Stereodivergent Silver-Catalyzed Synthesis of Pyroglutamic Acid Esters

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Supporting Information

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I. General Information

Unless otherwise specified, all reactions were conducted with stirring under an atmosphere of nitrogen. All reagents including anhydrous solvents were purchased from Sigma Aldrich, TCI or Alfa Aesar and used as received. The glycine imine esters **1a**-**1c** were commercially available. α,β-Unsaturated esters were synthesized by the Steglich esterification of the corresponding α,β-unsaturated acids with alcohols.[1] Flash column chromatography was performed on silica gel 60 (40—63 μm) as a stationary phase. Diastereomeric ratios were determined from the crude mixtures.

NMR spectra were recorded with a Bruker AVANCE III HD 300 (300 MHz) or a Bruker AVANCE III HD 400 (400 MHz) at Yonsei University, using $CDCl_3$ as the solvent. Chemical shifts were expressed in parts per million (ppm, δ), referenced to the residual signal of $CDCl_3$ (7.26 ppm for ^1H, 77.16 ppm for ^{13}C). All coupling constants (*J*) were expressed in Hertz (Hz). The following abbreviations were used for the descriptions of splitting patterns: s = singlet, d = doublet, t = triplet, m = multiplet.

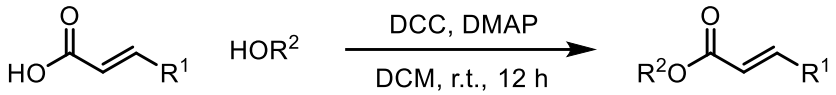
HPLC analyses were carried out on a Shimadzu LC-20A chromatograph with Daicel CHIRALCEL® columns (internal diameter 4.6mm, column length 250 mm, particle size 5μ).

High resolution mass spectra were obtained using an Agilent 6530 Accurate-Mass Q-TOF.

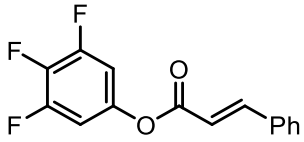
II. Synthesis of α,β-Unsaturated Esters

The procedures and yields have not been optimized for unsaturated aryl ester syntheses. Spectral data of (*E*)-**2a** matched those of the previous report.[2]

General procedure A: *Synthesis of α,β-unsaturated esters via Steglich esterification.*[1]



α,β-Unsaturated carboxylic acid (5.0 mmol, 1.0 equiv), the corresponding alcohol (5.5 mmol, 1.1 equiv) and DCM (30 mL) were added in a 100 mL round-bottom flask with a stir bar, and the mixture was then cooled to 0 °C for 10 min. To this suspension, DCC (5.5 mmol, 1.1 equiv) and DMAP (0.5 mmol, 0.1 equiv) were added. The reaction mixture was stirred at r.t. for 12 h. *aq*. HCl (1.0 M, 15 mL) was added at –10 °C. After 6 h, the resulting suspension was filtered over celite to remove urea, and the residue was washed with DCM. The organic phase was washed with sat. *aq*. $NaHCO_3$ and brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel (100/0 to 30/1 of hexane/EtOAc).



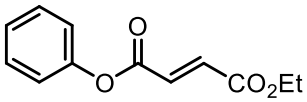
3,4,5-Trifluorophenyl cinnamate (Table 2, entry 3). The title compound was prepared with *trans*-cinnamic acid and 3,4,5-trifluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.03 g, 74% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88 (d, *J* = 16.0 Hz, 1H), 7.64 – 7.54 (m, 2H), 7.50 – 7.39 (m, 3H), 6.96 – 6.84 (m, 2H), 6.58 (d, *J* = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.57 (s), 152.54 – 149.56 (m), 147.92 (s), 145.71 – 145.17 (m), 139.47 – 136.55 (m), 133.77 (s), 131.18 (s), 129.11 (s), 128.47 (s), 116.04 (s), 107.26 – 106.88 (m).

^{19}F NMR (282 MHz, $CDCl_3$) δ -132.94 (d, *J* = 20.8 Hz), -161.06 – -166.31 (m).

HRMS (ESI) m/z calcd for $C_{15}H_9F_3O_2$ $[M + H]^+$: 279.0633, found: 279.0627.

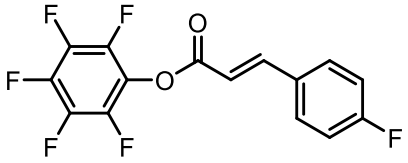


Ethyl phenyl fumarate(Table S3B, entry 1). The title compound was prepared with (*E*)-4-ethoxy-4-oxobut-2-enoic acid and phenol according to **General Procedure A**, affording the title compound as a colorless oil (1.05 g, 95% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63 – 7.55 (m, 2H), 7.48 – 7.41 (m, 1H), 7.40 – 7.33 (m, 2H), 7.26 (s, 2H), 4.48 (q, *J* = 7.1 Hz, 2H), 1.52 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 164.49 (s), 163.21 (s), 150.39 (s), 135.20 (s), 132.71 (s), 129.47 (s), 126.12 (s), 121.31 (s), 61.40 (s), 14.02 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{12}O_4$ $[M + H]^+$: 221.0814, found: 221.0808.



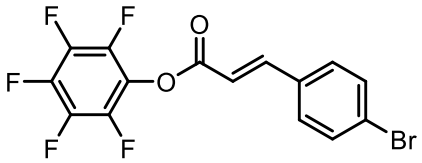
Perfluorophenyl (*E*)-3-(4-fluorophenyl)acrylate (2b). The title compound was prepared with 4-fluorocinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.49 g, 90% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94 (d, *J* = 16.0 Hz, 1H), 7.69 – 7.57 (m, 2H), 7.22 – 7.10 (m, 2H), 6.60 (dd, *J* = 16.0, 0.5 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 165.86 (s), 162.94 (d, *J* = 82.2 Hz), 148.02 (s), 130.64 (d, *J* = 8.8 Hz), 129.83 (d, *J* = 3.3 Hz), 116.33 (d, *J* = 22.1 Hz), 113.85 (d, *J* = 2.3 Hz).

^{19}F NMR (282 MHz, $CDCl_3$) δ -107.32 (s), -151.57 – -153.59 (m), -157.03 – -158.90 (m), -160.92 – -163.41 (m).

HRMS (ESI) m/z calcd for $C_{15}H_6F_6O_2$ $[M + H]^+$: 333.0345, found: 333.0272.



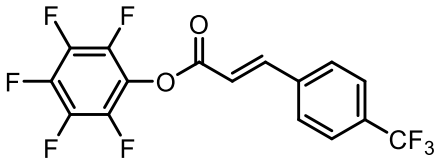
Perfluorophenyl (*E*)-3-(4-bromophenyl)acrylate (2c). The title compound was prepared with 4-bromocinnmic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.63 g, 83% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 16.0 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.47 (d, *J* = 8.4 Hz, 2H), 6.66 (d, *J* = 16.0 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.39 (s), 147.93 (s), 132.41 (s), 132.39 (s), 129.89 (s), 125.97 (s), 114.81 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -152.38 – -152.77 (m), -157.85 – -158.26 (m), -162.13 – -162.76 (m).

HRMS (ESI) m/z calcd for $C_{15}H_6BrF_5O_2$ $[M + H]^+$: 392.9544, found: 392.9471.

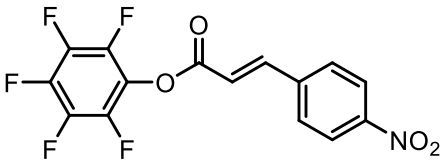


Perfluorophenyl (*E*)-3-(4-(trifluoromethyl)phenyl)acrylate (2d). The title compound was prepared according to **General Procedure A** from 4-(trifluoromethyl)cinnamic acid and pentafluorophenol, affording the title compound as a white solid (1.55 g, 81% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.99 (d, *J* = 16.0 Hz, 1H), 7.74 (s, 4H), 6.76 (d, *J* = 16.1 Hz, 1H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 162.10 (s), 147.34 (s), 128.68 (s), 126.13 (s), 126.08 (s), 126.03 (s), 125.97 (s), 116.84 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -62.66 – -63.47 (m), -152.46 (d, *J* = 16.7 Hz), -157.76 (s), -162.18 (d, *J* = 4.8 Hz).



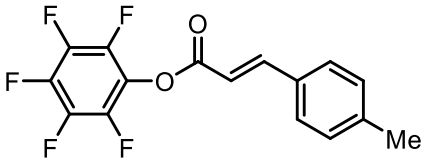
Perfluorophenyl (*E*)-3-(4-nitrophenyl)acrylate (2e). The title compound was prepared with 4-nitrocinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.51 g, 84% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (dd, *J* = 8.7, 1.9 Hz, 2H), 8.01 (d, *J* = 16.1 Hz, 1H), 7.86 – 7.73 (m, 2H), 6.81 (dd, *J* = 16.1, 1.6 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.80 (s), 149.12 (s), 146.22 (s), 139.38 (s), 129.24 (s), 124.35 (s), 118.54 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -152.01 – -152.67 (m), -157.04 – -157.76 (m), -161.61 – -162.37 (m).

HRMS (ESI) m/z calcd for $C_{15}H_6F_5NO_4$ $[M - H]^-$: 358.0144, found: 358.0217.



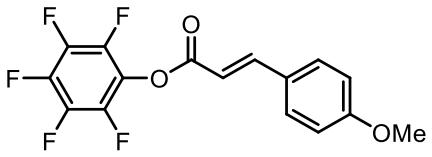
Perfluorophenyl (*E*)-3-(p-tolyl)acrylate (2f). The title compound was prepared with 4-methylcinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.58 g, 88% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.95 (d, *J* = 16.0 Hz, 1H), 7.53 (d, *J* = 8.2 Hz, 2H), 7.27 (d, *J* = 7.1 Hz, 2H), 6.62 (d, *J* = 16.0 Hz, 1H), 2.43 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.86 (s), 149.51 (s), 142.27 (s), 130.85 (s), 129.85 (s), 128.66 (s), 112.90 (s), 21.52 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -150.13 – -154.04 (m), -156.52 – -158.72 (m), -161.20 – -164.26 (m).

HRMS (ESI) m/z calcd for $C_{16}H_9F_5O_2$ $[M + H]^+$: 329.0601, found: 329.0595.



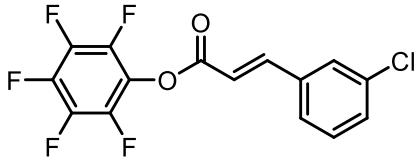
Perfluorophenyl (*E*)-3-(4-methoxyphenyl)acrylate (2g). The title compound was prepared with *trans*-4-methoxycinnmic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.48 g, 86% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (d, *J* = 15.9 Hz, 1H), 7.55 (d, *J* = 8.8 Hz, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 6.51 (d, *J* = 15.9 Hz, 1H), 3.87 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.94 (s), 162.44 (s), 149.11 (s), 130.45 (s), 126.28 (s), 114.47 (s), 111.20 (s), 55.28 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -152.19 – -153.41 (m), -158.46 – -159.50 (m), -162.26 – -163.85 (m).

HRMS (ESI) m/z calcd for $C_{16}H_9F_5O_3$ $[M + H]^+$: 345.0545, found: 345.0472.



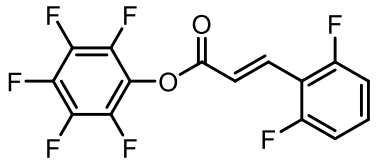
Perfluorophenyl (*E*)-3-(3-chlorophenyl)acrylate (2h). The title compound was prepared with 3-chlorocinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.29 g, 74% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.90 (d, *J* = 16.0 Hz, 1H), 7.62 (t, *J* = 1.8 Hz, 1H), 7.55 – 7.37 (m, 3H), 6.68 (d, *J* = 16.0 Hz, 1H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 162.24 (s), 147.70 (s), 135.30 (s), 135.24 (s), 131.30 (s), 130.37 (s), 128.28 (s), 126.77 (s), 115.74 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -151.92 – -153.12 (m), -157.62 – -158.47 (m), -161.66 – -162.90 (m).

HRMS (ESI) m/z calcd for $C_{15}H_6ClF_5O_2$ $[M + H]^+$: 349.0049, found: 348.9976.



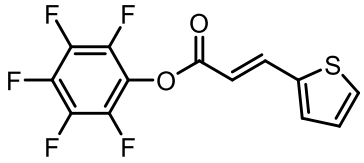
Perfluorophenyl (*E*)-3-(2,6-difluorophenyl)acrylate (2i). The title compound was prepared with 2,6-*trans*-difluorocinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as an off-white solid (1.33 g, 76% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 16.4 Hz, 1H), 7.48 – 7.35 (m, 1H), 7.05 – 7.00 (m, 2H), 6.98 (d, *J* = 11.6 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 163.21 (d, *J* = 6.3 Hz), 162.64 (s), 160.65 (d, *J* = 6.4 Hz), 135.33 (s), 132.56 (t, *J* = 11.2 Hz), 120.04 (t, *J* = 9.3 Hz), 112.26 – 111.58 (m).

^{19}F NMR (377 MHz, $CDCl_3$) δ -109.37 (s), -151.13 – -153.62 (m), -157.10 – -158.94 (m), -161.42 – -163.70 (m).

HRMS (ESI) m/z calcd for $C_{15}H_5F_7O_2$ $[M + H]^+$: 351.0251, found: 351.0178.



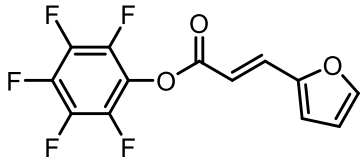
Perfluorophenyl (*E*)-3-(thiophen-2-yl)acrylate (2j). The title compound was prepared with 2-thiopheneacrylic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as an off-white solid (1.12 g, 70% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 15.6 Hz, 1H), 7.51 (t, *J* = 7.2 Hz, 1H), 7.40 (d, *J* = 3.6 Hz, 1H), 7.13 (dt, *J* = 9.3, 4.6 Hz, 1H), 6.44 (d, *J* = 15.6 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.56 (s), 141.57 (s), 138.72 (s), 132.86 (s), 130.42 (s), 128.48 (s), 112.45 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -149.71 – -154.04 (m), -156.88 – -160.22 (m), -161.00 – -165.33 (m).

HRMS (ESI) m/z calcd for $C_{13}H_5F_5O_2S$ $[M + H]^+$: 321.0003, found: 320.9930.



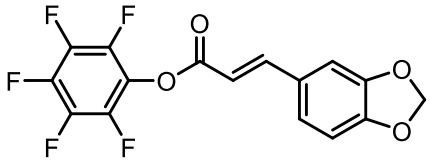
Perfluorophenyl (*E*)-3-(furan-2-yl)acrylate (2k). The title compound was prepared with 3-(2-furyl)acrylic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as an off-white solid (0.821 g, 54% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 15.6 Hz, 1H), 7.59 (d, *J* = 1.4 Hz, 1H), 6.79 (d, *J* = 3.4 Hz, 1H), 6.56 (dd, *J* = 3.4, 1.8 Hz, 1H), 6.54 – 6.48 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.74 (s), 150.30 (s), 146.07 (s), 134.87 (s), 117.34 (s), 112.80 (s), 111.39 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -151.66 – -153.47 (m), -158.00 – -159.29 (m), -161.99 – -163.80 (m).

HRMS (ESI) m/z calcd for $C_{13}H_5F_5O_3$ $[M + H]^+$: 305.0232, found: 305.0159.



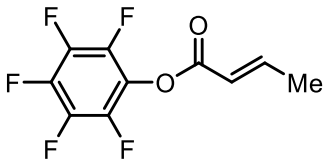
Perfluorophenyl (*E*)-3-(benzo[d][1,3]dioxol-5-yl)acrylate (2l). The title compound was prepared with 3,4-(methylenedioxy)cinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellow solid (1.18 g, 66% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.85 (d, *J* = 15.9 Hz, 1H), 7.11 – 7.06 (m, 2H), 6.89 – 6.82 (m, 1H), 6.46 (d, *J* = 15.9 Hz, 1H), 6.05 (s, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.85 (s), 150.71 (s), 149.10 (s), 148.58 (s), 127.99 (s), 125.76 (s), 111.72 (s), 108.64 (s), 106.55 (s), 101.89 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -148.72 – -155.24 (m), -155.67 – -160.42 (m), -160.78 – -172.06 (m).

HRMS (ESI) m/z calcd for $C_{16}H_7F_5O_4$ $[M + H]^+$: 359.0337, found: 359.0264.



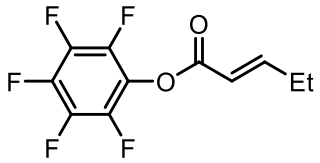
Perfluorophenyl (*E*)-but-2-enoate (2m). The title compound was prepared with crotonic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a colorless oil (1.10 g, 87% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.43 – 7.22 (m, 1H), 6.17 – 6.03 (m, 1H), 2.04 (dd, *J* = 7.0, 1.7 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 161.86 (s), 150.49 (s), 119.43 (s), 18.40 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -150.91 – -154.82 (m), -158.75 (dd, *J* = 24.5, 18.9 Hz), -161.42 – -165.53 (m).

HRMS (ESI) m/z calcd for $C_{10}H_5F_5O_2$ $[M + Na]^+$: 275.0102, found: 275.0107.



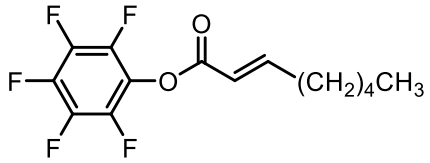
Perfluorophenyl (*E*)-pent-2-enoate (2n). The title compound was prepared with *trans*-pentenoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a colorless oil (1.22 g, 92% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38 (dt, *J* = 15.7, 6.3 Hz, 1H), 6.14 – 6.01 (m, 1H), 2.47 – 2.31 (m, 2H), 1.21 – 1.12 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.13 (s), 156.48 (s), 116.99 (s), 25.75 (s), 11.60 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -151.87 – -154.20 (m), -158.14 – -159.70 (m), -162.37 – -164.45 (m).

HRMS (ESI) m/z calcd for $C_{11}H_7F_5O_2$ $[M + H]^+$: 267.0439, found: 267.0366.



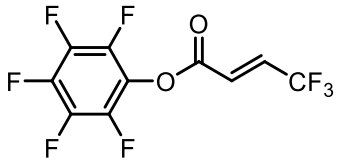
Perfluorophenyl (*E*)-oct-2-enoate (2o). The title compound was prepared with *trans*-2-octenoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a colorless oil (1.40 g, 91% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (dt, *J* = 15.6, 6.9 Hz, 1H), 6.08 (dt, *J* = 15.6, 1.5 Hz, 1H), 2.40 – 2.29 (m, 2H), 1.61 – 1.52 (m, 2H), 1.43 – 1.33 (m, 4H), 0.98 – 0.91 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.06 (s), 155.43 (s), 117.74 (s), 32.65 (s), 31.33 (s), 27.38 (s), 22.39 (s), 13.77 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -152.17 – -153.28 (m), -158.09 – -158.96 (m), -162.06 – -163.20 (m).

HRMS (ESI) m/z calcd for $C_{14}H_{13}F_5O_2$ $[M + Na]^+$: 331.0733, found: 331.0728.



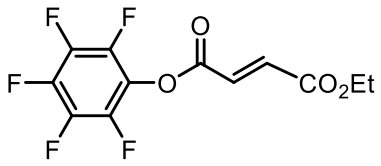
Perfluorophenyl (*E*)-4,4,4-trifluorobut-2-enoate (2p). The title compound was prepared with (*E*)-4,4,4-trifluorobut-2-enoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a colorless oil (1.36 g, 89% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18 – 6.98 (m, 1H), 6.84 – 6.67 (m, 1H).

^{13}C NMR (101 MHz, CDCl3) δ 159.73 (s), 135.34 (s), 125.48 (q, J = 6.3 Hz), 122.36 (t, J = 217.0 Hz).

^{19}F NMR (377 MHz, $CDCl_3$) δ -66.80 (s), -152.85 – -153.64 (m), -157.44 – -157.99 (m), -162.39 – -163.20 (m).

HRMS (ESI) m/z calcd for $C_{10}H_2F_8O_2$ [M - H]$^-$: 304.9849, found: 304.9854.



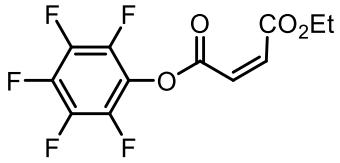
Ethyl (perfluorophenyl) fumarate (2q). The title compound was prepared with (*E*)-4-ethoxy-4-oxobut-2-enoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellowish oil (1.35 g, 87% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.17 – 7.01 (m, 2H), 4.32 (q, *J* = 7.1 Hz, 2H), 1.36 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 163.96 (s), 160.78 (s), 137.77 (s), 129.63 (s), 61.82 (s), 13.97 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -151.96 – -153.00 (m), -157.13 – -157.80 (m), -161.45 – -162.81 (m).

HRMS (ESI) m/z calcd for $C_{12}H_7F_5O_4$ [M + H]$^+$: 311.0343, found: 311.0337.



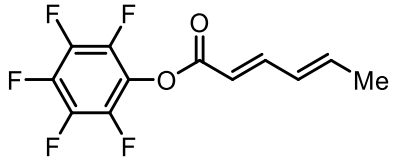
Ethyl (perfluorophenyl) maleate ((*Z*)-2q). The title compound was prepared with (*Z*)-4-Ethoxyoxy-4-oxobut-2-enoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellowish oil (1.32 g, 85% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.57 (d, *J* = 12.0 Hz, 1H), 6.46 (d, *J* = 12.0 Hz, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 1.30 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.59 (s), 160.50 (s), 134.79 (s), 124.97 (s), 61.88 (s), 13.63 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -151.29 – -153.16 (m), -157.18 – -158.60 (m), -161.64 – -163.19 (m).

HRMS (ESI) m/z calcd for $C_{12}H_7F_5O_4$ [M + H]$^+$: 311.0337, found:311.0265.



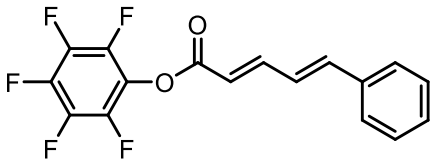
Perfluorophenyl (2*E*,4*E*)-hexa-2,4-dienoate (2r). The title compound was prepared with sorbic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.17 g, 84% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.61 – 7.42 (m, 1H), 6.42 – 6.24 (m, 2H), 6.00 (d, *J* = 15.0 Hz, 1H), 1.99 – 1.85 (m, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 162.78 (s), 149.68 (s), 143.00 (s), 129.49 (s), 114.83 (s), 18.71 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -151.32 – -154.14 (m), -157.83 – -161.46 (m), -161.63 – -164.84 (m).

HRMS (ESI) m/z calcd for $C_{12}H_7F_5O_2$ $[M + H]^+$: 279.0439, found:279.0366.



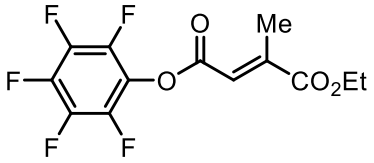
Perfluorophenyl (2*E*,4*E*)-5-phenylpenta-2,4-dienoate (2s). The title compound was prepared with 5-phenyl-2,4-pentadienoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.19 g, 70% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.74 (dd, *J* = 15.2, 9.9 Hz, 1H), 7.57 – 7.49 (m, 2H), 7.48 – 7.37 (m, 3H), 7.10 – 6.93 (m, 2H), 6.22 (d, *J* = 15.2 Hz, 1H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 162.63 (s), 149.32 (s), 143.43 (s), 135.52 (s), 129.81 (s), 128.95 (s), 127.58 (s), 125.51 (s), 116.78 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -150.56 – -155.24 (m), -156.52 – -160.00 (m), -160.78 – -165.75 (m).

HRMS (ESI) m/z calcd for $C_{17}H_9F_5O_2$ $[M + H]^+$: 341.0595, found:341.0523.



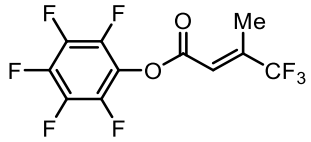
1-Ethyl 4-(perfluorophenyl) 2-methylfumarate (2t). The title compound was prepared with 4-(*tert*-butyl) 1-ethyl 2-methylfumarate[1] and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellow oil (1.20 g, 74% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.05 – 7.01 (m, 1H), 4.36 – 4.25 (m, 2H), 2.38 (d, *J* = 1.6 Hz, 3H), 1.44 – 1.32 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 166.03 (s), 161.32 (s), 149.74 (s), 122.46 (s), 62.06 (s), 14.75 (s), 13.96 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -152.09 – -153.09 (m), -157.74 – -158.27 (m), -162.11 – -162.84 (m).

HRMS (ESI) m/z calcd for C13H9F5O4 $[M + H]^+$: 325.0494, found:325.0421.

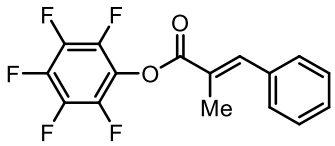


Perfluorophenyl (*E*)-4,4,4-trifluoro-3-methylbut-2-enoate (2u). The title compound was prepared with (*E*)-4,4,4-trifluoro-3-methylbut-2-enoic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a colorless oil (1.22 g, 76% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 6.64 (dt, *J* = 2.8, 1.4 Hz, 1H), 2.37 (d, *J* = 1.6 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 160.35 (s), 148.77 – 146.73 (m), 122.52 (q, *J* = 274.6 Hz), 118.04 (q, *J* = 6.0 Hz), 12.79 (d, *J* = 1.2 Hz).

^{19}F NMR (282 MHz, $CDCl_3$) δ -71.83 (s), -151.98 – -153.40 (m), -156.10 – -158.51 (m), -161.84 – -163.90 (m).



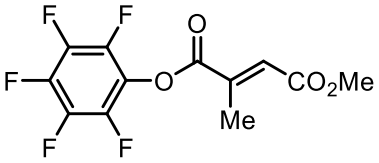
Perfluorophenyl (*E*)-2-methyl-3-phenylacrylate (2v). The title compound was prepared with *α*-methylcinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellowish solid (1.53 g, 93% yield).

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, *J* = 0.9 Hz, 1H), 7.57 – 7.43 (m, 5H), 2.33 (d, *J* = 1.3 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 164.56 (s), 143.32 (s), 134.96 (s), 130.02 (s), 129.33 (s), 128.58 (s), 125.36 (s), 14.19 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -149.28 – -155.88 (m), -156.88 – -160.21 (m), -160.42 – -166.10 (m).

HRMS (ESI) m/z calcd for $C_{16}H_9F_5O_2$ $[M + H]^+$: 329.0595, found: 329.0523.



4-Methyl 1-(perfluorophenyl) 2-methylfumarate (2w). The title compound was prepared with (*E*)-4-methoxy-2-methyl-4-oxobut-2-enoic acid[3] and pentafluorophenol according to **General Procedure A**, affording the title compound as a yellow oil (1.47 g, 95% yield).

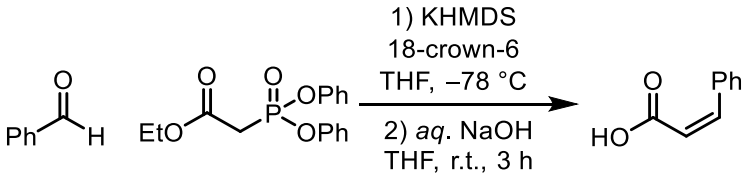
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 (dd, *J* = 3.0, 1.5 Hz, 1H), 3.82 (s, 3H), 2.42 (d, *J* = 1.6 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 165.38 (s), 163.14 (s), 140.42 (s), 129.97 (s), 51.89 (s), 14.23 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -152.69 – -153.11 (m), -157.54 – -157.98 (m), -162.12 – -162.73 (m).

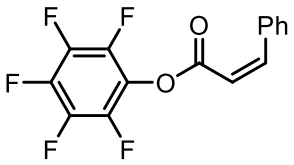
HRMS (ESI) m/z calcd for $C_{12}H_7F_5O_4$ $[M + H]^+$: 311.0343, found: 311.0337.

Preparation of (*Z*)-cinnamic acid: *Still-Gennari olefination and hydrolysis*[4]



Ethyl diphenylphosphonoacetate (14 mmol, 1.4 equiv) and 18-crown-6 (25 mmol, 2.5 equiv) and THF (200 mL) were added in a 250 mL round-bottom flask with a stir bar. The solution was treated with KHMDS (0.7 M in toluene, 14 mmol, 1.4 equiv) at –78 °C. After 30 min, benzaldehyde (10 mmol, 1.0 equiv) in THF (4.0 mL) was added dropwise. The reaction mixture was stirred at –78 °C until full consumption of starting aldehyde, checked by TLC (Hexane-Ethyl Acetate, 5:1). The reaction was quenched with sat. NH_4Cl solution. The organic phase was washed with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude mixture was used for the next step without further purification. The crude mixture was dissolved in THF (20 mL). The solution was treated with *aq*. NaOH (1.0 M, 40 mL) and stirred at r.t. for 3 h. The resulting solution was acidified by *aq*. HCl (1.0 M) to pH 2 and extracted with EtOAc. The organic phase was dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude mixture was purified by flash column chromatography on silica gel, affording (*Z*)-cinnamic acid as a white solid (1.02 g, 75% yield, *Z*/*E* = 15/1). Spectral data were in agreement with those reported in the literature.[5]

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (dt, *J* = 5.5, 3.7 Hz, 2H), 7.42 – 7.36 (m, 3H), 7.10 (d, *J* = 12.7 Hz, 1H), 6.01 (d, *J* = 12.7 Hz, 1H).



Perfluorophenyl (Z)-3-phenylacrylate ((*Z*)-2a). The title compound was prepared with (*Z*)-cinnamic acid and pentafluorophenol according to **General Procedure A**, affording the title compound as a white solid (1.40 g, 89% yield, *Z*/*E* = 33/1).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 – 7.65 (m, 2H), 7.43 – 7.36 (m, 3H), 7.30 (d, *J* = 12.6 Hz, 1H), 6.22 (d, *J* = 12.6 Hz, 1H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 161.37 (s), 149.47 (s), 133.83 (s), 130.28 (s), 130.25 (s), 128.27 (s), 115.07 (s).

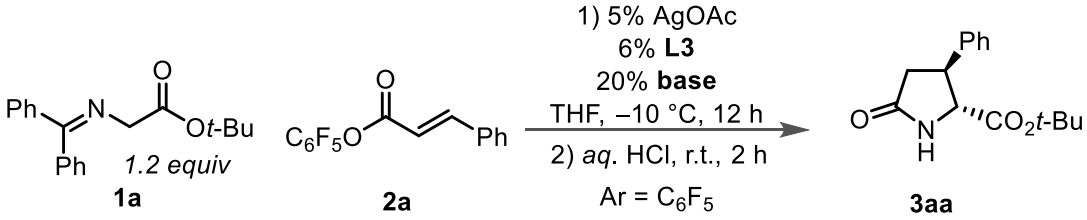
^{19}F NMR (377 MHz, $CDCl_3$) δ -152.06 – -152.46 (m), -158.07 – -158.49 (m), -162.19 – -162.93 (m).

III. Development of Stereodivergent 1,4-Additions and Lactamizations

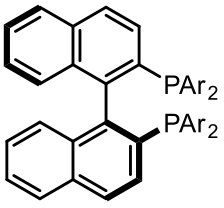
General Procedure for the optimization of reaction conditions. In a nitrogen-filled glovebox, metal catalyst (0.0025 mmol, 0.05 equiv), chiral ligand (0.003 mmol, 0.06 equiv), N-(diphenylmethylene)glycine *tert*-butyl ester (0.06 mmol, 1.2 equiv), and solvent (0.2 mL) were added in an oven-dried 4-mL vial with a stir bar. After capped with a septum-lined cap, the vial was removed from the glovebox. The vial was cooled to –10 °C for 20 min. A nitrogen-filled balloon was attached to the vial and then a solution of the α,β-unsaturated ester (0.05 mmol, 1.0 equiv) in THF (0.3 mL) and the base additive (0.01 mmol, 0.2 equiv) were added sequentially via syringe. The resulting solution was stirred at –10 °C for 12 h. The 1,4-addition product was observed, according to NMR spectroscopy. Due to the instability of this product, the reaction mixture was then treated with *aq*. HCl (1.0 M) at room temperature and allowed to stir for 2 h; the corresponding pyroglutamic acid ester was formed upon hydrolysis of amine followed by cyclizationThe resulting suspension was washed with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The yield and the diastereomeric ratio were determined by ^{1}H NMR spectroscopic analysis of crude reaction mixture with 1,1,2,2-tetrachloroethane as an internal standard. The enantiomeric excess was determined by HPLC analysis.

Note: The diastereomeric ratio of the product was determined in the silver-catalyzed 1,4-addition step, and no change in this ratio was observed after the hydrolysis step.

Table S1. Variation of base additives[a]



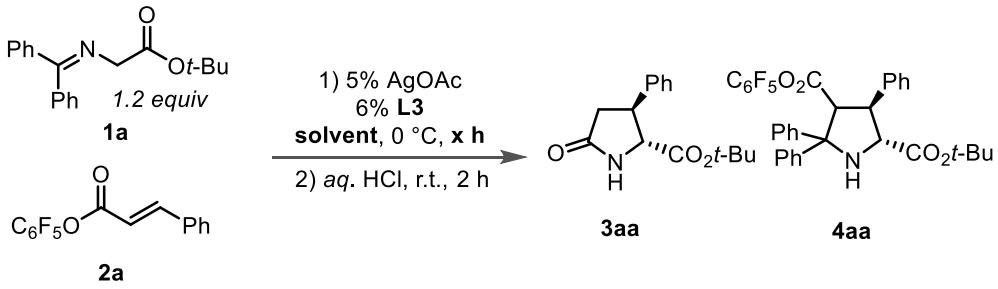
entry	base	yield (%)[b]	ee (%)[c]
1	NEt_3	68	93
2	DIPEA	70	93
3	DBU	95	93
4	DABCO	84	93
5	K_2CO_3	88	93
6	PPh_3	18	93
7	KO*t*-Bu	16	93



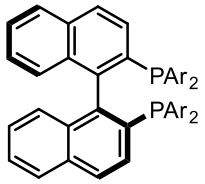
L3: (*S*)-tol-BINAP
(Ar= 4-MeC_6H_4)

[a]Reaction conditions: **1a** (0.06 mmol), **2a** (0.05 mmol), and 20% base in 0.5 mL THF. [b]Yields of **3aa** were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. **3aa** was obtained as a single diastereomer. [c]Enantiomeric excess (ee) of **3aa** was determined by HPLC analysis.

Table S2. Variation of reaction time, solvents and ligands[a]

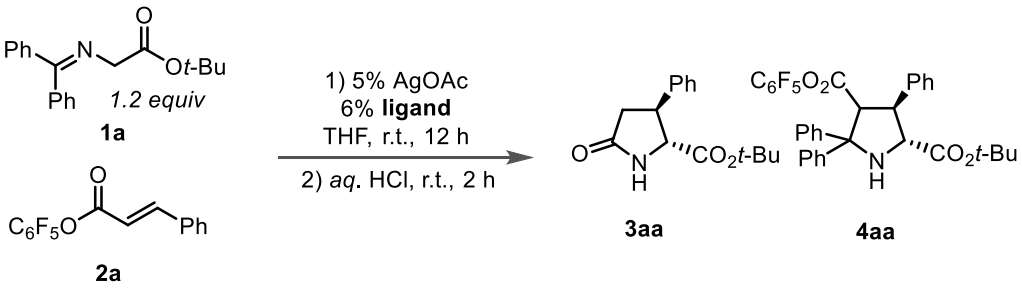


entry	x	Solvent	yield 3aa/4aa (%)[b]	ee (%)[c]
1	12	THF	62/0	90
2	18	THF	65/0	90
3	24	THF	65/0	87
4[d]	12	DCM	81/0	87
5[d]	12	Toluene	74/21	79

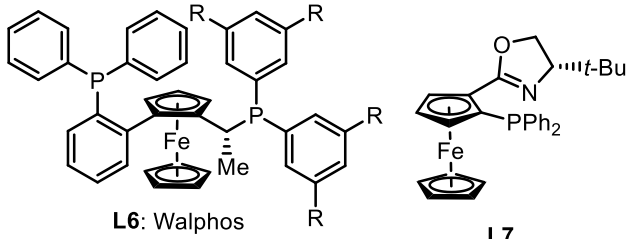


L3: (*S*)-tol-BINAP
(Ar= 4-MeC_6H_4)

[a]Reaction conditions: **1a** (0.06 mmol), **2a** (0.05 mmol) in 0.5 mL **solvent.** [b]Yields were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. **3aa** was obtained as a *anti*-single diastereomer [c]Enantiomeric excess (ee) of **3aa** was determined by HPLC analysis. [d]at –10 °C.



entry	ligand	yield (%)[b]	ee (%)[c]
1	**L6**	6/0	39
2	**L7**	66/32	–91



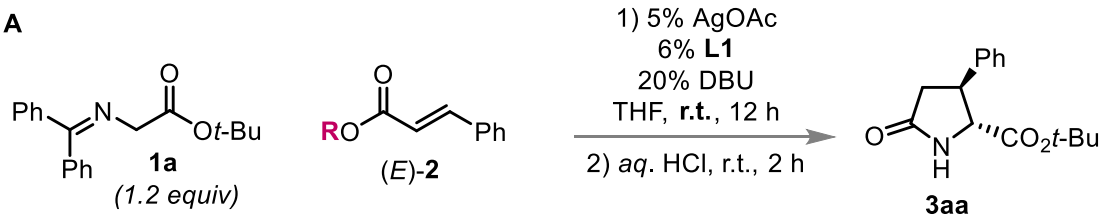
L6: Walphos
(R = CF_3)

L7

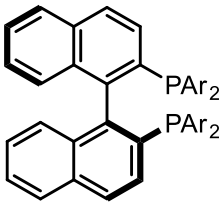
[a]Reaction conditions: **1a** (0.06 mmol), **2a** (0.05 mmol) in 0.5 mL THF. [b]Yields of **3aa**/**4aa** determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard.**3aa** was obtained as a single *anti*-diastereomer [c]Enantiomeric excess (ee) of **3aa** determined by HPLC analysis.

Table S3. Variation of the ester moiety of (*E*)-2[a]

A



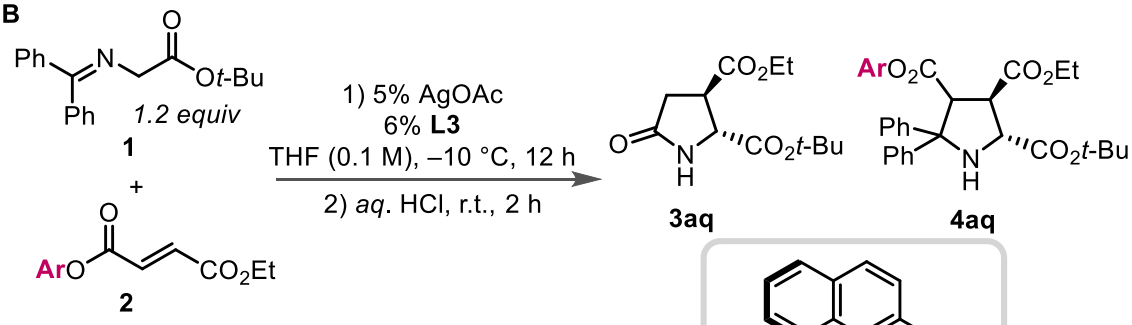
entry	R	yield (%)[b]	ee (%)[c]
1	Me	0	-
2	C_6H_5	0	-
3	3,4,5-$F_3C_6H_2$	24	56
4	4-$NO_2C_6H_4$	82	37
5	C_6F_5	82	79



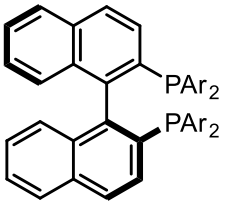
L1: (*S*)-BINAP
(Ar= C_6H_5)

[a]Reaction conditions: **1a** (0.06 mmol), **2q** (0.05 mmol) in 0.5 mL THF. [b]Yields of **3aa** were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. **3aa** was obtained as a single diastereomer. A trace amount of the corresponding cycloaddition adduct was obtained for all cases. [c]Enantiomeric excess (ee) of **3aa** was determined by HPLC analysis.

B



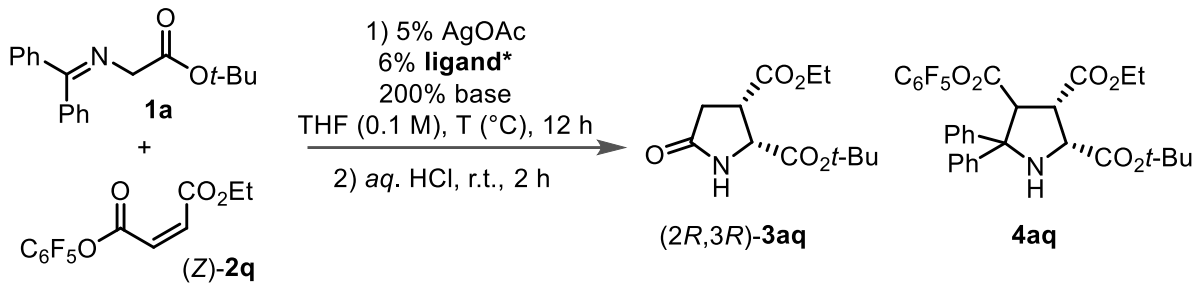
entry	Ar	yield **3aq**/**4aq** (%)[b]	ee (%)[c]
1	C_6H_5	0/100	-
2	C_6F_5	65/0	93



L3: (*S*)-tol-BINAP
(Ar= 4-MeC_6H_4)

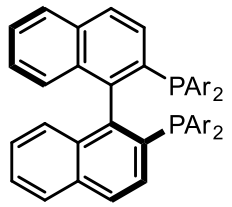
[a]Reaction conditions: **1a** (0.06 mmol), **2q** (0.05 mmol) in 0.5 mL THF. [b]Yields of **3aq**/**4aq** were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. [c]Enantiomeric excess (ee) was determined by HPLC analysis.

Table S4. Variation of ligands, temperatures, and base additives for the synthesis of *syn*-3aq[a]

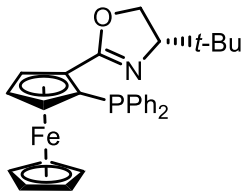


entry	ligand	T (°C)	base	yield (%)[b]	dr[c]	ee (%)[d]
1	none	0	NEt_3	66/20	>30:1	-
2	**L7**	0	NEt_3	70/11	>30:1	–77
3	**L7**	–20	NEt_3	54/16	>30:1	–77
4	**L7**	–20	none	40/17	>30:1	–71
5	**L1**	–20	NEt_3	60/5	11:1	95

[a]Reaction conditions: **1a** (0.05 mmol), **2q** (0.05 mmol) and 200% base in 0.5 mL THF. [b]Yields of **3aq**/**4aq** were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. [c]Diastereomeric ratio (dr) of **3aa** was determined by ^{1}H NMR analysis of the crude mixture. [d]Enantiomeric excess (ee) of **3aq** was determined by HPLC analysis.

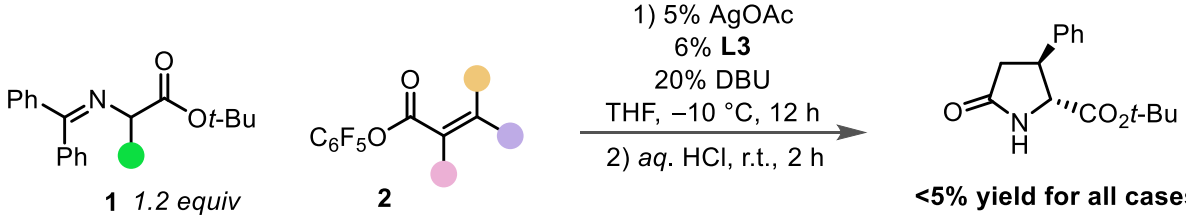


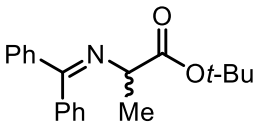
L1: (*S*)-BINAP
(Ar= C_6H_5)



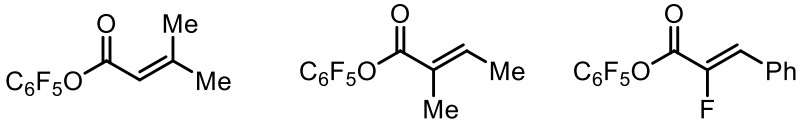
L7

Table S5. Unreactive substrates in the silver-catalyzed pyroglutamic acid ester synthesis



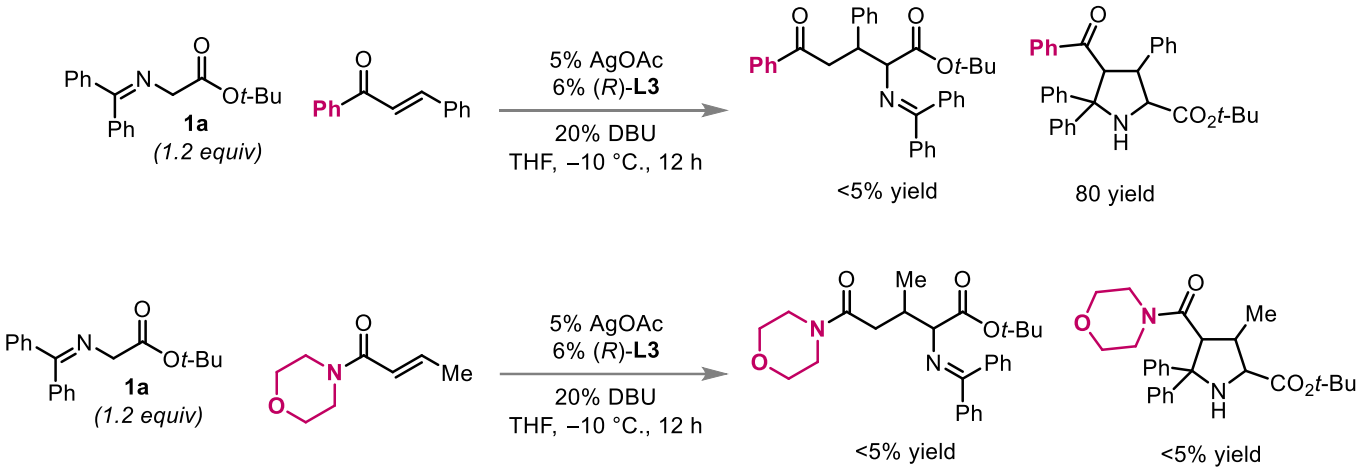


α-substituted
glycine imine ester



trisubstituted alkenes

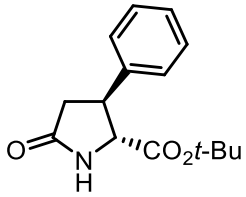
Scheme S1. Reactions of α,β-unsaturated ketones and amides[a]



[a]Yields were determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard.

IV. Enantio- and Diastereodivergent Synthesis of Pyroglutamic Acid Esters

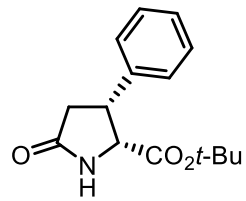
General Procedure. In a nitrogen-filled glovebox, AgOAc (0.015 mmol, 0.05 equiv), (*S*)-tol-BINAP (0.018 mmol, 0.06 equiv), glycine imine ester (0.36 mmol, 1.2 equiv) and THF (1.2 mL) were added in an oven-dried 20-mL vial with a stir bar. After capped with a septum-lined cap, the vial was removed from the glovebox. The vial was cooled to –10 °C for 20 min. A nitrogen-filled balloon was attached to the vial and then a solution of the corresponding α,β-unsaturated ester (0.30 mmol, 1.0 equiv) in THF (1.8 mL) and DBU (0.06 mmol, 0.2 equiv) were added sequentially via syringe. The resulting solution was stirred at –10 °C for 12 h. The reaction was treated with *aq*. HCl (1.0 M, 1.5 mL) and allowed to stir for 2 h at r.t. The resulting suspension was washed with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The diastereomeric ratio was determined by ^{1}H NMR spectroscopic analysis of crude reaction mixture. The crude mixture was purified by column chromatography (100/0 to 50/50 of hexane/EtOAc; $KMnO_4$ stain).



***tert*-Butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (Table 3, 3aa).** The title compound was prepared according to **General procedure**, using (*E*)-**2a** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (**1a**, 0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (72.9 mg, 93% yield). Spectral data were in agreement with those reported in the literature.[6]

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 26.10 min (major) and t_R = 14.66 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.39 – 7.32 (m, 2H), 7.28 (dt, *J* = 7.2, 2.1 Hz, 3H), 6.13 (d, *J* = 35.8 Hz, 1H), 4.14 (d, *J* = 6.0 Hz, 1H), 3.65 (dd, *J* = 16.0, 6.7 Hz, 1H), 2.84 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.54 (dd, *J* = 17.3, 7.4 Hz, 1H), 1.42 (s, 9H).



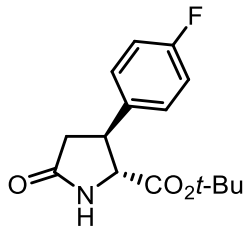
***tert*-Butyl (2*R*,3*R*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (Scheme 2, *cis*-3aa).** The title compound was prepared according to **General procedure**, using (*Z*)-**2a** (0.30 mmol, 1.0 equiv, *Z*/*E* = 33:1) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). The dr was determined by ^{1}H NMR analysis of the crude mixture to be 9:1. After purification by flash column

chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (58.8 mg, 75% yield). Spectral data were in agreement with those reported in the literature.[6]

The **enantiomeric excess** was determined by HPLC analysis to be 99% with t_R = 22.97 min (major) and t_R = 12.49 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33 – 7.25 (m, 3H), 7.25 – 7.21 (m, 2H), 6.18 (s, 1H), 4.50 (d, *J* = 7.9 Hz, 1H), 3.91 (td, *J* = 8.3, 5.9 Hz, 1H), 2.79 (dd, *J* = 16.8, 8.6 Hz, 1H), 2.68 (dd, *J* = 16.8, 5.9 Hz, 1H), 1.04 (s, 9H).

HRMS (ESI) m/z calcd for $C_{15}H_{19}NO_3$ $[M + H]^+$: 262.1443, found:262.1438.



***tert*-Butyl (2*R*,3*S*)-3-(4-fluorophenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ab).** The title compound was prepared according to **General procedure**, using **2b** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (78.8 mg, 94% yield).

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 11.08 min (major) and t_R = 7.28 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

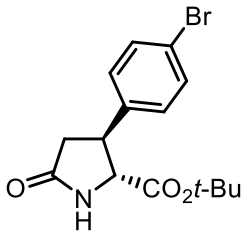
$[\alpha]_D^{20} = -100^o$ (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.27 (ddd, *J* = 8.2, 4.8, 2.6 Hz, 2H), 7.10 – 7.00 (m, 2H), 6.57 (s, 1H), 4.12 (d, *J* = 6.1 Hz, 1H), 3.70 – 3.60 (m, 1H), 2.85 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.51 (dd, *J* = 17.2, 7.5 Hz, 1H), 1.44 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.20 (s), 170.06 (s), 160.77 (s), 137.47 (s), 128.68 (d, *J* = 8.1 Hz), 115.77 (d, *J* = 21.4 Hz), 82.80 (s), 63.56 (s), 43.61 (s), 38.45 (s), 27.94 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -115.02 (d, *J* = 2.6 Hz).

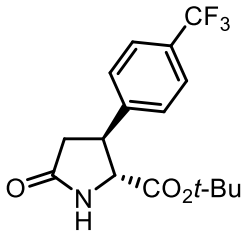
HRMS (ESI) m/z calcd for $C_{15}H_{18}FNO_3$ $[M + H]^+$: 280.1343, found: 280.1270.



***tert*-Butyl (2*R*,3*S*)-3-(4-bromophenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ac).** The title compound was prepared according to **General procedure**, using **2c** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (86.7 mg, 85% yield). Spectral data were in agreement with those reported in the literature.[6]

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 13.41 min (major) and t_R = 7.66 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

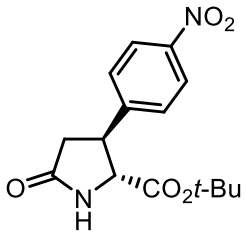
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 – 7.44 (m, 2H), 7.21 – 7.14 (m, 2H), 6.44 (s, 1H), 4.10 (d, *J* = 6.0 Hz, 1H), 3.67 – 3.58 (m, 1H), 2.84 (dd, *J* = 17.3, 9.5 Hz, 1H), 2.49 (dd, *J* = 17.3, 7.5 Hz, 1H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-5-oxo-3-(4-(trifluoromethyl)phenyl)pyrrolidine-2-carboxylate (Table 3, 3ad).** The title compound was prepared according to **General procedure**, using **2d** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (96.8 mg, 98% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 90% with t_R = 21.39 min (major) and t_R = 10.82 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

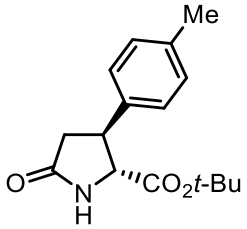
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.1 Hz, 2H), 7.43 (d, *J* = 8.1 Hz, 2H), 6.81 (s, 1H), 4.15 (d, *J* = 5.9 Hz, 1H), 3.73 (dt, *J* = 9.2, 7.1 Hz, 1H), 2.88 (dd, *J* = 17.3, 9.5 Hz, 1H), 2.53 (dd, *J* = 17.3, 7.4 Hz, 1H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-3-(4-nitrophenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ae).** The title compound was prepared according to **General procedure**, using **2e** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (78.1 mg, 85% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 89% with t_R = 28.88 min (major) and t_R = 18.90 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

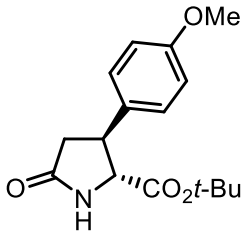
^{1}H NMR (300 MHz, $CDCl_3$) δ 8.26 – 8.18 (m, 2H), 7.52 – 7.44 (m, 2H), 6.51 (s, 1H), 4.16 (d, *J* = 6.0 Hz, 1H), 3.85 – 3.72 (m, 1H), 2.90 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.53 (dd, *J* = 17.3, 7.5 Hz, 1H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-5-oxo-3-(p-tolyl)pyrrolidine-2-carboxylate (Table 3, 3af).** The title compound was prepared according to **General procedure**, using **2f** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (70.2 mg, 85% yield). Spectral data were in agreement with those reported in the literature.[6]

The **enantiomeric excess** was determined by HPLC analysis to be 94% with t_R = 9.58 min (major) and t_R = 6.33 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

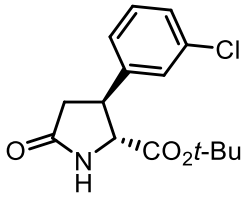
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.17 (s, 4H), 6.20 (s, 1H), 4.11 (d, *J* = 5.9 Hz, 1H), 3.62 (ddd, *J* = 9.4, 7.4, 5.9 Hz, 1H), 2.83 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.59 – 2.45 (m, 1H), 2.34 (s, 3H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-3-(4-methoxyphenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ag).** The title compound was prepared according to **General procedure**, using **2g** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (80.4 mg, 92% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 94% with t_R = 15.91 min (major) and t_R = 9.88 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (dd, *J* = 9.2, 2.5 Hz, 2H), 6.88 (dd, *J* = 9.2, 2.6 Hz, 2H), 6.56 (s, 1H), 4.10 (d, *J* = 6.1 Hz, 1H), 3.81 (d, *J* = 1.4 Hz, 3H), 3.60 (dt, *J* = 9.2, 7.5 Hz, 1H), 2.82 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.51 (dd, *J* = 17.3, 7.5 Hz, 1H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-3-(3-chlorophenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ah).** The title compound was prepared according to **General procedure**, using **2h** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (80.7 mg, 91% yield).

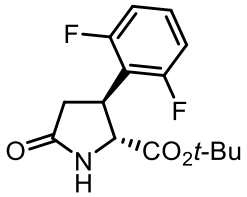
The **enantiomeric excess** was determined by HPLC analysis to be 91% with t_R = 9.85 min (major) and t_R =6.78 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –80° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.22 (m, 3H), 7.17 (d, *J* = 7.3 Hz, 1H), 6.48 (s, 1H), 4.12 (d, *J* = 6.0 Hz, 1H), 3.61 (dt, *J* = 9.1, 4.8 Hz, 1H), 2.83 (ddd, *J* = 17.2, 9.4, 0.8 Hz, 1H), 2.50 (dd, *J* = 17.3, 7.5 Hz, 1H), 1.43 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.26 (s), 170.00 (s), 143.82 (s), 134.63 (s), 130.22 (s), 127.60 (s), 127.51 (s), 125.24 (s), 82.83 (s), 63.33 (s), 43.85 (s), 38.18 (s), 27.93 (s).

HRMS (ESI) m/z calcd for $C_{15}H_{18}ClNO_3$ $[M + H]^+$: 296.1048, found: 296.0975.



***tert*-Butyl (2*R*,3*S*)-3-(2,6-difluorophenyl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ai).** The title compound was prepared according to **General procedure**, using **2i** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (81.2 mg, 91% yield).

The **enantiomeric excess** was determined by HPLC analysis to be 89% with t_R = 15.35 min (major) and t_R = 11.79 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

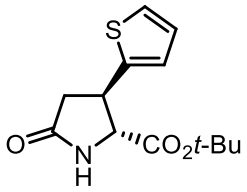
$[\alpha]_D^{20} = -230^o$ (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (ddd, *J* = 8.4, 6.4, 2.0 Hz, 1H), 6.99 – 6.90 (m, 2H), 6.29 (s, 1H), 4.37 (d, *J* = 8.5 Hz, 1H), 4.03 (dd, *J* = 18.6, 9.8 Hz, 1H), 2.82 (dd, *J* = 16.8, 10.1 Hz, 1H), 2.77 – 2.68 (m, 1H), 1.39 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 175.50 (s), 169.85 (s), 161.33 (dd, *J* = 248.0, 7.9 Hz), 129.13 (t, *J* = 10.7 Hz), 116.34 (s), 111.77 (d, *J* = 25.9 Hz), 82.66 (s), 60.44 (s), 36.09 (s), 33.42 (s), 27.67 (s).

^{19}F NMR (377 MHz, $CDCl_3$) δ -113.07 (s).

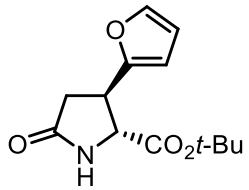
HRMS (ESI) m/z calcd for $C_{15}H_{17}F_2NO_3$ $[M + H]^+$: 298.1249, found: 298.1177.



***tert*-Butyl (2*R*,3*R*)-5-oxo-3-(thiophen-2-yl)pyrrolidine-2-carboxylate (Table 3, 3aj).** The title compound was prepared according to **General procedure**, using **2j** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (61.8 mg, 77% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 12.45 min (major) and t_R = 8.13 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

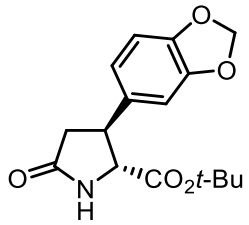
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (dd, *J* = 3.9, 2.3 Hz, 1H), 6.98 (dd, *J* = 4.0, 2.1 Hz, 2H), 6.02 (s, 1H), 4.18 (d, *J* = 6.1 Hz, 1H), 3.98 (dd, *J* = 15.0, 8.1 Hz, 1H), 2.94 – 2.84 (m, 1H), 2.61 (dd, *J* = 17.0, 7.7 Hz, 1H), 1.46 (t, *J* = 5.9 Hz, 9H).



***tert*-Butyl (2*R*,3*R*)-3-(furan-2-yl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3ak).** The title compound was prepared according to **General procedure**, using **2k** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (64.1 mg, 85% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 91% with t_R = 11.95 min (major) and t_R = 7.49 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

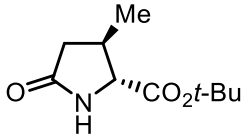
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 (dd, *J* = 1.8, 0.7 Hz, 1H), 6.33 (dd, *J* = 3.2, 1.9 Hz, 1H), 6.19 (d, *J* = 3.2 Hz, 1H), 6.08 (s, 1H), 4.24 (d, *J* = 6.3 Hz, 1H), 3.83 – 3.72 (m, 1H), 2.74 (dd, *J* = 17.0, 9.2 Hz, 1H), 2.65 (dd, *J* = 17.0, 7.9 Hz, 1H), 1.46 (s, 9H).



***tert*-Butyl (2*R*,3*S*)-3-(benzo[d][1,3]dioxol-5-yl)-5-oxopyrrolidine-2-carboxylate (Table 3, 3al).** The title compound was prepared according to **General procedure**, using **2l** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (77.9 mg 85% yield). Spectral data were in agreement with those reported in the literature.[7]

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 22.32 min (major) and t_R = 14.17 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

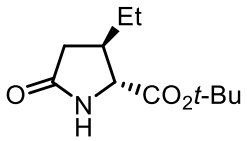
^{1}H NMR (400 MHz, $CDCl_3$) δ 6.77 (dd, *J* = 4.8, 3.1 Hz, 2H), 6.72 (dd, *J* = 8.0, 1.7 Hz, 1H), 6.26 (s, 1H), 5.96 (s, 2H), 4.07 (d, *J* = 6.0 Hz, 1H), 3.57 (ddd, *J* = 9.4, 7.4, 6.1 Hz, 1H), 2.81 (dd, *J* = 17.3, 9.4 Hz, 1H), 2.52 – 2.43 (m, 1H), 1.43 (s, 9H).



***tert*-Butyl (2*R*,3*R*)-3-methyl-5-oxopyrrolidine-2-carboxylate (Table 3, 3am).** The title compound was prepared according to **General procedure**, using **2m** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (56.8 mg, 95% yield). Spectral data were in agreement with those reported in the literature.[8]

The **enantiomeric excess** was determined by HPLC analysis to be 87% with t_R = 18.67 min (major) and t_R = 12.11 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (300 MHz, $CDCl_3$) δ 6.20 (s, 1H), 3.68 – 3.61 (m, 1H), 2.53 – 2.40 (m, 2H), 2.01 – 1.89 (m, 1H), 1.41 (s, 9H), 1.21 (d, *J* = 6.5 Hz, 3H).



***tert*-Butyl (2*R*,3*R*)-3-ethyl-5-oxopyrrolidine-2-carboxylate (Table 3, 3an).** The title compound was prepared according to **General procedure**, using **2n** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (55.7 mg, 87% yield).

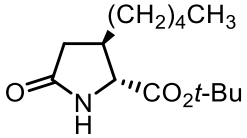
The **enantiomeric excess** was determined by HPLC analysis to be 91% with t_R = 15.59 min (major) and t_R = 10.07 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –110° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.94 (s, 1H), 3.75 (d, *J* = 5.5 Hz, 1H), 2.53 (dd, *J* = 16.9, 9.0 Hz, 1H), 2.36 (tdd, *J* = 14.6, 8.7, 5.8 Hz, 1H), 2.04 (dd, *J* = 16.9, 6.6 Hz, 1H), 1.77 (ddd, *J* = 13.5, 7.3, 5.9 Hz, 2H), 1.46 (s, 9H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 177.24 (s), 171.07 (s), 82.27 (s), 61.38 (s), 40.54 (s), 35.74 (s), 27.97 (s), 27.86 (s), 11.61 (s).

HRMS (ESI) m/z calcd for $C_{11}H_{19}NO_3$ $[M + H]^+$: 214.1443, found: 214.1438.



***tert*-Butyl (2*R*,3*R*)-5-oxo-3-pentylpyrrolidine-2-carboxylate (Table 3, 3ao).** The title compound was prepared according to **General procedure**, using **2o** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (75.1 mg, 98% yield).

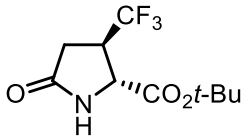
The **enantiomeric excess** was determined by HPLC analysis to be 92% with t_R = 11.05 min (major) and t_R = 7.84 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –130° (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 5.92 (s, 1H), 3.76 (d, *J* = 5.5 Hz, 1H), 2.54 (dd, *J* = 16.3, 9.0 Hz, 1H), 2.49 – 2.36 (m, 1H), 2.04 (dd, *J* = 16.3, 6.2 Hz, 1H), 1.79 – 1.68 (m, 1H), 1.48 (s, 9H), 1.41 – 1.23 (m, 7H), 0.90 (dd, *J* = 9.1, 4.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 177.35 (s), 171.09 (s), 82.27 (s), 61.64 (s), 38.94 (s), 36.21 (s), 34.92 (s), 31.51 (s), 27.97 (s), 26.82 (s), 22.47 (s), 14.00 (s).

HRMS (ESI) m/z calcd for $C_{14}H_{25}NO_3$ $[M + H]^+$: 256.1907, found: 256.1834.



***tert*-Butyl (2*R*,3*R*)-5-oxo-3-(trifluoromethyl)pyrrolidine-2-carboxylate (Table 3, 3ap).** The title compound was prepared according to **General procedure**, using **2p** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (67.6 mg, 89% yield).

The **enantiomeric excess** was determined by HPLC analysis to be 80% with t_R = 10.50 min (major) and t_R = 8.44 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

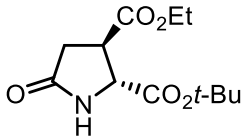
$[\alpha]_D^{20}$ = –100° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.90 – 6.77 (m, 1H), 4.20 (d, *J* = 4.0 Hz, 1H), 3.41 – 3.25 (m, 1H), 2.67 (dd, *J* = 17.8, 10.4 Hz, 1H), 2.50 (dd, *J* = 17.9, 5.3 Hz, 1H), 1.48 (s, 9H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 174.33 (s), 168.62 (s), 128.25 (dd, *J* = 317.9, 237.3 Hz), 83.82 (s), 55.93 (d, *J* = 2.7 Hz), 40.96 (q, *J* = 30.0 Hz), 29.62 (d, *J* = 2.3 Hz), 27.84 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -72.96 (d, *J* = 1.8 Hz).

HRMS (ESI) m/z calcd for $C_{10}H_{14}F_3NO_3$ $[M + H]^+$: 254.0999, found: 254.0926.



2-(*tert*-Butyl) 3-ethyl (2*R*,3*R*)-5-oxopyrrolidine-2,3-dicarboxylate (Table 3, 3aq). The title compound was prepared according to **General procedure**, using (*E*)-**2q** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv) in the absence of DBU. After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (50.2 mg, 65% yield).

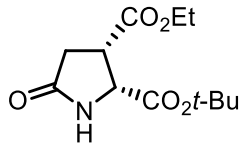
The **enantiomeric excess** was determined by HPLC analysis to be 97% with t_R = 8.33 min (major) and t_R = 9.50 min (minor) [AD-H, 0.5% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –170° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.92 (s, 1H), 4.44 (d, *J* = 6.1 Hz, 1H), 4.19 (q, *J* = 7.2 Hz, 2H), 3.32 (ddd, *J* = 9.6, 7.9, 6.1 Hz, 1H), 2.71 – 2.54 (m, 2H), 1.44 (s, 9H), 1.27 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 175.00 (s), 171.92 (s), 169.45 (s), 83.08 (s), 61.76 (s), 58.40 (s), 42.65 (s), 33.69 (s), 27.88 (s), 14.14 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{19}NO_5$ $[M + H]^+$: 258.1336, found: 258.1263.



2-(*tert*-Butyl) 3-ethyl (2*R*,3*S*)-5-oxopyrrolidine-2,3-dicarboxylate (Scheme 2, *cis*-3aq). The title compound was prepared according to **General procedure**, using (*Z*)-**2q** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv) in the absence of DBU. The dr was determined by ^{1}H NMR analysis of the crude mixture to be 7:1. After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (48.6 mg, 63% yield).

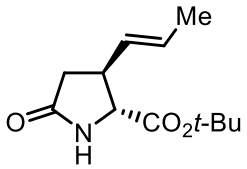
The **enantiomeric excess** was determined by HPLC analysis to be 95% with t_R = 17.83 min (major) and t_R = 10.46 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –120° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.09 (s, 1H), 4.30 (d, *J* = 8.0 Hz, 1H), 4.24 – 4.10 (m, 2H), 3.53 (dd, *J* = 17.1, 7.9 Hz, 1H), 2.77 (dd, *J* = 17.1, 7.7 Hz, 1H), 2.58 (dd, *J* = 17.0, 9.3 Hz, 1H), 1.45 (s, 9H), 1.27 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 175.87 (s), 170.52 (s), 168.70 (s), 83.08 (s), 61.44 (s), 57.82 (s), 42.54 (s), 32.87 (s), 27.84 (s), 14.06 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{19}NO_5$ $[M + H]^+$: 258.1341, found: 258.1336.



***tert*-Butyl (2*R*,3*S*)-5-oxo-3-((*E*)-prop-1-en-1-yl)pyrrolidine-2-carboxylate (Table 3, 3ar).** The title compound was prepared according to **General procedure**, using **2r** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a brown solid (23.0 mg, 32% yield).

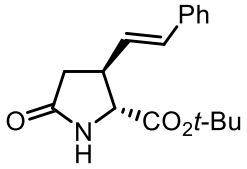
The **enantiomeric excess** was determined by HPLC analysis to be 92% with t_R = 7.51 min (major) and t_R = 5.05 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = –50° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.95 (s, 1H), 5.65 – 5.45 (m, 2H), 3.83 (d, *J* = 6.8 Hz, 1H), 3.11 – 2.98 (m, 1H), 2.52 (dt, *J* = 15.2, 7.6 Hz, 1H), 2.24 (dd, *J* = 16.9, 8.4 Hz, 1H), 1.74 – 1.65 (m, 3H), 1.47 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.28 (s), 170.30 (s), 130.41 (s), 127.83 (s), 82.50 (s), 61.48 (s), 42.56 (s), 36.48 (s), 28.01 (s), 17.82 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{19}NO_3$ $[M + H]^+$: 226.1438, found: 226.01365.



***tert*-Butyl (2*R*,3*S*)-5-oxo-3-((*E*)-styryl)pyrrolidine-2-carboxylate (Table 3, 3as).** The title compound was prepared according to **General procedure**, using **2s** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (28.4 mg, 33% yield).

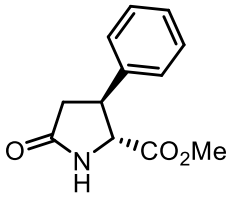
The **enantiomeric excess** was determined by HPLC analysis to be 92% with t_R = 20.04 min (major) and t_R = 12.85 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = +330° (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41 – 7.26 (m, 5H), 6.52 (d, *J* = 15.7 Hz, 1H), 6.24 (dd, *J* = 15.8, 8.0 Hz, 1H), 5.90 (s, 1H), 3.97 (d, *J* = 6.7 Hz, 1H), 3.39 – 3.20 (m, 1H), 2.66 (dd, *J* = 16.9, 8.8 Hz, 1H), 2.39 (dd, *J* = 16.9, 8.3 Hz, 1H), 1.48 (s, 9H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 176.01 (s), 170.06 (s), 136.43 (s), 132.10 (s), 128.90 (s), 128.68 (s), 127.85 (s), 126.30 (s), 82.74 (s), 61.42 (s), 42.80 (s), 36.46 (s), 28.05 (s).

HRMS (ESI) m/z calcd for $C_{17}H_{21}NO_3$ $[M + H]^+$: 288.1594, found: 288.1521.



Methyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (Table 3, 3ba). The title compound was prepared according to **General procedure**, using **2a** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine methyl ester (**1b**, 0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow solid (42.8 mg, 65% yield).

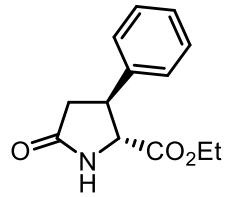
The **enantiomeric excess** was determined by HPLC analysis to be 66% with t_R = 12.59 min (major) and t_R = 9.26 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20} = -240^o$ (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.26 (m, 5H), 6.72 (s, 1H), 4.26 (d, *J* = 5.2 Hz, 1H), 3.76 (s, 3H), 3.72 (dt, *J* = 9.4, 5.9 Hz, 1H), 2.87 (dd, *J* = 17.4, 9.5 Hz, 1H), 2.53 (dd, *J* = 17.4, 6.5 Hz, 1H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 176.65 (s), 171.78 (s), 141.82 (s), 129.08 (s), 127.59 (s), 126.84 (s), 62.83 (s), 52.73 (s), 43.78 (s), 37.85 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{13}NO_3$ $[M + H]^+$: 220.0968, found: 220.0895.



Ethyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (Table 3, 3ca). The title compound was prepared according to **General procedure**, using **2a** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine ethyl ester (**1c**, 0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow oil (40.6 mg, 58% yield).

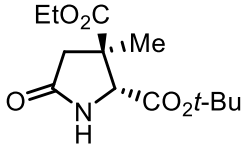
The **enantiomeric excess** was determined by HPLC analysis to be 72% with t_R = 12.95 min (major) and t_R = 8.92 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20} = -90^o$ (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40 – 7.33 (m, 2H), 7.32 – 7.27 (m, 3H), 6.20 (s, 1H), 4.28 – 4.15 (m, 3H), 3.78 – 3.67 (m, 1H), 2.87 (dd, *J* = 17.3, 9.5 Hz, 1H), 2.54 (dd, *J* = 17.3, 6.7 Hz, 1H), 1.26 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 176.68 (s), 171.26 (s), 141.80 (s), 129.01 (s), 127.54 (s), 126.91 (s), 62.95 (s), 61.81 (s), 43.90 (s), 37.93 (s), 14.12 (s).

HRMS (ESI) m/z calcd for $C_{13}H_{15}NO_3$ $[M + H]^+$: 234.1125, found: 234.1052.



2-(*tert*-Butyl) 3-ethyl (2*R*,3*R*)-3-methyl-5-oxopyrrolidine-2,3-dicarboxylate (Table 3, 3at). The title compound was prepared according to **General procedure**, using **2t** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a yellow soild (73.3 mg, 90% yield).

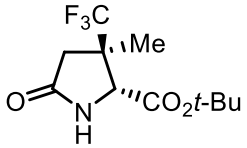
The **enantiomeric excess** was determined by HPLC analysis to be 76% with t_R = 24.84 min (major) and t_R = 14.50 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = +90° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.96 (s, 1H), 4.66 (s, 1H), 4.30 – 4.15 (m, 2H), 2.90 (d, *J* = 16.3 Hz, 1H), 2.27 (d, *J* = 16.3 Hz, 1H), 1.47 (s, 9H), 1.32 (d, *J* = 1.2 Hz, 3H), 1.30 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 174.46 (s), 173.35 (s), 168.21 (s), 83.13 (s), 62.39 (s), 61.83 (s), 48.70 (s), 43.18 (s), 27.98 (s), 18.62 (s), 14.13 (s).

HRMS (ESI) m/z calcd for $C_{13}H_{21}NO_5$ $[M + H]^+$: 272.1492, found: 272.1420.



***tert*-Butyl (2*R*,3*R*)-3-methyl-5-oxo-3-(trifluoromethyl)pyrrolidine-2-carboxylate (Table 3, 3au).** The title compound was prepared according to **General procedure**, using **2u** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (78.6 mg, 98% yield).

$[\alpha]_D^{20}$ = –80° (c = 0.01, $CHCl_3$).

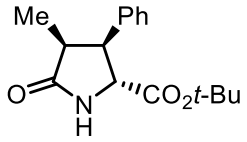
The **enantiomeric excess** was determined by HPLC analysis to be 96% with t_R = 18.98 min (major) and t_R = 8.28 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (300 MHz, $CDCl_3$) δ 6.15 (s, 1H), 4.31 (s, 1H), 2.76 (d, *J* = 17.2 Hz, 1H), 2.27 (d, *J* = 17.2 Hz, 1H), 1.50 (s, 9H), 1.35 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 173.94 (s), 167.89 (s), 127.16 (q, *J* = 280.7 Hz), 83.57 (s), 59.63 (d, *J* = 2.1 Hz), 46.84 (q, *J* = 27.3 Hz), 38.90 (s), 27.91 (s), 16.98 (d, *J* = 2.2 Hz).

^{19}F NMR (282 MHz, $CDCl_3$) δ -77.02 (s).

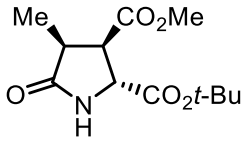
HRMS (ESI) m/z calcd for $C_{11}H_{16}F_3NO_3$ $[M + H]^+$: 268.1155, found: 268.1082.



***tert*-Butyl (2*R*,3*S*,4*S*)-4-methyl-5-oxo-3-phenylpyrrolidine-2-carboxylate (Table 3, 3av).** The title compound was prepared according to **General procedure**, using **2v** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv). The dr was determined by ^{1}H NMR analysis of the crude mixture to be 6:1. After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (44.6 mg, 54% yield). Spectral data were in agreement with those reported in the literature.[6]

The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 23.78 min (major) and t_R = 14.92 min (minor) [AD-H, 5.0% *i*-PrOH, 1.0 mL/min].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 – 7.25 (m, 3H), 7.24 – 7.17 (m, 2H), 6.42 (s, 1H), 4.27 (d, *J* = 3.4 Hz, 1H), 3.75 (dd, *J* = 8.8, 3.4 Hz, 1H), 2.92 – 2.81 (m, 1H), 1.43 (s, 9H), 0.82 (d, *J* = 7.4 Hz, 3H).



2-(*tert*-Butyl) 3-methyl (2*R*,3*R*,4*S*)-4-methyl-5-oxopyrrolidine-2,3-dicarboxylate (Table 3, 3aw). The title compound was prepared according to **General procedure**, using **2w** (0.30 mmol, 1.0 equiv) and N-(diphenylmethylene)glycine *tert*-butyl ester (0.36 mmol, 1.2 equiv) in the absence of DBU. The dr was determined by ^{1}H NMR analysis of the crude mixture to be 25:1. After purification by flash column chromatography (100/0 to 50/50 of Hexane/EtOAc), the title compound was isolated as a white solid (54.0 mg, 70% yield).

The **enantiomeric excess** was determined by HPLC analysis to be 87% with t_R = 10.92 min (major) and t_R = 9.96 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

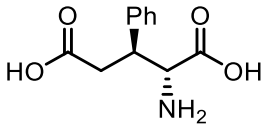
$[\alpha]_D^{20}$ = +160° (c = 0.01, $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.95 (s, 1H), 4.50 (d, *J* = 6.5 Hz, 1H), 3.77 (s, 3H), 3.48 (dd, *J* = 9.6, 6.5 Hz, 1H), 2.82 (dq, *J* = 9.6, 7.5 Hz, 1H), 1.46 (d, *J* = 1.8 Hz, 9H), 1.16 (t, *J* = 7.3 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 177.49 (s), 170.85 (s), 169.41 (s), 83.10 (s), 56.36 (s), 52.22 (s), 47.23 (s), 38.27 (s), 27.87 (s), 12.44 (s).

HRMS (ESI) m/z calcd for $C_{12}H_{19}NO_5$ $[M + H]^+$: 258.1336, found: 258.1263.

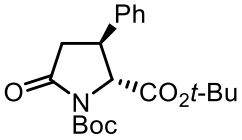
IV. Derivatizations of the Product



Hydrolysis[8]: (2*R*,3*S*)-2-Amino-3-phenylpentanedioic acid (Scheme 3, 5aa). *tert*-Butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (0.2 mmol, 1.0 equiv) was dissolved in 6N HCl solution (6 mL), and the mixture was heated under reflux for 24 h. The solvent was removed under reduced pressure. The residue was dissolved in MeOH and stirred for 1 h after adding propylene oxide. The solution was filtered, and the filter solid was washed with ether and dried to provide **5aa** as a white solid (30.4 mg, 68% yield). Spectral data were in agreement with those reported in the literature.[9]

^{1}H NMR (300 MHz, D_2O) δ 7.49 – 7.31 (m, 5H), 4.06 (d, *J* = 4.8 Hz, 1H), 3.76 – 3.68 (m, 1H), 3.07 (qd, *J* = 16.5, 7.9 Hz, 2H).

$[\alpha]_D^{20}$ = –50° (c = 0.01, 6N HCl). (lit.[9] $[\alpha]_D^{20}$ = +16.7° (c = 1.36, 6N HCl (2*S*,3*R*)).



Protection[10]: Di-*tert*-butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-1,2-dicarboxylate (Scheme 3, 6aa). In a 20 mL round-bottom flask, *tert*-butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate (0.3 mmol, 1.0 equiv) and toluene (1.2 mL) were combined. In the resulting solution, Boc_2O (0.6 mmol, 2.0 equiv) and DMAP (0.03 mmol, 0.1 equiv) were added, and the resulting mixture was cooled to 0°C. After 10 min, trimethylamine (1.5 mmol, 5.0 equiv) was added dropwise at 0°C. The reaction mixture was stirred at r.t. for 12 h. The reaction was quenched with saturated *aq*. $NaHCO_3$ solution and extracted with EtOAc. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered., and concentrated under reduced pressure. The residue was purified by flash chromatography as a yellowish solid (103 mg, 95% yield) (100/0 to 70/10 of Hexane/EtOAc).

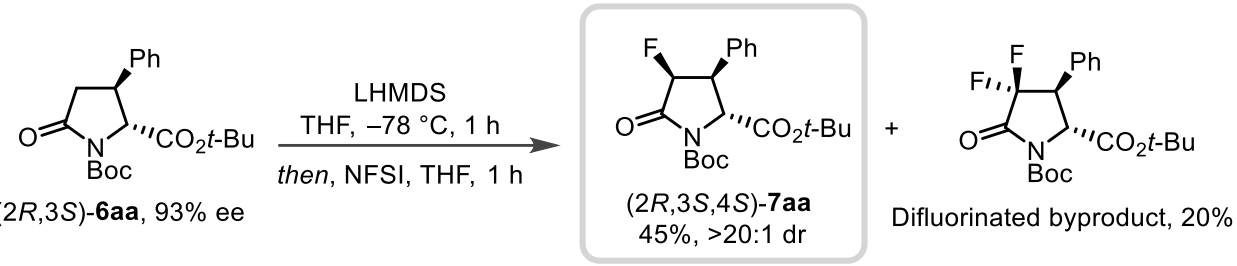
The **enantiomeric excess** was determined by HPLC analysis to be 93% with t_R = 5.70 min (major) and t_R = 24.73 min (minor) [AD-H, 10.0% *i*-PrOH, 1.0 mL/min].

$[\alpha]_D^{20}$ = +40° (c = 0.01, $CHCl_3$).

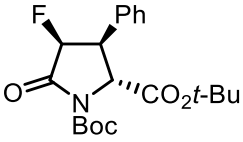
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.34 (m, 2H), 7.33 – 7.28 (m, 1H), 7.24 (dd, *J* = 5.2, 3.3 Hz, 2H), 4.43 (d, *J* = 3.5 Hz, 1H), 3.40 (dt, *J* = 9.1, 3.9 Hz, 1H), 3.05 (dd, *J* = 17.7, 9.4 Hz, 1H), 2.67 (dd, *J* = 17.7, 4.3 Hz, 1H), 1.50 (s, 9H), 1.49 (s, 9H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 172.73 (s), 169.58 (s), 149.15 (s), 141.55 (s), 129.15 (s), 127.74 (s), 126.58 (s), 83.63 (s), 82.50 (s), 66.98 (s), 39.94 (s), 38.92 (s), 27.96 (s), 27.90 (s).

HRMS (ESI) m/z calcd for $C_{20}H_{27}NO_5$ $[M + H]^+$: 362.1967, found: 362.1962.



Fluorination[11]**:** A solution of di-*tert*-butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-1,2-dicarboxylate (0.28 mmol, 1.0 equiv) in THF (0.3 mL) was added dropwise to a solution of LHMDS (0.28 mL, 1 M in THF, 1.0 equiv) in THF (0.6 mL) at –78˚C. The reaction mixture was warmed up to 0˚C and stirred for 40 min. The mixture was cooled to –78˚C, and NFSI (0.28 mmol, 1.0 equiv) in THF (0.3 mL) was added. Then the mixture was warmed up to 0˚C for 1 h. A saturated *aq*. NH_4Cl solution, water, and EtOAc were added to the reaction mixture with stirring. The aqueous layer was extracted with EtOAc, and the combined organic layer was concentrated under reduced pressure, diluted with DCM to forma cloudy yellow solution. The solution was then filtered through short column of silica gel, eluted with DCM, and concentrated *in vacuo*. The crude mixture was purified by flash chromatography, affording monofluorinated product **7aa** as a white solid (47.8 mg, 45% yield) and difluorinated byproduct as a white solid (50.1 mg, 20% yield). (100/0 to 95/5 of Hexane/EtOAc).



Monofluorinated product: di-*tert*-butyl (2*R*,3*S*,4*S*)-4-fluoro-5-oxo-3-phenylpyrrolidine-1,2-dicarboxylate (Scheme 3, 7aa).

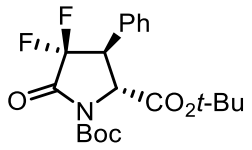
$[\alpha]_D^{20}$ = +30° (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.44 – 7.34 (m, 3H), 7.31 – 7.26 (m, 2H), 5.09 (dd, *J* = 51.1, 8.1 Hz, 1H), 4.41 (dd, *J* = 7.8, 0.9 Hz, 1H), 3.47 (dt, *J* = 22.7, 8.0 Hz, 1H), 1.54 (s, 9H), 1.39 (s, 9H).

^{13}C NMR (75 MHz, $CDCl_3$) δ 167.92 (s), 166.49 (d, *J* = 21.2 Hz), 148.76 (s), 135.54 (s), 129.27 (s), 128.52 (s), 127.41 (s), 93.58 (s), 90.99 (s), 84.80 (s), 83.05 (s), 61.73 (d, *J* = 4.7 Hz), 48.06 (d, *J* = 19.9 Hz), 27.84 (d, *J* = 3.6 Hz).

^{19}F NMR (282 MHz, $CDCl_3$) δ -189.31 (s).

HRMS (ESI) m/z calcd for $C_{20}H_{26}FNO_5$ $[M + H]^+$: 380.1873, found: 308.1868.



Difluorinated byproduct: di-*tert*-butyl (2*R*,3*S*)-4,4-difluoro-5-oxo-3-phenylpyrrolidine-1,2-dicarboxylate.

$[\alpha]_D^{20} = -210^o$ (c = 0.01, $CHCl_3$).

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.44 – 7.38 (m, 3H), 7.33 – 7.27 (m, 2H), 4.64 (d, *J* = 7.0 Hz, 1H), 3.60 (ddd, *J* = 16.4, 14.3, 7.0 Hz, 1H), 1.57 (s, 9H), 1.36 (s, 9H).

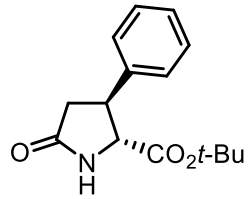
^{13}C NMR (101 MHz, $CDCl_3$) δ 167.32 (s), 161.61 – 160.43 (m), 148.52 (s), 130.02 (s), 129.08 (s), 129.02 (s), 128.90 (s), 117.46 – 111.96 (m), 85.61 (s), 83.56 (s), 60.15 (d, *J* = 4.8 Hz), 50.15 – 49.16 (m), 27.84 (s), 27.74 (s).

^{19}F NMR (282 MHz, $CDCl_3$) δ -108.07 (d, *J* = 267.5 Hz), -113.17 (d, *J* = 267.5 Hz).

HRMS (ESI) m/z calcd for $C_{20}H_{25}F_2NO_5$ $[M + H]^+$: 420.1599, found: 420.1593.

V. Assignment of Absolute and Relative Configurations

Assignment of the absolute configurations of *anti*-diastereomer.

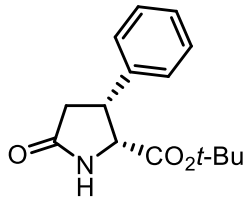


(2*R*,3*S*)-**3aa**, 93% ee

The absolute and relative configurations of *tert*-butyl (2*R*,3*S*)-5-oxo-3-phenylpyrrolidine-2-carboxylate were determined by comparison of HPLC data and spectral data with literature.[6] The absolute configuration of this product was determined to be (*R*) and (*S*). The configurations of the other *anti*-products were assigned by analogy.

HPLC analysis showed that the product obtained from (*E*)-**2a** with (*S*)-**L3** is the (slow)-eluting enantiomer on a AD-column: t_R = 26.10 min (major) and t_R = 14.66 min (minor).

Assignment of the absolute configurations of *syn*-diastereomer.

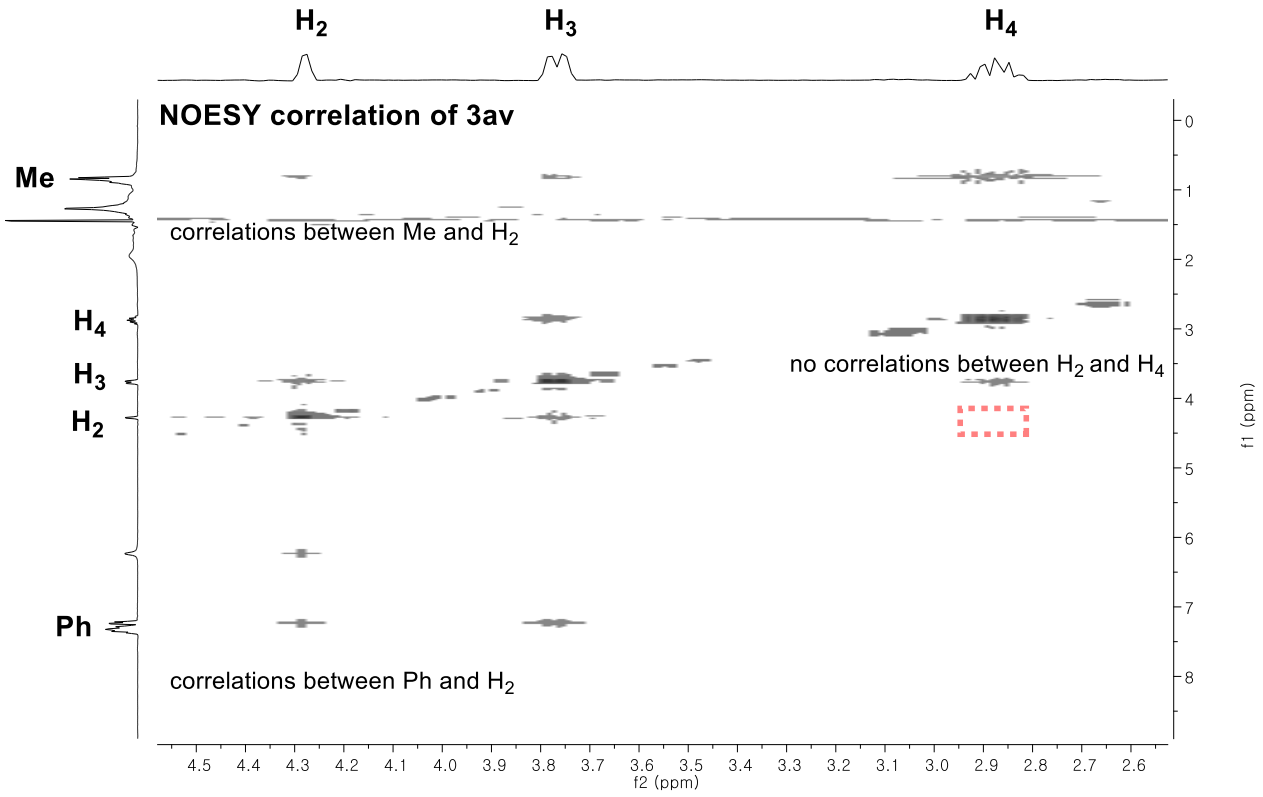


(2*R*,3*R*)-**3aa**, 99% ee

The absolute and relative configurations of *tert*-butyl (2*R*,3*R*)-5-oxo-3-phenylpyrrolidine-2-carboxylate were determined by comparison of HPLC data and spectral data with literature.[6] The absolute configuration of this product was determined to be (*R*) and (*R*). The configurations of other *syn*-products were assigned by analogy.

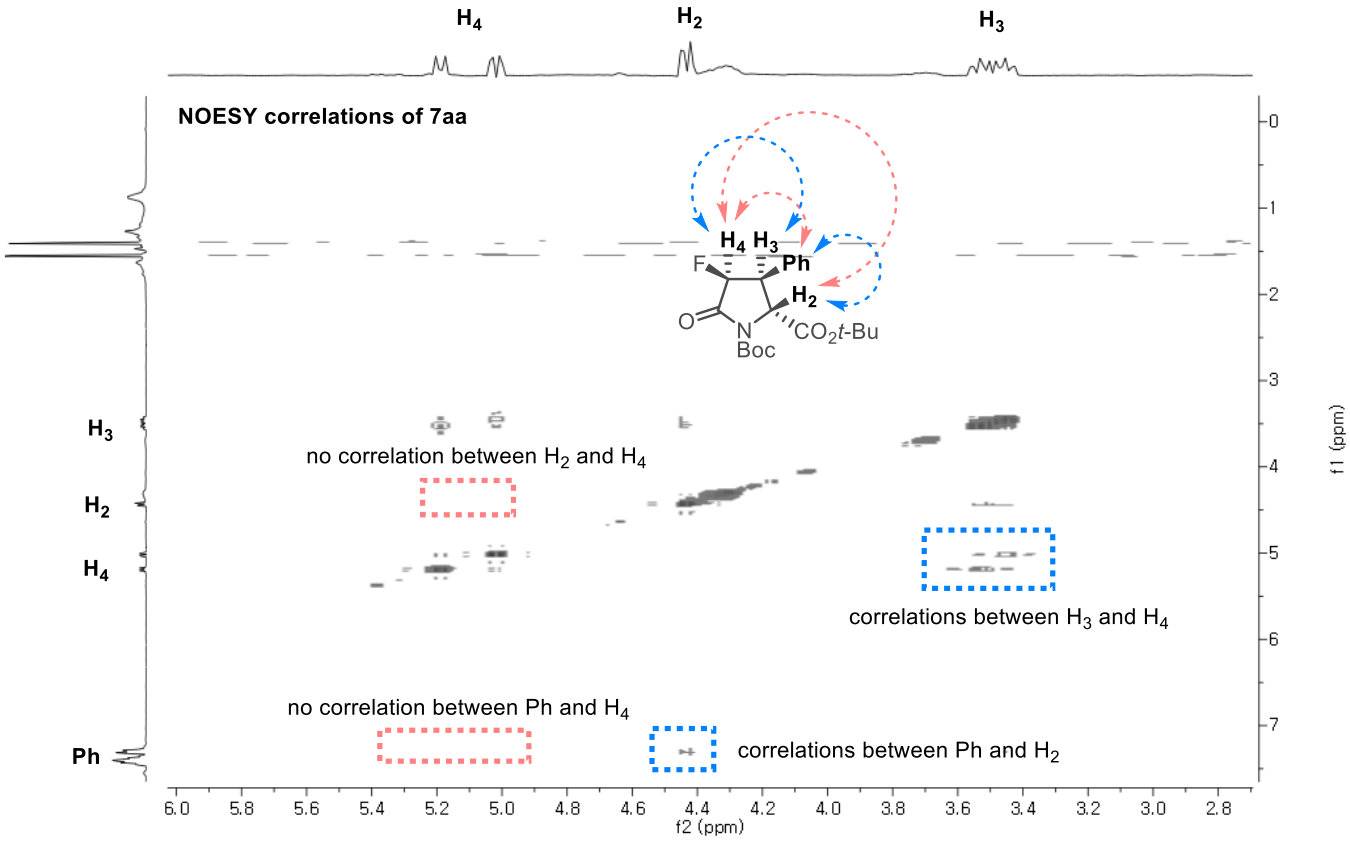
HPLC analysis showed that the product obtained from (*Z*)-**2a** and (*S*)-**L3** is the (slow)-eluting enantiomer on a AD-column: t_R = 22.97 min (major) and t_R = 12.49 (minor).

Assignment of the relative configurations of 3av.



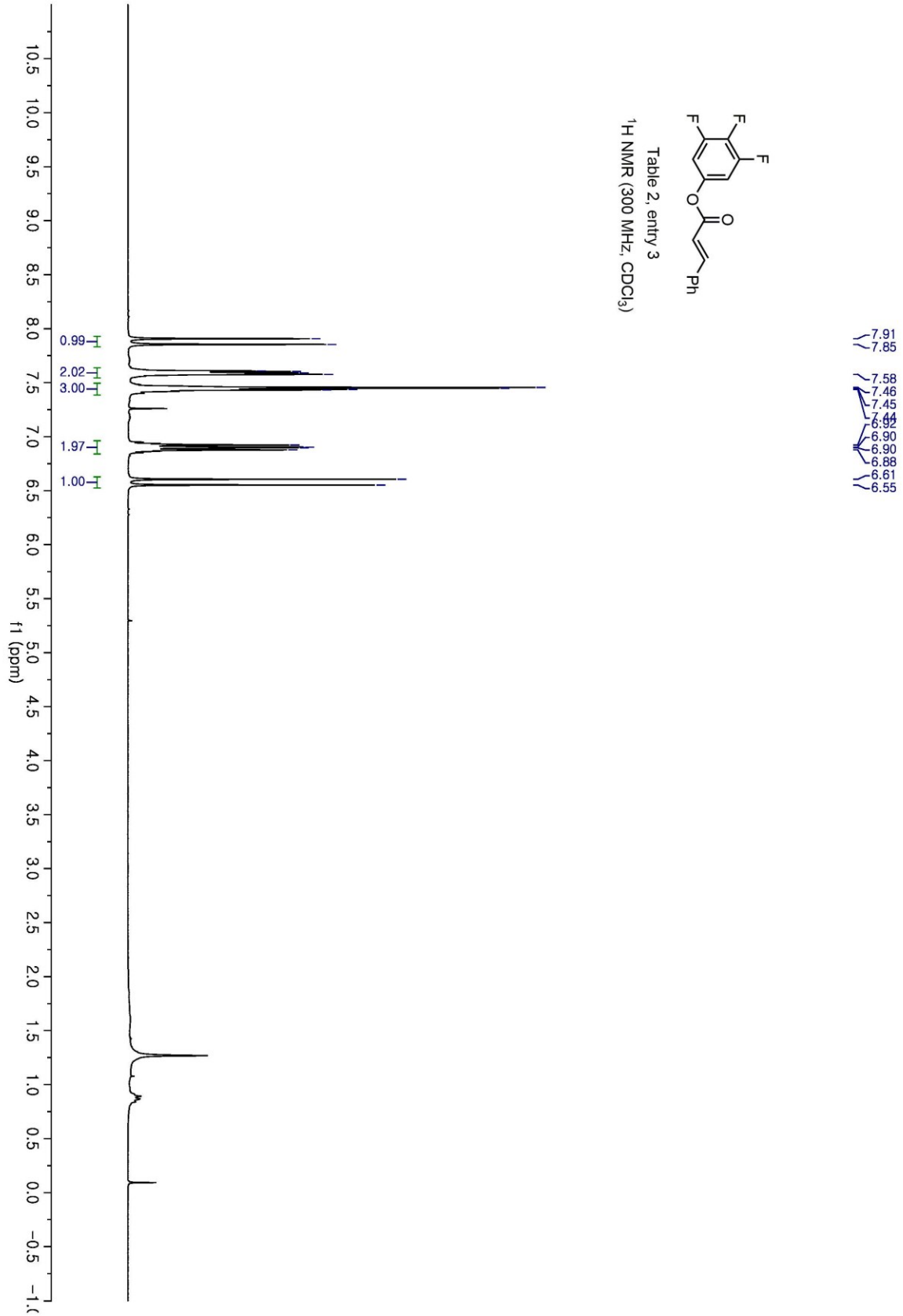
The relative configurations of **3av** were determined to be *cis* by ^{1}H-^{1}H NOESY correlation analysis. The relative stereochemistry **3aw** was assigned by analogy.

Assignment of the relative configurations of 7aa.



The relative configurations of **3av** were determined to be *cis* by ^{1}H-^{1}H NOESY correlation analysis.

VII. ^{1}H and ^{13}C NMR Spectra of Isolated Compounds



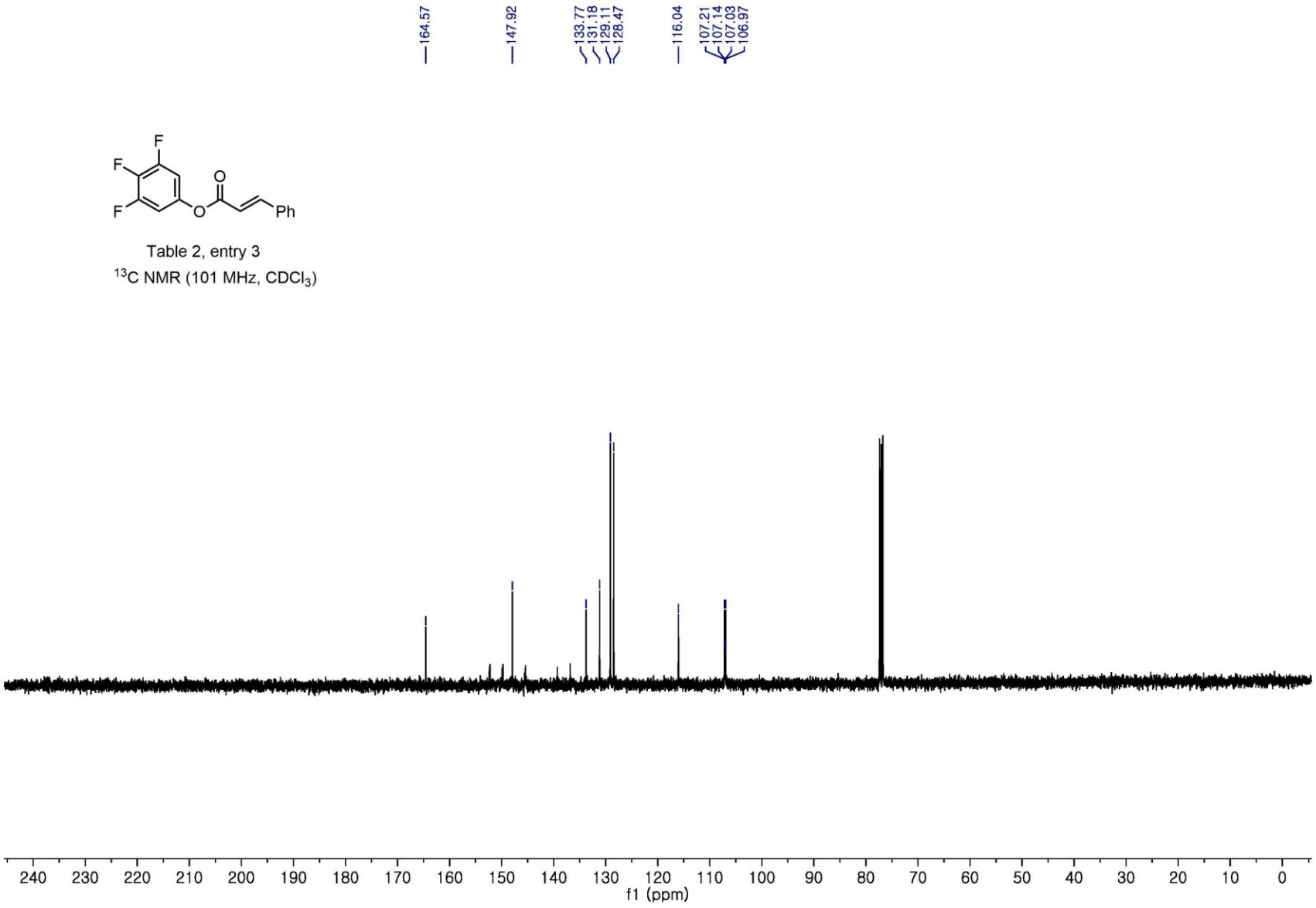


Table 2, entry 3

^{13}C NMR (101 MHz, $CDCl_3$)

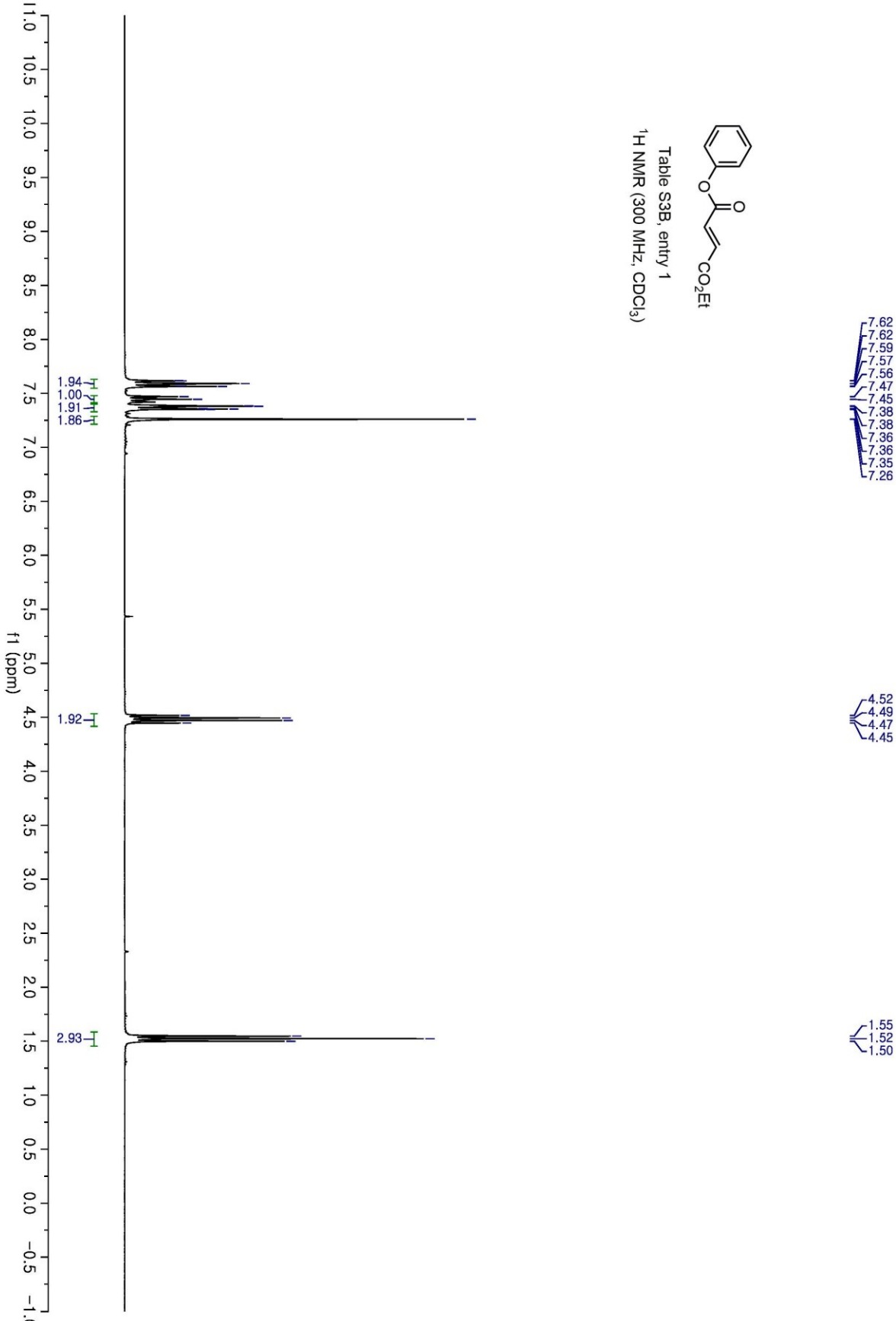


Table S3B, entry 1
^{1}H NMR (300 MHz, $CDCl_3$)
CO_2Et
7.62
7.62
7.59
7.57
7.56
7.47
7.45
7.38
7.38
7.36
7.36
7.35
7.26
4.52
4.49
4.47
4.45
1.55
1.52
1.50
1.94
1.00
1.91
1.86
1.92
2.93
f1 (ppm)

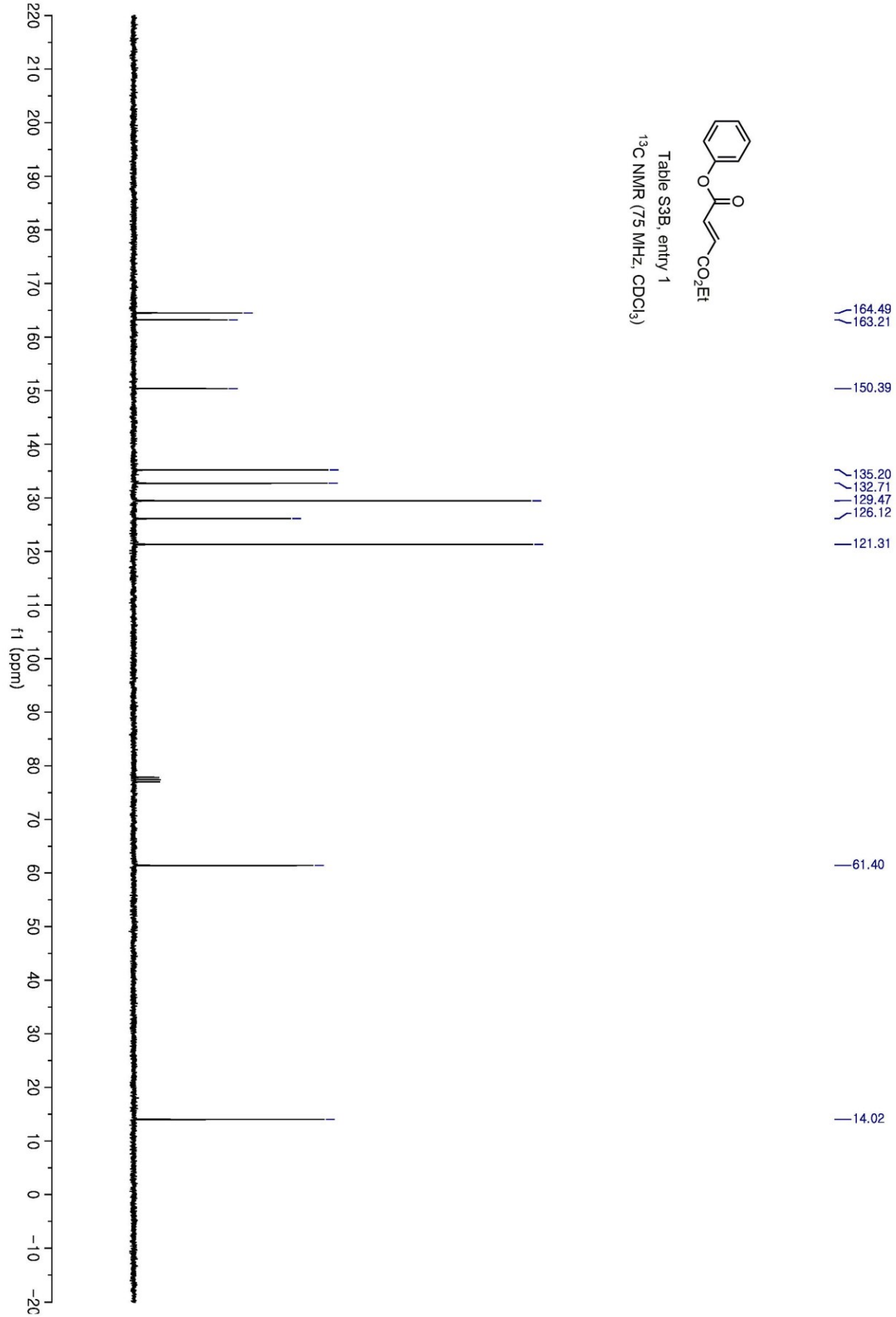
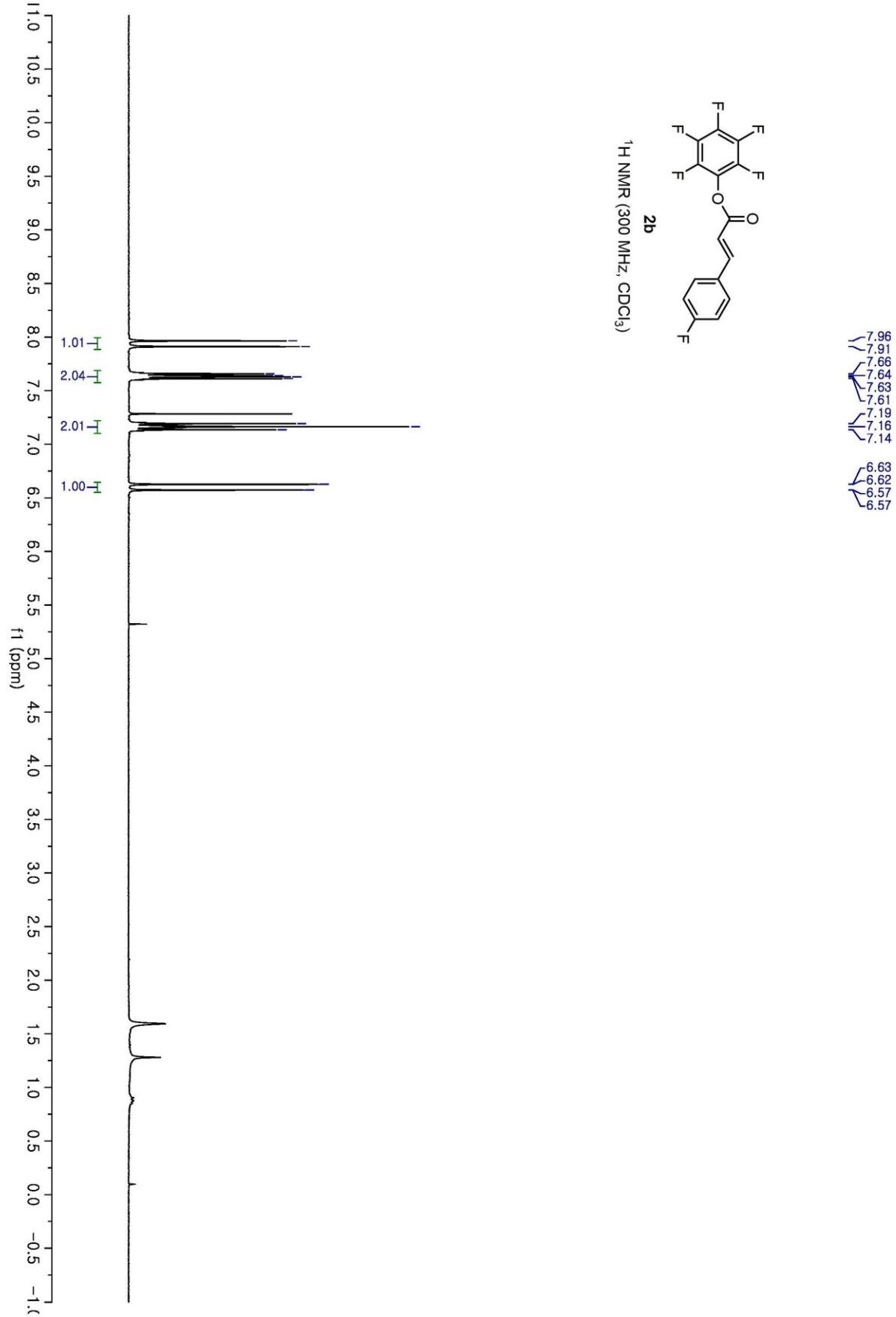
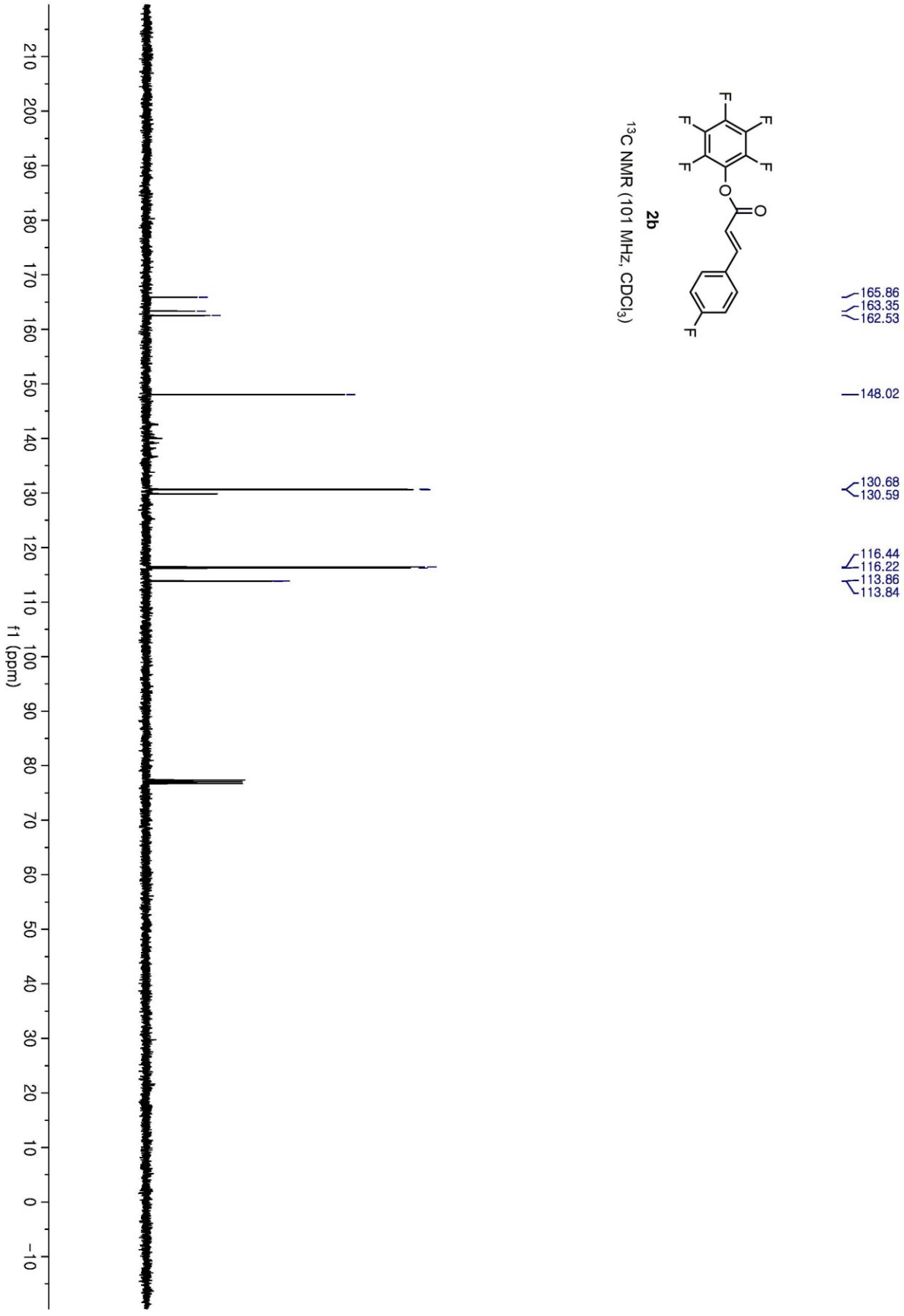
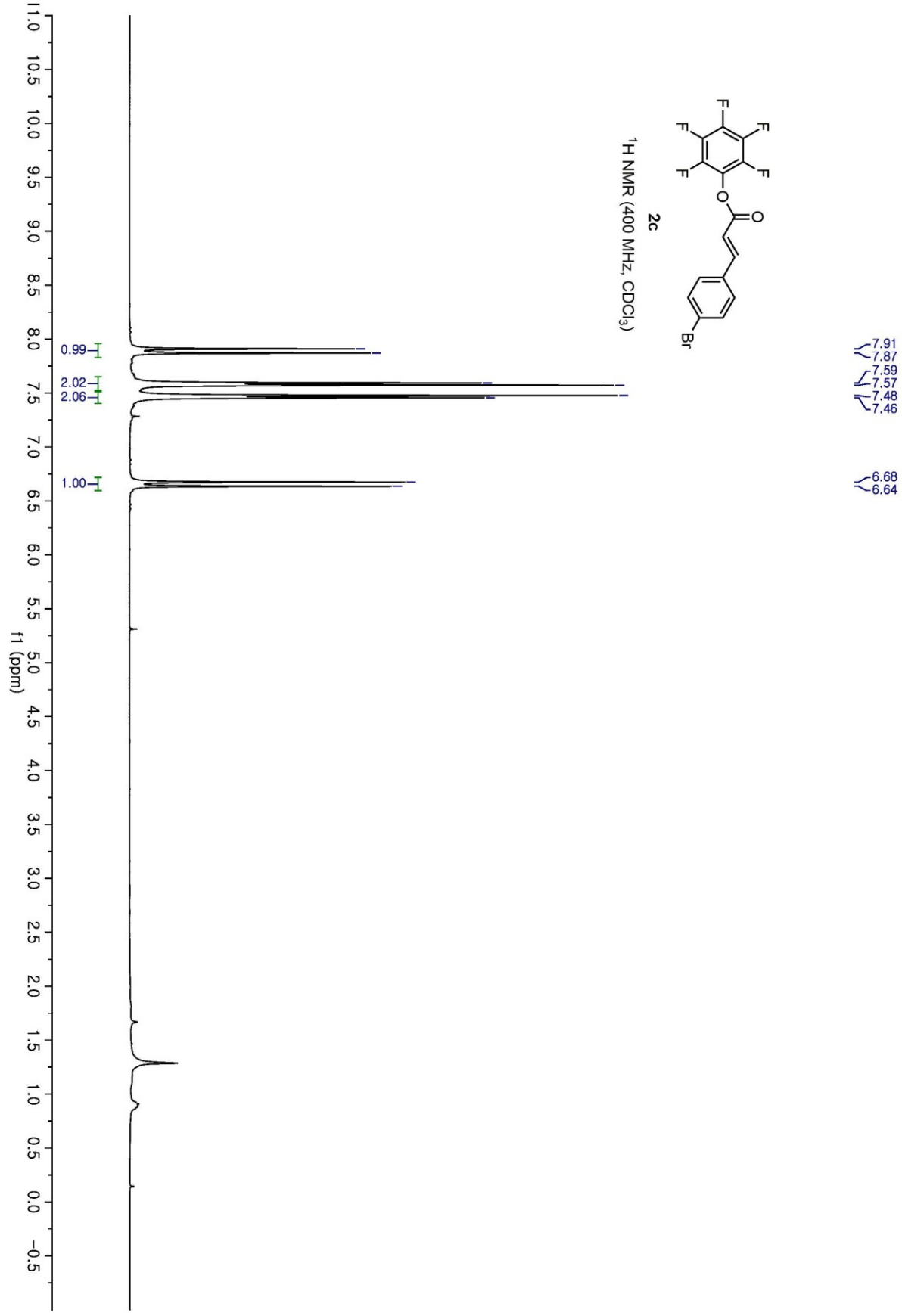
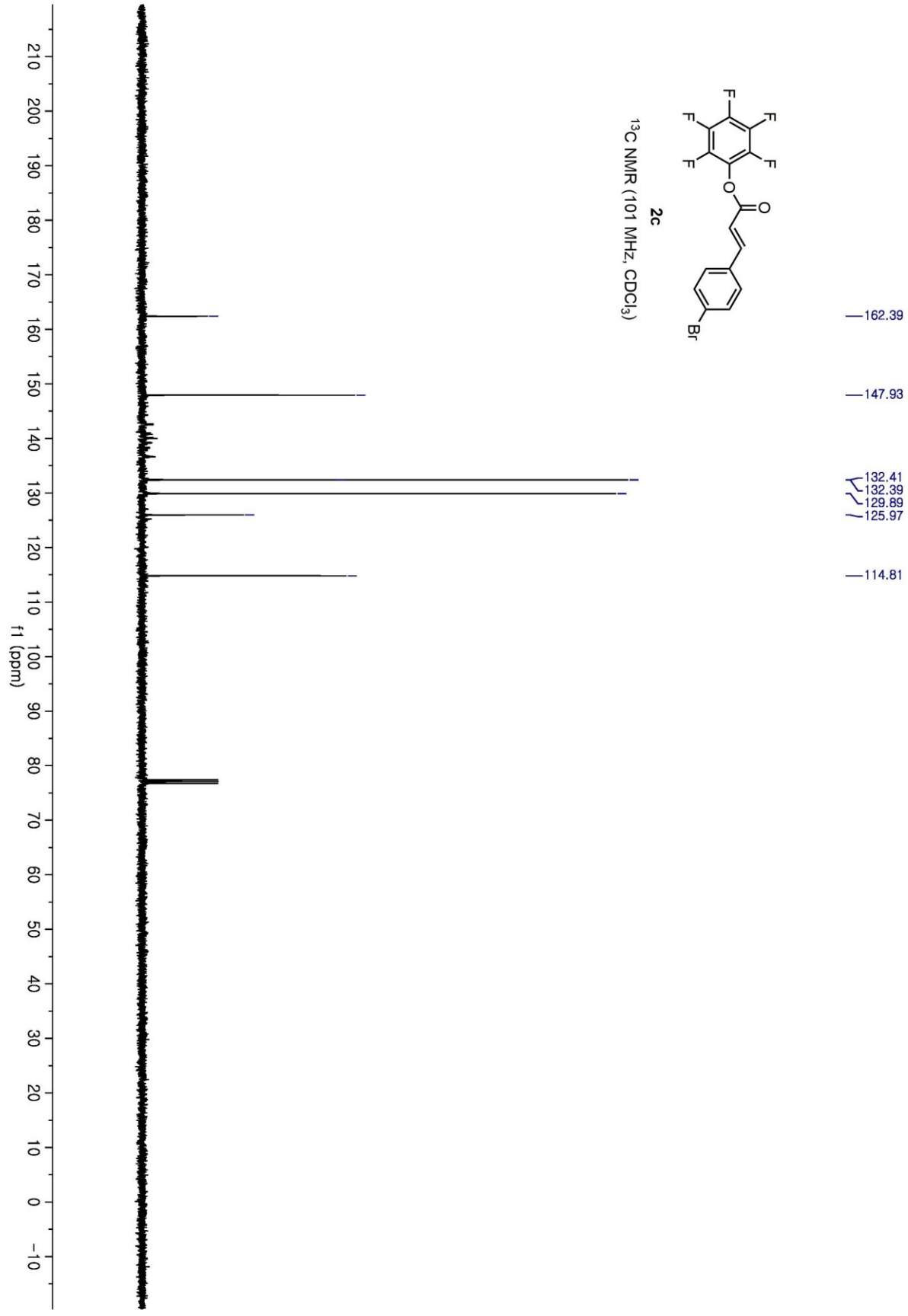


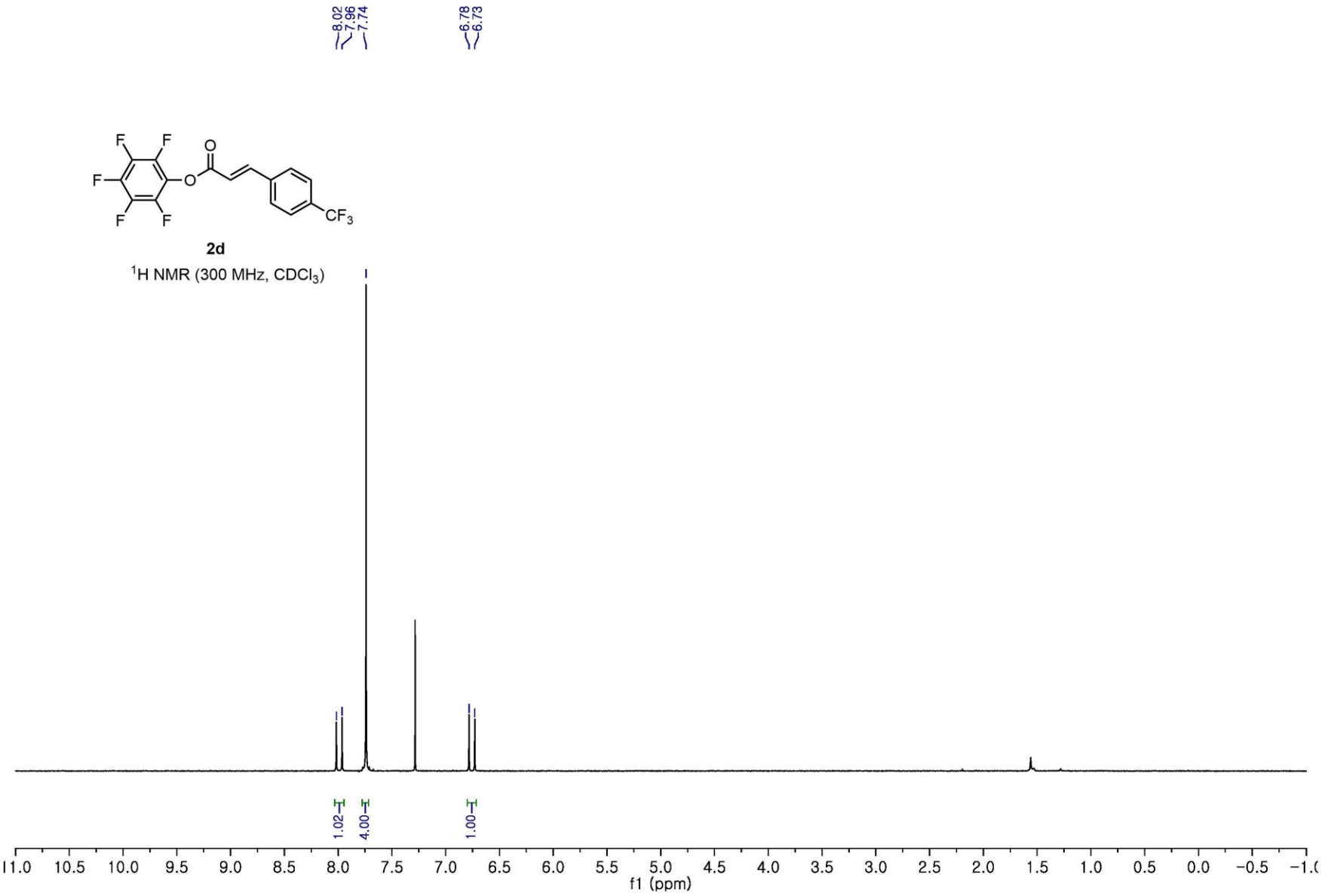
Table S3B, entry 1
^{13}C NMR (75 MHz, $CDCl_3$)
CO_2Et
164.49
163.21
150.39
135.20
132.71
129.47
126.12
121.31
61.40
14.02
f1 (ppm)

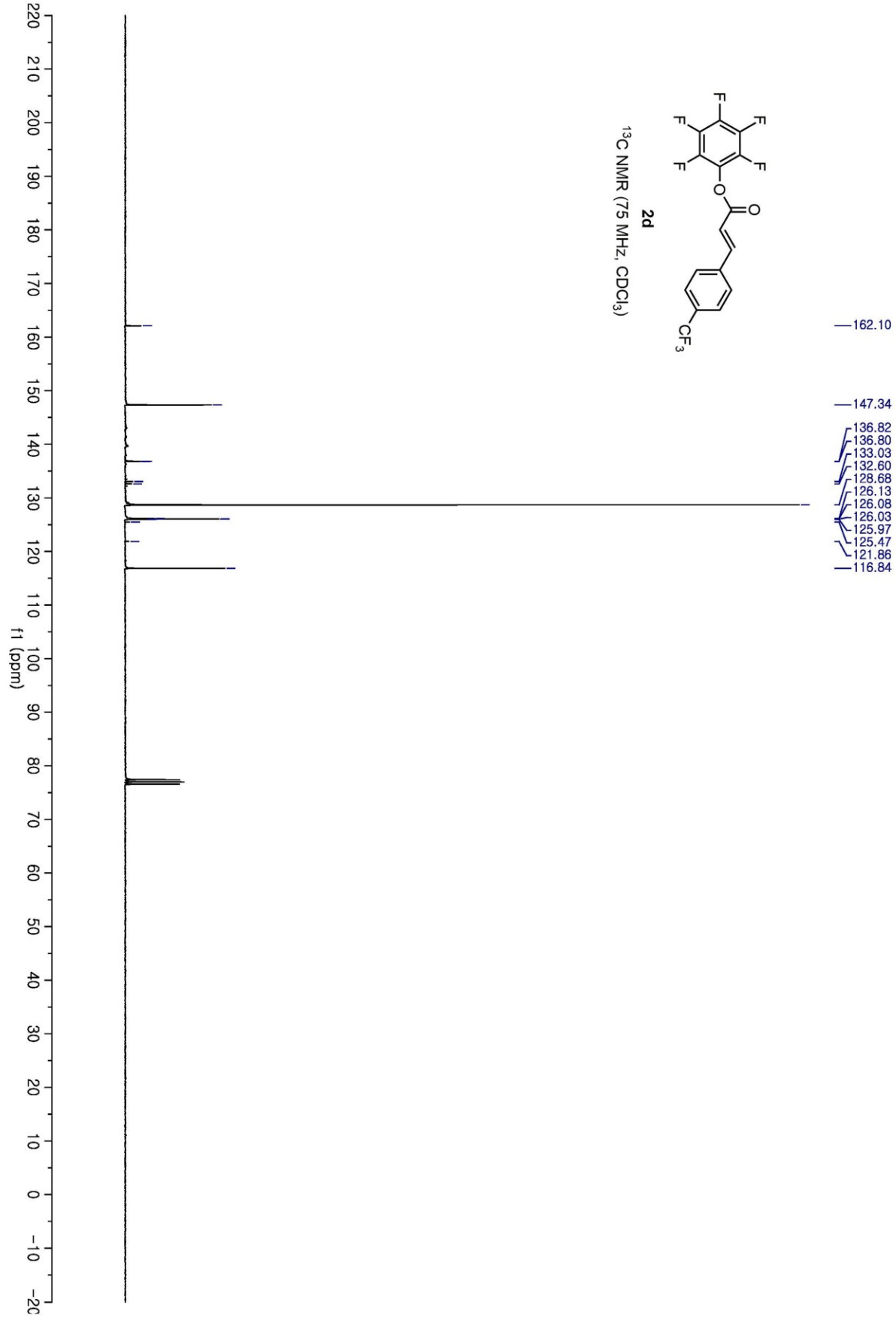

2b
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
F
7.96
7.91
7.66
7.64
7.63
7.61
7.19
7.16
7.14
6.63
6.62
6.57
6.57
1.01
2.04
2.01
1.00
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

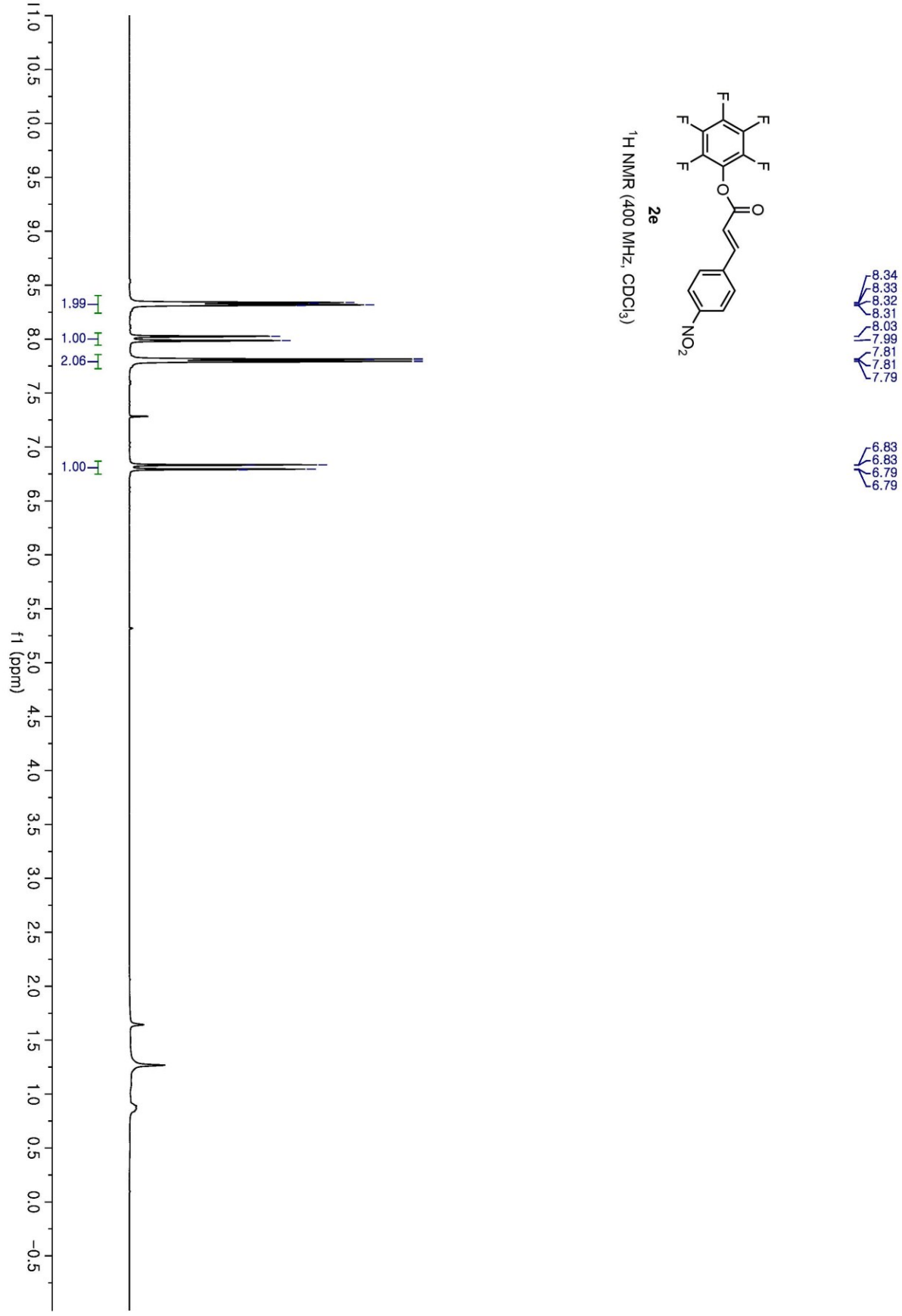

2b
^{13}C NMR (101 MHz, CDCl$_3$)
165.86
163.35
162.53
148.02
130.68
130.59
116.44
116.22
113.86
113.84
f1 (ppm)

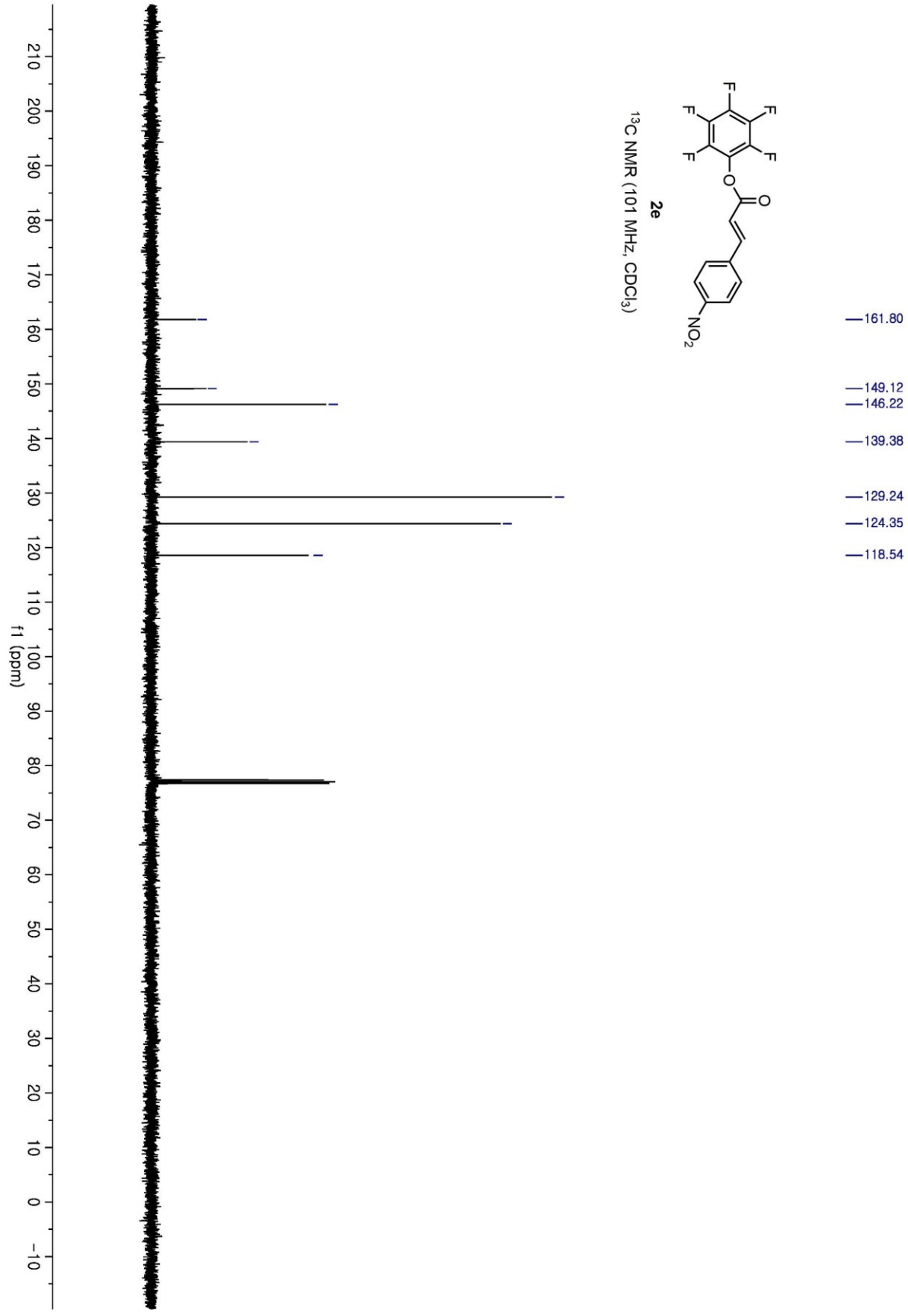

2c
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Br
7.91
7.87
7.59
7.57
7.48
7.46
6.68
6.64
0.99
2.02
2.06
1.00
f1 (ppm)

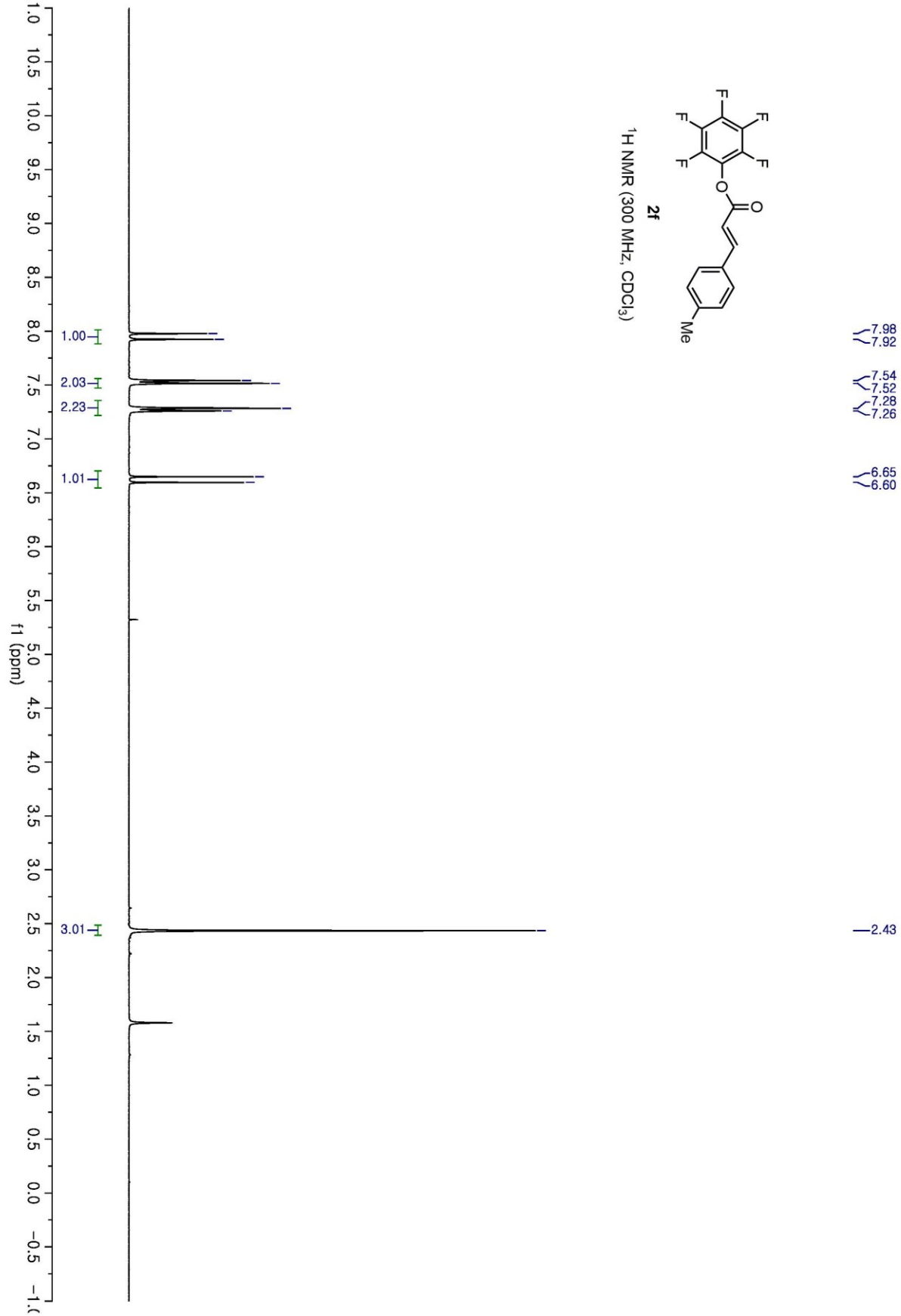

2c
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Br
162.39
147.93
132.41
132.39
129.89
125.97
114.81
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

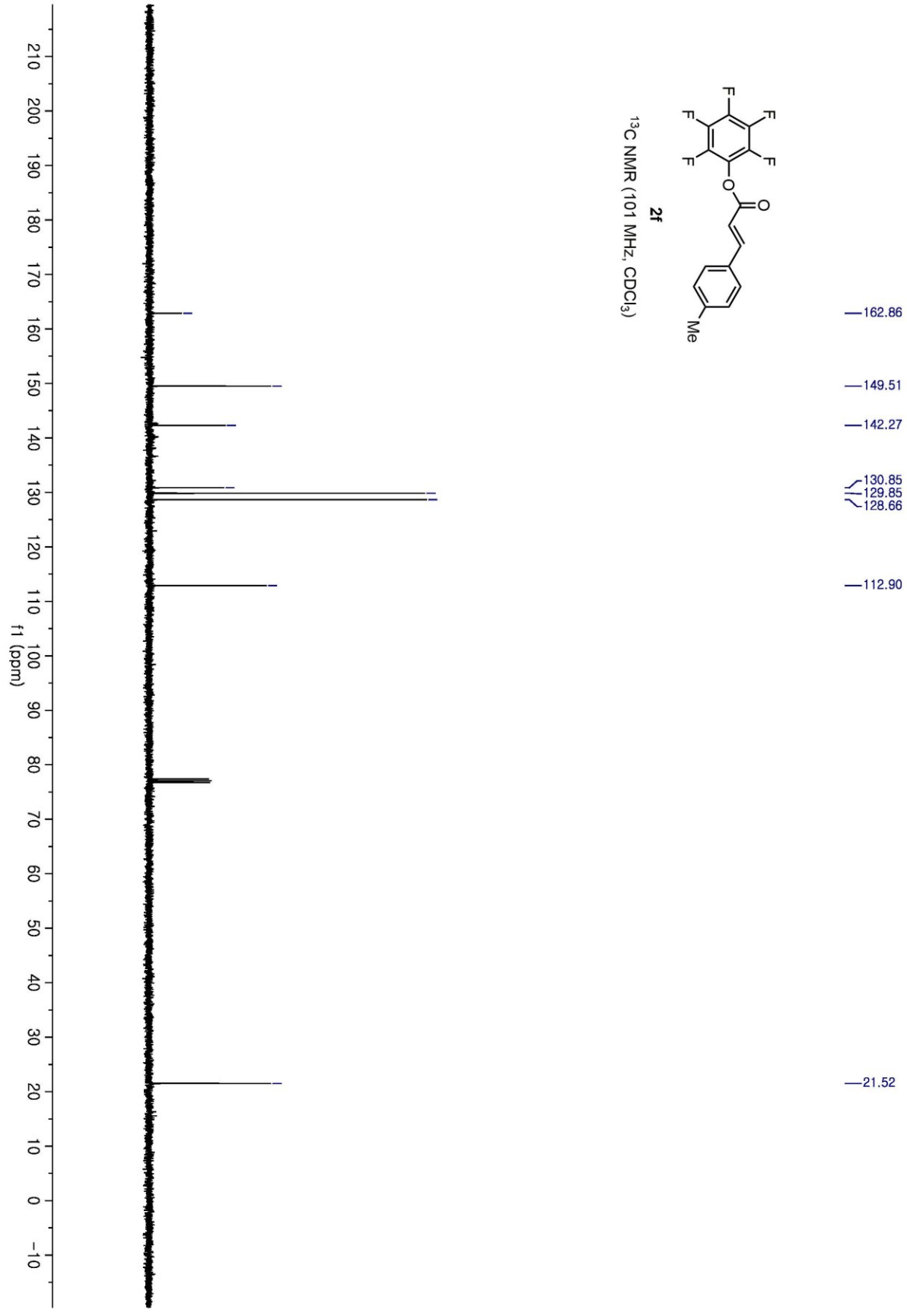

8.02
7.96
7.74
6.78
6.73
F
F
F
F
F
O
O
CF3
2d
1H NMR (300 MHz, CDCl3)
1.02
4.00
1.00
f1 (ppm)

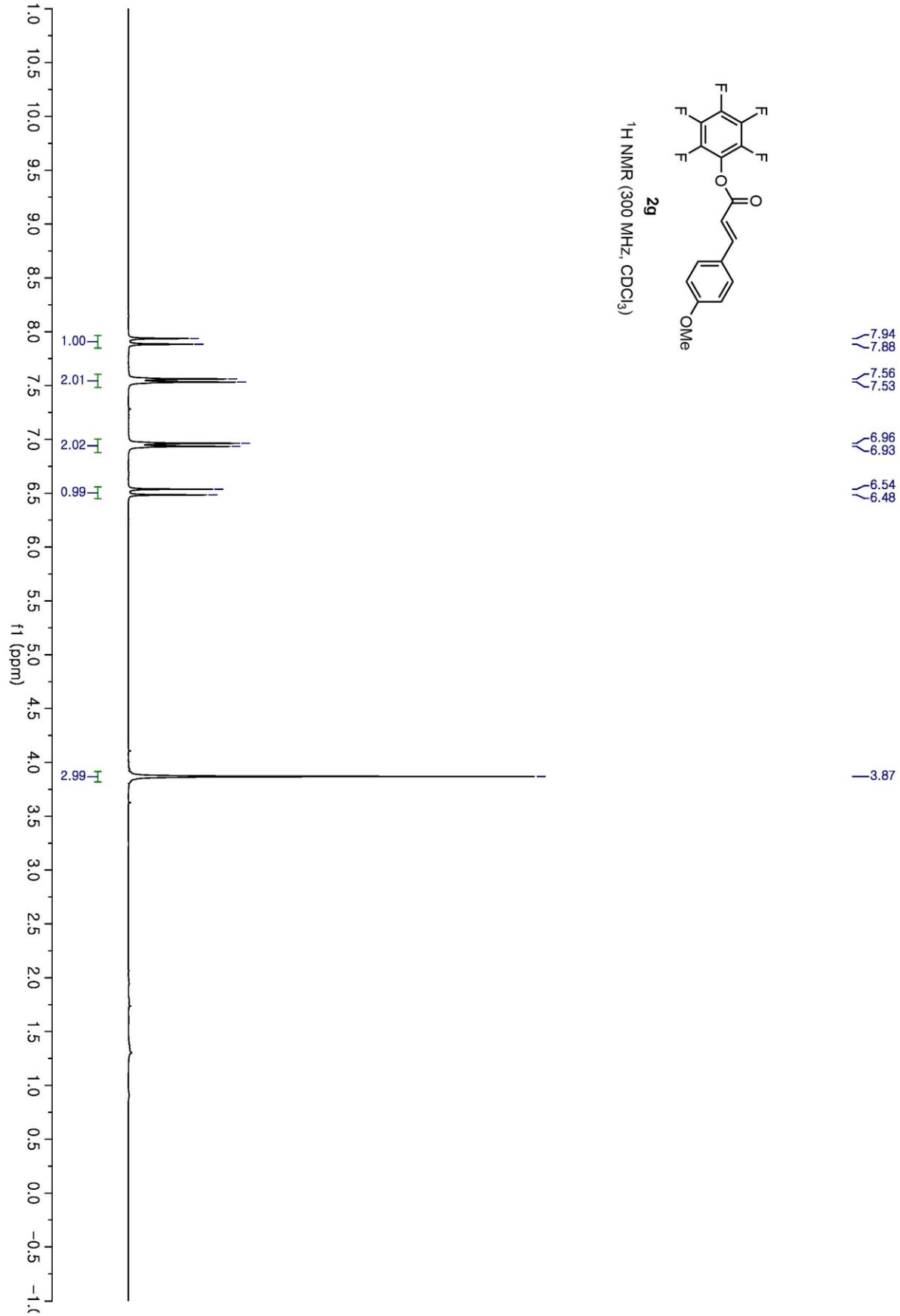

2d
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
CF$_3$
162.10
147.34
136.82
136.80
133.03
132.60
128.68
126.13
126.08
126.03
125.97
125.47
121.86
116.84
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20

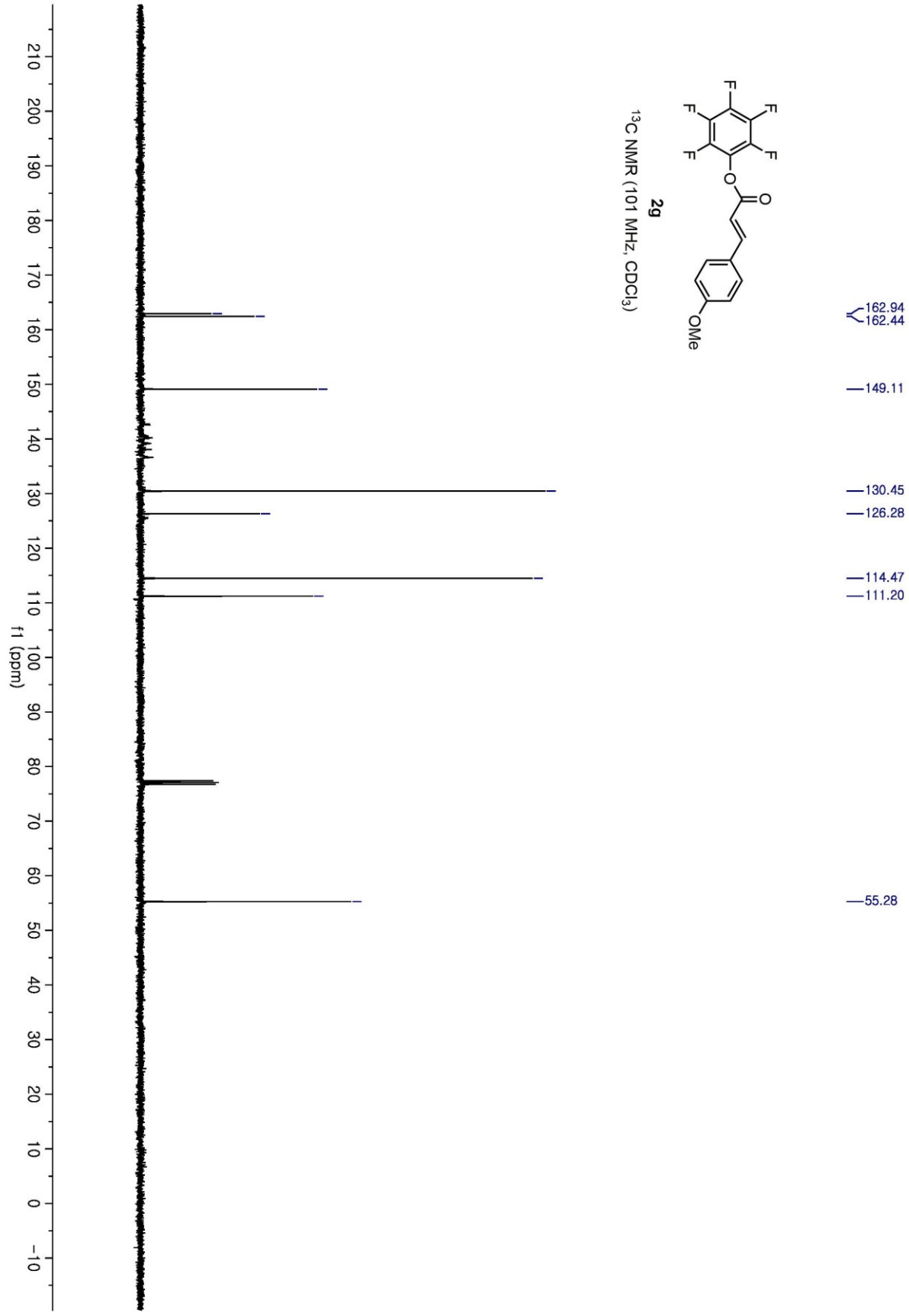

2e
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
NO$_2$
8.34
8.33
8.32
8.31
8.03
7.99
7.81
7.81
7.79
6.83
6.83
6.79
6.79
1.99
1.00
2.06
1.00
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

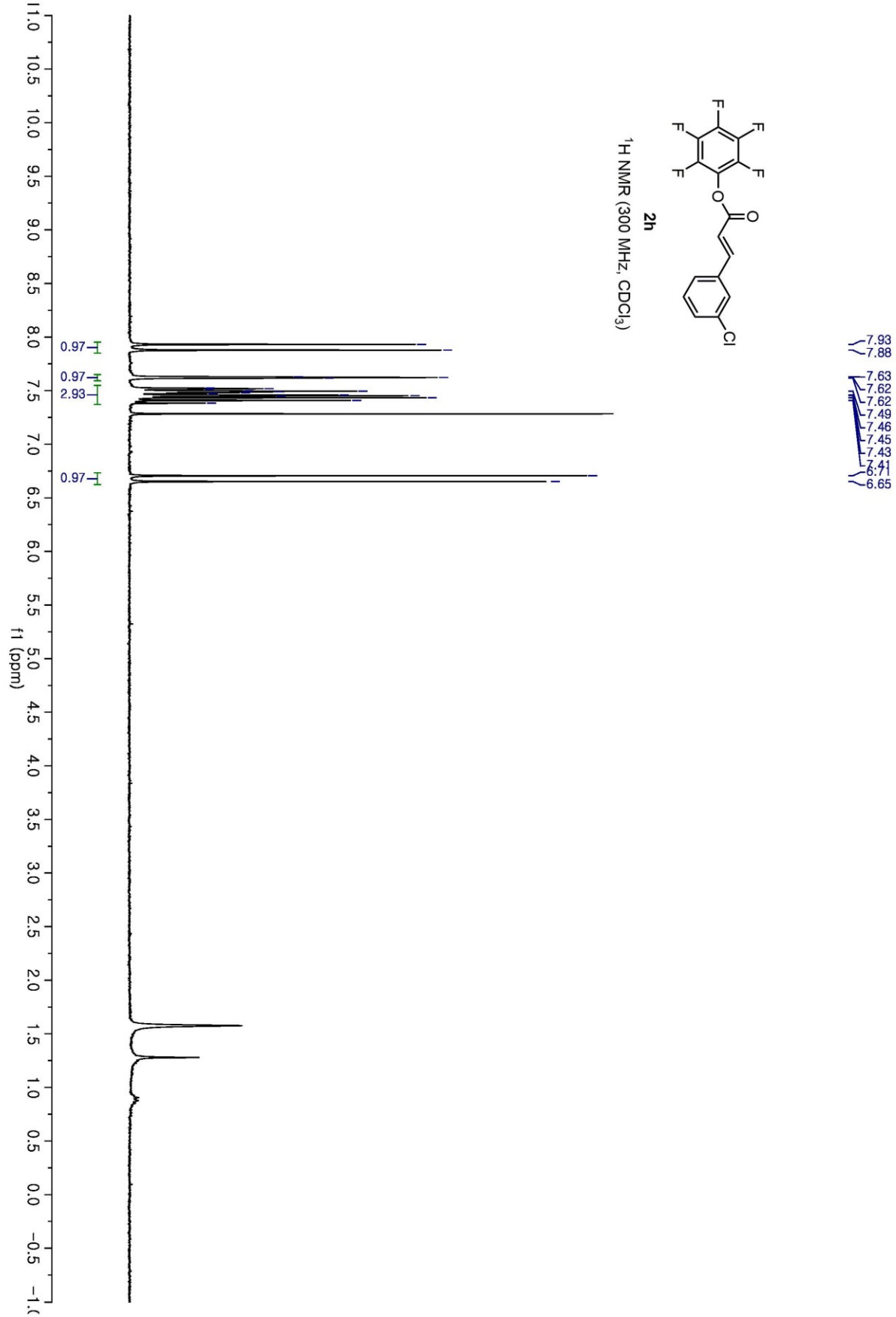

2e
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
NO$_2$
161.80
149.12
146.22
139.38
129.24
124.35
118.54
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

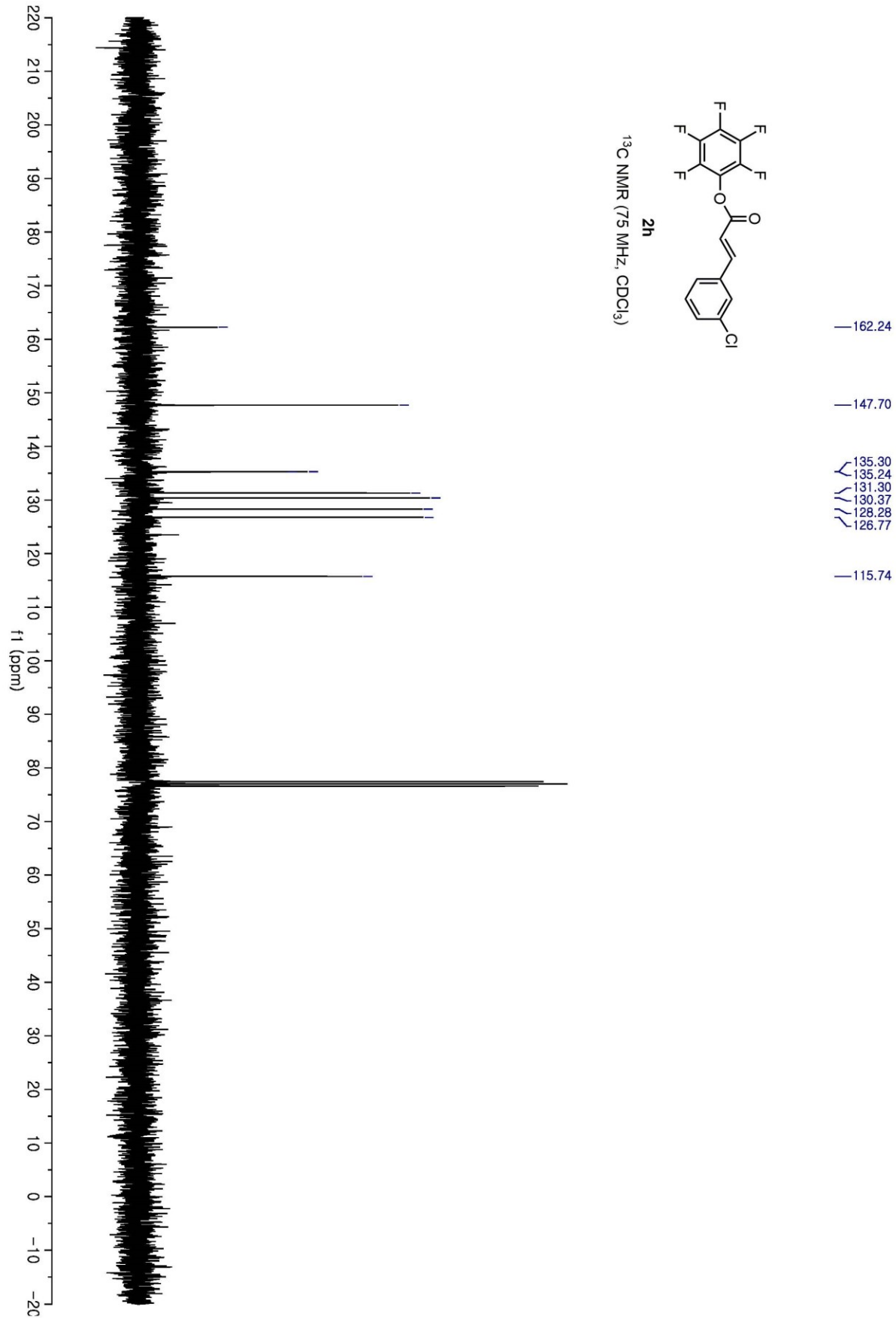

2f
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
7.98
7.92
7.54
7.52
7.28
7.26
6.65
6.60
2.43
1.00
2.03
2.23
1.01
3.01
f1 (ppm)

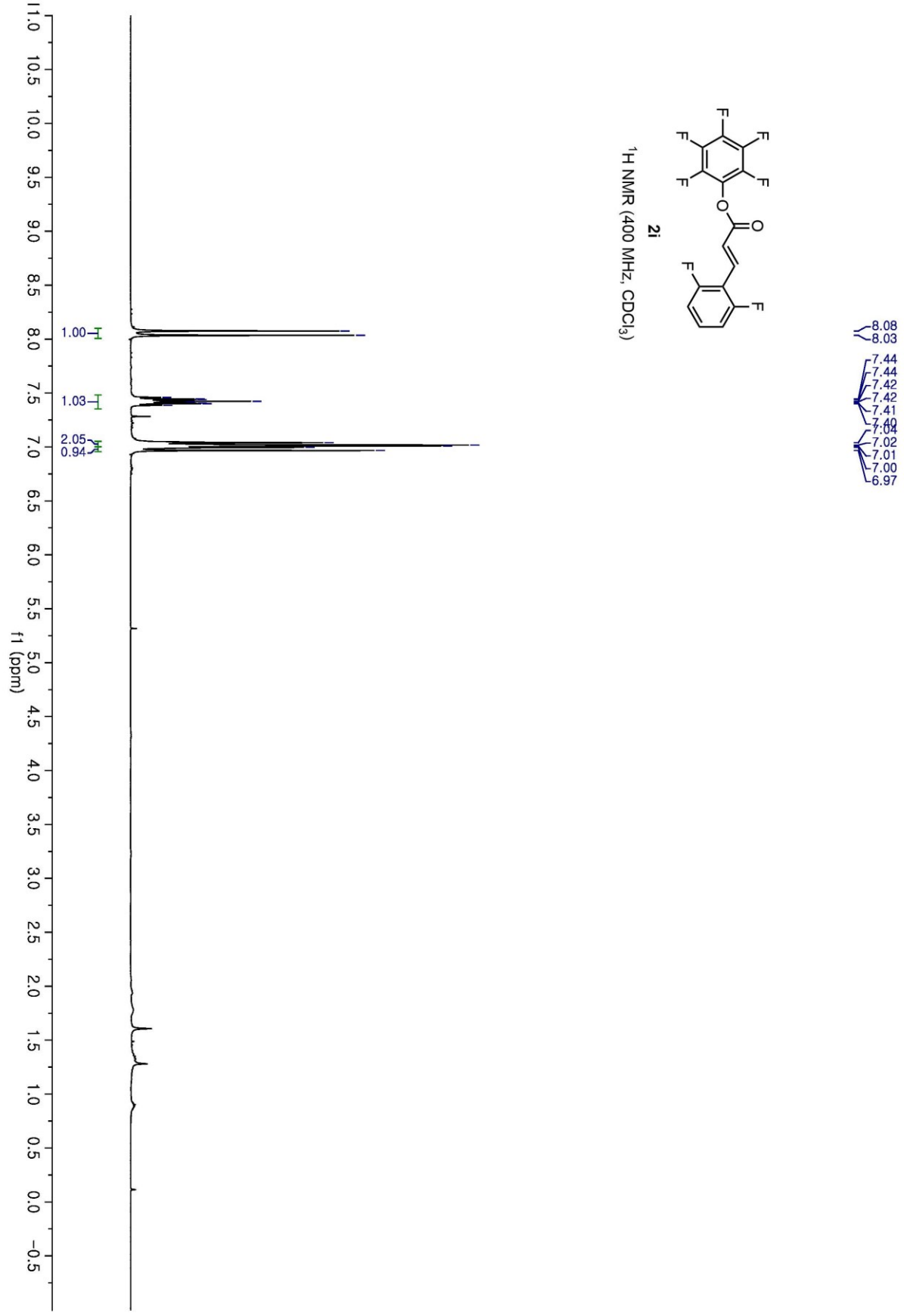

2f
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
162.86
149.51
142.27
130.85
129.85
128.66
112.90
21.52
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

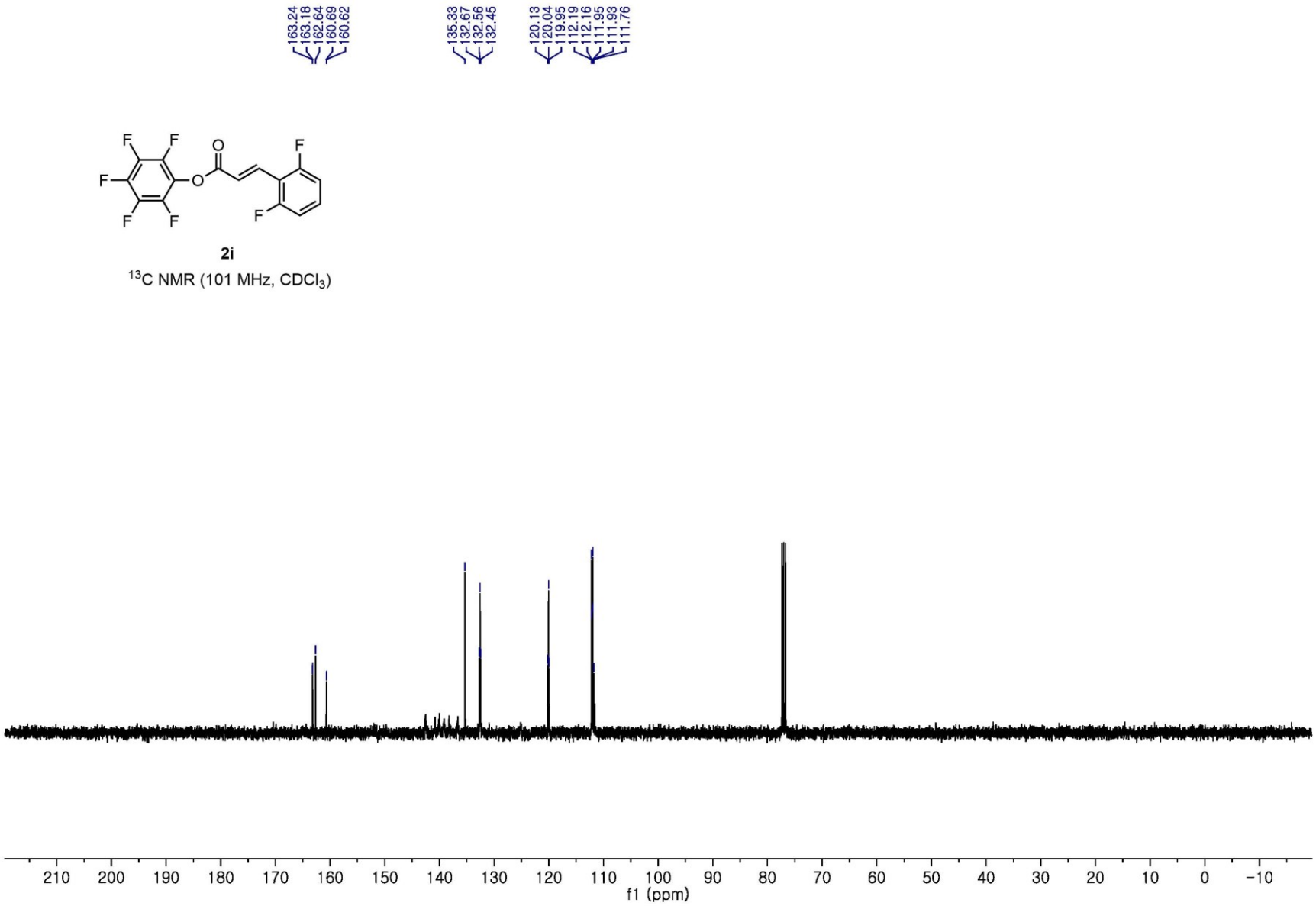

2g
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
OMe
7.94
7.88
7.56
7.53
6.96
6.93
6.54
6.48
3.87
1.00
2.01
2.02
0.99
2.99
f1 (ppm)

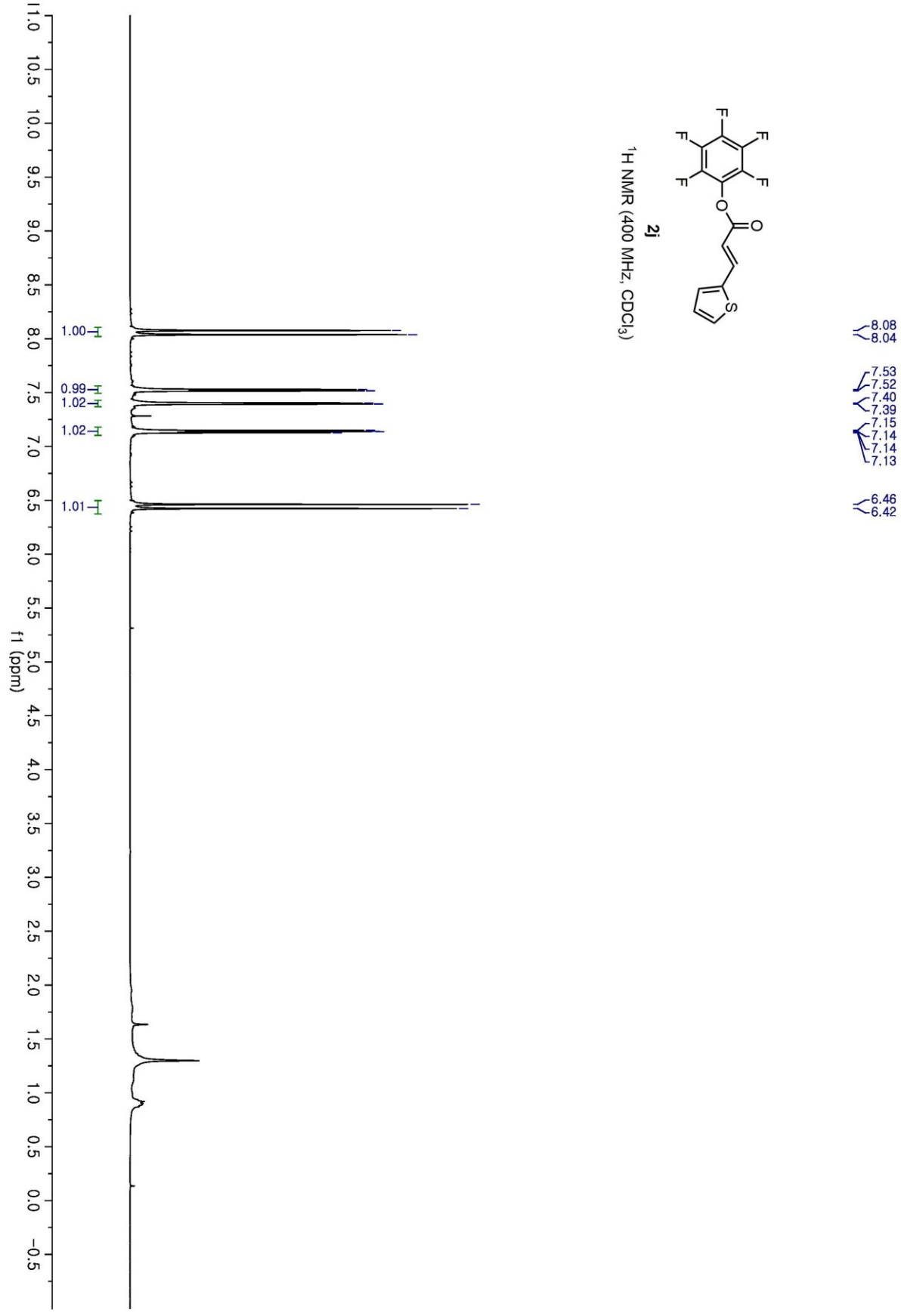

2g
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
OMe
162.94
162.44
149.11
130.45
126.28
114.47
111.20
55.28
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

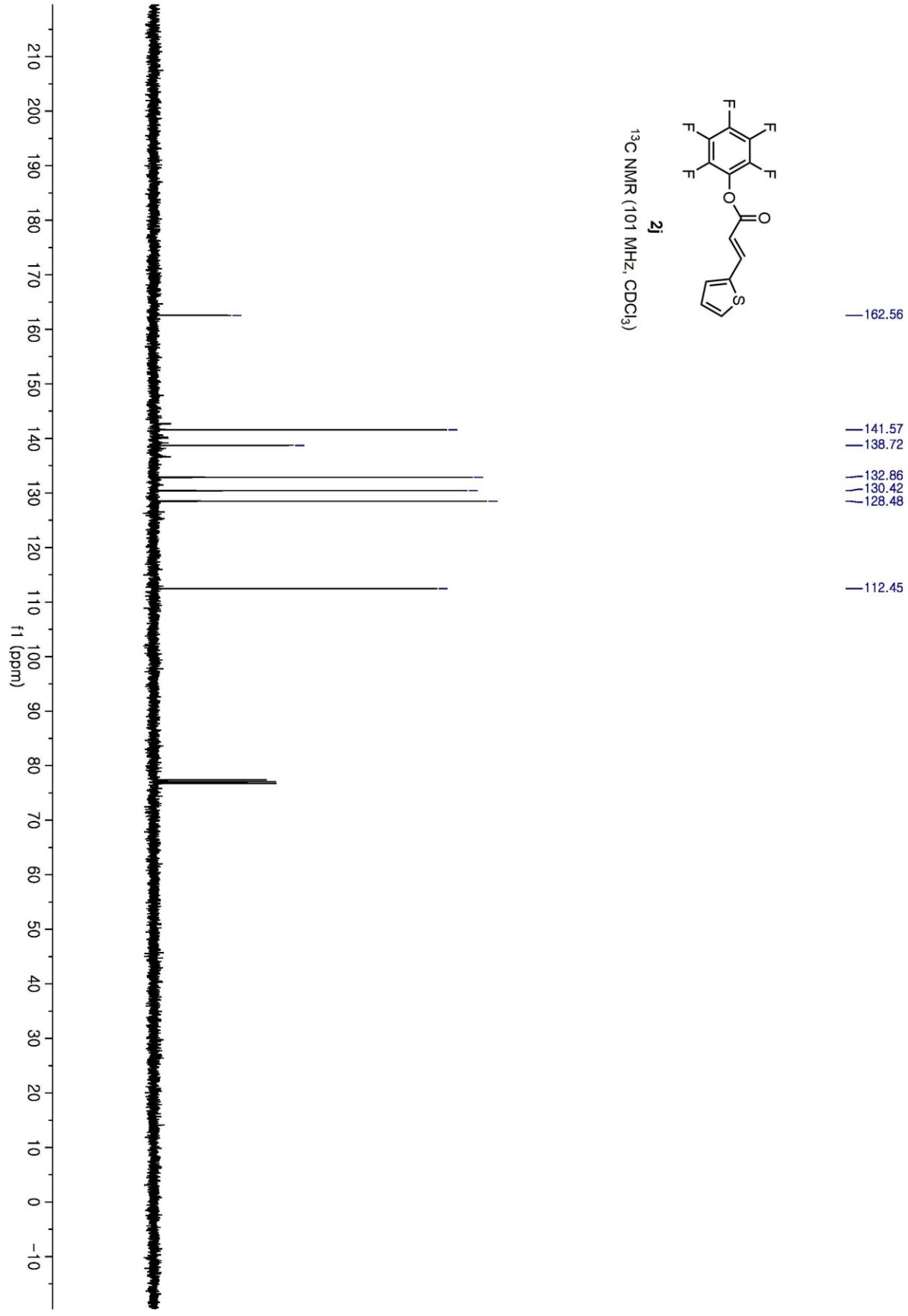

2h
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Cl
7.93
7.88
7.63
7.62
7.62
7.49
7.46
7.45
7.43
7.41
6.71
6.65
0.97
0.97
2.93
0.97
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

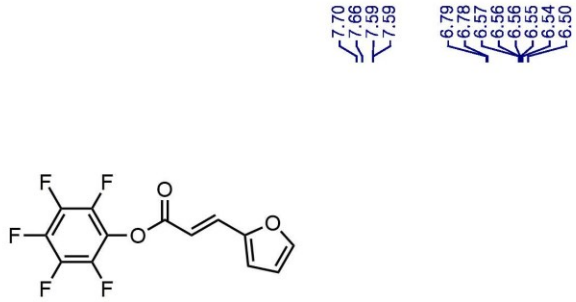

2h
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Cl
162.24
147.70
135.30
135.24
131.30
130.37
128.28
126.77
115.74
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20


2i
^{1}H NMR (400 MHz, CDCl$_3$)
8.08
8.03
7.44
7.44
7.42
7.42
7.41
7.40
7.04
7.02
7.01
7.00
6.97
1.00
1.03
2.05
0.94
f1 (ppm)


163.24
163.18
162.84
160.69
160.62
135.33
132.67
132.56
132.45
120.13
120.04
119.95
112.19
112.16
111.95
111.93
111.76
F
F
F
F
F
O
O
F
2i
13C NMR (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

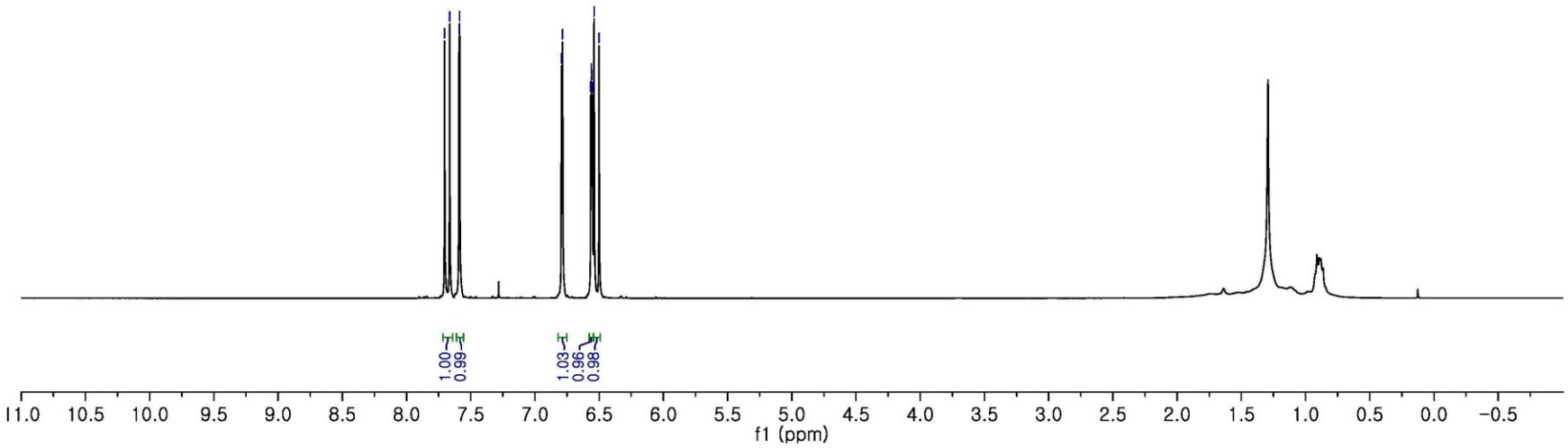

2j
^{1}H NMR (400 MHz, $CDCl_3$)
8.08
8.04
7.53
7.52
7.40
7.39
7.15
7.14
7.14
7.13
6.46
6.42
1.00
0.99
1.02
1.02
1.01
f1 (ppm)

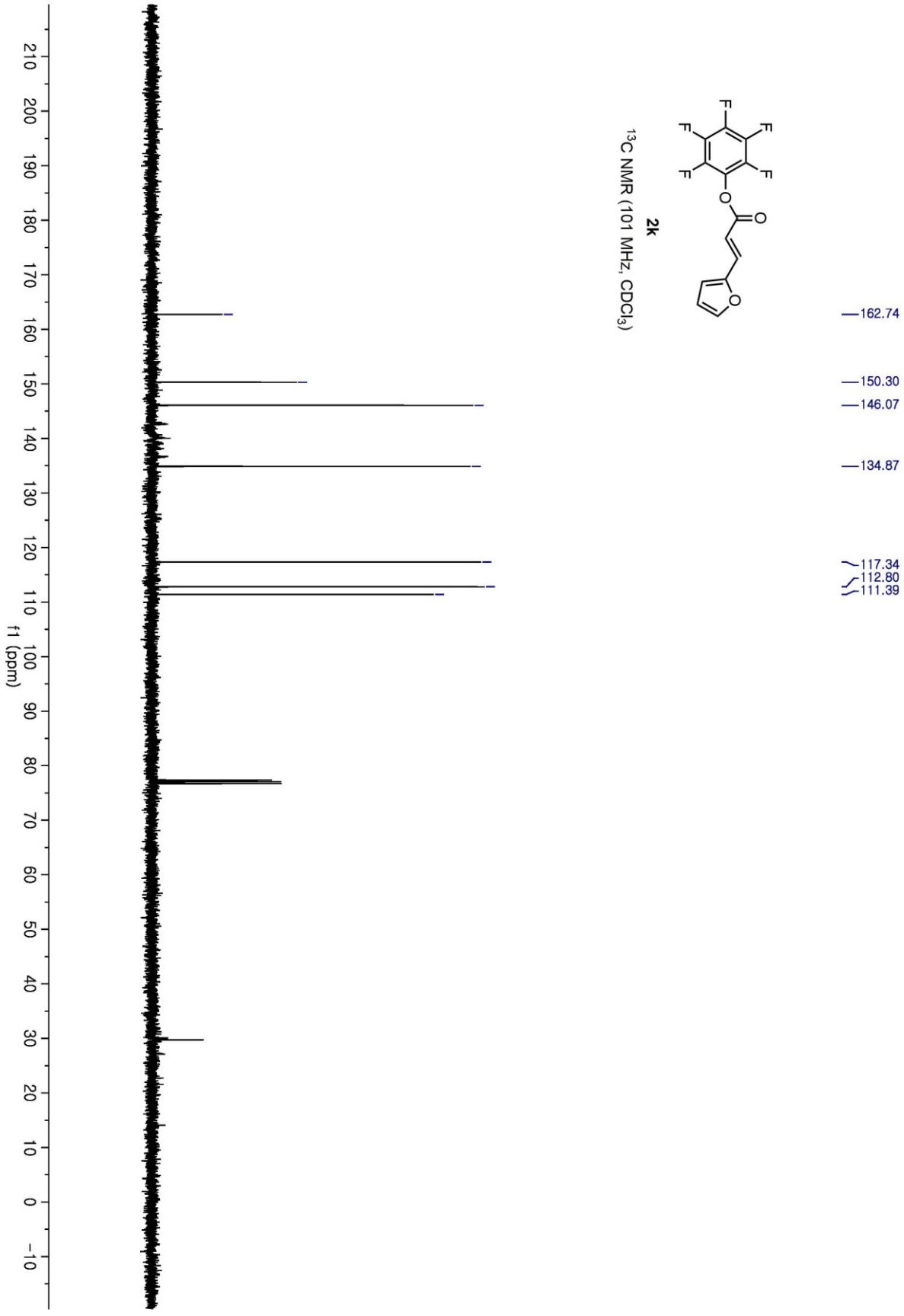

2j
^{13}C NMR (101 MHz, $CDCl_3$)
162.56
141.57
138.72
132.86
130.42
128.48
112.45
f1 (ppm)

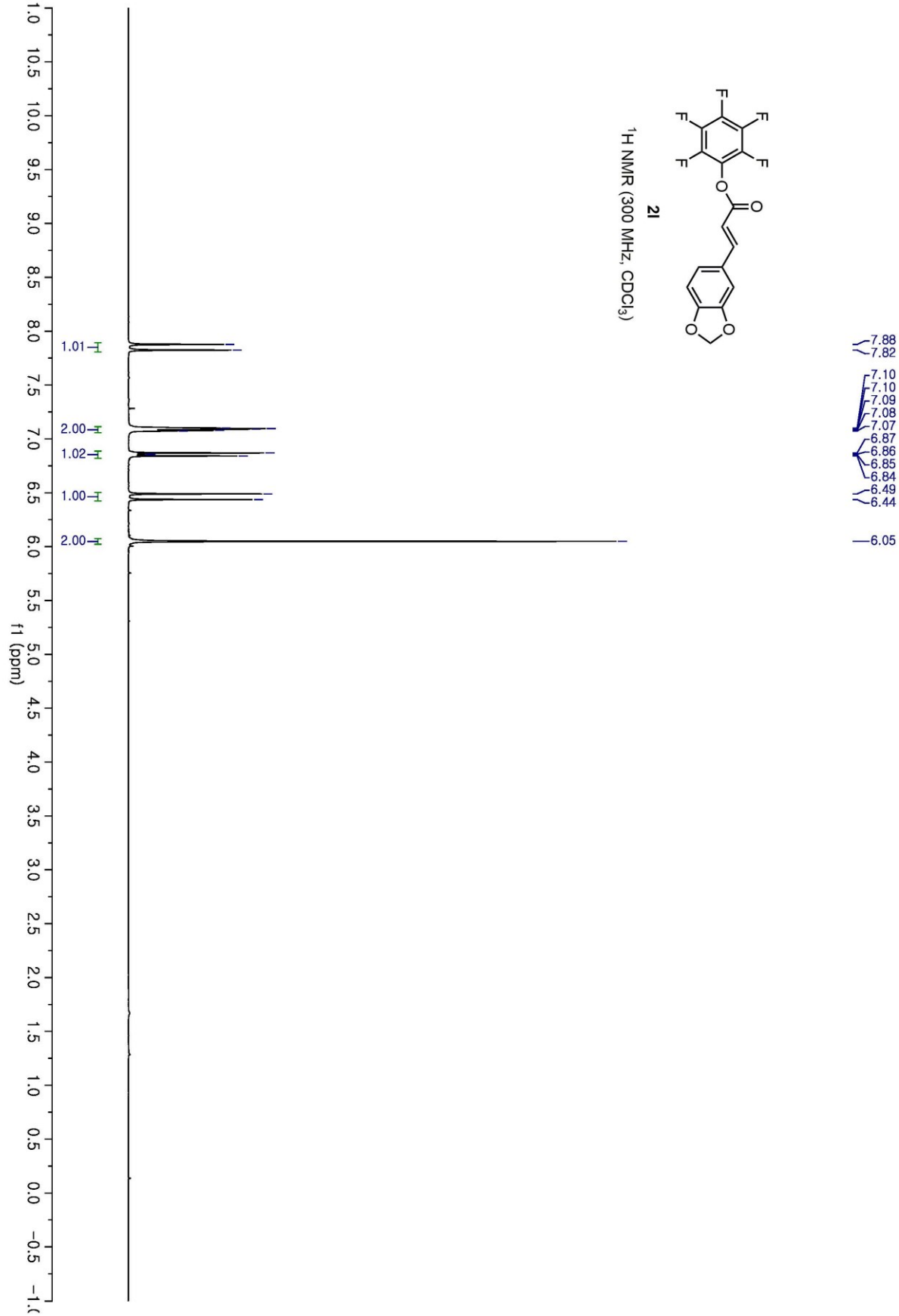


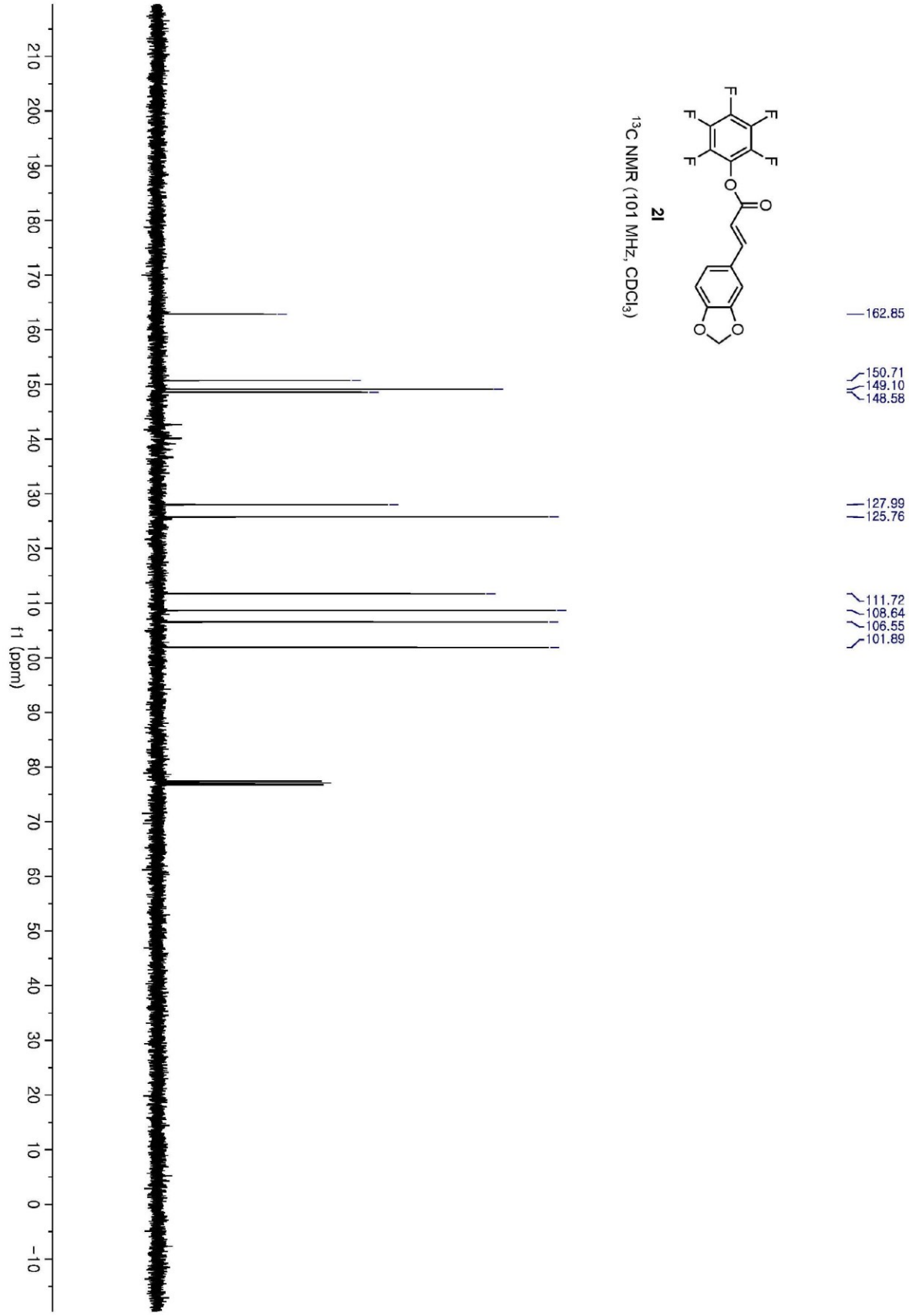
2k

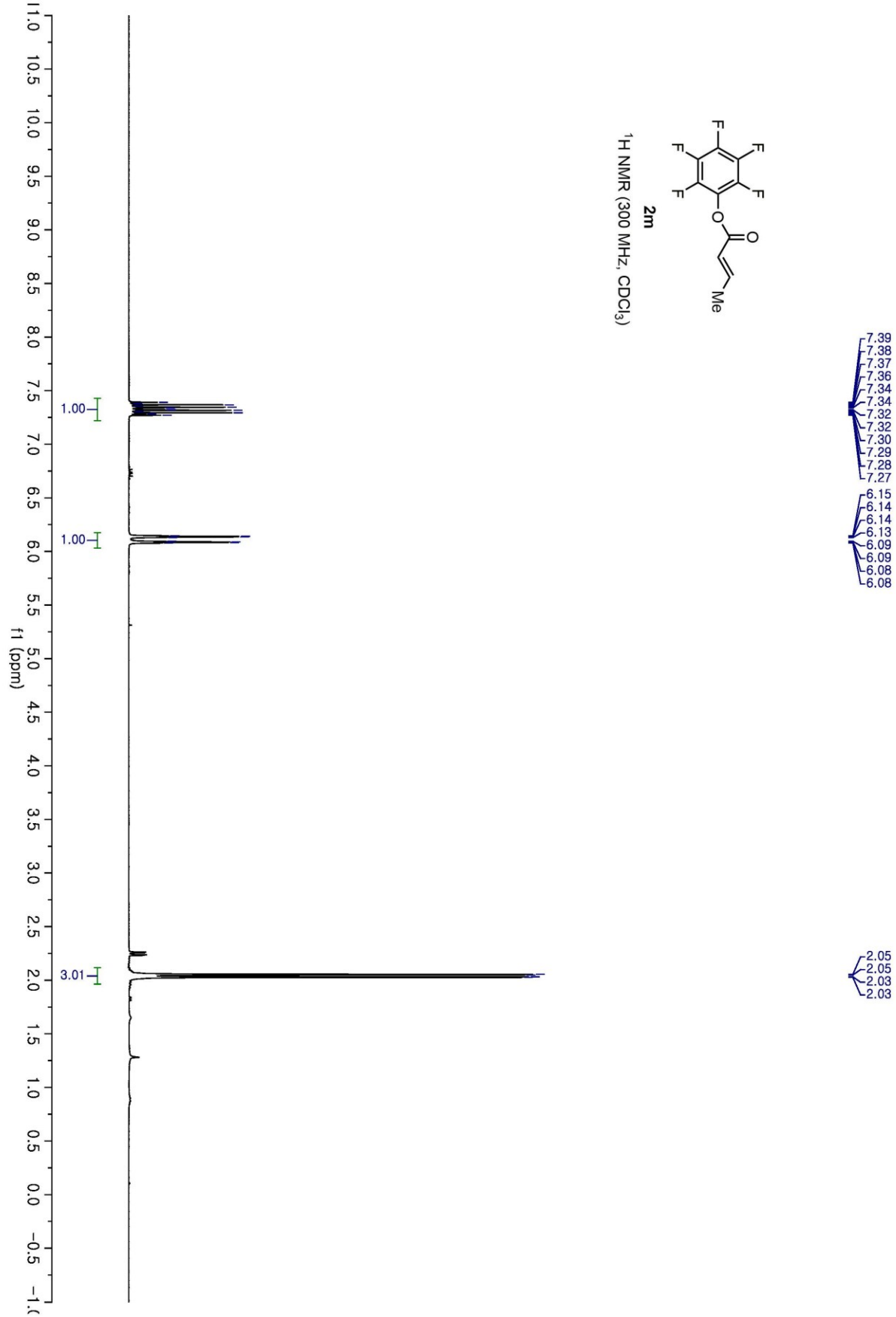
^{1}H NMR (400 MHz, $CDCl_3$)

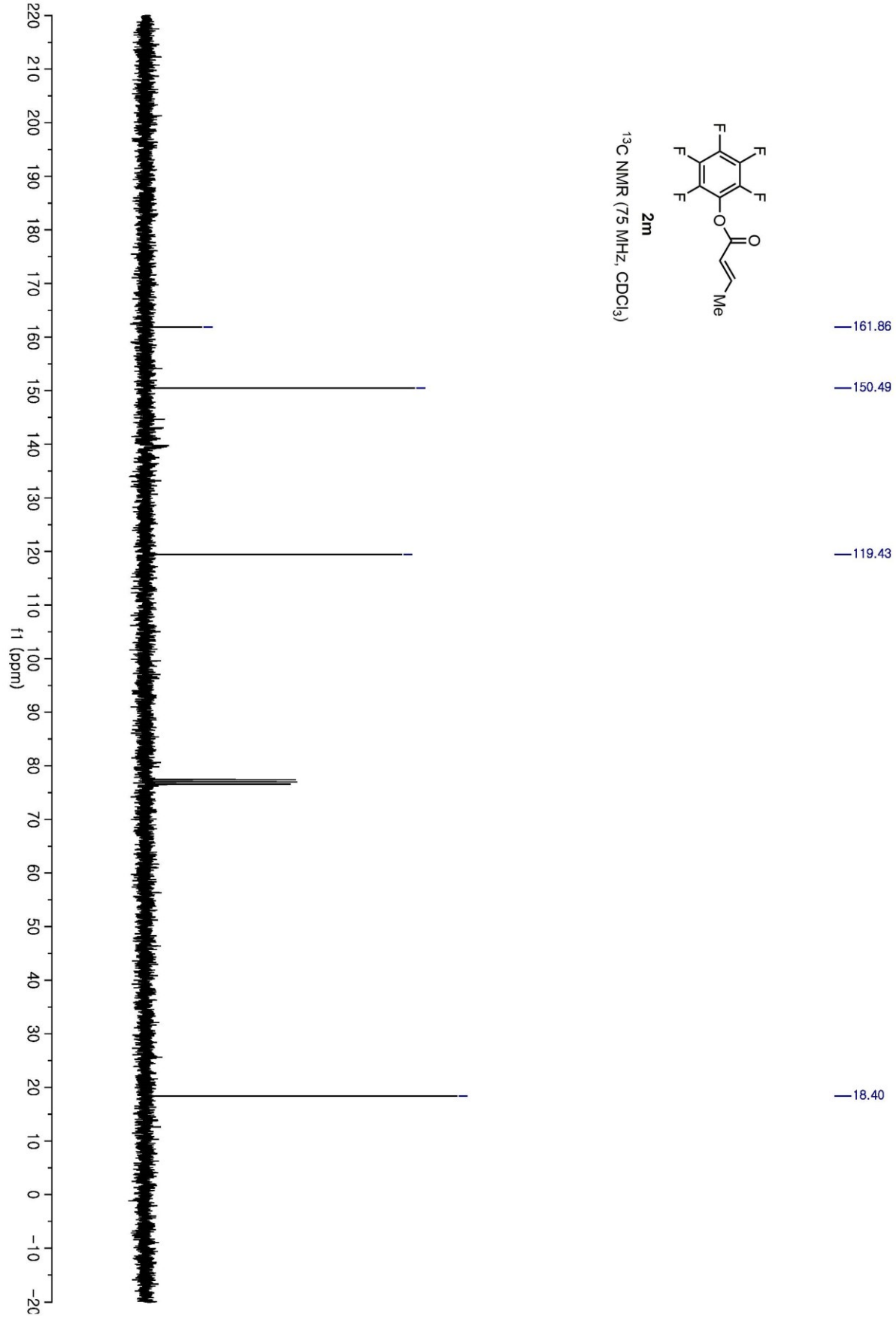


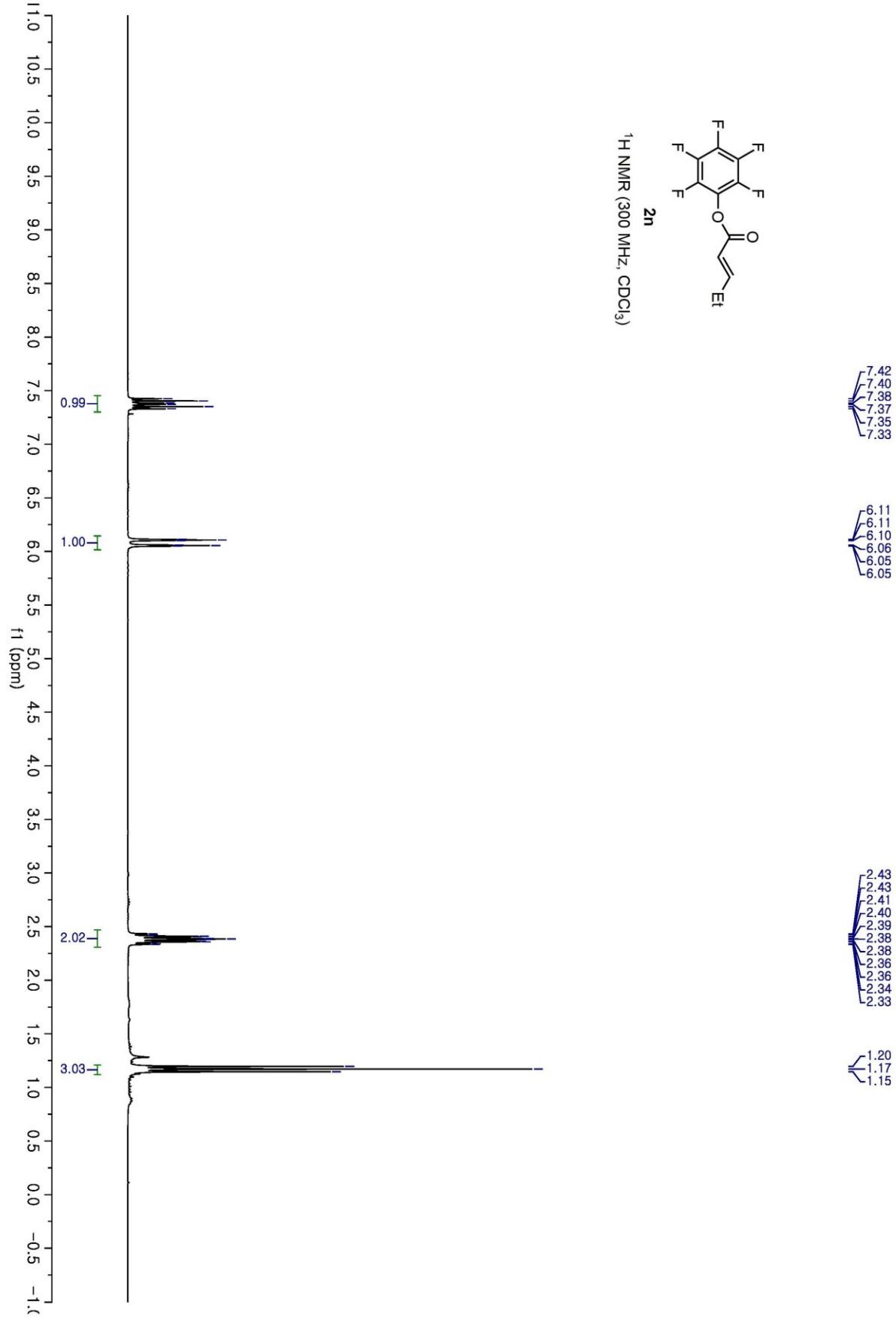

2k
^{13}C NMR (101 MHz, CDCl$_3$)
162.74
150.30
146.07
134.87
117.34
112.80
111.39
f1 (ppm)

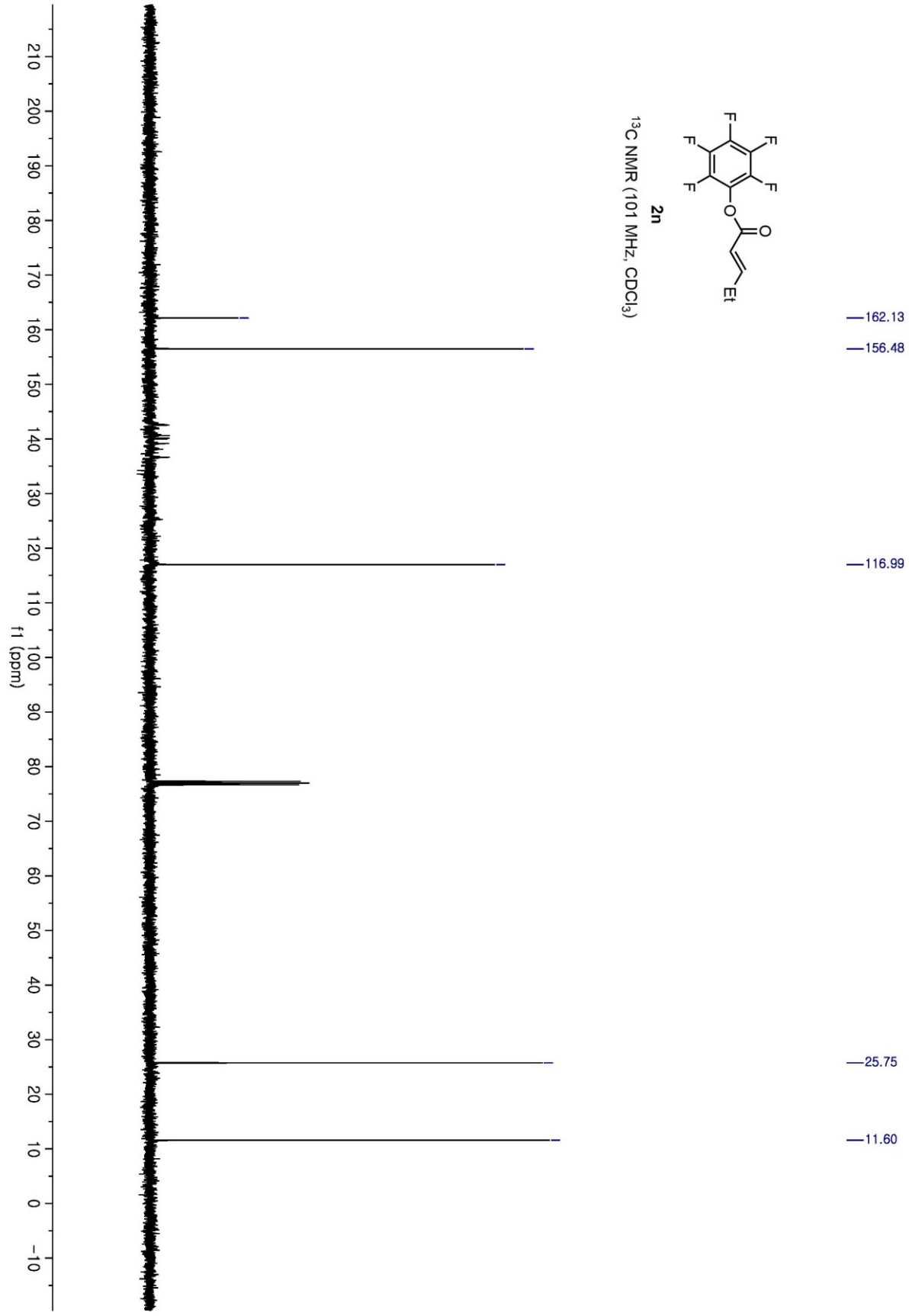

2l
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
O
O
1.01
2.00
1.02
1.00
2.00
7.88
7.82
7.10
7.10
7.09
7.08
7.07
6.87
6.86
6.85
6.84
6.49
6.44
6.05
f1 (ppm)

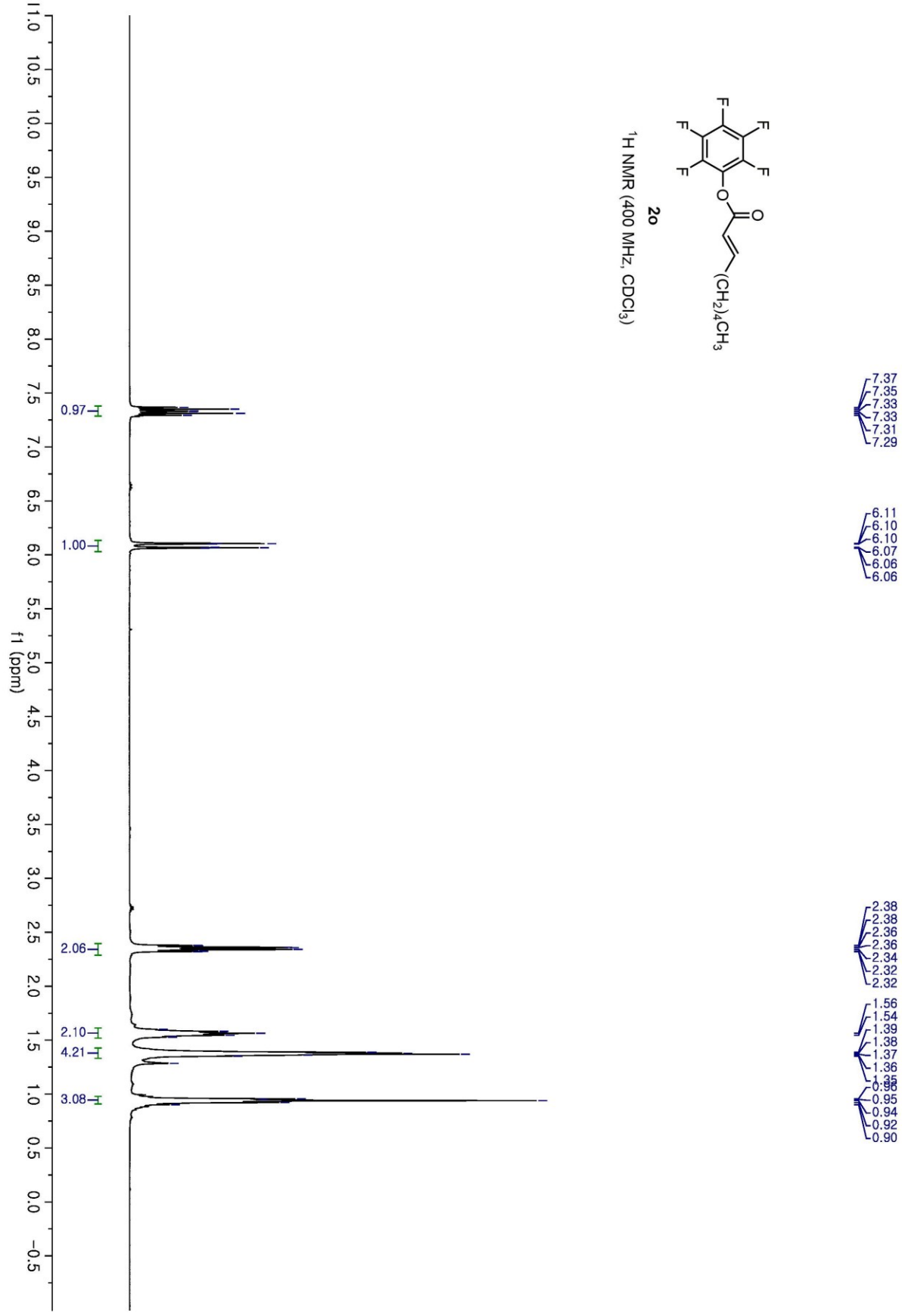

2l
^{13}C NMR (101 MHz, CDCl$_3$)
162.85
150.71
149.10
148.58
127.99
125.76
111.72
108.64
106.55
101.89
f1 (ppm)

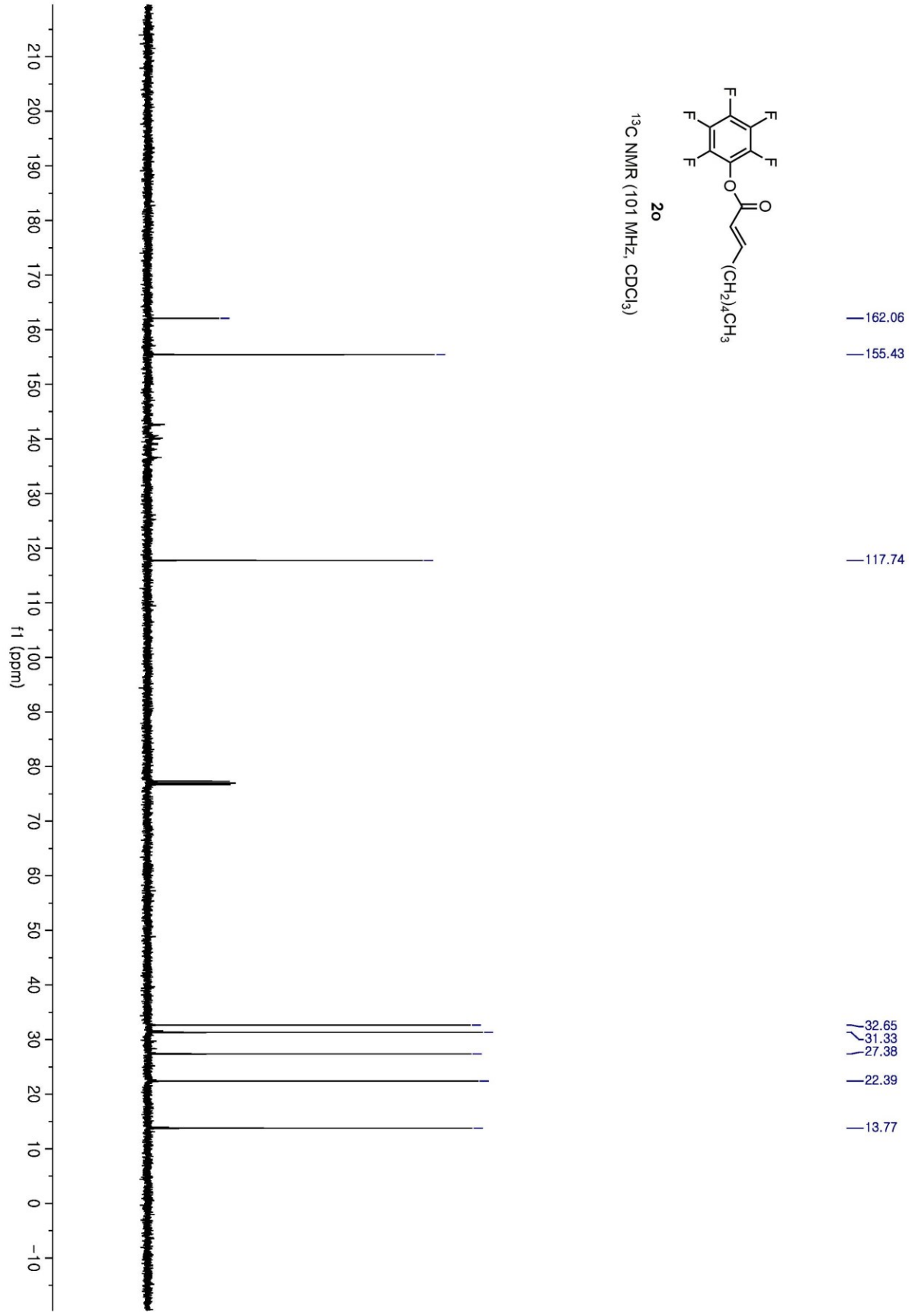

2m
^{1}H NMR (300 MHz, $CDCl_3$)
F
F
F
F
F
O
O
Me
7.39
7.38
7.37
7.36
7.34
7.34
7.32
7.32
7.30
7.29
7.28
7.27
6.15
6.14
6.14
6.13
6.09
6.09
6.08
6.08
2.05
2.05
2.03
2.03
1.00
1.00
3.01
f1 (ppm)

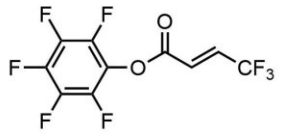

2m
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
161.86
150.49
119.43
18.40
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20


2n
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Et
7.42
7.40
7.38
7.37
7.35
7.33
6.11
6.11
6.10
6.06
6.05
6.05
2.43
2.43
2.41
2.40
2.39
2.38
2.38
2.36
2.36
2.34
2.33
1.20
1.17
1.15
0.99
1.00
2.02
3.03
f1 (ppm)


2n
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Et
162.13
156.48
116.99
25.75
11.60
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

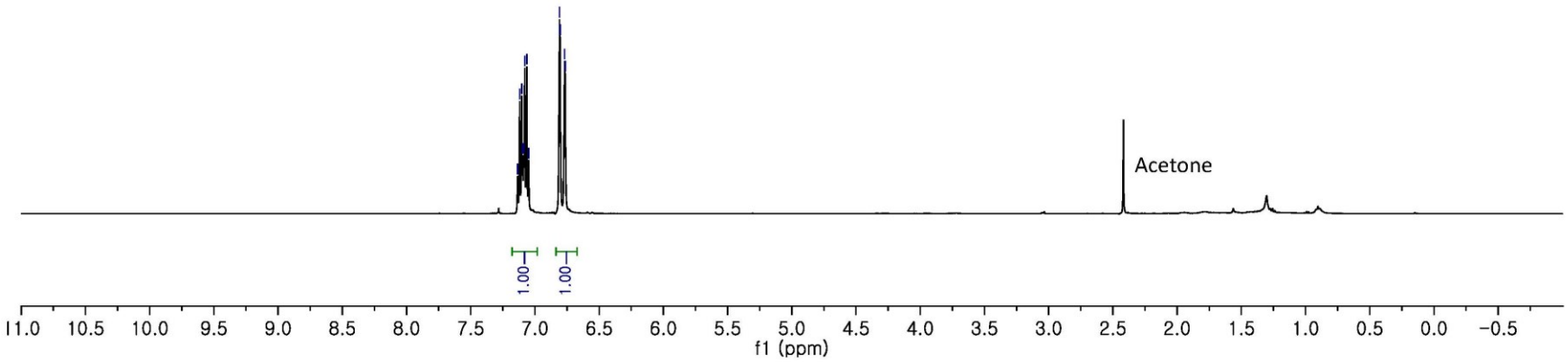

2o
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
(CH$_2$)$_4$CH$_3$
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.97
1.00
2.06
2.10
4.21
3.08
7.37
7.35
7.33
7.33
7.31
7.29
6.11
6.10
6.10
6.07
6.06
6.06
2.38
2.38
2.36
2.36
2.34
2.32
2.32
1.56
1.54
1.39
1.38
1.37
1.36
1.35
0.96
0.95
0.94
0.92
0.90

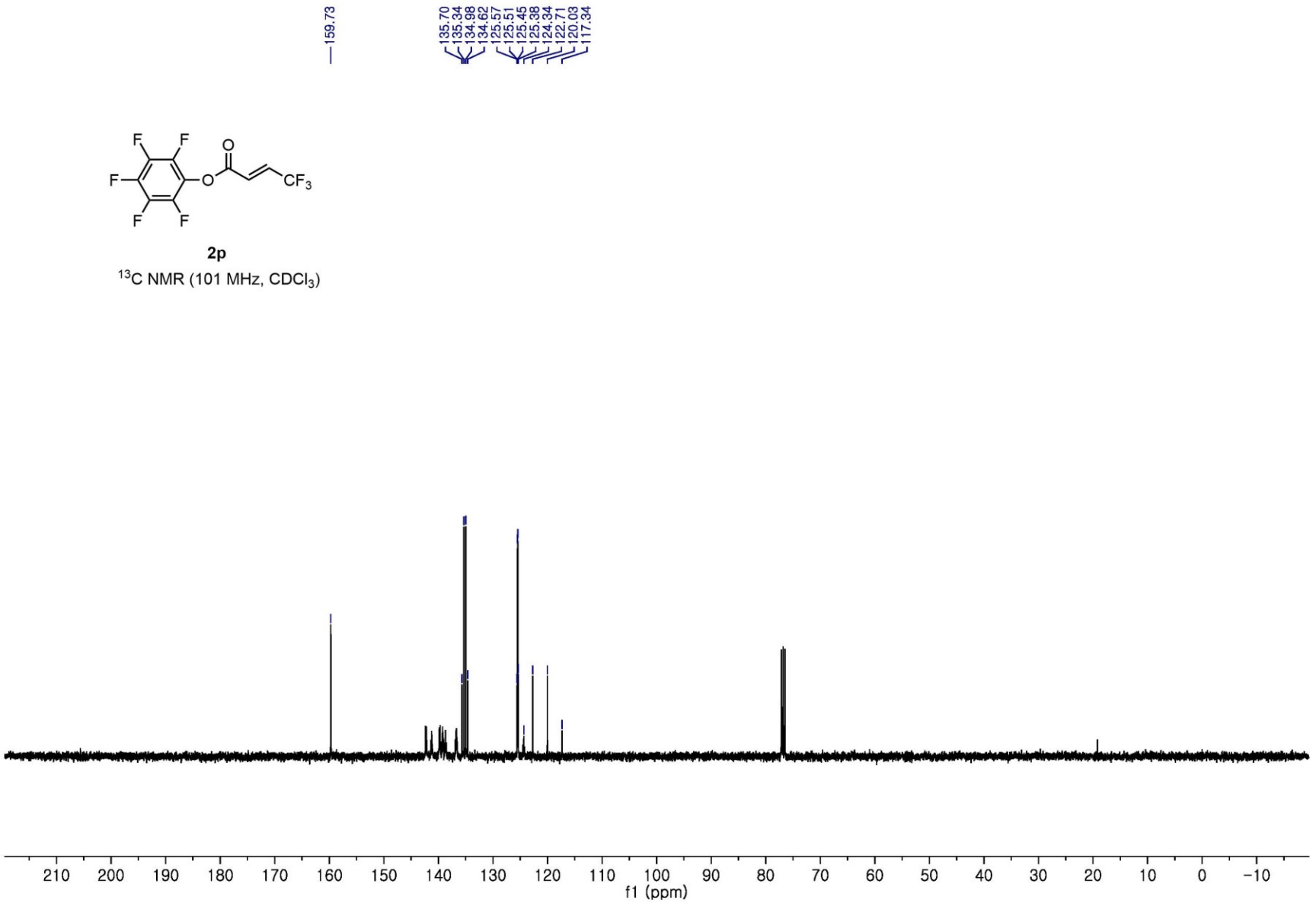

2o
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
(CH$_2$)$_4$CH$_3$
162.06
155.43
117.74
32.65
31.33
27.38
22.39
13.77
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

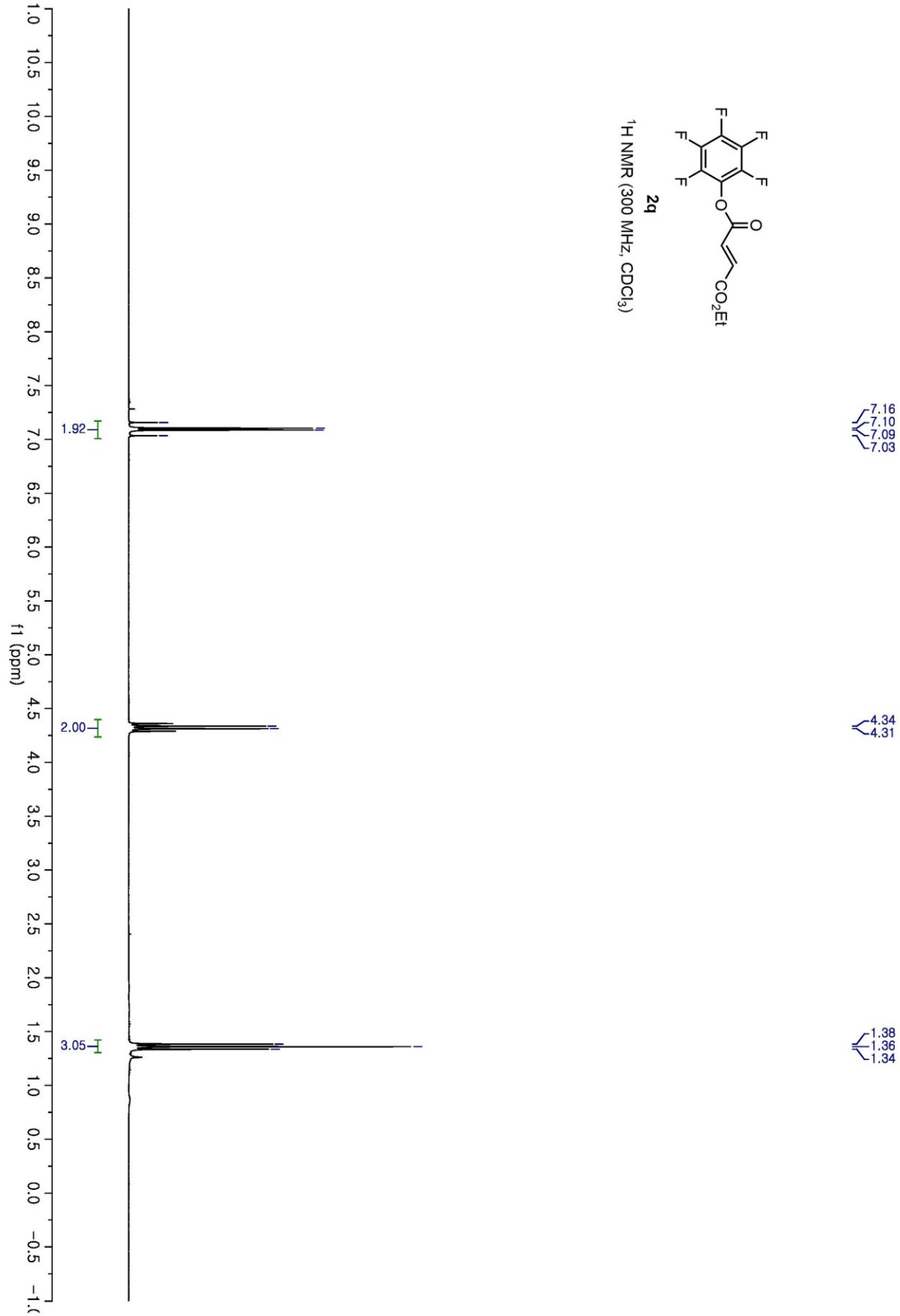


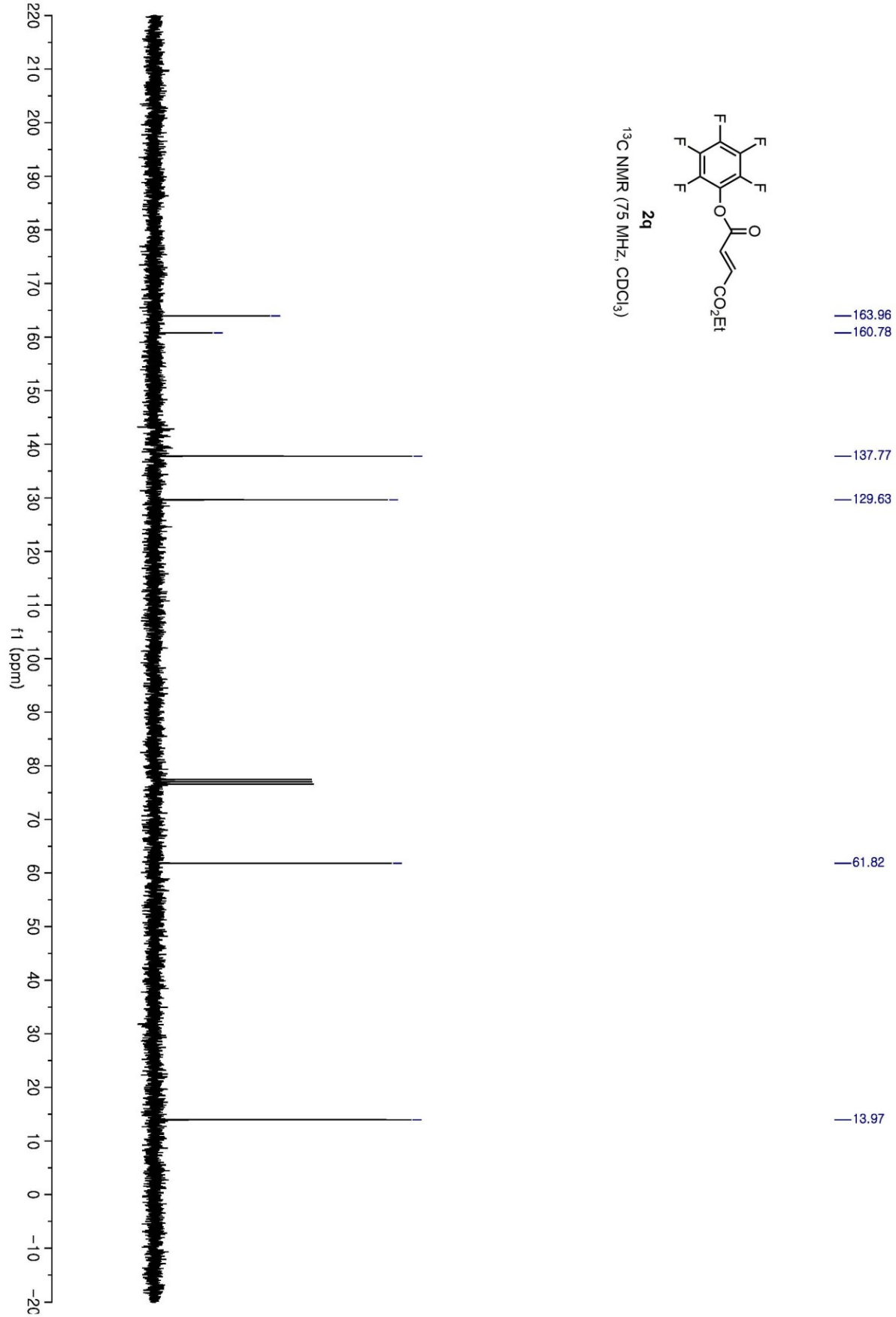
2p

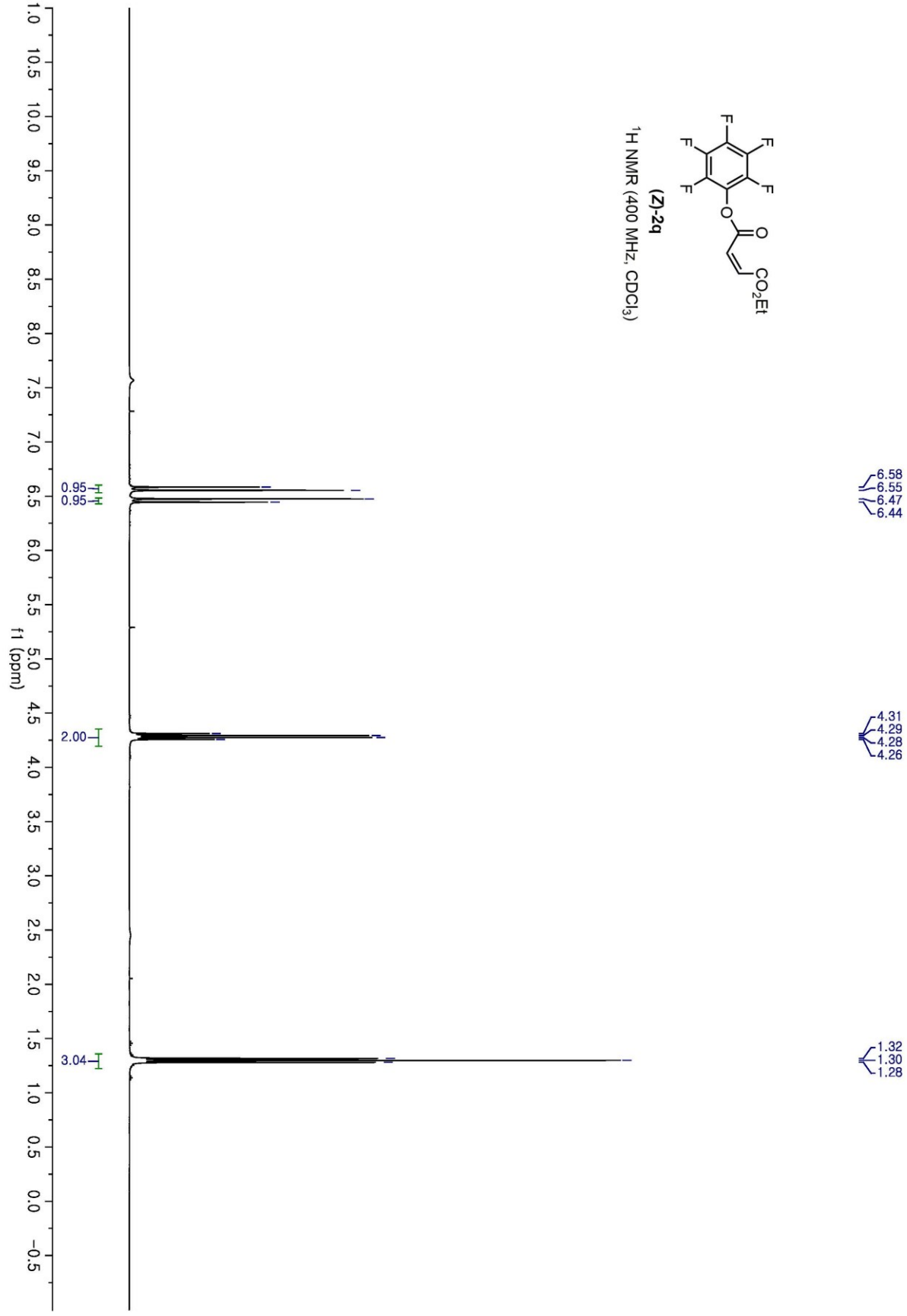
^{1}H NMR (400 MHz, $CDCl_3$)

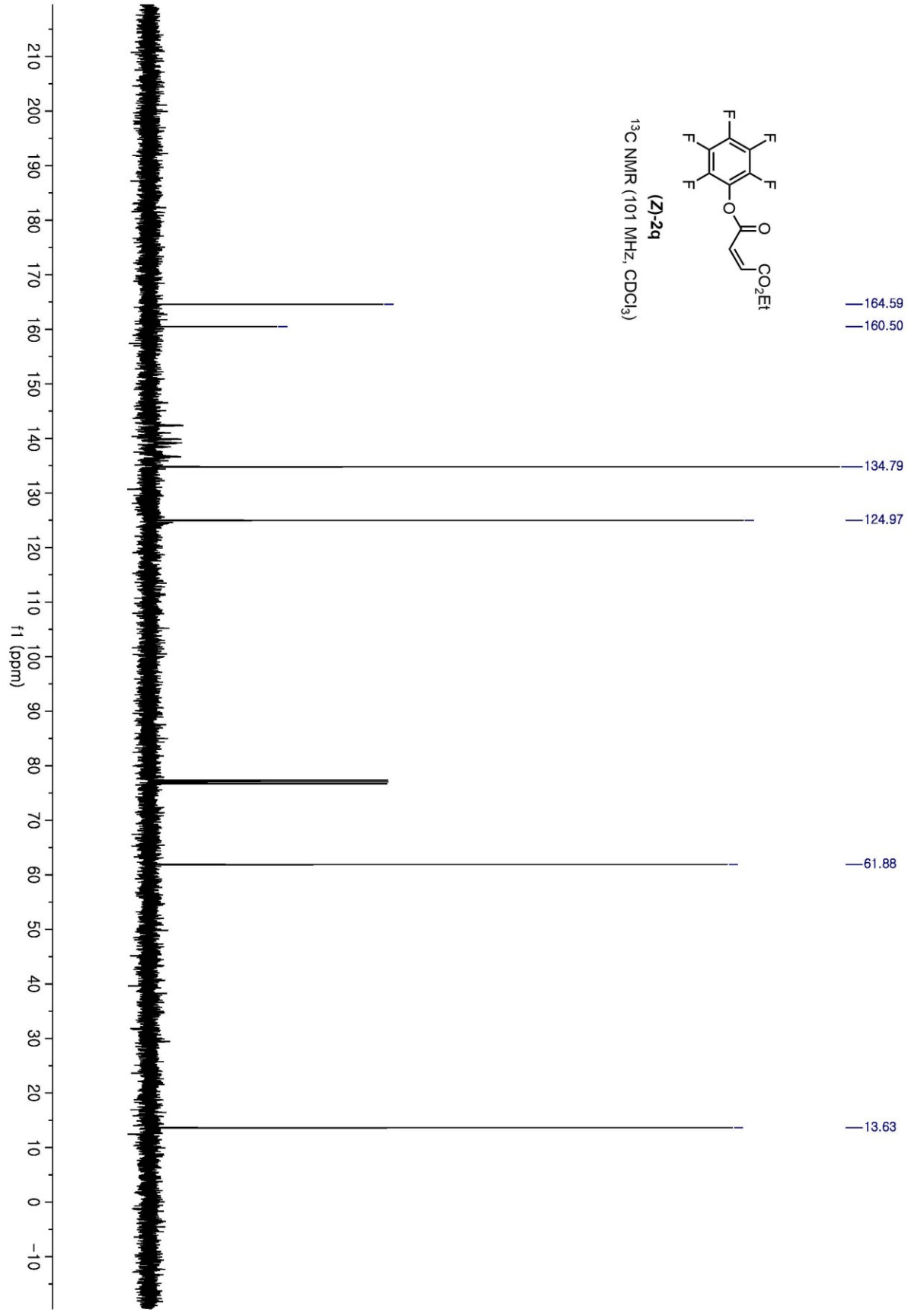


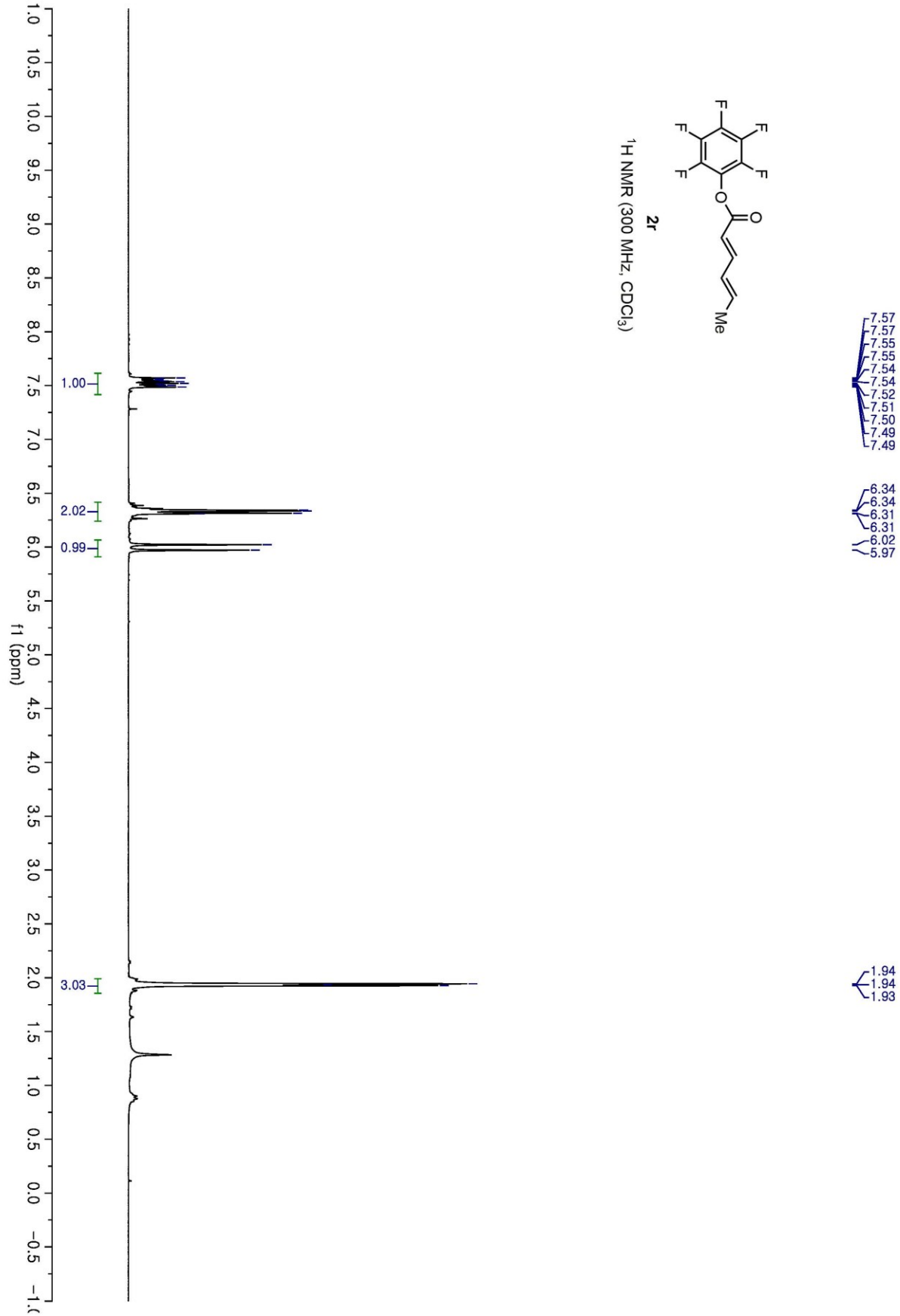

159.73
135.70
135.34
134.98
134.62
125.57
125.51
125.45
125.38
124.34
122.71
120.03
117.34
F
F
O
F
O
CF3
F
F
2p
13C NMR (101 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)

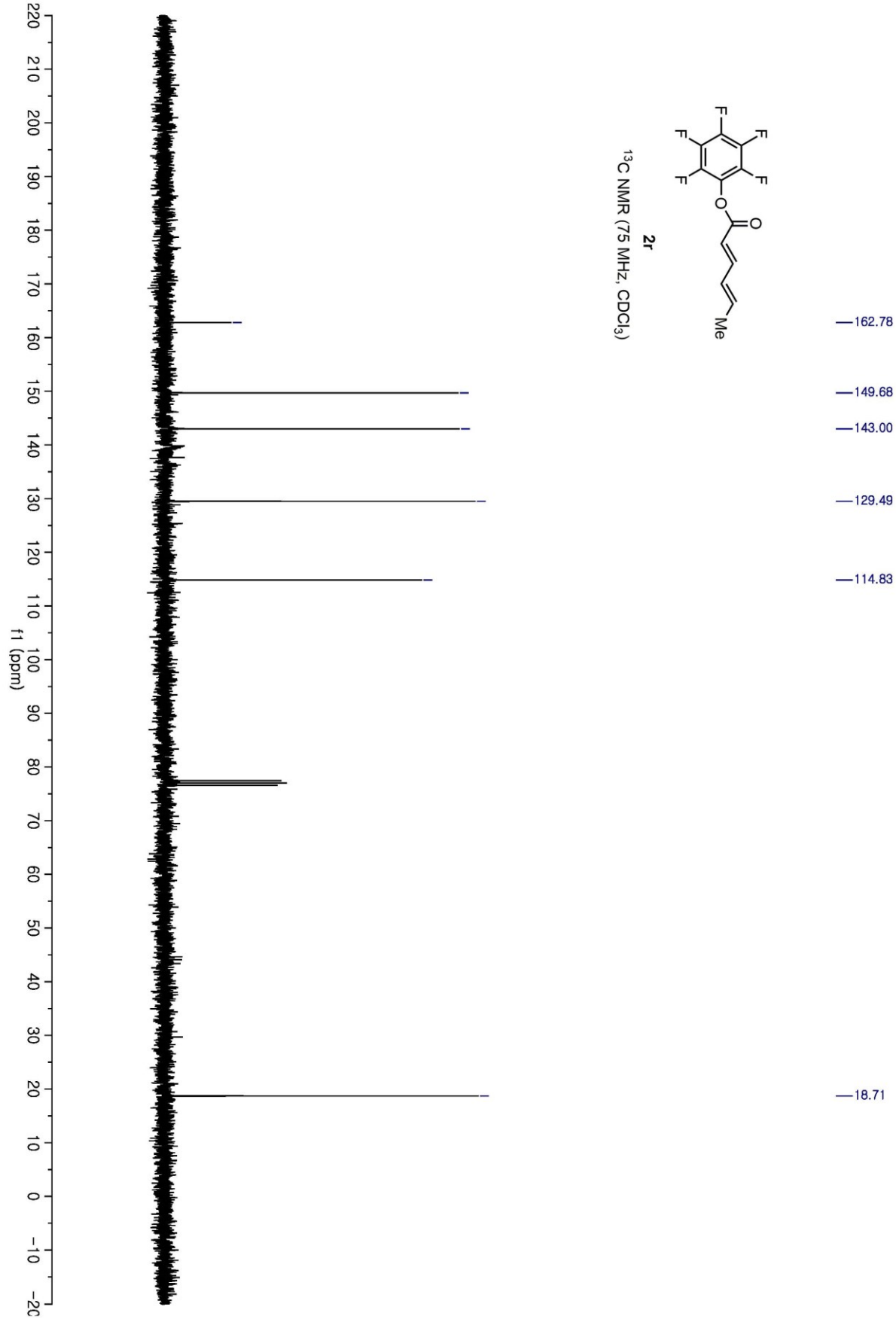

2q
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
CO$_2$Et
7.16
7.10
7.09
7.03
4.34
4.31
1.38
1.36
1.34
1.92
2.00
3.05
f1 (ppm)

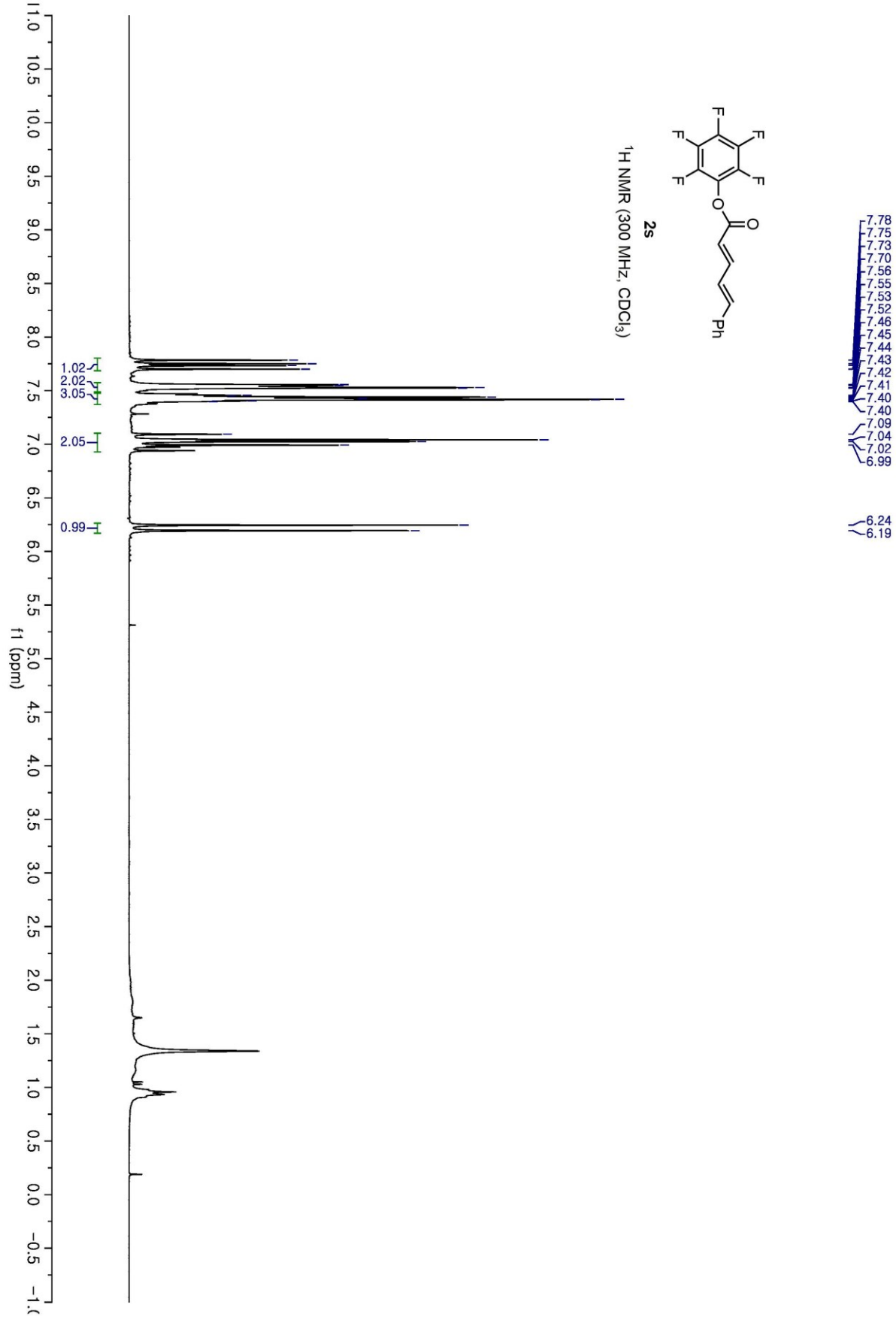

2q
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
CO$_2$Et
163.96
160.78
137.77
129.63
61.82
13.97
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20

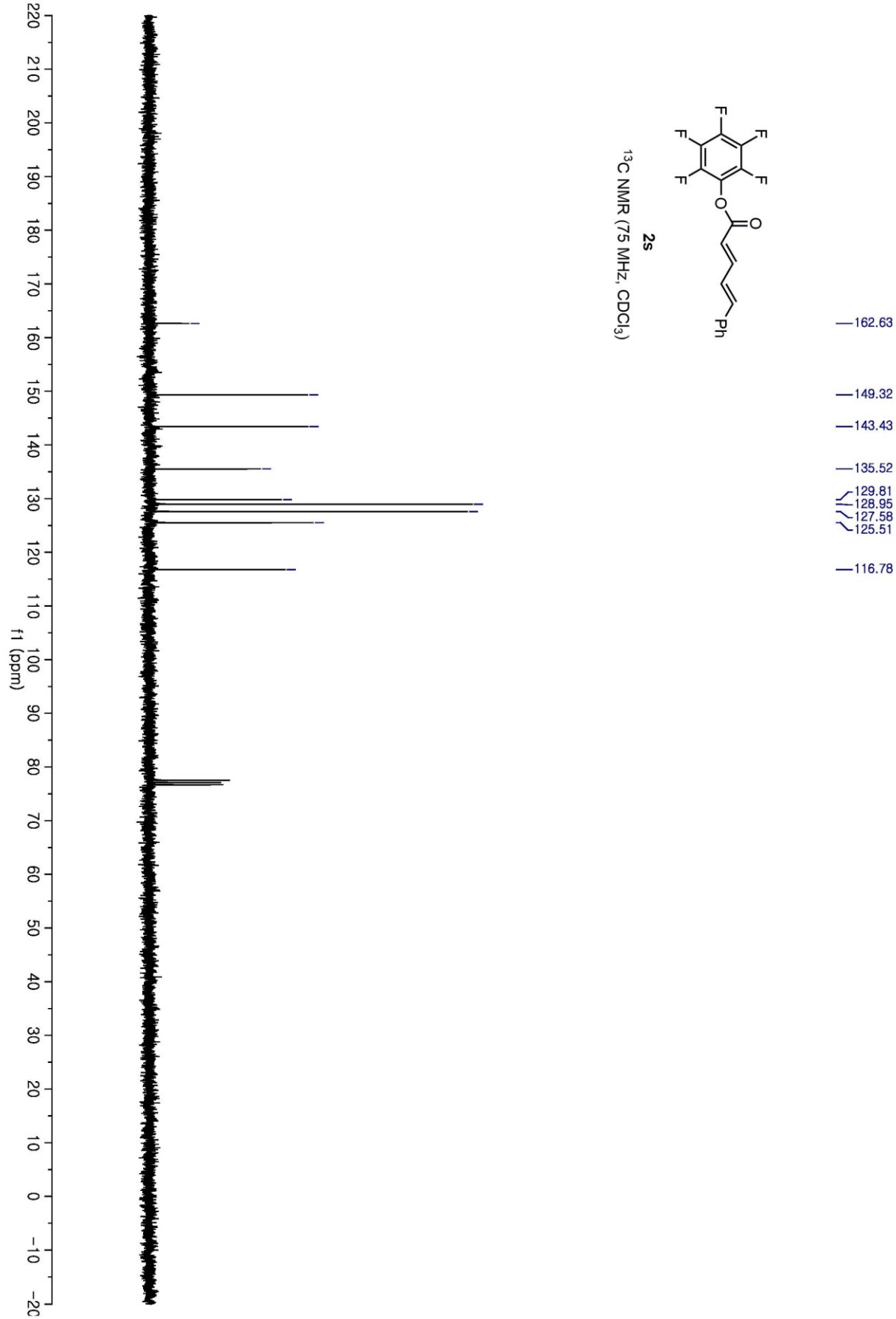

(Z)-2q
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
CO$_2$Et
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.95
0.95
2.00
3.04
6.58
6.55
6.47
6.44
4.31
4.29
4.28
4.26
1.32
1.30
1.28

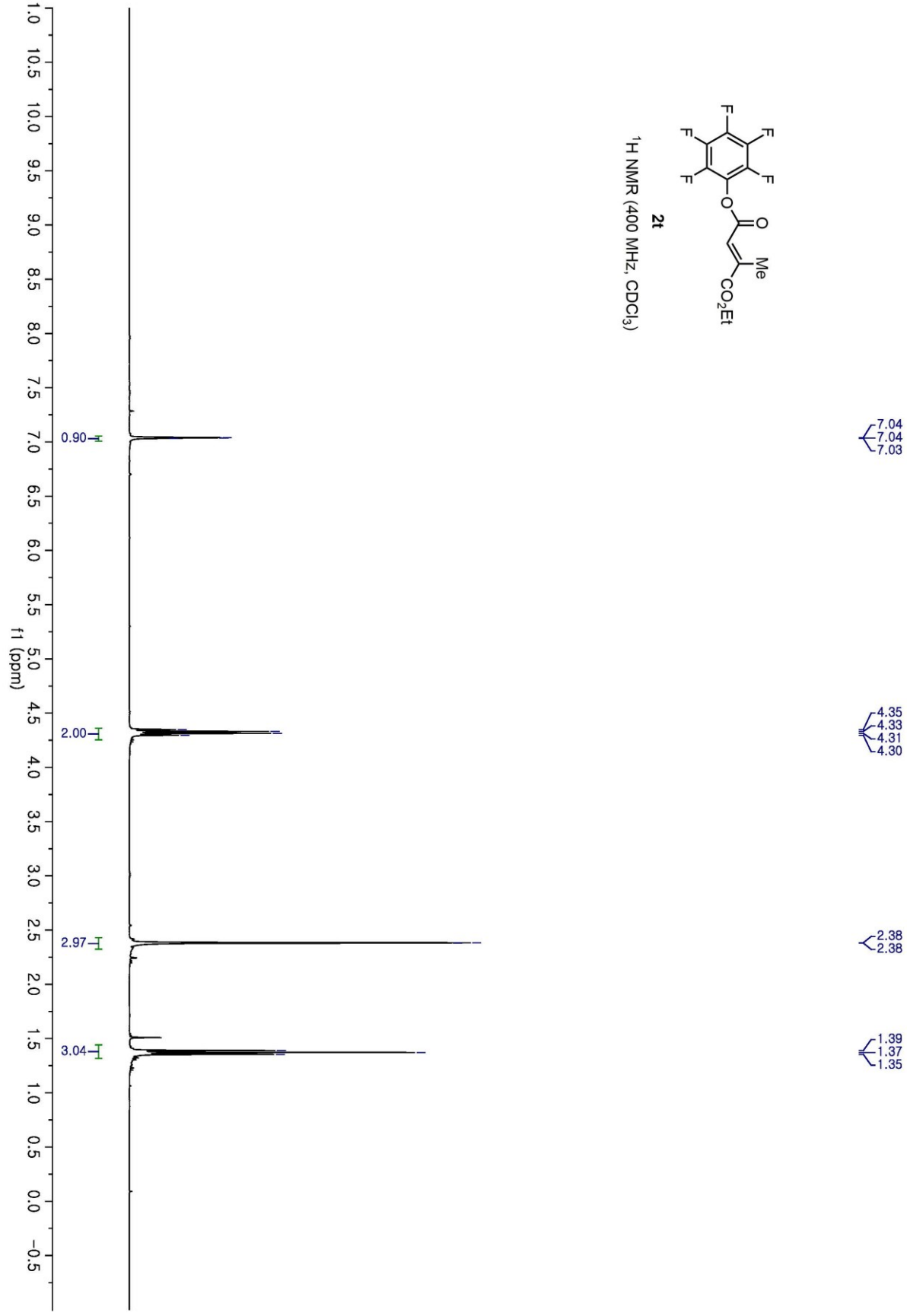

(Z)-2q
^{13}C NMR (101 MHz, CDCl$_3$)
CO$_2$Et
164.59
160.50
134.79
124.97
61.88
13.63
f1 (ppm)

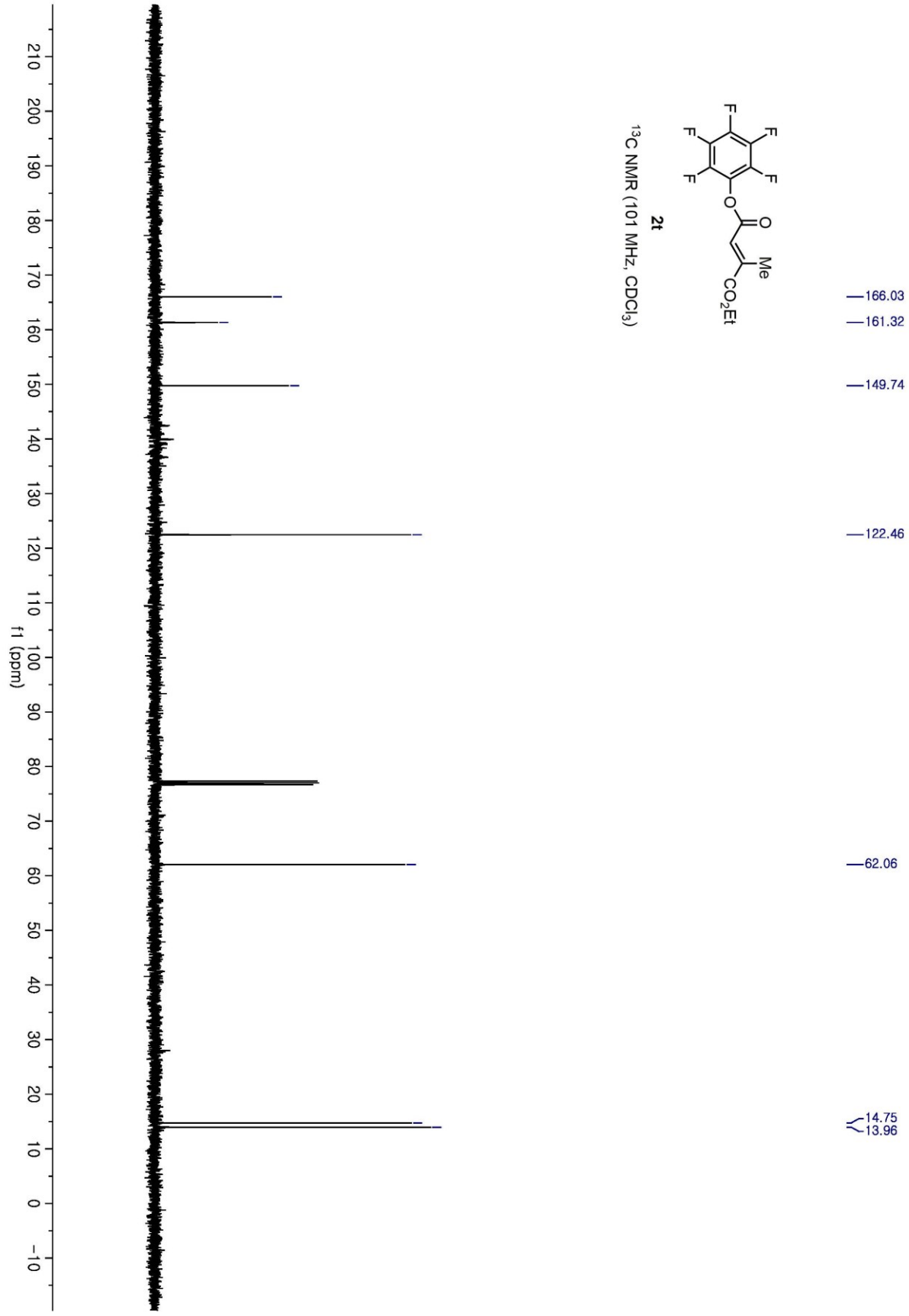

2r
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
7.57
7.57
7.55
7.55
7.54
7.54
7.52
7.51
7.50
7.49
7.49
6.34
6.34
6.31
6.31
6.02
5.97
1.94
1.94
1.93
1.00
2.02
0.99
3.03
f1 (ppm)

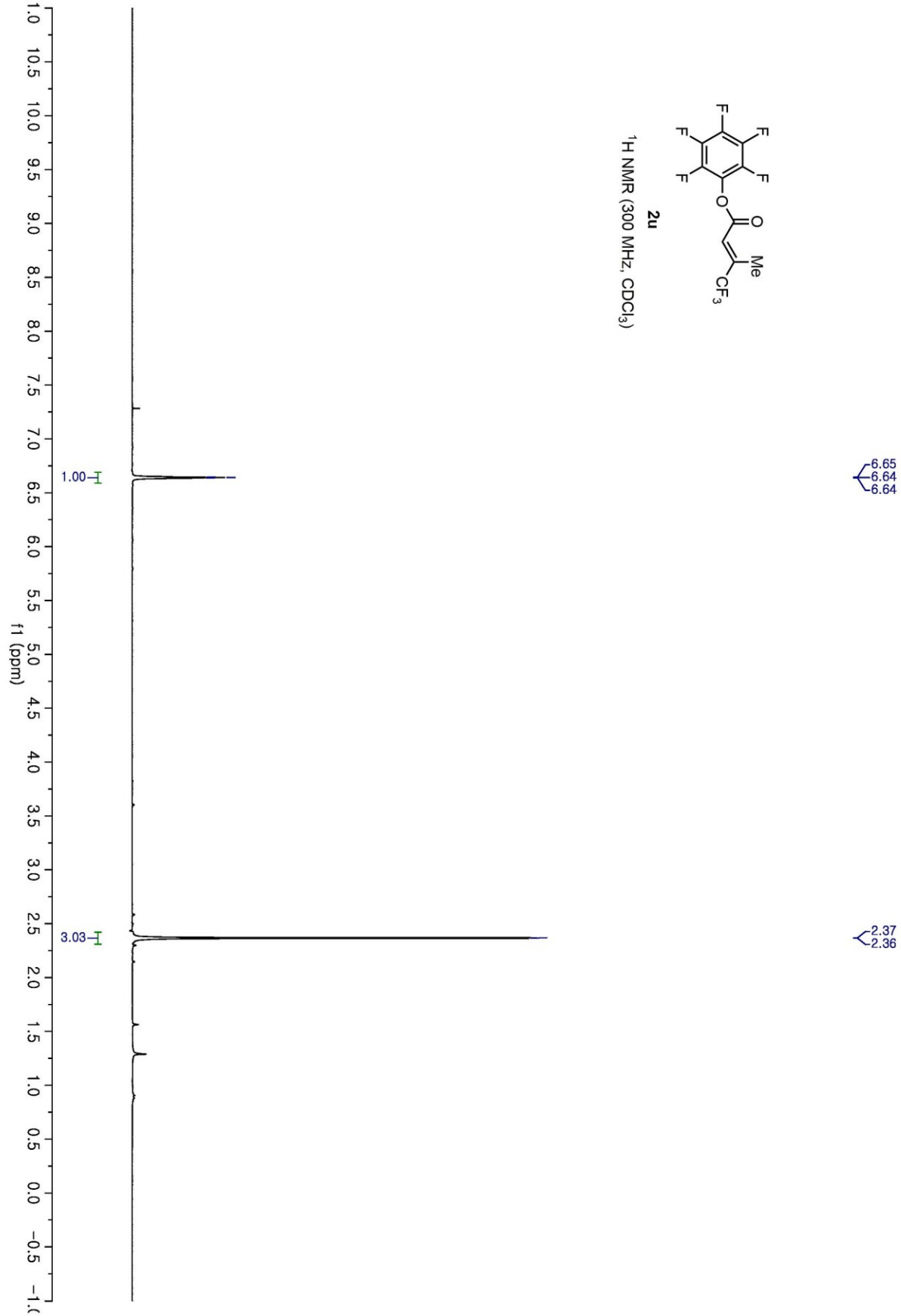

2r
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
162.78
149.68
143.00
129.49
114.83
18.71
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20

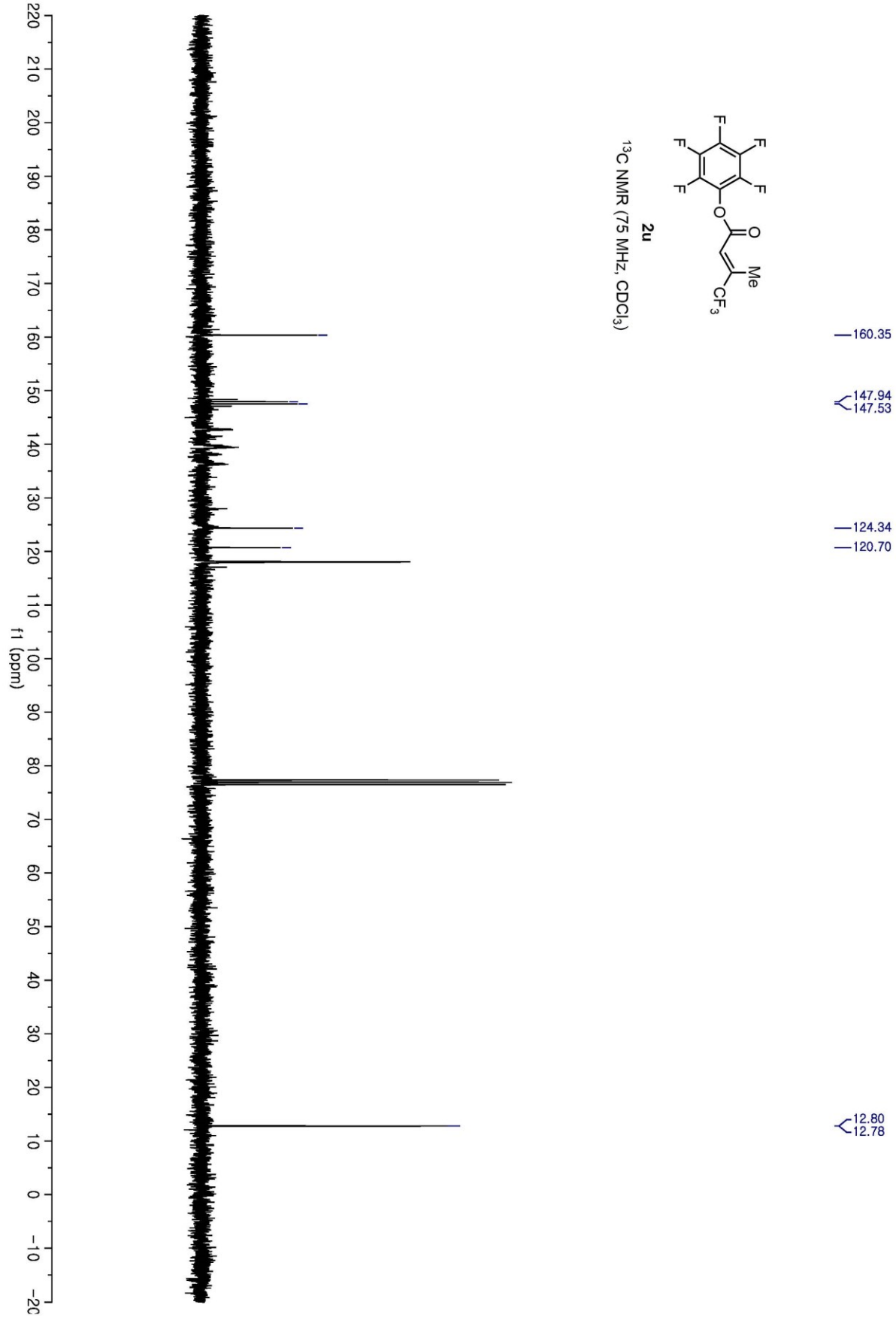

2s
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Ph
7.78
7.75
7.73
7.70
7.56
7.55
7.53
7.52
7.46
7.45
7.44
7.43
7.42
7.41
7.40
7.40
7.09
7.04
7.02
6.99
6.24
6.19
1.02
2.02
3.05
2.05
0.99
f1 (ppm)

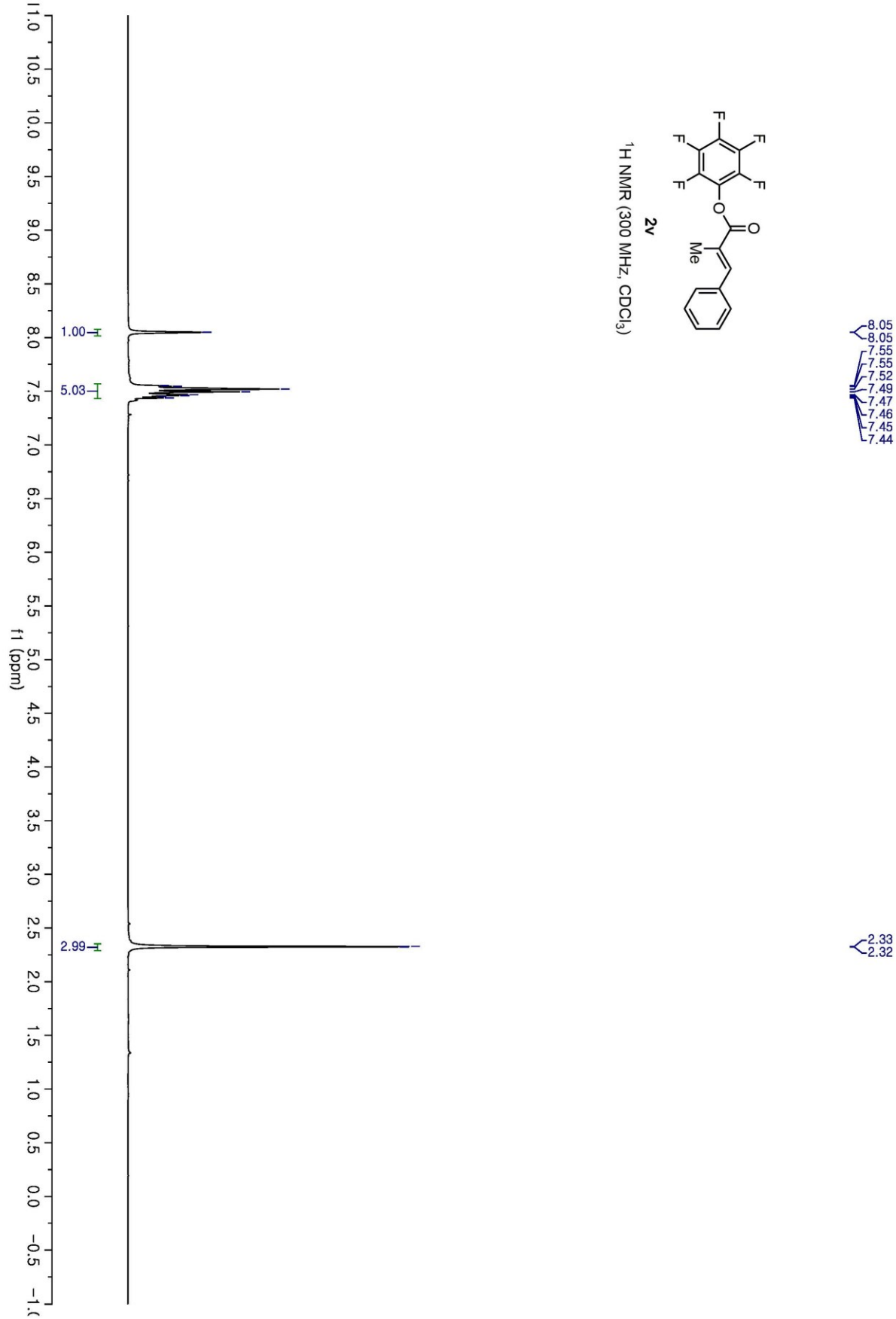

2s
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Ph
162.63
149.32
143.43
135.52
129.81
128.95
127.58
125.51
116.78
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20

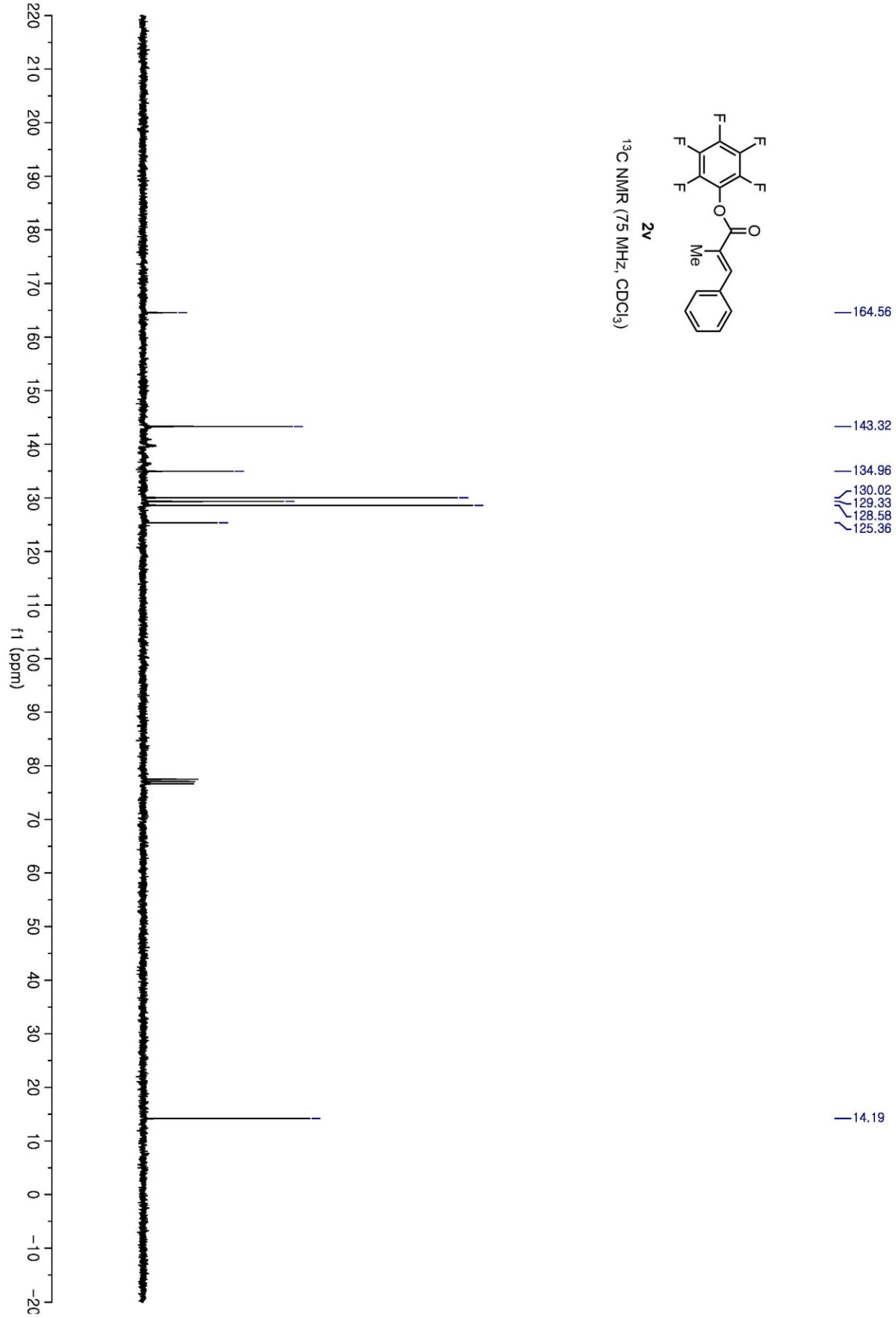

2t
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
CO$_2$Et
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.90
2.00
2.97
3.04
7.04
7.04
7.03
4.35
4.33
4.31
4.30
2.38
2.38
1.39
1.37
1.35

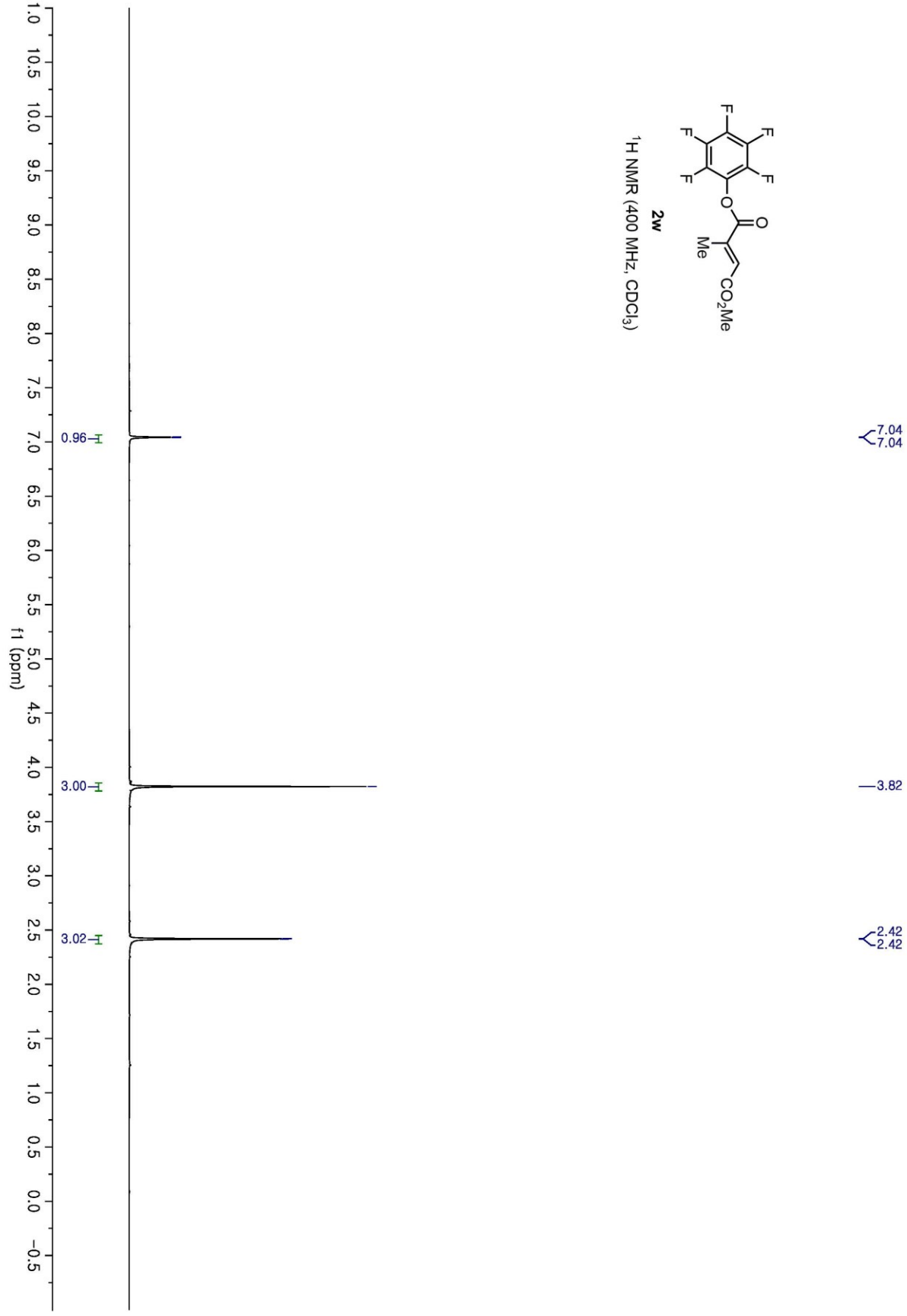

2t
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
CO$_2$Et
166.03
161.32
149.74
122.46
62.06
14.75
13.96
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

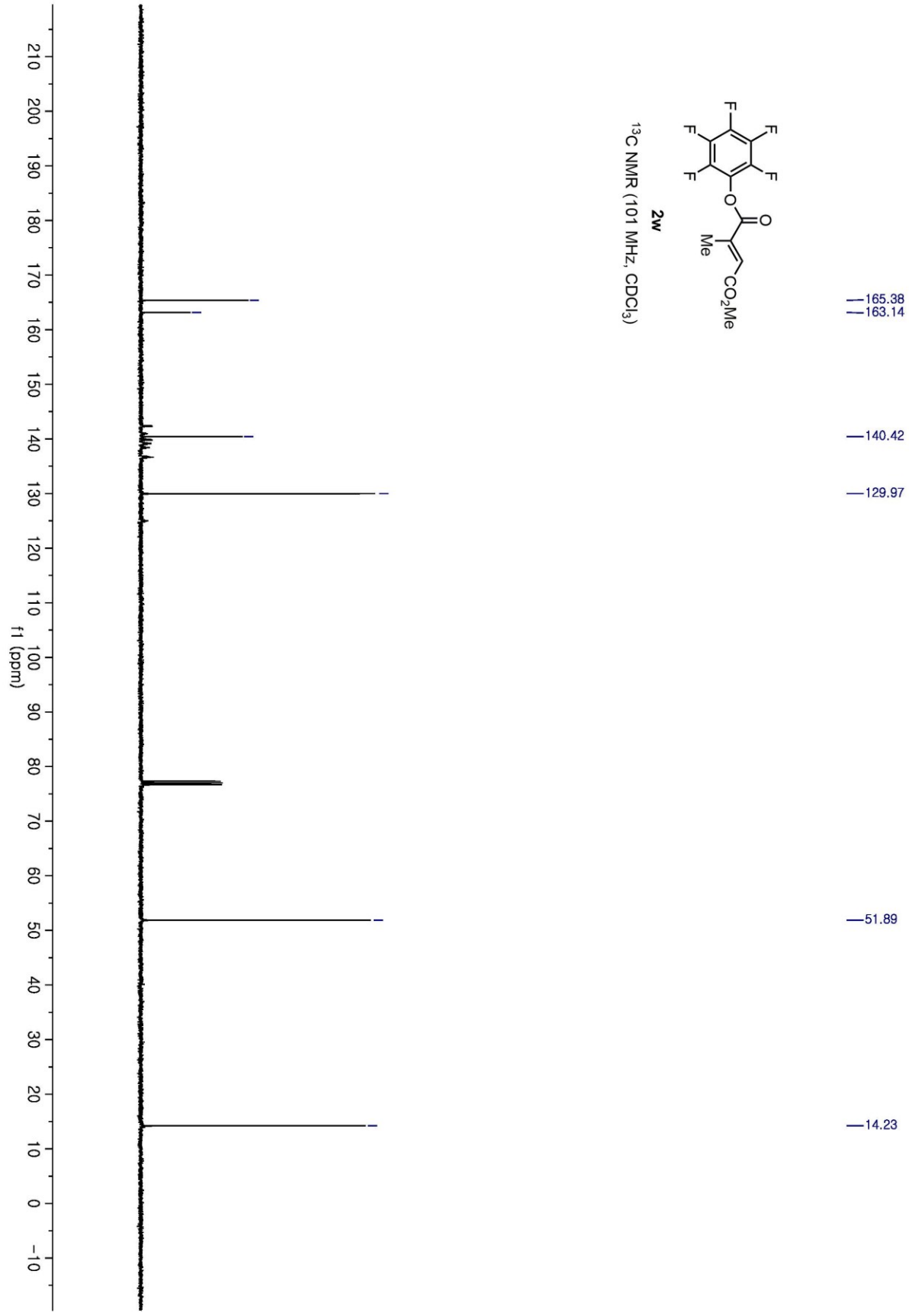

2u
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
CF$_3$
6.65
6.64
6.64
2.37
2.36
1.00
3.03
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5

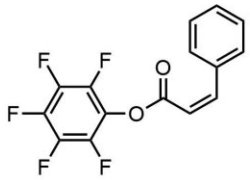

2u
^{13}C NMR (75 MHz, CDCl$_3$)
160.35
147.94
147.53
124.34
120.70
12.80
12.78
f1 (ppm)


2v
^{1}H NMR (300 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
8.05
8.05
7.55
7.55
7.52
7.49
7.47
7.46
7.45
7.44
2.33
2.32
1.00
5.03
2.99
f1 (ppm)


2v
^{13}C NMR (75 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
164.56
143.32
134.96
130.02
129.33
128.58
125.36
14.19
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20

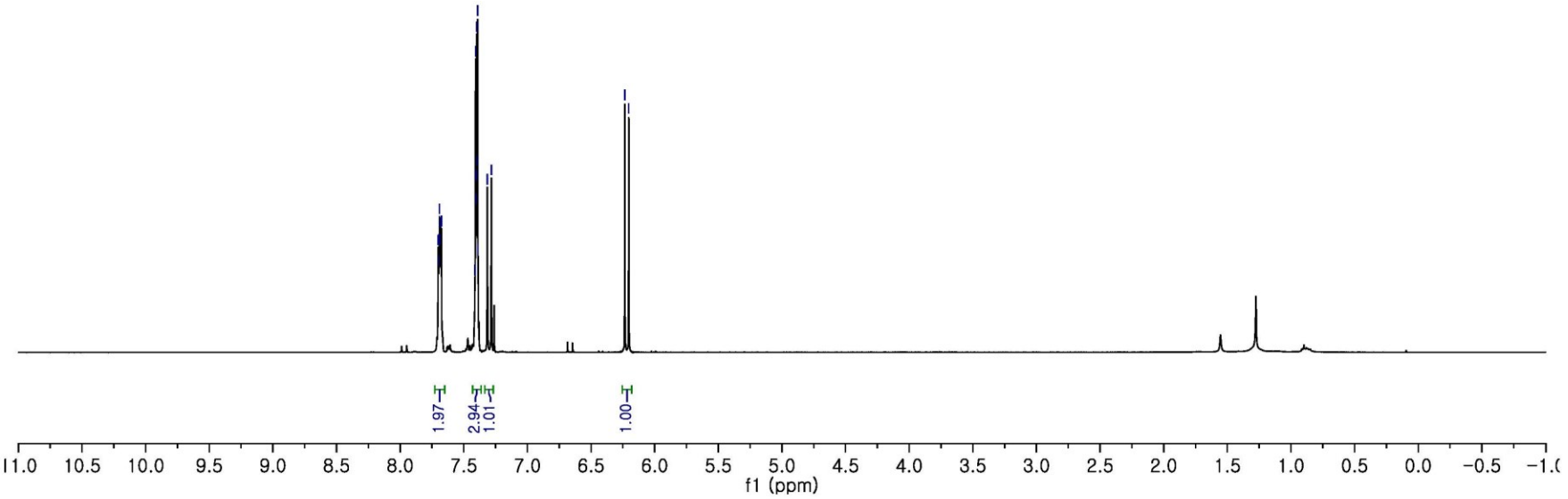

2w
^{1}H NMR (400 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
CO$_2$Me
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
f1 (ppm)
0.96
3.00
3.02
7.04
7.04
3.82
2.42
2.42

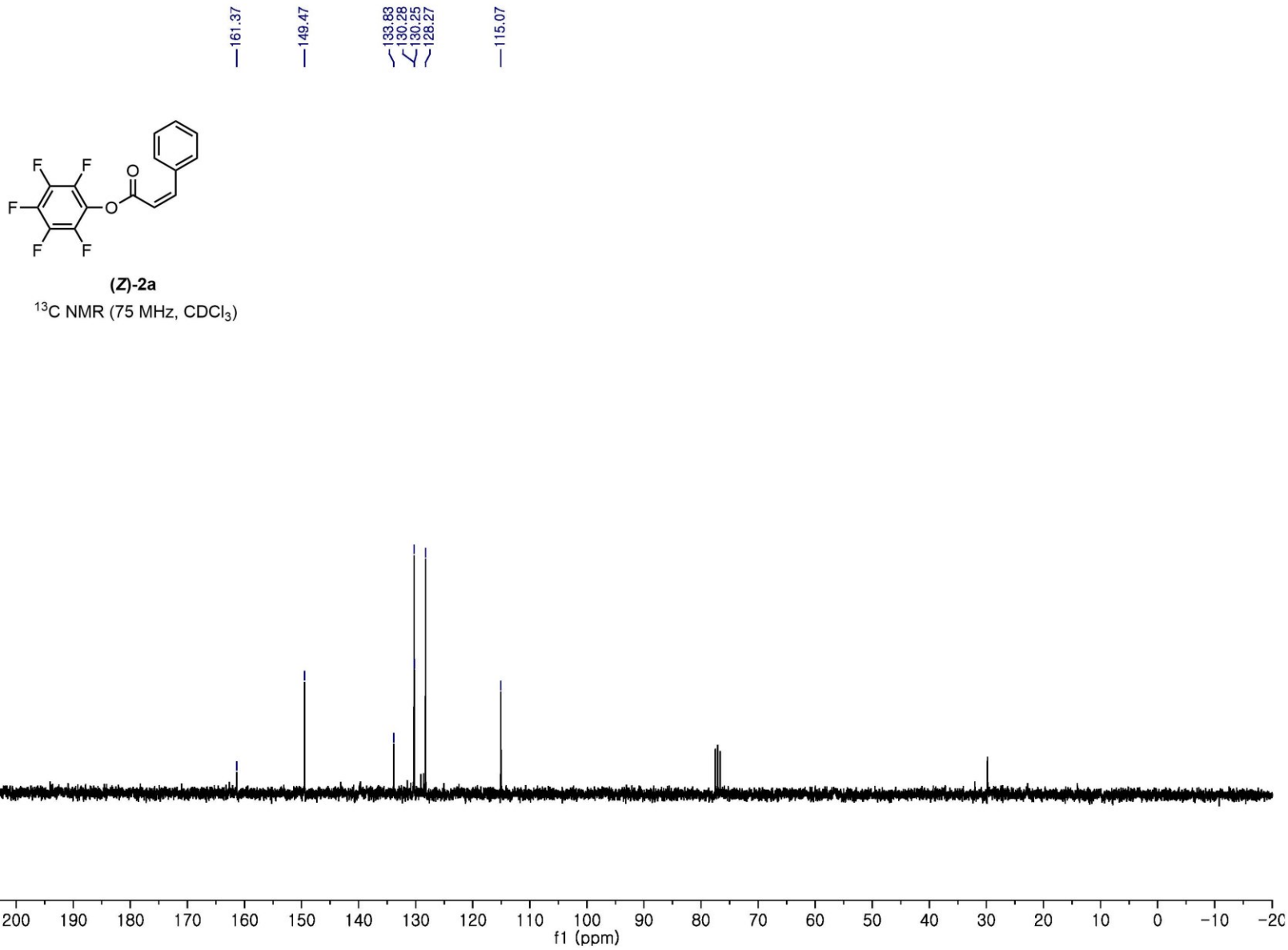

2w
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
F
F
F
O
O
Me
CO$_2$Me
165.38
163.14
140.42
129.97
51.89
14.23
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10



(*Z*)-2a

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




161.37
149.47
133.83
130.28
130.25
128.27
115.07
F
F
F
F
F
O
O
(Z)-2a
13C NMR (75 MHz, CDCl3)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20
f1 (ppm)

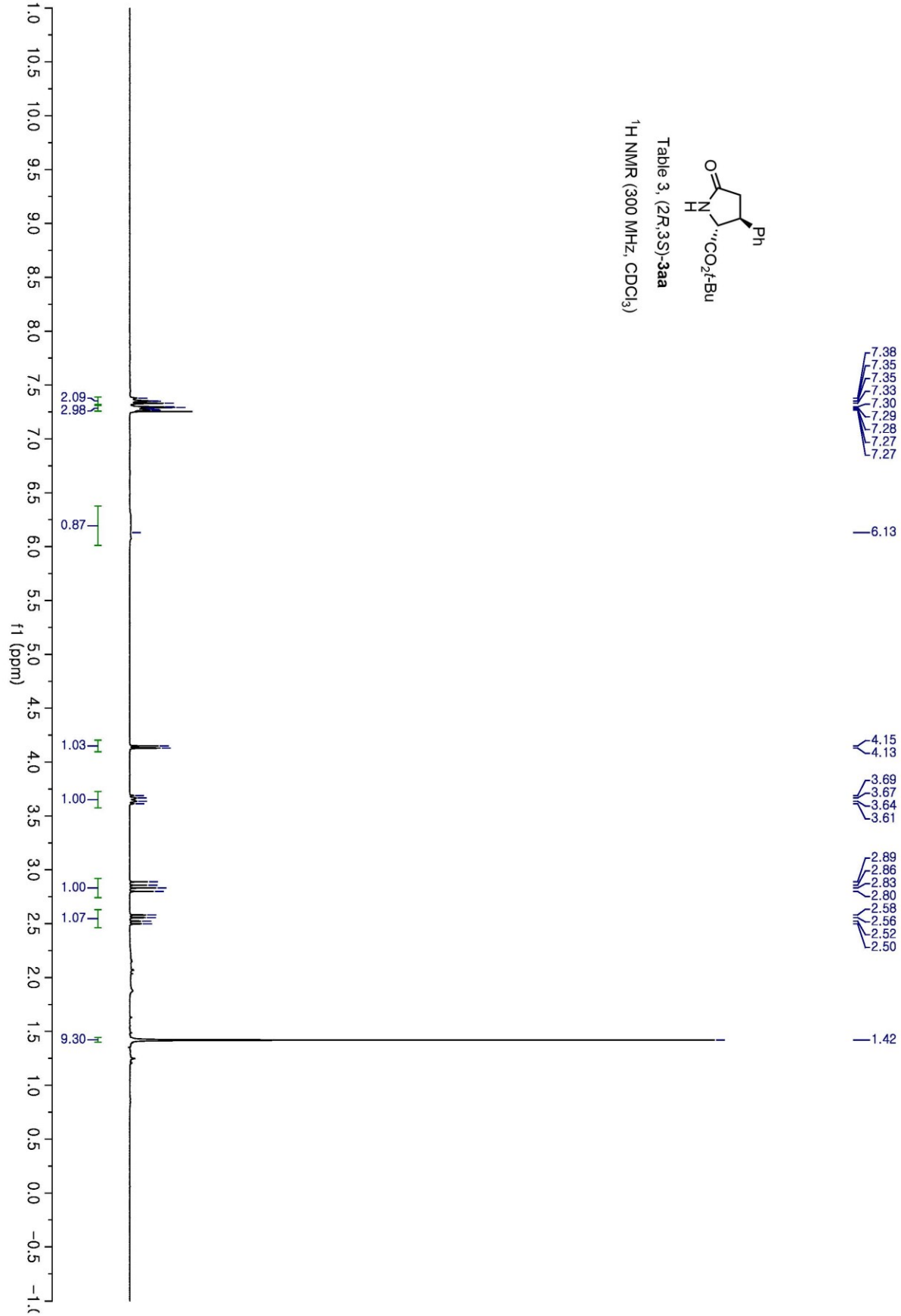
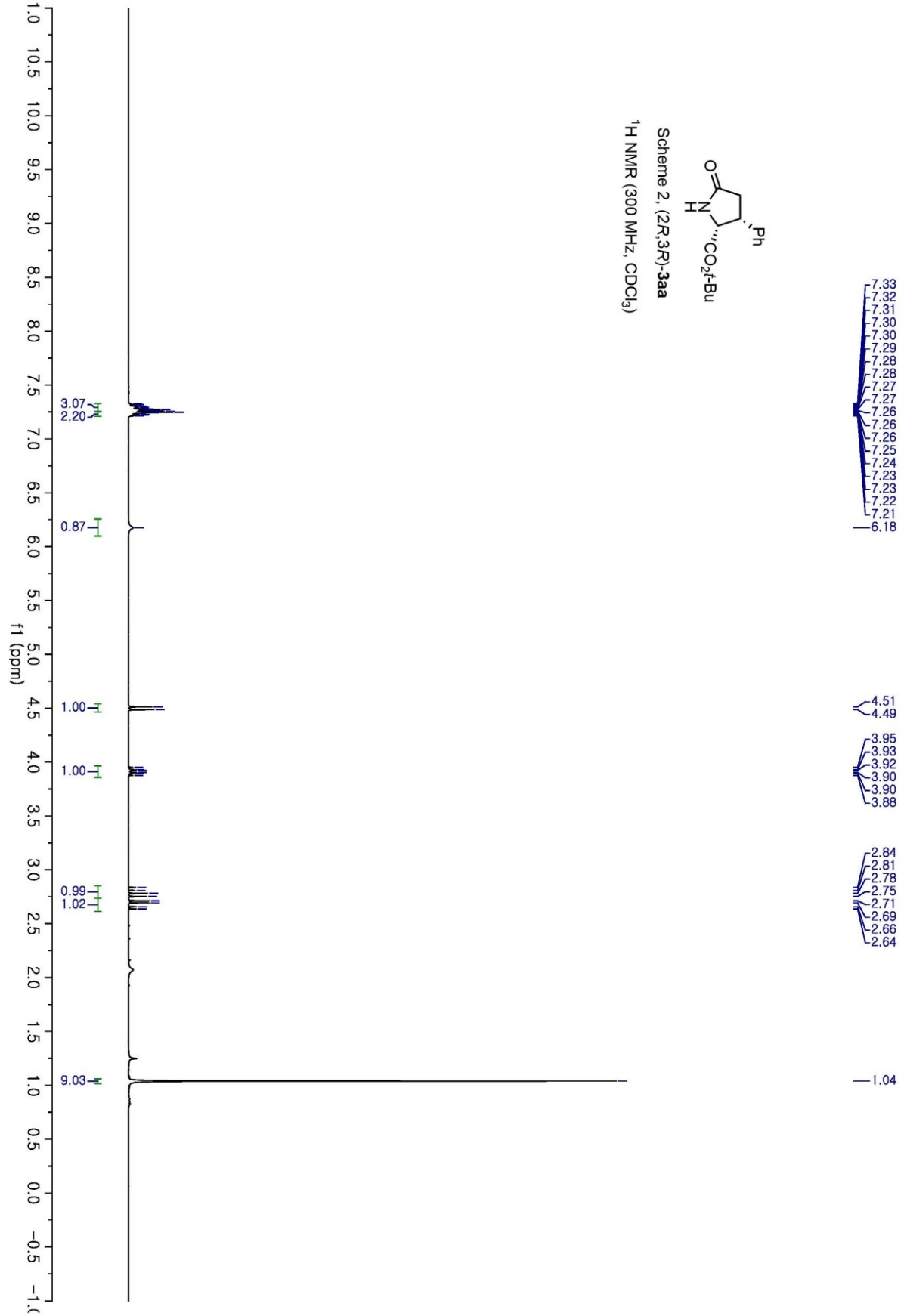


Table 3, (2R,3S)-3aa
^{1}H NMR (300 MHz, CDCl$_3$)
Ph
CO$_2$t-Bu
f1 (ppm)
2.09
2.98
0.87
1.03
1.00
1.00
1.07
9.30
7.38
7.35
7.35
7.33
7.30
7.29
7.28
7.27
7.27
6.13
4.15
4.13
3.69
3.67
3.64
3.61
2.89
2.86
2.83
2.80
2.58
2.56
2.52
2.50
1.42


Scheme 2, (2R,3R)-3aa
^{1}H NMR (300 MHz, CDCl$_3$)
f1 (ppm)
3.07
2.20
0.87
1.00
1.00
0.99
1.02
9.03
7.33
7.32
7.31
7.30
7.30
7.29
7.28
7.28
7.27
7.27
7.26
7.26
7.26
7.25
7.24
7.23
7.23
7.22
7.21
6.18
4.51
4.49
3.95
3.93
3.92
3.90
3.90
3.88
2.84
2.81
2.78
2.75
2.71
2.69
2.66
2.64
1.04

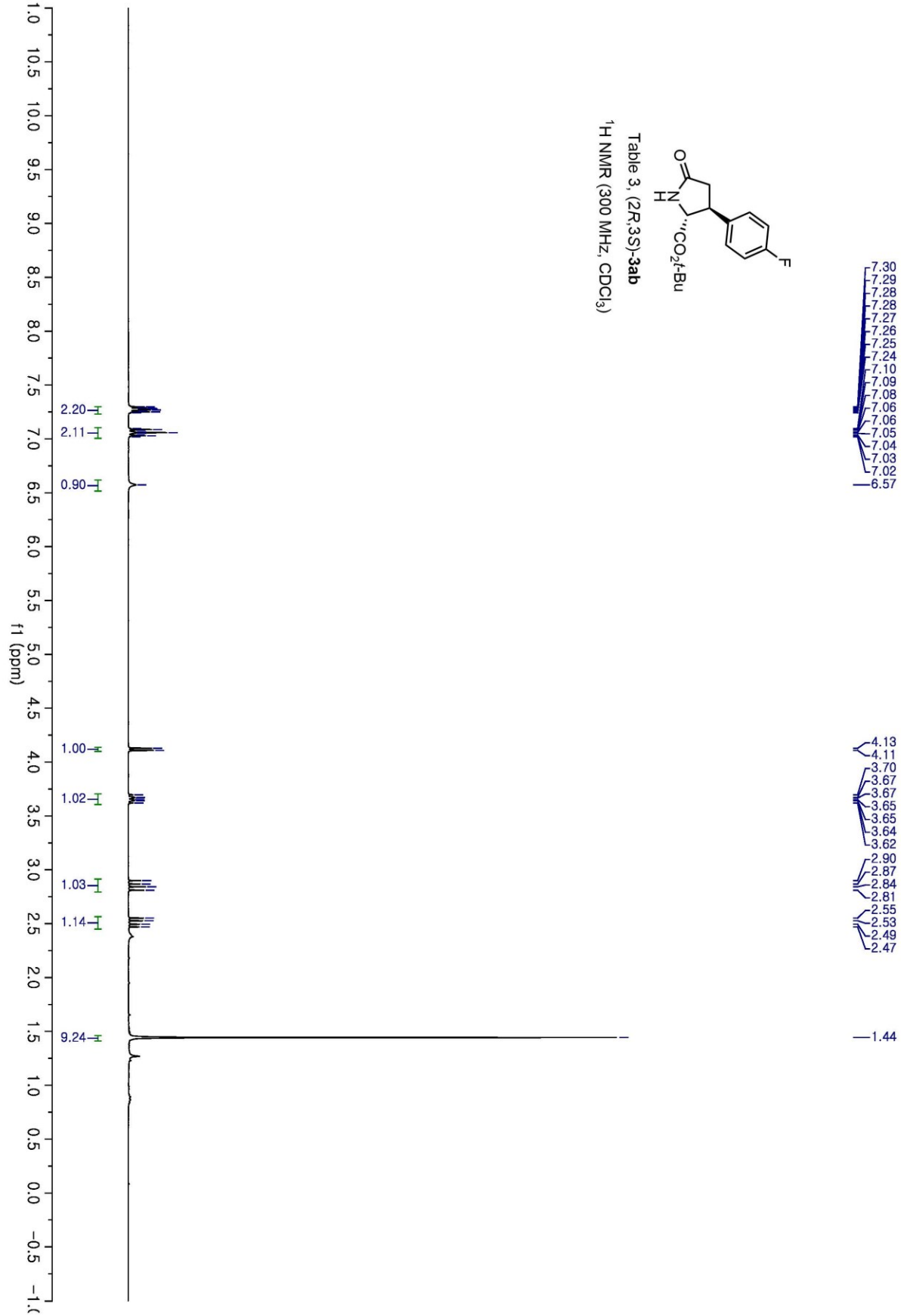


Table 3, (2R,3S)-3ab
1H NMR (300 MHz, CDCl3)
O
N
H
CO2t-Bu
F
7.30
7.29
7.28
7.28
7.27
7.26
7.25
7.24
7.10
7.09
7.08
7.06
7.06
7.05
7.04
7.03
7.02
6.57
4.13
4.11
3.70
3.67
3.67
3.65
3.65
3.64
3.62
2.90
2.87
2.84
2.81
2.55
2.53
2.49
2.47
1.44
2.20
2.11
0.90
1.00
1.02
1.03
1.14
9.24
f1 (ppm)

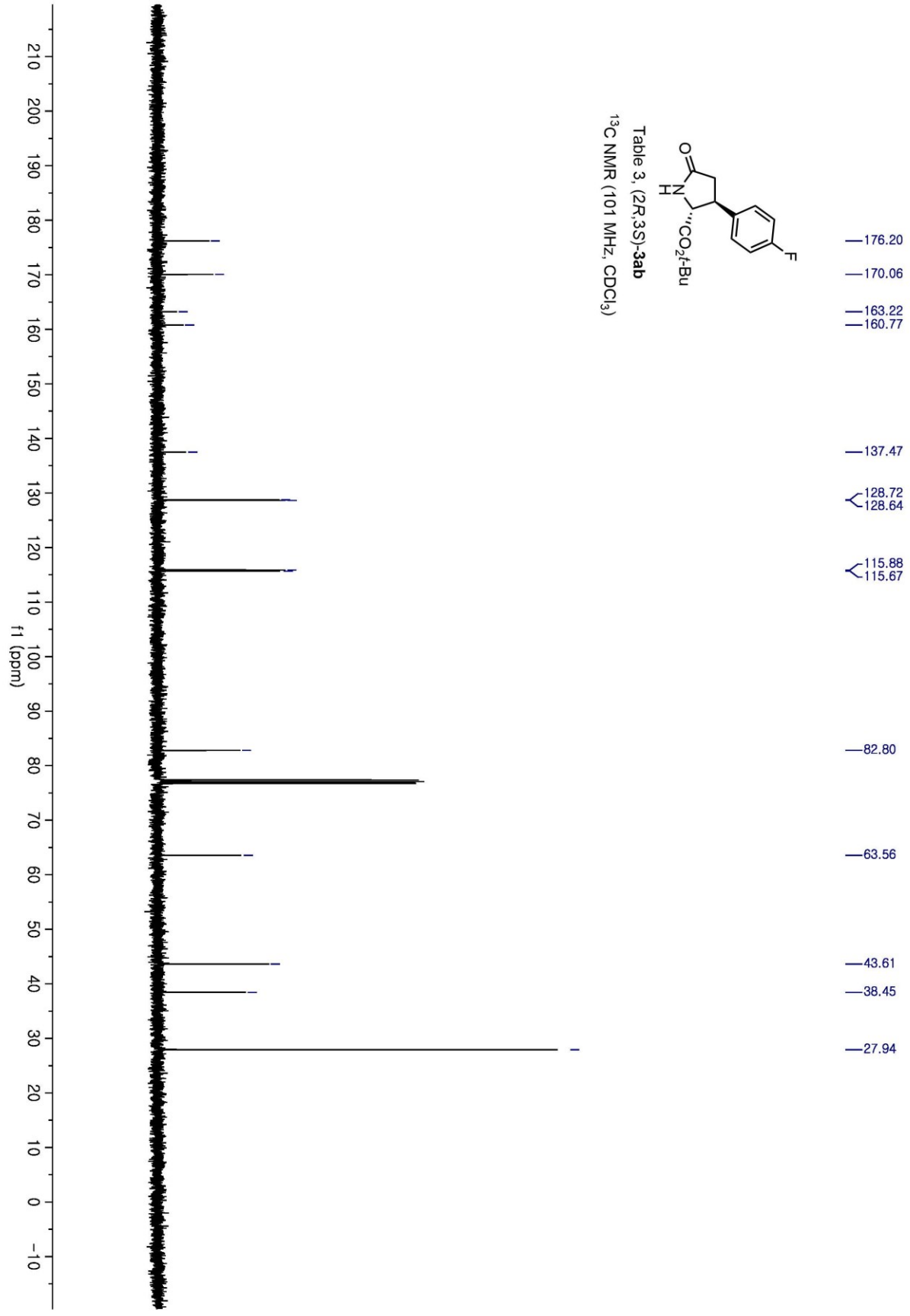


Table 3, (2R,3S)-3ab
13C NMR (101 MHz, CDCl3)
O
N
H
"CO2t-Bu
F
176.20
170.06
163.22
160.77
137.47
128.72
128.64
115.88
115.67
82.80
63.56
43.61
38.45
27.94
f1 (ppm)

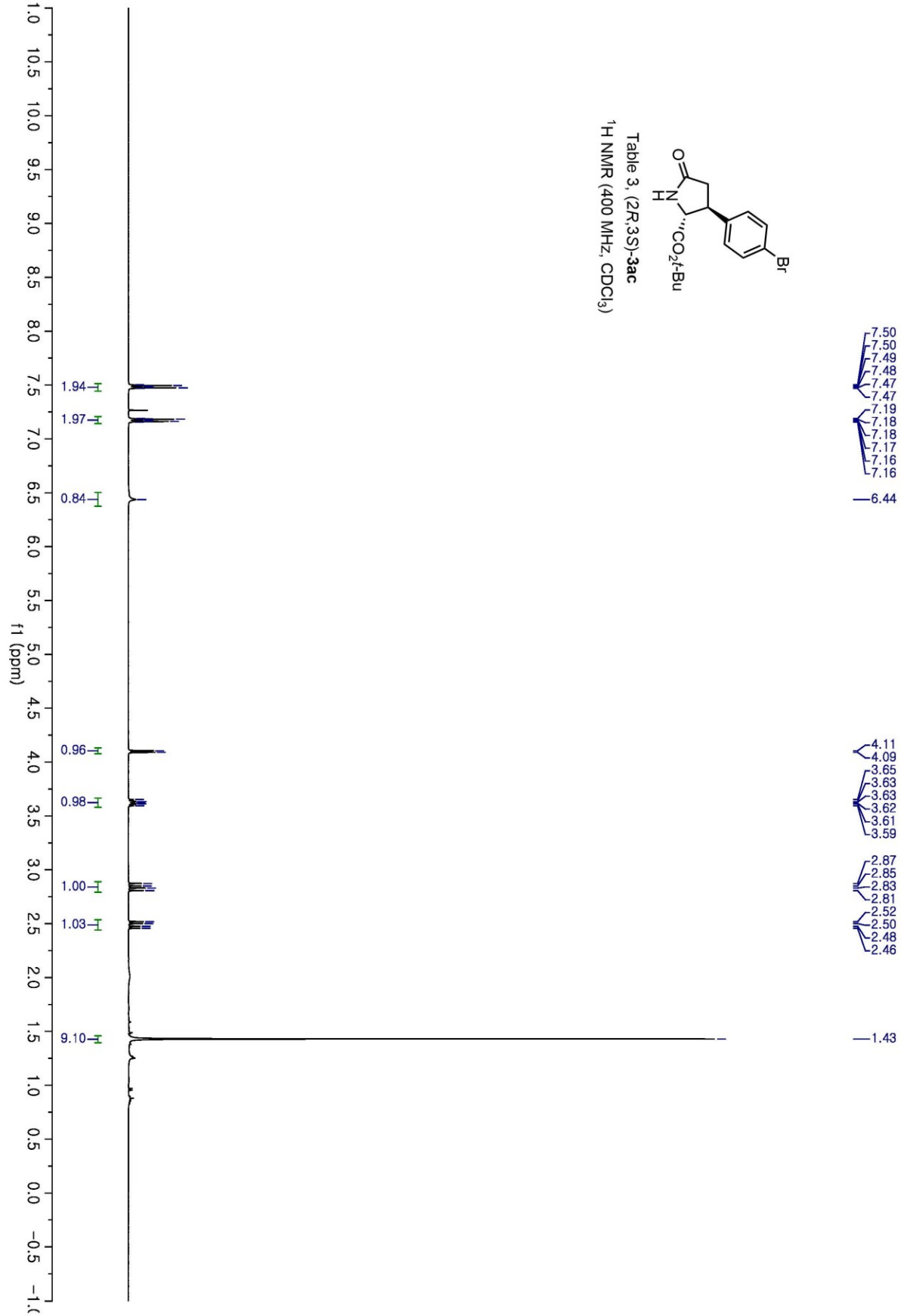


Table 3, (2R,3S)-3ac
1H NMR (400 MHz, CDCl3)
O
N
H
CO2t-Bu
Br
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
1.94
1.97
0.84
0.96
0.98
1.00
1.03
9.10
7.50
7.50
7.49
7.48
7.47
7.47
7.19
7.18
7.18
7.17
7.16
7.16
6.44
4.11
4.09
3.65
3.63
3.63
3.62
3.61
3.59
2.87
2.85
2.83
2.81
2.52
2.50
2.48
2.46
1.43

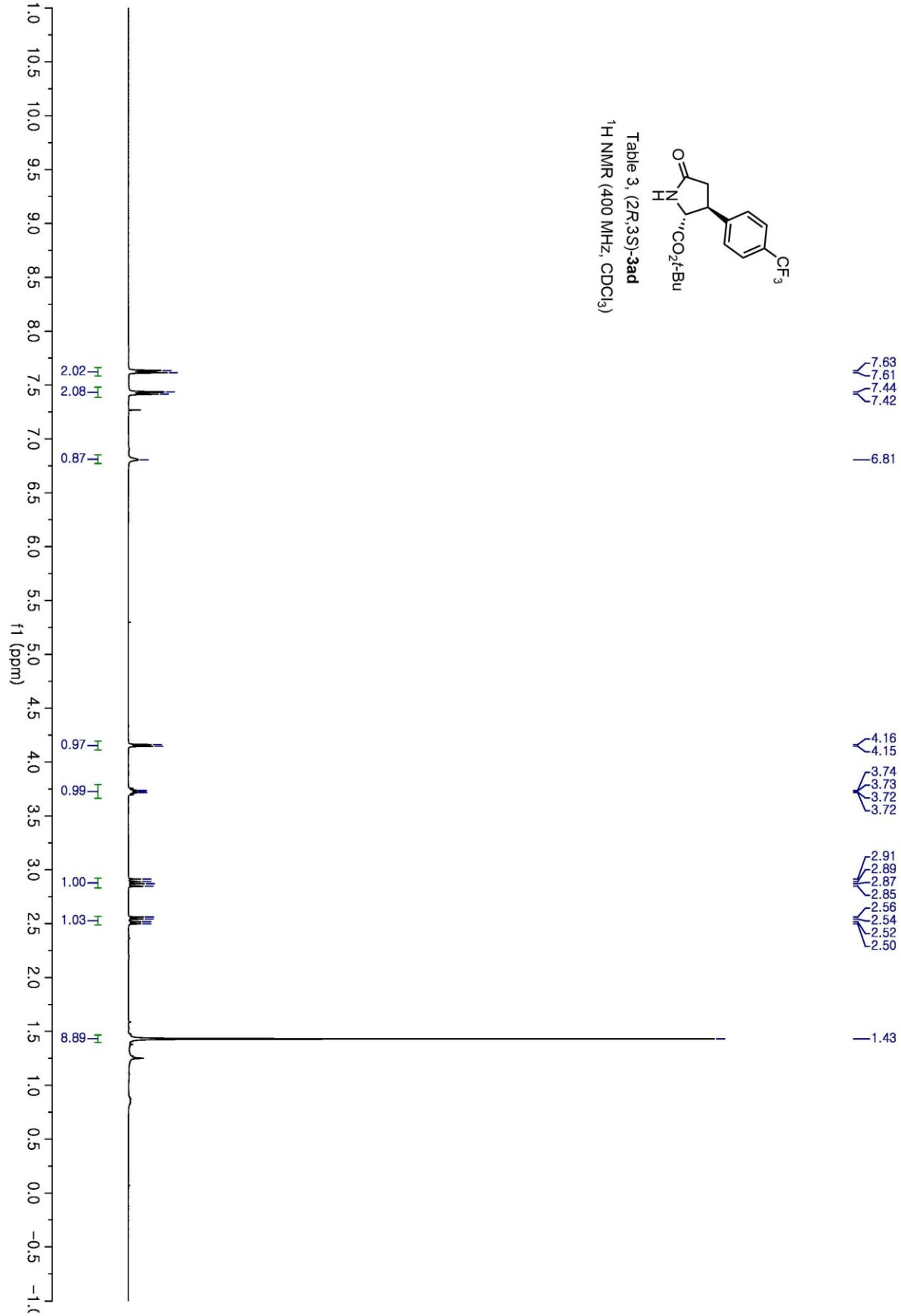


Table 3, (2R,3S)-3ad
¹H NMR (400 MHz, CDCl3)
O
N
H
CO2t-Bu
CF3
f1 (ppm)
2.02
2.08
0.87
0.97
0.99
1.00
1.03
8.89
7.63
7.61
7.44
7.42
6.81
4.16
4.15
3.74
3.73
3.72
3.72
2.91
2.89
2.87
2.85
2.56
2.54
2.52
2.50
1.43

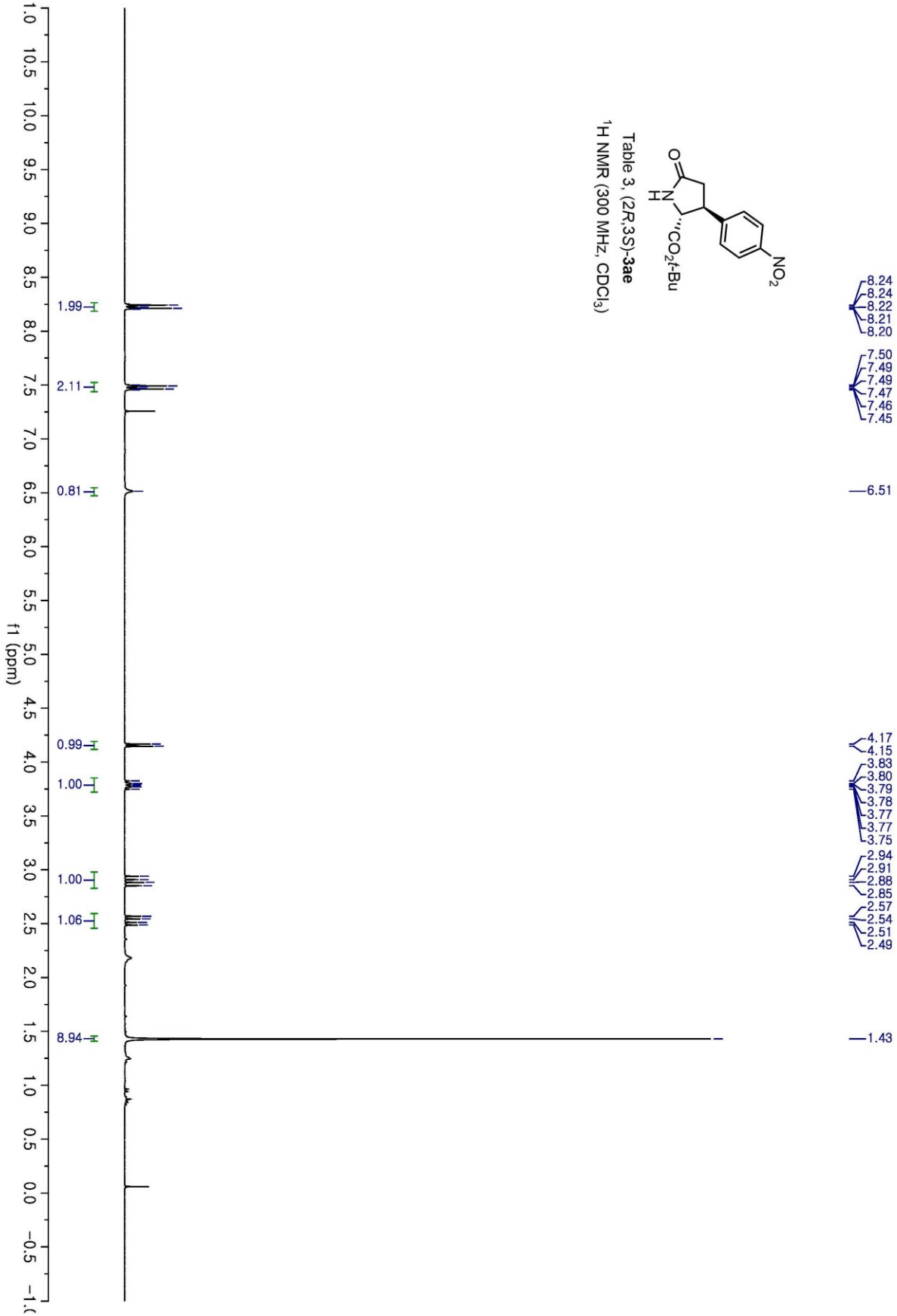


Table 3, (2R,3S)-3ae
^{1}H NMR (300 MHz, CDCl$_3$)
O
N
H
CO$_2$t-Bu
NO$_2$
8.24
8.24
8.22
8.21
8.20
7.50
7.49
7.49
7.47
7.46
7.45
6.51
4.17
4.15
3.83
3.80
3.79
3.78
3.77
3.77
3.75
2.94
2.91
2.88
2.85
2.57
2.54
2.51
2.49
1.43
1.99
2.11
0.81
0.99
1.00
1.00
1.06
8.94
f1 (ppm)

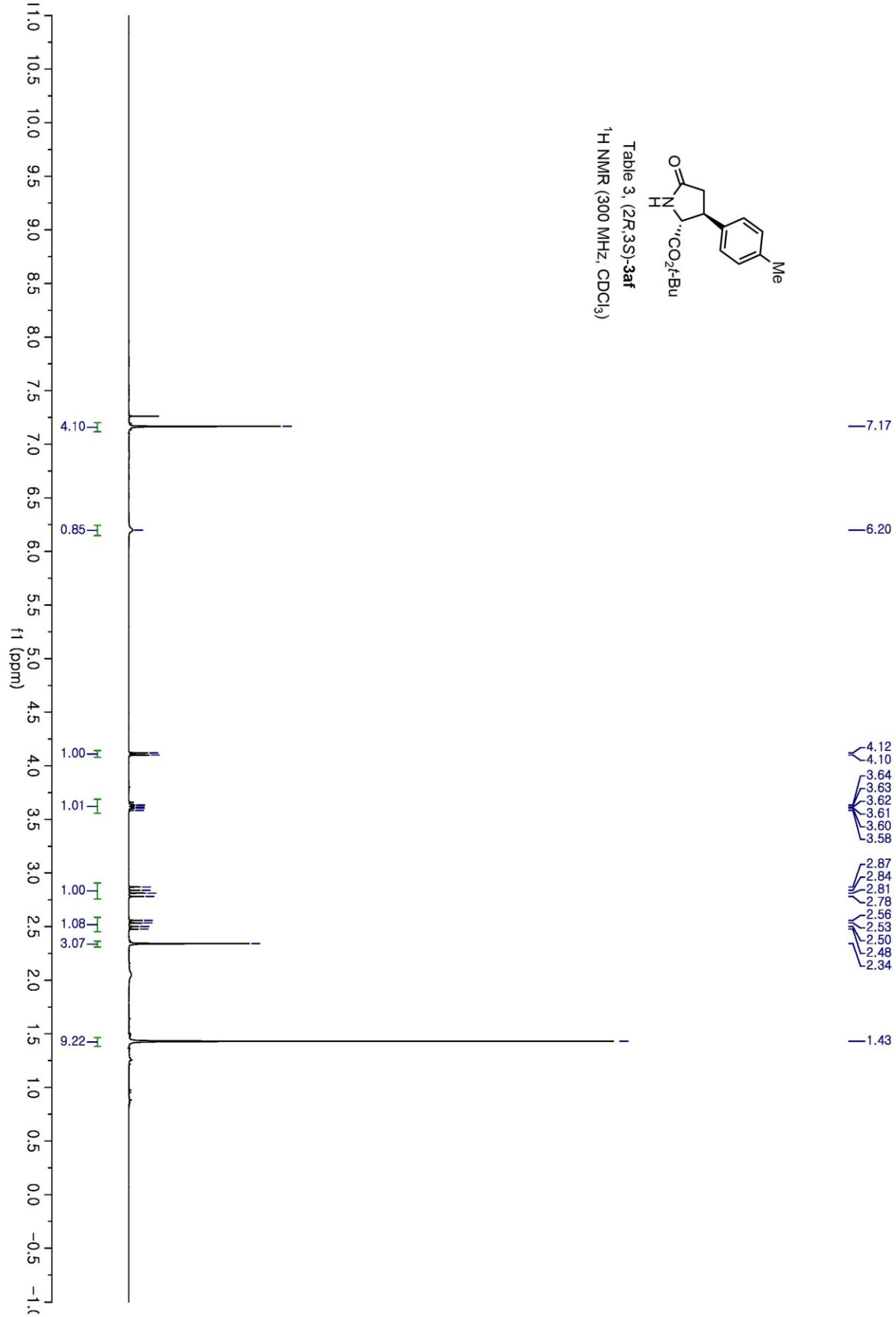


Table 3, (2R,3S)-3af
^{1}H NMR (300 MHz, CDCl$_3$)
Me
CO$_2$t-Bu
f1 (ppm)
4.10
0.85
1.00
1.01
1.00
1.08
3.07
9.22
7.17
6.20
4.12
4.10
3.64
3.63
3.62
3.61
3.60
3.58
2.87
2.84
2.81
2.78
2.56
2.53
2.50
2.48
2.34
1.43

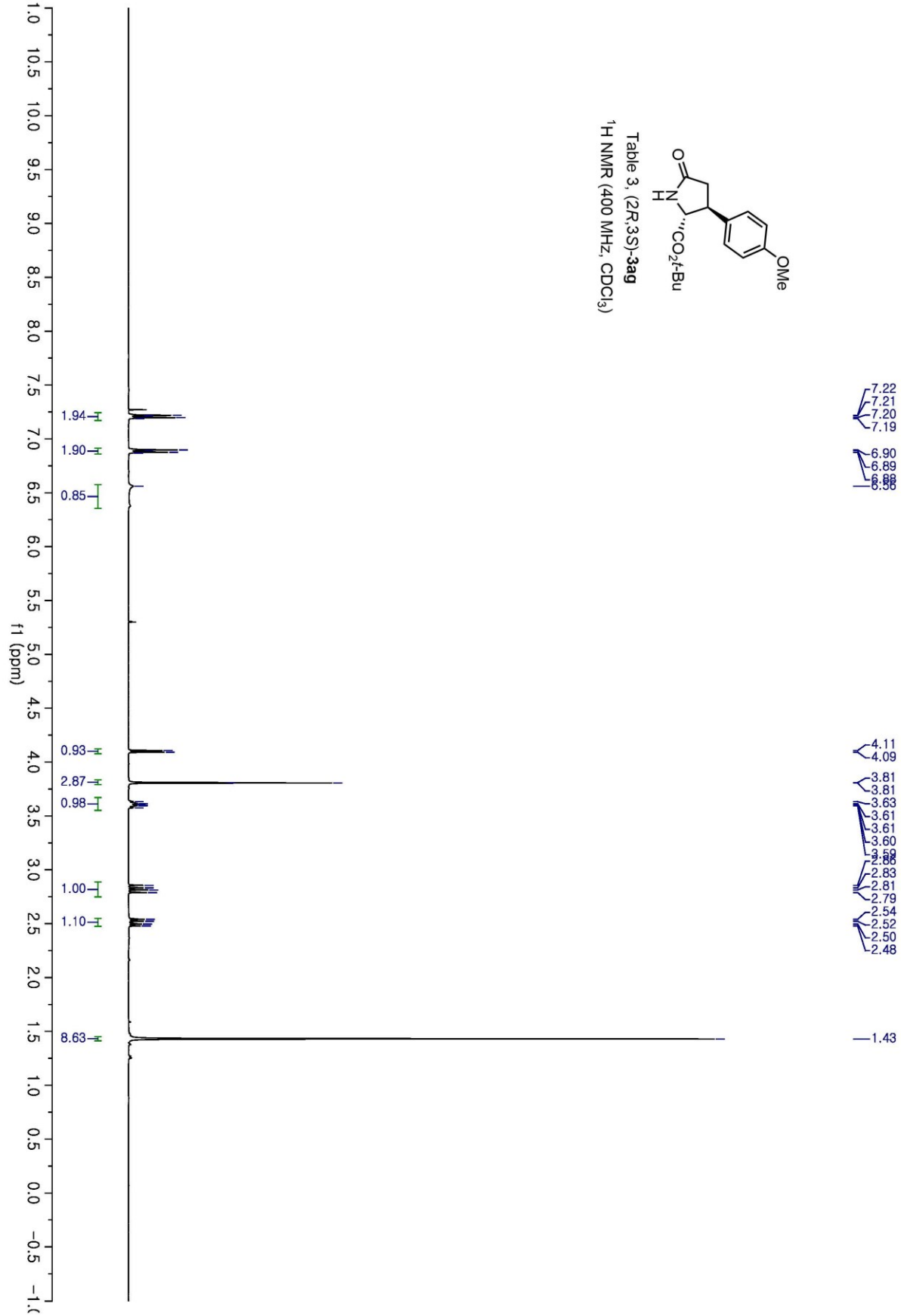


Table 3, (2R,3S)-3ag
1H NMR (400 MHz, CDCl3)
OMe
CO2t-Bu
f1 (ppm)
1.94
1.90
0.85
0.93
2.87
0.98
1.00
1.10
8.63
7.22
7.21
7.20
7.19
6.90
6.89
4.11
4.09
3.81
3.81
3.63
3.61
3.61
3.60
2.83
2.81
2.79
2.54
2.52
2.50
2.48
1.43

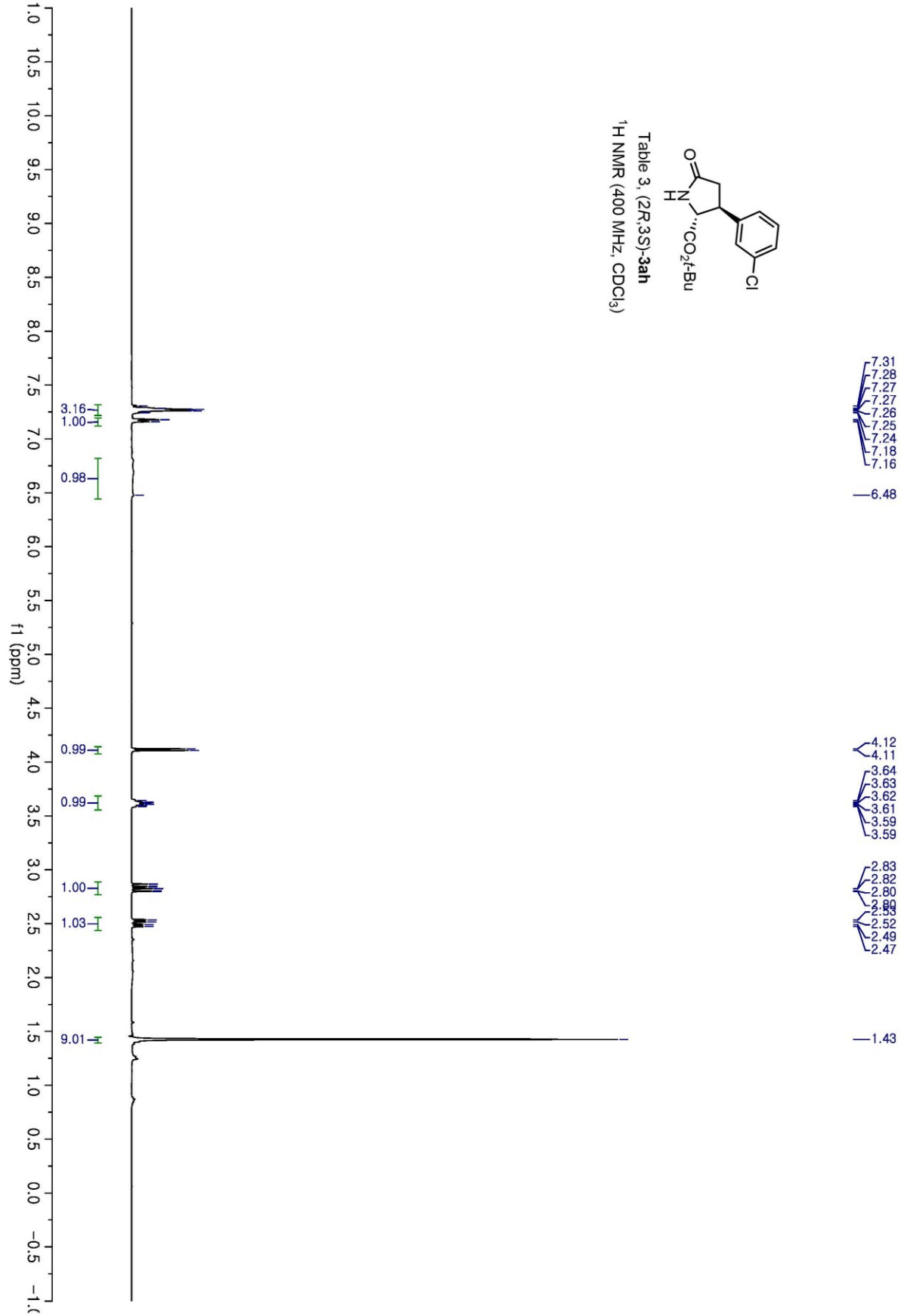


Table 3, (2R,3S)-3ah
1H NMR (400 MHz, CDCl3)
O
N
H
CO2t-Bu
Cl
7.31
7.28
7.27
7.27
7.26
7.25
7.24
7.18
7.16
6.48
4.12
4.11
3.64
3.63
3.62
3.61
3.59
3.59
2.83
2.82
2.80
2.52
2.49
2.47
1.43
3.16
1.00
0.98
0.99
0.99
1.00
1.03
9.01
f1 (ppm)

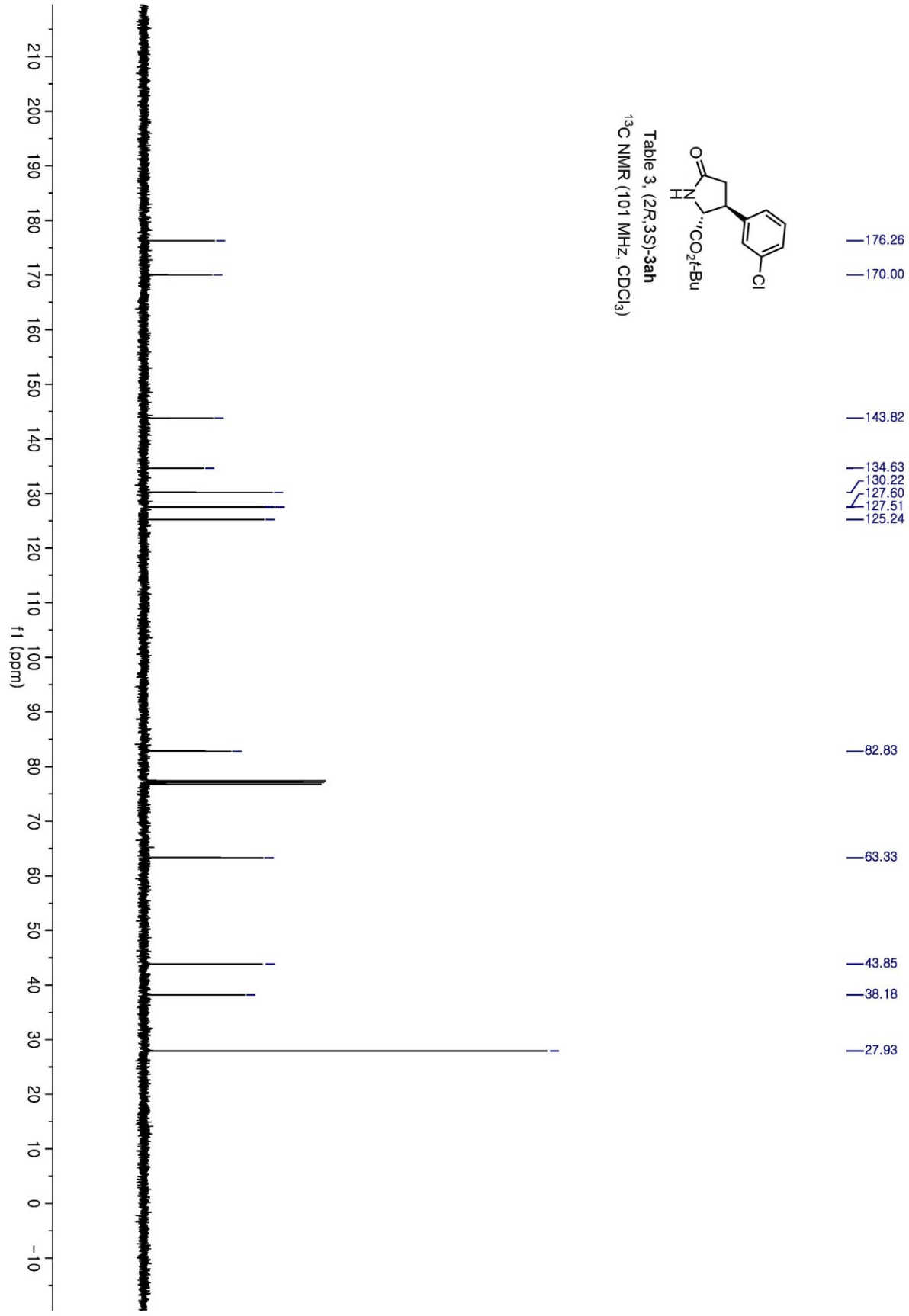


Table 3, (2R,3S)-3ah
13C NMR (101 MHz, CDCl3)
O
N
H
CO2t-Bu
Cl
176.26
170.00
143.82
134.63
130.22
127.60
127.51
125.24
82.83
63.33
43.85
38.18
27.93
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

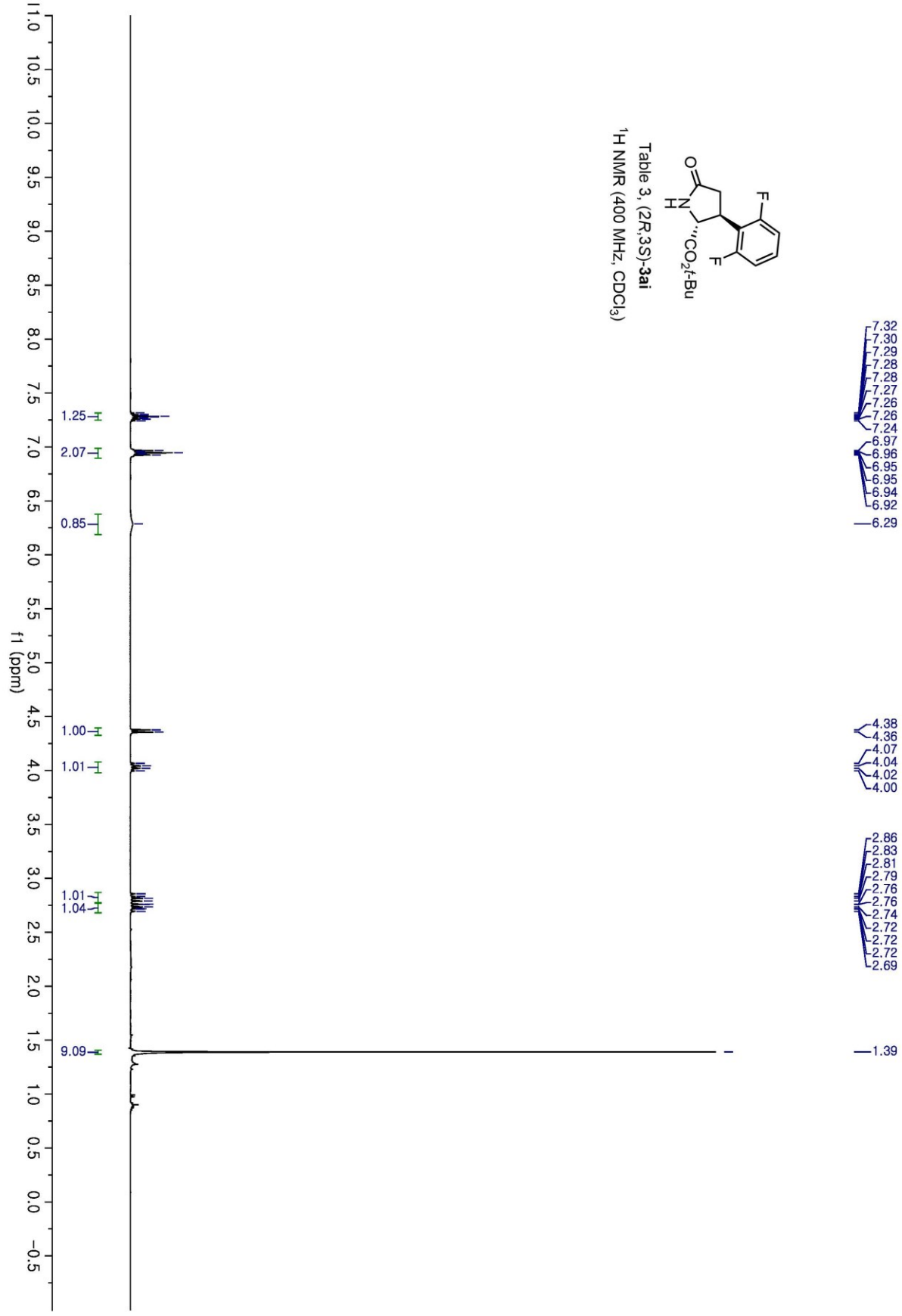


Table 3, (2R,3S)-3ai
^{1}H NMR (400 MHz, CDCl$_3$)
O
N
H
F
F
CO$_2$t-Bu
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
1.25
2.07
0.85
1.00
1.01
1.01
1.04
9.09
7.32
7.30
7.29
7.28
7.28
7.27
7.26
7.26
7.24
6.97
6.96
6.95
6.95
6.94
6.92
6.29
4.38
4.36
4.07
4.04
4.02
4.00
2.86
2.83
2.81
2.79
2.76
2.76
2.74
2.72
2.72
2.72
2.69
1.39

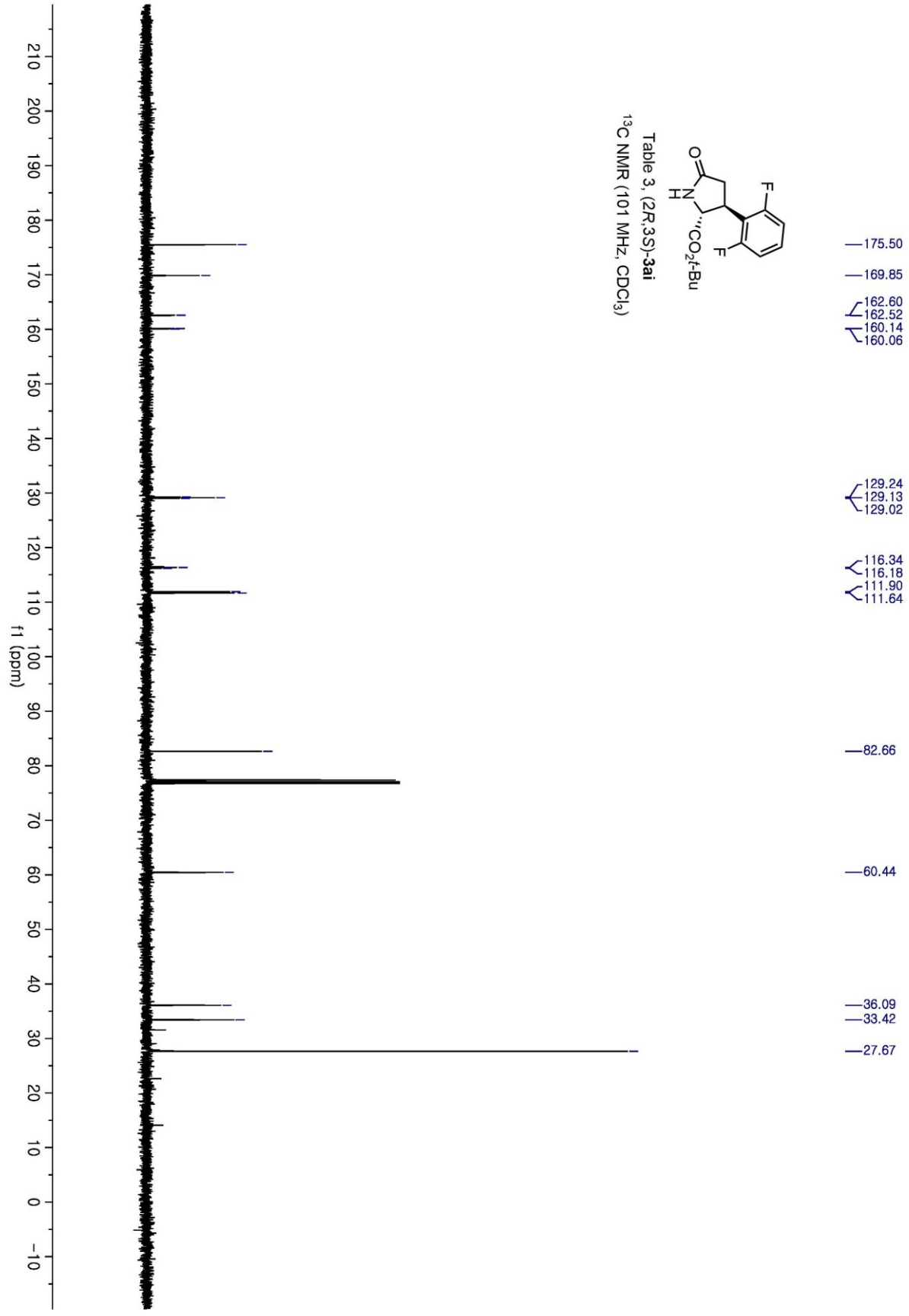


Table 3, (2R,3S)-3ai
13C NMR (101 MHz, CDCl3)
O
N
H
CO2t-Bu
F
F
175.50
169.85
162.60
162.52
160.14
160.06
129.24
129.13
129.02
116.34
116.18
111.90
111.64
82.66
60.44
36.09
33.42
27.67
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

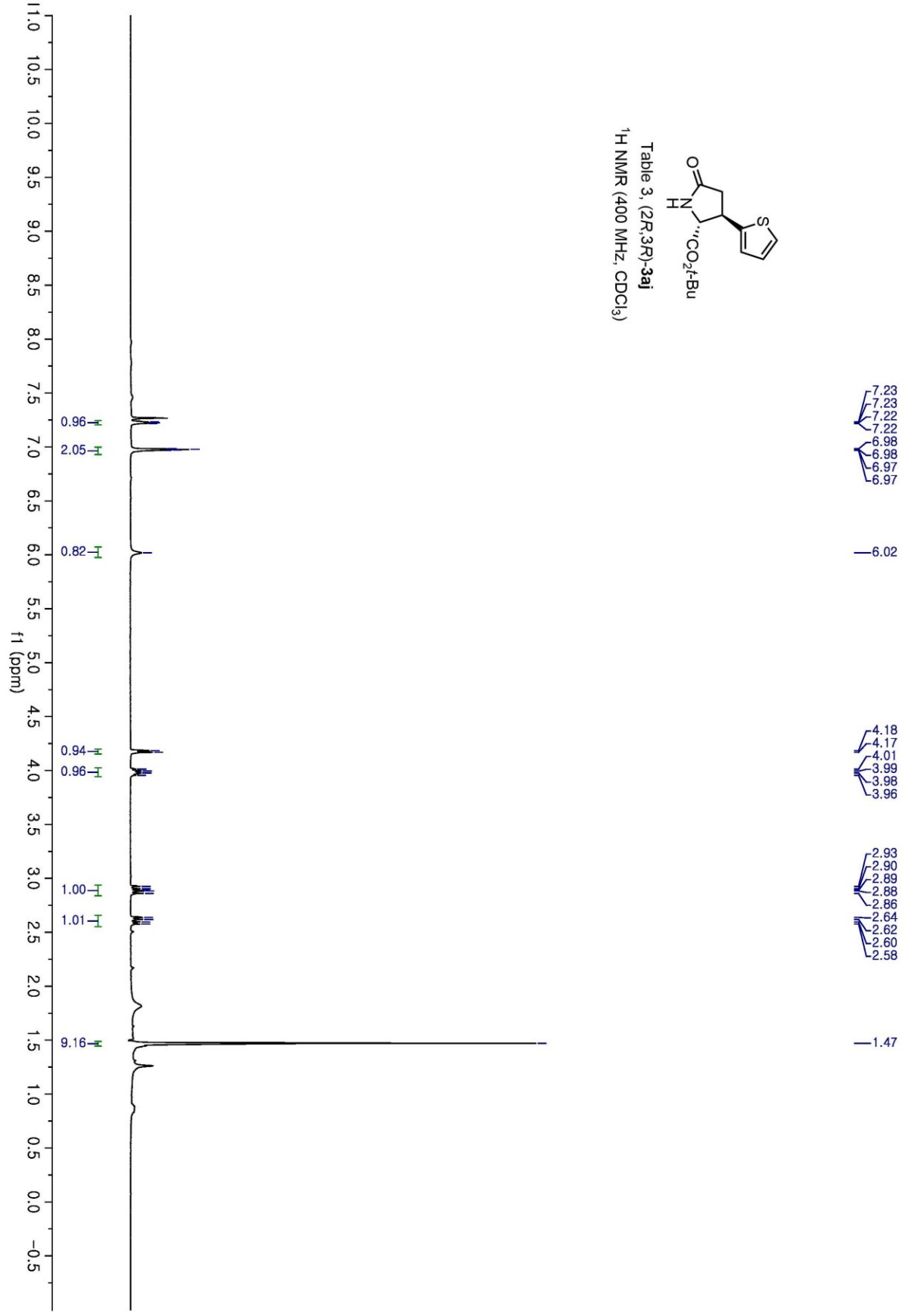


Table 3, (2R,3R)-3aj
1H NMR (400 MHz, CDCl3)
O
N
H
''CO2t-Bu
S
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.96
2.05
0.82
0.94
0.96
1.00
1.01
9.16
7.23
7.23
7.22
7.22
6.98
6.98
6.97
6.97
6.02
4.18
4.17
4.01
3.99
3.98
3.96
2.93
2.90
2.89
2.88
2.86
2.64
2.62
2.60
2.58
1.47

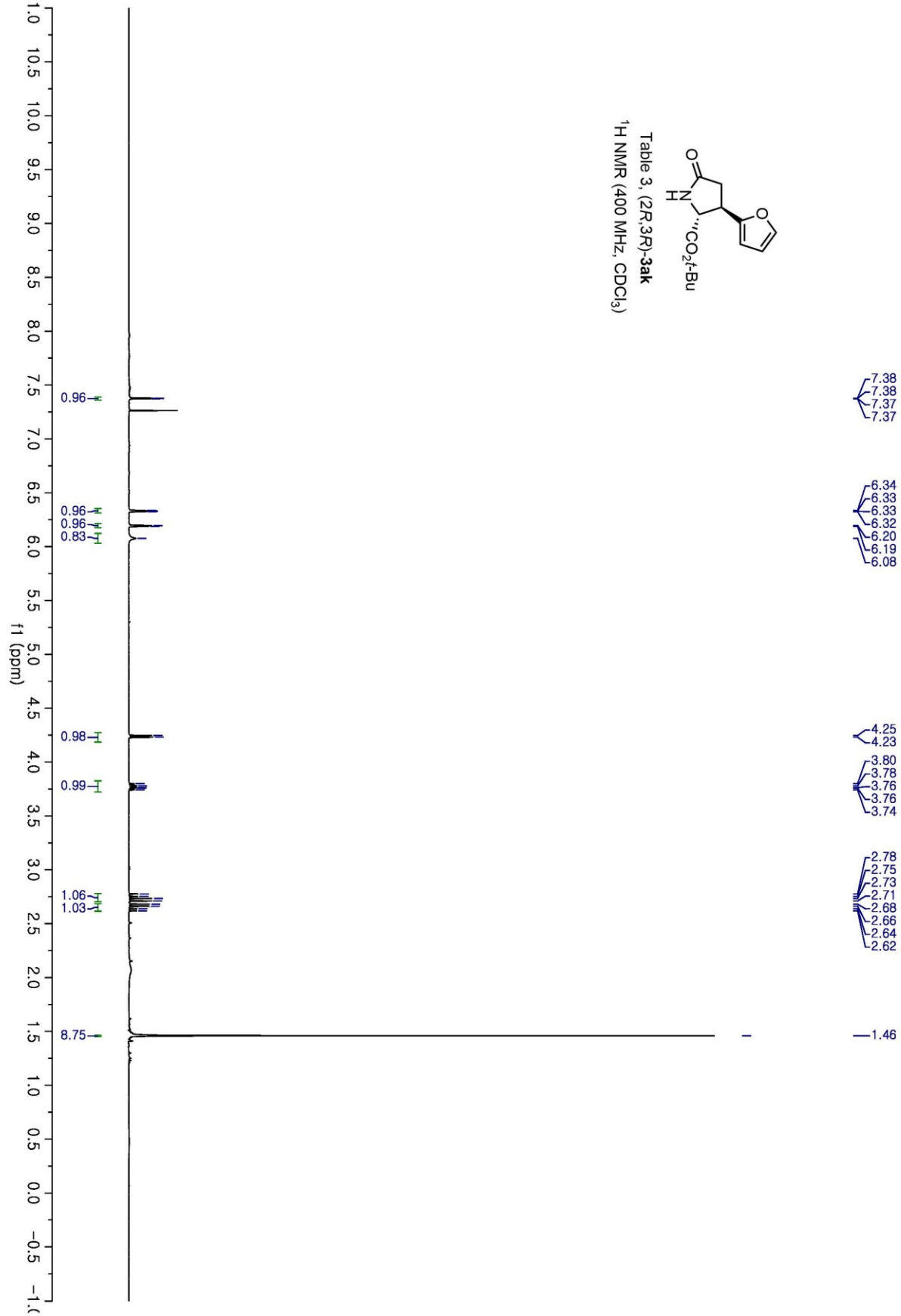


Table 3, (2R,3R)-3ak
^{1}H NMR (400 MHz, CDCl$_3$)
O
N
H
''CO$_2$t-Bu
O
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.96
0.96
0.96
0.83
0.98
0.99
1.06
1.03
8.75
7.38
7.38
7.37
7.37
6.34
6.33
6.33
6.32
6.20
6.19
6.08
4.25
4.23
3.80
3.78
3.76
3.76
3.74
2.78
2.75
2.73
2.71
2.68
2.66
2.64
2.62
1.46

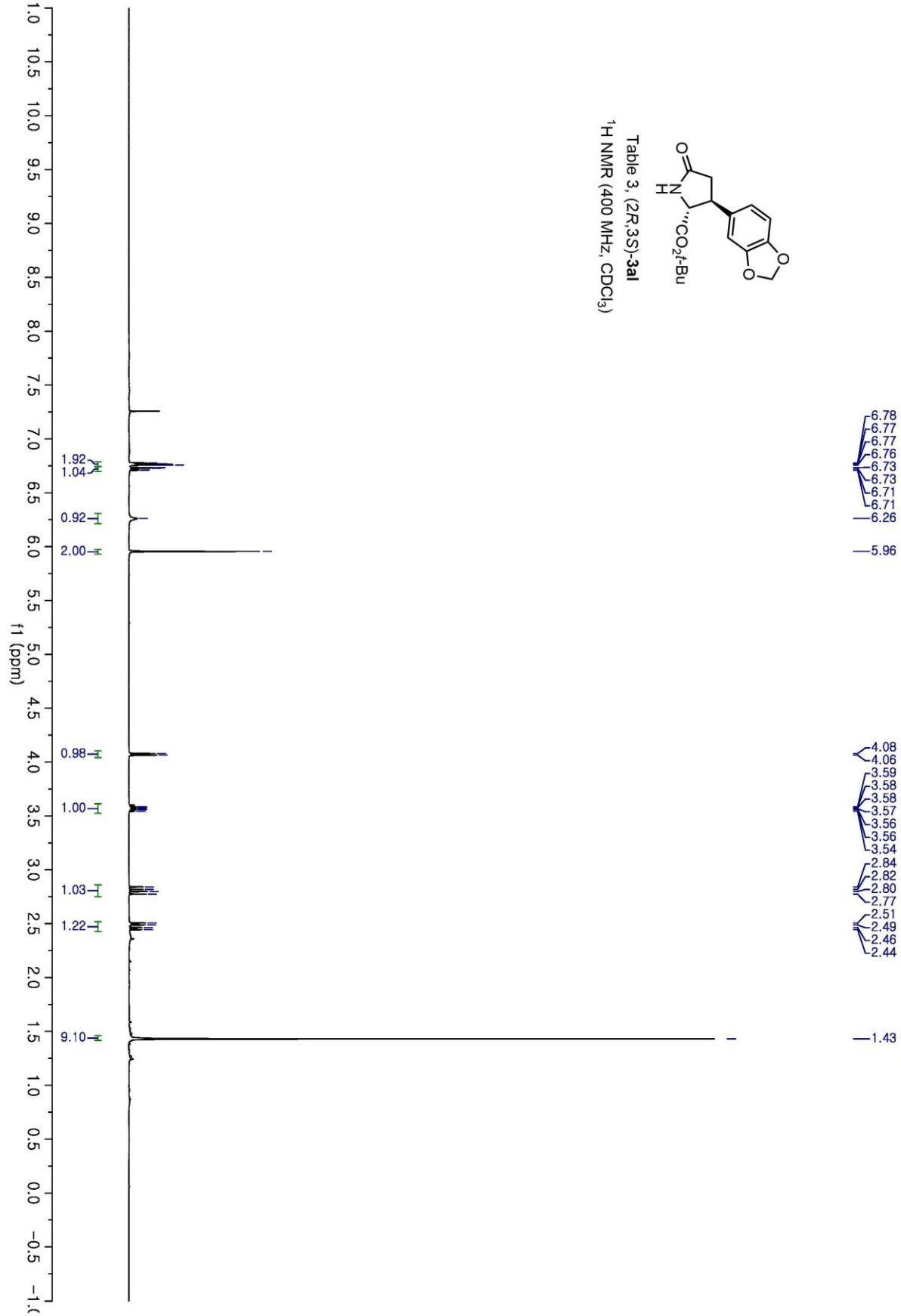


Table 3, (2R,3S)-3al
^{1}H NMR (400 MHz, CDCl$_3$)
O
N
H
''CO$_2$t-Bu
O
O
f1 (ppm)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
1.92
1.04
0.92
2.00
0.98
1.00
1.03
1.22
9.10
6.78
6.77
6.77
6.76
6.73
6.73
6.71
6.71
6.26
5.96
4.08
4.06
3.59
3.58
3.58
3.57
3.56
3.56
3.54
2.84
2.82
2.80
2.77
2.51
2.49
2.46
2.44
1.43

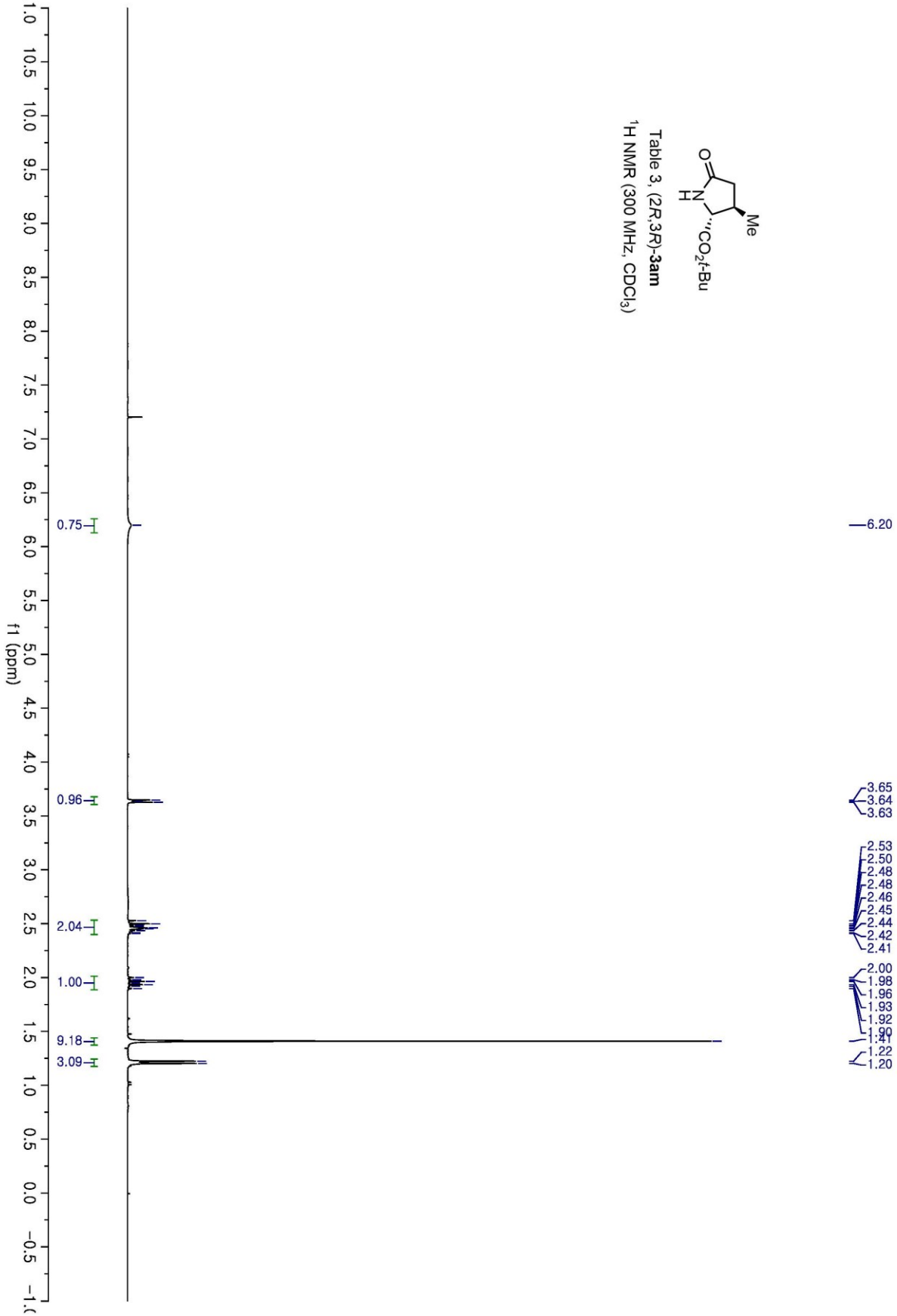


Table 3, (2R,3R)-3am
^{1}H NMR (300 MHz, CDCl$_3$)
Me
CO$_2$t-Bu
f1 (ppm)
0.75
0.96
2.04
1.00
9.18
3.09
6.20
3.65
3.64
3.63
2.53
2.50
2.48
2.48
2.46
2.45
2.44
2.42
2.41
2.00
1.98
1.96
1.93
1.92
1.90
1.22
1.20

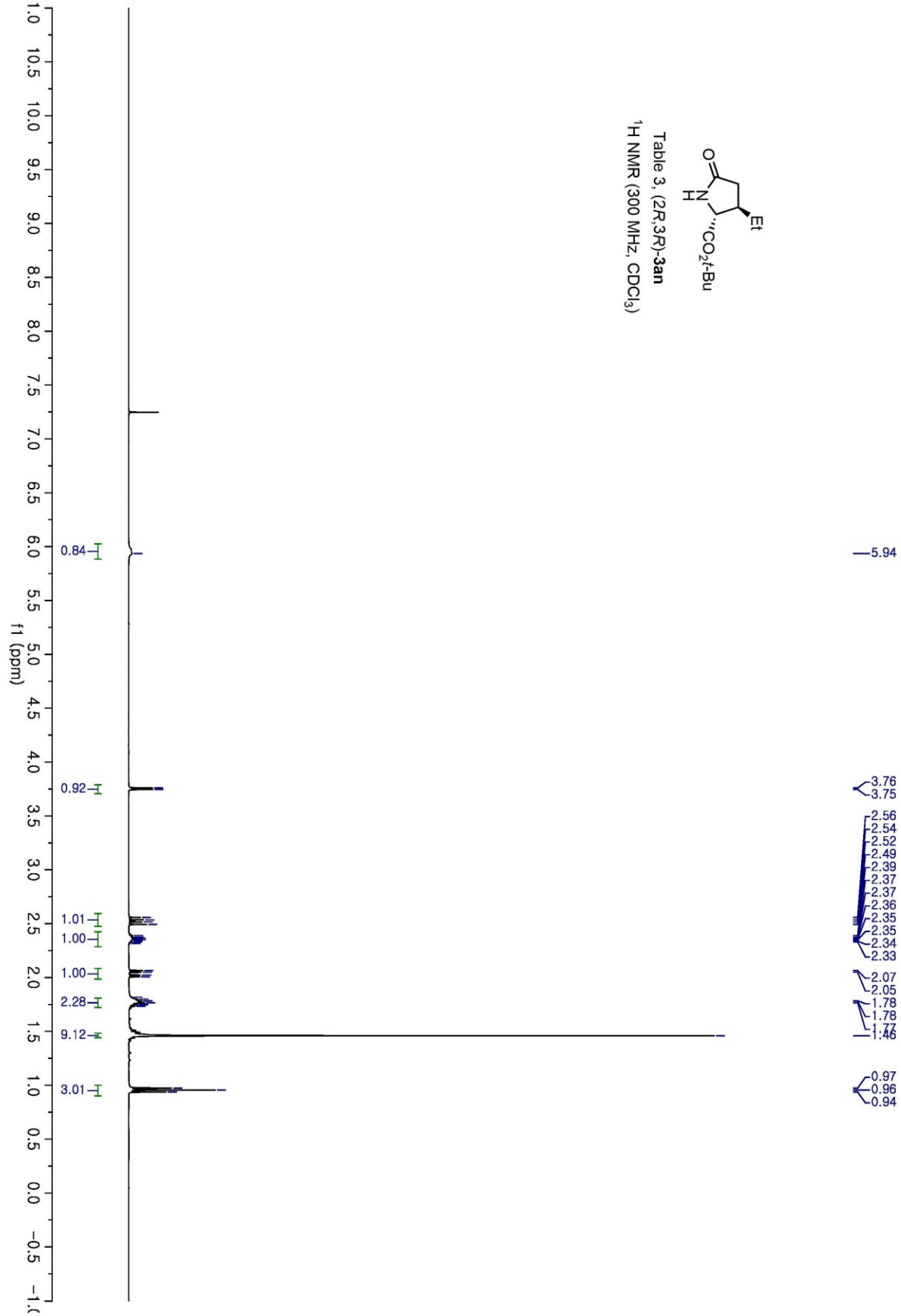


Table 3, (2R,3R)-3an
^{1}H NMR (300 MHz, CDCl$_3$)
Et
CO$_2$t-Bu
f1 (ppm)
0.84
0.92
1.01
1.00
1.00
2.28
9.12
3.01
5.94
3.76
3.75
2.56
2.54
2.52
2.49
2.39
2.37
2.37
2.36
2.35
2.35
2.34
2.33
2.07
2.05
1.78
1.78
1.77
1.46
0.97
0.96
0.94

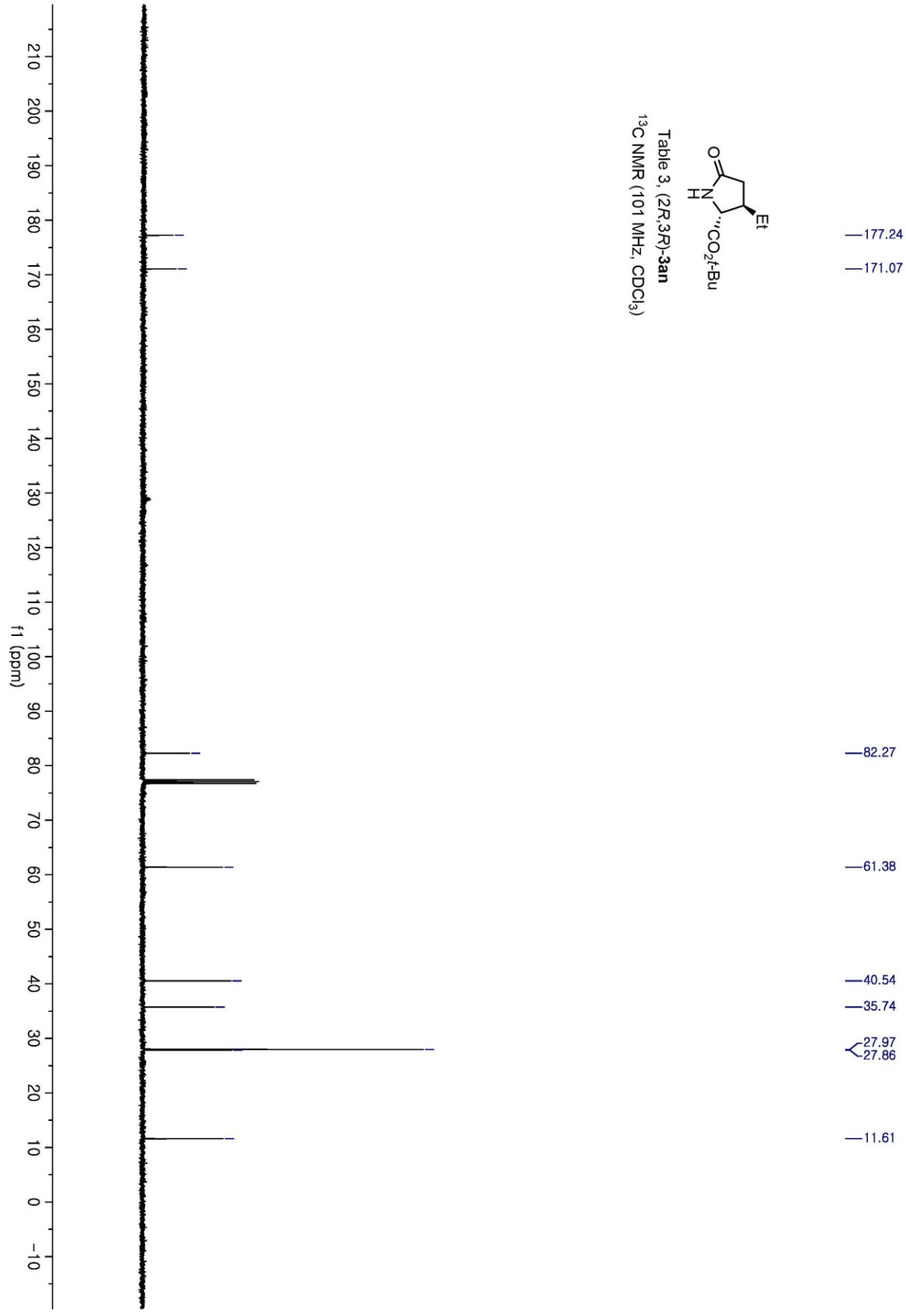


Table 3, (2R,3R)-3an
13C NMR (101 MHz, CDCl3)
Et
CO2t-Bu
177.24
171.07
82.27
61.38
40.54
35.74
27.97
27.86
11.61
f1 (ppm)

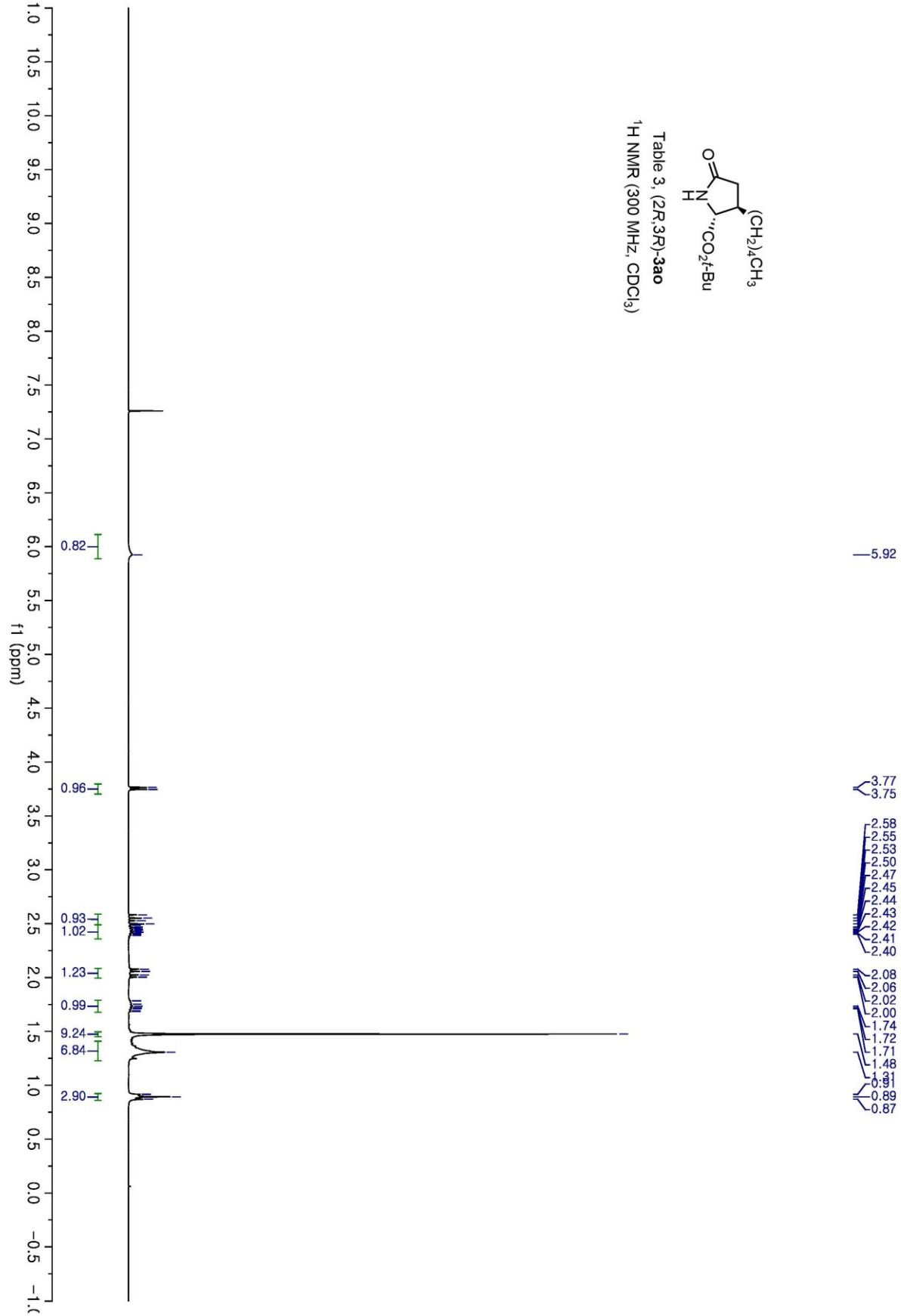


Table 3, (2R,3R)-3ao
1H NMR (300 MHz, CDCl3)
(CH2)4CH3
CO2t-Bu
f1 (ppm)
0.82
0.96
0.93
1.02
1.23
0.99
9.24
6.84
2.90
5.92
3.77
3.75
2.58
2.55
2.53
2.50
2.47
2.45
2.44
2.43
2.42
2.41
2.40
2.08
2.06
2.02
2.00
1.74
1.72
1.71
1.48
1.31
0.89
0.87

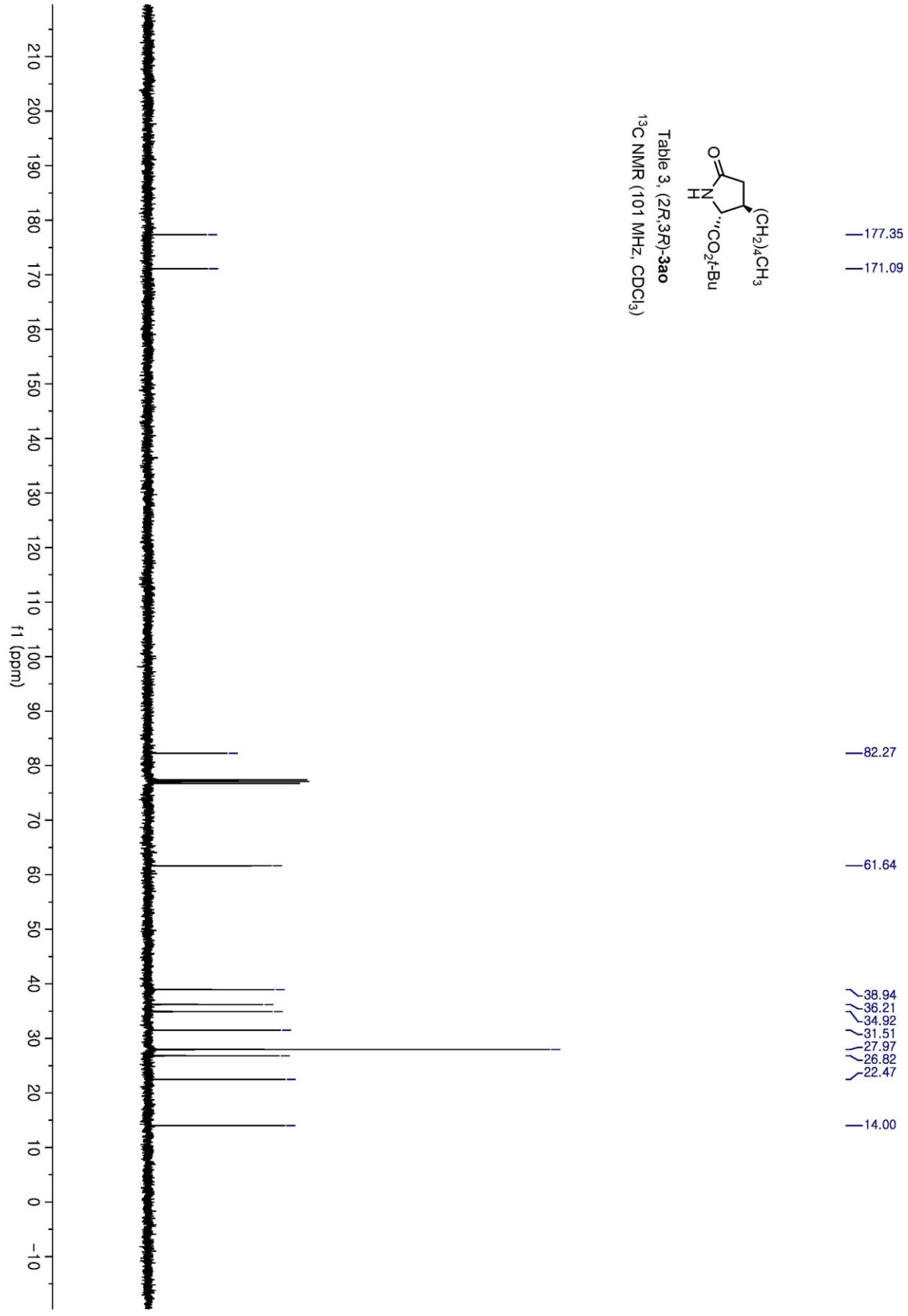


Table 3, (2R,3R)-3ao
13C NMR (101 MHz, CDCl3)
(CH2)4CH3
CO2t-Bu
177.35
171.09
82.27
61.64
38.94
36.21
34.92
31.51
27.97
26.82
22.47
14.00
f1 (ppm)

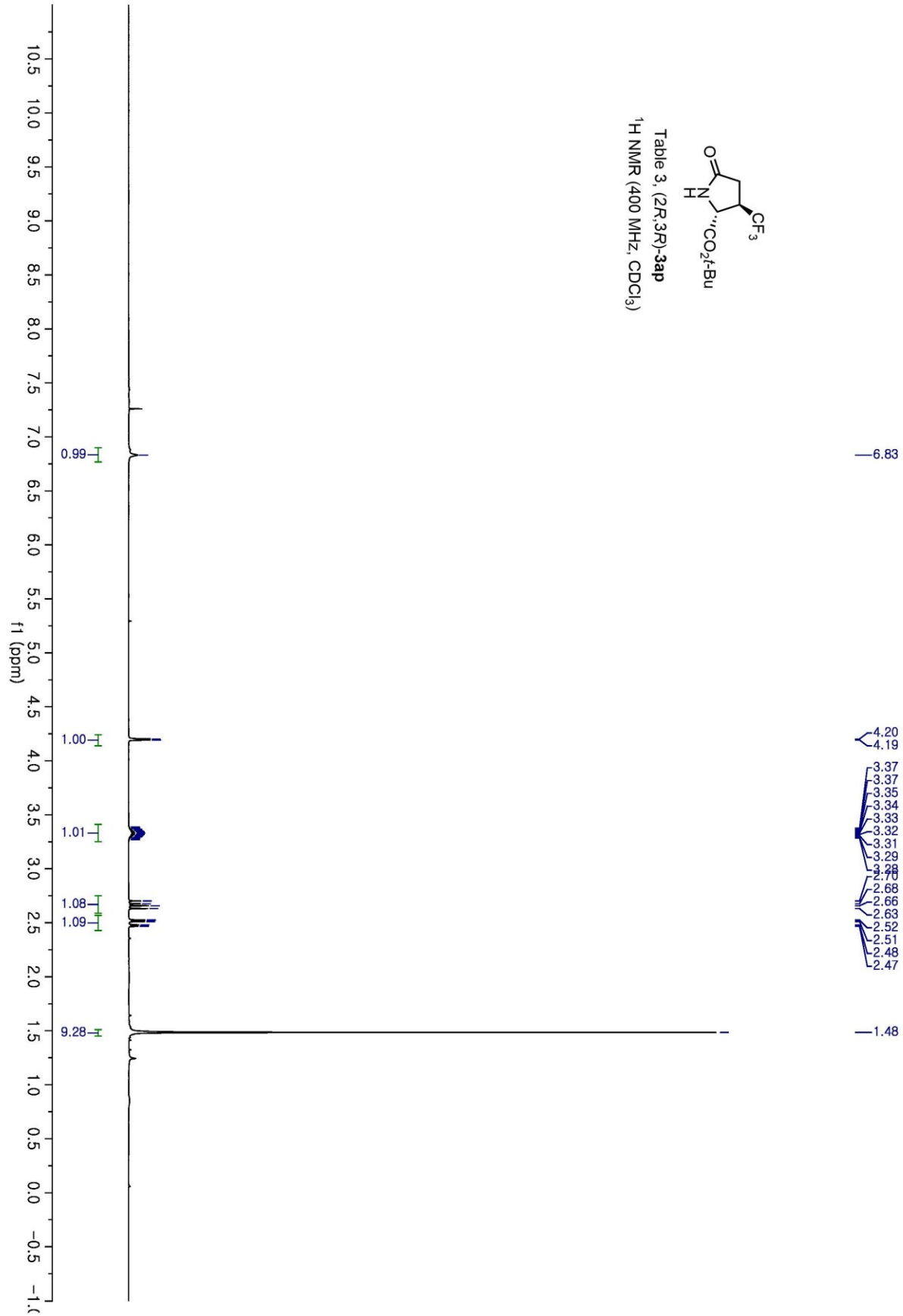


Table 3, (2R,3R)-3ap
1H NMR (400 MHz, CDCl3)
CF3
CO2t-Bu
f1 (ppm)
0.99
1.00
1.01
1.08
1.09
9.28
6.83
4.20
4.19
3.37
3.37
3.35
3.34
3.33
3.32
3.31
3.29
2.70
2.68
2.66
2.63
2.52
2.51
2.48
2.47
1.48

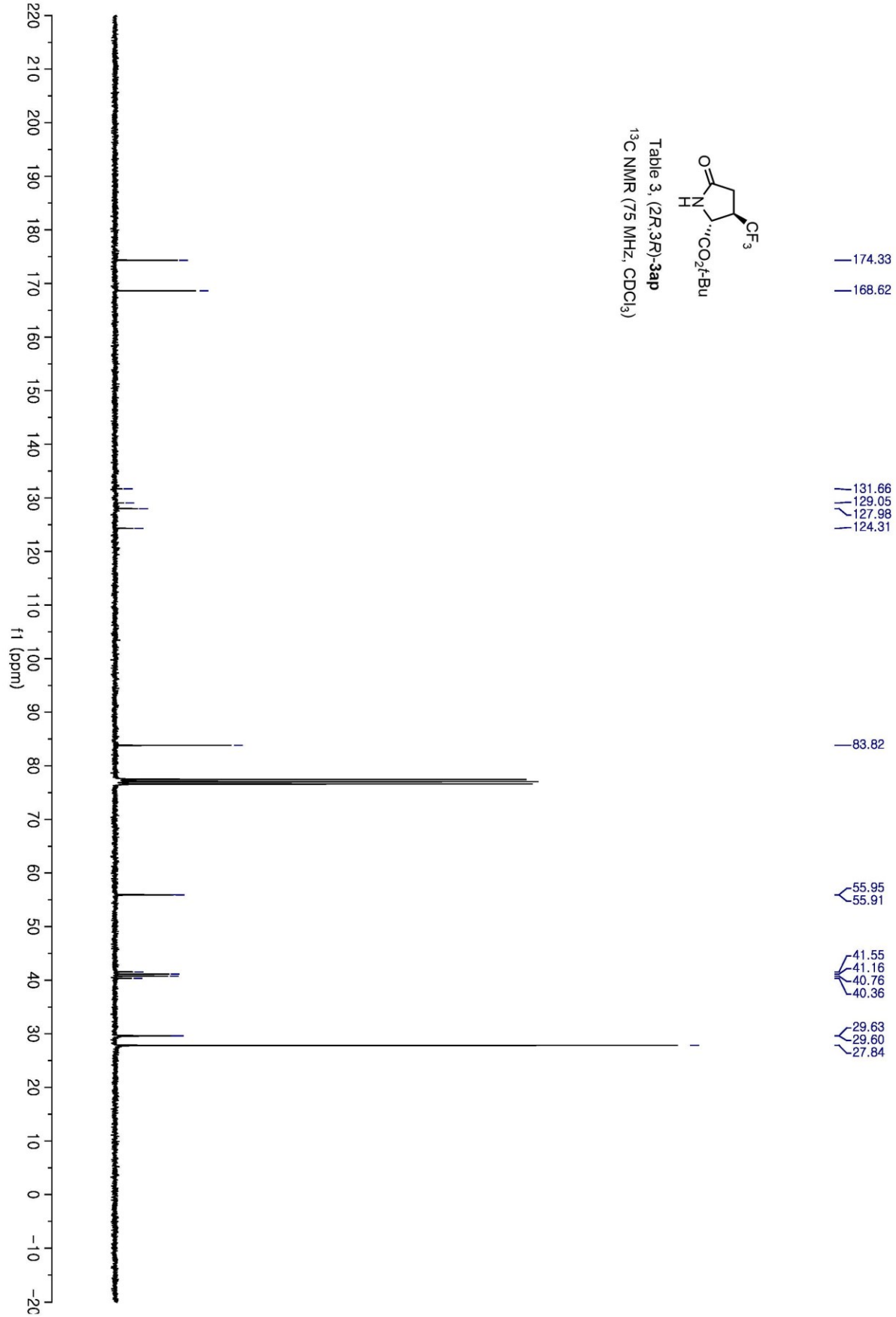


Table 3, (2R,3R)-3ap
13C NMR (75 MHz, CDCl3)
CF3
CO2t-Bu
174.33
168.62
131.66
129.05
127.98
124.31
83.82
55.95
55.91
41.55
41.16
40.76
40.36
29.63
29.60
27.84
f1 (ppm)

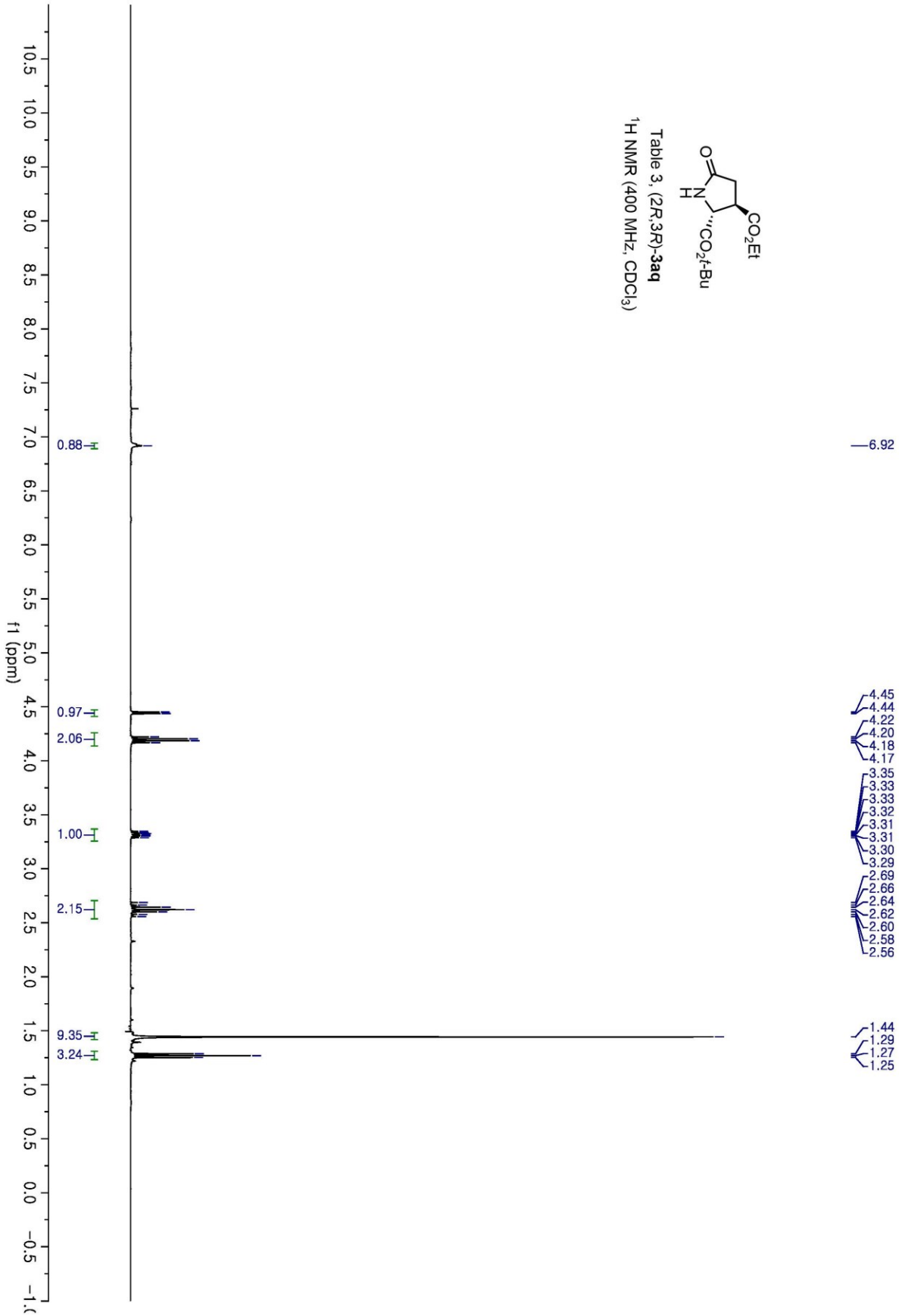


Table 3, (2R,3R)-3aq
^{1}H NMR (400 MHz, CDCl$_3$)
CO$_2$Et
CO$_2$t-Bu
f1 (ppm)
0.88
0.97
2.06
1.00
2.15
9.35
3.24
6.92
4.45
4.44
4.22
4.20
4.18
4.17
3.35
3.33
3.33
3.32
3.31
3.31
3.30
3.29
2.69
2.66
2.64
2.62
2.60
2.58
2.56
1.44
1.29
1.27
1.25

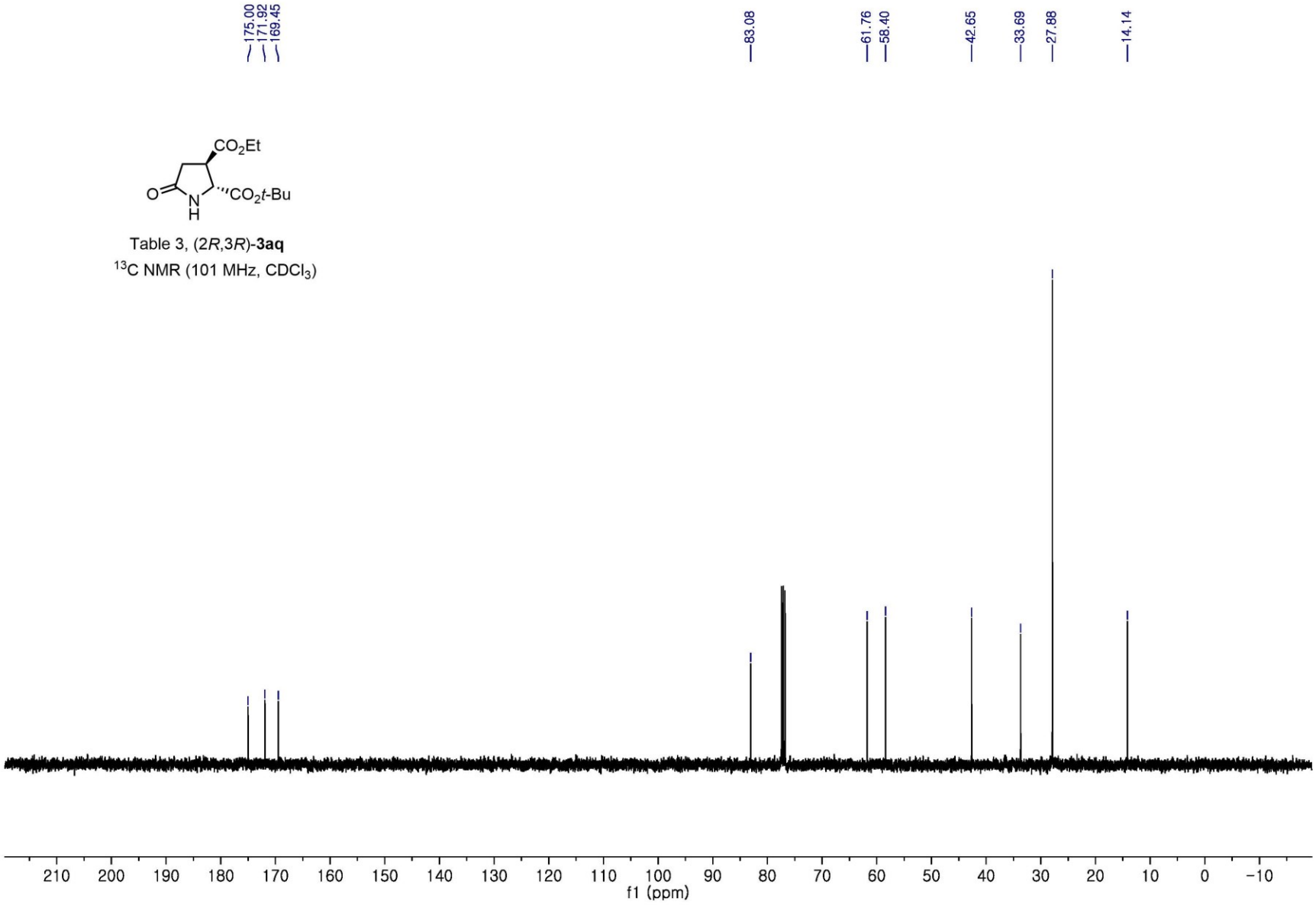
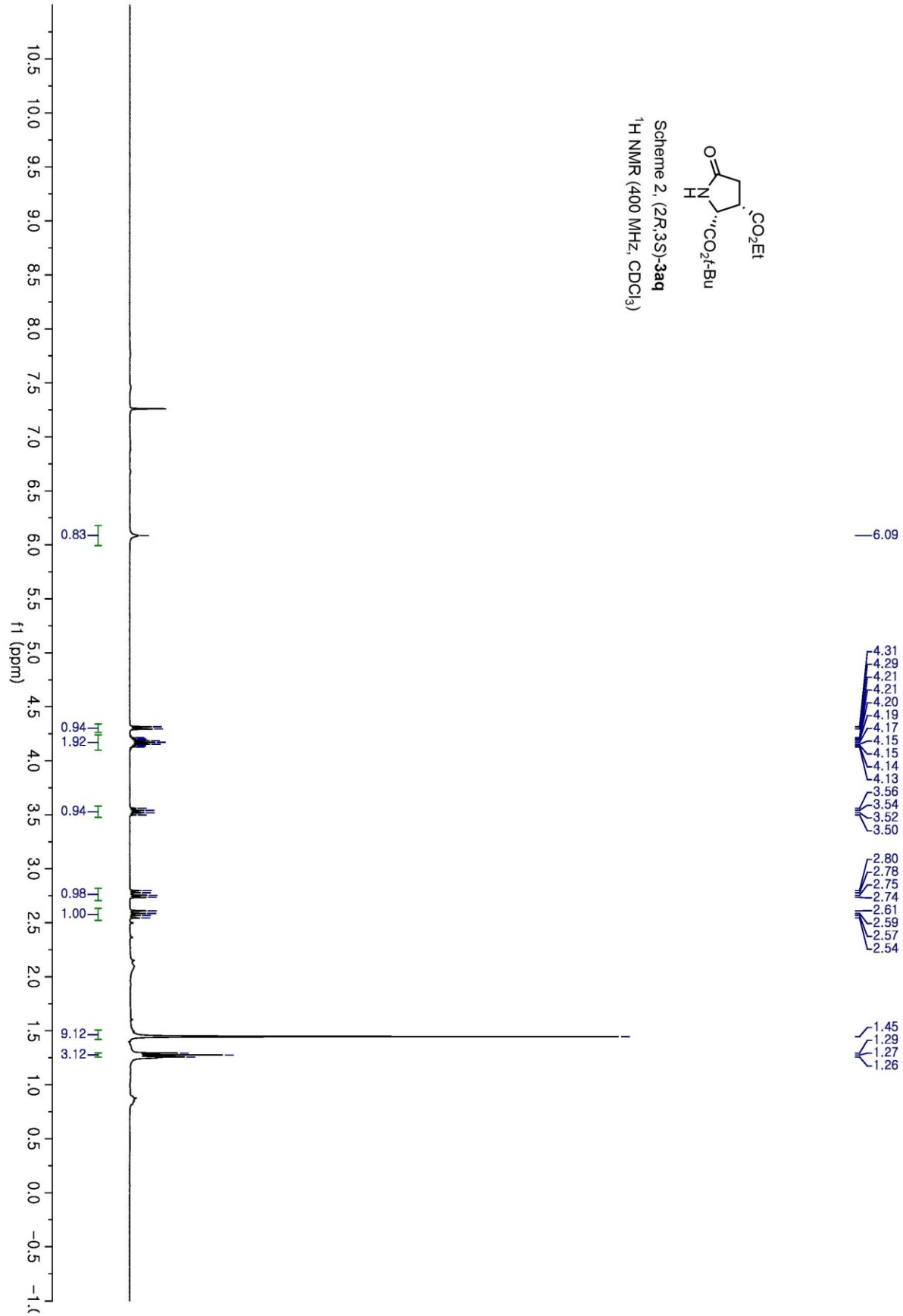
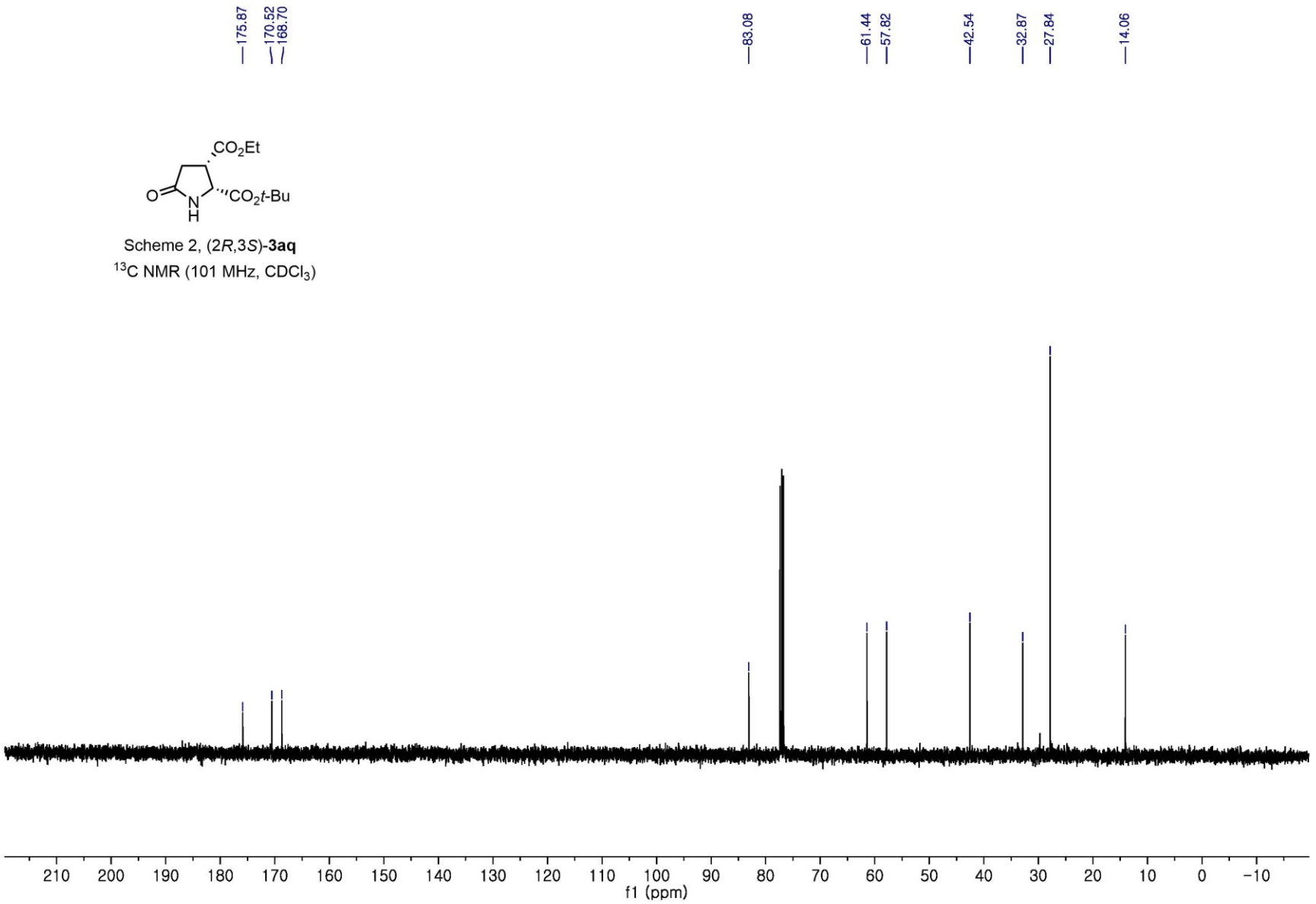


Table 3, (2*R*,3*R*)-**3aq**

^{13}C NMR (101 MHz, $CDCl_3$)


Scheme 2, (2R,3S)-3aq
^{1}H NMR (400 MHz, CDCl$_3$)
CO_2Et
CO_2t-Bu
f1 (ppm)
0.83
0.94
1.92
0.94
0.98
1.00
9.12
3.12
6.09
4.31
4.29
4.21
4.21
4.20
4.19
4.17
4.15
4.15
4.14
4.13
3.56
3.54
3.52
3.50
2.80
2.78
2.75
2.74
2.61
2.59
2.57
2.54
1.45
1.29
1.27
1.26



Scheme 2, (2*R*,3*S*)-**3aq**

^{13}C NMR (101 MHz, $CDCl_3$)

5.95
5.64
5.62
5.60
5.60
5.58
5.57
5.55
5.53
5.53
5.51
5.51
5.49
5.49
5.47
5.47
3.84
3.83
3.08
3.06
3.04
3.02
3.00
2.56
2.54
2.52
2.50
2.27
2.25
2.23
2.21
1.71
1.71
1.69
1.47
Me
O
N
H
CO2t-Bu
Table 3, (2R,3S)-3ar
1H NMR (400 MHz, CDCl3)
DCM
0.77
1.72
0.84
0.89
1.04
1.00
2.75
8.57
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

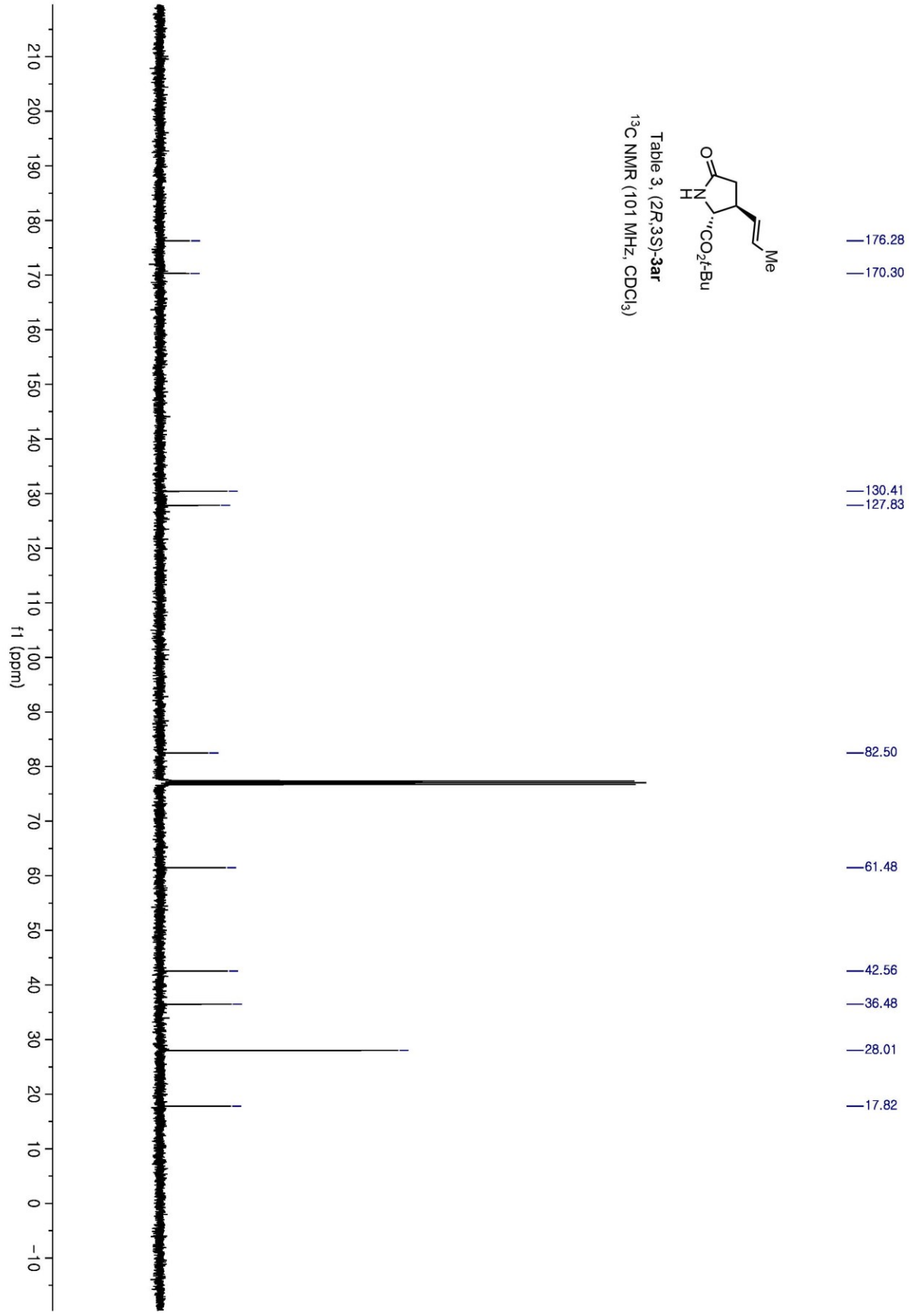


Table 3, (2R,3S)-3ar
13C NMR (101 MHz, CDCl3)
O
N
H
CO2t-Bu
Me
176.28
170.30
130.41
127.83
82.50
61.48
42.56
36.48
28.01
17.82
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

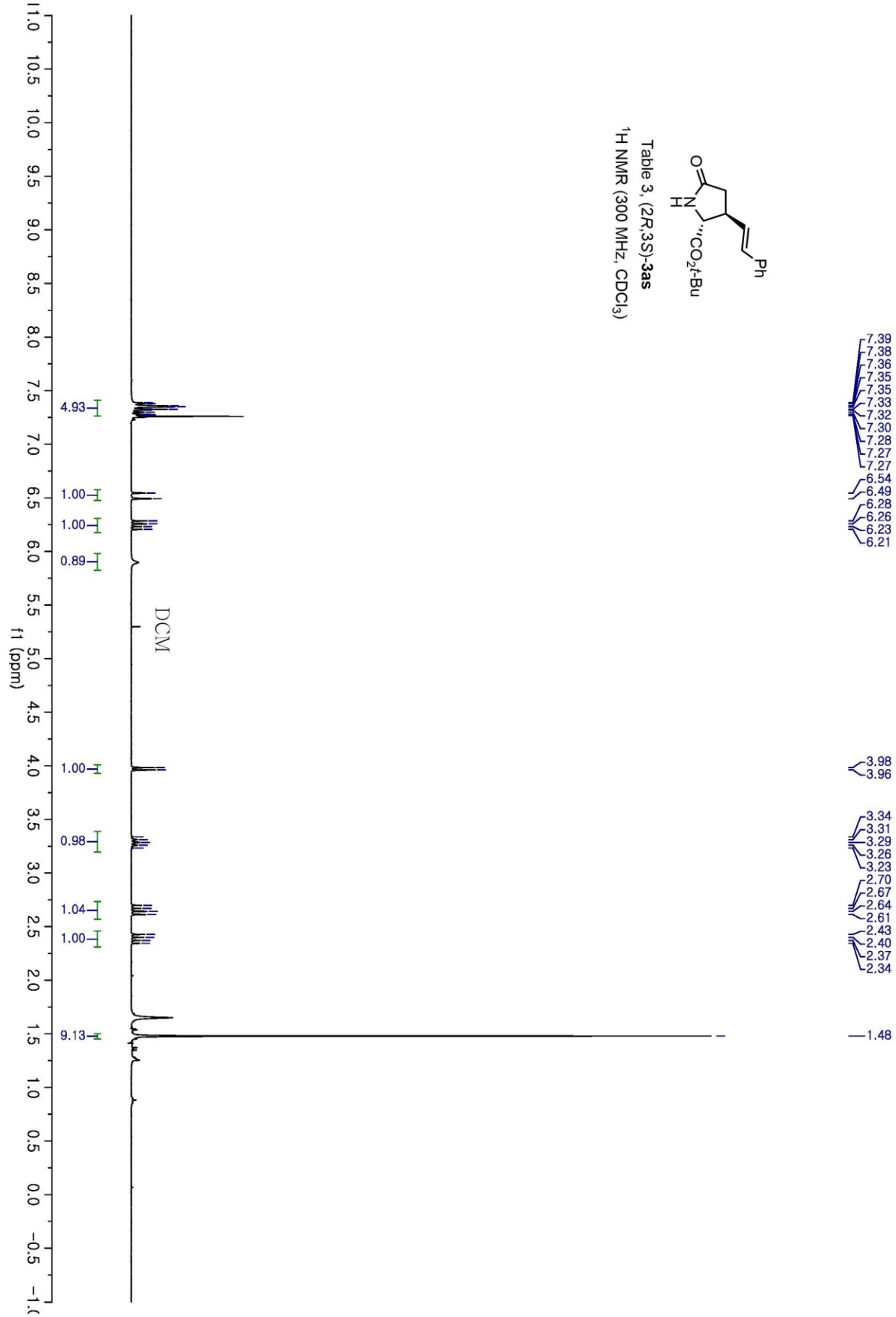


Table 3, (2R,3S)-3as
1H NMR (300 MHz, CDCl3)
CO2t-Bu
Ph
DCM
f1 (ppm)
4.93
1.00
1.00
0.89
1.00
0.98
1.04
1.00
9.13
7.39
7.38
7.36
7.35
7.35
7.33
7.32
7.30
7.28
7.27
7.27
6.54
6.49
6.28
6.26
6.23
6.21
3.98
3.96
3.34
3.31
3.29
3.26
3.23
2.70
2.67
2.64
2.61
2.43
2.40
2.37
2.34
1.48

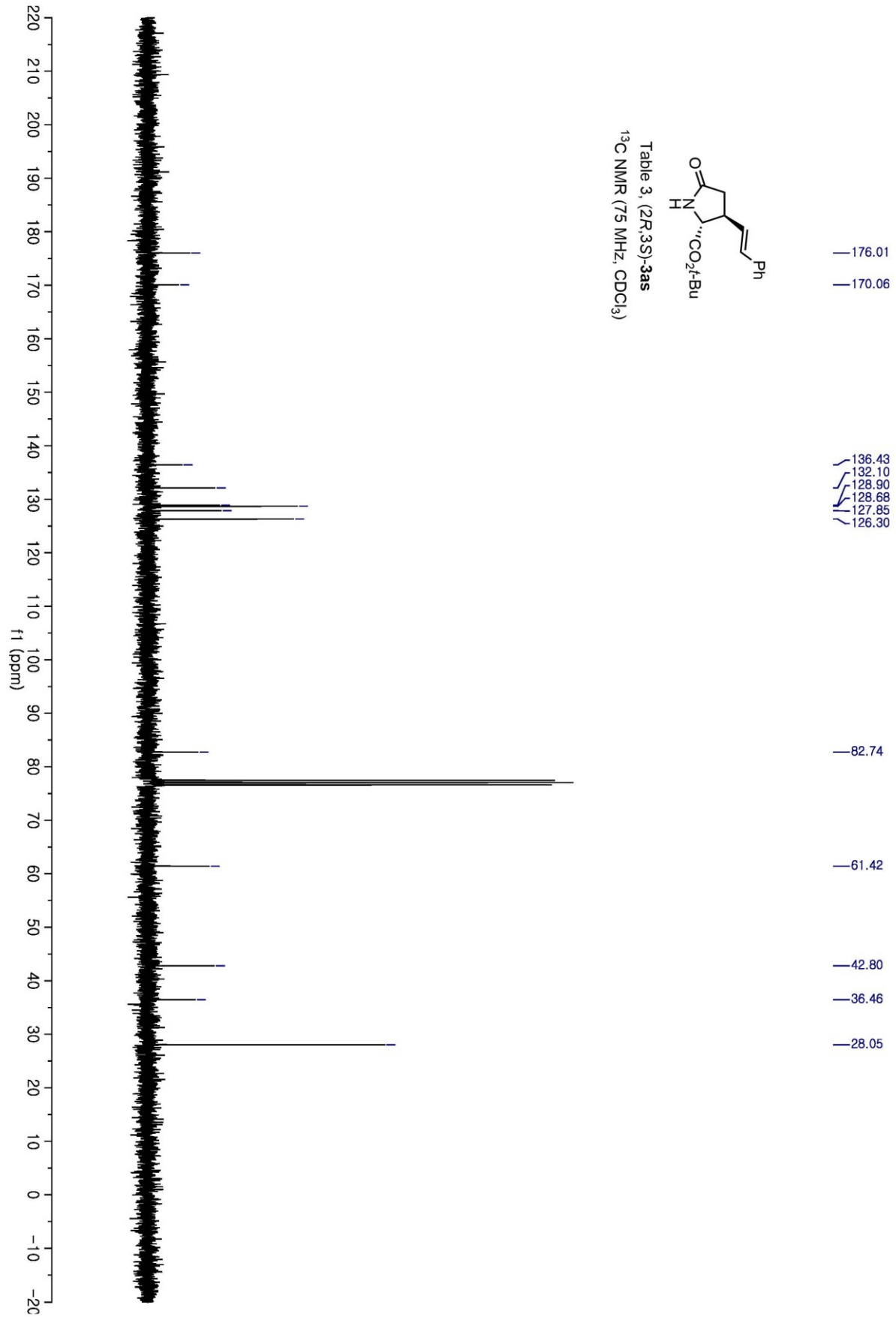


Table 3, (2R,3S)-3as
13C NMR (75 MHz, CDCl3)
O
N
H
CO2t-Bu
Ph
176.01
170.06
136.43
132.10
128.90
128.68
127.85
126.30
82.74
61.42
42.80
36.46
28.05
f1 (ppm)

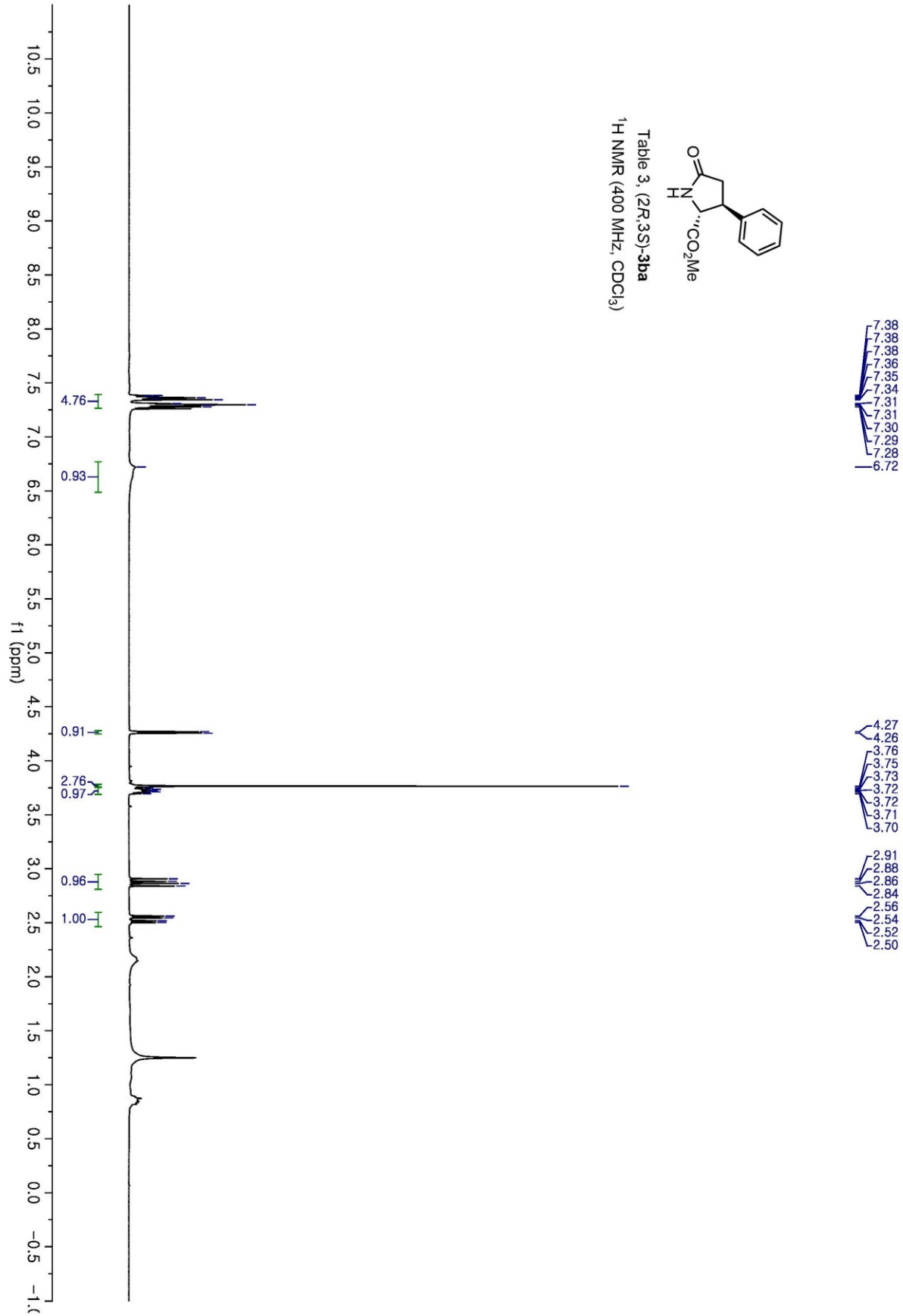


Table 3, (2R,3S)-3ba
1H NMR (400 MHz, CDCl3)
CO2Me
7.38
7.38
7.38
7.36
7.35
7.34
7.31
7.31
7.30
7.29
7.28
6.72
4.27
4.26
3.76
3.75
3.73
3.72
3.72
3.71
3.70
2.91
2.88
2.86
2.84
2.56
2.54
2.52
2.50
4.76
0.93
0.91
2.76
0.97
0.96
1.00
f1 (ppm)

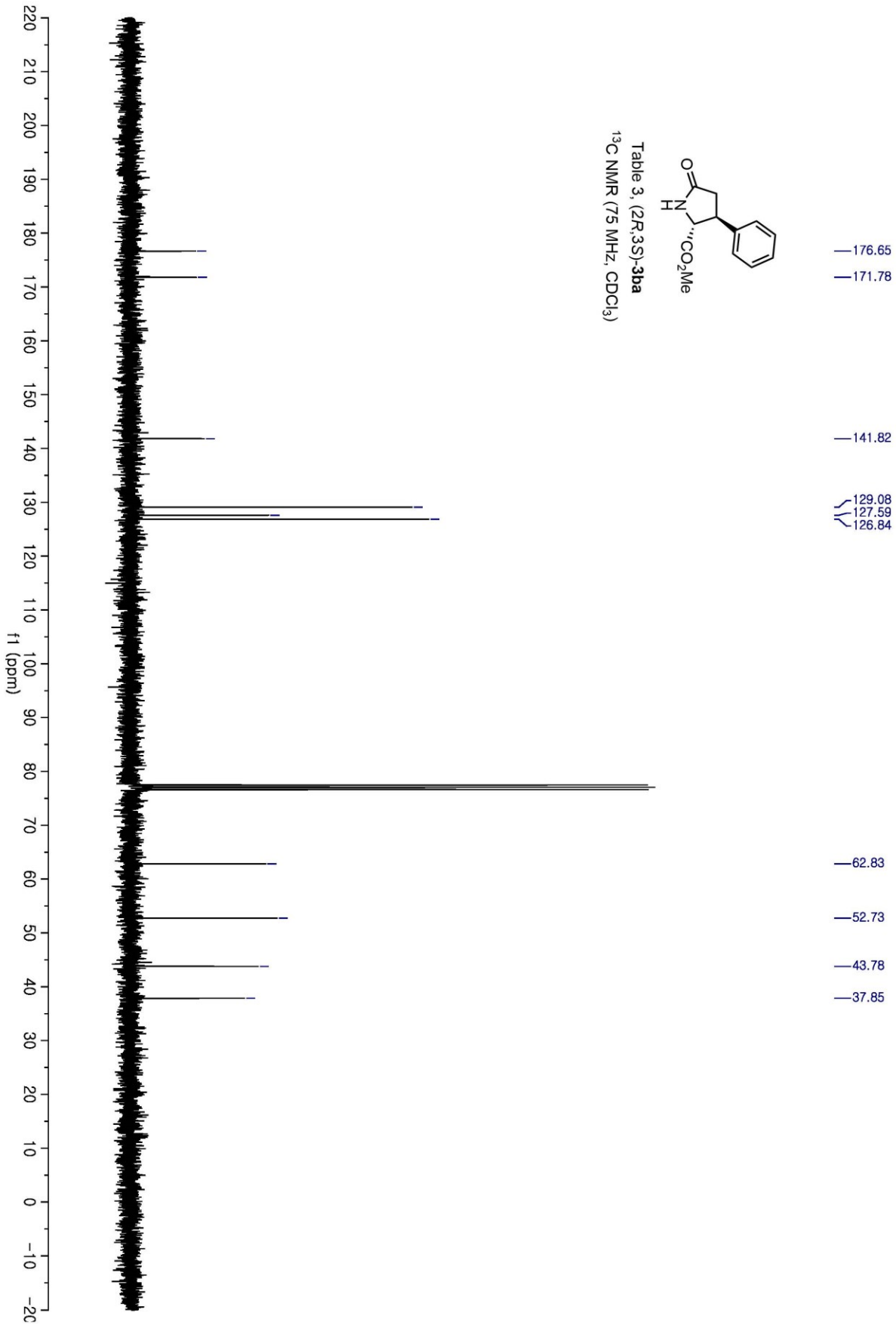


Table 3, (2R,3S)-3ba
13C NMR (75 MHz, CDCl3)
CO2Me
176.65
171.78
141.82
129.08
127.59
126.84
62.83
52.73
43.78
37.85
f1 (ppm)

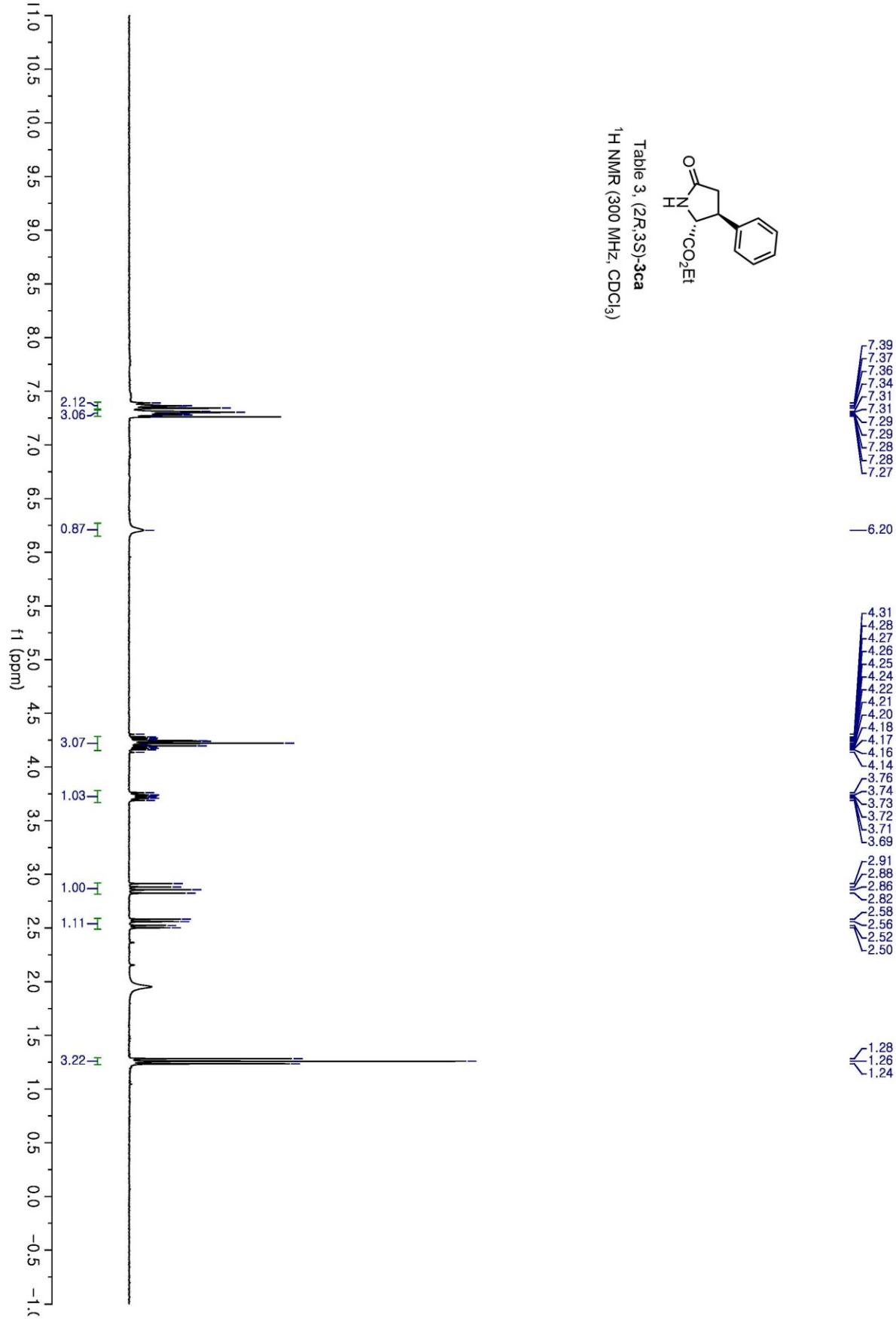


Table 3, (2R,3S)-3ca
1H NMR (300 MHz, CDCl3)
CO2Et
f1 (ppm)
2.12
3.06
0.87
3.07
1.03
1.00
1.11
3.22
7.39
7.37
7.36
7.34
7.31
7.31
7.29
7.29
7.28
7.28
7.27
6.20
4.31
4.28
4.27
4.26
4.25
4.24
4.22
4.21
4.20
4.18
4.17
4.16
4.14
3.76
3.74
3.73
3.72
3.71
3.69
2.91
2.88
2.86
2.82
2.58
2.56
2.52
2.50
1.28
1.26
1.24

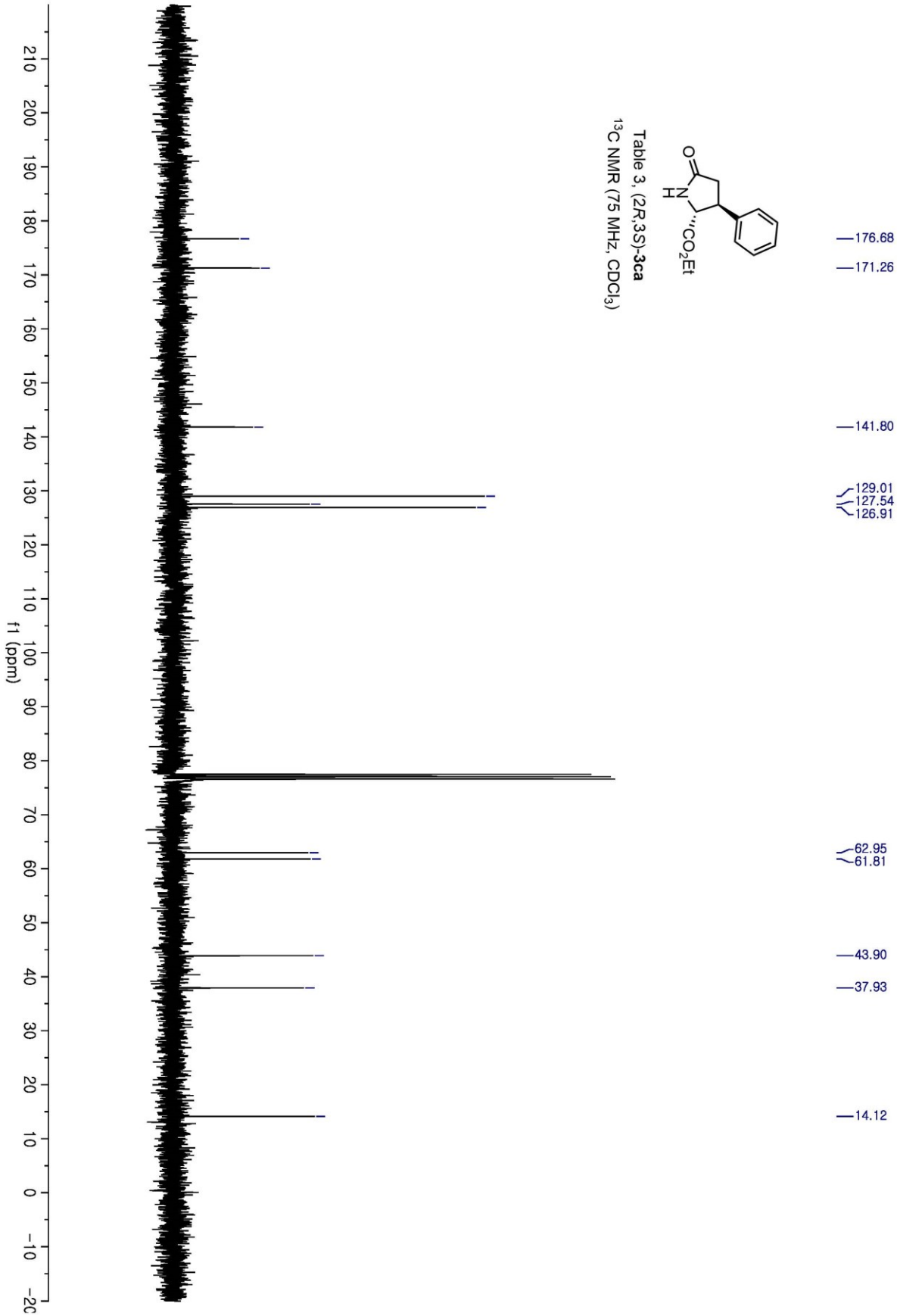


Table 3, (2R,3S)-3ca
13C NMR (75 MHz, CDCl3)
O
N
H
CO2Et
176.68
171.26
141.80
129.01
127.54
126.91
62.95
61.81
43.90
37.93
14.12
f1 (ppm)

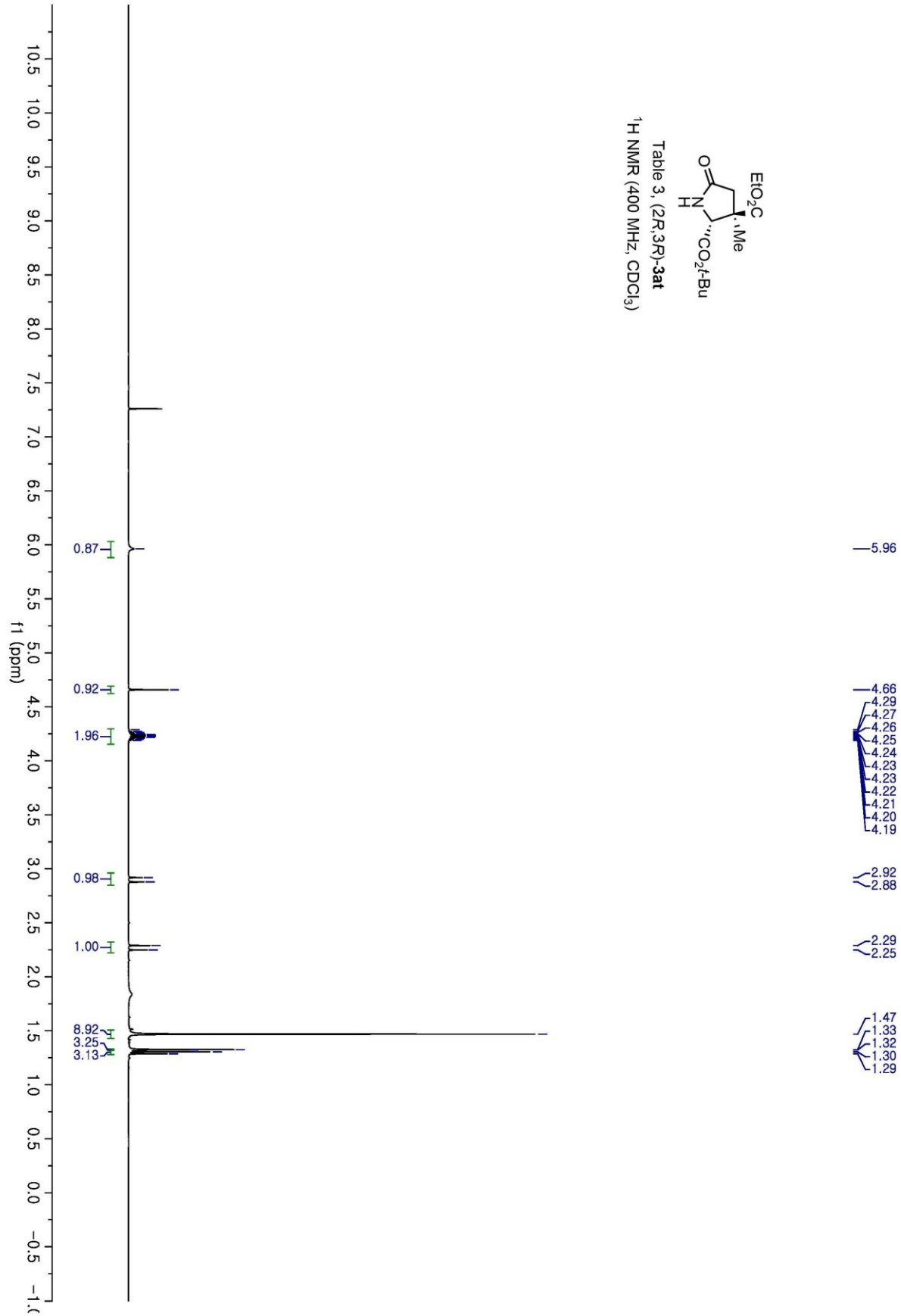


Table 3, (2R,3R)-3at
1H NMR (400 MHz, CDCl3)
EtO2C
Me
CO2t-Bu
f1 (ppm)
0.87
0.92
1.96
0.98
1.00
8.92
3.25
3.13
5.96
4.66
4.29
4.27
4.26
4.25
4.24
4.23
4.23
4.22
4.21
4.20
4.19
2.92
2.88
2.29
2.25
1.47
1.33
1.32
1.30
1.29

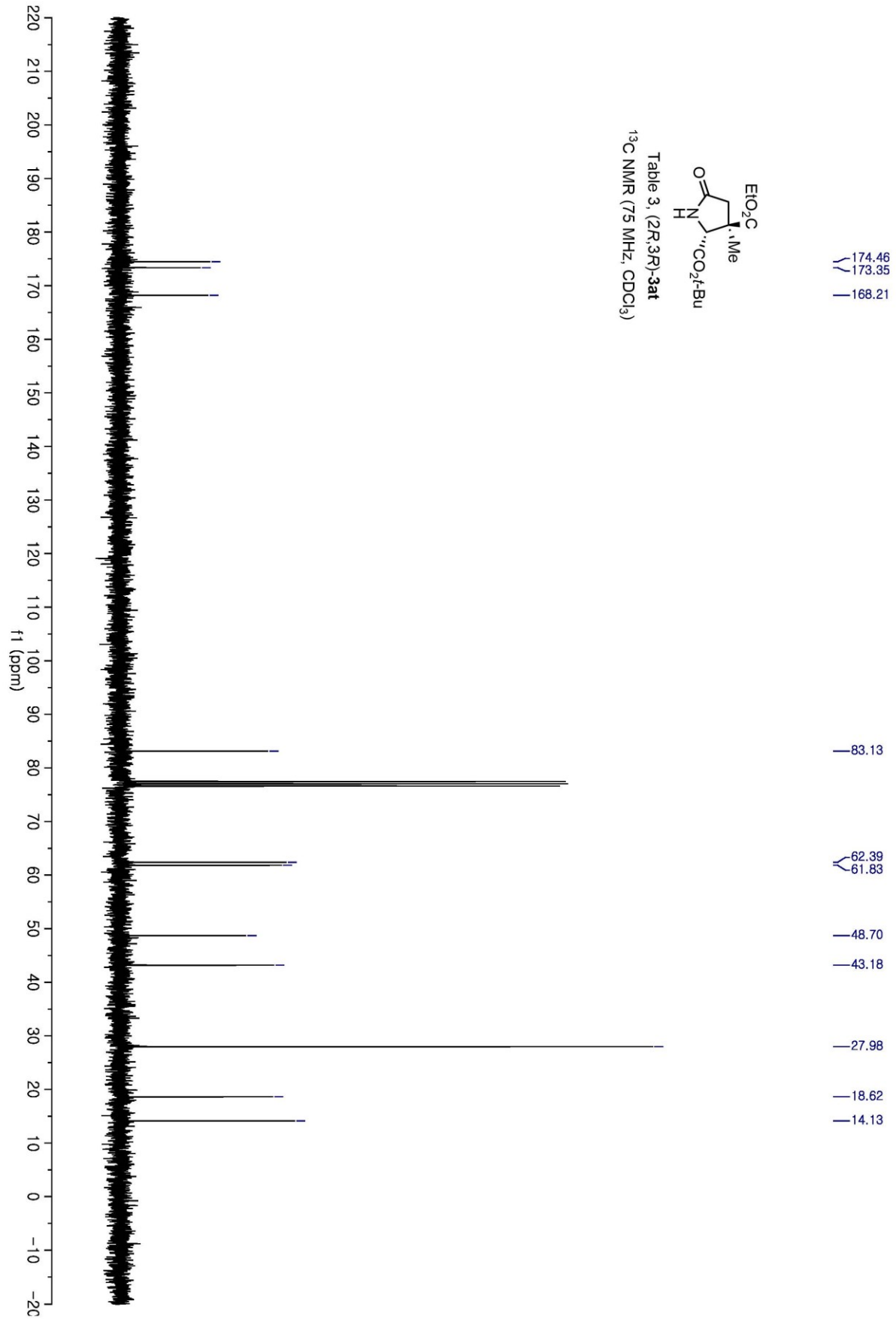


Table 3, (2R,3R)-3at
13C NMR (75 MHz, CDCl3)
EtO2C
Me
O
N
H
CO2t-Bu
174.46
173.35
168.21
83.13
62.39
61.83
48.70
43.18
27.98
18.62
14.13
f1 (ppm)

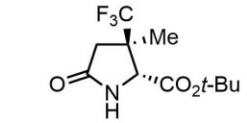
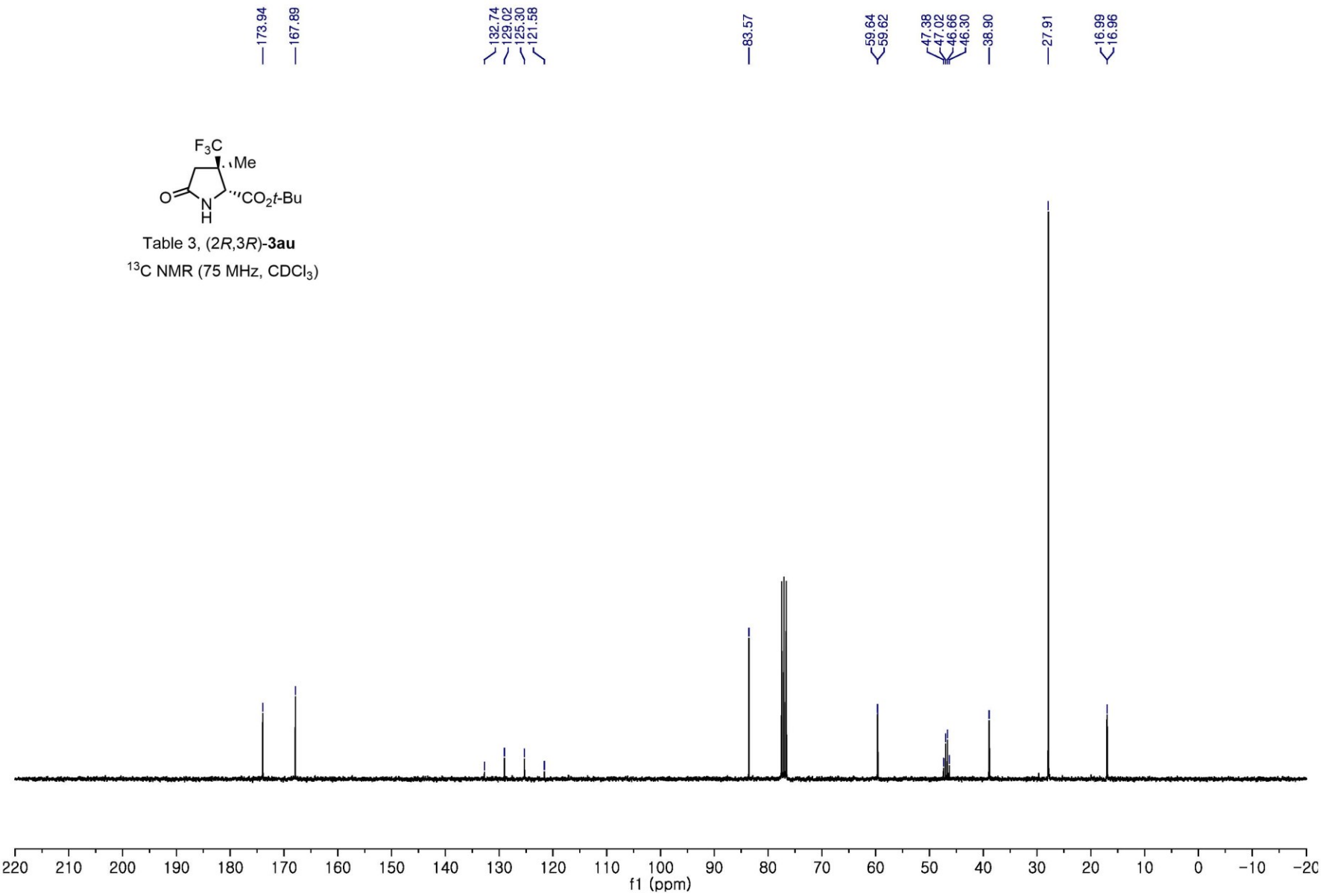


Table 3, (2*R*,3*R*)-**3au**

^{1}H NMR (300 MHz, $CDCl_3$)


173.94
167.89
132.74
129.02
125.30
121.58
83.57
59.64
59.62
47.38
47.02
46.66
46.30
38.90
27.91
16.99
16.96
F3C
Me
O
N
H
CO2t-Bu
Table 3, (2R,3R)-3au
13C NMR (75 MHz, CDCl3)
f1 (ppm)

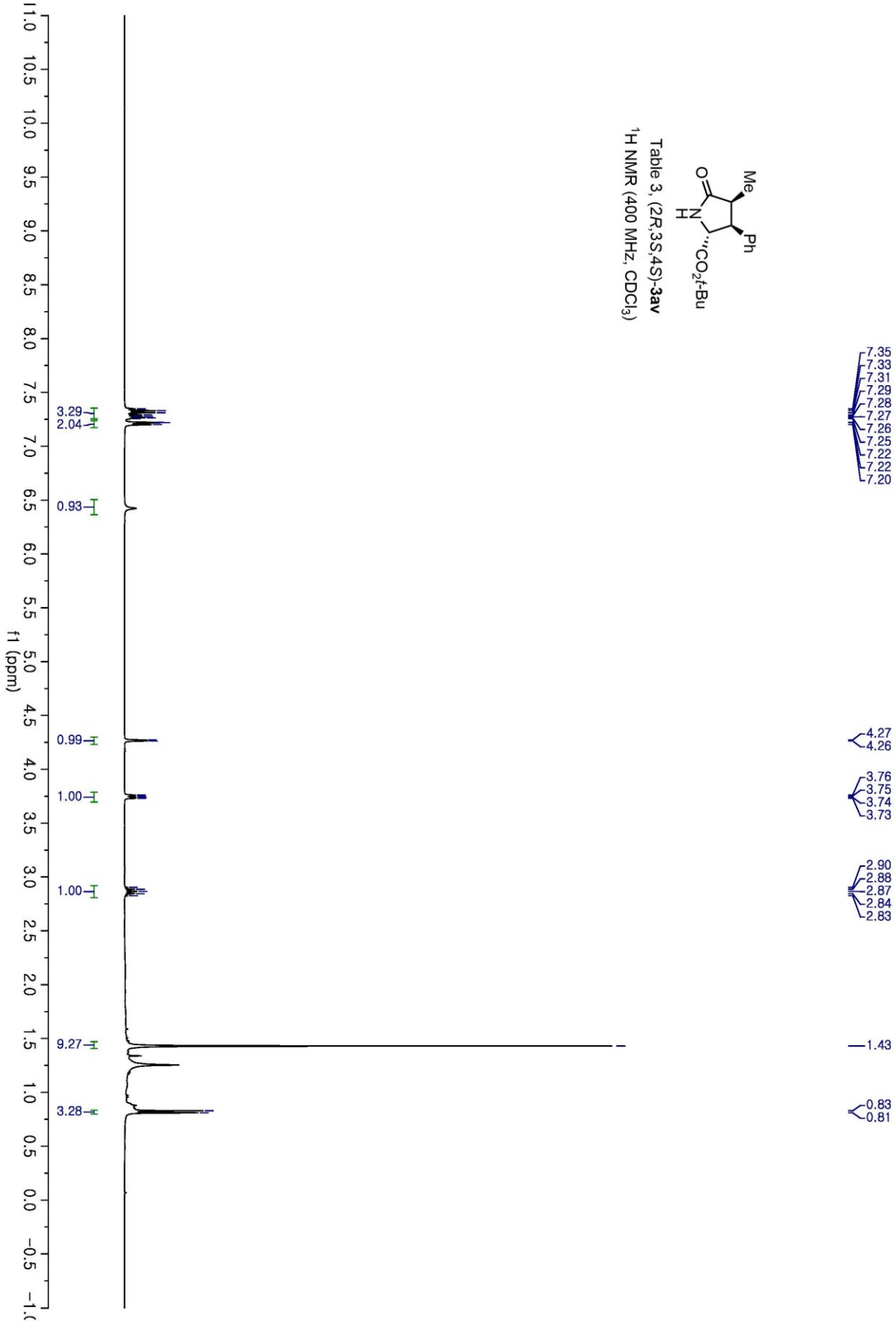
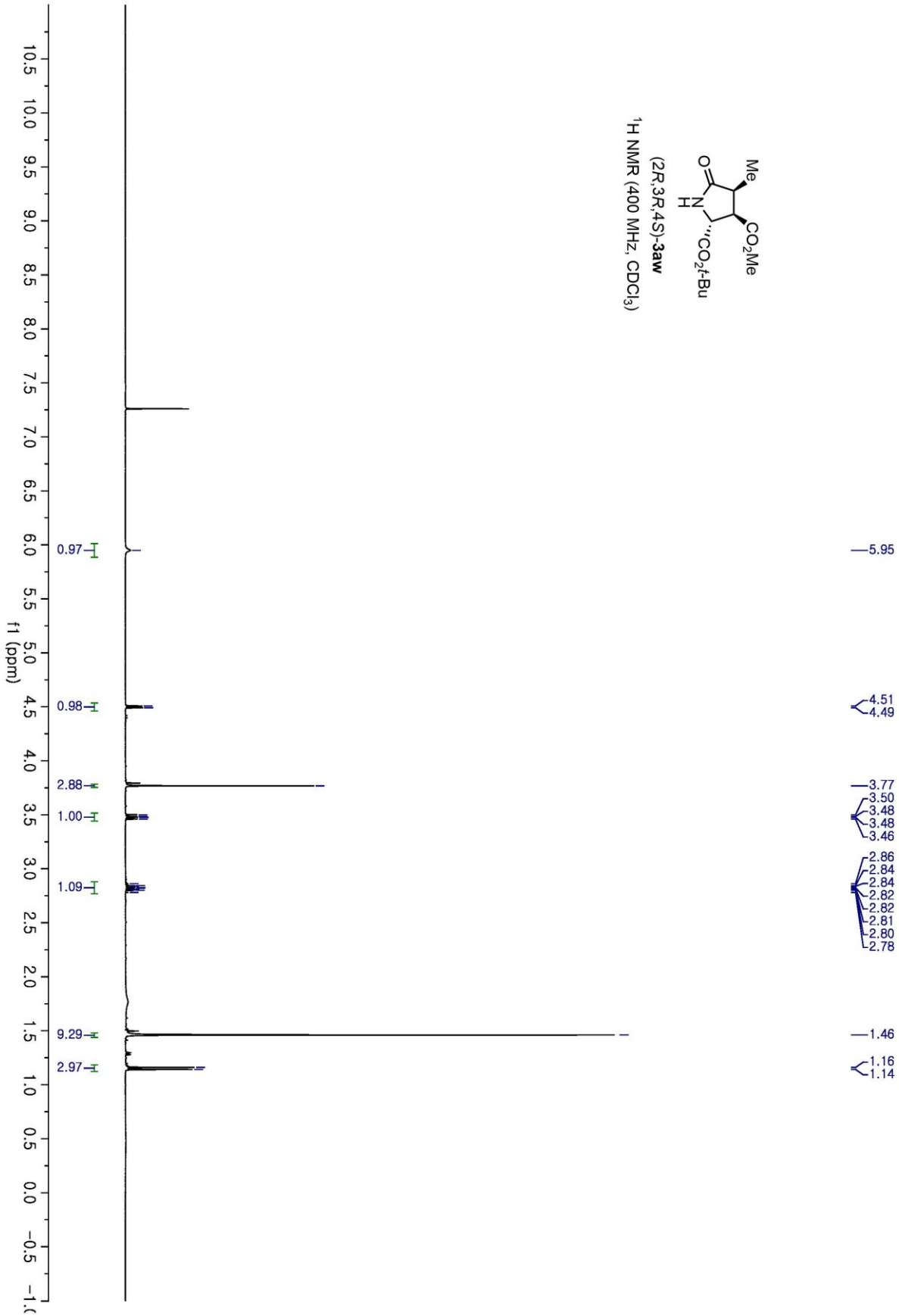
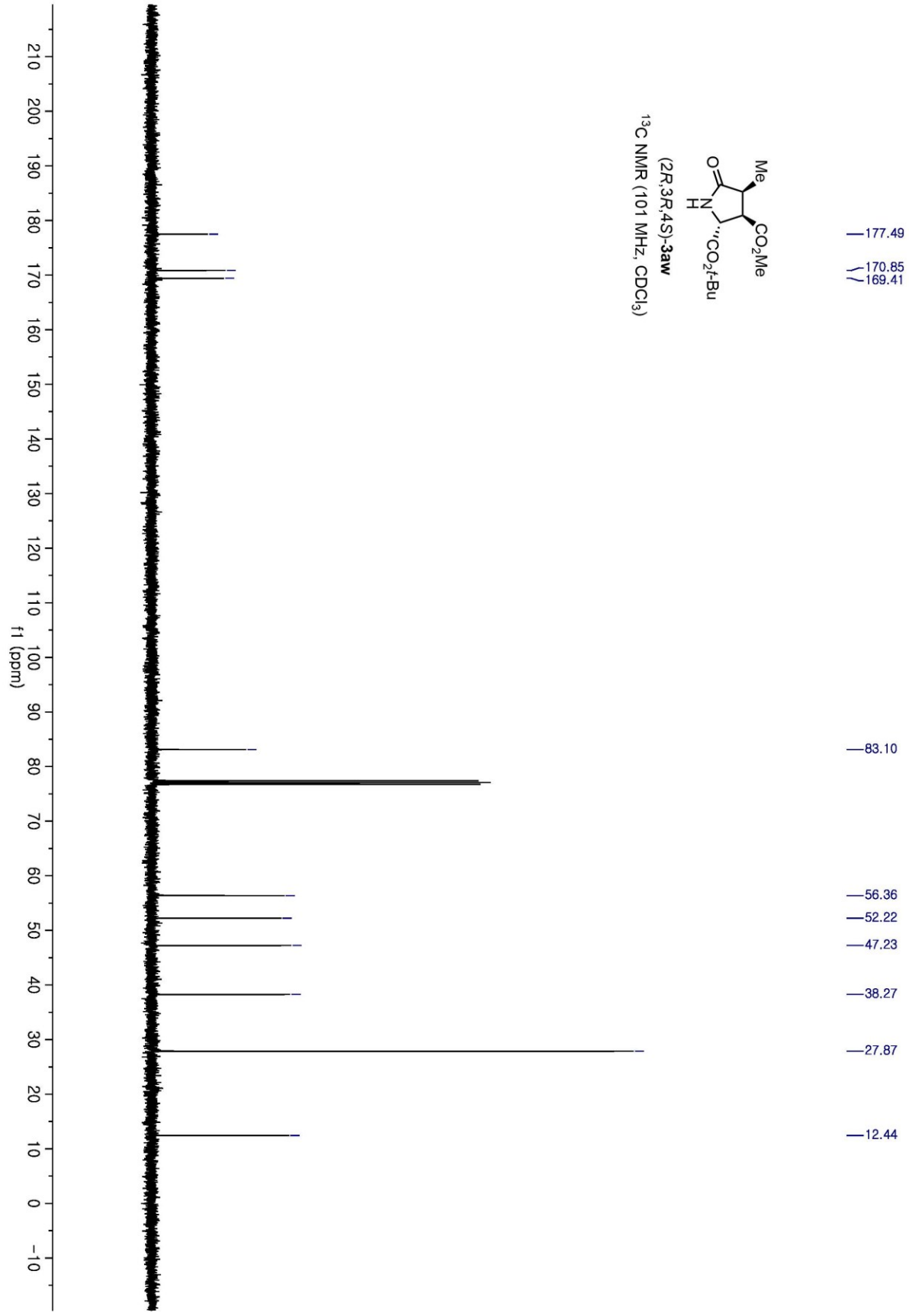
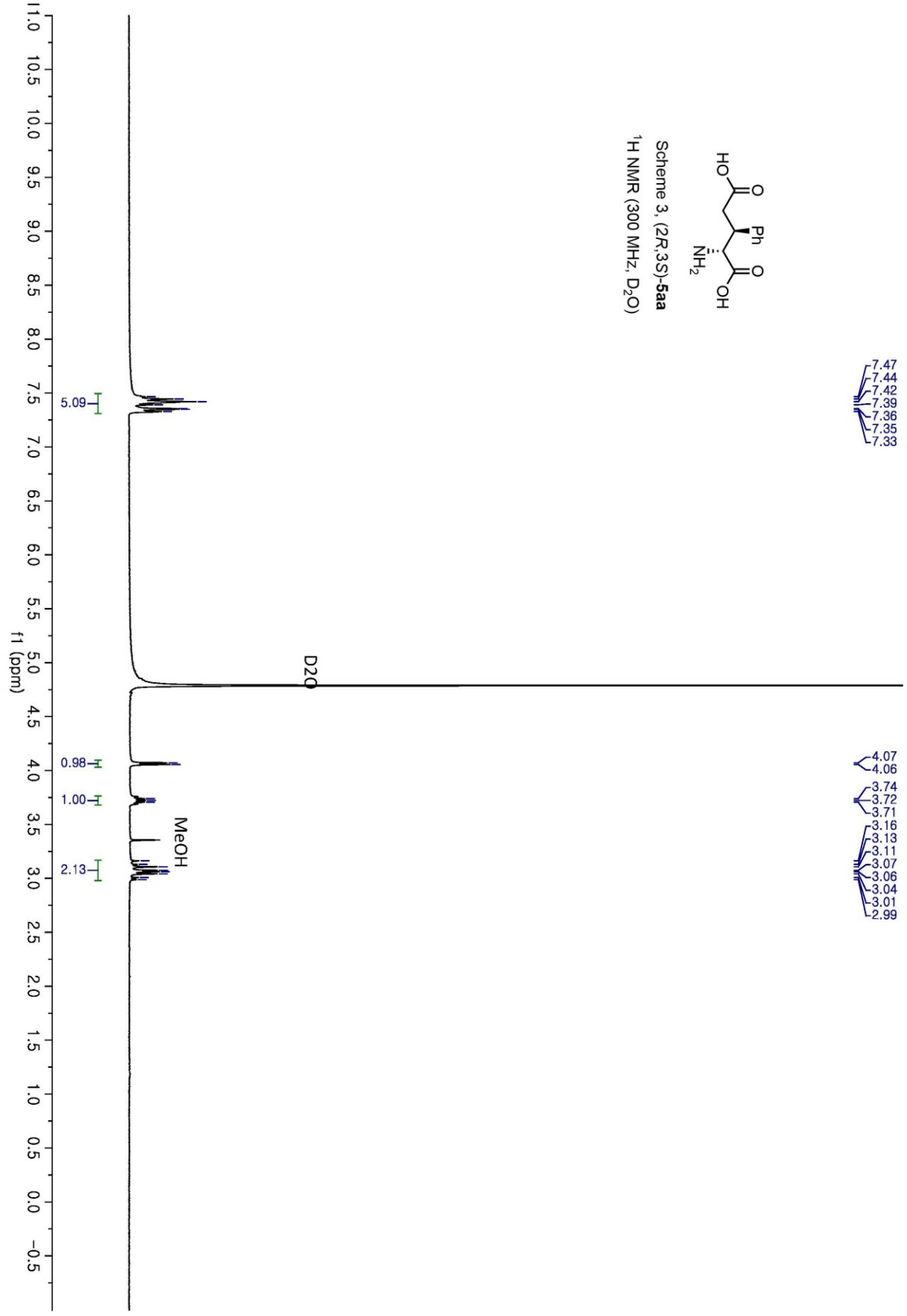
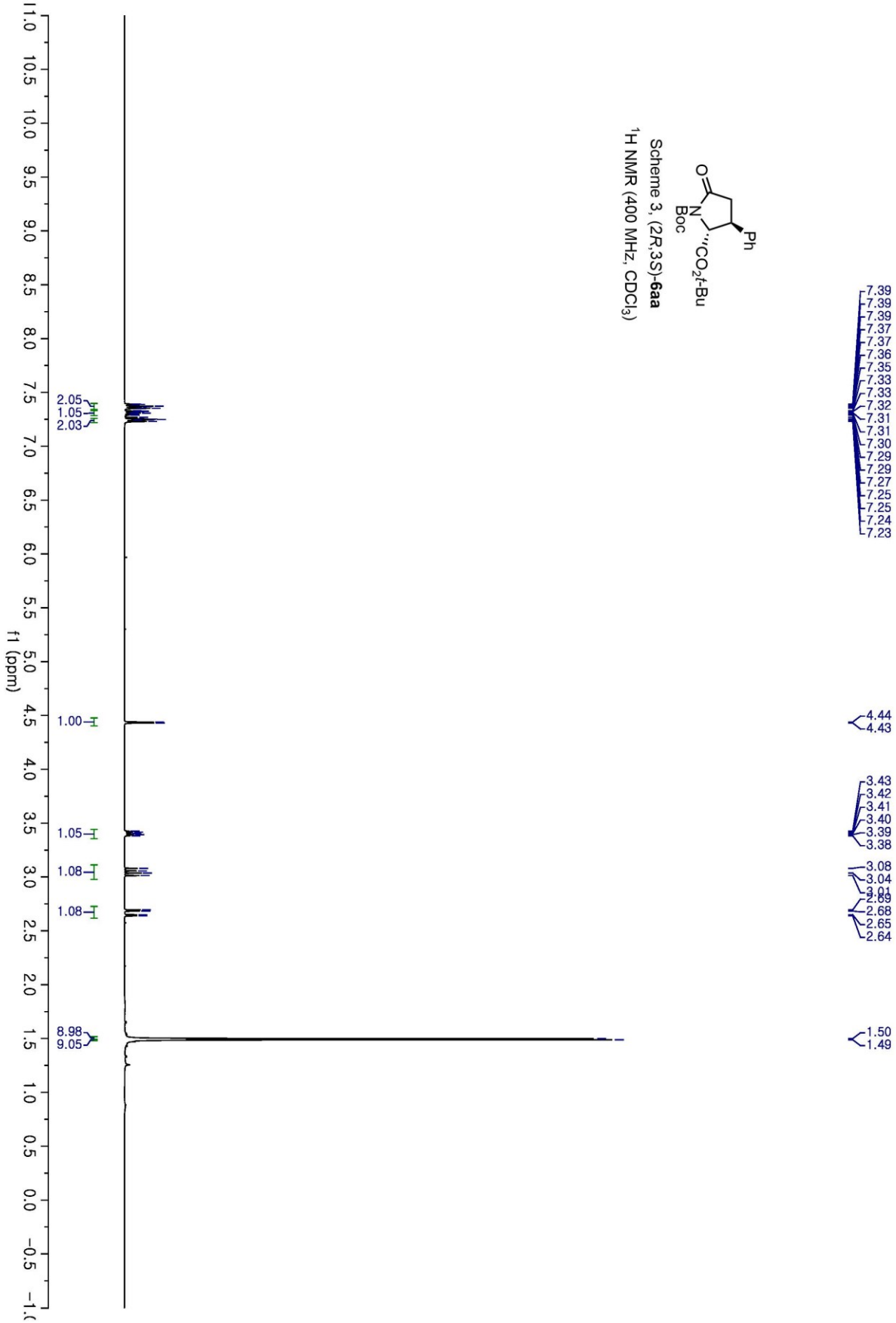


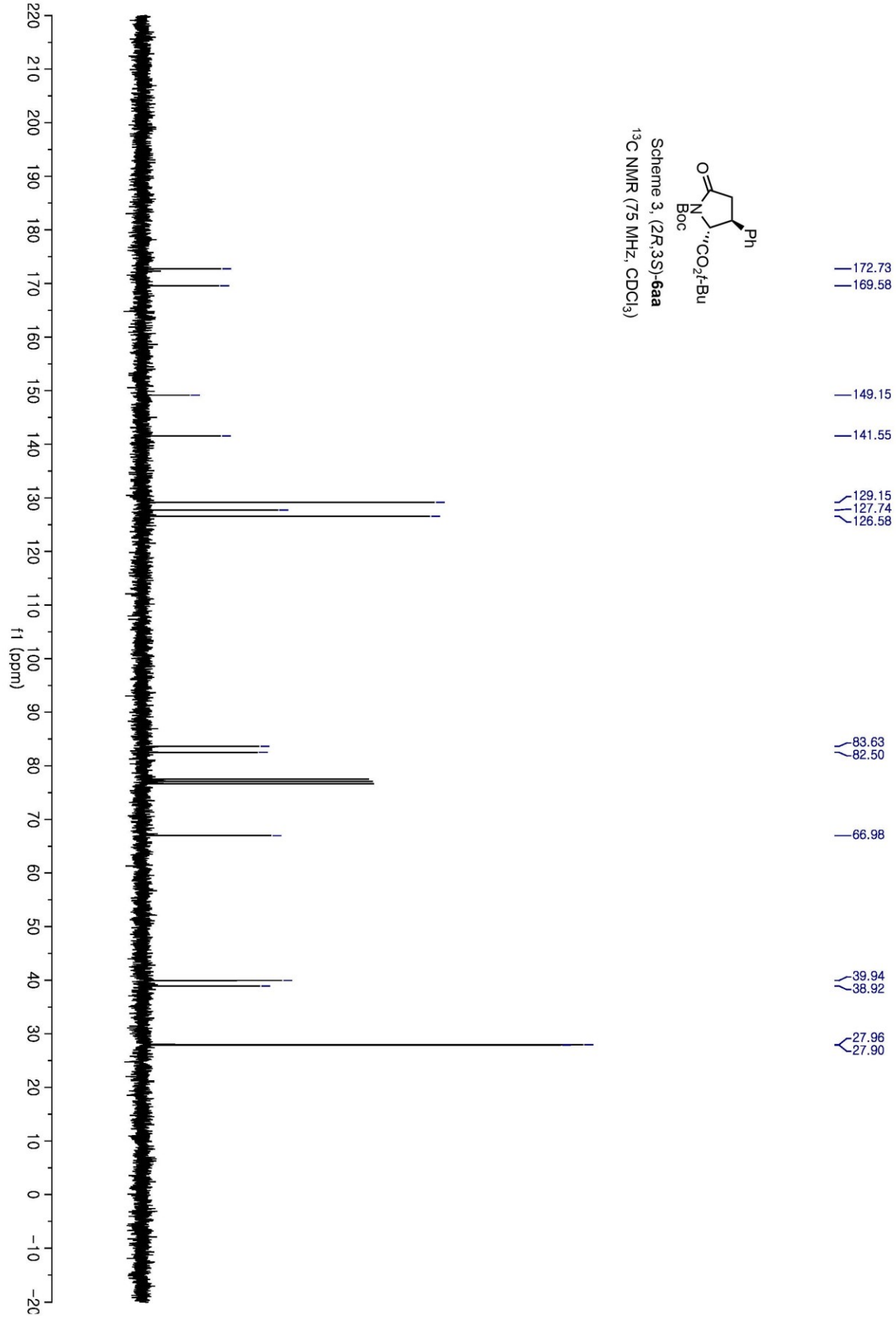
Table 3, (2R,3S,4S)-3av
1H NMR (400 MHz, CDCl3)
Me
Ph
CO2t-Bu
f1 (ppm)
7.35
7.33
7.31
7.29
7.28
7.27
7.26
7.25
7.22
7.22
7.20
4.27
4.26
3.76
3.75
3.74
3.73
2.90
2.88
2.87
2.84
2.83
1.43
0.83
0.81
3.29
2.04
0.93
0.99
1.00
1.00
9.27
3.28

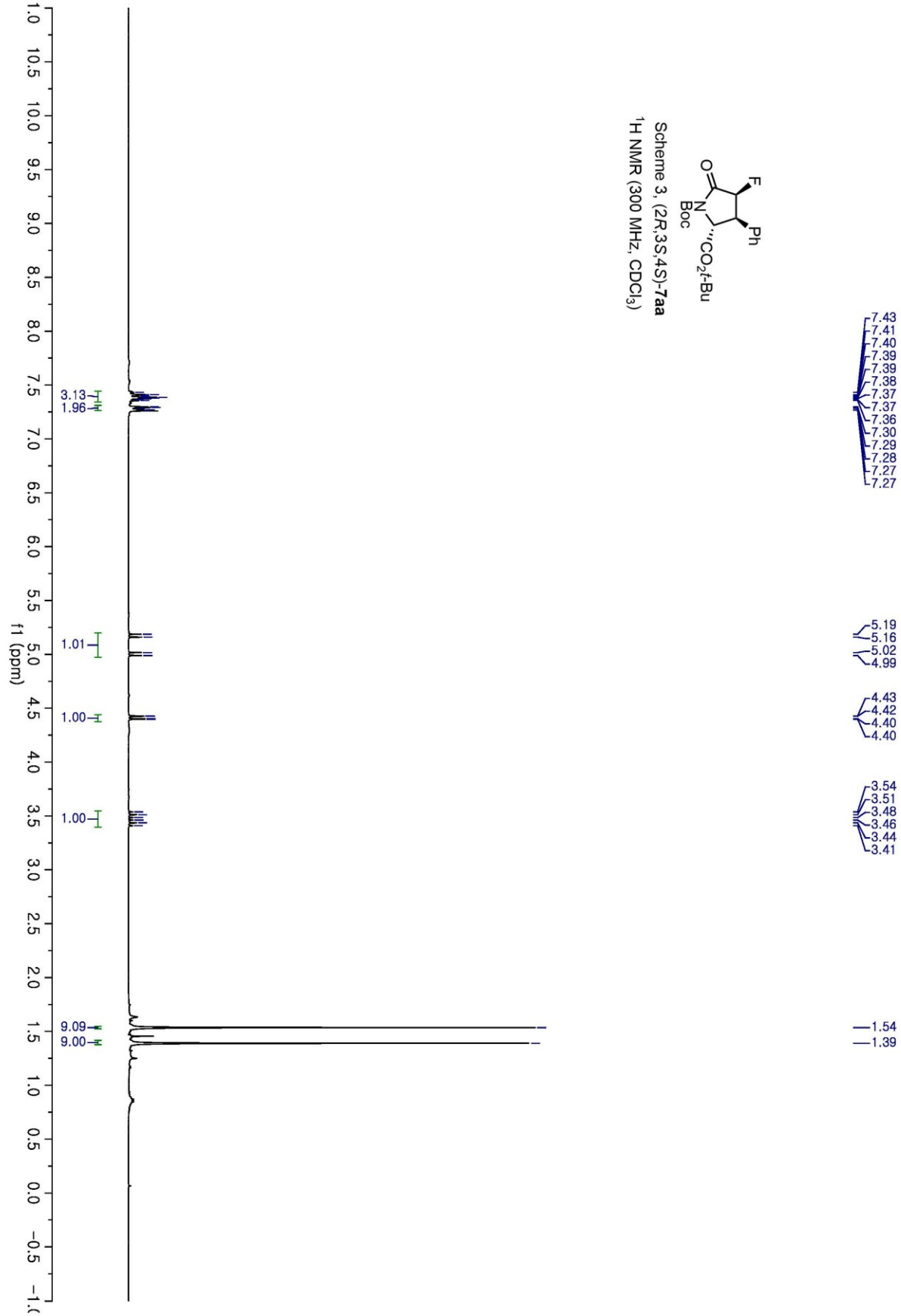

(2R,3R,4S)-3aw
^{1}H NMR (400 MHz, CDCl$_3$)
Me
CO$_2$Me
CO$_2$t-Bu
f1 (ppm)
0.97
0.98
2.88
1.00
1.09
9.29
2.97
5.95
4.51
4.49
3.77
3.50
3.48
3.48
3.46
2.86
2.84
2.84
2.82
2.82
2.81
2.80
2.78
1.46
1.16
1.14

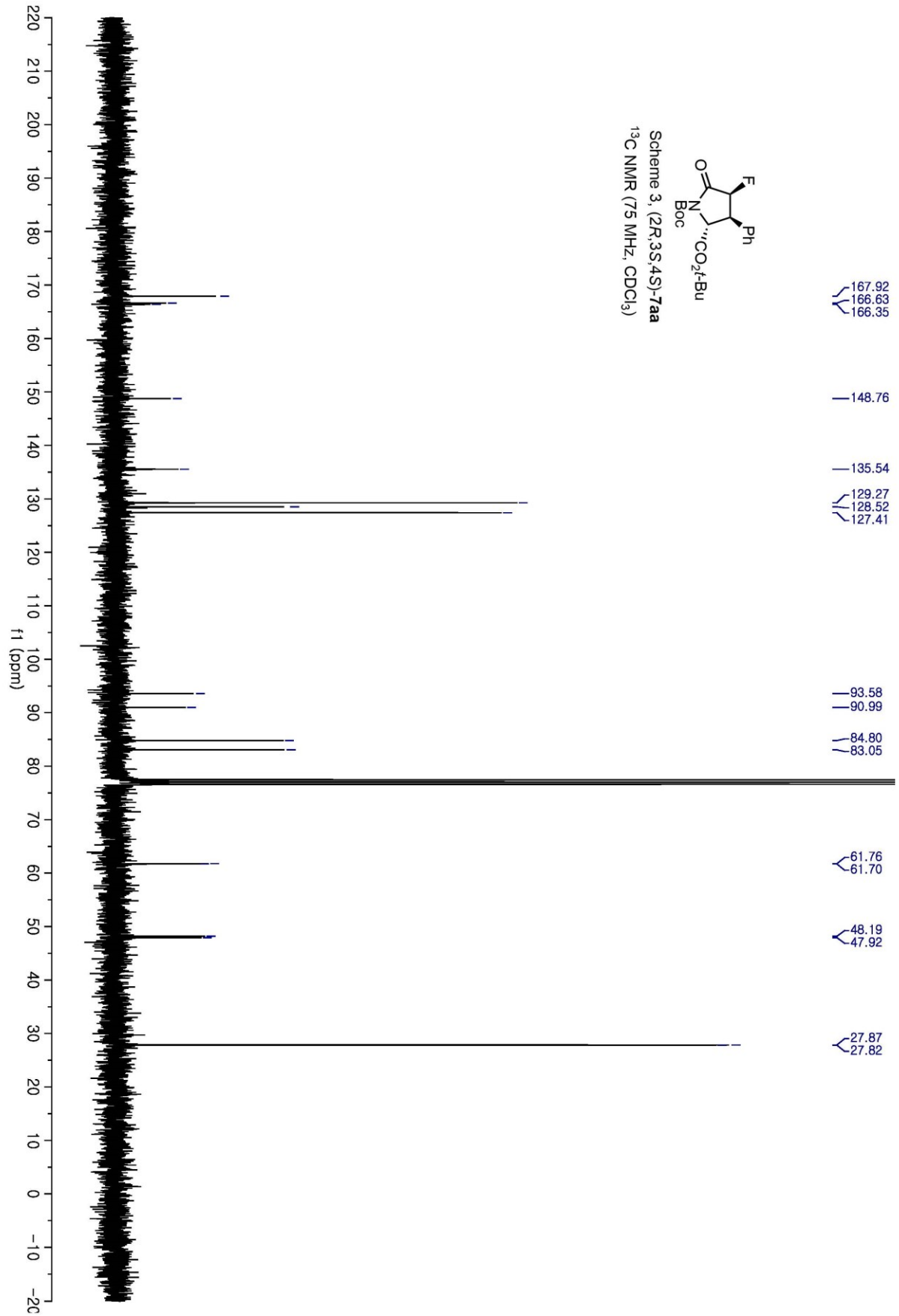

(2R,3R,4S)-3aw
^{13}C NMR (101 MHz, CDCl$_3$)
Me
CO$_2$Me
CO$_2$t-Bu
177.49
170.85
169.41
83.10
56.36
52.22
47.23
38.27
27.87
12.44
f1 (ppm)

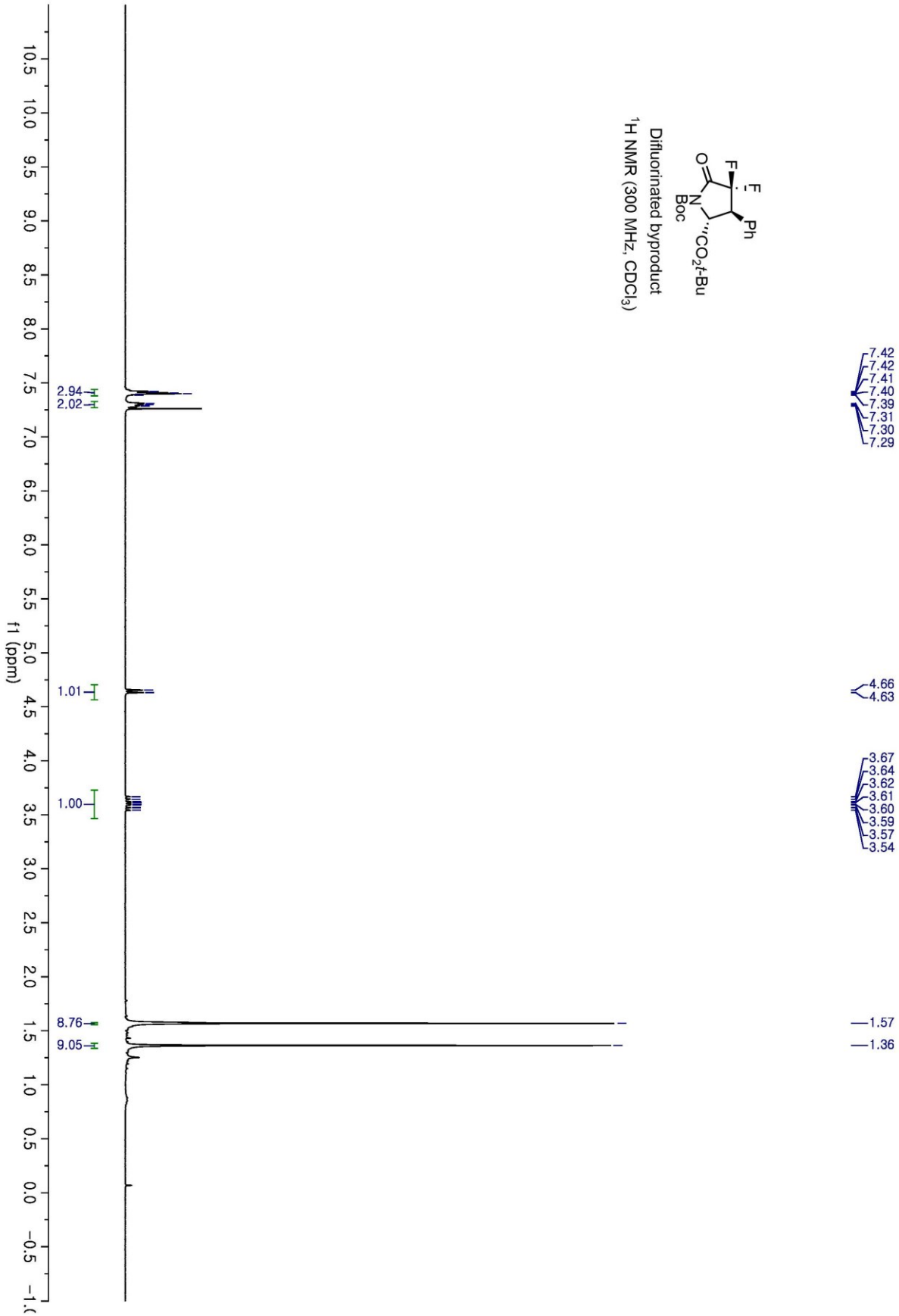

Scheme 3, (2R,3S)-5aa
1H NMR (300 MHz, D2O)
HO
O
Ph
O
NH2
OH
7.47
7.44
7.42
7.39
7.36
7.35
7.33
4.07
4.06
3.74
3.72
3.71
3.16
3.13
3.11
3.07
3.06
3.04
3.01
2.99
5.09
0.98
1.00
2.13
D2O
MeOH
f1 (ppm)

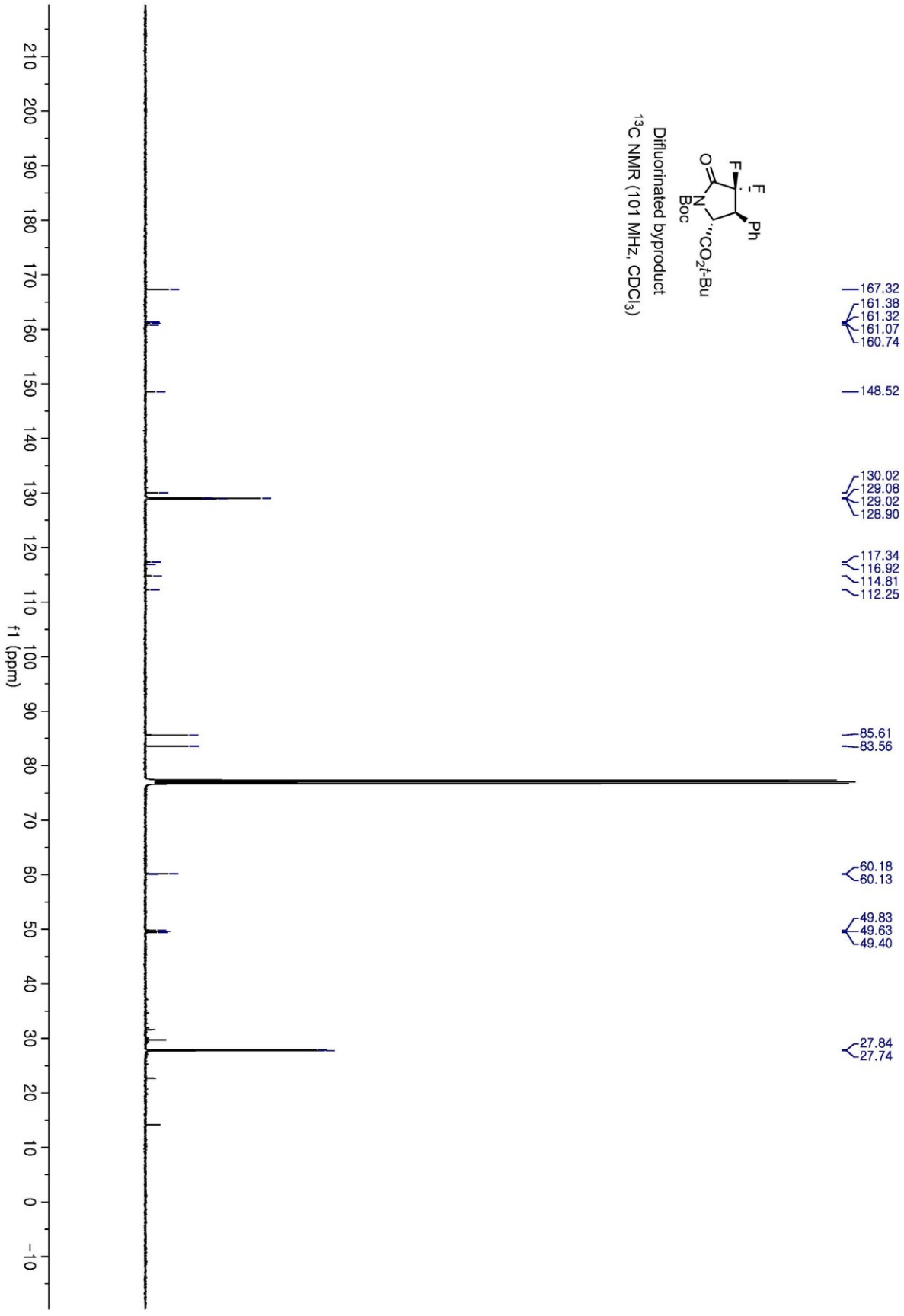

Scheme 3, (2R,3S)-6aa
1H NMR (400 MHz, CDCl3)
Boc
Ph
CO2t-Bu
f1 (ppm)
2.05
1.05
2.03
1.00
1.05
1.08
1.08
8.98
9.05
7.39
7.39
7.39
7.37
7.37
7.36
7.35
7.33
7.33
7.32
7.31
7.31
7.30
7.29
7.29
7.27
7.25
7.25
7.24
7.23
4.44
4.43
3.43
3.42
3.41
3.40
3.39
3.38
3.08
3.04
2.68
2.65
2.64
1.50
1.49


Scheme 3, (2R,3S)-6aa
13C NMR (75 MHz, CDCl3)
Boc
CO2t-Bu
Ph
172.73
169.58
149.15
141.55
129.15
127.74
126.58
83.63
82.50
66.98
39.94
38.92
27.96
27.90
f1 (ppm)


Scheme 3, (2R,3S,4S)-7aa
1H NMR (300 MHz, CDCl3)
Boc
CO2t-Bu
Ph
F
f1 (ppm)
3.13
1.96
1.01
1.00
1.00
9.09
9.00
7.43
7.41
7.40
7.39
7.39
7.38
7.37
7.37
7.36
7.30
7.29
7.28
7.27
7.27
5.19
5.16
5.02
4.99
4.43
4.42
4.40
4.40
3.54
3.51
3.48
3.46
3.44
3.41
1.54
1.39


Scheme 3, (2R,3S,4S)-7aa
13C NMR (75 MHz, CDCl3)
F
Ph
O
N
Boc
CO2t-Bu
167.92
166.63
166.35
148.76
135.54
129.27
128.52
127.41
93.58
90.99
84.80
83.05
61.76
61.70
48.19
47.92
27.87
27.82
f1 (ppm)

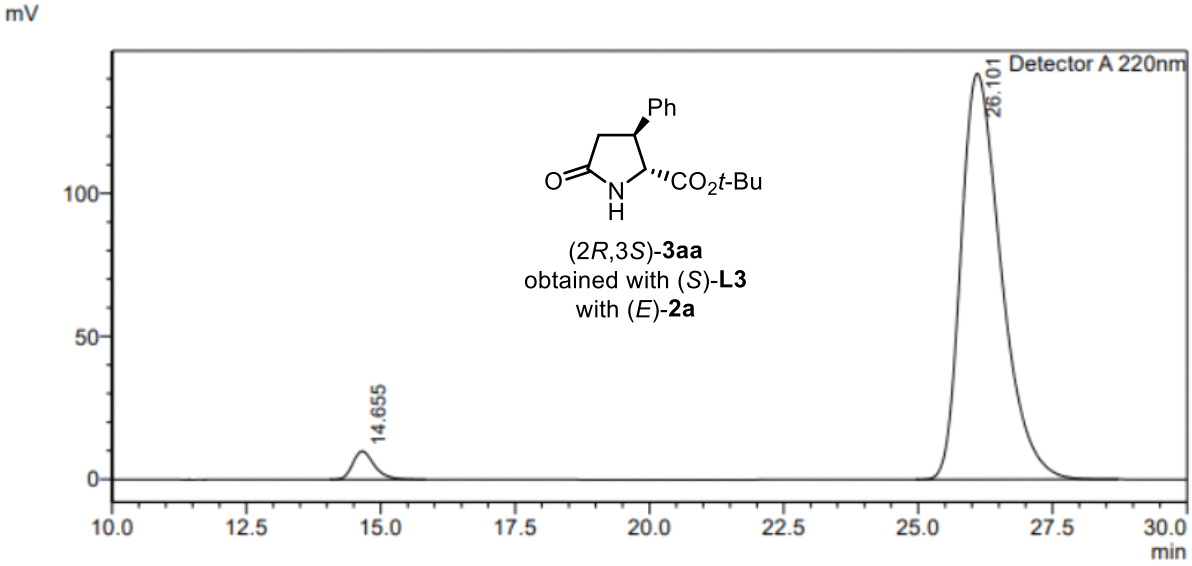

Difluorinated byproduct
^{1}H NMR (300 MHz, CDCl$_3$)
f1 (ppm)
2.94
2.02
1.01
1.00
8.76
9.05
7.42
7.42
7.41
7.40
7.39
7.31
7.30
7.29
4.66
4.63
3.67
3.64
3.62
3.61
3.60
3.59
3.57
3.54
1.57
1.36


Difluorinated byproduct
^{13}C NMR (101 MHz, CDCl$_3$)
F
F
Ph
O
N
Boc
CO$_2$t-Bu
167.32
161.38
161.32
161.07
160.74
148.52
130.02
129.08
129.02
128.90
117.34
116.92
114.81
112.25
85.61
83.56
60.18
60.13
49.83
49.63
49.40
27.84
27.74
f1 (ppm)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10

VIII. HPLC Traces

<Table 3, *anti*-3aa>

<Chromatogram>

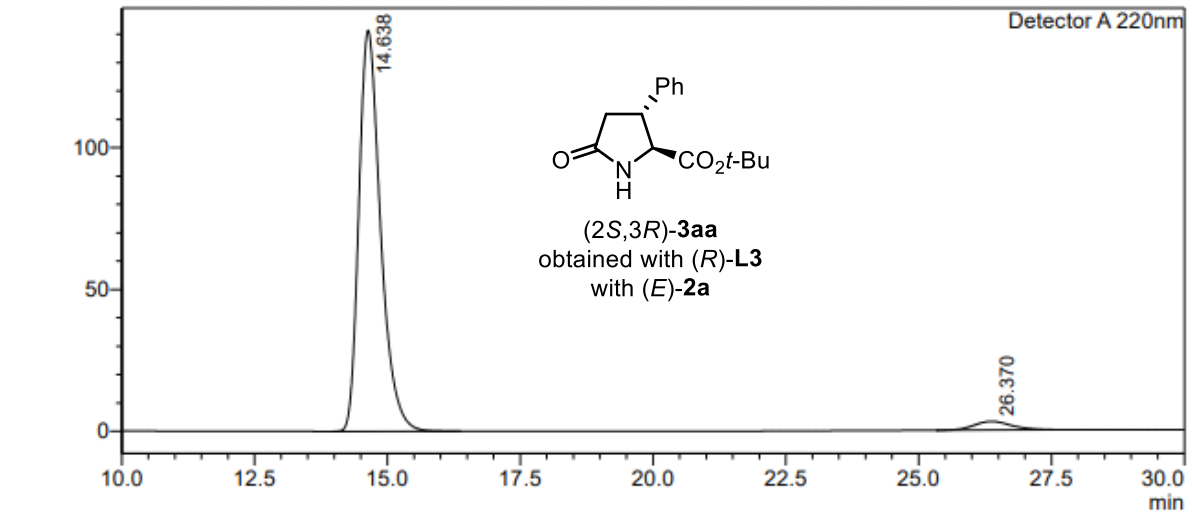


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.655	278046	9898	3.632			
2	26.101	7378237	141909	96.368			
Total		7656283	151808				

<Chromatogram>



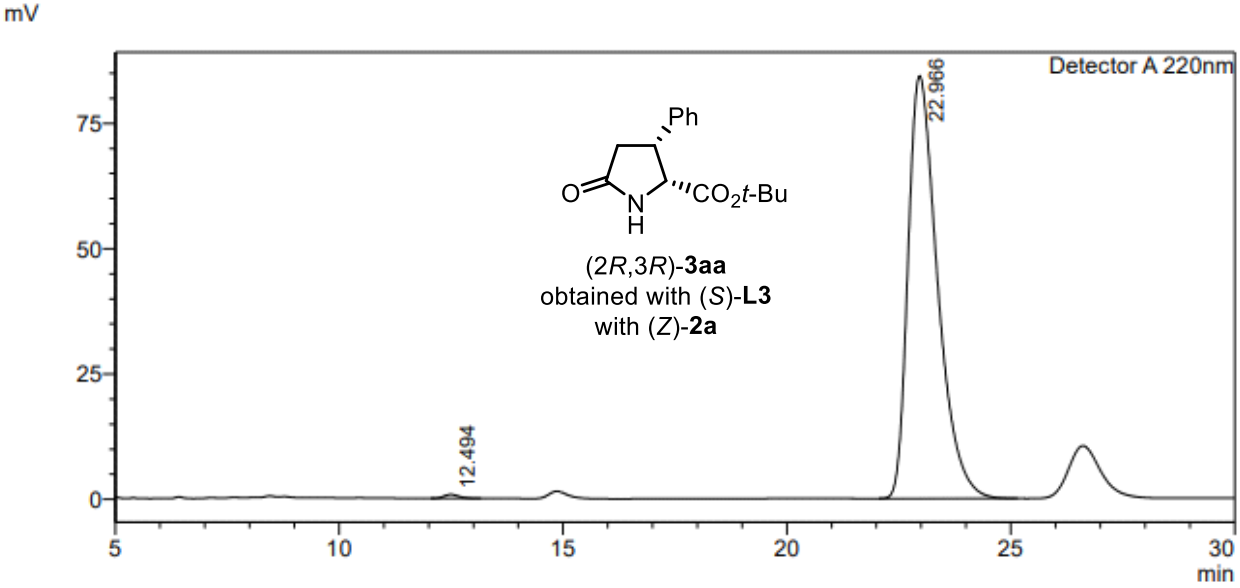
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.638	4017160	141370	96.334			
2	26.370	152858	3071	3.666			
Total		4170017	144441				

<Scheme 2, *cis*-3aa>

<Chromatogram>

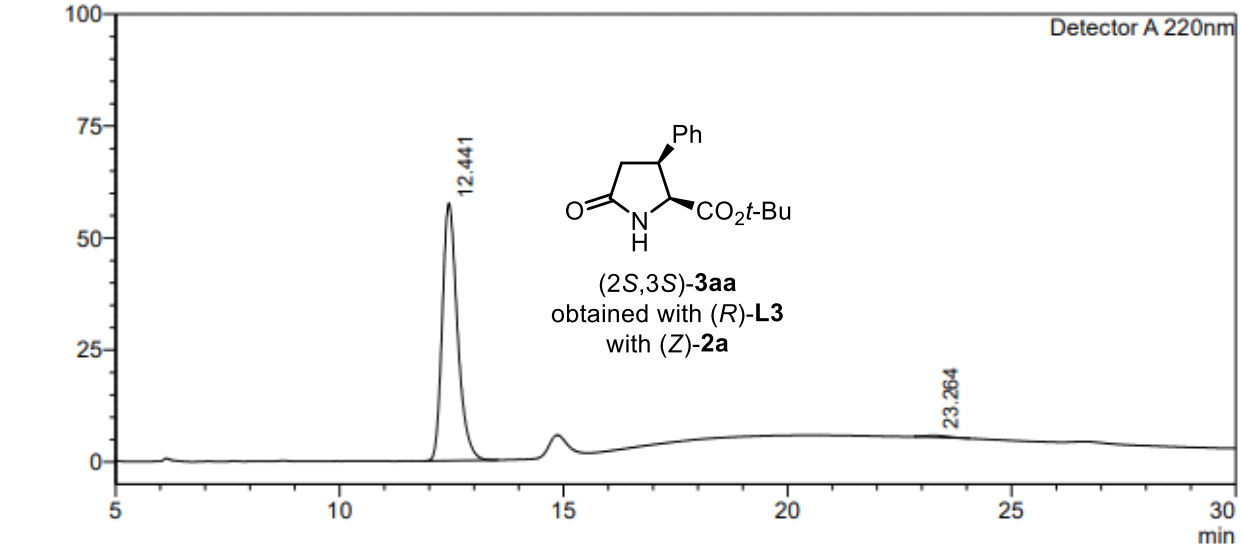


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.494	17891	788	0.460			
2	22.966	3867635	84320	99.540			
Total		3885526	85108				

<Chromatogram>



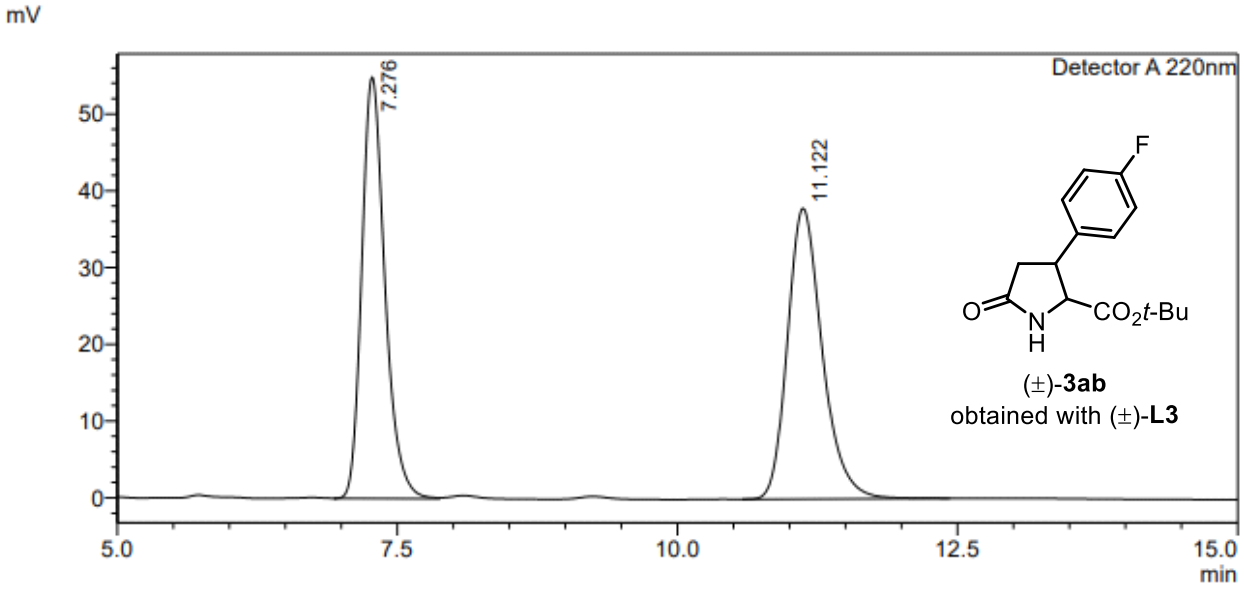
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.441	1355742	57494	98.981			
2	23.264	13962	387	1.019			
Total		1369703	57881				

<Table 3, *anti*-3ab>

<Chromatogram>

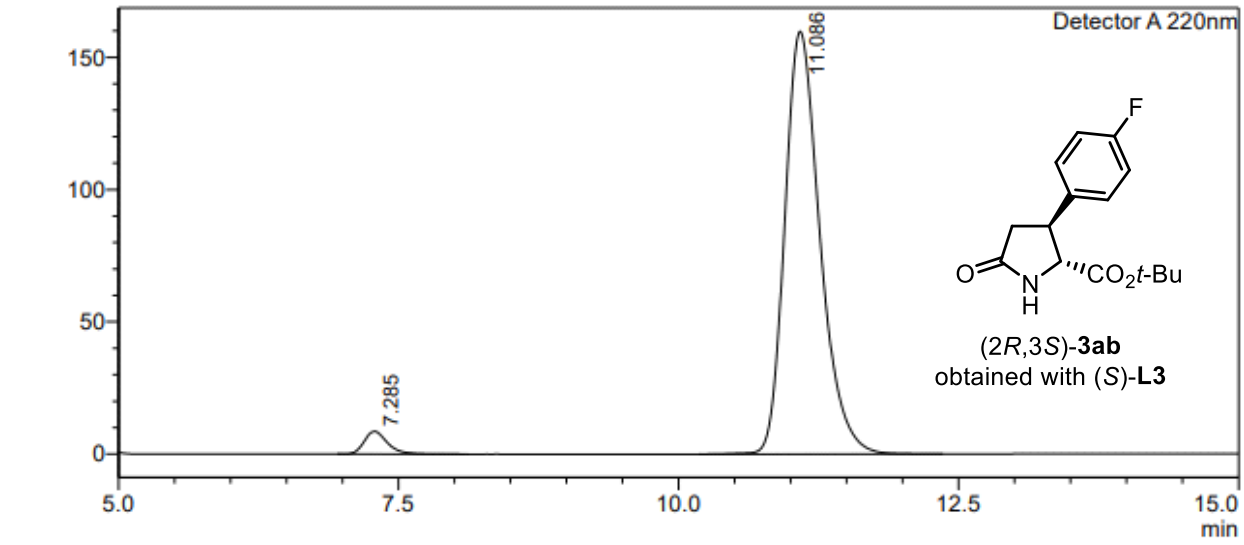


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.276	785457	54862	48.918			
2	11.122	820194	37852	51.082			
Total		1605650	92714				

<Chromatogram>



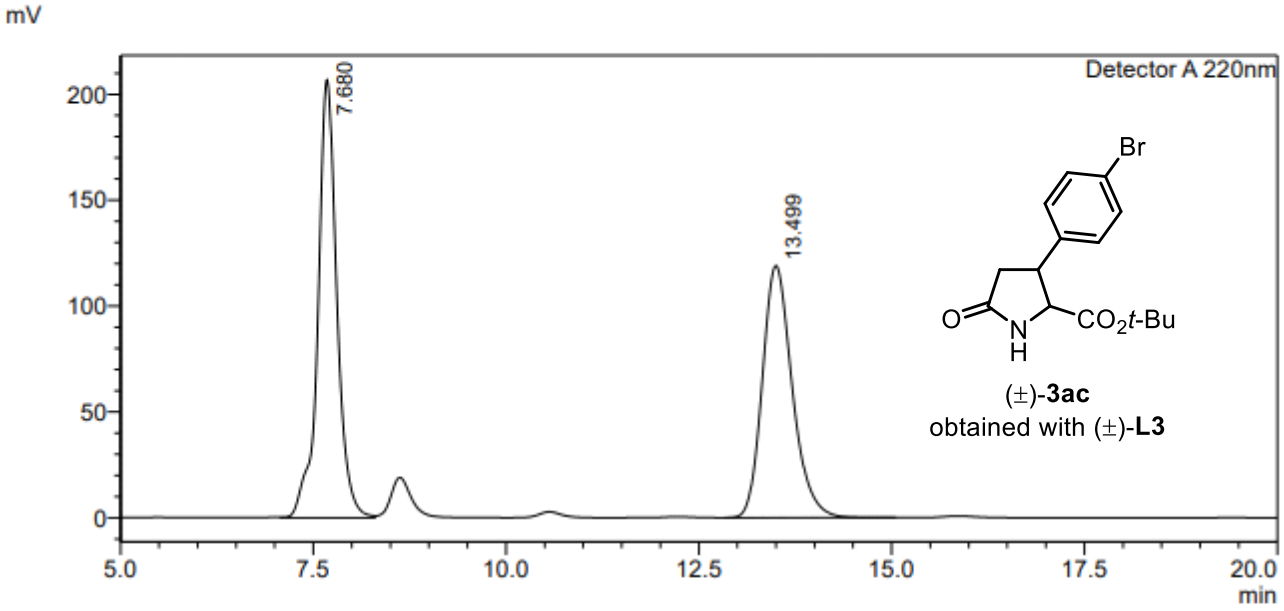
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.285	123898	8583	3.421			
2	11.086	3497677	159734	96.579			
Total		3621575	168316				

<Table 3, *anti*-3ac>

<Chromatogram>

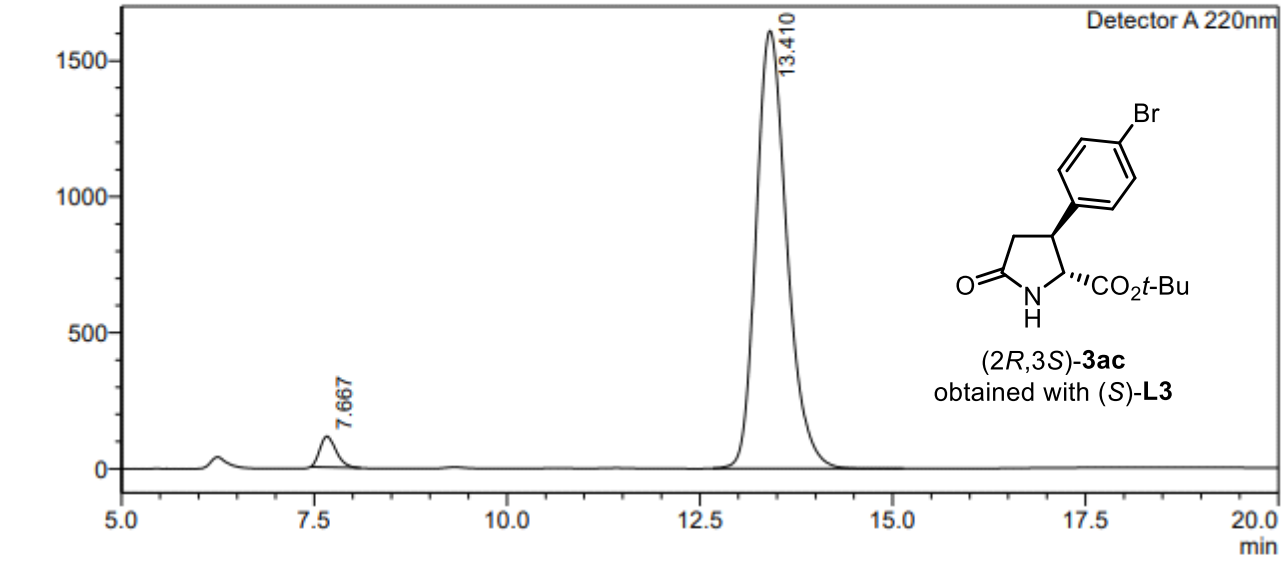


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.680	3518618	206848	52.202			
2	13.499	3221799	119092	47.798			
Total		6740416	325940				

<Chromatogram>



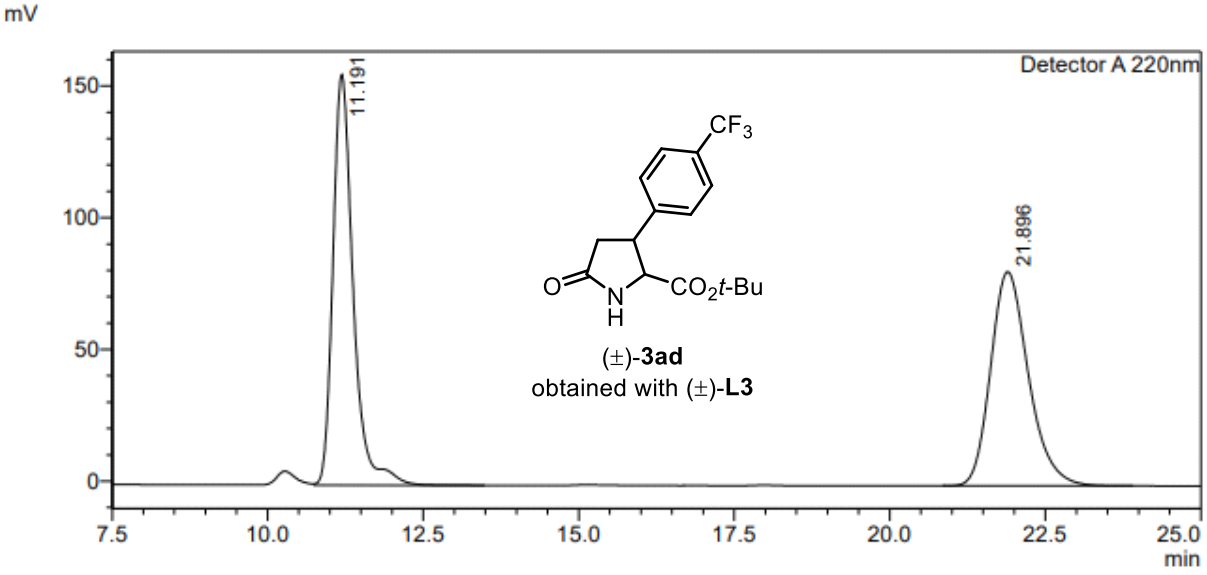
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.667	1666478	113627	3.597			
2	13.410	44657549	1608556	96.403			
Total		46324028	1722184				

<Table 3, *anti*-3ad>

<Chromatogram>

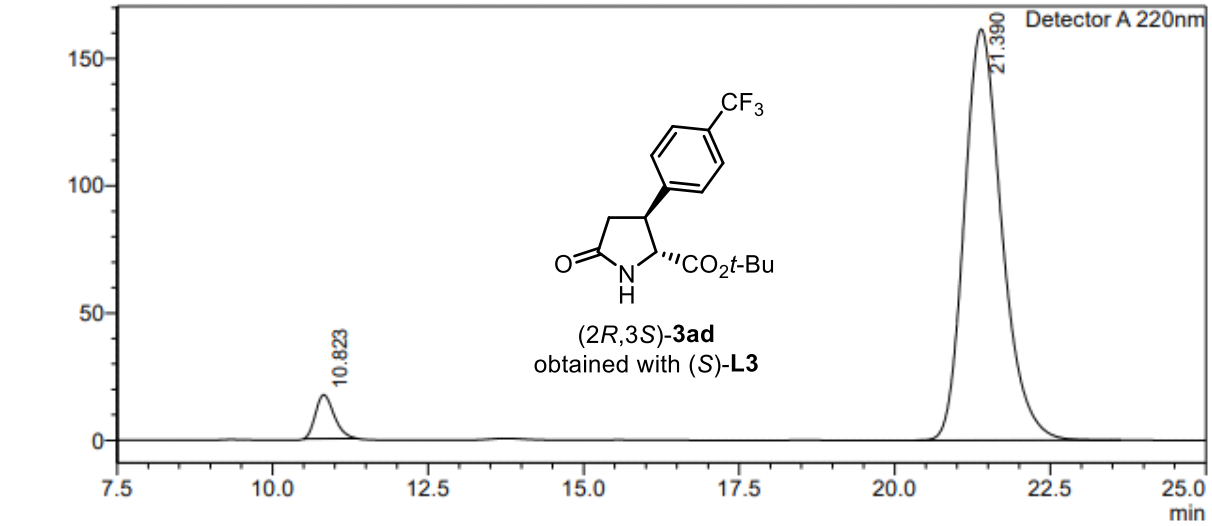


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	11.191	3526806	155789	50.666			
2	21.896	3434097	81185	49.334			
Total		6960904	236974				

<Chromatogram>



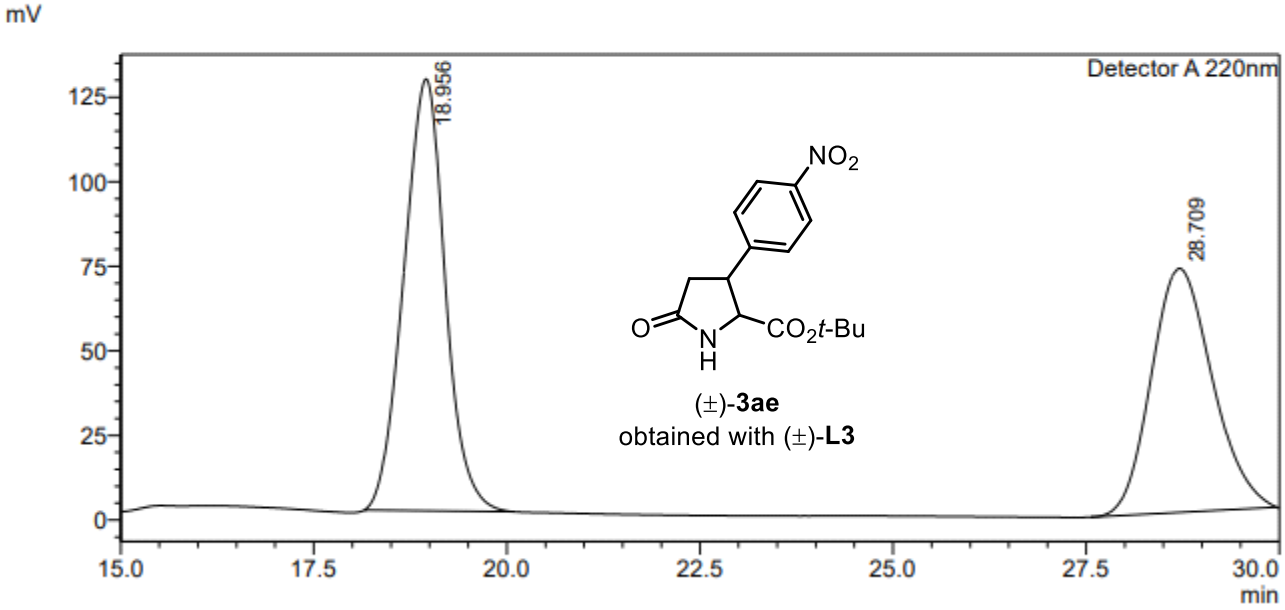
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	10.823	359233	17264	5.030			
2	21.390	6781893	161497	94.970			
Total		7141126	178761				

<Table 3, *anti*-3ae>

<Chromatogram>

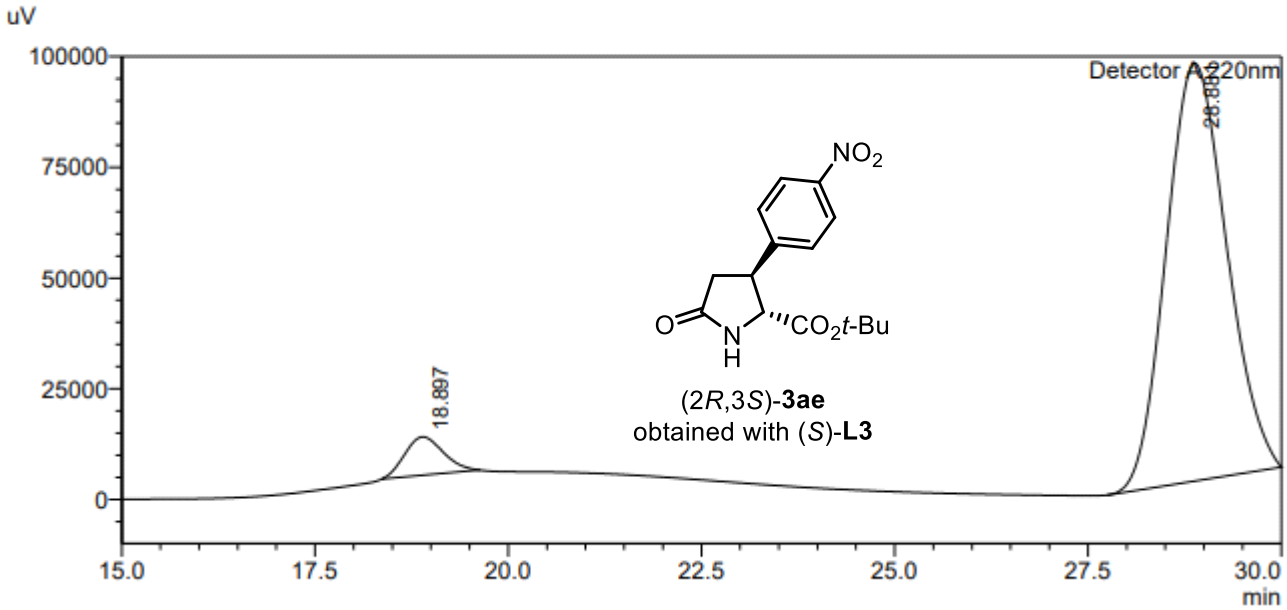


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	18.956	4762887	127582	54.568			
2	28.709	3965441	72071	45.432			
Total		8728328	199653				

<Chromatogram>



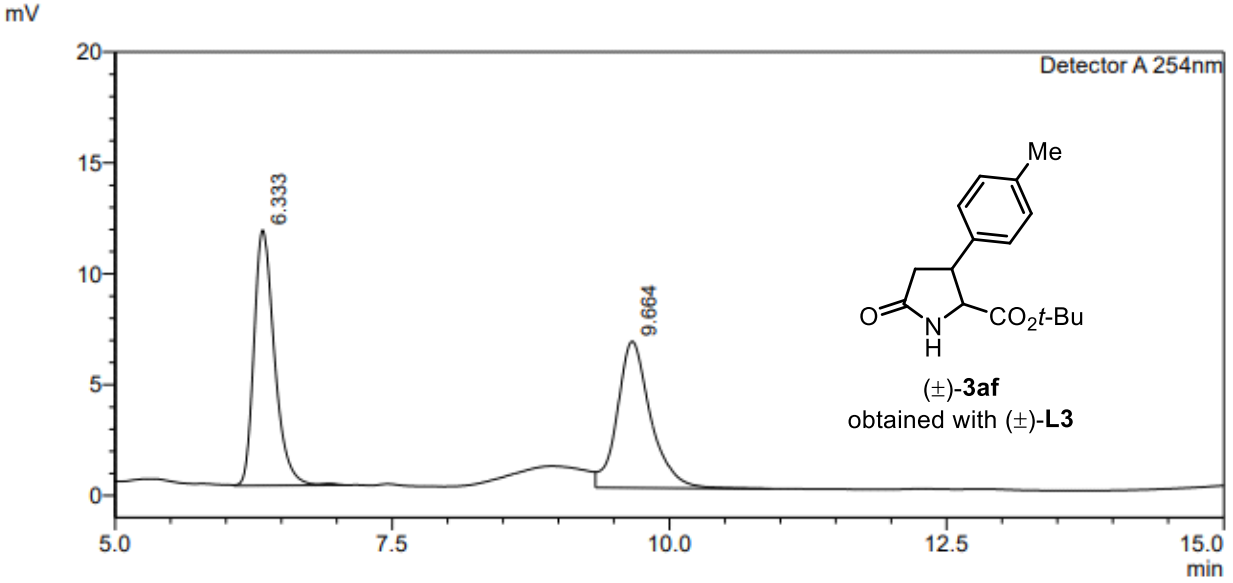
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	18.897	301482	8635	5.561			
2	28.881	5119932	94339	94.439			
Total		5421414	102974				

<Table 3, *anti*-3af>

<Chromatogram>

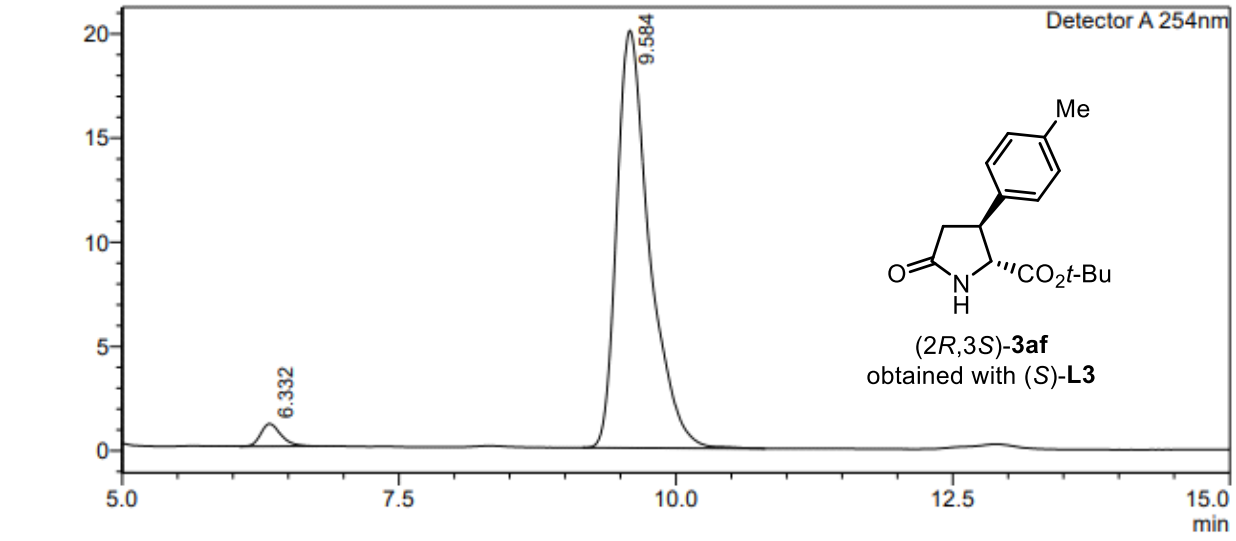


<Peak Table>

Detector A 254nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	6.333	147392	11516	51.599			
2	9.664	138259	6596	48.401			
Total		285651	18112				

<Chromatogram>



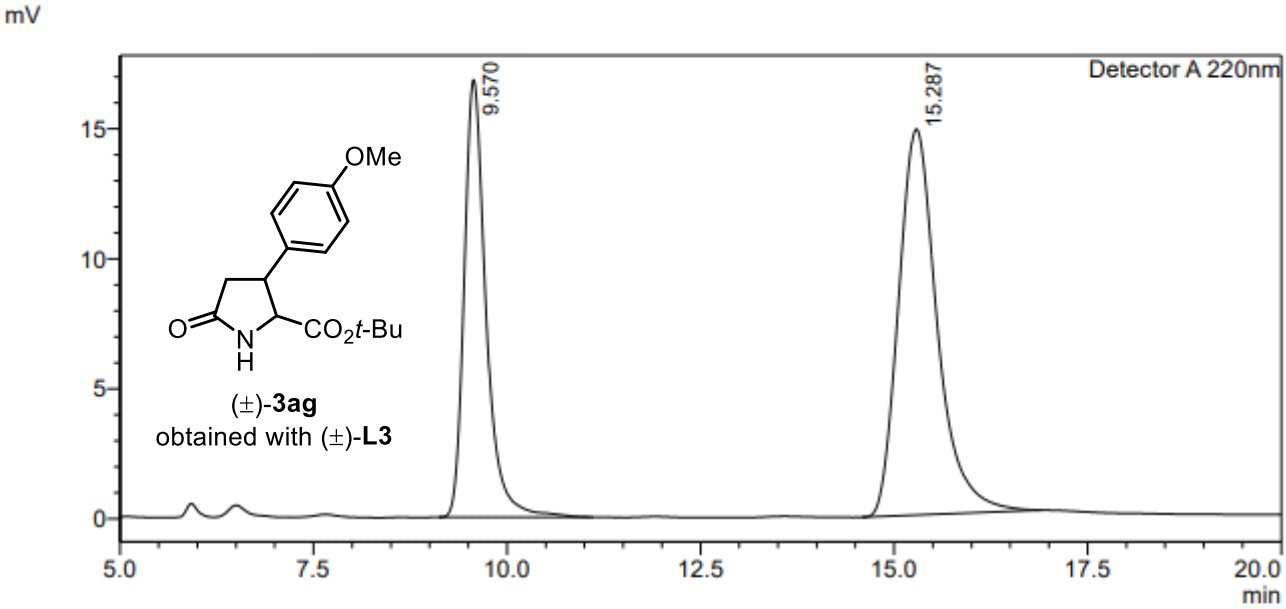
<Peak Table>

Detector A 254nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	6.332	13541	1078	3.195			
2	9.584	410260	20026	96.805			
Total		423802	21104				

<Table 3, *anti*-3ag>

<Chromatogram>

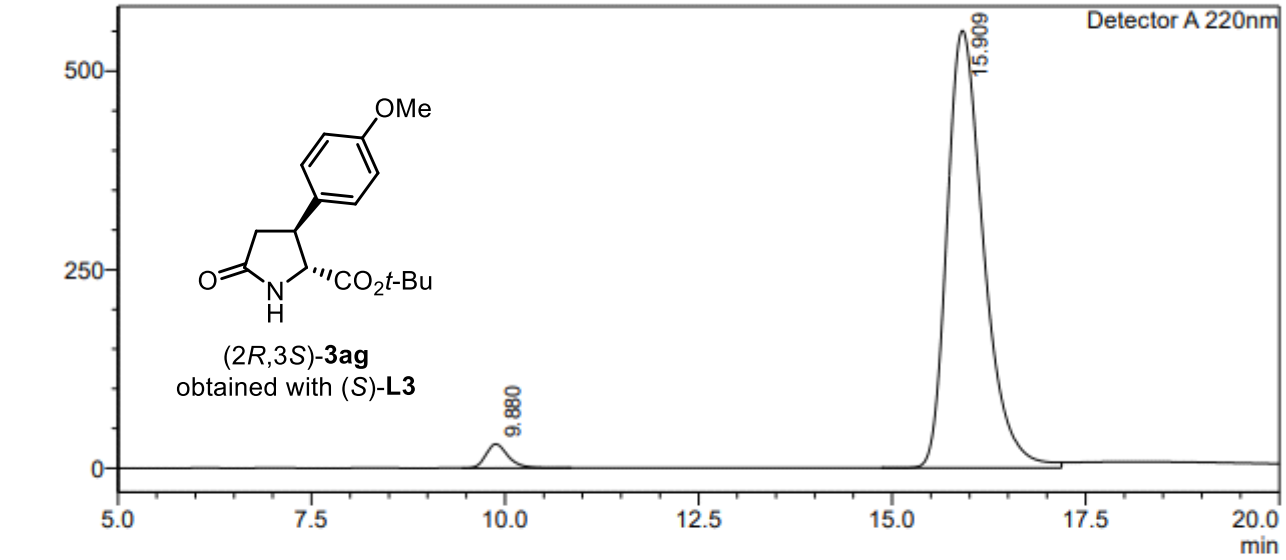


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.570	329887	16817	38.999			
2	15.287	516005	14838	61.001			
Total		845893	31655				

<Chromatogram>



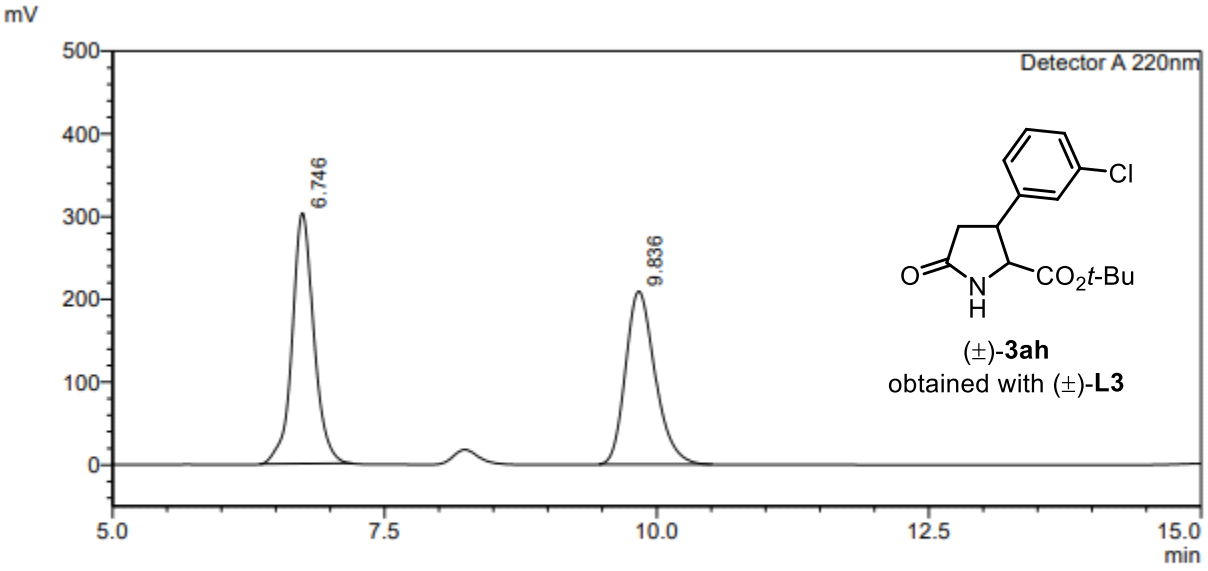
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.880	598029	30155	3.208		V	
2	15.909	18044342	550361	96.792			
Total		18642371	580515				

<Table 3, *anti*-3ah>

<Chromatogram>

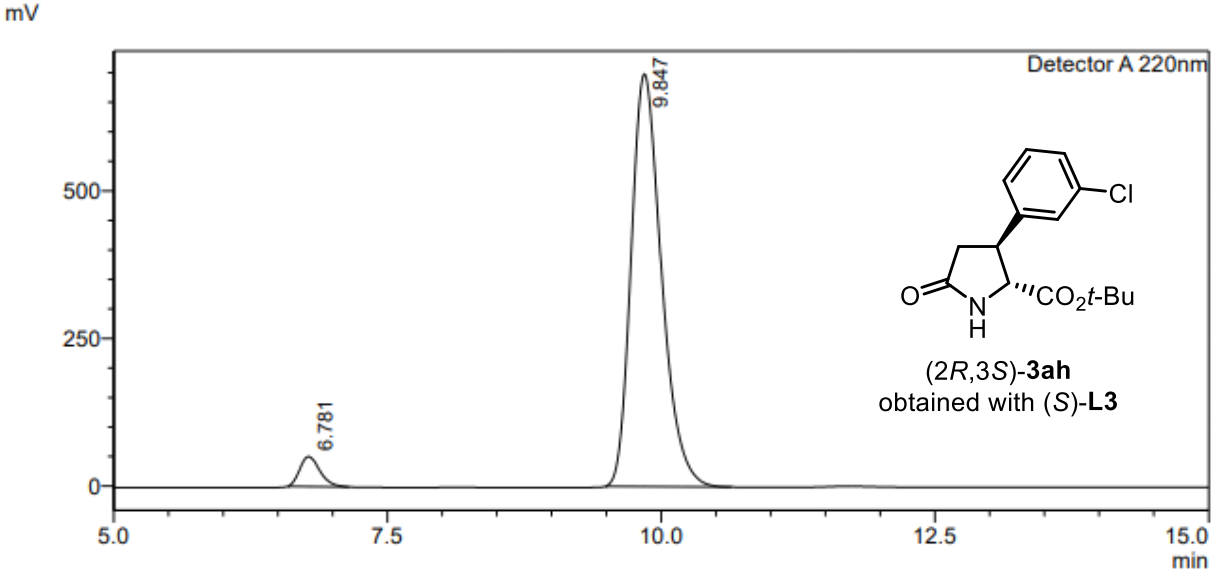


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	6.746	4193007	302868	51.394			
2	9.836	3965499	209099	48.606			
Total		8158506	511968				

<Chromatogram>



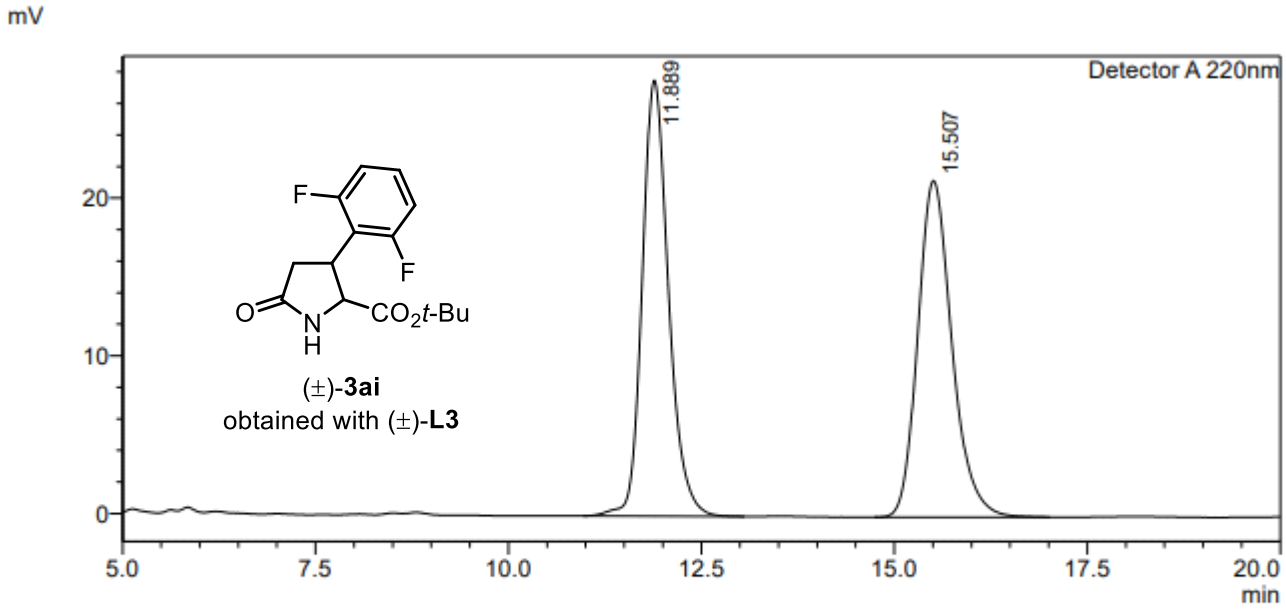
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	6.781	639688	50653	4.534			
2	9.847	13470513	698697	95.466			
Total		14110200	749350				

<Table 3, *anti*-3ai>

<Chromatogram>

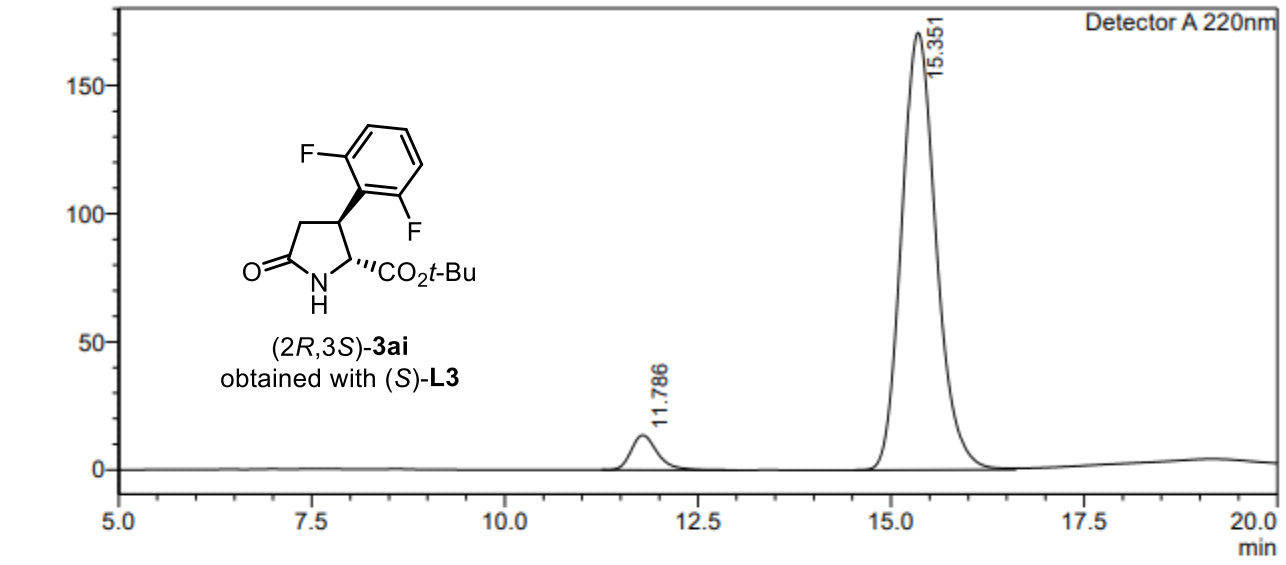


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	11.889	655199	27618	49.930			
2	15.507	657036	21324	50.070			
Total		1312235	48942				

<Chromatogram>



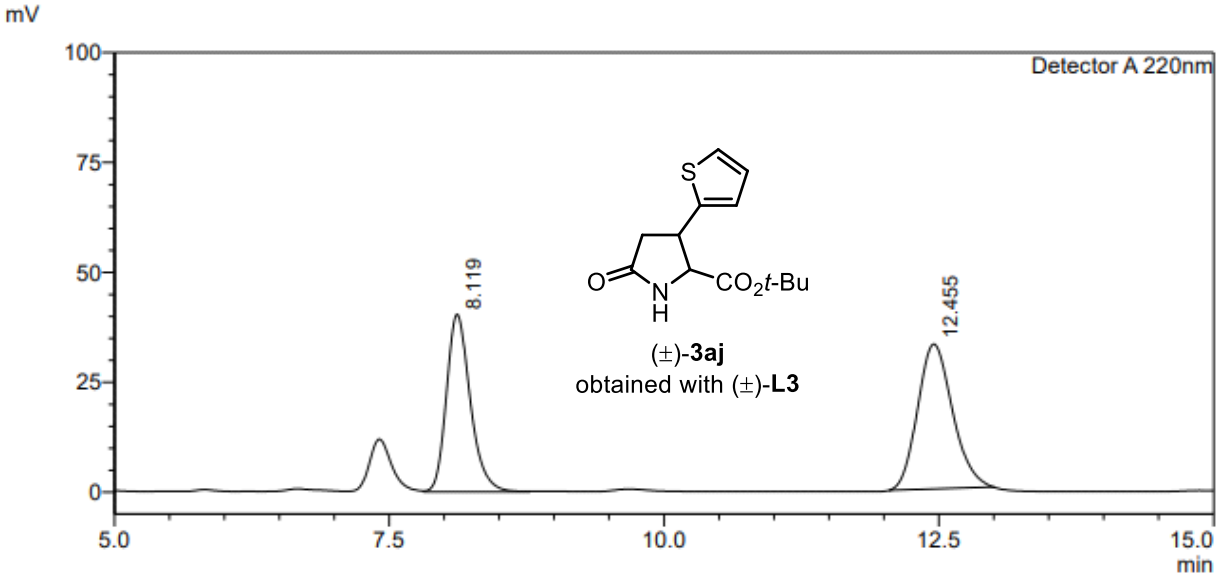
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	11.786	320282	13585	5.690			
2	15.351	5308390	170499	94.310			
Total		5628672	184084				

<Table 3, *anti*-3aj>

<Chromatogram>

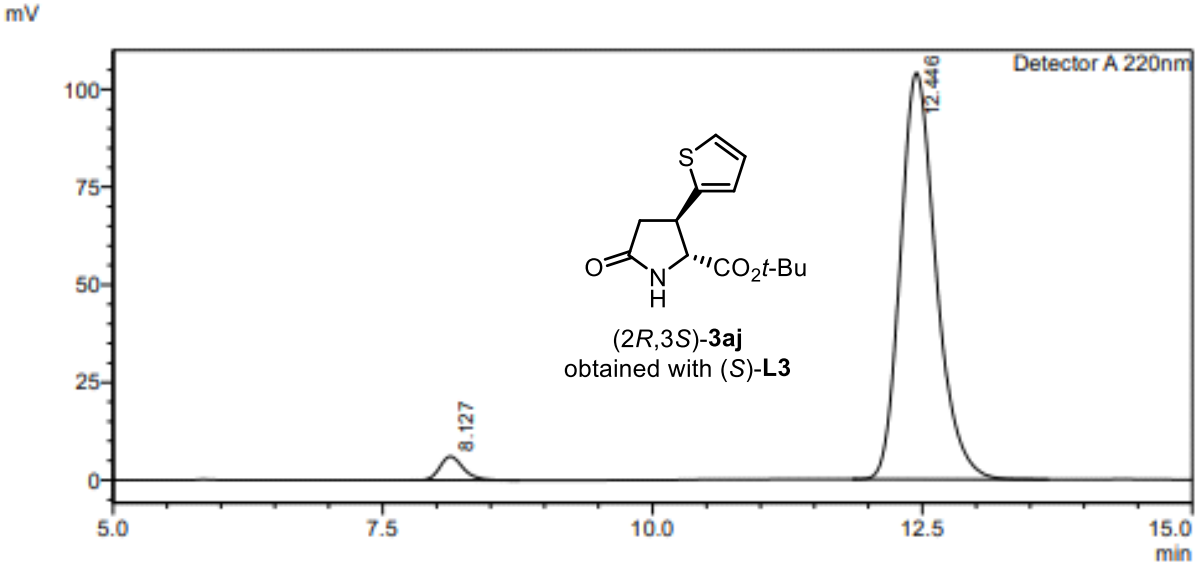


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.119	609651	40397	45.551			
2	12.455	728755	32904	54.449			
Total		1338406	73301				

<Chromatogram>



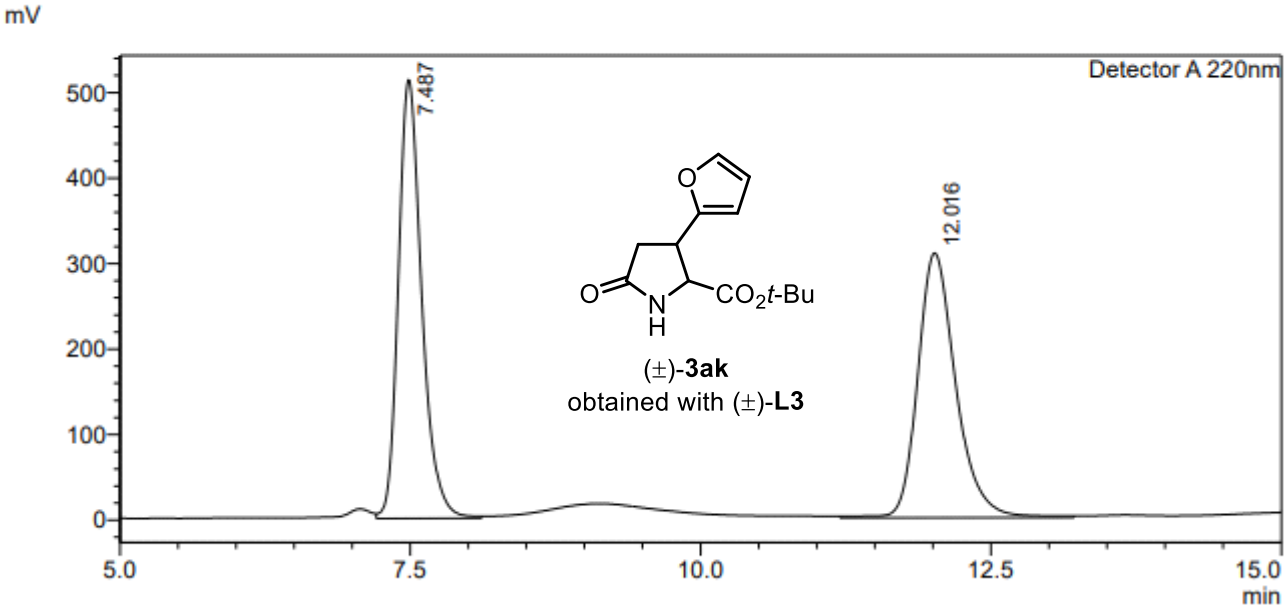
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.127	91314	6064	3.676			
2	12.446	2392774	103969	96.324			
Total		2484089	110033				

<Table 3, *anti*-3ak>

<Chromatogram>

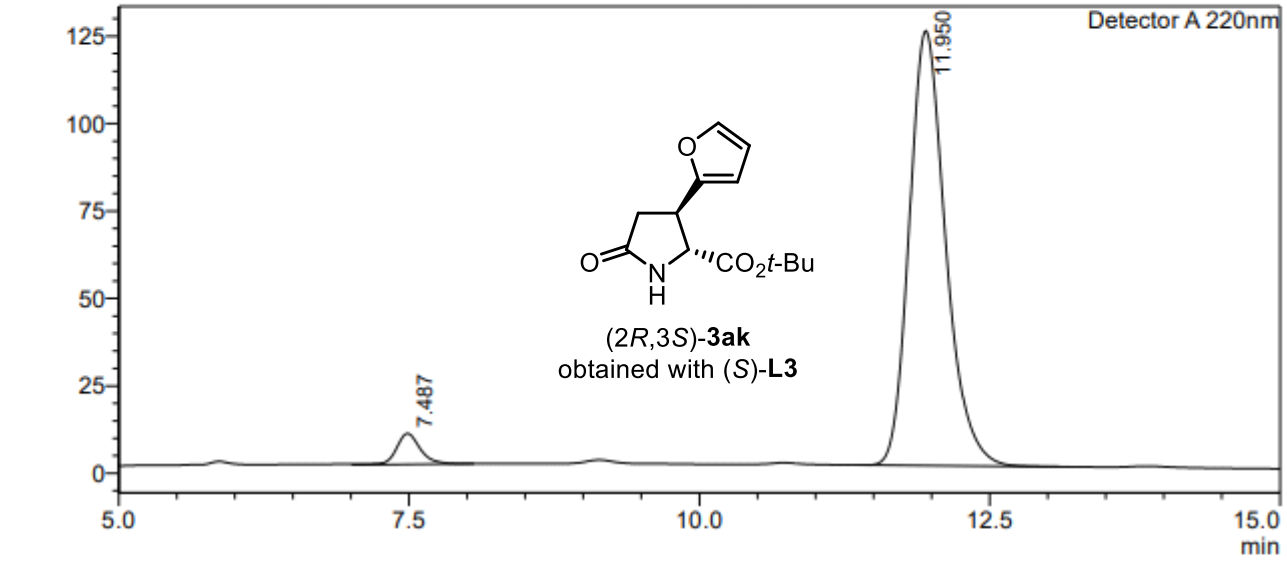


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.487	7217467	512726	50.482			
2	12.016	7079613	309424	49.518			
Total		14297080	822150				

<Chromatogram>



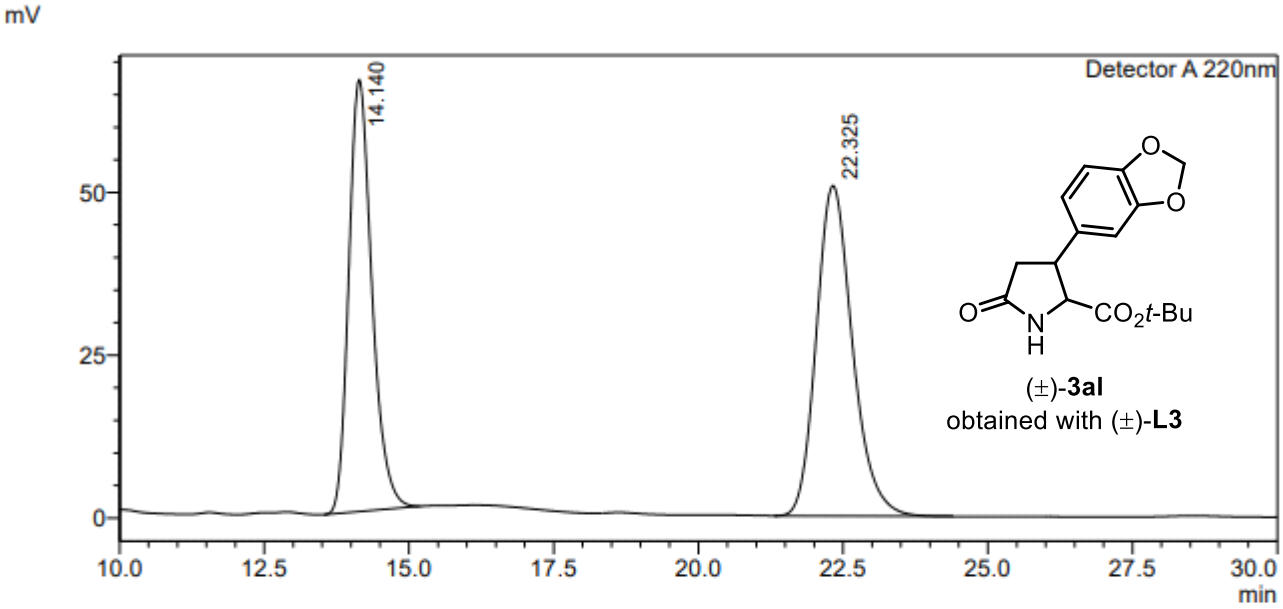
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.487	128390	8823	4.517			
2	11.950	2713717	124315	95.483			
Total		2842107	133138				

<Table 3, *anti*-3al>

<Chromatogram>

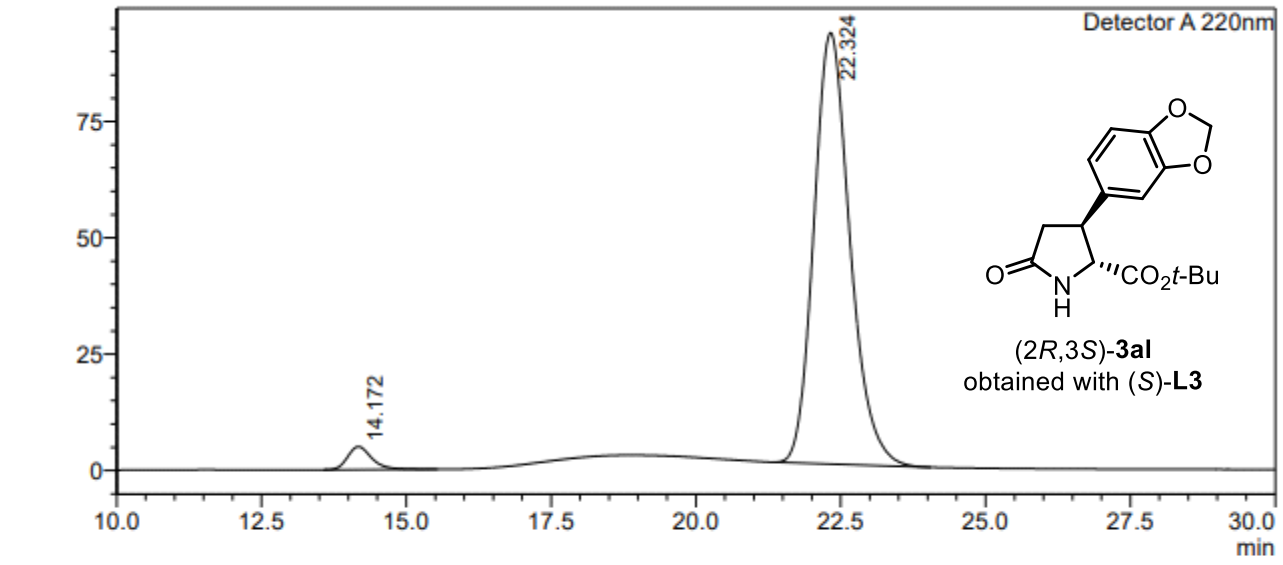


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.140	1843154	66279	45.509			
2	22.325	2206901	50698	54.491			
Total		4050055	116977				

<Chromatogram>



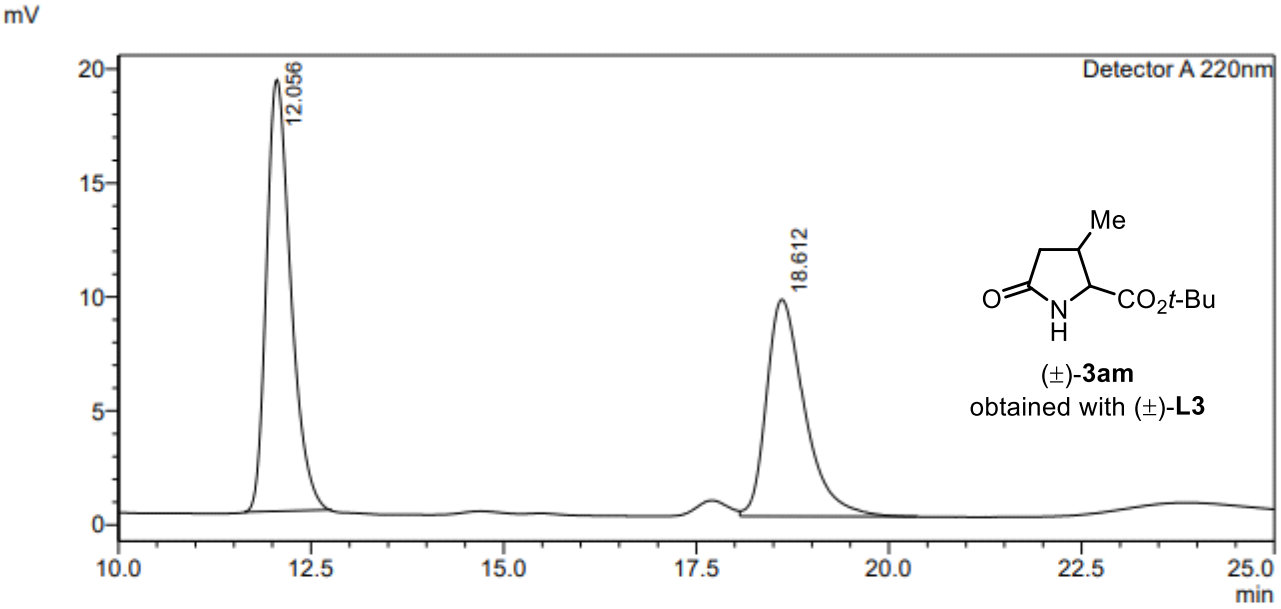
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.172	143691	4935	3.449			
2	22.324	4022965	92663	96.551			
Total		4166656	97598				

<Table 3, *anti*-3am>

<Chromatogram>

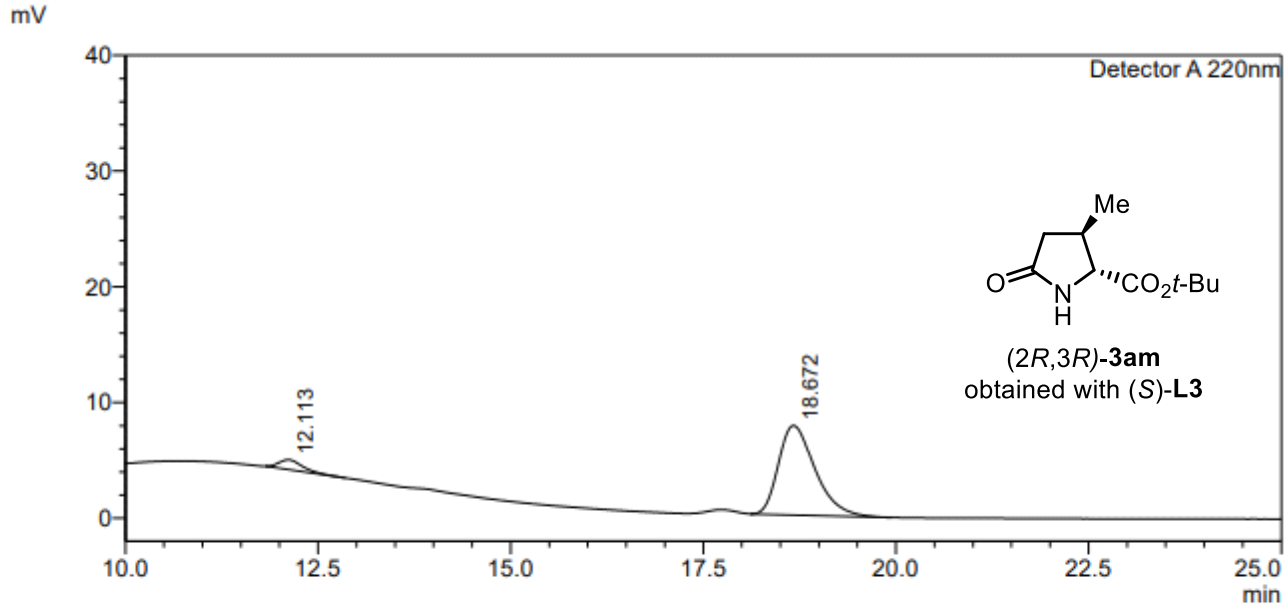


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.056	415470	18940	55.783			
2	18.612	329321	9517	44.217			
Total		744791	28457				

<Chromatogram>



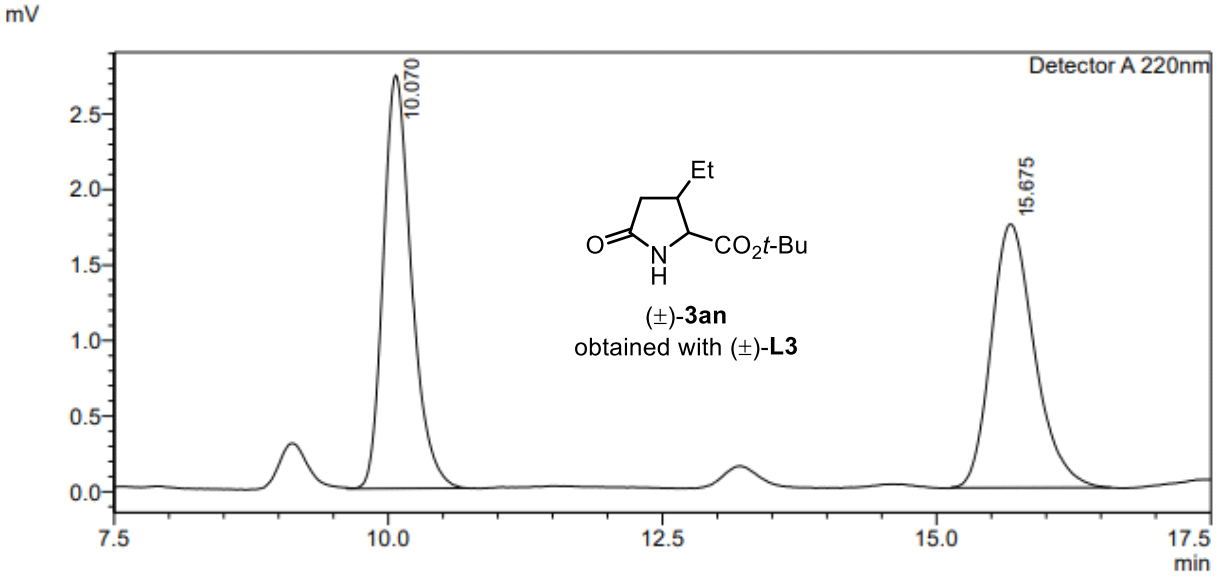
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.113	18128	843	6.613			
2	18.672	255995	7733	93.387			
Total		274122	8575				

<Table 3, *anti*-3an>

<Chromatogram>

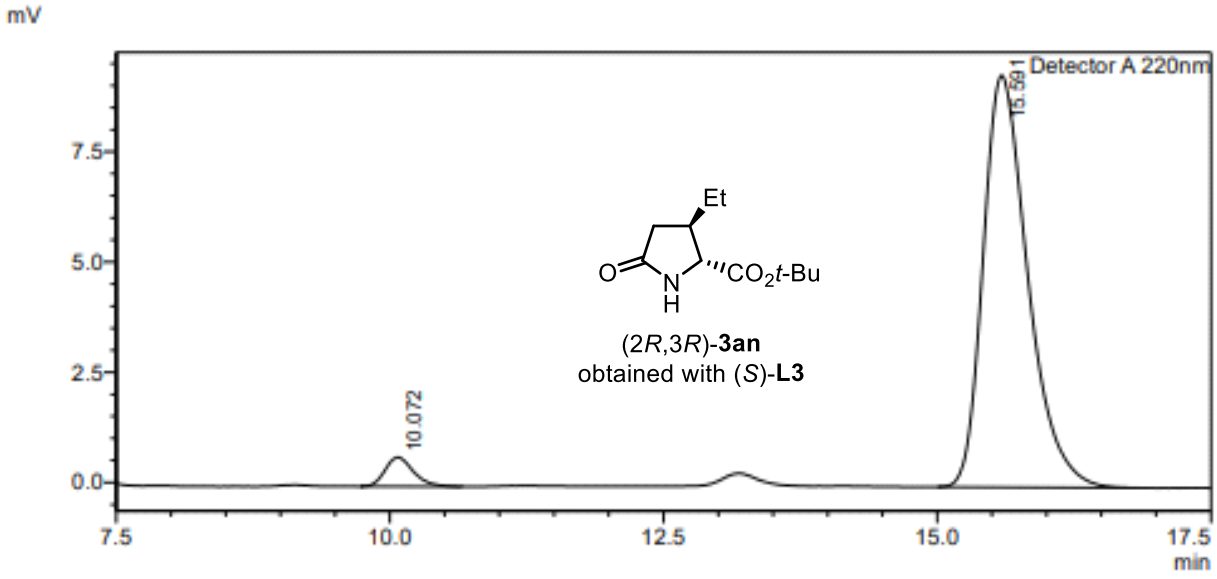


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	10.070	49251	2735	50.685			
2	15.675	47919	1746	49.315			
Total		97170	4480				

<Chromatogram>



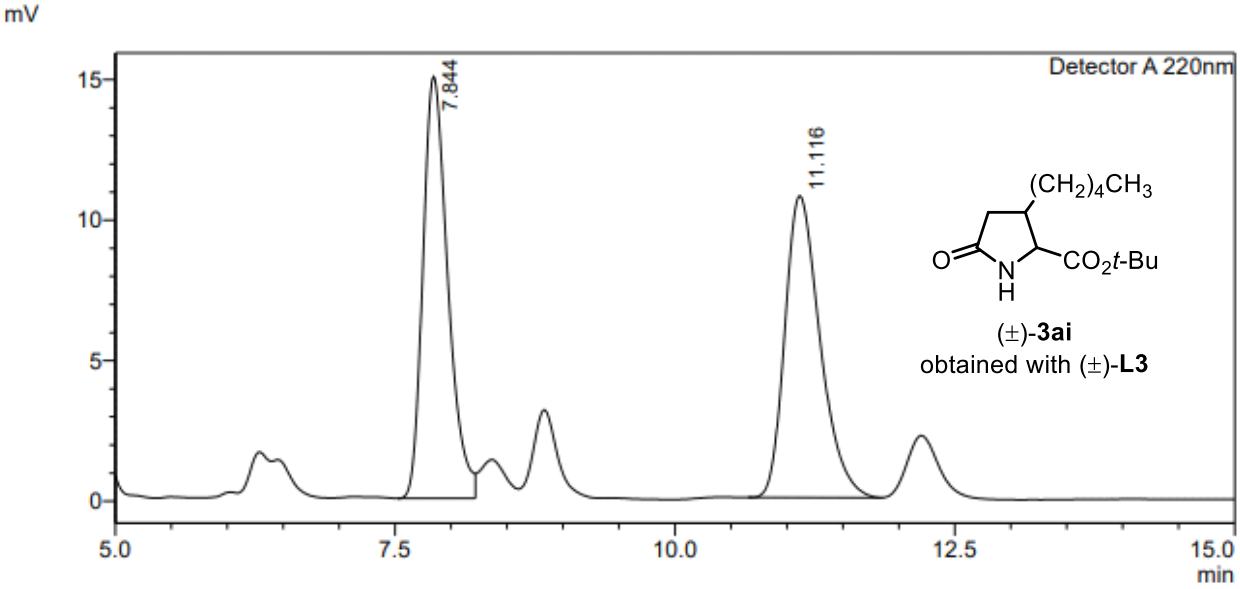
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	10.072	11957	662	4.321			
2	15.591	264730	9337	95.679			
Total		276687	9999				

<Table 3, *anti*-3ao>

<Chromatogram>

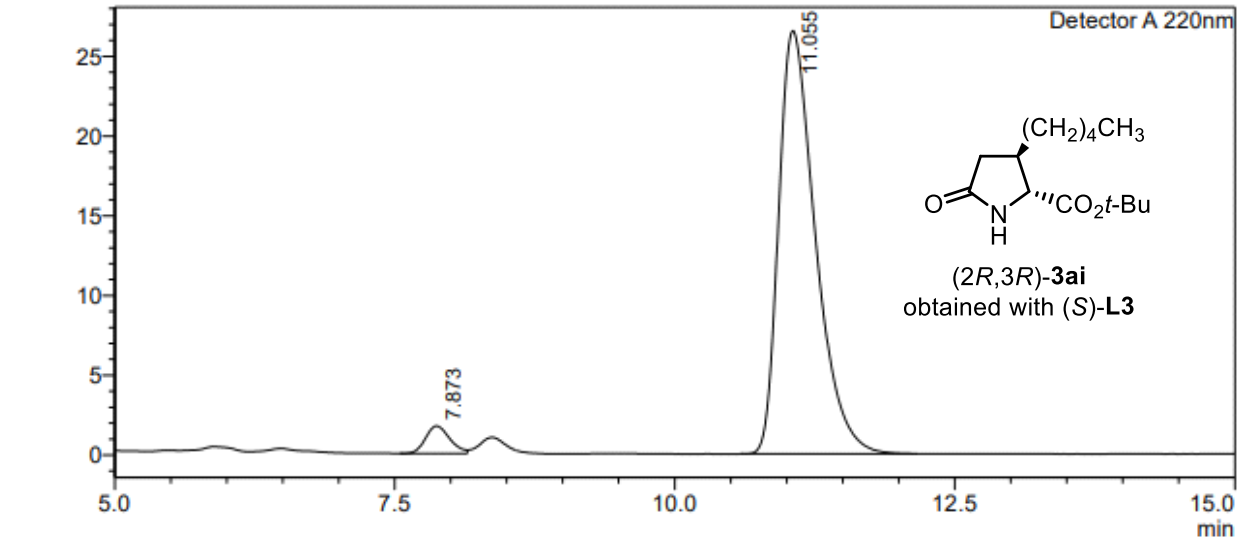


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.844	232560	15006	49.696			
2	11.116	235403	10739	50.304			
Total		467963	25746				

<Chromatogram>



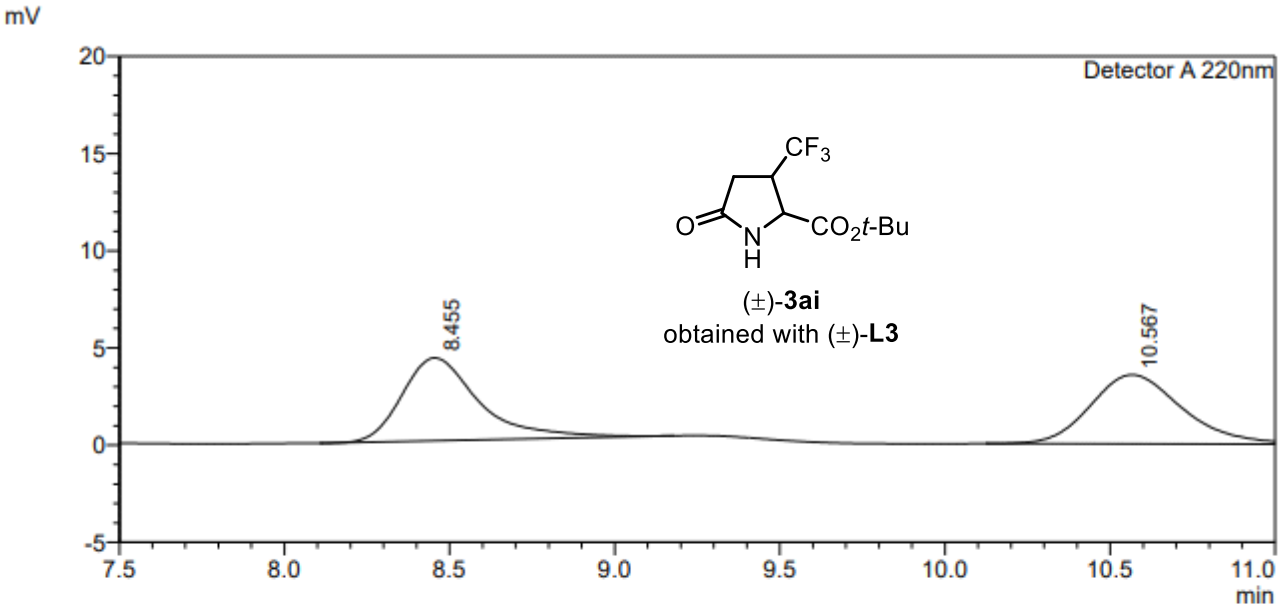
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	7.873	26100	1724	4.130			
2	11.055	605829	26526	95.870			
Total		631929	28250				

<Table 3, *anti*-3ap>

<Chromatogram>

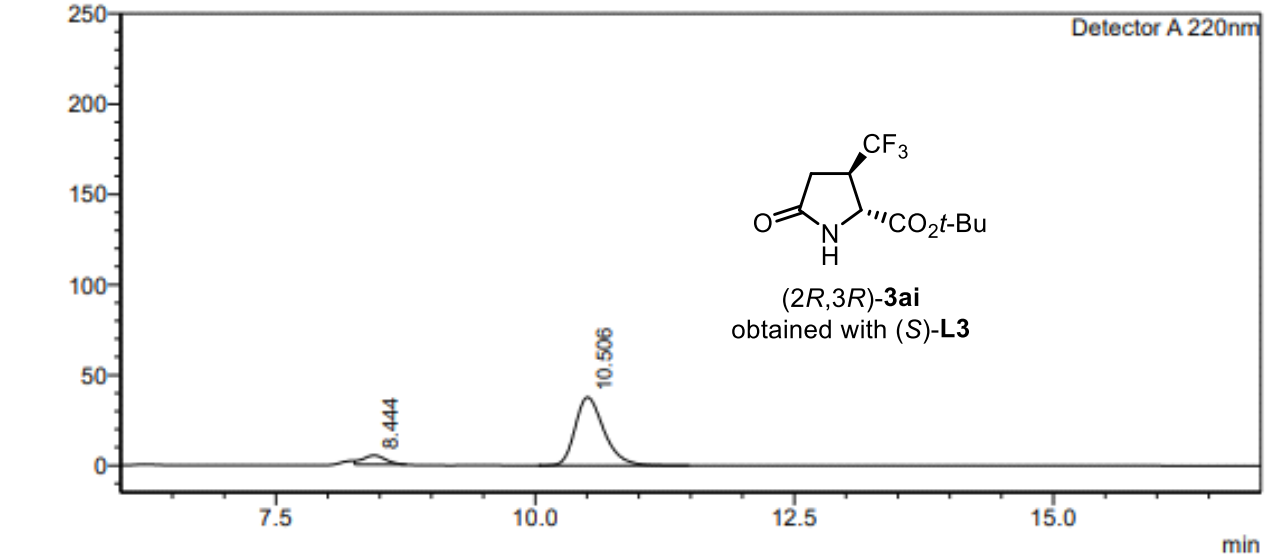


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.455	69366	4262	50.295			
2	10.567	68552	3544	49.705			
Total		137918	7806				

<Chromatogram>



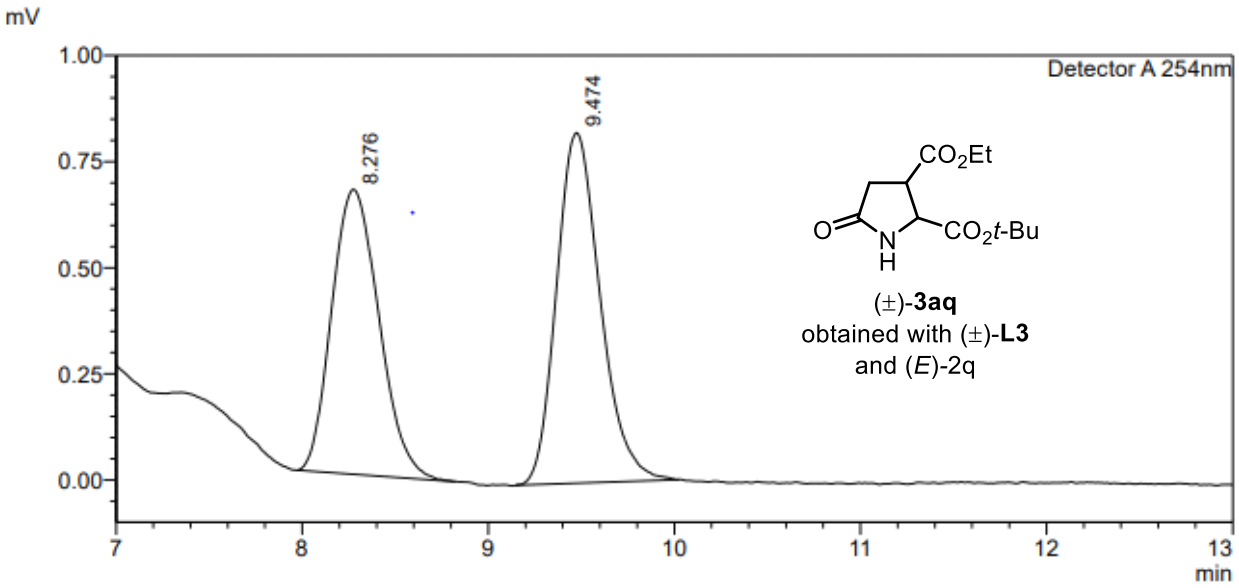
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.444	79032	5094	9.783			
2	10.506	728844	37720	90.217			
Total		807877	42815				

<Table 3, *anti*-3aq>

<Chromatogram>



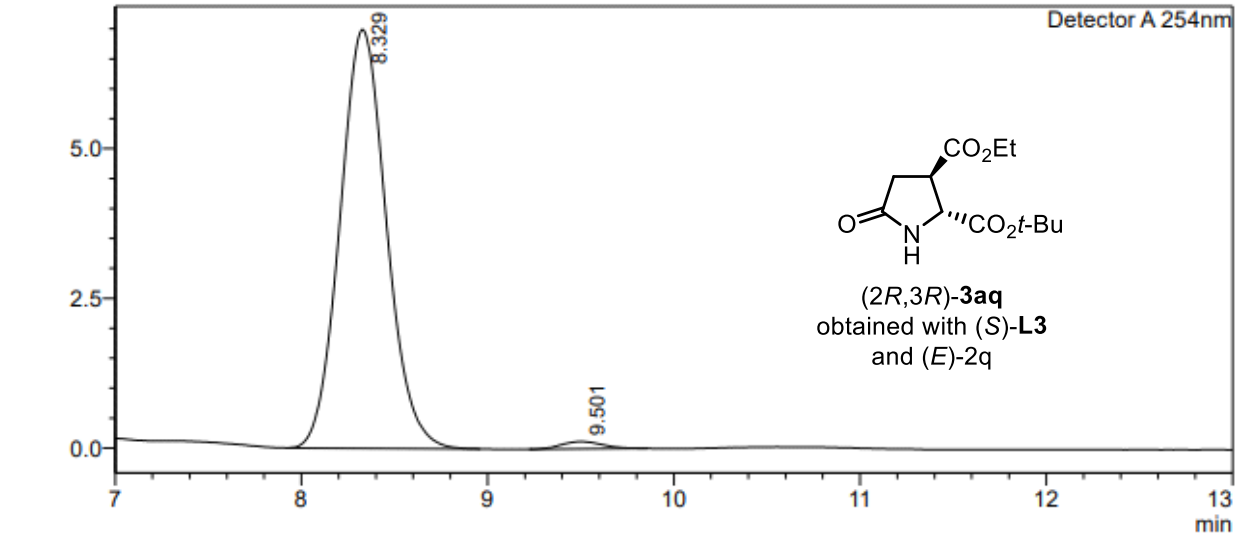
(±)-**3aq**
obtained with (±)-**L3**
and (*E*)-2q

<Peak Table>

Detector A 254nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.276	11858	672	46.783			
2	9.474	13489	826	53.217			
Total		25346	1497				

<Chromatogram>



(2*R*,3*R*)-**3aq**
obtained with (*S*)-**L3**
and (*E*)-2q

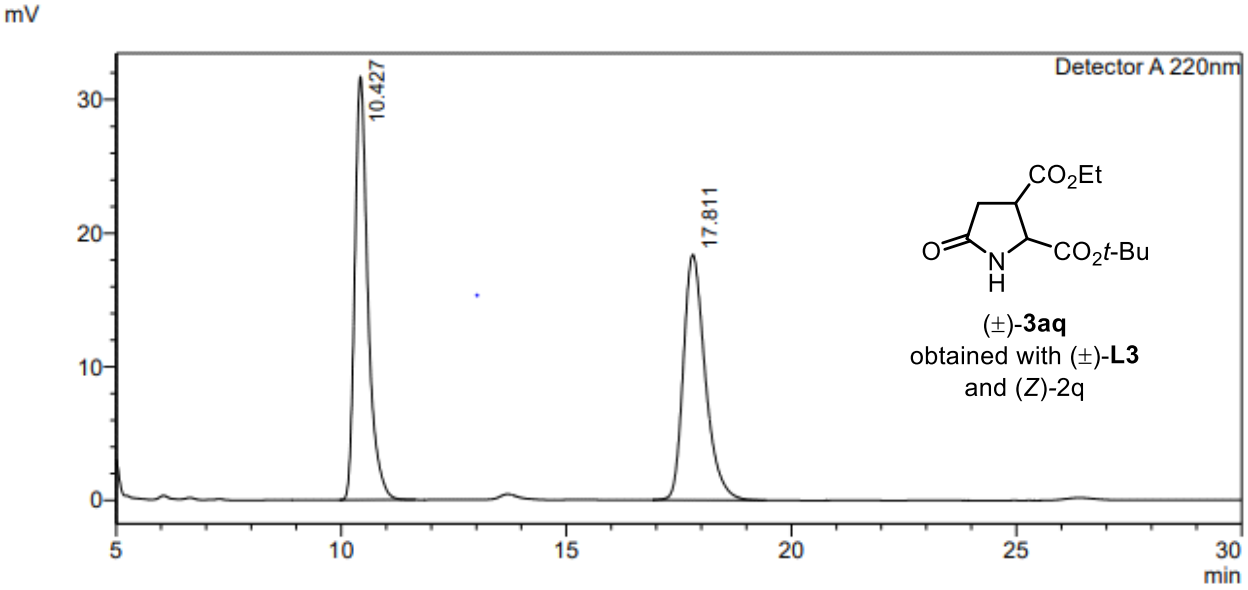
<Peak Table>

Detector A 254nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.329	121543	6990	98.452			
2	9.501	1912	125	1.548			
Total		123455	7115				

<Scheme 2, *syn*-3aq>

<Chromatogram>

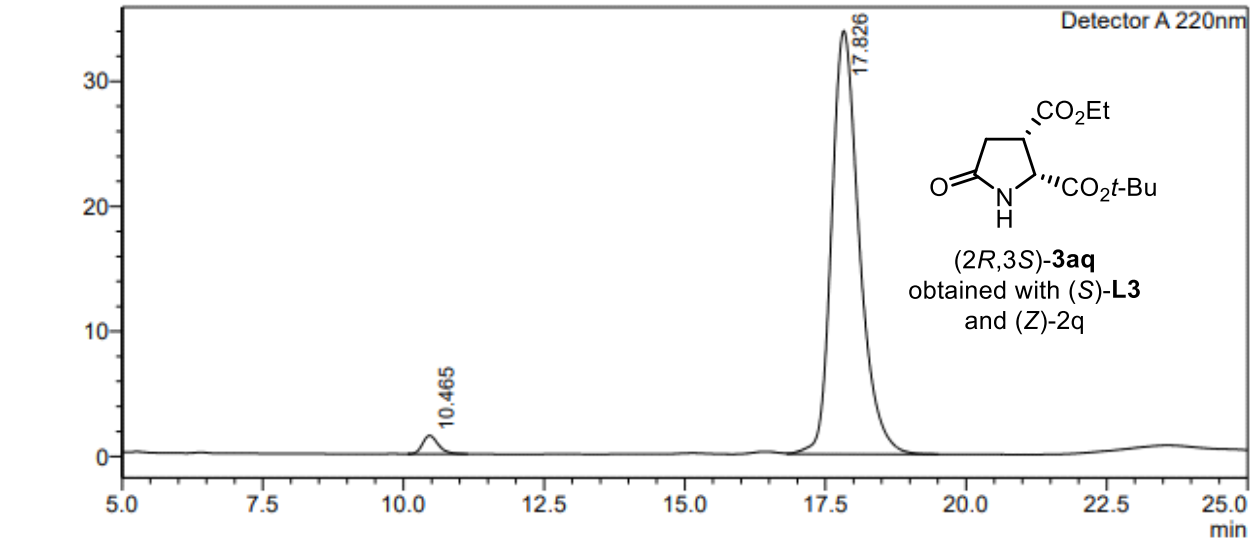


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	10.427	643571	31675	50.865			
2	17.811	621679	18378	49.135			
Total		1265250	50053				

<Chromatogram>



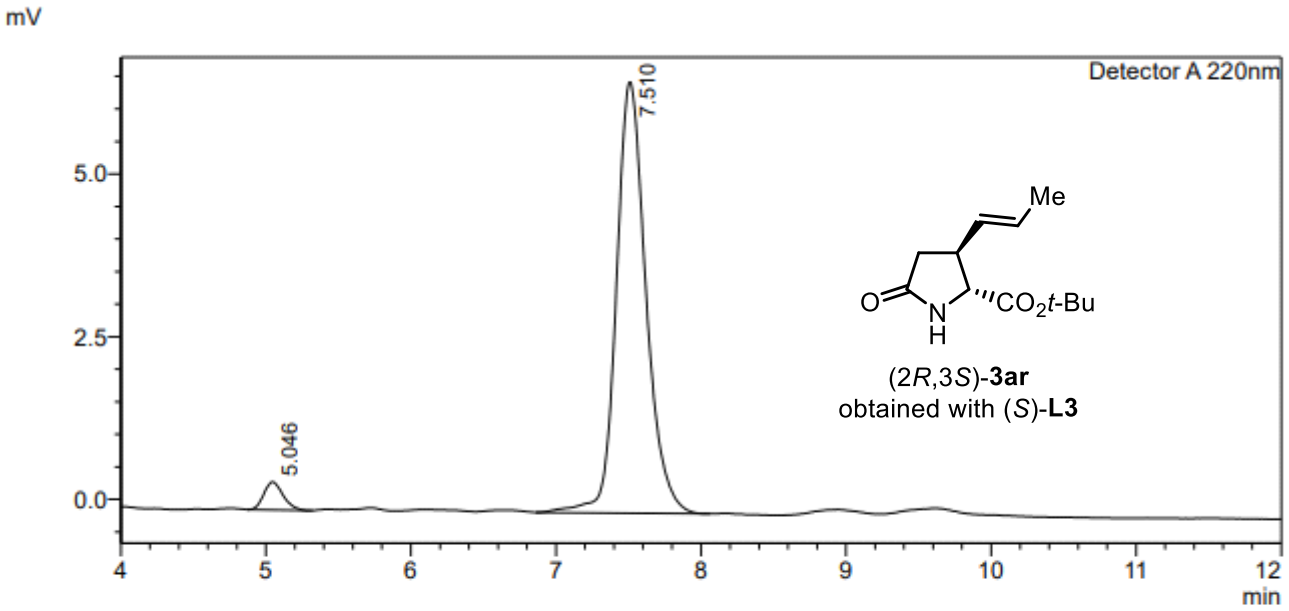
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	10.465	28339	1462	2.386			
2	17.826	1159621	33852	97.614			
Total		1187961	35314				

<Table 3, *anti*-3ar>

<Chromatogram>

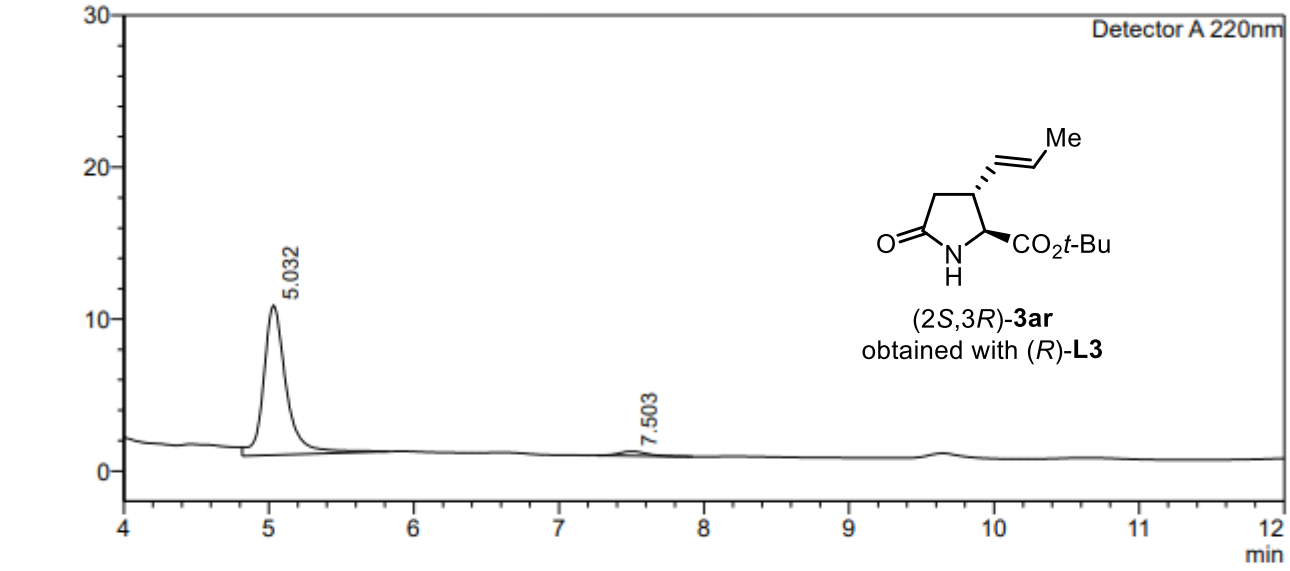


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	5.046	3968	428	4.038			
2	7.510	94308	6629	95.962			
Total		98276	7056				

<Chromatogram>



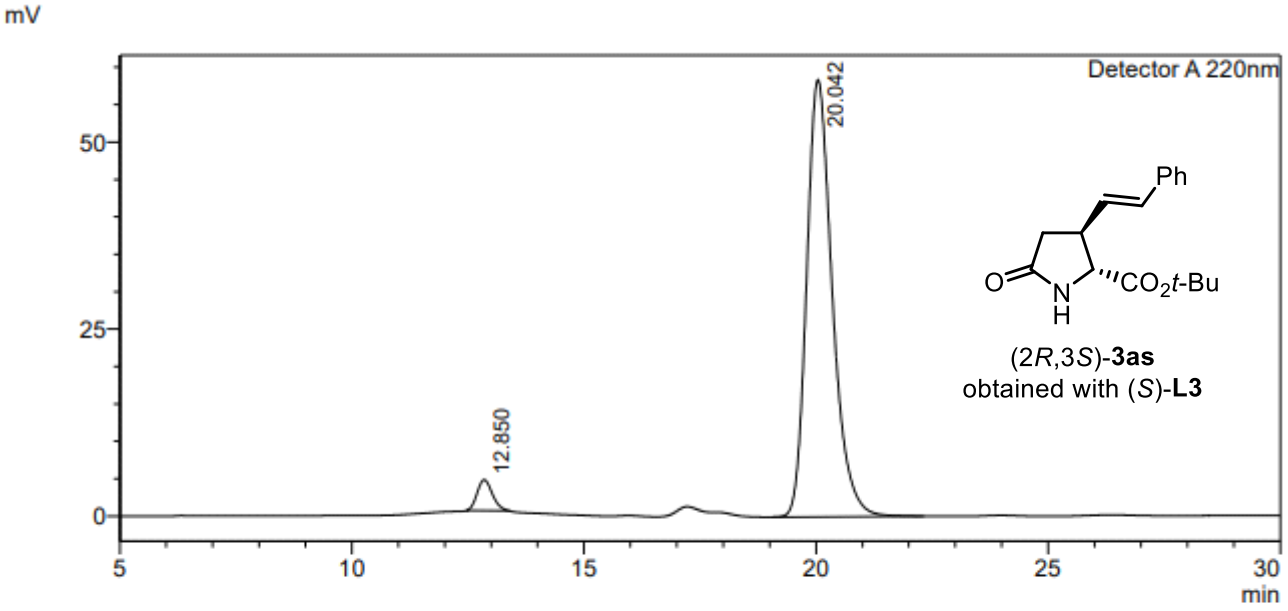
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	5.032	107487	9857	96.541			
2	7.503	3851	292	3.459			
Total		111338	10150				

<Table 3, *anti*-3as>

<Chromatogram>

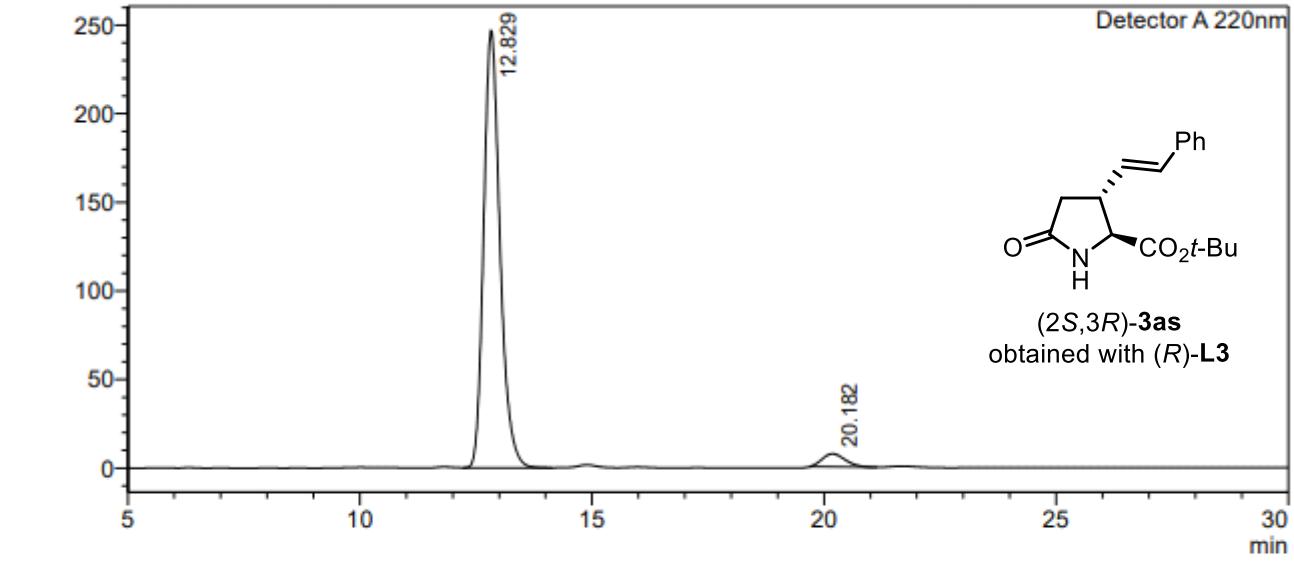


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.850	94063	4128	4.023			
2	20.042	2244119	58416	95.977			
Total		2338182	62544				

<Chromatogram>



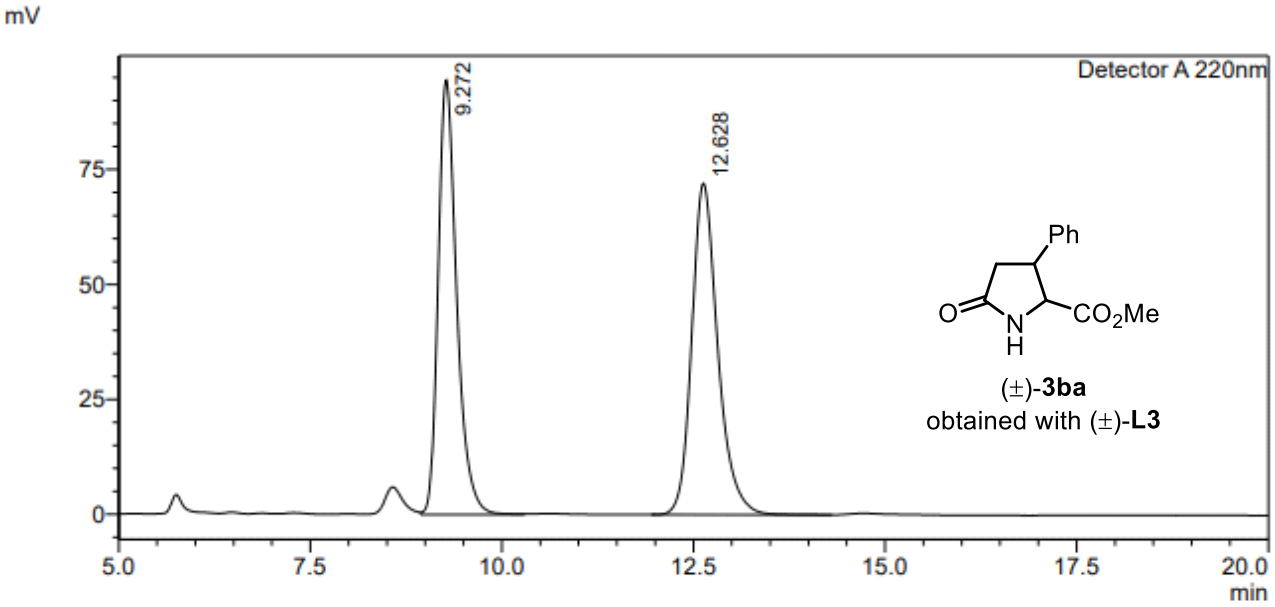
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	12.829	6045204	246705	95.884			
2	20.182	259510	7412	4.116			
Total		6304714	254117				

<Table 3, *anti*-3ba>

<Chromatogram>

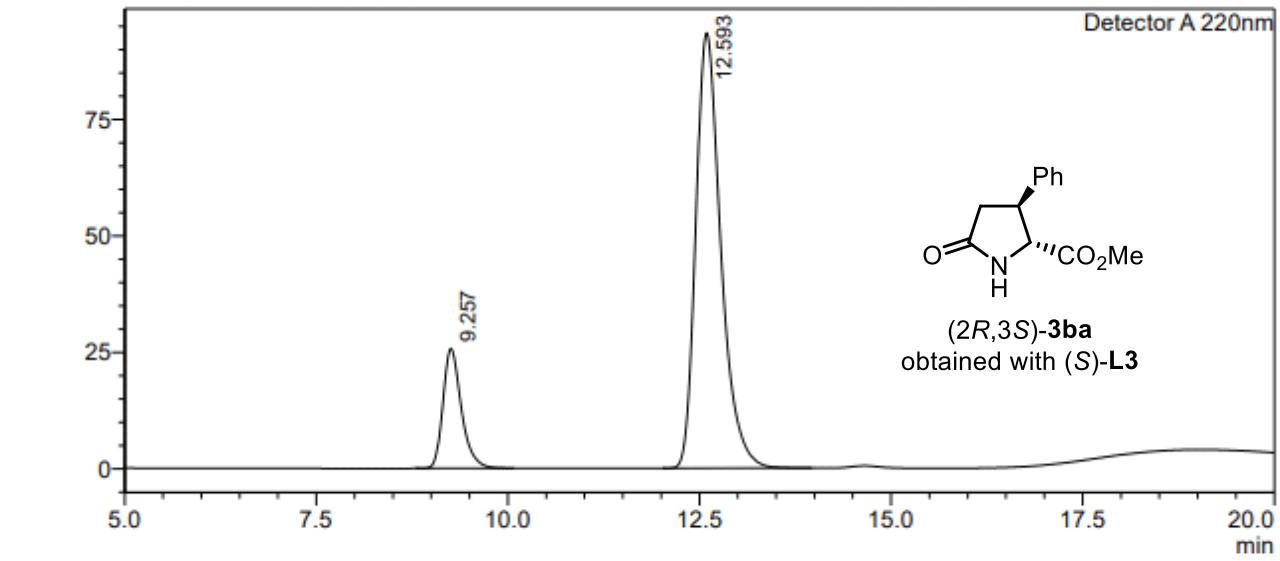


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.272	1599037	94506	48.419			
2	12.628	1703458	72068	51.581			
Total		3302495	166575				

<Chromatogram>



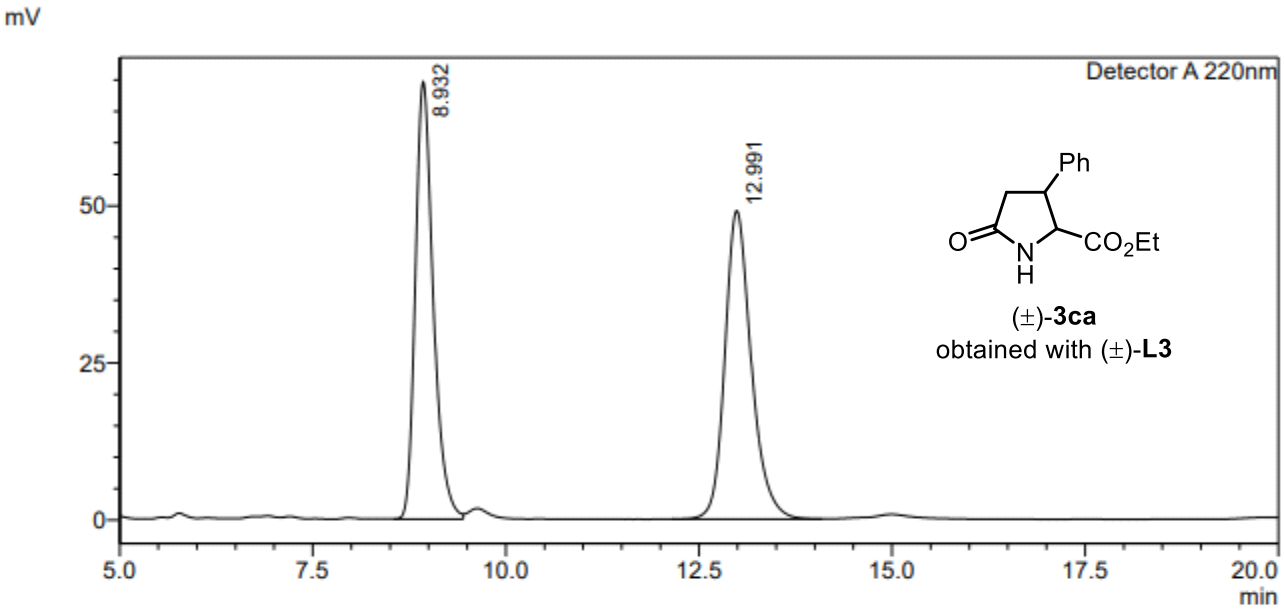
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.257	429169	25675	16.826			
2	12.593	2121480	93361	83.174			
Total		2550649	119035				

<Table 3, *anti*-3ca>

<Chromatogram>

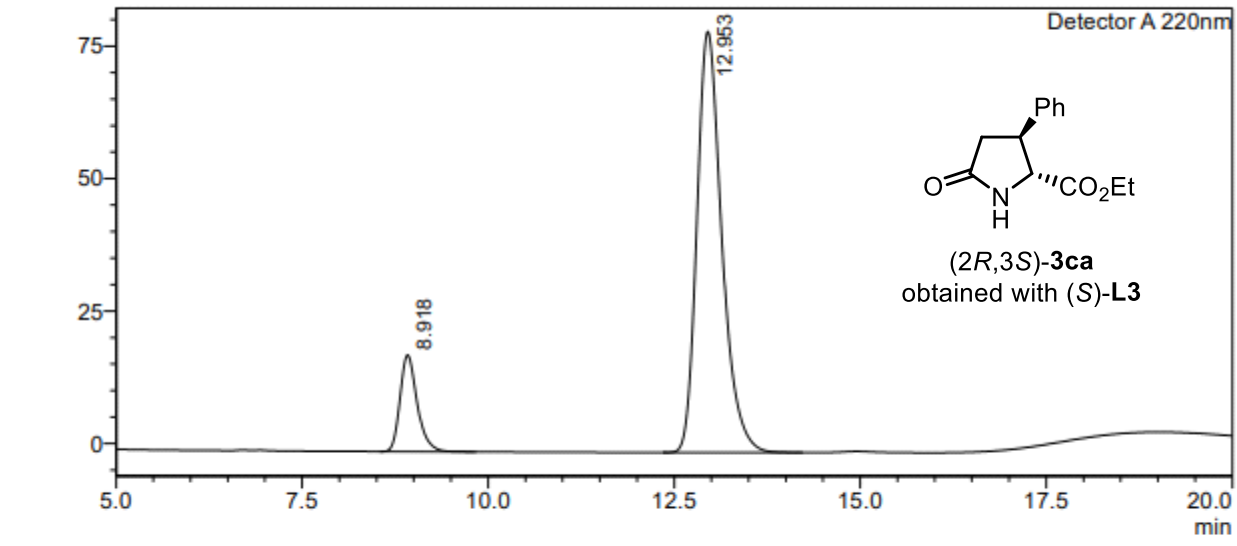


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.932	1123085	69566	48.977			
2	12.991	1169980	49091	51.023			
Total		2293064	118657				

<Chromatogram>



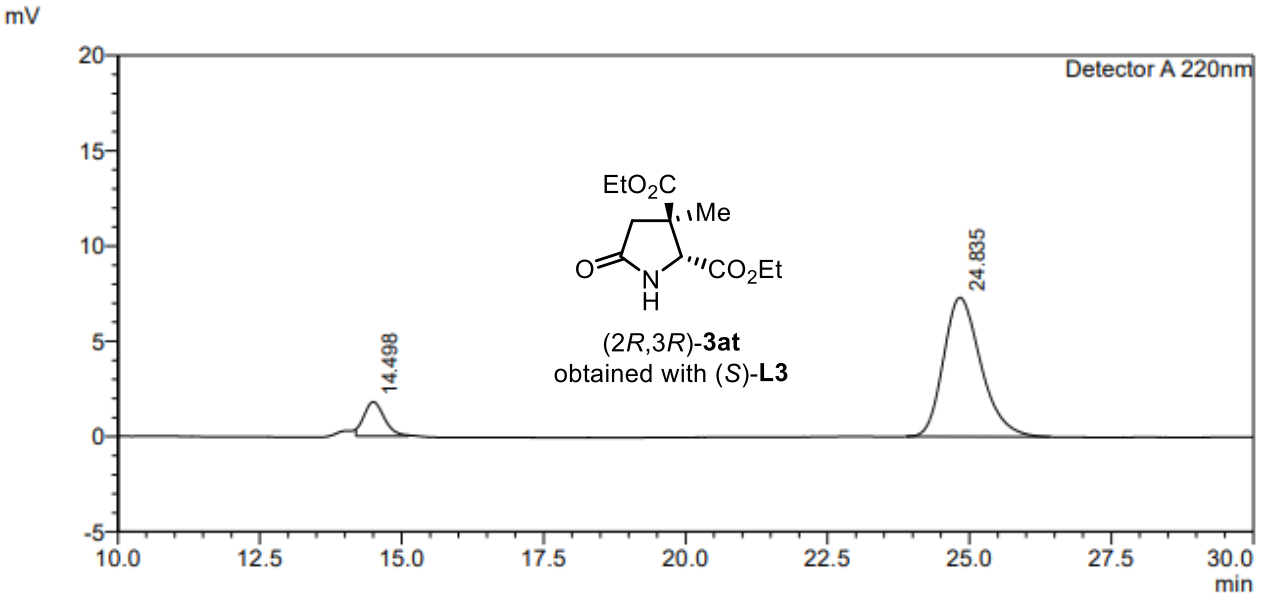
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.918	293092	18211	13.650			
2	12.953	1854145	79390	86.350			
Total		2147238	97602				

<Table 3, 3at>

<Chromatogram>

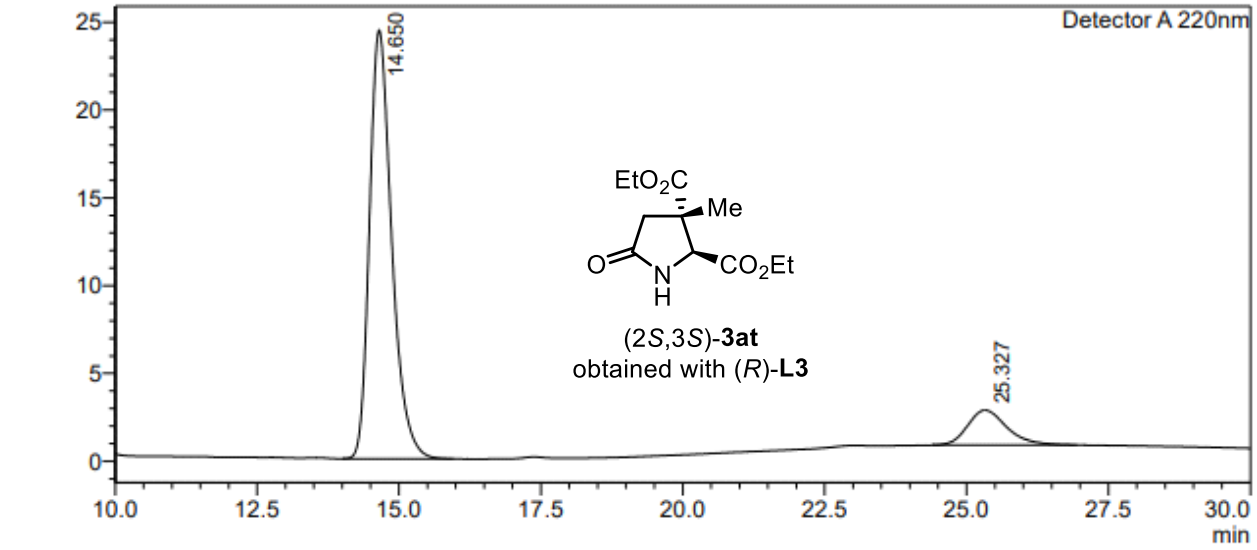


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.498	45464	1798	11.908			
2	24.835	336338	7303	88.092			
Total		381801	9100				

<Chromatogram>



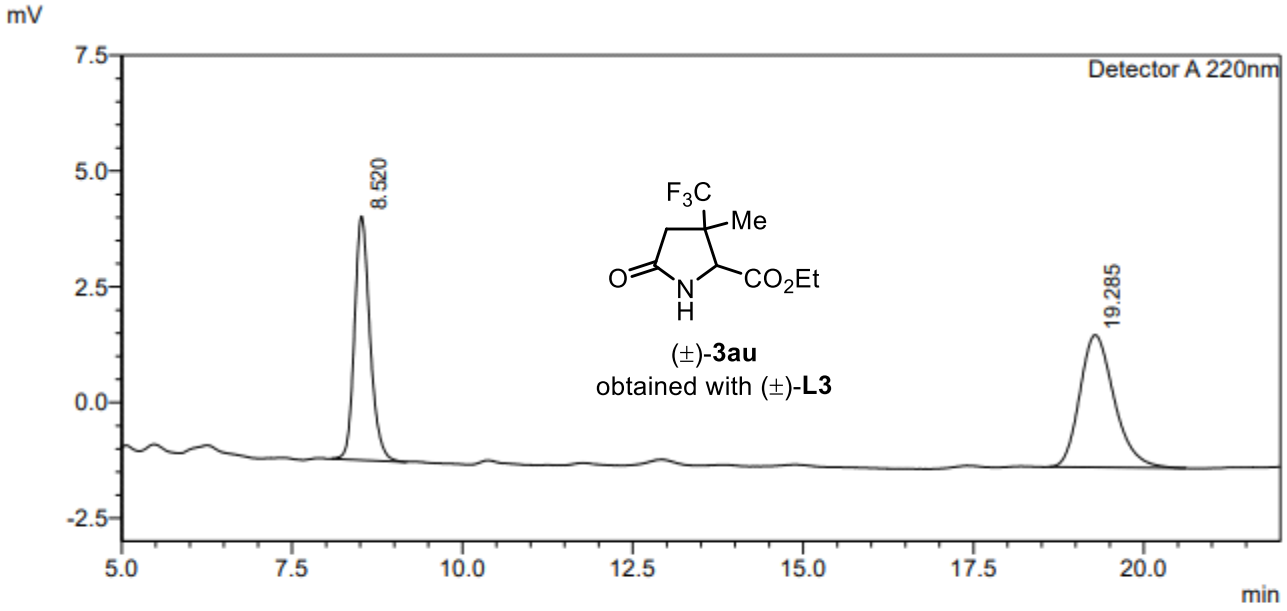
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.650	665290	24405	87.480			
2	25.327	95219	1987	12.520			
Total		760509	26391				

<Table 3, 3au>

<Chromatogram>

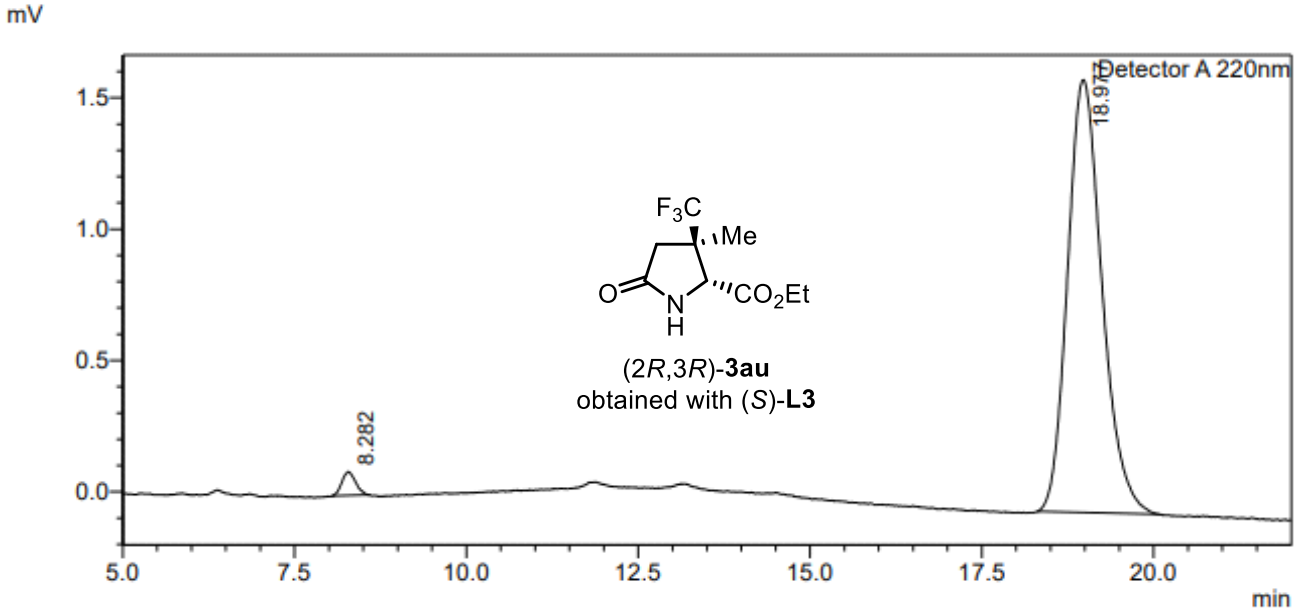


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.520	83108	5261	45.158			
2	19.285	100929	2861	54.842			
Total		184037	8122				

<Chromatogram>



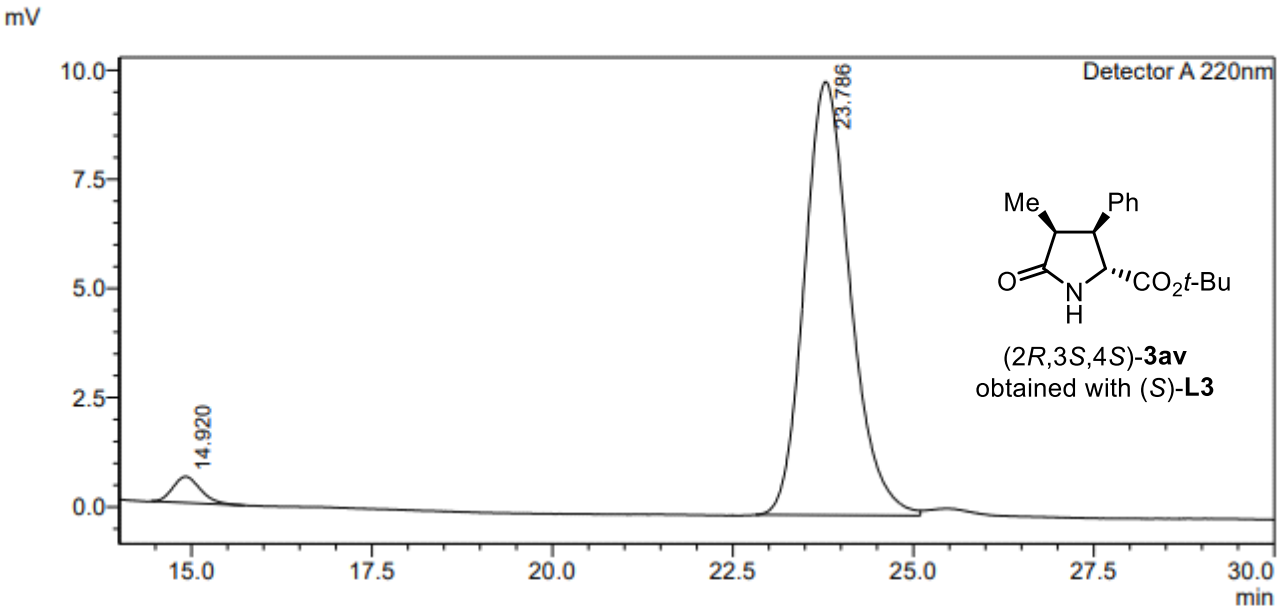
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	8.282	1250	90	2.127			
2	18.977	57497	1648	97.873			
Total		58746	1738				

<Table 3, 3av>

<Chromatogram>

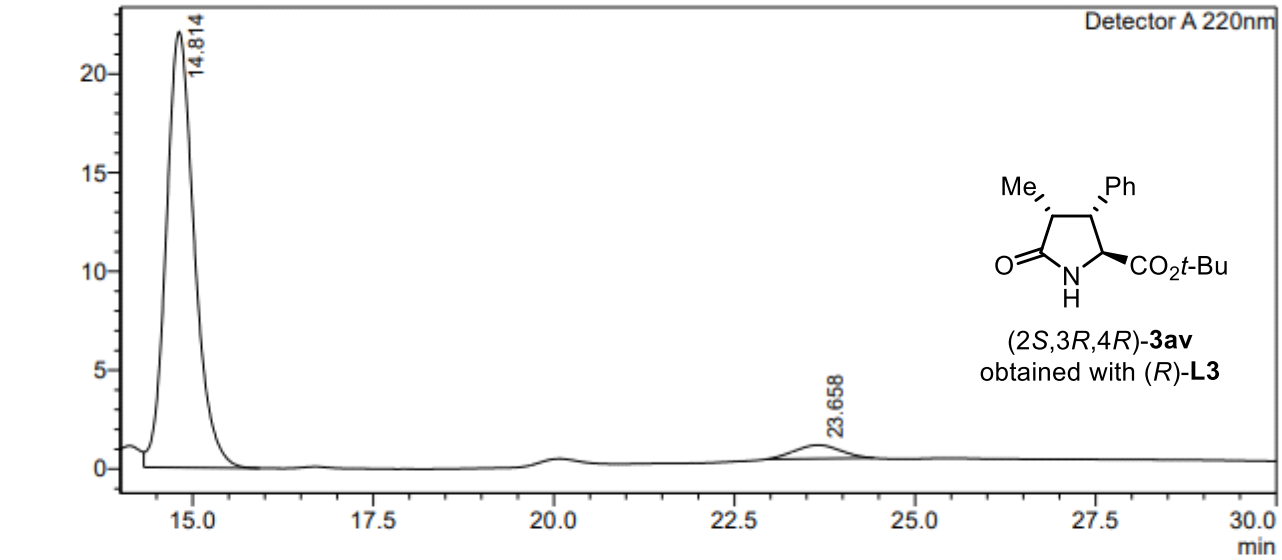


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.920	15988	599	3.509			
2	23.786	439658	9919	96.491			
Total		455646	10518				

<Chromatogram>



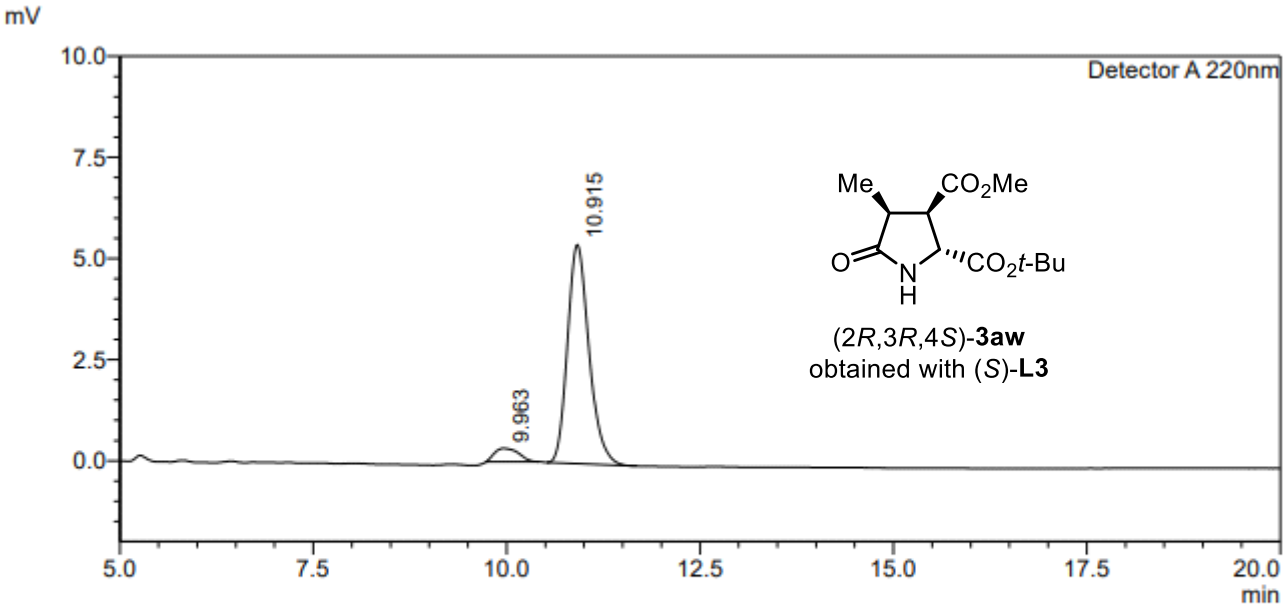
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	14.814	597841	22074	95.188			
2	23.658	30222	685	4.812			
Total		628063	22759				

<Table 3, 3w>

<Chromatogram>



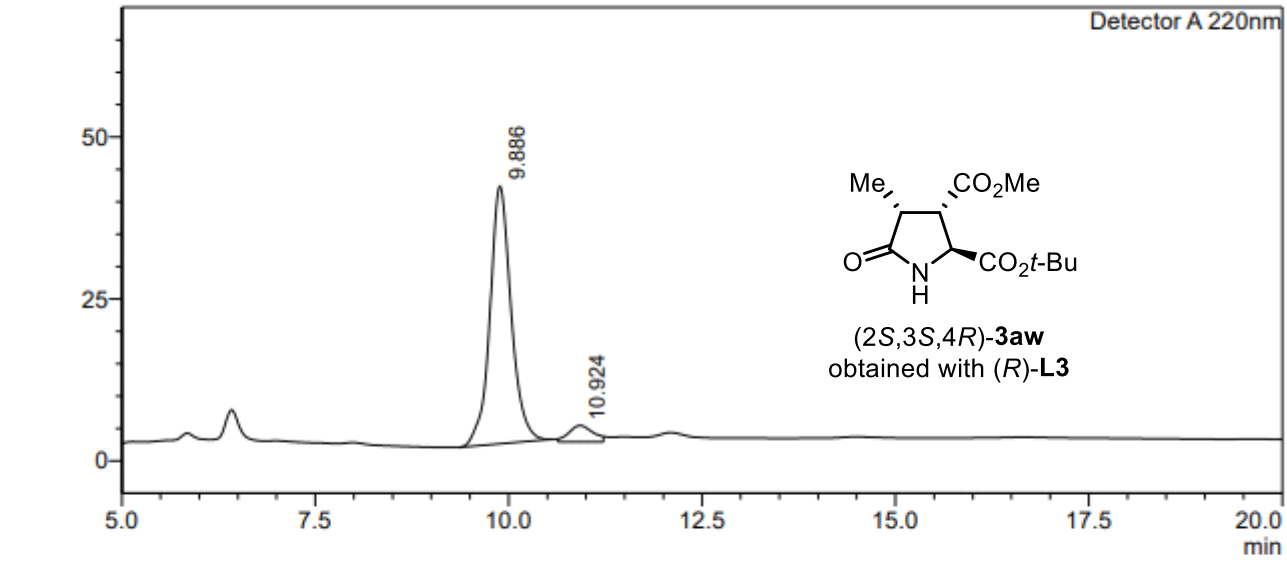
(2*R*,3*R*,4*S*)-**3aw**
obtained with (*S*)-**L3**

<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.963	7210	331	6.415			
2	10.915	105188	5410	93.585			
Total		112398	5740				

<Chromatogram>



(2*S*,3*S*,4*R*)-**3aw**
obtained with (*R*)-**L3**

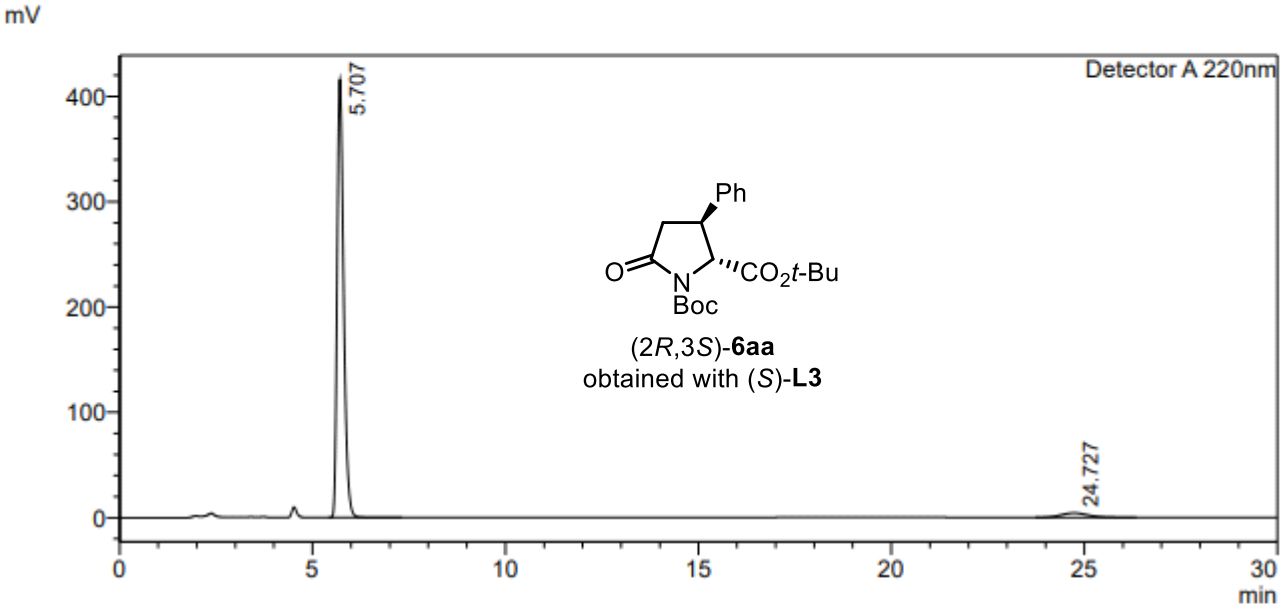
<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	9.886	759682	39752	93.176			
2	10.924	55634	2528	6.824			
Total		815316	42279				

<Scheme 3, 6aa>

<Chromatogram>

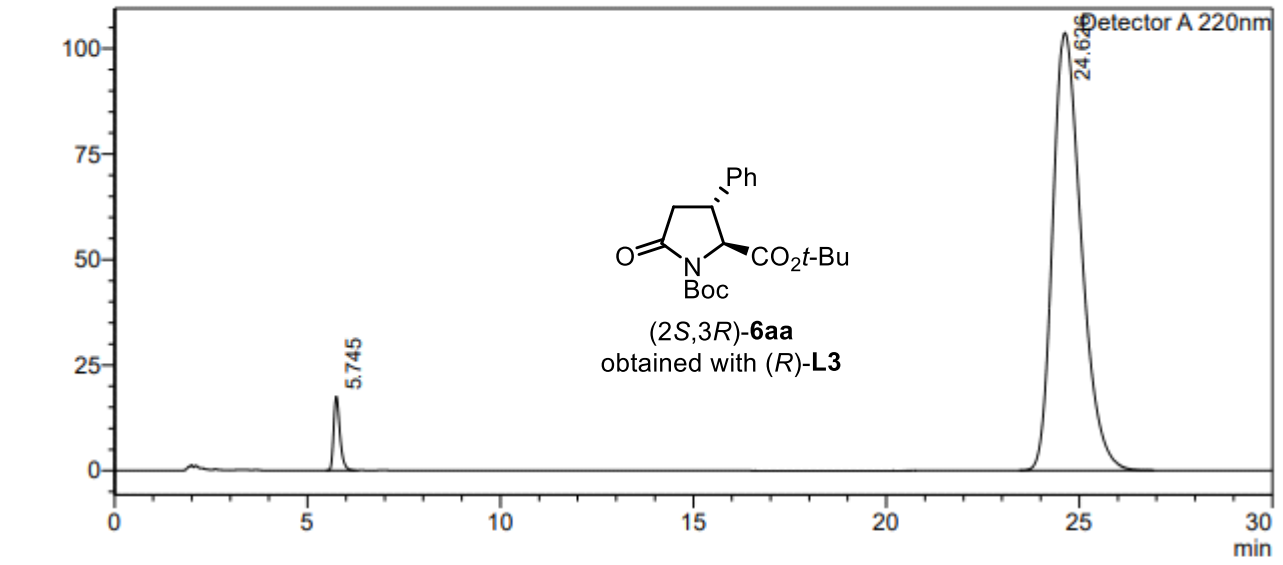


<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	5.707	4905725	415573	95.959		S	
2	24.727	206588	4205	4.041			
Total		5112313	419778				

<Chromatogram>



<Peak Table>

Detector A 220nm

Peak#	Ret. Time	Area	Height	Conc.	Unit	Mark	Name
1	5.745	200604	17511	3.620			
2	24.626	5340631	103686	96.380			
Total		5541235	121196				

IX. References

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