Electronic Supplementary Material (ESI) for ChemComm.

Haloarene-Guided Cascade Arylation of Cyclic Vinylogous Esters under Palladium Catalysis

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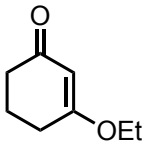
Supporting Information

Table of Contents

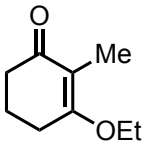
General Information

All air-sensitive reactions were carried out using flame-dried glassware under N_2 atmosphere with standard Schlenk line technique. Toluene and tetrahydrofuran were purified by passage over activated alumina using a commercial solvent purification system. Hexamethyldisilazane was freshly distilled over potassium hydroxide. All other solvents (ACS grade) and commercially obtained reagents were used as received. Aluminum heating blocks were applied to all thermal reactions. A solution of Lithium hexamethyldisilazide (LiHMDS, 2.4 mL) was prepared prior to use by deprotonating bis(trimethylsilyl)amine (0.32 mL, 1.5 mmol) in THF (1.5 mL) with *n*-butyllithium (2.5 M in hexanes, 0.6 mL, 1.5 mmol) under 0˚C for 15 min. Reactions were monitored by thin layer chromatography (TLC) on glass plates coated with silica gel (60 Å/F254), visualized by UV (254 nm) and $KMnO_4$ staining solution. Flash column chromatography was performed on silica gel (230-400 mesh) with indicated eluents. Melting points were uncorrected. NMR spectra were measured at 400 MHz for ^1H NMR spectra and 100 MHz for ^{13}C NMR spectra and calibrated from residual solvent signals (chloroform at 7.26 ppm for ^1H NMR spectra; chloroform at 77.00 ppm for ^{13}C NMR spectra). Chemical shifts were denoted in ppm (δ), and the following abbreviations were used to explain the multiplicities: s = singlet, br = broad, brs = broad singlet, brd = broad doublet, d = doublet, t = triplet, app. t = apparent triplet, q = quartet, p = pentet, dd = doublet doublet, td = triple doublet, dt = double triplet, m = multiplet. Coupling constants (*J*) are reported in Hertz (Hz). Infrared (IR) spectra were measured on KBr salt plates. High-resolution mass spectroscopy (HRMS) was performed on a TOF instrument with EI/ESI in positive ionization mode.

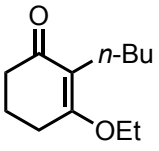
Synthesis and ^1H NMR Data of Known Compounds (1a-d)



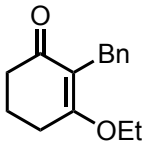
1a



1b



1c



1d

Compounds above were prepared by following previously described procedures. For the synthesis of compounds **1a**, **1b**, and **1c**, see: (a) Johnson, T.; Pultar, F.; Menke, F.; Lautens, M. *Org. Lett.* **2016**, *18*, 6488-6491. (b) Yang, Y.-C.; Lin, Y.-C.; Wu, Y.-K.

Org. Lett. **2019**, *21*, 9286-9290. For the synthesis of compound **1d**, see: (a) Carruthers, W.; Cumming, S. A. *J. Chem. Soc., Perkin Trans. 1* **1983**, *10*, 2383-2386. (b) Yang, Y.-C.; Lin, Y.-C.; Wu, Y.-K. *Org. Lett.* **2019**, *21*, 9286-9290.

3-ethoxycyclohex-2-en-1-one (1a): ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.31 (s, 1H), 3.87 (q, *J* = 7.0 Hz, 2H), 2.37 (t, *J* = 6.3 Hz, 2H), 2.31 (t, *J* = 6.2 Hz, 2H), 1.94 (p, *J* = 6.7 Hz, 2H), 1.33 (t, *J* = 7.1 Hz, 3H).

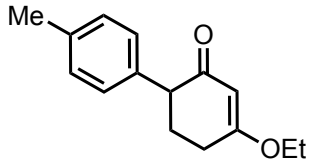
3-ethoxy-2-methylcyclohex-2-en-1-one (1b): ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.06 (q, *J* = 7.0 Hz, 2H), 2.57-2.51 (m, 2H), 2.34 (t, *J* = 6.2 Hz, 2H), 1.97 (p, *J* = 6.5 Hz, 2H), 1.70 (t, *J* = 1.6 Hz, 3H), 1.34 (t, *J* = 7.0 Hz, 3H).

2-butyl-3-ethoxycyclohex-2-en-1-one (1c): ^{1}H NMR (400 MHz, $CDCl_3$): δ 4.04 (q, *J* = 7.0 Hz, 2H), 2.53 (t, *J* = 6.2 Hz, 2H), 2.31 (t, *J* = 6.5 Hz, 2H), 2.25 (t, *J* = 6.8 Hz, 2H), 1.95 (p, *J* = 6.4 Hz, 2H), 1.33 (t, *J* = 7.0 Hz, 3H), 1.30-1.24 (m, 4H), 0.87 (t, *J* = 6.8 Hz, 3H).

2-benzyl-3-ethoxycyclohex-2-en-1-one (1d): ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28-7.24 (m, 2H), 7.20 (t, *J* = 7.2 Hz, 2H), 7.11 (t, *J* = 7.2 Hz, 1H), 4.05 (q, *J* = 7.0 Hz, 2H), 3.62 (s, 2H), 2.56 (t, *J* = 6.2 Hz, 2H), 2.36 (t, *J* = 6.3 Hz, 2H), 1.98 (p, *J* = 6.4 Hz, 2H), 1.34 (t, *J* = 7.0 Hz, 3H).

Synthesis and Characterization Data of 2a and 3a

4-ethoxy-4'-methyl-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (2a)

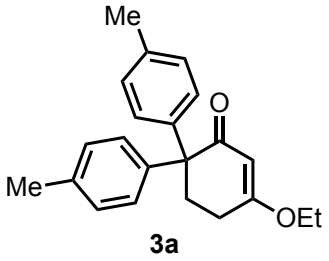


2a

To a reaction vessel containing vinylogous ester **1a** (0.5 mmol) were added tolyl bromide or iodide (0.6 mmol, 1.2 equiv.), $Pd(OAc)_2$ (10 mol%, 11 mg), $P(Ad)_3$ (12 mol%, 26 mg) was held under vacuum for 2 minutes. The whole system was backfilled with N_2, and then 5 mL of toluene was added to the flask. After stirring for 5 minutes, LiHMDS (3 equiv, 2.4 ml) was slowly added into the vessel at rt. The reaction mixture was stirred at rt for 30 min. The reaction was quenched with saturated $NH_4Cl_{(aq)}$ and

then diluted with ethyl acetate. The organic layer was extracted with saturated brine, filtered through celite, dried over $MgSO_4$, and then concentrated with a rotary evaporator. The crude residue was purified by flash column chromatography (hexanes/EtOAc = 3/1) to afford **2a** (w/ TolBr, 45%; w/ TolI, 60%) as yellow solid (m.p. 64-65 ˚C). R_f: 0.31 (hexanes/EtOAc = 3/1). **IR** (cast): 2981, 2938, 2869, 1654, 1604, 1514 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.14 (d, *J* = 7.8 Hz, 2H), 7.06 (d, *J* = 8.1 Hz, 2H), 5.50 (s, 1H), 3.99-3.89 (m, 2H), 3.49 (dd, *J* = 9.5, 5.5 Hz, 1H), 2.58-2.40 (m, 2H), 2.33 (s, 3H), 2.29-2.15 (m, 2H), 1.38 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 199.4, 177.2, 136.8, 136.3, 129.2, 128.1, 103.1, 64.3, 51.6, 29.4, 28.2, 21.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{15}H_{18}O_2$ calcd. 230.1301, found: 230.1304.

4'-ethoxy-4,4''-dimethyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (3a)[1]



3a

To a reaction vessel containing vinylogous ester **1a** (0.5 mmol) were added tolyl chloride or bromide (0.6 mmol, 1.2 equiv.), $Pd(OAc)_2$ (10 mol%, 11 mg), $P(Ad)_3$ (12 mol%, 26 mg) and toluene (5 ml). After stirring for 5 minutes, LiHMDS (3 equiv, 2.4 ml) was slowly added into the vessel at rt. The reaction mixture was stirred at 70 ˚C for 30 min. The reaction was quenched with saturated $NH_4Cl_{(aq)}$ and then diluted with ethyl acetate. The organic layer was extracted with saturated brine, filtered through celite, dried over $MgSO_4$, and then concentrated with a rotary evaporator. The crude residue was purified by flash column chromatography (hexanes/EtOAc = 3/1) to afford **3a** (w/ TolCl, 47 %; w/ TolBr, 74%). **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.12 (d, *J* = 8.1 Hz, 4H), 7.04 (d, *J* = 7.4 Hz, 4H), 5.55 (s, 1H), 3.88 (q, *J* = 7.0 Hz, 2H), 2.70 (t, *J* = 6.1 Hz, 2H), 2.41-2.34 (m, 2H), 2.33 (s, 6H), 1.33 (t, *J* = 7.0 Hz, 3H).

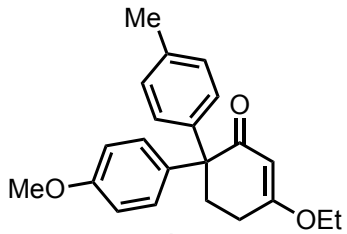
Synthesis and Characterization Data of 4a-m, 2b and 5a-f

General Procedure for the One-pot Sequential Diarylation.

A round-bottom flask containing a vinylogous ester (0.5 mmol), an aryl bromide

(1.1 equiv.), an aryl chloride (2.2 equiv.), $Pd(OAc)_2$ (10 mol %, 11 mg) and PAd_3 (12 mol %, 26 mg) was held under vacuumed for 2 minutes. The whole system was backfilled with N_2, and then 5 mL of toluene was added to the flask. A solution of LiHMDS (3 equiv., 2.4 mL) was added dropwise to the stirring mixture over 3 minutes at room temperature. The resulting mixture was then stirred at 70 °C for the indicated time. After completion of the reaction as indicated by TLC analysis, $NH_4Cl_{(aq)}$ was added to quench the reaction at room temperature. The reaction mixture was filtered through celite. The filtrate was diluted with ethyl acetate and extracted with water and then brine. The organic layer was dried over anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The crude residue thus obtained was purified by flash column chromatography.

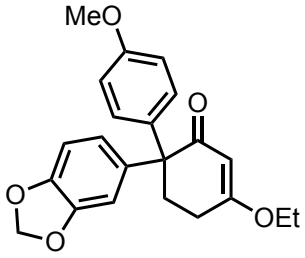
4'-ethoxy-4-methoxy-4''-methyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4a)



4a

The reaction was conducted with **1a**, 4-bromotoluene and 4-chloroanisole following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4a** (103 mg, 61%) as brown oil. R_f = 0.30 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2936, 2835, 1653, 1608, 1510 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.11-6.99 (m, 6H), 6.83 (d, *J* = 8.8 Hz, 2H), 5.52 (s, 1H), 3.87 (q, *J* = 7.1 Hz, 2H), 3.78 (s, 3H), 2.69-2.64 (m, 2H), 2.35 (t, *J* = 6.0 Hz, 2H), 2.32 (s, 3H), 1.32 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.4, 176.1, 158.2, 139.6, 136.3, 134.4, 129.5, 128.8, 128.3, 113.4, 103.3, 64.3, 57.6, 55.2, 34.1, 27.2, 21.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{22}H_{24}O_3$ calcd. 336.1720, found: 336.1719.

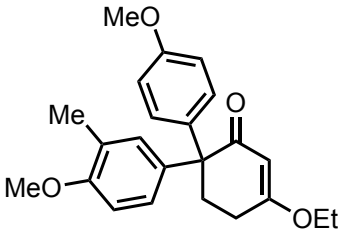
1-(Benzo[*d*][1,3]dioxol-5-yl)-4-ethoxy-4'-methoxy-5,6-dihydro-[1,1'-biphenyl]-2(1*H*)-one (4b)[1]



4b

The reaction was conducted with **1a**, 4-bromoanisole and 5-chloro-1,3-benzodioxole following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4b** (125 mg, 68%) as yellow oil. R_f: 0.33 (hexanes/EtOAc = 3/1). **IR** (film): 2954, 2837, 1653, 1608, 1510 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.08 (d, *J* = 8.9 Hz, 2H), 6.84 (d, *J* = 8.9 Hz, 2H), 6.72 (d, *J* = 8.2 Hz, 1H), 6.62-6.55 (m, 2H), 5.92 (s, 2H), 5.51 (s, 1H), 3.87 (q, *J* = 7.1 Hz, 2H), 3.79 (s, 3H), 2.69-2.57 (m, 2H), 2.36 (t, *J* = 6.0 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.1, 176.1, 158.3, 147.5, 146.2, 136.8, 133.9, 129.4, 121.5, 113.5, 109.4, 107.6, 103.1, 101.0, 64.3, 57.6, 55.2, 34.2, 27.1, 14.1; **HRMS** (EI, $[M]^+$) for $C_{22}H_{22}O_5$ calcd. 366.1462, found: 366.1467.

4'-ethoxy-4,4''-dimethoxy-3-methyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4c)

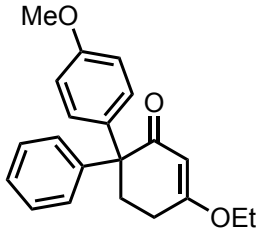


4c

The reaction was conducted with **1a**, 4-bromoanisole and 2-methyl-4-chloroanisole following the general procedure (reaction time = 60 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4c** (167 mg, 91%) as white solid (m.p. 154-155 ˚C). R_f: 0.23 (hexanes/EtOAc = 3/1). **IR** (cast): 2990, 2939, 2904, 1649, 1604, 1505 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.04 (d, *J* = 8.8 Hz, 2H), 6.93-6.88 (m, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 6.74 (d, *J* = 8.4 Hz, 1H), 5.52 (s, 1H), 3.87 (q, *J* = 7.0 Hz, 2H), 3.80 (s, 3H), 3.79 (s, 3H), 2.64 (t, *J* = 5.7 Hz, 2H), 2.43-2.30 (m, 2H), 2.16 (s, 3H), 1.32 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.6, 176.1, 158.2, 156.5, 134.8, 133.7, 130.6, 129.5, 126.8, 126.1, 113.4,

109.3, 103.2, 64.3, 57.3, 55.21, 55.16, 34.2, 27.2, 16.5, 14.1; **HRMS** (EI, $[M]^+$) for $C_{23}H_{26}O_4$ calcd. 366.1825, found: 366.1826.

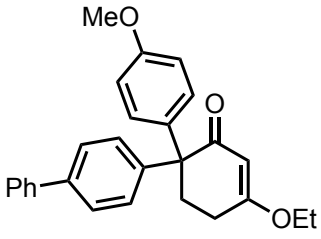
4'-ethoxy-4-methoxy-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4d)



4d

The reaction was conducted with **1a**, 4-bromoanisole and chlorobenzene following the general procedure (reaction time = 60 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4d** (95 mg, 59%) as yellow oil. R_f = 0.28 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2936, 2906, 1650, 1603, 1509 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.32-7.21 (m, 3H), 7.14-7.11 (m, 2H), 7.07 (d, *J* = 9.0 Hz, 2H), 6.84 (d, *J* = 9.0 Hz, 2H), 5.54 (s, 1H), 3.88 (q, *J* = 7.0 Hz, 2H), 3.79 (s, 3H), 2.69 (t, *J* = 6.0 Hz, 2H), 2.38-2.34 (m, 2H), 1.32 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.2, 176.2, 158.3, 142.8, 134.0, 129.6, 128.4, 128.0, 126.7, 113.4, 103.3, 64.3, 57.9, 55.2, 34.1, 27.1, 14.1; **HRMS** (EI, $[M]^+$) for $C_{21}H_{22}O_3$ calcd. 322.1563, found: 322.1568.

4'-ethoxy-4-methoxy-5',6'-dihydro-2'H-[1,1':1',1'':4'',1'''-quaterphenyl]-2'-one (4e)

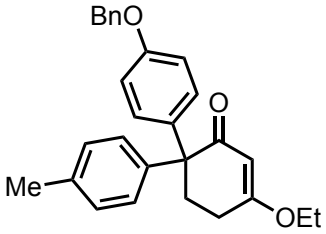


4e

The reaction was conducted with **1a**, 4-bromoanisole and 4'-biphenyl chloride following the general procedure (reaction time = 60 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4e** (145 mg, 73%) as yellow oil. R_f = 0.25 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2934, 2900, 1653, 1605, 1509 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.58 (d, *J* = 7.6 Hz, 2H),

7.53 (d, J = 8.4 Hz, 2H), 7.42 (app. t, J = 7.6 Hz, 2H), 7.33 (t, J = 7.6 Hz, 1H), 7.20 (d, J = 8.4 Hz, 2H), 7.14 (d, J = 8.8 Hz, 2H), 6.87 (d, J = 8.8 Hz, 2H), 5.57 (s, 1H), 3.90 (q, J = 7.0 Hz, 2H), 3.80 (s, 3H), 2.79-2.66 (m, 2H), 2.40 (t, J = 6.0 Hz, 2H), 1.34 (t, J = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.1, 176.2, 158.3, 142.1, 140.7, 139.4, 133.7, 129.5, 128.8, 128.7, 127.1, 127.0, 126.7, 113.5, 103.3, 64.3, 57.7, 55.2, 34.0, 27.1, 14.1; **HRMS** (EI, $[M]^+$) for $C_{27}H_{26}O_3$ calcd. 398.1876, found: 398.1879.

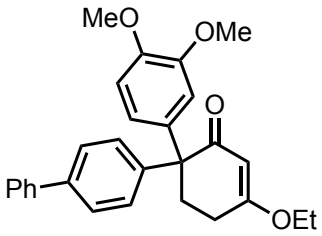
4-(benzyloxy)-4'-ethoxy-4''-methyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4f)



4f

The reaction was conducted with **1a**, 4-benzyloxybromobenzene and 4-chlorotoluene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 3/1) to afford **4f** (149 mg, 72%) as yellow oil. R_f = 0.30 (hexanes/EtOAc = 3/1). **IR** (film): 2979, 2936, 2863, 1653, 1606, 1508 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.45-7.29 (m, 5H), 7.12-7.08 (m, 2H), 7.08-7.01 (m, 4H), 6.91 (d, J = 9.0 Hz, 2H), 5.53 (s, 1H), 5.03 (s, 2H), 3.87 (q, J = 7.0 Hz, 2H), 2.67 (t, J = 6.2 Hz, 2H), 2.36 (t, J = 6.2 Hz, 2H), 2.32 (s, 3H), 1.32 (t, J = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.4, 176.1, 157.5, 139.5, 137.0, 136.3, 134.7, 129.6, 128.8, 128.5, 128.3, 127.9, 127.5, 114.3, 103.3, 70.0, 64.3, 57.6, 34.1, 27.2, 21.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{28}H_{28}O_3$ calcd. 412.2033, found: 412.2030.

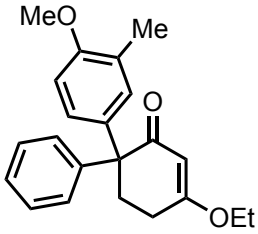
4'-Ethoxy-3,4-dimethoxy-5',6'-dihydro-2'*H*-[1,1':1',1'':4'',1'''-quaterphenyl]-2'-one (4g)[1]



4g

The reaction was conducted with **1a**, 4-bromoveratrole and 4'-biphenyl chloride following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 3/1) to afford **4g** (119 mg, 56%) as light brown solid (m.p. 64-65 ˚C). R_f: 0.41 (hexanes/ EtOAc = 3/1). **IR** (cast): 2953, 2935, 1652, 1608, 1516 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.58 (d, *J* = 7.5 Hz, 2H), 7.52 (d, *J* = 8.5 Hz, 2H), 7.42 (app. t, *J* = 7.5 Hz, 2H), 7.32 (t, *J* = 7.5 Hz, 1H), 7.18 (d, *J* = 8.5 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 1H), 6.80-6.76 (m, 2H), 5.57 (s, 1H), 3.94-3.86 (m, 5H), 3.79 (s, 3H), 2.79-2.67 (m, 2H), 2.51-2.36 (m, 2H), 1.34 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.1, 176.3, 148.6, 147.9, 142.2, 140.6, 139.4, 133.7, 128.8, 128.6, 127.1, 126.9, 126.6, 120.6, 112.1, 110.5, 103.2, 64.3, 58.0, 55.8, 55.7, 34.1, 27.1, 14.0; **HRMS** (EI, $[M]^+$) for $C_{28}H_{28}O_4$ calcd. 428.1988, found: 428.1983.

4'-ethoxy-4-methoxy-3-methyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4h)[1]

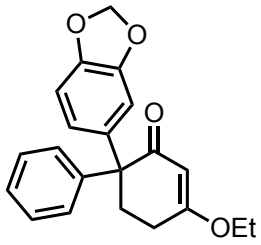


4h

The reaction was conducted with **1a**, 2-methyl-4-bromoanisole and chlorobenzene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/2) to afford **4h** (83 mg, 45%) as yellow oil. R_f: 0.2 (hexanes/ EtOAc = 3/1). **IR** (film): 2980, 2941, 1654, 1609, 1504 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.31-7.20 (m, 3H), 7.13-7.09 (m, 2H), 6.95-6.90 (m, 2H), 6.74 (d, *J* = 8.5 Hz, 1H), 5.53 (s, 1H), 3.87 (q, *J* = 7.0 Hz, 2H), 3.81 (s, 3H), 2.68 (t, *J* = 6.0 Hz, 2H), 2.44-2.30 (m, 2H), 2.16 (s, 3H), 1.32 (t, *J* =

7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.3, 176.1, 156.5, 143.0, 133.1, 130.6, 128.4, 127.9, 126.8, 126.6, 126.0, 109.3, 103.2, 64.2, 57.9, 55.1, 34.1, 27.1, 16.4, 14.1; **HRMS** (EI, $[M]^+$) for $C_{22}H_{24}O_3$ calcd. 336.1720, found: 336.1716.

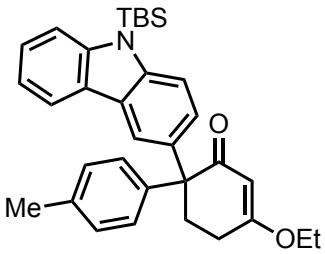
1-(benzo[d][1,3]dioxol-5-yl)-4-ethoxy-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (4i)



4i

The reaction was conducted with **1a**, 4-bromo-1,2-(methylenedioxy)benzene and chlorobenzene following the general procedure (reaction time = 60 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4i** (93 mg, 55%) as brown colloid. R_f = 0.30 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2933, 2900, 1652, 1607, 1503 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.33-7.23 (m, 3H), 7.17-7.13 (m, 2H), 6.73 (d, *J* = 8.2 Hz, 1H), 6.64-6.57 (m, 2H), 5.93 (s, 2H), 5.53 (s, 1H), 3.88 (q, *J* = 7.0 Hz, 2H), 2.73-2.60 (m, 2H), 2.43-2.28 (m, 2H), 1.33 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 199.9, 176.3, 147.5, 146.3, 142.3, 136.3, 128.4, 128.1, 126.8, 121.6, 109.5, 107.7, 103.3, 101.0, 64.4, 58.3, 34.2, 27.2, 14.1; **HRMS** (EI, $[M]^+$) for $C_{21}H_{20}O_4$ calcd. 336.1356, found: 336.1360.

1-(9-(tert-butyldimethylsilyl)-9H-carbazol-2-yl)-4-ethoxy-4'-methyl-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (4j)

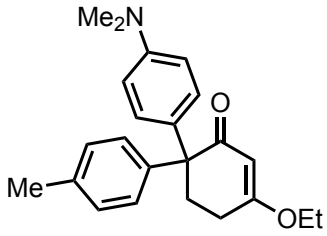


4j

The reaction was conducted with **1a**, *N*-tert-butyldimethylsilyl-3-bromocarbazole and 4-chlorotoluene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 3/1) to

afford **4j** (133 mg, 52%) as white solid (m.p. 104-105 ˚C). R_f: 0.56 (hexanes/ EtOAc = 3/1). **IR** (cast): 2954, 2928, 2891, 1653, 1608, 1511 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.96 (d, *J* = 7.7 Hz, 1H), 7.84 (s, 1H), 7.56 (d, *J* = 8.5 Hz, 1H), 7.50 (d, *J* = 8.8 Hz, 1H), 7.32 (app. t, *J* = 7.1 Hz, 1H), 7.19-7.15 (m, 2H), 7.10 (d, *J* = 8.3 Hz, 2H), 7.05 (d, *J* = 8.3 Hz, 2H), 5.59 (s, 1H), 3.92-3.84 (m, 2H), 2.85-2.77 (m, 2H), 2.45-2.37 (m, 2H), 2.32 (s, 3H), 1.31 (t, *J* = 7.0 Hz, 3H), 1.04 (s, 9H), 0.72 (s, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.8, 176.2, 145.3, 143.9, 140.4, 136.2, 132.9, 128.7, 128.5, 126.3, 126.1, 126.0, 125.1, 119.8, 119.5, 114.0, 113.7, 103.4, 64.3, 58.2, 34.5, 27.3, 26.6, 21.0, 20.5, 14.1, -1.4 [one aromatic carbon is missing due to peak overlapping]; **HRMS** (EI, $[M]^+$) for $C_{33}H_{39}NO_2Si$ calcd. 509.2744, found: 509.2745.

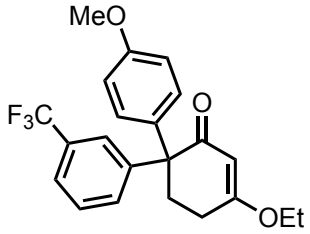
4-(dimethylamino)-4'-ethoxy-4''-methyl-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4k)



4k

The reaction was conducted with **1a**, 4-bromo-*N*,*N*-dimethylaniline and 4-chlorotoluene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 2/1) to afford **4k** (68 mg, 39%) as white solid (m.p. 60-63 ˚C). R_f: 0.34 (hexanes/EtOAc = 3/1). **IR** (cast): 2928, 1653, 1610, 1517 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.09-6.97 (m, 6H), 6.67 (d, *J* = 8.8 Hz, 2H), 5.51 (s, 1H), 3.85 (q, *J* = 7.0 Hz, 2H), 2.93 (s, 6H), 2.65 (t, *J* = 5.9 Hz, 2H), 2.44-2.33 (m, 2H), 2.31 (s, 3H), 1.31 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 200.8, 176.0, 149.2, 140.5, 136.0, 129.2, 129.1, 128.7, 128.4, 112.1, 103.3, 64.2, 57.5, 40.5, 34.1, 27.2, 21.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{23}H_{27}NO_2$ calcd. 349.2036, found: 349.2039.

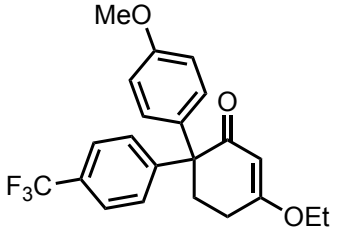
4'-ethoxy-4''-methoxy-3-(trifluoromethyl)-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4l)



4l

The reaction was conducted with **1a**, 4-bromoanisole and 3-chlorotrifluoromethylbenzene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **4l** (92 mg, 47%) as brown oil. R_f = 0.28 (hexanes/EtOAc = 3/1). **IR** (film): 2985, 2940, 2838, 1654, 1607, 1511 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.41-7.35 (m, 2H), 7.25 (d, *J* = 7.2 Hz, 1H), 7.10 (d, *J* = 9.0 Hz, 2H), 6.87 (d, *J* = 9.0 Hz, 2H), 5.55 (s, 1H), 3.94-3.83 (m, 2H), 3.80 (s, 3H), 2.76-2.63 (m, 2H), 2.45-2.29 (m, 2H), 1.33 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 199.3, 176.4, 158.6, 144.7, 132.5, 132.4, 130.2 (q, *J* = 31.9 Hz), 129.4, 128.3, 124.8 (q, *J* = 3.8 Hz), 124.2 (q, *J* = 271.1 Hz), 123.6 (q, *J* = 3.8 Hz), 113.8, 103.1, 64.5, 57.8, 55.2, 33.9, 27.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{22}H_{21}F_3O_3$ calcd. 390.1437, found: 390.1440.

4'-ethoxy-4-methoxy-4''-(trifluoromethyl)-5',6'-dihydro-2'H-[1,1':1',1''-terphenyl]-2'-one (4m)

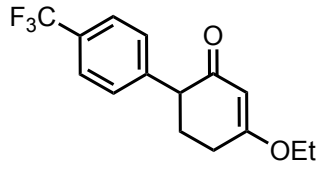


4m

The reaction was conducted with **1a**, 4-bromoanisole and 1-chloro-4-(trifluoromethyl)benzene following the general procedure (reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 3/1) to afford **4m** (146 mg, 75%) as yellow oil. R_f: 0.40 (hexanes/ EtOAc = 3/1). **IR** (film): 2993, 2939, 2841, 1650, 1603, 1510 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.52 (d, *J* = 8.1 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 2H), 7.10 (d, *J* = 8.6 Hz, 2H), 6.87 (d, *J* = 8.6 Hz, 2H), 5.54 (s, 1H), 3.93-3.84 (m, 2H), 3.80 (s, 3H), 2.71-2.66 (m, 2H), 2.40-2.29 (m,

2H), 1.33 (t, J = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 199.3, 176.4, 158.6, 147.8, 132.4, 129.4, 128.9, 128.8 (q, J = 32.2 Hz), 124.8 (q, J = 3.8 Hz), 124.2 (q, J = 270.7 Hz), 113.8, 103.1, 64.5, 57.9, 55.2, 33.9, 27.0, 14.1; **HRMS** (EI, $[M]^+$) for $C_{22}H_{21}F_3O_3$ calcd. 390.1437, found: 390.1438.

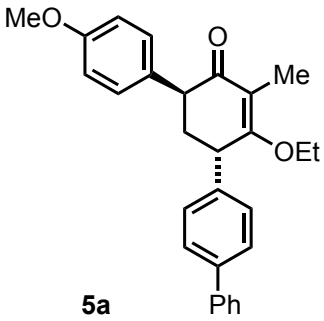
4-ethoxy-4'-(trifluoromethyl)-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (2b)



2b

The reaction was conducted with **1a**, 1-bromo-4-(trifluoromethyl)benzene and 4-chloroanisole following the general procedure (reaction time = 30 min); the expected diarylation **4m** was not obtained. The crude product was purified by flash column chromatography (hexanes/EtOAc = 3/1) to afford **2b** (88 mg, 62 %) as white solid (m.p. 93-94 ˚C). R_f: 0.28 (hexanes/EtOAc = 3/1). **IR** (cast): 2986, 2942, 1657, 1604 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.58 (d, J = 8.1 Hz, 2H), 7.29 (d, J = 8.1 Hz, 2H), 5.51 (s, 1H), 4.02-3.89 (m, 2H), 3.58 (dd, J = 10.2, 5.6 Hz, 1H), 2.64-2.42 (m, 2H), 2.31-2.16 (m, 2H), 1.39 (t, J = 7.1 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 198.1, 177.4, 144.0, 129.1 (q, J = 32.2 Hz), 128.8, 125.4 (q, J = 3.7 Hz), 124.2 (q, J = 272.6 Hz), 103.0, 64.5, 51.9, 29.2, 28.4, 14.1; **HRMS** (EI, $[M]^+$) for $C_{15}H_{15}O_2F_3$ calcd. 284.1019, found: 284.1020.

4'-ethoxy-4-methoxy-5'-methyl-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-6'(1'H)-one (5a)

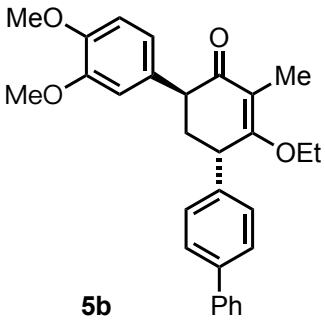


5a

The reaction was conducted with **1b**, 4-bromoanisole and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was

purified by flash column chromatography (hexanes/EtOAc = 9/1 to 7/1) to afford **5a** (105 mg, 51 %) as yellow oil. R_f = 0.70 (hexanes/EtOAc = 3/1). **IR** (film): 3028, 2926, 2861, 2832, 1645, 1608, 1511 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.63-7.58 (m, 4H), 7.46 (app. t, *J* = 7.2, 2H), 7.39-7.32 (m, 3H), 6.98 (d, *J* = 8.9 Hz, 2H), 6.82 (d, *J* = 8.9 Hz, 2H), 4.22 (brs, 1H), 4.04 (dq, *J* = 9.5, 7.0 Hz, 1H), 3.82-3.78 (m, 1H), 3.76 (s, 3H), 3.40 (dd, *J* = 13.3, 4.5 Hz, 1H), 2.72 (ddd, *J* = 13.3, 13.3 5.4 Hz, 1H), 2.27 (ddd, *J* = 13.3, 4.5, 2.7 Hz, 1H), 1.92 (s, 3H), 1.25 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 198.6, 169.7, 158.3, 140.4, 140.3, 137.5, 132.5, 129.6, 128.9, 128.3, 127.7, 127.5, 127.0, 117.0, 113.8, 63.5, 55.2, 46.3, 40.8, 38.4, 15.3, 8.2; **HRMS** (EI, $[M]^+$) for $C_{28}H_{28}O_3$ calcd. 412.2033, found: 412.2032.

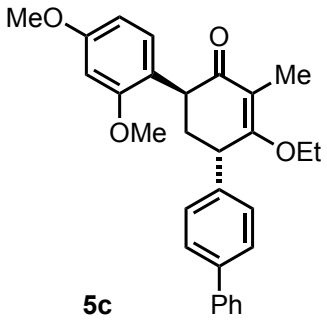
4'-ethoxy-3,4-dimethoxy-5'-methyl-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-6'(1'H)-one (5b)



5b

The reaction was conducted with **1b**, 4-bromoveratrole and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **5b** (102 mg, 46%) as yellow oil. R_f = 0.30 (hexanes/EtOAc = 3/1). **IR** (film): 2985, 2931, 2866, 1649, 1616, 1516 cm^{-1}; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.65-7.60 (m, 4H), 7.46 (app. t, *J* = 7.6 Hz, 2H), 7.39-7.34 (m, 3H), 6.78 (d, *J* = 8.0 Hz, 1H), 6.62-6.58 (m, 2H), 4.23 (brs, 1H), 4.09-4.00 (m, 1H), 3.96-3.87 (m, 1H), 3.83 (s, 3H), 3.82 (s, 3H), 3.39 (dd, *J* = 13.6, 4.4 Hz, 1H), 2.75 (ddd, *J* = 13.6, 13.6, 5.3 Hz, 1H), 2.32-2.26 (m, 1H), 1.93 (s, 3H), 1.26 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 198.4, 169.7, 148.7, 147.8, 140.34, 140.32, 137.5, 133.0, 128.9, 128.3, 127.8, 127.5, 127.0, 120.5, 117.0, 112.2, 111.2, 63.5, 55.9, 55.8, 46.7, 40.8, 38.3, 15.3, 8.2; **HRMS** (EI, $[M]^+$) for $C_{29}H_{30}O_4$ calcd. 442.2139, found: 442.2143.

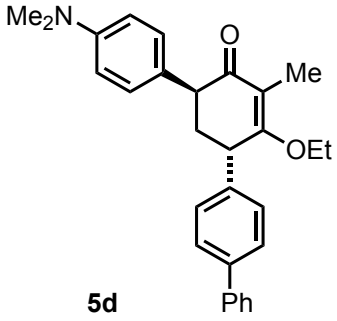
4'-ethoxy-2,4-dimethoxy-5'-methyl-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-6'(1'H)-one (5c)



5c

The reaction was conducted with **1b**, 1-bromo-2,4-dimethoxybenzene and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 3/1) to afford **5c** (102 mg, 46%) as yellow oil. R_f = 0.50 (hexanes/EtOAc = 3/1). **IR** (film): 2979, 2927, 2858, 1650, 1613, 1588, 1507 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.64-7.58 (m, 4H), 7.46 (app. t, *J* = 7.2 Hz, 2H), 7.39-7.32 (m, 3H), 6.86 (d, *J* = 8.3 Hz, 1H), 6.44-6.35 (m, 2H), 4.17 (brs, 1H), 4.09-3.99 (m, 1H), 3.81-3.77 (m, 1H), 3,76 (s, 3H), 3.65 (s, 3H), 3.57 (dd, *J* = 13.2, 4.5 Hz, 1H), 2.85 (ddd, *J* = 13.2, 13.2, 5.4 Hz, 1H), 2.11 (ddd, *J* = 13.2, 4.5, 2.5 Hz, 1H), 1.93 (s, 3H), 1.25 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 198.6, 169.0, 159.7, 158.3, 140.5, 140.1, 138.0, 130.3, 128.8, 128.3, 127.6, 127.4, 127.0, 122.1, 116.8, 104.2, 99.2, 63.4, 55.5, 55.3, 42.8, 40.8, 36.7, 15.3, 8.2; **HRMS** (EI, $[M]^+$) for $C_{29}H_{30}O_4$ calcd. 442.2139, found: 442.2135.

4-(dimethylamino)-4'-ethoxy-5'-methyl-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-6'(1'H)-one (5d)

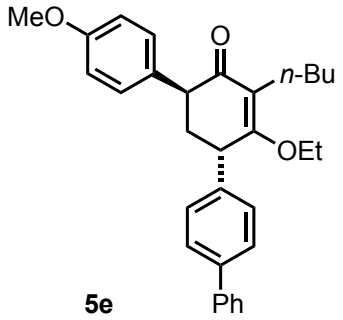


5d

The reaction was conducted with **1b**, 4-bromo-*N*,*N*-dimethylaniline and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 4/1) to afford

5d (86 mg, 40%) as brown oil. R_f = 0.63 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2924, 2855, 1887, 1611, 1521 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.62-7.58 (m, 4H), 7.46 (app. t, *J* = 7.97 Hz, 2H), 7.38-7.32 (m, 3H), 6.93 (d, *J* = 8.7 Hz, 2H), 6.67 (d, *J* = 8.7 Hz, 2H), 4.20 (brs, 1H), 4.03 (dq, *J* = 9.3, 7.0 Hz, 1H), 3.79 (dq, *J* = 9.3, 7.0 Hz, 1H), 3.36 (dd, *J* = 13.3, 4.4 Hz, 1H), 2.89 (s, 6H), 2.72 (ddd, *J* = 13.3, 13.3, 5.3 Hz, 1H), 2.27 (ddd, *J* = 13.3, 4.4, 2.8 Hz, 1H), 1.92 (s, 3H), 1.25 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 199.0, 169.5, 149.5, 140.5, 140.2, 137.8, 129.2, 128.8, 128.5, 128.3, 127.7, 127.4, 127.0, 117.1, 112.9, 63.5, 46.2, 40.83, 40.77, 38.5, 15.3, 8.2; **HRMS** (EI, $[M]^+$) for $C_{29}H_{31}NO_2$ calcd. 425.2349, found: 425.2341.

5'-butyl-4'-ethoxy-4-methoxy-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-6'(1'H)-one (5e)

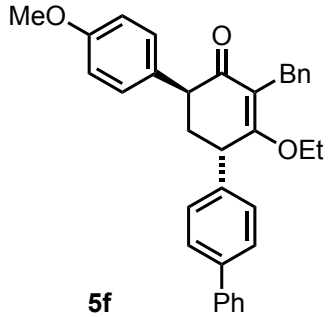


5e

The reaction was conducted with **1c**, 4-bromoanisole and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 8/1) to afford **5e** (100 mg, 44%) as brown oil. R_f = 0.80 (hexanes/EtOAc = 3/1). **IR** (film): 2953, 2925, 2855, 1646, 1606, 1510 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.64-7.60 (m, 4H), 7.46 (app. t, *J* = 7.4 Hz, 2H), 7.39-7.34 (m, 3H), 6.98 (d, *J* = 8.5 Hz, 2H), 6.82 (d, *J* = 8.5 Hz, 2H), 4.20 (brs, 1H), 4.07-3.97 (m, 1H), 3.84-3.75 (m, 4H), 3.39 (dd, *J* = 13.5, 4.4 Hz, 1H), 2.72 (ddd, *J* = 13.5, 13.5, 5.3 Hz, 1H), 2.51-2.44 (m, 2H), 2.31-2.23 (m, 1H), 1.50-1.33 (m, 4H), 1.25 (t, *J* = 7.0 Hz, 3H), 0.95 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 198.1, 169.5, 158.3, 140.4, 140.3, 137.6, 132.6, 129.6, 128.8, 128.2, 127.7, 127.5, 127.0, 122.1, 113.8, 63.4, 55.2, 46.3, 40.6, 38.4, 31.0, 22.9, 22.4, 15.2, 14.0; **HRMS** (EI, $[M]^+$) for $C_{31}H_{34}O_3$ calcd. 454.2503, found: 454.2500.

5'-benzyl-4'-ethoxy-4-methoxy-2',3'-dihydro-[1,1':3',1'':4'',1'''-quaterphenyl]-

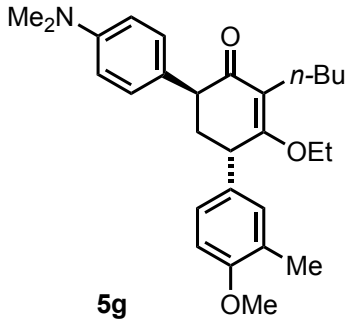
6'(1'H)-one (5f)



5f

The reaction was conducted with **1d**, 4-bromoanisole and 4'-biphenyl chloride following the general procedure (reaction time = 90 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 4/1) to afford **5f** (95 mg, 39%) as yellow oil. R_f = 0.68 (hexanes/EtOAc = 3/1). **IR** (film): 2982, 2927, 2829, 1645, 1604, 1511 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.61-7.55 (m, 4H), 7.45 (app. t, *J* = 7.4 Hz, 2H), 7.40-7.33 (m, 3H), 7.30-7.23 (m, 4H), 7.17 (t, *J* = 7.3 Hz, 1H), 6.96 (d, *J* = 8.4 Hz, 2H), 6.81 (d, *J* = 8.4 Hz, 2H), 4.21 (brs, 1H), 4.10-4.00 (m, 1H), 3.88-3.76 (m, 6H), 3.40 (dd, *J* = 13.6, 4.4 Hz, 1H), 2.72 (ddd, *J* = 13.6, 13.6, 5.2 Hz, 1H), 2.30-2.23 (m, 1H), 1.26 (t, *J* = 7.1 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 197.7, 170.2, 158.3, 142.1, 140.4, 140.3, 137.4, 132.4, 129.7, 129.1, 128.8, 128.2, 128.0, 127.8, 127.5, 127.0, 125.4, 121.4, 113.8, 63.6, 55.2, 46.2, 40.6, 38.3, 28.7, 15.2; **HRMS** (EI, $[M]^+$) for $C_{34}H_{32}O_3$ calcd. 488.2346, found: 488.2339.

(1'S,3'S)-5'-butyl-4''-(dimethylamino)-6'-ethoxy-4-methoxy-3-methyl-2',3'-dihydro-[1,1':3',1''-terphenyl]-4'(1'H)-one (5g)

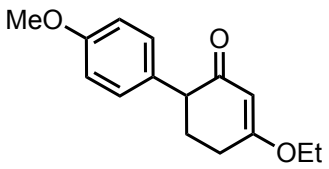


5g

The reaction was conducted with **1c**, 4-bromo-*N*,*N*-dimethylaniline and 2-methyl-4-chloroanisole following the general procedure (reaction time = 120 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 4/1) to afford **5f** (85 mg, 39%) as brown oil. R_f = 0.55 (hexanes/EtOAc = 3/1). **IR** (film): 2956,

2924, 2855, 1646, 1608, 1519 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.11-7.03 (m, 2H), 6.92 (d, *J* = 8.8 Hz, 2H), 6.85-6.76 (m, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 4.06 (brs, 1H), 4.03-3.93 (m, 1H), 3.84 (s, 3H), 3.80-3.70 (m, 1H), 3.31 (dd, *J* = 13.5, 4.4 Hz, 1H), 2.89 (s, 6H), 2.63 (ddd, *J* = 13.2, 13.2, 5.3 Hz, 1H), 2.44 (t, *J* = 7.5 Hz, 2H), 2.22-2.15 (m, 4H), 1.45-1.33 (m, 4H), 1.21 (t, *J* = 7.0 Hz, 3H), 0.93 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 198.7, 170.1, 156.9, 130.2, 130.0, 129.2, 127.2, 125.9, 121.7, 113.0, 110.1, 63.1, 55.3, 46.1, 40.9, 40.1, 38.6, 31.0, 22.9, 22.4, 16.4, 15.3, 14.1, 14.0 [two aromatic carbons are missing due to peak overlapping]; **HRMS** (ESI, $[M+H]^+$) for $C_{28}H_{38}NO_3$ calcd. 436.2847, found: 436.2850.

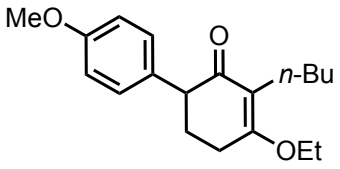
4-ethoxy-4'-methoxy-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (S1)



S1

The reaction was conducted with **1a**, 4-bromoanisole following the general procedure (reaction temperature = 30˚C; reaction time = 30 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 8/1 to 1/1) to afford **S1** (98 mg, 80%) as yellow solid (m.p. 83-84 ˚C). R_f = 0.15 (hexanes/EtOAc = 3/1). **IR** (cast): 2981, 2938, 2835, 1655, 1607, 1514 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.09 (d, *J* = 8.5 Hz, 2H), 6.86 (d, *J* = 8.5 Hz, 2H), 5.49 (s, 1H), 3.94 (q, *J* = 7.0 Hz, 2H), 3.78 (s, 3H), 3.47 (dd, *J* = 9.8, 5.2 Hz, 1H), 2.57-2.41 (m, 2H), 2.26-2.15 (m, 2H), 1.38 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 199.6, 177.2, 158.4, 131.9, 129.2, 113.9, 103.0, 64.3, 55.2, 51.1, 29.4, 28.3, 14.1; **HRMS** (EI, $[M]^+$) for $C_{15}H_{18}O_3$ calcd. 246.1251, found: 246.1246.

3-butyl-4-ethoxy-4'-methoxy-5,6-dihydro-[1,1'-biphenyl]-2(1H)-one (S2)



S2

The reaction was conducted with **1c** (3 mmol), 4-bromoanisole following the general

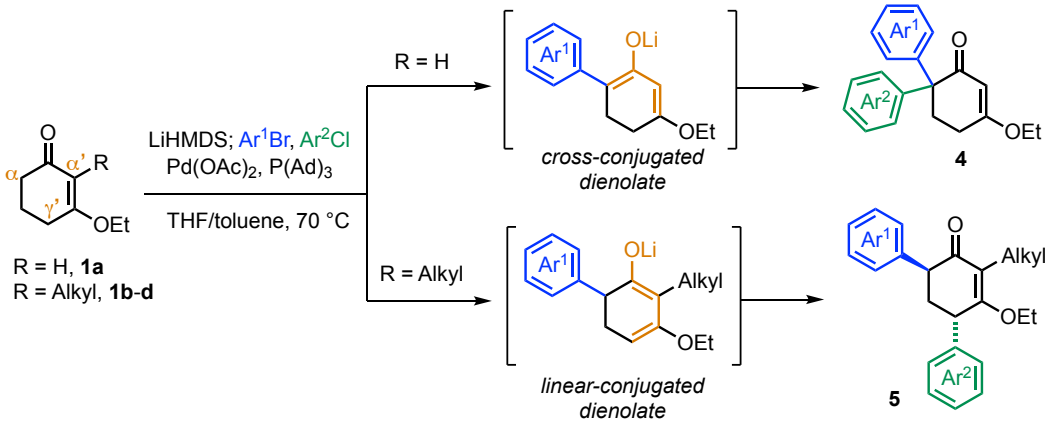
procedure (reaction temperature = 30˚C; reaction time = 60 min). The crude product was purified by flash column chromatography (hexanes/EtOAc = 9/1 to 4/1) to afford **S2** (453 mg, 50%) as brown oil. R_f = 0.53 (hexanes/EtOAc = 3/1). **IR** (film): 2927, 2857, 2835, 1644, 1607, 1511 cm^{-1}; **^{1}H NMR** ($CDCl_3$, 400 MHz): δ 7.06 (d, *J* = 8.7 Hz, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 4.05 (q, *J* = 7.0 Hz, 2H), 3.78 (s, 3H), 3.46 (dd, *J* = 9.1, 4.8 Hz, 1H), 2.57 (t, *J* = 6.2 Hz, 2H), 2.33 (t, *J* = 7.2 Hz, 2H), 2.29-2.12 (m, 2H), 1.37-1.25 (m, 7H), 0.89 (t, *J* = 6.9 Hz, 3H); **^{13}C NMR** ($CDCl_3$, 100 MHz): δ 198.2, 170.7, 158.2, 132.2, 129.1, 120.4, 113.8, 63.3, 55.2, 50.2, 30.9, 28.7, 24.0, 22.7, 22.1, 15.3, 14.0; **HRMS** (ESI, $[M+H]^+$) for $C_{19}H_{27}O_3$ calcd. 303.1955, found: 303.1953.

Reference

1. Yang, Y.-C.; Lin, Y.-C.; Wu, Y.-K. *Org. Lett.* **2019**, *21*, 9286-9290.

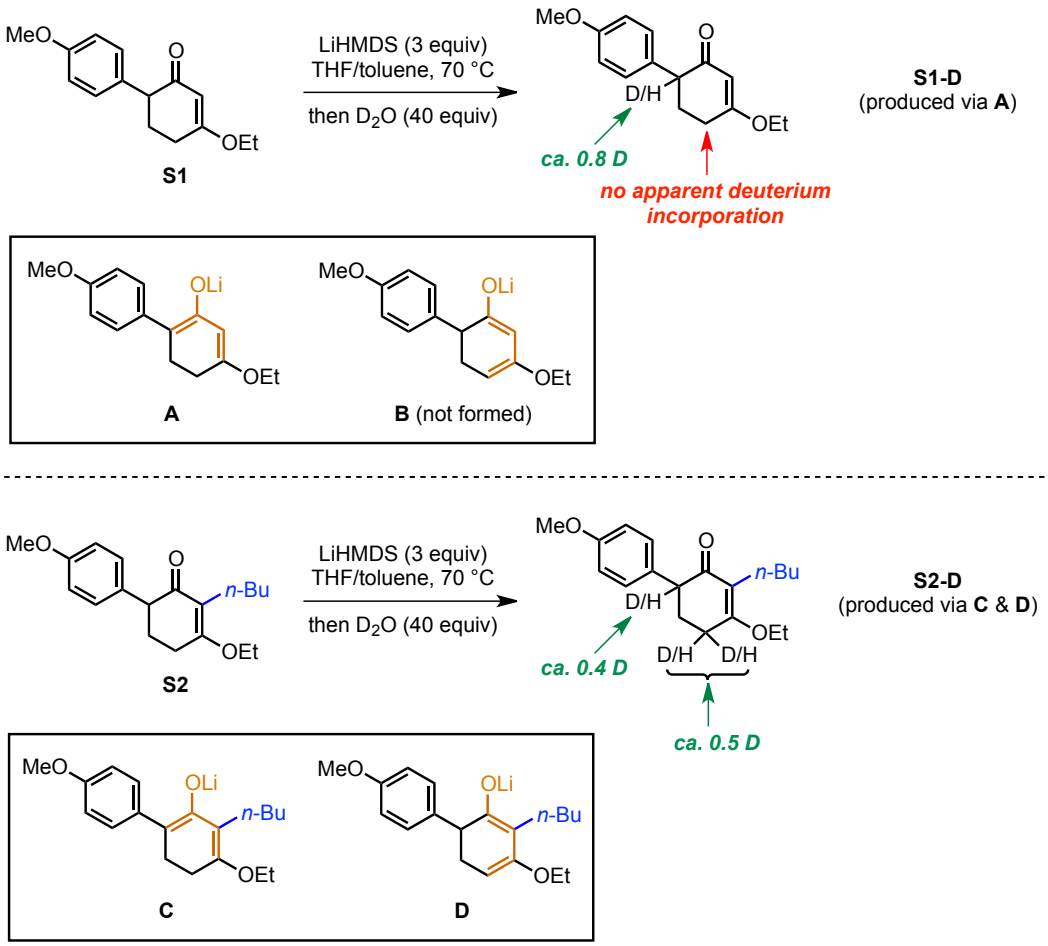
A Mechanistic Study: Deprotonation/D_2O-Quenching Experiments.

We have described that the reaction course of the cascade diarylation is dictated by the substitution pattern of the alkene moiety of the cyclic vinylogous esters. The α,α- and α,γ'-diarylated products were apparently obtained from the cross-conjugated and linear-conjugated dienolates, respectively (Scheme S1).

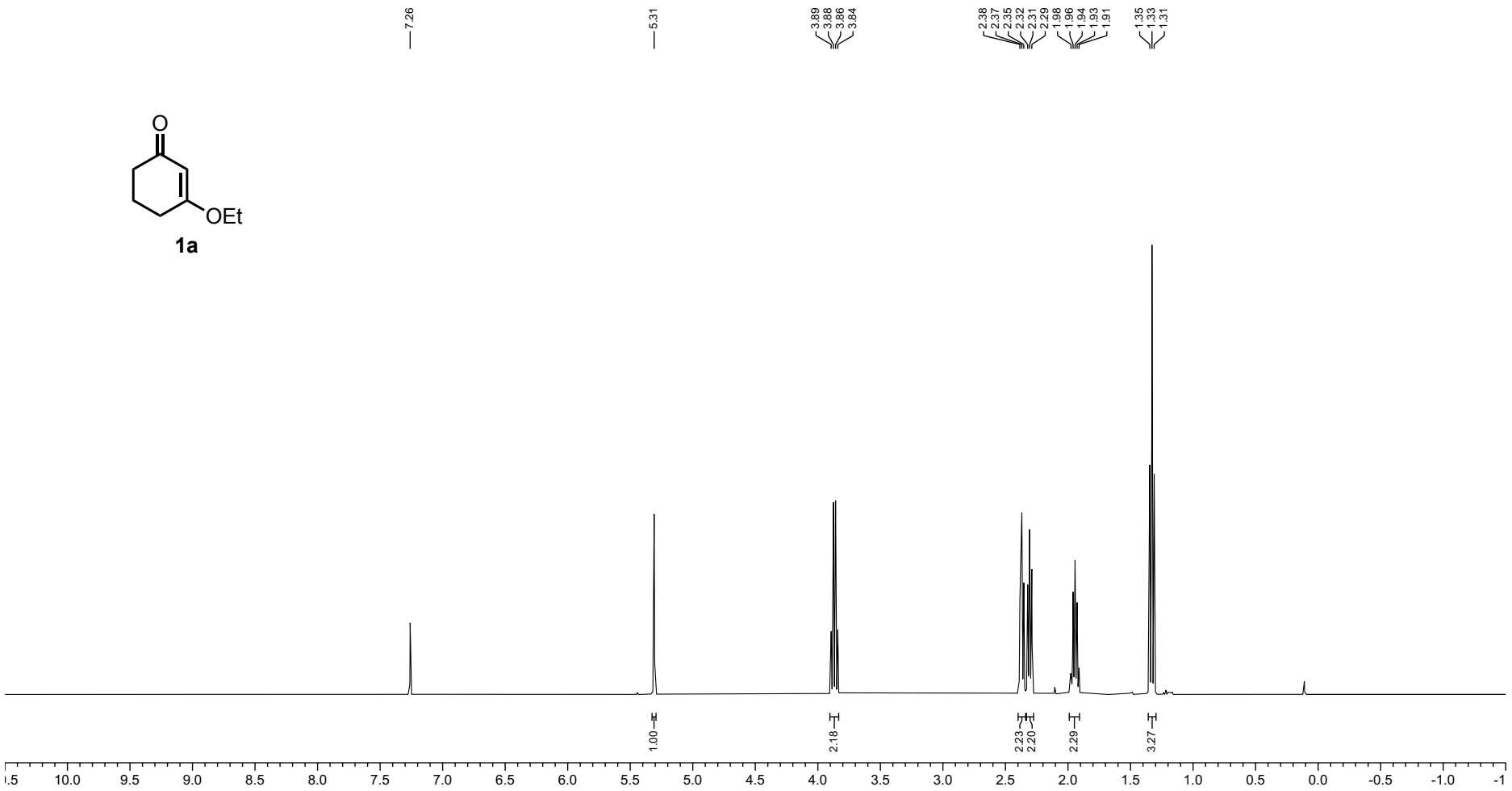


Scheme S1. The Cascade Diarylation Reactions.

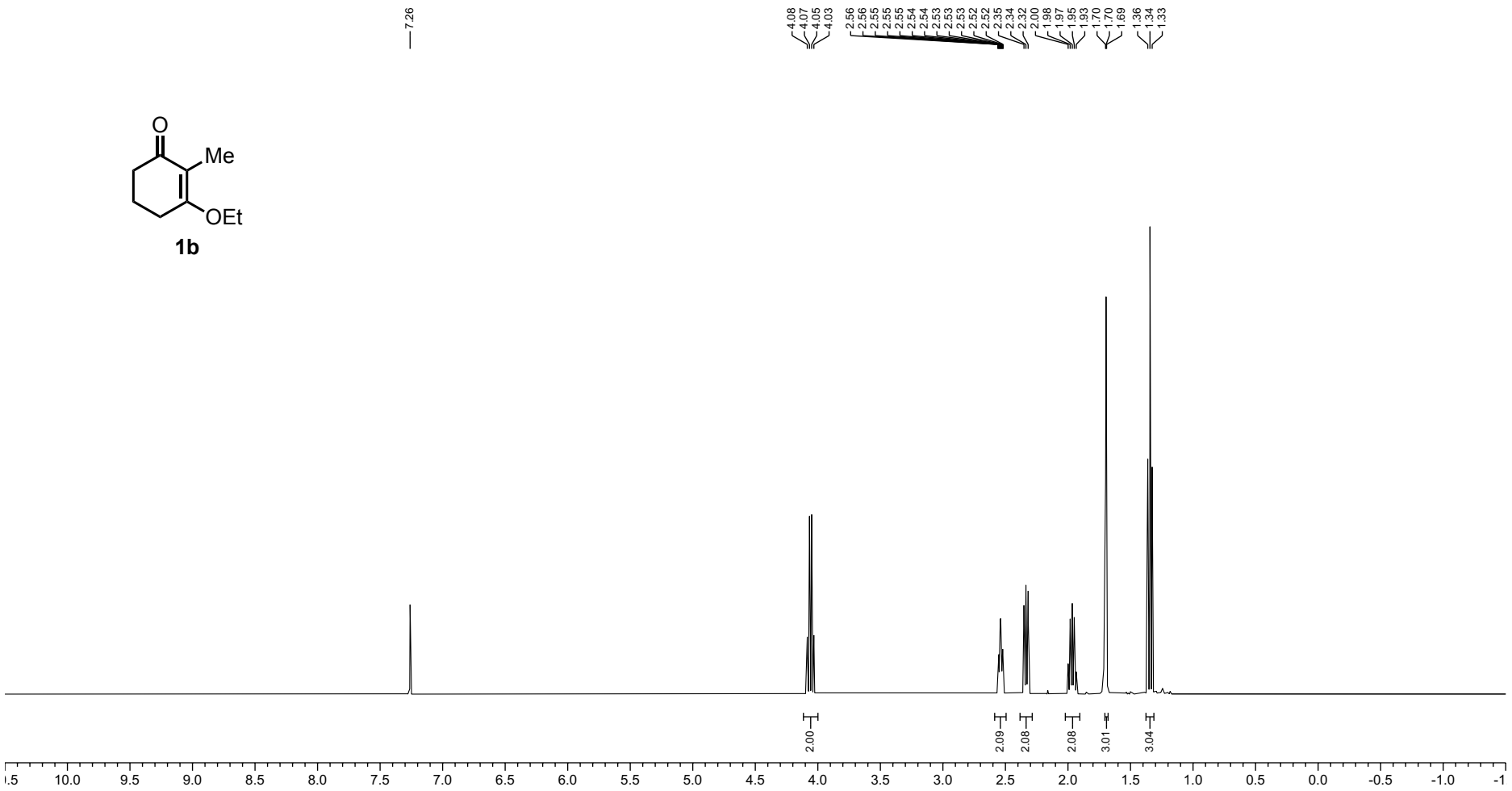
To probe the equilibrium between the cross- and linear-conjugated dienolates of the two transformations seen above, we conducted the deprotonation/D_2O-quenching experiments using monoarylated vinylogous esters **S1** and **S2** as model substrates (Scheme S2). Compounds **S1** and **S2** were individually treated with a solution of LiHMDS for 20 min at 70 ˚C, and the resulting mixtures were quenched with D_2O. The crude products were analyzed by proton NMR. In the case of **S1-D**, we found deuterium incorporation did not take place at the γ'-position. This result implies that intermediate **B** was not involved in the process, thus conforming to the fact that substrate **1a** only underwent α,α-diarylation reaction under the optimized conditions. On the other hand, when α'-alkyl vinylogous ester **S2** was applied, we observed deuterium was introduced at the α- or γ'-positions of **S2-D**, indicating that both **C** and **D** were produced under suitable basic conditions. These preliminary experiments offer useful insights regarding the switch of the reaction course for the second arylation event (**1a** vs **1b-d**). Further investigations on the subtle substitution effects are currently underway.



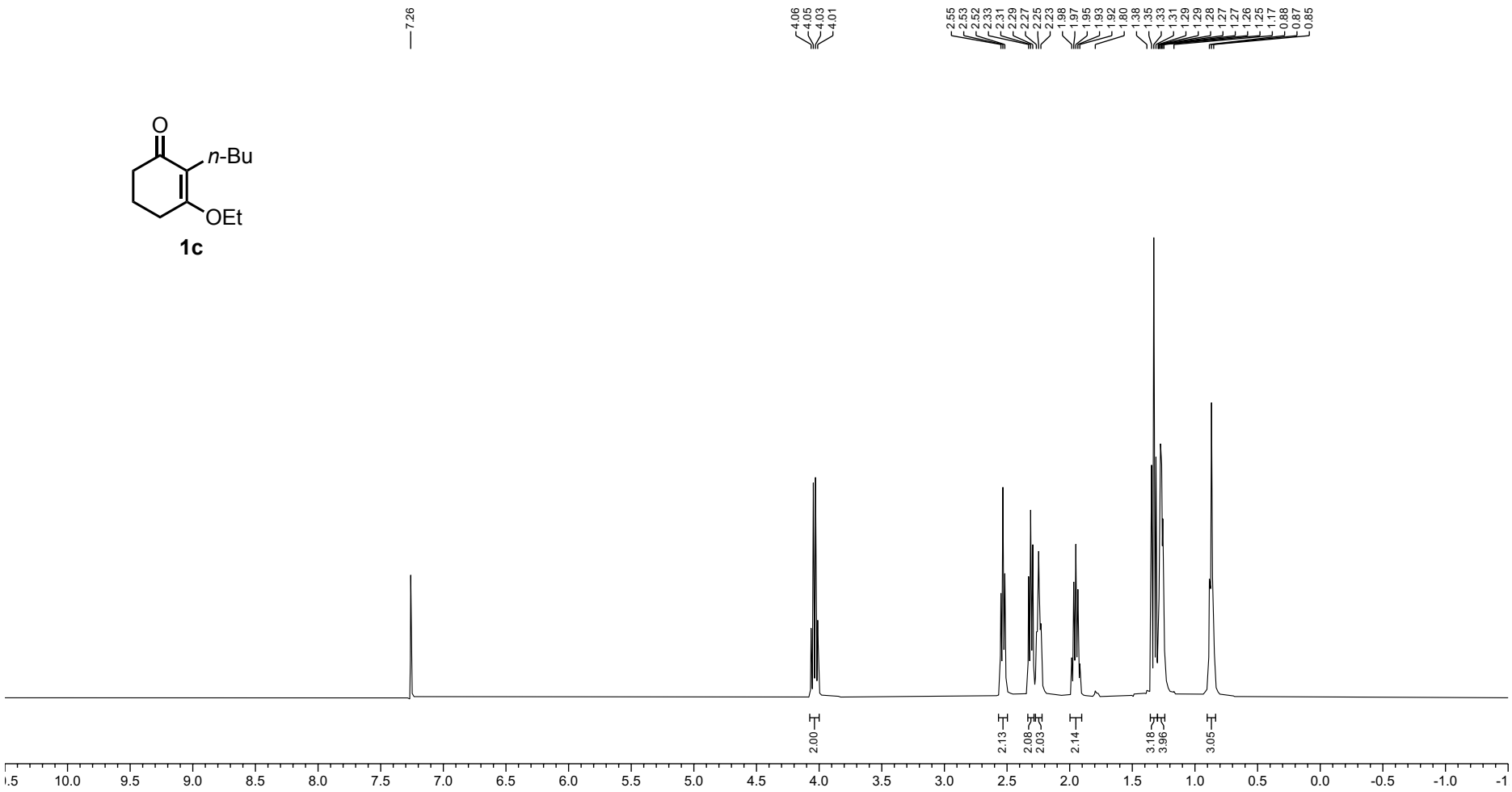
Scheme S2. The Deprotonation/D_2O-Quenching Experiments.



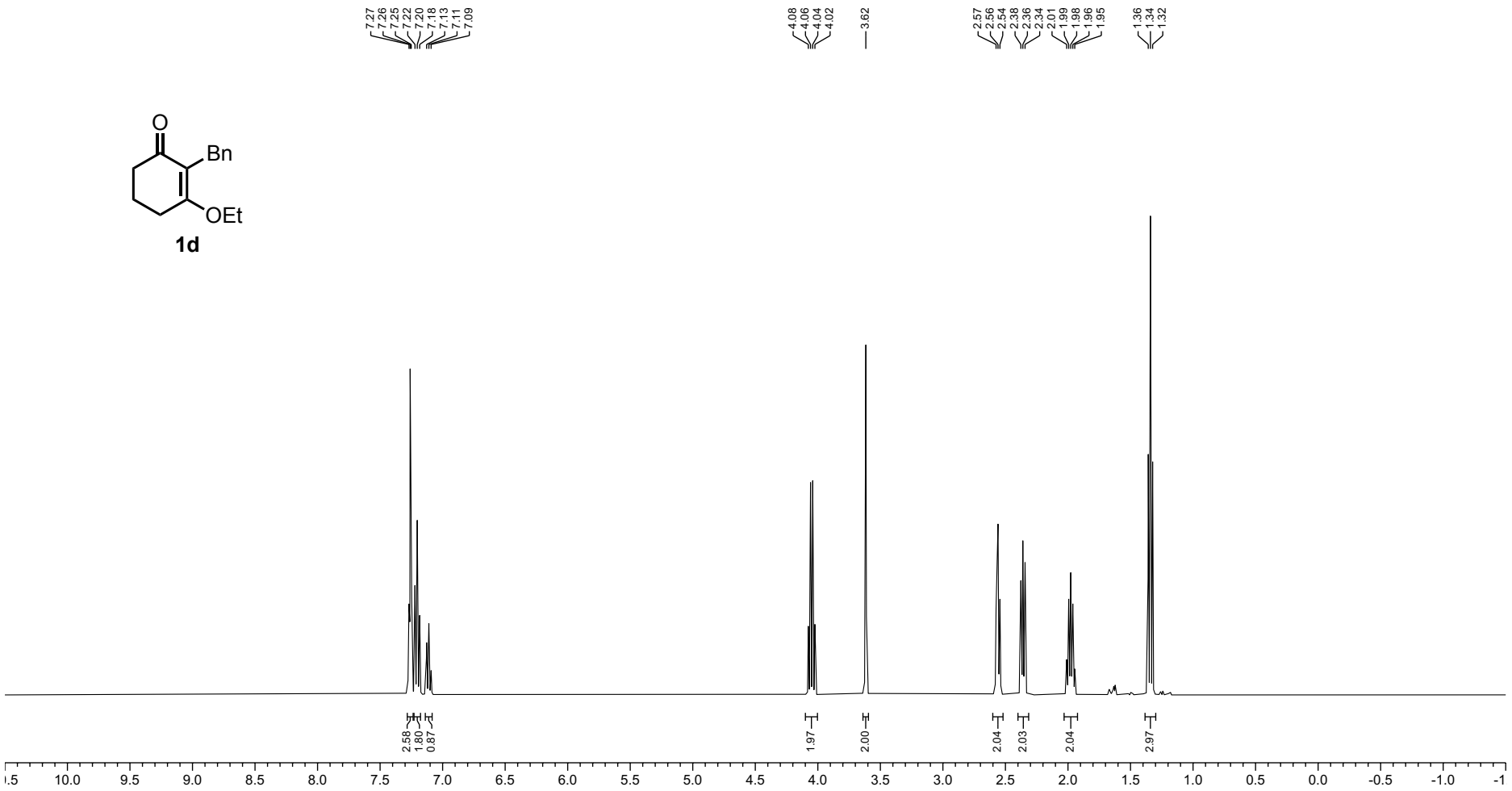
^{1}H NMR spectrum of **1a** (400 MHz, $CDCl_3$)



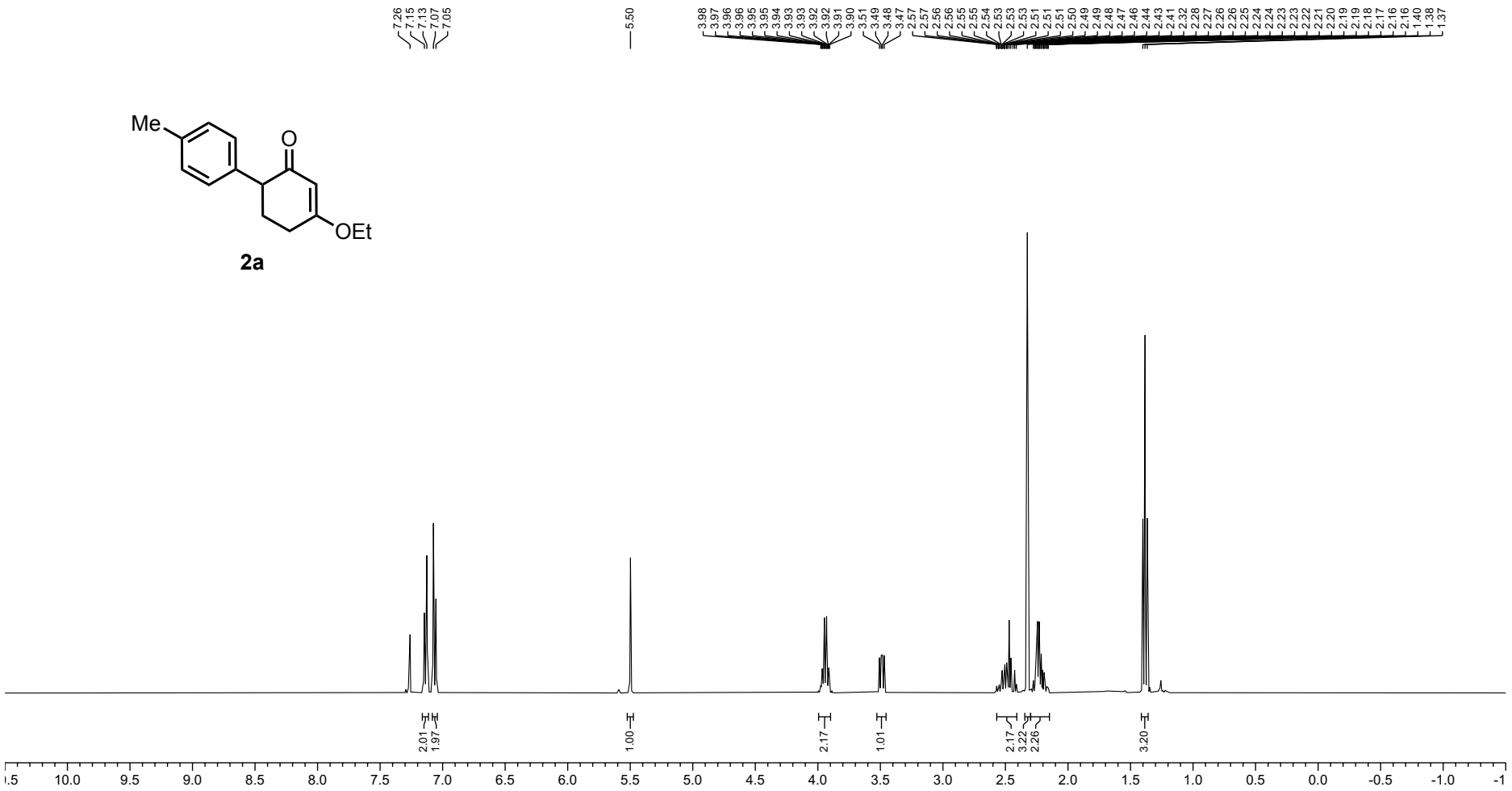
^{1}H NMR spectrum of **1b** (400 MHz, $CDCl_3$)



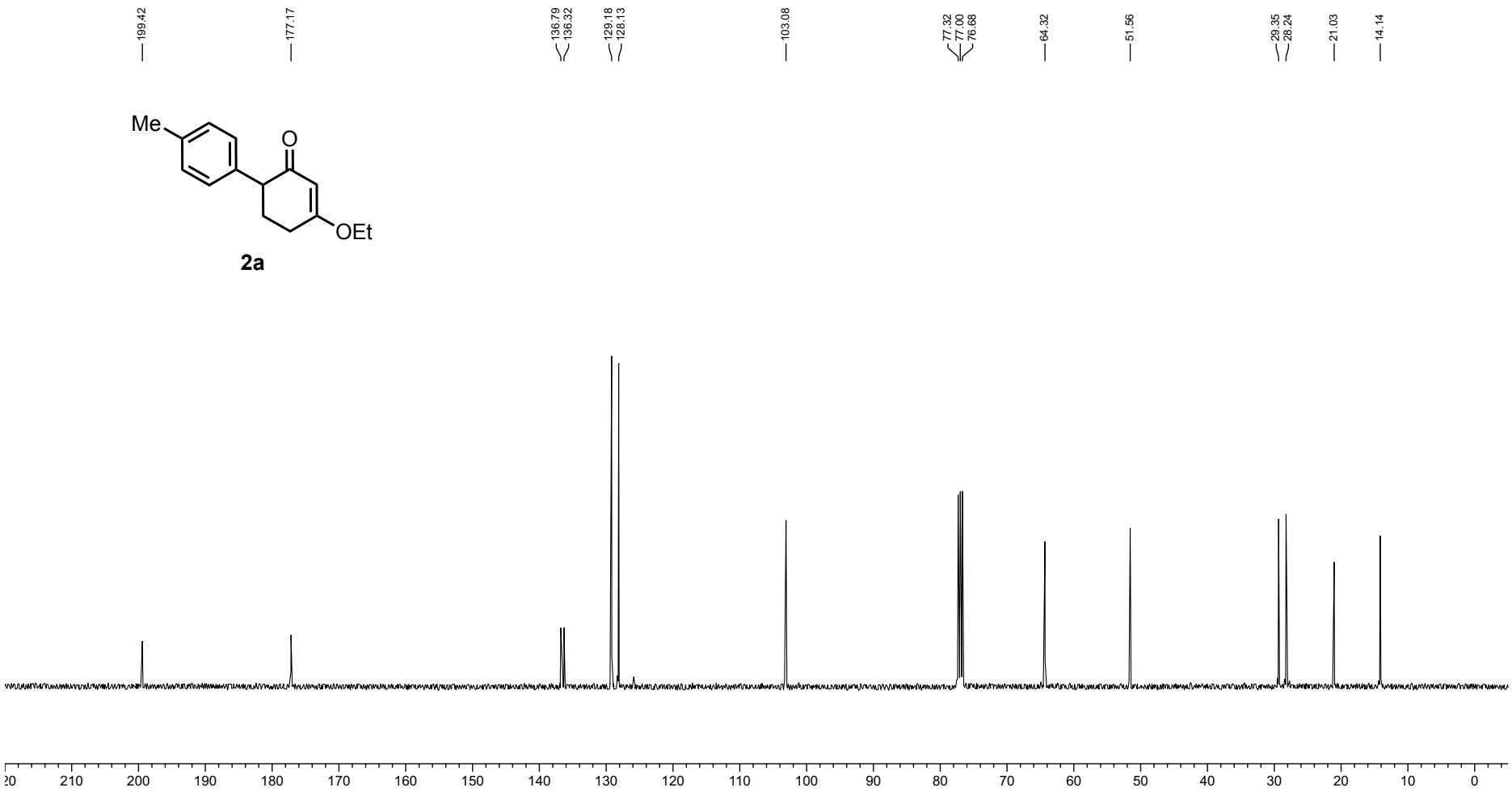
^{1}H NMR spectrum of **1c** (400 MHz, $CDCl_3$)



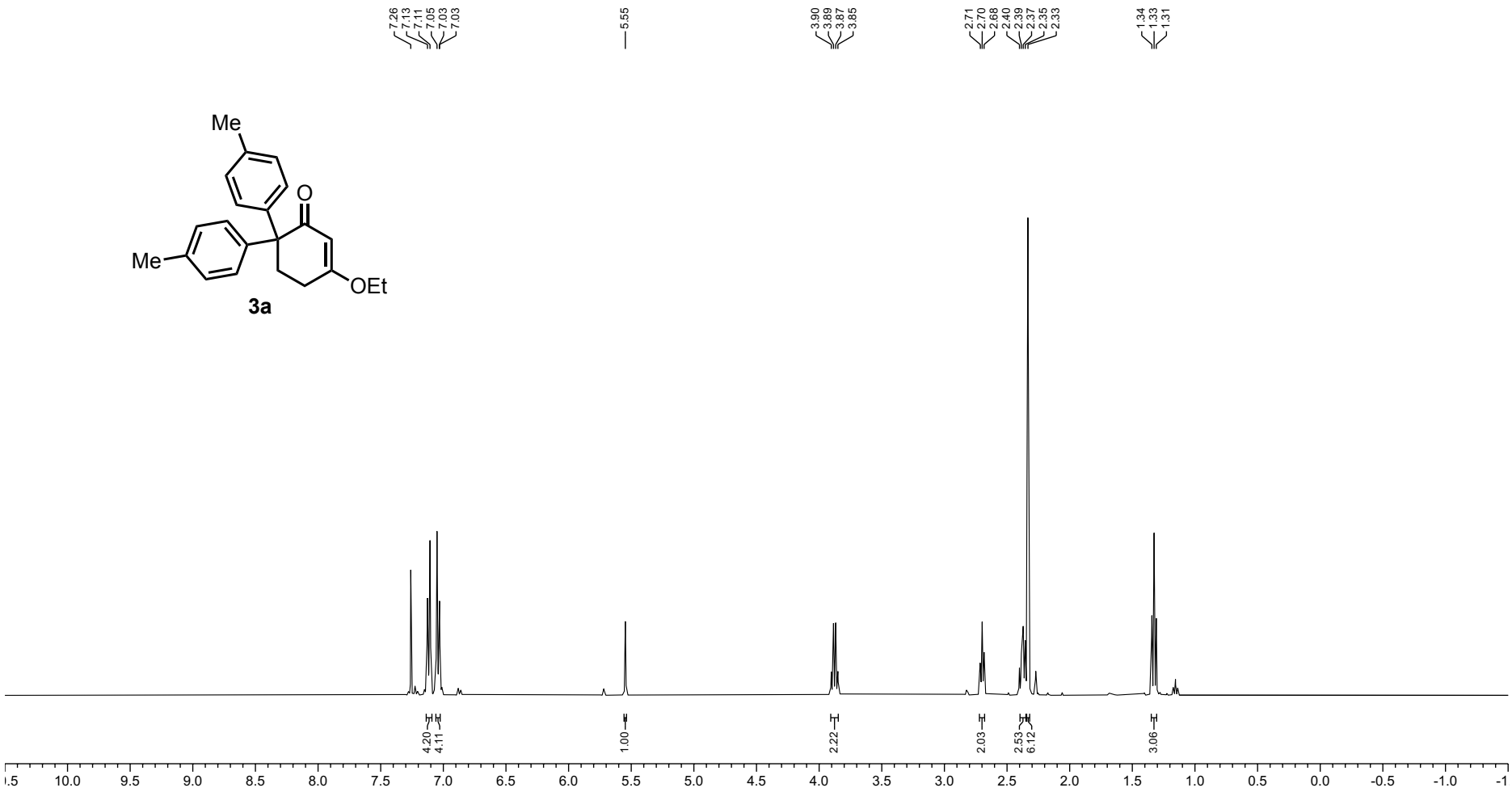
^{1}H NMR spectrum of **1d** (400 MHz, $CDCl_3$)



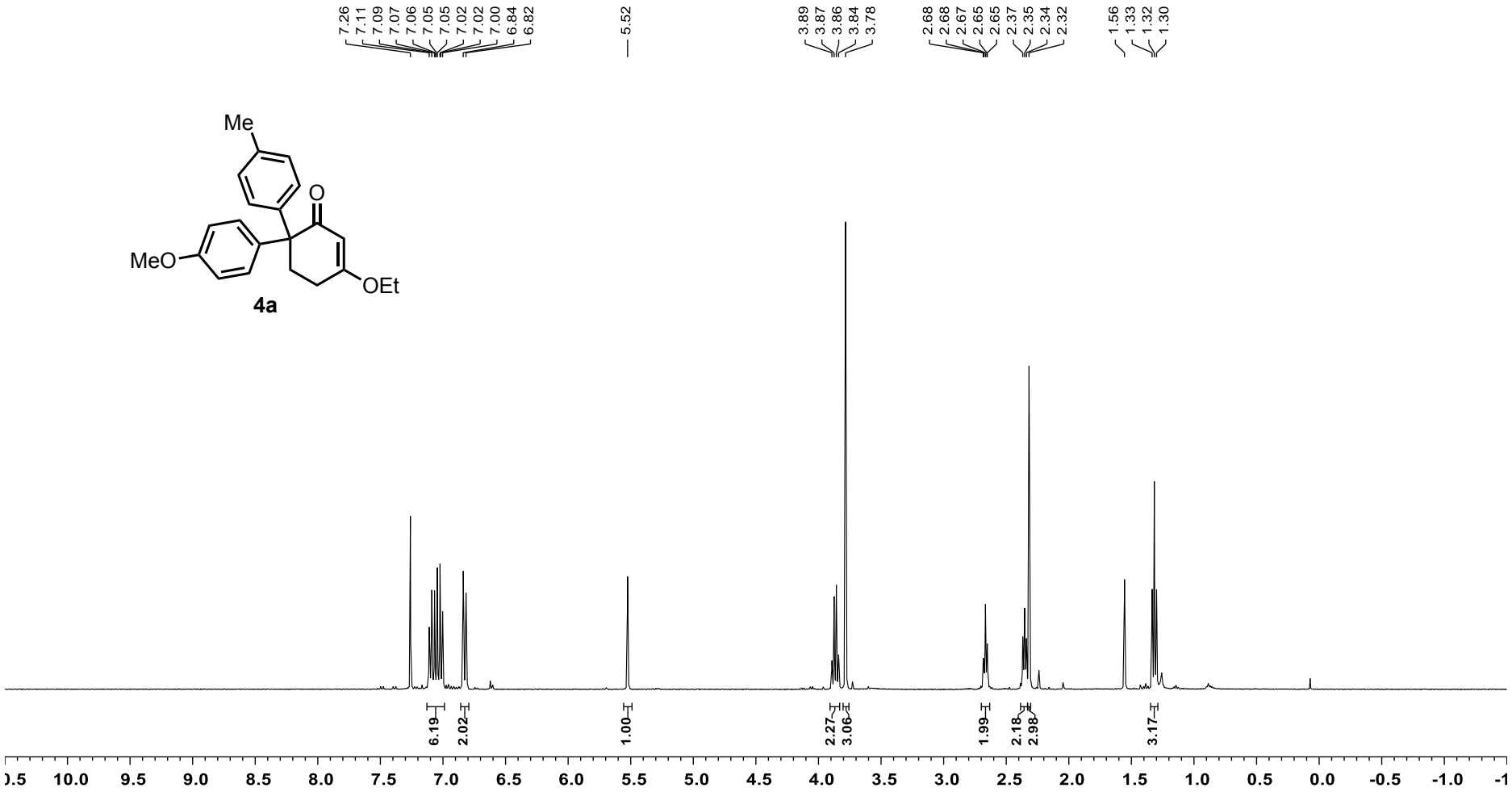
^{1}H NMR spectrum of **2a** (400 MHz, $CDCl_3$)



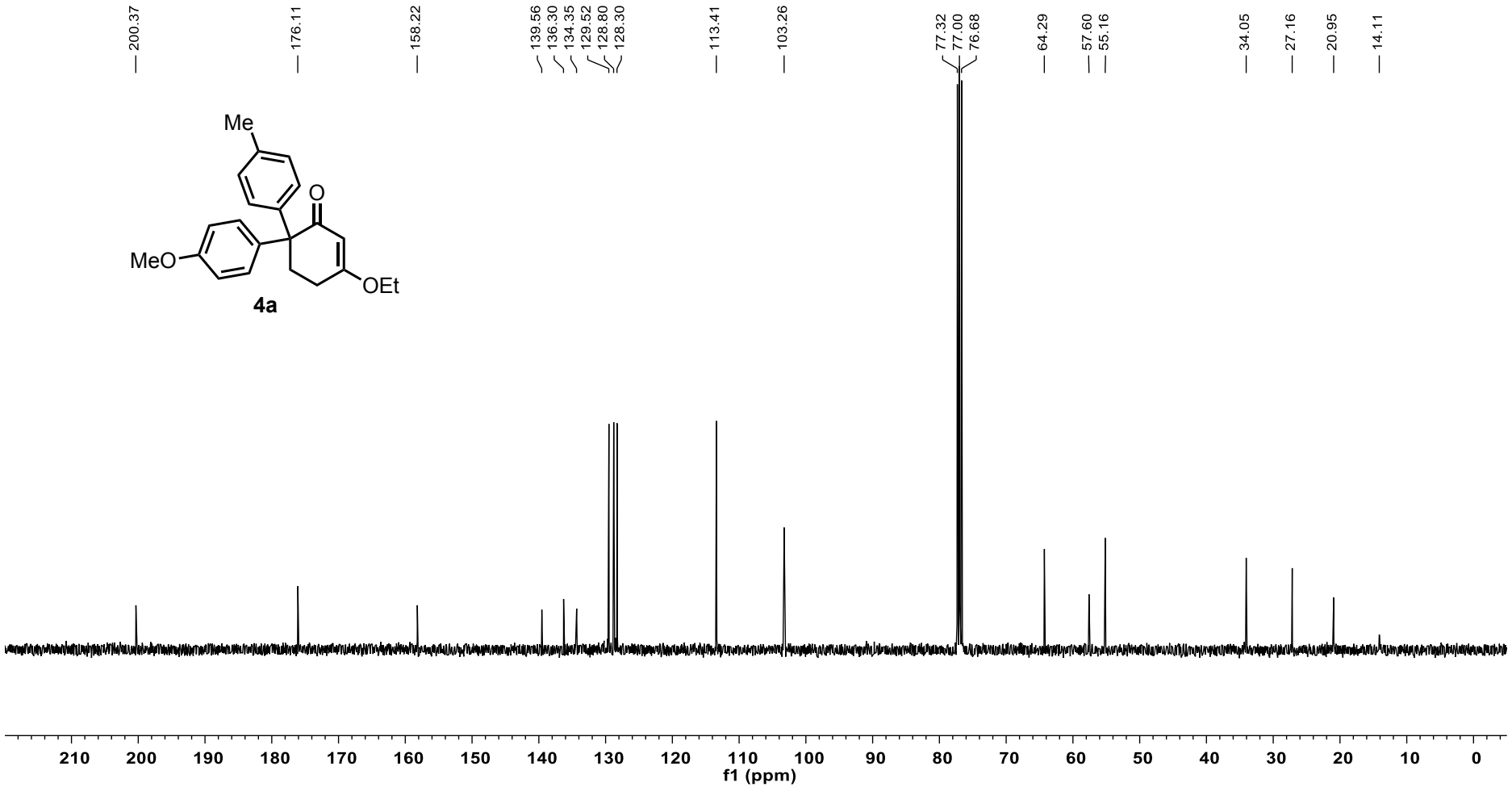
^{13}C NMR spectrum of **2a** (100 MHz, $CDCl_3$)



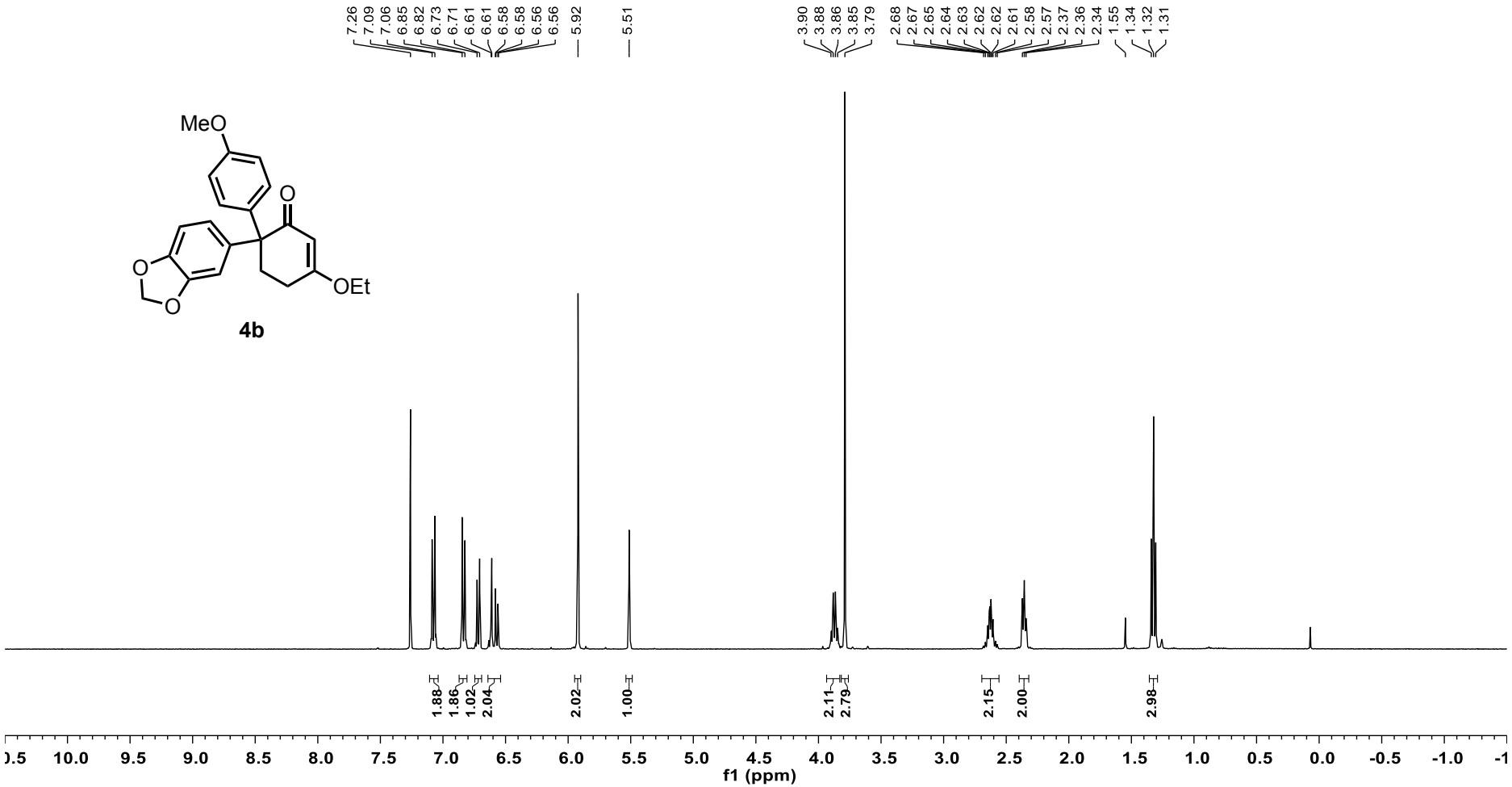
^{1}H NMR spectrum of **3a** (400 MHz, $CDCl_3$)



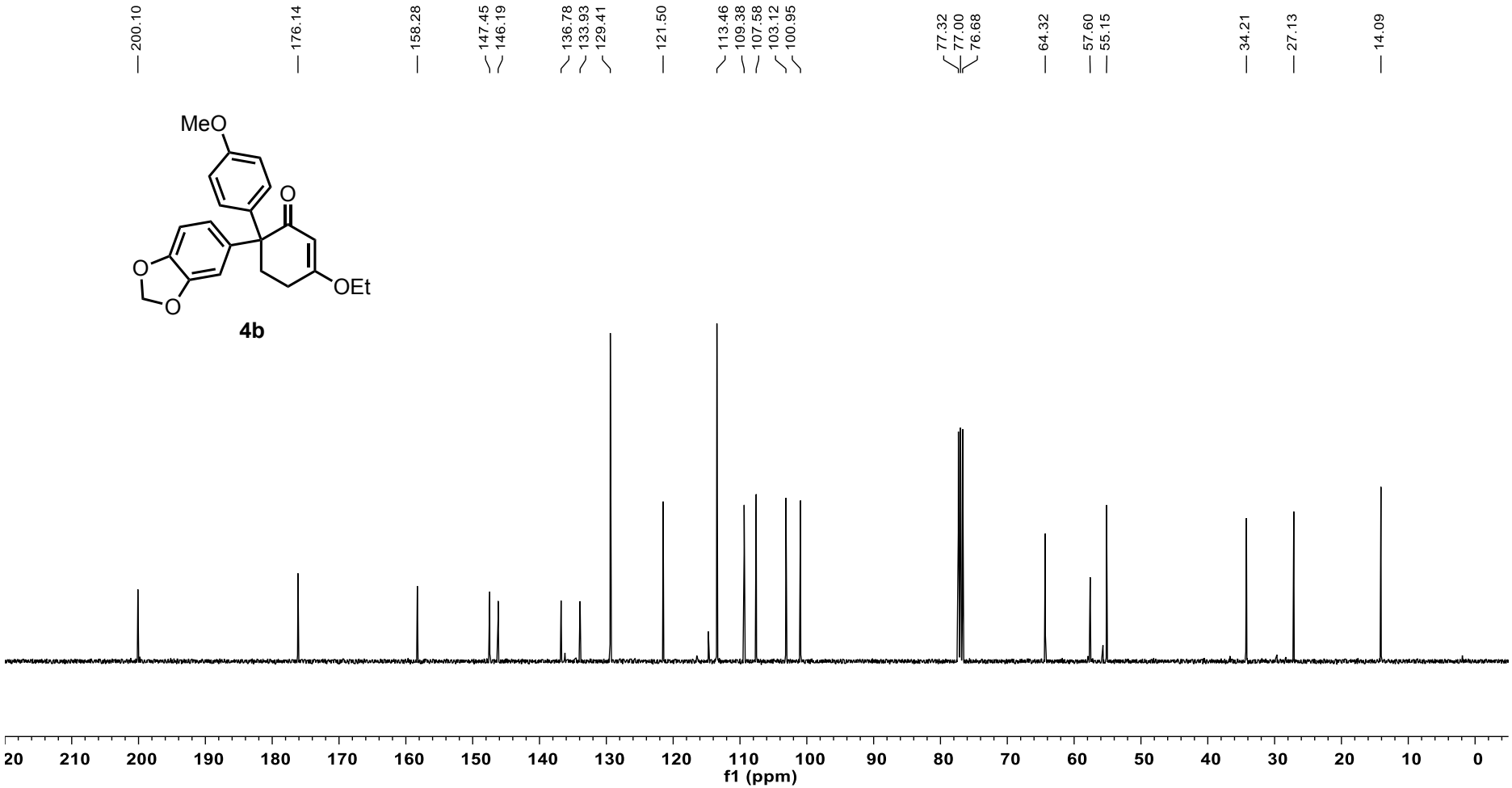
^{1}H NMR spectrum of **4a** (400 MHz, $CDCl_3$)



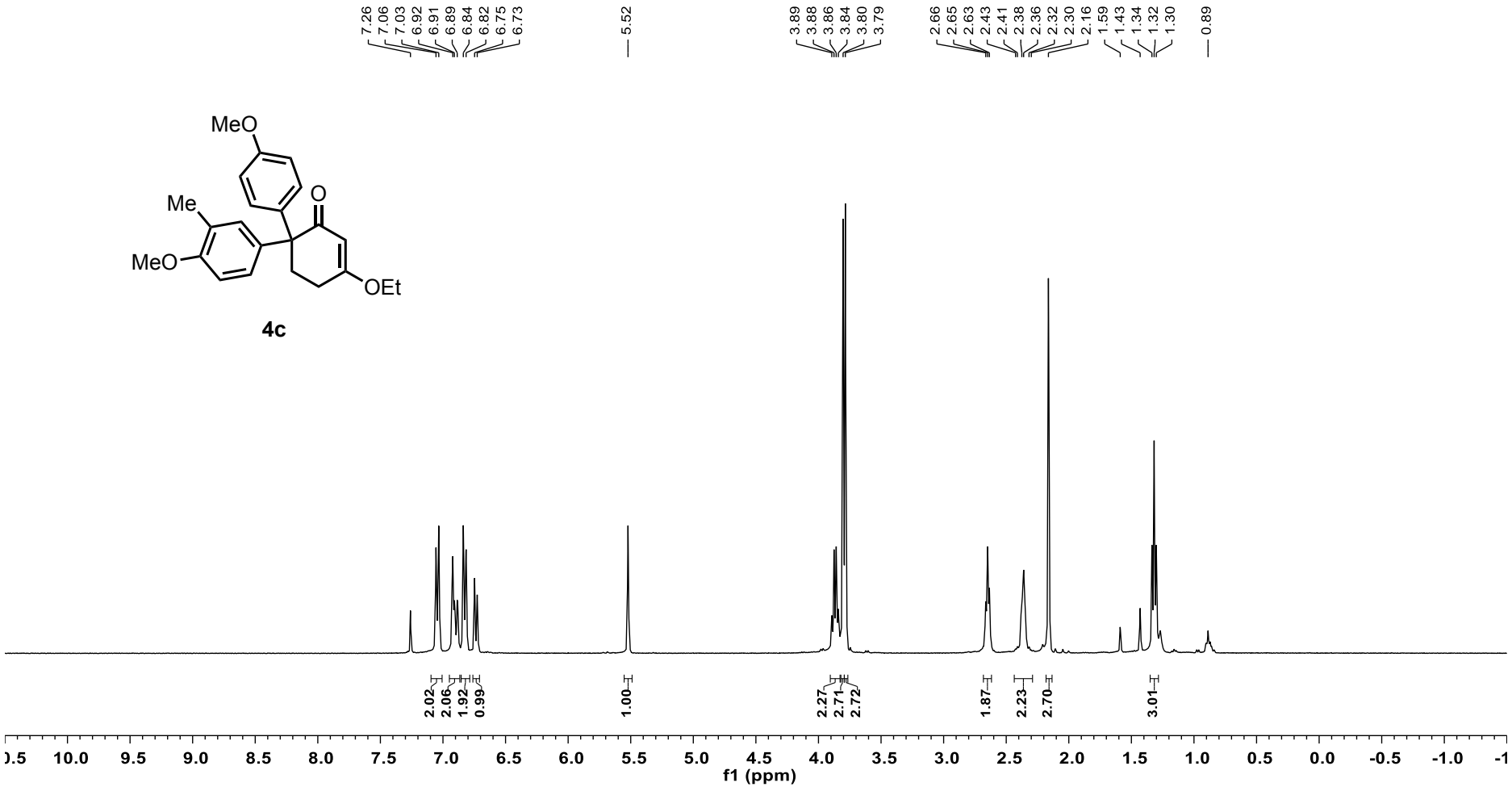
^{13}C NMR spectrum of **4a** (100 MHz, $CDCl_3$)



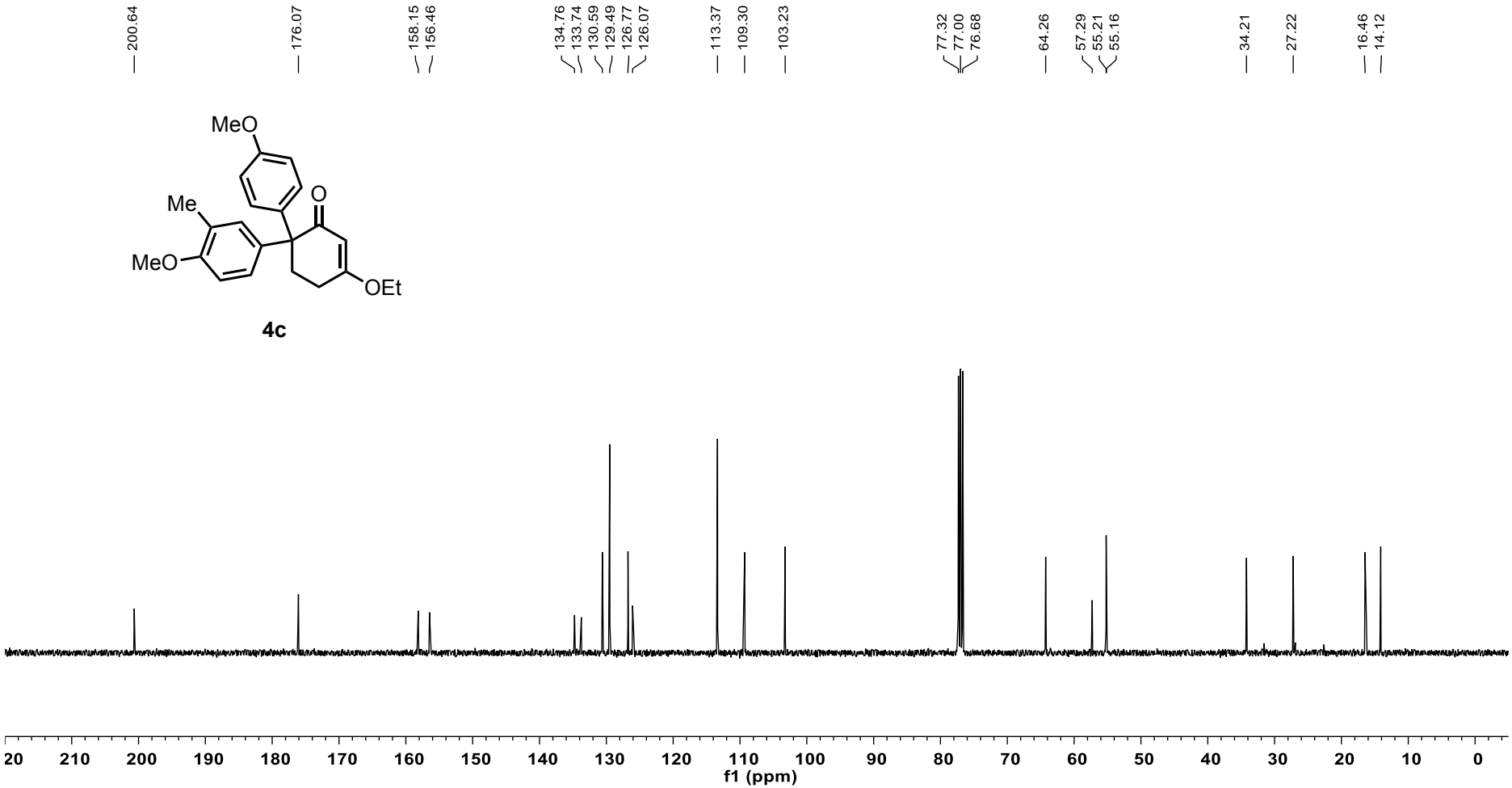
^{1}H NMR spectrum of **4b** (400 MHz, $CDCl_3$)



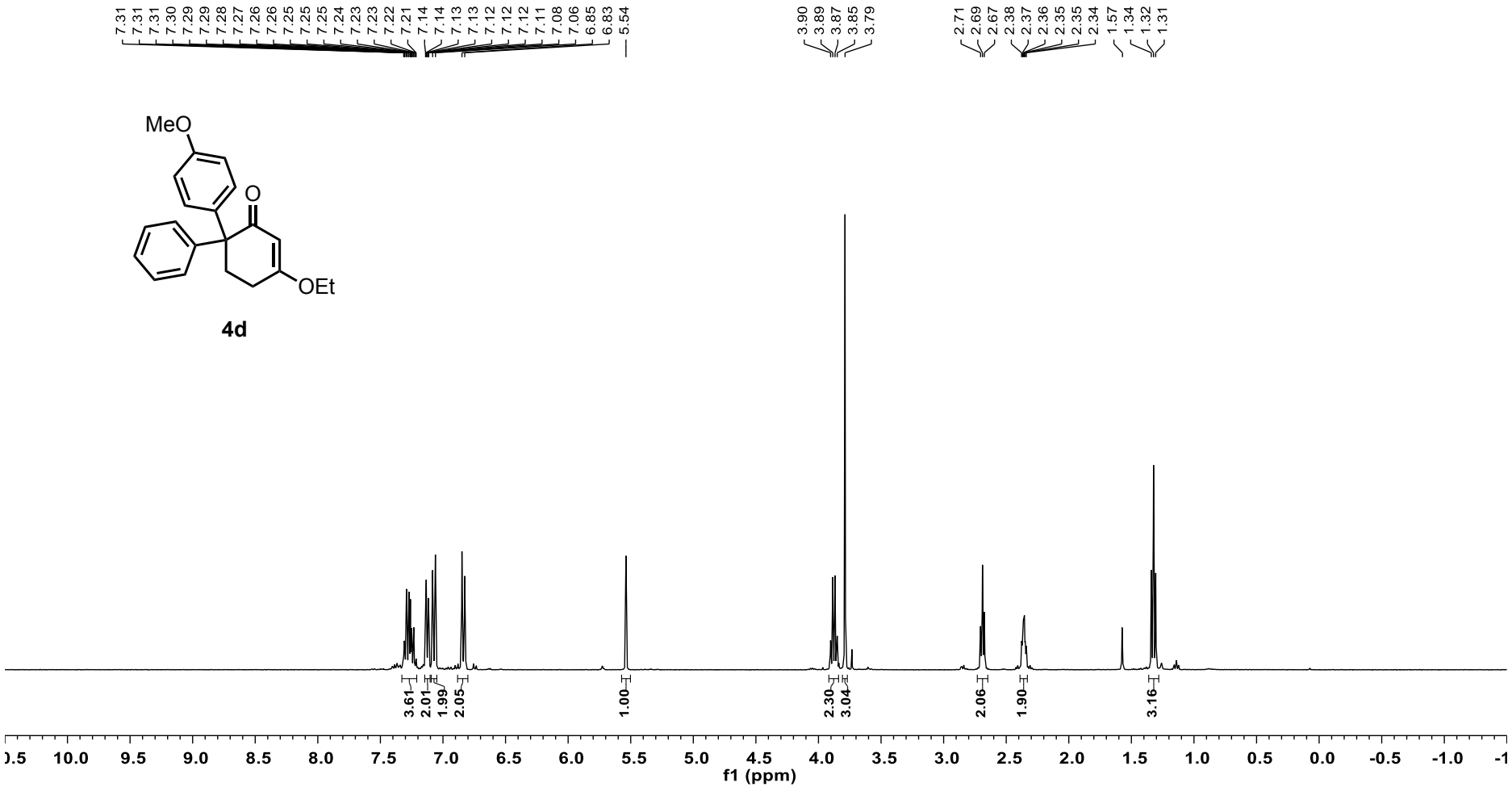
^{13}C NMR spectrum of **4b** (100 MHz, $CDCl_3$)



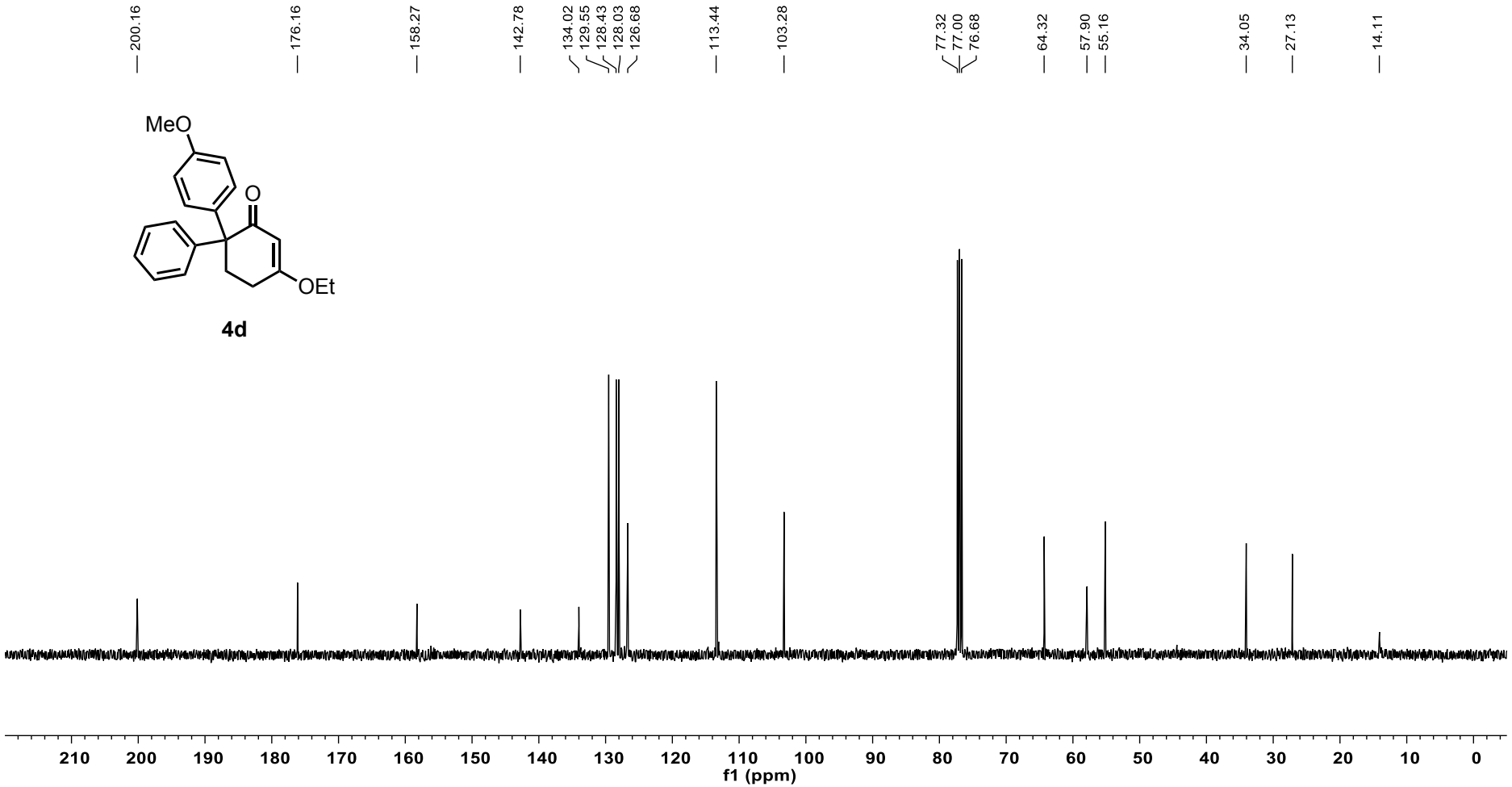
^{1}H NMR spectrum of **4c** (400 MHz, $CDCl_3$)



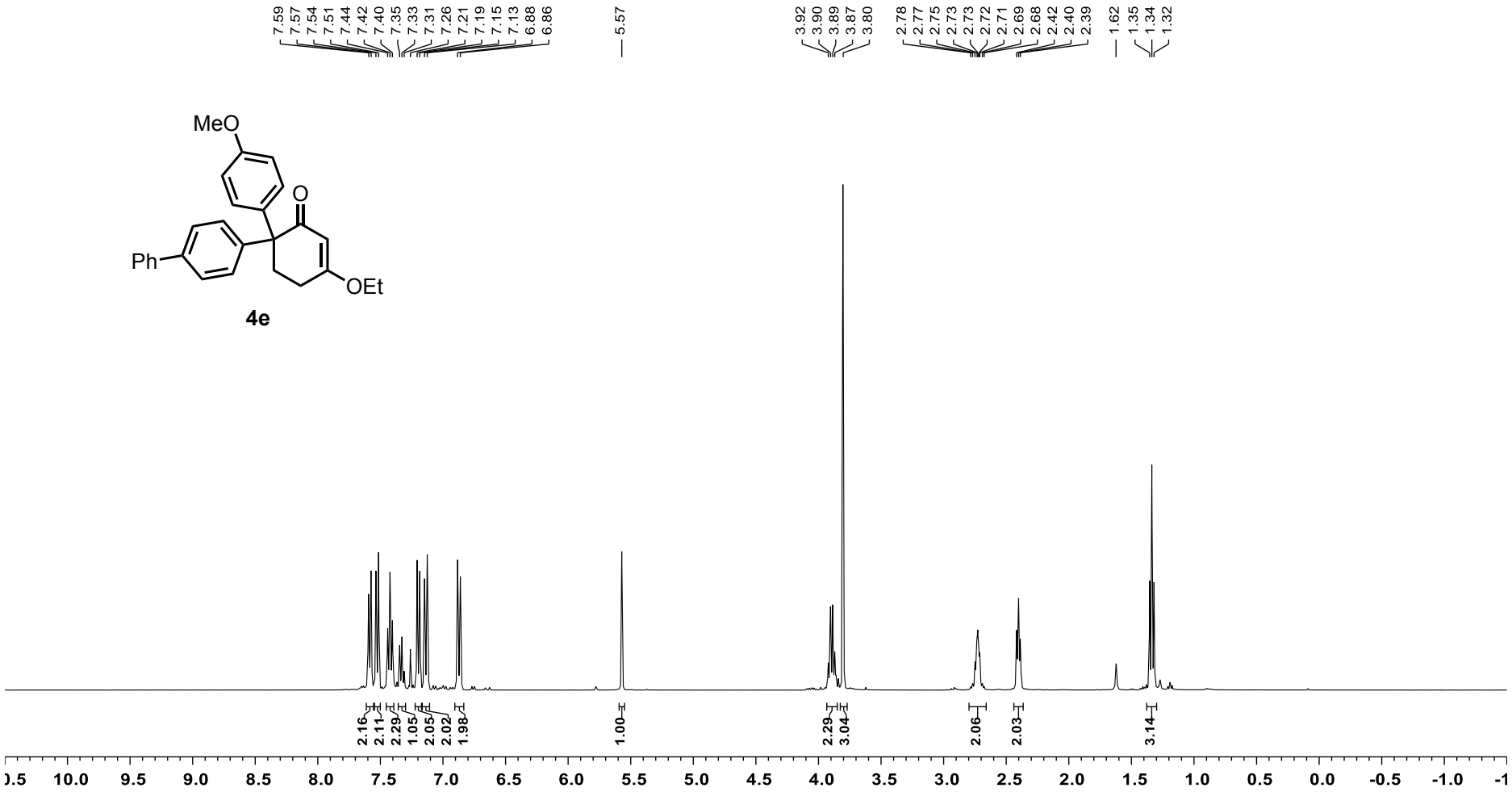
^{13}C NMR spectrum of **4c** (100 MHz, $CDCl_3$)



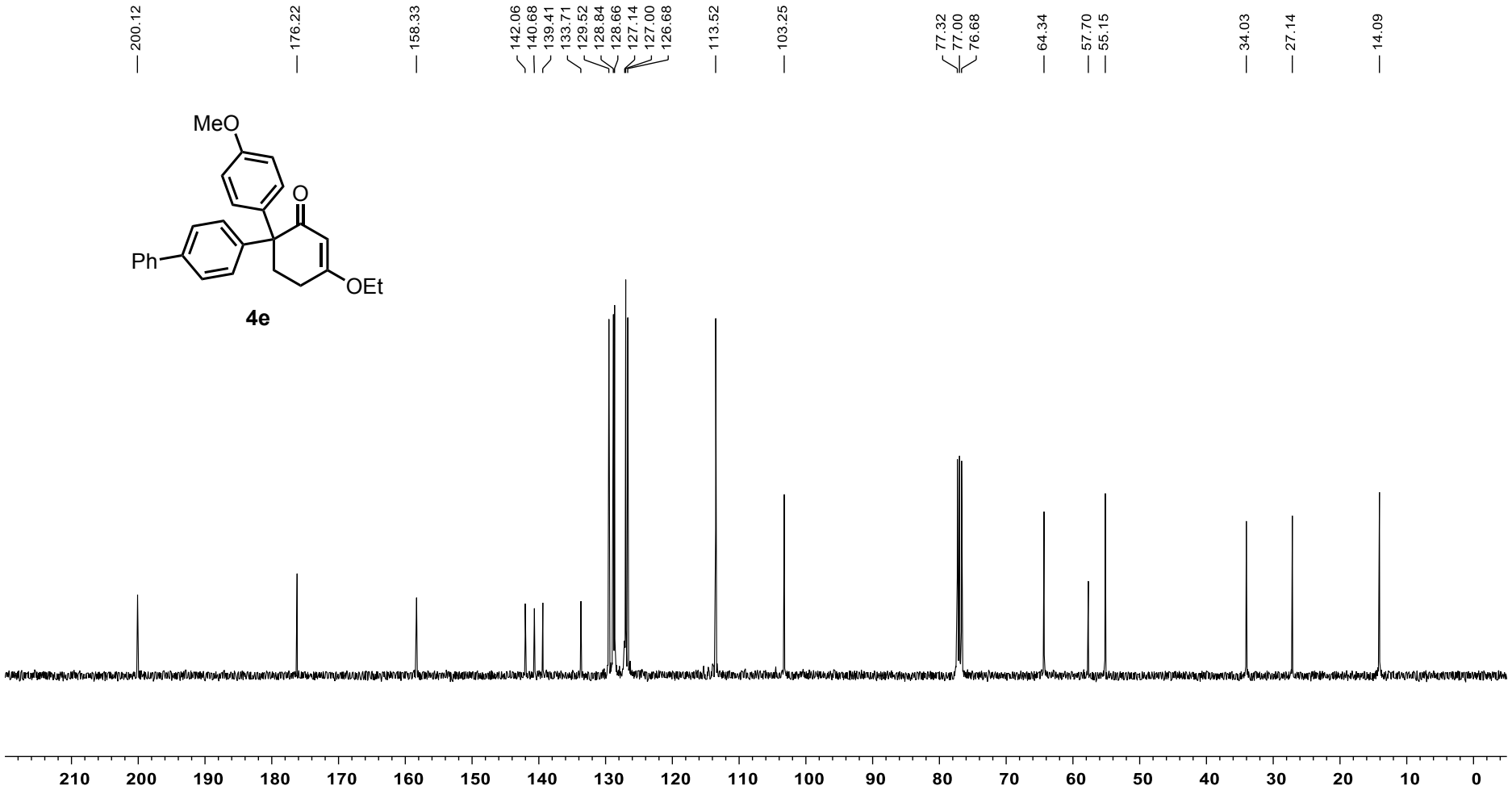
^{1}H NMR spectrum of **4d** (400 MHz, $CDCl_3$)



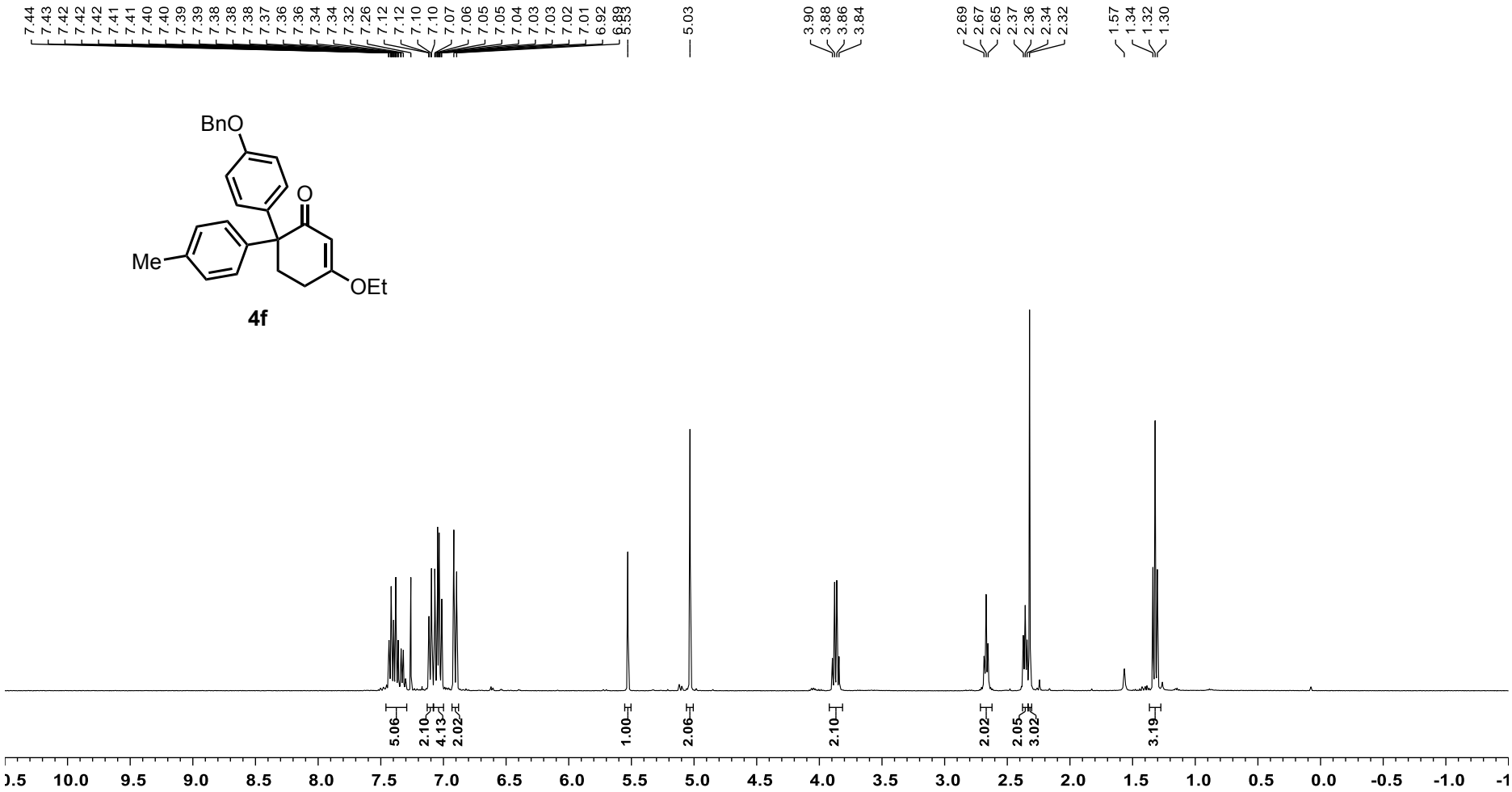
^{13}C NMR spectrum of **4d** (100 MHz, $CDCl_3$)



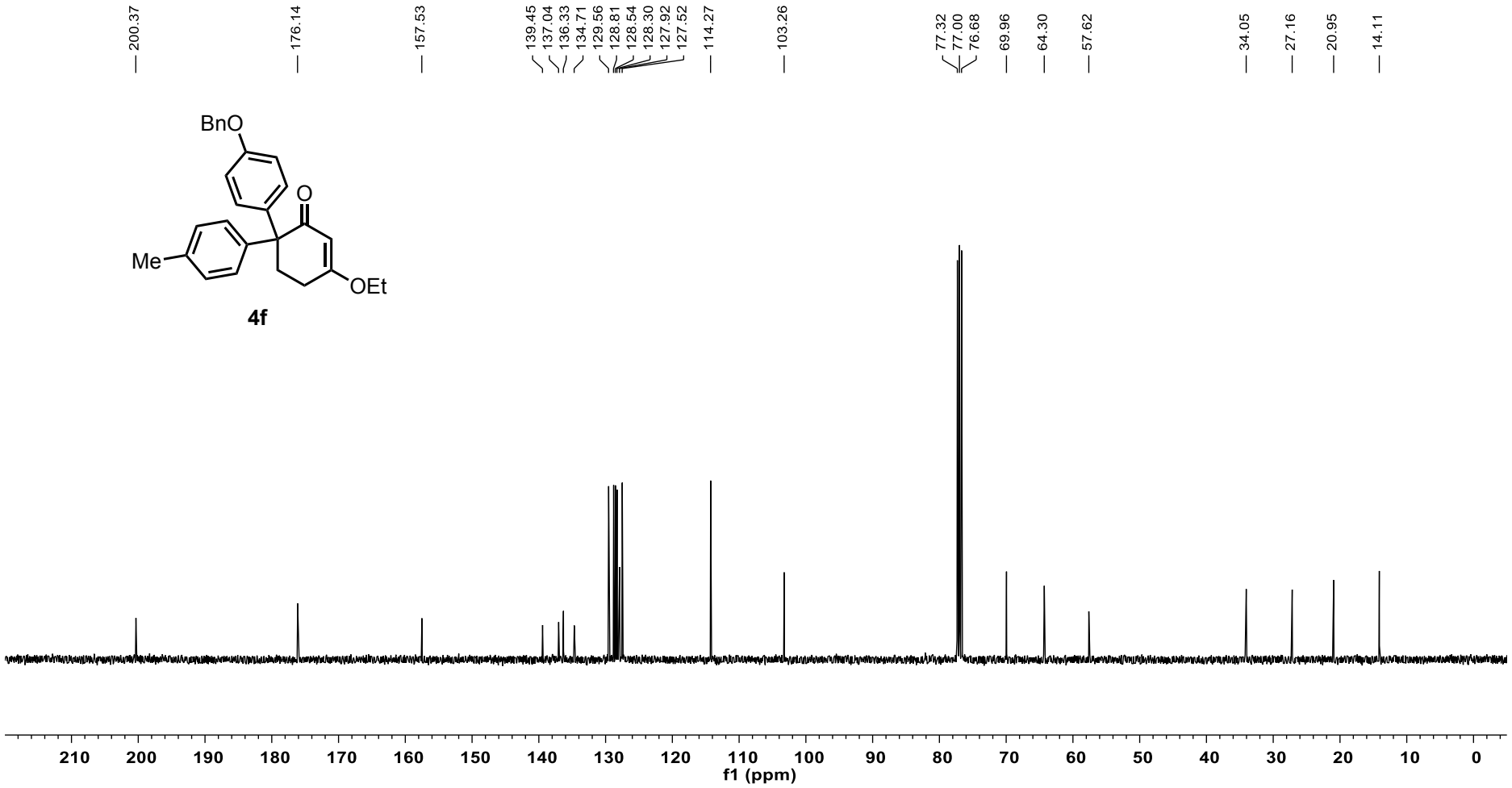
^{1}H NMR spectrum of **4e** (400 MHz, $CDCl_3$)



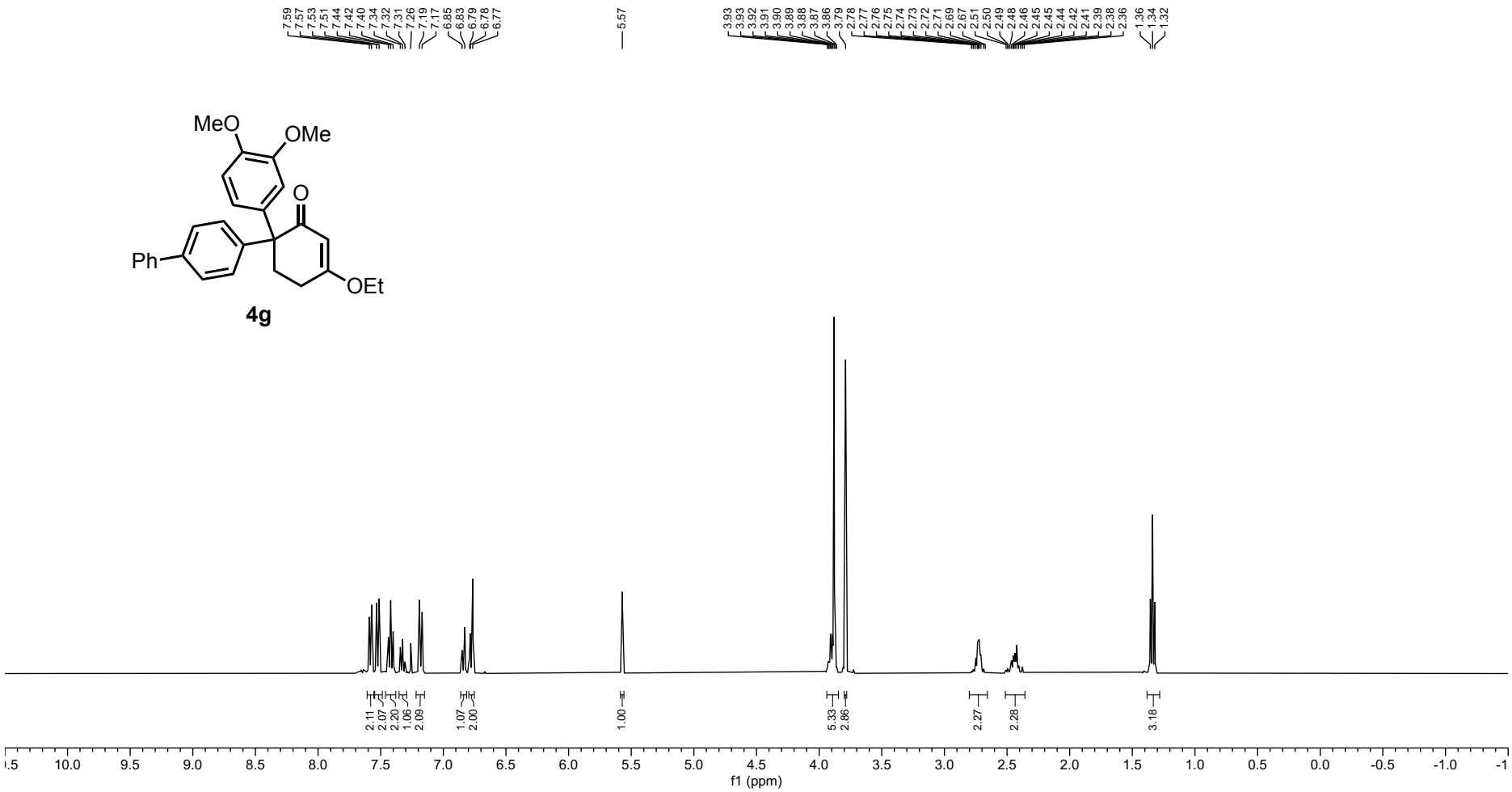
^{13}C NMR spectrum of **4e** (100 MHz, $CDCl_3$)



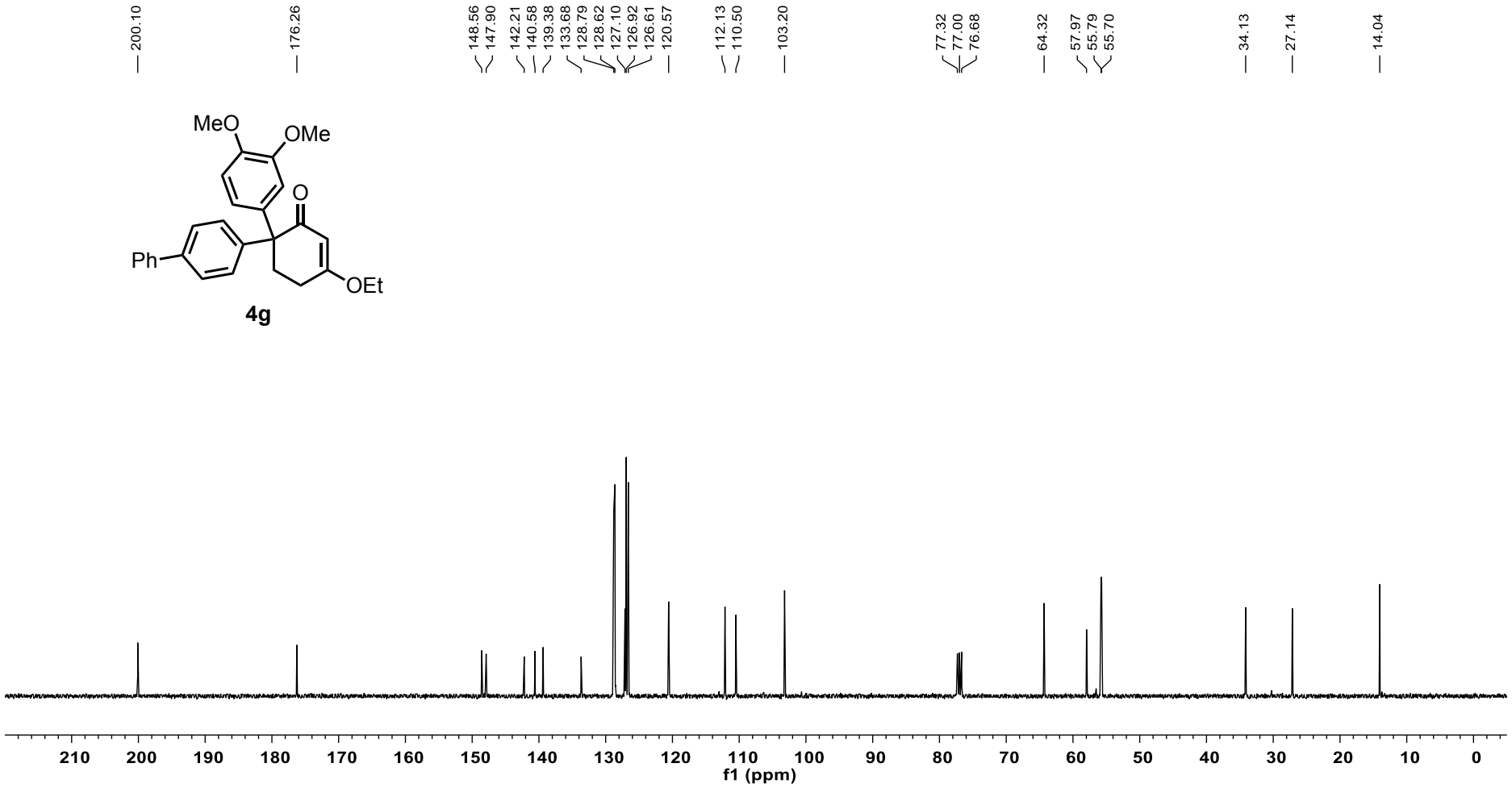
^{1}H NMR spectrum of **4f** (400 MHz, $CDCl_3$)



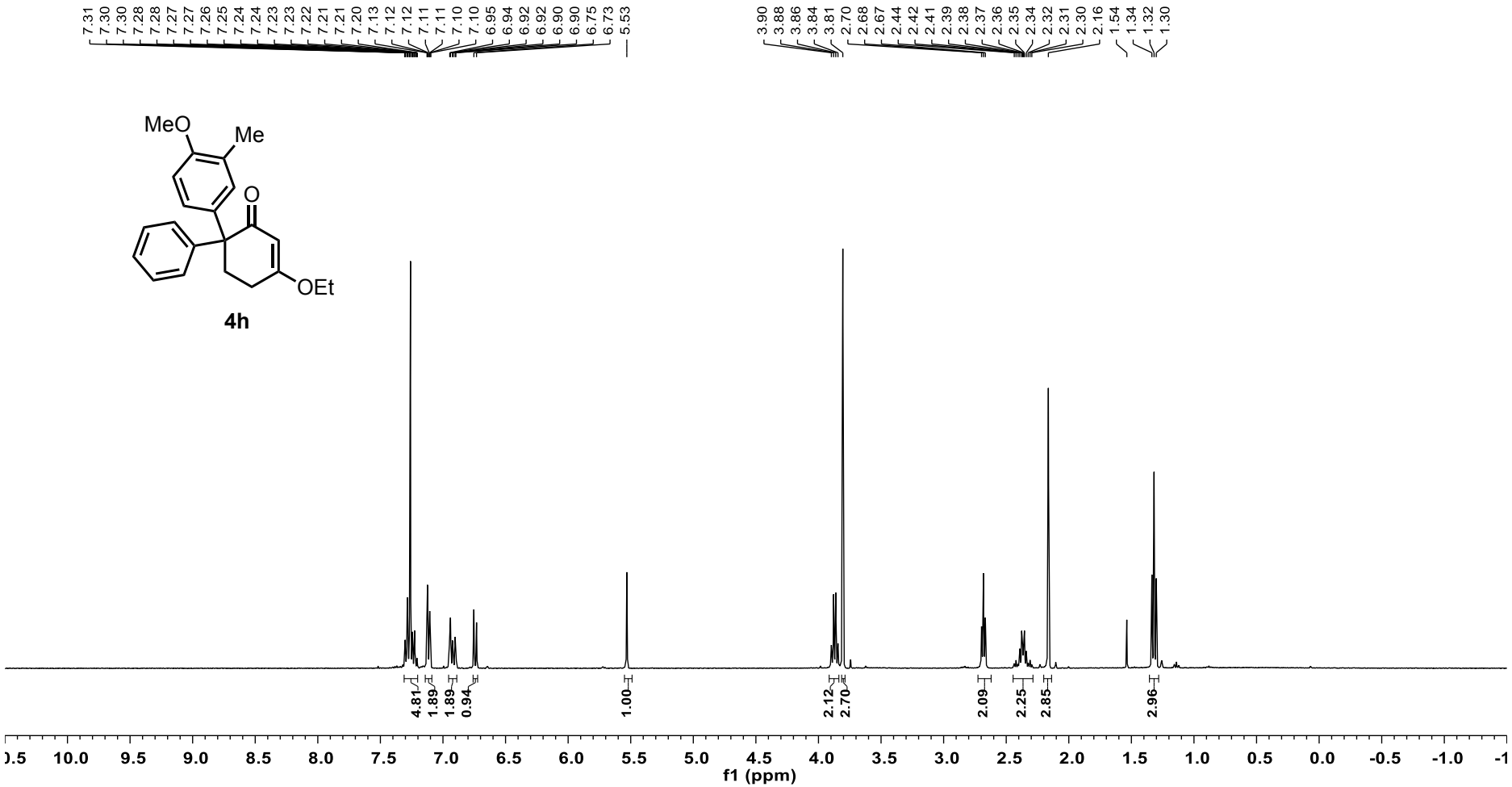
^{13}C NMR spectrum of **4f** (100 MHz, $CDCl_3$)



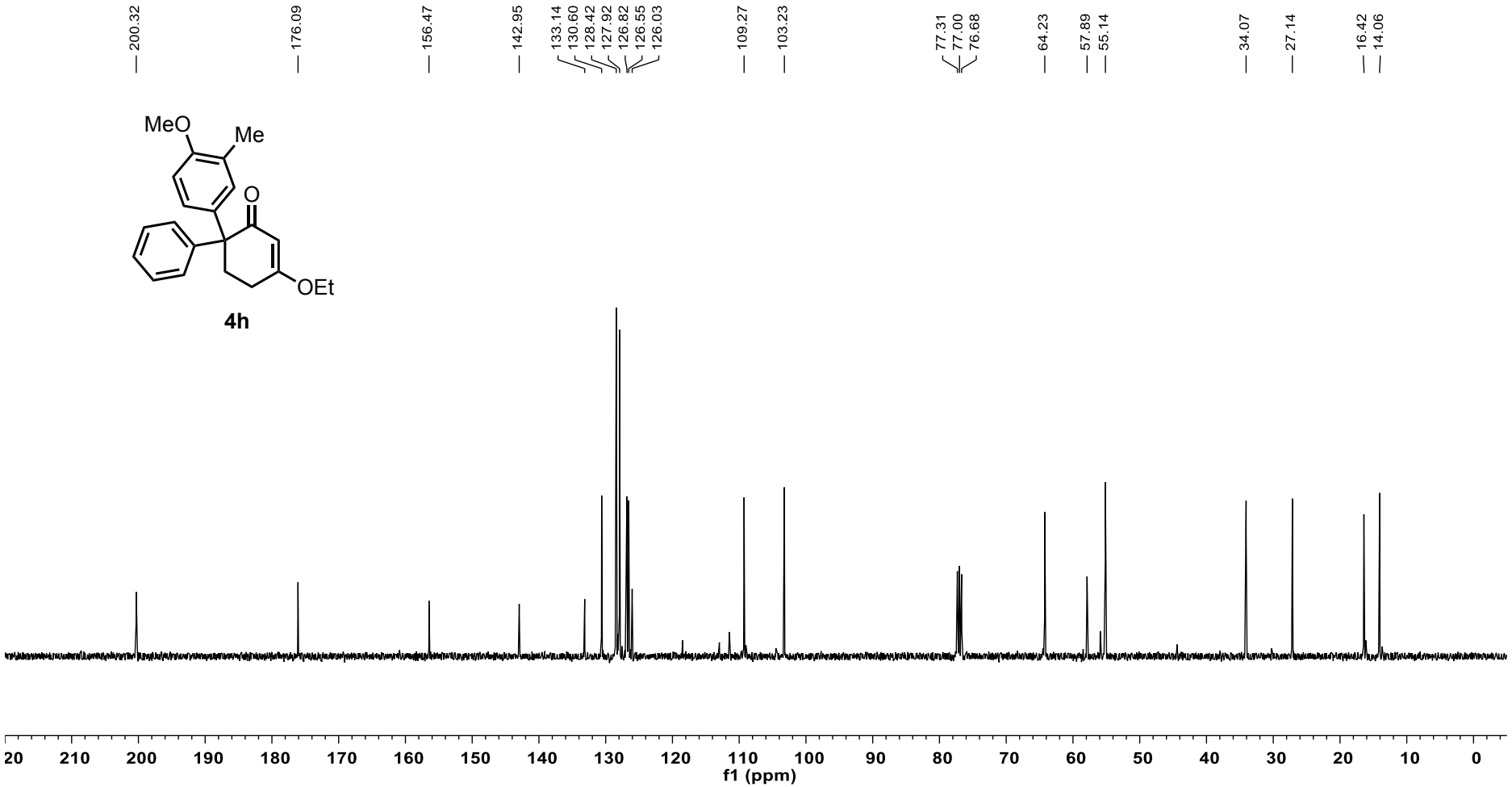
^{1}H NMR spectrum of **4g** (400 MHz, $CDCl_3$)



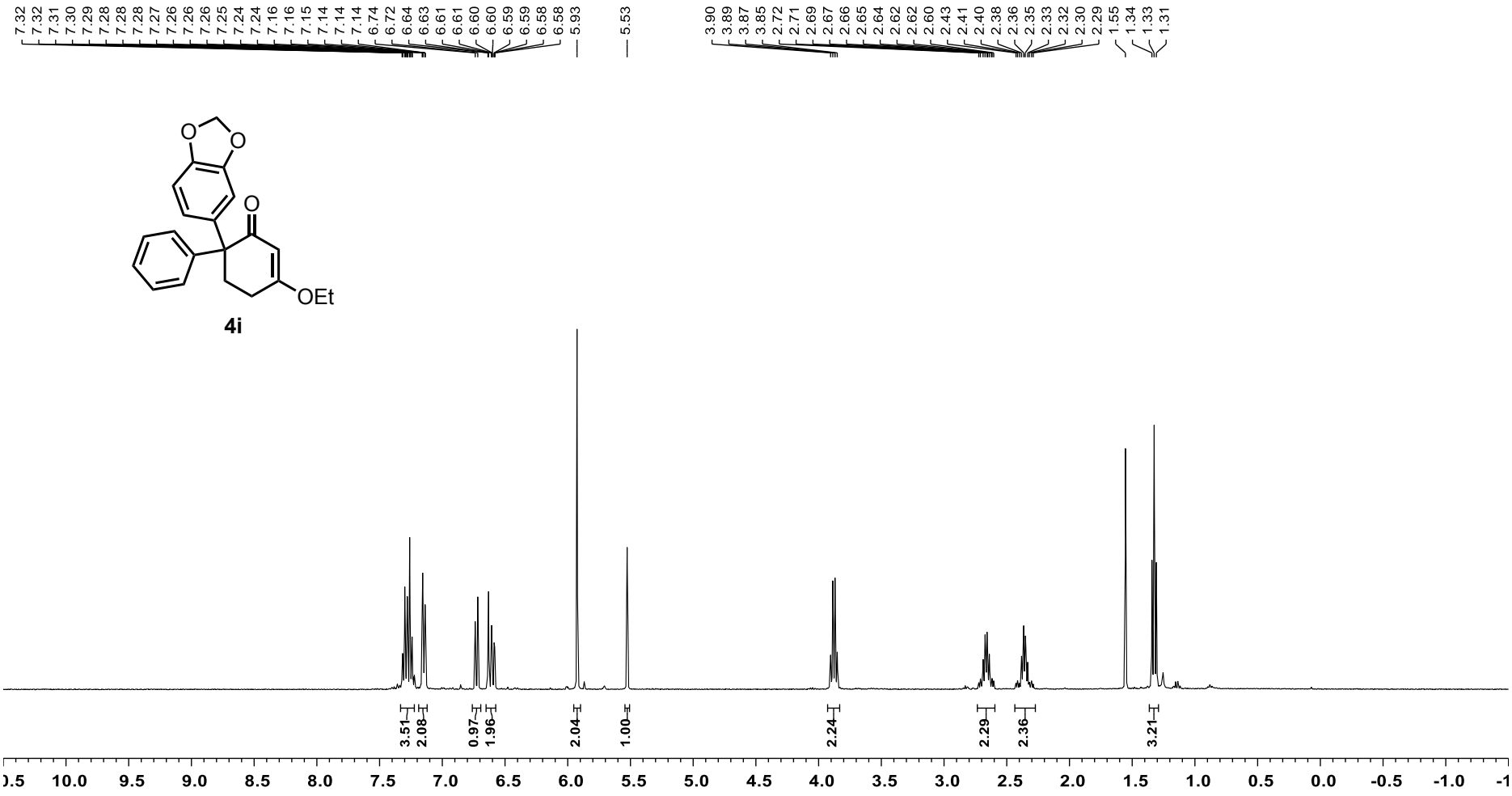
^{13}C NMR spectrum of **4g** (100 MHz, $CDCl_3$)



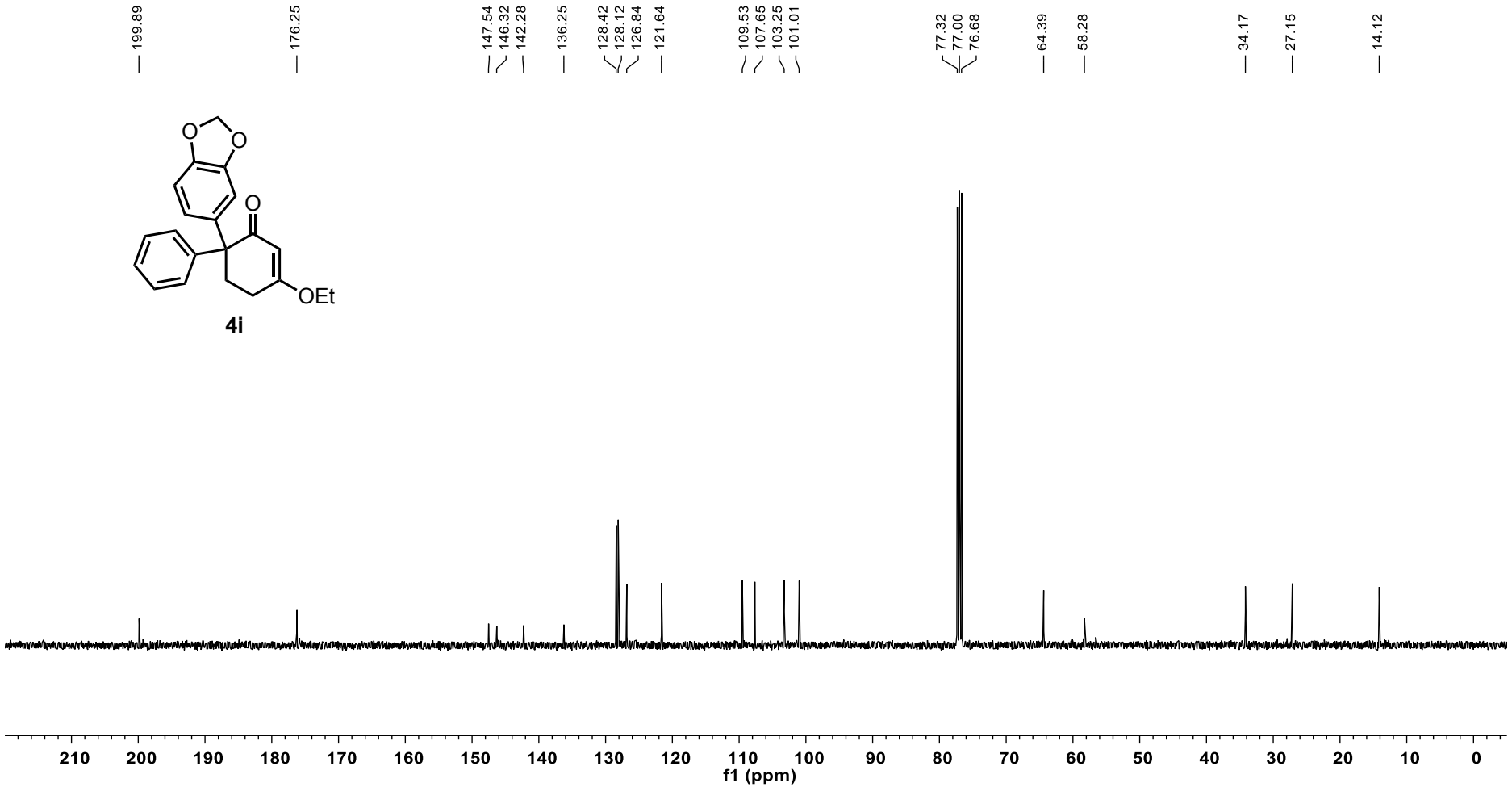
^{1}H NMR spectrum of **4h** (400 MHz, $CDCl_3$)



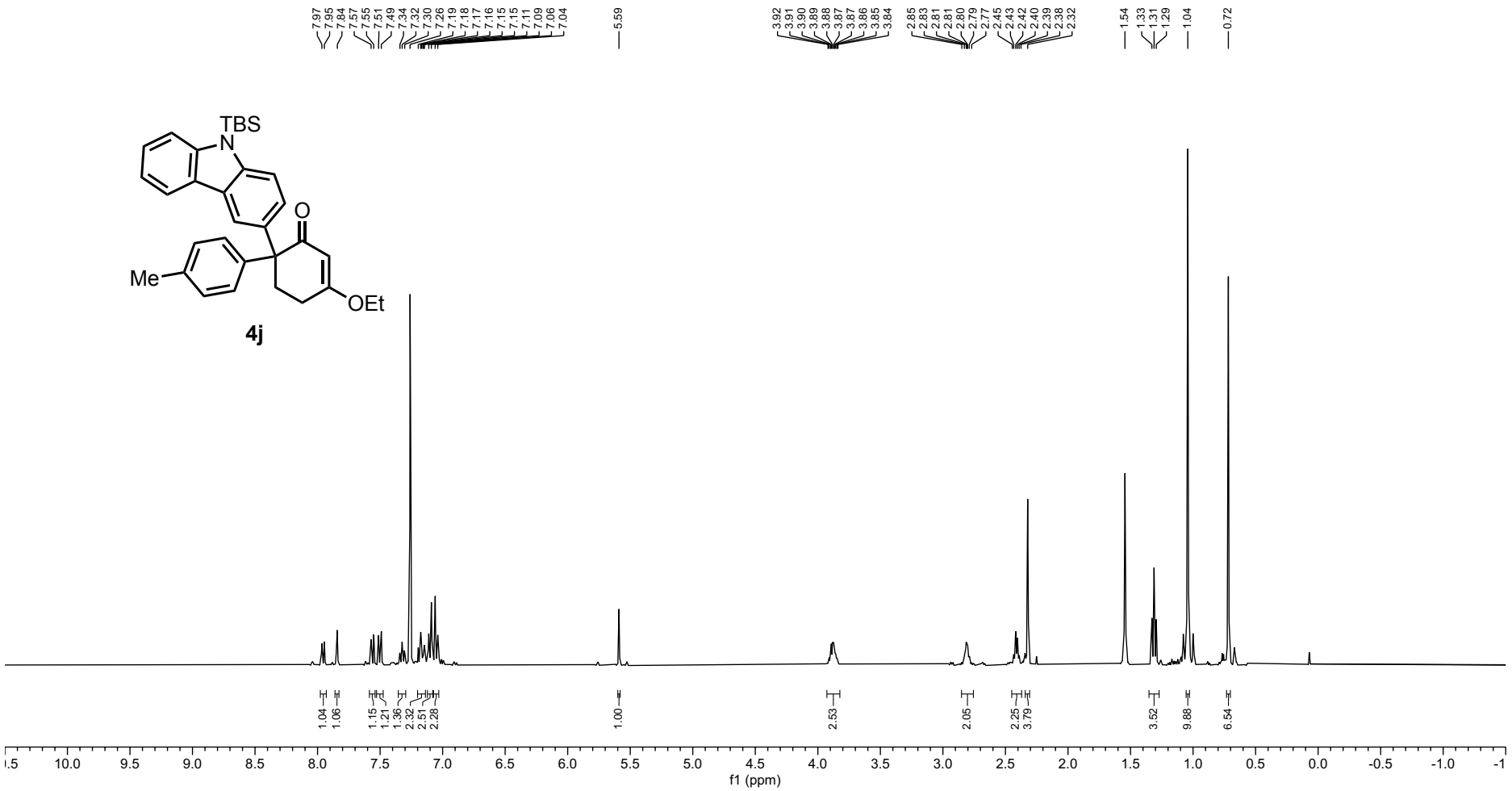
^{13}C NMR spectrum of **4h** (100 MHz, $CDCl_3$)



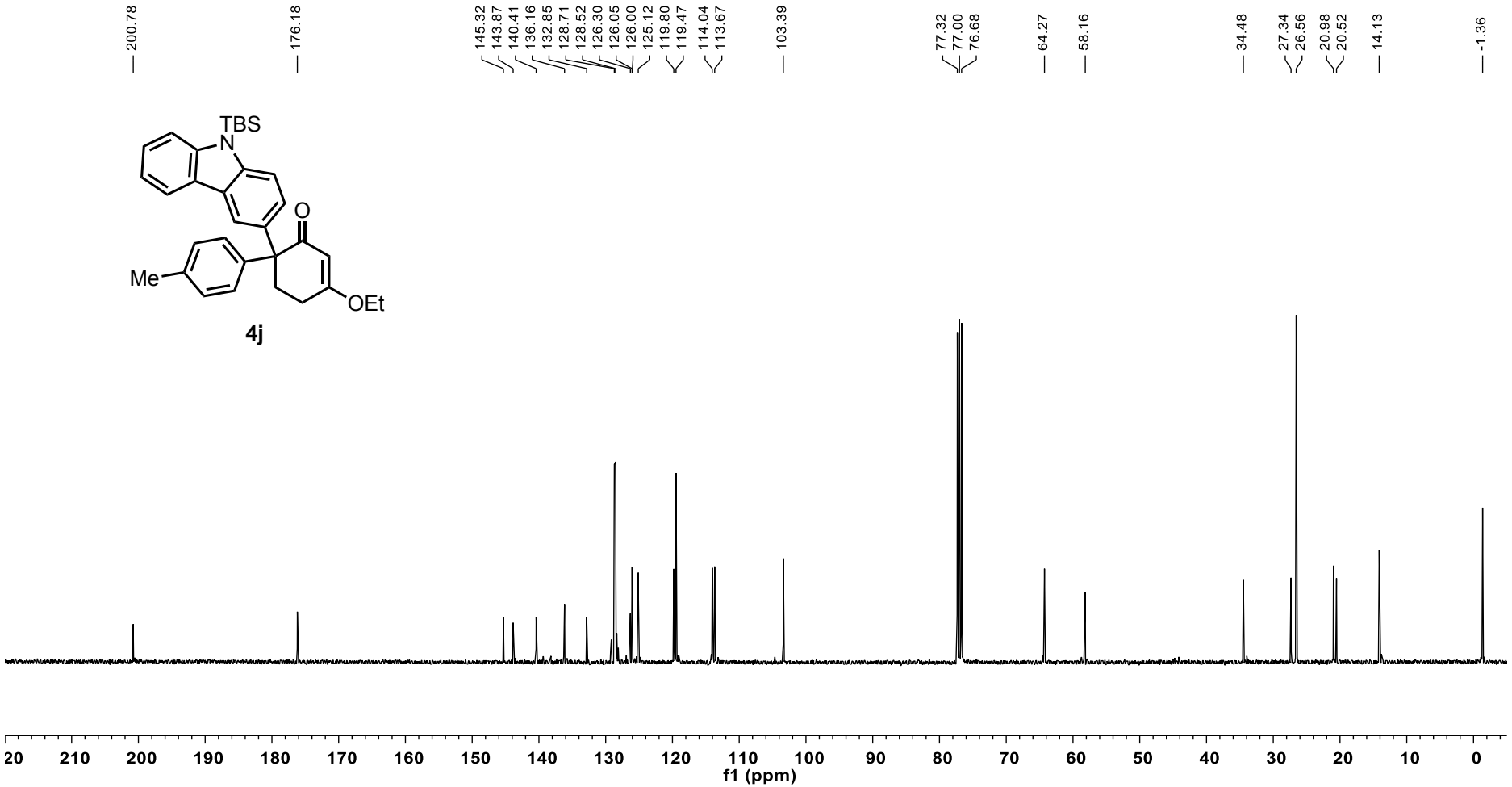
^{1}H NMR spectrum of **4i** (400 MHz, $CDCl_3$)



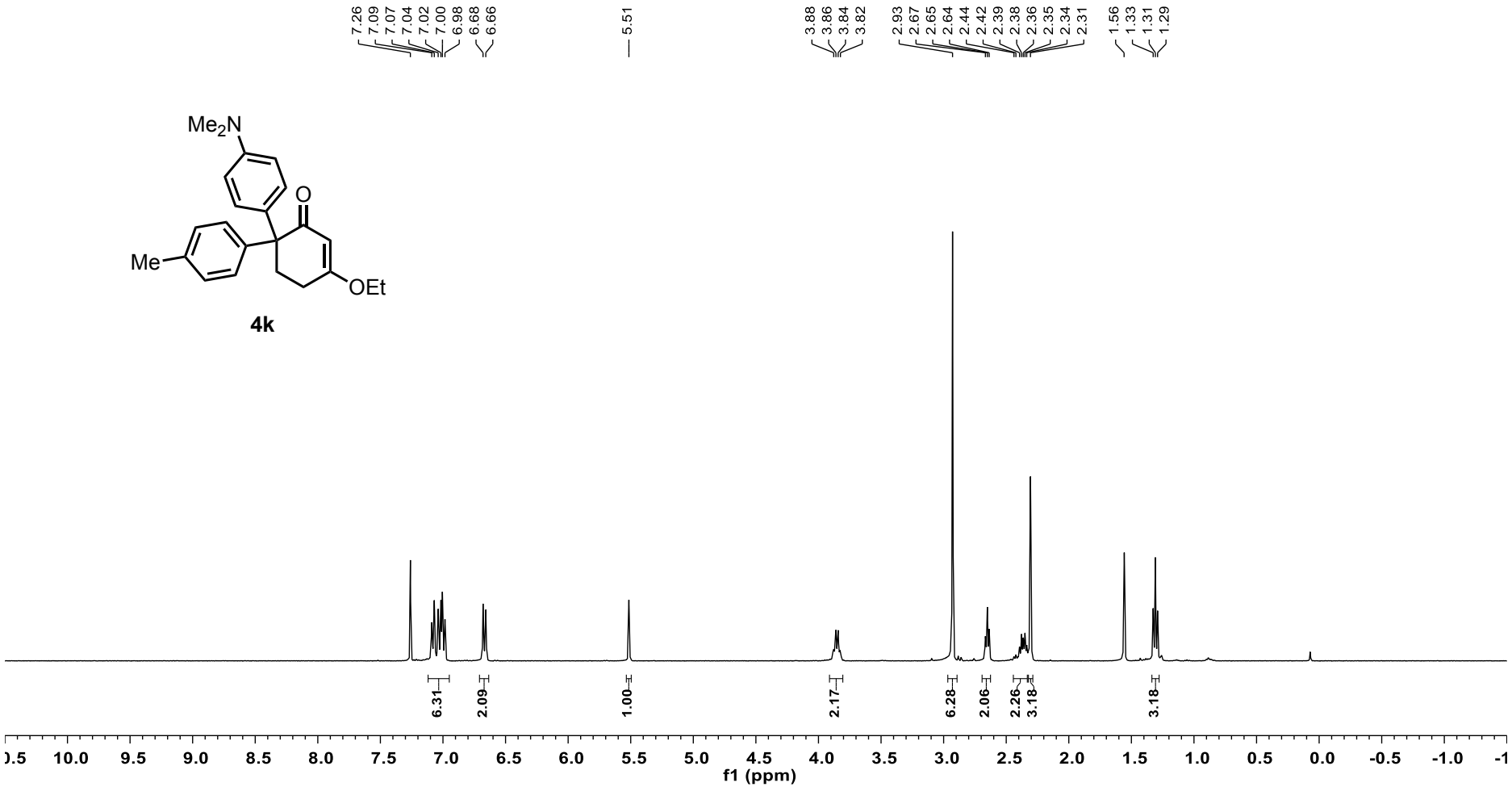
^{13}C NMR spectrum of **4i** (100 MHz, $CDCl_3$)



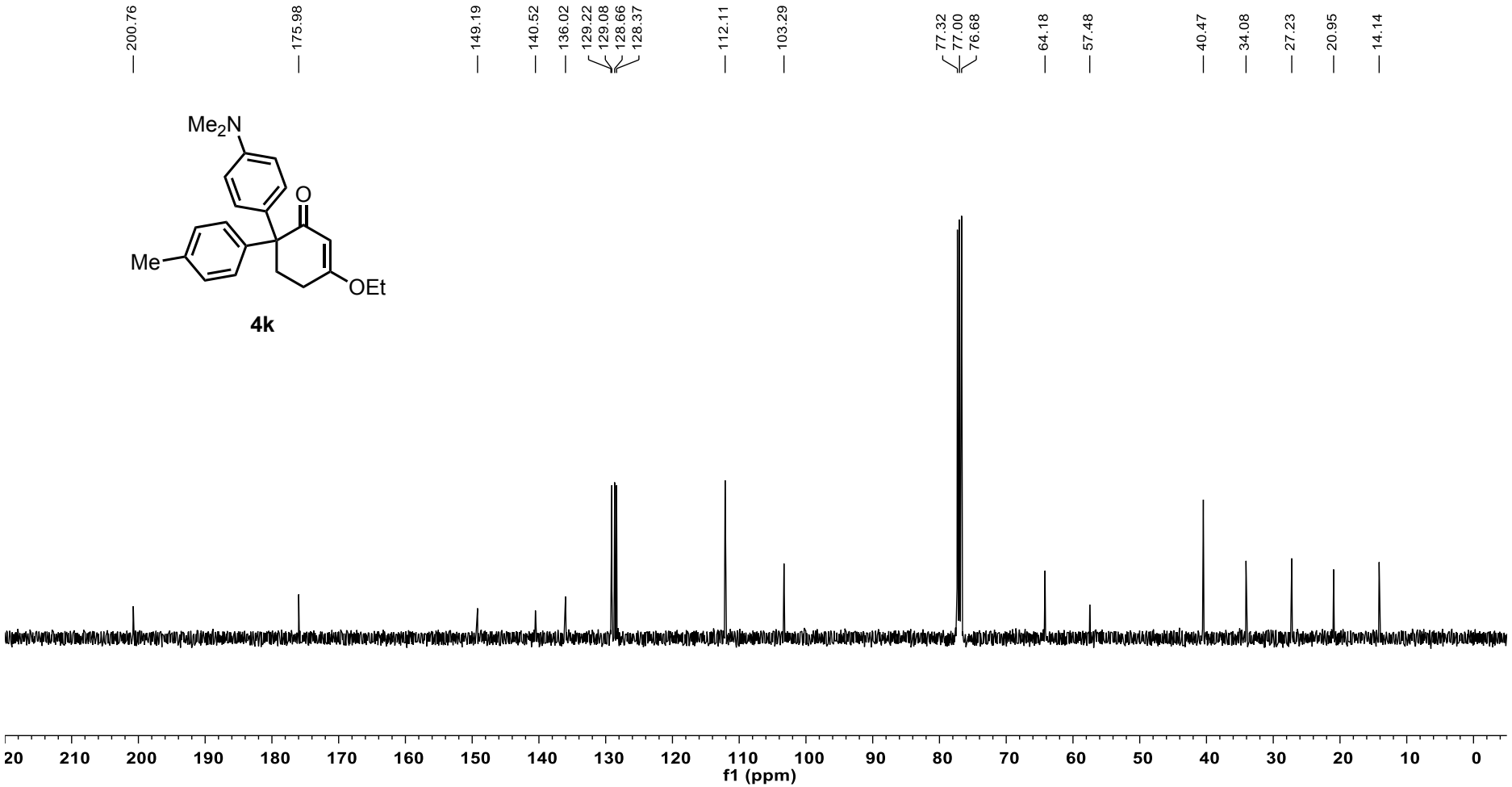
^{1}H NMR spectrum of **4j** (400 MHz, $CDCl_3$)



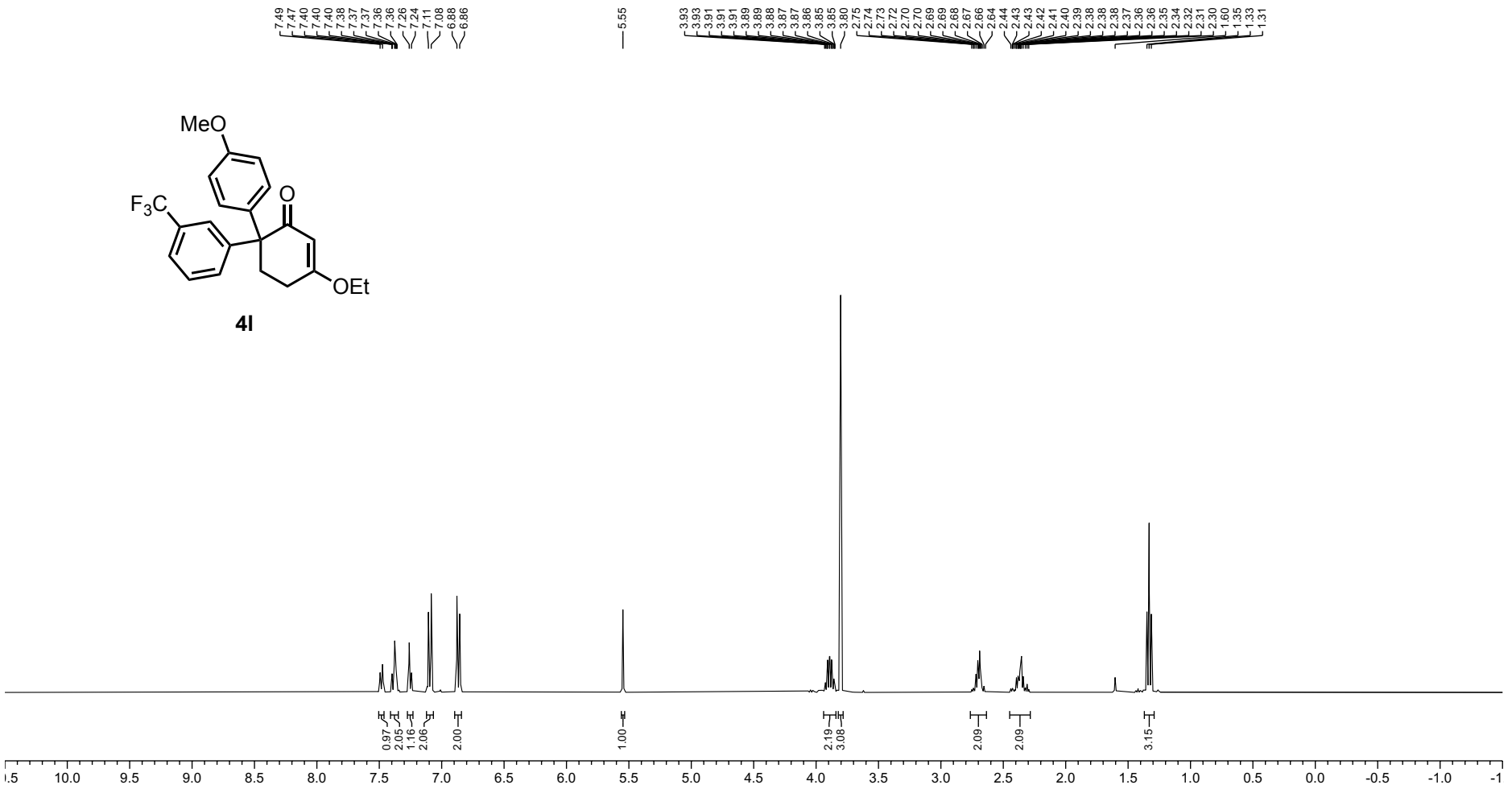
^{13}C NMR spectrum of **4j** (100 MHz, $CDCl_3$)



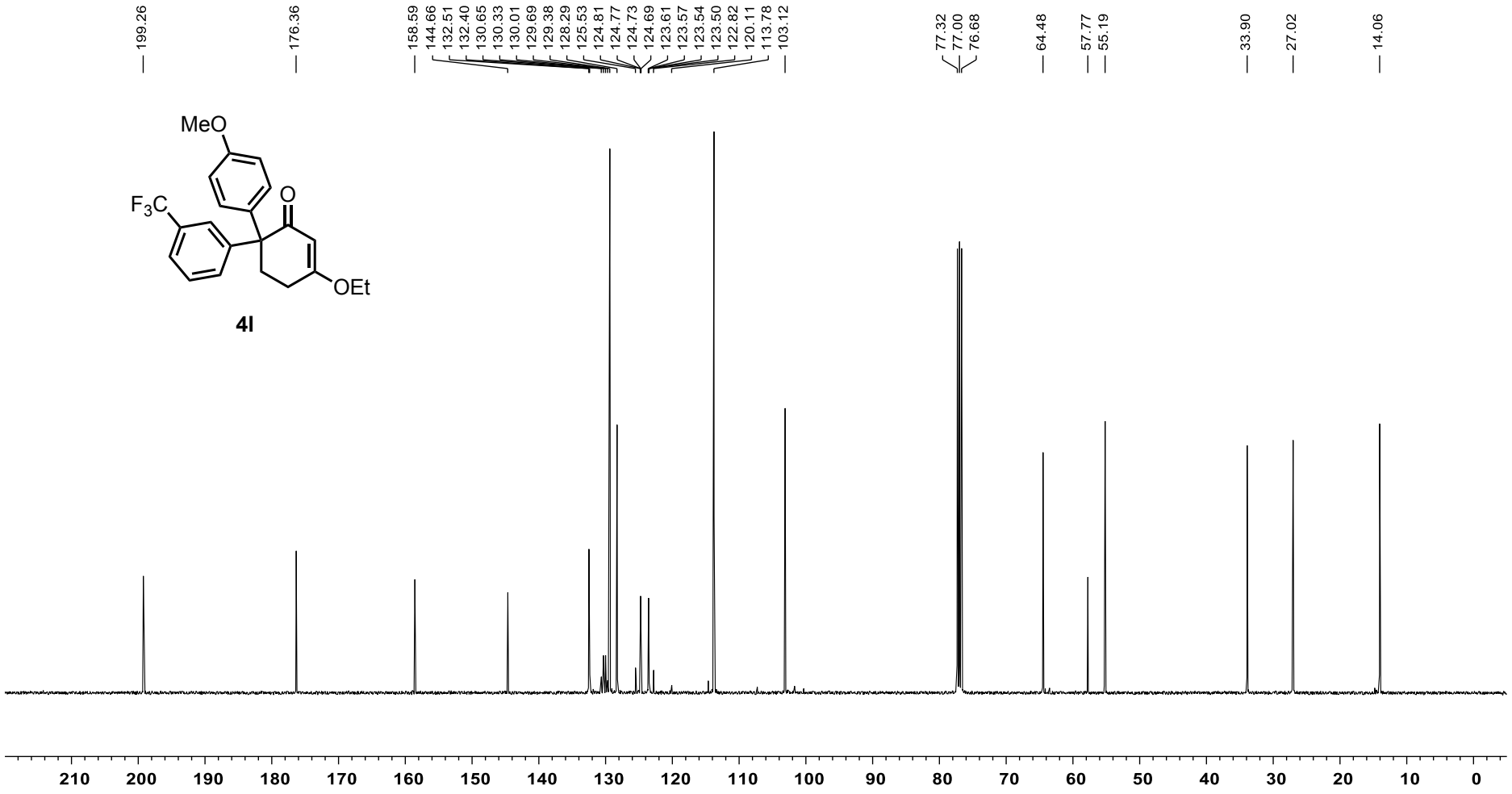
^{1}H NMR spectrum of **4k** (400 MHz, $CDCl_3$)



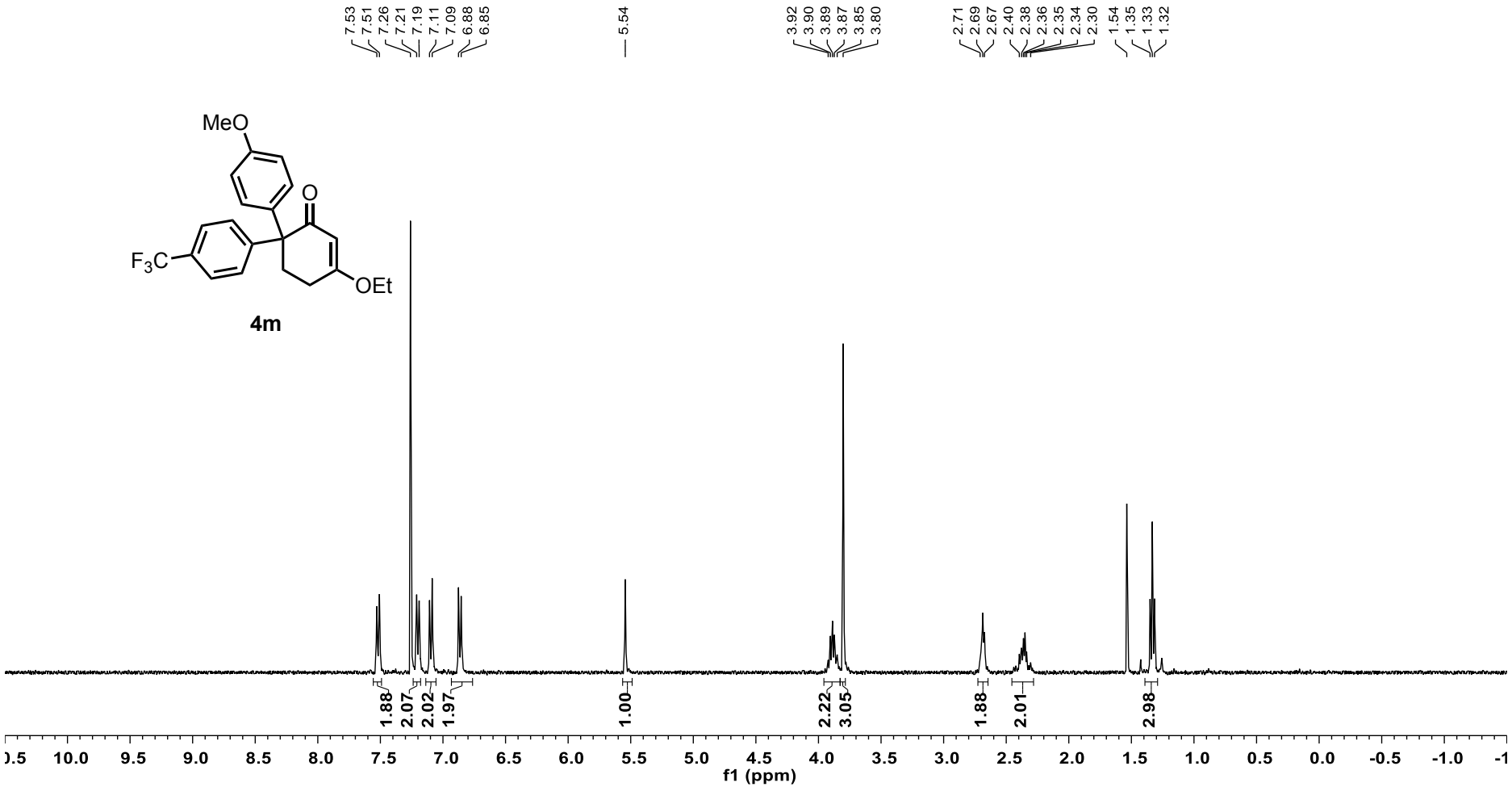
^{13}C NMR spectrum of **4k** (100 MHz, $CDCl_3$)



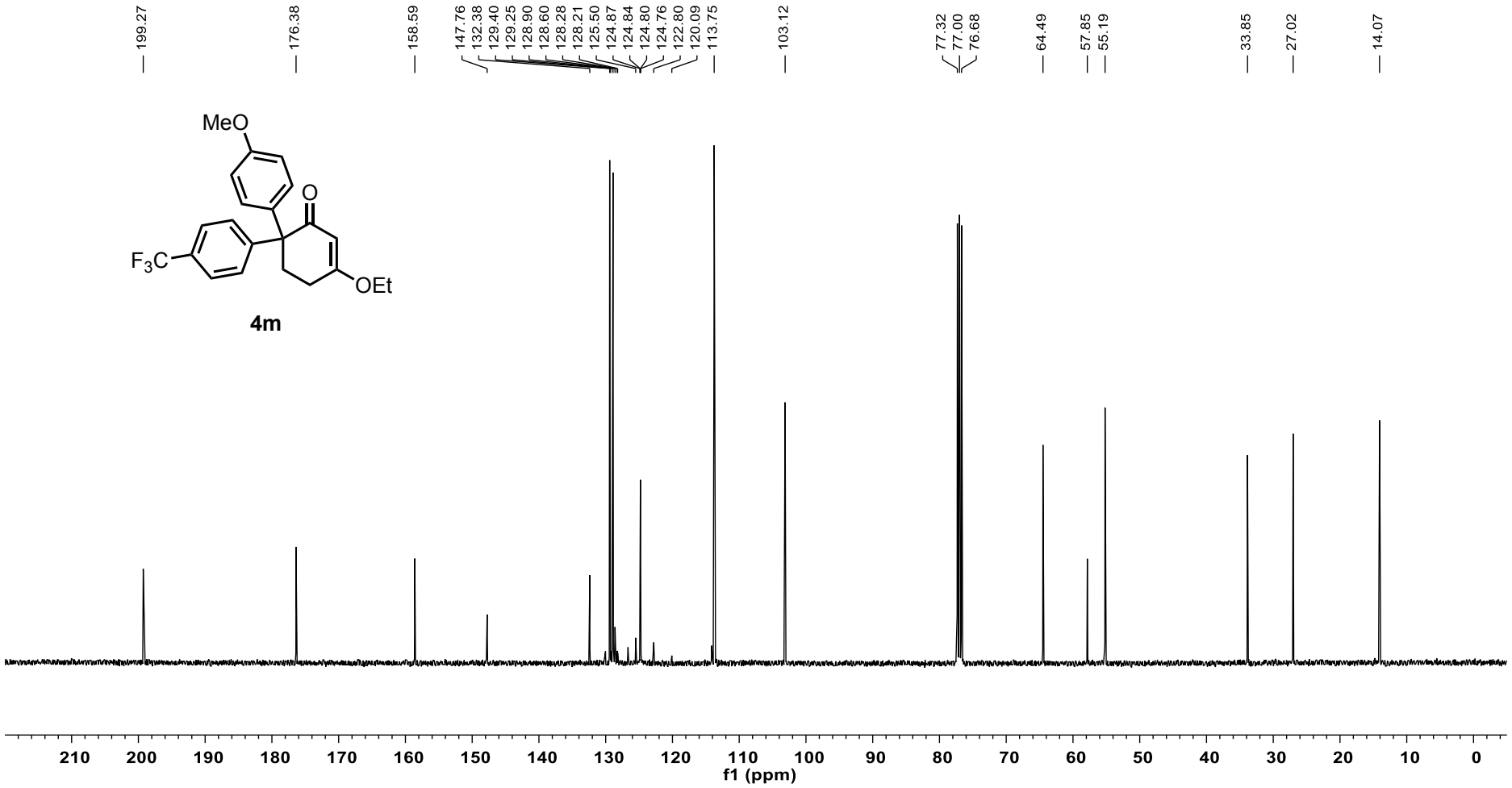
^{1}H NMR spectrum of **4l** (400 MHz, $CDCl_3$)



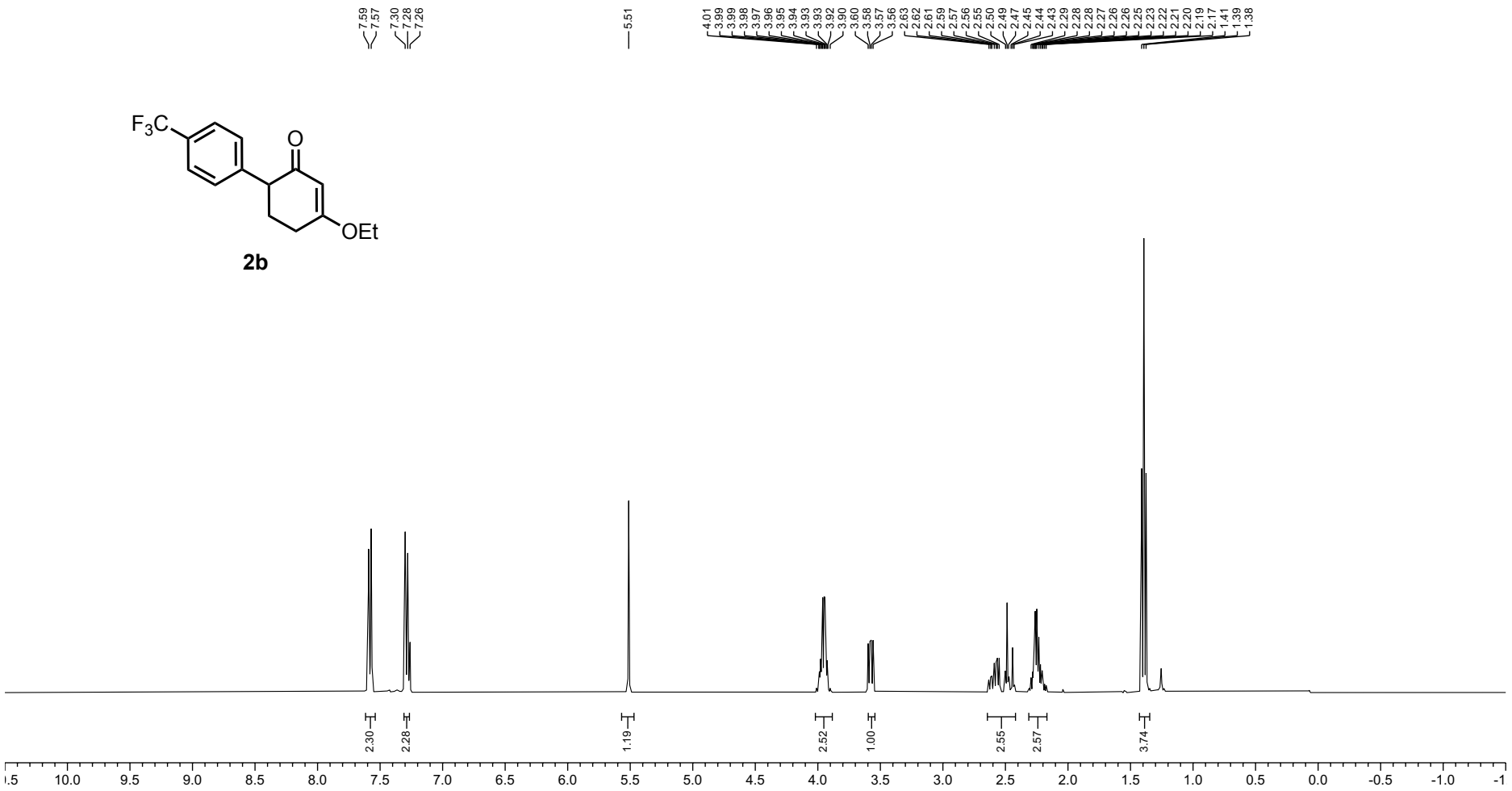
^{13}C NMR spectrum of **4l** (100 MHz, $CDCl_3$)



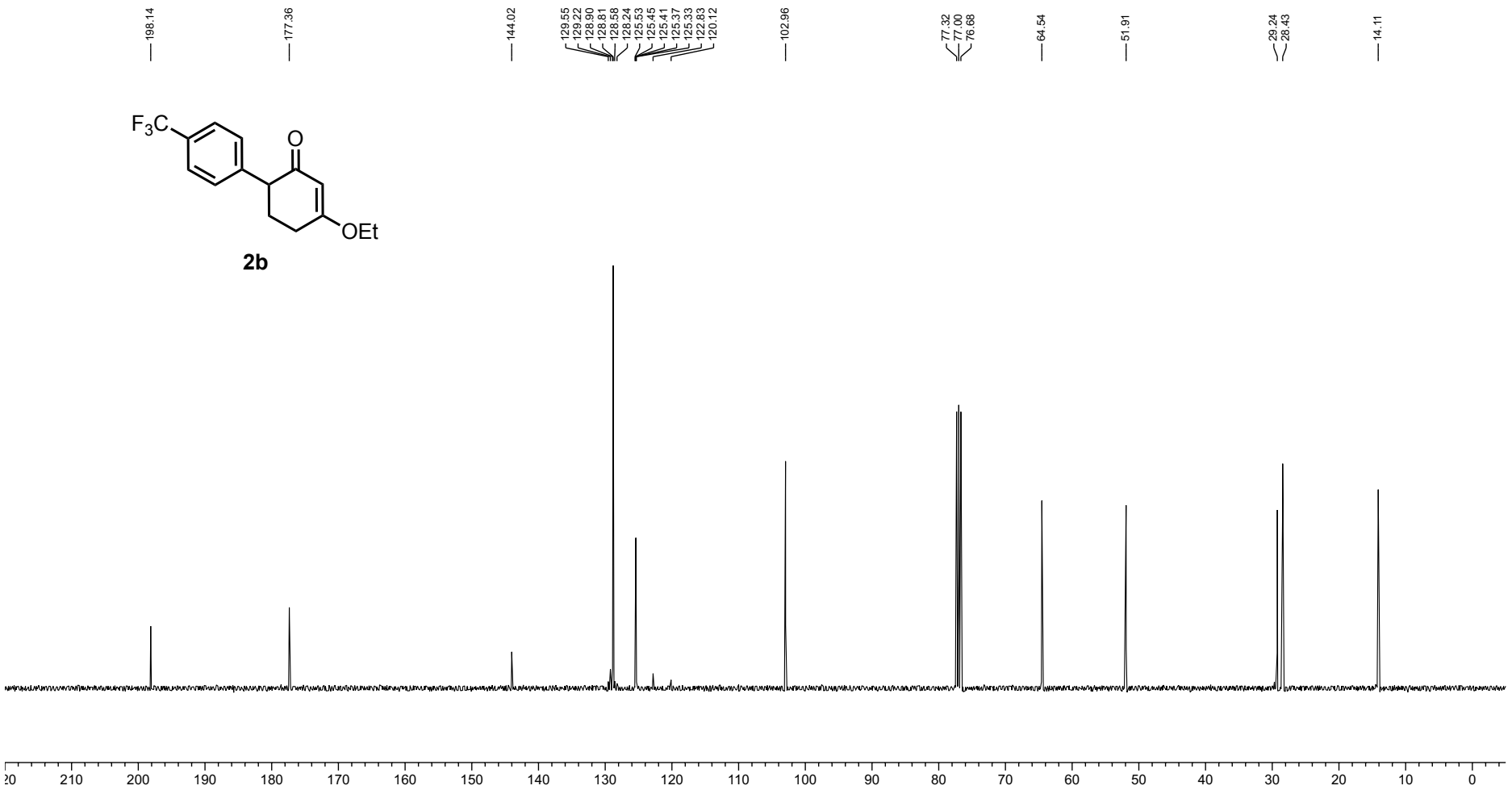
^{1}H NMR spectrum of **4m** (400 MHz, $CDCl_3$)



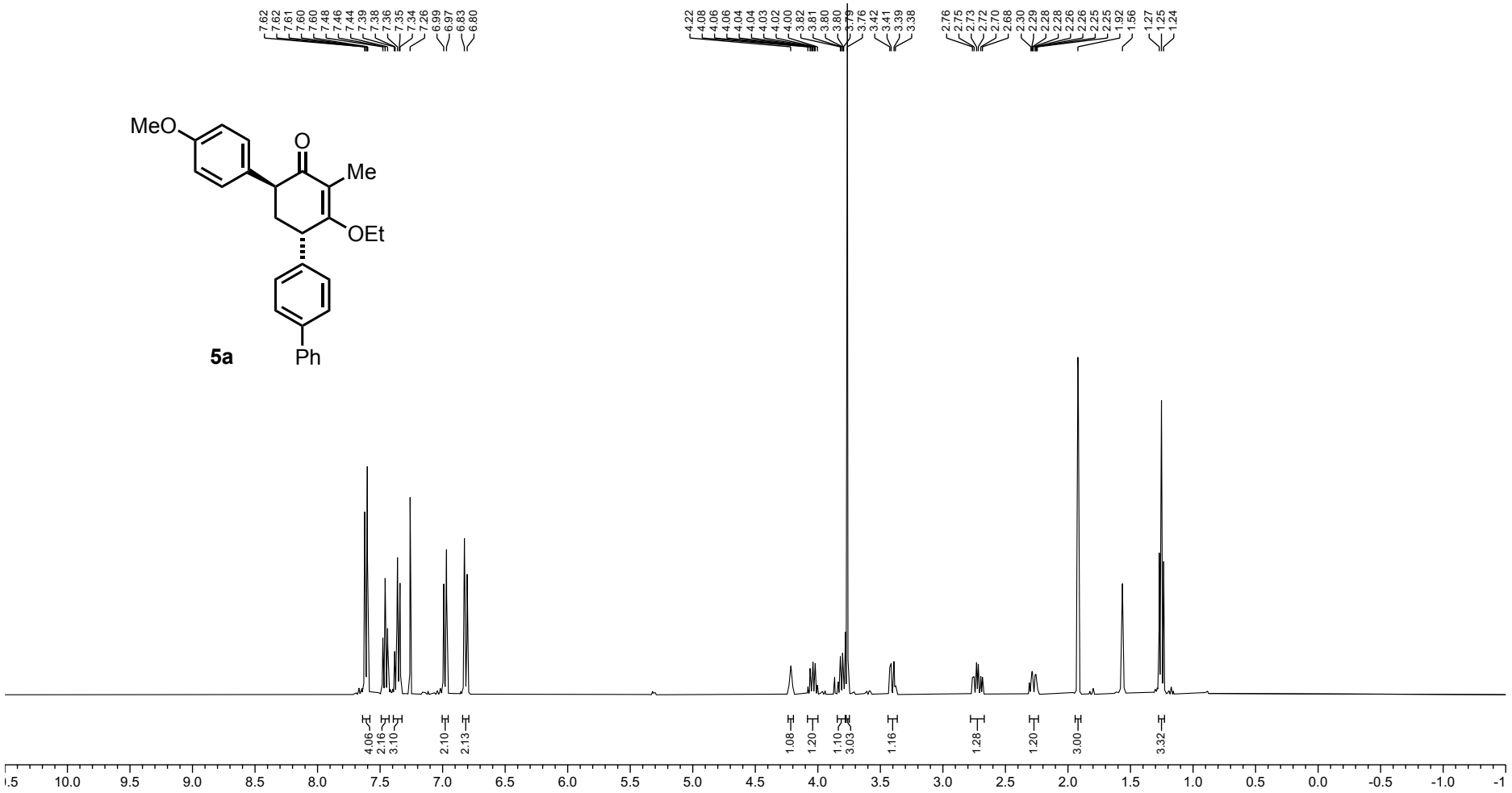
^{13}C NMR spectrum of **4m** (100 MHz, $CDCl_3$)



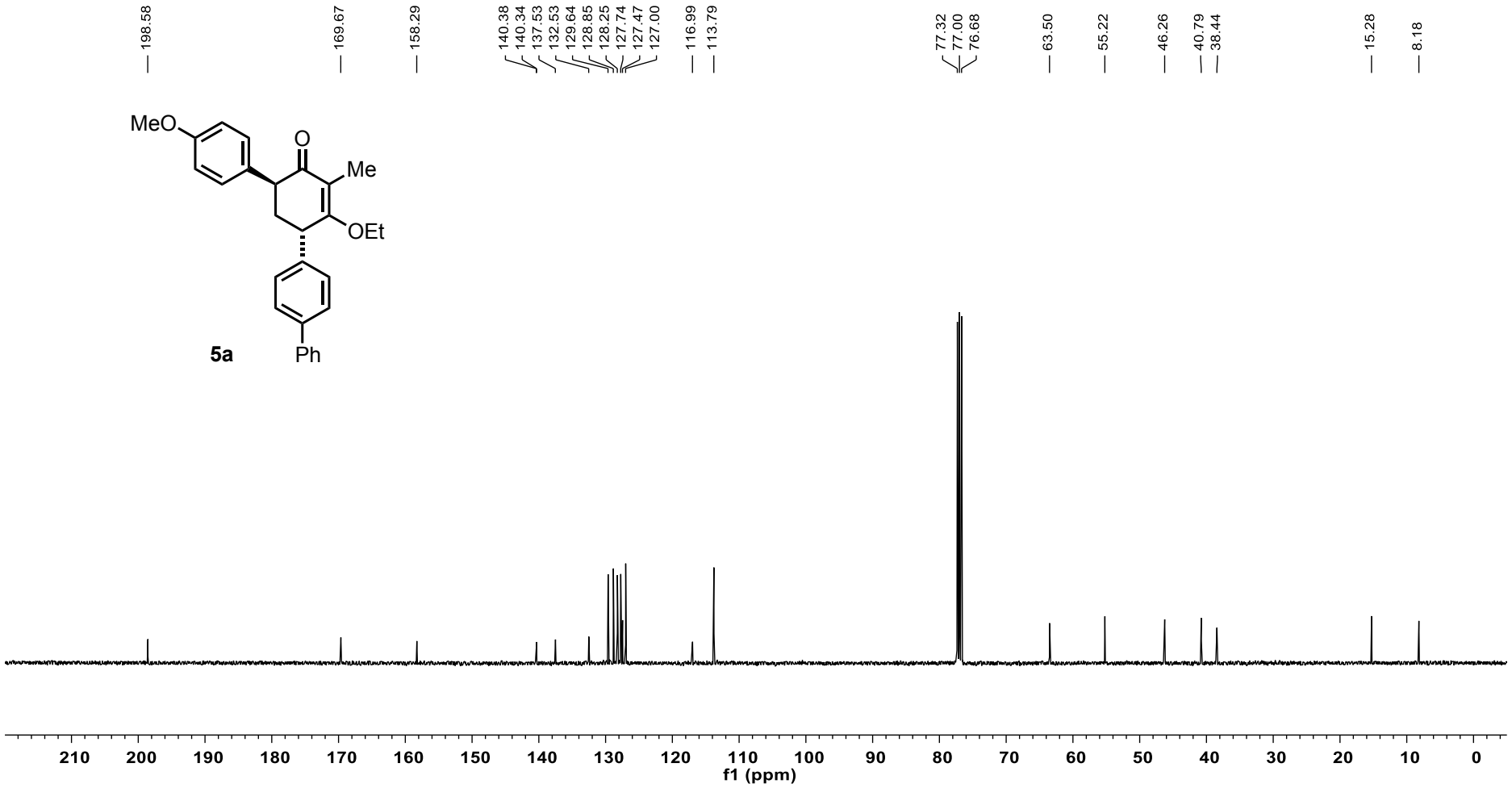
^{1}H NMR spectrum of **2b** (400 MHz, $CDCl_3$)



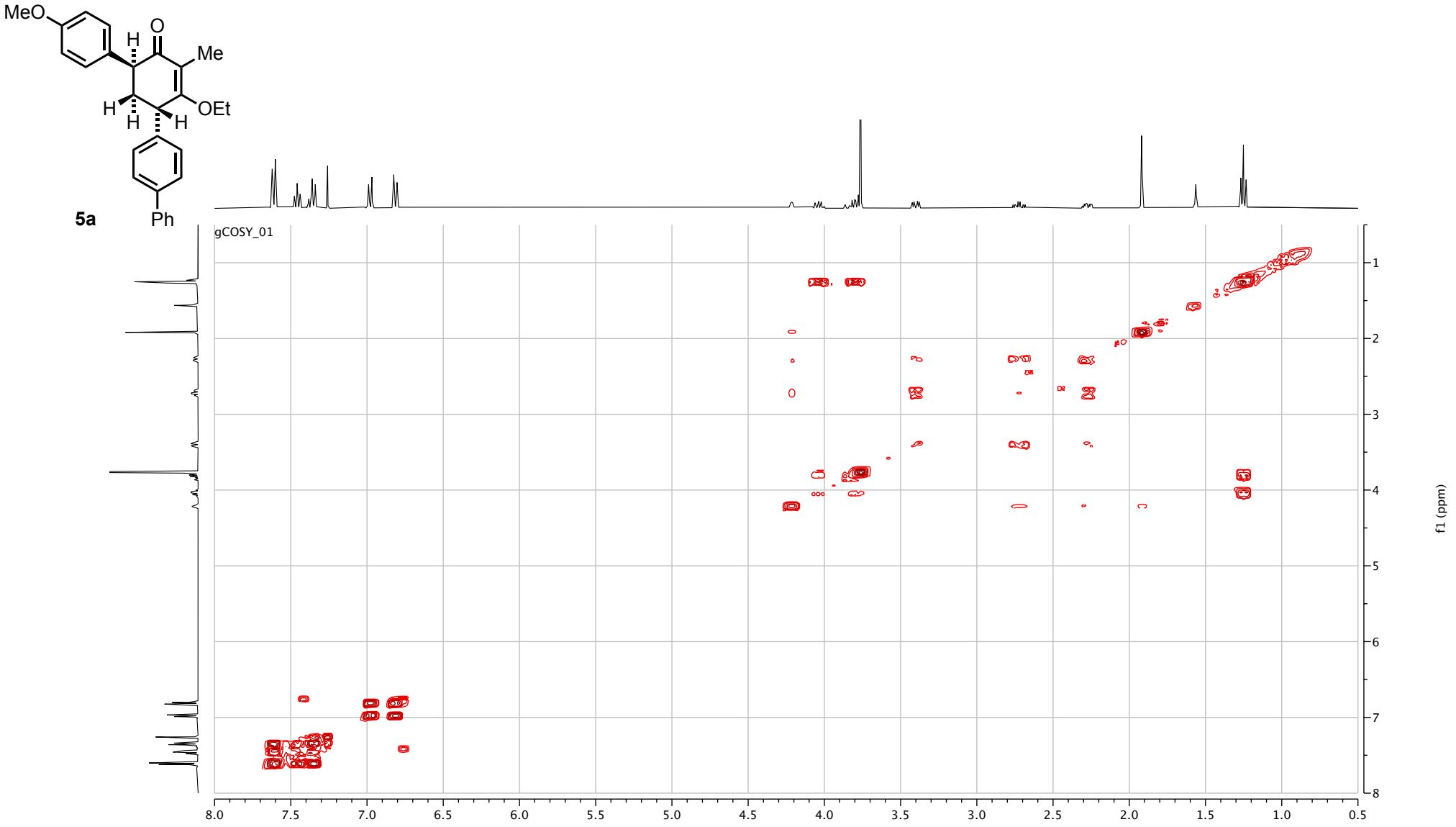
^{13}C NMR spectrum of **2b** (100 MHz, $CDCl_3$)



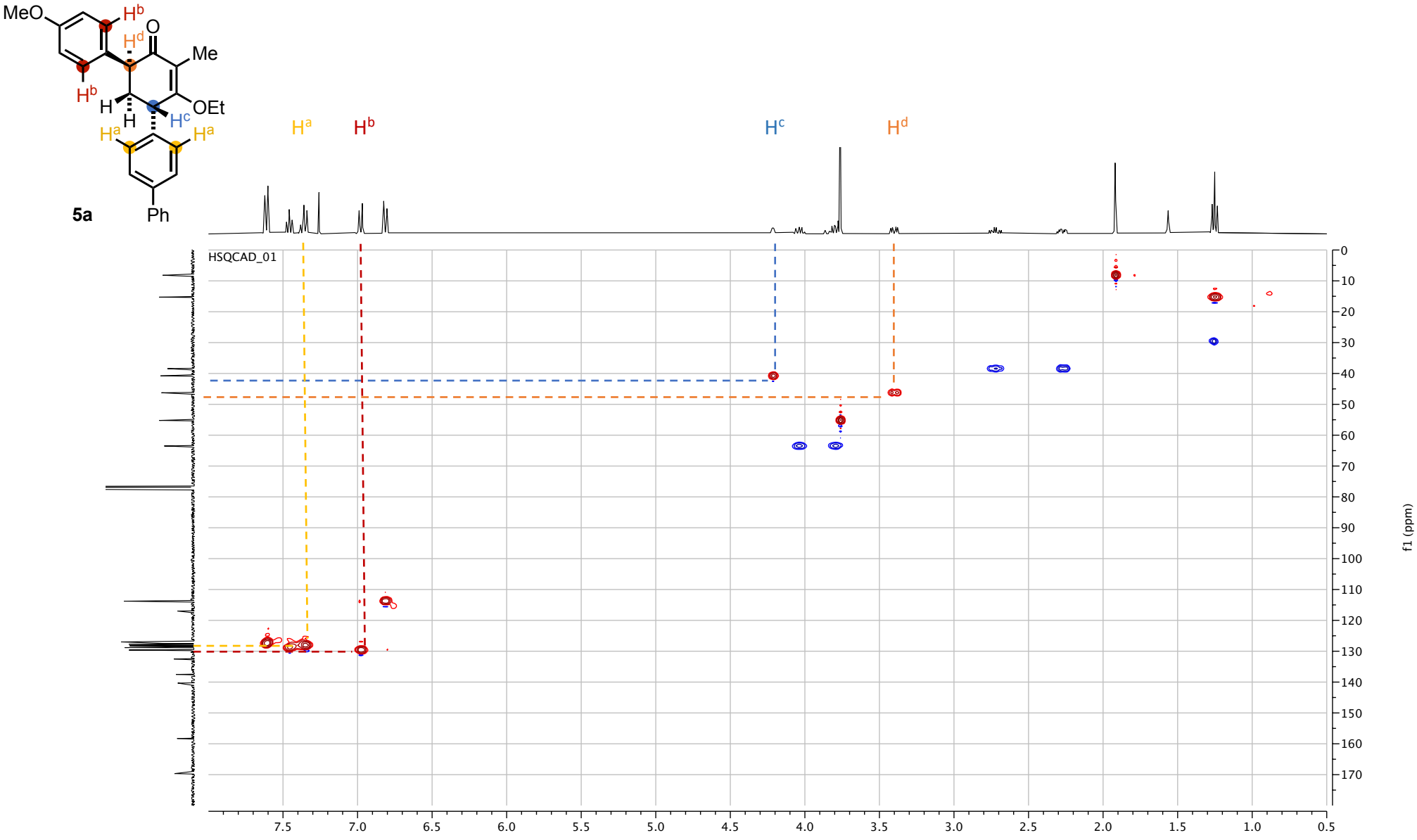
^{1}H NMR spectrum of **5a** (400 MHz, $CDCl_3$)



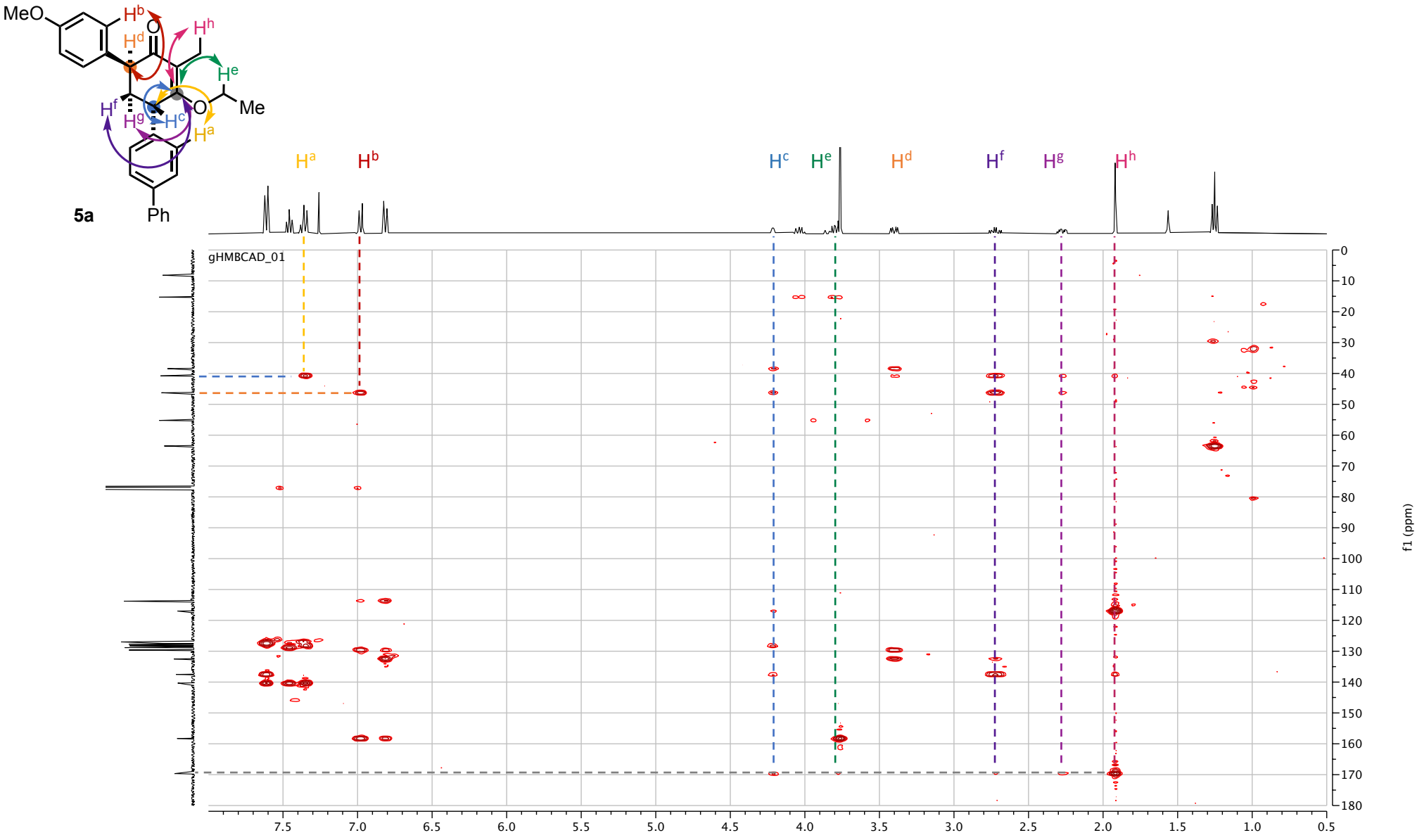
^{13}C NMR spectrum of **5a** (100 MHz, $CDCl_3$)



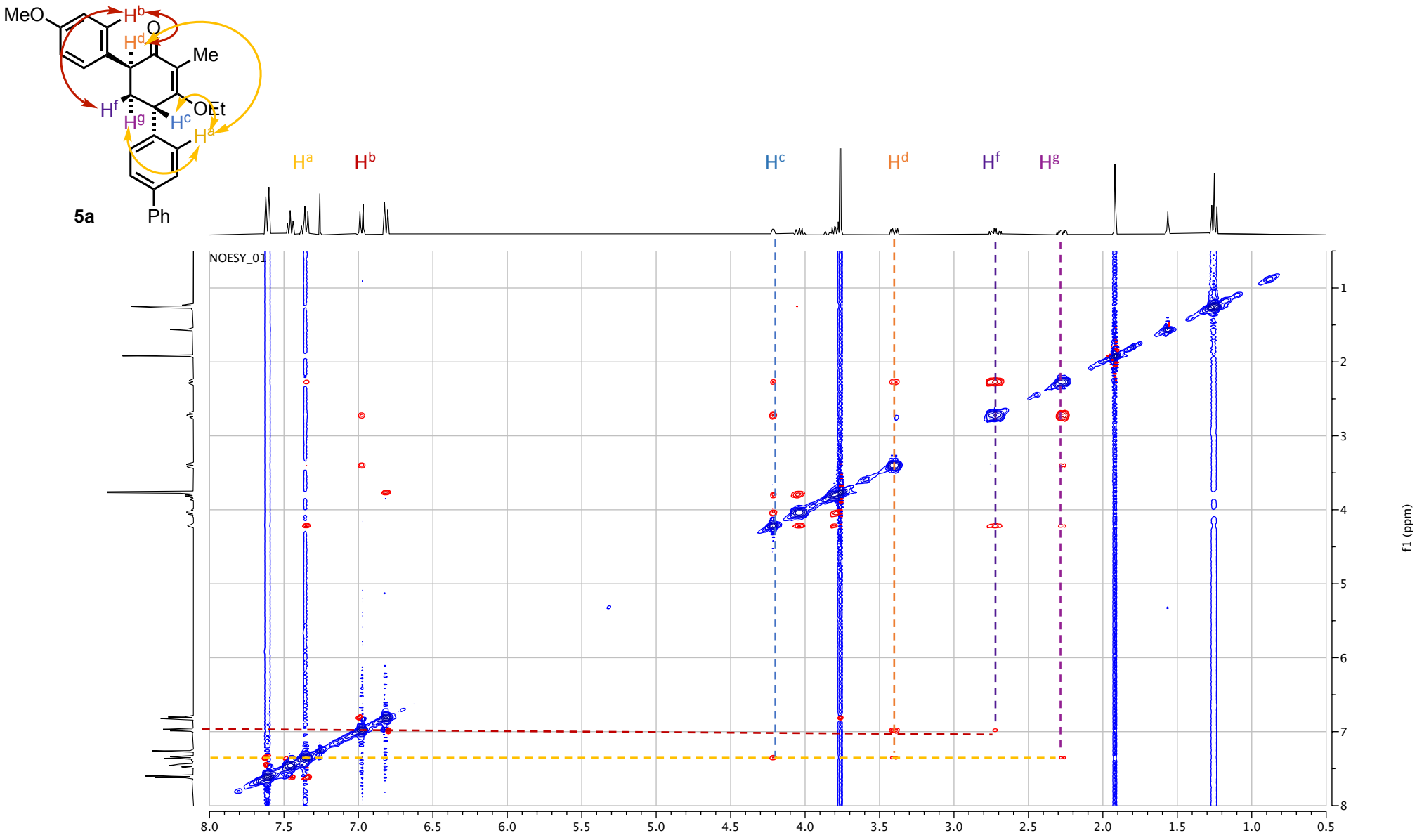
COSY spectrum of **5a**



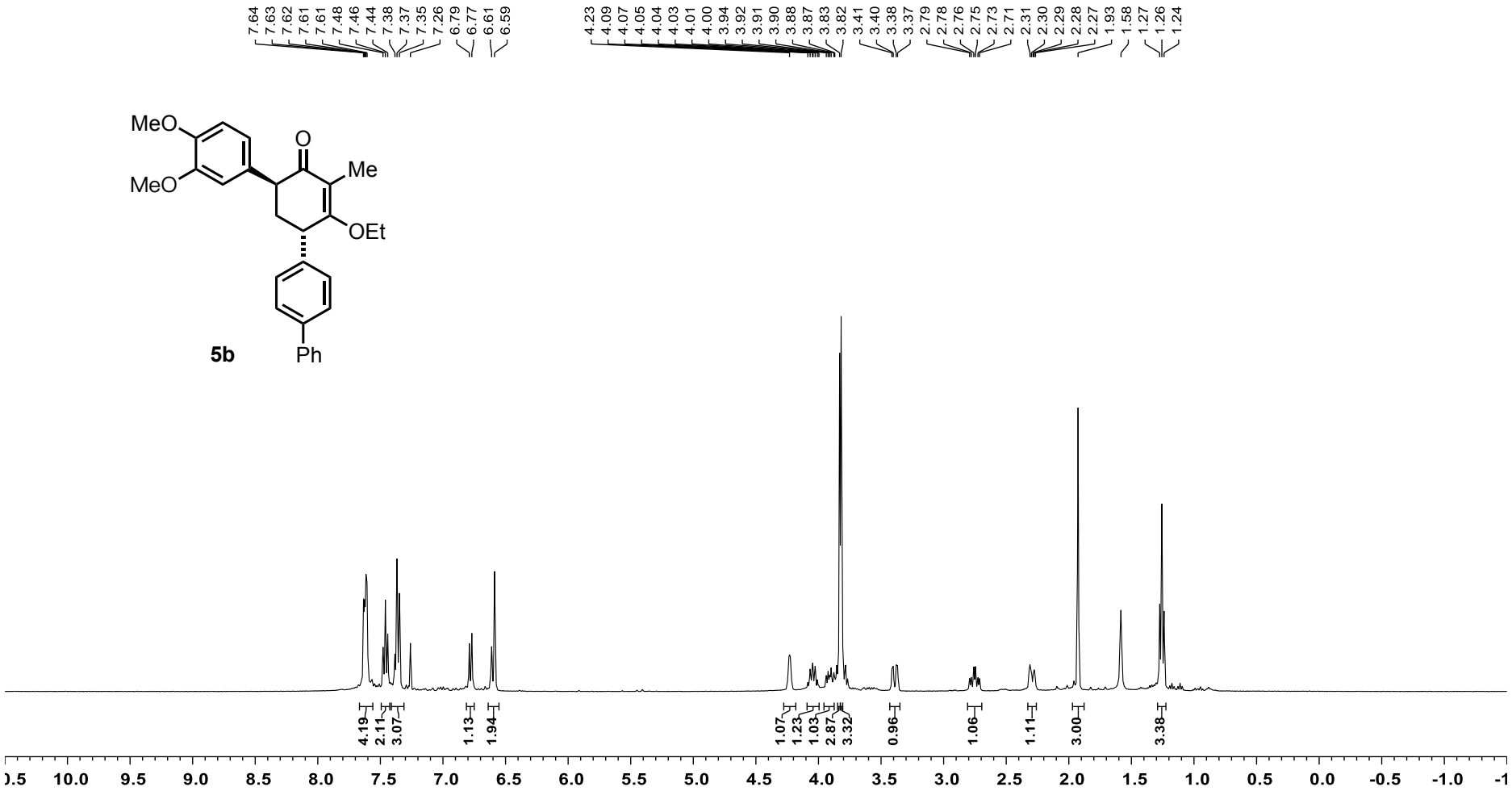
HSQC spectrum of **5a**



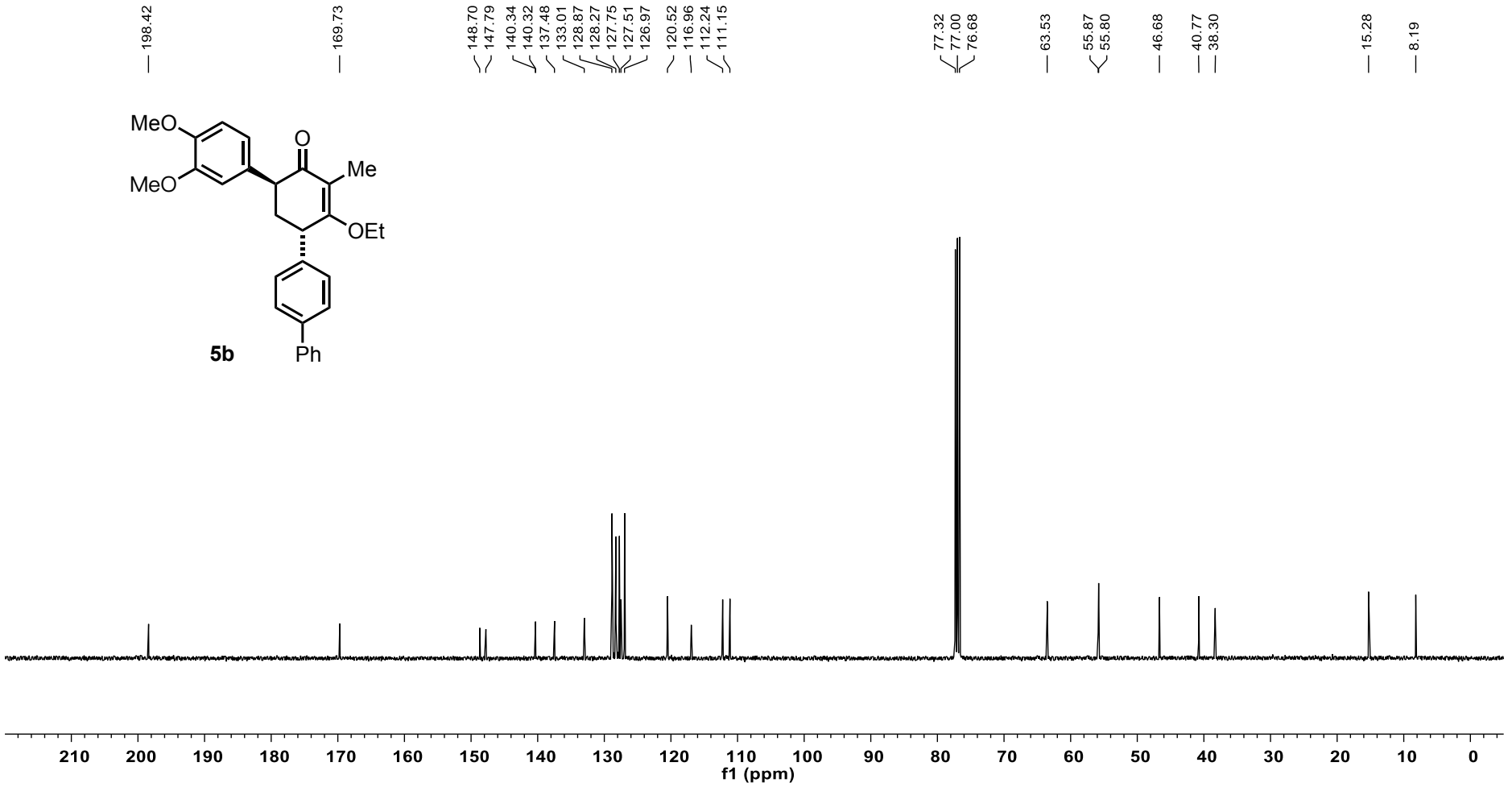
HMBC spectrum of **5a**



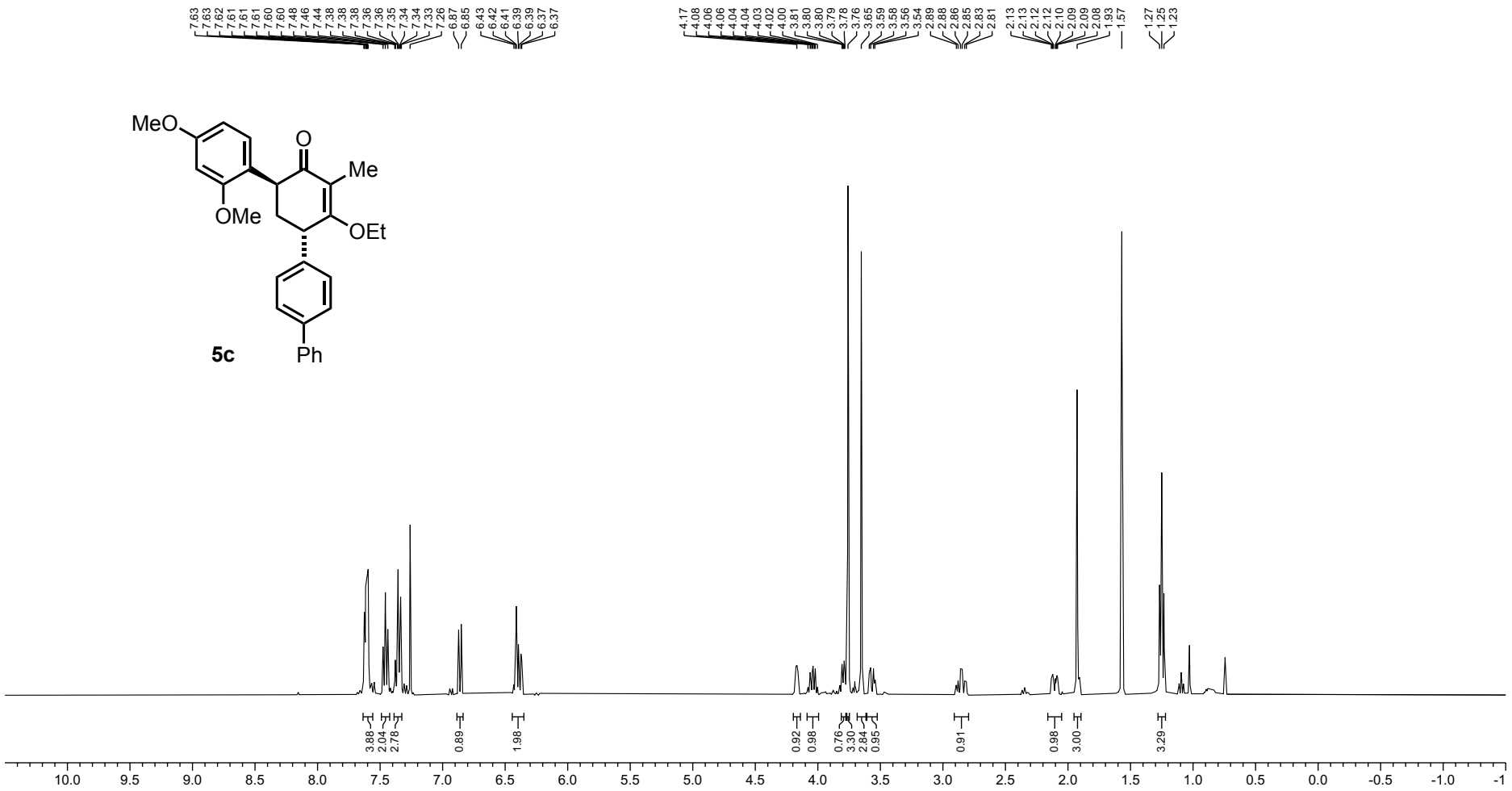
NOESY spectrum of **5a**



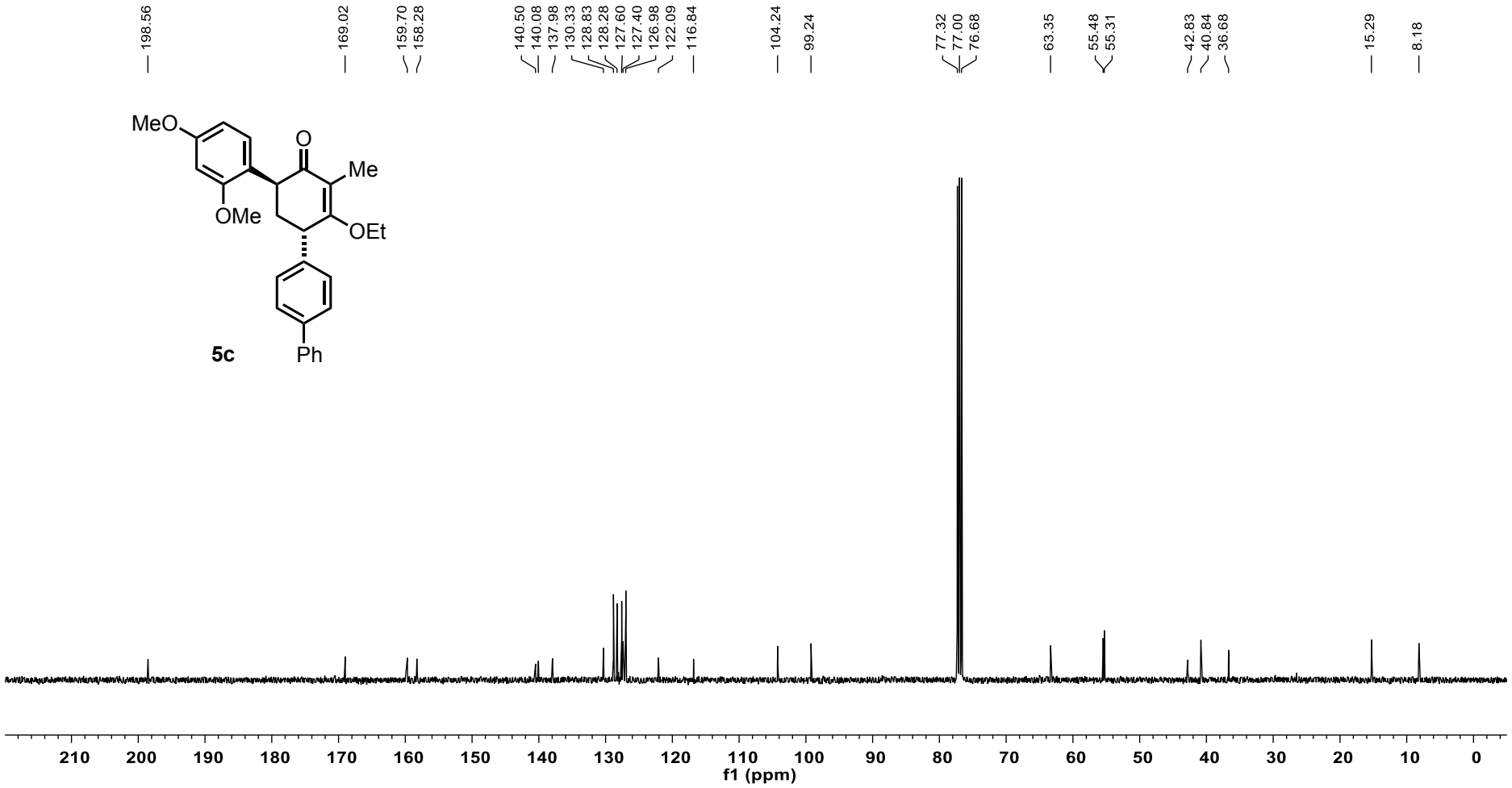
^{1}H NMR spectrum of **5b** (400 MHz, $CDCl_3$)



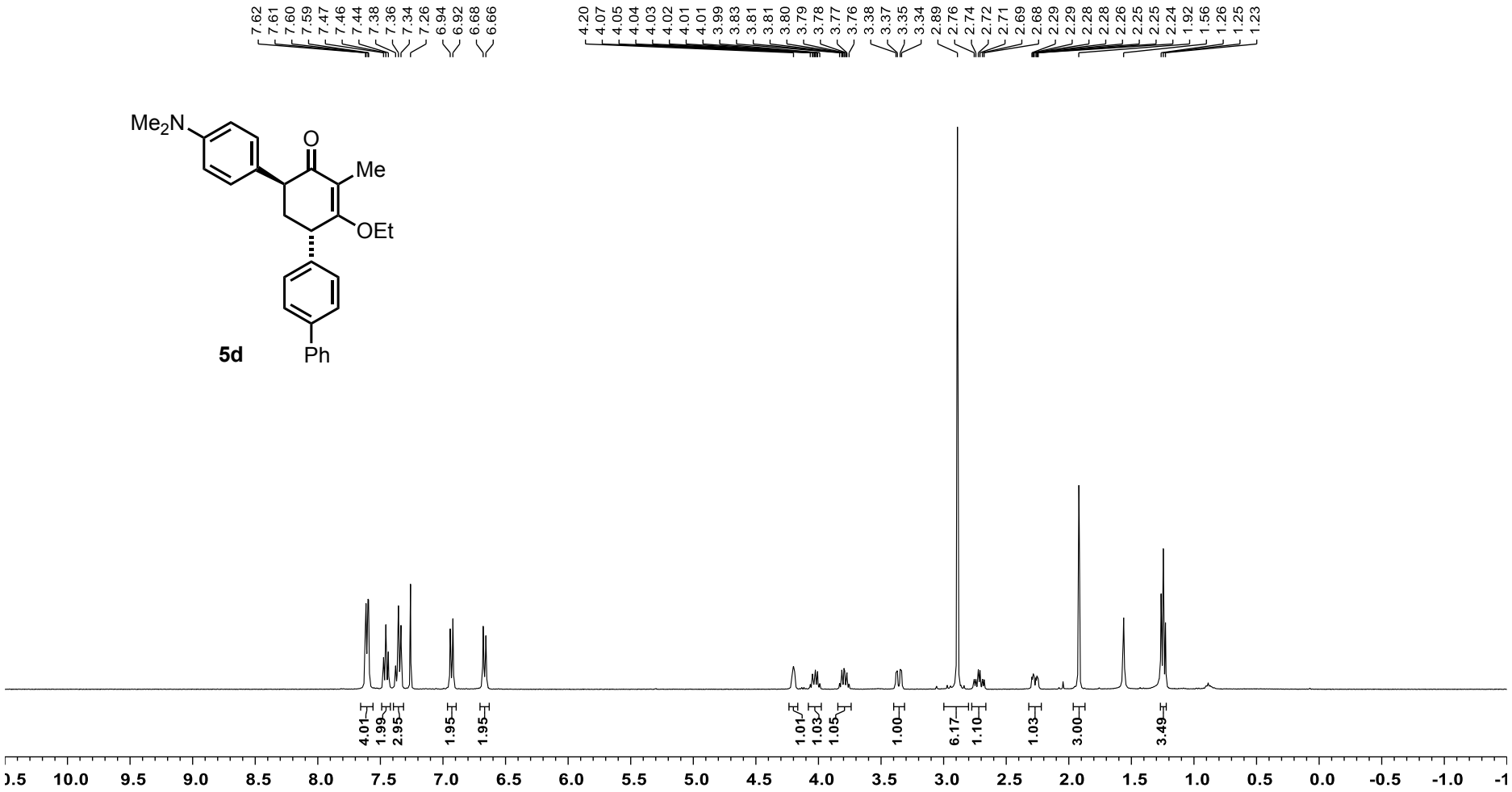
^{13}C NMR spectrum of **5b** (100 MHz, $CDCl_3$)



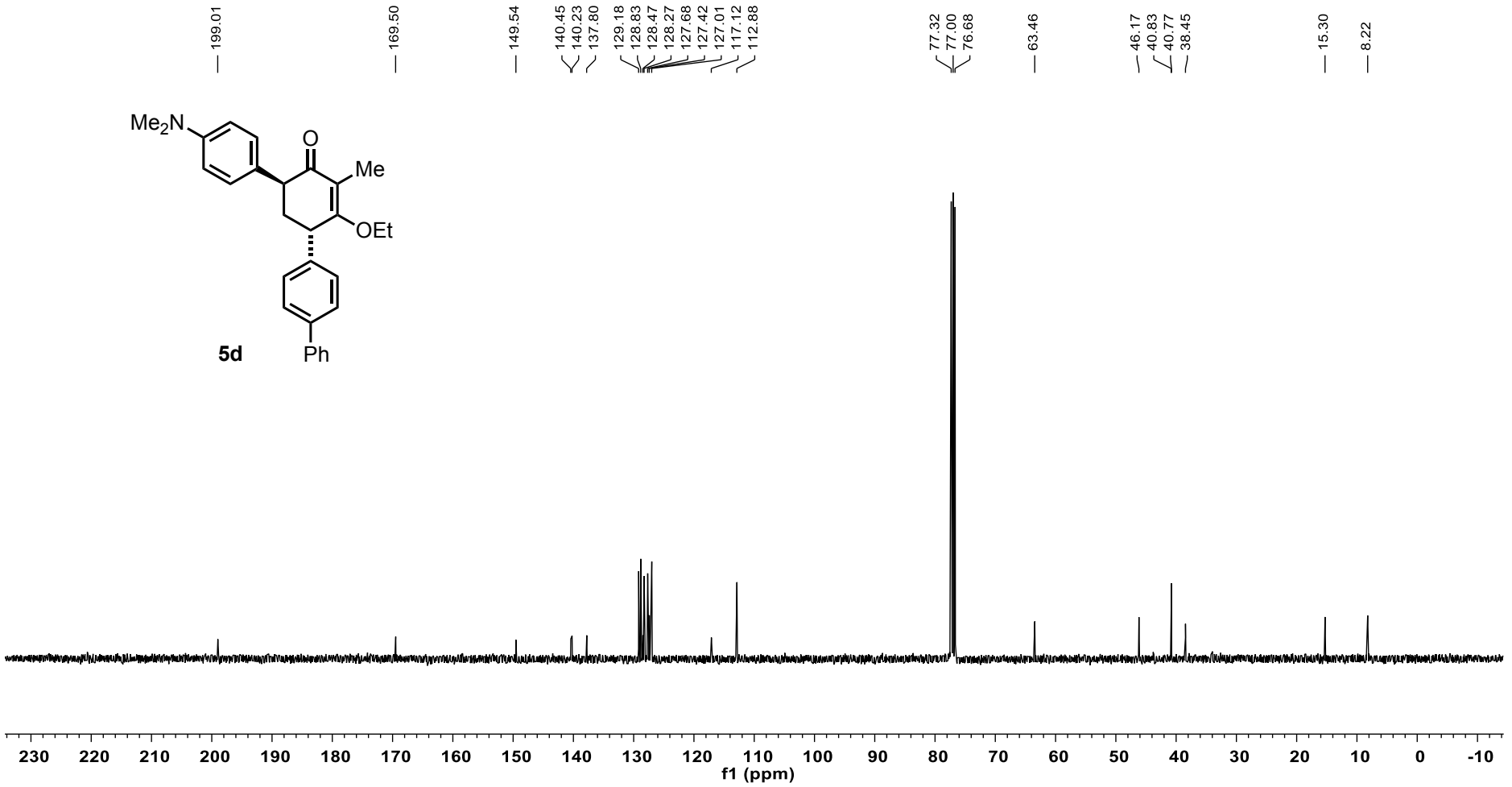
^{1}H NMR spectrum of **5c** (400 MHz, $CDCl_3$)



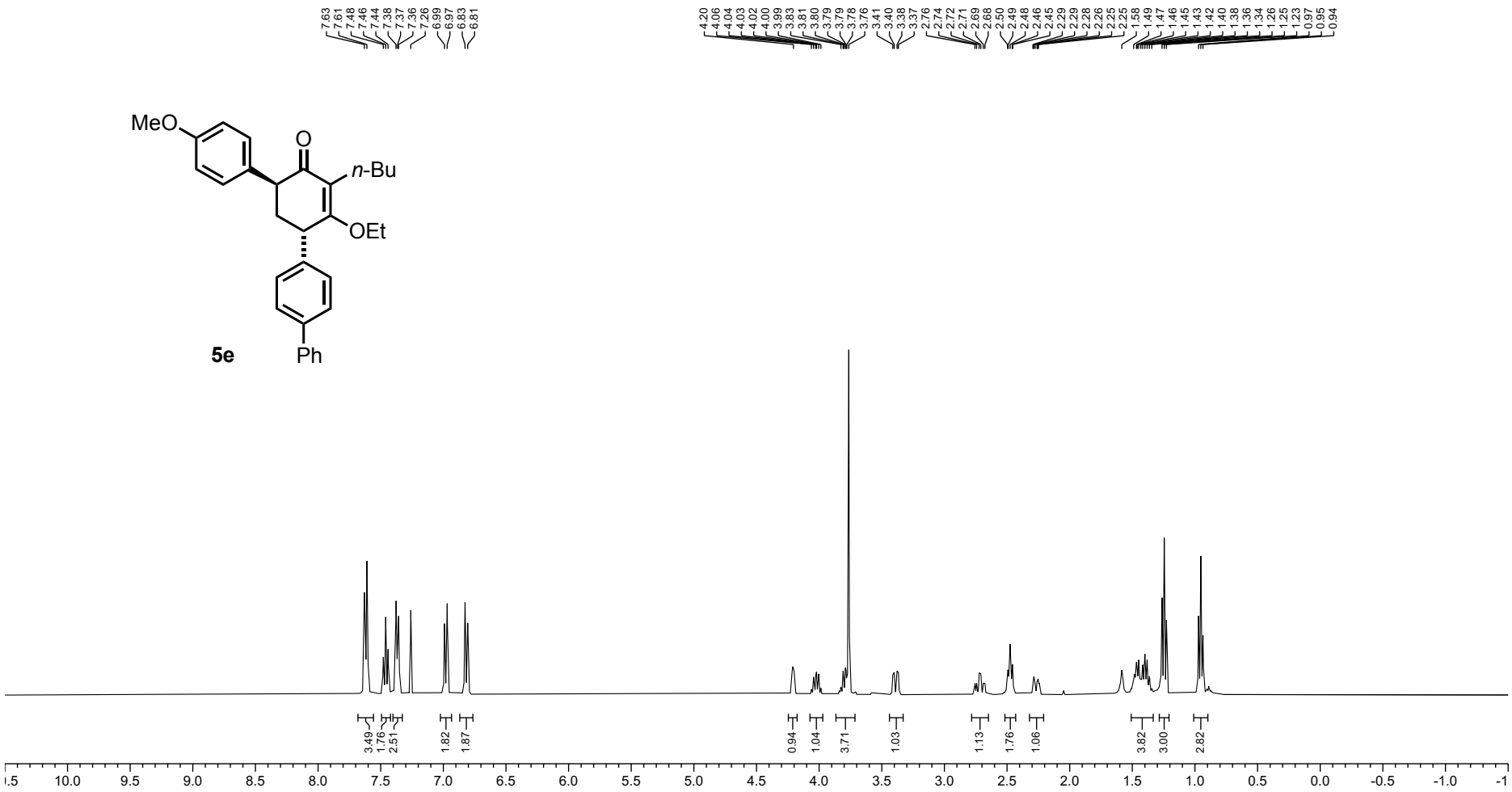
^{13}C NMR spectrum of **5c** (100 MHz, $CDCl_3$)



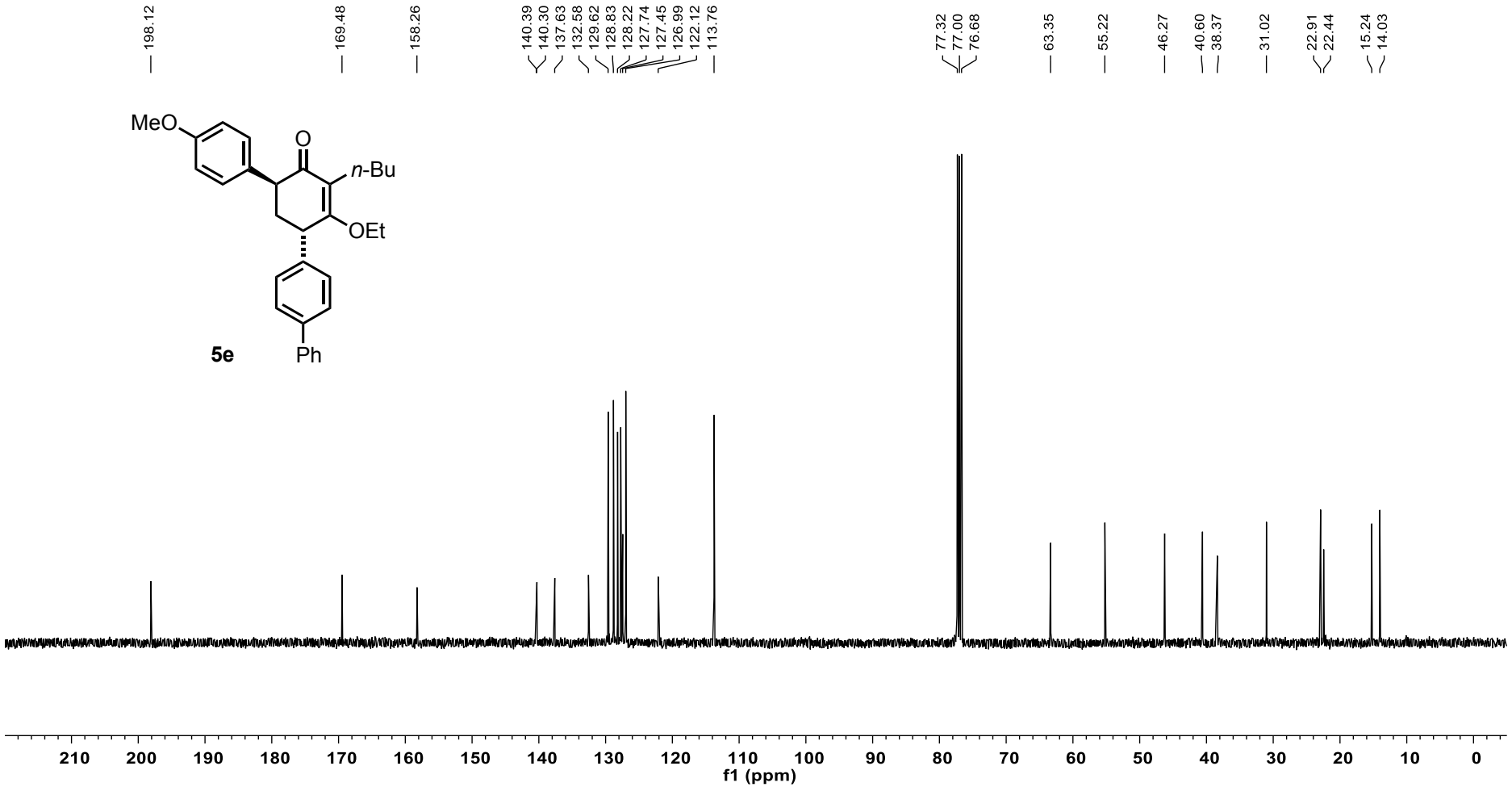
^{1}H NMR spectrum of **5d** (400 MHz, $CDCl_3$)



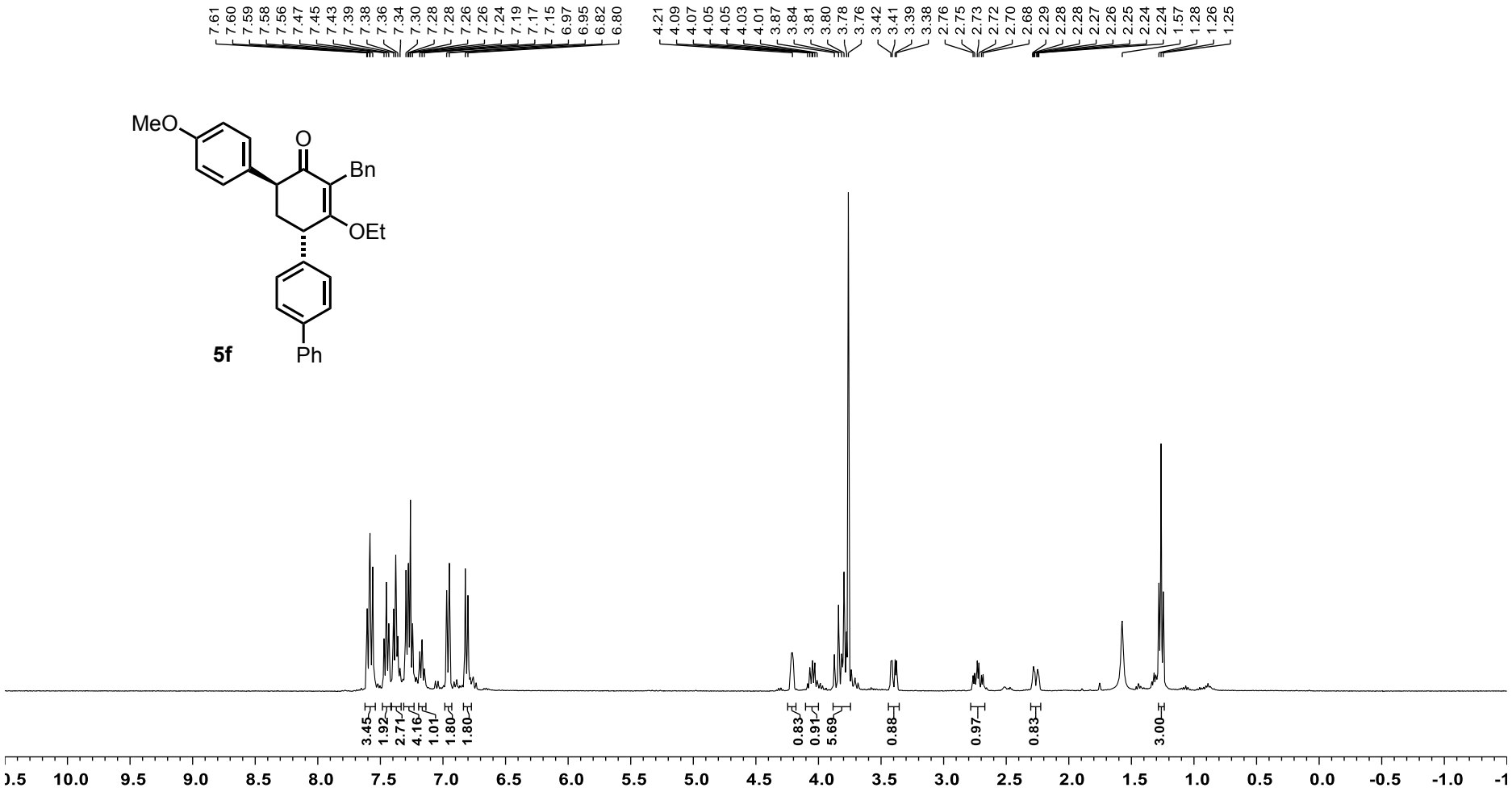
^{13}C NMR spectrum of **5d** (100 MHz, $CDCl_3$)



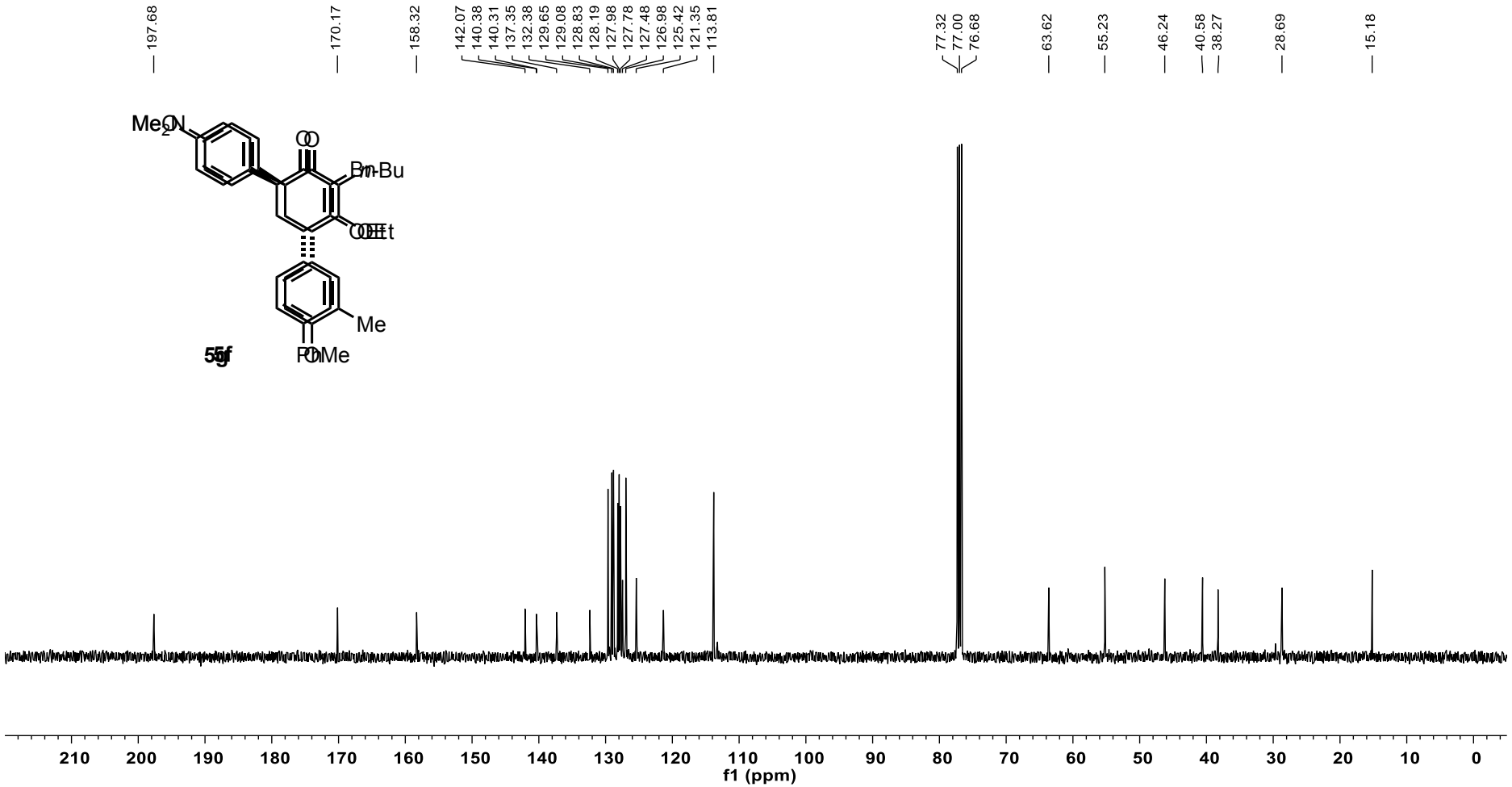
^{1}H NMR spectrum of **5e** (400 MHz, $CDCl_3$)



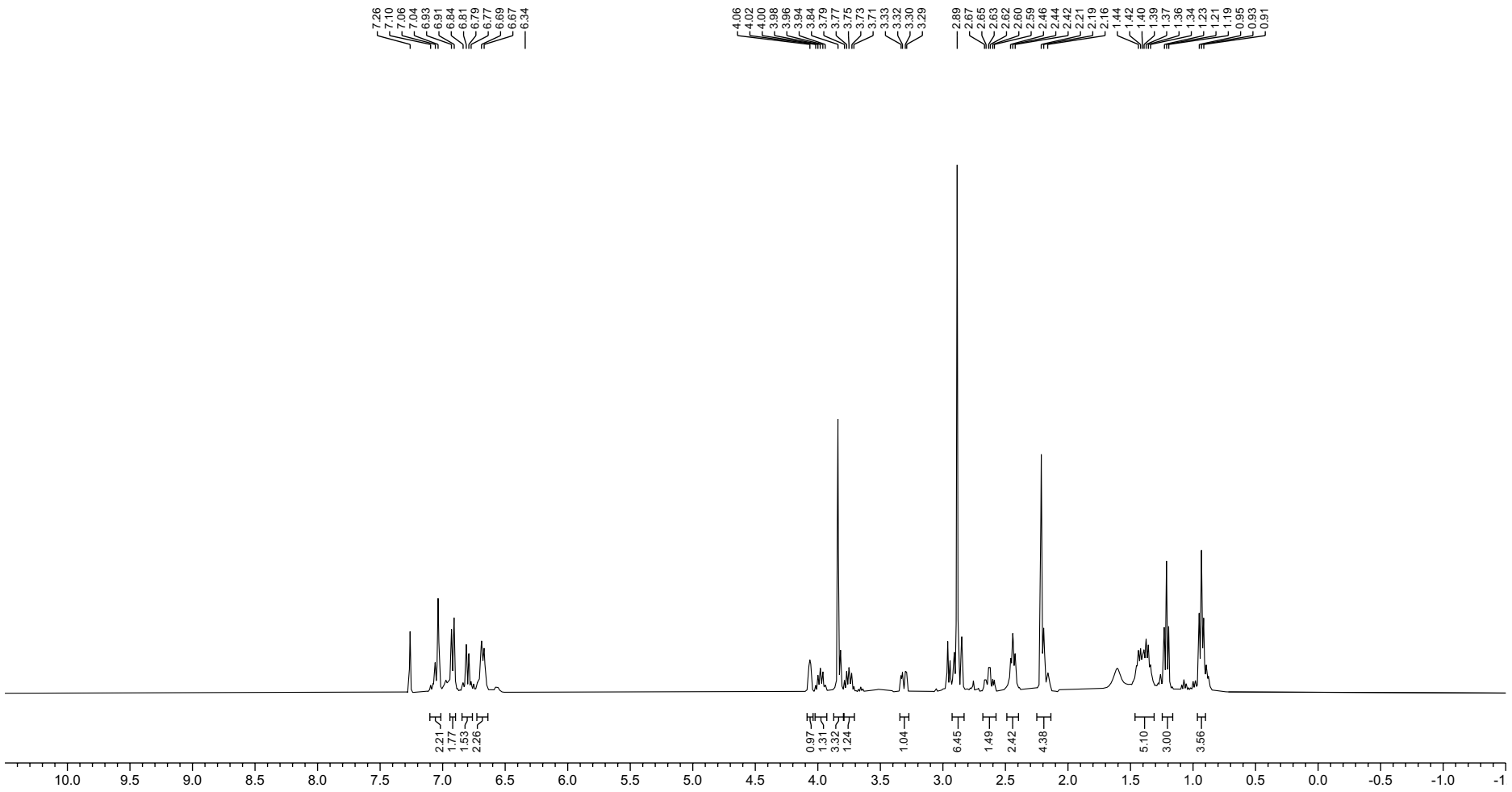
^{13}C NMR spectrum of **5e** (100 MHz, $CDCl_3$)



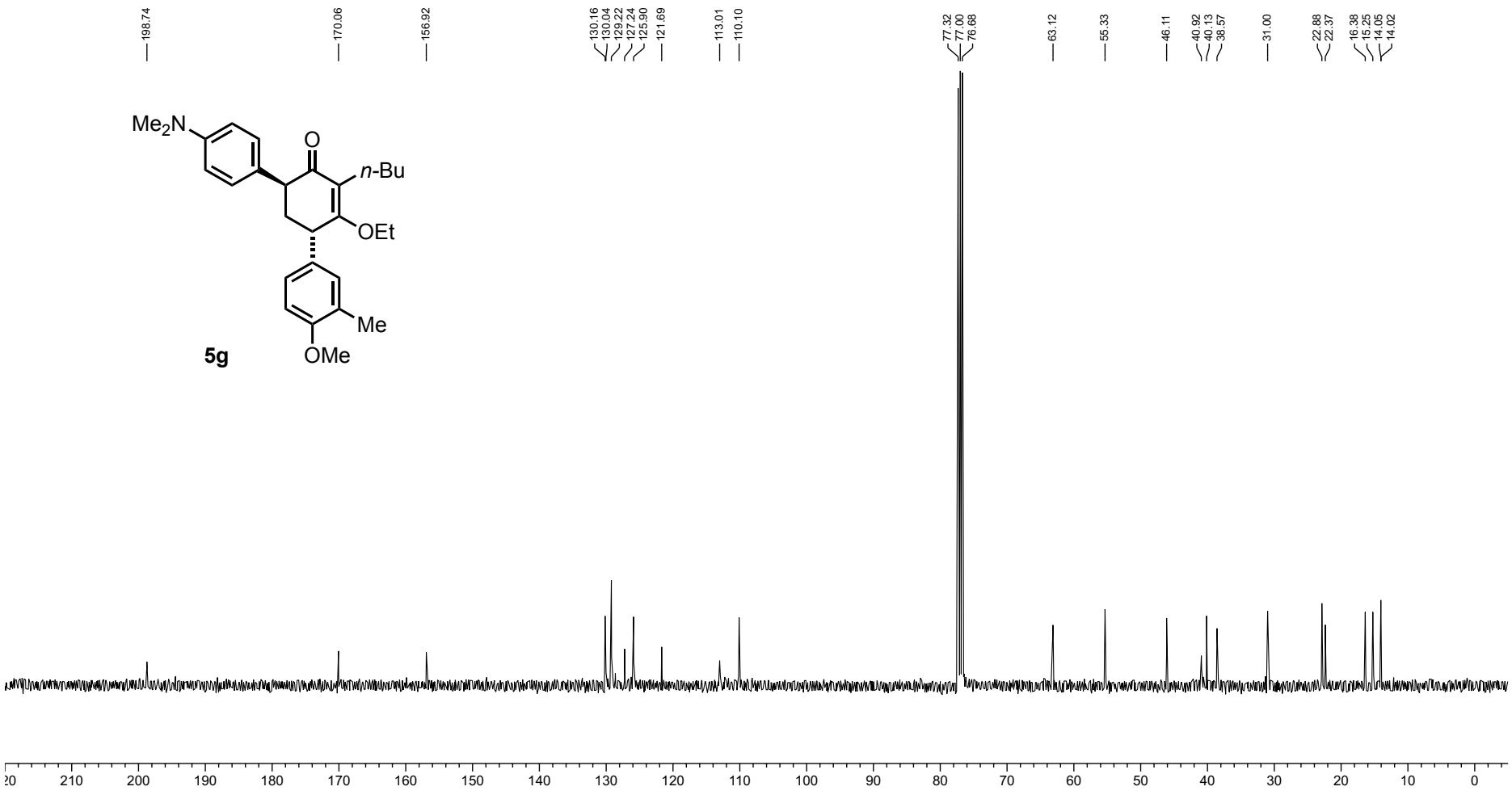
^{1}H NMR spectrum of **5f** (400 MHz, $CDCl_3$)



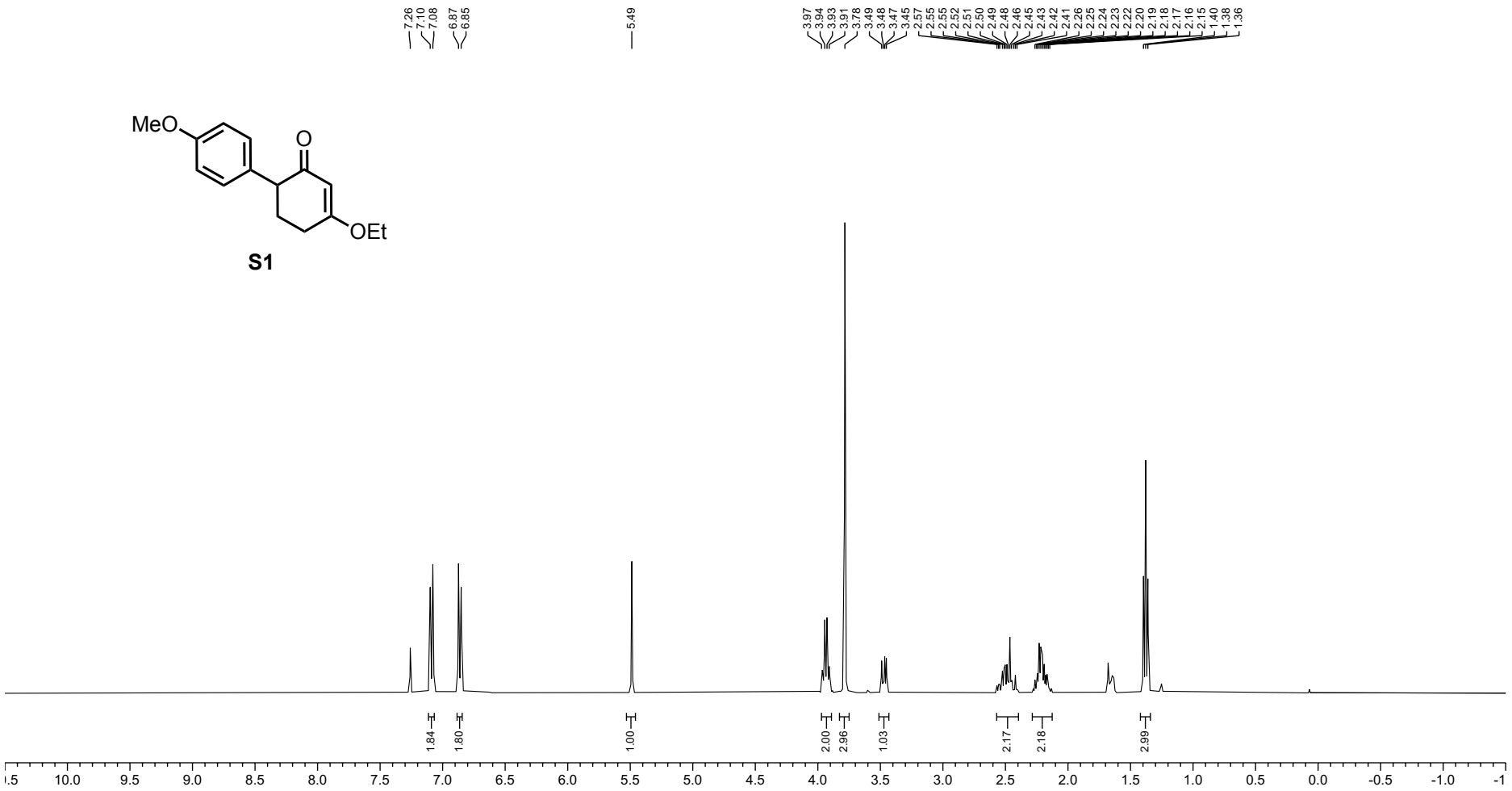
^{13}C NMR spectrum of **5f** (100 MHz, $CDCl_3$)



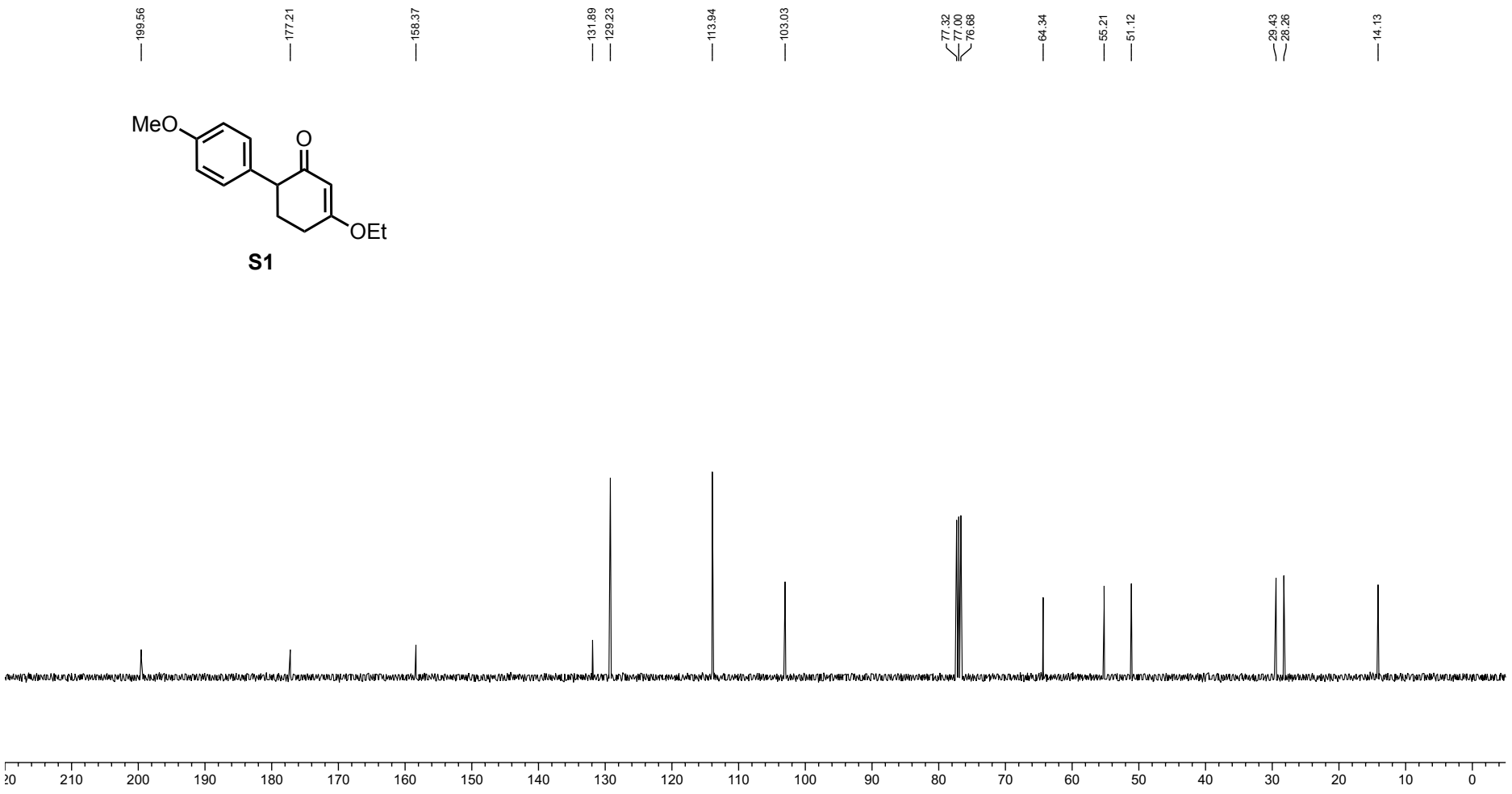
^{1}H NMR spectrum of **5g** (400 MHz, $CDCl_3$)



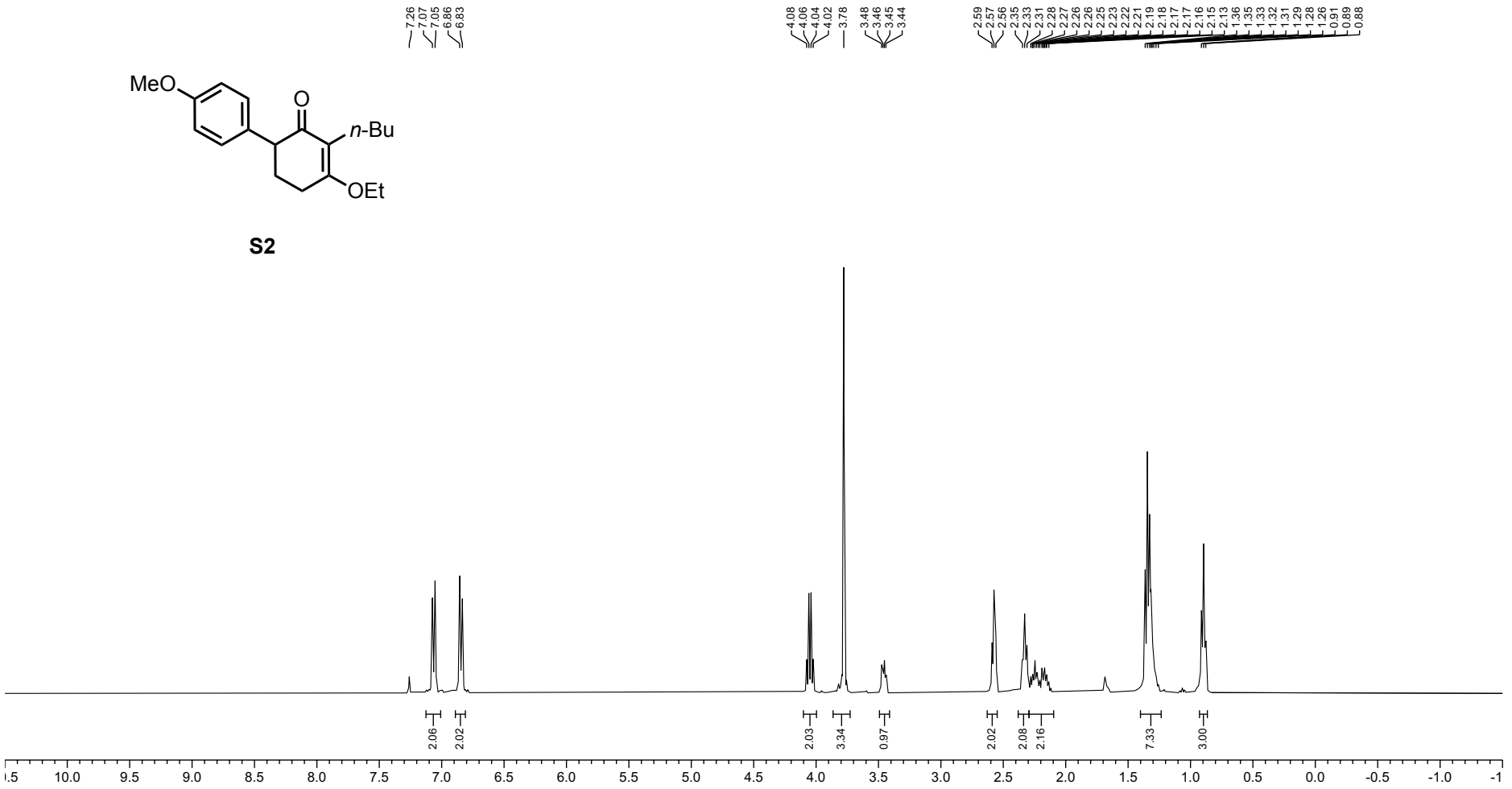
^{13}C NMR spectrum of **5g** (100 MHz, $CDCl_3$)



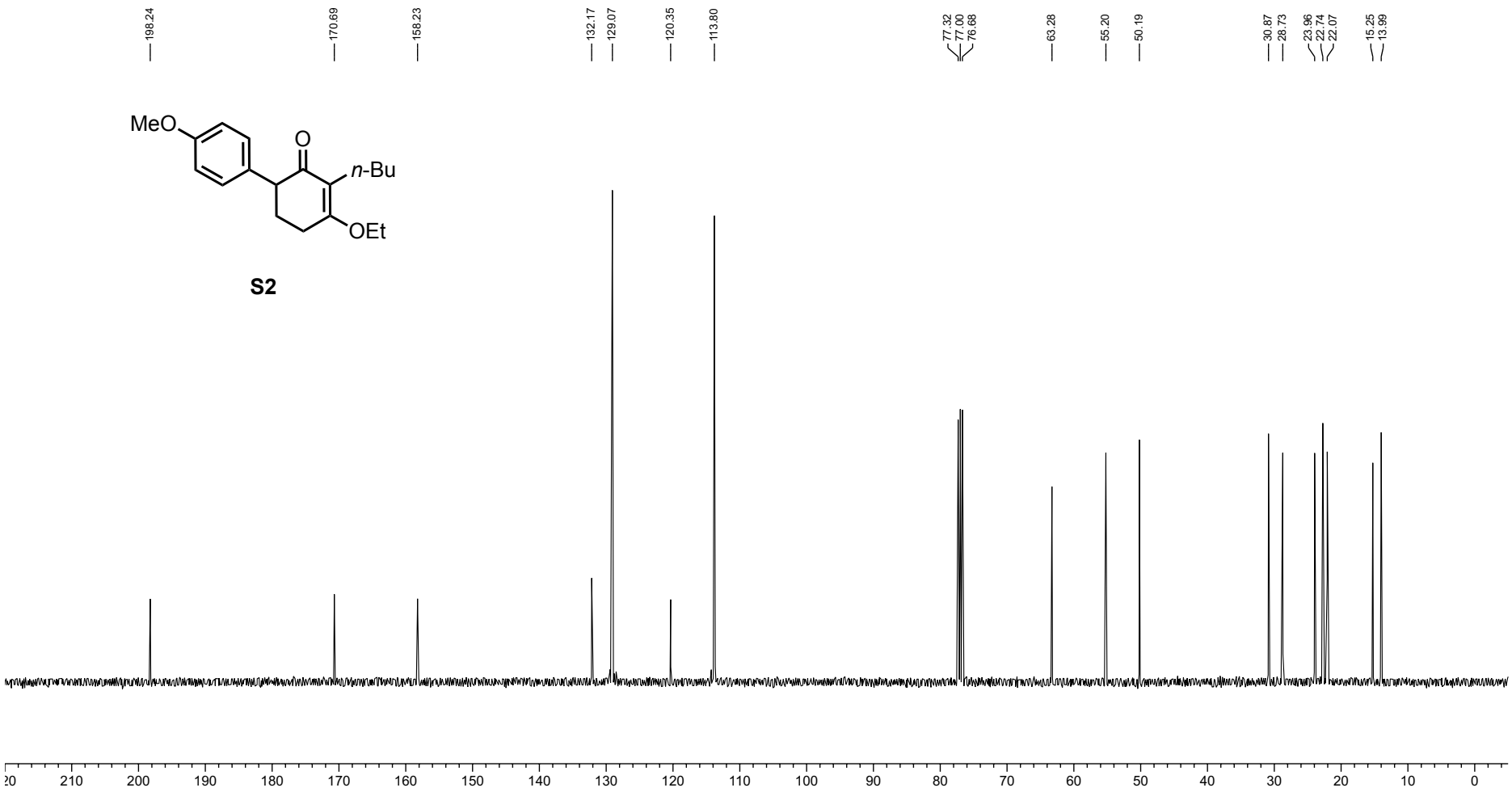
^{1}H NMR spectrum of **S1** (400 MHz, $CDCl_3$)



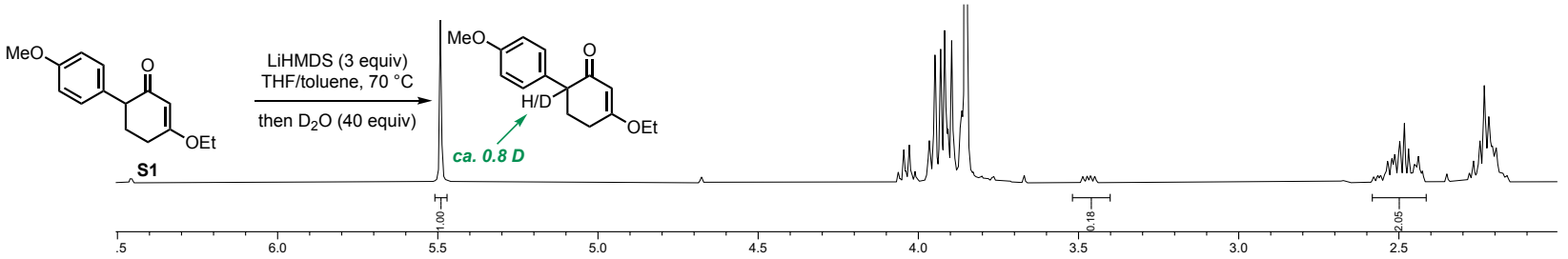
^{13}C NMR spectrum of **S1** (100 MHz, $CDCl_3$)



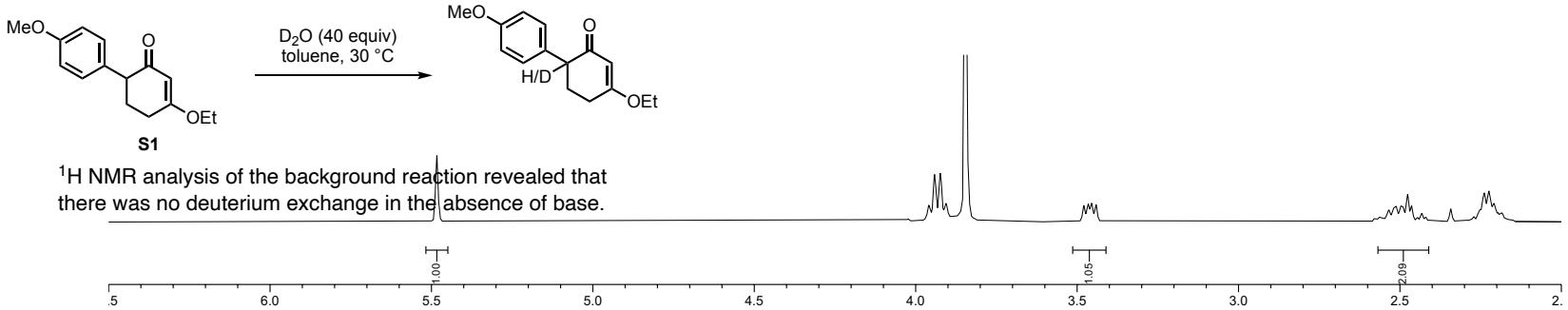
^{1}H NMR spectrum of **S2** (400 MHz, $CDCl_3$)



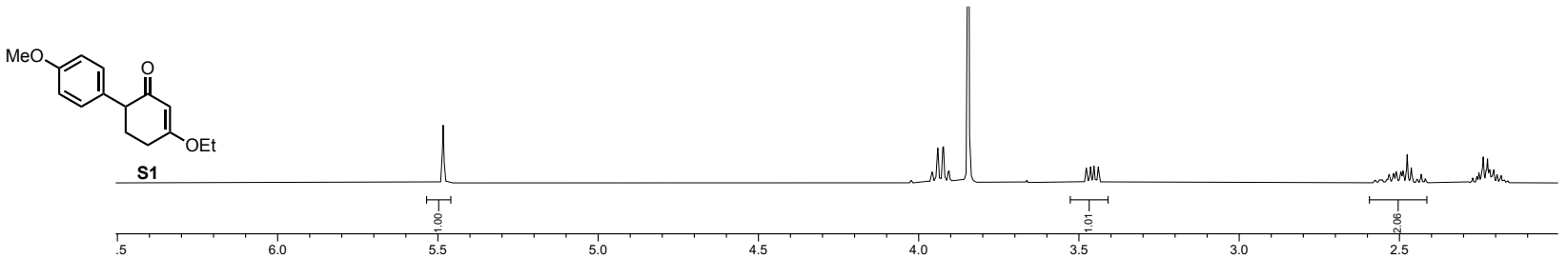
^{13}C NMR spectrum of **S2** (100 MHz, $CDCl_3$)



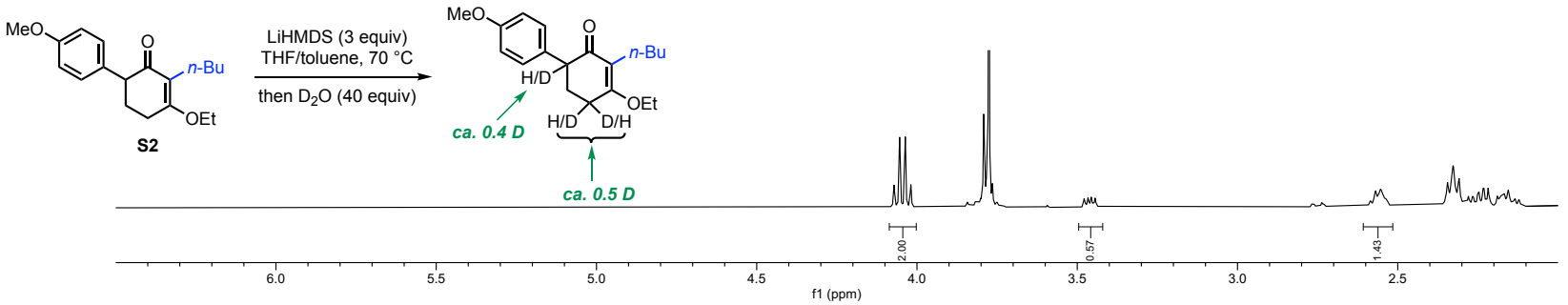
^{1}H NMR spectrum of **S1-D** with base (400 MHz, $CDCl_3$)



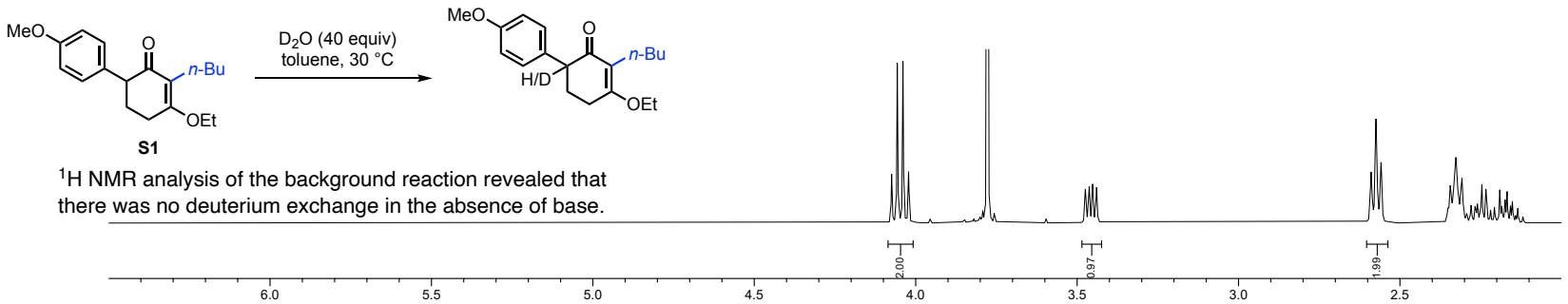
^{1}H NMR spectrum of **S1-D** without base (400 MHz, $CDCl_3$)



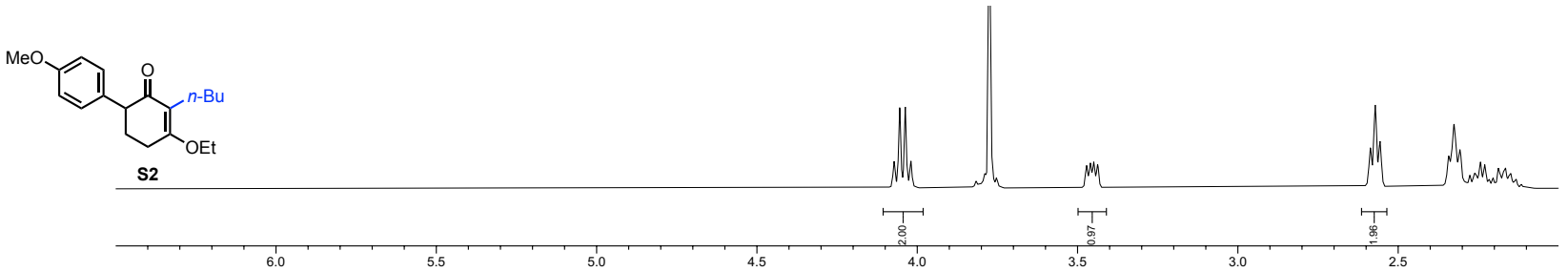
^{1}H NMR spectrum of **S1** (400 MHz, $CDCl_3$)



^{1}H NMR spectrum of **S2-D** with base (400 MHz, $CDCl_3$)



^{1}H NMR spectrum of **S2-D** without base (400 MHz, $CDCl_3$)



^{1}H NMR spectrum of **S2** (400 MHz, $CDCl_3$)