Three-component solvent-free synthesis of highly substituted tetrahydroimidazo[1,2-*a*]pyridines

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Supporting Information

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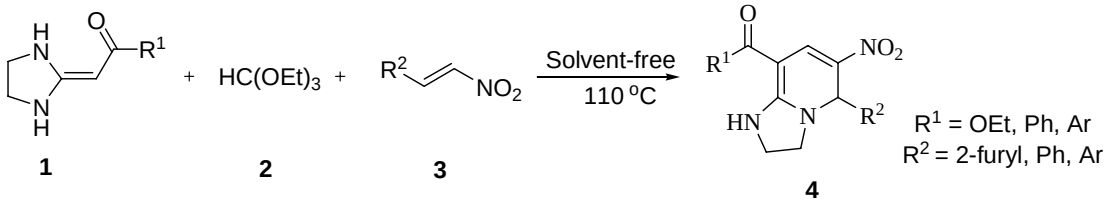
General Information

All compounds were fully characterized by spectroscopic data. The NMR spectra were recorded on a Bruker DRX500 (^{1}H: 500 MHz, ^{13}C: 125 MHz), chemical shifts (δ) are expressed in ppm, and J values are given in Hz, and deuterated $CDCl_3$ and DMSO-d_6 were used as solvent. IR spectra were recorded on a FT-IR Thermo Nicolet Avatar 360 using 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 Agllent LC/Msd TOF 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).

The substrates **1a~1d** were synthesized accroding to the literature.[1] Compound **1e** was prepared according to the literature.[2] The substrates **3a~3h** were synthesized accroding to the literature.[3]

General Procedure for the Preparation of Tetrahydroimidazo[1,2-*a*]pyridine Derivatives 4 *via* One-pot Three-component Reactions

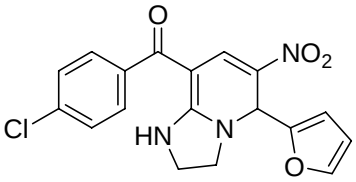


1 **2** **3** **4**

HKA derivatives **1** (2.5 mmol), triethoxy-methane **2** (3 mmol) and nitroalkene derivatives **3** (3 mmol) were charged into a 25 mL round-bottom flask and the mixture was heated to 110°C. The resulting solution was stirred for 20–38 min until the HKA derivatives **1** were completely consumed. The mixture was diluted with EtOAc (50 mL x 2) and quenched with water (50 mL). The organic layer was dried by Na_2SO_4, concentrated, and purified by flash column chromatography (Petro/AcOEt = 1/1) to afford product **4** with 73–93% yield. The products were further identified by FTIR, NMR and HRMS, being in good agreement with the assigned structures (See Supplementary Information).

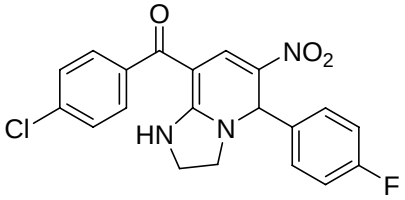
Spectroscopic Data of Tetrahydroimidazo[1,2-*a*]pyridine Derivatives 4

(4-Chlorophenyl)(5-(furan-2-yl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4a)



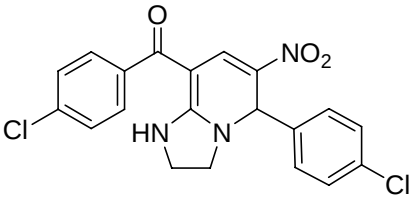
Yellow solid; Mp 257–258 °C; IR (KBr): 3288, 2900, 1594, 1408, 1292, 1228, 1163, 1075, 769 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.18–3.23 (m, 1H, NCH_2), 3.75–3.80 (m, 3H, NCH_2CH_2N), 6.02 (s, 1H, NCH), 6.48 (s, 1H, ArH), 6.54 (s, 1H, ArH), 7.55 (d, J = 8.1 Hz, 2H, ArH), 7.60 (d, J = 8.1 Hz, 2H, ArH), 7.67 (s,1H,ArH), 7.99 (s, 1H, CH=), 9.37 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.7, 45.9, 51.6, 91.4, 109.7, 111.1, 123.1, 128.9, 130.2, 135.6, 137.3, 138.4, 143.8, 150.2, 159.4, 188.3; HRMS (TOF ES^+): *m/z* calcd for $C_{18}H_{15}ClN_3O_4$ $[(M+H)^+]$, 372.0746; found, 372.0753.

(4-Chlorophenyl)(5-(4-fluorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4b)



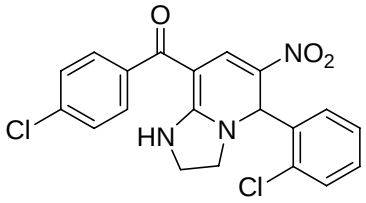
Yellow solid; Mp 267.0–269.5 °C; IR (KBr): 3312, 2889, 1588, 1408, 1224, 1072, 835 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.15 (m, 1H, NCH_2), 3.69–3.77 (m, 3H, NCH_2CH_2N), 5.85 (s, 1H, NCH), 7.24 (t, J = 8.8 Hz, 2H, ArH), 7.47–7.50 (m, 2H ArH), 7.59–7.63 (m, 4H, ArH), 8.03 (s, 1H, CH=), 9.35 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.5, 57.6, 91.1, 116.0, 116.1, 125.9, 128.9, 130.1, 130.2, 134.9, 135.5, 137.1, 138.4, 158.7, 188.3; HRMS (TOF ES^+): *m/z* calcd for $C_{20}H_{16}ClFN_3O_3$ $[(M+H)^+]$, 400.0859; found, 400.0867.

(4-Chlorophenyl)(5-(4-chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4c)



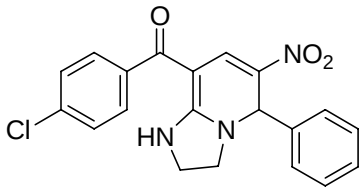
Yellow solid; Mp 167–171 °C; IR (KBr): 3281, 3073, 1589, 1409, 1217, 1080, 830 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.17 (m, 1H, NCH_2), 3.66–3.77 (m,3H, NCH_2CH_2N), 5.85 (s, 1H, NCH), 7.41–7.47 (m, 4H, ArH), 7.58–7.61 (m, 4H, ArH), 8.03 (s, 1H, CH=), 9.36 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.6, 57.7, 91.1, 125.7, 128.9, 129.2, 129.9, 130.2, 133.6, 135.6, 137.2, 137.6, 138.4, 158.7, 188.3; HRMS (TOF ES^+): *m/z* calcd for $C_{20}H_{16}Cl_2N_3O_3$ $[(M+H)^+]$, 416.0563; found, 416.0560.

(4-Chlorophenyl)(5-(2-chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4d)



Yellow solid; Mp 279–281 °C; IR (KBr): 3298, 3052, 1588, 1409, 1293, 1221, 1076, 760 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.15 (m, 1H, NCH_2), 3.69–3.77 (m, 3H, NCH_2CH_2N), 6.25 (s, 1H, NCH), 7.39–7.43 (m, 2H, ArH), 7.48–7.52 (m, 1H, ArH), 7.52–7.55 (m, 1H, ArH), 7.59–7.63 (m, 4H, ArH), 8.08 (s, 1H, CH=), 9.36 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.7, 45.6, 55.3, 91.2, 125.0, 128.9, 128.9, 129.8, 130.2, 130.2, 130.8, 130.8, 133.1, 135.6, 137.8, 138.4, 158.5, 188.3; HRMS (TOF ES^+): *m/z* calcd for $C_{20}H_{16}Cl_2N_3O_3$ $[(M+H)^+]$, 416.0563; found, 416.0562.

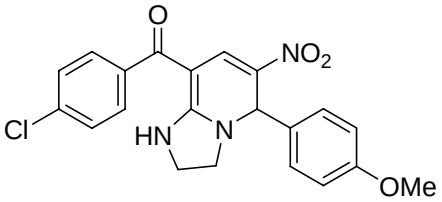
(4-Chlorophenyl)(1,2,3,5-tetrahydro-6-nitro-5-phenylimidazo[1,2-*a*]pyridin-8-yl) methanone (4e)



Yellow solid; Mp 260.0–265 °C; IR (KBr): 3355, 2966, 1595, 1404, 1227, 1080, 756 cm^{-1}; ^1H NMR (500MHz, $CDCl_3$+DMSO-d_6): δ = 2.50–2.54 (m, 1H, NCH_2), 2.94–2.98 (m, 1H, NCH_2), 3.04–3.11 (m, 2H, NCH_2), 5.04 (s, 1H, NCH), 6.63–6.71 (m, 5H, ArH), 6.75–6.78 (m, 2H, ArH), 6.80–6.84 (m, 2H, ArH), 7.38 (s, 1H, CH=),

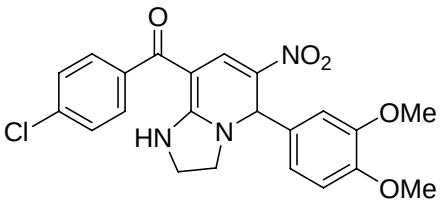
8.59 (br, 1H, NH); ^{13}C NMR (125 MHz, $CDCl_3$+DMSO-d_6): δ = 43.2, 45.4, 58.6, 90.5, 126.2, 127.5, 128.4, 128.7, 128.7, 128.8, 129.6, 135.8, 136.3, 137.9, 159.2, 188.2; HRMS (TOF ES$^+$): *m/z* calcd for $C_{20}H_{17}ClN_3O_3$ [(M+H)$^+$], 382.0953; found, 382.0950.

(4-Chlorophenyl)(1,2,3,5-tetrahydro-5-(4-methoxyphenyl)-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4f)



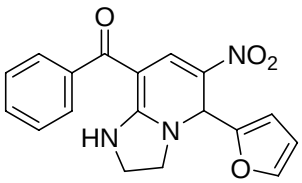
Yellow solid; Mp 233.5–235.5 °C; IR (KBr): 3332, 2964, 1590, 1506, 1404, 1233, 1077, 828 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.13–3.18 (m, 1H, NCH_2), 3.64–3.70 (m, 3H, NCH_2CH_2N), 3.74 (s, 3H, OCH_3), 5.74 (s, 1H, NCH), 6.95 (d, *J* = 8.6 Hz, 2H, ArH), 7.33 (d, *J* = 8.6 Hz, 2H, ArH), 7.57–7.60 (m, 4H, ArH), 8.00 (s, 1H, CH=), 9.27 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.5, 45.4, 55.5, 57.7, 91.1, 114.5, 126.4, 128.5, 128.9, 129.2, 130.2, 135.5, 136.8, 138.5, 158.8, 159.8, 188.3; HRMS (TOF ES$^+$): *m/z* calcd for $C_{21}H_{19}ClN_3O_4$ [(M+H)$^+$], 412.1059; found, 412.1063.

(4-Chlorophenyl)(1,2,3,5-tetrahydro-5-(3,4-dimethoxyphenyl)-6-nitroimidazo[1,2-*a*]pyridin-8-yl)methanone (4g)



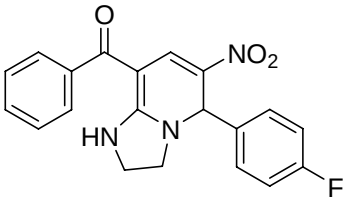
Yellow solid; Mp 178–179 °C; IR (KBr): 3372, 2971, 1597, 1514, 1399, 1213, 1168, 1079, 1025,765 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.16–3.21 (m, 1H, NCH_2), 3.68–3.76 (m, 3H, NCH_2CH_2N), 3.73 (s, 3H, OCH_3), 3.77 (s, 3H, OCH_3), 5.75 (s, 1H, NCH), 6.91–6.99 (m, 3H, ArH), 7.58–7.60 (m, 4H, ArH), 8.02 (s, 1H, CH=), 9.27 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.5, 55.9, 55.9, 58.0, 91.0, 111.7, 112.4, 119.9, 126.3, 128.9, 130.2, 130.9, 135.5, 136.8, 138.5, 149.1, 149.4, 158.8, 188.1; HRMS (TOF ES$^+$): *m/z* calcd for $C_{22}H_{21}ClN_3O_5$ [(M+H)$^+$], 442.1164; found, 442.1167.

(5-(Furan-2-yl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4h)



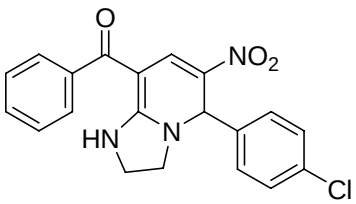
Orange-red solid; Mp 199–200 °C; IR (KBr): 3287, 3089, 1590, 1360, 1199, 1077, 1017, 745 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.22–3.26 (m, 1H, NCH_2), 3.71–3.80 (m, 3H, NCH_2CH_2N), 6.02 (s, 1H, NCH), 6.46–6.48 (m, 1H, ArH), 6.52–6.55 (m, 1H, ArH), 7.51–7.55 (m, 5H, ArH), 7.67–7.69 (m, 1H, ArH), 8.03 (s, 1H, CH=), 9.40 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 44.2, 46.4, 52.2, 92.1, 110.2, 111.6, 123.3, 128.7, 129.3, 131.3, 138.2, 140.2, 144.3, 150.8, 160.0, 190.3; HRMS (TOF ES^+): *m/z* calcd for $C_{18}H_{16}N_3O_4$ $[(M+H)^+]$, 338.1135; found, 338.1140.

(5-(4-Fluorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4i)



Yellow solid; Mp 222–224 °C; IR (KBr): 3328, 3060, 1592, 1295, 1223, 1168, 1074, 836, 742 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.16 (m, 1H, NCH_2), 3.69–3.75 (m, 3H, NCH_2CH_2N), 5.84 (s, 1H, NCH), 7.20–7.26 (m, 2H, ArH), 7.45–7.50 (m, 2H, ArH), 7.50–7.58 (m, 5H, ArH), 8.06 (s, 1H, CH=), 9.36 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.5, 57.6, 91.3, 116.0 (d, J = 21.3 Hz), 125.6, 128.3, 128.8, 130.1, 130.8, 134.9, 137.5, 139.7, 158.8, 162.4 (d, J = 243.8 Hz), 189.7; HRMS (TOF ES^+): *m/z* calcd for $C_{20}H_{17}FN_3O_3$ $[(M+H)^+]$, 366.1248; found, 366.1252.

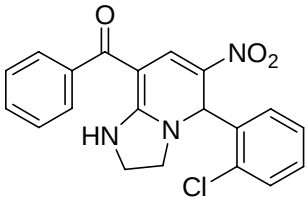
(5-(4-Chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4j)



Orange-red solid; Mp 253–256 °C; IR (KBr): 3376, 2890, 1588, 1393, 1209, 1077, 821, 741 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.07–3.15 (m, 1H, NCH_2), 3.71–3.75 (m, 3H, NCH_2CH_2N), 5.85 (s, 1H, NCH), 7.45–7.57 (m, 9H, ArH), 8.06 (s,

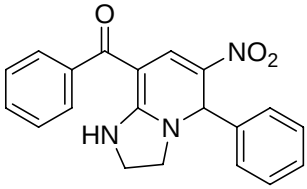
1H, CH=), 9.37 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.6, 57.7, 91.3, 125.4, 128.3, 128.8, 129.2, 129.9, 130.8, 133.6, 137.6, 139.7, 139.7, 158.8, 189.7; HRMS (TOF ES$^+$): *m/z* calcd for $C_{20}H_{17}ClN_3O_3$ [(M+H)$^+$], 382.0953; found, 382.0960.

(5-(2-Chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4k)



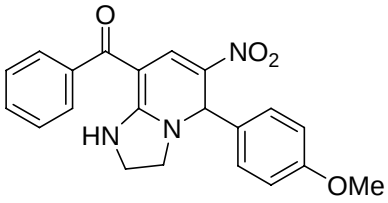
Orange-red solid; Mp 262–265 °C; IR (KBr): 3210, 2970, 1591, 1294, 1205, 1075, 748 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.15 (m, 1H, NCH_2), 3.65–3.75 (m, 3H, NCH_2CH_2N), 6.26 (s, 1H, NCH), 7.37–7.43 (m, 2H, ArH), 7.47–7.60 (m, 7H, ArH), 8.14 (s, 1H, CH=), 9.38 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.7, 45.6, 55.4, 91.4, 124.7, 128.3, 128.8, 129.8, 129.8, 130.8, 130.8, 130.8, 133.1, 135.7, 138.2, 139.7, 158.6, 189.8; HRMS (TOF ES$^+$): *m/z* calcd for $C_{20}H_{17}ClN_3O_3$ [(M+H)$^+$], 382.0953; found, 382.0955.

(1,2,3,5-Tetrahydro-6-nitro-5-phenylimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4l)



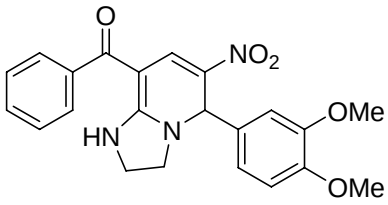
Orange-red solid; Mp 229–231 °C; IR (KBr): 3322, 3064, 1589, 1447, 1395, 1291, 1217, 1072, 743 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 3.30–3.35 (m, 1H, NCH_2), 3.54–3.3.59 (m, 1H, NCH_2), 3.75–3.81 (m, 2H, NCH_2), 5.74 (s, 1H, NCH), 7.33–7.41 (m, 5H, ArH), 7.41–7.50 (m, 3H, ArH), 7.56–7.58 (m, 2H, ArH), 8.29 (s, 1H, CH=), 9.24 (br, 1H, NH); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 43.4, 46.1, 59.6, 90.8, 127.5, 128.0, 128.8, 128.9, 129.7, 131.2, 132.2, 137.0, 138.0, 139.4, 161.0, 191.51; HRMS (TOF ES$^+$): *m/z* calcd for $C_{20}H_{18}N_3O_3$ [(M+H)$^+$], 348.1343; found, 348.1344.

(1,2,3,5-Tetrahydro-5-(4-methoxyphenyl)-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4m)



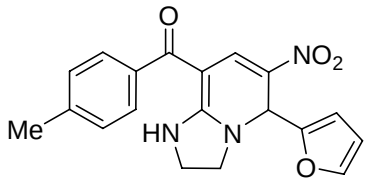
Yellow solid; Mp 253–255 °C; IR (KBr): 3368, 2958, 1592, 1508, 1395, 1210, 1026, 829, 739 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.14–3.18 (m, 1H, NCH_2), 3.72–3.76 (m, 3H, NCH_2CH_2N), 3.77 (s, 3H, OCH_3), 5.77 (s, 1H, NCH), 6.97 (d, J = 7.1 Hz, 2H, ArH), 7.34 (d, J = 7.1 Hz, 2H, ArH), 7.52–7.57 (m, 5H, ArH), 8.06 (s, 1H, CH=), 9.28 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.5, 45.4, 55.5, 57.8, 91.2, 114.6, 126.1, 128.2, 128.8, 129.2, 130.6, 130.7, 137.1, 139.8, 158.9, 159.8, 189.7; HRMS (TOF ES^+): *m/z* calcd for $C_{21}H_{20}N_3O_4$ $[(M+H)^+]$, 378.1448; found, 378.1456.

(1,2,3,5-Tetrahydro-5-(3,4-dimethoxyphenyl)-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(phenyl)methanone (4n)



Orange-red solid; Mp 219–220.5 °C; IR (KBr): 3324, 2958, 1596, 1510, 1405, 1290, 1223, 1072, 747 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.16–3.19 (m, 1H, NCH_2), 3.65–3.71 (m, 3H, NCH_2CH_2N), 3.74 (s, 3H, OCH_3), 3.76 (s, 3H, OCH_3), 5.74 (s, 1H, NCH), 6.92–6.98 (m, 3H, ArH), 7.53–7.56 (m, 5H, ArH), 8.07 (s, 1H, CH=), 9.30 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.5, 45.5, 55.8, 55.8, 58.0, 91.3, 111.6, 112.3, 119.8, 125.9, 128.2, 128.8, 130.8, 130.9, 137.3, 139.8, 149.0, 149.3, 158.9, 189.7; HRMS (TOF ES^+): *m/z* calcd for $C_{22}H_{22}N_3O_5$ $[(M+H)^+]$, 408.1554; found, 408.1558.

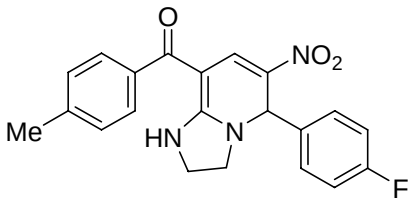
(5-(Furan-2-yl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(*p*-tolyl)methanone (4o)



Orange-red solid; Mp 229–230 °C; IR (KBr): 3271, 2895, 1594, 1408, 1294, 1229, 1164, 1071, 747 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 2.40 (s, 3H, CH_3), 3.25–3.27 (m, 1H, NCH_2), 3.76–3.80 (m, 3H, NCH_2CH_2N), 6.02 (s, 1H, NCH),

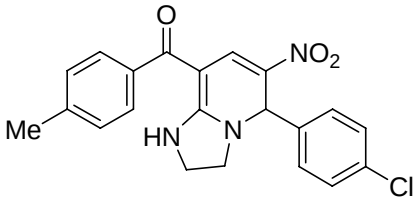
6.45–6.48 (m, 1H, ArH), 6.51–6.55 (m, 1H, ArH), 7.33–7.43 (m, 4H, ArH), 7.66–7.68 (m, 1H, ArH), 8.07 (s, 1H, CH=), 9.36 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.4, 43.7, 45.9, 51.6, 91.7, 109.6, 111.1, 122.6, 128.4, 129.3, 136.9, 137.9, 140.8, 143.8, 150.3, 159.6, 189.7; HRMS (TOF ES$^+$): *m/z* calcd for $C_{19}H_{18}N_3O_4$ [(M+H)$^+$], 352.1292; found, 352.1299.

(5-(4-Fluorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(*p*-tolyl)methanone (4p)



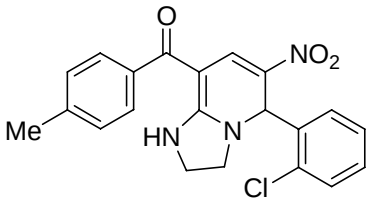
Orange-red solid; Mp 242–245°C; IR (KBr): 3314, 3064, 2888, 1598, 1405, 1292, 1231, 1072, 838, 767 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 2.39 (s, 3H, CH_3), 3.13–3.17 (m, 1H, NCH_2), 3.70–3.75 (m, 3H, NCH_2CH_2N), 5.84 (s, 1H, NCH), 7.24–7.26 (m, 2H, ArH), 7.33 (d, *J* = 7.8 Hz, 2H, ArH), 7.47–7.49 (d, *J* = 7.8 Hz, 4H, ArH), 8.10 (s, 1H, CH=), 9.35 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.4, 43.6, 45.5, 57.6, 91.4, 116.0 (d, *J* = 21.3 Hz), 125.4, 128.4, 128.9, 129.3, 130.0 (d, *J* = 7.5 Hz), 134.9, 136.9, 137.6, 140.8, 158.9, 162.4 (d, *J* = 242.5 Hz), 189.7; HRMS (TOF ES$^+$): *m/z* calcd for $C_{21}H_{19}FN_3O_3$ [(M+H)$^+$], 380.1405; found, 380.1407.

(5-(4-Chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(*p*-tolyl)methanone (4q)



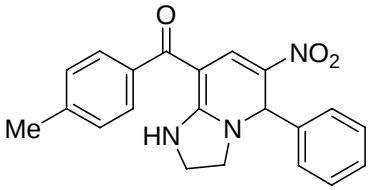
Orange-red solid; Mp 225–226 °C; IR (KBr): 3350, 2888, 1581, 1394, 1289, 1220, 1172, 1078, 828 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 2.39 (s, 3H, CH_3), 3.12–3.16 (m, 1H, NCH_2), 3.67–3.76 (m, 3H, NCH_2CH_2N), 5.84 (s, 1H, NCH), 7.30 (d, *J* = 7.8 Hz, 2H, ArH), 7.42–7.49 (m, 6H, ArH), 8.10 (s, 1H, CH=), 9.35 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.4, 43.6, 45.6, 57.7, 91.4, 125.2, 128.4, 128.9, 129.3, 129.3, 129.8, 133.6, 136.9, 137.7, 140.8, 158.9, 189.6; HRMS (TOF ES$^+$): *m/z* calcd for $C_{21}H_{19}ClN_3O_3$ [(M+H)$^+$], 396.1109; found, 396.1117.

(5-(2-Chlorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(*p*-tolyl)methanone (4r)



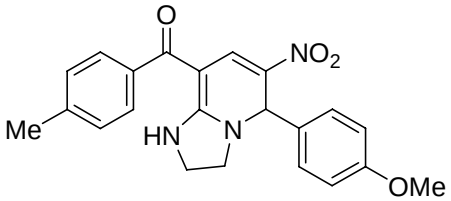
Orange-red solid; Mp 219–220.5 °C; IR (KBr): 3309, 2897, 1596, 1404, 1293, 1228, 1076, 763 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 2.40 (s, 3H, CH_3), 3.10–3.15 (m, 1H, NCH_2), 3.72–3.76 (m, 3H, NCH_2CH_2N), 6.25 (s, 1H, NCH), 7.33–7.43 (m, 4H, ArH), 7.47–7.52 (m, 4H, ArH), 8.17 (s, 1H, CH=), 9.37 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.4, 43.6, 45.6, 55.4, 91.4, 124.5, 128.4, 128.9, 129.3, 129.8, 129.8, 130.7, 133.1, 135.7, 136.9, 138.3, 140.8, 158.7, 189.7; HRMS (TOF ES^+): *m/z* calcd for $C_{21}H_{19}ClN_3O_3$ $[(M+H)^+]$, 396.1109; found, 396.1109.

(1,2,3,5-Tetrahydro-6-nitro-5-phenylimidazo[1,2-*a*]pyridin-8-yl)(*p*-tolyl)methano ne (4s)



Yellow solid; Mp 257–261 °C; IR (KBr): 3372, 2884, 1591, 1396, 1215, 1073, 762 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 2.39 (s, 3H, CH_3), 3.09–3.15 (m, 1H, NCH_2), 3.69–3.73 (m, 3H, NCH_2CH_2N), 5.81 (s, 1H, NCH), 7.32–7.48 (m, 9H, ArH), 8.11 (s, 1H, CH=), 9.34 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.9, 44.1, 46.1, 58.9, 91.9, 126.1, 128.4, 128.9, 129.5, 129.8, 129.8, 137.5, 138.0, 139.1, 141.2, 159.5, 190.1; HRMS (TOF ES^+): *m/z* calcd for $C_{21}H_{20}N_3O_3$ $[(M+H)^+]$, 362.1499; found, 362.1506.

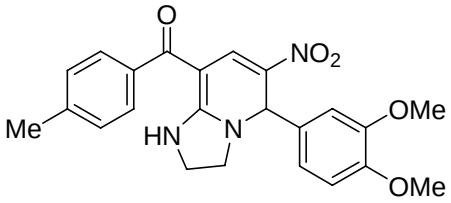
(1,2,3,5-Tetrahydro-5-(4-methoxyphenyl)-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(*p*-to lyl)methanone (4t)



Yellow solid; Mp 246–247 °C; IR (KBr): 3328, 2889, 1591, 1506, 1395, 1209, 1168, 1028, 832, 768 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 2.40 (s, 3H, CH_3),

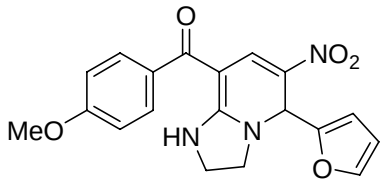
3.12–3.16 (m, 1H, NCH_2), 3.70–3.74 (m, 3H, NCH_2CH_2N), 3.76 (s, 3H, OCH_3), 5.76 (s, 1H, NCH), 6.96 (d, J = 7.4 Hz, 2H, ArH), 7.30–7.36 (m, 4H, ArH), 7.47 (d, J = 7.4 Hz, 2H, ArH), 8.09 (s, 1H, CH=), 9.28 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.4, 43.5, 45.4, 55.5, 57.8, 91.3, 114.6, 125.9, 128.4, 129.1, 129.3, 130.6, 137.0, 137.2, 140.7, 159.0, 159.8, 189.6; HRMS (TOF ES$^+$): *m/z* calcd for $C_{22}H_{22}N_3O_4$ [(M+H)$^+$], 392.1605; found, 392.1605.

(1,2,3,5-Tetrahydro-5-(3,4-dimethoxyphenyl)-6-nitroimidazo[1,2-a]pyridin-8-yl)(p-tolyl)methanone (4u)



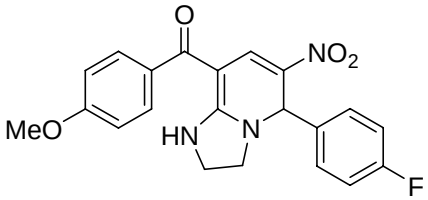
Yellow solid; Mp 172–174.5 °C; IR (KBr): 3313, 2947, 1595, 1512, 1406, 1289, 1223, 1073, 1024, 833, 765 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 2.38 (s, 3H, CH_3), 3.16–3.20 (m, 1H, NCH_2), 3.65–3.73 (m, 3H, NCH_2CH_2N), 3.75 (s, 3H, OCH_3), 3.76 (s, 3H, OCH_3), 5.74 (s, 1H, NCH), 6.92–7.00 (m, 3H, ArH), 7.33 (d, J = 7.8 Hz, 2H, ArH), 7.47 (d, J = 7.8 Hz, 2H, ArH), 8.12 (s, 1H, CH=), 9.29 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 21.3, 43.5, 45.5, 55.9, 58.1, 91.3, 111.7, 112.4, 119.9, 125.8, 128.4, 129.3, 131.0, 137.0, 137.3, 140.8, 149.1, 149.4, 159.0, 159.3, 189.6; HRMS (TOF ES$^+$): *m/z* calcd for $C_{23}H_{24}N_3O_5$ [(M+H)$^+$], 422.1710; found, 422.1709.

(5-(Furan-2-yl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(4-methoxyphenyl)methanone (4v)



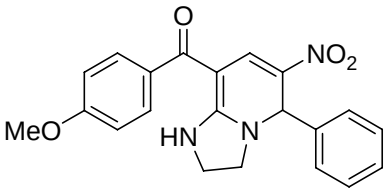
Orange-red solid; Mp 218–220.5 °C; IR (KBr): 3321, 2991, 1595, 1298, 1235, 1167, 1019, 770, 610 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 3.23–3.27 (m, 1H, NCH_2), 3.71–3.81 (m, 3H, NCH_2CH_2N), 3.84 (s, 3H, OCH_3), 6.02 (s, 1H, NCH), 6.47 (d, J = 2.6 Hz, 1H, ArH), 6.52–6.55 (m, 1H, ArH), 7.08 (d, J = 8.6 Hz, 2H, ArH), 7.53 (d, J = 8.6 Hz, 2H, ArH), 7.67–7.69 (m, 1H, ArH), 8.11 (s, 1H, CH=), 9.37 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.7, 45.9, 51.6, 55.7, 91.8, 109.6, 111.1, 114.1, 122.3, 130.4, 131.9, 143.8, 143.8, 150.3, 159.6, 161.6, 189.0. HRMS (TOF ES$^+$): *m/z* calcd for $C_{19}H_{18}N_3O_5$ [(M+H)$^+$], 368.1241; found, 368.1245.

(5-(4-Fluorophenyl)-1,2,3,5-tetrahydro-6-nitroimidazo[1,2-*a*]pyridin-8-yl)(4-methoxyphenyl)methanone (4w)



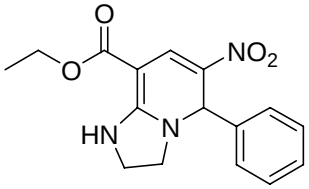
Orange-red solid; Mp 201–204 °C; IR (KBr): 3316, 2897, 1593, 1507, 1403, 1222, 1165, 1076, 839 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.12–3.16 (m, 1H, NCH_2), 3.70–3.75 (m, 3H, NCH_2CH_2N), 3.85 (s, 3H, OCH_3), 5.85 (s, 1H, NCH), 7.06–7.09 (m, 2H, ArH), 7.22–7.26 (m, 2H, ArH), 7.46–7.50 (m, 2H, ArH), 7.54–7.59 (m, 2H, ArH), 8.15 (s, 1H, CH=), 9.31 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.5, 55.7, 57.6, 91.4, 114.0, 116.0 (d, J = 21.3 Hz), 125.2, 130.0 (d, J = 7.5 Hz), 130.4, 131.9, 135.9, 137.6, 159.0, 161.6, 163.4, 188.9; HRMS (TOF ES^+): *m/z* calcd for $C_{21}H_{19}FN_3O_4$ [$(M+H)^+$], 396.1354; found, 396.1363.

(1,2,3,5-Tetrahydro-6-nitro-5-phenylimidazo[1,2-*a*]pyridin-8-yl)(4-methoxyphenyl)methanone (4x)



Orange-red solid; Mp 237–239 °C; IR (KBr): 3360, 2890, 1591, 1399, 1214, 1072, 836 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 3.10–3.14 (m, 1H, NCH_2), 3.69–3.73 (m, 3H, NCH_2CH_2N), 3.85 (s, 3H, OCH_3), 5.82 (s, 1H, NCH), 7.08 (d, J = 7.5 Hz, 2H, ArH), 7.36–7.43 (m, 5H, ArH), 7.56 (d, J = 7.5 Hz, 2H, ArH), 8.15 (s, 1H, CH=), 9.31 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 43.6, 45.6, 55.7, 58.4, 91.4, 114.1, 125.4, 127.9, 129.0, 129.2, 130.4, 132.0, 137.6, 138.6, 159.1, 161.5, 188.9; HRMS (TOF ES^+): *m/z* calcd for $C_{21}H_{20}N_3O_4$ [$(M+H)^+$], 378.1448; found, 378.1453.

Ethyl 1,2,3,5-tetrahydro-6-nitro-5-phenylimidazo[1,2-*a*]pyridine-8-carboxylate (4y)



Orange-red solid; Mp 182–185 °C; IR (KBr): 3360, 2897, 1668, 1564, 1404, 1334, 1215, 1147, 770 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 1.29 (t, J = 6.6 Hz, CH_3), 3.05–3.09 (m, 1H, NCH_2), 3.63–3.67 (m, 3H, NCH_2CH_2N), 4.19 (t, J = 6.6 Hz, 2H, CH_2), 5.78 (s, 1H, NCH), 7.32–7.39 (m, 5H, ArH), 8.35 (s, 1H, CH=), 8.51 (br, 1H, NH); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 14.8, 43.3, 45.9, 58.6, 59.7, 80.8, 125.0, 127.7, 128.9, 129.1, 135.7, 138.8, 158.4, 164.7; HRMS (TOF ES^+): *m/z* calcd for $C_{16}H_{18}N_3O_4$ [$(M+H)^+$], 316.1292; found, 316.1302.

X-ray Structure and Data[4] of 4f

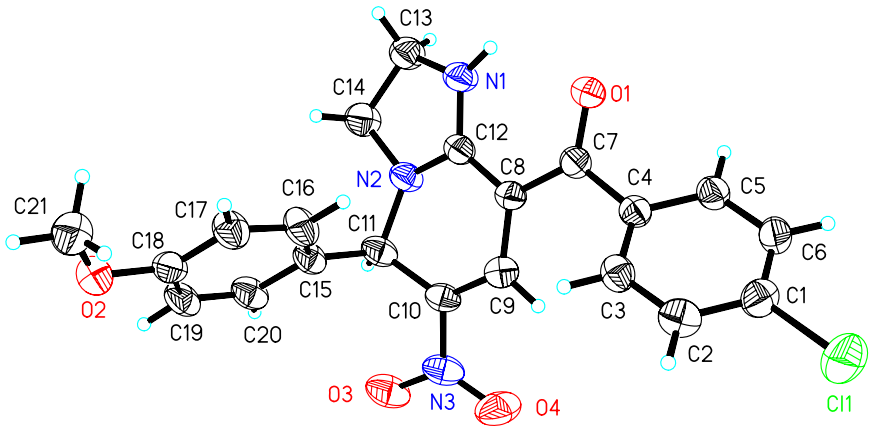


Figure S1 X-Ray crystal structure of **4f**

Table S1 Crystal data and structure refinement for **4f**

Identification code	100112a_0m
Empirical formula	C_{21} H_{18} Cl N_3 O_4
Formula weight	411.83
Temperature	293(2) K
Wavelength	0.71073 Å
Crystal system, space group	Monoclinic, P2(1)/c
Unit cell dimensions	a = 8.587(5) A alpha = 90.000(5) deg.
	b = 18.369(5) A beta = 92.329(5) deg.
	c = 12.335(5) A gamma = 90.000(5) deg.
Volume	1944.0(15) A^3
Z, Calculated density	4, 1.407 Mg/m^3
Absorption coefficient	0.230 mm^-1
F(000)	856
Crystal size	0.34 x 0.29 x 0.18 mm
Theta range for data collection	1.99 to 28.40 deg.
Limiting indices	-9<=h<=11, -23<=k<=23, -15<=l<=16
Reflection collected/unique	13201 / 4601 [R(int) = 0.0509]
Completeness to theta = 28.40	96.2 %

Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.9785 and 0.9456
Refinement method	Full-matrix least-squares on F^2
Data/restraints/parameters	4601 / 0 / 264
Goodness-of-fit on F^2	0.937
Final R indices [I>2sigma(I)]	R1 = 0.0479, wR2 = 0.1085
R indices (all data)	R1 = 0.1427, wR2 = 0.1450
Extinction coefficient	0.0163(16)
Largest diff. peak and hole	0.153 and -0.188 e.A^-3

Table S2 Bond lengths [A] and angles [deg] for **4f**

C(1)-C(6)	1.372(3)
C(1)-C(2)	1.374(4)
C(1)-Cl(1)	1.740(3)
N(1)-C(12)	1.325(3)
N(1)-C(13)	1.460(3)
N(1)-H(1)	0.8600
O(1)-C(7)	1.245(3)
C(2)-C(3)	1.382(3)
C(2)-H(2)	0.9300
N(2)-C(12)	1.337(3)
N(2)-C(11)	1.468(3)
N(2)-C(14)	1.471(3)
O(2)-C(18)	1.372(3)
O(2)-C(21)	1.424(3)
C(3)-C(4)	1.389(3)
C(3)-H(3)	0.9300
N(3)-O(4)	1.239(3)
N(3)-O(3)	1.248(3)
N(3)-C(10)	1.425(3)
C(4)-C(5)	1.387(3)
C(4)-C(7)	1.495(3)
C(5)-C(6)	1.372(3)
C(5)-H(5)	0.9300

C(6)-H(6)	0.9300
C(7)-C(8)	1.432(3)
C(8)-C(9)	1.410(3)
C(8)-C(12)	1.424(3)
C(9)-C(10)	1.355(3)
C(9)-H(9)	0.9300
C(10)-C(11)	1.509(3)
C(11)-C(15)	1.524(3)
C(11)-H(11)	0.9800
C(13)-C(14)	1.519(3)
C(13)-H(13A)	0.9700
C(13)-H(13B)	0.9700
C(14)-H(14A)	0.9700
C(14)-H(14B)	0.9700
C(15)-C(16)	1.375(3)
C(15)-C(20)	1.387(3)
C(16)-C(17)	1.382(3)
C(16)-H(16)	0.9300
C(17)-C(18)	1.377(3)
C(17)-H(17)	0.9300
C(18)-C(19)	1.376(3)
C(19)-C(20)	1.373(3)
C(19)-H(19)	0.9300
C(20)-H(20)	0.9300
C(21)-H(21A)	0.9600
C(21)-H(21B)	0.9600
C(21)-H(21C)	0.9600
C(6)-C(1)-C(2)	121.0(2)
C(6)-C(1)-Cl(1)	119.3(2)
C(2)-C(1)-Cl(1)	119.7(2)
C(12)-N(1)-C(13)	111.9(2)
C(12)-N(1)-H(1)	124.0
C(13)-N(1)-H(1)	124.0
C(1)-C(2)-C(3)	119.5(3)

C(1)-C(2)-H(2)	120.3
C(3)-C(2)-H(2)	120.3
C(12)-N(2)-C(11)	124.3(2)
C(12)-N(2)-C(14)	110.50(19)
C(11)-N(2)-C(14)	121.6(2)
C(18)-O(2)-C(21)	117.9(2)
C(2)-C(3)-C(4)	120.5(2)
C(2)-C(3)-H(3)	119.8
C(4)-C(3)-H(3)	119.8
O(4)-N(3)-O(3)	122.5(2)
O(4)-N(3)-C(10)	120.3(2)
O(3)-N(3)-C(10)	117.2(3)
C(5)-C(4)-C(3)	118.5(2)
C(5)-C(4)-C(7)	117.7(2)
C(3)-C(4)-C(7)	123.6(2)
C(6)-C(5)-C(4)	121.2(2)
C(6)-C(5)-H(5)	119.4
C(4)-C(5)-H(5)	119.4
C(1)-C(6)-C(5)	119.3(2)
C(1)-C(6)-H(6)	120.4
C(5)-C(6)-H(6)	120.4
O(1)-C(7)-C(8)	121.9(2)
O(1)-C(7)-C(4)	116.9(2)
C(8)-C(7)-C(4)	121.2(2)
C(9)-C(8)-C(12)	114.3(2)
C(9)-C(8)-C(7)	124.8(2)
C(12)-C(8)-C(7)	119.9(2)
C(10)-C(9)-C(8)	122.5(2)
C(10)-C(9)-H(9)	118.7
C(8)-C(9)-H(9)	118.7
C(9)-C(10)-N(3)	119.6(2)
C(9)-C(10)-C(11)	123.4(2)
N(3)-C(10)-C(11)	117.0(2)
N(2)-C(11)-C(10)	105.8(2)

N(2)-C(11)-C(15)	111.8(2)
C(10)-C(11)-C(15)	116.0(2)
N(2)-C(11)-H(11)	107.7
C(10)-C(11)-H(11)	107.7
C(15)-C(11)-H(11)	107.7
N(1)-C(12)-N(2)	110.2(2)
N(1)-C(12)-C(8)	127.4(2)
N(2)-C(12)-C(8)	122.3(2)
N(1)-C(13)-C(14)	102.3(2)
N(1)-C(13)-H(13A)	111.3
C(14)-C(13)-H(13A)	111.3
N(1)-C(13)-H(13B)	111.3
C(14)-C(13)-H(13B)	111.3
H(13A)-C(13)-H(13B)	109.2
N(2)-C(14)-C(13)	102.7(2)
N(2)-C(14)-H(14A)	111.2
C(13)-C(14)-H(14A)	111.2
N(2)-C(14)-H(14B)	111.2
C(13)-C(14)-H(14B)	111.2
H(14A)-C(14)-H(14B)	109.1
C(16)-C(15)-C(20)	117.3(2)
C(16)-C(15)-C(11)	122.1(2)
C(20)-C(15)-C(11)	120.5(2)
C(15)-C(16)-C(17)	121.9(2)
C(15)-C(16)-H(16)	119.0
C(17)-C(16)-H(16)	119.0
C(18)-C(17)-C(16)	119.8(3)
C(18)-C(17)-H(17)	120.1
C(16)-C(17)-H(17)	120.1
O(2)-C(18)-C(19)	115.7(2)
O(2)-C(18)-C(17)	125.1(3)
C(19)-C(18)-C(17)	119.2(3)
C(20)-C(19)-C(18)	120.4(2)
C(20)-C(19)-H(19)	119.8

C(18)-C(19)-H(19)	119.8
C(19)-C(20)-C(15)	121.4(3)
C(19)-C(20)-H(20)	119.3
C(15)-C(20)-H(20)	119.3
O(2)-C(21)-H(21A)	109.5
O(2)-C(21)-H(21B)	109.5
H(21A)-C(21)-H(21B)	109.5
O(2)-C(21)-H(21C)	109.5
H(21A)-C(21)-H(21C)	109.5
H(21B)-C(21)-H(21C)	109.5

Symmetry transformations used to generate equivalent atoms:

Table S3 Torsion angles [deg] for **4f**

C(6)-C(1)-C(2)-C(3)	1.0(4)
Cl(1)-C(1)-C(2)-C(3)	-177.73(18)
C(1)-C(2)-C(3)-C(4)	-1.0(4)
C(2)-C(3)-C(4)-C(5)	-0.7(3)
C(2)-C(3)-C(4)-C(7)	-176.3(2)
C(3)-C(4)-C(5)-C(6)	2.4(3)
C(7)-C(4)-C(5)-C(6)	178.3(2)
C(2)-C(1)-C(6)-C(5)	0.7(4)
Cl(1)-C(1)-C(6)-C(5)	179.42(19)
C(4)-C(5)-C(6)-C(1)	-2.4(4)
C(5)-C(4)-C(7)-O(1)	-39.3(3)
C(3)-C(4)-C(7)-O(1)	136.4(2)
C(5)-C(4)-C(7)-C(8)	138.8(2)
C(3)-C(4)-C(7)-C(8)	-45.5(3)
O(1)-C(7)-C(8)-C(9)	165.5(2)
C(4)-C(7)-C(8)-C(9)	-12.6(4)
O(1)-C(7)-C(8)-C(12)	-2.1(4)
C(4)-C(7)-C(8)-C(12)	179.8(2)
C(12)-C(8)-C(9)-C(10)	-9.8(3)
C(7)-C(8)-C(9)-C(10)	-178.0(2)
C(8)-C(9)-C(10)-N(3)	170.2(2)
C(8)-C(9)-C(10)-C(11)	-7.4(4)
O(4)-N(3)-C(10)-C(9)	-6.9(4)
O(3)-N(3)-C(10)-C(9)	173.1(2)

O(4)-N(3)-C(10)-C(11)	170.8(2)
O(3)-N(3)-C(10)-C(11)	-9.2(3)
C(12)-N(2)-C(11)-C(10)	-30.6(3)
C(14)-N(2)-C(11)-C(10)	172.9(2)
C(12)-N(2)-C(11)-C(15)	96.5(3)
C(14)-N(2)-C(11)-C(15)	-60.0(3)
C(9)-C(10)-C(11)-N(2)	25.5(3)
N(3)-C(10)-C(11)-N(2)	-152.1(2)
C(9)-C(10)-C(11)-C(15)	-99.1(3)
N(3)-C(10)-C(11)-C(15)	83.3(3)
C(13)-N(1)-C(12)-N(2)	-3.6(3)
C(13)-N(1)-C(12)-C(8)	172.9(2)
C(11)-N(2)-C(12)-N(1)	-165.7(2)
C(14)-N(2)-C(12)-N(1)	-7.0(3)
C(11)-N(2)-C(12)-C(8)	17.5(4)
C(14)-N(2)-C(12)-C(8)	176.3(2)
C(9)-C(8)-C(12)-N(1)	-171.0(2)
C(7)-C(8)-C(12)-N(1)	-2.1(4)
C(9)-C(8)-C(12)-N(2)	5.2(3)
C(7)-C(8)-C(12)-N(2)	174.0(2)
C(12)-N(1)-C(13)-C(14)	11.9(3)
C(12)-N(2)-C(14)-C(13)	13.8(3)
C(11)-N(2)-C(14)-C(13)	173.3(2)
N(1)-C(13)-C(14)-N(2)	-14.6(3)
N(2)-C(11)-C(15)-C(16)	-47.5(3)
C(10)-C(11)-C(15)-C(16)	73.9(3)
N(2)-C(11)-C(15)-C(20)	129.9(2)
C(10)-C(11)-C(15)-C(20)	-108.8(3)
C(20)-C(15)-C(16)-C(17)	-0.7(4)
C(11)-C(15)-C(16)-C(17)	176.7(2)
C(15)-C(16)-C(17)-C(18)	1.0(4)
C(21)-O(2)-C(18)-C(19)	-173.5(2)
C(21)-O(2)-C(18)-C(17)	7.3(4)
C(16)-C(17)-C(18)-O(2)	179.4(2)
C(16)-C(17)-C(18)-C(19)	0.2(4)
O(2)-C(18)-C(19)-C(20)	179.1(2)
C(17)-C(18)-C(19)-C(20)	-1.6(4)
C(18)-C(19)-C(20)-C(15)	2.0(4)

C(16)-C(15)-C(20)-C(19)	-0.8(4)
C(11)-C(15)-C(20)-C(19)	-178.2(2)

Table S4 Hydrogen bonds for **4f** [A and deg.]

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
C(11)-H(11)...O(3)	0.98	2.45	3.342(3)	151.2
N(1)-H(1)...O(1)^{i}	0.86	2.13	2.841(3)	140.2
N(1)-H(1)...O(1)^{ii}	0.86	2.15	2.683(3)	120.0

^{1}H NMR and ^{13}C NMR Spectra for Tetrahydroimidazo[1,2-*a*]pyridine Derivatives 4

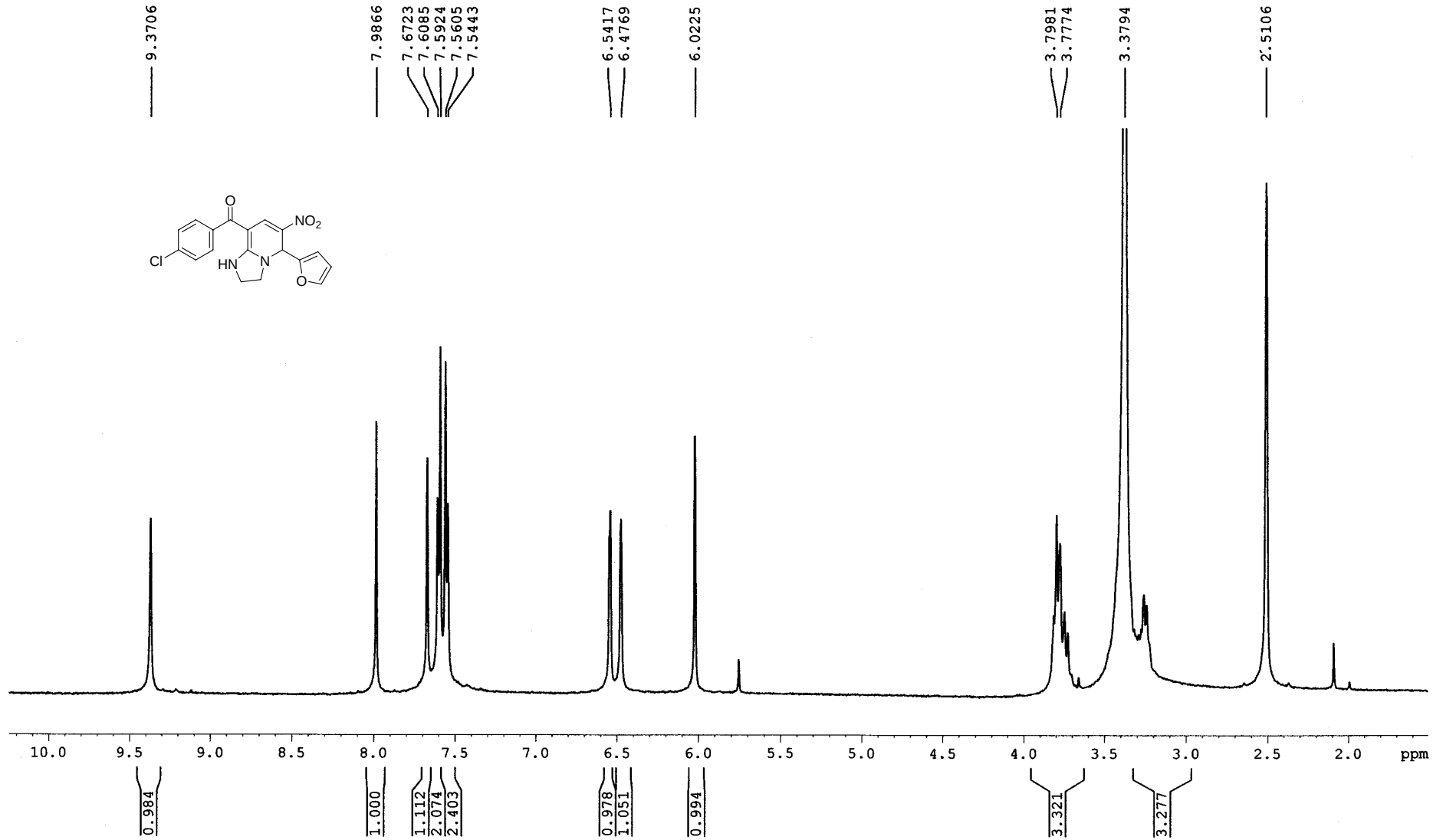


Figure 1. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4a**

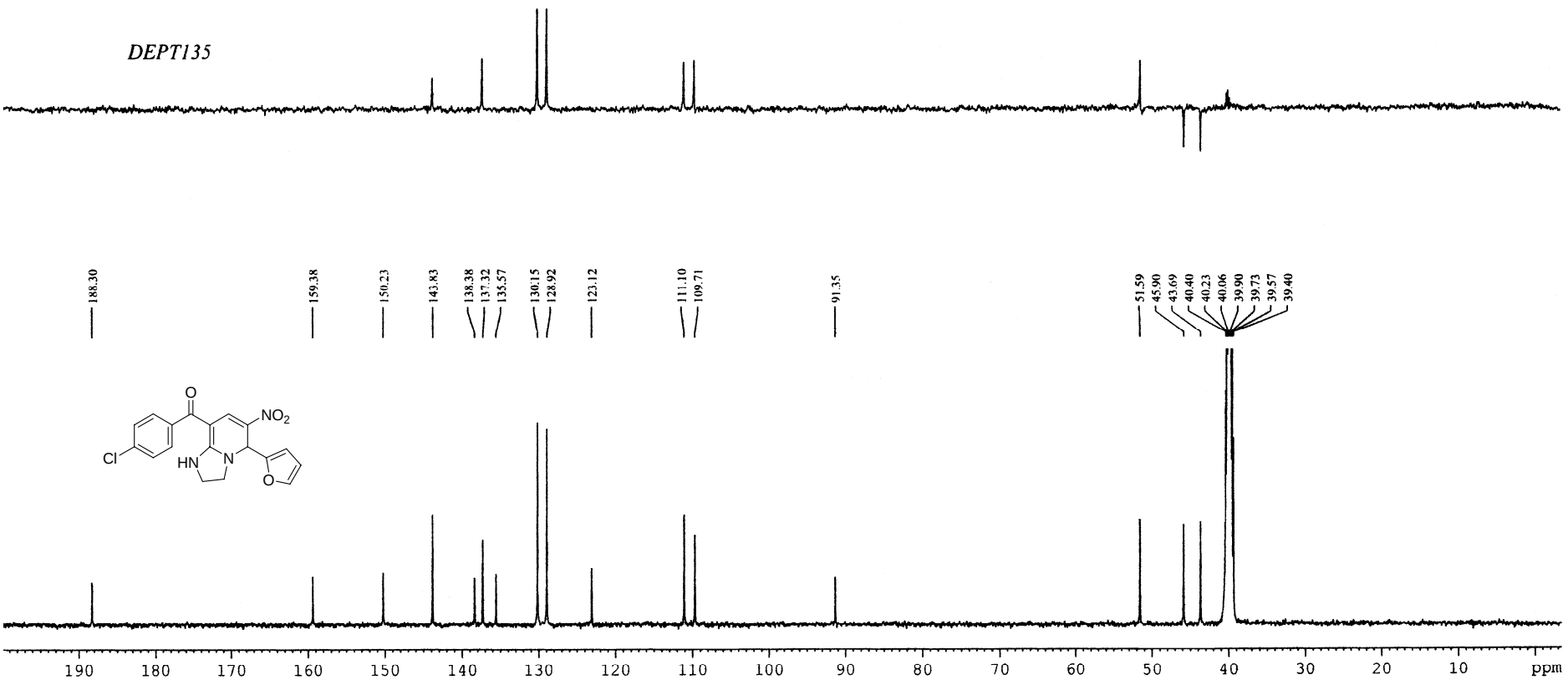


Figure 2. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4a**

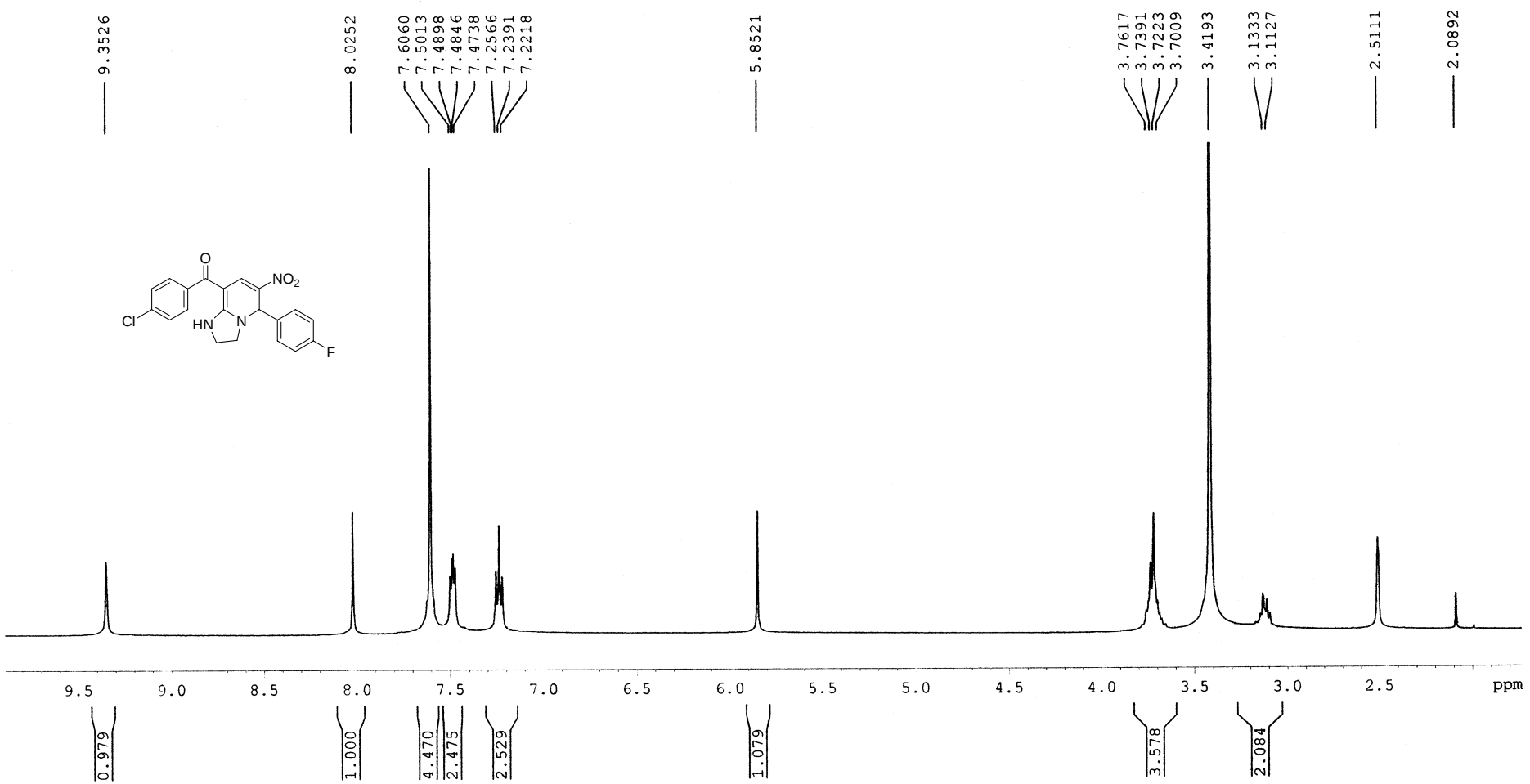


Figure 3. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4b**

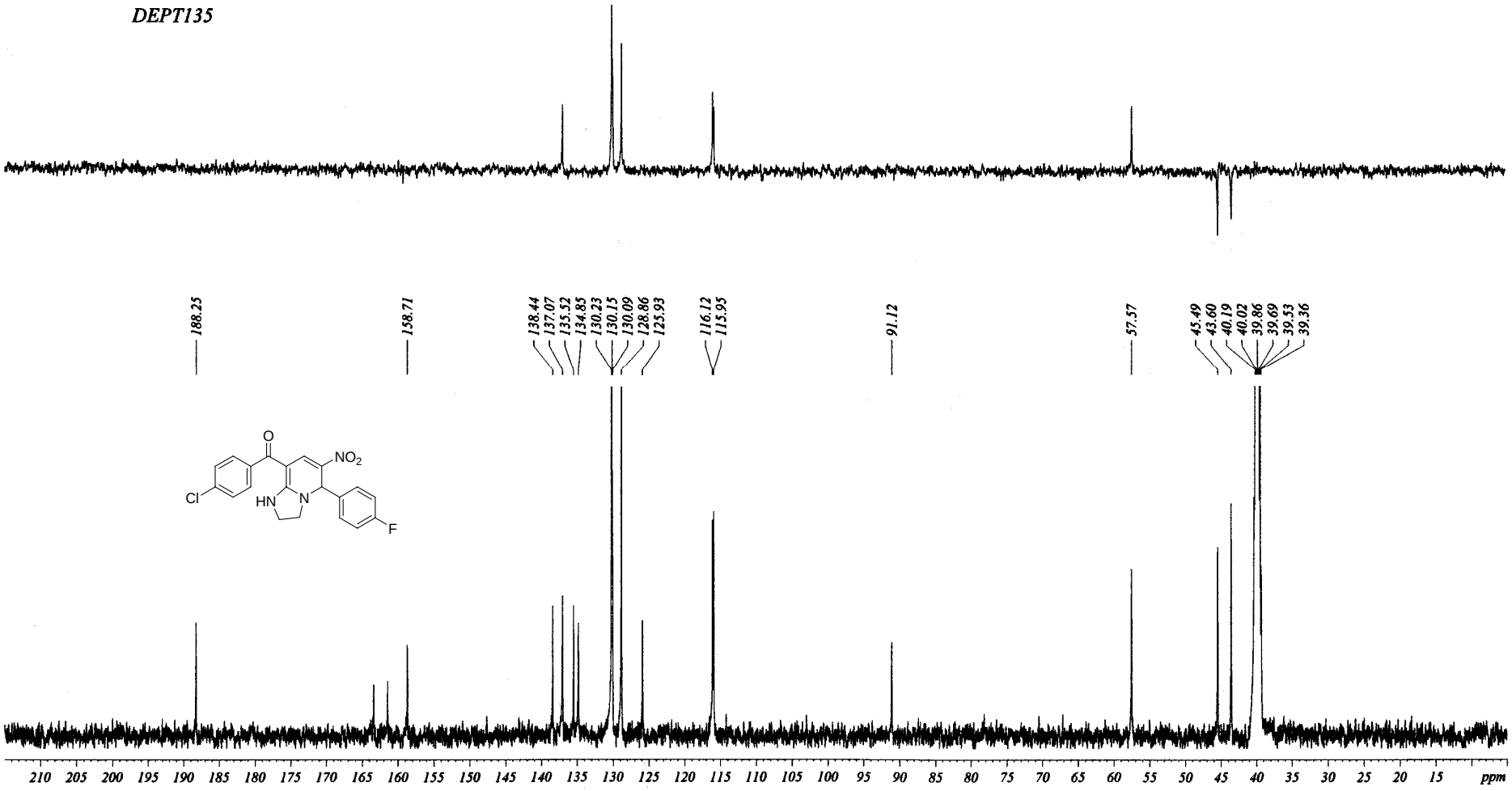


Figure 4. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4b**

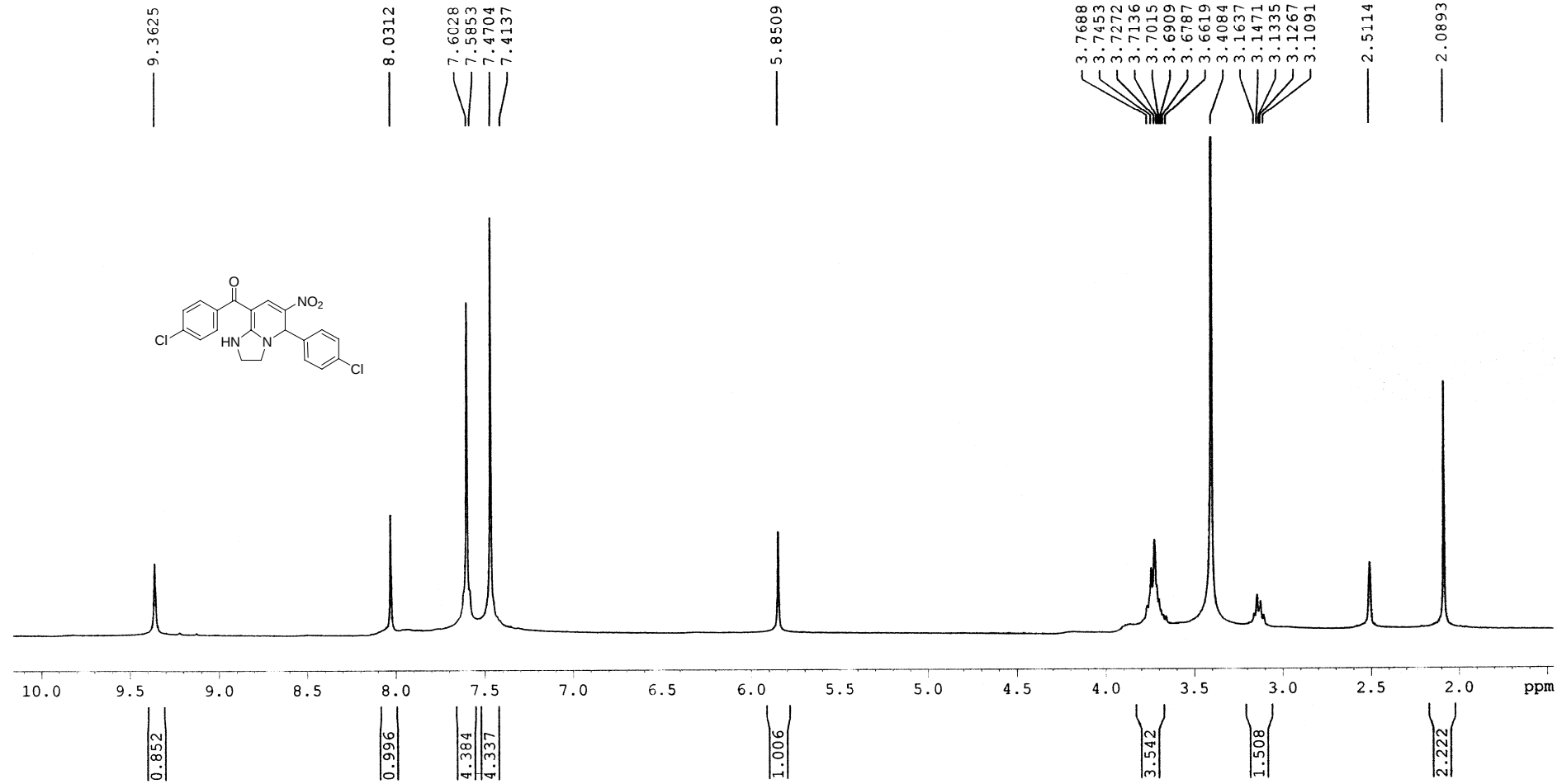


Figure 5. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4c**

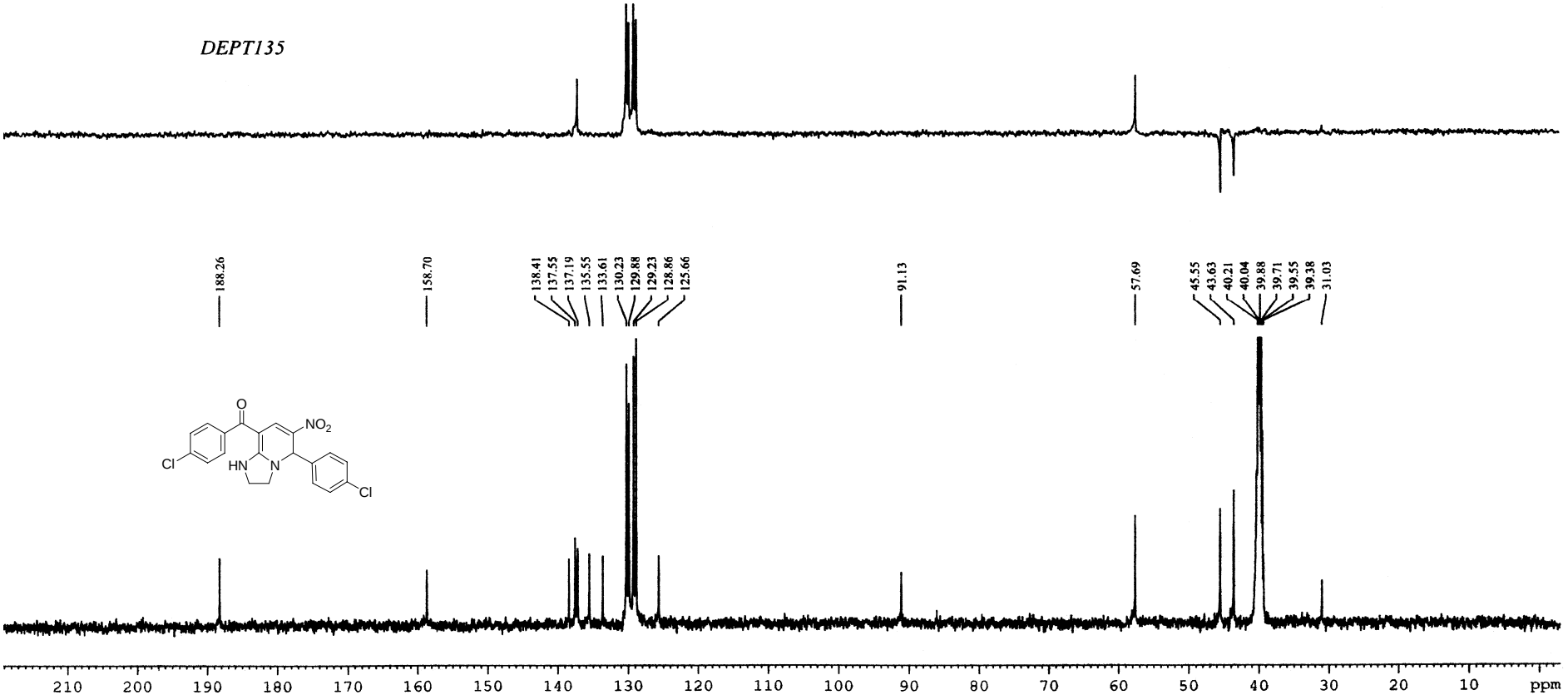


Figure 6. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4c**

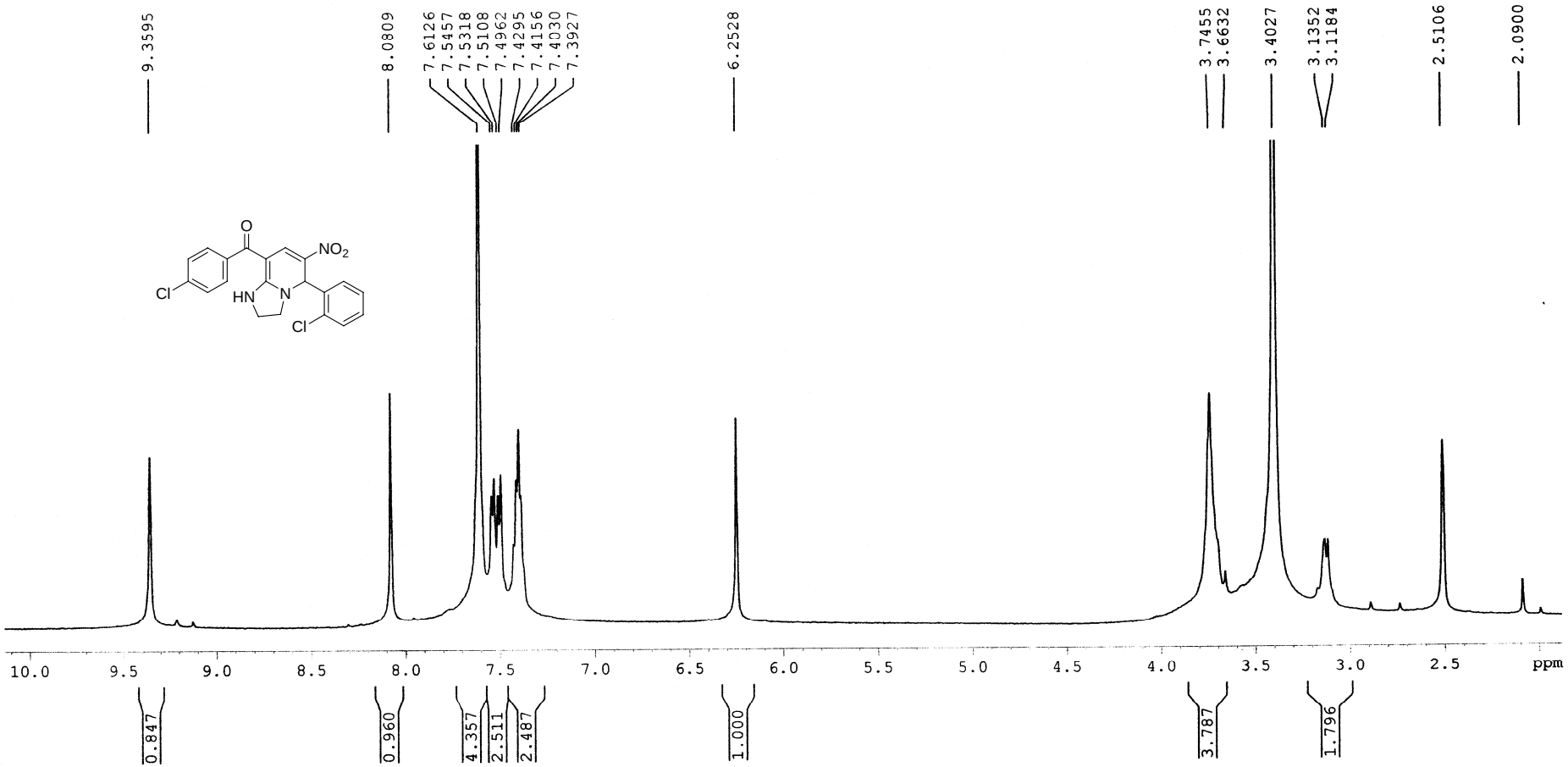


Figure 7. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4d**

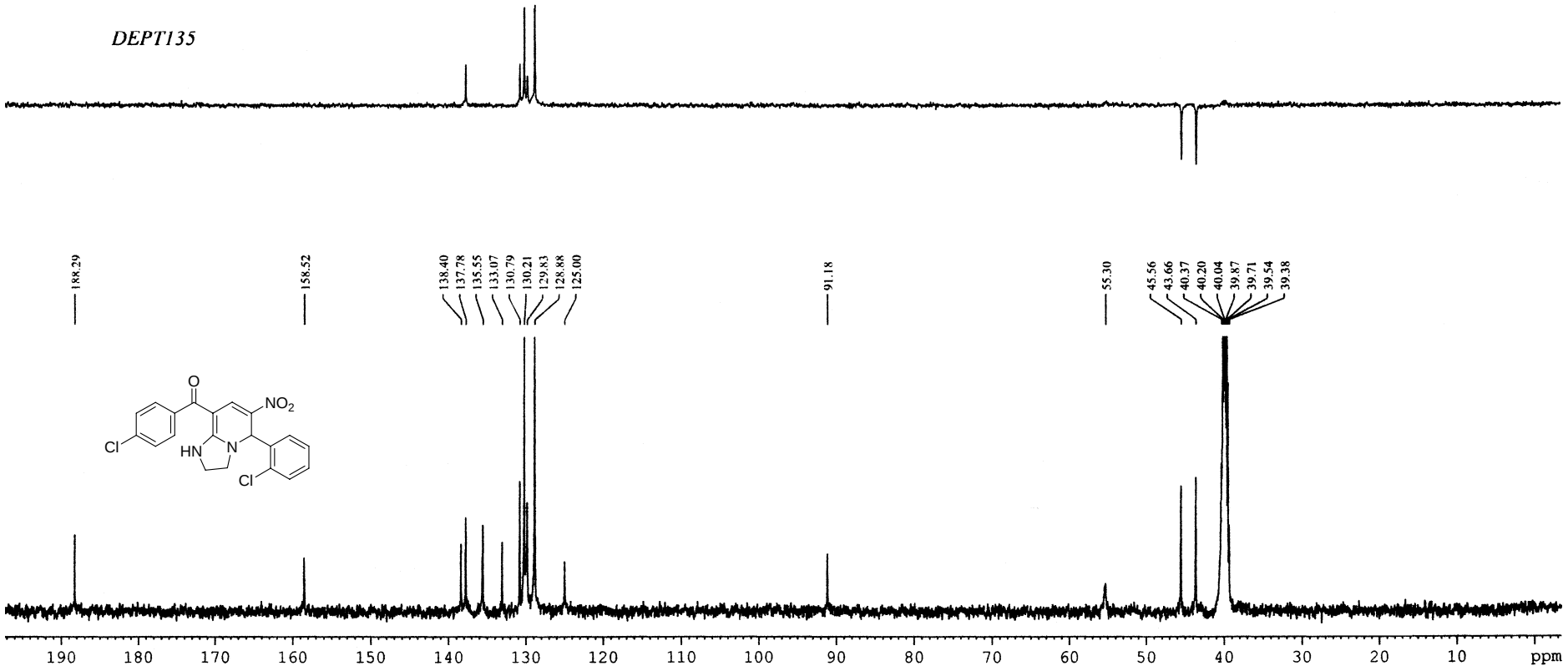


Figure 8. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4d**

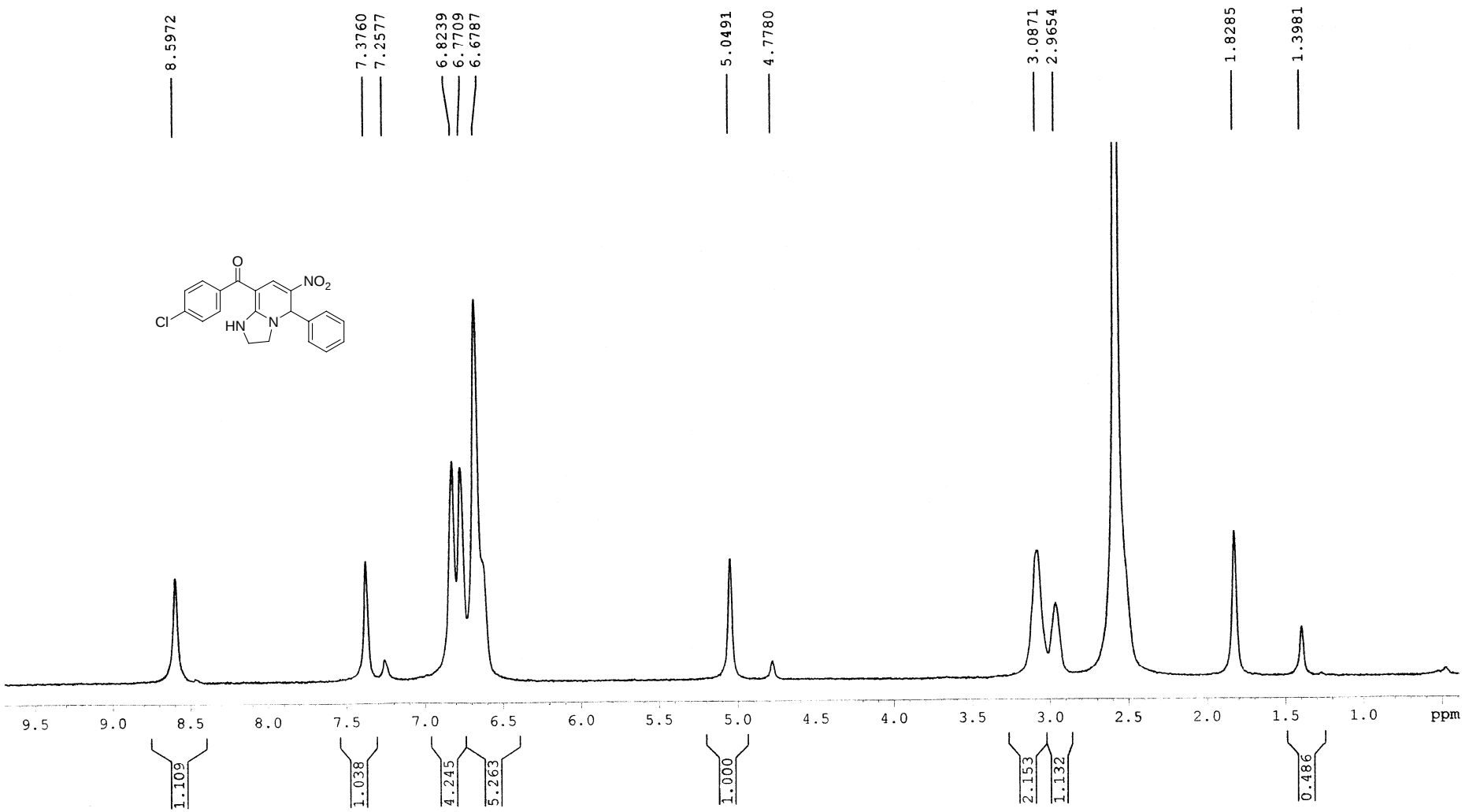


Figure 9. ^{1}H NMR (500 MHz, $CDCl_3$+DMSO-d_6) spectra of compound **4e**

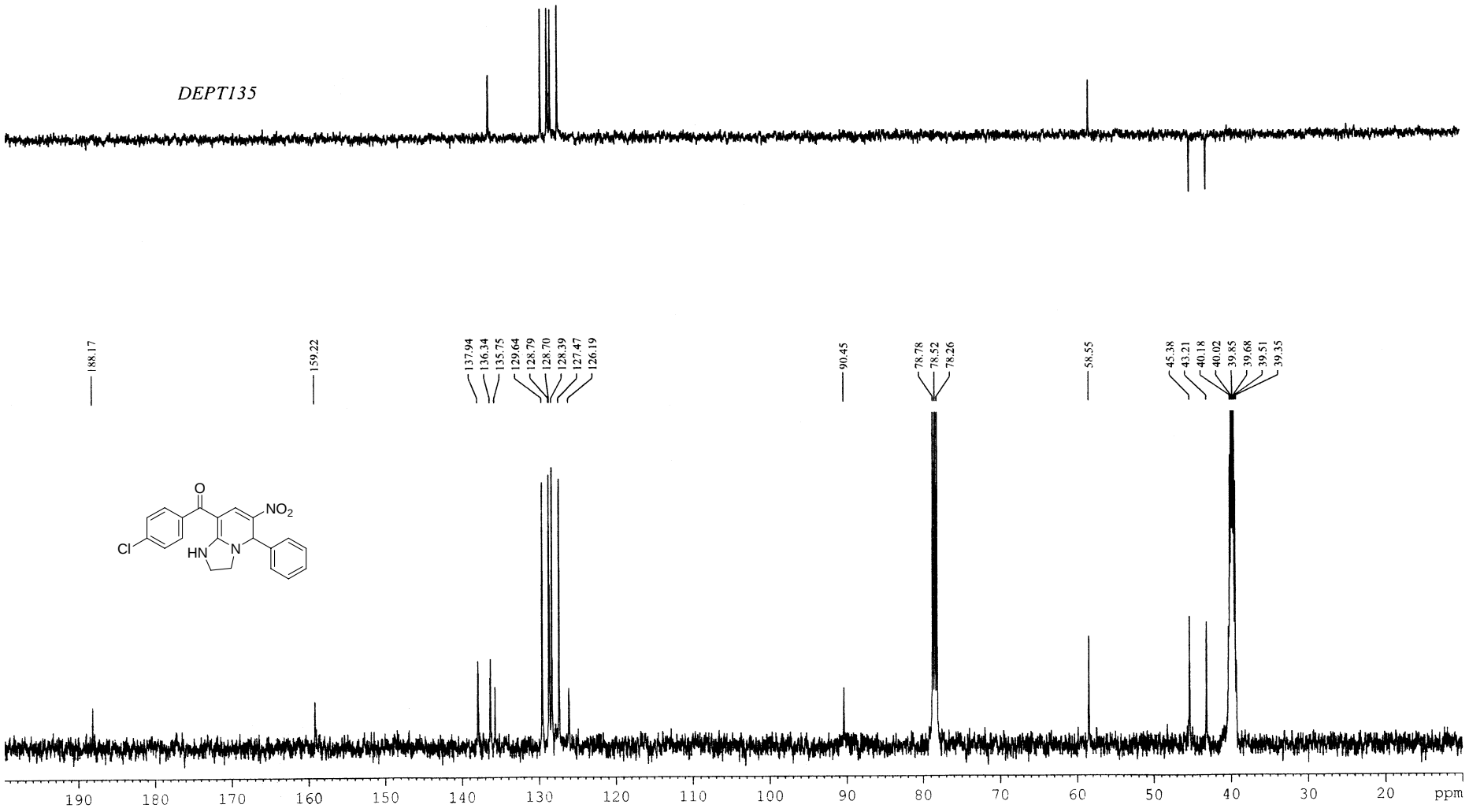


Figure 10. ^{13}C NMR (125 MHz, $CDCl_3$+DMSO-d_6) spectra of compound **4e**

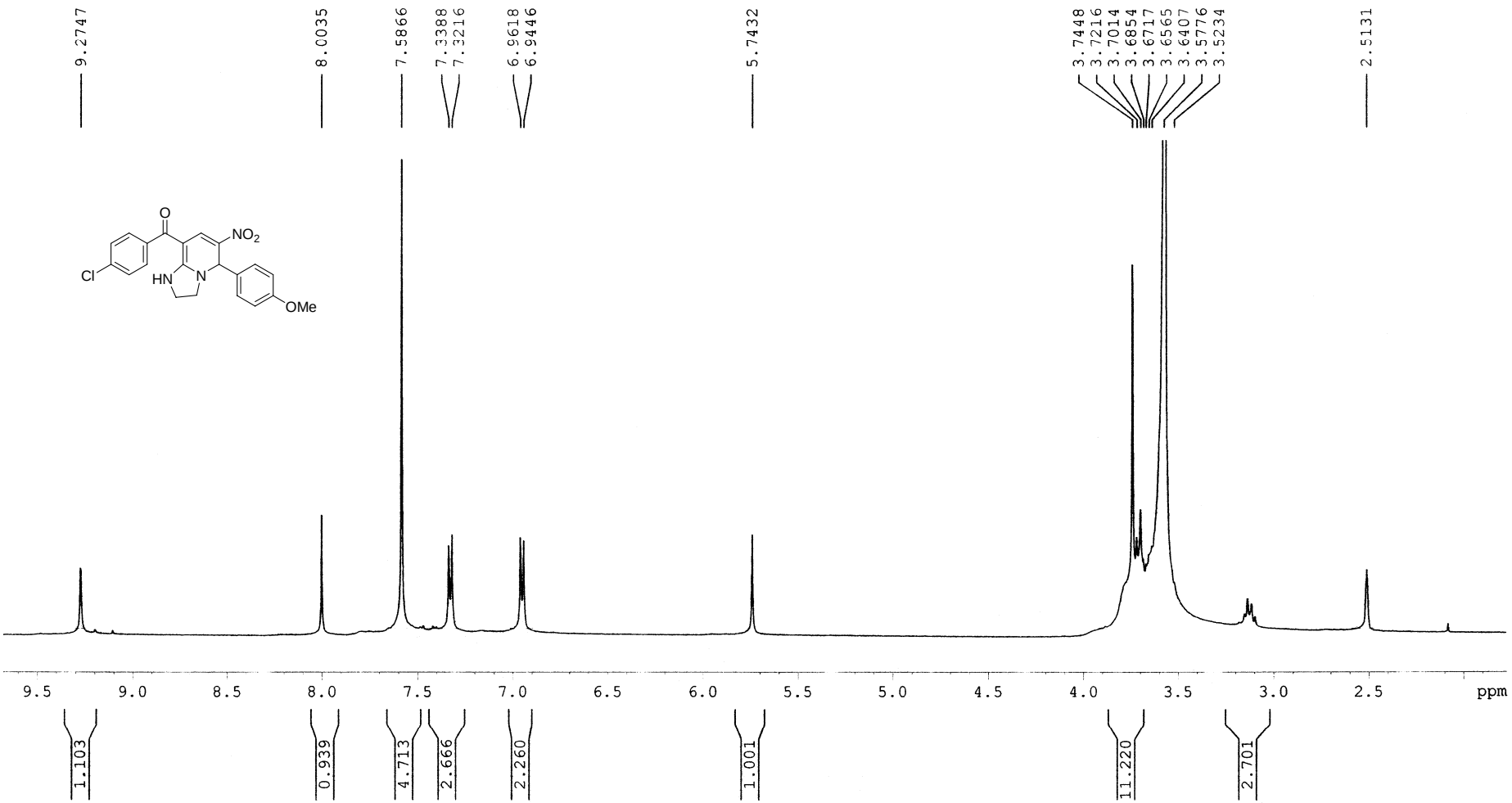


Figure 11. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4f**

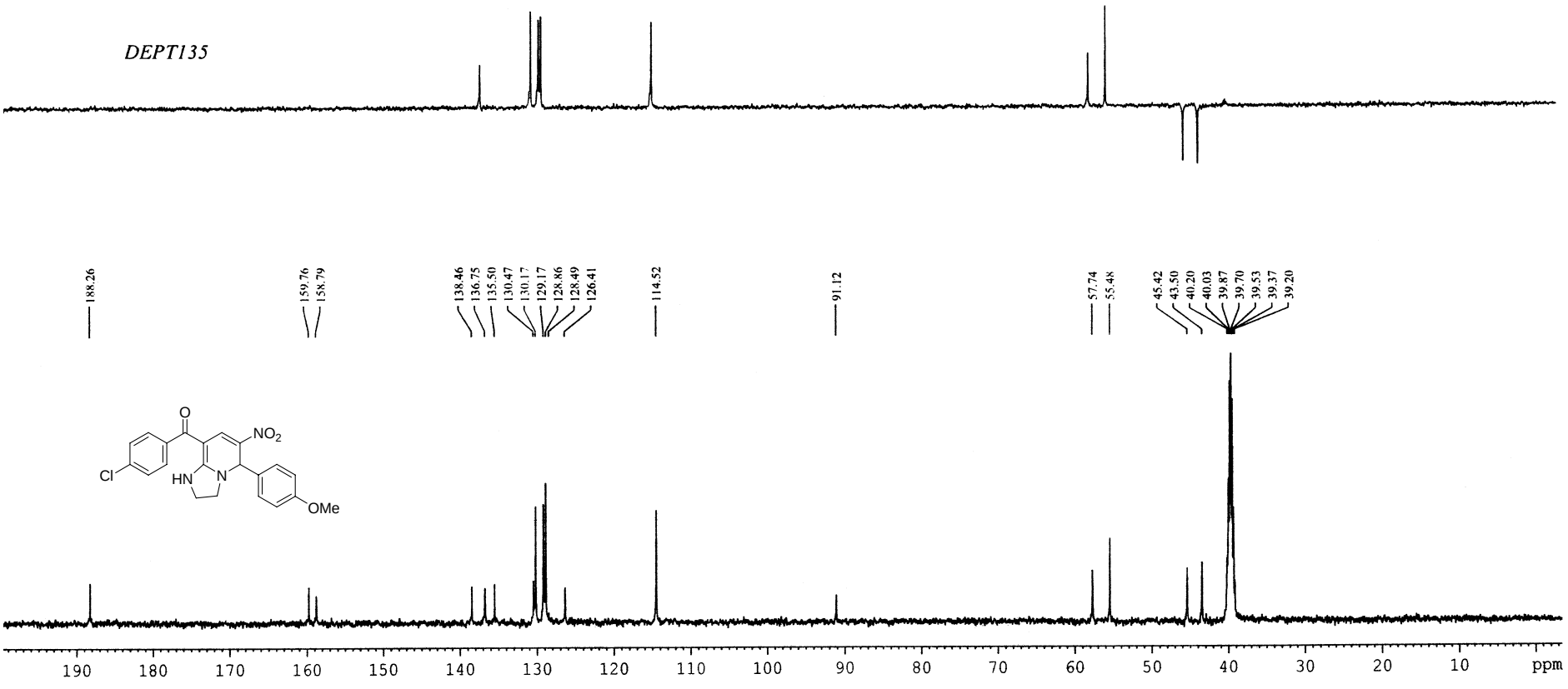


Figure 12. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4f**

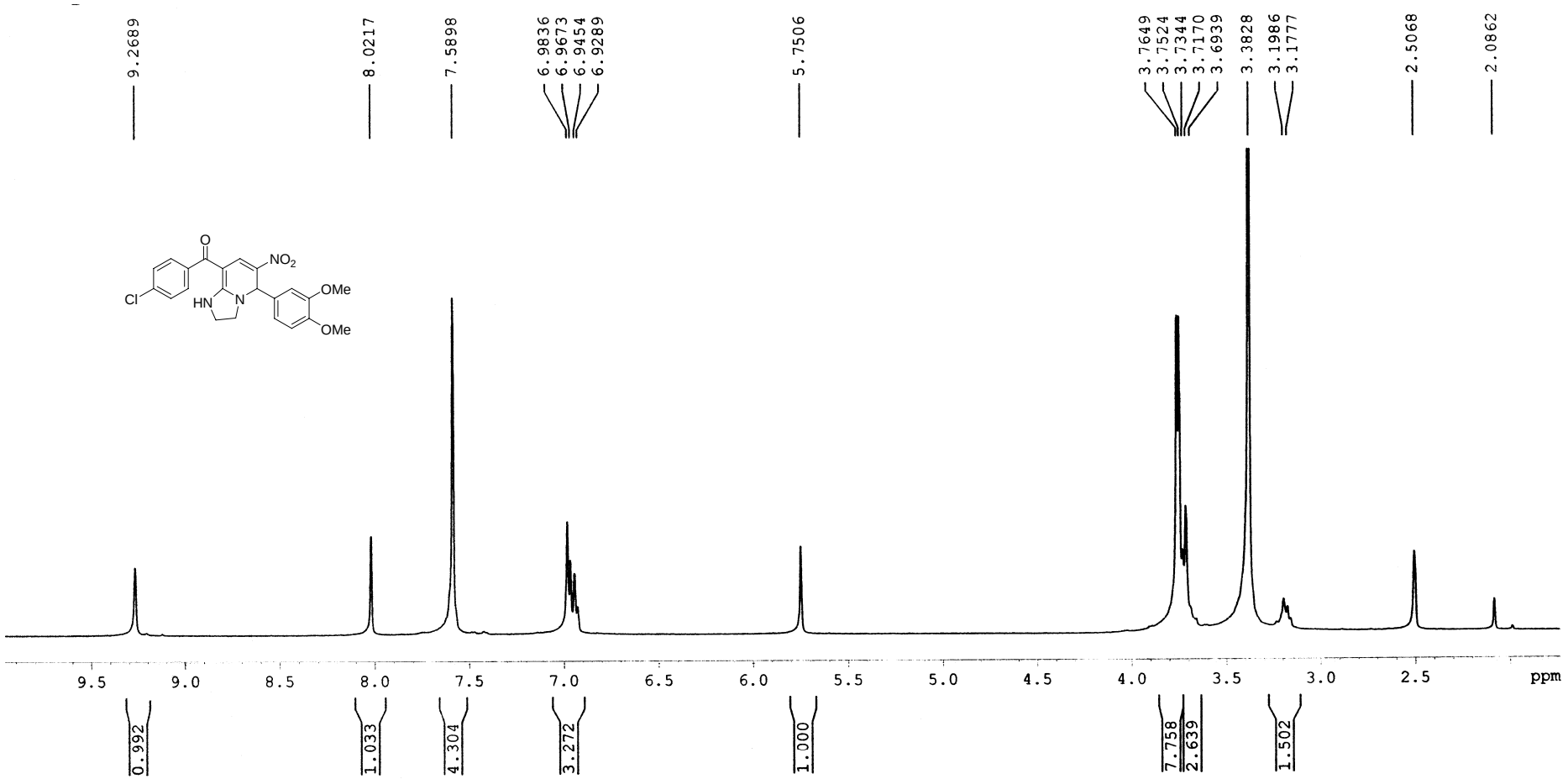


Figure 13. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4g**

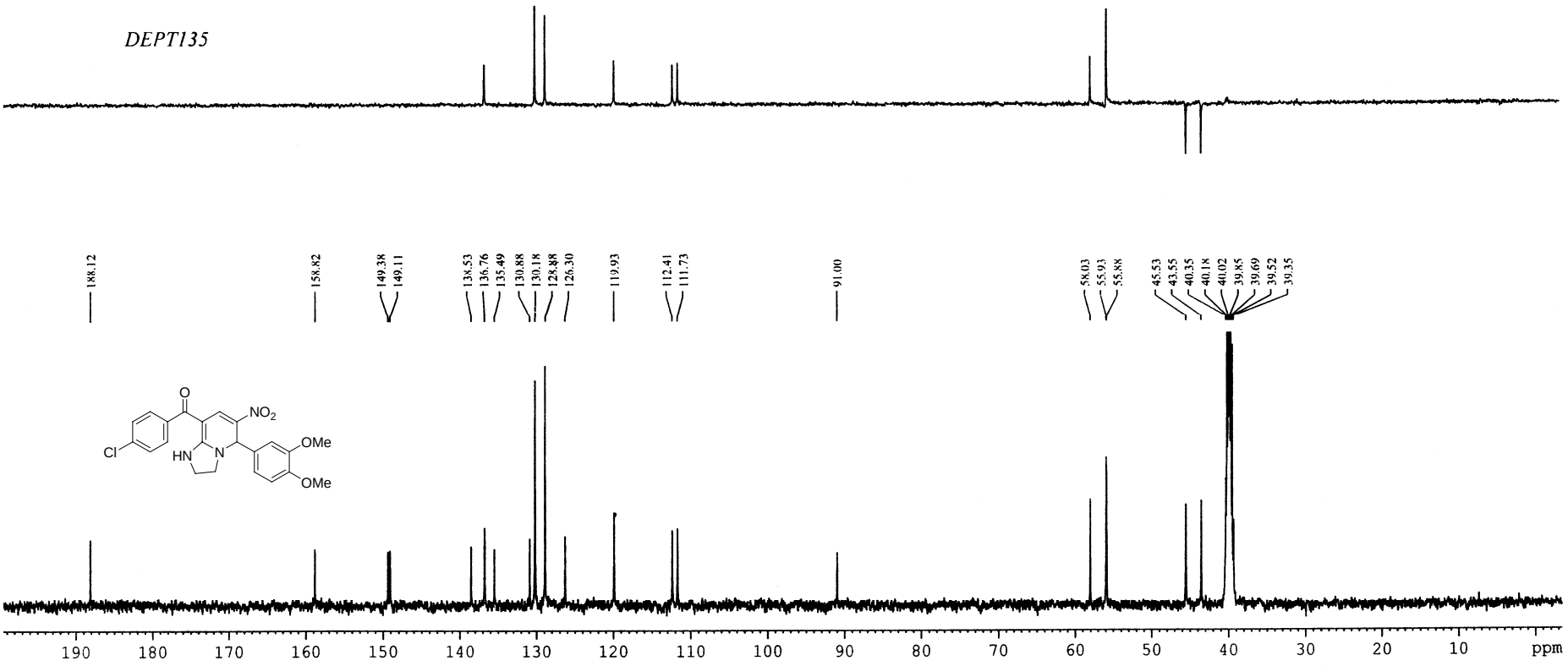


Figure 14. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4g**

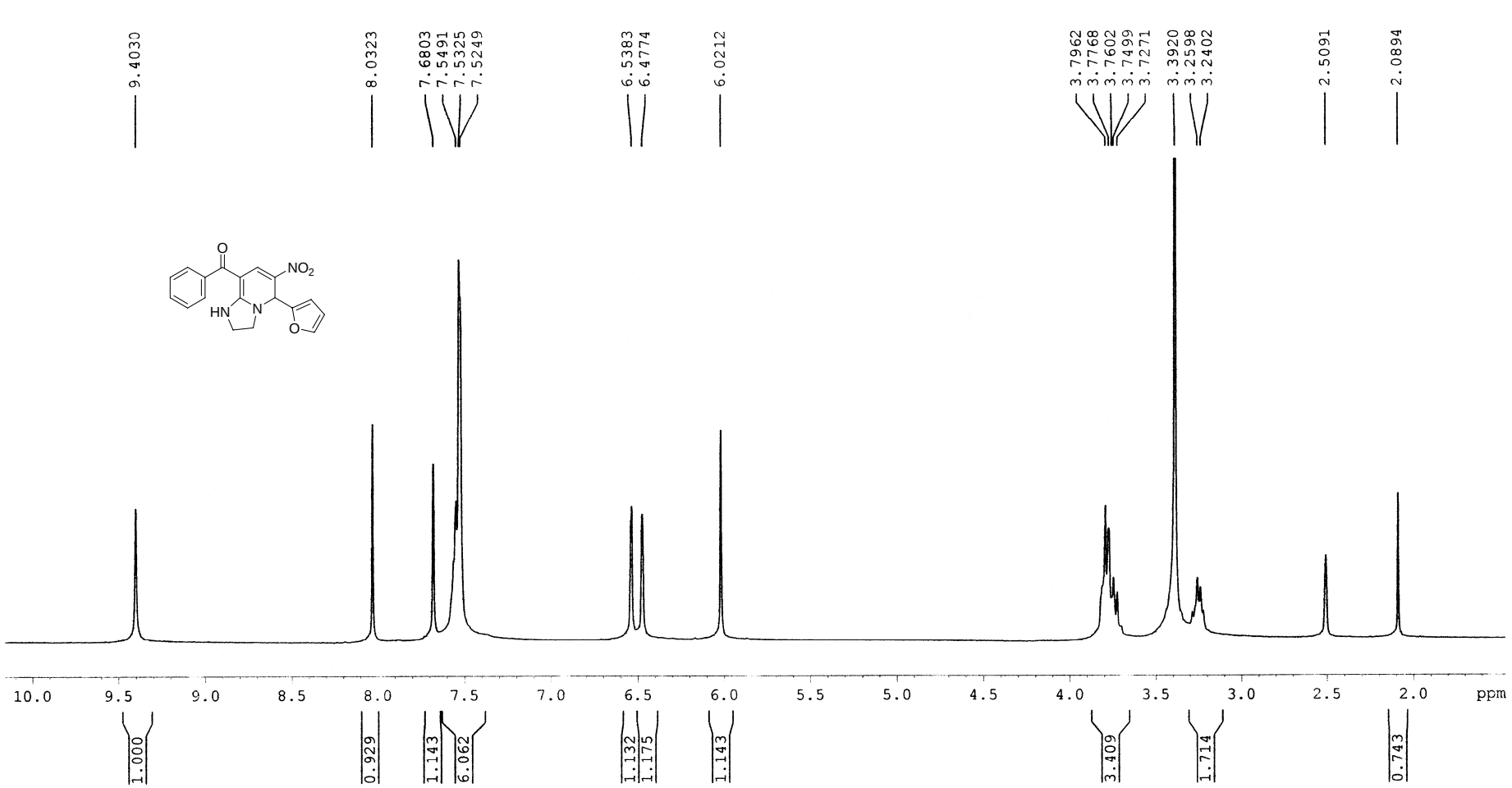


Figure 15. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4h**

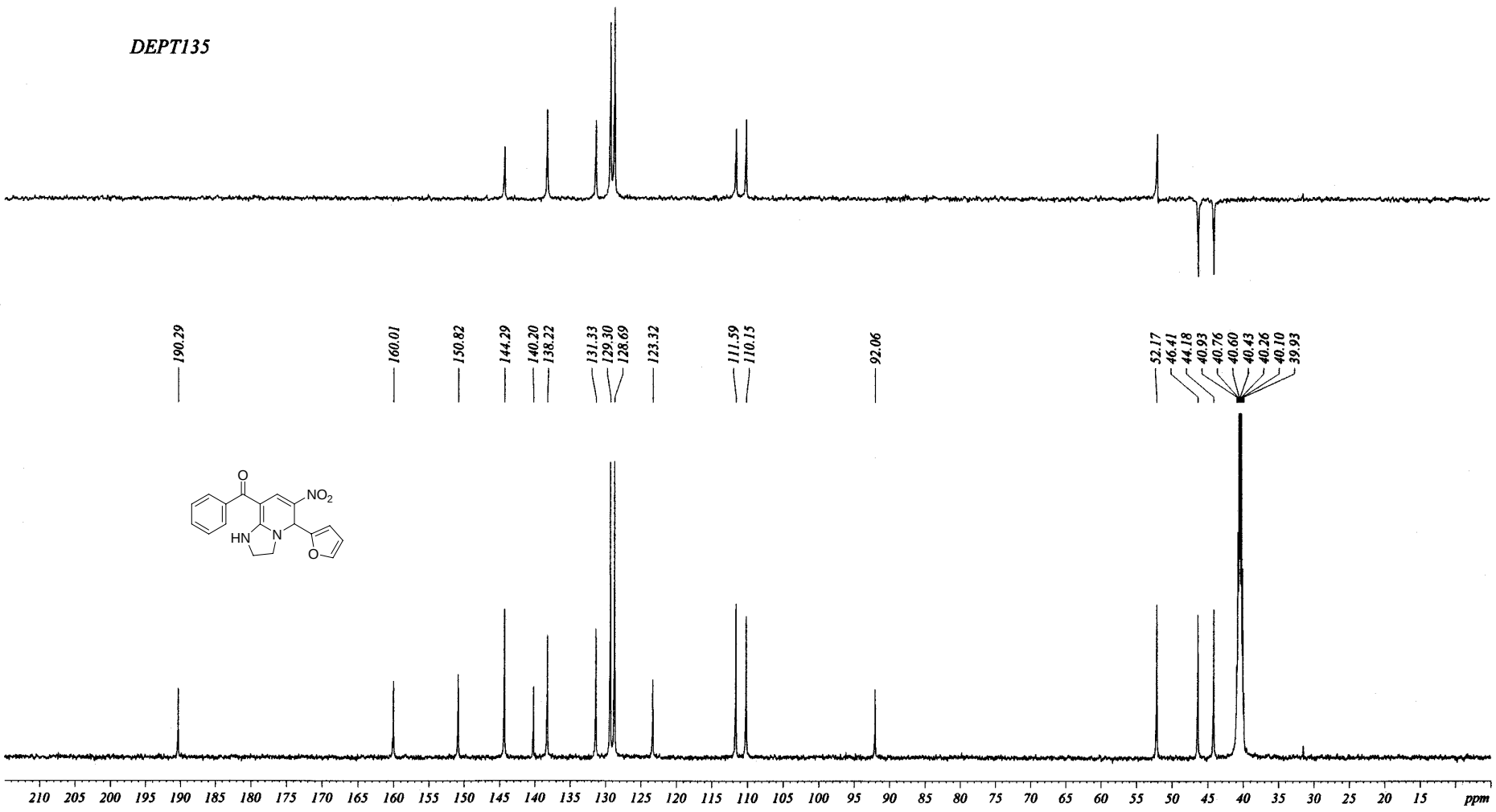


Figure 16. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4h**

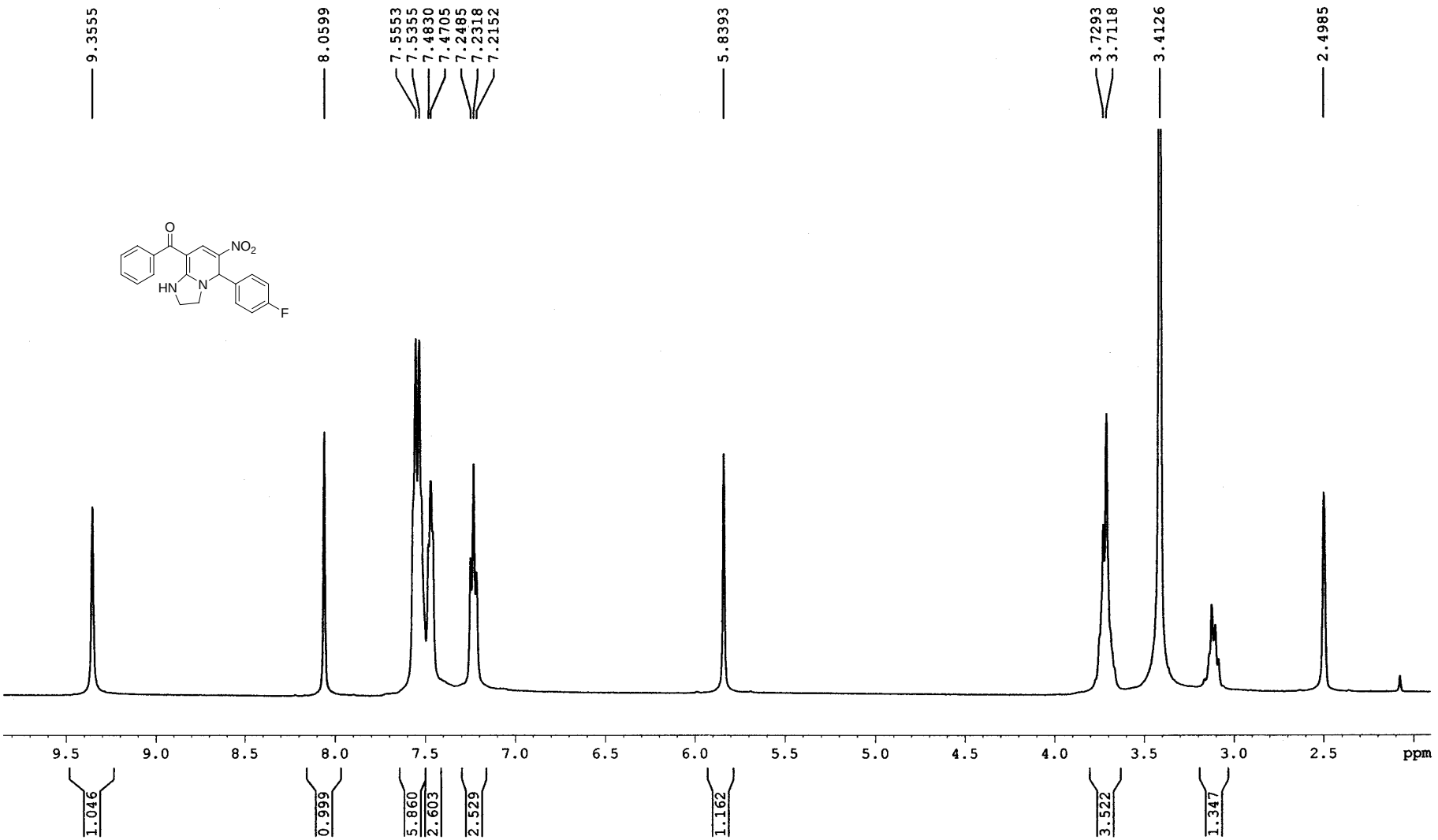


Figure 17. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4i**

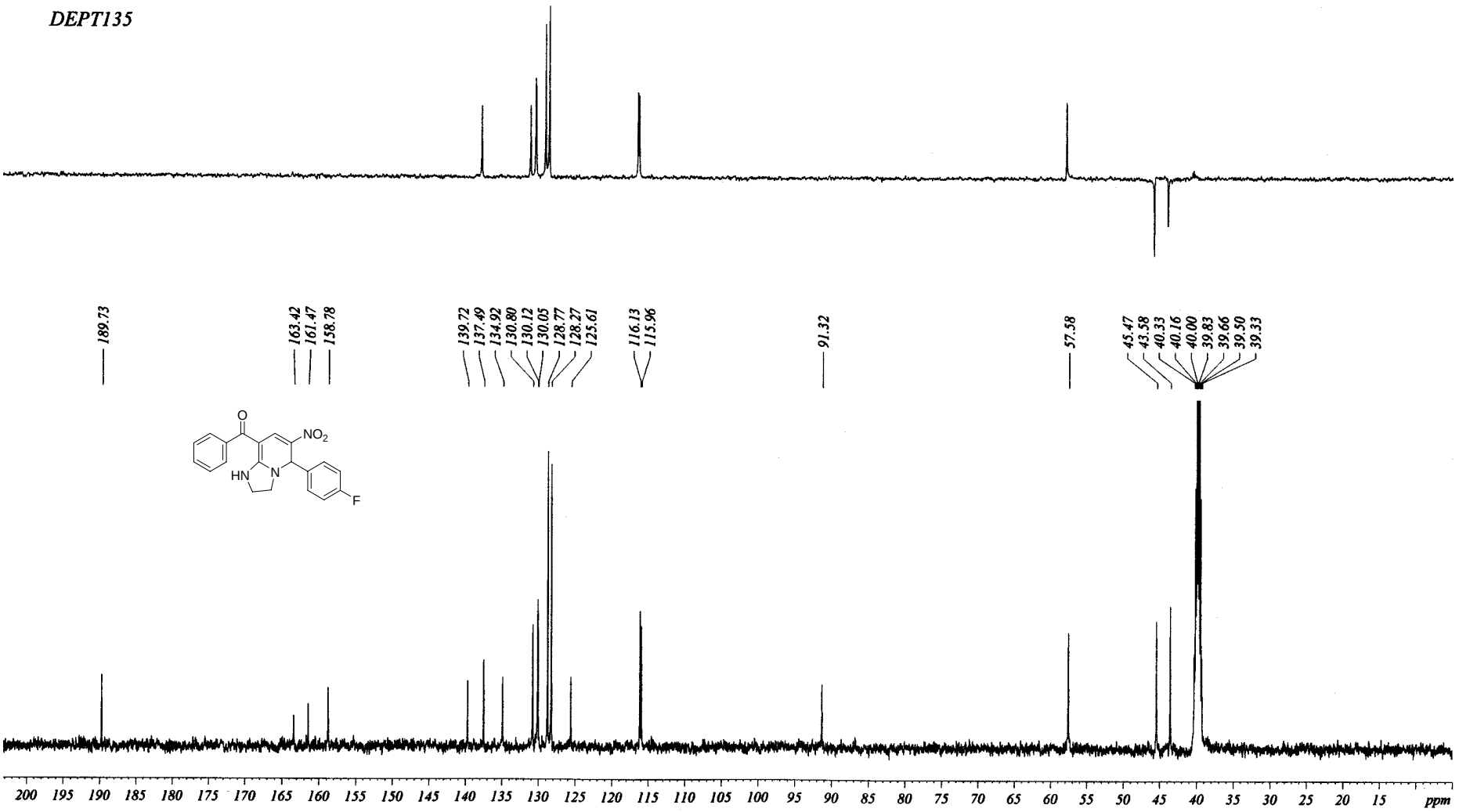


Figure 18. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4i**

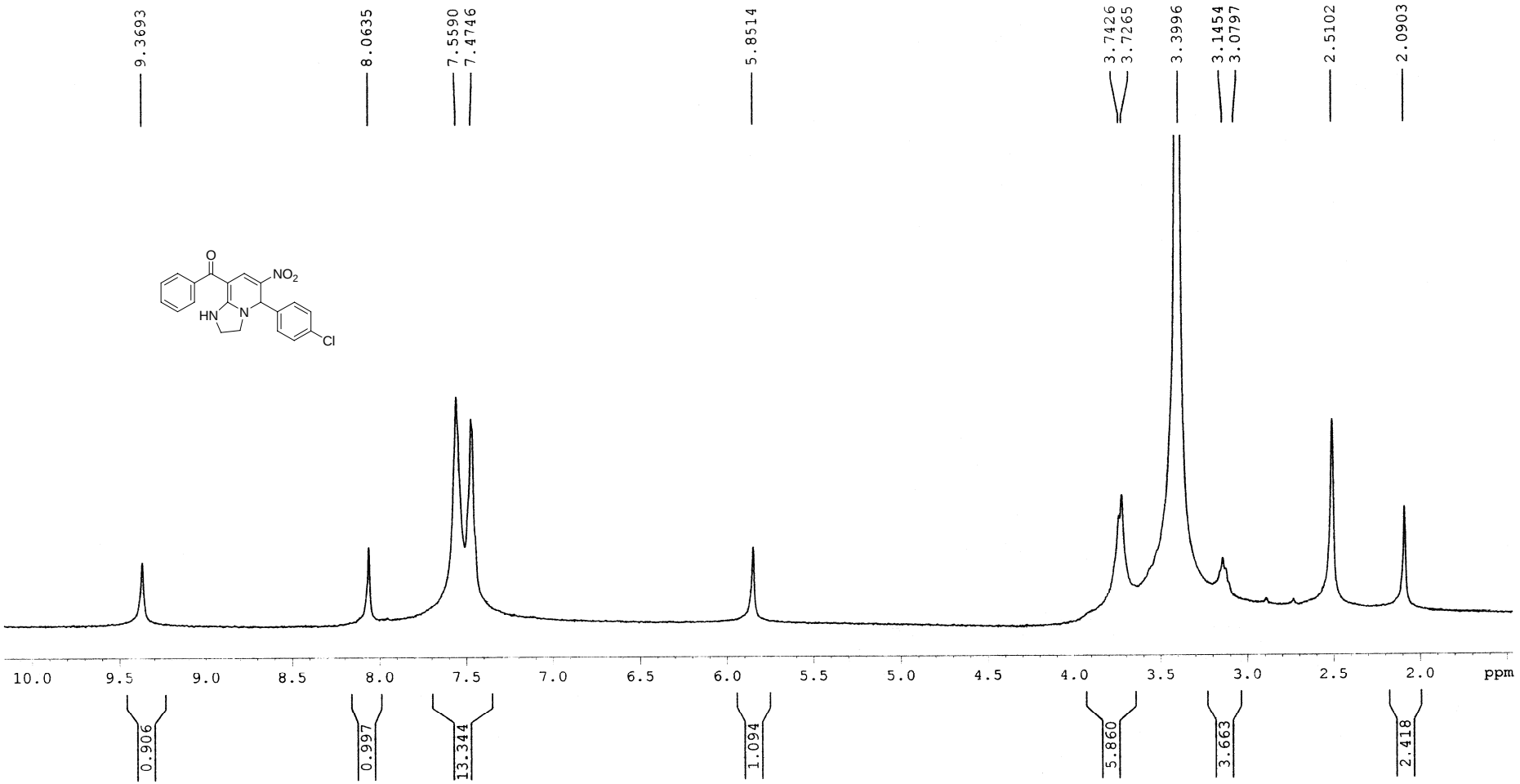


Figure 19. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4j**

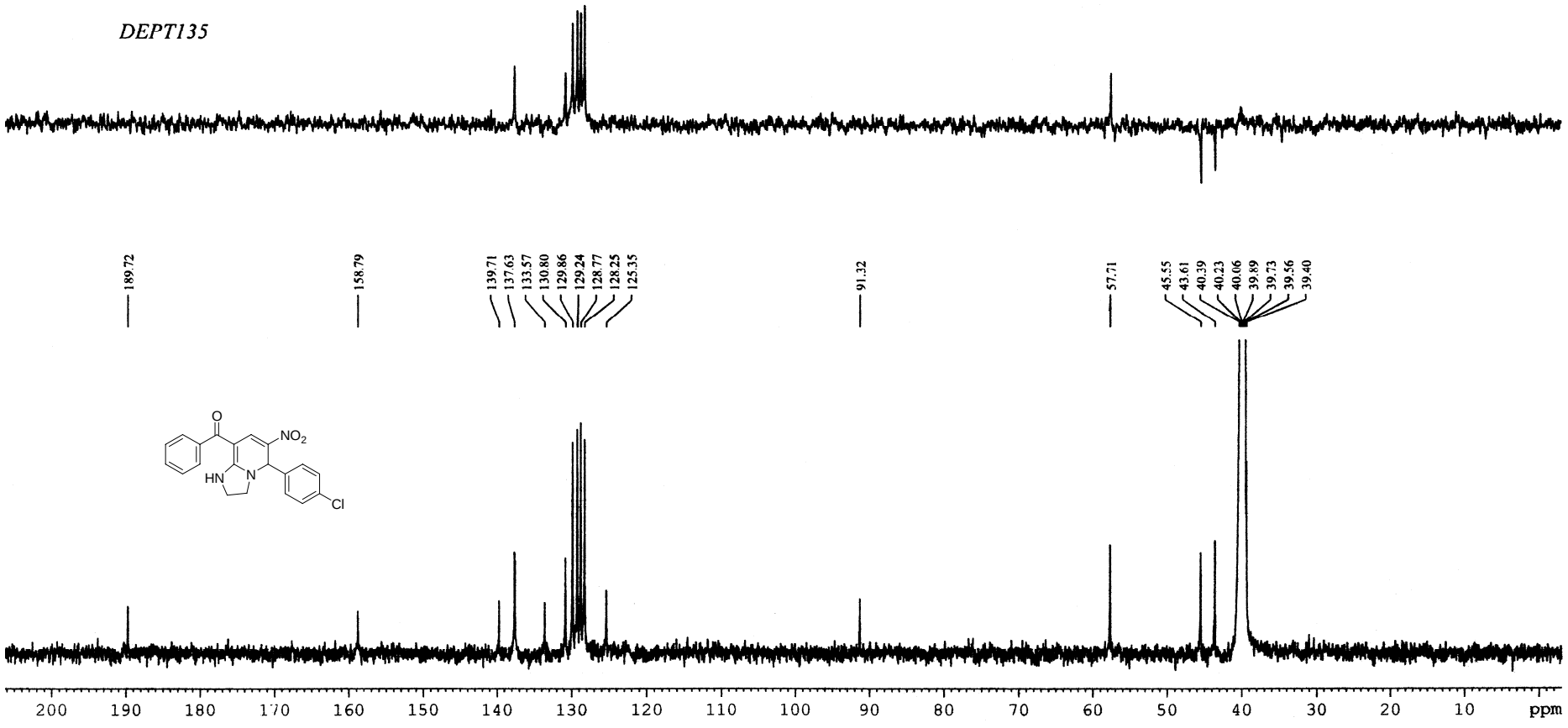


Figure 20. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4j**

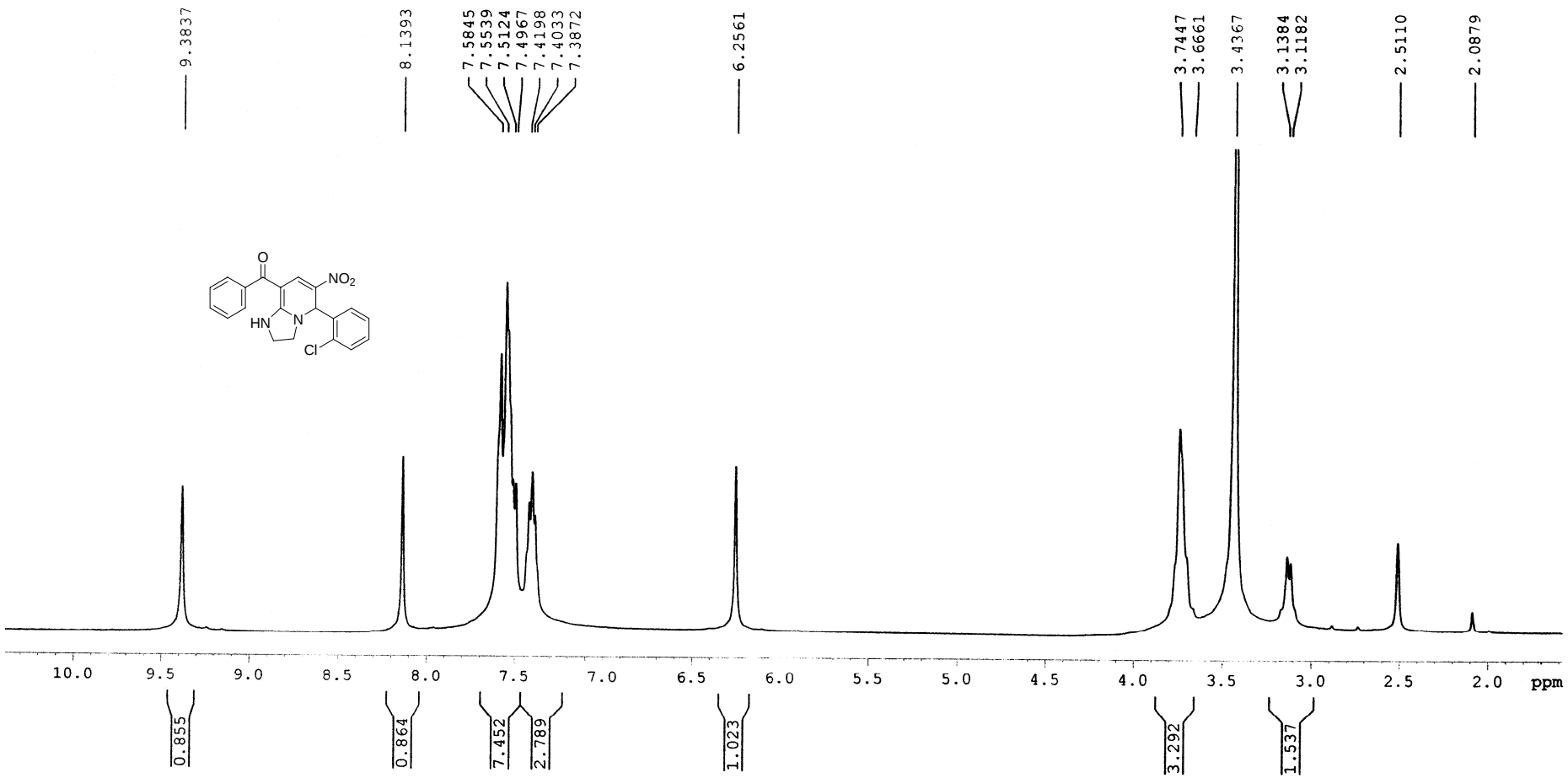


Figure 21. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4k**

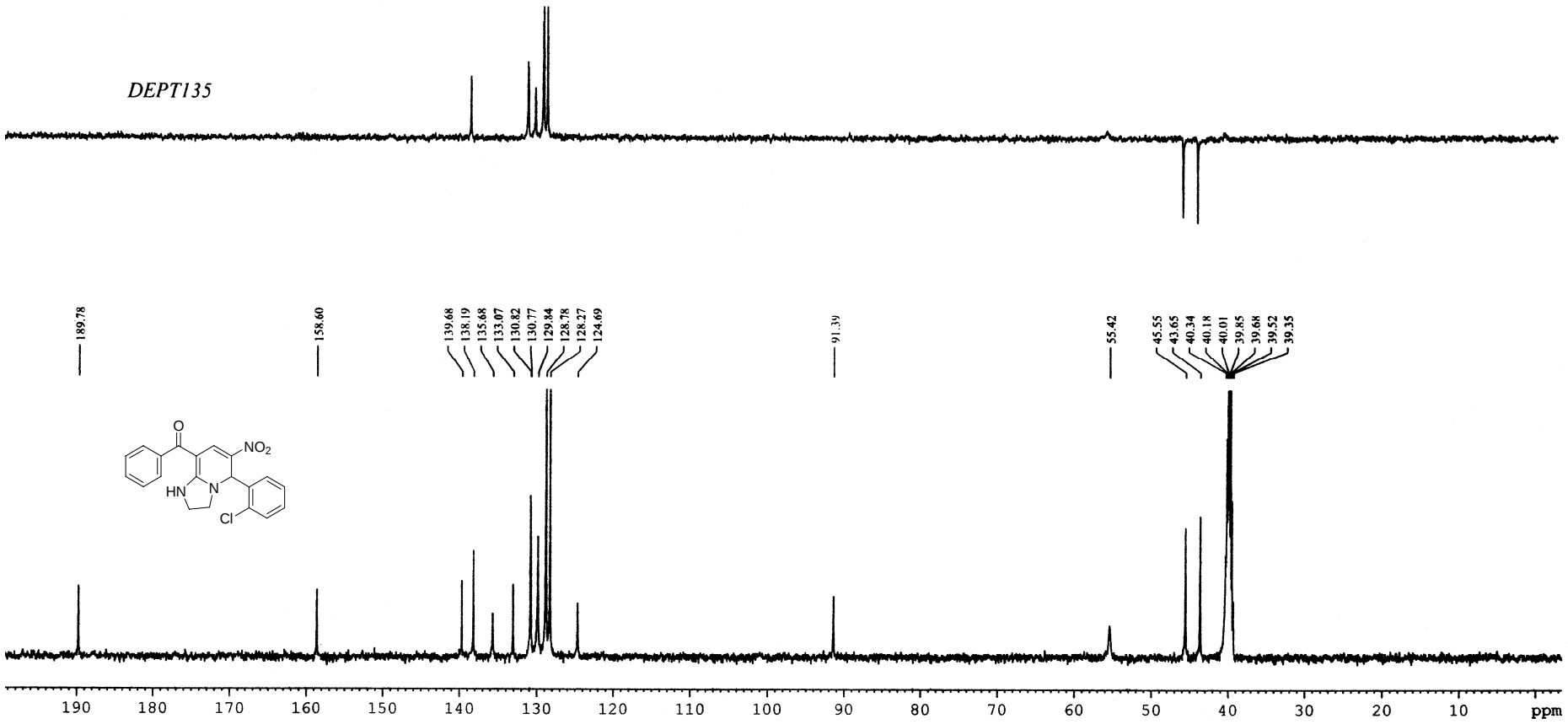


Figure 22. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4k**

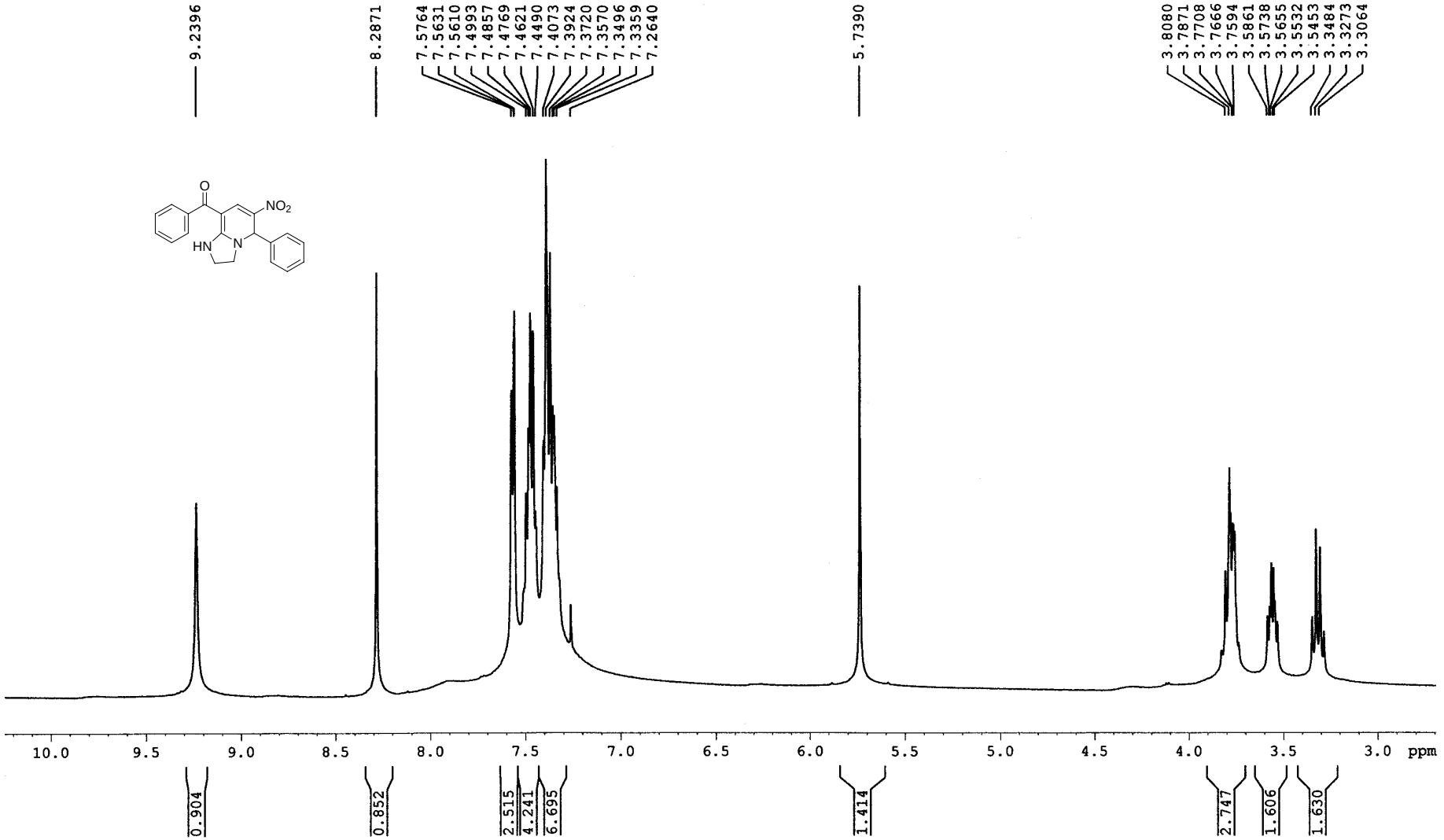


Figure 23. ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **4l**

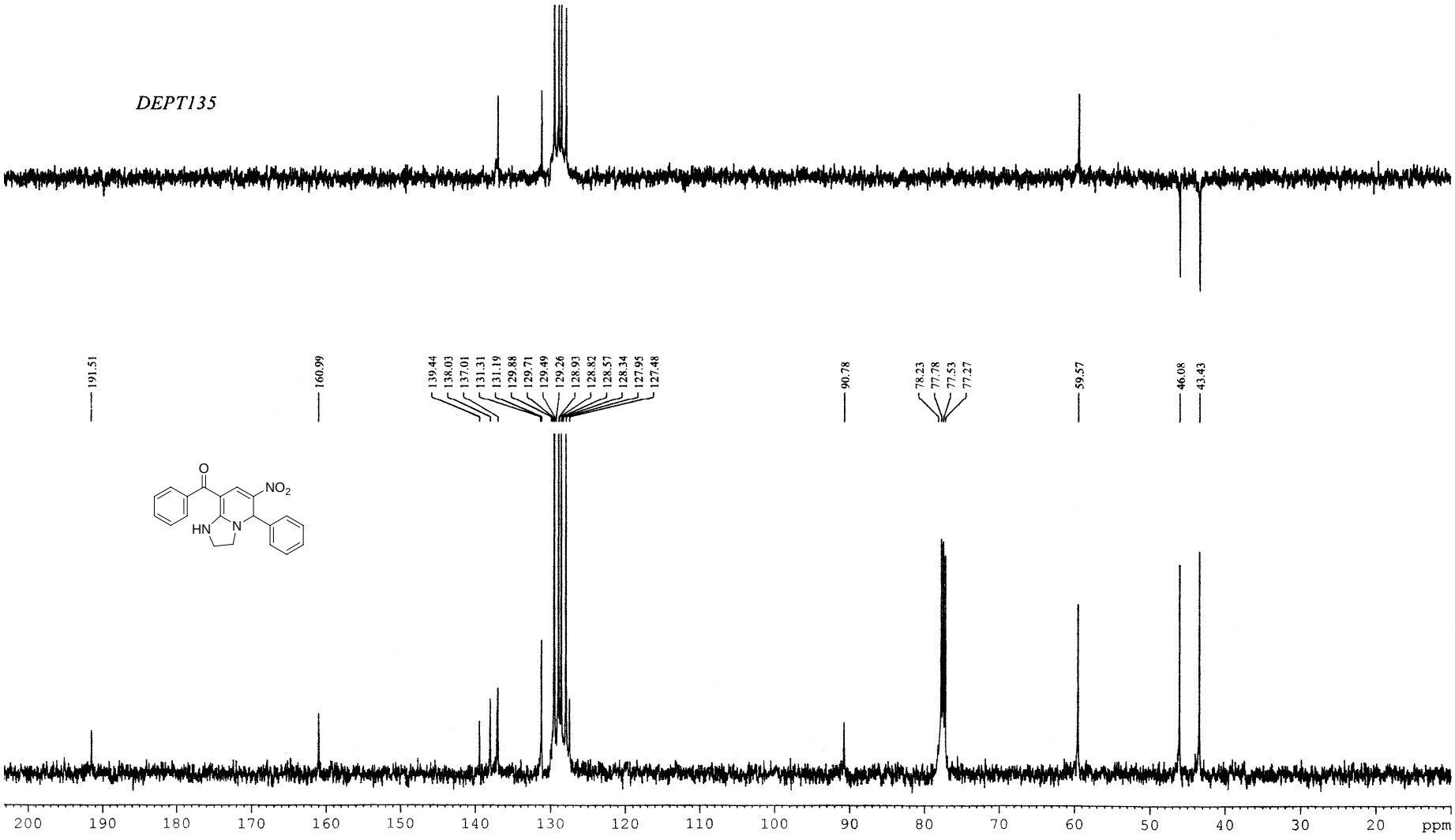


Figure 24. ^{13}C NMR (125 MHz, $CDCl_3$) spectra of compound **4l**

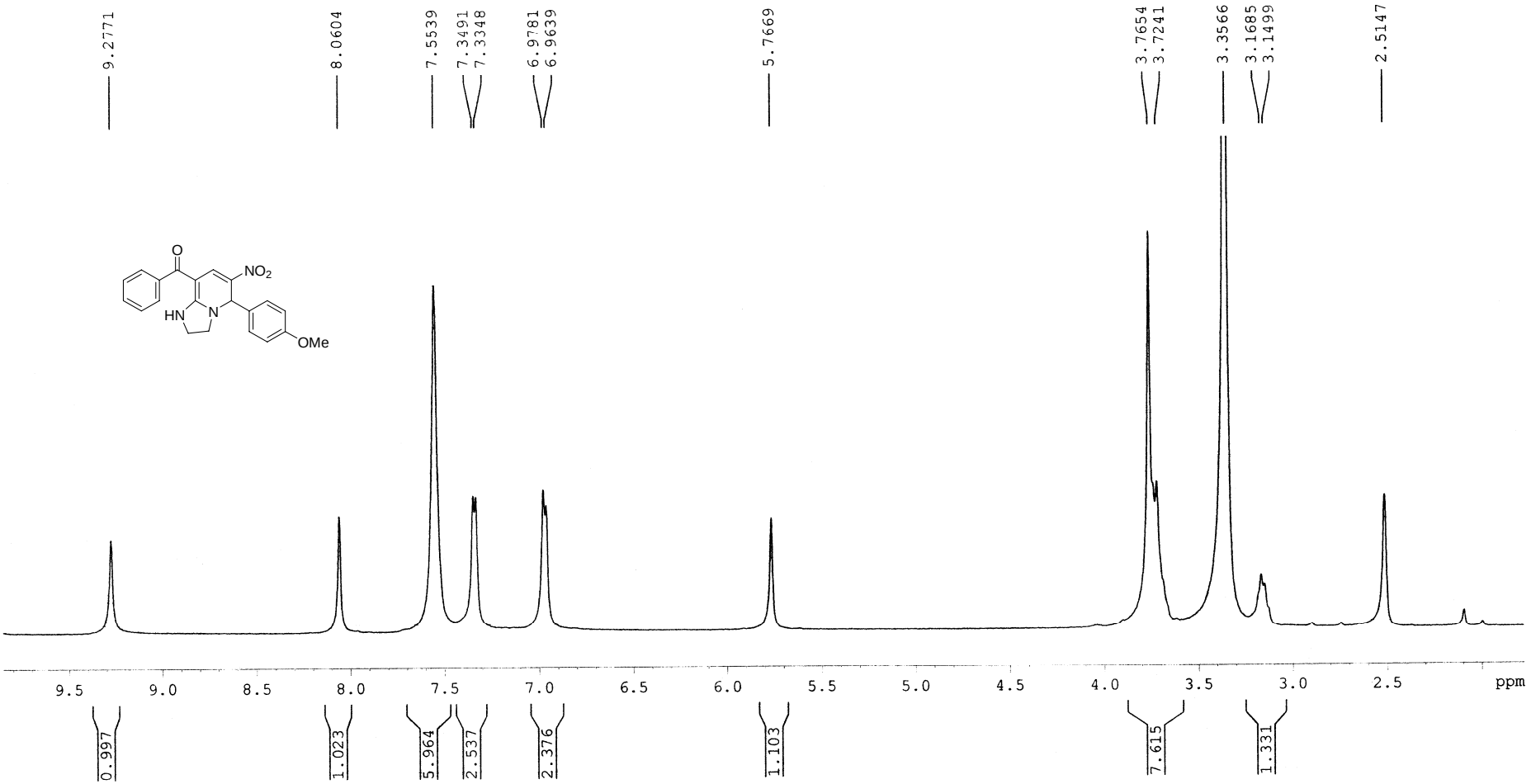


Figure 25. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4m**

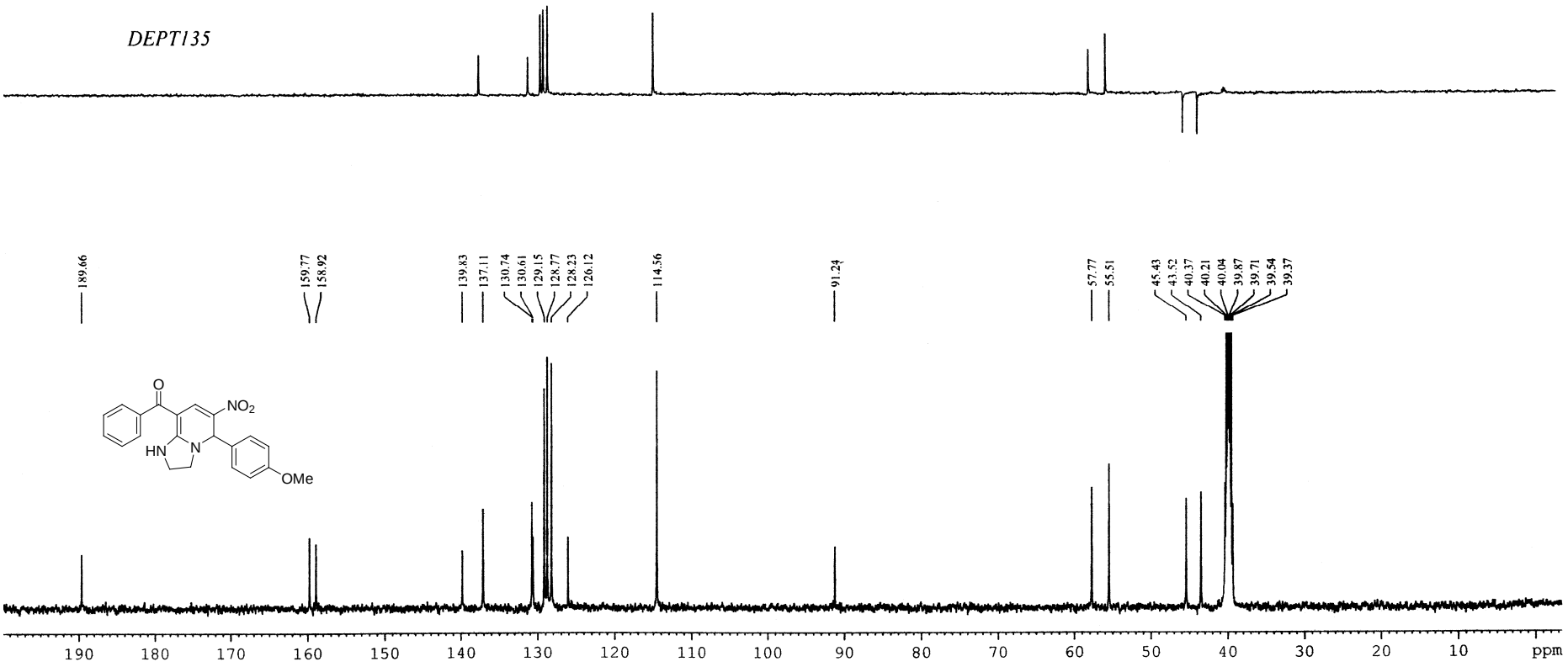


Figure 26. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4m**

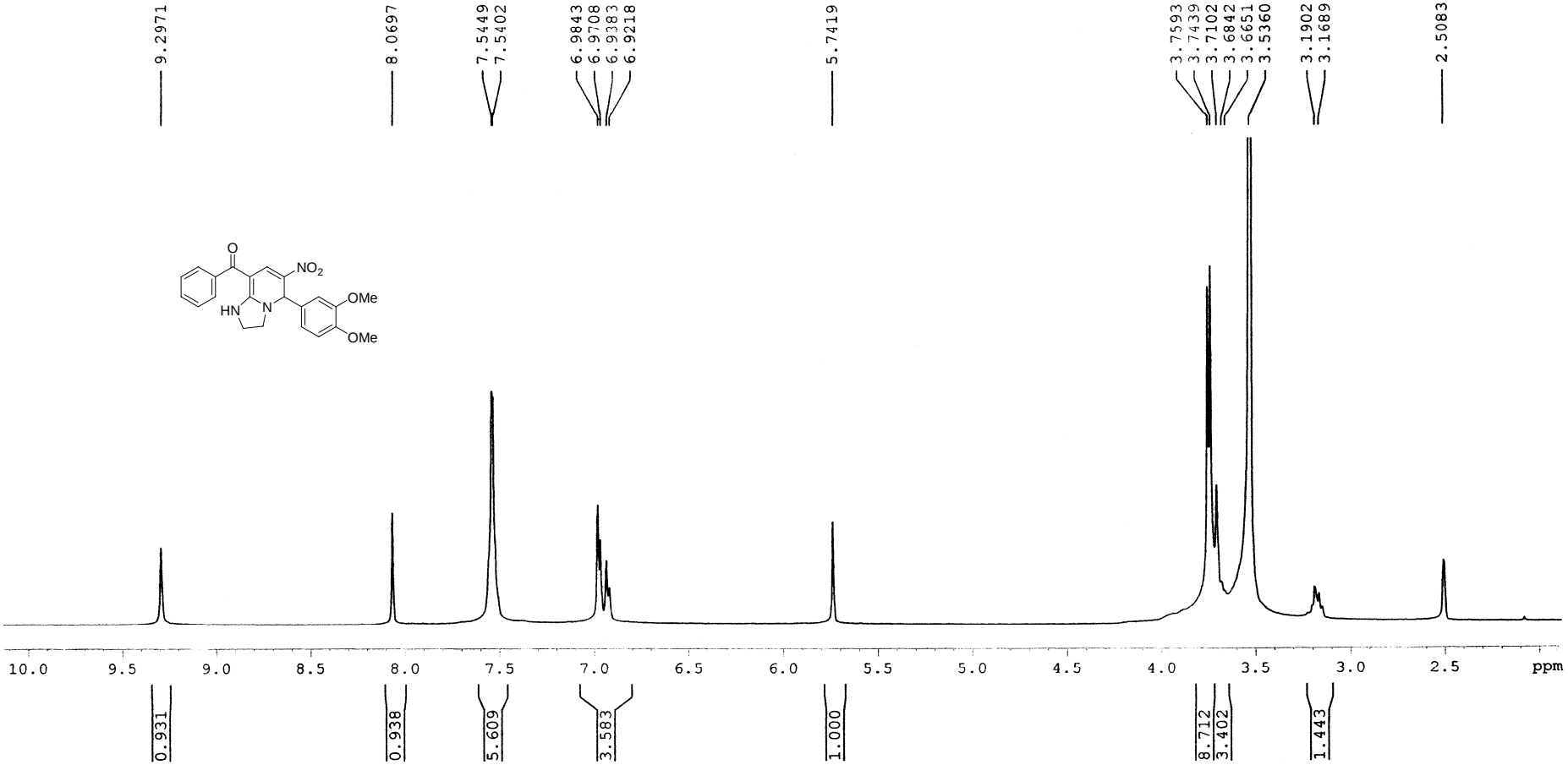


Figure 27. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4n**

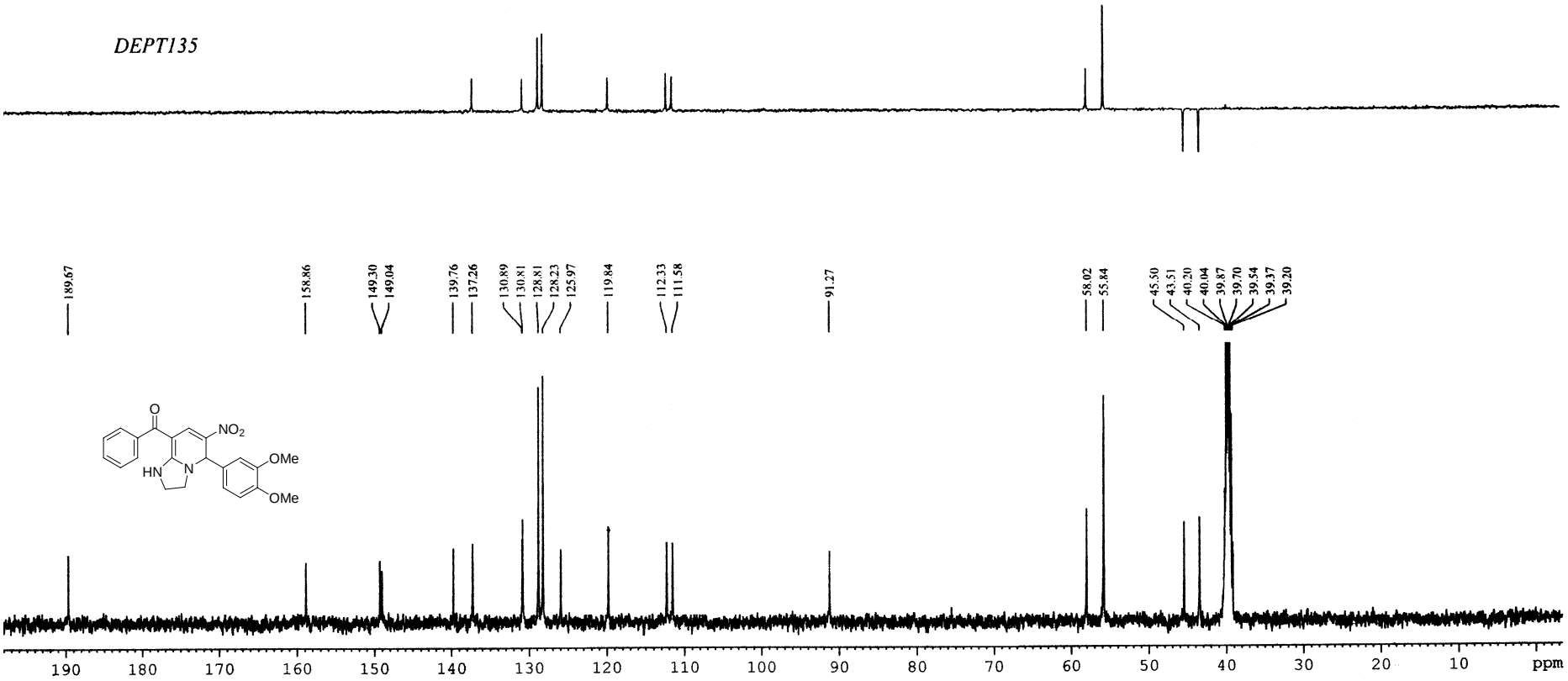


Figure 28. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4n**

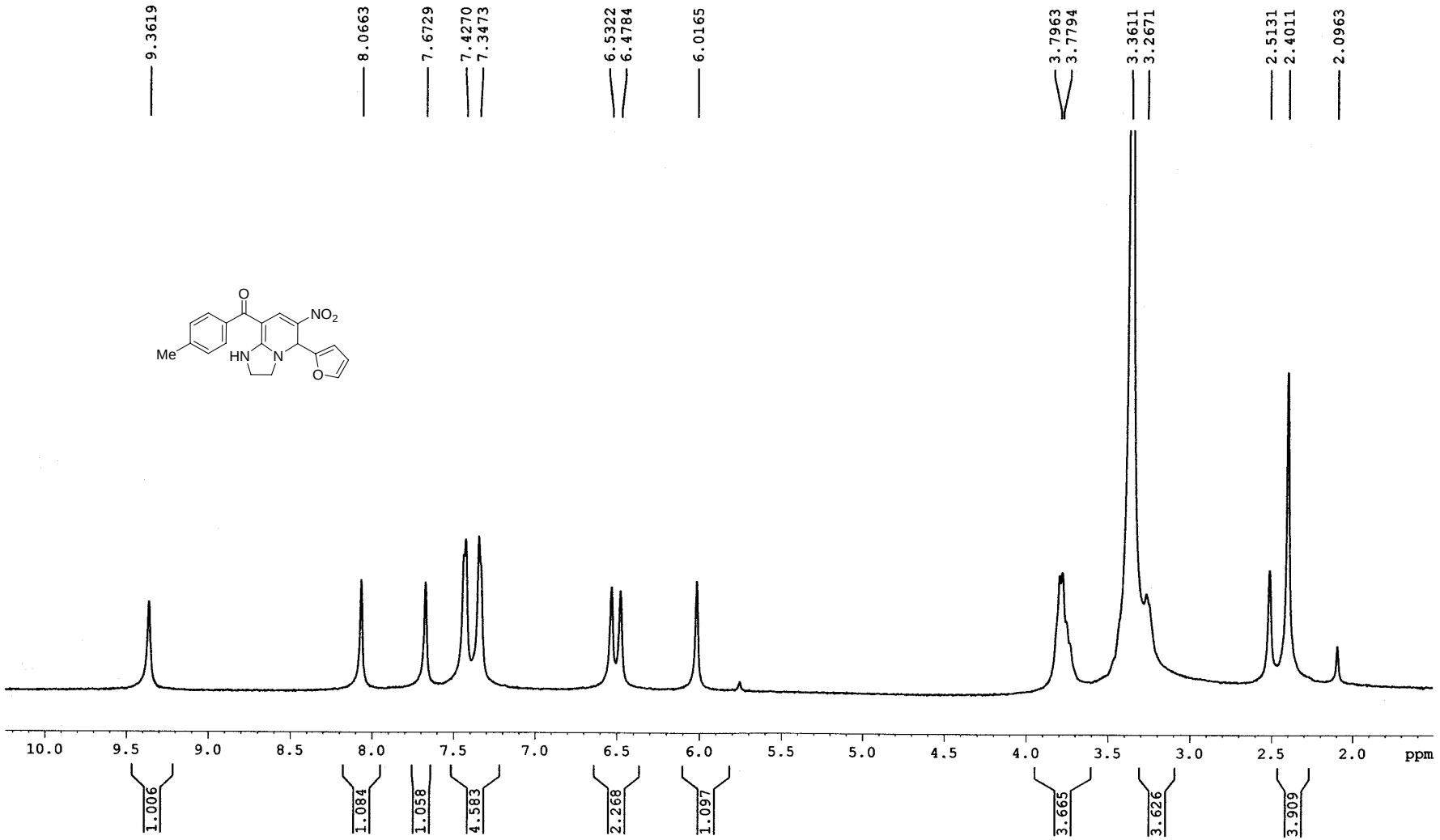


Figure 29. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4o**

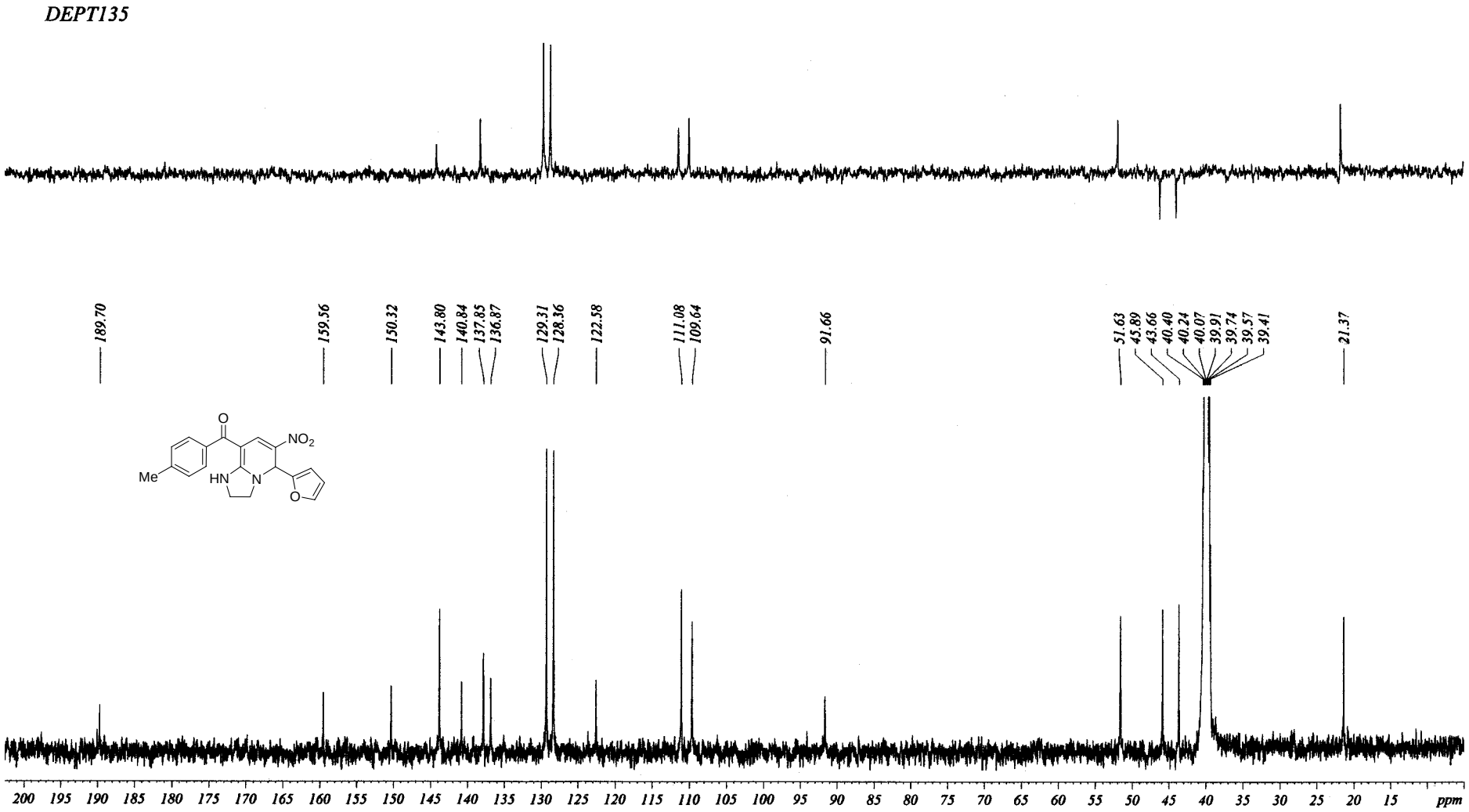


Figure 30. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4o**

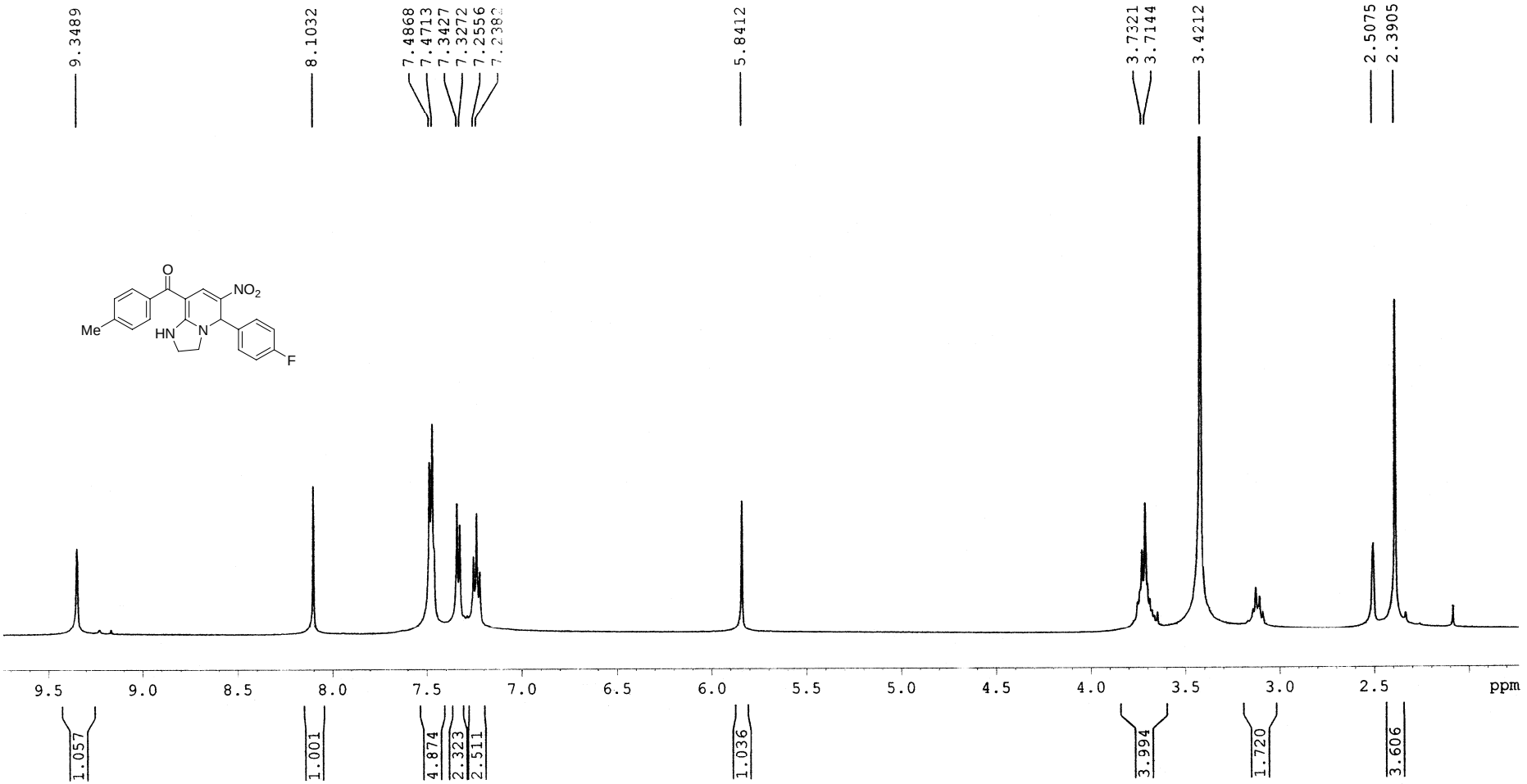


Figure 31. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4p**

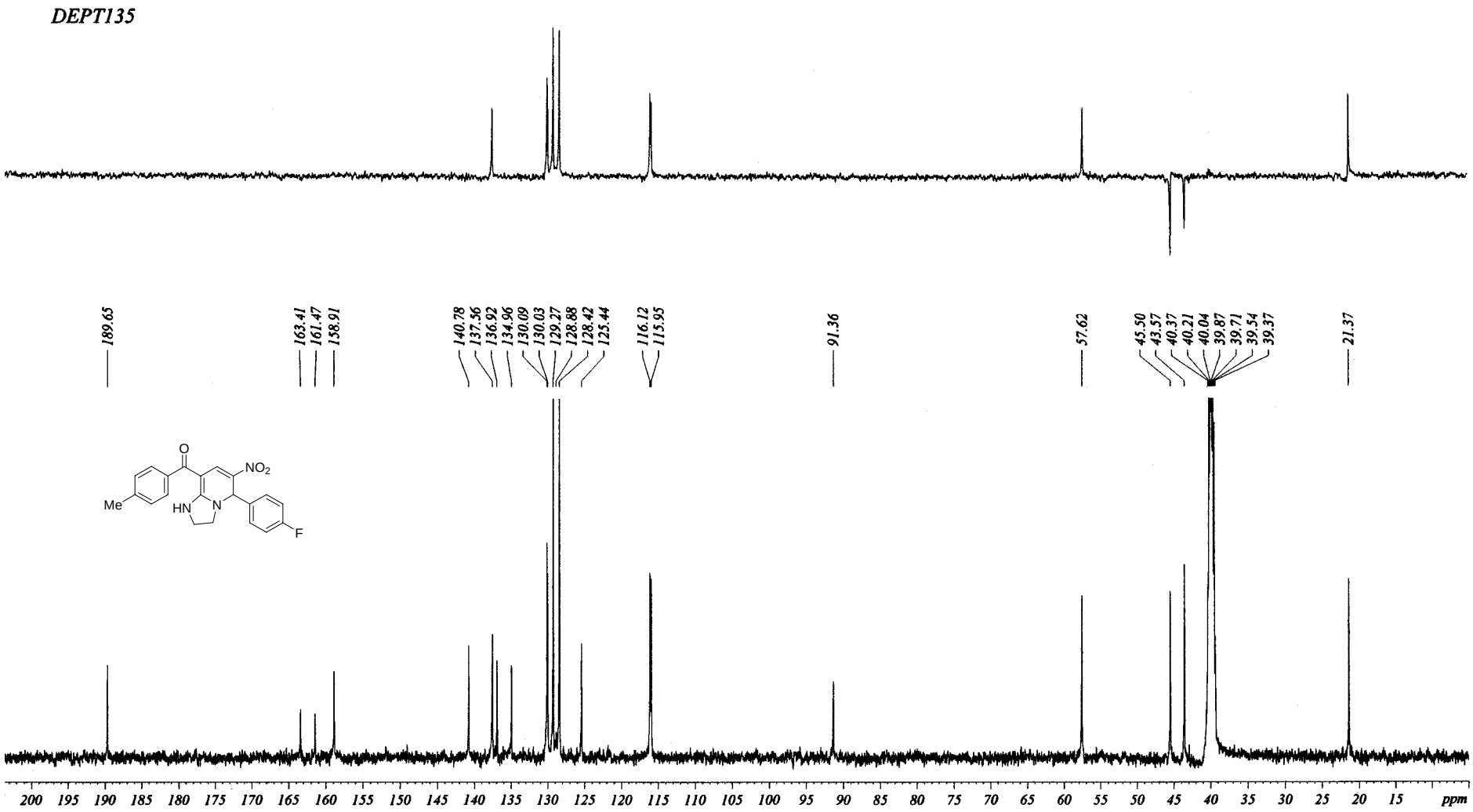


Figure 32. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4p**

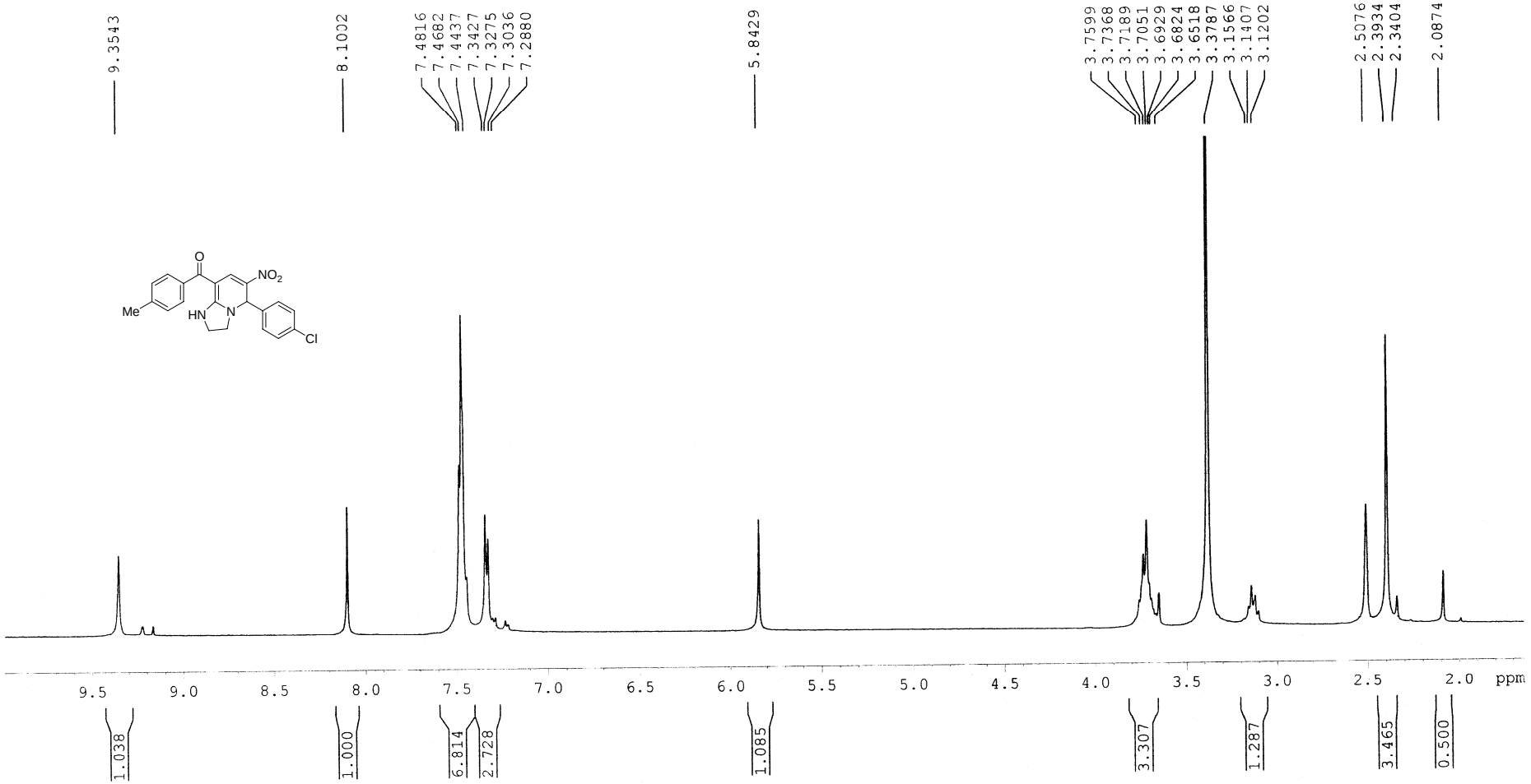


Figure 33. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4q**

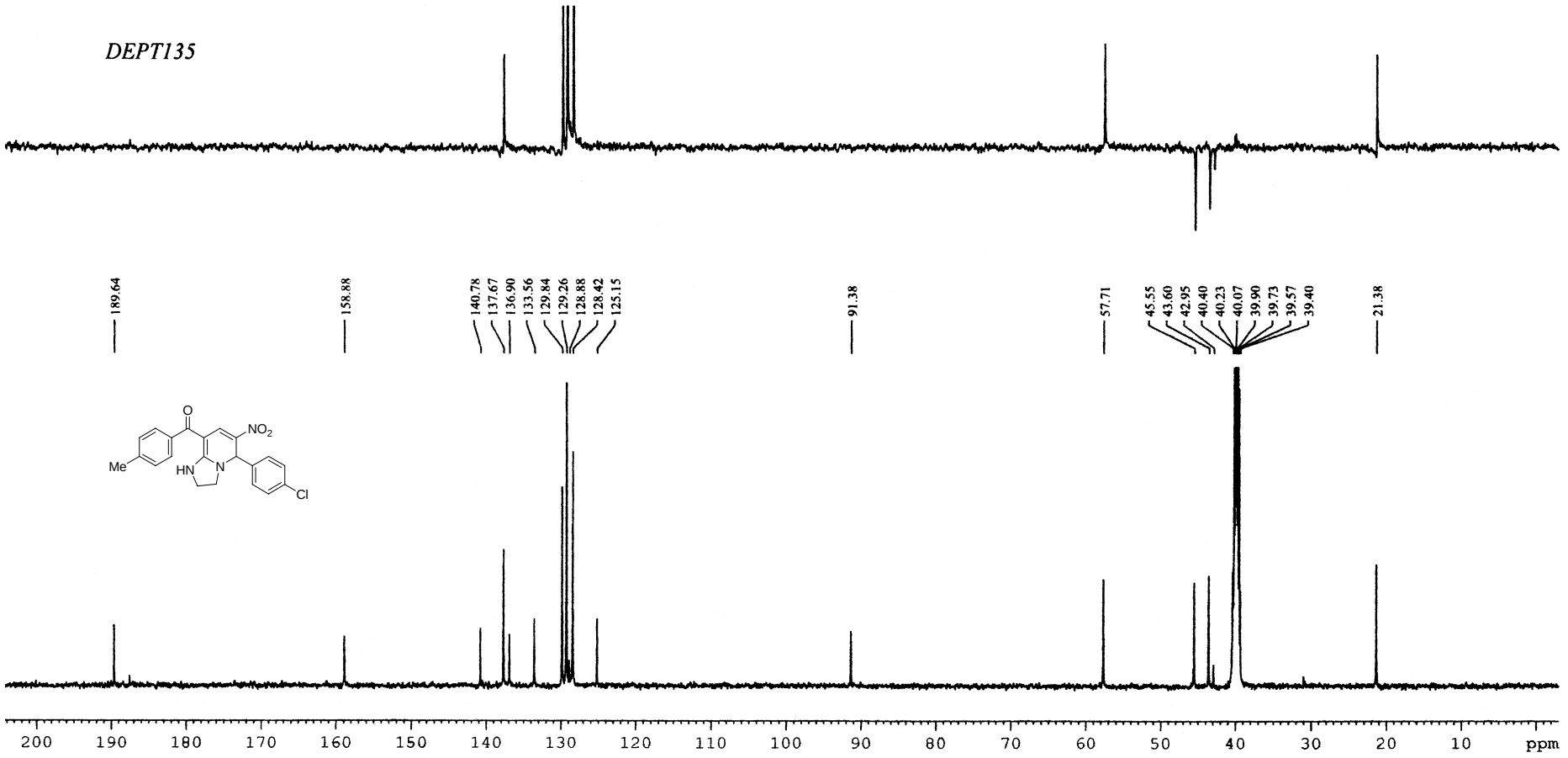


Figure 34. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4q**

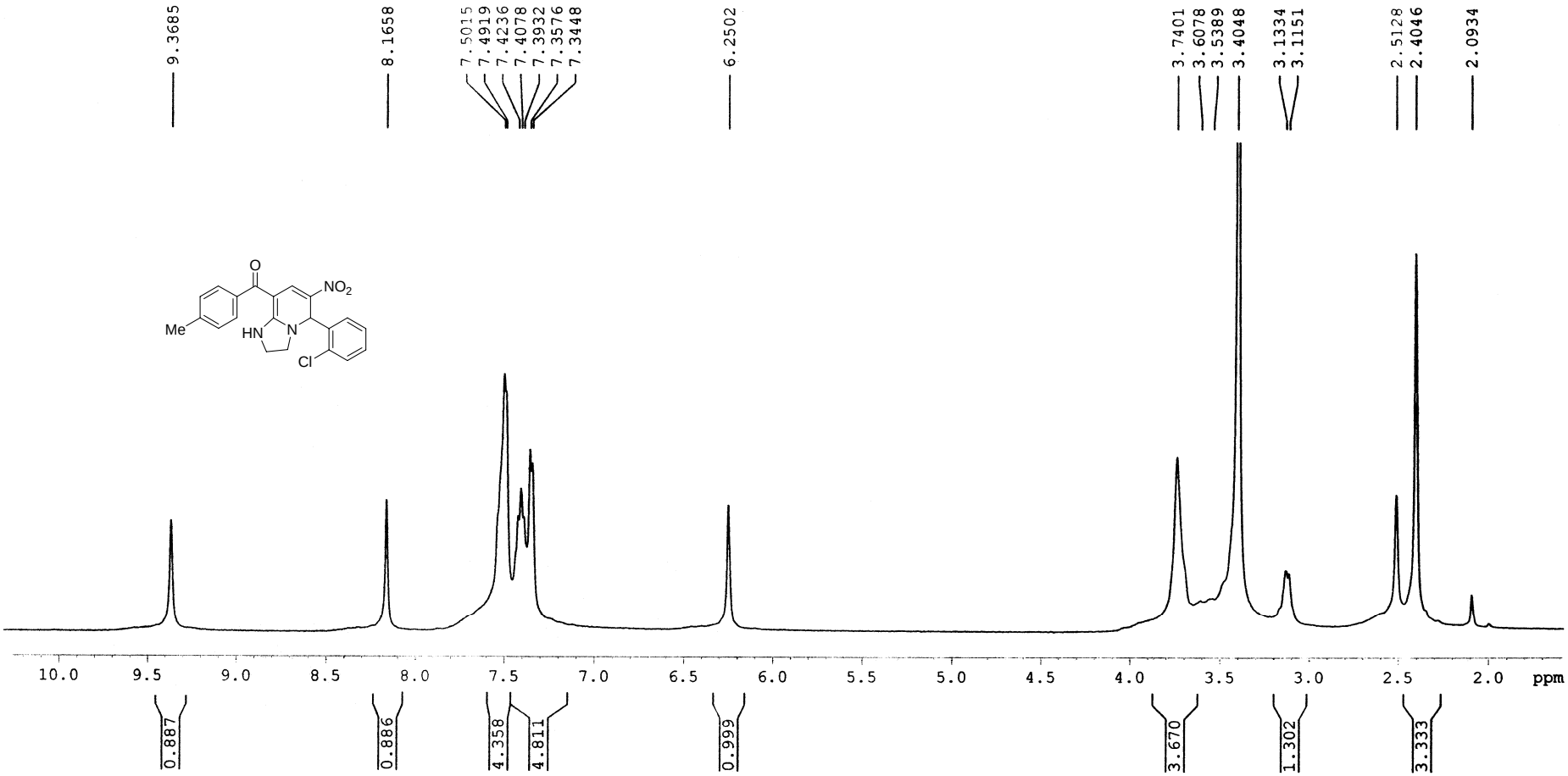


Figure 35. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4r**

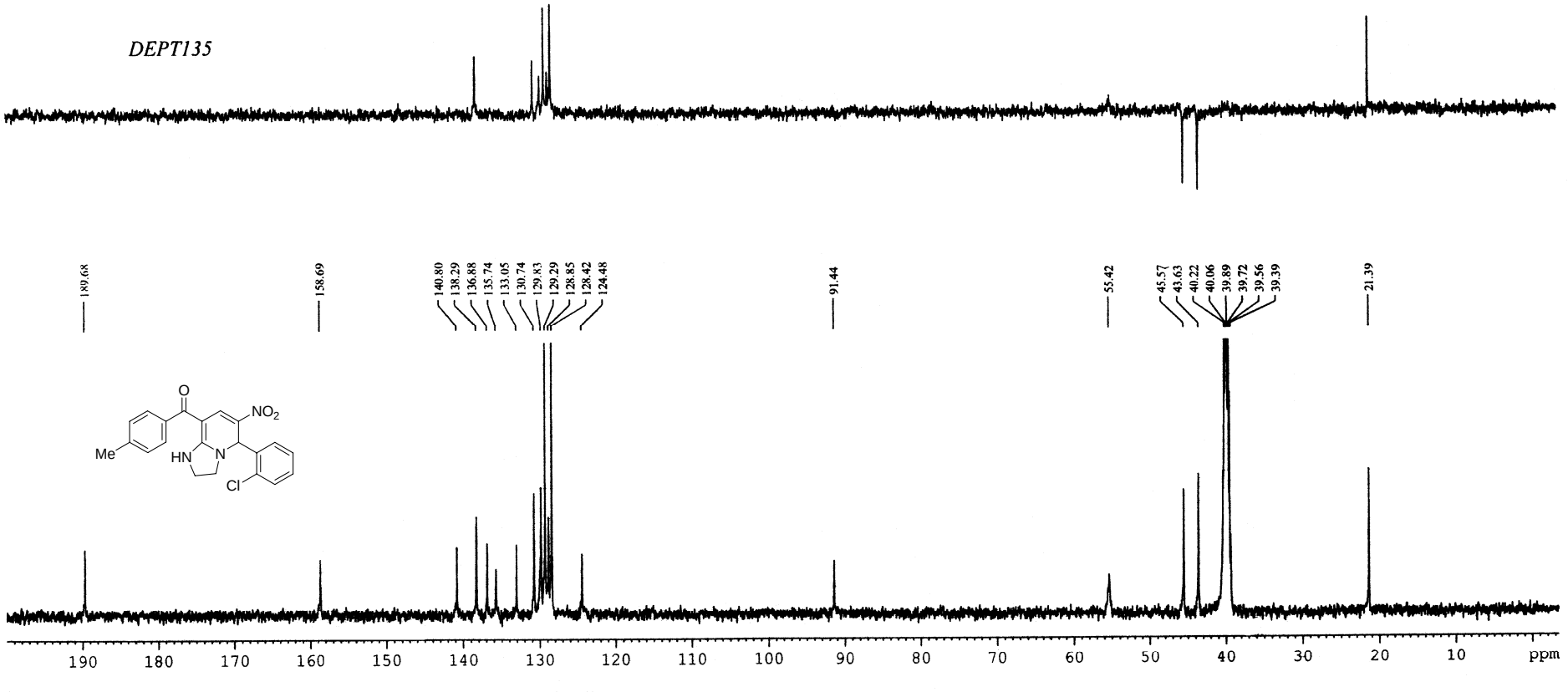


Figure 36. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4r**

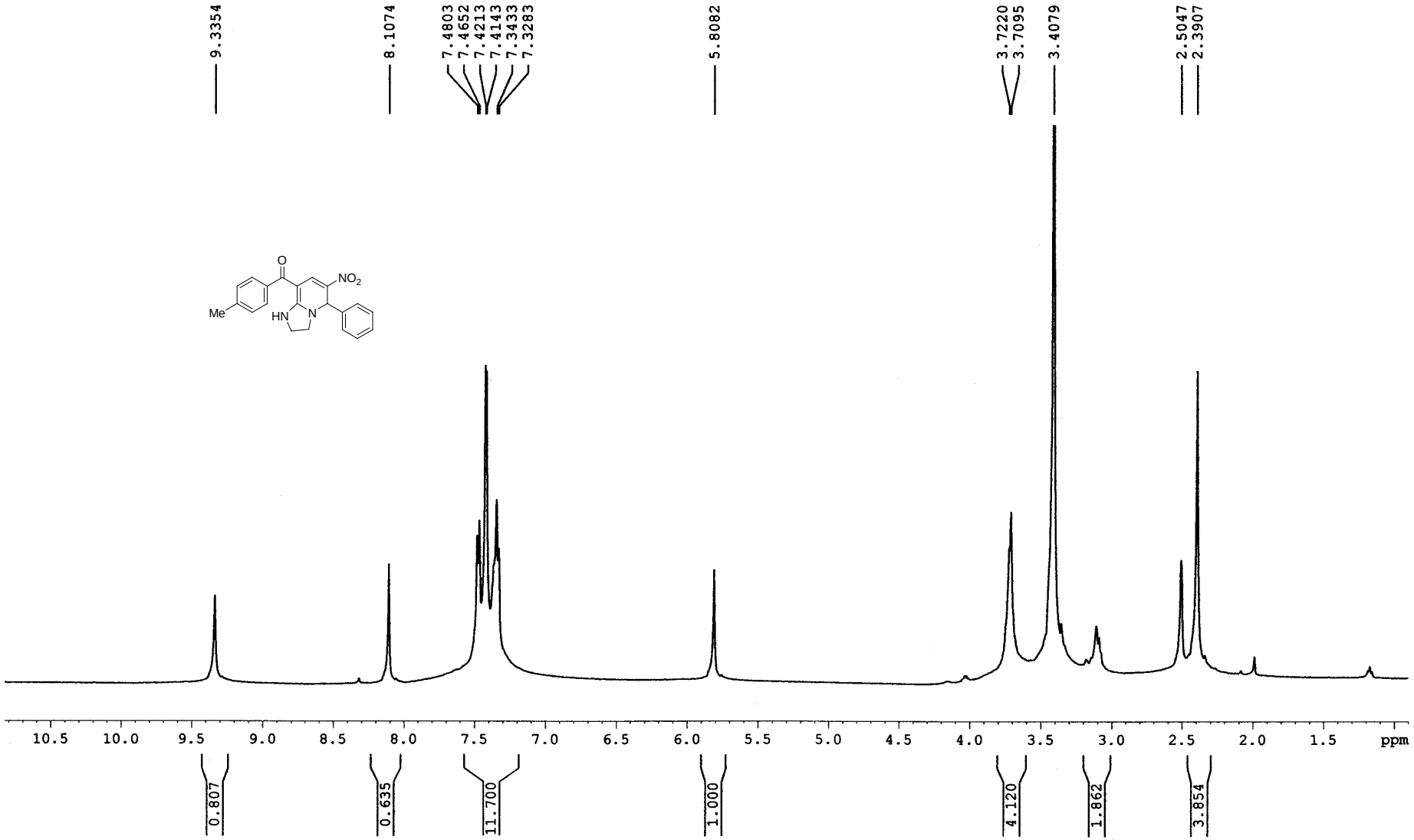


Figure 37. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4s**

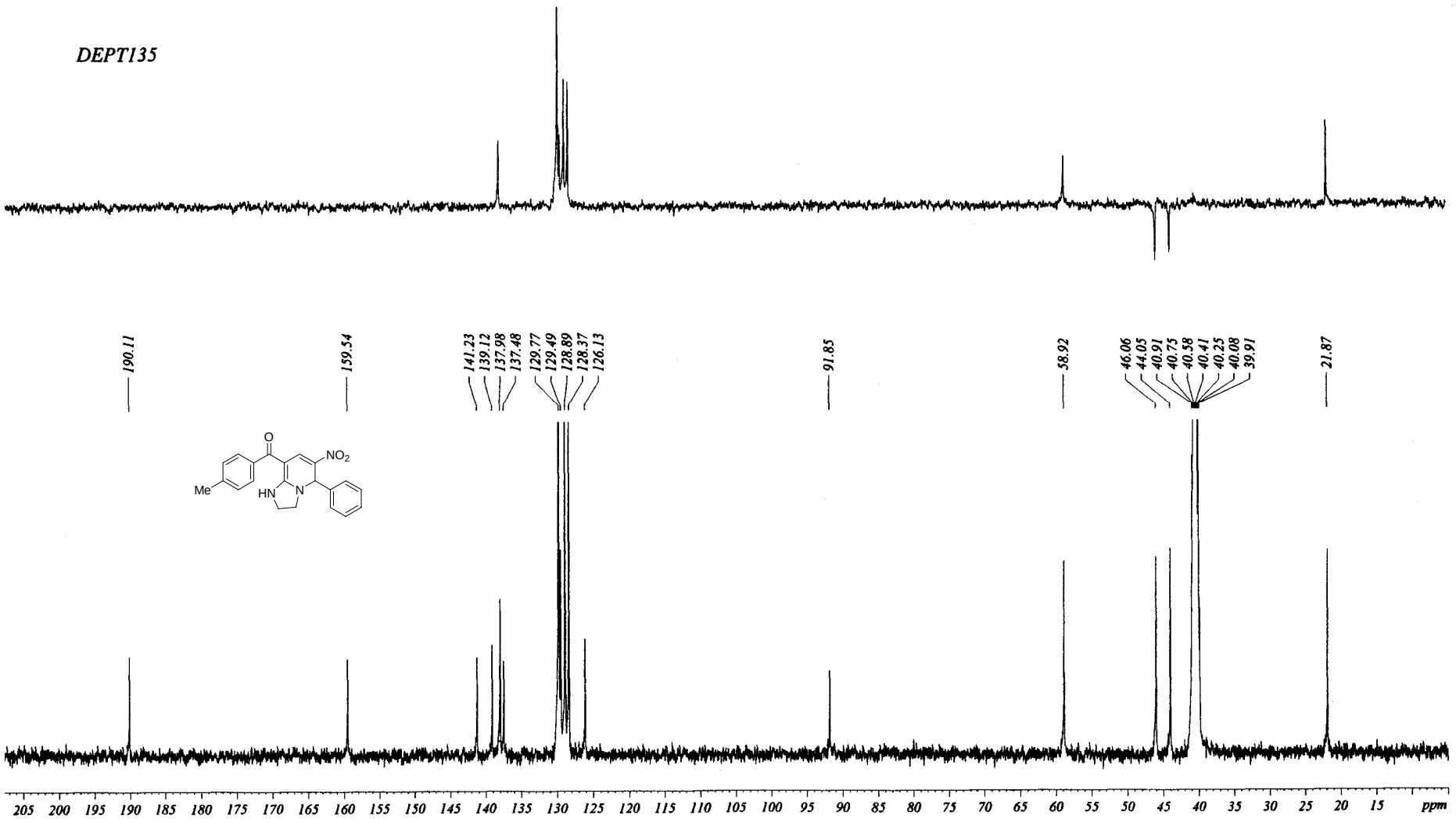


Figure 38. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4s**

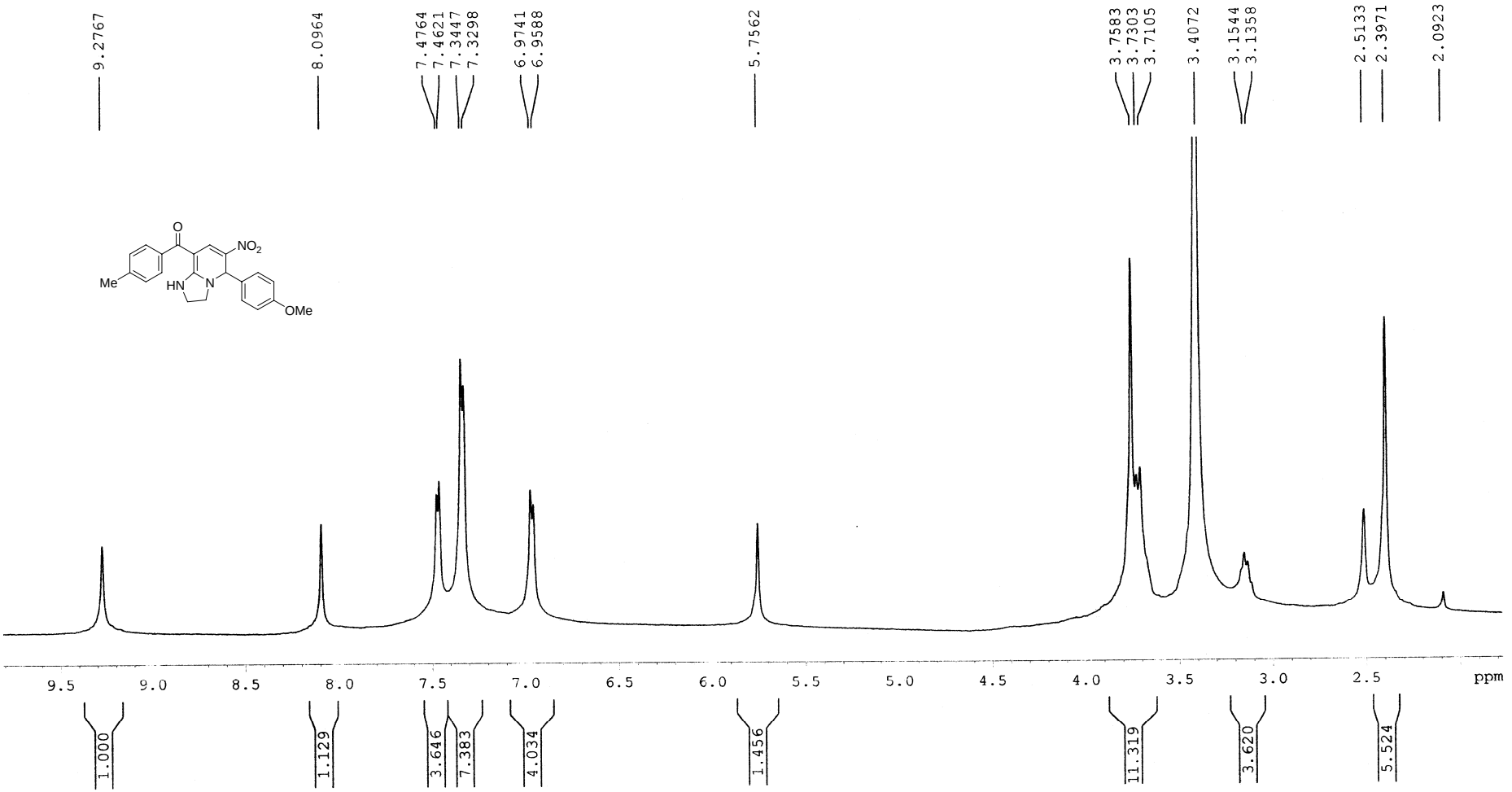


Figure 39. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4t**

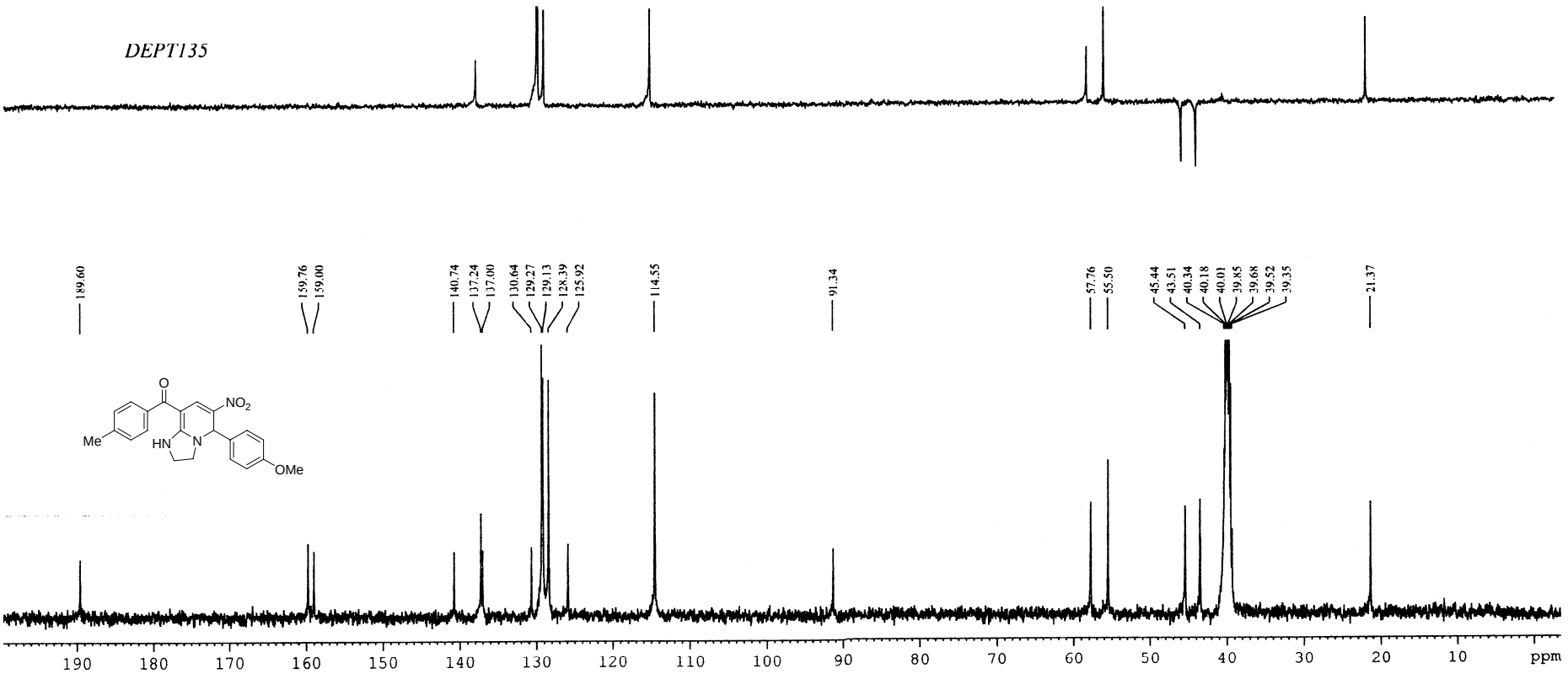


Figure 40. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4t**

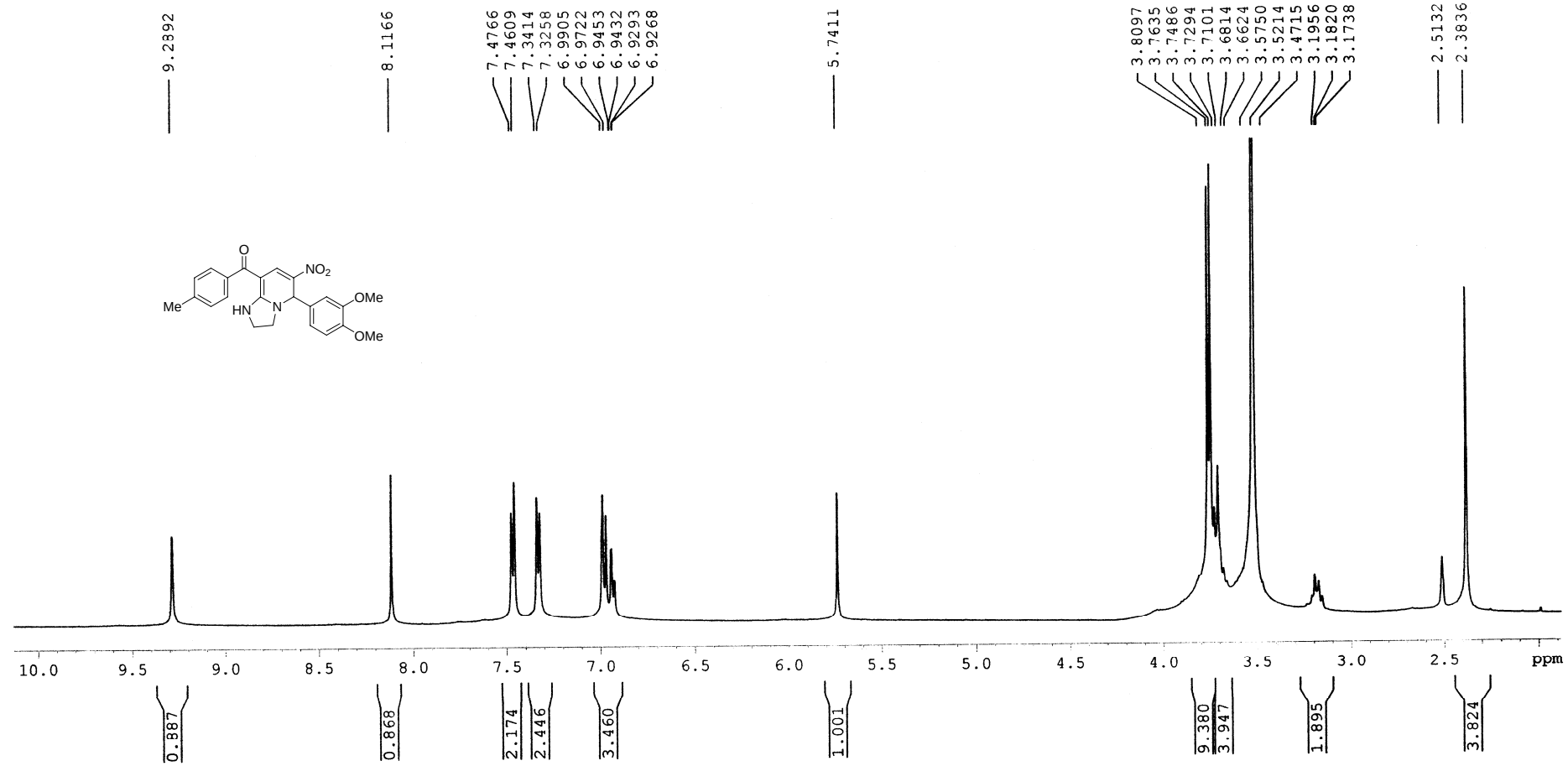


Figure 41. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4u**

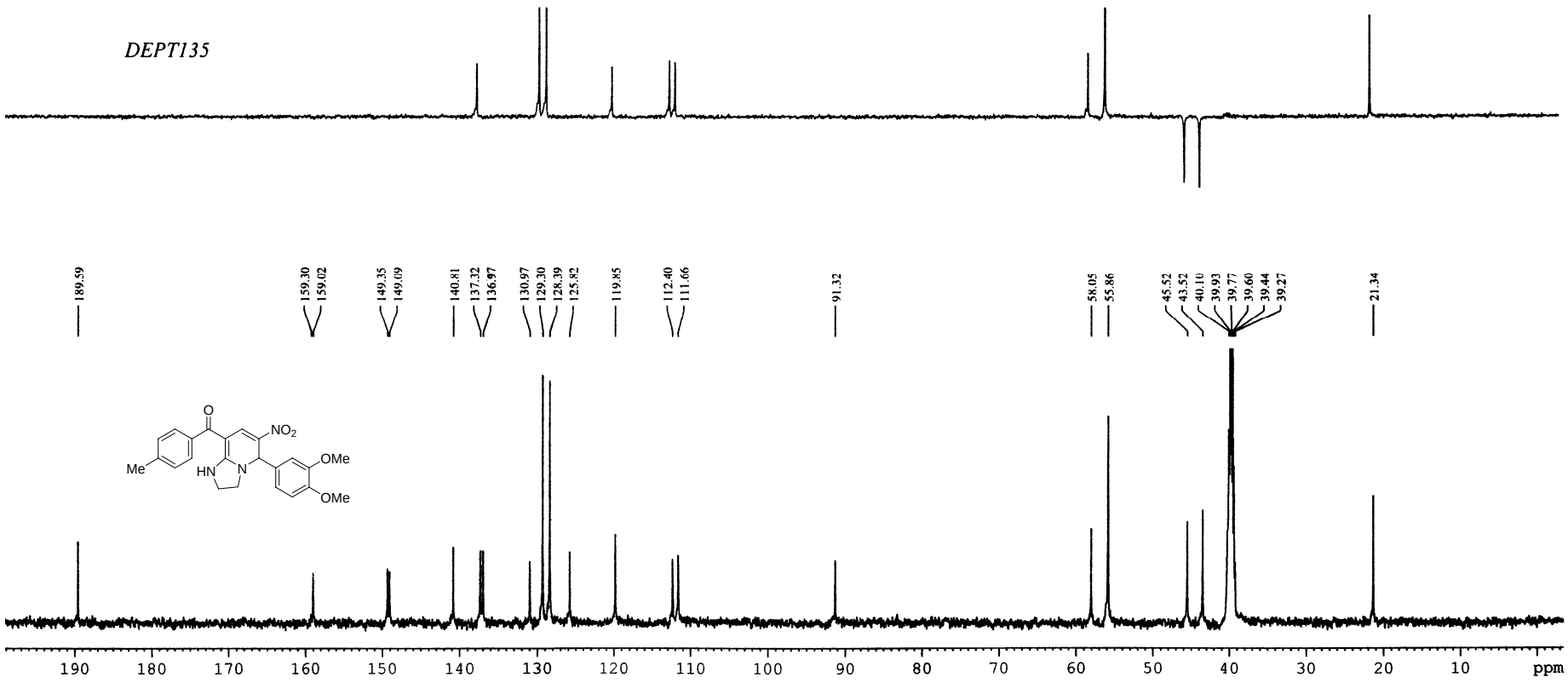


Figure 42. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4u**

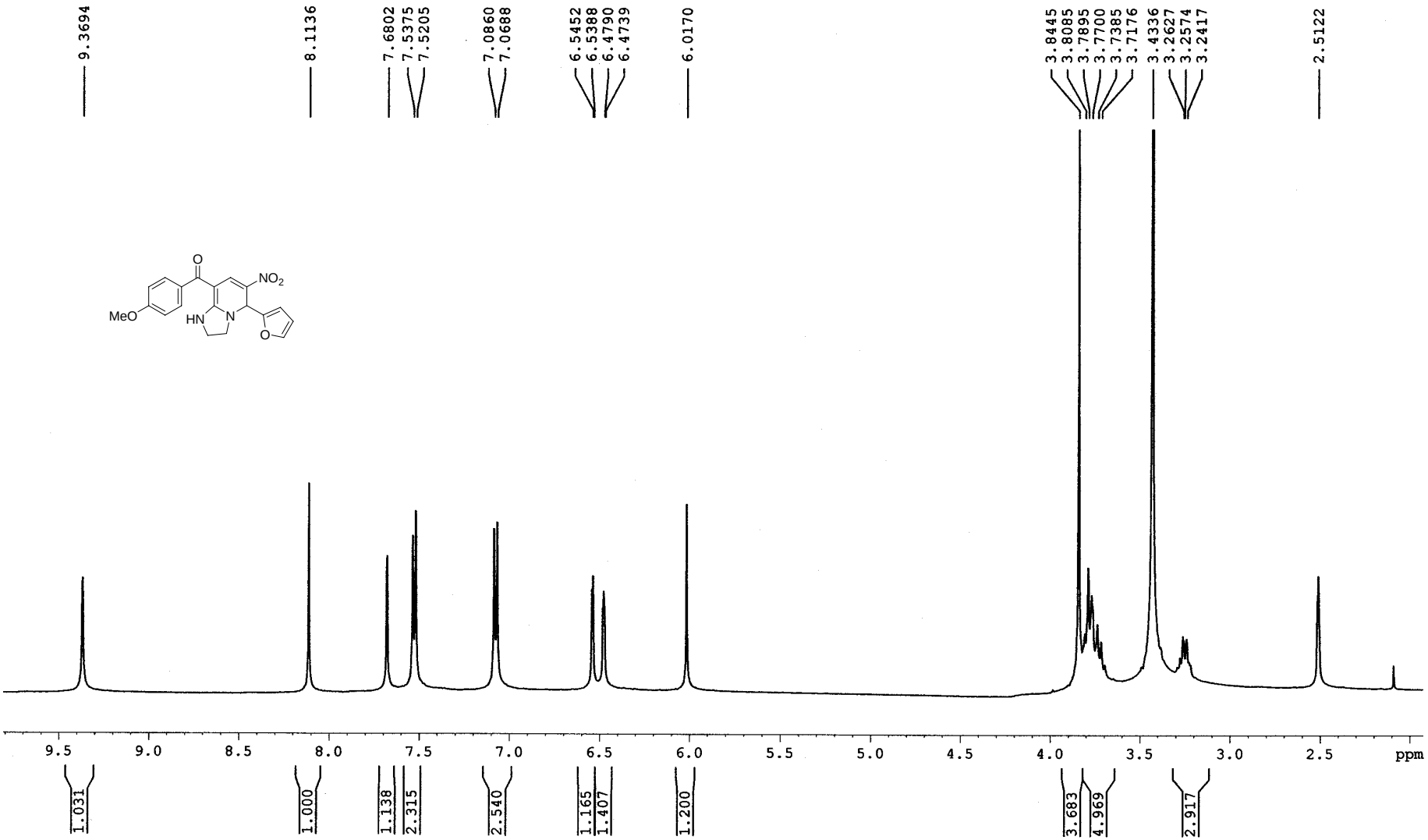


Figure 43. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4v**

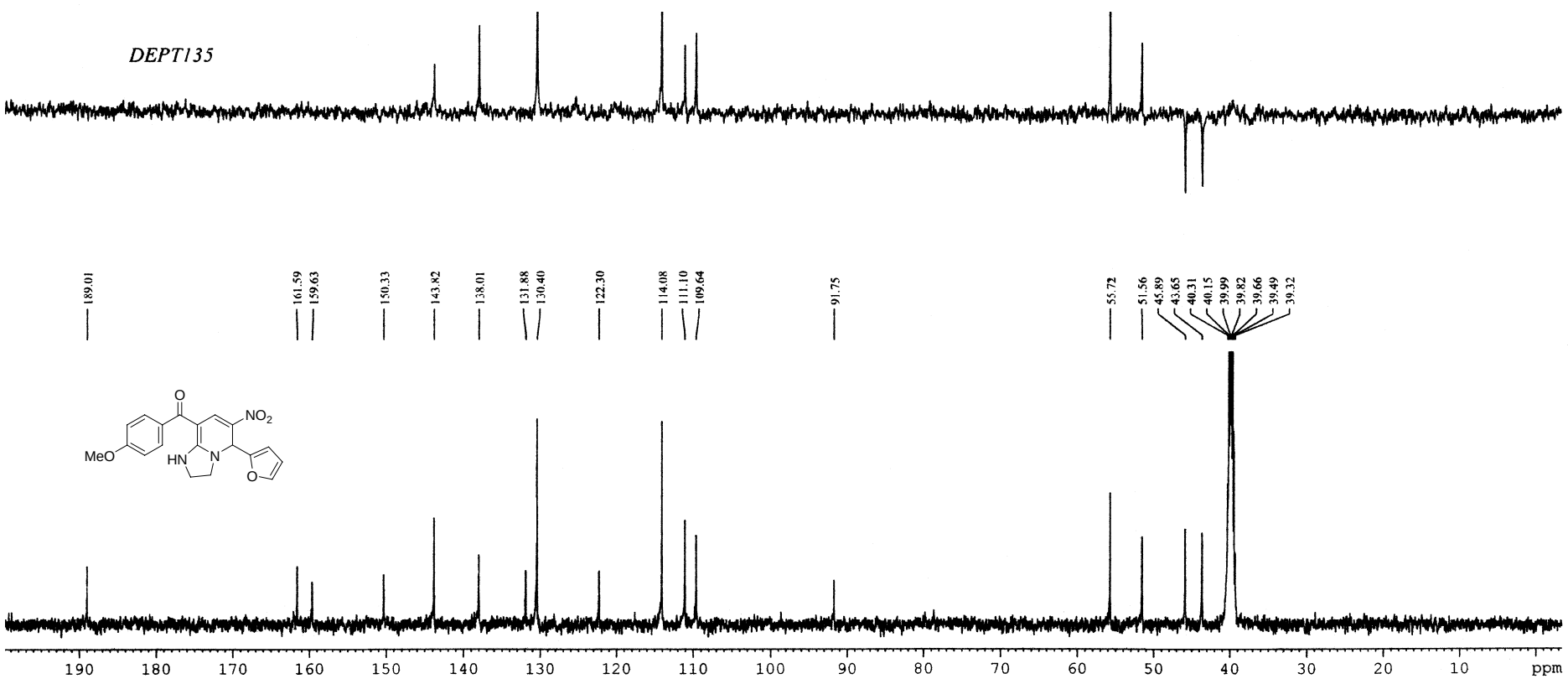


Figure 44. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4v**

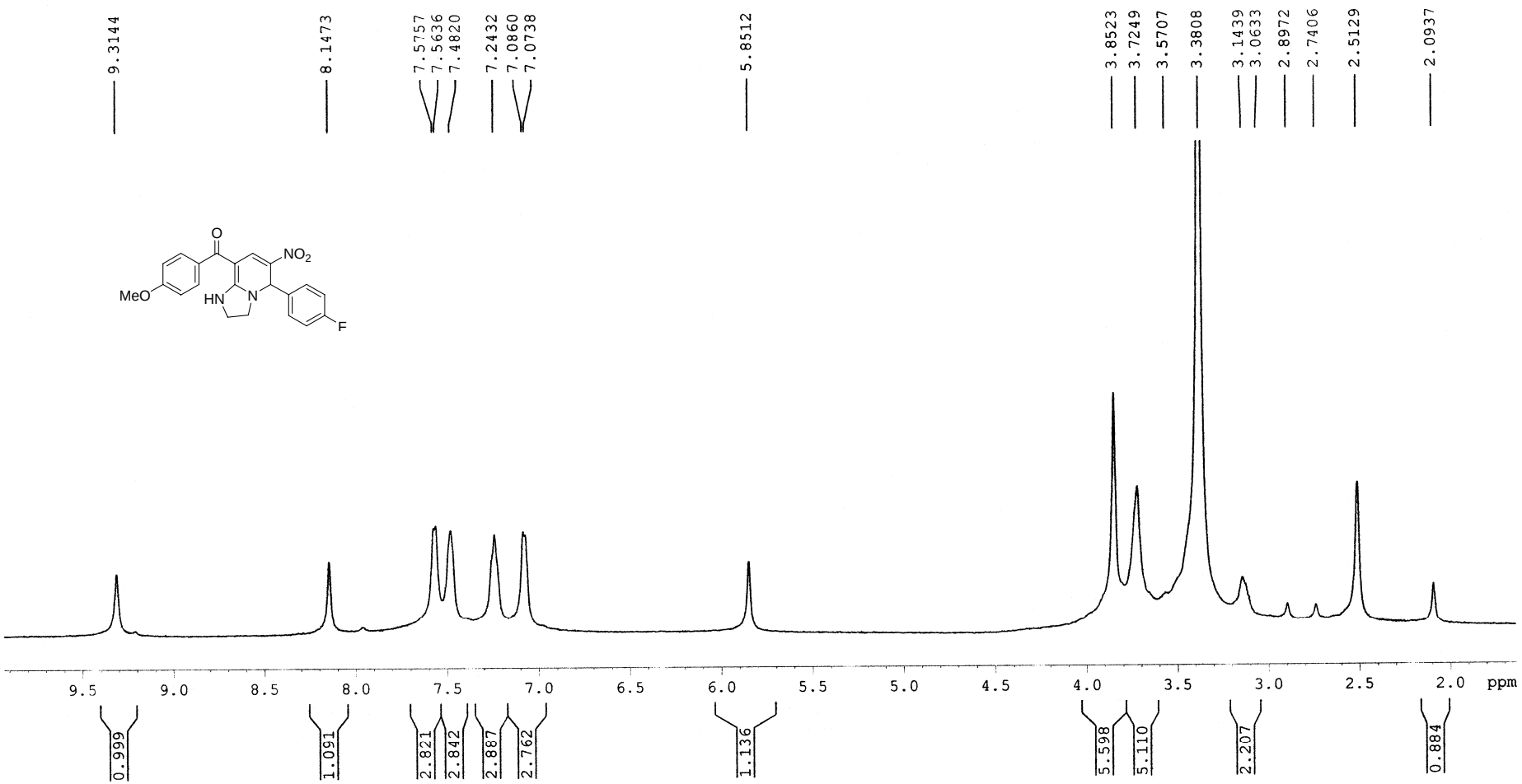


Figure 45. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4w**

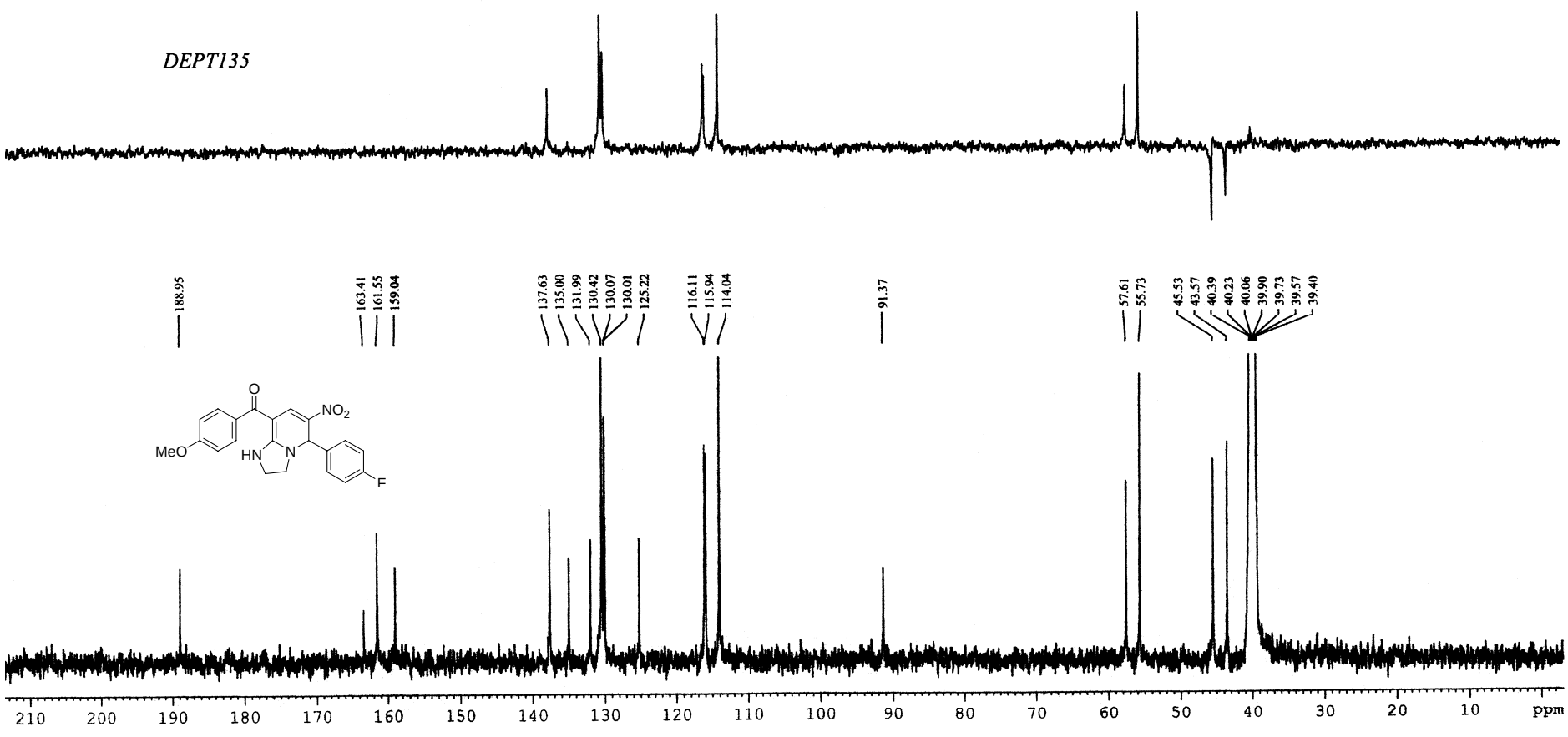


Figure 46. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4w**

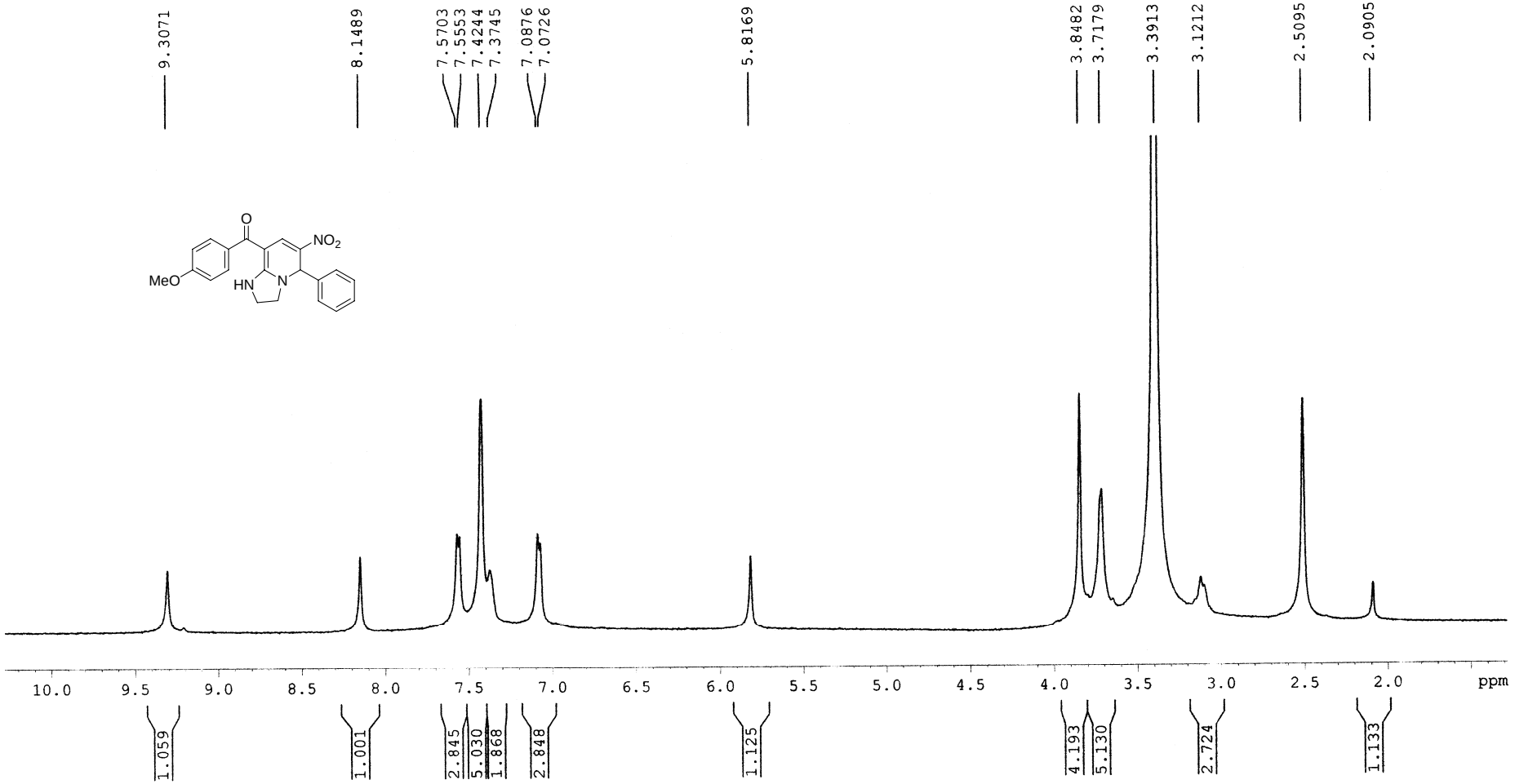


Figure 47. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4x**

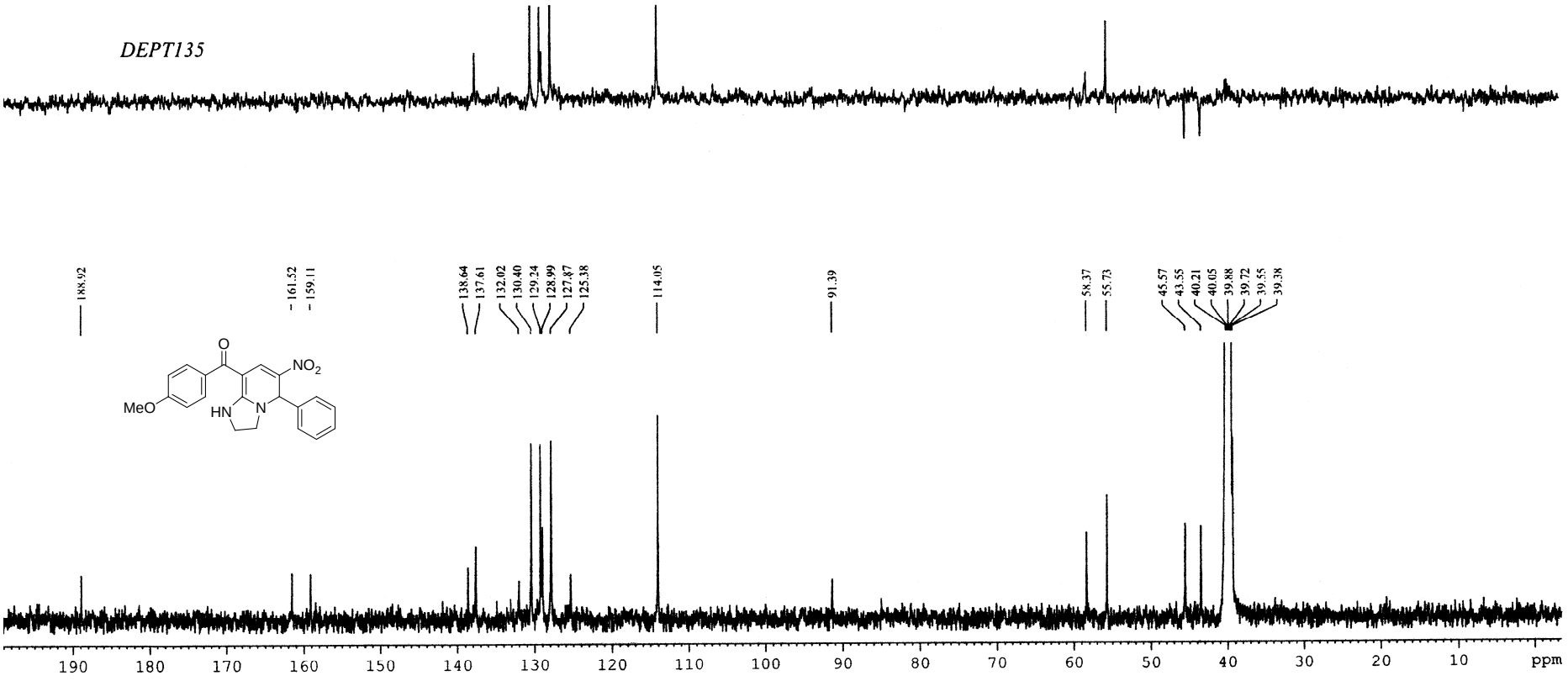


Figure 48. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4x**

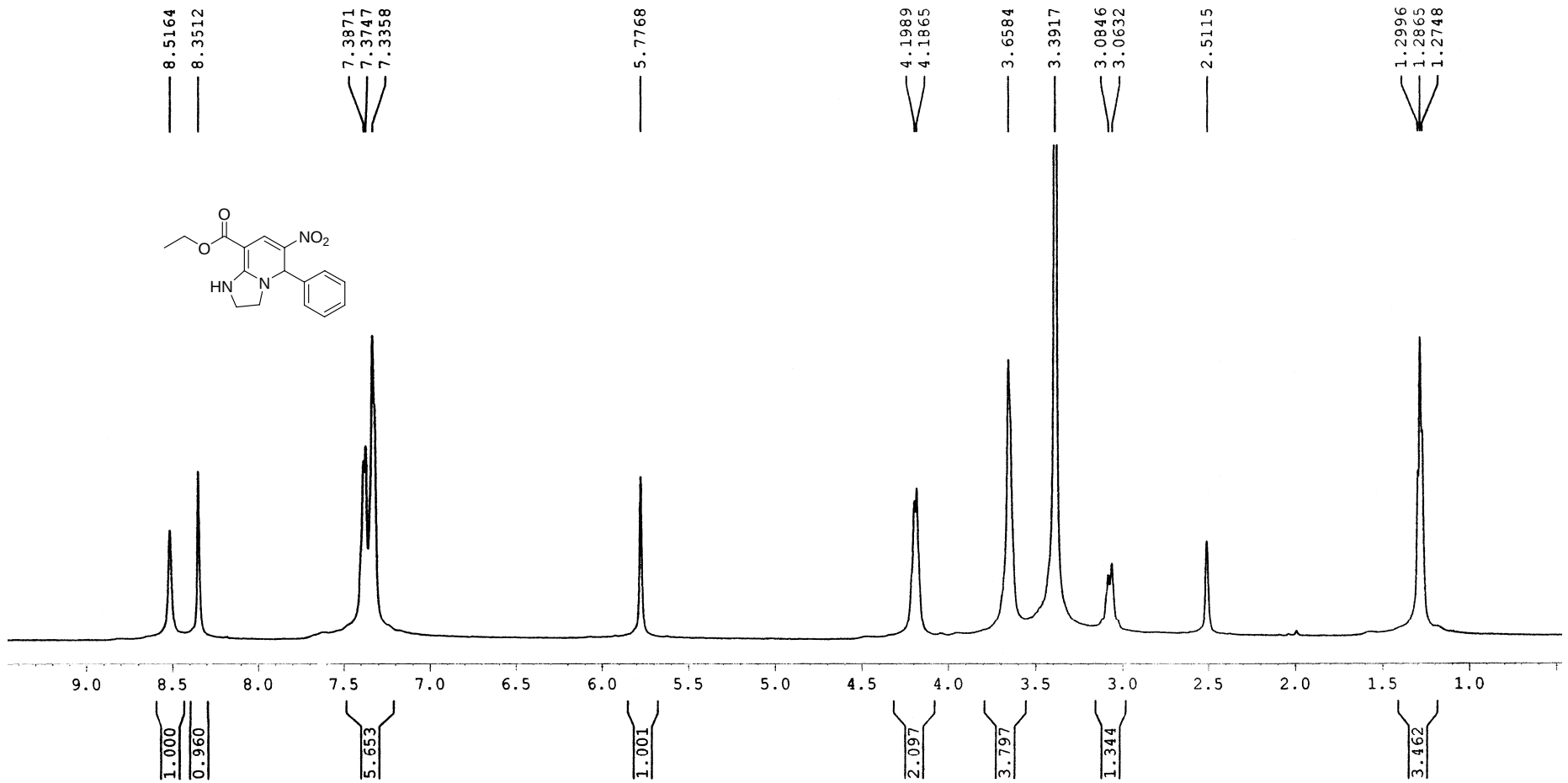


Figure 49. ^{1}H NMR (500 MHz, DMSO-d_6) spectra of compound **4y**

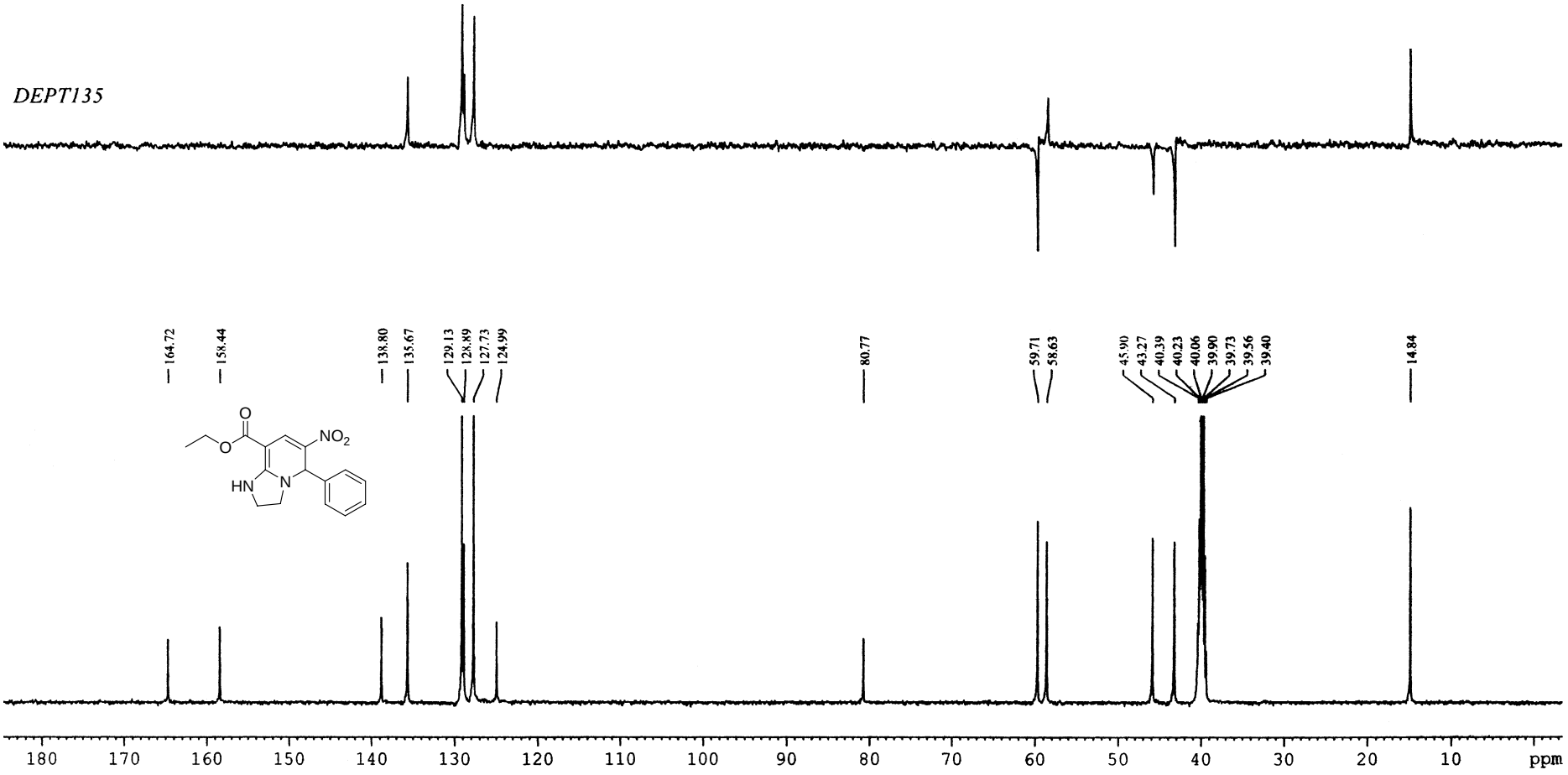


Figure 50. ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4y**

References and Notes

1. (a) Z.-T. Huang and M.-X. Wang, *Synthesis* 1992, **12**, 1273; (b) Z.-J. Li, and D. Charles, *Synth. Commun.,* 2001, **31**, 527.
2. M.-X. Zhao, M.-X. Wang and Z.-T. Huang, *Tetrahedron* 2002, ***58***, 1309.
3. (a) J.-T. Liu and C.-F. Yao, *Tetrahedron Lett.,* 2001, **42**, 6147; (b) G. Demicheli, R. Maggi, A. Mazzacani, P. Righi, G. Sartori and F. Bigi, *Tetrahedron Lett.,* 2001, **42**. 2401; (c) Y.-. Jang, W.-W. Lin, Y.-K. Shih, J.-T. Liu, M.-H. Hwang and C.-F. Yao, *Tetrahedron* 2003, **59**, 4979.
4. CCDC 818211 contain the supplementary crystallographic data for compound **4f**. These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif.