Efficient synthesis of substituted bicyclic 2-pyridones by regioselective annulations of heterocyclic ketene aminals with methacrylic anhydride or crotonic anhydride

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Supporting Information

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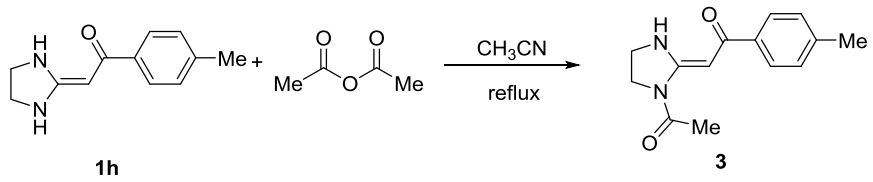
General information

All compounds were fully characterized by spectroscopic data. The NMR spectra were recorded on a Bruker Ascend III 600 or DRX500 (^{1}H: 600 or 500 MHz, ^{13}C: 150 or 125 MHz). Chemical shifts (δ) are expressed in ppm and J values are given in Hz. Deuterated $CDCl_3$ and DMSO-d_6 were 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 GF254. The melting points were determined on a XT-4A melting point apparatus and are uncorrected. HRMs were performed on an Agilent LC/Msd TOF instrument. Unless otherwise stated, all regents used are commercially available. Solvents for reactions were purified by stranded procedures. Compounds **1a**–**1n** were prepared according to the literature.[1] Materials **1o**–**1p** were synthesized according with the literature.[2]

Procedure for synthesis of compound 3



1h **3**

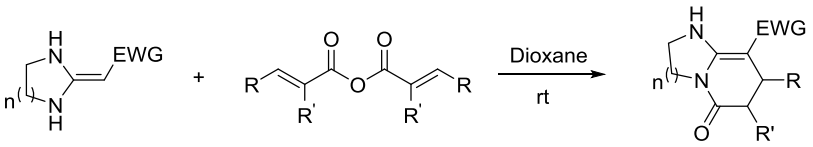
HKA **1h** (1.0 mmol), acetic anhydride (1.2 mmol) and dry CH_3CN (10 mL) were placed in a 25 mL round-bottom flask and trimethylamine (10 mmol%) was added and the mixture was stirred at reflux for 20 minutes. Upon completion, as monitored by TLC. Then the reaction mixture was cooled to room temperature and filted to give the pure crude product, which was further washed with petroleum ether-EtOAc(1:1) to give pure product **3** with a yield of 94%.

Spectroscopic data of bicyclic pyridones derivatives 3

2-(1-Acetylimidazolidin-2-ylidene)-1-(*p*-tolyl)ethan-1-one (**3**)

White solid: mp 207–208°C; IR (KBr): 3449, 3168, 2091, 1691, 1604, 1496, 1391, 1310, 1256, 767 cm^{-1}; ^{1}H NMR (500 MHz, DMSO-d_6): δ = 10.21 (br, 1H, NH), 7.68 (d, J = 8.0 Hz, 2H, PhH), 7.25 (d, J = 7.9 Hz, 2H, PhH), 6.86 (s, 1H, C=CH), 4.03–3.63 (m, 4H, NCH_2CH_2), 2.34 (s, 3H, CH_3), 2.24 (s, 3H, CH_3); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 186.6, 170.2, 158.6, 140.7, 138.1, 129.2, 126.9, 79.0, 45.8, 42.0, 25.5, 21.3; HRMS (ESI) *m/z* calcd for $C_{14}H_{17}N_2O_2$ $[M+H]^+$, 245.1285; found, 245.1284.

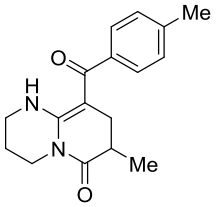
General procedure for the synthesis of bicyclic pyridones derivatives 4-5



HKA derivatives **1** (1.0 mmol) was added to a 25 mL round-bottom flask and dissolved in dry dioxane (10.0 mL). Methacrylic anhydride **2a** or crotonic anhydride **2b** (1.2 mmol) was added under stirring at room temperature, the mixture was stirred until TLC revealed that the conversion of the starting material was complete about 0.5-6 h. a small amount of H_2O (ca. 10 ml) was added and mixture was extracted with EtOAc (25 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4 and evaporated *in vacuo*. The crude residue was dried and recrystallized from petroleum ether-EtOAc to afford the pure products **4-5** with a yield of 83-96%.

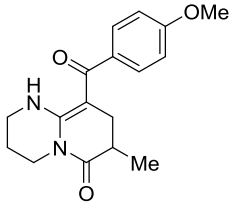
Spectroscopic data of bicyclic pyridones derivatives 4-5

7-Methyl-9-(4-methylbenzoyl)-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin -6-one (4a).



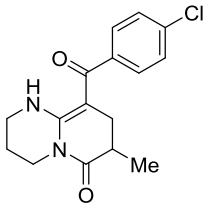
White solid: mp 157–158 °C; IR (KBr): 3423, 2967, 2815, 1695, 1605, 1575, 1241, 1155, 746 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 12.62 (br, 1H, NH), 7.23–7.22 (m, 2H, PhH), 7.19–7.17 (m, 2H, PhH), 3.84–3.56 (m, 2H, NCH_2), 3.44–3.36 (m, 2H, NCH_2), 3.48–3.44 (m, 2H, CH_2), 2.32 (s, 3H, CH_3), 2.31–2.26 (m, H, CH), 1.95–1.88 (m, 2H, CH_2), 1.03–1.02 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 187.3, 173.2, 156.5, 140.0, 138.3, 128.8, 127.2, 86.6, 39.6, 38.4, 30.0, 21.3, 20.7, 15.6; HRMS (ESI) *m/z* calcd for $C_{17}H_{21}N_2O_2$ $[M+H]^+$, 285.1598; found, 285.1598.

9-(4-Methoxybenzoyl)-7-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidi n-6 -one (4b)



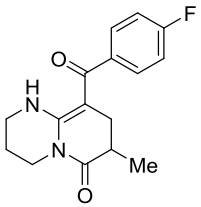
White solid: mp 178–179 °C; IR (KBr): 3553, 3415, 2968, 1686, 1601, 1451, 1274, 1153, 837, 603 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 12.63 (br, 1H, NH), 7.31 (d, J = 8.6 Hz, 2H, PhH), 6.93 (d, J = 8.6 Hz, 2H, PhH), 3.85–3.57 (m, 2H, NCH_2), 3.78 (s, 3H, OCH_3), 3.42–3.33 (m, 2H, NCH_2), 2.51–2.50 (m, H, CH), 2.49–2.36 (m, 2H, CH_2), 1.94–1.89 (m, 2H, CH_2), 1.05–1.04 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 186.9, 173.1, 159.9, 156.4, 135.1, 129.0, 113.6, 86.6, 55.6, 39.9, 38.4, 36.3, 30.2, 20.7, 16.6; HRMS (ESI) *m/z* calcd for $C_{17}H_{21}N_2O_3$ $[M+H]^+$, 301.1547; found, 301.1547.

9-(4-Chlorobenzoyl)-7-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin -6-one (4c).



White solid: mp 135–136 °C; IR (KBr): 3439, 2966, 1698, 1612, 1542, 1402, 1241, 1177, 841 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 12.58 (br, 1H, NH), 7.45 (d, J = 8.3 Hz, 2H, PhH), 7.36 (d, J = 8.3 Hz, 2H, PhH), 3.83–3.44 (m, 2H, NCH_2), 3.38–3.36 (m, 2H, NCH_2), 2.50–2.39 (m, 2H, CH_2), 2.31–2.26 (m, H, CH), 1.95–1.90 (m, 2H, CH_2), 1.05–1.03 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 185.6, 173.1, 156.8, 141.4, 133.4, 129.2, 128.4, 86.7, 39.6, 38.4, 36.3, 29.8, 20.5, 15.6; HRMS (ESI) *m/z* calcd for $C_{16}H_{18}ClN_2O_2$ $[M+H]^+$, 305.1051; found, 305.1052.

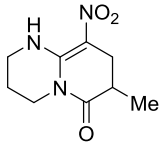
9-(4-Fluorobenzoyl)-7-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin-6-one (4d).



Light yellow solid: mp 157–158 °C; IR (KBr): 3450, 3073, 2974, 1698, 1654, 1535, 1241, 1158, 847, 600 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 12.58 (br, 1H, NH), 7.40–7.38 (m, 2H, PhH), 7.22–7.19 (m, 2H, PhH), 3.85–3.58 (m, 2H, NCH_2), 3.45–3.36 (m, 2H, NCH_2), 2.49–3.46 (m, H, CH), 2.42–2.27 (m, 2H, CH_2), 1.96–1.89

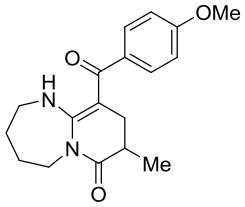
(m, 2H, CH_2), 1.04 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 185.9, 173.2, 162.4 (d, J = 244.5 Hz), 156.7, 139.2, 129.5, 115.2 (d, J = 21.0 Hz), 86.6, 39.6, 38.4, 36.3, 29.9, 20.6, 15.6; HRMS (ESI) *m/z* calcd for $C_{16}H_{18}FN_2O_2$ $[M+H]^+$, 289.1347; found, 289.1349.

7-Methyl-9-nitro-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin-6-one (4e).



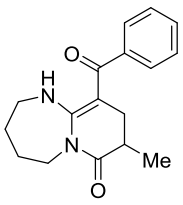
yellow solid: mp 228–232 °C; IR (KBr): 3395, 2976, 1705, 1623, 1500, 1394, 1243, 1140, 994, 811 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 11.75 (br, 1H, NH), 3.92–3.68 (m, 2H, NCH_2), 3.54–3.47 (m, 2H, NCH_2), 2.30–2.26 (m, H, CH), 2.64–2.47 (m, 2H, CH_2), 2.04–1.99 (m, 2H, CH_2), 1.24 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 172.3, 152.5, 106.3b 39.7, 39.1, 35.2b 27.9, 20.0, 15.5; HRMS (ESI) *m/z* calcd for $C_9H_{14}N_3O_3$ $[M+H]^+$, 212.1030; found, 212.1030.

10-(4-Methoxybenzoyl)-8-methyl-2,3,4,5,8,9-hexahydropyrido[1,2-*a*][1,3]diazepin-7(1*H*)-one (4f).



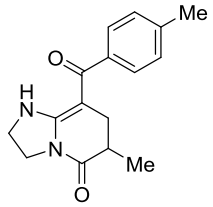
White solid: mp 126–127.5 °C; IR (KBr):3416, 2937, 1694, 1601, 1434, 1258, 1149, 999, 900, 642 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 11.63 (br, 1H, NH), 7.41 (d, J = 8.6 Hz, 2H, PhH), 6.92 (d, J = 8.3 Hz, 2H, PhH), 4.44–3.51 (m, 2H, NCH_2), 3.85 (s, 3H, OCH_3), 3.47–3.31 (m, 2H, NCH_2), 2.63–2.31(m, 2H, CH_2), 2.50–2.42 (m, H, CH), 2.03–1.79 (m, 4H, CH_2CH_2), 1.18–1.16 (m, 3H, CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 190.6, 174.5, 161.9, 160.3, 134.4, 128.7, 113.2, 92.5, 55.2, 45.1, 44.9, 37.8, 30.6, 26.5, 26.2, 14.6; HRMS (ESI) *m/z* calcd for $C_{18}H_{23}N_2O_3$ $[M+H]^+$, 315.1703; found, 315.1707.

10-Benzoyl-8-methyl-2,3,4,5,8,9-hexahydropyrido[1,2-*a*][1,3]diazepin-7(1*H*)-one (4g).



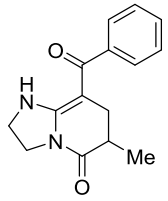
White solid: mp 131–132 °C; IR (KBr): 3438, 2937, 1697, 1602, 1473, 1432, 1242, 1150, 997, 708 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 11.66 (br, 1H, NH), 7.31 (m, 5H, PhH), 4.33–3.45 (m, 2H, NCH_2), 3.41–3.25 (m, 2H, NCH_2), 2.47–2.35 (m, 2H, CH_2), 2.23–2.18 (m, H, CH), 1.81–1.71 (m, 4H, CH_2CH_2), 1.08–1.06 (d, J = 6.7 Hz, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 191.0, 174.6, 162.1, 142.1, 129.1, 128.1, 126.8, 92.4, 45.2, 44.9, 37.8, 30.3, 26.5, 26.1, 14.7; HRMS (ESI) *m/z* calcd for $C_{17}H_{21}N_2O_2$ $[M+H]^+$, 285.1598; found, 285.1598.

6-Methyl-8-(4-methylbenzoyl)-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(*1H*) -one (4h).



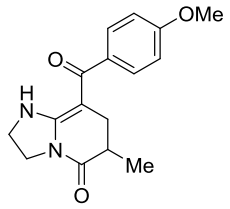
White solid: mp 162.5–164 °C; IR (KBr): 3291, 2962, 2817, 1686, 1634, 1525, 1439, 1286, 1033, 750 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 9.34 (br, 1H, NH), 7.30 (d, J = 8.0 Hz, 2H, PhH), 7.20 (d, J = 7.9 Hz, 2H, PhH), 3.88–3.67 (m, 4H, NCH_2CH_2), 3.34 (s, 3H, CH_3), 2.59–2.56 (m, H, CH), 2.51–2.40 (m, 2H, CH_2), 1.07–1.06 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 189.1, 172.0, 156.5, 139.5, 139.0, 128.9, 127.4, 84.4, 43.3, 42.2, 36.8, 30.9, 21.4, 15.6; HRMS (ESI) *m/z* calcd for $C_{16}H_{19}N_2O_2$ $[M+H]^+$, 271.1441; found, 271.1444.

8-Benzoyl-6-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*)-one (4i).



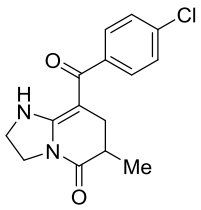
White solid: mp 144.5–145.5 °C; IR (KBr): 3320, 2970, 1689, 1632, 1526, 1382, 1285, 1211, 1035, 736 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 9.38 (br, 1H, NH), 7.42–7.38 (m, 5H, PhH), 3.89–3.68 (m, 4H, NCH_2CH_2), 2.58–2.55 (m, H, CH), 2.54–2.40 (m, 2H, CH_2), 1.08–1.07 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 189.1, 172.0, 156.6, 142.3, 129.4, 128.4, 127.2, 84.3, 43.3, 42.2, 36.8, 30.8, 15.6; HRMS (ESI) *m/z* calcd for $C_{15}H_{17}N_2O_2$ $[M+H]^+$, 257.1285; found, 257.1284.

8-(4-Methoxybenzoyl)-6-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*) -one (4j).



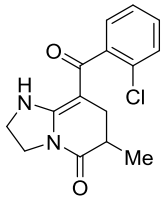
White solid: mp 164–165 °C; IR (KBr): 3416, 3285, 2971, 1683, 1633, 1577, 1496, 1289, 1167, 1022, 841 cm^{-1}; ^{1}H NMR (600 MHz, DMSO-d_6): δ = 9.33 (br, 1H, NH), 7.40 (d, J = 8.7 Hz, 2H, PhH), 6.95 (d, J = 8.7 Hz, 2H, PhH), 3.89–3.67 (m, 4H, NCH_2CH_2), 3.79 (s, 3H, OCH_3), 2.64–2.62 (m, H, CH), 2.52–2.45 (m, 2H, CH_2), 1.09–1.08 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 188.5, 172.0, 160.4, 156.4, 134.6, 129.2, 113.6, 84.4, 55.6, 43.3, 42.2, 36.8, 31.1, 15.6; HRMS (ESI) *m/z* calcd for $C_{16}H_{19}N_2O_3$ $[M+H]^+$, 287.1390; found, 287.1392.

8-(4-Chlorobenzoyl)-6-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*) -one (4k).



White solid: mp 191.5–192.5 °C; IR (KBr): 3424, 2975, 1683, 1635, 1504, 1439, 1292, 1024, 758 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ = 9.44 (br, 1H, NH), 7.42–7.37 (m, 4H, PhH), 4.07–3.83 (m, 4H, NCH_2CH_2), 2.73–2.69 (m, H, CH), 2.57–2.45 (m, 2H, CH_2), 1.24–1.22 (s, 3H, CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 189.9, 172.6, 157.6, 140.0, 135.7, 128.8, 128.6, 85.4, 43.3, 42.5, 37.5, 31.1, 15.7; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}ClN_2O_2$ $[M+H]^+$, 291.0895; found, 291.0894.

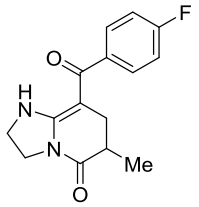
8-(2-Chlorobenzoyl)-6-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*] pyridin-5(1*H*)-one (4l).



White solid: mp 171–173°C; IR (KBr): 3415, 3306, 2966, 1691, 1634, 1513, 1283, 1036, 752 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 9.23 (br, 1H, NH), 7.32–7.31 (m, H, PhH), 7.23–7.20 (m, 2H, PhH), 7.16–7.14 (m, H, PhH), 3.98–3.77 (m, 4H, NCH_2CH_2), 2.51–2.48 (m, H, CH), 2.32–2.16 (m, 2H, CH_2), 1.13–1.12 (s, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 189.9, 172.3, 156.7, 140.7, 130.1, 129.6, 129.5, 127.7, 126.9,

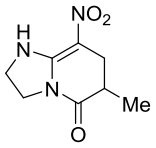
85.5, 42.9, 42.1, 37.0, 29.1, 15.4; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}ClN_2O_2$ $[M+H]^+$, 291.0895; found, 291.0897.

8-(4-Fluorobenzoyl)-6-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*] pyridin-5(1*H*)-one (4m).



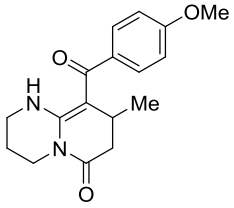
yellow solid: mp 154–155 °C; IR (KBr): 3415, 3311, 2979, 1683, 1637, 1600, 1441, 1286, 1155, 1034, 840 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ = 9.41 (br, 1H, NH), 7.49–7.46 (m, 2H, PhH), 7.11–7.08 (m, 2H, PhH), 4.08–3.84 (m, 4H, NCH_2CH_2), 2.75–2.72 (m, H, CH), 2.58–2.48 (m, 2H, CH_2), 1.25–1.24 (s, 3H, CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 190.1, 172.6, 163.7 (d, J = 248.0 Hz), 157.6, 137.7, 129.6, 115.4 (d, J = 21.0 Hz), 85.4, 43.3, 42.5, 37.6, 31.1, 15.7; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}FN_2O_2$ $[M+H]^+$, 275.1190; found, 275.1191.

6-Methyl-8-nitro-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*)-one (4n).



yellow solid: mp 240–250 °C; IR (KBr): 3415, 3238, 2989, 1700, 1625, 1491, 1376, 1289, 1184, 685 cm^{-1}; ^1H NMR (600 MHz, DMSO-d_6): δ = 9.53 (br, 1H, NH), 3.92–3.70 (m, 4H, NCH_2CH_2), 3.11–3.07 (m, H, CH), 2.74–2.43 (m, 2H, CH_2), 1.17–1.16 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 171.4, 153.0, 103.3, 43.8, 43.2, 35.6, 28.9, 15.8; HRMS (ESI) *m/z* calcd for $C_8H_{12}N_3O_3$ $[M+H]^+$, 198.0873; found, 198.0875.

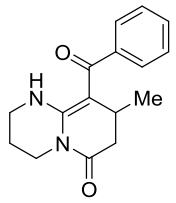
9-(4-Methoxybenzoyl)-8-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidi n -6-one (5a).



White solid: mp 154–156.5°C; IR (KBr): 3415, 2967, 1693, 1654, 1446, 1316, 1169, 1032, 837 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 12.69 (br, 1H, NH), 7.25 (d, J =

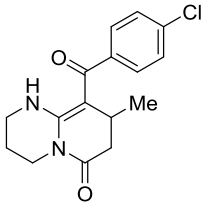
8.5 Hz, 2H, PhH), 6.93 (d, *J* = 8.5 Hz, 2H, PhH), 3.93–3.52 (m, 2H, NCH_2), 3.78 (s, 3H, OCH_3), 3.57–3.34 (m, 2H, NCH_2), 2.81–2.77 (m, 2H, CH_2), 2.32–2.28 (m, H, CH), 1.94–1.93 (m, 2H, CH_2), 0.82–0.81 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 187.7, 169.6, 159.4, 155.7, 135.5, 128.1, 113.6, 92.4, 55.5, 39.9, 38.8, 38.4, 26.2, 21.3, 20.5; HRMS (ESI) *m/z* calcd for $C_{17}H_{21}N_2O_3$ $[M+H]^+$, 301.1547; found, 301.1549.

9-Benzoyl-8-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin-6-one (5b).



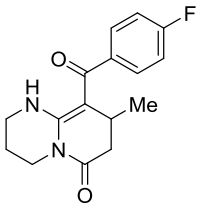
White solid: mp 125–127.5°C; IR (KBr): 3416, 2957, 1698, 1611, 1536, 1449, 1277, 1159, 713, 696 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 12.58 (br, 1H, NH), 7.41–7.34 (m, 3H, PhH), 7.29–7.27 (m, 2H, PhH), 3.93–3.53 (m, 2H, NCH_2), 3.47–3.35 (m, 2H, NCH_2), 2.80–2.67 (m, 2H, CH_2), 2.31–2.27 (m, H, CH), 1.94–1.93 (m, 2H, CH_2), 0.81–0.80 (m, 3H, CH_3); ^{13}C NMR (150 MHz, DMSO-d_6): δ = 188.0, 169.6, 155.8, 143.0, 128.3, 126.3, 92.3, 39.4, 38.8, 38.4, 26.1, 21.3, 20.4; HRMS (ESI) *m/z* calcd for $C_{16}H_{19}N_2O_2$ $[M+H]^+$, 271.1441; found, 271.1442.

9-(4-Chlorobenzoyl)-8-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin-6 -one (5c).



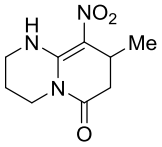
White solid: mp 135.5–136.5 °C; IR (KBr): 3438, 2959, 1696, 1618, 1541, 1384, 1275, 1155, 837, 674 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 12.66 (br, 1H, NH), 7.28 (d, *J* = 8.0 Hz, 2H, PhH), 7.21 (d, *J* = 7.9 Hz, 2H, PhH), 4.03–3.55 (m, 2H, NCH_2), 3.45–3.35 (m, 2H, NCH_2), 2.73–2.61 (m, 2H, CH_2), 2.36–2.35 (m, H, CH), 1.99–1.95 (m, 2H, CH_2), 0.85 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 188.0, 169.8, 156.0, 140.7, 134.1, 128.4, 127.7, 93.0, 39.6, 38.8, 38.6, 26.2, 21.1, 20.6; HRMS (ESI) *m/z* calcd for $C_{16}H_{18}ClN_2O_2$ $[M+H]^+$,305.1051; found, 305.1049.

9-(4-Fluorobenzoyl)-8-methyl-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*]pyrimidin-6 -one (5d).



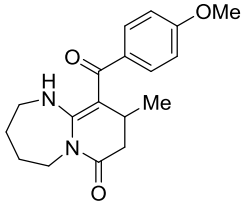
yellow solid: mp 130-132 °C; IR (KBr): 3437, 2958, 1697, 1599, 1529, 1383, 1153, 836 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 12.68 (br, 1H, NH), 7.26–7.24 (m, 2H, PhH), 7.00–6.97 (m, 2H, PhH), 4.03–3.54 (m, 2H, NCH_2), 3.45–3.35 (m, 2H, NCH_2), 2.75–2.72 (m, H, CH), 2.66–2.38 (m, 2H, CH_2), 1.99–1.95 (m, 2H, CH_2), 0.85-0.84 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 188.3, 169.8, 162.6 (d, J = 246.0 Hz), 156.0, 138.5, 128.1, 115.1 (d, J = 21.0 Hz), 93.0, 39.6, 38.8, 38.6, 26.2, 21.0, 20.7; HRMS (ESI) *m/z* calcd for $C_{16}H_{18}FN_2O_2$ $[M+H]^+$, 289.1347; found, 289.1346.

8-Methyl-9-nitro-1,2,3,4,7,8-hexahydro-6*H*-pyrido[1,2-*a*] pyrimidin-6-one (5e).



yellow solid: mp 212–214.5 °C; IR (KBr): 3408, 3073, 2960, 1713, 1617, 1511, 1391, 1161, 1051, 955, 784 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 4.03–3.63 (m, 2H, NCH_2), 3.62–3.53 (m, 2H, NCH_2), 3.52–2.46 (m, H, CH), 2.74–2.51 (m, 2H, CH_2), 2.04–1.99 (m, 2H, CH_2), 1.73 (br, 1H, NH), 1.06 (d, J = 6.9 Hz, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 168.9, 151.8, 111.4, 39.3, 39.1, 38.0, 26.3, 19.9, 17.4; HRMS (ESI) *m/z* calcd for $C_9H_{14}N_3O_3$ $[M+H]^+$, 212.1030; found, 212.1030.

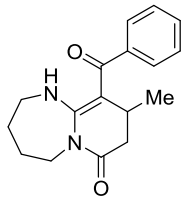
10-(4-Methoxybenzoyl)-9-methyl-2,3,4,5,8,9-hexahydropyrido[1,2-*a*][1,3] diazepin-7(1*H*)-one (5f).



Light yellow solid: mp 162.5–163.5 °C; IR (KBr): 3449, 2953, 1695, 1697, 1474, 1432, 1266, 1149, 1000, 849 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 11.40 (br, 1H, NH), 7.27 (d, J = 8.6 Hz, 2H, PhH), 6.83 (d, J = 8.6 Hz, 2H, PhH), 4.61–3.46 (m, 2H, NCH_2), 3.76 (s, 3H, OCH_3), 3.12–3.08 (m, 2H, NCH_2), 2.86–2.62 (m, 2H, CH_2), 2.35–2.32 (m, H, CH), 1.85–1.65 (m, 4H, CH_2CH_2), 0.85 (d, J = 7.0 Hz, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 191.6, 171.3, 161.4, 160.2, 134.9, 128.1, 113.4,

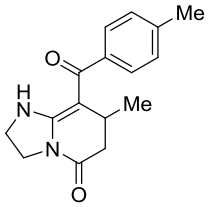
98.8, 55.3, 45.4, 44.8, 40.8, 26.9, 26.8, 26.6, 19.5; HRMS (ESI) *m/z* calcd for $C_{18}H_{23}N_2O_3$ $[M+H]^+$, 315.1703; found, 315.1705.

10-Benzoyl-9-methyl-2,3,4,5,8,9-hexahydropyrido[1,2-*a*][1,3] diazepin-7(1*H*)-one (5g).



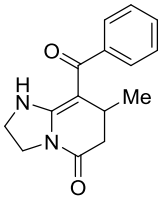
White solid: mp 157–159.5 °C; IR (KBr): 3290, 3066, 2951, 1696, 1596, 1471, 1310, 1147, 1004, 799, 710 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$+ DMSO-d_6): δ = 7.05–6.97 (m, 5H, PhH), 4.32–3.24 (m, 2H, NCH_2), 2.94–2.69 (m, 2H, NCH_2), 2.46–2.42 (m, H, CH), 2.38–2.00 (m, 2H, CH_2), 1.59–1.39 (m, 4H, CH_2CH_2), 1.44 (br, 1H, NH), 0.56 (d, J = 6.9 Hz, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$+ DMSO-d_6): δ = 190.6, 170.1, 160.7, 141.5, 127.7, 127.3, 125.1, 97.3, 44.4, 43.8, 39.8, 38.0, 25.7, 25.6, 18.7; HRMS (ESI) *m/z* calcd for $C_{17}H_{21}N_2O_2$ $[M+H]^+$, 285.1598; found, 285.1596.

7-Methyl-8-(4-methylbenzoyl)-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*) -one (5h).



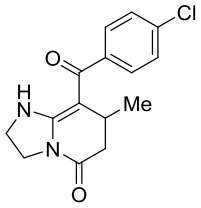
White solid: mp 173–176 °C; IR (KBr): 3449, 3299, 2957, 1694, 1625, 1528, 1371, 1320, 1201, 1025, 769 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ = 9.50 (br, 1H, NH), 7.32 (d, J = 7.8 Hz, 2H, PhH), 7.21 (d, J = 7.7 Hz, 2H, PhH), 4.12–3.77 (m, 4H, NCH_2CH_2), 3.09–3.07 (m, H, CH), 2.76–2.43 (m, 2H, CH_2), 2.39 (s, 3H, CH_3), 0.97–0.96 (m, 3H, CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 191.9, 168.8, 156.0, 138.9, 128.9, 126.4, 91.5, 42.5, 41.7, 39.7, 27.4, 22.0, 21.3; HRMS (ESI) *m/z* calcd for $C_{16}H_{19}N_2O_2$ $[M+H]^+$, 271.1441; found, 271.1440.

8-Benzoyl-7-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*)-one (5i).



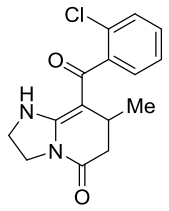
White solid: mp 138–139 °C; IR (KBr): 3289, 2958, 1695, 1625, 1524, 1439, 1328, 1207, 0127, 700 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 9.43 (br, 1H, NH), 7.31 (m, 5H, PhH), 4.04–3.71 (m, 4H, NCH_2CH_2), 2.96–2.93(m, H, CH), 2.67–2.33 (m, 2H, CH_2), 0.88–0.87 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 192.0, 168.9, 156.2, 141.7, 129.0, 128.2, 126.4, 91.5, 42.6, 41.8, 39.8, 27.5, 19.6; HRMS (ESI) *m/z* calcd for $C_{15}H_{17}N_2O_2$ $[M+H]^+$, 257.1285; found, 257.1286.

8-(4-Chlorobenzoyl)-7-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin-5(1*H*)-on e (5j).



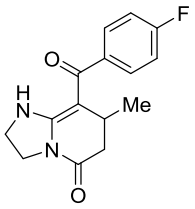
White solid: mp 144-145.5 °C; IR (KBr): 3415, 3316, 2945, 1691, 1625, 1520, 1445, 1329, 1025, 671 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ = 9.53 (br, 1H, NH), 7.39–7.35 (m, 4H, PhH), 4.13–3.80 (m, 4H, NCH_2CH_2), 3.01–2.99 (m, H, CH), 2.76–2.43 (m, 2H, CH_2), 0.97–0.96 (m, 3H, CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ = 190.8, 169.1, 156.9, 140.4, 135.3, 128.8, 128.3, 91.8, 43.0, 42.3, 40.1, 27.9, 22.5; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}ClN_2O_2$ $[M+H]^+$, 291.0895; found, 291.0898.

8-(2-Chlorobenzoyl)-7-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*] pyridin-5(1*H*)-one (5k).



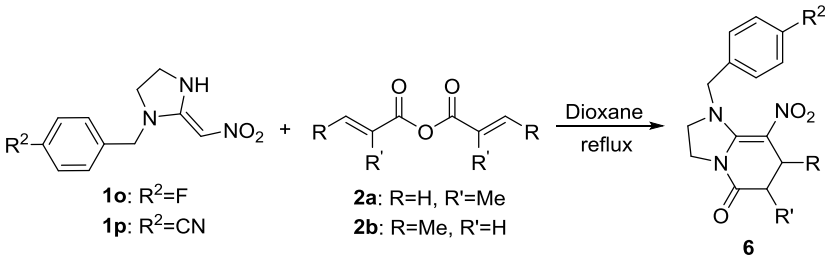
White solid: mp 228–229 °C; IR (KBr): 3415, 3319, 2959, 1697, 1630, 1529, 1375, 1208, 1027, 755 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 9.30 (br, 1H, NH), 7.31–7.18 (m, 4H, PhH), 4.05–3.75 (m, 4H, NCH_2CH_2), 2.68–2.58 (m, 2H, CH_2), 2.35–2.32 (m, H, CH), 0.84–0.83 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 189.0, 168.9, 156.1, 140.5, 130.2, 129.5, 127.8, 126.8, 91.8, 42.7, 41.8, 39.8, 27.4, 21.8; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}ClN_2O_2$ $[M+H]^+$, 291.0895; found, 291.0896.

8-(4-Fluorobenzoyl)-7-methyl-2,3,6,7-tetrahydroimidazo[1,2-*a*] pyridin-5(1*H*)-one (5l).



yellow solid: mp 143–144.5 °C; IR (KBr): 3290, 2961, 1703, 1622, 1527, 1371, 1226, 1026, 851, 772 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ = 9.39 (br, 1H, NH), 7.44–7.41 (m, 2H, PhH), 7.24–7.21 (m, 2H, PhH), 3.93–3.63 (m, 4H, NCH_2CH_2), 2.88–2.75 (m, 2H, CH_2), 2.27–2.24 (m, H, CH), 0.95–0.83 (s, 3H, CH_3); ^{13}C NMR (125 MHz, DMSO-d_6): δ = 188.6, 168.5, 162.4 (d, J = 243.0 Hz), 155.8, 139.1, 129.0, 115.2 (d, J = 21.0 Hz), 90.5, 42.9, 41.8, 39.4, 27.6, 22.2; HRMS (ESI) *m/z* calcd for $C_{15}H_{16}FN_2O_2$ $[M+H]^+$, 275.1190; found, 275.1191.

General procedure for the synthesis of compounds 6



1o: R^2=F
1p: R^2=CN

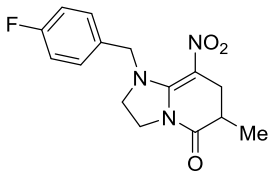
2a: R=H, R'=Me
2b: R=Me, R'=H

6

HKA derivatives **1** (1.0 mmol), methacrylic anhydride **2a** or crotonic anhydride **2b** (1.2 mmol) and dry dioxane (10.0 mL) were placed in a 25 mL round-bottom flask and the mixture was stirred at reflux for 3-8 h. Upon completion, as monitored by TLC. Then the reaction mixture was cooled to room temperature and filted to give the pure crude product, which was further washed with petroleum ether-EtOAc(1:1) to give pure product **6** with a yield of 87-93%.

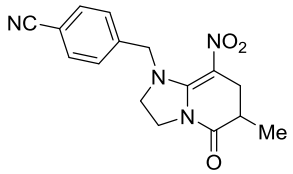
Spectroscopic data of bicyclic pyridones derivatives 6

1-(4-Fluorobenzyl)-6-methyl-8-nitro-2,3,6,7-tetrahydroimidazo[1,2-*a*]pyridin -5(1*H*)-one (6a).



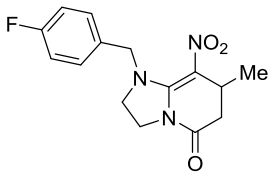
yellow solid: mp 188–189 °C; IR (KBr): 3415, 3063, 2974, 1711, 1609, 1436, 1380, 1221, 1156, 832 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 7.23–7.21 (m, 2H, PhH), 7.00–6.97 (m, 2H, PhH), 4.79 (d, J = 15 Hz, H, NCH), 4.73 (d, J = 15 Hz, H, NCH), 3.92–3.57 (m, 4H, NCH_2CH_2), 3.33–2.28 (m, H, CH), 2.63–2.59 (m, 2H, CH_2), 1.22–1.21 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 171.7, 162.7 (d, J = 246.0 Hz), 151.8, 130.5, 130.1, 116.0 (d, J = 21.0 Hz), 105.2, 54.3, 49.3, 41.3, 36.4, 30.8, 15.2; HRMS (ESI) *m/z* calcd for $C_{15}H_{17}FN_3O_3$ $[M+H]^+$, 306.1248; found, 306.1249.

4-((6-Methyl-8-nitro-5-oxo-2,3,6,7-tetrahydroimidazo[1,2-a]pyridin-1(5H)-yl)methyl)benzonitrile (6b)



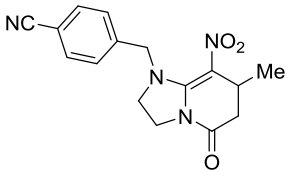
yellow solid: mp 166.5–167.5 °C; IR (KBr): 3432, 2978, 2230, 1694, 1606, 1255, 1189, 927, 823, 550 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ = 7.60 (d, J = 8.2 Hz, 2H, PhH), 7.40 (d, J = 8.1 Hz, 2H, PhH), 4.90 (d, J = 15.8 Hz, H, NCH), 4.79 (d, J = 15.7 Hz, H, NCH), 3.99–3.58 (m, 4H, NCH_2CH_2), 3.30–2.28 (m, H, CH), 2.64–2.60 (m, 2H, CH_2), 1.23–1.19 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 171.6, 151.9, 140.4, 132.7, 128.5, 118.3, 112.2, 105.6, 55.0, 50.1, 41.4, 36.3, 30.7, 15.1; HRMS (ESI) *m/z* calcd for $C_{16}H_{17}N_4O_3$ $[M+H]^+$, 313.1295; found, 313.1296.

1-(4-Fluorobenzyl)-7-methyl-8-nitro-2,3,6,7-tetrahydroimidazo[1,2-a]pyridin-5(1H)-one (6c)



yellow solid: mp 150–152 °C; IR (KBr): 3394, 2953, 1710, 1590, 1437, 1145, 758, 597 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ = 7.17–7.16 (m, 2H, PhH), 6.99–6.96 (m, 2H, PhH), 4.82-4.65 (m, 2H, NCH), 3.99–3.60 (m, 4H, NCH_2CH_2), 3.58–3.56 (m, H, CH), 2.74–2.41 (m, 2H, CH_2), 1.00-0.99 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$+ DMSO-d_6): δ = 172.4, 167.1 (d, J = 244.5 Hz), 155.5, 135.8, 134.7, 120.4 (d, J = 21.0 Hz), 115.7, 58.6, 54.9, 45.9, 43.3, 34.1, 23.8; HRMS (ESI) *m/z* calcd for $C_{15}H_{17}FN_3O_3$ $[M+H]^+$, 306.1248; found, 306.1244.

4-((7-Methyl-8-nitro-5-oxo-2,3,6,7-tetrahydroimidazo[1,2-a]pyridin-1(5H)-yl)methyl)benzonitrile (6d)



yellow solid: mp 163.5–164.5 °C; IR (KBr): 3438, 2966, 2230, 1705, 1598, 1309, 1138, 757, 564 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.59 (d, J = 8.0 Hz, 2H, PhH), 7.35 (d, J = 7.9 Hz, 2H, PhH), 4.85–4.79 (m, 2H, NCH_2), 4.04–3.60 (m, 4H, NCH_2CH_2), 3.58–3.53 (m, H, CH), 2.74–2.42 (m, 2H, CH_2), 1.01–1.00 (m, 3H, CH_3); ^{13}C NMR (150 MHz, $CDCl_3$): δ = 167.8, 150.4, 140.5, 132.7, 128.4, 118.3, 112.2, 111.6, 54.8, 50.4, 41.1, 38.5, 29.3, 19.2; HRMS (ESI) *m/z* calcd for $C_{16}H_{17}N_4O_3$ $[M+H]^+$, 313.1295; found, 313.1292.

X-ray Structure and Data[3] of 4j

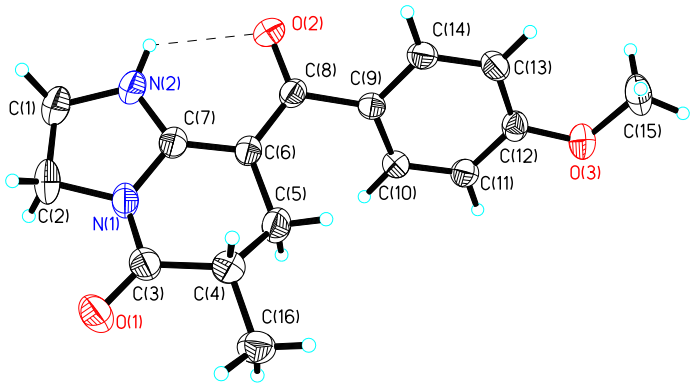


Figure 1 X-Ray crystal structure of **4j**

Table 1. Crystal data and structure refinement for **4j.**

Empirical formula	C16 H18 N2 O3
Formula weight	286.32
Temperature	293(2) K
Wavelength	0.71073 A
Crystal system, space group	Triclinic, P-1
Unit cell dimensions	a = 7.3821(12) A alpha = 94.965(2) deg. b = 9.8440(17) A beta = 103.154(2) deg. c = 10.9083(18) A gamma = 109.687(2) deg.
Volume	715.2(2) A^3
Z, Calculated density	2, 1.330 Mg/m^3
Absorption coefficient	0.093 mm^-1
F(000)	304
Crystal size	0.30 x 0.20 x 0.18 mm
Theta range for data collection	1.95 to 25.15 deg.
Limiting indices	-8<=h<=8, -11<=k<=11, -13<=l<=13
Reflections collected / unique	5725 / 2541 [R(int) = 0.0249]
Completeness to theta = 25.15	99.6 %
Max. and min. transmission	0.9835 and 0.9727
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2541 / 0 / 192
Goodness-of-fit on F^2	1.071
Final R indices [I>2sigma(I)]	R1 = 0.0633, wR2 = 0.1611
R indices (all data)	R1 = 0.0978, wR2 = 0.1910
Largest diff. peak and hole	0.384 and -0.213 e.A^-3

Table 2. Bond lengths [A] and angles [deg] for **4j**

N(1)-C(3)	1.368(4)	N(1)-C(2)-H(2B)	111.2
N(1)-C(7)	1.399(4)	C(1)-C(2)-H(2B)	111.2
N(1)-C(2)	1.474(4)	H(2A)-C(2)-H(2B)	109.1
N(2)-C(7)	1.332(4)	O(1)-C(3)-N(1)	120.4(3)
N(2)-C(1)	1.447(5)	O(1)-C(3)-C(4)	124.5(4)
N(2)-H(2)	0.8600	N(1)-C(3)-C(4)	115.0(3)
O(1)-C(3)	1.226(4)	C(5)-C(4)-C(16)	115.1(3)
O(2)-C(8)	1.253(4)	C(5)-C(4)-C(3)	113.4(3)
O(3)-C(12)	1.366(4)	C(16)-C(4)-C(3)	113.5(3)
O(3)-C(15)	1.429(4)	C(5)-C(4)-H(4)	104.4
C(1)-C(2)	1.535(6)	C(16)-C(4)-H(4)	104.4
C(1)-H(1A)	0.9700	C(3)-C(4)-H(4)	104.4
C(1)-H(1B)	0.9700	C(4)-C(5)-C(6)	115.7(3)
C(2)-H(2A)	0.9700	C(4)-C(5)-H(5A)	108.4
C(2)-H(2B)	0.9700	C(6)-C(5)-H(5A)	108.4
C(3)-C(4)	1.509(5)	C(4)-C(5)-H(5B)	108.4
C(4)-C(5)	1.463(5)	C(6)-C(5)-H(5B)	108.4
C(4)-C(16)	1.501(5)	H(5A)-C(5)-H(5B)	107.4
C(4)-H(4)	0.9800	C(7)-C(6)-C(8)	119.8(3)

C(5)-C(6)	1.517(4)	C(7)-C(6)-C(5)	115.3(3)
C(5)-H(5A)	0.9700	C(8)-C(6)-C(5)	124.9(3)
C(5)-H(5B)	0.9700	N(2)-C(7)-C(6)	130.9(3)
C(6)-C(7)	1.374(4)	N(2)-C(7)-N(1)	107.9(3)
C(6)-C(8)	1.426(4)	C(6)-C(7)-N(1)	121.1(3)
C(8)-C(9)	1.506(4)	O(2)-C(8)-C(6)	123.1(3)
C(9)-C(14)	1.387(4)	O(2)-C(8)-C(9)	117.5(3)
C(9)-C(10)	1.393(4)	C(6)-C(8)-C(9)	119.4(3)
C(10)-C(11)	1.371(4)	C(14)-C(9)-C(10)	117.5(3)
C(10)-H(10)	0.9300	C(14)-C(9)-C(8)	119.6(3)
C(11)-C(12)	1.383(4)	C(10)-C(9)-C(8)	122.9(3)
C(11)-H(11)	0.9300	C(11)-C(10)-C(9)	121.3(3)
C(12)-C(13)	1.392(5)	C(11)-C(10)-H(10)	119.3
C(13)-C(14)	1.382(4)	C(9)-C(10)-H(10)	119.3
C(13)-H(13)	0.9300	C(10)-C(11)-C(12)	120.4(3)
C(14)-H(14)	0.9300	C(10)-C(11)-H(11)	119.8
C(15)-H(15A)	0.9600	C(12)-C(11)-H(11)	119.8
C(15)-H(15B)	0.9600	O(3)-C(12)-C(11)	116.1(3)
C(15)-H(15C)	0.9600	O(3)-C(12)-C(13)	124.2(3)
C(16)-H(16A)	0.9600	C(11)-C(12)-C(13)	119.6(3)
C(16)-H(16B)	0.9600	C(14)-C(13)-C(12)	119.0(3)
C(16)-H(16C)	0.9600	C(14)-C(13)-H(13)	120.5
C(3)-N(1)-C(7)	124.9(3)	C(12)-C(13)-H(13)	120.5
C(3)-N(1)-C(2)	123.2(3)	C(13)-C(14)-C(9)	122.0(3)
C(7)-N(1)-C(2)	111.1(3)	C(13)-C(14)-H(14)	119.0
C(7)-N(2)-C(1)	113.6(3)	C(9)-C(14)-H(14)	119.0
C(7)-N(2)-H(2)	123.2	O(3)-C(15)-H(15A)	109.5
C(1)-N(2)-H(2)	123.2	O(3)-C(15)-H(15B)	109.5
C(12)-O(3)-C(15)	117.7(3)	H(15A)-C(15)-H(15B)	109.5
N(2)-C(1)-C(2)	103.5(3)	O(3)-C(15)-H(15C)	109.5
N(2)-C(1)-H(1A)	111.1	H(15A)-C(15)-H(15C)	109.5
C(2)-C(1)-H(1A)	111.1	H(15B)-C(15)-H(15C)	109.5
N(2)-C(1)-H(1B)	111.1	C(4)-C(16)-H(16A)	109.5
C(2)-C(1)-H(1B)	111.1	C(4)-C(16)-H(16B)	109.5
H(1A)-C(1)-H(1B)	109.0	H(16A)-C(16)-H(16B)	109.5
N(1)-C(2)-C(1)	102.8(3)	C(4)-C(16)-H(16C)	109.5
N(1)-C(2)-H(2A)	111.2	H(16A)-C(16)-H(16C)	109.5
C(1)-C(2)-H(2A)	111.2	H(16B)-C(16)-H(16C)	109.5

Table 3. Torsion angles [deg] for **4j.**

C(7)-N(2)-C(1)-C(2)	10.7(5)
C(3)-N(1)-C(2)-C(1)	172.1(3)
C(7)-N(1)-C(2)-C(1)	1.7(4)
N(2)-C(1)-C(2)-N(1)	-6.9(4)
C(7)-N(1)-C(3)-O(1)	176.2(3)
C(2)-N(1)-C(3)-O(1)	7.1(5)
C(7)-N(1)-C(3)-C(4)	-0.5(5)
C(2)-N(1)-C(3)-C(4)	-169.6(3)

O(1)-C(3)-C(4)-C(5)	153.8(4)
N(1)-C(3)-C(4)-C(5)	-29.6(5)
O(1)-C(3)-C(4)-C(16)	20.0(5)
N(1)-C(3)-C(4)-C(16)	-163.4(3)
C(16)-C(4)-C(5)-C(6)	177.5(3)
C(3)-C(4)-C(5)-C(6)	44.4(5)
C(4)-C(5)-C(6)-C(7)	-29.4(5)
C(4)-C(5)-C(6)-C(8)	151.3(3)
C(1)-N(2)-C(7)-C(6)	167.3(4)
C(1)-N(2)-C(7)-N(1)	-10.0(4)
C(8)-C(6)-C(7)-N(2)	1.2(6)
C(5)-C(6)-C(7)-N(2)	-178.1(3)
C(8)-C(6)-C(7)-N(1)	178.2(3)
C(5)-C(6)-C(7)-N(1)	-1.1(5)
C(3)-N(1)-C(7)-N(2)	-165.5(3)
C(2)-N(1)-C(7)-N(2)	4.8(4)
C(3)-N(1)-C(7)-C(6)	16.9(5)
C(2)-N(1)-C(7)-C(6)	-172.8(3)
C(7)-C(6)-C(8)-O(2)	8.8(5)
C(5)-C(6)-C(8)-O(2)	-171.9(3)
C(7)-C(6)-C(8)-C(9)	-171.6(3)
C(5)-C(6)-C(8)-C(9)	7.7(5)
O(2)-C(8)-C(9)-C(14)	46.4(4)
C(6)-C(8)-C(9)-C(14)	-133.2(3)
O(2)-C(8)-C(9)-C(10)	-132.3(3)
C(6)-C(8)-C(9)-C(10)	48.1(4)
C(14)-C(9)-C(10)-C(11)	0.4(4)
C(8)-C(9)-C(10)-C(11)	179.1(3)
C(9)-C(10)-C(11)-C(12)	2.0(5)
C(15)-O(3)-C(12)-C(11)	-177.7(3)
C(15)-O(3)-C(12)-C(13)	0.6(5)
C(10)-C(11)-C(12)-O(3)	176.5(3)
C(10)-C(11)-C(12)-C(13)	-1.8(5)
O(3)-C(12)-C(13)-C(14)	-179.0(3)
C(11)-C(12)-C(13)-C(14)	-0.8(5)
C(12)-C(13)-C(14)-C(9)	3.3(5)
C(10)-C(9)-C(14)-C(13)	-3.1(5)
C(8)-C(9)-C(14)-C(13)	178.2(3)

^{1}H NMR and ^{13}C NMR spectra for compound 3

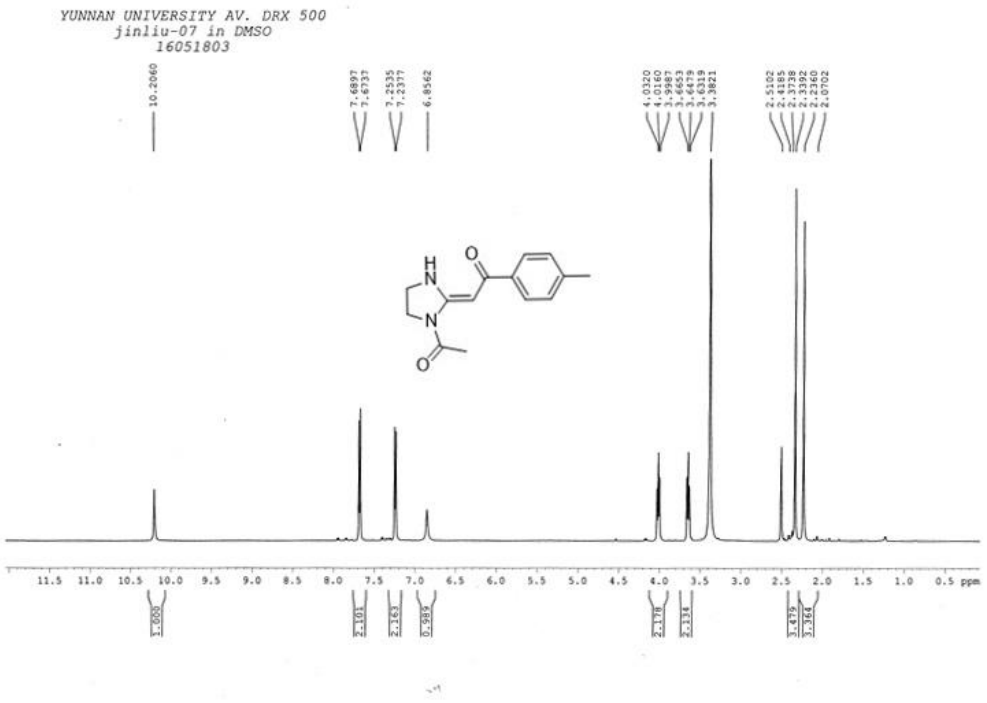


Figure 2a. ^{1}H NMR (500 MHz, DMSO-*d6*) spectra of compound **3**

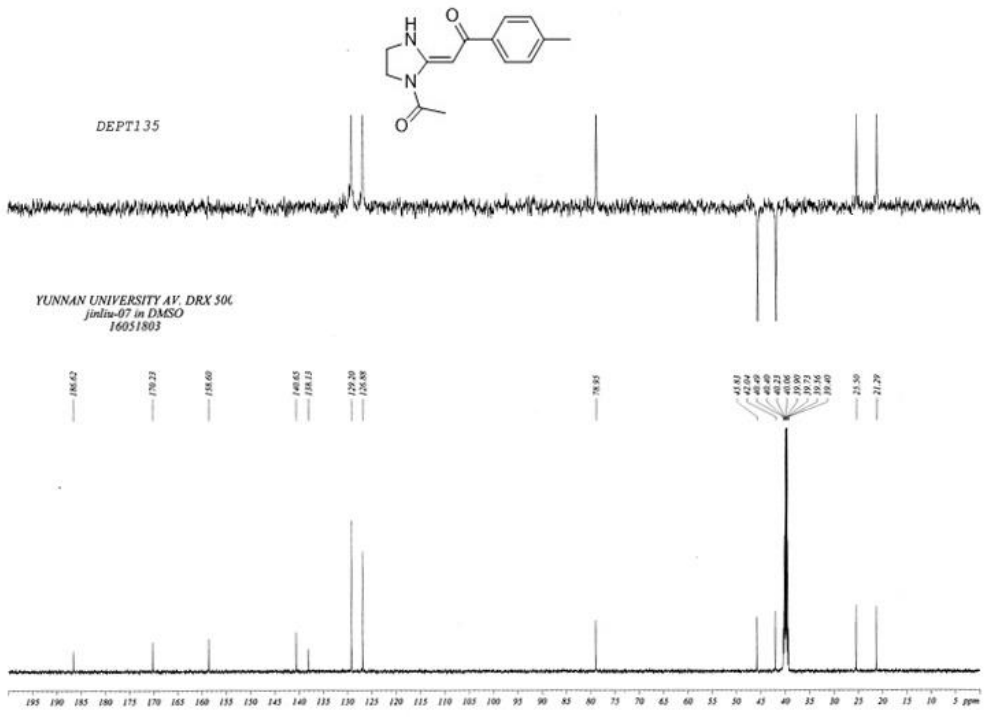


Figure 2b. ^{13}C NMR (125 MHz, DMSO-*d6*) spectra of compound **3**

^{1}H NMR and ^{13}C NMR spectra for bicyclic pyridones 4

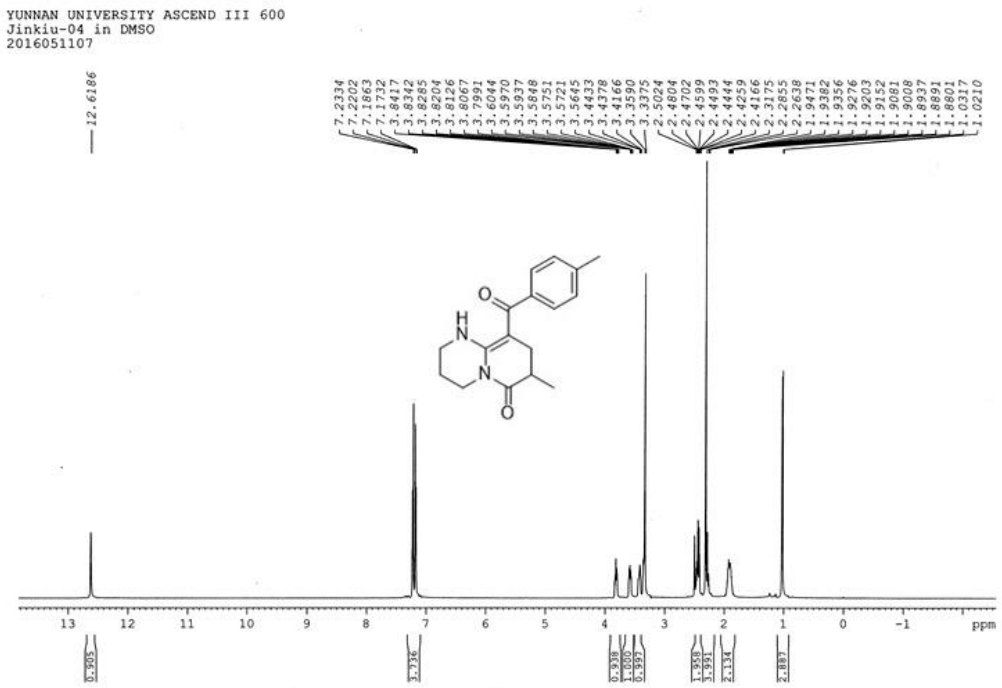


Figure 3a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4a**

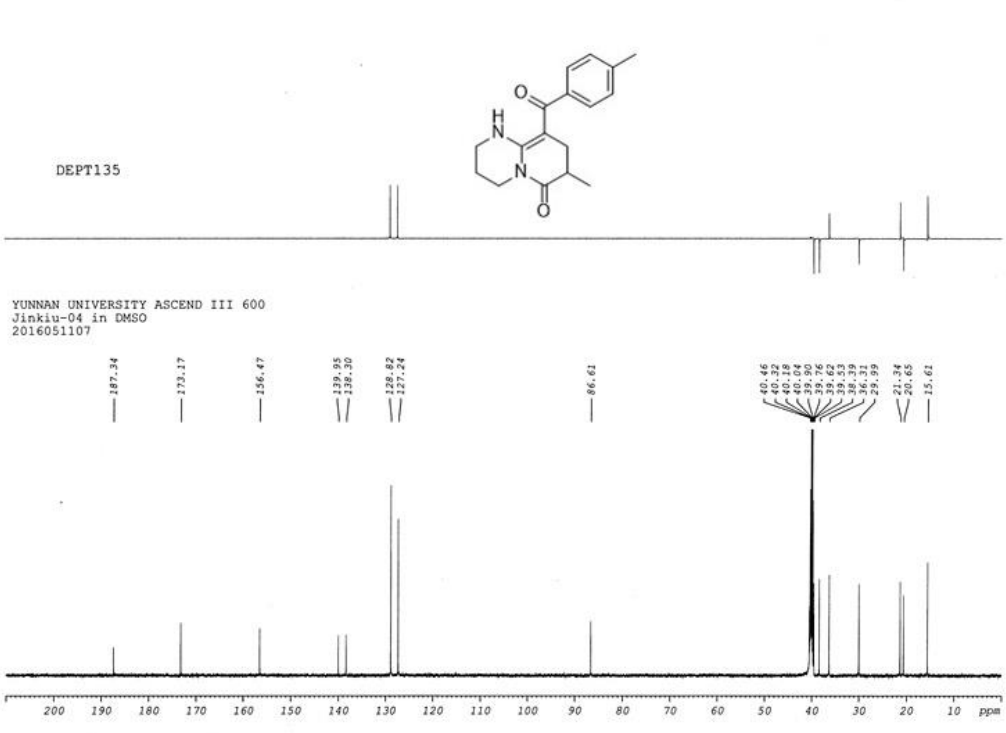


Figure 3b ^{13}C NMR (150 MHz, DMSO-*d6*) spectra of compound **4a**

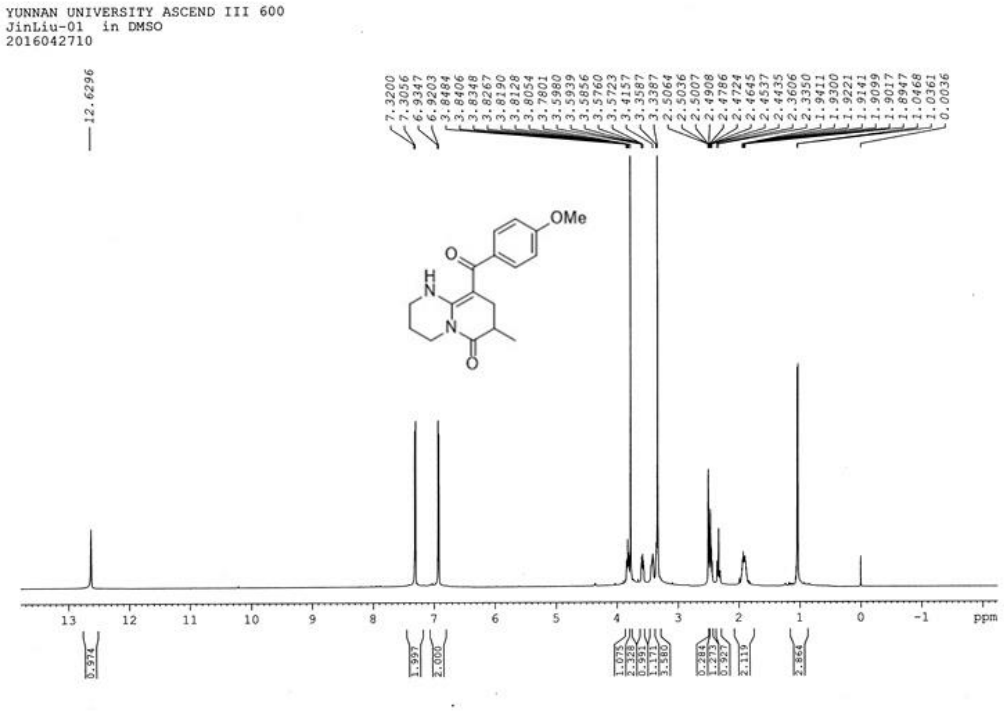


Figure 4a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4b**

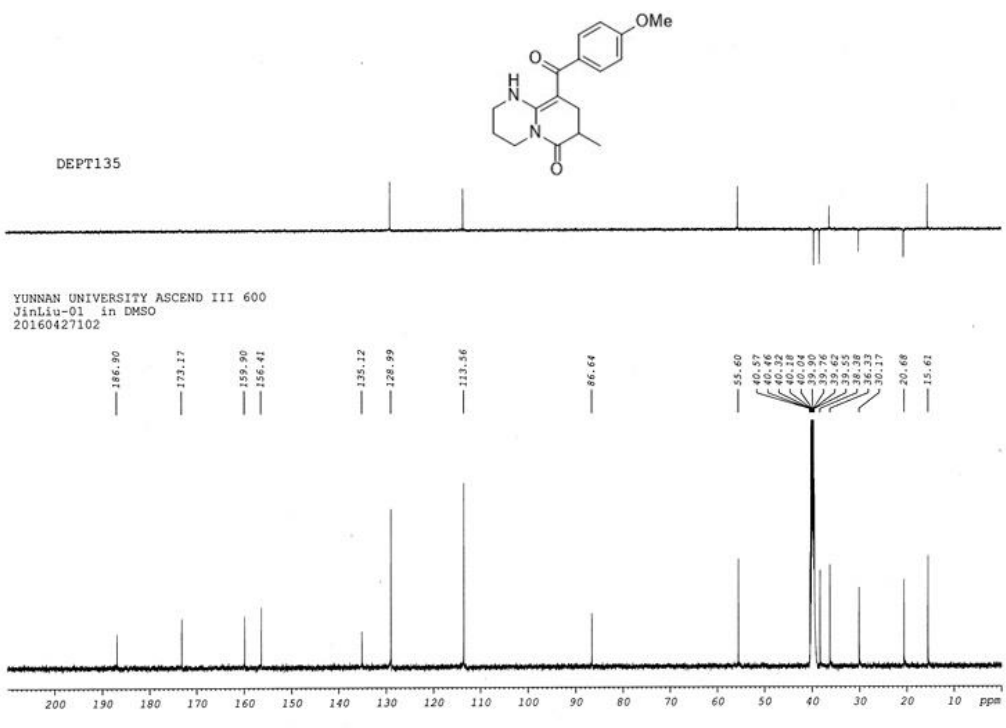


Figure 4b ^{13}C NMR (150 MHz, DMSO-*d6*) spectra of compound **4b**

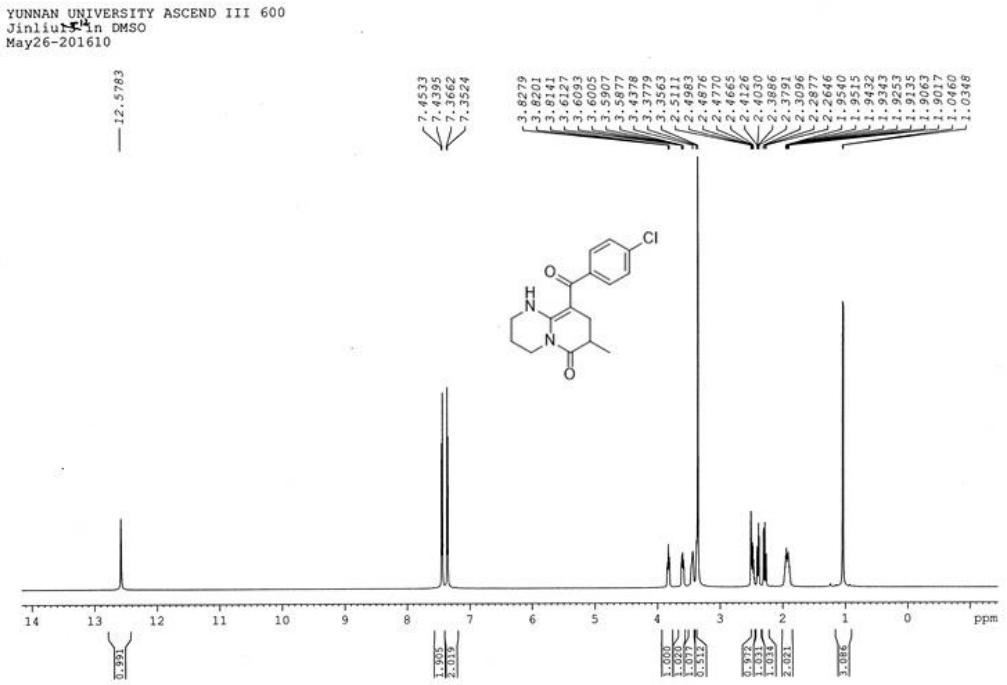


Figure 5a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4c**

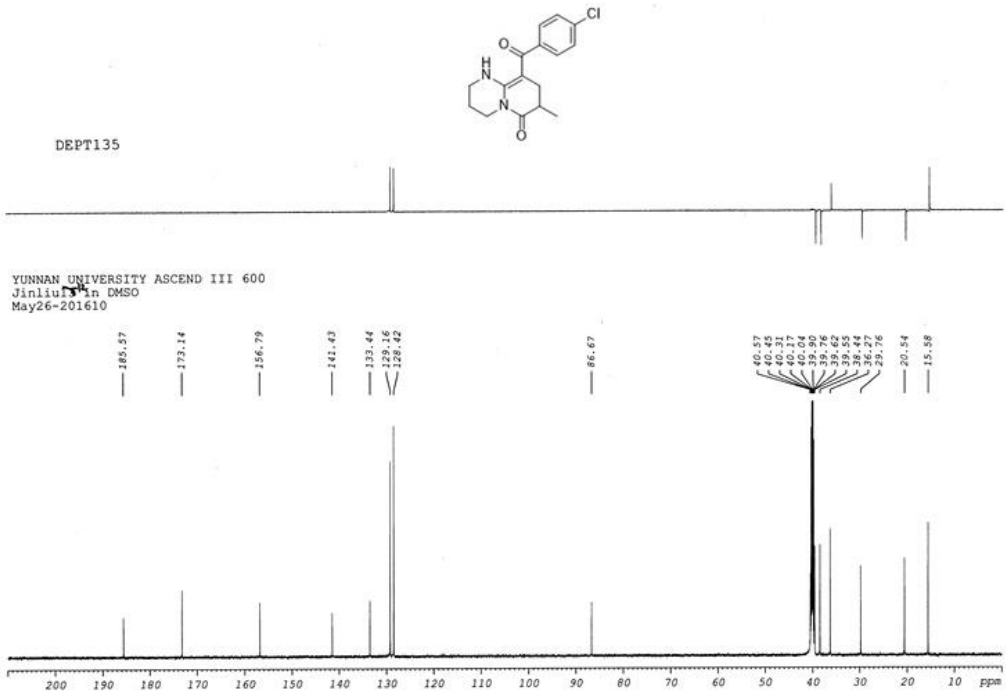


Figure 5b ^{13}C NMR (150 MHz, DMSO-d_6) spectra of compound **4c**

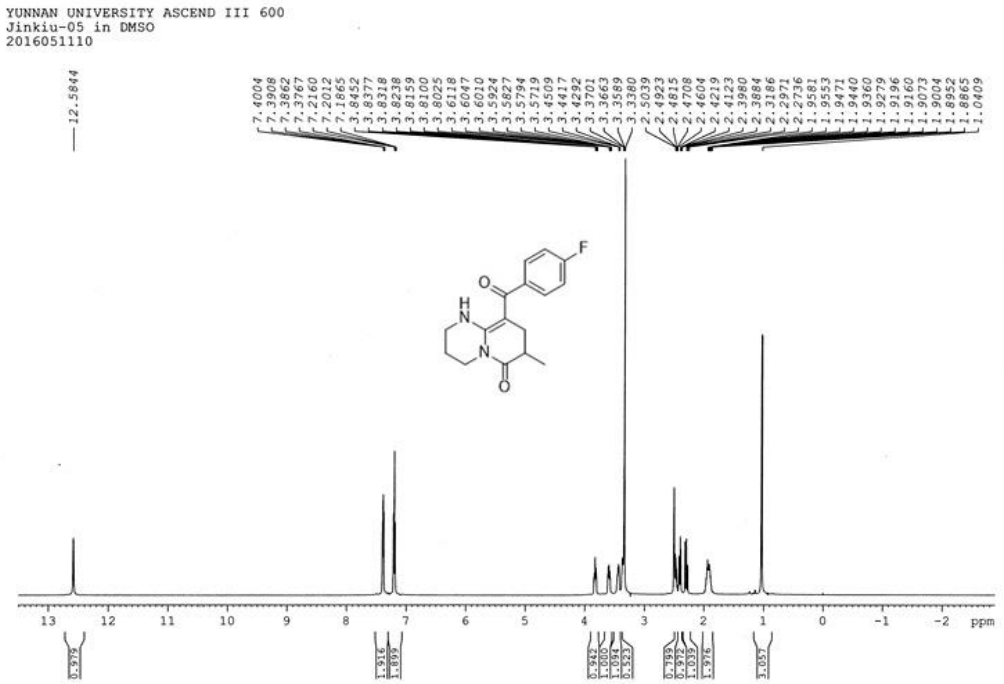


Figure 6a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4d**

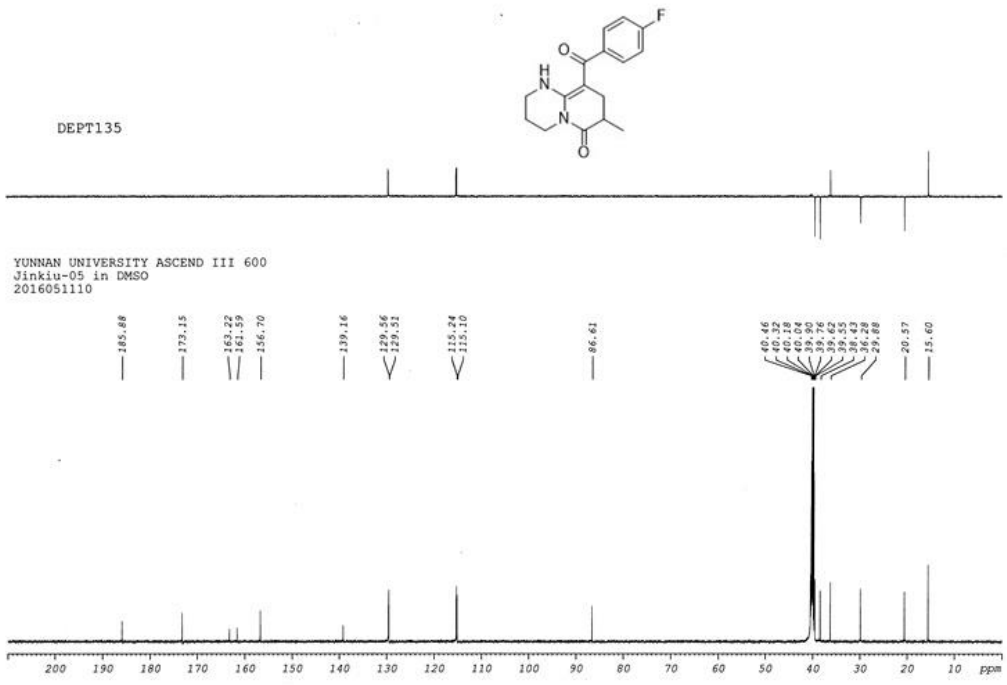


Figure 6b ^{13}C NMR (150 MHz, DMSO-d_6) spectra of compound **4d**

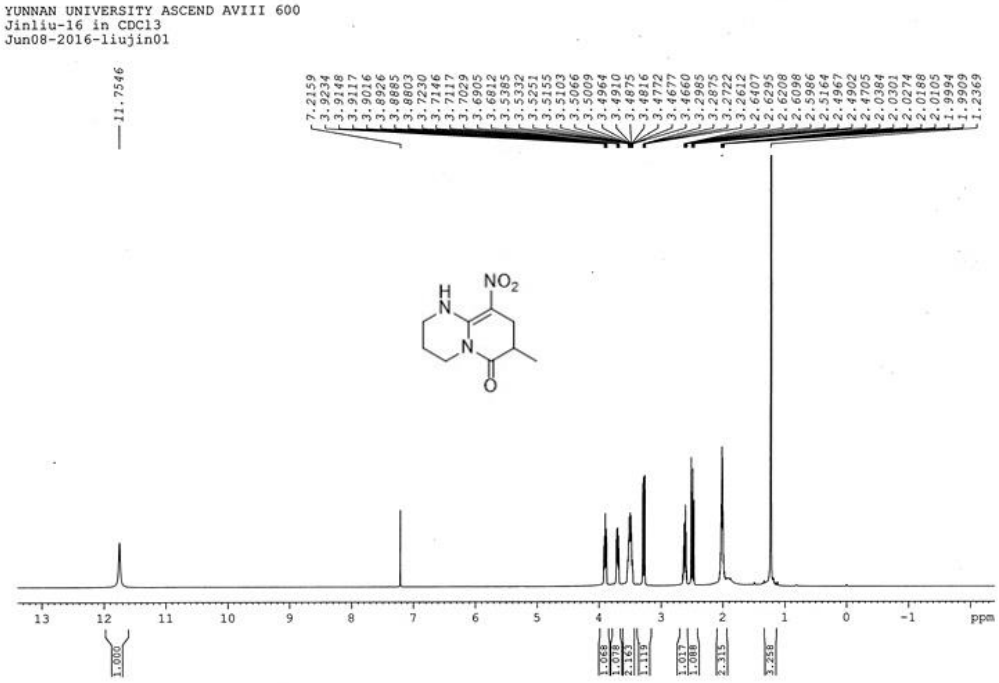


Figure 7a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **4e**

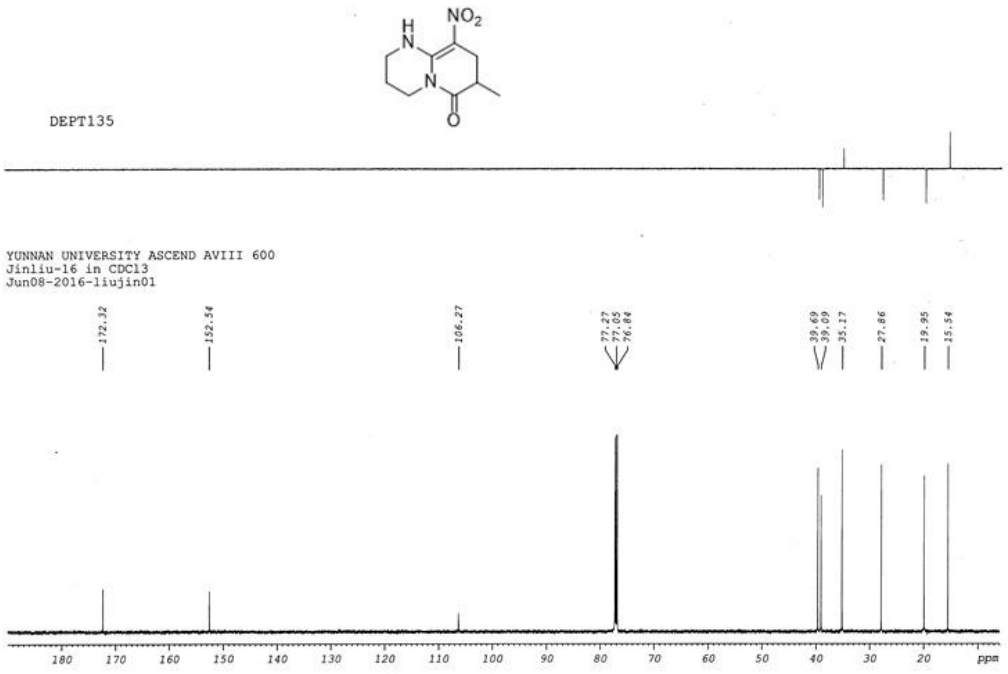


Figure 7b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **4e**

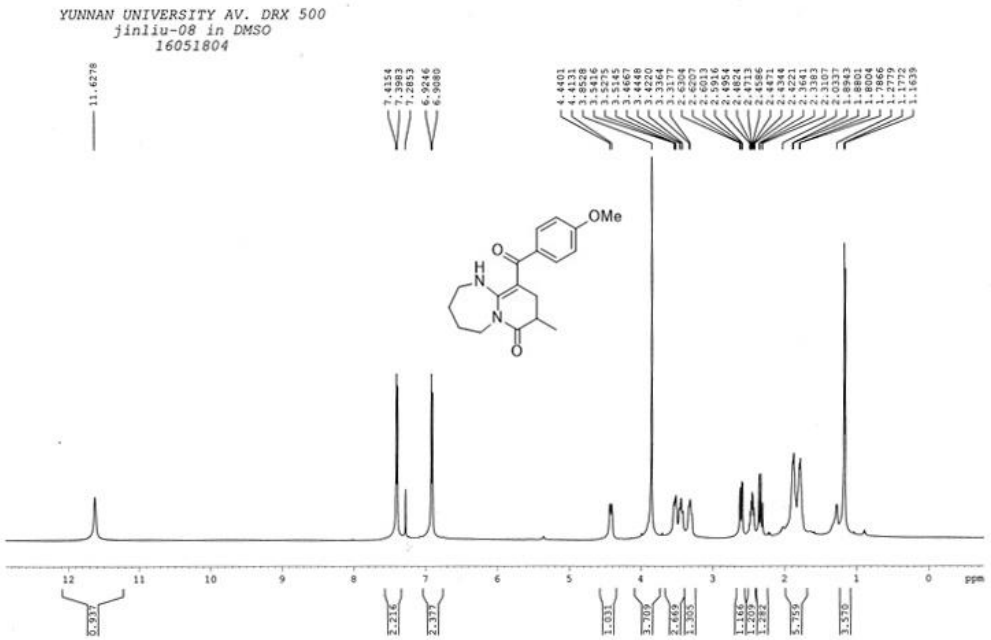


Figure 8a ^{1}H NMR (500 MHz, DMSO-*d6*) spectra of compound **4f**

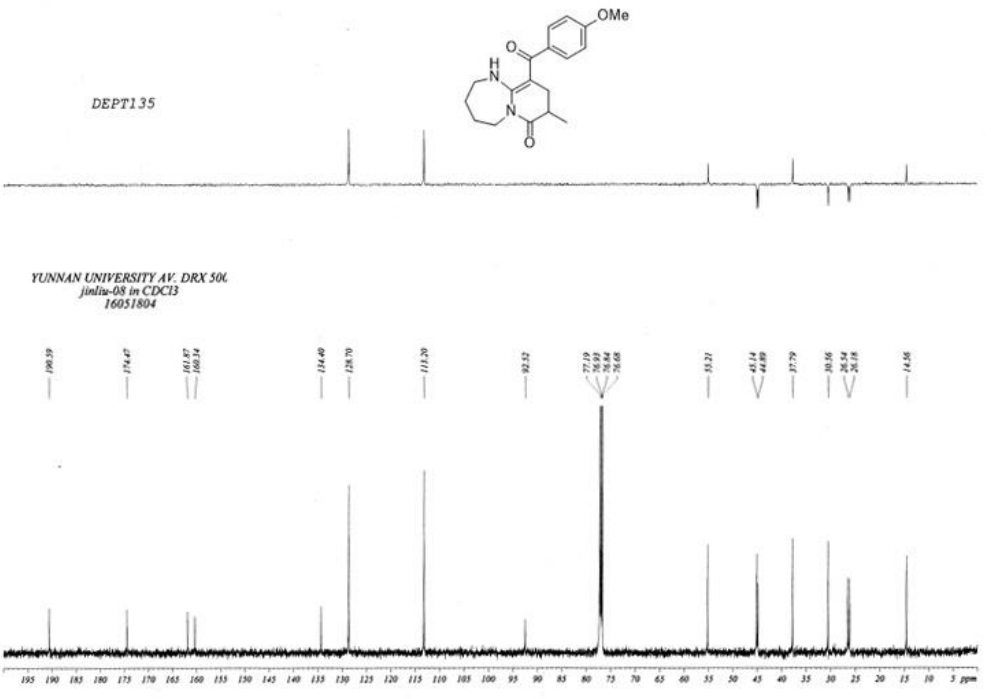


Figure 8b ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **4f**

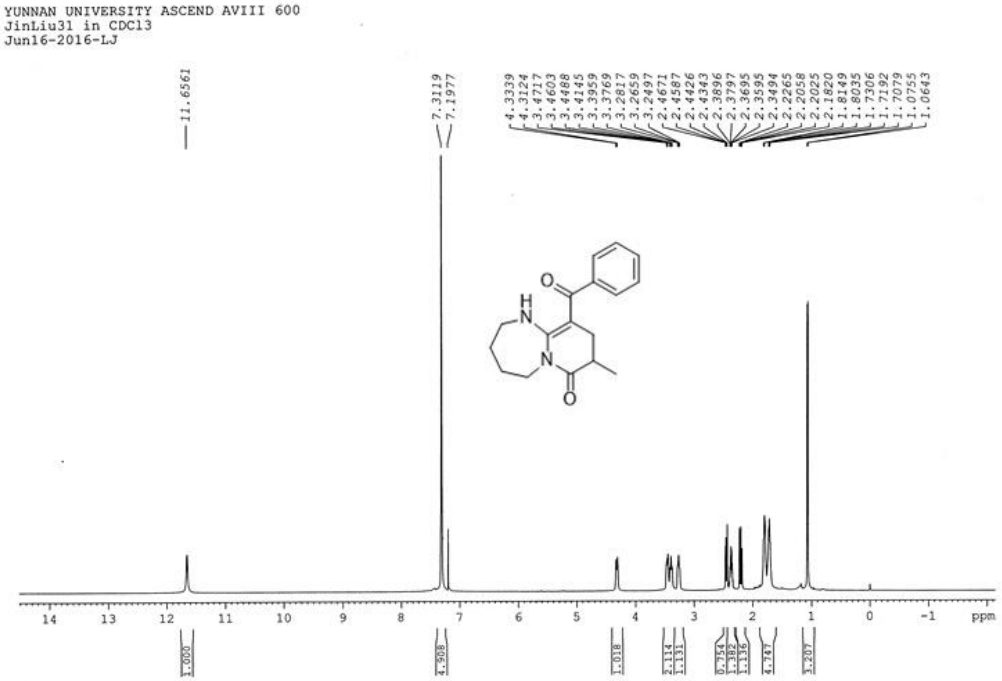


Figure 9a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **4g**

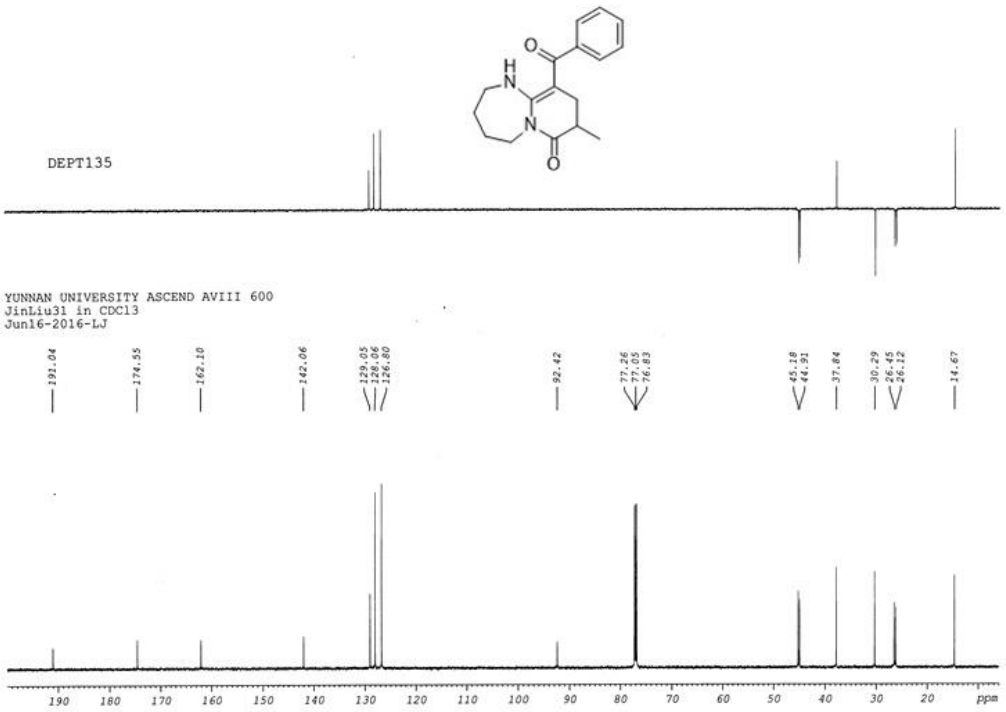


Figure 9b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **4g**

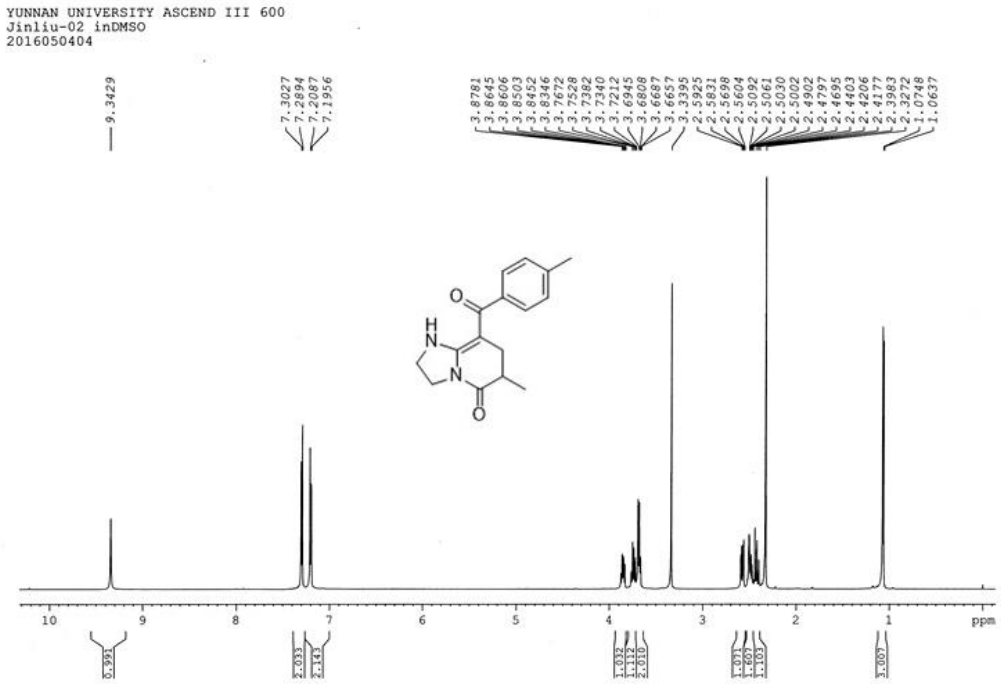


Figure 10a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4h**

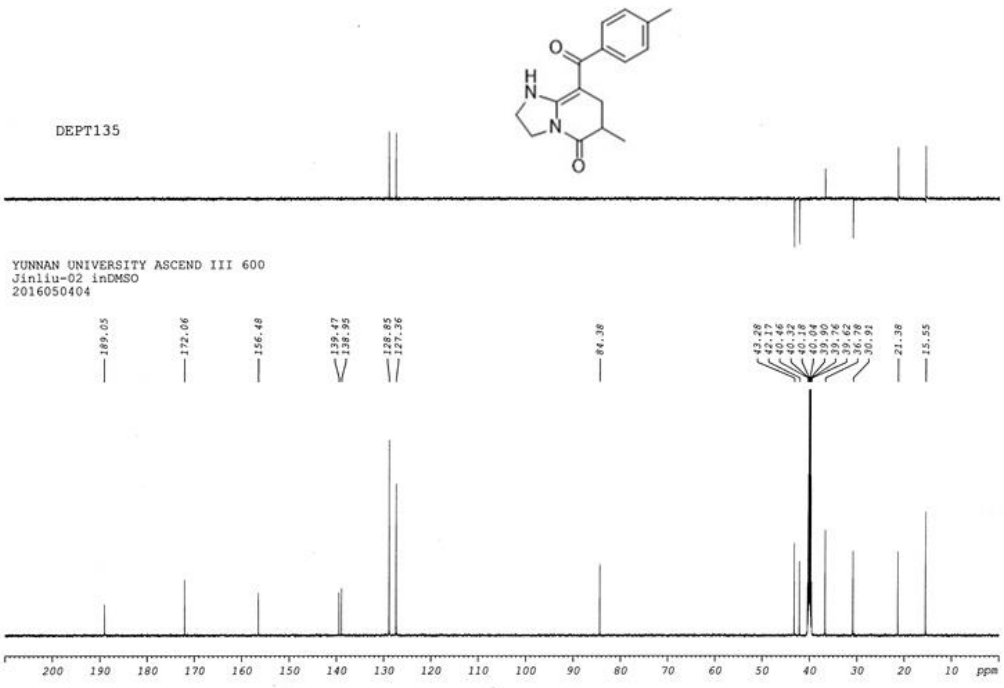


Figure 10b ^{13}C NMR (150 MHz, DMSO-d_6) spectra of compound **4h**

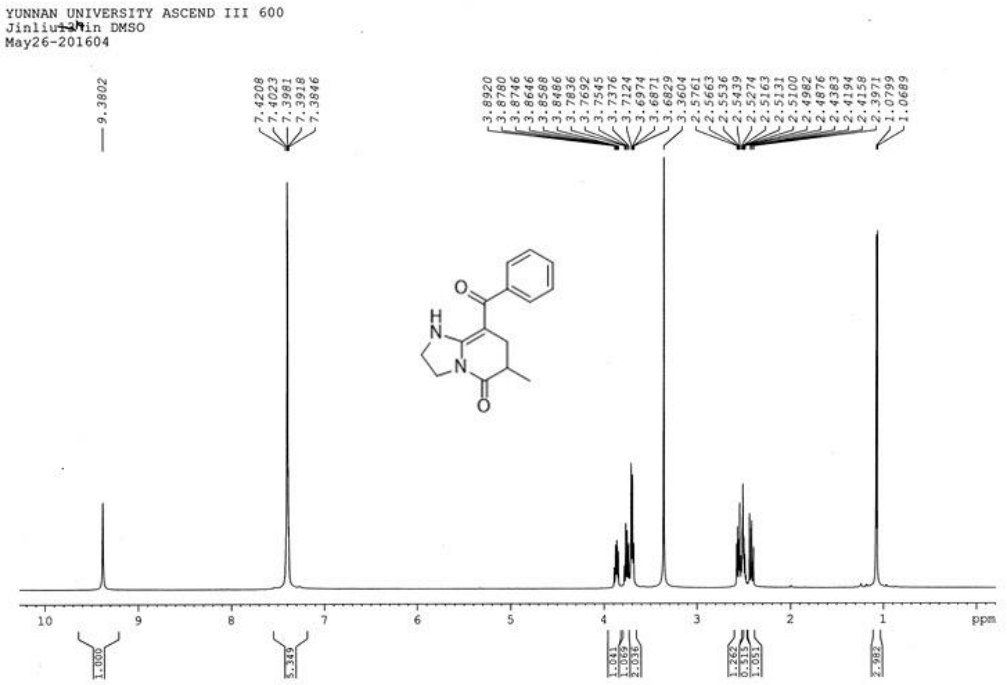


Figure 11a [1]H NMR (600 MHz, DMSO-*d6*) spectra of compound **4i**

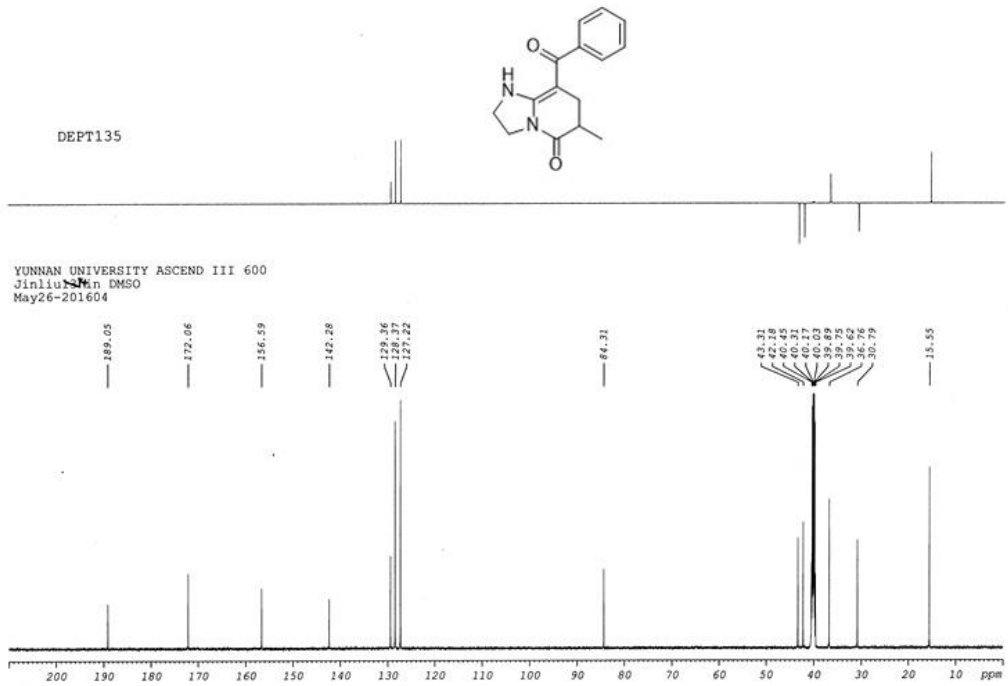


Figure 11b [13]C NMR (150 MHz, DMSO-d_6) spectra of compound **4i**

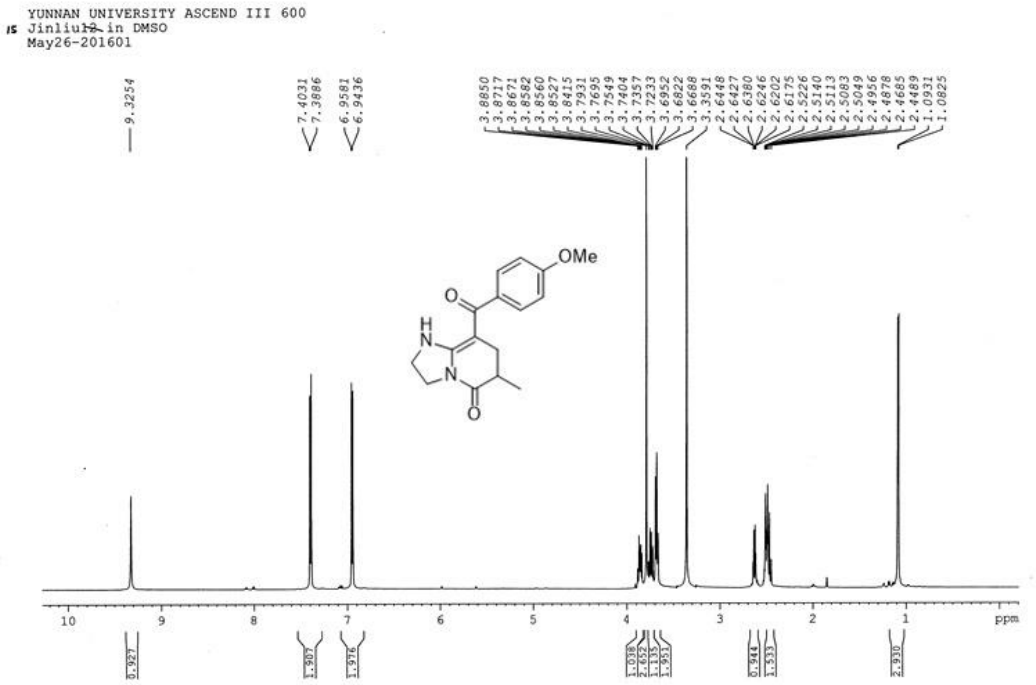


Figure 12a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4j**

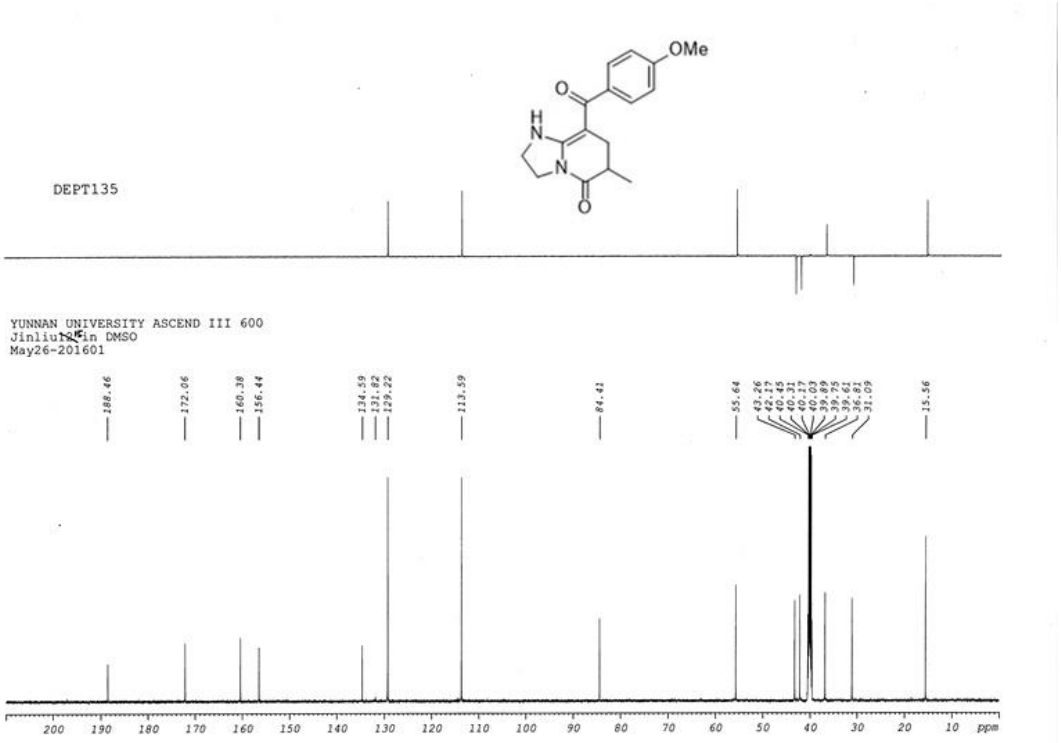


Figure 12b ^{13}C NMR (150 MHz, DMSO-d_6) spectra of compound **4j**

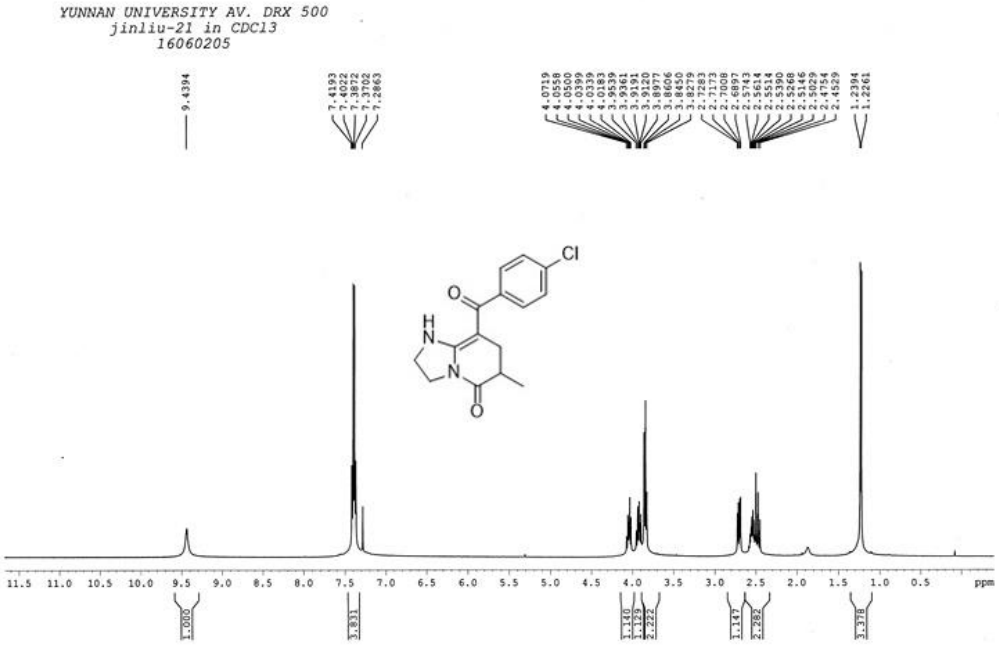


Figure 13a ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **4k**

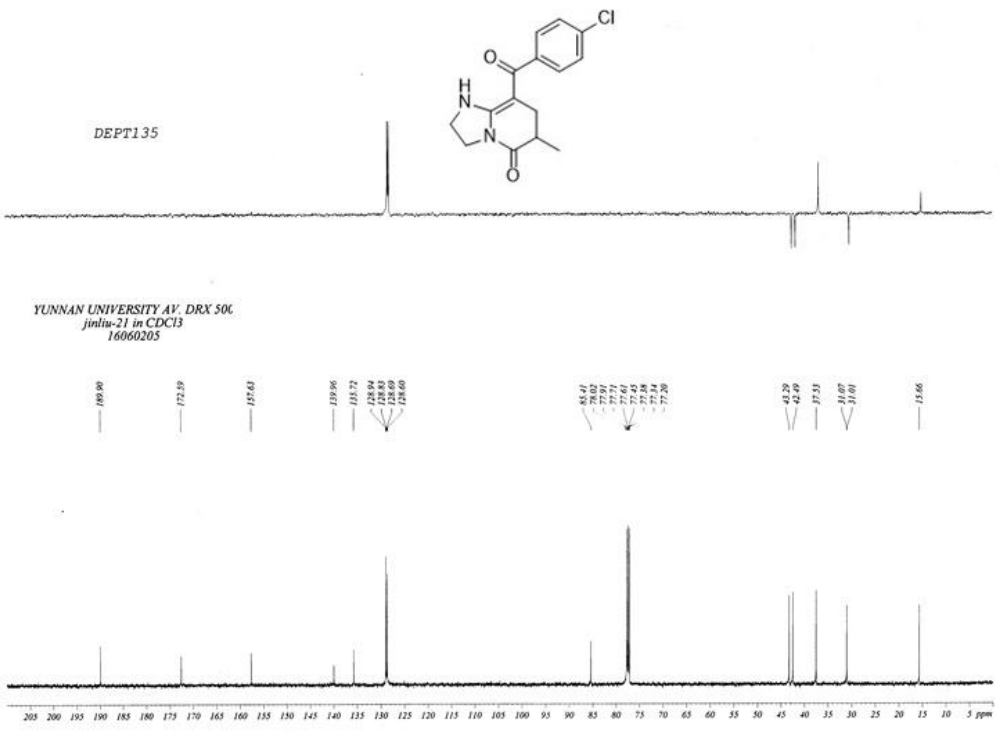


Figure 13b ^{13}C NMR (125 MHz, $CDCl_3$) spectra of compound **4k**

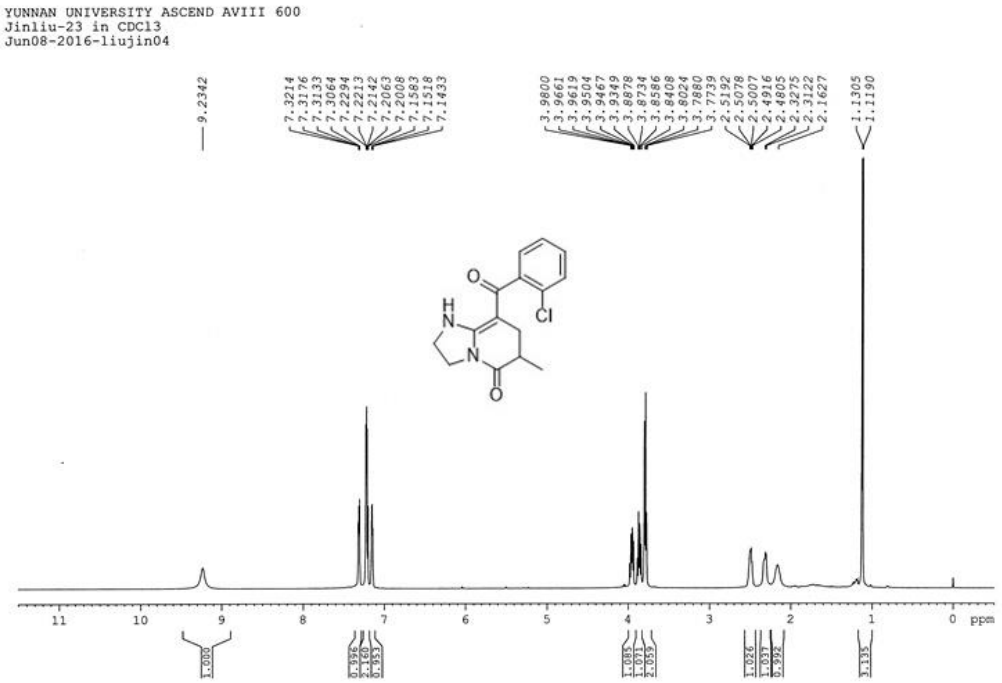


Figure 14a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **4l**

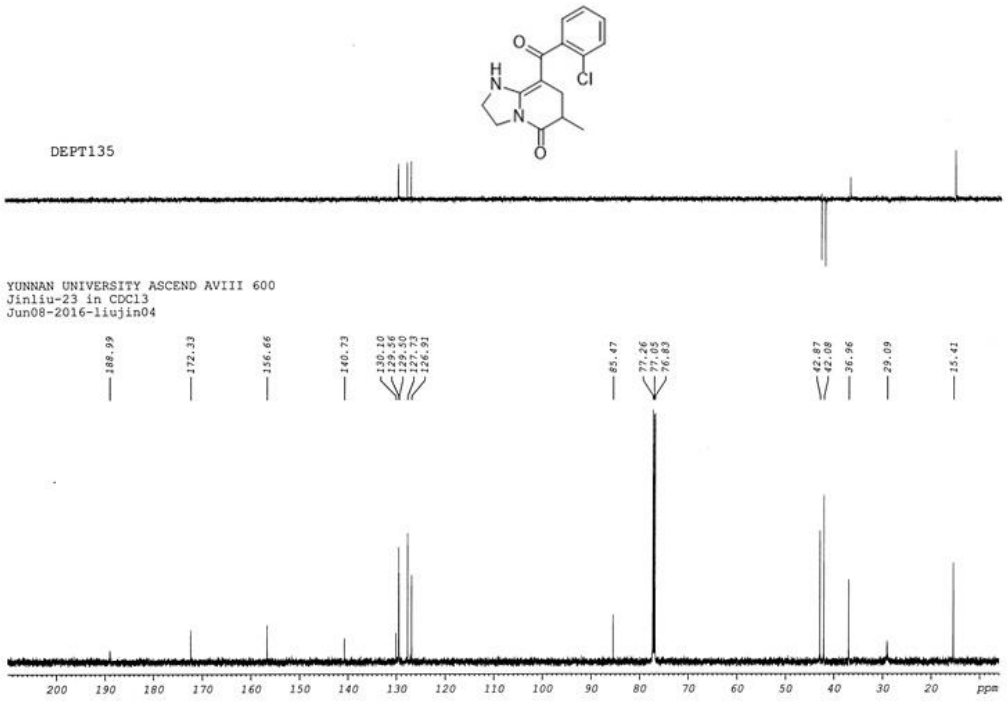


Figure 14b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **4l**

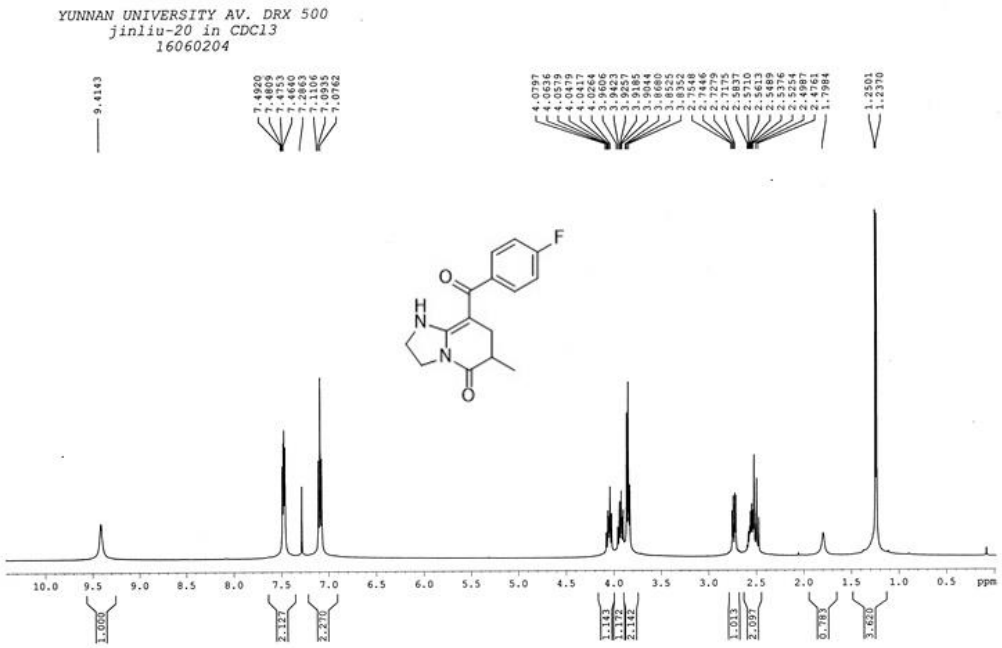


Figure 15a ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **4m**

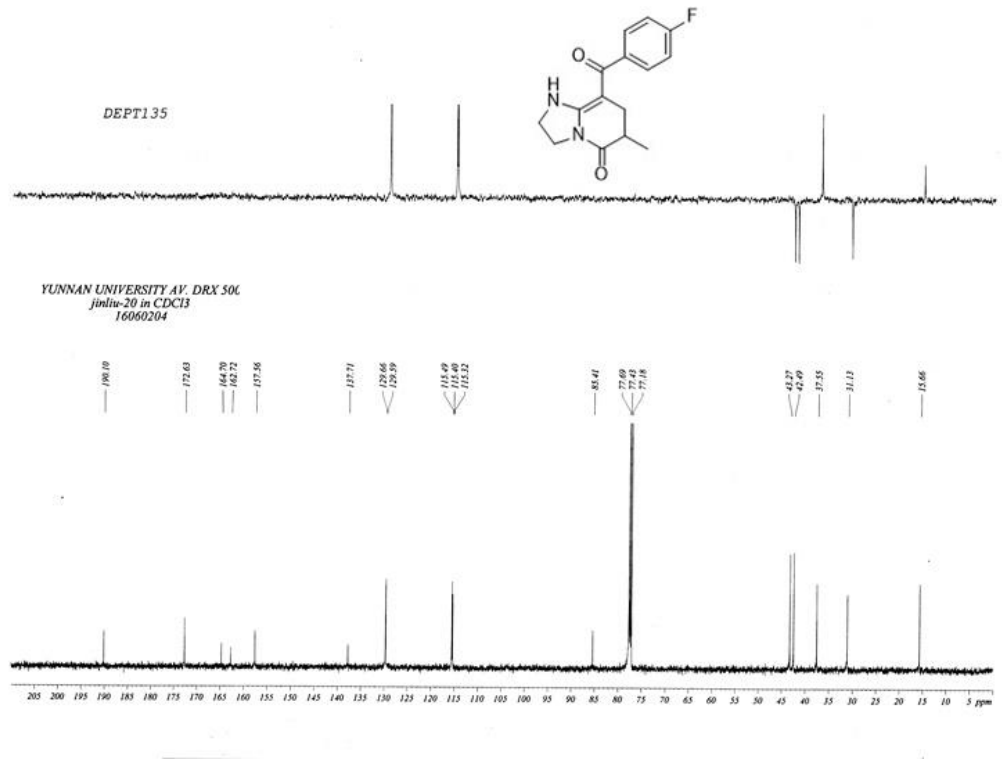


Figure 15b ^{13}C NMR (125 MHz, $CDCl_3$) spectra of compound **4m**

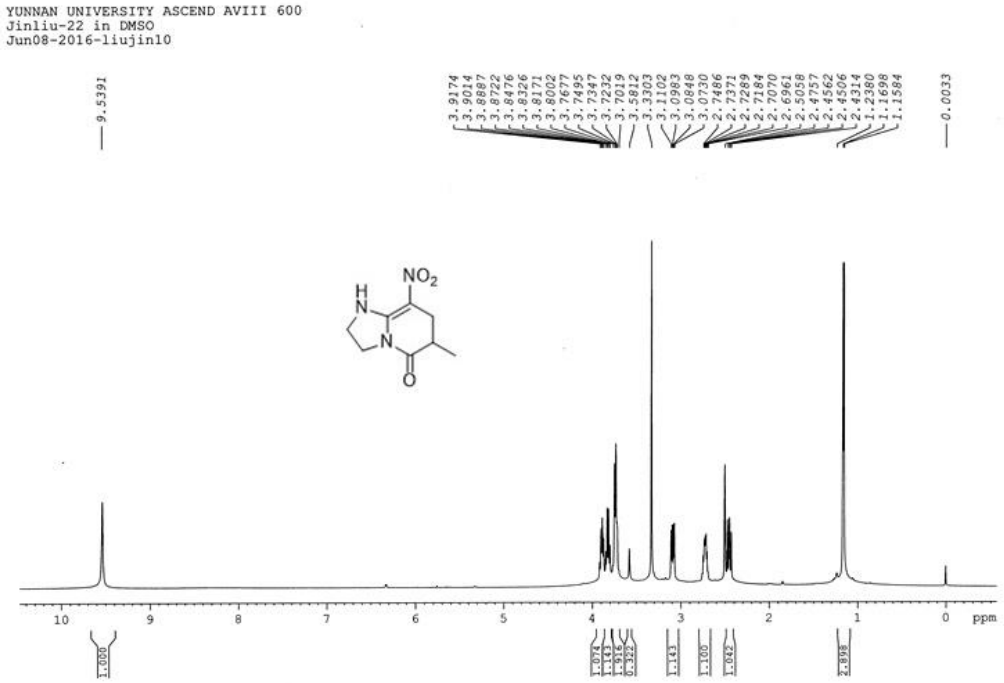


Figure 16a ^{1}H NMR (600 MHz, DMSO-*d6*) spectra of compound **4n**

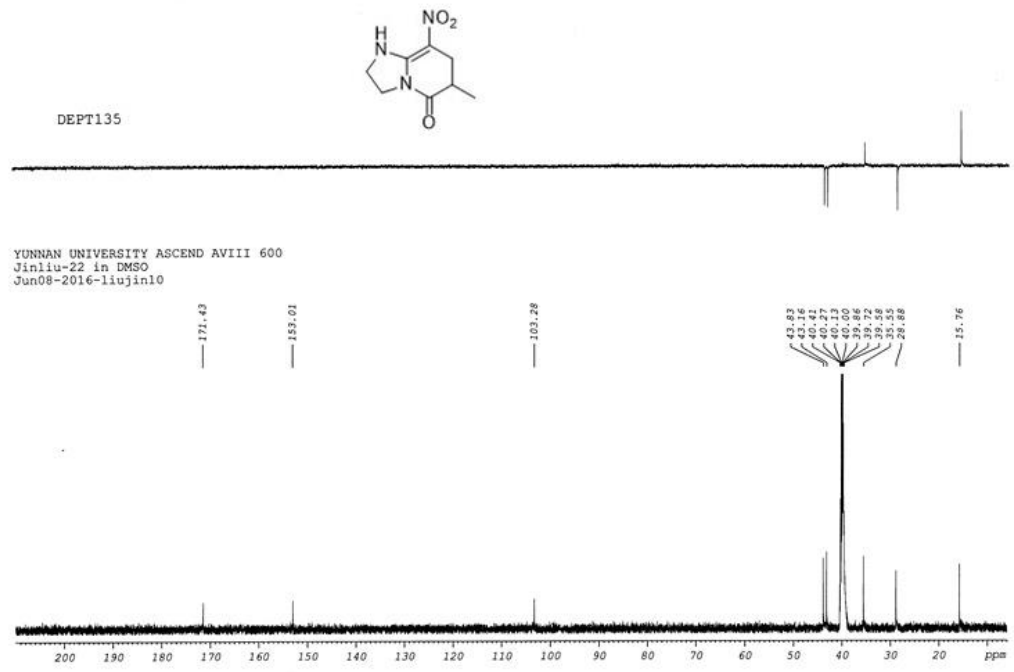


Figure 16b ^{13}C NMR (150 MHz, DMSO-d_6) spectra of compound **4n**

^{1}H NMR and 13C NMR spectra for bicyclic pyridones 5

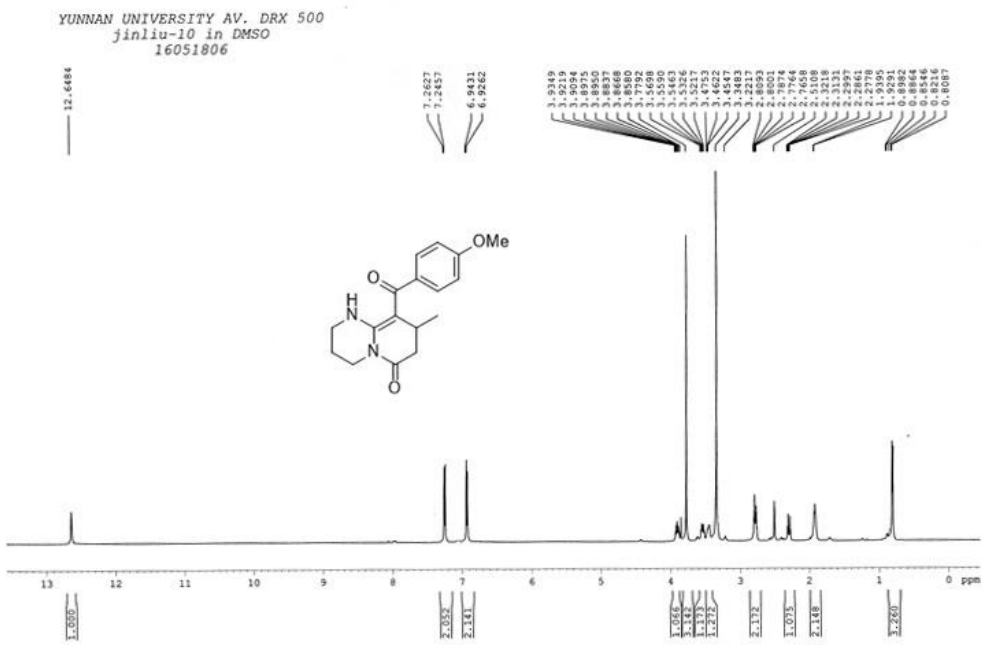


Figure 17a ^{1}H NMR (500 MHz, DMSO-*d6*) spectra of compound **5a**

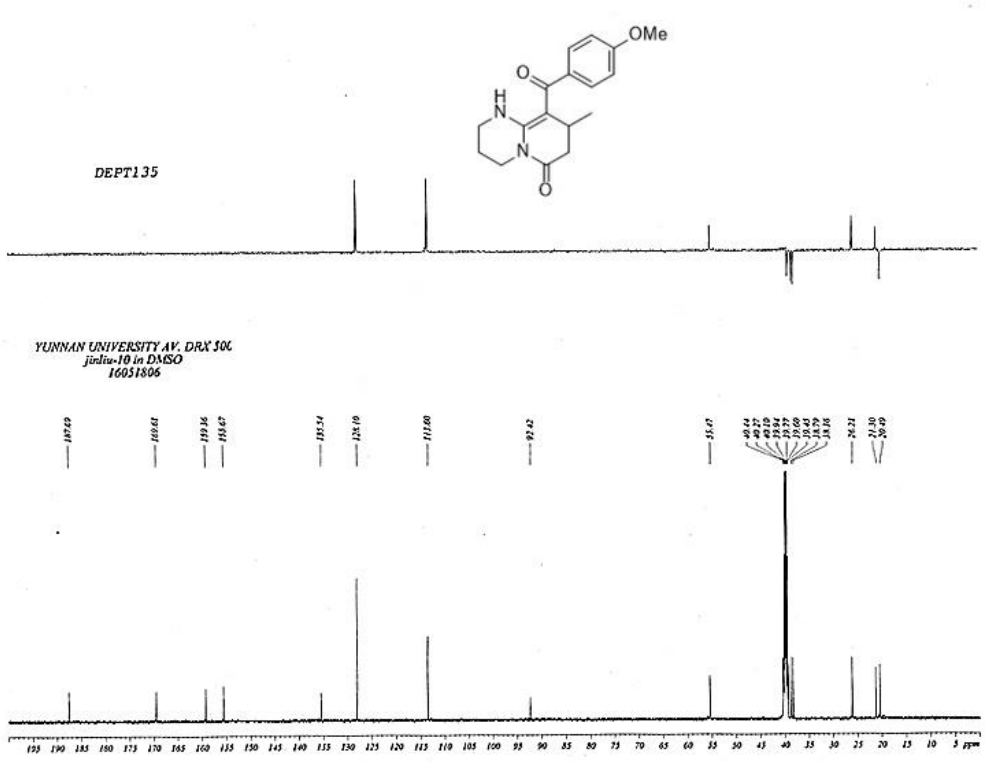


Figure 17b ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **5a**

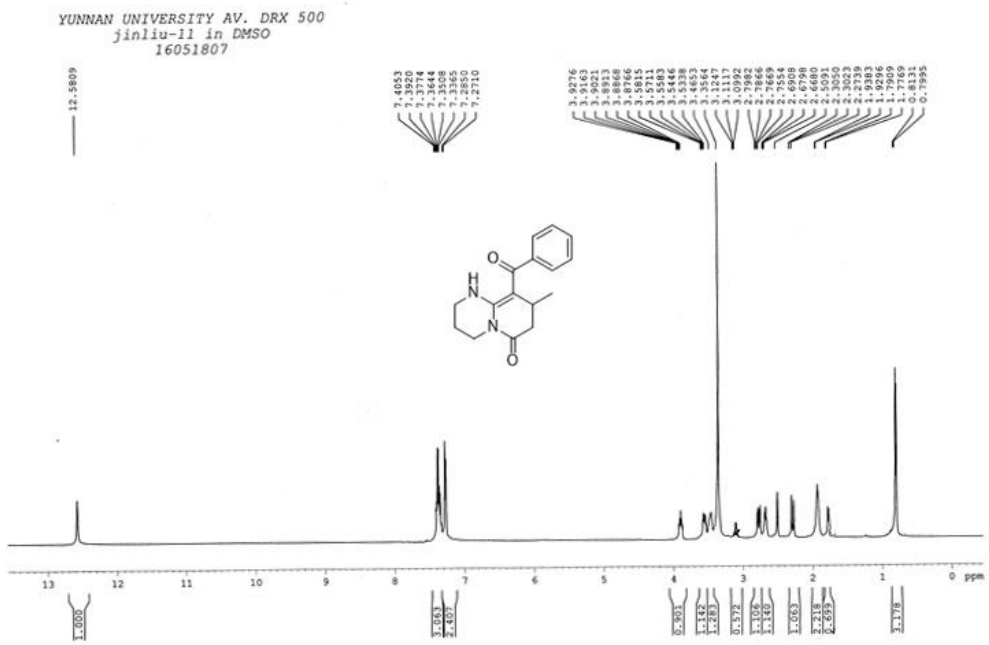


Figure 18a ^{1}H NMR (500 MHz, DMSO-*d6*) spectra of compound **5b**

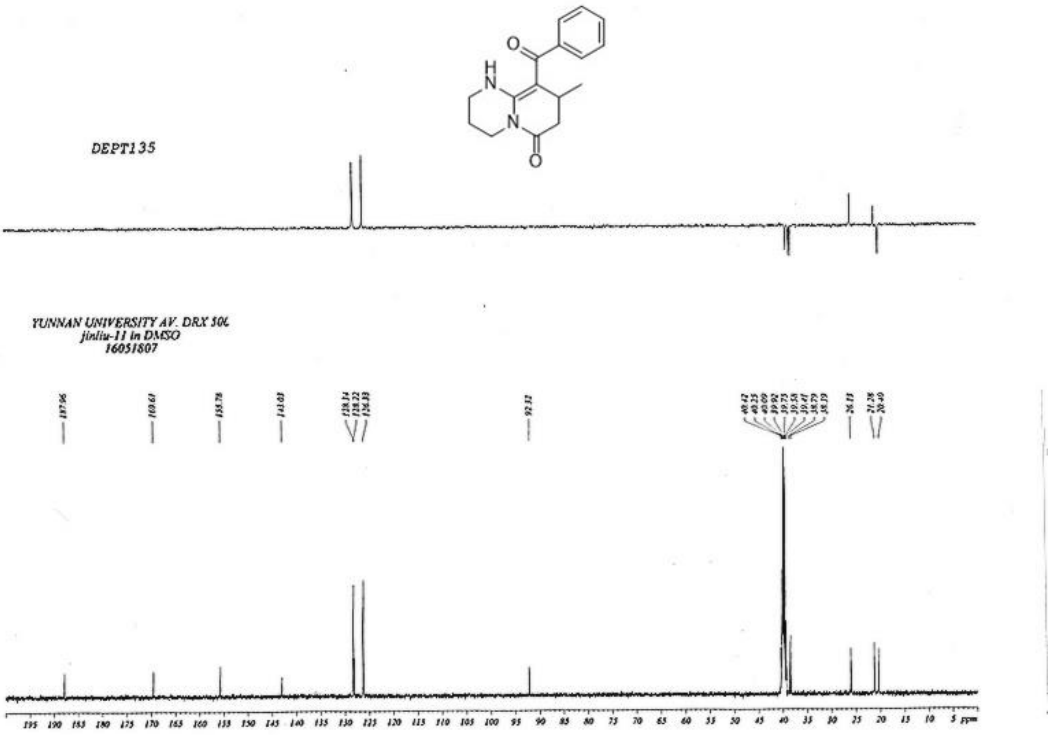


Figure 18b ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **5b**

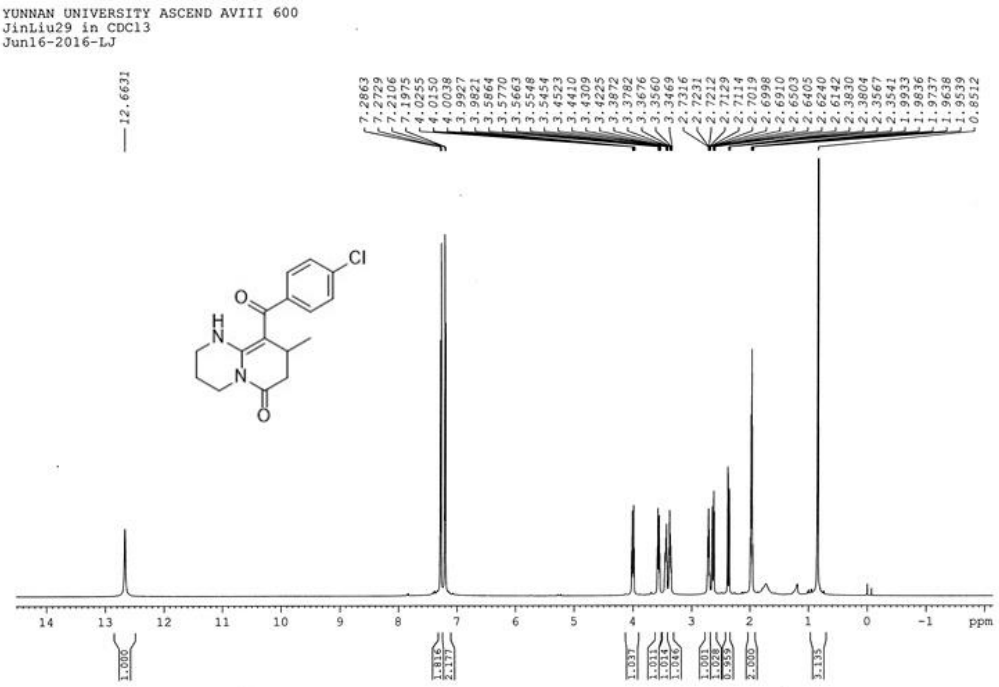


Figure 19a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5c**

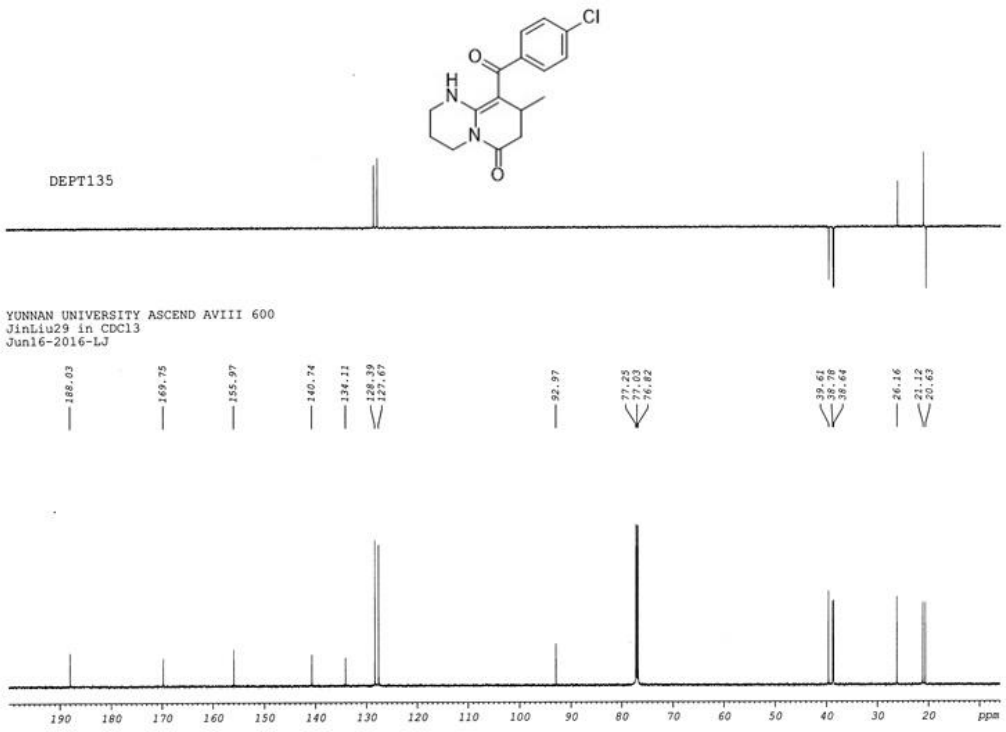


Figure 19b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5c**

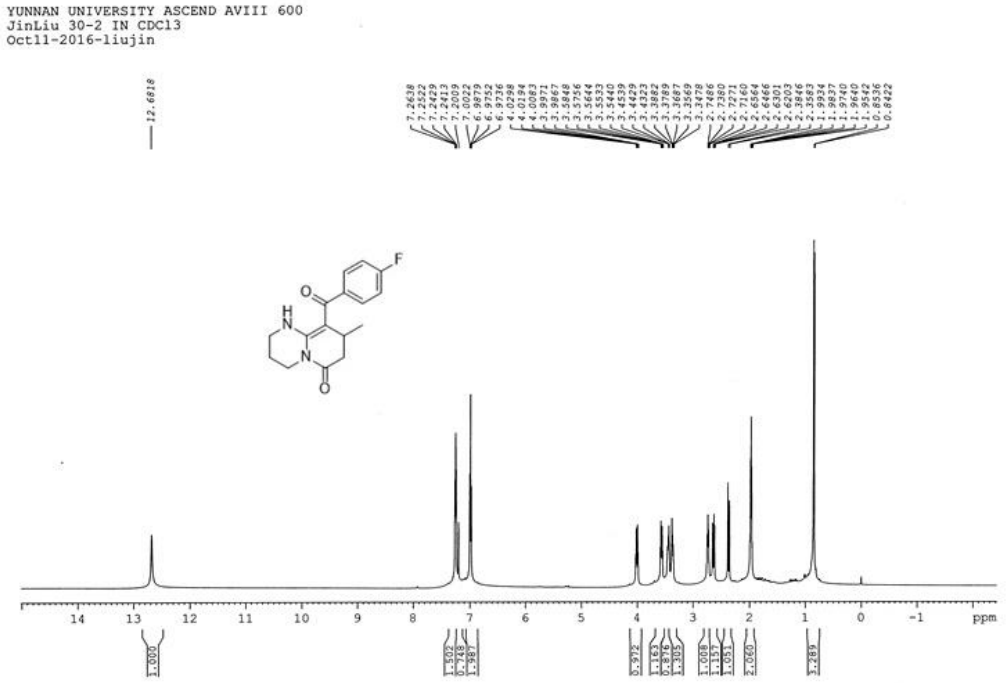


Figure 20a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5d**

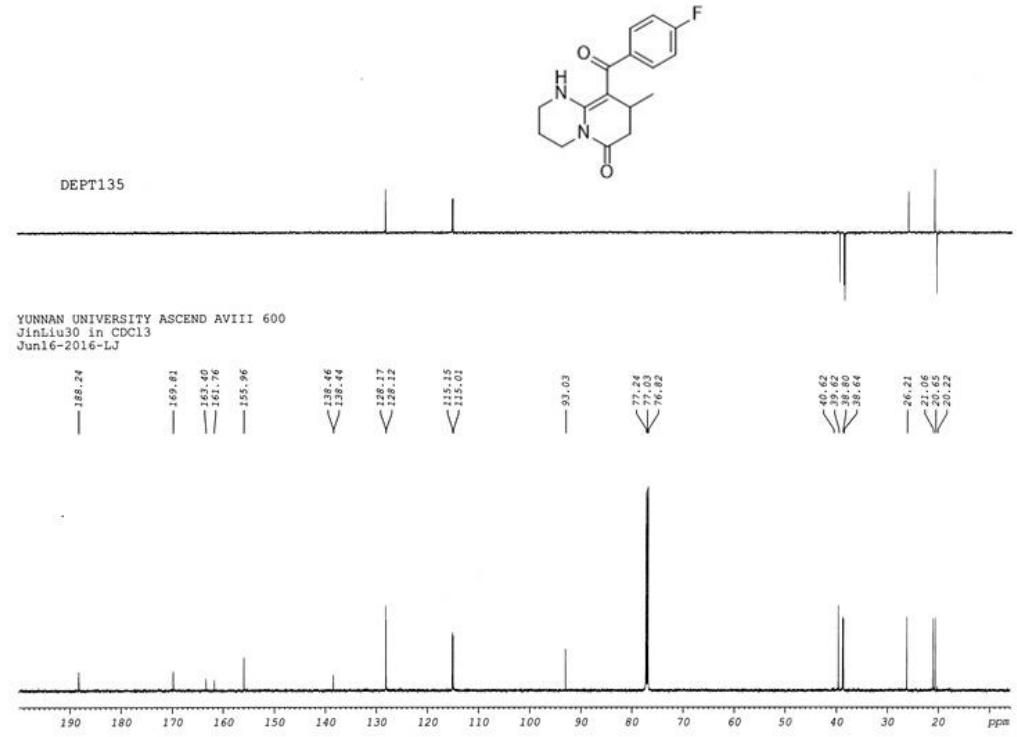


Figure 20b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5d**

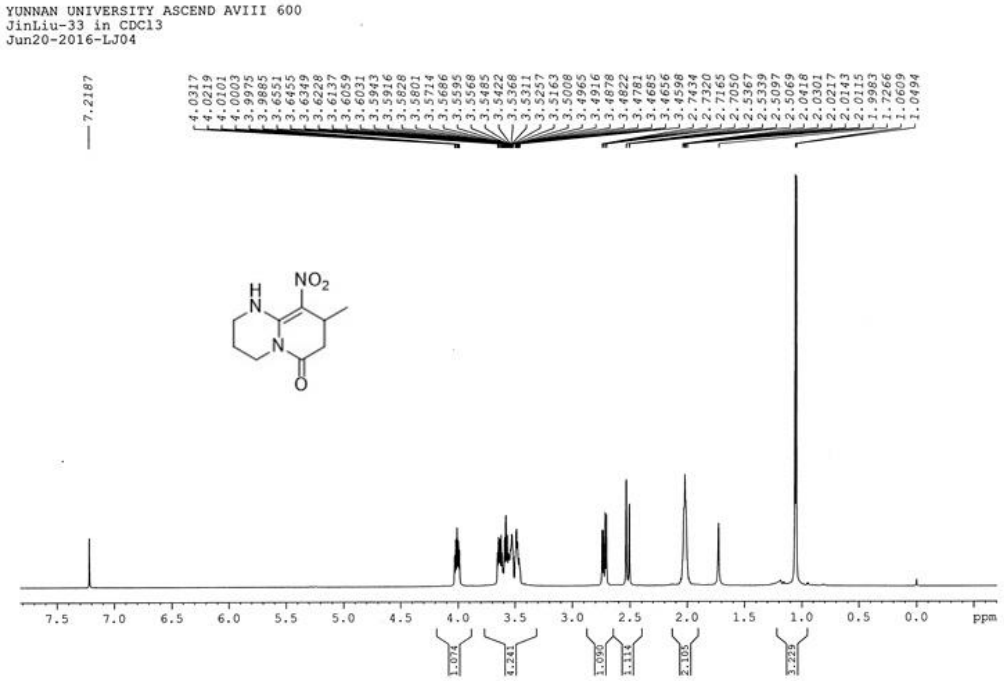


Figure 21a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5e**

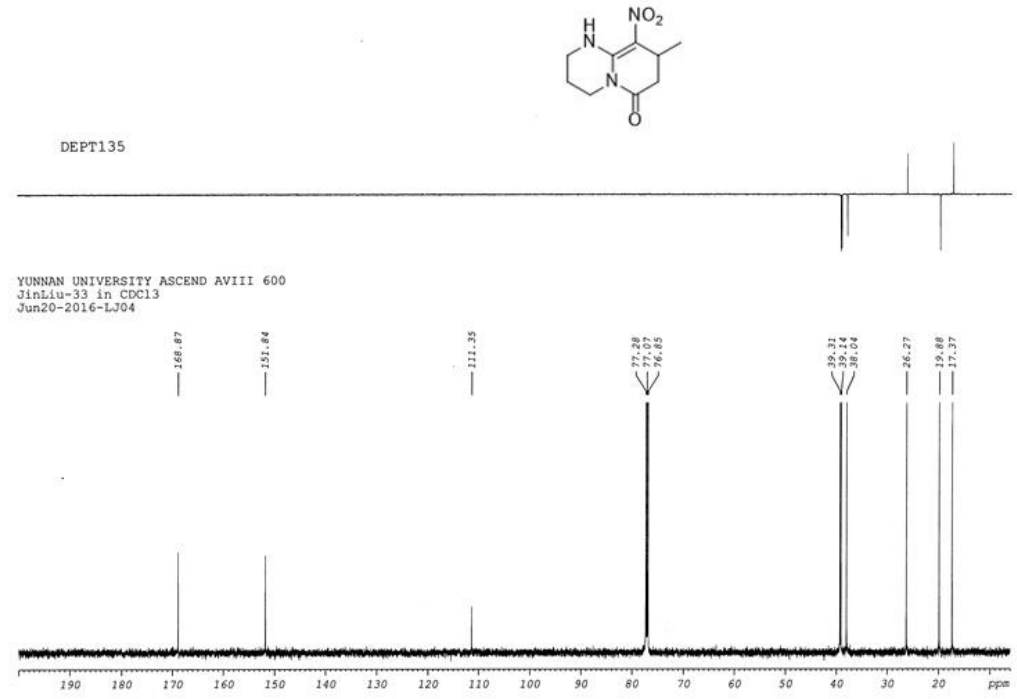


Figure 21b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5e**

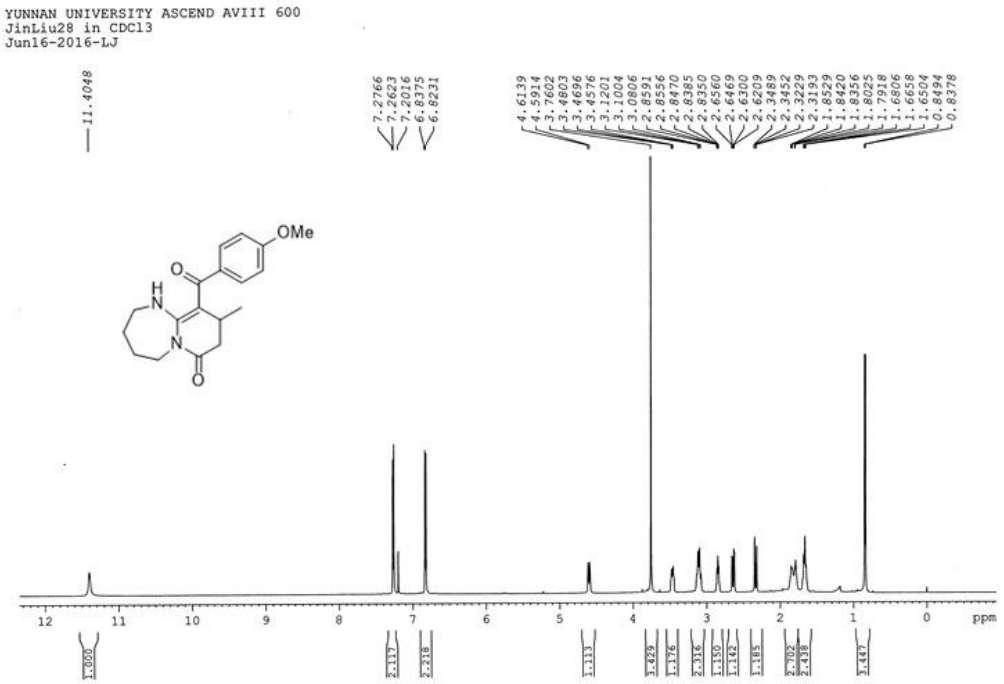


Figure 22a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5f**

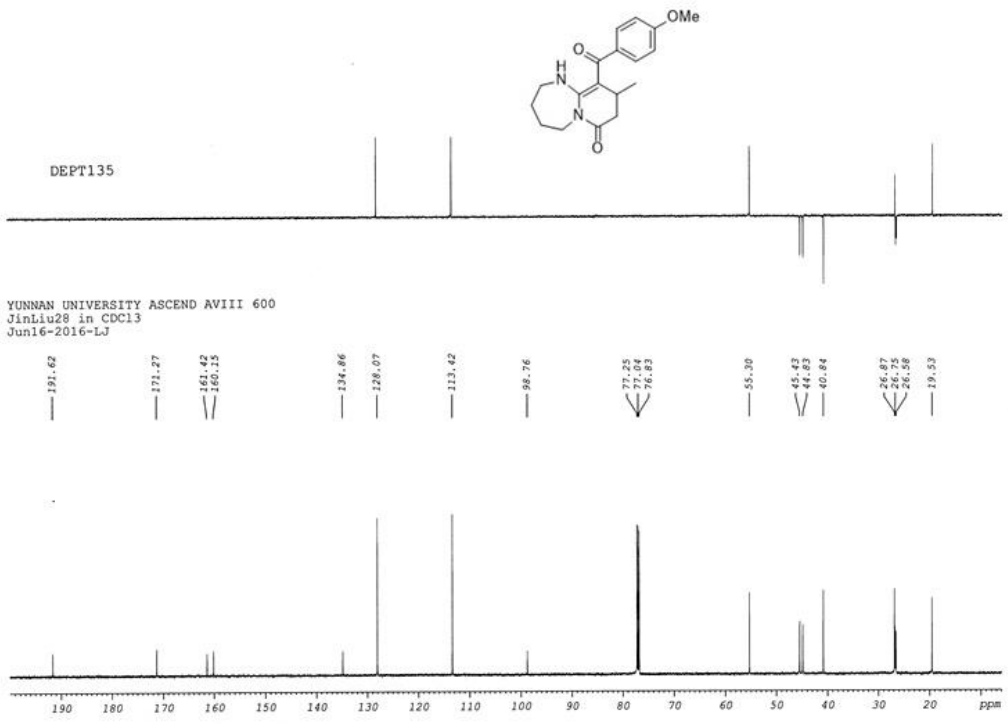


Figure 22b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5f**

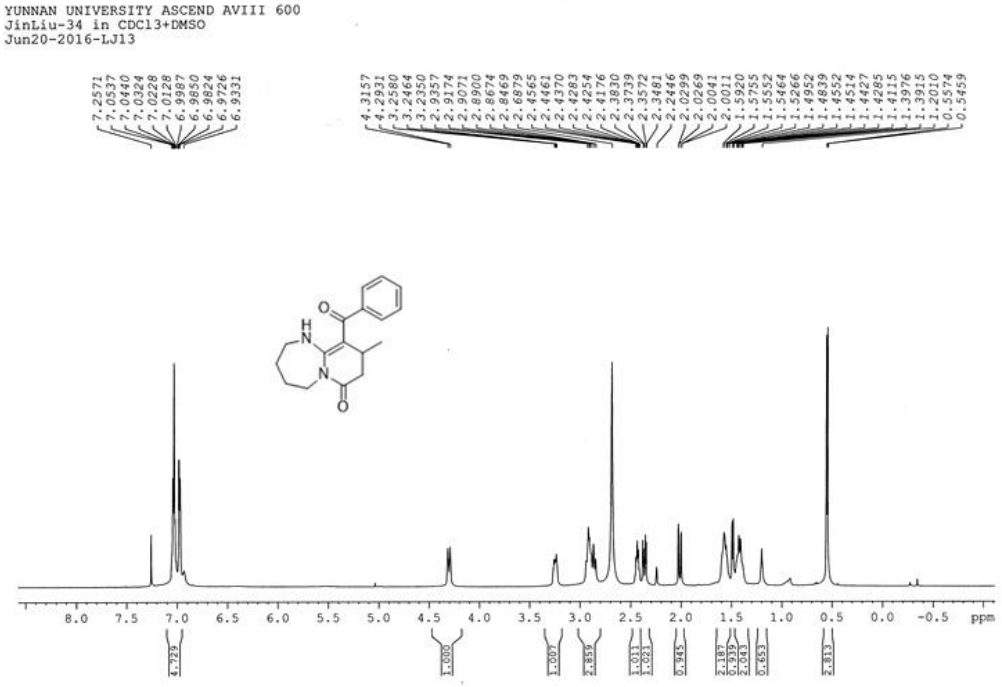


Figure 23a ^{1}H NMR (600 MHz, DMSO-*d6*+ $CDCl_3$) spectra of compound **5g**

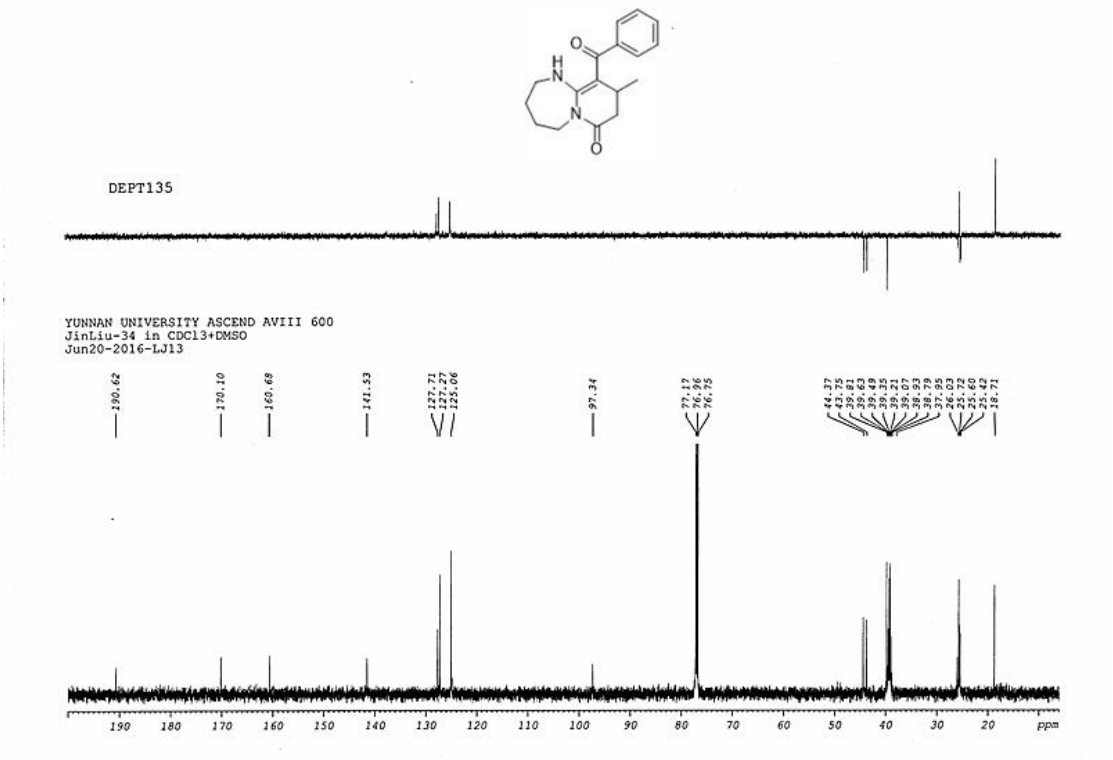


Figure 23b ^{13}C NMR (150 MHz, DMSO-*d6*+$CDCl_3$) spectra of compound **5g**

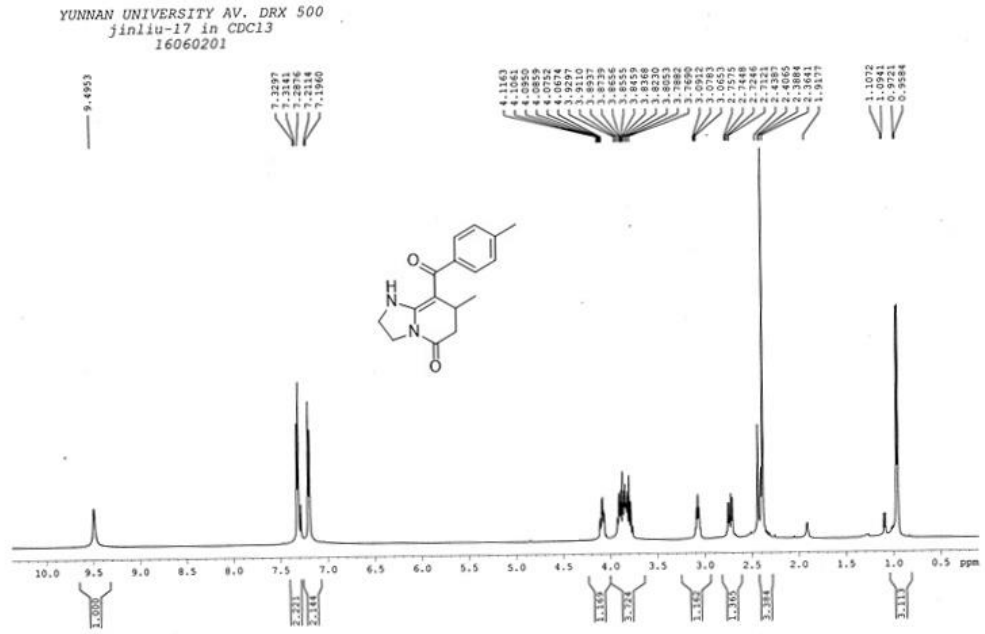


Figure 24a ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **5h**

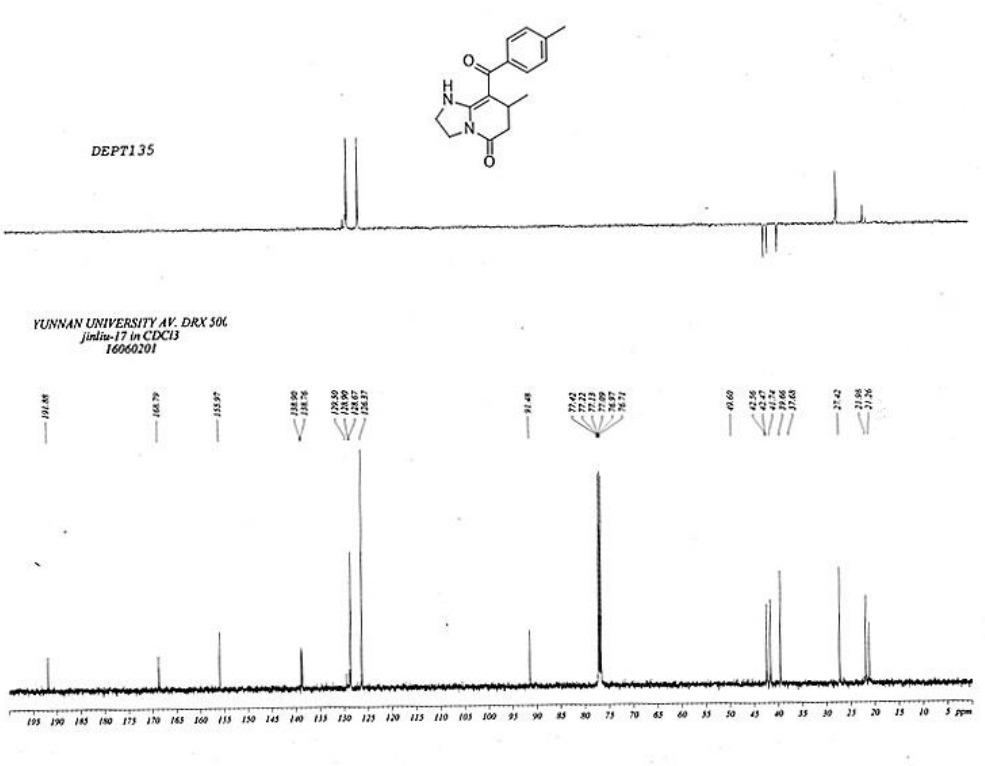


Figure 24b ^{13}C NMR (125 MHz, $CDCl_3$) spectra of compound **5h**

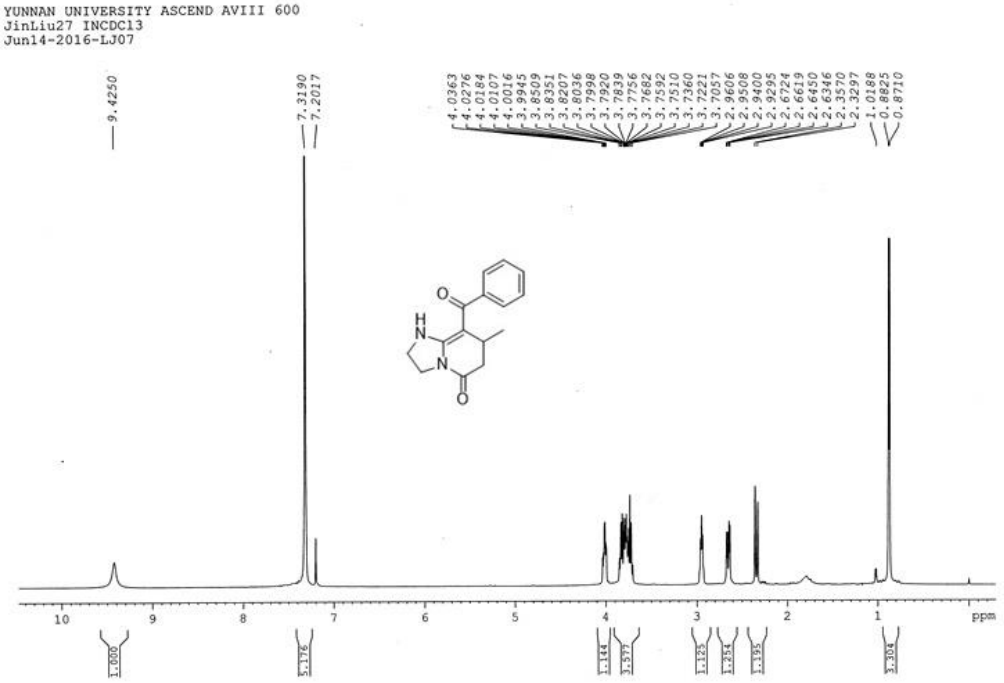


Figure 25a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5i**

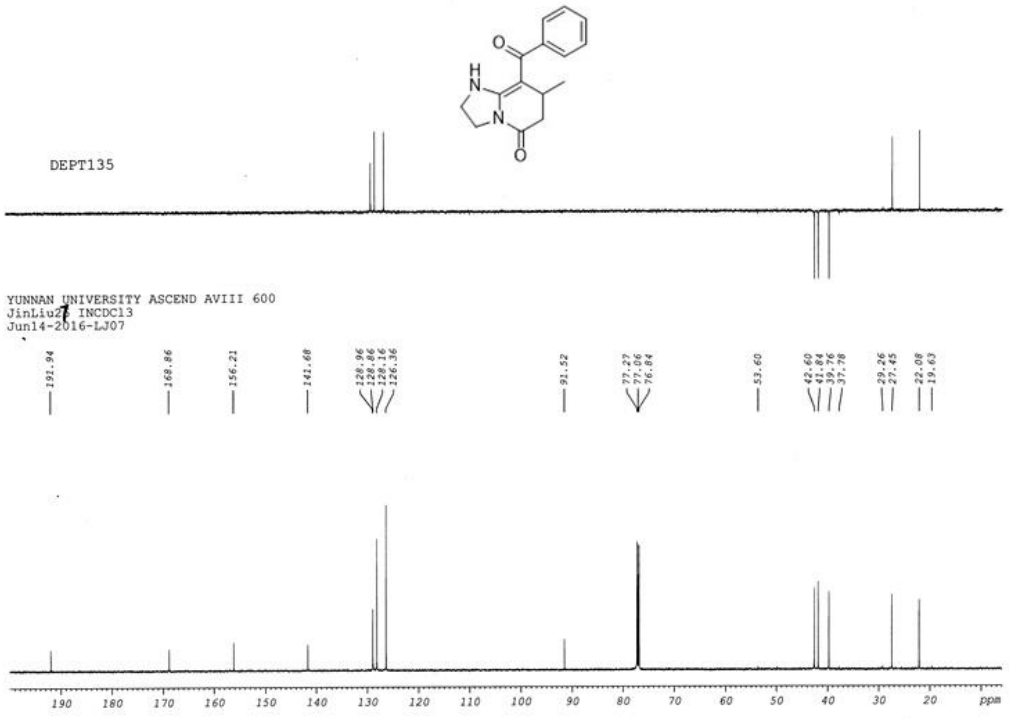


Figure 25b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5i**

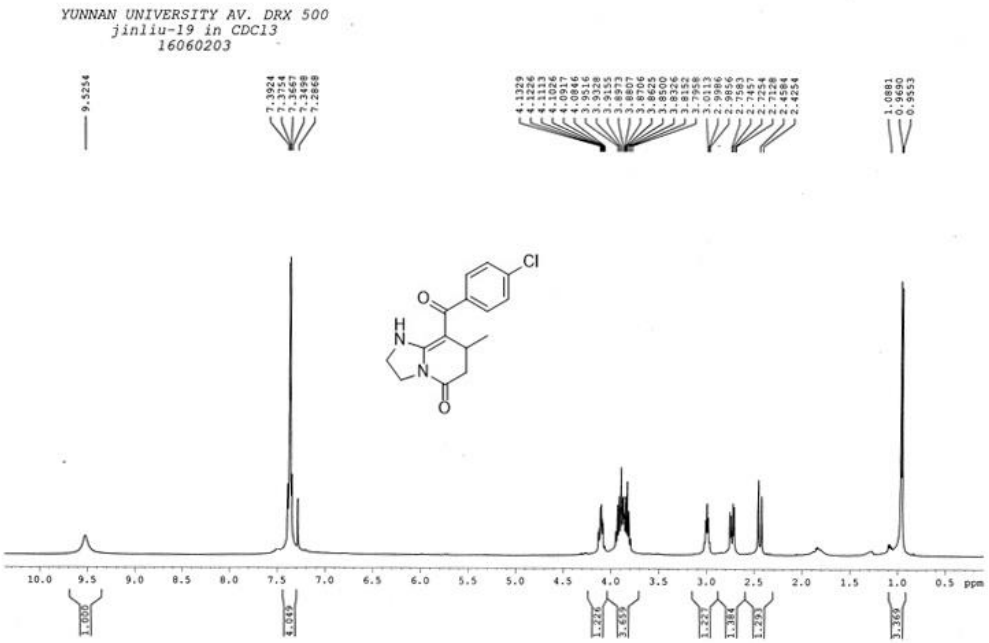


Figure 26a ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **5j**

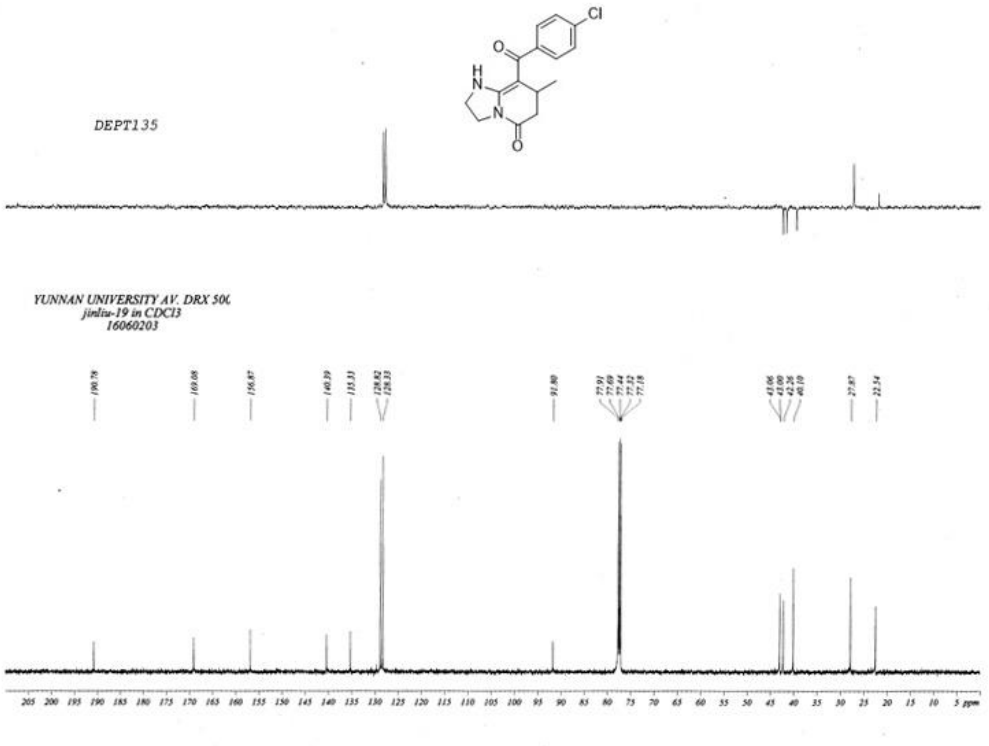


Figure 26b ^{13}C NMR (125 MHz, $CDCl_3$) spectra of compound **5j**

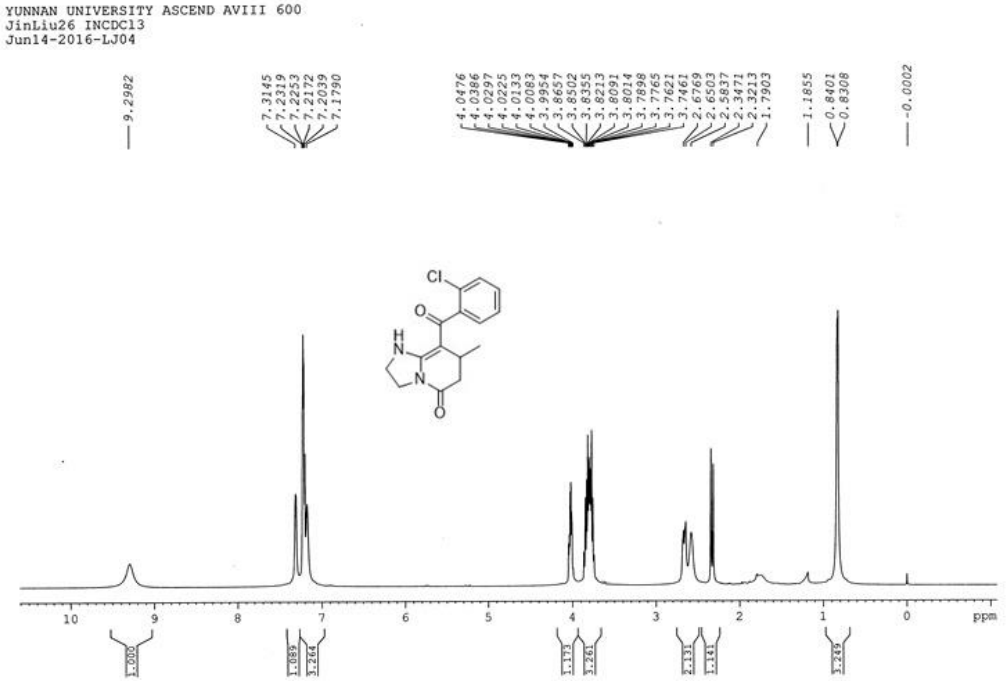


Figure 27a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **5k**

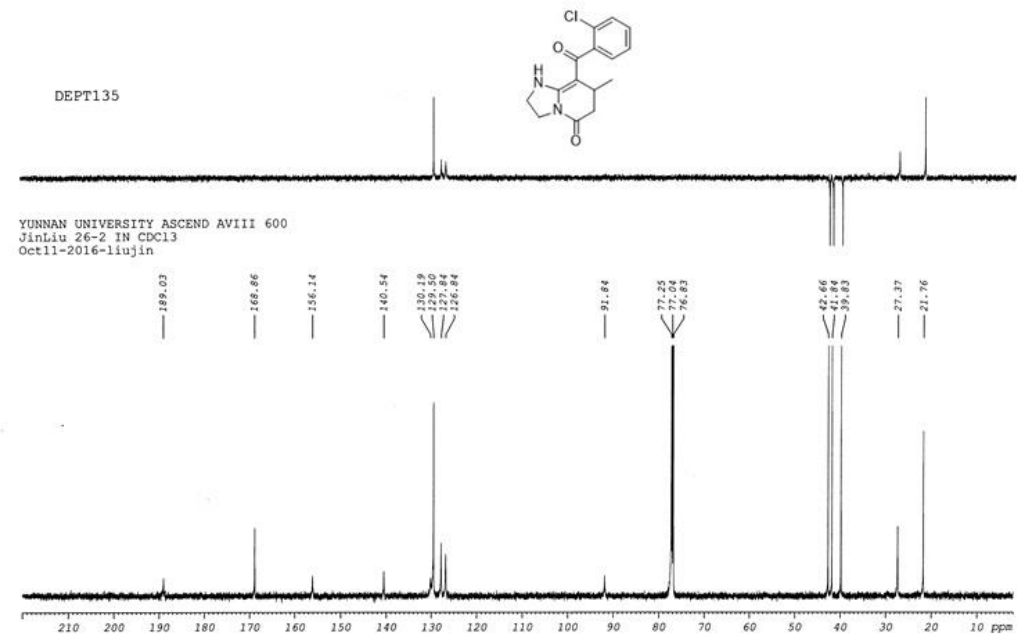


Figure 27b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **5k**

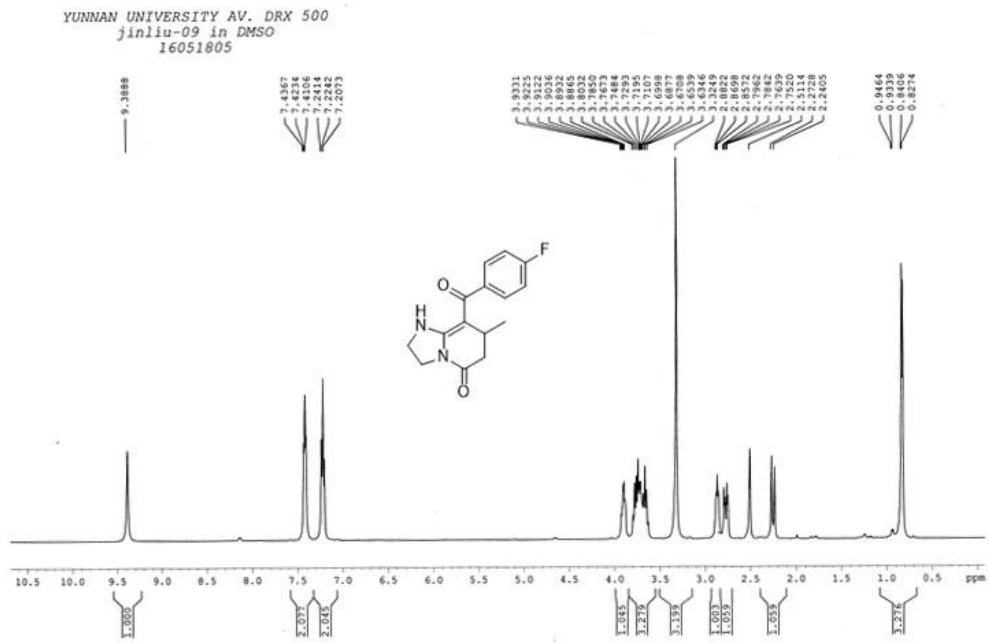


Figure 28a ^{1}H NMR (500 MHz, DMSO-*d6*) spectra of compound **5l**

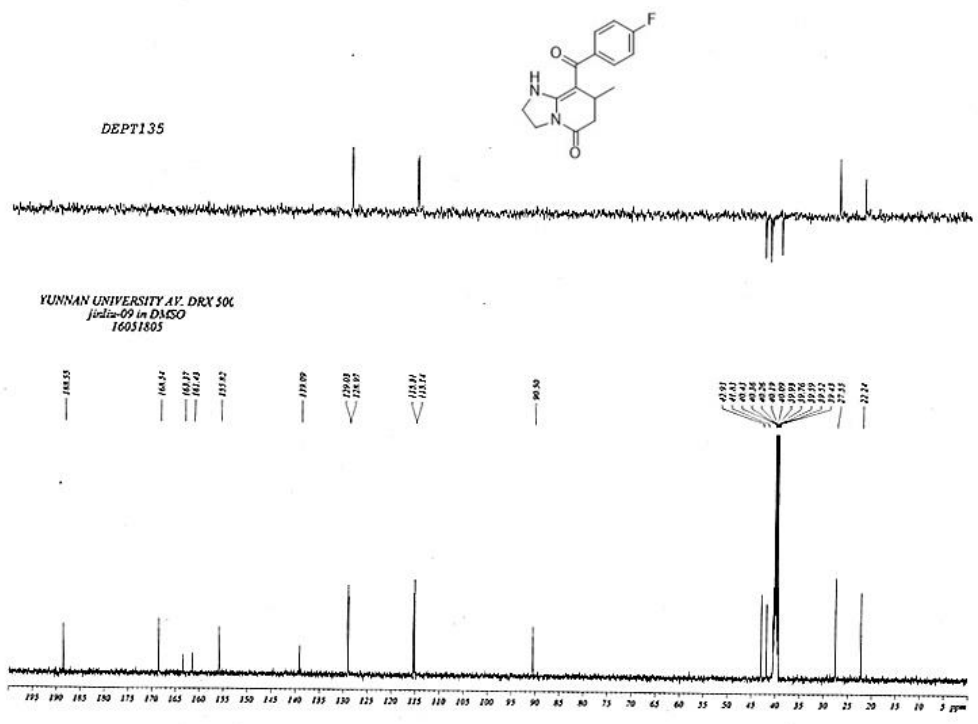


Figure 28b ^{13}C NMR (125 MHz, DMSO-d_6) spectra of compound **5l**

^{1}H NMR and ^{13}C NMR spectra for bicyclic pyridones 6

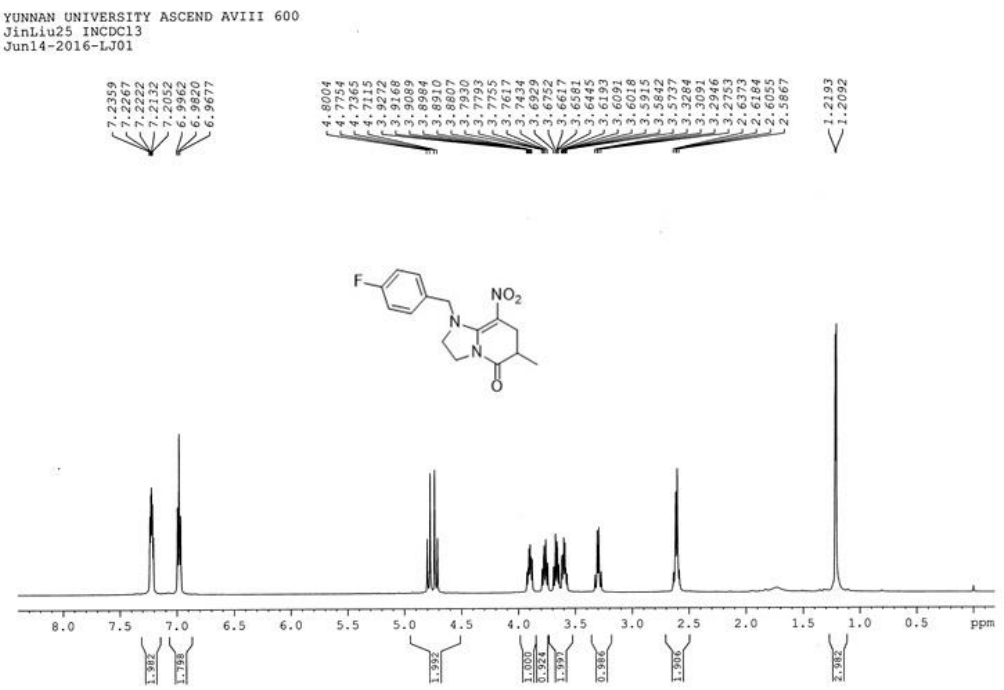


Figure 29a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **6a**

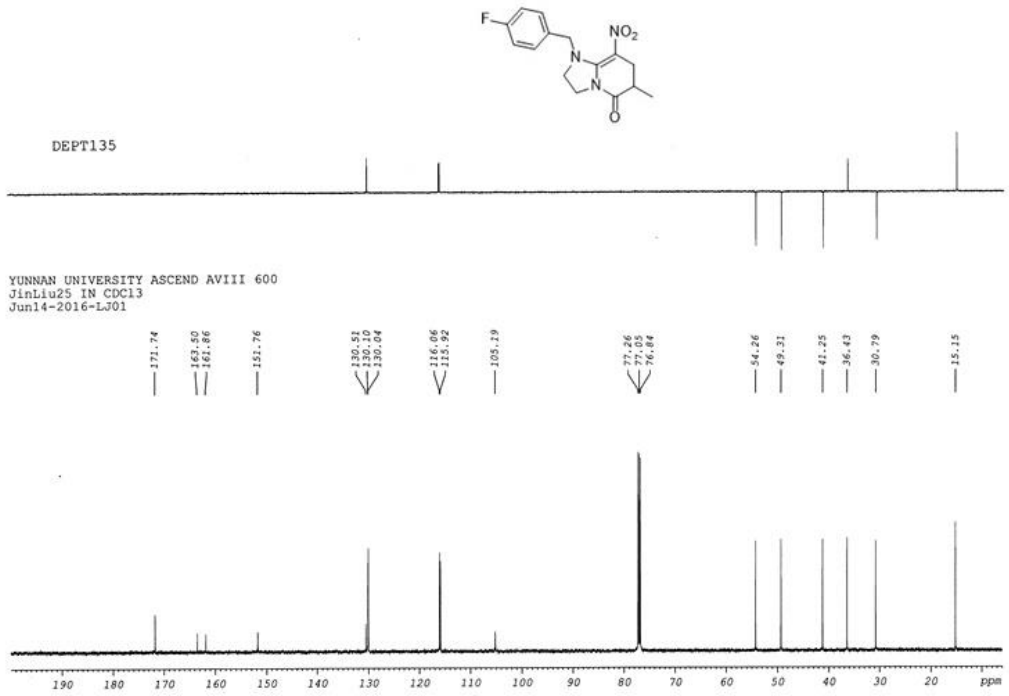


Figure 29b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **6a**

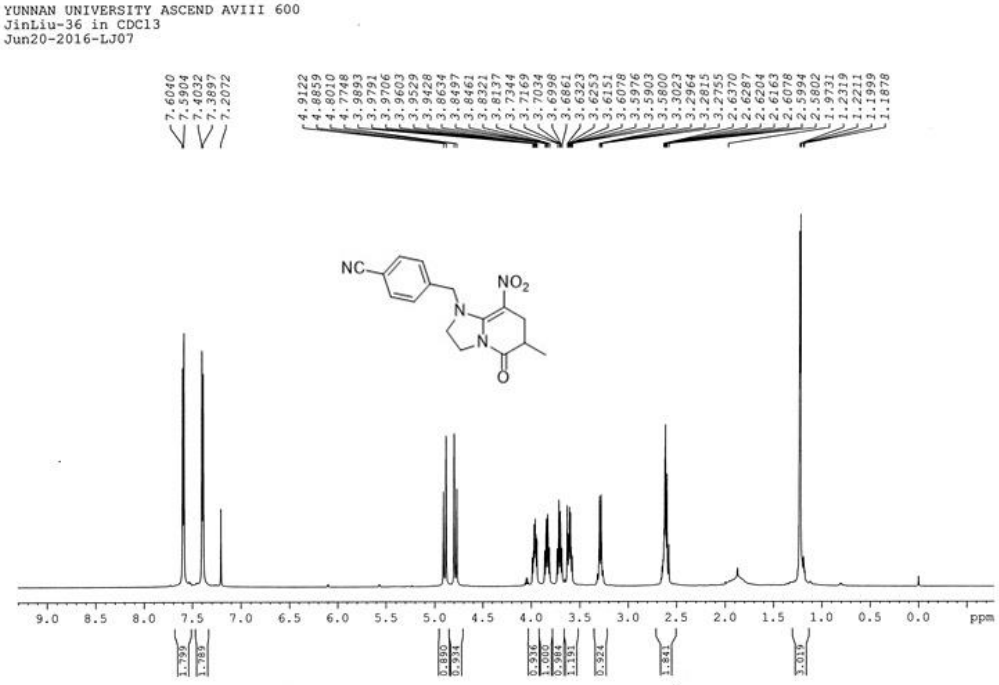


Figure 30a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **6b**

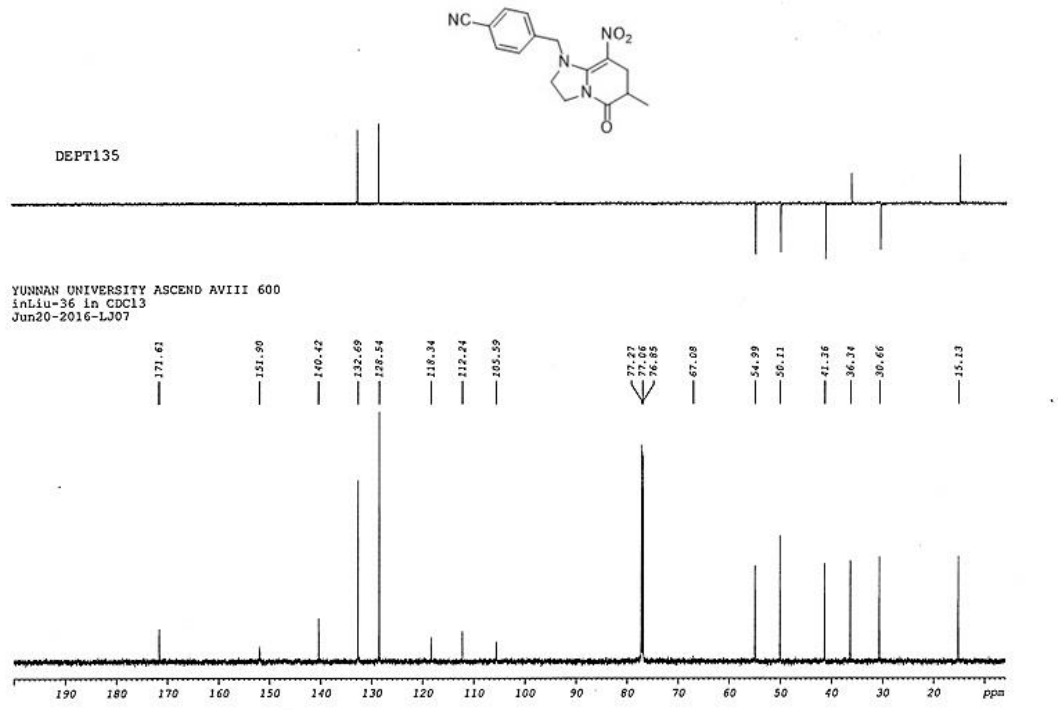


Figure 30b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **6b**

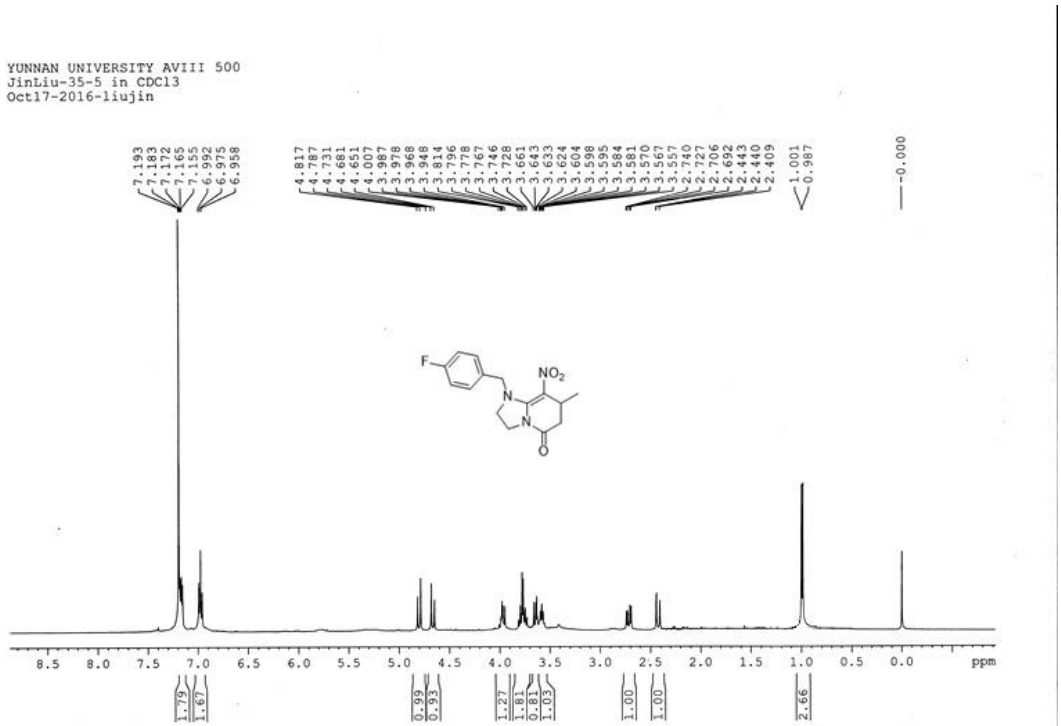


Figure 31a ^{1}H NMR (500 MHz, $CDCl_3$) spectra of compound **6c**

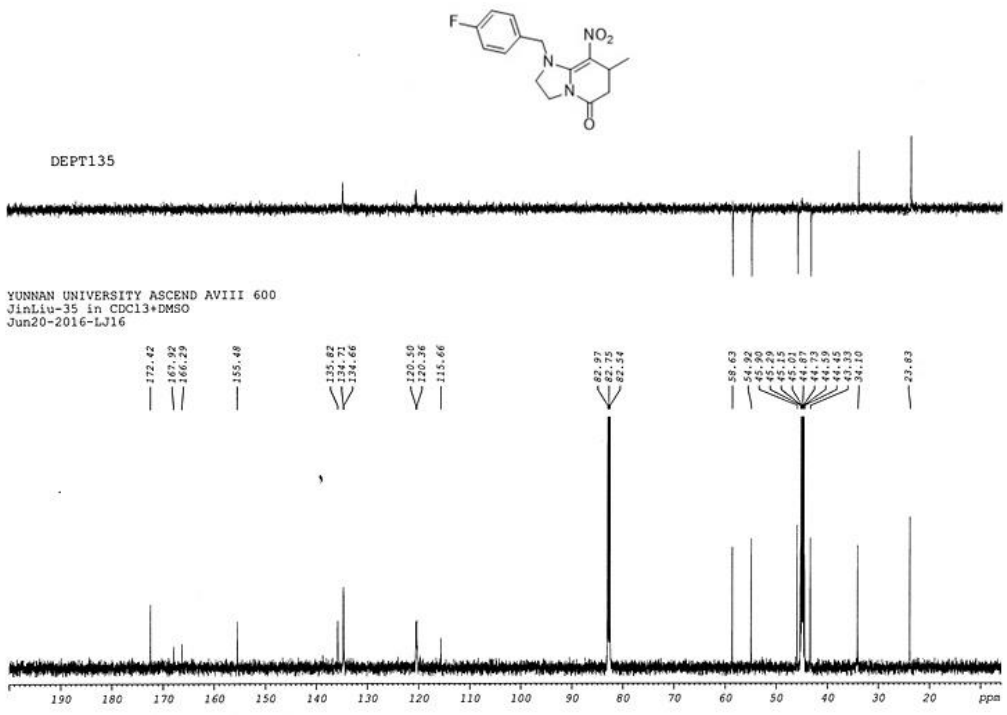


Figure 31b ^{13}C NMR (150 MHz, DMSO-*d6*+$CDCl_3$) spectra of compound **6c**

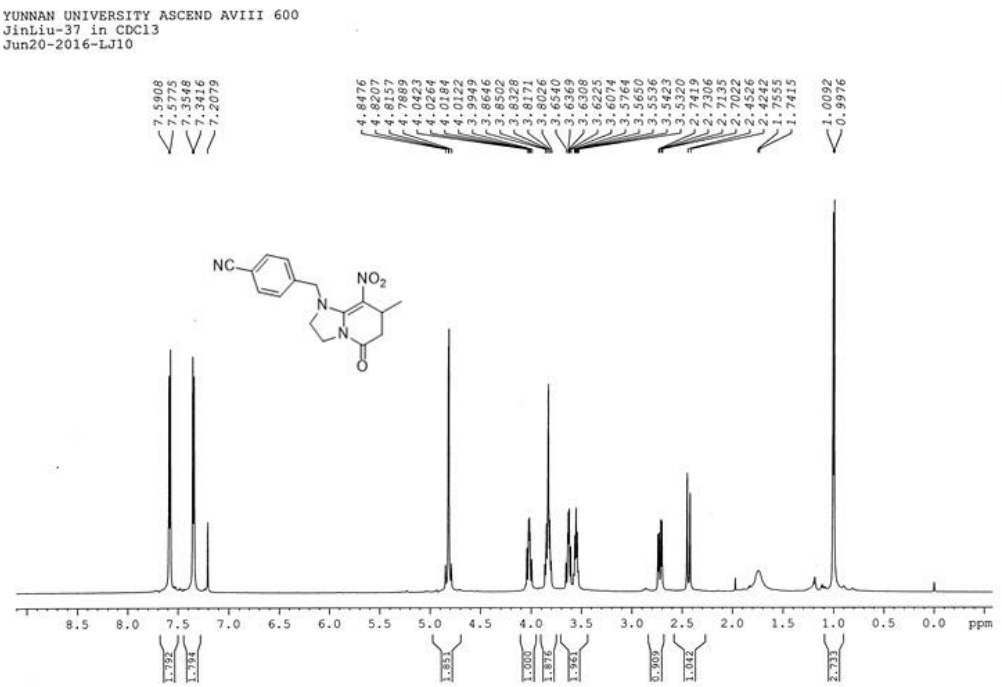


Figure 32a ^{1}H NMR (600 MHz, $CDCl_3$) spectra of compound **6d**

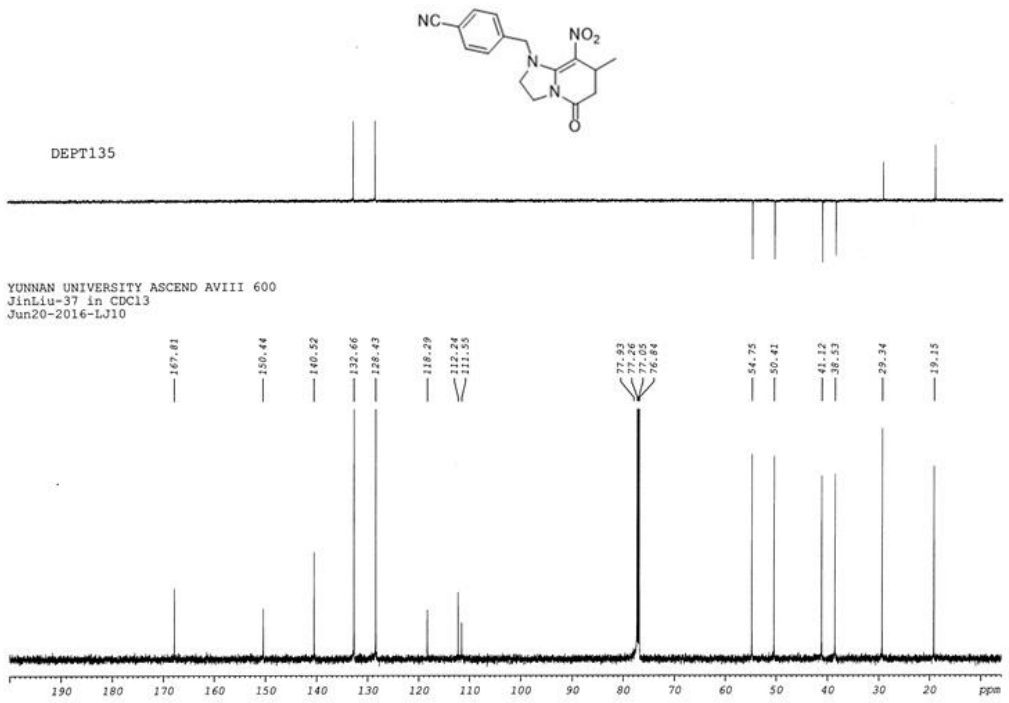


Figure 32b ^{13}C NMR (150 MHz, $CDCl_3$) spectra of compound **6d**

References

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 Y.-F. Fan, S. Liu, N.-Y. Chen, X.-S. Shao, X.-Y. Xu and Z. Li, *Synlett*, 2015, **26**, 393.