Electronic Supplementary Material (ESI) for Chemical Communications.

An Unprecedented Benzannulation of Oxindoles With Enalcarbenoids: A Regioselective Approach to Functionalized Carbazoles

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Supporting Information

Contents :

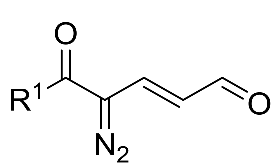
1. General methods

All the reactions performed in an oven-dried glassware under argon atmosphere. Solvents were dried using standard methods. Tetrahydrofuran and diethyl ether dried over sodium benzophenone ketyl. Acetonitrile, dichloromethane and toluene were distilled over calcium hydride. Unless otherwise stated, all the commercial reagents were used as received. The progress of the reaction was monitored by thin layer chromatography (Merck Silica gel 60 F-254, precoated plates on alumina). Column chromatographic purifications performed on Merck silica gel (100-200 mesh). Melting points recorded on a digital melting point apparatus and are uncorrected.

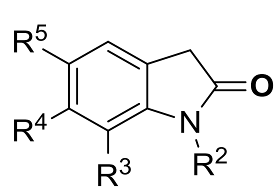
Spectroscopic characterizations were carried at the Central Instrumentation Facility (CIF), Indian Institute of Science Education and Research (IISER) Bhopal. ^{1}H-NMR spectra were recorded on Bruker Avance III FT-NMR spectrometers at 400 MHz, 500 or 700 MHz and ^{13}C-NMR spectra were recorded at 101 MHz, 126 MHz or 176 MHz. ^{1}H-NMR chemical shifts reported in ppm relative to the TMS (δ=0) and are abbreviated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br (broad). ^{13}C-NMR chemical shifts reported in ppm relative to the residual $CDCl_3$ signal (δ= 77.16). IR spectra recorded on a Perkin-Elmer FT-IR spectrometer. HRMS data obtained on a Bruker micro TOF-QII or Agilent 5975C high-resolution mass spectrometers.

2. Starting materials

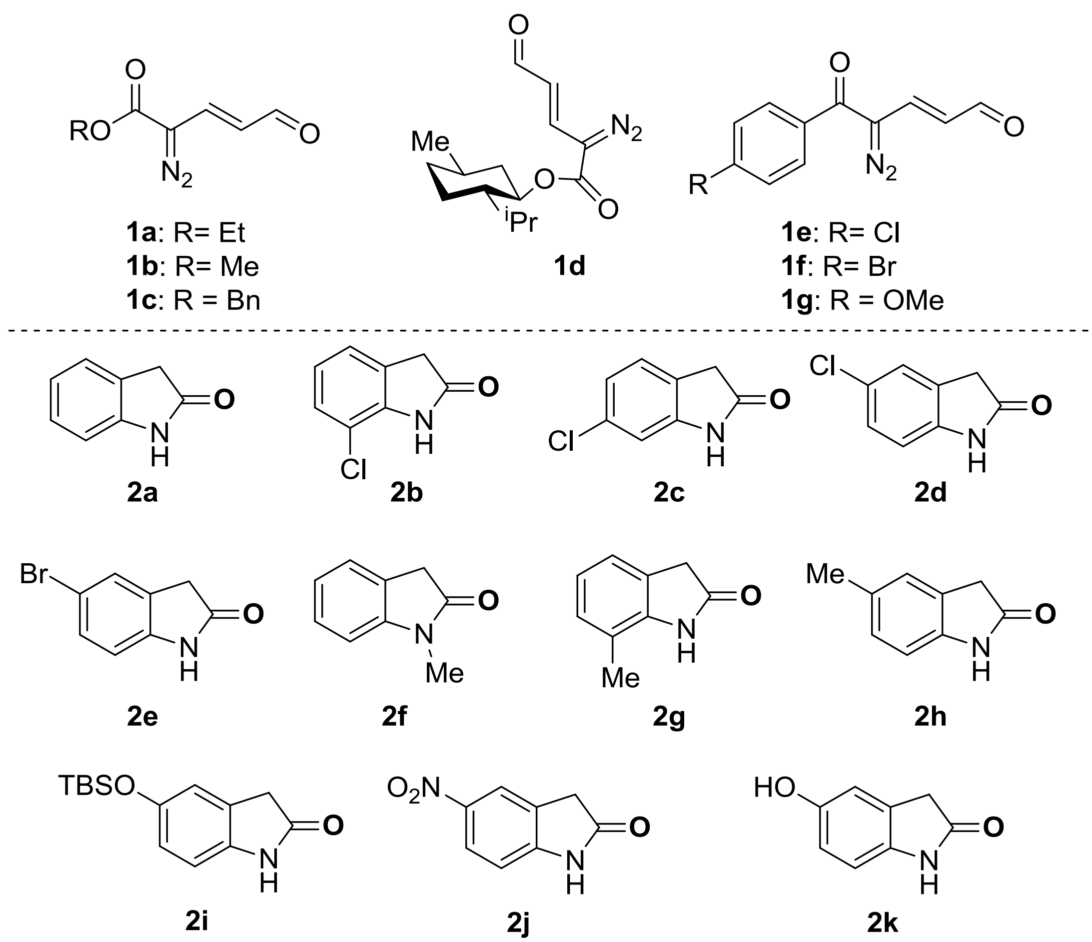
Preparation of diazoenals **1a-c** and **1e-g** was reported in our earlier work.[1] Oxindoles **2a-d** and **2i** were obtained from Sigma-Aldrich. Known oxindoles **2e-h**, **2j** and new oxindole **2k** were prepared according to the known procedures.[2-5]



1a-g

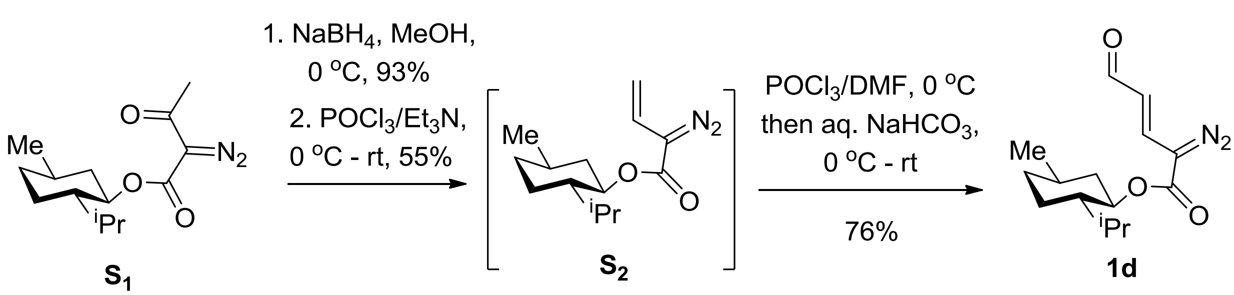


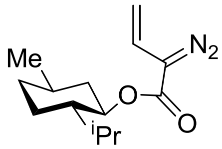
2a-k



Preparation of chiral menthyl ester diazoenal 1d

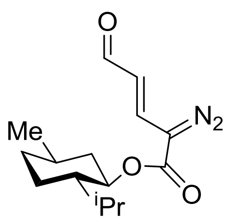
The new chiral menthyl ester diazoenal **1d** was prepared from the known keto diazo ester $\mathbf{S_1}$[6a] *via* new vinyldiazo ester $\mathbf{S_2}$.





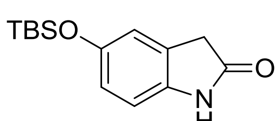
S₂

(*1R,2S,5R*)-2-isopropyl-5-methylcyclohexyl 2-diazobut-3-enoate ($\mathbf{S_2}$): The unstable vinyl diazoester $\mathbf{S_2}$ was prepared from the known keto diazo ester $\mathbf{S_1}$[6a] in two steps by following literature procedure.[6b] Obtained as a yellow liquid; yield = 51% (for two steps); R_f = 0.53 (ethyl acetate/hexane : 10:90); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.10 (dd, *J* = 17.4, 11.0 Hz, 1H), 5.03 (d, *J* = 11.0 Hz, 1H), 4.77 (d, *J* = 17.4 Hz, 1H), 4.76 – 4.65 (m, 1H), 2.02 – 1.92 (m, 1H), 1.84 – 1.74 (m, 1H), 1.66 – 1.57 (m, 2H), 1.49 – 1.28 (series of m, 2H), 1.05 – 0.90 (m, 2H), 0.84 (d, *J* = 5.4 Hz, 3H), 0.82 (d, *J* = 5.4 Hz, 3H), 0.84 – 0.78 (m, 1H), 0.71 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.4, 120.7, 107.1, 75.2, 63.3, 47.1, 41.2, 34.2, 31.4, 26.5, 23.7, 22.0, 20.7, 16.6; IR (neat): 2088, 1703, 1616 cm^{-1}.



1d

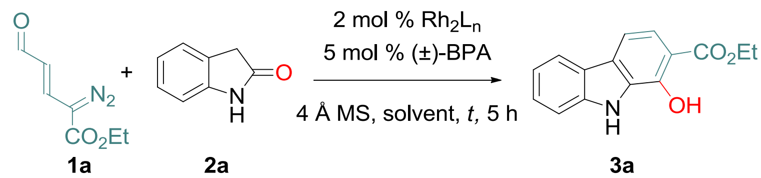
(*E*)-(*1R,2S,5R*)-2-isopropyl-5-methylcyclohexyl 2-diazo-5-oxopent-3-enoate (1d): Formylation of freshly the prepared vinyldiazo ester $\mathbf{S_2}$ by our earlier reported procedure[1] gave chiral menthyl ester diazoenal **1d**. Obtained as a yellow liquid; yield = 76%; R_f = 0.43 (Ethyl acetate/Hexane = 30:70); $[\alpha]_D^{23}$ – 59° (c 0.67, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.51 (d, *J* = 7.6 Hz, 1H), 7.16 (d, *J* = 15.7 Hz, 1H), 5.94 (dd, *J* = 15.7, 7.6 Hz, 1H), 4.85 (td, *J* = 10.9, 4.4 Hz, 1H), 2.06-1.99 (m, 1H), 1.85-1.76 (m, 1H), 1.72-1.64 (m, 2H), 1.55-1.37 (m, 2H), 1.12-0.96 (m, 2H), 0.90 (d, *J* = 6.0 Hz, 3H), 0.88 (d, *J* = 6.5 Hz, 3H), 0.88-0.81 (m, 1H), 0.76 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.7, 161.8, 139.4, 121.9, 47.1, 41.1, 34.0, 31.4, 26.6, 23.6, 21.9, 20.6, 16.5; IR (neat): 2102, 1713, 1679, 1609, 1320 cm^{-1}; HRMS (ESI) *m/z* calc. for $C_{15}H_{23}N_2O_3$ $(M+H)^+$ 279.1703, found 279.1687.



2i

5-((tert-butyldimethylsilyl)oxy)indolin-2-one (2i): Prepared from **2k** by TBS-protection of hydroxyl group. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 6.69 (m, 4H), 3.48 (s, 2H), 0.96 (s, 9H), 0.16 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 177.3, 151.3, 136.2, 126.4, 118.9, 117.3, 109.9, 36.6, 25.7, 18.2, -4.5; HRMS (ESI) m/z Calc. for $C_{14}H_{22}NO_2Si$ [M+H] 264.1414, Found: 264.1442.

3. Optimization of the tandem benzannulation reaction[a]



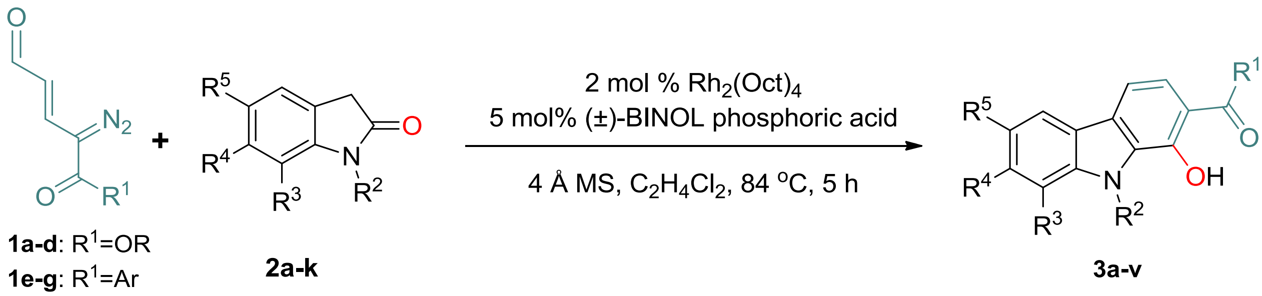
entry	Rh_2L_n	solvent	*t* (°C)	yield (%)[b]
1	$Rh_2(OAc)_4$	CH_2Cl_2	40	37
2	$Rh_2(TFA)_4$	CH_2Cl_2	40	18
3	$Rh_2(esp)_2$	CH_2Cl_2	40	21
4	Rh_2(*R*-DOSP)$_4$	CH_2Cl_2	40	17
5	$Rh_2(oct)_4$	CH_2Cl_2	40	46
6	$Rh_2(oct)_4$	$CHCl_3$	65	35
7	$Rh_2(oct)_4$	$C_2H_4Cl_2$	65	51
8	**$Rh_2(oct)_4$**	**$C_2H_4Cl_2$**	**84**	**62**
9	$Rh_2(oct)_4$	$PhCH_3$	110	34
10[c]	$Rh_2(oct)_4$	CH_2Cl_2	25	0

[a] Reaction conditions: **1a**/**2a** = 0.56/0.225 mmol. [b] Yield of isolated product. [c] Diazo compound was decomposed.

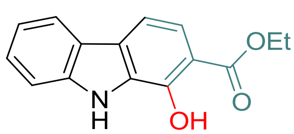
Optimization procedure:

A 0.28M solution of **1a** was added with a flow rate of 1 ml/h using a syringe pump to a 0.23 M solution of 2-oxindole **2a** (30 mg, 0.225 mmol) in a 10 ml round bottom flask containing Rh_2L_n, 5 mol% BINOL phosphoric acid (±)-BPA (4 mg, 0.011 mmol) and 4 Å MS (80 mg), at the respective temperature under argon atmosphere. After addition of **1a**, the reaction was continued at the same temperature for an additional 3 h (or as judged by TLC). Solvent was evaporated under reduced pressure and the carbazole product **3a** was purified by a silica gel flash column chromatography using Ethyl acetate/Hexanes (2:98) as the eluent.

4. Substrate scope of the benzannulation

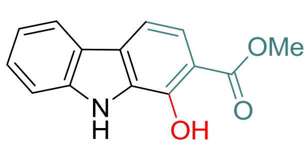


General procedure: A solution of **1** (0.56 mmol) in 2 ml DCM was added slowly with a flow rate of 1 ml/h using a syringe pump to a DCM solution (1 ml) of 2-oxindole **2** (0.225 mmol), $Rh_2(Oct)_4$ (3.5 mg, 0.0045 mmol) and (±)-BINOL phosphoric acid BPA (4 mg, 0.011 mmol) in a 10 ml round bottom flask in the presence of 4 Å MS (80 mg), maintained at 84 °C under argon atmosphere. After addition of **1** (2 h), reaction was continued at the same temperature for an additional 3 h. Solvent was evaporated under reduced pressure and the residue was purified by a silica gel flash column chromatography using Ethyl acetate/Hexanes as the eluent (2:98) to furnish carbazole **3** (R_f = 0.2 – 0.3; Ethyl acetate/Hexanes = 2:98).



3a

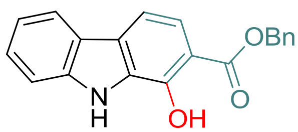
Ethyl 1-hydroxy-9H-carbazole-2-carboxylate (3a): White solid; 35 mg, yield = 62%; m.p.=176-178 ^{0}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.38 (s, 1H), 8.52 (s, 1H), 8.06 (d, *J* = 7.9 Hz, 1H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.55 (d, *J* = 8.4 Hz, 1H), 7.51 – 7.44 (m, 2H), 7.22-7.27 (m, 1H), 4.45 (q, *J* = 7.1 Hz, 2H), 1.45 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.4, 149.2, 140.4, 128.7, 128.5, 127.3, 123.2, 121.3, 120.1, 120.0, 111.6, 111.2, 108.1, 61.4, 14.4; IR (neat): 3425, 3311, 3001, 2921, 1715 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{15}H_{13}NO_3$ [M+H] 256.0968, Found: 256.0974.



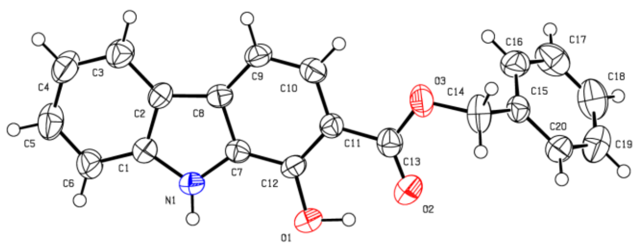
3b

Methyl 1-hydroxy-9H-carbazole-2-carboxylate (3b): White solid; 26 mg, yield = 48%; m.p.= 207-208 °C; ^{1}H NMR (500 MHz, $CDCl_3$)

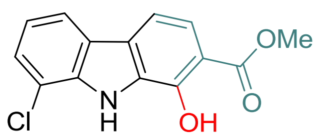
δ 11.32 (s, 1H), 8.54 (s, 1H), 8.10 (d, *J* = 7.8 Hz, 1H), 7.69 (d, *J* = 8.4 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 1H), 7.55 – 7.49 (m, 2H), 7.31 – 7.27(m, 1H), 4.03 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.7, 149.1, 140.4, 128.7, 128.4, 127.3, 123.2, 121.3, 120.1, 120.07, 111.6, 111.4, 107.9, 52.4; IR (neat): 3545, 3371, 3006, 2918, 1620 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{14}H_{10}NO_3$ [M-H] 240.0655, Found: 240.0658.



3c

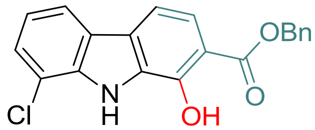


Benzyl 1-hydroxy-9H-carbazole-2-carboxylate (3c): White solid; 48 mg, yield = 68%; m.p. = 157-159 ^{0}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.28 (s, 1H), 8.52 (s, 1H), 8.05 (d, *J* = 7.8 Hz, 1H), 7.70 (d, *J* = 8.4 Hz, 1H), 7.54 (d, *J* = 8.4 Hz, 1H), 7.52 – 7.45 (m, 4H), 7.43 – 7.35 (m, 3H), 7.26 – 7.23 (m, 1H), 5.43 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.1, 149.3, 140.4, 135.7, 128.8, 128.6, 128.4, 128.36, 127.4, 123.2, 121.4, 120.2, 120.1, 113.3, 111.6, 111.4, 107.9, 67.0; IR (neat): 3536, 3365, 3011, 2921, 1685 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{20}H_{14}NaNO_3$ [M+Na] 340.0944, Found: 340.0925. CCDC 1033504 contains crystallographic data of this compound.



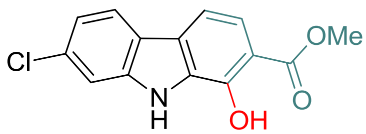
3d

Methyl 8-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3d): White solid; 32 mg, yield = 51%; m.p.= 182-184 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.32 (s, 1H), 8.67 (s, 1H), 7.93 (d, *J* = 7.9 Hz, 1H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.52 (d, *J* = 8.4 Hz, 1H), 7.46 (dd, *J* = 7.7, 0.6 Hz, 1H), 7.18 (t, *J* = 7.8 Hz, 1H), 3.99 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.41, 149.15, 137.51, 128.72, 128.22, 126.31, 124.47, 120.63, 120.61, 119.64, 116.84, 111.49, 108.35, 52.31; IR (neat): 3410, 3058, 2850, 1635 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{14}H_{11}ClNO_3$ [M+H] 276.0422, Found: 276.0383.



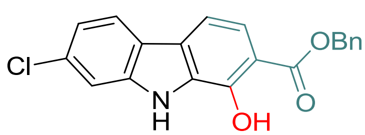
3e

Benzyl 8-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3e): White solid; 56 mg, yield = 71%; m.p. = 146-148 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.36 (s, 1H), 8.73 (s, 1H), 7.97 (dd, *J* = 7.6, 2.2 Hz, 1H), 7.75 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.56 - 7.51 (m, 3H), 7.49 (d, *J* = 7.7 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.41 (t, *J* = 7.2 Hz, 1H), 7.22 (td, *J* = 7.8, 1.7 Hz, 1H), 5.48 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 149.3, 137.5, 135.5, 128.8, 128.7, 128.5, 128.3, 128.2, 126.3, 124.5, 120.7, 120.6, 119.7, 116.8, 111.5, 108.4, 67.0; HRMS (ESI) m/z Calc. for $C_{20}H_{15}ClNO_3$ [M+H] 352.0735, Found: 352.0760.

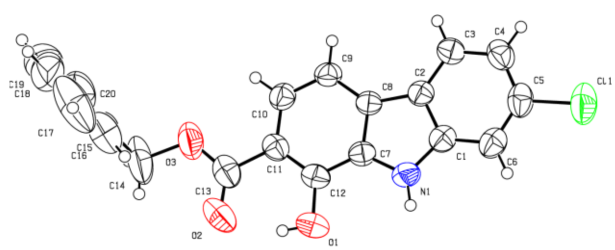


3f

Methyl 7-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3f): White solid; 35 mg, yield = 56%; m.p.= 206-208°C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.31 (s, 1H), 8.51 (s, 1H), 7.98 (d, *J* = 8.4 Hz, 1H), 7.70 (d, *J* = 8.4 Hz, 1H), 7.54 (d, *J* = 8.4 Hz, 1H), 7.51 (d, *J* = 1.7 Hz, 1H), 7.25 (dd, *J* = 8.4, 1.8 Hz, 1H), 4.03 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.6, 149.1, 140.7, 133.1, 128.7, 128.2, 122.2, 121.8, 120.9, 120.7, 111.6, 111.2, 108.2, 52.4. IR(neat): 3390, 3060, 29400, 2840, 1630 cm^{-1}; LRMS (ESI): 274.2 (M-H).

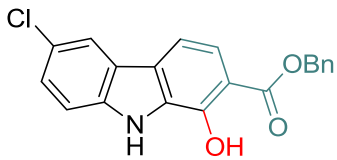


3g



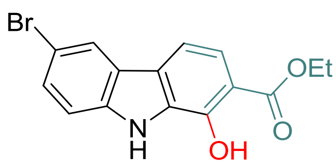
Benzyl 7-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3g): White solid; 58 mg, yield = 73%; m.p. = 169-170 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.27 (s, 1H), 8.48 (s, 1H), 7.93 (d, *J* = 8.4 Hz, 1H), 7.70 (d, *J* = 8.4 Hz, 1H), 7.50 - 7.45 (m, 4H), 7.44 – 7.39 (m, 2H), 7.39 - 7.35 (m, 1H), 7.20 (dd, *J* = 8.4, 1.8 Hz, 1H), 5.43 (s, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.8, 149.0, 140.6, 135.5, 133.0, 128.7, 128.5, 128.2, 128.1, 128.1, 122.1, 121.6, 120.7, 120.6, 111.4, 111.1, 108.0, 66.9; IR (neat): 3379, 3151, 3046, 2920, 2848, 1666 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{20}H_{13}ClNO_3$ [M-

H] 350.0578, Found: 350.0596. CCDC 1033505 contains crystallographic data of this compound.



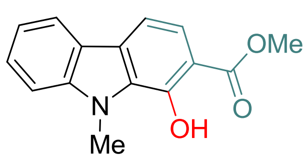
3h

Benzyl 6-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3h): White solid; 52 mg, yield = 66%; m.p. = 157-160 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.27 (s, 1H), 8.51 (s, 1H), 8.00 (s, 1H), 7.70 (d, *J* = 8.5 Hz, 1H), 7.51 – 7.45 (m, 3H), 7.44 – 7.32 (m, 5H), 5.43 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.0, 149.3, 138.6, 135.6, 129.1, 128.9, 128.7, 128.5, 128.4, 127.8, 127.5, 125.6, 124.3, 121.0, 120.5, 112.6, 111.4, 108.4, 67.1; IR (neat): 3395, 3309, 3006, 2912, 1642 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{20}H_{13}ClNO_3$ [M-H] 350.0578, Found: 350.0567.



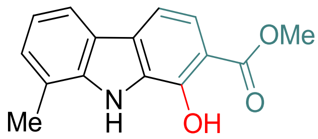
3i

Ethyl 6-bromo-1-hydroxy-9H-carbazole-2-carboxylate (3i): White solid; 38 mg, yield = 52%; m.p. = 187-189 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.39 (d, *J* = 6.5 Hz, 1H), 8.51 (s, 1H), 8.16 (d, *J* = 1.7 Hz, 1H), 7.67 (d, *J* = 8.5 Hz, 1H), 7.54 (dd, *J* = 7.1, 5.2 Hz, 1H), 7.48 (d, *J* = 8.4 Hz, 1H), 7.36 (d, *J* = 8.7 Hz, 1H), 4.45 (q, *J* = 7.1 Hz, 2H), 1.45 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.1, 149.1, 138.7, 129.9, 128.8, 127.4, 124.8, 123.9, 120.4, 112.9, 112.7, 111.1, 108.5, 61.4, 14.3; IR (neat) 3400, 3298, 2921, 2832, 1690 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{15}H_{12}BrNO_3$ [M^+] 332.9995, Found: 333.0013.



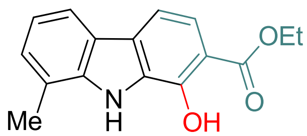
3j

Methyl 1-hydroxy-9-methyl-9H-carbazole-2-carboxylate (3j): White solid; 3 mg, yield = 6%; m.p.= 112-113 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.62 (s, 1H), 7.99 (d, *J* = 7.9 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.50 (d, *J* = 8.5 Hz, 1H), 7.48 – 7.43 (m, 1H), 7.36 (d, *J* = 8.3 Hz, 1H), 7.18 – 7.15 (m, 1H), 4.19 (s, 3H), 3.93 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.1, 150.9, 142.4, 128.7, 128.7, 127.0, 122.2, 121.0, 119.6, 119.3, 111.1, 109.2, 107.8, 52.2, 32.1; IR(neat): 3470, 3284, 3118, 2910, 1677, 1460 cm^{-1}



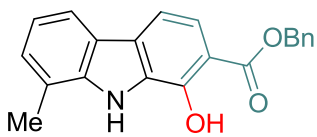
3k

Methyl 1-hydroxy-8-methyl-9H-carbazole-2-carboxylate (3k): White solid; 30 mg, yield = 52%; m.p.= 104-106 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.38 (s, 1H), 8.45 (s, 1H), 7.94 (d, *J* = 7.9 Hz, 1H), 7.69 (d, *J* = 8.4 Hz, 1H), 7.59 (d, *J* = 8.2 Hz, 1H), 7.33 – 7.30 (m, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 4.03 (s, 3H), 2.62 (s, 3H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 171.7, 149.0, 139.8, 129.2, 128.1, 127.6, 122.6, 120.7, 120.1, 120.0, 118.8, 111.4, 107.6, 52.2, 16.9; IR(neat): 3450, 3320, 3095, 2970, 1675 cm^{-1}. HRMS (ESI) m/z Calc. for $C_{15}H_{14}NO_3$ [M+H] 256.0968, Found: 256.0990.



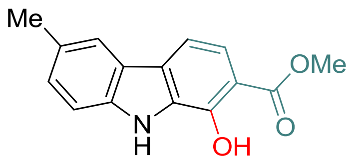
3l

Ethyl 1-hydroxy-8-methyl-9H-carbazole-2-carboxylate (3l): White solid; 33 mg, yield = 55%; m.p.= 132-134 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.47 (s, 1H), 8.43 (s, 1H), 7.94 (d, *J* = 7.9 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 1H), 7.32 (d, *J* = 7.2 Hz, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 4.49 (q, *J* = 7.1 Hz, 2H), 2.62 (s, 3H), 1.50 (t, *J* = 7.1 Hz, 4H); ^{13}C NMR (176 MHz, $CDCl_3$) δ 171.3, 149.1, 139.8, 129.1, 128.1, 127.6, 122.6, 120.7, 120.1, 120.0, 118.8, 111.3, 107.8, 61.3, 16.9, 14.3; IR(neat): 3465, 3350, 3091, 2950, 1660 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{16}H_{16}NO_3$ [M+H] 270.1125, Found: 270.1111.



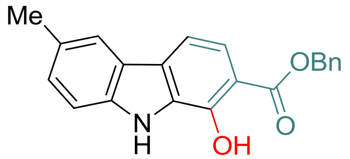
3m

Benzyl 1-hydroxy-8-methyl-9H-carbazole-2-carboxylate (3m): White solid; 46 mg, yield = 62%; m.p.= 116-118 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.36 (s, 1H), 8.44 (s, 1H), 7.94 (d, *J* = 7.9 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.54 – 7.50 (m, 2H), 7.48 – 7.43 (m, 2H), 7.41 (dd, *J* = 5.0 Hz, 3.6 Hz, 1H), 7.32 (d, *J* = 7.1 Hz, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 5.47 (s, 2H), 2.62 (s, 3H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 171.1, 149.2, 139.8, 135.6, 129.2, 128.7, 128.5, 128.3, 128.1, 127.7, 122.5, 120.7, 120.1, 120.1, 118.8, 111.4, 107.6, 66.9, 16.9; IR(neat): 3490, 3352, 2920, 1647 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{21}H_{18}NO_3$ [M+H] 332.1281, Found: 332.1292.



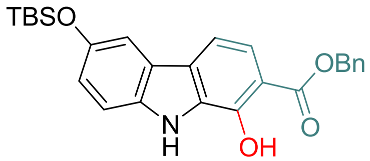
3n

Methyl 1-hydroxy-6-methyl-9H-carbazole-2-carboxylate (3n): White solid; 32 mg, yield = 55%; m.p.= 185-187 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.29 (s, 1H), 8.42 (s, 1H), 7.88 (s, 1H), 7.67 (d, J = 8.4 Hz, 1H), 7.56 (d, J = 8.4 Hz, 1H), 7.42 (d, J = 8.3 Hz, 1H), 7.33 (dd, J = 8.3, 1.2 Hz, 1H), 4.02 (s, 3H), 2.55 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.8, 149.1, 138.7, 129.5, 128.9, 128.7, 128.6, 123.4, 121.0, 119.9, 111.3, 111.2, 107.7, 52.3, 21.6; IR(neat): 3400, 3308, 2921, 2802, 1670 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{15}H_{14}NO_3$ [M+H] 256.0968, Found: 256.0950.



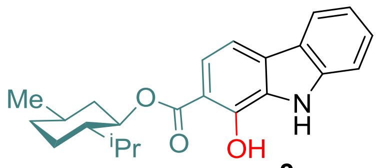
3o

Benzyl 1-hydroxy-6-methyl-9H-carbazole-2-carboxylate (3o): White solid; 49 mg, yield = 66%; m.p.= 133-134 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.29 (s, 1H), 8.43 (s, 1H), 7.88 (s, 1H), 7.72 (d, J = 8.4 Hz, 1H), 7.55 (d, J = 8.4 Hz, 1H), 7.52 (d, J = 7.1 Hz, 2H), 7.45 (t, J = 7.3 Hz, 2H), 7.42 – 7.38 (m, 2H), 7.33 (dd, J = 8.3, 1.1 Hz, 1H), 5.47 (s, 2H), 2.55 (s, 3H);. ^{13}C NMR (176 MHz, $CDCl_3$) δ 171.1, 149.3, 138.7, 135.8, 129.5, 128.9, 128.8, 128.7, 128.6, 128.4, 123.4, 121.1, 120.0, 111.3, 111.2, 107.7, 67.0, 21.6; IR(neat): 3450, 3309, 3085, 2980, 1670 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{21}H_{18}NO_3$ [M+H] 332.1281, Found: 332.1282.

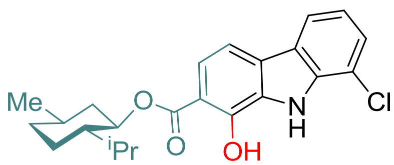


3p

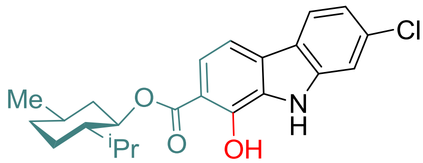
Benzyl 6-((tert-butyldimethylsilyl)oxy)-1-hydroxy-9H-carbazole-2-carboxylate (3p): White solid; 54 mg, yield = 54%; m.p.= 134-136 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.26 (s, 1H), 8.34 (s, 1H), 7.66 (d, J = 8.4 Hz, 1H), 7.53 – 7.30 (m, 8H), 7.02 (dd, J = 8.7, 2.3 Hz, 1H), 5.43 (s, 2H), 1.03 (s, 9H), 0.23 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.01, 149.44, 149.22, 135.71, 135.65, 129.08, 128.71, 128.49, 128.45, 128.22, 123.74, 121.22, 119.55, 111.81, 111.26, 110.84, 107.55, 66.81, 25.80, -4.37.IR(neat): 3520, 3395, 3061, 2921, 1665 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{26}H_{28}NNaO_4Si$ [M+Na] 470.1777, Found: 470.1758.



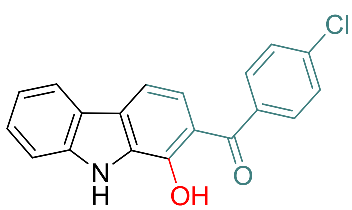
3q **(1S,3S,4R)-4-isopropyl-3-methylcyclohexyl 1-hydroxy-9H-carbazole-2-carboxylate (3q):** White solid; 43 mg, yield = 53%; m.p.= 56-58 ^{o}C; $[\alpha]_D^{23}$ – 69^{o} (c 0.36, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.58 (s, 1H), 8.61 (s, 1H), 8.11 (dd, *J* = 7.8, 0.6 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 1H), 7.54 – 7.49 (m, 2H), 7.31 – 7.27 (m, 1H), 5.07 (td, *J* = 10.9, 4.4 Hz, 1H), 2.25 - 2.19 (m, 1H), 2.09 – 2.02 (m, 1H), 1.83 - 1.76 (m, 2H), 1.70 - 1.59 (m, 2H), 1.26 – 1.15 (m, 2H), 1.00 (d, *J* = 3.8 Hz, 3H), 0.98 (d, *J* = 4.2 Hz, 3H), 0.97 - 0.92 (m, 1H), 0.87 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.9, 149.1, 140.3, 128.5, 128.4, 127.1, 123.1, 121.2, 120.0, 119.8, 111.4, 111.1, 108.3, 75.4, 47.2, 41.0, 34.3, 31.5, 26.6, 23.7, 22.1, 20.8, 16.6; IR (neat): 3391, 3020, 2987, 1667, 1313 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{23}H_{27}NaNO_3$ [M+Na] 388.1883, Found: 388.1909.



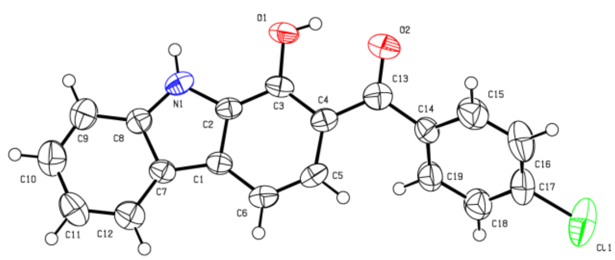
3r **(1S,3S,4R)-4-isopropyl-3-methylcyclohexyl 8-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3r):** White solid; 60 mg, yield = 67%; m.p = 114-116 ^{o}C; $[\alpha]_D^{23}$ – 74^{o} (c 0.34, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.61 (s, 1H), 8.76 (s, 1H), 7.98 (d, *J* = 7.9 Hz, 1H), 7.72 (d, *J* = 8.4 Hz, 1H), 7.56 (d, *J* = 8.4 Hz, 1H), 7.50 (dd, *J* = 7.7, 0.6 Hz, 1H), 7.21 (t, *J* = 7.8 Hz, 1H), 5.06 (td, *J* = 10.9, 4.4 Hz, 1H), 2.25 - 2.19 (m, 1H), 2.09 – 2.02 (m, 1H), 1.83 - 1.76 (m, 2H), 1.70 - 1.58 (m, 2H), 1.26 – 1.15 (m, 2H), 0.99 (d, *J* = 5.2 Hz, 3H), 0.98 (d, *J* = 5.6 Hz, 3H), 0.97 – 0.92 (m, 1H), 0.87 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.7, 149.3, 137.5, 128.6, 128.3, 126.2, 124.5, 120.63, 120.56, 119.6, 116.8, 111.3, 108.9, 75.6, 47.2, 41.0, 34.3, 31.5, 26.6, 23.7, 22.0, 20.7, 16.6; IR (neat): 3334, 3014, 2989, 1656, 1310 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{23}H_{26}ClNaNO_3$ [M+Na] 422.1493, Found: 422.1525.



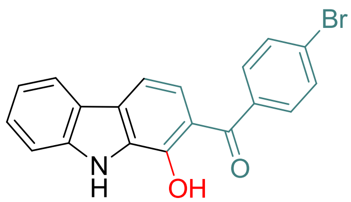
3s **(1S,3S,4R)-4-isopropyl-3-methylcyclohexyl 7-chloro-1-hydroxy-9H-carbazole-2-carboxylate (3s):** White solid; 68 mg, yield = 76%; m.p.= 158-160 ^{o}C; $[\alpha]_D^{23}$ – 66^{o} (c 0.35, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.58 (s, 1H), 8.60 (s, 1H), 7.97 (d, *J* = 8.4 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.53 (d, *J* = 8.4 Hz, 1H), 7.49 (d, *J* = 1.2 Hz, 1H), 7.24 (dd, *J* = 8.4, 1.8 Hz, 1H), 5.06 (td, *J* = 10.9, 4.4 Hz, 1H), 2.25 - 2.19 (m, 1H), 2.09 – 2.00 (m, 1H), 1.83 - 1.76 (m, 2H), 1.70 - 1.58 (m, 2H), 1.26 – 1.15 (m, 2H), 0.99 (d, *J* = 5.1 Hz, 1H), 0.98 (d, *J* = 5.5 Hz, 1H), 0.97 – 0.92 (m, 1H), 0.86 (d, *J* = 7.0 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.7, 149.0, 140.6, 132.9, 128.7, 127.9, 122.0, 121.7, 120.6, 120.5, 111.4, 110.9, 108.6, 75.6, 47.2, 40.9, 34.3, 31.5, 26.6, 23.7, 22.0, 20.7, 16.6; IR (neat): 3419, 3022, 2989, 1660, 1314 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{23}H_{26}ClNaNO_3$ [M+Na] 422.1493, Found: 422.1533.



3t

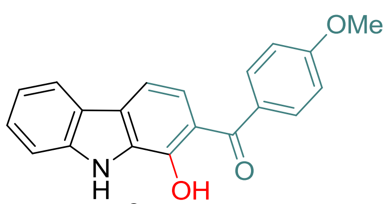


(4-Chlorophenyl)(1-hydroxy-9H-carbazol-2-yl)methanone (3t): Yellow solid; 25 mg, yield = 35% (reaction without (±)-BPA was clean and gave similar yield); m.p.= 130-132 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 12.84 (s, 1H), 8.69 (s, 1H), 8.11 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.75 – 7.72 (m, 2H), 7.59 – 7.53 (m, 5H), 7.39 (d, *J* = 8.5 Hz, 1H), 7.33 – 7.29 (m, 1H); ^{13}C NMR (176 MHz, $CDCl_3$) δ 200.7, 151.2, 140.8, 138.1, 137.0, 130.8, 129.4, 128.8, 128.7, 128.0, 123.7, 123.0, 121.6, 120.3, 114.9, 111.7, 111.0; IR (neat): 3372, 3010, 2918, 1629, 1590 cm^{-1}; HRMS (ESI) m/z Calc. For $C_{19}H_{13}ClNO_2$ [M+H] 322.0629, Found: 322.0601. CCDC 1033506 contains crystallographic data of this compound.



3u

(4-bromophenyl)(1-hydroxy-9H-carbazol-2-yl)methanone (3u): Yellow solid; 23 mg, yield = 29% (reaction without (±)-BPA was clean and gave similar yield); m.p. = 153-155 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 12.83 (s, 1H), 8.68 (s, 1H), 8.11 (d, *J* = 7.5 Hz, 1H), 7.72 – 7.65 (m, 4H), 7.59 – 7.53 (m, 3H), 7.39 (d, *J* = 8.5 Hz, 1H), 7.32 – 7.29 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 200.8, 151.2, 140.9, 137.5, 131.7, 131.0, 129.4, 128.7, 128.0, 126.6, 123.7, 123.0, 121.6, 120.3, 114.9, 111.7, 111.0; IR (neat): 3369, 2956, 3011, 2917, 1670, 1261 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{19}H_{12}BrNO_2$ [M^{-}] 365.9948, Found: 365.9965.

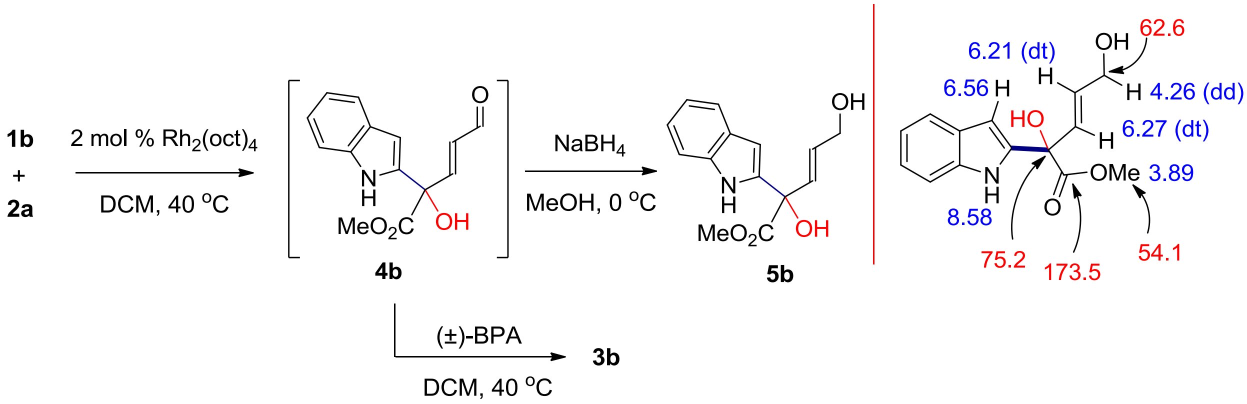


3v

(1-hydroxy-9H-carbazol-2-yl)(4-methoxyphenyl)methanone (3v): Yellow solid; 22 mg, yield = 31% (reaction without (±)-BPA was clean and gave similar yield); m.p.= 137-139 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 12.97 (s, 1H), 8.68 (s, 1H), 8.11 (d, *J* = 7.9 Hz, 1H), 7.82 (d, *J* = 8.8 Hz,, 2H), 7.57 (t, *J* = 8.2 Hz, 2H), 7.55 – 7.51 (m, 1H), 7.50 (d, *J* = 8.4 Hz, 1H), 7.31 – 7.29 (m, 1H), 7.05 (d, *J* = 8.8 Hz, 2H), 3.94 (s, 3H); ^{13}C NMR (176 MHz, $CDCl_3$) δ 200.7, 162.8, 150.9, 140.8, 132.0, 131.2, 128.95, 128.8, 127.7, 124.0, 123.1, 121.5, 120.2, 115.4, 113.7, 111.7, 110.7, 55.7; IR (neat): 3369, 3002, 2919, 2851, 1697, 1454 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{20}H_{16}NO_3$ [M+H] 318.1125, Found: 318.1140.

5. Mechanistic Studies:

Characterization of 5b

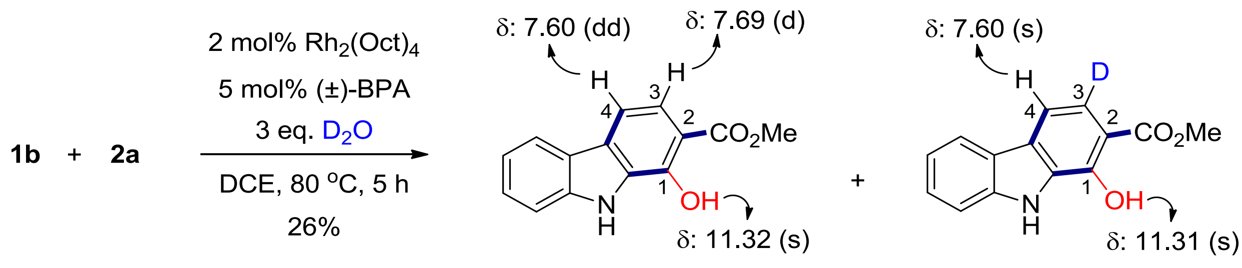


(E)-methyl 2,5-dihydroxy-2-(1H-indol-2-yl)pent-3-enoate (5b): A solution of the methyl ester diazoenal **1b** (290 mg, 1.87 mmol) in 2 ml CH_2Cl_2 was added over 2 h using a syringe pump to a solution of oxindole **2a** (100 mg, 0.75 mmol) and $Rh_2(OAc)_4$ (0.015 mmol, 2 mol%) in 2 ml CH_2Cl_2 maintained at 40 °C. The reaction was continued until all the diazoenal **1b** was consumed (additional 3 h). Thin layer chromatography (TLC) of the reaction mixture indicated the presence of an unstable intermediate. Attempts to isolate the intermediate by flash column chromatography (using silica gel or aluminium oxide) were unsuccessful due to decomposition in the column.

About half of the volume of the reaction mixture was evaporated at room temperature under reduced pressure and dried. To a solution of the residue (100 mg) in 2 ml methanol at 0 °C was added excess $NaBH_4$ and stirred for 20 min. TLC showed formation of one major product. The reaction was quenched with ice-cold water (2 ml) and extracted with 10 ml ethyl acetate. The organic phase was washed with water, brine and dried over anhydrous sodium sulphate. Solvent was evaporated at room temperature and the crude material was dried under vacuum. Purification of the residue by silica gel flash column chromatography (Ethyl acetate/Hexanes = 3:2) afforded partially purified alcohol **5b** as a white foam (28 mg). R_f = 0.12 (Ethyl Acetate/Hexane = 60:40); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.58 (s, 1H), 7.60 (d, *J* = 7.9 Hz, 1H), 7.37 (dd, *J* = 8.1, 0.8 Hz, 1H), 7.22 – 7.18 (m, 1H), 7.15 – 7.09 (m, 1H), 6.56 (dd, *J* = 2.1, 0.8 Hz, 1H), 6.27 (dt, *J* = 15.4, 1.3 Hz, 1H), 6.21 (dt, *J* = 15.4, 4.5 Hz, 1H), 4.26 (dd, *J* = 4.4, 0.9 Hz, 2H), 3.89 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 173.5, 137.1, 135.7, 131.0, 129.4, 128.4, 122.5, 120.8, 120.2, 111.2, 100.7, 75.2, 62.6, 54.1; IR (neat): 3361, 3021, 1731 cm^{-1}; HRMS (ESI) m/z Calc. for $C_{14}H_{14}NO_4$ [M-H] 260.0917, Found: 260.0895.

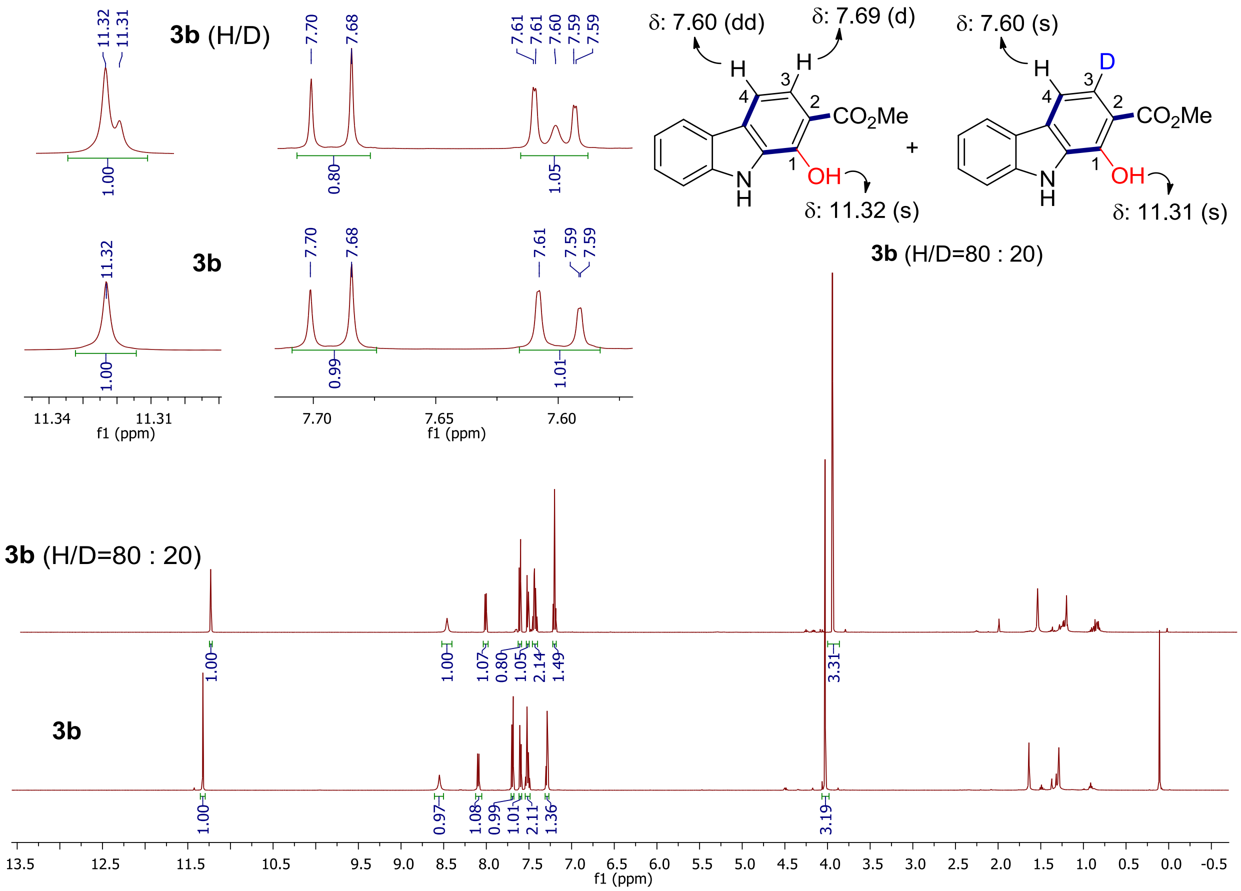
Remaining half of the volume of the reaction mixture was allowed to continue stirring at 40 ^oC in the presence of (±)-BINOL phosphoric acid. After 12 h the intermediate was completely consumed leading to carbazole **3b** as the only detectable product.

Formation of Deuterium Labeled Carbazole 3b



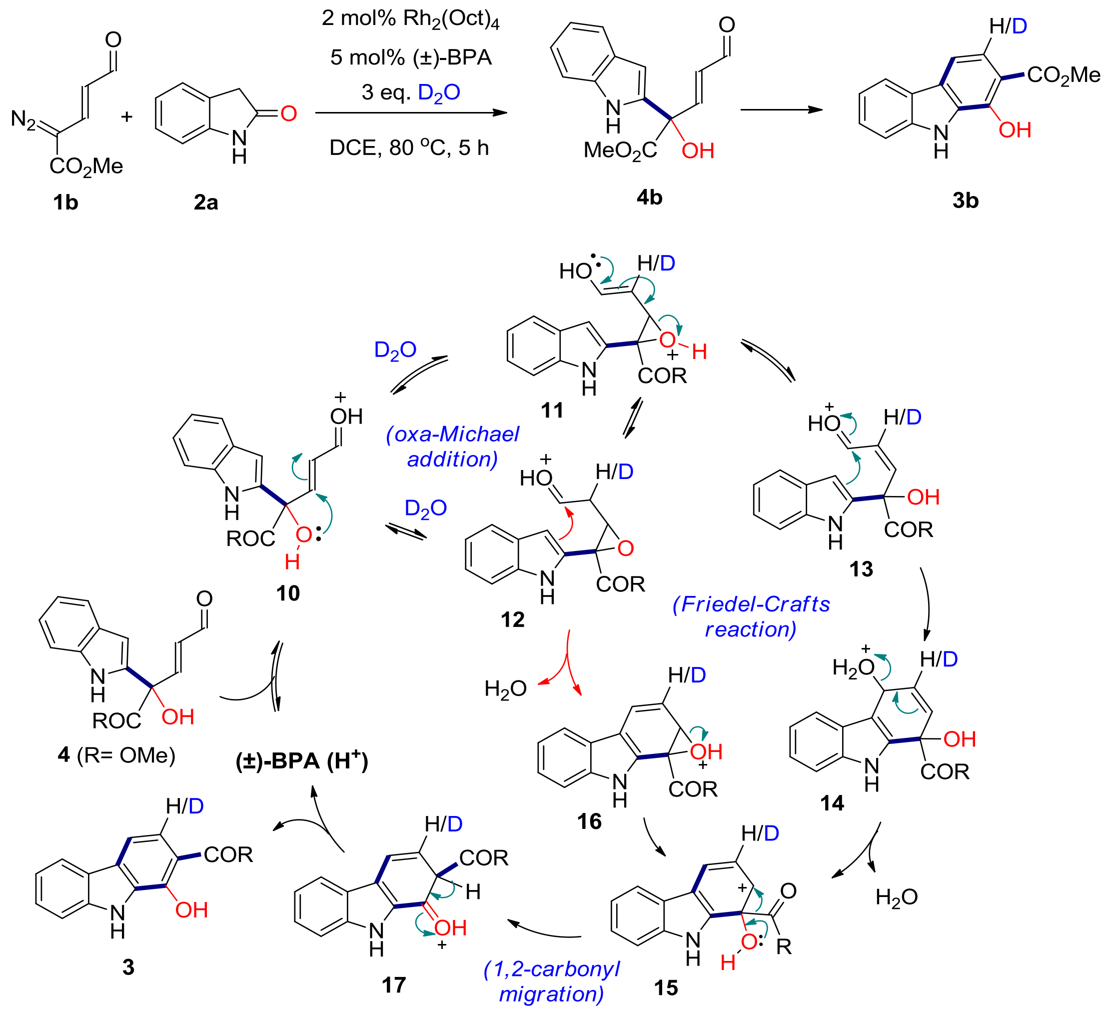
3b (H/D=80 : 20)

A solution of **1b** (87 mg, 0.58 mmol) in 2 ml DCM was added slowly with a flow rate of 1 ml/h using a syringe pump to a DCM solution (1 ml) of 2-oxindole **2a** (30 mg, 0.225 mmol), $Rh_2(OOct)_4$ (3.5 mg, 0.0045 mmol), (±)-BINOL phosphoric acid BPA (4 mg, 0.011 mmol) and D_2O (12 mg, 0.67 mmol) in a 10 ml round bottom flask, maintained at 84 ^oC under argon atmosphere. After addition of **1b** (2 h), the reaction was continued at the same temperature for an additional 3 h. Solvent was evaporated under the reduced pressure and the residue was purified by a silica gel flash column chromatography using Ethyl acetate/Hexanes as the eluent (2:98) which furnished carbazole **3b** as a white solid (12 mg, 26%). Based on the comparison of integration values of C-4 and C-3 attached protons in the ^1H-NMR spectra, 20% deuterium incorporation was observed at the C-3 position of the carbazole **3b**. A plausible mechanism for the formation of deuterium labeled carbazole **3b** (H/D= 80:20) is proposed below.

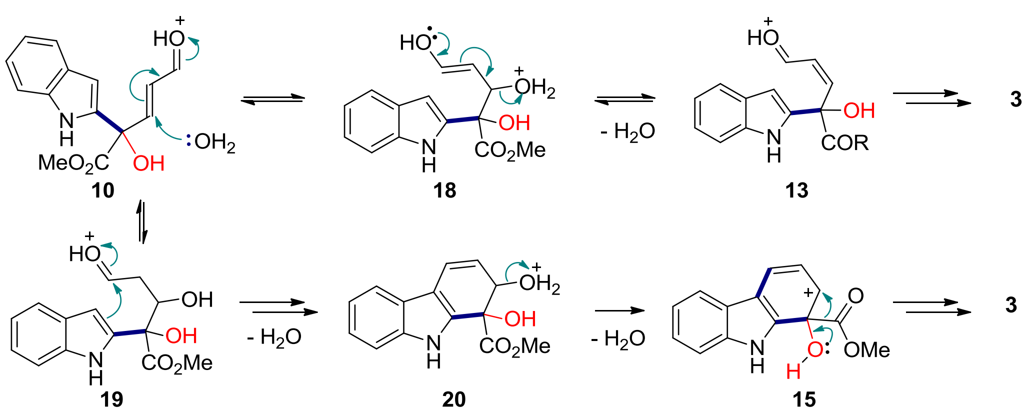


*[1]H NMR spectra of **3b** and deuterium labeled **3b** (H/D = 80:20)*

Plausible mechanism for the formation of deuterium labeled carbazole 3b



Plausible alternate mechanism of benzannulation via intermolecular oxa-Michael addition



6. References

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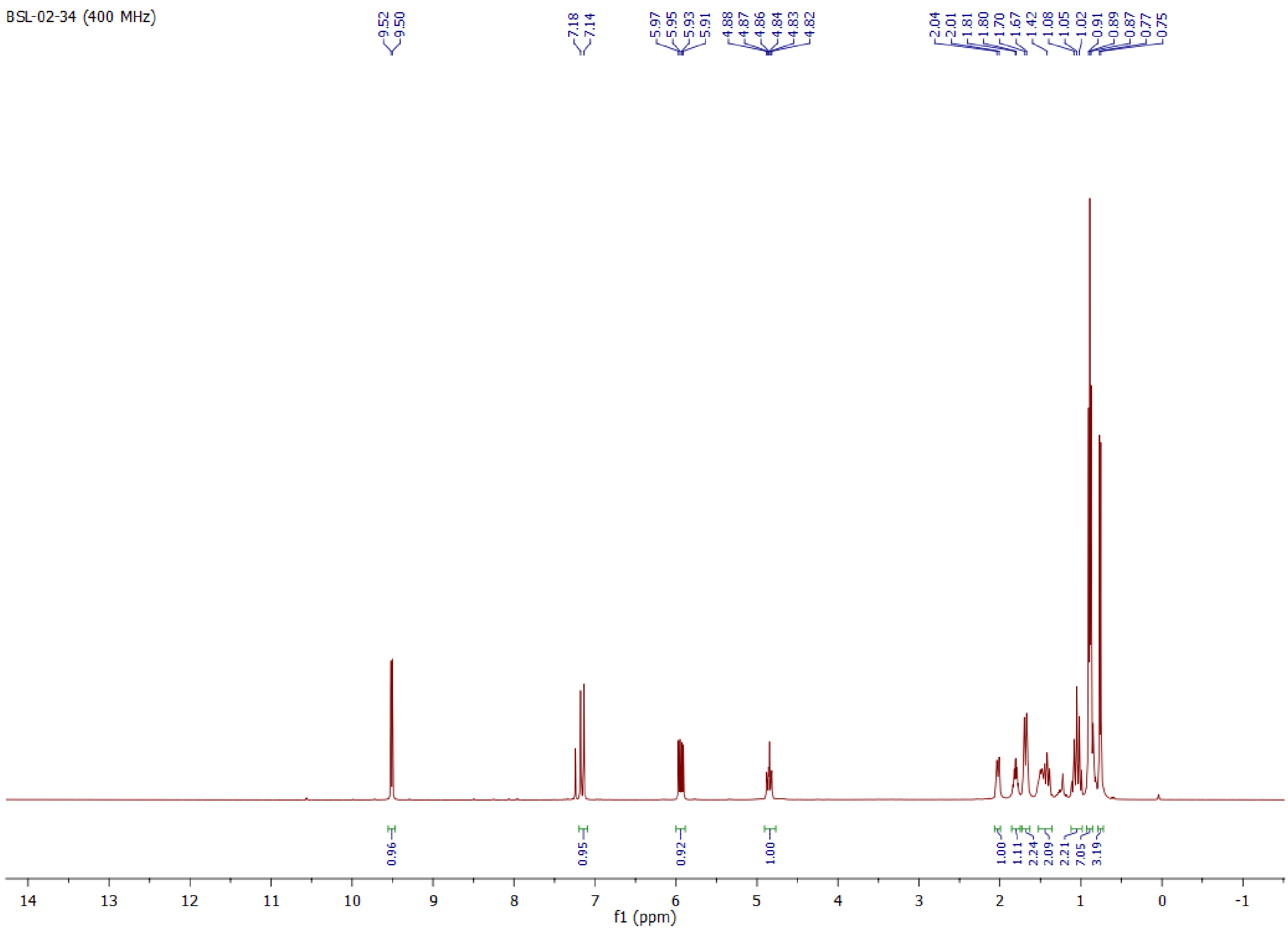
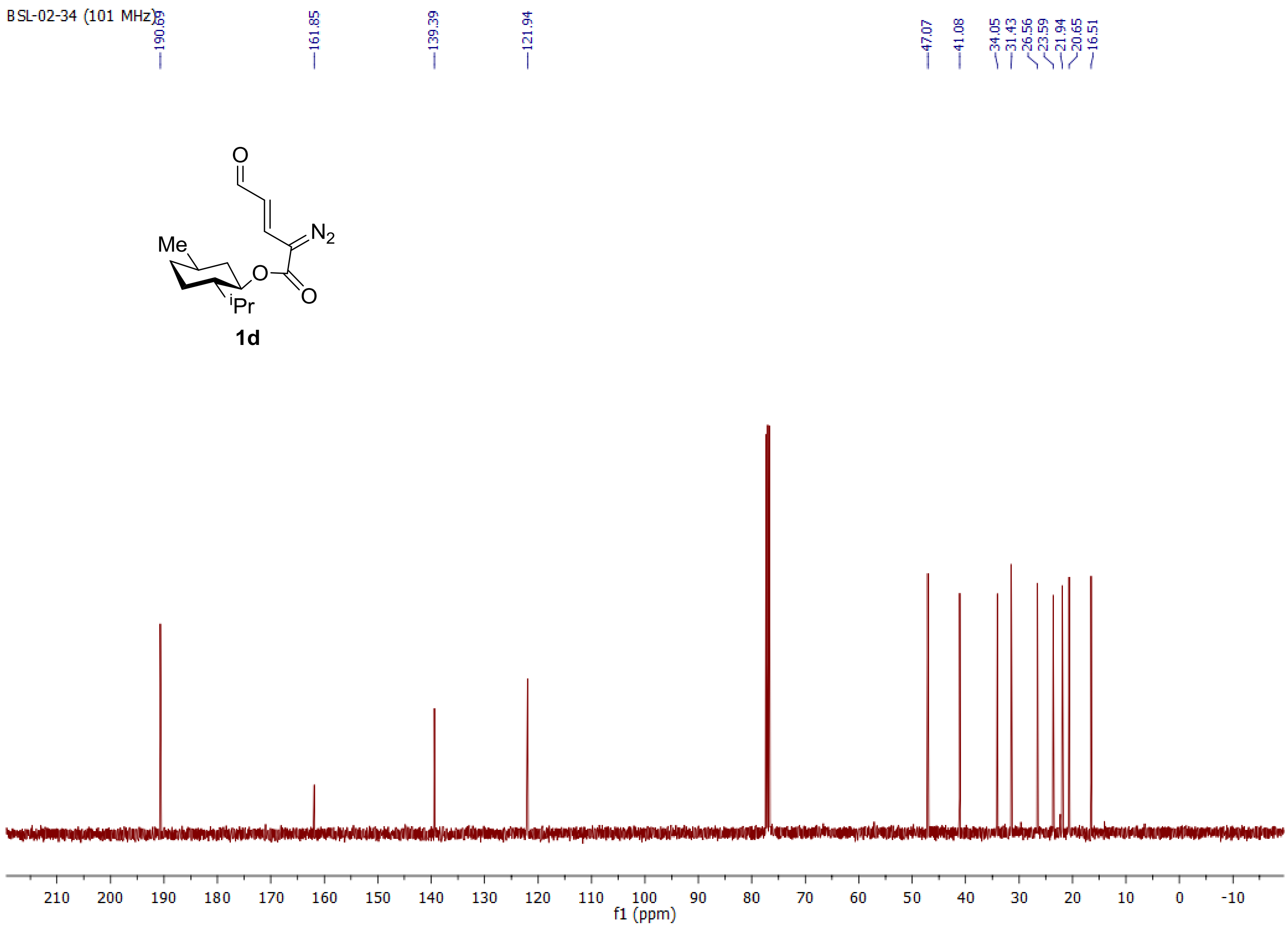
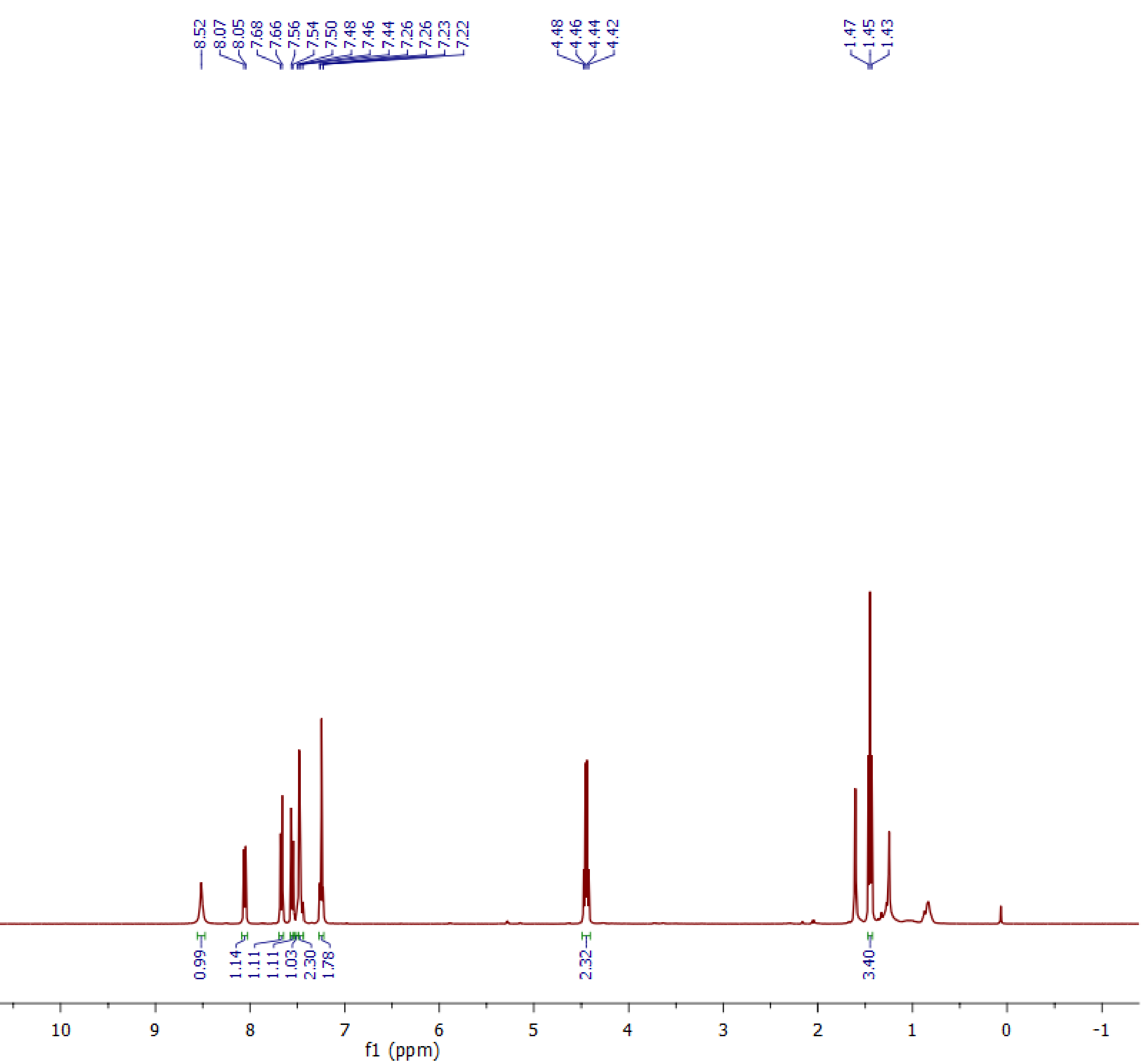
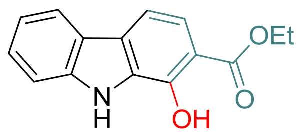
7. NMR spectra

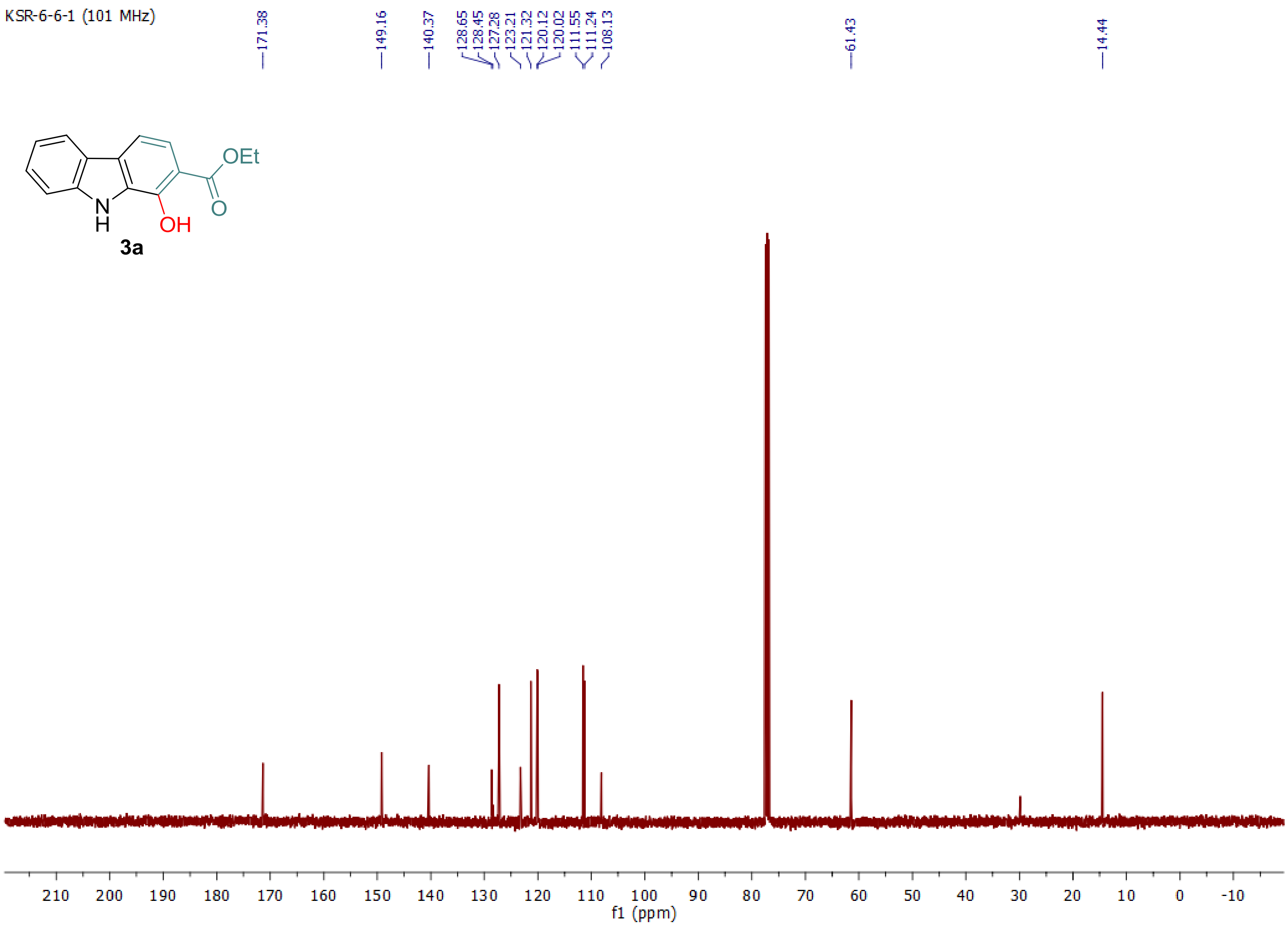



BSL-02-34 (101 MHz)
190.69
161.85
139.39
121.94
47.07
41.08
34.05
31.43
26.56
23.59
21.94
20.65
16.51
O
N2
Me
O
O
iPr
1d
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


KSR-6-6-1 (400 MHz)
11.38
8.52
8.07
8.05
7.68
7.66
7.56
7.54
7.50
7.48
7.46
7.44
7.26
7.26
7.23
7.22
4.48
4.46
4.44
4.42
1.47
1.45
1.43
1.00
0.99
1.14
1.11
1.11
1.03
2.30
1.78
2.32
3.40
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)


OEt
O
N
H
OH

3a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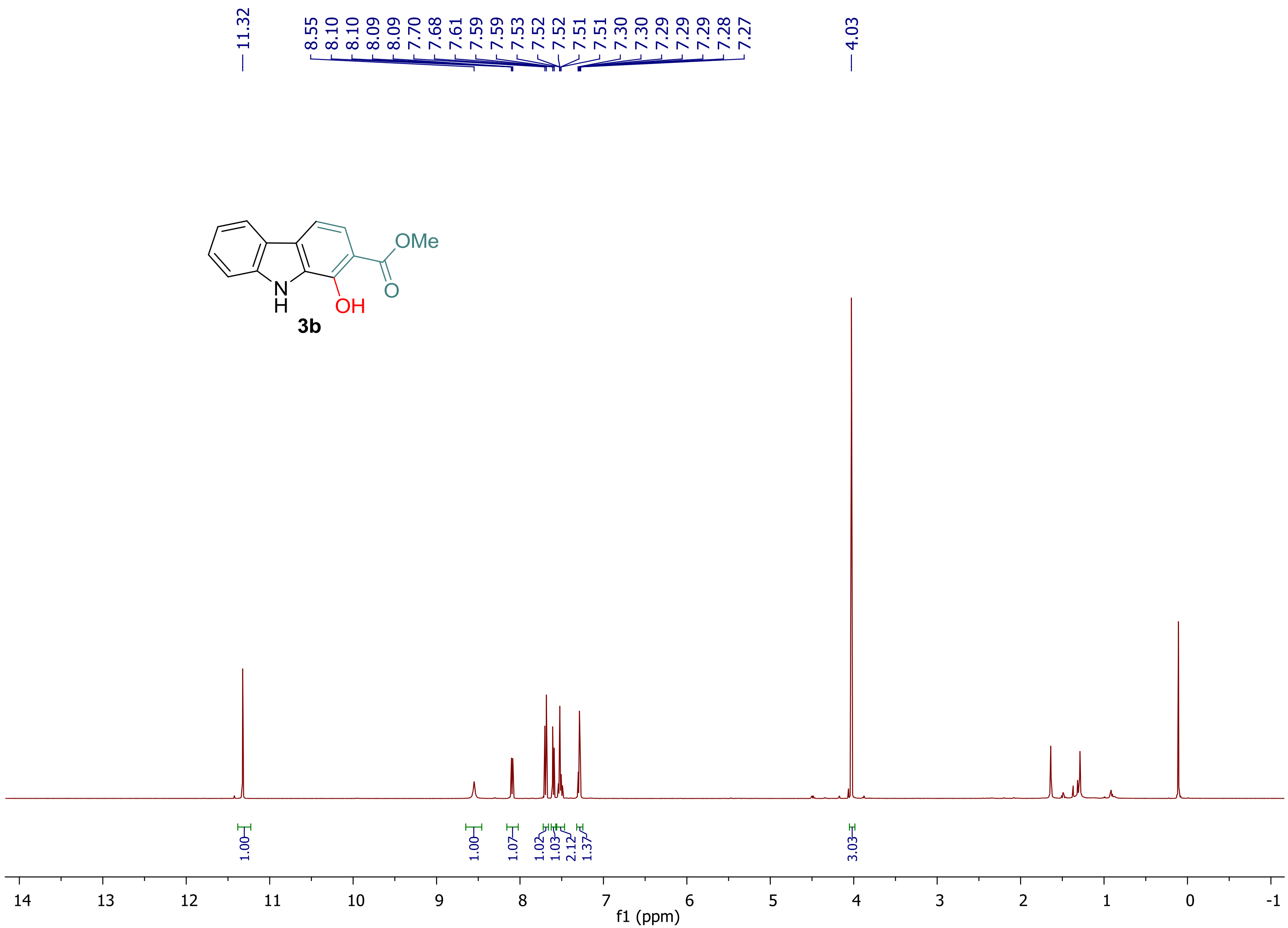
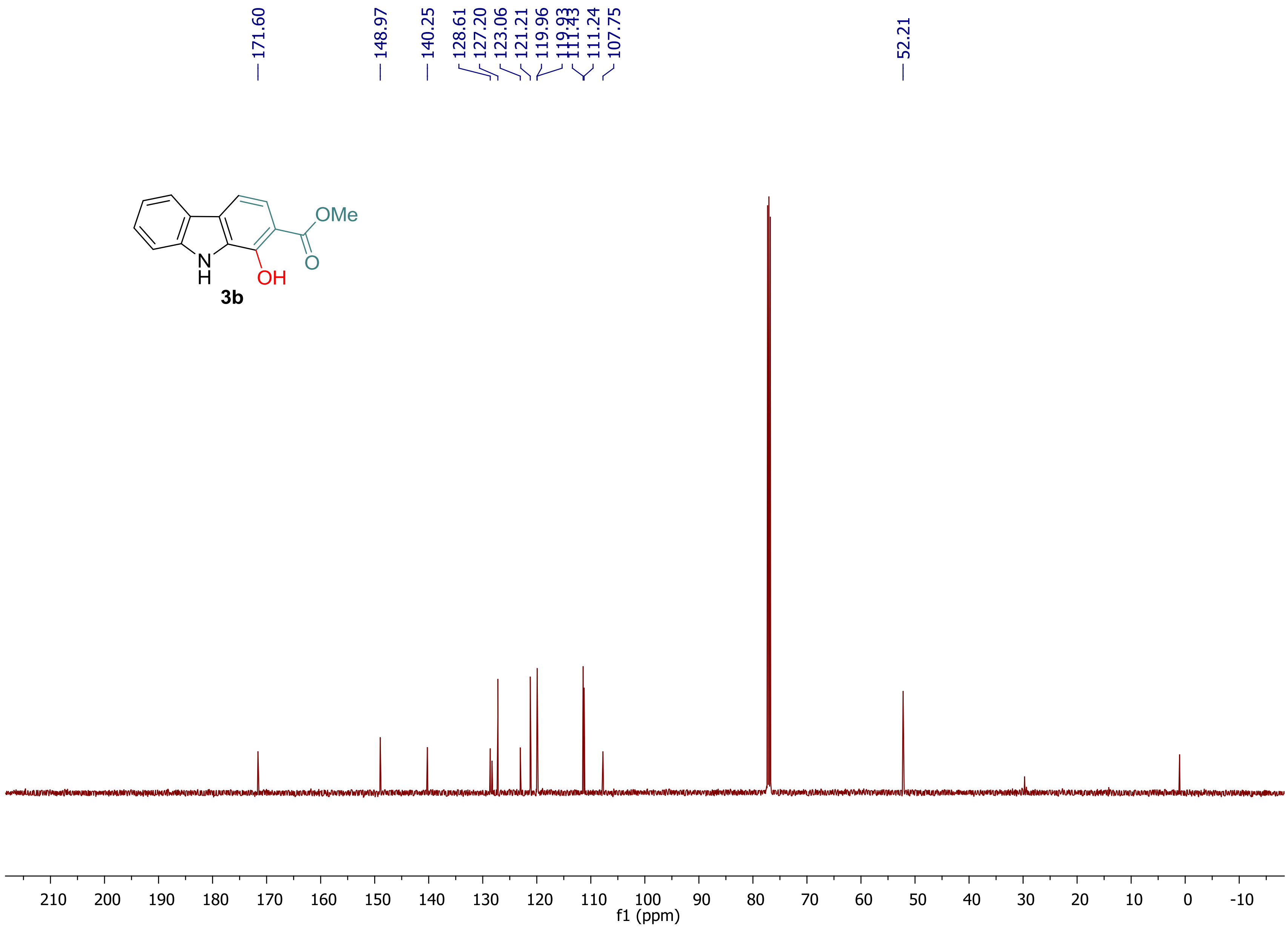
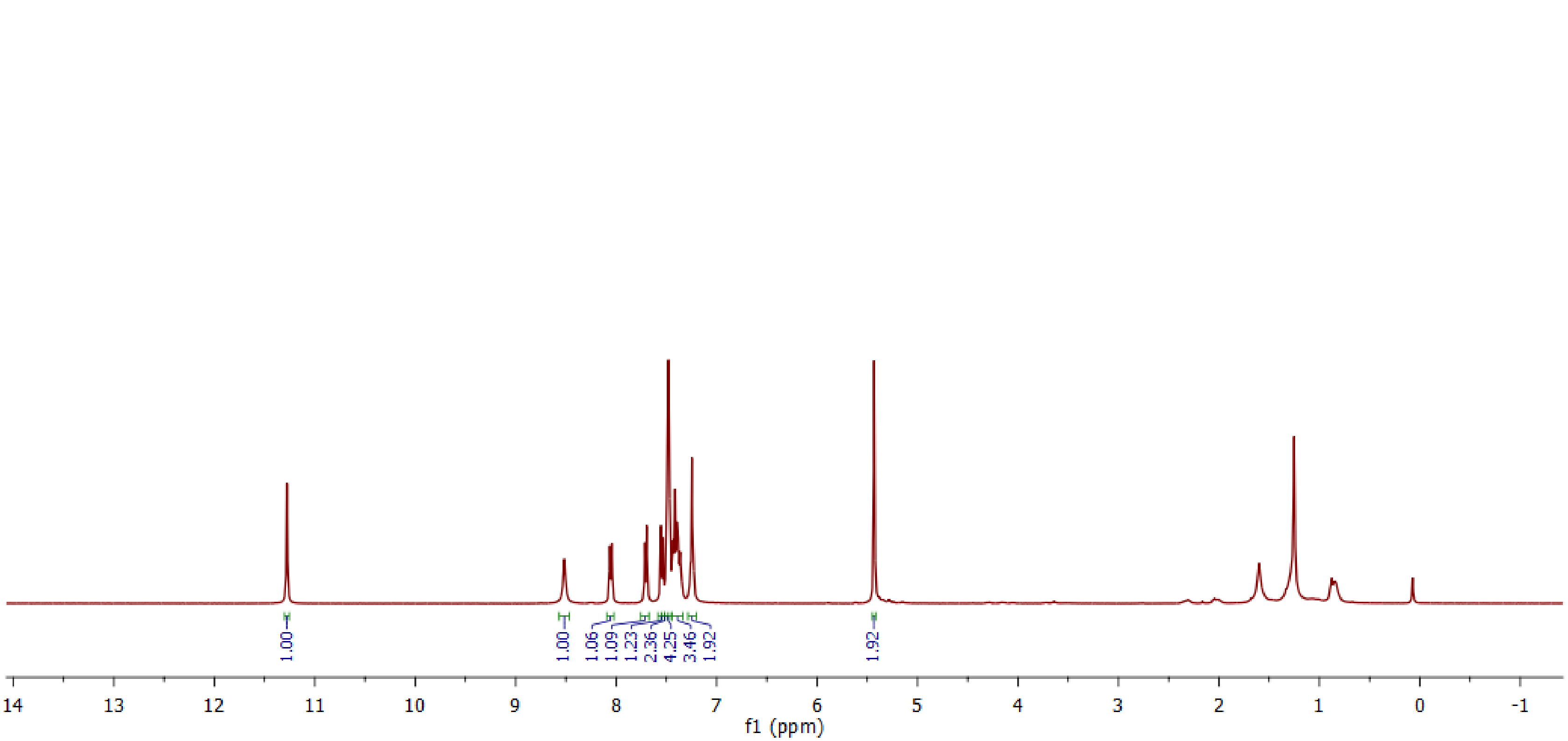
171.38
149.16
140.37
128.65
128.45
127.28
123.21
121.32
120.12
120.02
111.55
111.24
108.13
61.43
14.44
OEt
O
N
H
OH
3a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

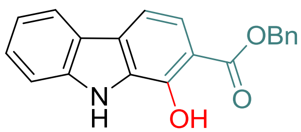


11.32
8.55
8.10
8.10
8.09
8.09
7.70
7.68
7.61
7.59
7.59
7.53
7.52
7.52
7.51
7.51
7.30
7.30
7.29
7.29
7.29
7.28
7.27
4.03
OMe
O
N
H
OH
3b
1.00
1.00
1.07
1.02
1.03
2.12
1.37
3.03
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)



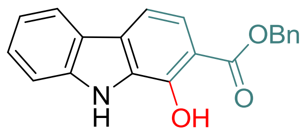
171.60
148.97
140.25
128.61
127.20
123.06
121.21
119.96
119.93
111.43
111.24
107.75
52.21
OMe
O
N
H
OH
3b
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


SK-KSR-6-7-1 (400 MHz)
11.28
8.52
8.06
8.04
7.72
7.69
7.55
7.53
7.49
7.48
7.43
7.41
7.40
7.38
7.36
7.24
5.43
1.00
1.00
1.06
1.09
1.23
2.36
4.25
3.46
1.92
1.92
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

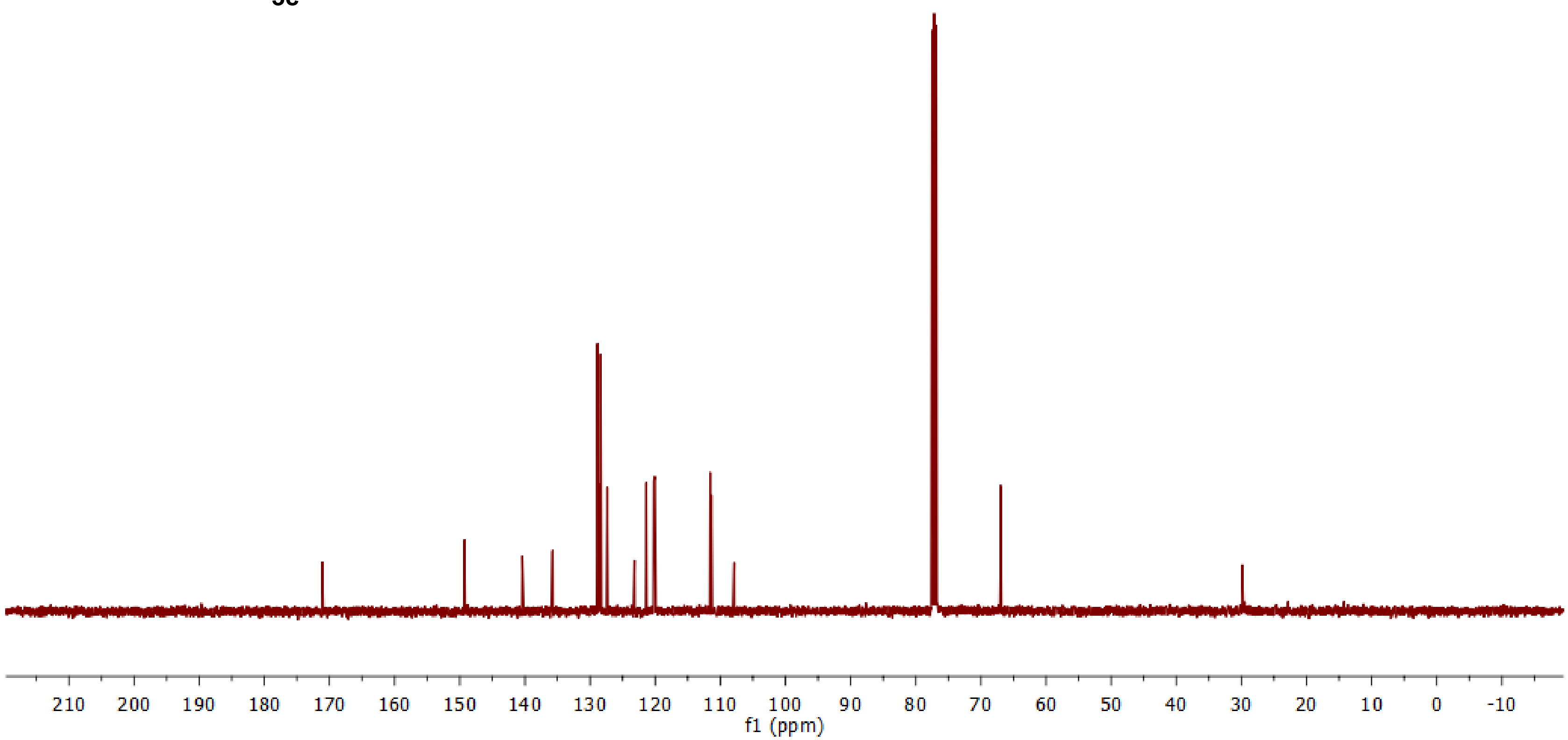

OBn
N
H
OH
O

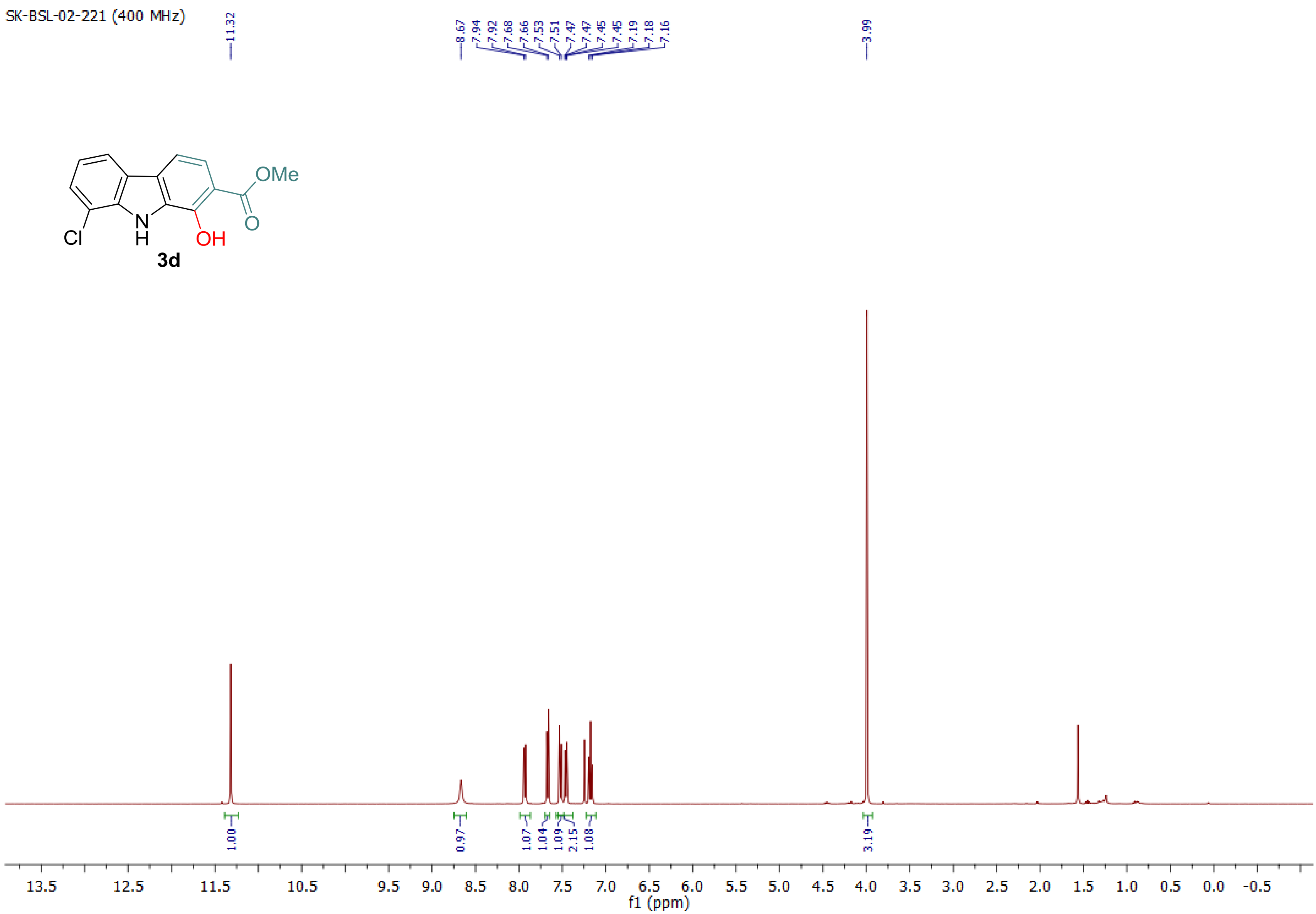
3c

SK-KSR-6-7-1 (101 MHz)



3c




SK-BSL-02-221 (400 MHz)
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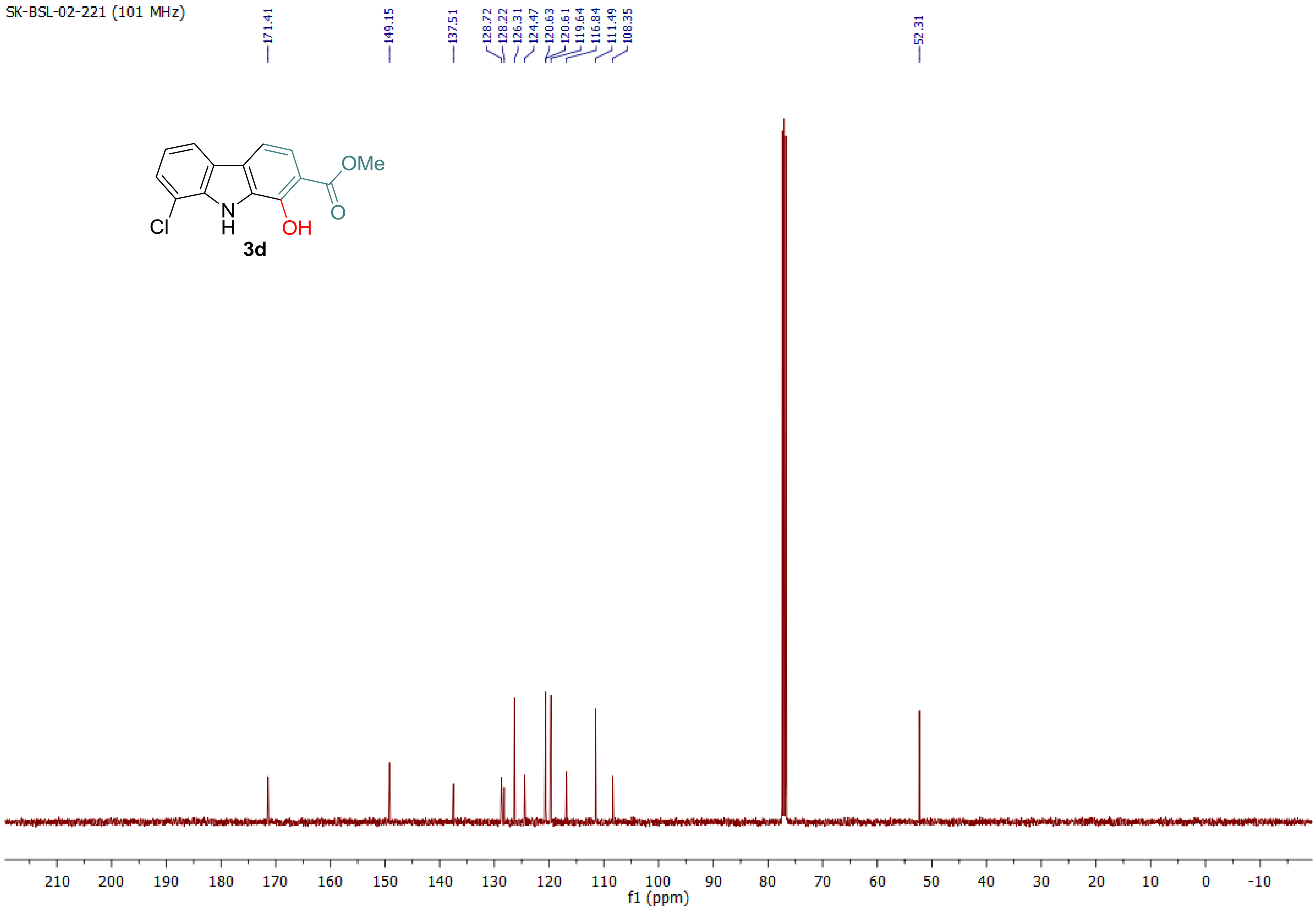
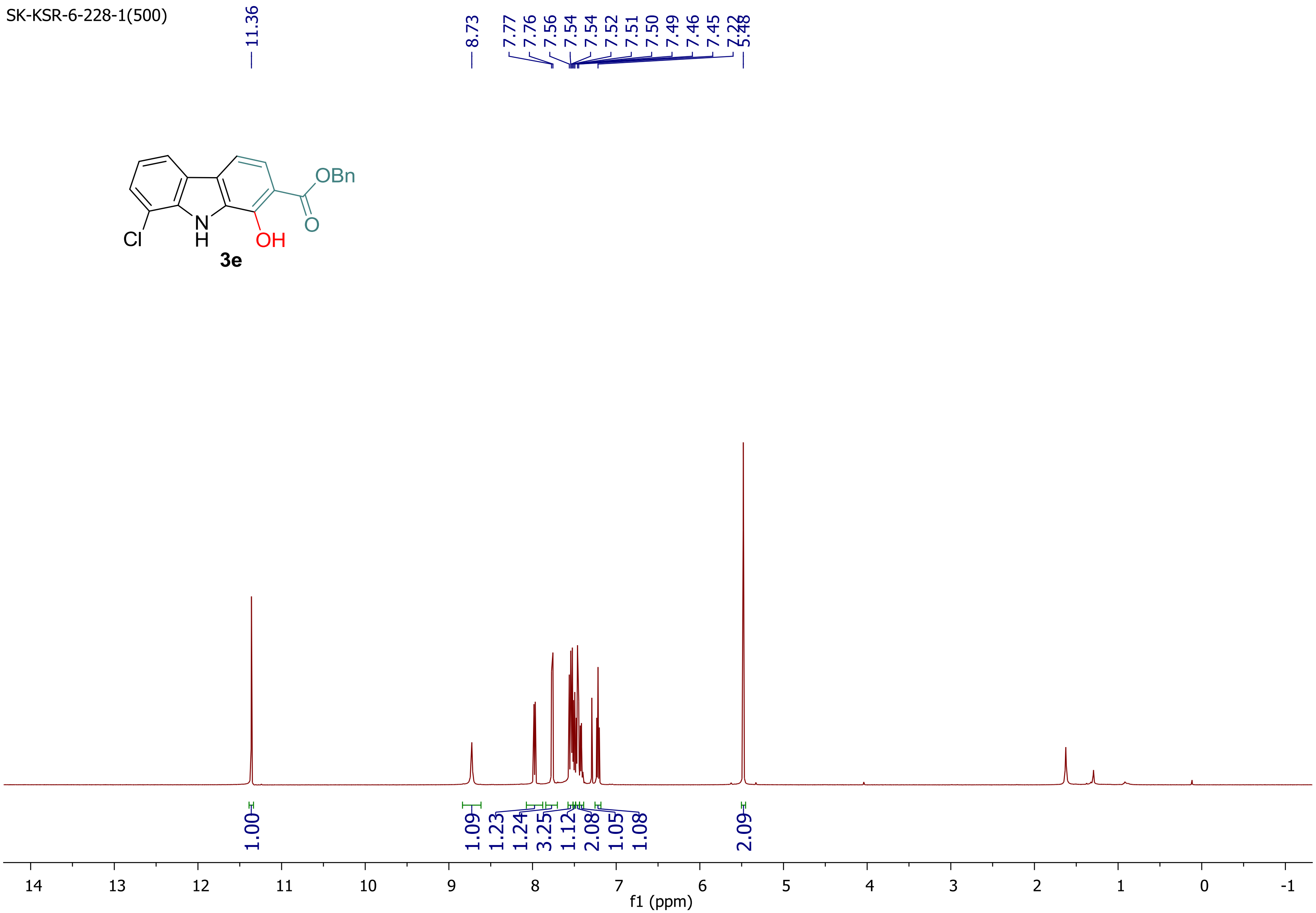
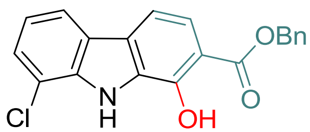
8.67
7.94
7.92
7.68
7.66
7.53
7.51
7.47
7.47
7.45
7.45
7.19
7.18
7.16
3.99
OMe
O
Cl
N
H
OH
3d
1.00
0.97
1.07
1.04
1.09
2.15
1.08
3.19
13.5
12.5
11.5
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

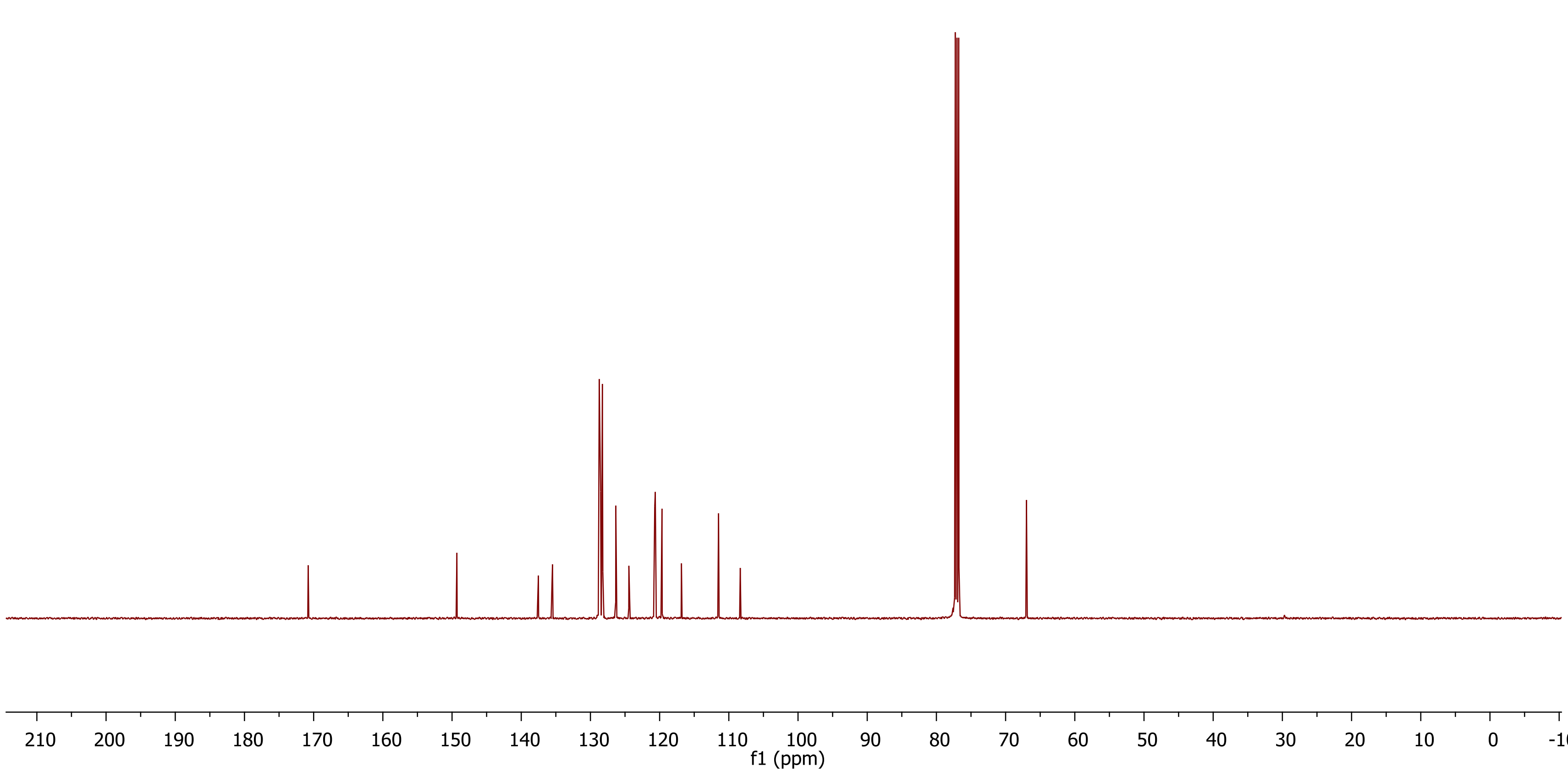

SK-BSL-02-221 (101 MHz)
171.41
149.15
137.51
128.72
128.22
126.31
124.47
120.63
120.61
119.64
116.84
111.49
108.35
52.31
OMe
O
N
H
OH
Cl
3d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

SK-KSR-6-228-1(500)




OBn
O
OH
N
H
Cl

3e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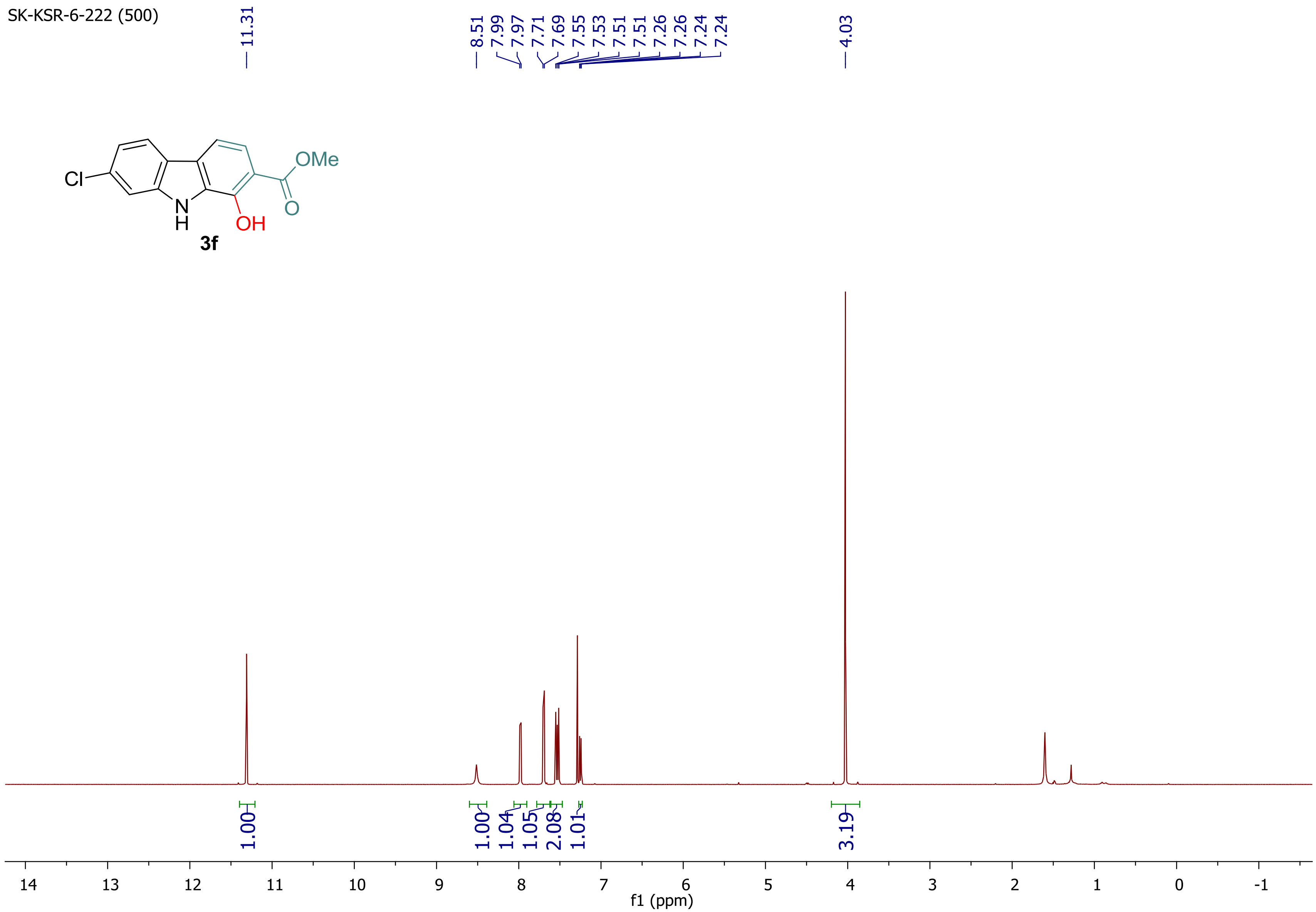
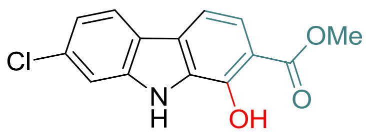
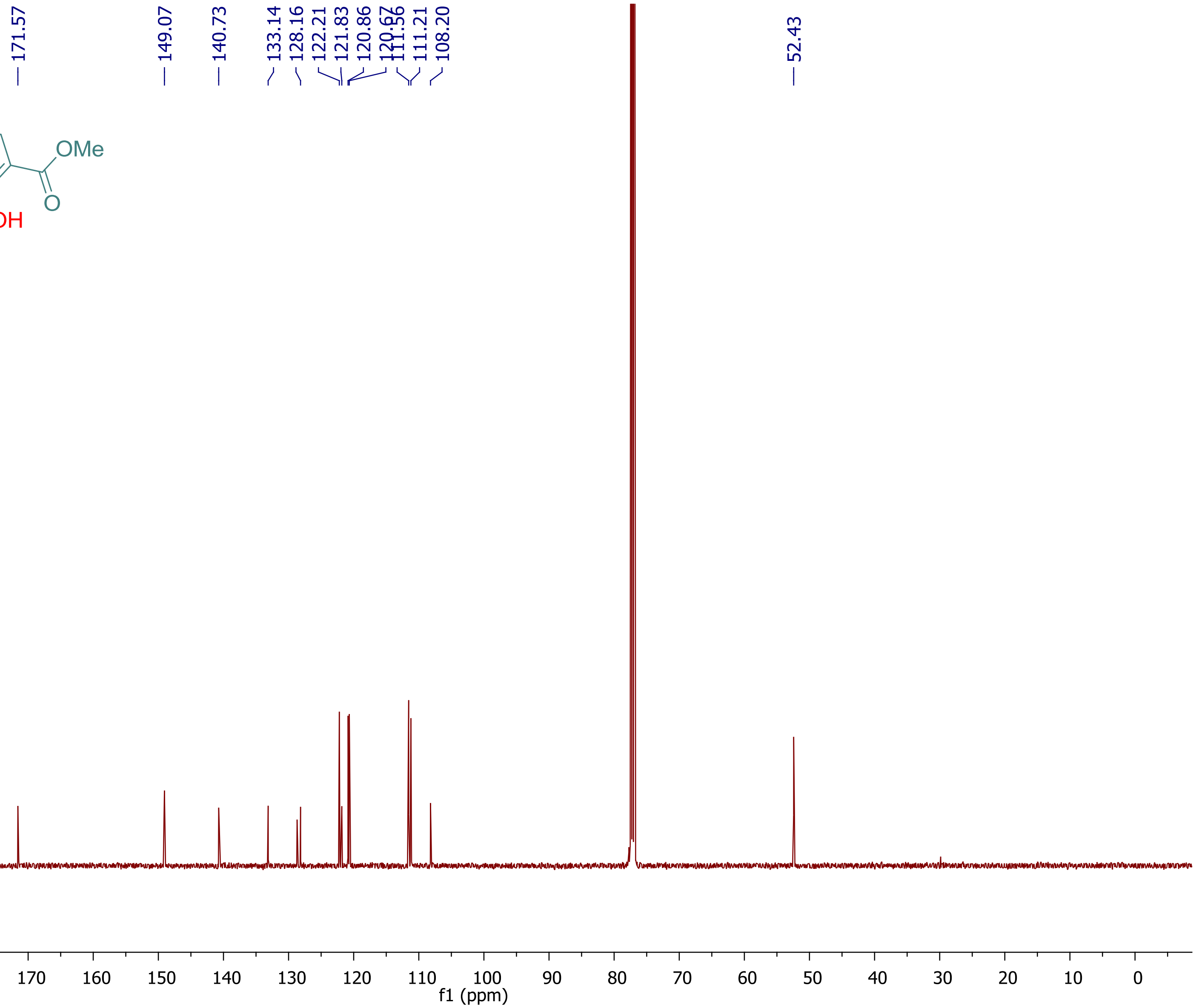
170.79
149.30
137.52
135.48
128.80
128.73
128.53
128.28
128.21
126.33
124.45
120.71
120.63
119.66
116.84
111.48
108.35
66.98
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

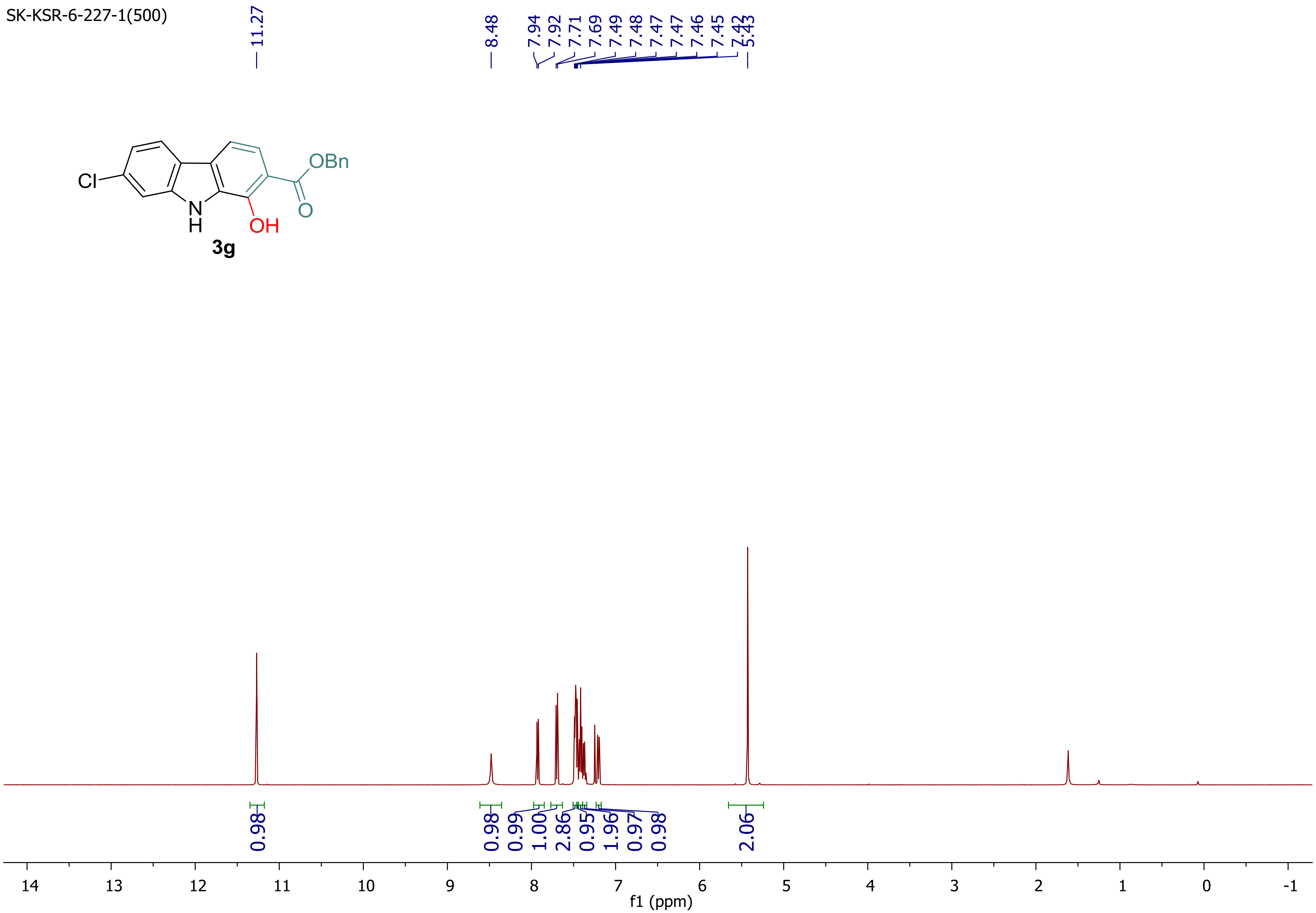

SK-KSR-6-222 (500)
11.31
8.51
7.99
7.97
7.71
7.69
7.55
7.53
7.51
7.51
7.26
7.26
7.24
7.24
4.03
Cl
N
H
OH
OMe
O
3f
1.00
1.00
1.04
1.05
2.08
1.01
3.19
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

SK-KSR-6-222-1P(500MHz)



3f




SK-KSR-6-227-1(500)
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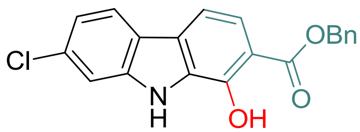
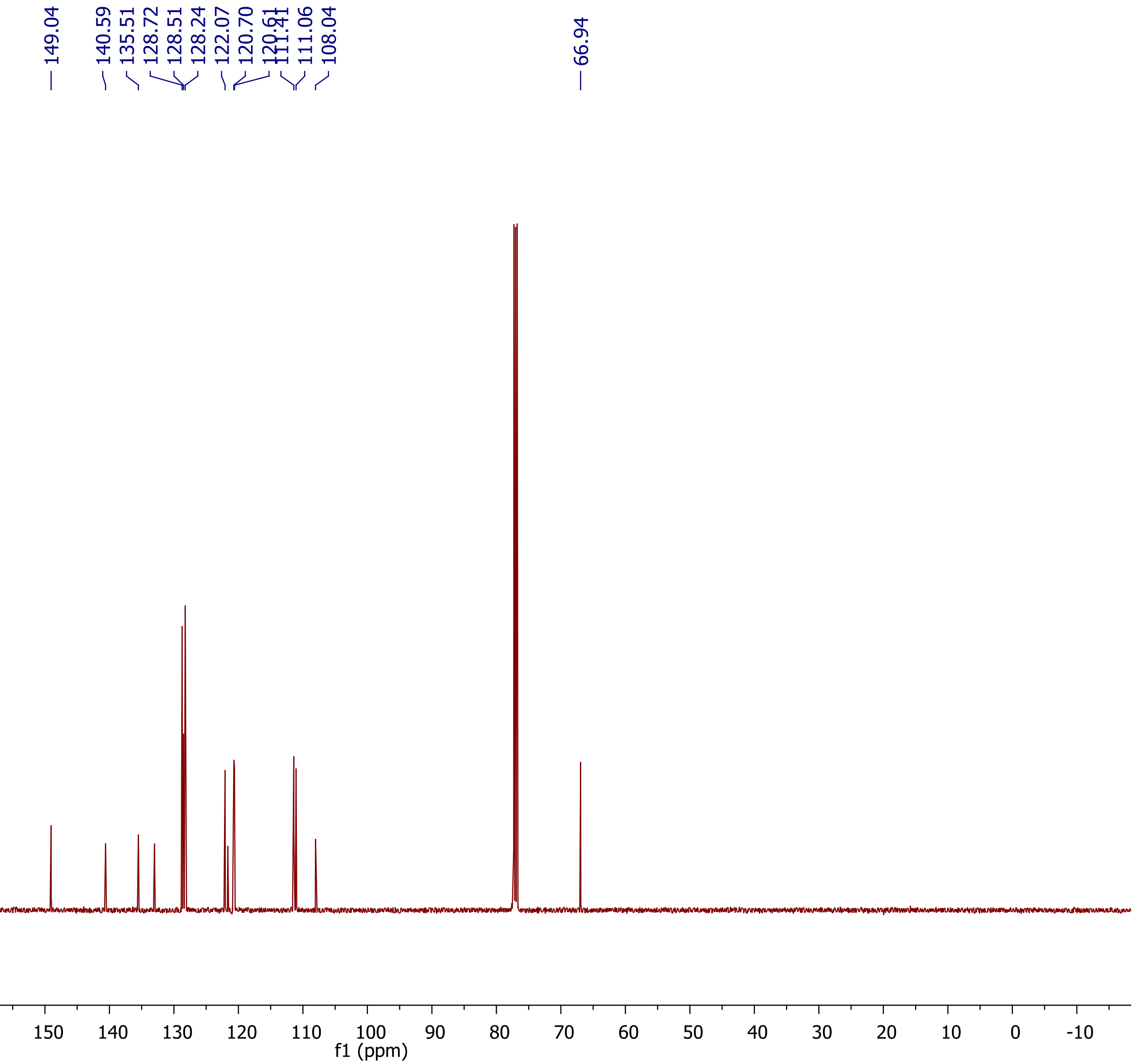
8.48
7.94
7.92
7.71
7.69
7.49
7.48
7.47
7.47
7.46
7.45
7.43
5.42
Cl
N
H
OH
OBn
O
3g
0.98
0.98
0.99
1.00
2.86
0.95
1.96
0.97
0.98
2.06
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

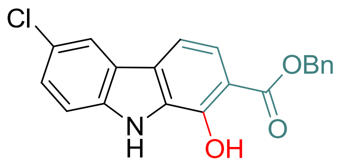
SK-KSR-6-227



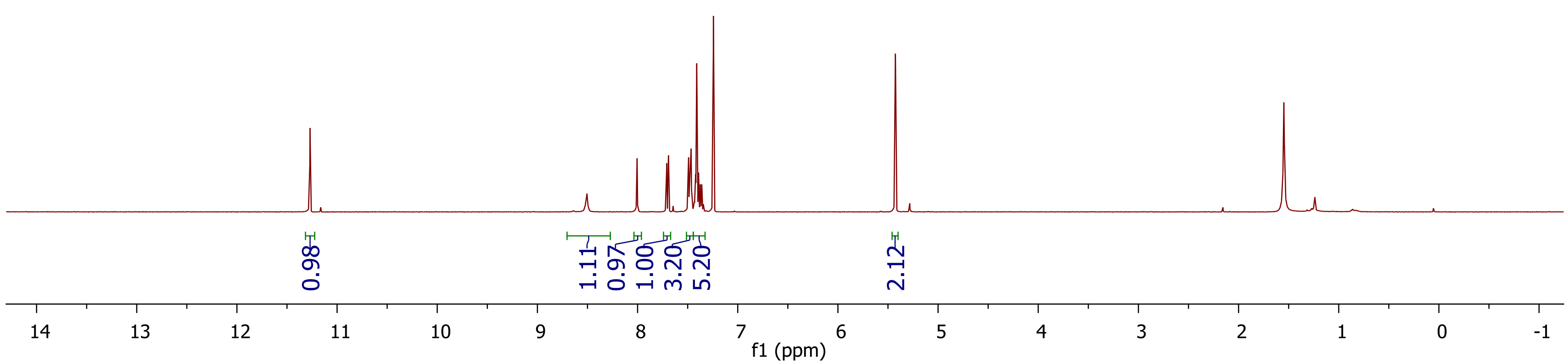
3g

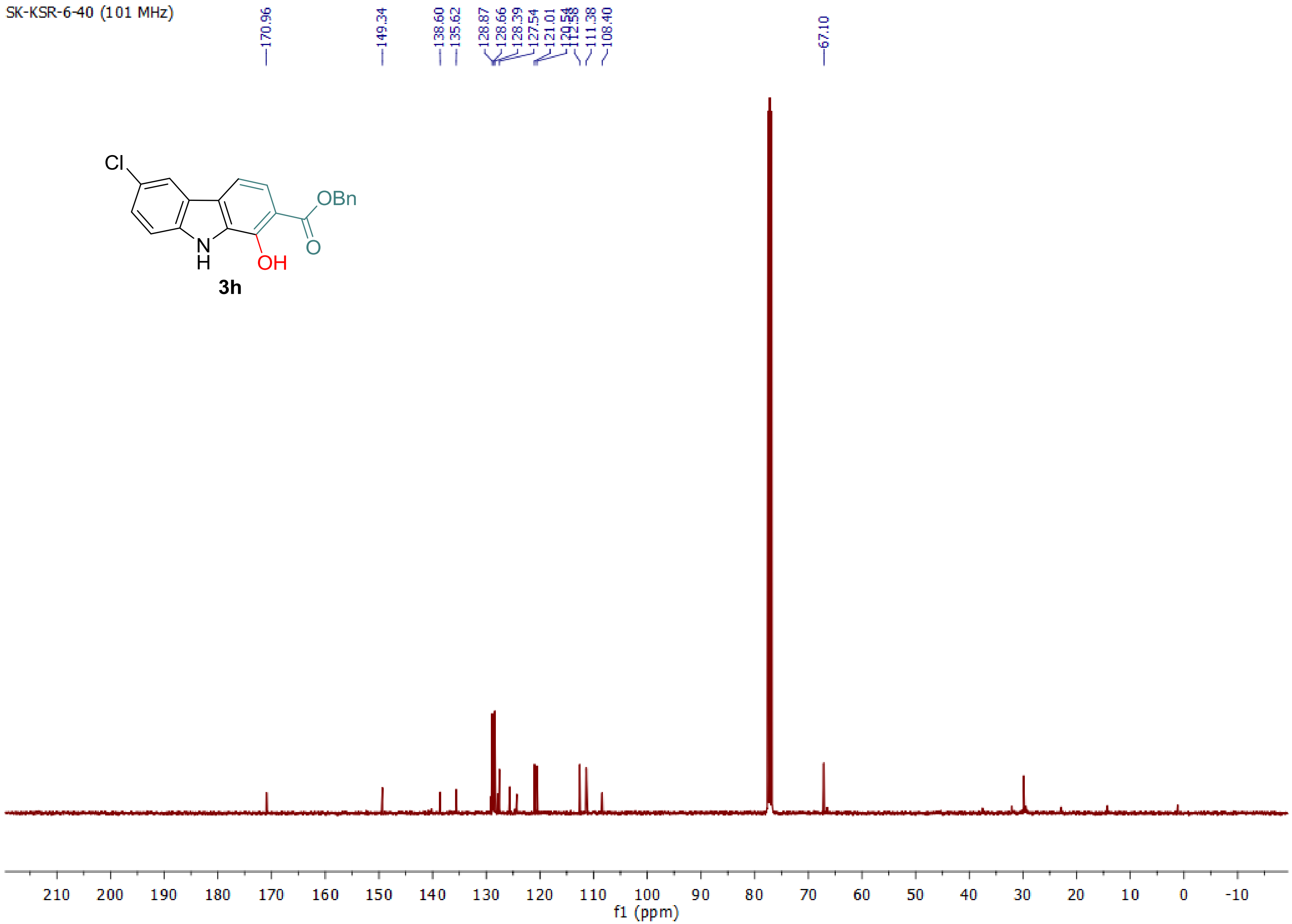


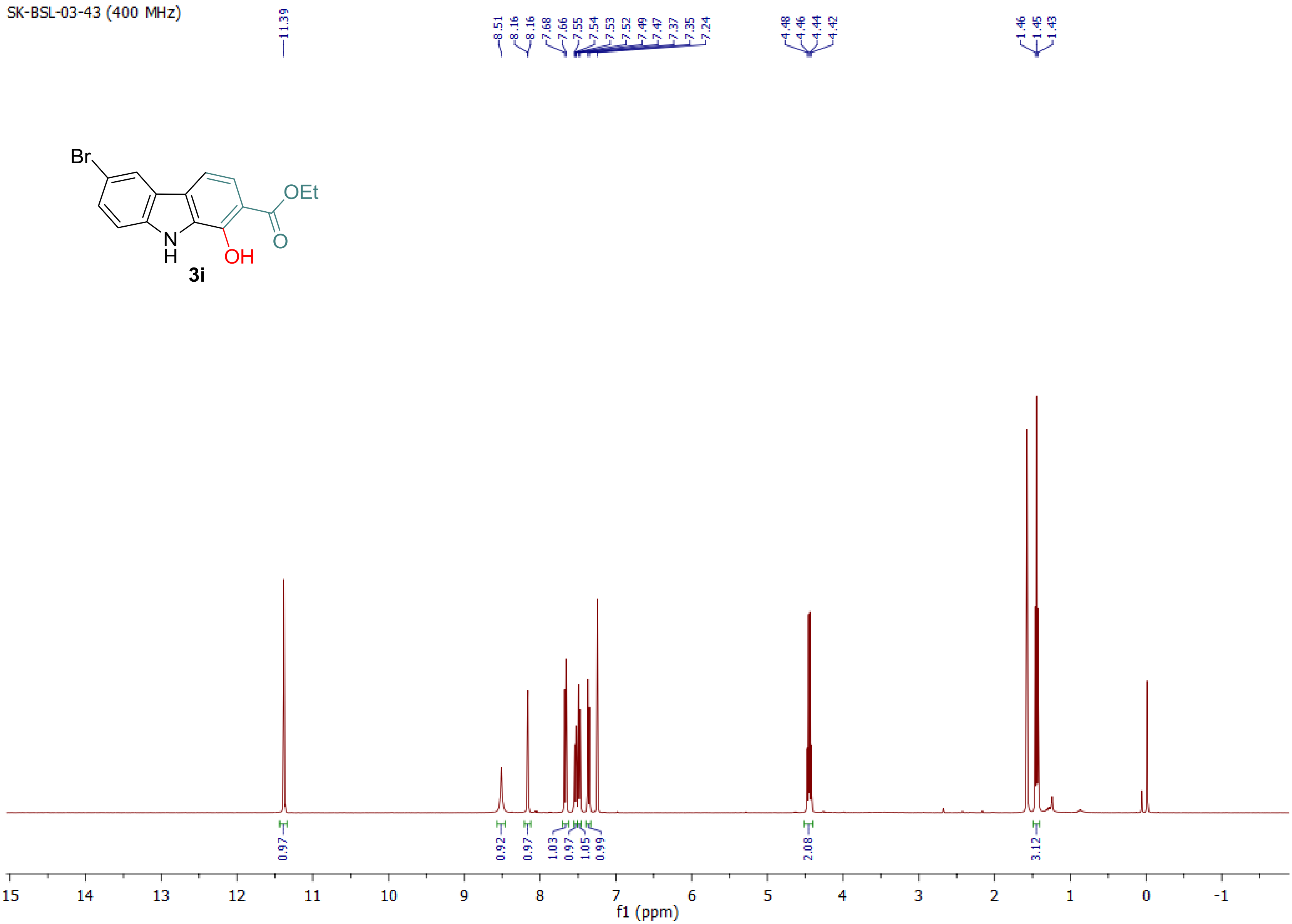
SK-KSR-6-40-1Rp(500MHz)

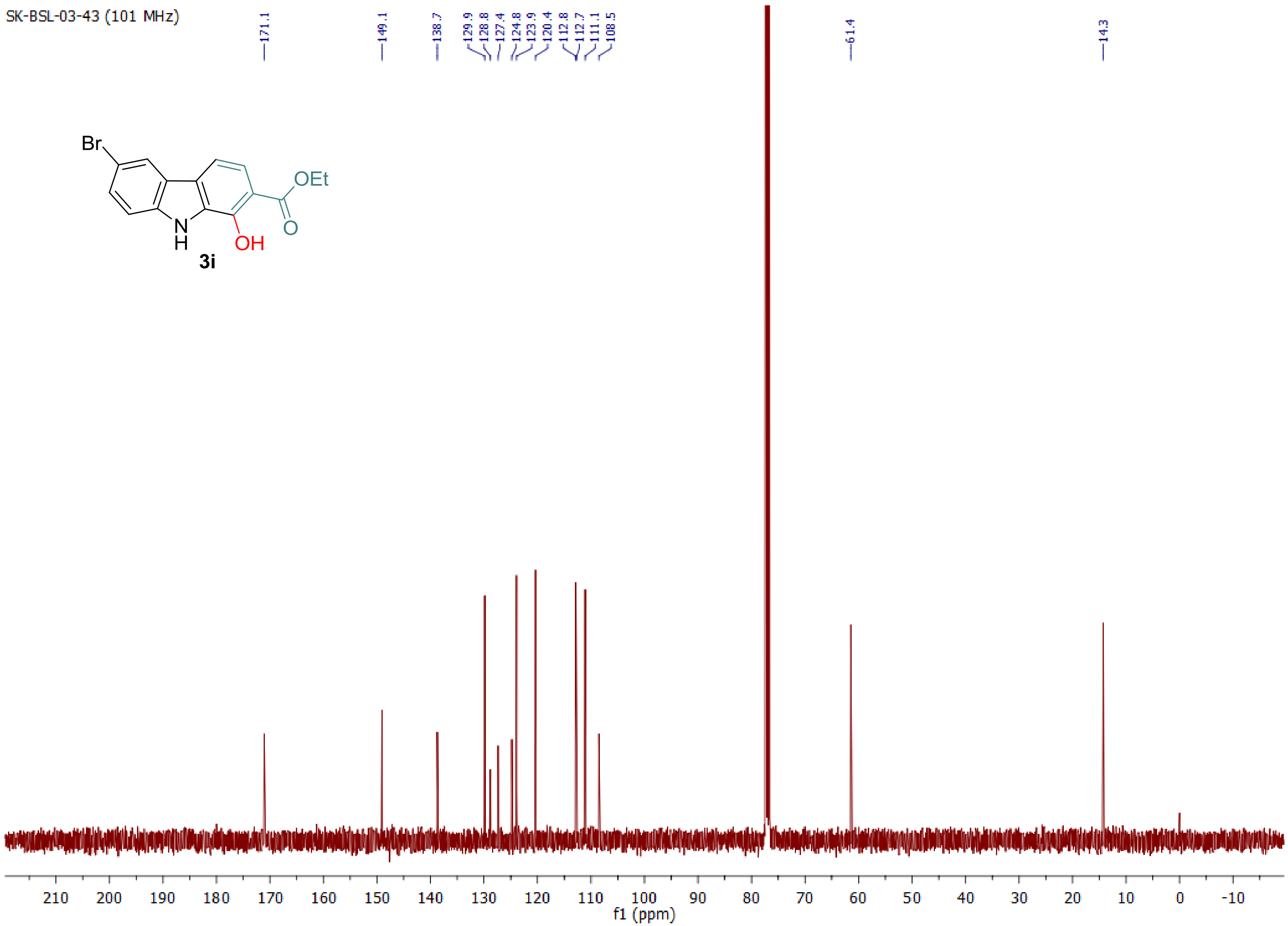


3h



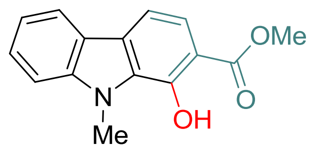

SK-KSR-6-40 (101 MHz)
170.96
149.34
138.60
135.62
128.87
128.66
128.39
127.54
121.01
111.38
108.40
67.10
Cl
OBn
O
N
H
OH
3h
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


SK-BSL-03-43 (400 MHz)
11.39
8.51
8.16
8.16
7.68
7.66
7.55
7.54
7.53
7.52
7.49
7.47
7.37
7.35
7.24
4.48
4.46
4.44
4.42
1.46
1.45
1.43
Br
OEt
O
N
H
OH
3i
0.97
0.92
0.97
1.03
0.97
1.05
0.99
2.08
3.12
f1 (ppm)

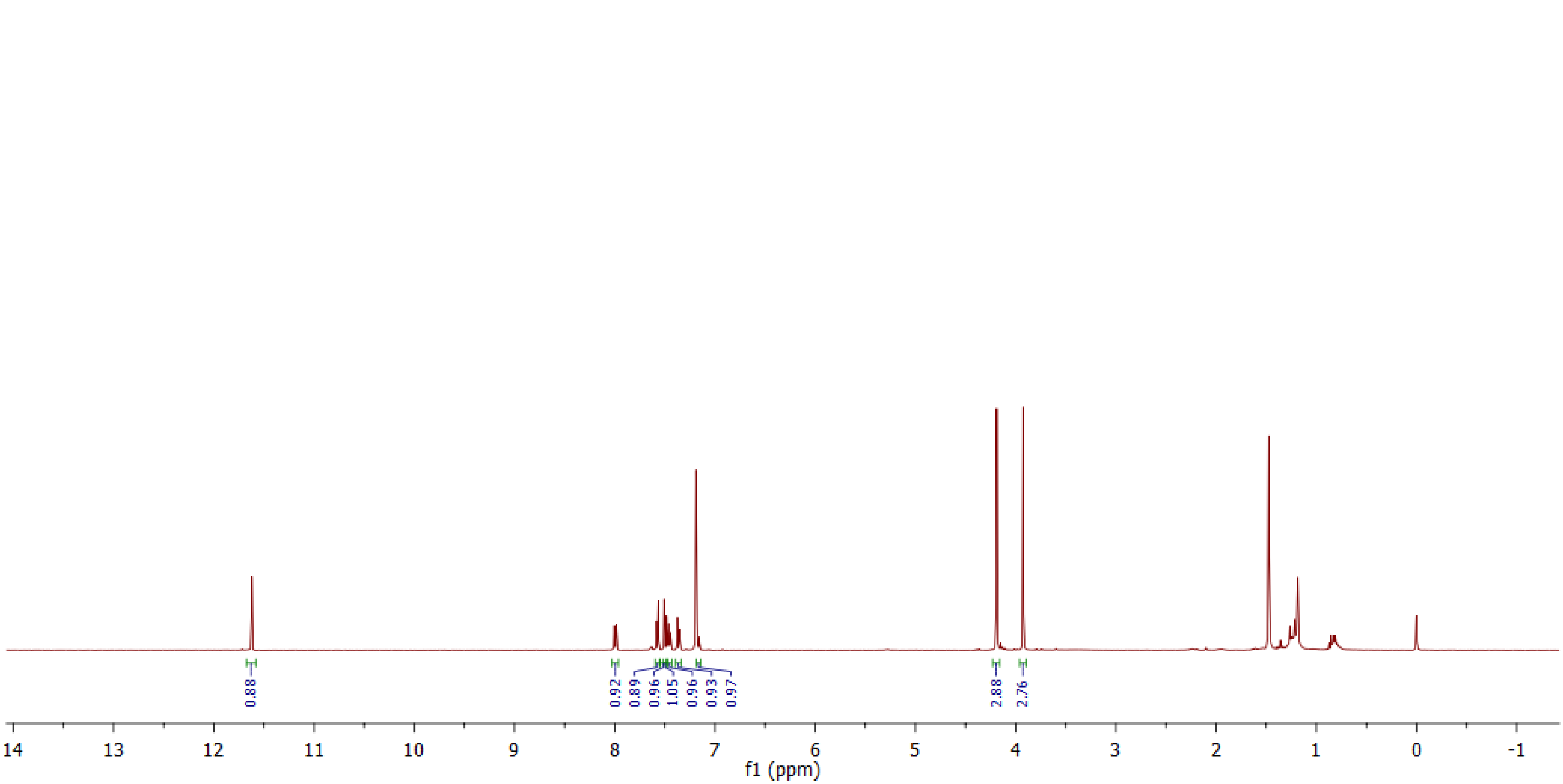

SK-BSL-03-43 (101 MHz)
171.1
149.1
138.7
129.9
128.8
127.4
124.8
123.9
120.4
112.8
112.7
111.1
108.5
61.4
14.3
Br
OEt
O
N
H
OH
f1 (ppm)

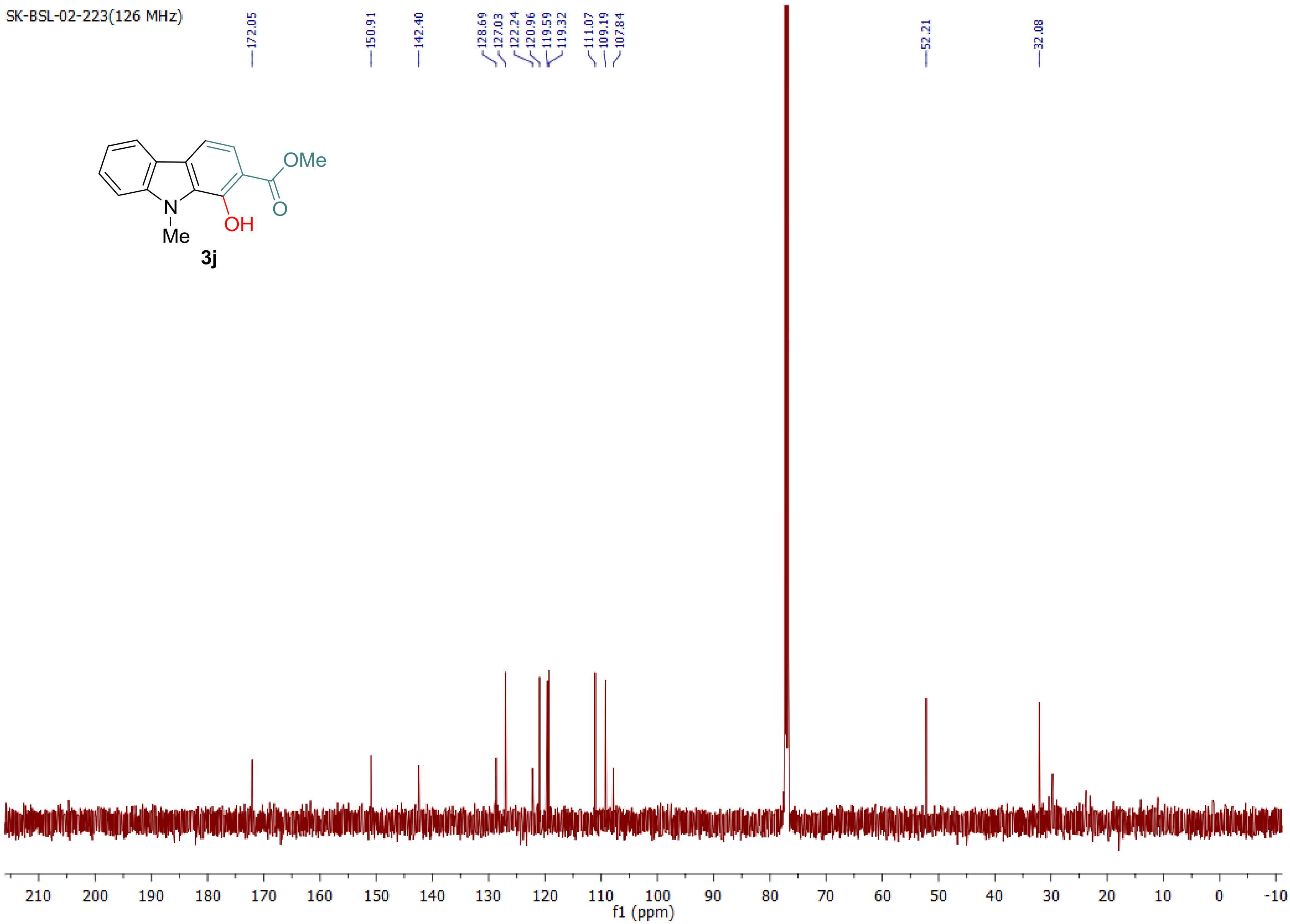
3i

SK-BSL-02-223 (400 MHz)

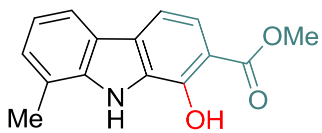


3j



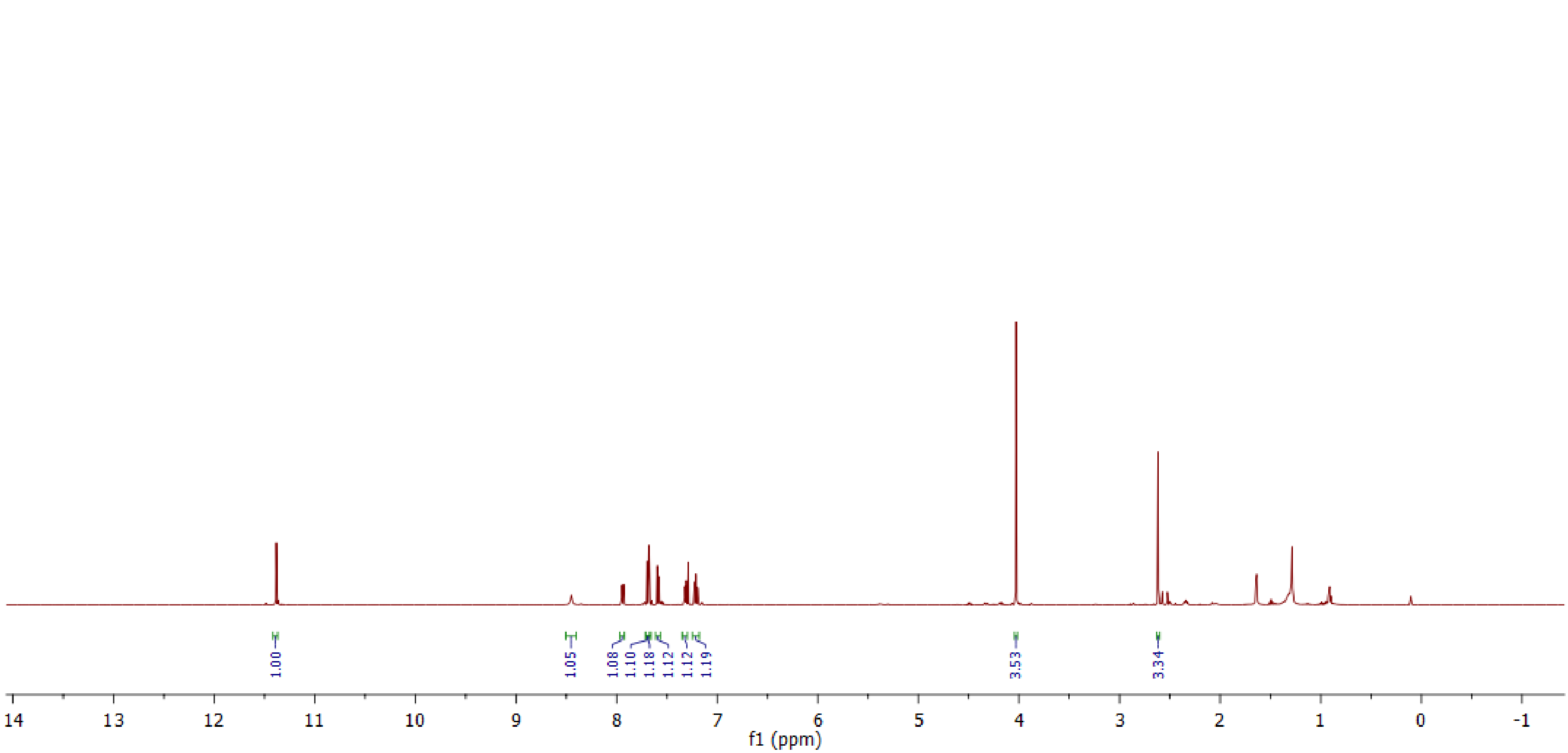


SK-BSL-02-223(126 MHz)
172.05
150.91
142.40
128.69
127.03
122.24
120.96
119.59
119.32
111.07
109.19
107.84
52.21
32.08
OMe
O
N
Me
OH
3j
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



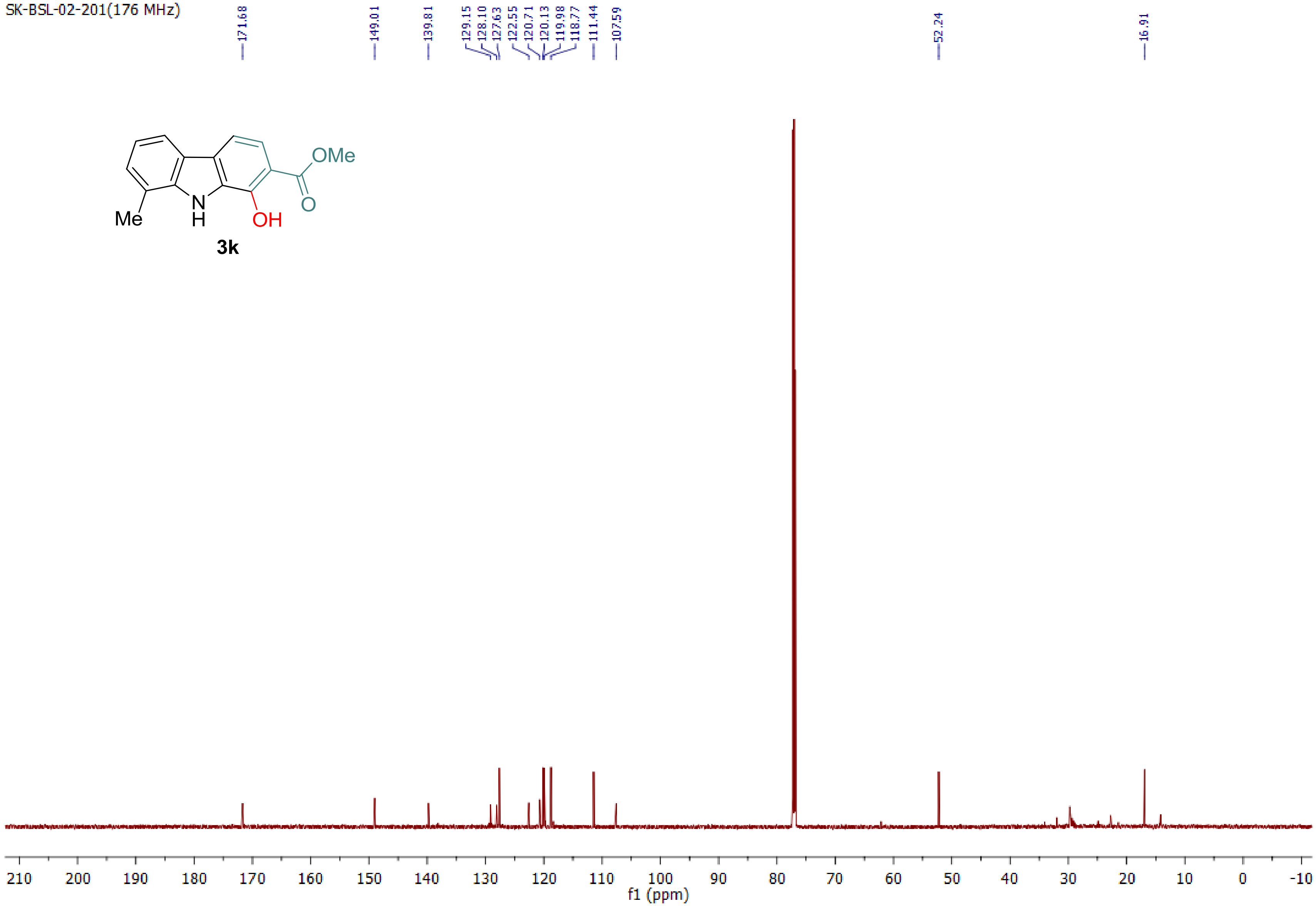
OMe
O
N
H
OH
Me

3k

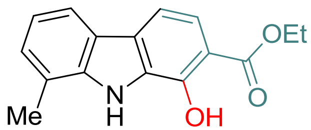


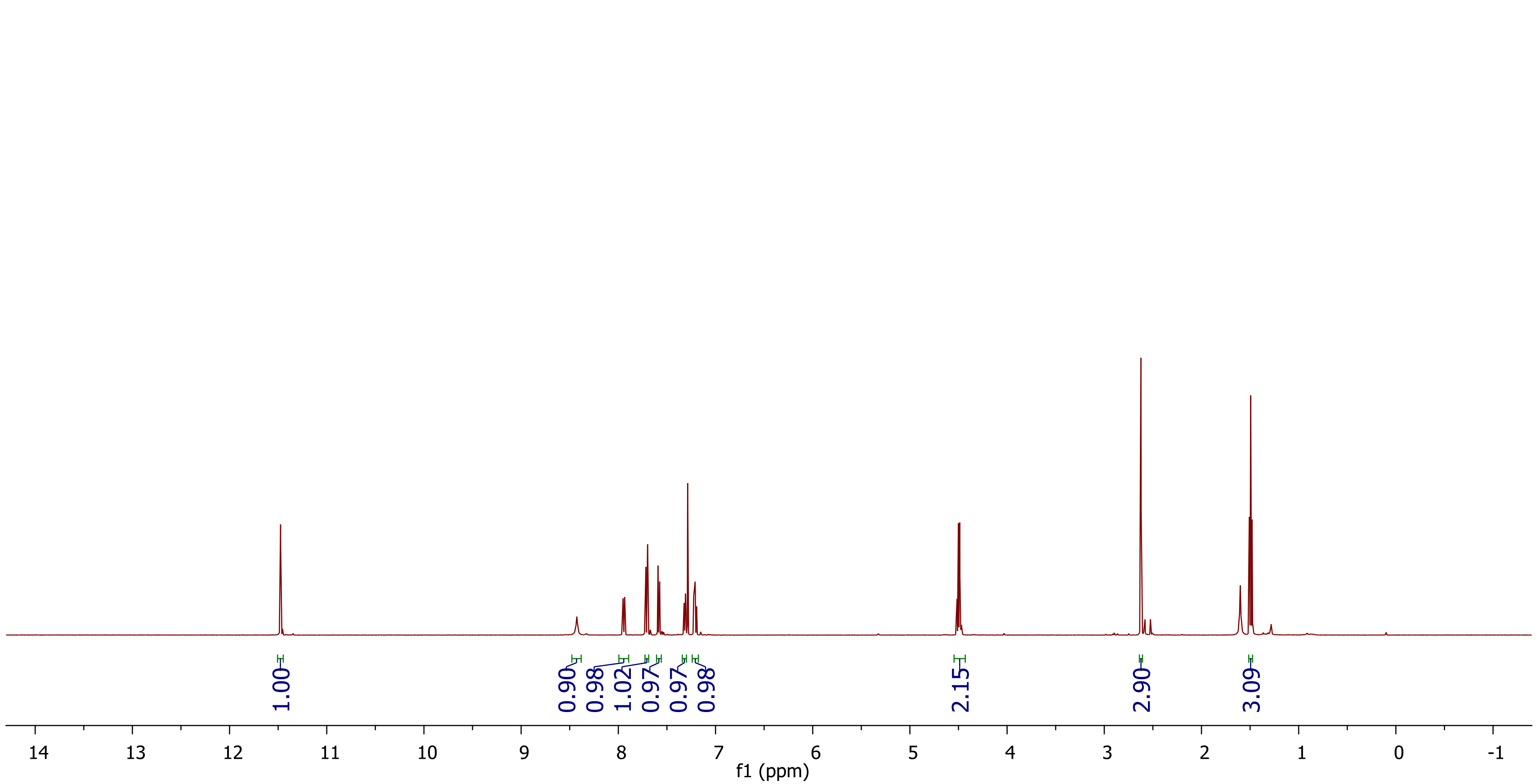
SK-BSL-02-201(500MHz)
11.38
8.45
7.95
7.93
7.70
7.68
7.60
7.58
7.32
7.32
7.32
7.31
7.31
7.31
7.29
7.22
7.21
7.19
4.03
2.62
1.00
1.05
1.08
1.10
1.18
1.12
1.12
1.19
3.53
3.34
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

SK-BSL-02-201(176 MHz)

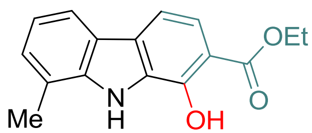


SK-KSR-6-200-1-Rep(500MHz)

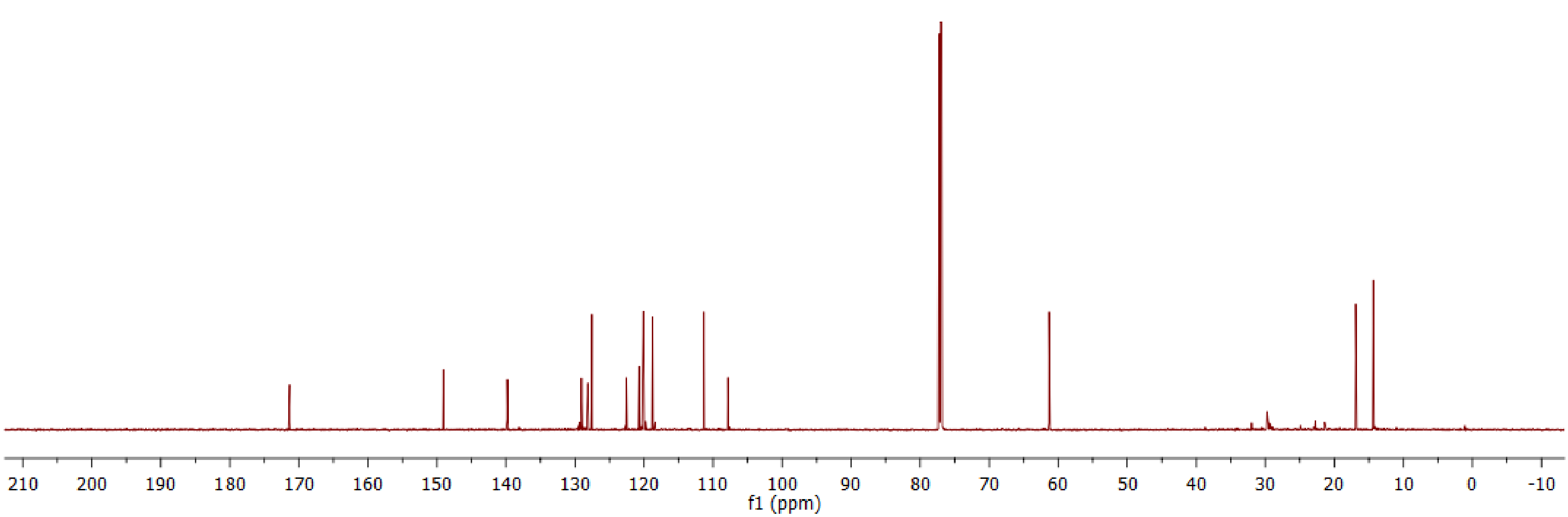

3l



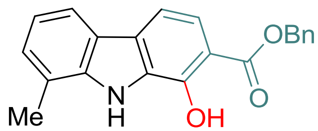
SK-BSL-02-200(176 MHz)



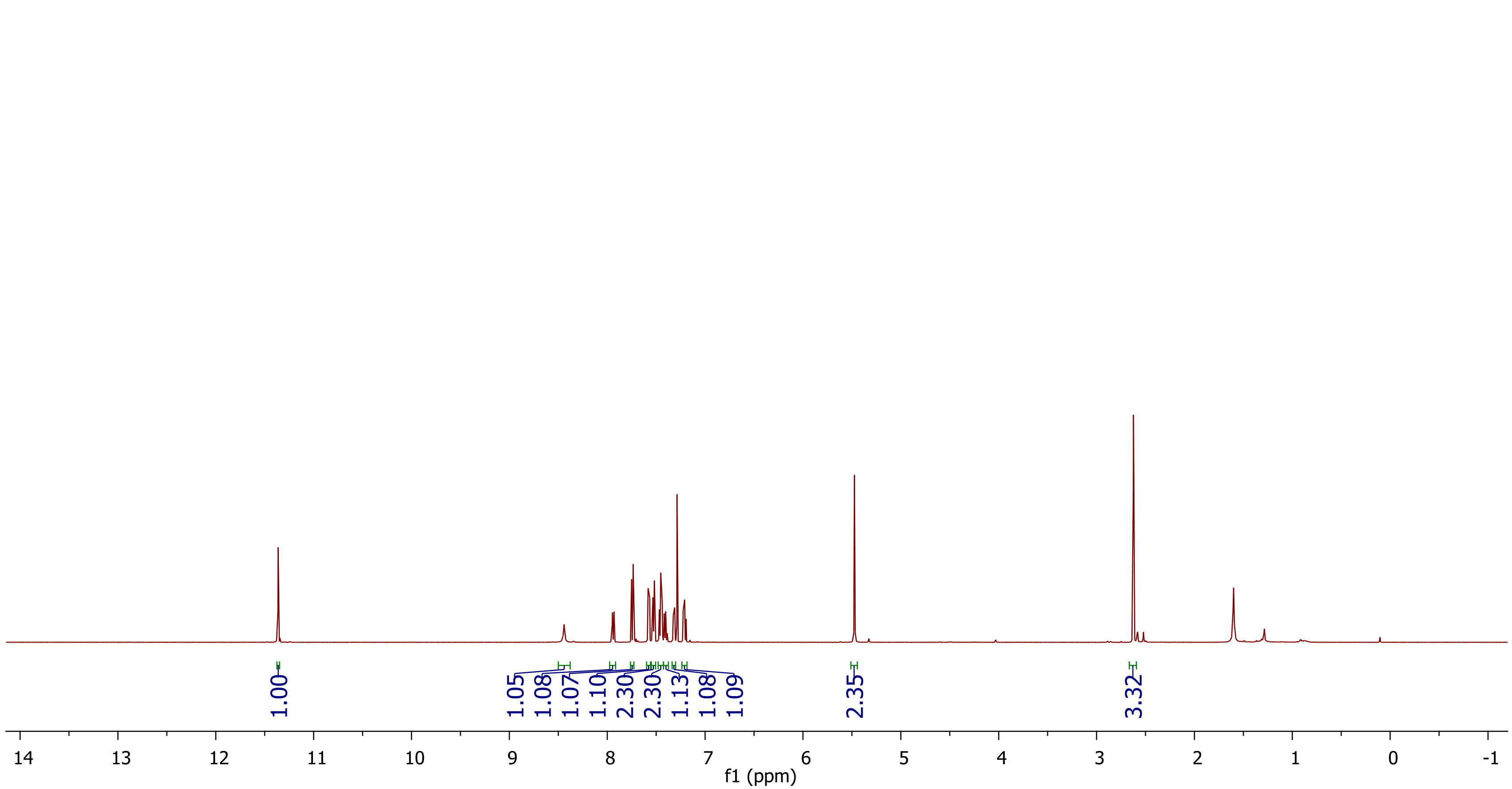
3l



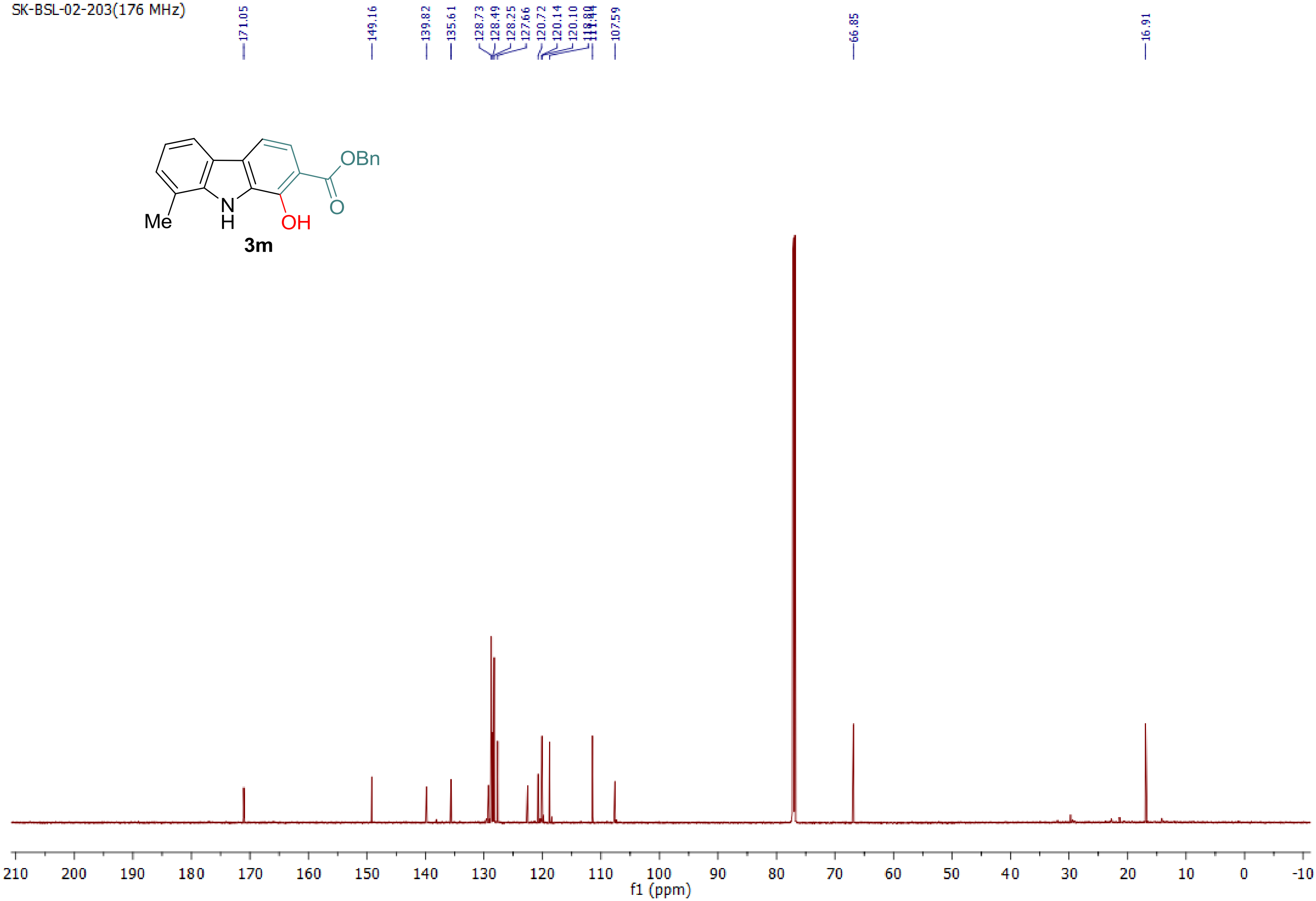
SK-KSR-6-203-1RP(500MHz)



3m

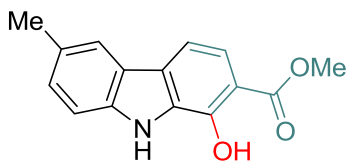


SK-BSL-02-203(176 MHz)

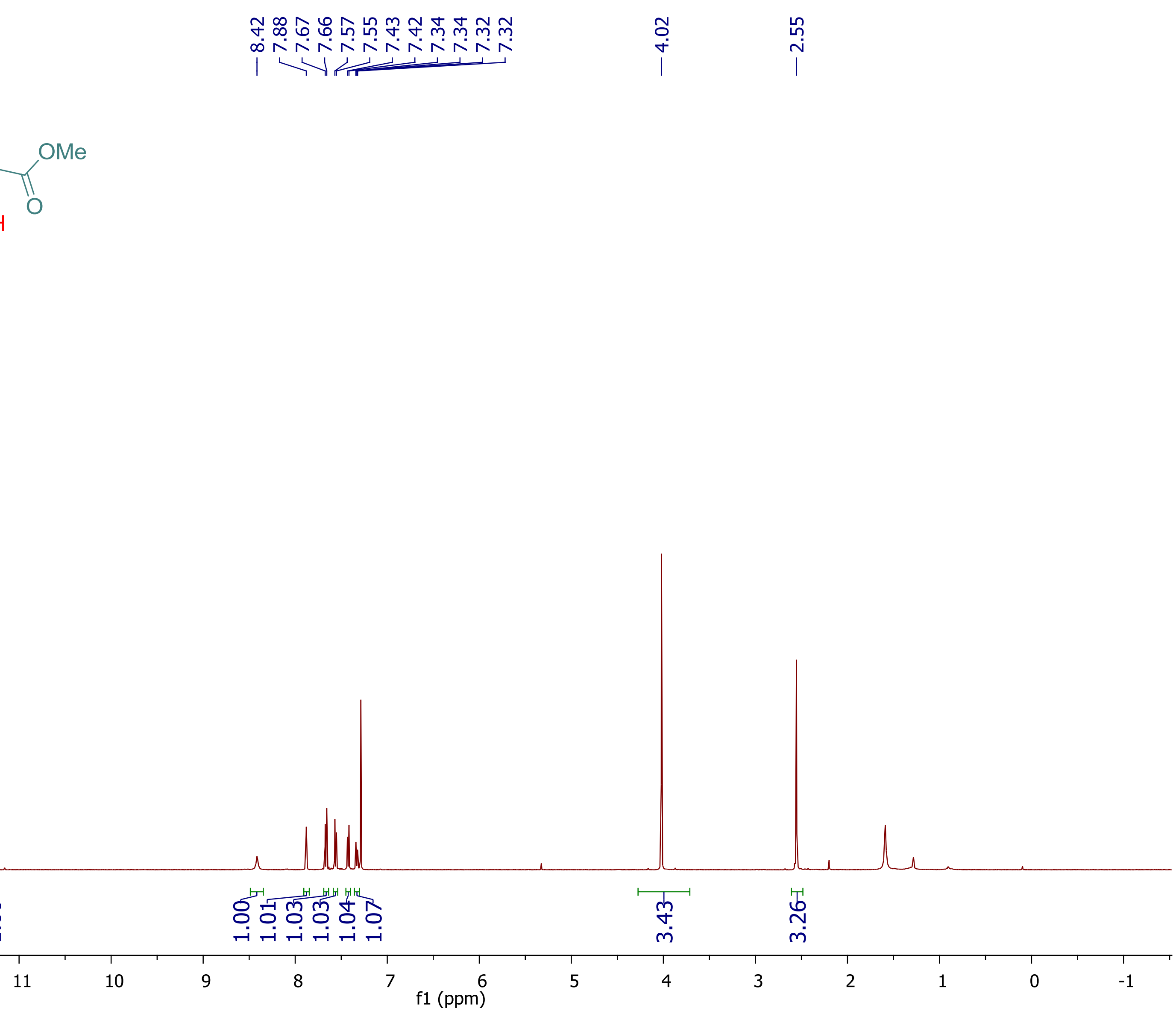


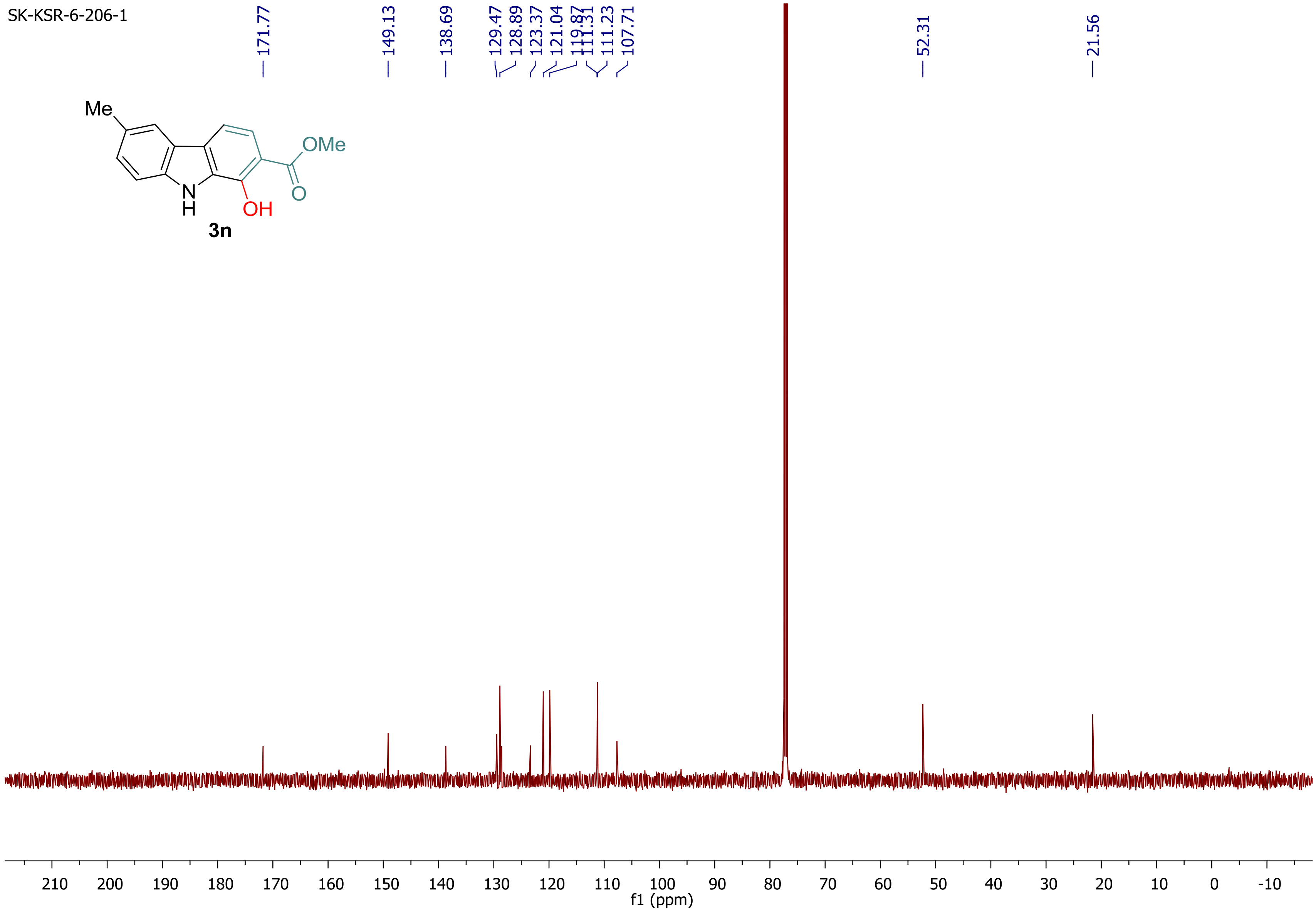
3m

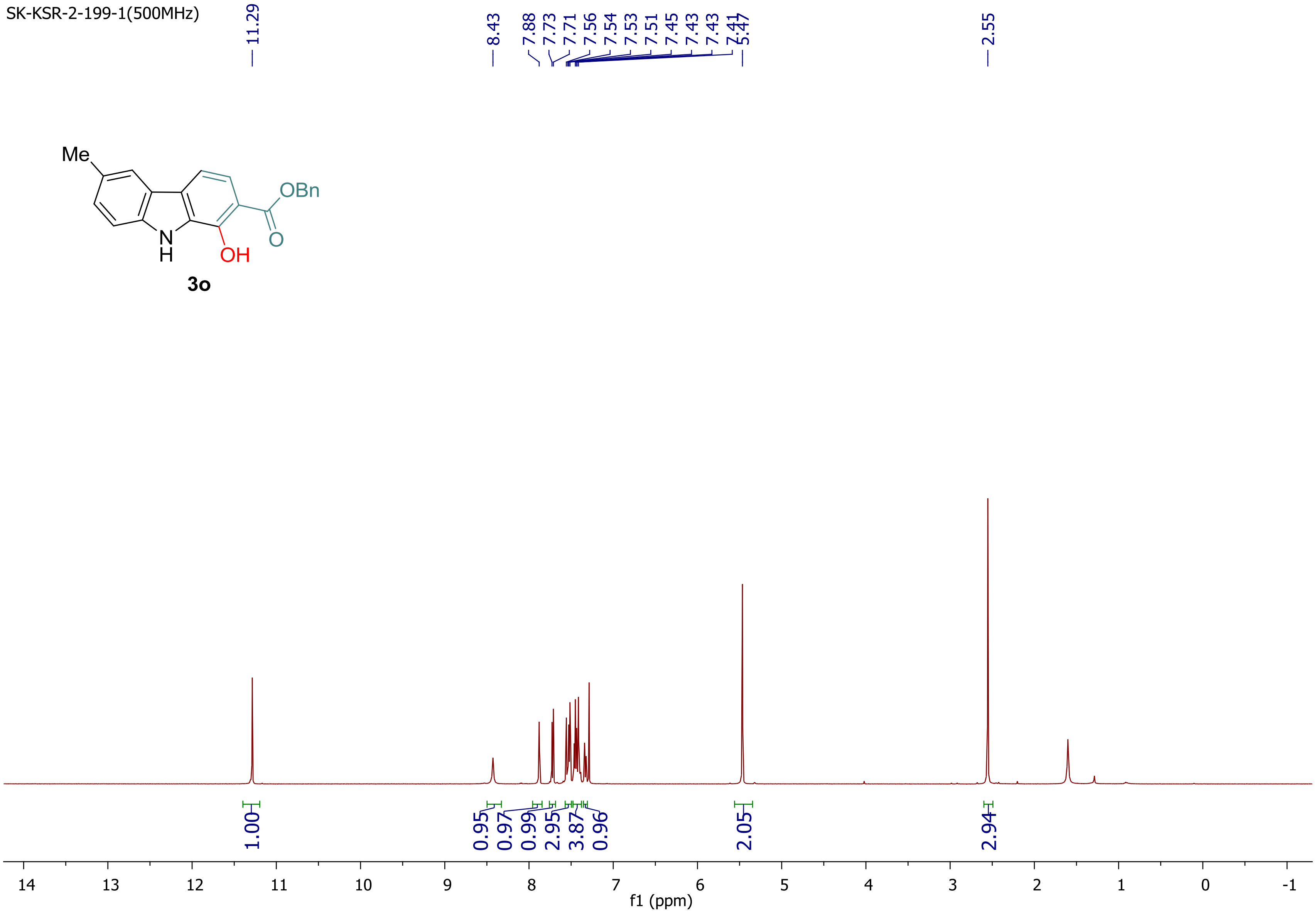
SK-KSR-6-206-1P(500MHz)



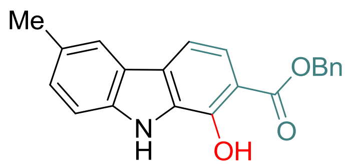
3n



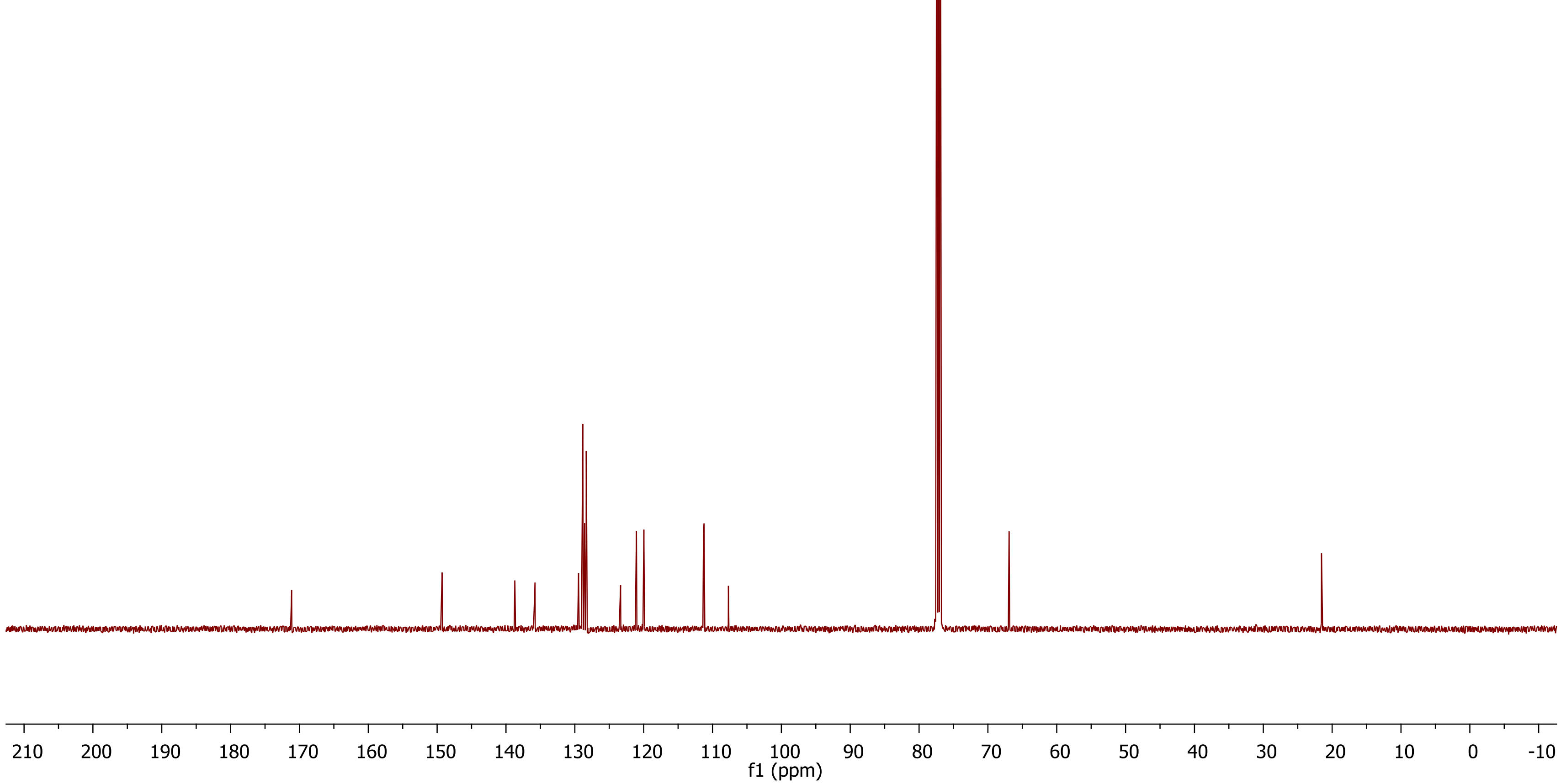

SK-KSR-6-206-1
171.77
149.13
138.69
129.47
128.89
123.37
121.04
119.87
111.31
111.23
107.71
52.31
21.56
Me
OMe
O
N
H
OH
3n
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

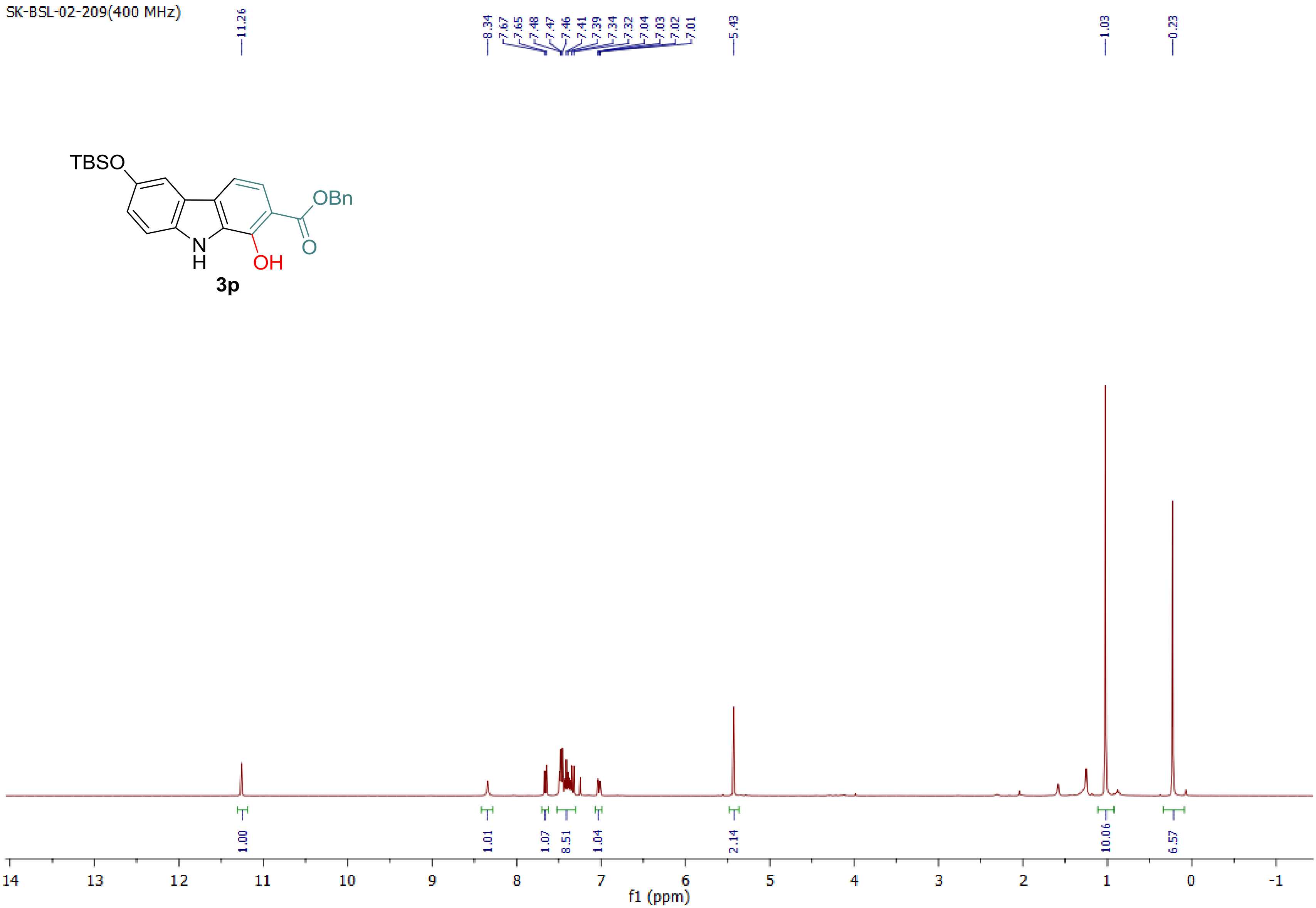

SK-KSR-2-199-1(500MHz)
11.29
8.43
7.88
7.73
7.71
7.56
7.54
7.53
7.51
7.45
7.43
7.43
7.41
5.47
2.55
1.00
0.95
0.97
0.99
2.95
3.87
0.96
2.05
2.94
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)
Me
OBn
O
N
H
OH

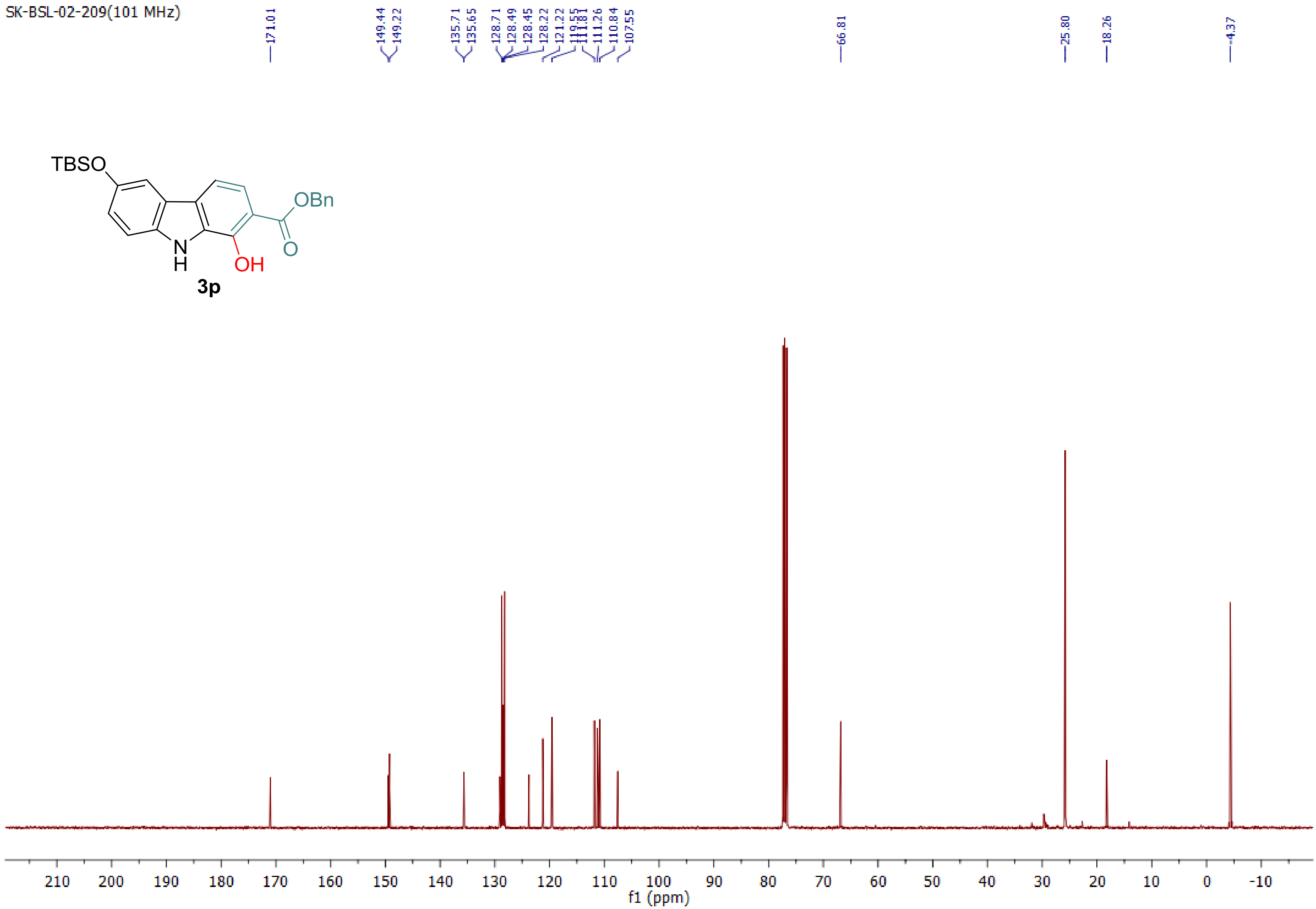
3o


Me
OBn
O
N
H
OH

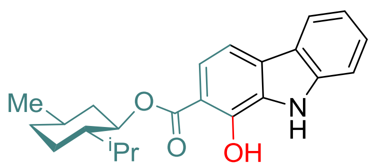
3o


SK-KSR-02-199
171.13
149.27
138.71
129.46
128.92
128.84
128.66
128.58
128.35
121.05
119.97
111.31
111.23
107.69
66.93
21.55
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


SK-BSL-02-209(400 MHz)
11.26
8.34
7.67
7.65
7.48
7.47
7.46
7.41
7.39
7.34
7.32
7.04
7.03
7.02
7.01
5.43
1.03
0.23
TBSO
OBn
O
N
H
OH
3p
1.00
1.01
1.07
8.51
1.04
2.14
10.06
6.57
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

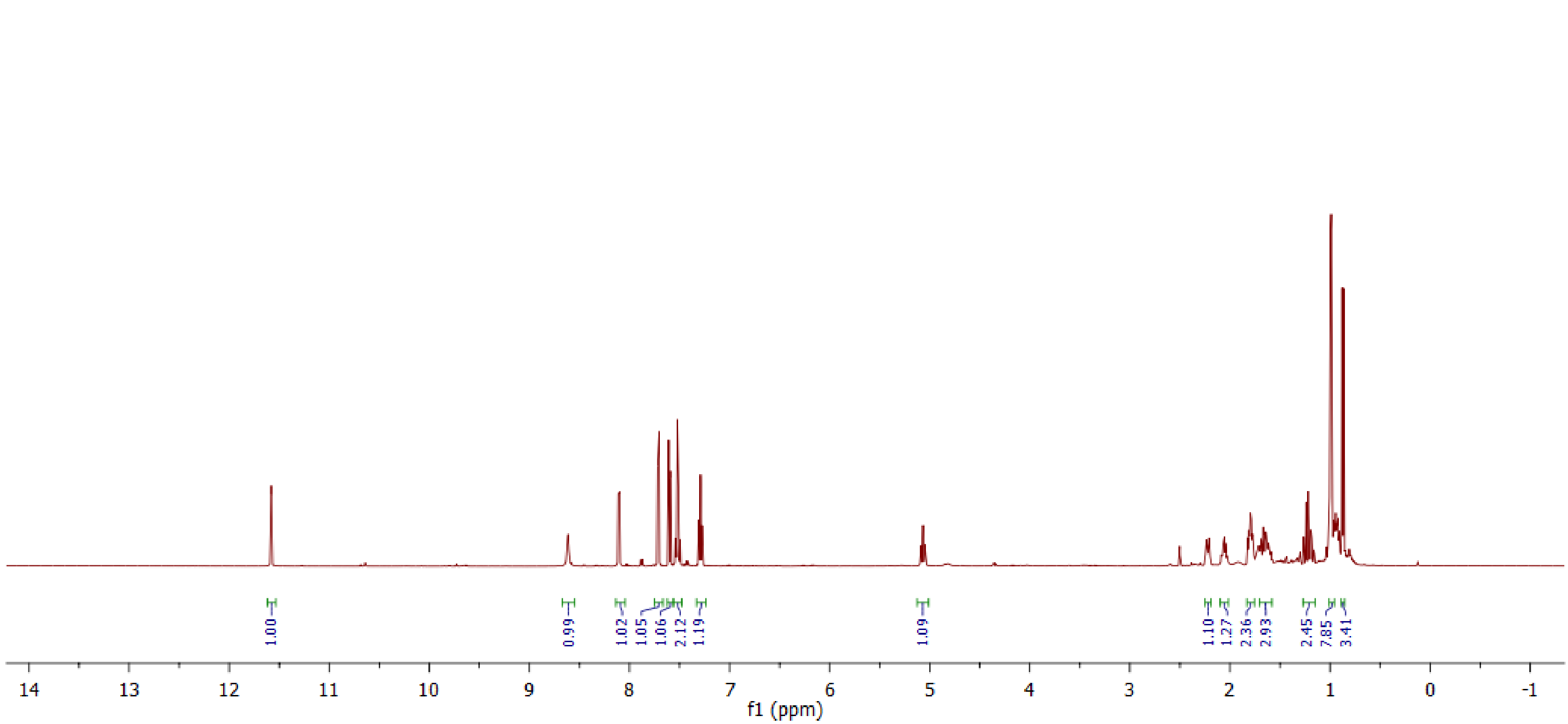

SK-BSL-02-209(101 MHz)
171.01
149.44
149.22
135.71
135.65
128.71
128.49
128.45
128.22
121.22
119.55
111.81
111.26
110.84
107.55
66.81
25.80
18.26
-4.37
TBSO
OBn
O
N
H
OH
3p
f1 (ppm)

BSL-03-58



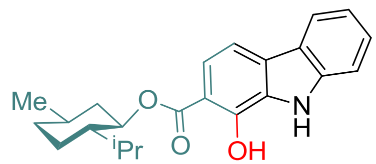
Me
O
O
OH
N
H
iPr

3q

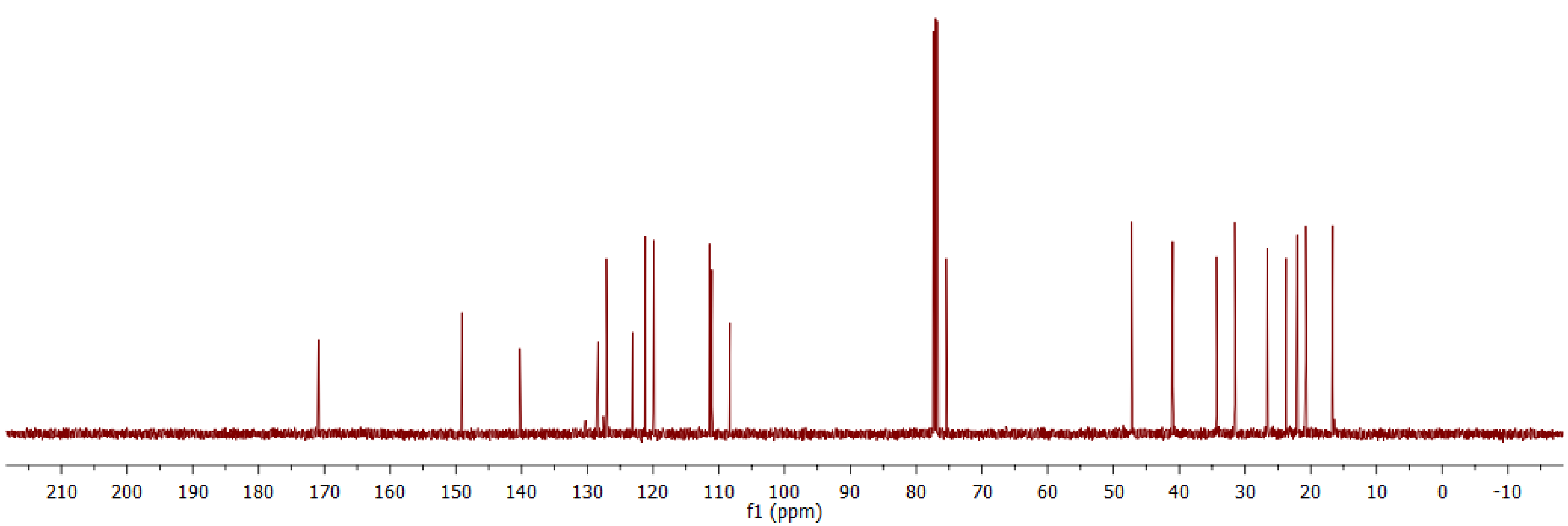


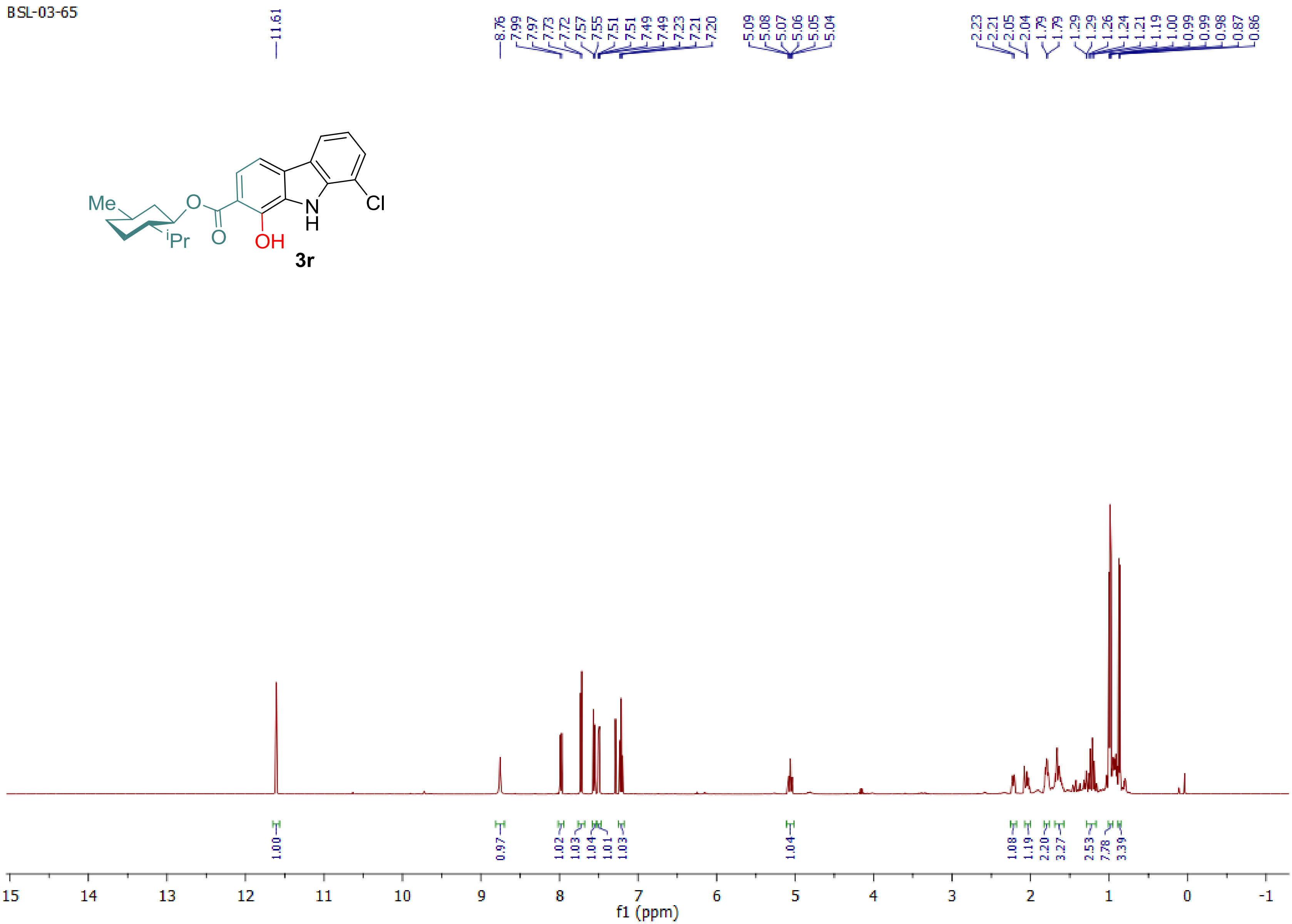
11.58
8.61
8.11
8.11
8.10
8.10
7.72
7.70
7.61
7.59
7.52
7.51
7.51
7.30
7.29
7.29
5.09
5.08
5.07
5.06
5.05
5.04
2.23
2.21
2.10
2.05
2.02
1.83
1.79
1.77
1.70
1.58
1.26
1.24
1.22
1.16
1.04
1.00
0.99
0.99
0.98
0.91
0.88
0.86
1.00
0.99
1.02
1.05
1.06
2.12
1.19
1.09
1.10
1.27
2.36
2.93
2.45
7.85
3.41
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

BSL-03-58



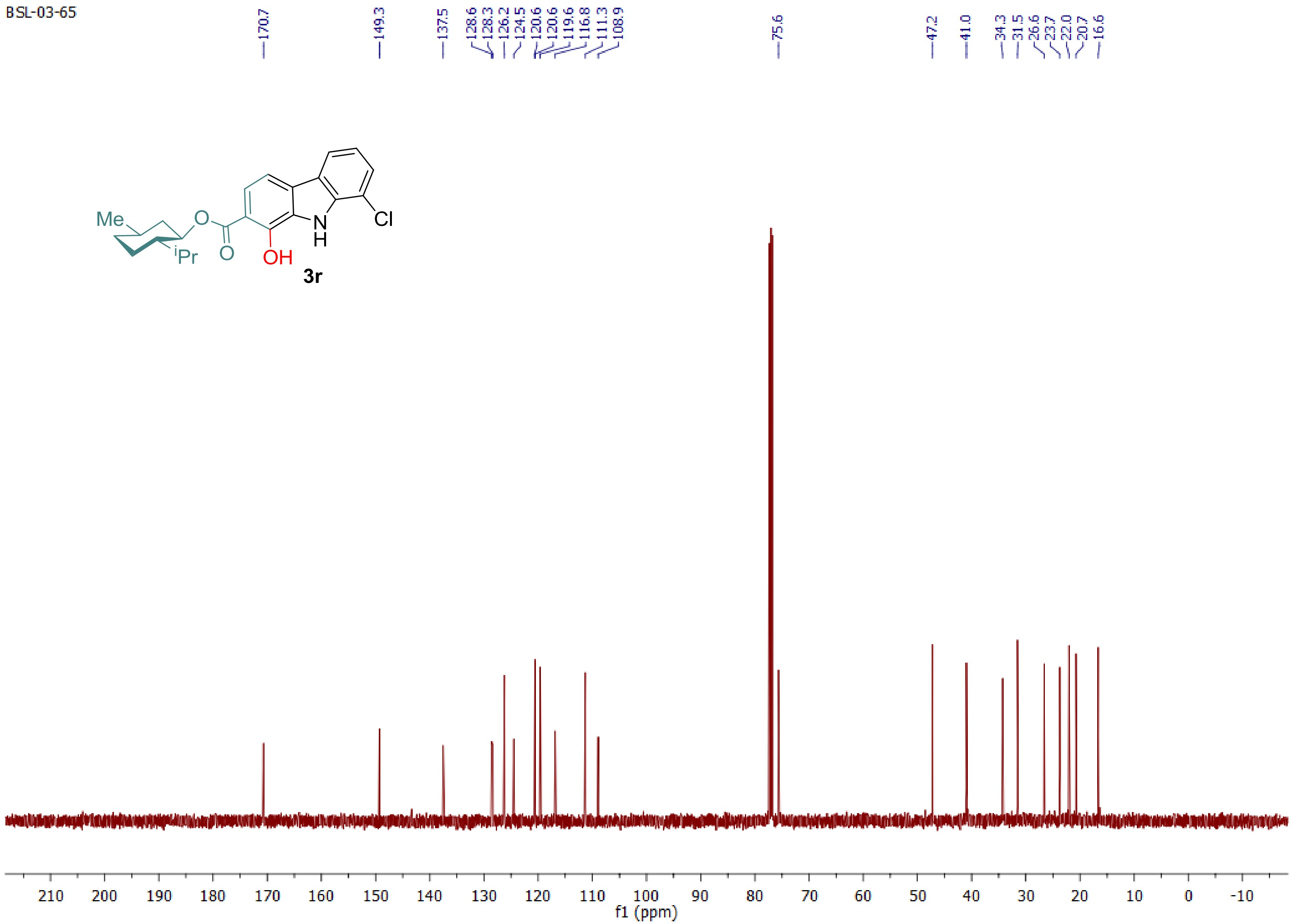
3q


170.9
149.1
140.3
128.5
128.4
127.1
123.1
121.2
120.0
119.8
111.4
111.1
108.3
75.4
47.2
41.0
34.3
31.5
26.6
23.7
22.1
20.7
16.6
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

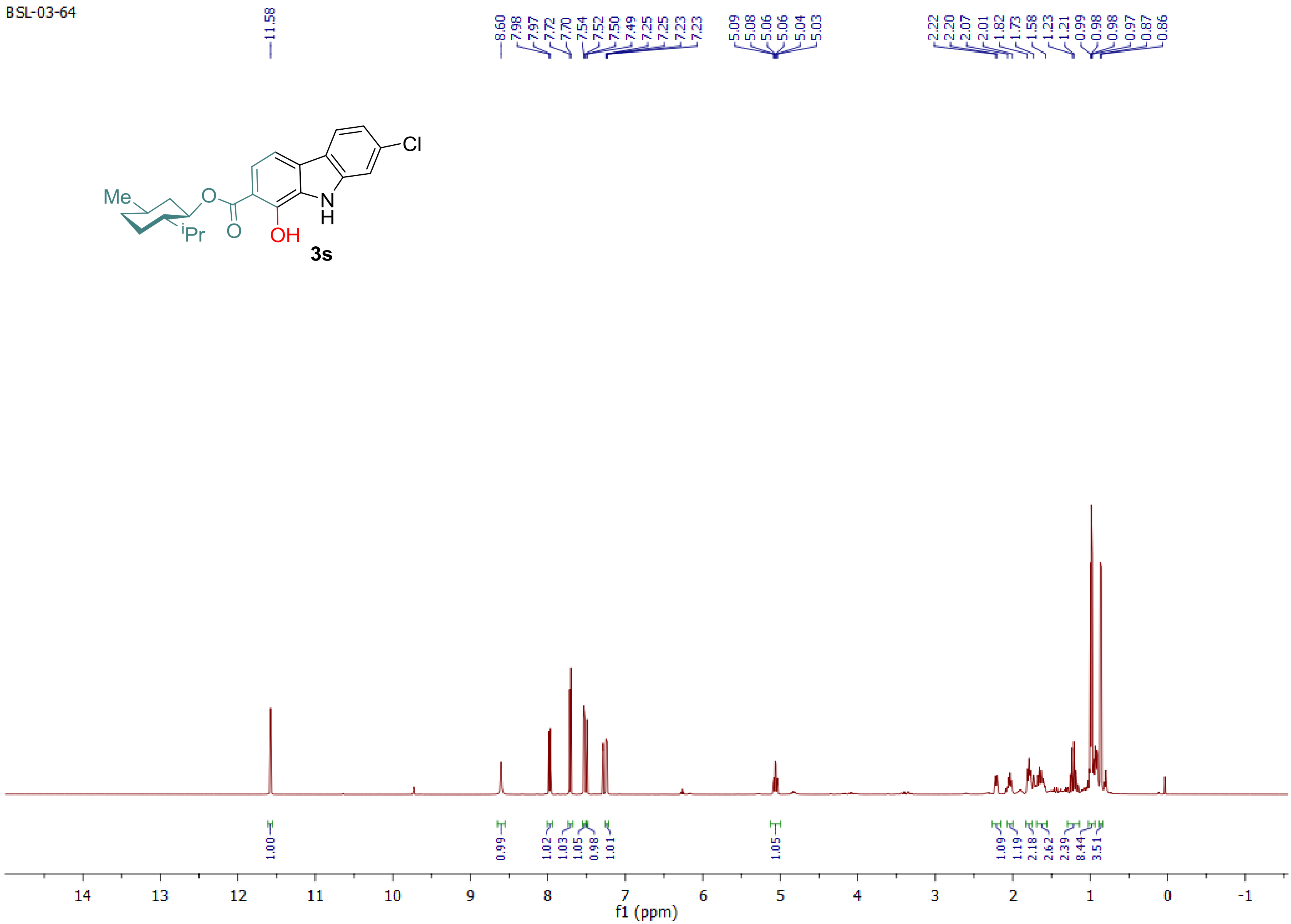

BSL-03-65
11.61
8.76
7.99
7.97
7.73
7.72
7.57
7.55
7.51
7.51
7.49
7.49
7.23
7.21
7.20
5.09
5.08
5.07
5.06
5.05
5.04
2.23
2.21
2.05
2.04
1.79
1.79
1.29
1.29
1.26
1.24
1.21
1.19
1.00
0.99
0.99
0.98
0.87
0.86
Me
O
O
iPr
OH
N
H
Cl
3r
1.00
0.97
1.02
1.03
1.04
1.01
1.03
1.04
1.08
1.19
2.20
3.27
2.53
7.78
3.39
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

BSL-03-65

3r

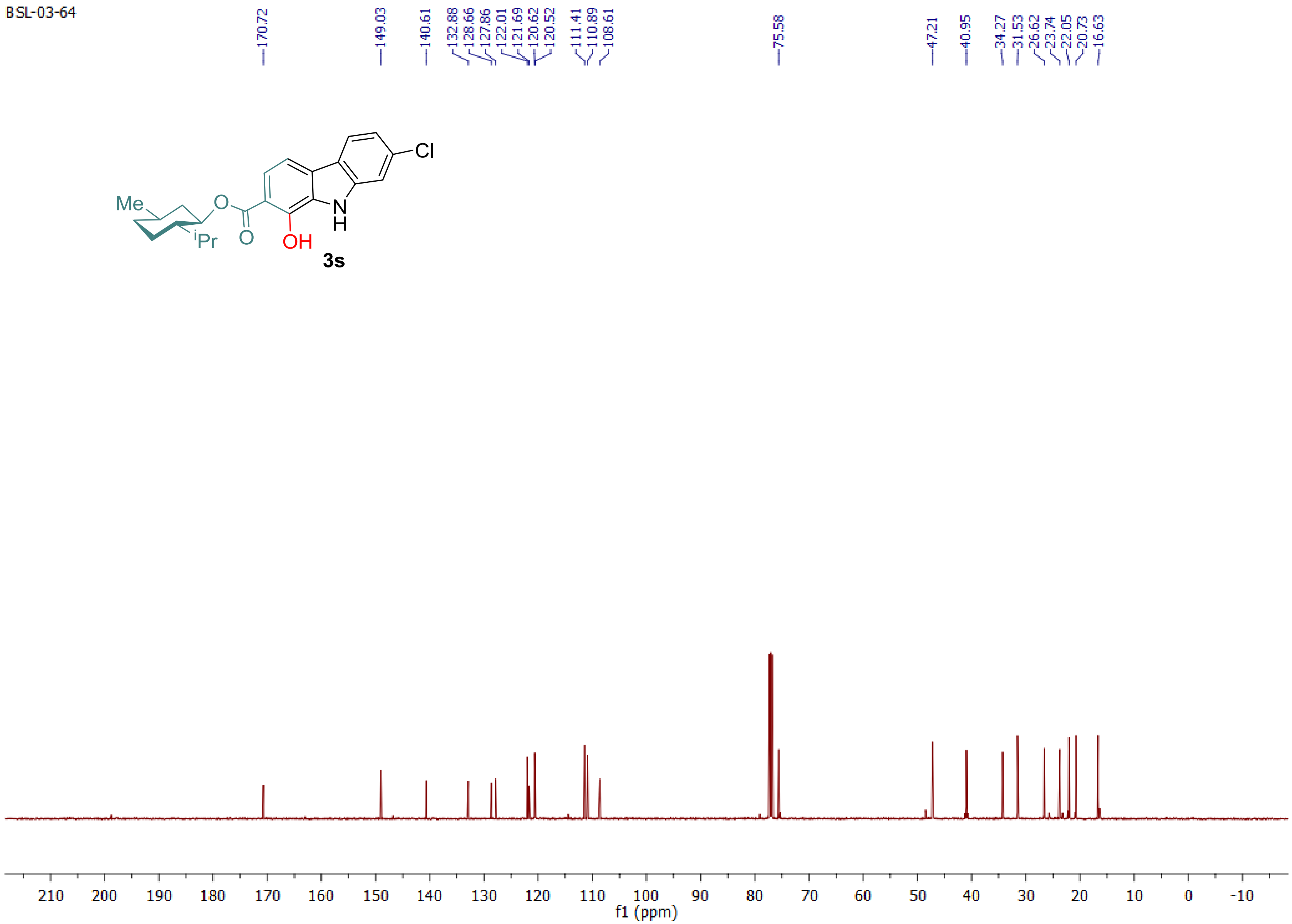

170.7
149.3
137.5
128.6
128.3
126.2
124.5
120.6
120.6
119.6
116.8
111.3
108.9
75.6
47.2
41.0
34.3
31.5
26.6
23.7
22.0
20.7
16.6
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

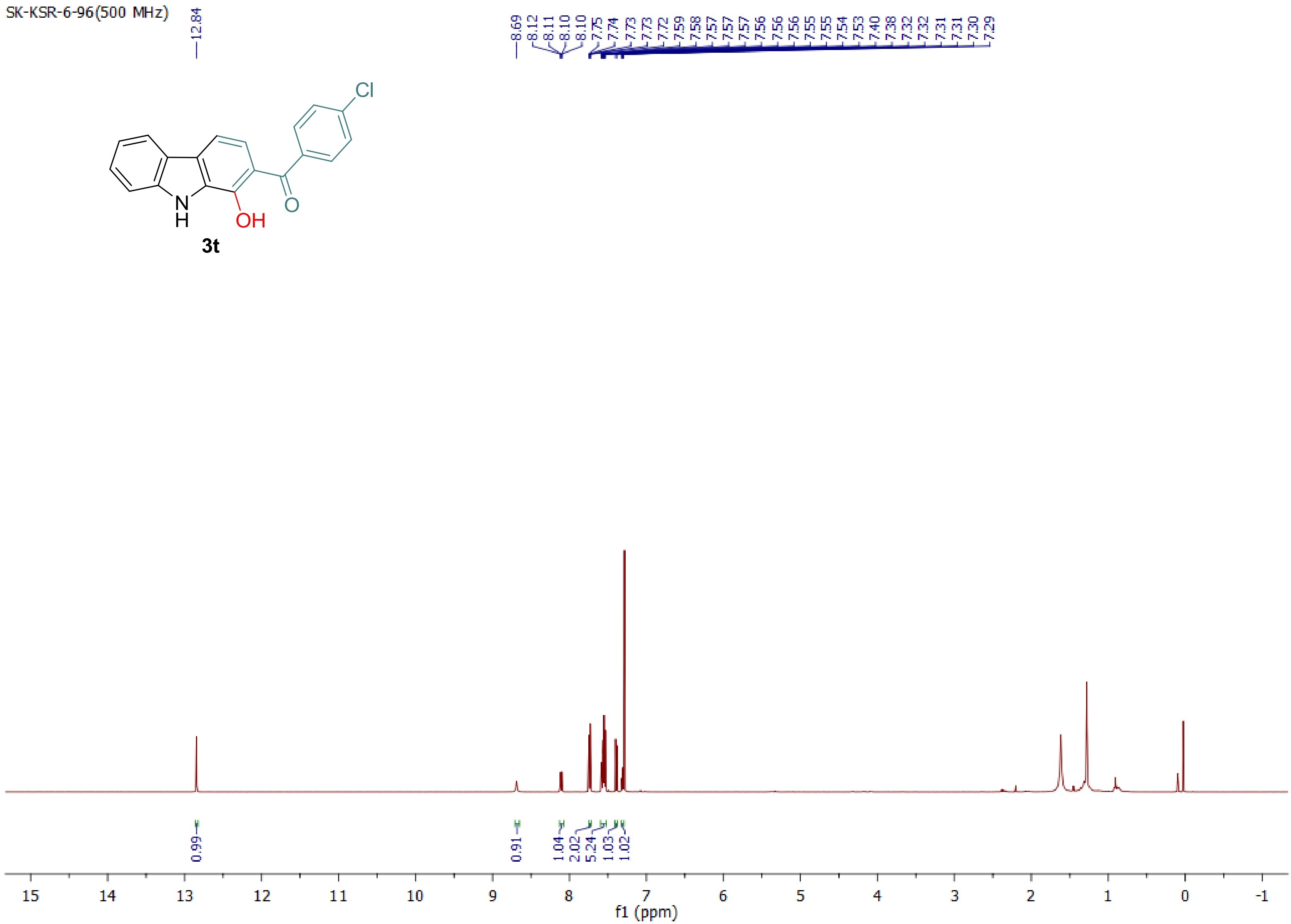
BSL-03-64

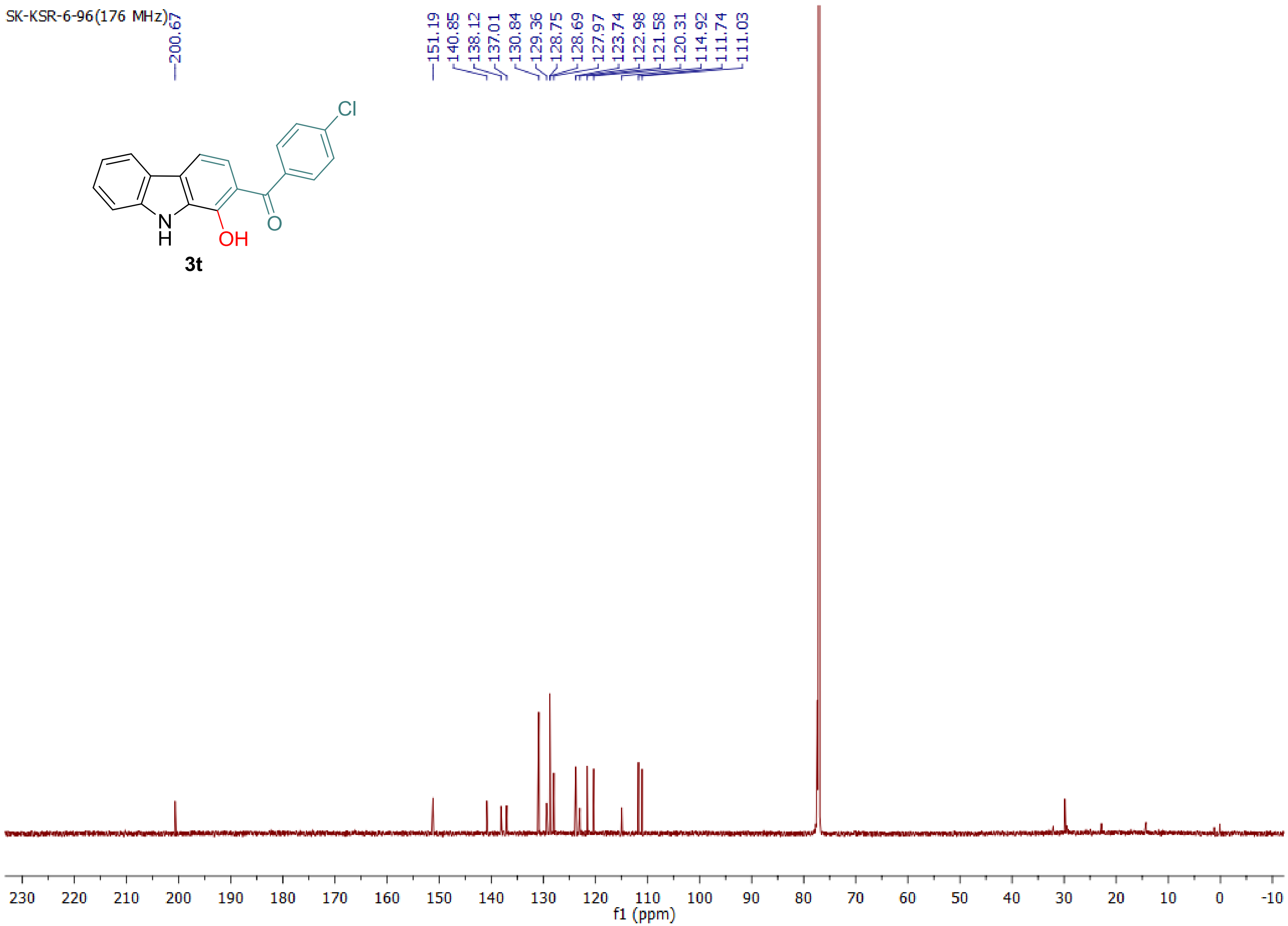


11.58
8.60 7.98 7.97 7.72 7.70 7.54 7.52 7.50 7.49 7.25 7.25 7.23 7.23
5.09 5.08 5.06 5.06 5.04 5.03
2.22 2.20 2.07 2.01 1.82 1.73 1.58 1.23 1.21 0.99 0.98 0.98 0.97 0.87 0.86
Me
O
O
iPr
OH
N
H
Cl
1.00
0.99
1.02 1.03 1.05 0.98 1.01
1.05
1.09 1.19 2.18 2.62 2.39 8.44 3.51
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

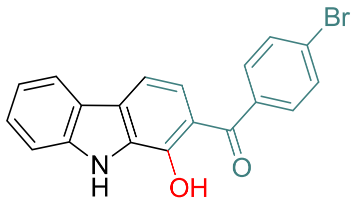
3s


BSL-03-64
170.72
149.03
140.61
132.88
128.66
127.86
122.01
121.69
120.62
120.52
111.41
110.89
108.61
75.58
47.21
40.95
34.27
31.53
26.62
23.74
22.05
20.73
16.63
Me
O
O
iPr
OH
N
H
Cl
3s
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

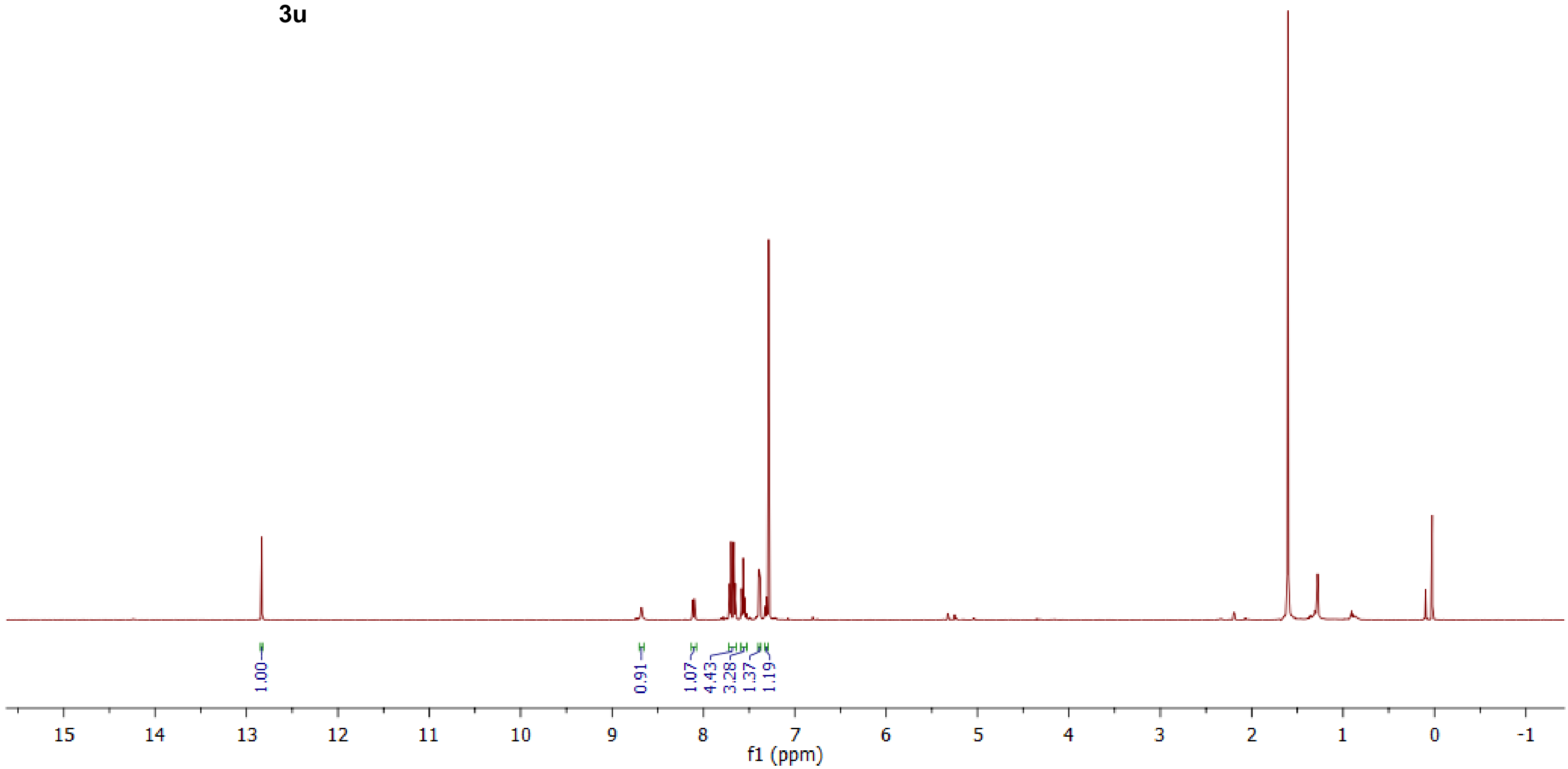

SK-KSR-6-96(500 MHz)
12.84
8.69
8.12
8.11
8.10
8.10
7.75
7.74
7.73
7.73
7.72
7.59
7.58
7.57
7.57
7.57
7.56
7.56
7.56
7.55
7.55
7.54
7.53
7.40
7.38
7.32
7.32
7.31
7.31
7.30
7.29
Cl
N
H
OH
O
3t
0.99
0.91
1.04
2.02
5.24
1.03
1.02
f1 (ppm)

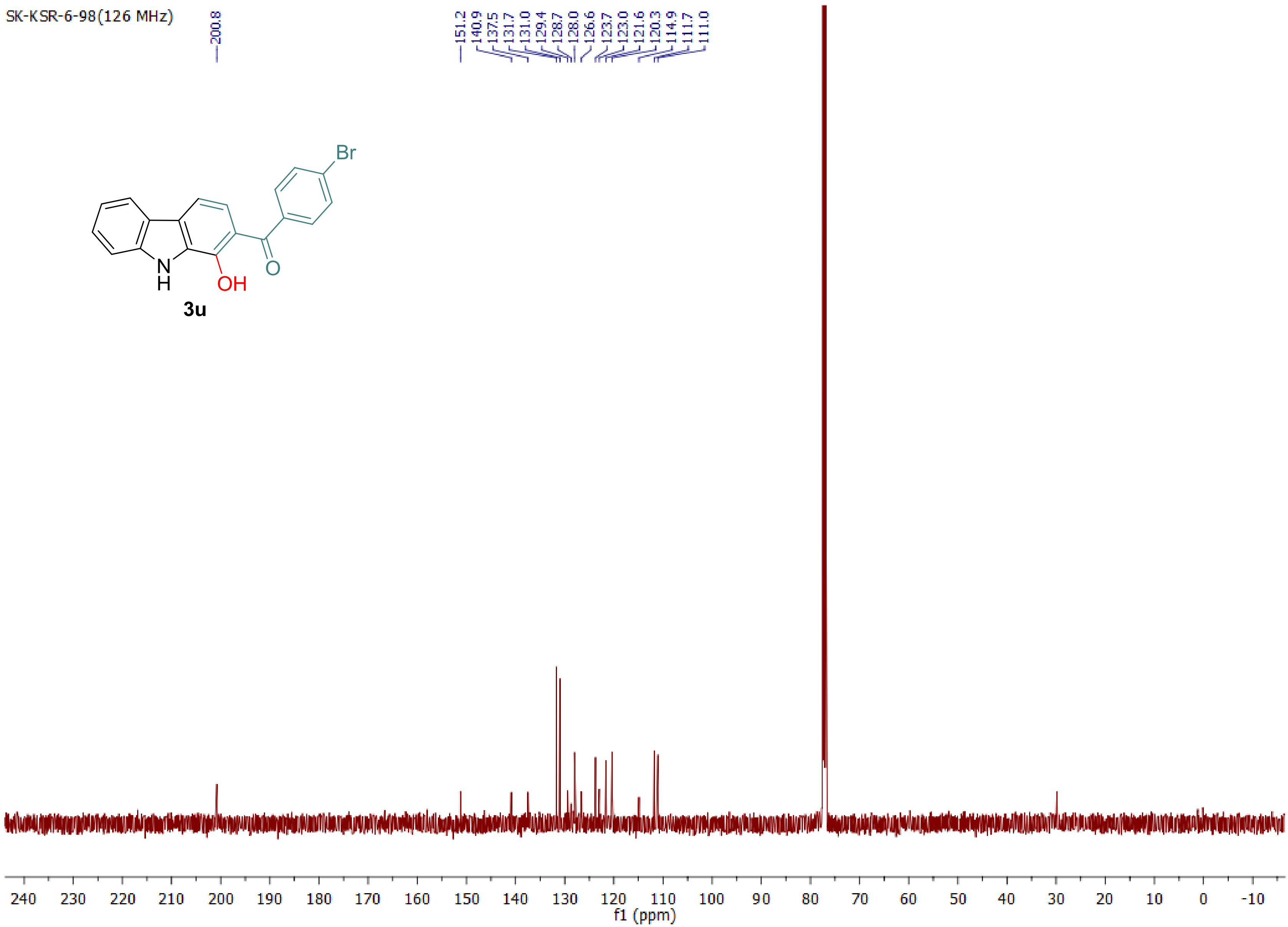

SK-KSR-6-96(176 MHz)
200.67
151.19
140.85
138.12
137.01
130.84
129.36
128.75
128.69
127.97
123.74
122.98
121.58
120.31
114.92
111.74
111.03
Cl
O
N
H
OH
3t
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

SK-KSR-6-98(500 MHz)



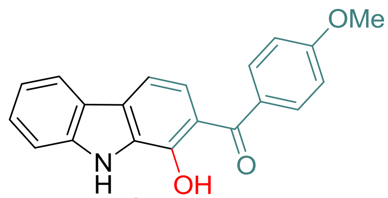
3u



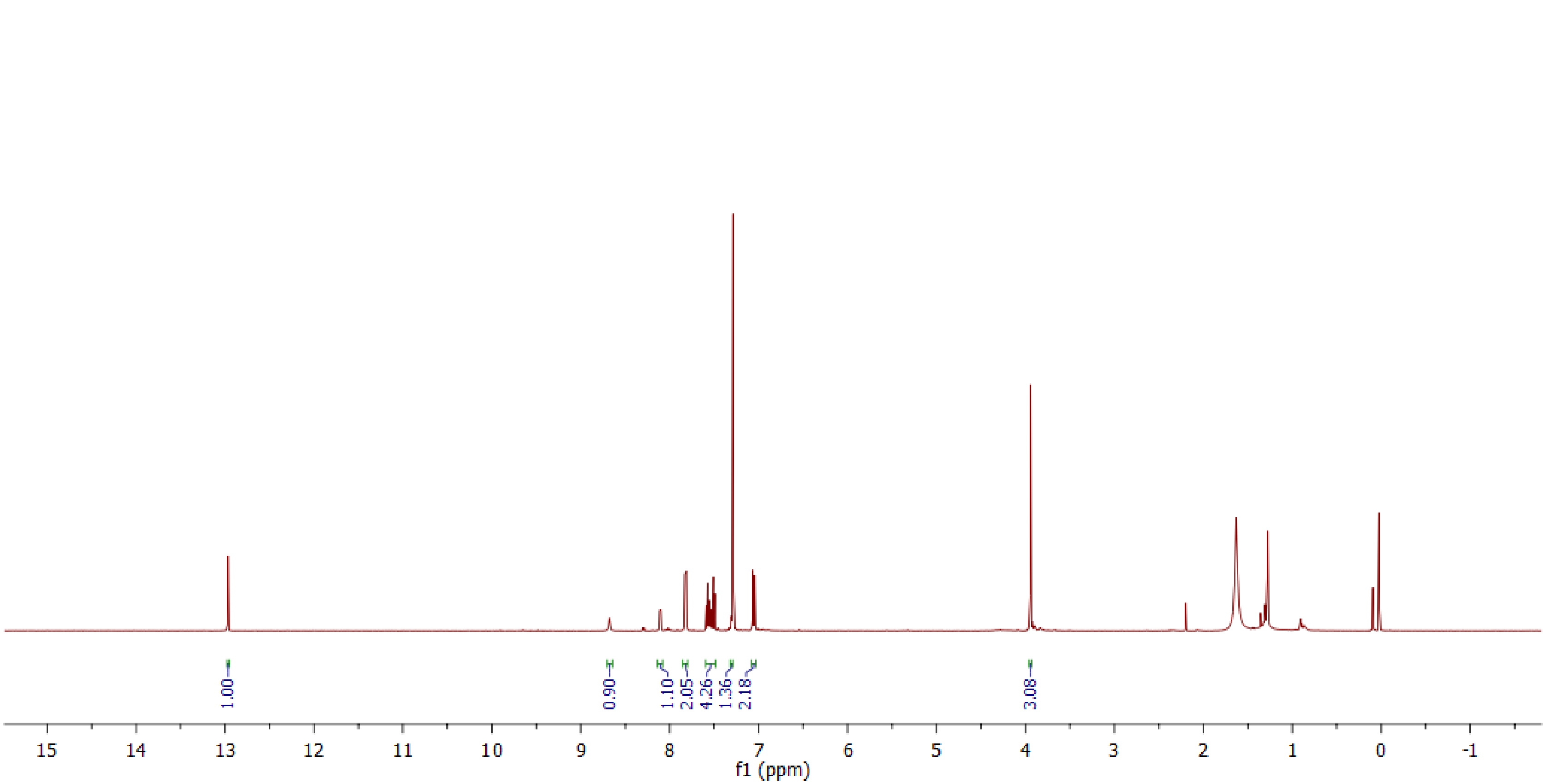


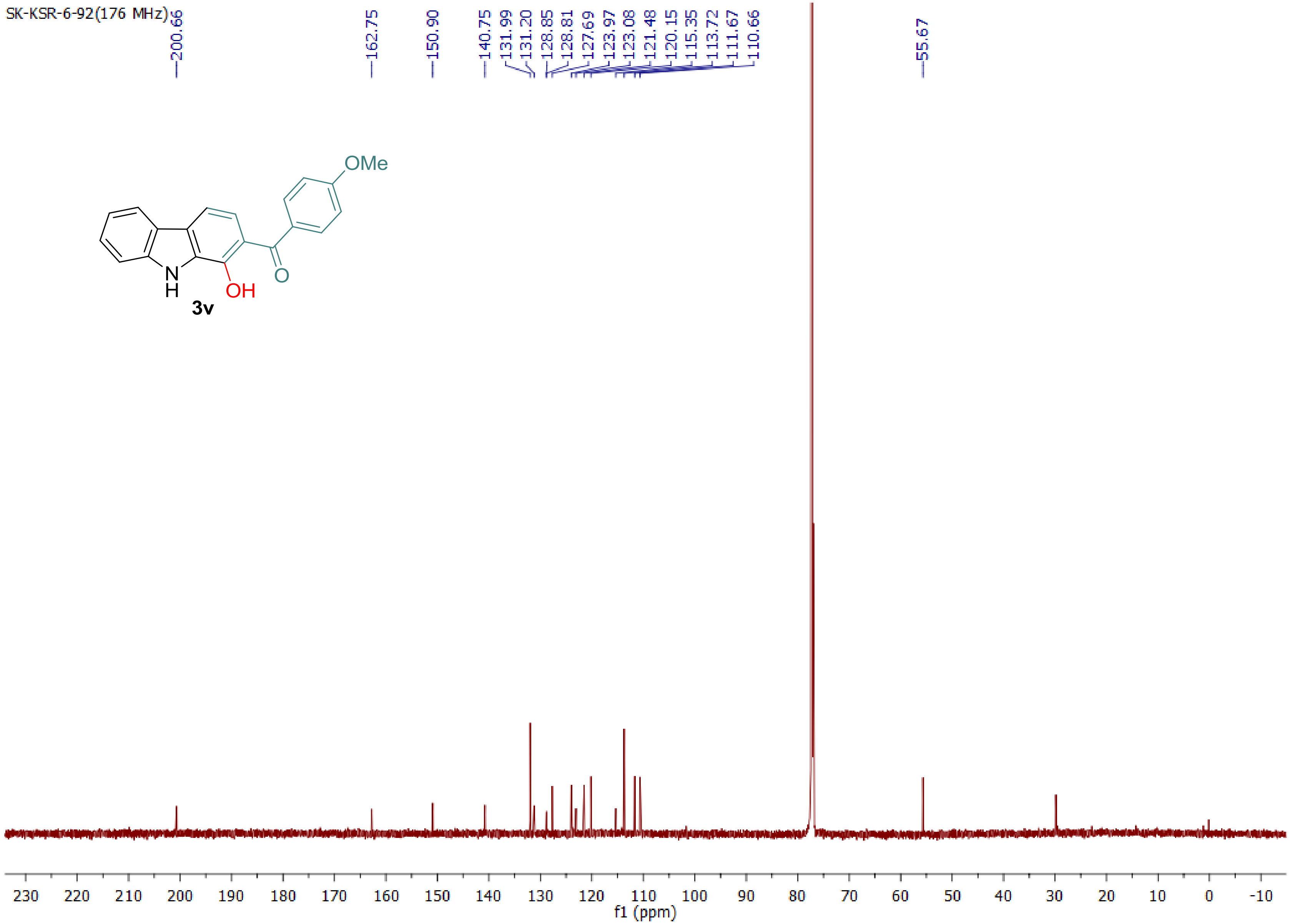
SK-KSR-6-98(126 MHz)
200.8
151.2
140.9
137.5
131.7
131.0
129.4
128.7
128.0
126.6
123.7
123.0
121.6
120.3
114.9
111.7
111.0
Br
O
N
H
OH
3u
240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

SK-KSR-6-92(500 MHz)

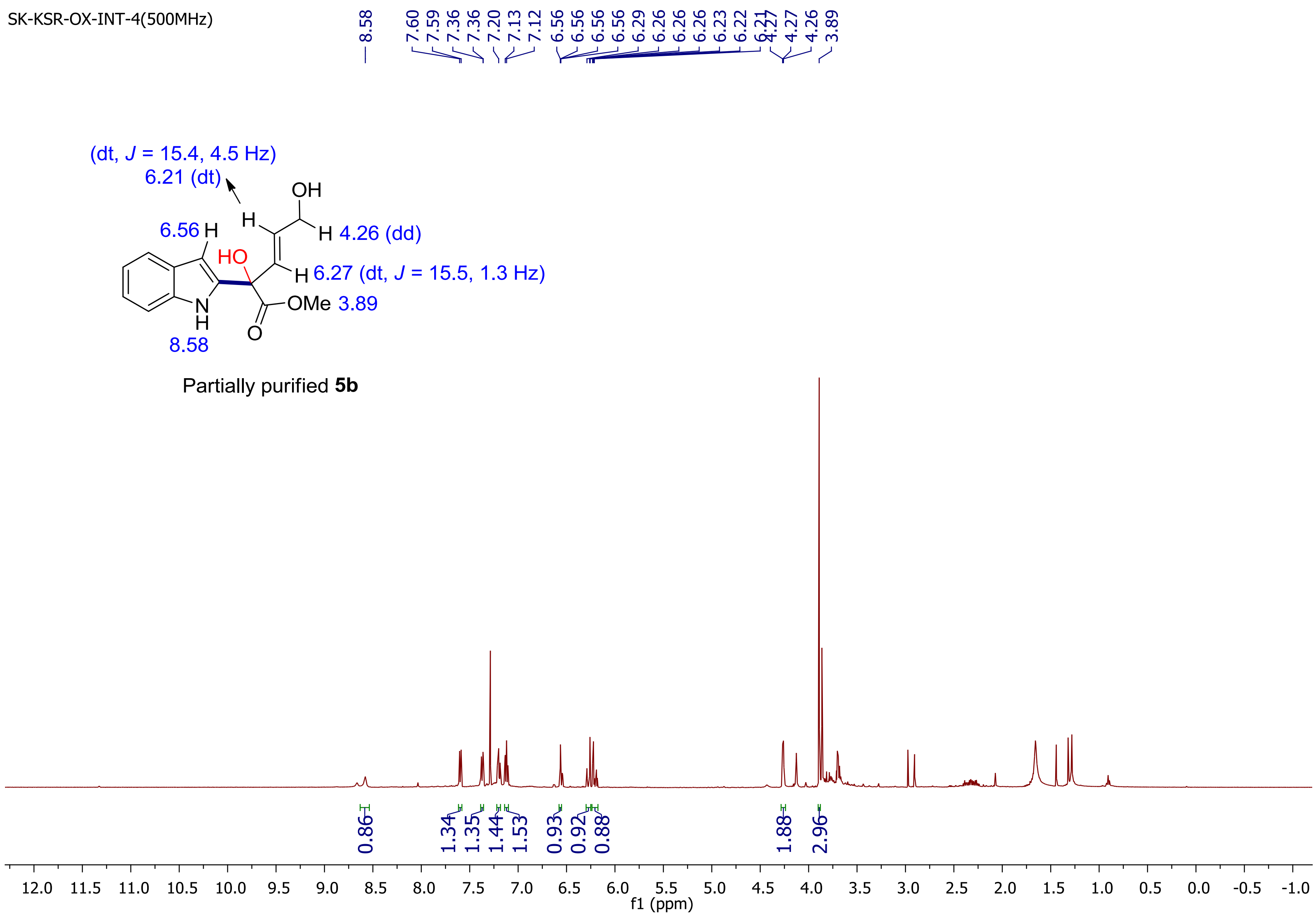


3v

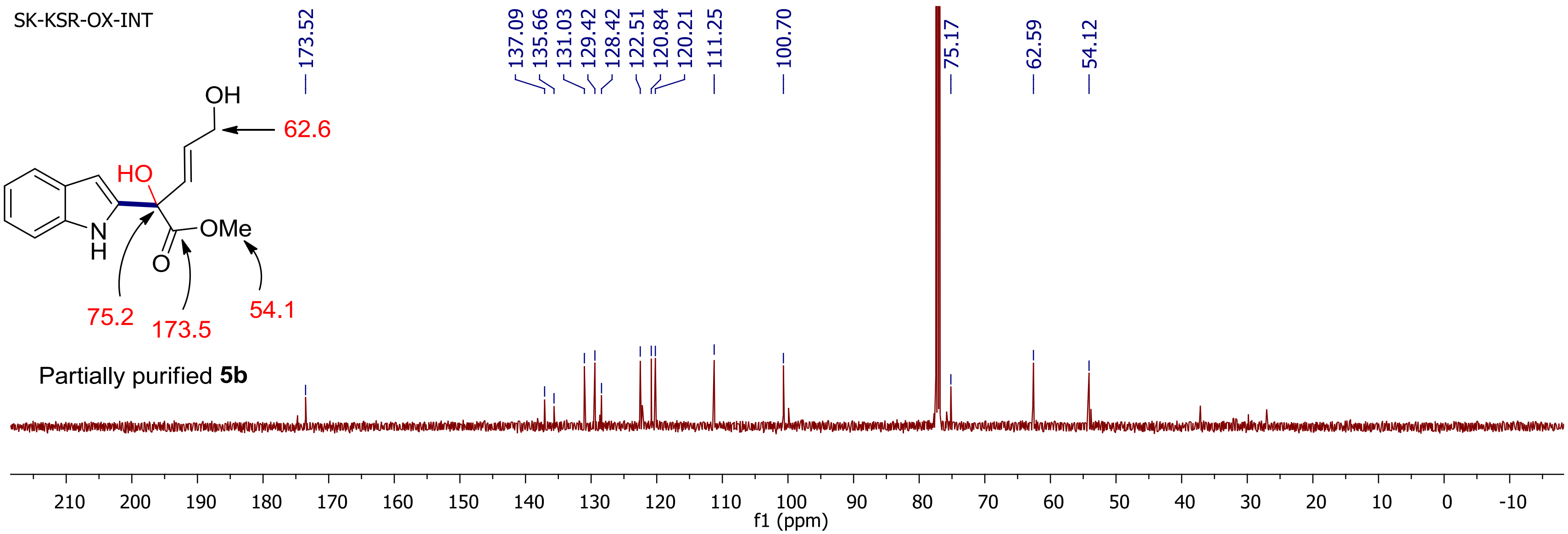


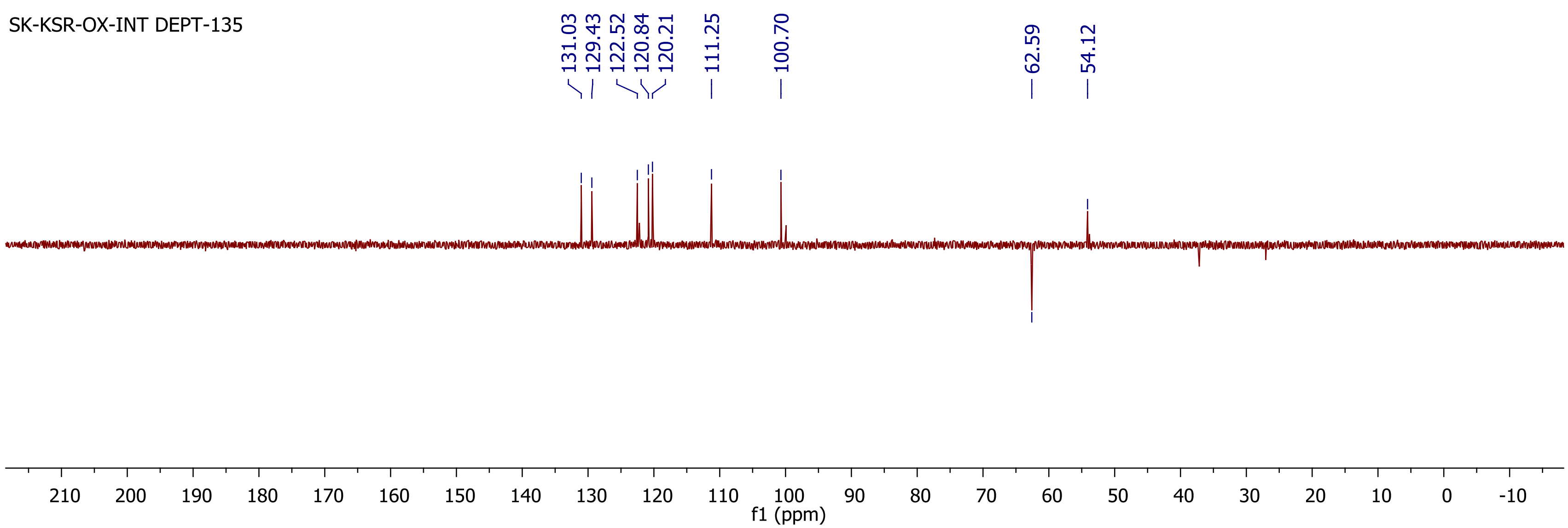


SK-KSR-6-92(176 MHz)
200.66
162.75
150.90
140.75
131.99
131.20
128.85
128.81
127.69
123.97
123.08
121.48
120.15
115.35
113.72
111.67
110.66
55.67
OMe
N
H
OH
O
3v
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



Partially purified **5b**


SK-KSR-OX-INT
173.52
137.09
135.66
131.03
129.42
128.42
122.51
120.84
120.21
111.25
100.70
75.17
62.59
54.12
OH
62.6
HO
N
H
O
OMe
75.2
173.5
54.1
Partially purified **5b**
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


SK-KSR-OX-INT DEPT-135
131.03
129.43
122.52
120.84
120.21
111.25
100.70
62.59
54.12
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)