Electronic Supplementary Information *for*

# Synthesis of chiral γ-amino-butyric acid derivatives via enantioconvergent ring opening of racemic 2-(hetero)aryl aziridines with ketene silyl acetals

Ling Qi, Pei-Jun Yang, Wen-Tao Ji, Gui-De Tao, Gaosheng Yang and Zhuo Chai*

## Table of Contents

General Information .....S2

Sources of ketene silyl acetals **1** and aziridines **2** used in this study.....S3

Typical procedure for the enantioconvergent ring opening of aziridines with ketene silyl acetals .....S4

Procedure for the transformation of *(R/S)*-**3ak** to *(R/S)*-rolipram .....S12

References.....S13

Copies of HPLC Traces .....S14

Copies of $^{1}$H NMR and $^{13}$C NMR Spectra for All New Compounds .....S42

## General Information

Unless otherwise noted, commercial reagents and solvents were purified prior to use following the guidelines of Perrin and Armarego,[1] and the purified solvents of $CH_3CN$, toluene and *m*-xylene were stored over activated molecular sieves 4Å. $[(CH_3CN)_4Cu]PF_6$, chiral diphosphine ligands were purchased from commercial vendors and used as received. Chromatographic purification of products was accomplished by using forced-flow chromatography on Silicycle SiliaFlash® F60 40–63 μm, 60 Å silica gel. Thin-layer chromatography (TLC) was performed on silica gel plates (HSGF 254). Visualization of the developed chromatogram was performed by UV light, staining with iodine (dispersed in silica gel), or by $KMnO_4$ stain.

$^1H$ NMR spectra (500 MHz), $^{13}C$ NMR (125 MHz) and $^{19}F$ NMR (471 MHz) spectra data were recorded on Bruker AVANCE-500 spectrometers. $^1H$ NMR chemical shifts are reported in parts per million (ppm) and are referenced to residual protium in the NMR solvent ($\delta$ 7.26 for $CHCl_3$). $^{13}C$ NMR chemical shifts are reported in parts per million (ppm) and are referenced to the carbon resonances of the solvent residual peak ($\delta$ 77.16 for $CDCl_3$). $^{19}F$ NMR data recorded are listed by using $CFCl_3$ as external reference. Data for $^1H$ NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constant (Hz) and integration. Data for $^{13}C$ NMR are recorded with broad-band proton decoupling technique and are reported in terms of chemical shift. Melting points were determined on a SGW X-4 melting apparatus and are uncorrected. Mass spectra were obtained on a Bruker Apex IV RTMS. High performance liquid chromatography (HPLC) was performed on a DIONEX UltiMate 3000 LC systems using Daicel CHIRALPAK® columns as noted.

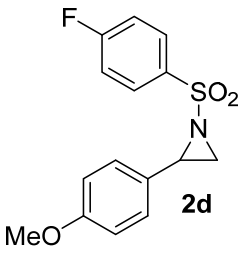
## Sources of ketene silyl acetals 1 and aziridines 2 used in this study

Ketene silyl acetals **1a**–**1g** were prepared following literature methods.[2]

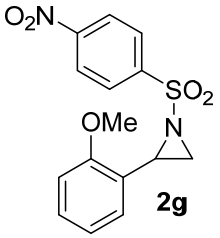
Aziridines **2** were prepared from the corresponding alkenes (8 mmol) and PhI=$NSO_2Ar$ (4 mmol) following Evans' procedure by using $Cu(acac)_2$ (8 mol%) as catalyst in 30 mL of $CH_3CN$.[3a]

The spectroscopic data of all known compounds are in agreement with those previously reported.

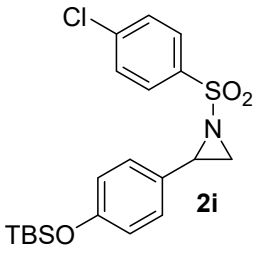
Analytical data for aziridine substrates previously not reported:



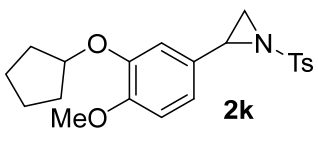

White solid (0.84 g, 68% yield). **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.08 (m, 2H), 7.21 (pseudo t, *J* = 8.8 Hz, 2H), 7.12 (d, *J* = 8.8 Hz, 2H), 6.82 (d, *J* = 8.8 Hz, 2H), 3.77 (s, 3H), 3.76 (dd, *J* = 7.1, 4.4 Hz, 1H), 2.99 (d, *J* = 7.1 Hz, 1H), 2.42 (d, *J* = 4.4 Hz, 1H); **$^{13}$C NMR** (125 M Hz, $CDCl_3$): δ 165.8 (d, $^1J_{C–F}$ = 256.2 Hz), 159.9, 134.4 (d, $^4J_{C–F}$ = 2.8 Hz), 130.8 (d, $^3J_{C–F}$ = 9.0 Hz), 127.9, 126.7, 116.5 (d, $^2J_{C–F}$ = 22.7 Hz), 114.2, 55.4, 41.3, 36.1; **$^{19}$F NMR** (471 MHz, $CDCl_3$): δ -103.5 (m); **HRMS** (ESI-TOF) Calculated for $C_{14}H_{12}BrClNO_2S$ ($[M+H]^+$): $C_{15}H_{15}FNO_3S$ ($[M+H]^+$): 308.0751, found: 308.0747.



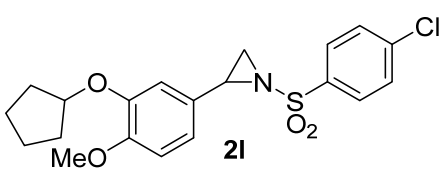

Primrose solid (0.87 g, 65% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.38 (d, *J* = 8.8 Hz, 2H), 8.20 (d, *J* = 8.8 Hz, 2H), 7.26 (m,1H), 7.04 (m, 1H), 6.89–6.83 (m, 2H), 4.20 (dd, *J* = 7.2, 4.9 Hz, 1H), 3.78 (s, 3H), 3.11 (d, *J* = 7.7 Hz, 1H), 2.49 (d, *J* = 5.0 Hz, 1H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 158.3, 150.7, 144.3, 129.9, 129.5, 126.5, 124.3, 122.6, 120.8, 110.4, 55.5, 38.4, 35.5; **HRMS** (ESI-TOF) Calculated for $C_{15}H_{15}N_2O_5S$ ($[M+H]^+$): 335.0696, found: 335.0700.




White solid (1.21 g, 72% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.8 Hz, 2H), 7.51 (d, *J* = 8.8 Hz, 2H), 7.06 (d, *J* = 8.8 Hz, 2H), 6.76 (d, *J* = 8.8 Hz, 2H), 3.77 (dd, *J* = 7.2, 4.4 Hz, 1H), 2.98 (d, *J* = 7.1 Hz, 1H), 2.41 (d, *J* = 4.4 Hz, 1H), 0.96 (s, 9H), 0.17 (s, 6H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 156.1, 140.4, 136.8, 129.6, 129.5, 127.9, 127.3, 120.4, 41.4, 36.2, 25.7, 18.3, -4.3; **HRMS** (ESI-TOF) Calculated for $C_{20}H_{27}ClNO_3SSi$ ($[M+H]^+$): 424.1164, found: 424.1165.

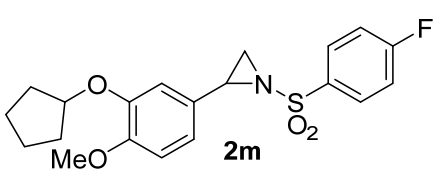



White solid (1.16 g, 75% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.86 (d, *J* = 8.3 Hz, 2H), 7.32 (d, *J* = 7.7 Hz, 2H), 6.75 (m, 2H), 6.64 (s, 1H), 4.66 (m, 1H), 3.79 (s, 3H), 3.69 (dd, *J* = 7.2, 4.4 Hz, 1H), 2.97 (d, *J* = 7.2 Hz, 1H), 2.42 (s, 3H), 2.38 (d, *J* = 4.4 Hz, 1H), 1.87–1.76 (m, 6H), 1.59 (m, 2H)； **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 150.2, 147.9, 144.7, 135.2, 129.8, 128.0, 127.3, 119.1, 113.1, 111.9, 80.5, 56.2, 41.4, 35.7, 32.8, 24.1, 21.7; **HRMS** (ESI-TOF) Calculated for $C_{21}H_{26}NO_4S$ ($[M+H]^+$): 388.1577, found: 388.1570.



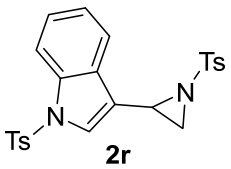
**2l**

White solid (1.18 g, 72% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.8 Hz, 2H), 7.50 (d, *J* = 8.2 Hz, 2H), 6.78–6.73 (m, 2H), 6.63 (m, 1H), 4.67 (m, 1H), 3.80 (s, 3H), 3.73 (dd, *J* = 7.2, 4.4 Hz, 1H), 3.00 (d, *J* = 7.2 Hz, 1H), 2.43 (d, *J* = 4.4 Hz, 1H), 1.87–1.77 (m, 6H), 1.59 (m, 2H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 150.4, 147.9, 140.4, 136.9, 129.6, 129.4, 126.9, 119.1, 113.0, 111.9, 80.5, 56.2, 41.8, 35.9, 32.9, 24.2; **HRMS** (ESI-TOF) Calculated for $C_{20}H_{23}ClNO_4S$ ([M+H]$^+$): 408.1031, found: 408.1026.



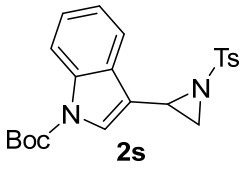
**2m**

White solid (1.13 g, 72% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.06–7.94 (m, 2H), 7.21 (m, 2H), 6.78–6.73 (m, 2H), 6.65 (m, 1H), 4.68 (m, 1H), 3.80 (s, 3H), 3.72 (dd, *J* = 7.2, 4.4 Hz, 1H), 3.00 (d, *J* = 7.2 Hz, 1H), 2.42 (d, *J* = 4.4 Hz, 1H), 1.90–1.77 (m, 6H), 1.62–1.57 (m, 2H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 165.8 (d, $^1J_{C–F}$ = 256.1 Hz), 150.4, 147.9, 134.4 (d, $^4J_{C–F}$ = 2.8 Hz), 130.8 (d, $^3J_{C–F}$ = 9.0 Hz), 127.0, 119.2, 116.5 (d, $^2J_{C–F}$ = 22.7 Hz), 113.1, 112.0, 80.6, 56.2, 41.7, 35.9, 32.8, 24.1; **$^{19}$F NMR** (471 MHz, $CDCl_3$) δ -103.5 (m); **HRMS** (ESI-TOF) Calculated for $C_{20}H_{23}FNO_4S$ ([M+H]$^+$): 392.1326, found: 392.1327.



**2r**

White solid (1.12 g, 60% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.2 Hz, 1H), 7.88 (d, *J* = 8.8 Hz, 2H), 7.72 (d, *J* = 8.2 Hz, 2H), 7.48 (d, *J* = 7.7 Hz, 1H), 7.45 (s, 1H), 7.34 (d, *J* = 8.2 Hz, 2H), 7.33–7.29 (m, 1H), 7.22–7.18 (m, 3H), 3.86 (dd, *J* = 7.1, 4.4 Hz, 1H), 2.99 (d, *J* = 7.2 Hz, 1H), 2.54 (d, *J* = 4.4 Hz, 1H), 2.45 (s, 3H), 2.34 (s, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 145.4, 145.0, 135.2, 135.1, 134.9, 130.1, 130.0, 129.2, 128.2, 127.0, 125.3, 124.5, 123.6, 119.9, 117.3, 113.7, 34.7, 34.6, 21.8, 21.7; **HRMS** (ESI-TOF) Calculated for $C_{24}H_{23}N_2O_4S_2$ ([M+H]$^+$): 467.1094, found: 467.1099.



**2s**

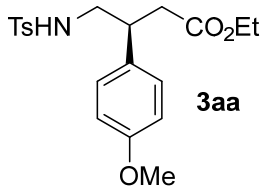
White solid (1.17 g, 71% yield). **$^1$H NMR** (500 MHz, $CDCl_3$) δ 8.09 (m, 1H), 7.89 (d, *J* = 8.2 Hz, 2H), 7.49–7.44 (m, 2H), 7.35–7.30 (m, 3H), 7.19 (pseudo t, *J* = 7.7 Hz, 1H), 3.90 (dd, *J* = 7.2, 4.4 Hz, 1H), 3.04 (d, *J* = 7.2 Hz, 1H), 2.61 (d, *J* = 4.4 Hz, 1H), 2.44 (s, 3H), 1.64 (s, 9H); **$^{13}$C NMR** (125 MHz, $CDCl_3$) δ 149.5, 144.9, 135.6, 135.1, 129.9, 129.0, 128.1, 125.0, 124.4, 123.0, 119.3, 115.5, 84.2, 35.2, 34.4, 28.3, 21.8; **HRMS** (ESI-TOF) Calculated for $C_{22}H_{25}N_2O_4S$ ([M+H]$^+$): 413.1530, found: 413.1531.

## Typical procedure for the enantioconvergent ring opening of aziridines with ketene silyl acetals.

Under argon atmosphere, to an oven-dried Schlenk tube was added $[(CH_3CN)_4Cu]PF_6$ (1.8 mg, 0.005 mmol) and (*S*)-BINAP (3.8 mg, 0.006 mmol). The system was evacuated under vacuum and back-

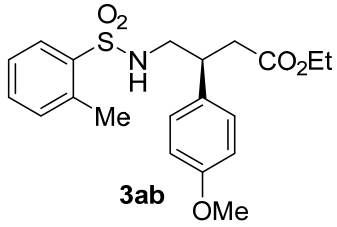
filled with argon (repeated twice). Then 1.0 mL of toluene was added and the resulting mixture was stirred at rt for 20 mins to give a white suspension, followed by the sequential addition of the aziridine **2** (0.1 mmol), ketene silyl acetal **1** (0.11 mmol) and 1.0 mL of toluene. The reaction mixture was stirred at 25±2 °C until the disappearance of **2** as monitored by TLC (visualized by staining with iodine and UV light). Then 10 mL of saturated aqueous $NaHCO_3$ solution and 10 mL of ethyl acetate (EtOAc) were added, and the phases were separated. The aqueous phase was extracted with EtOAc (3 x 5 mL). The combined organic phases were dried over anhydrous $Na_2SO_4$ and concentrated via rotary evaporation under reduced pressure to provide the crude mixture. Then the crude mixture was purified by column chromatography (eluting with petroleum ether/EtOAc (v/v): 10:1–1:1 containing 0.5 v% triethylamine) to furnish the desired products. As noted in Table 1, in cases where the formation of the byproduct **3aa'** was considerable as judged by TLC, the crude mixture was pretreated with 1.0 mL of TBAF (1 M in THF) by stirring at rt for 1 h before being subjected to flash chromatography to provide the desired product.

The corresponding racemic products for HPLC assay were prepared following a similar procedure with $[(CH_3CN)_4Cu]PF_6$ (5 mol%), *rac*-BINAP (6 mol%), 0.11 mmol of the ketene silyl acetal **1** and 0.1 mmol of aziridine **2** in toluene.



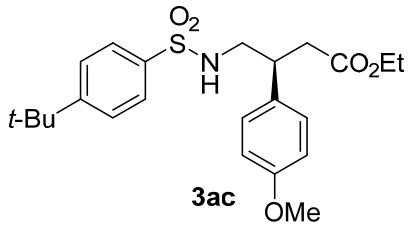
**3aa**

Compound **3aa** was obtained as a white solid following the general procedure (34.1 mg, 87% yield). ee = 92%, $[\alpha]_D^{23}$ = -99.3 (*c* = 0.62, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 16.2 min, $t_R$(major) = 17.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.2 Hz, 2H), 7.27 (d, *J* = 7.7 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 7.79 (d, *J* = 8.8 Hz, 2H), 4.50 (m, 1H), 4.04 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.77 (s, 3H), 3.25–3.17 (m, 2H), 3.05–3.00 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 2H), 2.42 (s, 3H), 1.15 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 159.0, 143.6, 137.0, 132.2, 129.8, 128.7, 127.2, 114.4, 60.8, 55.4, 48.1, 40.9, 38.6, 21.7, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{20}H_{26}NO_5S$ ($[M+H]^+$):392.1526, found:392.1535.

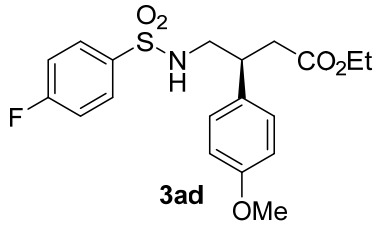


**3ab**

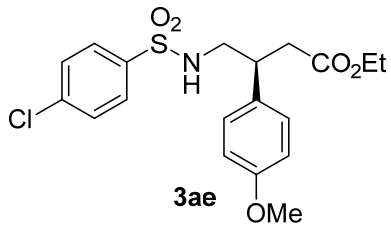
Compound **3ab** was obtained as a colorless viscous oil following the general procedure (22.4 mg, 57% yield). ee = 90%, $[\alpha]_D^{23}$ = +72.8 (*c* = 0.19, EtOH), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 12.4 min, $t_R$(major) = 13.1 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.91 (d, *J* = 8.2 Hz, 1H), 7.45 (m, 1H), 7.32–7.25 (m, 2H), 6.97 (d, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.2 Hz, 2H), 4.47 (m, 1H), 4.03 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.78 (s, 3H), 3.28–3.16 (m, 2H), 3.05–2.99 (m, 1H), 2.56 (ABM, *J* = 15.9, 7.1 Hz, 2H), 2.42 (s, 3H), 1.15 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.8, 159.1, 137.7, 137.1, 132.9, 132.7, 132.1, 129.7, 128.6, 126.3, 114.5, 60.8, 55.4, 48.0, 41.0, 38.7, 20.2, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{20}H_{26}NO_5S$ ($[M+H]^+$): 392.1526, found: 392.1533.



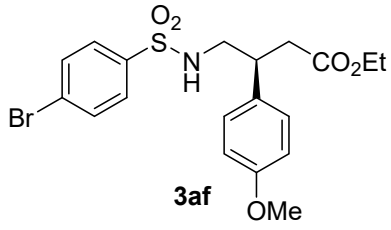

Compound **3ac** was obtained as a colorless viscous oil following the general procedure (36.5 mg, 84% yield). ee = 93%, $[\alpha]_D^{23}$ = -43.1 (*c* = 0.70, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 13.0 min, $t_R$(major) = 16.7 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.3 Hz, 2H), 7.49 (d, *J* = 8.3 Hz, 2H), 6.99 (d, *J* = 8.3 Hz, 2H), 6.80 (d, *J* = 8.2 Hz, 2H), 4.35 (m, 1H), 4.04 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.78 (s, 3H), 3.29–3.19 (m, 2H), 3.09–3.03 (m, 1H), 2.60 (ABM, *J* = 16.0, 7.2 Hz, 2H), 1.34 (s, 9H), 1.16 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 159.0, 156.6, 137.0, 132.2, 128.7, 127.0, 126.2, 114.5, 60.8, 55.4, 48.2, 41.0, 38.6, 35.3, 31.2, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{23}H_{32}NO_5S$ ($[M+H]^+$): 434.1996, found: 434.1992.




Compound **3ad** was obtained as a primrose solid following the general procedure (31.1 mg, 78% yield). ee = 94%, $[\alpha]_D^{23}$ = -35.0 (*c* = 0.60, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 16.1 min, $t_R$(major) = 17.1 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.77 (m, 2H), 7.14 (pseudo t, *J* = 8.8 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 6.79 (d, *J* = 8.8 Hz, 2H), 4.66 (dd, *J* = 7.2, 5.0 Hz, 1H), 4.04 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.76 (s, 3H), 3.28–3.17 (m, 2H), 3.07–3.03 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 2H), 1.16 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 165.1 (d, $^1J_{C-F}$ =254.3 Hz), 159.0, 136.1 (d, $^4J_{C-F}$ = 2.7 Hz) , 132.1, 129.9 (d, $^3J_{C-F}$ = 9.0 Hz), 128.6, 116.4 (d, $^2J_{C-F}$ = 22.7 Hz), 114.4, 60.8, 55.3, 48.1, 40.9, 38.5, 14.2; **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -105.4 (m); **HRMS** (ESI-TOF) Calculated for $C_{19}H_{23}FNO_5S$ ($[M+H]^+$): 396.1275, found: 396.1280.

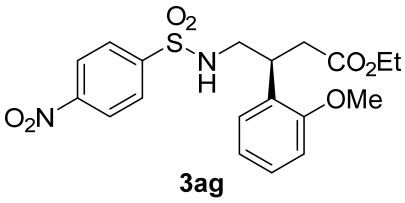



Compound **3ae** was obtained as a white solid following the general procedure (34.3 mg, 83% yield). ee = 94%, $[\alpha]_D^{23}$ = -96.1 (*c* = 0.69, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ= 254 nm, Hexanes/IPA = 9:1, 1.0 mL/min, $t_R$(minor) = 37.6 min, $t_R$(major) = 39.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.8 Hz, 2H), 7.43 (d, *J* = 8.8 Hz, 2H), 6.97 (d, *J* = 8.3 Hz, 2H), 6.79 (d, *J* = 8.8 Hz, 2H), 4.67 (dd, *J* = 7.2, 5.0 Hz, 1H), 4.04 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.77 (s, 3H), 3.29–3.17 (m, 2H), 3.08–3.03 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 1H), 1.16 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 159.0, 139.2, 138.6, 132.0, 129.5, 128.6, 114.4, 60.8, 55.4, 48.2, 40.9, 38.5, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{19}H_{23}ClNO_5S$ ($[M+H]^+$): 412.0980, found: 412.0987.



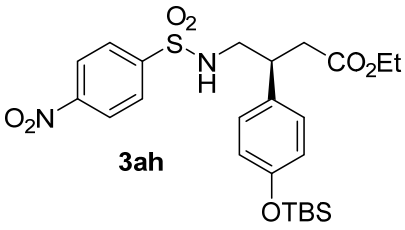

Compound **3af** was obtained as a white solid following the general procedure (30.3 mg, 66% yield). ee = 97%, $[\alpha]_D^{23}$ = -22.3 (*c* = 0.58, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ =254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 31.5 min, $t_R$(minor) = 36.7 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.61 (m,

4H), 6.98 (d, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 4.60 (dd, *J* = 7.2, 5.0 Hz, 1H), 4.05 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.78 (s, 3H), 3.29–3.23 (m, 2H), 3.08–3.03 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 2H), 1.17 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 159.0, 139.1, 132.5, 132.0, 128.7, 128.6, 127.7, 114.5, 60.8, 55.4, 48.2, 40.9, 38.5, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{19}H_{23}BrNO_5S$ ($[M+H]^+$): 456.0475, found: 456.0467.



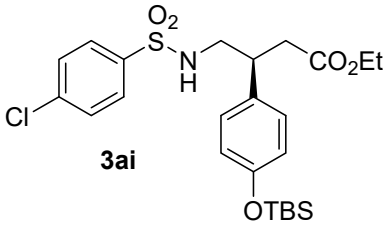
**3ag**

Compound **3ag** was obtained as a white solid following the general procedure (12.3 mg, 39% yield). ee = 92%, $[\alpha]_D^{23}$ = +132.1 (*c* = 0.16, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ＝254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 35.2 min, $t_R$(minor) = 41.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.26 (d, *J* = 8.8 Hz, 2H), 7.88 (d, *J* = 8.8 Hz, 2H), 7.22–7.19 (m, 1H), 6.95 (dd, *J* = 7.2, 1.7 Hz, 1H), 6.85 (dd, *J* = 7.7, 6.6 Hz, 1H), 6.80 (d, *J* = 8.3 Hz, 1H), 4.92 (pseudo t, *J* = 5.8 Hz, 1H), 4.07 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.75 (s, 3H), 3.62–3.55 (m, 1H), 3.41–3.36 (m, 1H), 3.30–3.25 (m, 1H), 2.67 (ABM, *J* = 16.0, 6.0 Hz, 2H), 1.18 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 172.4, 157.2, 150.0, 146.1, 128.8, 128.5, 128.3, 128.0, 124.3, 121.2, 111.1, 60.9, 55.5, 46.9, 36.8, 36.3, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{19}H_{23}N_2O_7S$ ($[M+H]^+$): 423.1220, found: 423.1229.



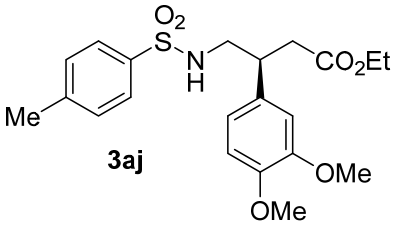
**3ah**

Compound **3ah** was obtained as a colorless viscous oil following the general procedure (25.8 mg, 51% yield). ee = 90%, $[\alpha]_D^{23}$ = -4.4 (*c* = 0.25, EtOH), **HPLC**: Daicel CHIRALCEL AS-H column, λ ＝ 254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 8.4 min, $t_R$(major) = 10.8 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.31 (d, *J* = 8.8 Hz, 2H), 7.94 (d, *J* = 8.8 Hz, 2H), 6.90 (d, *J* = 8.2 Hz, 2H), 6.72 (d, *J* = 8.2 Hz, 2H), 4.79 (dd, *J* = 7.1, 5.0 Hz, 1H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.38–3.32 (m, 1H), 3.21–3.10 (m, 2H), 2.59 (ABM, *J* = 16.0, 7.7 Hz, 2H), 1.17 (t, *J* = 7.2 Hz, 3H), 0.97 (s, 9H), 0.18 (s, 6H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 172.0, 155.3, 150.2, 146.1, 132.4, 128.5, 128.4, 124.5, 120.7, 61.0, 48.3, 41.0, 38.5, 25.8, 18.3, 14.2, -4.3; **HRMS** (ESI-TOF) Calculated for $C_{24}H_{35}N_2O_7SSi$ ($[M+H]^+$): 523.1929, found: 523.1923.



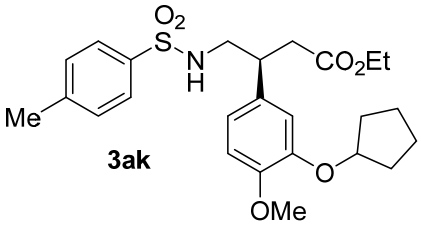
**3ai**

Compound **3ai** was obtained as a colorless viscous oil following the general procedure (48.0 mg, 94% yield). ee = 95%, $[\alpha]_D^{23}$ = +19.7 (*c* = 0.95, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ＝254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 7.4 min, $t_R$(major) = 10.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8.8 Hz, 2H), 7.45 (d, *J* = 8.2 Hz, 2H), 6.91 (d, *J* = 8.2 Hz, 2H), 6.73 (d, *J* = 8.8 Hz, 2H), 4.54 (brs, 1H), 4.05 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.30–3.24 (m, 1H), 3.21–3.15 (m, 1H), 3.08–3.03 (m, 1H), 2.67 (ABM, *J* = 15.9, 7.7 Hz, 2H), 1.16 (t, *J* = 7.1 Hz, 3H), 0.97 (s, 9H), 0.18 (s, 6H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 155.2, 139.3, 138.6, 132.6, 129.5, 128.6, 128.5, 120.6, 60.8, 48.1, 40.9, 38.5, 25.8, 18.3, 14.2, -4.3; **HRMS** (ESI-TOF) Calculated for $C_{24}H_{35}ClNO_5SSi$ ($[M+H]^+$): 512.1688, found: 512.1686.



**3aj**

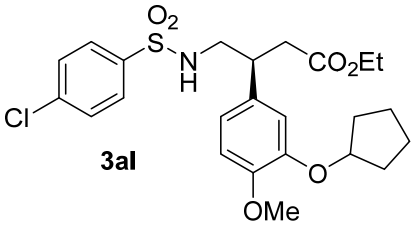
Compound **3aj** was obtained as a colorless viscous oil following the general procedure (27.7 mg, 66% yield). ee = 83%, $[\alpha]_D^{23}$ = +51.1 (*c* = 0.28, EtOH), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(major) = 19.8 min, $t_R$(minor) = 22.9 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ δ 7.64 (d, *J* = 7.7 Hz, 2H), 7.27 (d, *J* = 8.8 Hz, 2H), 6.76 (d, *J* = 7.7 Hz, 1H), 6.62 (d, *J* = 7.7 Hz, 1H), 6.55 (s, 1H), 4.41 (dd, *J* = 7.1, 5.0 Hz, 1H), 4.05 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.84 (s, 3H), 3.80 (s, 3H), 3.28–3.17 (m, 2H), 3.06–3.02 (m, 1H), 2.60 (ABM, *J* = 16.0, 7.2 Hz, 2H), 2.41 (s, 3H), 1.17 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 149.3, 148.5, 143.6, 137.0, 132.7, 129.8, 127.2, 119.6, 111.6, 110.7, 60.8, 56.0, 55.95, 48.1, 41.3, 38.5, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{21}H_{28}NO_6S$ ($[M+H]^+$): 422.1632, found: 422.1625.



**3ak**

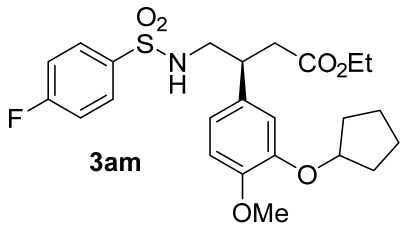
Compound (*S*)-**3ak** was obtained as a white solid following the general procedure (42.6 mg, 89% yield). ee = 89%, $[\alpha]_D^{23}$ = +33.0 (*c* = 0.84, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 21.3 min, $t_R$(minor) = 27.9 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.64 (d, *J* = 8.2 Hz, 2H), 7.26 (d, *J* = 8.2 Hz, 2H), 6.74 (d, *J* = 8.2 Hz, 1H), 6.61–6.55 (m, 2H), 4.67 (m, 1H), 4.49 (dd, *J* = 7.3, 5.0 Hz, 1H), 4.04 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.80 (s, 3H), 3.26–3.14 (m, 2H), 3.04–2.99 (m, 1H), 2.60 (ABM, *J* = 16.0, 7.2 Hz, 2H), 2.41 (s, 3H), 1.92–1.78 (m, 6H), 1.59 (m, 2H), 1.16 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 149.4, 148.0, 143.5, 136.9, 132.5, 129.8, 127.2, 119.6, 114.3, 112.3, 80.5, 60.8, 56.2, 48.1, 41.2, 38.5, 32.9, 24.1, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{25}H_{34}NO_6S$ ($[M+H]^+$): 476.2101, found: 476.2109.

The compound (*R*)-**3ak** was obtained as a white solid following the general procedure (42.6 mg, 89% yield) except that (*R*)-BINAP was used as ligand. The spectral data are in agreement with those of (*S*)-**3ak**. ee = 89%, $[\alpha]_D^{23}$ = -34.2 (*c* = 0.80, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 22.0 min, $t_R$(major) = 26.3 min.



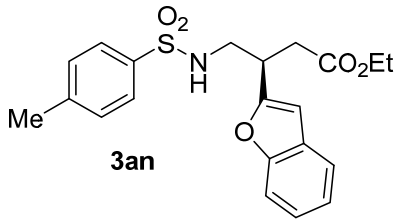
**3al**

Compound **3al** was obtained as a white solid following the general procedure (35.2 mg, 71% yield). ee = 88%, $[\alpha]_D^{23}$ = -89.1 (*c* = 0.68, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ=254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 21.1 min, $t_R$(minor) = 26.7 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.8 Hz, 2H), 7.45 (d, *J* = 8.8 Hz, 2H), 6.75 (d, *J* = 8.3 Hz, 1H), 6.59–6.55 (m, 2H), 4.67 (m, 1H), 4.48 (dd, *J* = 7.7, 4.4 Hz, 1H), 4.07 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.81 (s, 3H), 3.31–3.26 (m, 1H), 3.20–3.13 (m, 1H), 3.07–3.01 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 2H), 1.90–1.78(m, 6H), 1.60 (m, 2H), 1.18 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 149.5, 148.1, 139.2, 138.5, 132.3, 129.5, 128.6, 119.5, 114.3, 112.3, 80.6, 60.9, 56.2, 48.1, 41.1, 38.5, 32.9, 24.2, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{24}H_{31}ClNO_6S$ ($[M+H]^+$): 496.1555, found: 496.1563.



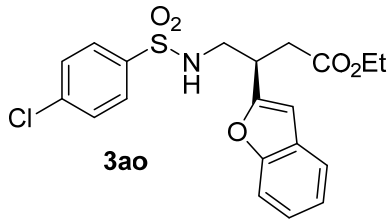
**3am**

Compound **3am** was obtained as a white solid following the general procedure (34.6 mg, 72% yield). ee = 88%, $[\alpha]_D^{23}$ = -31.8 (*c* = 0.69, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ = 254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 20.3min, $t_R$(minor) = 26.7 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.77 (m, 2H), 7.15 (pseudo t, *J* = 8.2 Hz, 2H), 6.74 (d, *J* = 8.3 Hz, 1H), 6.60–6.55 (m, 2H), 4.67 (m, 1H), 4.57 (dd, *J* = 7.2, 4.9 Hz, 1H), 4.05 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.80 (s, 3H), 3.29–3.24 (m, 1H), 3.20–3.14 (m, 1H), 3.06–3.00 (m, 1H), 2.59 (ABM, *J* = 16.0, 7.2 Hz, 2H), 1.92–1.76 (m, 6H), 1.59 (m, 2H), 1.16 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.9, 165.1 (d, $^1J_{C-F}$ = 254.3 Hz), 149.5, 147.8, 136.0 (d, $^4J_{C-F}$ = 3.6 Hz), 132.4, 129.8 (d, $^3J_{C-F}$ = 9.1 Hz), 119.6, 116.4 (d, $^2J_{C-F}$ = 22.8 Hz), 114.2, 112.3, 80.5, 60.8, 56.1, 48.1, 41.1, 38.5, 32.8, 24.1, 14.2; **$^{19}$F NMR** (470 MHz, $CDCl_3$) δ -105.3 (m); **HRMS** (ESI-TOF) Calculated for $C_{24}H_{31}FNO_6S$ ($[M+H]^+$): 480.1851, found: 480.1845.



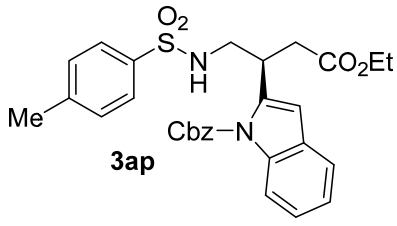
**3an**

Compound **3an** was obtained as a white solid following the general procedure (28.2 mg, 70% yield). ee = 89%, $[\alpha]_D^{23}$ = +19.3 (*c* = 0.55, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ = 254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, λ = 254 nm, $t_R$(major) = 21.9min, $t_R$(minor) = 30.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.2 Hz, 2H), 7.47 (m, 1H), 7.35 (d, *J* = 7.7 Hz, 1H), 7.26–7.17 (m, 4H), 6.45 (s, 1H), 4.77 (pseudo t, *J* = 6.6 Hz, 1H), 4.10 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.57–3.52 (m, 1H), 3.38–3.29 (m, 2H), 2.76 (d, *J* = 7.1 Hz, 2H), 2.39 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.5, 156.7, 154.8, 143.6, 136.9, 129.8, 128.2, 127.1, 124.2, 123.0, 120.9, 111.1, 104.1, 61.0, 45.5, 36.0, 35.5, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{21}H_{24}NO_5S$ ($[M+H]^+$): 402.1370, found: 402.1365.



**3ao**

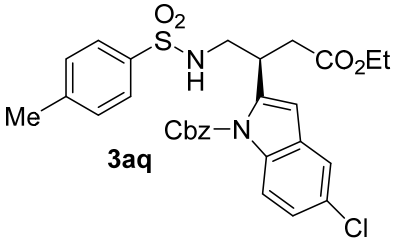
Compound **3ao** was obtained as a white solid following the general procedure (22.3 mg, 53% yield). ee = 95%, $[\alpha]_D^{23}$ = +36.5 (*c* = 0.44, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AS-H column, λ = 254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(major) = 18.2 min, $t_R$(minor) = 24.1 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.70 (m, 2H), 7.47 (m, 1H), 7.39–7.33 (m, 3H), 7.27–7.19 (m, 2H), 6.45 (s, 1H), 4.86 (pseudo t, *J* = 6.6 Hz, 1H), 4.11 ($ABX_3$, *J* = 11.0, 7.1 Hz, 2H), 3.57–3.50 (m, 1H), 3.41–3.31 (m, 2H), 2.75 (ABM, *J* = 15.9, 7.1 Hz, 2H), 1.21 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.4, 156.4, 154.8, 139.3, 138.5, 129.5, 128.5, 128.1, 124.3, 123.1, 121.0, 111.1, 104.2, 61.1, 45.5, 36.0, 35.5, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{20}H_{21}ClNO_5S$ ($[M+H]^+$): 422.0823, found: 422.0832.



**3ap**

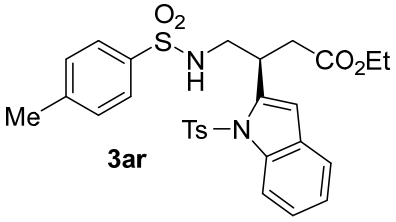
Compound **3ap** was obtained as a primrose solid following the general procedure (40.0 mg, 75% yield). ee = 87%, $[\alpha]_D^{23}$ = -39.8 (*c* = 0.80, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 24.3 min, $t_R$(major) = 31.9 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.15 (brs, 1H), 7.59 (d, *J* = 8.2 Hz, 2H), 7.49 (m, 2H), 7.46–7.38 (m,

5H), 7.32 (pseudo t, *J* = 7.7 Hz, 1H), 7.21–7.16 (m, 3H), 5.43 (AB, *J* = 12.1 Hz, 2H), 4.60 (pseudo t, *J* = 6.6 Hz, 1H), 4.11 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.59 (m, 1H), 3.34–3.25 (m, 2H), 2.75 (ABM, *J* = 16.0, 6.6 Hz, 2H), 2.37 (s, 3H), 1.17 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 172.0, 150.7 (brs, this signal is weak due to the $^{14}$N quadrupole relaxation effect of the neighboring N atom of the Cbz group), 143.5, 136.8, 135.8, 135.0, 129.7, 129.1, 128.95, 128.92, 128.8, 127.0, 125.2, 123.2, 122.7, 120.7, 119.1, 115.6, 69.0, 61.0, 46.4, 36.9, 33.0, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{29}H_{31}N_2O_6S$ ($[M+H]^+$): 535.1897, found: 535.1889.



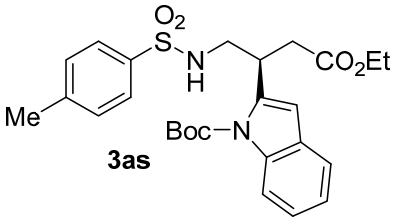
**3aq**

Compound **3aq** was obtained as a primrose solid following the general procedure (43.5 mg, 76% yield). ee = 90%, $[\alpha]_D^{23}$ = -18.5 (*c* = 0.86, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 20.3 min, $t_R$(major) = 25.0 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.05 (brs, 1H), 7.58 (d, *J* = 8.3 Hz, 2H), 7.48 (m, 2H), 7.45–7.38 (m, 4H), 7.29 (m, 1H), 7.24 (m, 1H), 7.17 (d, *J* = 8.2 Hz, 2H), 5.42 (AB, *J* = 12.1 Hz, 2H), 4.71 (m, 1H), 4.07 (q, *J* = 7.2 Hz, 2H), 3.51–3.46 (m, 1H), 3.26 (pseudo t, *J* = 6.6 Hz, 2H), 2.71 (ABM, *J* = 16.0, 7.1 Hz, 2H), 2.38 (s, 3H), 1.17 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.7, 150.3, 143.7, 136.7, 134.8, 134.1, 130.3, 129.8, 129.1, 129.0, 128.9, 128.87, 127.0, 125.3, 124.1, 120.1, 118.7, 116.6, 69.2, 61.0, 46.3, 36.9, 32.9, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for $C_{29}H_{30}ClN_2O_6S$ ($[M+H]^+$): 569.1508, found: 569.1516.



**3ar**

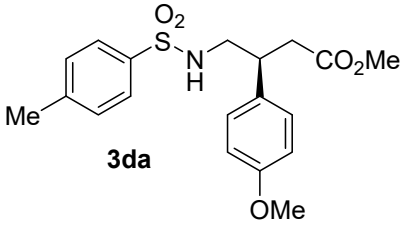
Compound **3ar** was obtained as a white solid following the general procedure (41.7 mg, 77% yield). ee = 81%, $[\alpha]_D^{23}$ = +43.6 (*c* = 0.81, $CHCl_3$), **HPLC**: Daicel CHIRALCEL OD-H column, λ=254 nm, Hexanes/IPA = 86:14, 1.0 mL/min, $t_R$(minor) = 23.7 min, $t_R$(major) = 27.3 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.94 (d, *J* = 8.2 Hz, 1H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.37 (m, 2H), 7.30 (pseudo t, *J* = 7.1 Hz, 1H), 7.23–7.15 (m, 5H), 4.62 (pseudo t, *J* = 6.6 Hz, 1H), 4.11 ($ABX_3$, *J* = 11.0, 7.2 Hz, 2H), 3.58–3.52 (m, 1H), 3.30–3.19 (m, 2H), 2.73 (ABM, *J* = 16.0, 7.7 Hz, 2H), 2.39 (s, 3H), 2.32 (s, 3H), 1.13 (t, *J* = 7.1 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.8, 145.2, 143.6, 136.8, 135.4, 135.1, 130.1, 129.8, 129.5, 127.0, 126.9, 125.2, 123.6, 123.4, 121.9, 119.5, 114.0, 60.9, 46.4, 37.0, 33.2, 21.7, 21.6, 14.1; **HRMS** (ESI-TOF) Calculated for $C_{28}H_{31}N_2O_6S_2$ ($[M+H]^+$): 555.1618, found: 555.1625.



**3as**

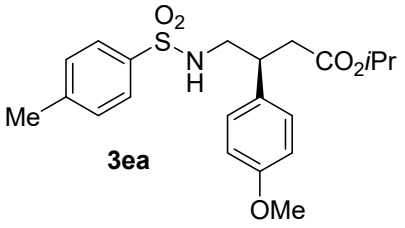
Compound **3as** was obtained as a primrose viscous oil following the general procedure (31.1 mg, 62% yield). ee = 68%, $[\alpha]_D^{23}$ = +31.4 (*c* = 0.60, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 86:14, 1.0 mL/min, $t_R$(minor) = 32.7 min, $t_R$(major) = 35.6 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 8.12 (brs, 1H), 7.61 (d, *J* = 8.3 Hz, 2H), 7.38 (m, 2H), 7.30 (m, 1H), 7.21–7.15 (m, 3H), 4.65 (m, 1H), 4.09 (q, *J* = 7.2 Hz, 2H), 3.61–3.56 (m, 1H), 3.33–3.25 (m, 2H), 2.73 (ABM, *J* = 15.9, 7.7 Hz, 2H), 2.39 (s, 3H), 1.67 (s, 9H), 1.20 (t, *J* = 7.2 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 172.0, 149.5, 143.5, 136.8, 135.7, 129.7, 129.0, 127.0, 124.9, 123.1, 122.7, 119.6, 119.0, 115.6, 84.1, 60.9, 46.4, 37.0, 33.0, 28.3, 21.6, 14.2; **HRMS** (ESI-TOF) Calculated for

$C_{26}H_{33}N_2O_6S$ ([M+H]$^+$): 501.2054, found: 501.2045.



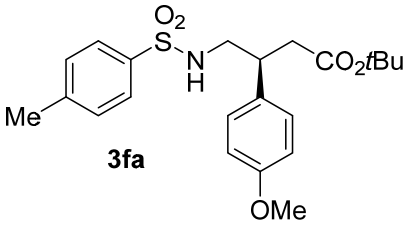
**3da**

Compound **3da** was obtained as a white solid following the general procedure (15.1 mg, 40% yield). ee = 80%, $[\alpha]_D^{23}$ = -91.6 (*c* = 0.26, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ =254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 18.2 min, $t_R$(major) = 19.6 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.2 Hz, 2H), 7.27 (d, *J* = 8.2 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 4.45 (m, 1H), 3.77 (s, 3H), 3.59 (s, 3H), 3.26–3.18 (m, 2H), 3.07–2.99 (m, 1H), 2.61 (ABM, *J* = 16.0, 7.2 Hz, 2H), 2.42 (s, 3H); **$^{13}$C NMR** (125MHz, $CDCl_3$): δ 172.4, 159.0, 143.6, 136.9, 132.1, 129.8, 128.6, 127.2, 114.5, 55.4, 51.9, 48.1, 40.8, 38.2, 21.6; **HRMS** (ESI-TOF) Calculated for $C_{19}H_{24}NO_5S$ ([M+H]$^+$): 378.1370, found: 378.1367.



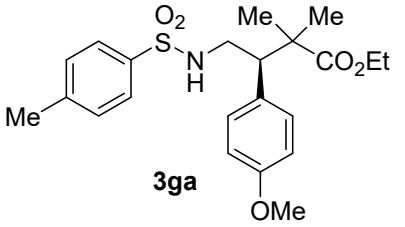
**3ea**

Compound **3ea** was obtained as a white solid following the general procedure (21.9 mg, 54% yield). ee = 88%, $[\alpha]_D^{23}$ = +5.0 (*c* = 0.32, EtOH), **HPLC**: Daicel CHIRALCEL IC column, λ= 254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 34.0 min, $t_R$(major) = 36.0 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.1 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 6.79 (d, *J* = 8.8 Hz, 2H), 4.90 (m, 1H), 4.39 (dd, *J* = 7.2, 4.9 Hz, 1H), 3.77 (s, 3H), 3.26–3.15 (m, 2H), 3.05–3.00 (m, 1H), 2.56 (ABM, *J* = 15.4, 7.1 Hz, 2H), 2.42 (s, 3H), 1.14 (d, *J* = 6.1 Hz, 3H), 1.10 (d, *J* = 6.7 Hz, 3H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.4, 159.0, 143.6, 137.0, 132.1, 129.8, 128.7, 127.2, 114.4, 68.2, 55.4, 48.2, 41.0, 38.9, 21.8, 21.79, 21.6; **HRMS** (ESI-TOF) Calculated for $C_{21}H_{28}NO_5S$ ([M+H]$^+$): 406.1683, found: 406.1686.



**3fa**

Compound **3fa** was obtained as a white solid following the general procedure (7.0 mg, 16% yield). ee = 78%, $[\alpha]_D^{23}$ = -252.7 (*c* = 0.10, $CHCl_3$), **HPLC**: Daicel CHIRALCEL ID column, λ =254 nm, Hexanes/IPA = 7:3, 1.0 mL/min, $t_R$(minor) = 12.5 min, $t_R$(major) = 13.8 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.2 Hz, 2H), 7.27 (d, *J* = 8.3 Hz, 2H), 6.98 (d, *J* = 8.8 Hz, 2H), 6.80 (d, *J* = 8.8 Hz, 2H), 4.36 (dd, *J* = 7.7, 5.0 Hz, 1H), 3.78 (s, 3H), 3.25–3.19 (m, 1H), 3.17–3.11 (m, 1H), 3.03–2.98 (m, 1H), 2.51 (ABM, *J* = 15.4, 7.1 Hz, 2H), 2.42 (s, 3H), 1.32 (s, 9H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 171.2, 158.9, 143.5, 137.0, 132.3, 129.8, 128.7, 127.2, 114.4, 81.0, 55.4, 48.2, 41.1, 39.8, 28.1, 21.7; **HRMS** (ESI-TOF) Calculated for $C_{22}H_{30}NO_5S$ ([M+H]$^+$): 420.1839, found: 420.1847.

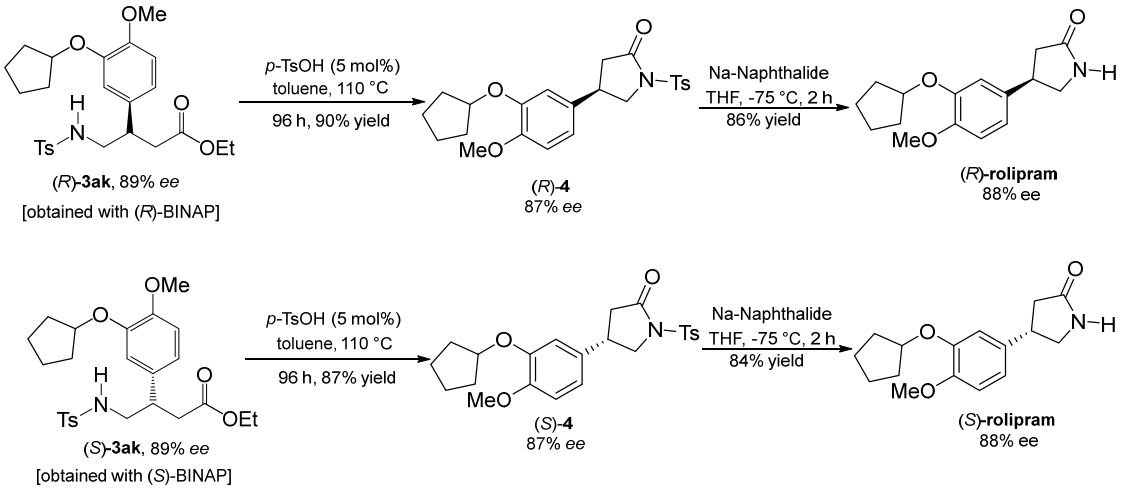


**3ga**

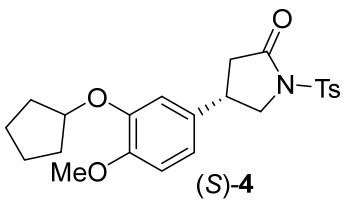
Compound **3ga** was obtained as a primrose solid following the general procedure (14.2 mg, 34% yield). ee = 94%, $[\alpha]_D^{23}$ = -53.3 (*c* = 0.25, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 11.8 min, $t_R$(major) = 16.0 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.62 (d, *J* = 7.7 Hz, 2H), 7.29 (d, *J* = 8.3 Hz, 2H), 6.82 (AB, *J* = 8.8 Hz, 4H), 4.07 (brs, 1H), 4.06 (q, *J* = 7.2 Hz, 2H), 3.79 (s, 3H), 3.37–3.32 (m, 1H), 3.19 (m, 1H), 3.00 (dd, *J* = 11.5, 4.5 Hz, 1H), 2.44 (s, 3H), 1.20 (t, *J* = 7.2 Hz, 3H), 1.04 (s, 3H), 0.99 (s, 3H); **$^{13}$C NMR**

(125 MHz, $CDCl_3$): δ 171.2, 158.9, 143.5, 137.0, 132.3, 129.8, 128.7, 127.2, 114.4, 81.0, 55.4, 48.2, 41.1, 39.8, 28.1, 21.7; **HRMS** (ESI-TOF) Calculated for $C_{22}H_{30}NO_5S$ ($[M+H]^+$): 420.1839, found: 420.1830.

## Procedure for the transformation of *(R/S)*-3ak to *(R/S)*-rolipram



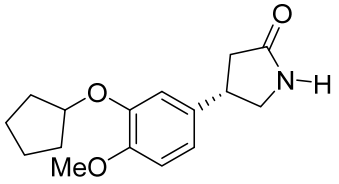

Under argon atmosphere, to a stirred solution of the (*S*)-**3ak** (47.6 mg, 0.1 mmol, 89% ee) in dry toluene (4.0 mL) was added *p*-tolylsulfonic acid (0.9 mg, 0.005 mmol, 5 mol%), and the resulting reaction mixture was refluxed for 96 h. After being cooled down to room temperature, the reaction mixture was quenched by dropwise addition of saturated aqueous $NaHCO_3$ solution (4.0 mL), extracted with EtOAc (10 mL x 3). The combined organic extracts were dried over anhydrous $Na_2SO_4$ and concentrated in vacuo by rotary evaporation. The residue was purified by flash chromatography on silica gel (eluting with EtOAc/petroleum ether (v/v) = 1:4) to afford the product (*S*)-**4** as a white solid in 87% yield (37.4 mg).




Ee = 87%, $[\alpha]_D^{23}$ = +38.2 (*c* = 0.11, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(major) = 13.4 min, $t_R$(minor) = 15.7 min; **$^1$H NMR** (500 MHz, $CDCl_3$): δ 7.92 (d, *J* = 8.2 Hz, 2H), 7.33 (d, *J* = 8.2 Hz, 2H), 6.77 (m, 1H), 6.65 (m, 2H), 4.68 (m, 1H), 4.28 (dd, *J* = 9.9, 8.2 Hz, 1H), 3.81 (s, 3H), 3.75 (dd, *J* = 9.9, 7.7 Hz, 1H), 3.55–3.49 (m, 1H), 2.80 (dd, *J* = 17.0, 8.2 Hz, 1H), 2.57 (dd, *J* = 17.1, 8.8 Hz, 1H), 2.44 (s, 3H), 1.92–1.77 (m, 6H), 1.59 (m, 2H); **$^{13}$C NMR** (125 MHz, $CDCl_3$): δ 172.4, 149.6, 148.1, 145.3, 135.2, 132.4, 129.8, 128.2, 118.6, 113.4, 112.2, 80.6, 56.2, 54.0, 39.8, 36.8, 32.9, 24.1, 21.8; **HRMS** (ESI-TOF) Calculated for $C_{23}H_{27}NO_5S$ ($[M+H]^+$): 430.1683, found: 430.1691.

The compound (*R*)-**4** was prepared by following the same procedure from (*R*)-**3ak**. White solid (38.6 mg, 90% yield), ee = 87%, $[\alpha]_D^{23}$ = -44.4 (*c* = 0.59, $CHCl_3$), **HPLC**: Daicel CHIRALCEL AD-H column, λ=254 nm, Hexanes/IPA = 4:1, 1.0 mL/min, $t_R$(minor) = 13.1 min, $t_R$(major) = 15.2 min. The spectral data agree with those of (*S*)-**4**.

Under argon atmosphere, to a stirred solution of naphthalene (80.0 mg, 0.624 mmol) in 1.0 mL of dried THF was added freshly cut sodium turnings (11.5 mg, 0.5 mmol) and the resulting mixture was stirred at rt for 2 h to give a deep green solution. Then a solution of (*S*)-**4** (43.0 mg, 0.1 mmol, 87% ee) in dried THF (1.0 mL) was added dropwise to the above solution at -78 ºC, and the resulting reaction mixture was stirred at -78 ºC for 0.5 h before being allowed to warm to rt for another 1.5 h of stirring. Then the reaction mixture was quenched by dropwise addition of saturated aqueous $NH_4Cl$ solution (2.0 mL), diluted with 10.0 mL of deionized water, and extracted with EtOAc (10 mL x 3). The combined organic extracts were dried over anhydrous $Na_2SO_4$ and concentrated in vacuo by rotary evaporation. The residue was purified by flash chromatography on silica gel (eluting with EtOAc/petroleum ether (v/v) = 2:1) to afford the product (*S*)-rolipram as a white solid in 84% yield (23.1 mg).



(*S*)-rolipram

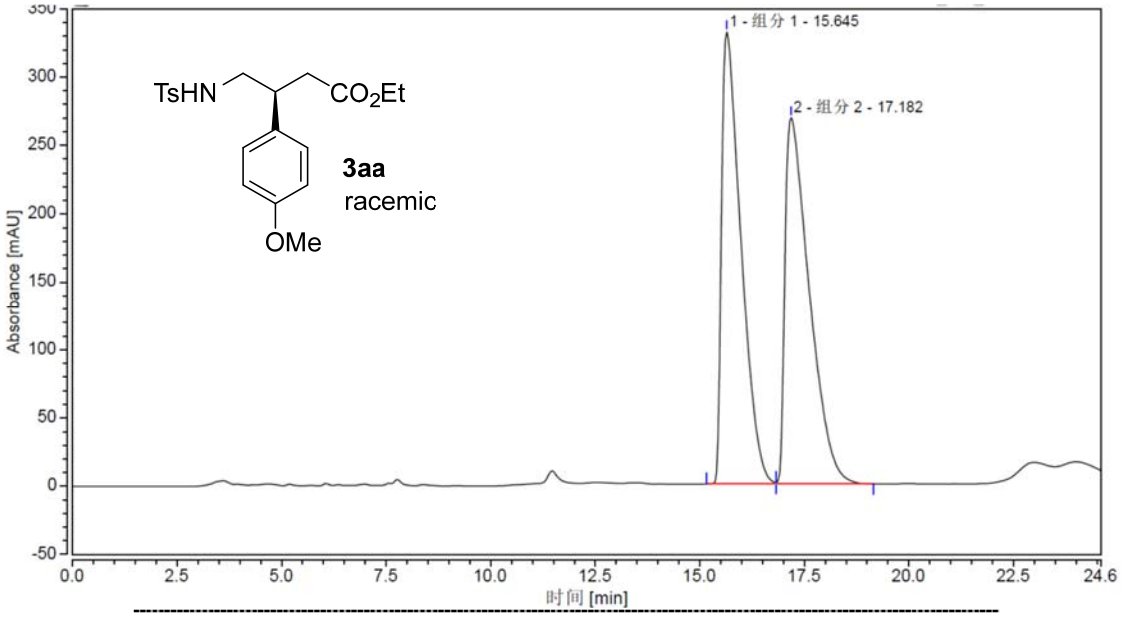
Ee = 88%, $[\alpha]_D^{23}$ = +28.3 (*c* = 0.49, MeOH) {lit.[4] $[\alpha]_D^{25}$ = +26.2 (*c* = 0.60, MeOH) for 98% ee (*S*)}, **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 86:14, 1.0 mL/min, $t_R$(minor) = 13.6 min, $t_R$(major) = 14.4 min. The spectral data are in good agreement with those of literature report.[4]

The compound (*R*)-rolipram was prepared by following the same procedure from (*R*)-**4**. White solid (23.6 mg, 86% yield), ee = 88%, $[\alpha]_D^{23}$ = -34.9 (*c* = 0.69, MeOH), **HPLC**: Daicel CHIRALCEL ID column, λ=254 nm, Hexanes/IPA = 86:14, 1.0 mL/min, $t_R$(major) = 13.1min, $t_R$(minor) = 15.0 min.

## References

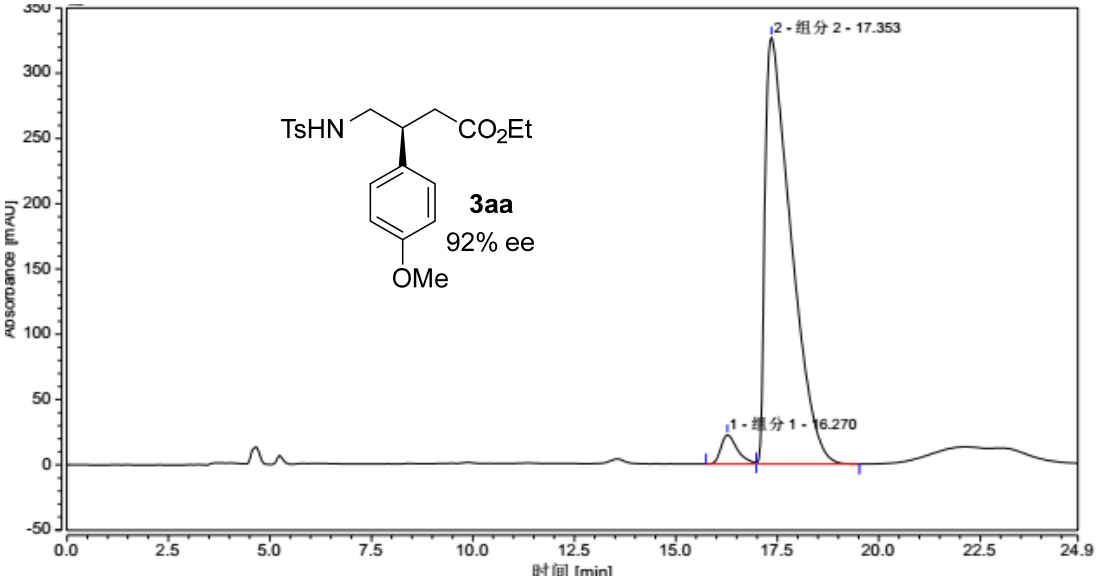

1. D. D. Perrin and W. L. F. Armarego, *Purification of Laboratory Chemicals;* 3rd ed., Pergamon Press, Oxford, 1988.
2. A. G. Wenzel and E. N. Jacobsen, Asymmetric Catalytic Mannich Reactions Catalyzed by Urea Derivatives: Enantioselective Synthesis of *β*-Aryl-*β*-Amino Acids, *J. Am. Chem. Soc.,* 2002, **124**, 12964–12965.
3. **2a**: (a) D. A. Evans, M. M. Faul and M. T. Bilodeau, Development of the Copper-Catalyzed Olefin Aziridination Reaction, *J. Am. Chem. Soc.,* 1994, **116**, 2742–2732; (b) **2b**, **2c**, **2e**, **2f**, **2h**, **2j**, **2n**, **2o**, **2p** and **2q**: P.-J. Yang, L. Qi, Z. Liu, G. Yang and Z. Chai, Lewis Acid-Catalyzed Dynamic Kinetic Asymmetric Transformation of Racemic *N*-Sulfonylaziridines, *J. Am. Chem. Soc.,* 2018, **140**, 17211–17217.
4. C. Palomo, A. Landa, A. Mielgo, M. Oiarbide, Á. Puente and S. Vera, Water-Compatible Iminium Activation: Organocatalytic Michael Reactions of Carbon-Centered Nucleophiles with Enals, *Angew. Chem., Int. Ed.,* 2007, **46**, 8431–8435.

## Copies of HPLC Traces



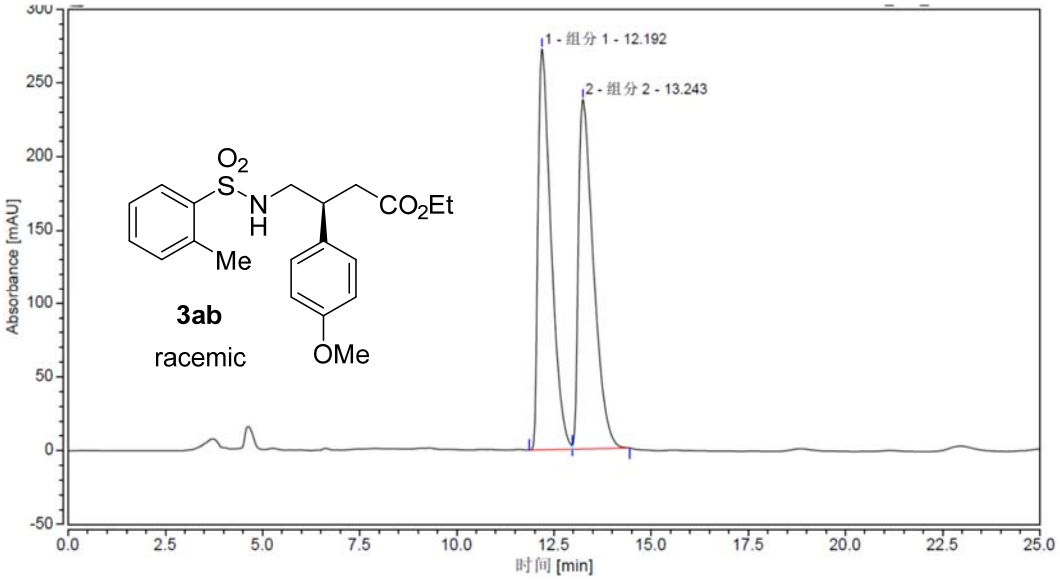

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 15.645 | 179.079 | 331.712 | 49.75 | 55.24 |
| 2 | 17.182 | 180.858 | 268.792 | 50.25 | 44.76 |



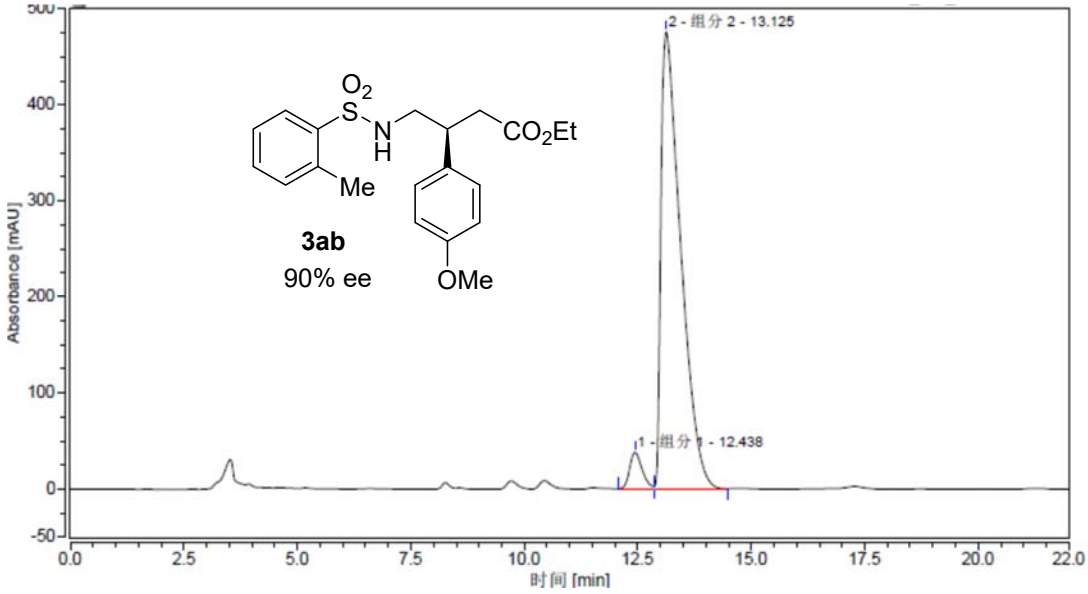

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 16.270 | 10.463 | 22.316 | 4.13 | 6.39 |
| 2 | 17.353 | 242.978 | 326.936 | 95.87 | 93.61 |



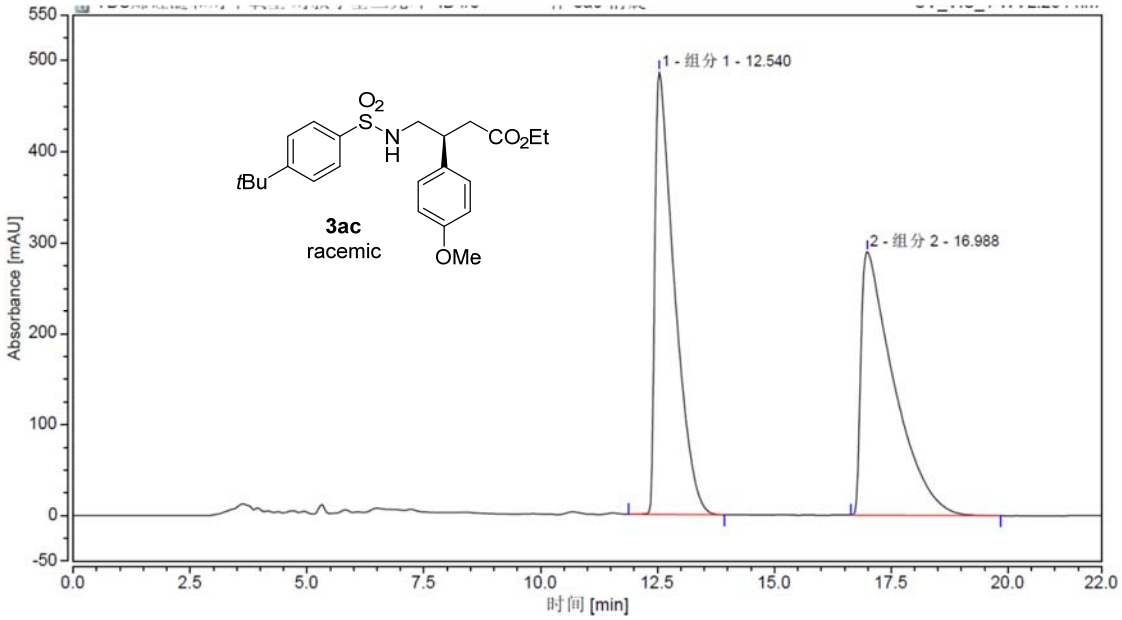

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 12.192 | 106.480 | 272.315 | 49.44 | 53.33 |
| 2 | 13.243 | 108.879 | 238.303 | 50.56 | 46.67 |



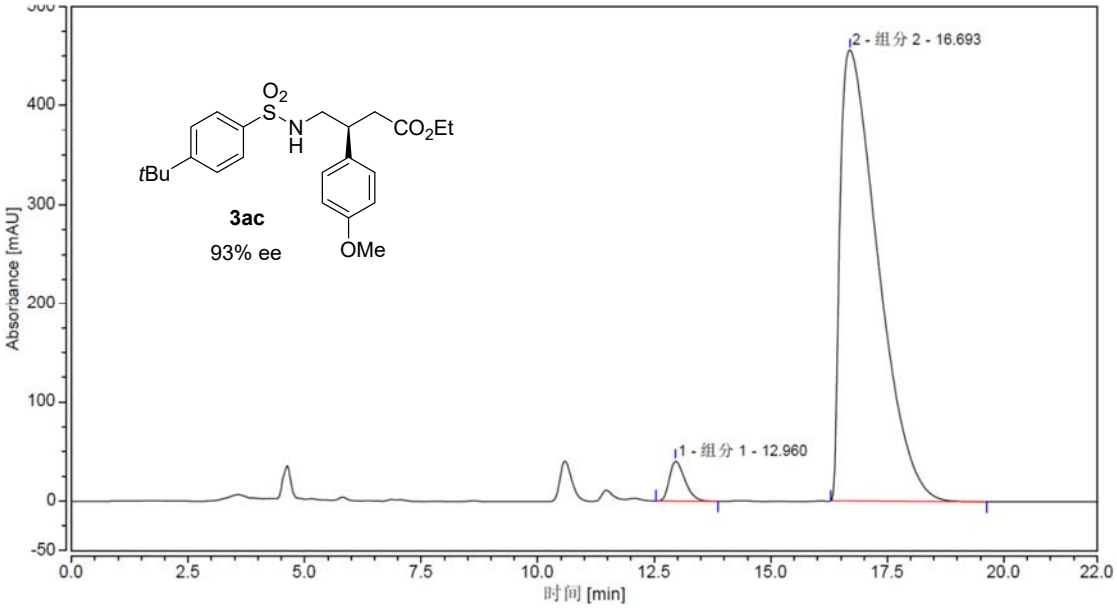

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 12.438 | 12.167 | 38.247 | 4.82 | 7.44 |
| 2 | 13.125 | 240.077 | 475.518 | 95.18 | 92.56 |



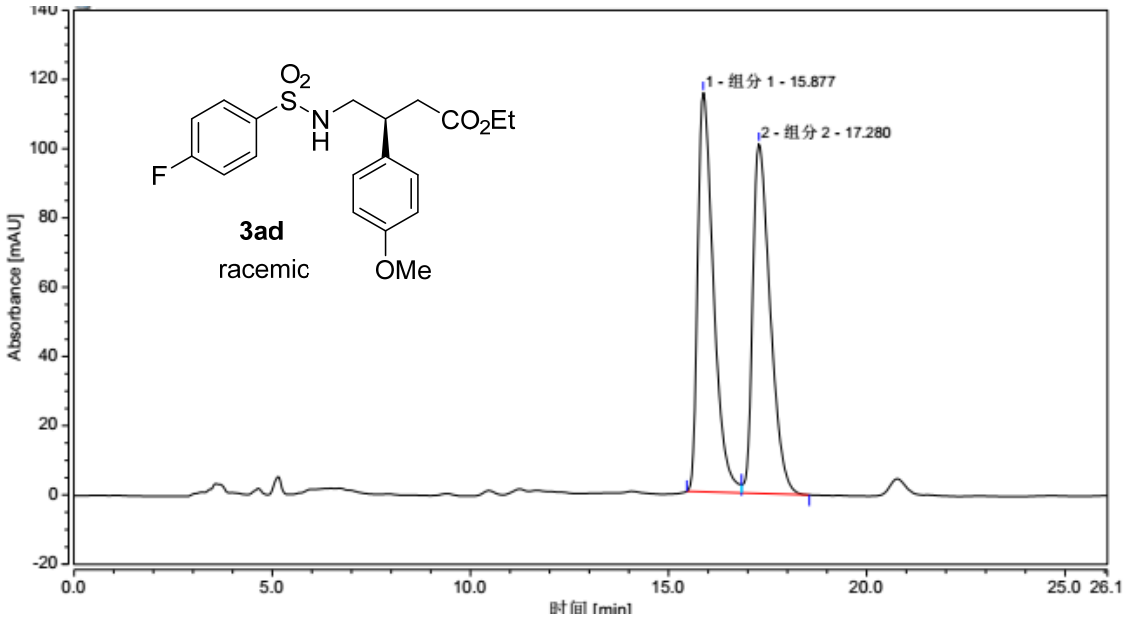

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 12.540 | 235.474 | 486.570 | 49.92 | 62.65 |
| 2 | 16.988 | 236.271 | 290.114 | 50.08 | 37.35 |



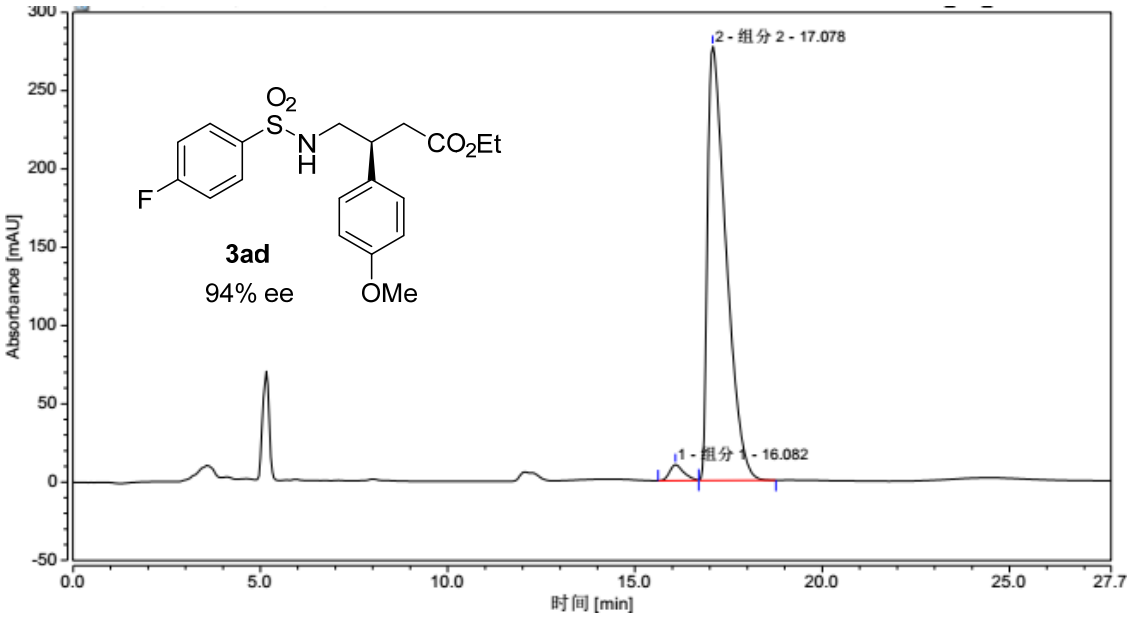

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 12.960 | 15.628 | 40.268 | 3.52 | 8.11 |
| 2 | 16.693 | 427.791 | 456.085 | 96.48 | 91.89 |



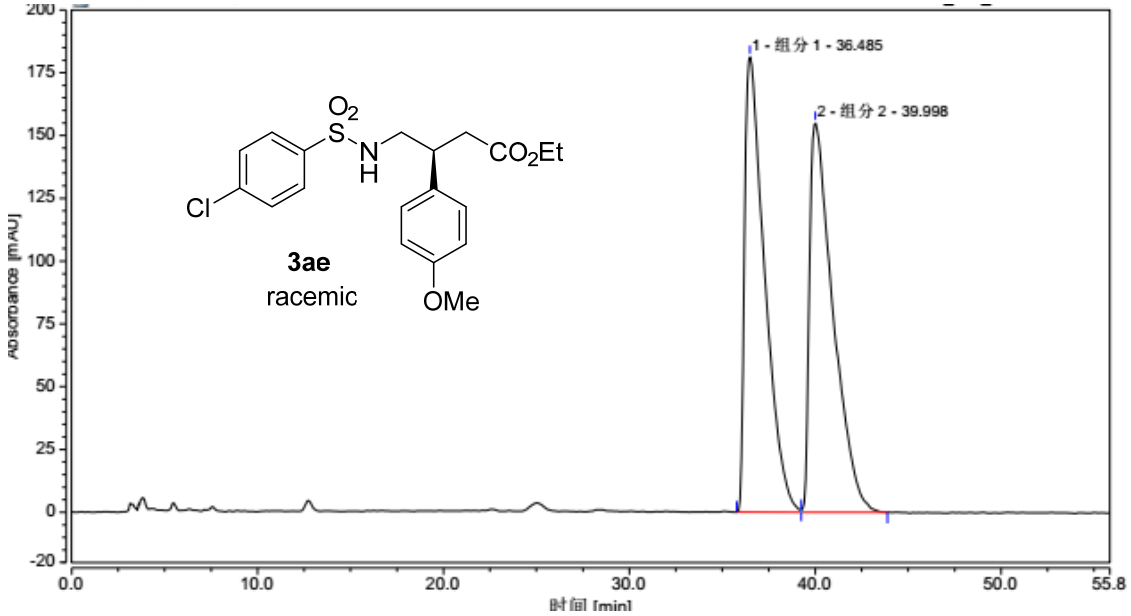

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 15.877 | 53.207 | 115.268 | 50.80 | 53.29 |
| 2 | 17.280 | 51.526 | 101.054 | 49.20 | 46.71 |



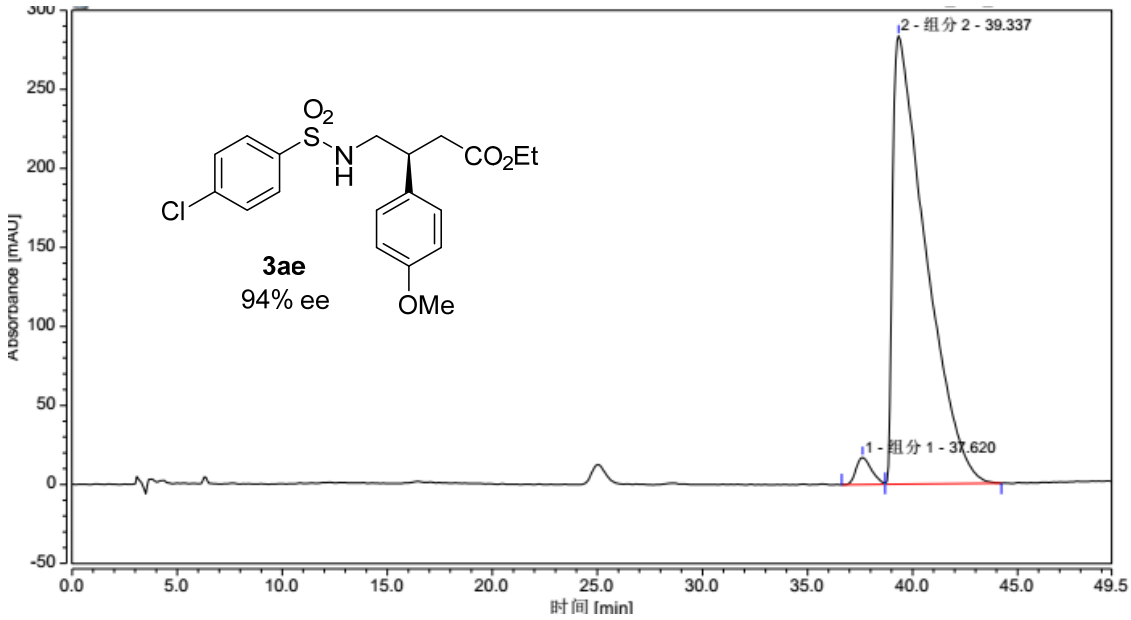

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 16.082 | 4.490 | 10.213 | 2.73 | 3.55 |
| 2 | 17.078 | 159.723 | 277.320 | 97.27 | 96.45 |



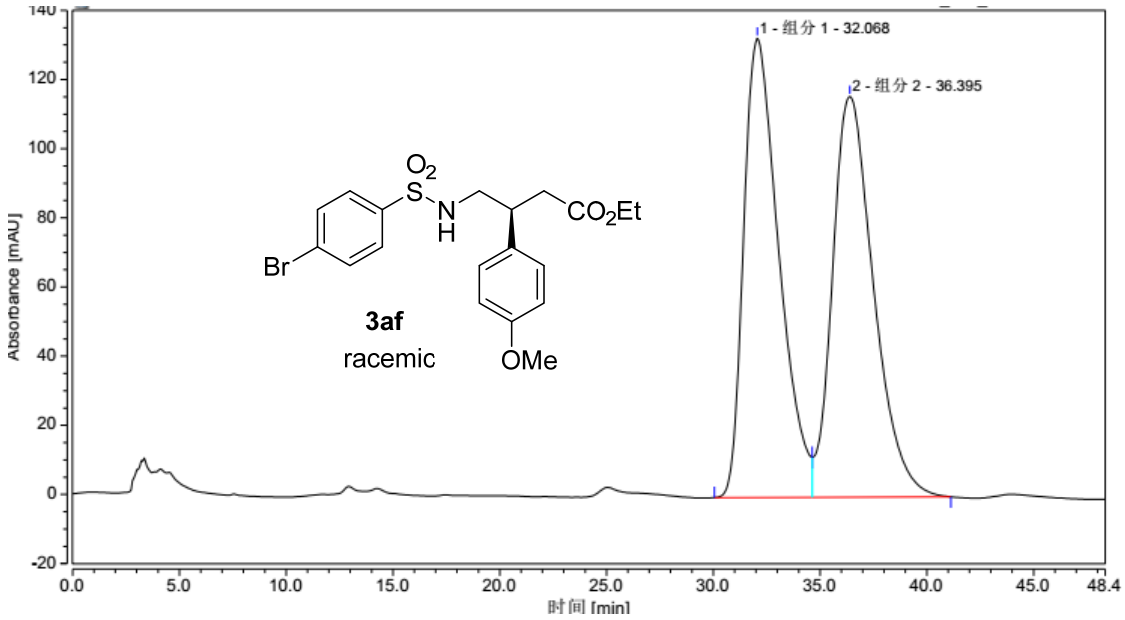

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 36.485 | 226.735 | 181.403 | 49.94 | 53.90 |
| 2 | 39.998 | 227.263 | 155.155 | 50.06 | 46.10 |



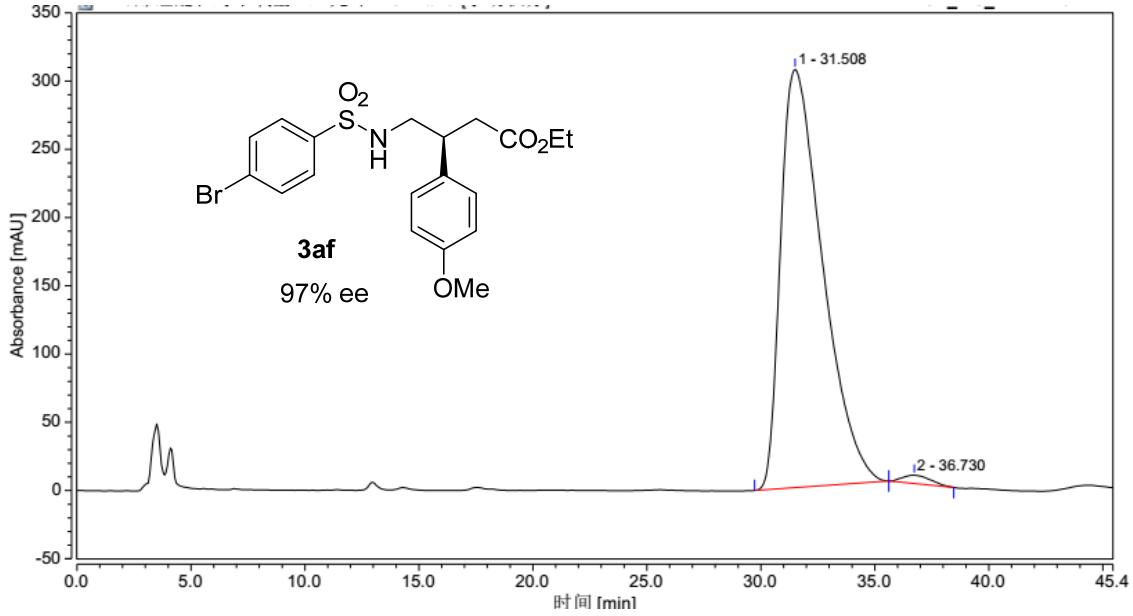

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 37.620 | 14.546 | 17.081 | 2.74 | 5.68 |
| 2 | 39.337 | 516.919 | 283.593 | 97.26 | 94.32 |



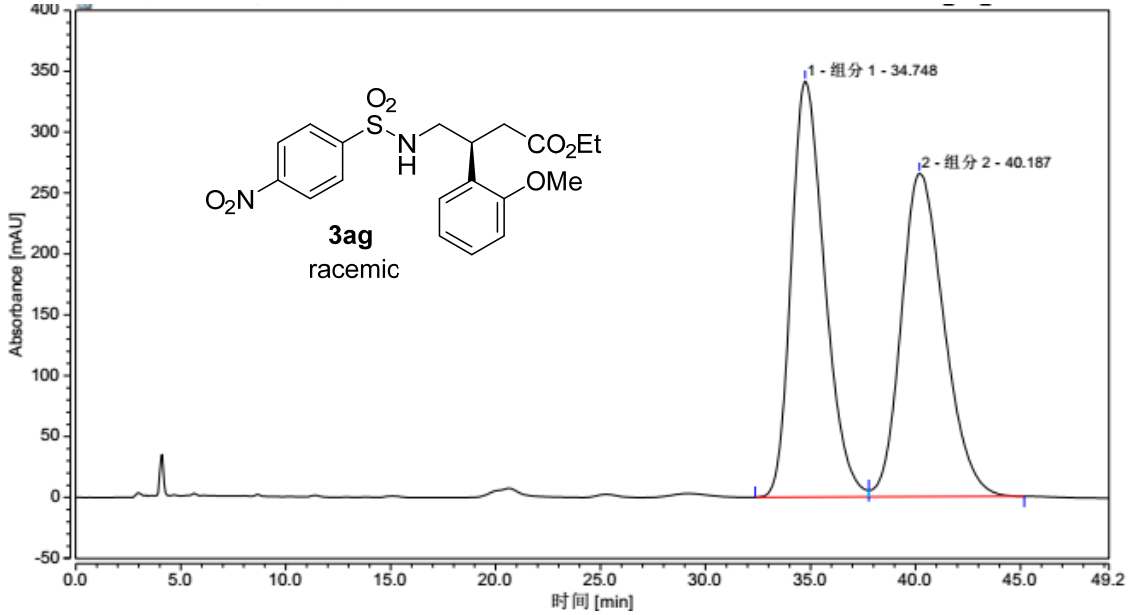

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 32.068 | 254.036 | 132.814 | 49.49 | 53.41 |
| 2 | 36.395 | 259.322 | 115.865 | 50.51 | 46.59 |



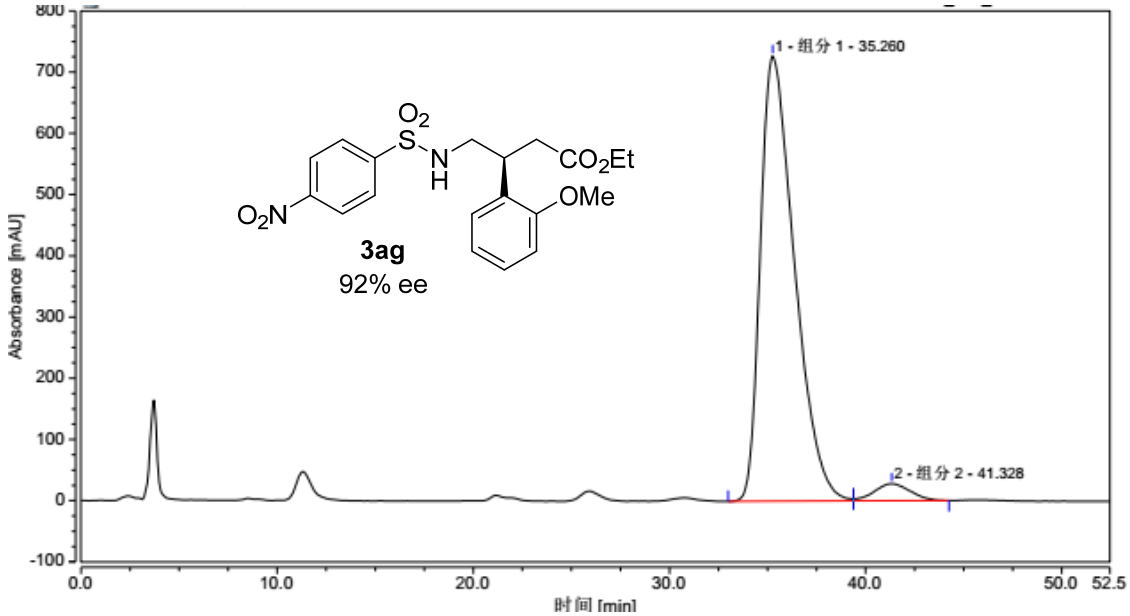

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 31.508 | 652.744 | 306.448 | 98.66 | 98.05 |
| 2 | 36.730 | 8.834 | 6.087 | 1.34 | 1.95 |



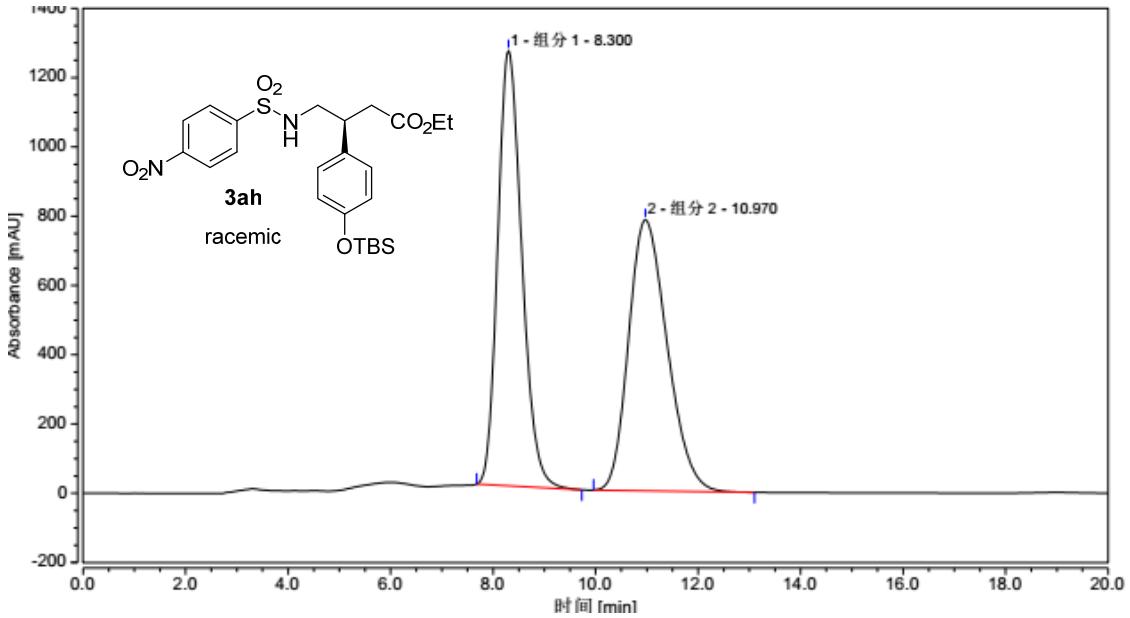

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 34.748 | 628.768 | 341.583 | 50.03 | 56.28 |
| 2 | 40.187 | 627.892 | 265.312 | 49.97 | 43.72 |



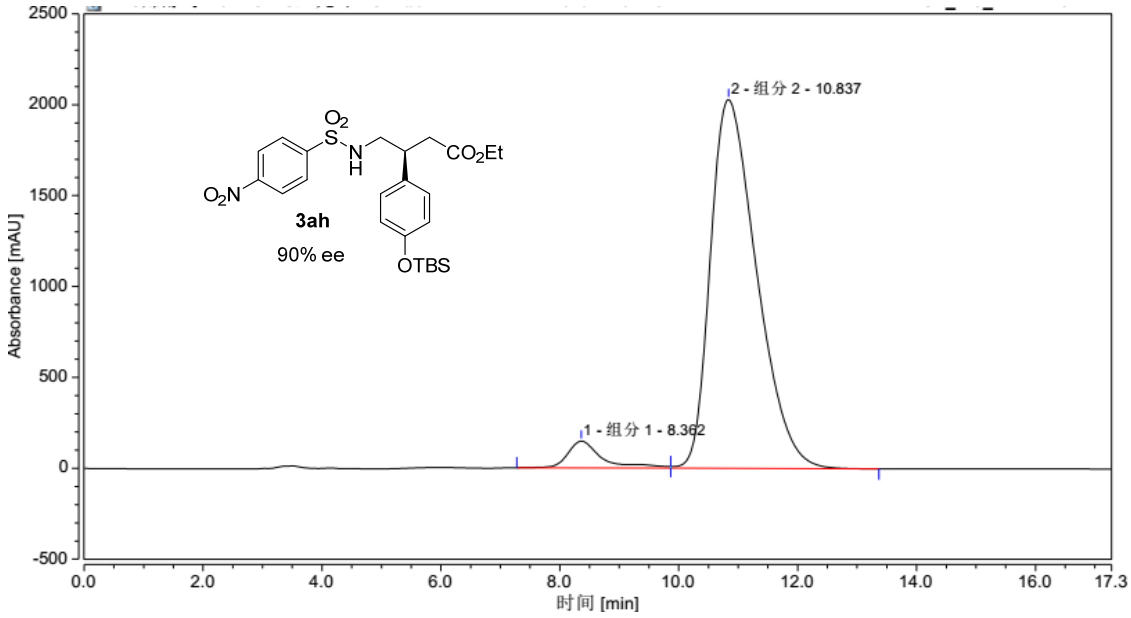

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 35.260 | 1463.022 | 727.369 | 96.11 | 96.32 |
| 2 | 41.328 | 59.269 | 27.795 | 3.89 | 3.68 |



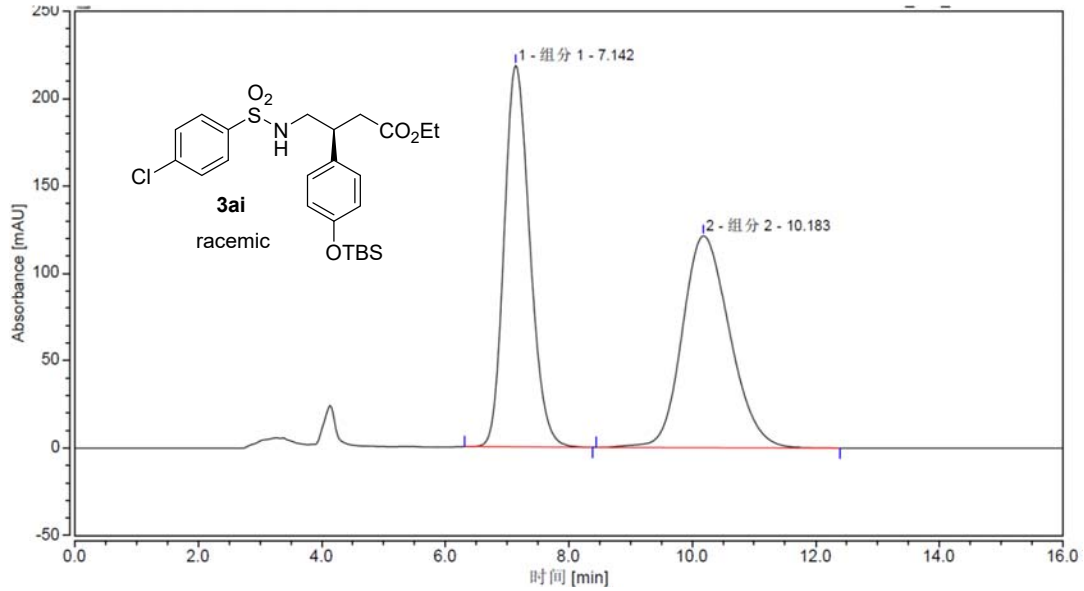

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 8.300 | 683.592 | 1256.698 | 50.06 | 61.63 |
| 2 | 10.970 | 681.887 | 782.281 | 49.94 | 38.37 |



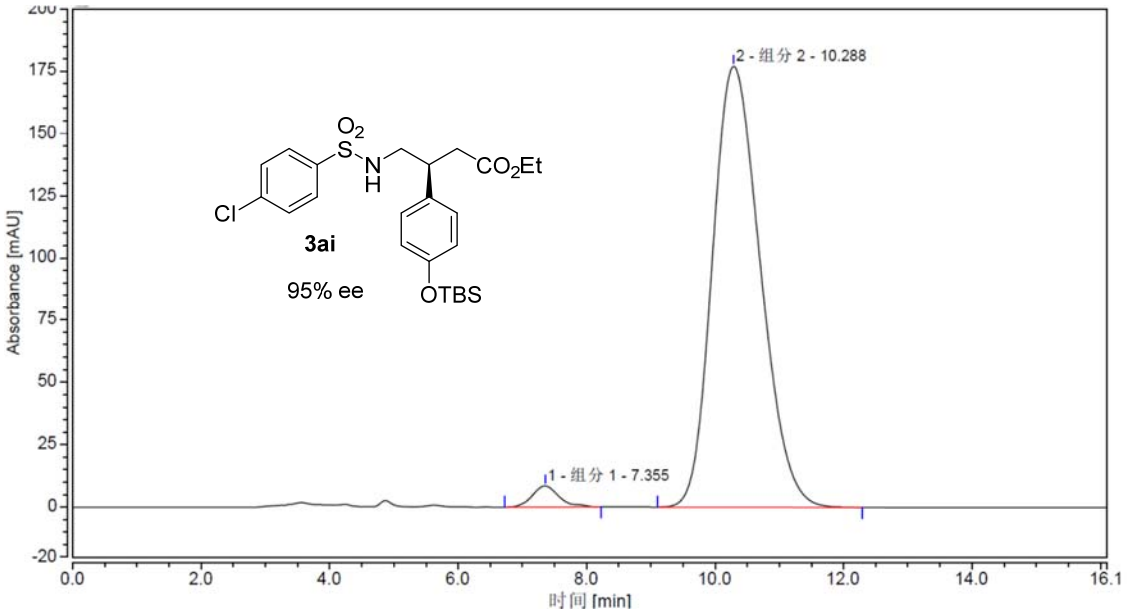

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 8.362 | 99.037 | 147.490 | 5.13 | 6.78 |
| 2 | 10.837 | 1829.986 | 2029.306 | 94.87 | 93.22 |



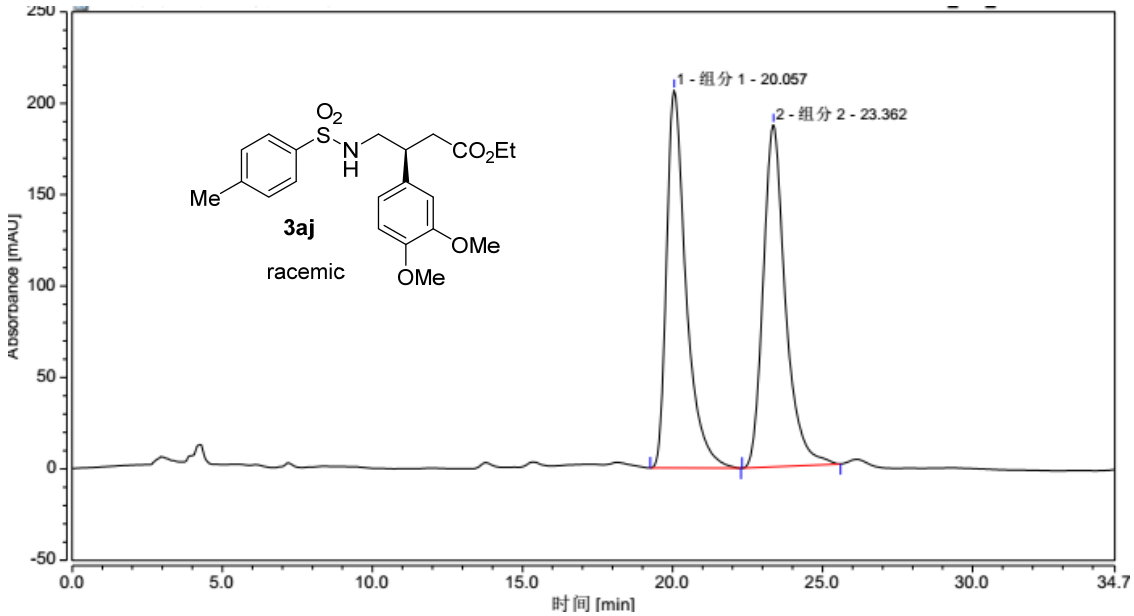

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 7.142 | 105.103 | 218.426 | 49.37 | 64.29 |
| 2 | 10.183 | 107.789 | 121.330 | 50.63 | 35.71 |



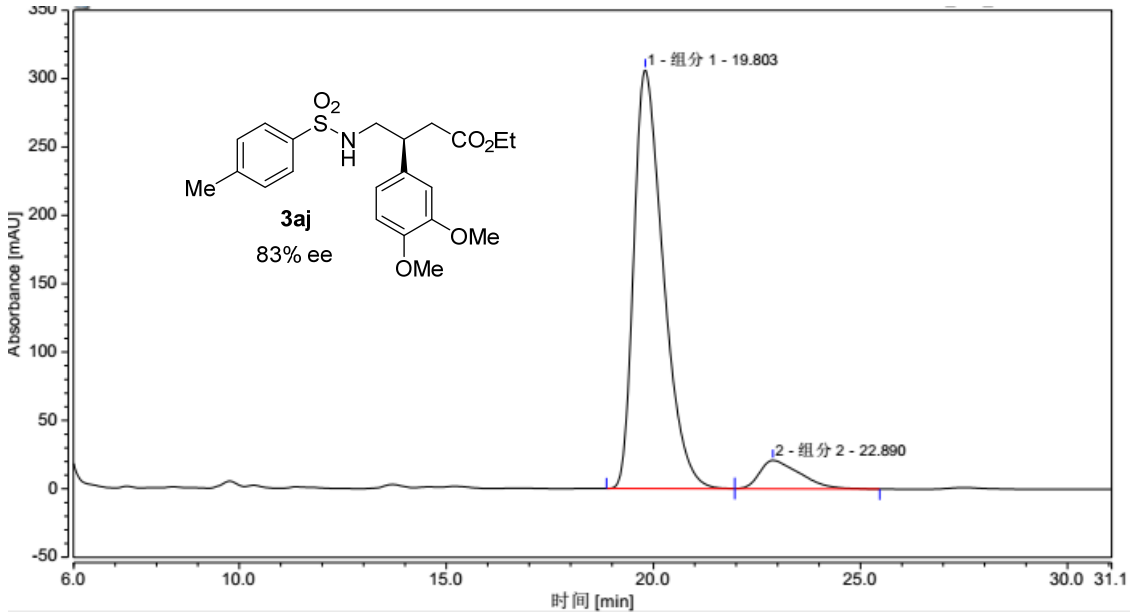

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 7.355 | 4.118 | 8.458 | 2.62 | 4.56 |
| 2 | 10.288 | 152.782 | 177.069 | 97.38 | 95.44 |



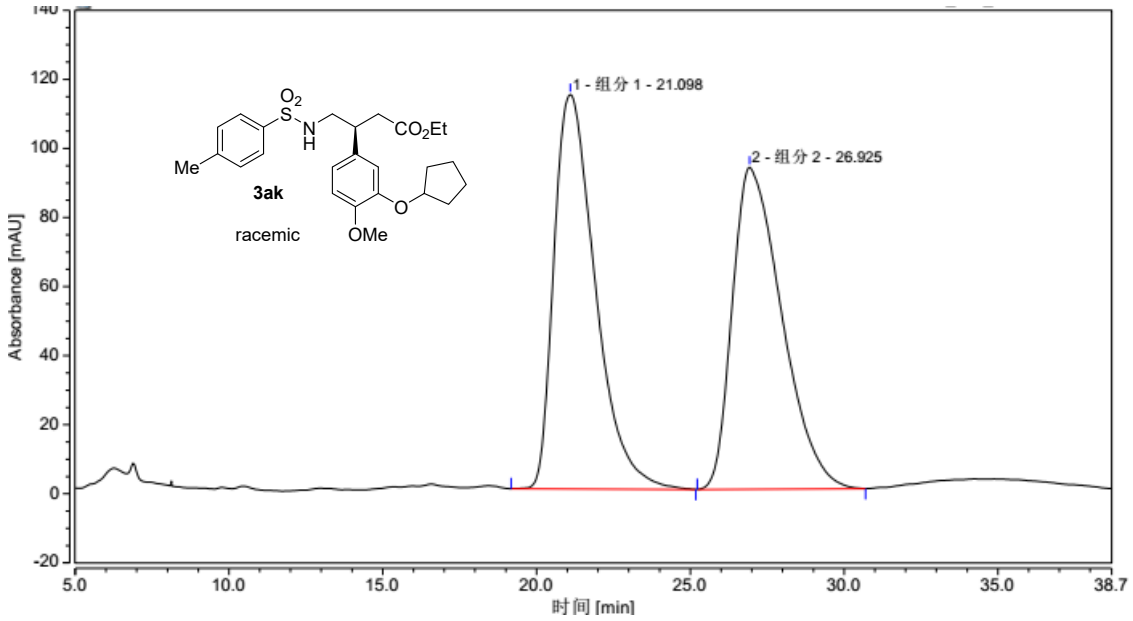

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 20.057 | 155.617 | 206.701 | 49.25 | 52.48 |
| 2 | 23.362 | 160.345 | 187.138 | 50.75 | 47.52 |



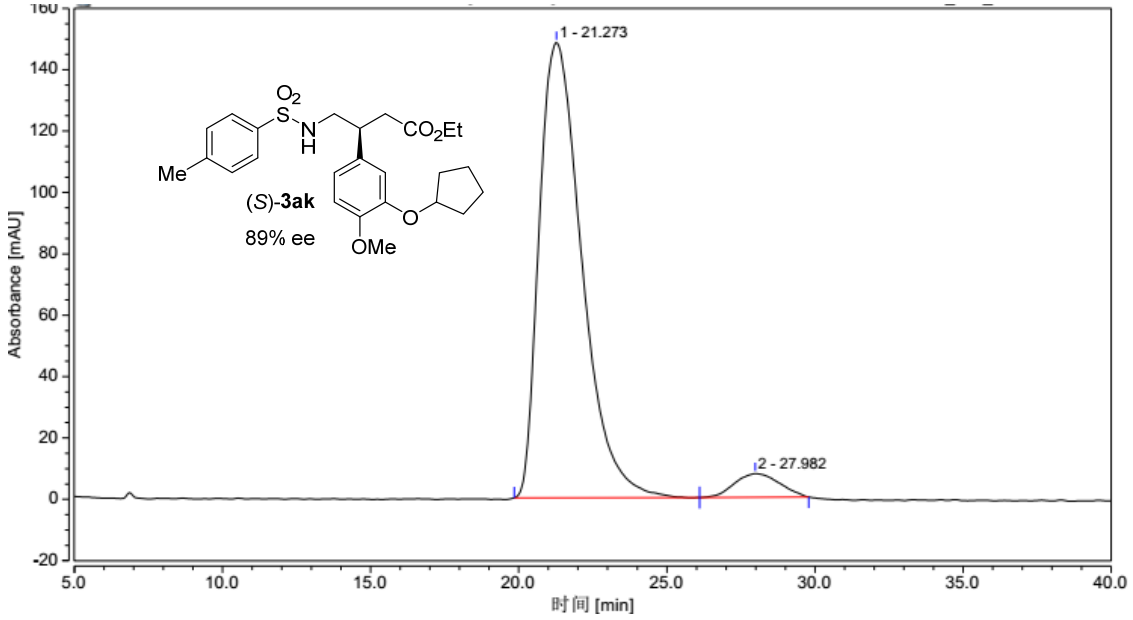

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 19.803 | 252.297 | 306.295 | 91.43 | 93.62 |
| 2 | 22.890 | 23.641 | 20.872 | 8.57 | 6.38 |



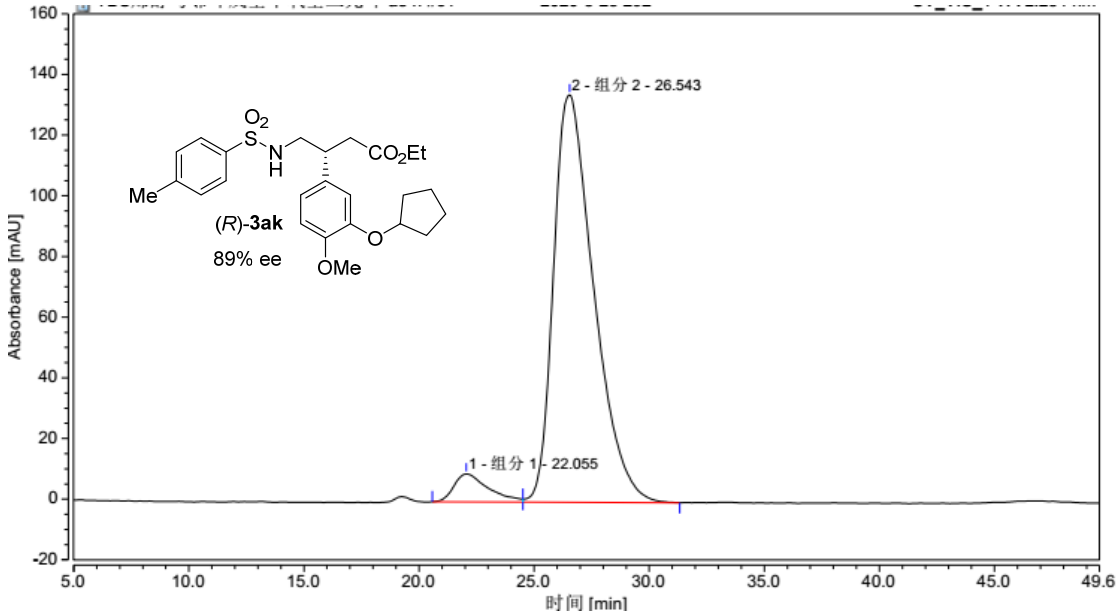

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 21.098 | 177.983 | 114.205 | 50.62 | 55.06 |
| 2 | 26.925 | 173.628 | 93.225 | 49.38 | 44.94 |



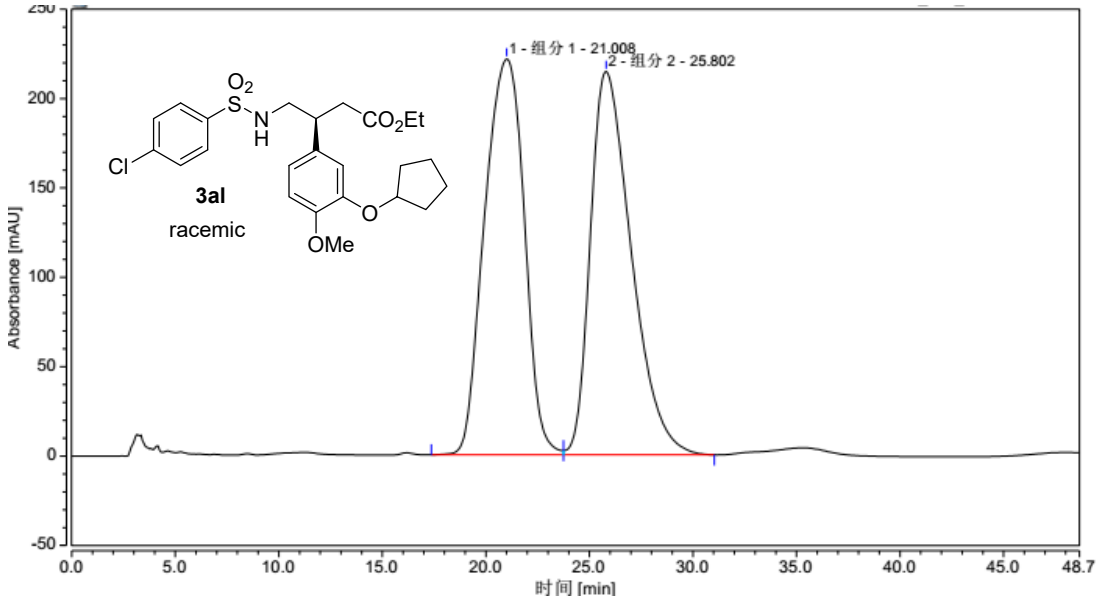

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 21.273 | 247.493 | 148.386 | 94.79 | 95.06 |
| 2 | 27.982 | 13.616 | 7.717 | 5.21 | 4.94 |



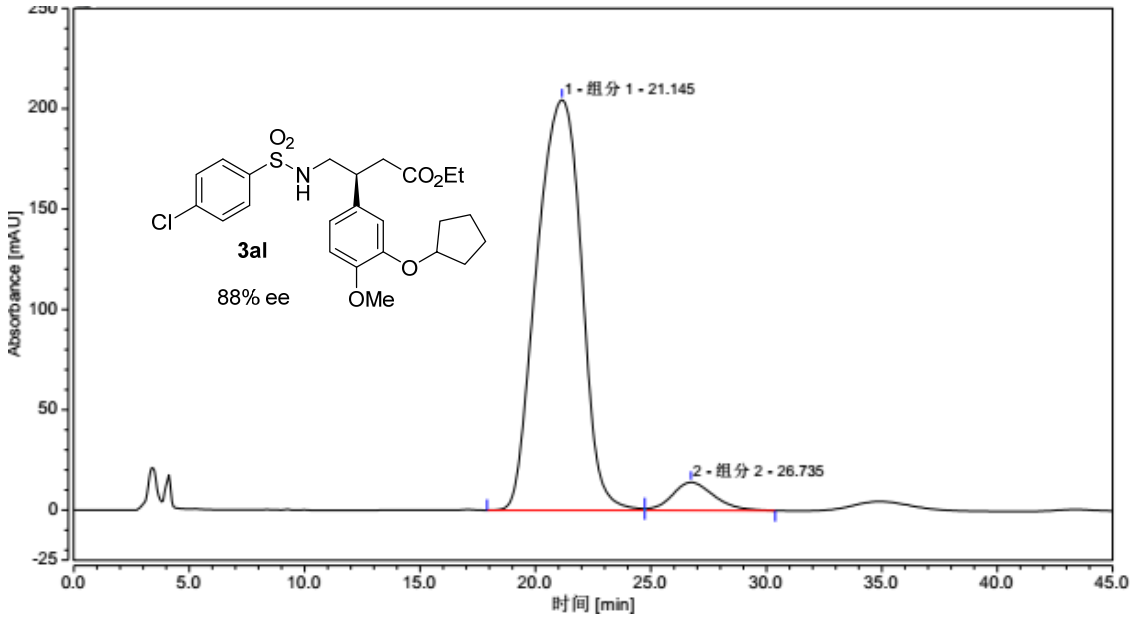

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area% | Height% |
|---|---|---|---|---|---|
| 1 | 22.055 | 15.816 | 9.168 | 5.50 | 6.39 |
| 2 | 26.543 | 271.906 | 134.314 | 94.50 | 93.61 |



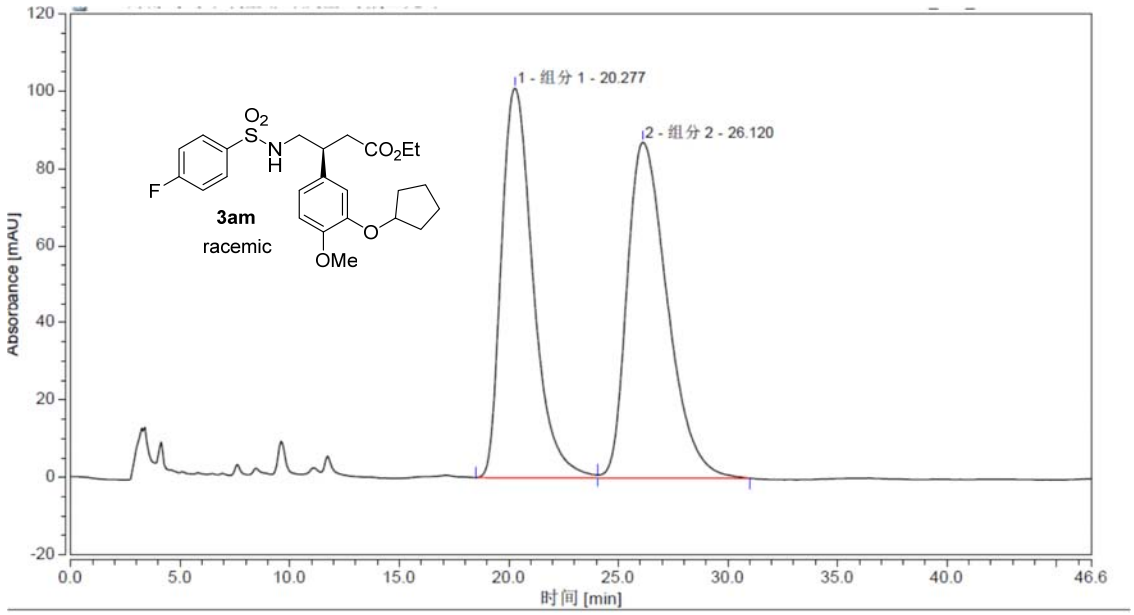

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 21.008 | 492.594 | 221.457 | 50.06 | 50.80 |
| 2 | 25.802 | 491.503 | 214.514 | 49.94 | 49.20 |



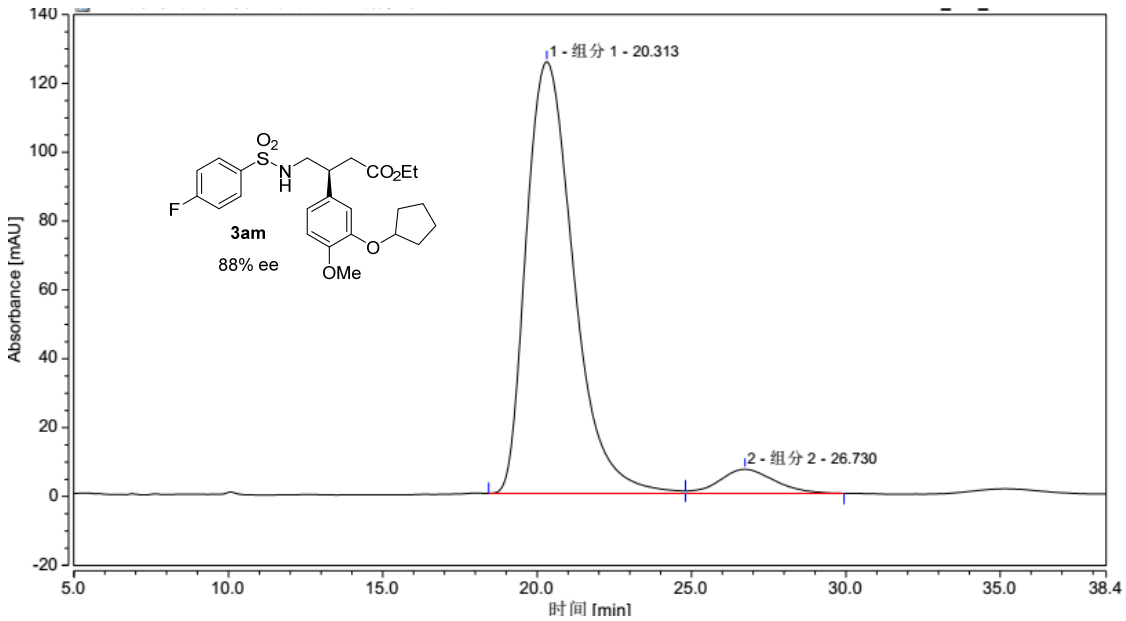

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 21.145 | 459.736 | 204.485 | 93.97 | 93.59 |
| 2 | 26.735 | 29.478 | 14.000 | 6.03 | 6.41 |



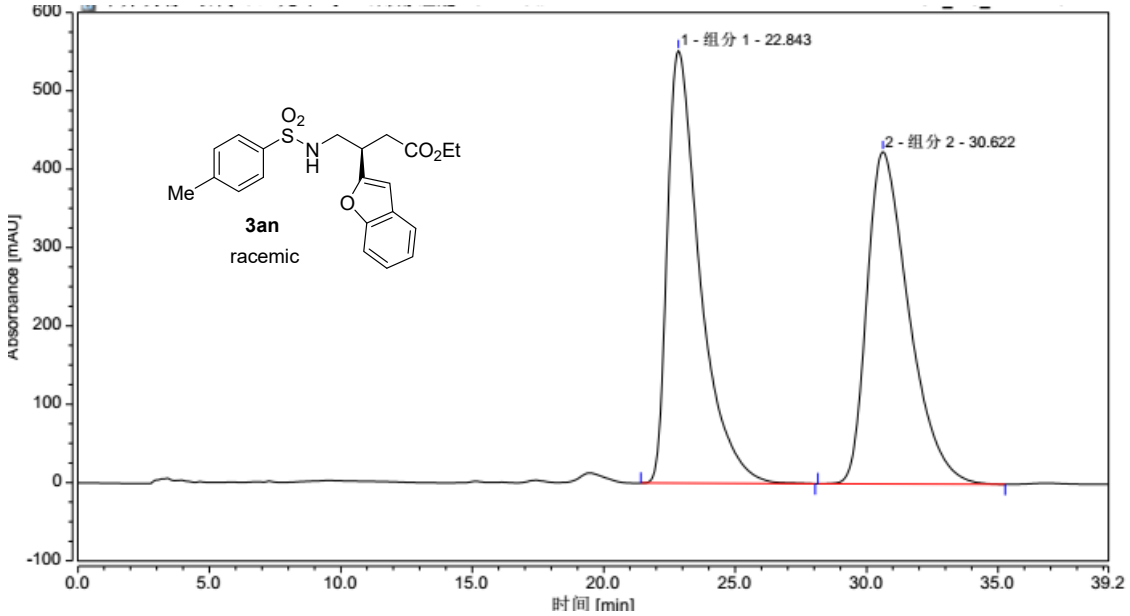

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 20.277 | 168.820 | 100.827 | 47.69 | 53.72 |
| 2 | 26.120 | 185.153 | 86.858 | 52.31 | 46.28 |



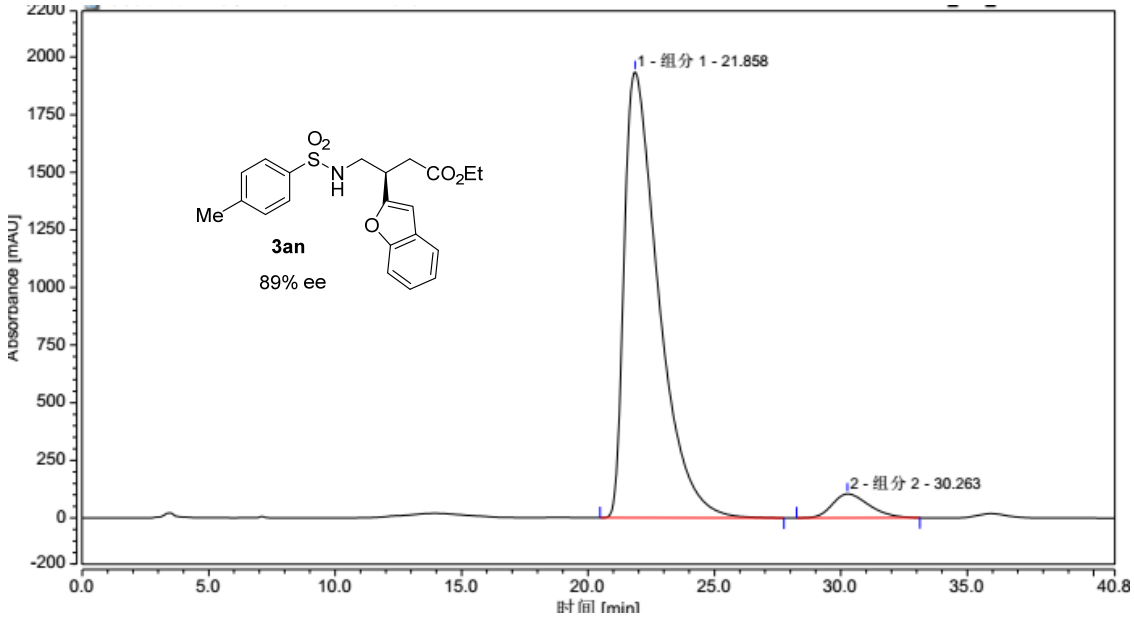

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 20.313 | 222.875 | 125.369 | 93.96 | 94.73 |
| 2 | 26.730 | 14.329 | 6.969 | 6.04 | 5.27 |



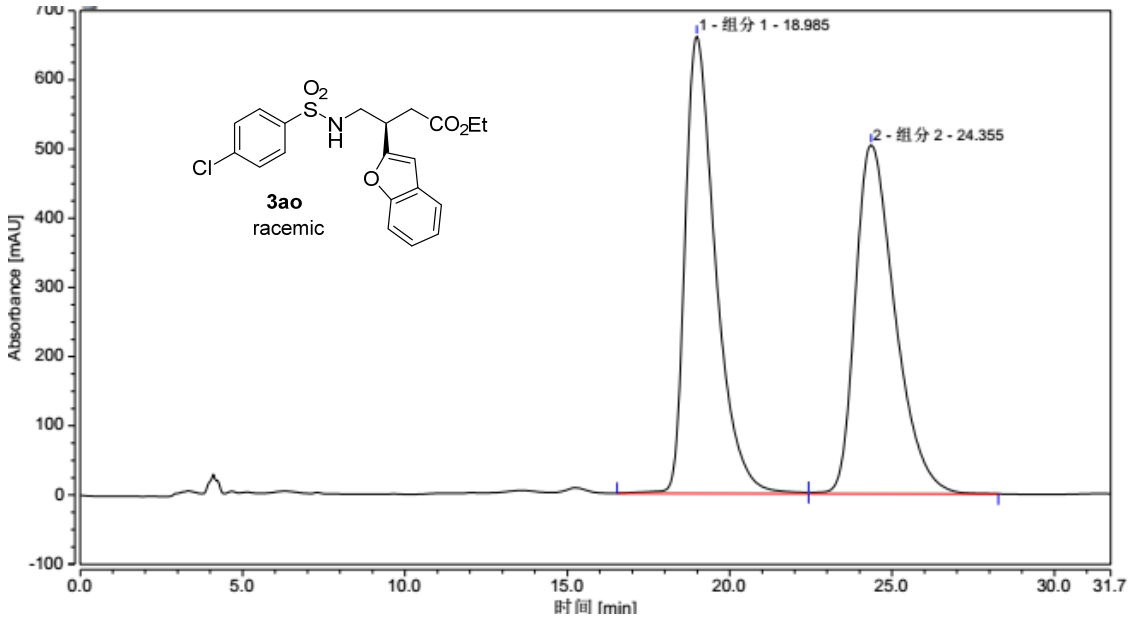

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 22.843 | 793.696 | 552.029 | 50.32 | 56.56 |
| 2 | 30.622 | 783.473 | 424.004 | 49.68 | 43.44 |



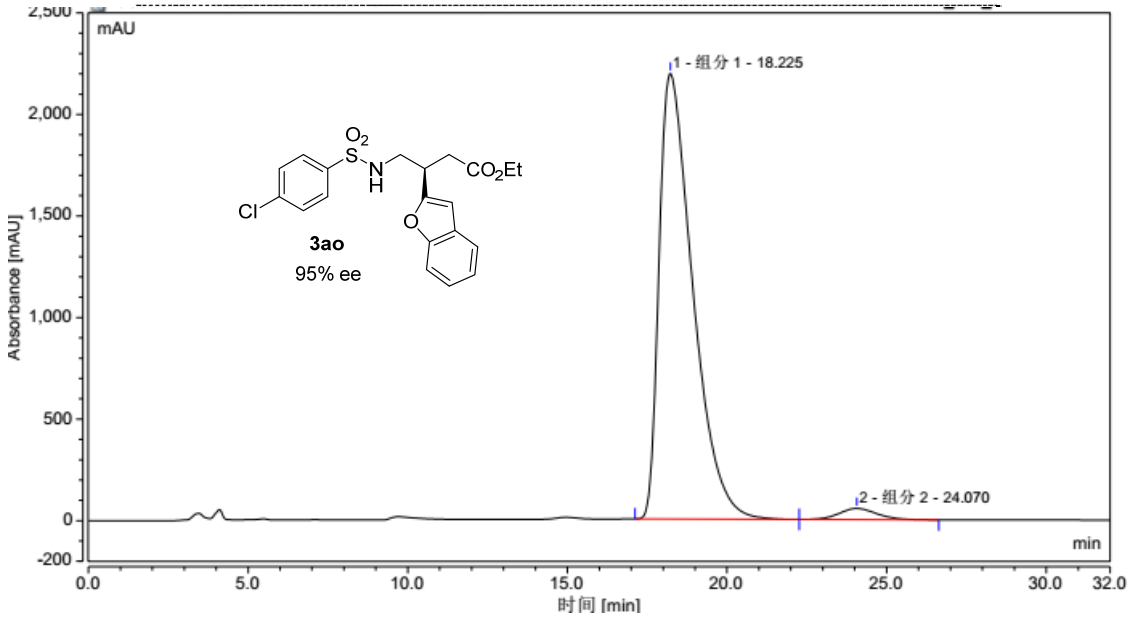

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 21.858 | 3040.802 | 1935.431 | 94.55 | 94.91 |
| 2 | 30.263 | 175.797 | 103.852 | 5.45 | 5.09 |



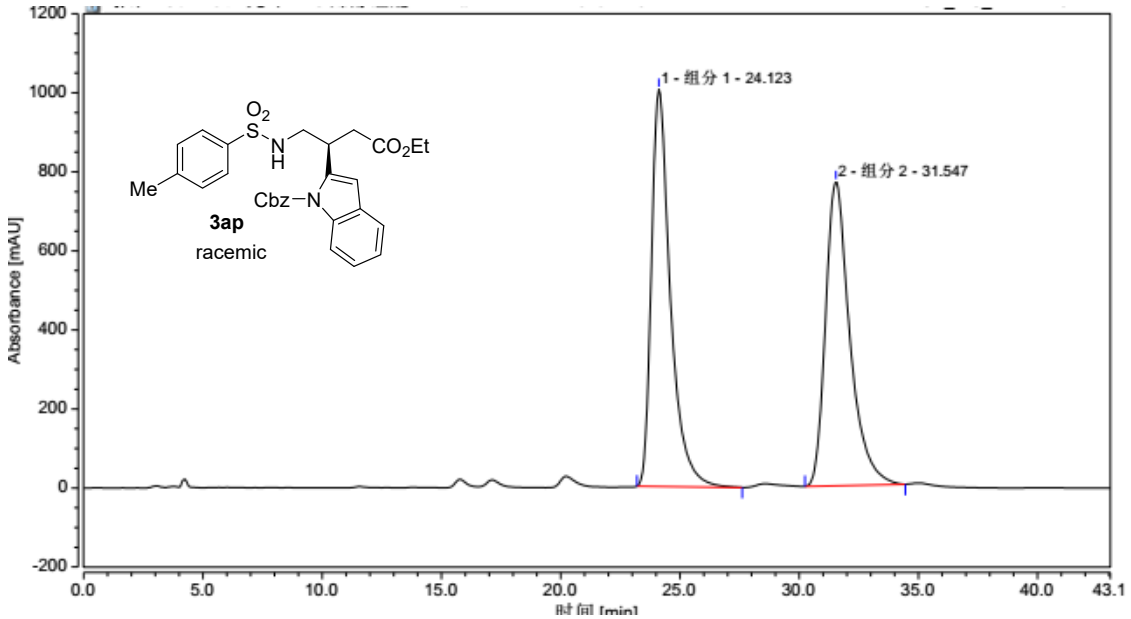

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 18.985 | 718.422 | 660.627 | 50.21 | 56.73 |
| 2 | 24.355 | 712.455 | 503.879 | 49.79 | 43.27 |



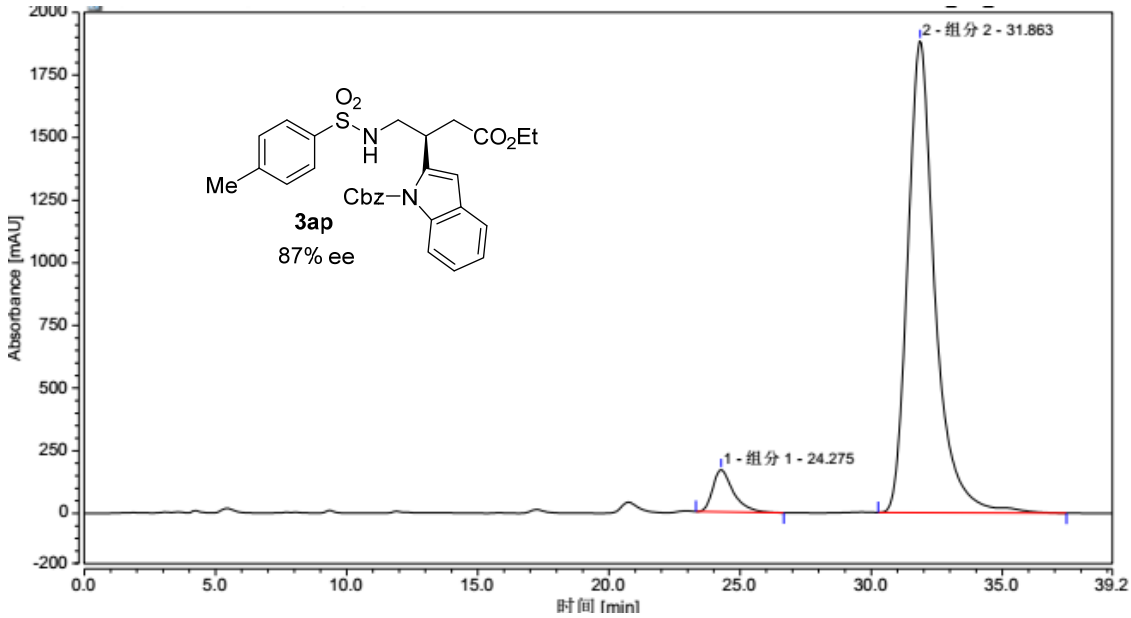

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 18.225 | 2679.058 | 2194.841 | 97.26 | 97.56 |
| 2 | 24.070 | 75.450 | 54.954 | 2.74 | 2.44 |



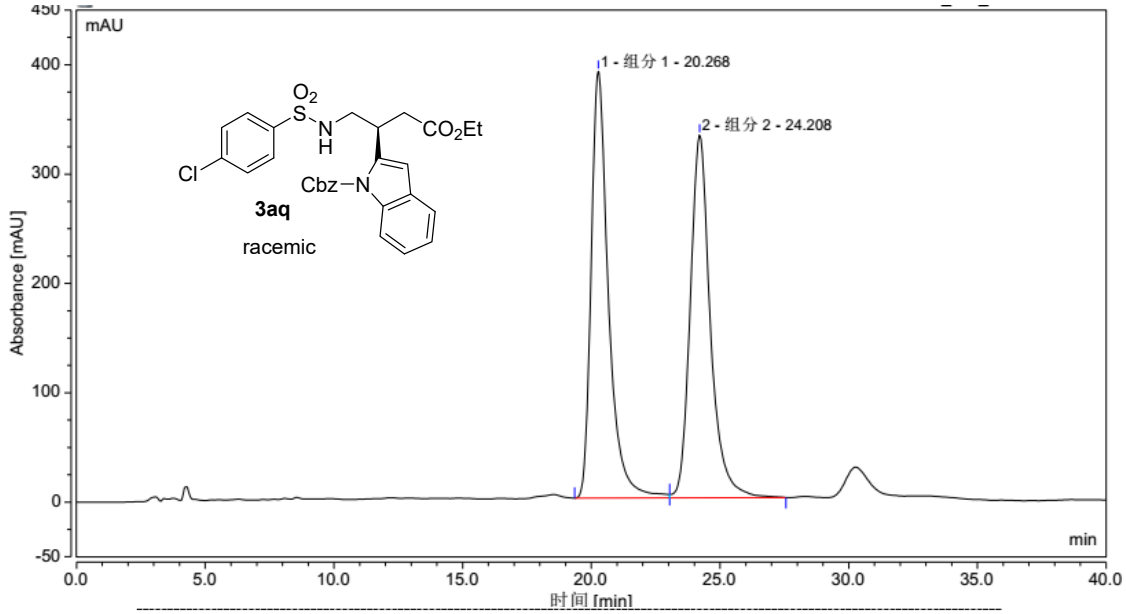

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 24.123 | 927.190 | 1004.609 | 50.55 | 56.65 |
| 2 | 31.547 | 906.845 | 768.735 | 49.45 | 43.35 |



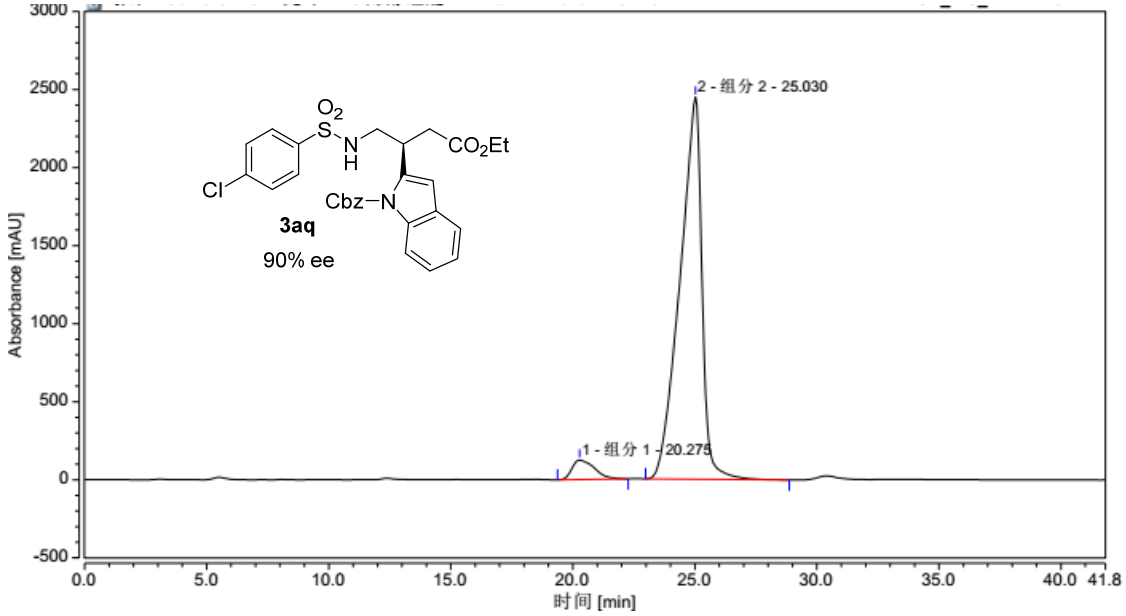

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 24.275 | 153.485 | 168.334 | 6.34 | 8.20 |
| 2 | 31.863 | 2267.590 | 1884.634 | 93.66 | 91.80 |



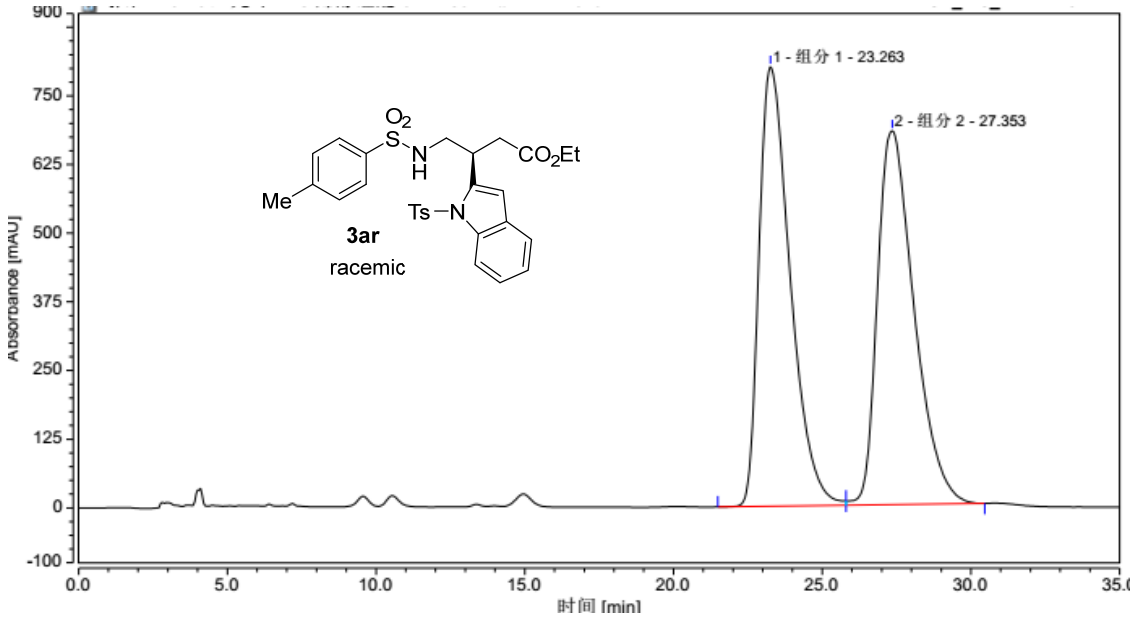

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 20.268 | 304.496 | 390.214 | 50.28 | 54.04 |
| 2 | 24.208 | 301.134 | 331.882 | 49.72 | 45.96 |



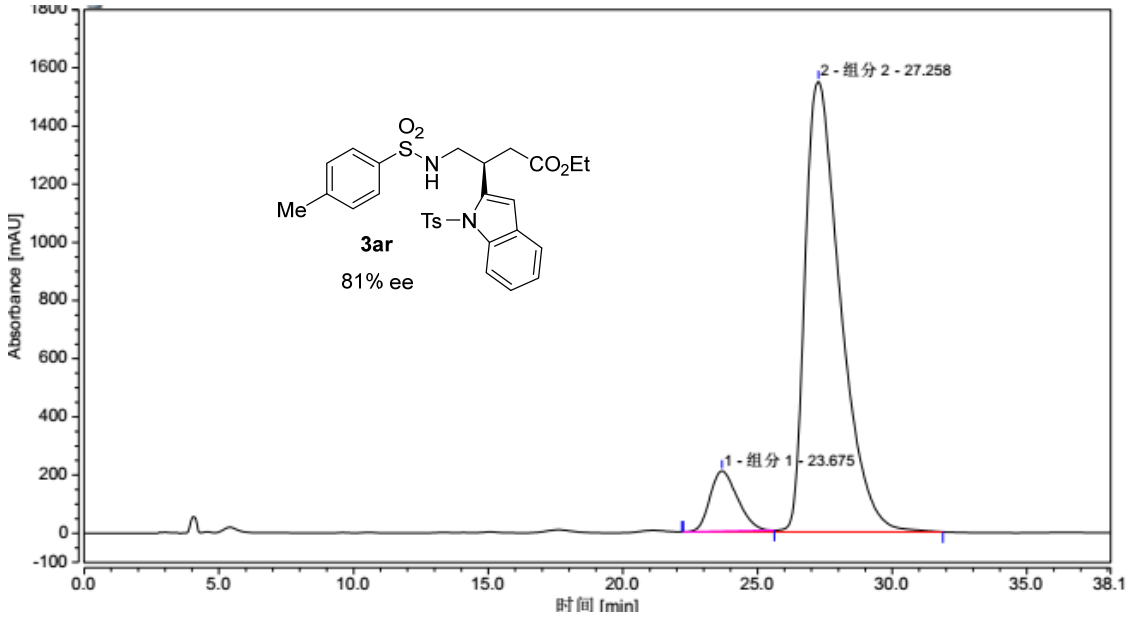

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 20.275 | 131.909 | 124.356 | 4.92 | 4.84 |
| 2 | 25.030 | 2548.352 | 2447.098 | 95.08 | 95.16 |



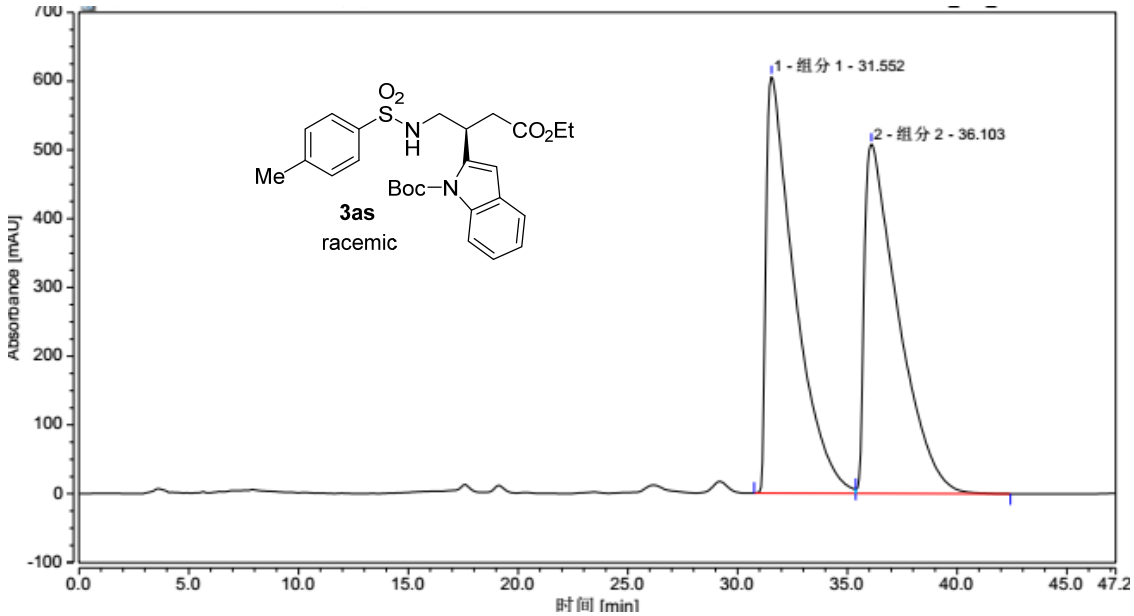

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 23.263 | 968.460 | 800.255 | 49.94 | 54.06 |
| 2 | 27.353 | 970.825 | 680.547 | 50.06 | 45.94 |



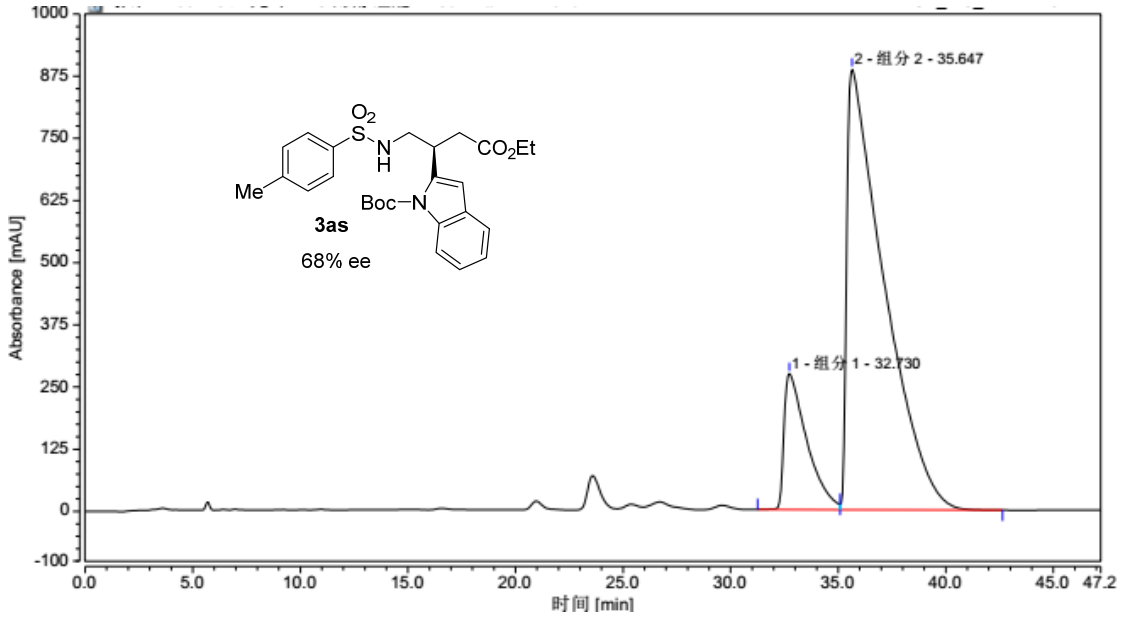

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 23.675 | 245.290 | 207.043 | 9.39 | 11.79 |
| 2 | 27.258 | 2367.231 | 1548.801 | 90.61 | 88.21 |



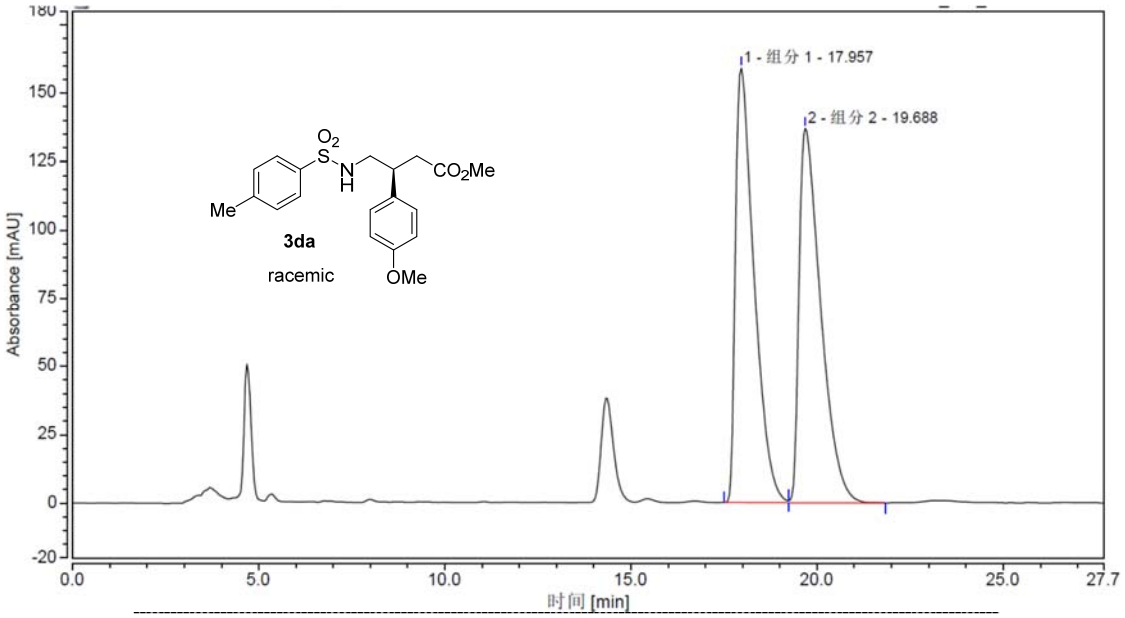

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 31.552 | 914.433 | 605.655 | 50.19 | 54.38 |
| 2 | 36.103 | 907.671 | 508.065 | 49.81 | 45.62 |



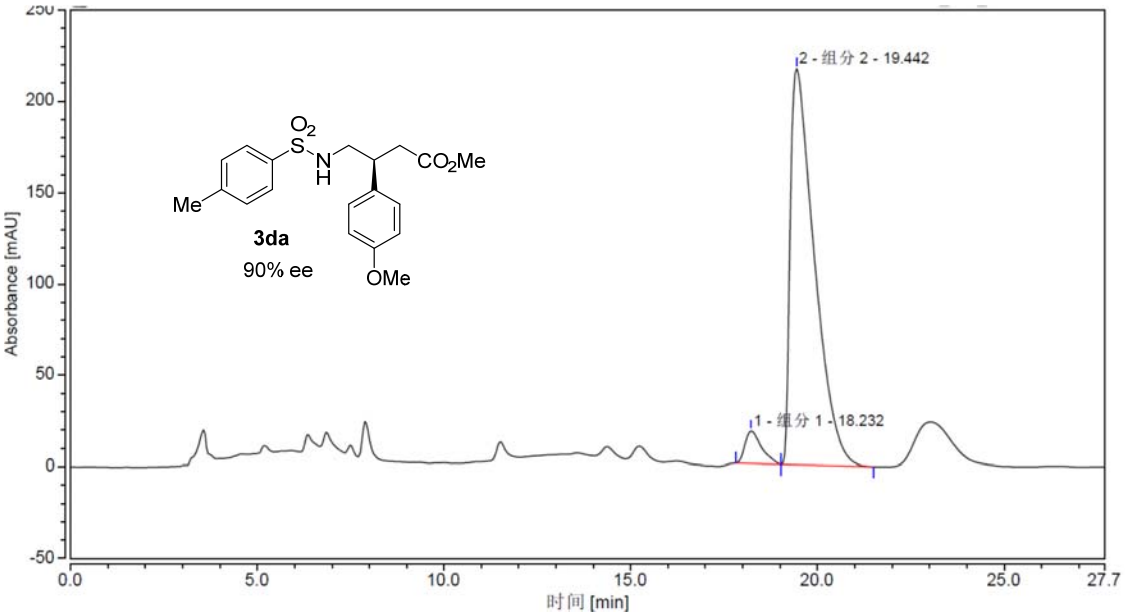

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 32.730 | 334.737 | 273.200 | 15.85 | 23.57 |
| 2 | 35.647 | 1777.441 | 885.828 | 84.15 | 76.43 |



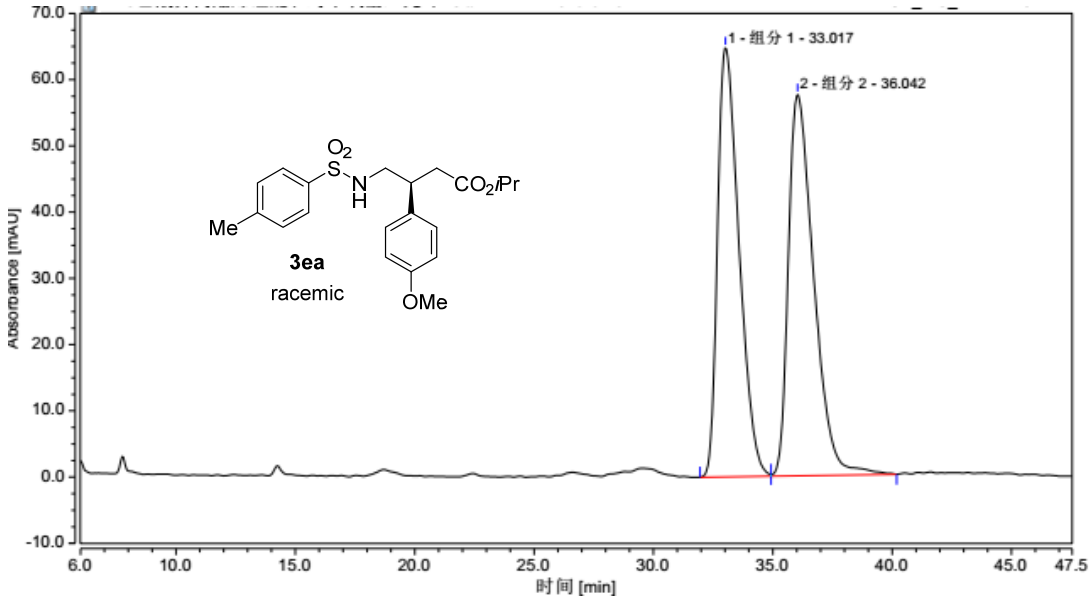

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 17.957 | 91.802 | 158.766 | 49.90 | 53.70 |
| 2 | 19.688 | 92.156 | 136.901 | 50.10 | 46.30 |



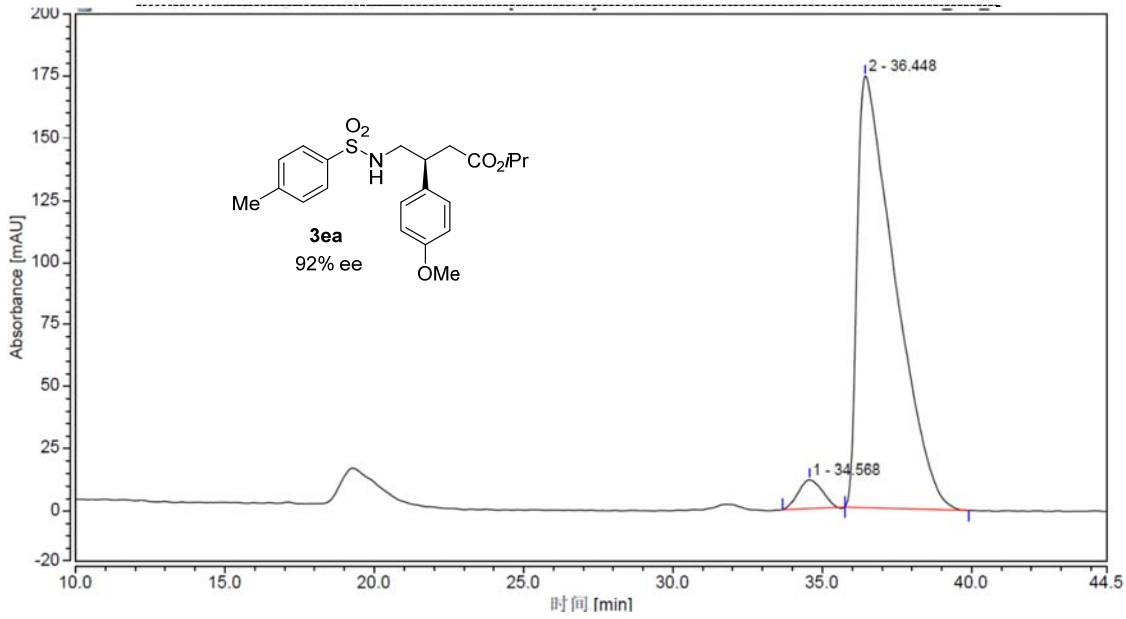

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 18.232 | 8.484 | 17.080 | 4.98 | 7.30 |
| 2 | 19.442 | 161.981 | 216.869 | 95.02 | 92.70 |



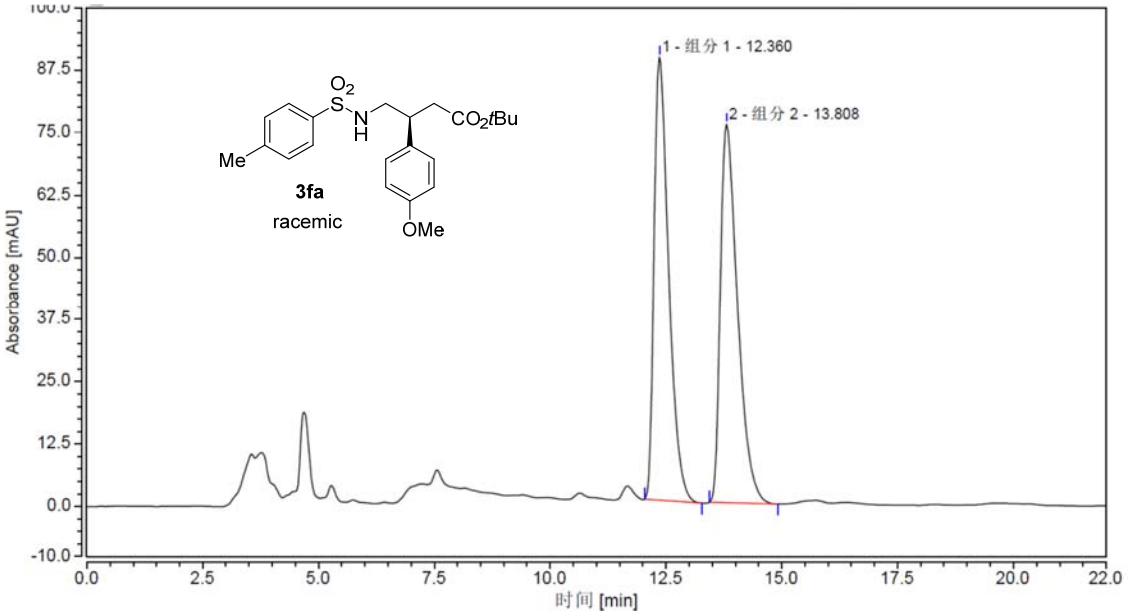

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 33.017 | 67.563 | 64.813 | 48.78 | 52.95 |
| 2 | 36.042 | 70.937 | 57.595 | 51.22 | 47.05 |



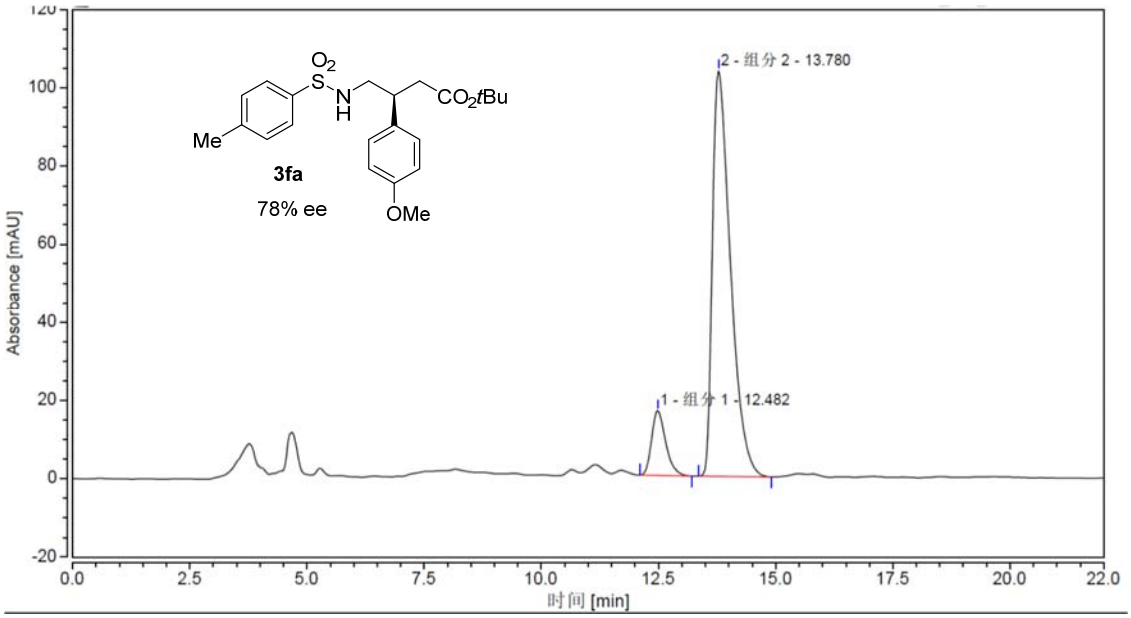

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 34.568 | 10.550 | 11.527 | 3.99 | 6.23 |
| 2 | 36.448 | 253.589 | 173.606 | 96.01 | 93.77 |



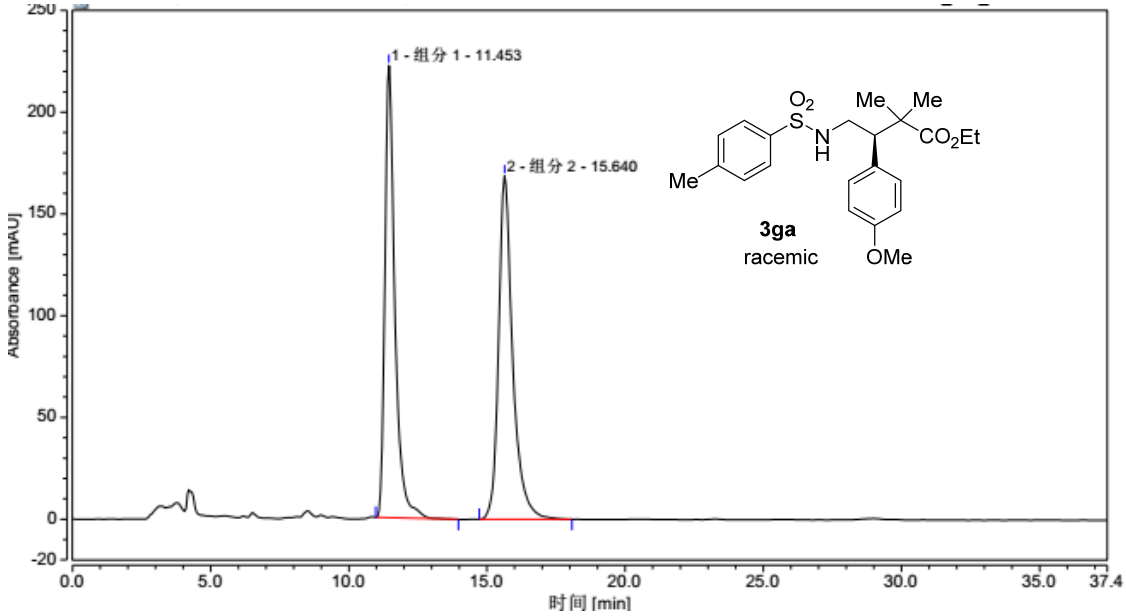

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 12.360 | 32.404 | 88.877 | 49.79 | 53.95 |
| 2 | 13.808 | 32.671 | 75.873 | 50.21 | 46.05 |



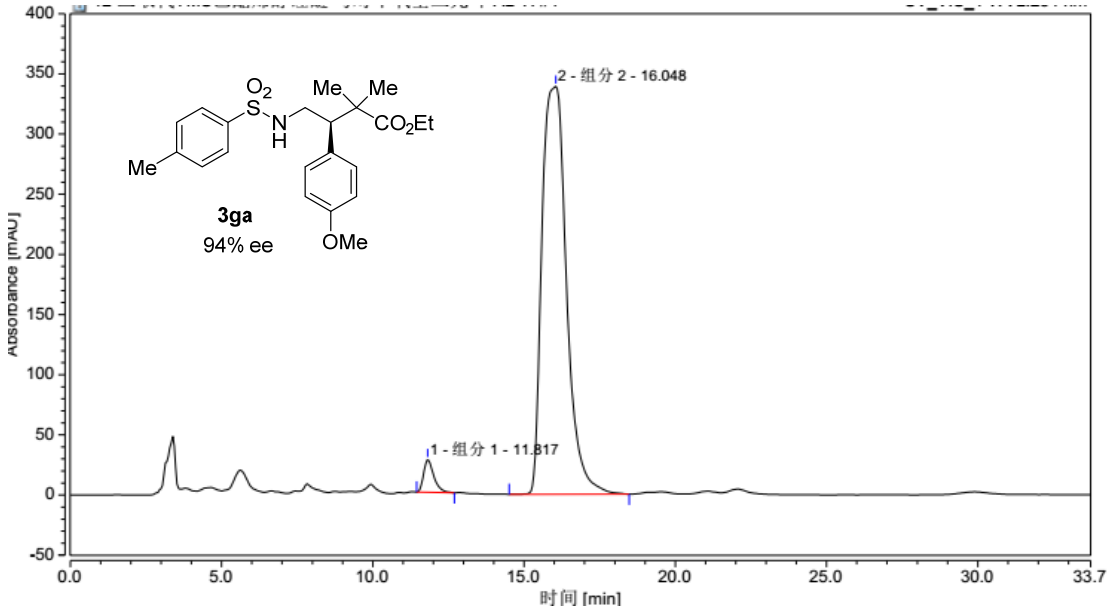

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 12.482 | 5.778 | 16.593 | 11.11 | 13.78 |
| 2 | 13.780 | 46.211 | 103.780 | 88.89 | 86.22 |



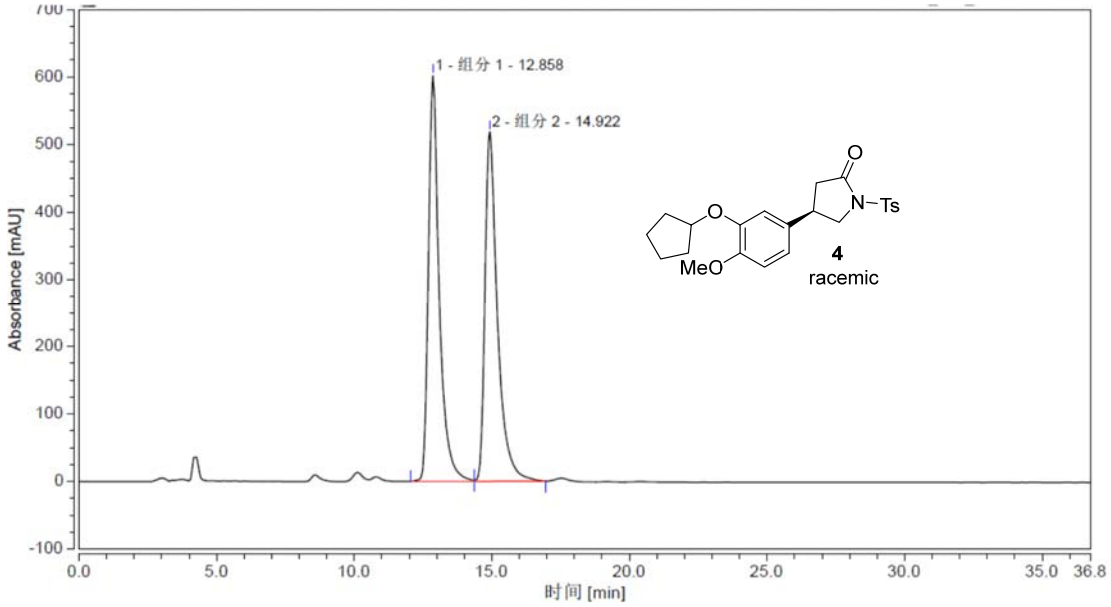

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 11.453 | 92.932 | 222.208 | 48.20 | 56.84 |
| 2 | 15.640 | 99.854 | 168.728 | 51.80 | 43.16 |



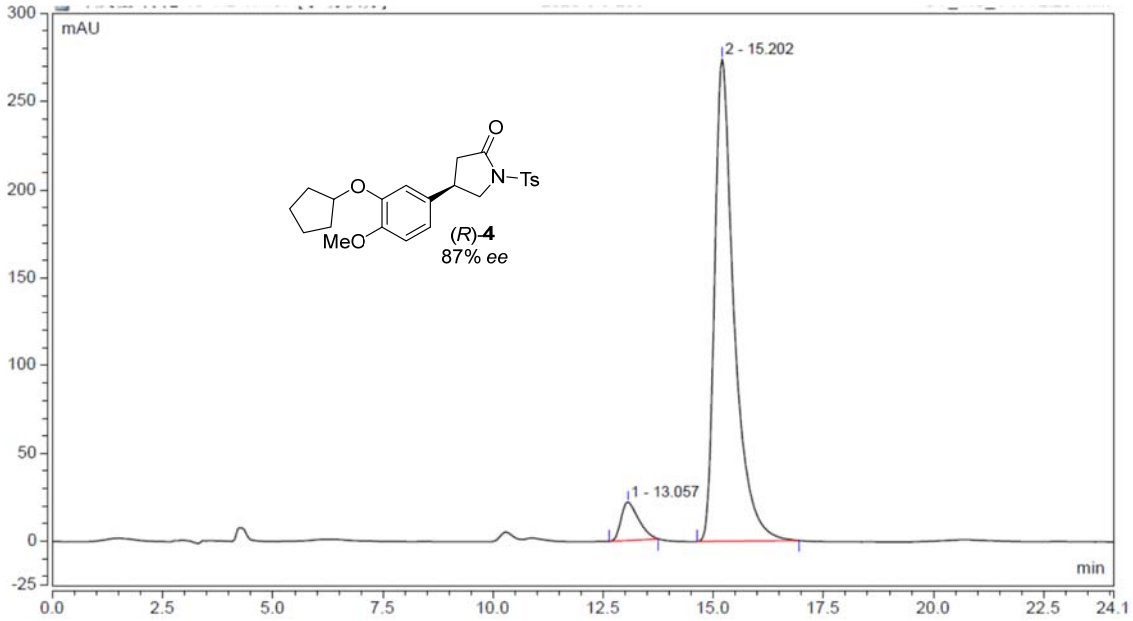

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 11.817 | 10.667 | 27.154 | 3.25 | 7.42 |
| 2 | 16.048 | 317.995 | 338.949 | 96.75 | 92.58 |



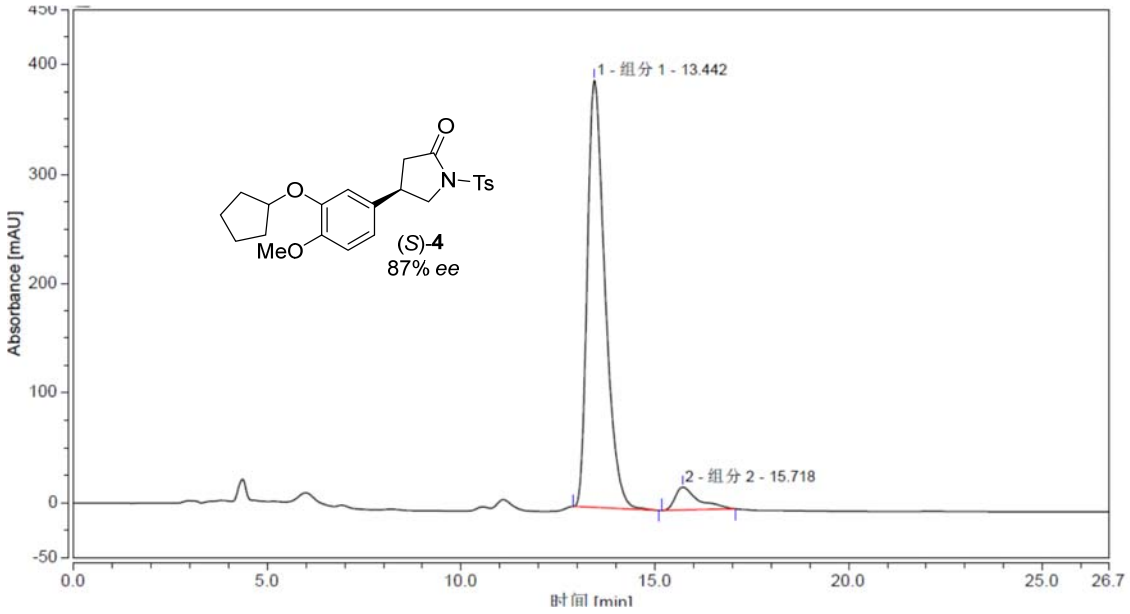

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 12.858 | 275.507 | 602.185 | 50.30 | 53.74 |
| 2 | 14.922 | 272.170 | 518.402 | 49.70 | 46.26 |



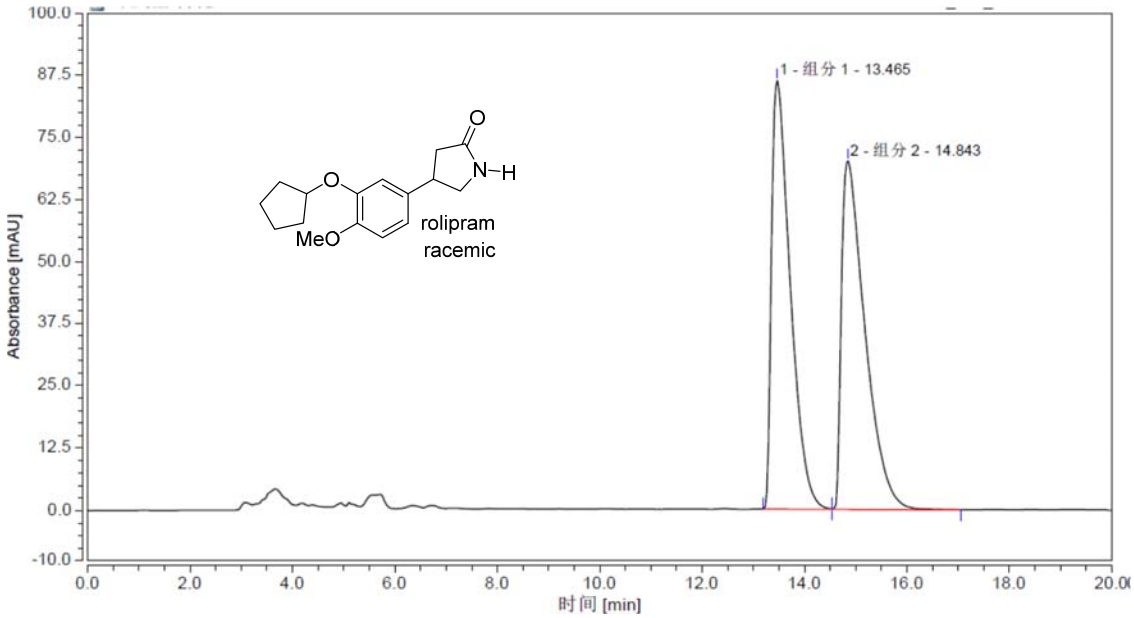

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 13.057 | 10.016 | 21.808 | 6.66 | 7.37 |
| 2 | 15.202 | 140.266 | 274.162 | 93.34 | 92.63 |



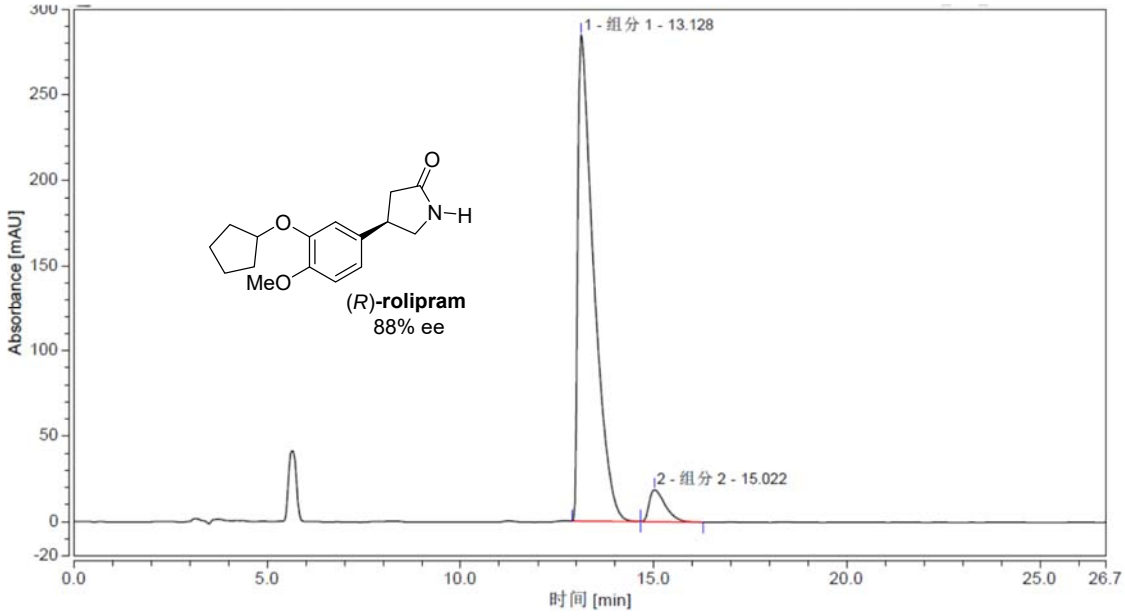

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 13.422 | 205.266 | 389.448 | 93.43 | 94.94 |
| 2 | 15.718 | 14.440 | 20.774 | 6.57 | 5.06 |



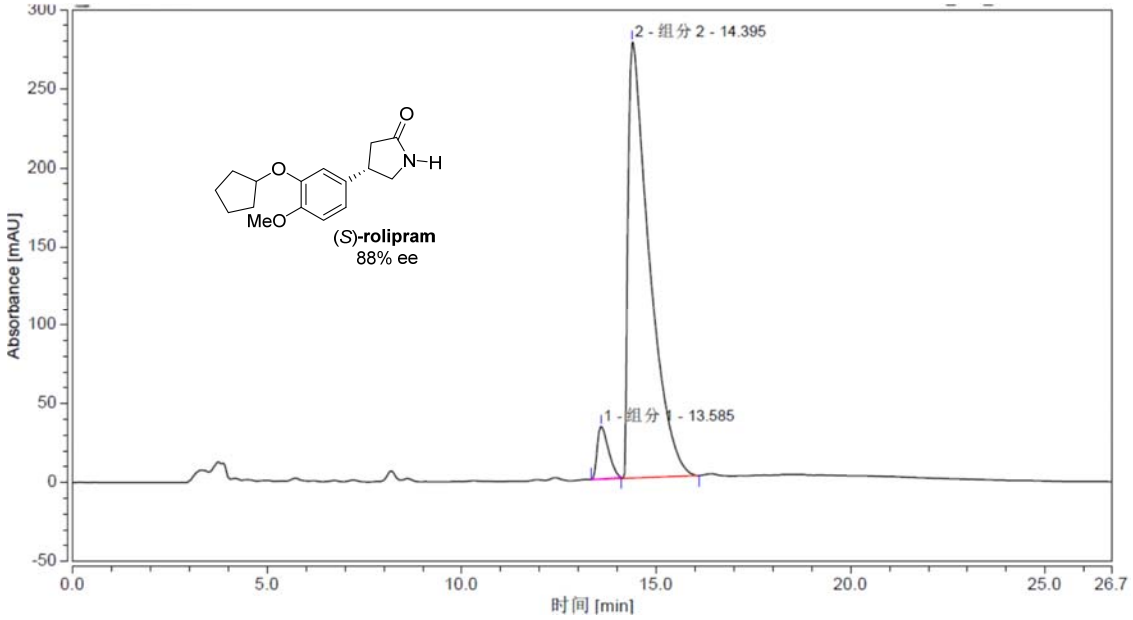

Area Percent Report

| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 13.465 | 36.500 | 86.221 | 49.55 | 55.14 |
| 2 | 14.843 | 37.166 | 70.140 | 50.45 | 44.86 |




Area Percent Report

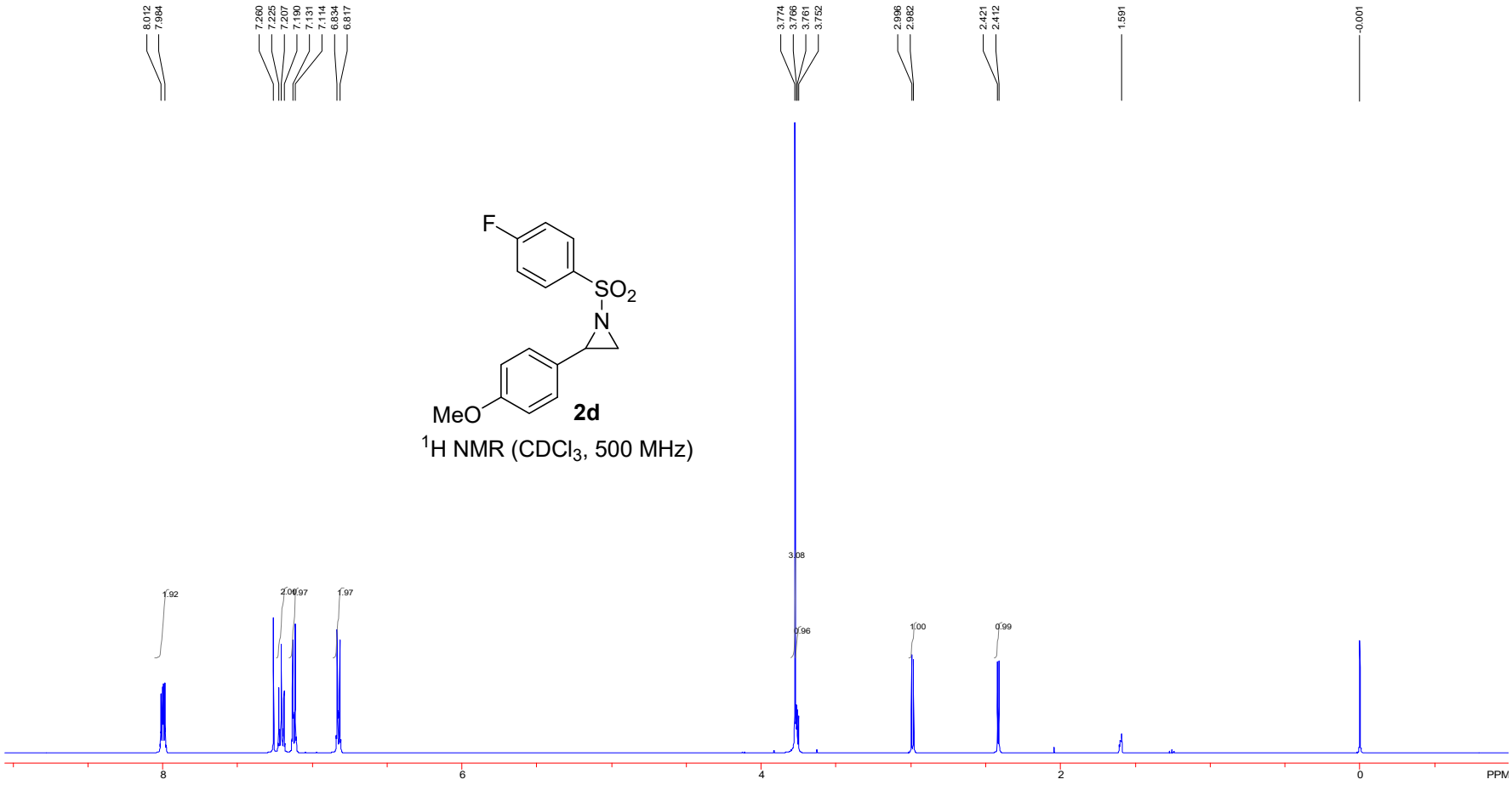
| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 13.128 | 136.660 | 284.941 | 93.81 | 93.82 |
| 2 | 15.022 | 9.011 | 18.760 | 6.19 | 6.18 |

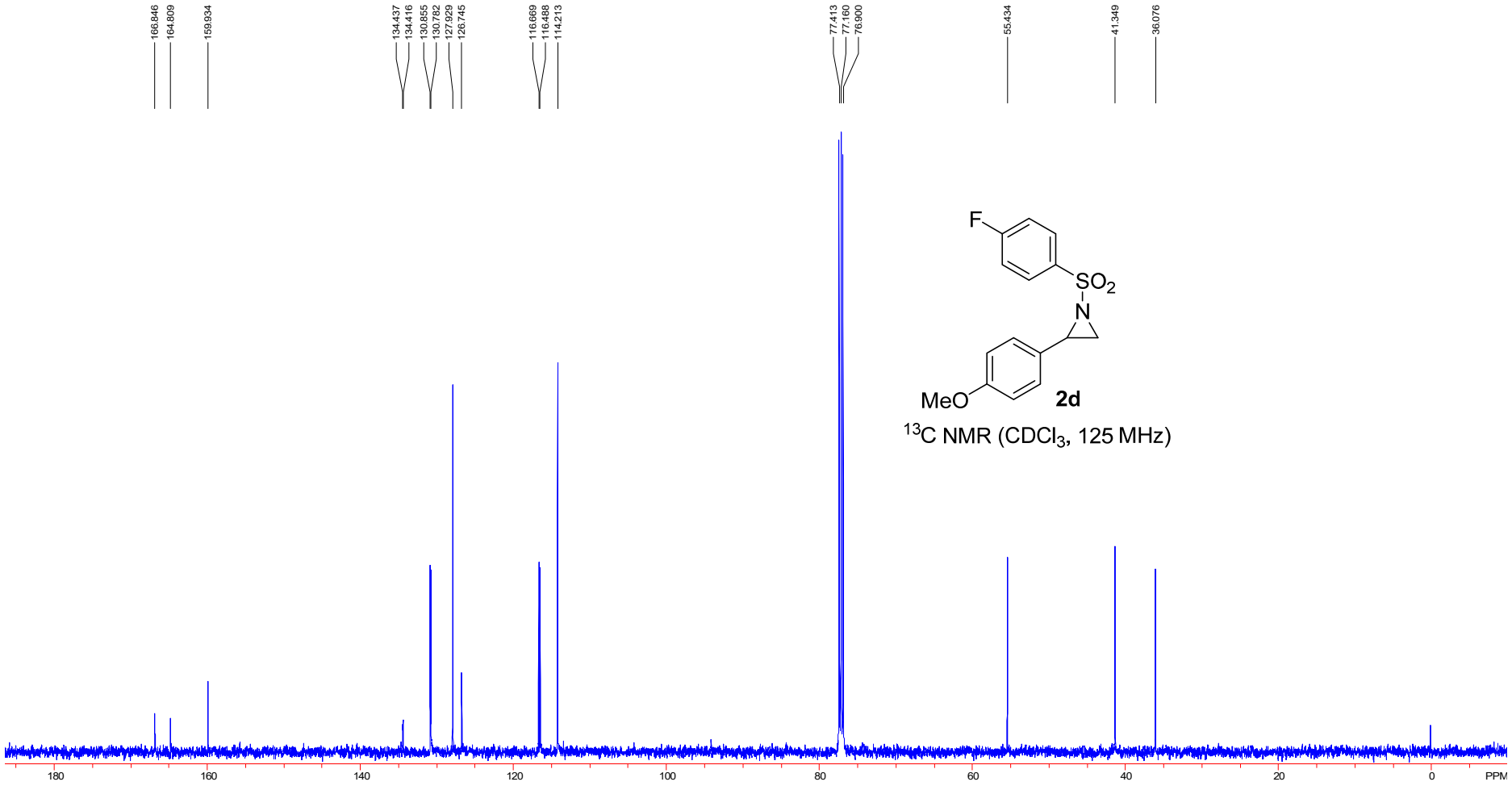


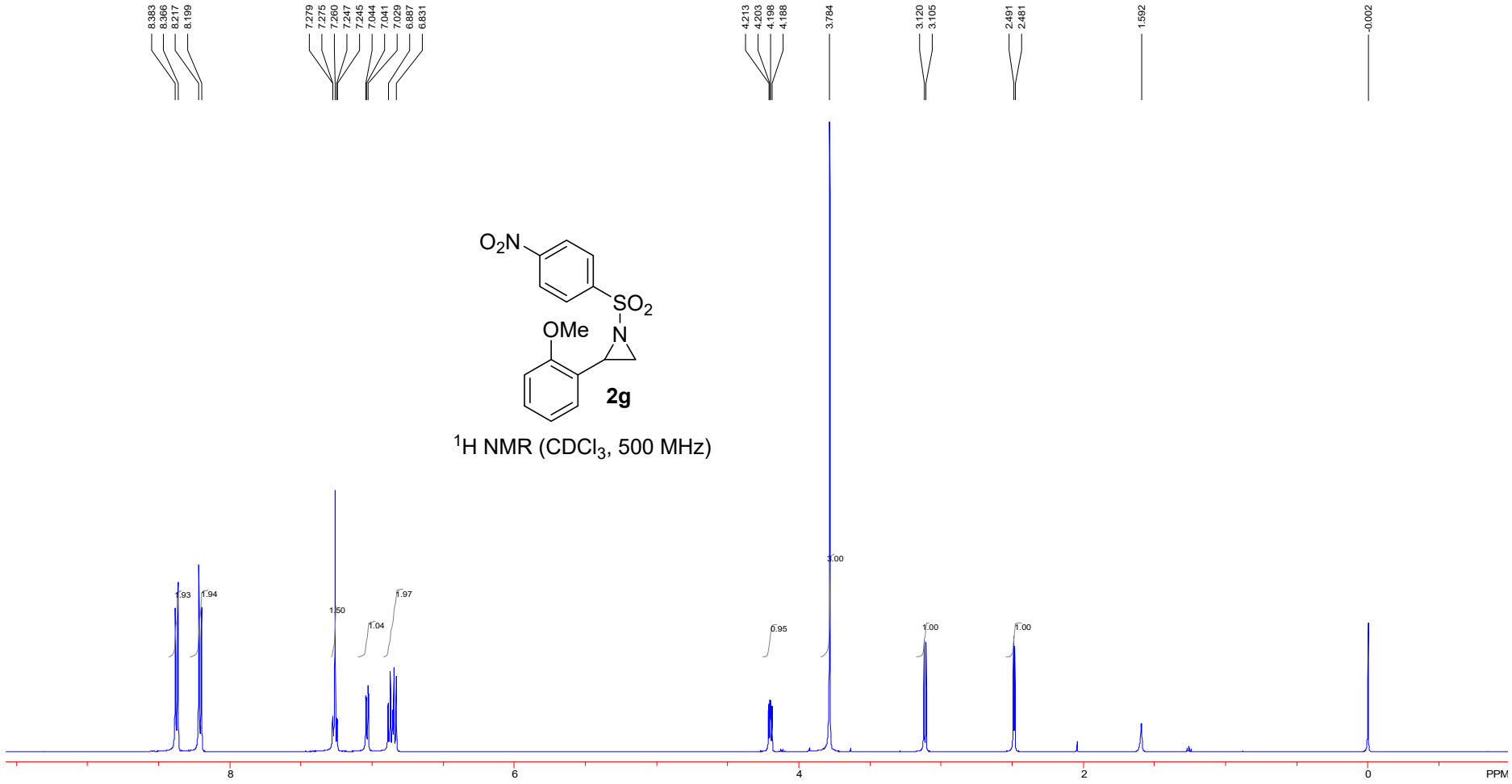

Area Percent Report

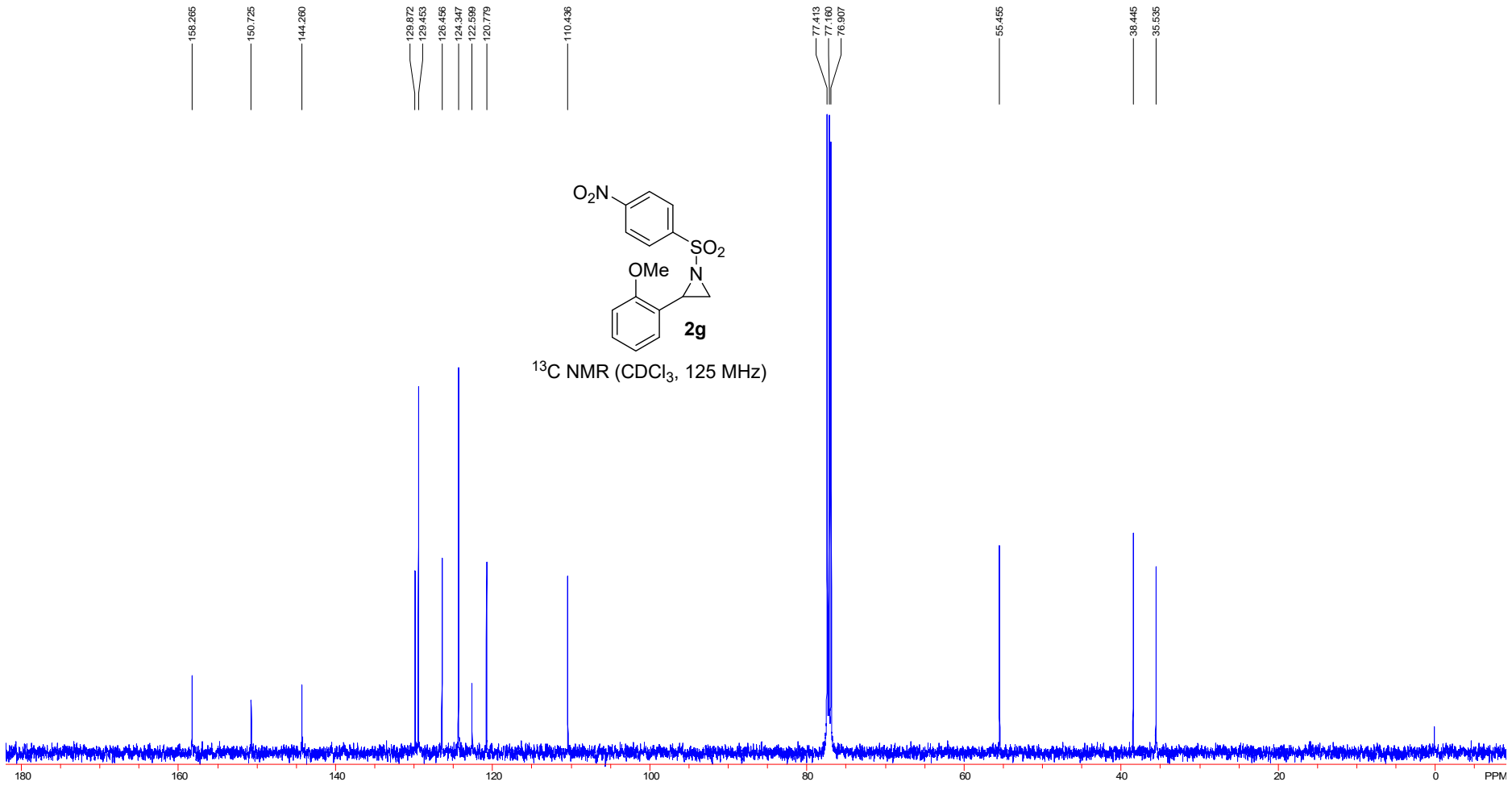
| Peak # | RetTime [min] | Area [mAU *min] | Height [mAU] | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 13.585 | 11.095 | 33.289 | 5.97 | 10.73 |
| 2 | 14.395 | 174.899 | 276.859 | 94.03 | 89.27 |

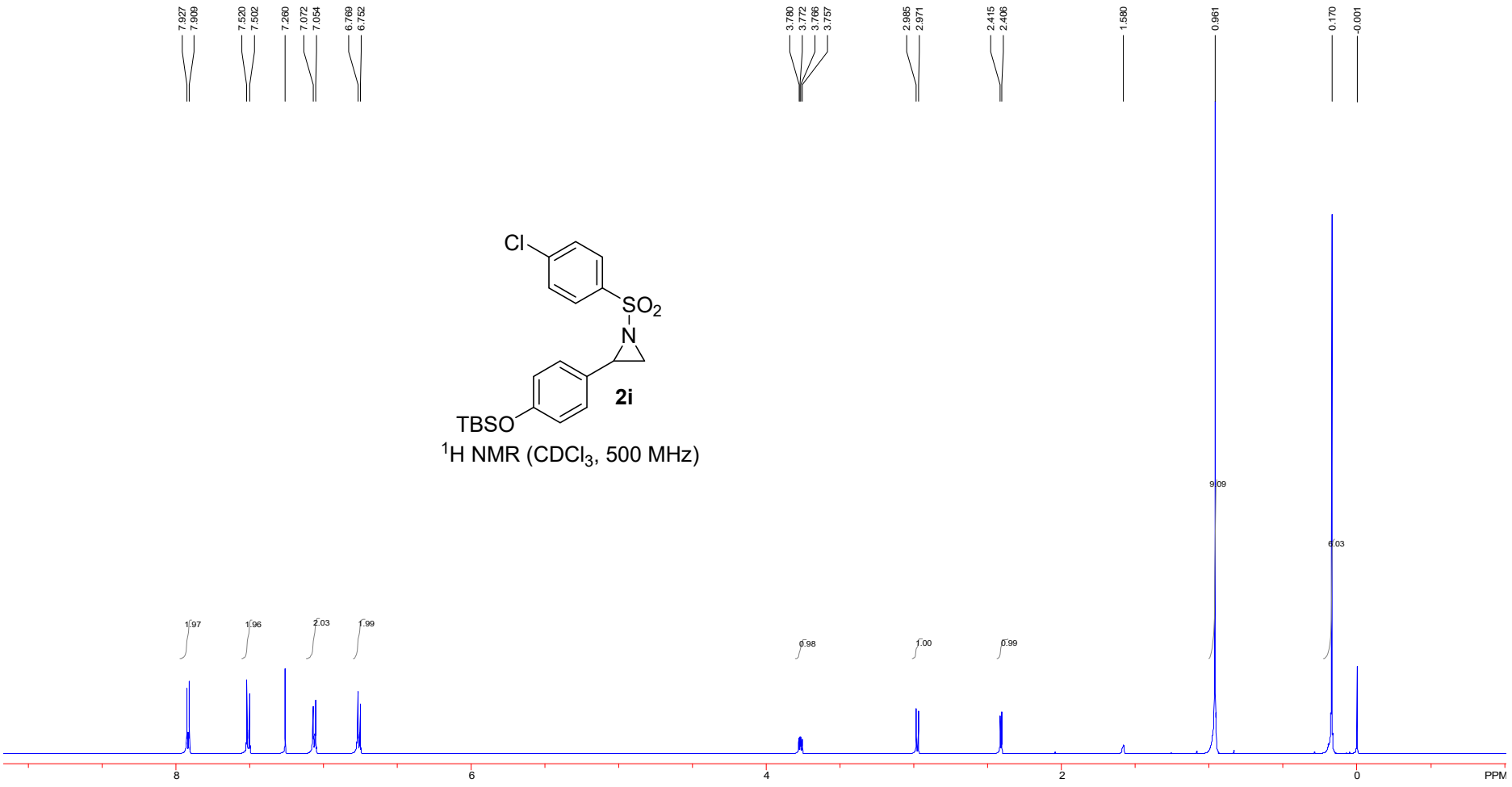
# Copies of $^{1}$H NMR and $^{13}$C NMR Spectra for All New Compounds

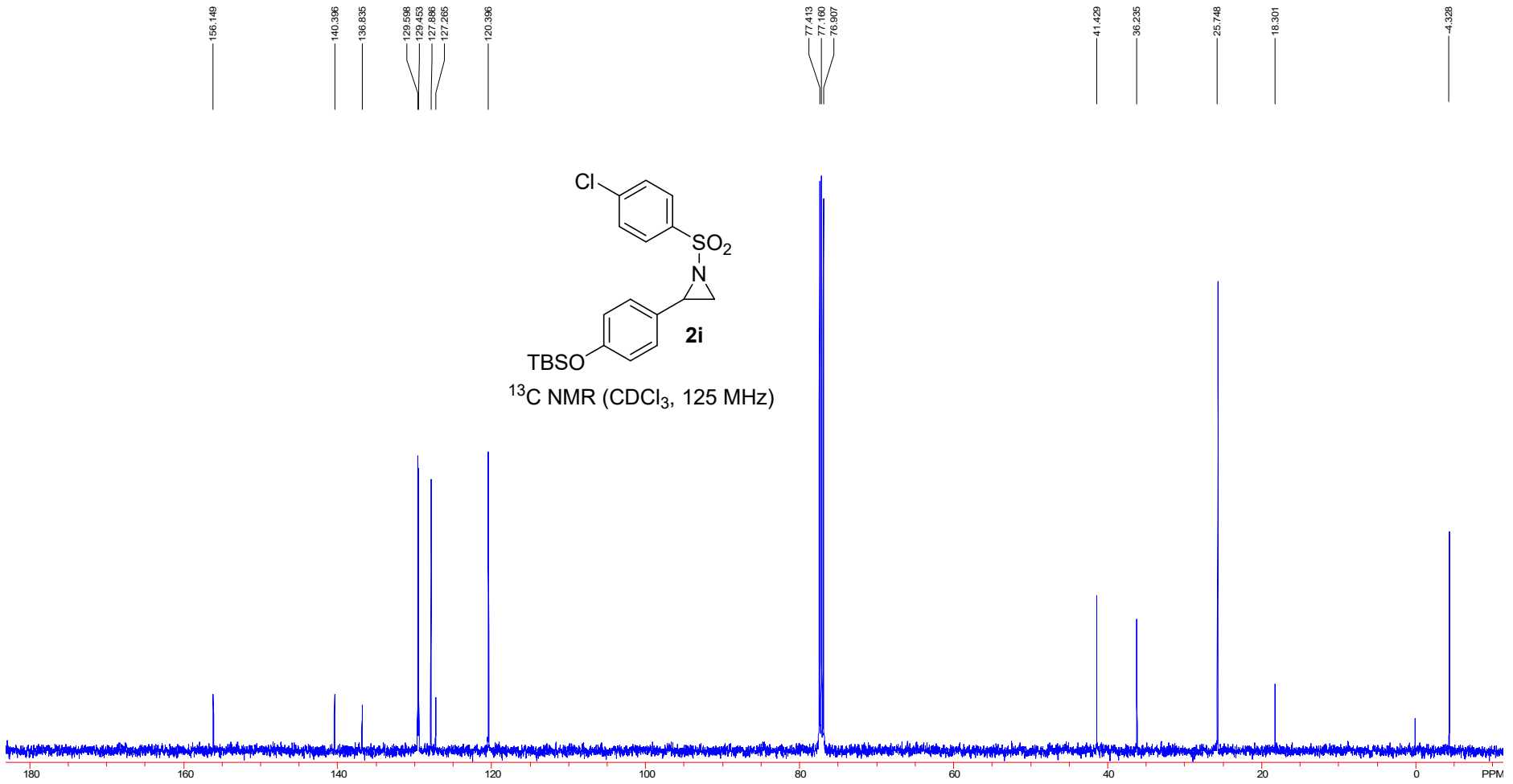


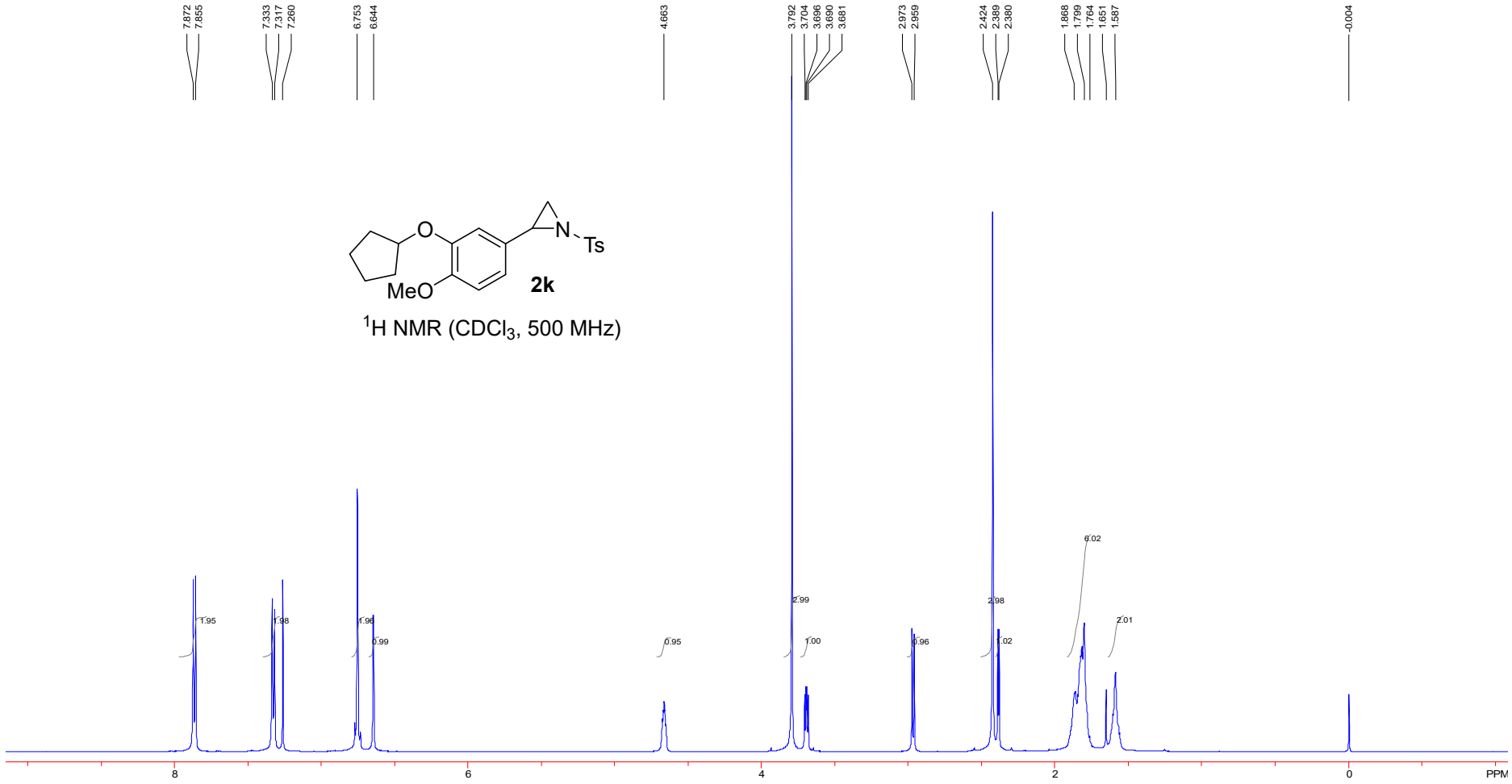

166.846
164.809
159.934
134.437
134.416
130.855
130.782
127.929
126.745
116.669
116.488
114.213
77.413
77.160
76.900
55.434
41.349
36.076
F
SO2
N
MeO
2d
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

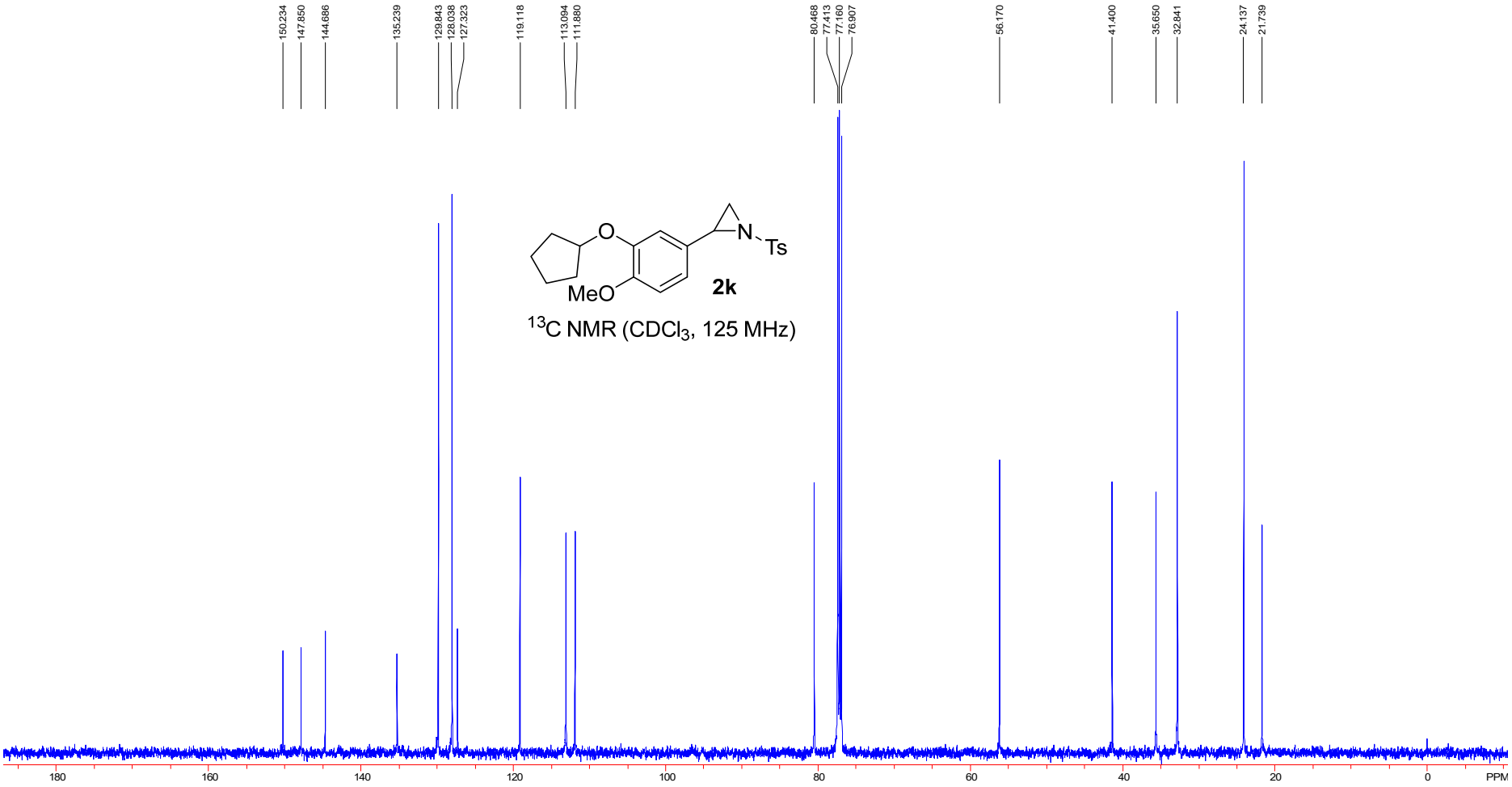

8.383
8.366
8.217
8.199
7.279
7.275
7.260
7.247
7.245
7.044
7.041
7.029
6.887
6.831
4.213
4.203
4.198
4.188
3.784
3.120
3.105
2.491
2.481
1.592
-0.002
O2N
SO2
OMe
N
2g
1H NMR (CDCl3, 500 MHz)
1.93
1.94
1.50
1.04
1.97
0.95
3.00
1.00
1.00
8
6
4
2
0
PPM

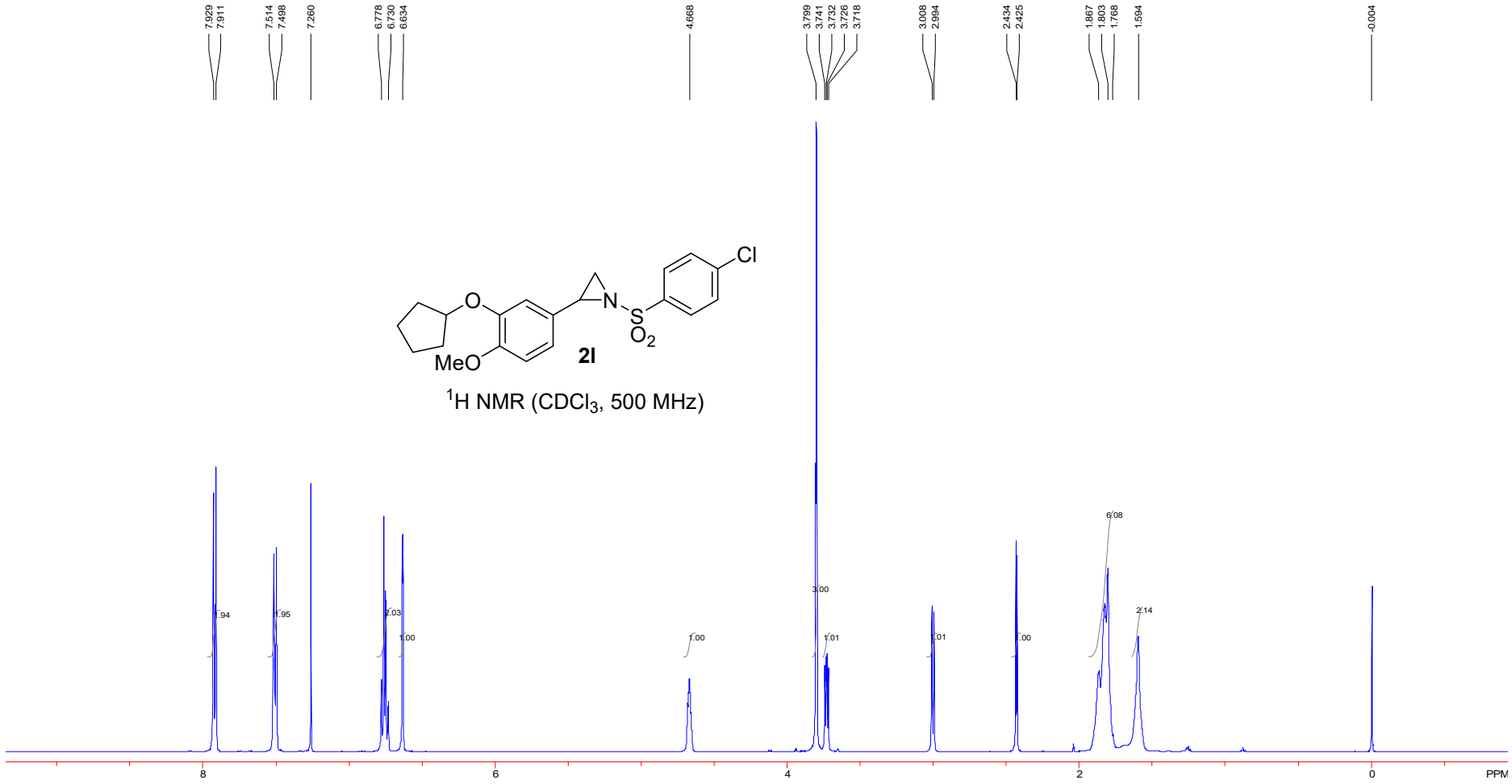

158.265
150.725
144.260
129.872
129.453
126.456
124.347
122.599
120.779
110.436
77.413
77.160
76.907
55.455
38.445
35.535
O2N
SO2
N
OMe
2g
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

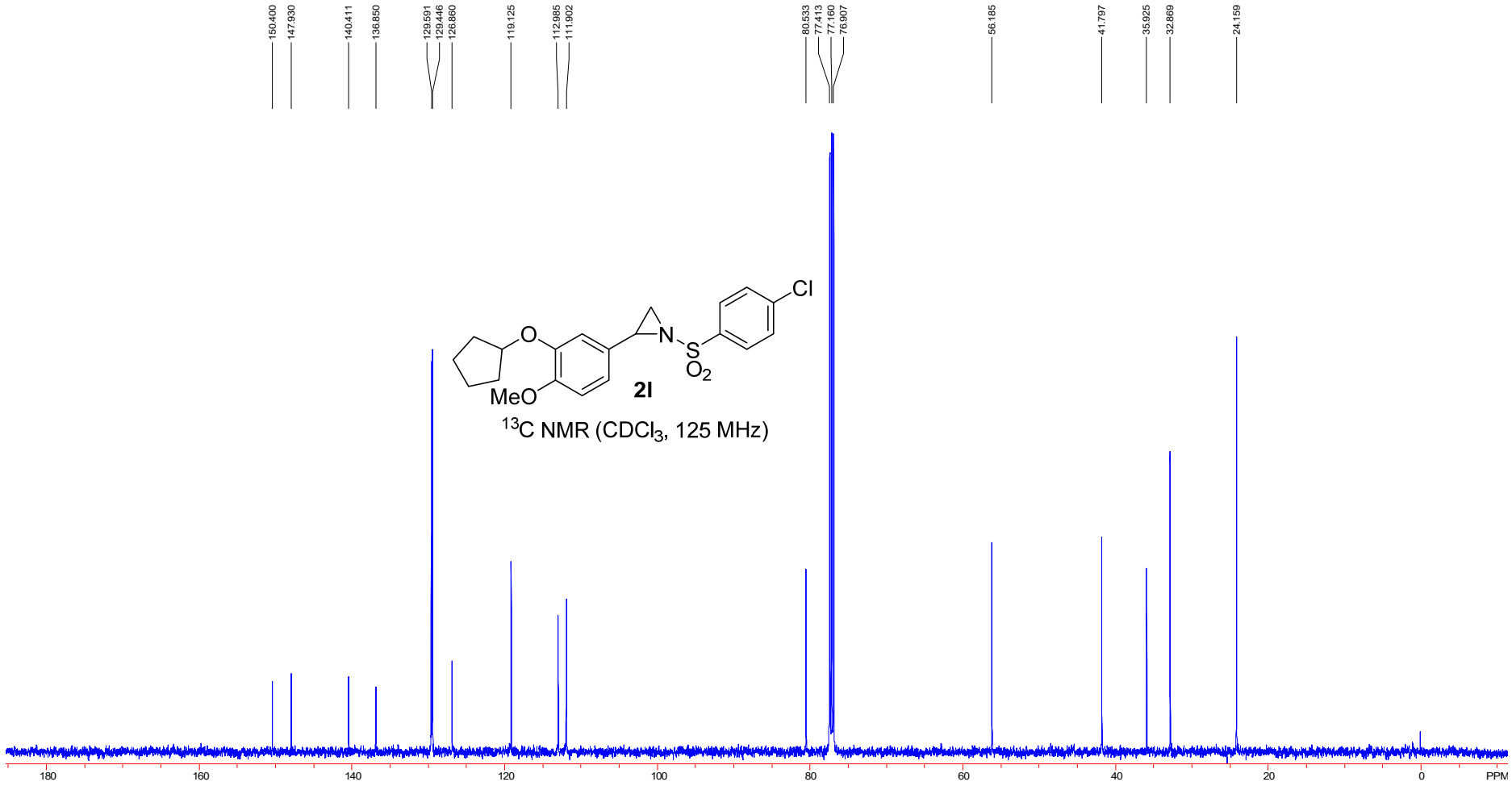

7.927
7.909
7.520
7.502
7.260
7.072
7.054
6.769
6.752
3.780
3.772
3.766
3.757
2.985
2.971
2.415
2.406
1.580
0.961
0.170
-0.001
Cl
SO2
N
TBSO
2i
1H NMR (CDCl3, 500 MHz)
9.09
6.03
1.97
1.96
2.03
1.99
0.98
1.00
0.99
8
6
4
2
0
PPM

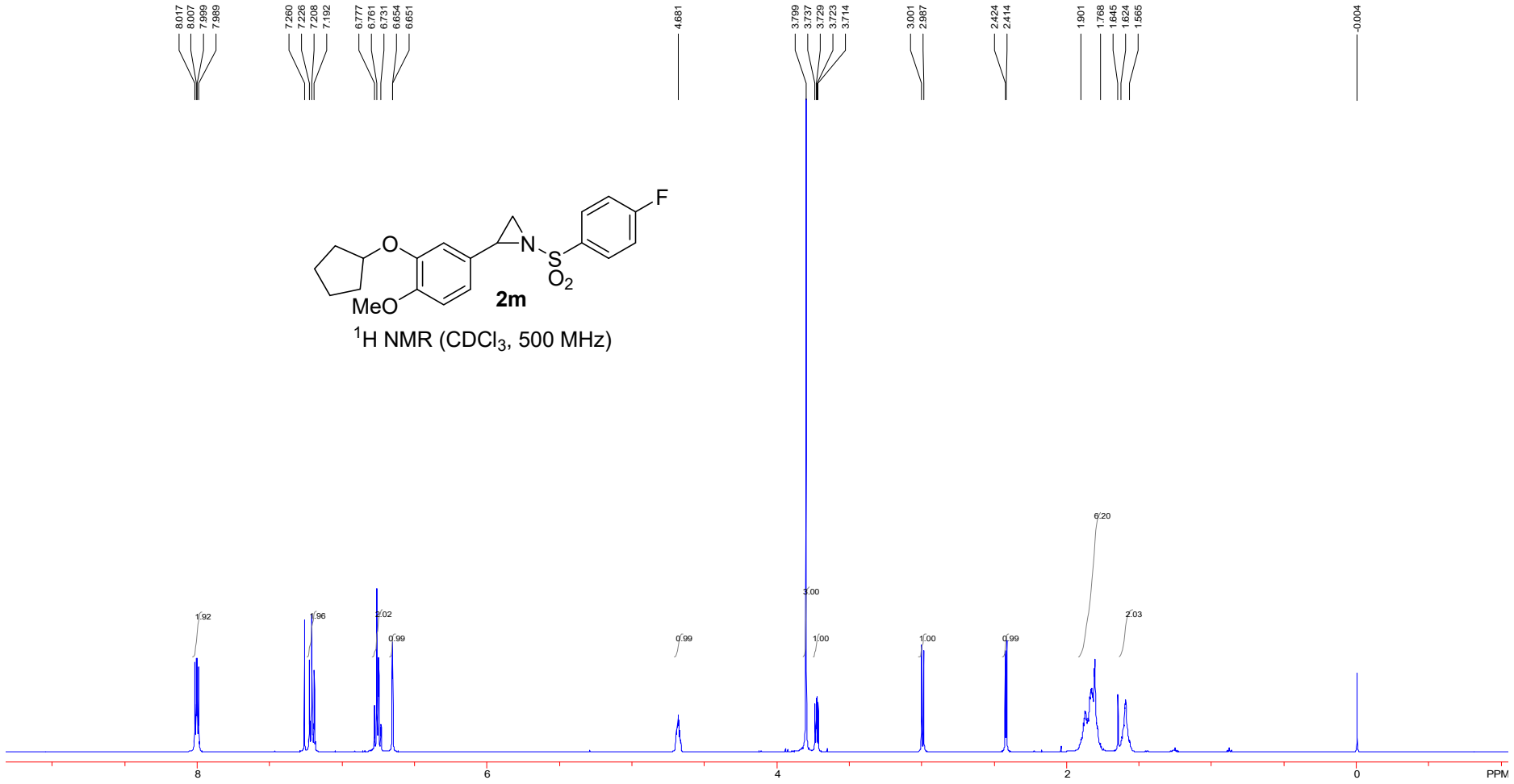

156.149
140.396
136.835
129.598
129.453
127.886
127.265
120.396
77.413
77.160
76.907
41.429
36.235
25.748
18.301
-4.328
Cl
SO2
N
TBSO
2i
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

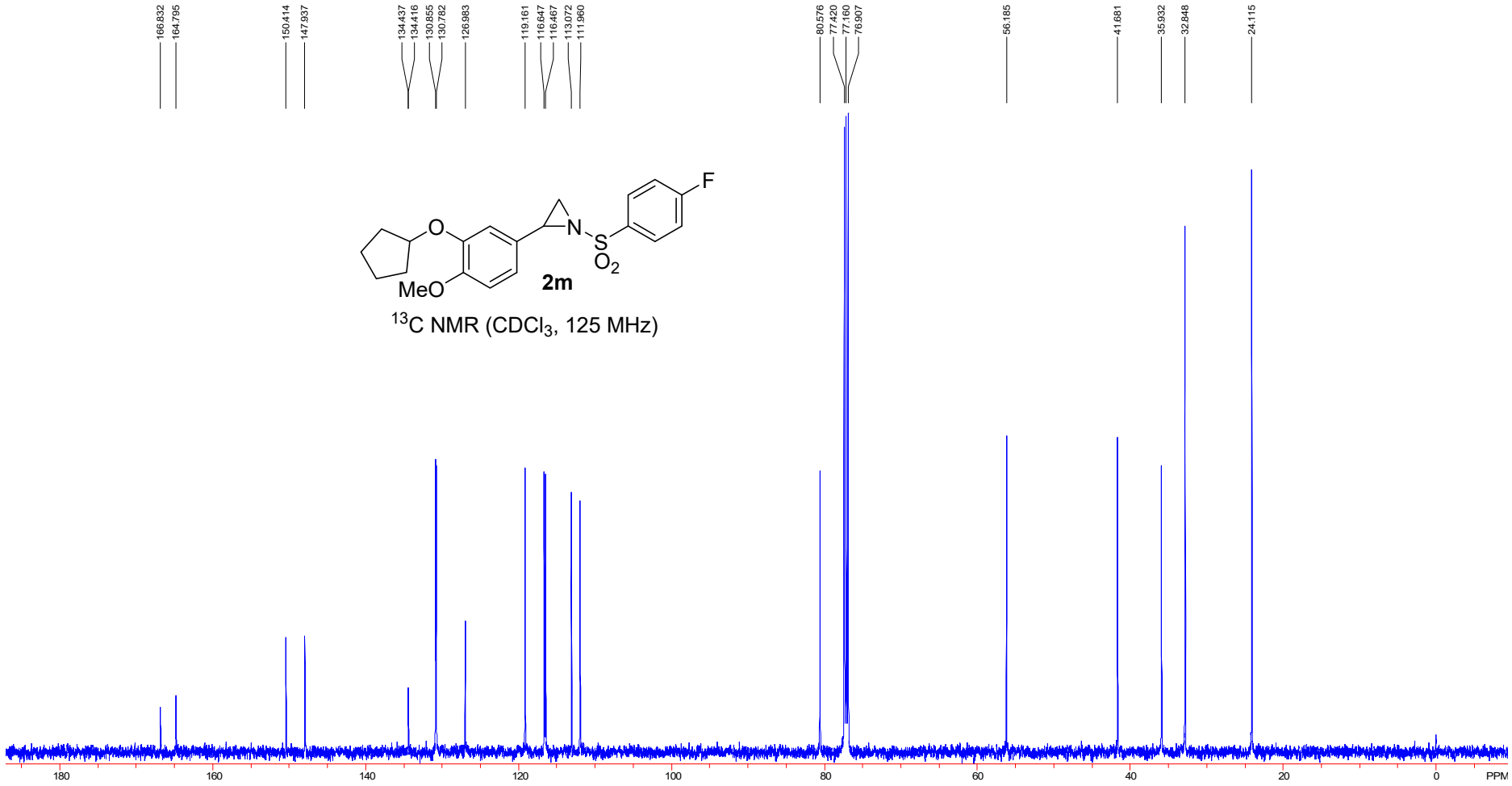

7.872
7.855
7.333
7.317
7.260
6.753
6.644
4.663
3.792
3.704
3.696
3.690
3.681
2.973
2.959
2.424
2.389
2.380
1.868
1.799
1.764
1.651
1.587
-0.004
O
N
Ts
MeO
2k
1H NMR (CDCl3, 500 MHz)
1.95
1.98
1.96
0.99
0.95
2.99
1.00
0.96
2.98
1.02
6.02
2.01
8
6
4
2
0
PPM


150.234
147.850
144.686
135.239
129.843
128.038
127.323
119.118
113.094
111.880
80.468
77.413
77.160
76.907
56.170
41.400
35.650
32.841
24.137
21.739
O
N
Ts
MeO
2k
$^{13}$C NMR ($CDCl_3$, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

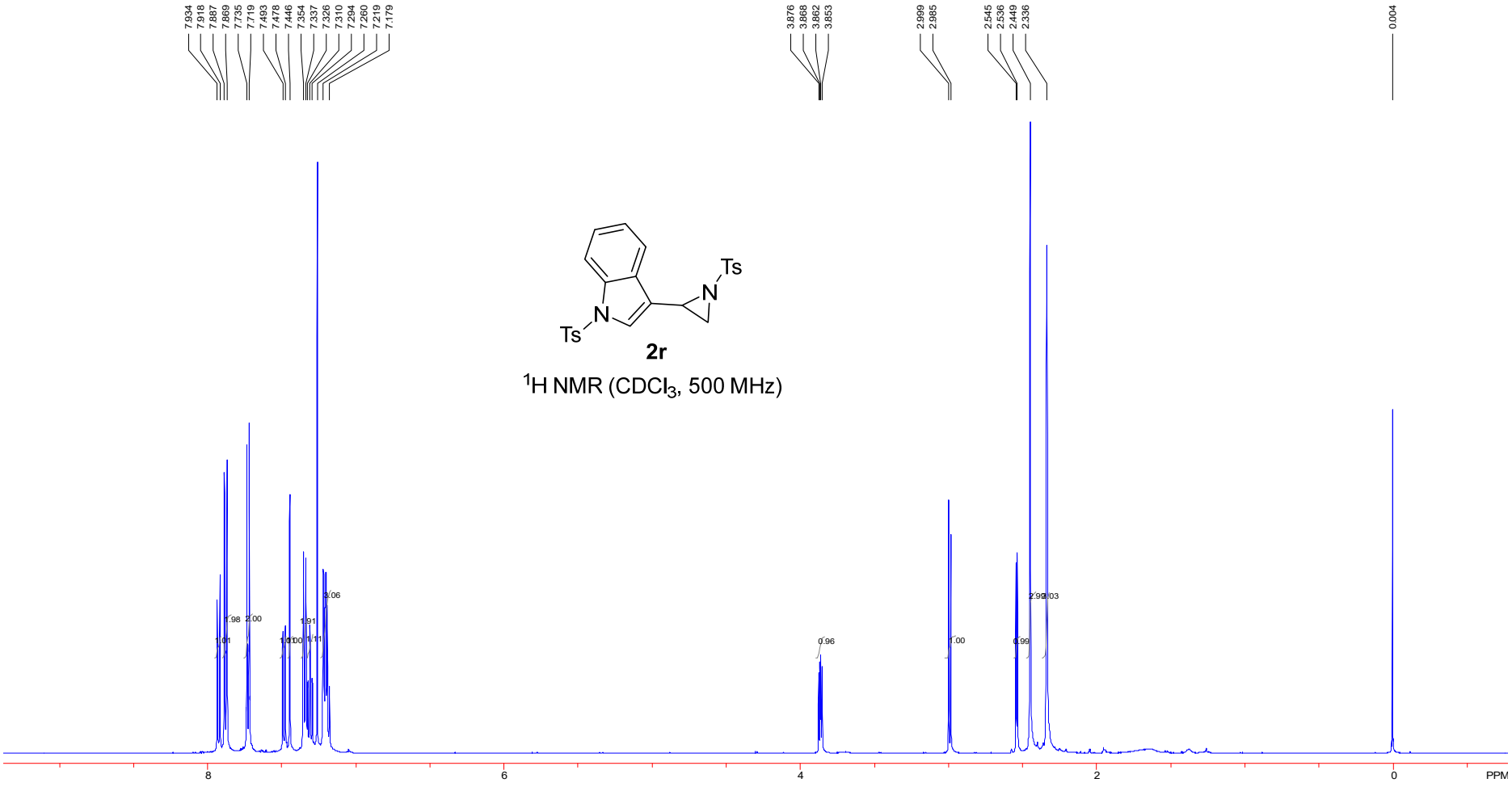

7.929
7.911
7.514
7.498
7.260
6.778
6.730
6.634
4.668
3.799
3.741
3.732
3.726
3.718
3.008
2.994
2.434
2.425
1.867
1.803
1.768
1.594
0.004
Cl
O
N
S
O2
MeO
2l
1H NMR (CDCl3, 500 MHz)
1.94
1.95
2.03
1.00
1.00
3.00
1.01
1.01
1.00
6.08
2.14
8
6
4
2
0
PPM

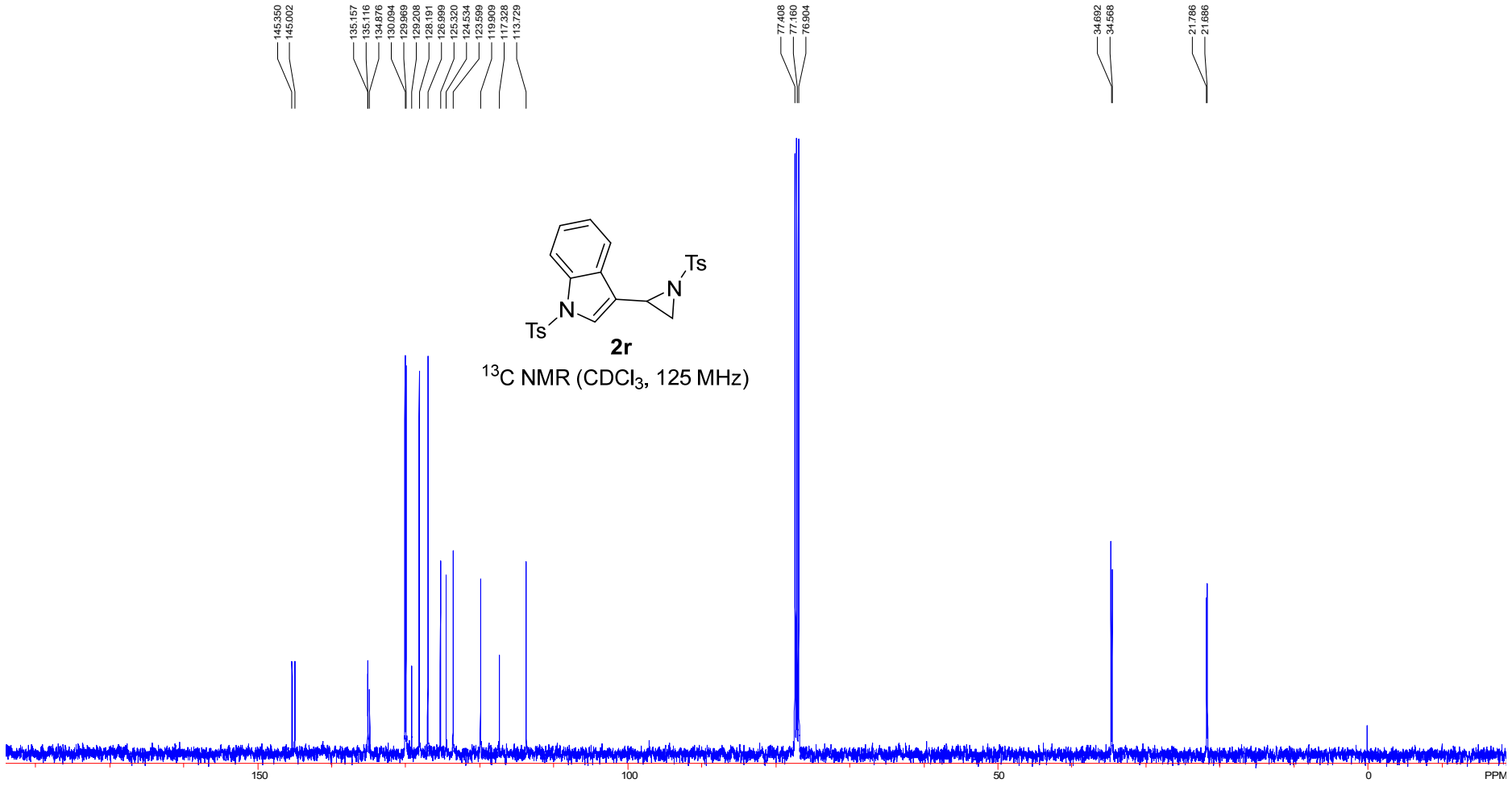

150.400
147.930
140.411
136.850
129.591
129.446
126.860
119.125
112.985
111.902
80.533
77.413
77.160
76.907
56.185
41.797
35.925
32.869
24.159
Cl
O
N
S
O2
MeO
2l
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

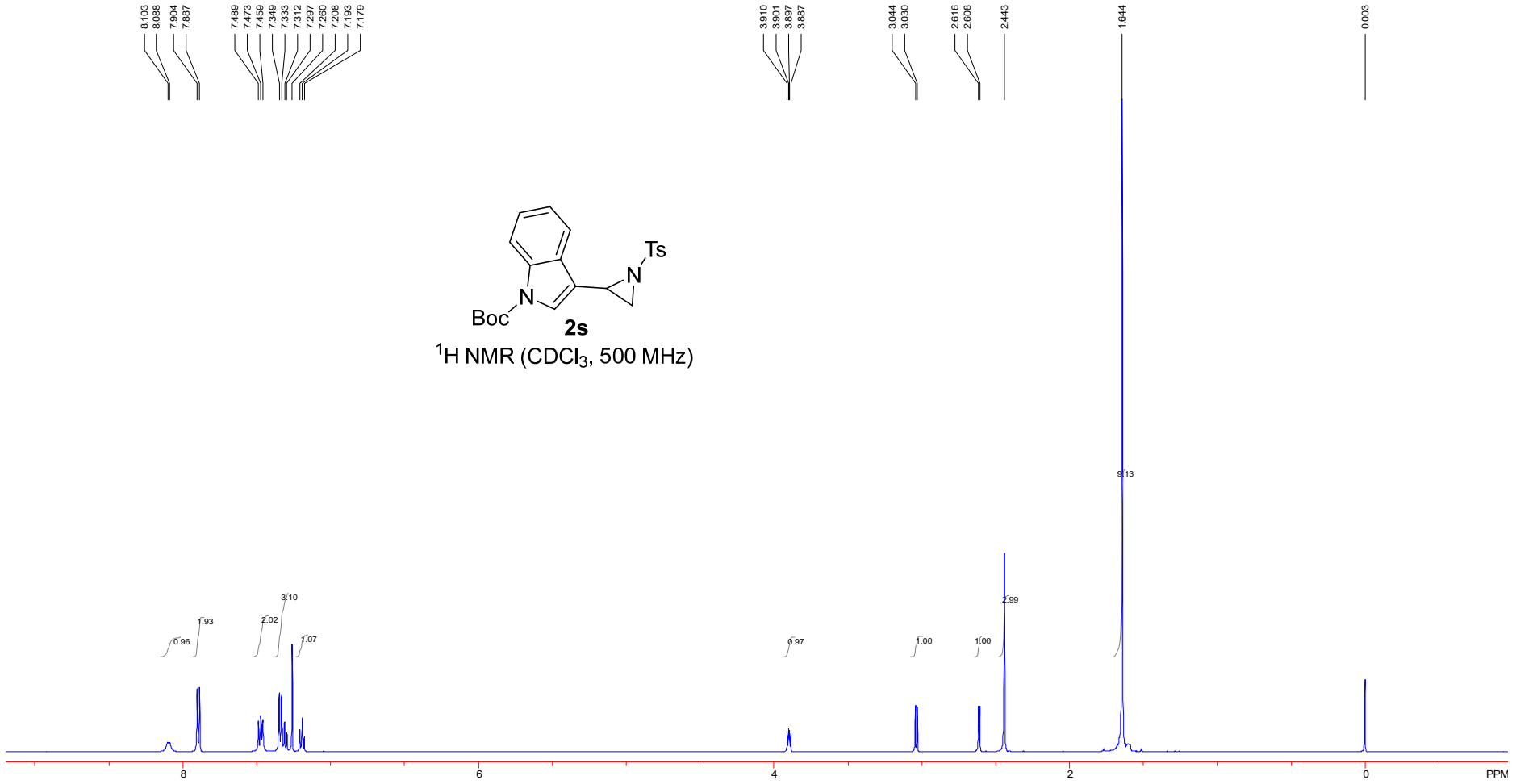

8.017
8.007
7.999
7.989
7.260
7.226
7.208
7.192
6.777
6.761
6.731
6.654
6.651
4.681
3.799
3.737
3.729
3.723
3.714
3.001
2.987
2.424
2.414
1.901
1.768
1.645
1.624
1.565
-0.004
F
O
N
S
O2
MeO
2m
1H NMR (CDCl3, 500 MHz)
1.92
1.96
2.02
0.99
0.99
3.00
1.00
1.00
0.99
6.20
2.03
8
6
4
2
0
PPM

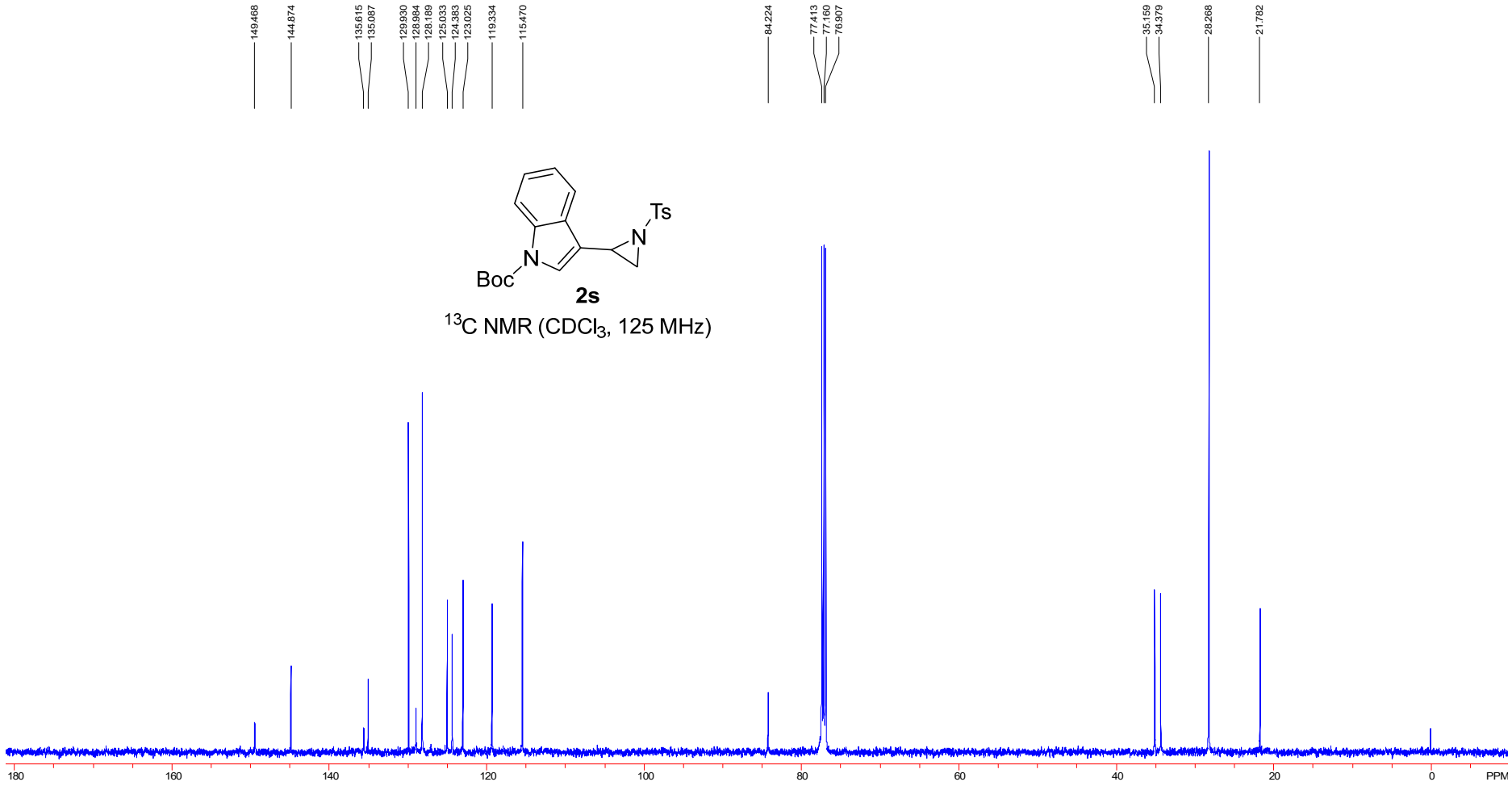


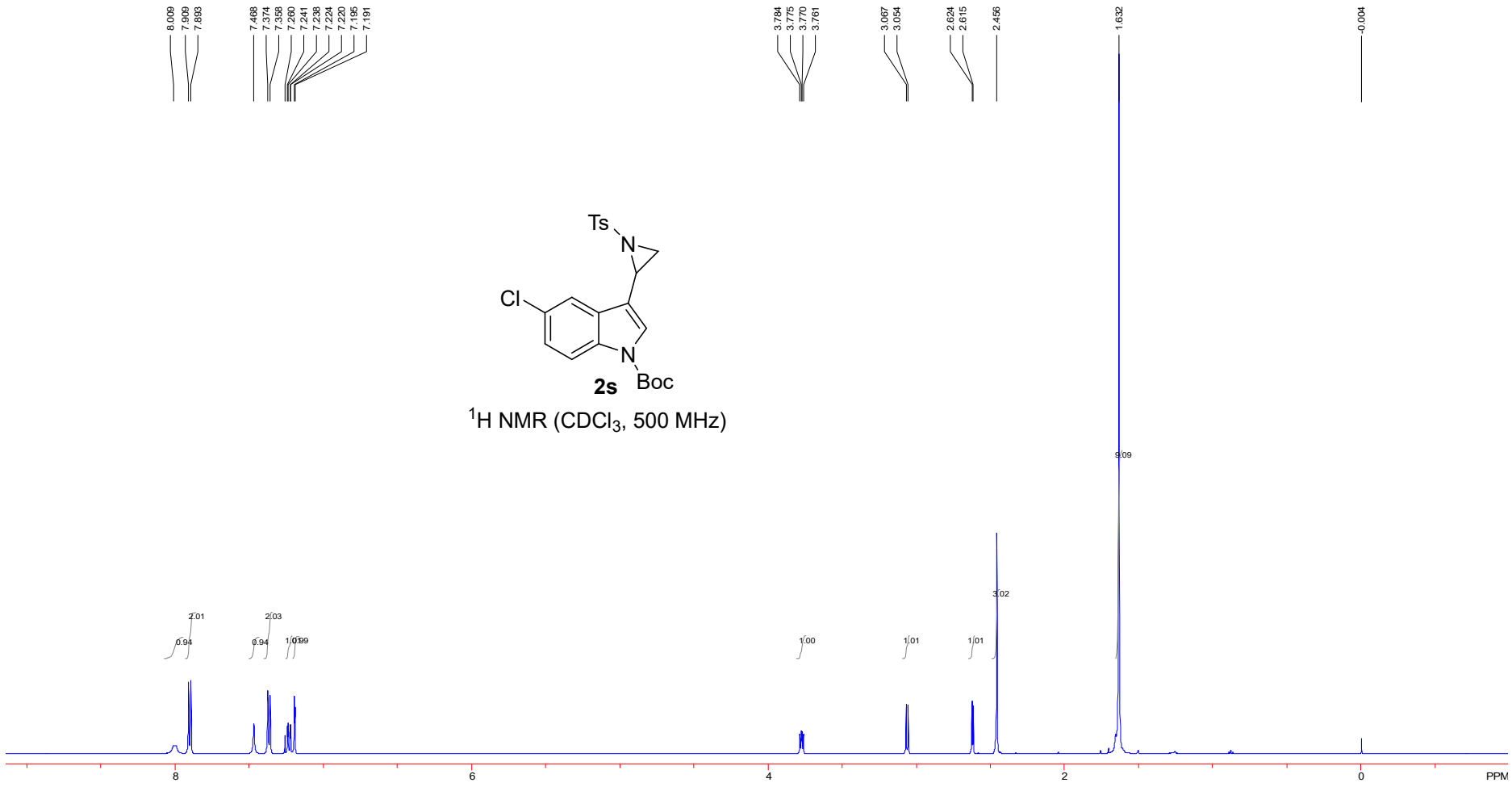

$^{13}C$ NMR ($CDCl_3$, 125 MHz)


7.934
7.918
7.887
7.869
7.735
7.719
7.493
7.478
7.446
7.354
7.337
7.326
7.310
7.294
7.260
7.219
7.179
3.876
3.868
3.862
3.853
2.999
2.985
2.545
2.536
2.449
2.336
0.004
Ts
N
N
Ts
2r
1H NMR (CDCl3, 500 MHz)
1.98
2.00
1.91
3.06
0.96
1.00
2.99
3.03
8
6
4
2
0
PPM

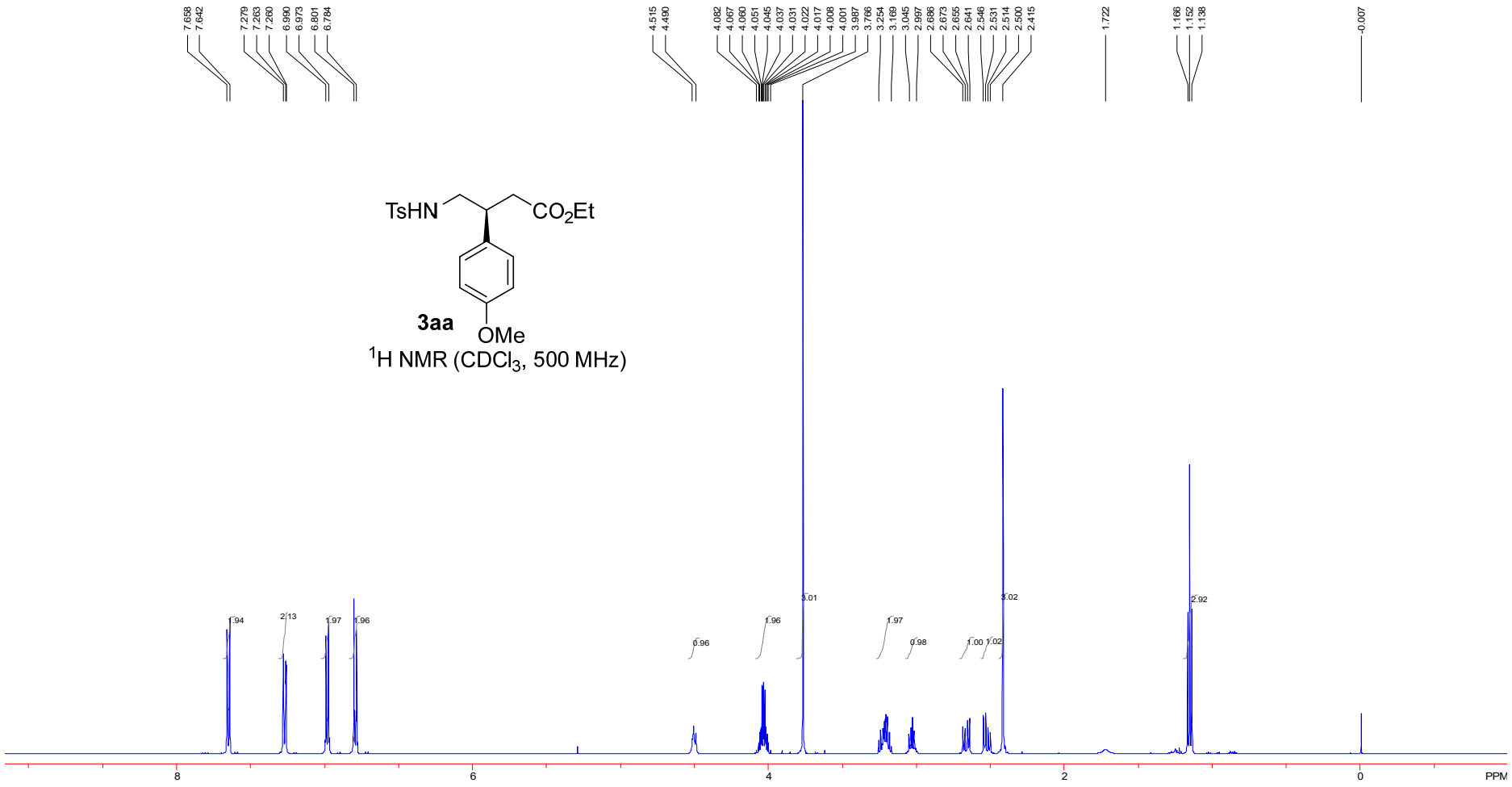

145.350
145.002
135.157
135.116
134.876
130.094
129.969
129.208
128.191
126.999
125.320
124.534
123.599
119.909
117.328
113.729
77.408
77.160
76.904
34.692
34.568
21.786
21.686
Ts
N
N
Ts
2r
13C NMR (CDCl3, 125 MHz)
150
100
50
0
PPM

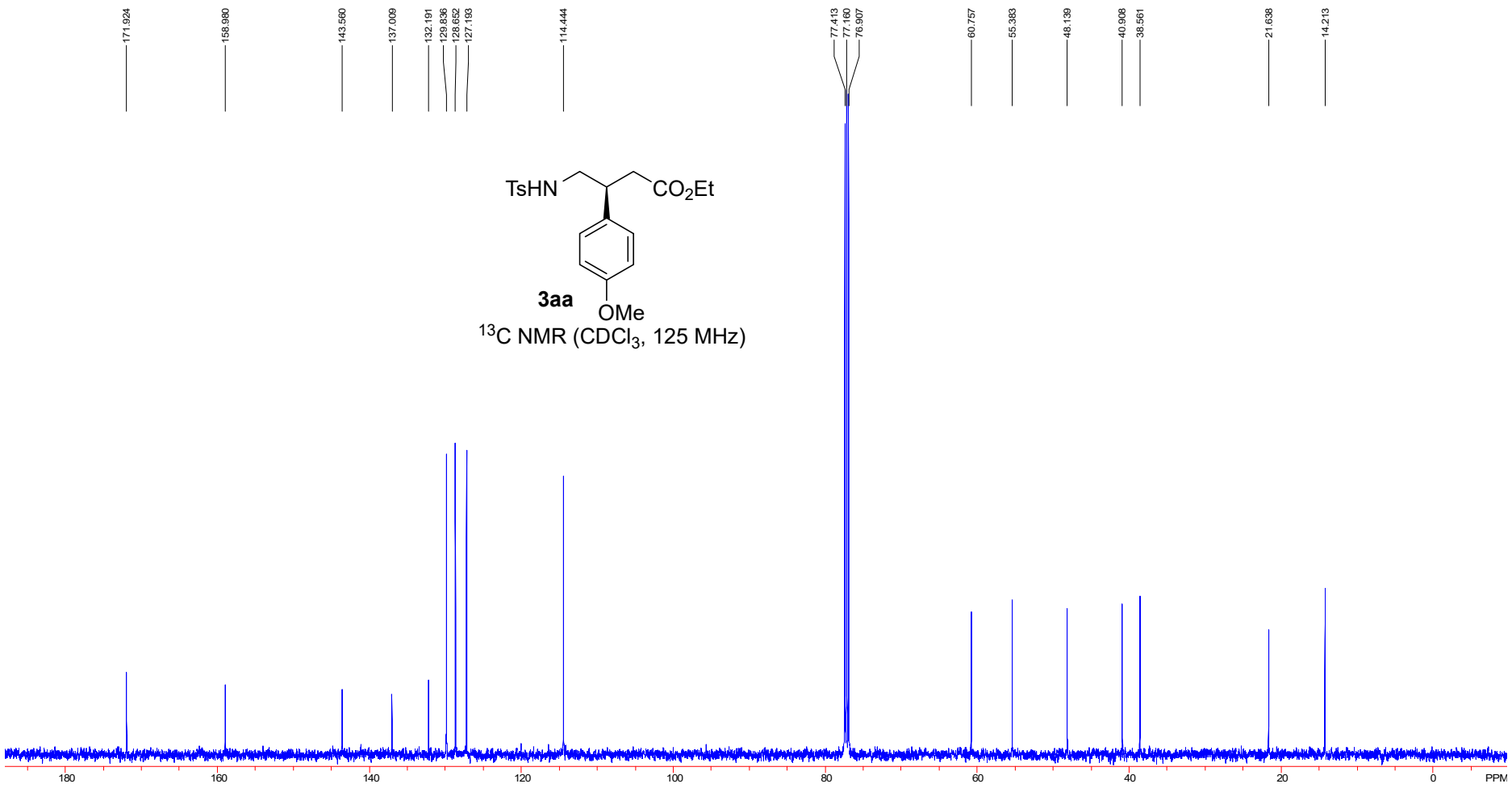

8.103
8.088
7.904
7.887
7.489
7.473
7.459
7.349
7.333
7.312
7.297
7.260
7.208
7.193
7.179
3.910
3.901
3.897
3.887
3.044
3.030
2.616
2.608
2.443
1.644
0.003
Ts
N
N
Boc
2s
1H NMR (CDCl3, 500 MHz)
9.13
3.10
2.99
1.93
2.02
1.07
0.96
0.97
1.00
1.00
8
6
4
2
0
PPM

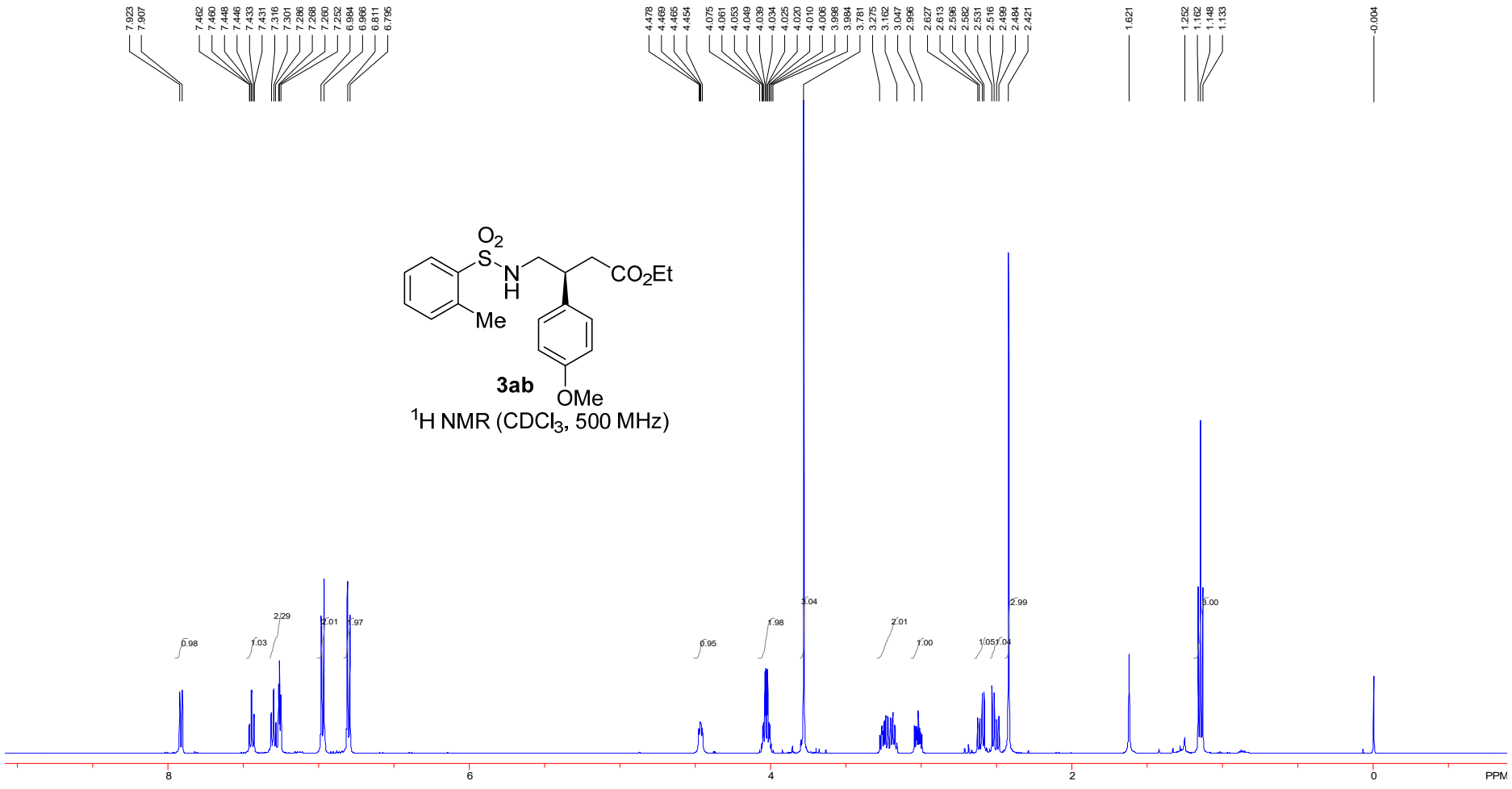

149.468
144.874
135.615
135.087
129.930
128.984
128.189
125.033
124.383
123.025
119.334
115.470
84.224
77.413
77.160
76.907
35.159
34.379
28.268
21.782
Ts
N
N
Boc
2s
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

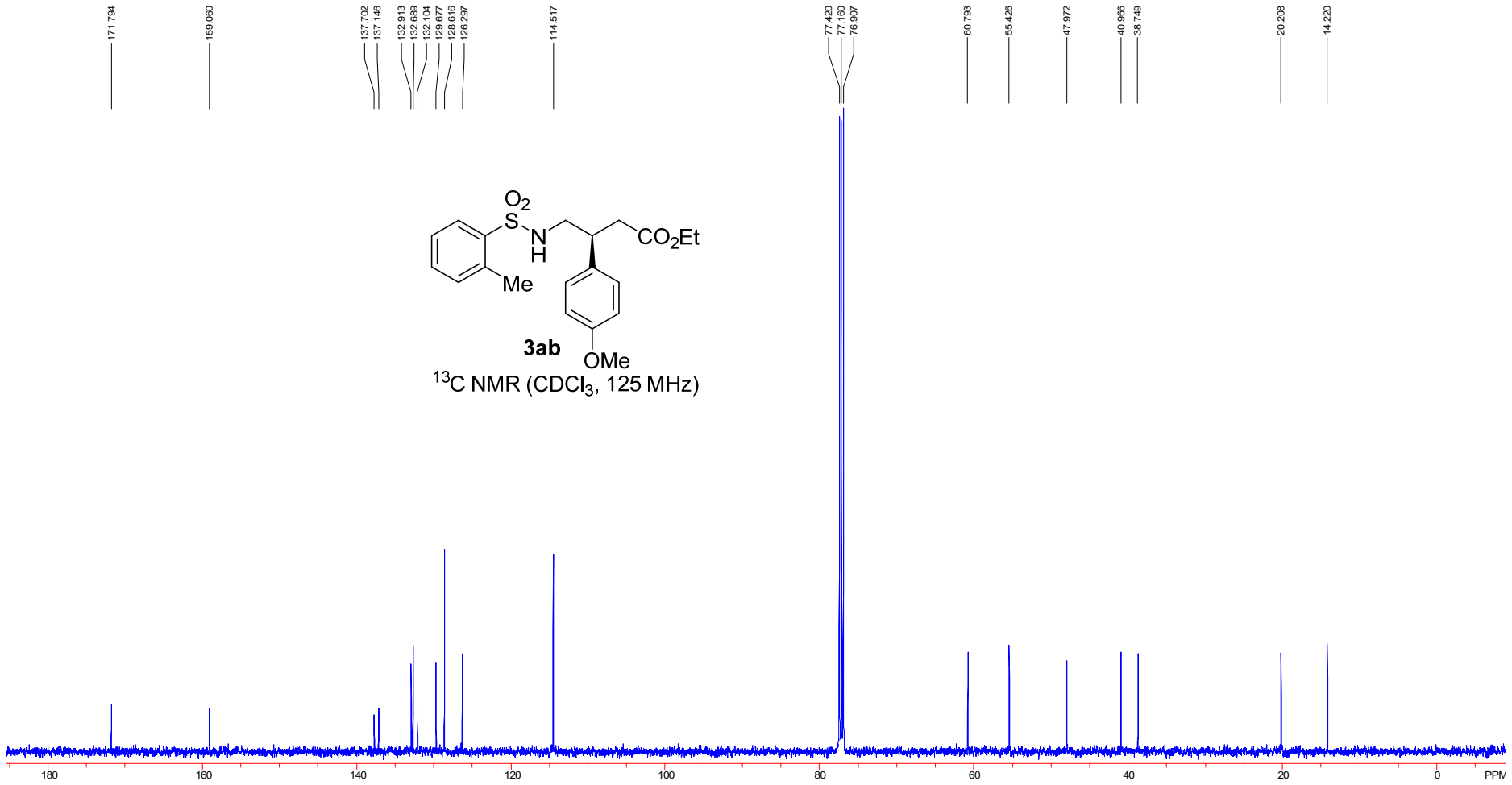


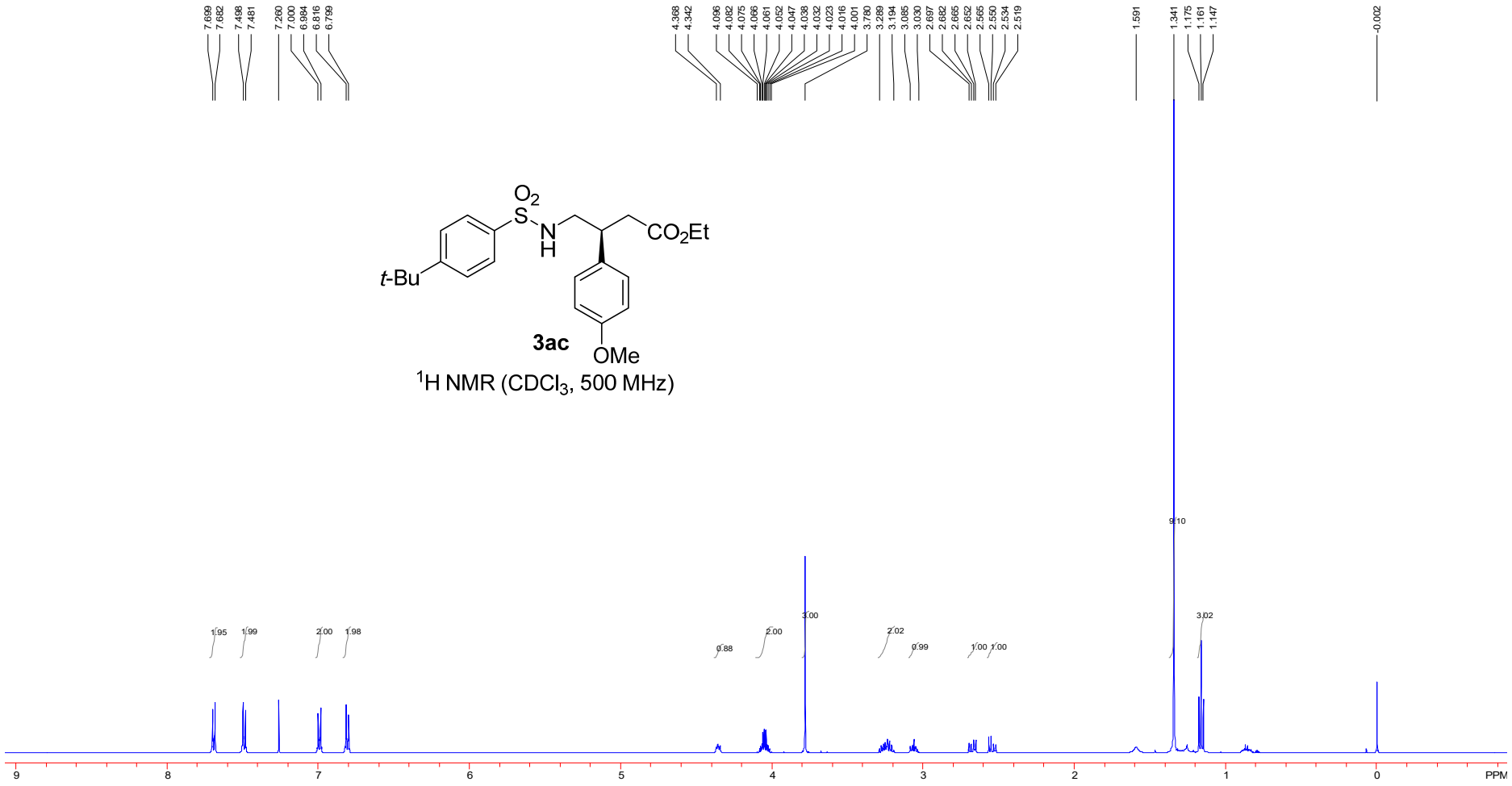

$^1$H NMR ($CDCl_3$, 500 MHz)

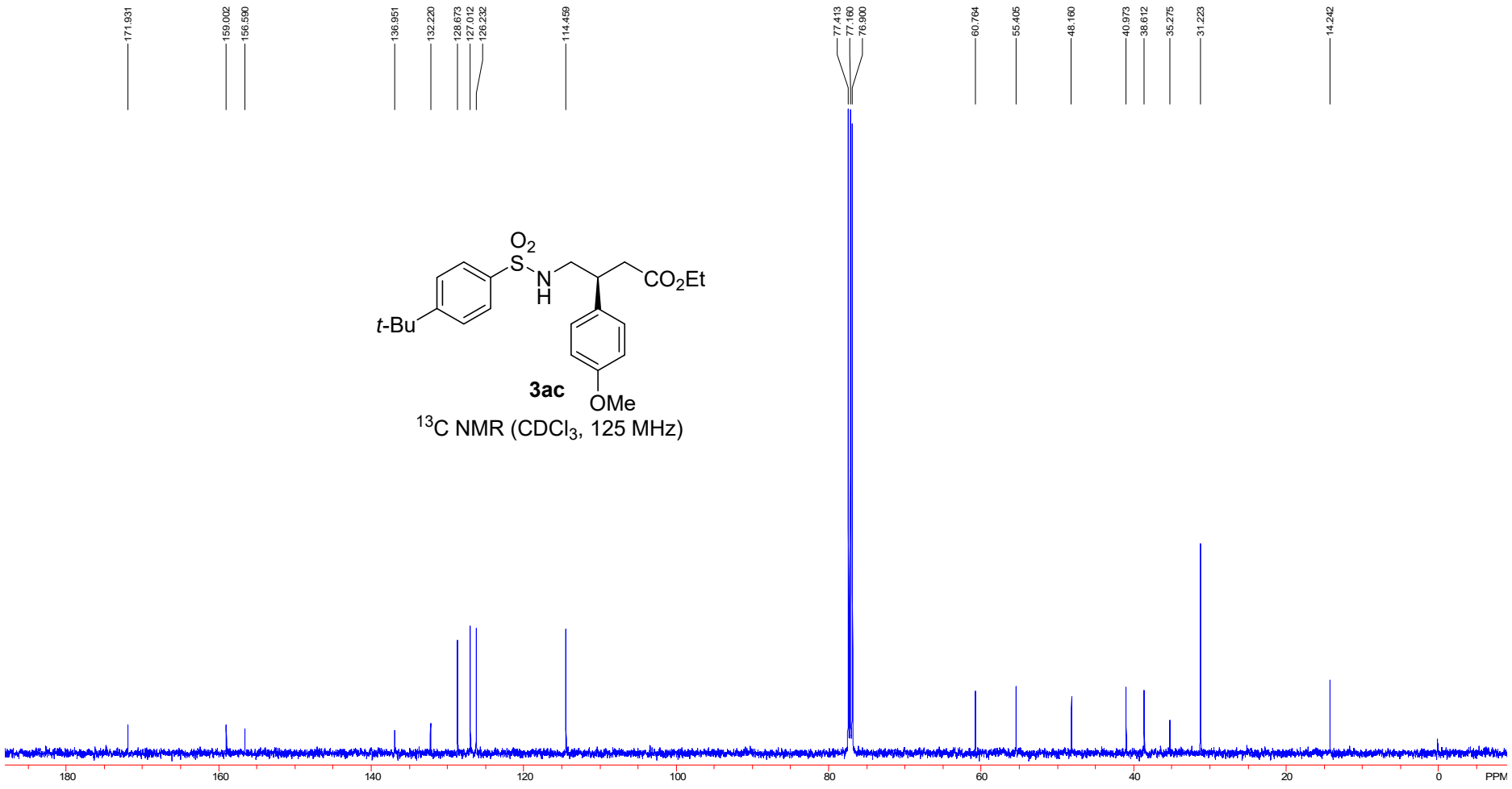

7.658
7.642
7.279
7.263
7.260
6.990
6.973
6.801
6.784
4.515
4.490
4.082
4.067
4.060
4.051
4.045
4.037
4.031
4.022
4.017
4.008
4.001
3.987
3.766
3.254
3.169
3.045
2.997
2.686
2.673
2.655
2.641
2.546
2.531
2.514
2.500
2.415
1.722
1.166
1.152
1.138
-0.007
TsHN
CO2Et
3aa
OMe
1H NMR (CDCl3, 500 MHz)
1.94
2.13
1.97
1.96
0.96
1.96
3.01
1.97
0.98
1.00
1.02
3.02
2.92
8
6
4
2
0
PPM

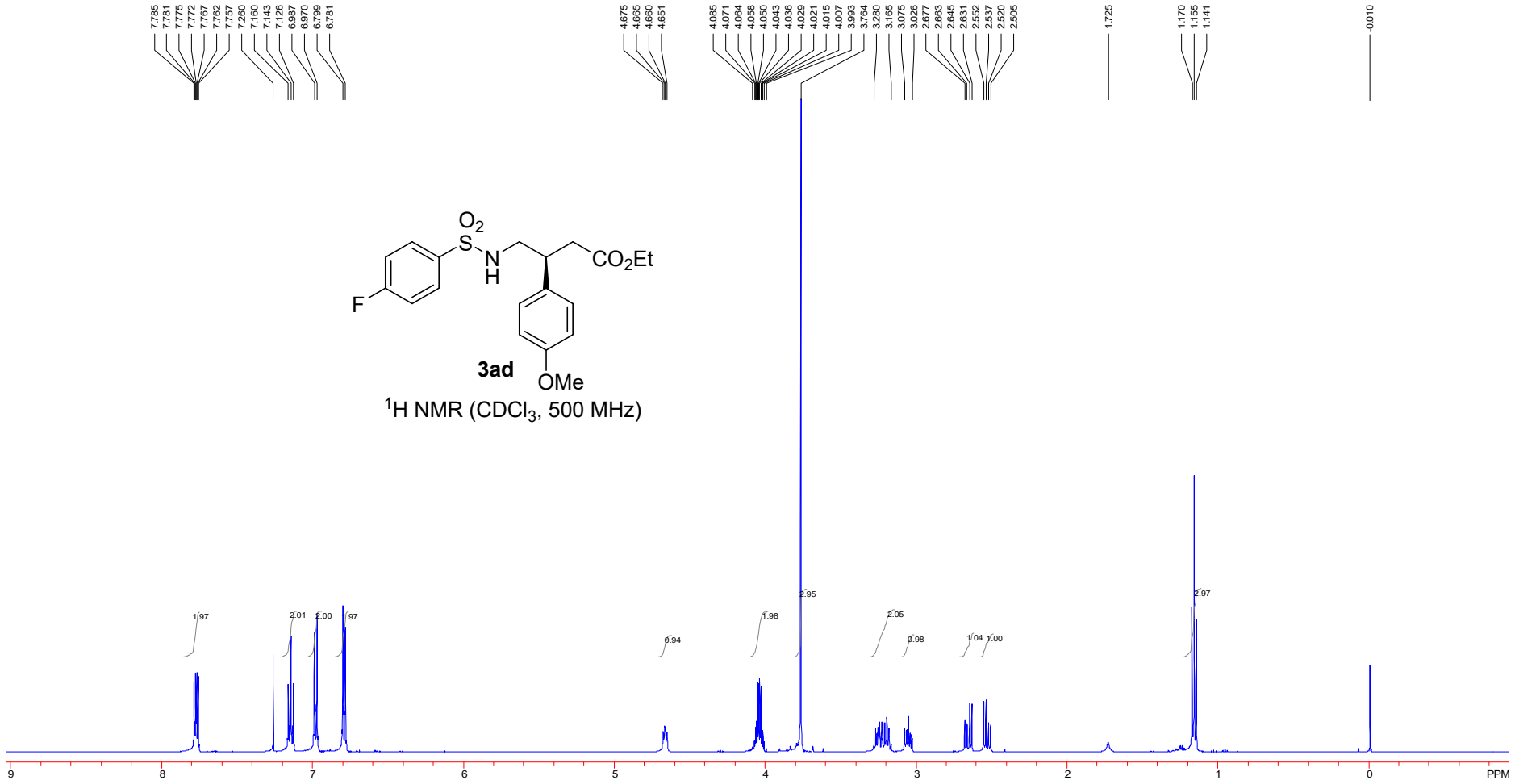

171.924
158.980
143.560
137.009
132.191
129.836
128.652
127.193
114.444
77.413
77.160
76.907
60.757
55.383
48.139
40.908
38.561
21.638
14.213
TsHN
CO2Et
OMe
3aa
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

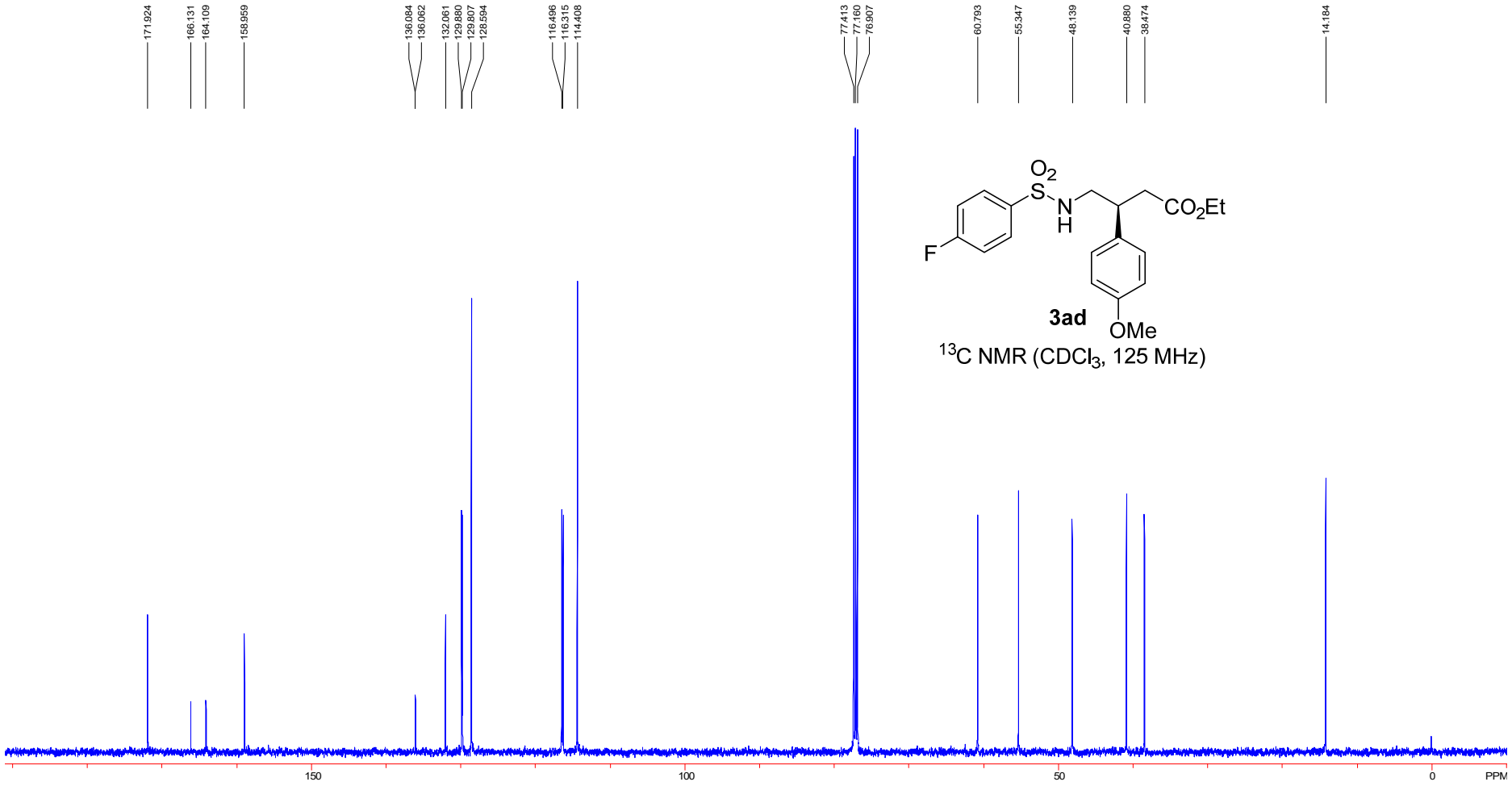

7.923
7.907
7.462
7.460
7.448
7.446
7.433
7.431
7.316
7.301
7.286
7.268
7.260
7.252
6.984
6.966
6.811
6.795
4.476
4.469
4.465
4.454
4.075
4.061
4.053
4.049
4.039
4.034
4.025
4.020
4.010
4.006
3.998
3.984
3.781
3.275
3.162
3.047
2.996
2.627
2.613
2.596
2.582
2.531
2.516
2.499
2.484
2.421
1.621
1.252
1.162
1.148
1.133
-0.004
O2
S
N
H
CO2Et
Me
OMe
3ab
1H NMR (CDCl3, 500 MHz)
0.98
1.03
2.29
2.01
1.97
0.95
1.98
3.04
2.01
1.00
1.05
1.04
2.99
3.00
8
6
4
2
0
PPM

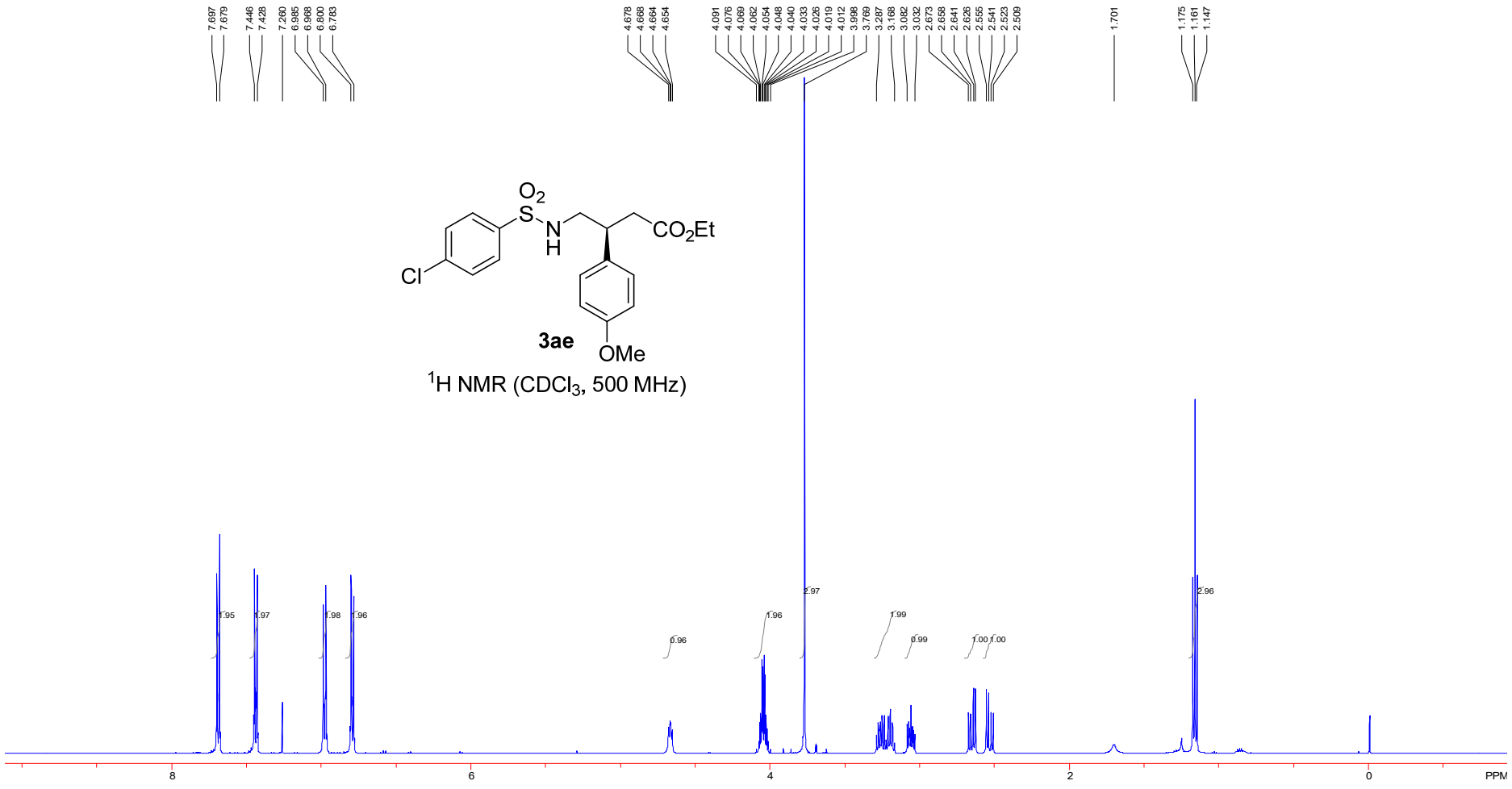

171.794
159.060
137.702
137.146
132.913
132.688
132.104
129.677
128.616
126.297
114.517
77.420
77.160
76.907
60.793
55.426
47.972
40.966
38.749
20.208
14.220
O2
S
N
H
CO2Et
Me
OMe
3ab
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

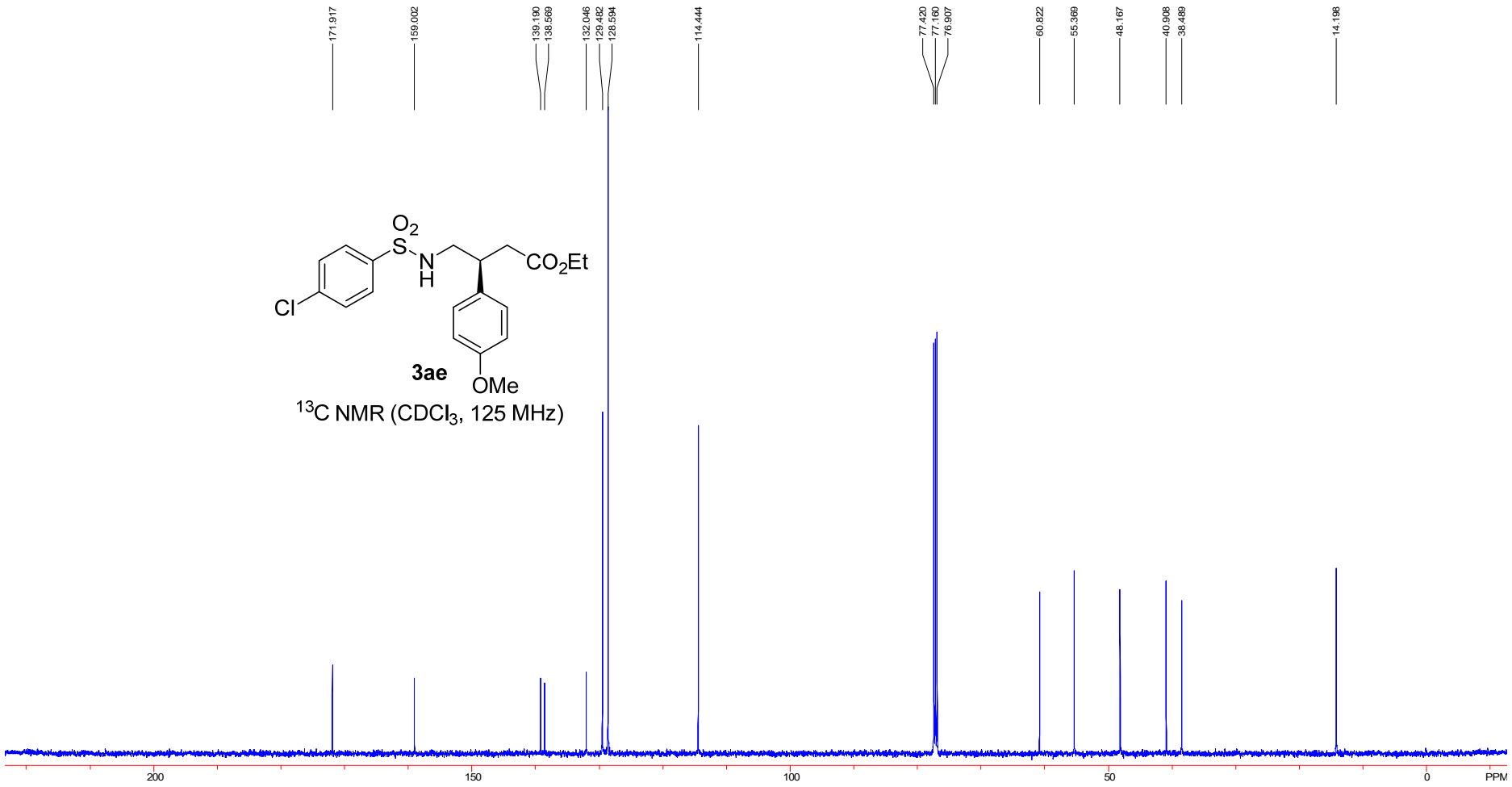

7.699
7.682
7.498
7.481
7.260
7.000
6.984
6.816
6.799
4.368
4.342
4.096
4.082
4.075
4.066
4.061
4.052
4.047
4.038
4.032
4.023
4.016
4.001
3.780
3.289
3.194
3.085
3.030
2.697
2.682
2.665
2.652
2.565
2.550
2.534
2.519
1.591
1.341
1.175
1.161
1.147
-0.002
O2
S
N
H
CO2Et
t-Bu
OMe
3ac
1H NMR (CDCl3, 500 MHz)
9.10
3.02
3.00
2.02
2.00
2.00
1.99
1.98
1.00
1.00
0.99
0.88
9
8
7
6
5
4
3
2
1
0
PPM

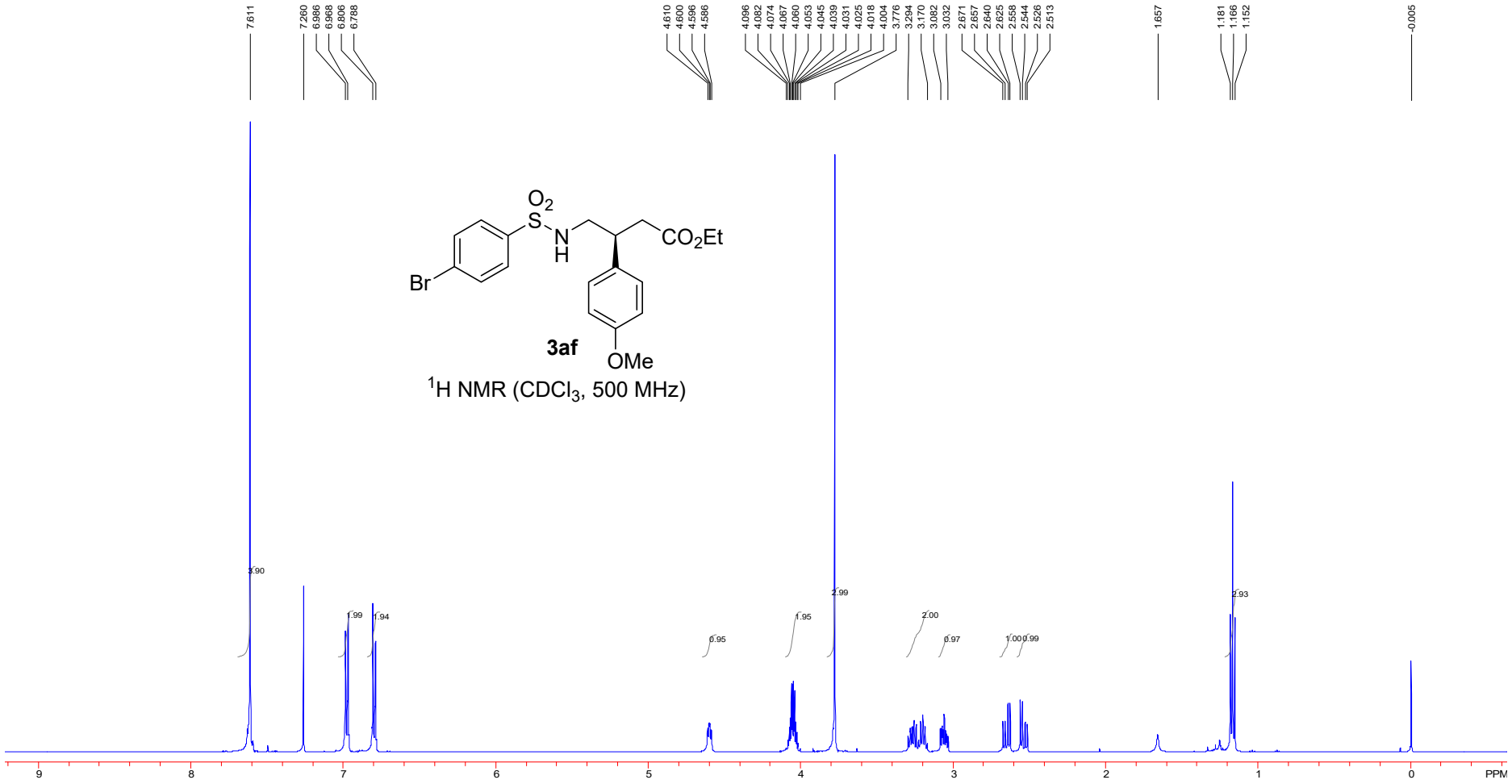

171.931
159.002
156.590
136.951
132.220
128.673
127.012
126.232
114.459
77.413
77.160
76.900
60.764
55.405
48.160
40.973
38.612
35.275
31.223
14.242
O2
S
N
H
CO2Et
t-Bu
OMe
3ac
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

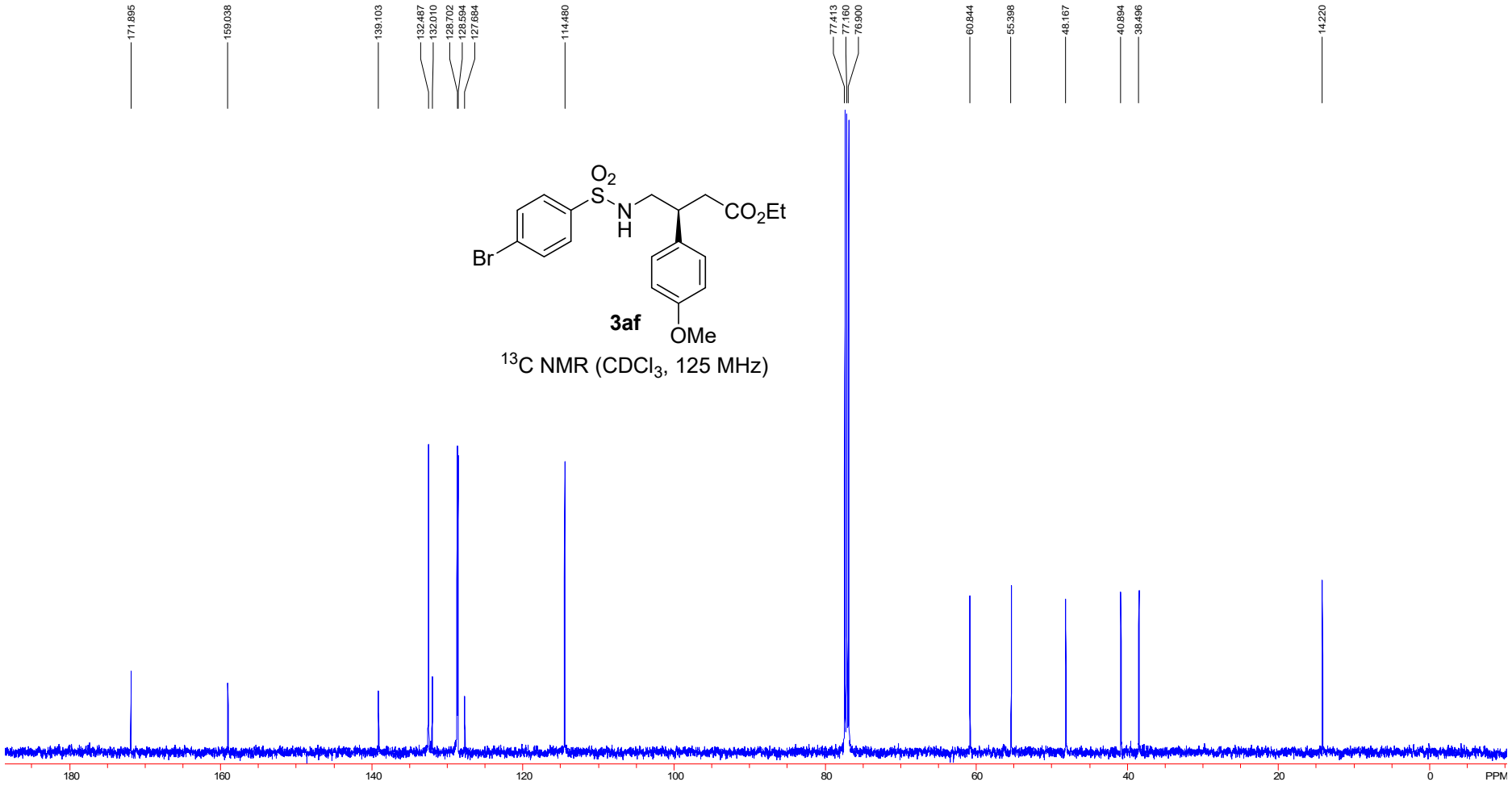

7.785
7.781
7.775
7.772
7.767
7.762
7.757
7.260
7.160
7.143
7.126
6.987
6.970
6.799
6.781
4.675
4.665
4.660
4.651
4.085
4.071
4.064
4.058
4.050
4.043
4.036
4.029
4.021
4.015
4.007
3.993
3.764
3.280
3.165
3.075
3.026
2.677
2.663
2.645
2.631
2.552
2.537
2.520
2.505
1.725
1.170
1.155
1.141
-0.010
O2
S
N
H
CO2Et
F
OMe
3ad
1H NMR (CDCl3, 500 MHz)
1.97
2.01
2.00
1.97
0.94
1.98
2.95
2.05
0.98
1.04
1.00
2.97
9
8
7
6
5
4
3
2
1
0
PPM

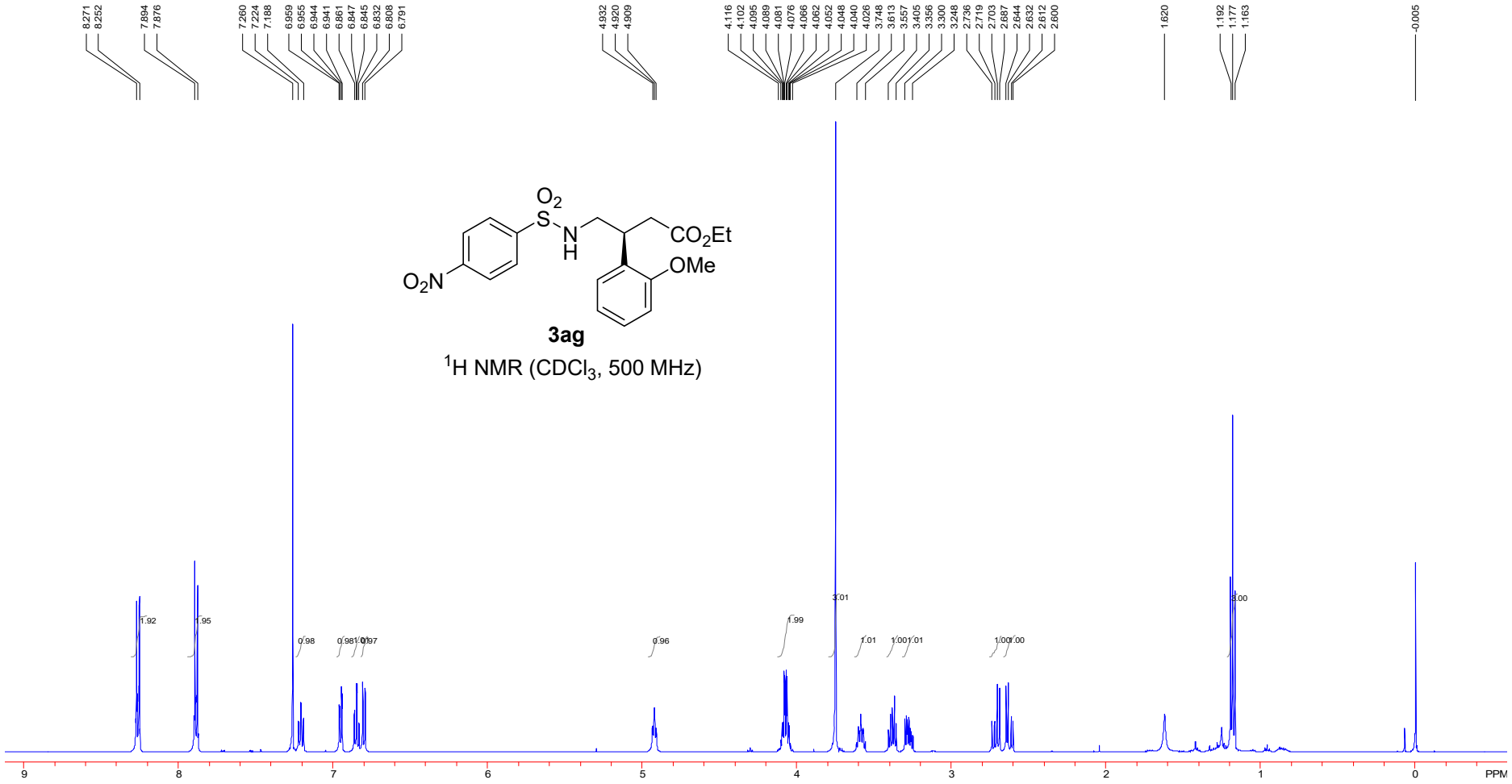

171.924
166.131
164.109
158.959
136.084
136.062
132.061
129.880
129.807
128.594
116.496
116.315
114.408
77.413
77.160
76.907
60.793
55.347
48.139
40.880
38.474
14.184
O2
S
N
H
CO2Et
F
OMe
3ad
13C NMR (CDCl3, 125 MHz)
150
100
50
0
PPM

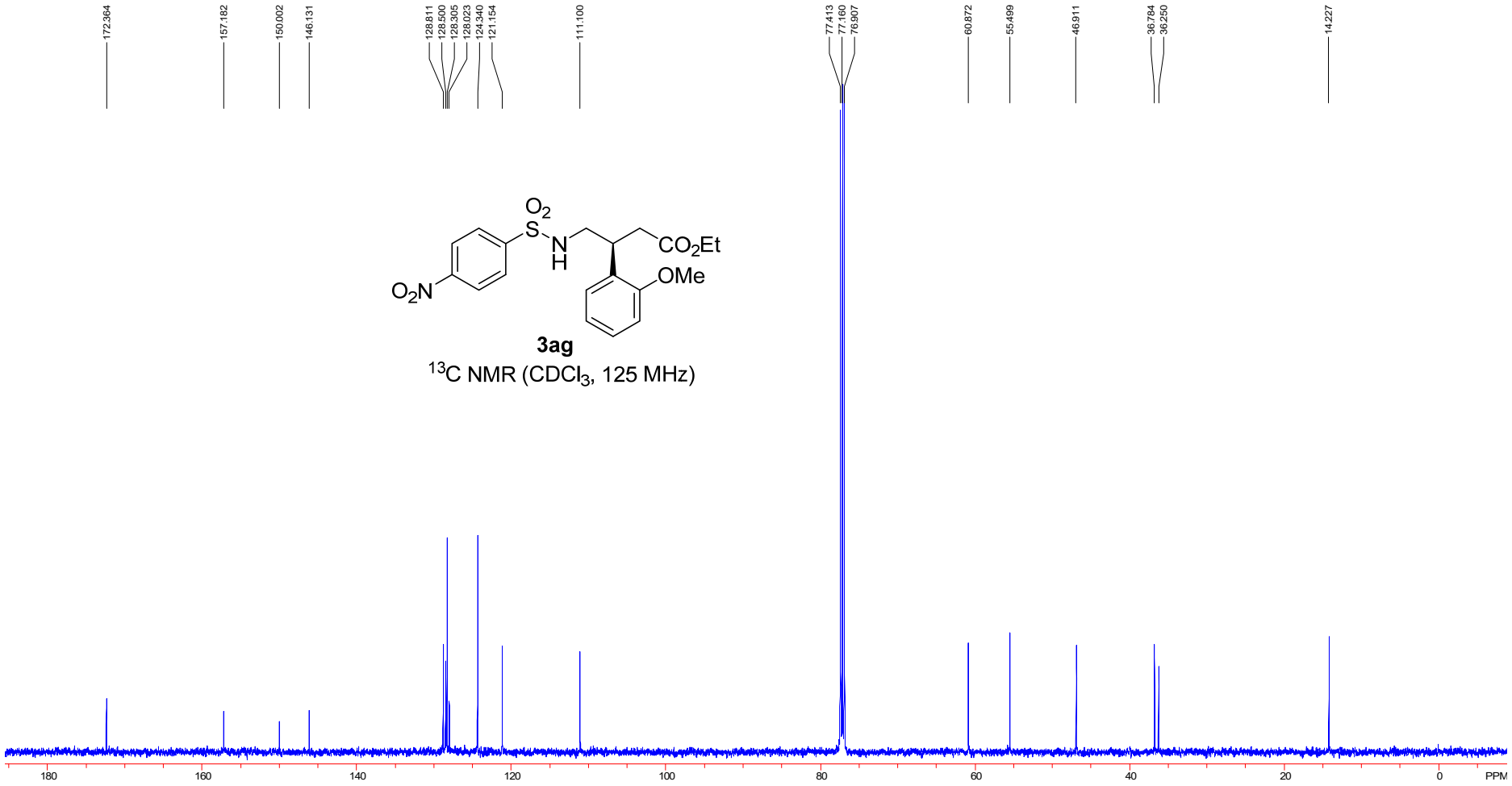

7.697
7.679
7.446
7.428
7.260
6.985
6.968
6.800
6.783
4.675
4.668
4.664
4.654
4.091
4.076
4.069
4.062
4.054
4.048
4.040
4.033
4.026
4.019
4.012
3.998
3.789
3.287
3.168
3.082
3.032
2.673
2.658
2.641
2.626
2.555
2.541
2.523
2.509
1.701
1.175
1.161
1.147
O2
S
N
H
CO2Et
Cl
3ae
OMe
1H NMR (CDCl3, 500 MHz)
1.95
1.97
1.98
0.96
0.96
1.96
2.97
1.99
0.99
1.00
1.00
2.96
8
6
4
2
0
PPM

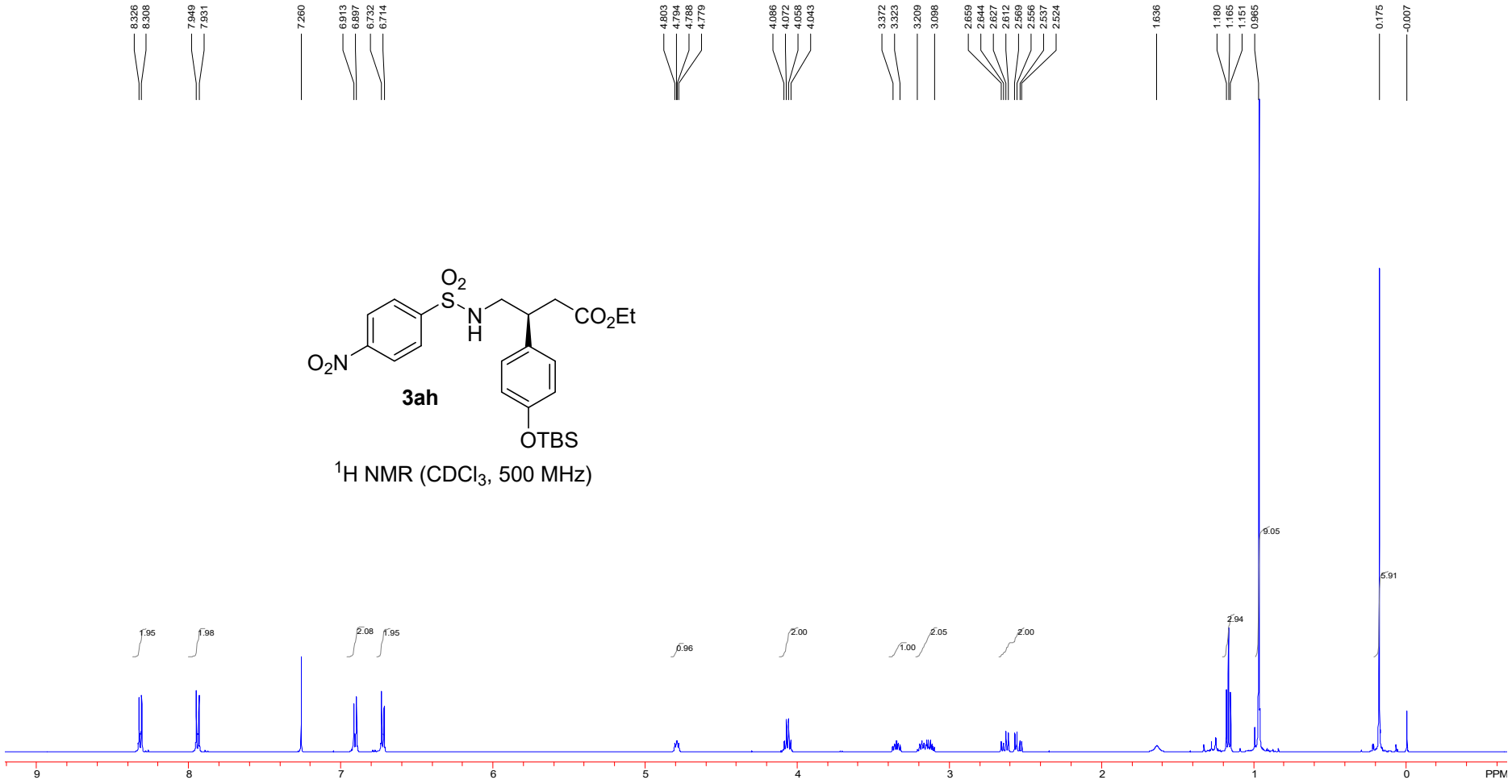

171.917
159.002
139.190
138.569
132.046
129.482
128.594
114.444
77.420
77.160
76.907
60.822
55.369
48.167
40.908
38.489
14.198
O2
S
N
H
CO2Et
Cl
OMe
3ae
13C NMR (CDCl3, 125 MHz)
200
150
100
50
0
PPM

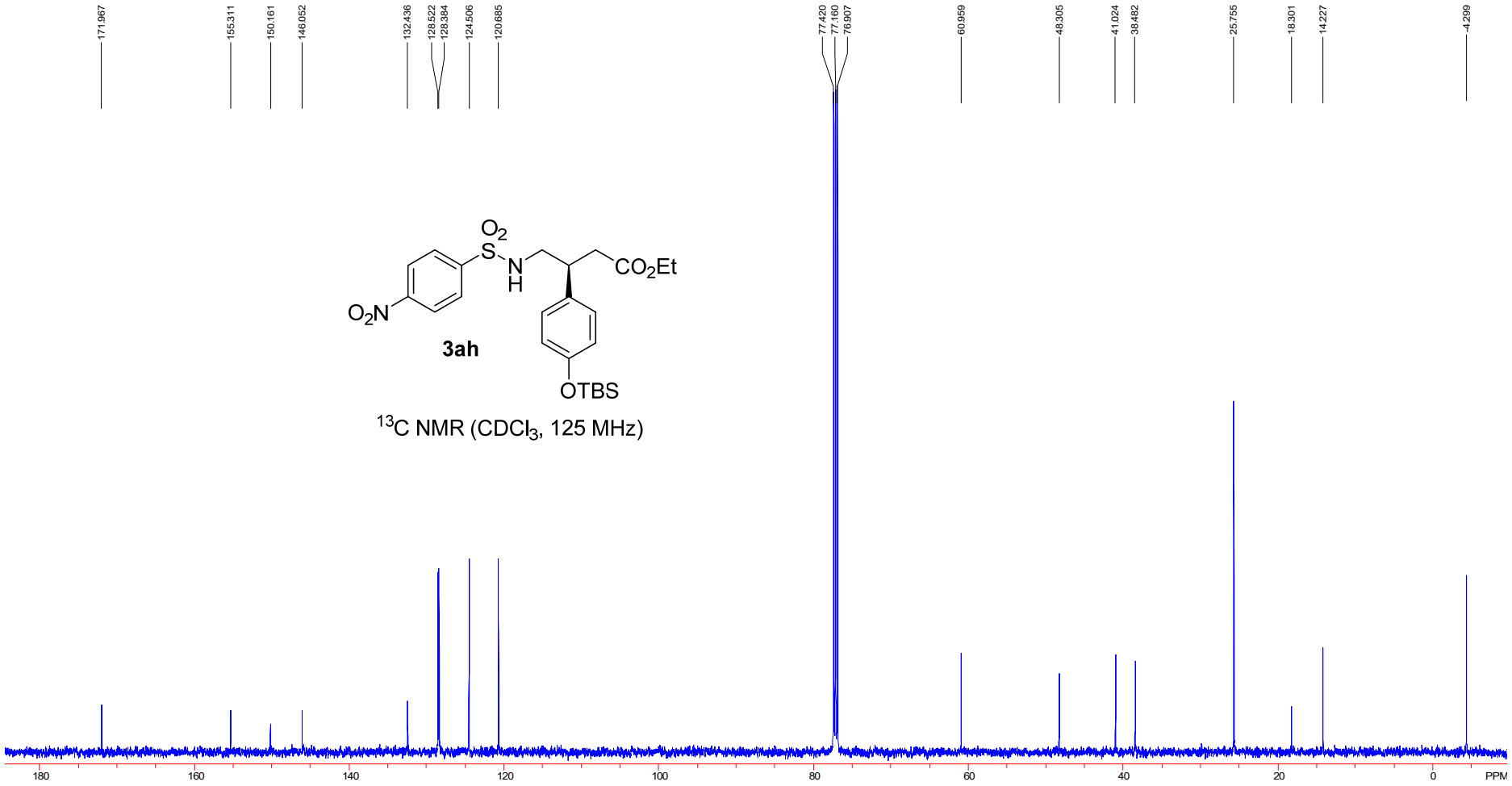

7.611
7.260
6.986
6.968
6.806
6.788
4.610
4.600
4.596
4.586
4.096
4.082
4.074
4.067
4.060
4.053
4.045
4.039
4.031
4.025
4.018
4.004
3.776
3.294
3.170
3.082
3.032
2.671
2.657
2.640
2.625
2.558
2.544
2.526
2.513
1.657
1.181
1.166
1.152
0.005
O2
S
N
H
CO2Et
Br
3af
OMe
1H NMR (CDCl3, 500 MHz)
2.90
1.99
1.94
0.95
1.95
2.99
2.00
0.97
1.00
0.99
2.93
9
8
7
6
5
4
3
2
1
0
PPM

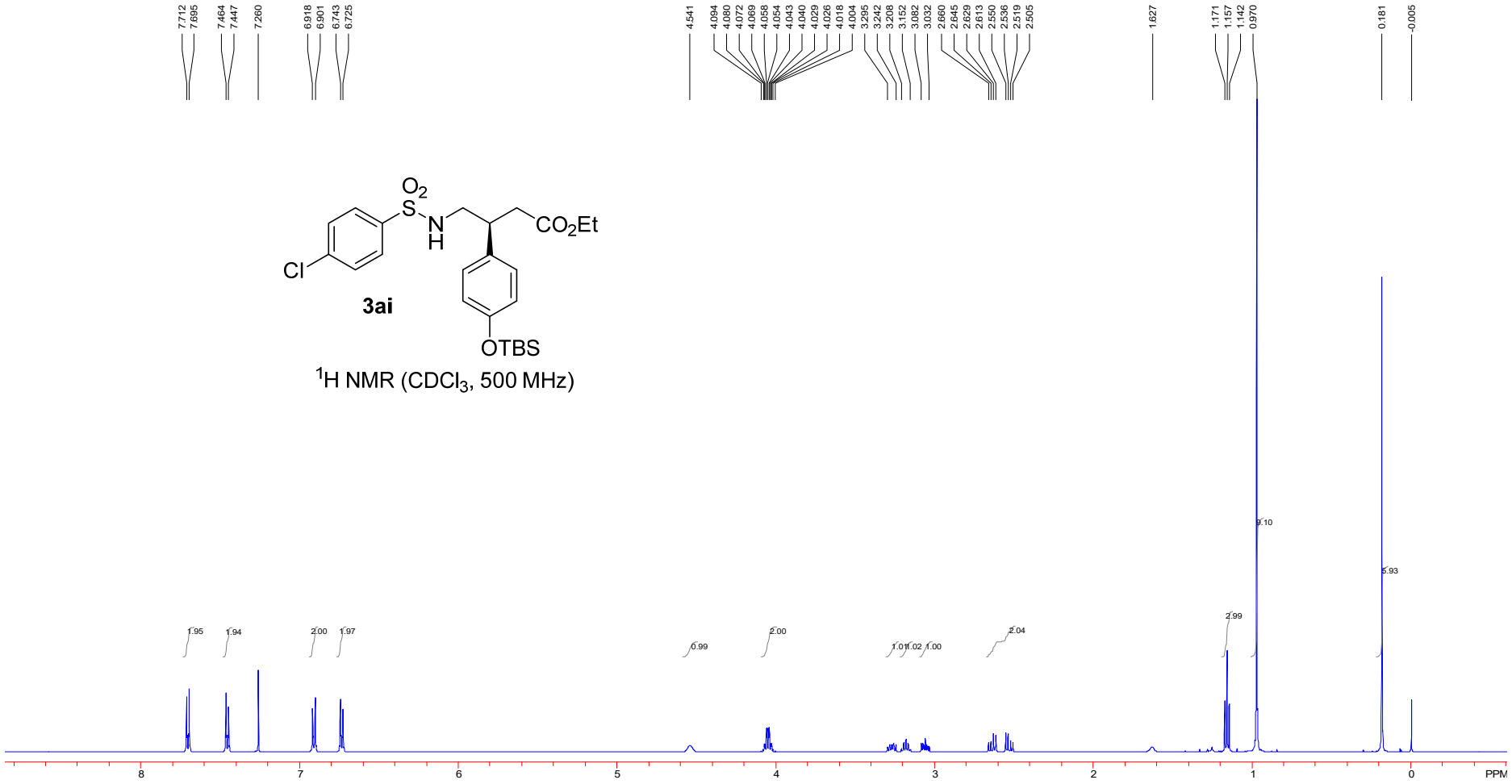

171.895
159.038
139.103
132.487
132.010
128.702
128.594
127.684
114.480
77.413
77.160
76.900
60.844
55.398
48.167
40.894
38.496
14.220
O2
S
N
H
CO2Et
Br
3af
OMe
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

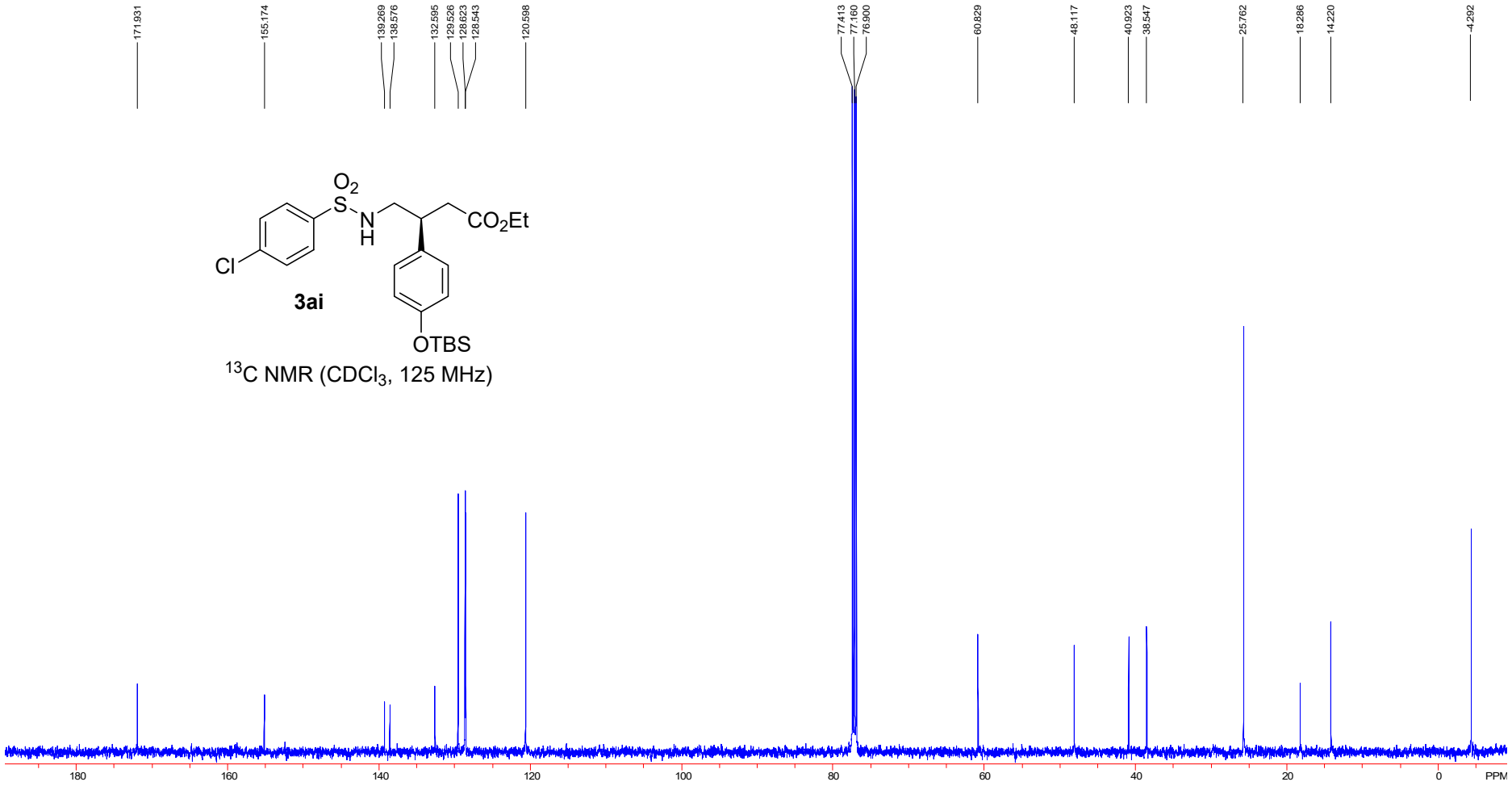

8.271
8.252
7.894
7.876
7.260
7.224
7.188
6.959
6.955
6.944
6.941
6.861
6.847
6.845
6.832
6.808
6.791
4.932
4.920
4.909
4.116
4.102
4.095
4.089
4.081
4.076
4.066
4.062
4.052
4.048
4.040
4.026
3.748
3.613
3.557
3.405
3.356
3.300
3.248
2.736
2.719
2.703
2.687
2.644
2.632
2.612
2.600
1.620
1.192
1.177
1.163
0.005
O2
S
N
H
CO2Et
OMe
O2N
3ag
1H NMR (CDCl3, 500 MHz)
1.92
1.95
0.98
0.96
1.99
3.01
1.01
1.00
1.01
2.00
9
8
7
6
5
4
3
2
1
0
PPM


172.364
157.182
150.002
146.131
128.811
128.500
128.305
128.023
124.340
121.154
111.100
77.413
77.160
76.907
60.872
55.499
46.911
36.784
36.250
14.227
O2
S
N
H
CO2Et
OMe
O2N
3ag
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM


8.326
8.308
7.949
7.931
7.260
6.913
6.897
6.732
6.714
4.803
4.794
4.788
4.779
4.086
4.072
4.058
4.043
3.372
3.323
3.209
3.098
2.659
2.644
2.627
2.612
2.569
2.556
2.537
2.524
1.636
1.180
1.165
1.151
0.965
0.175
-0.007
O2
S
N
H
CO2Et
O2N
3ah
OTBS
1H NMR (CDCl3, 500 MHz)
1.95
1.98
2.08
1.95
0.96
2.00
1.00
2.05
2.00
2.94
9.05
5.91
9
8
7
6
5
4
3
2
1
0
PPM

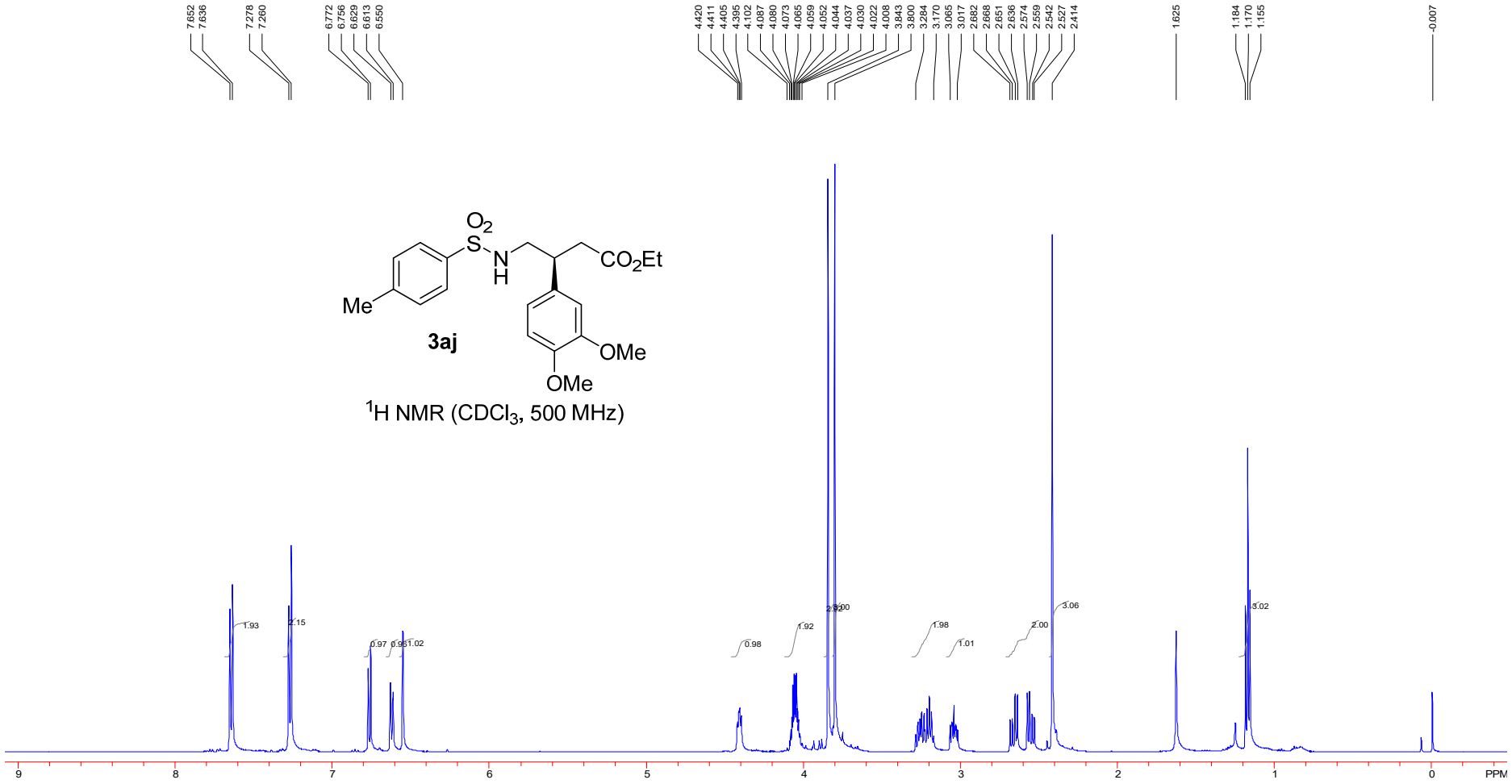

171.967
155.311
150.161
146.052
132.436
128.522
128.384
124.506
120.685
77.420
77.160
76.907
60.959
48.305
41.024
38.482
25.755
18.301
14.227
4.299
O2
S
N
H
CO2Et
O2N
3ah
OTBS
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

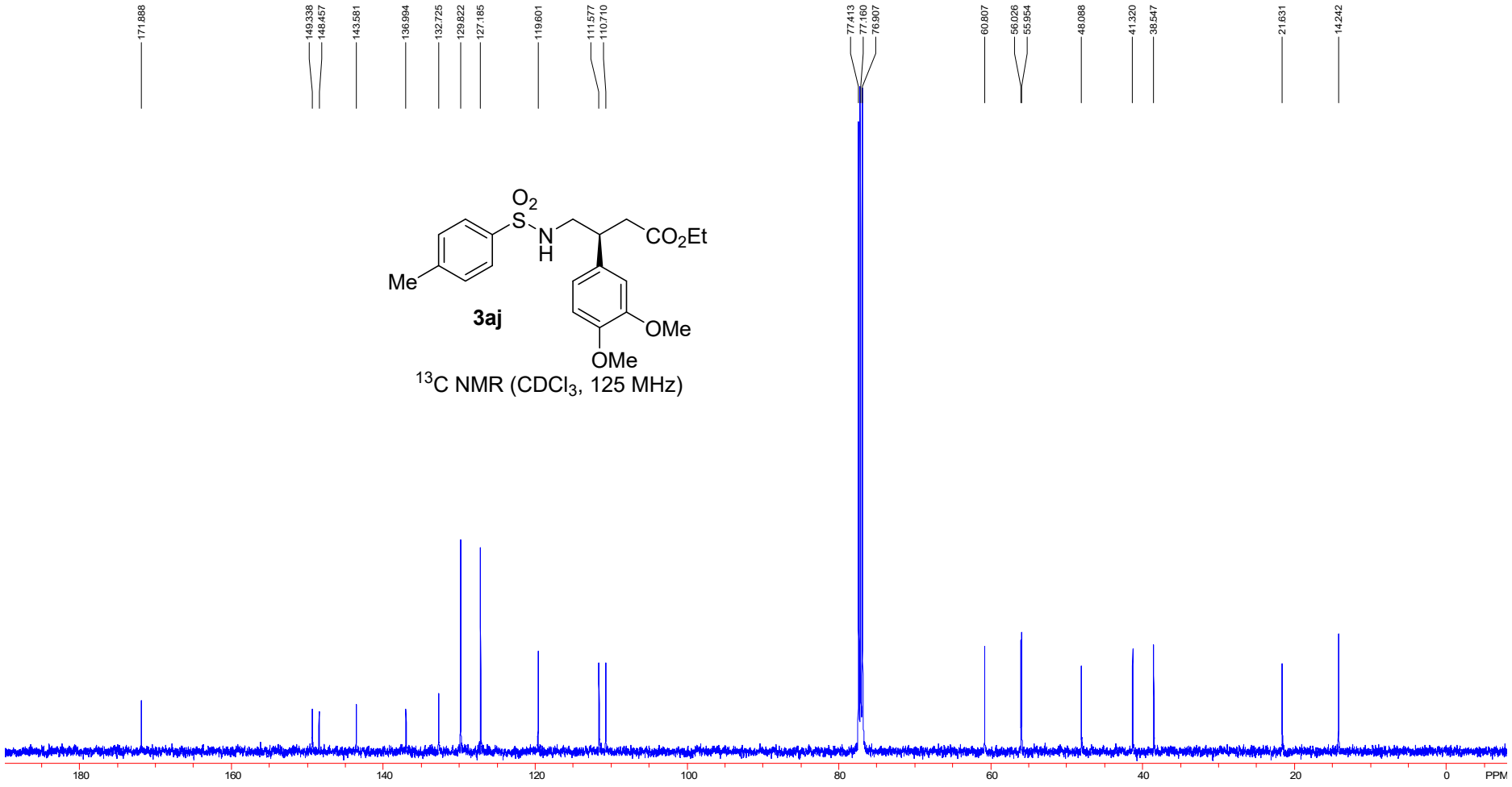

7.712
7.695
7.464
7.447
7.260
6.918
6.901
6.743
6.725
4.541
4.094
4.080
4.072
4.069
4.058
4.054
4.043
4.040
4.029
4.026
4.018
4.004
3.295
3.242
3.208
3.152
3.082
3.032
2.660
2.645
2.629
2.613
2.550
2.536
2.519
2.505
1.627
1.171
1.157
1.142
0.970
0.181
-0.005
O2
S
N
H
CO2Et
Cl
OTBS
3ai
1H NMR (CDCl3, 500 MHz)
1.95
1.94
2.00
1.97
0.99
2.00
1.01
1.02
1.00
2.04
2.99
9.10
5.93
8
7
6
5
4
3
2
1
0
PPM

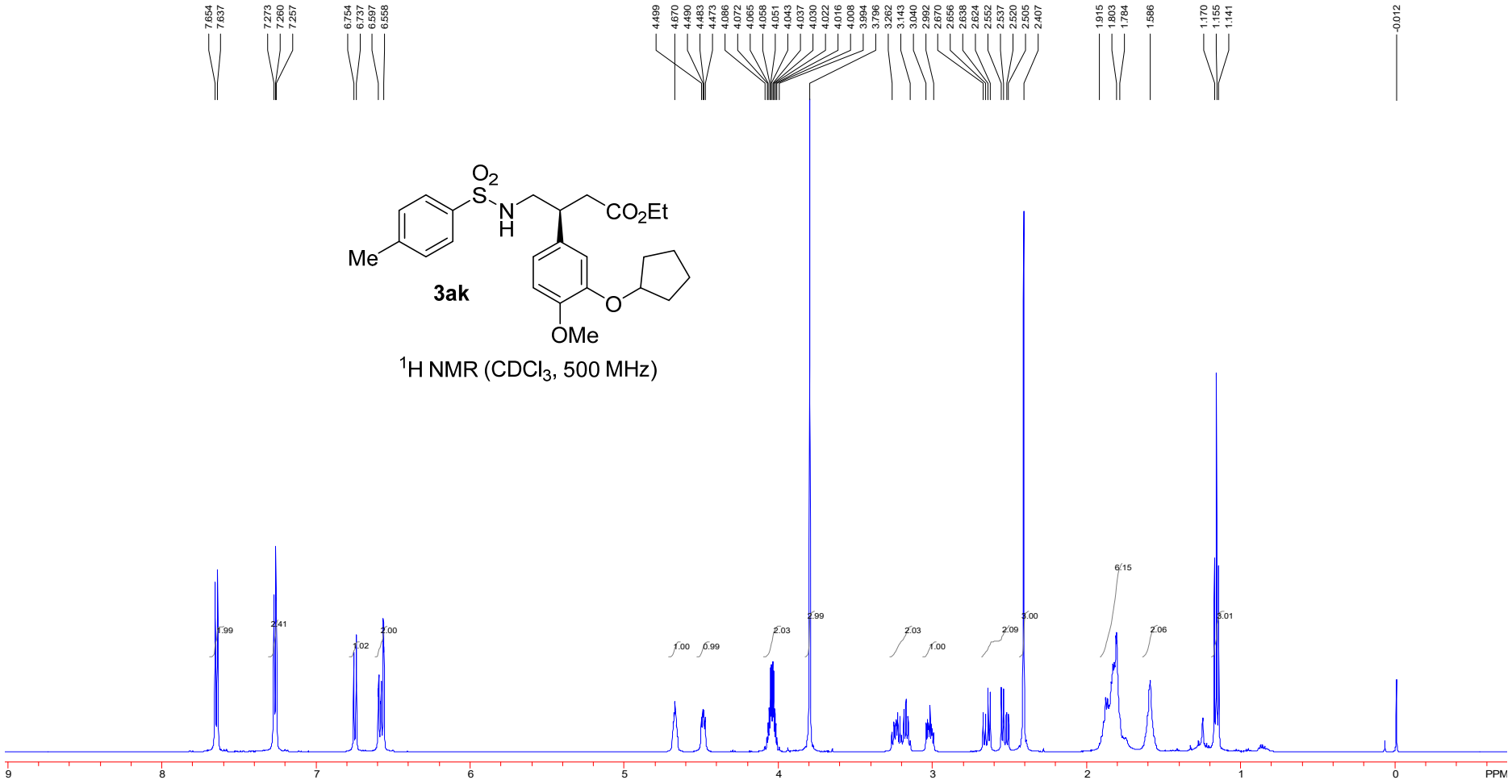


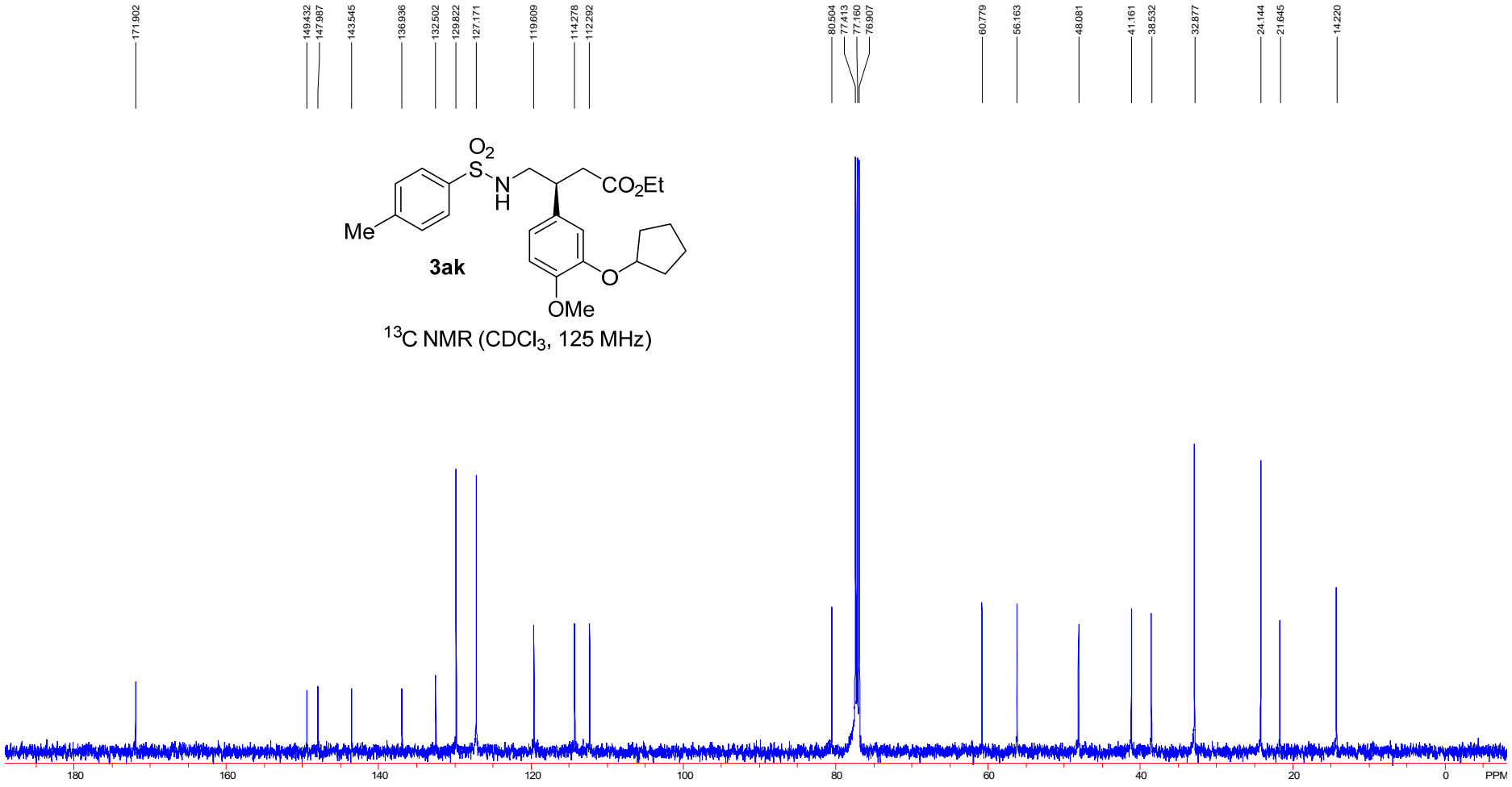

**3ai**

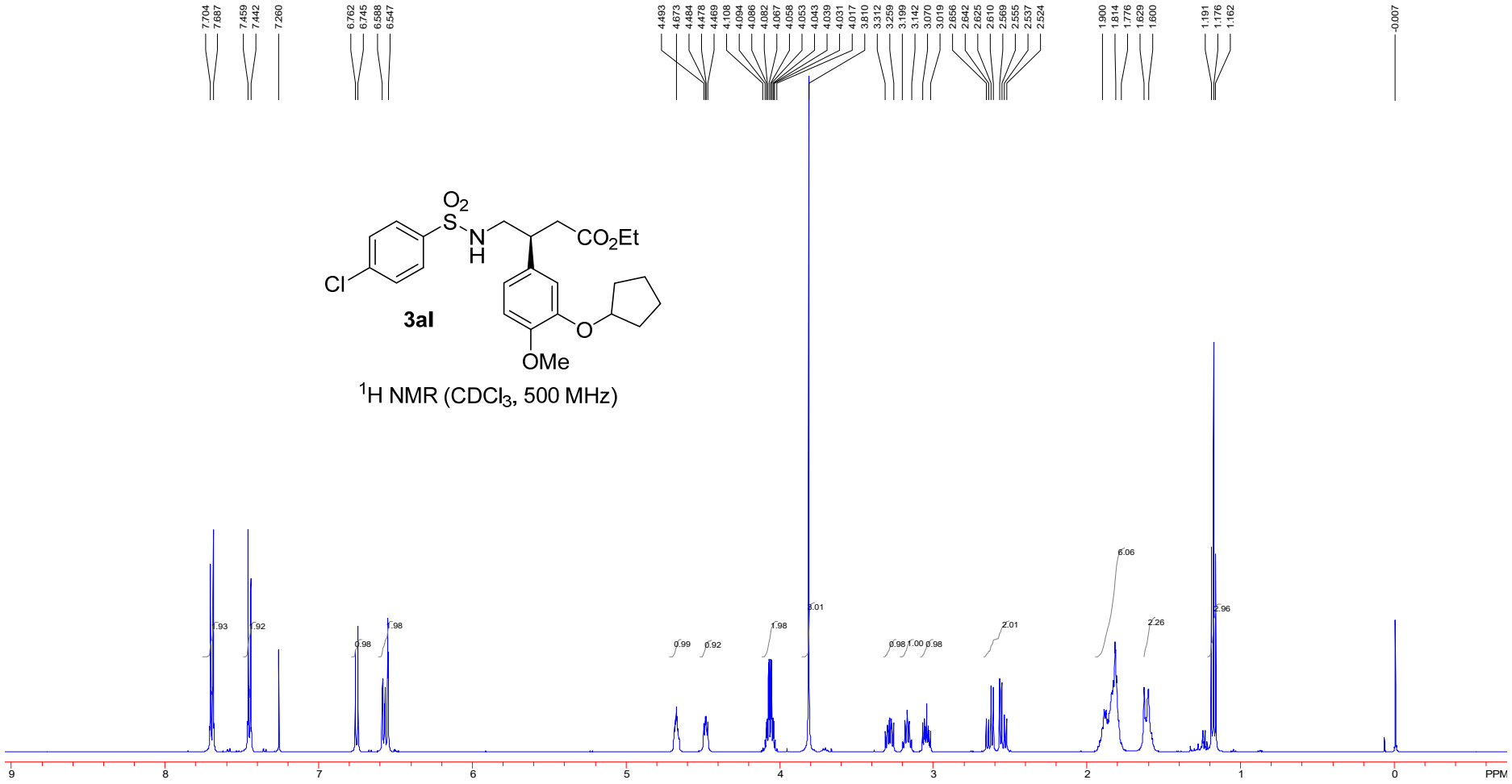
$^{13}C$ NMR ($CDCl_3$, 125 MHz)


7.652
7.636
7.278
7.260
6.772
6.756
6.629
6.613
6.550
4.420
4.411
4.405
4.395
4.102
4.087
4.080
4.073
4.065
4.059
4.052
4.044
4.037
4.030
4.022
4.008
3.843
3.800
3.284
3.170
3.065
3.017
2.682
2.668
2.651
2.636
2.574
2.559
2.542
2.527
2.414
1.625
1.184
1.170
1.155
-0.007
O2
S
N
H
CO2Et
Me
OMe
OMe
3aj
1H NMR (CDCl3, 500 MHz)
1.93
2.15
0.97
0.95
1.02
0.98
1.92
2.00
1.98
1.01
2.00
3.06
3.02
9
8
7
6
5
4
3
2
1
0
PPM


171.888
149.338
148.457
143.581
136.994
132.725
129.822
127.185
119.601
111.577
110.710
77.413
77.160
76.907
60.807
56.026
55.954
48.088
41.320
38.547
21.631
14.242
O2
S
N
H
CO2Et
Me
OMe
OMe
3aj
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

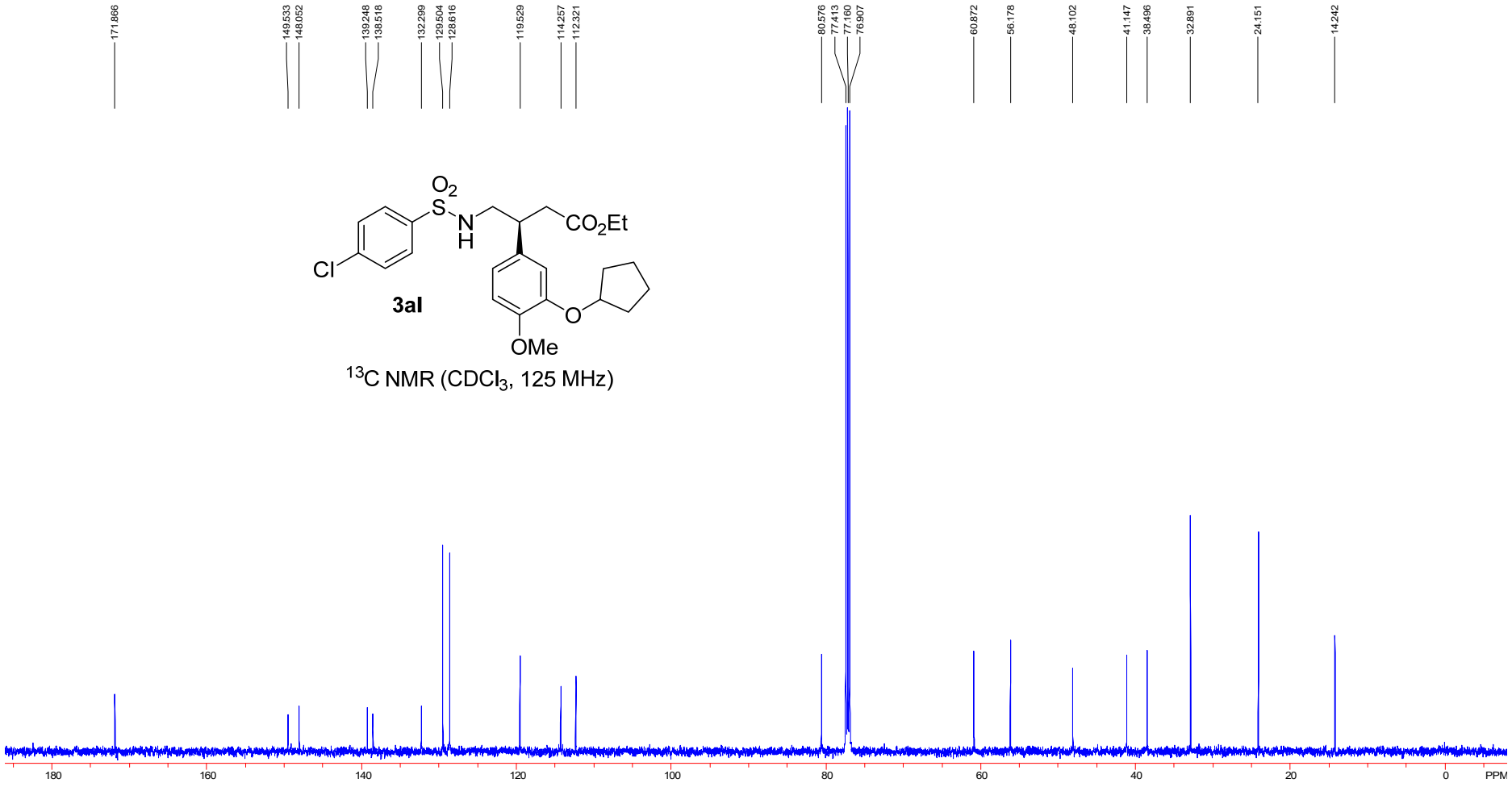

7.654
7.637
7.273
7.260
7.257
6.754
6.737
6.597
6.558
4.499
4.670
4.490
4.483
4.473
4.086
4.072
4.065
4.058
4.051
4.043
4.037
4.030
4.022
4.016
4.008
3.994
3.796
3.262
3.143
3.040
2.992
2.670
2.656
2.638
2.624
2.552
2.537
2.520
2.505
2.407
1.915
1.803
1.784
1.586
1.170
1.155
1.141
0.012
O2
S
N
H
CO2Et
Me
O
OMe
3ak
1H NMR (CDCl3, 500 MHz)
1.99
2.41
1.02
2.00
1.00
0.99
2.03
2.99
2.03
1.00
2.09
3.00
6.15
2.06
3.01
9
8
7
6
5
4
3
2
1
0
PPM

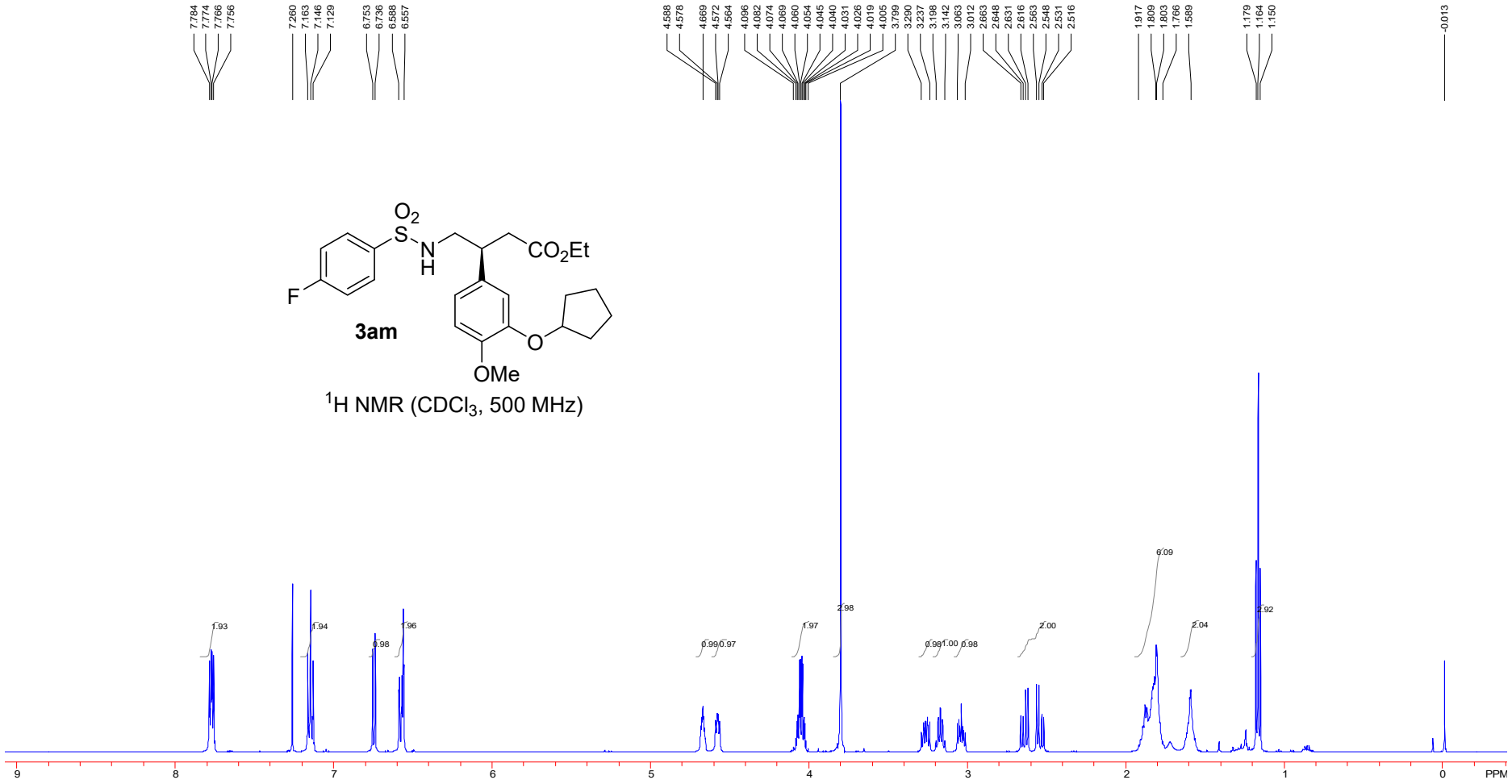

171.902
149.432
147.987
143.545
136.936
132.502
129.822
127.171
119.609
114.278
112.292
80.504
77.413
77.160
76.907
60.779
56.163
48.081
41.161
38.532
32.877
24.144
21.645
14.220
O2
S
N
H
CO2Et
Me
3ak
O
OMe
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

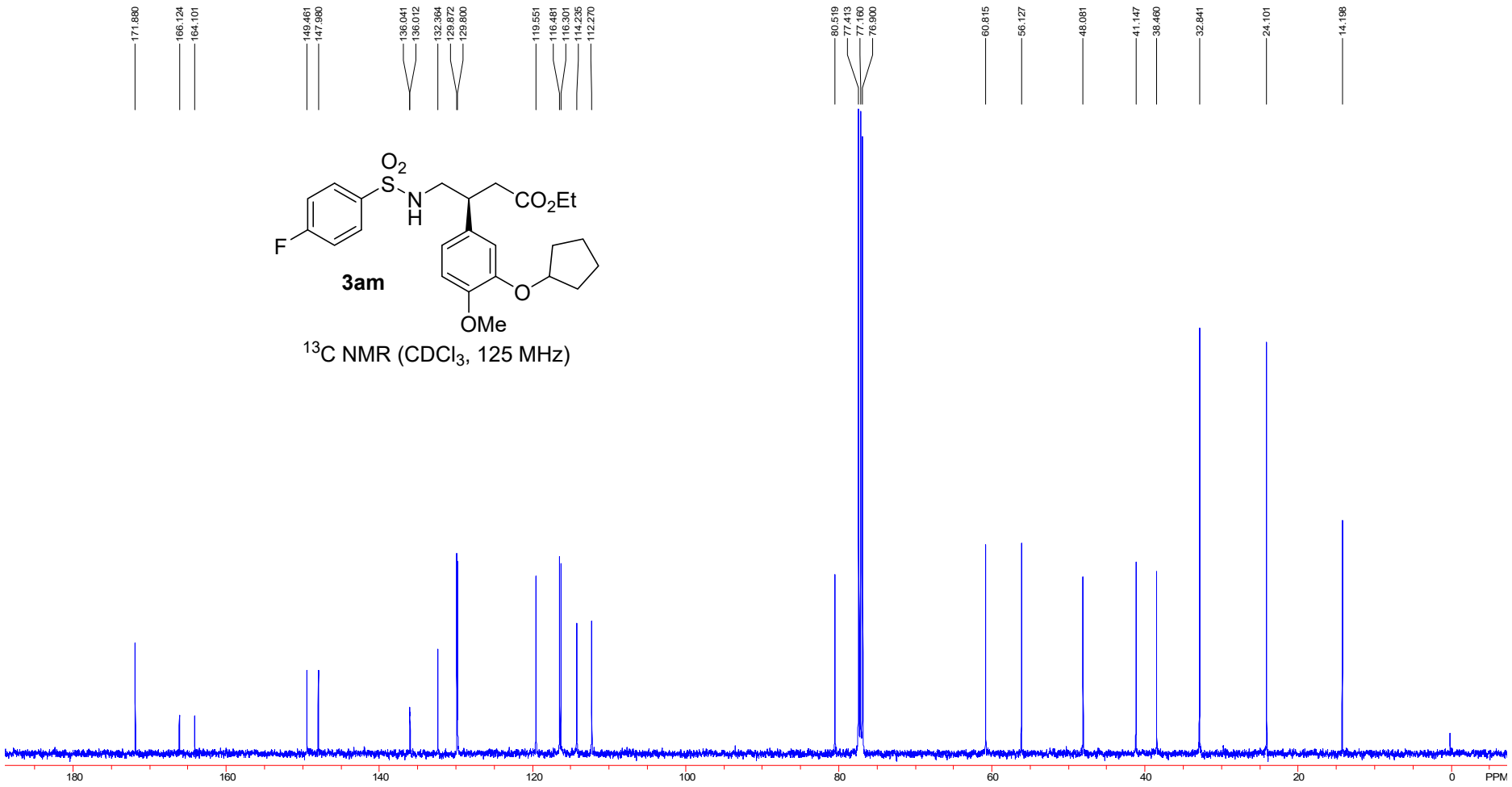


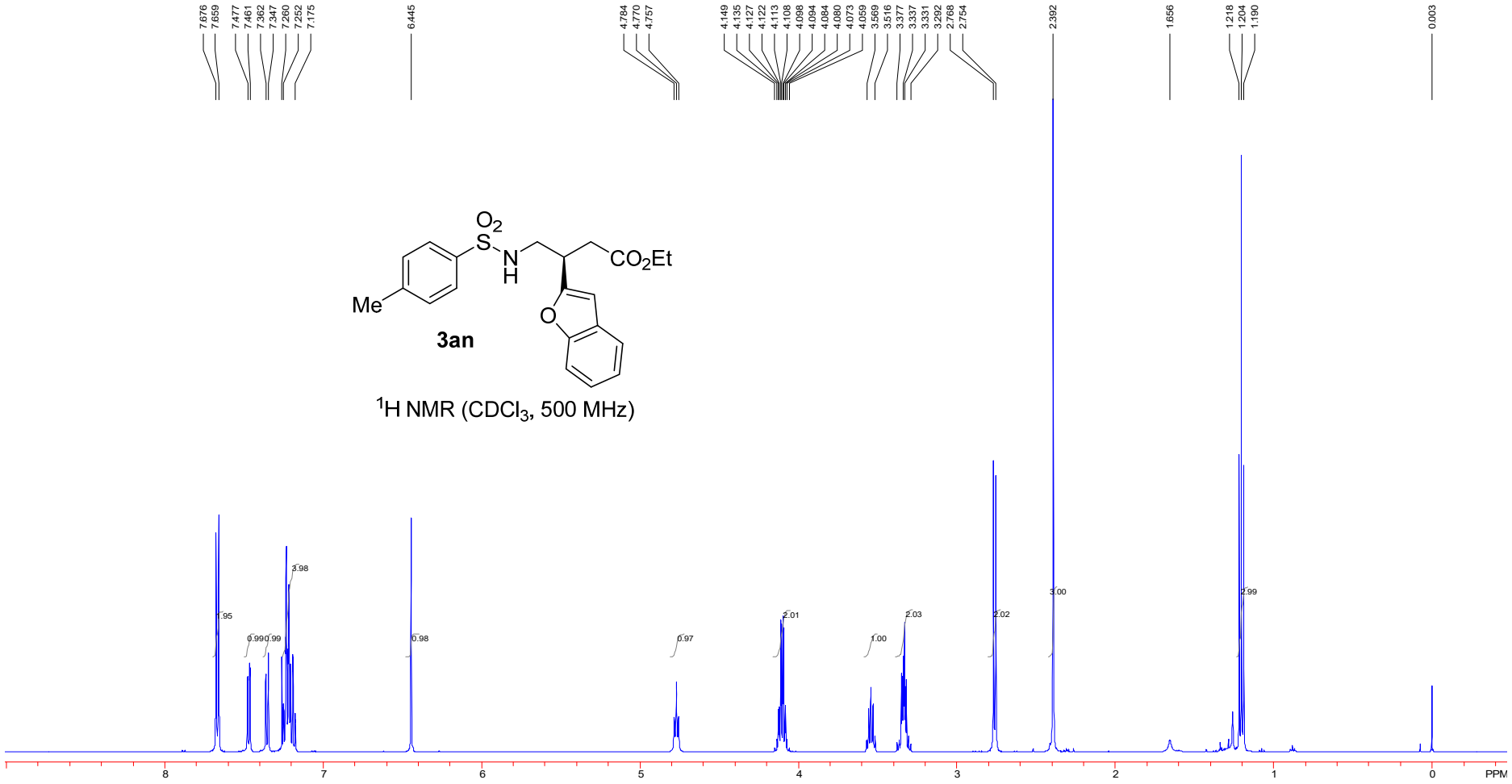

**3aI**

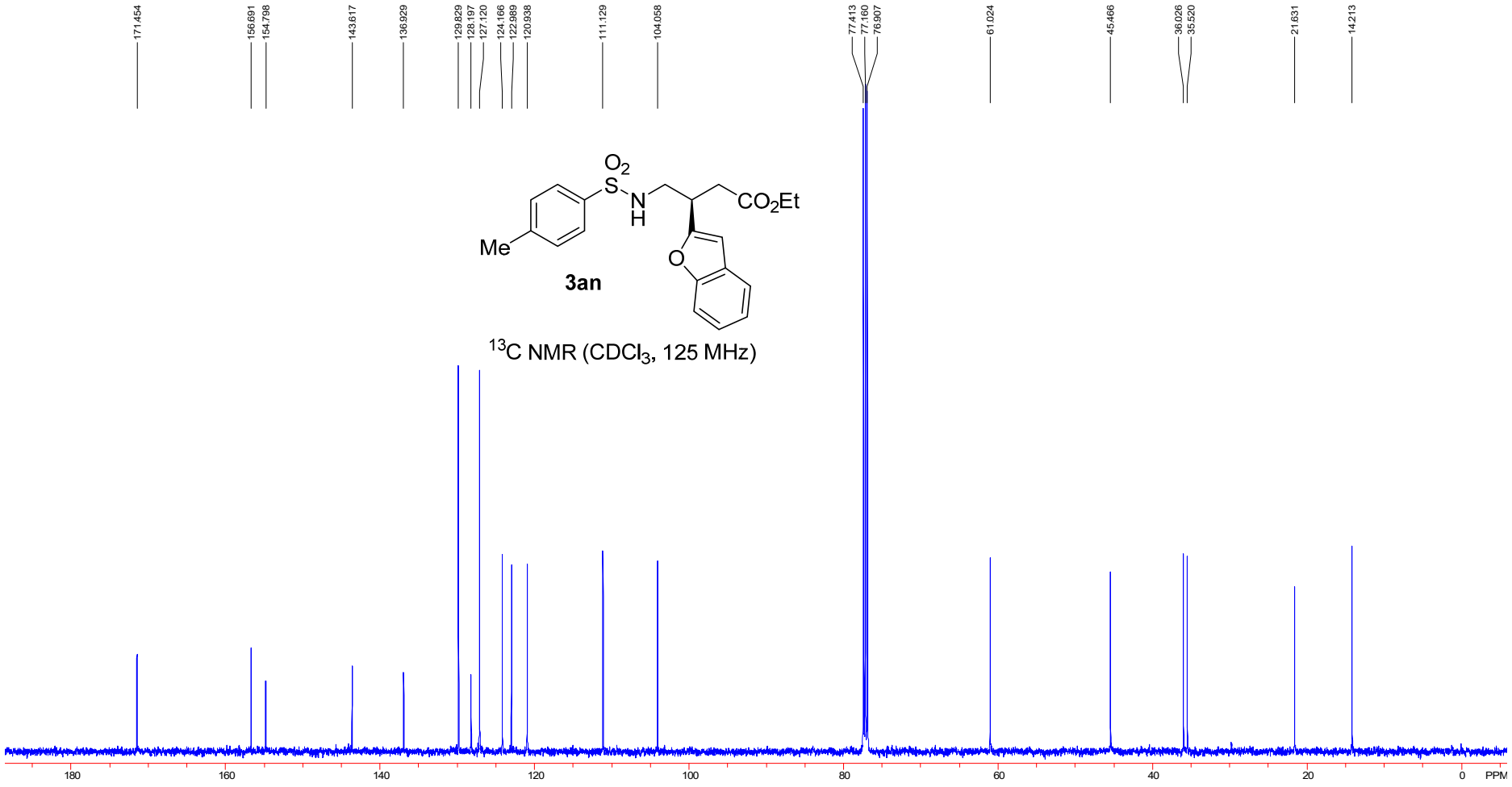
$^1$H NMR ($CDCl_3$, 500 MHz)

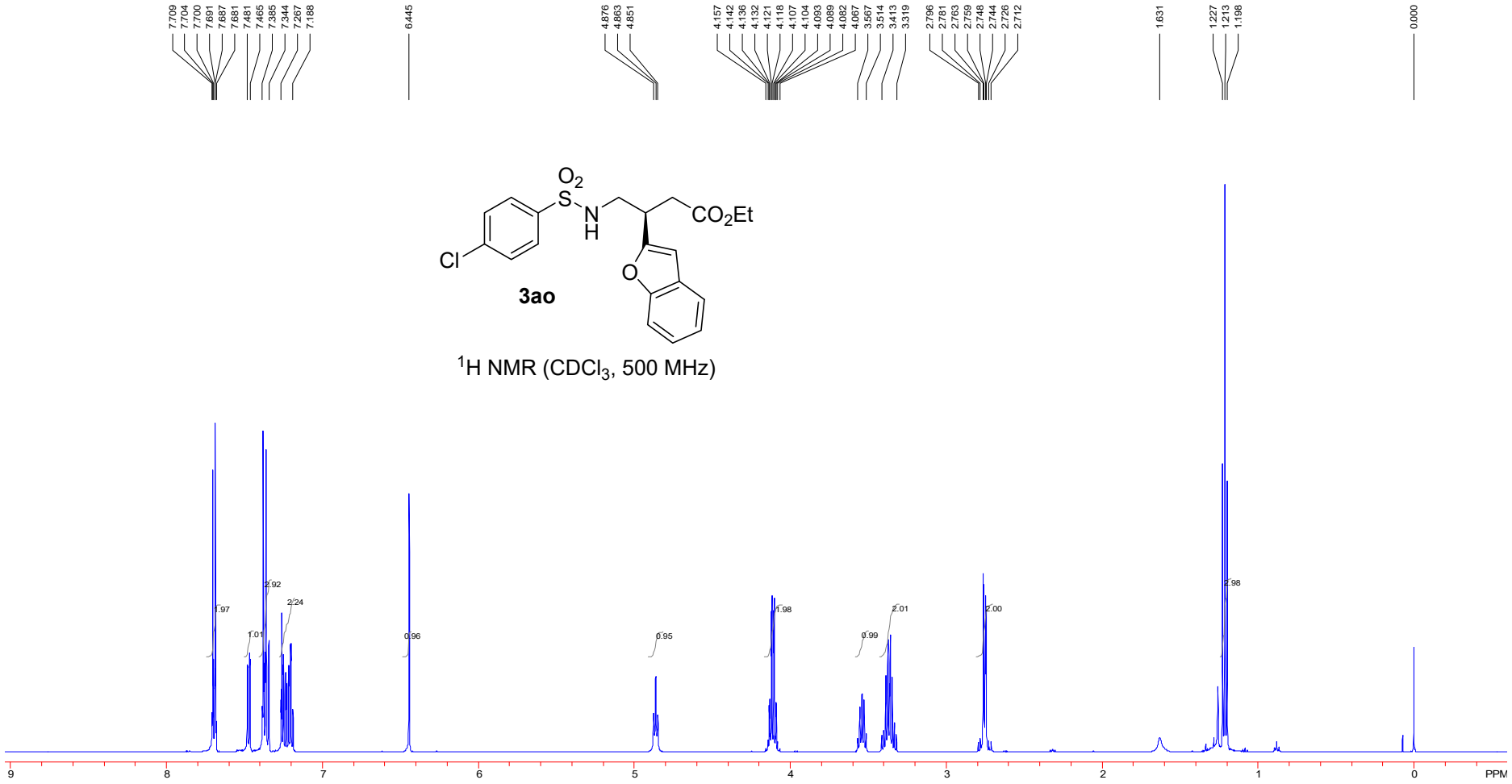

171.866
149.533
148.052
139.248
138.518
132.299
129.504
128.616
119.529
114.257
112.321
80.576
77.413
77.160
76.907
60.872
56.178
48.102
41.147
38.496
32.891
24.151
14.242
O2
S
N
H
CO2Et
Cl
O
OMe
3al
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

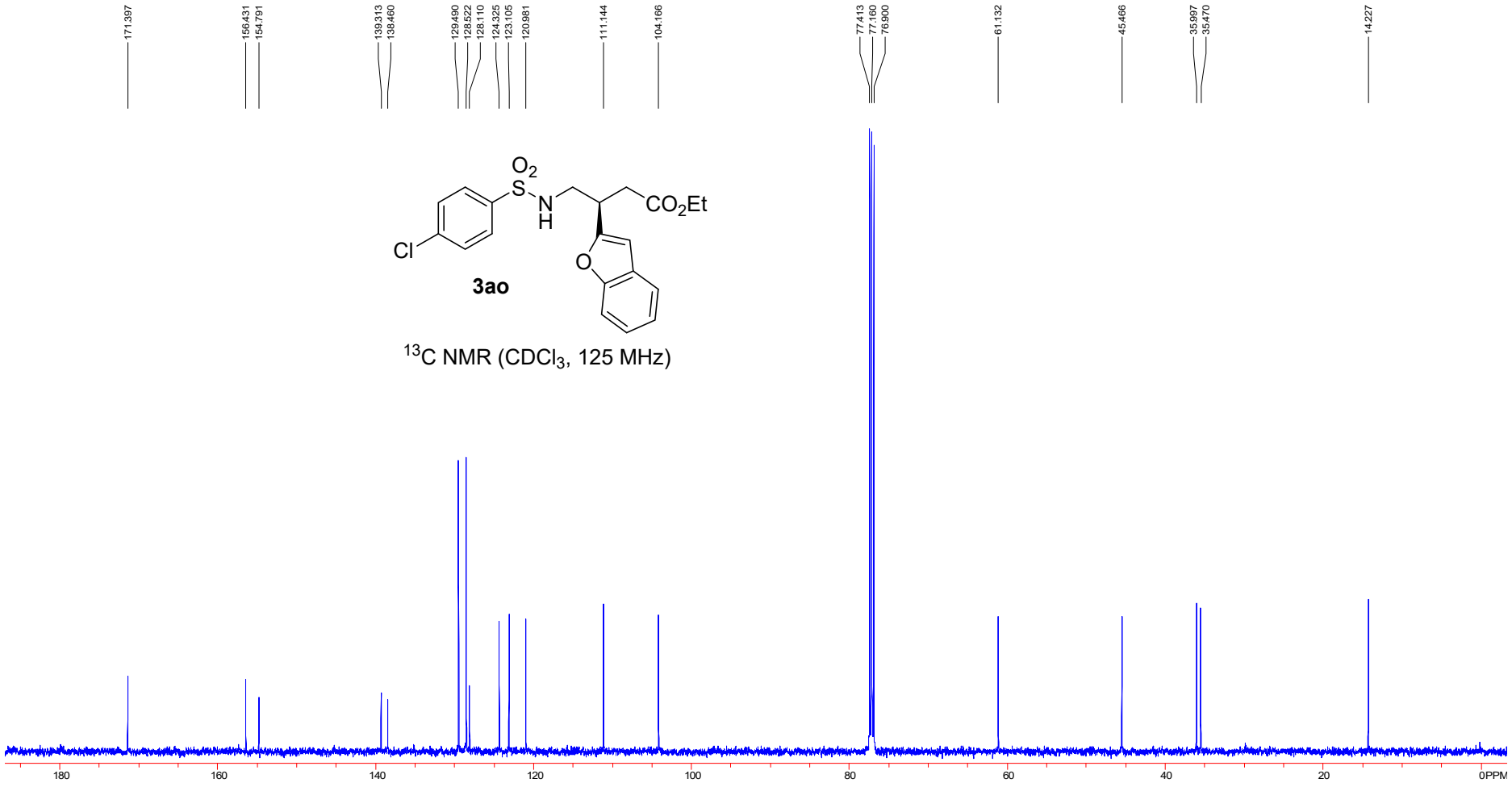

7.784
7.774
7.766
7.756
7.260
7.163
7.146
7.129
6.753
6.736
6.588
6.557
4.588
4.578
4.669
4.572
4.564
4.096
4.082
4.074
4.069
4.060
4.054
4.045
4.040
4.031
4.026
4.019
4.005
3.799
3.290
3.237
3.198
3.142
3.063
3.012
2.663
2.648
2.631
2.616
2.563
2.548
2.531
2.516
1.917
1.809
1.803
1.766
1.589
1.179
1.164
1.150
-0.013
O2
S
N
H
CO2Et
F
3am
O
OMe
1H NMR (CDCl3, 500 MHz)
1.93
1.94
0.98
1.96
0.99
0.97
1.97
2.98
0.98
1.00
0.98
2.00
6.09
2.04
2.92
9
8
7
6
5
4
3
2
1
0
PPM

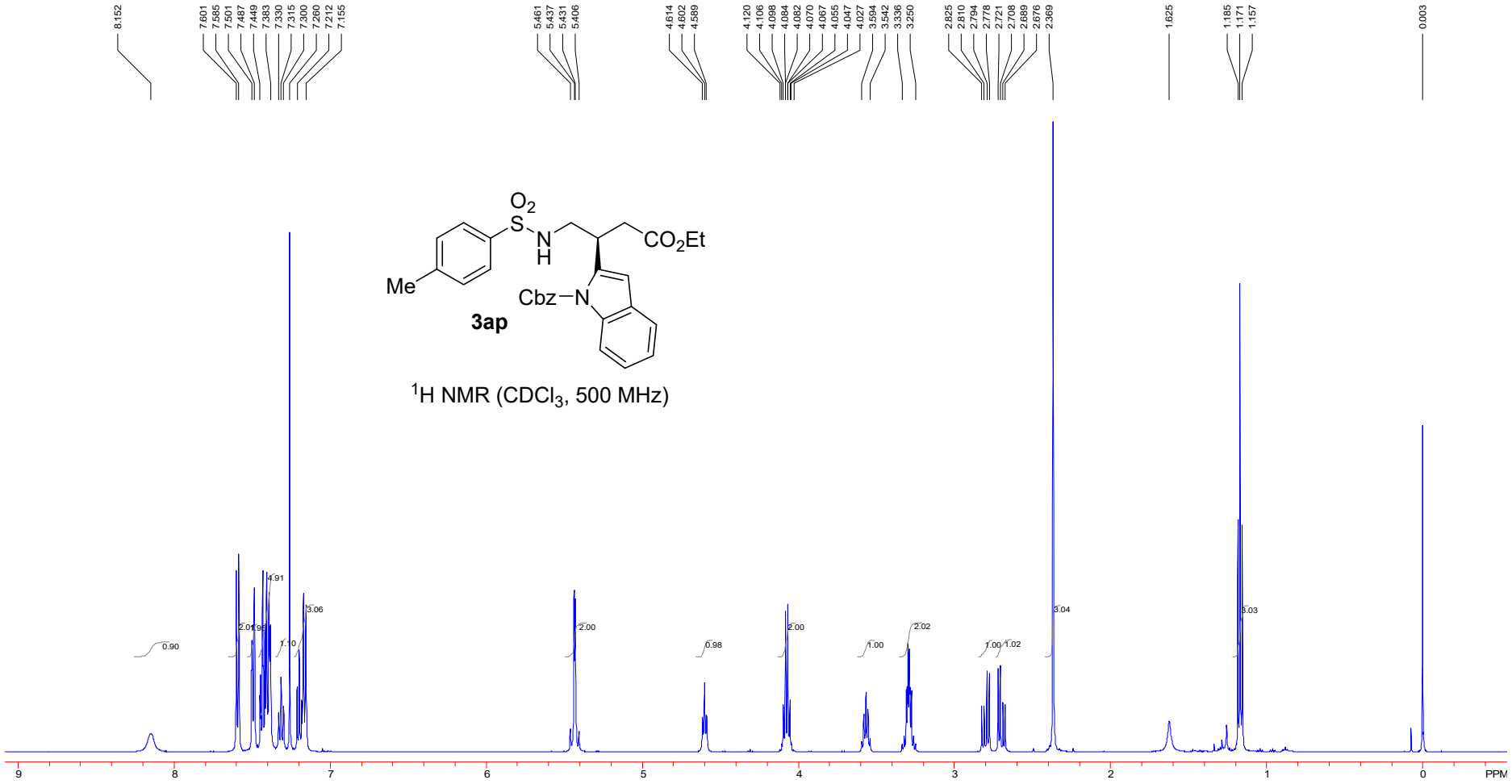

171.880
166.124
164.101
149.461
147.980
136.041
136.012
132.364
129.872
129.800
119.551
116.481
116.301
114.235
112.270
80.519
77.413
77.160
76.900
60.815
56.127
48.081
41.147
38.480
32.841
24.101
14.198
O2
S
N
H
CO2Et
F
3am
O
OMe
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

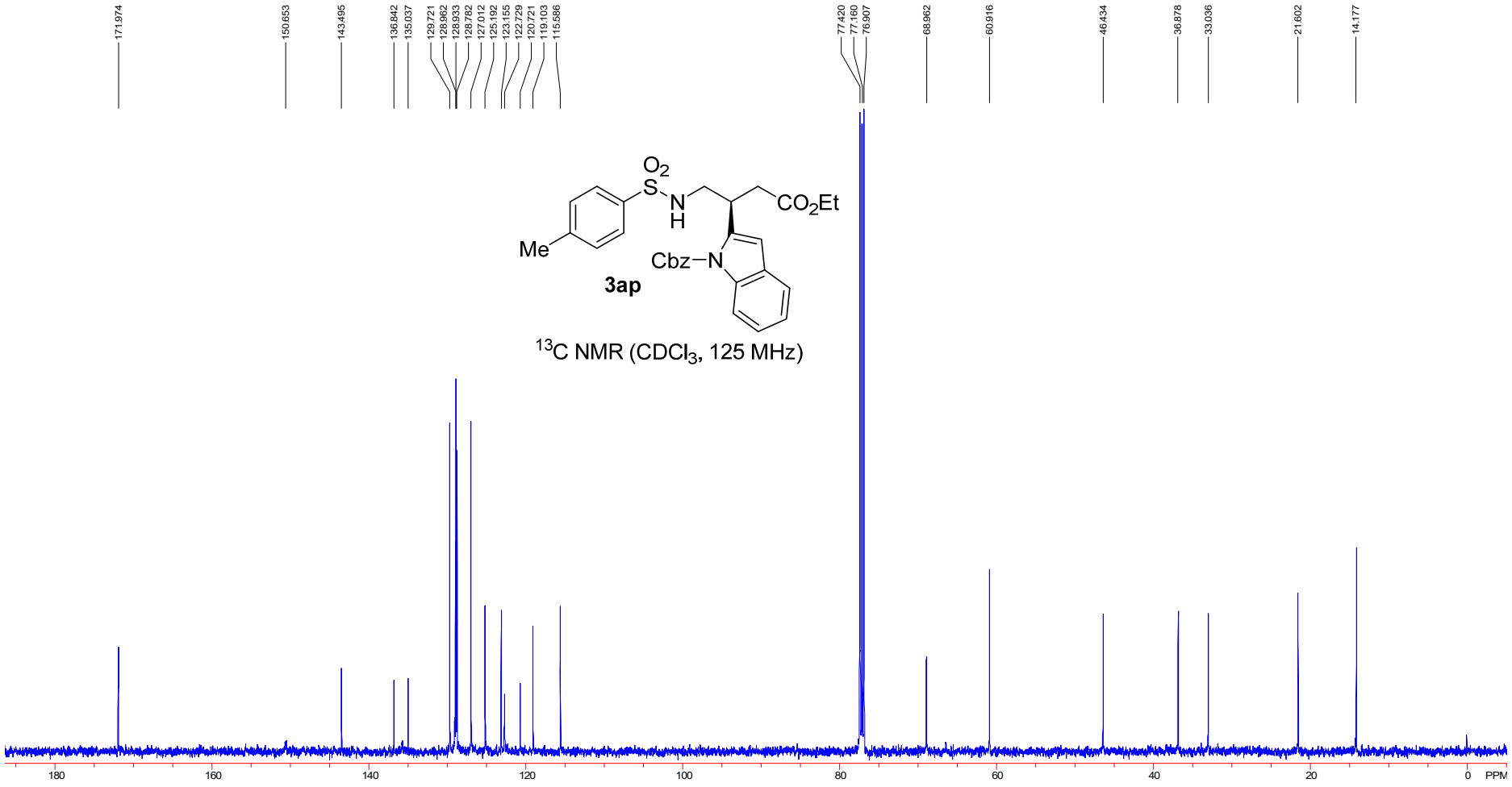

7.676
7.659
7.477
7.461
7.362
7.347
7.260
7.252
7.175
6.445
4.784
4.770
4.757
4.149
4.135
4.127
4.122
4.113
4.108
4.098
4.094
4.084
4.080
4.073
4.059
3.569
3.516
3.377
3.337
3.331
3.292
2.768
2.754
2.392
1.656
1.218
1.204
1.190
0.003
O2
S
N
H
CO2Et
Me
O
3an
1H NMR (CDCl3, 500 MHz)
3.98
1.95
0.99
0.99
0.98
0.97
2.01
1.00
2.03
2.02
3.00
2.99
8
7
6
5
4
3
2
1
0
PPM

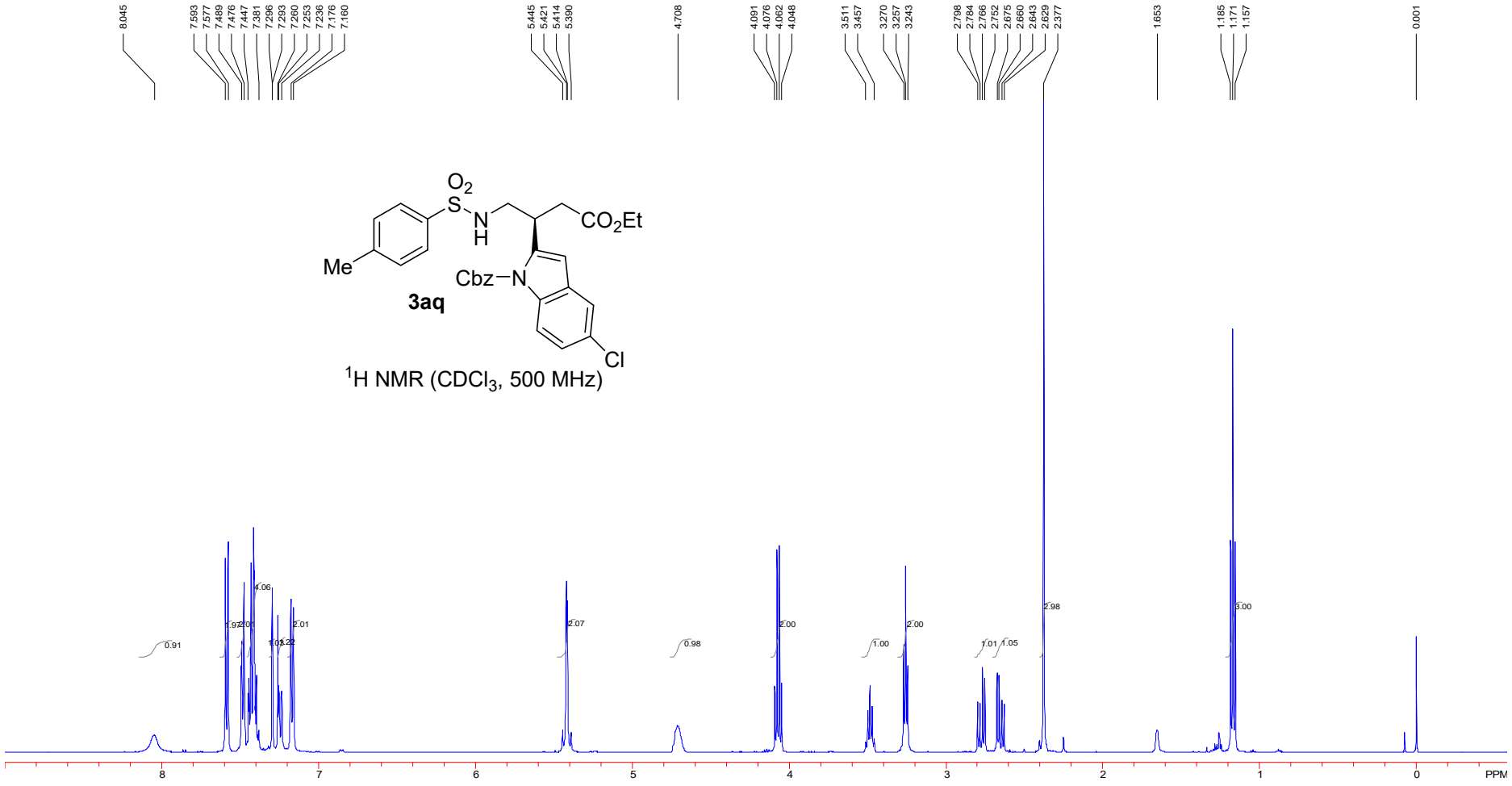

171.454
156.691
154.798
143.617
136.929
129.829
128.197
127.120
124.166
122.989
120.938
111.129
104.058
77.413
77.160
76.907
61.024
45.466
36.026
35.520
21.631
14.213
O2
S
N
H
CO2Et
Me
O
3an
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

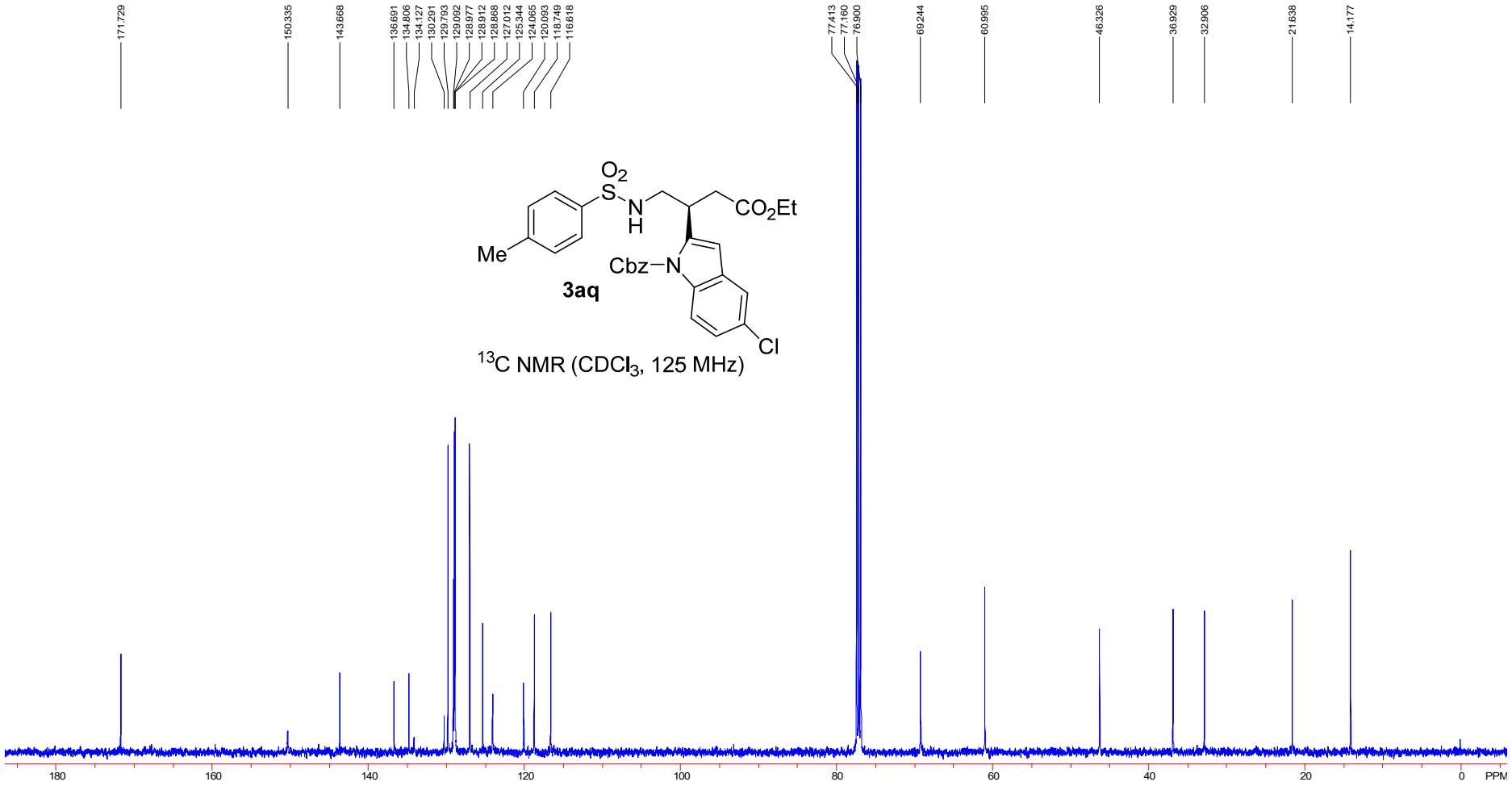

7.709
7.704
7.700
7.691
7.687
7.681
7.481
7.465
7.385
7.344
7.267
7.188
6.445
4.876
4.863
4.851
4.157
4.142
4.136
4.132
4.121
4.118
4.107
4.104
4.093
4.089
4.082
4.067
3.567
3.514
3.413
3.319
2.796
2.781
2.763
2.759
2.748
2.744
2.726
2.712
1.631
1.227
1.213
1.198
0.000
O2
S
N
H
CO2Et
Cl
O
3ao
1H NMR (CDCl3, 500 MHz)
1.97
2.92
2.24
1.01
0.96
0.95
1.98
0.99
2.01
2.00
2.98
9
8
7
6
5
4
3
2
1
0
PPM

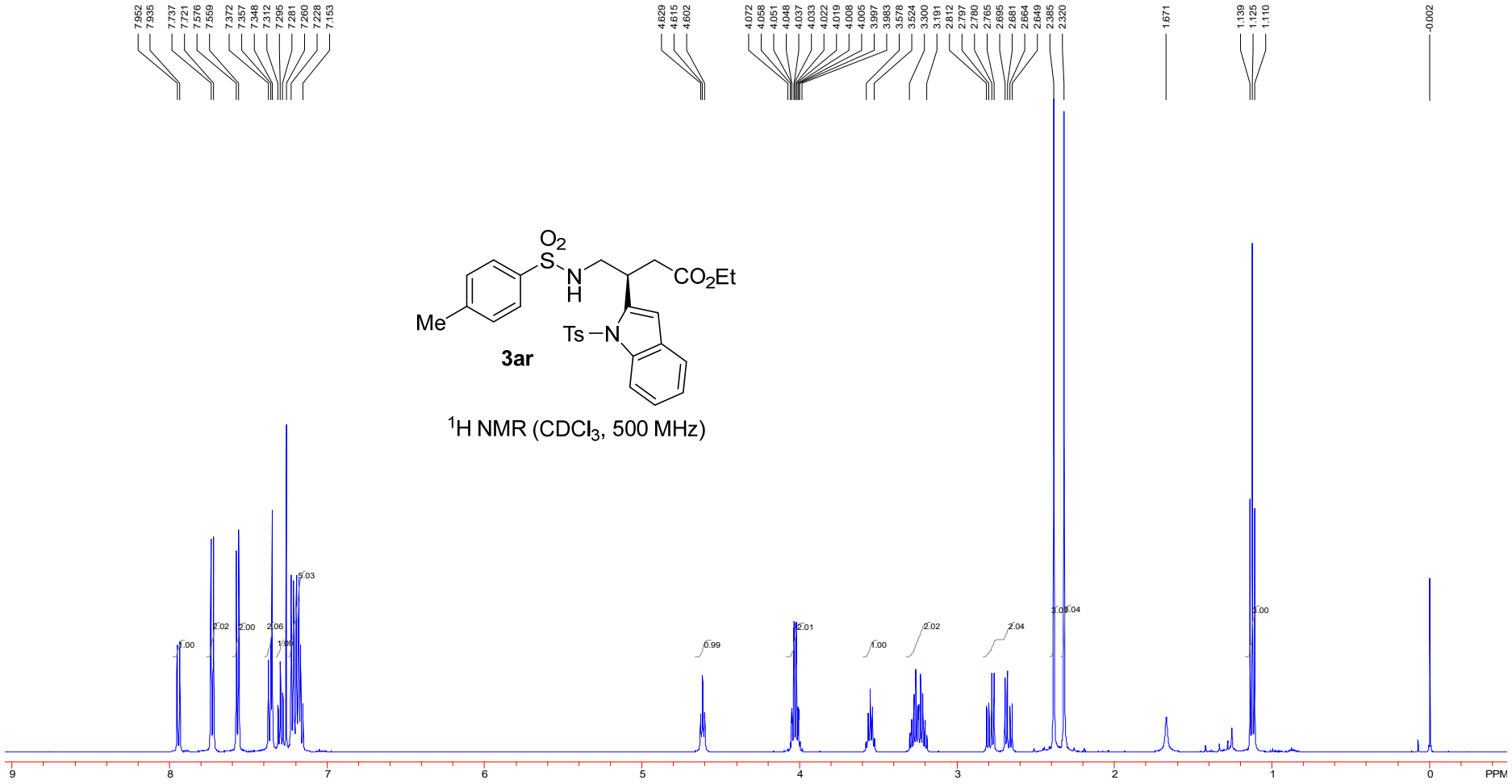

171.397
156.431
154.791
139.313
138.460
129.490
128.522
128.110
124.325
123.105
120.981
111.144
104.166
77.413
77.160
76.900
61.132
45.466
35.997
35.470
14.227
O2
S
N
H
CO2Et
Cl
O
3ao
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0PPM

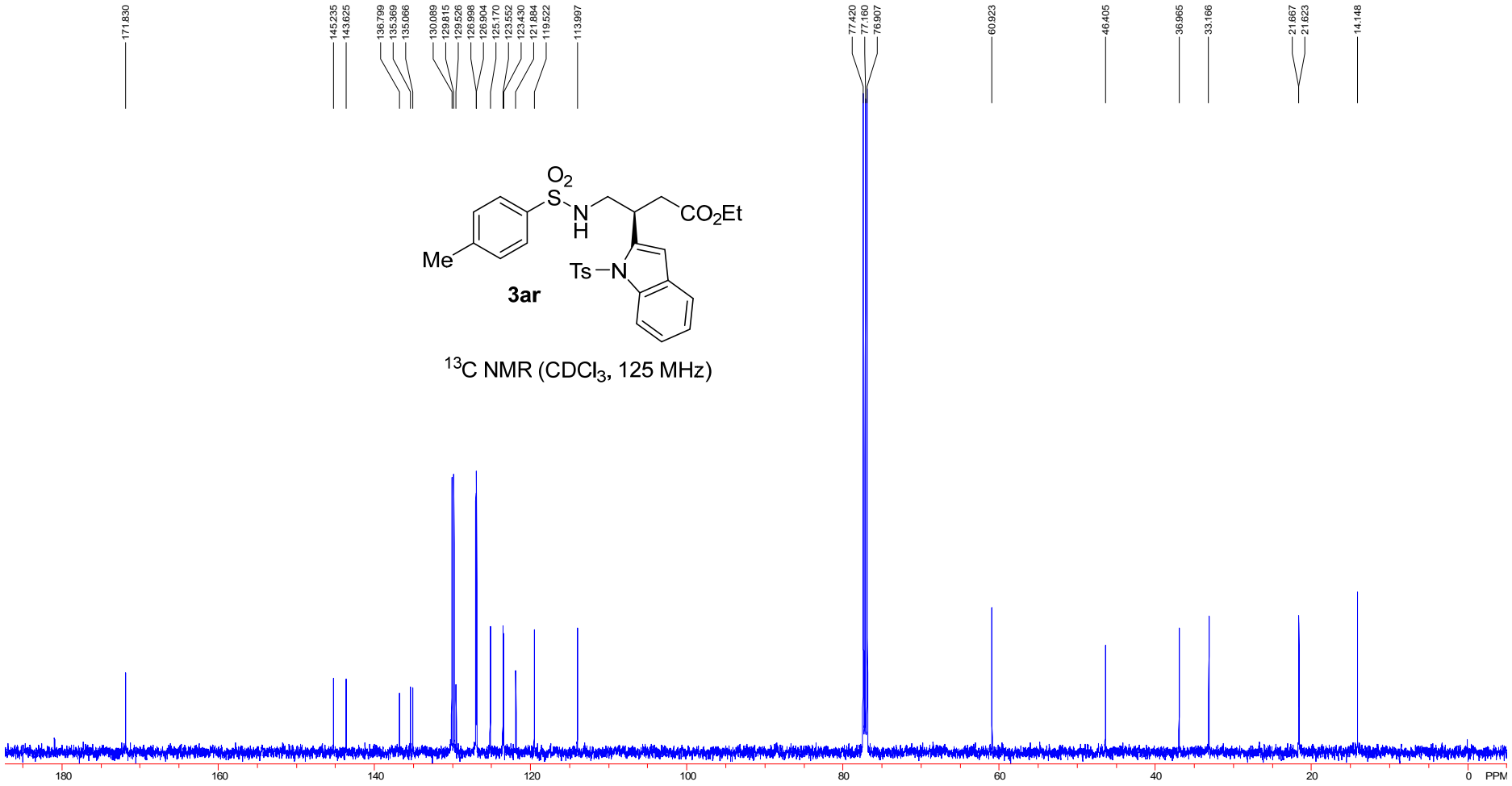

8.152
7.601
7.585
7.501
7.487
7.449
7.383
7.330
7.315
7.300
7.260
7.212
7.155
5.461
5.437
5.431
5.406
4.614
4.602
4.589
4.120
4.106
4.098
4.084
4.082
4.070
4.067
4.055
4.047
4.027
3.594
3.542
3.336
3.250
2.825
2.810
2.794
2.778
2.721
2.708
2.689
2.676
2.369
1.625
1.185
1.171
1.157
0.003
O2
S
N
H
CO2Et
Me
Cbz–N
3ap
1H NMR (CDCl3, 500 MHz)
0.90
2.01
1.96
4.91
1.10
3.06
2.00
0.98
2.00
1.00
2.02
1.00
1.02
3.04
3.03
9
8
7
6
5
4
3
2
1
0
PPM

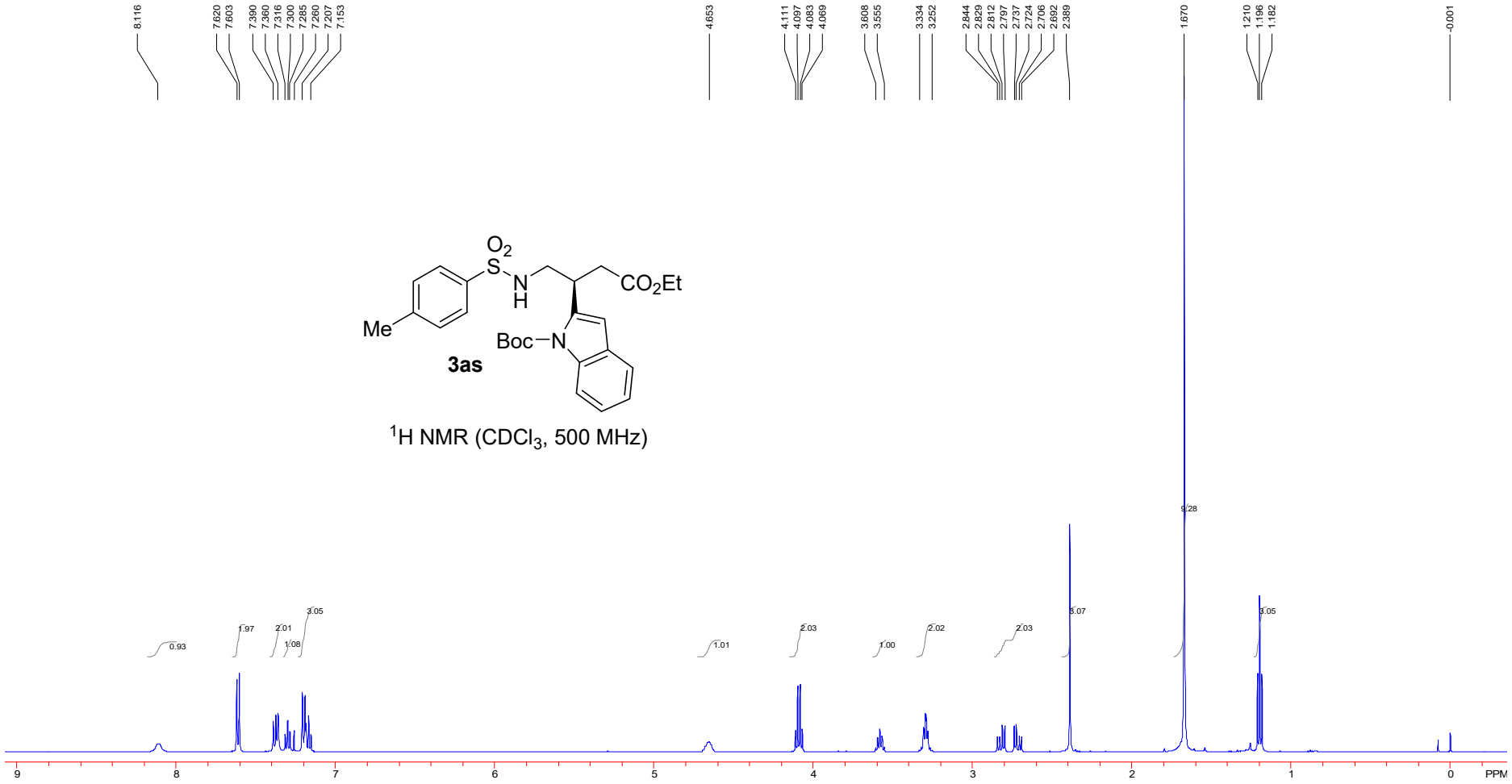

171.974
150.653
143.495
136.842
135.037
129.721
128.962
128.933
128.782
127.012
125.192
123.155
122.729
120.721
119.103
115.586
77.420
77.160
76.907
68.962
60.916
46.434
36.878
33.036
21.602
14.177
O2
S
N
H
CO2Et
Me
Cbz–N
3ap
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

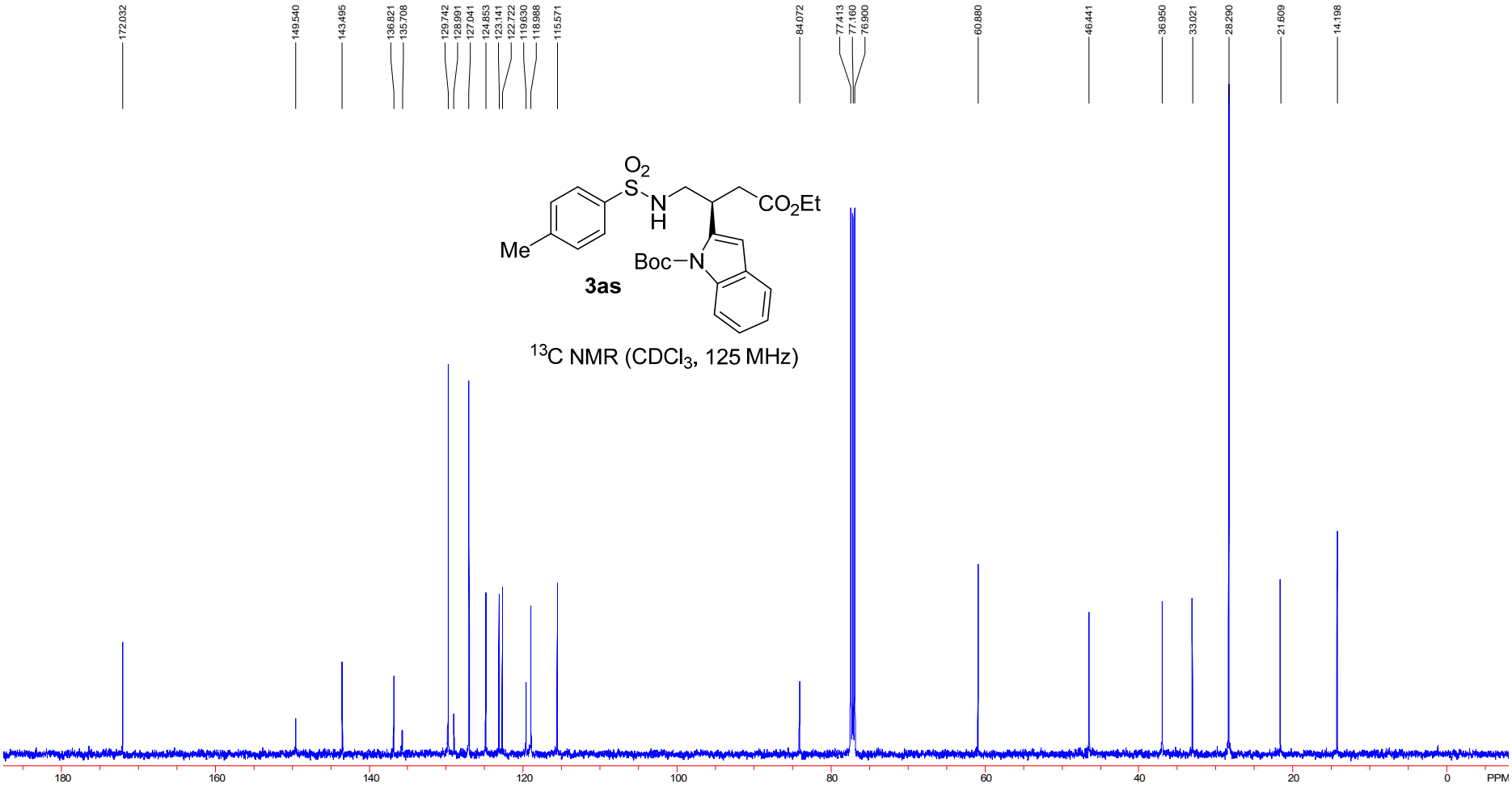

8.045
7.593
7.577
7.489
7.476
7.447
7.381
7.296
7.293
7.260
7.253
7.236
7.176
7.160
5.445
5.421
5.414
5.390
4.708
4.091
4.076
4.062
4.048
3.511
3.457
3.270
3.257
3.243
2.798
2.784
2.766
2.752
2.675
2.660
2.643
2.629
2.377
1.653
1.185
1.171
1.157
0.001
O2
S
N
H
CO2Et
Me
Cbz—N
Cl
3aq
1H NMR (CDCl3, 500 MHz)
0.91
4.06
2.01
2.07
0.98
2.00
1.00
2.00
1.01
1.05
2.98
3.00
8
7
6
5
4
3
2
1
0
PPM

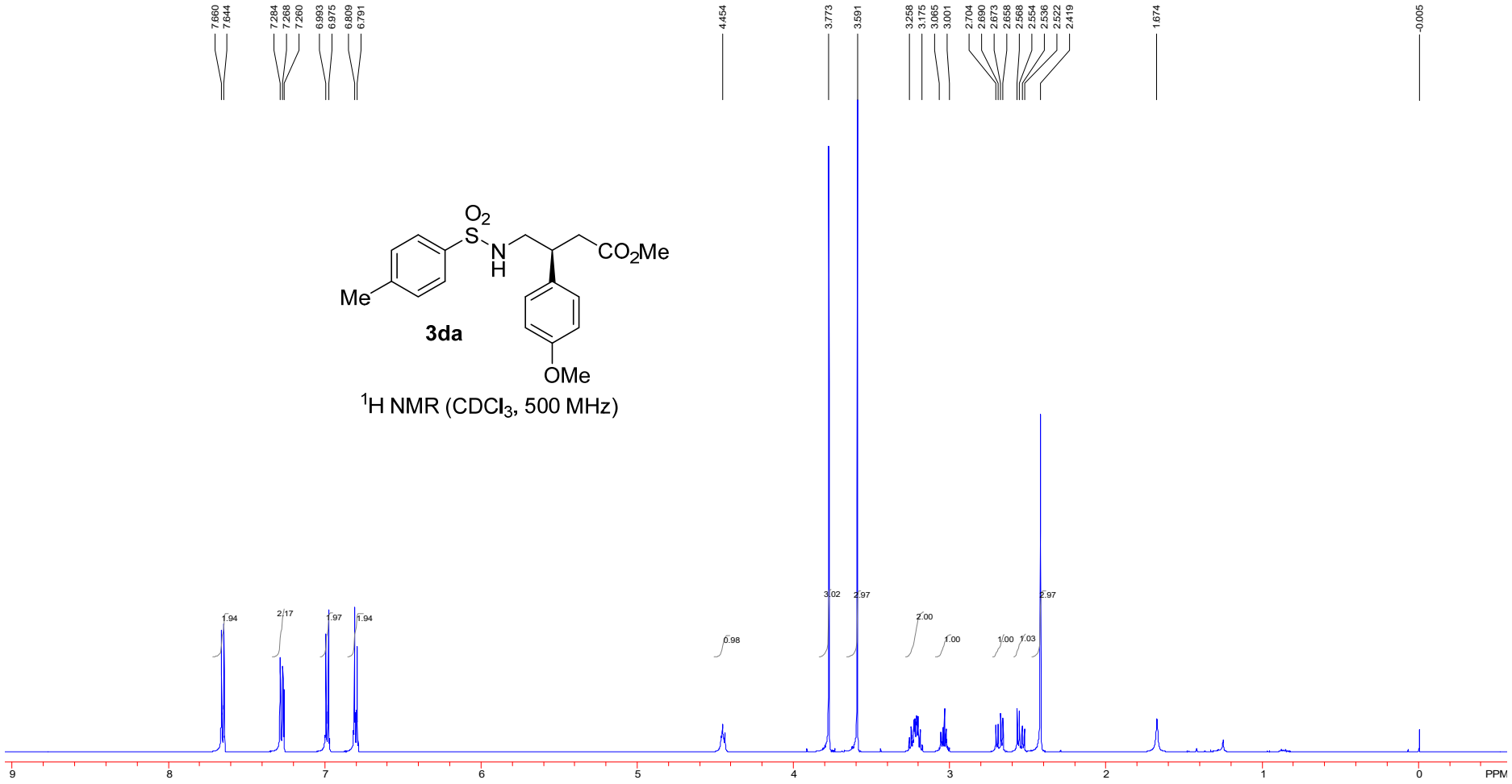

171.729
150.335
143.668
136.691
134.806
134.127
130.291
129.793
129.092
128.977
128.912
128.868
127.012
125.344
124.065
120.093
118.749
116.618
77.413
77.160
76.900
69.244
60.995
46.326
36.929
32.906
21.638
14.177
O2
S
N
H
CO2Et
Me
Cbz–N
Cl
3aq
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

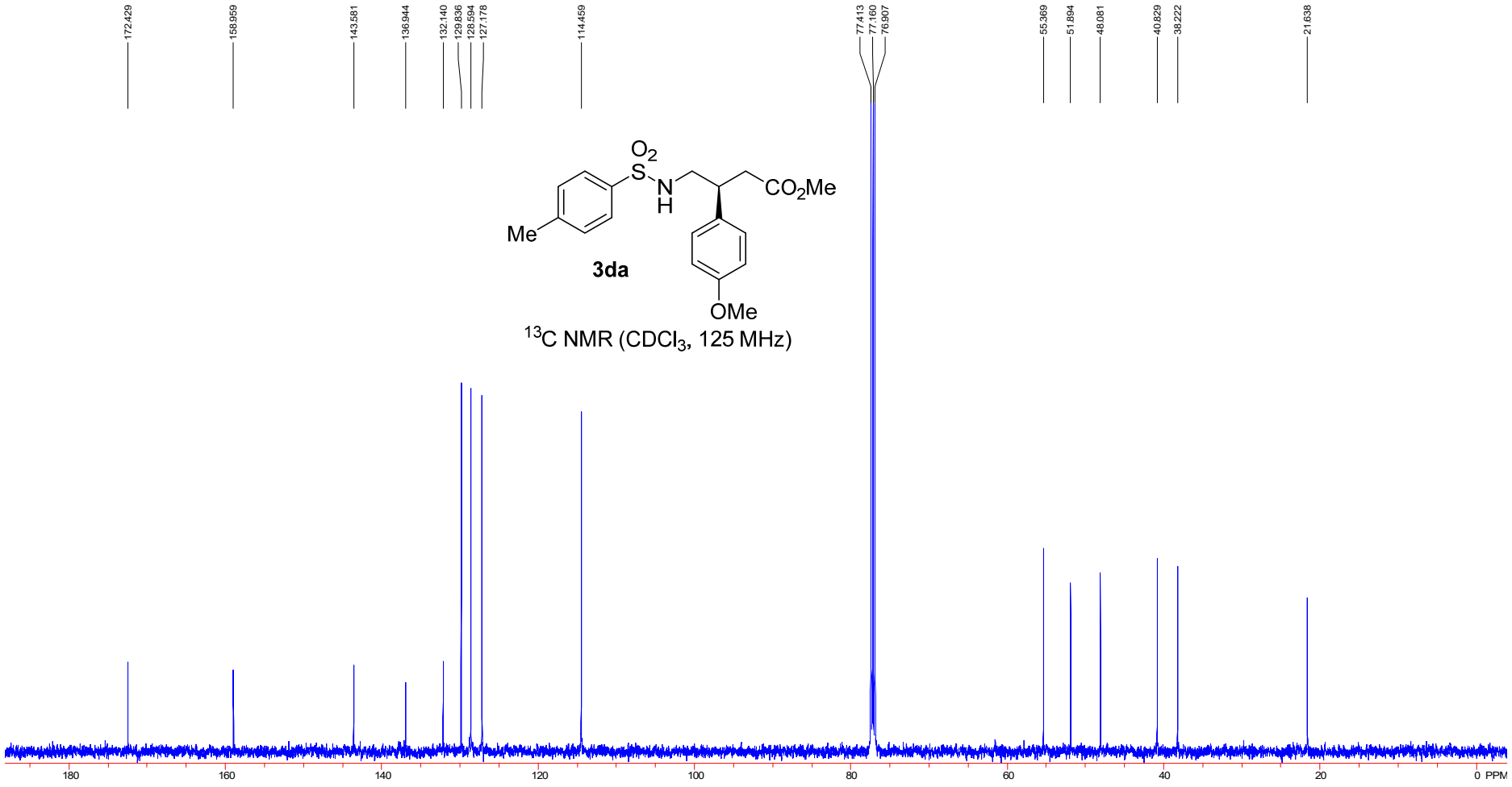

7.952
7.935
7.737
7.721
7.576
7.559
7.372
7.357
7.348
7.312
7.295
7.281
7.260
7.228
7.153
4.629
4.615
4.602
4.072
4.058
4.051
4.048
4.037
4.033
4.022
4.019
4.008
4.005
3.997
3.983
3.578
3.524
3.300
3.191
2.812
2.797
2.780
2.765
2.695
2.681
2.664
2.649
2.385
2.320
1.671
1.139
1.125
1.110
-0.002
O2
S
N
H
CO2Et
Me
Ts
N
3ar
1H NMR (CDCl3, 500 MHz)
1.00
2.02
2.00
2.06
1.00
5.03
0.99
2.01
1.00
2.02
2.04
3.00
3.04
3.00
9
8
7
6
5
4
3
2
1
0
PPM

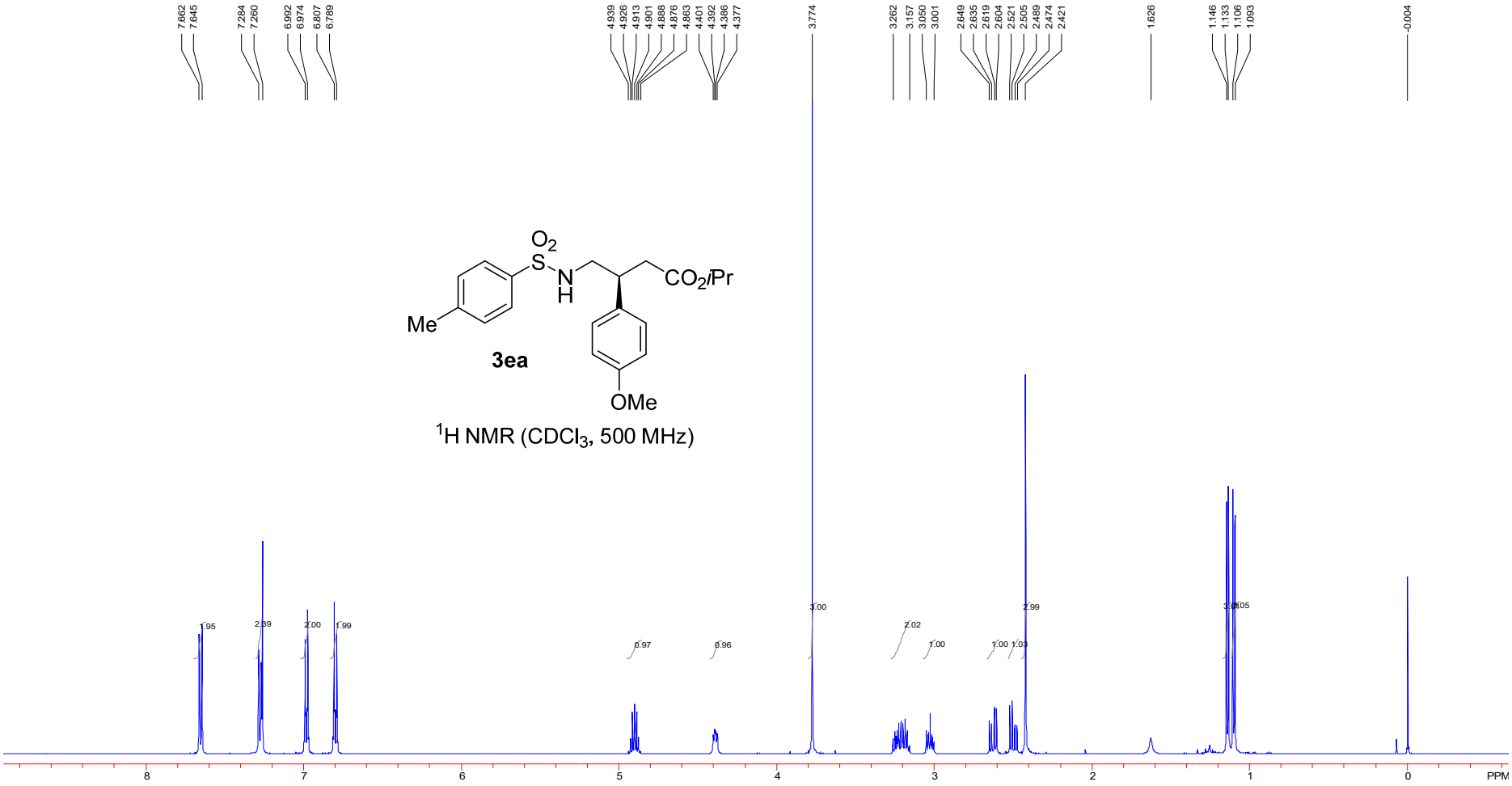

171.830
145.235
143.625
136.799
135.369
135.066
130.089
129.815
129.526
126.998
126.904
125.170
123.552
123.430
121.884
119.522
113.997
77.420
77.160
76.907
60.923
46.405
36.965
33.166
21.667
21.623
14.148
O2
S
N
H
CO2Et
Me
Ts
N
3ar
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

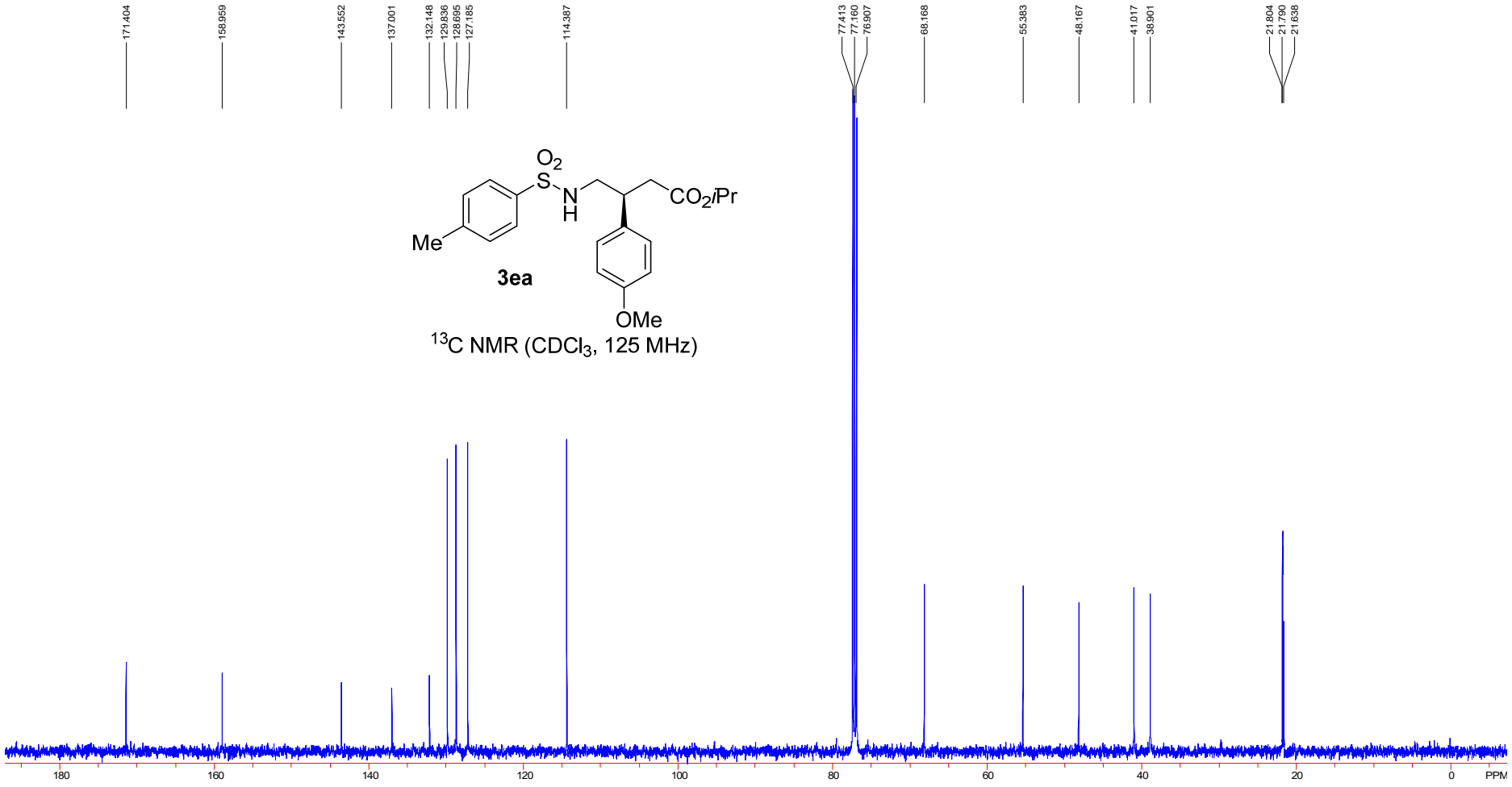

8.116
7.620
7.603
7.390
7.360
7.316
7.300
7.285
7.260
7.207
7.153
4.653
4.111
4.097
4.083
4.069
3.608
3.555
3.334
3.252
2.844
2.829
2.812
2.797
2.737
2.724
2.706
2.692
2.389
1.670
1.210
1.196
1.182
-0.001
O2
S
N
H
CO2Et
Me
Boc−N
3as
1H NMR (CDCl3, 500 MHz)
0.93
1.97
2.01
1.08
3.05
1.01
2.03
1.00
2.02
2.03
6.07
9.28
3.05
9
8
7
6
5
4
3
2
1
0
PPM

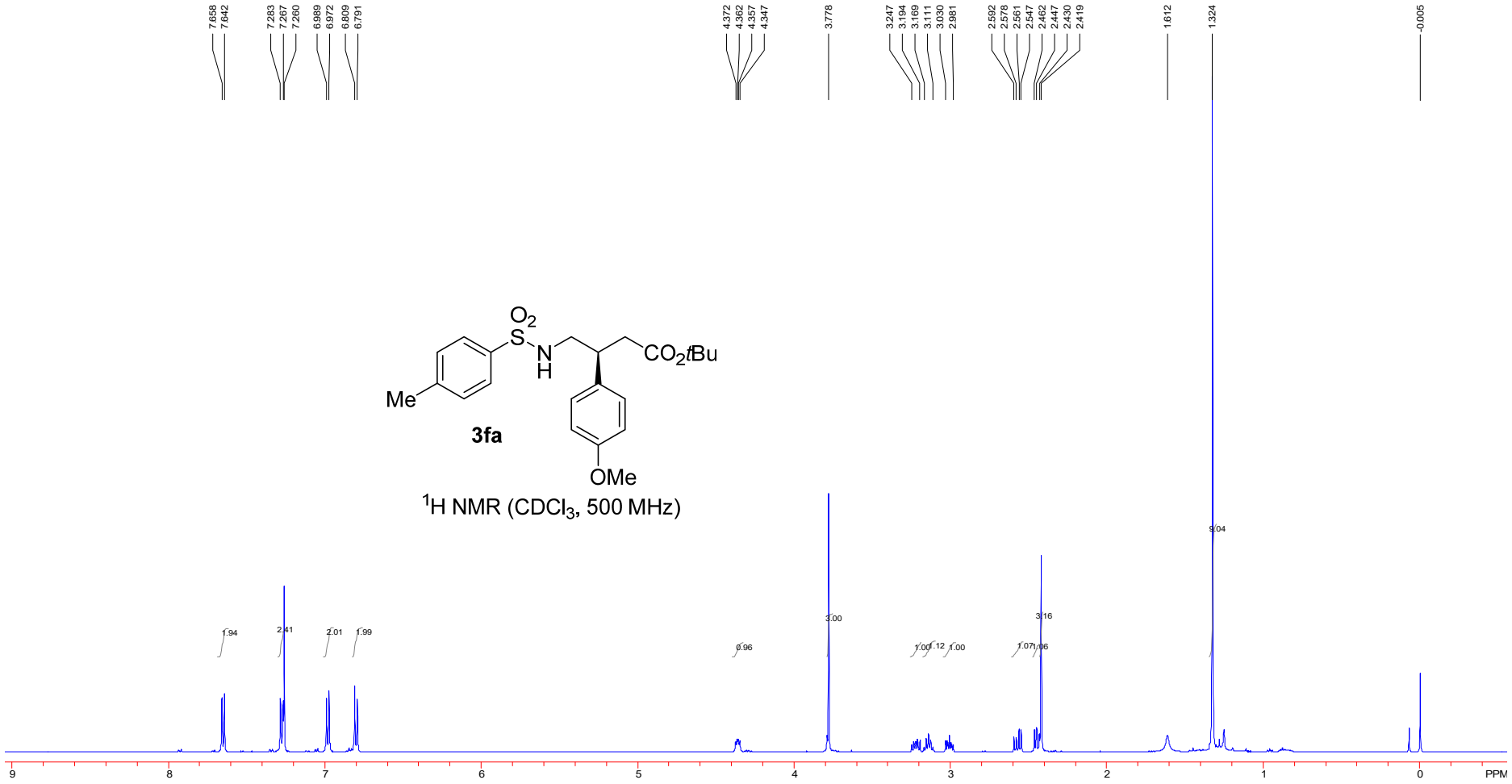

172.032
149.540
143.495
136.821
135.708
129.742
128.991
127.041
124.853
123.141
122.722
119.630
118.988
115.571
84.072
77.413
77.160
76.900
60.880
46.441
36.950
33.021
28.290
21.609
14.198
O2
S
N
H
CO2Et
Me
Boc—N
3as
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

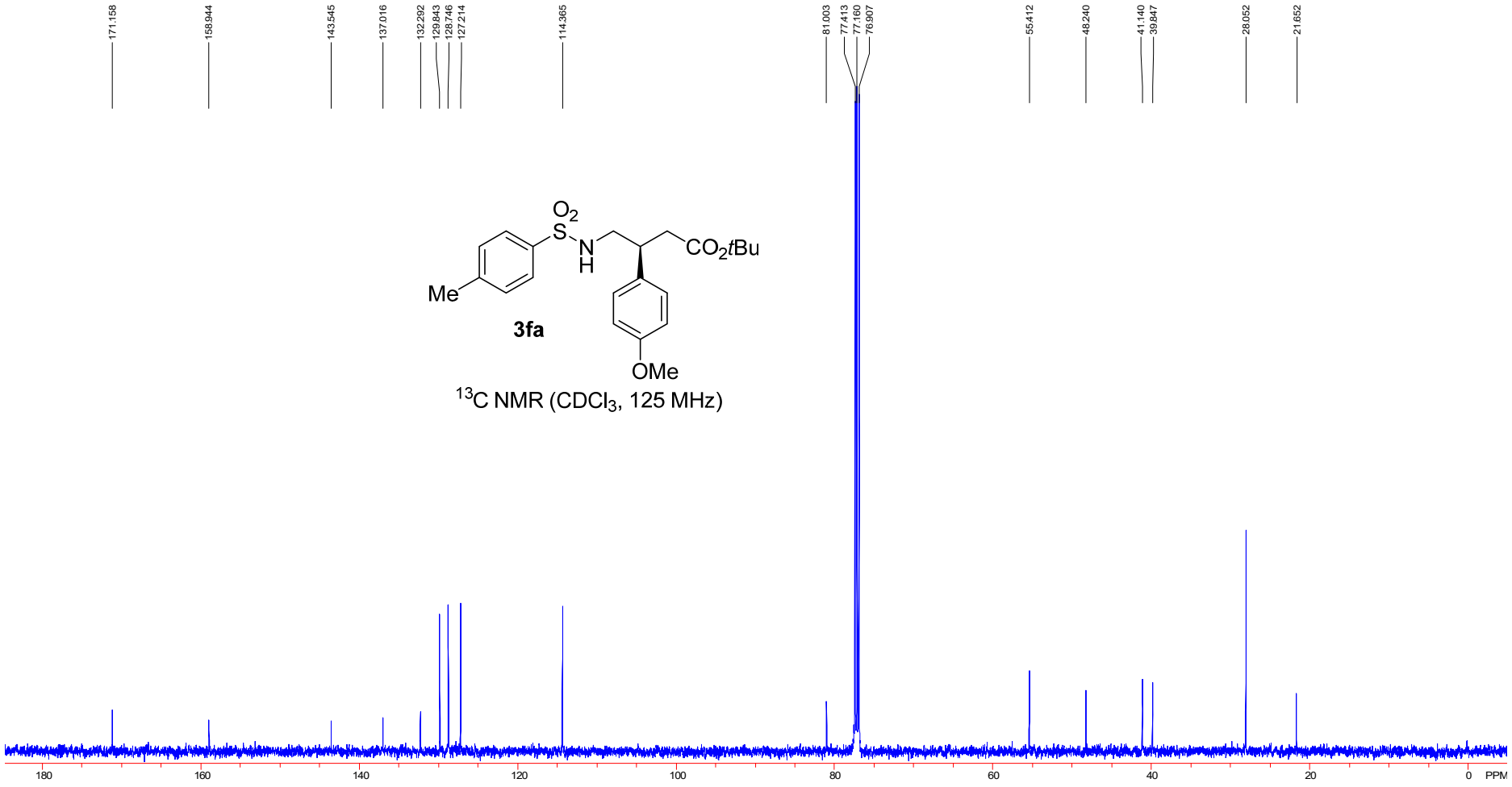

7.660
7.644
7.284
7.268
7.260
6.993
6.975
6.809
6.791
4.454
3.773
3.591
3.258
3.175
3.065
3.001
2.704
2.690
2.673
2.658
2.568
2.554
2.536
2.522
2.419
1.674
0.005
O2
S
N
H
CO2Me
Me
OMe
3da
1H NMR (CDCl3, 500 MHz)
1.94
2.17
1.97
1.94
0.98
3.02
2.97
2.00
1.00
1.00
1.03
2.97
9
8
7
6
5
4
3
2
1
0
PPM

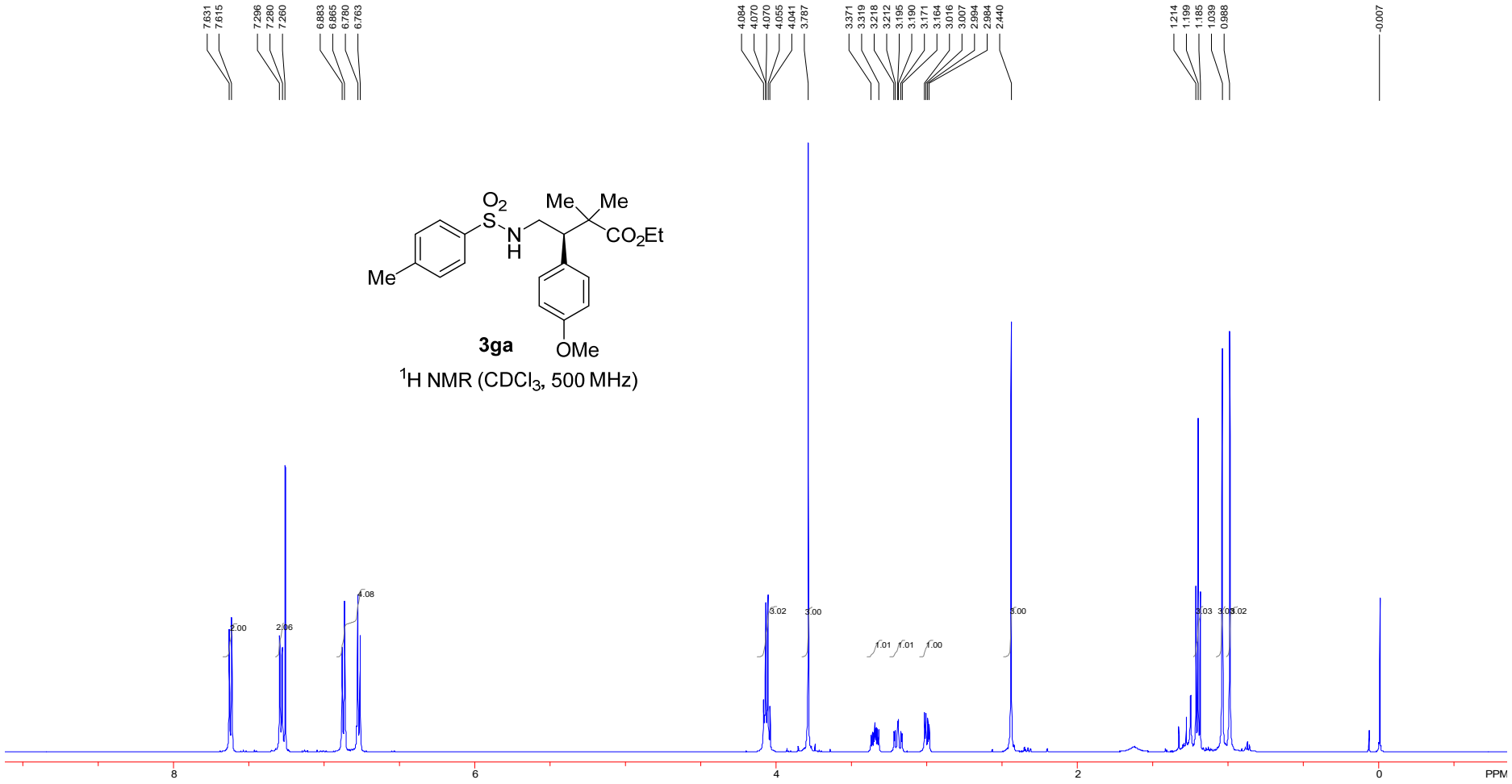

172.429
158.959
143.581
136.944
132.140
129.836
128.594
127.178
114.459
77.413
77.160
76.907
55.369
51.894
48.081
40.829
38.222
21.638
O2
S
N
H
CO2Me
Me
OMe
3da
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0 PPM

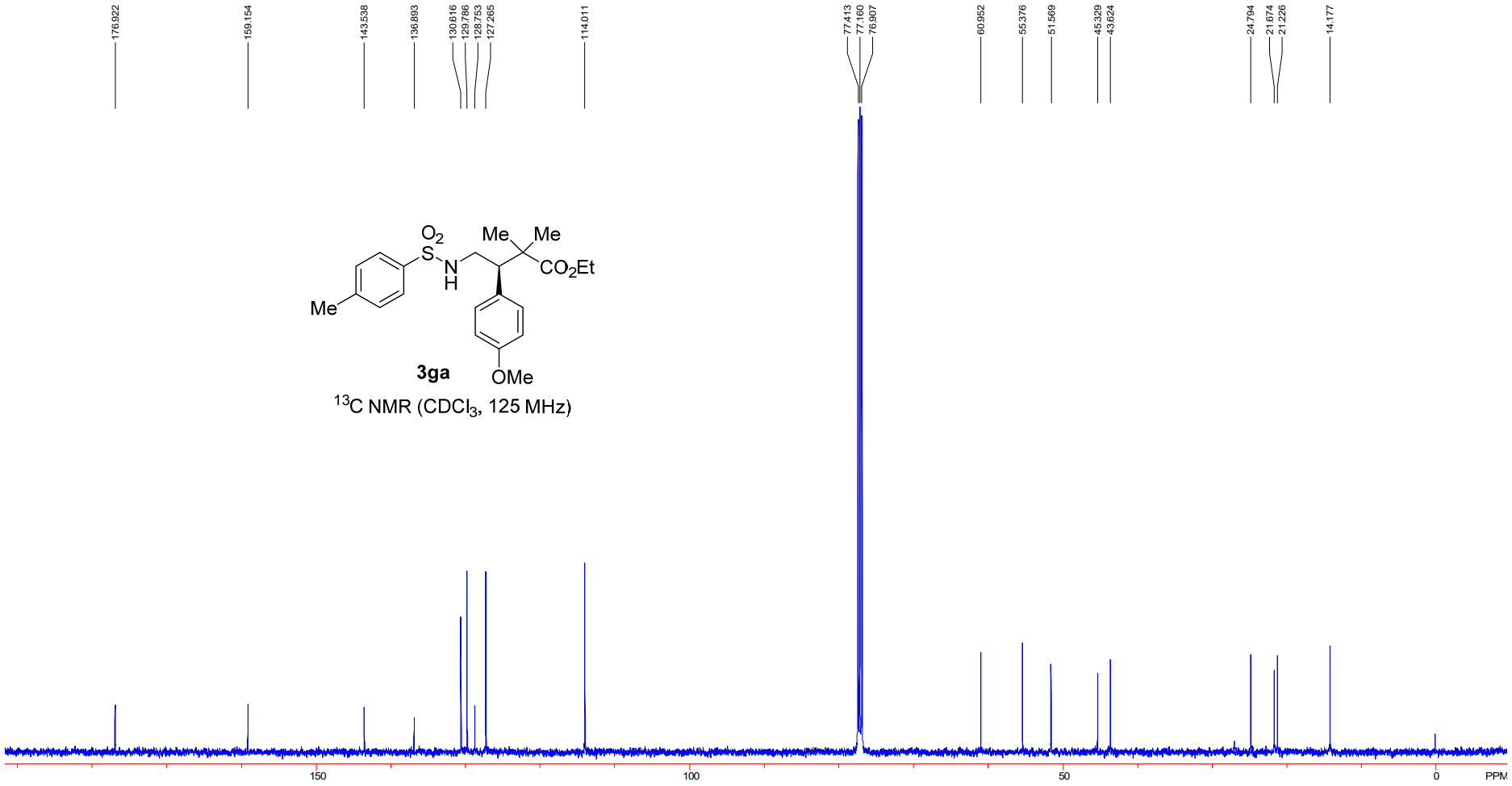

7.662
7.645
7.284
7.260
6.992
6.974
6.807
6.789
4.939
4.926
4.913
4.901
4.888
4.876
4.863
4.401
4.392
4.386
4.377
3.774
3.262
3.157
3.050
3.001
2.649
2.635
2.619
2.604
2.521
2.505
2.489
2.474
2.421
1.626
1.146
1.133
1.106
1.093
0.004
O2
S
N
H
CO2iPr
Me
OMe
3ea
1H NMR (CDCl3, 500 MHz)
1.95
2.39
2.00
1.99
0.97
0.96
3.00
2.02
1.00
1.00
1.03
2.99
3.05
8
7
6
5
4
3
2
1
0
PPM


171.404
158.959
143.552
137.001
132.148
129.836
128.695
127.185
114.387
77.413
77.160
76.907
68.168
55.383
48.167
41.017
38.901
21.804
21.790
21.638
O2
S
N
H
CO2iPr
Me
OMe
3ea
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM


7.658
7.642
7.283
7.267
7.260
6.989
6.972
6.809
6.791
4.372
4.362
4.357
4.347
3.778
3.247
3.194
3.169
3.111
3.030
2.981
2.592
2.578
2.561
2.547
2.462
2.447
2.430
2.419
1.612
1.324
-0.005
O2
S
N
H
CO2tBu
Me
OMe
3fa
1H NMR (CDCl3, 500 MHz)
1.94
2.41
2.01
1.99
0.96
3.00
1.00
1.12
1.00
1.07
3.16
1.06
9.04
9
8
7
6
5
4
3
2
1
0
PPM

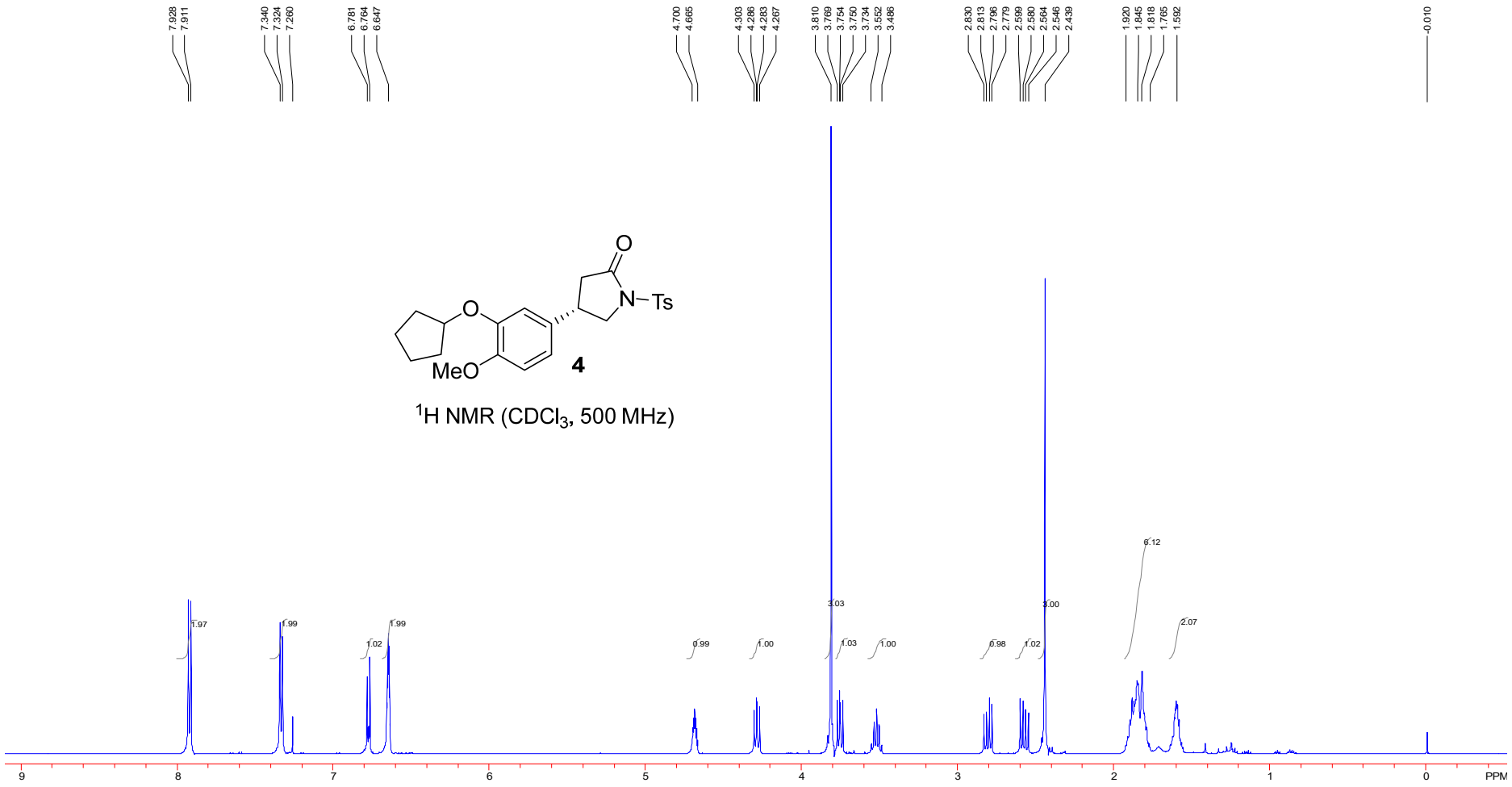

171.158
158.944
143.545
137.016
132.292
129.843
128.746
127.214
114.365
81.003
77.413
77.160
76.907
55.412
48.240
41.140
39.847
28.052
21.652
O2
S
N
H
CO2tBu
Me
OMe
3fa
13C NMR (CDCl3, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM

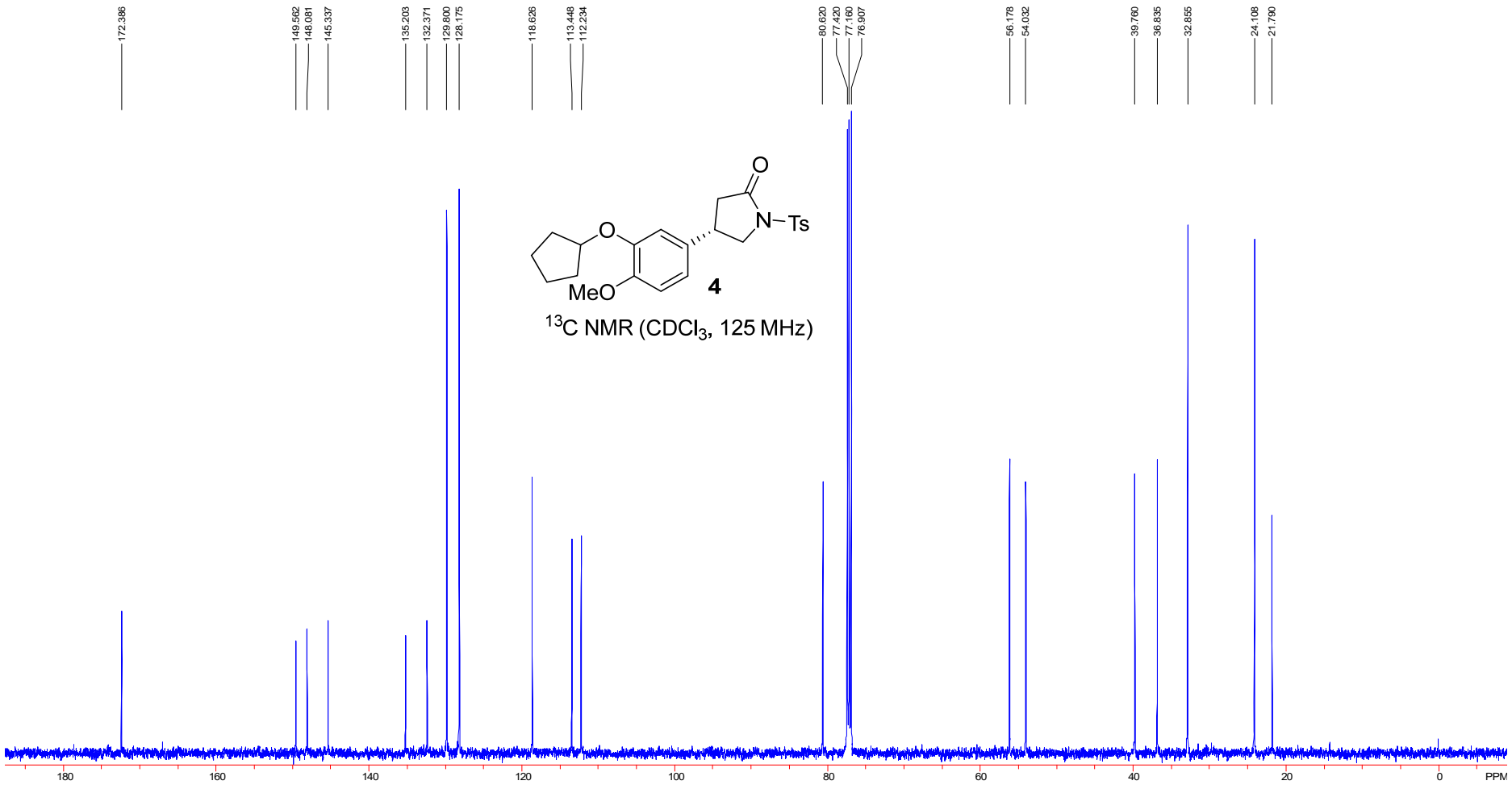

7.631
7.615
7.296
7.280
7.260
6.883
6.865
6.780
6.763
4.084
4.070
4.070
4.055
4.041
3.787
3.371
3.319
3.218
3.212
3.195
3.190
3.171
3.164
3.016
3.007
2.994
2.984
2.440
1.214
1.199
1.185
1.039
0.988
-0.007
O2
S
N
H
Me
Me
Me
CO2Et
OMe
3ga
1H NMR (CDCl3, 500 MHz)
2.00
2.06
4.08
3.02
3.00
1.01
1.01
1.00
3.00
3.03
3.03
3.02
8
6
4
2
0
PPM




**3ga**

$^{13}C$ NMR ($CDCl_3$, 125 MHz)


7.928
7.911
7.340
7.324
7.280
6.781
6.764
6.647
4.700
4.665
4.303
4.286
4.283
4.267
3.810
3.769
3.754
3.750
3.734
3.552
3.486
2.830
2.813
2.796
2.779
2.599
2.580
2.564
2.546
2.439
1.920
1.845
1.818
1.765
1.592
0.010
O
N–Ts
O
MeO
4
1H NMR (CDCl3, 500 MHz)
1.97
1.99
1.02
1.99
0.99
1.00
3.03
1.03
1.00
0.98
1.02
3.00
6.12
2.07
9
8
7
6
5
4
3
2
1
0
PPM


172.386
149.562
148.081
145.337
135.203
132.371
129.800
128.175
118.626
113.448
112.234
80.620
77.420
77.160
76.907
56.178
54.032
39.760
36.835
32.855
24.108
21.790
O
N–Ts
O
MeO
4
$^{13}$C NMR ($CDCl_3$, 125 MHz)
180
160
140
120
100
80
60
40
20
0
PPM