Supporting Information

Unexpected isocyanide-based three-component bicyclizations for stereoselective synthesis of densely functionalized pyrano[3,4-*c*]pyrroles

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Experimental

General Information

^{1}H NMR (^{13}C NMR) spectra were measured on a Bruker DPX 400 MHz spectrometer in $CDCl_3$ (DMSO-d_6) with chemical shift (δ) given in ppm relative to TMS as internal standard [(s = singlet, d = doublet, t = triplet, brs = broad singlet, m = multiplet), coupling constant (Hz)]. HRMS (APCI-TOF) was determined by using microTOF-Q Ⅱ HRMS/MS instrument (BRUKER). X-Ray crystallographic analysis was performed with a Siemens SMART CCD and a Siemens P4 diffractometer.

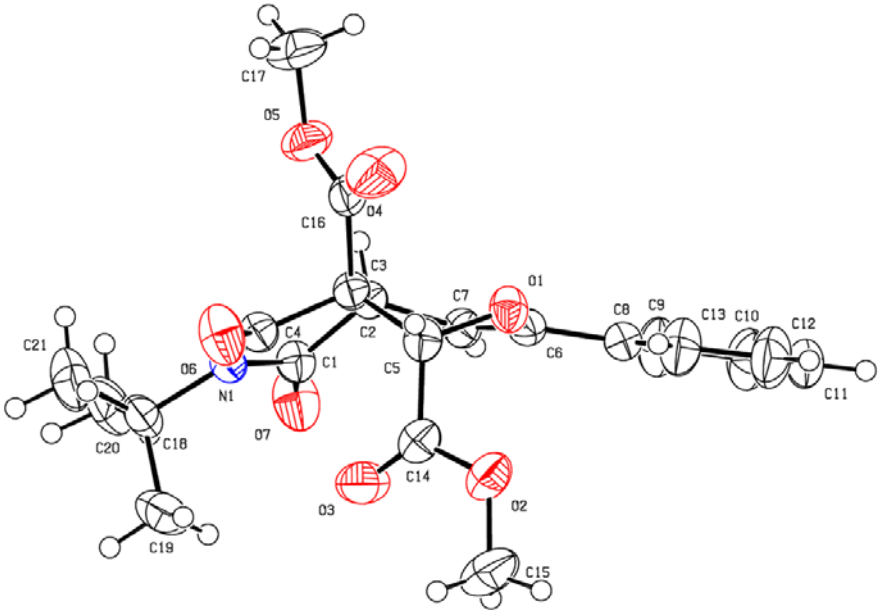
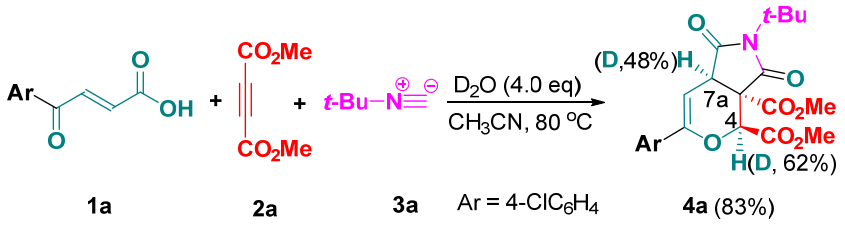
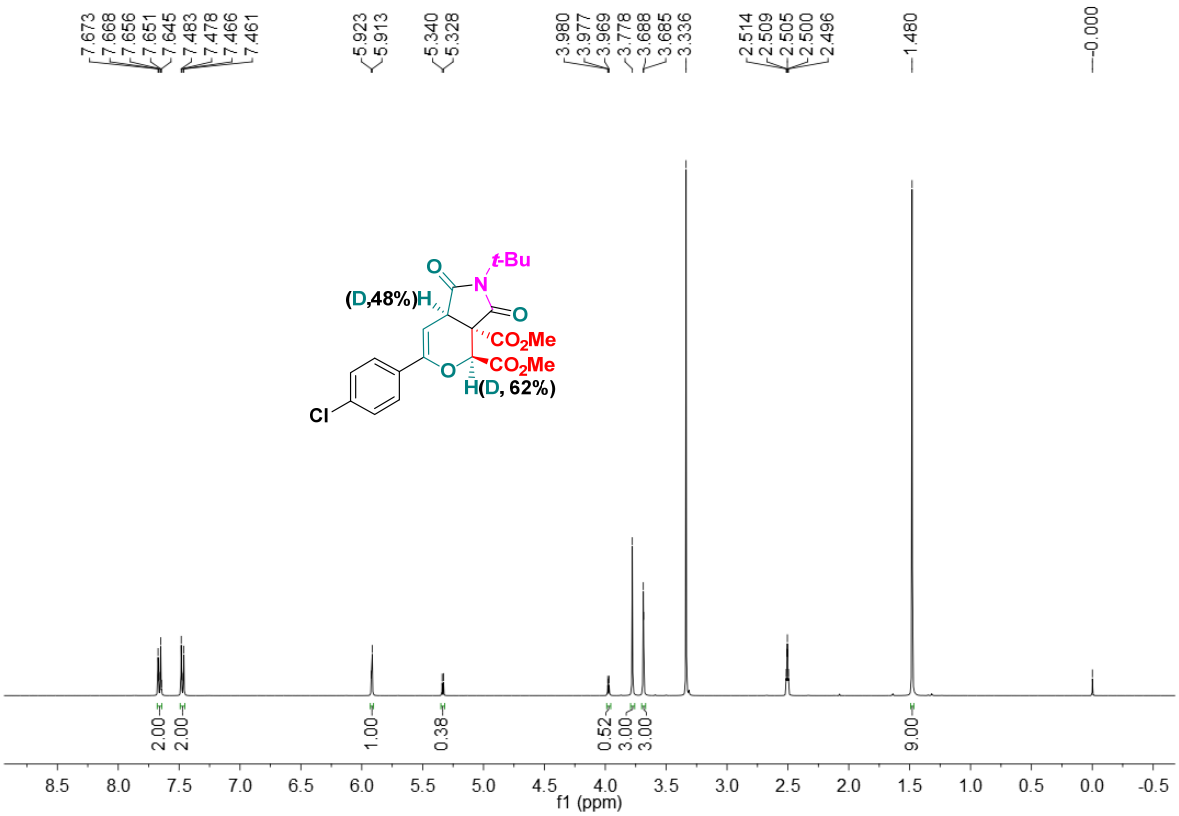


Fig 1, X-ray Structure of **4b**



Scheme 1. Hydrogen-deuterium exchange experiment



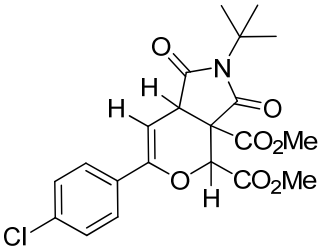
^{1}H NMR of Compound 4a via Hydrogen-Deuterium Exchange

General Procedure for the Synthesis of Products 4

Example for the synthesis of **4a**: Dimethyl 2-(*tert*-butyl)-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate

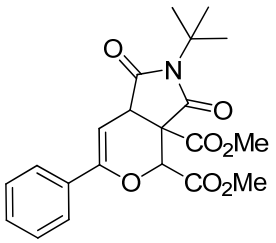
4-(4-chlorophenyl)-4-oxobut-2-enoic acid (**1a**, 0.5 mmol), dimethyl but-2-ynedioate **2a** (0.6 mmol, 1.2 equiv) and *t*-butyl isonitrile **3a** (0.6 mmol, 1.2 equiv) were introduced into a 25-mL Schlenk reaction flask, CH_3CN (4.0 mL) was then successively added into this reaction mixture. The reaction system was stirred at 80 ^oC for 6.0 hours. After completion of the reaction as indicated by TLC, the solvent was removed under vacuum. The residue was separated by column chromatography on silica gel (eluent, petroleum ether/ethyl acetate 10:1 v/v) to afford the pure white solid **4a**.

Dimethyl 2-(*tert*-butyl)-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4a)



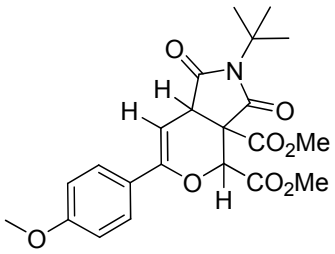
White solid, mp: 147-148 °C.
IR (KBr, *v*, cm^{-1}): 2977, 2957, 1751, 1707, 1492, 1435, 1357, 1334, 1253, 1225, 1113, 1013, 835, 777.
^1H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.4 Hz, 2H, ArH), 7.33 (d, *J* = 8.8 Hz, 2H, ArH), 5.74 (d, *J* = 4.4 Hz, 1H, CH), 5.30 (s, 1H, CH), 3.88 (s, 3H, CH_3), 3.79 (s, 3H, CH_3), 3.78 (d, *J* = 4.0 Hz, 1H, CH), 1.57 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 171.8, 168.3, 167.6, 152.4, 135.4, 131.5, 128.6, 126.5, 94.8, 74.2, 59.5, 57.3, 53.9, 53.0, 43.4, 27.9.
HRMS (APCI): m/z calcd for: $C_{21}H_{22}ClNO_7$, 436.1163 $[M+H]^+$; found: 436.1155.

Dimethyl 2-(*tert*-butyl)-1,3-dioxo-6-phenyl-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole -3a,4-dicarboxylate (4b)



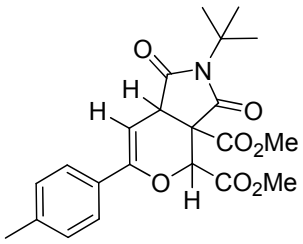
White solid, mp: 103-104 °C.
IR (KBr, *v*, cm^{-1}): 2984, 2955, 1784, 1749, 1705, 1496, 1425, 1354, 1335, 1249, 1221, 1163, 1107, 1012, 877, 763, 690.
^1H NMR (400 MHz, $CDCl_3$) δ 7.63–7.60 (m, 2H, ArH), 7.37–7.34 (m, 3H, ArH), 5.75 (d, *J* = 4.4 Hz, 1H, CH), 5.27 (s, 1H, CH), 3.87 (s, 3H, CH_3), 3.81 (s, 3H, CH_3), 3.78 (d, *J* = 4.0 Hz, 1H, CH), 1.57 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 171.9, 168.4, 167.7, 153.5, 133.1, 129.5, 128.4, 125.2, 94.3, 74.2, 59.4, 57.5, 53.9, 52.9, 43.7, 27.9.
HRMS (APCI): m/z calcd for: $C_{21}H_{23}NO_7$, 402.1553$[M+H]^+$; found: 402.1559.

Dimethyl 2-(*tert*-butyl)-6-(4-methoxyphenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4c)
White solid, mp: 155-156 °C.
IR (KBr, *v*, cm^{-1}): 3008, 2985, 2880, 2847, 1774, 1696, 1610, 1516, 840, 765, 678.
^1H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.8 Hz, 2H, ArH), 6.87 (d, *J* = 8.8 Hz, 2H, ArH), 5.60 (d, *J* = 8.8 Hz, 1H, CH), 5.25 (s, 1H, CH), 3.87 (s, 3H, CH_3), 3.82 (s, 3H, CH_3), 3.81 (s, 3H, CH_3), 3.75 (d, *J* = 4.4 Hz, 1H, CH), 1.57 (s, 9H, CH_3).



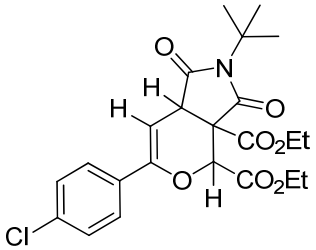
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.3, 172.0, 168.5, 167.8, 160.6, 153.4, 126.7, 125.7, 113.7, 92.4, 74.2, 59.3, 57.6, 55.3, 53.8, 52.9, 43.7, 28.0.
HRMS (APCI): m/z calcd for: $C_{22}H_{25}NO_8$, 432.1658[M+H]$^+$; found: 432.1656.

Dimethyl 2-(*tert*-butyl)-1,3-dioxo-6-(*p*-tolyl)-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole -3a,4-dicarboxylate (4d)



White solid, mp: 139-140 °C.
IR (KBr, *v*, cm^{-1}): 2984, 2957, 1778, 1738, 1705, 1259, 1110, 1052, 860, 827, 798, 765.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.4 Hz, 2H, ArH), 7.16 (d, *J* = 8.0 Hz, 2H, ArH), 5.68 (d, *J* = 4.0 Hz, 1H, CH), 5.25 (s, 1H, CH), 3.87 (s, 3H, CH_3), 3.81 (s, 3H, CH_3), 3.75 (d, *J* = 4.4 Hz, 1H, CH), 2.35 (s, 3H, CH_3), 1.56 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.2, 172.0, 168.5, 167.8, 153.6, 139.6, 130.3, 129.1, 125.2, 93.4, 74.1, 59.3, 57.6, 53.8, 52.9, 43.7, 28.0, 21.3.
HRMS (APCI): m/z calcd for: $C_{22}H_{25}NO_7$, 416.1709[M+H]$^+$; found: 416.1709.

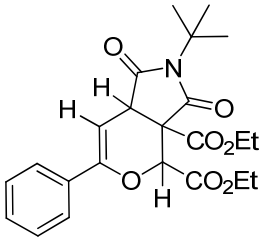
Diethyl 2-(*tert*-butyl)-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4e)



White solid, mp: 88-89 °C.
IR (KBr, *v*, cm^{-1}): 2982, 2941, 1744, 1706, 1491, 1402, 1371, 1333, 1246, 1218, 1161, 1025, 835, 774.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.8 Hz, 2H, ArH), 7.32 (d, *J* = 8.8 Hz, 2H, ArH), 5.75 (d, *J* = 4.0 Hz, 1H, CH), 5.30 (s, 1H, CH), 4.34–4.29 (m, 2H, CH_2), 4.27–4.21 (m, 2H, CH_2), 3.77 (d, *J* = 4.4 Hz, 1H, CH), 1.57 (s, 9H, CH_3), 1.33 (t, *J* = 6.8 Hz, 3H, CH_3), 1.22 (t, *J* = 7.2 Hz, 3H, CH_3).

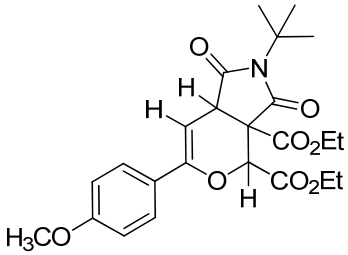
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 171.8, 167.9, 167.0, 152.4, 135.3, 131.7, 128.5, 126.6, 94.9, 74.3, 63.1, 62.2, 59.3, 57.3, 43.4, 27.9, 13.9, 13.9.
HRMS (APCI): m/z calcd for: $C_{23}H_{26}ClNO_7$, 464.1476$[M+H]^+$; found: 464.1469.

Diethyl 2-(*tert*-butyl)-1,3-dioxo-6-phenyl-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole -3a,4-dicarboxylate (4f)



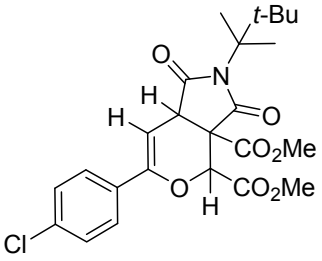
White solid, mp: 81-82 °C.
IR (KBr, *v*, cm^{-1}): 2990, 1767, 1735, 1710, 1345, 1266, 1141, 861, 760, 681.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67–7.60 (m, 2H, ArH), 7.38–7.31 (m, 3H, ArH), 5.76 (d, *J* = 4.0 Hz, 1H, CH), 5.28 (s, 1H, CH), 4.35–4.29 (m, 2H, CH_2), 4.28–4.20 (m, 2H, CH_2), 3.77 (d, *J* = 4.4 Hz, 1H, CH), 1.57 (s, 9H, CH_3), 1.33 (t, *J* = 6.8 Hz, 3H, CH_3), 1.24 (t, *J* = 7.2 Hz, 3H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.2, 172.0, 168.0, 167.2, 153.4, 133.2, 129.4, 128.3, 125.3, 94.3, 74.2, 63.1, 62.1, 59.3, 57.4, 43.6, 28.0, 13.9.
HRMS (APCI): m/z calcd for: $C_{23}H_{27}NO_7$, 430.1866$[M+H]^+$; found: 430.1860.

Diethyl 2-(*tert*-butyl)-6-(4-methoxyphenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4g)



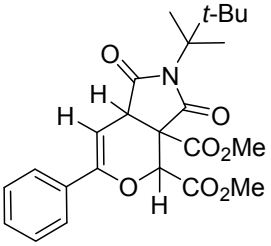
White solid, mp: 110-111 °C.
IR (KBr, *v*, cm^{-1}): 2985, 2907, 2879, 1762, 1740, 1712, 1607, 1515, 1341, 1267, 1242, 1183, 1138, 1026, 841, 682, 637.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.8 Hz, 2H, ArH), 6.79 (d, *J* = 8.8 Hz, 2H, ArH), 5.54 (d, *J* = 4.0 Hz, 1H, CH), 5.18 (s, 1H, CH), 4.25–4.22 (m, 2H, CH_2), 4.20–4.15 (m, 2H, CH_2), 3.74 (s, 3H, CH_3), 3.67 (d, *J* = 4.0 Hz, 1H, CH), 1.50 (s, 9H, CH_3), 1.25 (t, *J* = 7.2 Hz, 3H, CH_3), 1.16 (t, *J* = 6.8 Hz, 3H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.4, 172.1, 168.1, 167.3, 160.6, 153.3, 130.5, 126.8, 113.6, 92.5, 74.2, 63.0, 62.0, 59.2, 57.5, 55.3, 43.6, 27.9, 13.9, 13.9.
HRMS (APCI): m/z calcd for: $C_{24}H_{29}NO_8$, 460.1971$[M+H]^+$; found: 460.1976.

Dimethyl 6-(4-chlorophenyl)-1,3-dioxo-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate (4h)



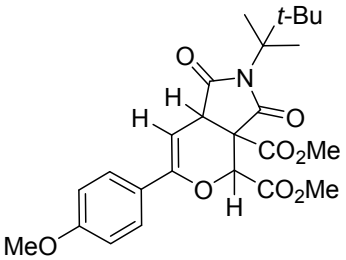
White solid, mp: 138-139 °C.
IR (KBr, *v*, cm^{-1}): 2956, 1763, 1748, 1707, 1491, 1435, 1344, 1257, 1128, 1012, 857, 813, 680.
^1H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.8 Hz, 2H, ArH), 7.32 (d, *J* = 8.8 Hz, 2H, ArH), 5.68 (d, *J* = 4.4 Hz, 1H, CH), 5.18 (s, 1H, CH), 3.86 (s, 3H), 3.84 (s, 3H), 3.73 (d, *J* = 4.4 Hz, 1H, CH), 2.02–1.80 (m, 2H, CH_2), 1.67 (s, 3H, CH_3), 1.63 (s, 3H, CH_3), 0.89 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 172.3, 168.4, 167.5, 152.7, 135.4, 131.5, 128.6, 126.5, 94.6, 74.1, 63.6, 57.7, 53.7, 53.0, 50.1, 44.0, 31.5, 31.0, 29.0, 29.0.
HRMS (APCI): m/z calcd for: $C_{25}H_{30}ClNO_7$, 492.1789$[M+H]^+$; found: 492.1791.

Dimethyl 1,3-dioxo-6-phenyl-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-hexahydropyrano [3,4-*c*]pyrrole-3a,4-dicarboxylate (4i)



White solid, mp: 98-99 °C.
IR (KBr, *v*, cm^{-1}): 2955, 1761, 1740, 1709, 1433, 1345, 1258, 1227, 1126, 861, 777, 758, 689.
^1H NMR (400 MHz, $CDCl_3$) δ 7.61–7.57 (m, 2H, ArH), 7.37–7.33 (m, 3H, ArH), 5.69 (d, *J* = 4.4 Hz, 1H, CH), 5.17 (s, 1H, CH), 3.86 (s, 3H, CH_3), 3.85 (s, 3H, CH_3), 3.73 (d, *J* = 4.4 Hz, 1H, CH), 2.03–1.80 (m, 2H, CH_2), 1.67 (s, 3H, CH_3), 1.63 (s, 3H, CH_3), 0.89 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.2, 172.4, 168.5, 167.7, 153.8, 133.1, 129.5, 128.4, 125.2, 94.1, 74.1, 63.5, 57.9, 53.7, 52.9, 50.1, 44.2, 31.5, 31.0, 29.0, 29.0.
HRMS (APCI): m/z calcd for: $C_{25}H_{31}NO_7$, 458.2179$[M+H]^+$; found: 458.2180.

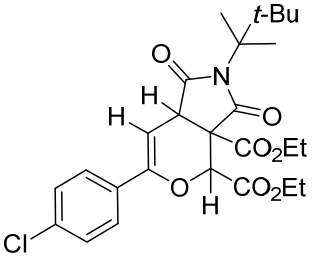
Dimethyl 6-(4-methoxyphenyl)-1,3-dioxo-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate (4j)



White solid, mp: 117-118 °C.
IR (KBr, *v*, cm^{-1}): 2955, 1759, 1747, 1708, 1608, 1512, 1345, 1242, 1175, 1127, 842, 684.
^1H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.8 Hz, 2H, ArH), 6.87 (d, *J* = 8.8 Hz, 2H, ArH), 5.55

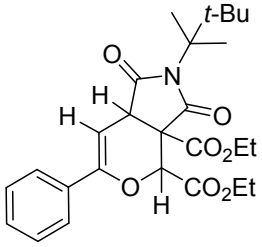
(d, J = 4.0 Hz, 1H, CH), 5.15 (s, 1H, CH), 3.85 (s, 3H, CH_3), 3.84 (s, 3H, CH_3), 3.82 (s, 3H, CH_3), 3.70 (d, J = 4.0 Hz, 1H, CH), 2.02–1.80 (m, 2H, CH_2), 1.67 (s, 3H, CH_3), 1.62 (s, 3H, CH_3), 0.89 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.4, 172.5, 168.6, 167.8, 160.6, 153.7, 126.7, 125.7, 113.7, 92.3, 74.1, 63.5, 58.0, 55.3, 53.6, 52.9, 50.1, 44.2, 31.5, 31.0, 29.1, 29.0.
HRMS (APCI): m/z calcd for: $C_{26}H_{33}NO_8$, 488.2284$[M+H]^+$; found: 488.2274.

Diethyl 6-(4-chlorophenyl)-1,3-dioxo-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate (4k)



White solid, mp: 124-125 °C.
IR (KBr, v, cm^{-1}): 2952, 1748, 1731, 1704, 1300, 1261, 1220, 1106, 1019, 860, 844, 763.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, J = 8.8 Hz, 2H, ArH), 7.25 (d, J = 8.8 Hz, 2H, ArH), 5.63 (d, J = 4.4 Hz, 1H, CH), 5.15 (s, 1H, CH), 4.25–4.22 (m, 2H, CH_2), 4.21–4.15 (m, 2H, CH_2), 3.65 (d, J = 4.4 Hz, 1H, CH), 1.98–1.71 (m, 2H, CH_2), 1.61 (s, 3H, CH_3), 1.56 (s, 3H, CH_3), 1.25 (t, J = 7.2 Hz, 3H, CH_3), 1.17 (t, J = 7.2 Hz, 3H, CH_3), 0.83 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.2, 172.3, 167.9, 166.9, 152.6, 135.3, 131.7, 128.5, 126.5, 94.6, 74.2, 63.5, 63.1, 62.1, 57.5, 50.1, 43.8, 31.5, 31.0, 29.0, 28.9, 14.0, 13.9.
HRMS (APCI): m/z calcd for: $C_{27}H_{34}ClNO_7$, 520.2102$[M+H]^+$; found: 520.2098.

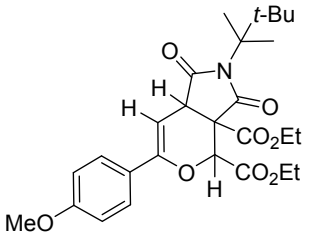
Diethyl 1,3-dioxo-6-phenyl-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-hexahydropyrano [3,4-*c*]pyrrole-3a,4-dicarboxylate (4l)



White solid, mp: 110-111 °C.
IR (KBr, v, cm^{-1}): 2980, 2952, 1741, 1698, 1339, 1251, 1221, 1098, 1023, 858, 757, 688.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56–7.51 (m, 2H, ArH), 7.30–7.25 (m, 3H, ArH), 5.63 (d, J = 4.4 Hz, 1H, CH), 5.14 (s, 1H, CH), 4.25–4.22 (m, 2H, CH_2), 4.22–4.15 (m, 2H, CH_2), 3.66 (d, J = 4.4 Hz, 1H, CH), 1.98–1.72 (m, 2H, CH_2), 1.61 (s, 3H, CH_3), 1.56 (s, 3H, CH_3), 1.25 (t, J = 7.2 Hz, 3H, CH_3), 1.18 (t, J = 7.2 Hz, 3H, CH_3), 0.83 (s, 9H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.4, 172.4, 168.0, 167.1, 153.7, 133.2, 129.4, 128.3, 125.2, 94.1, 74.2, 63.4, 63.0, 62.0, 57.7, 50.1, 43.9, 31.5, 31.0, 29.0, 28.9, 14.0, 13.9.
HRMS (APCI): m/z calcd for: $C_{27}H_{35}NO_7$, 486.2492$[M+H]^+$; found: 486.2495.

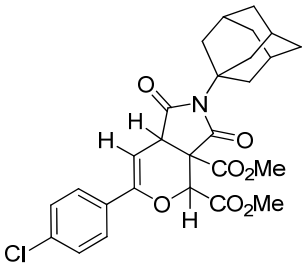
Diethyl 6-(4-methoxyphenyl)-1,3-dioxo-2-(2,4,4-trimethylpentan-2-yl)-1,2,3,3a,4,7a-

hexahydropyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate (4m)



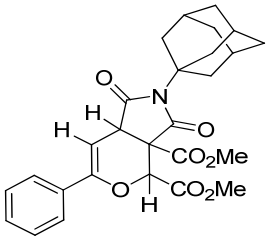
White solid, mp: 108-109 °C.
IR (KBr, *v*, cm^{-1}): 2979, 2953, 1767, 1744, 1707, 1512, 1248, 1176, 1127, 1031, 852, 805, 682, 603.
^1H NMR (400 MHz, DMSO) δ 7.55 – 7.50 (m, 2H, ArH), 6.97 – 6.93 (m, 2H, ArH), 5.62 (d, *J* = 4.4 Hz, 1H, CH), 5.15 (s, 1H, CH), 4.24 – 4.14 (m, 4H, CH_2), 3.81 (d, *J* = 4.4 Hz, 1H, CH), 3.77 (s, 3H, CH_3), 1.93 – 1.76 (m, 2H, CH_2), 1.59 (s, 3H, CH_3), 1.54 (s, 3H, CH_3), 1.22 (t, *J* = 7.2 Hz, 3H, CH_3), 1.17 (t, *J* = 7.2 Hz, 3H, CH_3), 0.82 (s, 9H, CH_3).
^{13}C NMR (100 MHz, DMSO) δ 174.8, 172.5, 167.5, 166.5, 160.0, 152.5, 126.3, 125.4, 113.6, 92.4, 73.3, 62.4, 62.1, 61.2, 57.3, 55.1, 49.3, 43.4, 31.0, 30.6, 28.7, 28.5, 13.6, 13.5.
HRMS (APCI): m/z calcd for: $C_{28}H_{37}NO_8$, 516.2597$[M+H]^+$; found: 516.2598.

Dimethyl 2-(adamantan-1-yl)-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano [3,4-*c*]pyrrole-3a,4-dicarboxylate (4n)



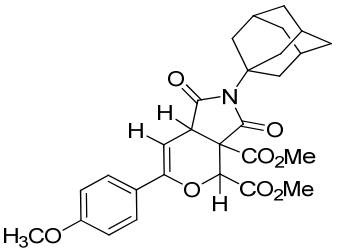
White solid, mp: 150-151 °C.
IR (KBr, *v*, cm^{-1}): 2910, 2849, 1741, 1705, 1491, 1304, 1156, 1112, 1013, 837, 773, 643.
^1H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.8 Hz, 2H, ArH), 7.33 (d, *J* = 8.8 Hz, 2H, ArH), 5.72 (d, *J* = 4.4 Hz, 1H, CH), 5.23 (s, 1H, CH), 3.87 (s, 3H, CH_3), 3.81 (s, 3H, CH_3), 3.73 (d, *J* = 4.4 Hz, 1H, CH), 2.38 (d, *J* = 2.4 Hz, 6H), 2.11 (s, 3H), 1.76–1.62 (m, 6H).
^{13}C NMR (100 MHz, $CDCl_3$) δ 174.9, 172.0, 168.4, 167.6, 152.4, 135.4, 131.6, 128.6, 126.5, 94.8, 74.1, 62.2, 57.4, 53.9, 53.0, 43.7, 38.9, 36.1, 29.7.
HRMS (APCI): m/z calcd for: $C_{27}H_{28}ClNO_7$, 514.1633$[M+H]^+$; found: 516.1634.

Dimethyl 2-(adamantan-1-yl)-1,3-dioxo-6-phenyl-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole -3a,4-dicarboxylate (4o)



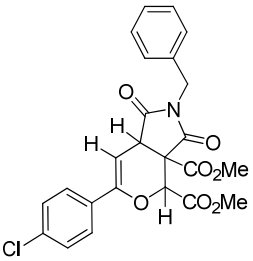
White solid, mp: 107-108 °C.
IR (KBr, *v*, cm^{-1}): 2951, 2901, 2844, 1740, 1708, 1447, 1304, 1232, 1113, 1050, 864, 756, 691.
^1H NMR (400 MHz, $CDCl_3$) δ 7.67–7.57 (m, 2H, ArH), 7.41–7.31 (m, 3H, ArH), 5.72 (d, *J* = 4.4 Hz, 1H, CH), 5.20 (s, 1H, CH), 3.87 (s, 3H, CH_3), 3.83 (s, 3H, CH_3), 3.73 (d, *J* = 4.4 Hz, 1H, CH), 2.38 (d, *J* = 2.4 Hz, 6H), 2.10 (s, 3H), 1.74–1.63 (m, 6H).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 172.2, 168.5, 167.8, 153.5, 133.1, 129.5, 128.4, 125.2, 94.3, 74.1, 62.1, 57.5, 53.8, 52.9, 43.9, 38.9, 36.1, 29.7.
HRMS (APCI): m/z calcd for: $C_{27}H_{29}NO_7$, 480.2022$[M+H]^+$; found: 480.2019.

Dimethyl 2-(adamantan-1-yl)-6-(4-methoxyphenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydro pyrano[3,4-*c*]pyrrole-3a,4-dicarboxylate (4p)



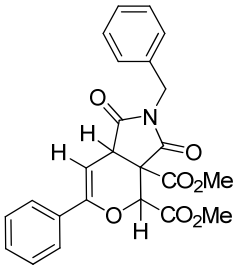
White solid, mp: 161-162 °C.
IR (KBr, *v*, cm^{-1}): 2903, 2844, 1743, 1699, 1608, 1514, 1335, 1303, 1257, 1183, 1154, 1103, 847, 794, 769, 661.
^1H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.8 Hz, 2H, ArH), 6.87 (d, *J* = 8.8 Hz, 2H, ArH), 5.58 (d, *J* = 4.0 Hz, 1H, CH), 5.18 (s, 1H, CH), 3.86 (s, 3H, CH_3), 3.83–3.80 (m, 6H), 3.70 (d, *J* = 4.0 Hz, 1H, CH), 2.38 (d, *J* = 2.8 Hz, 6H), 2.10 (s, 3H), 1.73–1.64 (m, 6H).
^{13}C NMR (100 MHz, $CDCl_3$) δ 175.4, 172.3, 168.6, 167.9, 160.6, 153.4, 130.5, 126.7, 113.7, 92.5, 74.1, 62.0, 57.6, 55.3, 53.8, 52.9, 43.9, 38.9, 36.1, 29.7.
HRMS (APCI): m/z calcd for: $C_{28}H_{31}NO_8$, 510.2128$[M+H]^+$; found: 510.2130.

Dimethyl 2-benzyl-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4q)



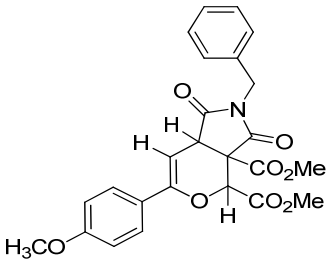
White solid, mp: 131-132 °C.
IR (KBr, *v*, cm^{-1}): 2963, 2873, 1740, 1706, 1492, 1398, 1259, 1092, 1001, 838, 772, 744, 701, 630.
^1H NMR (400 MHz, $CDCl_3$) δ 7.57–7.49 (m, 2H, ArH), 7.34–7.25 (m, 7H, ArH), 5.74 (d, *J* = 4.4 Hz, 1H, CH), 5.31 (s, 1H, CH), 4.75–4.62 (m, 2H, CH_2), 3.92 (d, *J* = 4.0 Hz, 1H, CH), 3.80 (s, 3H, CH_3), 3.72 (s, 3H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4, 170.8, 167.8, 167.2, 153.0, 135.6, 134.8, 131.3, 128.6, 128.6, 128.4, 128.0, 126.6, 94.3, 74.4, 57.8, 54.0, 53.0, 43.8, 43.2.
HRMS (APCI): m/z calcd for: $C_{24}H_{20}ClNO_7$, 470.1007$[M+H]^+$; found: 470.1007.

Dimethyl 2-benzyl-1,3-dioxo-6-phenyl-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole -3a,4-dicarboxylate (4r)



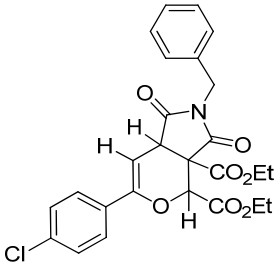
White solid, mp: 126-127 °C.
IR (KBr, *v*, cm^{-1}): 2955, 1785, 1745, 1716, 1438, 1335, 1273, 1126, 1020, 804, 761, 723, 696.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57–7.49 (m, 2H, ArH), 7.32–7.26 (m, 3H, ArH), 7.25–7.17 (m, 5H, ArH), 5.68 (d, *J* = 4.0 Hz, 1H, CH), 5.22 (s, 1H, CH), 4.66–4.56 (m, 2H, CH_2), 3.85 (d, *J* = 4.4 Hz, 1H, CH), 3.74 (s, 3H, CH_3), 3.68 (s, 3H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 173.6, 170.9, 167.9, 167.4, 154.1, 134.8, 132.8, 129.6, 128.6, 128.4, 128.3, 127.9, 125.3, 93.9, 74.3, 58.0, 53.9, 53.0, 44.0, 43.1.
HRMS (APCI): m/z calcd for: $C_{24}H_{21}NO_7$, 436.1396$[M+H]^+$; found: 436.1398.

Dimethyl 2-benzyl-6-(4-methoxyphenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4s)



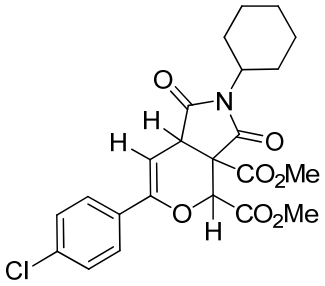
White solid, mp: 127-128 °C.
IR (KBr, *v*, cm^{-1}): 2952, 2894, 1747, 1712, 1610, 1514, 1395, 1259, 1174, 1115, 999, 839, 762, 692, 631.
^{1}H NMR (400 MHz, DMSO) δ 7.58 – 7.54 (m, 2H, ArH), 7.28 – 7.23 (m, 3H, ArH), 7.21 – 7.16 (m, 2H, ArH), 6.99 – 6.94 (m, 2H, ArH), 5.75 (d, *J* = 4.8 Hz, 1H, CH), 5.27 (s, 1H, CH), 4.67 – 4.59 (m, 2H, CH_2), 4.16 (d, *J* = 4.4 Hz, 1H, CH), 3.78 (s, 3H, CH_3), 3.76 (s, 3H, CH_3), 3.68 (s, 3H, CH_3).
^{13}C NMR (100 MHz, DMSO) δ 173.4, 171.1, 167.4, 166.9, 160.1, 153.0, 135.1, 128.4, 127.4, 126.9, 126.4, 125.1, 113.7, 92.7, 73.8, 57.8, 55.1, 53.5, 52.4, 43.6, 41.8.
HRMS (APCI): m/z calcd for: $C_{25}H_{23}NO_8$, 466.1502$[M+H]^+$; found: 466.1501.

diethyl 2-benzyl-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-c] pyrrole-3a,4-dicarboxylate (4t)
White solid, mp: 132-133 °C.
IR (KBr, *v*, cm^{-1}): 2992, 1751, 1734, 1707, 1400, 1303, 1255, 1221, 1091, 1016, 937, 837, 768, 749, 701, 629.
^{1}H NMR (400 MHz, DMSO) δ 7.69 – 7.64 (m, 2H, ArH), 7.51 – 7.46 (m, 2H, ArH), 7.31 – 7.24 (m, 3H, ArH), 7.23 – 7.18 (m, 2H, ArH), 5.99 (d, *J* = 4.4 Hz, 1H, CH), 5.33 (s, 1H, CH), 4.68 – 4.59 (m, 2H, CH_2), 4.24 – 4.18 (m, 3H), 4.18 – 4.12 (m, 2H, CH_2), 1.21 – 1.12 (m, 6H, CH_3).



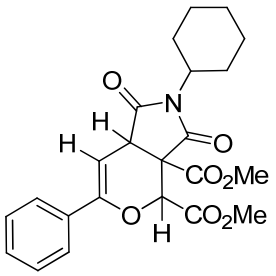
^{13}C NMR (100 MHz, DMSO) δ 173.2, 171.0, 166.8, 166.2, 151.8, 135.1, 133.9, 131.6, 128.4, 128.4, 127.5, 127.0, 126.6, 95.6, 73.8, 62.6, 61.4, 57.6, 43.4, 41.9, 13.6, 13.5.
HRMS (APCI): m/z calcd for: $C_{26}H_{24}ClNO_7$, 498.1320[M+H]$^+$; found: 498.1321.

Dimethyl 6-(4-chlorophenyl)-2-cyclohexyl-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*] pyrrole-3a,4-dicarboxylate (4u)



White solid, mp: 130-131 °C.
IR (KBr, *v*, cm^{-1}): 2957, 2929, 2853, 1779, 1739, 1701, 1492, 1370, 1261, 1187, 1106, 1046, 1000, 851, 776, 641.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51–7.44 (m, 2H, ArH), 7.30–7.22 (m, 2H, ArH), 5.69 (d, *J* = 4.0 Hz, 1H, CH), 5.24 (s, 1H, CH), 3.92–3.84 (m, 1H, CH), 3.80 (s, 3H, CH_3), 3.76 (d, *J* = 4.4 Hz, 1H, CH), 3.72 (s, 3H, CH_3), 2.07–1.93 (m, 2H), 1.78–1.54 (m, 5H), 1.27–1.08 (m, 3H).
^{13}C NMR (100 MHz, $CDCl_3$) δ 173.9, 171.1, 168.1, 167.4, 152.7, 135.5, 131.4, 128.6, 126.5, 94.7, 74.3, 57.4, 54.0, 53.0, 52.8, 43.4, 28.6, 28.2, 25.7, 25.7, 25.0.
HRMS (APCI): m/z calcd for: $C_{23}H_{24}ClNO_7$, 462.1320[M+H]$^+$; found: 462.1329.

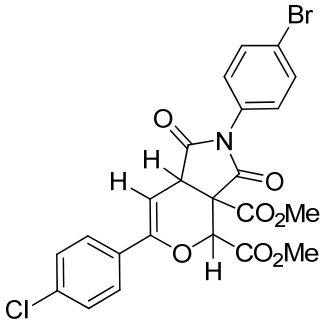
Dimethyl 2-cyclohexyl-1,3-dioxo-6-phenyl-1,2,3,3a,4,7a-hexahydropyrano[3,4-*c*]pyrrole -3a,4-dicarboxylate (4v)



White solid, mp: 94-95 °C.
IR (KBr, *v*, cm^{-1}): 2954, 2855, 1742, 1733, 1704, 1368, 1269, 1106, 999, 896, 764, 694.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64–7.59 (m, 2H, ArH), 7.37–7.33 (m, 3H, ArH), 5.76 (d, *J* = 4.4 Hz, 1H, CH), 5.29 (s, 1H, CH), 3.99–3.92 (m, 1H, CH), 3.87 (s, 3H, CH_3), 3.83 (d, *J* = 4.4 Hz, 1H, CH), 3.81 (s, 3H, CH_3), 2.14–2.02 (m, 2H), 1.83–1.62 (m, 5H), 1.32–1.17 (m, 3H).

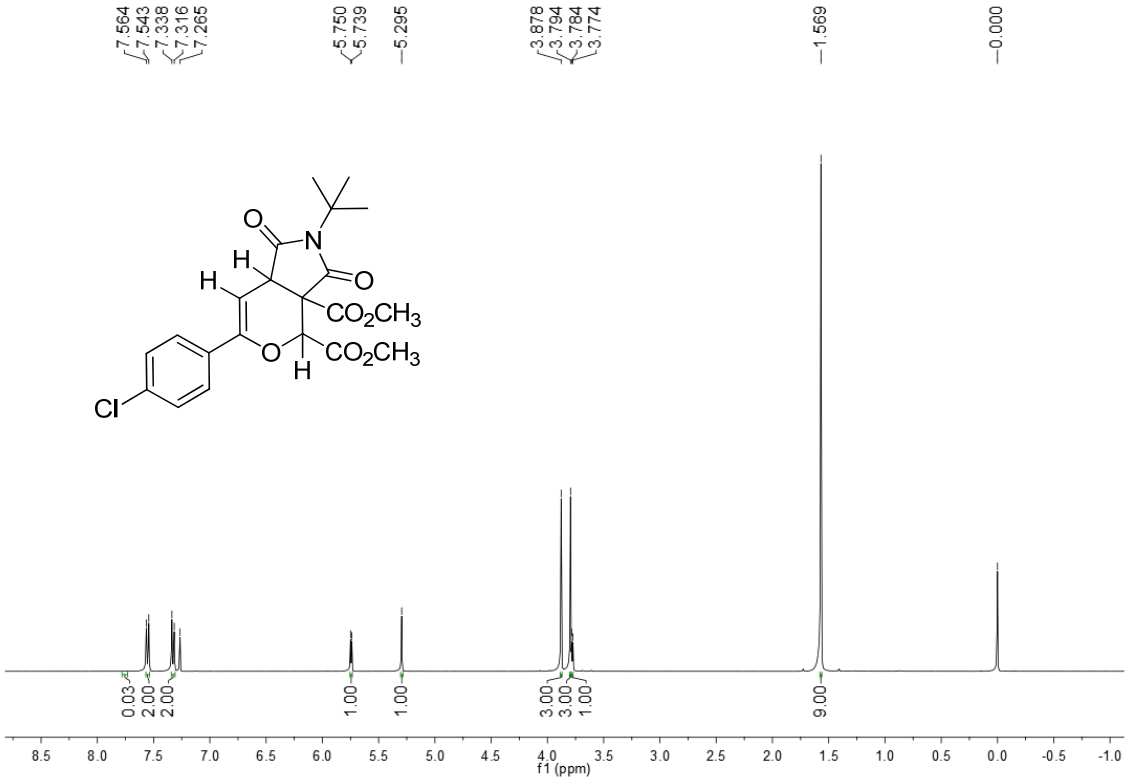
^{13}C NMR (100 MHz, $CDCl_3$) δ 174.1, 171.2, 168.2, 167.5, 153.7, 133.0, 129.5, 128.4, 125.2, 94.2, 74.3, 57.5, 53.9, 53.0, 52.7, 43.6, 28.7, 28.2, 25.7, 25.7, 25.0.
HRMS (APCI): m/z calcd for: $C_{23}H_{25}NO_7$, 428.1709$[M+H]^+$; found: 428.1704.

Dimethyl 2-(4-bromophenyl)-6-(4-chlorophenyl)-1,3-dioxo-1,2,3,3a,4,7a-hexahydropyrano [3,4-*c*]pyrrole-3a,4-dicarboxylate (4w)

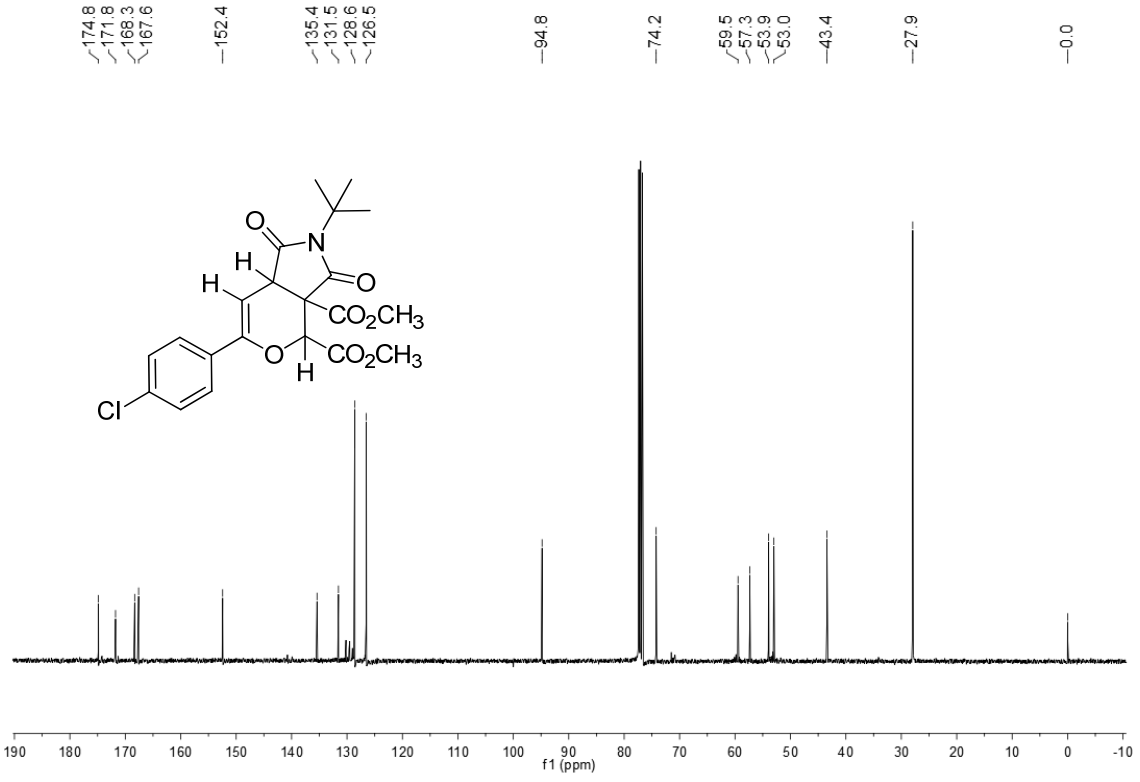


White solid, mp: 175-176 °C.
IR (KBr, *v*, cm^{-1}): 2953, 2878, 1741, 1716, 1490, 1381, 1255, 1113, 1094, 1046, 1014, 820, 770, 618.
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62–7.57 (m, 4H, ArH), 7.37–7.33 (m, 2H, ArH), 7.28 (s, 1H, ArH), 7.25 (s, 1H, ArH), 5.88 (d, *J* = 4.0 Hz, 1H, CH), 5.61 (s, 1H, CH), 4.18 (d, *J* = 4.0 Hz, 1H, CH), 3.94 (s, 3H, CH_3), 3.74 (s, 3H, CH_3).
^{13}C NMR (100 MHz, $CDCl_3$) δ 172.8, 169.8, 167.7, 167.4, 153.0, 135.7, 132.4, 131.3, 130.5, 128.7, 128.0, 126.7, 122.9, 94.2, 74.8, 57.4, 54.4, 53.3, 42.6.
HRMS (APCI): m/z calcd for: $C_{23}H_{17}BrClNO_7$, 533.9955$[M+H]^+$; found: 533.9956.

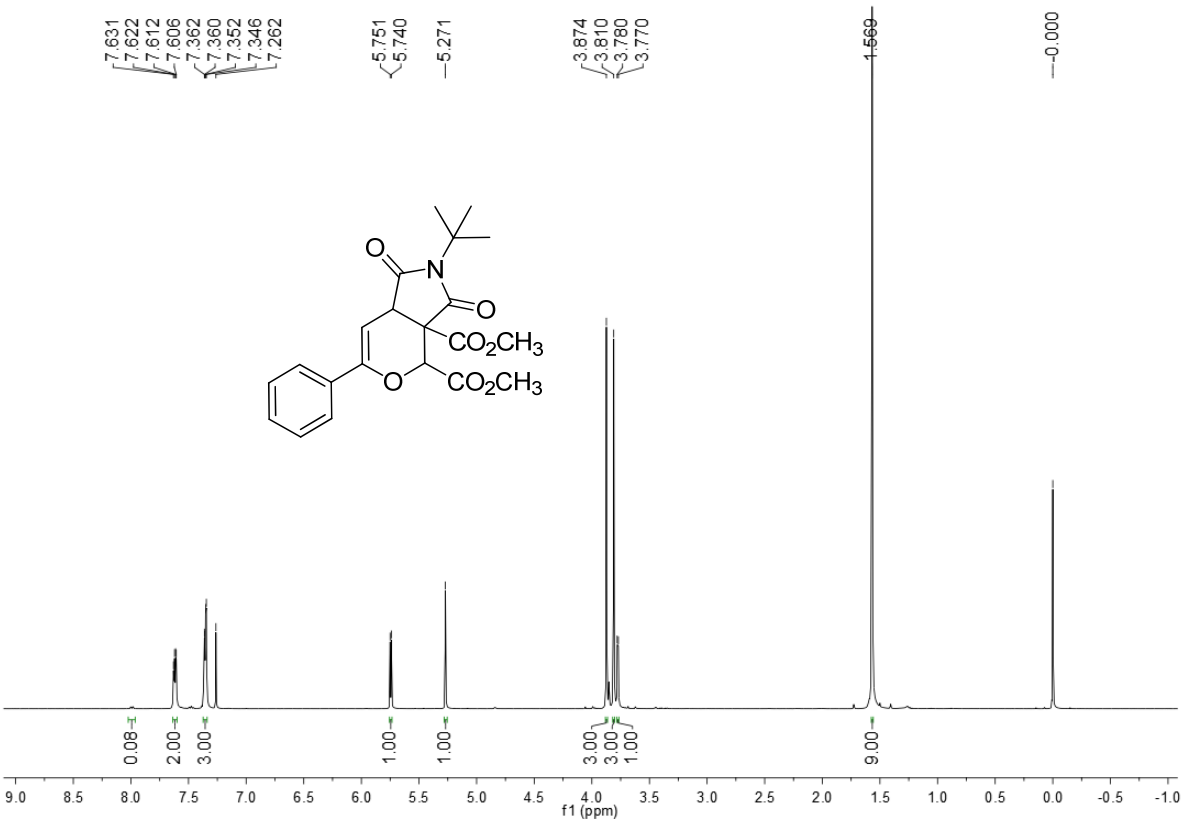
Copies of ^{1}H NMR and ^{13}C NMR of compounds 4



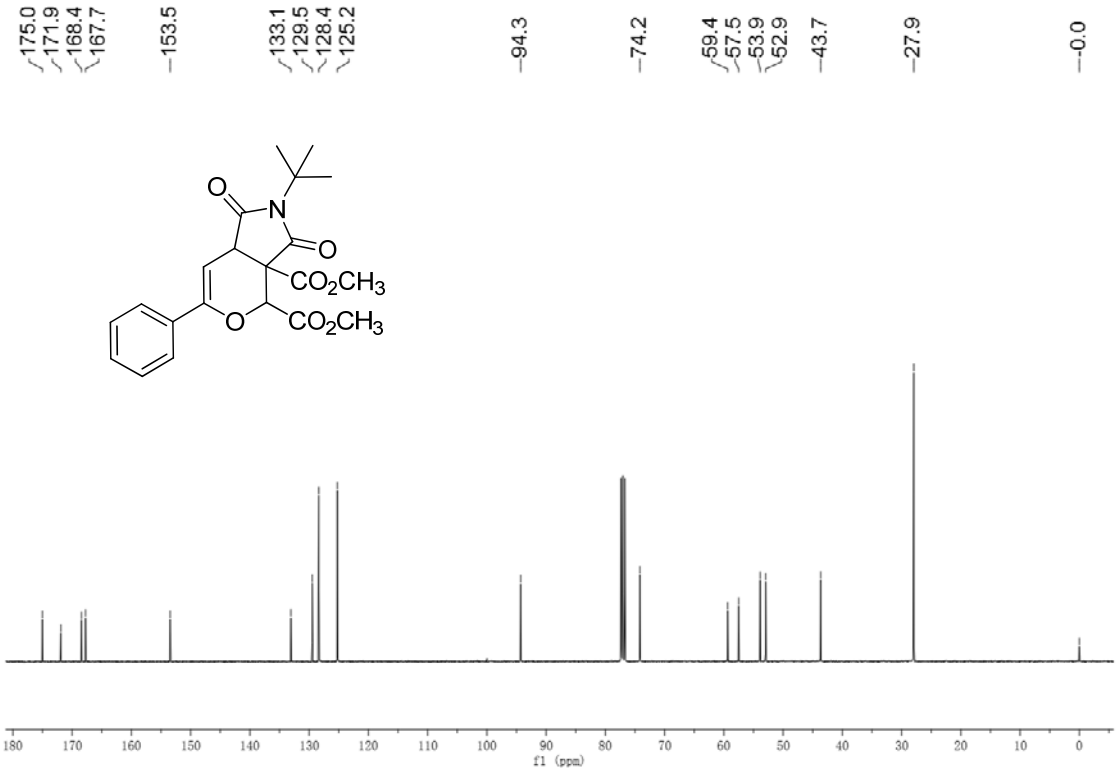
^{1}H NMR Spectrum of Compound 4a



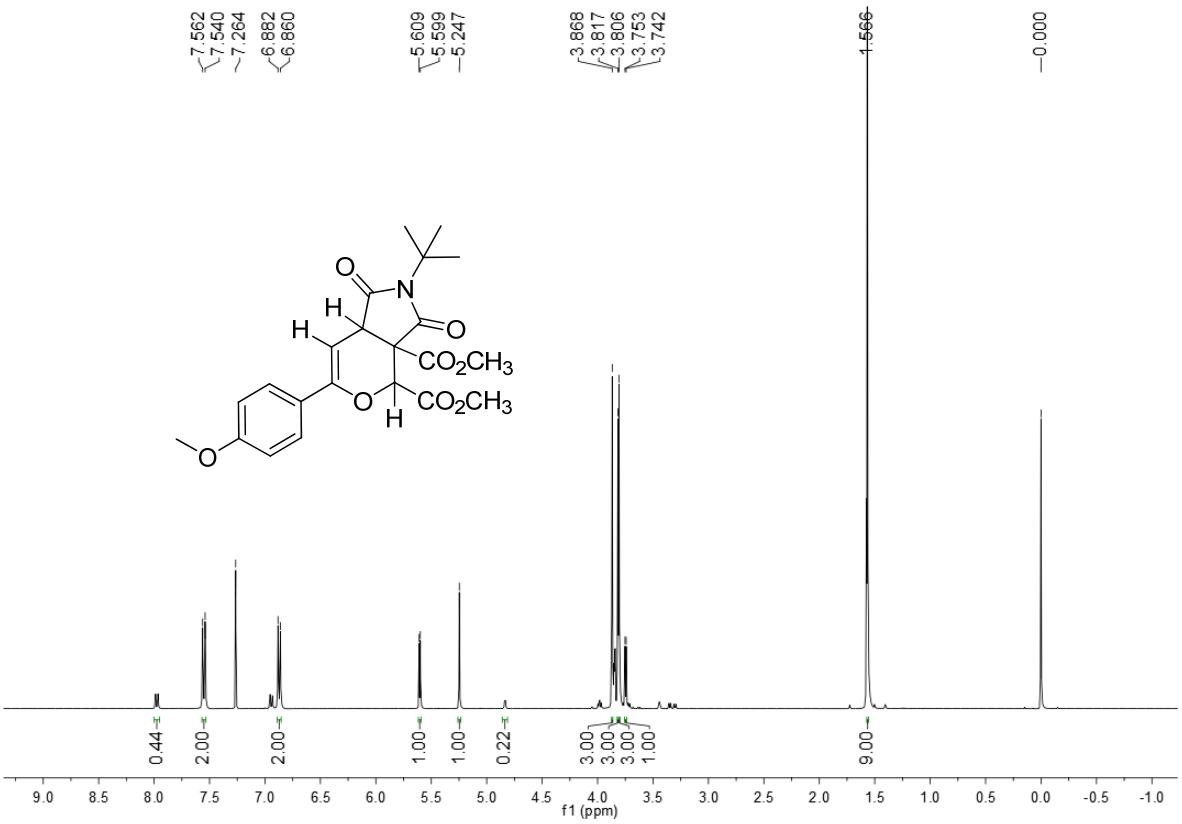
^{13}C NMR Spectrum of Compound 4a



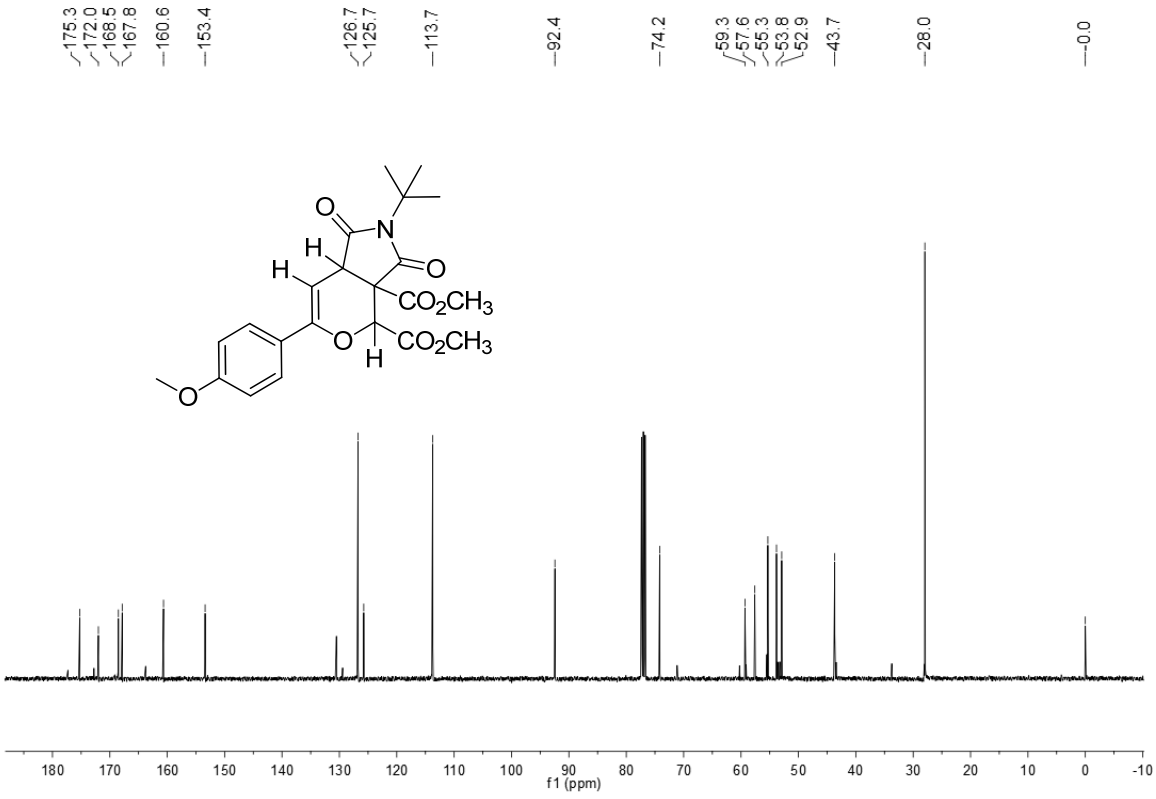
^{1}H NMR Spectrum of Compound 4b



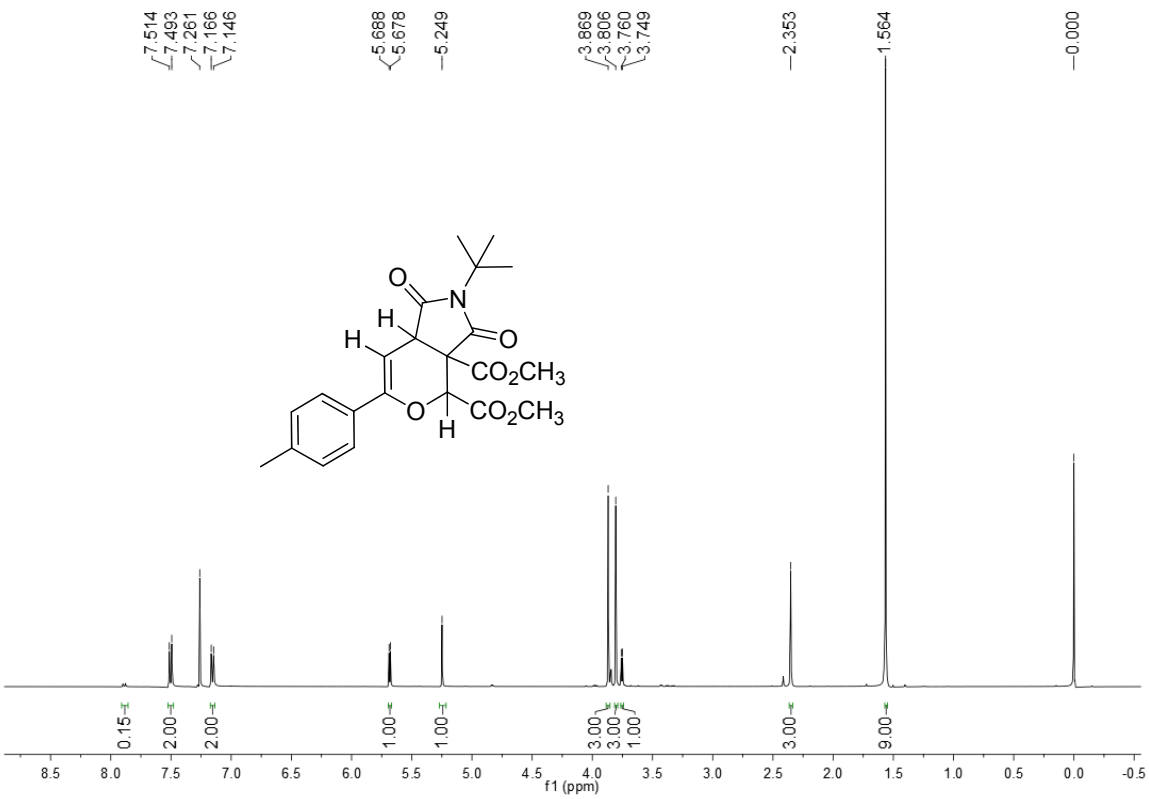
^{13}C NMR Spectrum of Compound 4b



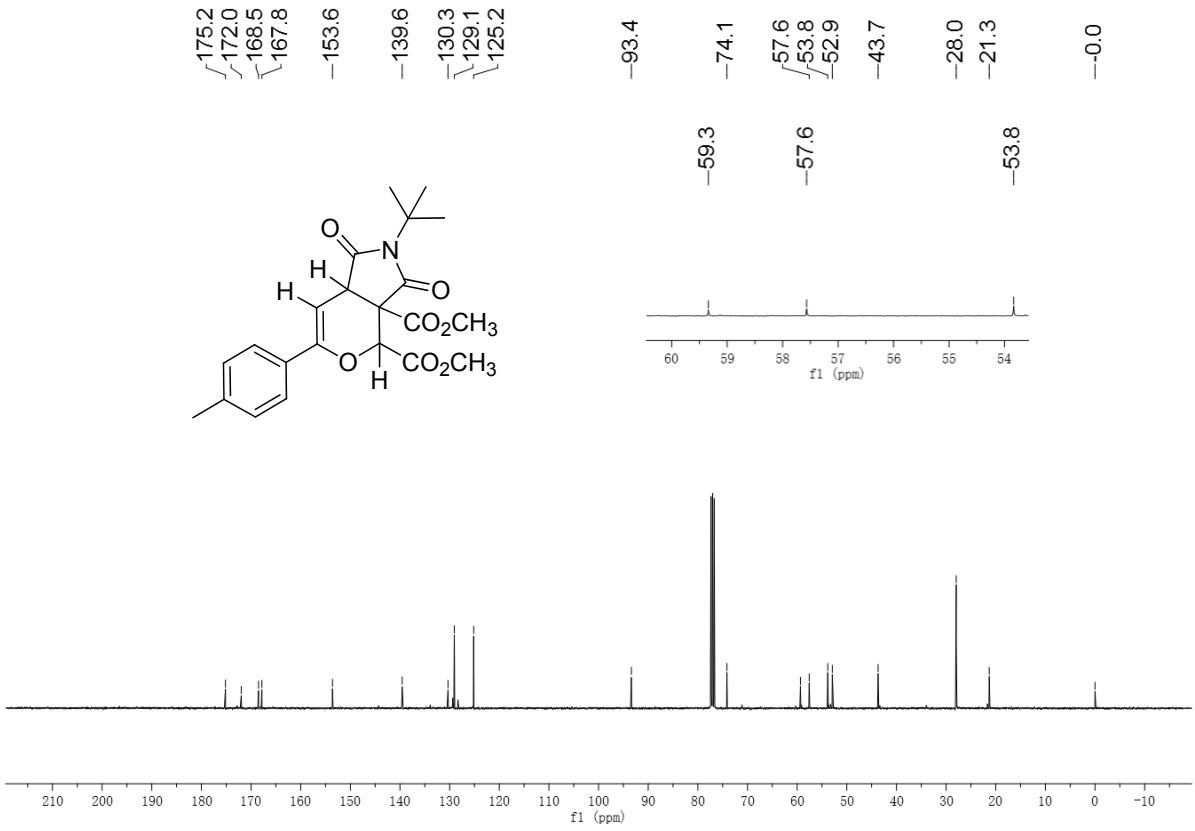
^{1}H NMR Spectrum of Compound 4c



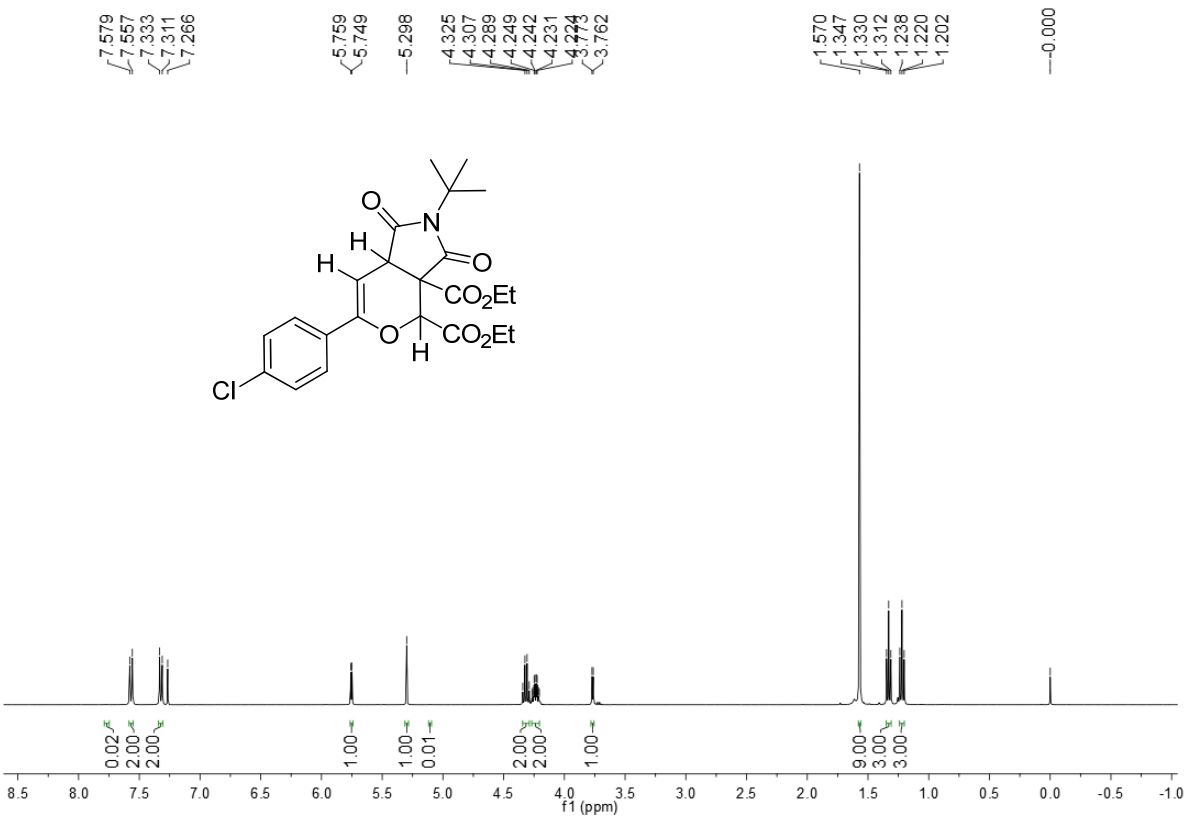
^{13}C NMR Spectrum of Compound 4c



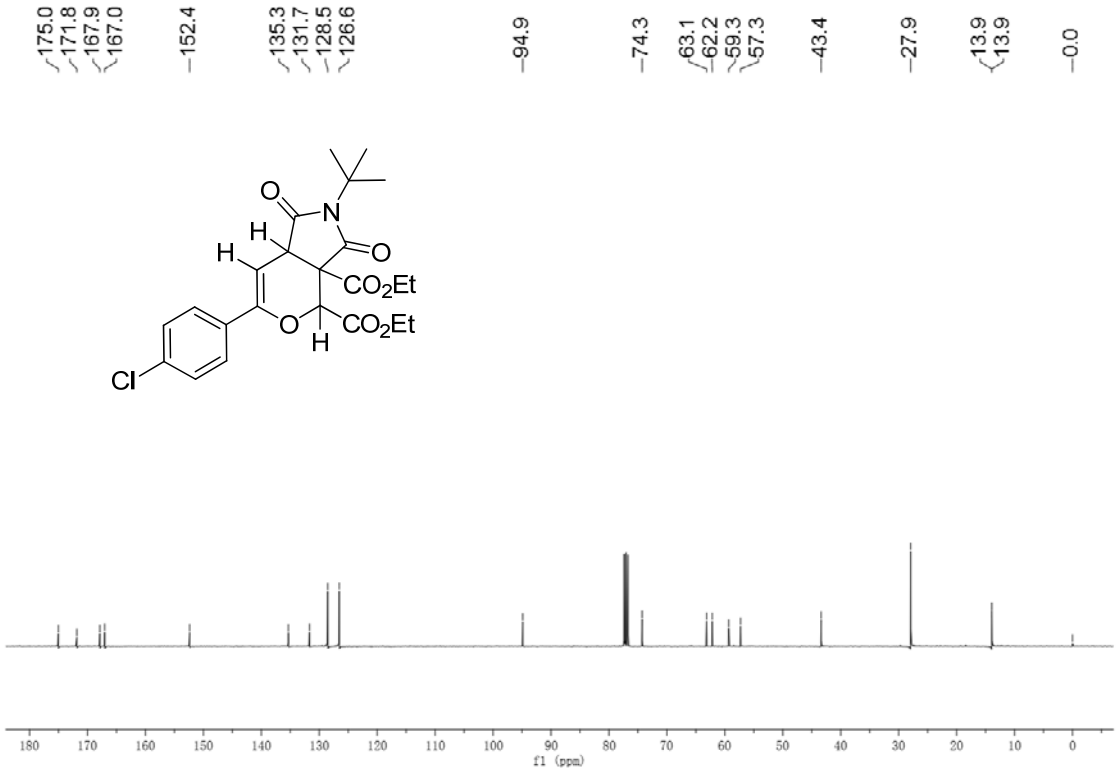
^{1}H NMR Spectrum of Compound 4d



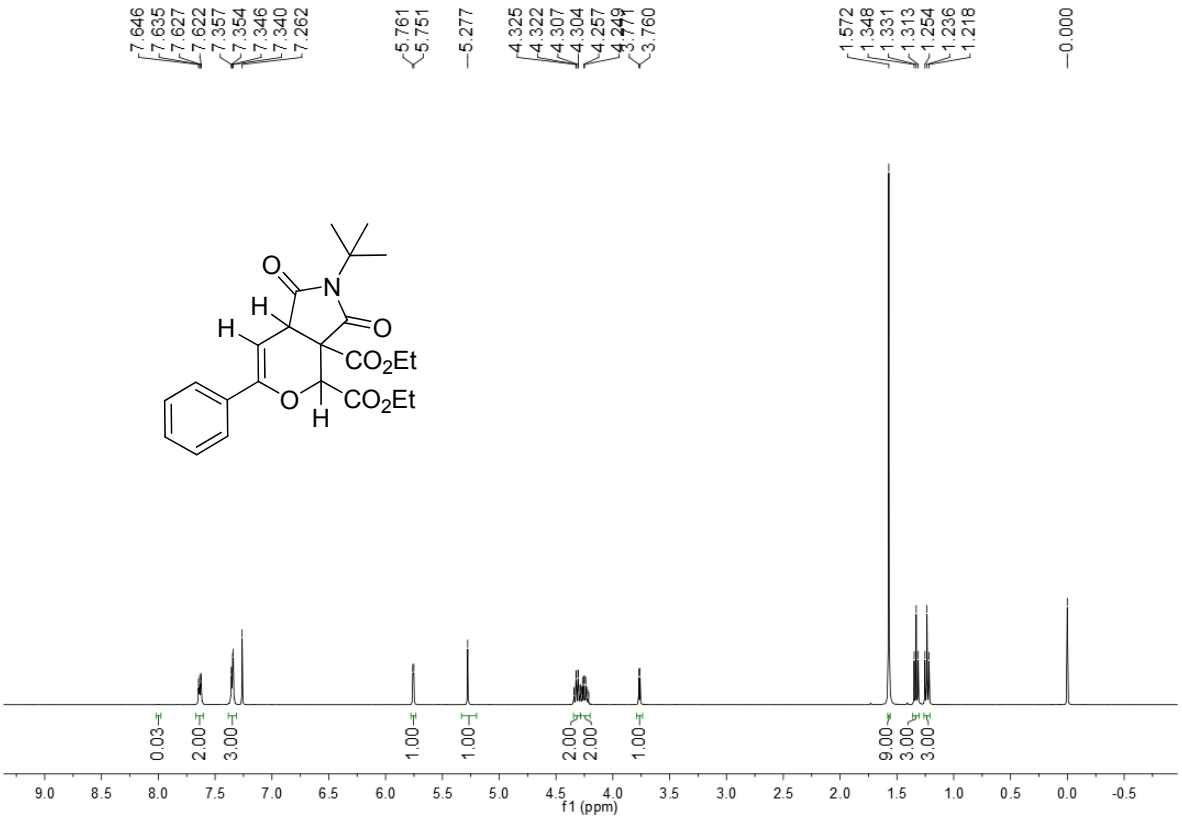
^{13}C NMR Spectrum of Compound 4d



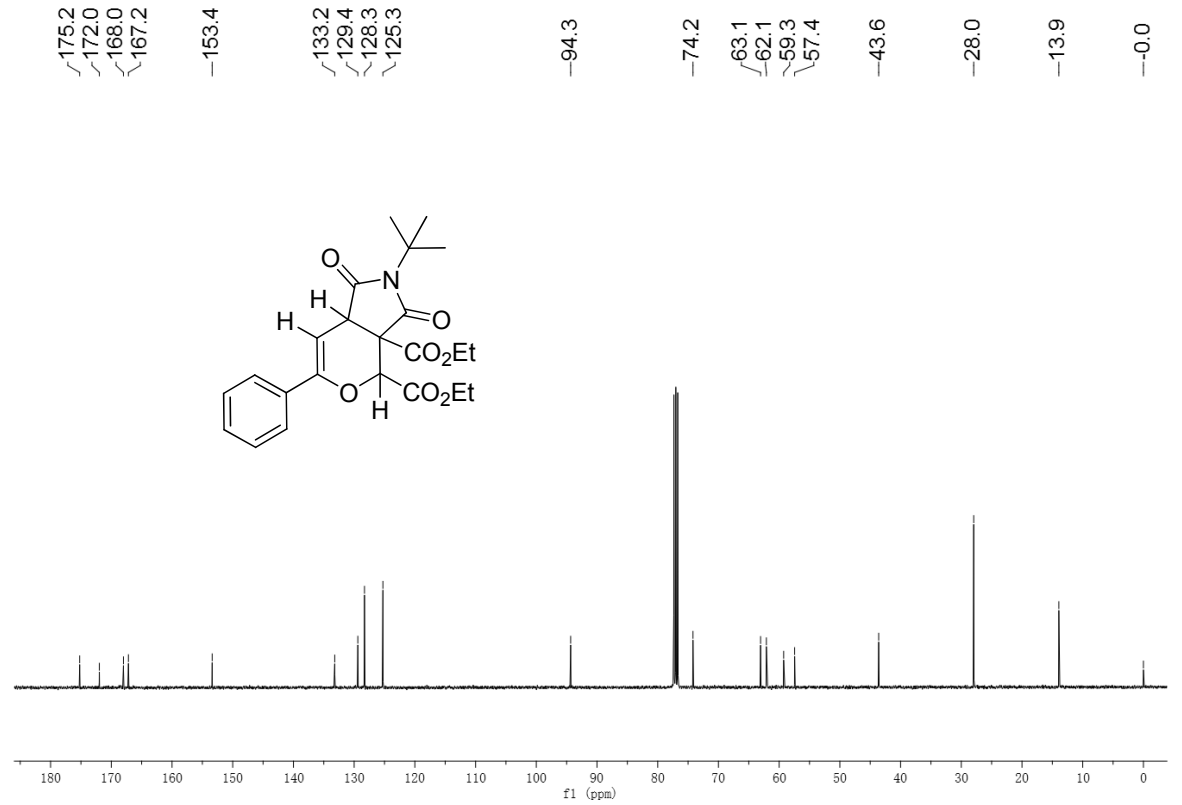
^{1}H NMR Spectrum of Compound 4e



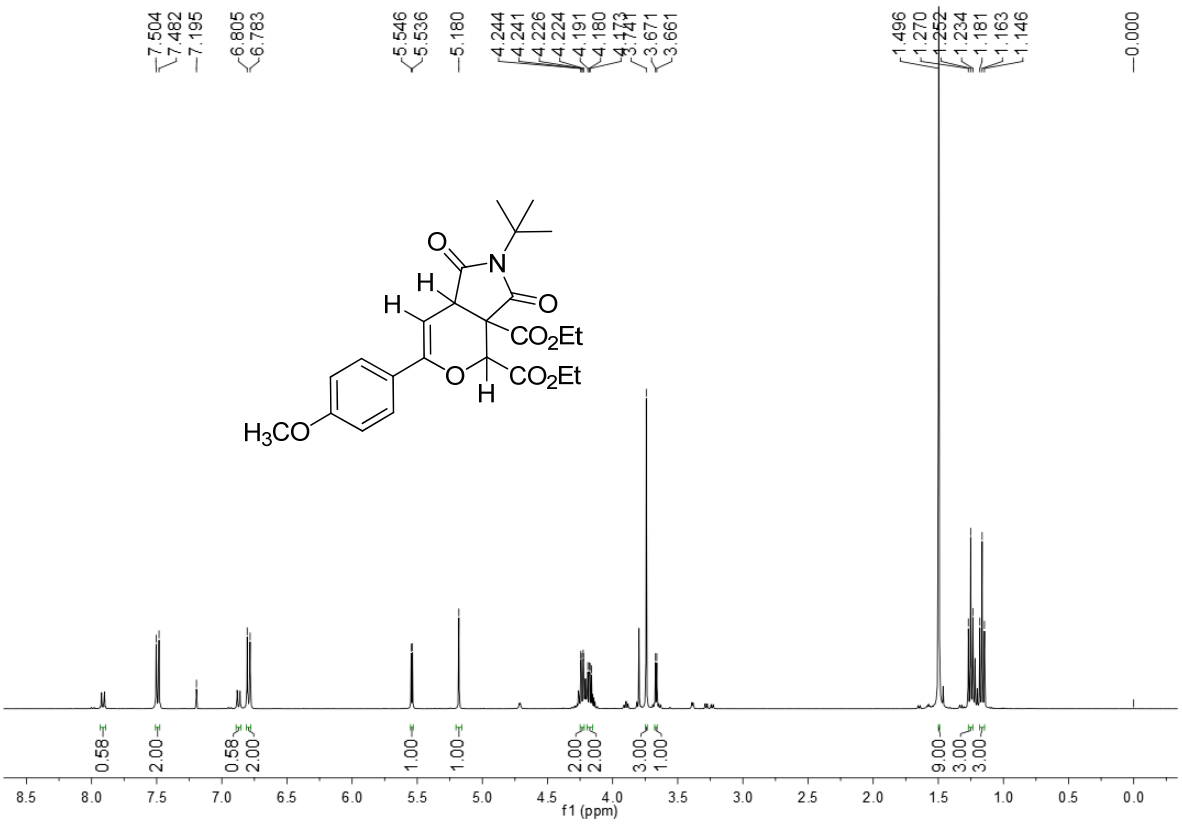
^{13}C NMR Spectrum of Compound 4e



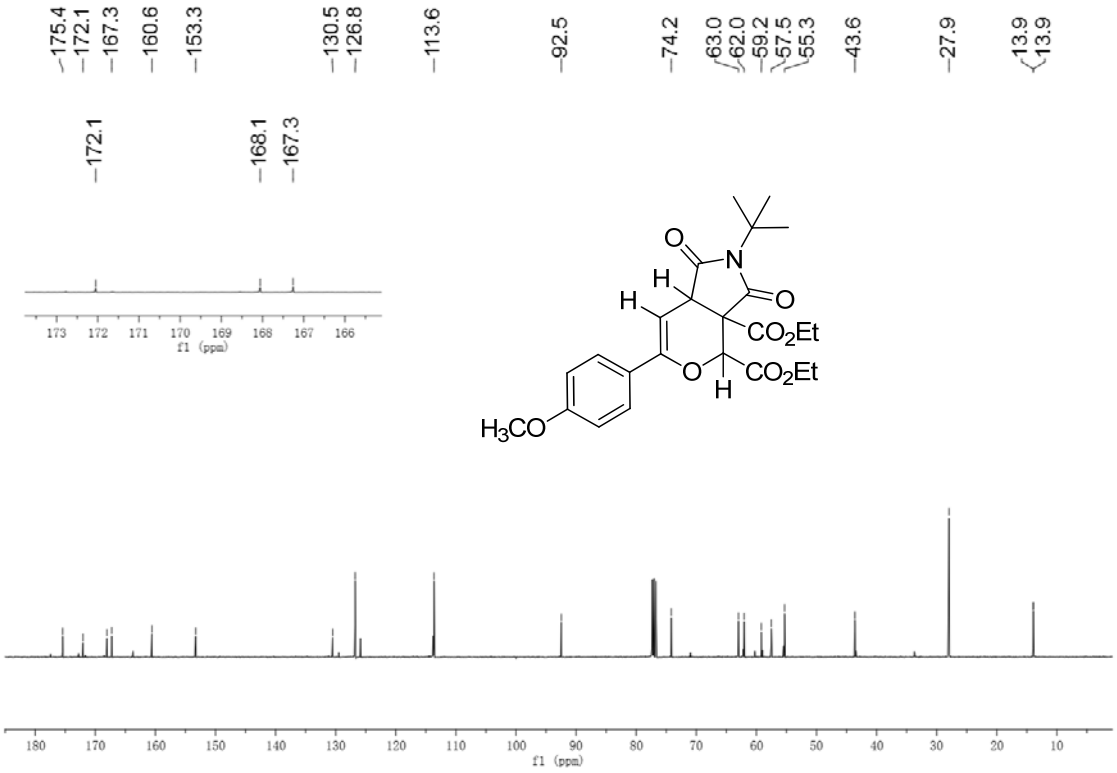
^{1}H NMR Spectrum of Compound 4f



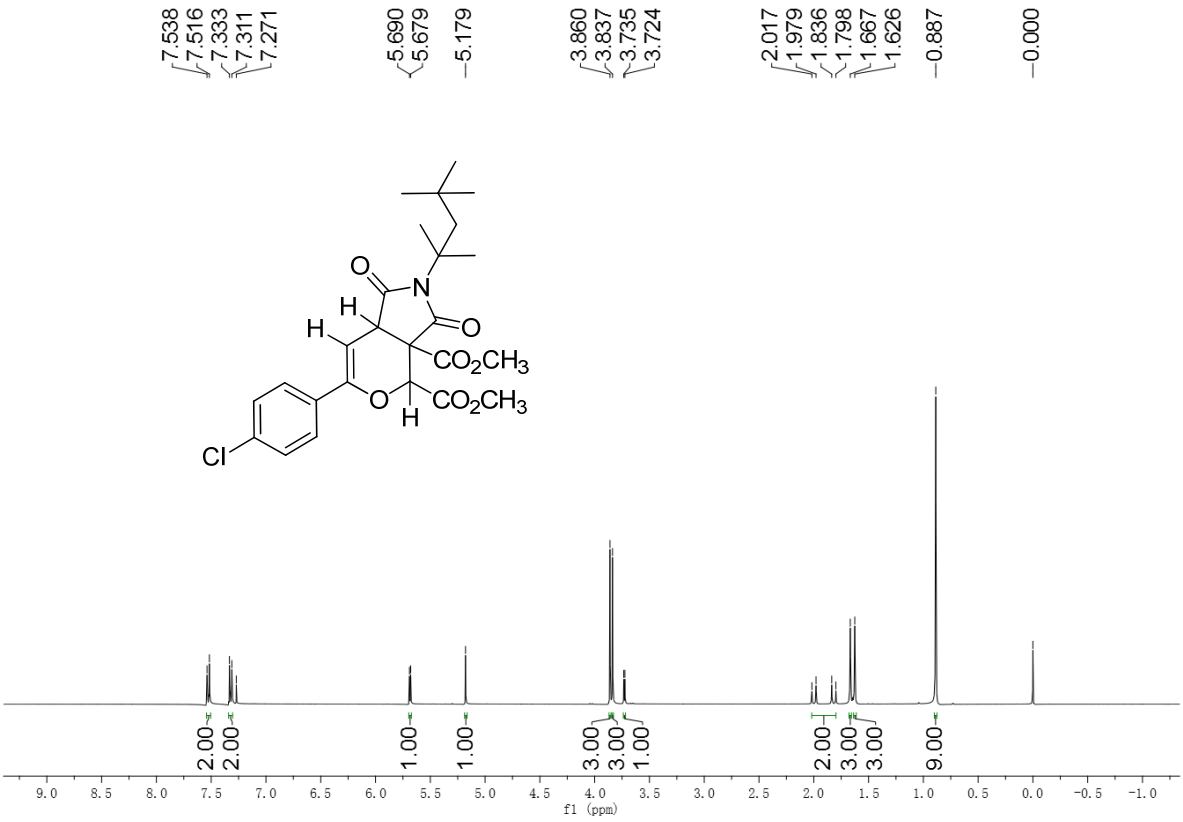
^{13}C NMR Spectrum of Compound 4f



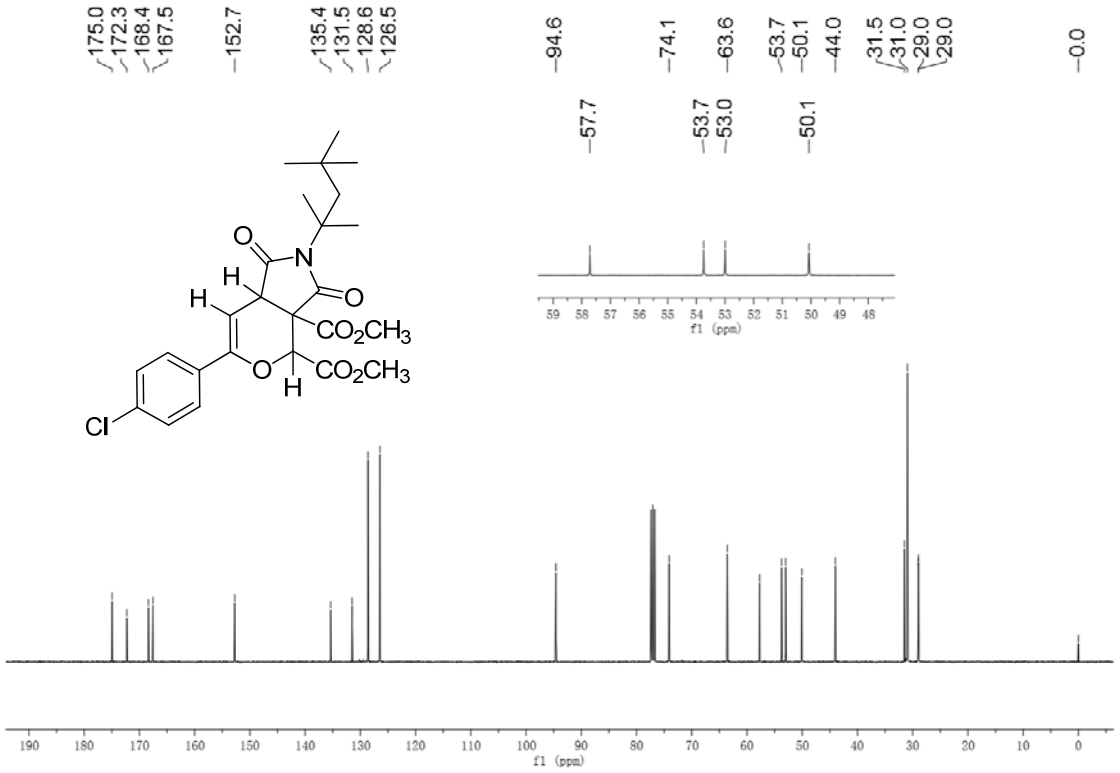
^{1}H NMR Spectrum of Compound 4g



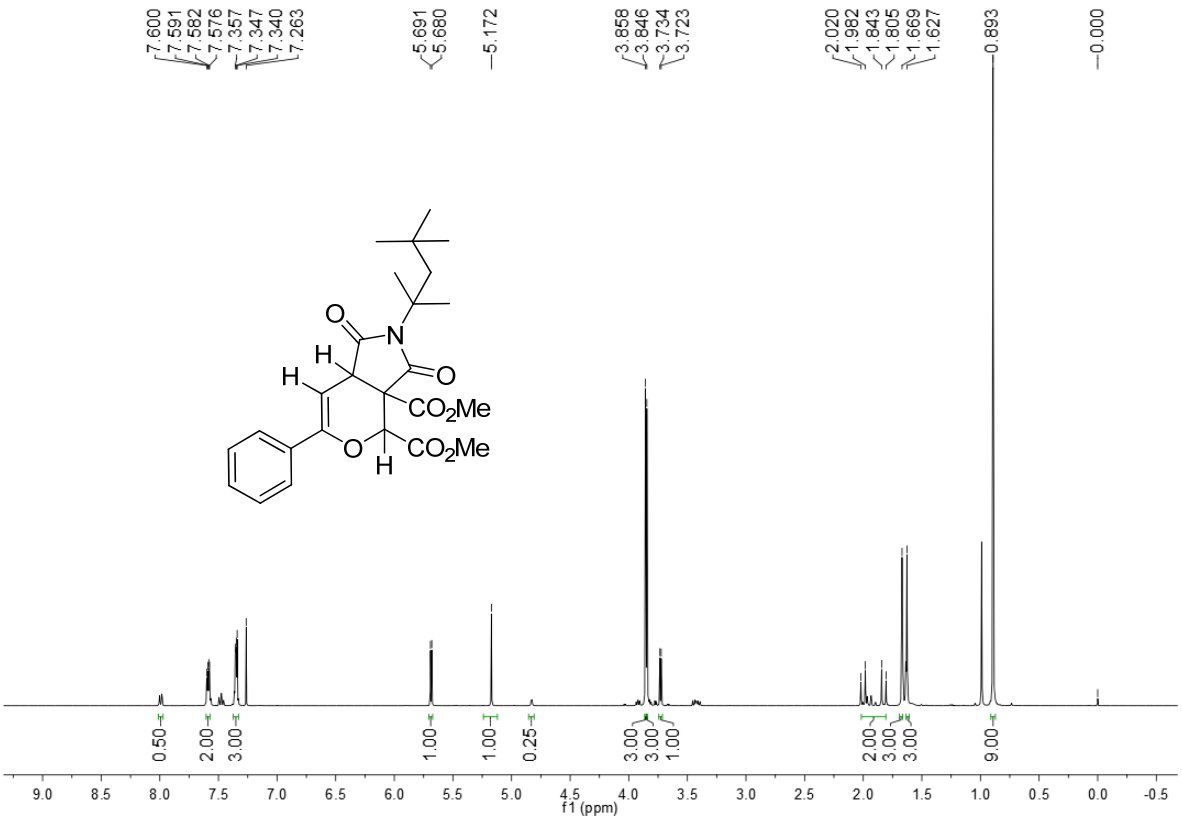
^{13}C NMR Spectrum of Compound 4g



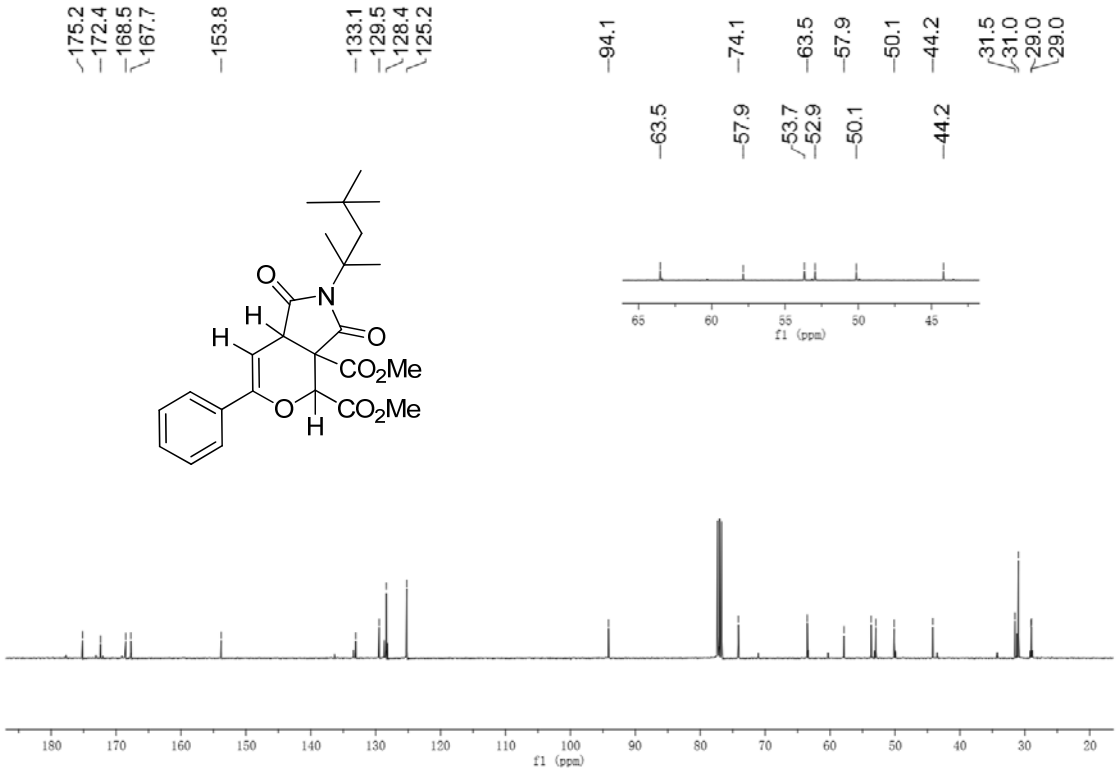
^{1}H NMR Spectrum of Compound 4h



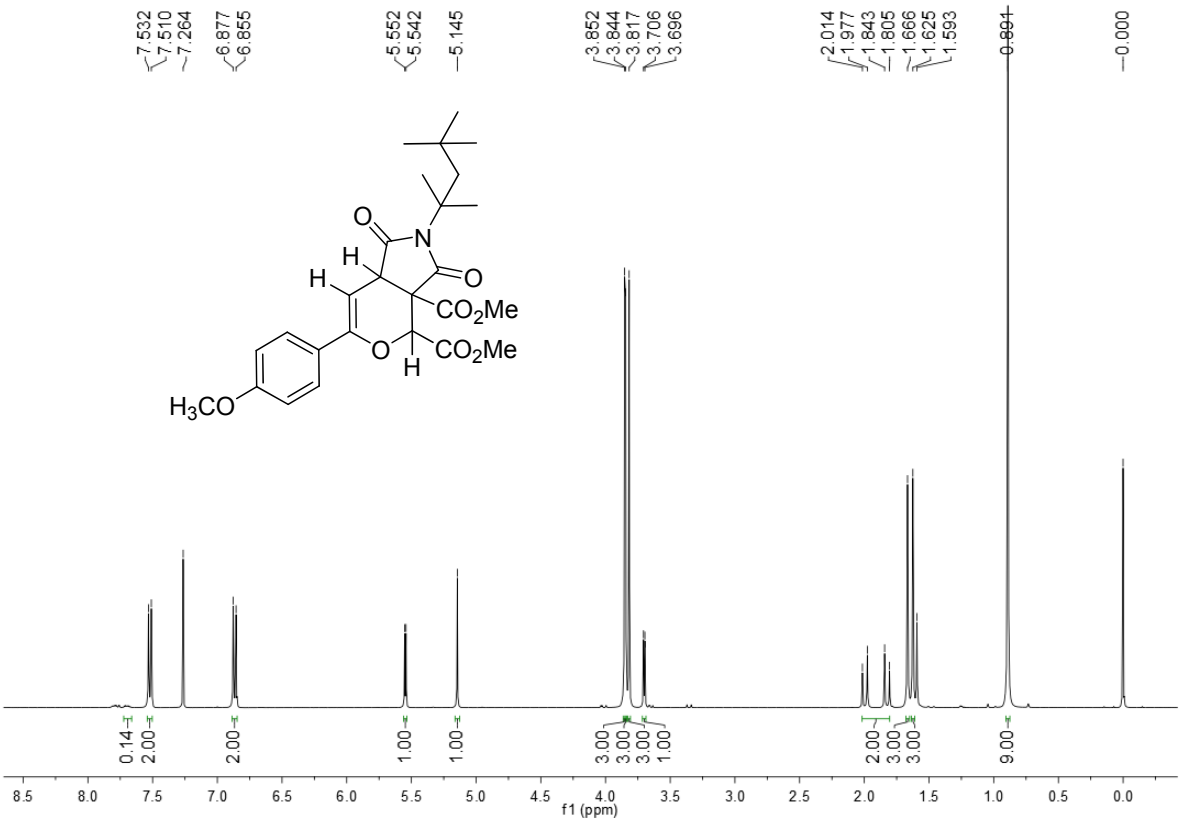
^{13}C NMR Spectrum of Compound 4h



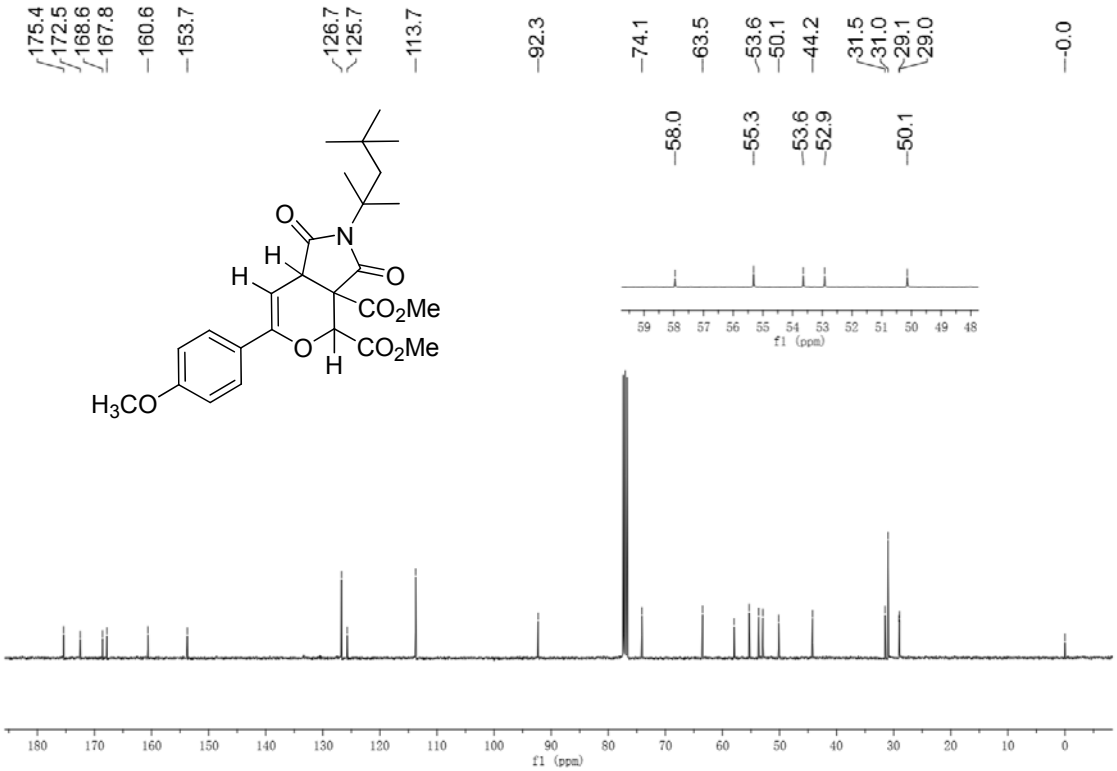
[1]H NMR Spectrum of Compound 4i



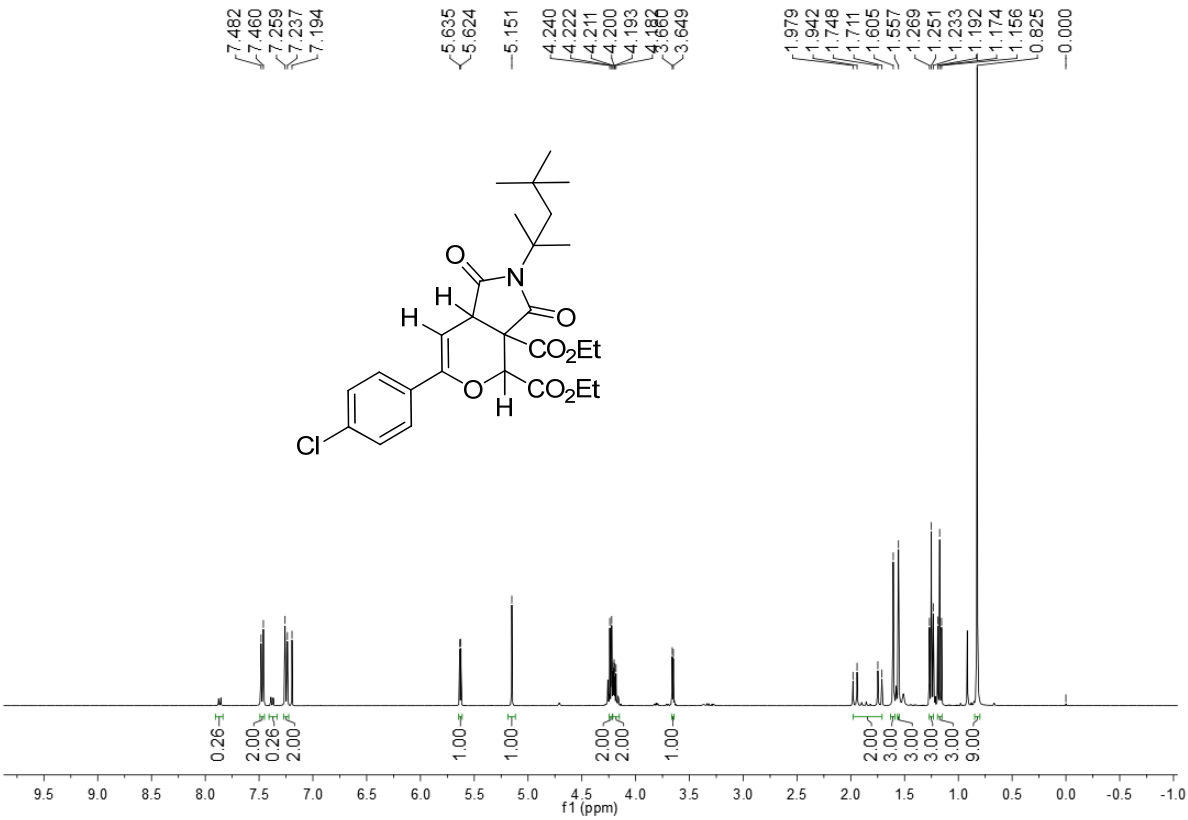
[13]C NMR Spectrum of Compound 4i



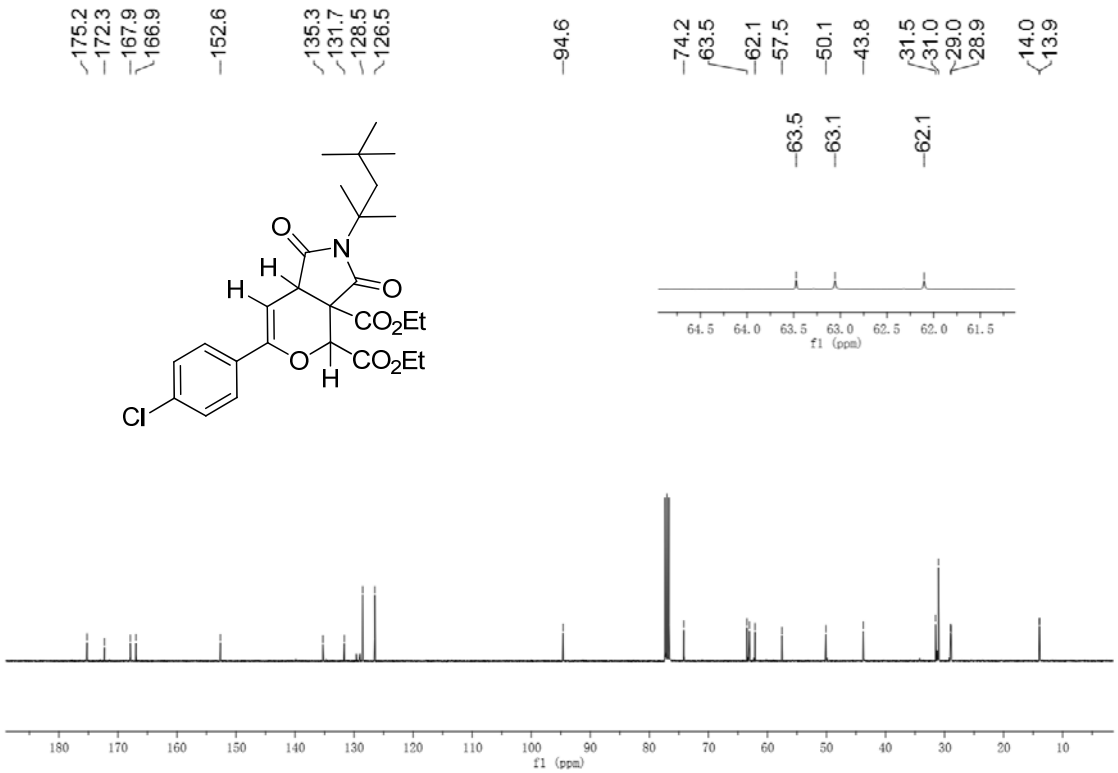
[1]H NMR Spectrum of Compound 4j



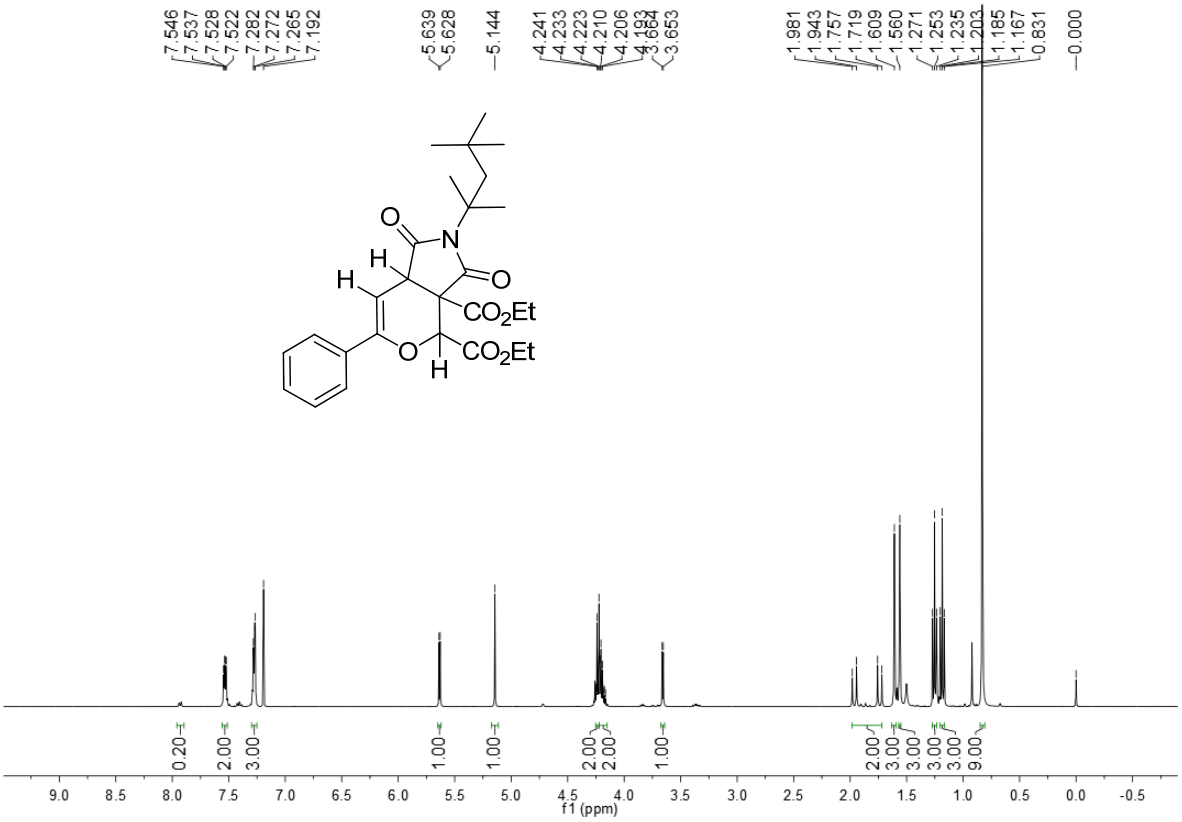
[13]C NMR Spectrum of Compound 4j



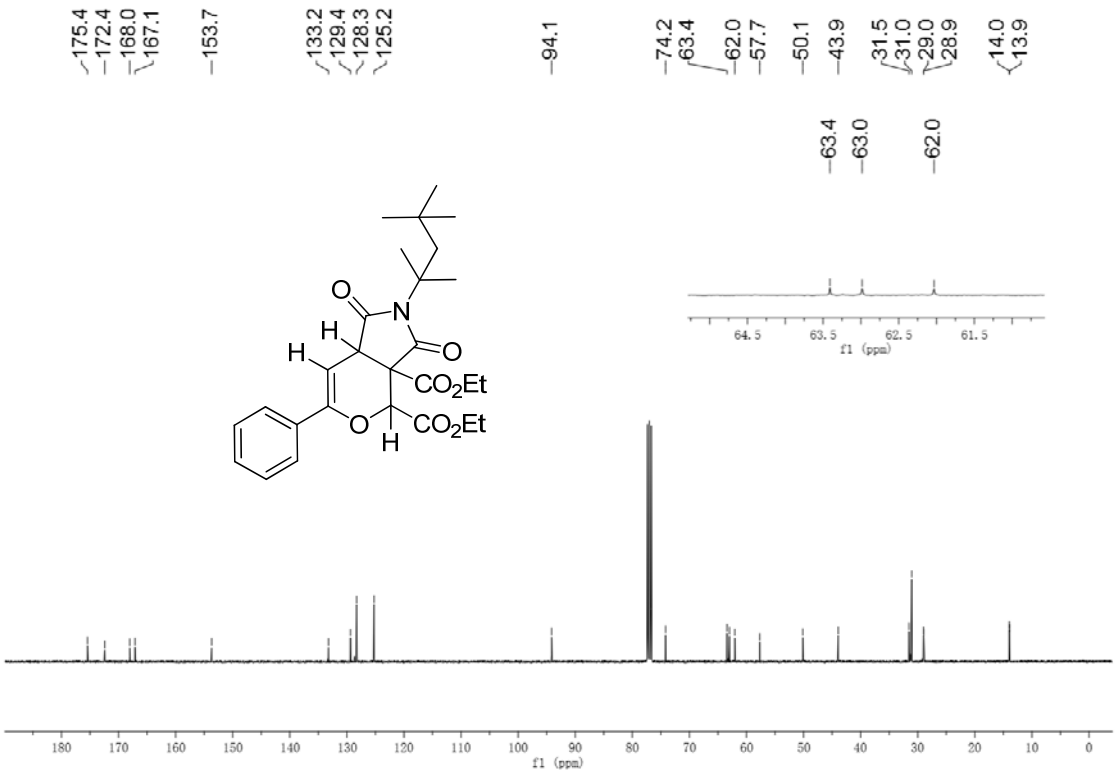
^{1}H NMR Spectrum of Compound 4k



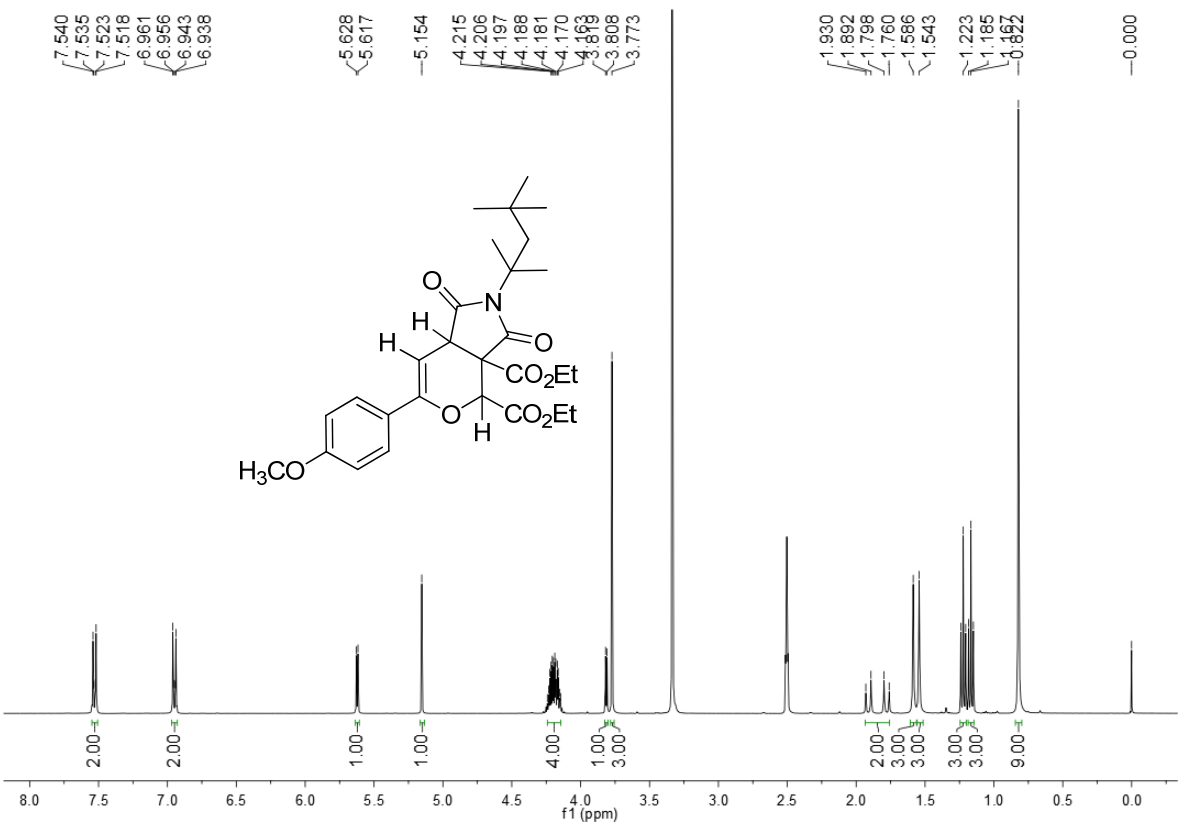
^{13}C NMR Spectrum of Compound 4k



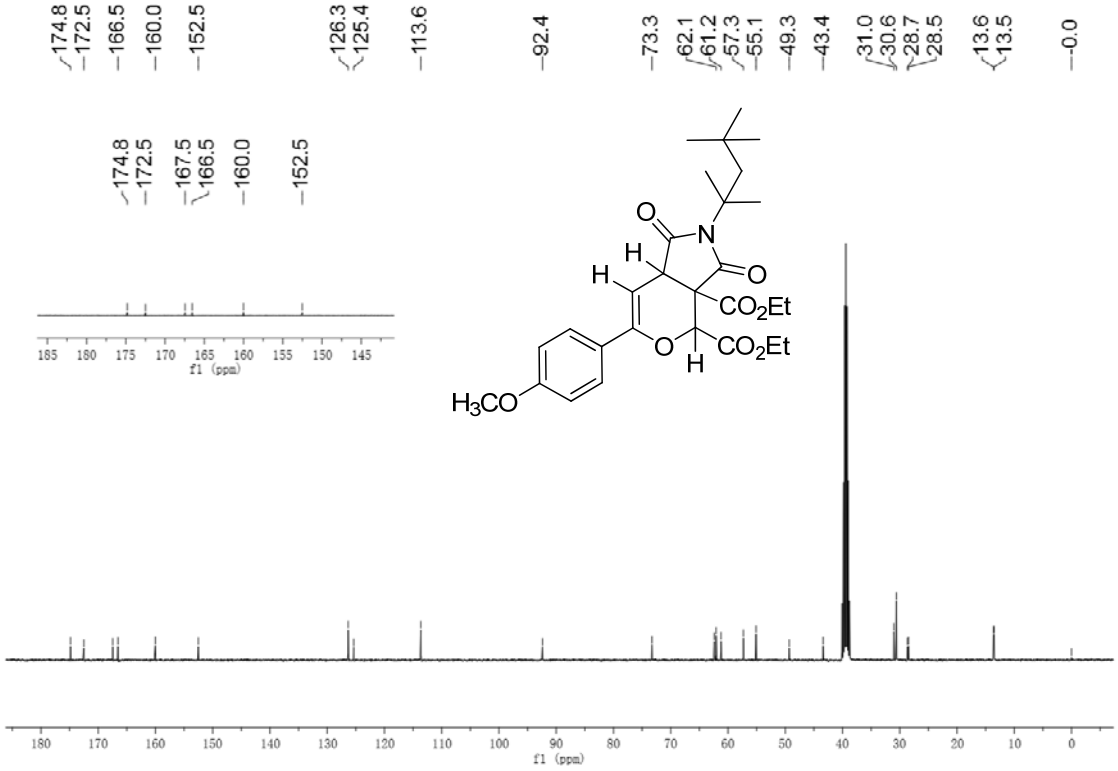
^{1}H NMR Spectrum of Compound 4l



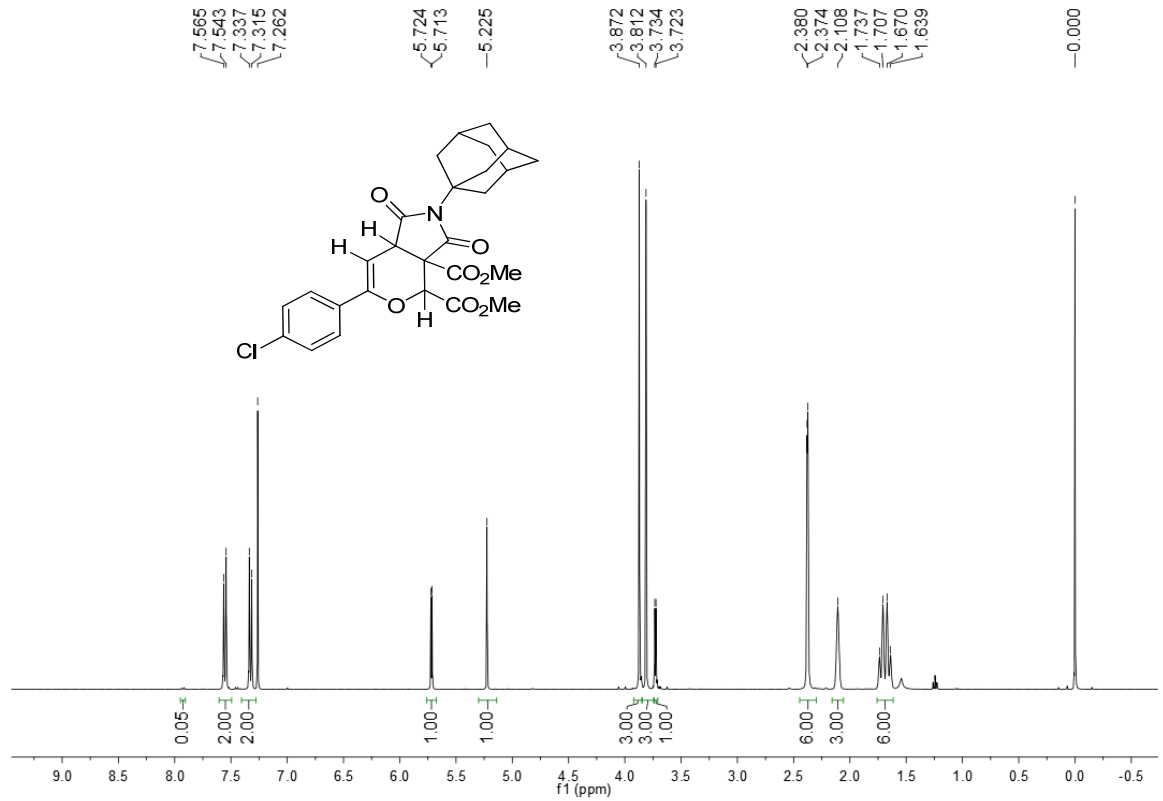
^{13}C NMR Spectrum of Compound 4l



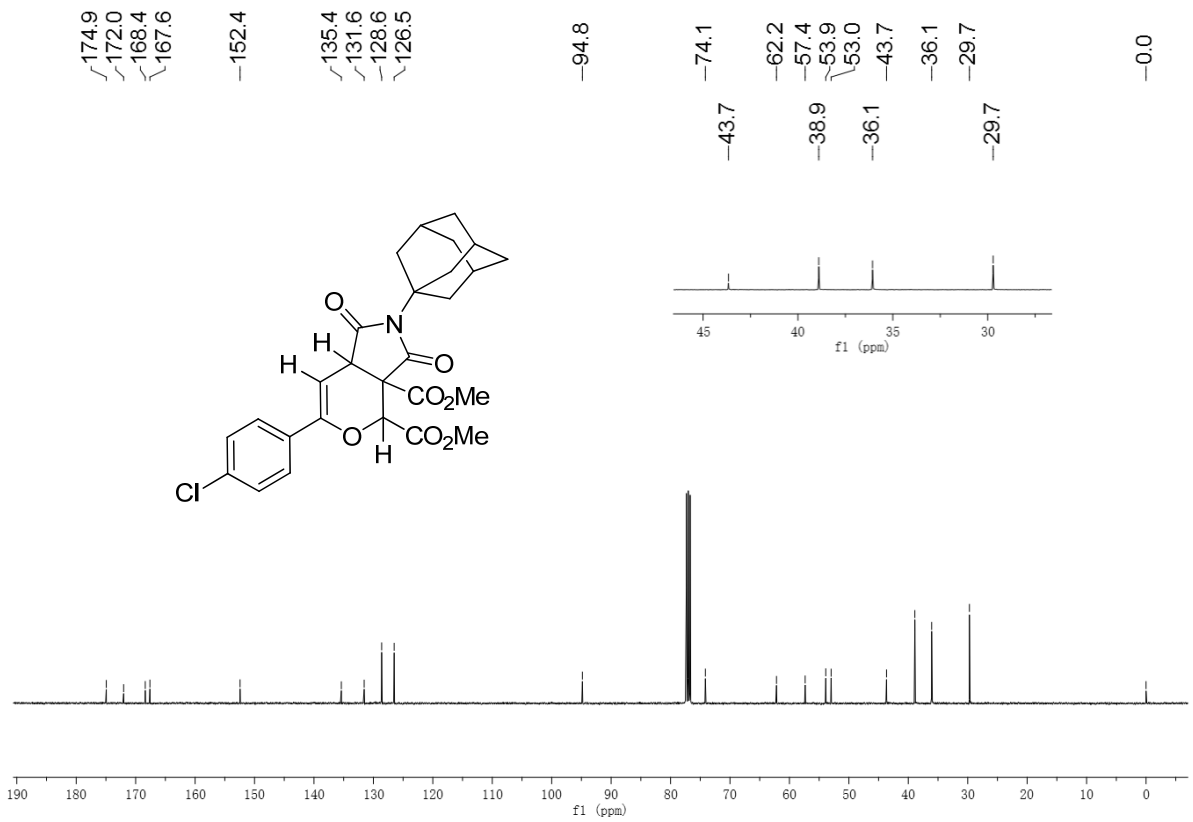
^{1}H NMR Spectrum of Compound 4m



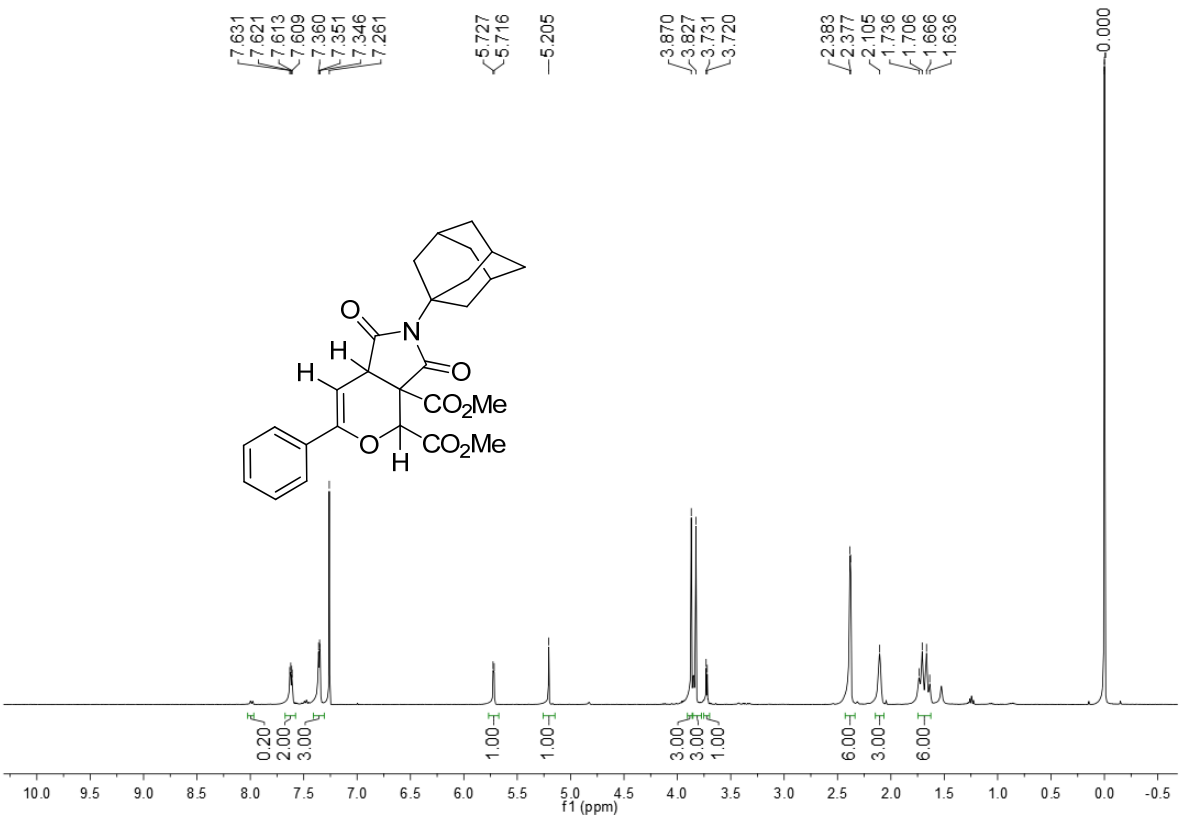
^{13}C NMR Spectrum of Compound 4m



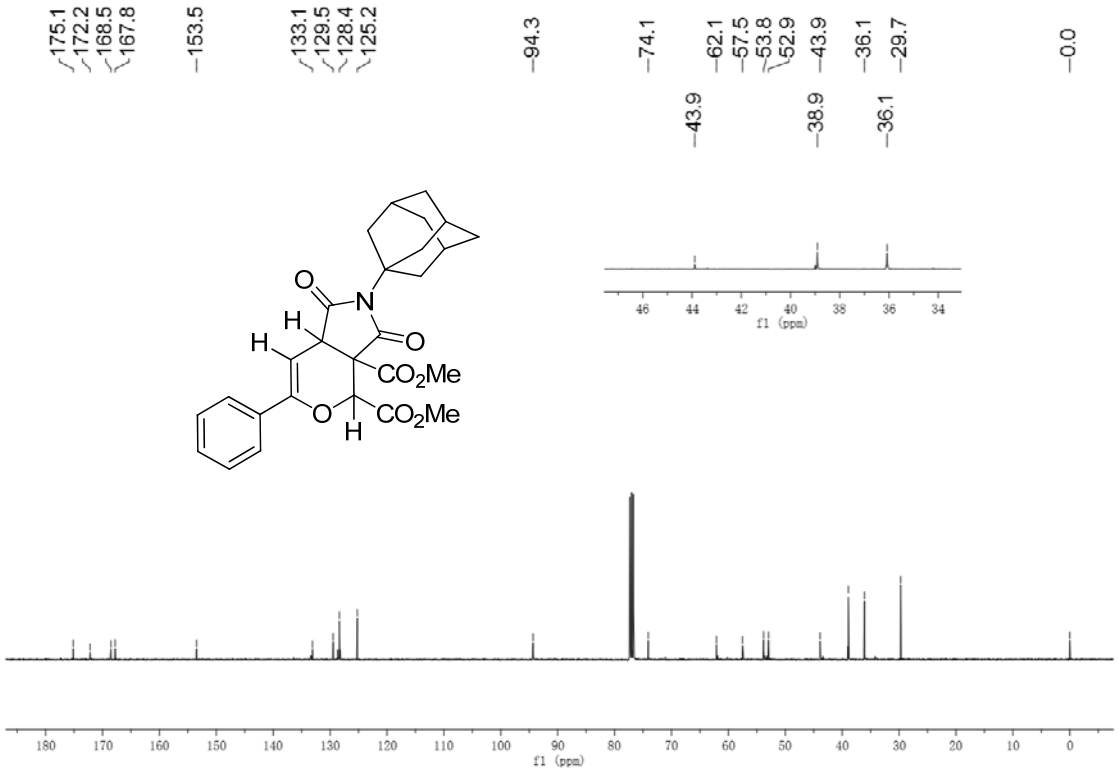
^{1}H NMR Spectrum of Compound 4n



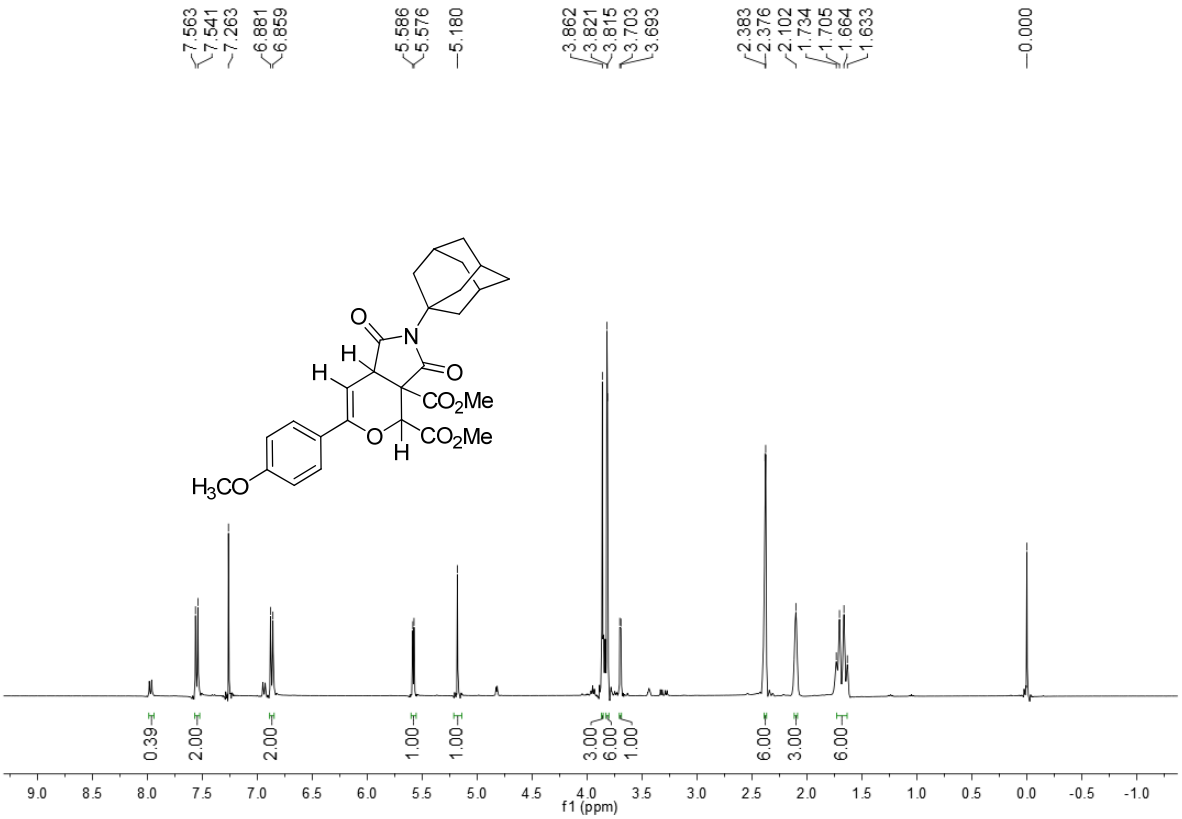
^{13}C NMR Spectrum of Compound 4n



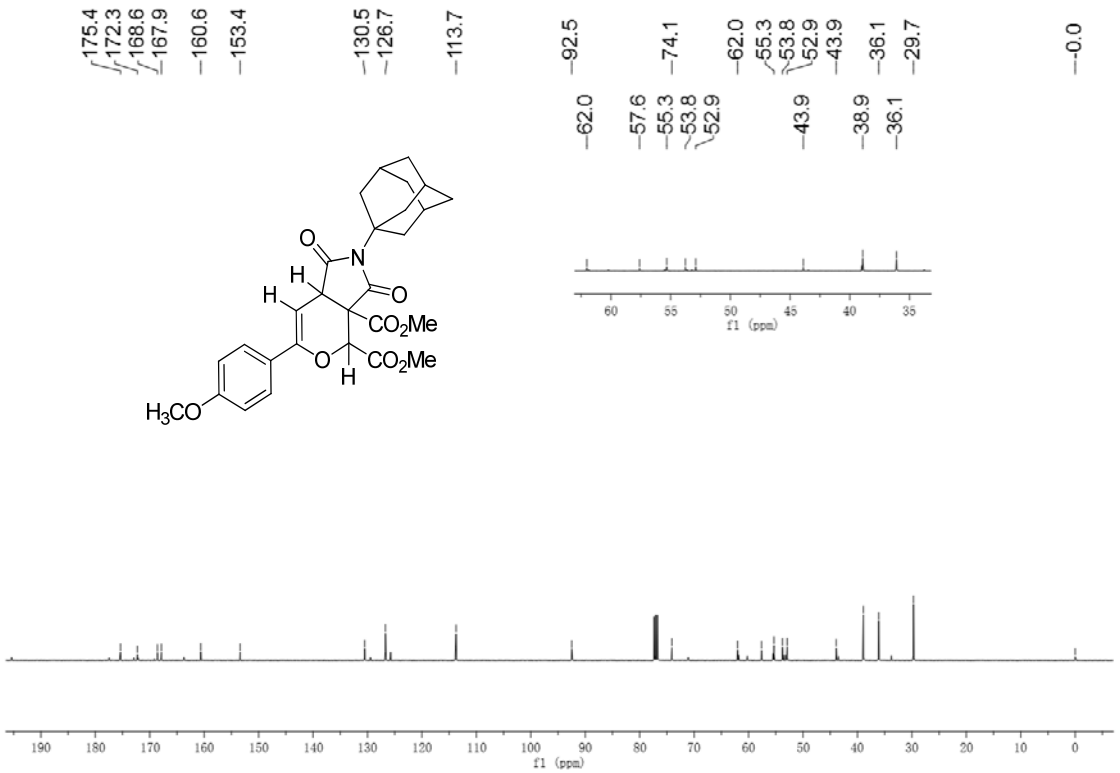
^{1}H NMR Spectrum of Compound 4o



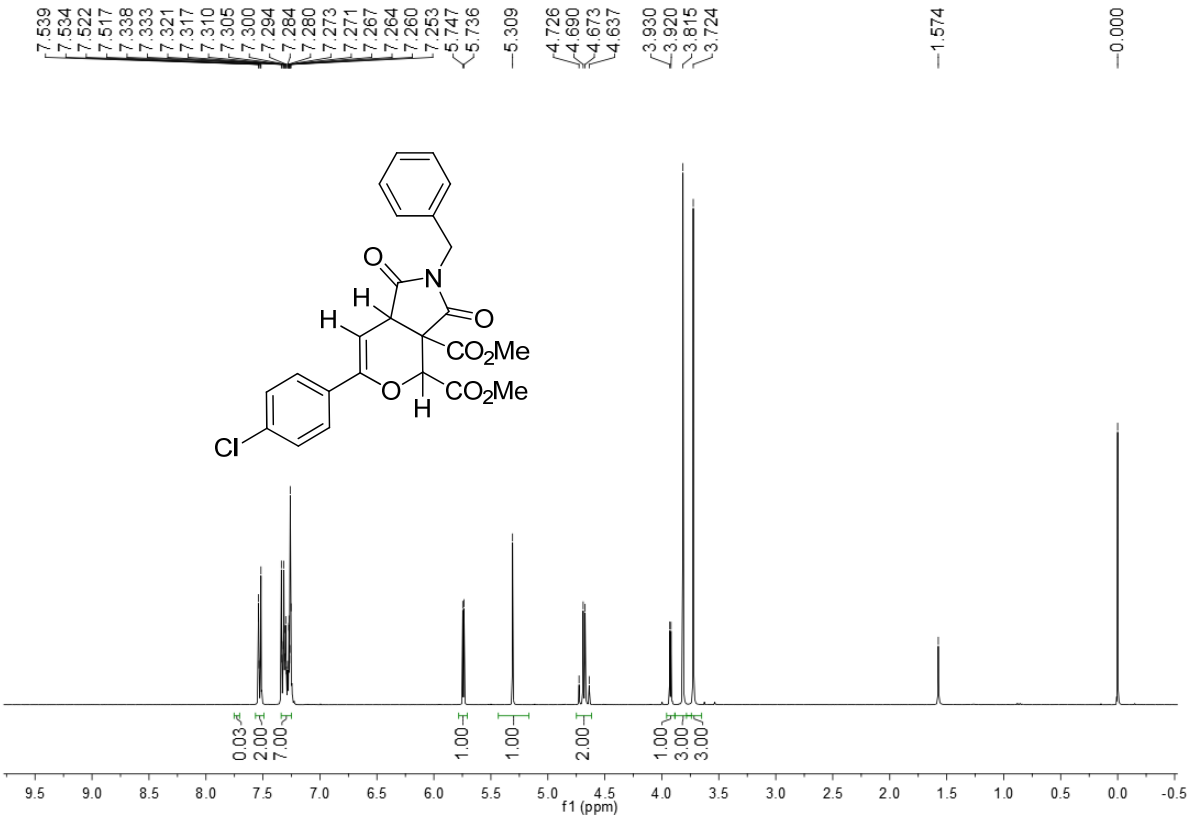
^{13}C NMR Spectrum of Compound 4o



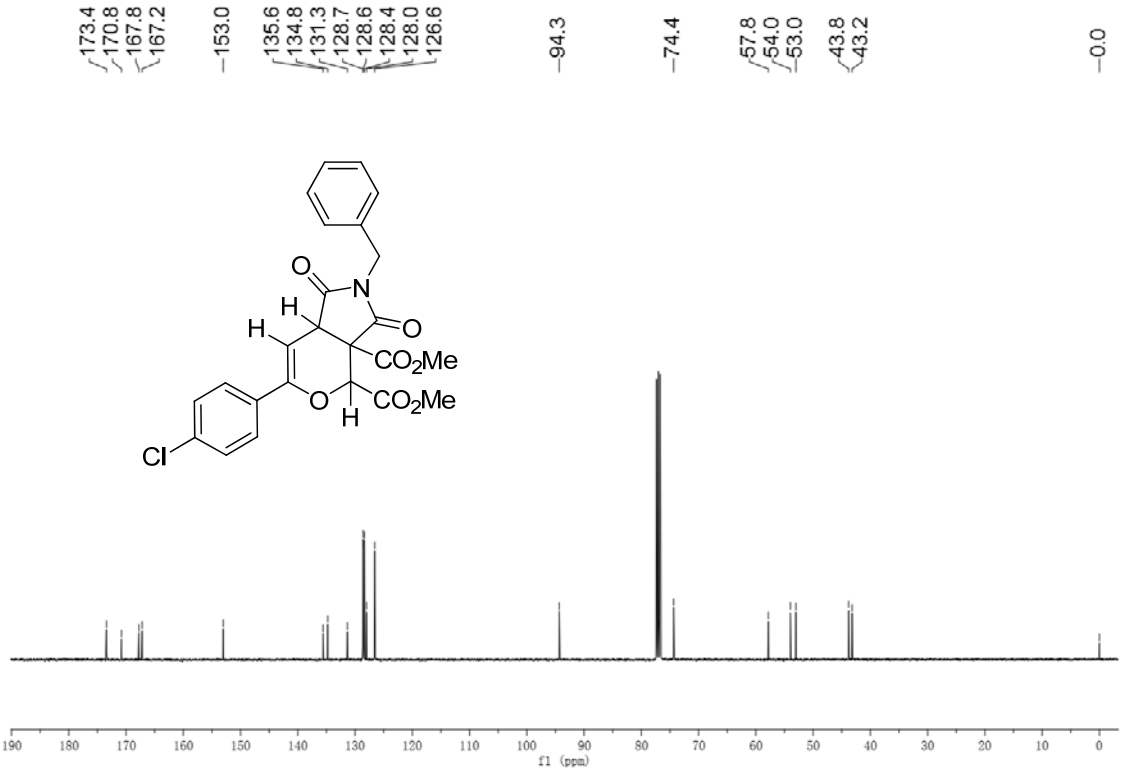
^{1}H NMR Spectrum of Compound 4p



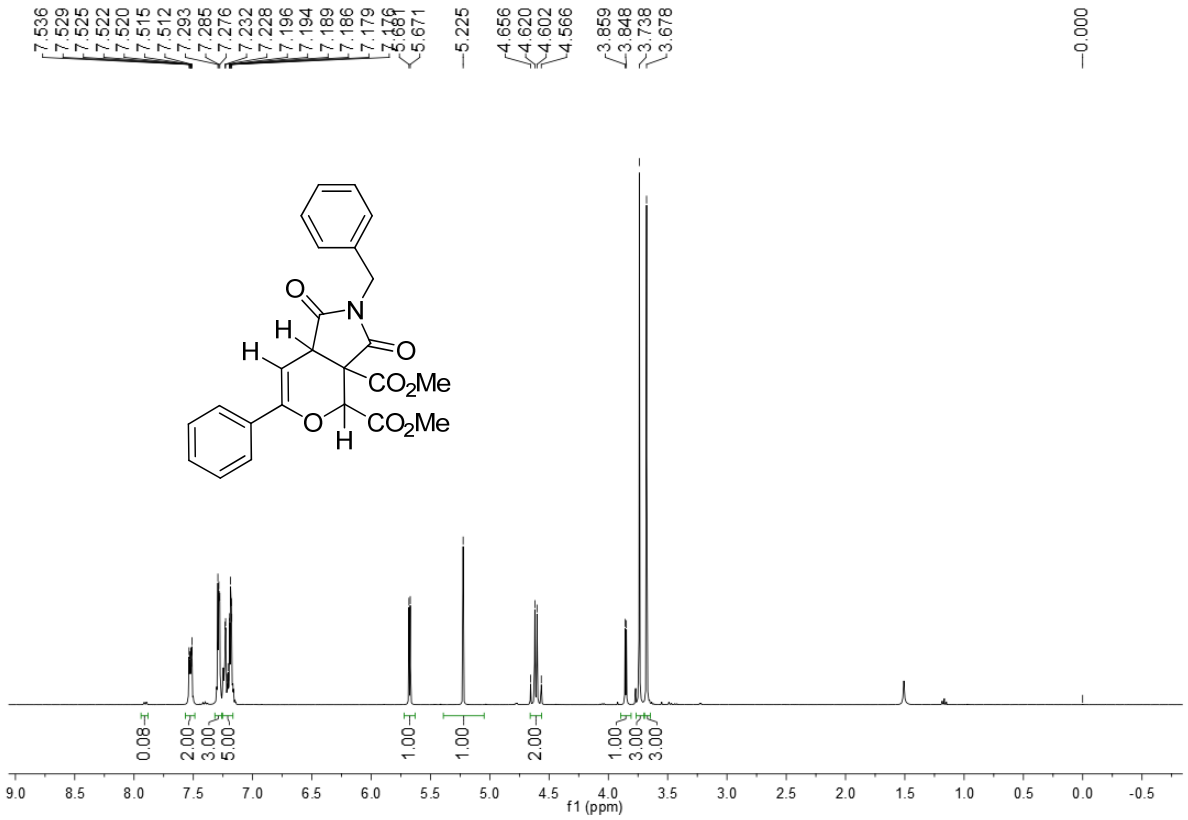
^{13}C NMR Spectrum of Compound 4p



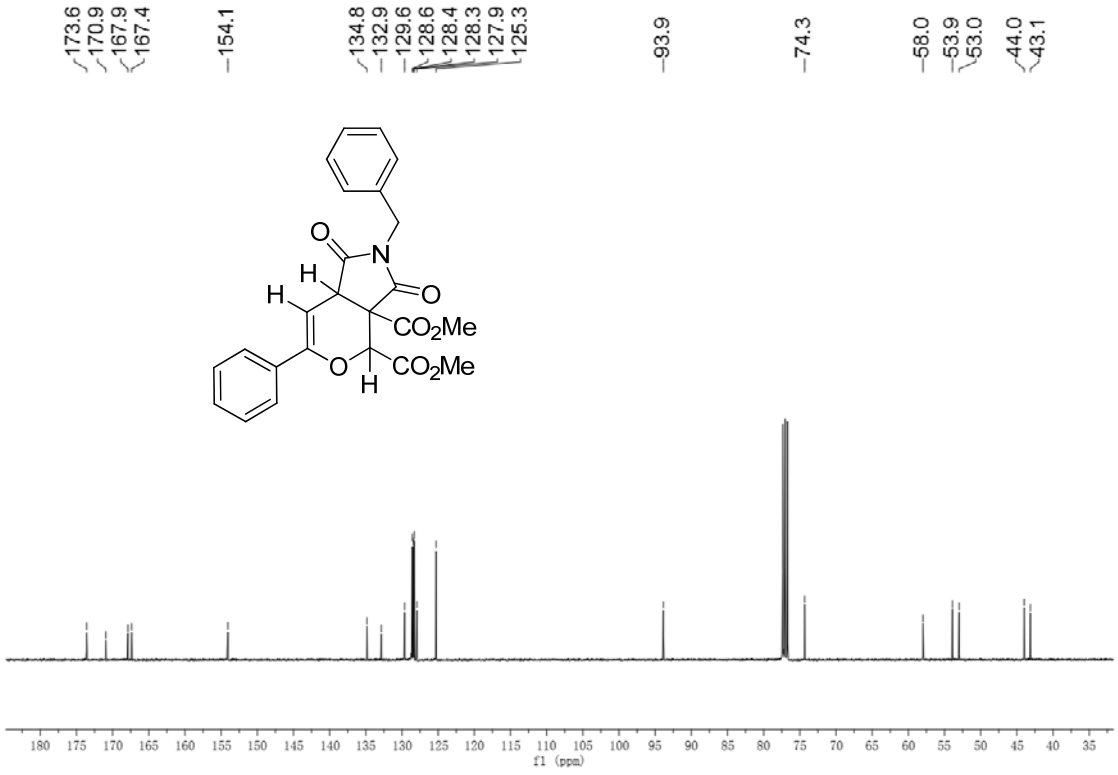
^{1}H NMR Spectrum of Compound 4q



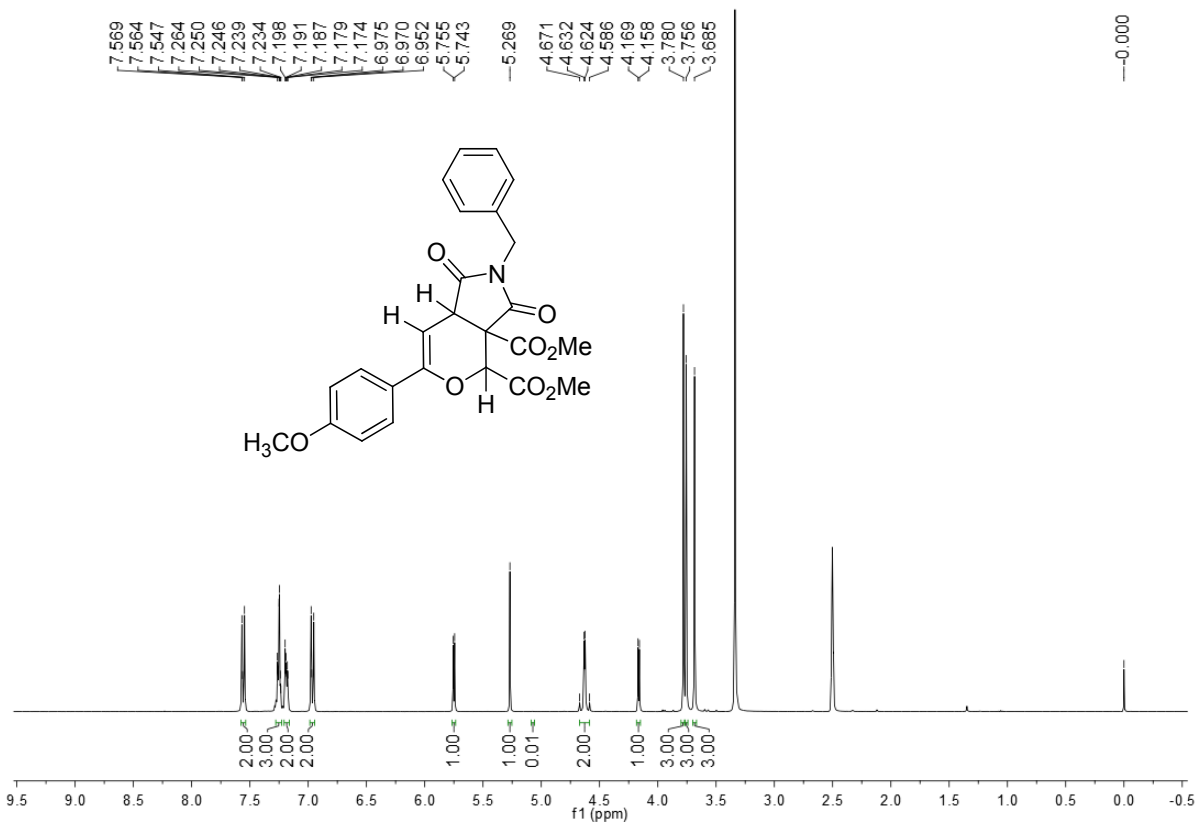
^{13}C NMR Spectrum of Compound 4q



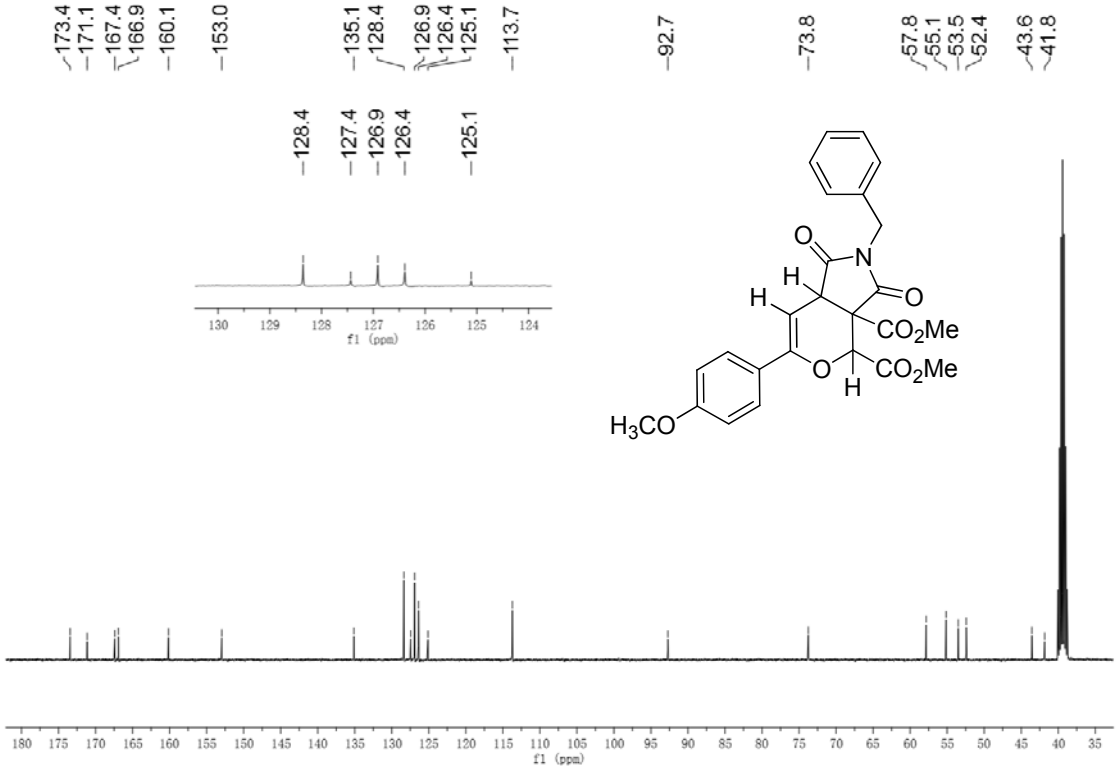
^{1}H NMR Spectrum of Compound 4r



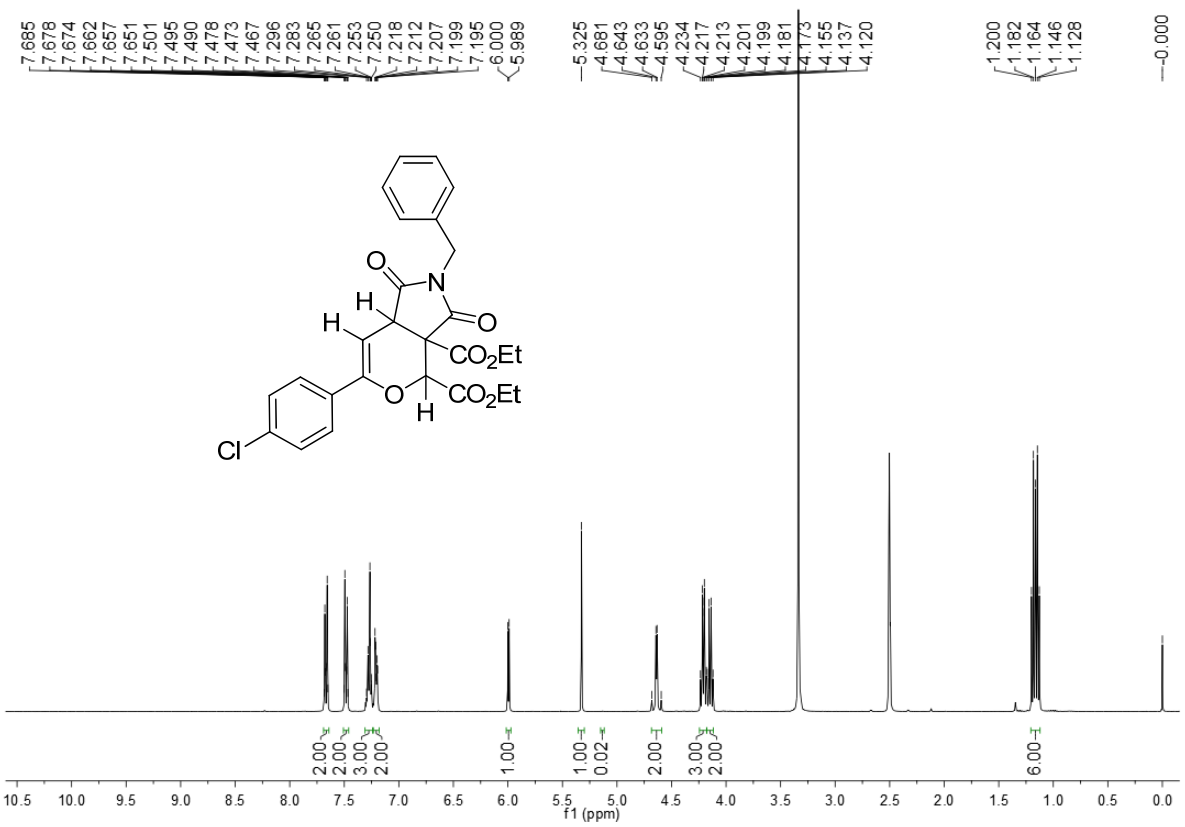
^{13}C NMR Spectrum of Compound 4r



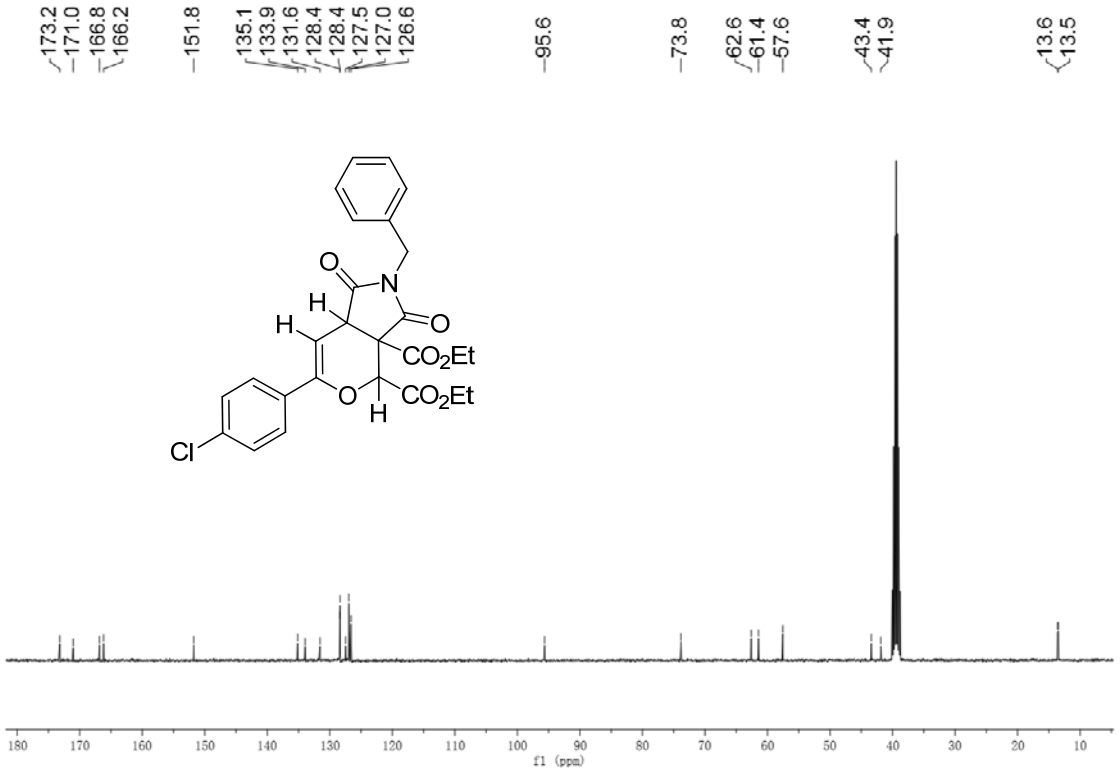
[1]H NMR Spectrum of Compound 4s



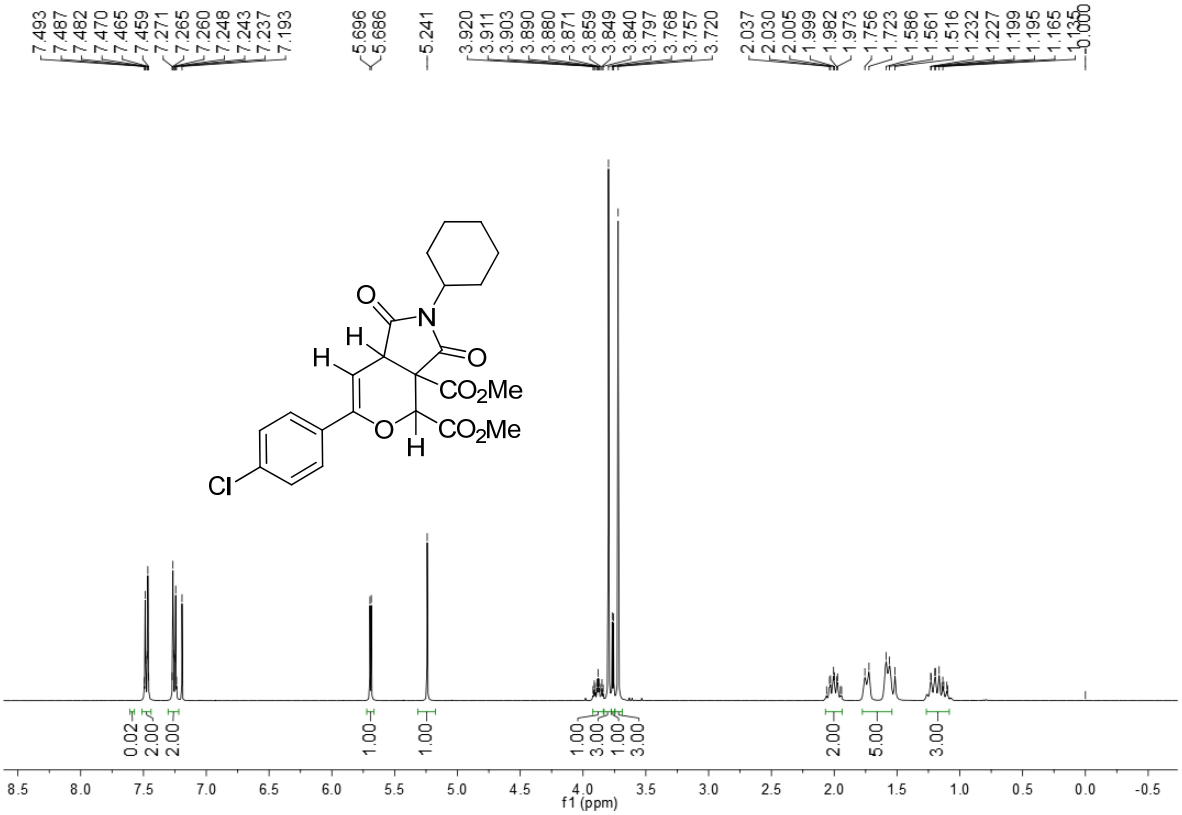
[13]C NMR Spectrum of Compound 4s



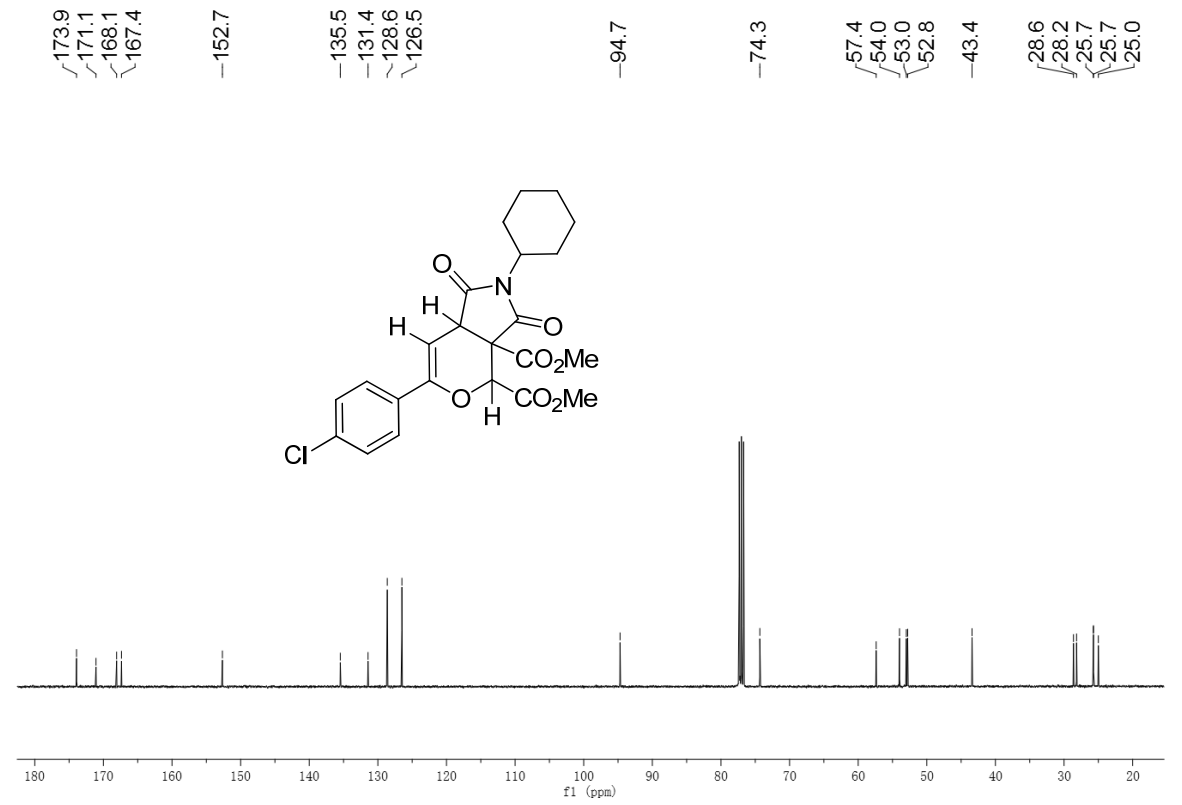
^{1}H NMR Spectrum of Compound 4t



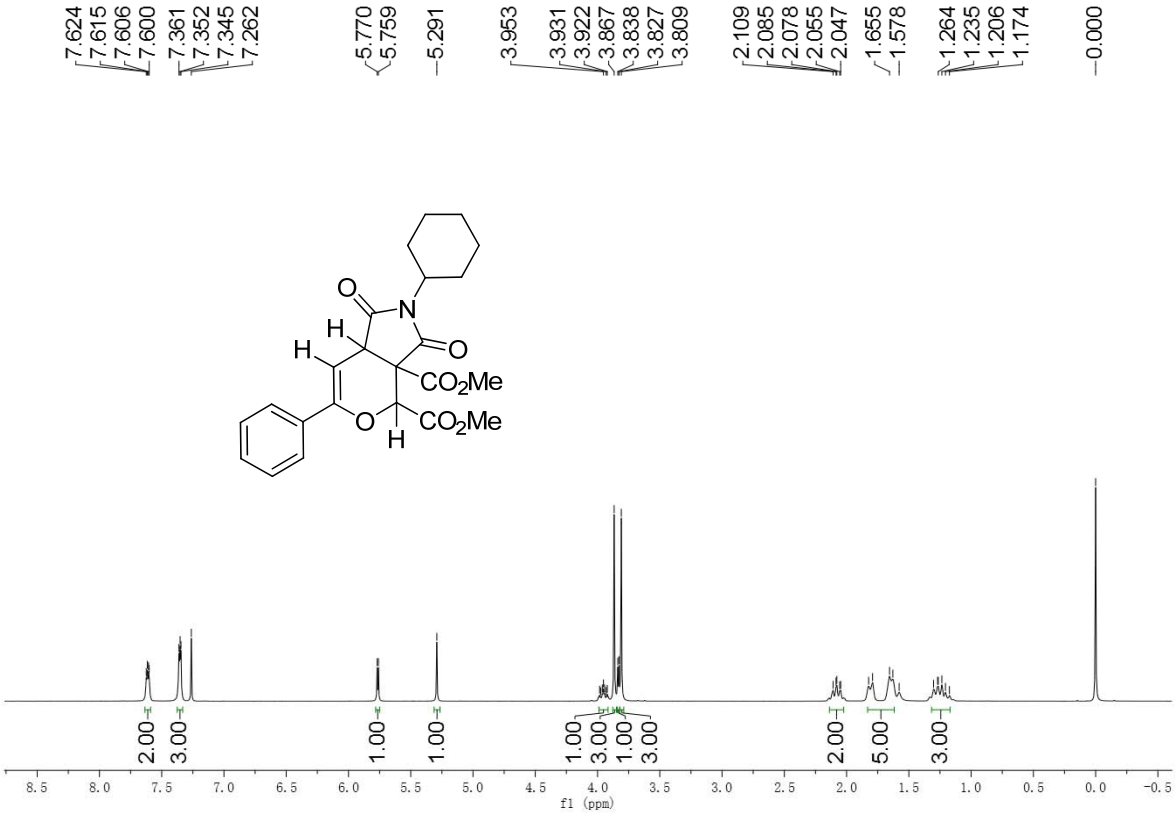
^{13}C NMR Spectrum of Compound 4t



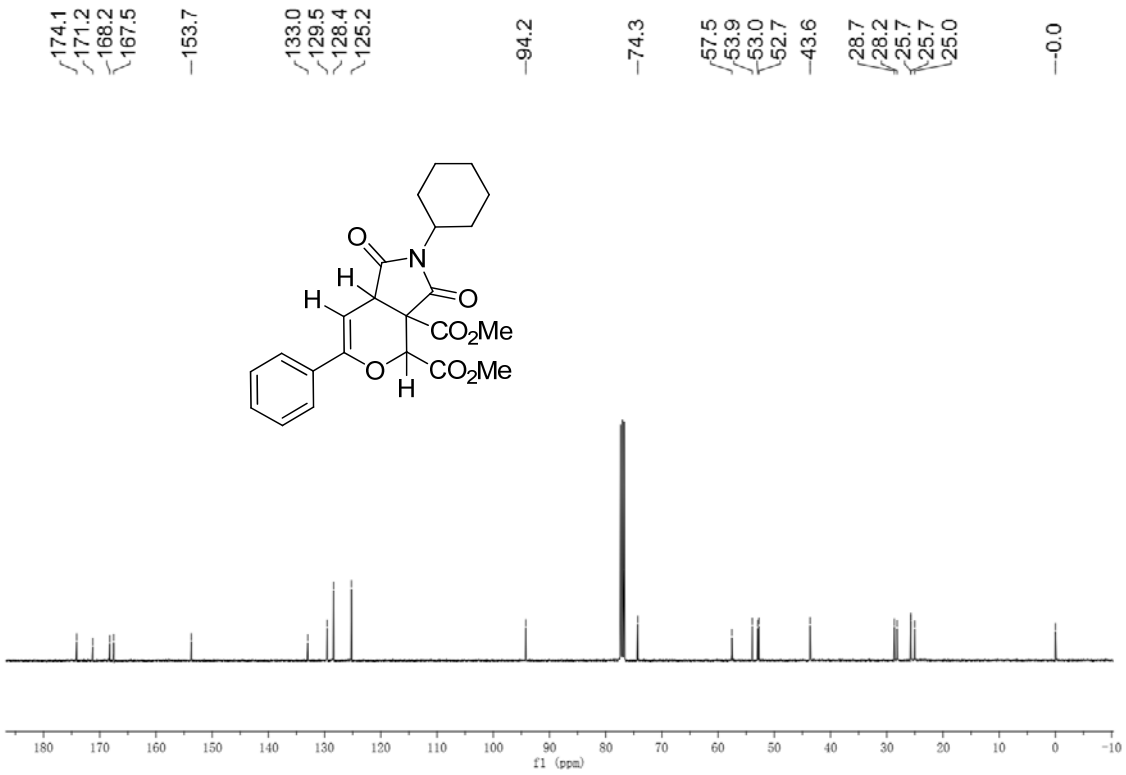
^{1}H NMR Spectrum of Compound 4u



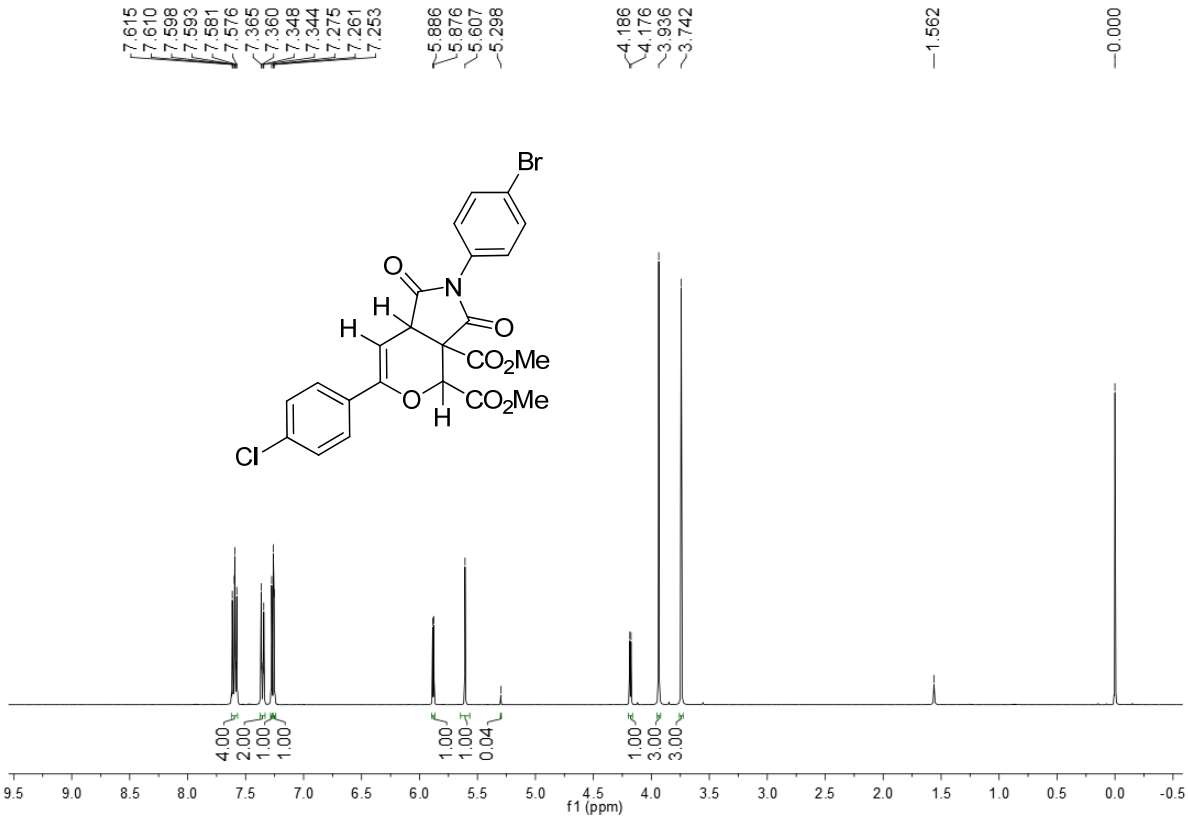
^{13}C NMR Spectrum of Compound 4u



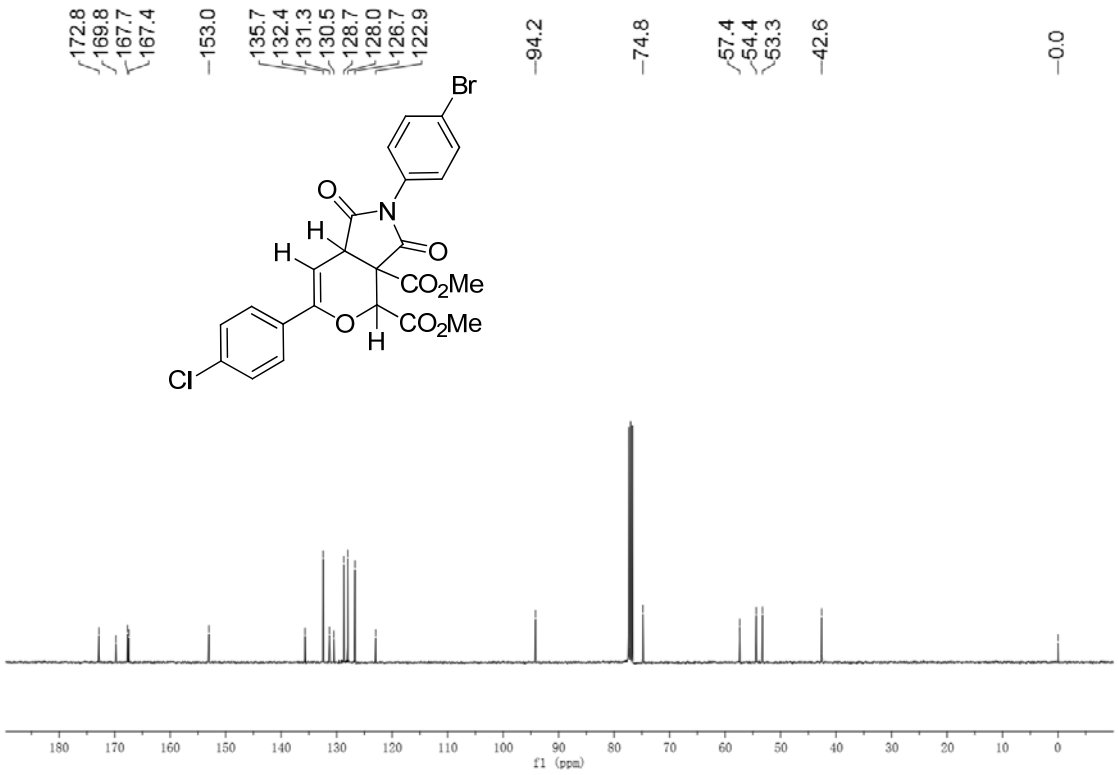
^{1}H NMR Spectrum of Compound 4v



^{13}C NMR Spectrum of Compound 4v



^{1}H NMR Spectrum of Compound 4w



^{13}C NMR Spectrum of Compound 4w