.5, 33.6, 28.1, 20.2, 13.4, 11.3 ppm. HRMS (ESI): m/z calcd. for $C_{33}H_{35}N_2O_8S_2$ $[M + H]^+$ 651.1829, found 651.1814.



3r

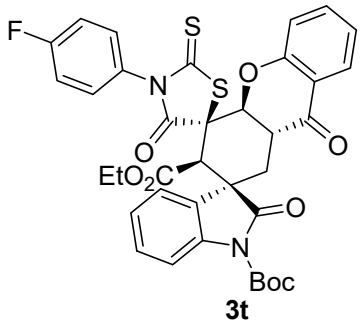
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-benzyl-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3r). From **1a** (47.0 mg, 0.12 mmol) and **2h** (30.7 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 61.9 mg (89% yield) compound **3r** as a white solid, m.p. 161–162 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 9.5 min (minor), t_R = 21.4 min (major); 93% ee. $[\alpha]_D^{25}$ = –39.2° (c = 2.36, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, J = 8.4 Hz, 1H, ArH), 7.78 (dd, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 1H, ArH), 7.57 (dd, J_1 = 7.8 Hz, J_2 = 1.8 Hz, 2H, ArH), 7.43–7.39 (m, 1H, ArH), 7.38–7.31 (m, 4H, ArH), 7.17 (d, J = 4.4 Hz, 2H, ArH), 7.01 (t, J = 8.0 Hz, 1H, ArH), 6.50 (d, J = 8.4 Hz, 1H, ArH), 5.43 (d, J = 14.4 Hz, 1H, CH_2), 5.19 (d, J = 14.0 Hz, 1H, CH_2), 4.85 (d, J = 13.6 Hz, 1H, CH), 4.09 (s, 1H, CH), 3.96–3.88 (m, 1H, CH), 3.72–3.61 (m, 2H, CH_2), 2.61 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.75 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.65 (s, 9H, CH_3), 0.92 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.7, 190.4, 177.7, 176.2, 166.5, 159.4, 148.8, 139.5, 136.3, 134.8, 130.8, 129.1, 129.0, 128.4, 128.1, 127.0, 124.7, 122.3, 121.0, 119.9, 117.7, 115.5, 84.8, 82.4, 64.7, 62.5, 53.0, 47.9, 47.0,

39.5, 33.6, 28.1, 13.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{37}H_{35}N_2O_8S_2$ $[M + H]^+$ 699.1829, found 699.1809.



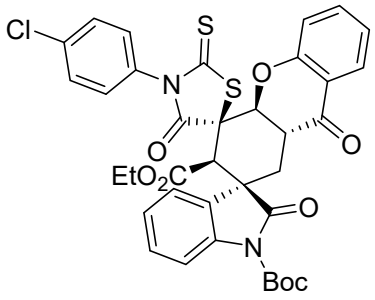
3s

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-cyclohexyl-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3s). From **1a** (47.0 mg, 0.12 mmol) and **2i** (29.9 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 62.9 mg (91% yield) compound **3s** as a light yellow solid, m.p. 181–183 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 10.0 min (minor), t_R = 16.9 min (major); 94% ee. $[\alpha]_D^{25}$ = –6.7° (*c* = 1.70, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, *J* = 8.0 Hz, 1H, ArH), 7.81 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.50–7.46 (m, 1H, ArH), 7.35–7.31 (m, 1H, ArH), 7.17 (d, *J* = 4.4 Hz, 2H, ArH), 7.04 (t, *J* = 7.6 Hz, 1H, ArH), 6.83 (d, *J* = 8.0 Hz, 1H, ArH), 5.06 (t, *J* = 12.2 Hz, 1H, CH), 4.79 (d, *J* = 13.6 Hz, 1H, CH), 4.05–3.97 (m, 2H, CH + CH_2), 3.93–3.85 (m, 1H, CH_2), 3.68–3.61 (m, 1H, CH), 2.60 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 2.44–2.35 (m, 2H, CH_2), 1.91 (t, *J* = 10.8 Hz, 2H, CH_2), 1.80–1.71 (m, 3H, CH_2), 1.66 (s, 9H, CH_3), 1.50–1.22 (m, 4H, CH_2), 1.00 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 203.2, 190.6, 177.6, 176.1, 166.7, 159.6, 148.9, 139.5, 136.5, 130.9, 129.0, 127.1, 124.6, 122.3, 120.9, 119.9, 117.7, 115.4, 84.8, 82.8, 62.5, 62.3, 58.3, 52.8, 47.0, 39.5, 33.7, 28.1, 27.6, 27.4, 26.0, 25.9, 25.1, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{39}N_2O_8S_2$ $[M + H]^+$ 691.2142, found 691.2117.



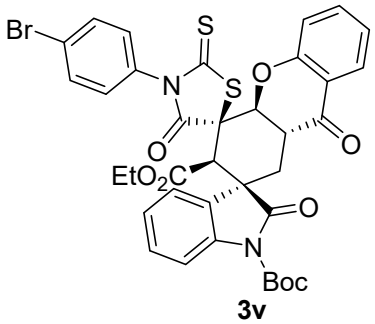
3t

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-(4-fluorophenyl)-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3t). From **1a** (47.0 mg, 0.12 mmol) and **2j** (31.1 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 68.9 mg (98% yield) compound **3t** as a light yellow solid, m.p. 179–181 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 14.9 min (minor), t_R = 12.7 min (major); 92% ee. $[\alpha]_D^{25}$ = +17.3° (*c* = 2.88, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8.0 Hz, 1H, ArH), 7.84 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.55–7.50 (m, 1H, ArH), 7.37–7.30 (m, 3H, ArH), 7.27–7.23 (m, 2H, ArH), 7.20–7.16 (m, 2H, ArH), 7.07 (t, *J* = 8.0 Hz, 1H, ArH), 6.94 (d, *J* = 8.0 Hz, 1H, ArH), 4.94 (d, *J* = 13.6 Hz, 1H, CH), 4.15 (s, 1H, CH), 4.06–3.97 (m, 2H, CH_2), 3.76–3.69 (m, 1H, CH), 2.64 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.80 (dd, J_1 = 15.2 Hz, J_2 = 11.6 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.03 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.9, 190.3, 177.3, 176.1, 166.8, 162.9 (d, $^1J_{C–F}$ = –248.5 Hz), 159.4, 148.8, 139.4, 136.6, 131.1 (d, $^4J_{C–F}$ = 3.2 Hz), 130.7, 130.0 (d, $^3J_{C–F}$ = 9.0 Hz), 129.1, 127.2, 124.8, 122.5, 121.0, 120.0, 117.7, 116.7 (d, $^2J_{C–F}$ = 23.0 Hz), 115.4, 84.9, 82.6, 65.6, 62.8, 53.2, 47.0, 39.6, 33.7, 28.1, 13.5 ppm. ^{19}F NMR (376 MHz, $CDCl_3$): δ –110.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}FN_2O_8S_2$ $[M + H]^+$ 703.1579, found 703.1587.



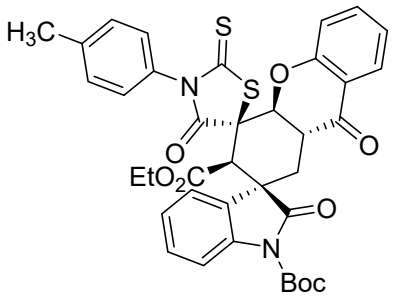
3u

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-(4-chlorophenyl)-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3u). From **1a** (47.0 mg, 0.12 mmol) and **2k** (32.8 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 60.9 mg (85% yield) compound **3u** as a light yellow solid, m.p. 177–179 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 9.6 min (minor), t_R = 18.0 min (major); 94% ee. $[\alpha]_D^{25}$ = +8.6° (*c* = 2.59, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87–7.82 (m, 2H, ArH), 7.55–7.50 (m, 3H, ArH), 7.37–7.33 (m, 1H, ArH), 7.30–7.26 (m, 2H, ArH), 7.20–7.16 (m, 2H, ArH), 7.07 (t, *J* = 8.0 Hz, 1H, ArH), 6.94 (d, *J* = 8.0 Hz, 1H, ArH), 4.93 (d, *J* = 13.6 Hz, 1H, CH), 4.15 (s, 1H, CH), 4.06–3.97 (m, 2H, CH_2), 3.76–3.69 (m, 1H, CH), 2.64 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.80 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.02 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.7, 190.2, 177.1, 176.1, 166.8, 159.4, 148.8, 139.4, 136.6, 135.7, 133.7, 130.7, 129.9, 129.5, 129.1, 127.2, 124.8, 122.6, 121.0, 120.0, 117.7, 115.4, 84.9, 82.6, 65.7, 62.8, 53.2, 47.0, 39.6, 33.7, 28.1, 13.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}ClN_2O_8S_2$ $[M + H]^+$ 719.1283, found 719.1291.



3v

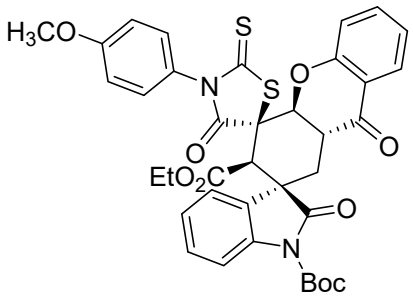
(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-(4-bromophenyl)-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3v). From **1a** (47.0 mg, 0.12 mmol) and **2k** (37.2 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 68.0 mg (89% yield) compound **3v** as a light yellow solid, m.p. 201–203 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 10.0 min (minor), t_R = 18.1 min (major); 94% ee. $[\alpha]_D^{25}$ = +4.9° (*c* = 1.90, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87–7.83 (m, 2H, ArH), 7.72–7.68 (m, 2H, ArH), 7.55–7.51 (m, 1H, ArH), 7.37–7.33 (m, 1H, ArH), 7.24–7.18 (m, 4H, ArH), 7.08 (t, *J* = 8.0 Hz, 1H, ArH), 6.94 (d, *J* = 8.0 Hz, 1H, ArH), 4.93 (d, *J* = 14.0 Hz, 1H, CH), 4.14 (s, 1H, CH), 4.06–3.97 (m, 2H, CH_2), 3.76–3.69 (m, 1H, CH), 2.65 (dd, J_1 = 15.2 Hz, J_2 = 3.2 Hz, 1H, CH_2), 1.80 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.02 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 201.6, 190.2, 177.1, 176.1, 166.8, 159.4, 148.8, 139.4, 136.6, 134.3, 132.9, 130.7, 129.8, 129.1, 127.2, 124.8, 123.9, 122.6, 121.0, 120.0, 117.7, 115.4, 85.0, 82.6, 65.8, 62.8, 53.2, 47.0, 39.6, 33.8, 28.1, 13.5 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}{}^{79}BrN_2O_8S_2$ $[M + H]^+$ 763.0778, found 763.0790; calcd. for $C_{36}H_{32}{}^{81}BrN_2O_8S_2$ $[M + H]^+$ 765.0758, found 765.0733.



3w

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 2,4'',9'-trioxo-2''-thioxo-3''-(p-tolyl)-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1,3'-dicarboxylate (3w). From **1a** (47.0 mg, 0.12 mmol) and **2l** (30.7 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 65.0 mg (93% yield) compound **3w** as a light yellow solid, m.p. 192–194 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 14.4 min (minor), t_R = 17.8 min (major); 95% ee. $[\alpha]_D^{25}$ = +8.0° (*c* = 2.54,

CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.4 Hz, 1H, ArH), 7.83 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.54–7.50 (m, 1H, ArH), 7.39–7.32 (m, 3H, ArH), 7.22–7.17 (m, 4H, ArH), 7.06 (t, J = 8.0 Hz, 1H, ArH), 6.95 (d, J = 8.0 Hz, 1H, ArH), 4.93 (d, J = 14.0 Hz, 1H, CH), 4.16 (s, 1H, CH), 4.09–3.98 (m, 2H, CH_2), 3.77–3.70 (m, 1H, CH), 2.64 (dd, J_1 = 15.2 Hz, J_2 = 3.6 Hz, 1H, CH_2), 2.43 (s, 3H, CH_3), 1.79 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.2, 190.4, 177.3, 176.1, 166.8, 159.5, 148.9, 139.8, 139.4, 136.5, 132.7, 130.8, 130.3, 129.0, 127.7, 127.1, 124.7, 122.5, 121.0, 120.0, 117.7, 115.4, 84.9, 82.7, 65.5, 62.7, 53.1, 47.0, 39.6, 33.7, 28.1, 21.4, 13.6 ppm. HRMS (ESI): m/z calcd. for $C_{37}H_{35}N_2O_8S_2$ $[M + H]^+$ 699.1829, found 699.1830.

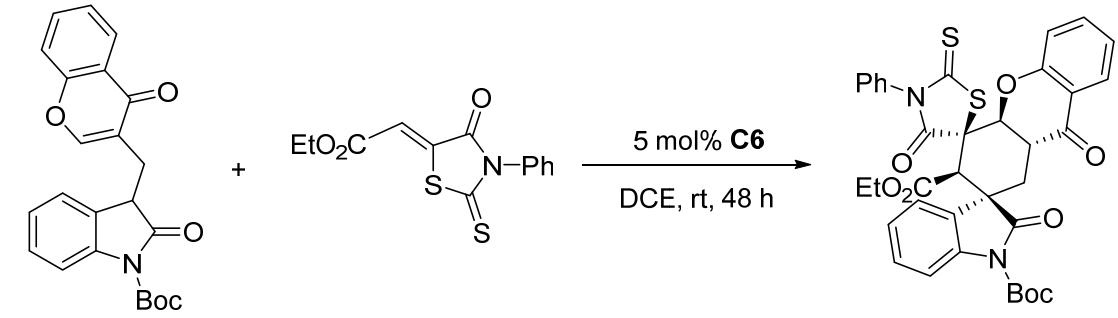


3x

(3*R*,3'*S*,4'*R*,4a'*S*,9a'*R*)-1-(*tert*-Butyl) 3'-ethyl 3''-(4-methoxyphenyl)-2,4'',9'-trioxo-2''-thioxo-4a',9a'-dihydro-1'*H*,3'*H*,9'*H*-dispiro[indoline-3,2'-xanthene-4',5''-thiazolidine]-1, 3'-dicarboxylate (3x). From **1a** (47.0 mg, 0.12 mmol) and **2m** (32.3 mg, 0.10 mmol), purified by silica gel (200-300 mesh) column chromatography using dichloromethane/petroleum ether (1/2) as eluent to obtain 66.1 mg (92% yield) compound **3x** as a light yellow solid, m.p. 196–198 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 41.0 min (minor), t_R = 29.2 min (major); 94% ee. $[\alpha]_D^{25}$ = +4.5° (c = 2.33, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, J = 8.0 Hz, 1H, ArH), 7.83 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.54–7.50 (m, 1H, ArH), 7.37–7.33 (m, 1H, ArH), 7.26–7.23 (m, 2H, ArH), 7.20–7.18 (m, 2H, ArH), 7.08–7.05 (m, 3H, ArH), 6.94 (d, J = 8.4 Hz, 1H, ArH), 4.93 (d, J = 13.6 Hz, 1H, CH), 4.16 (s, 1H, CH), 4.08–3.97 (m, 2H, CH_2), 3.86 (s, 3H, OCH_3), 3.77–3.70 (m, 1H, CH), 2.64 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.79 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, J = 7.0 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.4, 190.4, 177.4, 176.1,

166.8, 160.2, 159.5, 148.9, 139.4, 136.5, 130.8, 129.1, 129.0, 127.8, 127.1, 124.7, 122.5, 121.0, 120.0, 117.7, 115.4, 114.8, 84.9, 82.7, 65.4, 62.7, 55.5, 53.1, 47.0, 39.6, 33.7, 28.1, 13.6 ppm. HRMS (ESI): *m/z* calcd. for $C_{37}H_{35}N_2O_9S_2$ $[M + H]^+$ 715.1778, found 715.1779.

5. Gram-scale synthesis of 3a



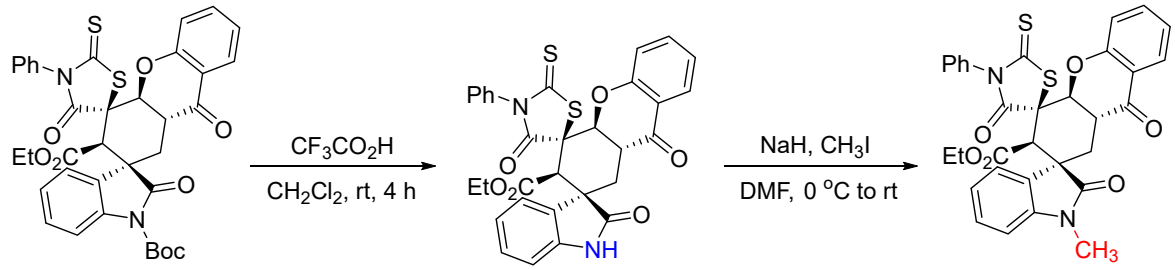
1a
2.4 mmol, 782.8 mg

2a
2.0 mmol, 586.8 mg

3a
1.86 mmol, 1.2737 g
>20:1 *dr*, 95% *ee*

Rhodamine derivative **2a** (586.8 mg, 2.0 mmol) and catalyst **C6** (64.0 mg, 5 mol %) were dissolved in dry DCE (20 mL) at room temperature for 15 min. Then, oxindole-chromone **1a** (782.8 mg, 2.4 mmol) was added. After stirring at room temperature for 48 h, the reaction mixture was concentrated and directly purified by silica gel column chromatography (petroleum ether/CH_2Cl_2, 2:1) to afford the desired product **3a** as a white solid (1.2737 g, 93% yield) with >20:1 dr and 95% ee.

6. Procedure and the characterization data of compounds 3b and 3c



3a, >20:1 *dr*, 95% *ee*

3b, 95% yield

3c, 88% yield
>20:1 *dr*, 93% *ee*

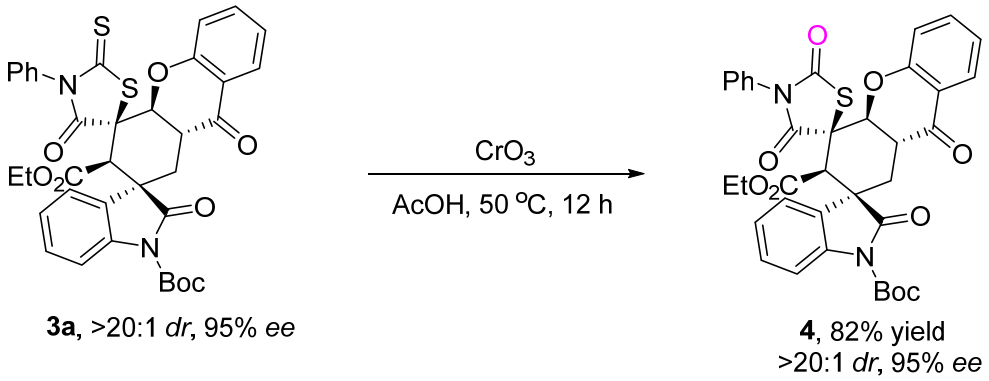
Compound **3a** (165.5 mg, 0.24 mmol) was dissolved in dry CH_2Cl_2 (5 mL) at at room temperature. Trifluoroacetic acid (0.3 mL) was added dropwise and the reaction mixture was stirred at room temperature for 4 h. After that, the reaction mixture was concentrated and directly purified by silica gel column chromatography (CH_2Cl_2 to CH_2Cl_2/CH_3OH, 30:1) to afford the desired product **3b** as a light yellow solid (133.3 mg, 95% yield), but cannot be separated by HPLC. m.p. 194–196 °C. $[\alpha]_D^{25}$ = +54.9° (*c* = 2.64, DMSO). ^{1}H NMR (400

MHz, DMSO-d_6): δ 10.71 (s, 1H, NH), 7.78–7.76 (m, 1H, ArH), 7.67–7.62 (m, 3H, ArH), 7.59–7.56 (m, 1H, ArH), 7.41 (d, J = 7.6 Hz, 1H, ArH), 7.34 (d, J = 7.6 Hz, 2H, ArH), 7.23 (td, J_1 = 7.6 Hz, J_2 = 0.9 Hz, 1H, ArH), 7.18–7.14 (m, 2H, ArH), 7.00 (t, J = 7.6 Hz, 1H, ArH), 6.90 (d, J = 7.6 Hz, 1H, ArH), 5.34 (d, J = 13.6 Hz, 1H, CH), 4.31 (s, 1H, CH), 4.09–4.02 (m, 1H, CH_2), 4.00–3.92 (m, 1H, CH_2), 3.69–3.62 (m, 1H, CH), 2.25 (dd, J_1 = 14.4 Hz, J_2 = 11.6 Hz, 1H, CH_2), 2.14 (dd, J_1 = 14.4 Hz, J_2 = 3.6 Hz, 1H, CH_2), 0.96 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, DMSO-d_6): δ 202.9, 190.3, 179.4, 176.4, 167.0, 158.9, 141.7, 136.6, 135.1, 133.1, 129.7, 129.6, 128.2, 128.0, 126.6, 122.5, 121.8, 121.7, 119.9, 117.7, 109.6, 81.8, 79.1, 65.8, 61.8, 51.3, 46.6, 32.0, 13.4 ppm. HRMS (ESI): m/z calcd. for $C_{31}H_{25}N_2O_6S_2$ $[M + H]^+$ 585.1149, found 585.1163.

To a stirred solution of **3b** (116.9 mg, 0.2 mmol) in DMF (5 mL) was added NaH (12.0 mg, 0.3 mmol) at 0 °C. Then methyl iodide (42.6 mg, 0.3 mmol) in 2 mL DMF was added dropwise into the stirred reaction mixture. The reaction mixture was allowed to stir at room temperature for another 12 h, the product **3b** was completely consumped as detected by TLC analysis. After that, the mixture was treated with water (20 mL) and extracted with CH_2Cl_2 (3 × 10 mL). The combined organic extracts was washed by brine, dried over Na_2SO_4, and the solvent was removed under vacuum. The crude product was purified by flash column chromatography on silica gel (petroleum ether/CH_2Cl_2, 1:2 to CH_2Cl_2) to afford the pure product **3c** as a white soild (111.4 mg, 93% yield), m.p. 191–193 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 90:10, flow rate 1.0 mL/min, detection at 254 nm): t_R = 30.7 min (minor), t_R = 40.4 min (major); 93% ee. $[\alpha]_D^{25}$ = +42.5° (c = 2.87, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.60–7.56 (m, 2H, ArH), 7.55–7.51 (m, 2H, ArH), 7.35–7.31 (m, 3H, ArH), 7.17 (d, J = 6.8 Hz, 1H, ArH), 7.09–7.05 (m, 2H, ArH), 6.97 (d, J = 8.0 Hz, 1H, ArH), 6.90 (d, J = 7.6 Hz, 1H, ArH), 4.95 (d, J = 13.6 Hz, 1H, CH), 4.17 (s, 1H, CH), 4.13–4.05 (m, 1H, CH_2), 4.00–3.92 (m, 1H, CH_2), 3.90–3.83 (m, 1H, CH), 3.27 (s, 3H, CH_3), 2.51 (dd, J_1 = 14.8 Hz, J_2 = 3.2 Hz, 1H, CH_2), 1.84 (dd, J_1 = 15.0 Hz, J_2 = 11.8 Hz, 1H, CH_2), 1.03 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 202.2, 190.7, 177.6, 177.4, 166.9, 159.6, 143.4, 136.5, 135.5, 132.0, 129.7, 129.6, 128.8, 128.1, 127.1, 122.8, 122.4, 121.1, 120.1, 117.8, 108.6, 83.0, 65.7, 62.4, 52.5, 46.7, 39.5,

33.3, 26.3, 13.8 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{32}H_{27}N_2O_6S_2$ $[M + H]^+$ 599.1305, found 599.1325.

7. Procedure and the characterization data of compound 4

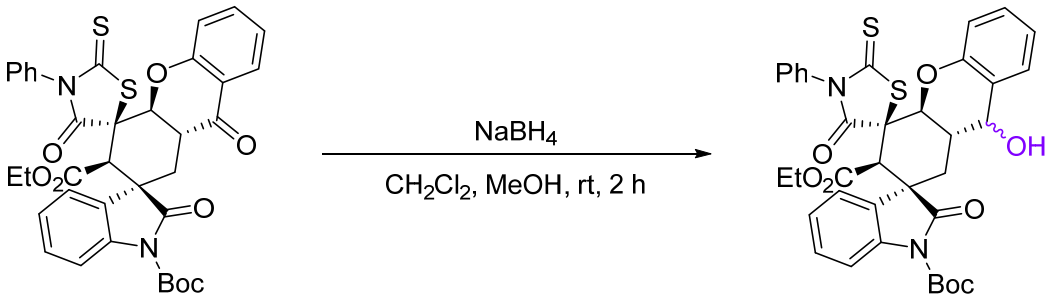


3a, >20:1 *dr*, 95% *ee*

4, 82% yield
>20:1 *dr*, 95% *ee*

To a solution of compound **3a** (124.5 mg, 0.18 mmol) in acetic acid (3.0 mL) was added chromium trioxide (54.0 mg, 0.54 mmol) in three portions over 30 min at room temperature. The solution was stirred at 50 °C for 12 h. The mixture was treated with water (20 mL) and extracted with EtOAc (3 × 10 mL). The combined organic extracts was washed by brine, dried over Na_2SO_4, and the solvent was removed under vacuum. The crude product was purified by flash column chromatography on silica gel (petroleum ether/CH_2Cl_2, 1:2) to afford the pure product **4** as a white soild (98.7 mg, 82% yield), m.p. 196–197 °C. HPLC (Daicel Chiralpak IC, *n*-hexane/ethyl acetate = 85:15, flow rate 1.0 mL/min, detection at 254 nm): t_R = 9.1 min (minor), t_R = 17.2 min (major); 95% ee. $[\alpha]_D^{25}$ = +15.3° (*c* = 1.37, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87–7.84 (m, 2H, ArH), 7.57–7.50 (m, 3H, ArH), 7.49–7.46 (m, 1H, ArH), 7.40–7.33 (m, 3H, ArH), 7.21–7.15 (m, 2H, ArH), 7.07 (t, *J* = 8.0 Hz, 1H, ArH), 6.96 (d, *J* = 8.4 Hz, 1H, ArH), 4.94 (d, *J* = 13.6 Hz, 1H, CH), 4.21 (s, 1H, CH), 4.12–3.99 (m, 2H, CH_2), 3.78–3.71 (m, 1H, CH), 2.66 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.81 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.67 (s, 9H, CH_3), 1.05 (t, *J* = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.5, 176.1, 175.3, 171.5, 166.9, 159.5, 148.9, 139.5, 136.6, 133.1, 130.8, 129.4, 129.3, 129.1, 127.2, 127.0, 124.7, 122.5, 121.1, 120.0, 117.7, 115.4, 84.9, 82.4, 64.1, 62.6, 53.3, 47.1, 39.7, 33.9, 28.1, 13.6 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{32}N_2O_9SNa$ $[M + Na]^+$ 691.1721, found 691.1741.

8. Procedure and the characterization data of compound 5



3a, >20:1 *dr*, 95% *ee*

5, 76% yield
10:1 *dr*, 94% *ee*

To a solution of compound **3a** (161.8 mg, 0.236 mmol) in CH_2Cl_2 (5.0 mL) was added $NaBH_4$ (53.9 mg, 1.42 mmol) at 0 °C. Methanol (3.0 mL) was then added dropwise to the reaction solution. The solution was stirred at room temperature for 2 h. The mixture was treated with water (20 mL) and extracted with CH_2Cl_2 (3 × 10 mL). The combined organic extracts was washed by brine, dried over Na_2SO_4, and the solvent was removed under vacuum. The crude product was purified by flash column chromatography on silica gel (petroleum ether/CH_2Cl_2, 1:2 to CH_2Cl_2) to afford the pure product **5** as a white soild (123.2 mg, 76% yield), m.p. 182–184 °C. HPLC (Daicel Chiralpak IB, *n*-hexane/ethyl acetate = 75:25, flow rate 1.0 mL/min, detection at 254 nm): t_R = 11.2 min (minor), t_R = 11.9 min (major); 94% ee. $[\alpha]_D^{25}$ = +91.5° (*c* = 1.46, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 8.0 Hz, 1H, ArH), 7.84 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H, ArH), 7.62–7.52 (m, 4H, ArH), 7.44–7.41 (m, 2H, ArH), 7.37–7.33 (m, 1H, ArH), 7.20–7.16 (m, 2H, ArH), 7.08 (t, J = 8.0 Hz, 1H, ArH), 6.97 (d, J = 8.0 Hz, 1H, ArH), 4.89 (d, J = 13.6 Hz, 1H, CH), 4.10 (s, 1H, CH), 4.07–3.99 (m, 2H, CH_2), 3.82–3.75 (m, 1H, CH), 3.67–3.52 (m, 1H, CH), 2.67 (dd, J_1 = 15.0 Hz, J_2 = 3.4 Hz, 1H, CH_2), 1.81 (dd, J_1 = 15.2 Hz, J_2 = 12.0 Hz, 1H, CH_2), 1.66 (s, 9H, CH_3), 1.02 (t, J = 7.2 Hz, 3H, CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ 199.8, 190.2, 175.6, 173.2, 166.7, 159.3, 149.0, 139.5, 136.6, 133.7, 130.8, 130.7, 130.3, 129.0, 127.2, 126.3, 124.7, 122.5, 120.9, 119.9, 117.7, 115.4, 84.9, 82.8, 64.5, 62.8, 53.3, 47.0, 39.4, 33.8, 28.0, 13.3 ppm. HRMS (ESI): *m*/*z* calcd. for $C_{36}H_{35}N_2O_8S_2$ $[M + H]^+$ 687.1829, found 687.1823.

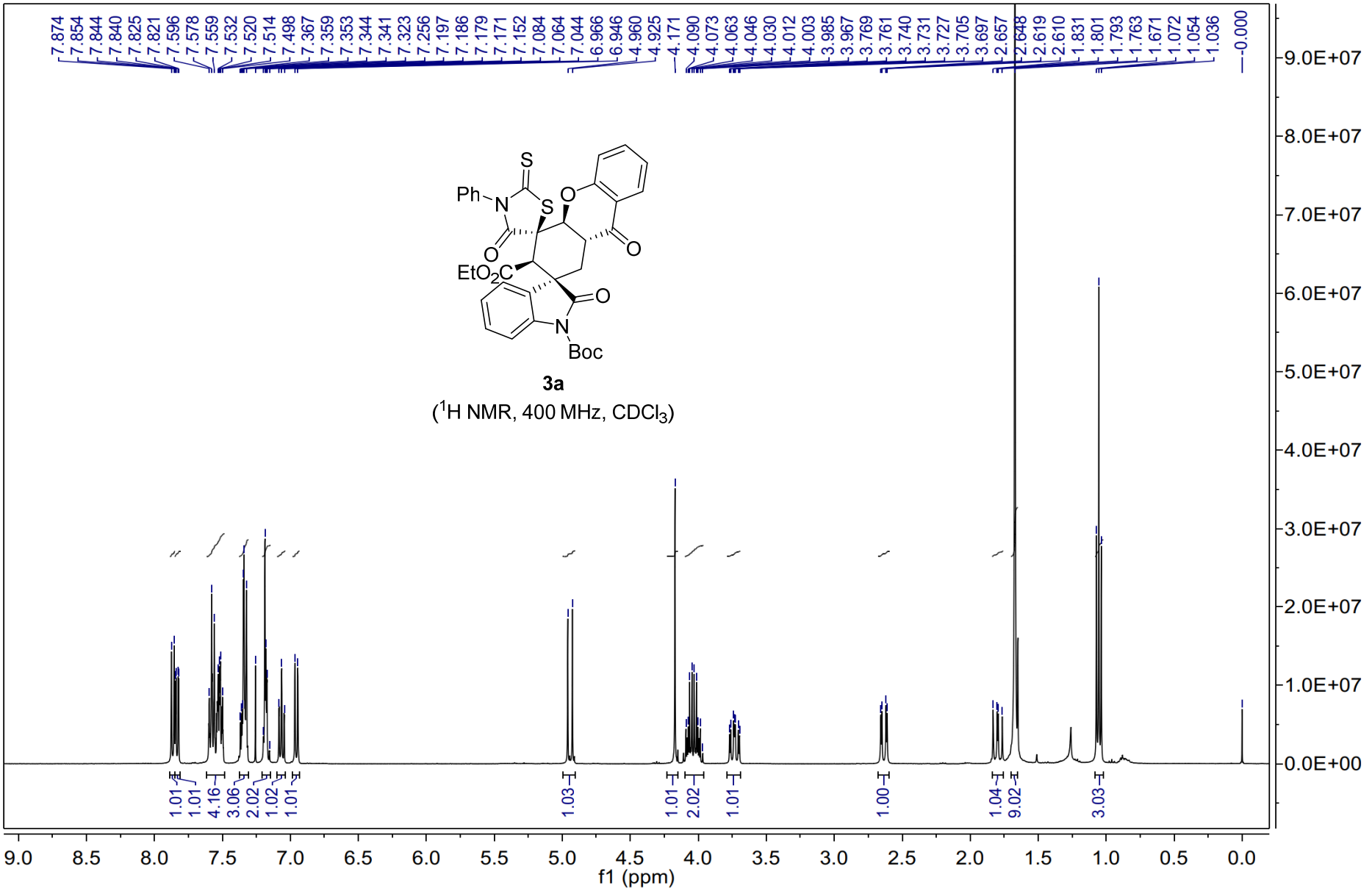
9. Reference

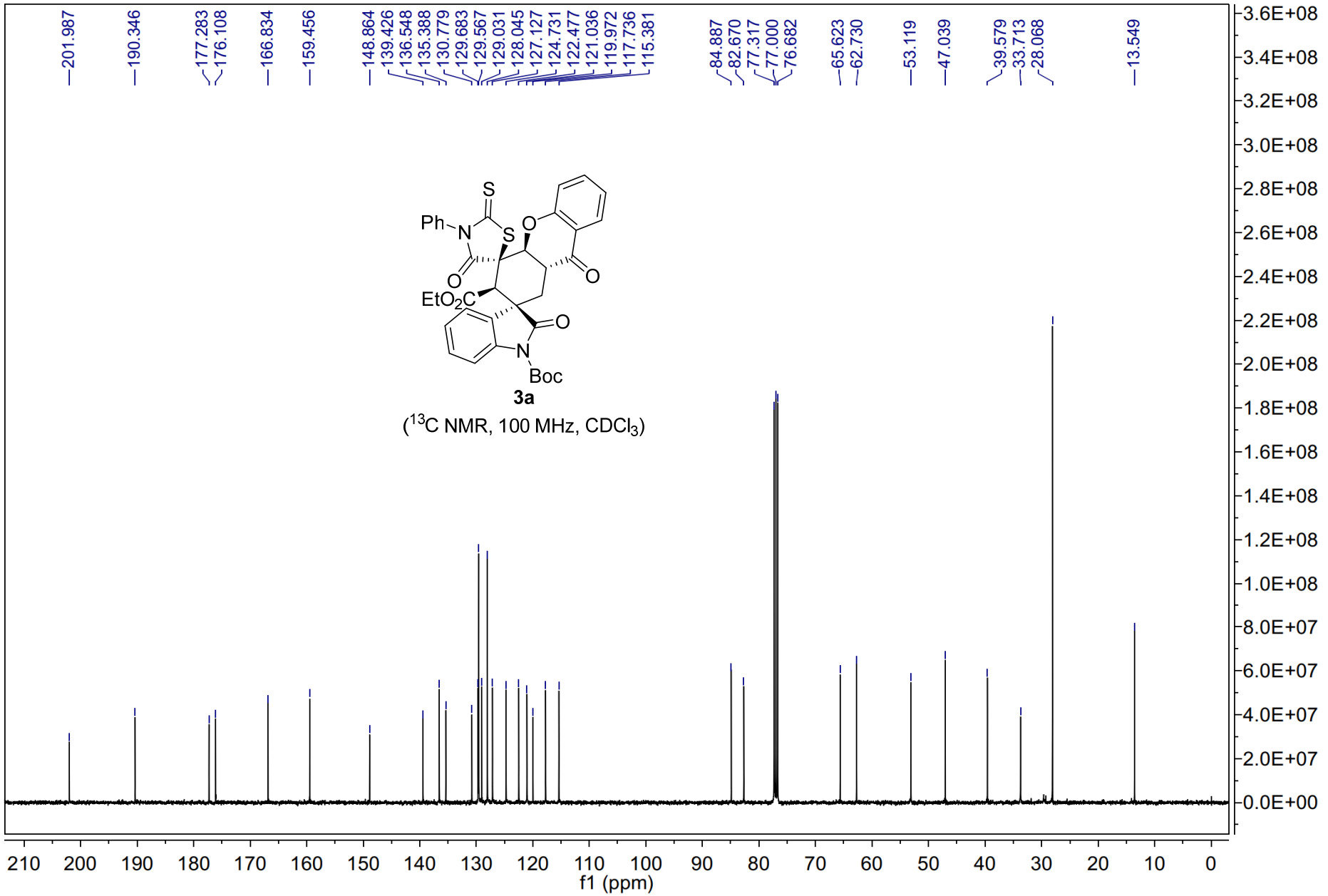
[1] X. Li. Liu, G. Zhou, Y. Gong, Z. Yao, X. Zuo, W. H. Zhang and Y. Zhou, *Org. Lett.*, 2019, **21**, 2528−2531.

[2] (a) T. Shailendra, K. P. Singh, K. Akhilesh, P. Poonam and N. F. Ansari, *J. Applicable. Chem.*, 2014, **3**, 2372–2377. (b) S. Jin, M. Tagliazucchi, H. J. Son, R. D. Harris, K. O. Aruda, D. J. Weinberg, A. B. Nepomnyashchii, O. K. Farha, J. T. Hupp and E. A. Weiss, *J. Phys. Chem. C*, 2015, **119**, 5195–5202. (c) Ş. H. Üngören, S. Albayrak, A. Günay, L. Yurtseven and N. Yurttaş, *Tetrahedron*, 2015, **71**, 4312–4323.

[3] (a) Y. Zhu, J. P. Malerich and V. H. Rawal, *Angew. Chem. Int. Ed.*, 2010, **49**, 153–156; *Angew. Chem.* **2010**, 122, 157–160. (b) W. Yang and D. M. Du, *Org. Lett.*, 2010, **12**, 5450–5453. (c) W. Yang and D. M. Du, *Adv. Synth. Catal.*, 2011, **353**, 1241–1246. (d) B. Vakulya, S. Varga, A. Csampai and T. Soós, *Org. Lett.*, 2005, **7**, 1967–1969.

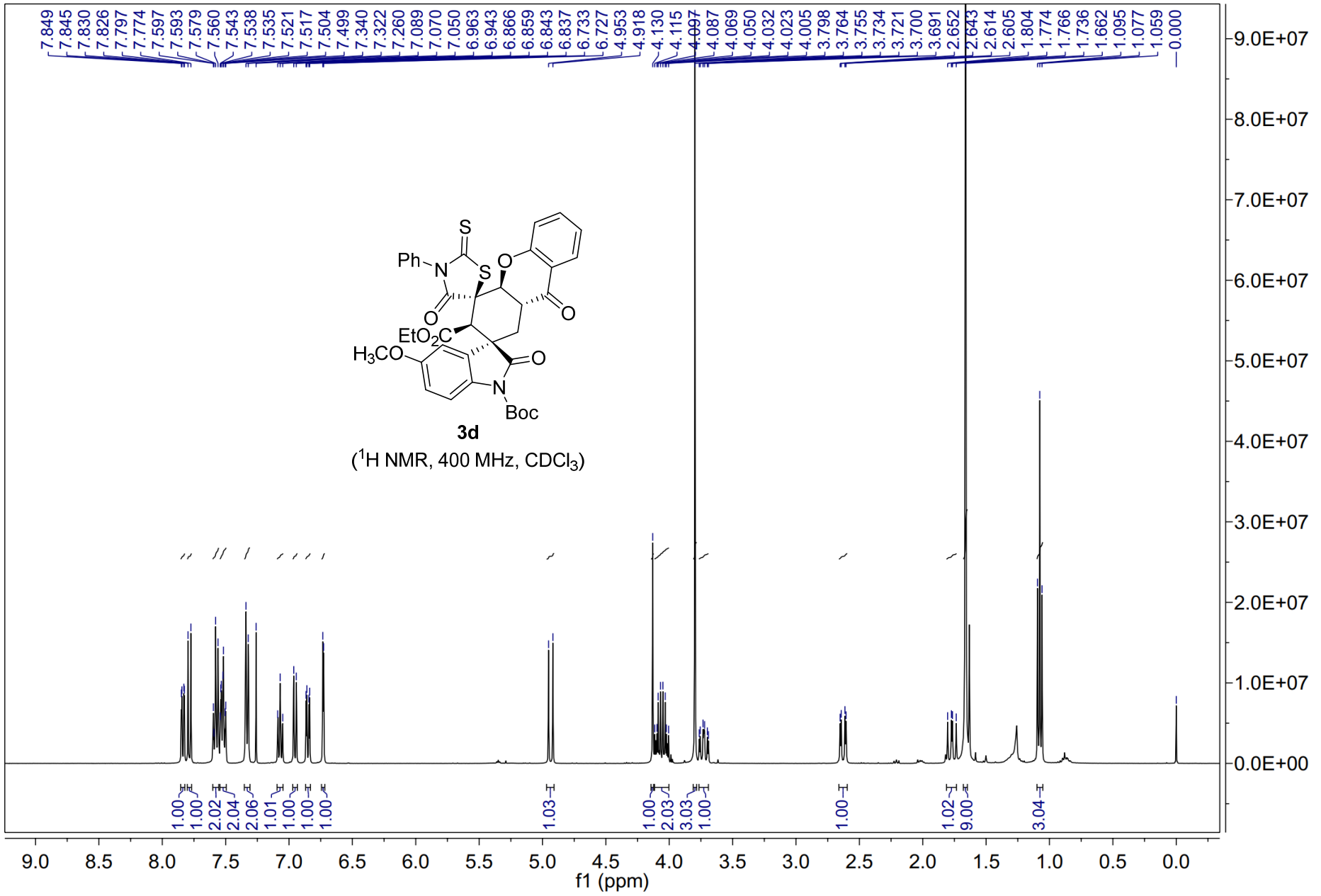
10. Copies of ^{1}H and ^{13}C NMR spectra of new compounds





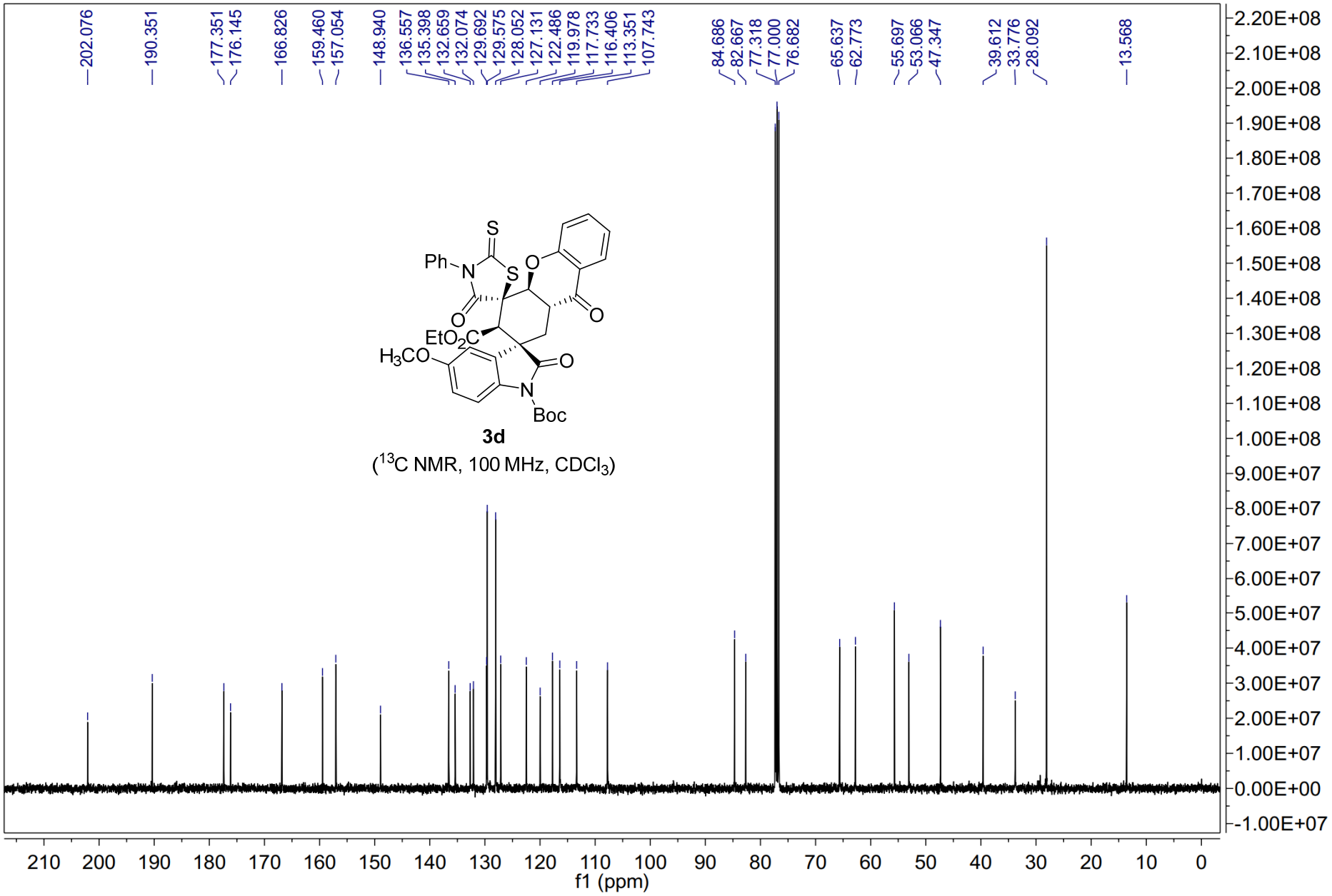
3a

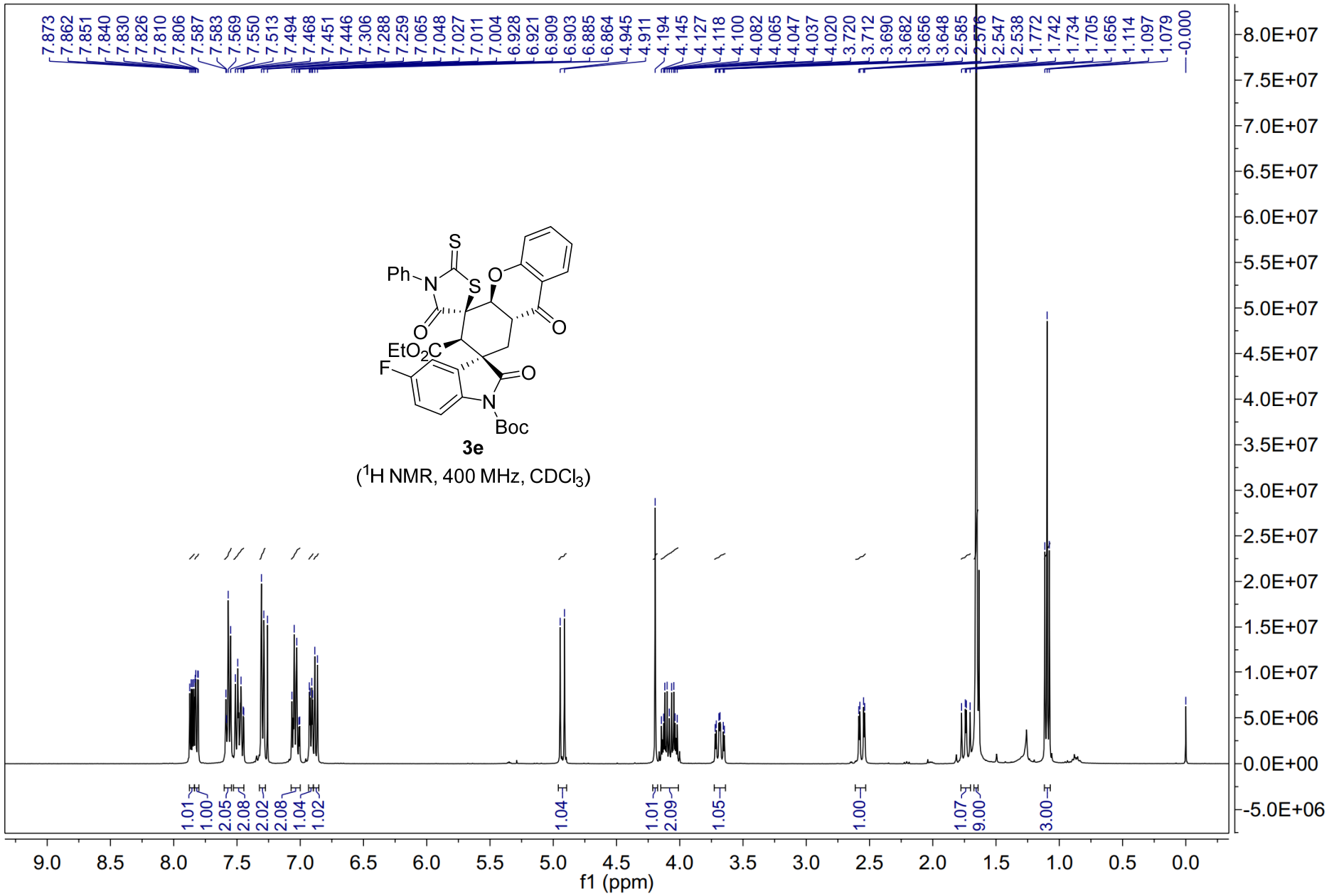
(^{13}C NMR, 100 MHz, $CDCl_3$)



3d

(^{1}H NMR, 400 MHz, $CDCl_3$)


202.076
190.351
177.351
176.145
166.826
159.460
157.054
148.940
136.557
135.398
132.659
132.074
129.692
129.575
128.052
127.131
122.486
119.978
117.733
116.406
113.351
107.743
84.686
82.667
77.318
77.000
76.682
65.637
62.773
55.697
53.066
47.347
39.612
33.776
28.092
13.568
S
Ph
N
S
O
O
O
EtO2C
H3CO
O
N
Boc
3d
(13C NMR, 100 MHz, CDCl3)
2.20E+08
2.10E+08
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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7.862
7.851
7.840
7.830
7.826
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7.806
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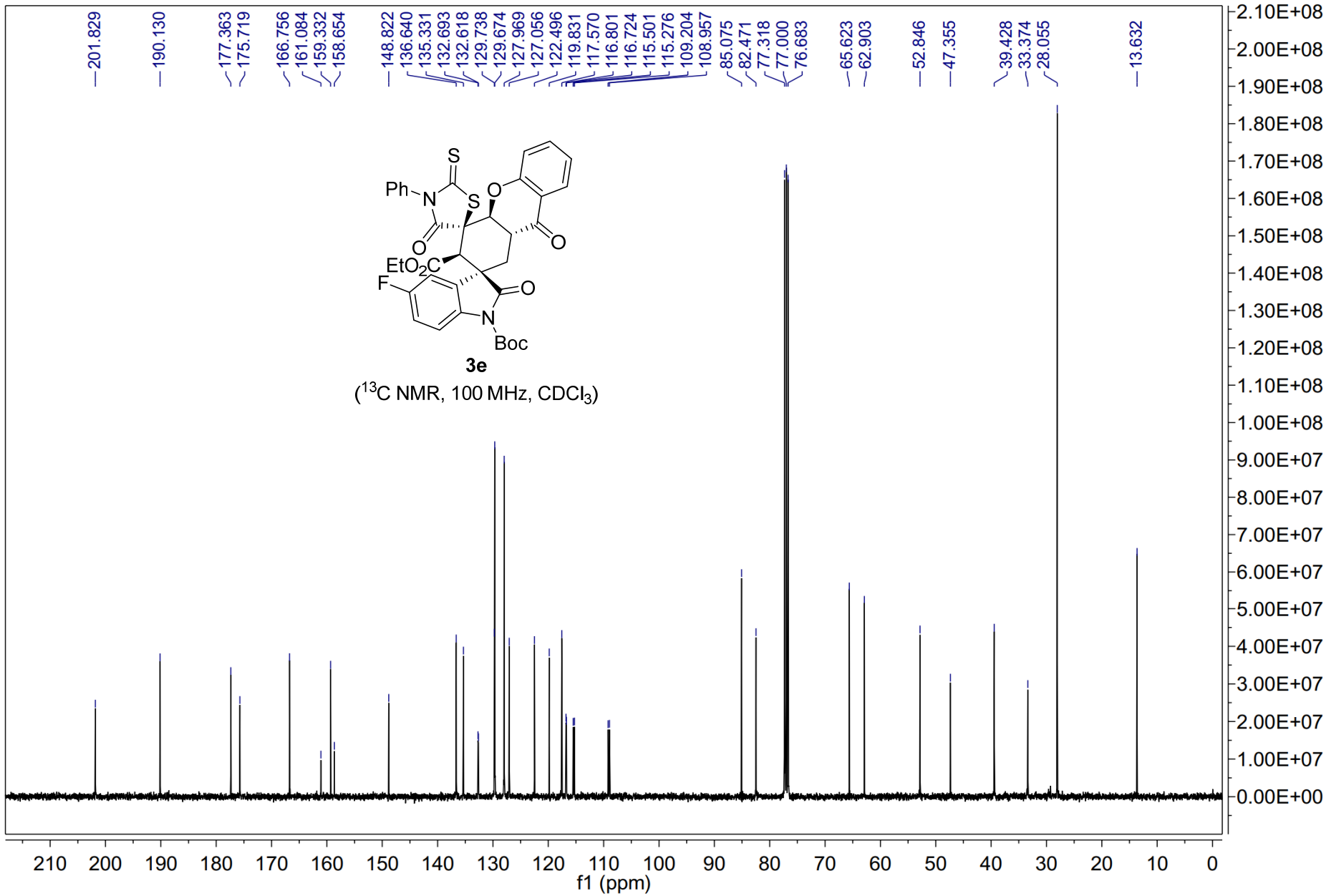
7.583
7.569
7.550
7.513
7.494
7.468
7.451
7.446
7.306
7.288
7.259
7.065
7.048
7.027
7.011
7.004
6.928
6.921
6.909
6.903
6.885
6.864
4.945
4.911
4.194
4.145
4.127
4.118
4.100
4.082
4.065
4.047
4.037
4.020
3.720
3.712
3.690
3.682
3.656
3.648
2.585
2.576
2.547
2.538
1.772
1.742
1.734
1.705
1.656
1.114
1.097
1.079
-0.000
Ph
N
S
S
O
O
O
EtO2C
F
O
N
Boc
3e
(1H NMR, 400 MHz, CDCl3)
1.01
1.00
2.05
2.08
2.02
2.08
1.04
1.02
1.04
1.01
2.09
1.05
1.00
1.07
9.00
3.00
f1 (ppm)


201.829
190.130
177.363
175.719
166.756
161.084
159.332
158.654
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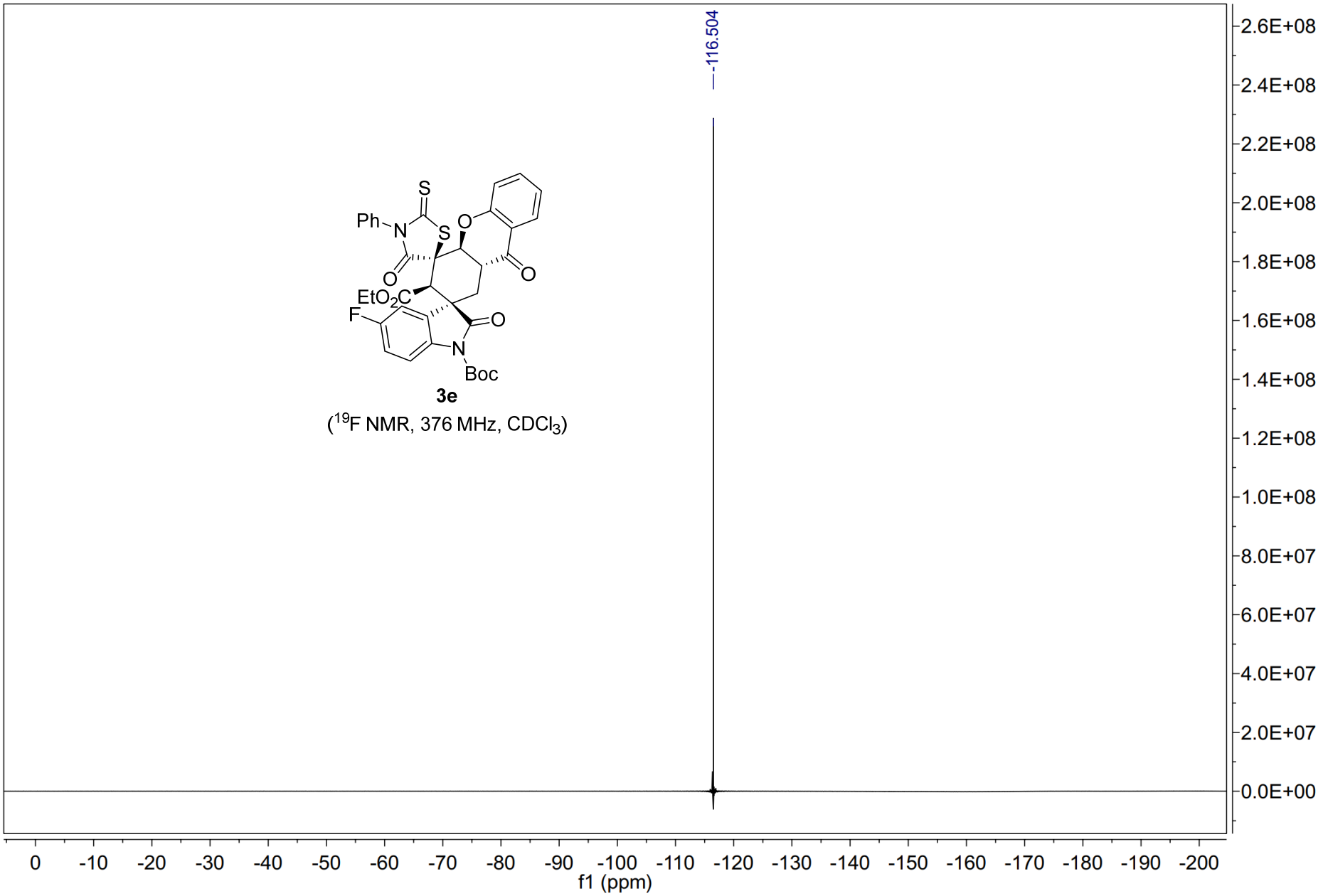
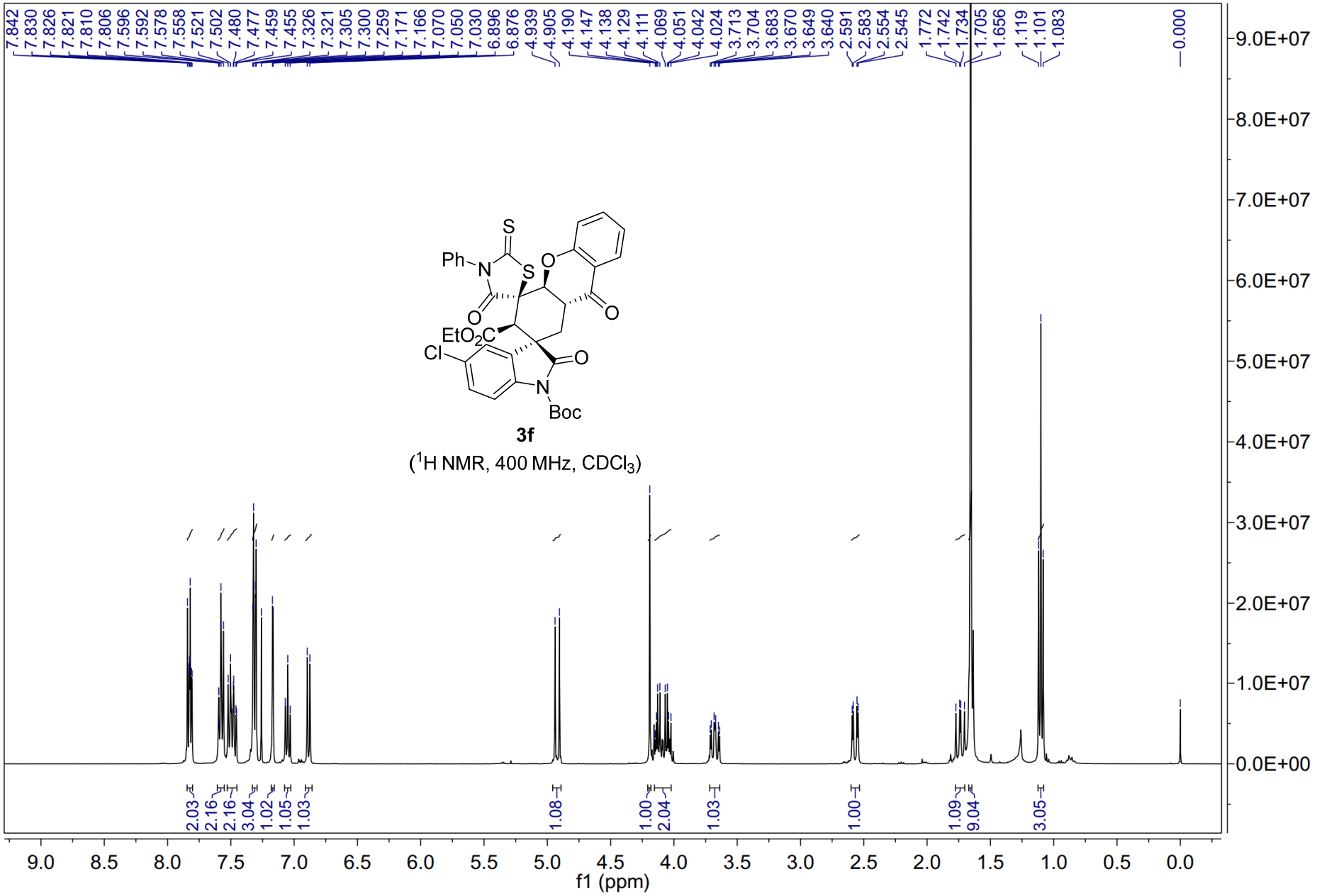
136.640
135.331
132.693
132.618
129.738
129.674
127.969
127.056
122.496
119.831
117.570
116.801
116.724
115.501
115.276
109.204
108.957
85.075
82.471
77.318
77.000
76.683
65.623
62.903
52.846
47.355
39.428
33.374
28.055
13.632
Ph
N
S
S
O
O
O
O
EtO2C
F
O
N
Boc
3e
(13C NMR, 100 MHz, CDCl3)
2.10E+08
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



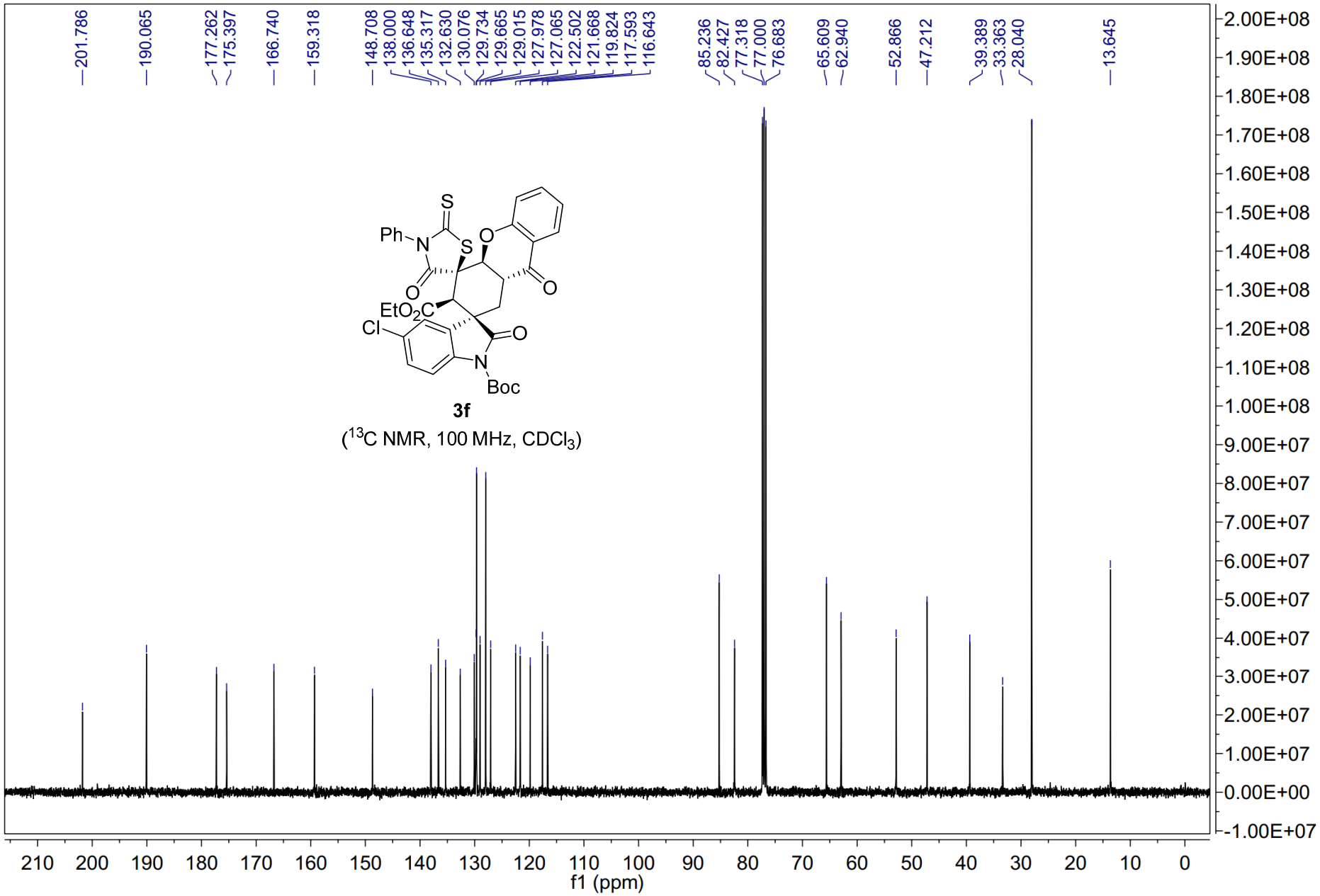
3e

(^{19}F NMR, 376 MHz, $CDCl_3$)



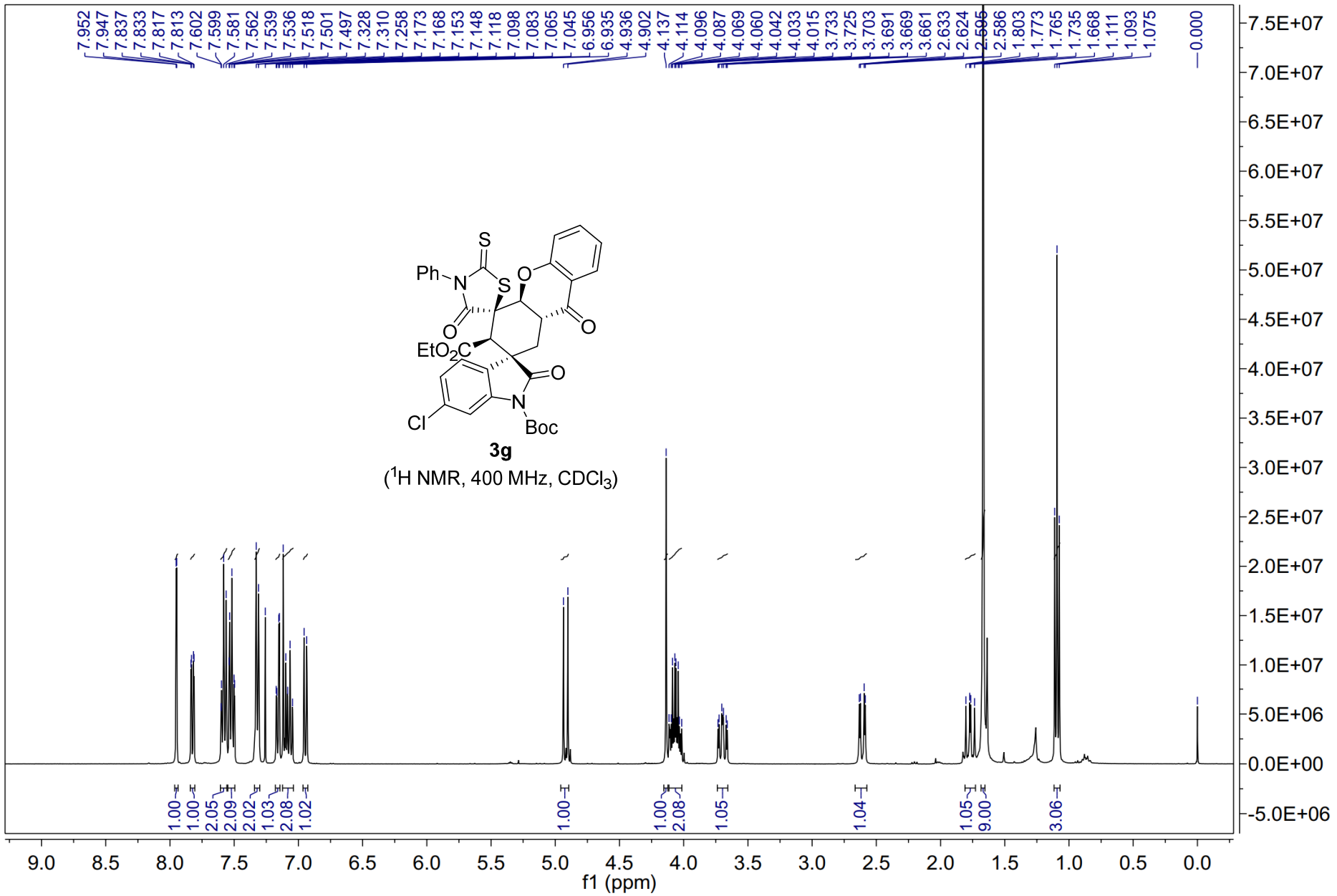
3f

(^{1}H NMR, 400 MHz, $CDCl_3$)



3f

(^{13}C NMR, 100 MHz, $CDCl_3$)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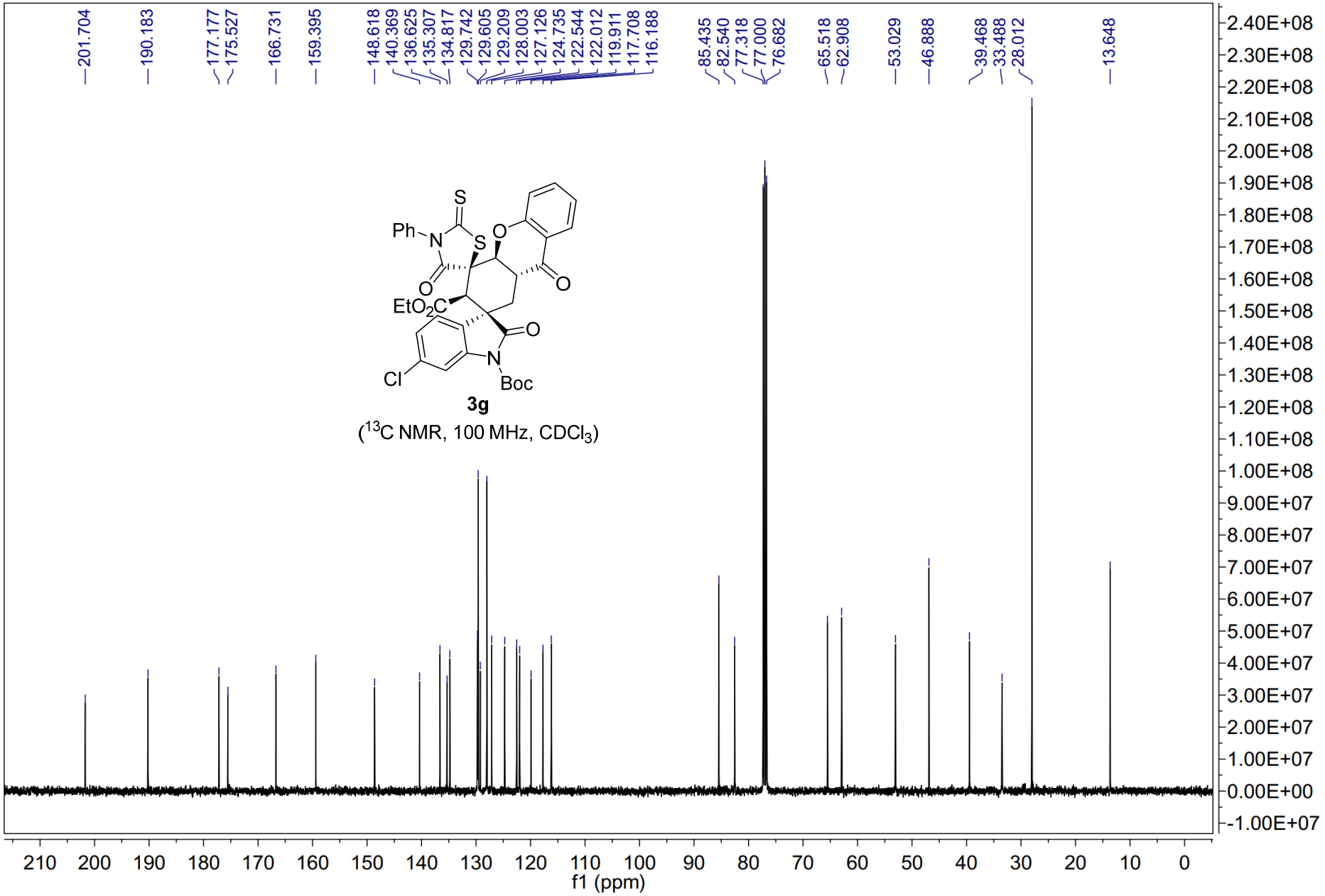
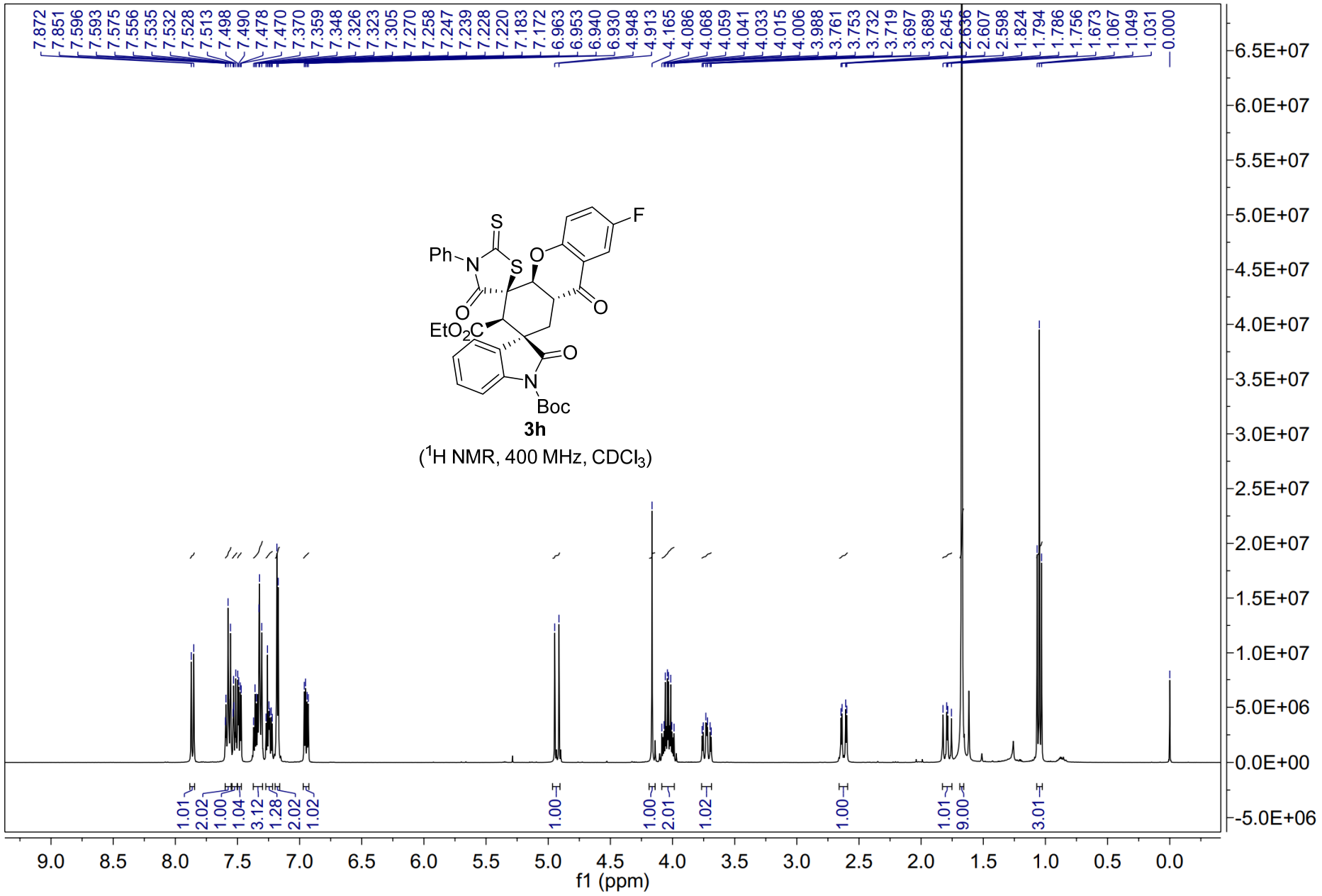
7.833
7.817
7.813
7.602
7.599
7.581
7.562
7.539
7.536
7.518
7.501
7.497
7.328
7.310
7.258
7.173
7.168
7.153
7.148
7.118
7.098
7.083
7.065
7.045
6.956
6.935
4.936
4.902
4.137
4.114
4.096
4.087
4.069
4.060
4.042
4.033
4.015
3.733
3.725
3.703
3.691
3.669
3.661
2.633
2.624
2.595
2.586
1.803
1.773
1.765
1.735
1.668
1.111
1.093
1.075
0.000
Ph
N
S
S
O
O
O
EtO2C
O
N
Boc
Cl
3g
(1H NMR, 400 MHz, CDCl3)
1.00
1.00
2.05
2.09
2.02
1.03
2.08
1.02
1.00
1.00
2.08
1.05
1.04
1.05
9.00
3.06
7.5E+07
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3g

(^{13}C NMR, 100 MHz, $CDCl_3$)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7.596
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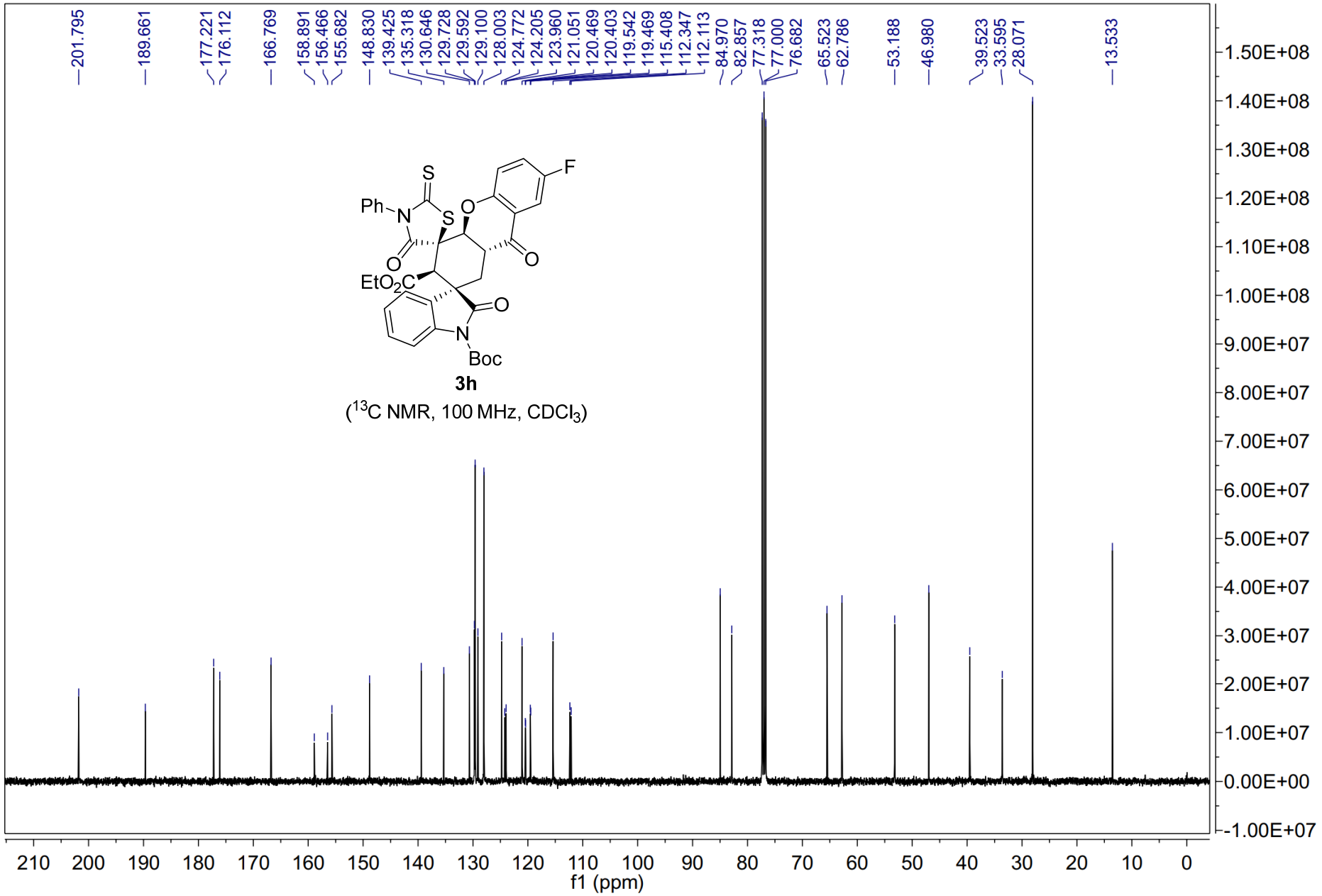
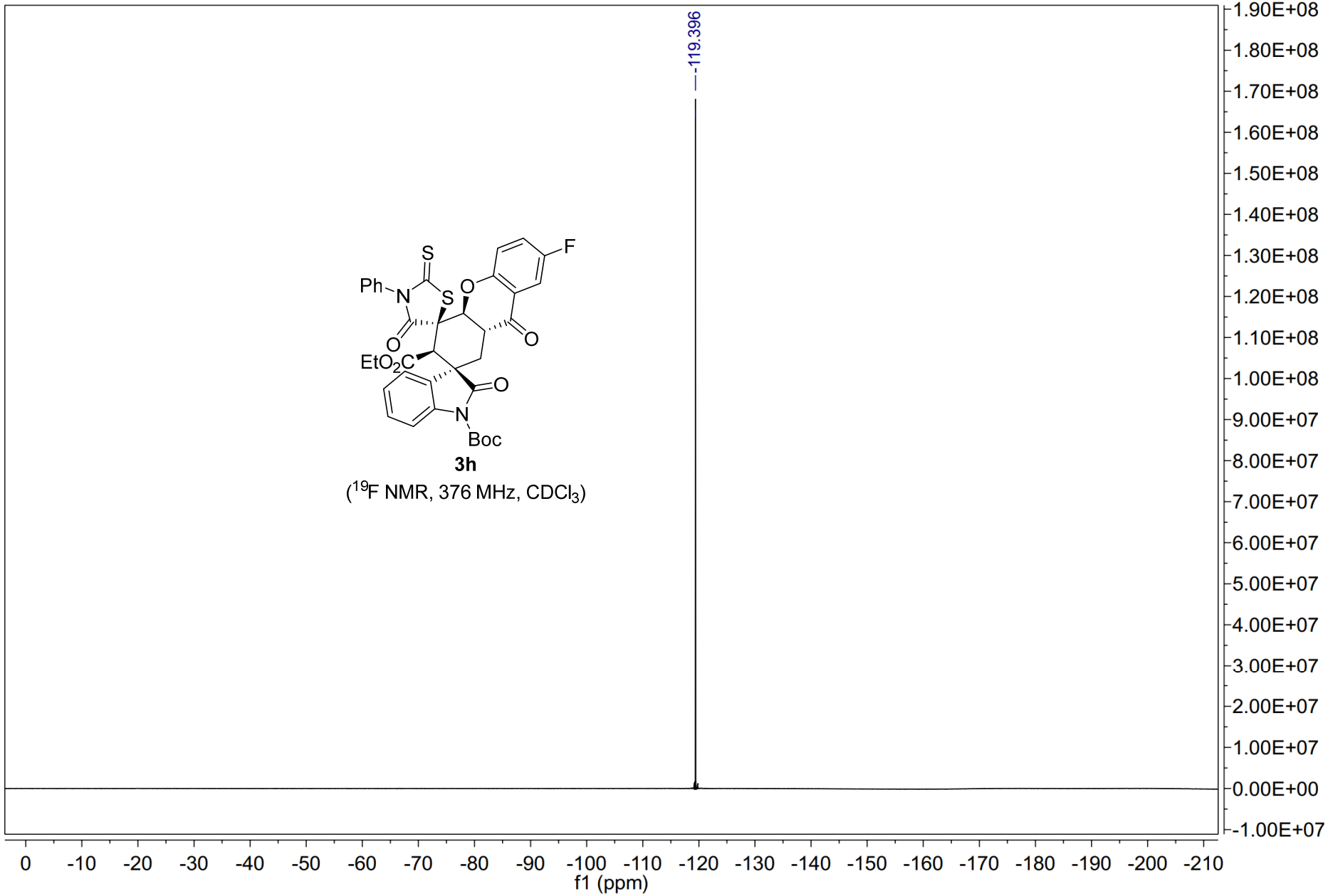
7.575
7.556
7.535
7.532
7.528
7.513
7.498
7.490
7.478
7.470
7.370
7.359
7.348
7.326
7.323
7.305
7.270
7.258
7.247
7.239
7.228
7.220
7.183
7.172
6.963
6.953
6.940
6.930
6.948
4.913
4.165
4.086
4.068
4.059
4.041
4.033
4.015
4.006
3.988
3.761
3.753
3.732
3.719
3.697
3.689
2.645
2.636
2.607
2.598
1.824
1.794
1.786
1.756
1.673
1.067
1.049
1.031
0.000
S
F
Ph
N
S
O
O
O
EtO2C
O
N
Boc
3h
(1H NMR, 400 MHz, CDCl3)
1.01
2.02
1.00
1.04
3.12
1.28
2.02
1.02
1.00
1.00
2.01
1.02
1.00
1.01
9.00
3.01
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



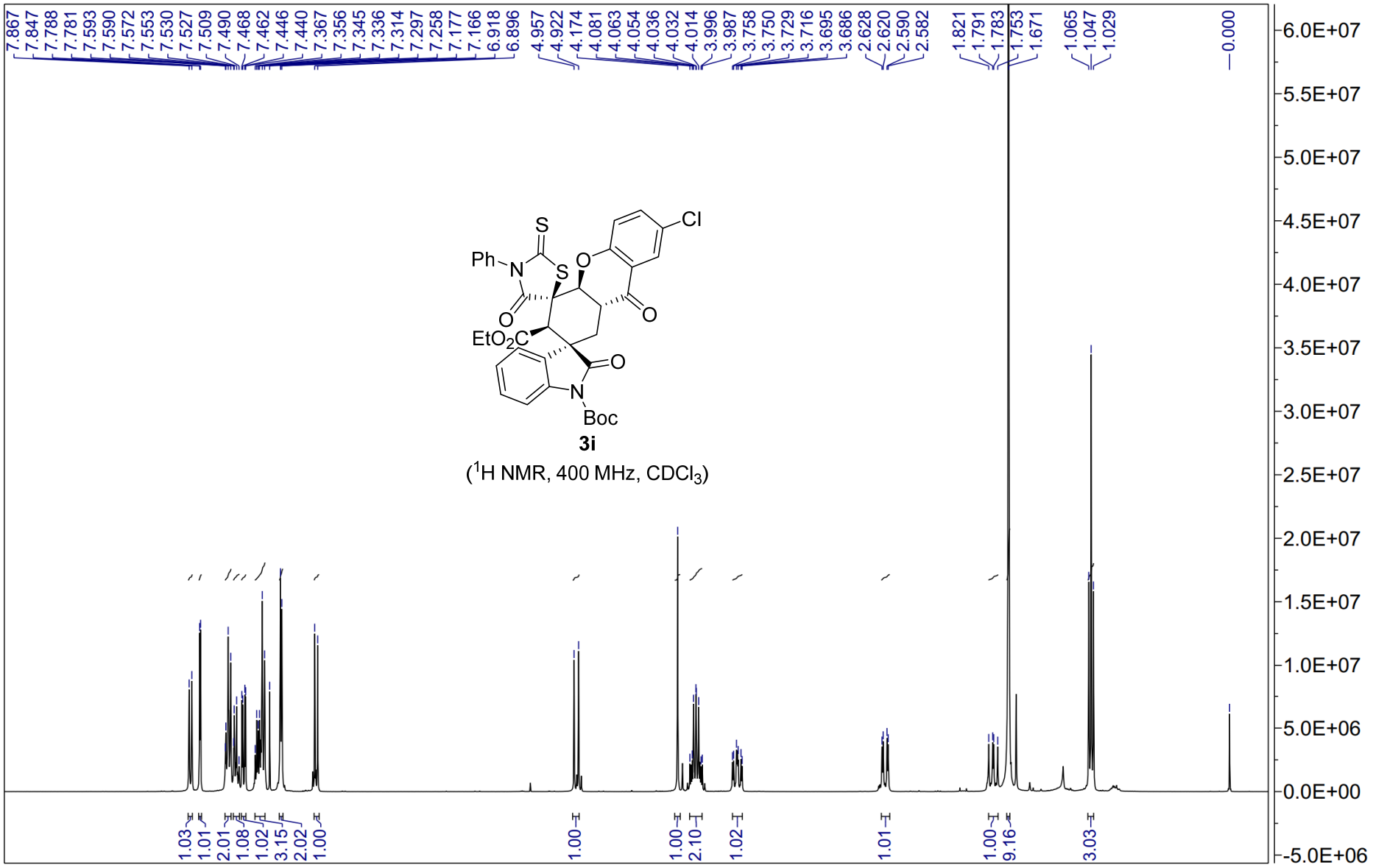
3h

(^{13}C NMR, 100 MHz, $CDCl_3$)



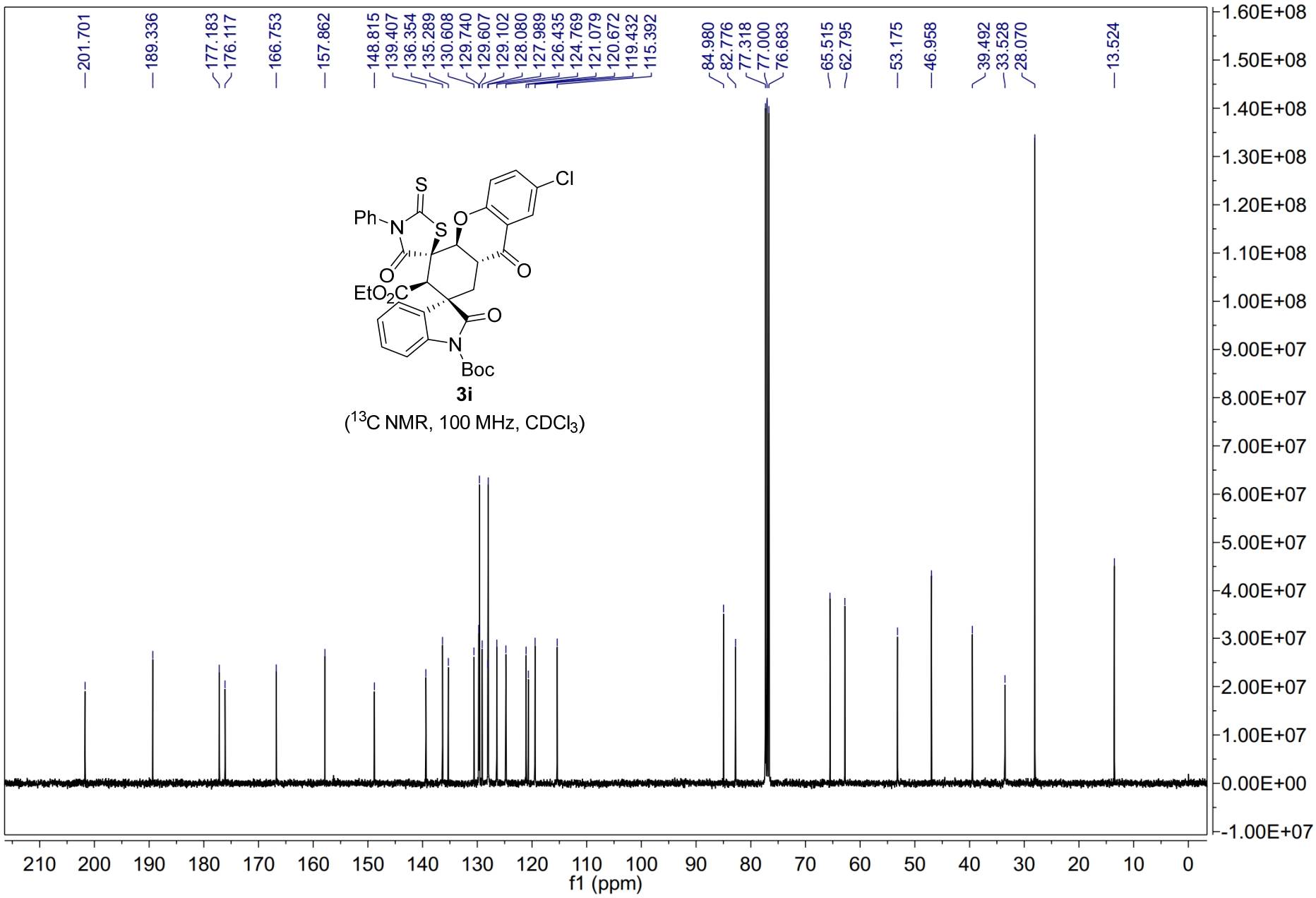
3h

(^{19}F NMR, 376 MHz, $CDCl_3$)



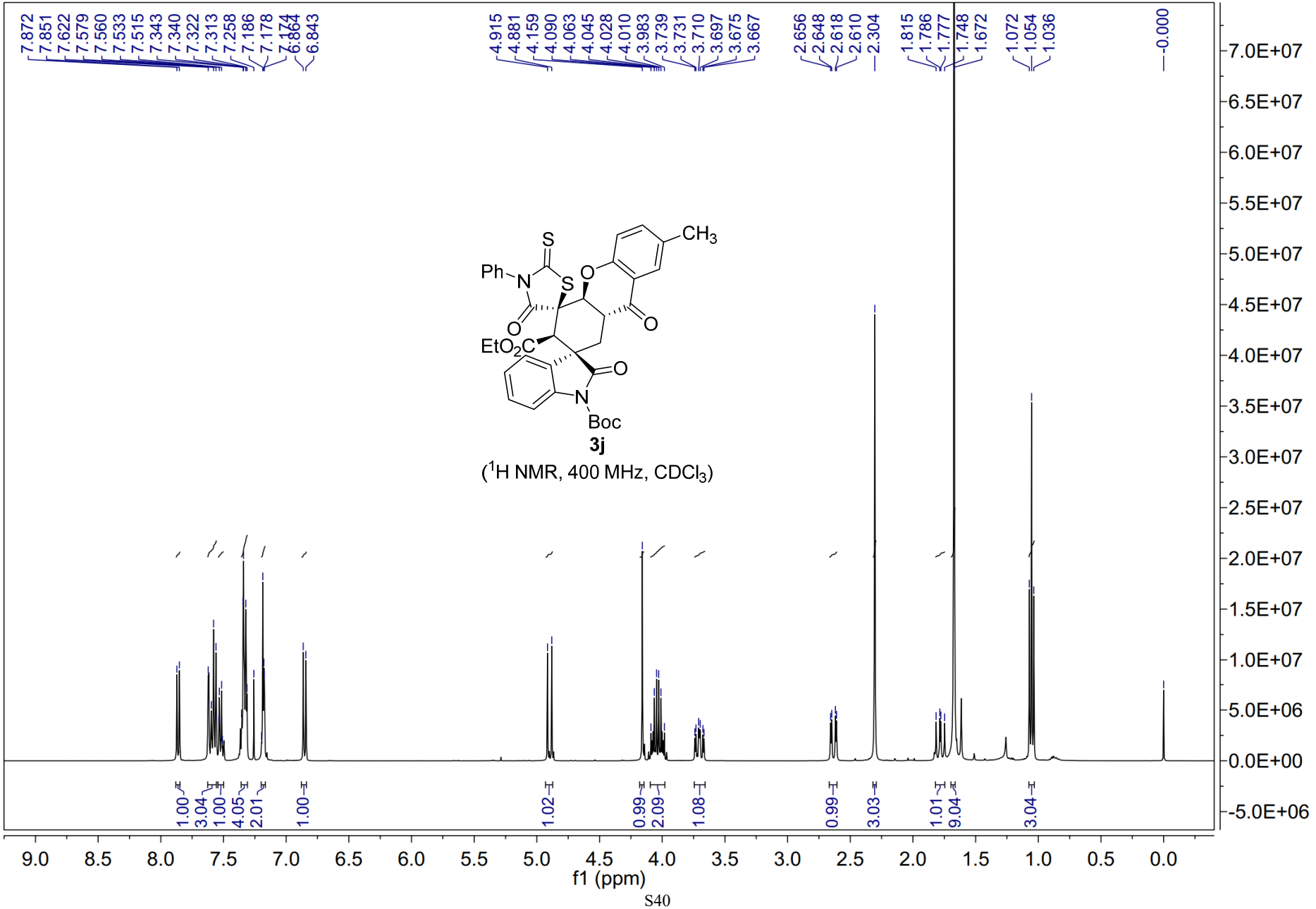
3i

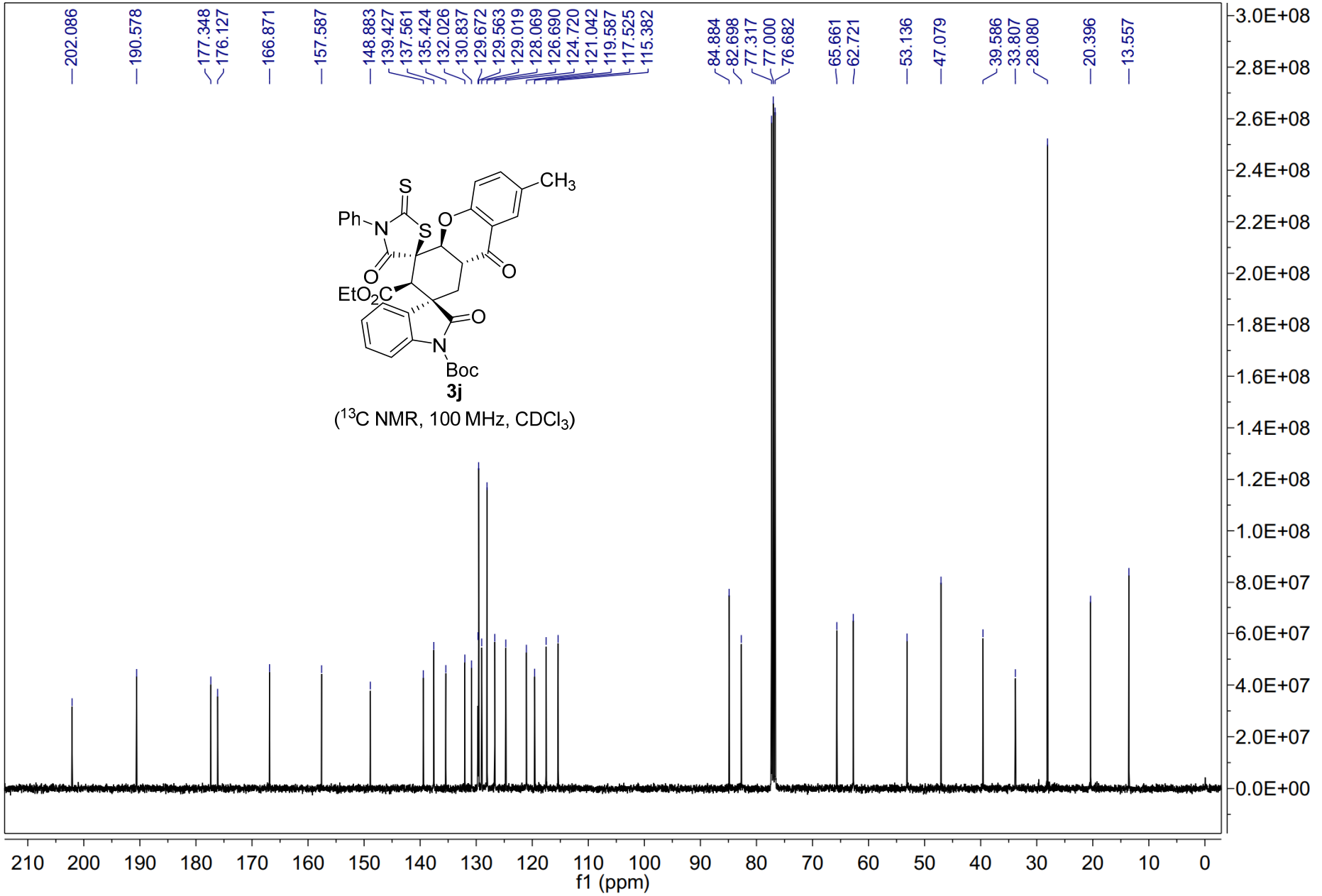
(^{1}H NMR, 400 MHz, $CDCl_3$)



3i

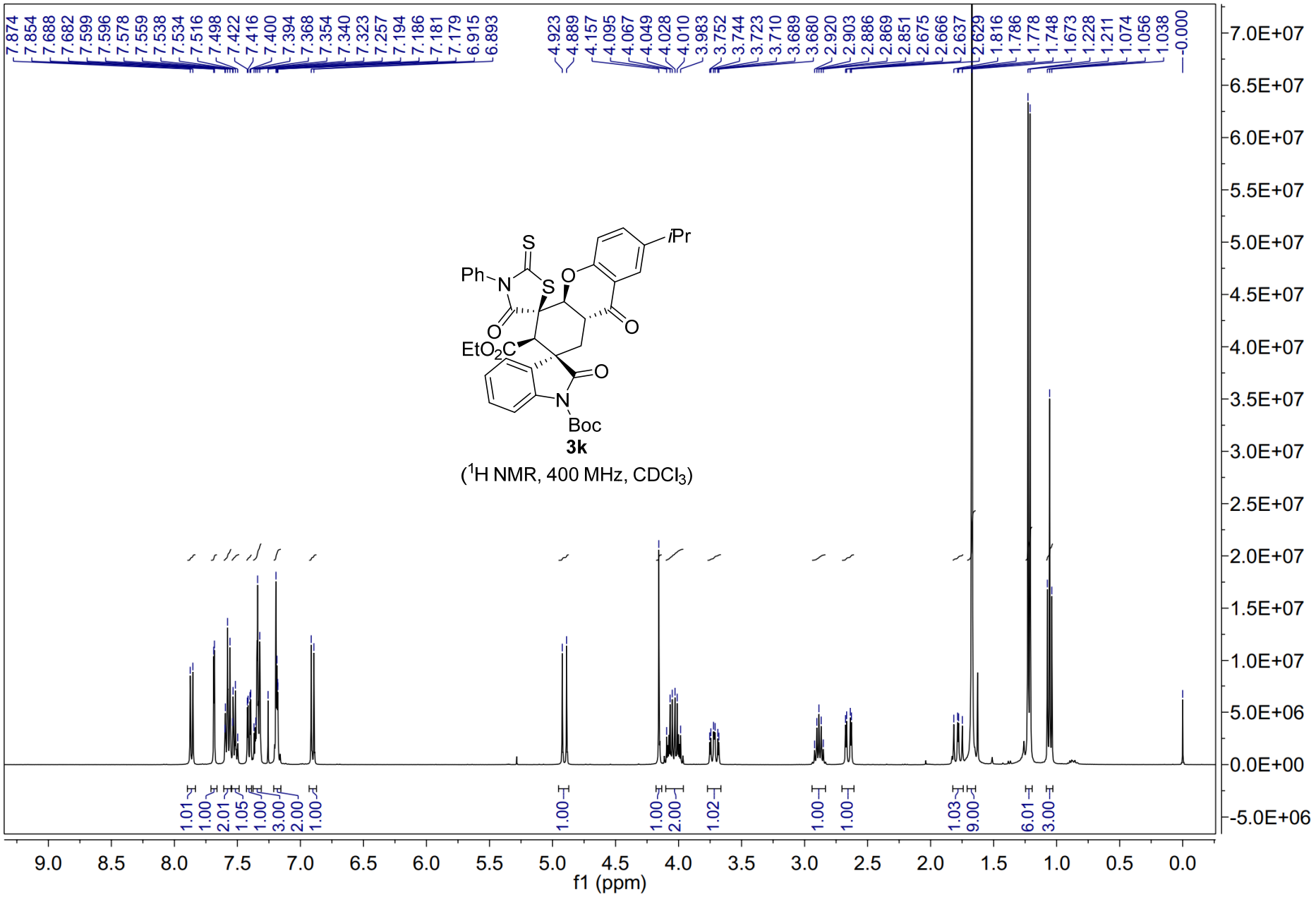
(^{13}C NMR, 100 MHz, $CDCl_3$)

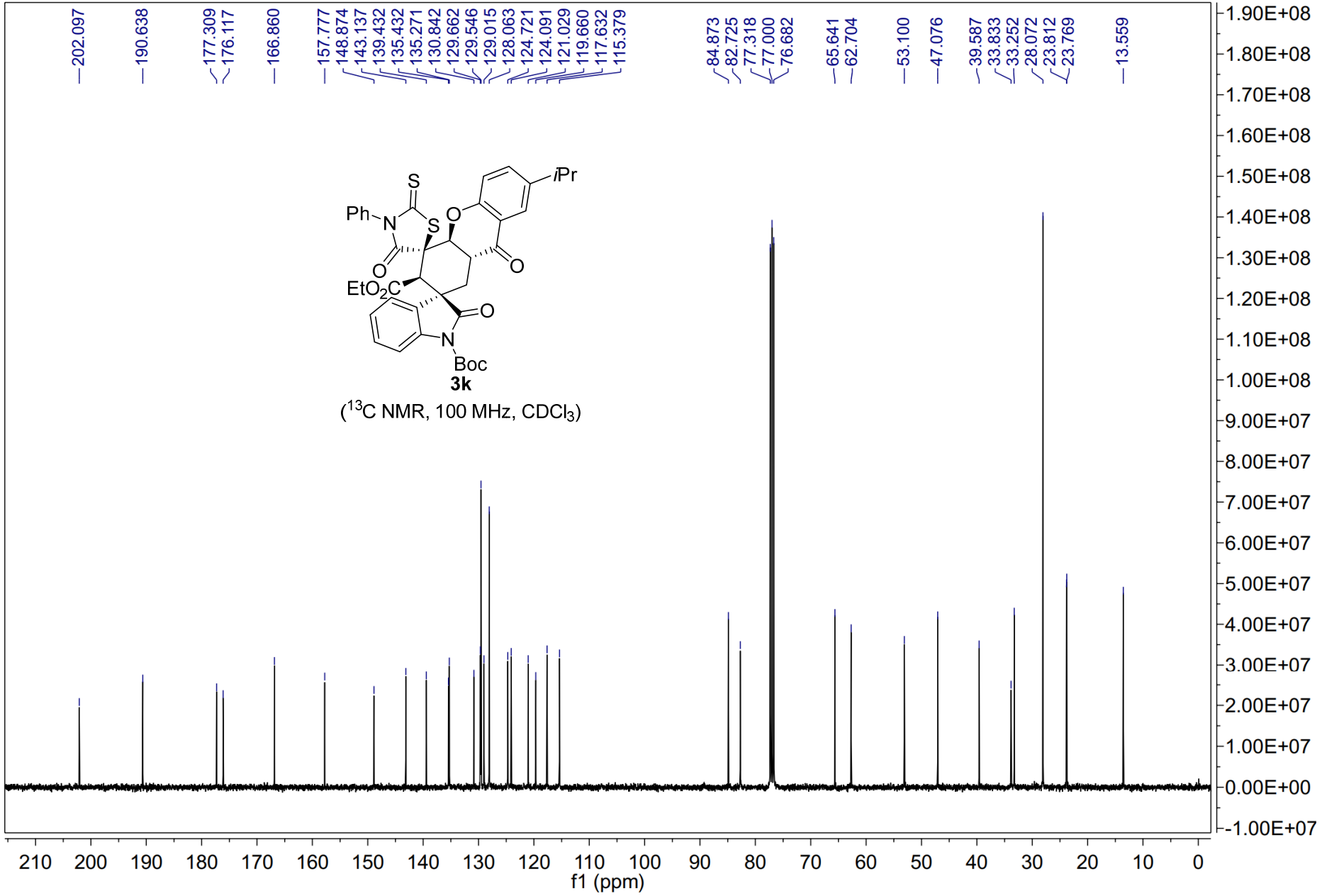

7.872
7.851
7.622
7.579
7.560
7.533
7.515
7.343
7.340
7.322
7.313
7.258
7.186
7.178
6.864
6.843
4.915
4.881
4.159
4.090
4.063
4.045
4.028
4.010
3.983
3.739
3.731
3.710
3.697
3.675
3.667
2.656
2.648
2.618
2.610
2.304
1.815
1.786
1.777
1.748
1.672
1.072
1.054
1.036
-0.000
Ph
N
S
S
O
O
O
O
EtO2C
O
N
Boc
CH3
3j
(1H NMR, 400 MHz, CDCl3)
1.00
3.04
1.00
4.05
2.01
1.00
1.02
0.99
2.09
1.08
0.99
3.03
1.01
9.04
3.04
f1 (ppm)

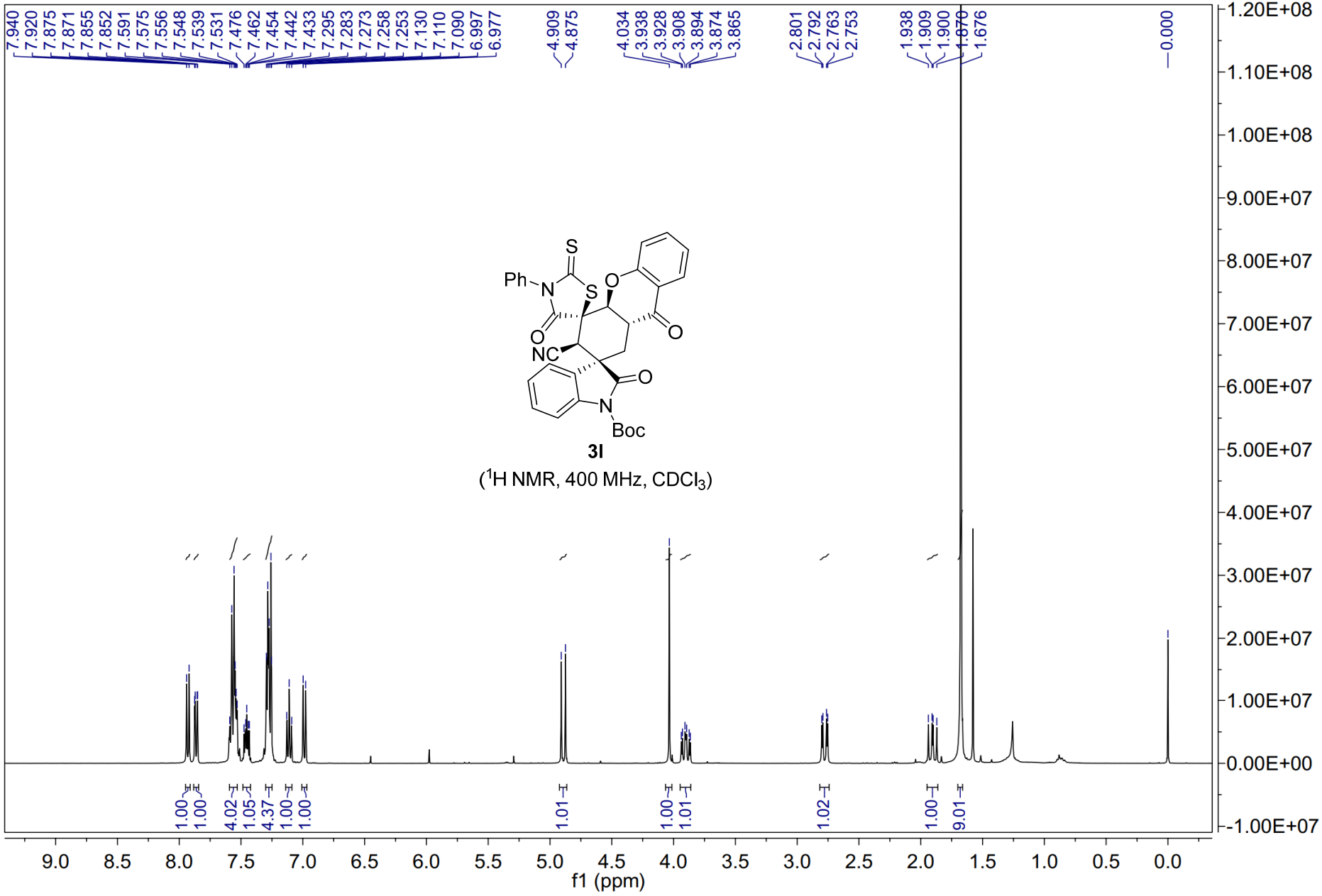


3j

(^{13}C NMR, 100 MHz, $CDCl_3$)

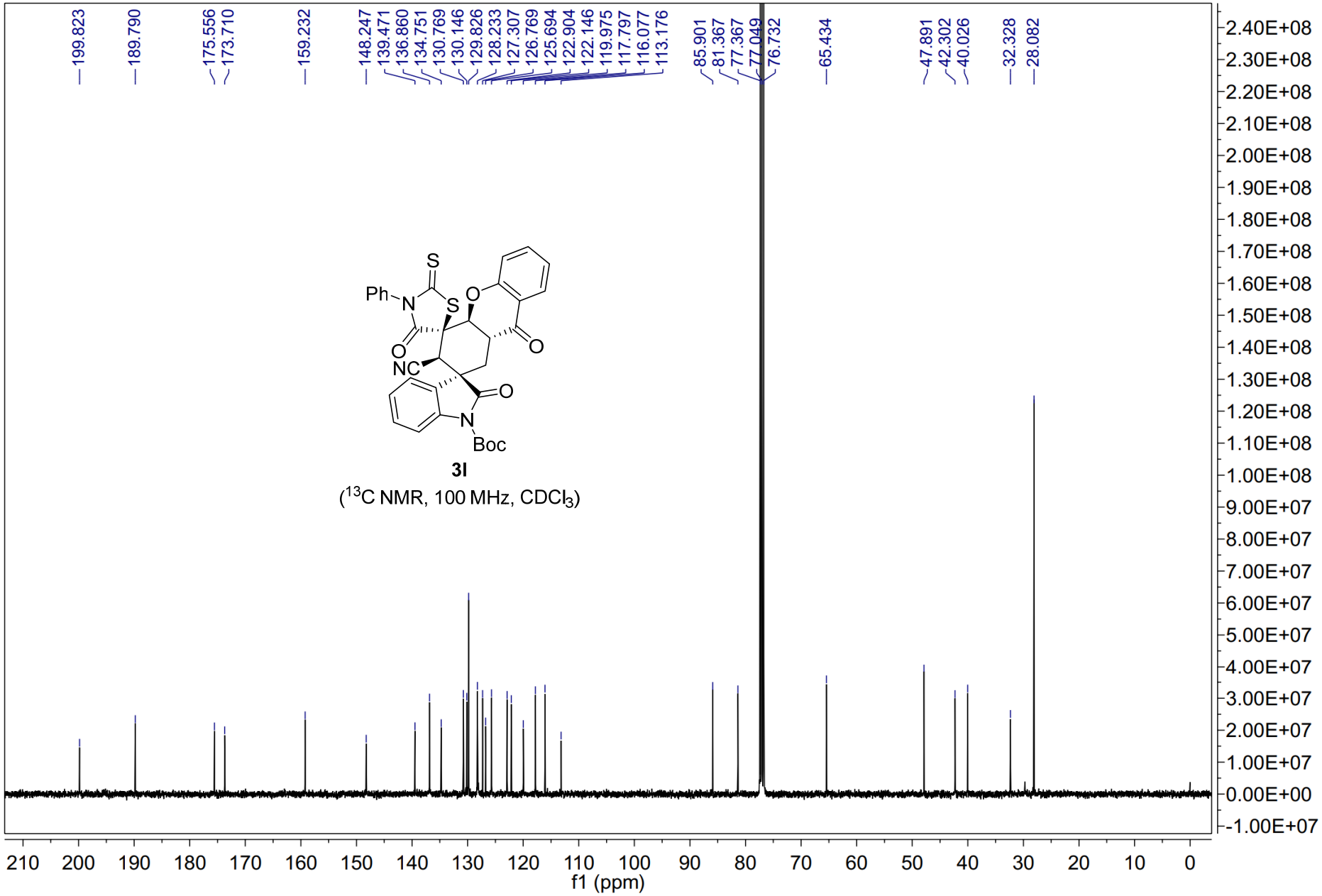

7.874
7.854
7.688
7.682
7.599
7.596
7.578
7.559
7.538
7.534
7.516
7.498
7.422
7.416
7.400
7.394
7.368
7.354
7.340
7.323
7.257
7.194
7.186
7.181
7.179
6.915
6.893
4.923
4.889
4.157
4.095
4.067
4.049
4.028
4.010
3.983
3.752
3.744
3.723
3.710
3.689
3.680
2.920
2.903
2.886
2.869
2.851
2.675
2.666
2.637
2.629
1.816
1.786
1.778
1.748
1.673
1.228
1.211
1.074
1.056
1.038
-0.000
Ph
N
S
S
O
O
O
EtO2C
O
N
Boc
iPr
3k
(1H NMR, 400 MHz, CDCl3)
1.01
1.00
2.01
1.05
1.00
3.00
2.00
1.00
1.00
1.00
2.00
1.02
1.00
1.00
1.03
9.00
6.01
3.00
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


202.097
190.638
177.309
176.117
166.860
157.777
148.874
143.137
139.432
135.432
135.271
130.842
129.662
129.546
129.015
128.063
124.721
124.091
121.029
119.660
117.632
115.379
84.873
82.725
77.318
77.000
76.682
65.641
62.704
53.100
47.076
39.587
33.833
33.252
28.072
23.812
23.769
13.559
Ph
N
S
S
O
O
O
O
EtO2C
O
N
Boc
iPr
3k
(13C NMR, 100 MHz, CDCl3)
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



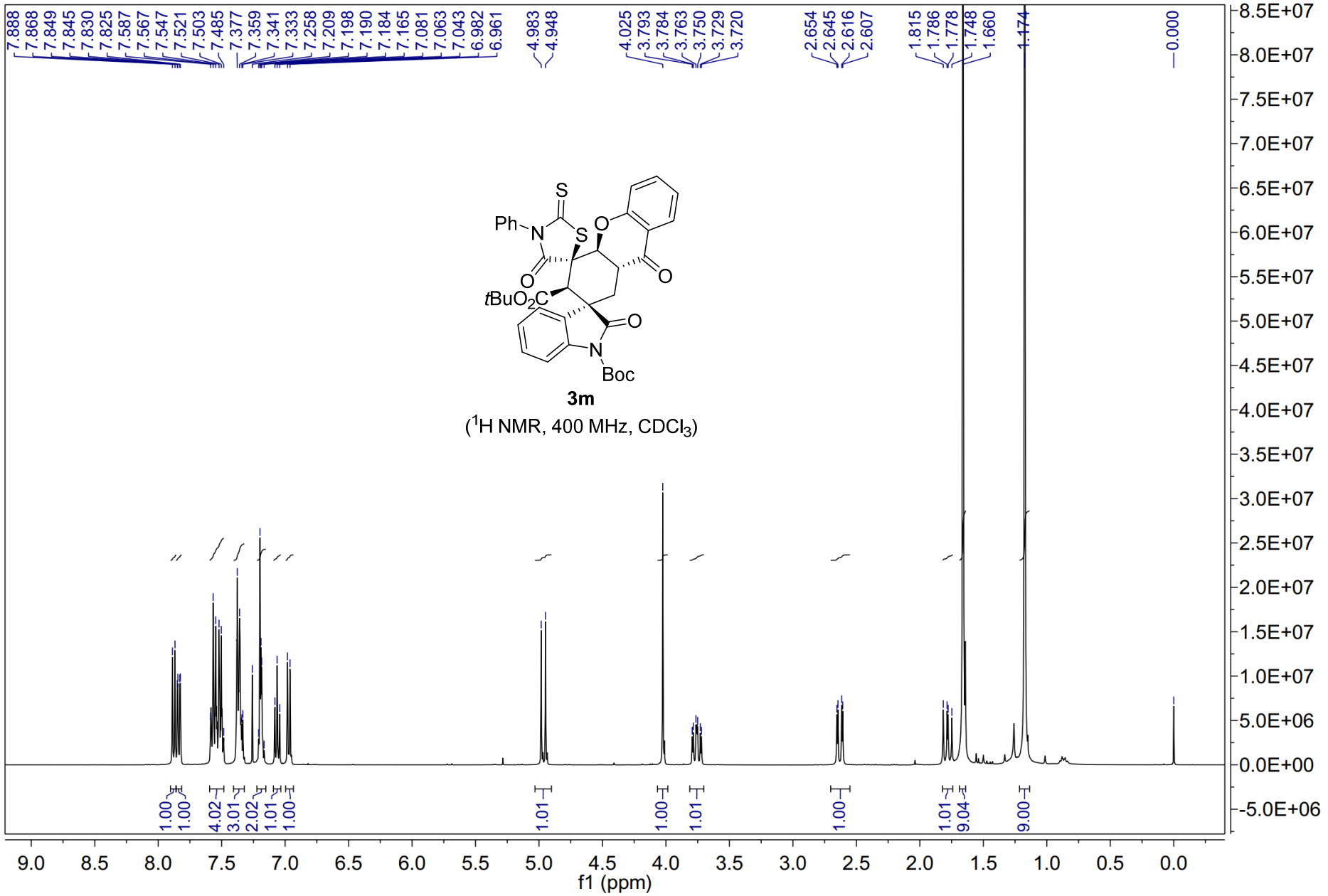
3l

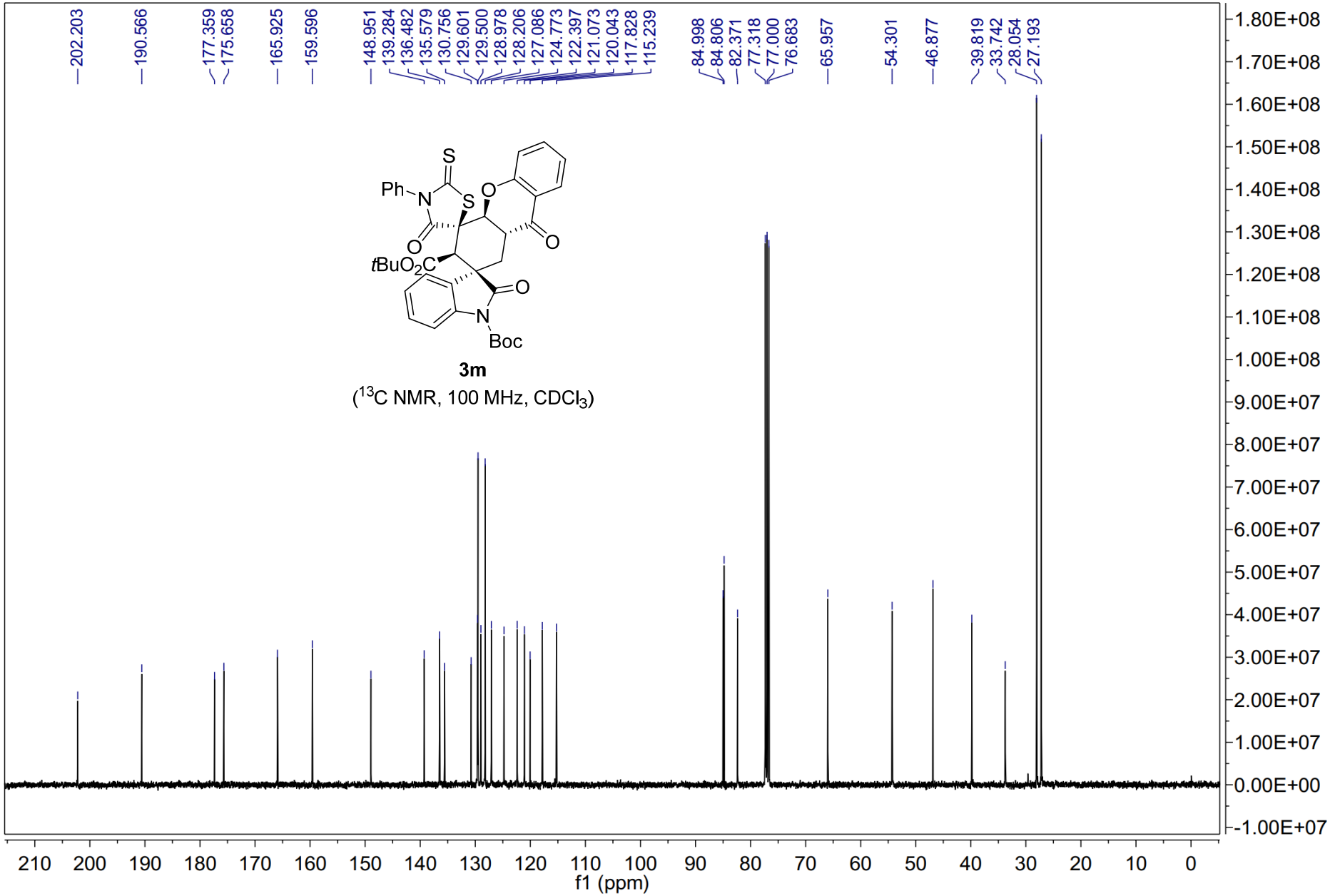
(^{1}H NMR, 400 MHz, $CDCl_3$)



3l

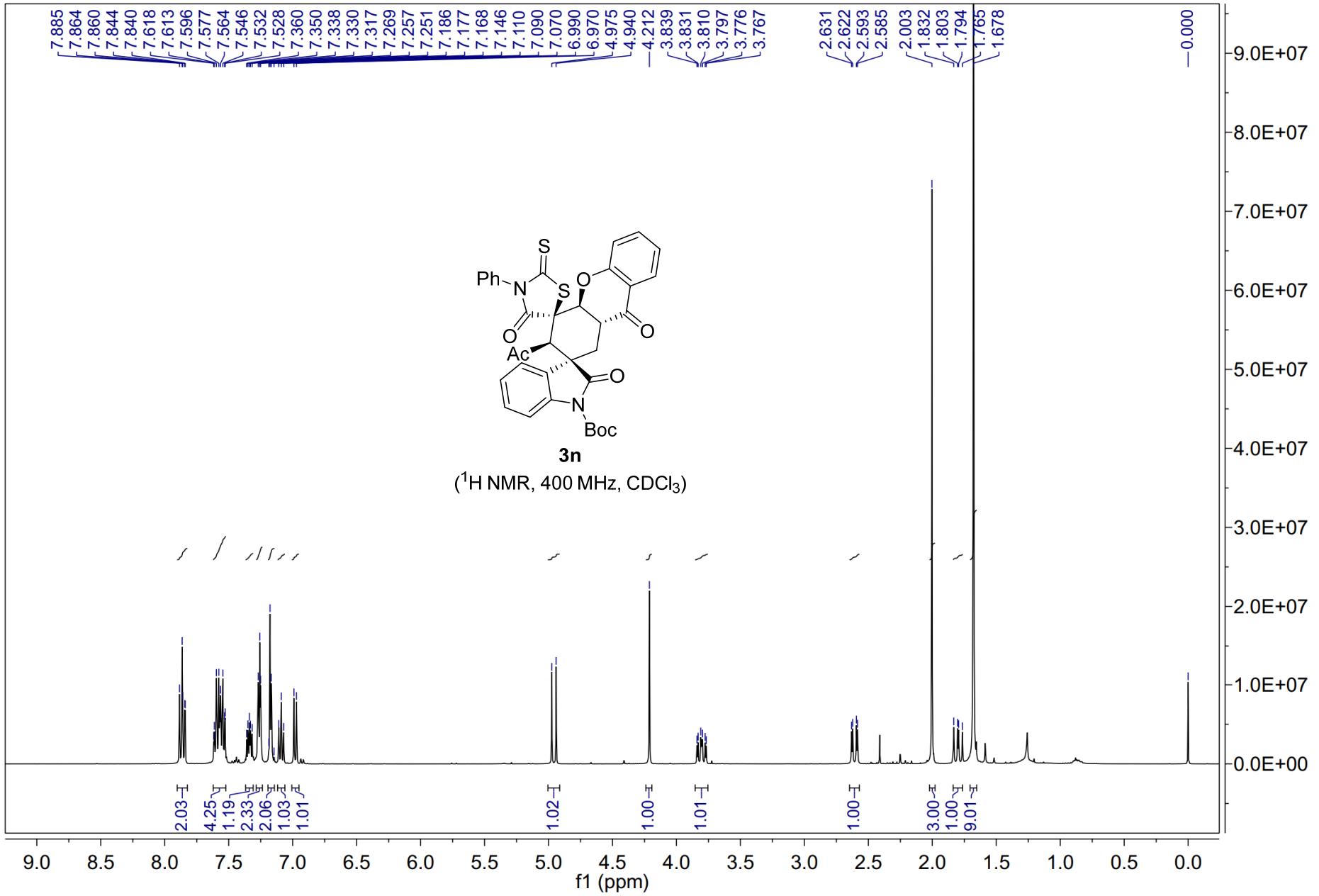
(^{13}C NMR, 100 MHz, $CDCl_3$)

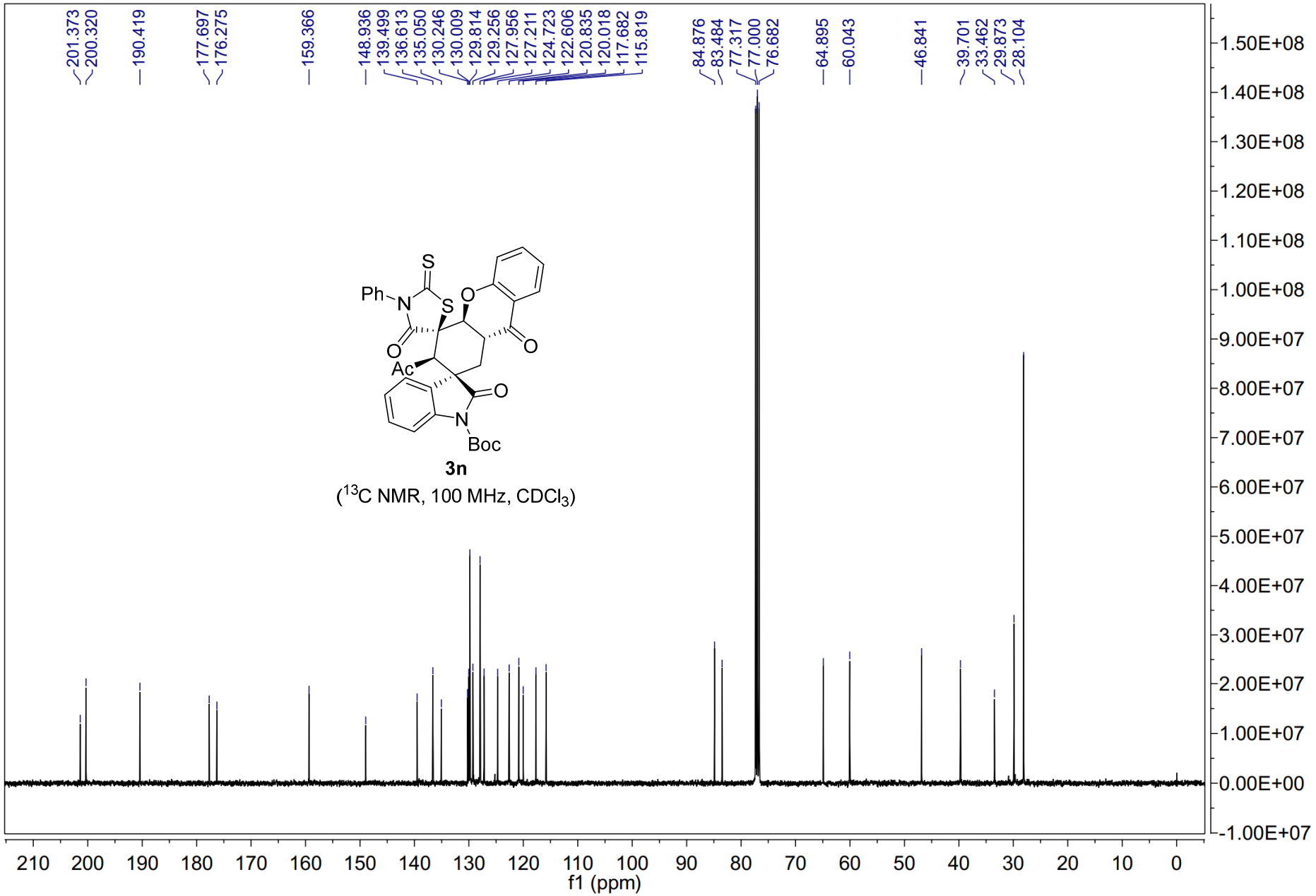

7.888
7.868
7.849
7.845
7.830
7.825
7.587
7.567
7.547
7.521
7.503
7.485
7.377
7.359
7.341
7.333
7.258
7.209
7.198
7.190
7.184
7.165
7.081
7.063
7.043
6.982
6.961
4.983
4.948
4.025
3.793
3.784
3.763
3.750
3.729
3.720
2.654
2.645
2.616
2.607
1.815
1.786
1.778
1.748
1.660
1.174
0.000
Ph
N
S
S
O
O
O
O
tBuO2C
O
N
Boc
3m
(1H NMR, 400 MHz, CDCl3)
1.00
1.00
4.02
3.01
2.02
1.01
1.00
1.01
1.00
1.00
1.01
1.01
9.04
9.00
f1 (ppm)



3m

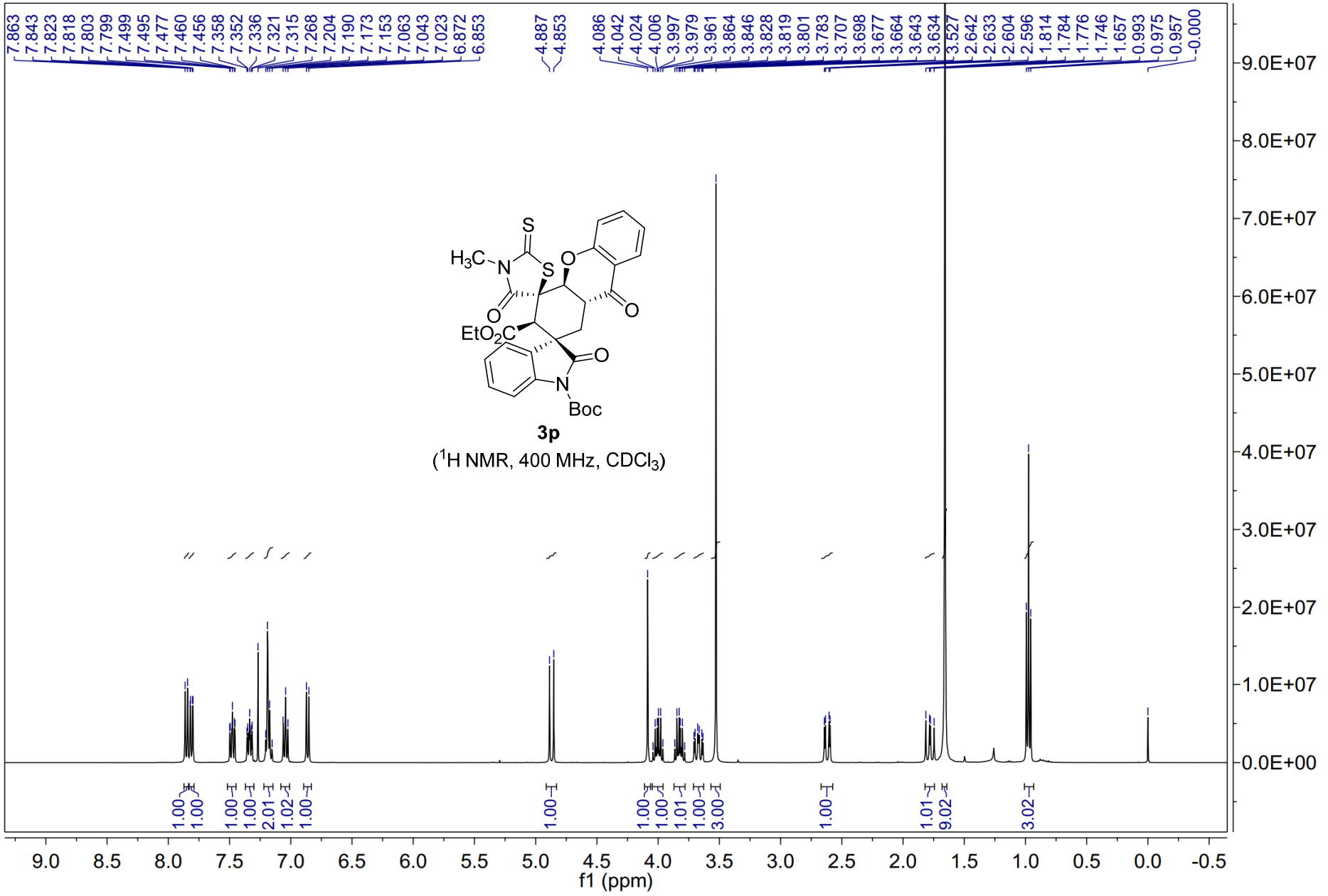
(^{13}C NMR, 100 MHz, $CDCl_3$)


7.885
7.864
7.860
7.844
7.840
7.618
7.613
7.596
7.577
7.564
7.546
7.532
7.528
7.360
7.350
7.338
7.330
7.317
7.269
7.257
7.251
7.186
7.177
7.168
7.146
7.110
7.090
7.070
6.990
6.970
4.975
4.940
4.212
3.839
3.831
3.810
3.797
3.776
3.767
2.631
2.622
2.593
2.585
2.003
1.832
1.803
1.794
1.765
1.678
0.000
S
Ph
N
S
O
O
O
Ac
O
N
Boc
3n
(1H NMR, 400 MHz, CDCl3)
9.0E+07
8.0E+07
7.0E+07
6.0E+07
5.0E+07
4.0E+07
3.0E+07
2.0E+07
1.0E+07
0.0E+00
2.03
4.25
1.19
2.33
2.06
1.03
1.01
1.02
1.00
1.01
1.00
3.00
1.00
9.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)



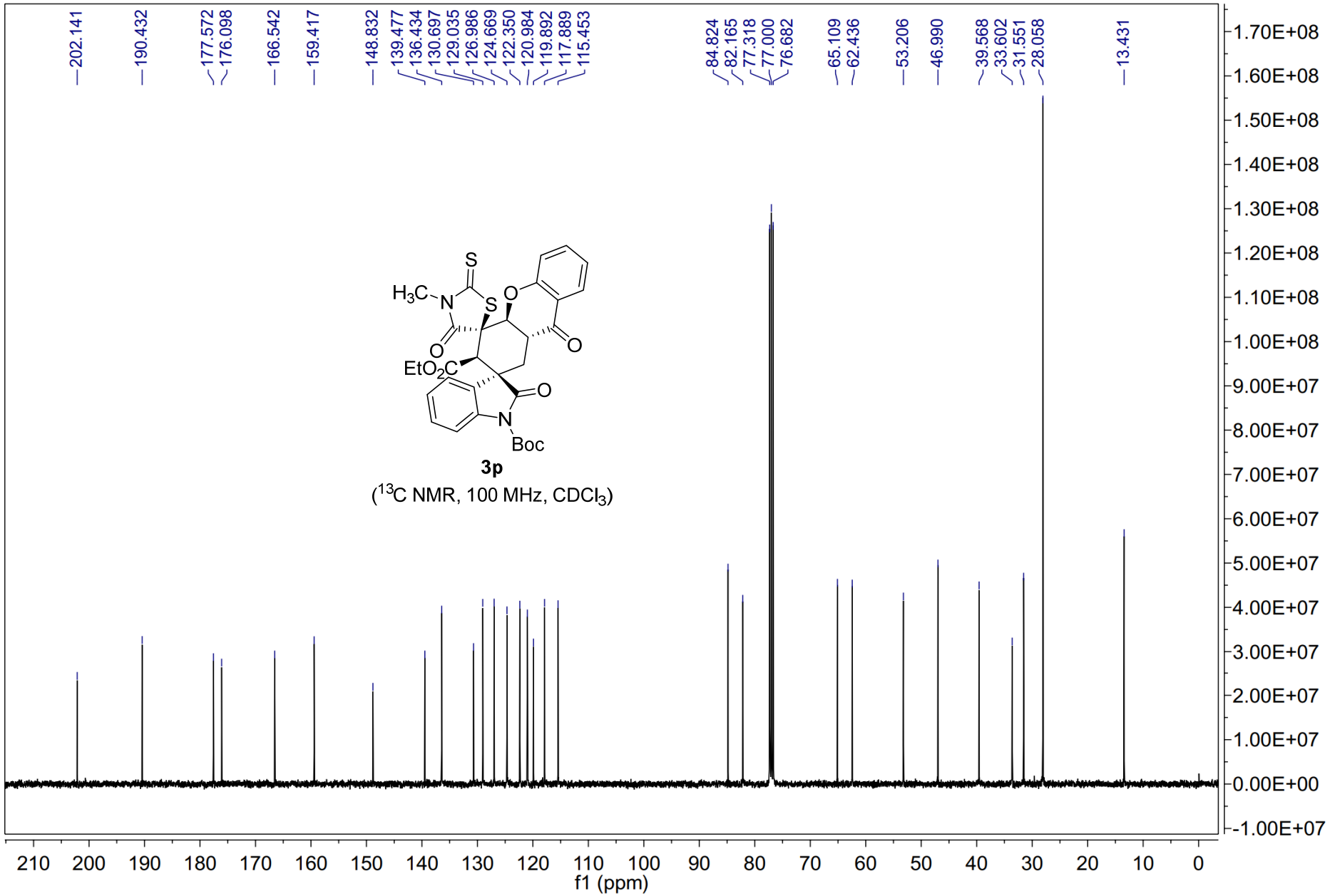
3n

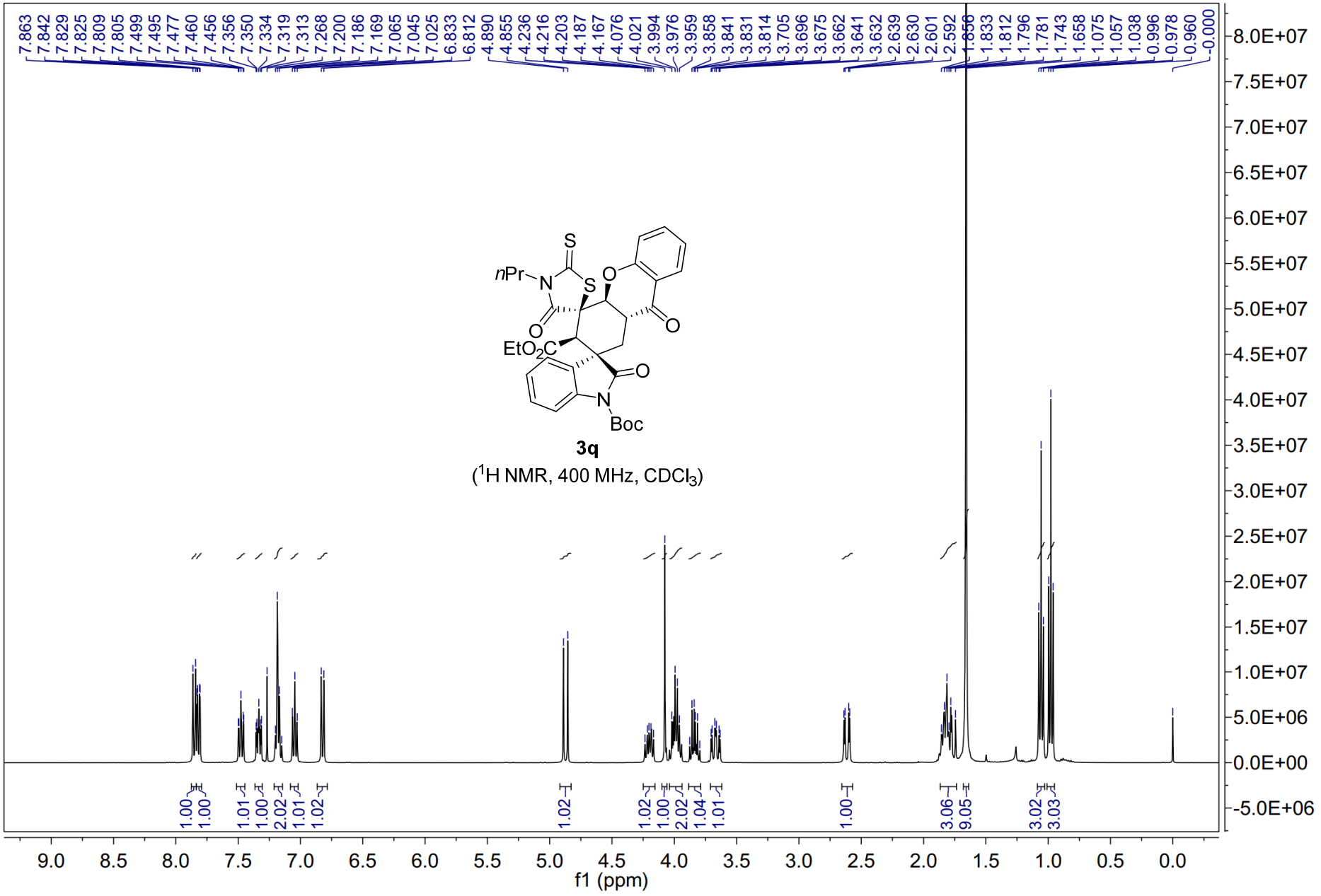
(^{13}C NMR, 100 MHz, $CDCl_3$)

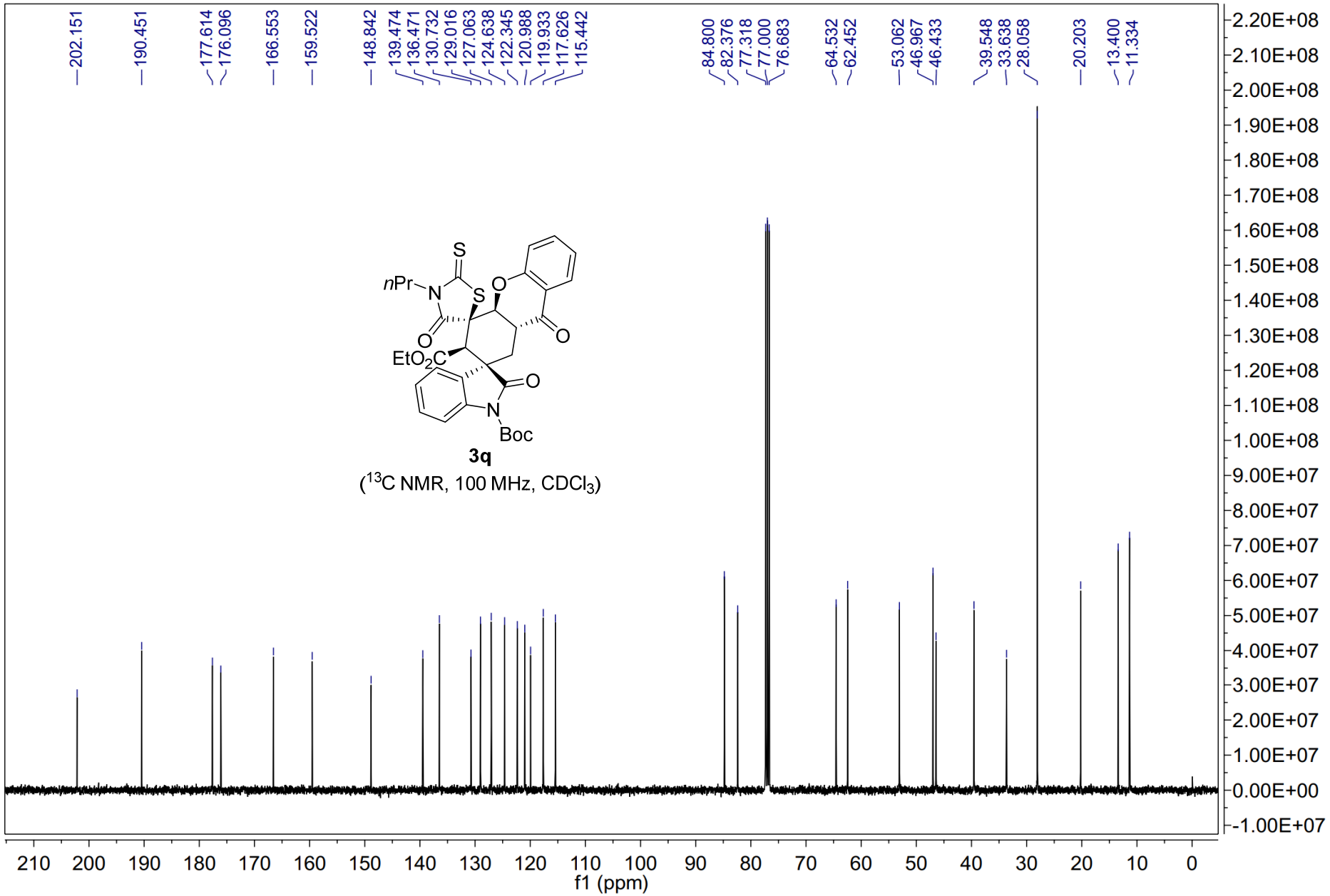


3p

(^{1}H NMR, 400 MHz, $CDCl_3$)

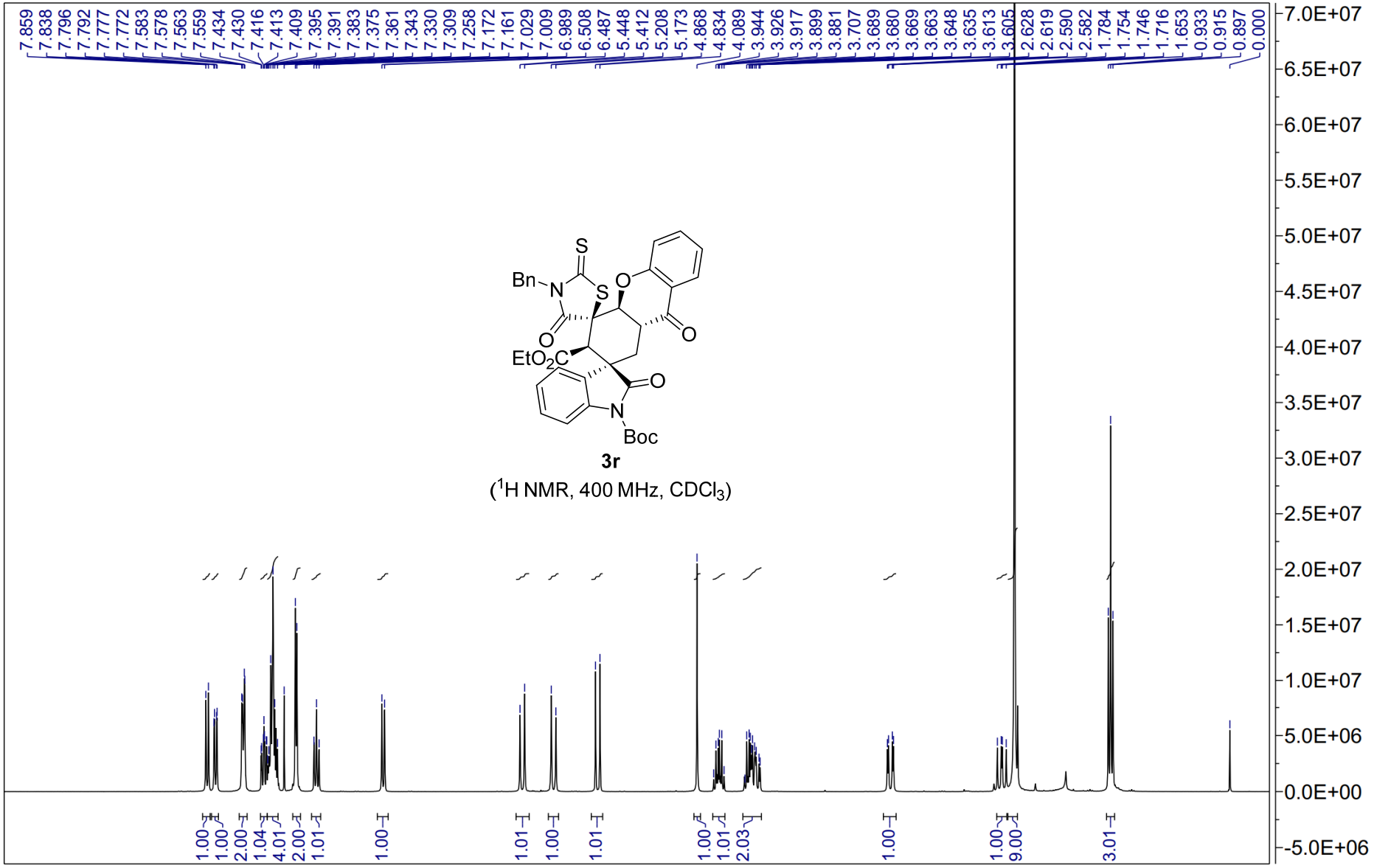

202.141
190.432
177.572
176.098
166.542
159.417
148.832
139.477
136.434
130.697
129.035
126.986
124.669
122.350
120.984
119.892
117.889
115.453
84.824
82.165
77.318
77.000
76.682
65.109
62.436
53.206
46.990
39.568
33.602
31.551
28.058
13.431
S
H3C
N
S
O
O
O
EtO2C
O
N
Boc
3p
(13C NMR, 100 MHz, CDCl3)
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

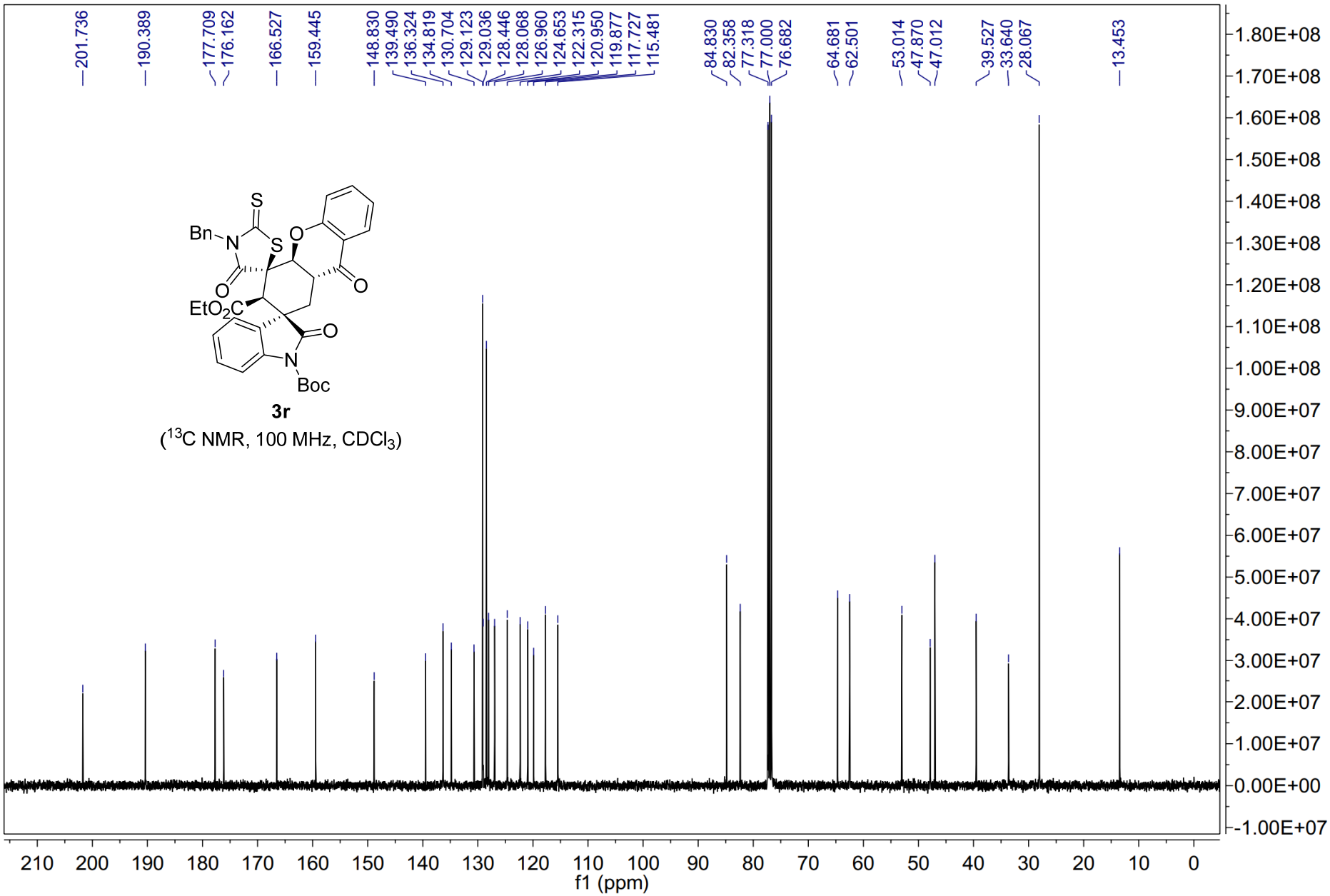

7.863
7.842
7.829
7.825
7.809
7.805
7.499
7.495
7.477
7.460
7.456
7.356
7.350
7.334
7.319
7.313
7.268
7.200
7.186
7.169
7.065
7.045
7.025
6.833
6.812
4.890
4.855
4.236
4.216
4.203
4.187
4.167
4.076
4.021
3.994
3.976
3.959
3.858
3.841
3.831
3.814
3.705
3.696
3.675
3.662
3.641
3.632
2.639
2.630
2.601
2.592
1.856
1.833
1.812
1.796
1.781
1.743
1.658
1.075
1.057
1.038
0.996
0.978
0.960
-0.000
nPr
N
S
S
O
O
O
EtO2C
O
N
Boc
3q
(1H NMR, 400 MHz, CDCl3)
1.00
1.00
1.01
1.00
2.02
1.01
1.02
1.02
1.02
1.00
2.02
1.04
1.01
1.00
3.06
9.05
3.02
3.03
8.0E+07
7.5E+07
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3q

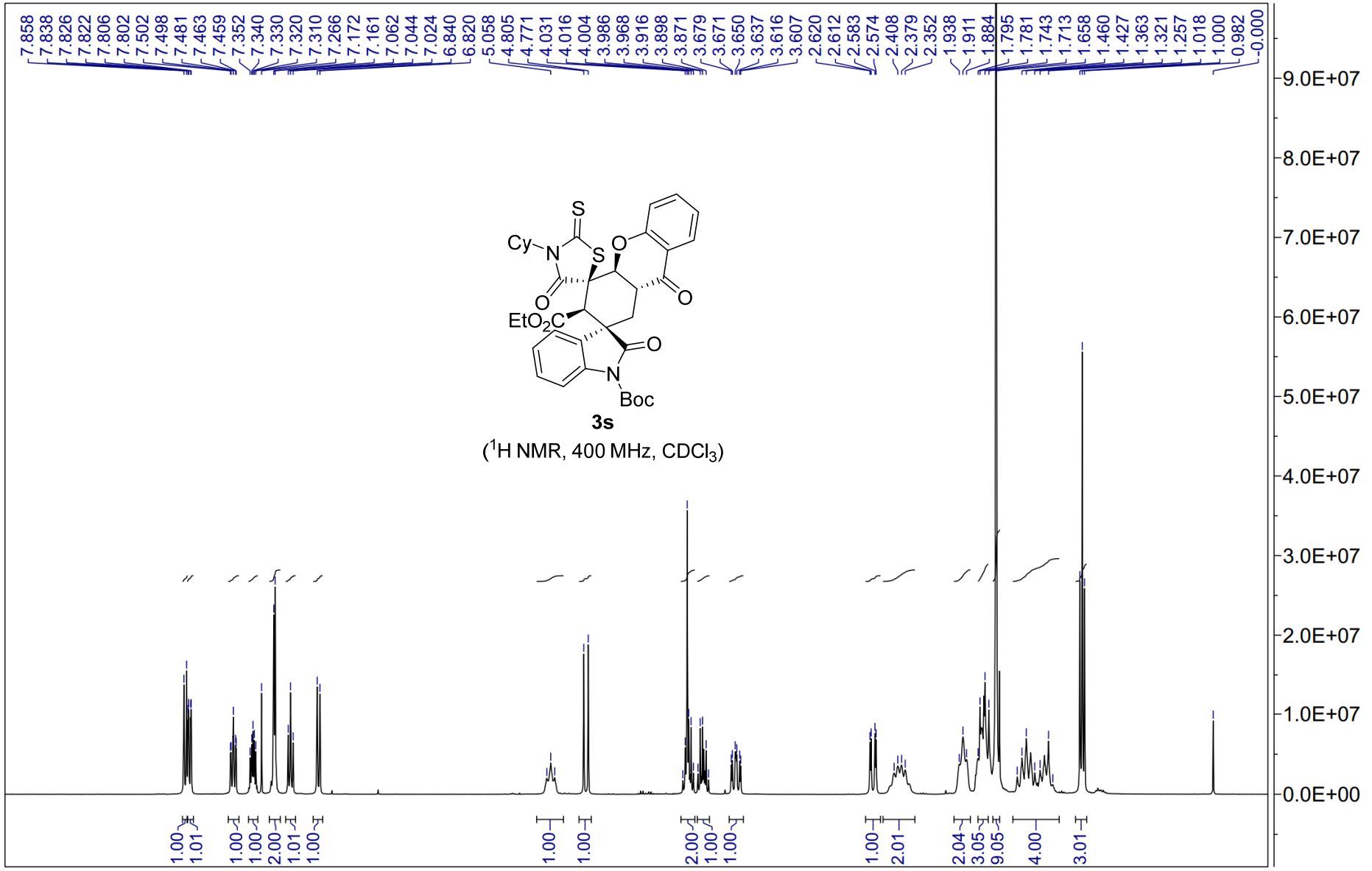
(^{13}C NMR, 100 MHz, $CDCl_3$)

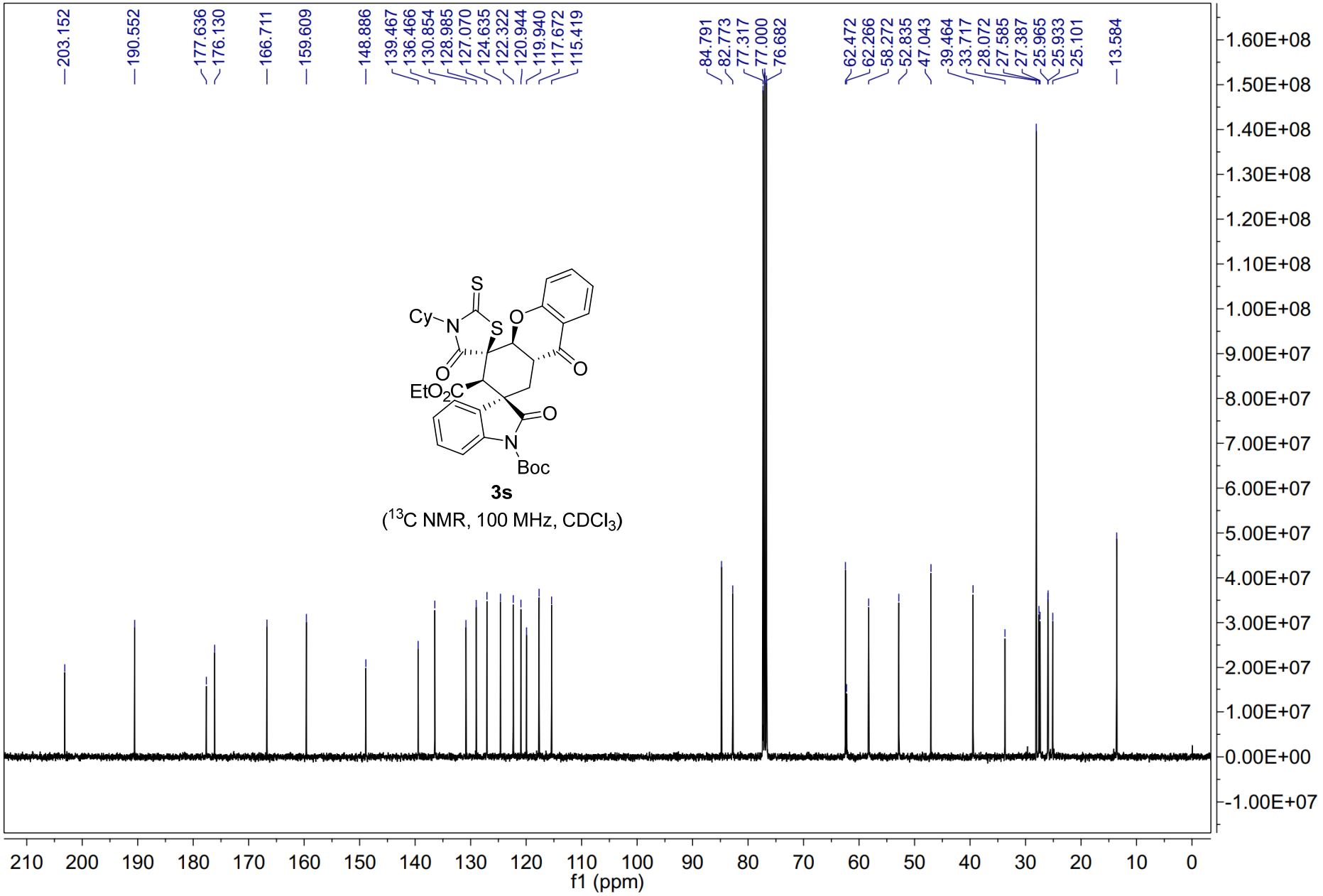

7.859
7.838
7.796
7.792
7.777
7.772
7.583
7.578
7.563
7.559
7.434
7.430
7.416
7.413
7.409
7.395
7.391
7.383
7.375
7.361
7.343
7.330
7.309
7.258
7.172
7.161
7.029
7.009
6.989
6.508
6.487
5.448
5.412
5.208
5.173
4.868
4.834
4.089
3.944
3.926
3.917
3.899
3.881
3.707
3.689
3.680
3.669
3.663
3.648
3.635
3.613
3.605
2.628
2.619
2.590
2.582
1.784
1.754
1.746
1.716
1.653
0.933
0.915
0.897
0.000
Bn
N
S
S
O
O
O
O
EtO2C
O
N
Boc
3r
(1H NMR, 400 MHz, CDCl3)
1.00
1.00
2.00
1.04
4.01
2.00
1.01
1.00
1.01
1.00
1.01
1.00
1.01
2.03
1.00
1.00
9.00
3.01
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3r

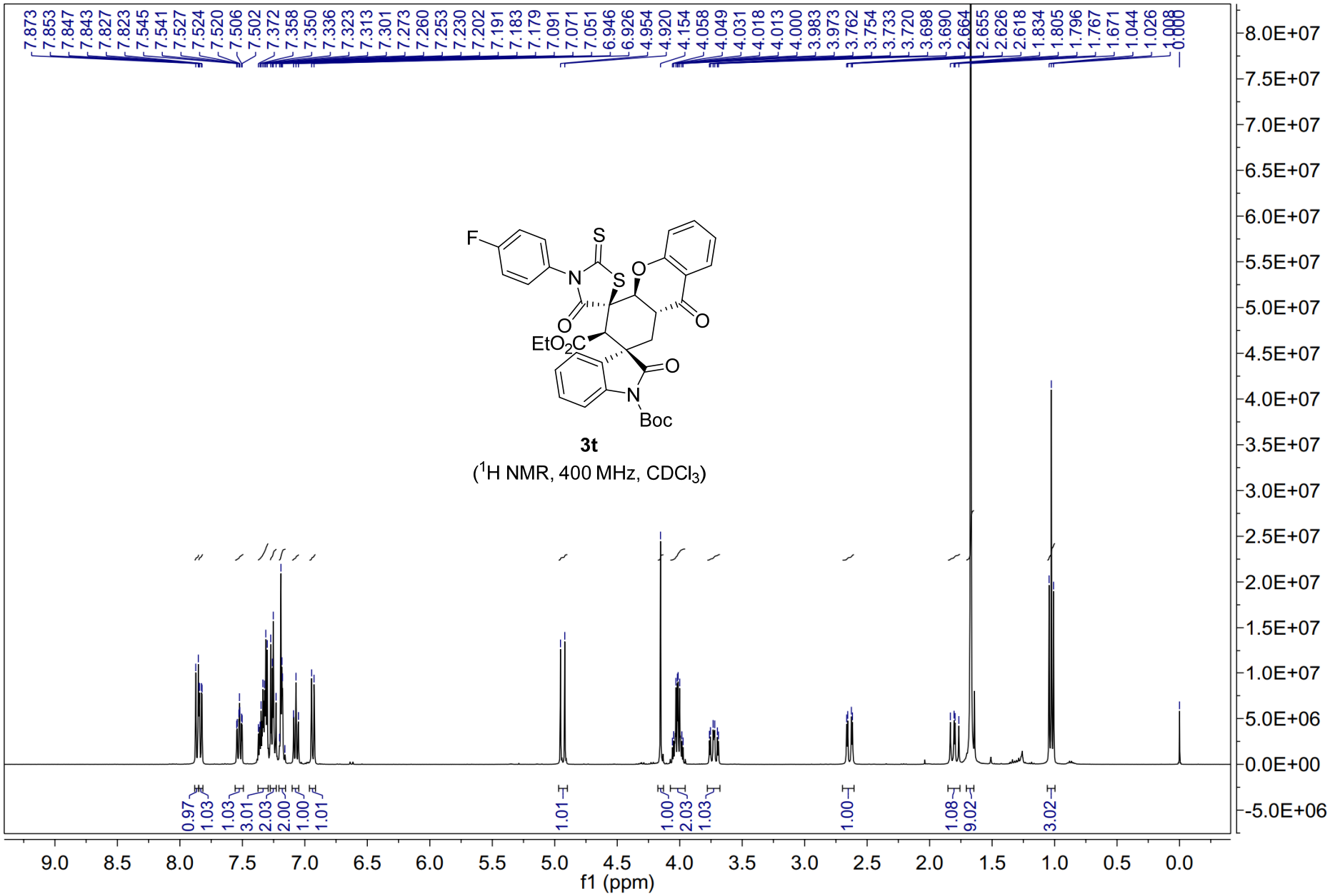
(^{13}C NMR, 100 MHz, $CDCl_3$)

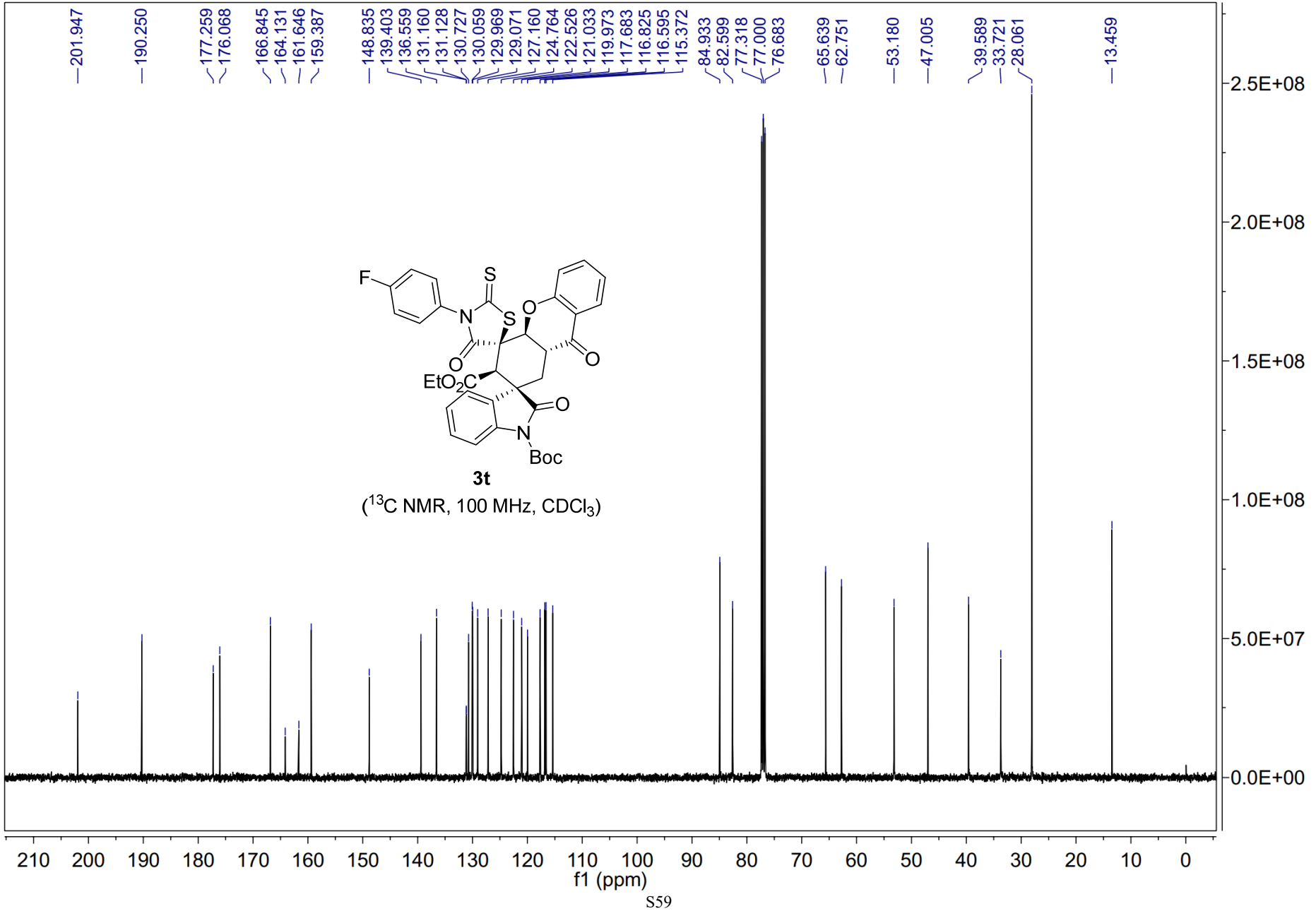

7.858
7.838
7.826
7.822
7.806
7.802
7.502
7.498
7.481
7.463
7.459
7.352
7.340
7.330
7.320
7.310
7.266
7.172
7.161
7.062
7.044
7.024
6.840
6.820
5.058
4.805
4.771
4.031
4.016
4.004
3.986
3.968
3.916
3.898
3.871
3.679
3.671
3.650
3.637
3.616
3.607
2.620
2.612
2.583
2.574
2.408
2.379
2.352
1.938
1.911
1.884
1.795
1.781
1.743
1.713
1.658
1.460
1.427
1.363
1.321
1.257
1.018
1.000
0.982
-0.000
S
Cy
N
S
O
O
O
EtO2C
O
N
Boc
3s
(1H NMR, 400 MHz, CDCl3)
9.0E+07
8.0E+07
7.0E+07
6.0E+07
5.0E+07
4.0E+07
3.0E+07
2.0E+07
1.0E+07
0.0E+00
1.00
1.01
1.00
1.00
2.00
1.01
1.00
1.00
1.00
2.00
1.00
1.00
2.01
2.04
3.05
9.05
4.00
3.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3s

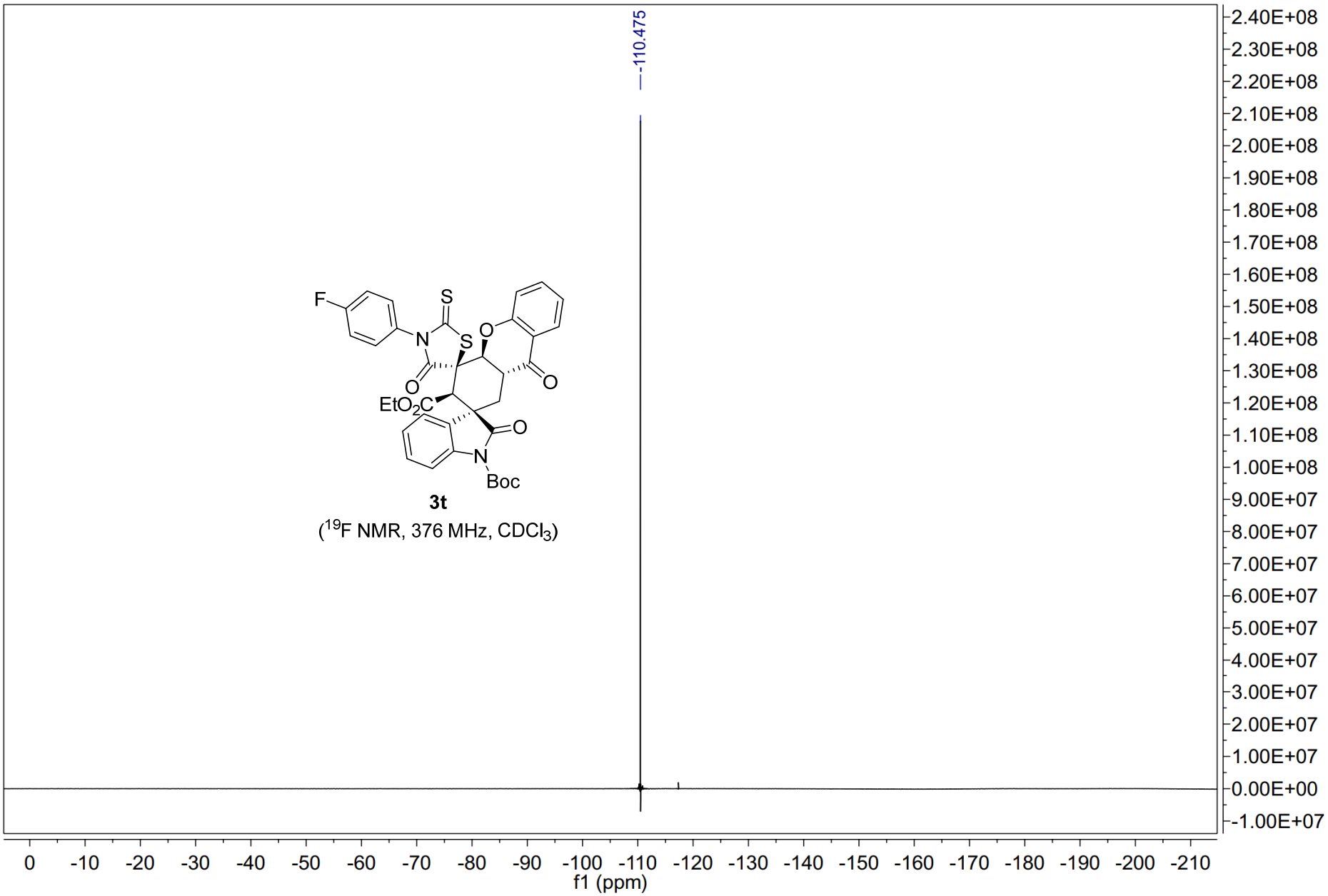
(^{13}C NMR, 100 MHz, $CDCl_3$)


7.873
7.853
7.847
7.843
7.827
7.823
7.545
7.541
7.527
7.524
7.520
7.506
7.502
7.372
7.358
7.350
7.336
7.323
7.313
7.301
7.273
7.260
7.253
7.230
7.202
7.191
7.183
7.179
7.091
7.071
7.051
6.946
6.926
6.954
4.920
4.154
4.058
4.049
4.031
4.018
4.013
4.000
3.983
3.973
3.762
3.754
3.733
3.720
3.698
3.690
2.664
2.655
2.626
2.618
1.834
1.805
1.796
1.767
1.671
1.044
1.026
0.000
F
S
N
S
O
O
O
EtO2C
O
N
Boc
3t
(1H NMR, 400 MHz, CDCl3)
0.97
1.03
1.03
3.01
2.03
2.00
1.00
1.01
1.01
1.00
2.03
1.03
1.00
1.08
9.02
3.02
8.0E+07
7.5E+07
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



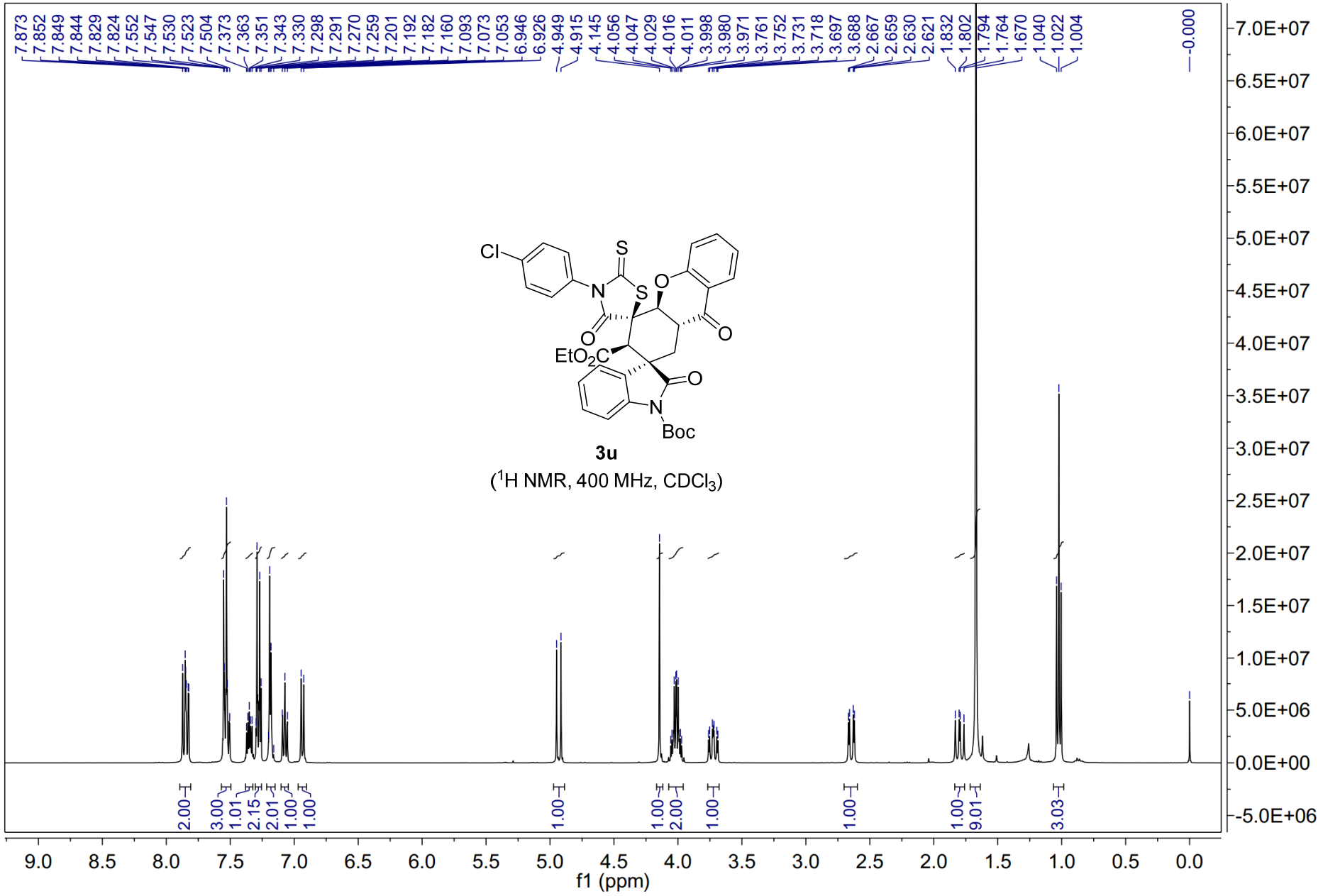
3t

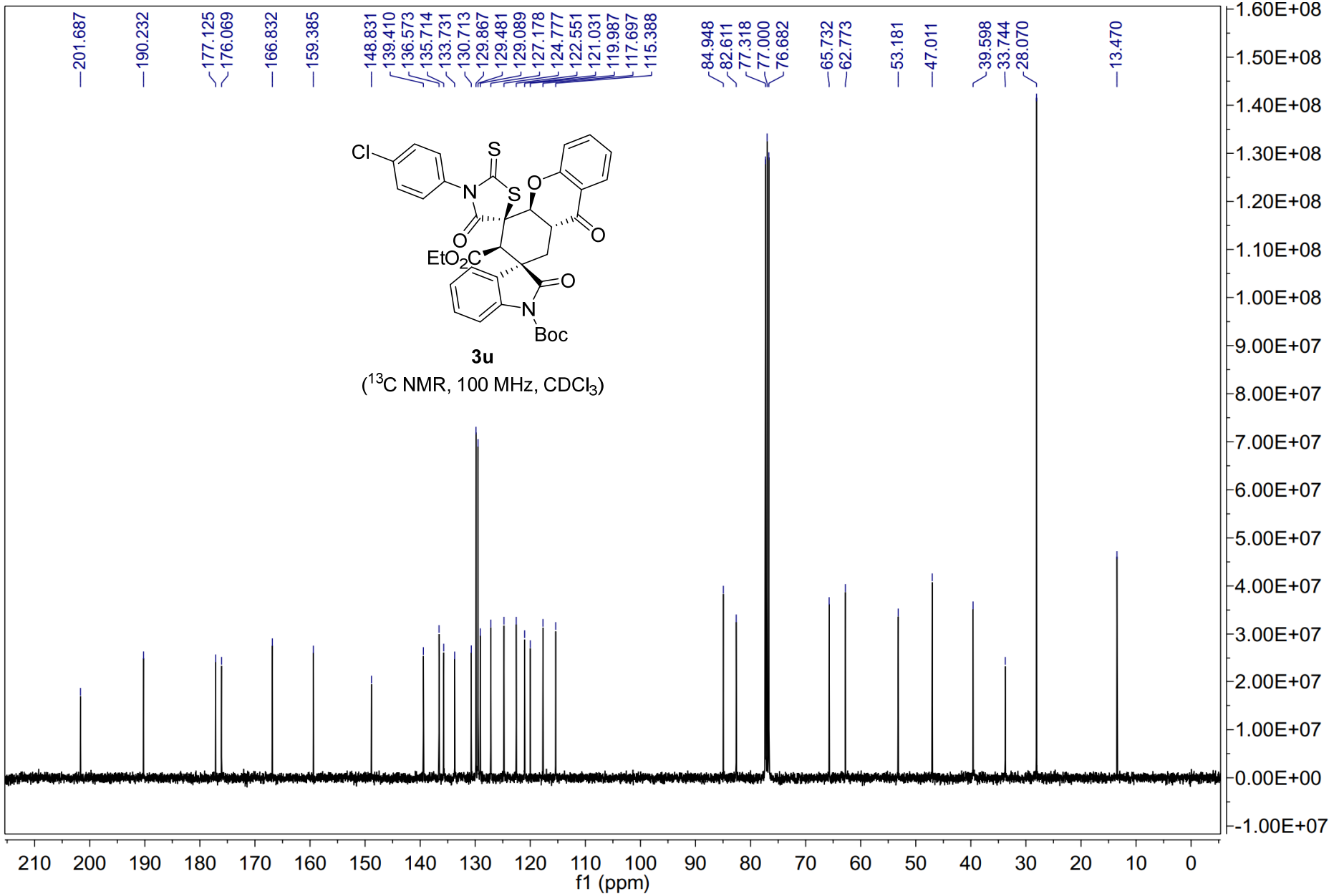
(^{13}C NMR, 100 MHz, $CDCl_3$)



3t

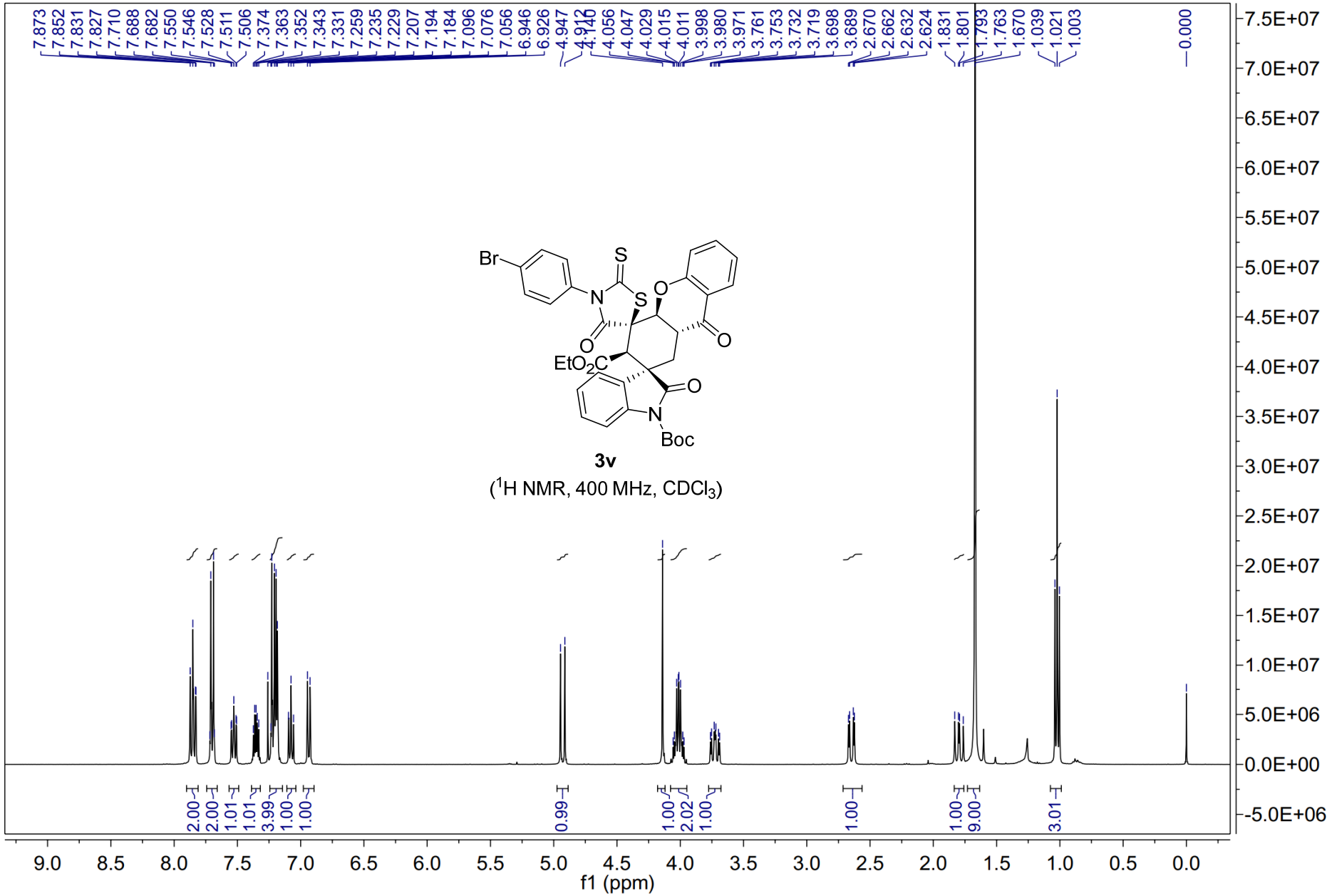
(^{19}F NMR, 376 MHz, $CDCl_3$)

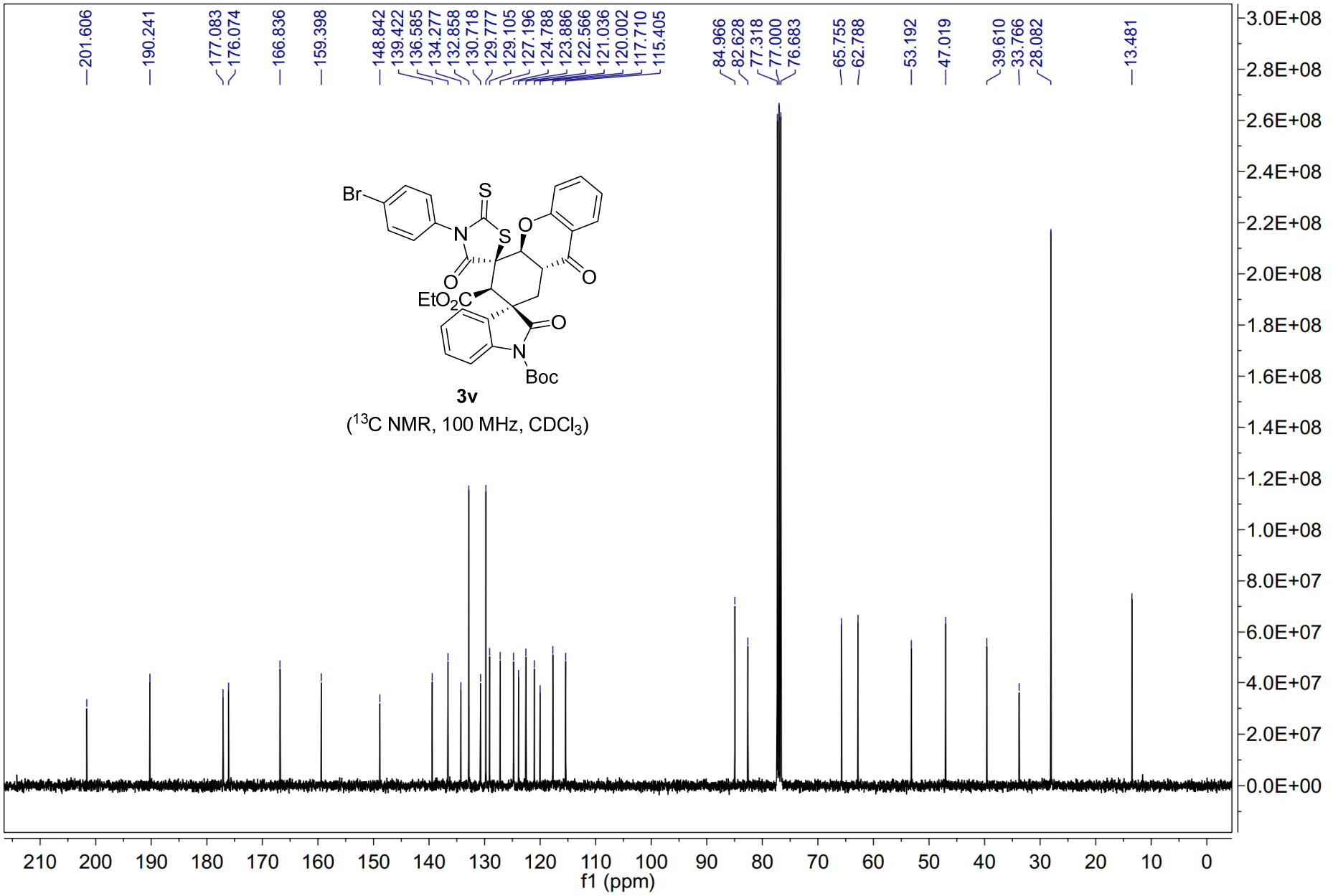

7.873
7.852
7.849
7.844
7.829
7.824
7.552
7.547
7.530
7.523
7.504
7.373
7.363
7.351
7.343
7.330
7.298
7.291
7.270
7.259
7.201
7.192
7.182
7.160
7.093
7.073
7.053
6.946
6.926
4.949
4.915
4.145
4.056
4.047
4.029
4.016
4.011
3.998
3.980
3.971
3.761
3.752
3.731
3.718
3.697
3.688
2.667
2.659
2.630
2.621
1.832
1.802
1.794
1.764
1.670
1.040
1.022
1.004
-0.000
Cl
S
N
S
O
O
O
EtO2C
O
N
Boc
3u
(1H NMR, 400 MHz, CDCl3)
2.00
3.00
1.01
2.15
2.01
1.00
1.00
1.00
1.00
2.00
1.00
1.00
1.00
9.01
3.03
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3u

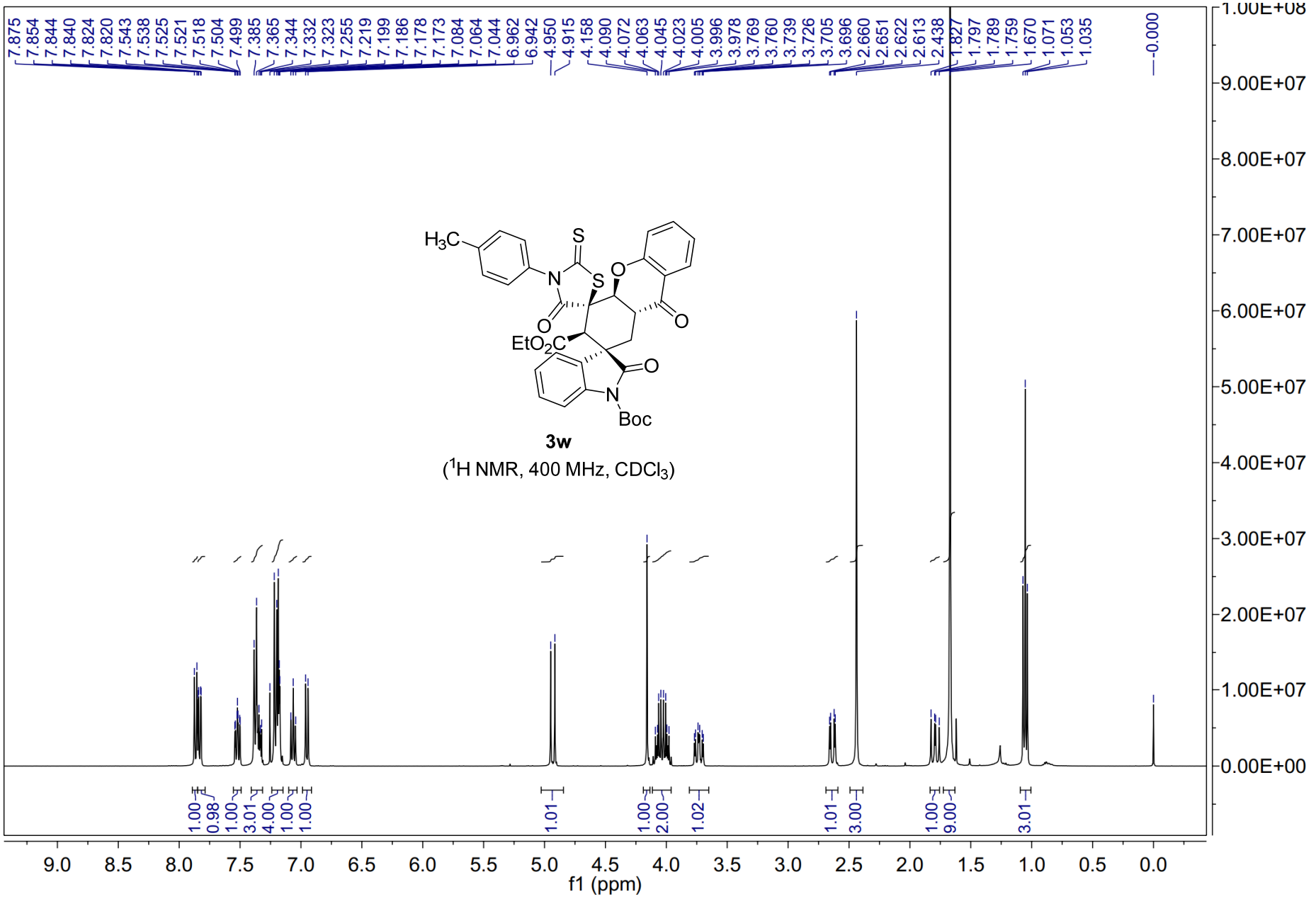
(^{13}C NMR, 100 MHz, $CDCl_3$)

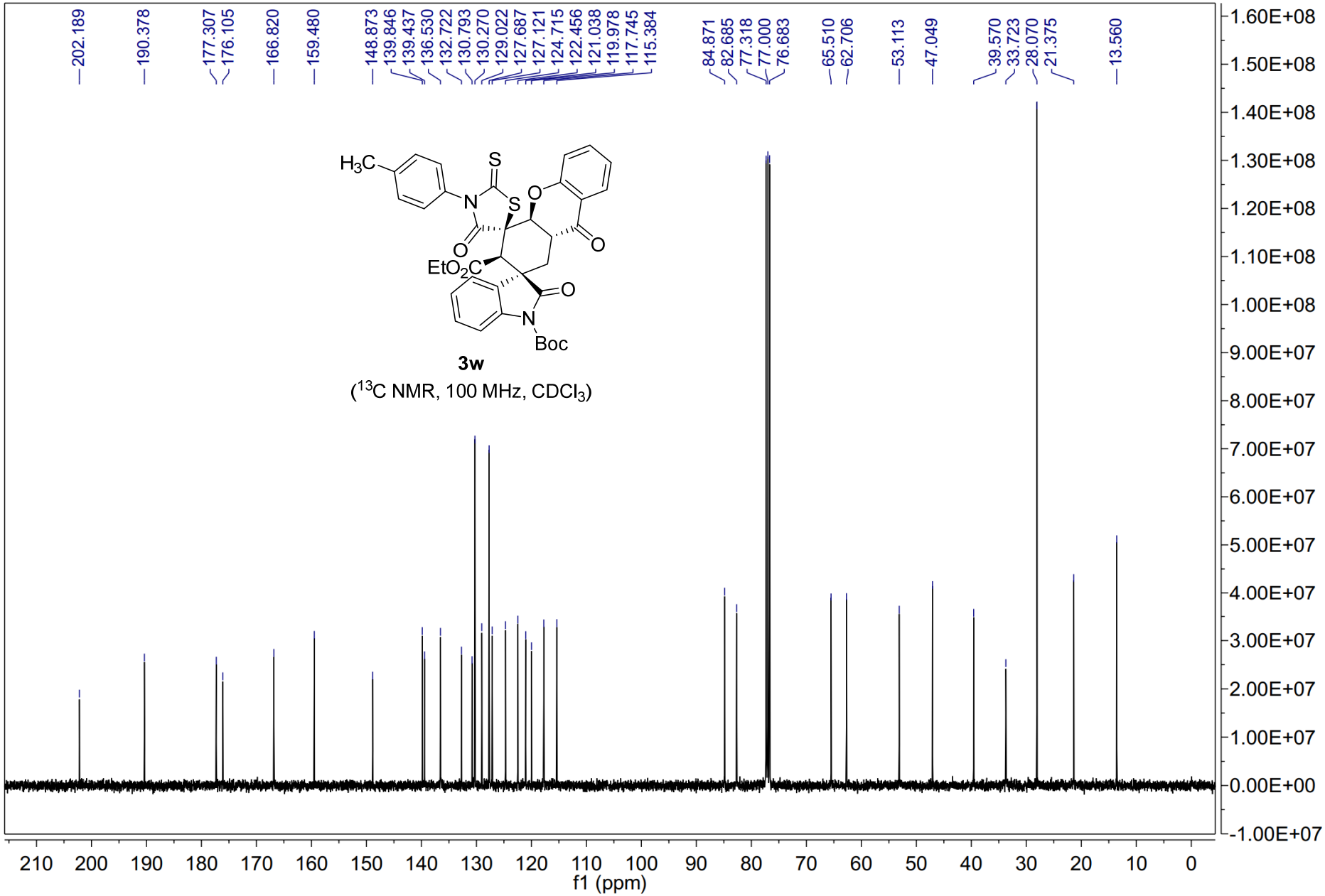

7.873
7.852
7.831
7.827
7.710
7.688
7.682
7.550
7.546
7.528
7.511
7.506
7.374
7.363
7.352
7.343
7.331
7.259
7.235
7.229
7.207
7.194
7.184
7.096
7.076
7.056
6.946
6.926
4.947
4.912
4.146
4.056
4.047
4.029
4.015
4.011
3.998
3.980
3.971
3.761
3.753
3.732
3.719
3.698
3.689
2.670
2.662
2.632
2.624
1.831
1.801
1.793
1.763
1.670
1.039
1.021
1.003
0.000
Br
S
N
S
O
O
O
EtO2C
O
N
Boc
3v
(1H NMR, 400 MHz, CDCl3)
2.00
2.00
1.01
1.01
3.99
1.00
1.00
0.99
1.00
2.02
1.00
1.00
1.00
9.00
3.01
7.5E+07
7.0E+07
6.5E+07
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

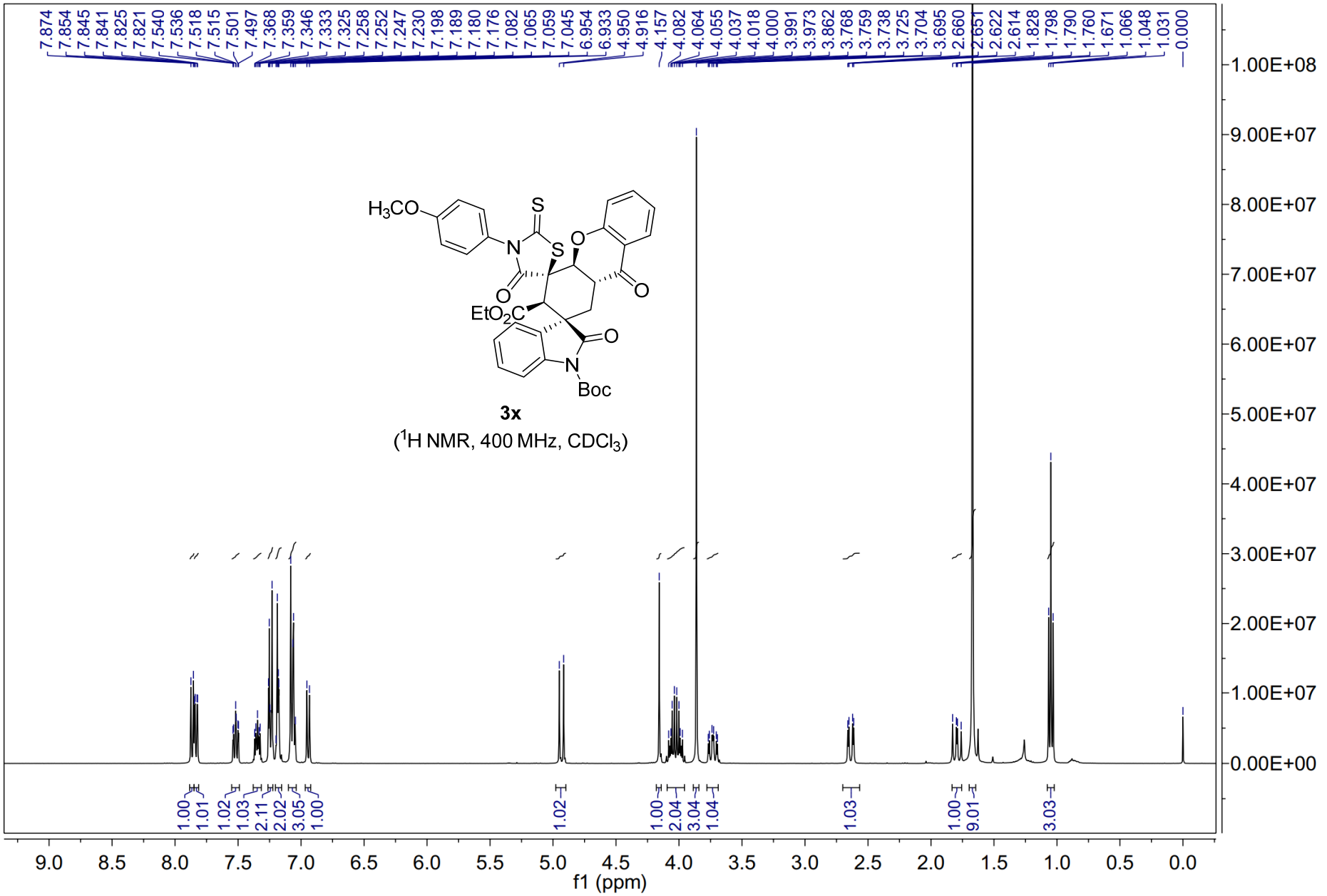


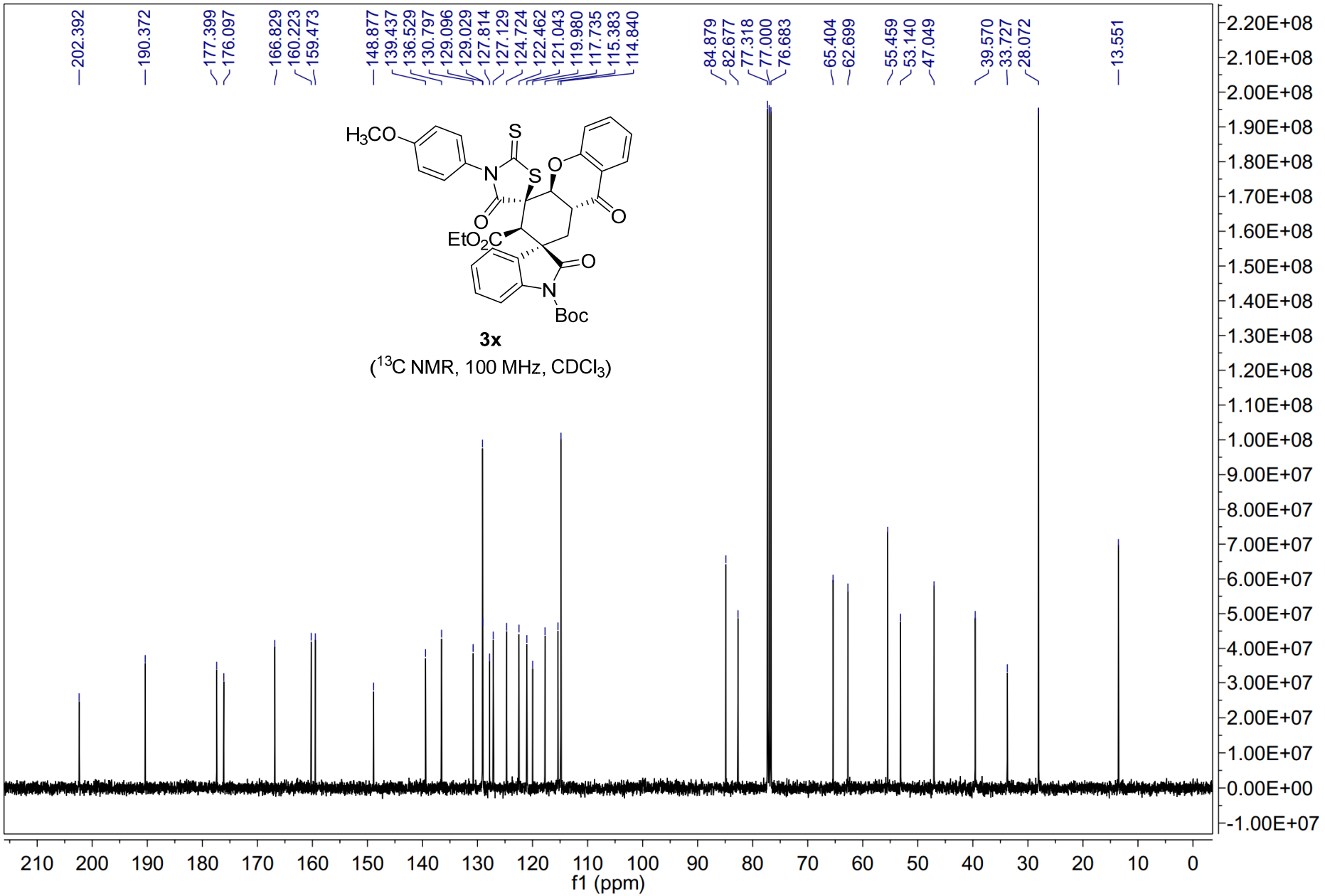
3v

(^{13}C NMR, 100 MHz, $CDCl_3$)


7.875
7.854
7.844
7.840
7.824
7.820
7.543
7.538
7.525
7.521
7.518
7.504
7.499
7.385
7.365
7.344
7.332
7.323
7.255
7.219
7.199
7.186
7.178
7.173
7.084
7.064
7.044
6.962
6.942
4.950
4.915
4.158
4.090
4.072
4.063
4.045
4.023
4.005
3.996
3.978
3.769
3.760
3.739
3.726
3.705
3.696
2.660
2.651
2.622
2.613
2.438
1.827
1.797
1.789
1.759
1.670
1.071
1.053
1.035
-0.000
H3C
S
N
S
O
O
O
EtO2C
O
N
Boc
3w
(1H NMR, 400 MHz, CDCl3)
1.00
0.98
1.00
3.01
4.00
1.00
1.00
1.01
1.00
2.00
1.02
1.01
3.00
1.00
9.00
3.01
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

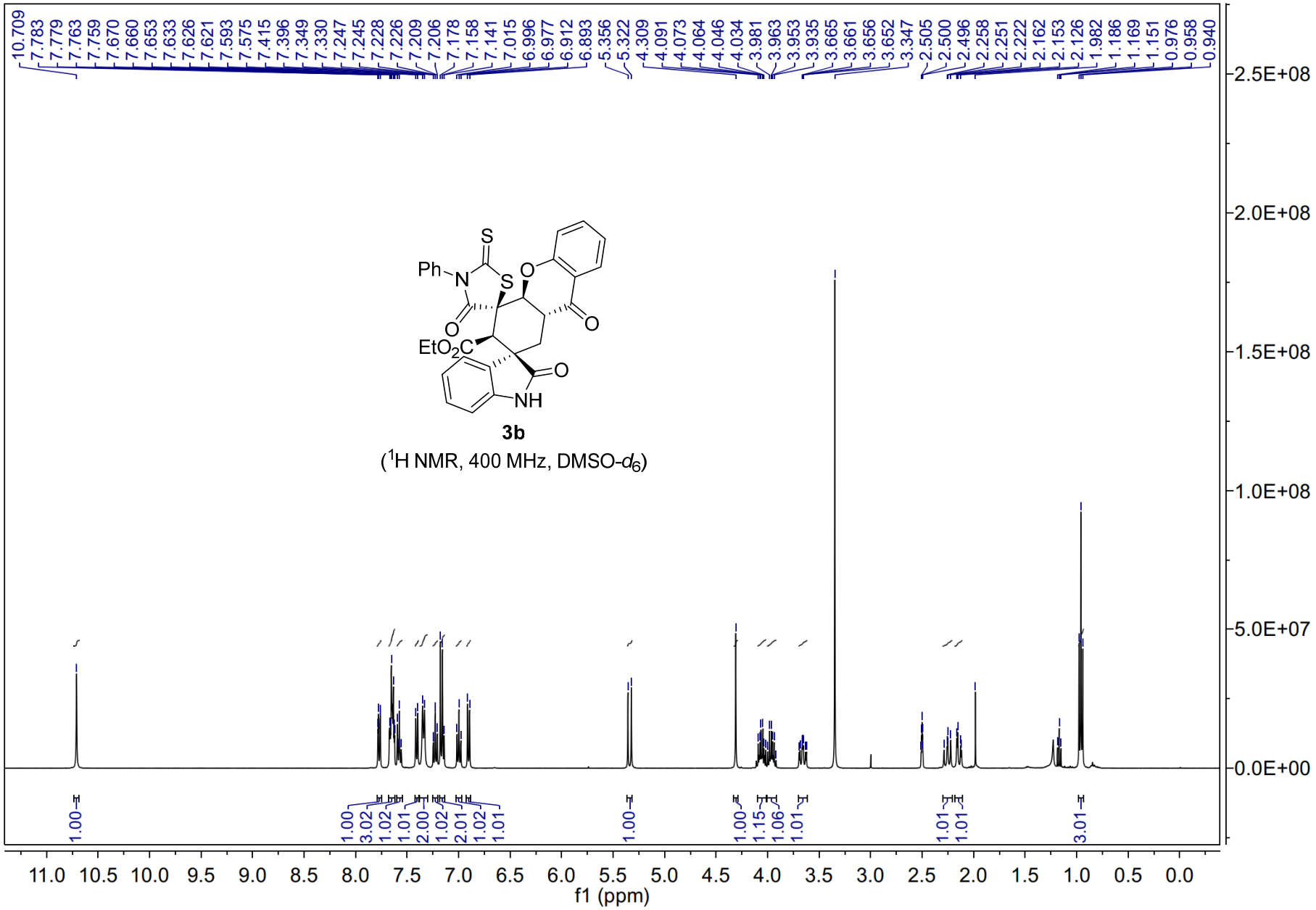

202.189
190.378
177.307
176.105
166.820
159.480
148.873
139.846
139.437
136.530
132.722
130.793
130.270
129.022
127.687
127.121
124.715
122.456
121.038
119.978
117.745
115.384
84.871
82.685
77.318
77.000
76.683
65.510
62.706
53.113
47.049
39.570
33.723
28.070
21.375
13.560
H3C
S
N
S
O
O
O
EtO2C
O
N
Boc
3w
(13C NMR, 100 MHz, CDCl3)
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.874
7.854
7.845
7.841
7.825
7.821
7.540
7.536
7.518
7.515
7.501
7.497
7.368
7.359
7.346
7.333
7.325
7.258
7.252
7.247
7.230
7.198
7.189
7.180
7.176
7.082
7.065
7.059
7.045
6.954
6.933
6.950
4.916
4.157
4.082
4.064
4.055
4.037
4.018
4.000
3.991
3.973
3.862
3.768
3.759
3.738
3.725
3.704
3.695
2.660
2.651
2.622
2.614
1.828
1.798
1.790
1.760
1.671
1.066
1.048
1.031
0.000
H3CO
S
N
S
O
O
O
EtO2C
O
N
Boc
3x
(1H NMR, 400 MHz, CDCl3)
1.00
1.01
1.02
1.03
2.11
2.02
3.05
1.00
1.02
1.00
2.04
3.04
1.04
1.03
1.00
9.01
3.03
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



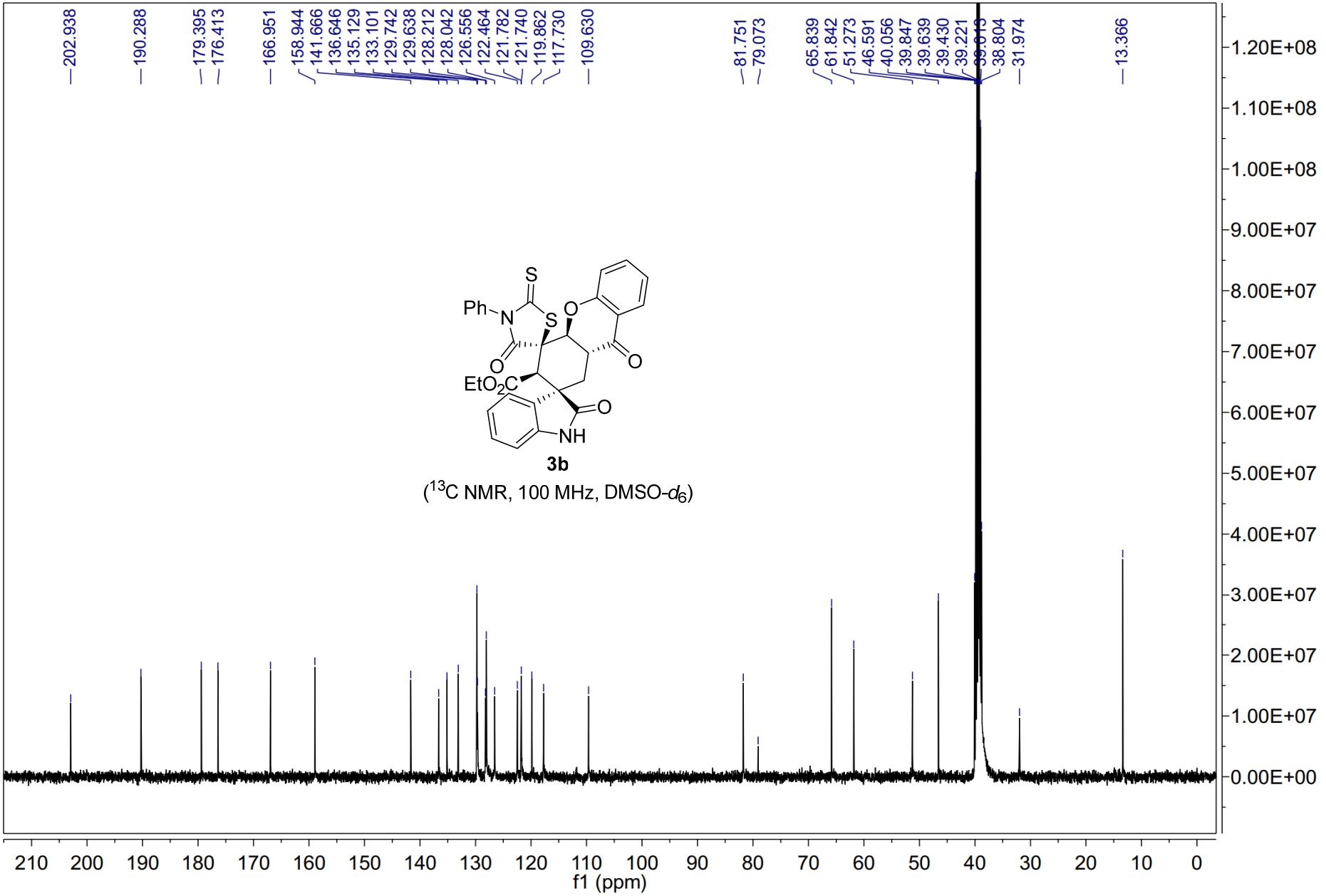
3x

(^{13}C NMR, 100 MHz, $CDCl_3$)



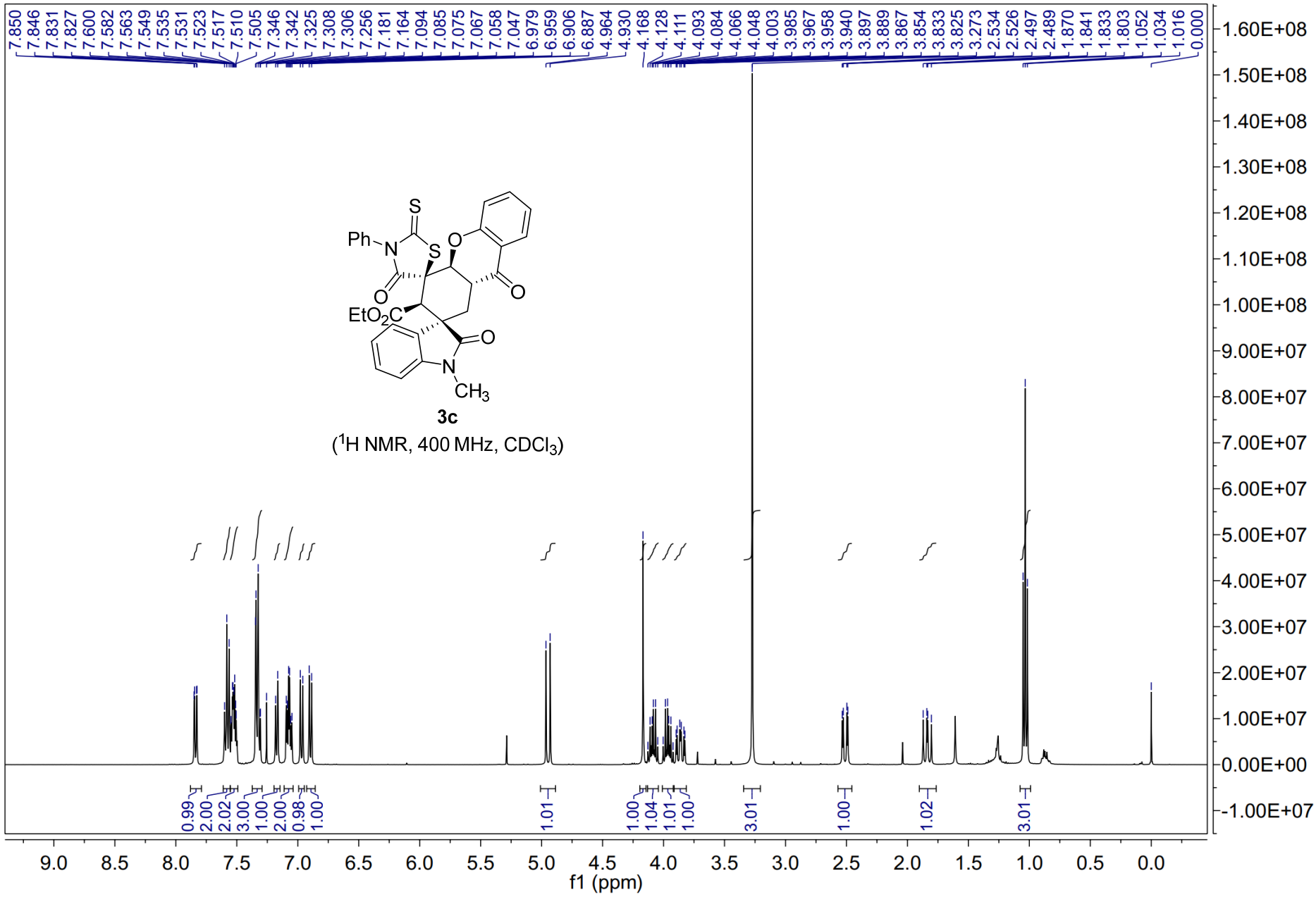
3b

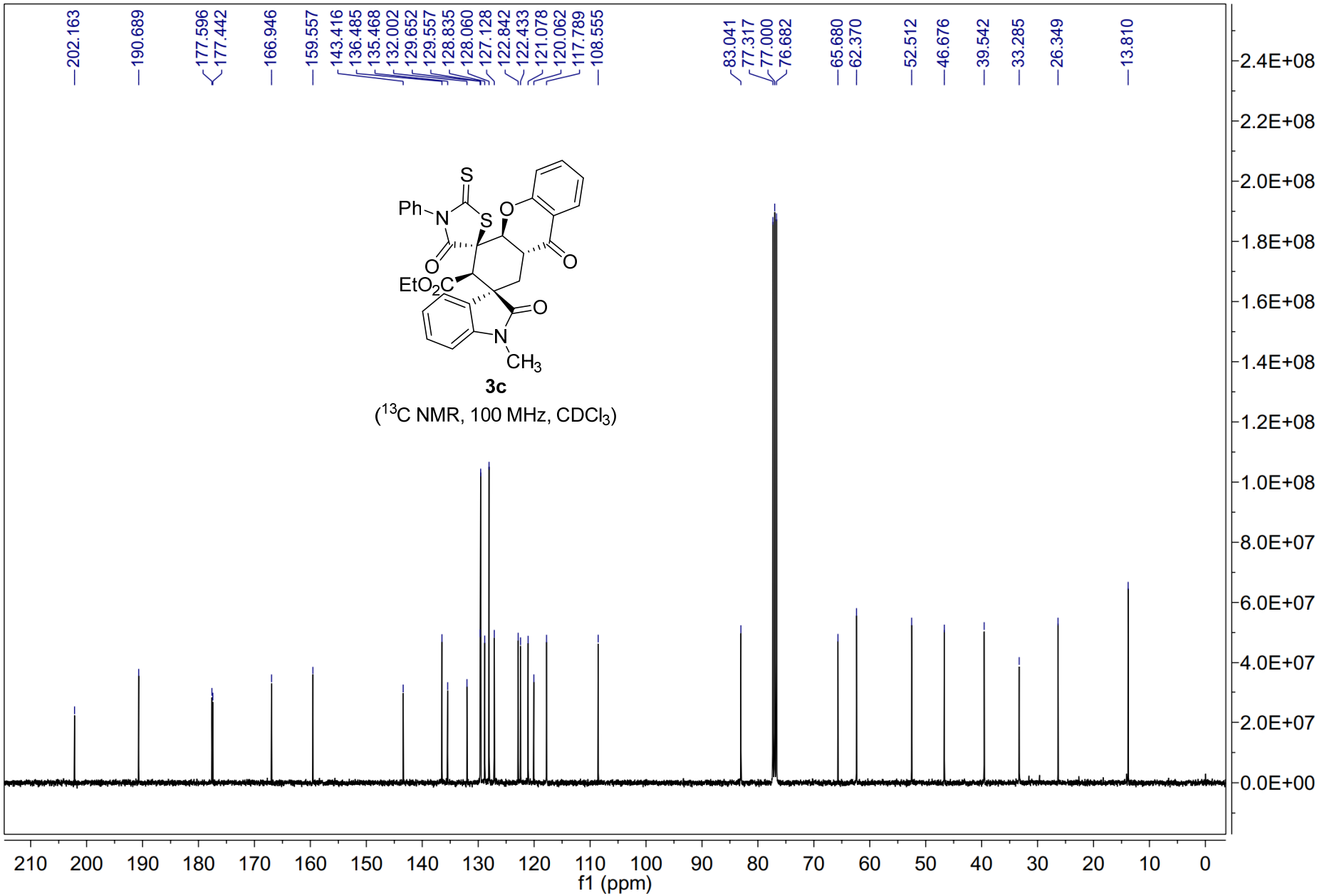
(^{1}H NMR, 400 MHz, DMSO-d_6)



3b

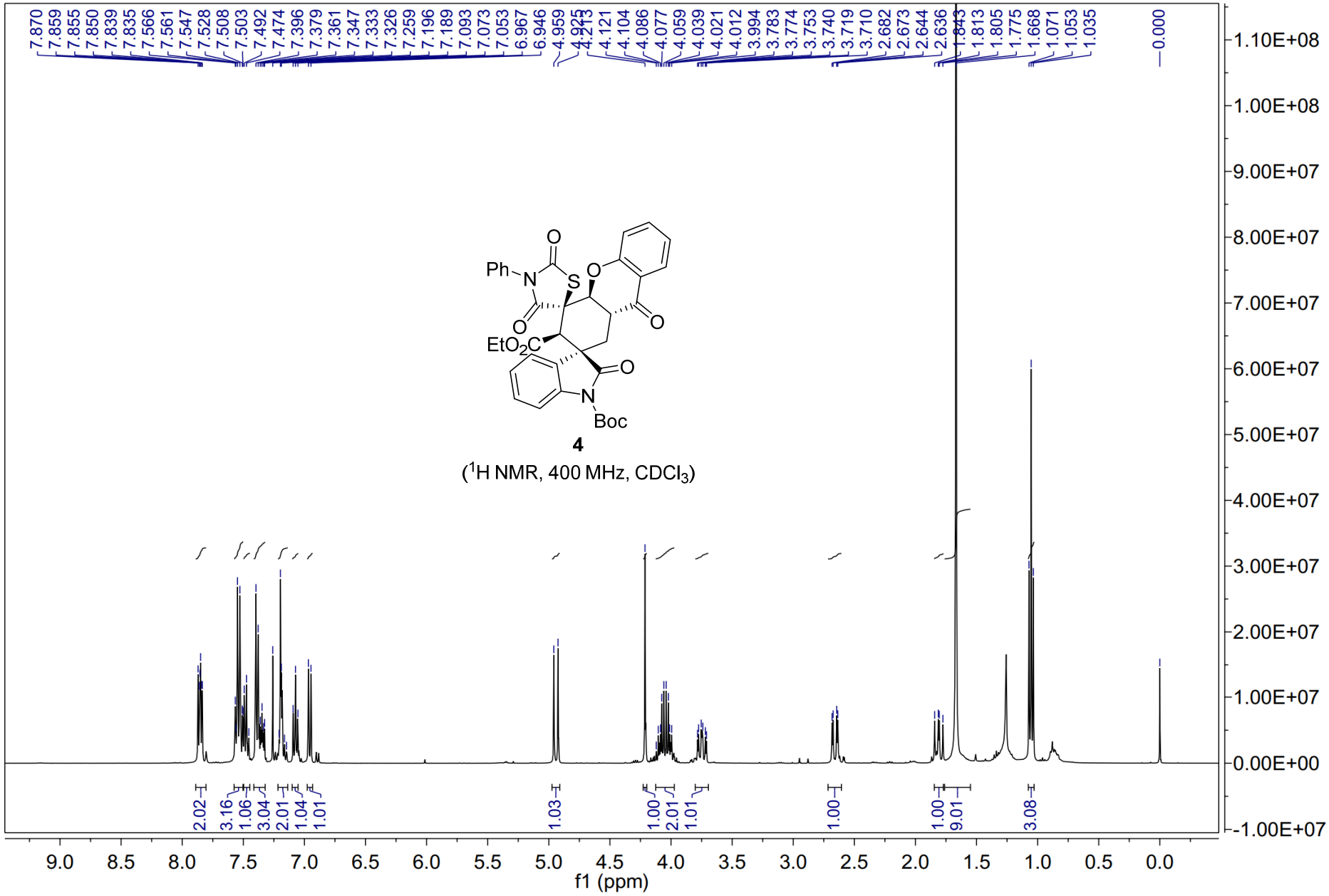
(^{13}C NMR, 100 MHz, DMSO-d_6)

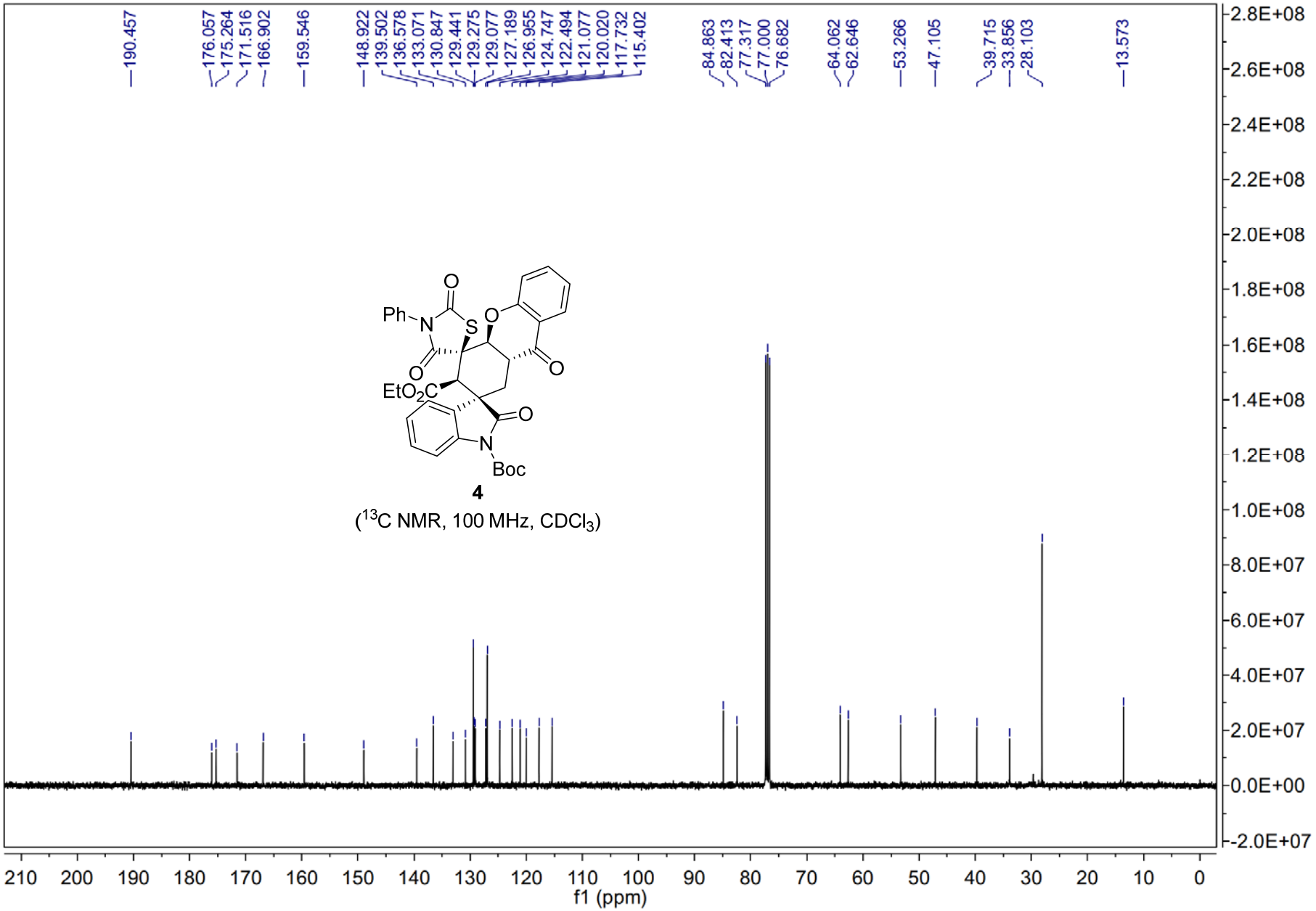

7.850
7.846
7.831
7.827
7.600
7.582
7.563
7.549
7.535
7.531
7.523
7.517
7.510
7.505
7.346
7.342
7.325
7.308
7.306
7.256
7.181
7.164
7.094
7.085
7.075
7.067
7.058
7.047
6.979
6.959
6.906
6.887
4.964
4.930
4.168
4.128
4.111
4.093
4.084
4.066
4.048
4.003
3.985
3.967
3.958
3.940
3.897
3.889
3.867
3.854
3.833
3.825
3.273
2.534
2.526
2.497
2.489
1.870
1.841
1.833
1.803
1.052
1.034
1.016
0.000
Ph
N
S
S
O
O
O
O
EtO2C
O
N
CH3
3c
(1H NMR, 400 MHz, CDCl3)
0.99
2.00
2.02
3.00
1.00
2.00
0.98
1.00
1.01
1.00
1.04
1.01
1.00
3.01
1.00
1.02
3.01
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



3c

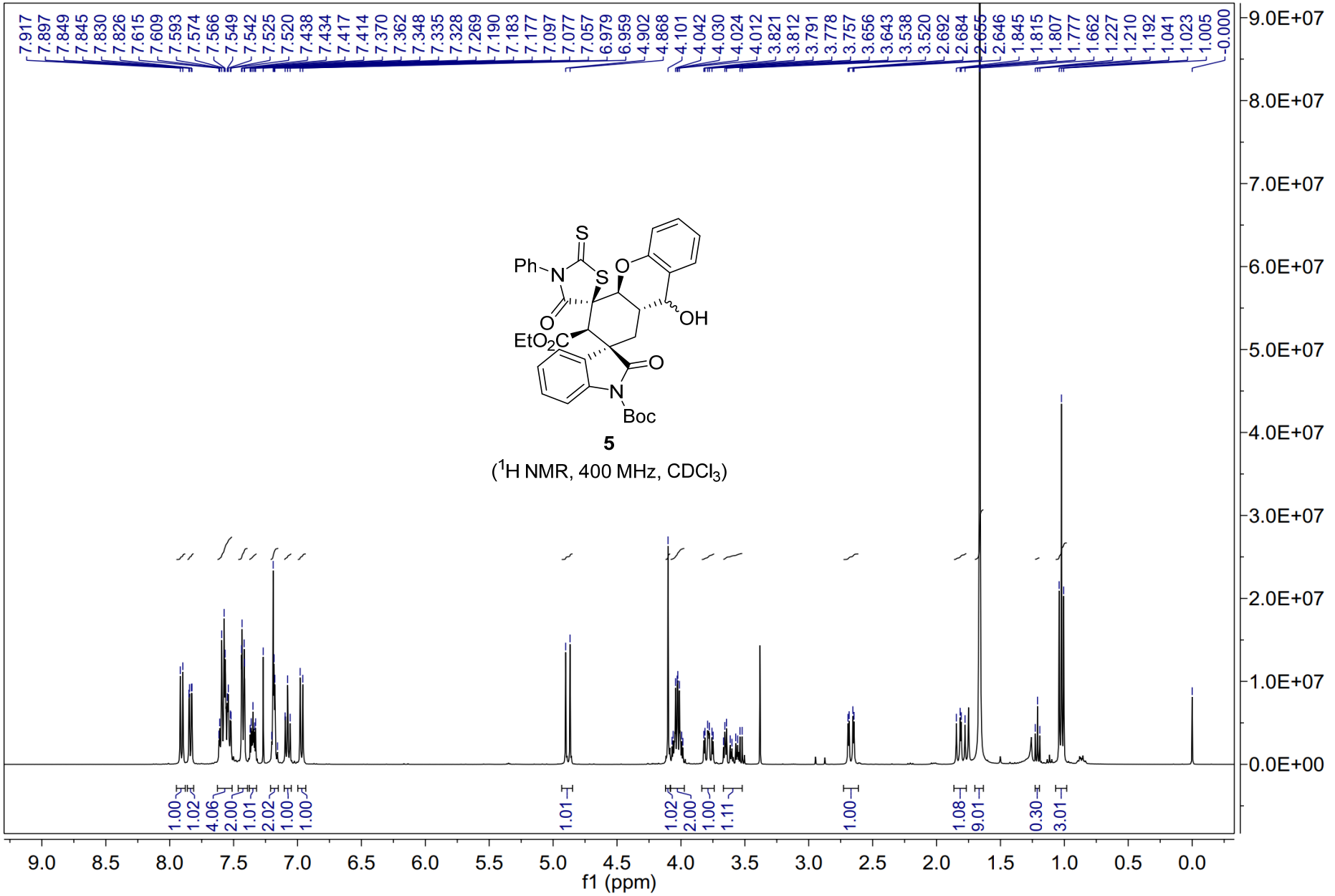
(^{13}C NMR, 100 MHz, $CDCl_3$)


7.870
7.859
7.855
7.850
7.839
7.835
7.566
7.561
7.547
7.528
7.508
7.503
7.492
7.474
7.396
7.379
7.361
7.347
7.333
7.326
7.259
7.196
7.189
7.093
7.073
7.053
6.967
6.946
4.959
4.925
4.213
4.121
4.104
4.086
4.077
4.059
4.039
4.021
4.012
3.994
3.783
3.774
3.753
3.740
3.719
3.710
2.682
2.673
2.644
2.636
1.843
1.813
1.805
1.775
1.668
1.071
1.053
1.035
0.000
Ph
N
S
O
O
O
O
O
EtO2C
O
N
Boc
4
(1H NMR, 400 MHz, CDCl3)
2.02
3.16
1.06
3.04
2.01
1.04
1.01
1.03
1.00
2.01
1.01
1.00
1.00
9.01
3.08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



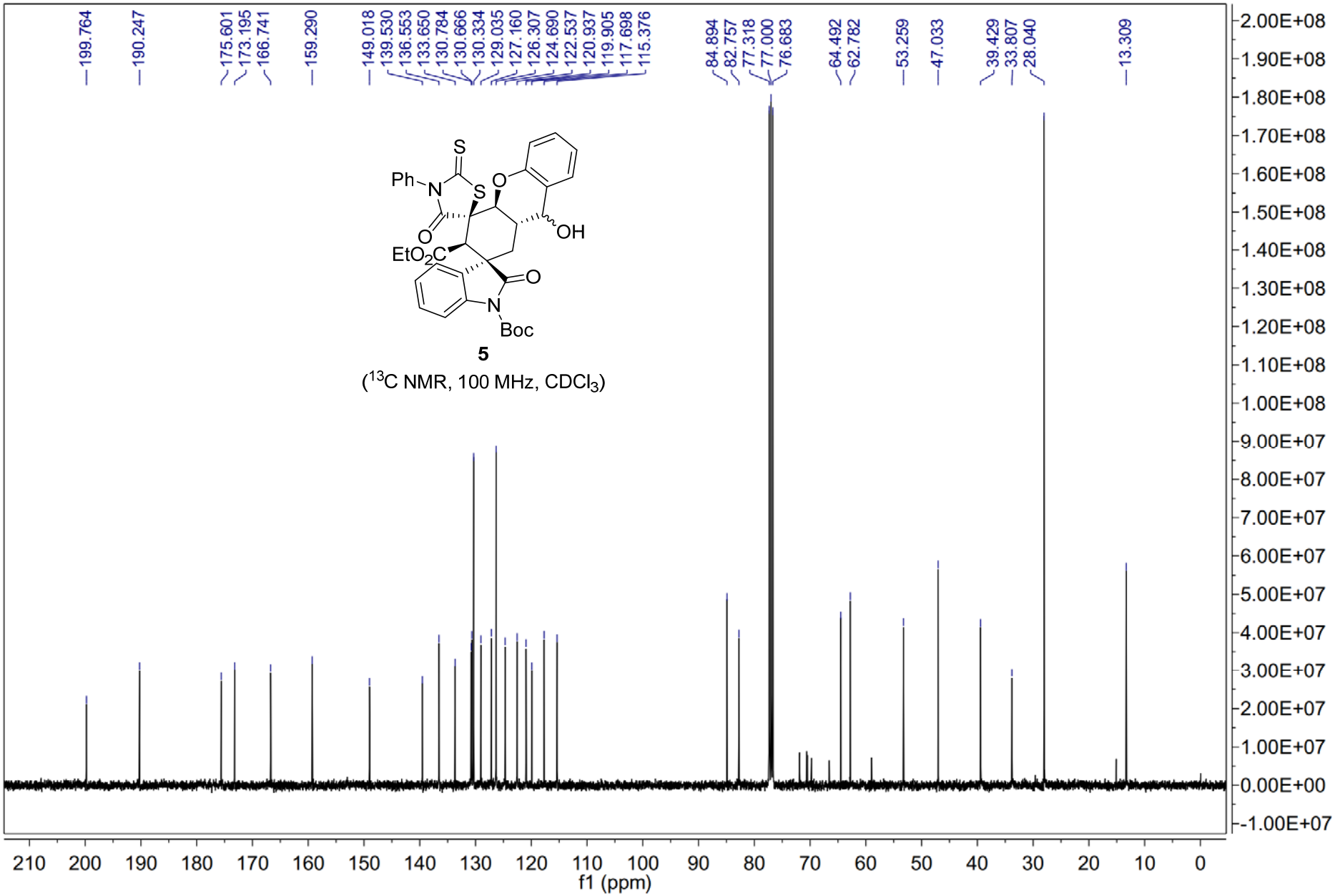
4

(^{13}C NMR, 100 MHz, $CDCl_3$)



5

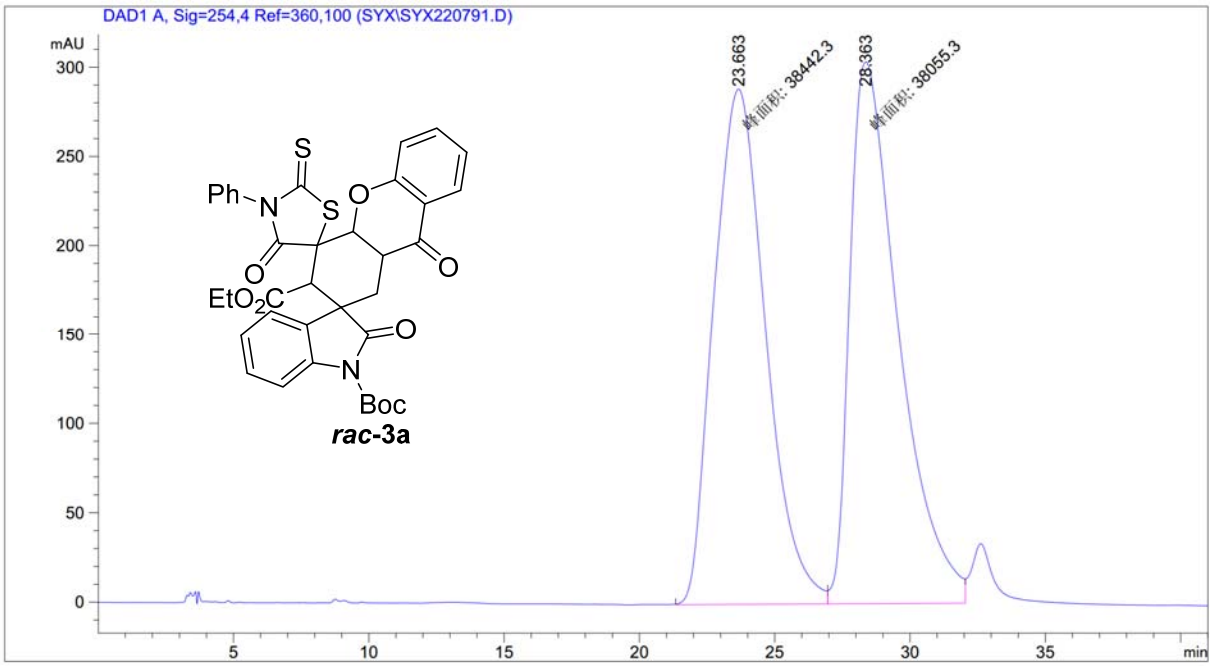
(^{1}H NMR, 400 MHz, $CDCl_3$)



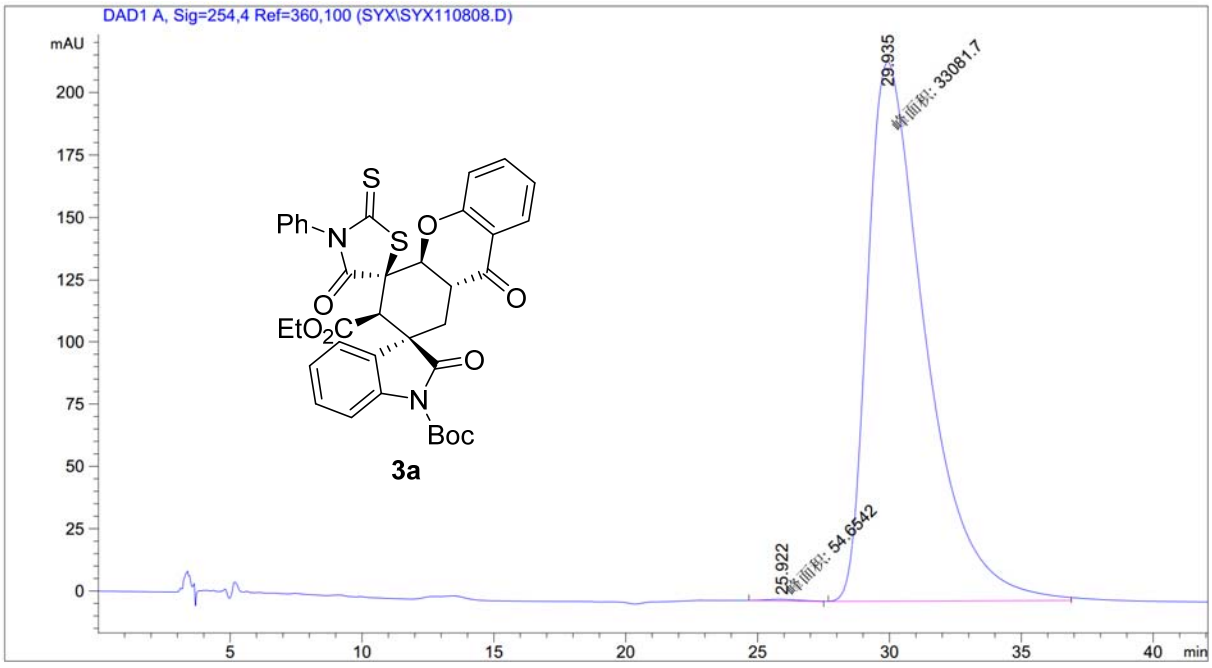
5

(^{13}C NMR, 100 MHz, $CDCl_3$)

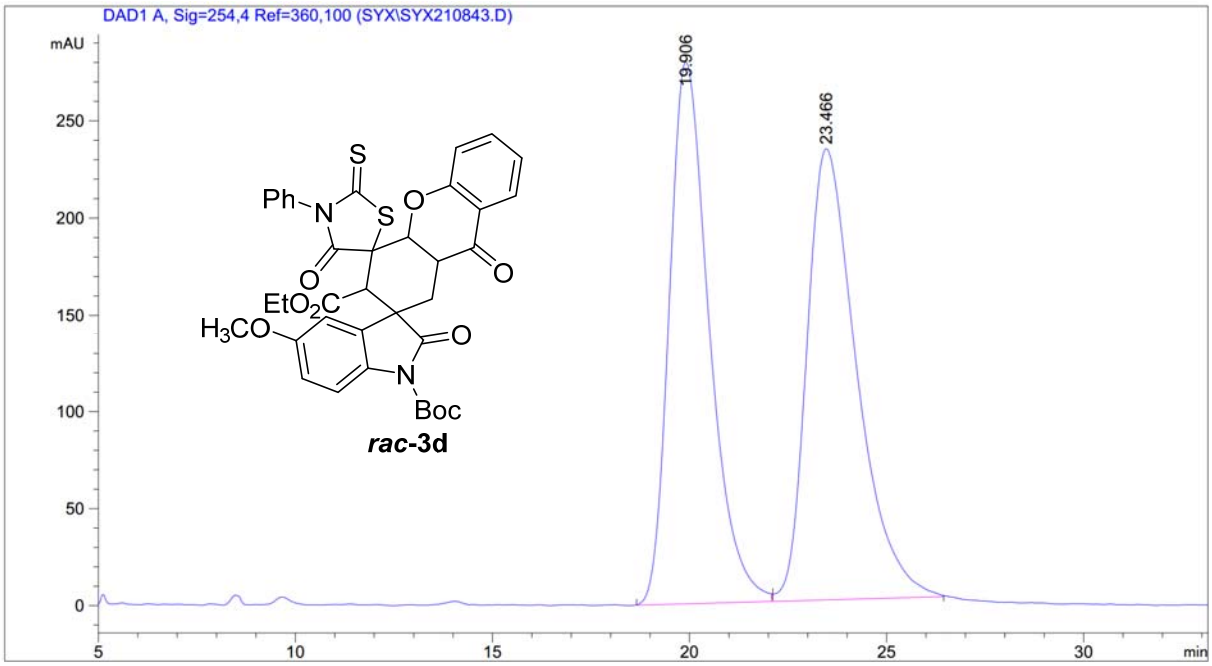
11. Copies of HPLC chromatograms



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.663	MF	2.2169	3.84423e4	289.01483	50.2530
2	28.363	MF	2.0873	3.80553e4	303.87057	49.7470

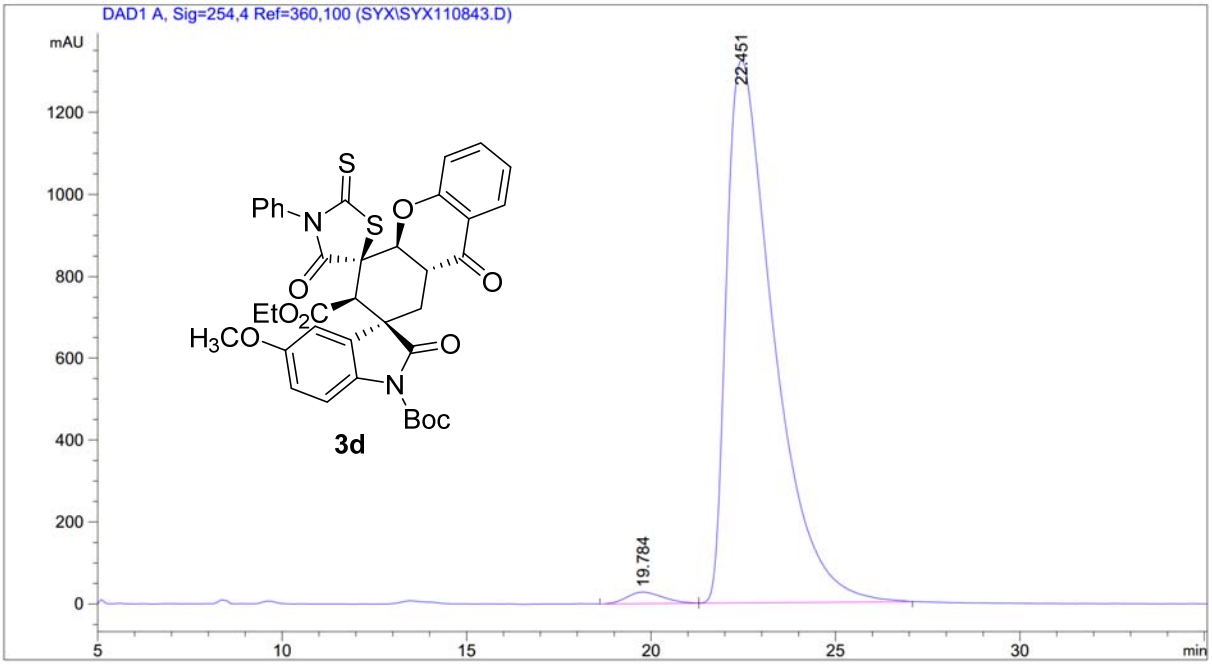


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.922	MM	1.5565	54.65420	5.85229e-1	0.1649
2	29.935	MF	2.5480	3.30817e4	216.39006	99.8351



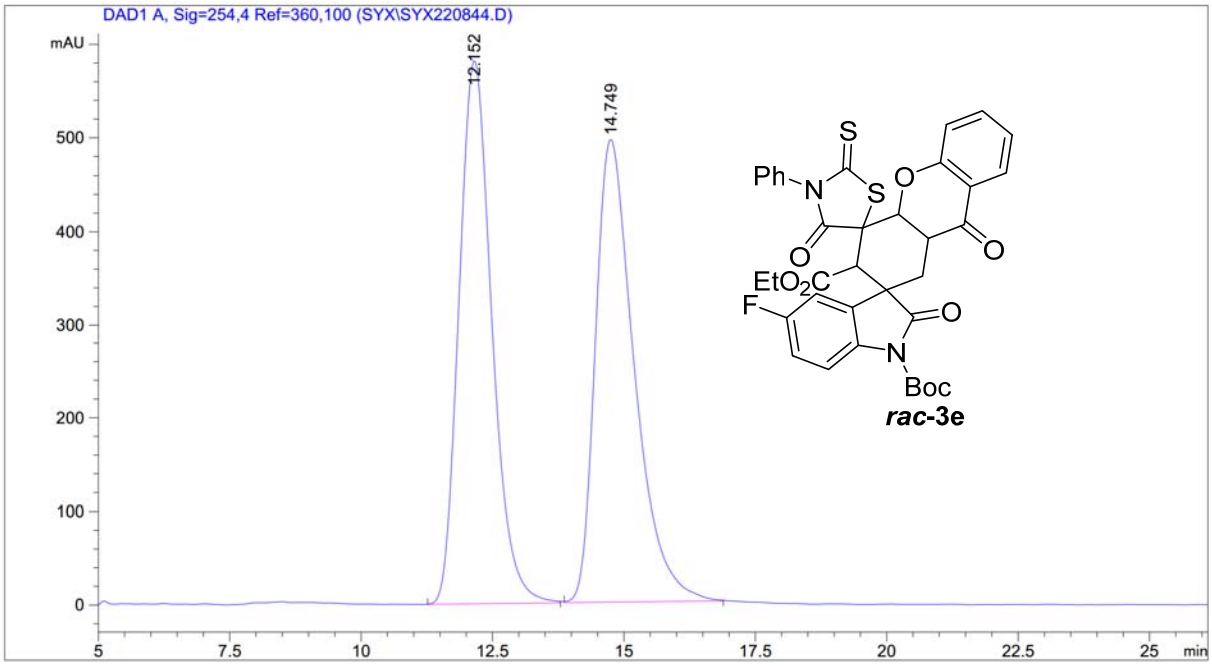
***rac*-3d**

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.906	BB	1.0698	1.96359e4	279.45636	49.0242
2	23.466	BB	1.2716	2.04176e4	232.70374	50.9758

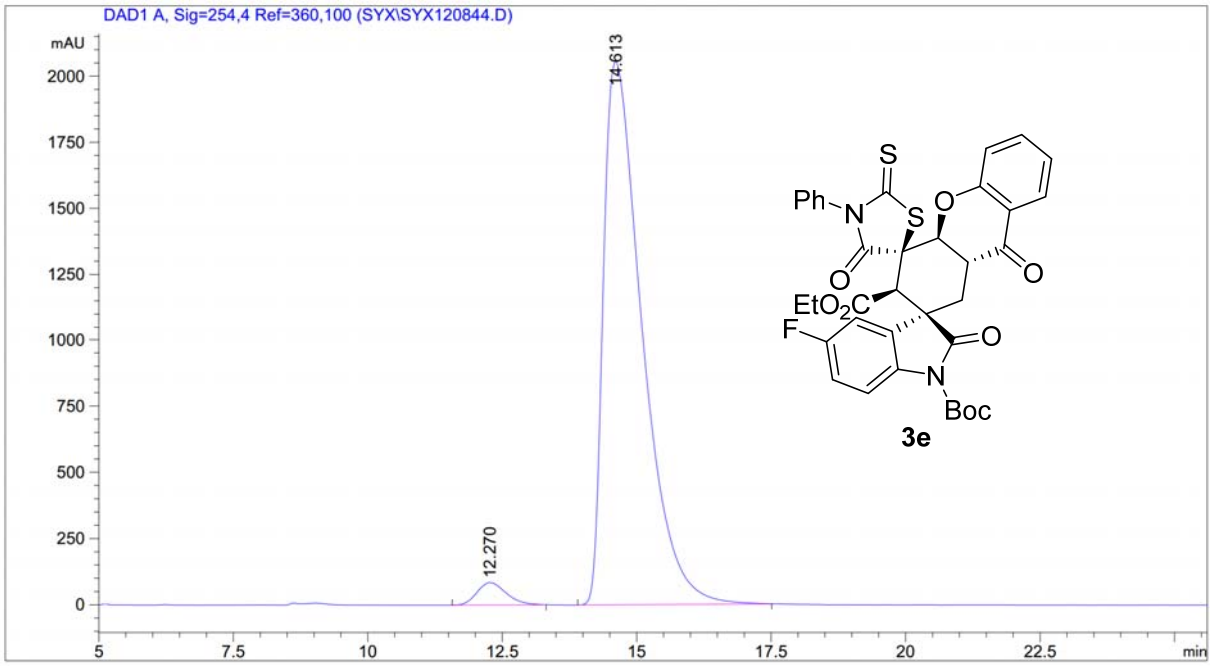


3d

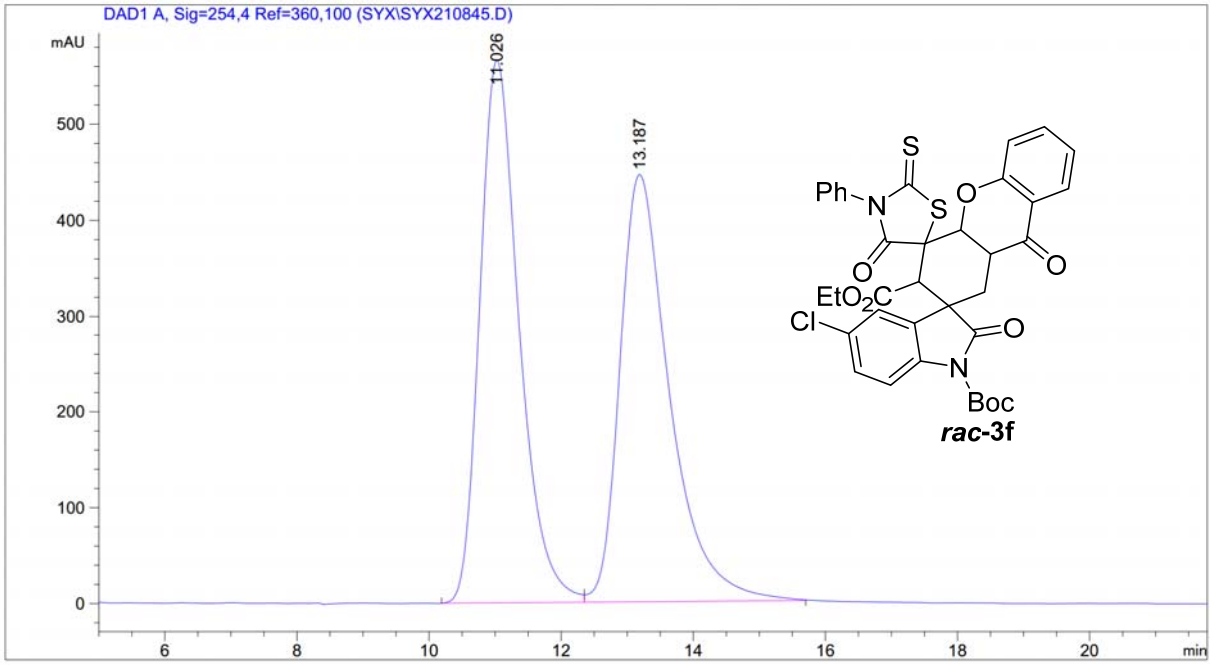
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.784	BV	0.8161	1910.21118	28.06273	1.5968
2	22.451	VB	1.2259	1.17721e5	1323.27209	98.4032



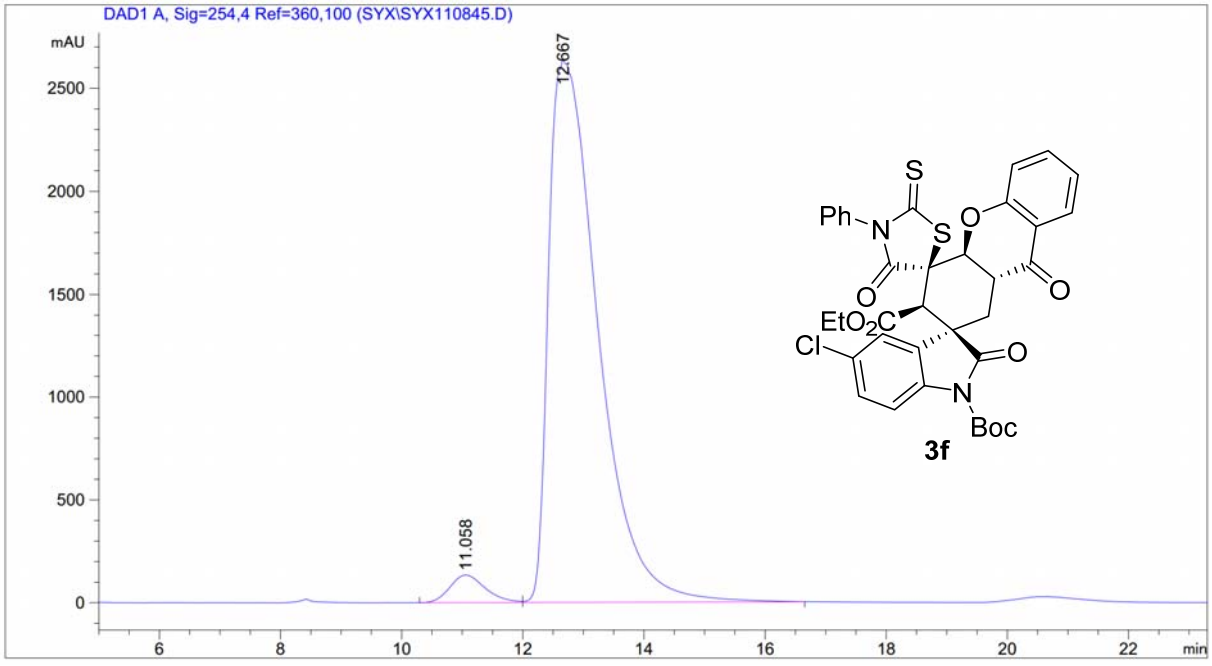
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.152	BB	0.6696	2.51759e4	580.88934	49.7418
2	14.749	BB	0.7736	2.54372e4	494.94943	50.2582



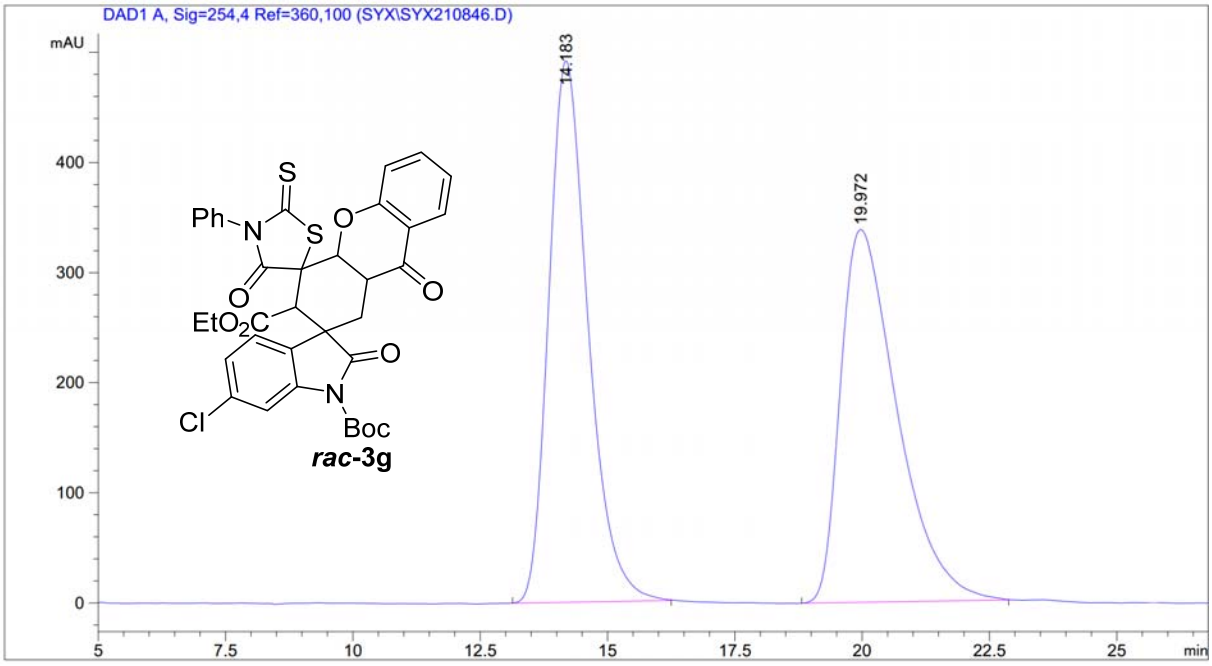
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.270	BB	0.5801	3179.92334	84.29928	3.0035
2	14.613	BB	0.6606	1.02696e5	2056.56860	96.9965



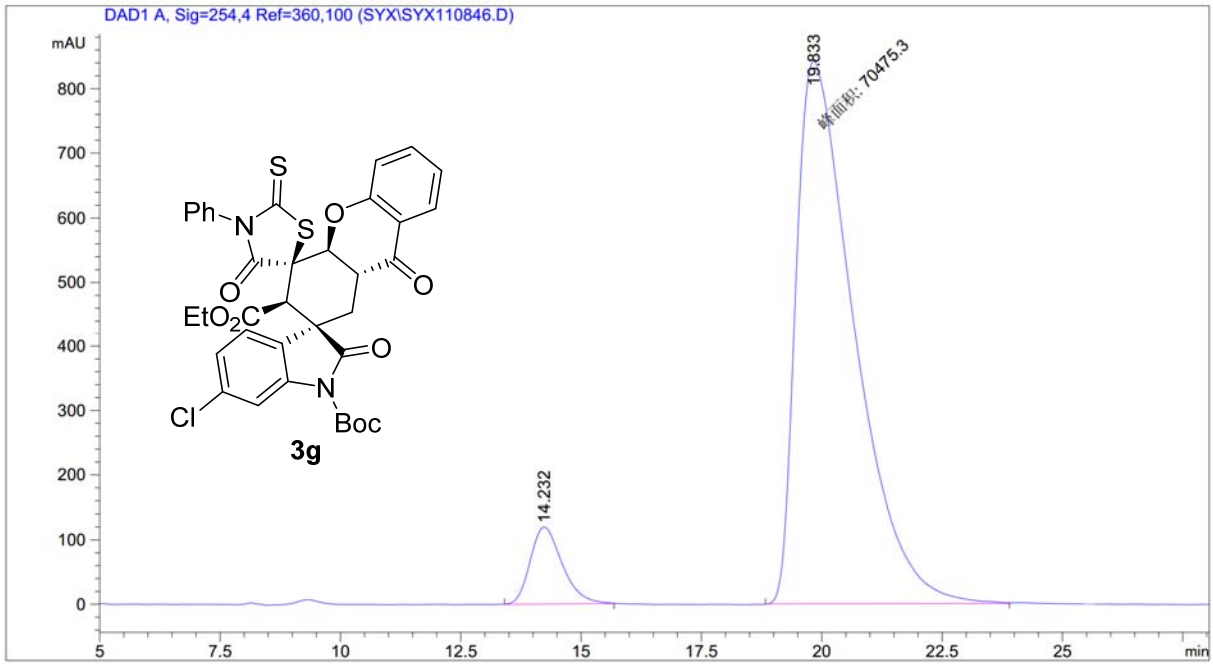
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.026	BV	0.6310	2.34169e4	565.57068	50.1171
2	13.187	VB	0.7862	2.33074e4	445.63153	49.8829



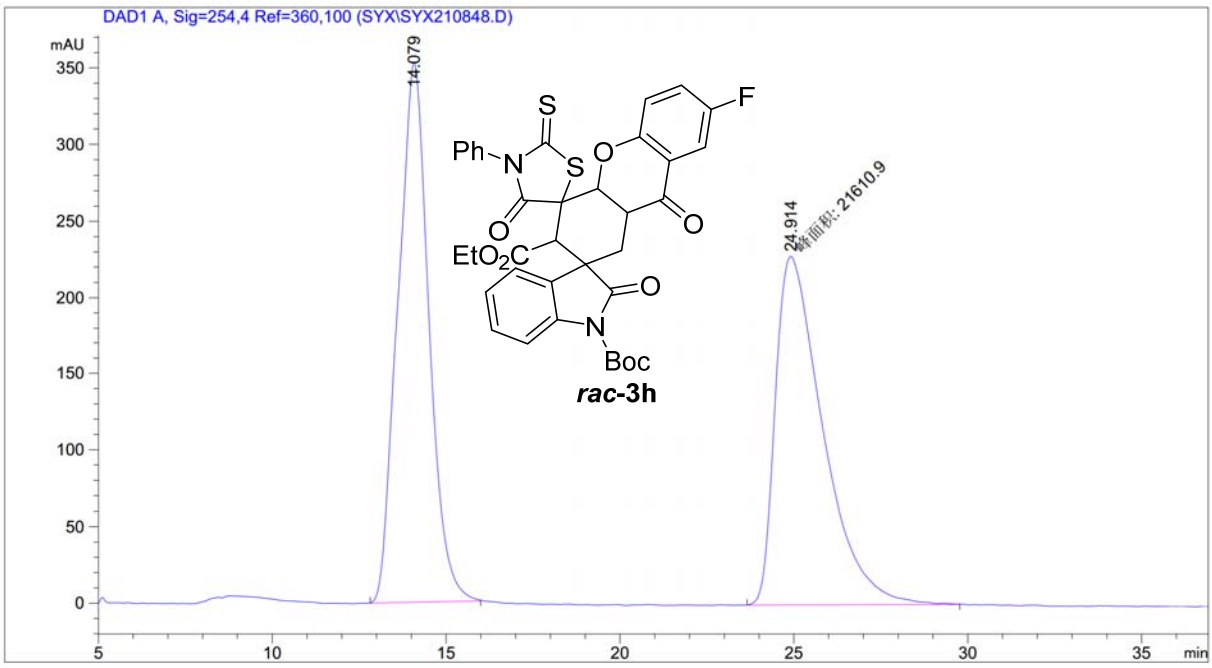
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.058	BV	0.6220	5447.13330	134.08180	3.5214
2	12.667	VB	0.6750	1.49237e5	2634.17163	96.4786



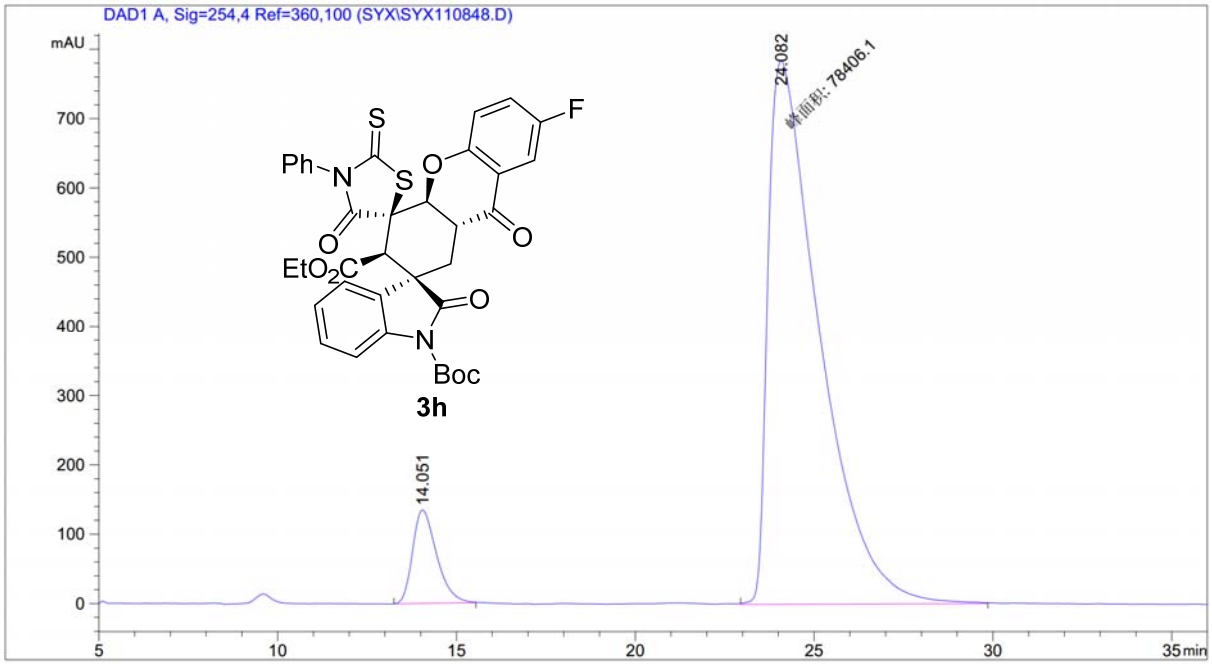
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.183	BB	0.8161	2.63848e4	491.67566	50.2248
2	19.972	BB	1.1633	2.61486e4	338.47537	49.7752



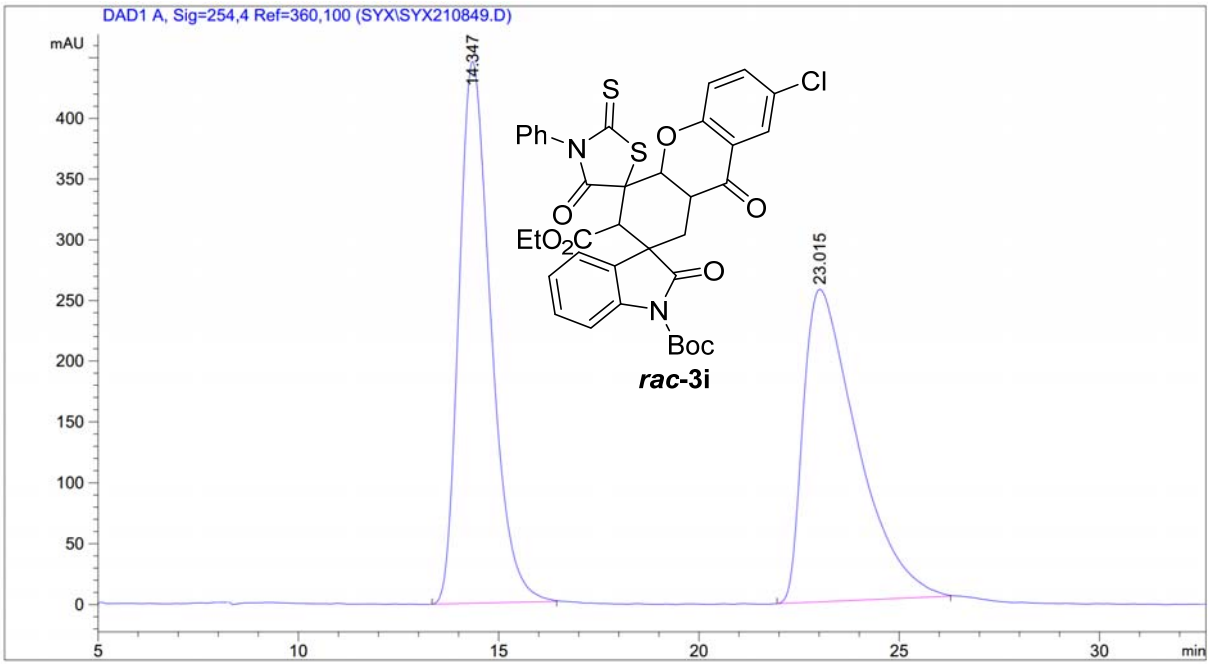
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.232	BB	0.6976	5527.49463	119.50448	7.2728
2	19.833	MM	1.3950	7.04753e4	841.97900	92.7272



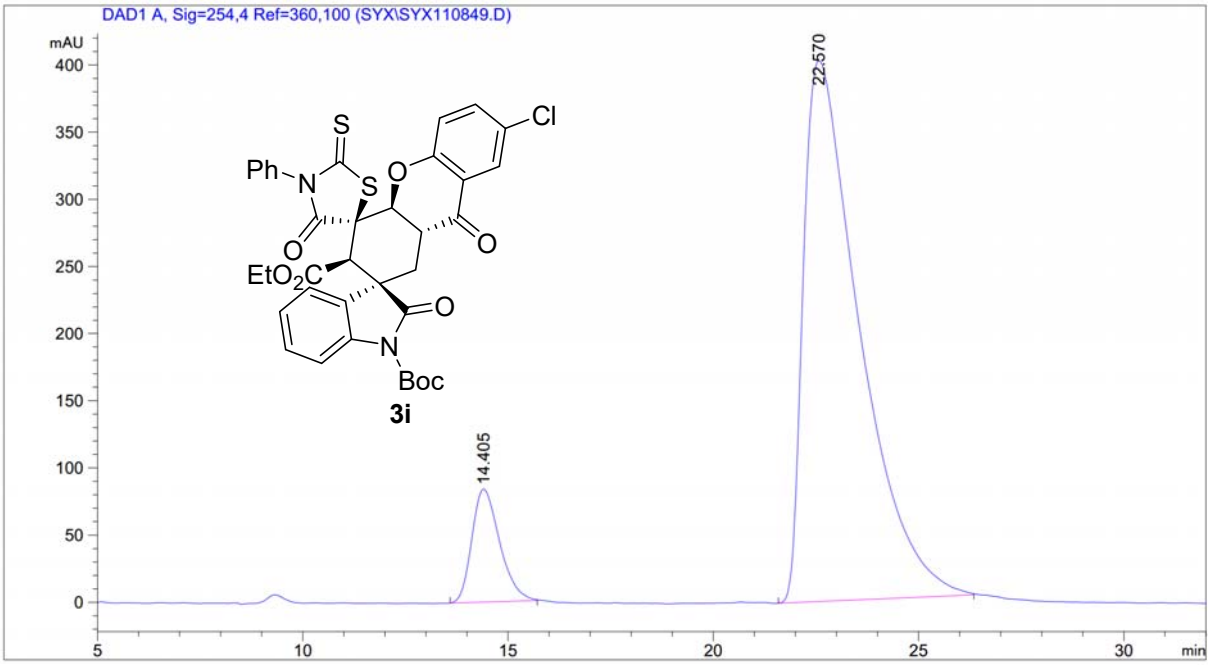
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.079	BB	0.8892	2.18039e4	352.71237	50.2223
2	24.914	MM	1.5787	2.16109e4	228.15353	49.7777



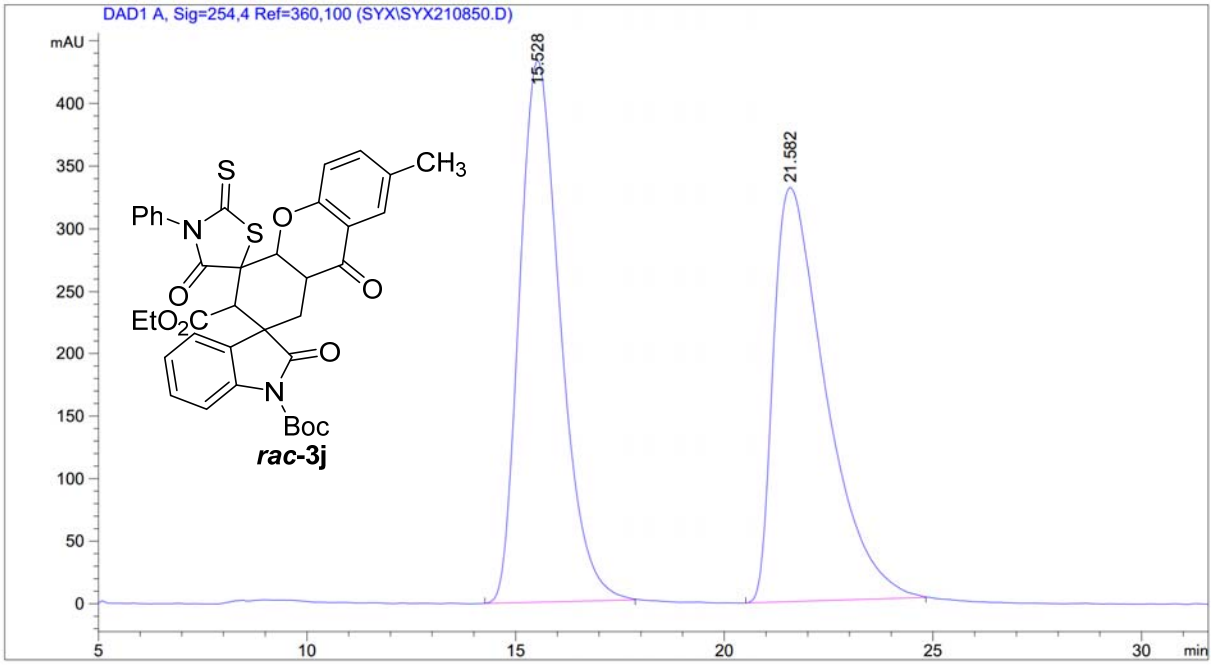
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.051	BB	0.7067	6287.44727	134.66396	7.4238
2	24.082	MM	1.6658	7.84061e4	784.47076	92.5762



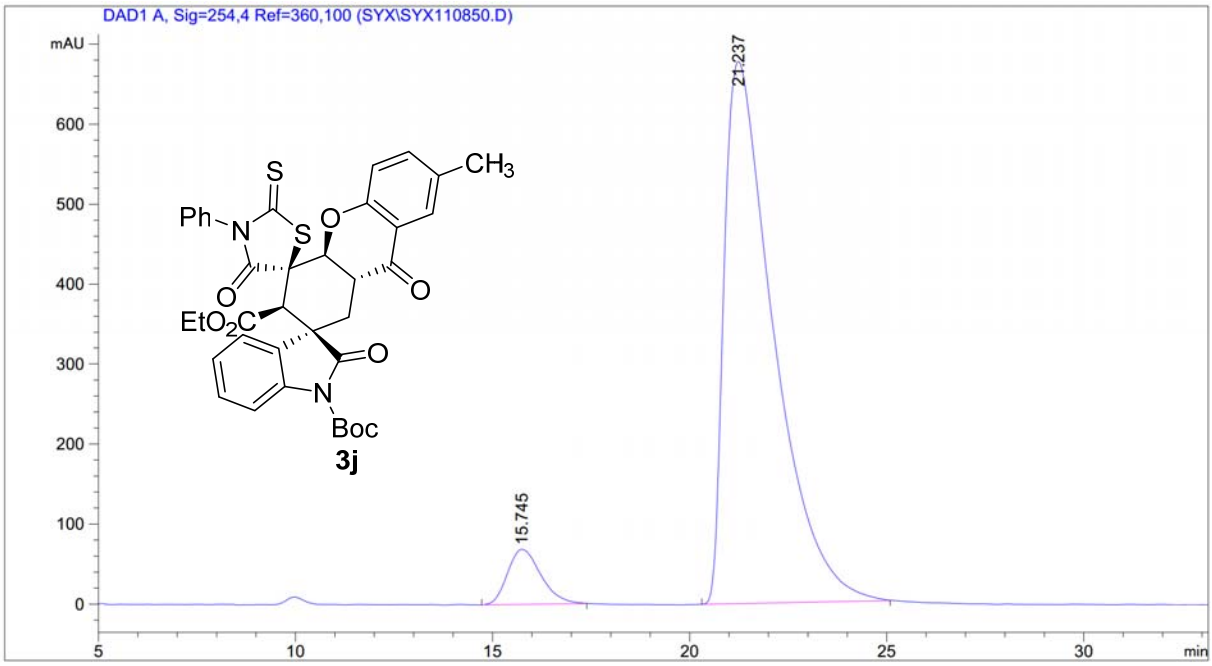
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.347	BB	0.8413	2.46600e4	445.85992	50.7348
2	23.015	BB	1.3092	2.39456e4	256.96802	49.2652



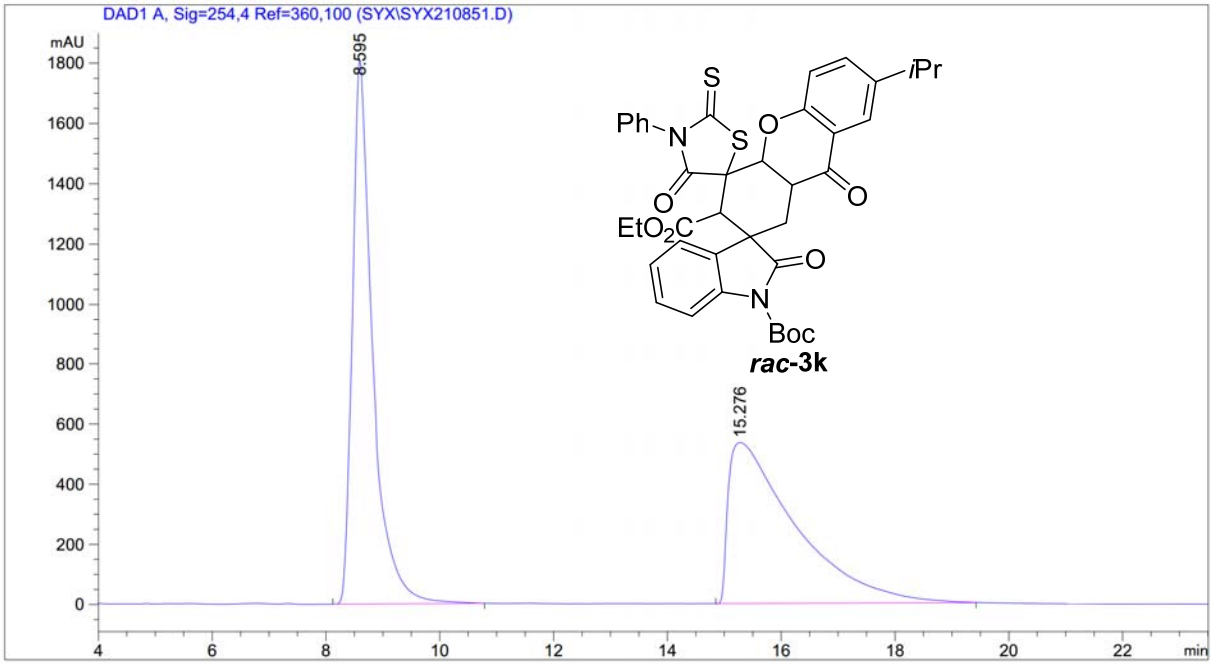
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.405	BB	0.7195	3954.70801	83.96357	9.4047
2	22.570	BB	1.3344	3.80958e4	402.43219	90.5953



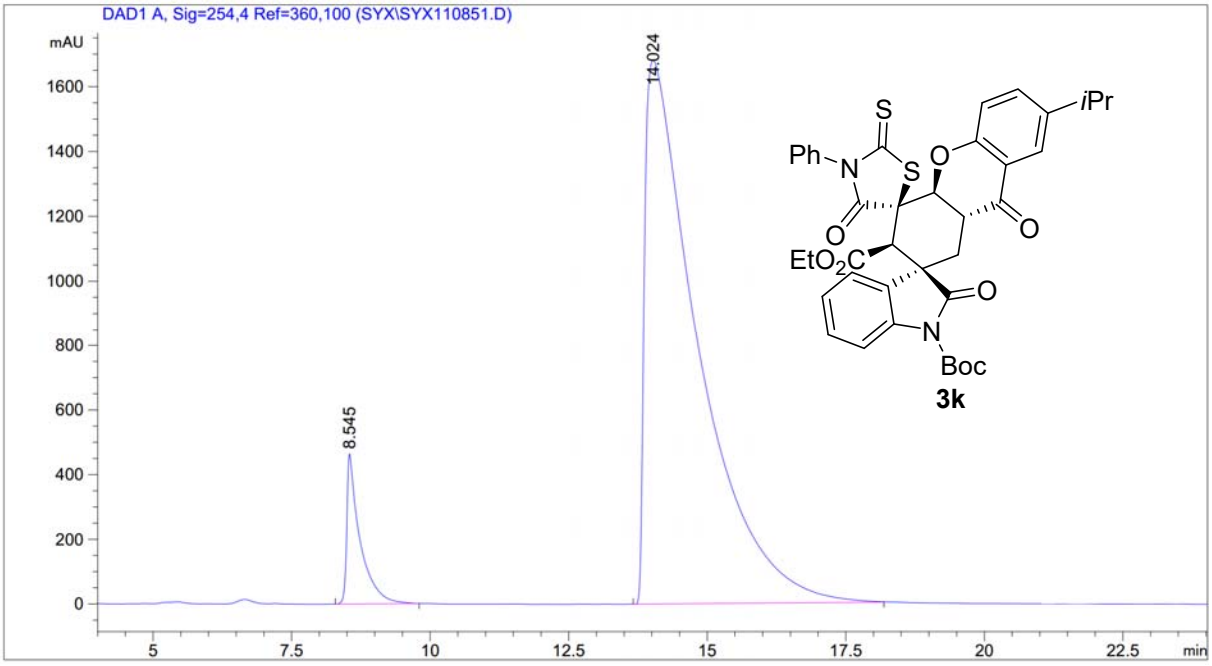
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.528	BB	0.9909	2.93550e4	433.01993	50.4630
2	21.582	BB	1.2370	2.88163e4	331.22510	49.5370



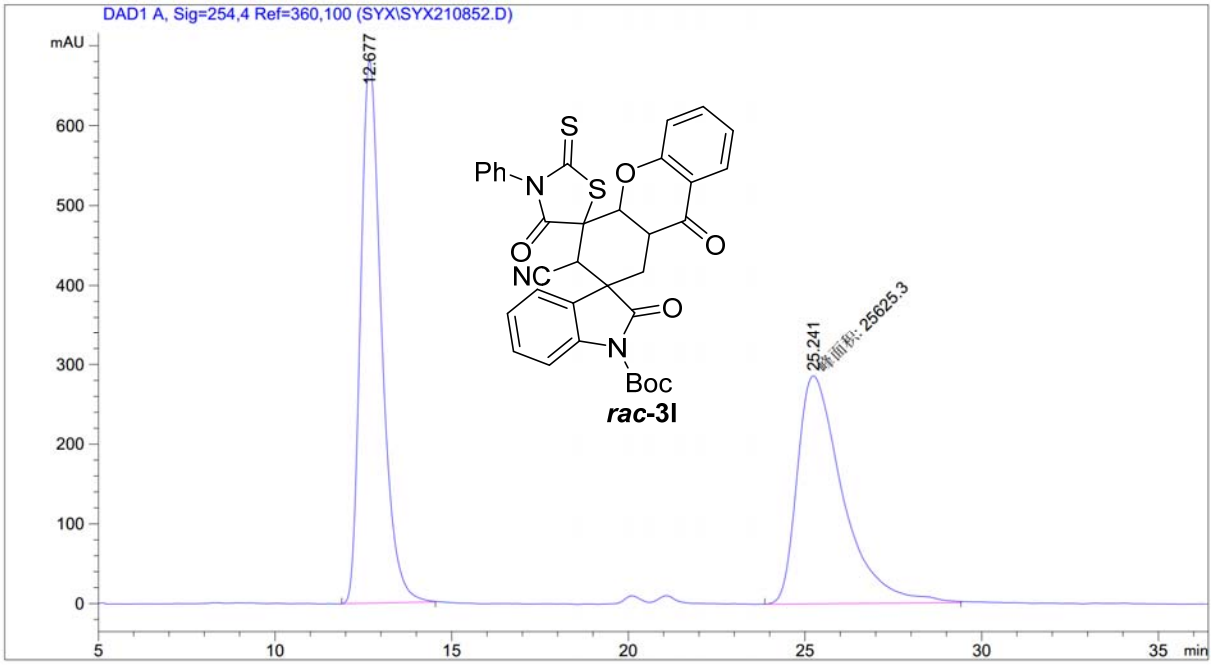
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.745	BB	0.8658	4043.66260	68.78854	6.4210
2	21.237	BB	1.2726	5.89320e4	677.64038	93.5790



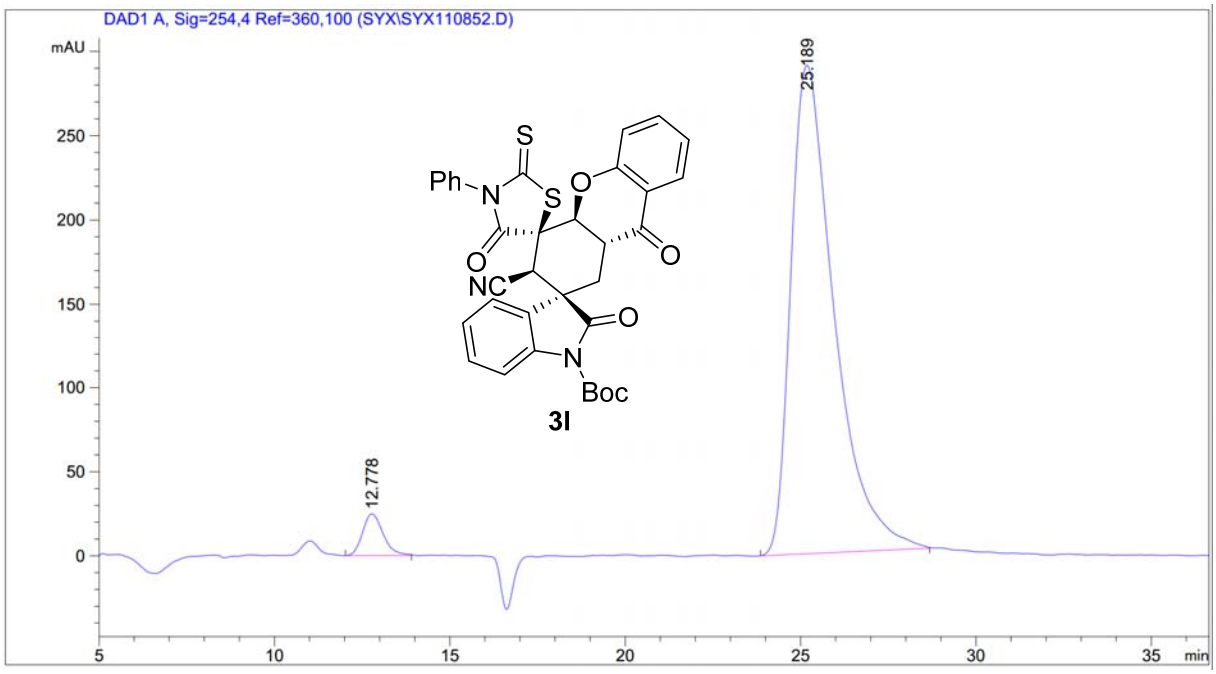
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.595	BB	0.3502	4.46543e4	1807.60303	50.4349
2	15.276	BB	1.0961	4.38841e4	535.46771	49.5651



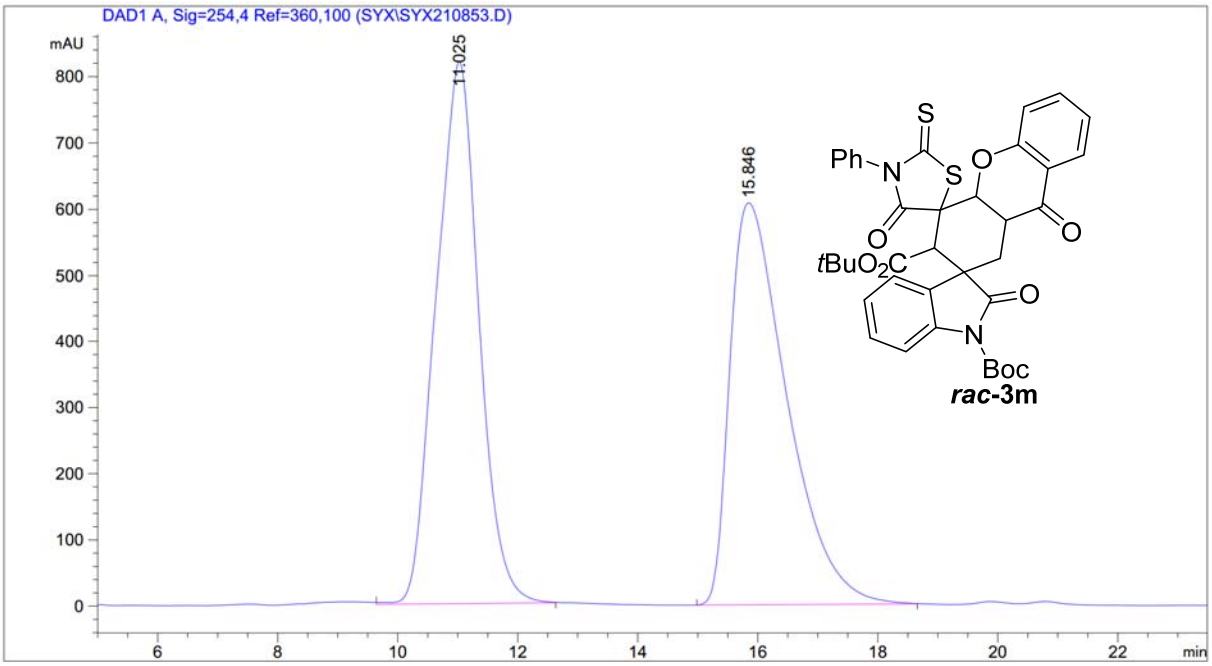
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.545	BB	0.2136	7630.12109	464.62888	6.3499
2	14.024	BB	0.8572	1.12531e5	1680.66382	93.6501



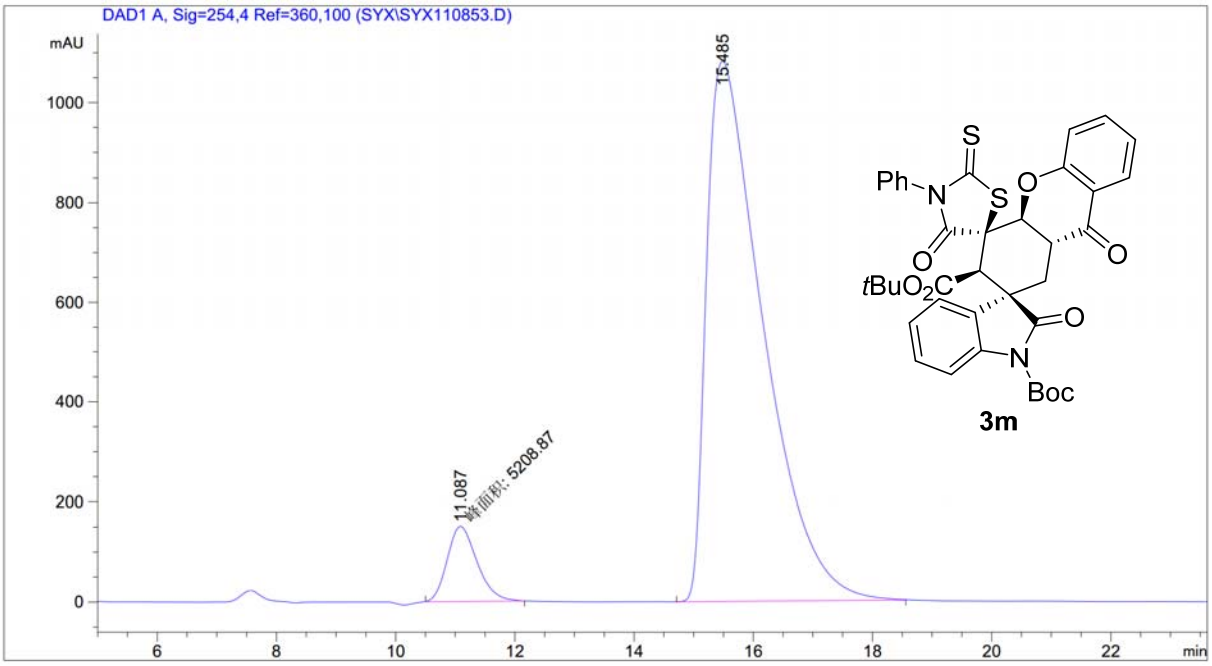
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.677	BB	0.6336	2.81153e4	681.11914	52.3167
2	25.241	MM	1.4937	2.56253e4	285.93057	47.6833



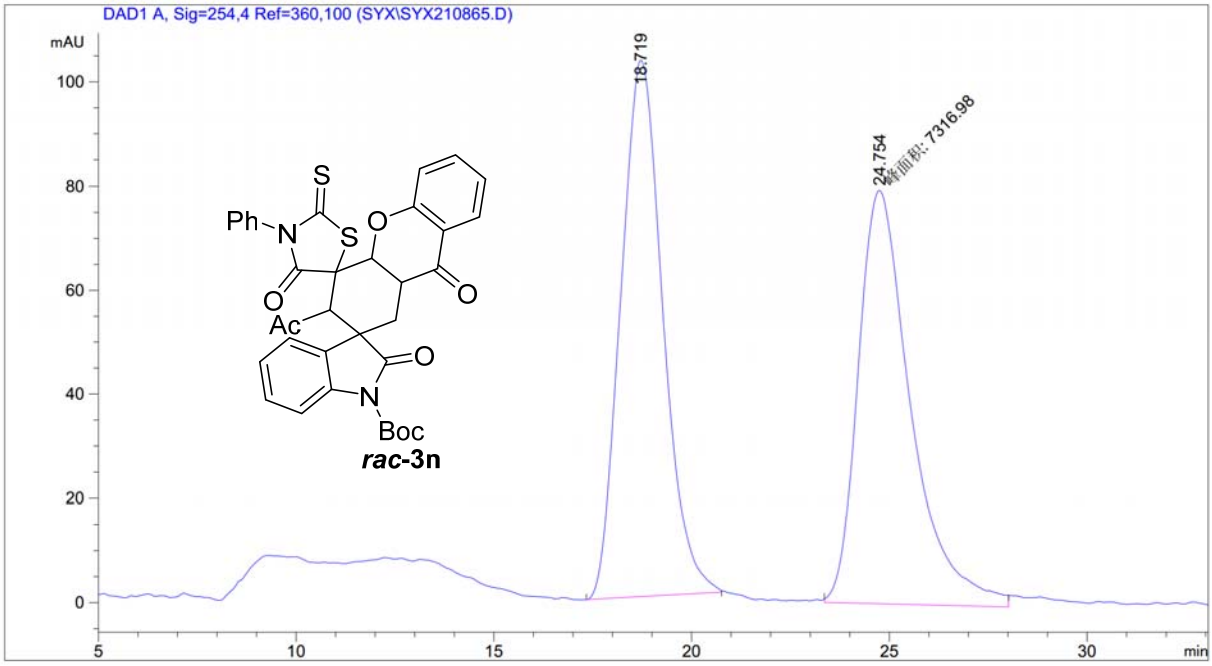
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.778	BB	0.6111	1006.79053	24.72140	3.8854
2	25.189	BB	1.2184	2.49056e4	290.43900	96.1146



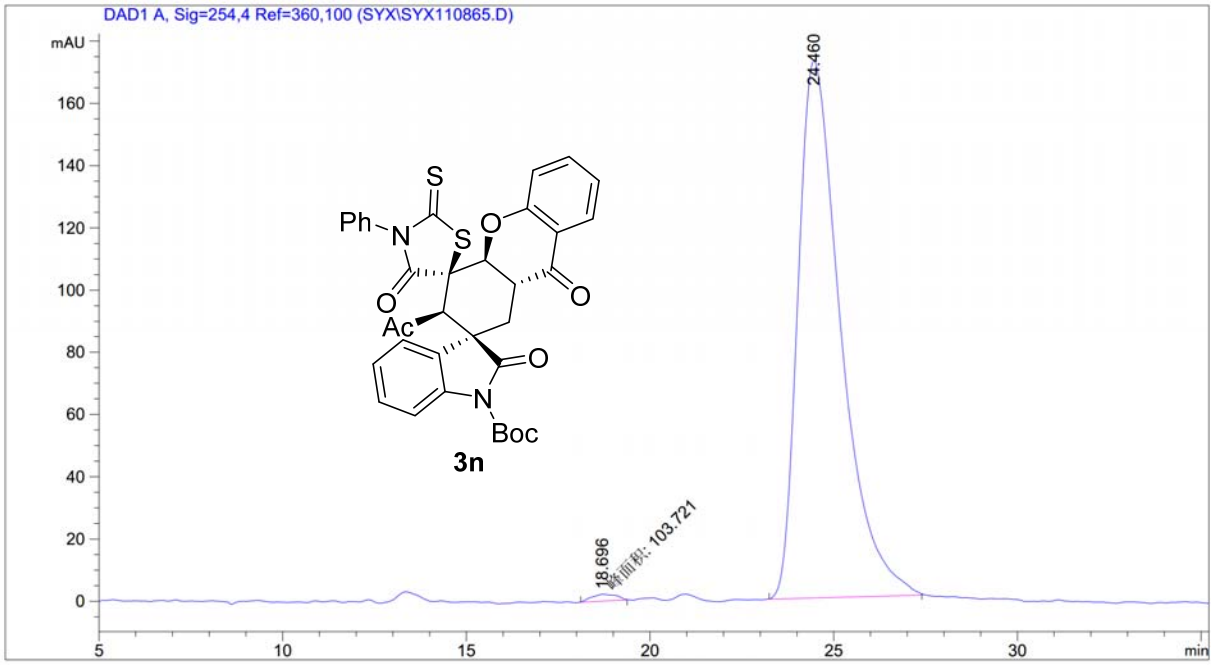
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.025	VB	0.7189	4.06117e4	818.42493	50.3378
2	15.846	BB	0.9810	4.00666e4	607.83887	49.6622



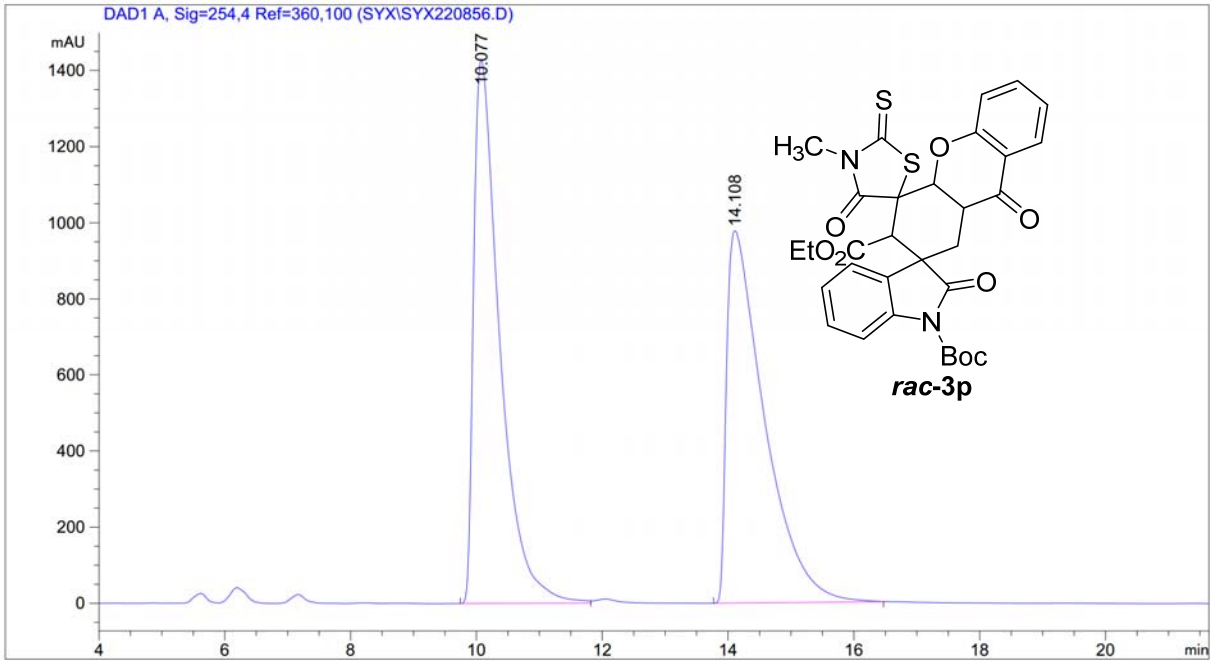
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.087	MM	0.5780	5208.86621	150.20609	6.8171
2	15.485	BB	0.9297	7.12003e4	1082.07019	93.1829



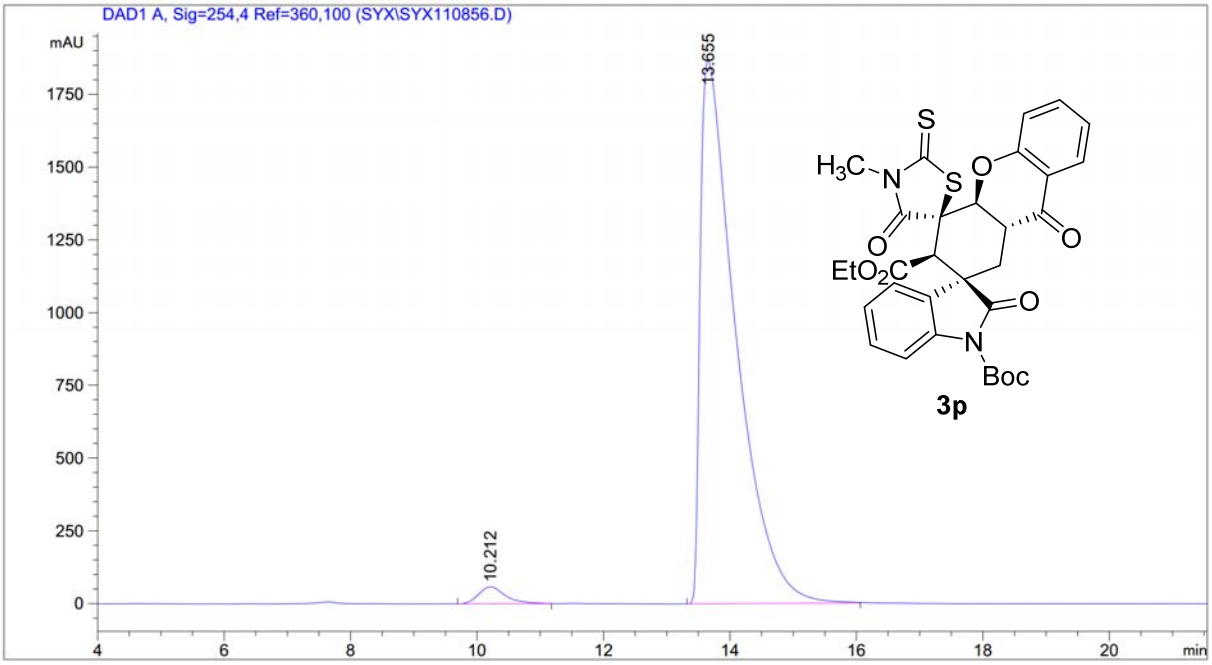
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.719	BB	0.9996	7604.99561	102.97774	50.9651
2	24.754	MM	1.5355	7316.98145	79.42027	49.0349



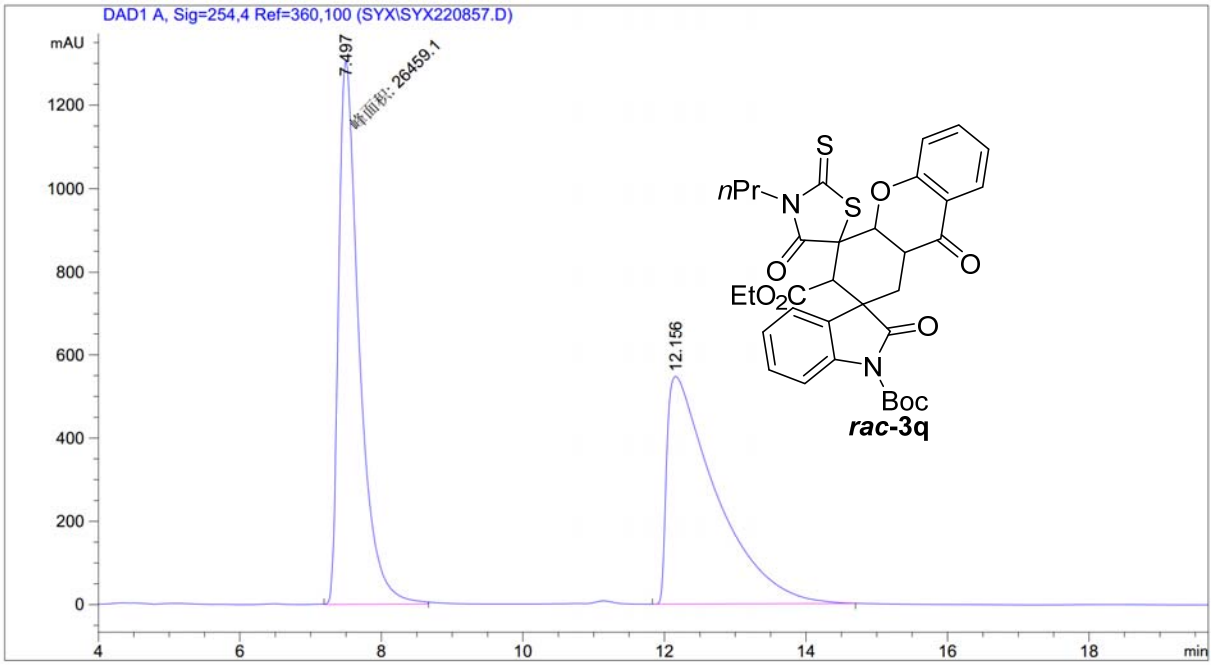
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.696	MM	0.7713	103.72121	2.24132	0.7367
2	24.460	BB	1.1707	1.39750e4	172.57716	99.2633



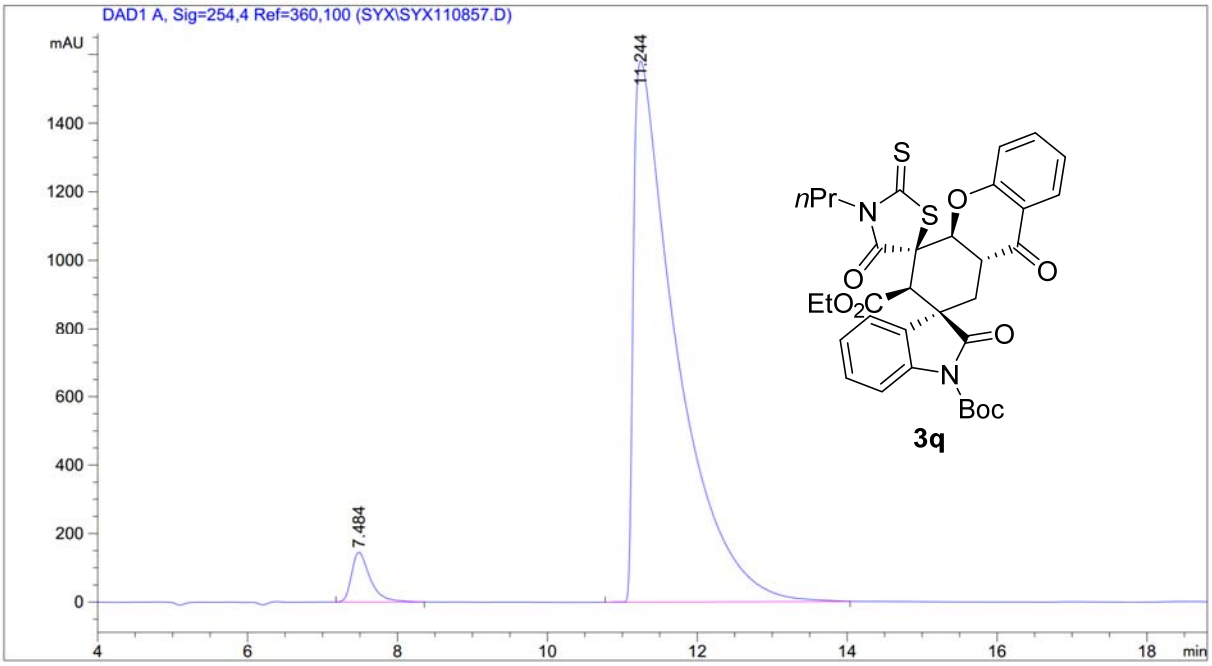
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.077	BB	0.4320	4.11081e4	1427.34863	50.2181
2	14.108	BB	0.5921	4.07510e4	978.01001	49.7819



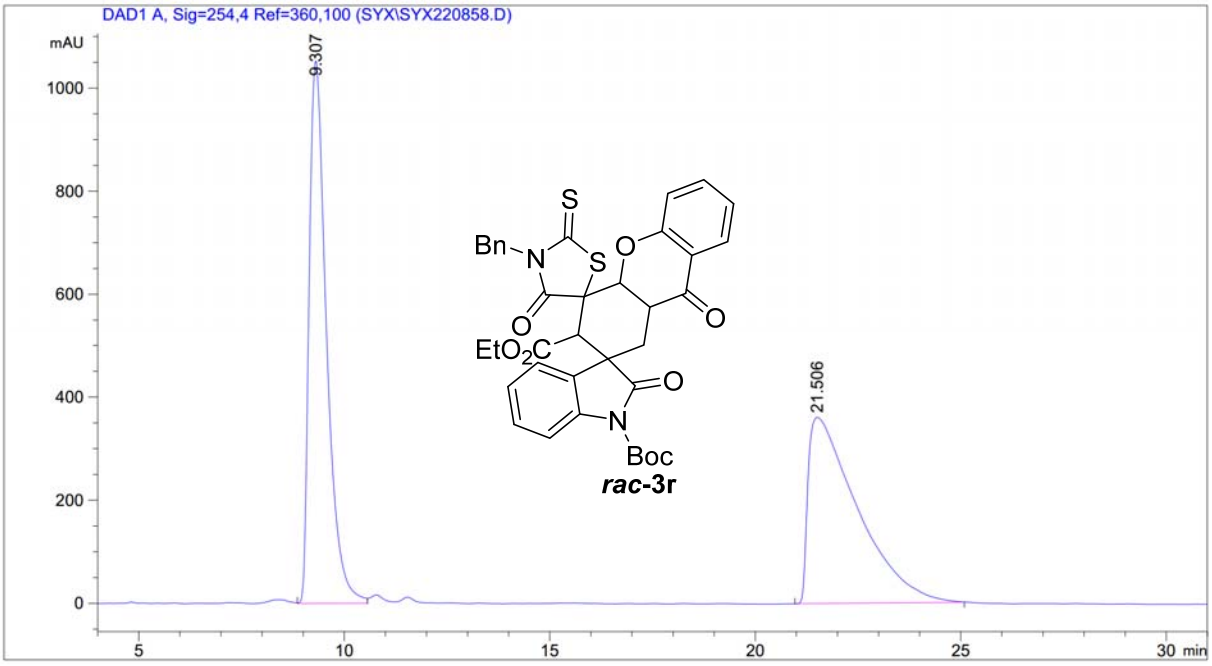
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.212	BB	0.4507	1713.11597	58.32838	2.2932
2	13.655	BB	0.5362	7.29896e4	1866.63208	97.7068



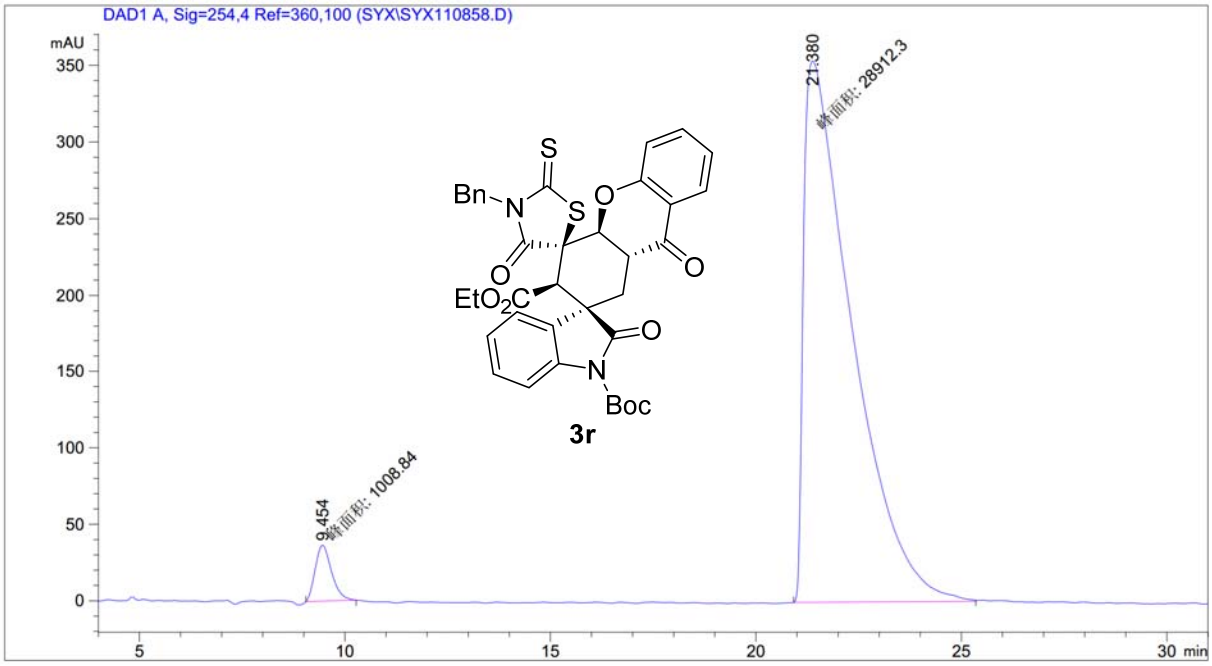
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.497	MF	0.3378	2.64591e4	1305.30627	49.9891
2	12.156	BB	0.6610	2.64707e4	546.60748	50.0109



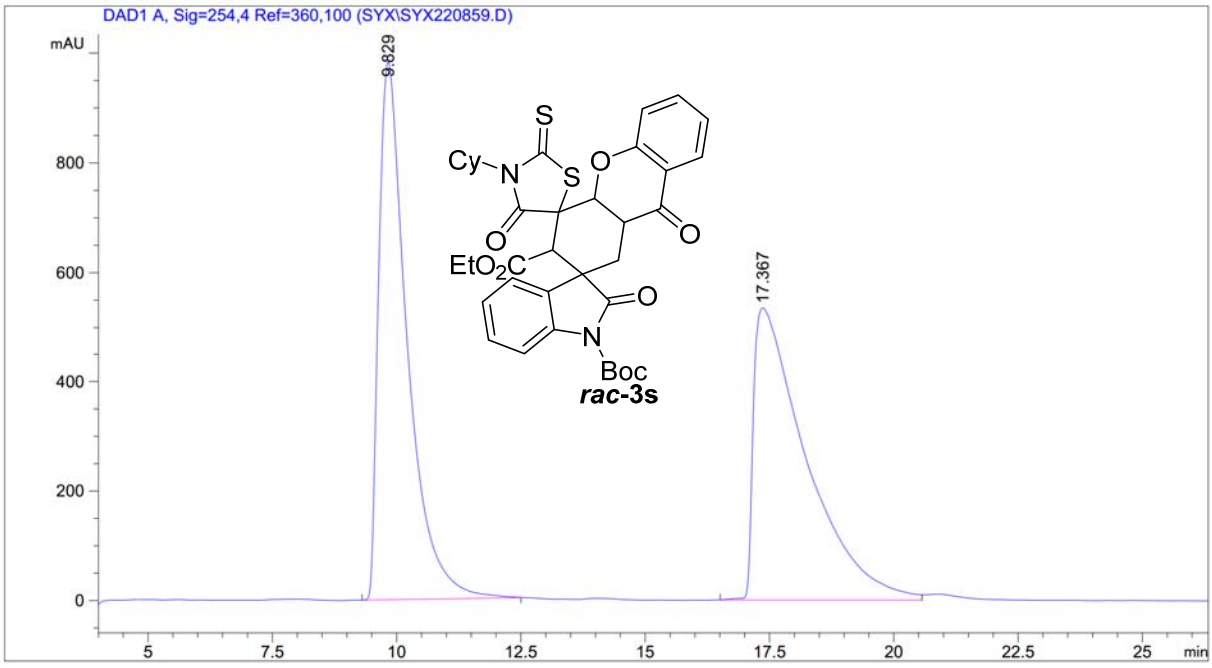
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.484	BB	0.2590	2502.57227	145.23837	3.8093
2	11.244	BB	0.5383	6.31930e4	1581.22510	96.1907



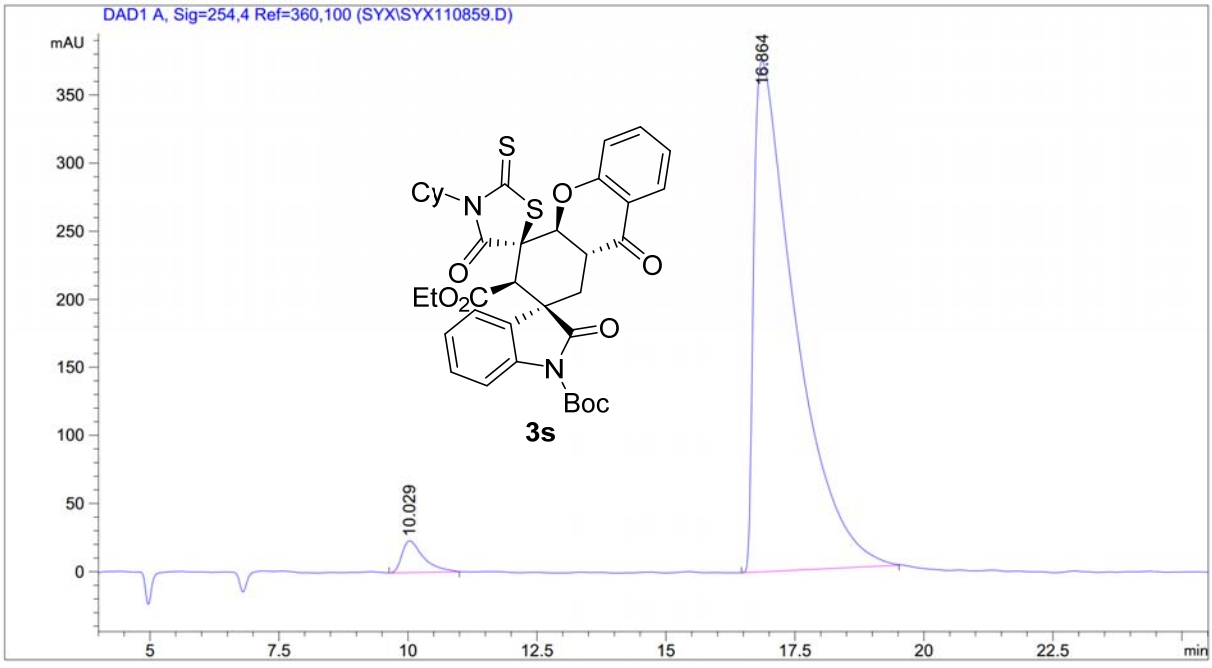
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.307	VV	0.4520	3.08622e4	1052.93384	50.6350
2	21.506	BB	1.1269	3.00881e4	360.80914	49.3650



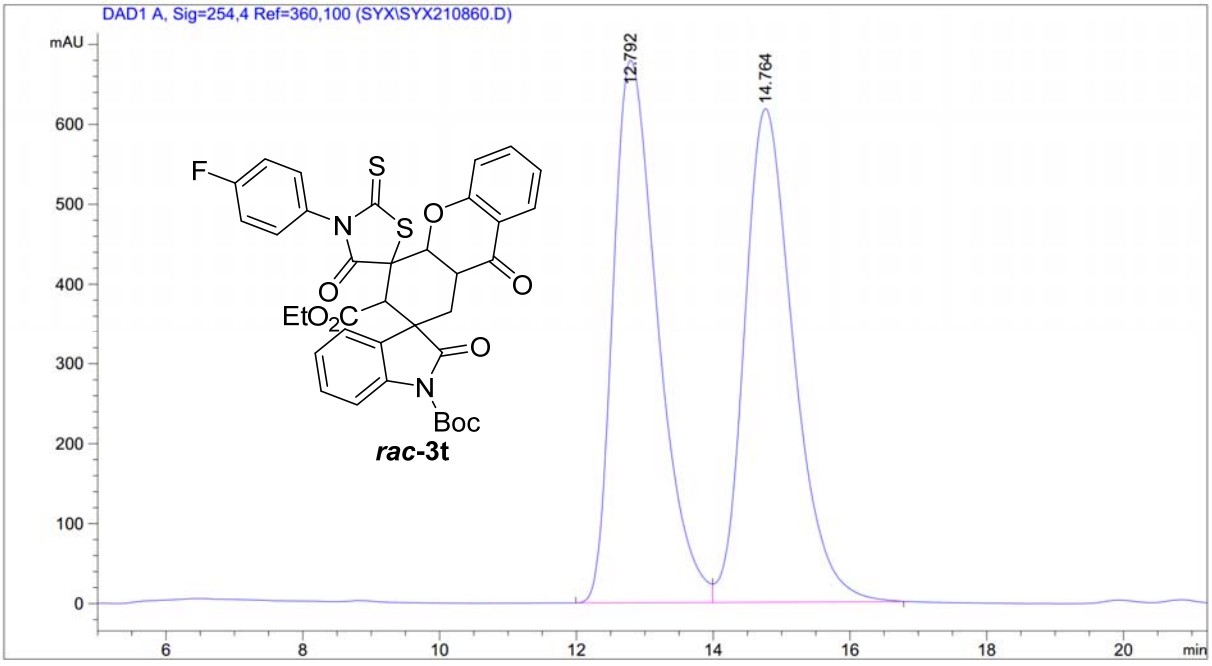
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.454	MM	0.4611	1008.84003	36.46187	3.3717
2	21.380	MM	1.3621	2.89123e4	353.78326	96.6283



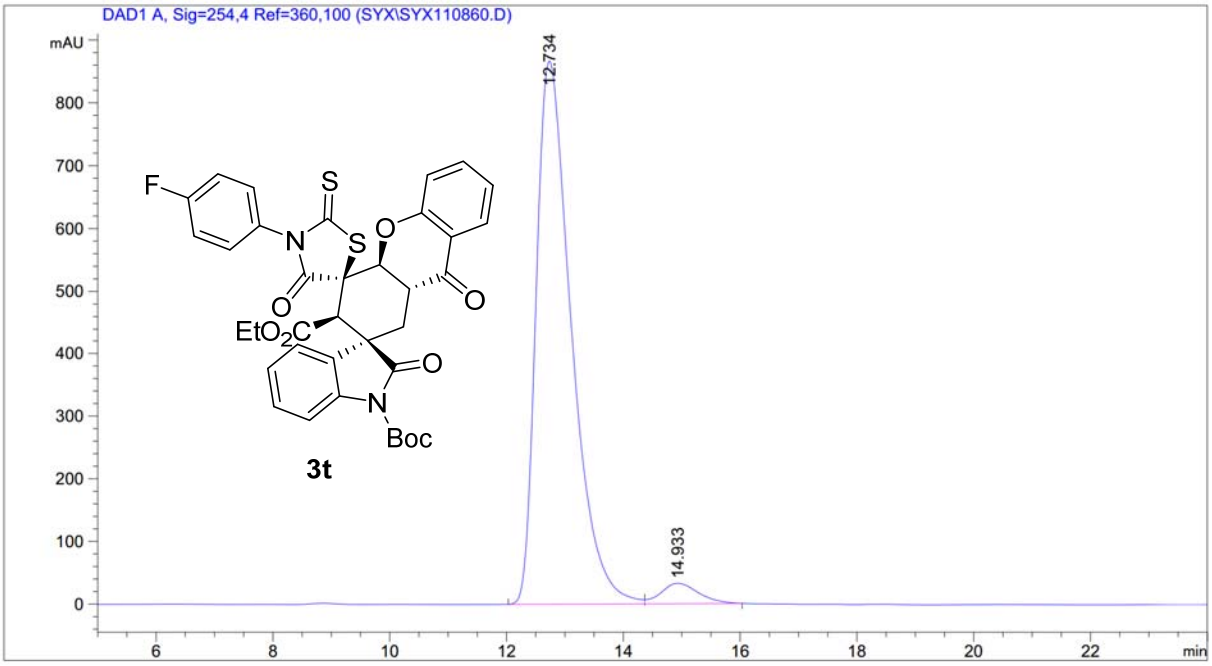
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.829	BB	0.5953	3.93657e4	982.77747	50.0628
2	17.367	BB	0.9946	3.92669e4	534.78662	49.9372



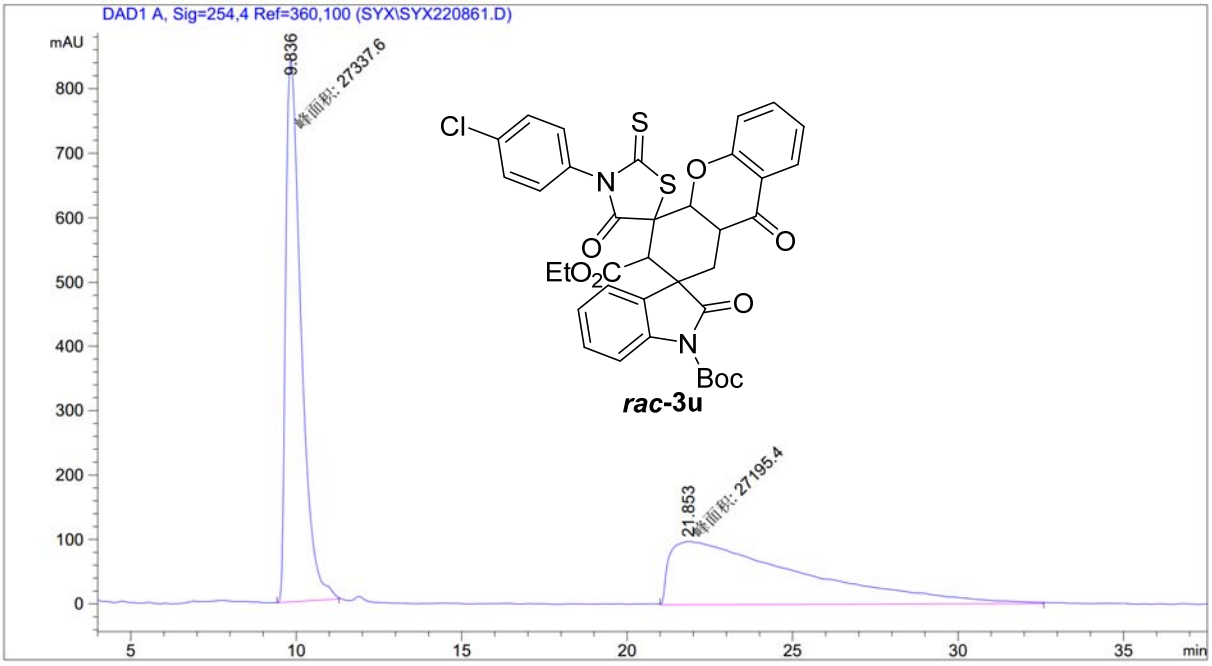
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.029	BB	0.4273	677.47961	23.29821	3.1285
2	16.864	BB	0.7902	2.09773e4	375.21716	96.8715



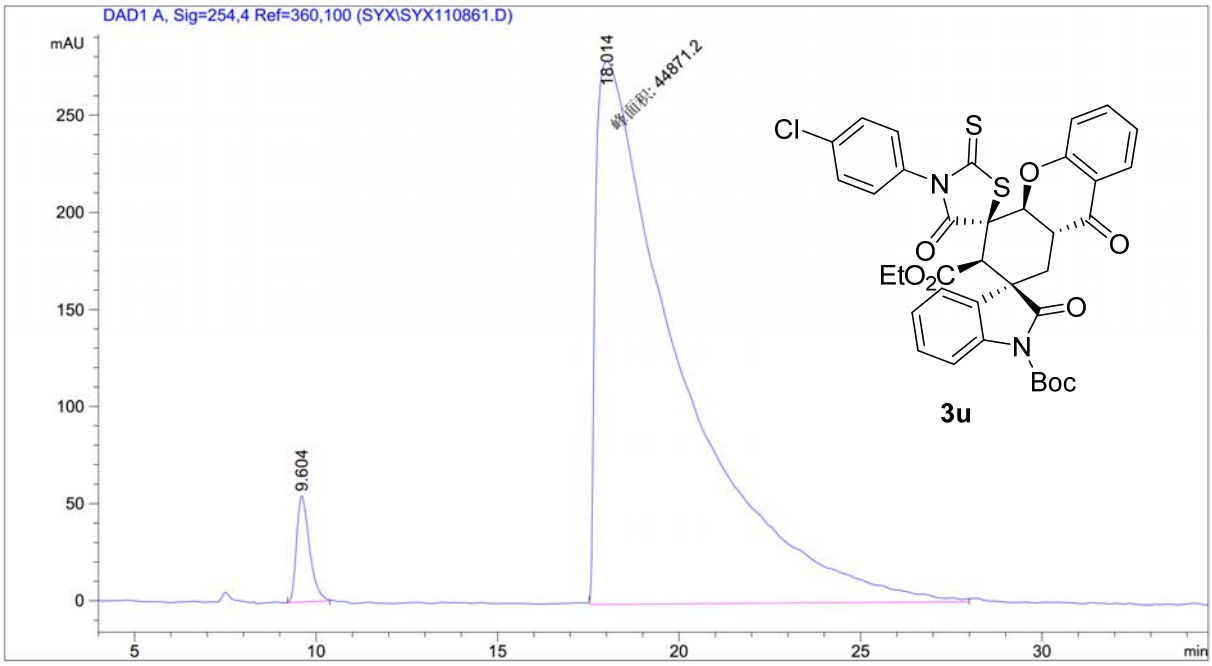
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.792	BV	0.6956	3.07201e4	679.25500	49.9999
2	14.764	VB	0.7621	3.07202e4	617.85596	50.0001



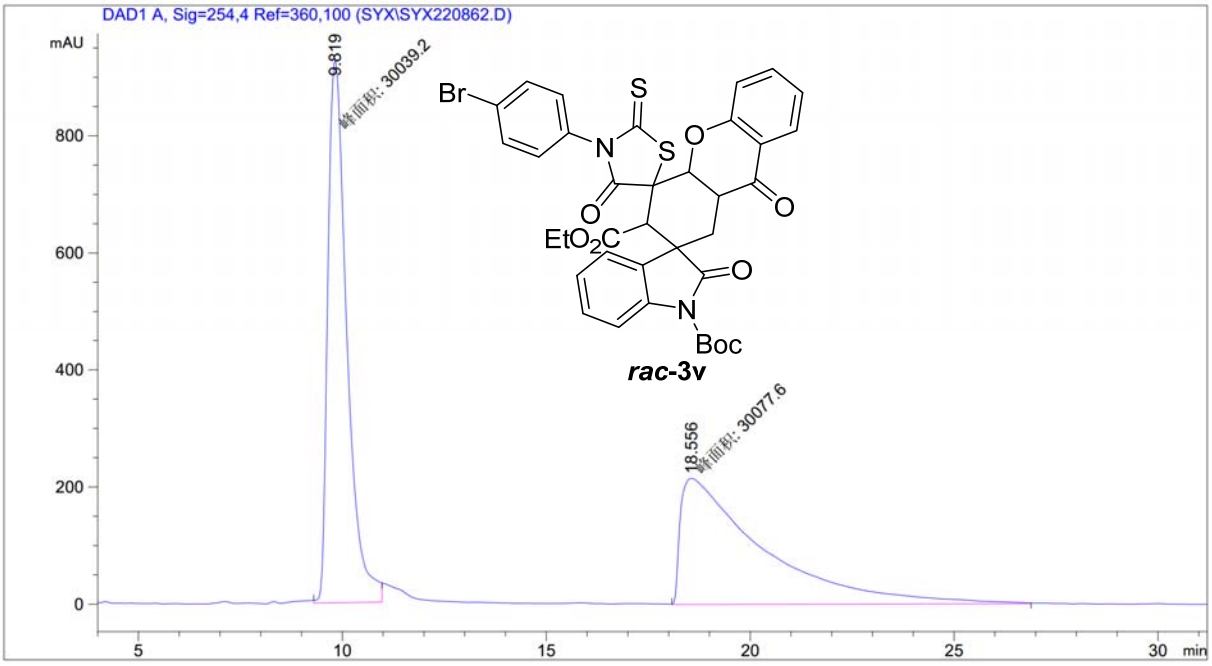
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.734	BB	0.6371	3.61938e4	866.80304	96.1107
2	14.933	BB	0.6364	1464.63257	32.70927	3.8893



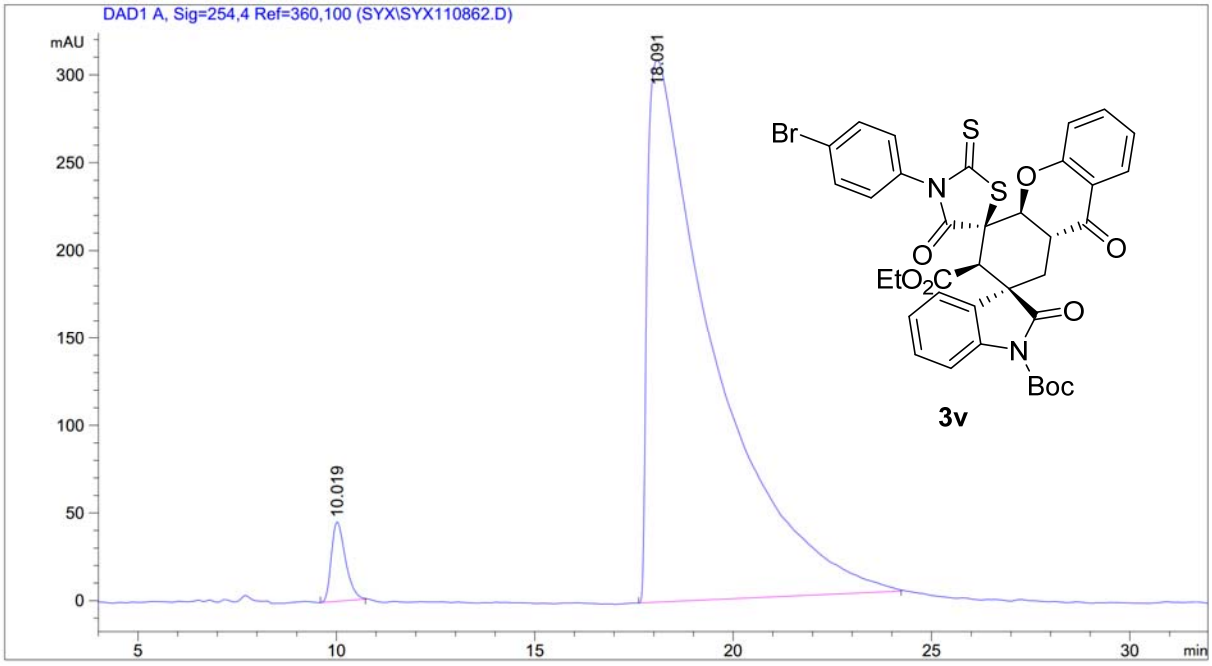
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.836	MM	0.5419	2.73376e4	840.75775	50.1304
2	21.853	MM	4.6210	2.71954e4	98.08566	49.8696



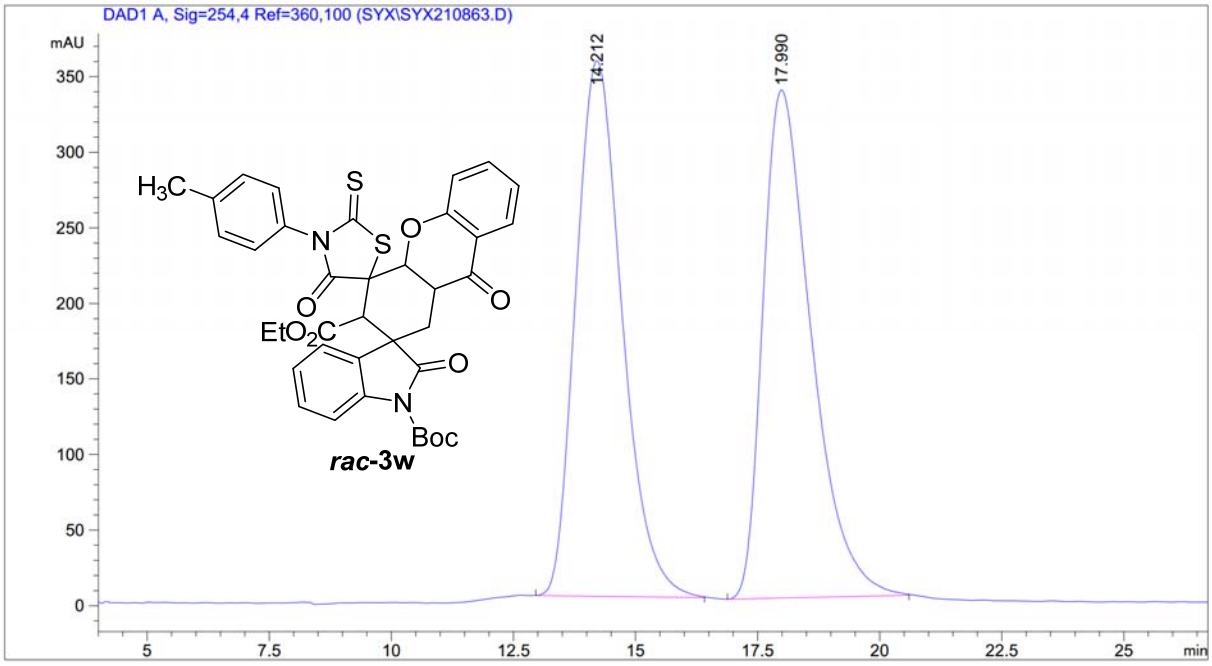
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.604	BB	0.3761	1353.75757	54.44183	2.9286
2	18.014	MM	2.6761	4.48712e4	279.45758	97.0714



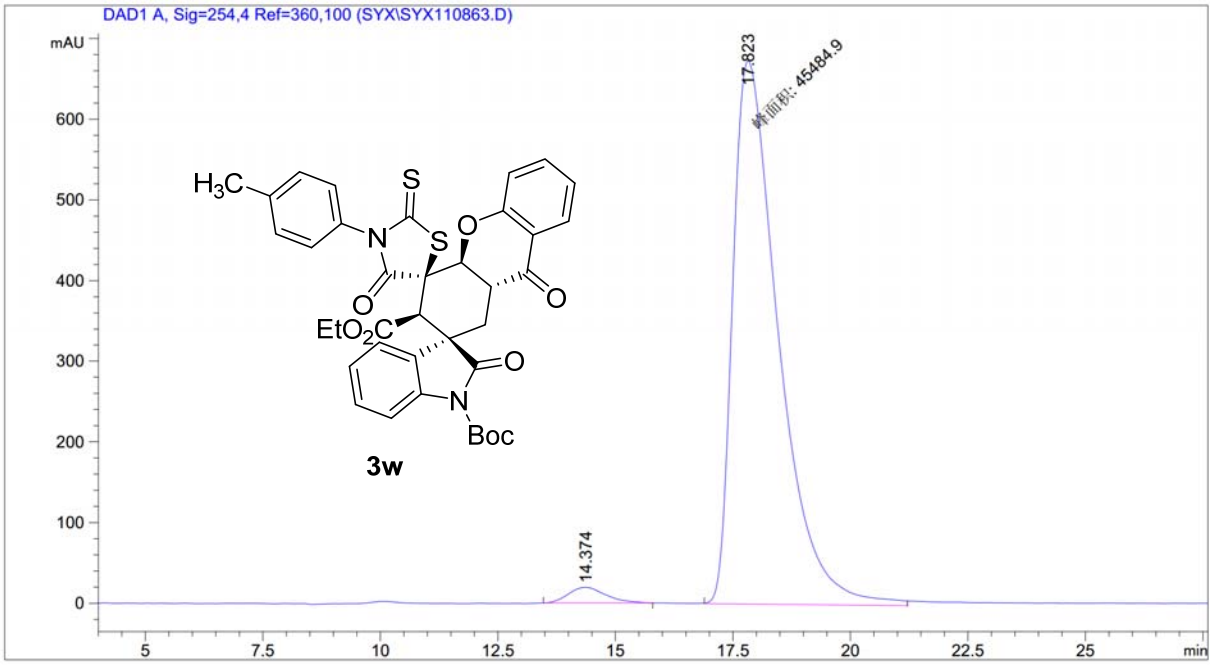
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.819	MF	0.5409	3.00392e4	925.65521	49.9680
2	18.556	MM	2.3276	3.00776e4	215.37292	50.0320



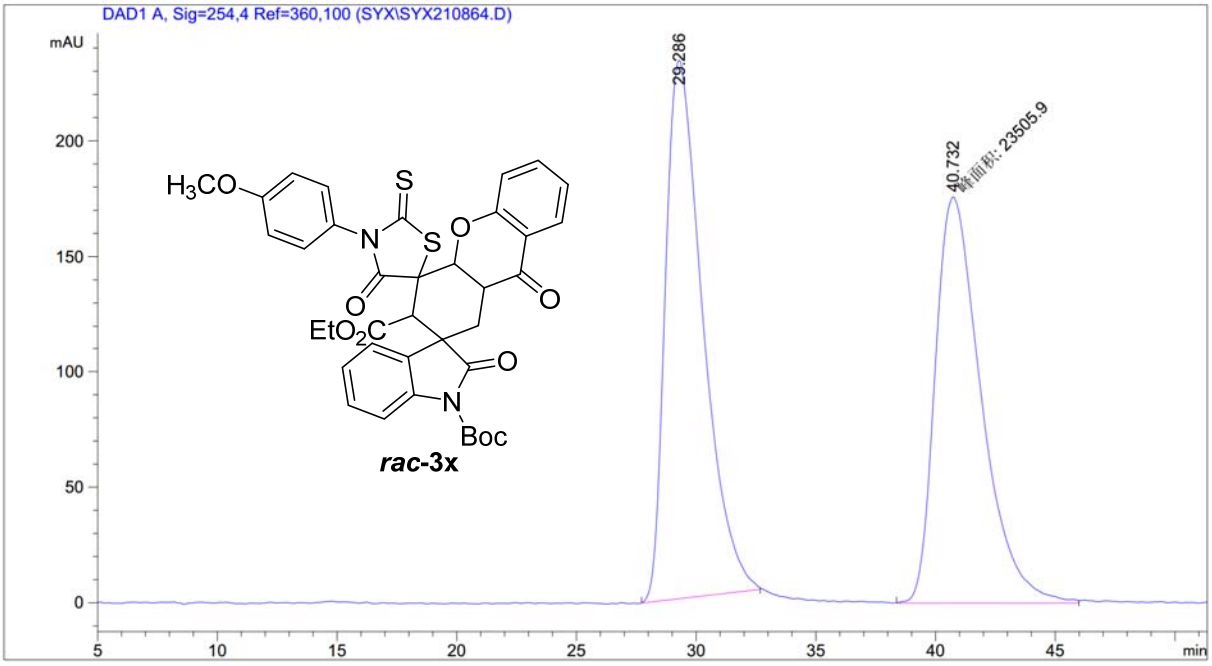
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.019	BB	0.3782	1116.14893	45.18058	2.9921
2	18.091	BB	1.5182	3.61874e4	309.03043	97.0079



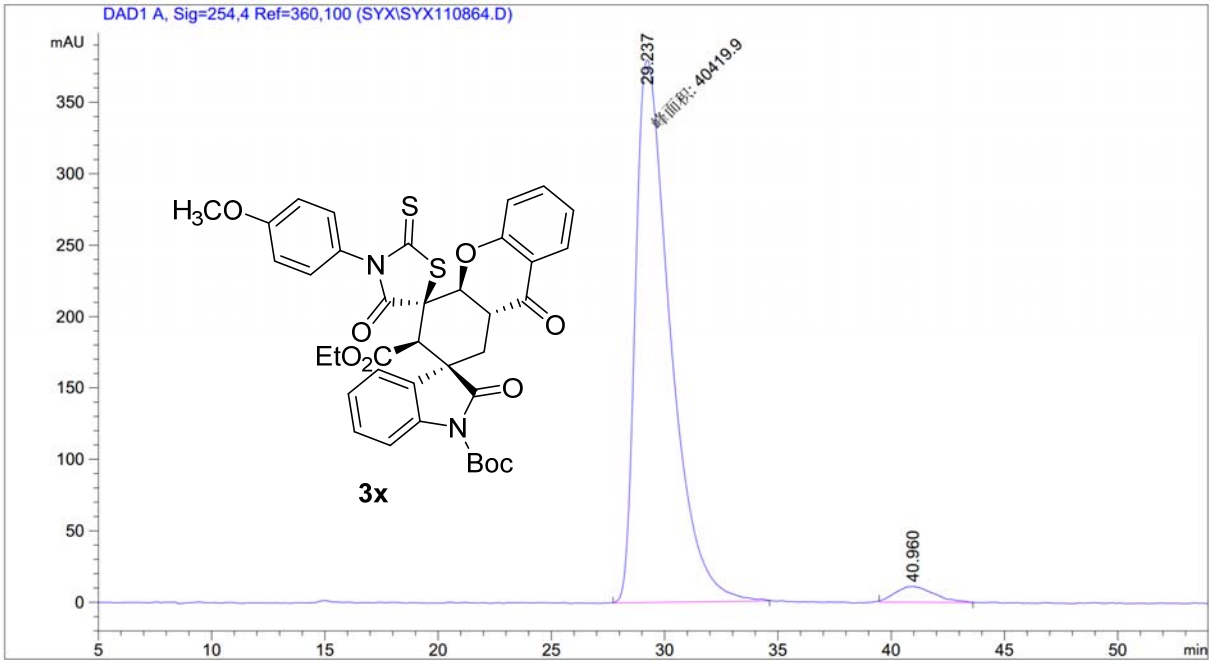
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.212	BB	1.0275	2.33029e4	354.21991	50.1565
2	17.990	BB	1.0139	2.31574e4	336.08426	49.8435



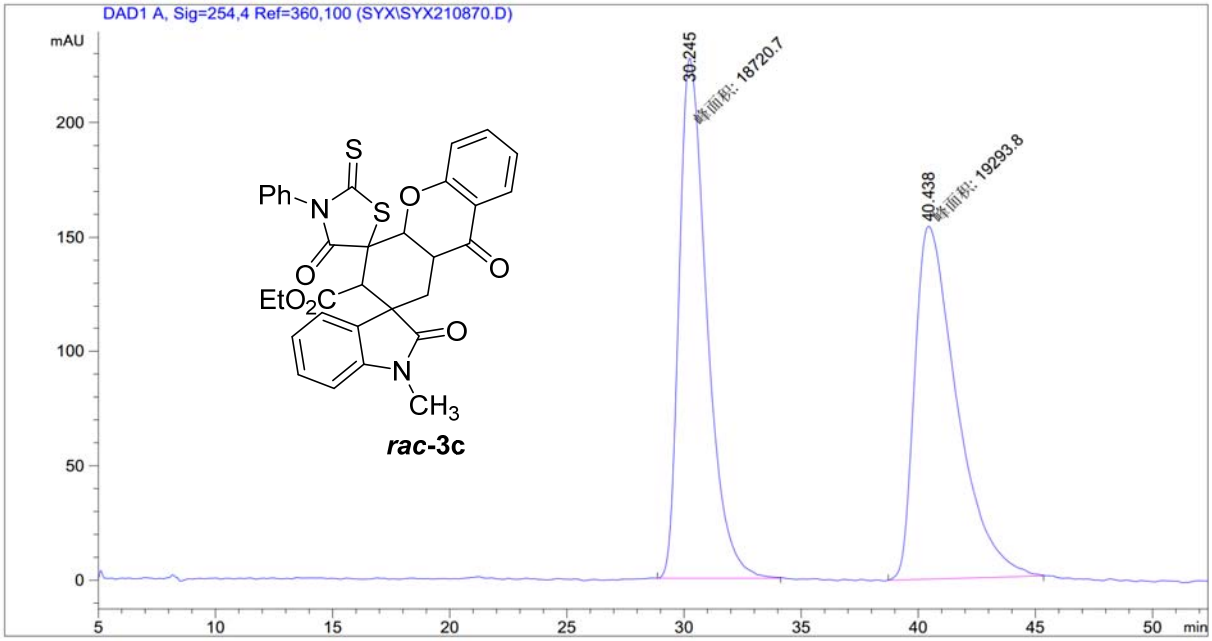
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.374	BB	0.6669	1070.32007	19.36193	2.2990
2	17.823	MM	1.1261	4.54849e4	673.20355	97.7010



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.286	BB	1.5299	2.52733e4	232.92610	51.8116
2	40.732	MM	2.2265	2.35059e4	175.95927	48.1884

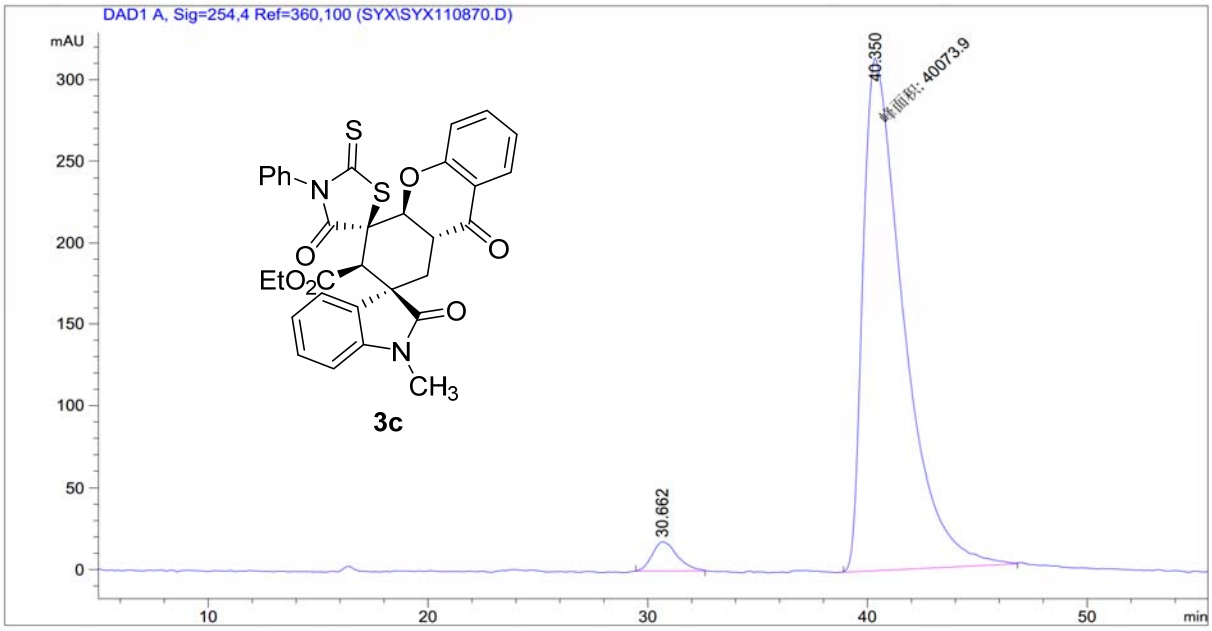


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.237	MM	1.7750	4.04199e4	379.53232	96.8665
2	40.960	BB	1.4051	1307.51282	10.94971	3.1335



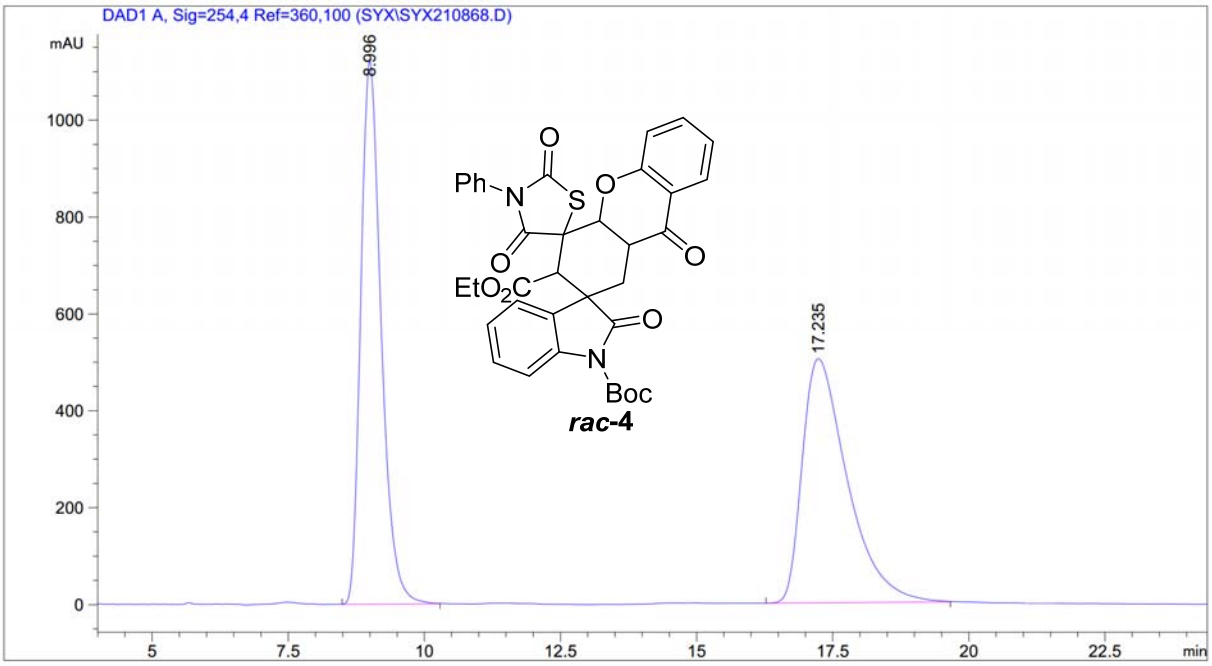
rac-3c

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.245	MM	1.3736	1.87207e4	227.14859	49.2462
2	40.438	MM	2.0825	1.92938e4	154.41595	50.7538

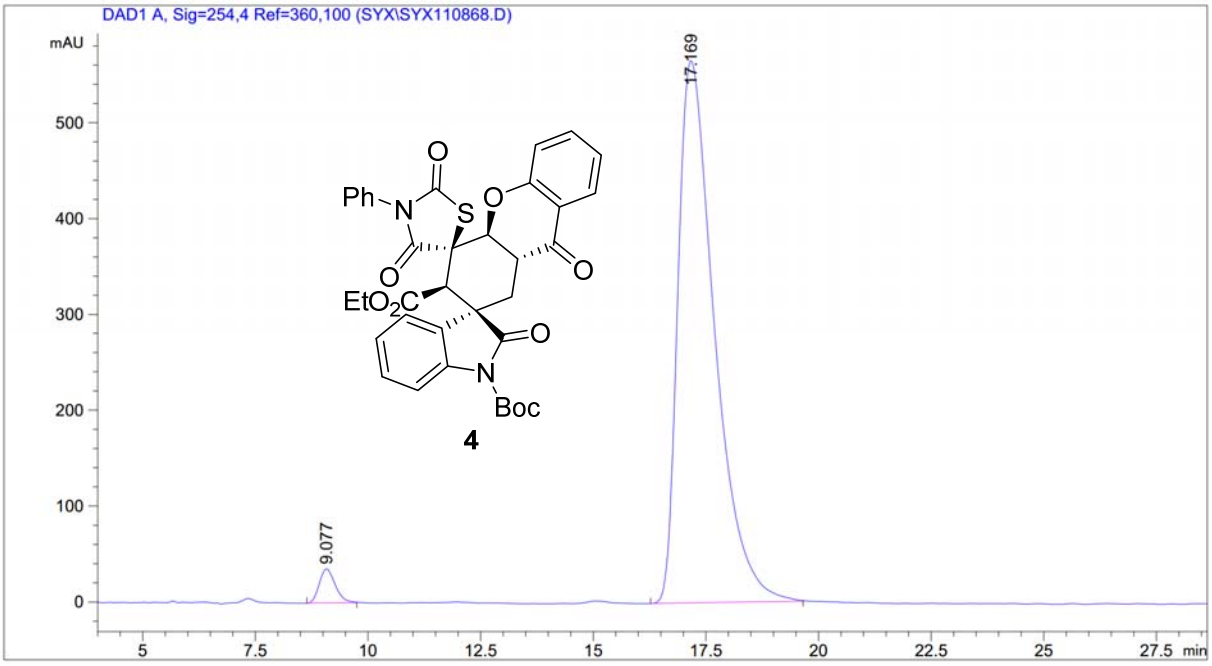


3c

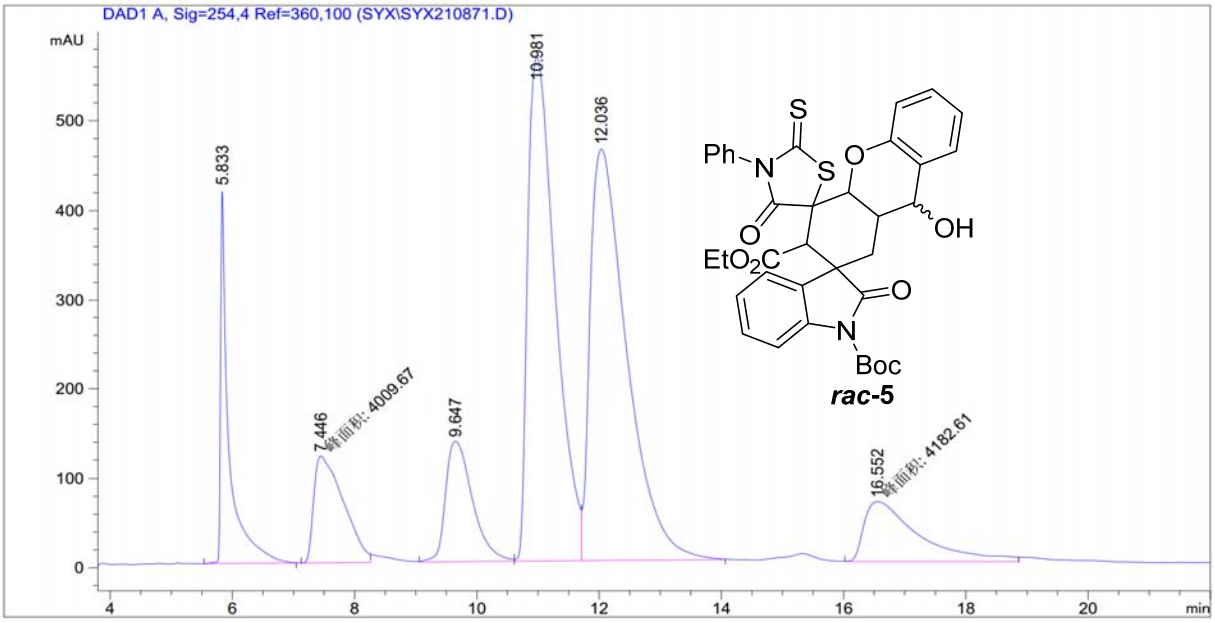
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.662	BB	0.9432	1435.18921	18.02044	3.4575
2	40.350	MM	2.1273	4.00739e4	313.97202	96.5425



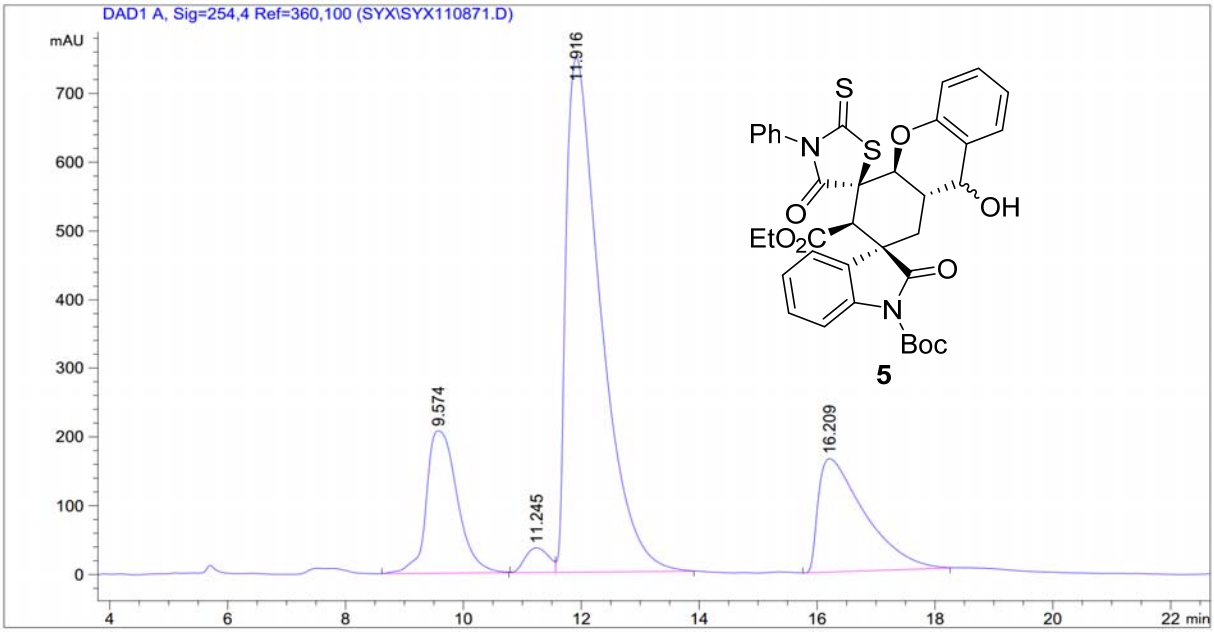
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.996	BB	0.4022	2.92082e4	1120.01135	50.2001
2	17.235	BB	0.8555	2.89753e4	503.41330	49.7999



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.077	BB	0.3732	872.90979	35.45610	2.6613
2	17.169	BB	0.8248	3.19275e4	565.38837	97.3387



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	5.833	BB	0.1235	3933.65039	419.01163	7.3865
2	7.446	MF	0.5612	4009.66553	119.07928	7.5292
3	9.647	BV	0.4722	4125.06396	134.36517	7.7459
4	10.981	VV	0.4793	1.77401e4	563.56036	33.3116
5	12.036	VB	0.6303	1.92638e4	460.29123	36.1729
6	16.552	MM	1.0362	4182.60986	67.27588	7.8539



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.574	BB	0.5671	7538.98535	206.92812	15.6354
2	11.245	BV	0.4520	987.40973	35.77127	2.0478
3	11.916	VB	0.6025	3.06845e4	748.13361	63.6377
4	16.209	VB	0.7636	9006.57129	164.80785	18.6791