Sequential Sonagashira and Larock Indole Synthesis Reactions in a General Strategy To Prepare Biologically Active β-Carboline-Containing Alkaloids

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Supporting Information

Table of Contents

General Information

^{1}H NMR spectra were recorded on a Brüker Ultrashield 400 at 400 MHz. Chemical shifts are reported in parts per million (ppm) using an internal standard, $CHCl_3$ (δ 7.26), MeOH (δ 3.34) or DMSO (δ 2.54). ^{13}C NMR spectra were record on a Brüker Ultrashield 400 at 100 MHz. Chemical shifts are reported in parts per million (ppm) using an internal standard, $CHCl_3$ (δ 77.36), MeOH (δ 49.86) or DMSO (δ 40.45). High resolution mass spectra were recorded on an Agilent 6230 TOF LC/MS spectrometer. Infrared (IR) spectra were collected on a Perkin Elmer Spectrum One FT-IR spectrometer. Reagents and anhydrous solvents were used as obtained from commercial vendors.

Experimental Procedures

General procedure for Sonagashira coupling reactions: preparation of compound 8. A solution of 2-bromopyridine (3.16 g, 20 mmol), 3-butyn-1-ol (1.68 g, 24 mmol), $PdCl_2(PPh_3)_2$ (421 mg, 0.6 mmol), CuI (228 mg, 1.2 mmol) in dry Et_3N (20 mL) was stirred at room temperature for 2 h. Silica gel was added, and the resulting mixture was evaporated and separated by flash chromatography (SiO_2, hexanes/EtOAc = 1/2), providing compound **8** (2.87 g, 98%) as an oil: IR (neat cm^{-1}) 3271, 1585, 1464, 1047, 775; ^1H NMR (400 MHz, $CDCl_3$) δ 8.44 (d, *J* = 3.6 Hz, 1H), 7.58 (td, *J* = 8.0 and 1.2 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.15 (dd, *J* = 6.8 and 4.0 Hz, 1H), 4.84 (br, 1H), 3.84 (t, *J* = 6.8 Hz, 2H), 2.67 (t, *J* = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.62, 143.43, 136.68, 127.07, 122.86, 88.92, 81.45, 60.68, 24.00; HRMS (ES) *m*/*e* calc'd for $C_9H_{10}NO$ $(M+H)^+$ 148.0757, found 148.0761.

General procedure for Larock indole synthesis reactions: preparation of compound 10. 2-bromoaniline (35 mg, 0.2 mmol), alkyne **8** (30 mg, 0.2 mmol), $Pd(OAc)_2$ (1.2 mg, 0.005 mmol), 1,1'-bis(diphenylphosphino)ferrocene (5.6 mg, 0.01 mmol), and $KHCO_3$ (60 mg, 0.6 mmol; note, in some later examples K_2CO_3 was instead used) were added to dry and degassed DMF (1 mL). The solution was heated for 4 h at 110 °C, after which time the reaction was complete, as determined by LCMS analysis. Water was added and the mixture was extracted with ethyl acetate. The organic extracts were combined, dried and purified by flash chromatography (SiO_2, hexanes/EtOAc = 1/1), providing compound **10** (44.8 mg, 95%) as a solid: IR (neat cm^{-1}) 3174, 2849, 1596, 1066, 788; ^1H NMR (400 MHz, $CDCl_3$) δ 9.29 (s, 1H), 8.51 (d, *J* = 4.4 Hz, 1H), 7.76 (m,

1H), 7.74 (td, *J* = 8.0 and 1.6 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 1H), 7.22 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.17-7.13 (m, 1H), 7.12-7.08 (m, 1H), 4.08 (t, *J* = 6.0 Hz, 2H), 3.33 (t, *J* = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.67, 148.89, 137.62, 136.48, 133.71, 129.58, 123.9, 122.26, 121.64, 120.11, 119.51, 113.07, 111.77, 63.5, 28.01; HRMS (ES) *m*/*e* calc'd for $C_{15}H_{15}N_2O$ $(M+H)^+$ 239.1179, found 239.1180.

In optimizing this procedure, the crude reaction mixtures were analyzed with LCMS. Bases such as K_3PO_4, Cs_2CO_3, K_2CO_3, Na_2CO_3, $KHCO_3$, $NaHCO_3$, Et_3N were studied, but only $KHCO_3$ and K_2CO_3 gave the best and similar results. Catalysts such as $Pd(PPh_3)_4$, $Pd(OAc)_2/PPh_3$ and $Pd(OAc)_2$/DPPF were tested, $Pd(OAc)_2$/DPPF was much better. The addition of LiCl lowered the yield probably due to the moisture in LiCl. The catalyst ($Pd(OAc)_2$/DPPF) loading was lowered to 1%, and the yield was 90% after 12 h.

General procedure for triflate cyclization reactions: preparation of compound 11. To a solution of compound **10** (36 mg, 0.15 mmol) and Et_3N (24 mg, 0.225 mmol) in dry $CHCl_3$ (1.4 mL) at 0 °C was slowly added trifluoromethanesulfonic anhydride (34 μL, 0.18 mmol). After stirring for an additional 5 min the resulting yellow precipitate was collected by filtration, the solid was washed with $CHCl_3$, and then was identified as compound **11** (52.2 mg, 94%): IR (neat cm^{-1}) 3281, 1557, 1256, 1149, 746; ^{1}H NMR (400 MHz, DMSO) δ 12.36 (s, 1H), 8.98 (d, *J* = 5.6 Hz, 1H), 8.61 (td, *J* = 8.0 and 1.2 Hz, 1H), 8.26 (d, *J* = 7.2 Hz, 1H), 7.87 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.78 (t, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 1H), 7.44 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.24 (td, *J* = 7.6 and 0.8 Hz, 1H), 4.96 (t, *J* = 7.2 Hz, 2H), 3.44 (t, *J* = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 146.45, 146.35, 143.95, 140.31, 127.29, 126.07, 125.61, 124.27, 123.22, 121.74, 121.63, 118.62,

113.59, 56.66, 19.76; HRMS (ES) *m*/*e* calc'd for $C_{15}H_{13}N_2$ $(M\text{-}OTf)^+$ 221.1079, found 221.1080.

Indolopyridocoline triflate 12. A solution of **11** (100 mg, 0.27 mmol) and 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (92 mg, 0.405 mmol) in acetic acid (1 mL) was stirred at 100 °C for 12 h. After cooling to room temperature the resulting precipitate was filtered and washed with acetic acid and acetone to provide **12** (90 mg, 90%) as a brown solid: IR (neat cm^{-1}) 3185, 1245, 1153, 1029, 751; ^1H NMR (400 MHz, DMSO) δ 13.54 (s, 1H), 9.49 (d, *J* = 6.4 Hz, 1H), 9.17 (d, *J* = 6.4 Hz, 1H), 9.01 (d, *J* = 8.4 Hz, 1H), 8.93 (d, *J* = 6.8 Hz, 1H), 8.53–8.49 (m, 2H), 8.10 (t, *J* = 6.4 Hz, 1H), 7.94 (d, *J* = 8.0 Hz, 1H), 7.82 (t, *J* = 7.6 Hz, 1H), 7.56 (t, *J* = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, DMSO) δ 142.17, 137.96, 136.87, 133.20, 131.44, 130.45, 128.44, 123.86, 123.04, 122.84, 122.59, 122.39, 121.47, 117.66, 113.68; HRMS (ES) *m*/*e* calc'd for $C_{15}H_{11}N_2$ $(M\text{-}OTf)^+$ 219.0922, found 219.0929.

Norketoyobyrine 13. A solution of **22** (105 mg, 0.25 mmol), $K_3Fe(CN)_6$ (165 mg, 0.5 mmol) and NaOH (300 mg, 7.5 mmol) in THF (2 mL) and H_2O (1 mL) was stirred at room temperature for 12 h and extracted with ethyl acetate. The extracts were combined, dried and purified by flash chromatography (SiO_2, hexanes/EtOAc = 4/1) to provide **13** (36 mg, 51%) as a solid. All data for this compound matched that previously reported (Grigg, R.; Sridharan, V.; Stevenson, P.; Sukirthalingam, S.; Worakun, T. *Tetrahedron*, **1990**, *46*, 4003).

Rutaecarpine 14. A solution of **26** (40 mg, 0.125 mmol) and HCl (6 M, 0.05 mL) in *n*-BuOH (1 mL) was stirred at 120 °C for 7 d and then was cooled to room temperature. Saturated $NaHCO_3$ was added to adjust the solution pH to 8. Silica gel was added, and

the resulting mixture was dried and separated by flash chromatography (SiO_2, hexanes/EtOAc = 1/1) to provide **14** (29 mg, 81%) as a solid. All data for this compound matched that previously reported (Tseng, M.-C.; Cheng, H.-T.; Shen, M.-J.; Chu, Y.-H. *Org*. *Lett*., **2011**, *13*, 4434).

Compound 20. By the general Sonagashira coupling procedure, isoquinolin-3-yl triflate **19** (368 mg, 1.32 mmol), 3-butyn-1-ol (112 mg, 1.59 mmol), $PdCl_2(PPh_3)_2$ (28 mg, 0.04 mmol), CuI (15.2 mg, 0.08 mmol) in Et_3N (5 mL) at 80 °C for 2 h provided **20** (254 mg, 98%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3207, 1623, 1580, 1053, 757; ^1H NMR (400 MHz, $CDCl_3$) δ 9.18 (s, 1H), 7.95 (dd, *J* = 8.0 and 0.8 Hz, 1H), 7.80 (s, 1H), 7.77 (d, *J* = 7.6 Hz, 1H), 7.71 (td, *J* = 6.8 and 1.2 Hz, 1H), 7.62 (td, *J* = 6.8 and 1.2 Hz, 1H), 3.92 (q, *J* = 5.6 Hz, 1H), 2.79 (t, *J* = 6.4 Hz, 2H), 2.72 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.88, 136.73, 136.05, 131.28, 128.13, 128.03, 127.85, 126.59, 124.08, 87.72, 82.44, 61.20, 24.32; HRMS (ES) *m*/*e* calc'd for $C_{13}H_{12}NO$ $(M+H)^+$ 198.0913, found 198.0924.

Compound 21. By the general Larock indole synthesis procedure, 2-bromoaniline (35 mg, 0.2 mmol), alkyne **20** (40 mg, 0.2 mmol), $Pd(OAc)_2$ (1.2 mg, 0.005 mmol), 1,1'-bis(diphenylphosphino)ferrocene (5.6 mg, 0.01 mmol), $KHCO_3$ (60 mg, 0.6 mmol) in DMF (1 mL) for 4 h provided **21** (53.5 mg, 93%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3054, 2843, 1626, 1333, 739; ^1H NMR (400 MHz, $CDCl_3$) δ 9.55 (s, 1H), 8.70 (s, 1H), 7.84 (s, 1H), 7.72 (d, *J* = 8.0 Hz, 1H), 7.64–7.58 (m, 2H), 7.50–7.43 (m, 2H), 7.17 (d, *J* = 8.0 Hz, 1H), 7.05 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.00 (td, *J* = 7.2 and 1.2 Hz, 1H), 4.20 (t, *J* = 6.0 Hz, 2H), 3.34 (t, *J* = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.31, 144.43, 136.72, 136.62, 134.23, 131.30,

129.25, 128.02, 127.28, 127.24, 126.98, 123.36, 119.78, 118.84, 117.62, 112.54, 111.63, 63.62, 27.54; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{17}N_2O$ $(M+H)^+$ 289.1335, found 289.1336.

Compound 22. By the general triflate cyclization procedure, **21** (44 mg, 0.15 mmol), Et_3N (24 mg, 0.225 mmol), Tf_2O (34 μL, 0.18 mmol) in $CHCl_3$ (1.4 mL) provided **22** (60.8 mg, 97%) as a yellow solid: IR (neat cm^{-1}) 3306, 1645, 1251, 1160, 746; ^1H NMR (400 MHz, DMSO) δ 12.24 (s, 1H), 10.10 (s, 1H), 8.61 (s, 1H), 8.46 (d, *J* = 8.0 Hz, 1H), 8.26–8.20 (m, 2H), 8.00 (td, *J* = 8.0 and 1.6 Hz, 1H), 7.75 (d, *J* = 8.0 Hz, 1H), 7.59 (d, *J* = 8.4 Hz, 1H), 7.38 (td, *J* = 8.0 and 0.8 Hz, 1H), 7.21 (t, *J* = 7.6 Hz, 1H), 5.11 (t, *J* = 6.8 Hz, 2H), 3.48 (t, *J* = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 152.60, 139.64, 138.91, 138.13, 135.91, 131.58, 131.08, 127.99, 126.70, 126.26, 126.18, 126.02, 121.38, 121.00, 117.65, 115.77, 113.25, 57.81, 19.98; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{15}N_2$ $(M-OTf)^+$ 271.1235, found 271.1243.

Demethoxycarbonyl dihydrogambirtannine 23. A solution of **22** (42 mg, 0.1 mmol) and PtO_2 (1.2 mg, 0.005 mmol) in MeOH (1 mL) was stirred under 50 psi H_2 for 1 h. Saturated Na_2CO_3 (1 mL) was added and the resulting mixture was then extracted with ethyl acetate. The organic extracts were combined, dried, and purified by flash chromatography (SiO_2, hexanes/EtOAc = 1/1) to provide **23** (27.2 mg, 100%) as a solid: IR (neat cm^{-1}) 3407, 2927, 1450, 737, 725; ^1H NMR (400 MHz, $CDCl_3$) δ 7.87 (br, 1H), 7.54 (d, *J* = 7.2 Hz, 1H), 7.35 (d, *J* = 7.6 Hz, 1H), 7.20–7.10 (m, 6H), 4.14 (d, *J* = 14.8 Hz, 1H), 3.81 (d, *J* = 15.2 Hz, 1H), 3.73 (dt, *J* = 11.6 and 1.6 Hz, 1H), 3.33 (dd, *J* = 10.8 and 4.4 Hz, 1H), 3.24 (dd, *J* = 16.0 and 4.0 Hz, 1H), 3.12–3.00 (m, 2H), 2.86–2.81 (m, 1H), 2.79 (td, *J* = 11.2 and 4.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 136.62, 134.81, 134.65, 133.45, 128.98, 127.47, 126.77, 126.71, 126.46, 121.96, 119.86, 118.59, 111.16,

109.05, 58.10, 56.64, 52.71, 35.11, 21.81; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{19}N_2$ $(M+H)^+$ 275.1543, found 275.1555.

Compound 25. By the general Sonagashira coupling procedure, 2-chloro-4-methoxyquinazoline **24** (500 mg, 2.58 mmol), 3-butyn-1-ol (198 mg, 2.84 mmol), $PdCl_2(PPh_3)_2$ (54 mg, 0.077 mmol), CuI (29 mg, 0.155 mmol) in Et_3N (3 mL) at 80 °C for 13 h provided **25** (541 mg, 92%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/2): IR (neat cm^{-1}) 3186, 1499, 1355, 1050, 782; ^1H NMR (400 MHz, $CDCl_3$) δ 8.10 (dd, *J* = 8.0 and 0.8 Hz, 1H), 7.88 (d, *J* = 8.4 Hz, 1H), 7.82 (td, *J* = 6.8 and 1.2 Hz, 1H), 7.54 (td, *J* = 6.8 and 0.8 Hz, 1H), 4.17 (s, 3H), 3.96 (t, *J* = 6.4 Hz, 2H), 3.39 (br, 1H), 2.81 (t, *J* = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.40, 151.03, 148.08, 134.35, 127.78, 127.53, 123.79, 115.82, 86.42, 82.24, 60.88, 55.04, 24.27; HRMS (ES) *m*/*e* calc'd for $C_{13}H_{13}N_2O_2$ $(M+H)^+$ 229.0972, found 229.0977.

Compounds 26 and 27. By the general Larock indole synthesis procedure, 2-bromoaniline (43 mg, 0.25 mmol), alkyne **25** (57 mg, 0.25 mmol), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol), 1,1'-bis(diphenylphosphino)ferrocene (28 mg, 0.05 mmol), $KHCO_3$ (75 mg, 0.75 mmol) in DMF (1.5 mL) for 1 h provided **26** (65 mg, 82%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 2943, 1563, 1375, 1041, 729; ^1H NMR (400 MHz, $CDCl_3$) δ 9.50 (s, 1H), 8.09 (dd, *J* = 8.0 and 0.8 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.80 (td, *J* = 6.8 and 1.2 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.49 (td, *J* = 7.6 and 1.2 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 1H), 7.26 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.12 (td, *J* = 7.2 and 1.2 Hz, 1H), 4.25 (s, 3H), 4.16 (t, *J* = 6.0 Hz, 2H), 3.68 (t, *J* = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.35, 155.57, 151.19, 136.23, 134.34, 132.29, 129.80, 127.29, 126.72, 124.68, 123.99, 120.07, 120.04, 117.50, 115.25, 111.73, 64.58,

54.96, 28.29; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{18}N_3O_2$ $(M+H)^+$ 320.1394, found 320.1396; and **27** (8 mg, 10%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 2839, 1540, 1377, 768, 680; ^1H NMR (400 MHz, $CDCl_3$) δ 9.21 (s, 1H), 8.57 (d, *J* = 8.0 Hz, 1H), 8.13 (dd, *J* = 8.0 and 1.2 Hz, 1H), 7.90 (d, *J* = 8.4 Hz, 1H), 7.77 (td, *J* = 6.8 and 1.2 Hz, 1H), 7.46 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.28 (d, *J* = 7.6 Hz, 1H), 7.24 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.17 (td, *J* = 8.0 and 1.2 Hz, 1H), 4.30 (s, 3H), 4.08 (t, *J* = 5.6 Hz, 2H), 3.47 (t, *J* = 5.6 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.17, 159.69, 150.94, 141.85, 135.80, 134.04, 127.80, 126.47, 125.92, 123.90, 122.58, 121.97, 121.30, 114.59, 113.37, 111.23, 63.35, 54.93, 31.10; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{18}N_3O_2$ $(M+H)^+$ 320.1394, found 320.1396.

Compound 28. A solution of **26** (25 mg, 0.078 mmol), pyridine (9.3 mg, 0.117 mmol), DMAP (0.5 mg, 0.0039 mmol) in $CHCl_3$ (0.5 mL) was added a solution of 4-toluenesulfonyl chloride (19 mg, 0.1 mmol) in $CHCl_3$ (0.5 mL) slowly. After stirring for 4 h the resulting precipitate was filtered and washed with $CHCl_3$ to provide **28** (26 mg, 99%) as a yellow solid: IR (neat cm^{-1}) 3191, 1590, 1545, 1384, 679; ^1H NMR (400 MHz, DMSO) δ 12.55 (s, 1H), 8.51 (d, *J* = 8.8 Hz, 1H), 8.42 (d, *J* = 8.0 Hz, 1H), 8.34 (t, *J* = 7.6 Hz, 1H), 7.93 (t, *J* = 7.6 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.26 (t, *J* = 7.6 Hz, 1H), 5.10 (t, *J* = 7.6 Hz, 2H), 4.57 (s, 3H), 3.60 (t, *J* = 7.6 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 169.34, 151.94, 142.56, 141.55, 139.04, 129.40, 128.78, 126.64, 126.53, 125.50, 124.08, 122.47, 122.01, 118.68, 115.26, 114.17, 58.29, 47.98, 20.04; HRMS (ES) *m*/*e* calc'd for $C_{19}H_{16}N_3O$ $(M-Cl)^+$ 302.1293, found 302.1295.

Compound 29. A solution of **28** (20 mg, 0.059 mmol) in DMSO 1 (mL) was stirred at 120 °C for 10 min. Evaporation of DMSO under high vacuum provided **29** (17 mg, 100%) as a solid: IR (neat cm^{-1}) 3148, 1591, 1514, 736, 685; ^1H NMR (400 MHz, DMSO) δ 12.08 (s, 1H), 8.19 (dd, *J* = 8.0 and 1.6 Hz, 1H), 7.99 (d, *J* = 8.4 Hz, 1H), 7.90 (td, *J* = 6.8 and 1.6 Hz, 1H), 7.75 (d, *J* = 8.4 Hz, 1H), 7.54–7.50 (m, 2H), 7.35 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.17 (td, *J* = 6.8 and 0.8 Hz, 1H), 4.65 (t, *J* = 7.2 Hz, 2H), 3.39 (t, *J* = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 168.54, 151.60, 142.13, 139.66, 134.84, 128.40, 127.89, 126.10, 125.93, 125.71, 121.24, 120.87, 120.79, 118.95, 116.67, 113.70, 45.40, 20.28; HRMS (ES) *m*/*e* calc'd for $C_{18}H_{14}N_3O$ $(M+H)^+$ 288.1131, found 288.1135.

Compound 31. By the general Sonagashira coupling procedure, 2-bromo-5-methoxypyridine **30** (301 mg, 1.6 mmol), 3-butyn-1-ol (124 mg, 1.76 mmol), $PdCl_2(PPh_3)_2$ (12 mg, 0.016 mmol), CuI (6 mg, 0.032 mmol) in Et_3N (2 mL) for 12 h provided **31** (270 mg, 96%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/2): IR (neat cm^{-1}) 3232, 1567, 1221, 1031, 829; ^1H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 2.8 Hz, 1H), 7.25 (d, *J* = 8.8 Hz, 1H), 7.06 (dd, *J* = 8.8 and 3.2 Hz, 1H), 4.53 (br, 1H), 3.81 (t, *J* = 6.8 Hz, 2H), 3.76 (s, 3H), 2.64 (t, *J* = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.04, 137.50, 135.58, 127.51, 120.93, 86.83, 81.08, 60.80, 55.82, 23.94; HRMS (ES) *m*/*e* calc'd for $C_{10}H_{12}NO_2$ $(M+H)^+$ 178.0863, found 178.0873.

Compound 32. By the general Larock indole synthesis procedure, 2-bromoaniline (35 mg, 0.2 mmol), alkyne **31** (36 mg, 0.2 mmol), $Pd(OAc)_2$ (2.3 mg, 0.01 mmol), 1,1'-bis(diphenylphosphino)ferrocene (11 mg, 0.02 mmol), $KHCO_3$ (60 mg, 0.6 mmol) in DMF (1 mL) for 2 h provided **32** (51 mg, 95%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3192, 2839, 1273, 845, 735; ^1H NMR (400

MHz, $CDCl_3$) δ 9.19 (s, 1H), 8.21 (d, *J* = 2.8 Hz, 1H), 7.73 (d, *J* = 8.8 Hz, 1H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.35 (d, *J* = 8.4 Hz, 1H), 7.28–7.25 (m, 1H), 7.20 (t, *J* = 7.2 Hz, 1H), 7.11 (t, *J* = 7.2 Hz, 1H), 4.05 (t, *J* = 6.0 Hz, 2H), 3.87 (s, 3H), 3.29 (t, *J* = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.96, 143.44, 136.25, 136.16, 133.69, 129.61, 123.38, 122.46, 122.27, 119.98, 119.21, 111.64, 111.29, 63.46, 56.06, 27.98; HRMS (ES) *m*/*e* calc'd for $C_{16}H_{17}N_2O_2$ $(M+H)^+$ 269.1285, found 269.1285.

Compound 33. By the general triflate cyclization procedure, **32** (28 mg, 0.1 mmol), Et_3N (16 mg, 0.15 mmol), Tf_2O (22 μL, 0.12 mmol) in $CHCl_3$ (1 mL) provided **33** (38.4 mg, 96%) as a yellow solid: IR (neat cm^{-1}) 3294, 1562, 1282, 1028, 749; ^1H NMR (400 MHz, DMSO) δ 12.22 (s, 1H), 8.90 (d, *J* = 2.0 Hz, 1H), 8.36 (dd, *J* = 9.2 and 2.8 Hz, 1H), 8.22 (d, *J* = 9.2 Hz, 1H), 7.74 (d, *J* = 8.0 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.39 (t, *J* = 7.6 Hz, 1H), 7.21 (t, *J* = 7.6 Hz, 1H), 4.95 (t, *J* = 7.2 Hz, 2H), 4.04 (s, 3H), 3.41 (t, *J* = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 155.89, 139.72, 137.79, 133.47, 132.76, 126.46, 126.08, 125.75, 122.43, 121.55, 121.17, 116.09, 113.39, 58.27, 57.33, 19.72; HRMS (ES) *m*/*e* calc'd for $C_{16}H_{15}N_2O$ $(M-OTf)^+$ 251.1184, found 251.1188.

Compound 36. By the general Sonagashira coupling procedure, tert-butyl 6-chloronicotinate **35** (426 mg, 2.0 mmol), 3-butyn-1-ol (154 mg, 2.2 mmol), $PdCl_2(PPh_3)_2$ (42 mg, 0.06 mmol), CuI (23 mg, 0.12 mmol) in Et_3N (4 mL) at 80 °C for 4 h provided **36** (396 mg, 80%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3253, 2227, 1592, 1118, 779; ^1H NMR (400 MHz, $CDCl_3$) δ 9.01 (s, 1H), 8.15 (dd, *J* = 8.0 and 2.0 Hz, 1H), 7.40 (d, *J* = 8.0 Hz, 1H), 3.93 (br, 1H), 3.88 (t, *J* = 6.0 Hz, 2H), 2.73 (t, *J* = 6.0 Hz, 2H), 1.56 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.10,

150.91, 146.67, 137.51, 126.54, 126.52, 91.65, 82.61, 81.62, 60.76, 28.40, 24.21; HRMS (ES) *m*/*e* calc'd for $C_{14}H_{18}NO_3$ $(M+H)^+$ 248.1281, found 248.1285.

Compound 37. By the general Larock indole synthesis procedure, 2-bromoaniline (35 mg, 0.2 mmol), alkyne **36** (50 mg, 0.2 mmol), $Pd(OAc)_2$ (2.3 mg, 0.01 mmol), 1,1'-bis(diphenylphosphino)ferrocene (11 mg, 0.02 mmol), $KHCO_3$ (60 mg, 0.6 mmol) in DMF (1 mL) for 2 h provided **37** (55 mg, 82%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 2/1): IR (neat cm^{-1}) 3259, 1705, 1284, 1126, 845; ^1H NMR (400 MHz, $CDCl_3$) δ 9.41 (s, 1H), 9.03 (d, *J* = 2.0 Hz, 1H), 8.19 (dd, *J* = 8.4 and 1.6 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.59 (d, *J* = 8.0 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 1H), 7.24 (t, *J* = 7.6 Hz, 1H), 7.11 (t, *J* = 7.6 Hz, 1H), 4.08 (t, *J* = 6.0 Hz, 2H), 3.37 (t, *J* = 6.0 Hz, 2H), 1.63 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.37, 153.36, 150.34, 138.23, 136.68, 132.94, 129.61, 125.62, 124.56, 120.33, 120.24, 119.77, 114.96, 111.95, 82.35, 63.66, 28.55, 28.24; HRMS (ES) *m*/*e* calc'd for $C_{20}H_{23}N_2O_3$ $(M+H)^+$ 339.1703, found 339.1704.

Compound 38. By the general triflate cyclization procedure, **37** (52 mg, 0.15 mmol), Et_3N (24 mg, 0.225 mmol), Tf_2O (34 μL, 0.18 mmol) in $CHCl_3$ (1.4 mL) provided **38** (64.2 mg, 91%) as a yellow solid: IR (neat cm^{-1}) 3281, 1720, 1256, 1135, 748; ^1H NMR (400 MHz, DMSO) δ 12.50 (s, 1H), 9.42 (s, 1H), 8.88 (d, *J* = 8.4 Hz, 1H), 8.27 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.25 (t, *J* = 7.2 Hz, 1H), 5.06 (t, *J* = 6.4 Hz, 2H), 3.47 (t, *J* = 6.4 Hz, 2H), 1.66 (s, 9H); ^{13}C NMR (100 MHz, DMSO) δ 162.04, 147.95, 146.06, 145.26, 141.11, 128.30, 126.59, 125.94, 125.53, 122.09, 122.05, 121.46, 121.24, 113.76, 84.44, 56.93, 28.61, 19.77; HRMS (ES) *m*/*e* calc'd for $C_{20}H_{21}N_2O_2$ $(M-OTf)^+$ 321.1603, found 321.1609.

Isonauclefidine triflate 39. A solution of **38** (33 mg, 0.7 mmol) in trifluoroacetic acid (0.5 mL) was stirred at room temperature for 1 h. Evaporation of trifluoroacetic acid provided **39** (29 mg, 100%) as a yellow solid: IR (neat cm^{-1}) 3070, 1550, 1225, 1028, 751; ^{1}H NMR (400 MHz, DMSO) δ 14.36 (br, 1H), 12.51 (s, 1H), 9.51 (d, *J* = 7.2 Hz, 1H), 8.94 (dd, *J* = 8.8 and 2.0 Hz, 1H), 8.30 (d, *J* = 8.8 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.61 (d, *J* = 8.4 Hz, 1H), 7.47 (td, *J* = 7.2 and 1.2 Hz, 1H), 7.25 (td, *J* = 8.0 and 0.8 Hz, 1H), 5.05 (t, *J* = 7.2 Hz, 2H), 3.47 (t, *J* = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, DMSO) δ 164.48, 148.20, 146.06, 145.61, 141.08, 128.26, 126.48, 126.00, 125.55, 122.06, 122.05, 121.52, 121.12, 113.79, 56.84, 19.79; HRMS (ES) *m*/*e* calc'd for $C_{16}H_{13}N_2O_2$ $(M\text{-}OTf)^+$ 265.0977, found 265.0980.

Compound 42. By the general Sonagashira coupling procedure, 2-bromopyridine (158 mg, 1.0 mmol), ethyl 2-hydroxypent-4-ynoate **41** (157 mg, 1.1 mmol), $PdCl_2(PPh_3)_2$ (7 mg, 0.01 mmol), CuI (3.8 mg, 0.02 mmol) in Et_3N (1 mL) for 12 h provided **42** (201 mg, 92%) as an oil after flash chromatography (SiO_2, hexanes/EtOAc = 1/2): IR (neat cm^{-1}) 3223, 1732, 1195, 1094, 777; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, *J* = 4.4 Hz, 1H), 7.58 (td, *J* = 8.0 and 1.6 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.16 (t, *J* = 4.8 Hz, 1H), 4.43 (t, *J* = 5.2 Hz, 1H), 4.28–4.18 (m, 2H), 4.06 (br, 1H), 2.97 (qd, *J* = 17.2 and 5.2 Hz, 2H), 1.26 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.2, 149.91, 143.32, 136.42, 127.28, 122.94, 85.65, 82.82, 67.85, 62.21, 26.13, 14.41; HRMS (ES) *m*/*e* calc'd for $C_{12}H_{14}NO_3$ $(M+H)^+$ 220.0968, found 220.0979.

Compound 43. By the general Larock indole synthesis procedure, 2-bromoaniline (26 mg, 0.15 mmol), alkyne **42** (33 mg, 0.15 mmol), $Pd(OAc)_2$ (1.7 mg, 0.0075 mmol), 1,1'-bis(diphenylphosphino)ferrocene (8.3 mg, 0.015 mmol), $KHCO_3$ (30 mg, 0.3 mmol) in

DMF (1 mL) for 4 h provided **43** (38 mg, 82%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3277, 1729, 1204, 1156, 745; ^1H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 8.20 (d, *J* = 4.4 Hz, 1H), 7.63–7.56 (m, 2H), 7.46 (d, *J* = 7.6 Hz, 1H), 7.04 (t, *J* = 5.6 Hz, 1H), 6.99–6.91 (m, 3H), 4.74 (t, *J* = 5.2 Hz, 1H), 4.36–4.30 (m, 1H), 4.24–4.16 (m, 1H), 3.47 (d, *J* = 5.6 Hz, 2H), 1.40 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.62, 149.86, 147.93, 137.68, 136.93, 134.14, 128.68, 123.71, 122.40, 122.17, 119.67, 118.72, 112.03, 110.76, 72.55, 61.51, 29.28, 14.55; HRMS (ES) *m*/*e* calc'd for $C_{18}H_{19}N_2O_3$ $(M+H)^+$ 311.1390, found 311.1393.

Compound 44. By the general triflate cyclization procedure, **43** (48 mg, 0.15 mmol), Et_3N (24 mg, 0.225 mmol), Tf_2O (34 μL, 0.18 mmol) in $CHCl_3$ (1.4 mL) provided **44** (52 mg, 79%) as a yellow solid: IR (neat cm^{-1}) 3238, 1756, 1555, 1223, 752; ^1H NMR (400 MHz, DMSO) δ 12.48 (s, 1H), 9.00 (d, *J* = 6.0 Hz, 1H), 8.75 (td, *J* = 8.4 and 1.2 Hz, 1H), 8.37 (d, *J* = 8.0 Hz, 1H), 8.00 (td, *J* = 7.6 and 1.2 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 1H), 7.45 (td, *J* = 8.0 and 0.8 Hz, 1H), 7.25 (t, *J* = 7.2 Hz, 1H), 6.30 (d, *J* = 6.0 Hz, 1H), 4.13 (q, *J* = 6.8 Hz, 2H), 4.00 (d, *J* = 17.2 Hz, 1H), 3.80 (dd, *J* = 17.6 and 6.8 Hz, 1H), 1.08 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, DMSO) δ 168.86, 147.97, 147.44, 143.67, 140.54, 127.75, 125.60, 125.50, 124.53, 122.13, 122.09, 121.75, 116.13, 113.76, 67.57, 63.82, 23.19, 14.66; HRMS (ES) *m*/*e* calc'd for $C_{18}H_{17}N_2O_2$ $(M\text{-}OTf)^+$ 293.1290, found 293.1289.

Compound 46. By the general Sonagashira coupling procedure, 2-bromo-5-methylcarbonylpyridine **45** (400 mg, 2.0 mmol), 3-butyn-1-ol (154 mg, 2.2 mmol), $PdCl_2(PPh_3)_2$ (14 mg, 0.02 mmol), CuI (7.6 mg, 0.04 mmol) in Et_3N (3 mL) for 12 h provided **46** (360 mg, 95%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc

= 1/2): IR (neat cm^{-1}) 3402, 1670, 1587, 1041, 849; ^1H NMR (400 MHz, $CDCl_3$) δ 9.06 (d, *J* = 2.4 Hz, 1H), 8.18 (dd, *J* = 8.0 and 2.4 Hz, 1H), 7.48 (d, *J* = 8.0 Hz, 1H), 3.90 (q, *J* = 6.0 Hz, 2H), 2.98 (t, *J* = 6.0 Hz, 1H), 2.77 (t, *J* = 6.0 Hz, 2H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.31, 150.24, 147.38, 136.09, 130.99, 127.05, 92.01, 81.82, 60.91, 27.07, 24.26; HRMS (ES) *m*/*e* calc'd for $C_{11}H_{12}NO_2$ $(M+H)^+$ 190.0863, found 190.0868.

Compound 47. By the general Larock indole synthesis procedure, 2-bromoaniline (26 mg, 0.15 mmol), alkyne **46** (42.5 mg, 0.225 mmol), $Pd(OAc)_2$ (1.7 mg, 0.0075 mmol), 1,1'-bis(diphenylphosphino)ferrocene (8.3 mg, 0.015 mmol), $KHCO_3$ (45 mg, 0.45 mmol) in DMF (1 mL) for 4 h provided **47** (30 mg, 71%) as a solid after flash chromatography (SiO_2, hexanes/EtOAc = 1/1): IR (neat cm^{-1}) 3358, 1677, 1589, 1263, 733; ^1H NMR (400 MHz, $CDCl_3$) δ 9.58 (s, 1H), 8.95 (d, *J* = 2.0 Hz, 1H), 8.14 (dd, *J* = 8.0 and 1.6 Hz, 1H), 7.78 (d, *J* = 8.4 Hz, 1H), 7.57 (d, *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 1H), 7.21 (t, *J* = 7.2 Hz, 1H), 7.08 (t, *J* = 7.6 Hz, 1H), 4.10 (t, *J* = 6.0 Hz, 2H), 3.36 (t, *J* = 6.0 Hz, 2H), 2.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.09, 153.72, 149.32, 136.90, 136.88, 132.68, 130.02, 129.44, 124.79, 120.80, 120.41, 119.79, 115.60, 112.07, 63.70, 28.14, 26.90; HRMS (ES) *m*/*e* calc'd for $C_{17}H_{17}N_2O_2$ $(M+H)^+$ 281.1285, found 281.1288.

Compound 48. By the general triflate cyclization procedure, **47** (42 mg, 0.15 mmol), Et_3N (24 mg, 0.225 mmol), Tf_2O (34 µL, 0.18 mmol) in $CHCl_3$ (1.4 mL) provided **48** (57.4 mg, 93%) as a yellow solid: IR (neat cm^{-1}) 3267, 1702, 1245, 1026, 745; ^1H NMR (400 MHz, DMSO) δ 12.49 (s, 1H), 9.54 (s, 1H), 8.98 (d, *J* = 8.4 Hz, 1H), 8.31 (d, *J* = 8.4 Hz, 1H), 7.81 (d, *J* = 8.0 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 1H),

7.26 (t, *J* = 7.6 Hz, 1H), 5.06 (t, *J* = 7.2 Hz, 2H), 3.49 (t, *J* = 7.2 Hz, 2H), 2.74 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 194.73, 147.67, 145.84, 144.41, 141.17, 131.34, 128.35, 125.97, 125.55, 122.09, 122.07, 121.39, 121.29, 113.78, 56.92, 27.86, 19.82; HRMS (ES) *m*/*e* calc'd for $C_{17}H_{15}N_2O$ $(M\text{-}OTf)^+$ 263.1184, found 263.1184.

Compound 52. To a solution of **46** (136 mg, 0.72 mmol) in MeOH (2 mL) at 0 °C was added $NaBH_4$ (55 mg, 1.44 mmol). After stirring for 3 h silica gel was added, and the resulting mixture was concentrated and the components were purified by flash chromatography (SiO_2, EtOAc) to provide **52** (136 mg, 99%) as a solid: IR (neat cm^{-1}) 3151, 1478, 1044, 850, 765; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (br, 1H), 7.65 (dd, *J* = 8.4 and 1.2 Hz, 1H), 7.30 (d, *J* = 7.6 Hz, 1H), 4.88 (q, *J* = 6.4 Hz 1H), 4.61 (br, 2H), 3.80 (t, *J* = 6.0 Hz, 2H), 2.65 (t, *J* = 6.0 Hz, 2H), 1.44 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.23, 142.03, 141.18, 134.28, 126.84, 89.18, 81.46, 67.66, 60.80, 25.17, 24.23; HRMS (ES) *m*/*e* calc'd for $C_{11}H_{14}NO_2$ $(M+H)^+$ 192.1019, found 192.1025.

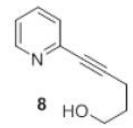
Compound 54. By the general Larock indole synthesis procedure, 2-bromo-3-methoxyaniline **53** (43 mg, 0.21 mmol), alkyne **52** (29 mg, 0.15 mmol), $Pd(OAc)_2$ (5 mg, 0.0225 mmol), 1,1'-bis(diphenylphosphino)ferrocene (25 mg, 0.045 mmol), $KHCO_3$ (45 mg, 0.45 mmol) in DMF (1 mL) for 10 h provided **54** (28 mg, 60%) as a solid after flash chromatography (SiO_2, EtOAc): IR (neat cm^{-1}) 3237, 1358, 1250, 1105, 733; ^{1}H NMR (400 MHz, MeOD) δ 8.62 (d, *J* = 2.0 Hz, 1H), 7.95 (dd, *J* = 8.4 and 2.4 Hz, 1H), 7.81 (d, *J* = 8.4 Hz, 1H), 7.12 (t, *J* = 8.0 Hz, 1H), 7.04 (d, *J* = 8.0 Hz, 1H), 6.53 (d, *J* = 7.6 Hz, 1H), 4.97 (q, *J* = 6.8 Hz, 1H), 4.00 (t, *J* = 6.4 Hz, 2H), 3.95 (s, 3H), 3.46 (t, *J* = 6.4 Hz, 2H), 1.55 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, MeOD) δ 157.50, 152.33, 148.22, 142.14, 140.50, 136.82, 134.32, 125.68, 123.70, 120.82, 114.52, 106.62, 101.10, 69.22,

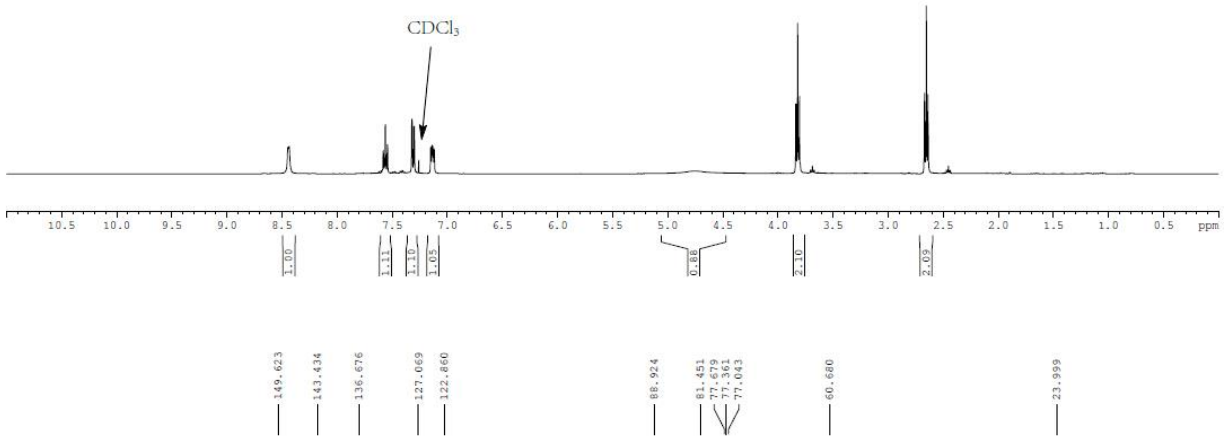
65.74, 56.35, 30.55, 26.12; HRMS (ES) *m*/*e* calc'd for $C_{18}H_{21}N_2O_3$ $(M+H)^+$ 313.1547, found 313.1549.

Compound 55. A solution of **54** (32 mg, 0.102 mmol), pyridine (12 mg, 0.153 mmol), DMAP (0.6 mg, 0.005 mmol) in $CHCl_3$ (0.6 mL) was added a solution of 4-toluenesulfonyl chloride (22 mg, 0.11 mmol) in $CHCl_3$ (0.6 mL) slowly. After being stirred for 4 h, the resulting precipitate was filtered and washed with $CHCl_3$ to provide **55** (30.6 mg, 91%) as a yellow solid: IR (neat cm^{-1}) 2987, 1558, 1259, 1103, 740; ^1H NMR (400 MHz, DMSO) δ 12.91 (s, 1H), 8.95 (s, 1H), 8.54 (d, *J* = 8.4 Hz, 1H), 8.44 (d, *J* = 8.4 Hz, 1H), 7.30 (t, *J* = 8.0 Hz, 1H), 7.13 (d, *J* = 8.4 Hz, 1H), 6.62 (d, *J* = 7.6 Hz, 1H), 6.00 (br, 1H), 4.97 (q, *J* = 6.4 Hz, 1H), 4.94 (t, *J* = 7.2 Hz, 2H), 3.93 (s, 3H), 3.52 (t, *J* = 7.2 Hz, 2H), 1.49 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, DMSO) δ 155.94, 143.36, 143.28, 143.14, 142.50, 141.60, 128.25, 124.86, 121.56, 117.64, 116.54, 106.41, 101.18, 66.06, 56.66, 56.32, 25.78, 21.50; HRMS (ES) *m*/*e* calc'd for $C_{18}H_{19}N_2O_2$ $(M-Cl)^+$ 295.1447, found 295.1449.

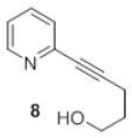
^{1}H and ^{13}C NMR spectrum of 8 ($CDCl_3$)

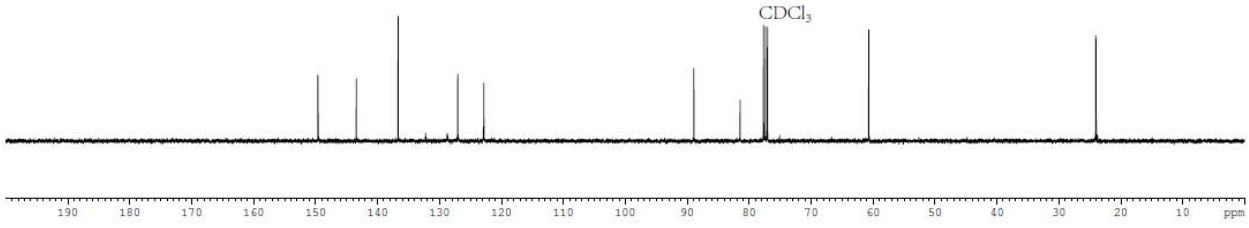
^{1}H NMR($CDCl_3$,400 MHz)



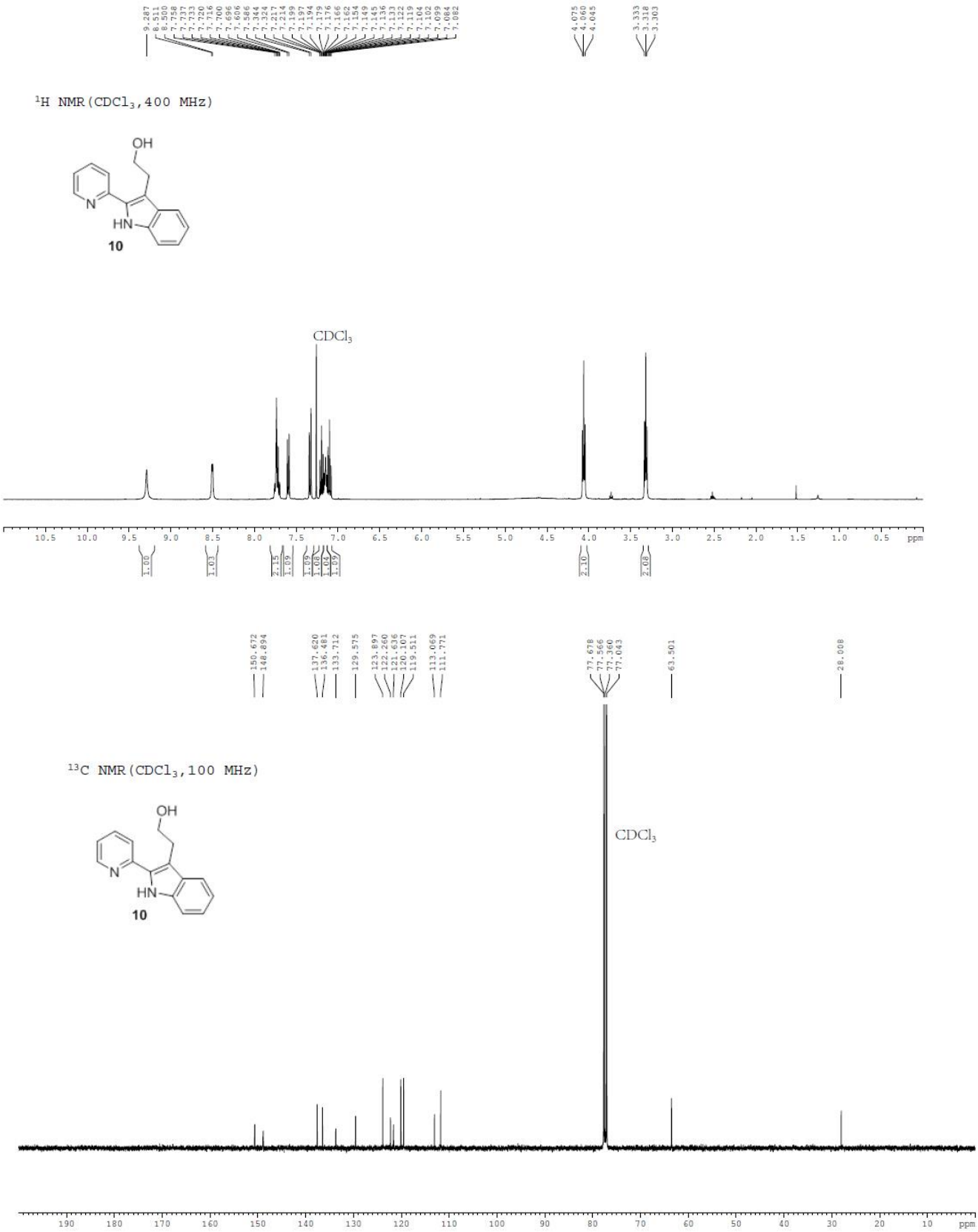


^{13}C NMR($CDCl_3$,100 MHz)

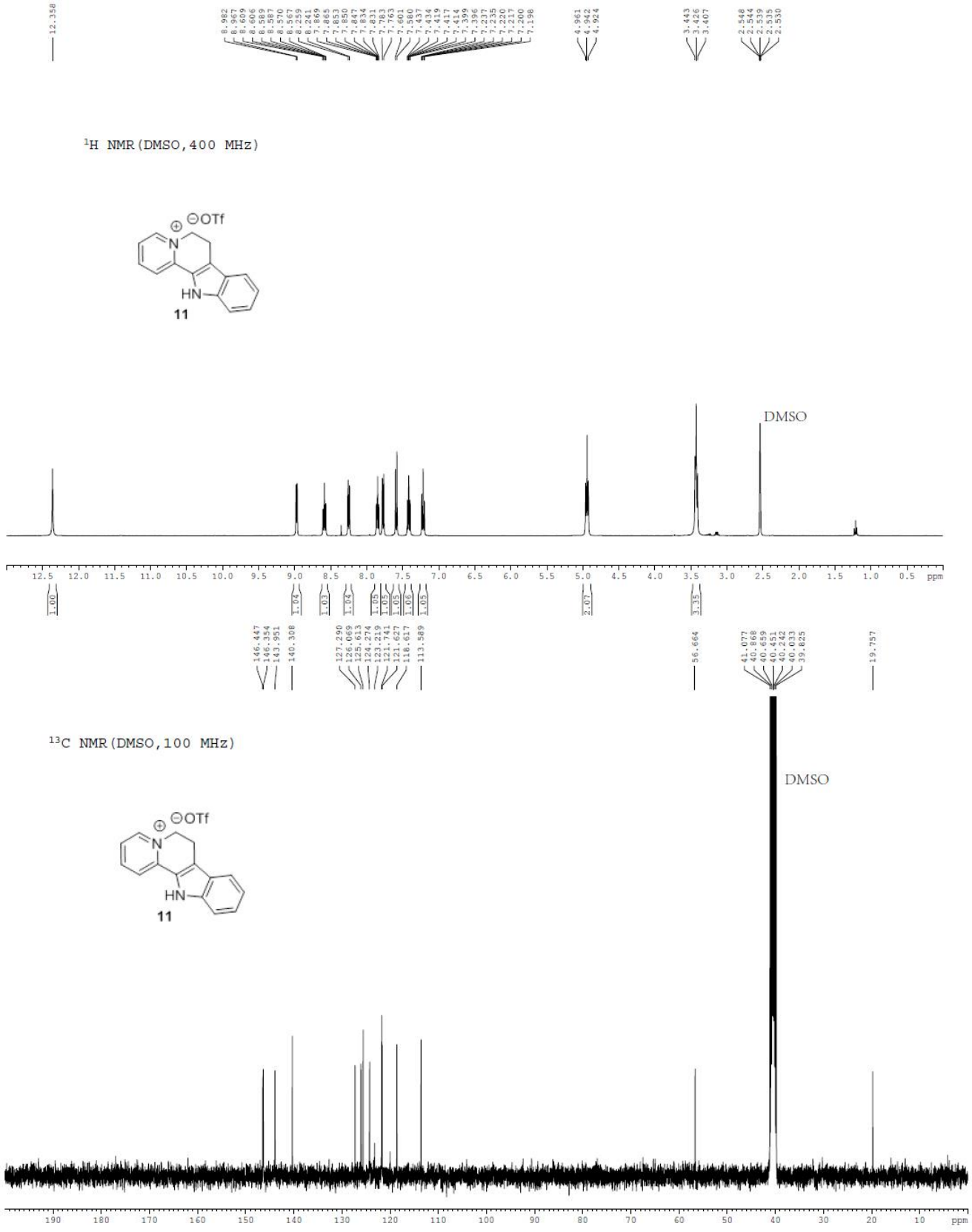




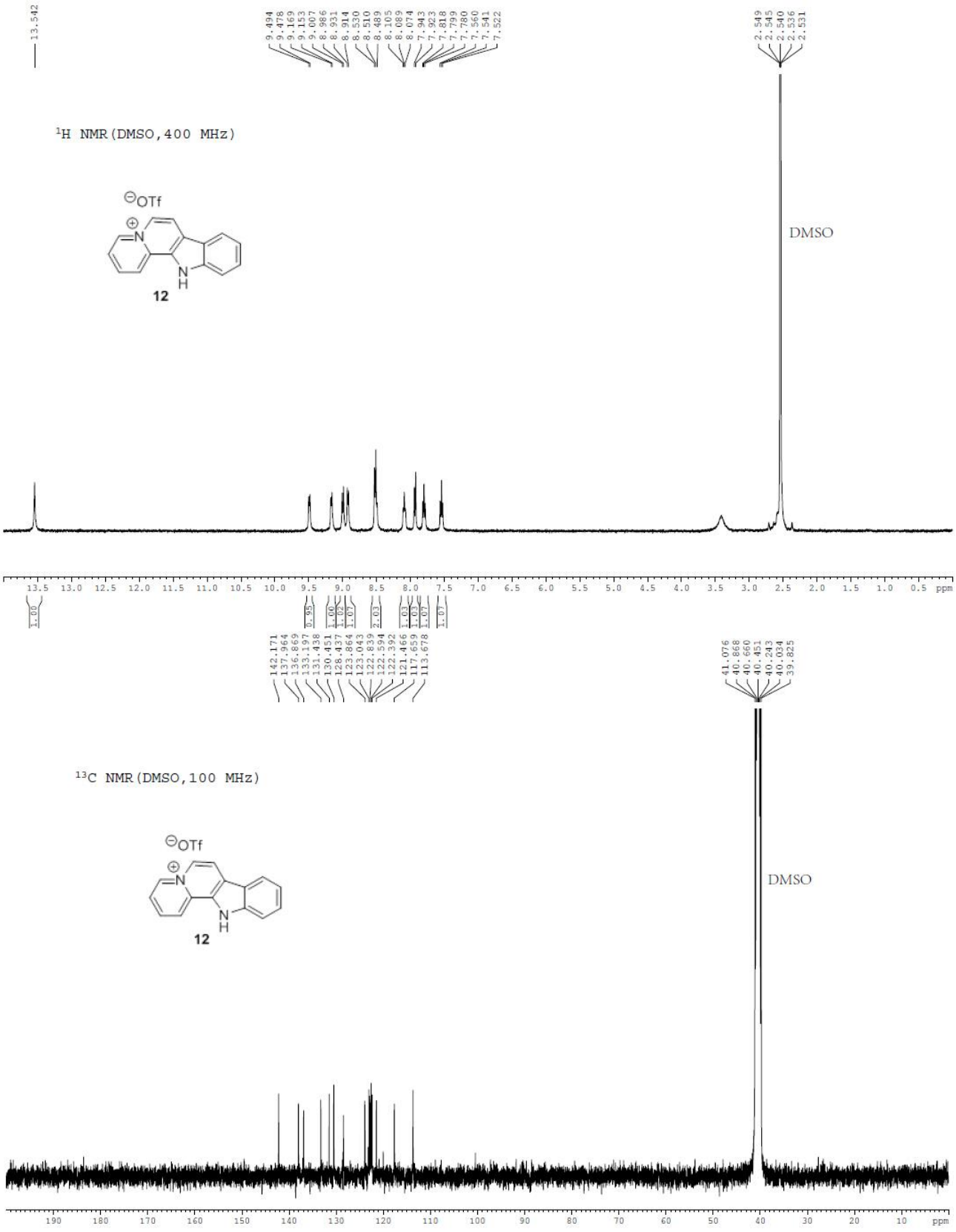
^{1}H and ^{13}C NMR spectrum of 10 ($CDCl_3$)



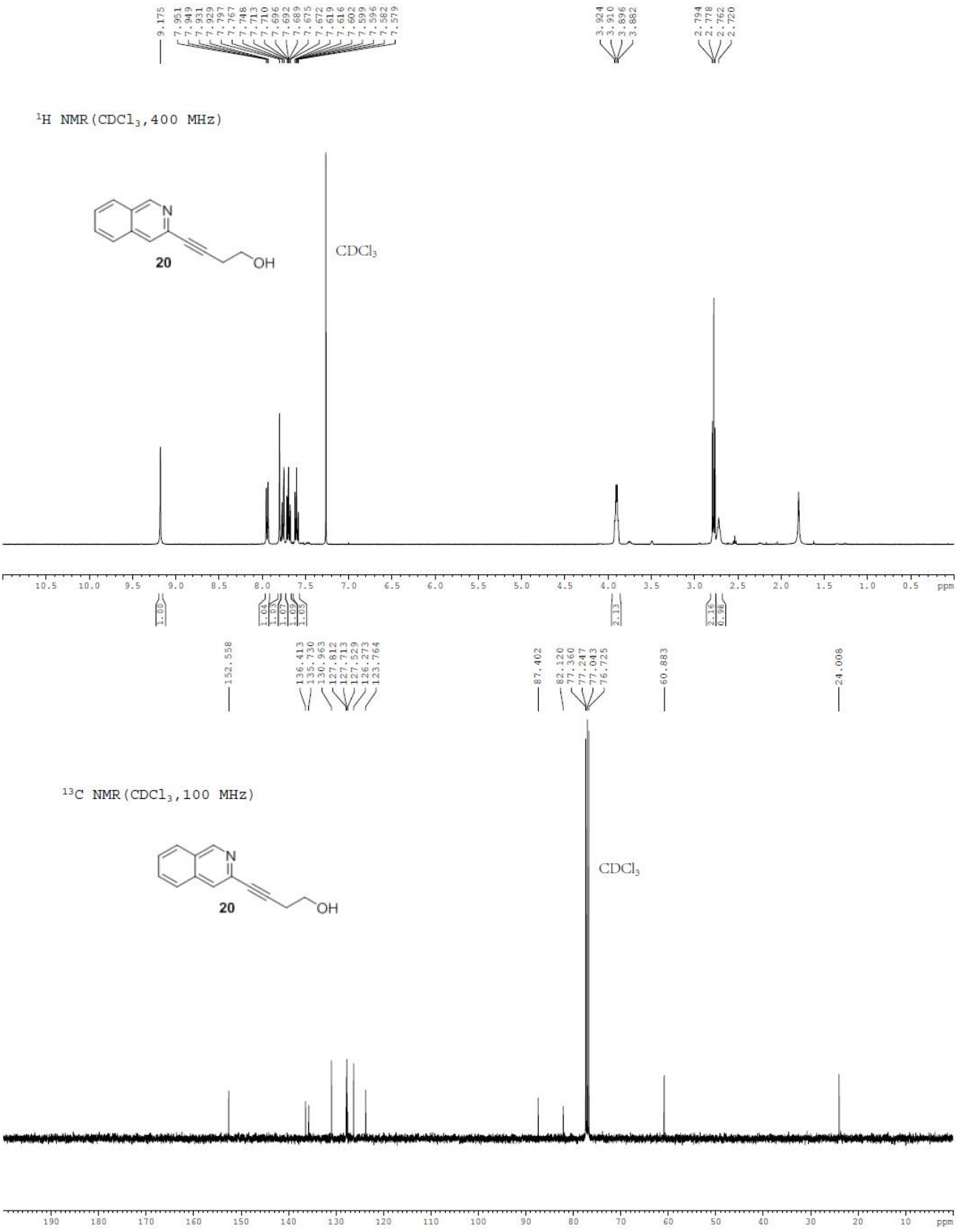
^{1}H and ^{13}C NMR spectrum of 11 (DMSO)



^{1}H and ^{13}C NMR spectrum of 12 (DMSO)

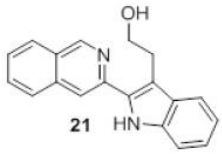


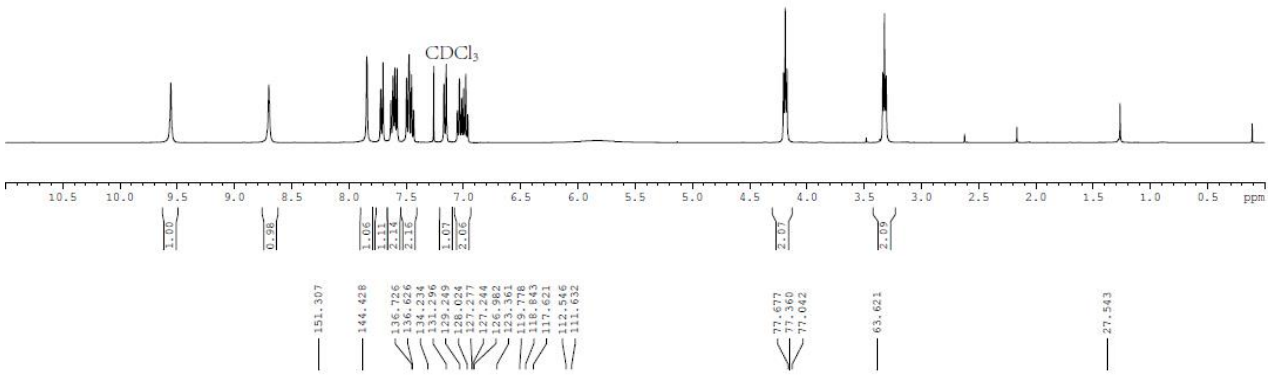
^{1}H and ^{13}C NMR spectrum of 20 ($CDCl_3$)



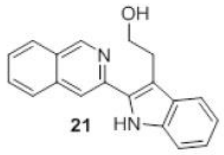
^{1}H and ^{13}C NMR spectrum of 21 ($CDCl_3$)

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

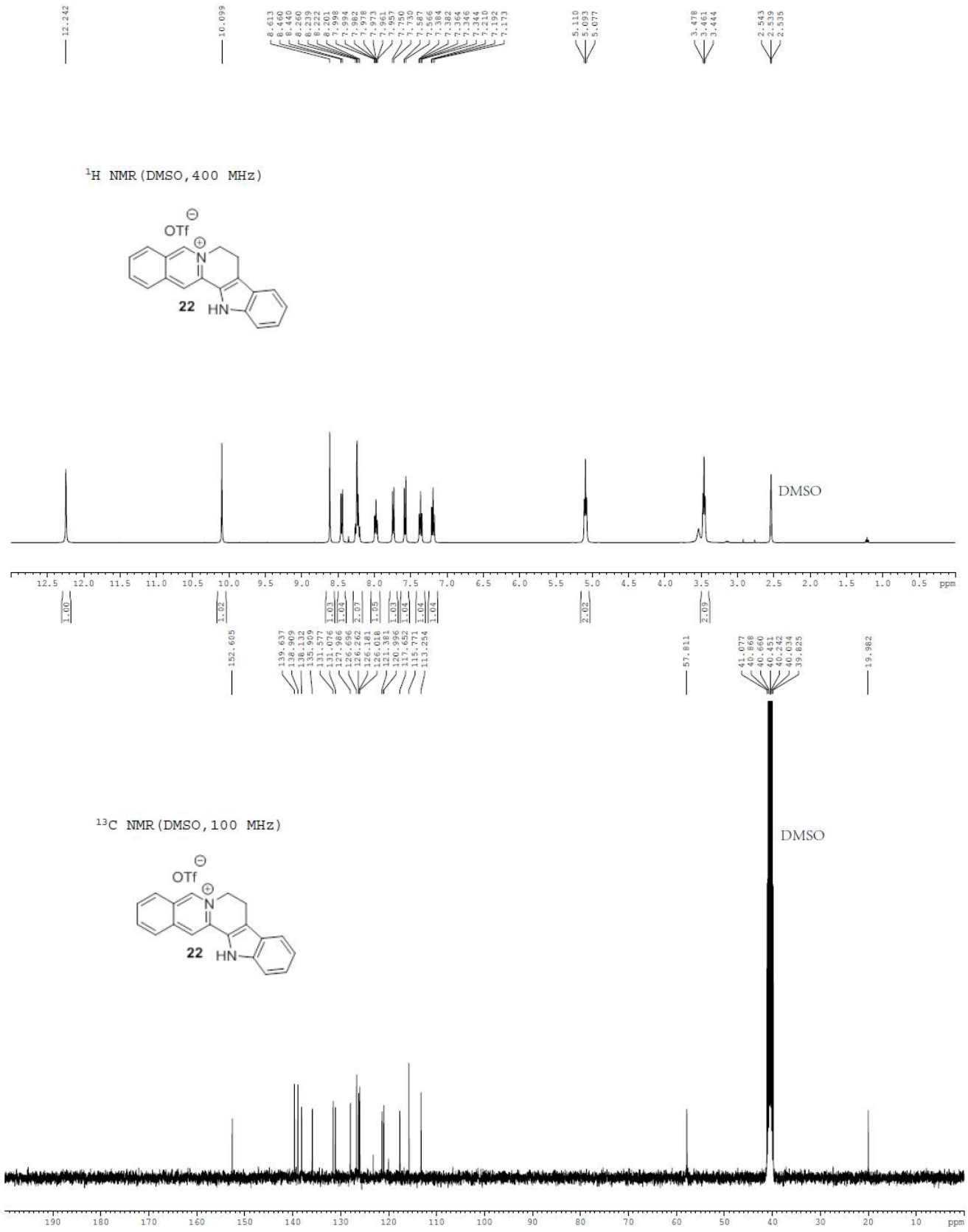




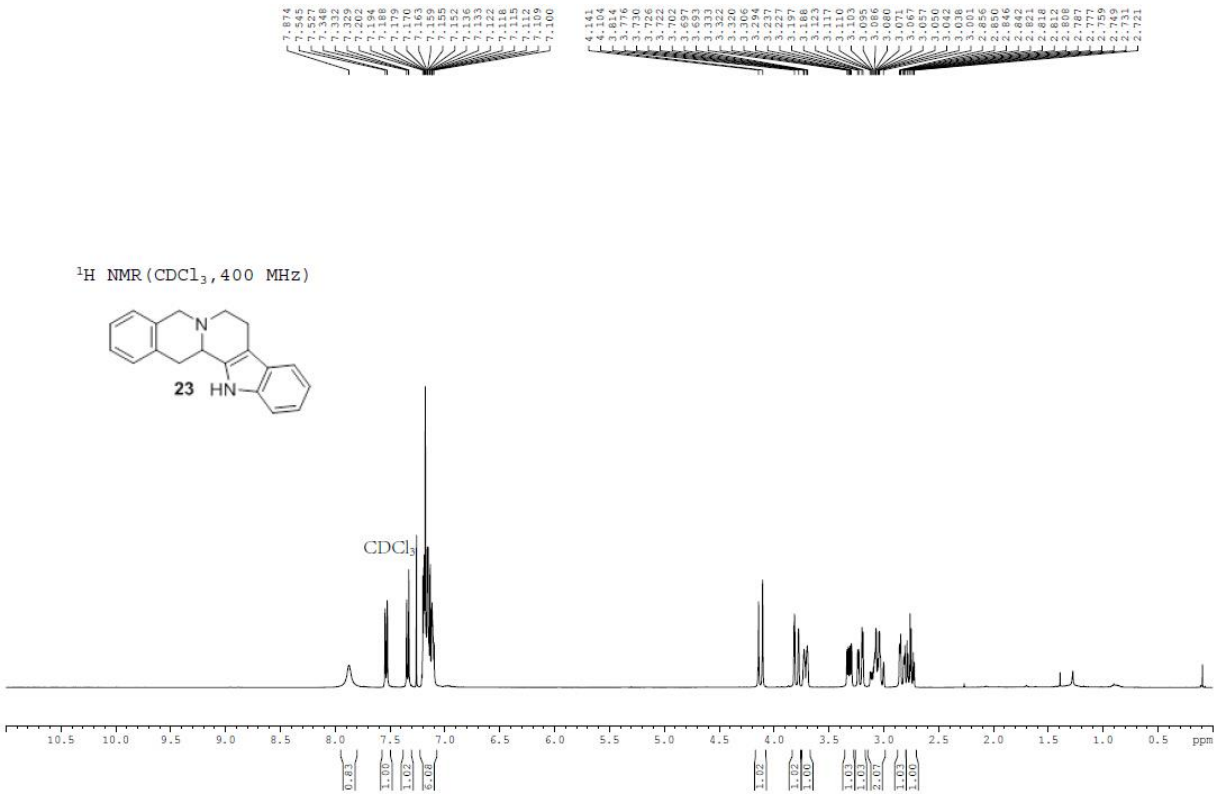
^{13}C NMR($CDCl_3$,100 MHz)



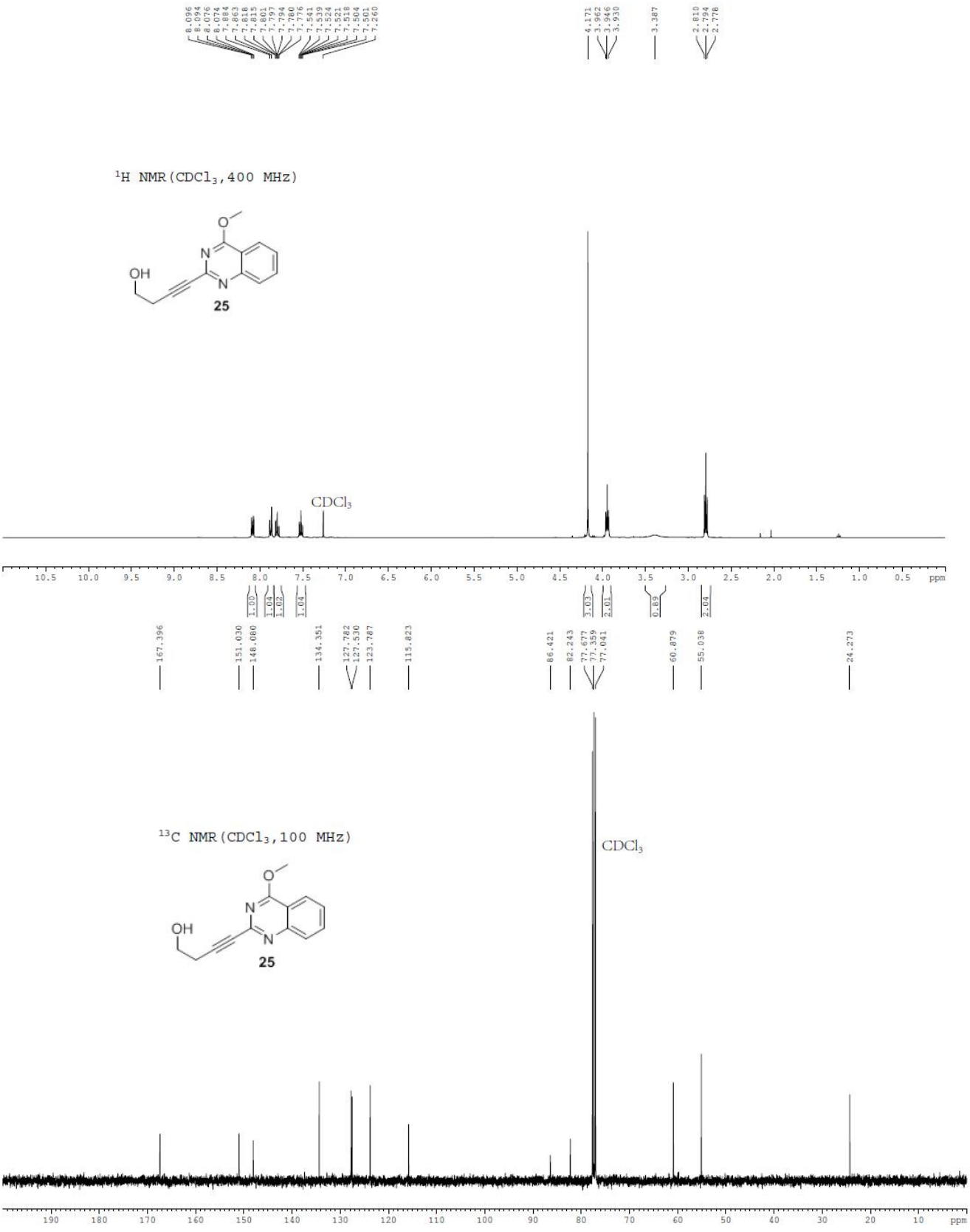
^{1}H and ^{13}C NMR spectrum of 22 (DMSO)



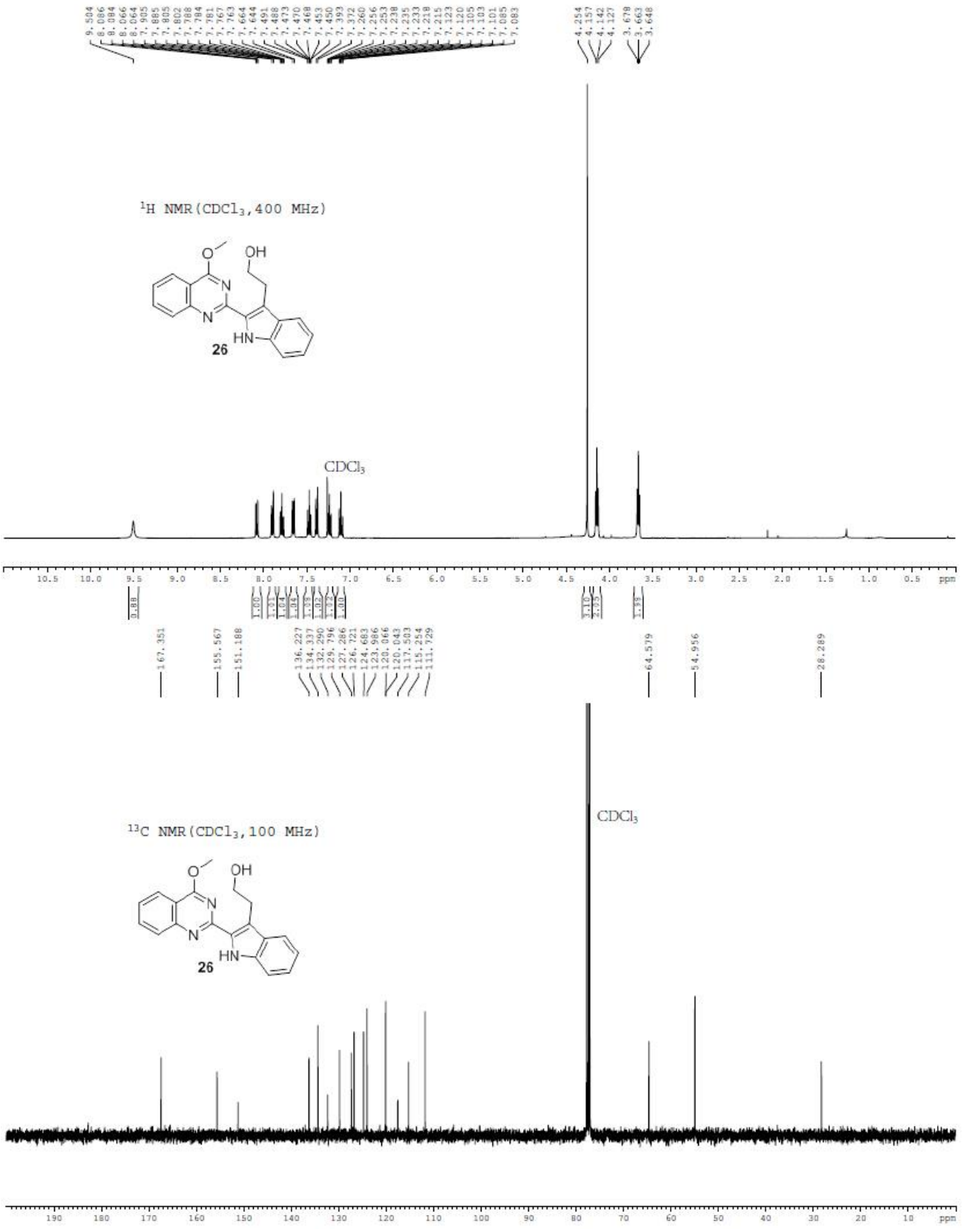
^{1}H and ^{13}C NMR spectrum of 23 ($CDCl_3$)



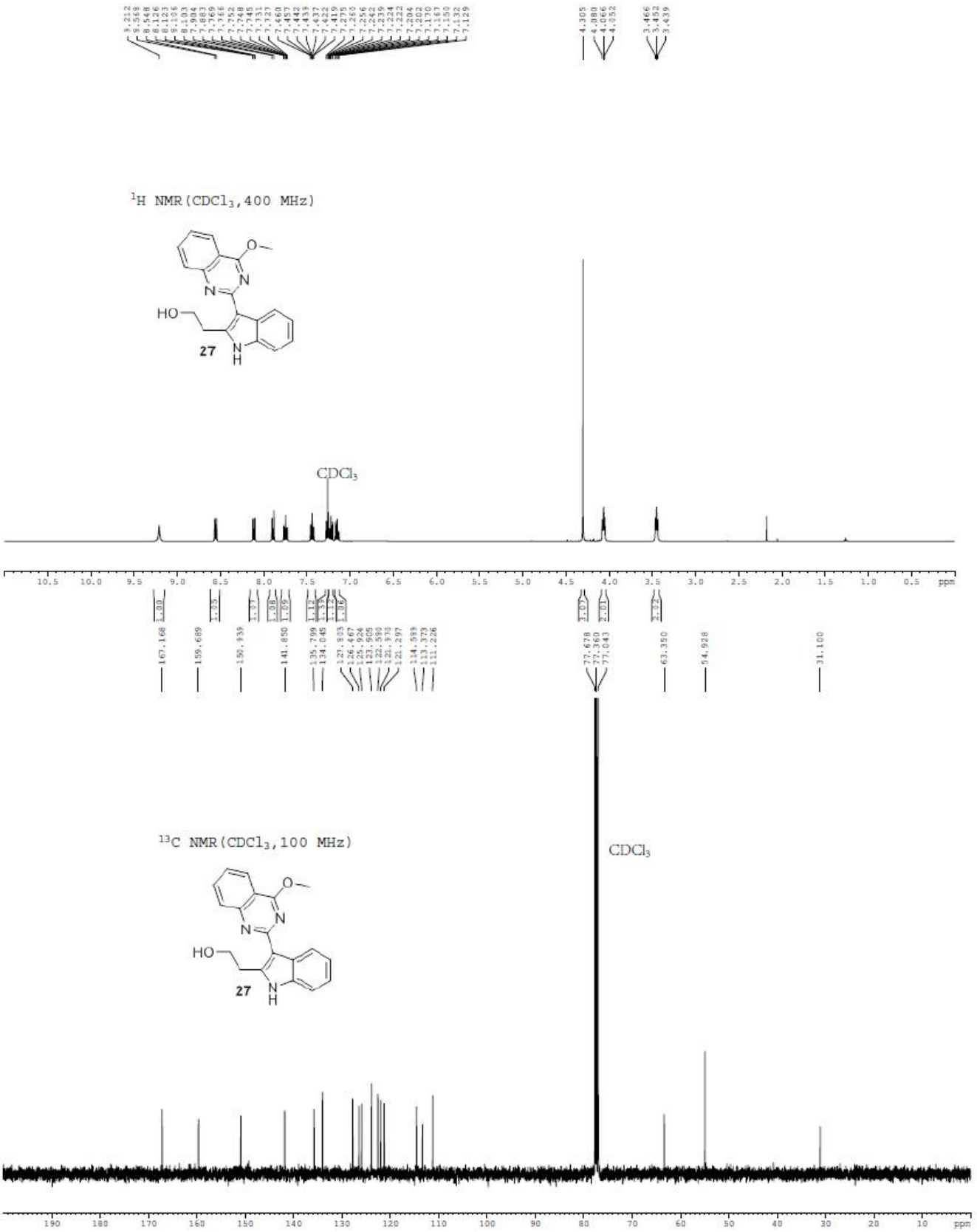
^{1}H and ^{13}C NMR spectrum of 25 ($CDCl_3$)



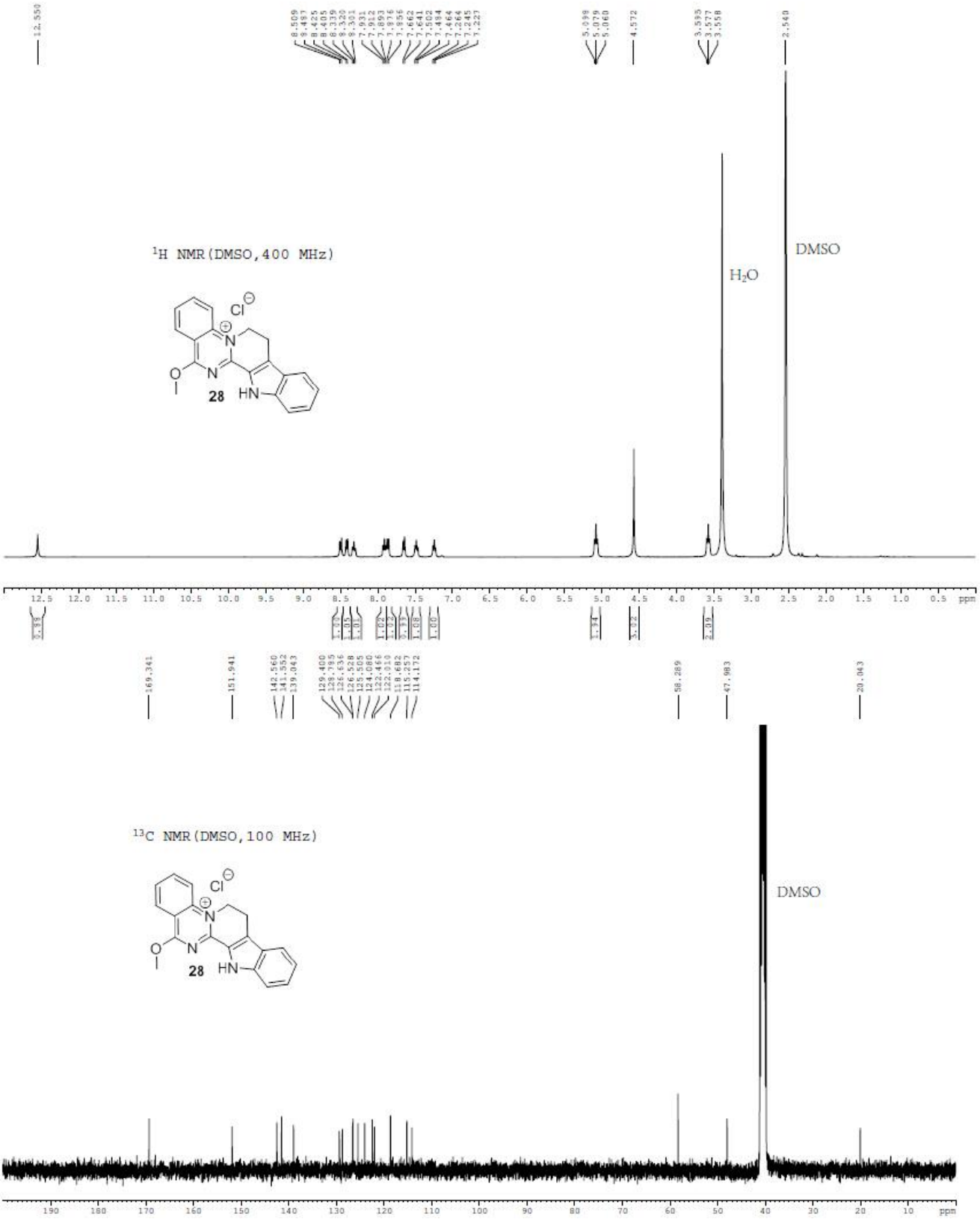
^{1}H and ^{13}C NMR spectrum of 26 ($CDCl_3$)



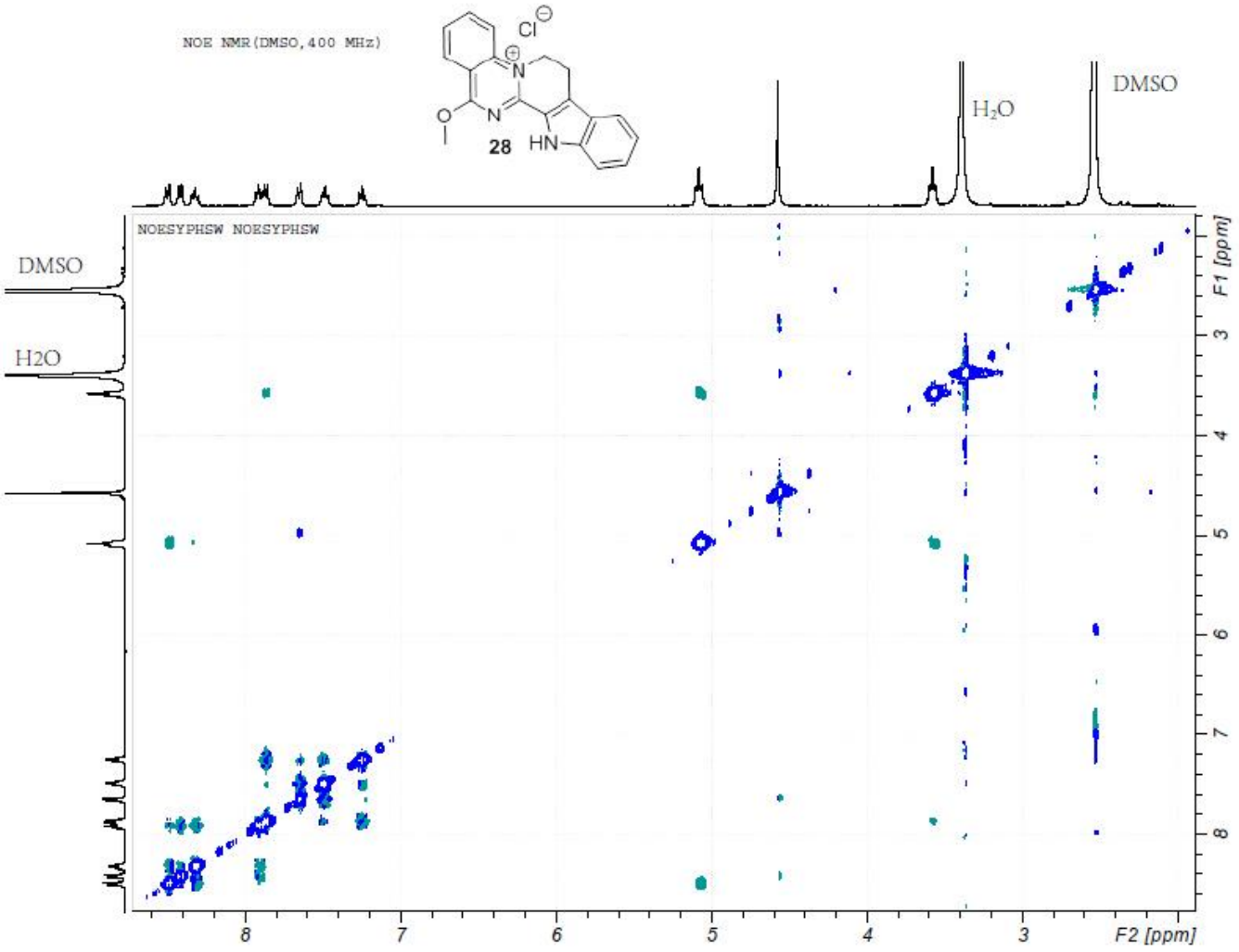
^{1}H and ^{13}C NMR spectrum of 27 ($CDCl_3$)



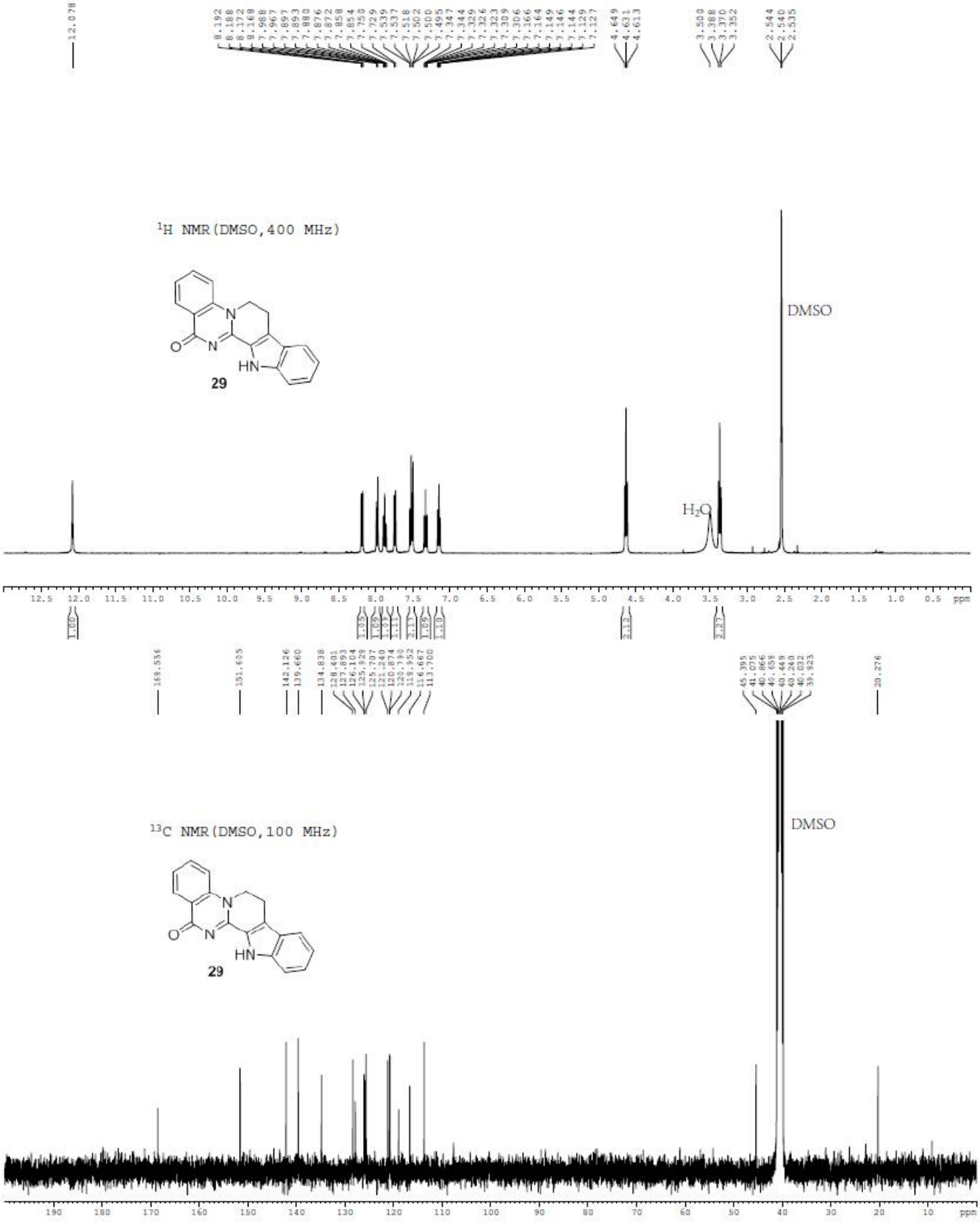
^{1}H and ^{13}C NMR spectrum of 28 (DMSO)



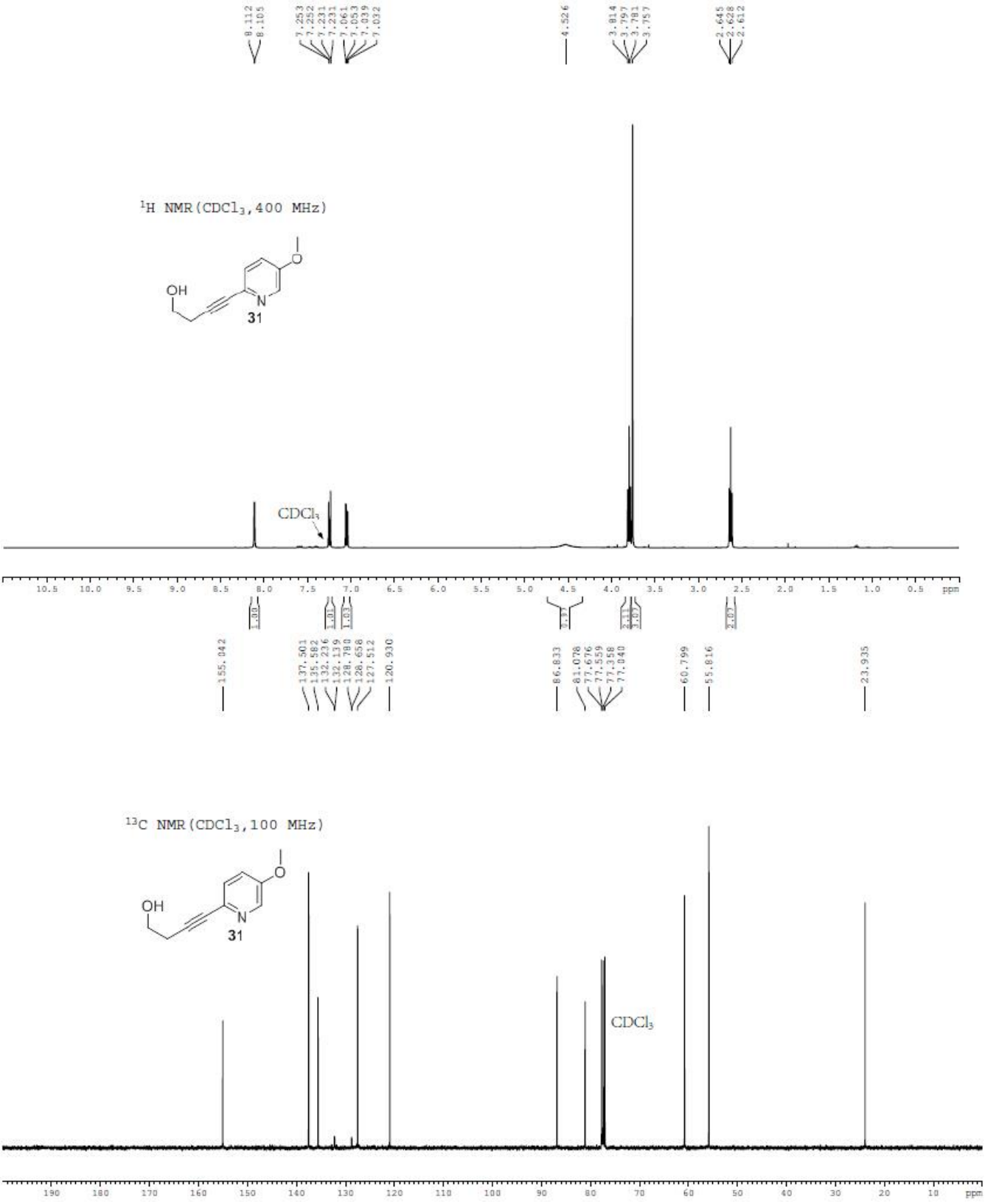
NOE NMR spectrum of 28 (DMSO)



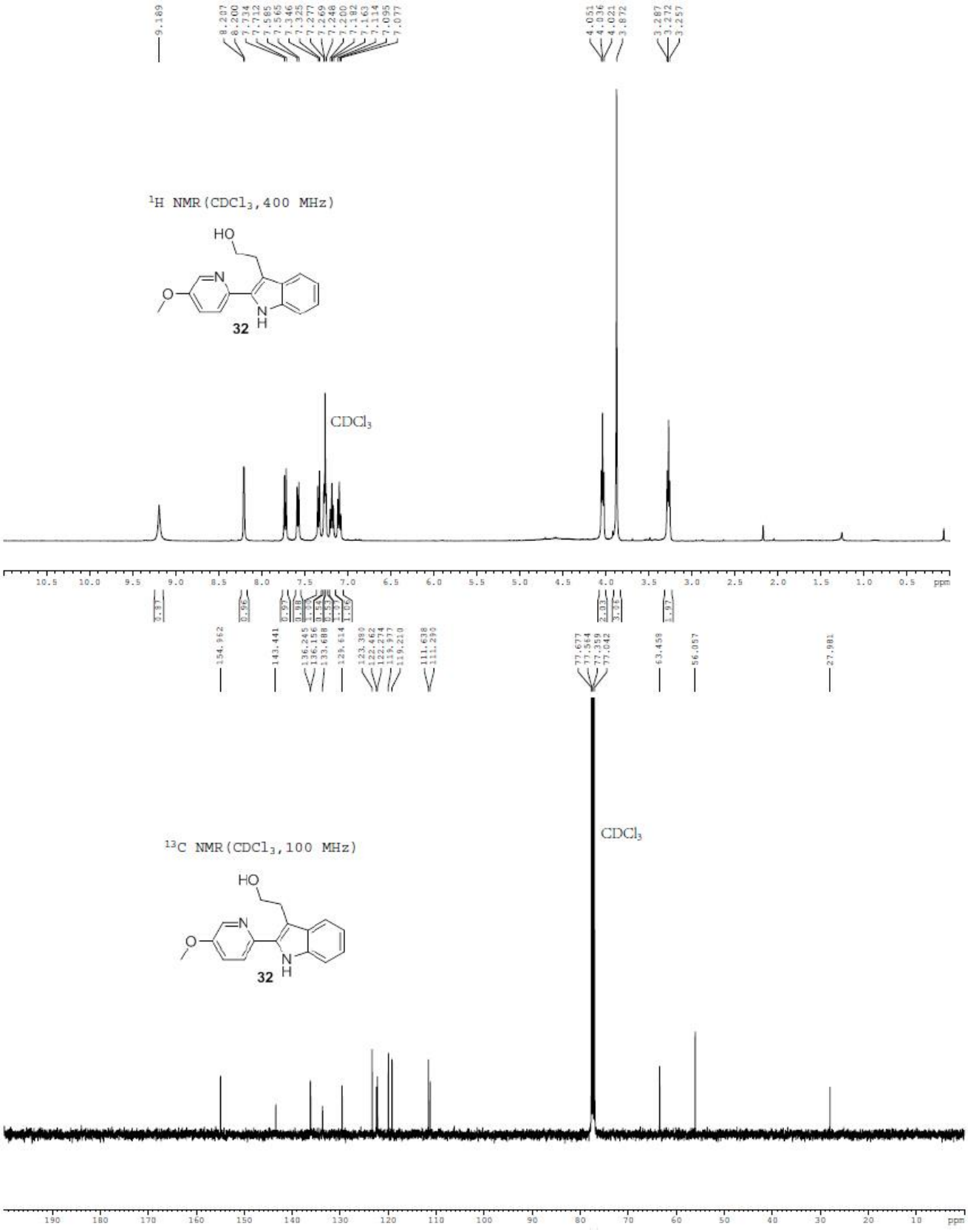
^{1}H and ^{13}C NMR spectrum of 29 (DMSO)



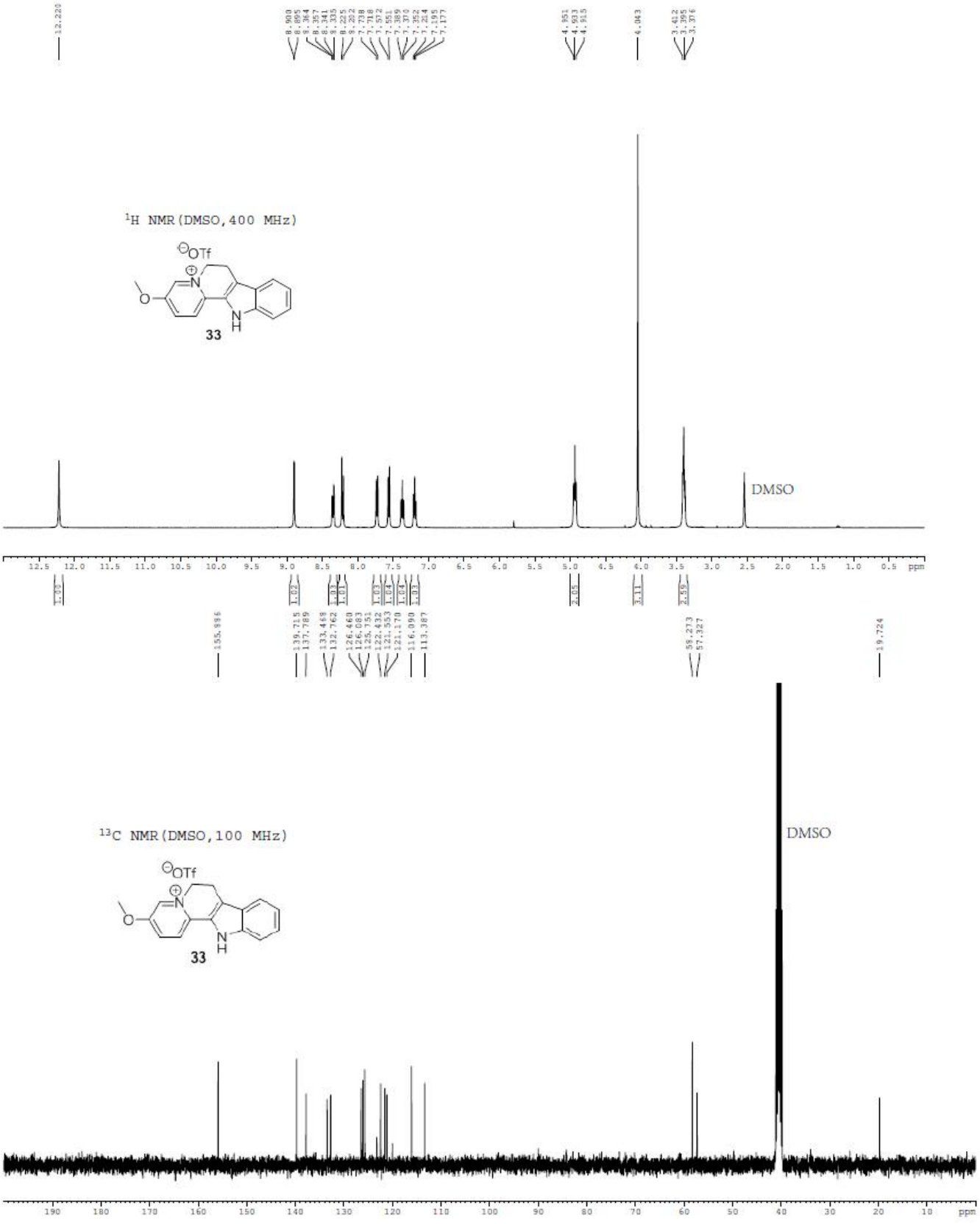
^{1}H and ^{13}C NMR spectrum of 31 ($CDCl_3$)



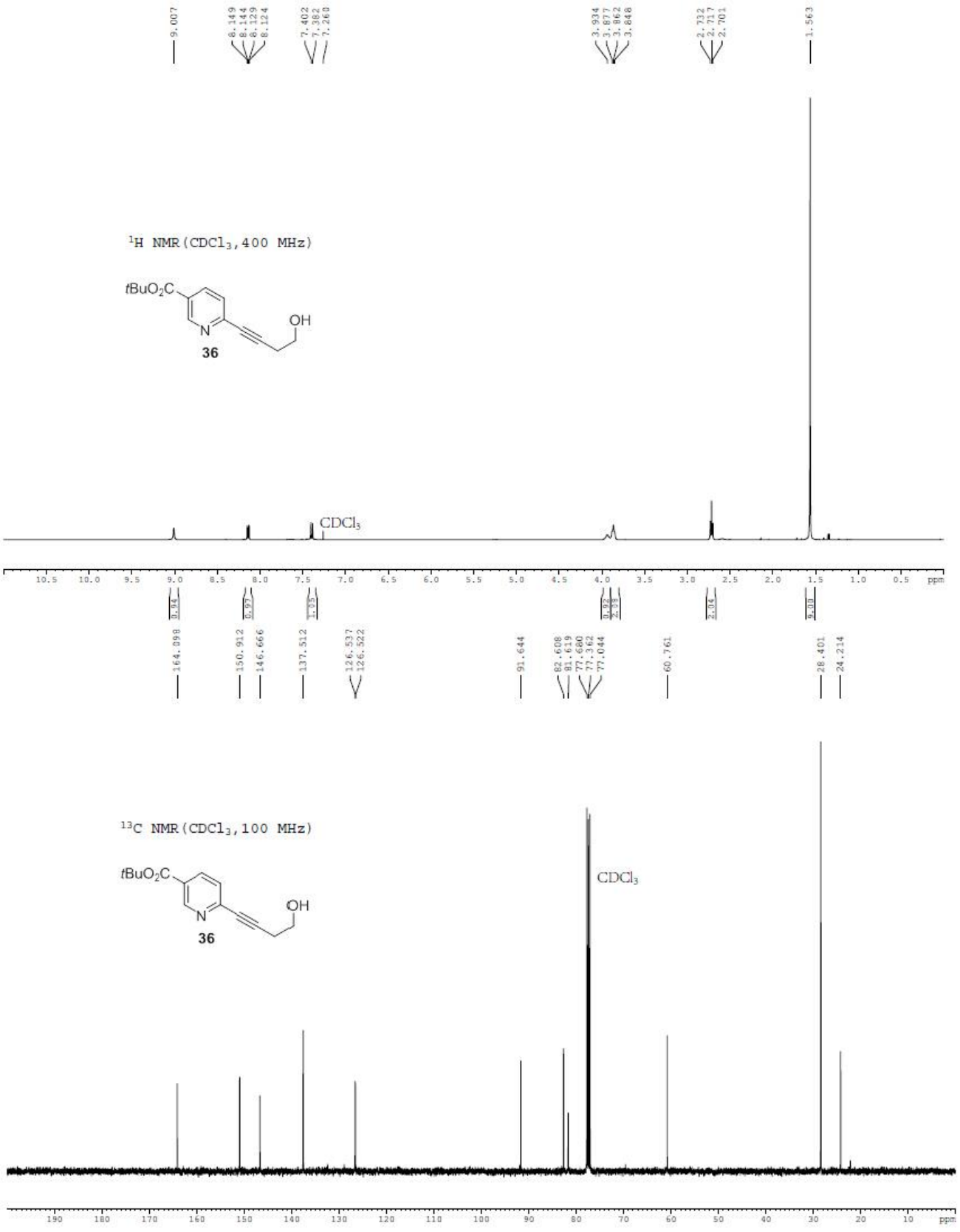
^{1}H and ^{13}C NMR spectrum of 32 ($CDCl_3$)



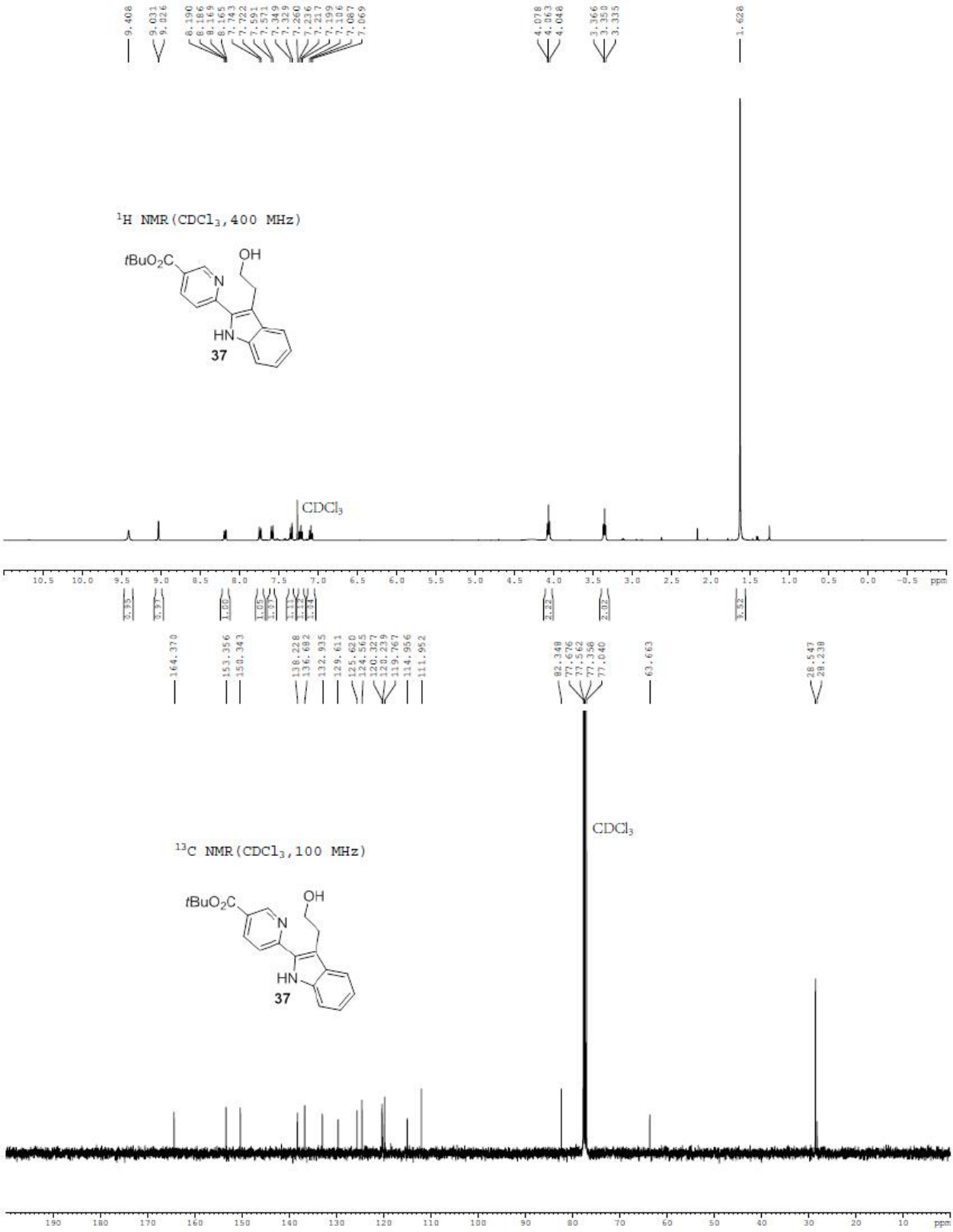
^{1}H and ^{13}C NMR spectrum of 33 (DMSO)



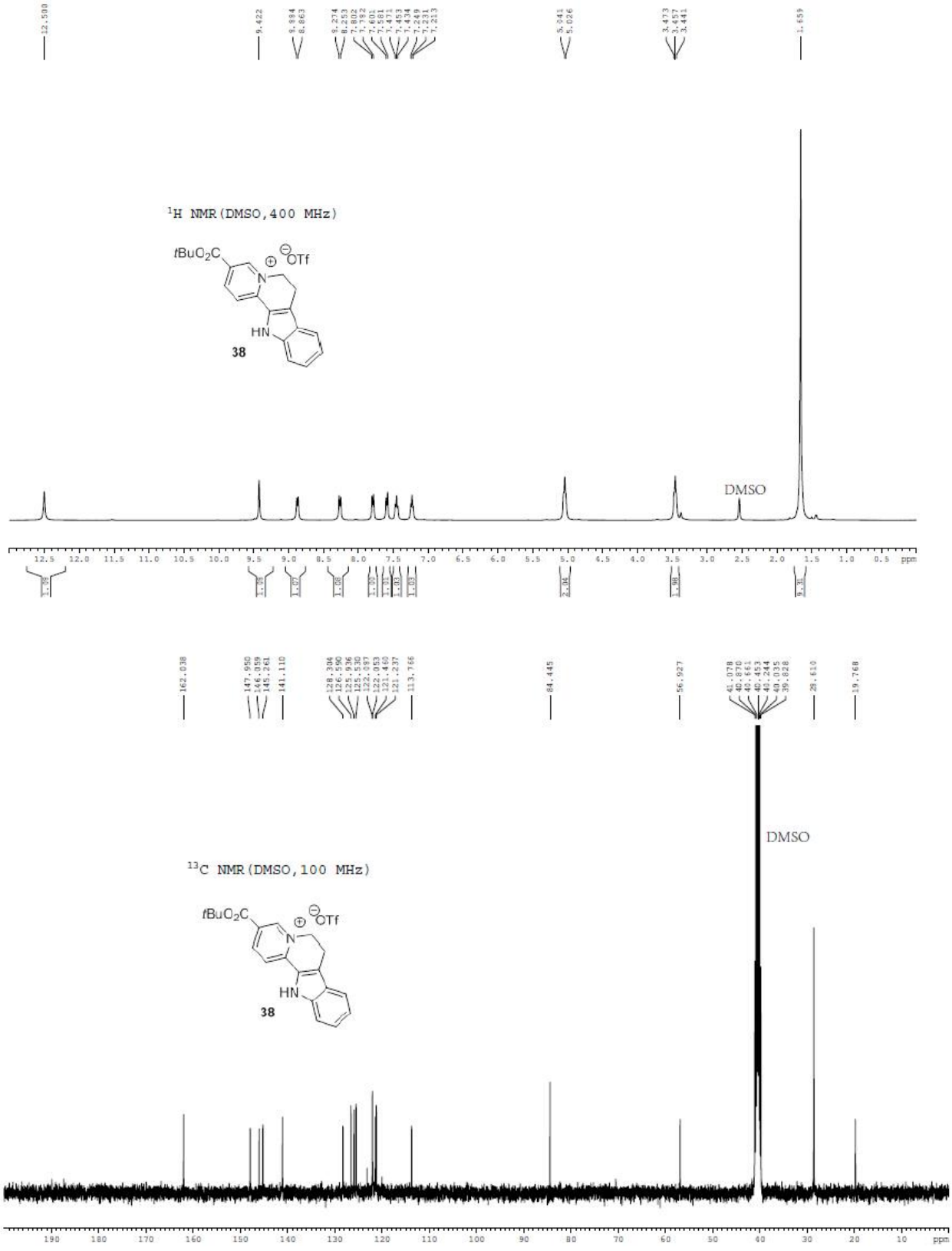
^{1}H and ^{13}C NMR spectrum of 36 ($CDCl_3$)



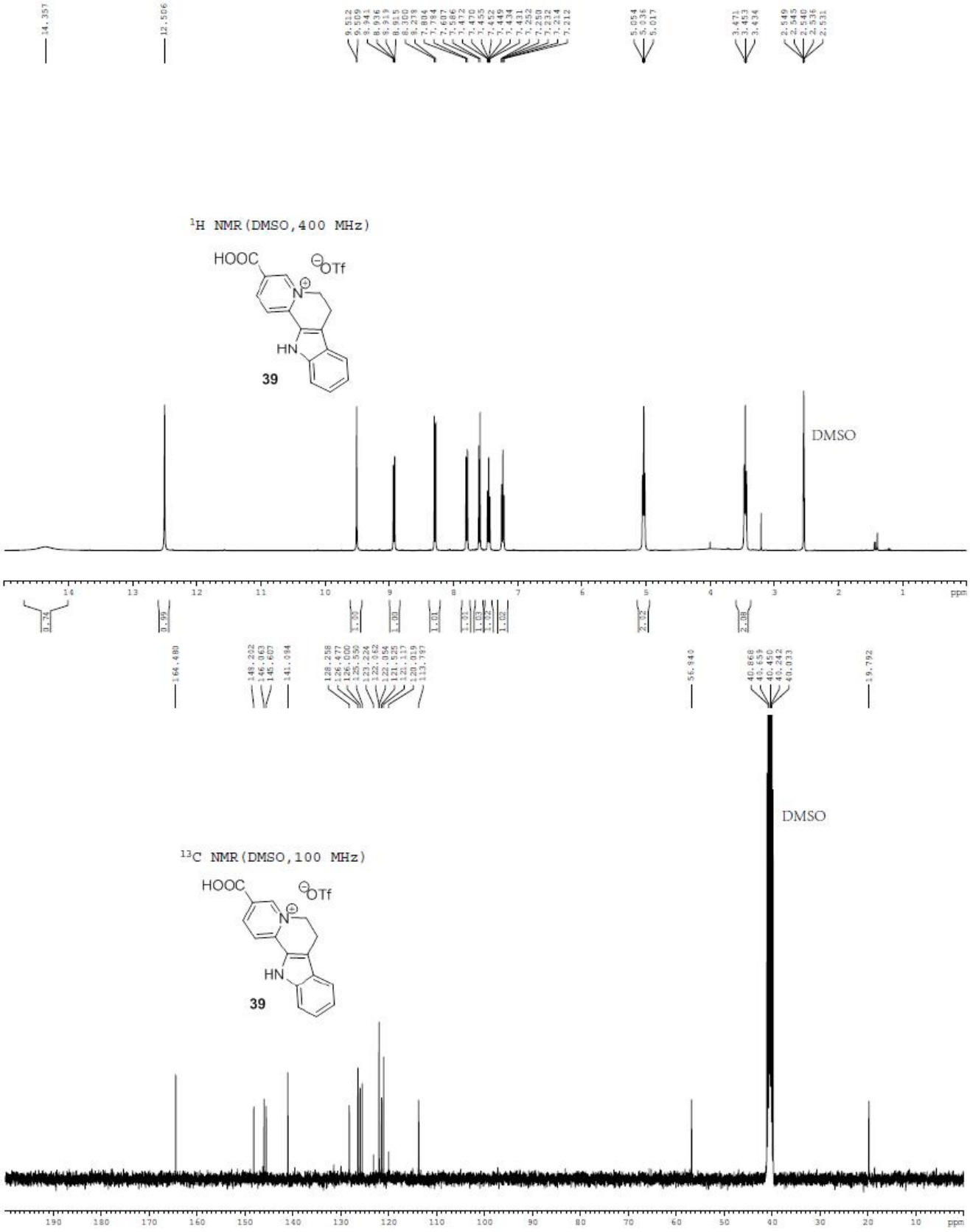
^{1}H and ^{13}C NMR spectrum of 37 ($CDCl_3$)



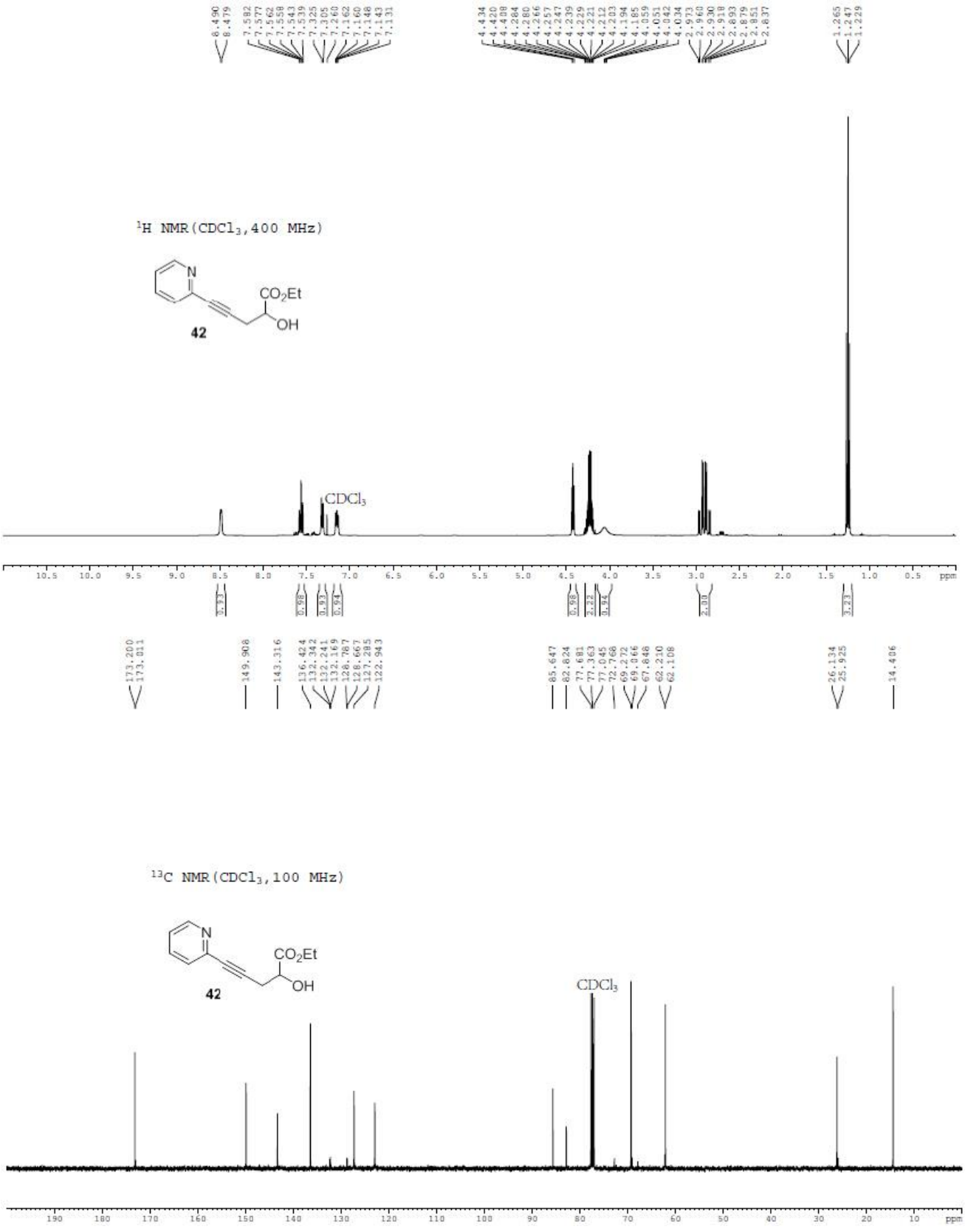
^{1}H and ^{13}C NMR spectrum of 38 (DMSO)



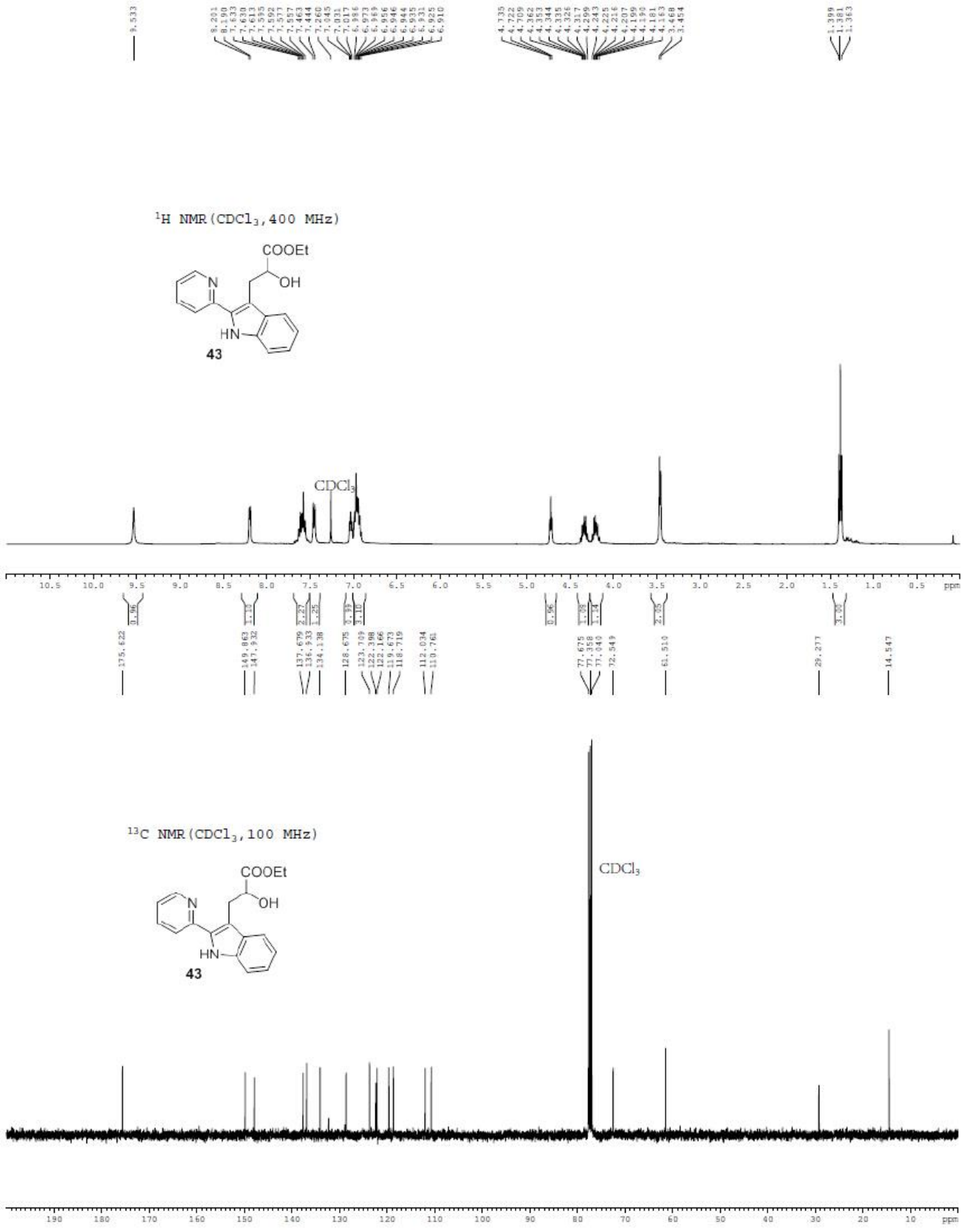
^{1}H and ^{13}C NMR spectrum of 39 (DMSO)



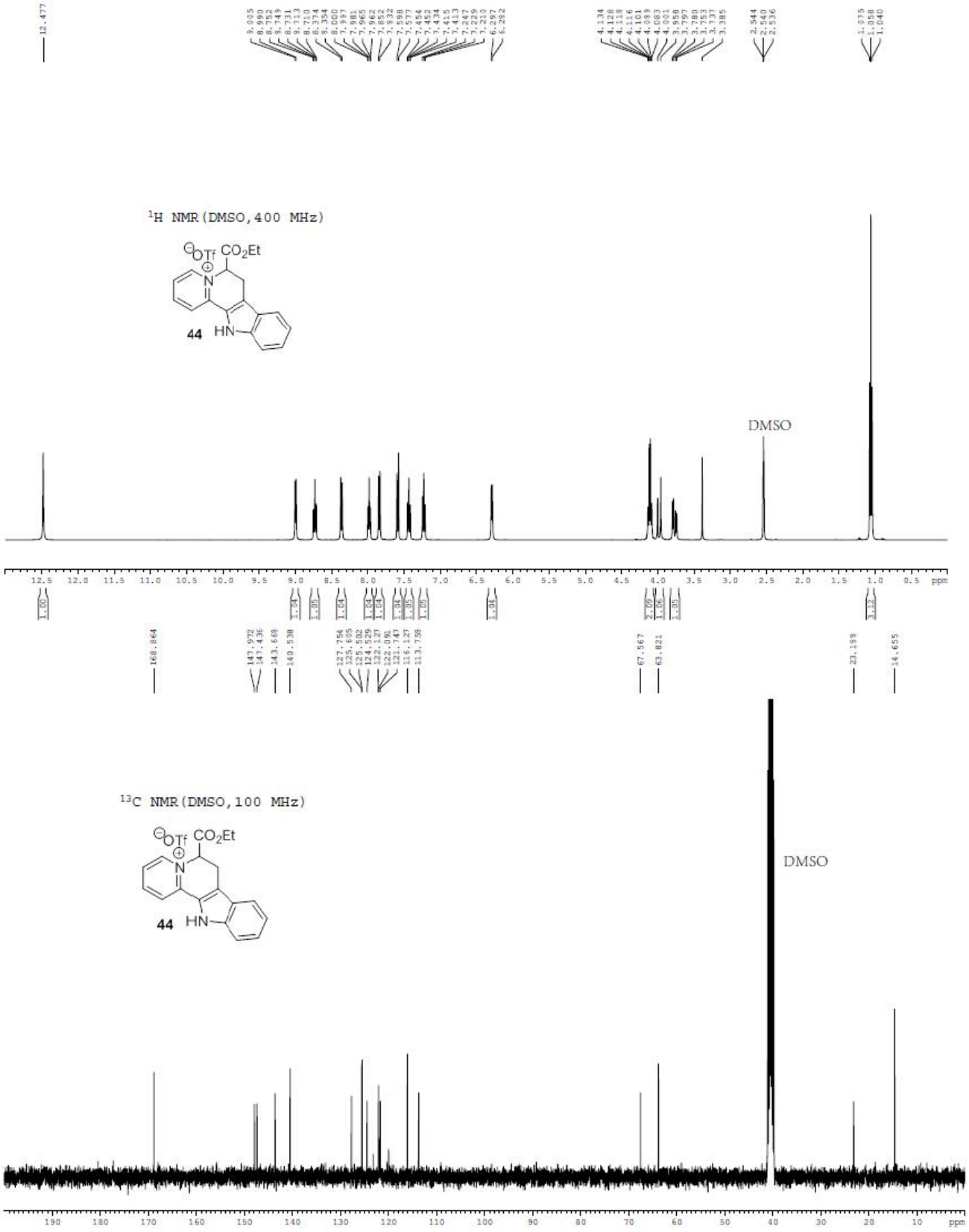
^{1}H and ^{13}C NMR spectrum of 42 ($CDCl_3$)



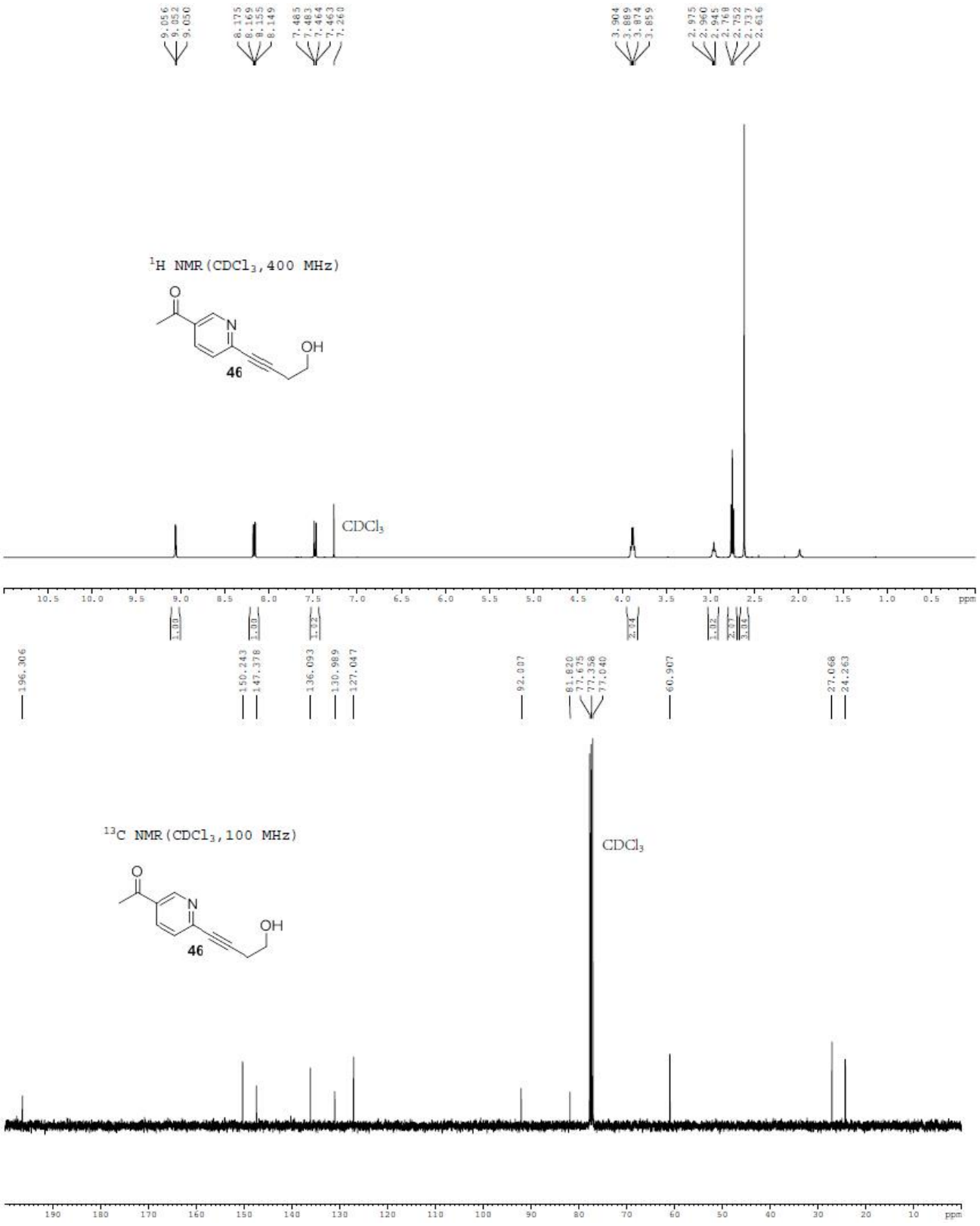
^{1}H and ^{13}C NMR spectrum of 43 ($CDCl_3$)



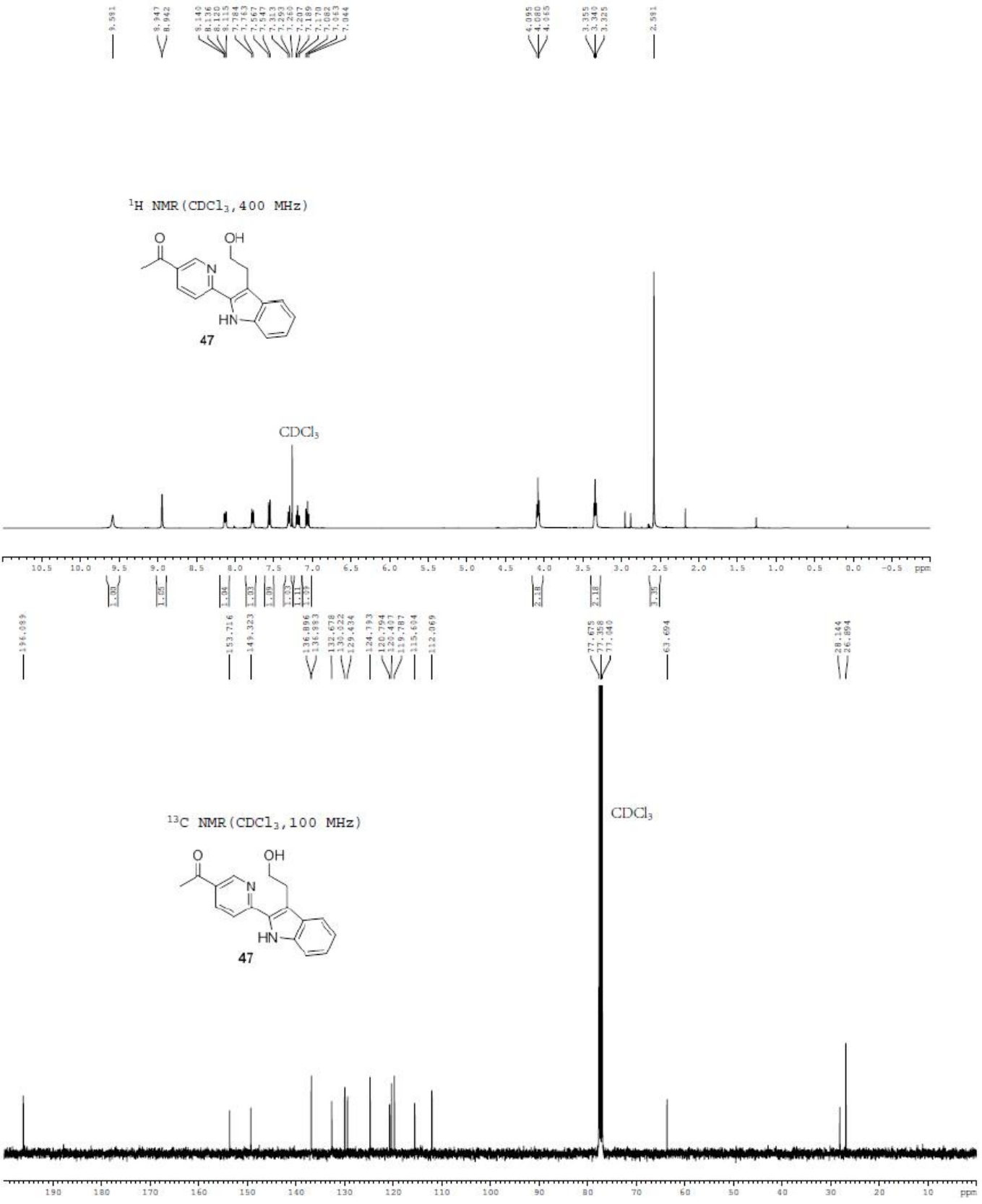
^{1}H and ^{13}C NMR spectrum of 44 (DMSO)



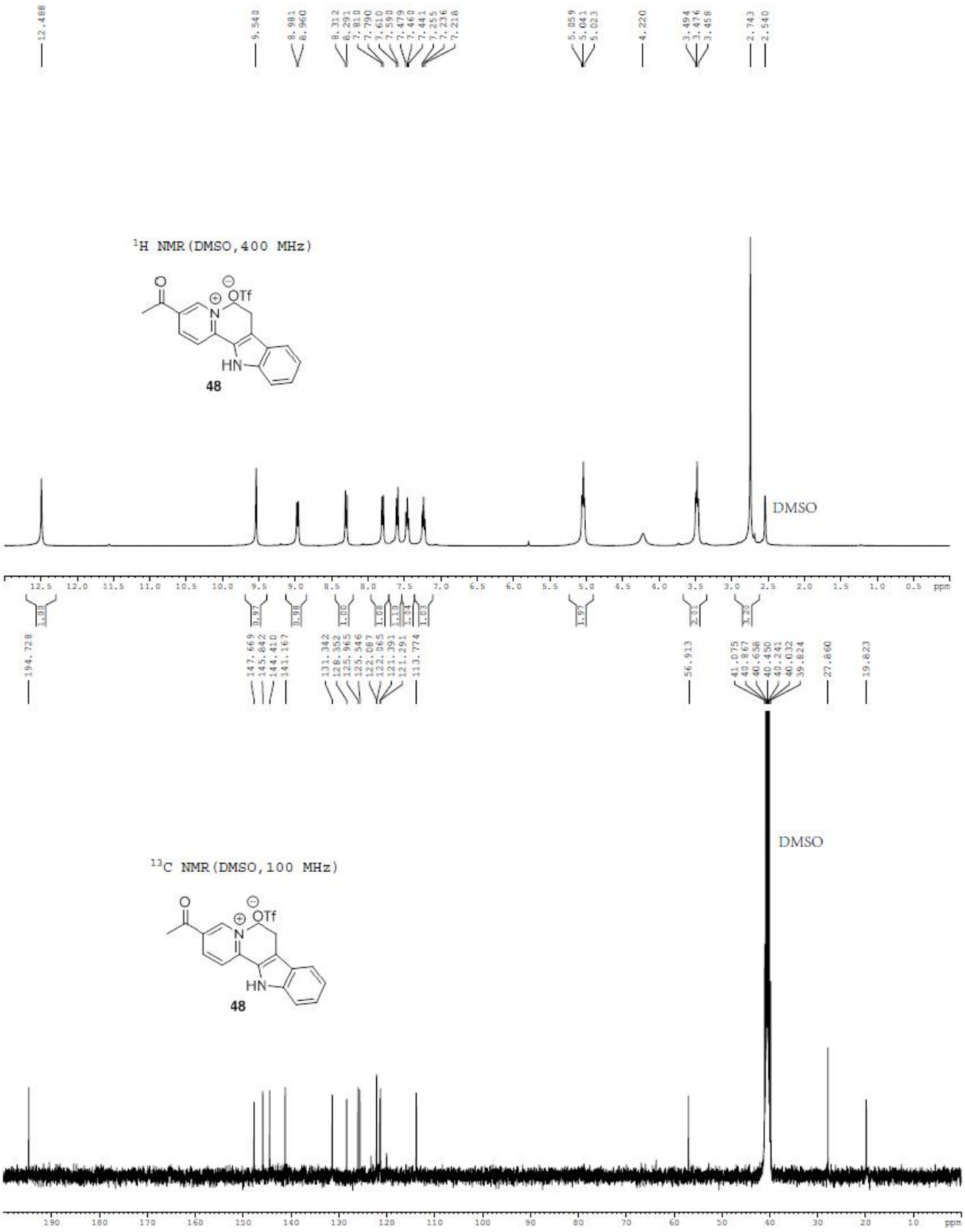
^{1}H and ^{13}C NMR spectrum of 46 ($CDCl_3$)



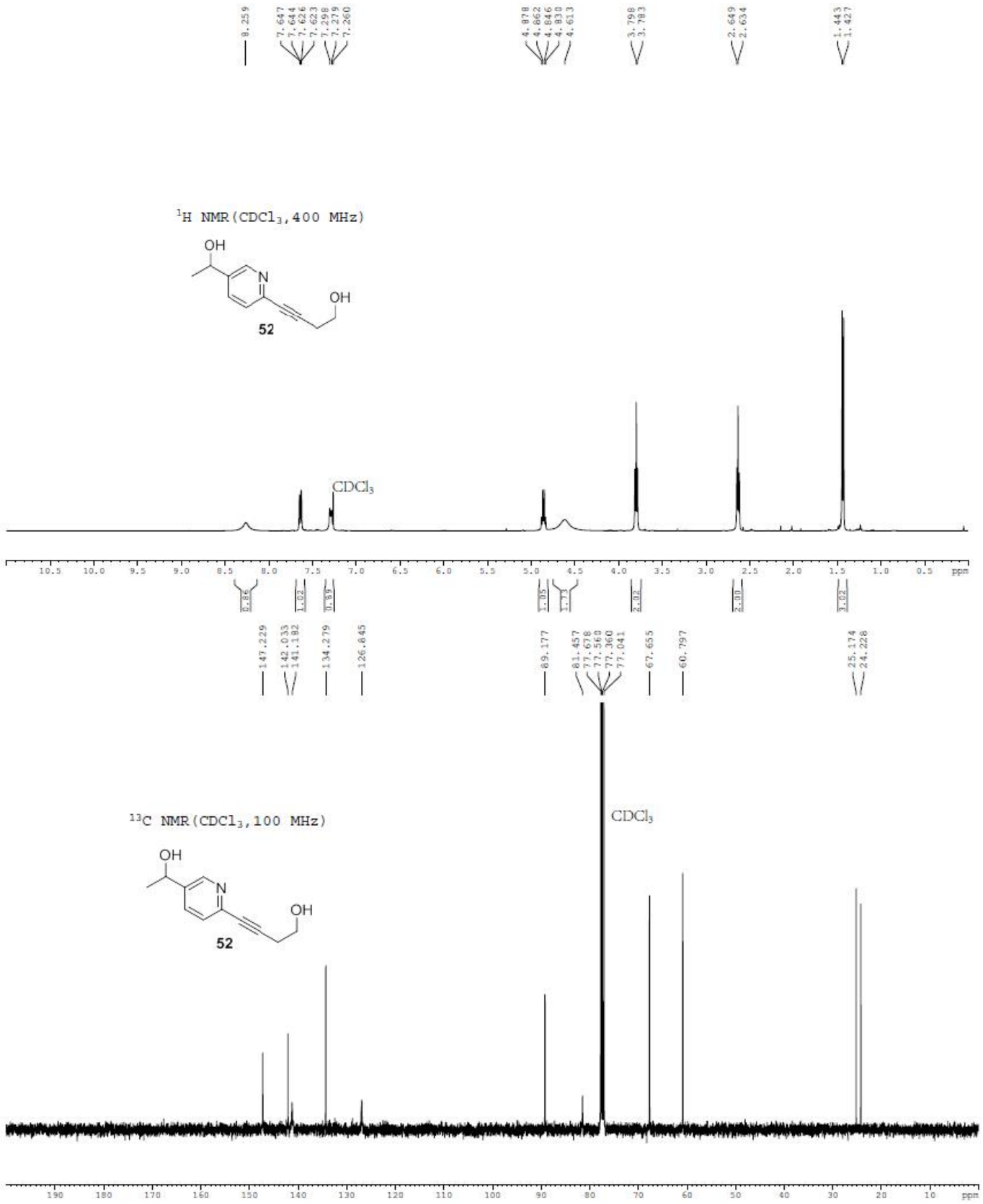
^{1}H and ^{13}C NMR spectrum of 47 ($CDCl_3$)



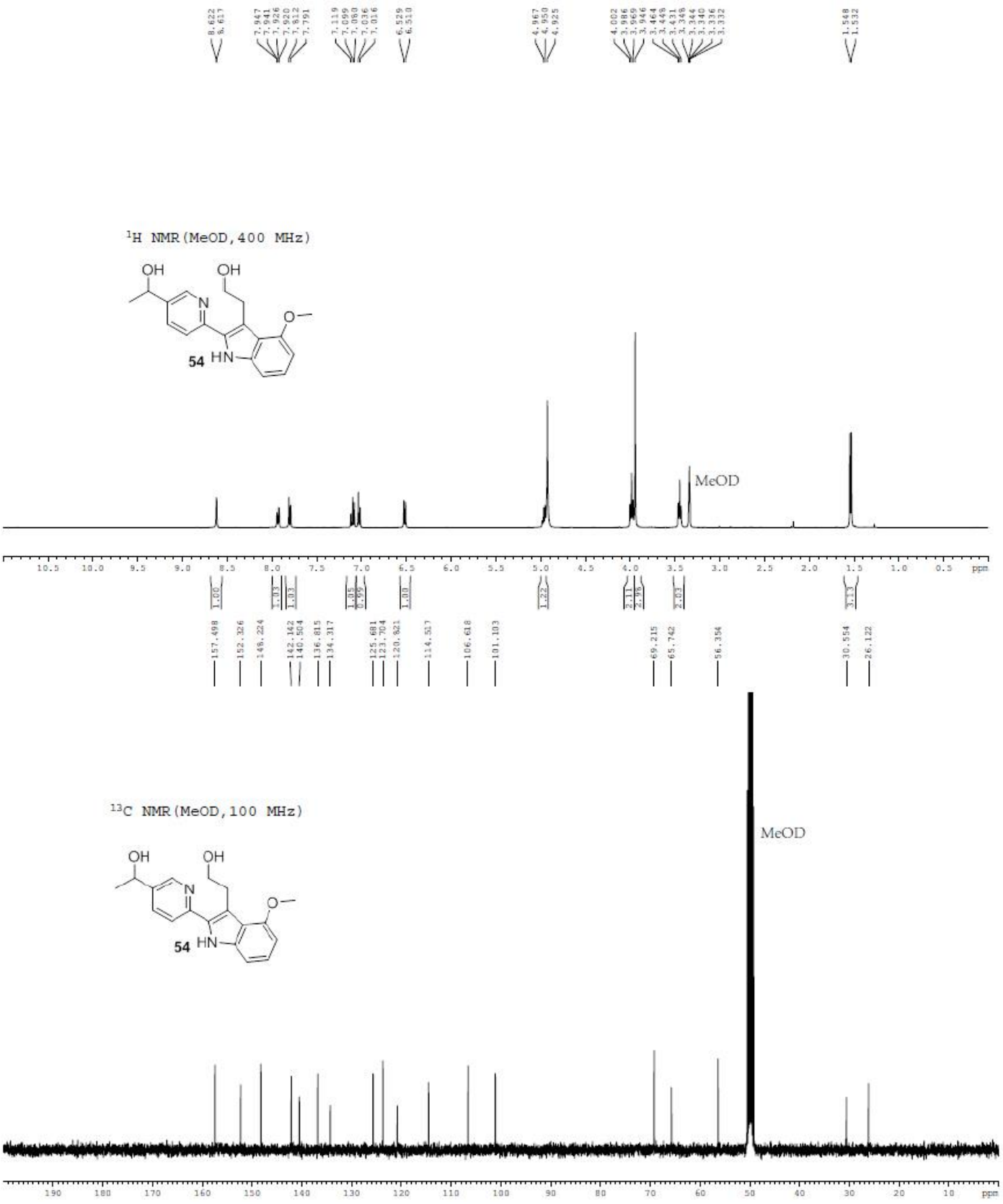
^{1}H and ^{13}C NMR spectrum of 48 (DMSO)



^{1}H and ^{13}C NMR spectrum of 52 ($CDCl_3$)



^{1}H and ^{13}C NMR spectrum of 54 (MeOD)



^{1}H and ^{13}C NMR spectrum of 55 (DMSO)