Electronic Supplementary Material (ESI) for RSC Advances

Catalyst-free Concise Synthesis of Imidazo[1,2-*a*]-pyrrolo[3,4-*e*]pyridine derivatives

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Supporting Information

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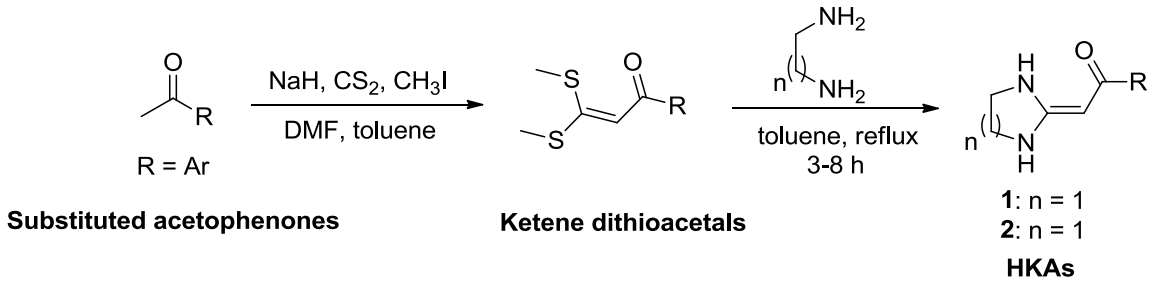
General Information

All compounds were fully characterised by spectroscopic data. The NMR spectra were recorded on Bruker DRX500 (^{1}H: 500 MHz, ^{13}C: 125 MHz) or Bruker AVIII-400 (^{1}H: 400 MHz, ^{13}C: 100 MHz), chemical shifts (δ) are expressed in ppm, and J values are given in Hz, DMSO-d_6 was used as solvent. IR spectra were recorded on a FT-IR Thermo Nicolet Avatar 360 using a KBr pellet. The reactions were monitored by thin-layer chromatography (TLC) using silica gel GF_{254}. The melting points were determined on XT-4A melting point apparatus and are uncorrected. HRMs were performed on a Agilent LC/Msd TOF and Monosiotopic Mass instrument.

All chemicals and solvents were used as received without further purification unless otherwise stated. Column chromatography was performed on silica gel (200–300 mesh).

General Procedure for the Preparation of HKAs 1 & 2[1]



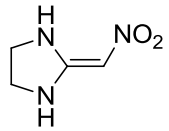
Substituted acetophenones **Ketene dithioacetals**

Dimethylformamide (40 mL), toluene (400 mL), substituted acetophenones (0.2 mol) were charged into a 1 L round-bottom flask. The mixture was stirred at room temperature and sodium hydride (12 g, 80%, 0.4 mol) was added in batches. Then, adding dropwise of carbon disulfide (22.8 g, 0.3 mol) in half hour. Then the whole mixture was cooled in ice bath, and methyl iodide (85.2 g, 0.6 mol) was added dropwise and stirred 2 h in ice bath. The misture was diluted with toluene (400 mL) and treated with ice water (500 mL). The toluene layer was separated and dried with anhydrous sodium sulfate. After removal of toluene, the crude poduct (**ketene dithioacetals**) was recrystallized from EtOAc/petroleum ether.

A mixture of **ketene dithioacetals** (8 mmol) and the corresponding diamines (10 mmol) in toluene (50 mL) was heated at reflux for 3 h, whereupon, a white solid precipitated. The precipitate was filtered, washed with cold enthol, and dried under vacuum.

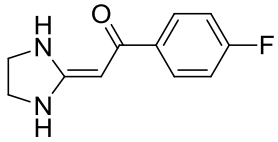
Spectroscopic Data of Heterocyclic Ketene Aminals 1–2

2-(Nitromethylene)imidazolidine (1a)



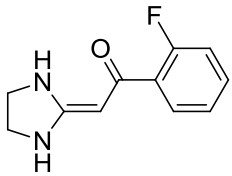
White solid; Mp 171–172 °C (lit[2] 169–170 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 8.30 (br, 2H, NH), 6.34 (s, 1H, CH), 3.56–3.60 (m, 4H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 160.7, 96.2, 43.5.

1-(4-Fluorophenyl)-2-(imidazolidin-2-ylidene)ethanone (1b)



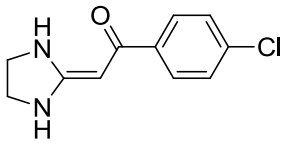
White solid; Mp 230–232 °C (lit[1b] 224–225 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.26 (br, 1H, NH), 7.76–7.80 (m, 2H, ArH), 7.41 (br, 1H, NH), 7.15–7.20 (m, 2H, ArH), 5.25 (s, 1H, CH), 3.57–3.63 (m, 2H, NCH_2), 3.43–3.48 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 181.0, 165.9, 163.4 (d, J = 245.0 Hz), 138.4, 128.9, 128.8, 115.2 (d, J = 22.0 Hz), 115.0 (d, J = 22.0 Hz), 73.3, 43.9, 42.2;

1-(2-Fluorophenyl)-2-(imidazolidin-2-ylidene)ethanone (1c)



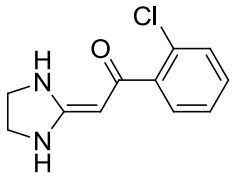
White solid; Mp 155–157 °C; IR (KBr): 3166, 2896, 1593, 1483, 1299, 1204, 759, 598 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.17 (br, 1H, NH), 7.65–7.70 (m, 1H, ArH), 7.50 (br, 1H, NH), 7.34–7.39 (m, 1H, ArH), 7.12–7.21 (m, 2H, ArH), 5.13 (s, 1H, CH), 3.57–3.63 (m, 2H, NCH_2), 3.44–3.48 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 178.5, 165.6, 159.8 (d, J = 243.0 Hz), 131.0, 130.5, 124.5, 116.2 (d, J = 23.0 Hz), 78.3, 43.9, 42.2; HRMS (ESI-TOF): m/z calcd for $C_{11}H_{11}FN_2ONa$ [$(M+Na)^+$], 229.0748; found, 229.0744.

1-(4-Chlorophenyl)-2-(imidazolidin-2-ylidene)ethanone (1d)



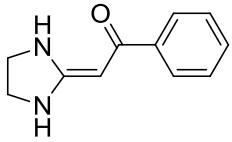
White solid; Mp 243–246 °C (lit[3] 236–239 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.23 (br, 1H, NH), 7.70–7.75 (m, 2H, ArH), 7.42 (br, 1H, NH), 7.38–7.41 (m, 2H, ArH), 5.25 (s, 1H, CH), 3.57–3.62 (m, 2H, NCH_2), 3.49–3.53 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 180.8, 165.9, 140.7, 134.4, 128.4, 128.4, 73.5, 43.9, 42.3.

1-(2-Chlorophenyl)-2-(imidazolidin-2-ylidene)ethanone (1e)



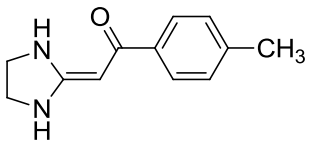
White solid; Mp 145–146 °C; IR (KBr): 3134, 2872, 1605, 1483, 1373, 1185, 743, 563 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 8.99 (br, 1H, NH), 7.47 (br, 1H, NH), 7.26–7.38 (m, 4H, ArH), 5.25 (s, 1H, CH), 3.58–3.63 (m, 2H, NCH_2), 3.42–3.47 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 183.4, 165.0, 143.6, 129.9, 129.6, 129.2, 127.2, 77.7, 43.9, 42.2; HRMS (ESI-TOF): *m*/*z* calcd for $C_{11}H_{12}ClN_2O$ [$(M+H)^+$], 223.0633; found, 223.0638.

2-(Imidazolidin-2-ylidene)-1-phenylethanone (1f)



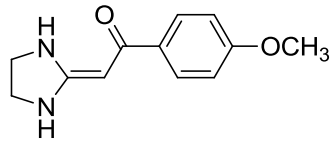
White solid; Mp 210–211°C (lit[3] 208–210 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 10.33 (br, 1H, NH), 8.74–8.80 (m, 2H, ArH), 8.45 (br, 1H, NH), 8.39–8.41 (m, 3H, ArH), 6.32 (s, 1H, CH), 8.74–8.80 (m, 2H, ArH), 4.62–4.66 (m, 2H, NCH_2), 4.45–4.51 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 183.5, 166.9, 143.0, 130.9, 129.4, 127.6, 74.6, 45.0, 43.0.

2-(Imidazolidin-2-ylidene)-1-(p-tolyl)ethanone (1g)



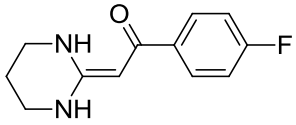
White solid; Mp 264–266 °C (lit[4] 256–258 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.28 (br, 1H, NH), 7.63 (d, J = 8.0 Hz, 2H, ArH), 7.28 (br, 1H, NH), 6.90 (d, J = 8.0 Hz, 2H, ArH), 5.26 (s, 1H, CH), 3.56–3.61 (m, 2H, NCH_2), 3.42–3.47 (m, 2H, NCH_2), 2.31 (s, 1H, OCH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 182.5, 165.9, 139.3, 139.2, 128.9, 126.6, 73.3, 43.9, 42.2, 21.3.

2-(Imidazolidin-2-ylidene)-1-(4-methoxyphenyl)ethanone (1h)



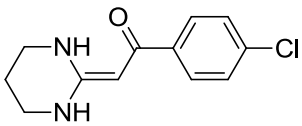
White solid; Mp 218–219 °C (lit[3] 217–219°C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.24 (br, 1H, NH), 7.69 (d, J = 8.8 Hz, 2H, ArH), 7.29 (br, 1H, NH), 6.90 (d, J = 8.8 Hz, 2H, ArH), 5.23 (s, 1H, CH), 3.77 (s, 1H, OCH_3), 3.56–3.61 (m, 2H, NCH_2), 3.40–3.46 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 182.0, 165.7, 160.8, 134.4, 128.2, 113.6, 72.8, 55.6, 43.9, 42.2.

1-(4-Fluorophenyl)-2-(tetrahydropyrimidin-2(1H)-ylidene)ethanone (2a)



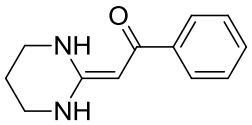
White solid; Mp 236–238 °C (lit[1b] 228–230 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 11.04 (br, 1H, NH), 7.67–7.71 (m, 2H, ArH), 7.37 (br, 1H, NH), 7.12–7.16 (m, 2H, ArH), 7.39 (d, J = 8.5 Hz, 2H, ArH), 5.04 (s, 1H, CH), 3.20–3.30 (m, 4H, NCH_2), 1.79–1.85 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 178.4, 163.0 (d, J = 243.0 Hz), 139.0, 128.4, 128.3, 115.1 (d, J = 21.0 Hz), 114.9 (d, J = 21.0 Hz), 77.0, 37.9, 20.6.

1-(4-Chlorophenyl)-2-(tetrahydropyrimidin-2(1H)-ylidene)ethanone (2b)



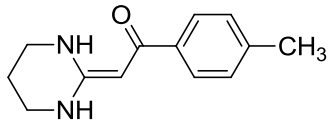
White solid; Mp 222–224 °C (lit[3] 213–215°C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 11.05 (br, 1H, NH), 7.67 (d, J = 8.5 Hz, 2H, ArH), 7.39 (d, J = 8.5 Hz, 2H, ArH), 5.06 (s, 1H, CH), 3.22–3.30 (m, 4H, NCH_2), 1.80–1.86 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 178.1, 160.1, 141.3, 133.8, 128.3, 128.0, 77.2, 37.9, 20.5.

1-Phenyl-2-(tetrahydropyrimidin-2(1H)-ylidene)ethanone (2c)



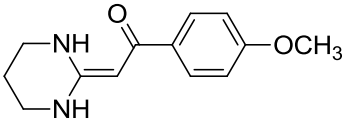
White solid; Mp 210–212 °C (lit[3] 205–207 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 11.14 (br, 1H, NH), 7.63–7.67 (m, 2H, ArH), 7.36 (br, 1H, NH), 7.30–7.36 (m, 3H, ArH), 5.08 (s, 1H, CH), 3.20–3.30 (m, 4H, NCH_2), 1.79–1.85 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 179.8, 160.1, 142.6, 129.2, 128.3, 126.2, 77.1, 37.9, 20.6.

2-(Tetrahydropyrimidin-2(1H)-ylidene)-1-(p-tolyl)ethanone (2d)



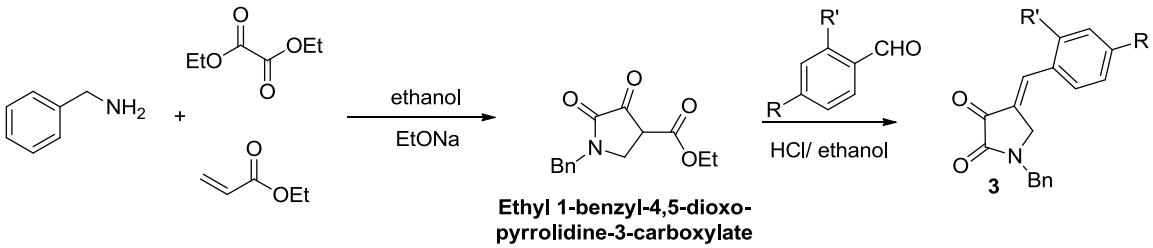
White solid; Mp 240–242 °C (lit[4] 248–250 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 11.11 (br, 1H, NH), 7.55 (d, J = 8.0 Hz, 2H, ArH), 7.34 (br, 1H, NH), 7.13 (d, J = 8.0 Hz, 2H, ArH), 5.06 (s, 1H, CH), 3.20–3.30 (m, 4H, NCH_2), 2.29 (s, 3H, CH_3), 1.79–1.85 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 179.8, 160.1, 139.8, 138.7, 128.8, 126.2, 76.8, 37.9, 21.3, 20.7.

1-(4-Methoxyphenyl)-2-(tetrahydropyrimidin-2(1H)-ylidene)ethanone (2e)



White solid; Mp 207–209 °C (lit[3] 206–208 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 11.08 (br, 1H, NH), 7.61 (d, J = 8.7 Hz, 2H, ArH), 7.28 (br, 1H, NH), 6.88 (d, J = 8.7 Hz, 2H, ArH), 5.02 (s, 1H, CH), 3.76 (s, 3H, OCH_3), 3.20–3.30 (m, 4H, NCH_2), 1.79–1.85 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 179.5, 160.4, 160.0, 135.0, 127.7, 113.5, 76.3, 55.5, 37.9, 20.7.

General Procedure for the Preparation of Dioxopyrrolidines 3[5]

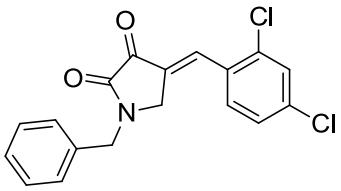


A mixture of benzylamine (7.26 g, 66.0 mmol), ethyl acrylate (7.2 mL, 66.0 mmol) in EtOH (15 mL) was stirred at room temperature for 16 h. Diethyl oxalate (9.0 mL, 66 mmol) and freshly-made sodium ethoxide solution in EtOH (generated from 2.0 g of sodium metal, 80.0 mmol, in 15 mL EtOH) was added. The mixture was heated at reflux for 1 h and it solidified. The volatiles were removed in vacuo. The crude product was diluted with H_2O (80 mL) and the pH of the mixture was adjusted to 1 by adding conc.HCl. The mixture was subjected to filtration to afford **6** as a white solid.

A mixture of **6** (2.6 g, 9.8 mmol), benzaldehyde (9.8 mmol) in EtOH (20 mL) / 20 percent aq. HCl (50 mL) was heated at reflux for 4 h. After cooling down to ambient temperature, the aqueous layer was decanted. The obtained chunky solid was collected and further recrystallized from EtOAc to afford **3** as a bright yellow solid.

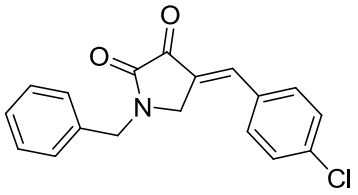
Spectroscopic Data of Preparation of dioxopyrrolidines 3

(*E*)-1-benzyl-4-(2,4-dichlorobenzylidene)pyrrolidine-2,3-dione (3a)



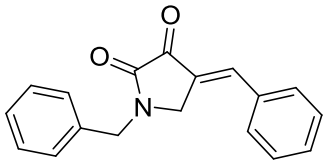
Yellow solid; Mp 269–271 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.79 (d, J = 8.0 Hz, 1H, ArH), 7.67 (s, 1H, ArH), 7.60 (d, J = 8.6 Hz, 1H, ArH), 7.50 (d, J = 8.5 Hz, 1H, ArH), 7.34–7.38 (m, 4H, ArH), 7.30–7.34 (m, 1H, ArH), 4.69 (s, 2H, $ArCH_2$), 4.50 (s, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.2, 160.3, 136.8, 136.6, 135.9, 132.0, 130.4, 130.3, 129.4, 129.2, 128.6, 128.5, 128.1, 47.6, 46.7; HRMS (ESI-TOF): m/z calcd for $C_{18}H_{14}Cl_2NO_2$ [$(M+H)^+$], 368.0216; found, 368.0213.

(*E*)-1-benzyl-4-(4-chlorobenzylidene)pyrrolidine-2,3-dione (3b)



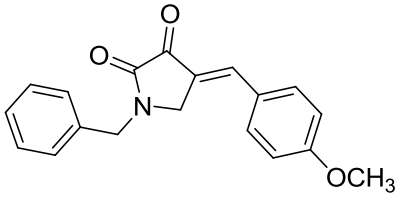
Yellow solid; Mp 230–231 °C; IR (KBr): 3788, 3427, 1699, 1638, 1253, 1168, 735, 657 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.62 (d, J = 8.4 Hz, 2H, ArH), 7.51–7.57 (m, 3H, ArH), 7.36–7.40 (m, 4H, ArH), 7.30–7.35 (m, 1H, ArH), 4.72 (s, 2H, $ArCH_2$), 4.54 (s, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.2, 160.6, 136.3, 136.0, 134.7, 133.4, 132.8, 129.8, 129.2, 128.4, 128.1, 127.2, 47.6, 47.0; HRMS (ESI-TOF): m/z calcd for $C_{18}H_{15}ClNO_2Na$ [$(M+Na)^+$], 334.0605; found, 334.0603.

(*E*)-1-benzyl-4-benzylidenepyrrolidine-2,3-dione (3c)



Yellow solid; Mp 179–181 °C (lit[5] 182–183 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.60–7.64 (m, 2H, ArH), 7.55–7.59 (m, 1H, ArH), 7.47–7.53 (m, 3H, ArH), 7.32–7.40 (m, 5H, ArH), 4.73 (s, 2H, $ArCH_2$), 4.54 (s, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.3, 160.6, 136.2, 136.0, 133.8, 131.8, 131.6, 129.7, 129.2, 128.7, 128.5, 128.1, 127.9, 126.6, 47.5, 47.1.

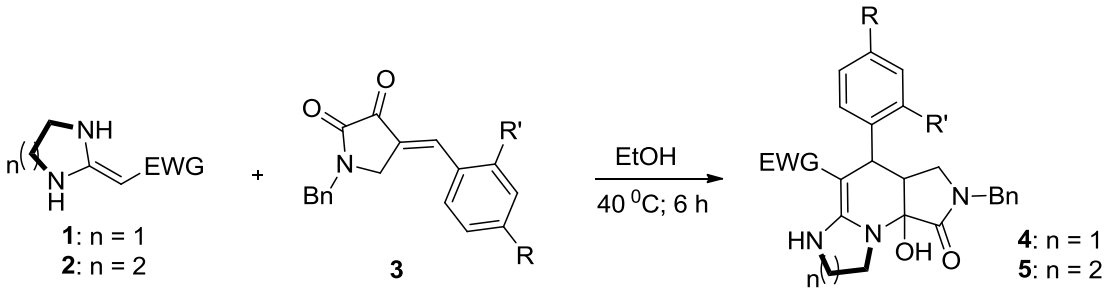
(*E*)-1-benzyl-4-(4-methoxybenzylidene)pyrrolidine-2,3-dione (3d)



Yellow solid; Mp 185–187 °C (lit[6] 188–189 °C); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 7.54–7.61 (m, 3H, ArH), 7.30–7.39 (m, 5H, ArH), 7.05 (d, J = 8.7 Hz, 2H, 4H, ArH), 4.72 (s, 2H, $ArCH_2$), 4.50 (s, 2H, NCH_2), 3.82 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 186.8, 162.2, 161.0, 136.5, 136.1, 134.1, 129.2, 128.5, 128.1, 126.5, 124.2, 115.4, 56.0, 47.5, 47.0.

Electronic Supplementary Material (ESI) for RSC Advances

General Procedure for the Preparation of Imidazo[1,2-*a*]- pyrrolo-[3,4-*e*]pyridine Derivatives 4 &5

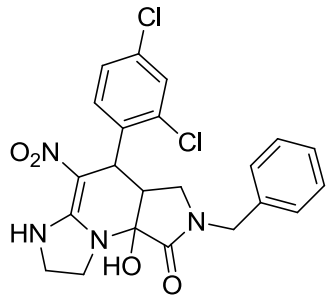


HKAs **1** or **2** (1mmol), dioxopyrrolidines **3** (1.1 mmol), solvent EtOH (15 mL) were charged into a 25mL round-bottom flask, and the mixture was stirred at 40 ℃ until the HKA was completely consumed. The mixture was cooled to room temperature. Then the precipitation was filtered and successively washed by ethanol to afford the pure products **4** and **5** in a good yield (81%–95%).

Spectroscopic Data of Imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridine Derivatives

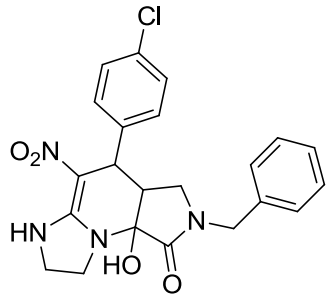
4–5

2-Benzyl-4-(2,4-dichlorophenyl)-9a-hydroxy-5-nitro-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4a)



White solid; Mp 289–290 °C; IR (KBr): 3788, 3427, 1699, 1638, 1253, 1168, 735, 657 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.28 (br, 1H, NH), 7.57 (s, 1H, ArH), 7.32–7.41 (m, 2H, ArH), 7.28–7.34 (m, 2H, ArH), 7.19 (d, J = 7.1 Hz, 2H, ArH), 7.01 (d, J = 8.4 Hz, 1H, ArH), 6.90 (br, 1H, OH), 4.48 (AB, 2H, $ArCH_2$), 4.35 (d, J = 15.0 Hz, 1H, CH), 3.73–3.84 (m, 2H, NCH_2), 3.60–3.68 (m, 2H, NCH_2), 3.38–3.48 (m, 1H, CH), 2.92–2.97 (m, 1H, NCH_2), 2.70–2.76 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 169.1, 155.8, 139.2, 136.5, 133.9, 132.1, 129.9, 129.3, 128.0, 127.8, 127.4, 102.2, 82.5, 46.7, 46.3, 44.9, 44.1, 43.2, 36.2; HRMS (ESI-TOF): m/z calcd for $C_{22}H_{21}Cl_2N_4O_4$ [$(M+H)^+$], 475.0943; found, 475.0941.

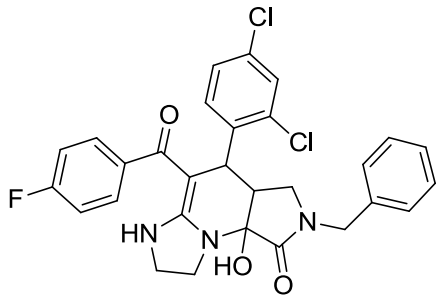
2-Benzyl-4-(4-chlorophenyl)-9a-hydroxy-5-nitro-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4b)



White solid; Mp 250–253 °C; IR (KBr): 3788, 3427, 1699, 1638, 1253, 1168, 735, 657 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.24 (br, 1H, NH), 7.35–7.39 (m, 2H, ArH), 7.26–7.32 (m, 3H, ArH), 7.18–7.28 (m, 4H, ArH), 6.85 (br, 1H, OH), 4.40 (AB, 2H, $ArCH_2$), 4.24–4.28 (m, 1H, CH), 3.74–3.85 (m, 2H, NCH_2), 3.55–3.68 (m, 2H, NCH_2), 3.32–3.34 (m, 1H, CH), 2.82–2.90 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ =

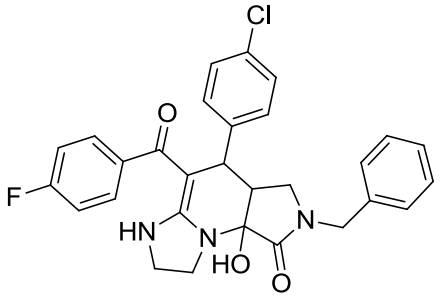
169.3, 155.5, 142.3, 136.6, 131.0, 130.0, 129.2, 128.2, 128.0; 128.0; 103.5, 82.7, 47.0, 46.8, 46.2, 44.1, 43.1, 38.6; HRMS (ESI-TOF): *m*/*z* calcd for $C_{22}H_{22}ClN_4O_4$ [$(M+H)^+$], 441.1324; found, 441.1320.

2-Benzyl-4-(2,4-dichlorophenyl)-5-(4-fluorobenzoyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4c)



White solid; Mp 225–227 °C; IR (KBr): 3329, 1703, 1599, 1512, 1142, 843, 536 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.48 (br, 1H, NH), 7.27–7.38 (m, 5H, ArH), 7.12–7.17 (m, 3H, ArH), 6.91–6.96 (m, 2H, ArH), 6.78–6.82 (m, 2H, ArH), 6.50 (br,1H, OH), 4.47 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 4.32 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 3.76 (d, *J* = 10.3 Hz, 1H, CH), 3.66–3.74 (m, 2H, NCH_2), 3.54–3.60 (m, *2*H, NCH_2), 3.27–3.31 (m, 1H, CH), 3.01–3.08 (m, 1H, NCH_2), 2.57–2.65 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.1, 169.7, 161.8 (d, *J* =243.0 Hz), 159.9, 142.1, 139.4, 136.7, 133.0, 132.4, 131.6; 129.3, 128.5, 128.0, 127.3, 115.0 (d, *J* =22.0 Hz), 114.8 (d, *J* =22.0 Hz), 82.4, 82.2, 46.8, 46.2, 45.2, 43.4, 42.8, 36.2; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{25}Cl_2FN_3O_3$ [$(M+H)^+$], 552.1252; found, 552.1253.

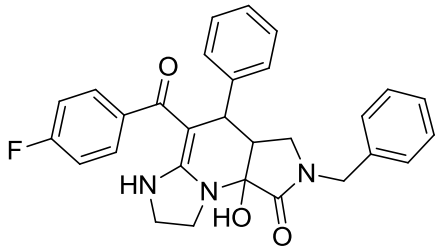
2-Benzyl-4-(4-chlorophenyl)-5-(4-fluorobenzoyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4d)



White solid; Mp 224–226 °C; IR (KBr): 3312, 1703, 1595, 1512, 1215, 837, 580 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.55 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.28–7.33 (m, 1H, ArH), 7.20 (d, *J* = 7.7 Hz, 4H, ArH), 7.02 (d, *J* = 8.0 Hz, 2H, ArH), 6.93–6.99 (m, 2H, ArH), 6.87–6.92 (m, 2H, ArH), 6.42 (br, 1H, OH), 4.44 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 4.38 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 3.71–3.74 (m, 1H, CH), 3.66–3.90 (m,

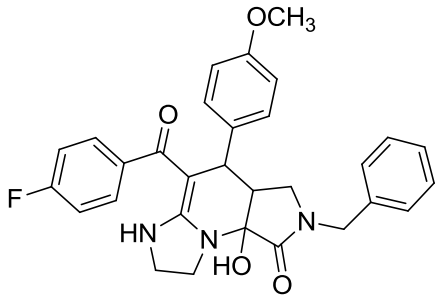
2H, NCH_2), 3.58–3.62 (m, 2H, NCH), 3.34–3.37 (m, 1H, CH), 3.04 (t, *J* = 9.5 Hz, 1H, NCH_2), 2.74–2.80 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.0, 170.0, 162.0 (d, *J* =242.0 Hz), 159.9, 145.5, 139.7, 136.8, 130.6, 130.2, 129.3, 128.6; 128.6, 128.1, 115.0 (d, *J* =22.0 Hz), 114.8 (d, *J* =22.0 Hz), 83.1, 82.7, 47.6, 47.1, 46.2, 43.4, 42.7, 40.6; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{26}ClFN_3O_3$ $[(M+H)^+]$, 518.1641; found, 518.1645.

2-Benzyl-5-(4-fluorobenzoyl)-9a-hydroxy-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4e)



White solid; Mp 194-197 °C; IR (KBr): 3324, 1701, 1596, 1515, 1214, 1008, 739 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.57 (br, 1H, NH), 7.32–7.38 (m, *J* = 6.8 Hz, 2H, ArH), 7.29–7.34 (m, 1H, ArH), 7.20 (d, *J* = 6.8 Hz, 2H, ArH), 7.11–7.15 (m, 2H, ArH), 7.01–7.06 (m, 1H, ArH), 7.00 (d, *J* = 6.8 Hz, 2H, ArH), 6.86–6.96 (m, 4H, ArH), 6.36 (br, 1H, OH), 4.43 (AB, 2H, $ArCH_2$), 3.72–3.75 (m, 1H, CH), 3.67–3.74 (m, 2H, NCH_2), 3.57–3.61 (m, 1H, NCH_2), 3.48–3.52 (m, 1H, NCH_2), 3.05 (t, *J* = 9.3 Hz, 1H, NCH_2), 2.78–2.83 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.9, 170.1, 161.5 (d, *J* = 232.0 Hz); 160.0, 146.4, 139.7, 136.8, 129.2, 128.6, 128.5, 128.3; 128.1, 128.0; 126.0; 114.8 (d, *J* =21.0 Hz); 114.6 (d, *J* =21.0 Hz), 83.4, 82.8, 47.6, 47.2, 46.2, 43.4, 42.6, 39.3; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{27}FN_3O_3$ $[(M+Na)^+]$, 506.1850; found, 506.1859.

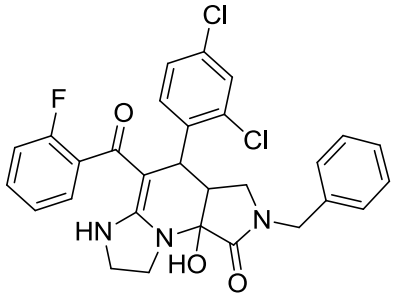
2-Benzyl-5-(4-fluorobenzoyl)-9a-hydroxy-4-(4-methoxyphenyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4f)



White solid; Mp 215-218 °C; IR (KBr): 3462, 1696, 1599, 1511, 1240, 751, 649 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.59 (br, 1H, NH), 7.37–7.42 (m, 2H, ArH), 7.30–7.34 (m, 1H, ArH), 7.22 (d, *J* = 7.4 Hz, 2H, ArH), 6.92–7.00 (m, 6H, ArH), 6.74 (d, *J* = 8.3 Hz,

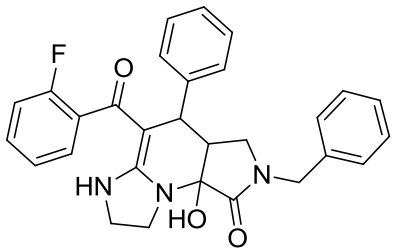
2H, ArH), 6.34 (br, 1H, OH), 4.43 (AB, 2H, $ArCH_2$), 3.76–3.78 (m, 1H, CH), 3.70–3.76 (m, 2H, CH_2), 3.66 (s, 3H, OCH_3), 3.60–3.63 (m, 1H, CH), 3.50–3.54 (m, 1H, NCH_2), 3.03–3.06 (m, 1H, NCH_2), 2.78–2.83 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.8, 170.1, 160.5 (d, J =234.0 Hz); 159.9, 157.6, 139.7, 138.2, 136.8, 129.2, 129.2, 128.6; 128.0; 114.8 (d, J =21.0 Hz), 114.6 (d, J =21.0 Hz); 113.5; 83.6, 82.7, 55.3, 47.8, 47.1, 46.2, 43.3, 42.6, 39.0; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{29}FN_3O_4$ [$(M+H)^+$], 514.2137; found, 514.2142.

2-Benzyl-4-(2,4-dichlorophenyl)-5-(2-fluorobenzoyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4g)



White solid; Mp 251-254 °C; IR (KBr): 3333, 1703, 1602, 1516, 1018, 755, 541 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.34 (br, 1H, NH), 7.34–7.40 (m, 2H, ArH), 7.24–7.32 (m, 3H, ArH), 7.15–7.23 (m, 3H, ArH), 6.86–6.98 (m, 2H, ArH), 6.54–6.58 (m, 1H, ArH), 6.53 (br,1H, OH), 4.47–4.53 (m, 1H, $ArCH_2$), 4.31–4.37 (m, 1H, $ArCH_2$), 3.84–3.88 (m, 1H, CH), 3.70–3.76 (m, 2H, CH_2), 3.59–3.63 (m, 1H, CH), 3.31–3.38 (m, 2H, NCH_2), 3.00–3.08 (m, 1H, NCH_2), 2.54–2.62 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 184.4, 169.7, 159.4, 141.7, 136.7, 133.0, 132.4, 131.4; 129.9, 128.0, 127.0, 124.4, 115.7 (d, J =22.0 Hz), 115.5 (d, J =22.0 Hz), 82.3, 82.4, 46.6, 46.2, 45.1, 43.3, 42.8, 35.6; HRMS (ESI-TOF): m/z calcd for $C_{29}H_{25}Cl_2FN_3O_3$ [$(M+H)^+$], 552.1252; found, 552.1250.

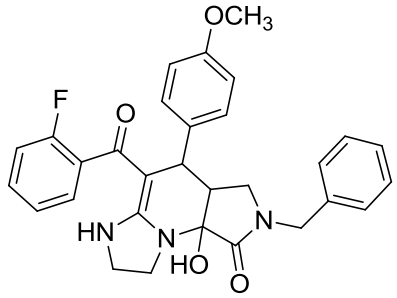
2-Benzyl-5-(2-fluorobenzoyl)-9a-hydroxy-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4h)



White solid; Mp 216–219 °C; IR (KBr): 3430, 1701, 1599, 1517, 1135, 748, 551 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.40 (br, 1H, NH), 7.36–7.41 (m, 2H, ArH), 7.28–7.33 (m, 1H, ArH), 7.16–7.24 (m, 3H, ArH), 6.95–7.08 (m, 4H, ArH), 6.84–6.91 (m,

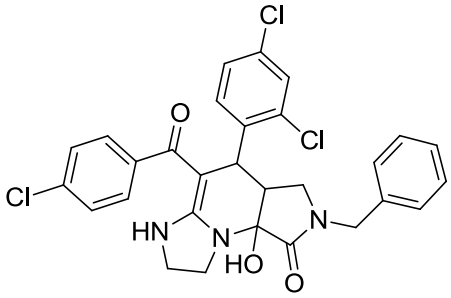
3H, ArH), 6.58–6.64 (m, 1H, ArH), 6.43 (br, 1H, OH), 4.43 (AB, 2H, $ArCH_2$), 3.71–3.77 (m, 2H, NCH_2), 3.60–3.63 (m, 1H, CH), 3.47–3.53 (m, 2H, NCH_2), 3.38–3.42 (m, 1H, CH), 3.06 (t, J = 9.5 Hz, 1H, NCH_2), 2.74–2.79 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 184.3, 170.0, 159.4; 145.9, 136.8, 130.9, 129.7, 129.2, 128.6, 128.2, 128.0; 127.8, 125.9; 124.1; 115.6; 115.4, 84.7, 82.6, 47.3, 47.0, 46.2, 43.3, 42.7, 39.3; HRMS (ESI-TOF): m/z calcd for $C_{29}H_{27}FN_3O_3$ [$(M+H)^+$], 484.2031; found, 484.2031.

2-Benzyl-5-(2-fluorobenzoyl)-9a-hydroxy-4-(4-methoxyphenyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4i)



White solid; Mp 221–224 °C; IR (KBr): 3435, 1700, 1599, 1513, 1244, 749, 547 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.39 (br, 1H, NH), 7.36–7.40 (m, 2H, ArH), 7.30–7.33 (m, 1H, ArH), 7.17–7.27 (m, 3H, ArH), 6.96-7.02 (m, 1H, ArH), 6.87– 6.93 (m, 1H, ArH), 6.80 (d, J = 6.7 Hz, 2H, ArH), 6.60–6.68 (m, 3H, ArH), 6.40 (br, 1H, OH), 4.43 (AB, 2H, $ArCH_2$), 3.70–3.74 (m, 1H, CH), 3.64–3.68 (m, 2H, CH_2), 3.63 (s, 3H, OCH_3), 3.45–3.51 (m, 1H, CH), 3.36–3.46 (m, 2H, NCH_2), 3.01–3.08 (m, 1H, NCH_2), 2.62–2.68 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 184.3, 170.1, 159.3; 157.5, 137.9, 136.8, 129.6, 129.2, 129.1, 128.6, 128.0; 124.1; 115.5, 113.2; 84.9, 82.7, 55.3, 47.4, 47.0, 46.2, 43.3, 42.7, 38.7; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{29}FN_3O_4$ [$(M+H)^+$], 514.2137; found, 514.2142.

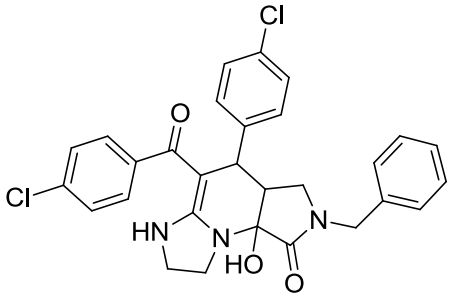
2-Benzyl-5-(4-chlorobenzoyl)-4-(2,4-dichlorophenyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4j)



White solid; Mp 223-226 °C; IR (KBr): 3424, 1701, 1601, 1511, 1204, 841, 543 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.50 (br, 1H, NH), 7.31–7.40 (m, 5H, ArH), 7.17–7.25

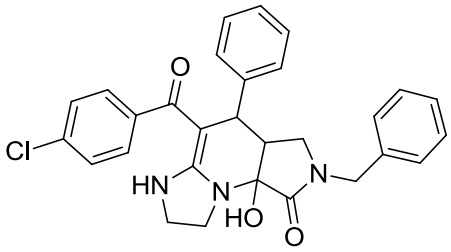
(m, 5H, ArH), 6.80 (d, *J* = 7.1 Hz, 2H, ArH), 6.53 (br, 1H, OH), 4.49 (d, *J* = 14.8 Hz, 1H, $ArCH_2$), 4.35 (d, *J* = 14.8 Hz, 1H, $ArCH_2$), 3.96–3.99 (m, 1H, CH), 3.70–3.78 (m, 2H, NCH_2), 3.59–3.63 (m, 1H, CH_2), 3.45–3.51 (m, 1H, NCH_2), 3.29–3.33 (m, 1H, CH), 3.04–3.09 (m, 1H, NCH_2), 2.63–2.67 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.0, 169.7, 159.9, 142.0, 141.6, 136.7, 133.0, 132.6, 132.4; 131.6, 129.3, 128.5, 128.1, 128.1, 128.0, 127.8, 127.3, 82.4, 82.2, 46.7, 46.2, 45.2, 43.4, 42.8, 36.2; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{25}Cl_3N_3O_3$ $[(M+H)^+]$, 568.0956; found, 568.0949.

2-Benzyl-5-(4-chlorobenzoyl)-4-(4-chlorophenyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4k)



White solid; Mp 230–233 °C; IR (KBr): 3319, 1703, 1599, 1513, 1281, 827, 546 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.54 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.28–7.32 (m, 1H, ArH), 7.17–7.23 (m, 6H, ArH), 7.03 (d, *J* = 7.9 Hz, 2H, ArH), 6.86 (d, *J* = 7.8 Hz, 2H, ArH), 6.43 (br, 1H, OH), 4.44 (d, *J* = 15.1 Hz, 1H, $ArCH_2$), 4.38 (d, *J* = 15.1 Hz, 1H, $ArCH_2$), 3.72–3.74 (m, 1H, CH), 3.69–3.72 (m, 2H, CH_2), 3.59–3.62 (m, 1H, CH_2), 3.47–3.50 (m, 1H, NCH_2), 3.04 (t, *J* = 9.5 Hz, 1H, NCH), 2.74–2.80 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.6, 170.0, 159.9, 145.3, 141.9, 136.8, 132.6, 130.5, 130.1, 129.2, 128.2; 128.2, 128.1, 128.0, 82.9, 82.6, 47.5, 46.9, 46.2, 43.4, 42.7, 39.0; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{26}Cl_2N_3O_3$ $[(M+H)^+]$, 534.1346; found, 534.1348.

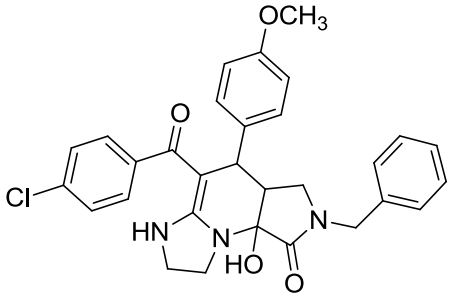
2-Benzyl-5-(4-chlorobenzoyl)-9a-hydroxy-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4l)



White solid; Mp 200–202 °C; IR (KBr): 3325, 1703, 1596, 1515, 1278, 1013, 751 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.57 (br, 1H, NH), 7.35–7.39 (m, 2H, ArH),

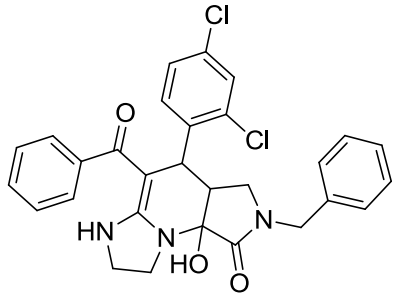
7.26–7.32 (m, 1H, ArH), 7.13–7.22 (m, 6H, ArH), 7.05–7.09 (m, 1H, ArH), 6.99–7.04 (m, 2H, ArH), 6.85 (d, *J* = 7.7 Hz, 2H, ArH), 6.37 (br, 1H, OH), 4.42 (AB, 2H, $ArCH_2$), 3.74–3.77 (m, 1H, CH), 3.64–3.72 (m, 2H, CH_2), 3.57–3.62 (m, 1H, NCH_2), 3.49–3.53 (m, 1H, NCH_2), 3.05 (t, *J* = 9.4 Hz, 1H, NCH_2), 2.78–2.83 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.7, 170.1, 160.1, 146.4, 142.1, 136.9, 132.6, 129.3, 128.4, 128.2, 128.2, 128.0, 126.1, 83.4, 82.7, 47.7, 47.2, 46.2, 43.4, 42.7, 40.4; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{27}ClN_3O_3$ $[(M+H)^+]$, 500.1735; found, 500.1743.

2-Benzyl-5-(4-chlorobenzoyl)-9a-hydroxy-4-(4-methoxyphenyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4m)



White solid; Mp 237–239 °C; IR (KBr): 3328, 1699, 1597, 1511, 1246, 1019, 833 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.55 (br, 1H, NH), 7.35–7.38 (m, 2H, ArH), 7.29–7.32 (m, 1H, ArH), 7.16–7.21 (m, 4H, ArH), 6.92 (d, *J* = 7.8 Hz, 2H, ArH), 6.87 (d, *J* = 7.8 Hz, 2H, ArH), 6.72 (d, *J* = 7.8 Hz, 2H, ArH), 6.32 (br, 1H, OH), 4.43 (AB, 2H, $ArCH_2$), 3.68–3.72 (m, 1H, CH), 3.68 (s, 3H, OCH_3), 3.58–3.64 (m, 2H, CH_2), 3.50 (d, *J* = 7.6 Hz, 1H, CH), 3.02 (t, *J* = 9.3 Hz, 1H, NCH_2), 2.75–2.80 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 187.5, 170.1, 160.7; 157.6, 142.0, 138.2, 136.8, 132.6, 129.2, 129.2, 128.3, 128.0; 128.0, 113.5, 83.6, 82.7, 55.3, 47.8, 47.1, 46.2, 43.3, 42.6, 38.8; HRMS (ESI-TOF): *m*/*z* calcd for $C_{30}H_{29}ClN_3O_4$ $[(M+H)^+]$, 530.1841; found, 530.1846.

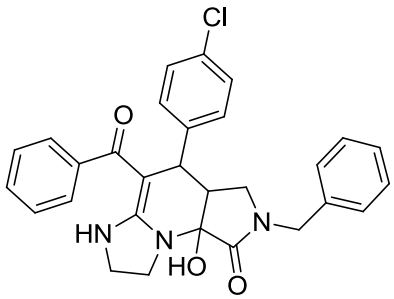
5-Benzoyl-2-benzyl-4-(2,4-dichlorophenyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4n)



White solid; Mp 222–225 °C; IR (KBr): 3283, 1703, 1602, 1513, 1208, 701, 600 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.53 (br, 1H, NH), 7.26–7.40 (m, 5H, ArH),

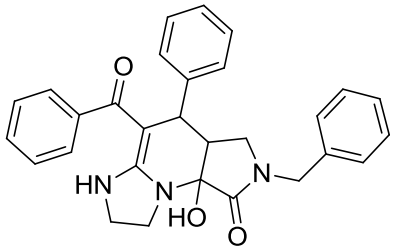
7.10–7.21 (m, 6H, ArH), 6.77 (d, *J* = 7.4 Hz, 2H, ArH), 6.52 (br, 1H, OH), 4.49 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 4.34 (t, *J* = 15.0 Hz, 1H, $ArCH_2$), 3.98–4.02 (m, 1H, CH), 3.73–7.77 (m, 2H, CH_2), 3.59–3.63 (m, 1H, CH_2), 3.45–3.49 (m, 1H, NCH_2), 3.30 (t, *J* = 8.9 Hz, 1H, NCH_2), 3.06 (t, *J* = 9.8 Hz, 1H, CH), 2.64 (t, *J* = 8.9 Hz, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.3, 169.7, 160.0, 142.9, 142.2, 136.7, 133.1, 132.4, 131.5, 129.2, 128.8, 128.4, 128.0, 127.8, 127.4, 127.2, 125.8, 82.4, 82.1, 46.7, 46.2, 45.2, 43.4, 42.8, 36.3; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{26}Cl_2N_3O_3$ [$(M+H)^+$], 534.1346; found, 534.1351.

5-Benzoyl-2-benzyl-4-(4-chlorophenyl)-9a-hydroxy-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4o)



White solid; Mp 216–219 °C; IR (KBr): 3432, 1704, 1598, 1511, 1281, 1012, 694 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.56 (br, 1H, NH), 7.35–7.38 (m, 2H, ArH), 7.29–7.33 (m, 1H, ArH), 7.10–7.24 (m, 7H, ArH), 7.00–7.04 (m, 2H, ArH), 6.83–6.87 (m, 2H, ArH), 6.41 (br, 1H, OH), 4.44 (d, *J* = 14.8 Hz, 1H, $ArCH_2$), 4.39 (d, *J* = 14.8 Hz, 1H, $ArCH_2$), 3.72–3.74 (m, 1H, CH), 3.68–3.72 (m, 2H, CH_2), 3.59–3.63 (m, 1H, CH_2), 3.46–3.50 (m, 1H, NCH_2), 3.05 (t, *J* = 8.7 Hz, 1H, NCH_2), 2.75–2.83 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.1, 170.0, 159.8, 145.5, 143.1, 136.8, 130.4, 130.1, 129.2, 128.0, 128.0, 128.0, 126.3, 82.9, 82.7, 47.5, 47.0, 46.2, 43.4, 42.6, 39.1; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{27}ClN_3O_3$ [$(M+H)^+$], 500.1735; found, 500.1735.

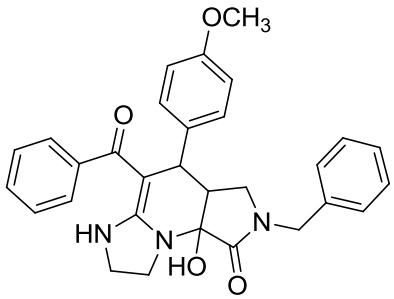
5-Benzoyl-2-benzyl-9a-hydroxy-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4p)



White solid; Mp 202–205 °C; IR (KBr): 3324, 1702, 1597, 1513, 1277, 1009, 698 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 9.60 (br, 1H, NH), 7.36–7.40 (m, 2H, ArH),

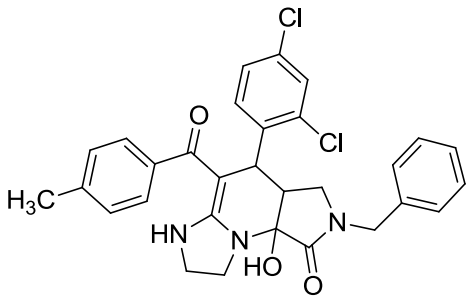
7.29–7.34 (m, 2H, ArH), 7.22–7.26 (m, 2H, ArH), 7.10–7.20 (m, 5H, ArH), 7.04–7.09 (m, 1H, ArH), 7.01 (d, *J* = 7.5 Hz, 2H, ArH), 6.85 (d, *J* = 7.5 Hz, 2H, ArH), 6.36 (br, 1H, OH), 4.42 (AB, 2H, $ArCH_2$), 3.73–3.77 (m, 1H, CH), 3.68–3.74 (m, 2H, CH_2), 3.58–3.65 (m, 1H, CH_2), 3.38–3.53 (m, 1H, NCH_2), 3.32–3.36 (m, 1H, CH), 3.07 (t, *J* = 9.6 Hz, 1H, NCH_2), 2.81–2.85 (m, 1H, NCH_2); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 189.5, 170.5, 160.4; 146.8, 143.7, 137.2, 129.6, 129.2, 128.7, 128.4, 128.4, 128.3; 126.8, 126.3, 83.7, 83.1, 48.0, 47.6, 46.6, 43.8, 43.1, 40.4; HRMS (ESI-TOF): *m*/*z* calcd for $C_{29}H_{28}N_3O_3$ $[(M+H)^+]$, 466.2125; found,466.2132.

5-Benzoyl-2-benzyl-9a-hydroxy-4-(4-methoxyphenyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4q)



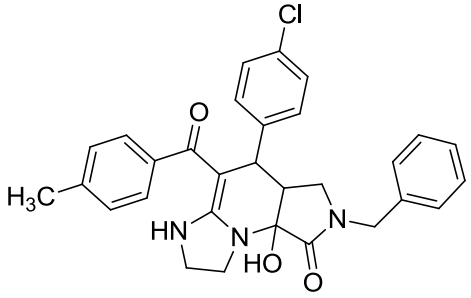
White solid; Mp 217–230 °C; IR (KBr): 3431, 1698, 1598, 1511, 1245, 1021, 702 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.59 (br, 1H, NH), 7.35–3.40 (m, 2H, ArH), 7.28–7.32 (m, 1H, ArH), 7.16–7.22 (m, 3H, ArH), 7.11–7.15 (m, 2H, ArH), 6.92 (d, *J* = 8.4 Hz, 2H, ArH), 6.86 (d, *J* = 7.2 Hz, 2H, ArH), 6.71 (d, *J* = 8.4 Hz, 2H, ArH), 6.32 (br, 1H, OH), 4.41 (AB, 2H, $ArCH_2$), 3.75 (d, *J* = 8.8 Hz, 1H, CH), 3.69–3.74 (m, 2H, CH_2), 3.66 (s, 3H, OCH_3), 3.57–3.61 (m, 1H, CH), 3.51 (t, *J* = 6.9 Hz, 1H, CH_2), 3.04 (t, *J* = 9.6 Hz, 1H, NCH_2), 2.77–2.83 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.0, 170.1, 160.7; 157.5, 143.3, 138.3, 136.8, 129.2, 129.2, 128.0, 127.9, 126.4, 113.4; 83.6, 82.8, 55.3, 47.8, 47.1, 46.2, 43.4, 42.6, 38.9; HRMS (ESI-TOF): *m*/*z* calcd for $C_{30}H_{30}N_3O_4$ $[(M+H)^+]$, 496.2231; found, 496.2239.

2-Benzyl-4-(2,4-dichlorophenyl)-9a-hydroxy-5-(4-methylbenzoyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4r)



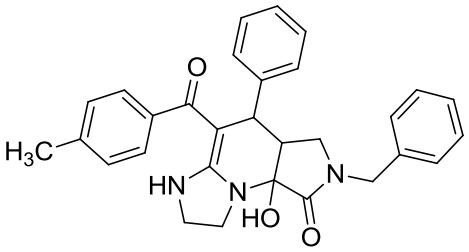
White solid; Mp 234–237 °C; IR (KBr): 3788, 3427, 1699, 1638, 1253, 1168, 735, 657 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.58 (br, 1H, NH), 7.43 (s, 1H, ArH), 7.32–7.39 (m, 4H, ArH), 7.20–7.25 (m, 3H, ArH), 6.96 (d, J = 7.0 Hz, 2H, ArH), 6.70 (d, J = 7.0 Hz, 2H, ArH), 6.50 (br, 1H, OH), 4.51 (d, J = 14.7 Hz, 1H, $ArCH_2$), 4.36 (d, J = 14.8 Hz, 1H, $ArCH_2$), 4.03–4.07 (m, 1H, CH), 3.70–3.78 (m, 2H, CH_2), 3.62 (d, J = 7.5 Hz, 1H, CH), 3.48 (d, J = 5.4 Hz, 1H, NCH_2), 3.31 (d, J = 7.9 Hz, 1H, NCH_2), 3.05 (t, J = 9.4 Hz, 1H, NCH_2), 2.68–3.73 (m, 1H, NCH_2), 2.23 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.1, 169.8, 160.0, 142.2, 140.1, 137.4, 136.7, 133.1, 132.4, 131.5, 129.2, 128.5, 128.0, 127.2, 125.9, 82.4, 82.0, 46.7, 46.2, 45.2, 43.4, 42.7, 36.4, 21.2; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{28}Cl_2N_3O_3$ $[(M+H)^+]$, 548.1502; found, 548.1500.

2-Benzyl-4-(4-chlorophenyl)-9a-hydroxy-5-(4-methylbenzoyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4s)



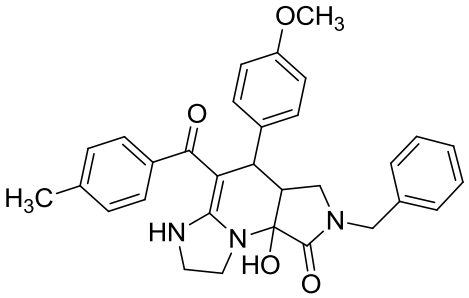
White solid; Mp 228–230 °C; IR (KBr): 3312, 1703, 1595, 1512, 1215, 837, 580 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.58 (br, 1H, NH), 7.35–7.39 (m, 2H, ArH), 7.28–7.32 (m, 1H, ArH), 7.18–7.24 (m, 4H, ArH), 7.05 (d, J = 7.9 Hz, 2H, ArH), 6.95 (d, J = 7.4 Hz, 2H, ArH), 6.77 (d, J = 7.4 Hz, 2H, ArH), 6.37 (br, 1H, OH), 4.43 (d, J = 15.3 Hz, 1H, $ArCH_2$), 4.38 (d, J = 15.3 Hz, 1H, $ArCH_2$), 3.74–3.78 (m, 1H, CH), 3.65–3.71 (m, 2H, CH_2), 3.56–3.60 (m, 1H, CH_2), 3.46–3.50 (m, 1H, NCH_2), 3.35–3.39 (m, 1H, CH), 3.03 (t, J = 9.5 Hz, 1H, NCH_2), 2.78–2.83 (m, 1H, NCH_2), 2.21 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.1, 170.0, 159.9, 145.5, 140.3, 137.4, 136.8, 130.4, 130.1, 129.2, 128.5, 128.0, 128.0, 126.4, 82.8, 82.7, 47.6, 47.0, 46.1, 43.4, 42.6, 39.1, 21.2; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{29}ClN_3O_3$ $[(M+H)^+]$, 514.1892; found, 514.1890.

2-Benzyl-9a-hydroxy-5-(4-methylbenzoyl)-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4t)



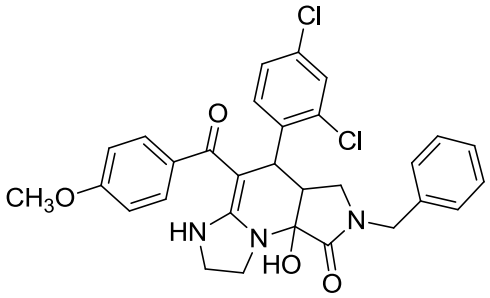
White solid; Mp 213–216 °C; IR (KBr): 3335, 1704, 1597, 1514, 1279, 907, 698 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.61 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.25–7.29 (m, 1H, ArH), 7.10–7.25 (m, 4H, ArH), 7.02–7.08 (m, 3H, ArH), 6.92 (d, J = 7.6 Hz, 2H, ArH), 6.76 (d, J = 7.6 Hz, 2H, ArH), 6.30 (br, 1H, OH), 4.41 (AB, 2H, $ArCH_2$), 3.73–3.77 (m, 1H, CH), 3.62–3.68 (m, 2H, CH_2), 3.57–3.61 (m, 1H, CH), 3.48–3.52 (m, 1H, NCH_2), 3.04 (t, J = 9.5 Hz, 1H, NCH_2), 2.82–2.88 (m, 1H, NCH_2), 2.20 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.0, 170.1, 160.0; 146.5, 140.4, 137.3, 136.8, 129.2, 128.8, 128.4, 128.3; 128.1, 128.0; 127.8; 126.5; 126.0, 83.2, 82.7, 47.7, 47.1, 46.1, 43.4, 42.6, 39.3, 21.2; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{30}N_3O_3$ [$(M+H)^+$], 480.2287; found, 480.2287.

2-Benzyl-9a-hydroxy-4-(4-methoxyphenyl)-5-(4-methylbenzoyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4u)



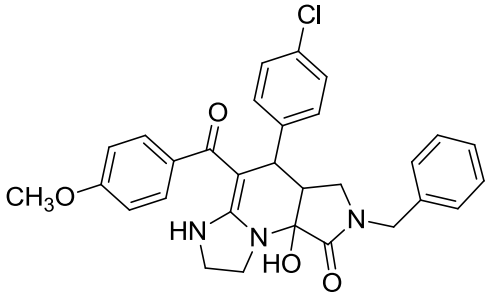
White solid; Mp 222–225 °C; IR (KBr): 3416, 1700, 1598, 1510, 1246, 1022, 758 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.60 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.29–7.33 (m, 1H, ArH), 7.20 (d, J = 7.1 Hz, 2H, ArH), 6.91–6.97 (m, 4H, ArH), 6.79 (d, J = 7.9 Hz, 2H, ArH), 6.73 (d, J = 8.6 Hz, 2H, ArH), 6.26 (br, 1H, OH), 4.40 (AB, 2H, $ArCH_2$), 3.65–3.69 (m, 1H, CH), 3.61–3.67 (m, 2H, CH_2), 3.63 (s, 3H, OCH_3), 3.57–3.61 (m, 1H, CH), 3.48–3.52 (m, 1H, CH_2), 3.02 (t, J = 9.5 Hz, 1H, NCH_2), 2.80–2.84 (m, 1H, NCH_2), 2.21 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 189.0, 170.2, 160.7, 157.5, 140.5, 138.3, 137.3, 136.8, 129.2, 129.2, 128.4, 128.0, 126.5, 113.5, 83.5, 82.8, 55.3, 47.8, 47.1, 46.1, 43.4, 42.6, 38.9, 21.2; HRMS (ESI-TOF): m/z calcd for $C_{31}H_{32}N_3O_4$ [$(M+H)^+$], 510.2387; found, 510.2398.

2-Benzyl-4-(2,4-dichlorophenyl)-9a-hydroxy-5-(4-methoxybenzoyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4v)



White solid; Mp 229–231 °C; IR (KBr): 3419, 1703, 1598, 1509, 1250, 838, 749 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.54 (br, 1H, NH), 8.29 (br, 1H, OH), 7.41 (s, 1H, ArH), 7.26–7.37 (m, 4H, ArH), 7.15–7.18 (m, 3H, ArH), 6.76 (d, J = 8.6 Hz, 2H, ArH), 6.66 (d, J = 8.6 Hz, 2H, ArH), 4.47 (d, J = 15.0 Hz, 1H, $ArCH_2$), 4.31 (d, J = 15.0 Hz, 1H, $ArCH_2$), 4.05–4.09 (m, 1H, CH), 3.67–3.71 (m, 2H, CH_2), 3.64 (s, 3H, OCH_3) , 3.55–3.59 (m, 1H, CH), 3.43–3.47 (m, 1H, NCH_2), 3.26–3.30 (m, 1H, NCH_2), 2.98–3.02 (m, 1H, NCH_2), 2.64–2.68 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.6, 169.8, 160.1, 159.3, 142.2, 136.7, 135.3, 133.1, 132.3, 131.5, 129.2, 128.6, 128.6, 128.0, 127.6, 127.3, 113.3, 82.4, 82.0, 55.5, 46.7, 46.2, 45.3, 43.4, 42.7, 36.5; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{28}Cl_2N_3O_4$ $[(M+Na)^+]$, 586.1271; found, 586.1270.

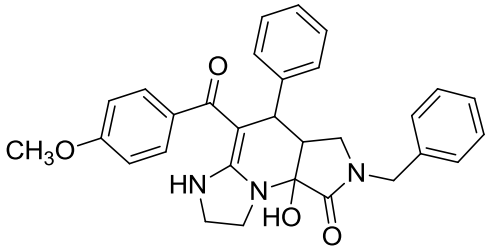
2-Benzyl-4-(4-chlorophenyl)-9a-hydroxy-5-(4-methoxybenzoyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4w)



White solid; Mp 230–232 °C; IR (KBr): 3420, 1705, 1597, 1510, 1249, 1017, 649 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.59 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.28–7.33 (m, 1H, ArH), 7.19–7.24 (m, 4H, ArH), 7.08 (d, J = 8.1 Hz, 2H, ArH), 6.86 (d, J = 8.2 Hz, 2H, ArH), 6.69 (d, J = 8.2 Hz, 2H, ArH), 6.36 (br, 1H, OH), 4.342 (AB, 2H, $ArCH_2$), 3.81–3.84 (m, 1H, CH), 3.72 (s, 3H, OCH_3), 3.67–3.71 (m, 2H, CH_2), 3.56–3.60 (m, 1H, CH), 3.46–3.50 (m, 1H, NCH_2), 3.03 (t, J = 4.8 Hz, 1H, NCH_2), 2.79–2.84 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.5, 170.0, 159.9, 159.3, 145.5, 136.8, 135.5, 130.4, 130.1, 129.2, 128.1, 128.0, 128.1, 113.2, 82.8, 82.7, 55.4, 47.6, 47.0, 46.1, 43.4, 42.6, 39.1; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{29}ClN_3O_4$ $[(M+H)^+]$,

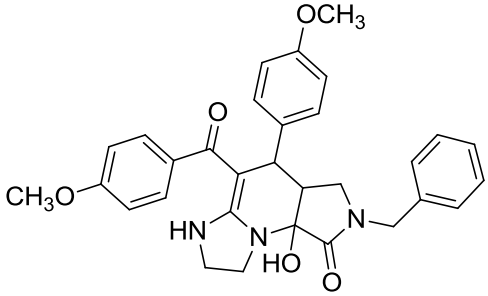
530.1841; found, 530.1840.

2-Benzyl-9a-hydroxy-5-(4-methoxybenzoyl)-4-phenyl-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4x)



White solid; Mp 192–194 °C; IR (KBr): 3328, 1705, 1594, 1247, 1023,694, 576 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.62 (br, 1H, NH), 7.35–3.40 (m, 2H, ArH), 7.28–7.32 (m, 1H, ArH), 7.15–7.22 (m, 4H, ArH), 7.05–7.08 (m, 3H, ArH), 6.86 (d, J = 8.1 Hz, 2H, ArH), 6.67 (d, J = 8.1 Hz, 2H, ArH), 6.28 (br, 1H, OH), 4.41 (AB, 2H, $ArCH_2$), 3.80–3.84 (m, 1H, CH), 3.69–3.75 (m, 2H, CH_2), 3.67 (s, 3H, OCH_3), 3.56–3.60 (m, 1H, CH), 3.49–3.53 (m, 1H, NCH_2), 3.43–3.47 (m, 1H, NCH_2), 3.05 (t, J = 9.4 Hz, 1H, NCH_2), 2.84–2.89 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.5, 170.1, 160.1; 159.3, 146.5, 136.8, 135.6, 129.2, 128.3, 128.2, 128.2, 128.0, 126.0, 113.1, 83.2, 82.7, 55.4, 47.7, 47.2, 46.1, 43.4, 42.6, 39.4; HRMS (ESI-TOF): m/z calcd for $C_{30}H_{30}N_3O_4$ $[(M+H)^+]$, 496.2231; found, 496.2239.

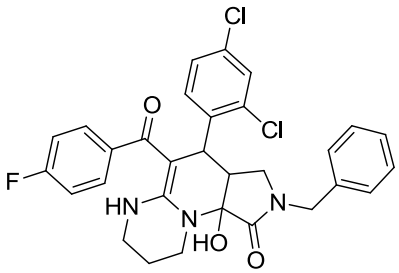
2-Benzyl-9a-hydroxy-5-(4-methoxybenzoyl)-4-(4-methoxyphenyl)-2,3,3a,4,6,7,8,9a-octahydro-1*H*-imidazo[1,2-*a*]pyrrolo[3,4-*e*]pyridin-1-one (4y)



White solid; Mp 216–219 °C; IR (KBr): 3431, 1698, 1599, 1510, 1246, 833, 408 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 9.62 (br, 1H, NH), 7.35–7.40 (m, 2H, ArH), 7.28–7.32 (m, 1H, ArH), 7.20 (d, J = 7.4 Hz, 2H, ArH), 6.97 (d, J = 8.4 Hz, 2H, ArH), 6.88 (d, J = 8.4 Hz, 2H, ArH), 6.74 (d, J = 8.4 Hz, 2H, ArH), 6.68 (d, J = 8.4 Hz, 2H, ArH), 6.25 (br, 1H, OH), 4.40 (AB, 2H, $ArCH_2$), 3.74–3.78 (m, 1H, CH), 3.69 (s, 3H, OCH_3), 3.65–3.69 (m, 2H, CH_2), 3.66 (s, 3H, OCH_3), 3.61–3.65 (m, 1H, CH), 3.55–3.59 (m, 1H, CH_2), 3.48–3.52 (m, 1H, CH_2), 3.02 (t, J = 9.5 Hz, 1H, NCH_2), 2.81–2.86 (m, 1H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 188.4, 170.2, 160.0, 159.3, 157.5, 138.4,

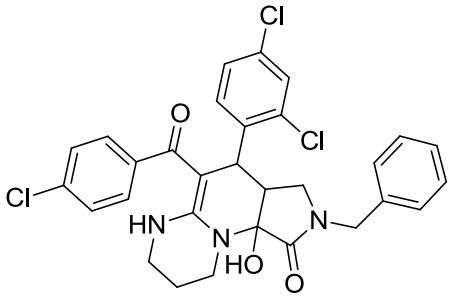
136.8, 135.6, 129.2, 128.2, 128.0, 113.5, 113.1, 83.5, 82.8, 55.4, 55.3, 47.9, 47.1, 46.1, 43.4, 42.6, 39.0; HRMS (ESI-TOF): *m*/*z* calcd for $C_{31}H_{32}N_3O_5$ [$(M+H)^+$], 526.2336; found, 526.2344.

2-Benzyl-4-(2,4-dichlorophenyl)-5-(4-fluorobenzoyl)-10a-hydroxy-2,3,3a,4,6,7,8,9-octahydropyrrolo[3',4':5,6]pyrido[1,2-*a*]pyrimidin-1(10a*H*)-one (5a)



White solid; Mp 187-190 °C; IR (KBr): 3403, 1703, 1595, 1545, 1237, 841, 541 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ = 12.55 (br, 1H, NH), 7.17–7.40 (m, 8H, ArH), 6.90–6.96 (m, 2H, ArH), 6.68–6.74 (m, 2H, ArH), 6.46 (br, 1H, OH), 4.47 (d, *J* = 14.7 Hz, 1H, $ArCH_2$), 4.33 (d, *J* = 14.7 Hz, 1H, $ArCH_2$), 3.79–3.83 (m, 1H, CH), 3.41–3.54 (m, 2H, CH_2), 3.24–3.28 (m, 1H, CH), 3.12–3.18 (m, 1H, NCH_2), 2.64–2.72 (m, 1H, NCH_2), 1.79–1.99 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 185.8, 169.8, 157.5, 141.8, 139.8, 136.7, 133.0, 132.7, 131.5, 129.2, 128.8, 128.5, 128.0, 127.8, 127.4, 115.1 (d, *J* =22.0 Hz), 114.9 (d, *J* =22.0 Hz), 83.9, 83.2, 46.5, 46.3, 44.4, 40.6, 40.4, 38.5, 36.4, 20.7; HRMS (ESI-TOF): *m*/*z* calcd for $C_{30}H_{27}Cl_2FN_3O_3$ [$(M+H)^+$], 566.1408; found, 566.1412.

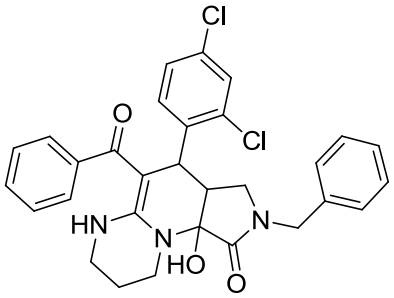
2-Benzyl-5-(4-chlorobenzoyl)-4-(2,4-dichlorophenyl)-10a-hydroxy-2,3,3a,4,6,7,8,9-octahydropyrrolo[3',4':5,6]pyrido[1,2-*a*]pyrimidin-1(10a*H*)-one (5b)



White solid; Mp 193–196 °C; IR (KBr): 3402, 1703, 1593, 1547, 1244, 842,517 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$-*d*): δ =12.61 (br, 1H, NH), 7.25–7.29 (m, 3H, ArH), 7.17–7.21 (m, 1H, ArH), 7.12–7.16 (m, 2H, ArH), 7.05–7.11 (m, 2H, ArH), 7.03 (d, *J* = 8.1 Hz, 2H, ArH), 6.65 (d, *J* = 8.1 Hz, 2H, ArH), 4.35 (AB, 2H, $ArCH_2$), 4.09 (s, 1H, CH), 3.82 (br, 1H, OH), 3.31–3.44 (m, 4H, CH_2), 3.09–3.18 (m, 2H, CH_2), 2.78 (t, *J* = 8.4 Hz, 1H, CH), 1.79–1.92 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, $CDCl_3$-*d*): δ = 186.6, 169.7,

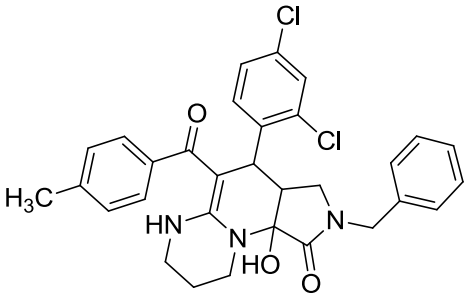
157.5, 140.6, 140.3, 134.9, 133.6, 133.3, 132.8, 131.1, 129.1, 128.3, 128.1, 127.9, 127.1, 127.0, 84.3, 82.9, 47.2, 46.7, 44.7, 39.8, 38.6, 36.1, 20.7; HRMS (ESI-TOF): *m*/*z* calcd for $C_{30}H_{27}Cl_3N_3O_3$ [$(M+H)^+$], 582.1113; found, 582.1112.

5-Benzoyl-2-benzyl-4-(2,4-dichlorophenyl)-10a-hydroxy-2,3,3a,4,6,7,8,9-octahydropyrrolo[3',4':5,6]pyrido[1,2-*a*]pyrimidin-1(10a*H*)-one (5c)



White solid; Mp 188–190 °C; IR (KBr): 3456, 1703, 1598, 1544, 1049, 700, 459 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ =12.61 (br, 1H, NH), 7.33–7.41 (m, 5H, ArH), 7.09–7.31 (m, 6H, ArH), 6.65–6.61 (m, 2H, ArH), 6.44 (br, 1H, OH), 4.48 (d, *J* = 14.9 Hz, 1H, $ArCH_2$), 4.34 (d, *J* = 14.9 Hz, 1H, $ArCH_2$), 3.85 (d, *J* = 1.6 Hz, 1H, CH), 3.55–3.61 (m, 2H, CH_2), 3.44–3.51 (m, 2H, CH_2), 3.25–3.29 (m, 1H, CH), 3.14–3.18 (m, 1H, NCH_2), 2.70–2.76 (m, 1H, NCH_2), 1.90–1.96 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 186.9, 169.9, 157.6, 143.3, 141.9, 136.7, 133.1, 132.6, 131.4; 129.2, 128.4, 128.1, 128.0, 127.6, 127.3, 125.6, 83.8, 83.3, 46.5, 46.3, 44.5, 40.6, 38.5, 36.5, 20.8; HRMS (ESI-TOF): *m*/*z* calcd for $C_{30}H_{28}Cl_2N_3O_3$ [$(M+H)^+$], 548.1502; found, 548.1501.

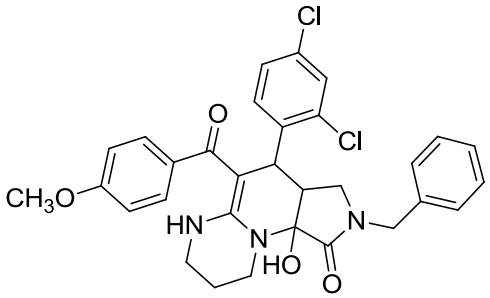
2-Benzyl-4-(2,4-dichlorophenyl)-10a-hydroxy-5-(4-methylbenzoyl)-2,3,3a,4,6,7,8,9-octahydropyrrolo[3',4':5,6]pyrido[1,2-*a*]pyrimidin-1(10a*H*)-one (5d)



White solid; Mp 195–197 °C; IR (KBr): 3422, 1702, 1545, 1247, 1123, 761, 703 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ =12.72 (br, 1H, NH), 7.39–7.45 (m, 4H, ArH), 7.35–7.39 (m, 1H, ArH), 7.31–7.35 (m, 1H, ArH), 7.22–7.28 (m, 2H, ArH), 6.95 (d, *J* = 7.8 Hz, 2H, ArH), 6.62 (d, *J* = 7.8 Hz, 2H, ArH), 4.51 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 4.36 (d, *J* = 15.0 Hz, 1H, $ArCH_2$), 3.88–3.92 (m, 1H, CH), 3.82 (br, 1H, OH), 3.59–3.64 (m,

4H, CH_2), 3.27–3.31 (m, 1H, CH), 3.13–3.17 (m, 1H, CH_2), 2.76 (t, *J* = 8.8 Hz, 1H, CH_2), 1.22 (s, 3H, CH_3), 1.83–1.93 (m, 2H, NCH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 186.9, 169.9, 157.6, 142.0, 140.5, 136.8, 136.7, 133.1, 132.6, 131.4, 129.2, 128.6, 128.0, 127.3, 125.6, 83.8, 83.3, 46.5, 46.3, 44.5, 39.3, 38.5, 36.6, 21.2, 20.8; HRMS (ESI-TOF): *m*/*z* calcd for $C_{31}H_{30}Cl_2N_3O_3$ [$(M+H)^+$], 562.1659; found, 561.1663.

2-Benzyl-4-(2,4-dichlorophenyl)-10a-hydroxy-5-(4-methoxybenzoyl)-2,3,3a,4,6,7,8,9-octahydropyrrolo[3',4':5,6]pyrido[1,2-*a*]pyrimidin-1(10a*H*)-one (5e)



White solid; Mp 179–182 °C; IR (KBr): 3408, 1700, 1596, 1544, 1244, 1041, 702 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ =12.75 (br, 1H, NH), 7.43 (s, 1H, ArH), 7.35–7.40 (m, 2H, ArH), 7.31–7.34 (m, 1H, ArH), 7.29–7.33 (m, 1H, ArH), 7.21–7.25 (m, 2H, ArH), 6.67–6.73 (m, 4H, ArH), 6.62 (br, 1H, OH), 4.49 (d, *J* = 14.9 Hz, 1H, $ArCH_2$), 4.34 (d, *J* = 14.9 Hz, 1H, $ArCH_2$), 3.92–3.95 (m, 1H, CH), 3.64 (s, 3H, OCH_3), 3.42–3.49 (m, 2H, CH_2), 3.26–3.30 (m, 1H, CH), 3.10–3.19 (m, 1H, CH_2), 2.76 (t, *J* = 8.8 Hz, 1H, CH_2), 1.80–1.90 (m, 2H, NCH_2), 1.83–1.93 (m, 2H, CH_2); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 186.2, 169.6, 158.5, 157.4, 141.7, 136.4, 135.5, 132.8, 132.3, 131.1; 128.9, 128.2, 127.7, 127.0, 126.9, 113.1, 83.5, 82.9, 55.1, 46.2, 46.0, 44.2, 40.2, 38.2, 36.4, 20.5; HRMS (ESI-TOF): *m*/*z* calcd for $C_{31}H_{30}Cl_2N_3O_4$ [$(M+H)^+$], 578.1608; found, 578.1615.

X-ray Structure and Data[7] of 5a

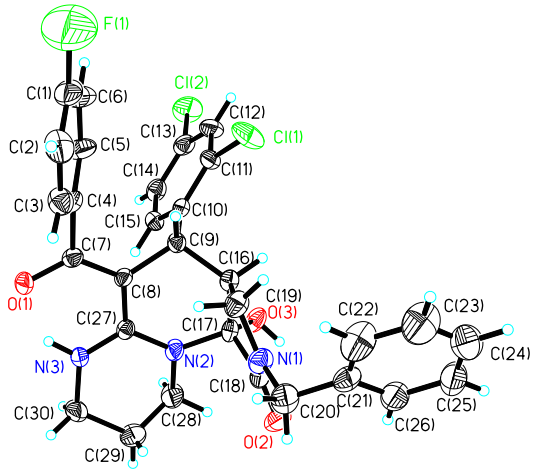


Figure S1 X-Ray crystal structure of **5a**

Table S1 Crystal data and structure refinement for **5a**

Empirical formula	$C_{30}H_{26}Cl_2FN_3O_3$
Formula weight	566.44
Temperature	298(2) K
Wavelength	0.71073 Å
Crystal system, space group	Monoclinic, P2(1)/c
Unit cell dimensions	a =17.159(3) A alpha = 90.00 deg. b = 8.7584(13) A beta = 109.581(2) deg. c = 20.018(3) A gamma = 90.00 deg.
Volume	2834.3(7) A^3
Z, Calculated density	4, 1.327 Mg/m^3
Absorption coefficient	0.272 mm^-1
F(000)	1176
Crystal size	0.30 x 0.20 x 0.15 mm
Theta range for data collection	2.16 to 25.15 deg.
Limiting indices	-20<=h<=19, -7<=k<=10, -23<=l<=23
Reflection collected/unique	15524 / 5056 [R(int) = 0.0680]
Completeness to theta = 28.40	99.7 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.9604 and 0.9229
Refinement method	SHELXL
Data/restraints/parameters	5056 / 0 / 353
Goodness-of-fit on F^2	1.000
Final R indices [I>2sigma(I)]	R1 = 0.0596, wR2 = 0.1492
R indices (all data)	R1 = 0.1310, wR2 = 0.1929
Largest diff. peak and hole	0.352 and -0.317 e.A^-3

Table S2 Bond lengths [A] and angles [deg] for **5a**

Cl(1)-C(11)	1.761(4)
Cl(2)-C(13)	1.742(4)
F(1)-C(1)	1.576(6)
N(1)-C(18)	1.350(5)
N(1)-C(17)	1.443(5)
N(1)-C(20)	1.469(4)
N(2)-C(27)	1.368(4)
N(2)-C(28)	1.472(4)
N(2)-C(19)	1.477(4)
N(3)-C(27)	1.328(4)
N(3)-C(30)	1.476(4)
N(3)-H(3)	0.8600
O(1)-C(7)	1.281(4)
O(2)-C(18)	1.229(4)
O(3)-C(19)	1.403(4)
O(3)-H(3A)	0.8200
C(1)-C(6)	1.362(7)
C(1)-C(2)	1.364(6)
C(2)-C(3)	1.389(6)
C(2)-H(2)	0.9300
C(3)-C(4)	1.393(5)
C(3)-H(3B)	0.9300
C(4)-C(5)	1.387(5)
C(4)-C(7)	1.516(5)
C(5)-C(6)	1.392(6)
C(5)-H(5)	0.9300
C(6)-H(6)	0.9300
C(7)-C(8)	1.404(5)
C(8)-C(27)	1.431(4)
C(8)-C(9)	1.518(4)
C(9)-C(10)	1.526(4)
C(9)-C(16)	1.559(5)
C(9)-H(9)	0.9800
C(10)-C(11)	1.397(4)
C(10)-C(15)	1.398(5)
C(11)-C(12)	1.383(5)
C(12)-C(13)	1.383(5)
C(12)-H(12)	0.9300
C(13)-C(14)	1.387(5)
C(14)-C(15)	1.387(4)
C(14)-H(14)	0.9300
C(15)-H(15)	0.9300
C(16)-C(19)	1.523(5)
C(16)-C(17)	1.541(5)
C(16)-H(16)	0.9800
C(17)-H(17A)	0.9700
C(17)-H(17B)	0.9700
C(18)-C(19)	1.563(5)

C(20)-C(21)	1.510(6)
C(20)-H(20A)	0.9700
C(20)-H(20B)	0.9700
C(21)-C(22)	1.377(6)
C(21)-C(26)	1.378(6)
C(22)-C(23)	1.411(8)
C(22)-H(22)	0.9300
C(23)-C(24)	1.336(9)
C(23)-H(23)	0.9300
C(24)-C(25)	1.365(7)
C(24)-H(24)	0.9300
C(25)-C(26)	1.392(6)
C(25)-H(25)	0.9300
C(26)-H(26)	0.9300
C(28)-C(29)	1.439(6)
C(28)-H(28A)	0.9700
C(28)-H(28B)	0.9700
C(29)-C(30)	1.525(6)
C(29)-H(29A)	0.9700
C(29)-H(29B)	0.9700
C(30)-H(30A)	0.9700
C(30)-H(30B)	0.9700
C(18)-N(1)-C(17)	114.5(3)
C(18)-N(1)-C(20)	123.0(4)
C(17)-N(1)-C(20)	122.5(4)
C(27)-N(2)-C(28)	118.2(3)
C(27)-N(2)-C(19)	125.4(3)
C(28)-N(2)-C(19)	116.3(3)
C(27)-N(3)-C(30)	126.7(3)
C(27)-N(3)-H(3)	116.6
C(30)-N(3)-H(3)	116.6
C(19)-O(3)-H(3A)	109.5
C(6)-C(1)-C(2)	117.2(4)
C(6)-C(1)-F(1)	120.8(5)
C(2)-C(1)-F(1)	122.0(5)
C(1)-C(2)-C(3)	122.0(4)
C(1)-C(2)-H(2)	119.0
C(3)-C(2)-H(2)	119.0
C(2)-C(3)-C(4)	120.9(4)
C(2)-C(3)-H(3B)	119.6
C(4)-C(3)-H(3B)	119.6
C(5)-C(4)-C(3)	116.9(4)
C(5)-C(4)-C(7)	123.7(3)
C(3)-C(4)-C(7)	119.2(3)
C(4)-C(5)-C(6)	120.5(4)
C(4)-C(5)-H(5)	119.8
C(6)-C(5)-H(5)	119.8
C(1)-C(6)-C(5)	122.4(4)
C(1)-C(6)-H(6)	118.8

C(5)-C(6)-H(6)	118.8
O(1)-C(7)-C(8)	124.7(3)
O(1)-C(7)-C(4)	116.2(3)
C(8)-C(7)-C(4)	119.1(3)
C(7)-C(8)-C(27)	121.4(3)
C(7)-C(8)-C(9)	121.2(3)
C(27)-C(8)-C(9)	117.3(3)
C(8)-C(9)-C(10)	113.6(3)
C(8)-C(9)-C(16)	110.1(3)
C(10)-C(9)-C(16)	111.6(3)
C(8)-C(9)-H(9)	107.0
C(10)-C(9)-H(9)	107.0
C(16)-C(9)-H(9)	107.0
C(11)-C(10)-C(15)	115.7(3)
C(11)-C(10)-C(9)	121.5(3)
C(15)-C(10)-C(9)	122.7(3)
C(12)-C(11)-C(10)	122.9(3)
C(12)-C(11)-Cl(1)	117.2(3)
C(10)-C(11)-Cl(1)	119.9(3)
C(13)-C(12)-C(11)	119.2(3)
C(13)-C(12)-H(12)	120.4
C(11)-C(12)-H(12)	120.4
C(12)-C(13)-C(14)	120.4(4)
C(12)-C(13)-Cl(2)	119.4(3)
C(14)-C(13)-Cl(2)	120.2(3)
C(15)-C(14)-C(13)	118.9(4)
C(15)-C(14)-H(14)	120.6
C(13)-C(14)-H(14)	120.6
C(14)-C(15)-C(10)	122.9(3)
C(14)-C(15)-H(15)	118.5
C(10)-C(15)-H(15)	118.5
C(19)-C(16)-C(17)	105.5(3)
C(19)-C(16)-C(9)	115.4(3)
C(17)-C(16)-C(9)	111.7(3)
C(19)-C(16)-H(16)	108.0
C(17)-C(16)-H(16)	108.0
C(9)-C(16)-H(16)	108.0
N(1)-C(17)-C(16)	104.5(3)
N(1)-C(17)-H(17A)	110.9
C(16)-C(17)-H(17A)	110.9
N(1)-C(17)-H(17B)	110.9
C(16)-C(17)-H(17B)	110.9
H(17A)-C(17)-H(17B)	108.9
O(2)-C(18)-N(1)	126.9(4)
O(2)-C(18)-C(19)	125.1(4)
N(1)-C(18)-C(19)	108.0(3)
O(3)-C(19)-N(2)	107.4(3)
O(3)-C(19)-C(16)	112.8(3)
N(2)-C(19)-C(16)	112.6(3)

O(3)-C(19)-C(18)	113.2(3)
N(2)-C(19)-C(18)	107.9(3)
C(16)-C(19)-C(18)	102.9(3)
N(1)-C(20)-C(21)	112.3(3)
N(1)-C(20)-H(20A)	109.1
C(21)-C(20)-H(20A)	109.1
N(1)-C(20)-H(20B)	109.1
C(21)-C(20)-H(20B)	109.1
H(20A)-C(20)-H(20B)	107.9
C(22)-C(21)-C(26)	117.7(5)
C(22)-C(21)-C(20)	122.8(5)
C(26)-C(21)-C(20)	119.5(4)
C(21)-C(22)-C(23)	120.2(6)
C(21)-C(22)-H(22)	119.9
C(23)-C(22)-H(22)	119.9
C(24)-C(23)-C(22)	120.7(6)
C(24)-C(23)-H(23)	119.6
C(22)-C(23)-H(23)	119.6
C(23)-C(24)-C(25)	120.3(6)
C(23)-C(24)-H(24)	119.9
C(25)-C(24)-H(24)	119.9
C(24)-C(25)-C(26)	119.6(6)
C(24)-C(25)-H(25)	120.2
C(26)-C(25)-H(25)	120.2
C(21)-C(26)-C(25)	121.5(5)
C(21)-C(26)-H(26)	119.3
C(25)-C(26)-H(26)	119.3
N(3)-C(27)-N(2)	118.5(3)
N(3)-C(27)-C(8)	120.6(3)
N(2)-C(27)-C(8)	120.9(3)
C(29)-C(28)-N(2)	111.1(4)
C(29)-C(28)-H(28A)	109.4
N(2)-C(28)-H(28A)	109.4
C(29)-C(28)-H(28B)	109.4
N(2)-C(28)-H(28B)	109.4
H(28A)-C(28)-H(28B)	108.0
C(28)-C(29)-C(30)	111.0(4)
C(28)-C(29)-H(29A)	109.4
C(30)-C(29)-H(29A)	109.4
C(28)-C(29)-H(29B)	109.4
C(30)-C(29)-H(29B)	109.4
H(29A)-C(29)-H(29B)	108.0
N(3)-C(30)-C(29)	108.8(3)
N(3)-C(30)-H(30A)	109.9
C(29)-C(30)-H(30A)	109.9
N(3)-C(30)-H(30B)	109.9
C(29)-C(30)-H(30B)	109.9
H(30A)-C(30)-H(30B)	108.3

Symmetry transformations used to generate equivalent atoms:

Table S3 Torsion angles [deg] for **5a**

C(6)-C(1)-C(2)-C(3)	-0.1(8)
F(1)-C(1)-C(2)-C(3)	-177.7(5)
C(1)-C(2)-C(3)-C(4)	1.9(7)
C(2)-C(3)-C(4)-C(5)	-2.9(6)
C(2)-C(3)-C(4)-C(7)	-178.7(4)
C(3)-C(4)-C(5)-C(6)	2.1(6)
C(7)-C(4)-C(5)-C(6)	177.8(4)
C(2)-C(1)-C(6)-C(5)	-0.7(8)
F(1)-C(1)-C(6)-C(5)	177.0(5)
C(4)-C(5)-C(6)-C(1)	-0.3(8)
C(5)-C(4)-C(7)-O(1)	-110.9(4)
C(3)-C(4)-C(7)-O(1)	64.7(4)
C(5)-C(4)-C(7)-C(8)	71.2(5)
C(3)-C(4)-C(7)-C(8)	-113.2(4)
O(1)-C(7)-C(8)-C(27)	-3.6(5)
C(4)-C(7)-C(8)-C(27)	174.1(3)
O(1)-C(7)-C(8)-C(9)	174.2(3)
C(4)-C(7)-C(8)-C(9)	-8.2(4)
C(7)-C(8)-C(9)-C(10)	-91.4(4)
C(27)-C(8)-C(9)-C(10)	86.4(3)
C(7)-C(8)-C(9)-C(16)	142.5(3)
C(27)-C(8)-C(9)-C(16)	-39.7(4)
C(8)-C(9)-C(10)-C(11)	152.2(3)
C(16)-C(9)-C(10)-C(11)	-82.5(4)
C(8)-C(9)-C(10)-C(15)	-23.4(4)
C(16)-C(9)-C(10)-C(15)	101.9(4)
C(15)-C(10)-C(11)-C(12)	-0.1(5)
C(9)-C(10)-C(11)-C(12)	-176.0(3)
C(15)-C(10)-C(11)-Cl(1)	179.1(3)
C(9)-C(10)-C(11)-Cl(1)	3.2(5)
C(10)-C(11)-C(12)-C(13)	0.2(6)
Cl(1)-C(11)-C(12)-C(13)	-179.0(3)
C(11)-C(12)-C(13)-C(14)	-0.3(6)
C(11)-C(12)-C(13)-Cl(2)	-178.4(3)
C(12)-C(13)-C(14)-C(15)	0.3(6)
Cl(2)-C(13)-C(14)-C(15)	178.4(3)
C(13)-C(14)-C(15)-C(10)	-0.2(6)
C(11)-C(10)-C(15)-C(14)	0.1(5)
C(9)-C(10)-C(15)-C(14)	175.9(3)
C(8)-C(9)-C(16)-C(19)	49.1(4)

C(10)-C(9)-C(16)-C(19)	-78.1(3)
C(8)-C(9)-C(16)-C(17)	-71.4(4)
C(10)-C(9)-C(16)-C(17)	161.5(3)
C(18)-N(1)-C(17)-C(16)	-10.4(4)
C(20)-N(1)-C(17)-C(16)	169.9(3)
C(19)-C(16)-C(17)-N(1)	19.7(4)
C(9)-C(16)-C(17)-N(1)	145.8(3)
C(17)-N(1)-C(18)-O(2)	178.4(4)
C(20)-N(1)-C(18)-O(2)	-1.9(6)
C(17)-N(1)-C(18)-C(19)	-3.3(4)
C(20)-N(1)-C(18)-C(19)	176.4(3)
C(27)-N(2)-C(19)-O(3)	-127.4(3)
C(28)-N(2)-C(19)-O(3)	55.1(4)
C(27)-N(2)-C(19)-C(16)	-2.6(5)
C(28)-N(2)-C(19)-C(16)	179.9(3)
C(27)-N(2)-C(19)-C(18)	110.2(4)
C(28)-N(2)-C(19)-C(18)	-67.2(4)
C(17)-C(16)-C(19)-O(3)	-143.4(3)
C(9)-C(16)-C(19)-O(3)	92.8(4)
C(17)-C(16)-C(19)-N(2)	94.9(3)
C(9)-C(16)-C(19)-N(2)	-28.9(4)
C(17)-C(16)-C(19)-C(18)	-21.0(3)
C(9)-C(16)-C(19)-C(18)	-144.8(3)
O(2)-C(18)-C(19)-O(3)	-44.0(5)
N(1)-C(18)-C(19)-O(3)	137.7(3)
O(2)-C(18)-C(19)-N(2)	74.7(4)
N(1)-C(18)-C(19)-N(2)	-103.7(3)
O(2)-C(18)-C(19)-C(16)	-166.1(4)
N(1)-C(18)-C(19)-C(16)	15.6(4)
C(18)-N(1)-C(20)-C(21)	103.5(5)
C(17)-N(1)-C(20)-C(21)	-76.8(5)
N(1)-C(20)-C(21)-C(22)	95.9(5)
N(1)-C(20)-C(21)-C(26)	-83.2(5)
C(26)-C(21)-C(22)-C(23)	-1.0(7)
C(20)-C(21)-C(22)-C(23)	179.9(5)
C(21)-C(22)-C(23)-C(24)	1.4(10)
C(22)-C(23)-C(24)-C(25)	-0.9(11)
C(23)-C(24)-C(25)-C(26)	0.1(9)
C(22)-C(21)-C(26)-C(25)	0.2(7)
C(20)-C(21)-C(26)-C(25)	179.3(4)
C(24)-C(25)-C(26)-C(21)	0.3(7)

C(30)-N(3)-C(27)-N(2)	7.0(5)
C(30)-N(3)-C(27)-C(8)	-174.4(3)
C(28)-N(2)-C(27)-N(3)	8.8(5)
C(19)-N(2)-C(27)-N(3)	-168.6(3)
C(28)-N(2)-C(27)-C(8)	-169.9(3)
C(19)-N(2)-C(27)-C(8)	12.8(5)
C(7)-C(8)-C(27)-N(3)	9.8(5)
C(9)-C(8)-C(27)-N(3)	-168.0(3)
C(7)-C(8)-C(27)-N(2)	-171.6(3)
C(9)-C(8)-C(27)-N(2)	10.6(4)
C(27)-N(2)-C(28)-C(29)	-42.3(5)
C(19)-N(2)-C(28)-C(29)	135.3(4)
N(2)-C(28)-C(29)-C(30)	58.9(5)
C(27)-N(3)-C(30)-C(29)	10.4(6)
C(28)-C(29)-C(30)-N(3)	-42.8(5)

^{1}H NMR and ^{13}C NMR Spectra for Heterocyclic Ketene Aminals Derivatives 1–2

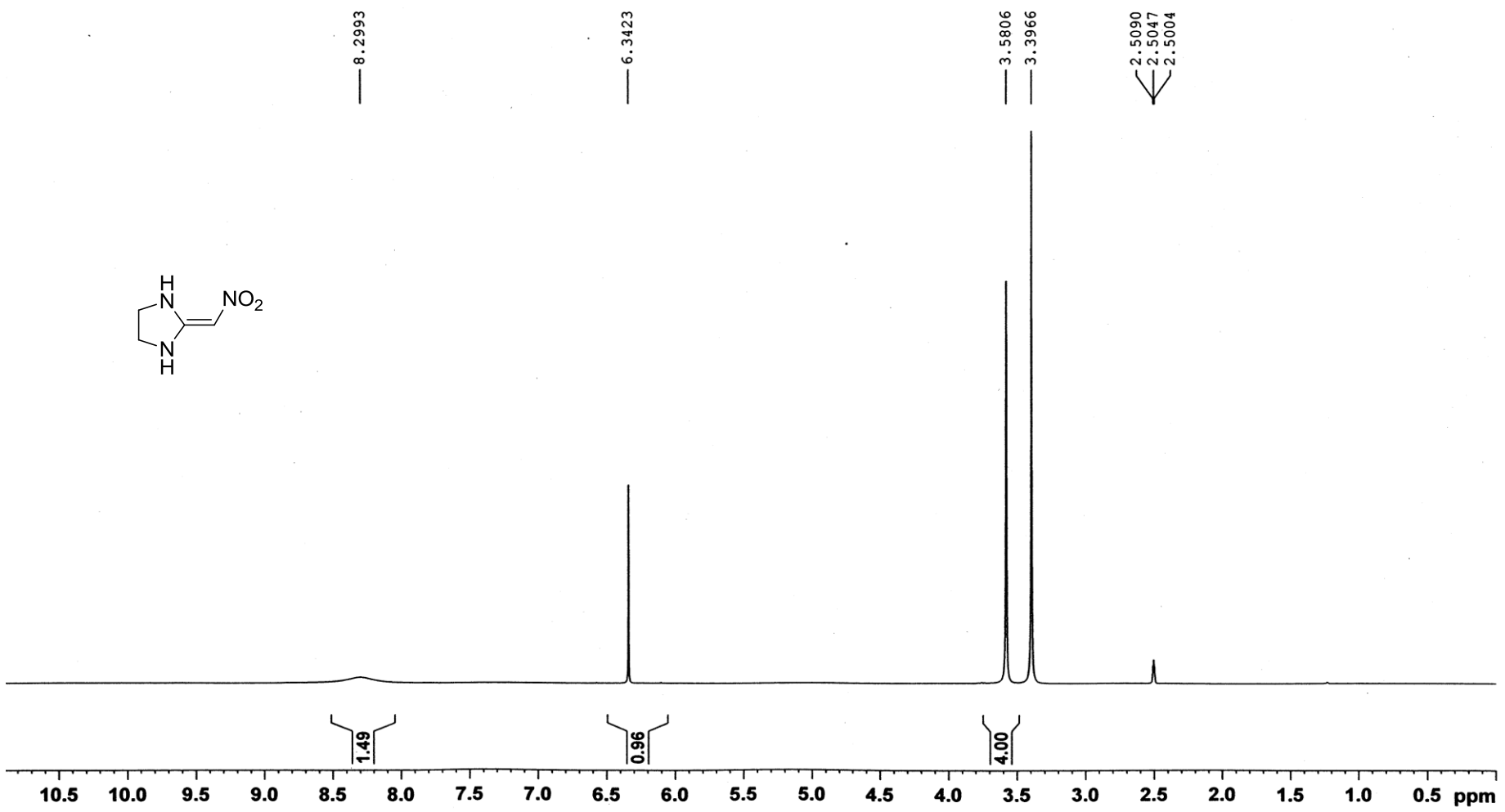


Figure 1. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1a**

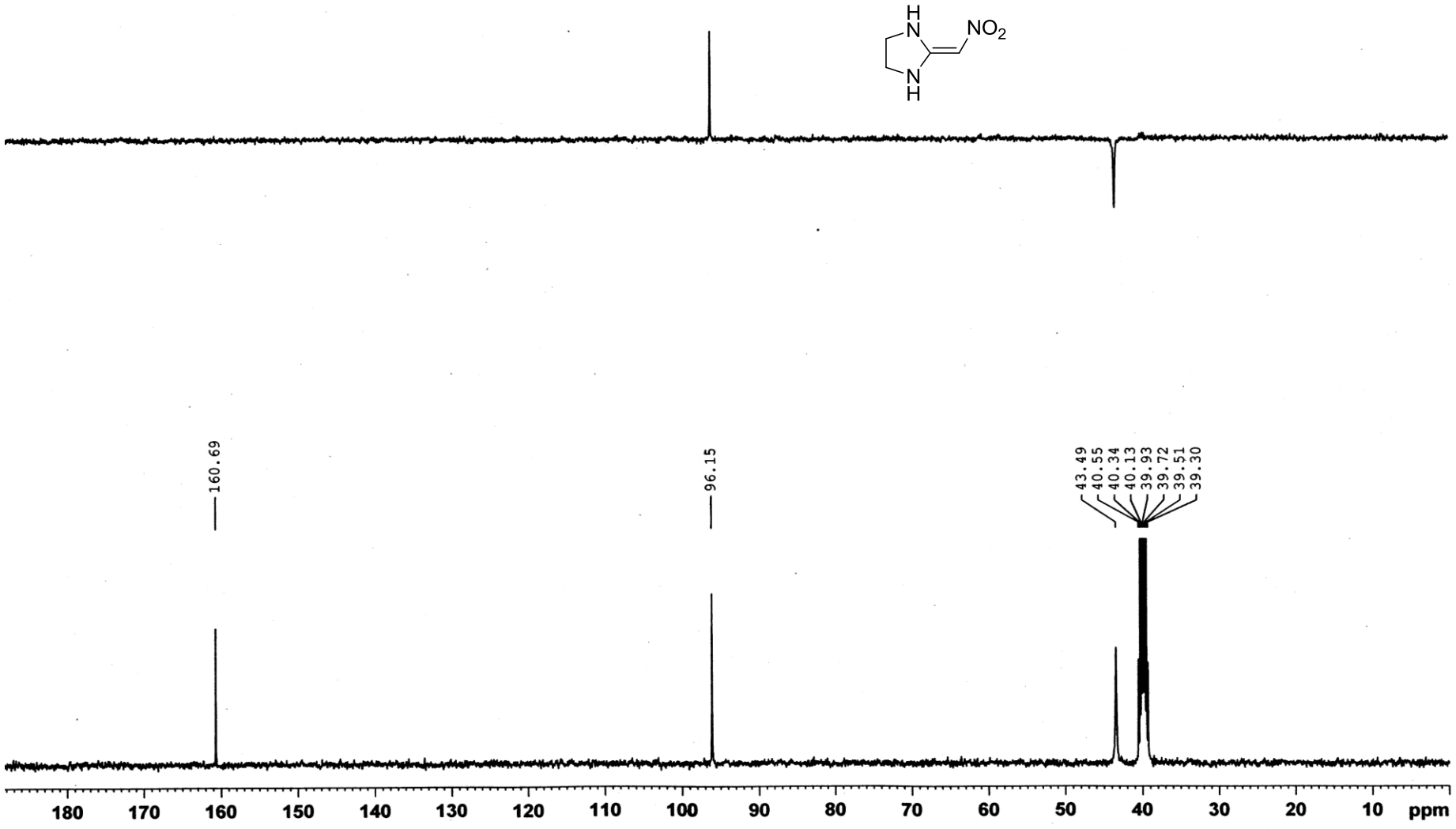


Figure 2. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1a**

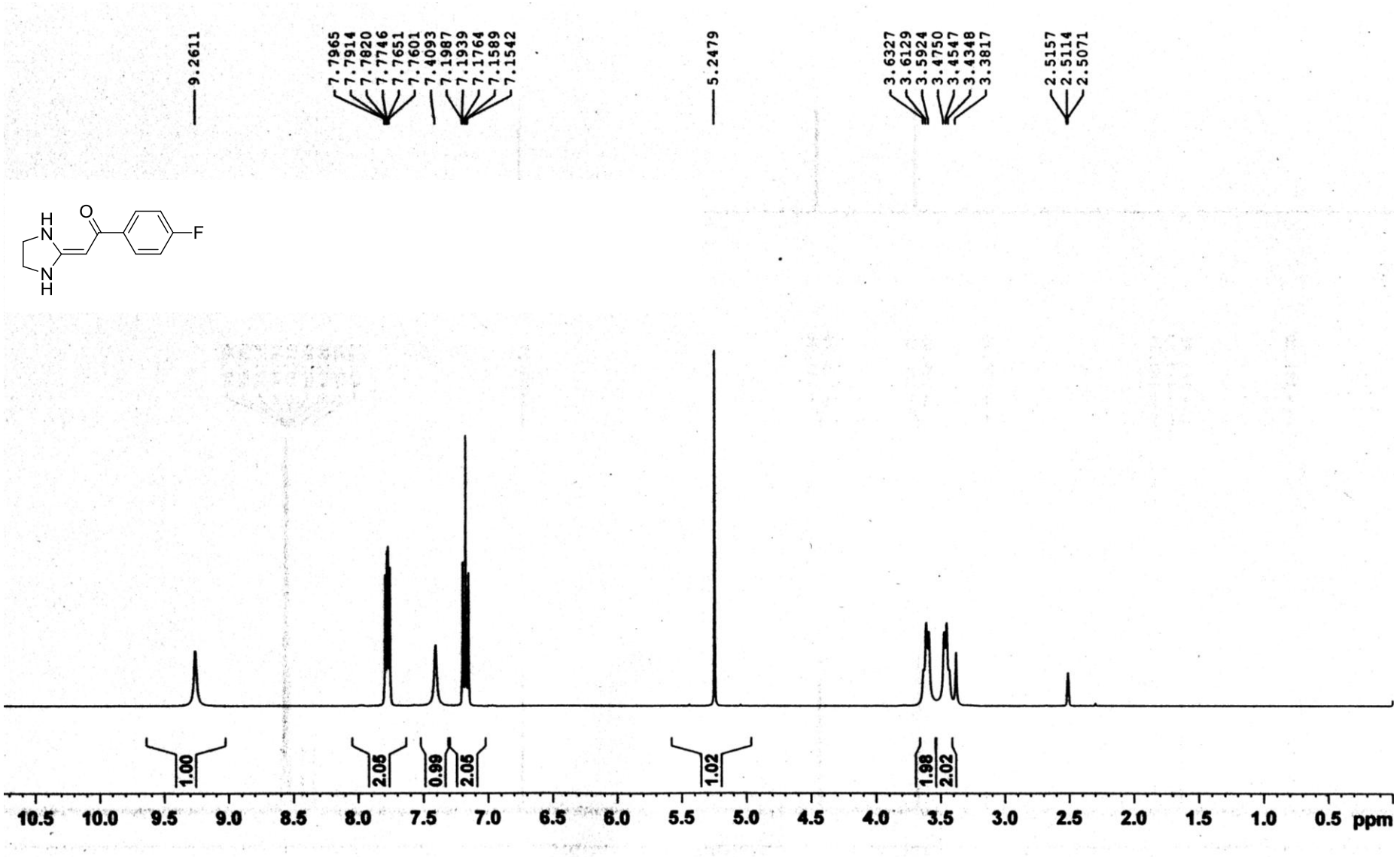


Figure 3. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1b**

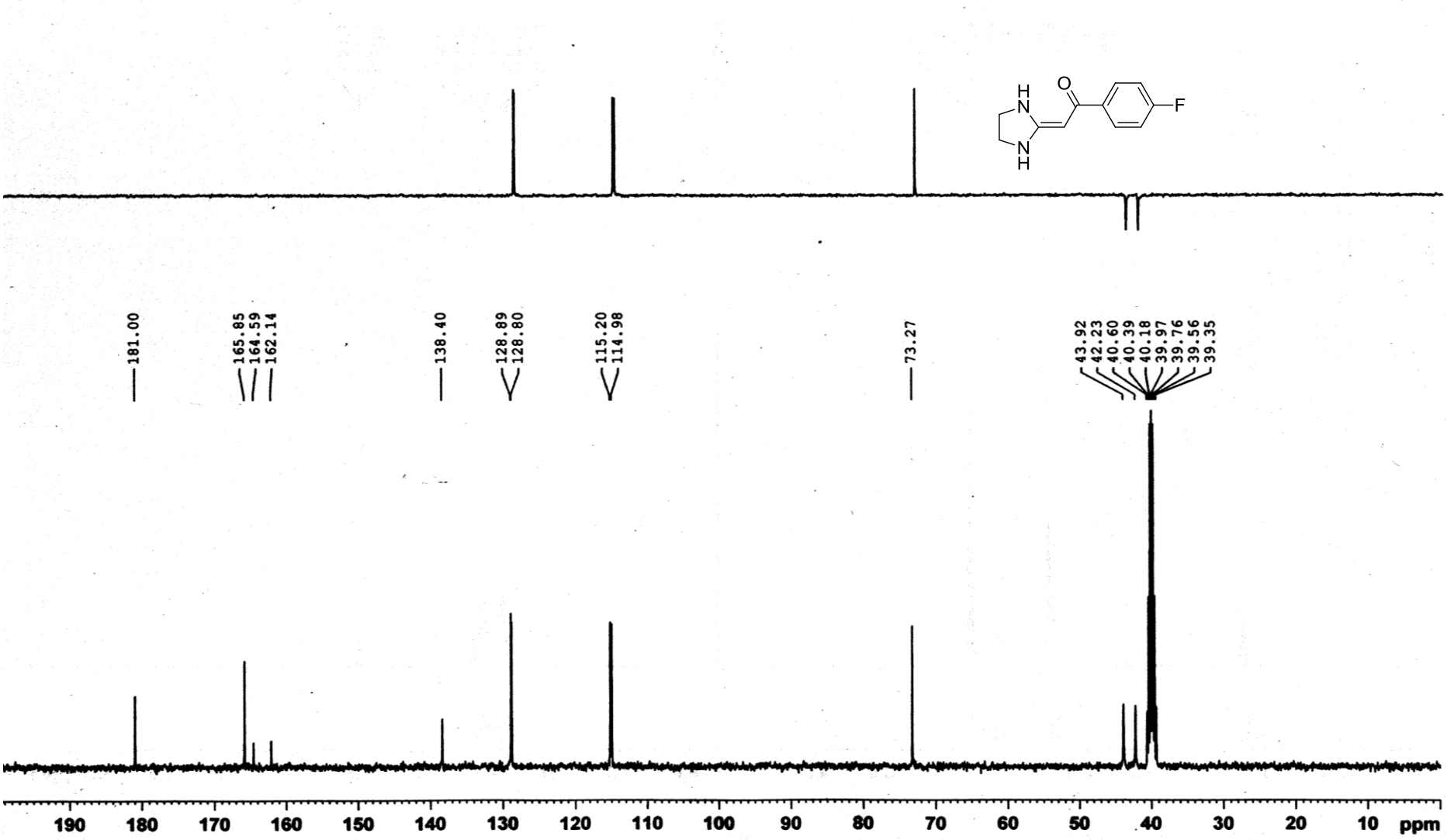


Figure 4. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1b**

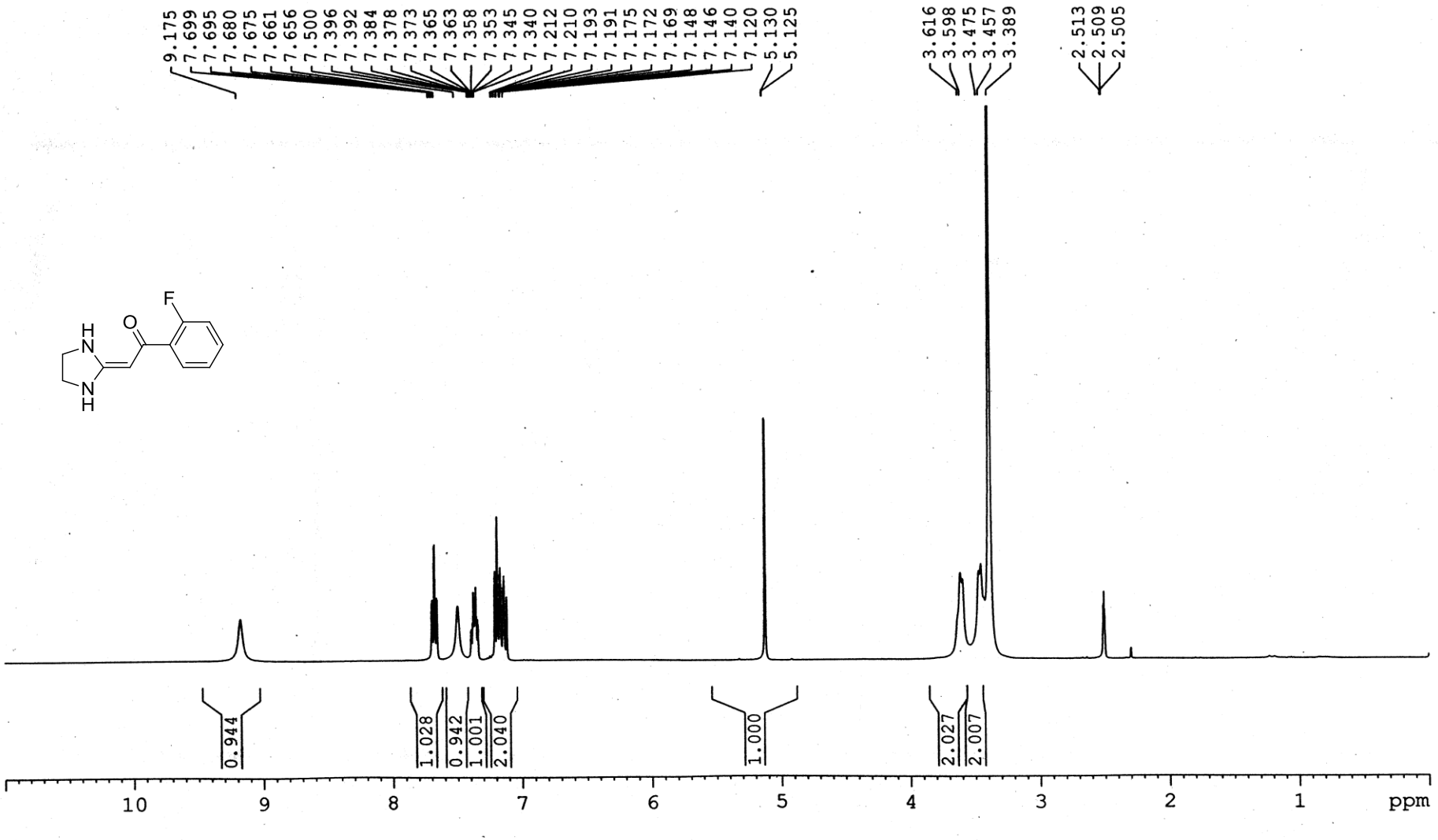


Figure 5. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1c**

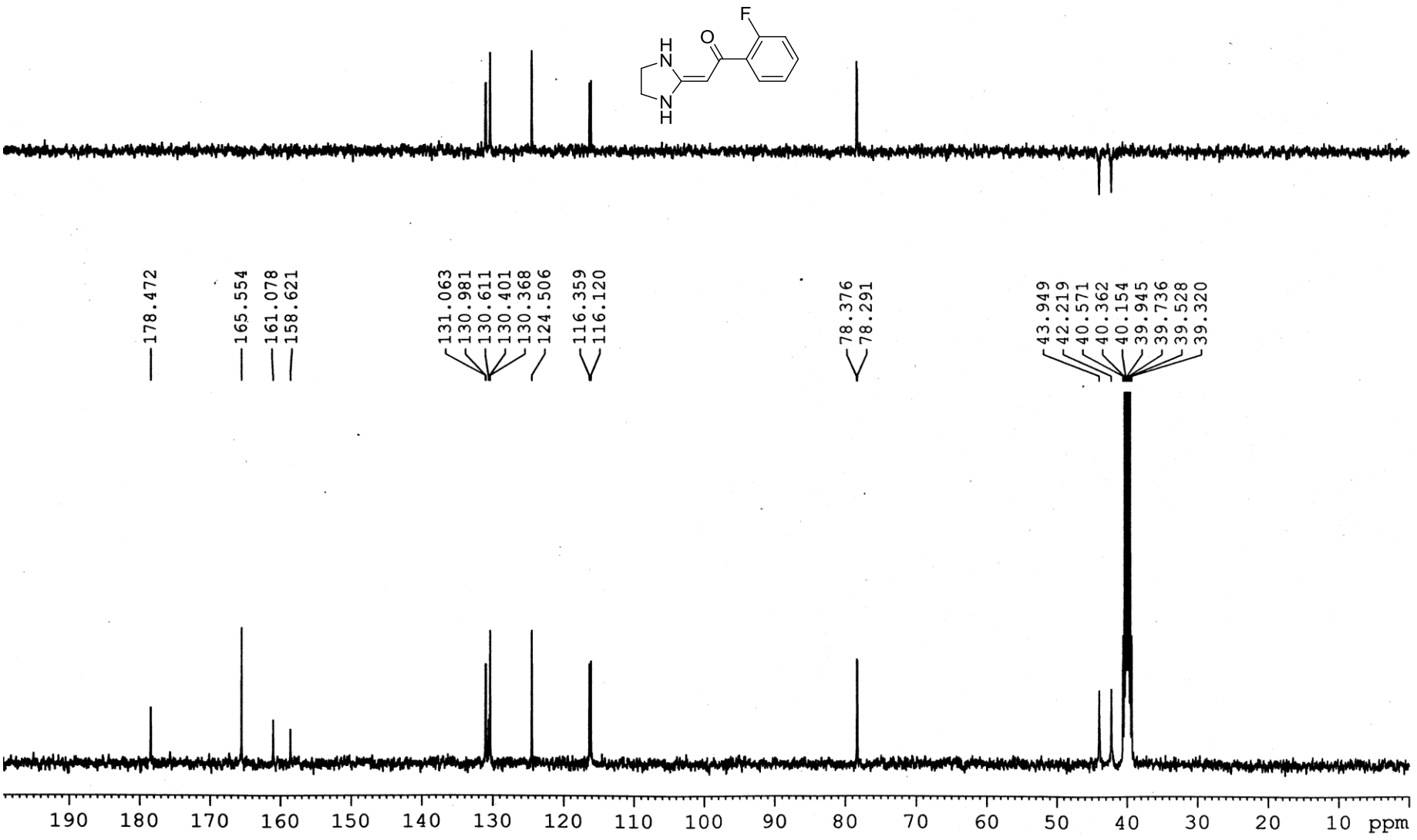


Figure 6. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1c**

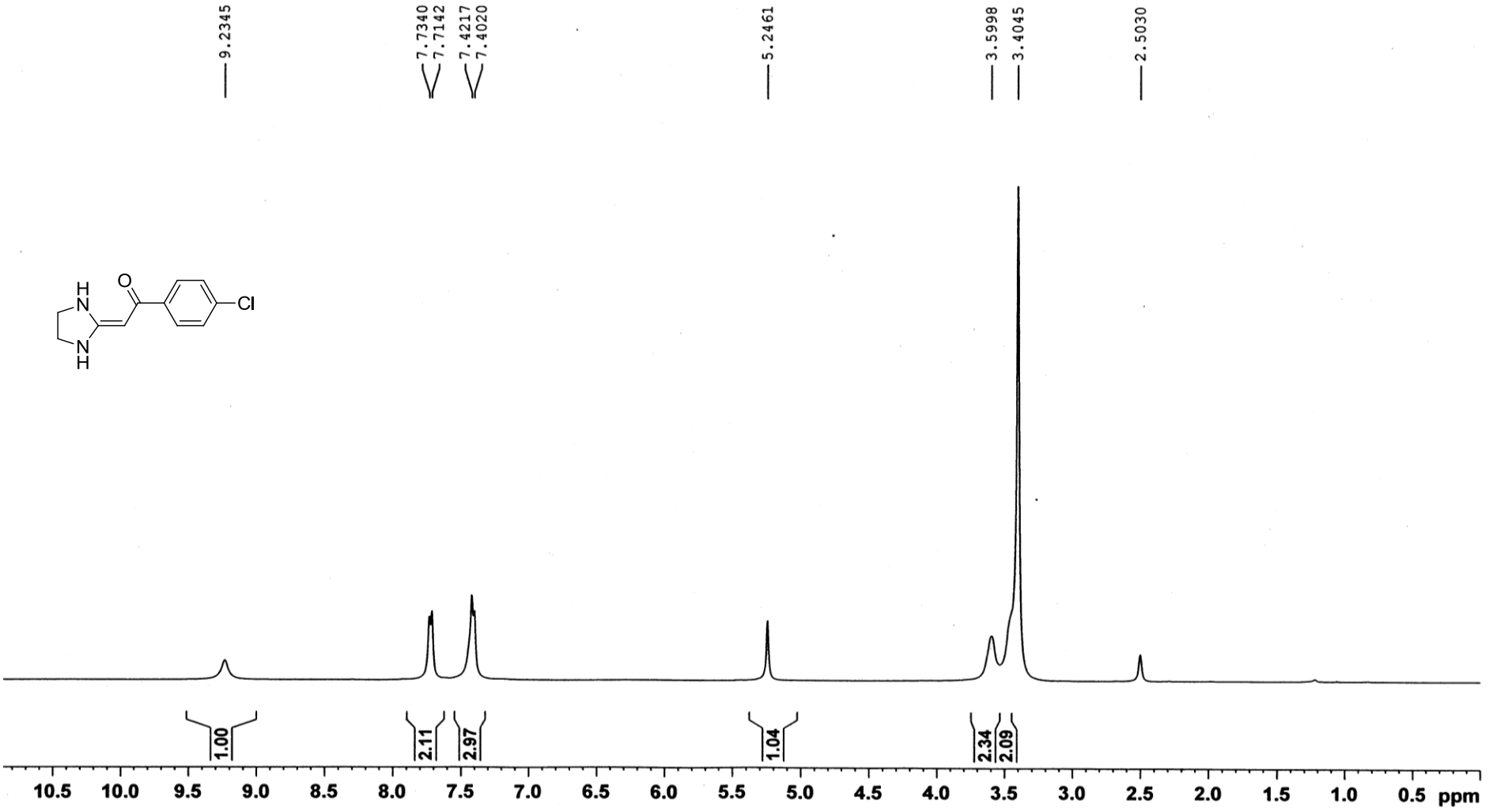


Figure 7. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1d**

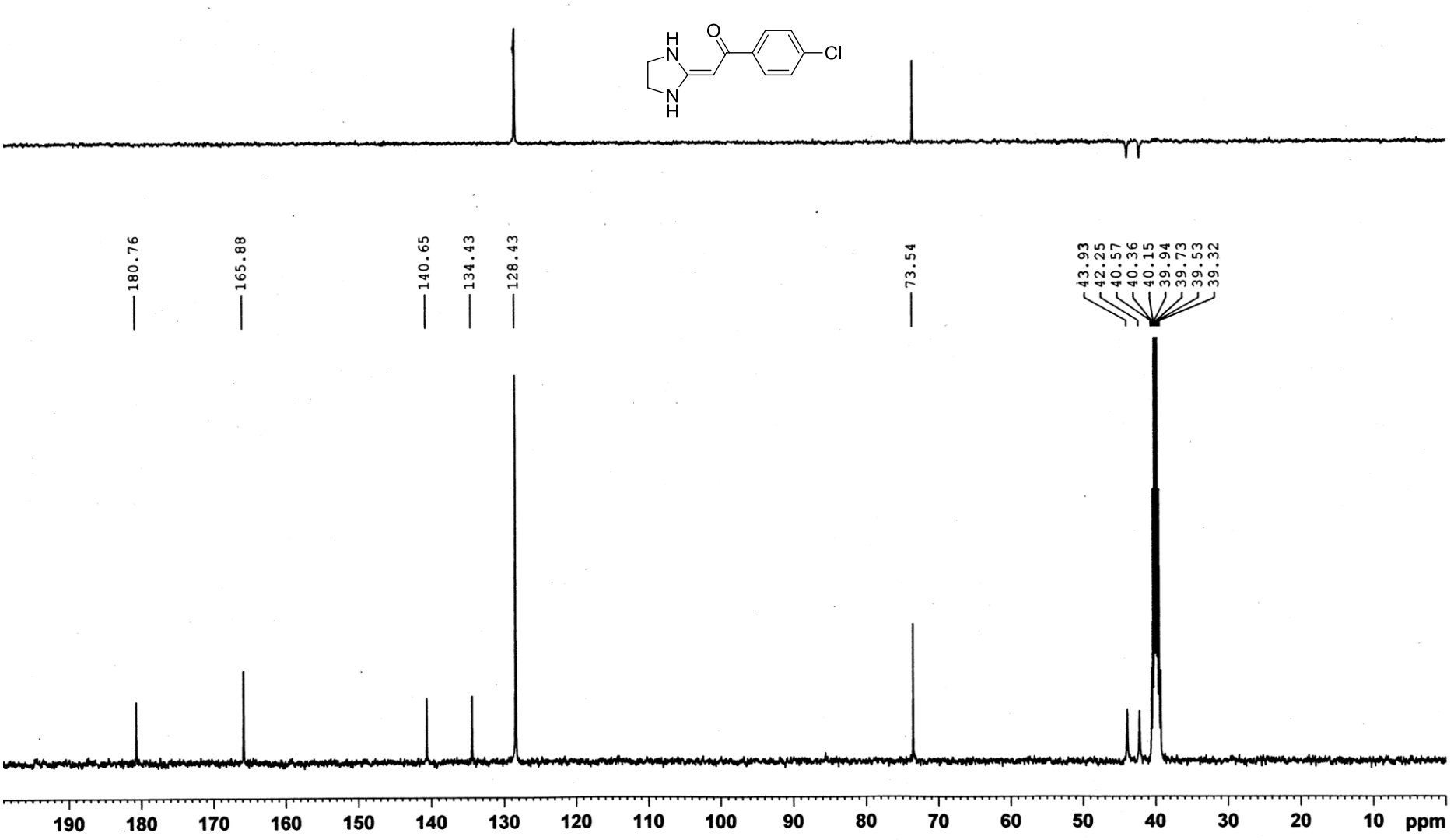


Figure 8. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1d**

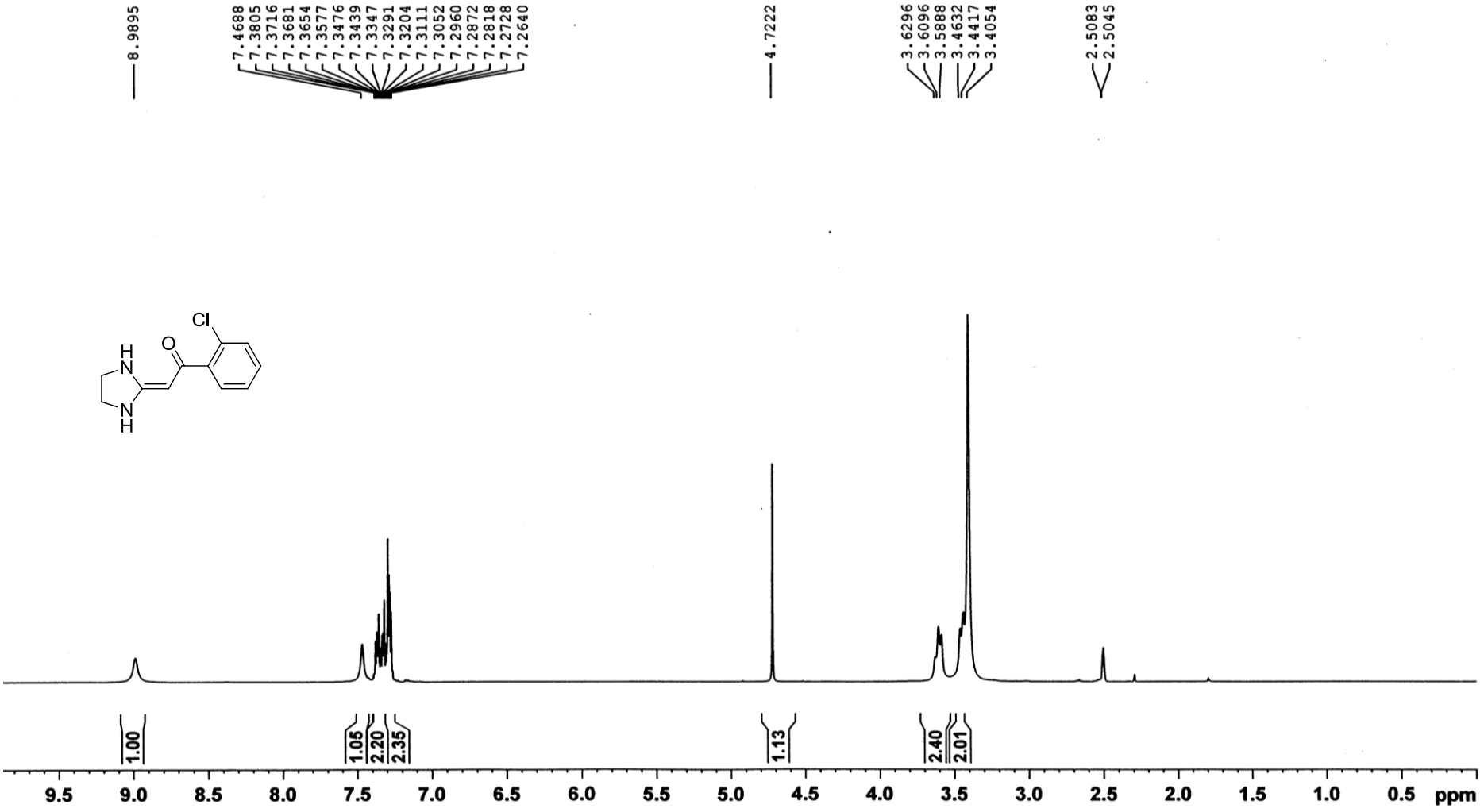


Figure 9. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1e**

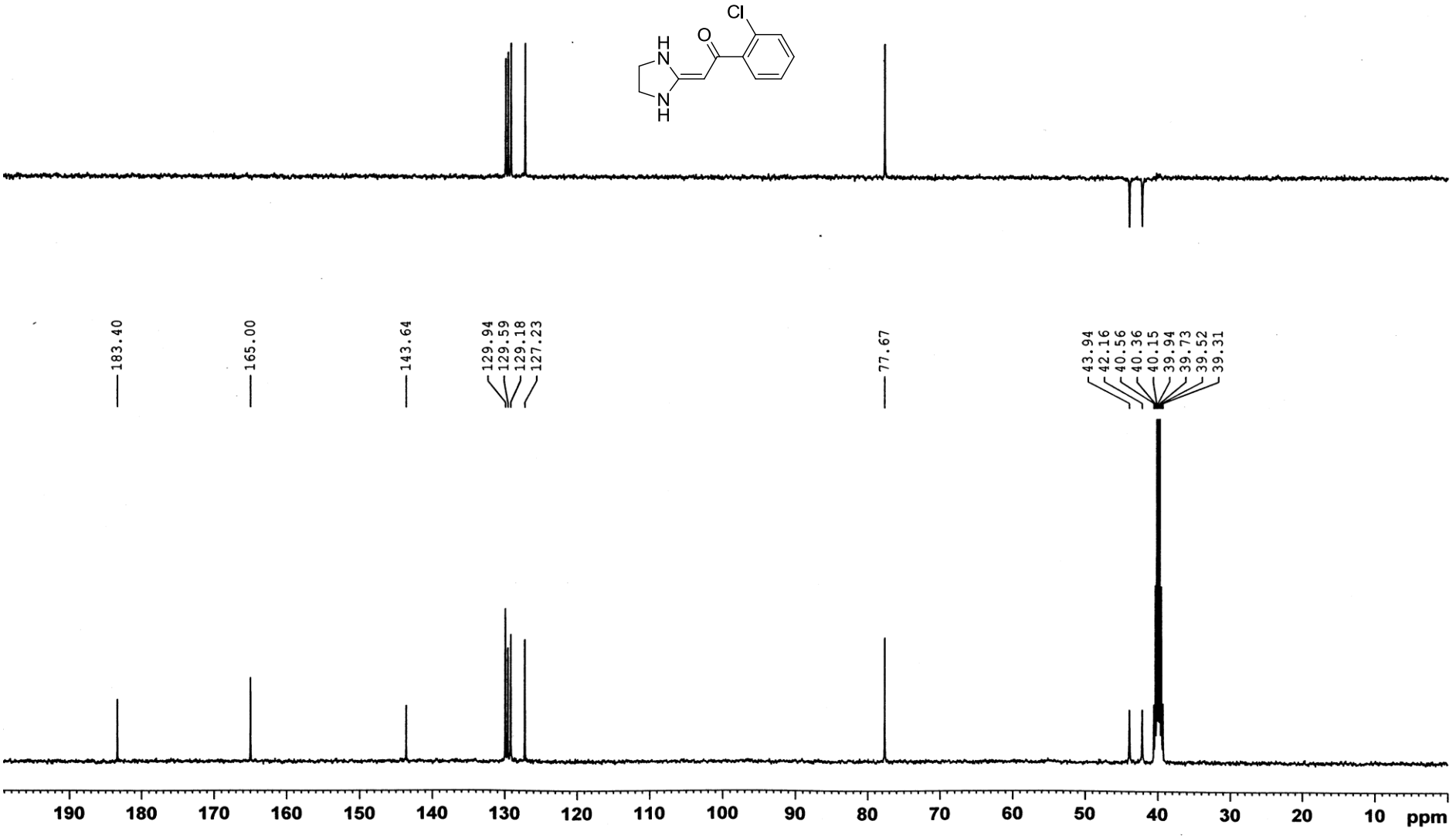


Figure 10. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1e**

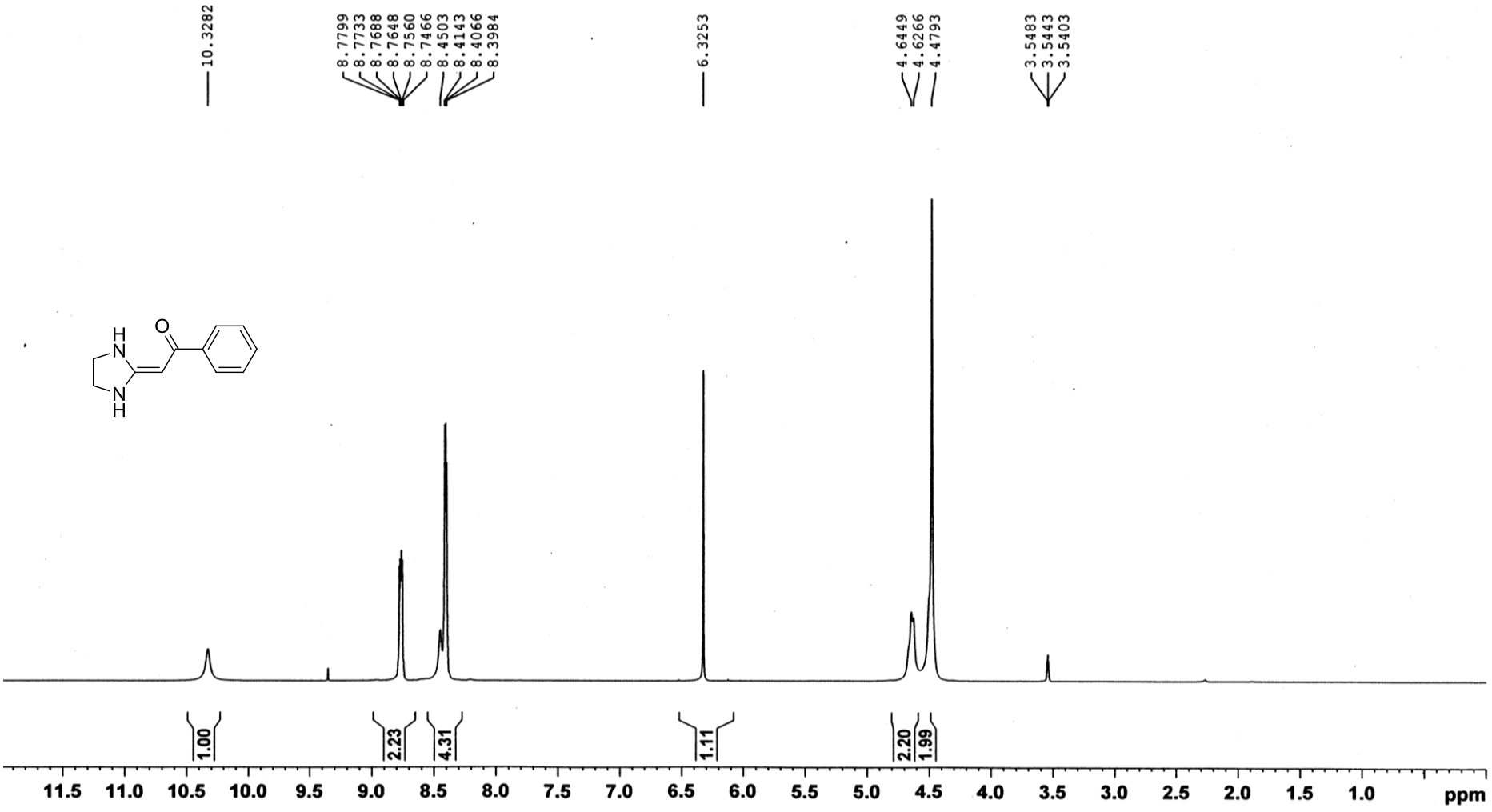


Figure 11. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1f**

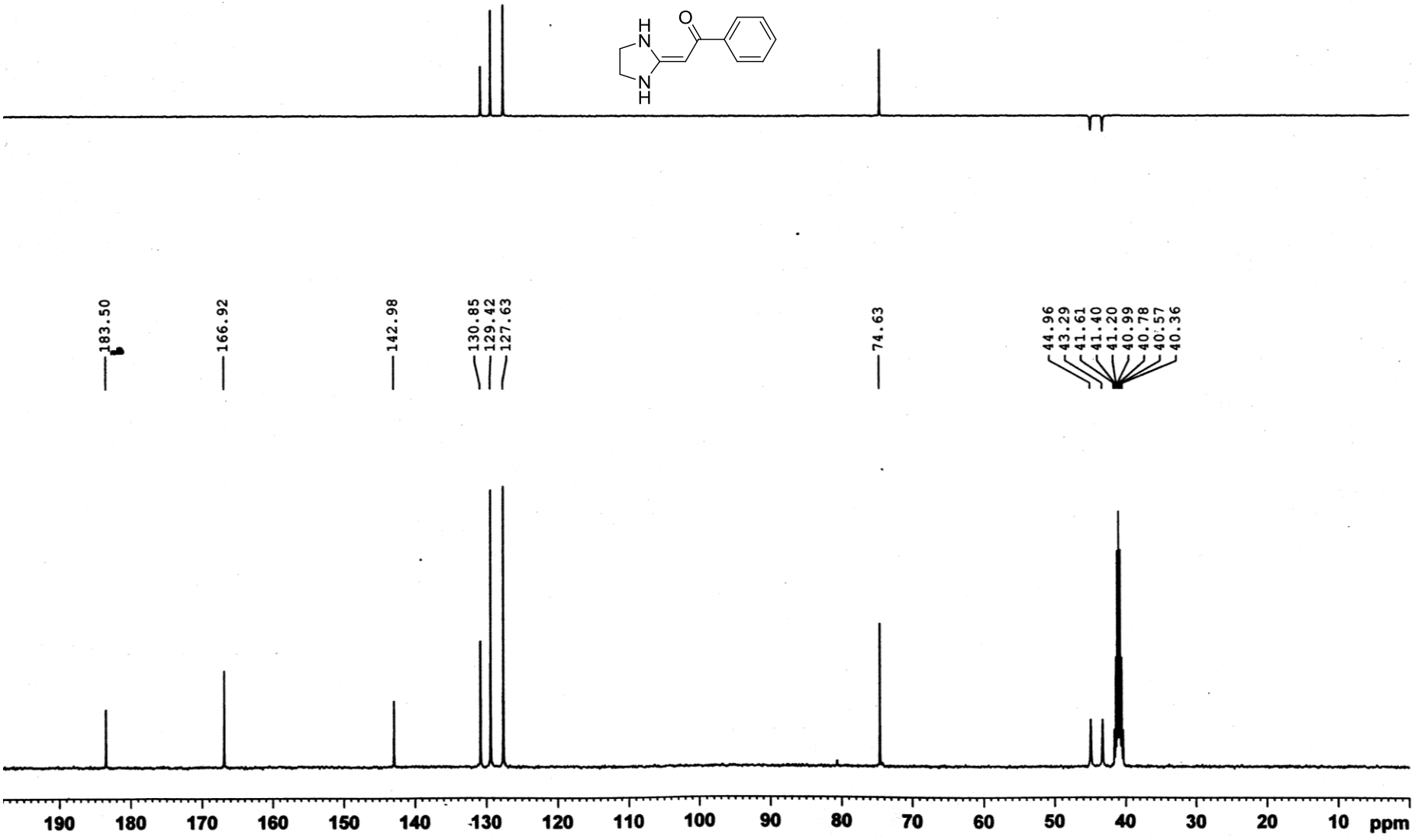


Figure 12. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1f**

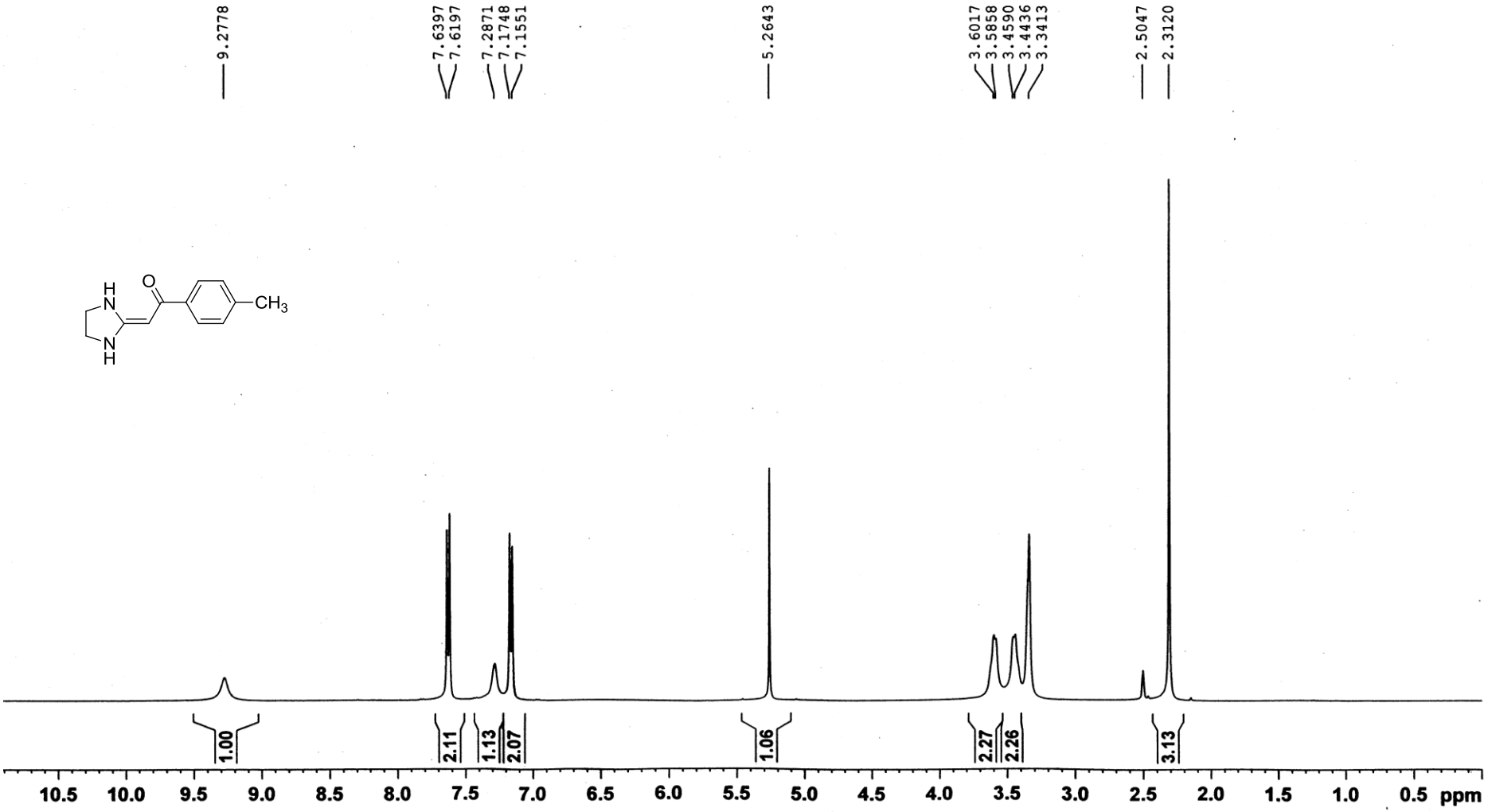


Figure 13. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1g**

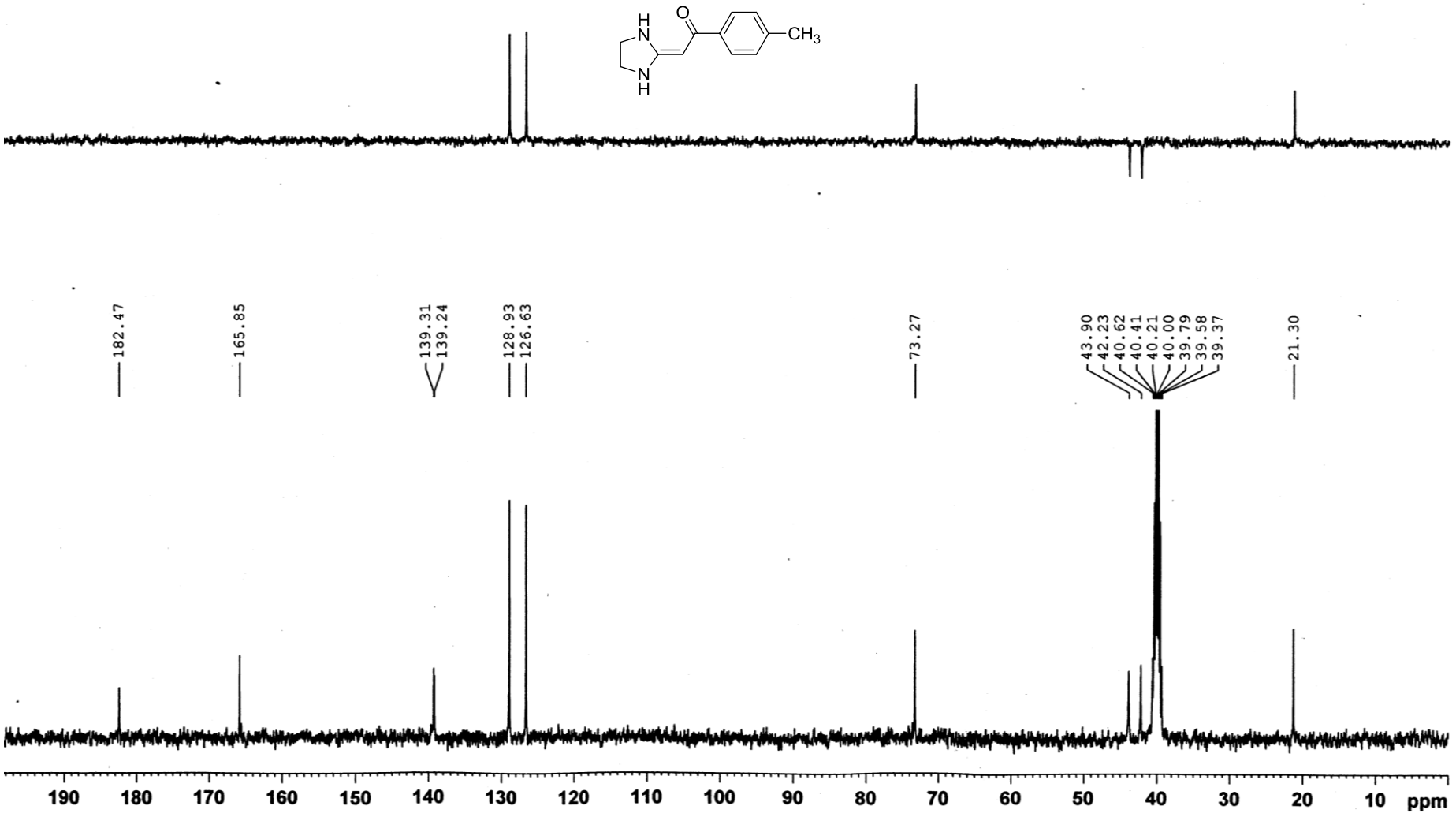


Figure 14. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1g**

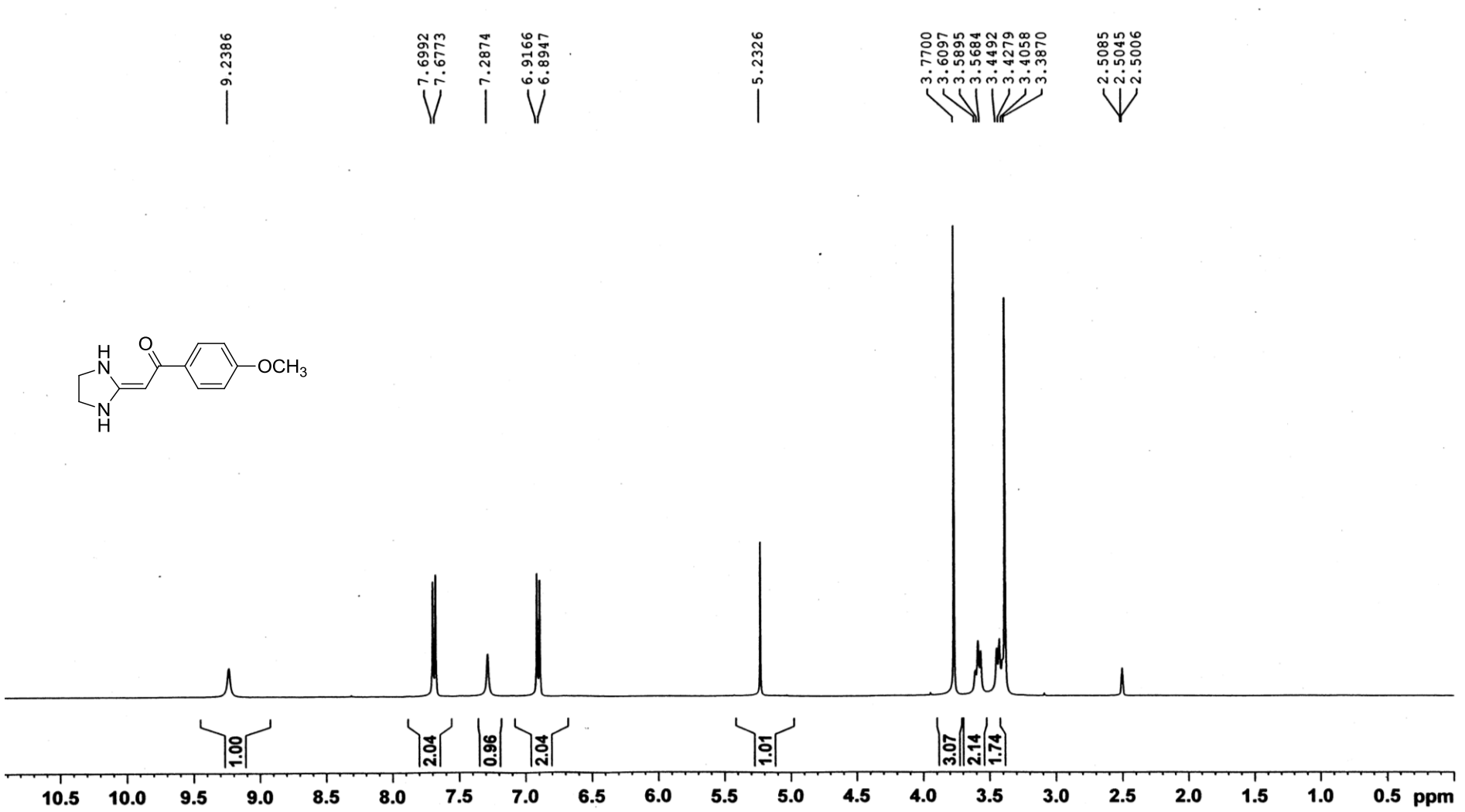


Figure 15. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **1h**

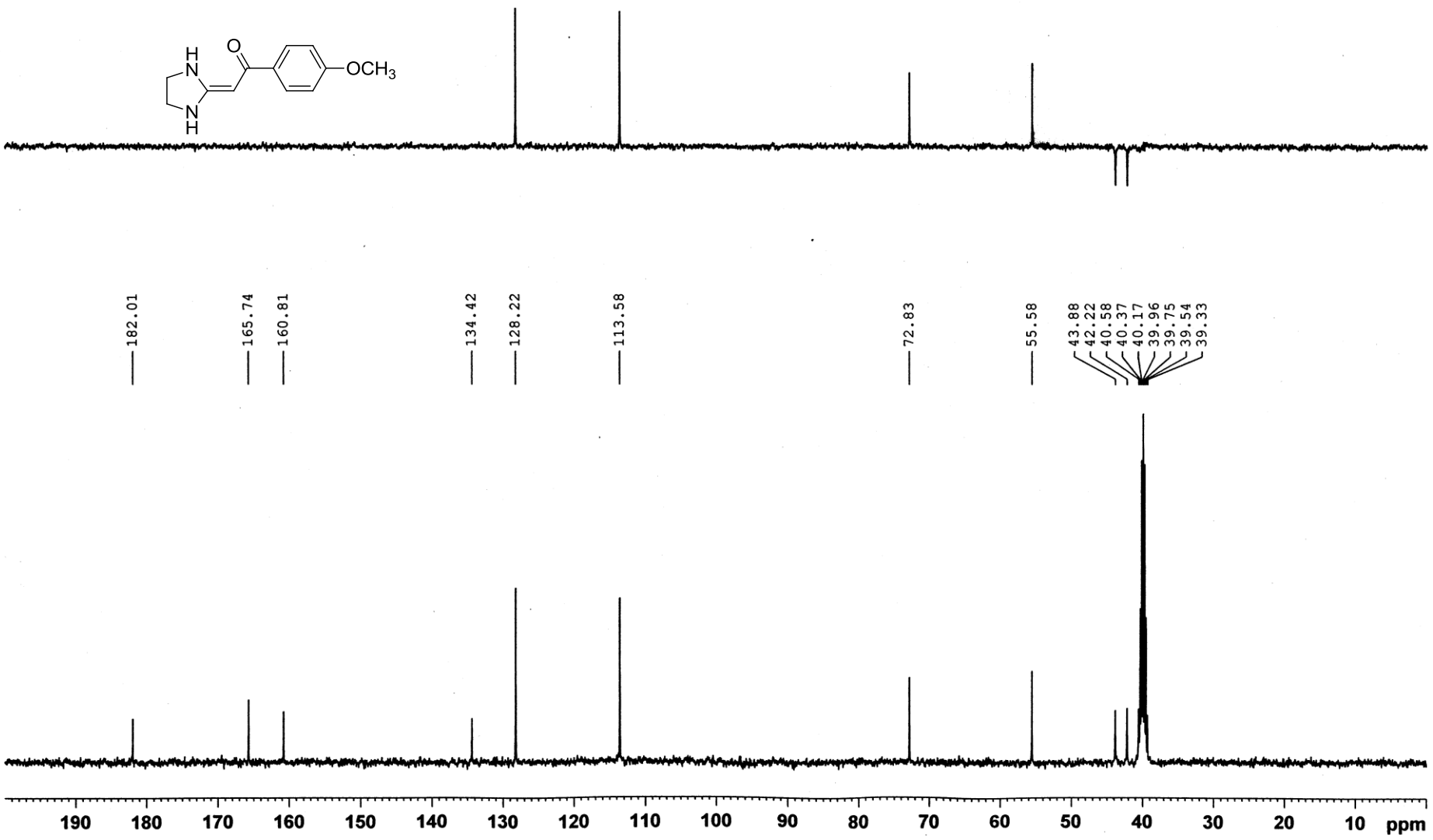


Figure 16. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **1h**

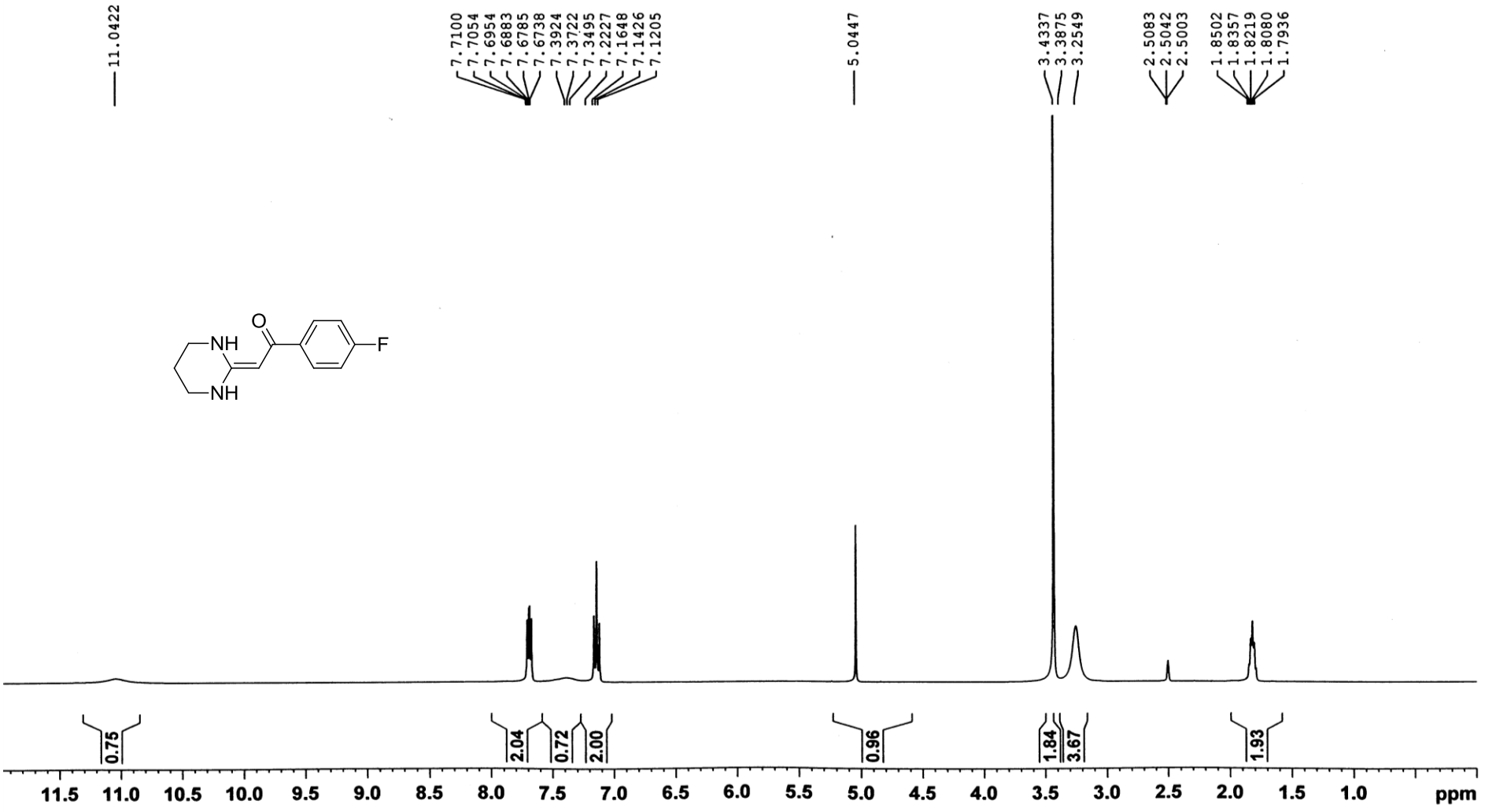


Figure 17. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **2a**

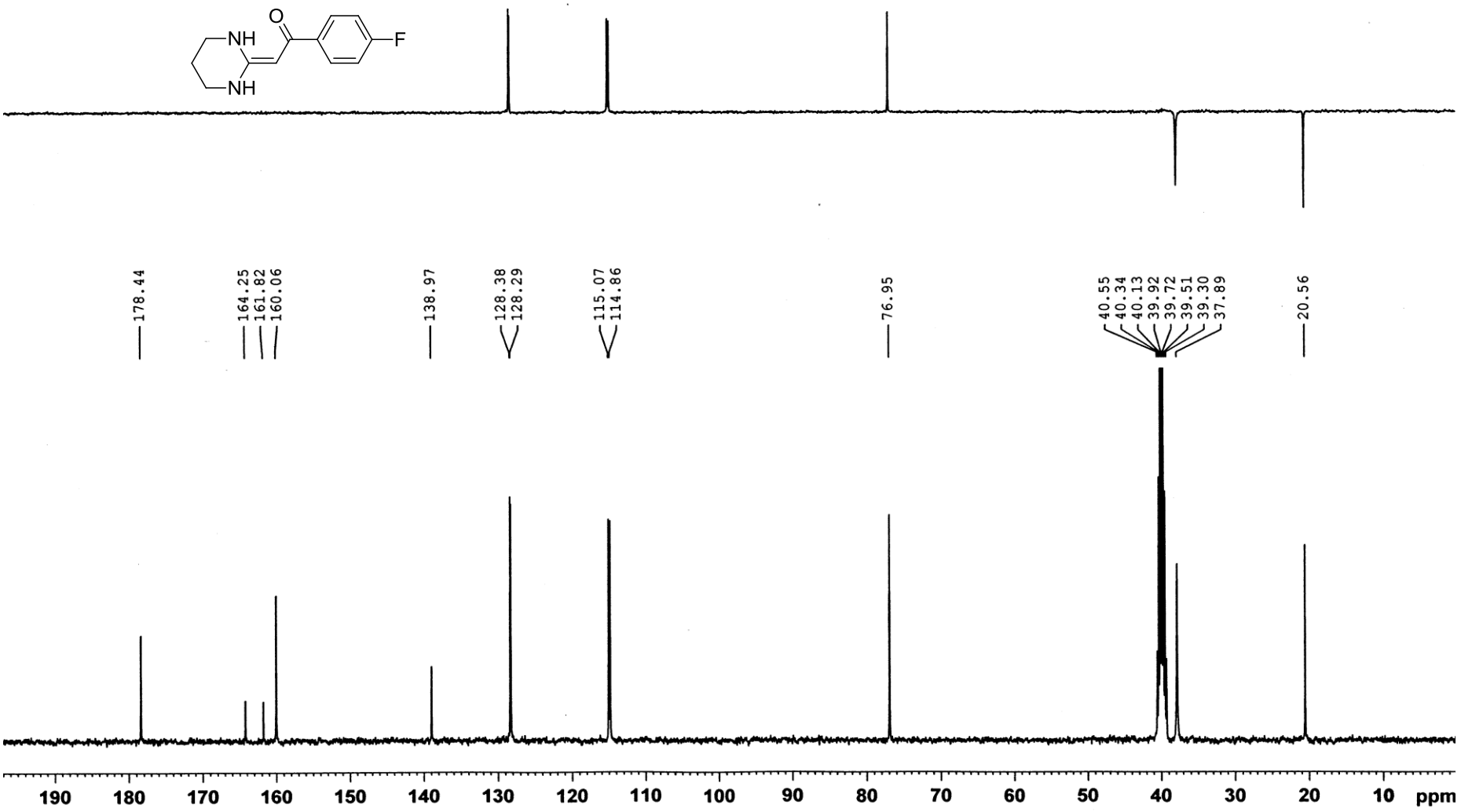


Figure 18. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **2a**

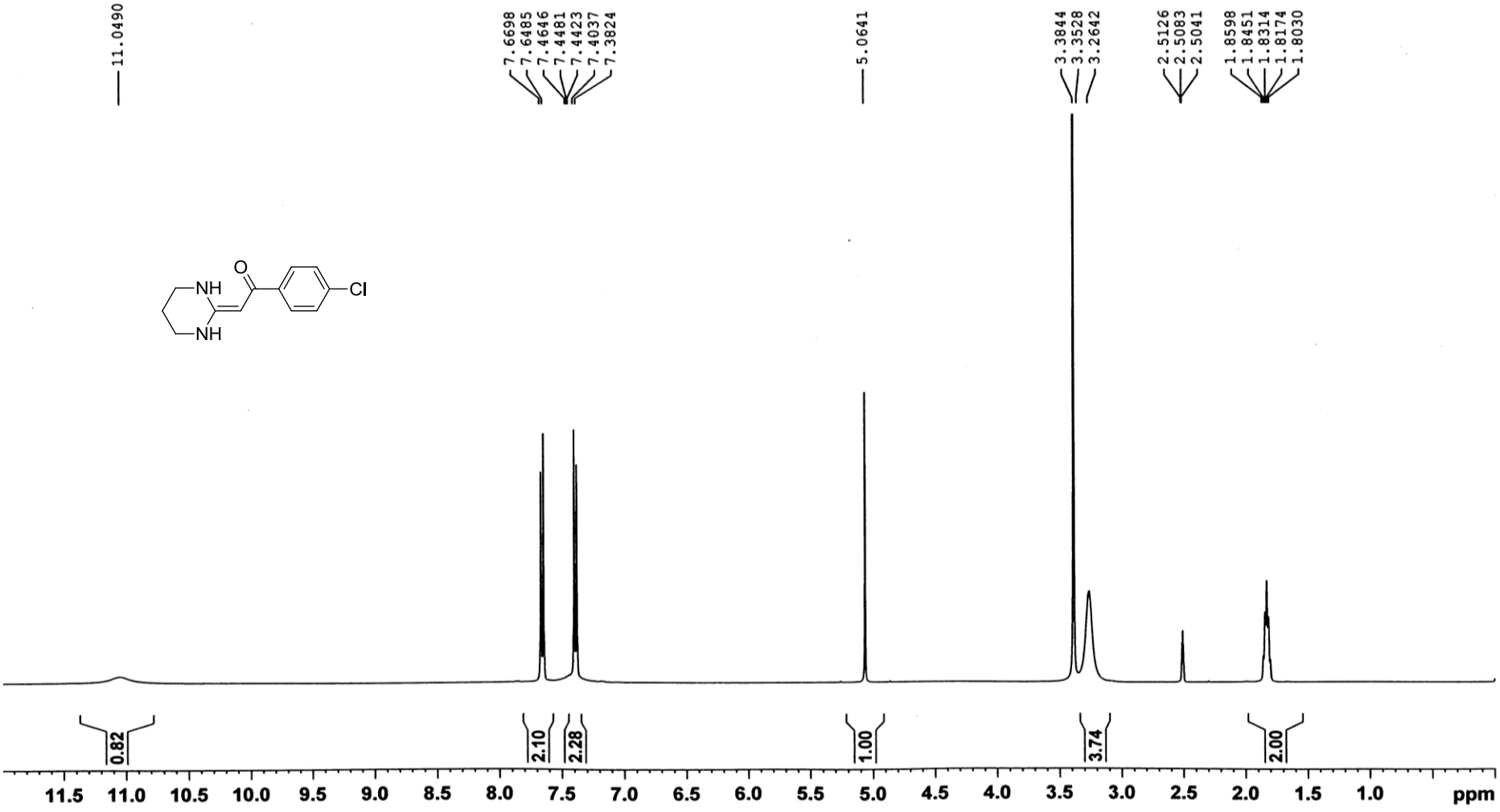


Figure 19. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **2c**

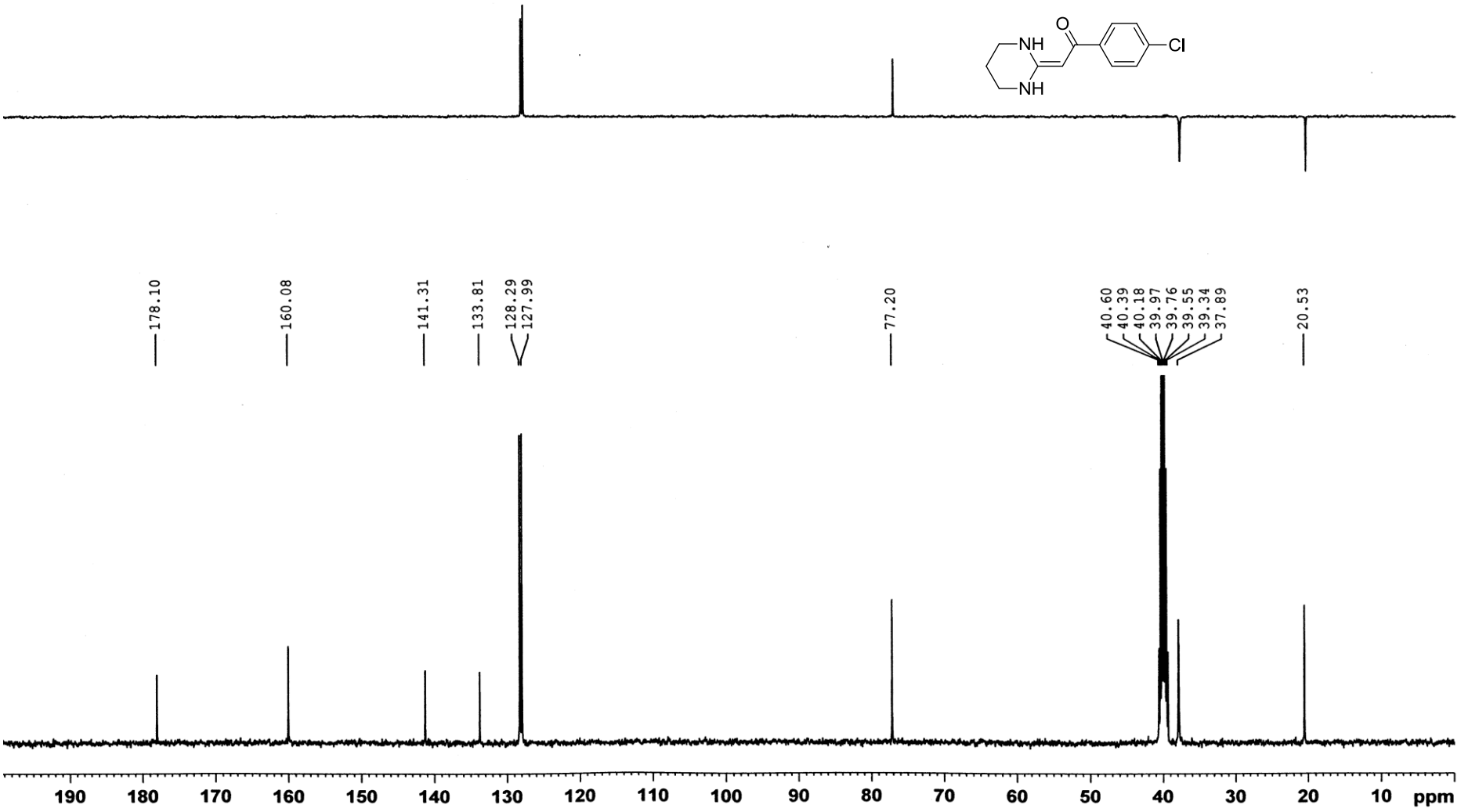


Figure 20. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **2c**

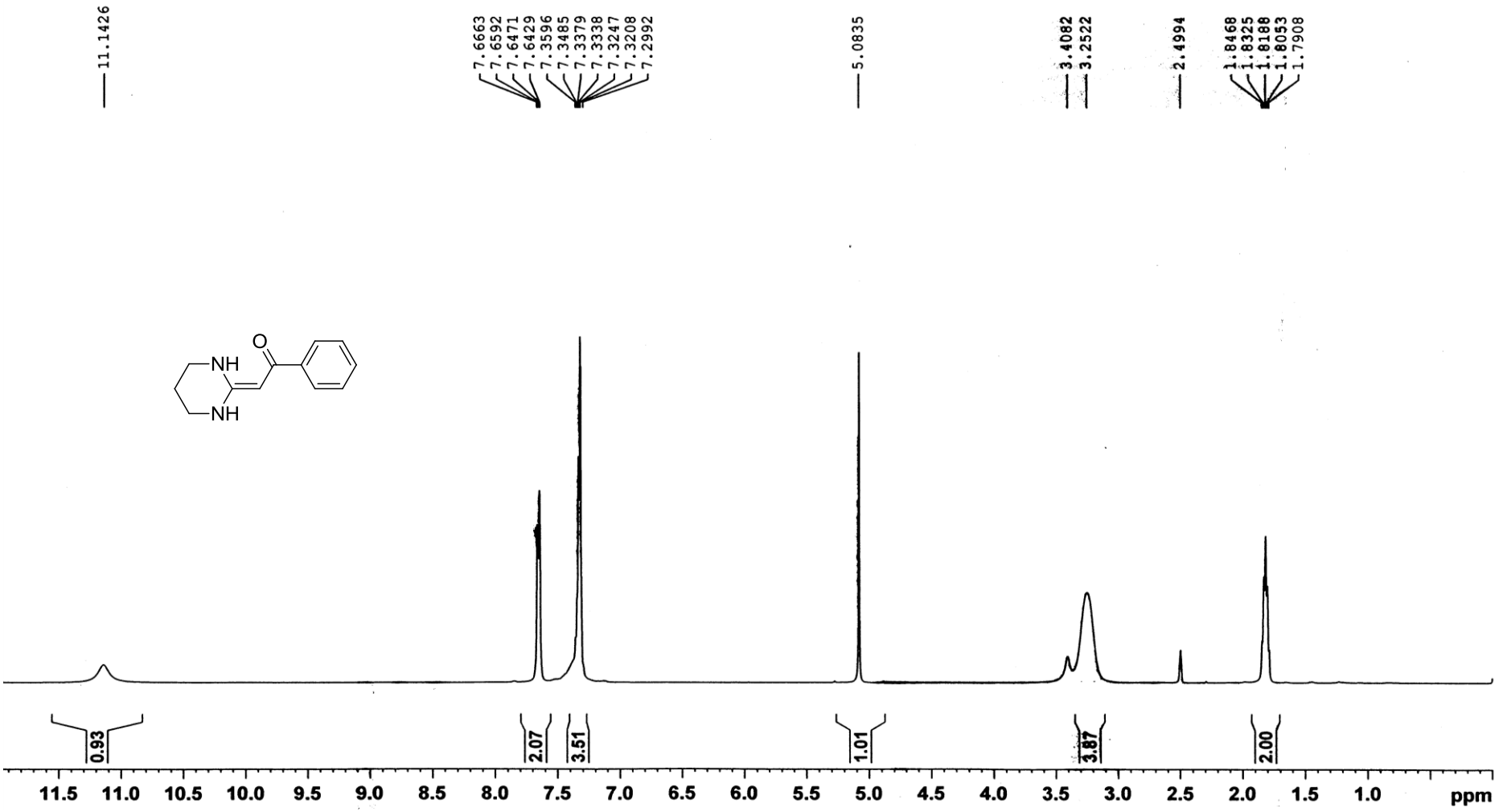


Figure 21. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **2d**

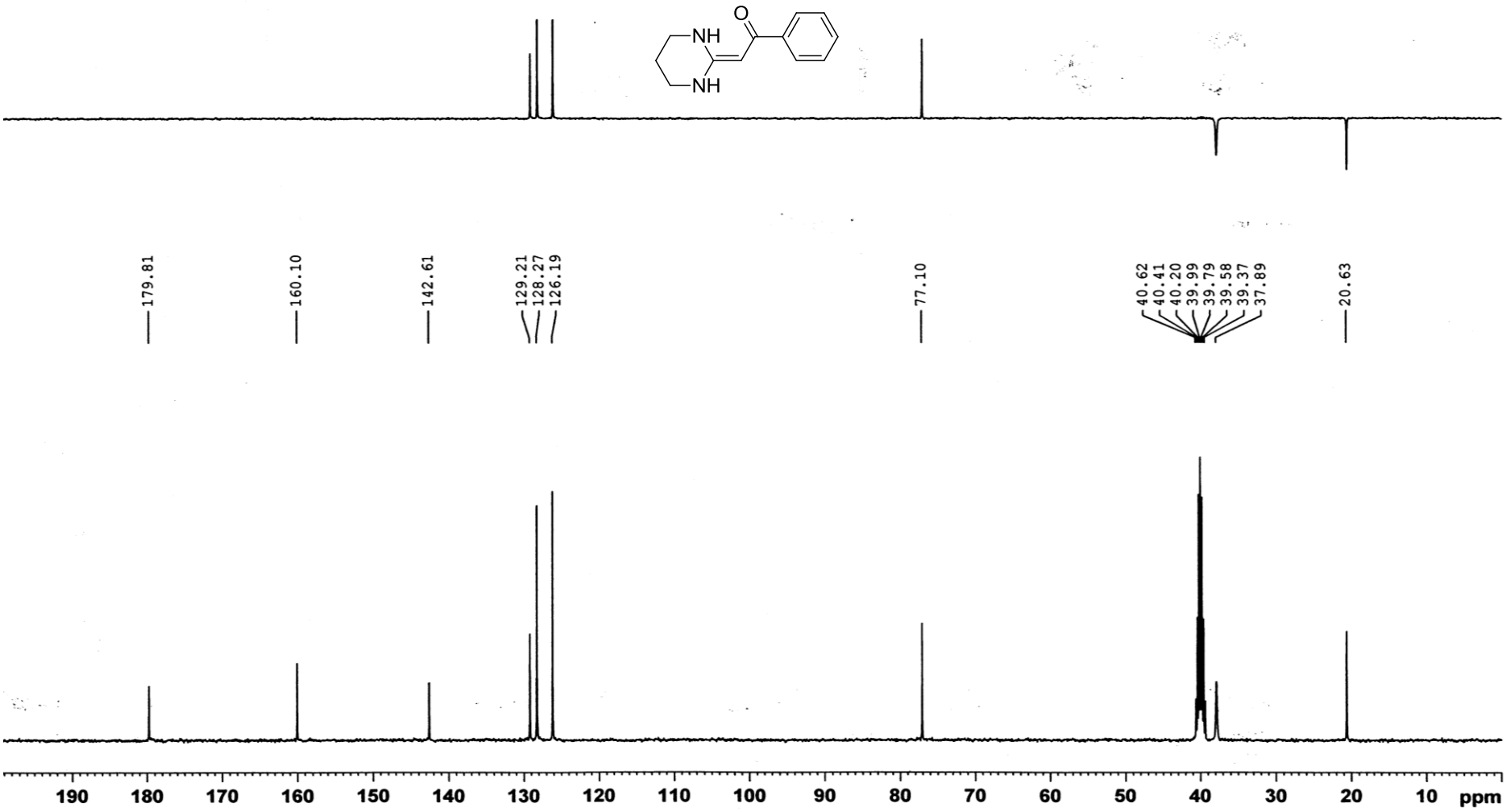


Figure 22. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **2d**

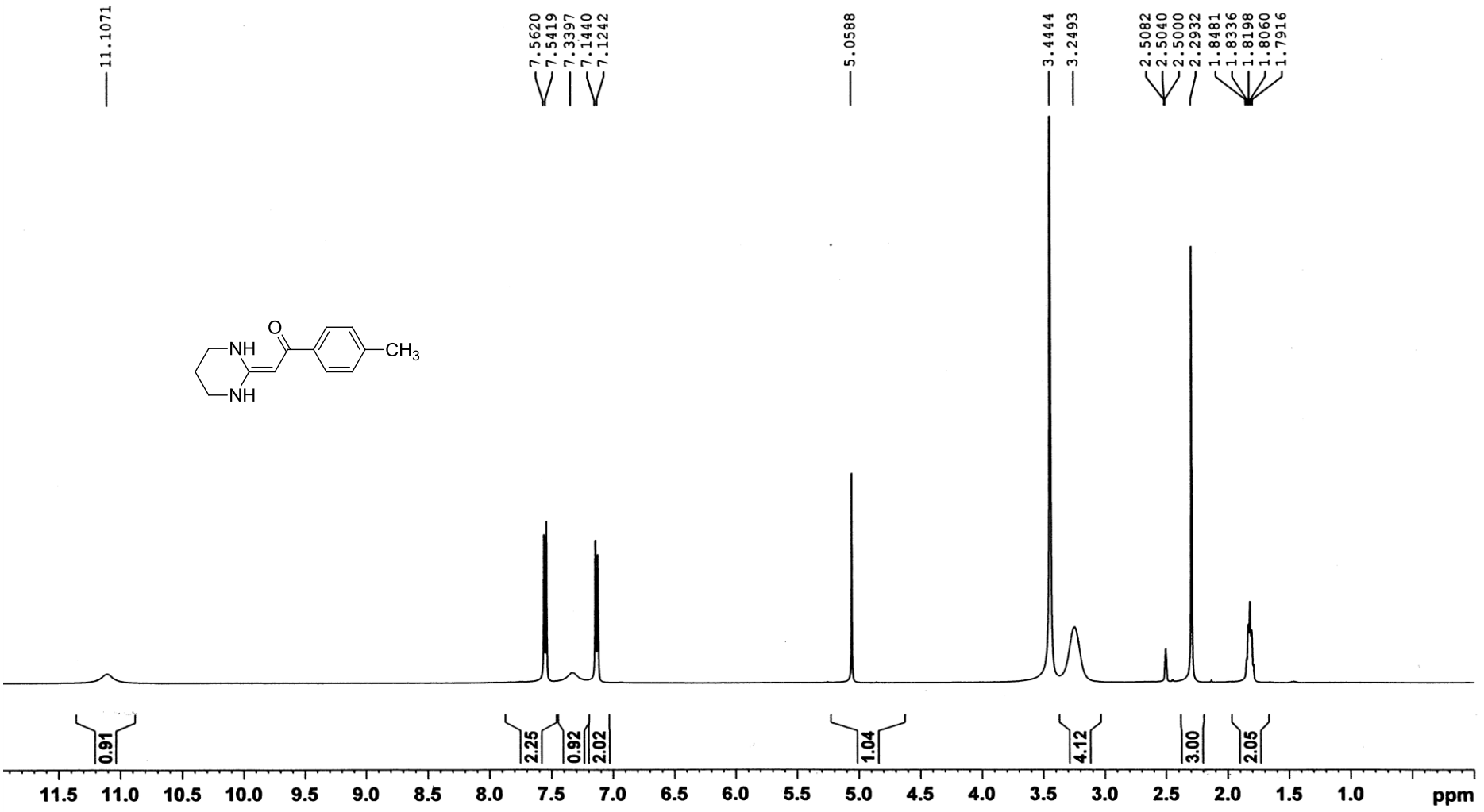


Figure 23. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **2e**

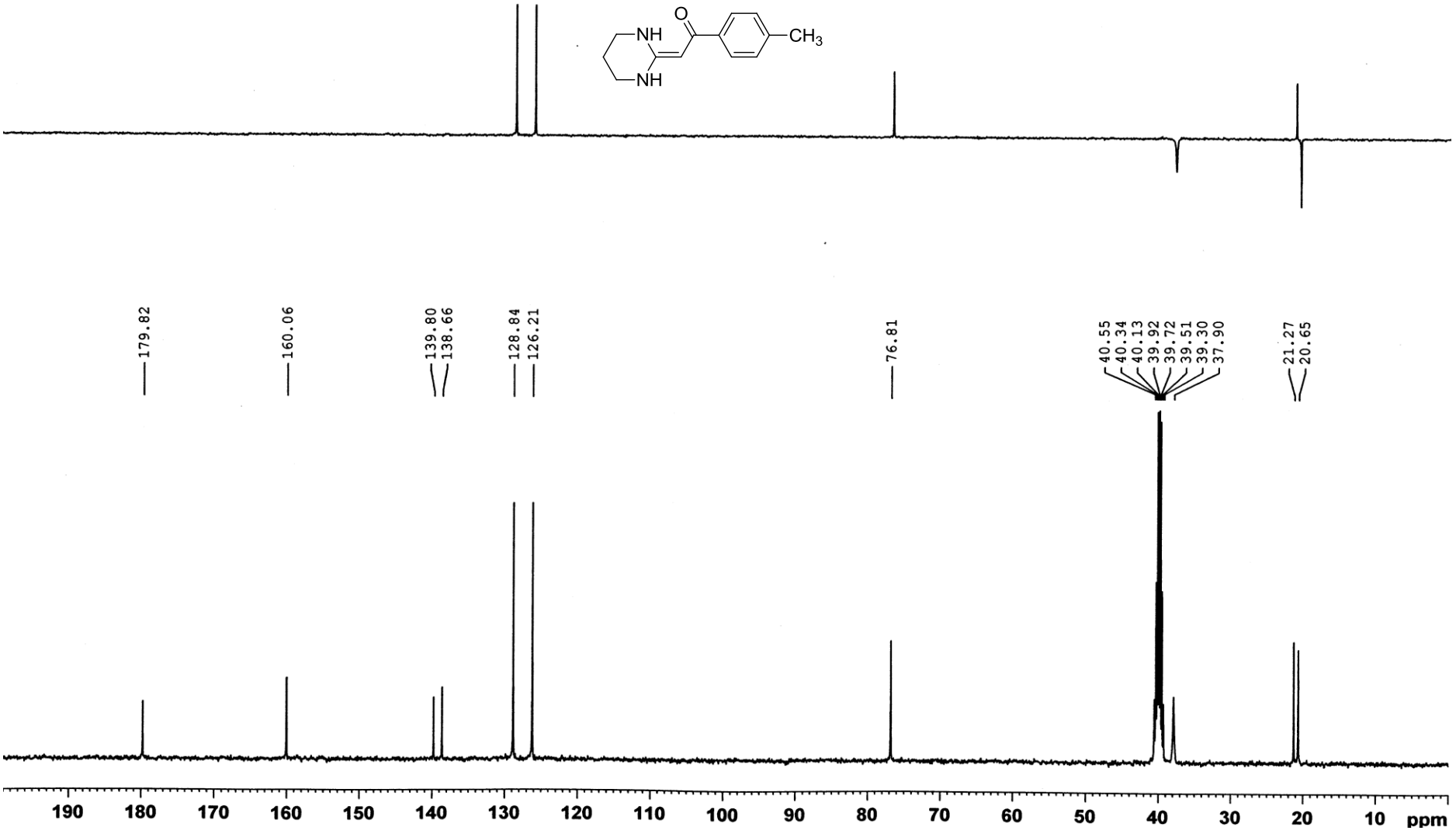


Figure 24. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **2e**

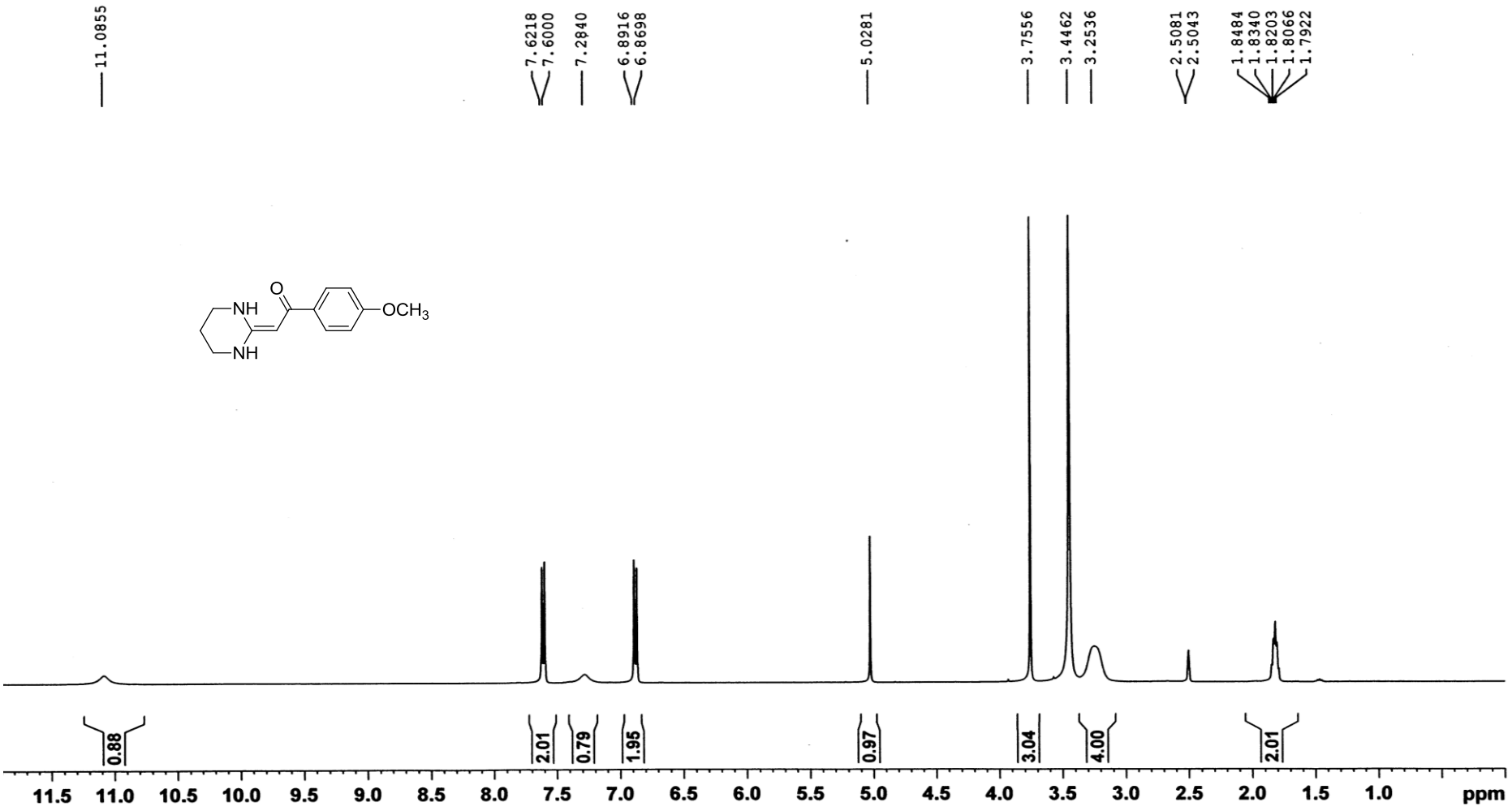


Figure 25. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **2f**

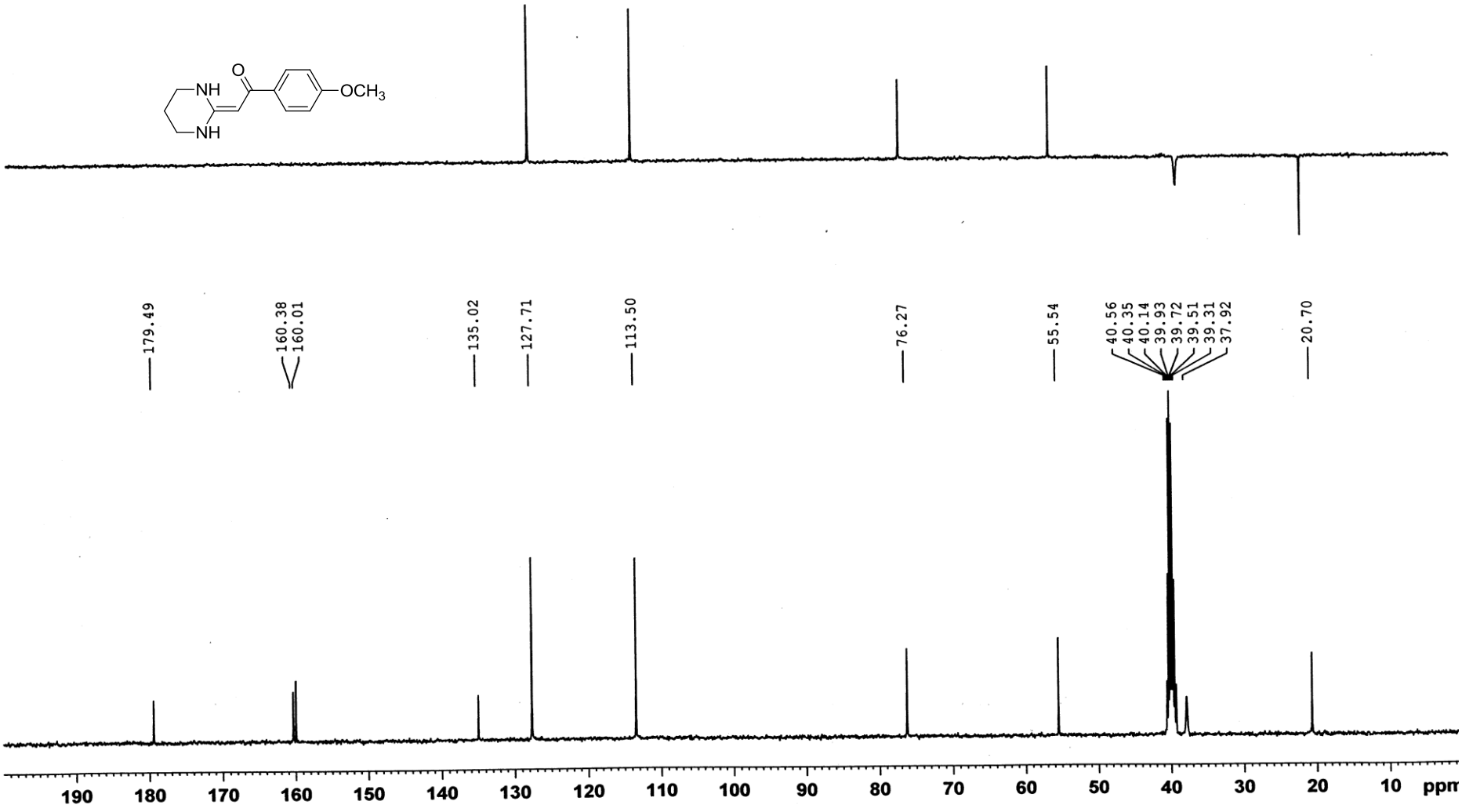


Figure 26. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **2f**

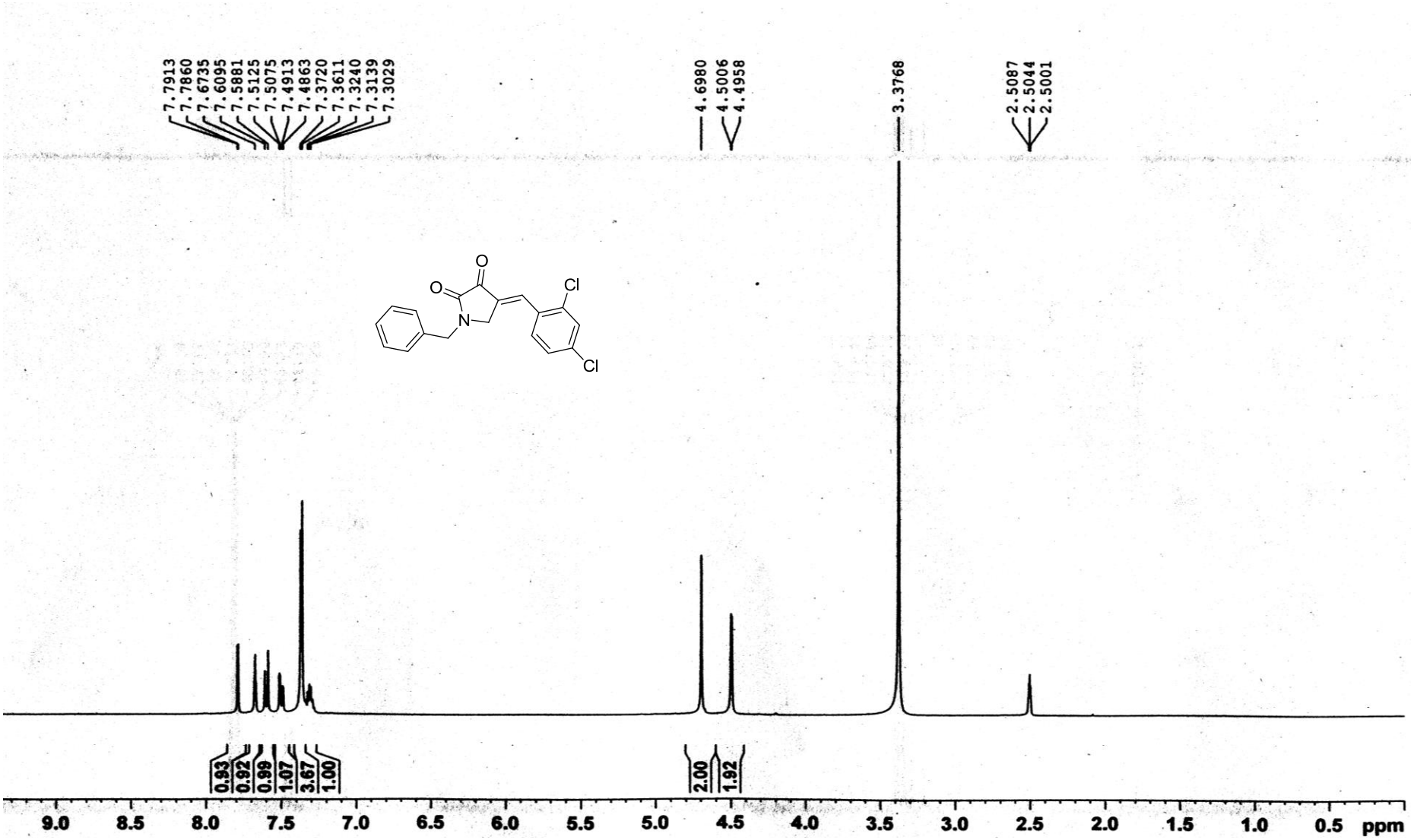


Figure 27. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **3a**

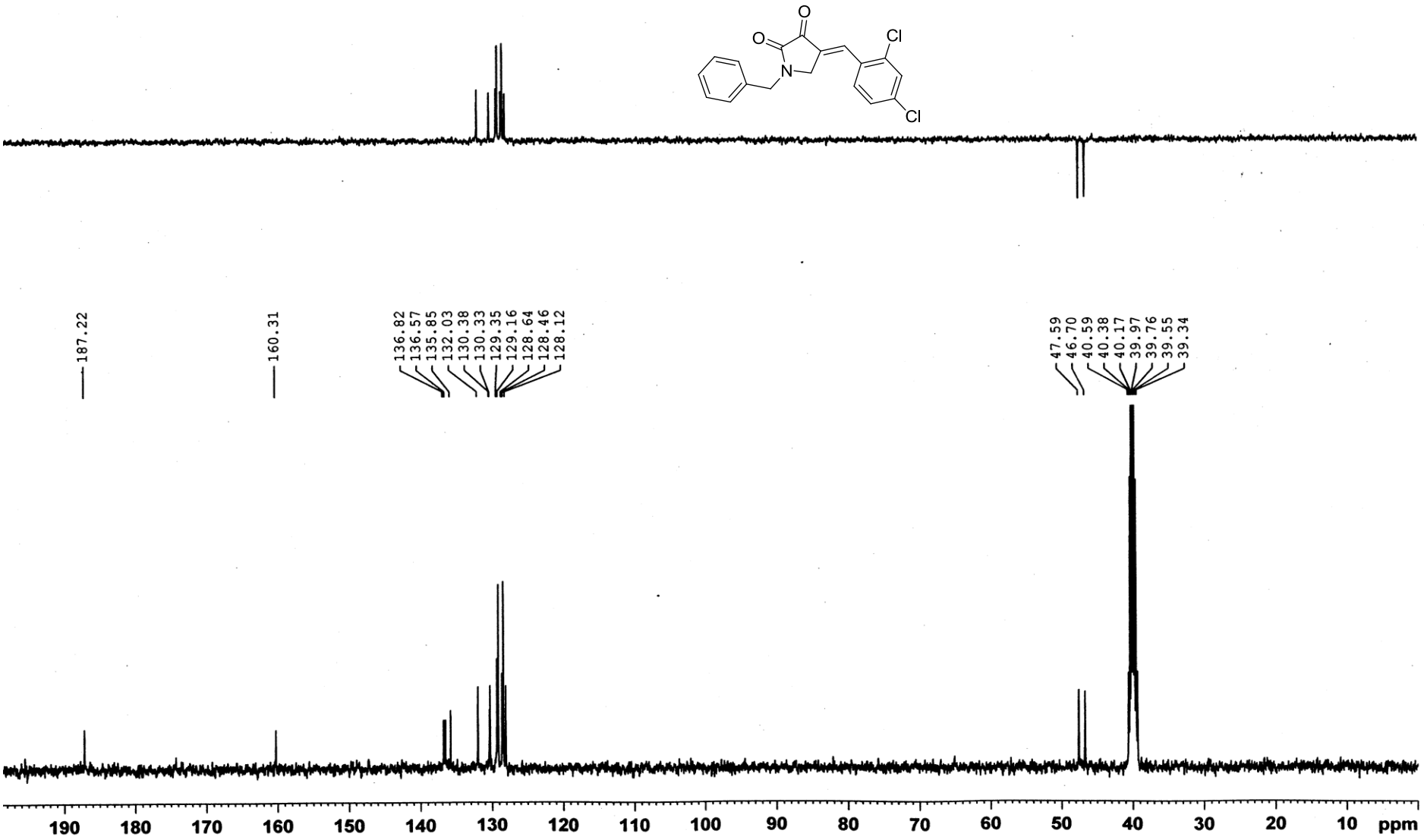


Figure 28. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **3a**

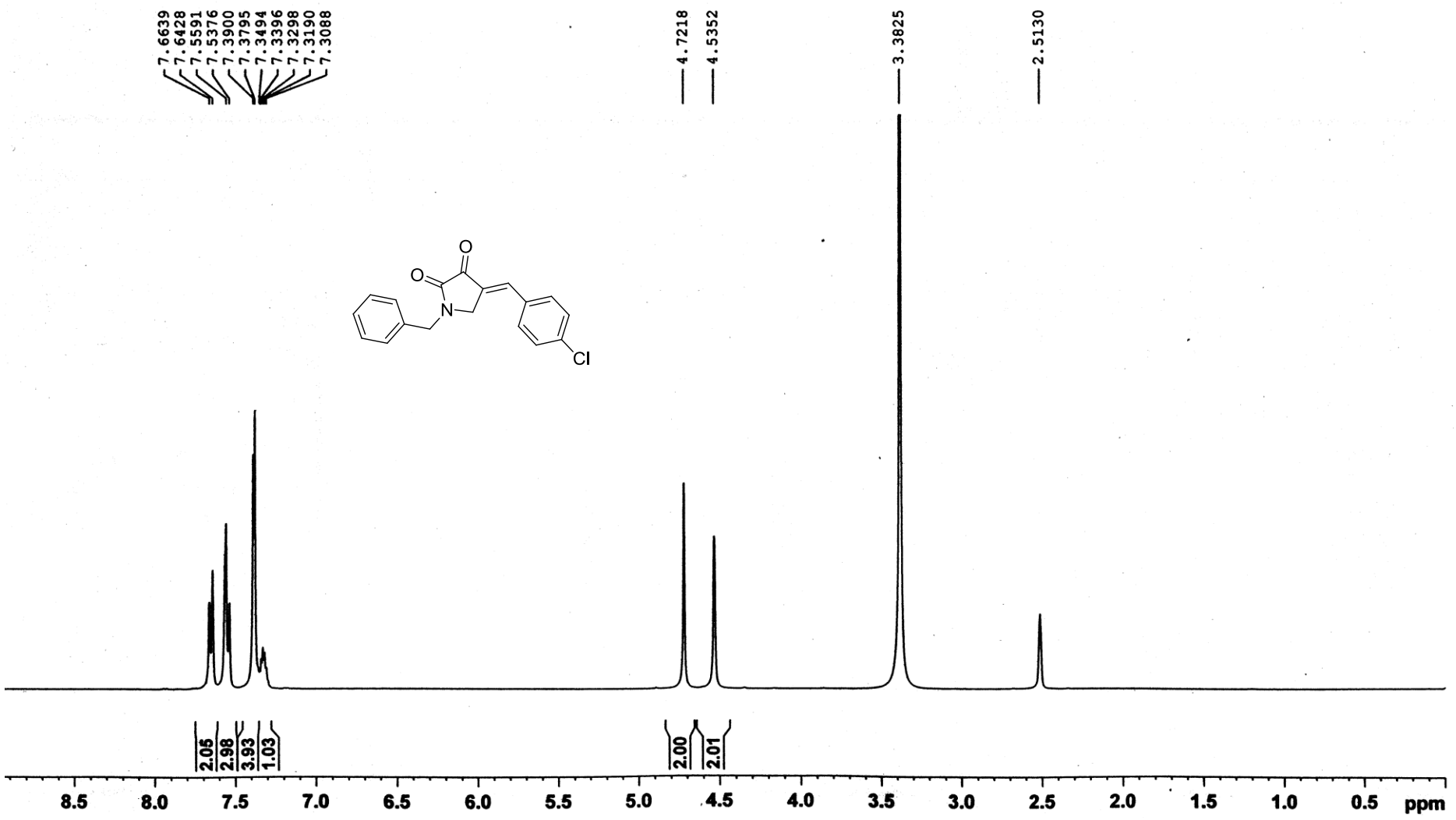


Figure 29. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **3b**

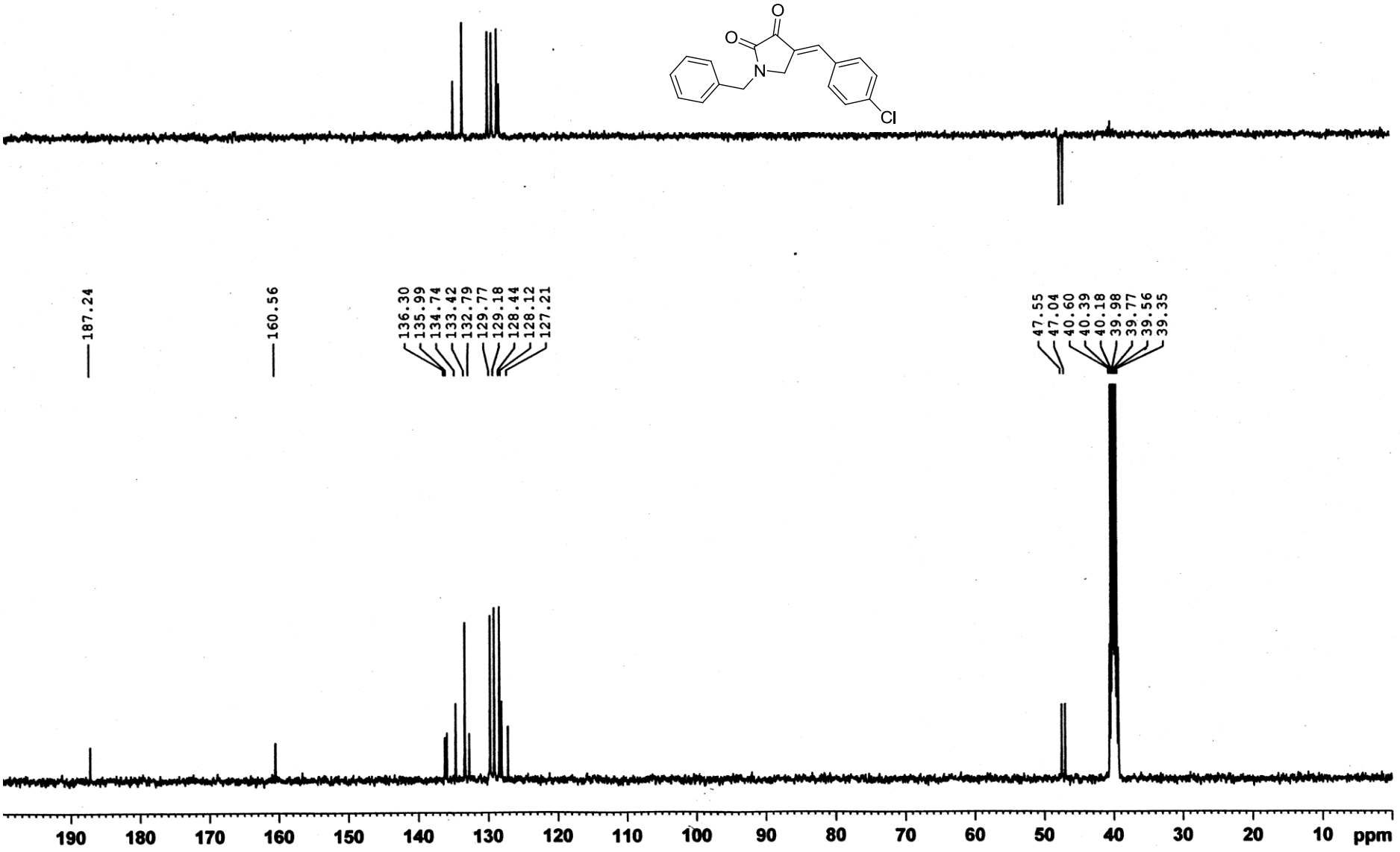


Figure 30. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **3b**

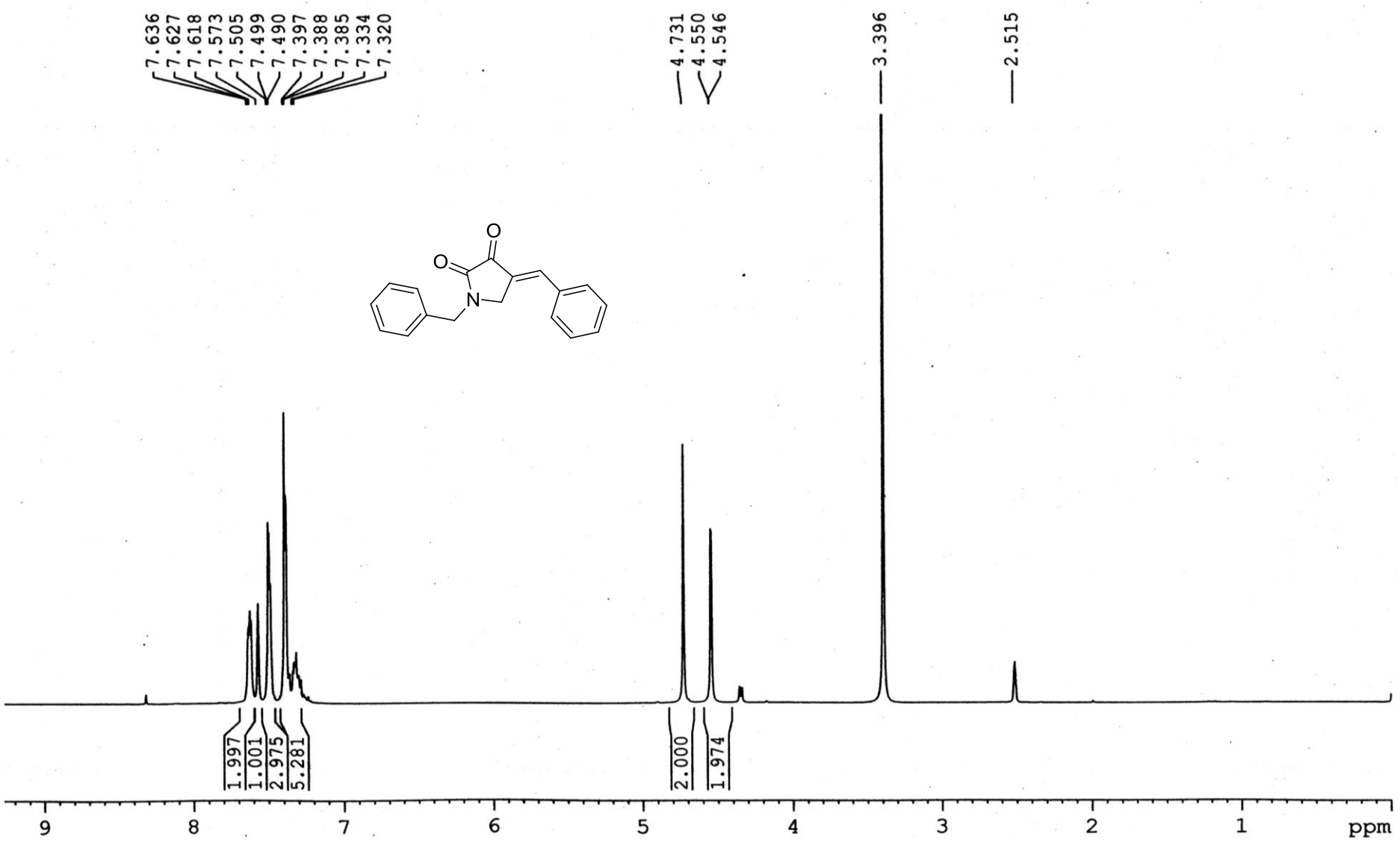


Figure 31. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **3c**

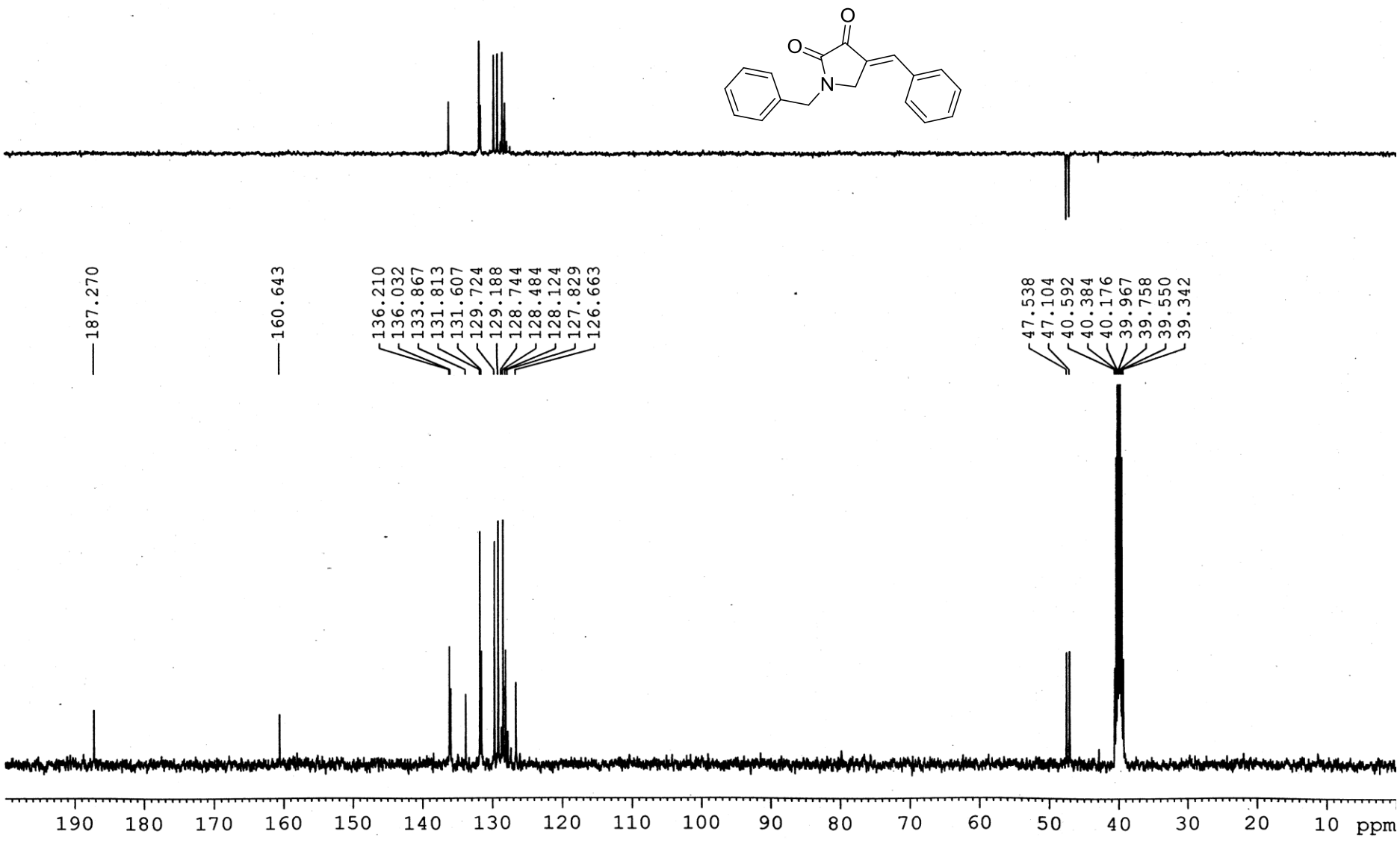


Figure 32. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **3c**

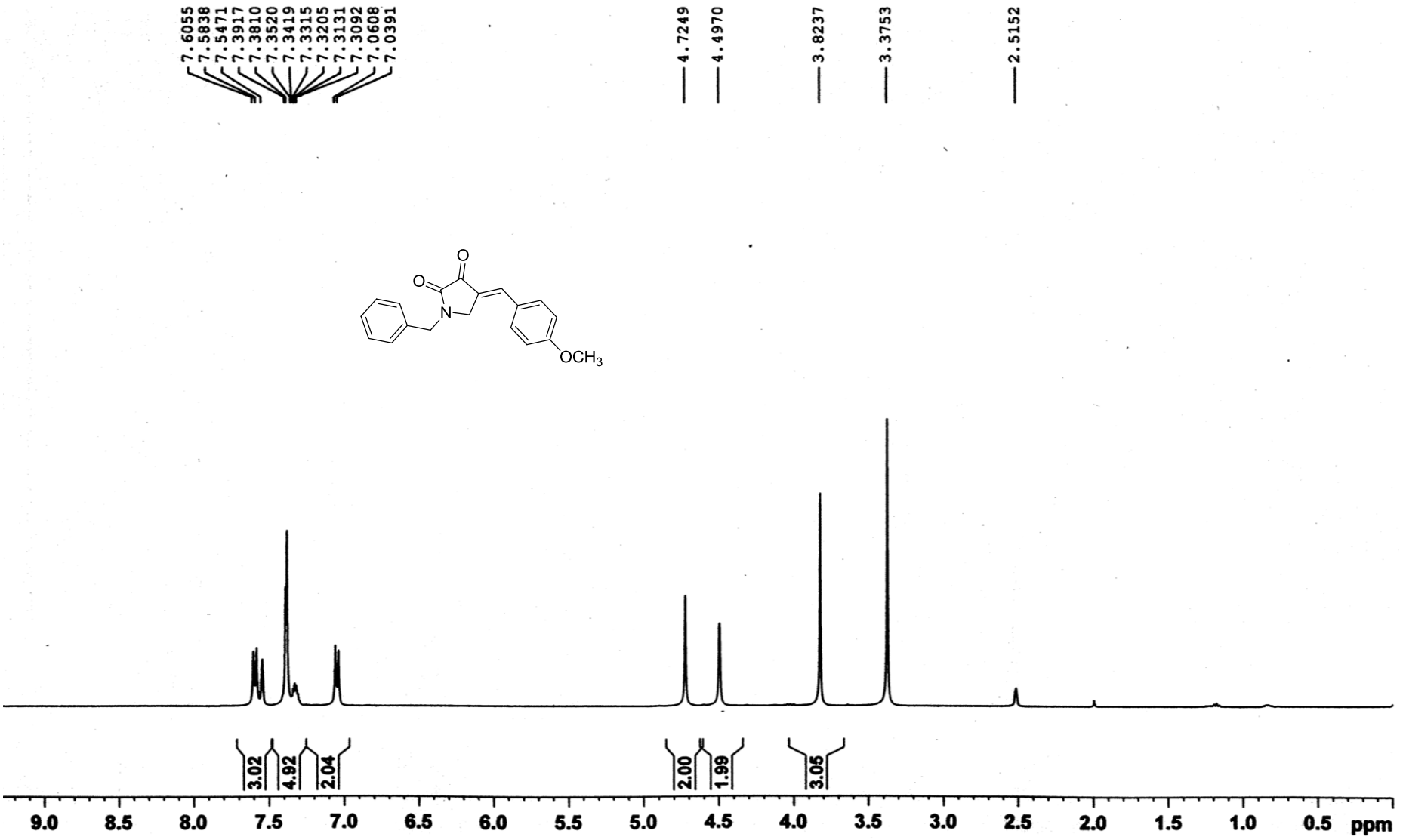


Figure 33. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **3d**

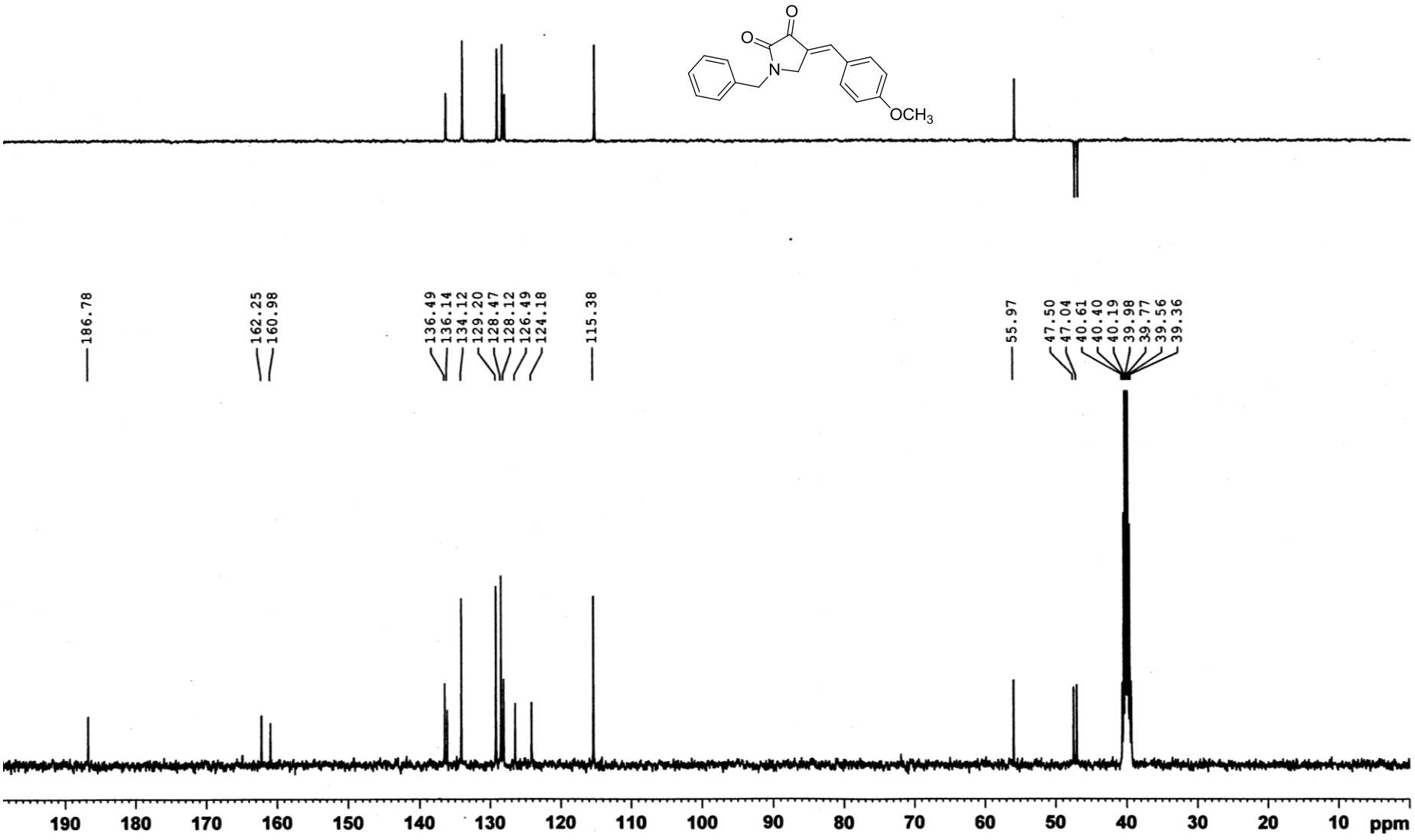


Figure 34. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **3d**

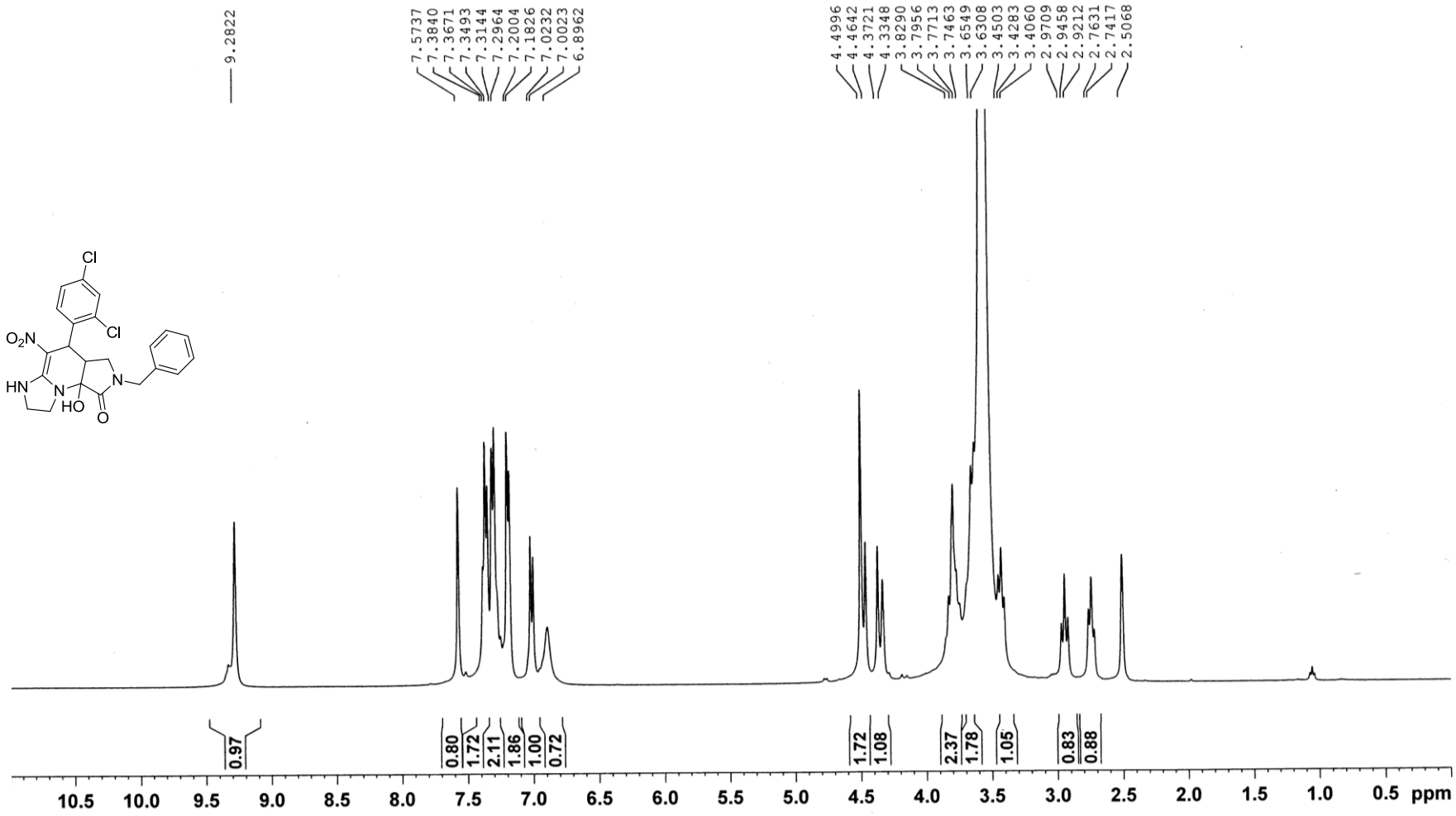


Figure 35. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4a**

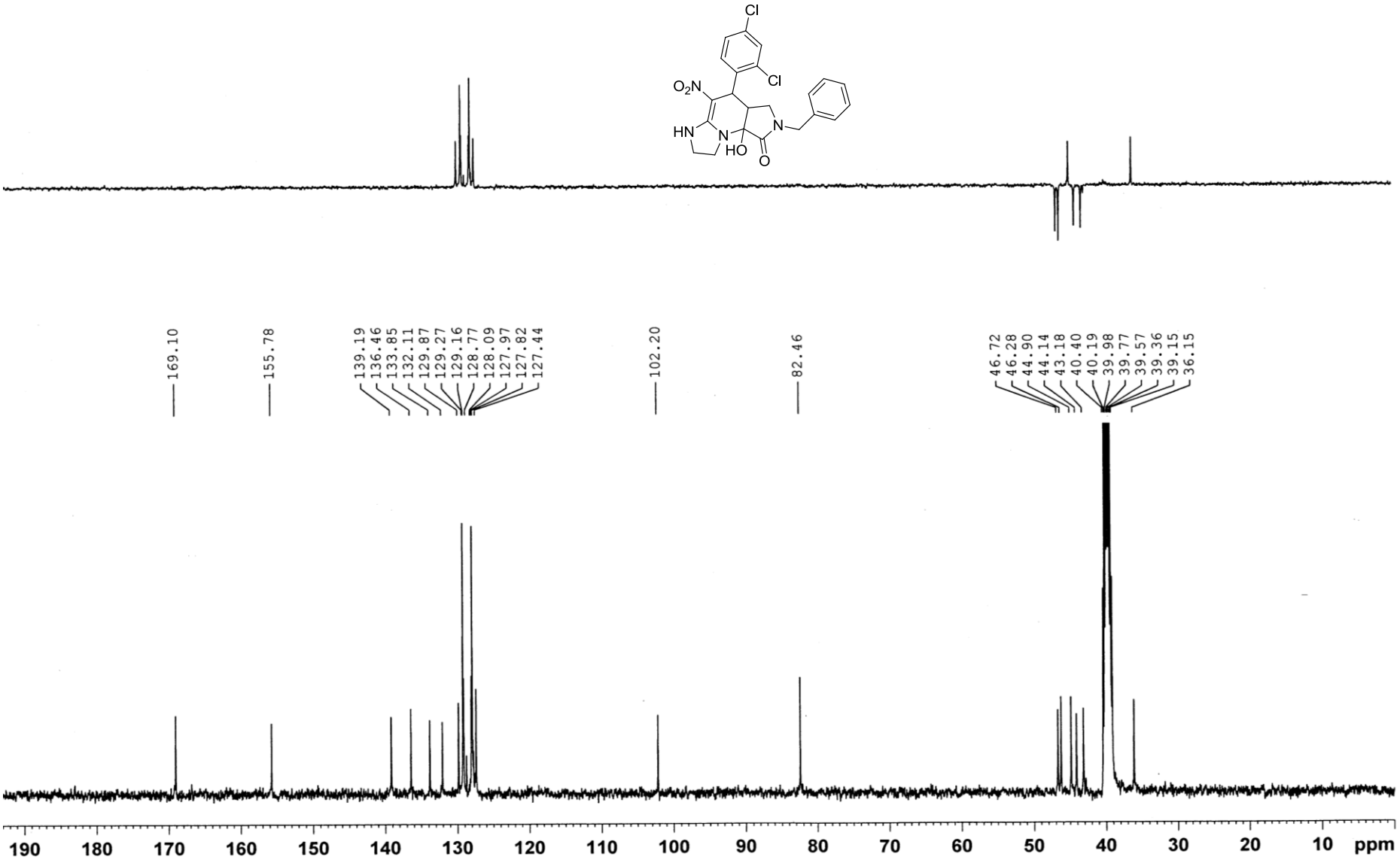


Figure 36. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4a**

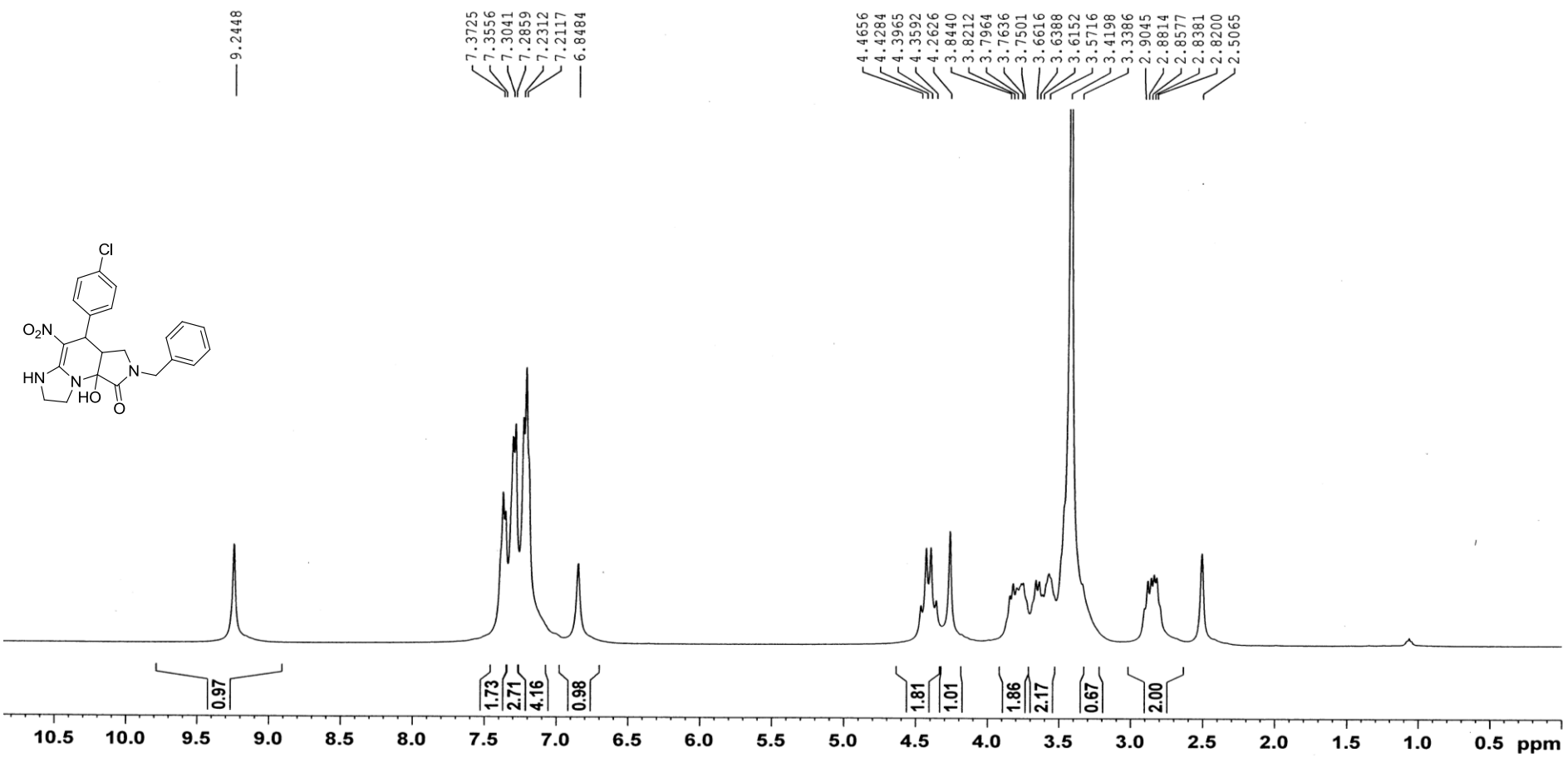


Figure 37. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4b**

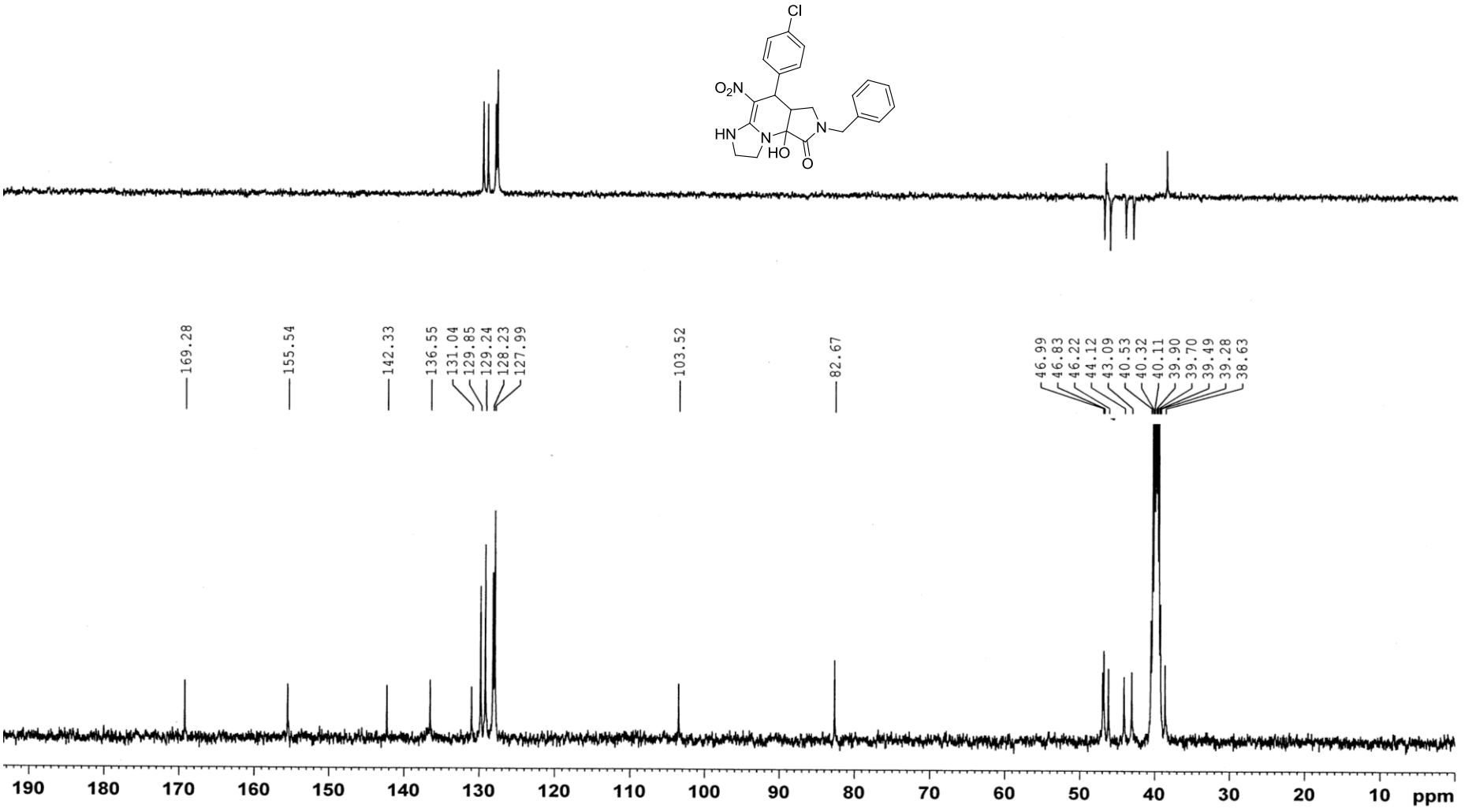


Figure 38. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4b**

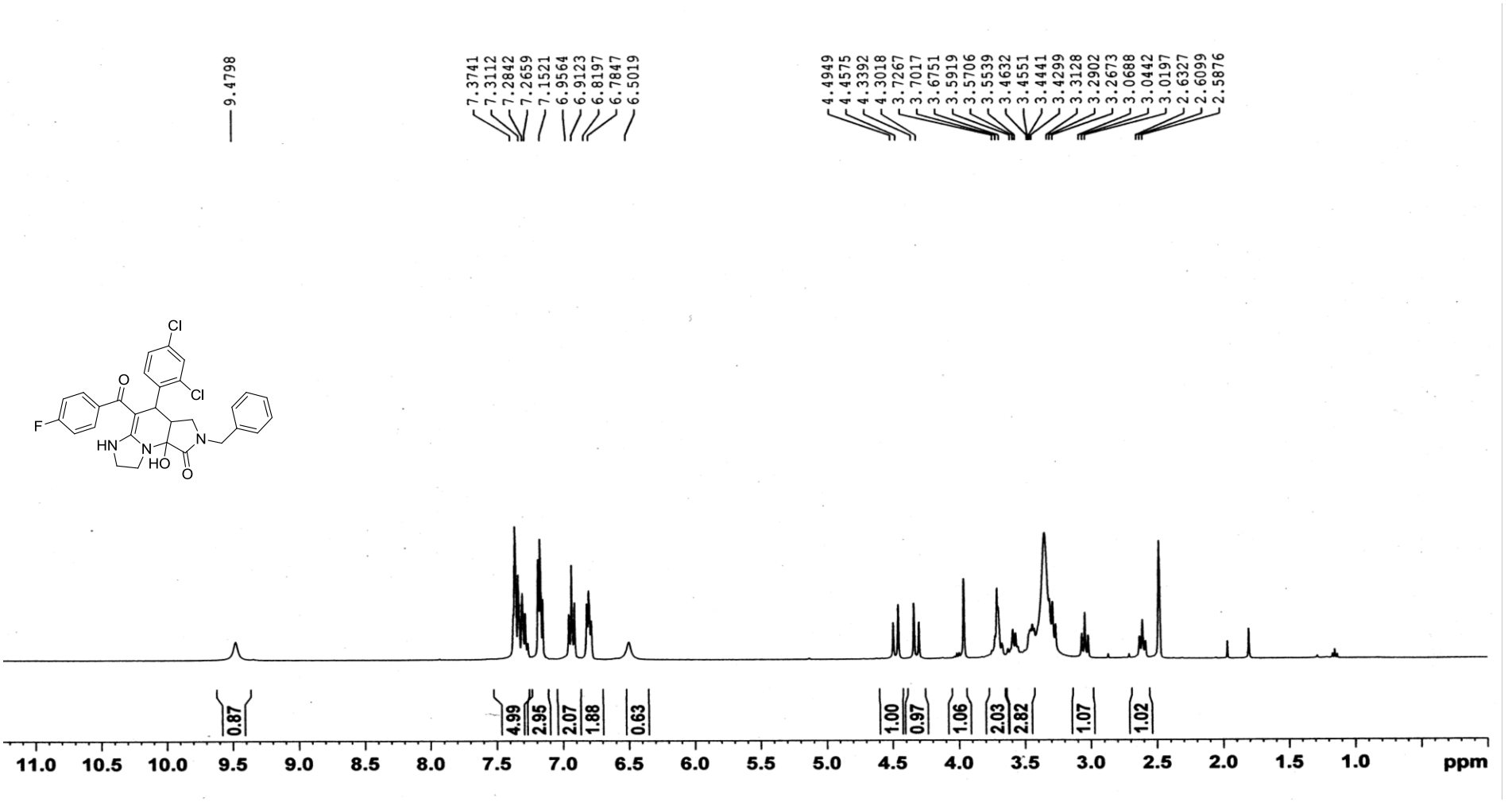


Figure 39. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4c**

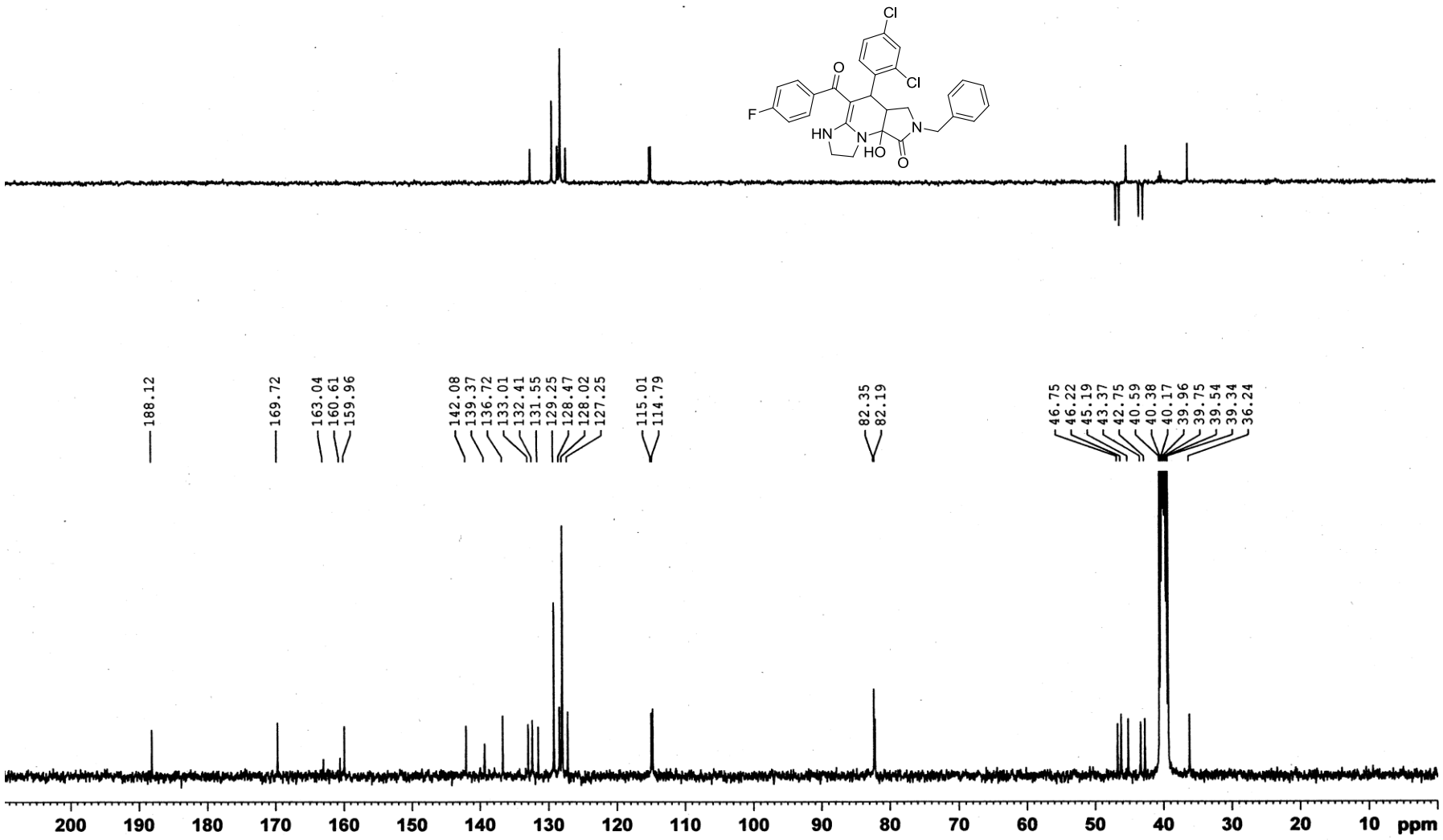


Figure 40. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4c**

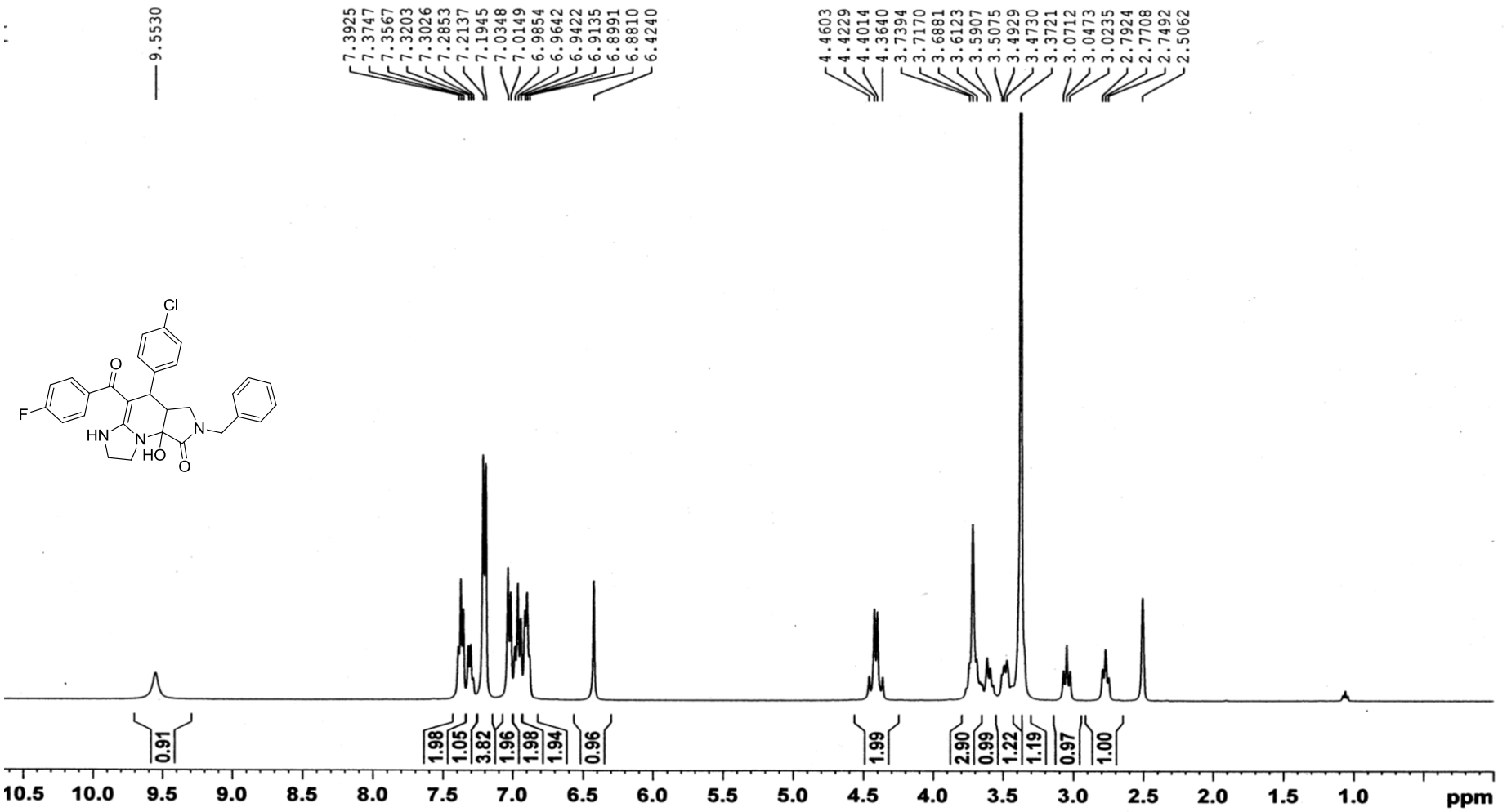


Figure 41. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4d**

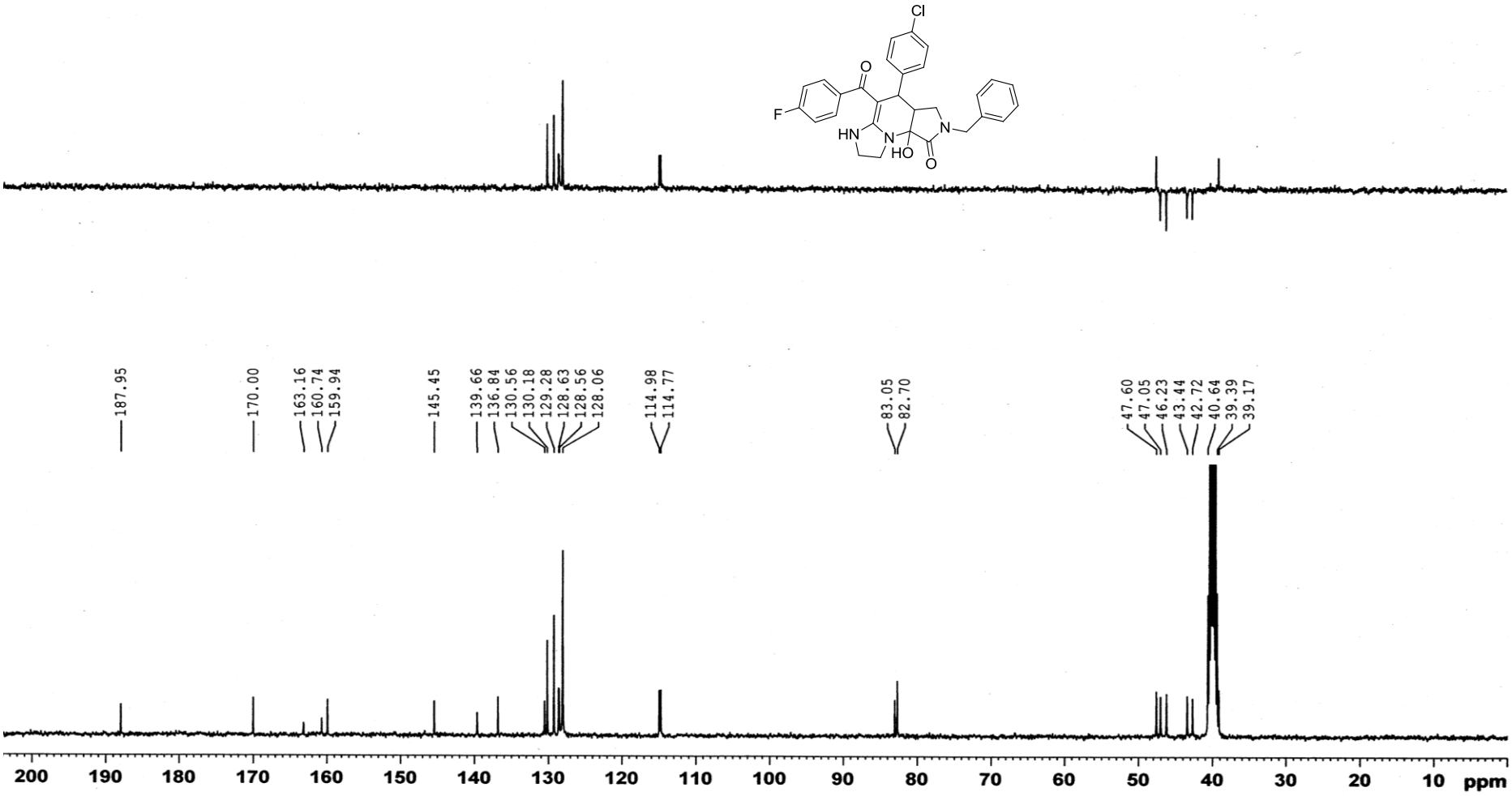


Figure 42. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4d**

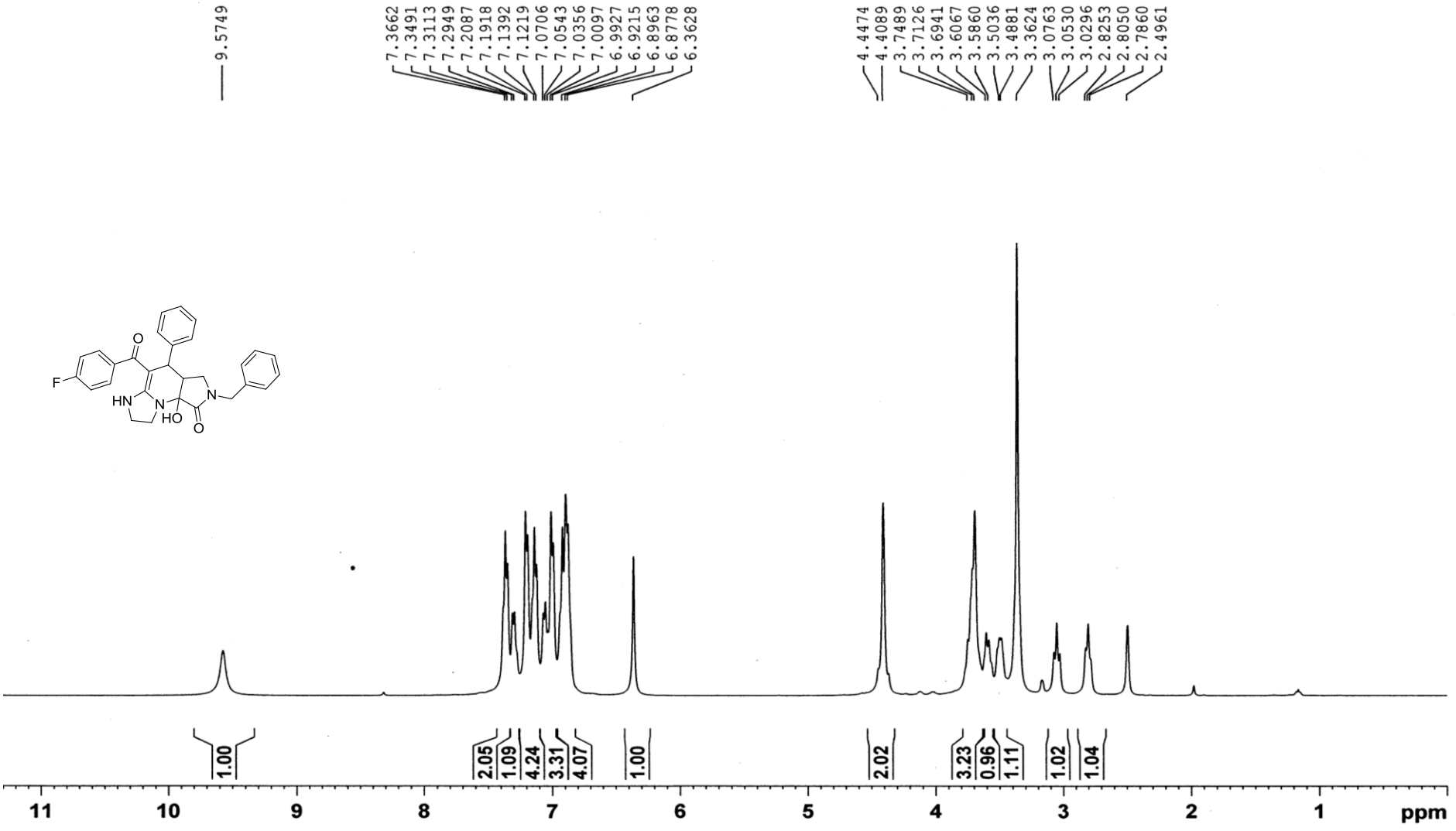


Figure 43. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4e**

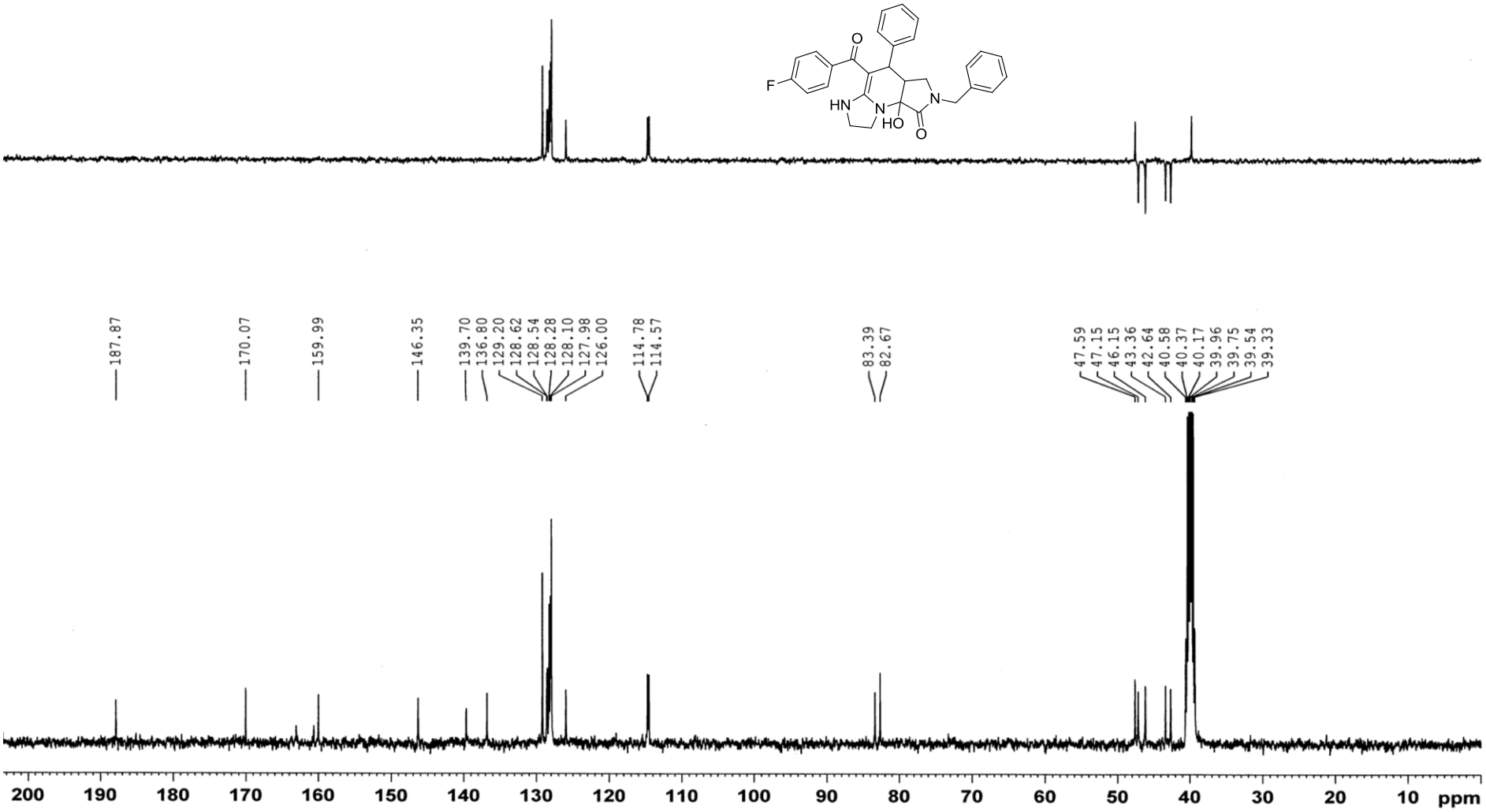


Figure 44. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4e**

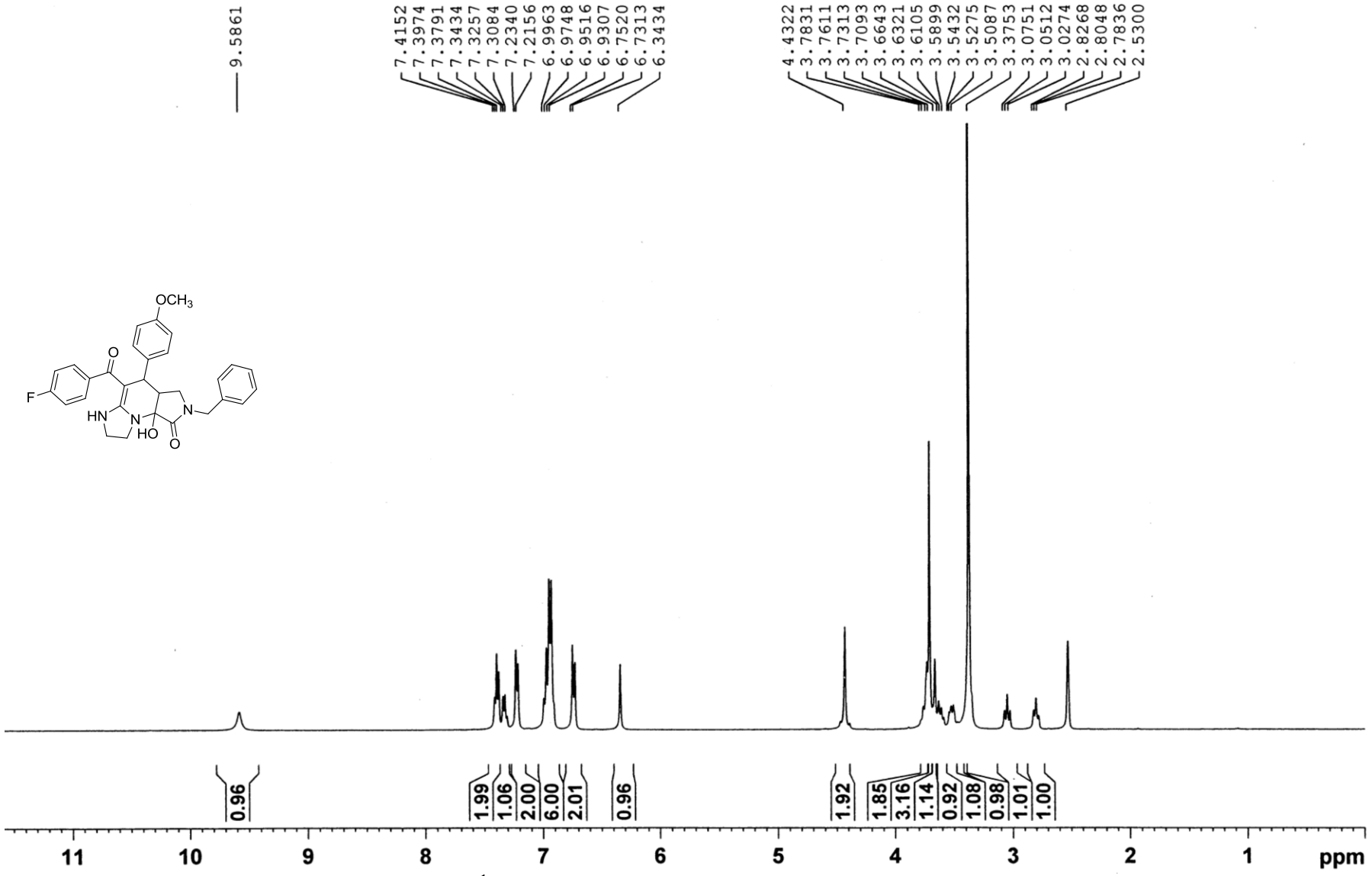


Figure 45. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4f**

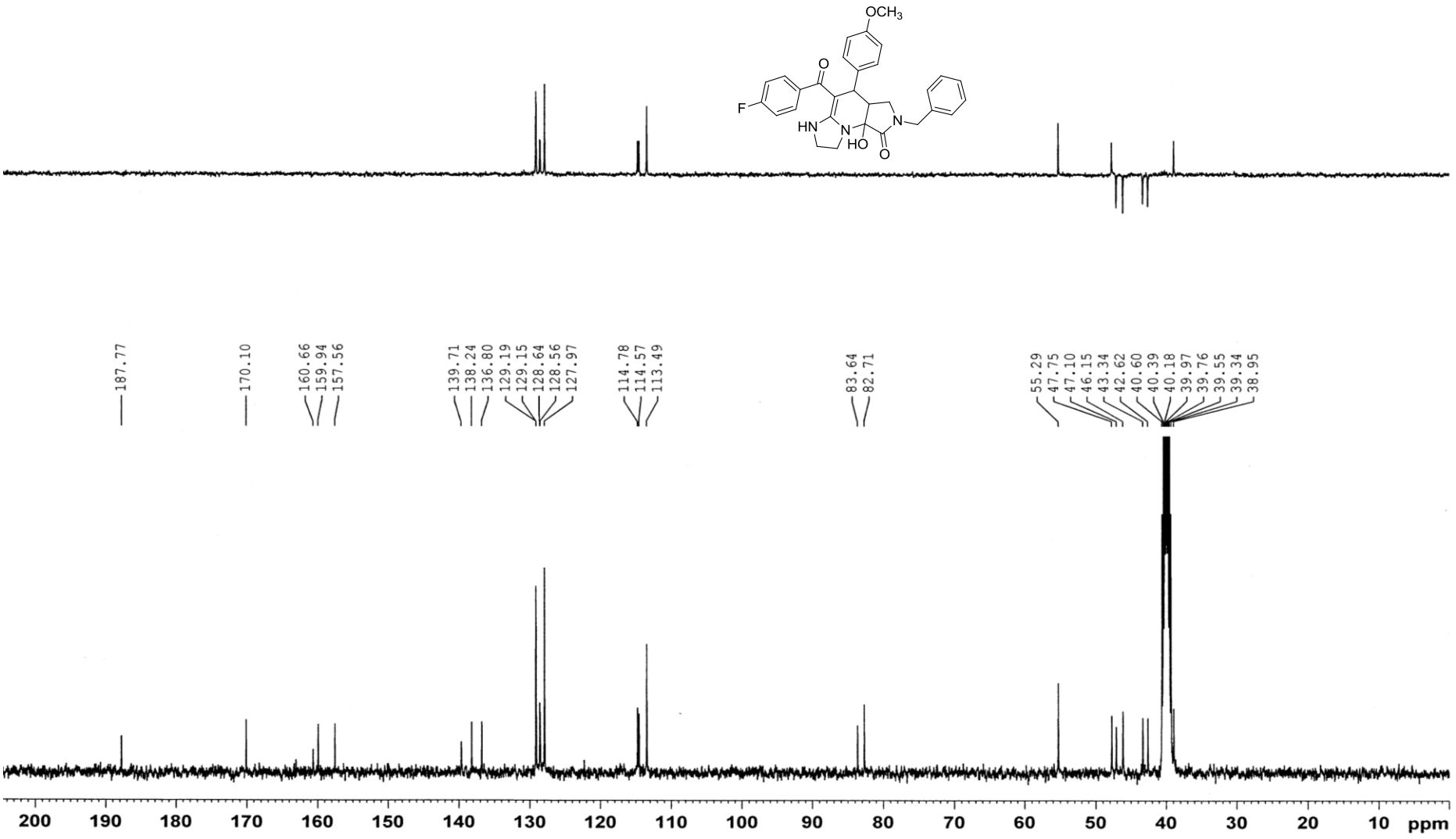


Figure 46. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4f**

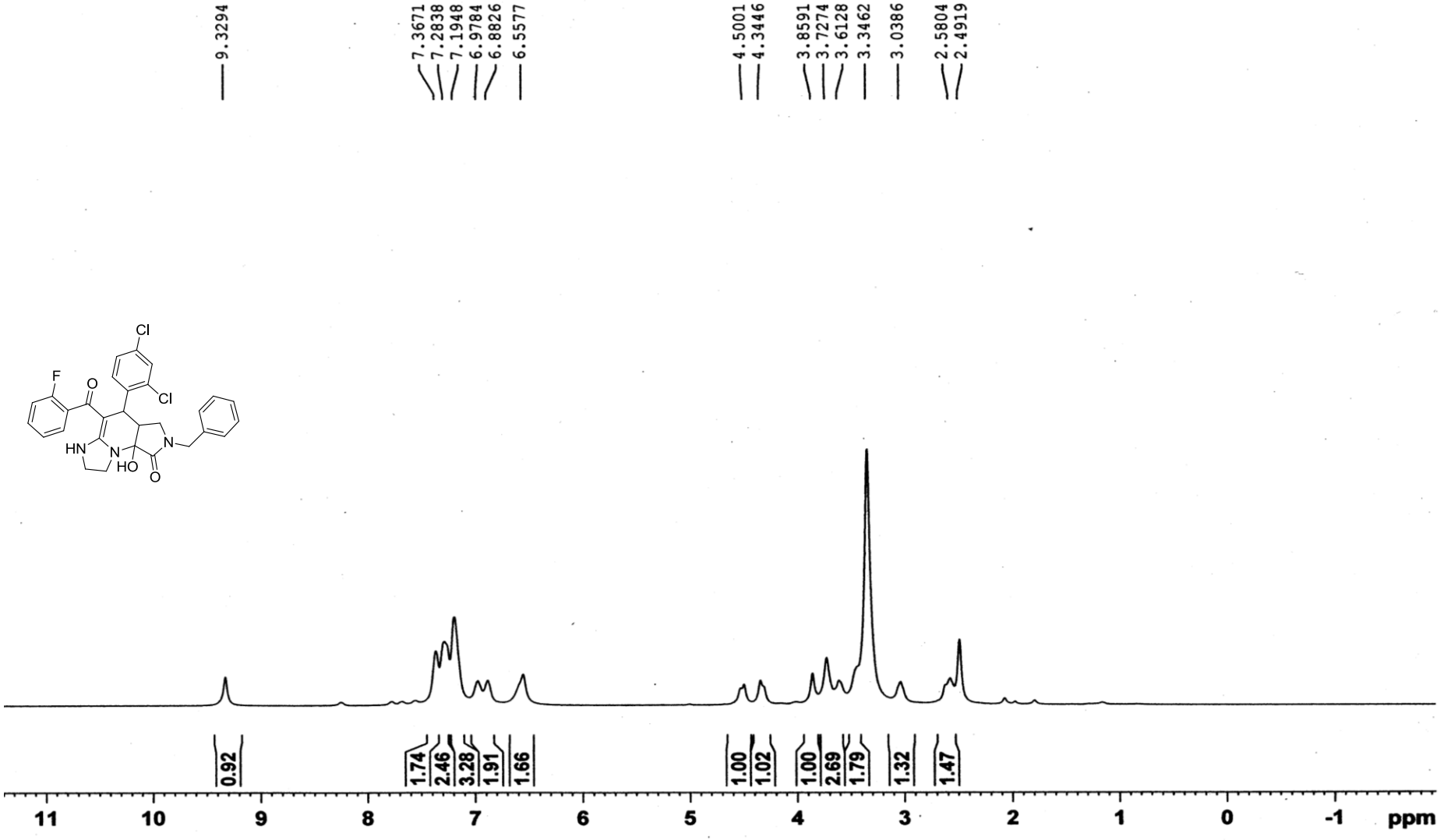


Figure 47. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4g**

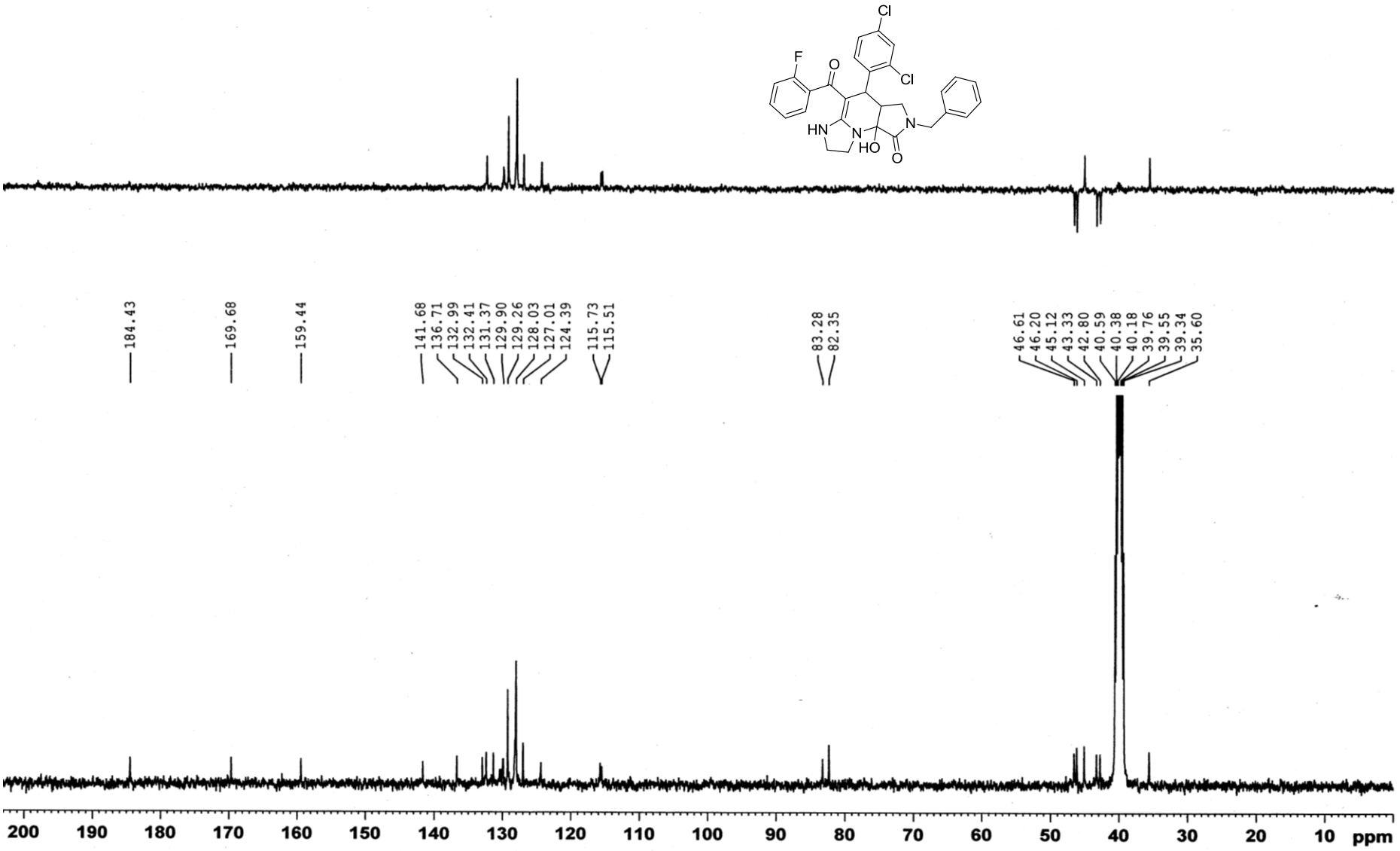


Figure 48. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4g**

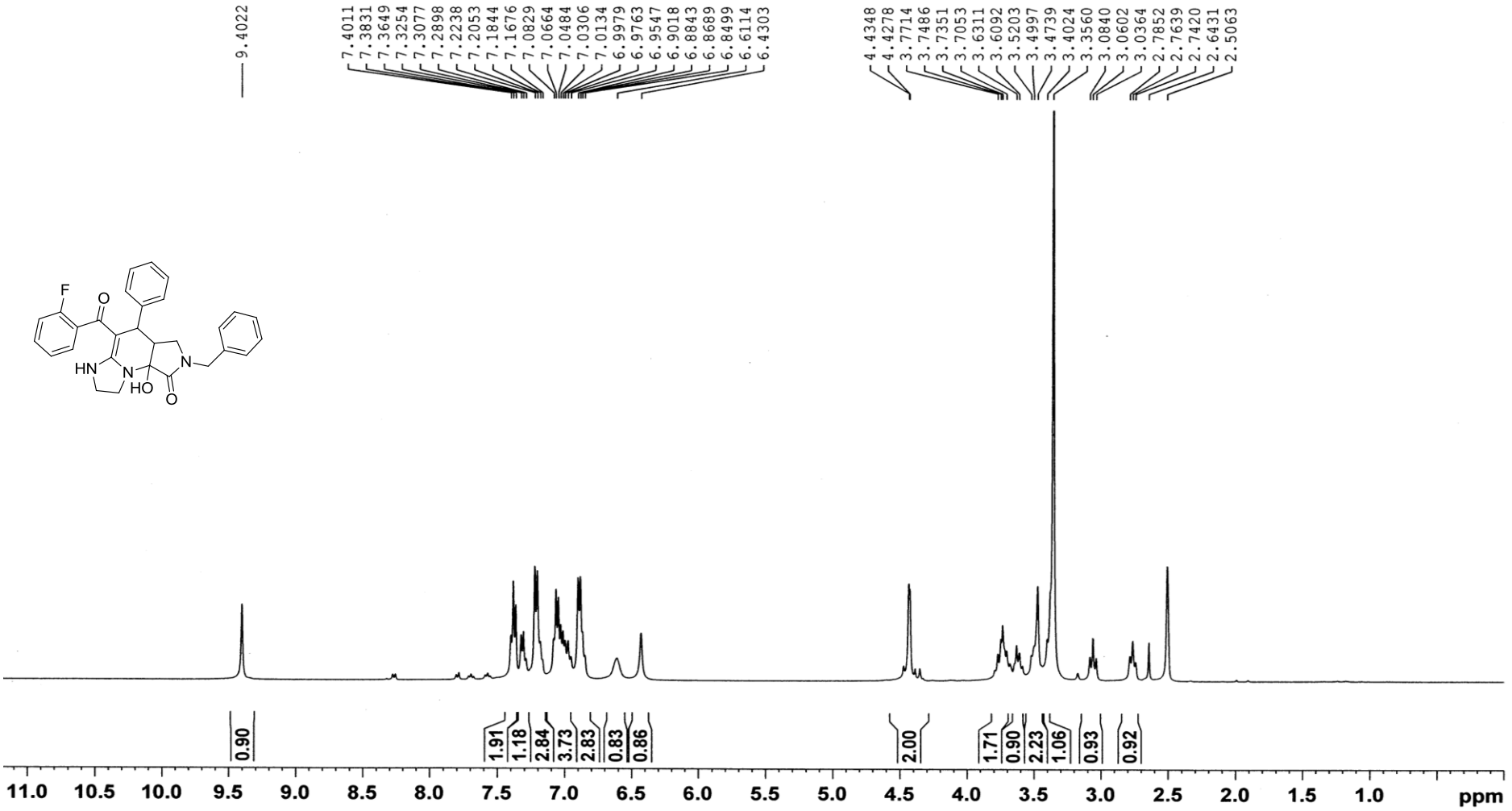


Figure 49. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4h**

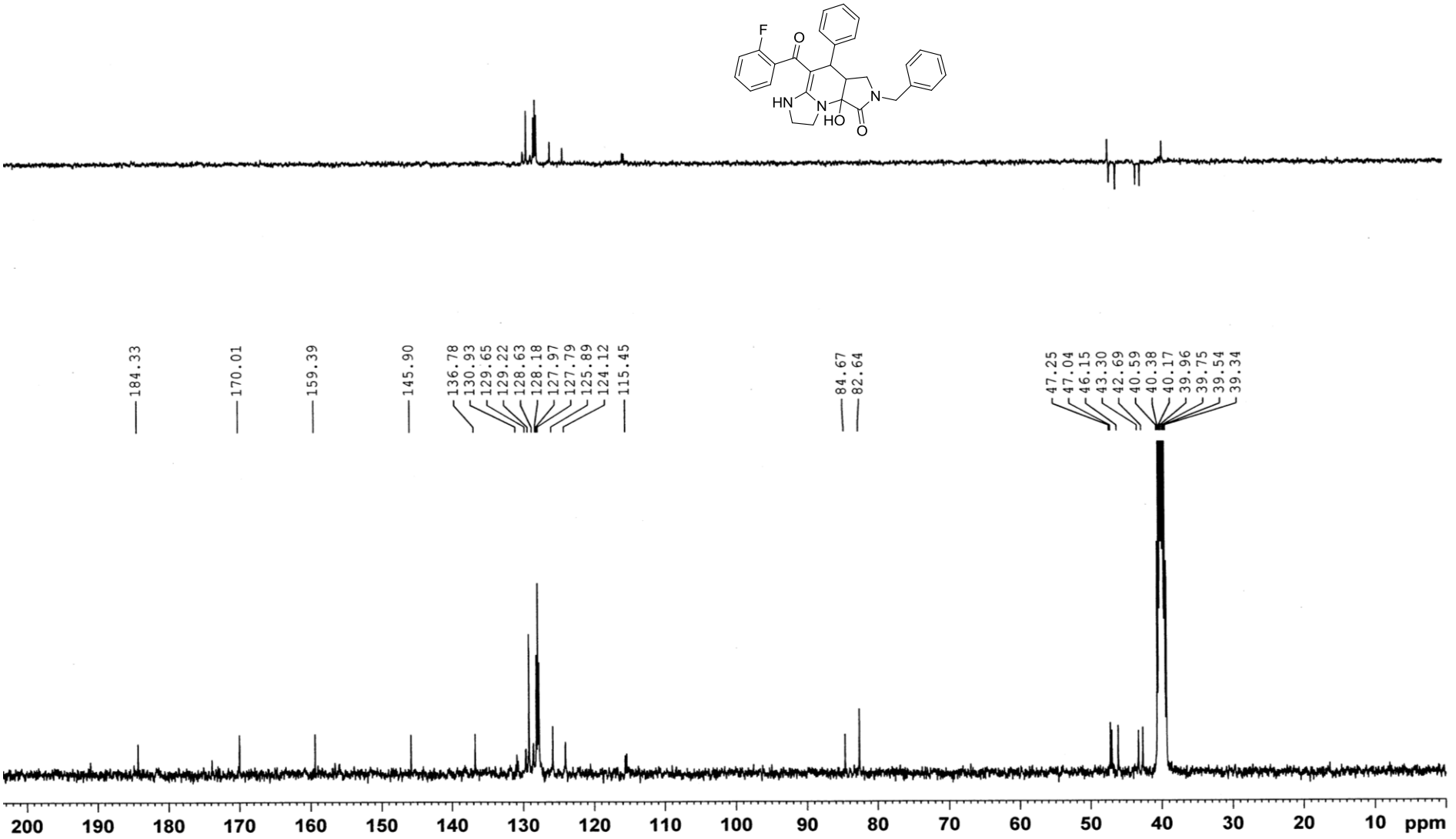


Figure 50. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4h**

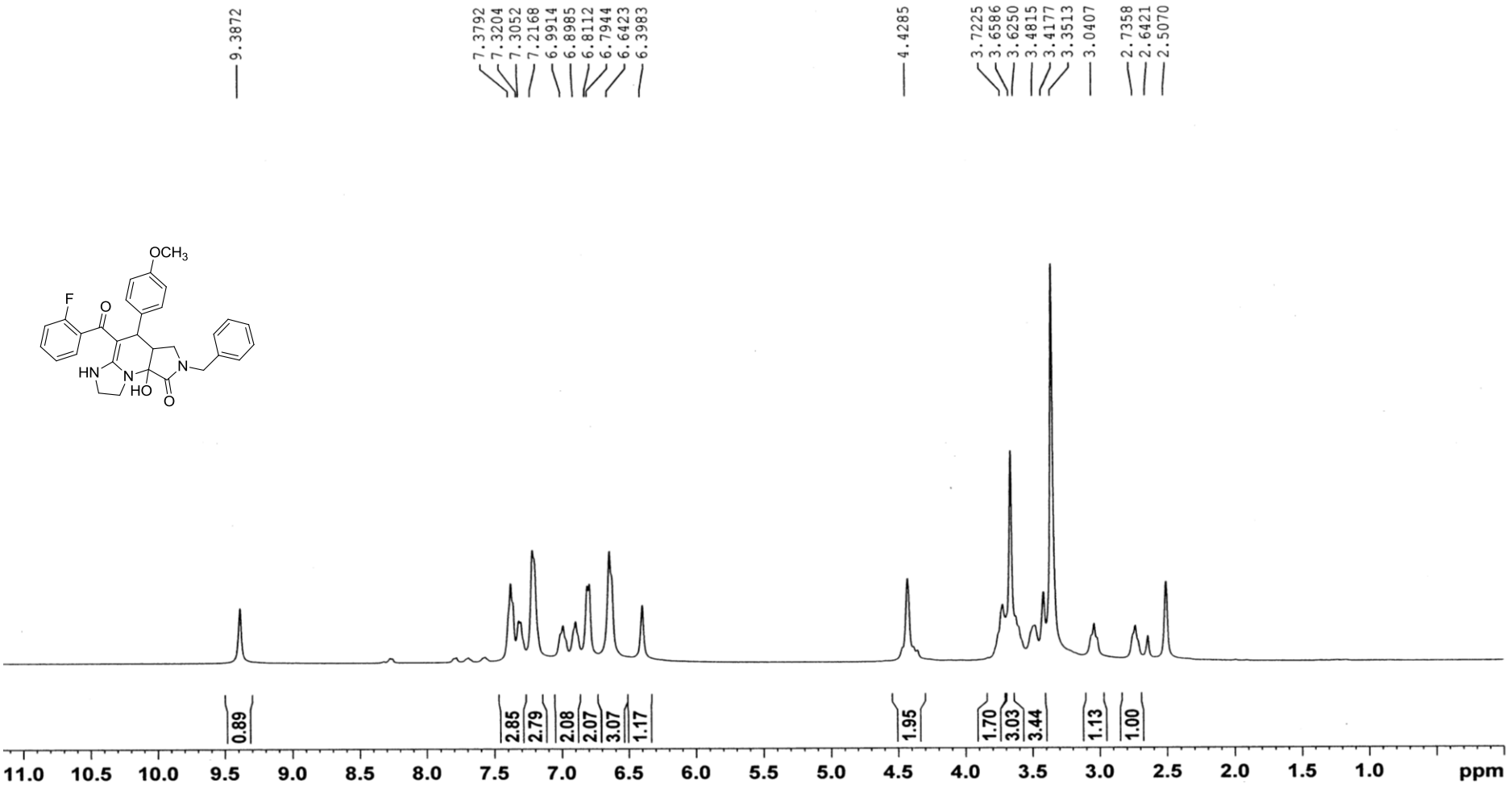


Figure 51. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4i**

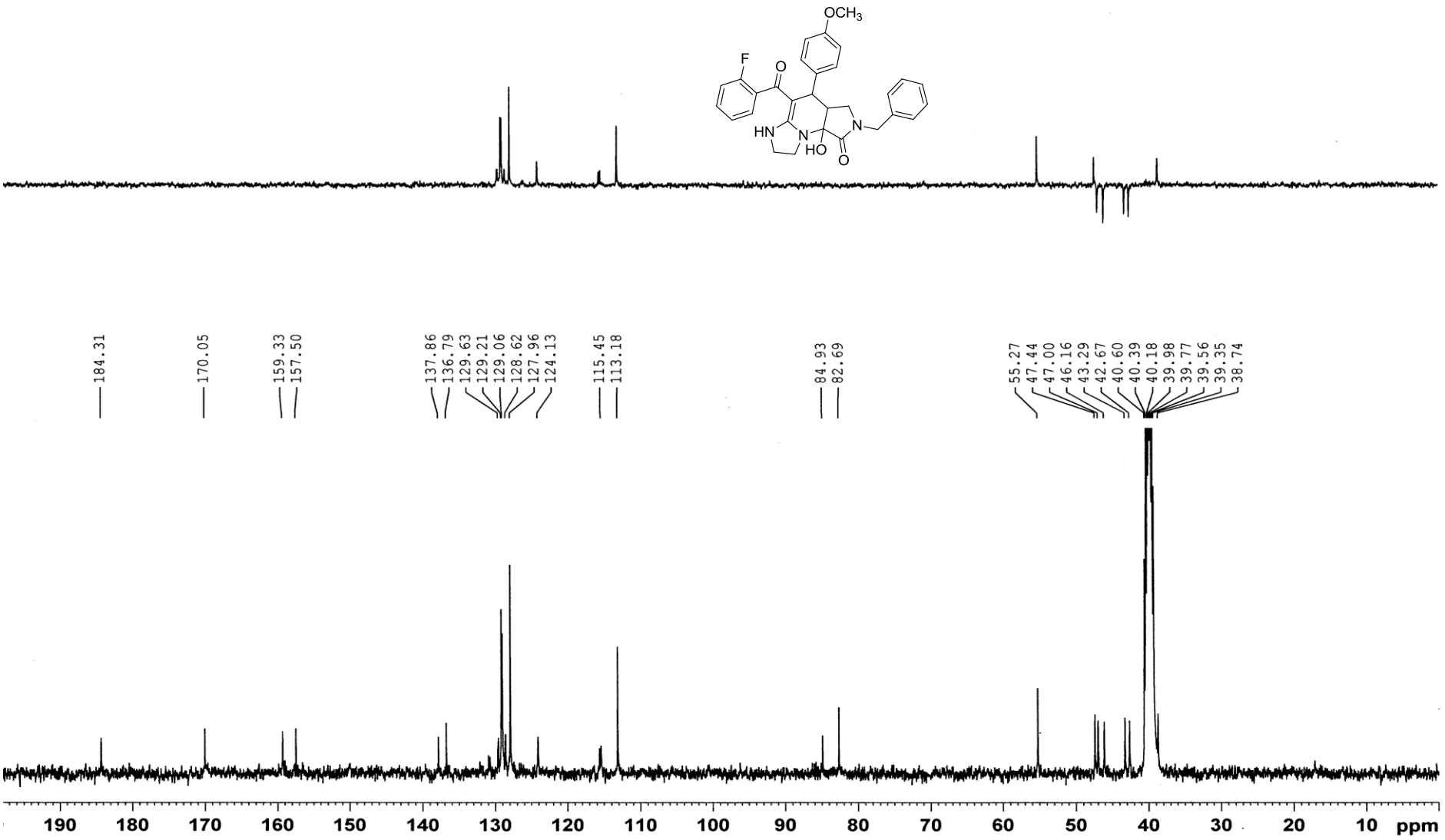


Figure 52. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4i**

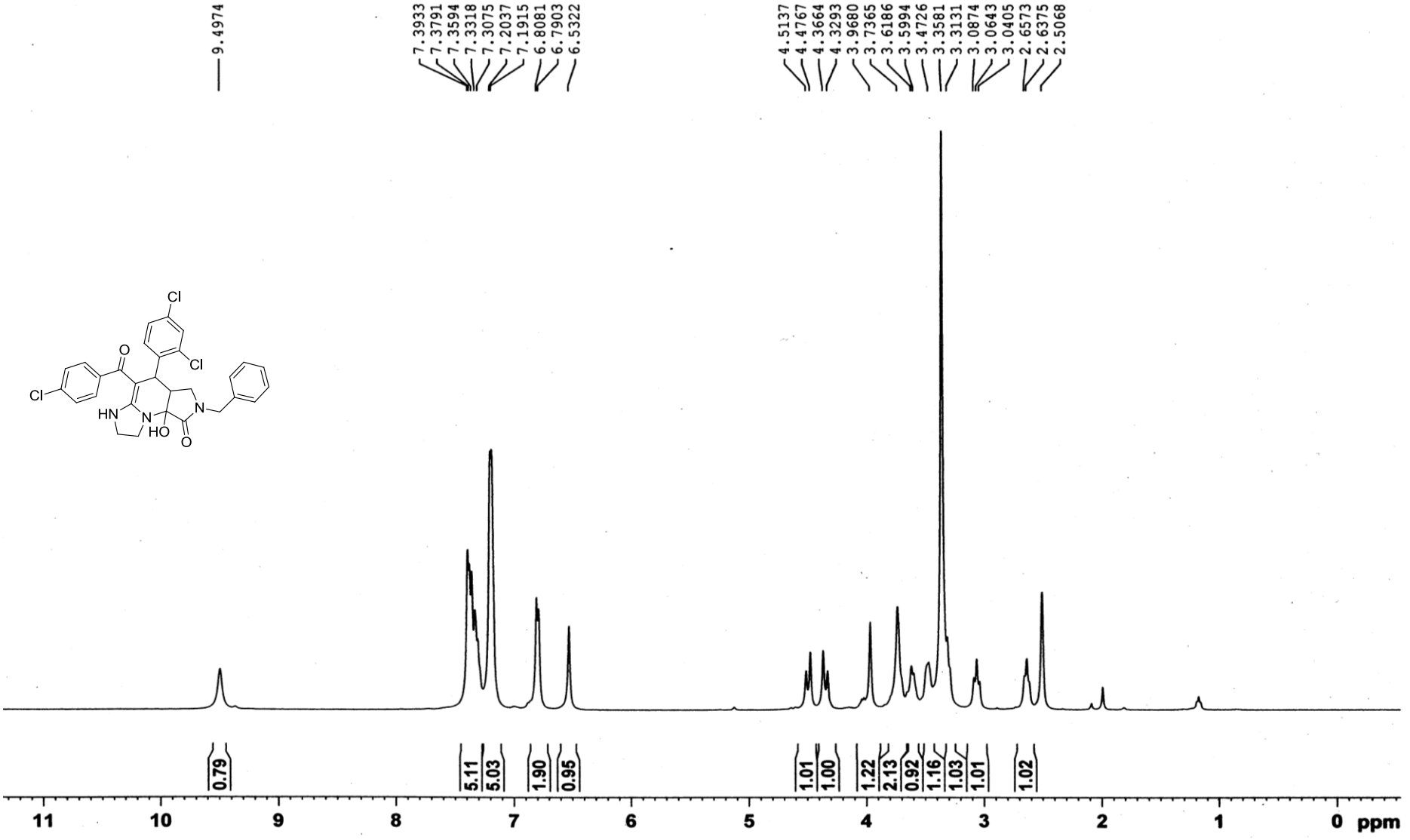


Figure 53. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4j**

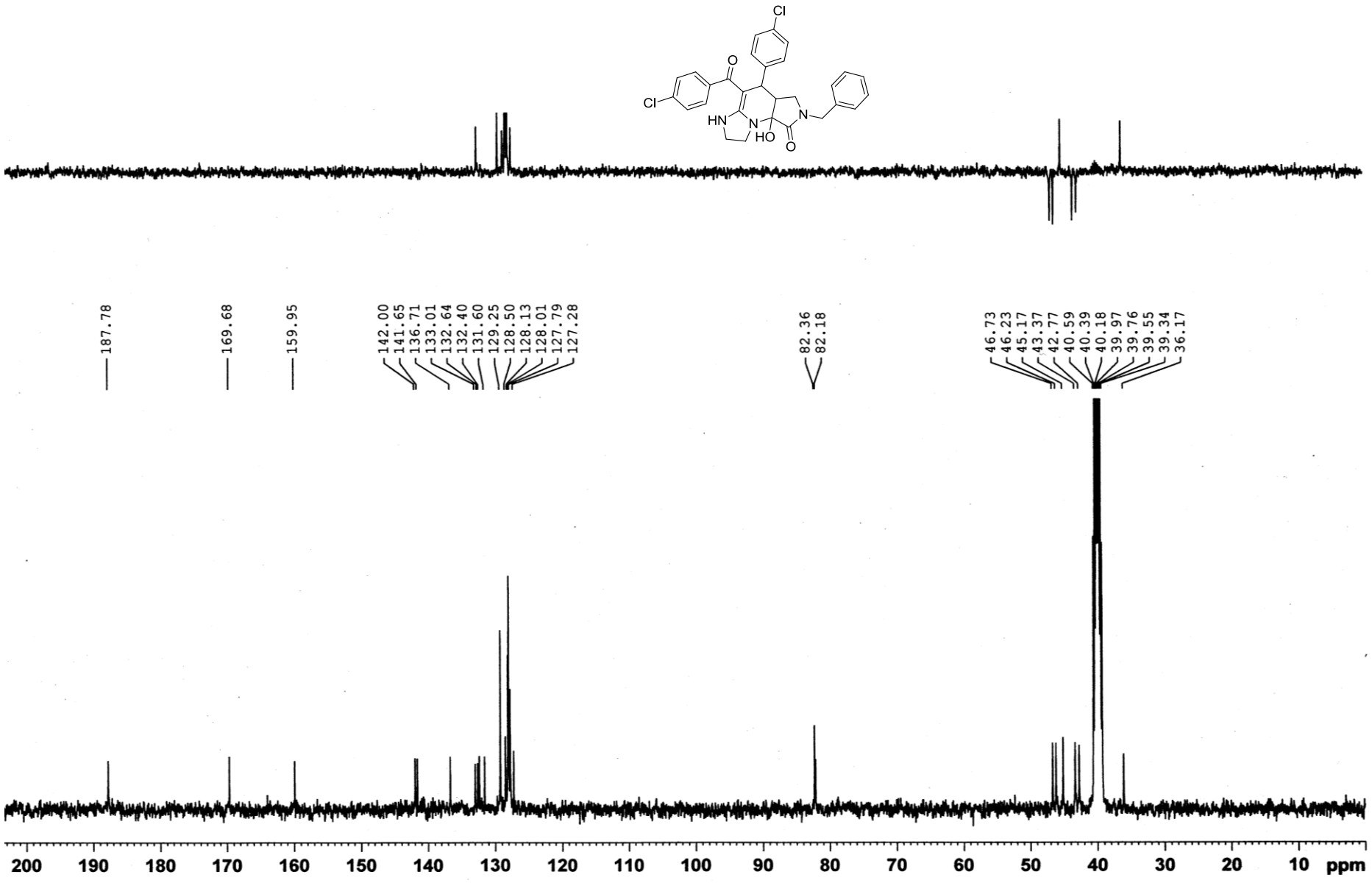


Figure 54. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4j**

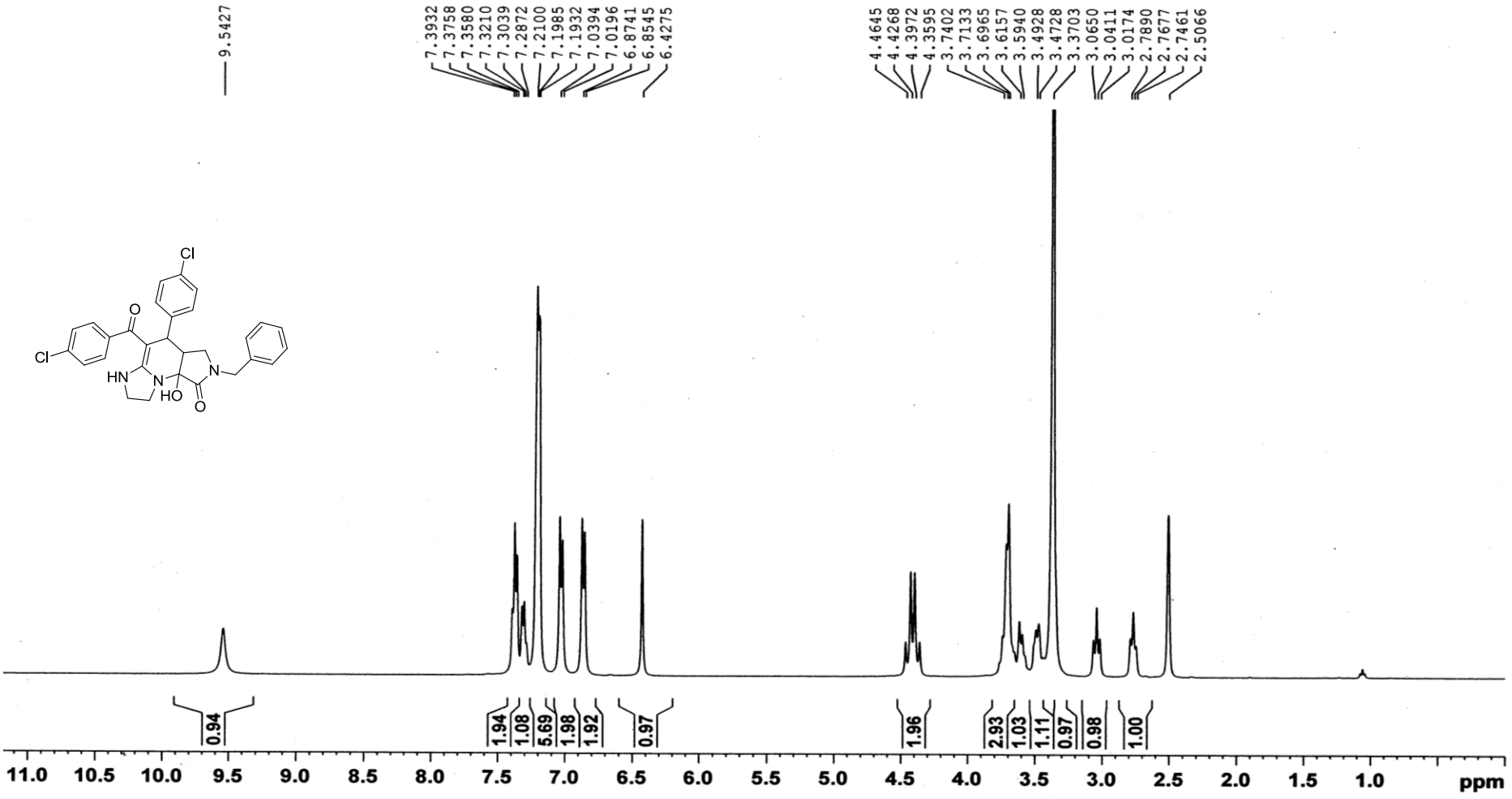


Figure 55. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4k**

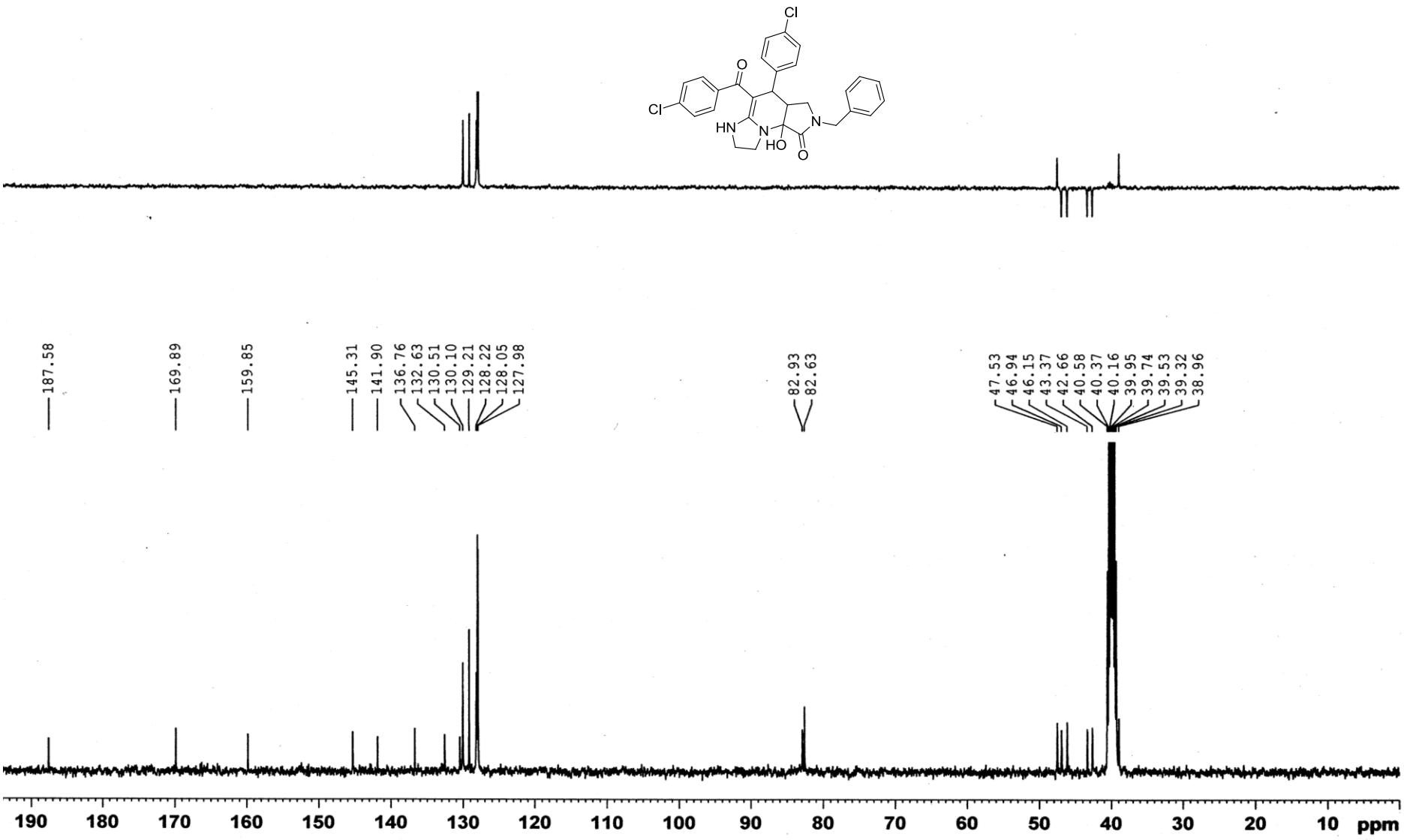


Figure 56. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4k**

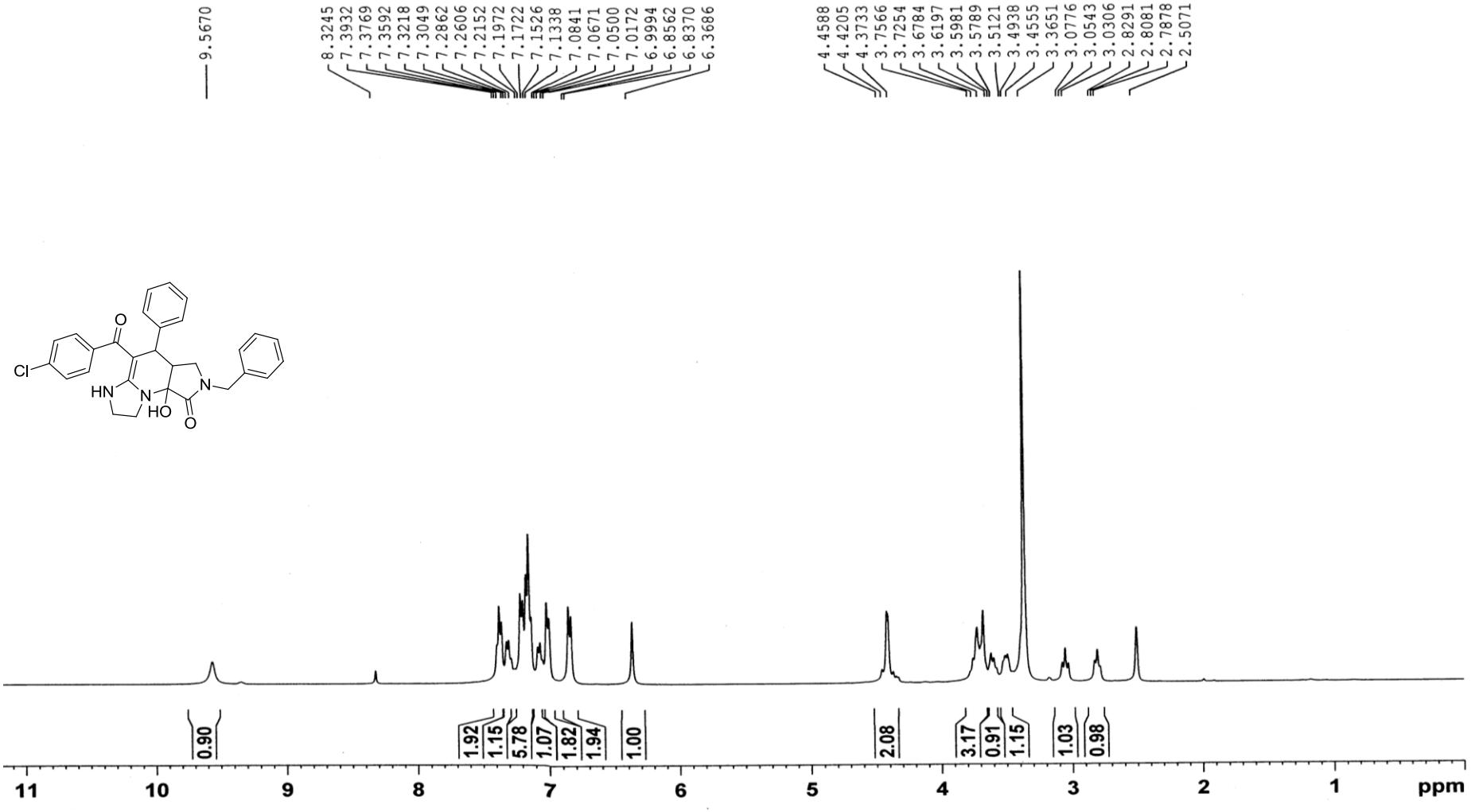


Figure 57. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4l**

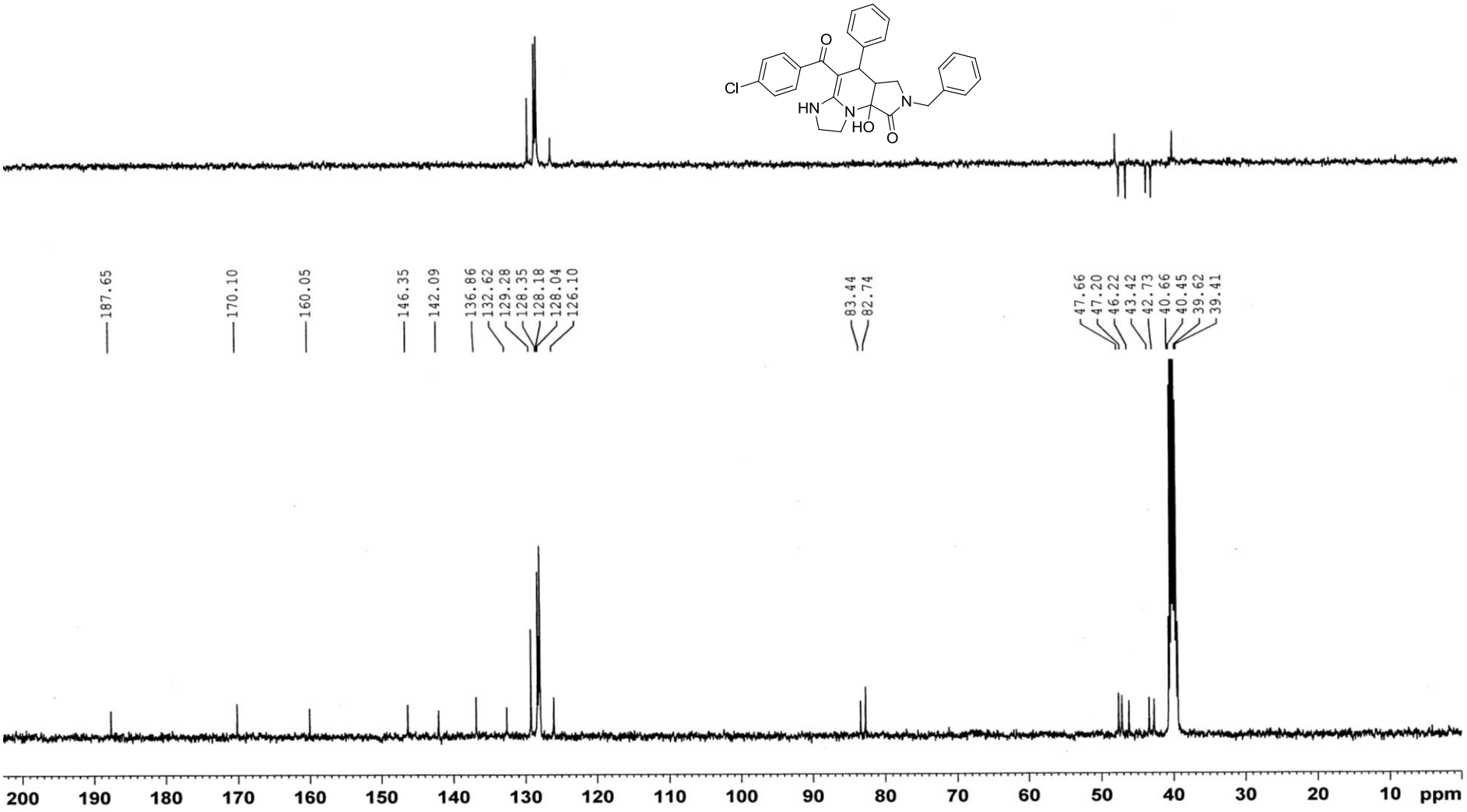


Figure 58. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4l**

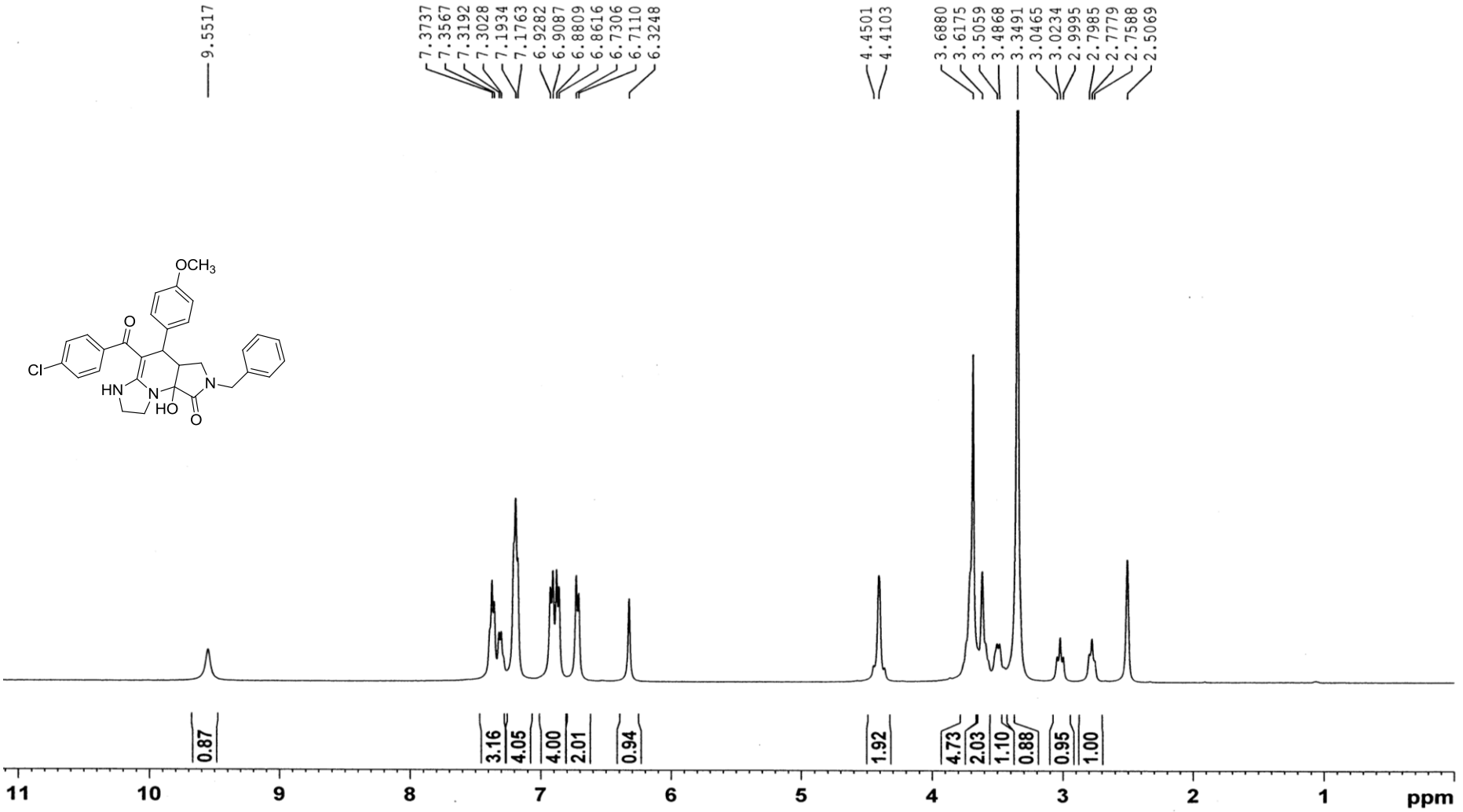


Figure 59. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4m**

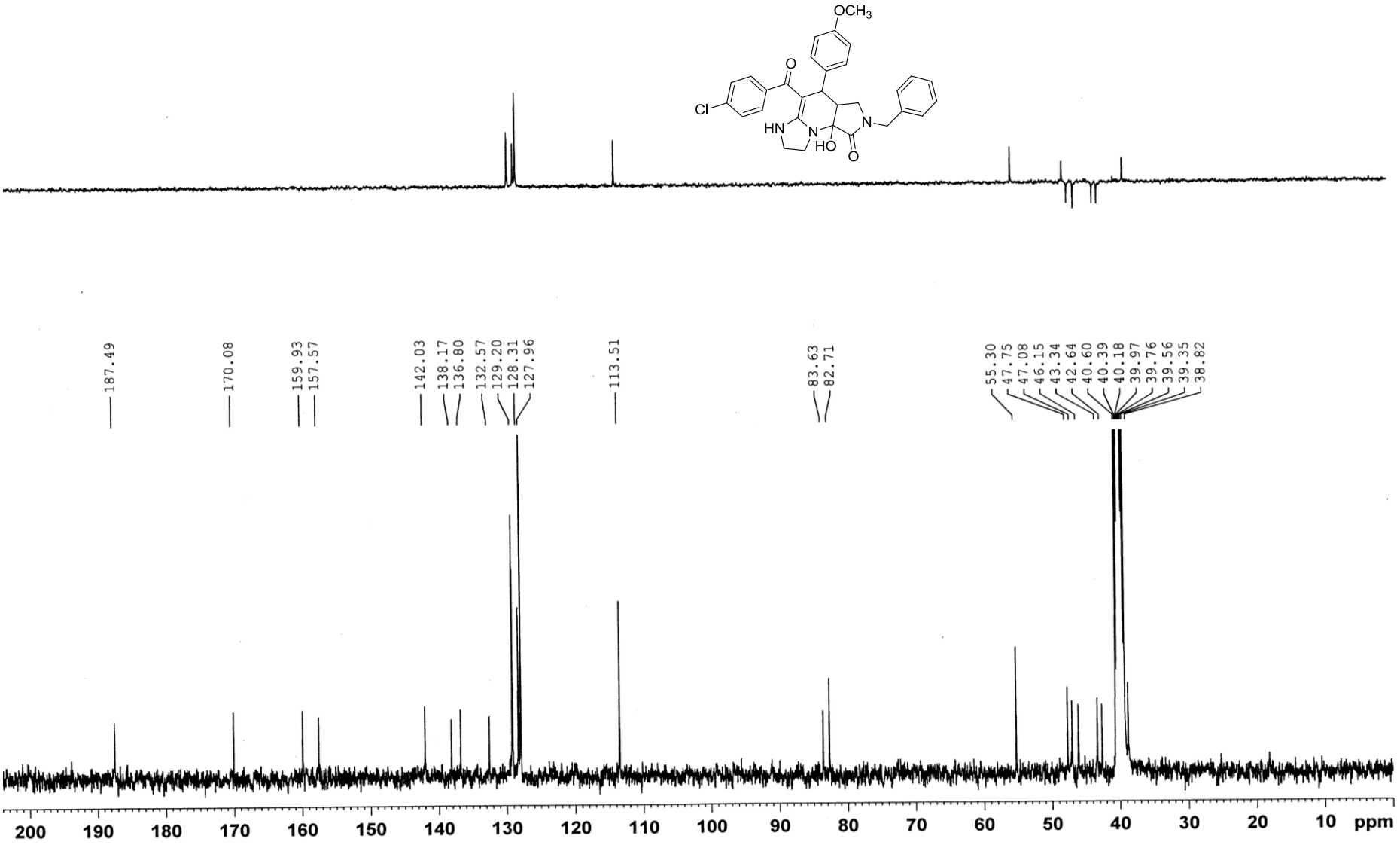


Figure 60. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4m**

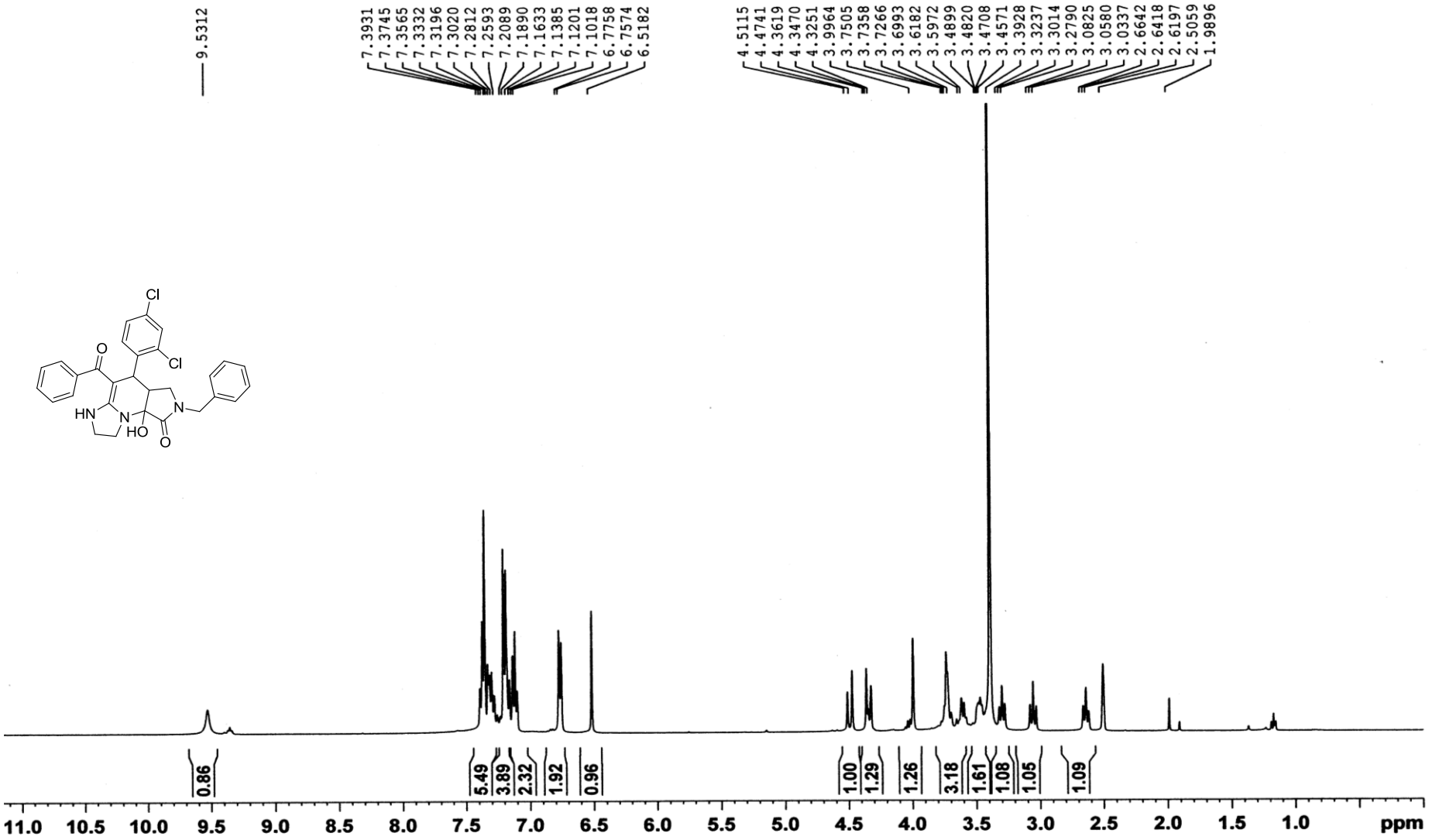


Figure 61. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4n**

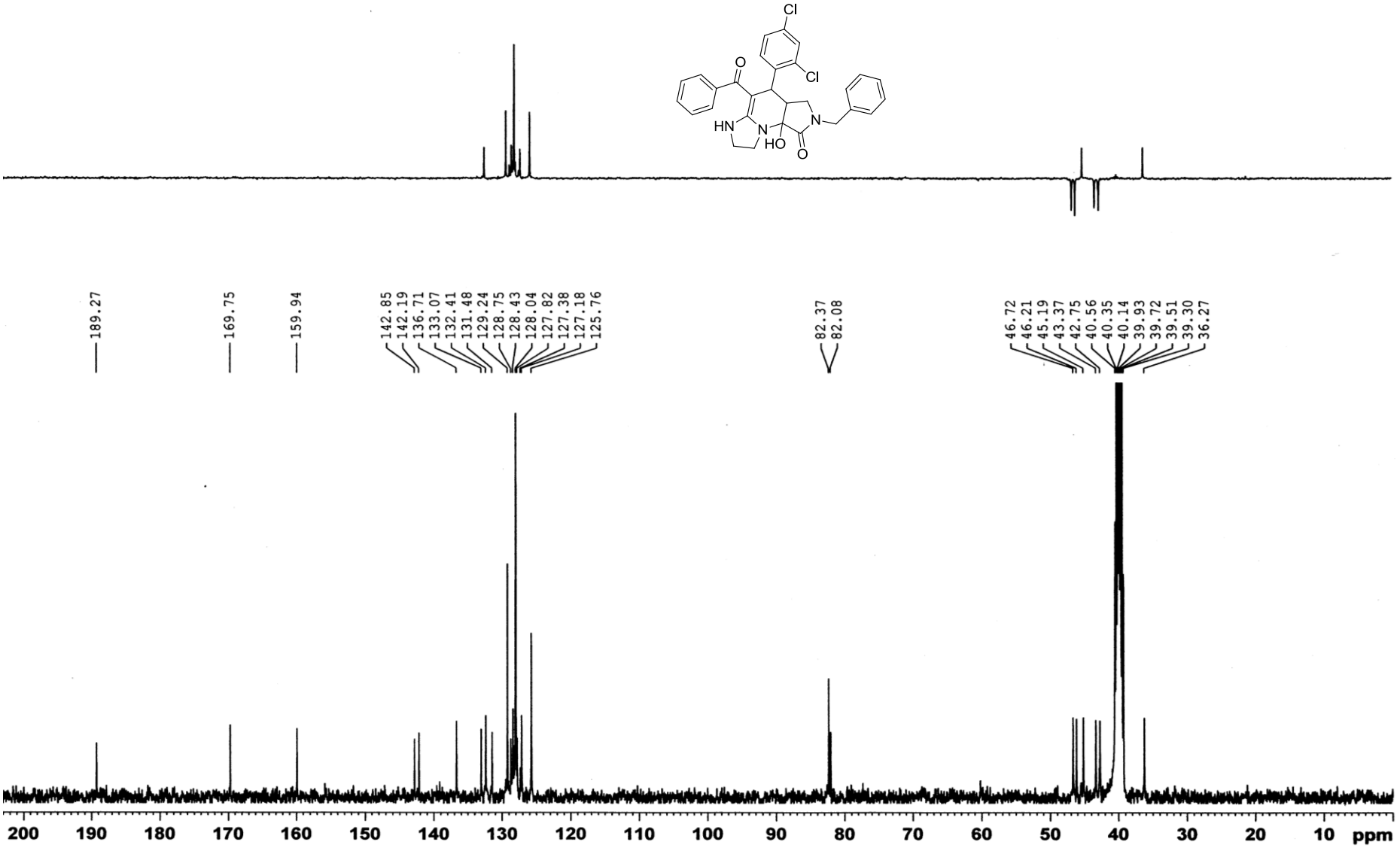


Figure 62. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4n**

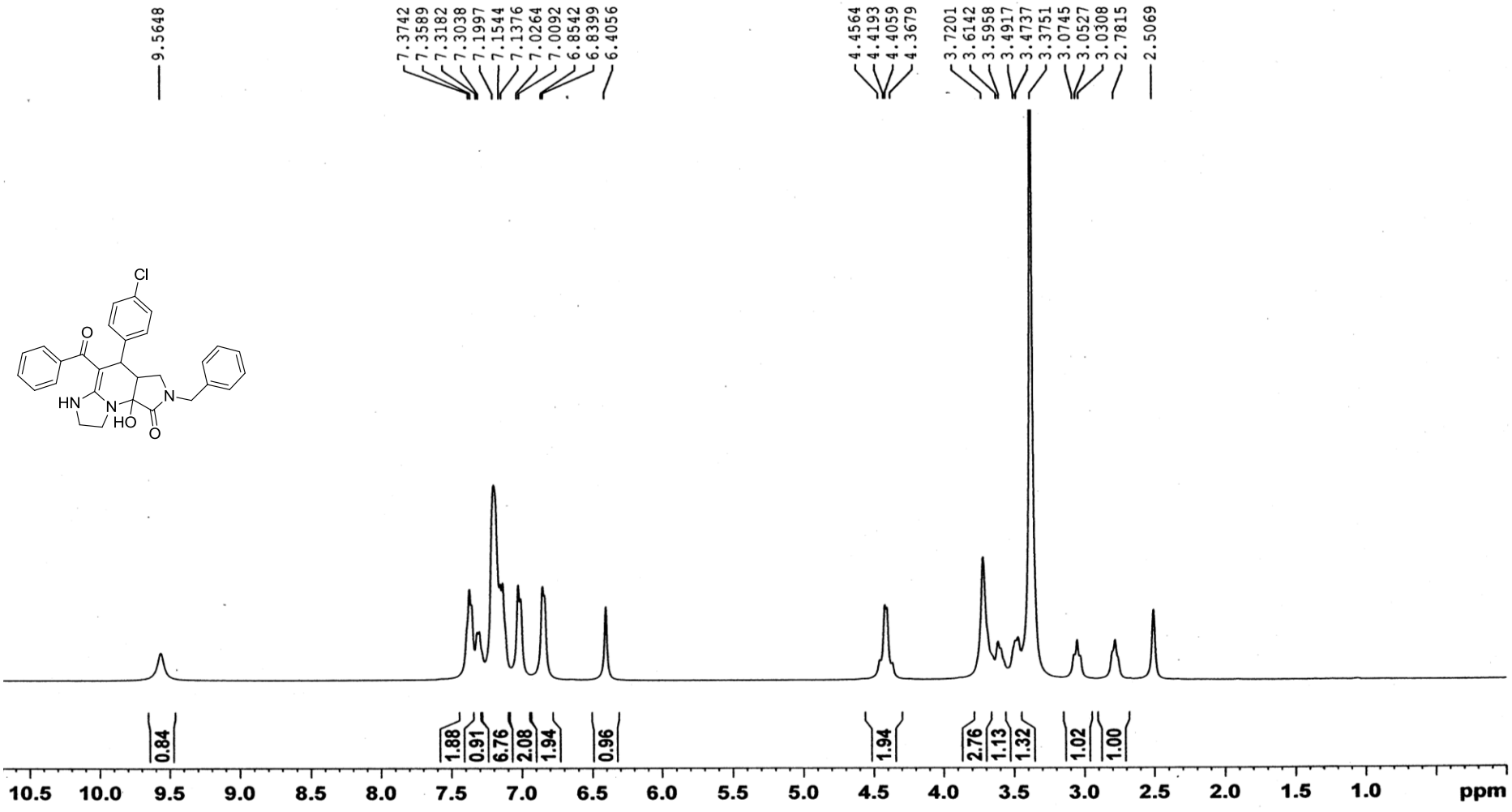


Figure 63. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4o**

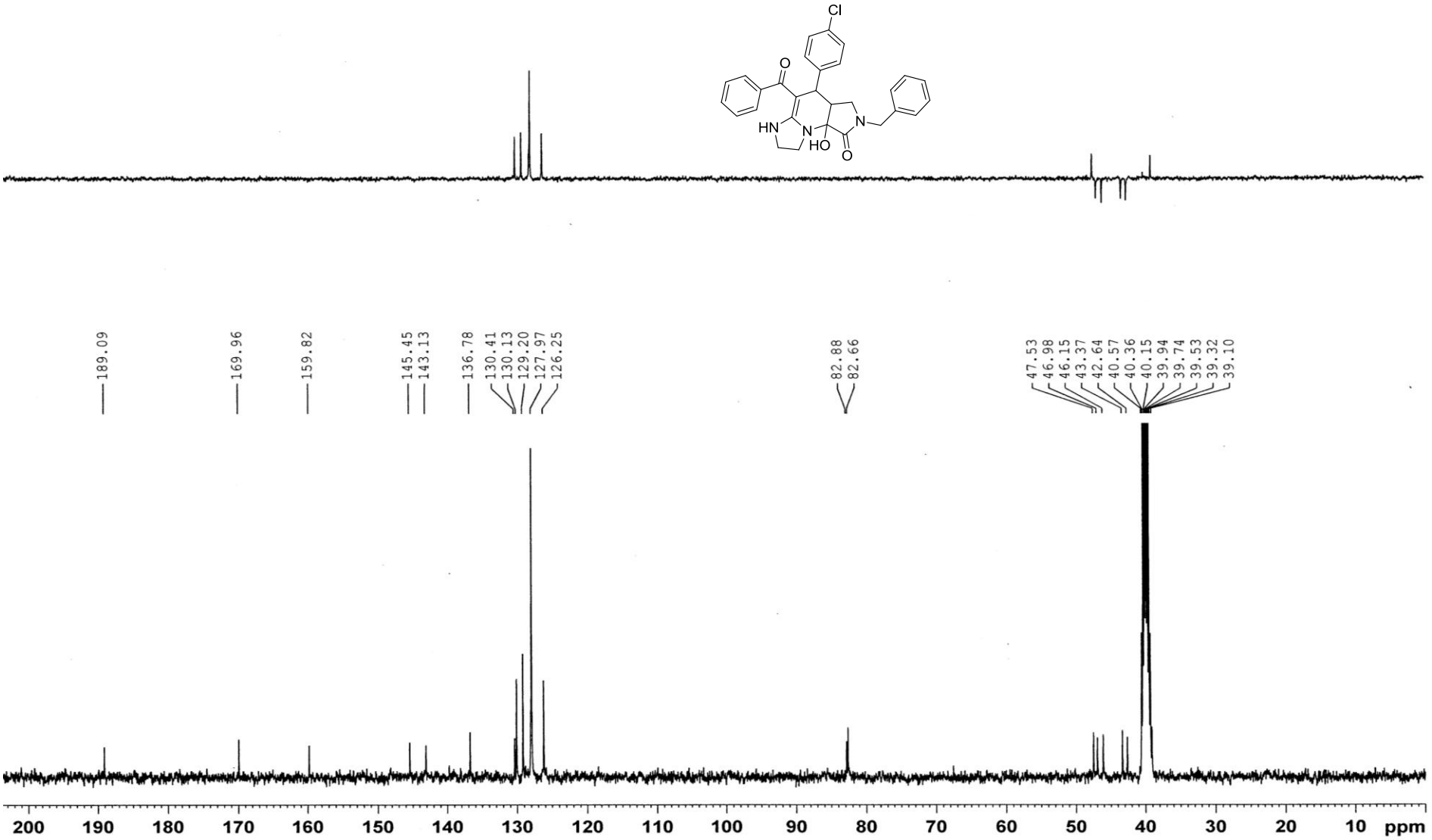


Figure 64. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4o**

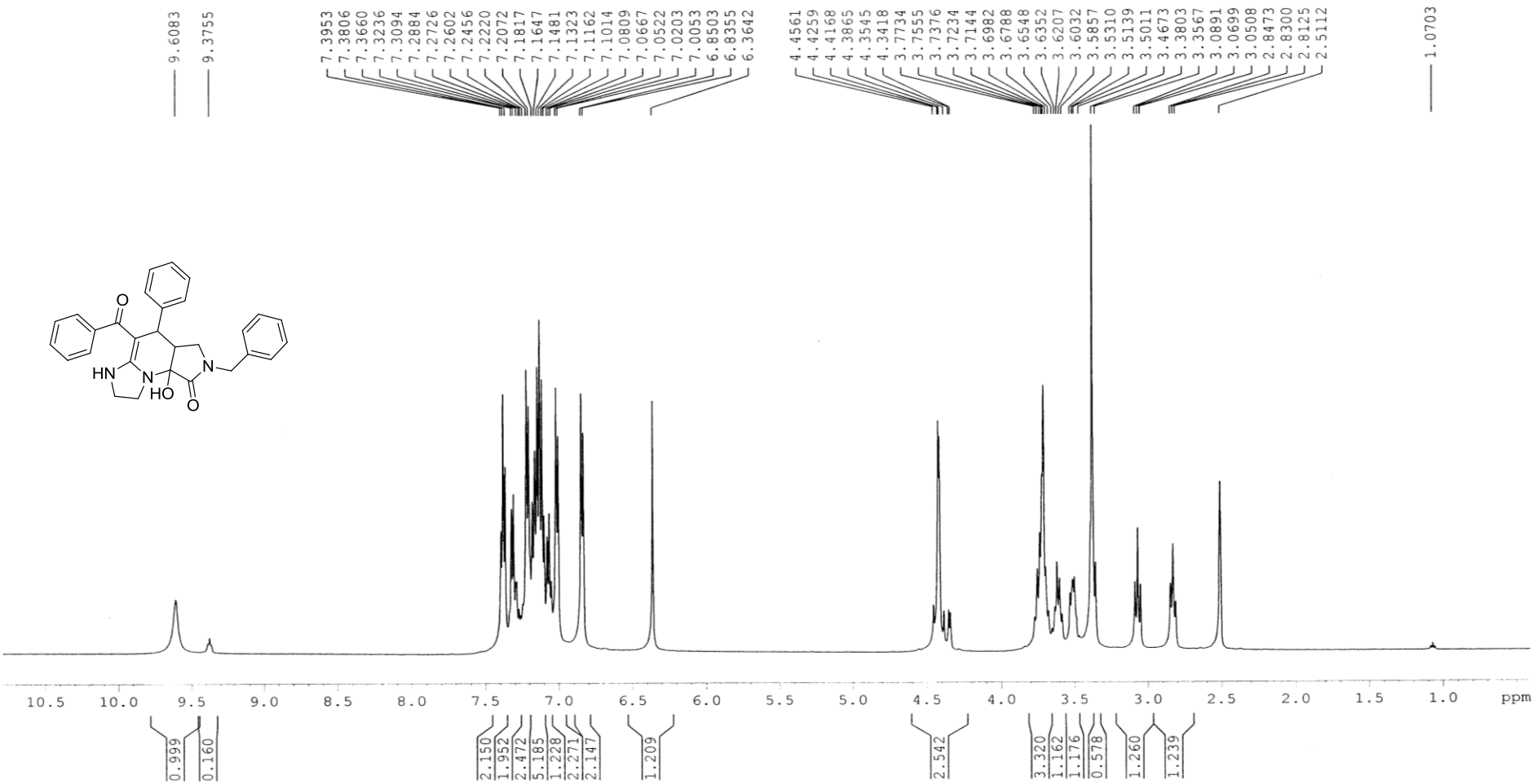


Figure 65. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4p**

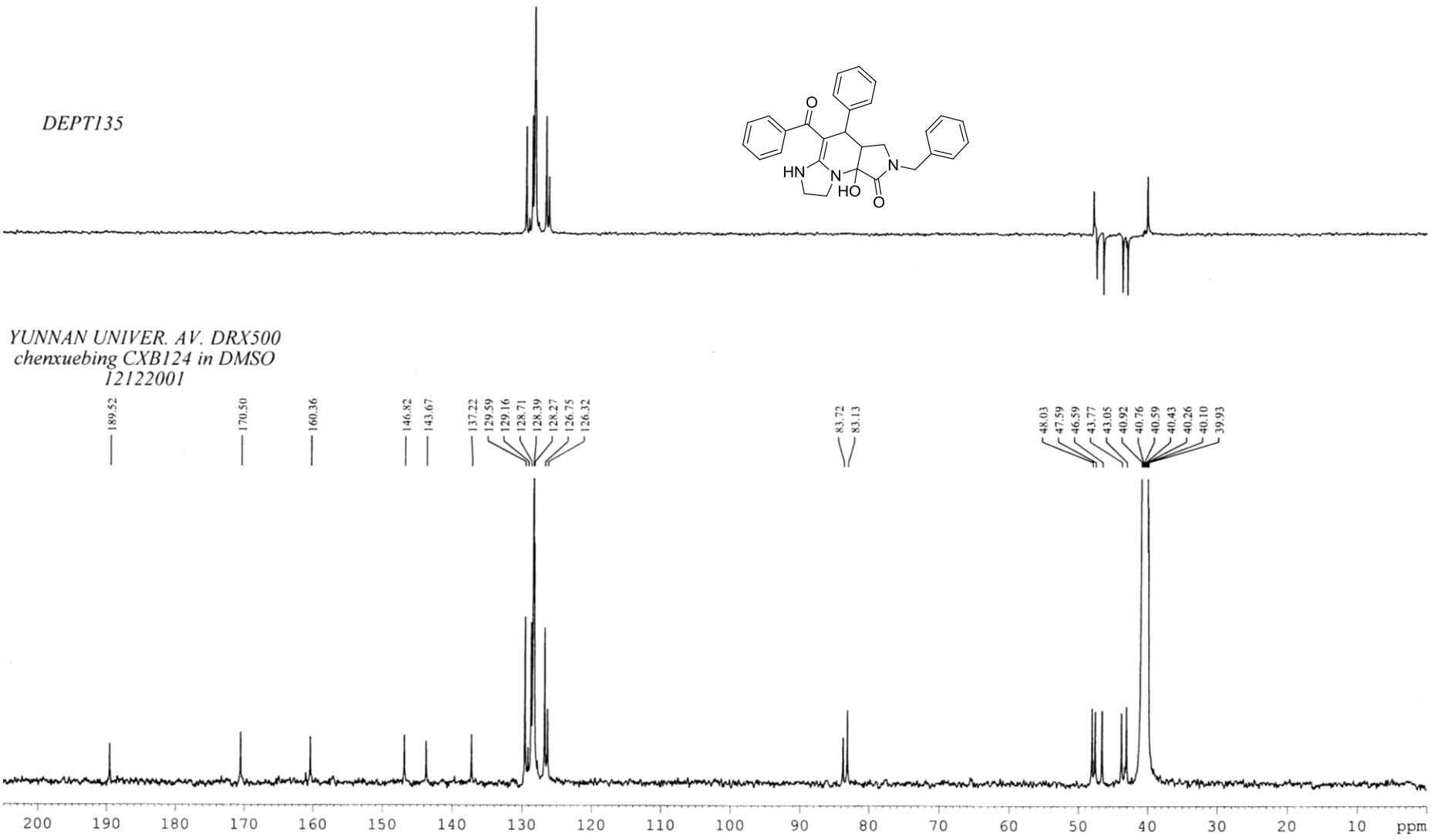


Figure 66. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4p**

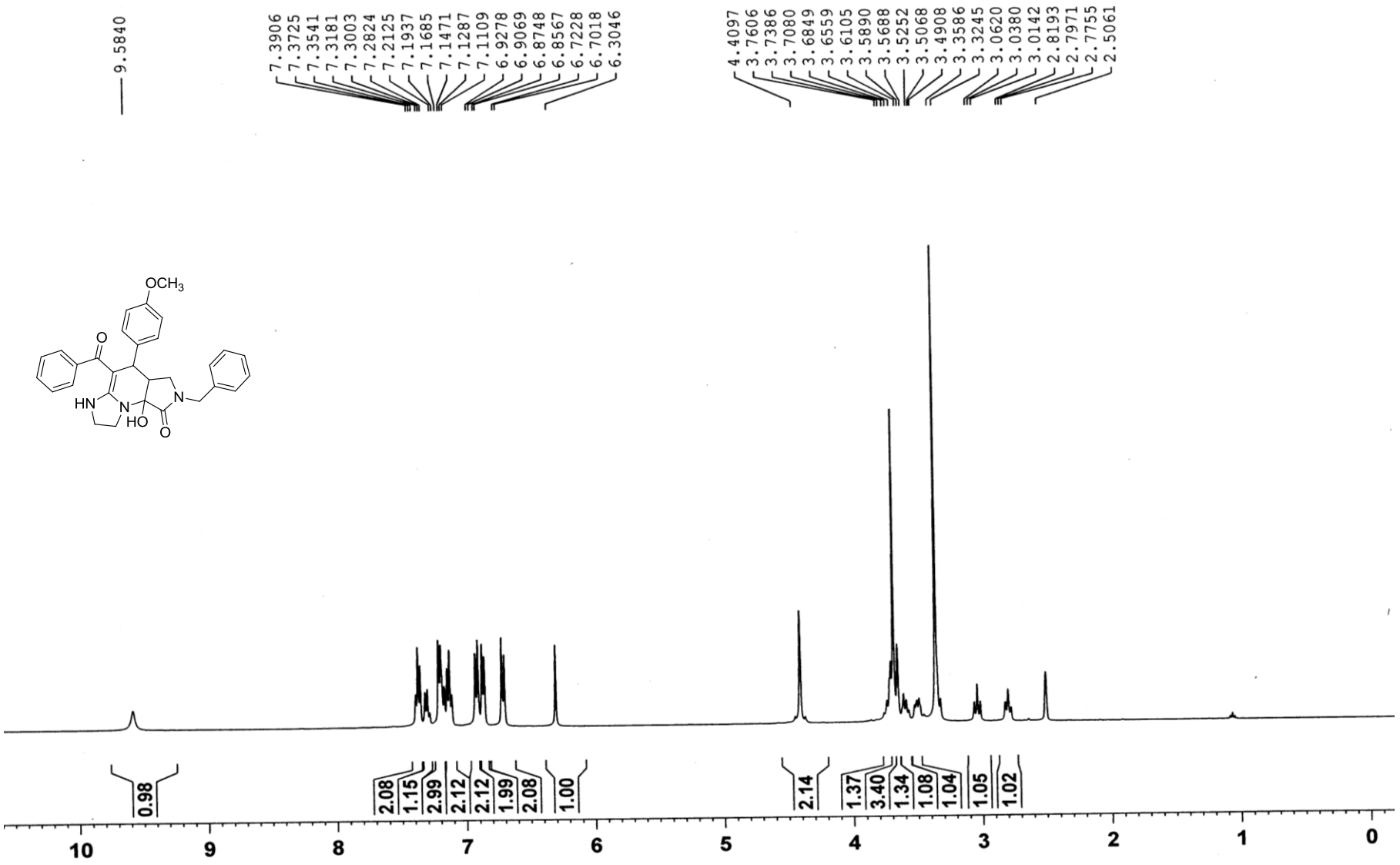


Figure 67. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4q**

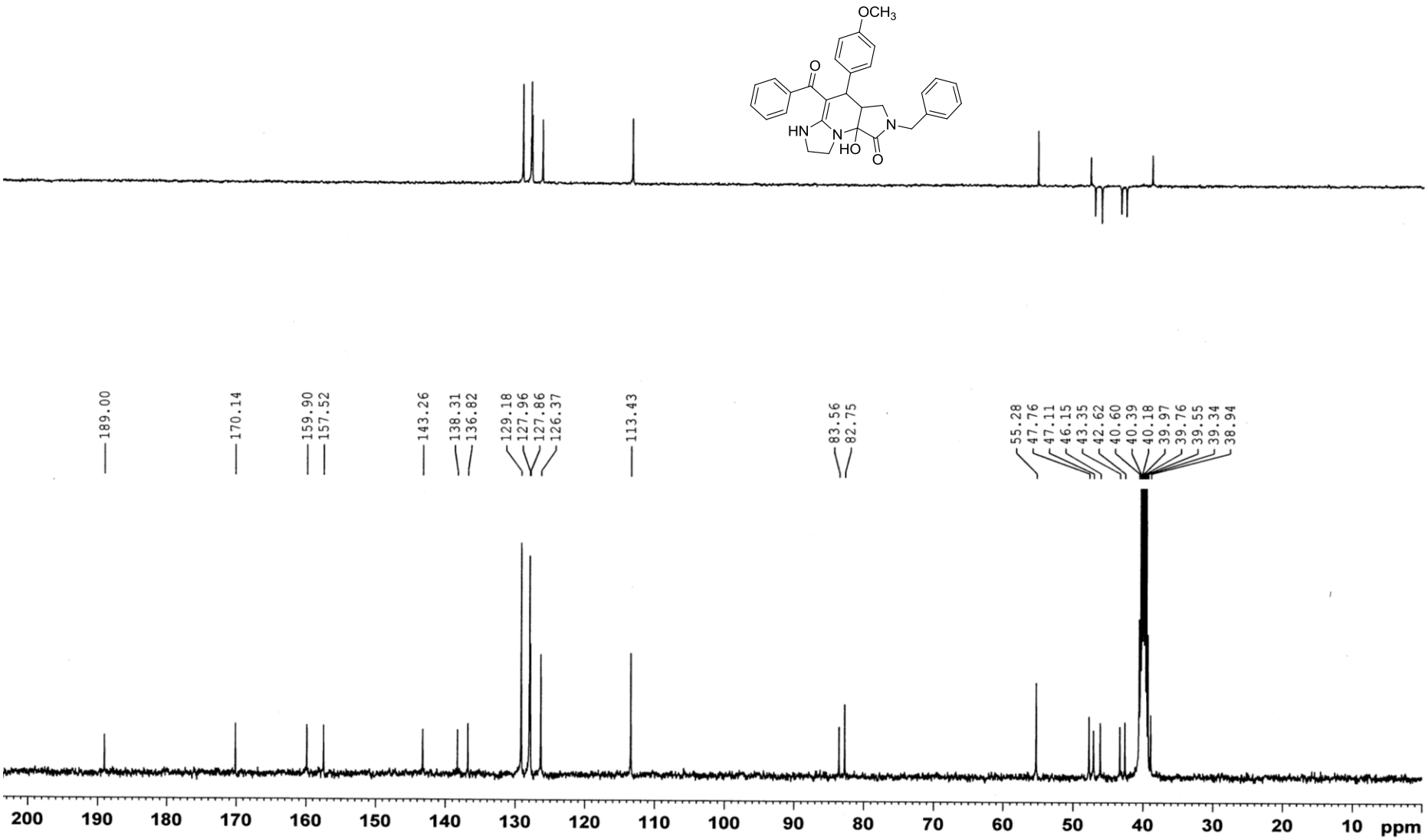


Figure 68. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4q**

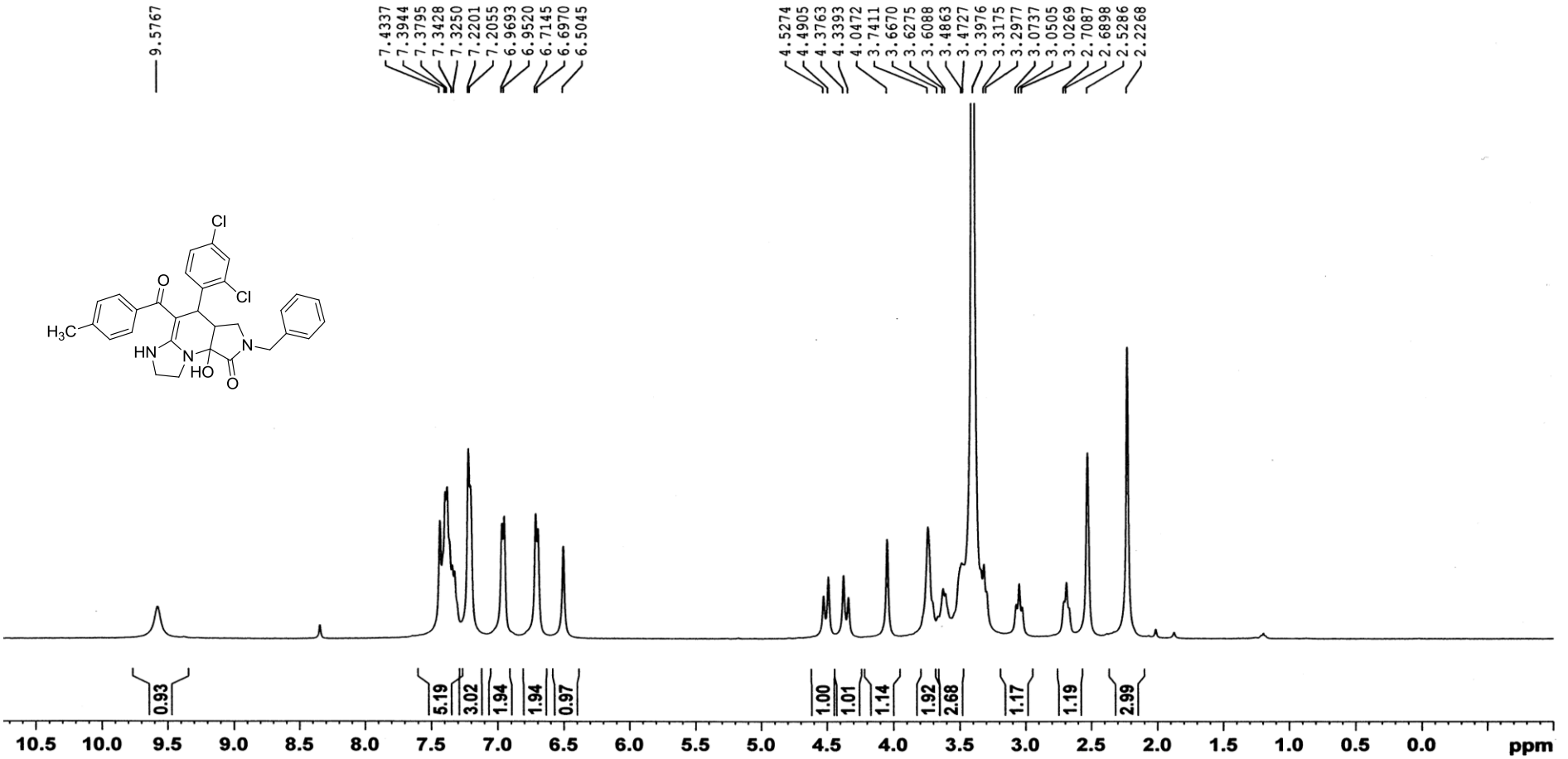


Figure 69. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4r**

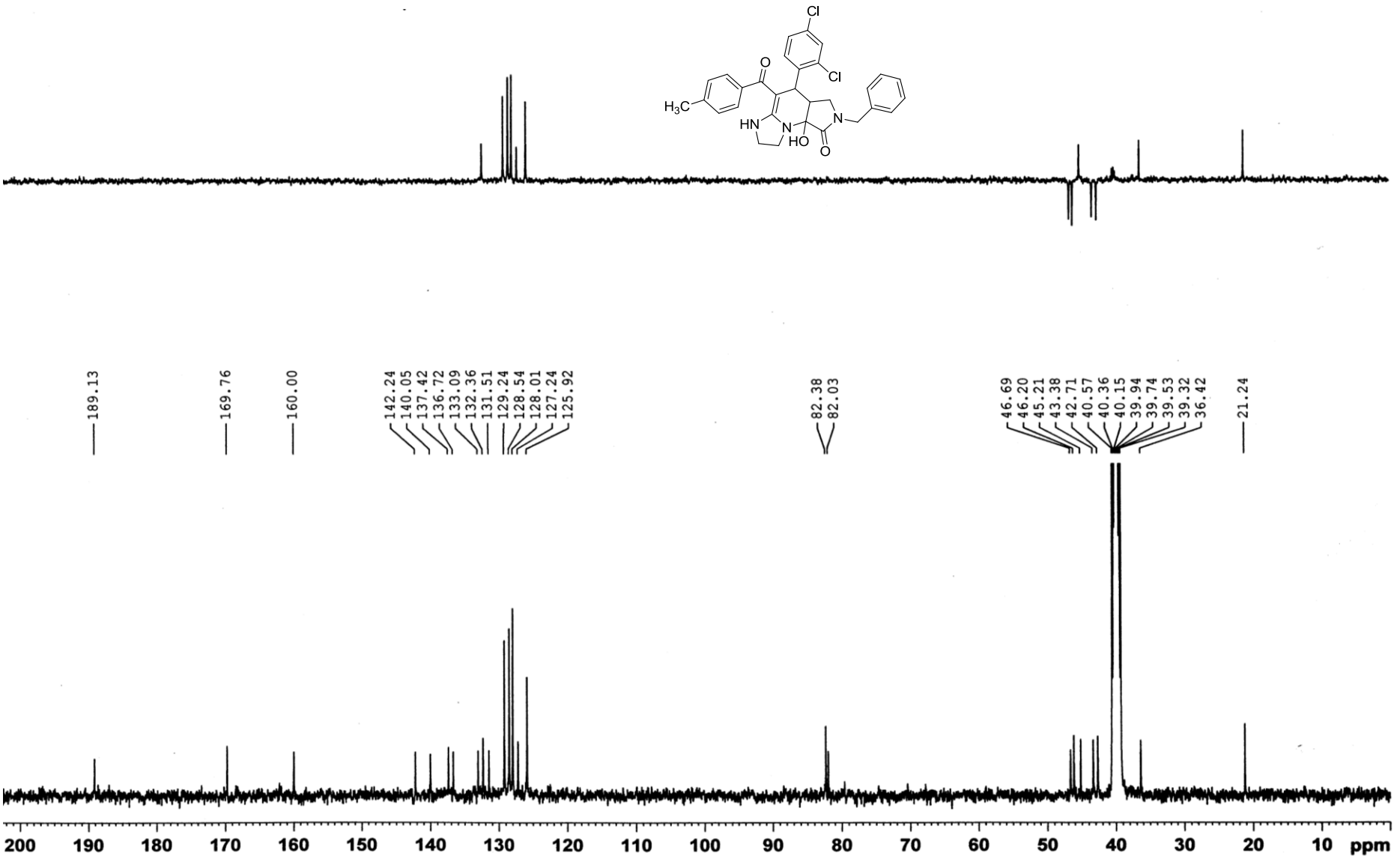


Figure 70. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4r**

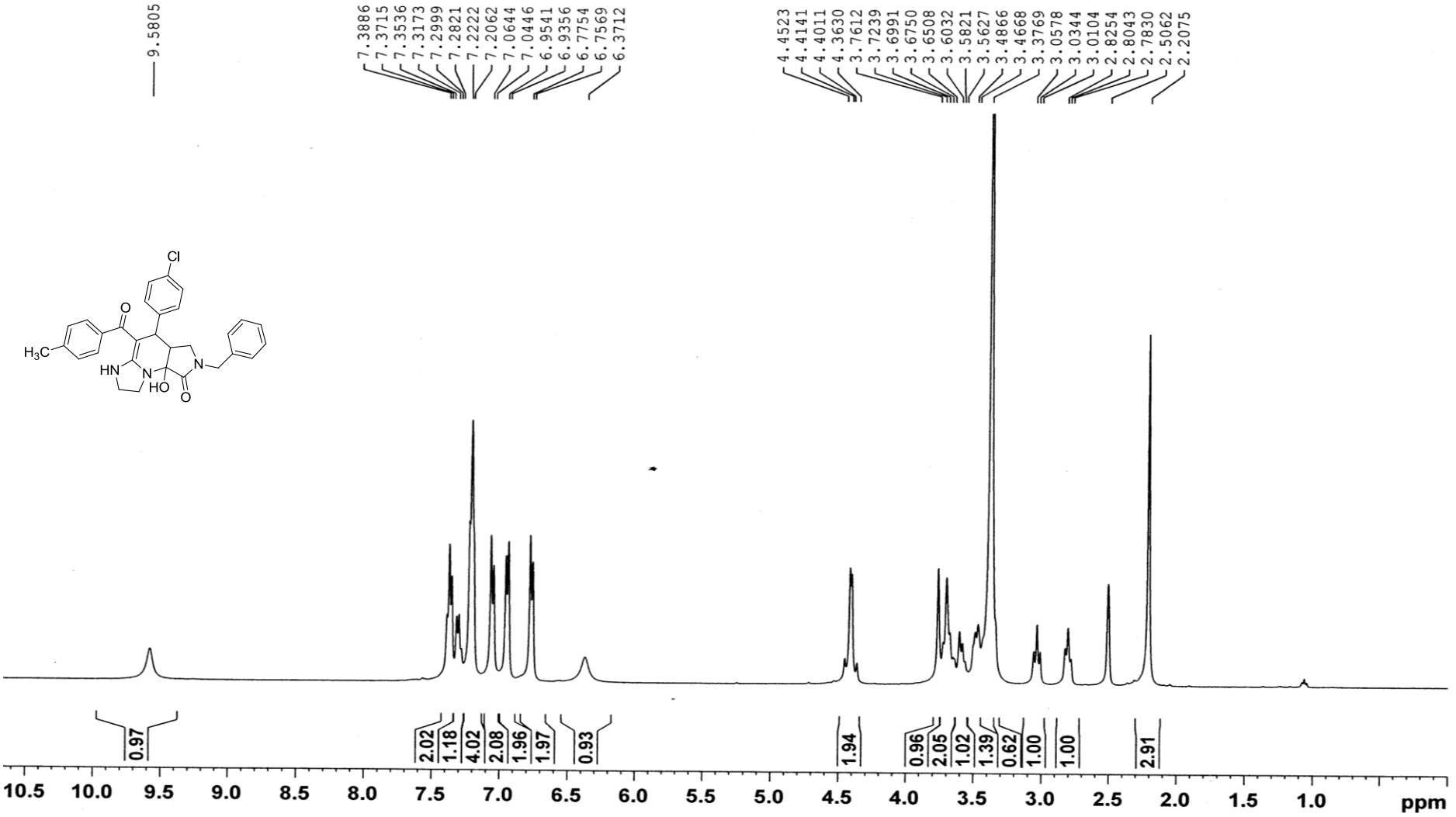


Figure 71. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4s**

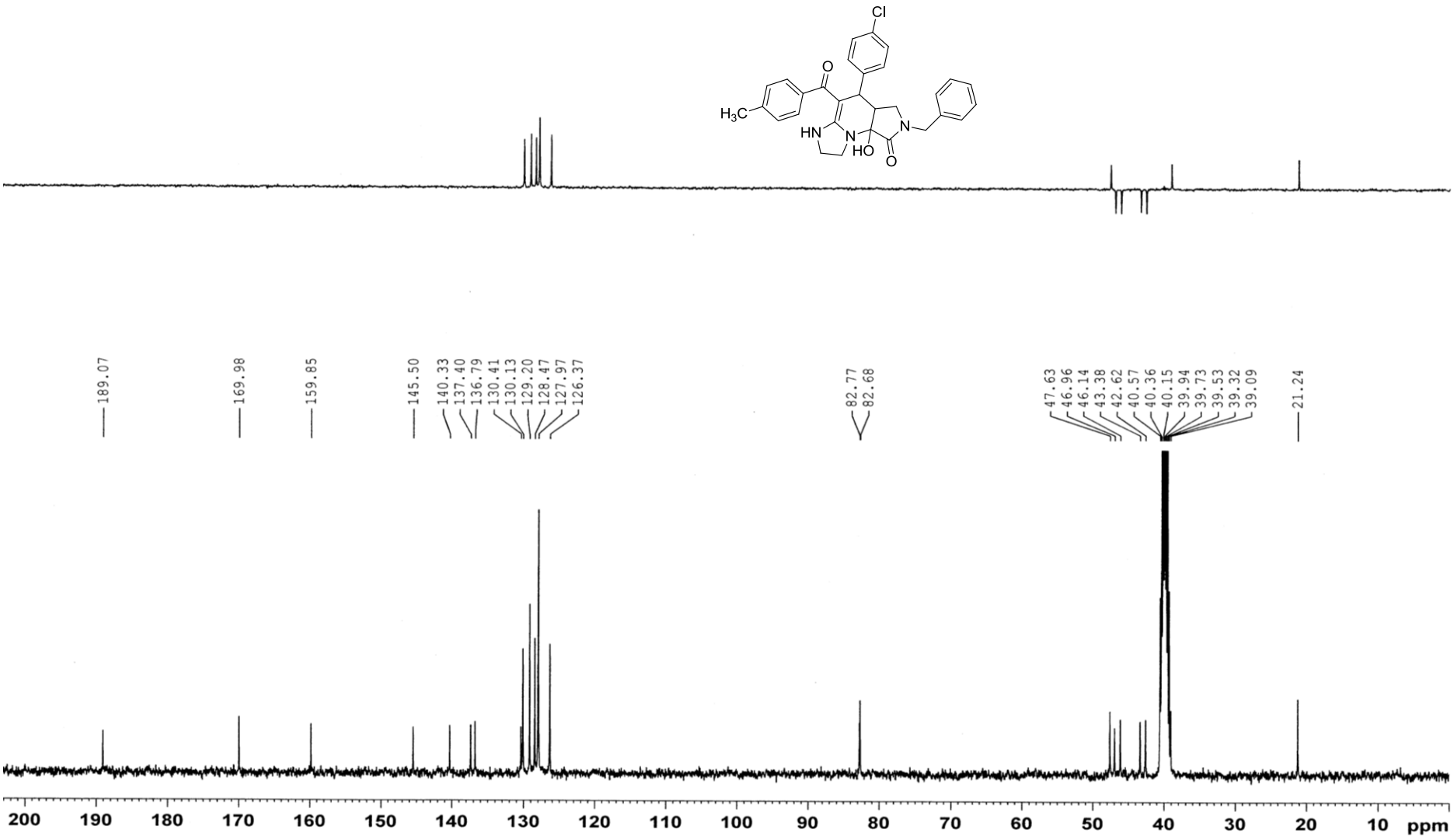


Figure 72. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4s**

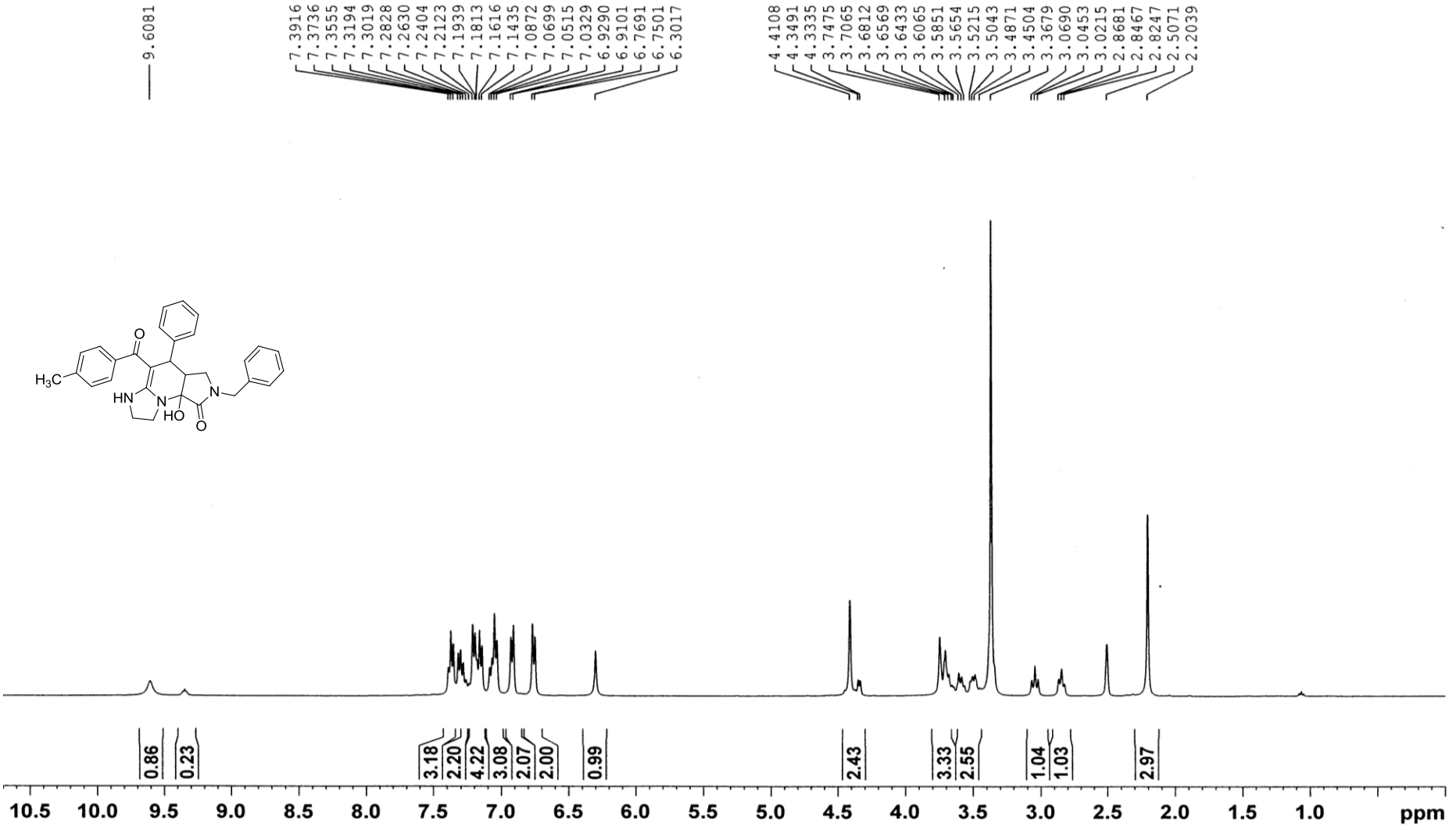


Figure 73. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4t**

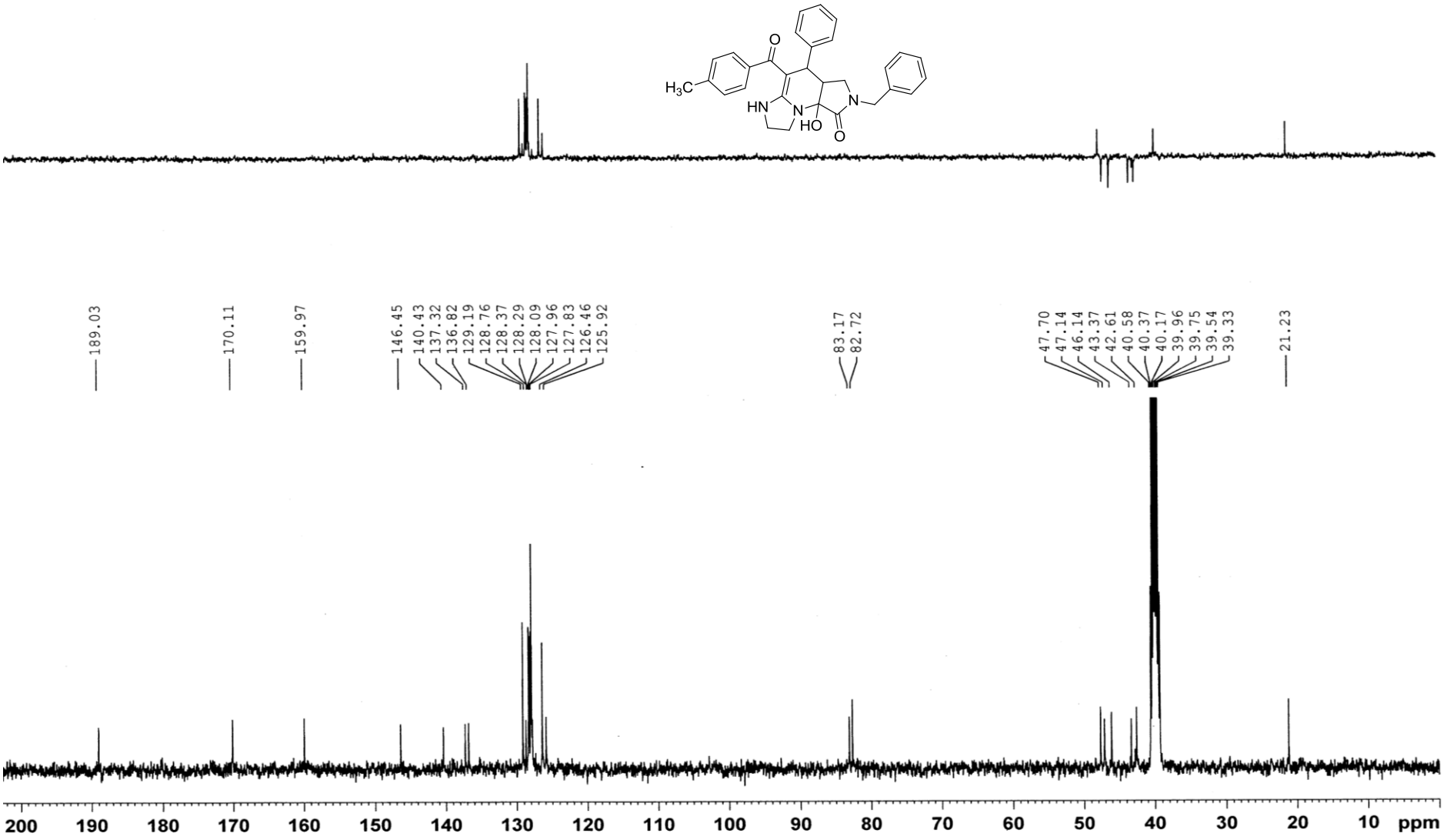


Figure 74. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4t**

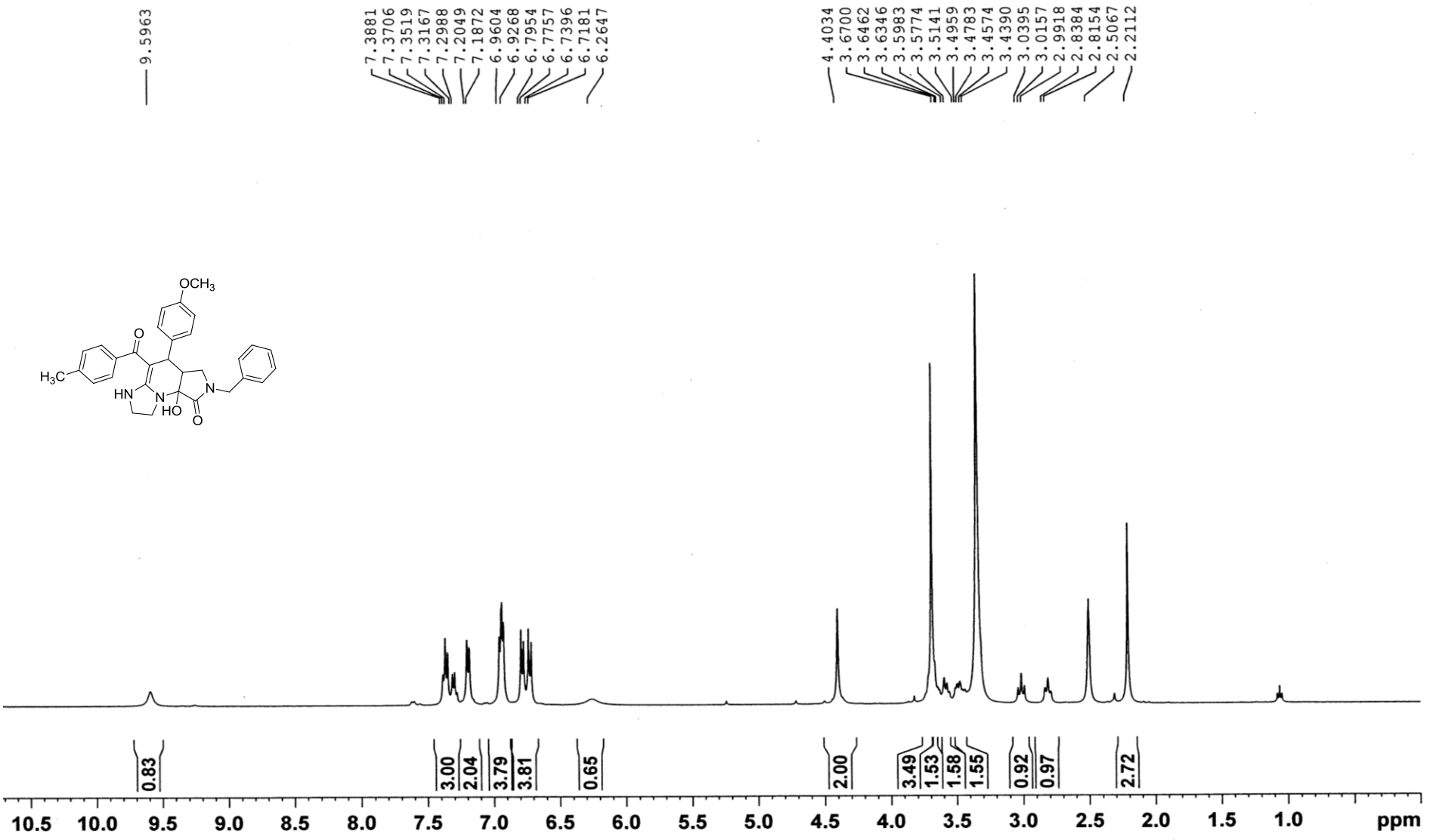


Figure 75. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4u**

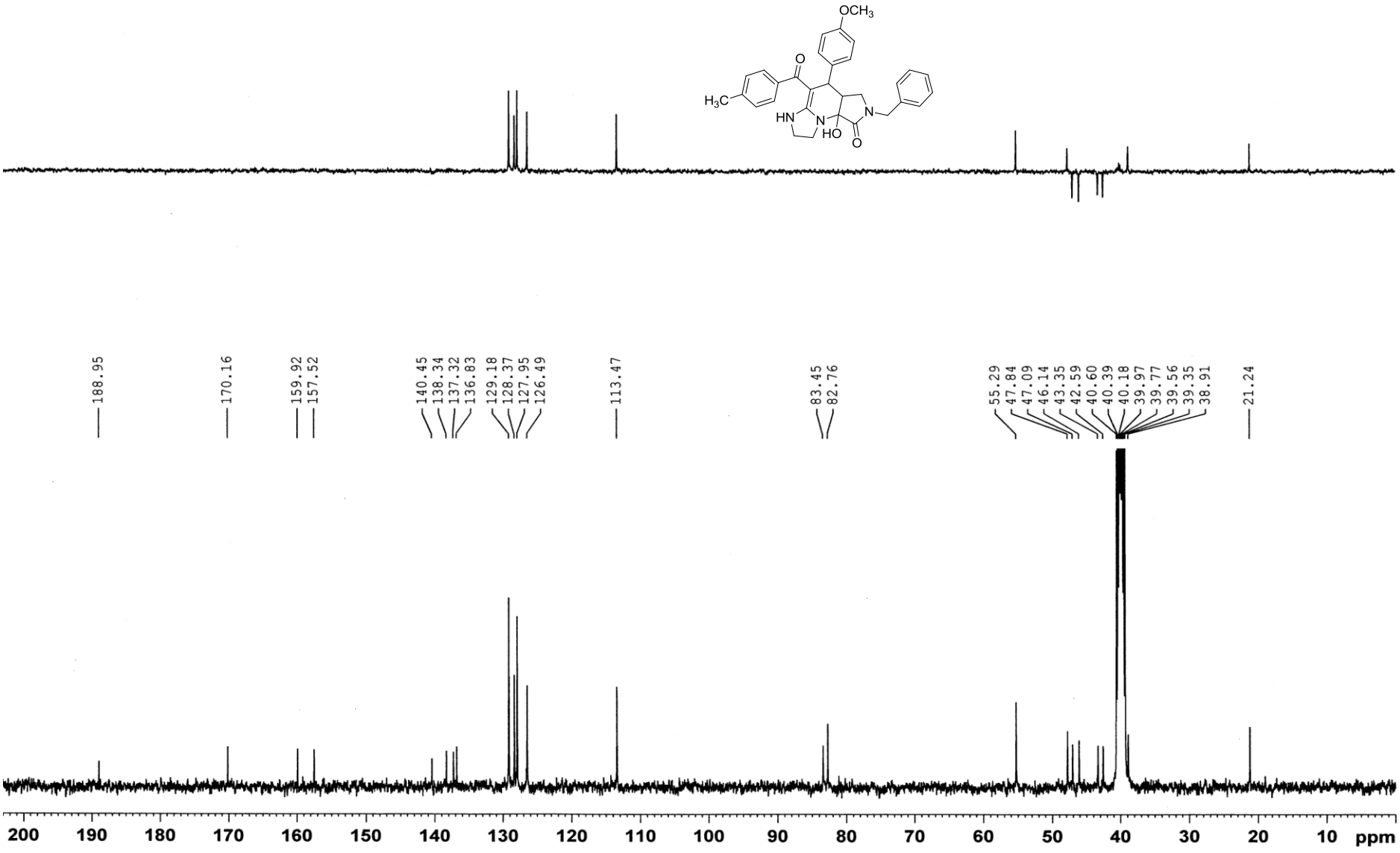


Figure 76. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4u**

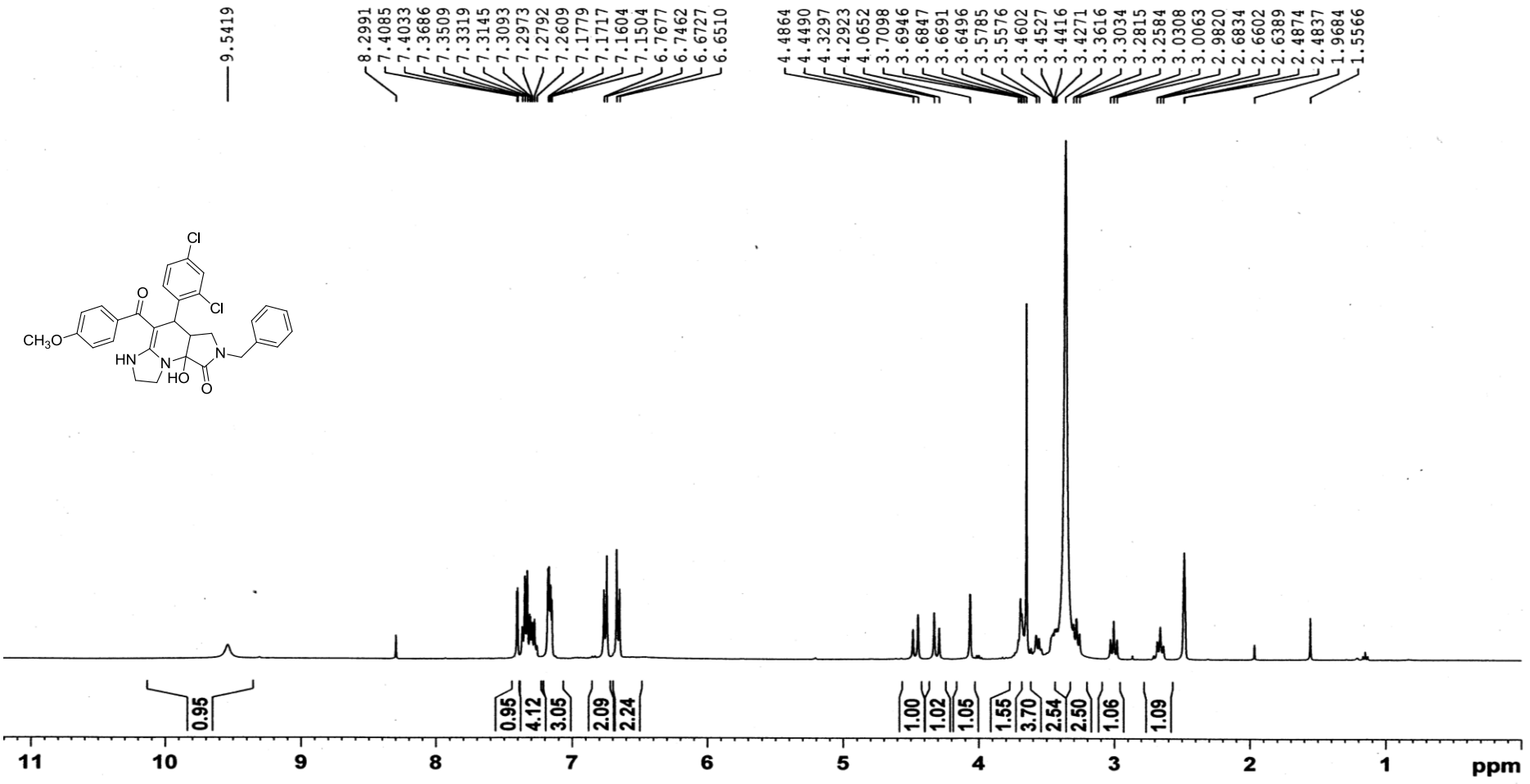


Figure 77. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4v**

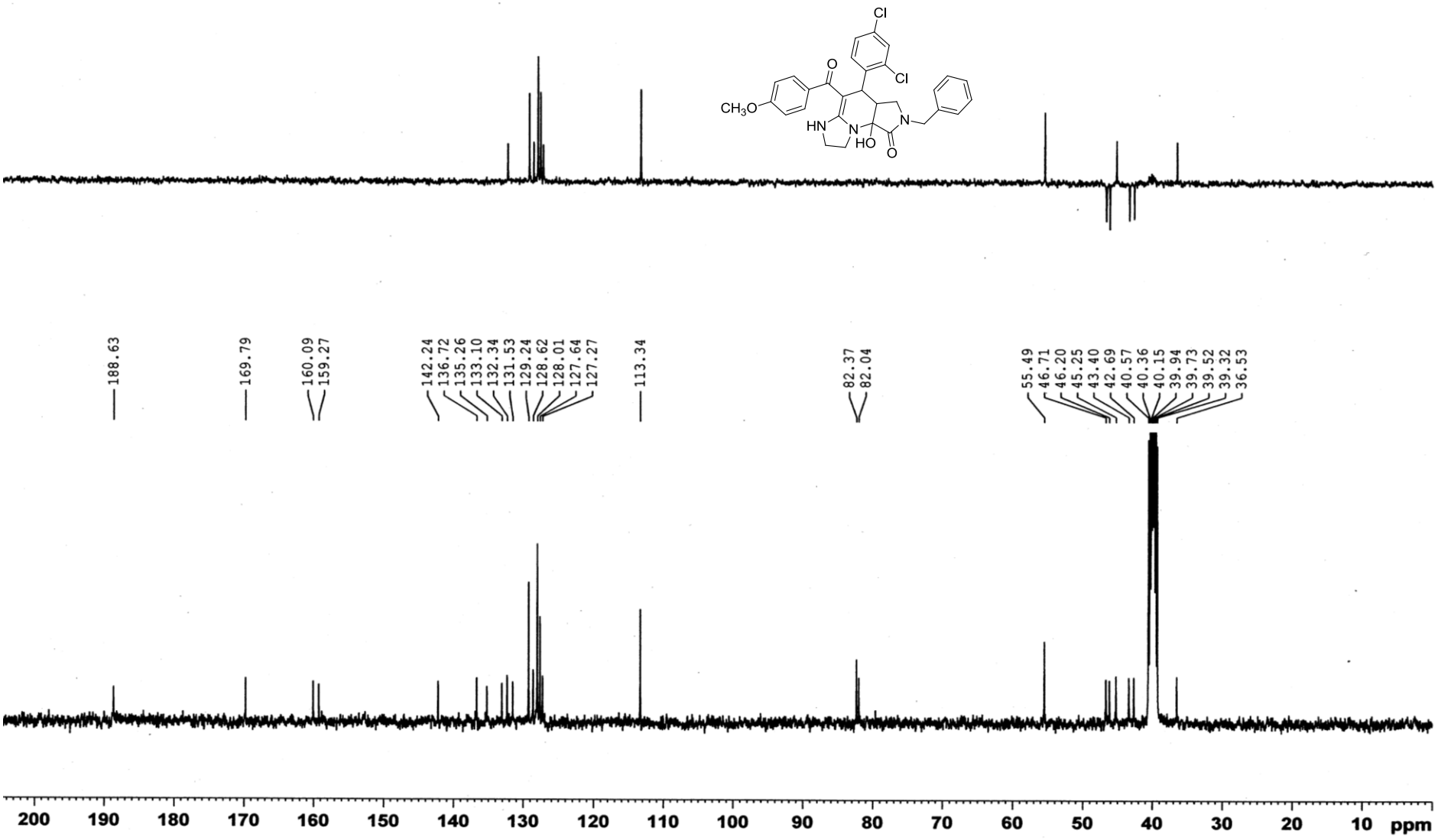


Figure 78. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4v**

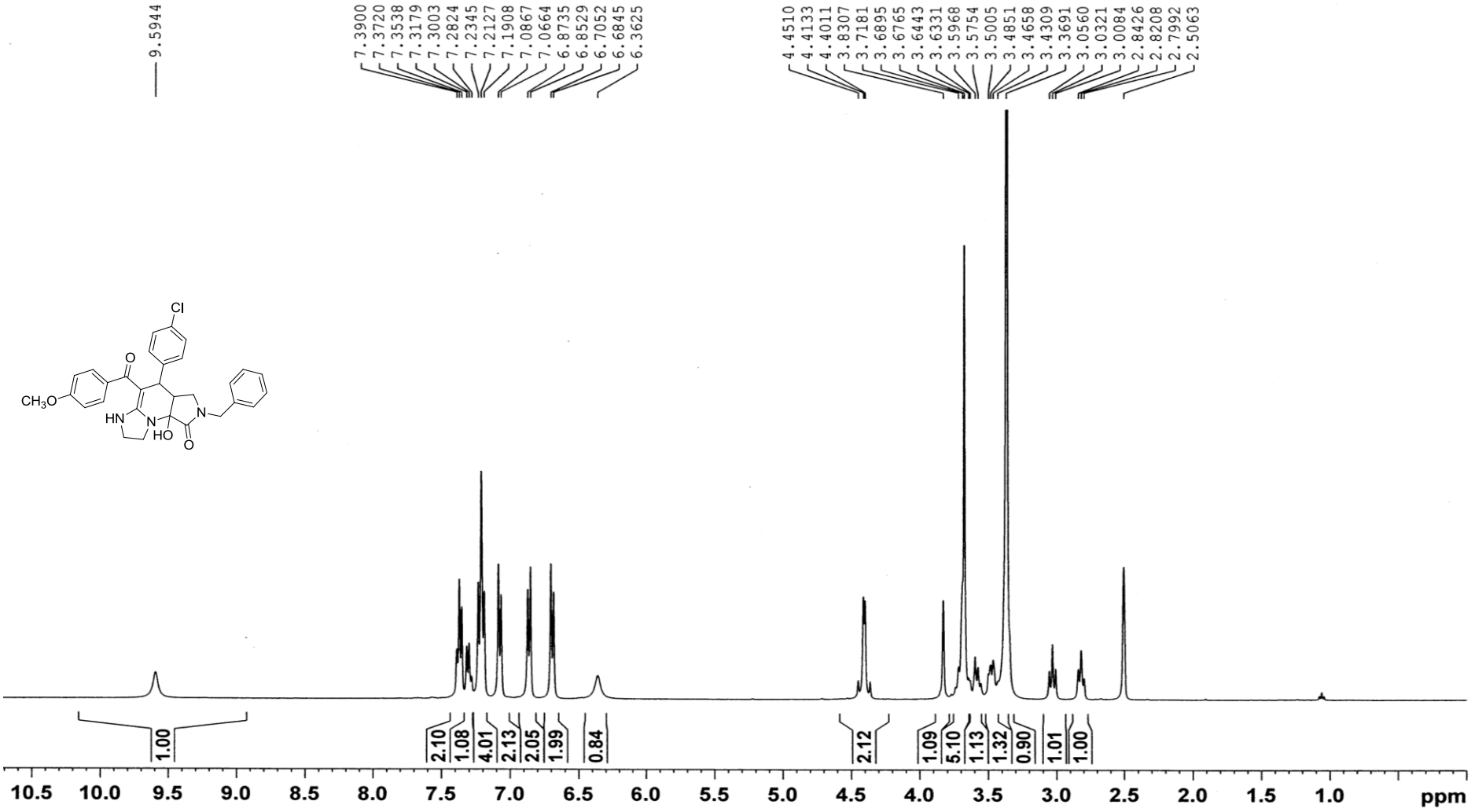


Figure 79. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4w**

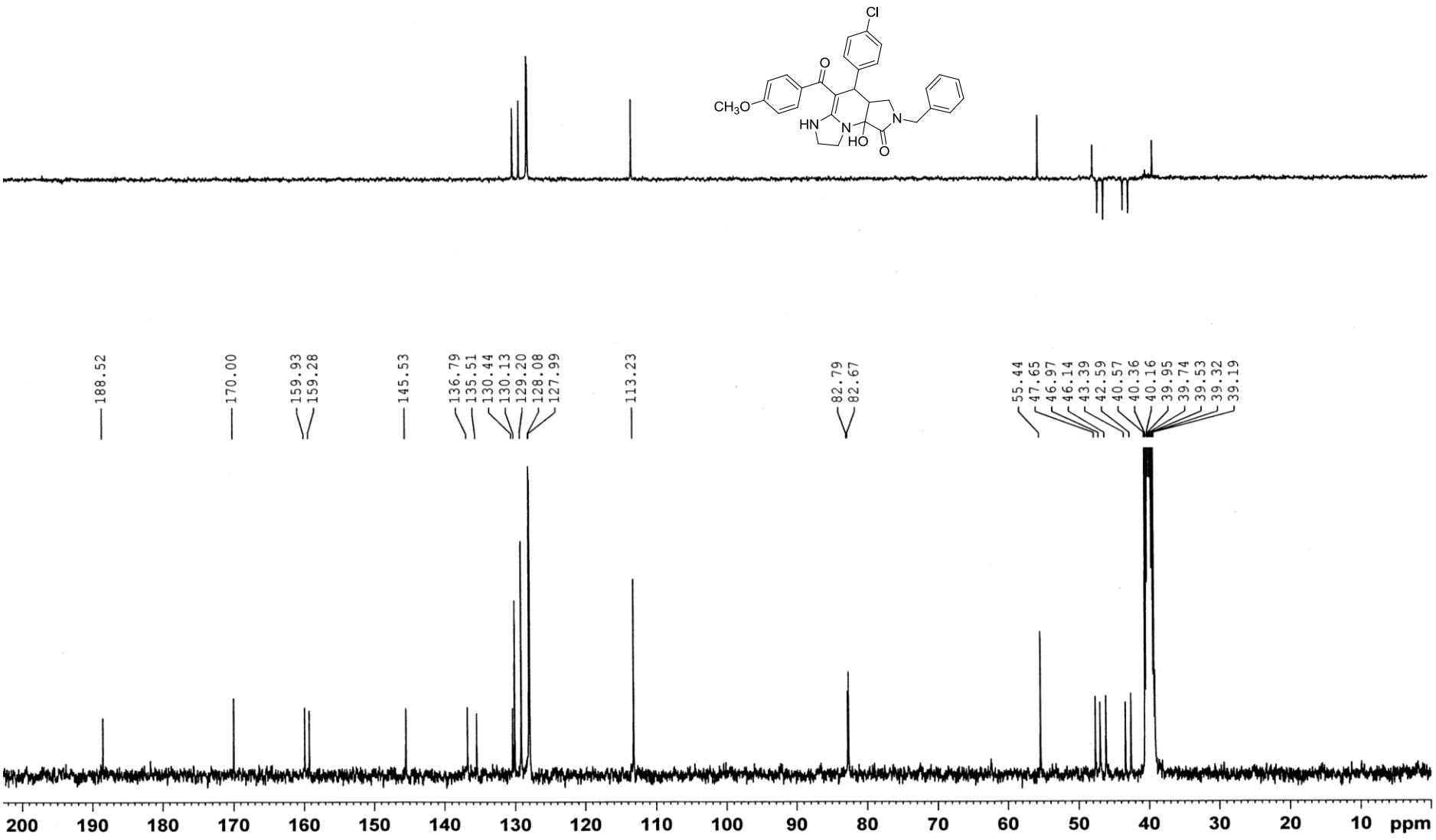


Figure 80. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4w**

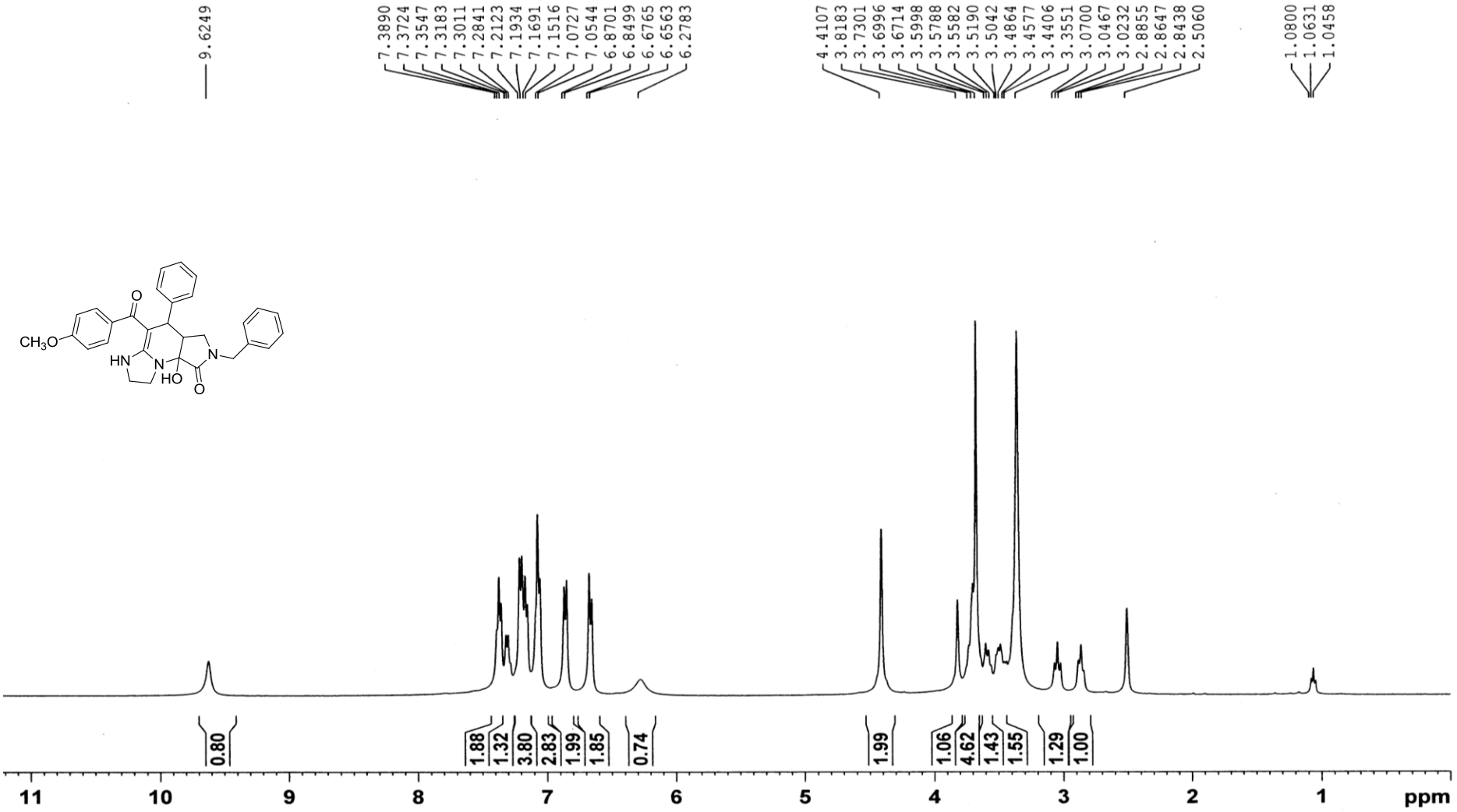


Figure 81. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4x**

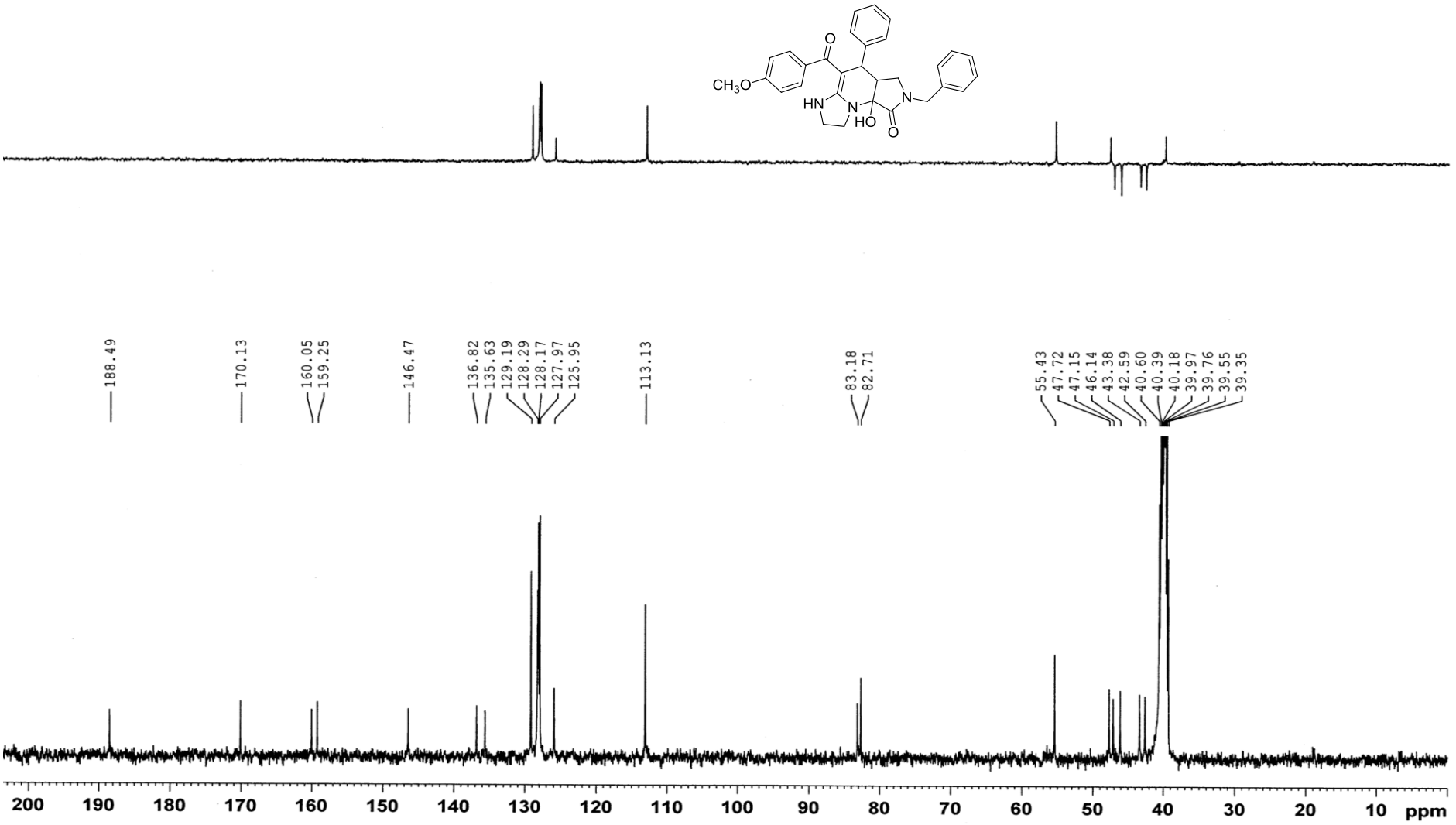


Figure 82. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4x**

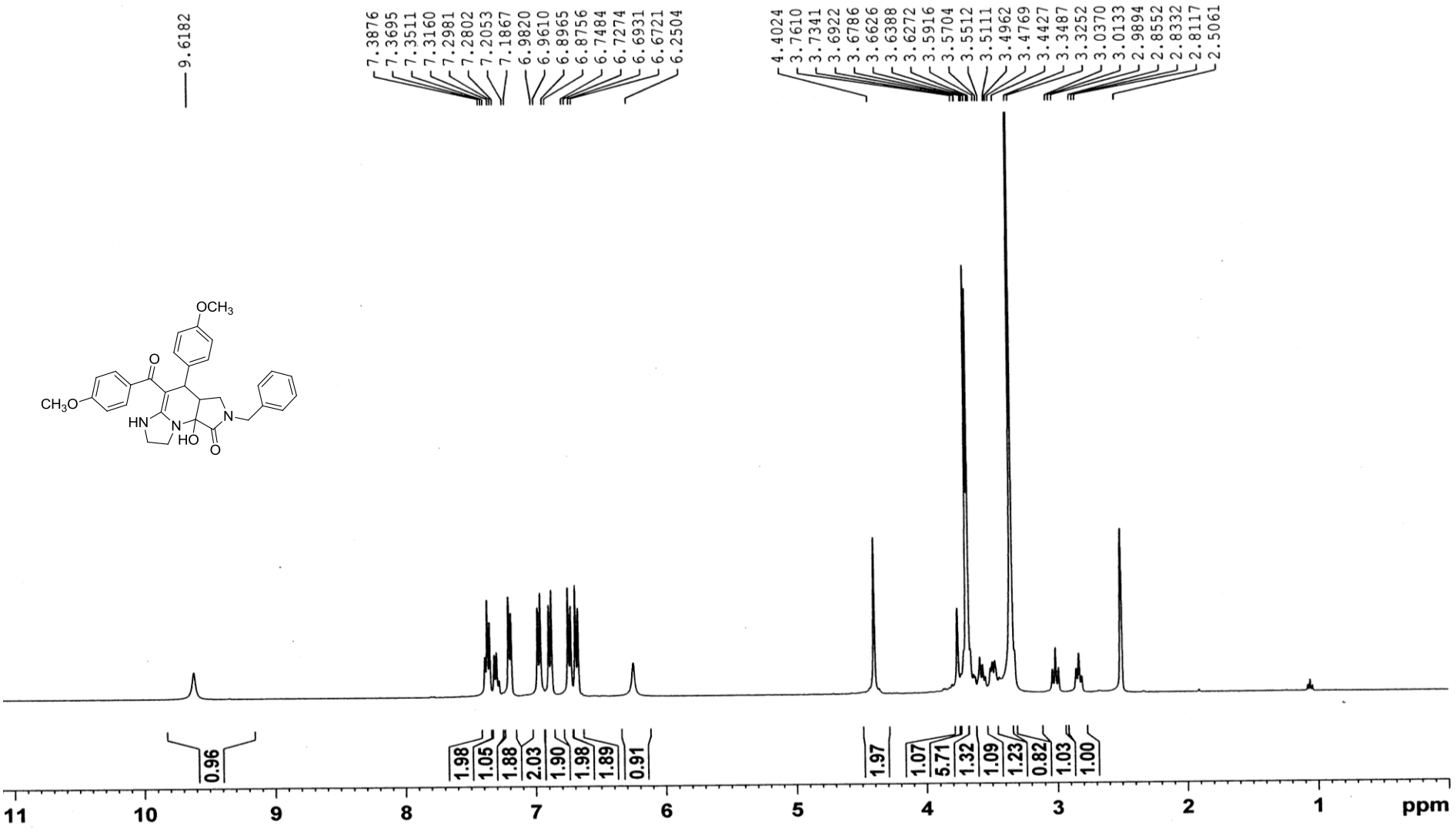


Figure 83. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **4y**

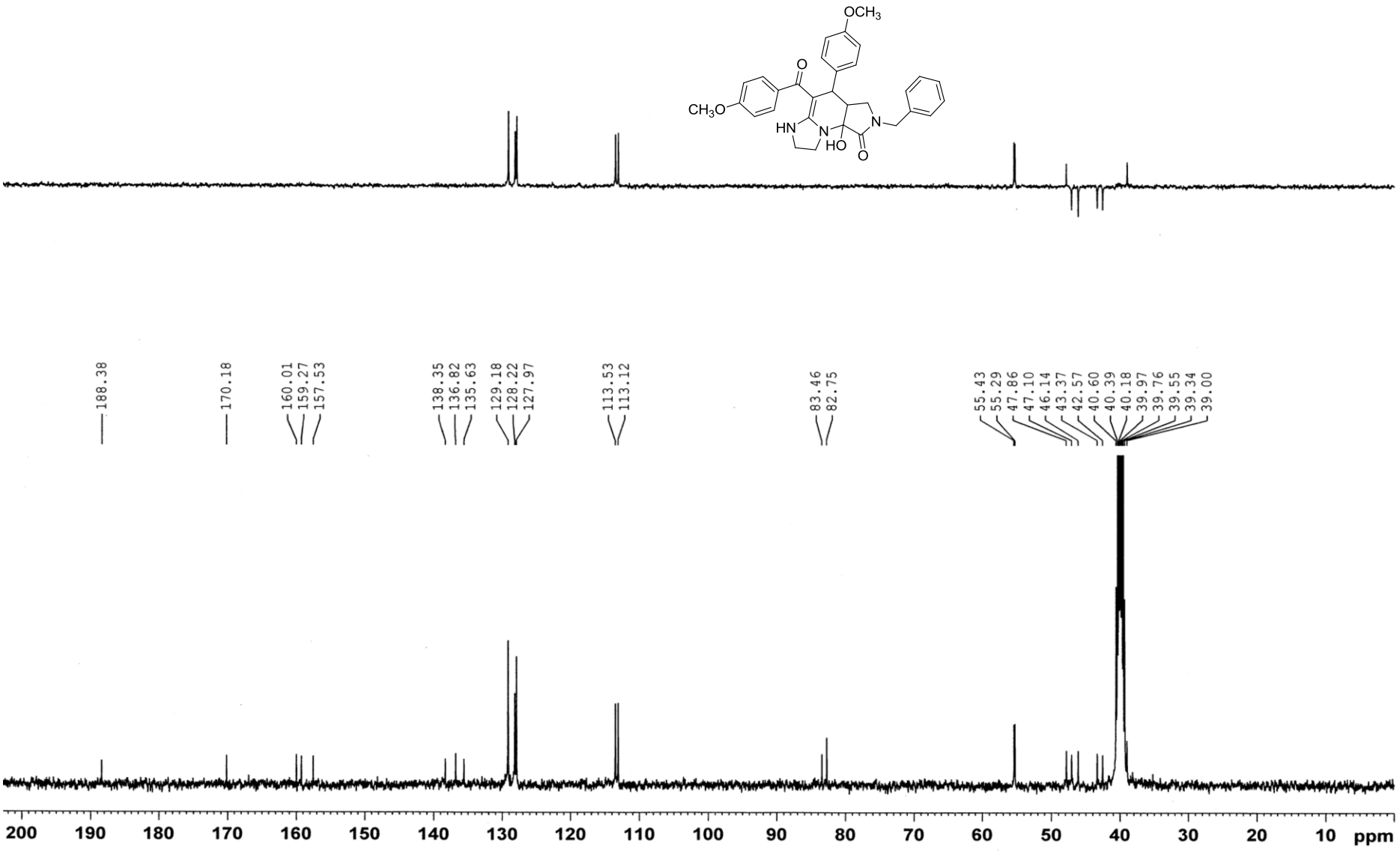


Figure 84. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **4y**

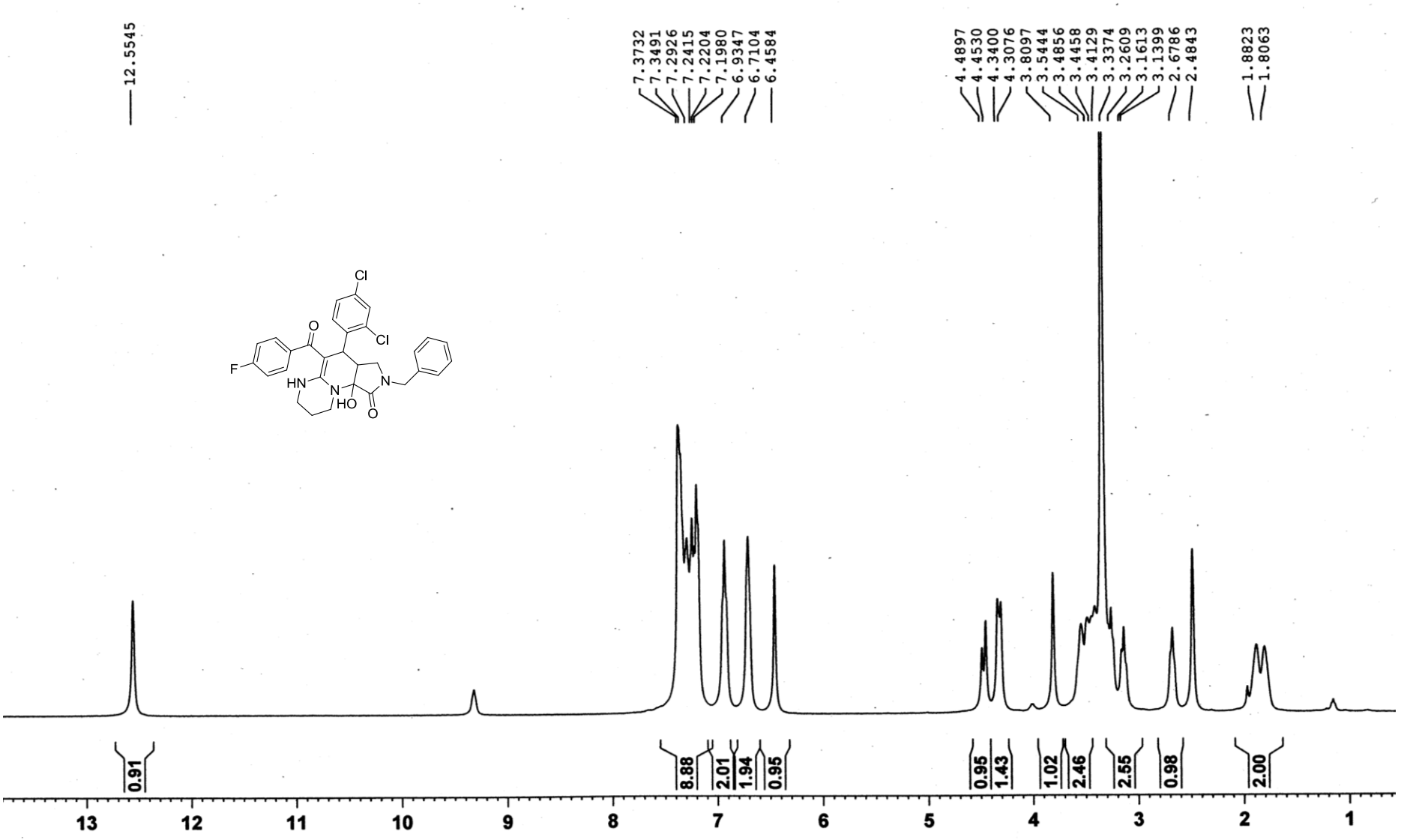


Figure 85. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **5a**

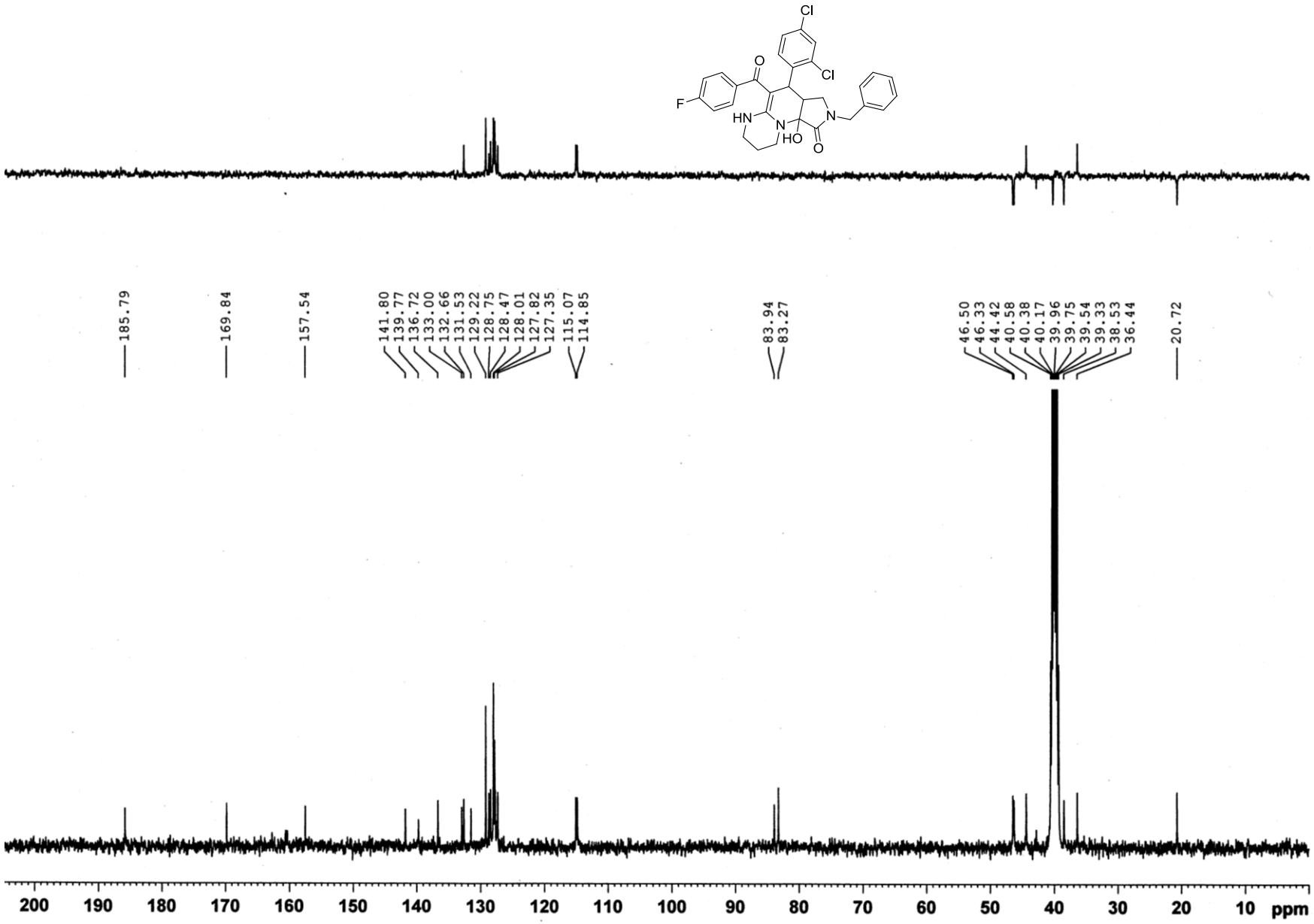


Figure 86. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **5a**

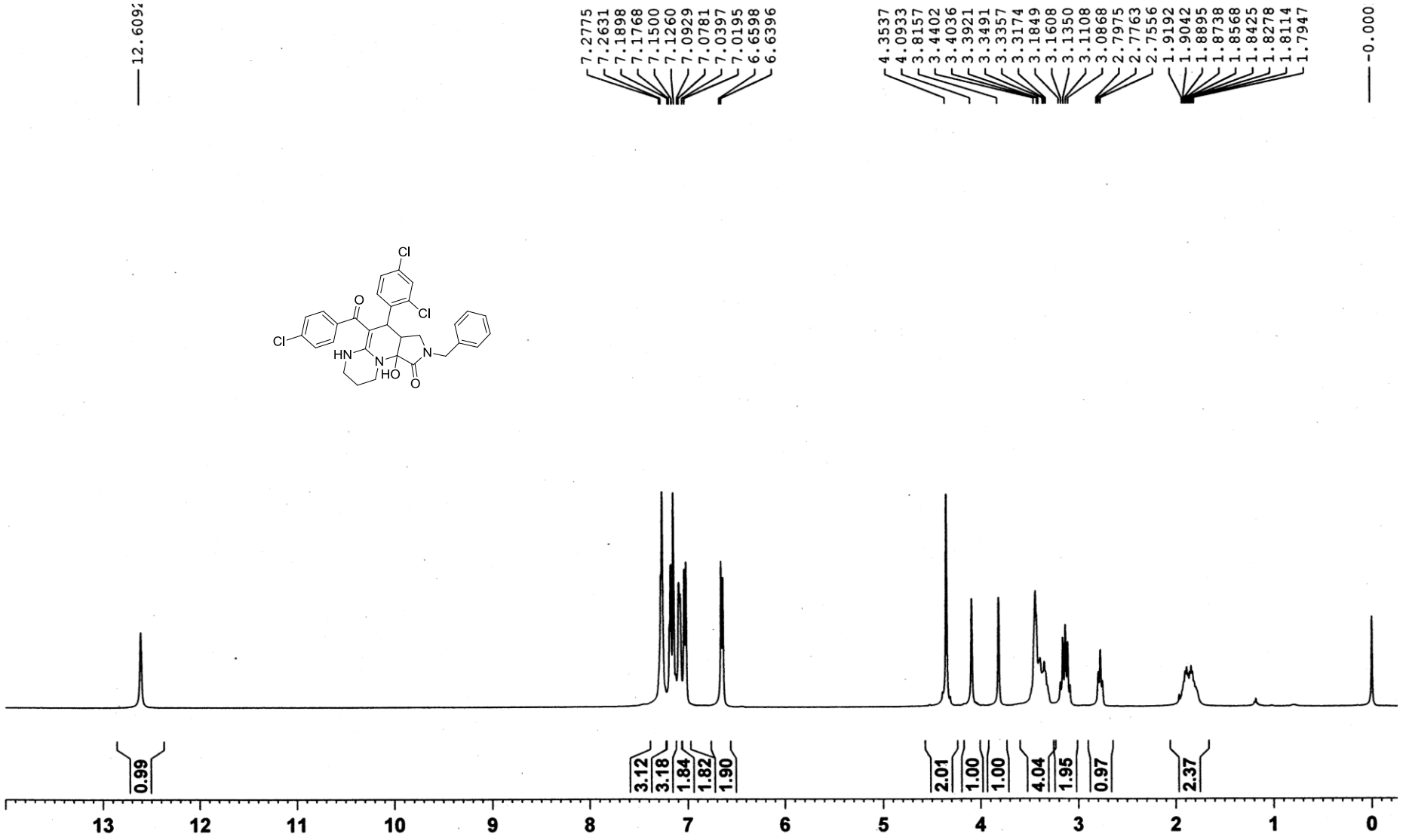


Figure 87. ^{1}H NMR (400 MHz, $CDCl_3$-*d*) spectra of compound **5b**

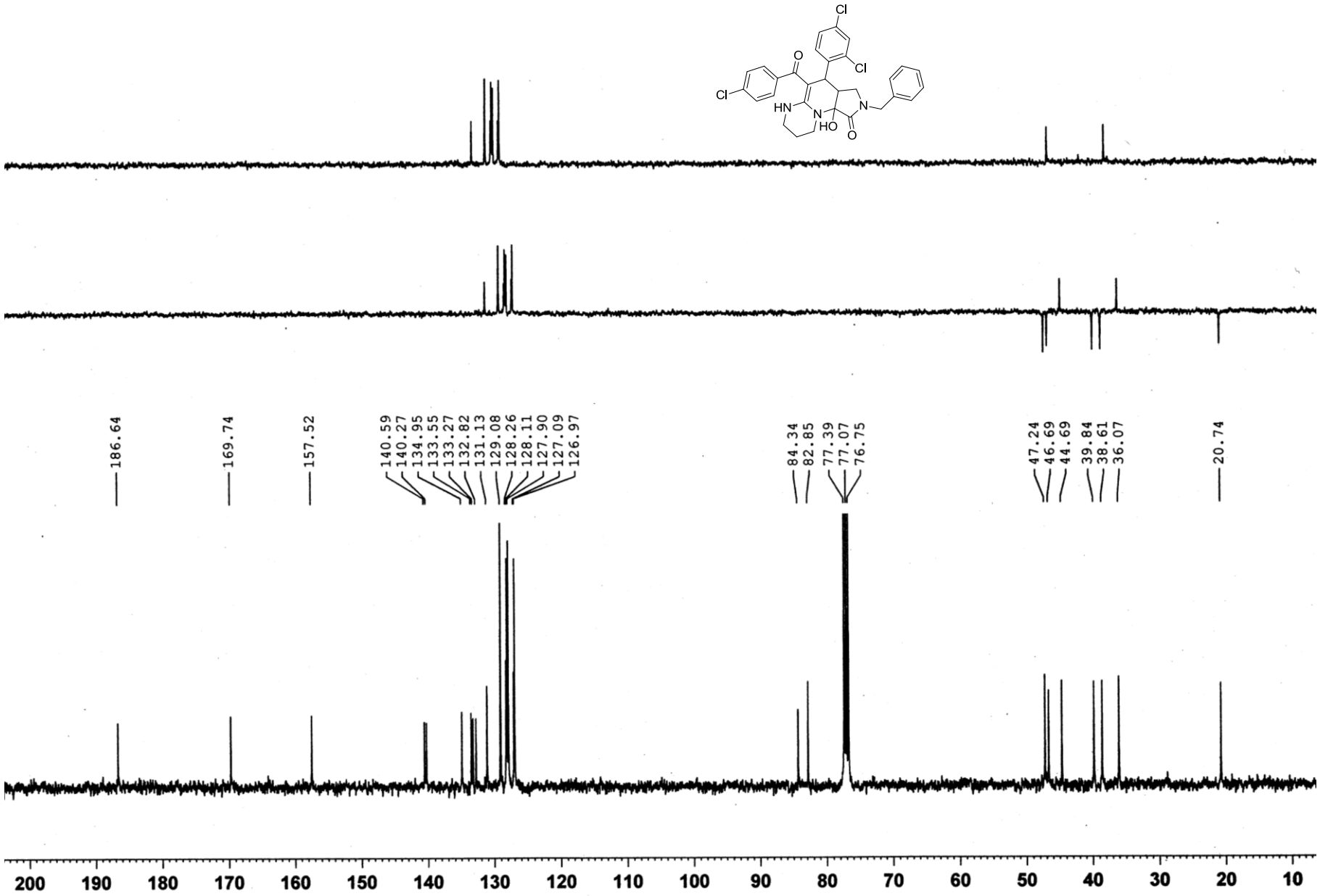


Figure 88. ^{13}C NMR (100 MHz, $CDCl_3$-*d*) spectra of compound **5b**

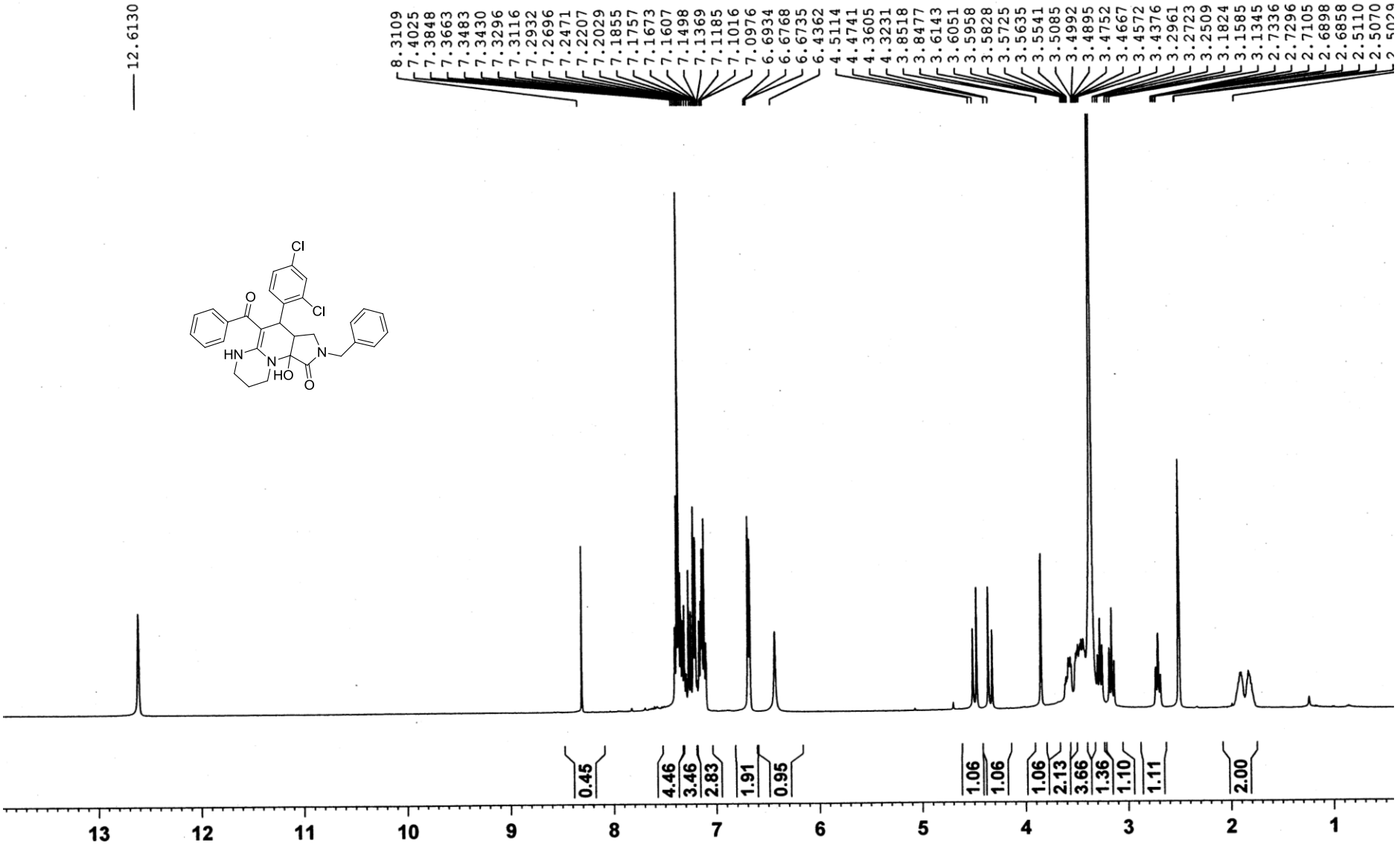


Figure 89. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **5c**

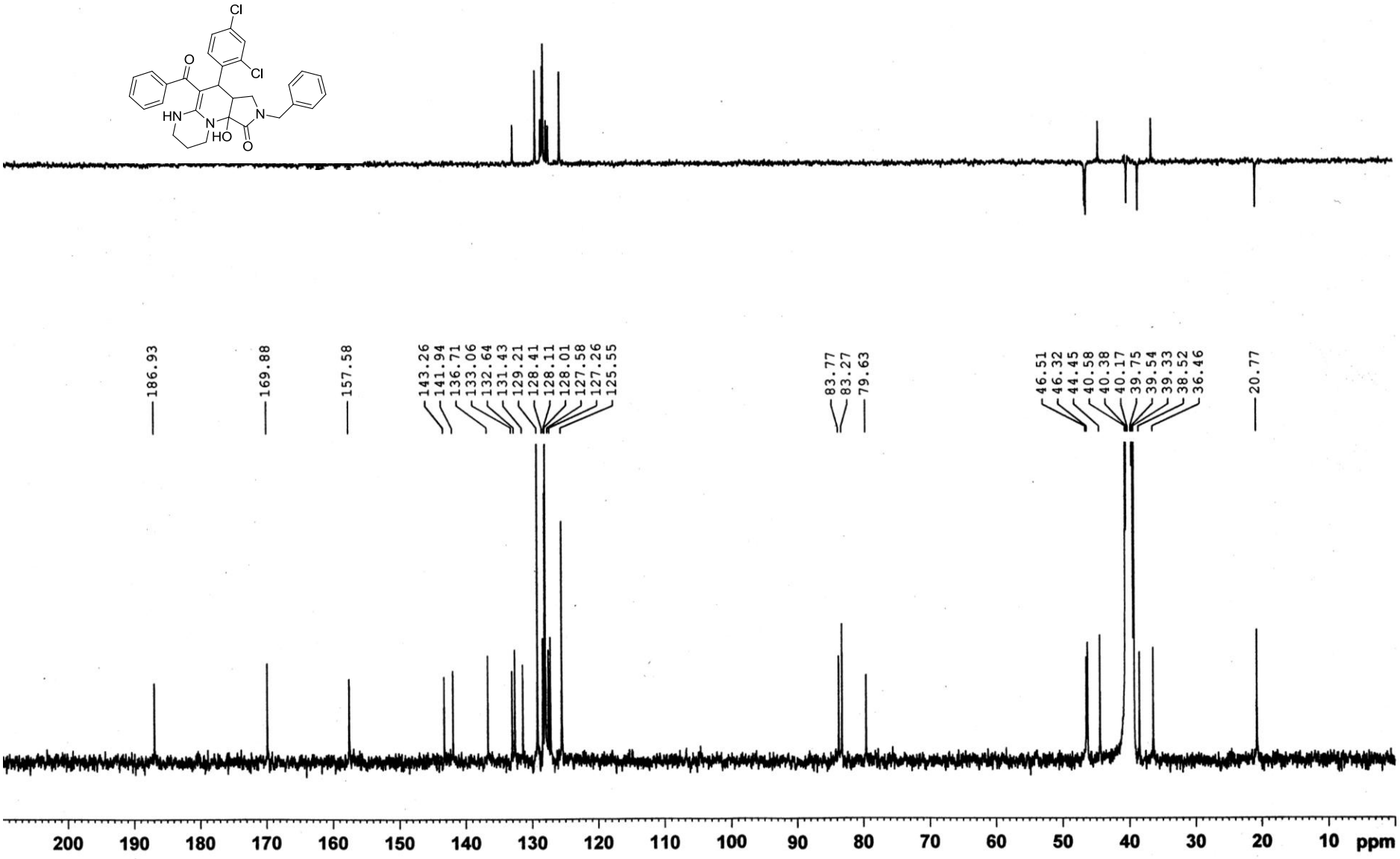


Figure 90. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **5c**

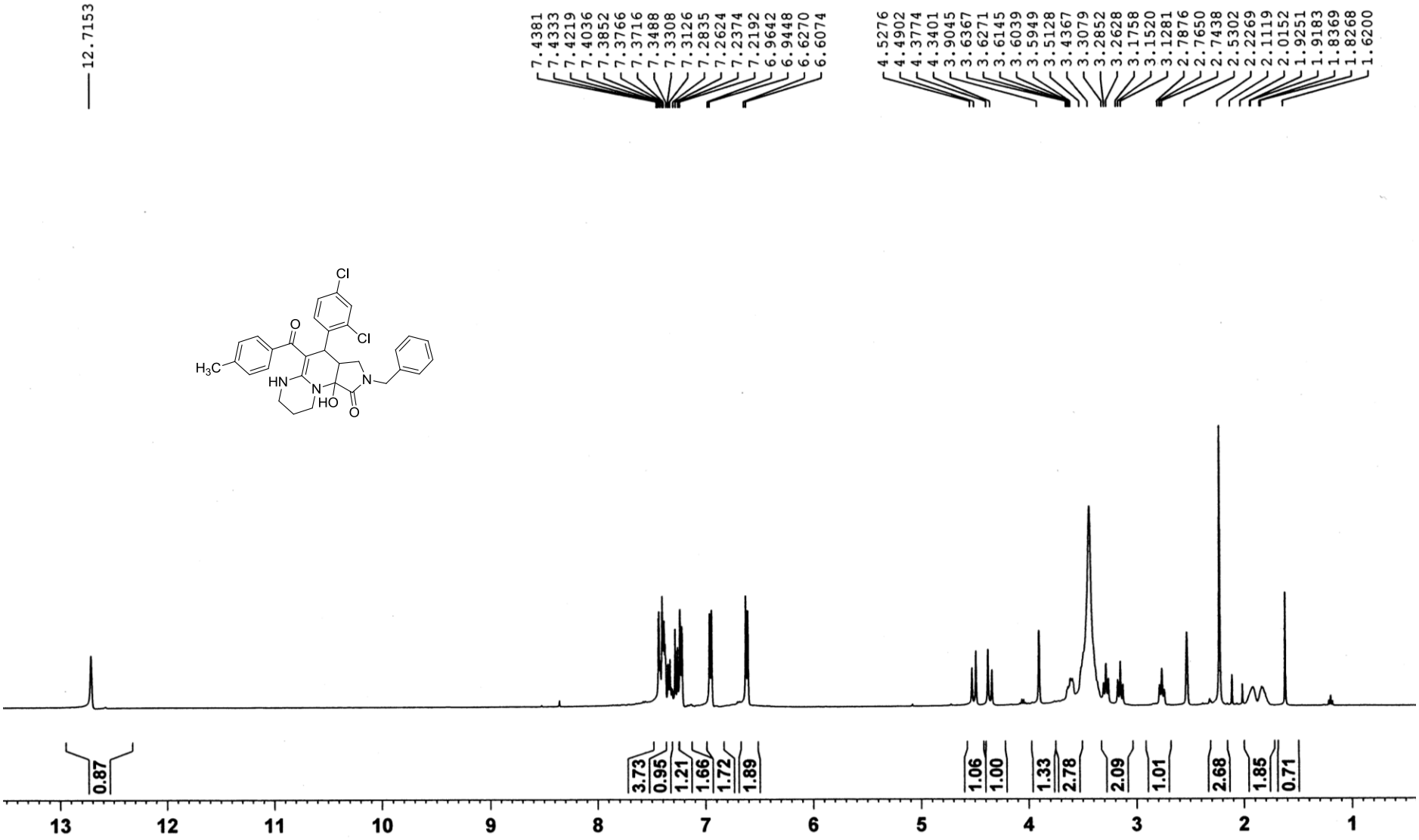


Figure 91. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **5d**

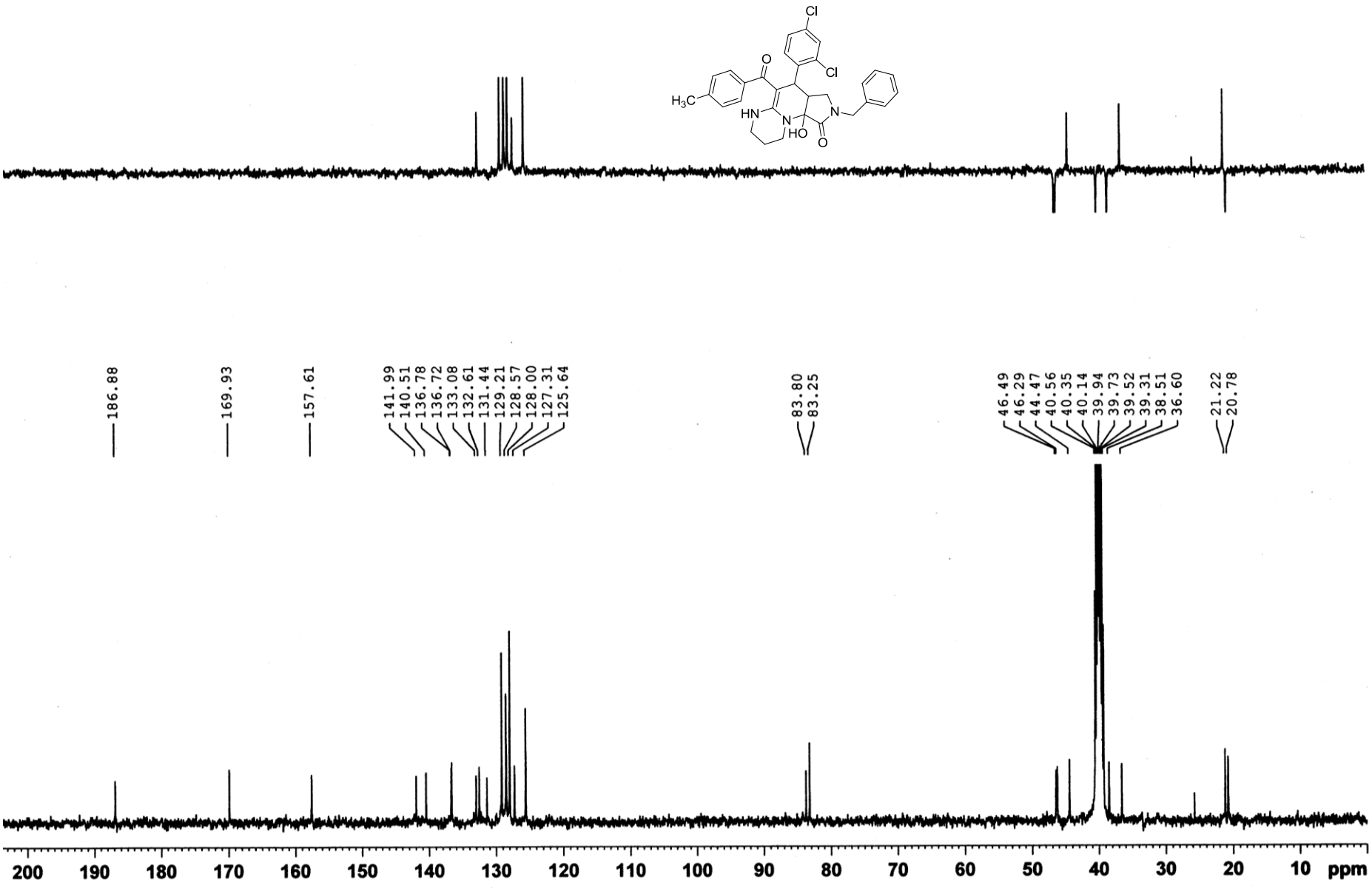


Figure 92. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **5d**

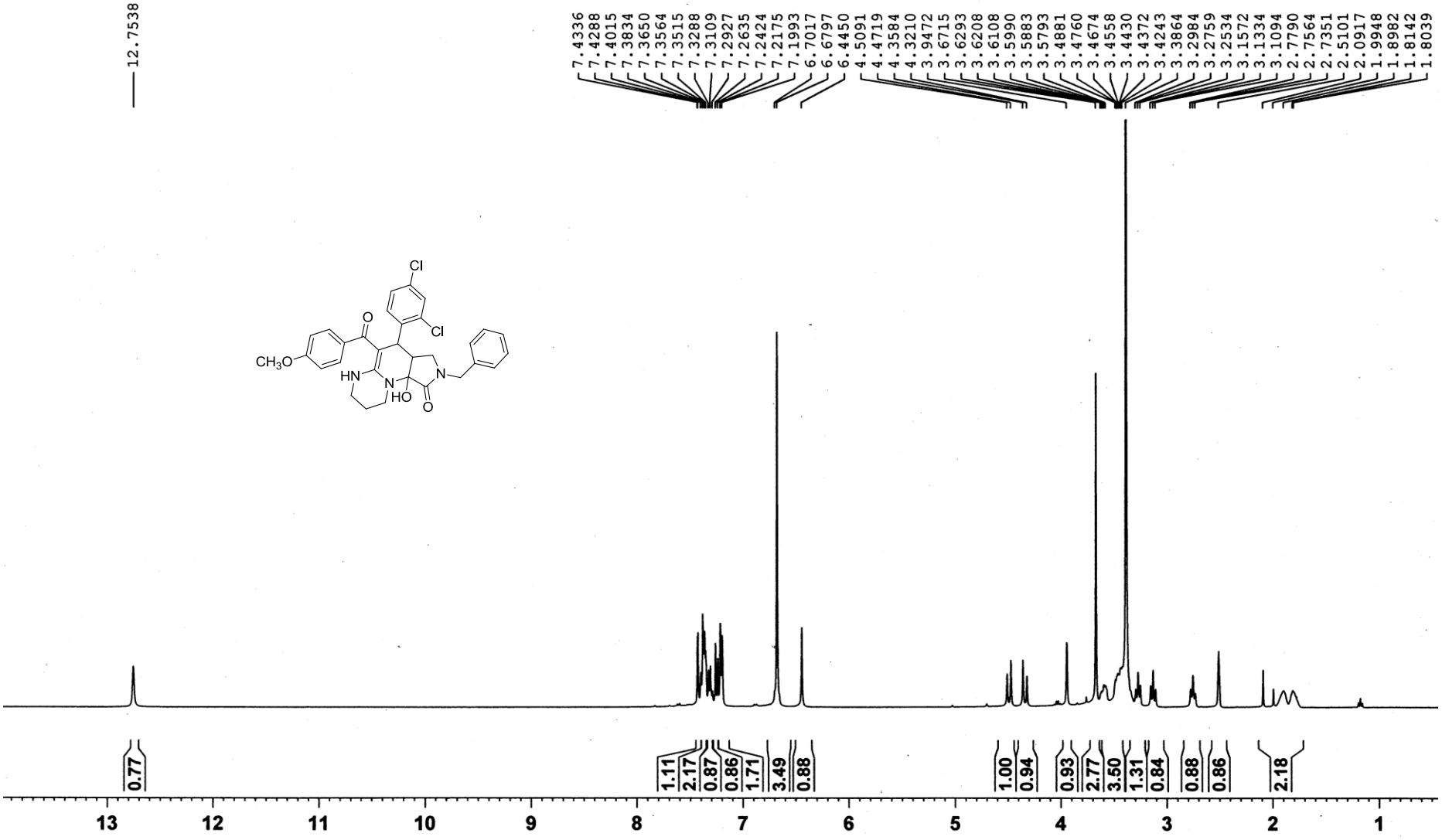


Figure 93. ^{1}H NMR (400 MHz, DMSO-d_6) spectra of compound **5e**

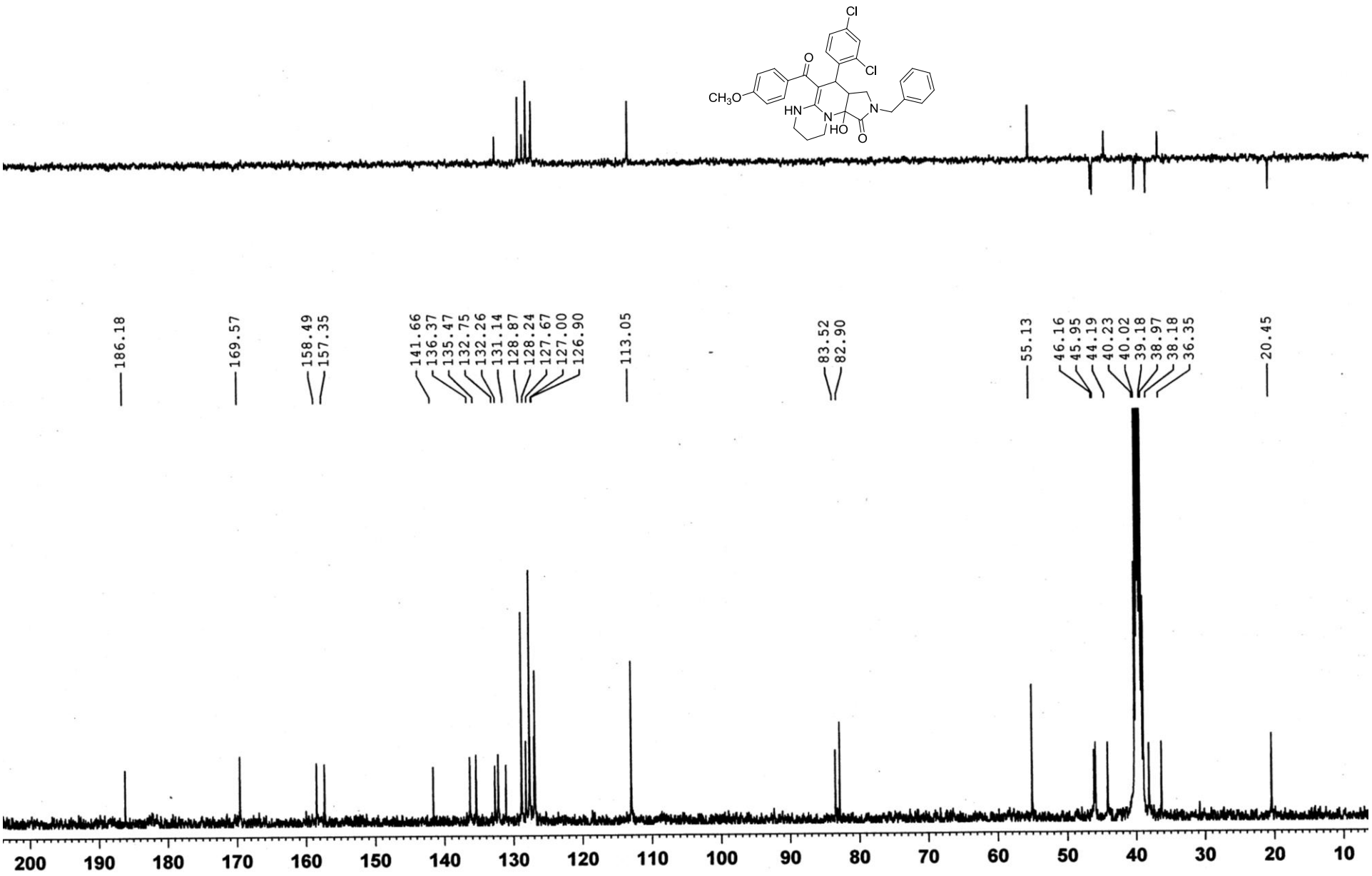


Figure 94. ^{13}C NMR (100 MHz, DMSO-d_6) spectra of compound **5e**

References and Notes

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2. G. Rudolf, *Chemische Berichte* 1967, **100**, 591.
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4. Z.-T. Huang, Z.-R. Liu, *Synth. Commun.*, 1989, **19**, 943.
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6. C. A. Snyder, *J. Heterocyclic Chem.*, 1982, **3**, 603.
7. CCDC 962808 contain the supplementary crystallographic data for compound **5a**. These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif.