Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Catalytic Asymmetric Propargyl- and Allylboration of Hydrazonoesters. A Metal-free Approach to Sterically Encumbered Chiral α-Amino Acid Derivatives

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Contents:

General Information

Boronic acids **3a-g**[1, 2] and hydrazonoester **2**[3] were synthesized according to methods previously reported in literature. All other chemicals were obtained from commercial sources and used as received. Dry degassed toluene and activated molecular sieves (3Å pellets) were stored in an argon-filled glove box. ^{1}H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ (internal standard: 7.26 ppm, ^{1}H; 77.16 ppm, ^{13}C) using 400 MHz and 500 MHz spectrometers. High resolution mass data (HRMS) were obtained using the ESI technique. For column chromatography, silica gel (35-70 microns) was used. TLC was performed on aluminium backed plates pre-coated (0.25 mm) with Silica Gel 60 F254 with a suitable solvent system and was visualized using UV fluorescence and/or developed with phosphomolybdic acid or permanganate stain. Chiral SFC was performed using Chiralpak IF, Chiralpak IB, Chiralpak IA, Chiralpak OJ-H, Chiralpak AS-H, Chiralpak IC, and Chiralpak OZ-H columns (4.6 × 250 mm × 5 μm) eluting with MeOH/CO_2 and monitored by DAD (Diode Array Detector). Retentions times (t_R) are quoted in minutes. Optical rotation was measured on a AUTOPOL IV polarimeter.

Experimental Procedures and Spectral Data

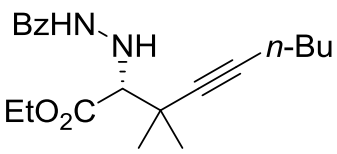
Synthesis of Boronic Acids 3a-g: Allenyl and allylboronic acids **3a-g** were synthesized according to previously described literature methods.[1, 2]

Synthesis of Hydrazonoester 2: Hydrazonoester **2** was synthesized according to a modified literature method.[3] Ethyl glyoxalate (1.2 equiv) in toluene was added to benzoyl hydrazide (1 equiv) in THF. The reaction mixture was stirred overnight during which the product precipitated. The product was filtered off, washed with Et_2O, pentanes, and dried *en vacuo*.

General Procedure for Asymmetric Propargylboration and Allylboration of 2:

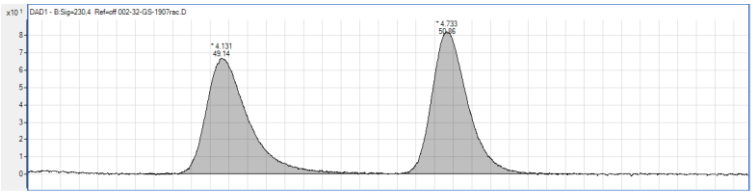
To a screw capped glass vial (2.0 mL) under air was added BINOL **1a** (2.9 mg, 0.01 mmol) and hydrazonoester **2** (22 mg, 0.1 mmol) and was equipped with a magnetic stirrer. The vial was taken inside of an Ar-filled glove box and molecular sieves (3 Å) (30-40 mg) and degassed anhydrous toluene were added. The vial was removed from the glove box and placed in a cooling bath set on a stir plate at 0 °C. Boronic acid **3** (0.12 mmol, solution in toluene) was added was

added via syringe dropwise. The reactions were allowed to stir for the times given in Table 2. Subsequently, the crude product was purified by silica gel chromatography.



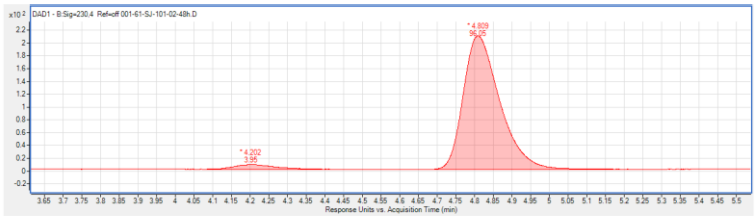
Ethyl (R)-2-(2-benzoylhydrazinyl)-3,3-dimethylnon-4-ynoate (4a) The compound was prepared according to the above general procedure. Product **4a** was isolated in 79% yield (27.3 mg, 0.079 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{24}$ +8.605 (*c* 0.43, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.82 (s, 1H), 7.71-7.69 (m, 2H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.4 Hz, 2H), 4.69 (bs, 1H), 4.30-4.16 (m, 2H), 3.63 (s, 1H), 2.19 (t, *J* = 7.0 Hz, 2H), 1.52-1.44 (m, 2H), 1.42-1.39 (m, 2H), 1.39 (s, 3H), 1.29 (s, 3H), 1.28 (t, *J* = 7.1 Hz, 3H), 0.89 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.3, 167.0, 132.9, 132.0, 128.8, 127.0, 83.7, 83.2, 71.3, 61.1, 34.3, 31.2, 27.9, 26.0, 22.1, 18.6, 14.4, 13.8; **HRMS** (pos. ESI) m/z: calcd. for $C_{20}H_{28}N_2NaO_3$ $[M+Na]^+$ 367.1992. Found, 367.1992.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm *ϕ*, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 4.20 min (minor enantiomer), 4.81 min (major enantiomer); *ee* (major enantiomer) = 92% (e.r. = 96 : 4)



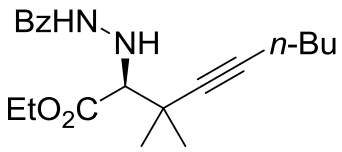
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	3.926	4.131	4.572	66.75	520.36	49.14
2	4.585	4.733	5.064	82	538.64	50.86



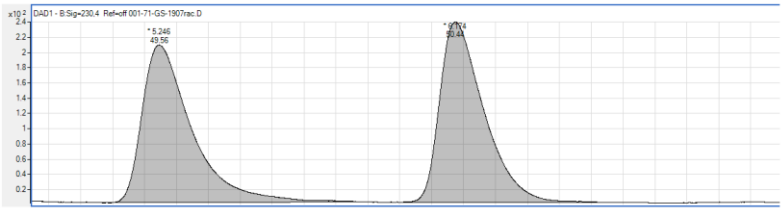
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	4.074	4.202	4.51	7.44	58.4	3.95
2	4.626	4.809	5.251	208.59	1420.26	96.05



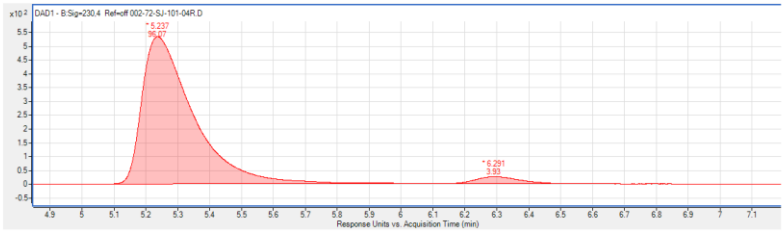
Ethyl (S)-2-(2-benzoylhydrazinyl)-3,3-dimethylnon-4-ynoate (4b) The compound was prepared according to the above general procedure. Product **4b** was isolated in 81% yield (27.9 mg, 0.081 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{25}$ -8.095 (*c* 0.42, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.80 (s, 1H), 7.71-7.69 (m, 2H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 4.30-4.16 (m, 2H), 3.63 (s, 1H), 2.19 (t, *J* = 7.0 Hz, 2H), 1.52-1.44 (m, 2H), 1.42-1.37 (m, 2H), 1.39 (s, 3H), 1.29 (s, 3H), 1.28 (t, *J* = 7.1 Hz, 3H), 0.89 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.3, 167.0, 132.9, 132.0, 128.8, 127.0, 83.7, 83.2, 71.3, 61.1, 34.3, 31.2, 27.9, 26.0, 22.1, 18.6, 14.4, 13.8; **HRMS** (pos. ESI) m/z: calcd. for $C_{20}H_{28}N_2NaO_3$ $[M+Na]^+$ 367.1992. Found, 367.2000.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm ϕ, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 5.24 min (major enantiomer), 6.29 min (minor enantiomer); *ee* (major enantiomer) = 92% (e.r. = 96 : 4)



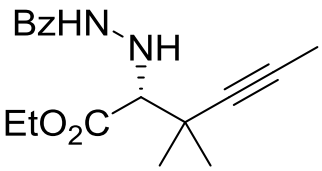
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	5.059	5.246	5.906	206.74	2233.52	49.56
2	6	6.174	6.688	236.9	2273.18	50.44



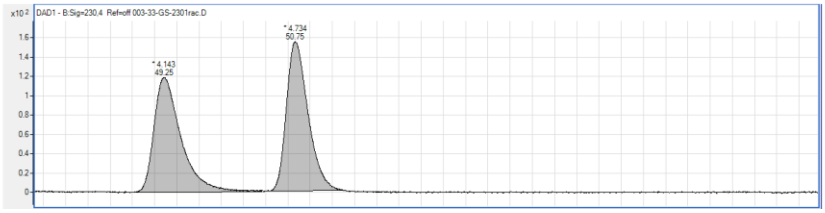
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	5.047	5.237	5.992	533.74	5933.49	96.07
2	6.127	6.291	6.584	25.21	242.97	3.93



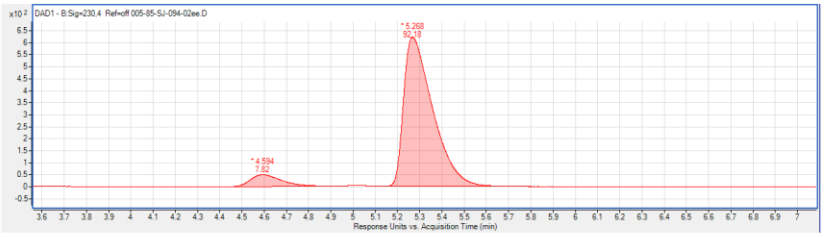
Ethyl (R)-2-(2-benzoylhydrazinyl)-3,3-dimethylhex-4-ynoate (4c) The compound was prepared according to the above general procedure. Product **4c** was isolated in 66% yield (19.8 mg, 0.066 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{21}$ +14.200 (*c* 0.50, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.86 (bs, 1H), 7.72-7.70 (m, 2H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 4.77 (bs, 1H), 4.31-4.16 (m, 2H), 3.63 (s, 1H), 1.83 (s, 3H), 1.38 (s, 3H), 1.28 (s, *J* = 3H), 1.28 (t, *J* = 7.12 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.3, 167.1, 132.9, 132.0, 128.8, 127.0, 82.9, 78.5, 71.3, 61.1, 34.3, 27.9, 25.9, 14.4, 3.8; **HRMS** (pos. ESI) m/z: calcd. for $C_{17}H_{22}N_2NaO_3$ $[M+Na]^+$ 325.1523. Found, 325.1529.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm *ϕ*, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 4.59 min (minor enantiomer), 5.27 min (major enantiomer); *ee* (major enantiomer) = 84% (e.r. = 92 : 8)



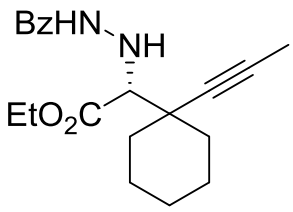
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	3.956	4.143	4.582	119.05	1011.69	49.25
2	4.618	4.734	4.949	154.5	1042.54	50.75

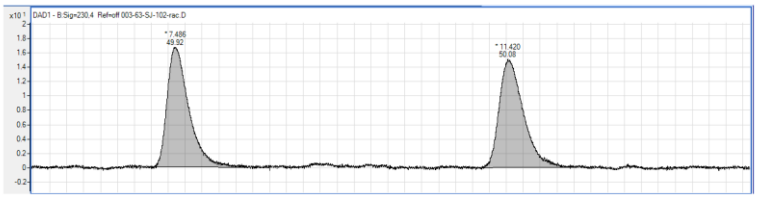


Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	4.401	4.594	4.916	49.46	479.33	7.82
2	5.127	5.268	5.72	621.65	5646.79	92.18

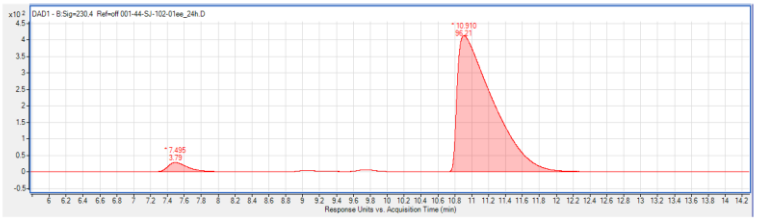


Ethyl (R)-2-(2-benzoylhydrazinyl)-2-(1-(prop-1-yn-1-yl)cyclohexyl)acetate (4d) The compound was prepared according to the above general procedure. Product **4d** was isolated in 63% yield (21.4 mg, 0.063 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\boldsymbol{\alpha}]_{\mathbf{D}}^{\mathbf{25}}$ +13.214 (*c* 0.28, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.83 (s, 1H), 7.71-7.69 (m, 2H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 4.30-4.18 (m, 2H), 3.60 (s, 1H), 1.98 (d, *J* = 11.4 Hz, 1H), 1.87 (s, 3H), 1.79 (d, *J* = 11.9 Hz, 1H), 1.71-1.57 (m, 5H), 1.46 (t, *J* = 12.7 Hz, 1H), 1.36 (dd, *J* = 12.5, 3.7 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.16-1.11 (m, 1H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.4, 167.0, 132.9, 131.9, 128.8, 127.0, 81.2, 80.1, 71.8, 61.1, 40.0, 35.6, 34.4, 26.0, 22.8, 22.8, 14.4, 3.8; **HRMS** (pos. ESI) m/z: calcd. for $C_{20}H_{26}N_2NaO_3$ $[M+Na]^+$ 365.1836. Found, 365.1843. **Determination of *ee*: Chiral SFC** (Diacel IA, 35 bar, 40 °C, 0.46 cm ϕ, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 7.50 min (minor enantiomer), 10.91 min (major enantiomer); *ee* (major enantiomer) = 92% (e.r. = 96 : 4)



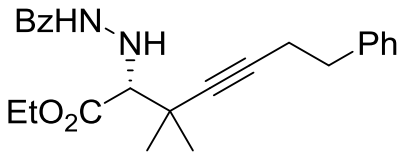
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	7.197	7.486	8.333	16.67	295.88	49.92
2	11.104	11.42	12.201	15.09	296.79	50.08



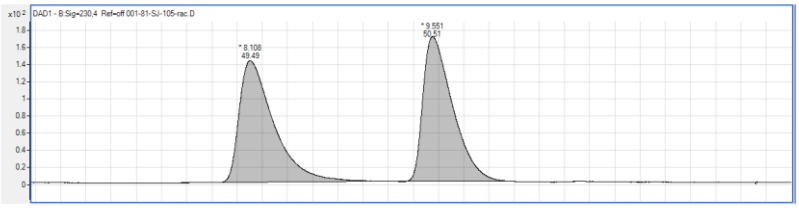
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	7.095	7.495	8.314	28.21	472.96	3.79
2	10.7	10.91	12.302	412.13	11996.12	96.21



Ethyl (R)-2-(2-benzoylhydrazinyl)-3,3-dimethyl-7-phenylhept-4-ynoate (4e) The compound was prepared according to the above general procedure. Product **4e** was isolated in 66% yield (26.1 mg, 0.066 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{24}$ +7.111 (*c* 0.45, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.76 (s, 1H), 7.71-7.68 (m, 2H), 7.51 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 2H), 7.29-7.22 (m, 4H), 7.18 (t, *J* = 7.0 Hz, 1H), 5.33. (bs, 1H), 4.30-4.15 (m, 2H), 3.63 (s, 1H), 2.83 (t, *J* = 7.5 Hz, 2H), 2.50 (t, *J* = 7.5 Hz, 2H), 1.37 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.27 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.3, 167.1, 140.9, 132.9, 132.0, 128.8, 128.7, 128.4, 127.0, 126.3, 84.7, 82.3, 71.2, 61.1, 35.4, 34.3, 27.9, 25.8, 21.1, 14.4; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{24}H_{28}N_2NaO_3$ $[M+Na]^+$ 415.1992. Found, 415.1990.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm ϕ, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 8.41 min (minor enantiomer), 9.69 min (major enantiomer); *ee* (major enantiomer) = 90% (e.r. = 95 : 5)



Integration Peak List

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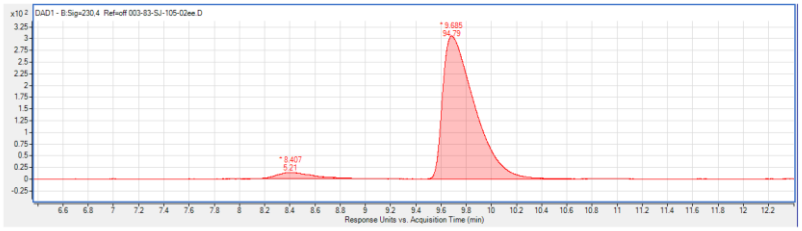
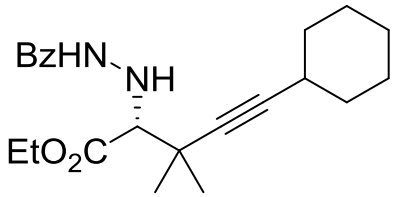
1	7.544	8.108	9.135	141.95	2705.56	49.49
2	9.284	9.551	10.188	169.01	2761.83	50.51



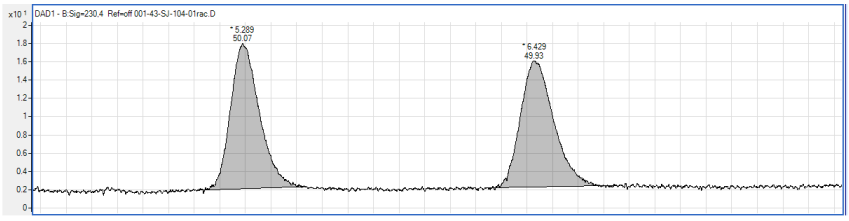
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	8.019	8.407	9.219	13.68	293.62	5.21
2	9.449	9.685	10.649	305.15	5344.31	94.79



Ethyl (R)-2-(2-benzoylhydrazinyl)-5-cyclohexyl-3,3-dimethylpent-4-ynoate (4f) The compound was prepared according to above general procedure. Product **4f** was isolated in 56% yield (20.8 mg, 0.056 mmol) as a solid using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. **Melting point** 107 °C. $[\alpha]_D^{25}$ +14.800 (*c* 0.25, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.72-7.69 (m, 1H + 2H, overlapping), 7.50 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 2H), 4.31-4.18 (m, 2H), 3.64 (s, 1H), 2.42-2.40 (m, 1H), 1.80-1.78 (m, 2H), 1.73-1.68 (m, 2H), 1.53-1.42 (m, 3H), 1.40 (s, 3H), 1.33-1.26 (m, 3H), 1.30 (s, 3H), 1.29 (t, *J* = 7.12 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 171.3, 167.0, 133.0, 132.0, 128.8, 127.0, 87.6, 83.7, 71.3, 61.2, 34.2, 33.0, 29.1, 28.0, 26.1, 25.0, 14.4; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{22}H_{30}N_2NaO_3$ $[M+Na]^+$ 393.2149. Found, 393.2150.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm ϕ, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 5.35 min (minor enantiomer), 6.53 min (major enantiomer); *ee* (major enantiomer) = 91% (e.r. = 96 : 4)



Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
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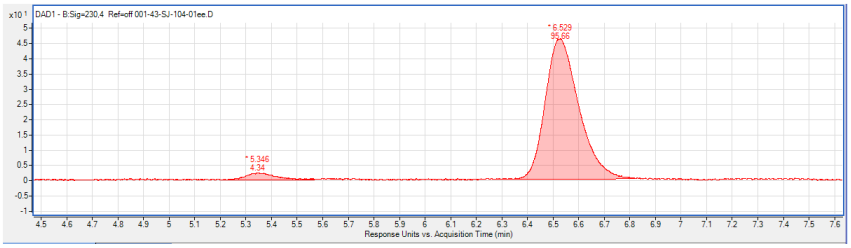
2	6.246	6.429	6.743	13.81	124.06	49.93



Integration Peak List

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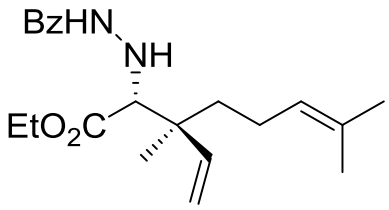
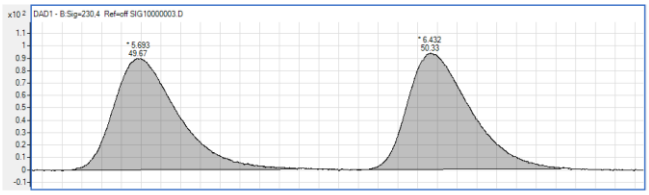
2	6.296	6.529	6.826	46.05	421.06	95.66



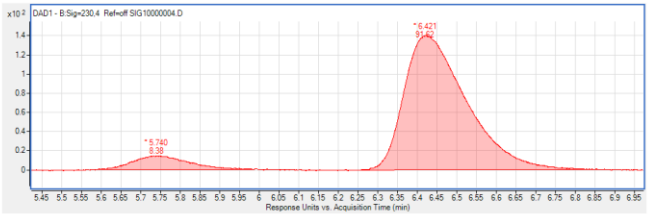
Ethyl (2R,3S)-2-(2-benzoylhydrazinyl)-3,7-dimethyl-3-vinyloct-6-enoate (4g) The compound was prepared according to the above general procedur. Product **4g** was isolated in 71% yield (25.6 mg, 0.071 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{21}$ +16.857 (*c* 0.35, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.70-7.68 (m, 2H + 1H, overlapping), 7.50 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 5.91 (dd, *J* = 17.6, 11.0 Hz, 1H), 5.17 (d, *J* = 10.8 Hz, 1H), 5.08 (s, 1H), 5.07 (d, *J* = 17.1 Hz, 1H), 4.26-4.10 (m, 2H), 3.59 (s, 1H), 1.98-1.92 (m, 2H), 1.66 (s, 3H), 1.61-1.45 (m, *J* = 2H), 1.58 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H), 1.21 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 172.2, 167.3, 142.3, 132.8, 132.0, 131.7, 128.8, 127.0, 124.4, 114.7, 71.4, 60.9, 43.0, 37.8, 25.8, 22.7, 19.3, 17.7, 14.4; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{21}H_{30}N_2NaO_3$ $[M+Na]^+$ 381.2149. Found, 381.2149.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm *ϕ*, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 5.74 min (major diastereomer, minor enantiomer), 6.42 (major diastereomer, major enantiomer); *ee* (major diastereomer) = 83% (e.r. = 92 : 8)



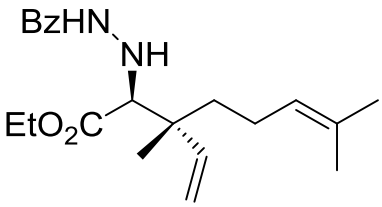
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	5.479	5.693	6.096	89.68	1012.01	49.67
2	6.241	6.432	6.781	93.65	1025.28	50.33



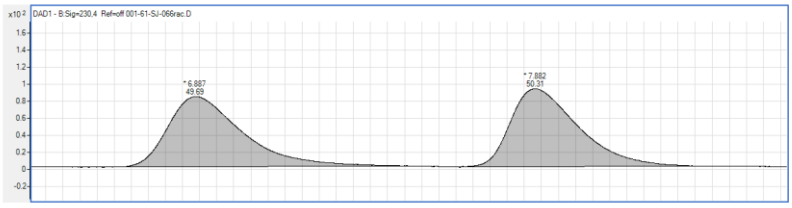
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	5.576	5.74	5.987	14.19	139.96	8.38
2	6.233	6.421	6.857	140.27	1529.81	91.62



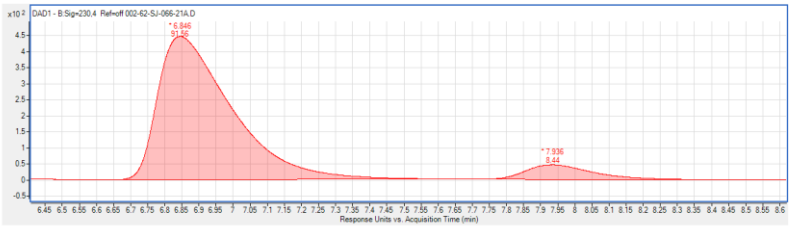
Ethyl (2S,3R)-2-(2-benzoylhydrazinyl)-3,7-dimethyl-3-vinyloct-6-enoate (4h) The compound was prepared according to the above general procedure. Product **4h** was isolated in 78% yield (28.0 mg, 0.078 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{21}$ -14.947 (*c* 0.48, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.70-7.68 (m, 2H + 1H, overlapping), 7.50 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 5.90 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.17 (dd, *J* = 10.9, 0.9 Hz, 1H), 5.07 (s, 1H), 5.07 (d, *J* = 17.2 Hz, 1H), 4.26-4.13 (m, 2H), 3.59 (s, 1H), 1.98-1.92 (m, 2H), 1.66 (s, 3H), 1.58 (s, 3H), 1.56-1.45 (m, 2H), 1.25 (t, *J* = 7.1 Hz, 3H), 1.21 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 172.2, 167.3, 142.3, 132.8, 132.0, 131.7, 128.8, 127.0, 124.4, 114.8, 71.4, 60.9, 43.0, 37.8, 25.8, 22.6, 19.3, 17.8, 14.4; **HRMS** (pos. ESI) m/z: calcd. for $C_{21}H_{30}N_2NaO_3$ $[M+Na]^+$ 381.2149. Found, 381.2135.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm *ϕ*, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 6.85 min (major diastereomer, major enantiomer), 7.94 (major diastereomer, minor enantiomer); *ee* (major diastereomer) = 83% (e.r. = 92 : 8)



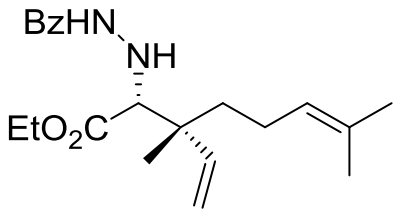
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	6.494	6.887	7.539	82.26	1238.22	49.69
2	7.635	7.882	8.516	91.13	1253.68	50.31



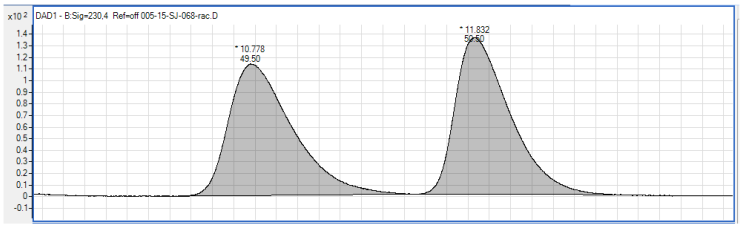
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	6.614	6.846	7.606	445.81	6674.32	91.56
2	7.699	7.936	8.473	45.16	614.85	8.44



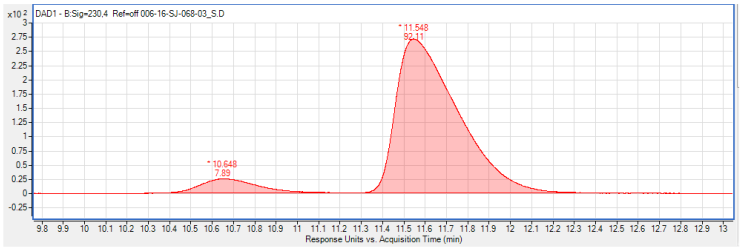
Ethyl (2R,3R)-2-(2-benzoylhydrazinyl)-3,7-dimethyl-3-vinyloct-6-enoate (4i) The compound was prepared according to the above general procedure. Product **4i** was isolated in 81% yield (29.2 mg, 0.081 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{19}$ +30.435 (*c* 0.58, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.72-7.68 (m, 2H + 1H, overlapping), 7.50 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 5.96 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.30 (d, *J* = 10.8 Hz, 1H), 5.18 (d, *J* = 17.4 Hz, 1H), 5.06 (t, *J* = 7.0 Hz, 1H), 4.29-4.19 (m, 2H), 3.71 (s, 1H), 1.99-1.93 (m, 2H), 1.66 (s, 3H), 1.58 (s, 3H), 1.51-1.46 (m, *J* = 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.13 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 172.0, 167.5, 142.5, 132.7, 132.1, 131.7, 128.8, 127.0, 124.4, 115.8, 69.8, 61.0, 43.2, 38.9, 25.8, 22.6, 18.0, 17.8, 14.5; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{21}H_{30}N_2NaO_3$ $[M+Na]^+$ 381.2149. Found, 381.2151.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 ºC, 0.46 cm *ϕ*, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 10.65 min (major diastereomer, minor enantiomer), 11.55 (major diastereomer, major enantiomer); *ee* (major diastereomer) = 84% (e.r. = 92 : 8)



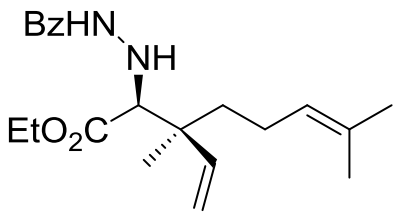
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	10.324	10.778	11.546	113.44	2357.73	49.5
2	11.574	11.832	12.48	135.09	2404.97	50.5



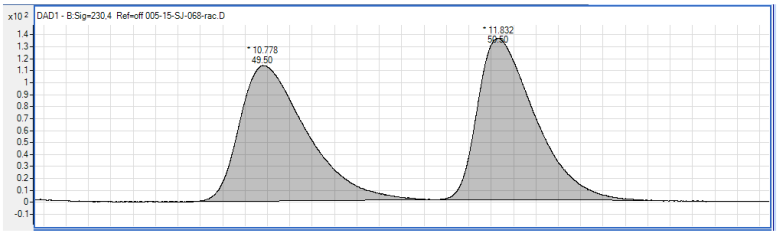
Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	10.286	10.648	11.151	25.32	463.97	7.89
2	11.308	11.548	12.366	270.4	5419.01	92.11



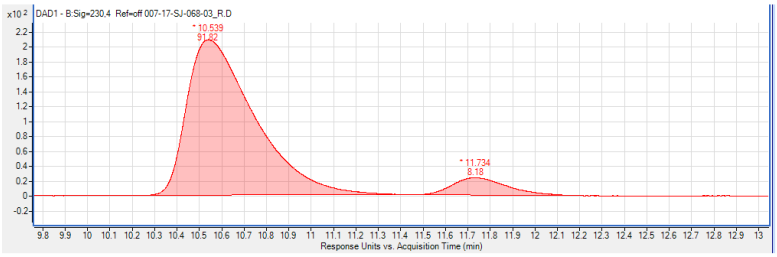
Ethyl (2S,3S)-2-(2-benzoylhydrazinyl)-3,7-dimethyl-3-vinyloct-6-enoate (4j) The compound was prepared according to the above general procedure. Product **4j** was isolated in 75% yield (27.0 mg, 0.075 mmol) as an oil using Pet. Ether:EtOAc:TEA (75:25:0.5) as eluent for silica gel chromatography. $[\alpha]_D^{18}$ -35.810 (*c* 0.53, $CHCl_3$); **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.72-7.68 (m, 2H + 1H, overlapping), 7.50 (t, *J* = 7.4 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 2H), 5.96 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.30 (d, *J* = 10.8 Hz, 1H), 5.18 (d, *J* = 17.4 Hz, 1H), 5.06 (t, *J* = 7.0 Hz, 1H), 4.31-4.18 (m, 2H), 3.71 (s, 1H), 1.99-1.93 (m, 2H), 1.66 (s, 3H), 1.58 (s, 3H), 1.51-1.46 (m, *J* = 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.13 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 172.0, 167.5, 142.5, 132.7, 132.0, 131.7, 128.8, 127.0, 124.4, 115.8, 69.8, 61.0, 43.2, 38.9, 25.8, 22.6, 18.0, 17.8, 14.5; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{21}H_{30}N_2NaO_3$ $[M+Na]^+$ 381.2149. Found, 381.2145.

Determination of *ee*: Chiral SFC (Diacel IA, 35 bar, 40 °C, 0.46 cm ϕ, 25 cm column, 10% MeOH in CO_2, flow rate: 2.0 mL/min; t_R: 10.54 min (major diastereomer, major enantiomer), 11.73 (major diastereomer, minor enantiomer); *ee* (major diastereomer) = 84% (e.r. = 92 : 8)



Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	10.324	10.778	11.546	113.44	2357.73	49.5
2	11.574	11.832	12.48	135.09	2404.97	50.5



Integration Peak List

Peak	Start	RT	End	Height	Area	AreaSumPercent
1	10.247	10.539	11.395	208.38	4357.05	91.82
2	11.45	11.734	12.183	23.12	388.29	8.18

Determination of the Absolute Stereochemistry

The absolute stereochemistry of product **4a** was determined using the Mosher amide NMR method[4,5]. Hydrazine **4a** was transformed into amino ester **5a** according to a procedure reported by Burk and co-workers.[6] Then, amino ester **5a** was derivatized to the corresponding (*R*)-MPTA amide **7a** using (*S*)-MPTA-Cl **6a**. In the same way, the (*S*)-MPTA amide **7b** was obtained from **5a** and (*R*)-MPTA-Cl **6b** (Figure 1).

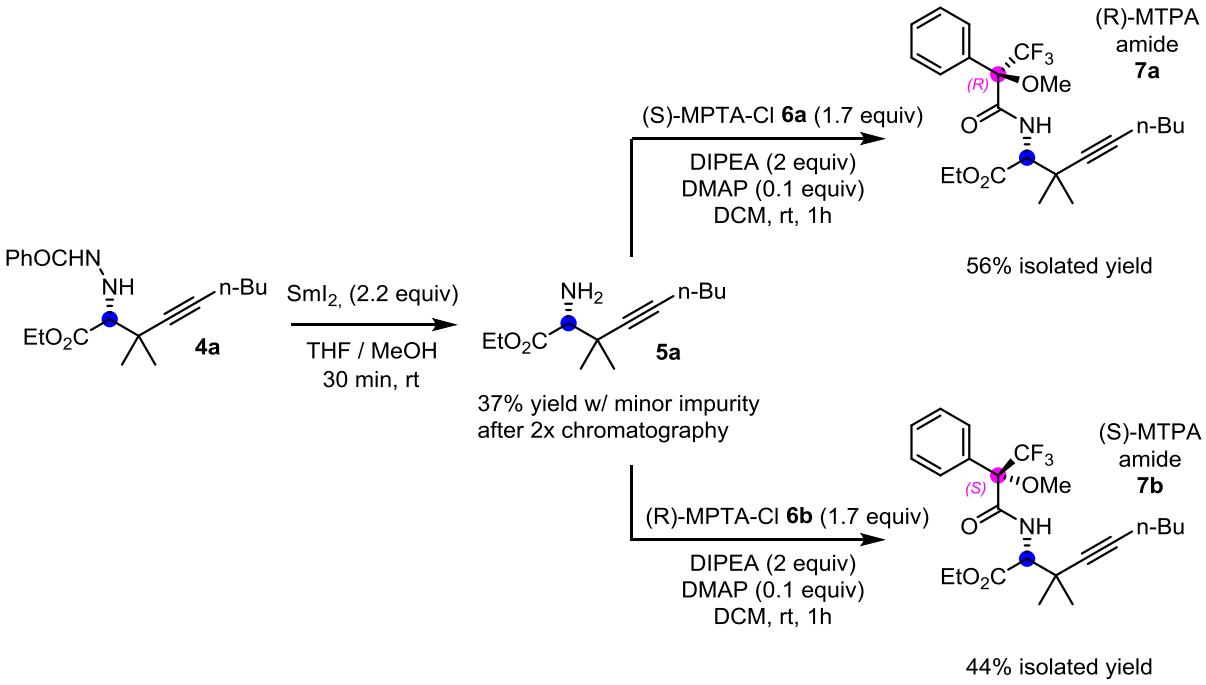


Figure 1. Derivatisation of **4a** for determination of the absolute configuration (indicated by blue dot) by the Mosher- method.

The difference in ^{1}H NMR shift between the (*S*)-MPTA amide **7b** and the (*R*)-MPTA amide **7a** was used to determine the absolute configuration at the stereogenic tertiary carbon in amino ester **5a**. Figure 2 below shows the chemical shifts that were found for the (*S*)-MPTA amide **7b** and the (*R*)-MPTA amide **7a**. The difference between these shifts $\Delta\delta^{SR}$ is calculated by δ(S) - δ(R). As is shown, $\Delta\delta^{SR}$ has the opposite sign for the two enantiotopic groups on the stereogenic tertiary carbon.

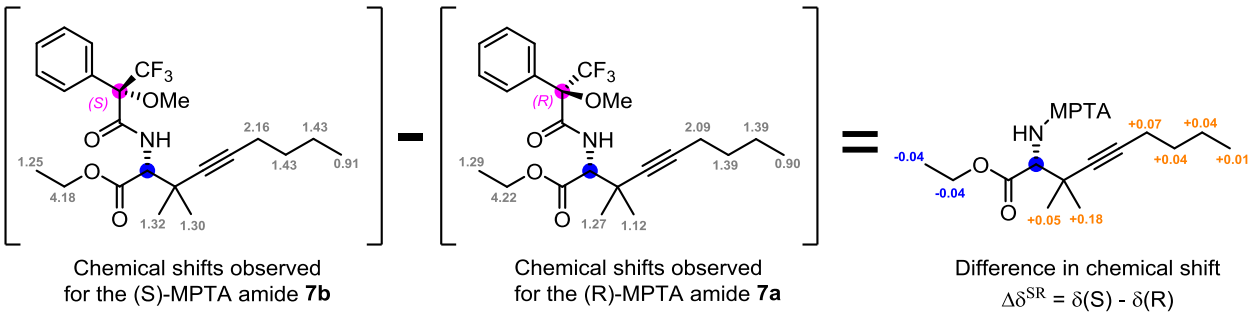


Figure 2. Differences of the chemical shifts between the two diastereomeric derivatives of **4a**. The sign of the difference $\Delta\delta^{SR}$ is diagnostic for the abosolute configuration of the aminoacid carbon (blue dot).

In Figure 3 a simplified version of amino ester **5a** is shown, where the enantiotopic groups are represented by R^1 (blue) and R^2 (orange). If the amino acid carbon in **7a-b** (and **4a**, **5a**) has an R-configuration than the $\Delta\delta^{SR}$ will be positive for R^1, and negative for R^2 in **7b**. The reason is the anistropic shielding of R^1 by the phenyl group of (S)-MPTA moiety (arising from **6b**) in **7b**.[4,5] Likewise, in **7a** R^2 is positive, as it is shielded by the phenyl group of the (R)-MPTA moiety (arising from **6a**). In conclusion, the absolute configuration at the stereogenic tertiary carbon in product **4a** can be unambigiously assigned as *R*. N.B. According to the C.I.P. convention the configuration label (R, S) of the corresponding stereocenters (magenta dot) in **6b** and **7b** (also in **6a-7a**) is different, despite the fact that the absolute configuration of this carbon is the same.

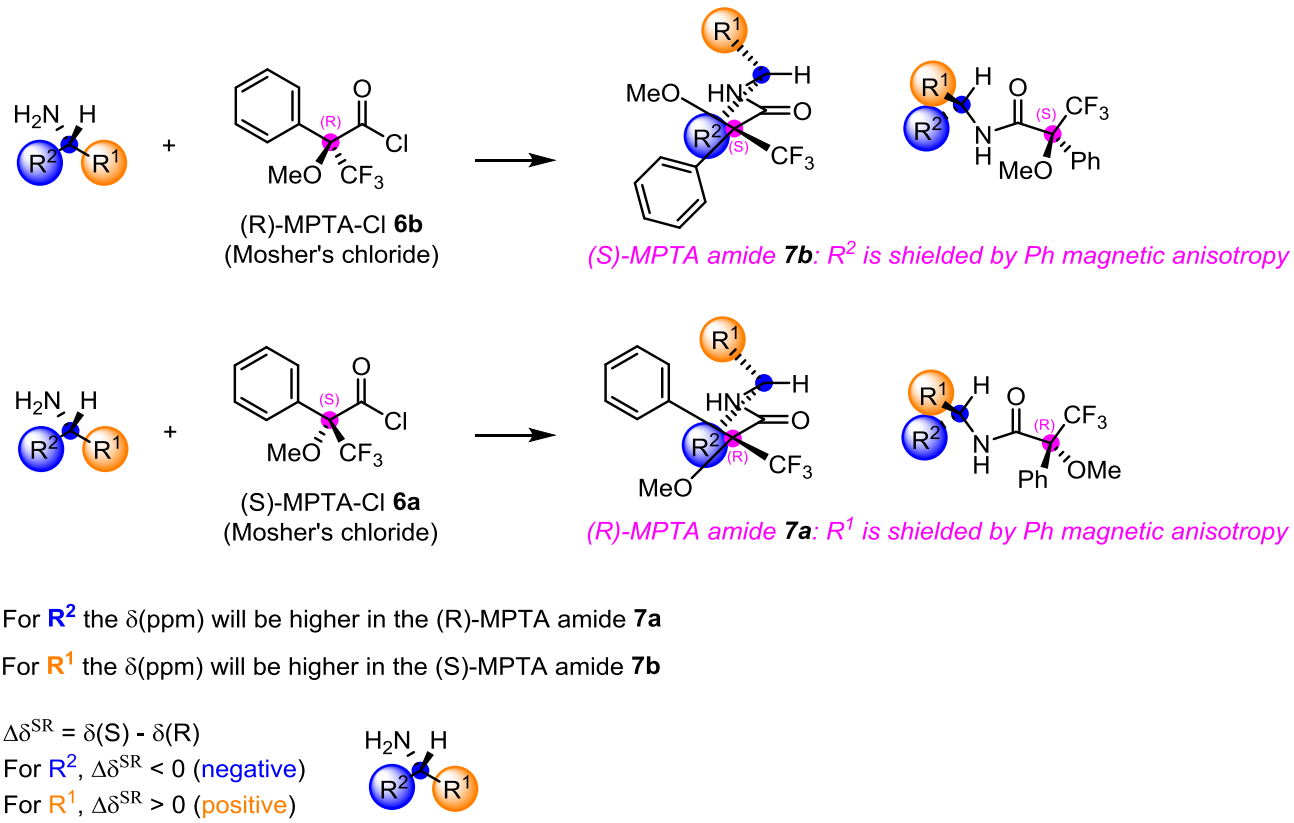


Figure 3. Explanation of the different sign of $\Delta\delta^{SR}$ in the two diastereomers **7a-b**.

A similar Mosher amide analysis was also performed for allyl hydrazine **4g**. The corresponding free amino ester **5b** was obtained and isolated, from which the MPTA amides were prepared (Figure 4).

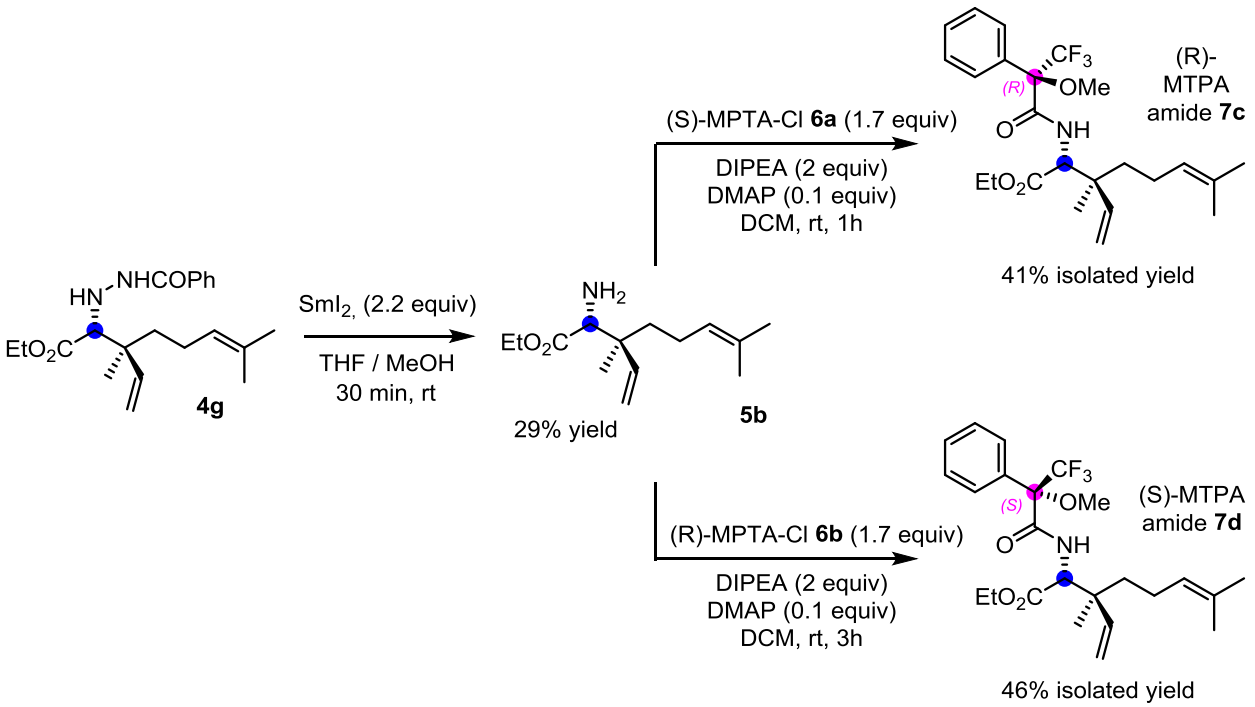


Figure 4. Derivatisation of allyl derivative **4g** for determination of the absolute configuration of the amino-acid carbon (indicated by blue dot) by the Mosher- method.

Based on the sign of the $\Delta\delta^{SR}$ the absolute configuration at the stereogenic tertiary carbon in product **4g** can be unambigiously assigned as *R*.

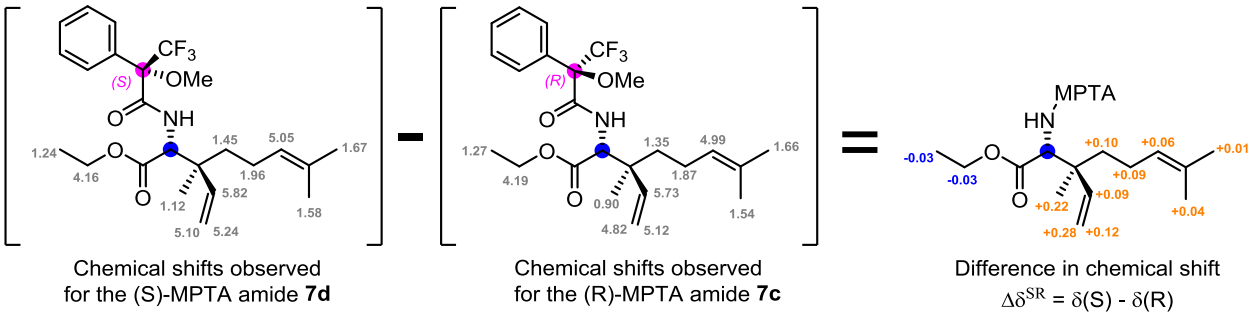
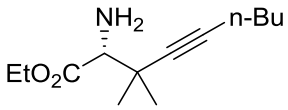
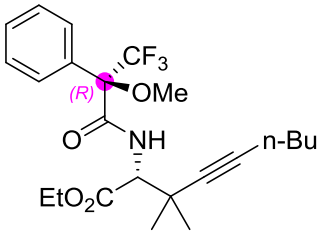


Figure 5. $\Delta\delta^{SR}$ values for allyl aminoacid derivatives (blue dot).

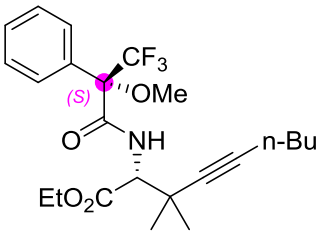
Considering the similar similar structure and formation (using S-BINOL **1a**) of products **4a** and **4c-f** as well as **4g** and **4i** and the absolute configuration of the α-amino acid carbon is assigned to R-configuration. In case of the products obtained by the R-BINOL catalyst (**4b**, **4h** and **4j**) the S-configuration is assigned to the α-amino acid carbon.



Ethyl (R)-2-amino-3,3-dimethylnon-4-ynoate (5a) The compound was prepared according to a previously described literature method.[6] . Product **5a** was obtained in 37 % yield (24.2 mg, 0.107 mmol) as an oil using Pet. Ether:EtOAc:TEA (1:2:0.05) as eluent for silica gel chromatography. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.17 (q, *J* = 7.2 Hz, 2H), 3.70 (s, *impurity*), 3.26 (s, 1H), 2.14 (t, *J* = 6.9 Hz, 2H), 1.77 (bs, 2H), m (1.49-1.33, 4H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.27 (s, 3H), 1.19 (s, 3H), 0.89 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): δ 173.3, 84.1, 82.6, 63.0, 60.7, 51.7 (*impurity*), 36.3, 31.2, 27.4, 25.5, 22.0, 18.5, 14.4, 13.7; **HRMS** (pos. ESI) m/z: Calcd for $C_{13}H_{23}NO_2$ $[M+H]^+$ 226.1802. Found, 226.1805.

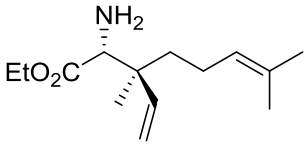


Ethyl (R)-3,3-dimethyl-2-((R)-3,3,3-trifluoro-2-methoxy-2-phenylpropanamido)non-4-ynoate (7a) The compound was prepared according to a previously described literature method [4, 5]. Product **7a** was isolated in 56% yield (12.1 mg, 0.027 mmol) as an oil using Pet. Ether:EtOAc (20:1) as eluent for silica gel chromatography **^{1}H NMR** (400 MHz, $CDCl_3$): δ7.61-7.59 (m, 2H), 7.41-7.37 (m, 3H), 7.32 (d, *J* = 9.1 Hz, 1H), 4.39 (d, *J* = 9.3 Hz, 1H), 4.29-4.16 (m, 2H), 3.55 (d, *J* = 1.6 Hz, 3H), 2.09 (t, *J* = 6.74 Hz, 2H), 1.44-1.33 (m, 4H), 1.29 (t, *J* = 7.5 Hz, 3H), 1.28 (s, 3H), 1.12 (s, 3H), 0.90 (t, *J* = 7.14 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): δ 169.4, 166.1, 132.9, 129.5, 128.4, 127.4, 123.6 (app d, *J* = 289.5 Hz), 84.0 (app d, J = 26.4 Hz), 83.6, 81.8, 61.3, 59.4, 55.3, 55.3, 35.2, 30.9, 28.1, 26.8, 21.8, 18.2, 14.1, 13.6; **^{19}F NMR** (377 MHz, $CHCl_3$): δ 68.91; **HRMS** (pos. ESI) m/z: calcd. for $C_{23}H_{30}F_3NO_4Na$ $[M+Na]^+$ 464.2019 Found, 464.2022.

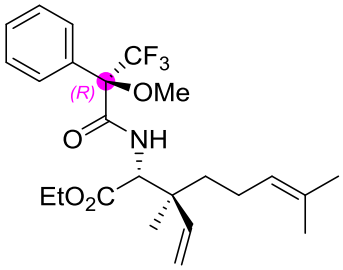


Ethyl (R)-3,3-dimethyl-2-((S)-3,3,3-trifluoro-2-methoxy-2-phenylpropanamido)non-4-ynoate (7b) The compound was prepared according to a previously described literature method [4, 5]. Product **7b** was isolated in 44% yield (9.4 mg, 0.021 mmol) as an oil using Pet. Ether:EtOAc (20:1) as eluent for silica gel chromatography. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.63 (d, *J* = 9.0 Hz, 1H), 7.56-7.54 (m, 2H), 7.42-7.38 (m, 3H),

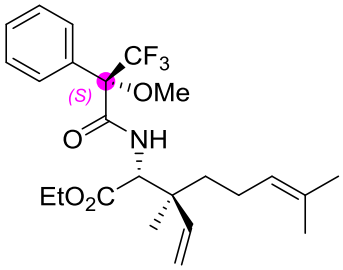
4.40 (d, *J* = 9.2 Hz, 1H), 4.24-4.12 (m, 2H), 3.41 (d, *J* = 1.32 Hz, 3H), 2.16 (t, *J* = 6.84 Hz, 2H), 1.50-1.36 (m, 4H), 1.32 (s, 3H), 1.30 (s, 3H), 1.25 (t, *J* = 7.14 Hz, 3H), 0.91 (t, *J* = 7.16 Hz, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 169.6, 166.2, 132.2, 129.6, 128.7, 128.2, 128.2, 124.0 (app d, *J* = 289.8 Hz), 84.3 (app d, *J* = 26.1 Hz), 83.8, 82.1, 61.4, 59.8, 55.1, 55.1, 35.2, 31.1, 28.3, 27.1, 22.0, 18.4, 14.3, 13.8; **^{19}F NMR** (377 MHz, $CHCl_3$): *δ* 69.10; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{23}H_{30}F_3NO_4Na$ $[M+Na]^+$ 464.2019 Found, 464.2017.



Ethyl (2R,3S)-2-amino-3,7-dimethyl-3-vinyloct-6-enoate (5b) The compound was prepared according to a previously described literature method.[6] . Product **5b** was obtained in 29 % yield (19.0 mg, 0.079 mmol) as an oil using Pet. Ether:EtOAc:TEA (1:2:0.05) as eluent for silica gel chromatography. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 5.81 (dd, *J* = 17.7, 10.9 Hz, 1H), 5.15 (dd, *J* = 10.8, 1.3 Hz, 1H), 5.06 (tt, *J* = 10.6, 1.4, 1.4 Hz, 1H), 5.0 (dd, *J* = 17.5, 1.3 Hz, 1H), 4.14 (dq, *J* = 14.3, 7.1, 0.8 Hz, 2H), 3.27 (s, 1H), 1.97-1.83 (m, 2H), 1.67 (d, *J* = 0.8 Hz, 3H), 1.57 (s, 3H), 1.53-1.31 (m, 2H), 1.26 (t, *J* = 7.1 Hz, 3H), 1.07 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 174.4, 142.5, 131.6, 124.6, 114.8, 62.2, 60.6, 43.9, 38.1, 25.8, 22.8, 18.2, 17.8, 14.4; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{14}H_{26}NO_2$ $[M+H]^+$ 240.1958. Found, 240.1961.



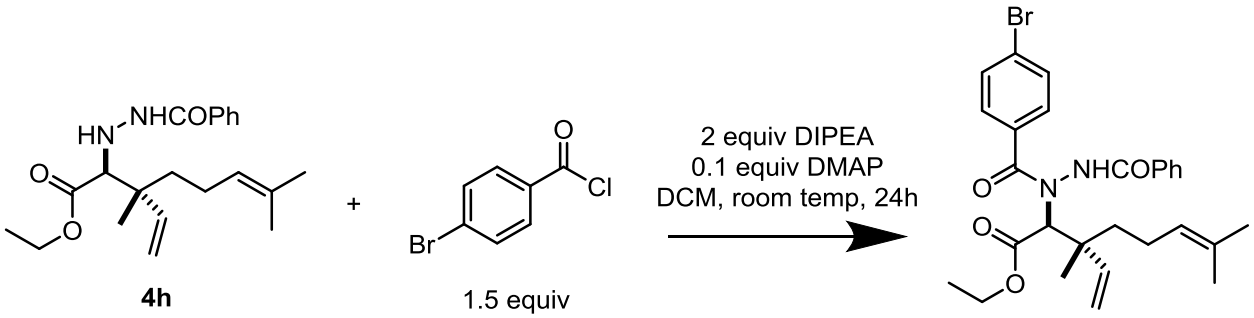
Ethyl (2R,3S)-3,7-dimethyl-2-((R)-3,3,3-trifluoro-2-methoxy-2-phenylpropanamido)-3-vinyloct-6-enoate (7c) The compound was prepared according to a previously described literature method [4, 5]. Product **7c** was isolated in 41% yield (5.5 mg, 0.012 mmol) as an oil using Pet. Ether:EtOAc (20:1) as eluent for silica gel chromatography.**^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.59-7.57 (m, 2H), 7.41-7.37 (m, 3H), 6.94 (d, *J* = 9.5 Hz, 1H), 5.73 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.12 (dd, *J* = 10.8, 1.0 Hz, 1H), 4.99 (t, *J* = 7.0 Hz, 1H), 4.82 (dd, *J* = 17.5, 1.0 Hz, 1H), 4.53 (d, *J* = 9.7 Hz, 1H), 4.25-4.12 (m, 2H), 3.53-3.52 (m, 3H), 1.98-1.78 (m, 2H), 1.66 (s, 3H), 1.54 (s, 3H), 1.44-1.30 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 0.90 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 170.4, 166.3, 141.3, 133.2, 131.9, 129.6, 128.5, 127.4, 124.1, 123.6 (app d, *J* = 289.6 Hz), 115.7, 83.9, 61.4, 58.3, 55.5, 44.0, 38.3, 25.8, 22.7, 18.8, 17.8, 14.3; **^{19}F NMR** (377 MHz, $CHCl_3$): *δ* 68.86; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{24}H_{32}F_3NO_4Na$ $[M+Na]^+$ 478.2182 Found, 478.2176.



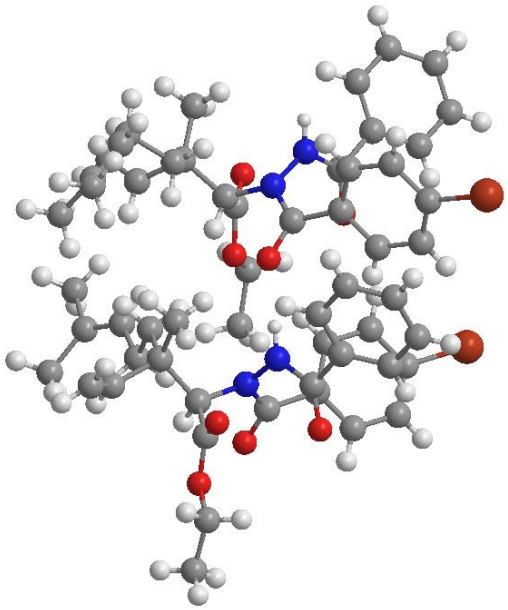
Ethyl (2R,3S)-3,7-dimethyl-2-((S)-3,3,3-trifluoro-2-methoxy-2-phenylpropanamido)-3-vinyloct-6-enoate (7d) The compound was prepared according to a previously described literature method [4, 5]. Product **7d** was isolated in 46% yield (7.0 mg, 0.015 mmol) as an oil using Pet. Ether:EtOAc (20:1) as eluent for silica gel chromatography **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.51-7.49 (m, 2H), 7.40-7.36 (m, 4H), 5.82 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.24 (dd, *J* = 10.8, 1.0 Hz, 1H), 5.10 (dd, *J* = 17.5, 1.0 Hz, 1H), 5.05 (t, *J* = 7.0 Hz, 1H), 4.53 (d, *J* = 9.4 Hz, 1H), 4.22-4.10 (m, 2H), 3.35 (d, *J* = 1.2 Hz, 3H), 2.07-1.85 (m, 2H), 1.67 (s, 3H), 1.58 (s, 3H), 1.56-1.34 (m, 2H), 1.24 (t, *J* = 7.1 Hz, 3H), 1.12 (s, 3H); **^{13}C NMR** (100 MHz, $CHCl_3$): *δ* 170.5, 166.1, 141.4, 132.0, 131.9, 129.6, 128.7, 128.2, 124.1, 124.0 (app d, *J* = 289.7 Hz), 115.9, 84.3 (app d, *J* = 26.5 Hz), 61.3, 58.7, 55.1, 43.7, 38.4, 25.8, 22.7, 19.0, 17.7, 14.3; **^{19}F NMR** (377 MHz, $CHCl_3$): *δ* 69.10; **HRMS** (pos. ESI) m/*z*: calcd. for $C_{24}H_{32}F_3NO_4Na$ $[M+Na]^+$ 478.2182 Found, 478.2176.

Determination of the Relative Stereochemistry by derivatization of 4g

All products **4g-j** were oils at room temperature and resisted crystallization. However, **4h** could be derivatised to give solid product **4h-amide** according to a procedure previously described in the literature [7]. Thus **4h-amide** (15 mg) was slowly recrystallized from 1 mL of EtOH stored at 7 ^{o}C over a period of 3 weeks. The obtained crystals of **4h-amide** were suitable to determine the relative configuration of the two stereocenters by X-ray diffraction.

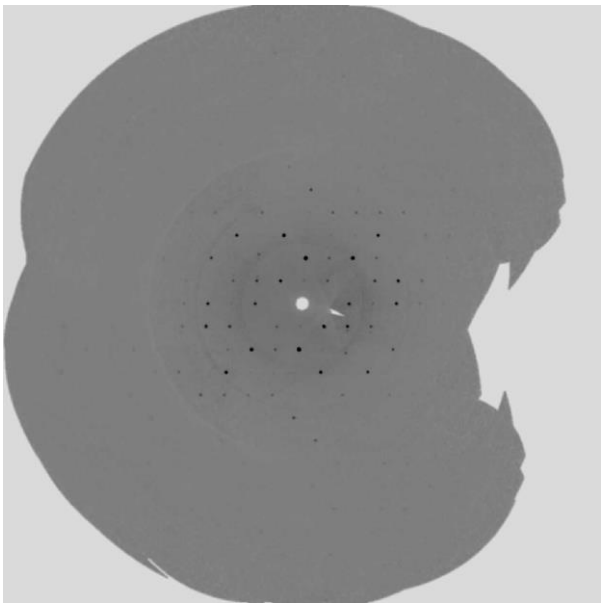


The crystallographic data for **4h-amide** is given in file: 4h_amide.cif. The crystal structure has been deposited at the Cambridge Crystallographic Data Centre and has been assigned deposition number: CCDC 1850578.

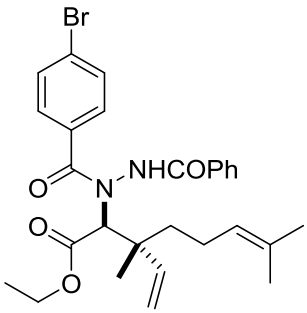


Level B alert "The value of Rint is greater than ..." in the 4h_amid checkcif file

The unusually high Rint is due to the small size and the limited highest angle for significant scattering from these crystals. As shown in the attached reconstruction for the hk0 plane in reciprocal space where the edge is at 0.8 Å one clearly sees that the scattering essentially ceases around 1,5 Å halfway to the center. Thus there is a very large part of reflections that are weak and more or less contributes quite a lot to the internal R-value. With reflection limited to 1.5 Å the Rint is actually quite much lower (0.0695) but then mostly significant reflection has been merged. The high Rint value (caused the B-level alert) does not affect the determination of the relative stereochemistry of 4h_amide, which is given in the paper and SI.



Reconstruction for the hk0 plane in reciprocal space



Ethyl (2S,3R)-2-(2-benzoyl-1-(4-bromobenzoyl)hydrazinyl)-3,7-dimethyl-3-vinyloct-6-enoate (4h-amide). The compound was prepared according to a previously described literature method [7]. Product **4h-amide** was isolated in 47% yield (15.0 mg, 0.028 mmol) as a solid using Pet. Ether:EtOAc (5 : 1) as eluent for silica gel chromatography. **Melting point** 169 °C. **^{1}H NMR** (500 MHz, $CDCl_3$, temp = -18 °C, mixture of two forms): δ 9.33 (s, 0.5H), 7.51-7.38 (m, 9.5H), 6.75 (dd, *J* = 17.8, 10.8 Hz, 0.5H), 5.71 (dd, *J* = 17.2, 10.8 Hz, 0.5H), 5.52 (s, 0.5H), 5.45 (d, *J* = 10.9 Hz, 0.5H), 5.36 (d, *J* = 17.8 Hz, 0.5H), 5.03 (app d, *J* = 7.1 Hz, 1H), 4.91 (d, *J* = 17.3 Hz, 0.5H), 4.76 (d, *J* =

10.8 Hz, 0.5H), 4.40-4.24 (m, 1H), 4.16-4.02 (m, 1H), 2.03-1.93 (m, 1.5H), 1.66 (s, 3H), 1.56 (app d, *J* = 8.1 Hz, 3H), 1.39-1.35 (m, 4.5H), 1.27-1.22 (m, 3.5H); **HRMS** (pos. ESI) m/z: Calcd for $C_{28}H_{33}BrN_2O_4Na$ $[M+Na]^+$ 563.1516. Found, 563.1519.

Proposed catalytic cycle

The process is suppused to be initiated by esterification of **3a** by BINOL to give **INT1** (Figure 6). The boron atom in the BINOL ester is strongly Lewis acidic (electrophilic) and therefore it can relatively easily coordinate to the imino-nitrogen of **2**. Formation of an initial adduct between **INT1** (numbered as **5** in the main text) and **2** probably has two effects: i) preforming the TS structure for the stereoinduction step (Figure 2 in the main text); and ii) solubilizing hydrazonoester **2**, which is otherwise poorly soluble in cold toluene. The latter is probably highly beneficial for the enantioselectivity of the reaction, as the undissolved **2** cannot react with **3a** avoiding the racemic background reaction. After the stereoinduction step (Figure 2 in the main text) adduct **INT2** is formed, which after hydrolysis gives the final product **4a** and regenerates the catalyst.

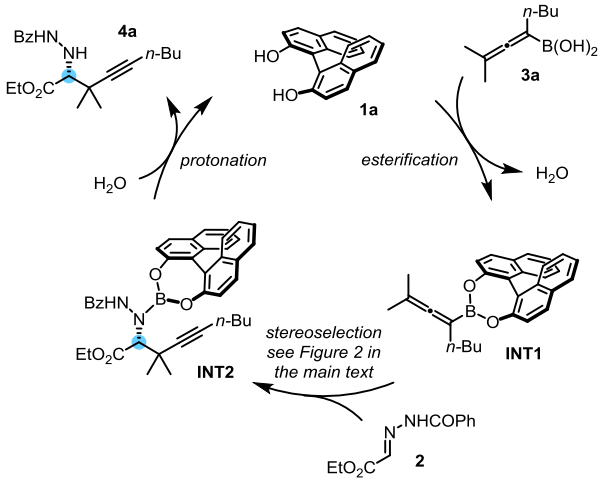


Figure 6. Proposed mechanism for the catalytic asymmetric propargylation

References

1. J. Zhao, S. J. T. Jonker, D. N. Meyer, G. Schulz, C. D. Tran, L. Eriksson, K. J. Szabo, *Chem. Sci.* 2018**, 9**, 3305-3312.

2. M. Raducan, R. Alam, K. J. Szabó, *Angew. Chem. Int. Ed.* 2012**, 51**, 13050-13053.

3. R. Magnus, M. N. Sudan, K. H. Başpınar, A. Iuliana, *Angew. Chem. Int. Ed.* 2012**, 51** , 12864-12868.

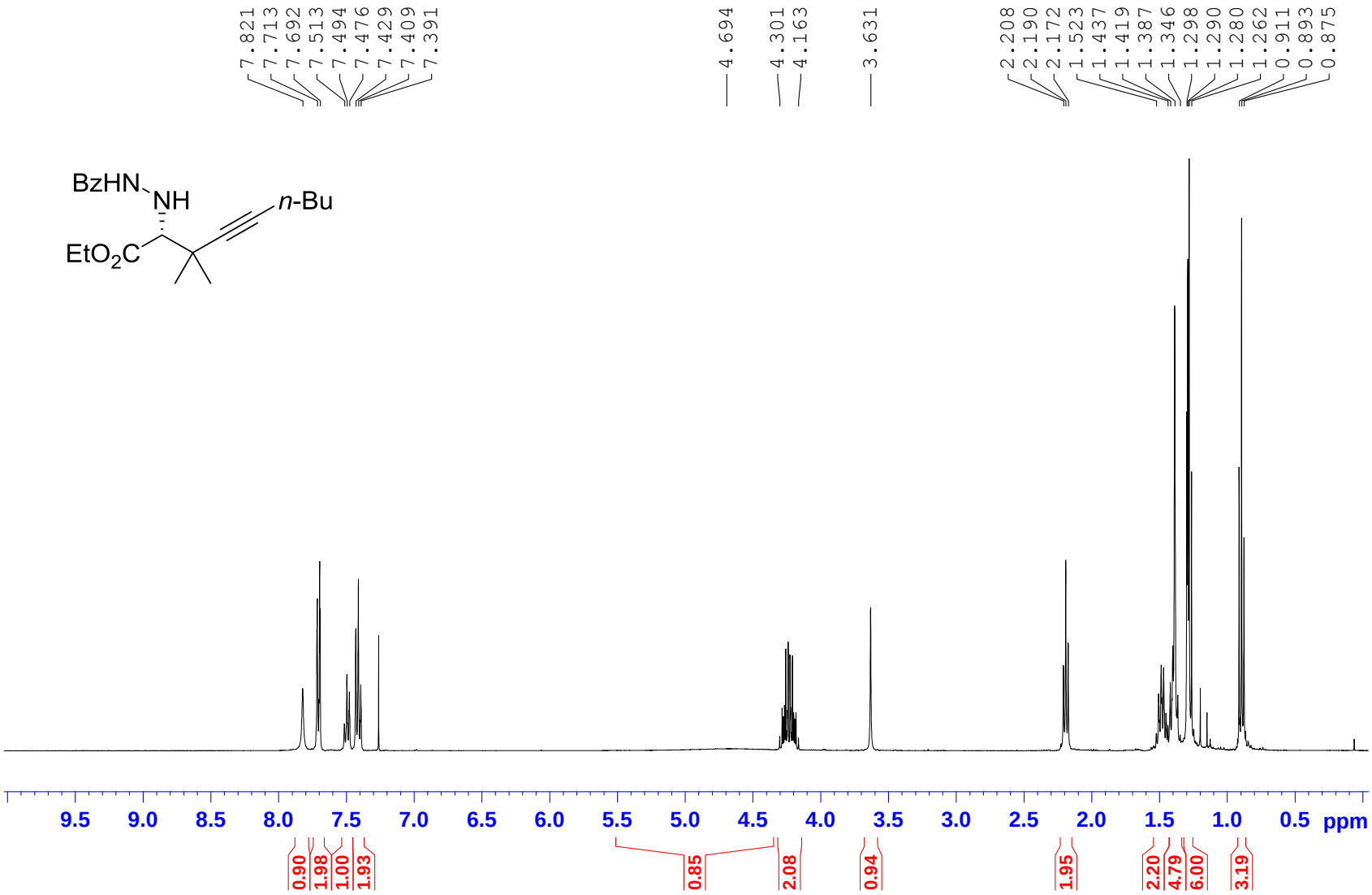
4. D. A. Allen, A. E. Tomaso, O. P. Priest, D. F. Hindson, J. L. Hurlburt, *J. Chem. Education* 2008**, 85** , 698.

5. T. R. Hoye, C. S. Jeffrey, F. Shao, *Nature Protocols* 2007**, 2**, 2451.

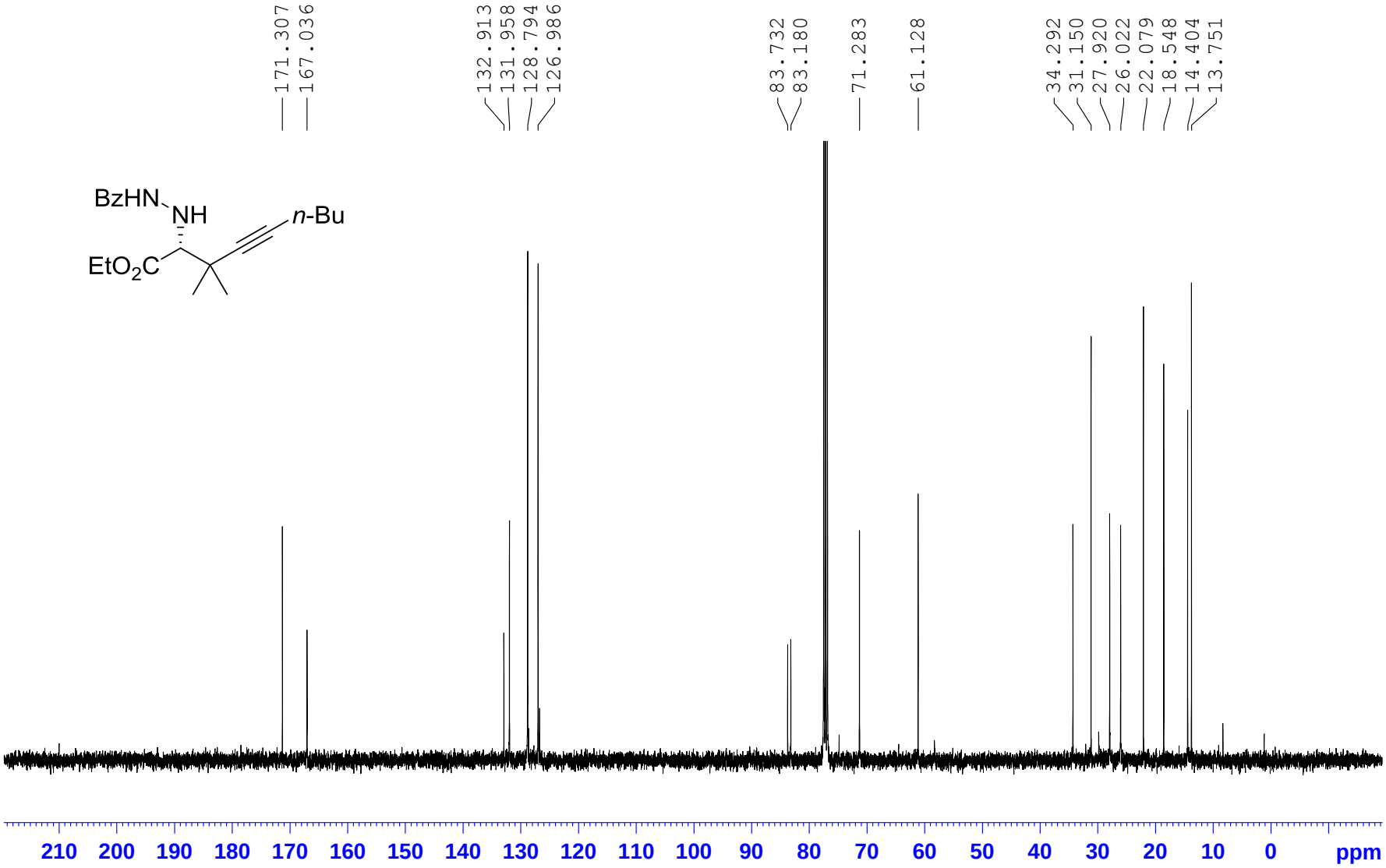
6. M. J. Burk, J. P. Martinez, J. E. Feaster, N. Cosford, *Tetrahedron* 1994**, 50**, 4399-4428.

7. D. Ke, X. Qian, F. Liu, N. Wang, F. Fan, Z. Li, Q. Yang, *Eur. J. Med. Chem.* 2009**, 44**, 2985-2993.

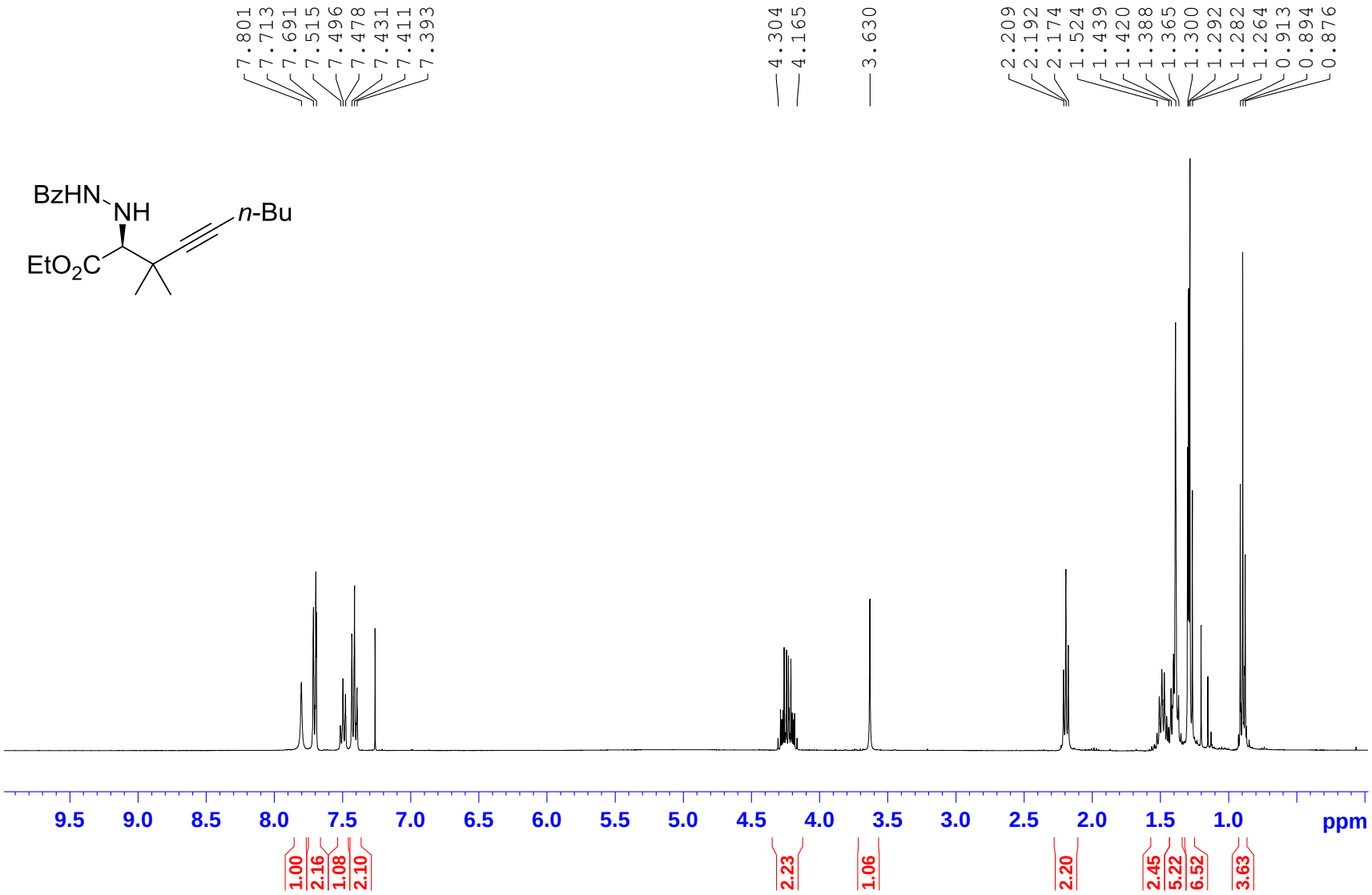
^{1}H NMR of compound **4a** (CDCl3, 400 MHz)



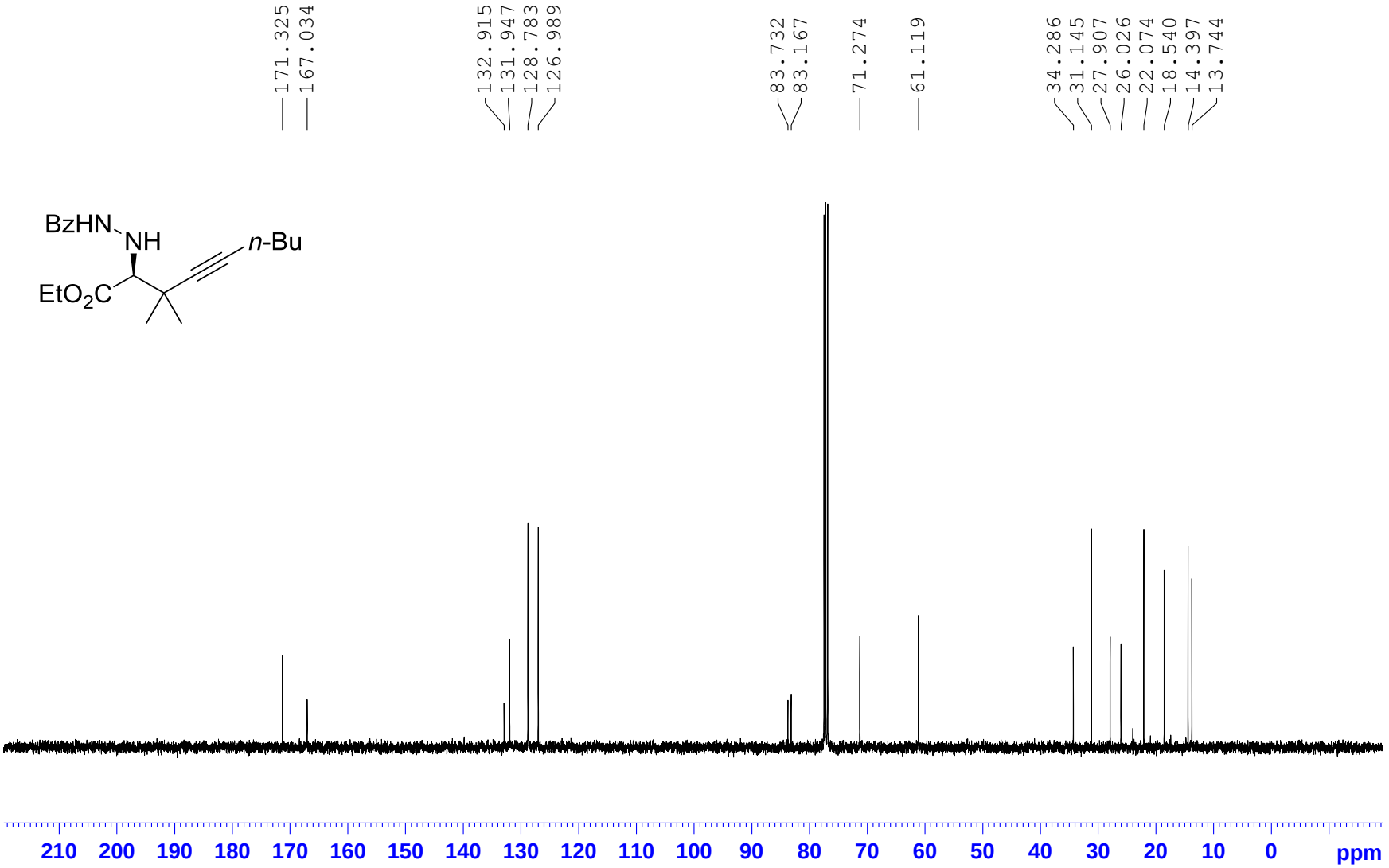
^{13}C NMR of compound **4a** (CDCl3, 100 MHz)



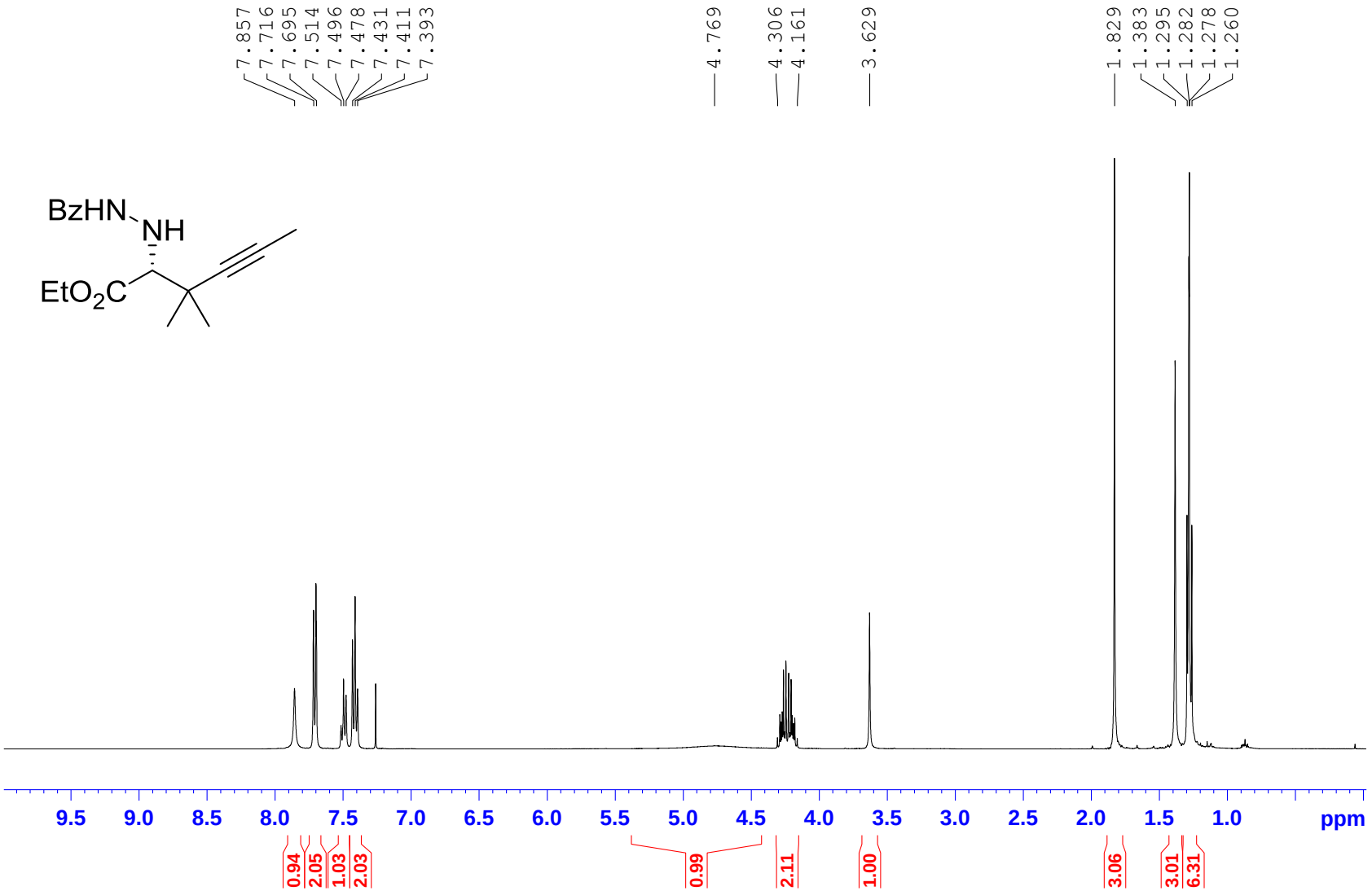
^{1}H NMR of compound **4b** (CDCl3, 400 MHz)



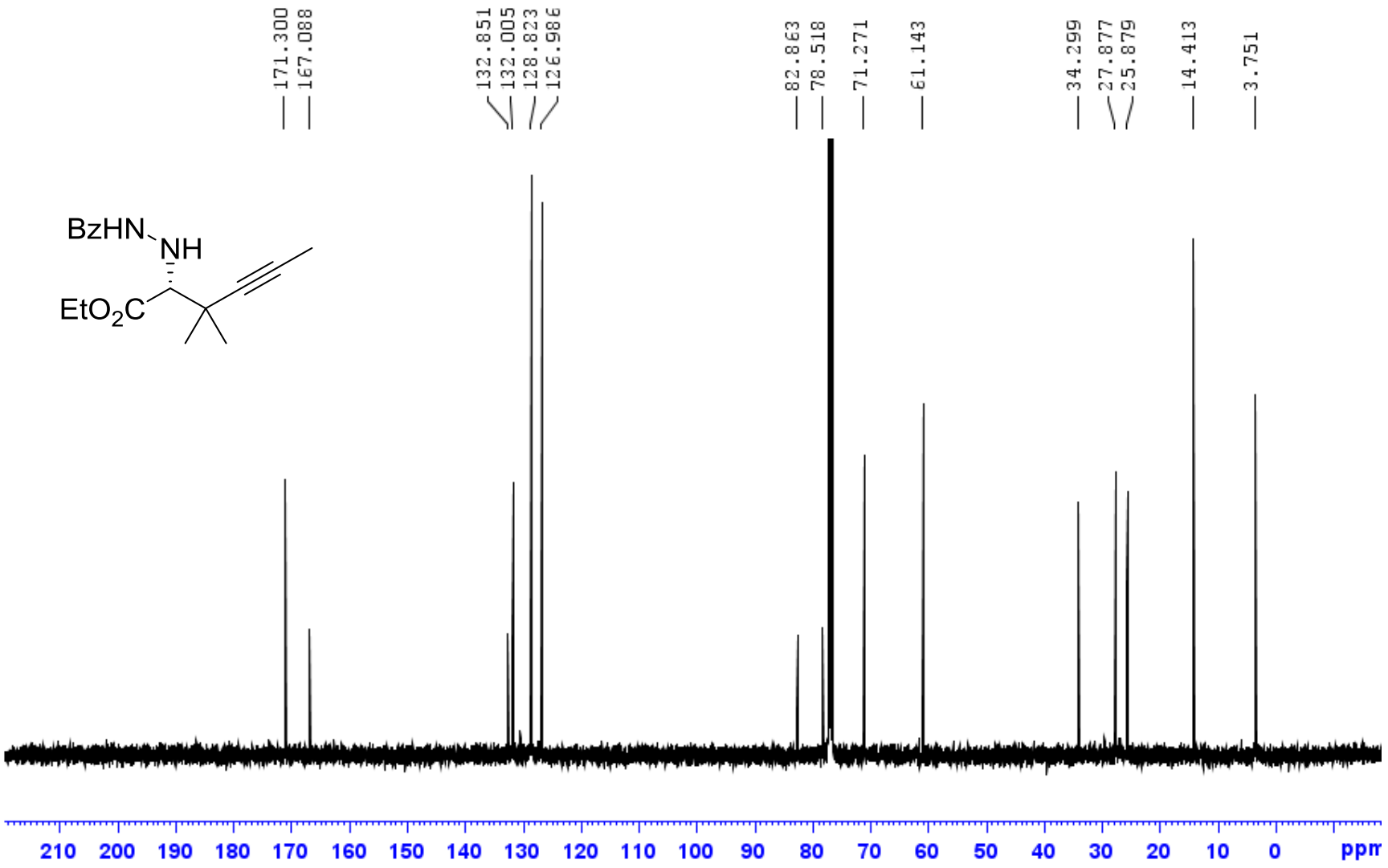
^{13}C NMR of compound **4b** (CDCl3, 100 MHz)



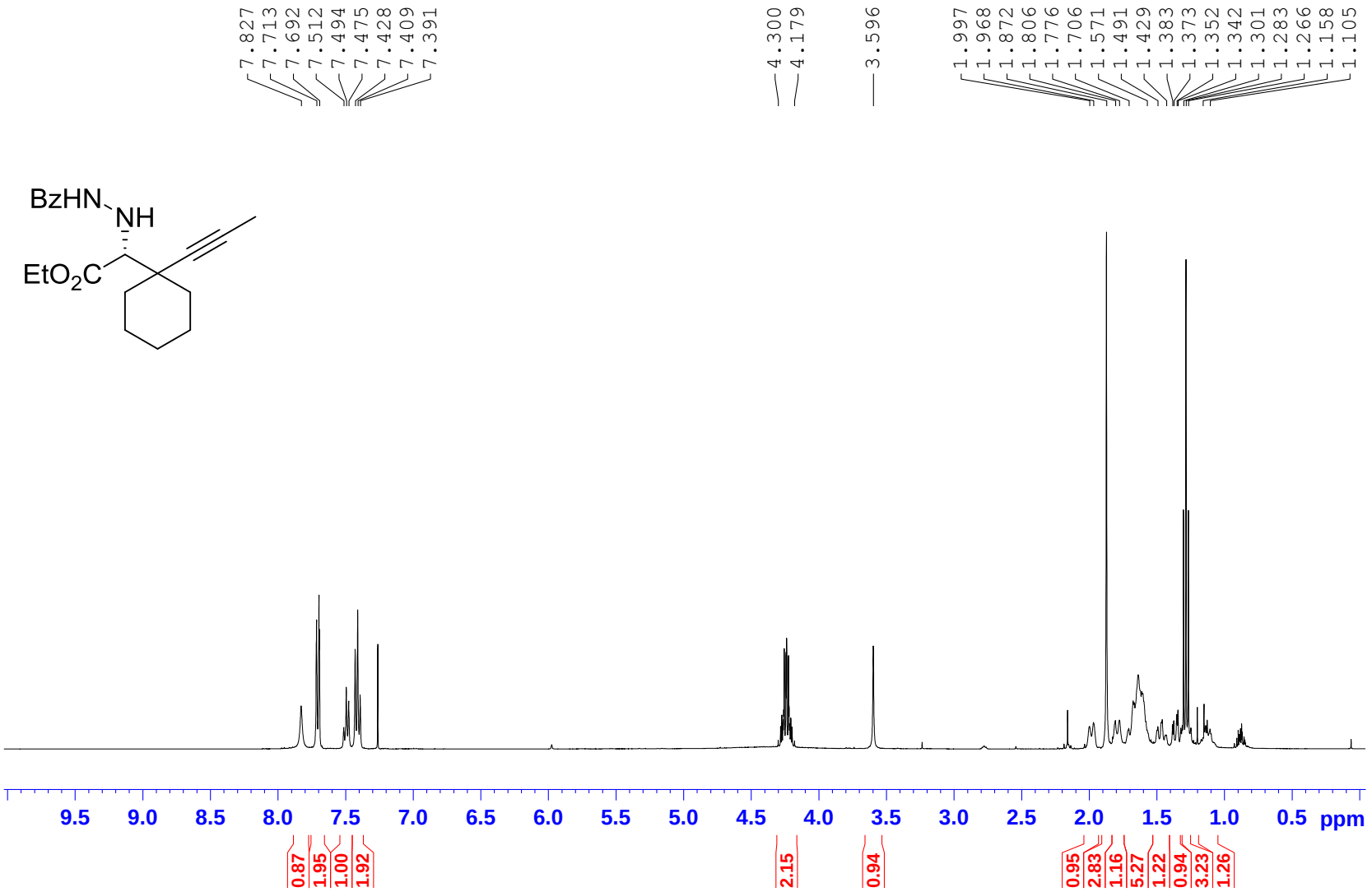
^{1}H NMR of compound **4c** (CDCl3, 400 MHz)



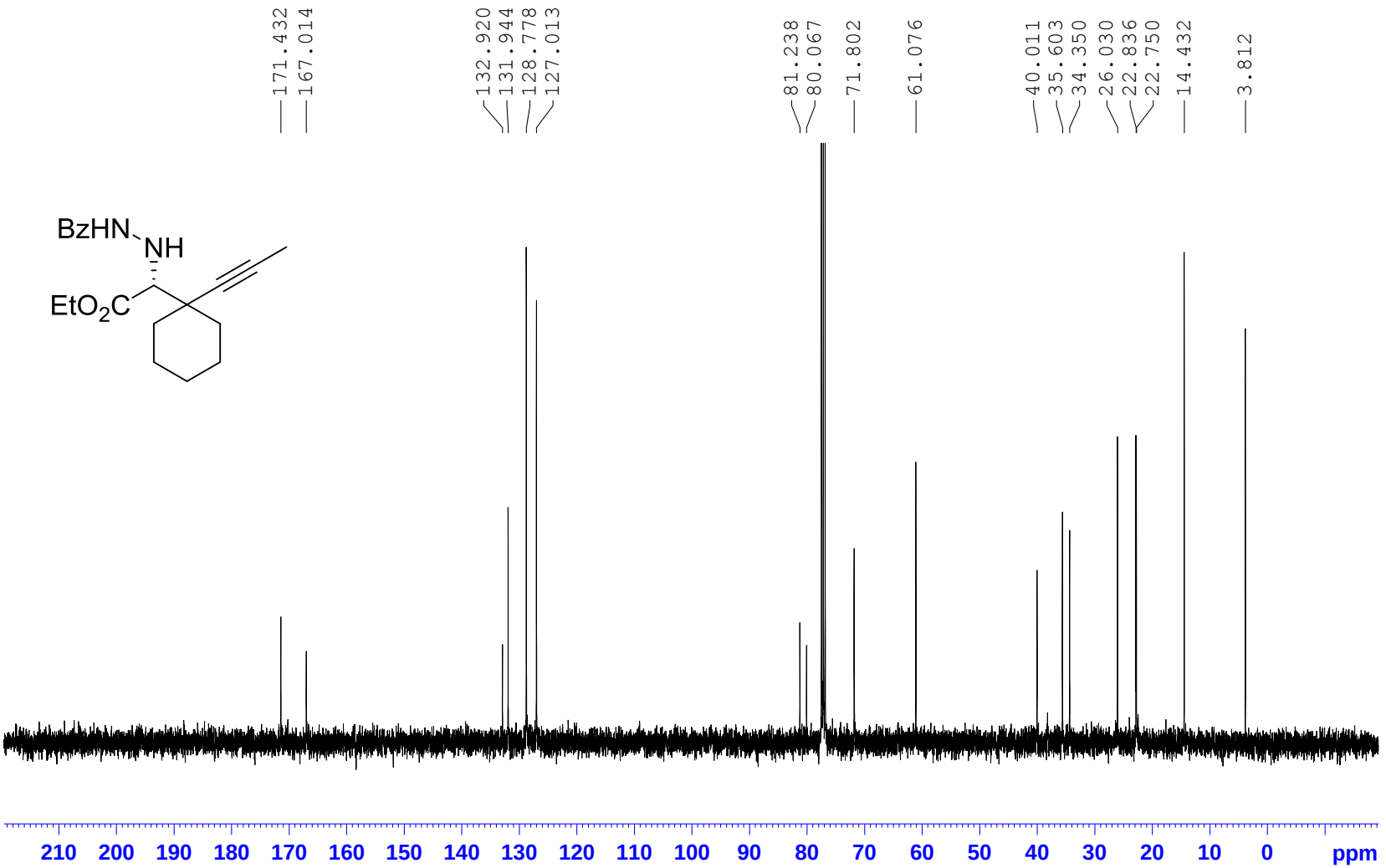
^{13}C NMR of compound **4c** (CDCl3, 100 MHz)



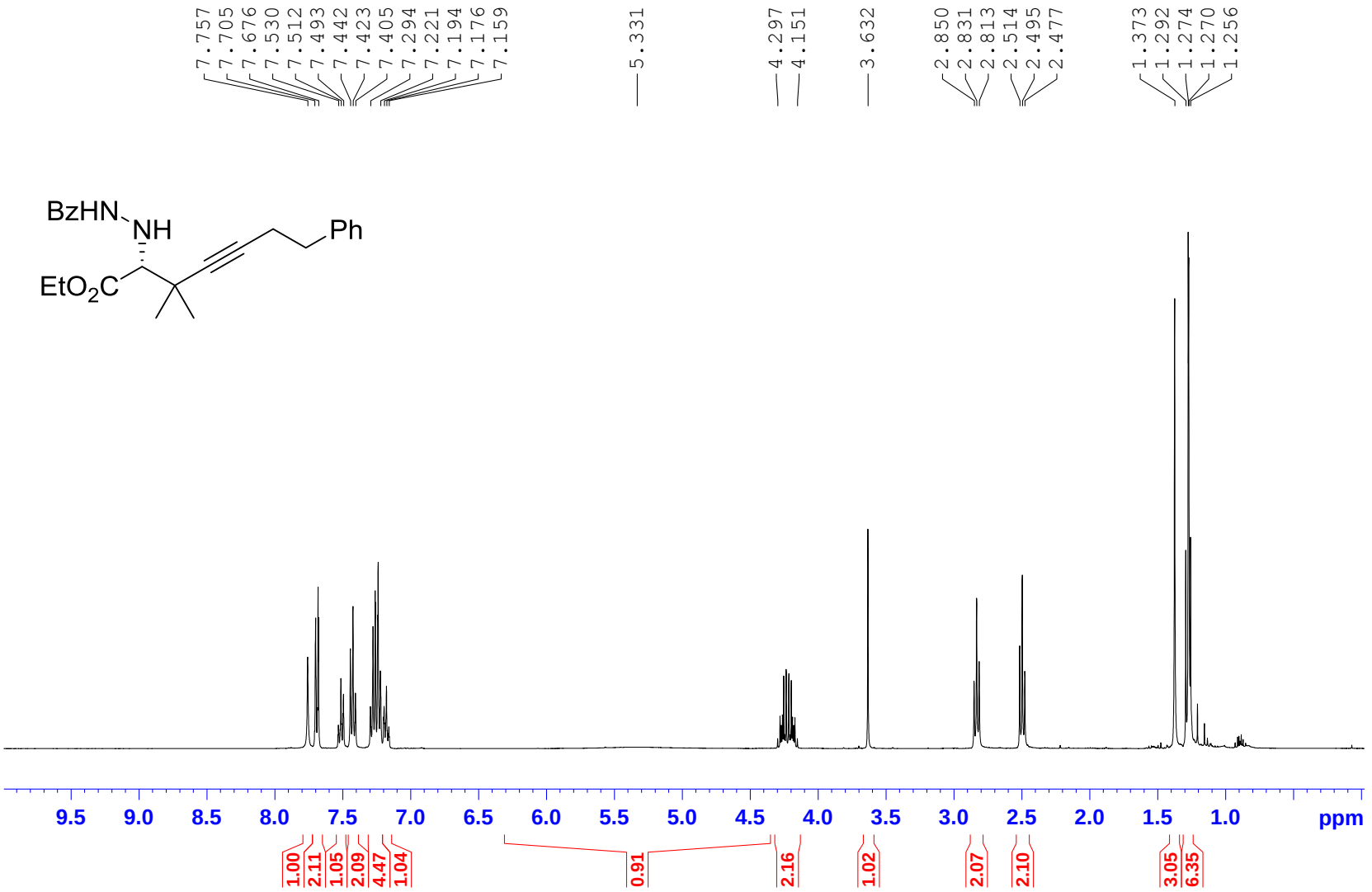
^{1}H NMR of compound **4d** (CDCl3, 400 MHz)



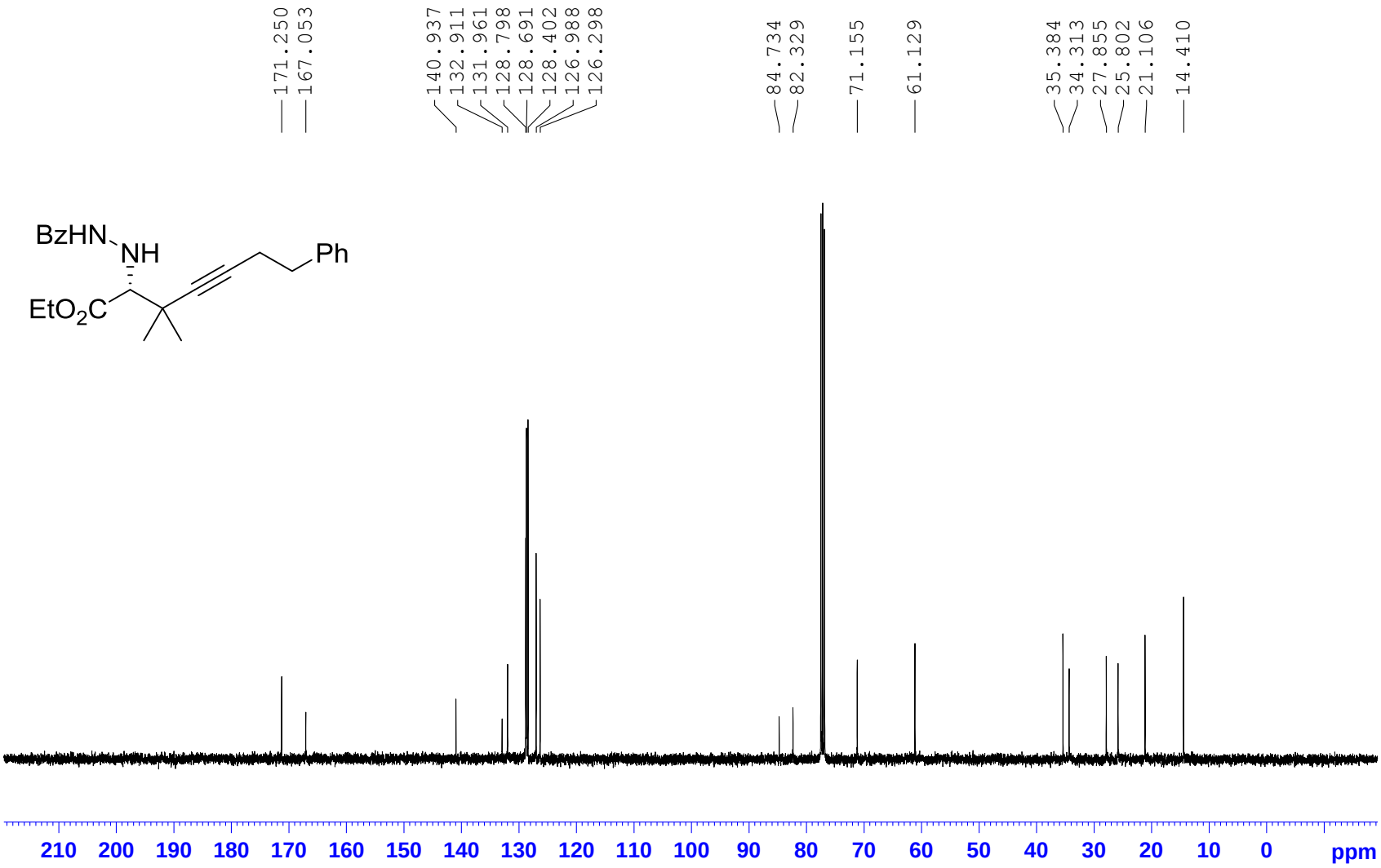
^{13}C NMR of compound **4d** (CDCl3, 100 MHz)



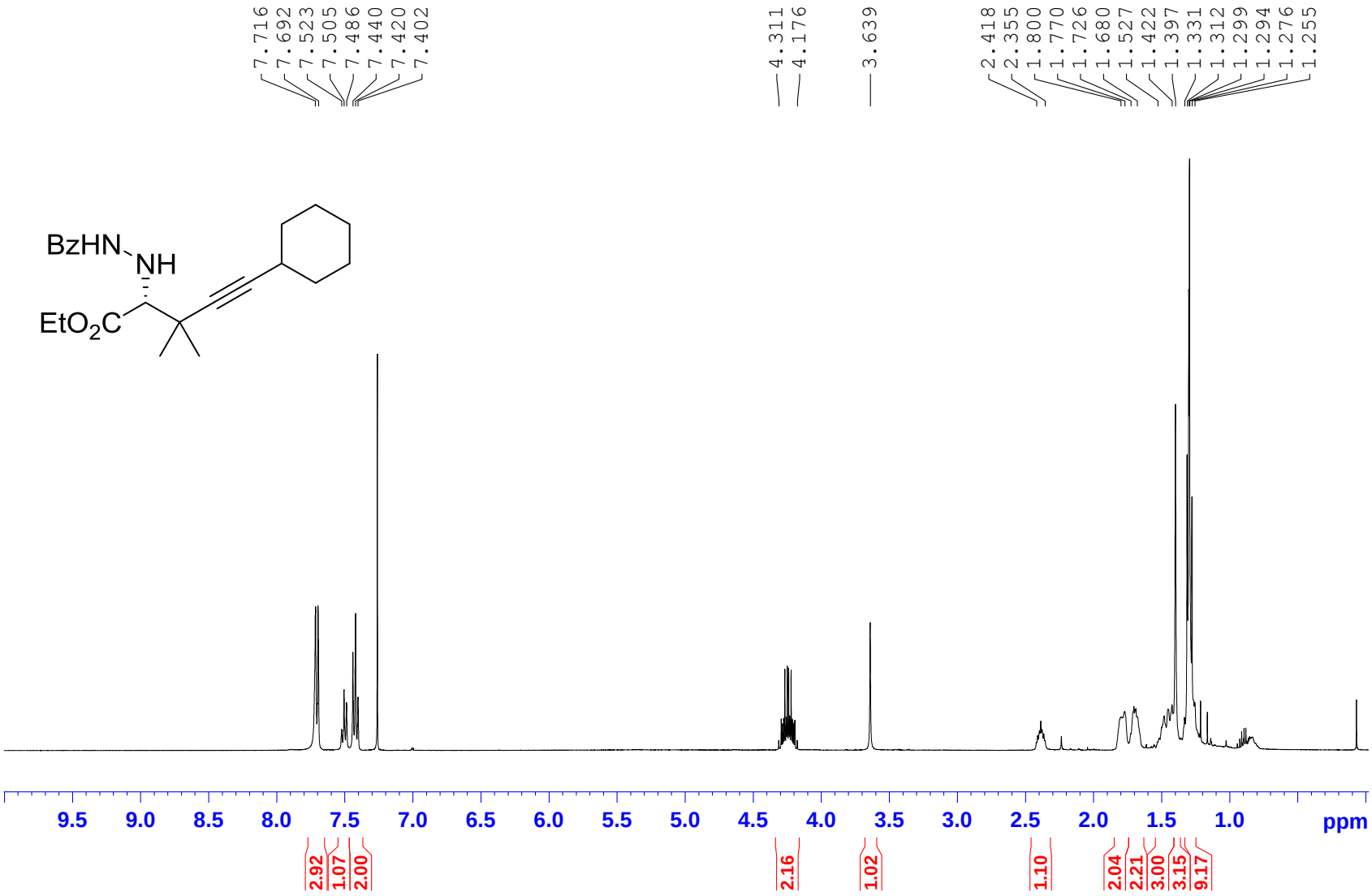
^{1}H NMR of compound **4e** (CDCl3, 400 MHz)



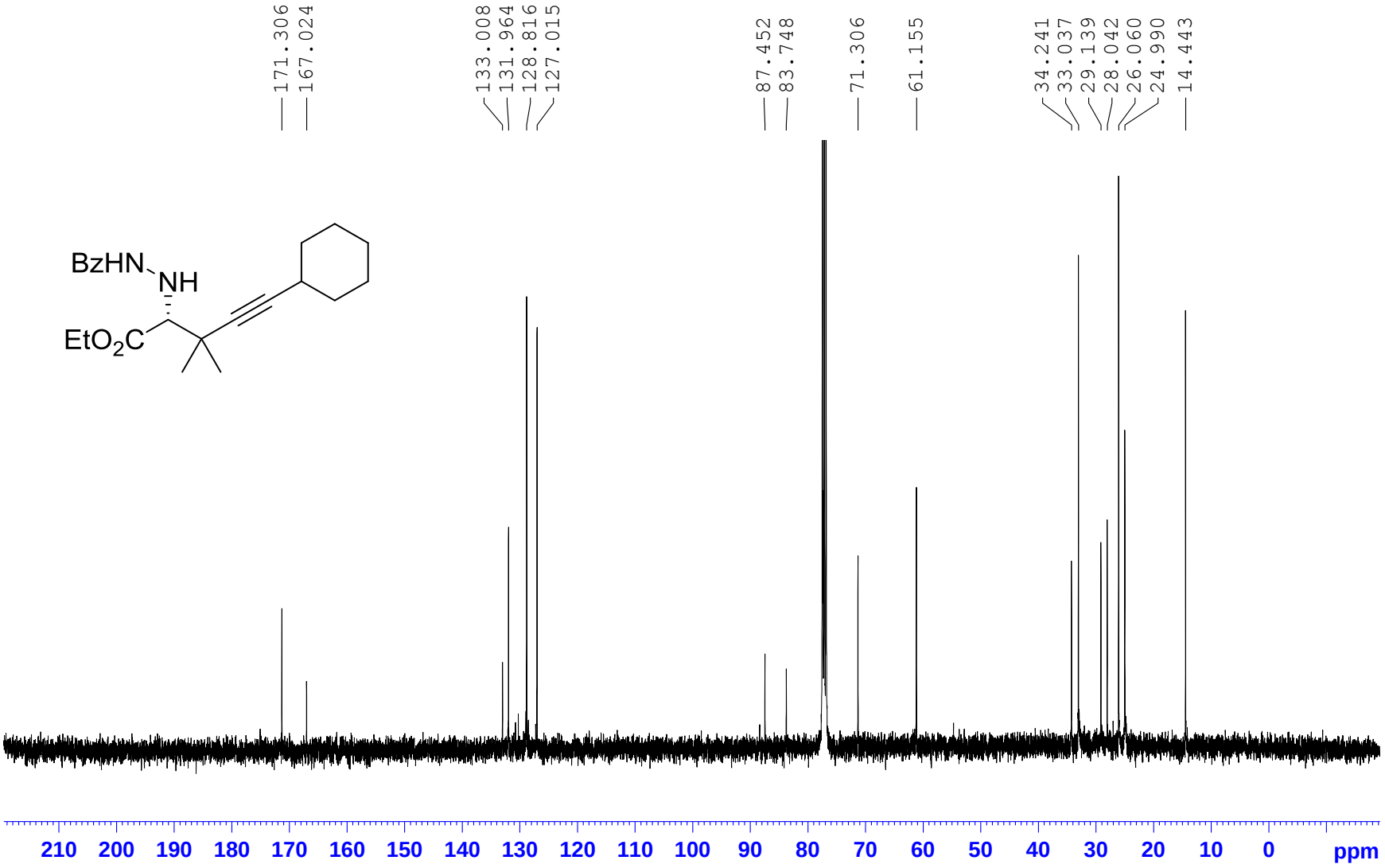
^{13}C NMR of compound **4e** (CDCl3, 100 MHz)



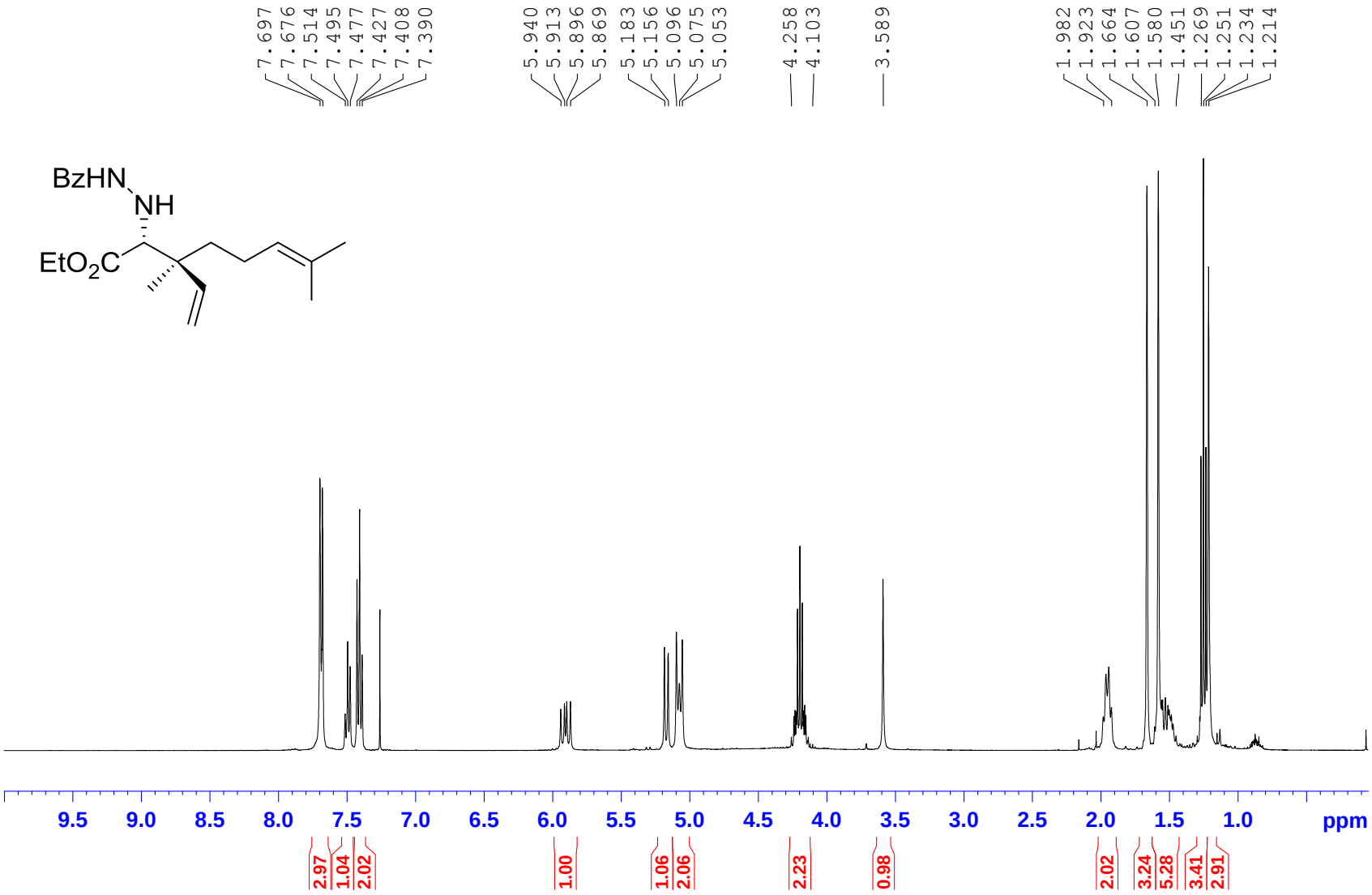
^{1}H NMR of compound **4f** (CDCl3, 400 MHz)



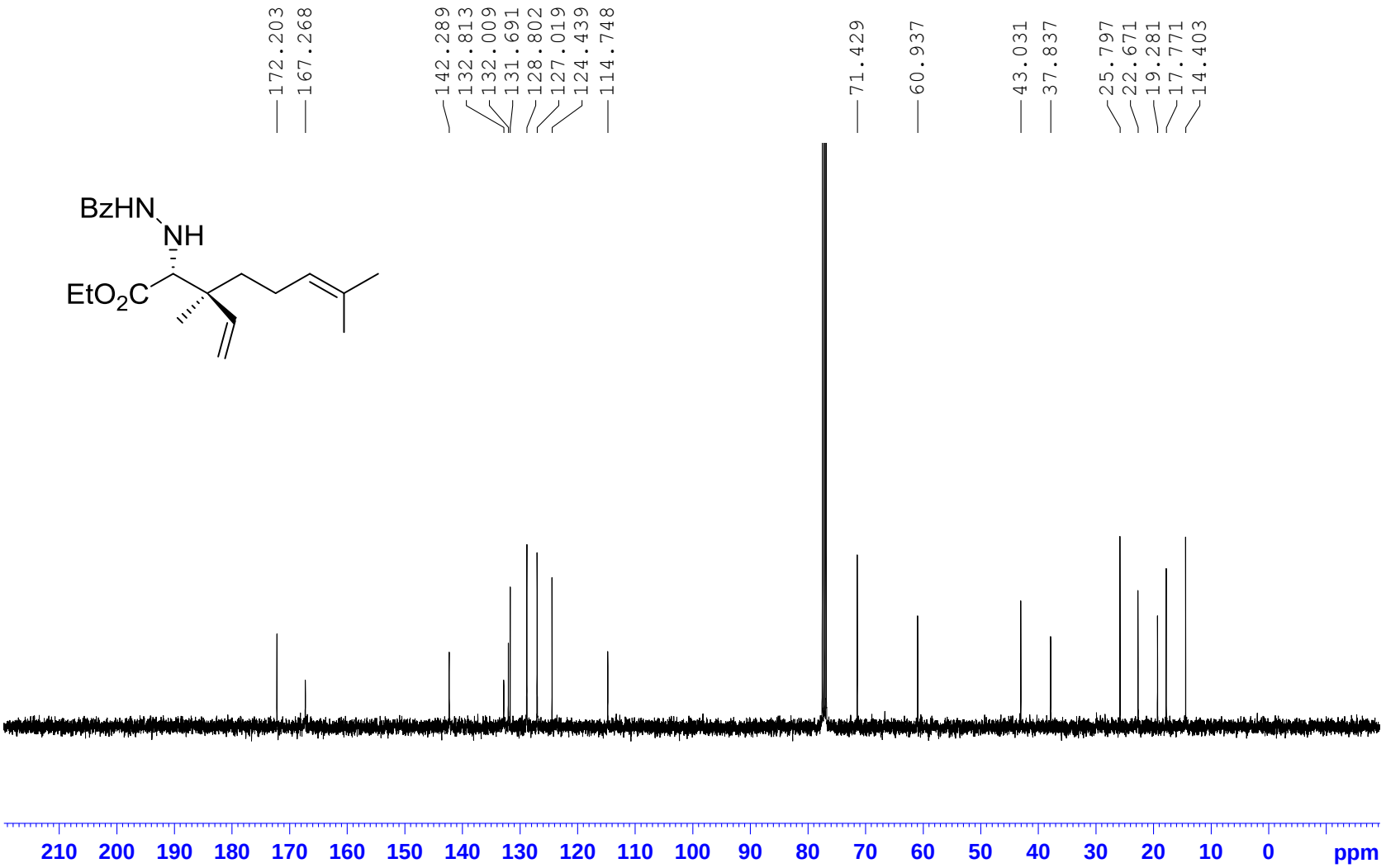
^{13}C NMR of compound **4f** (CDCl3, 100 MHz)



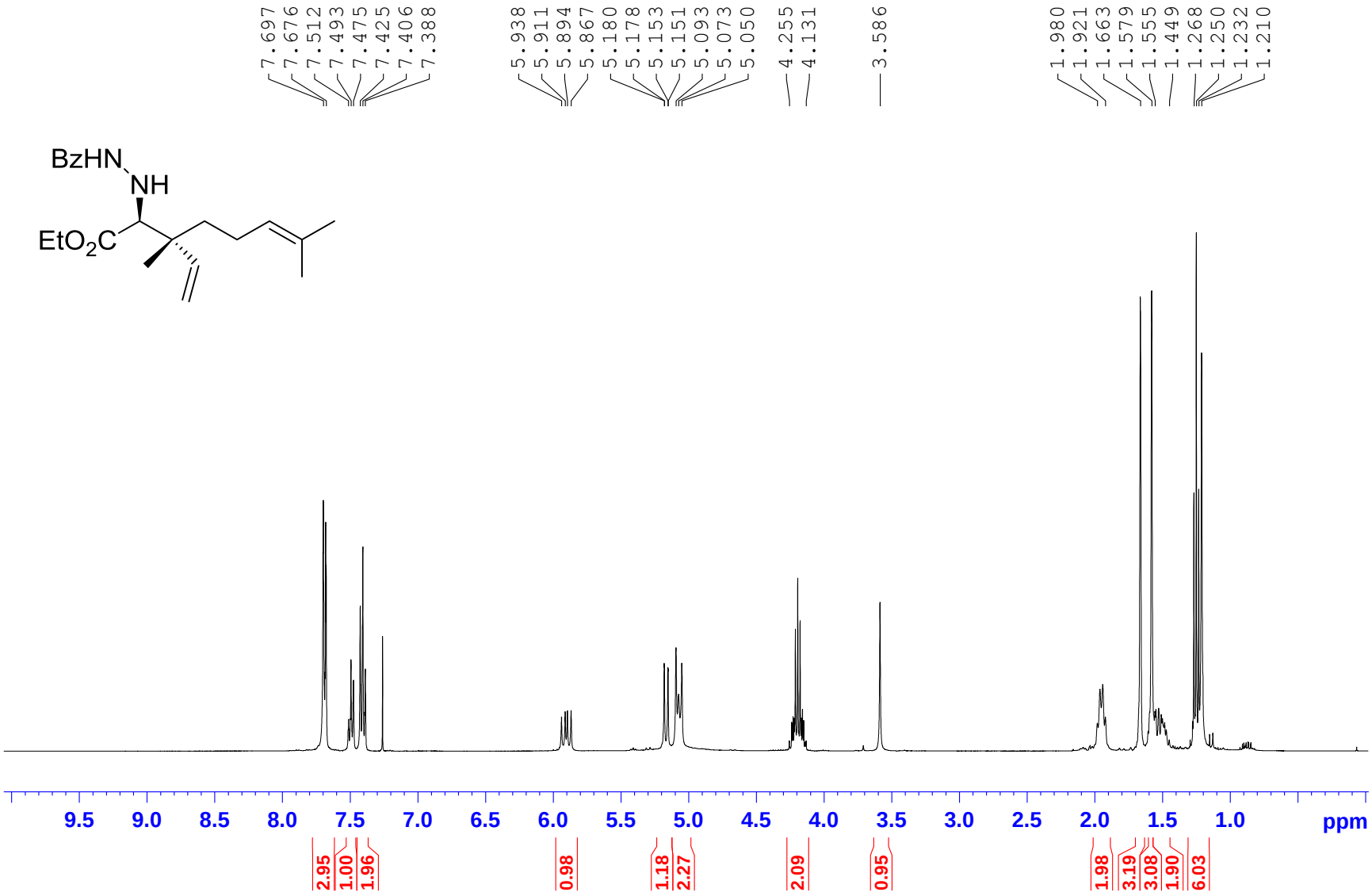
^{1}H NMR of compound **4g** (CDCl3, 400 MHz)



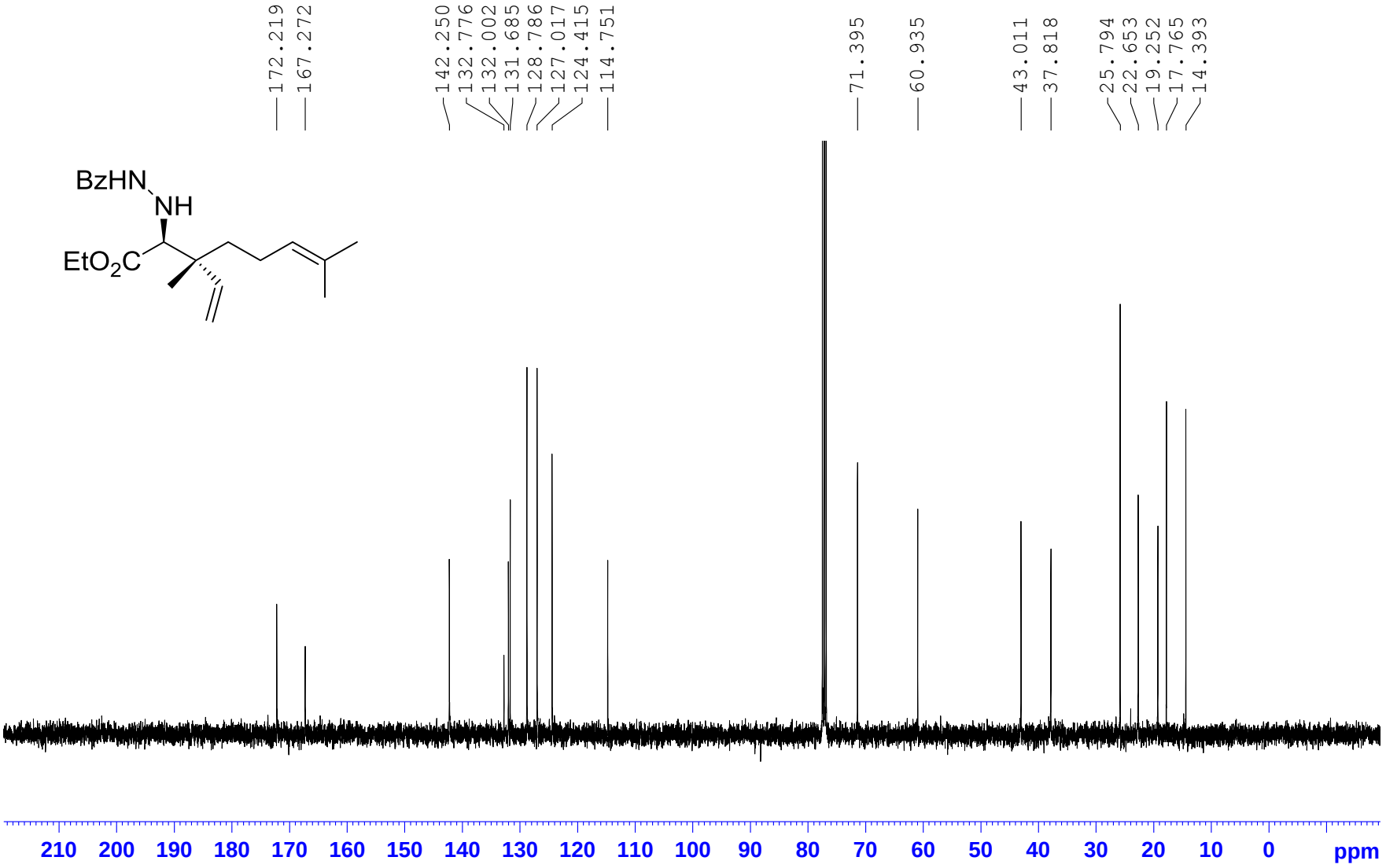
^{13}C NMR of compound **4g** (CDCl3, 100 MHz)



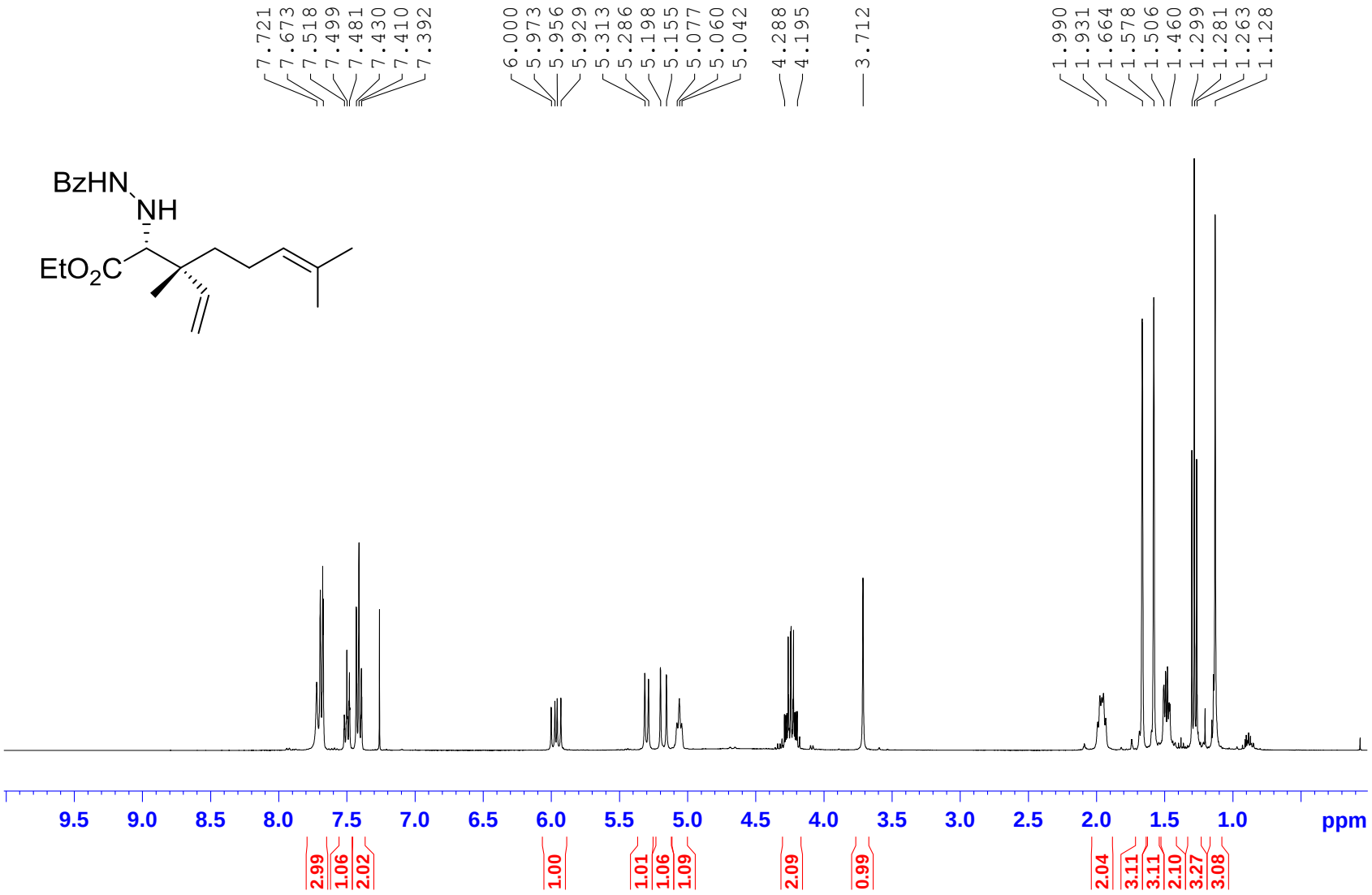
^{1}H NMR of compound **4h** (CDCl3, 400 MHz)



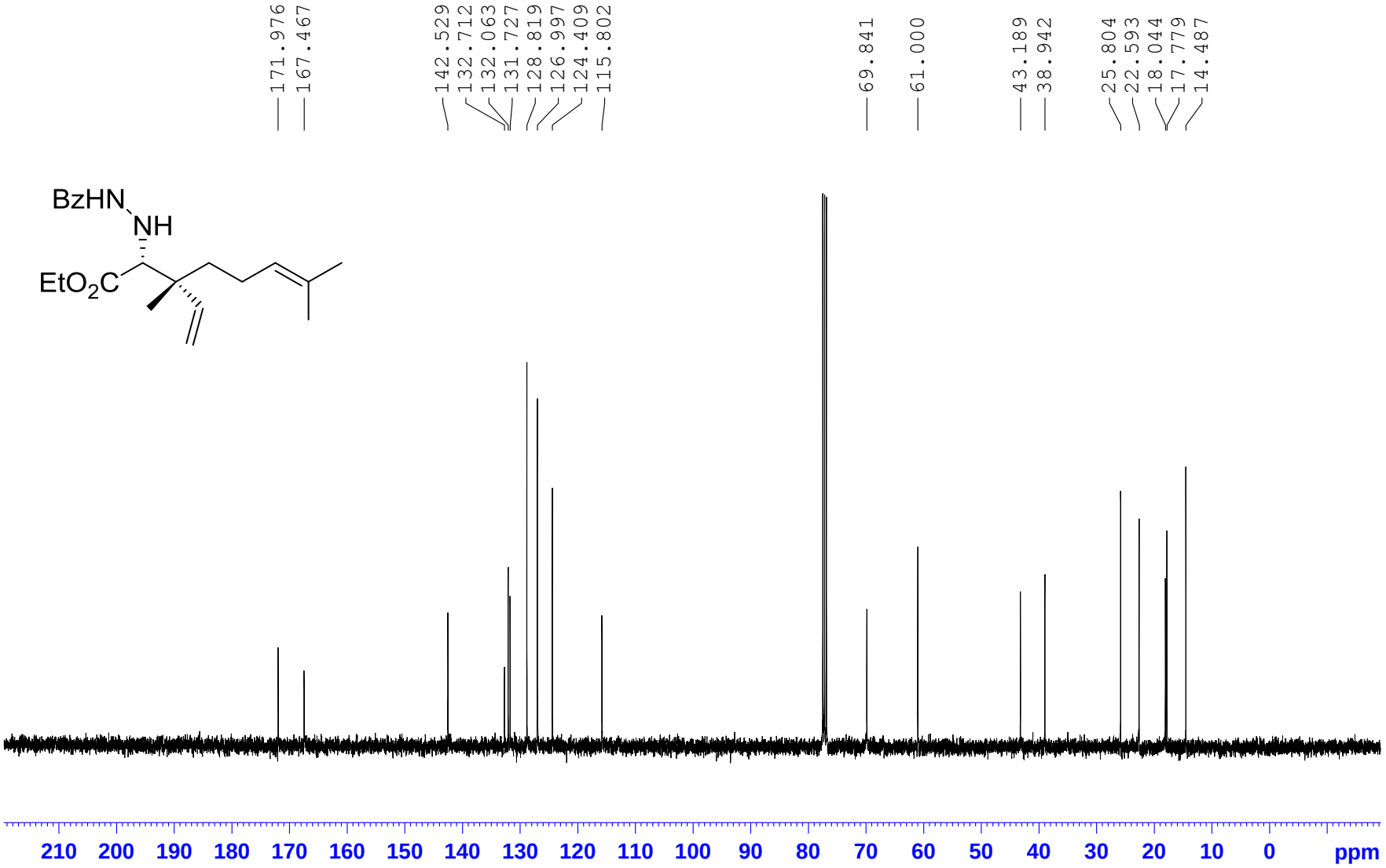
^{13}C NMR of compound **4h** (CDCl3, 100 MHz)



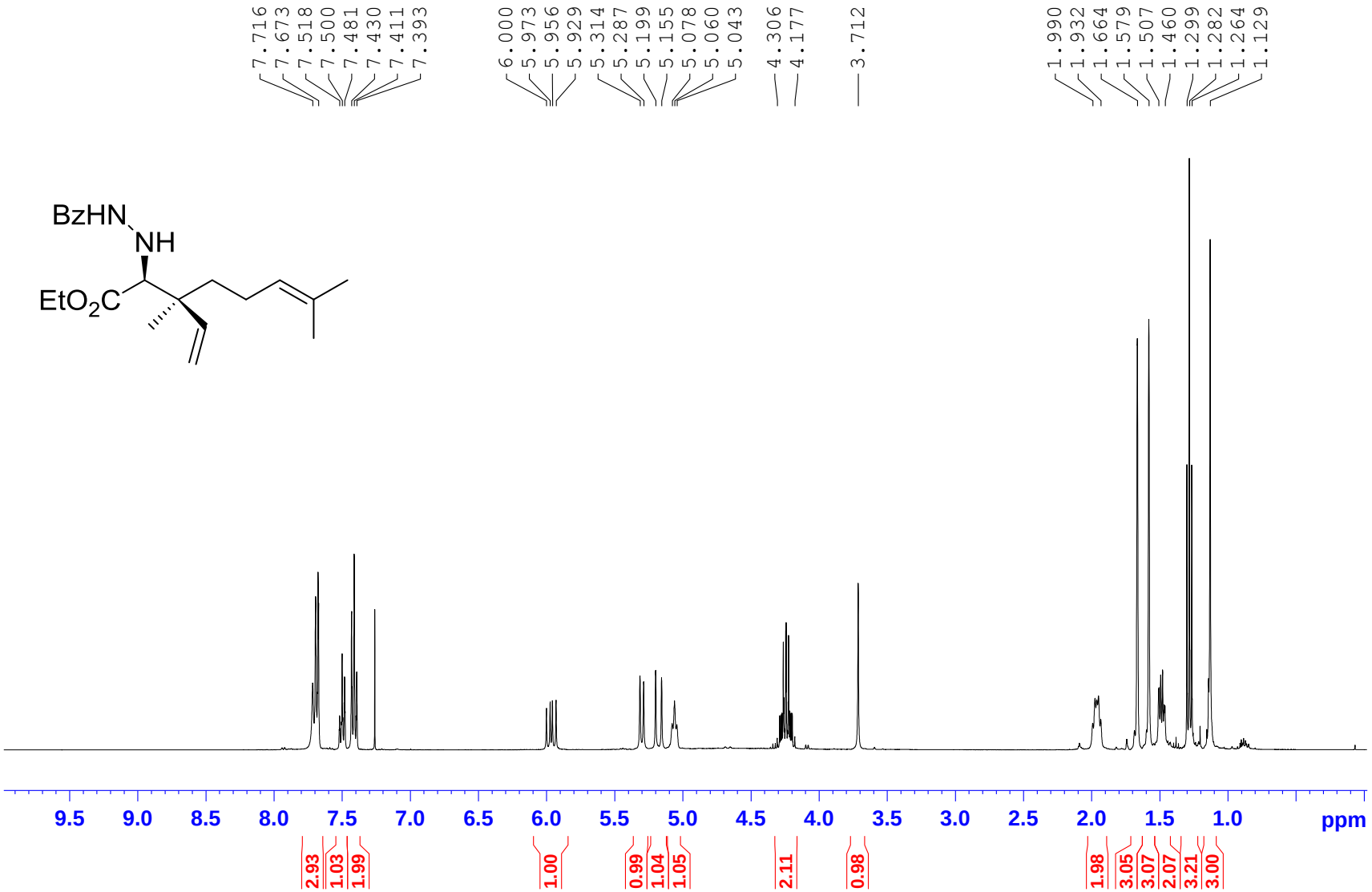
^{1}H NMR of compound **4i** (CDCl3, 400 MHz)



^{13}C NMR of compound **4i** (CDCl3, 100 MHz)



^{1}H NMR of compound **4j** (CDCl3, 400 MHz)



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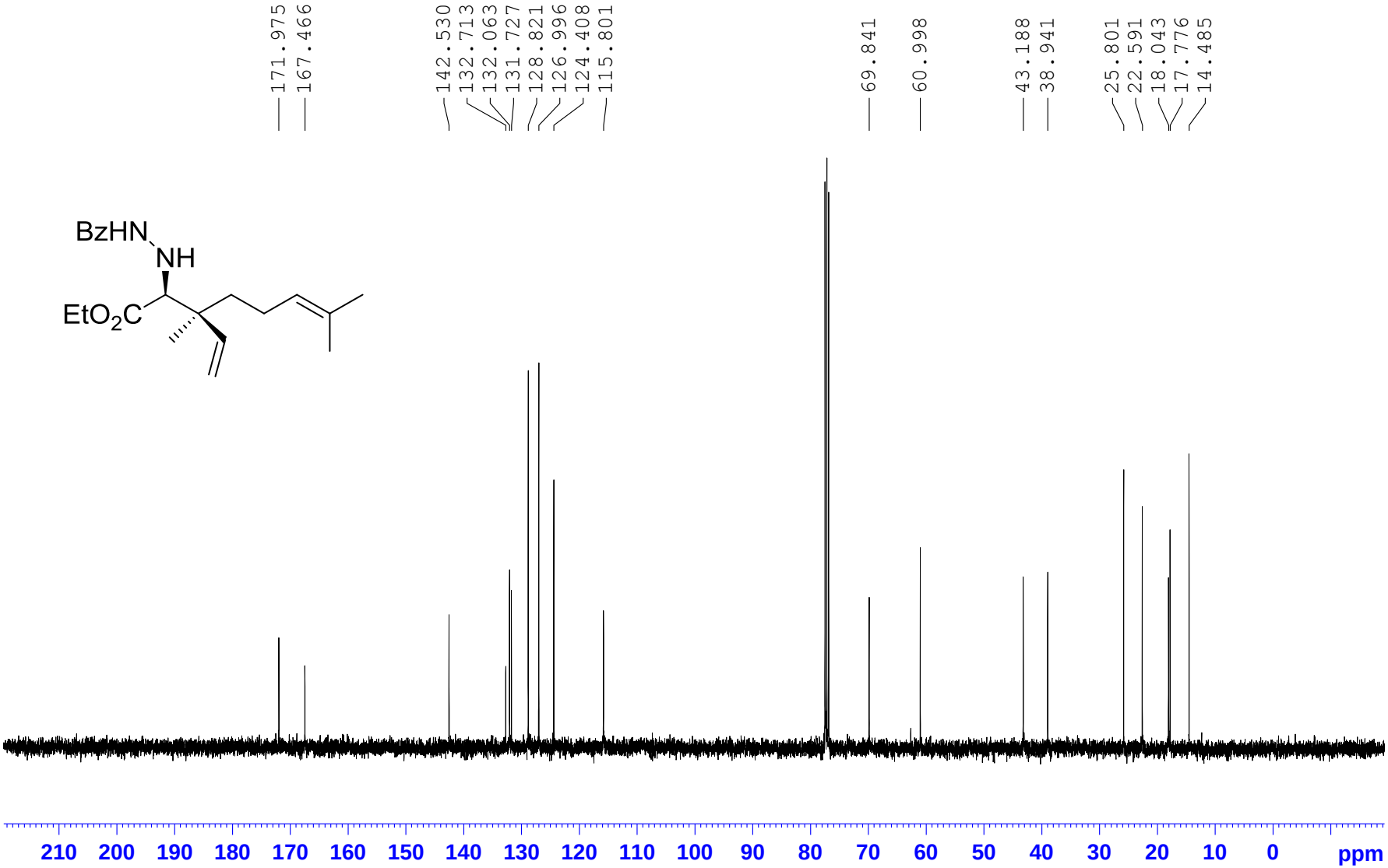
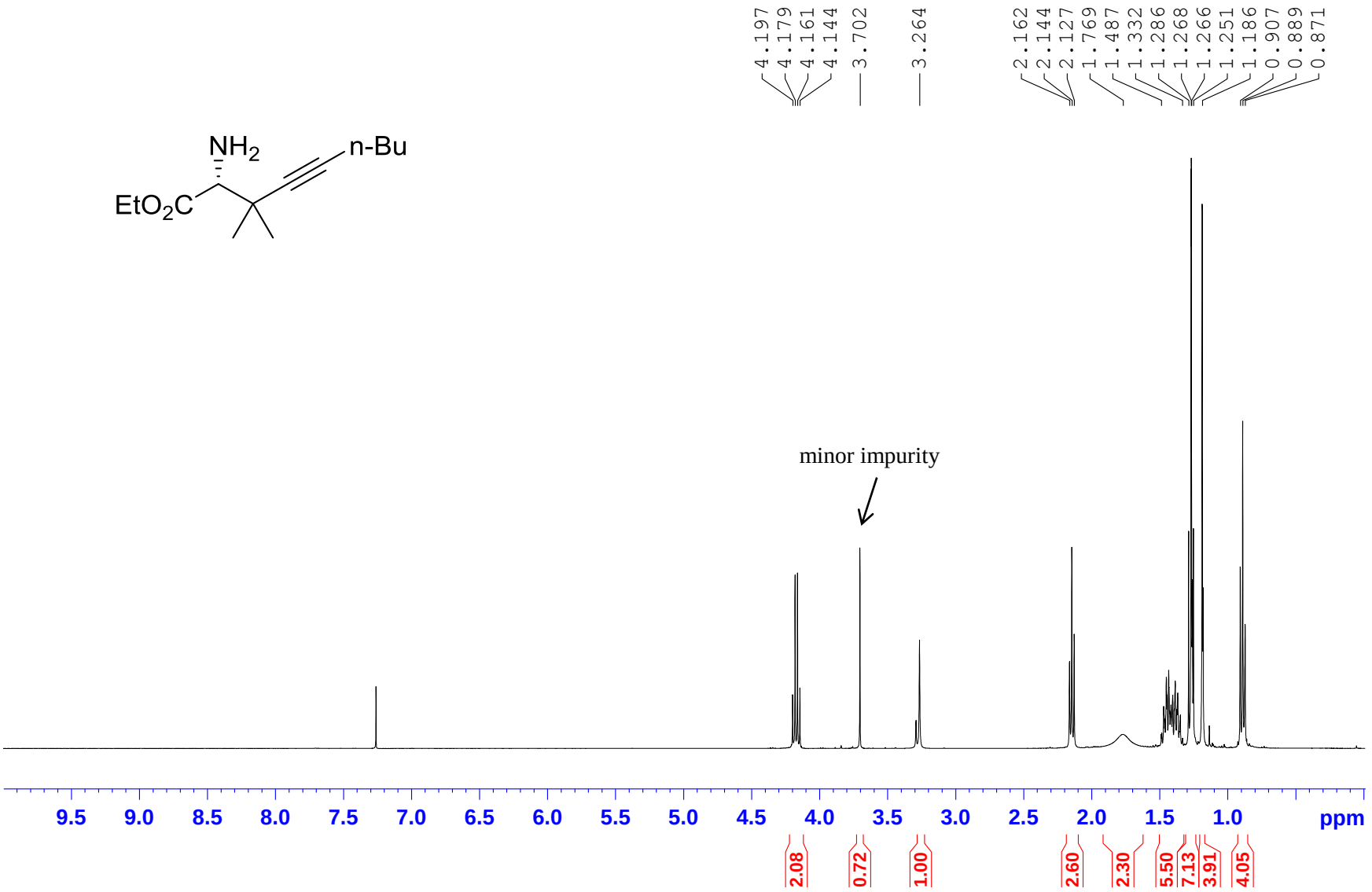


^{1}H NMR of compound **5a** (CDCl3, 400 MHz)



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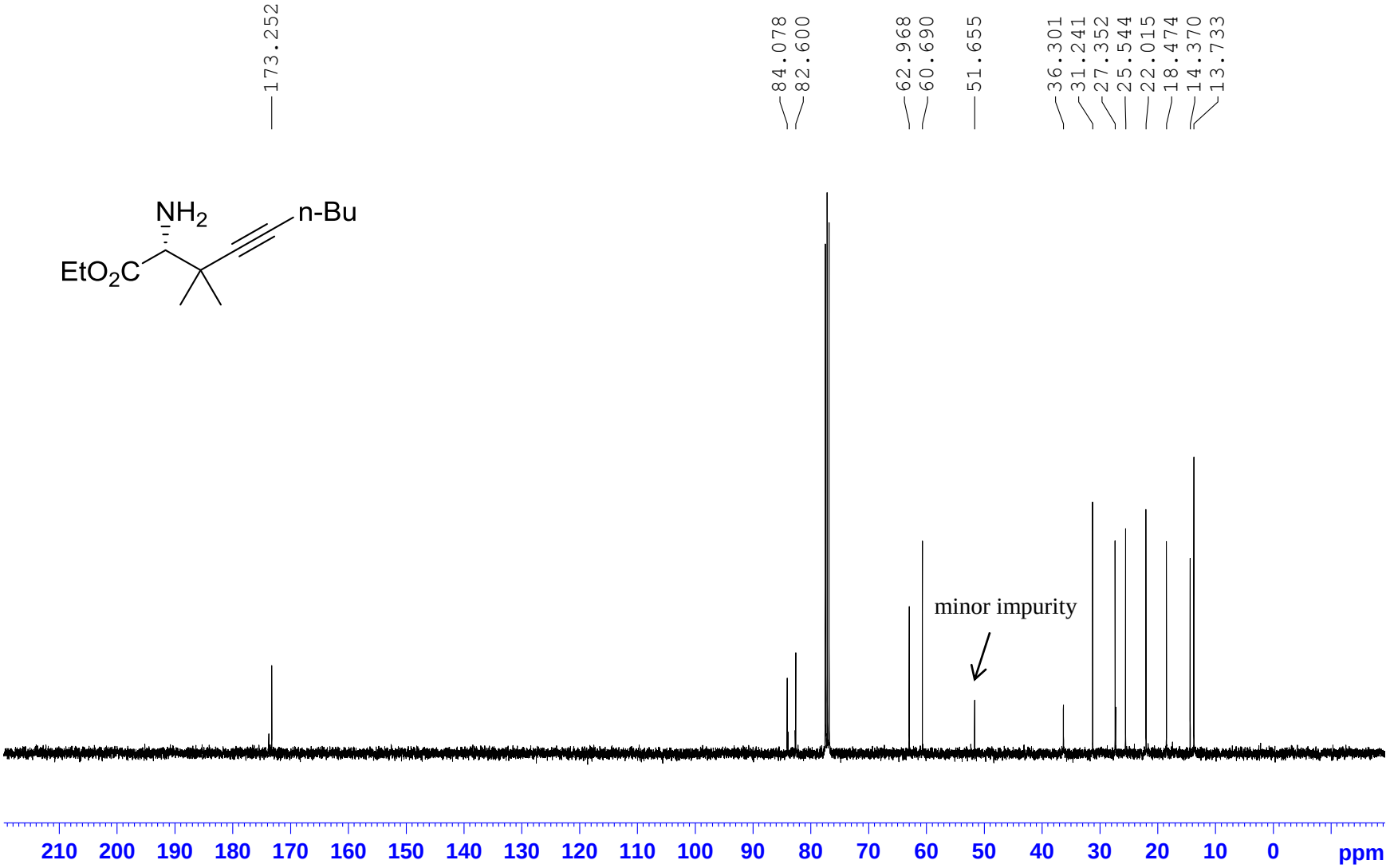
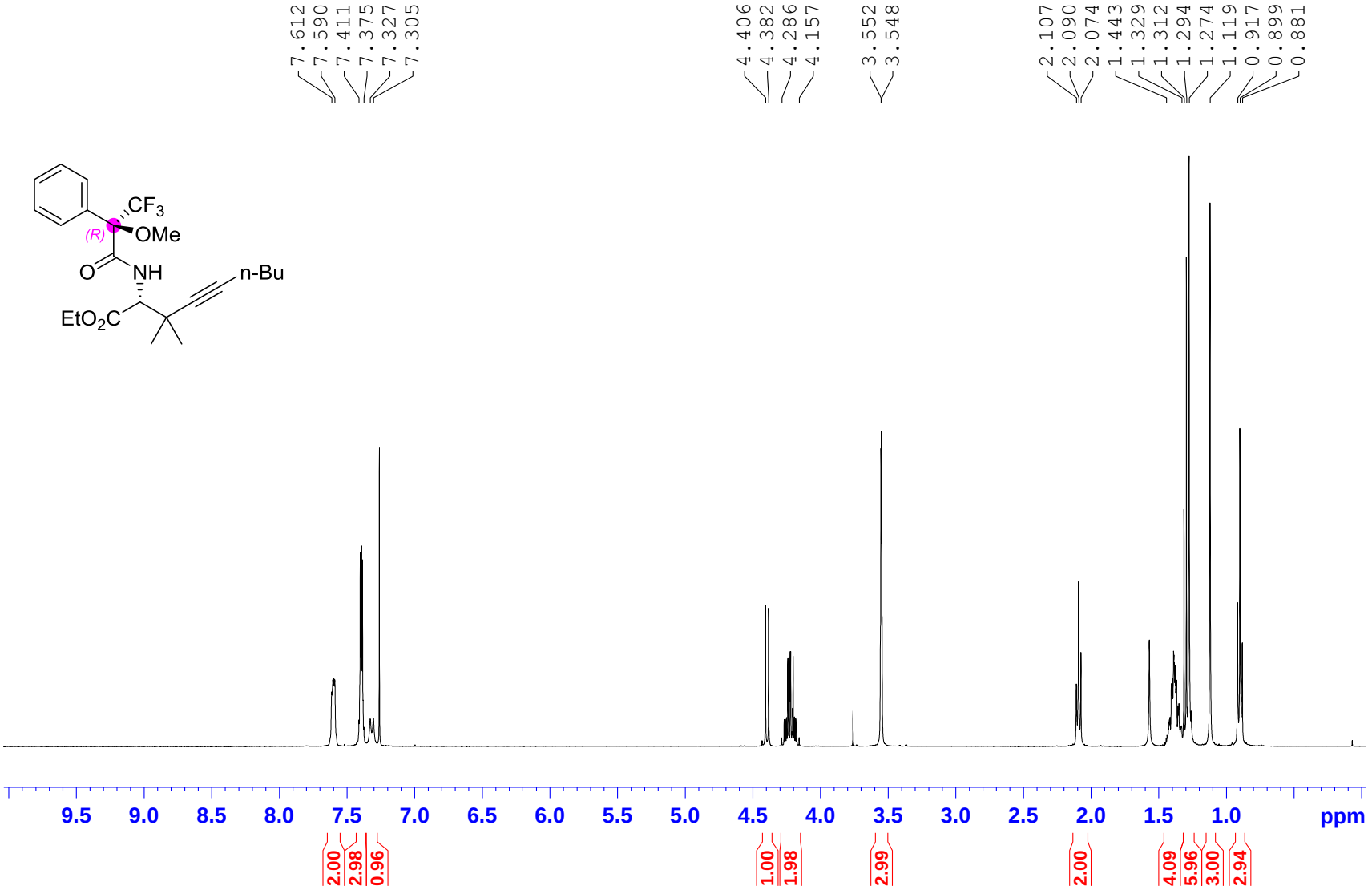
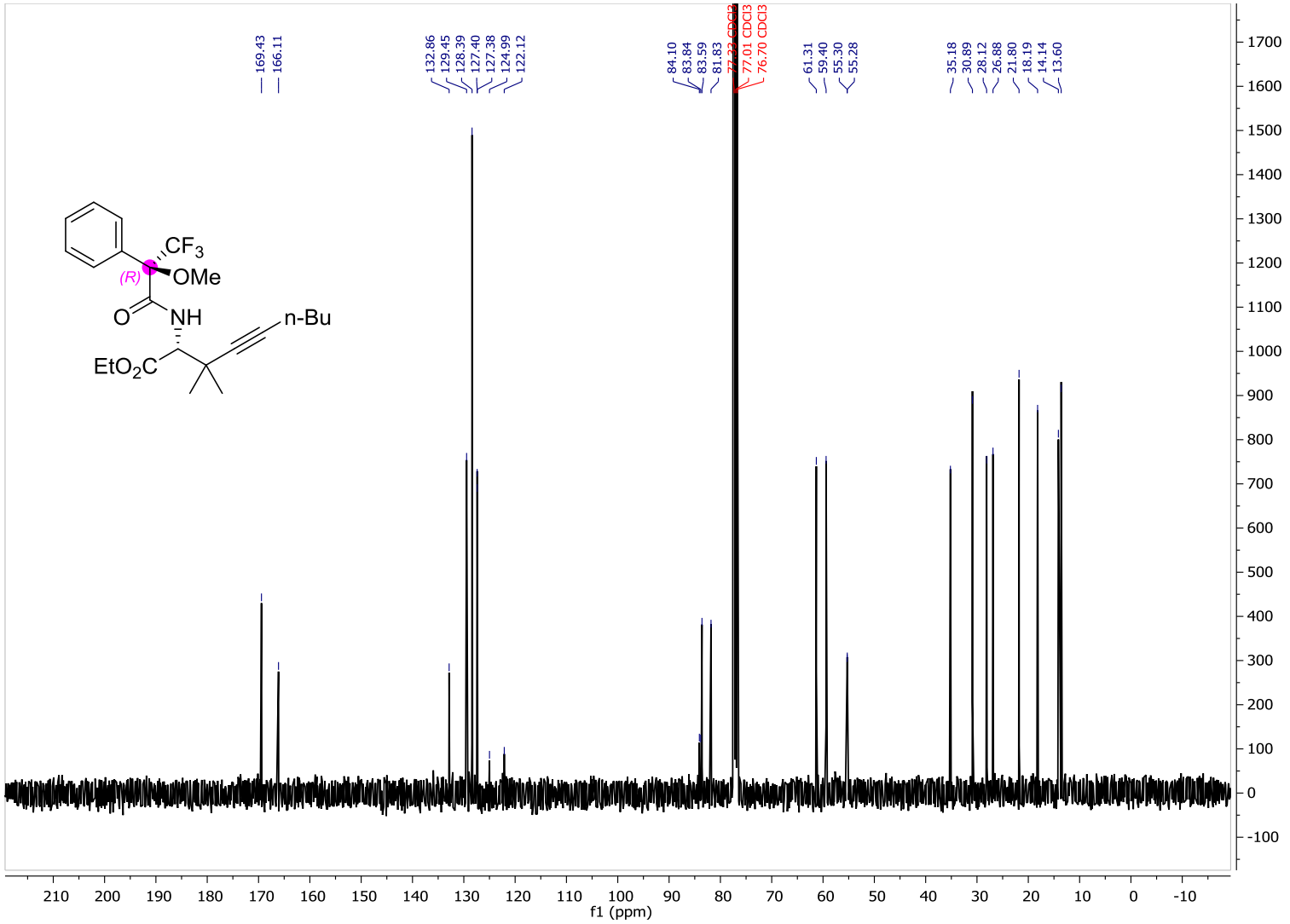


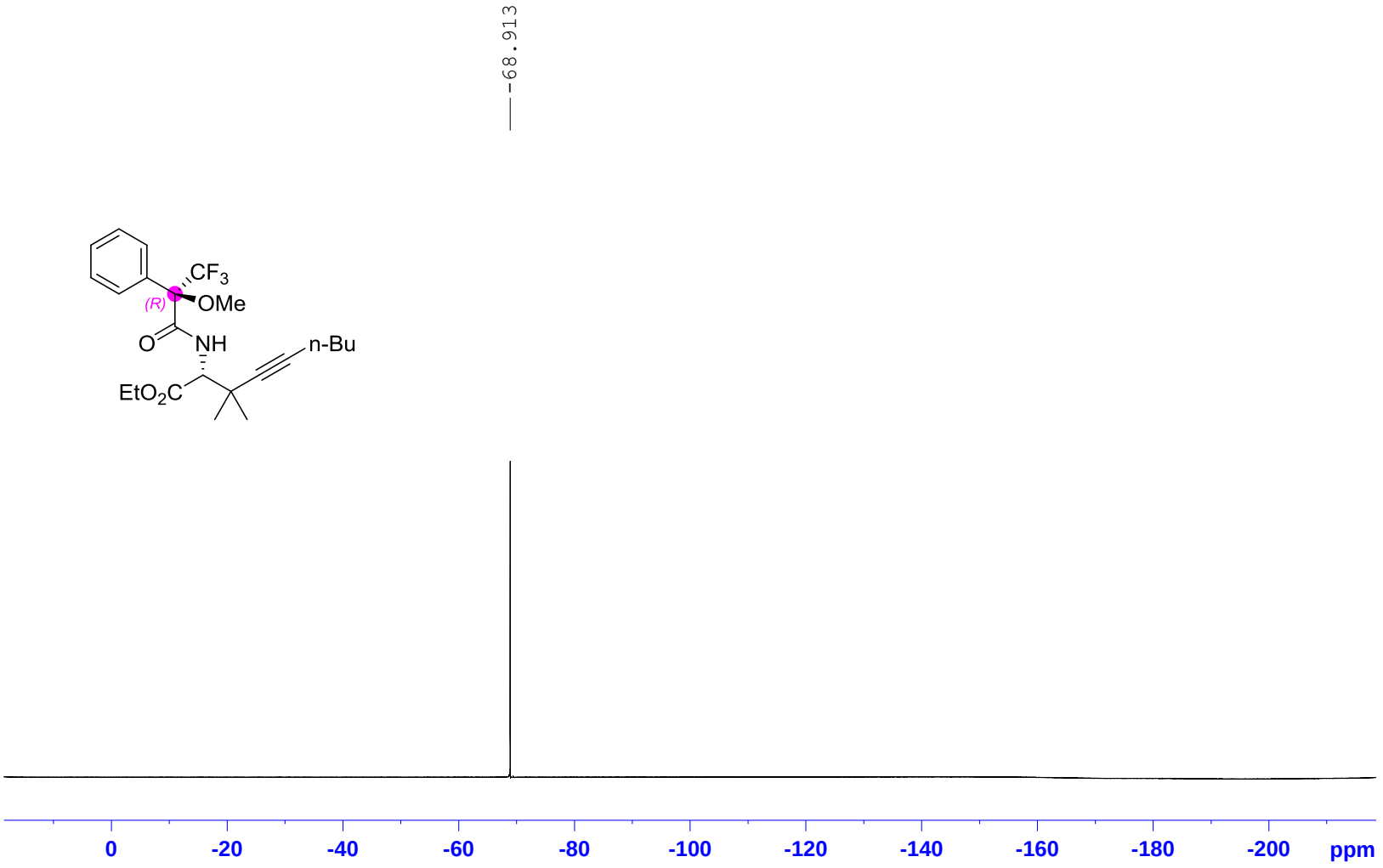
^{1}H NMR of compound **7a** (CDCl3, 400 MHz)



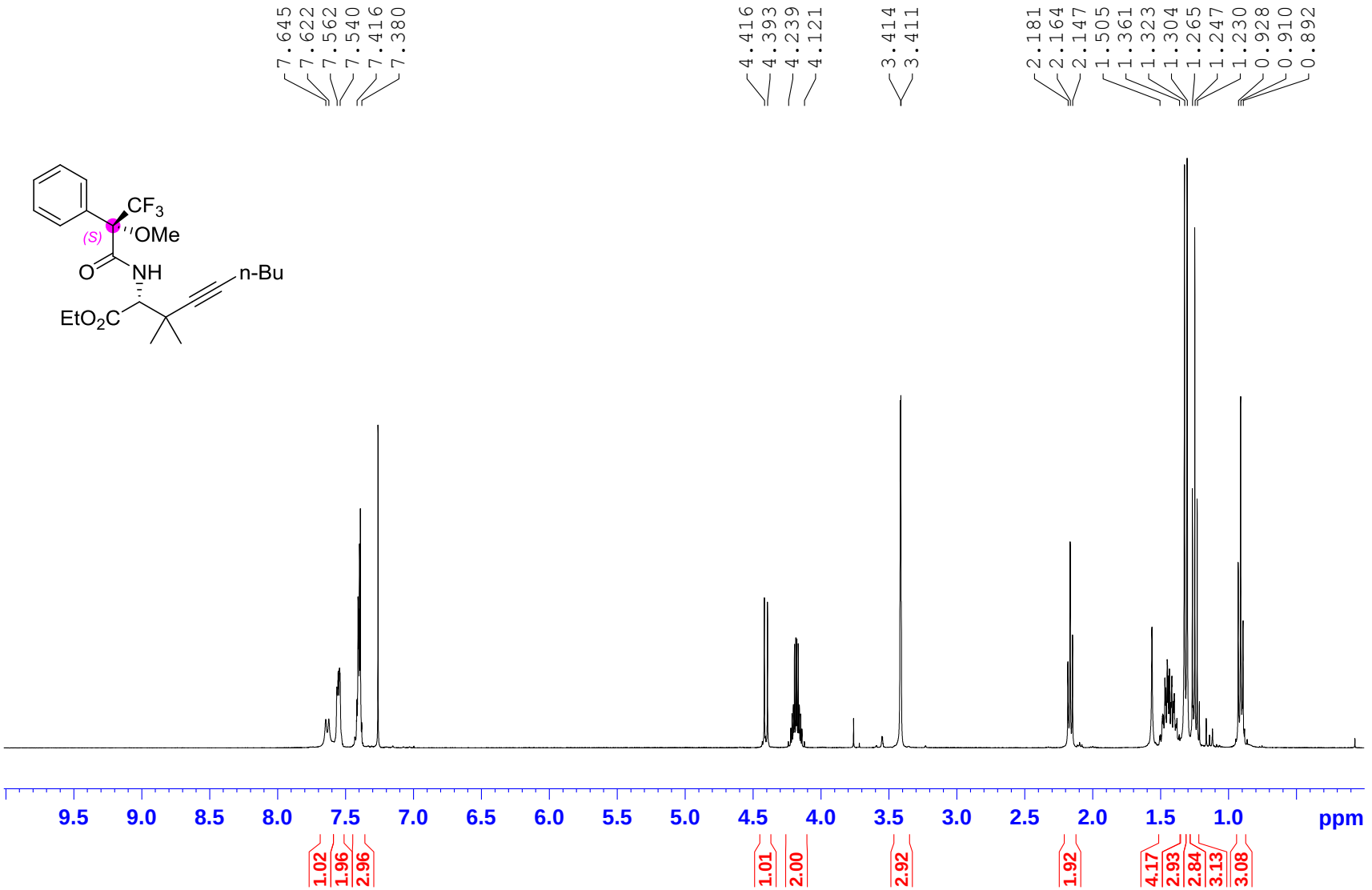
^{13}C NMR of compound **7a** (CDCl3, 100 MHz)



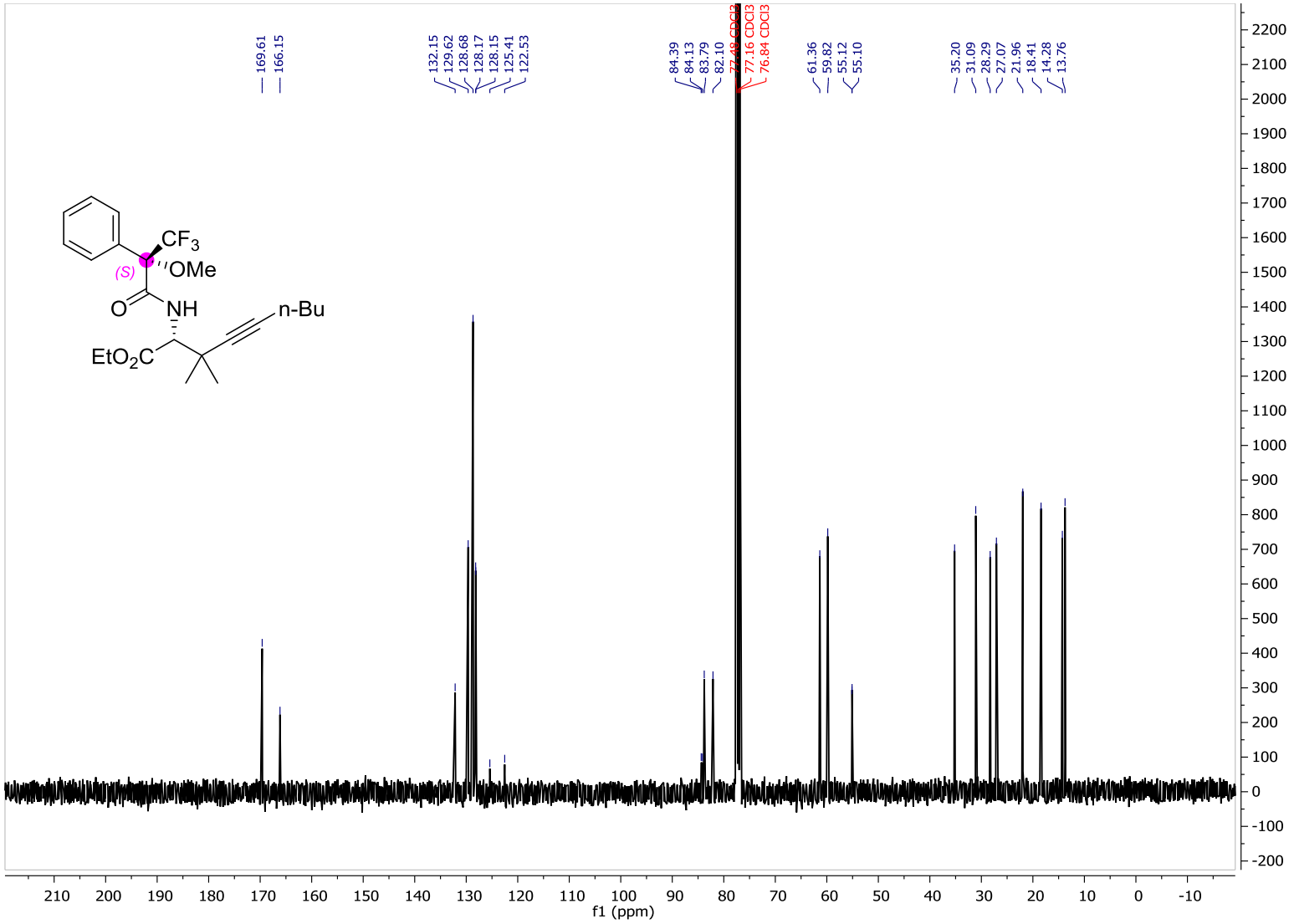
^{19}F NMR of compound **7a** (CDCl3, 377 MHz)



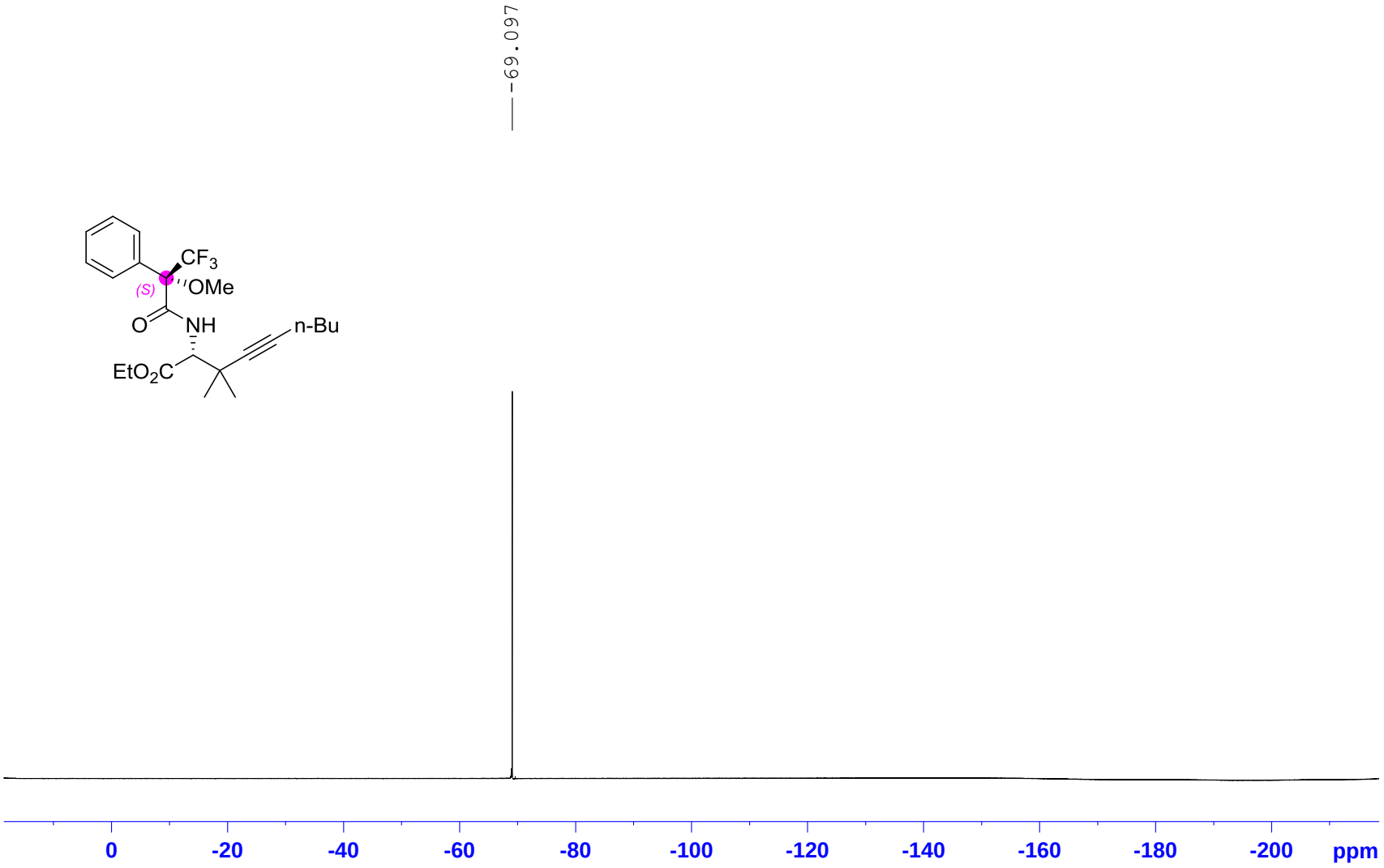
^{1}H NMR of compound **7b** (CDCl3, 400 MHz)



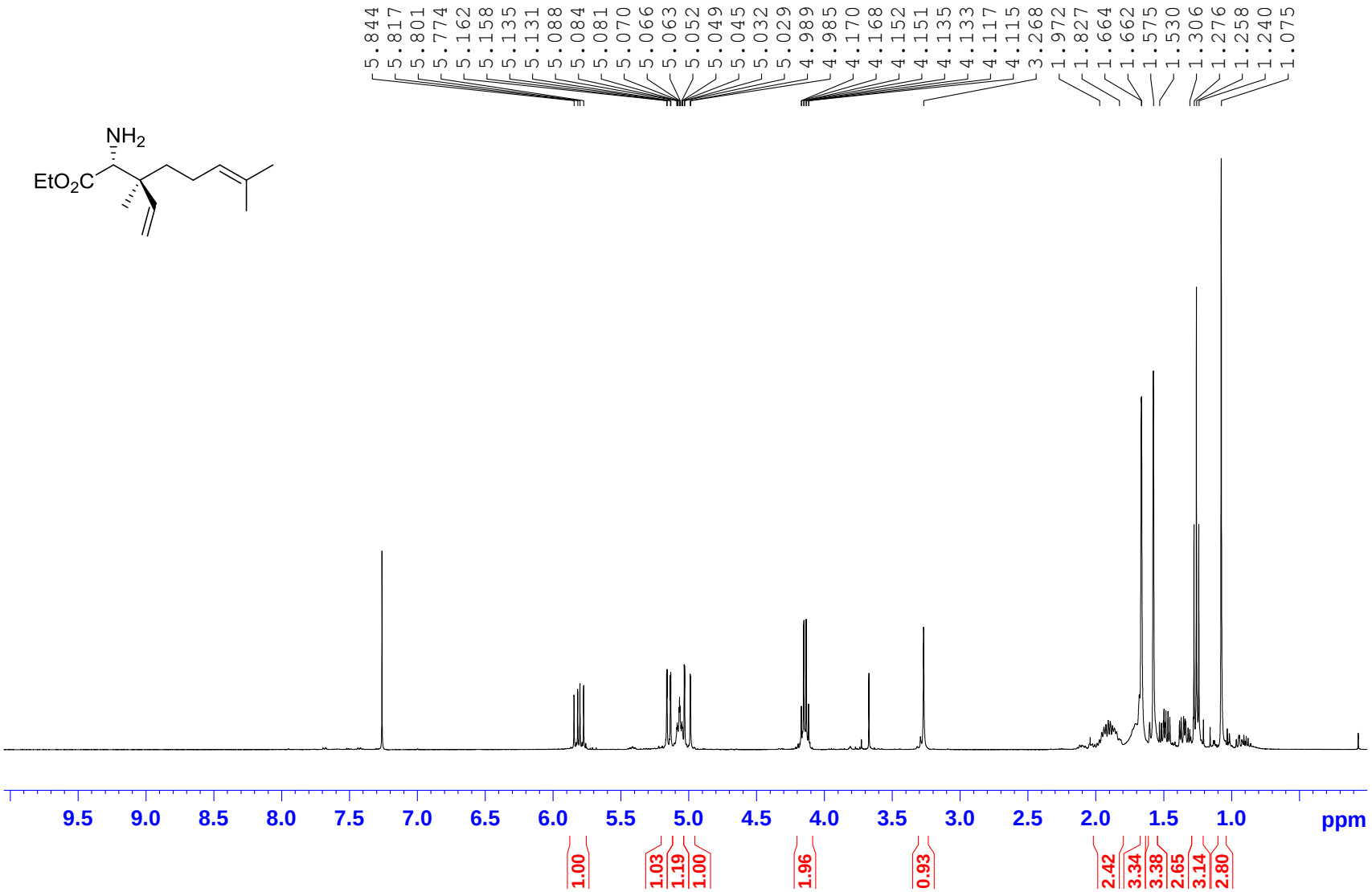
^{13}C NMR of compound **7b** (CDCl3, 100 MHz)



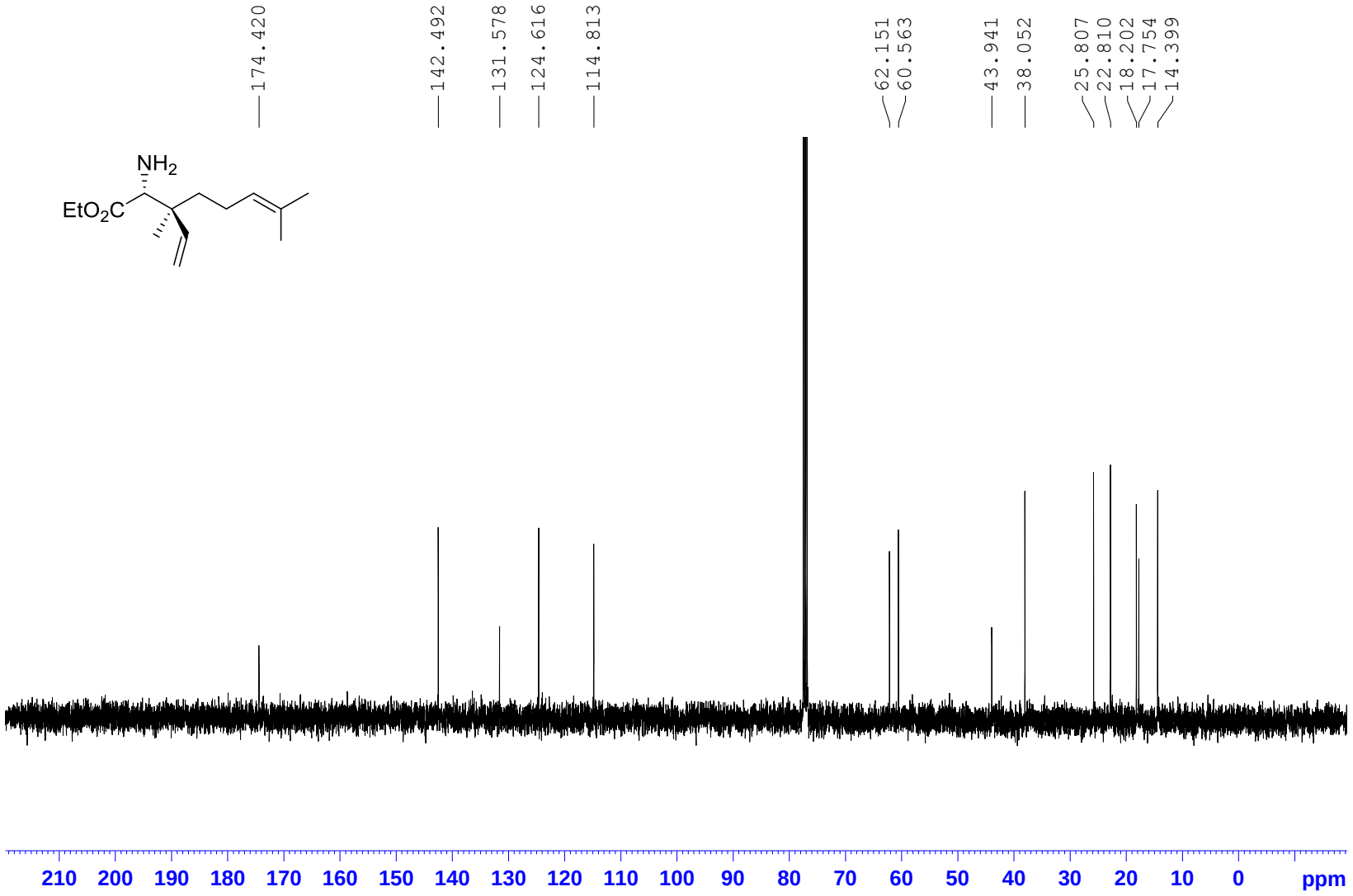
^{19}F NMR of compound **7b** (CDCl3, 377 MHz)



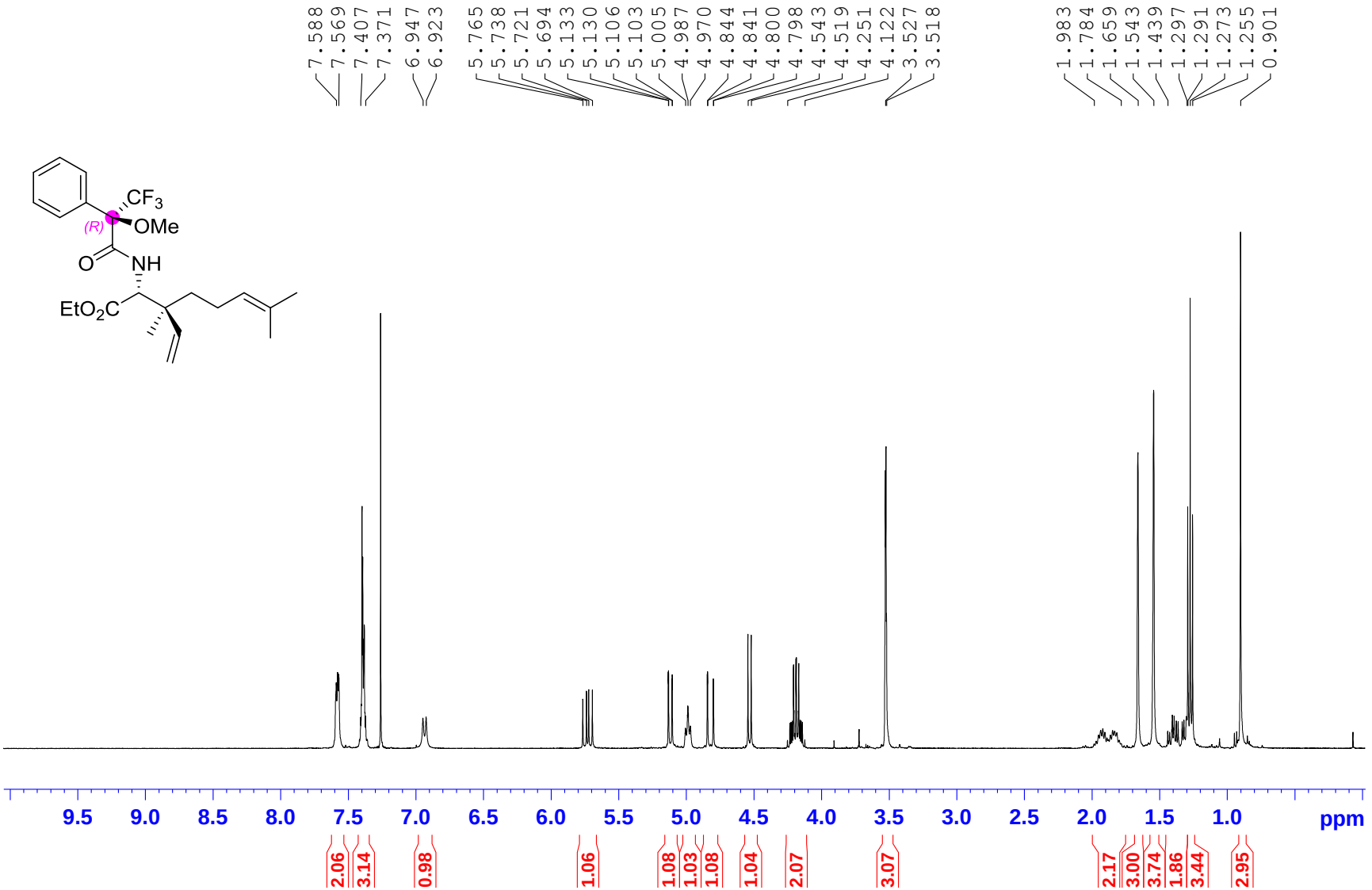
^{1}H NMR of compound **5b** (CDCl3, 400 MHz)



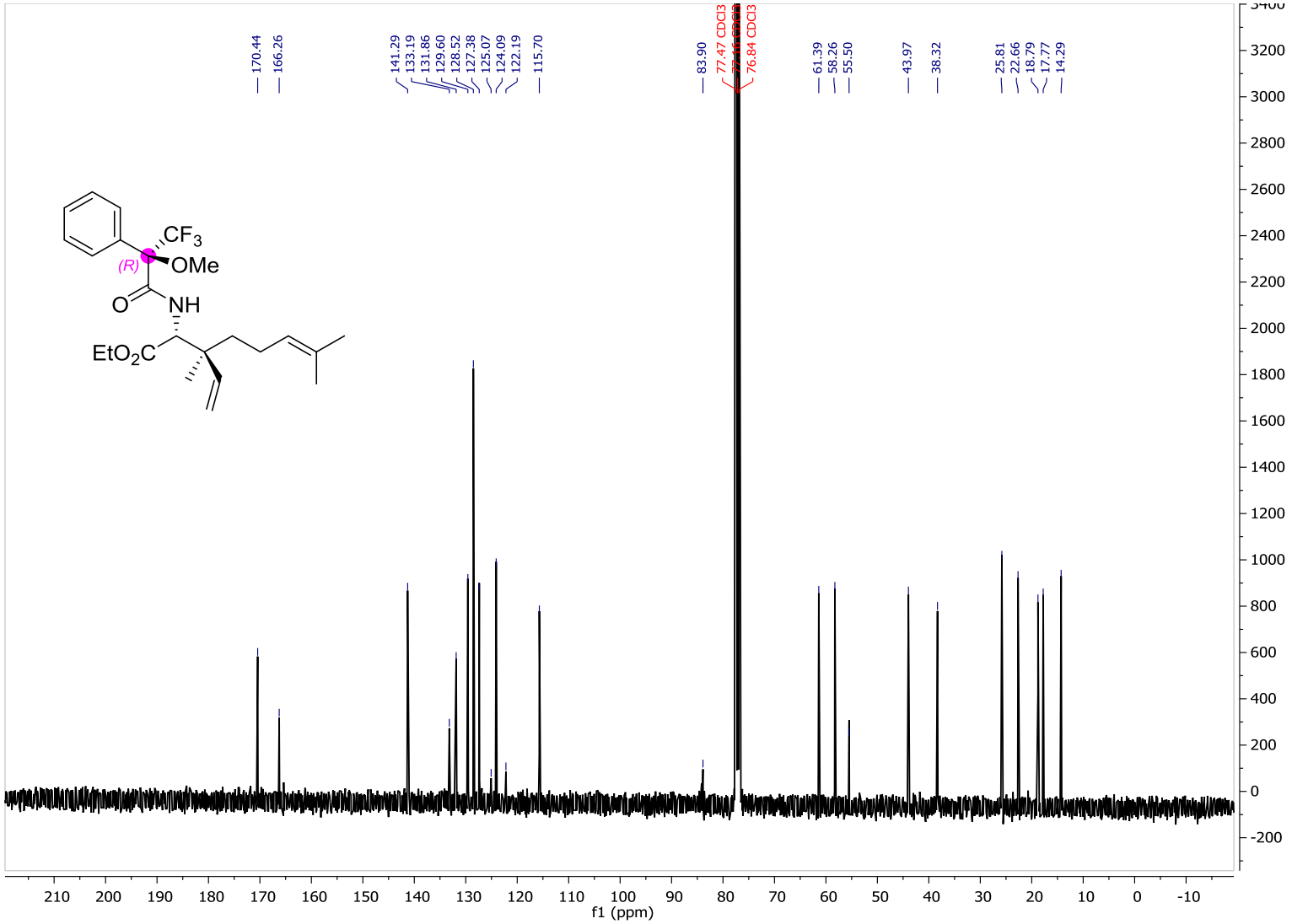
^{13}C NMR of compound **5b** (CDCl3, 100 MHz)



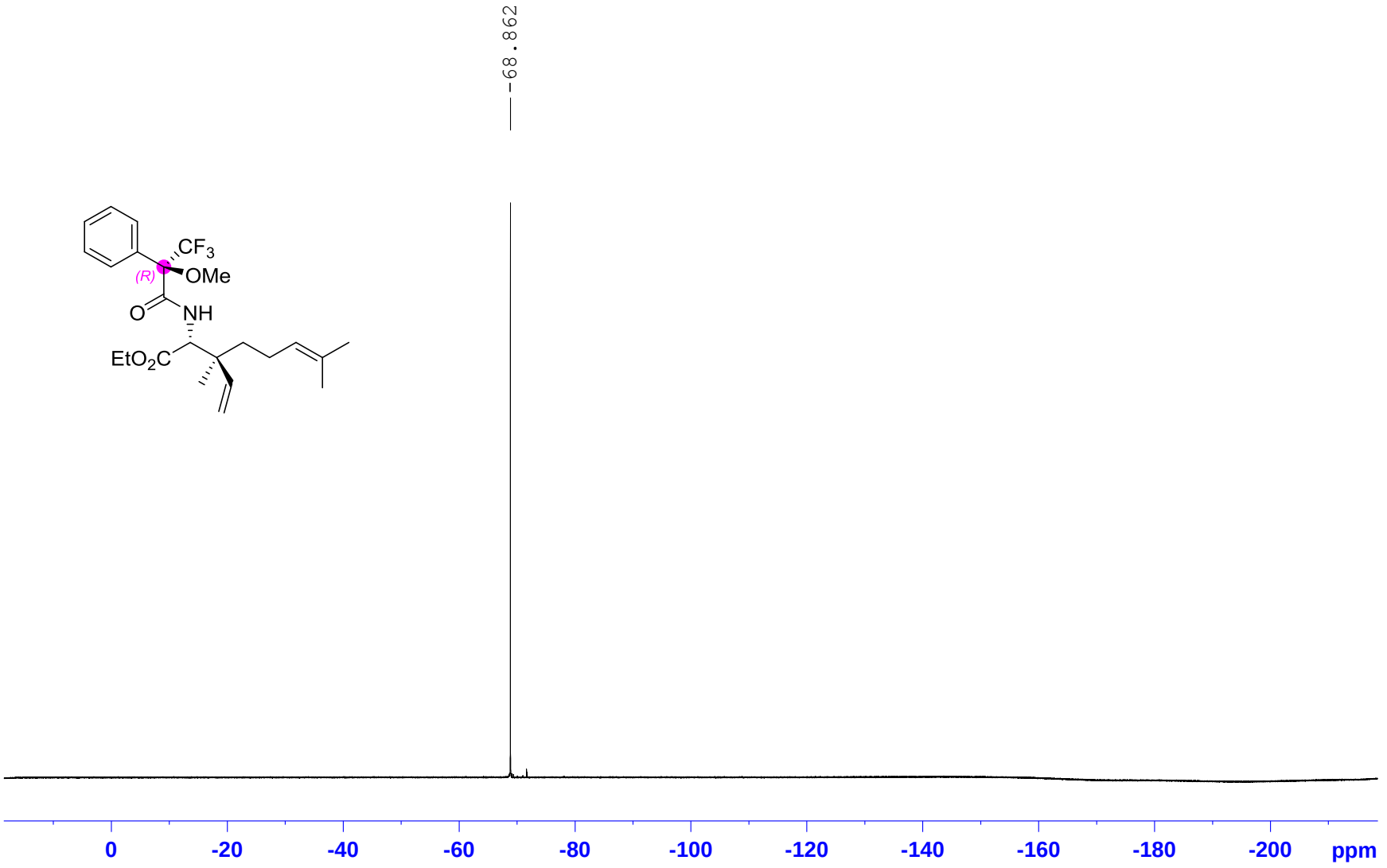
^{1}H NMR of compound **7c** (CDCl3, 400 MHz)



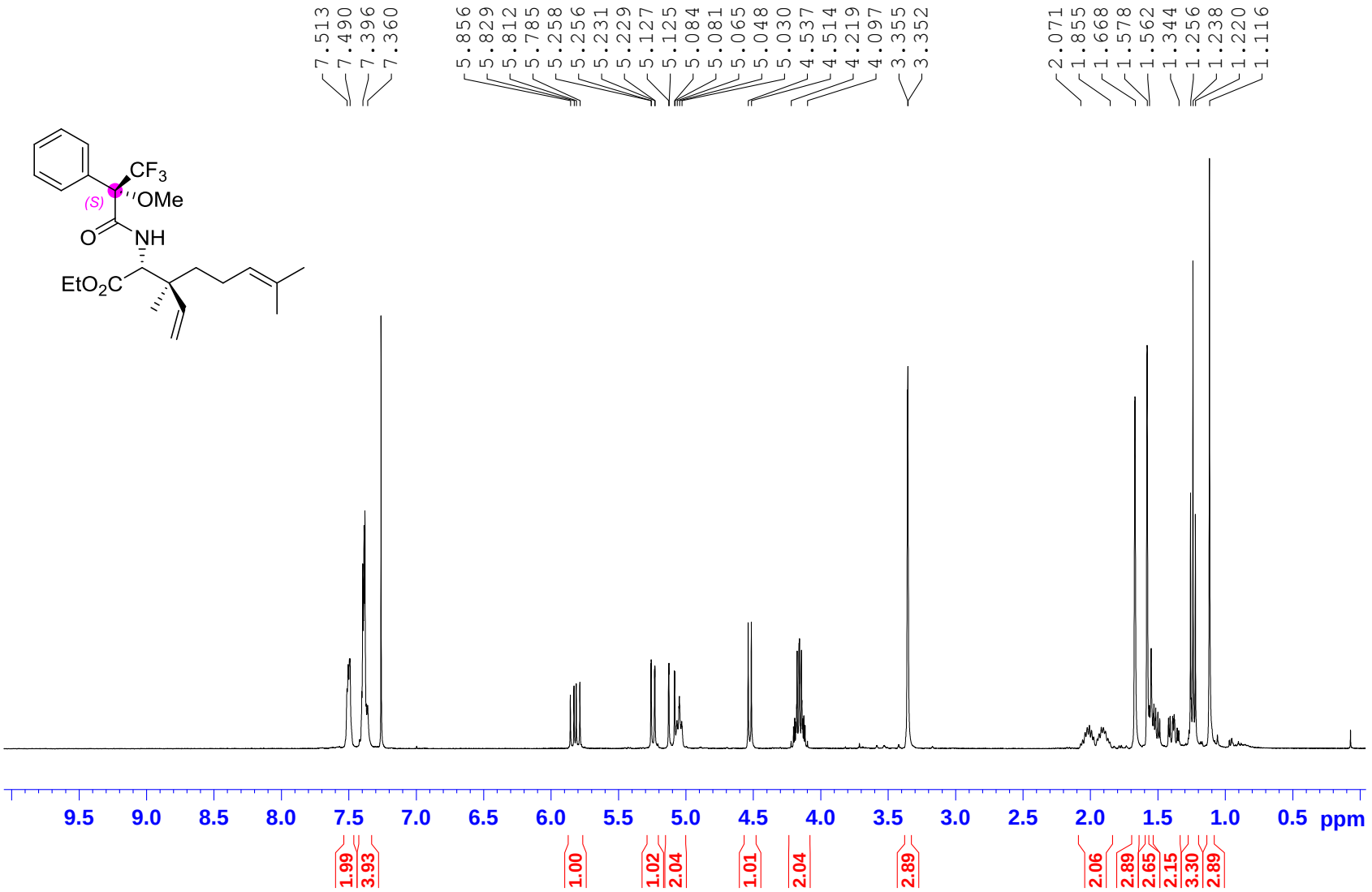
^{13}C NMR of compound **7c** (CDCl3, 100 MHz)



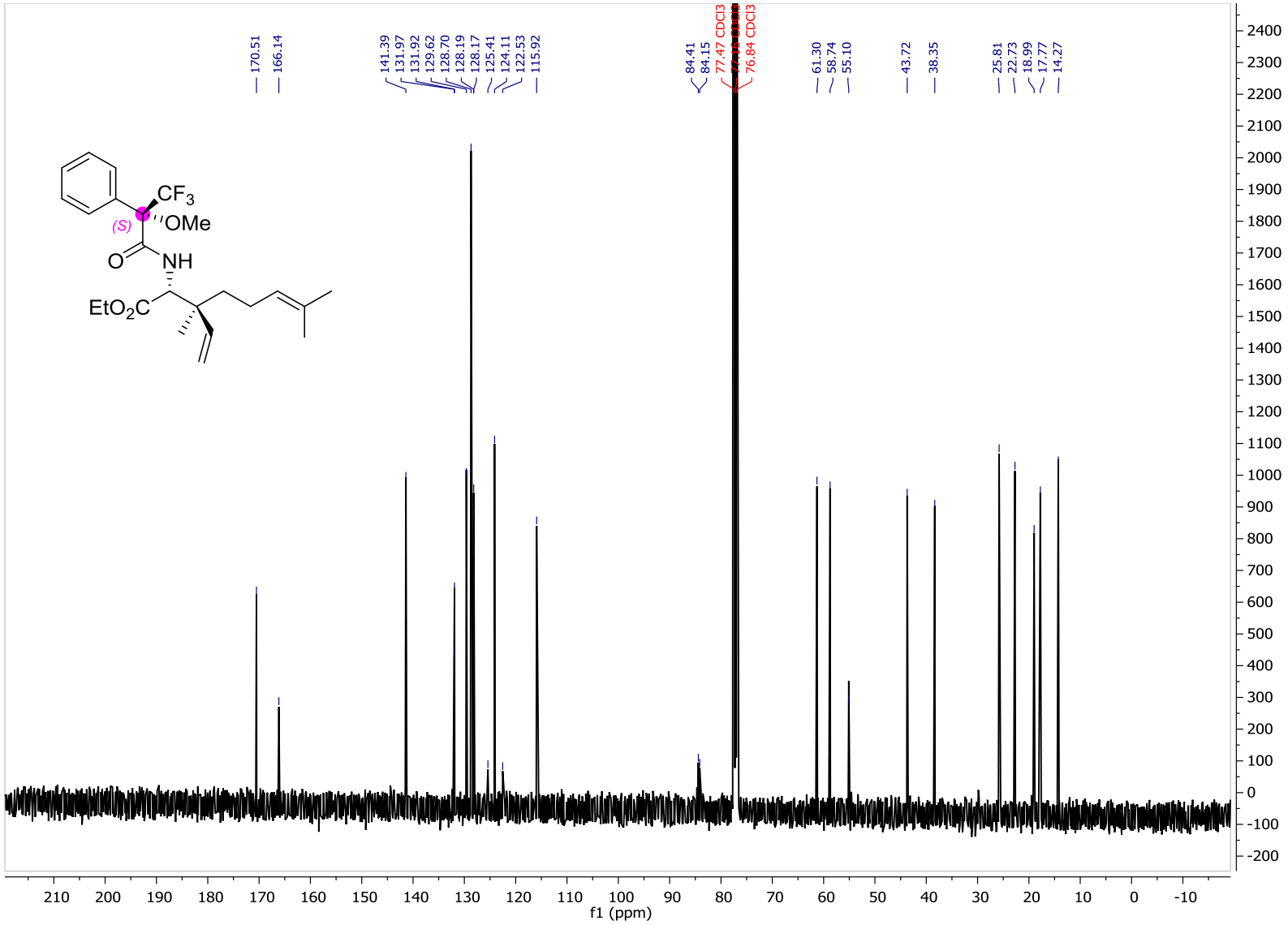
^{19}F NMR of compound **7c** (CDCl3, 377 MHz)



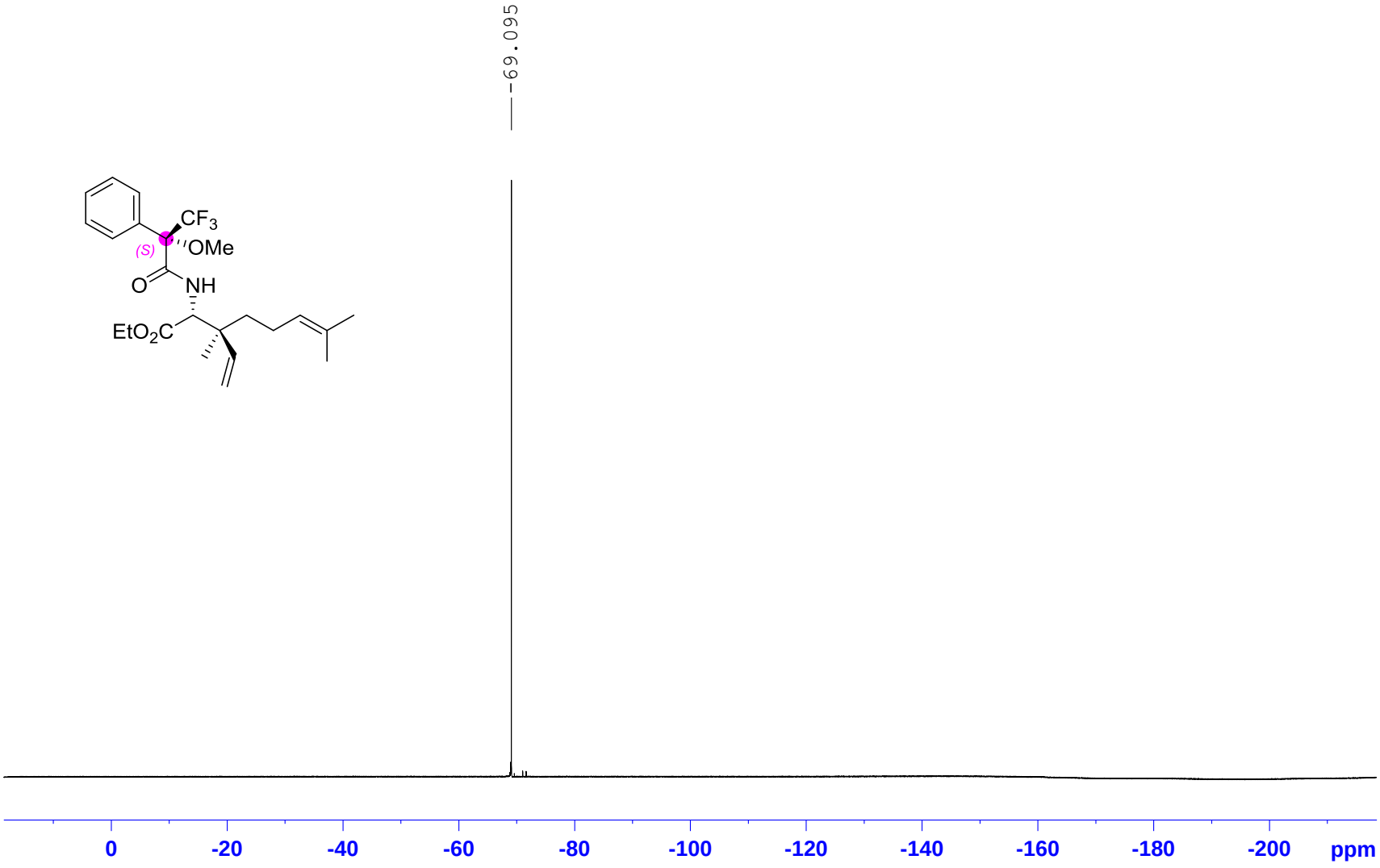
^{1}H NMR of compound **7d** (CDCl3, 400 MHz)



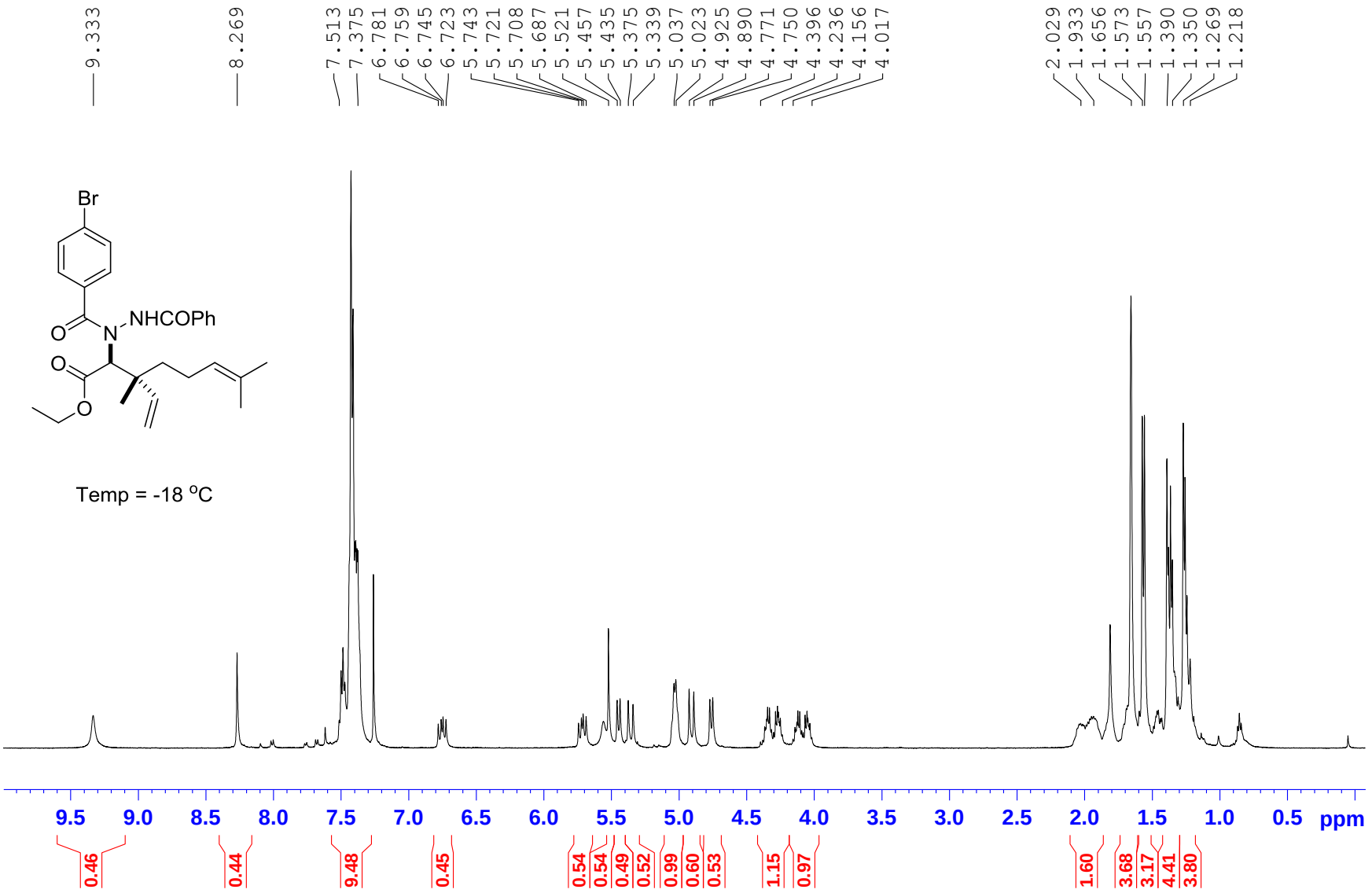
^{13}C NMR of compound **7d** (CDCl3, 100 MHz)



^{19}F NMR of compound **7d** (CDCl3, 377 MHz)



^{1}H NMR of compound **4h-amide** (CDCl3, 500 MHz), -18 ^{o}C



^{1}H NMR of compound **4h-amide** (CDCl3, 400 MHz), room temperature