Unprecedented formation of spiro[indoline-3,7'-pyrrolo[1,2-a]azepine] via multicomponent reaction of L-proline, isatin and two molecular but-2-ynedioates

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Supporting Information

HRMS were measured at Bruker UHR-TOF maXis spectrometer. X-ray data were collected on a Bruker Smart APEX-2 diffractometer.

X-Ray Crystallographic Data: CIF in separate file.

Crystallographic data **1a** (CCDC 1043442), **1k** (CCDC 1043443), **1m** (CCDC 1043444), **2d** (CCDC 1043445) and **2f** (CCDC 1043446) have been deposited at the Cambridge Crystallographic Database Centre (http//www.ccdc.cam.ac.uk).

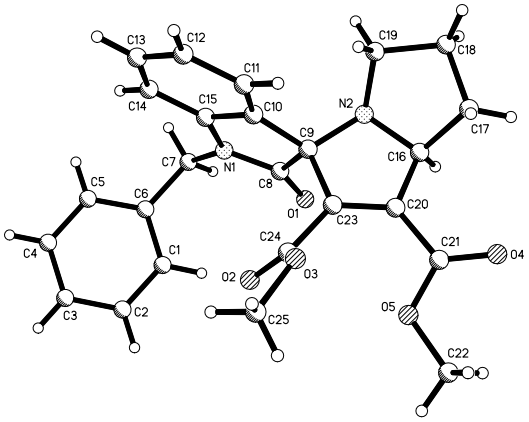


Fig. s1 Molecular structure of compound 1a

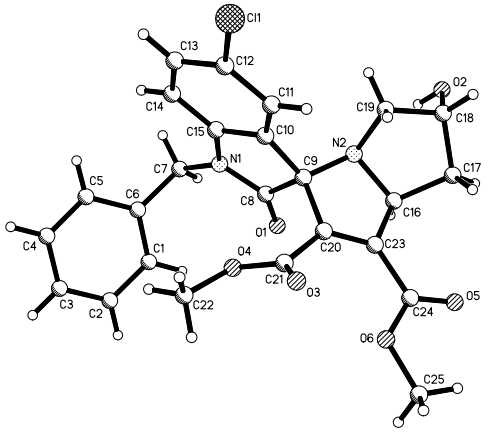


Fig. s2 Molecular structure of compound 1k

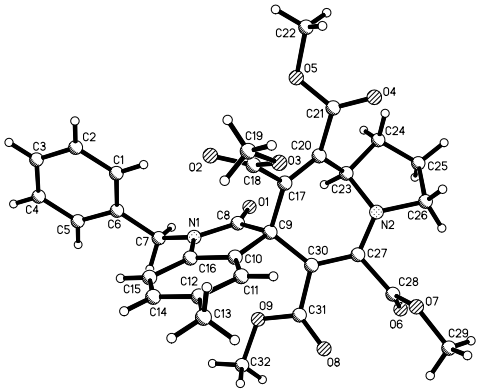


Fig. s3 Molecular structure of compound 2d

1. General procedure for the preparation of spirooxindoles 1a-1m from three-component reactions of α-amino acid, isatin and dialkyl but-2-ynedioate: A mixture of isatin (1.2 mmol), α-amino acid (1.0 mmol) and dialkyl but-2-ynedioate (1.2 mmol) in methanol (15.0 mL) was stirred at room temperature for 24 hours. The solvent was removed under reduced pressure. The resulting oily residue was titrated with ethanol to give the crude product, which was recystallized in a mixture of methylene dichloride and methanol to give the pure product **1a-1m** for analysis.

Dimethyl 2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (**1a**): yellowish solid, 70%, m.p. 154-156 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 10.41 (s, 1H, NH), 7.23 (t, *J* = 7.6 Hz, 1H, ArH), 7.11 (d, *J* = 7.2 Hz, 1H, ArH), 6.96 (t, *J* = 7.6 Hz, 1H, ArH), 6.84 (d, *J* = 7.6 Hz, 1H, ArH), 4.62 (t, *J* = 7.2 Hz, 1H, CH), 3.78 (s, 3H, OCH_3), 3.45 (s, 3H, OCH_3), 2.75-2.69 (m, 1H, CH), 2.47-2.42 (m, 1H, CH), 2.12-2.06 (m, 1H, CH), 1.82-1.73 (m, 2H, CH, CH), 1.71-1.63 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 176.8, 164.3, 162.6, 145.3, 143.6, 135.9, 130.6, 127.0, 124.9, 124.7, 110.5, 78.0, 72.0, 52.8, 52.5, 49.2, 30.5, 26.4; IR(KBr) υ: 3483, 3032, 2975, 2929, 1757, 1709, 1651, 1560, 1517, 1444, 1358, 1317, 1273, 1238, 1135, 1100, 1081, 1009, 957, 932, 873, 815, 759cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{18}H_{19}N_2O_9$ ([M+H]$^+$): 343.1284, found: 343.1287.

Dimethyl 1-benzyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1b): Light yellow solid, 61%, m.p. 155-156℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.33-7.30 (m, 4H, ArH), 7.28-7.21 (m, 2H, ArH), 7.17 (d, *J* = 7.2Hz, 1H, ArH), 6.99 (t, *J* = 7.2Hz, 1H, ArH), 6.87 (d, *J* = 8.0Hz, 1H, ArH), 4.91 (d, *J* = 16.0Hz, 1H, CH), 4.80 (d, *J* = 16.0Hz, 1H, CH), 4.66 (t, *J* = 7.2Hz, 1H, CH), 3.77 (s, 3H, OCH_3), 3.36 (s, 3H, OCH_3), 2.72-2.66 (m, 1H, CH), 2.48-2.41 (m, 1H, CH), 2.12-2.05 (m, 1H, CH), 1.83-1.73 (m, 2H, CH_2), 1.68-1.62 (m, 1H, CH); ^{13}C NMR (100M Hz, DMSO-d_6) δ: 175.5, 164.3, 162.4, 146.4, 143.9, 136.5, 135.1, 130.6, 129.0, 127.8, 127.5, 126.9, 124.3, 122.5, 110.1, 77.5, 72.3, 52.9, 52.5, 49.2, 43.3, 30.5, 26.5; IR(KBr) υ: 3457, 2973, 2944, 2864, 2371, 1715, 1650, 1607, 1485, 1436, 1346, 1295, 1245, 1187, 1139, 1027, 986, 933, 872, 819, 752 cm^{-1}; HRMS (ESI) Calcd. for $C_{25}H_{24}N_2NaO_5$ ([M+Na]$^+$): 455.1577. Found: 455.1578.

Dimethyl 1-benzyl-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1c): white solid, 83%, m.p. 138-140 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.32 (d, *J* = 3.6 Hz, 4H, ArH), 7.26 (d, *J* = 4.0 Hz, 1H, ArH), 7.08 (d, *J* = 8.0 Hz, 1H, ArH), 7.01 (s, 1H, ArH), 6.77 (d, *J* = 8.0 Hz, 1H, ArH), 4.92 (d, *J* = 16.0 Hz, 1H, CH), 4.80 (d, *J* = 16.0 Hz, 1H, CH), 4.68 (t, *J* = 7.2 Hz, 1H, CH), 3.80 (s, 3H, OCH_3), 3.40 (s, 3H, OCH_3), 2.76-2.70 (m, 1H, CH), 2.45 (t, *J* = 8.0 Hz, 1H, CH), 2.24 (s, 3H, CH_3), 2.16-2.08 (m, 1H, CH), 1.83-1.76 (m, 2H, CH, CH), 1.73-1.65 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.5, 164.4, 162.4, 146.5, 141.6, 136.6, 135.1, 131.6, 130.8, 129.0, 127.7, 127.5, 127.4, 124.4, 109.8, 77.6, 72.3, 52.9, 52.5, 49.2, 43.3, 30.5, 26.5, 20.9; IR(KBr) υ: 3027, 2952, 2882, 1720, 1653, 1617, 1496, 1439, 1345, 1295, 1275, 1250, 1188, 1146, 1116, 1058, 1019, 983, 919, 870, 809, 737, 700cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{26}H_{27}N_2O_5$ ([M+H]$^+$): 447.1914, found: 447.1922.

Dimethyl 1-butyl-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (**1d**): white solid, 78%, m.p. 113-115 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.16 (d, *J* = 7.2 Hz, 1H, ArH), 6.97-6.95 (m, 2H, ArH), 4.63 (t, *J* = 7.2 Hz, 1H, CH), 3.79 (s, 3H, OCH_3), 3.65-3.57 (m, 2H, CH_2), 3.42 (s, 3H, OCH_3), 2.74-2.68 (m, 1H, CH), 2.44-2.39 (m, 1H, CH), 2.27 (s, 3H, CH_3), 2.12-2.05 (m, 1H, CH), 1.86-1.73 (m, 2H, CH, CH), 1.72-1.63 (m, 1H, CH), 1.57-1.50 (m, 2H, CH_2), 1.34-1.25 (m, 2H, CH_2), 0.89 (t, *J* = 7.6 Hz, 3H, CH_3); ^{13}C NMR

(100 MHz, DMSO-d_6) δ: 175.2, 164.4, 162.3, 146.0, 142.0, 135.4, 131.1, 130.9, 127.3, 124.4, 109.3, 77.5, 72.4, 52.8, 52.4, 49.0, 39.5, 30.6, 29.3, 26.6, 20.9, 19.8, 14.1; IR(KBr) υ: 3035, 2953, 2934, 2875, 1741, 1719, 1662, 1618, 1497, 1455, 1431, 1382, 1338, 1308, 1266, 1195, 1118, 1026, 824, 790, 741cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{23}H_{29}N_2O_5$ ([M+H]$^+$): 413.2071, found: 413.2080.

Dimethyl 1-benzyl-5-fluoro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1e): Light yellow solid, 68%, m.p. 156-158℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.36-7.27 (m, 5H, ArH), 7.21-7.13 (m, 2H, ArH), 6.92-6.89 (m, 1H, ArH), 4.95 (d, *J* = 16.0Hz, 1H, CH), 4.83 (d, *J* = 16.0Hz, 1H, CH), 4.70 (t, *J* = 7.2Hz, 1H, CH), 3.81 (s, 3H, OCH_3), 3.42 (s, 3H, OCH_3), 2.79-2.73 (m, 1H, CH), 2.48-2.46 (m, 1H, CH), 2.13-2.07 (m, 1H, CH), 1.87-1.79 (m, 2H, CH_2), 1.73-1.66 (m, 1H, CH); ^{13}C NMR (100M Hz, DMSO-d_6) δ: 175.5, 164.3, 162.2, 159.7, 157.3, 147.3, 140.2 (d, *J* = 1.7Hz), 136.3, 134.2, 129.0, 127.8, 127.5, 126.1 (d, *J* = 7.7Hz), 117.1, 116.8, 115.0, 114.8, 110.9 (d, *J* = 8.0Hz), 77.5, 72.4, 53.0, 52.6, 49.2, 43.4, 30.2, 26.5; IR(KBr) υ: 3496, 3415, 3067, 2953, 2874, 2372, 1725, 1653, 1614, 1556, 1494, 1446, 1350, 1260, 1176, 1119, 1030, 959, 882, 813, 770 cm^{-1}; HRMS (ESI) Calcd. for $C_{25}H_{23}FN_2NaO_5$ ([M+Na]$^+$): 473.1483. Found: 473.1494.

Dimethyl 1-butyl-5-fluoro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1f): white solid, 75%, m.p. 148-150 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.22 (t, *J* = 7.6 Hz, 1H, ArH), 7.15 (d, *J* = 6.8 Hz, 1H, ArH), 7.11-7.08 (m, 1H, ArH), 4.65 (t, *J* = 6.8 Hz, 1H, CH), 3.79 (s, 3H, OCH_3), 3.69-3.60 (m, 2H, CH_2), 3.45 (s, 3H, OCH_3), 2.76-2.71 (m, 1H, CH), 2.47-2.43 (m, 1H, CH), 2.13-2.05 (m, 1H, CH), 1.90-1.76 (m, 2H, CH, CH), 1.72-1.64 (m, 1H, CH), 1.55-1.52 (m, 2H, CH_2), 1.32-1.27 (m, 2H, CH_2), 0.89 (t, *J* = 7.6 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.2, 164.3, 162.1, 158.3 (d, *J* = 237.0 Hz), 146.8, 140.6, 134.5, 126.1 (d, *J* = 7.5 Hz), 116.9 (d, *J* = 23.3 Hz), 114.7 (d, *J* = 24.7 Hz), 110.4 (d, *J* = 7.6 Hz), 77.4, 72.4, 52.9, 52.5, 49.0, 39.6, 30.2, 29.1, 26.5, 19.7, 14.0; IR(KBr) υ: 3024, 2952, 2873, 1745, 1716, 1650, 1619, 1496, 1447, 1335, 1264, 1191, 1141, 1112, 1049, 1023, 987, 903, 874, 822, 791, 740cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{22}H_{26}FN_2O_5$ ([M+H]$^+$): 417.1821, found: 417.1831.

Dimethyl 1-benzyl-5-chloro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1g): Light yellow solid, 70%, m.p. 172-174℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.36-7.24 (m, 7H, ArH), 6.90 (d, *J* = 7.6Hz, 1H, ArH), 4.92 (d, *J* = 16.0Hz, 1H, CH), 4.80 (d, *J* = 16.0Hz, 1H, CH), 4.66 (t, *J* = 7.2Hz, 1H, CH), 3.78 (s, 3H, OCH_3), 3.40 (s, 3H, OCH_3), 2.74-2.68 (m, 1H, CH), 2.47-2.42 (m, 1H, CH), 2.10 (m, 1H, CH), 1.84-1.77 (m, 2H, CH_2), 1.71-1.63 (m, 1H, CH); ^{13}C NMR (100M Hz, DMSO-d_6) δ: 175.5, 164.3, 162.2, 159.7, 157.3, 147.3, 140.2, 140.1, 136.3, 134.2, 129.0, 127.8, 127.5, 126.1(2C), 117.1, 116.8, 115.0, 114.8, 110.9(2C), 77.5, 72.4, 53.0, 52.6, 49.2, 43.4, 30.2, 26.5; IR(KBr) υ: 3447, 3358, 2950, 2871, 2372, 1886, 1722, 1653, 1607, 1537, 1484, 1436, 1337, 1285, 1244, 1180, 1116, 1073, 1026, 991, 941, 865, 826, 790 cm^{-1}; HRMS (ESI) Calcd. for $C_{25}H_{23}ClN_2NaO_5$ ([M+Na]$^+$): 489.1188. Found: 489.1183.

Diethyl 1-benzyl-5-chloro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1h): yellowish solid, 66%, m.p. 114-116 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.39-7.28 (m, 7H, ArH), 6.97-6.94 (m, 1H, ArH), 4.95-4.84 (m, 2H, CH_2), 4.71-4.69 (m, 1H, CH), 4.28-4.26 (m, 2H, CH_2), 3.97-3.90 (m, 1H, CH), 3.84-3.79 (m, 1H, CH), 2.80-2.75 (m, 1H, CH), 2.50 (brs, 1H, CH), 2.11-2.08 (m, 1H, CH), 1.85 (brs, 1H, CH), 1.70 (brs, 1H, CH), 1.27 (t, *J* = 6.8 Hz, 3H, CH_3), 0.77 (t, *J* = 6.8 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.4, 163.8, 161.6, 147.4, 142.9, 136.2, 134.0, 130.4, 129.0, 127.9, 127.6, 126.9, 126.8, 126.5, 111.5, 77.3,

72.5, 61.8, 61.2, 49.3, 43.4, 30.2, 26.5, 14.3, 13.7; IR(KBr) υ: 3027, 2978, 2920, 2873, 1742, 1714, 1654, 1607, 1480, 1424, 1374, 1324, 1278, 1238, 1176, 1122, 1025, 945, 877, 861, 818, 790, 732cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{27}H_{28}ClN_2O_5$ ([M+H]$^+$): 495.1681, found: 495.1689.

Dimethyl 1-benzyl-2-oxo-3',7a'-dihydro-1'H-spiro[indoline-3,5'-pyrrolo[1,2-c]thiazole]-6',7'-dicarboxylate (1i): yellowish solid, 50%, m.p. 142-144 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.35-7.27 (m, 7H, ArH), 7.04 (t, *J* = 7.6 Hz, 1H, ArH), 6.94 (d, *J* = 7.6 Hz, 1H, ArH), 4.98-4.94 (m, 2H, CH_2), 4.85 (d, *J* = 15.6 Hz, 1H, CH), 3.89 (d, *J* = 10.8 Hz, 1H, CH), 3.83 (s, 3H, OCH_3), 3.49 (d, *J* = 10.8 Hz, 1H, CH), 3.40 (s, 3H, OCH_3), 3.32-3.25 (m, 1H, CH), 3.17-3.13 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 174.9, 163.7, 161.6, 144.0, 143.5, 136.5, 135.1, 131.3, 129.1, 127.9, 127.6, 127.1, 123.1, 122.7, 110.1, 78.3, 75.2, 54.8, 53.2, 52.8, 43.6, 37.0; IR(KBr) υ: 3024, 2950, 1722, 1654, 1607, 1485, 1465, 1433, 1338, 1300, 1269, 1178, 1122, 1080, 1021, 974, 840, 756, 707cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{24}H_{23}N_2O_5S$ ([M+H]$^+$): 451.1322, found: 451.1322.

Dimethyl 1-benzyl-5-chloro-2-oxo-3',7a'-dihydro-1'H-spiro[indoline-3,5'-pyrrolo[1,2-c]-thiazole]-6',7'-dicarboxylate (**1j**): white solid, 58%, m.p. 157-159 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.42-7.28 (m, 7H, ArH), 6.97(d, *J* = 8.4 Hz, 1H, ArH), 5.00-4.96 (m, 2H, CH_2), 4.85 (d, *J* = 16.0 Hz, 1H, CH), 3.91 (d, *J* = 11.2 Hz, 1H, CH), 3.84 (s, 3H, OCH_3), 3.52 (d, *J* = 10.8 Hz, 1H, CH), 3.43 (s, 3H, OCH_3), 3.25 (d, *J* = 7.6 Hz,1H, CH), 3.20-3.16 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 174.6, 163.6, 161.3, 144.5, 142.9, 136.1, 133.9, 131.1, 129.1, 128.0, 127.6, 125.1, 111.5, 78.1, 75.3, 54.8, 53.3, 53.0, 43.7, 36.7; IR(KBr) υ: 3028, 2955, 2864, 1734, 1710, 1670, 1612, 1472, 1433, 1341, 1301, 1267, 1185, 1124, 1056, 1019, 942, 839, 791, 765, 716cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{24}H_{22}ClN_2O_5S$ ([M+Na]$^+$): 485.0930, found: 485.0933.

Dimethyl 1-benzyl-6'-hydroxy-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (**1k**): white solid, 73%, m.p. 152-154 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.33-7.26 (m, 6H, ArH), 7.11 (d, *J* = 7.2 Hz, 1H, ArH), 7.02 (t, *J* = 7.2 Hz, 1H, ArH), 6.90 (d, *J* = 7.6 Hz, 1H, ArH), 4.94 (d, *J* = 16.0 Hz, 1H, CH), 4.87 (brs, 2H, CH_2), 4.84 (brs, 1H, CH), 4.33 (s, 1H, OH), 3.80 (s, 3H, OCH_3), 3.39 (s, 3H, OCH_3), 2.84-2.81 (m, 1H, CH), 2.38 (d, *J* = 10.4 Hz, 1H, CH), 2.07-2.02 (m, 1H, CH), 1.95-1.88 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.7, 164.2, 162.2, 146.4, 143.8, 136.6, 134.8, 130.7, 129.0, 127.8, 127.5, 126.7, 124.4, 122.6, 110.1, 77.5, 72.0, 71.6, 56.5, 53.0, 52.6, 43.3, 40.4; IR(KBr) υ: 3473, 3031, 2953, 2930, 2907, 1714, 1652, 1610, 1489, 1468, 1434, 1349, 1293, 1181, 1119, 1082, 1041, 983, 949, 878, 801, 763, 740cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{25}H_{25}N_2O_6$ ([M+H]$^+$): 449.1707, found: 449.1715.

Dimethyl 1-benzyl-6'-hydroxy-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1l): yellowish solid, 80%, m.p. 177-179 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.33-7.27 (m, 5H, ArH), 7.08 (s, 1H, ArH), 6.92 (s, 1H, ArH), 6.78 (t, *J* = 6.4 Hz, 1H, ArH)， 4.93-4.79 (m, 1H, CH_2, CH, CH), 4.33 (s, 1H, OH), 3.80 (s, 3H, OCH_3), 3.40 (s, 3H, OCH_3), 2.85-2.82 (m, 1H, CH), 2.38-2.36 (m, 1H, CH), 2.24 (s, 3H, CH_3), 2.05-2.01 (m, 1H, CH), 1.94-1.88 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.7, 164.3, 162.2, 146.5, 141.4, 136.6, 134.7, 131.7, 130.9, 129.0, 127.7, 127.5, 127.1, 124.4, 109.9, 77.6, 72.0, 71.6, 56.5, 52.9, 52.5, 43.3, 40.4, 20.9; IR(KBr) υ: 3400, 3031, 2950, 1744, 1718, 1694, 1652, 1495, 1435, 1375, 1342, 1243, 1180, 1143, 1096, 993, 829, 774, 747, 701cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{26}H_{27}N_2O_6$ ([M+H]$^+$): 463.1864, found: 463.1861.

Dimethyl 1-benzyl-5-chloro-6'-hydroxy-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (**1m**): yellowish solid, 85%, m.p. 171-173 ℃; ^{1}H NMR (400

MHz, DMSO-d_6) δ: 7.33-7.24 (m, 7H, ArH), 6.94 (s, 1H, ArH), 4.96 (d, J = 16.0 Hz, 1H, CH), 4.87 (brs, 4H, CH_2, CH, CH), 4.35 (s, 1H, OH), 3.81 (s, 3H, OCH_3), 3.43 (s, 3H, OCH_3), 2.86-2.84 (m, 1H, CH), 2.40 (d, J = 7.2 Hz,, 1H, CH), 2.00 (brs, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.5, 164.2, 162.0, 147.5, 142.7, 136.2, 133.6, 130.6, 129.0, 127.9, 127.5, 126.9, 126.6, 111.6, 77.3, 72.0, 71.9, 56.5, 53.0, 52.7, 43.4, 39.9; IR(KBr) υ: 3404, 3020, 2950, 2884, 1720, 1652, 1607, 1483, 1434, 1331, 1271, 1246, 1179, 1145, 1104, 1079, 994, 955, 859, 832, 755, 701cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{25}H_{24}ClN_2O_6$ ([M+H]$^+$): 483.1317, found: 483.1320.

2. General procedure for the preparation of spiro[indoline-3,7'-pyrrolo[1,2-a]azepines] 2a-2l from multicomponent reaction of α-amino acid, isatins and diethyl but-2-ynedioate: A mixture of isatin (1.0 mmol), α-amino acid (1.2 mmol) and dialkyl but-2-ynedioate (5.0 mmol) in methanol (15.0 mL) was stirred at room temperature about one hour. Then the mixture was heated to about 50℃ for overnight. The solvent was removed under reduced pressure. The resulting oily residue was subjected to preparative thin-layer chromatography (silica gel GF254, 20x30 cm) with light petroleum and ethyl acetate (V/V = 2:1) as developing agent to give the pure product **2a-2l** for analysis.

Tetramethyl 2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-Tetracarboxylate (2a): yellowish solid, 69%, m.p. 182-184 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 10.65 (s, 1H, NH), 7.14 (t, J = 7.2 Hz, 1H, ArH), 6.88-6.82 (m, 2H, ArH), 6.75 (d, J = 7.6 Hz, 1H, ArH), 5.79-5.76 (m, 1H, CH), 3.74 (m, 3H, OCH_3), 3.63 (s, 3H, OCH_3), 3.45-3.40 (m, 1H, CH), 3.25-3.19 (m, 1H, CH), 3.05 (s, 3H, OCH_3), 2.94 (s, 3H, OCH_3), 2.23-2.16 (m, 1H, CH), 2.11-2.04 (m, 1H, CH), 1.88-1.83(m, 1H, CH), 1.80-1.76 (m, 1H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 177.5 , 167.6, 166.2, 165.5, 165.3, 149.9, 143.3, 140.4, 138.6, 134.5, 129.2, 123.4, 121.6, 109.3, 97.2, 57.1, 55.9, 53.0, 52.8, 52.0, 50.9, 50.2, 28.6, 24.5; IR(KBr) υ: 3475, 3053, 2950, 2912, 1718, 1641, 1577, 1525, 1464, 1339, 1310, 1280, 1122, 1107, 1053, 1017, 949, 952, 843, 806, 741cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{24}H_{24}N_2NaO_9$ ([M+Na]$^+$): 507.1375, found: 507.1372.

Tetramethyl 1-benzyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2b): white solid, 74%, m.p. 194-196℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.50-7.48 (m, 2H, ArH), 7.38-7.35 (m, 2H, ArH), 7.31-7.27 (m, 1H, ArH), 7.19-7.16 (m, 1H, ArH), 6.95-6.87 (m, 3H, ArH), 5.86 (dd, J_1 = 9.2Hz, J_2 = 3.6Hz, 1H, CH), 4.98 (d, J = 15.6Hz, 1H, CH), 4.90 (d, J = 15.6Hz, 1H, CH), 3.74 (s, 3H, OCH_3), 3.64 (s, 3H, OCH_3), 3.46-3.42 (m, 1H, CH), 3.27-3.23 (m, 1H, CH), 2.94 (s, 3H, OCH_3), 2.66 (s, 3H, OCH_3), 2.27-2.20 (m, 1H, CH), 2.14-2.07 (m, 1H, CH), 1.89-1.78 (m, 2H, CH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 176.2, 167.6, 166.1, 165.4, 165.2, 150.4, 143.9, 140.8, 138.2, 136.6, 133.8, 129.2, 128.9, 128.2, 127.9, 123.2, 122.6, 109.0, 96.3, 57.0, 55.2, 53.1, 52.9, 52.0, 50.8, 50.3, 44.3, 28.6, 24.6; IR (KBr) υ: 2951, 2900, 1727, 1609, 1561, 1485, 1458, 1434, 1408, 1339, 1304, 1263, 1233, 1190, 1156, 1139, 1121, 1082, 1052, 1029, 988, 959, 885, 860, 818, 756, 709 cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{31}H_{30}N_2NaO_9$ ([M+Na]$^+$): 597.1844. Found: 597.1851.

Tetramethyl 1-butyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2c): white solid, 70%, m.p. 163-165℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.23-7.19 (m, 1H, ArH), 6.96-6.89 (m, 2H, ArH), 6.86-6.84 (m, 1H, ArH), 5.77 (dd, J_1 = 8.8Hz, J_2 = 3.2Hz, 1H, CH), 3.71 (s, 3H, OCH_3), 3.69-3.65 (m, 2H, CH), 3.59 (s, 3H, OCH_3), 3.43-3.38 (m, 1H, CH), 3.24-3.18 (m, 1H, CH), 2.99 (s, 3H, OCH_3), 2.87 (s, 3H, OCH_3), 2.21-

2.14 (m, 1H, CH), 2.09-2.02 (m, 1H, CH), 1.87-1.73 (m, 2H, CH), 1.61-1.54 (m, 2H, CH_2) , 1.42-1.35 (m, 2H, CH_2) , 0.91 (t, J = 7.2Hz, 3H, CH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 175.7, 167.5, 166.1, 165.3, 165.2, 150.3, 144.2, 140.6, 138.4, 133.8, 129.3, 123.2, 122.2, 108.5, 96.7, 57.1, 55.2, 53.0, 52.8, 52.0, 50.9, 50.3, 29.5, 28.6, 24.5, 19.9, 14.1; IR (KBr) υ: 2953, 2903, 2874, 1711, 1610, 1577, 1486, 1461, 1434, 1406, 1352, 1305, 1264, 1234, 1188, 1120, 1076, 1051, 986, 960, 924, 888, 860, 823, 759, 726 cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{28}H_{32}N_2NaO_9$ ([M+Na]$^+$): 563.2000. Found: 563.2009.

Tetramethyl 1-benzyl-5-methyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2d): white solid, 82%, m.p. 195-196℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.49-7.47 (m, 2H, ArH), 7.38-7.34 (m, 2H, ArH), 7.30-7.26 (m, 1H, ArH), 6.98-6.96 (m, 1H, ArH), 6.76-6.71 (m, 2H, ArH), 5.86 (dd, J_1 = 8.8Hz, J_2 = 3.2Hz, 1H, CH), 4.95 (d, J = 15.6Hz, 1H, CH), 4.87 (d, J = 15.6Hz, 1H, CH), 3.74 (s, 3H, OCH_3), 3.64 (s, 3H, OCH_3), 3.47-3.40 (m, 1H, CH), 3.29-3.23 (m, 1H, CH), 3.00 (s, 3H, OCH_3), 2.68 (s, 3H, OCH_3), 2.26-2.21 (m, 1H, CH), 2.17 (s, 3H, CH_3), 2.11-2.06 (m, 1H, CH), 1.88-1.78 (m, 2H, CH); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 176.1, 167.6, 166.1, 165.3, 165.2, 150.4, 141.5, 140.6, 138.3, 136.7, 133.8, 131.5, 129.2, 128.9, 128.2, 127.9, 123.8, 108.8, 96.5, 57.0, 55.3, 53.1, 52.8, 52.0, 50.8, 50.3, 44.3, 28.6, 24.5, 20.9; IR (KBr) υ: 3057, 2953, 2870, 1727, 1709, 1605, 1573, 1497, 1454, 1435, 1345, 1306, 1266, 1236, 1193, 1140, 1121, 1075, 1028, 979, 959, 890, 823, 782, 731 cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{32}H_{32}N_2NaO_9$ ([M+Na]$^+$): 611.2000. Found: 611.2002.

Tetramethyl 1-butyl-5-methyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2e): white solid, 77%, m.p. 140-142 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.04 (d, J = 7.6 Hz, 1H, ArH), 6.85 (d, J = 8.0 Hz, 1H, ArH), 6.71 (s, 1H, ArH), 5.80-5.77 (m, 1H, CH), 3.74 (s, 3H, OCH_3), 3.67 (t, J = 7.2 Hz, 2H, CH_2), 3.62 (s, 3H, OCH_3), 3.45-3.40 (m, 1H, CH), 3.27-3.20 (m, 1H, CH), 3.03 (s, 3H, OCH_3), 2.92 (s, 3H, OCH_3), 2.26-2.14 (m, 1H, CH), 2.20 (s, 3H, CH_3), 2.12-2.05 (m, 1H, CH), 1.88-1.82 (m, 1H, CH), 1.81-1.76 (m, 1H, CH), 1.62-1.55 (m, 2H, CH_2), 1.44-1.35 (m, 2H, CH_2), 0.93 (t, J = 7.6 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.6, 167.6, 166.2, 165.4, 165.3, 150.3, 141.9, 140.4, 138.5, 133.9, 131.1, 129.3, 123.9, 108.3, 97.0, 57.1, 55.3, 53.1, 52.8, 52.0, 50.9, 50.3, 40.3, 29.5, 28.6, 24.5, 20.9, 19.9, 14.1; IR(KBr) υ: 3019, 2953, 2870, 1727, 1707, 1578, 1496, 1435, 1414, 1372, 1344, 1269, 1236, 1195, 1124, 1075, 1040, 962, 888, 820, 774, 736cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{29}H_{34}N_2NaO_9$ ([M+Na]$^+$): 577.2175, found: 577.2167.

Tetramethyl 1-benzyl-5-fluoro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2f): white solid, 79%, m.p. 175-177℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.50-7.48 (m, 2H, ArH), 7.39-7.35 (m, 2H, ArH), 7.31-7.28 (m, 1H, ArH), 7.07-7.03 (m, 1H, ArH), 6.90-6.88 (m, 1H, ArH), 6.71 (d, J = 7.6Hz, 1H, ArH), 5.85 (d, J = 7.6Hz, 1H, CH), 4.98 (d, J = 15.6Hz, 1H, CH), 4.91 (d, J = 15.6Hz, 1H, CH), 3.76 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 3.46-3.43 (m, 1H, CH), 3.30-3.26 (m, 1H, CH), 3.06 (s, 3H, OCH_3), 2.74 (s, 3H, OCH_3), 2.28-2.20 (m, 1H, CH), 2.14-2.07 (m, 1H, CH), 1.88-1.81 (m, 2H, CH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 176.1, 167.3, 165.9, 165.3, 165.1, 158.4 (d, J = 237.3Hz), 150.9, 141.2, 140.3, 137.5, 136.4, 135.6, 135.5, 128.9, 128.3, 128.0, 115.3 (d, J = 22.4Hz), 111.0 (d, J = 25.4Hz), 109.9 (d, J = 8.1Hz), 95.5, 57.1, 55.6, 53.2, 52.9, 52.3, 50.9, 50.3, 44.4, 28.6, 24.5, 19.0 ; IR (KBr) υ: 3083, 3000, 2951, 2903, 1727, 1616, 1557, 1494, 1434, 1410, 1327, 1302, 1263, 1232, 1190, 1166, 1139, 1121, 1084, 1051, 1021, 979, 959, 929, 882, 826, 799, 762, 709 cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{31}H_{29}FN_2NaO_9$ ([M+Na]$^+$): 615.1749. Found: 615.1761.

Tetramethyl 1-butyl-5-fluoro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2g): white solid, 74%, m.p. 148-150 ℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.09 (t, J = 8.4 Hz, 1H, ArH), 7.00-6.98 (m, 1H, ArH), 6.69-6.67 (m, 1H, ArH), 5.76 (dd, J_1 = 9.2 Hz, J_2 = 3.2 Hz 1H, CH), 3.74 (s, 3H, OCH_3), 3.68 (t, J = 8.4 Hz, 2H, CH_2), 3.62 (s, 3H, OCH_3), 3.44-3.39 (m, 1H, CH), 3.28-3.22 (m, 1H, CH), 3.09 (s, 3H, OCH_3), 2.96 (s, 3H, OCH_3), 2.25-2.16 (m, 1H, CH), 2.13-2.04 (m, 1H, CH), 1.87-1.81 (m, 1H, CH), 1.80-1.75 (m, 1H, CH), 1.61-1.53 (m, 2H, CH_2), 1.42-1.33 (m, 2H, CH_2), 0.92 (t, J = 7.6 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.6, 167.3, 166.0, 165.3, 165.1, 158.2 (d, J = 237.3 Hz), 150.8, 141.0, 140.6 (d, J = 1.7 Hz), 137.6, 135.6 (d, J = 7.6 Hz), 115.3 (d, J = 22.7 Hz), 110.9 (d, J = 25.1 Hz), 109.4 (d, J = 7.9 Hz), 96.0, 57.2, 55.6, 53.1, 52.9, 52.2, 51.0, 50.3, 40.4, 29.4, 28.6, 24.5, 19.9, 14.1; IR(KBr) υ: 3077, 2954, 2870, 1713, 1618, 1573, 1494, 1437, 1405, 1346, 1262, 1223, 1188, 1120, 1077, 1050, 981, 957, 927, 880, 857, 831, 784cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{28}H_{31}FN_2NaO_9$ ([M+Na]$^+$): 581.1906, found: 581.1915.

Tetramethyl 1-butyl-5-chloro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2h): white solid, 78%, m.p. 155-157℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.34-7.32 (m, 1H, ArH), 7.04(d, J = 7.6 Hz, 1H, ArH), 6.83 (d, J = 2.4 Hz, 1H, ArH), 5.76-5.73 (m, 1H, CH), 3.74 (s, 3H, OCH_3), 3.70 (t, J = 7.2 Hz, 2H, CH_2), 3.64 (s, 3H, OCH_3), 3.46-3.41 (m, 1H, CH), 3.29-3.25 (m, 1H, CH), 3.12 (s, 3H, OCH_3), 2.99 (s, 3H, OCH_3), 2.26-2.18 (m, 1H, CH), 2.13-2.06 (m, 1H, CH), 1.91-1.83 (m, 1H, CH), 1.82-1.76 (m, 1H, CH), 1.62-1.54 (m, 2H, CH_2), 1.44-1.34 (m, 2H, CH_2), 0.93 (t, J = 7.6 Hz, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 175.5, 167.2, 165.9, 165.2, 165.1, 151.0, 143.3, 141.0, 137.5, 136.0, 129.1, 126.1, 122.9, 106.0, 95.8, 57.2, 55.4, 53.2, 52.9, 52.2, 51.1, 50.3, 40.4, 29.3, 280.6, 24.5, 19.9, 14.1; IR(KBr) υ: 3006, 2956, 2871, 1738, 1707, 1608, 1576, 1557, 1517, 1488, 1439, 1406, 1341, 1307, 1240, 1216, 1117, 1043, 996, 971, 885, 825, 788cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{28}H_{31}ClN_2NaO_9$ ([M+Na]$^+$): 597.1610, found: 597.1619.

Tetramethyl 1-benzyl-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]azepine]-5',6',8',9'-tetracarboxylate (2i): white solid, 54%, m.p. 143-145℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.40-7.32 (m, 5H, ArH), 7.27 (t, J = 7.2 Hz, 2H, ArH), 7.08 (t, J = 7.2 Hz, 1H, ArH), 6.88 (d, J = 7.6 Hz, 1H, ArH), 6.03 (s, 1H, CH), 4.92-4.82 (m, 2H, CH_2), 4.13 (d, J = 10.4 Hz, 1H, CH), 4.01 (d, J = 10.4 Hz, 1H, CH), 3.08 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 3.61-3.56 (m, 1H, CH), 3.46 (d, J = 12.0 Hz, 1H, CH), 3.41 (s, 3H, OCH_3), 2.90 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 173.4, 166.0, 164.1, 163.0, 161.9, 149.8, 143.6, 141.0, 138.4, 136.5, 130.6, 129.0, 127.9, 127.7, 127.6, 125.2, 123.3, 113.5, 109.9, 80.3, 76.7, 55.6, 53.5, 53.2, 52.8, 52.1, 43.6, 35.0; IR(KBr) υ: 3023, 2952, 2911, 1716, 1653, 1590, 1489, 1466, 1437, 1355, 1287, 1253, 1192, 1171, 1096, 1015, 920, 852, 742cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{30}H_{28}N_2NaO_9S$ ([M+Na]$^+$): 615.1410, found: 615.1407.

Tetramethyl 1-benzyl-5-methyl-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2j): white solid, 57%, m.p. 162-164℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.33-7.20 (m, 6H, ArH), 7.05 (d, J = 7.6 Hz, 1H, ArH), 6.74 (d, J = 7.6 Hz, 1H, ArH), 6.03 (s, 1H, CH), 4.87-4.78 (m, 2H, CH_2), 4.10 (d, J = 10.4 Hz, 1H, CH), 3.99 (d, J = 10.0 Hz, 1H, CH), 3.78 (s, 3H, OCH_3), 3.63 (s, 3H, OCH_3), 3.57-3.53 (m, 1H, CH), 3.44 (d, J = 14.4 Hz, 1H, CH), 3.40 (s, 3H, OCH_3), 2.90 (s, 3H, OCH_3), 2.23 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 173.4, 166.0, 164.1, 163.1, 161.8, 149.8, 141.4, 141.3, 138.1, 136.6, 132.3, 130.8, 129.0, 127.8, 127.7, 125.8, 113.5, 109.6, 80.2, 76.8, 55.6, 53.5, 53.2, 52.8, 52.2, 43.6, 34.9,

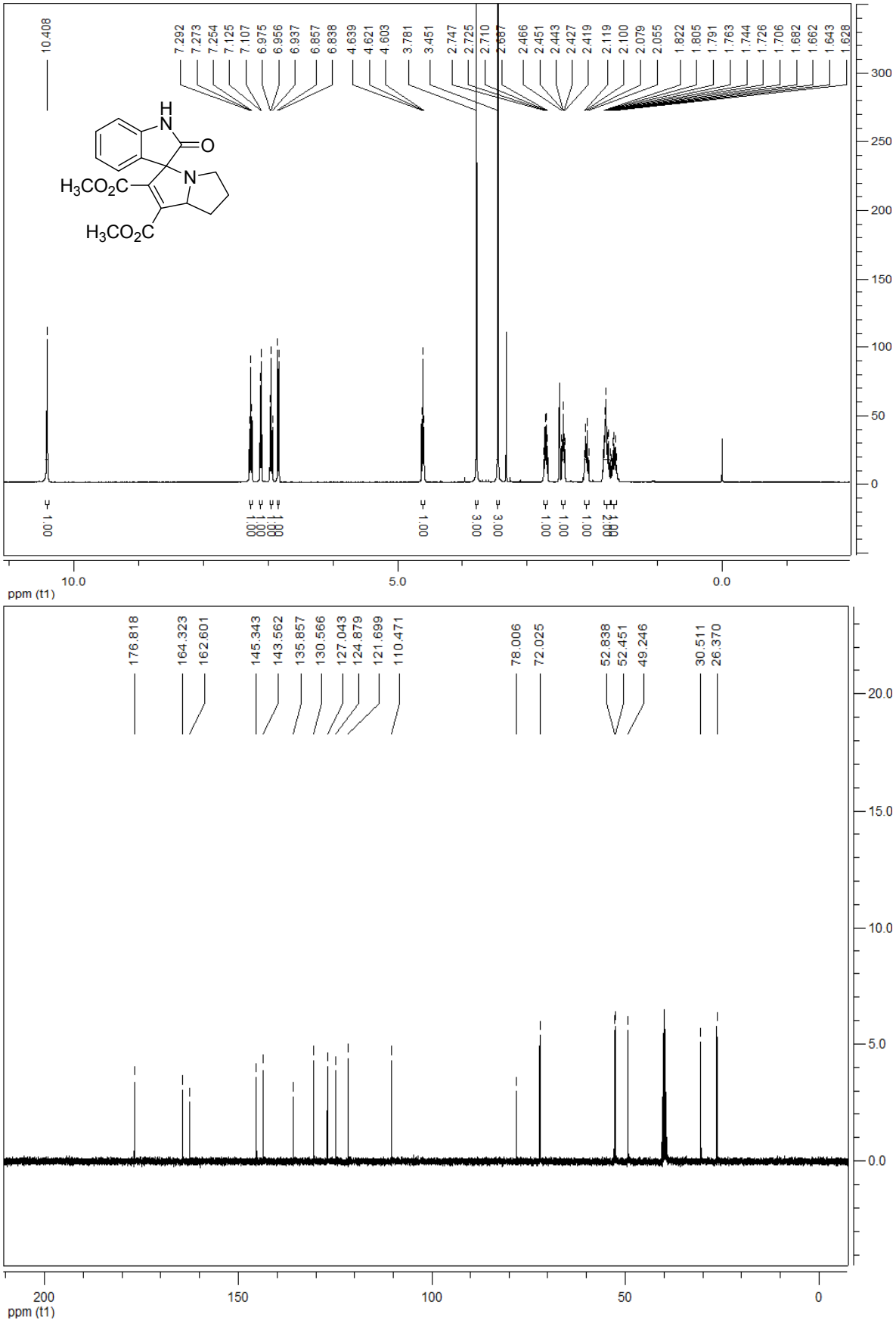
21.1; IR(KBr) υ: 3029, 2952, 2883, 1741, 1711, 1656, 1589, 1469, 1435, 1435, 1348, 1287, 1252, 1193, 1170, 1095, 1037, 1019, 974, 918, 890, 853, 742cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{31}H_{30}N_2NaO_9S$ ([M+Na]$^+$): 629.1566, found: 629.1564.

Tetramethyl 1-benzyl-5-fluoro-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2k): white solid, 50%, m.p. 173-175℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.36-7.32 (m, 4H, ArH), 7.28 (d, J = 6.0 Hz, 1H, ArH), 7.22 (d, J = 5.6 Hz, 1H, ArH), 7.14 (t, J = 8.4 Hz, 1H, ArH), 6.89 (dd, J_1 = 8.0 Hz, J_2 = 3.6 Hz 1H, ArH), 6.07 (s, 1H, CH), 4.93-4.83 (m, 2H, CH_2), 4.15 (d, J = 10.4 Hz, 1H, CH), 4.08 (d, J = 10.0 Hz, 1H, CH), 3.79 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 3.61-3.57 (m, 1H, CH), 3.46 (brs, 1H, CH), 3.43 (s, 3H, OCH_3), 2.91 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 173.2, 166.0, 164.1, 163.0, 161.6, 157.8 (d, J = 238.1 Hz), 149.2, 142.3, 139.7, 136.9, 136.2, 130.0 (d, J = 7.6 Hz), 129.0, 127.9, 127.7, 116.8 (d, J = 23.1 Hz), 113.7, 112.6 (d, J = 24.6 Hz), 110.8 (d, J = 8.0 Hz), 80.3, 76.7, 66.2, 55.6, 53.5, 53.2, 52.9, 52.2, 43.7, 34.8; IR(KBr) υ: 3002, 2953, 2912, 2875, 1715, 1655, 1590, 1492, 1438, 1353, 1329, 1289, 1255, 1191, 1172, 1093, 1038, 1014, 958, 918, 888, 810, 782, 733cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{30}H_{27}FN_2NaO_9S$ ([M+Na]$^+$): 633.1313, found: 633.1323.

Tetramethyl 1-benzyl-5-chloro-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2l): white solid, 63%, m.p. 169-171℃; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.40 (d, J = 2.4 Hz, 1H, ArH), 7.37-7.34 (m, 5H, ArH), 7.30-7.26 (m, 1H, ArH), 6.91 (d, J = 8.4 Hz, 1H, ArH), 6.06 (s, 1H, CH), 4.93-4.83 (m, 2H, CH_2), 4.14-4.08 (m, 2H, CH, CH), 3.80 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 3.61-3.57 (m, 1H, CH), 3.47 (d, J = 2.4 Hz, 1H, CH), 3.44 (s, 3H, OCH_3), 2.92 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 173.1, 165.9, 164.1, 163.1, 161.5, 149.3, 142.8, 142.5, 136.5, 136.1, 130.4, 130.2, 129.0, 128.0, 127.7, 123.7, 125.0, 113.8, 111.5, 80.2, 76.5, 55.6, 53.5, 53.3, 53.0, 52.2, 43.7, 34.7; IR(KBr) υ: 3030, 2990, 2952, 2916, 2838, 1716, 1660, 1590, 1486, 1435, 1350, 1284, 1254, 1169, 1098, 1042, 1018, 975, 919, 889, 816, 742, 700cm^{-1}; MS (*m*/*z*): HRMS (ESI) Calcd. for $C_{30}H_{27}ClN_2NaO_9S$ ([M+Na]$^+$): 649.1018, found: 649.1026.

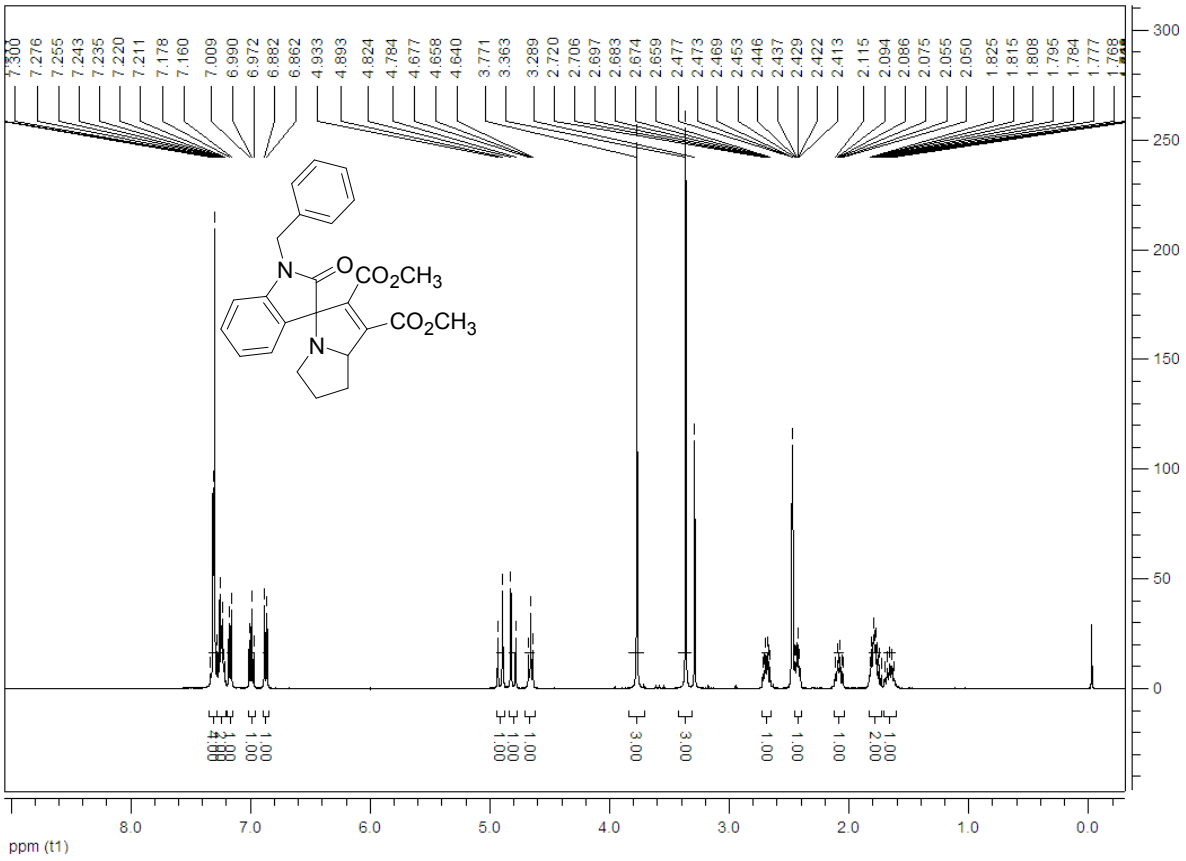
Dimethyl 2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate

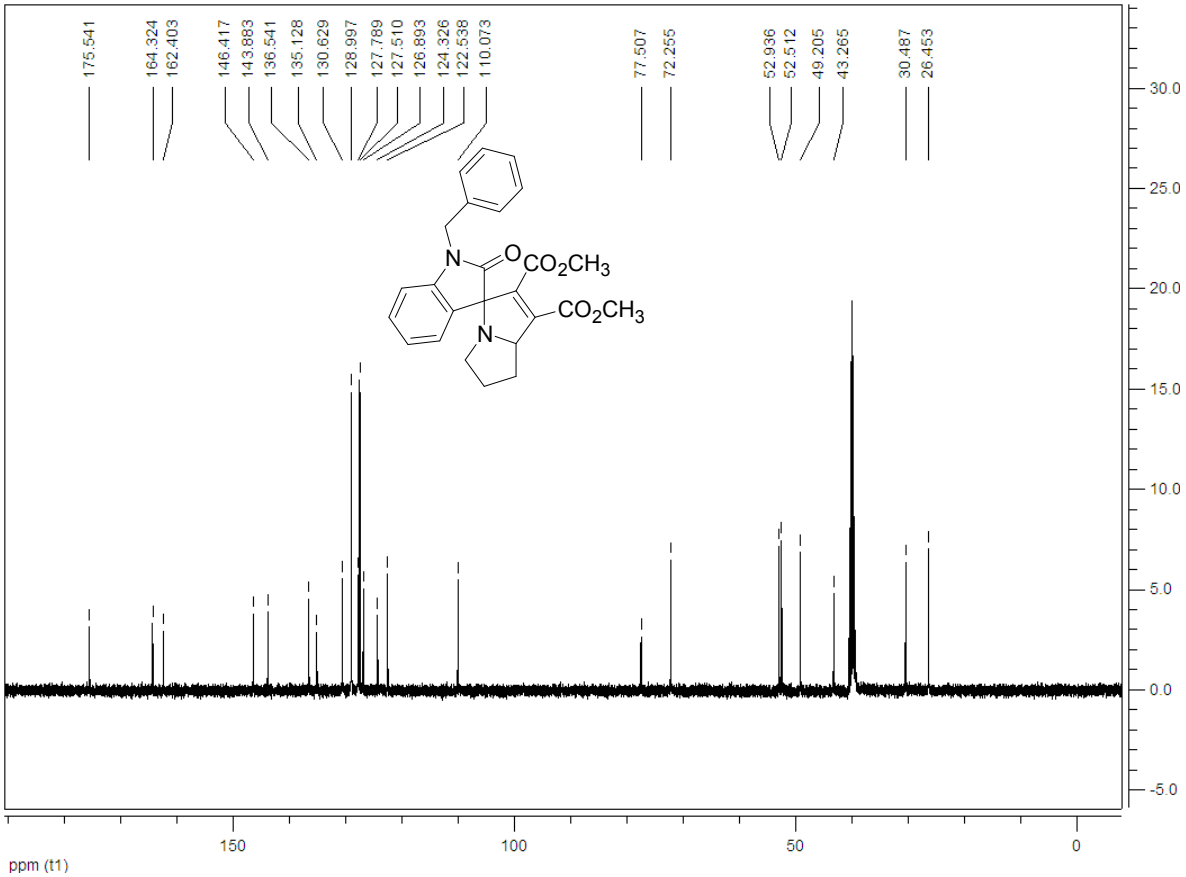
(**1a**):



Dimethyl 1-benzyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-

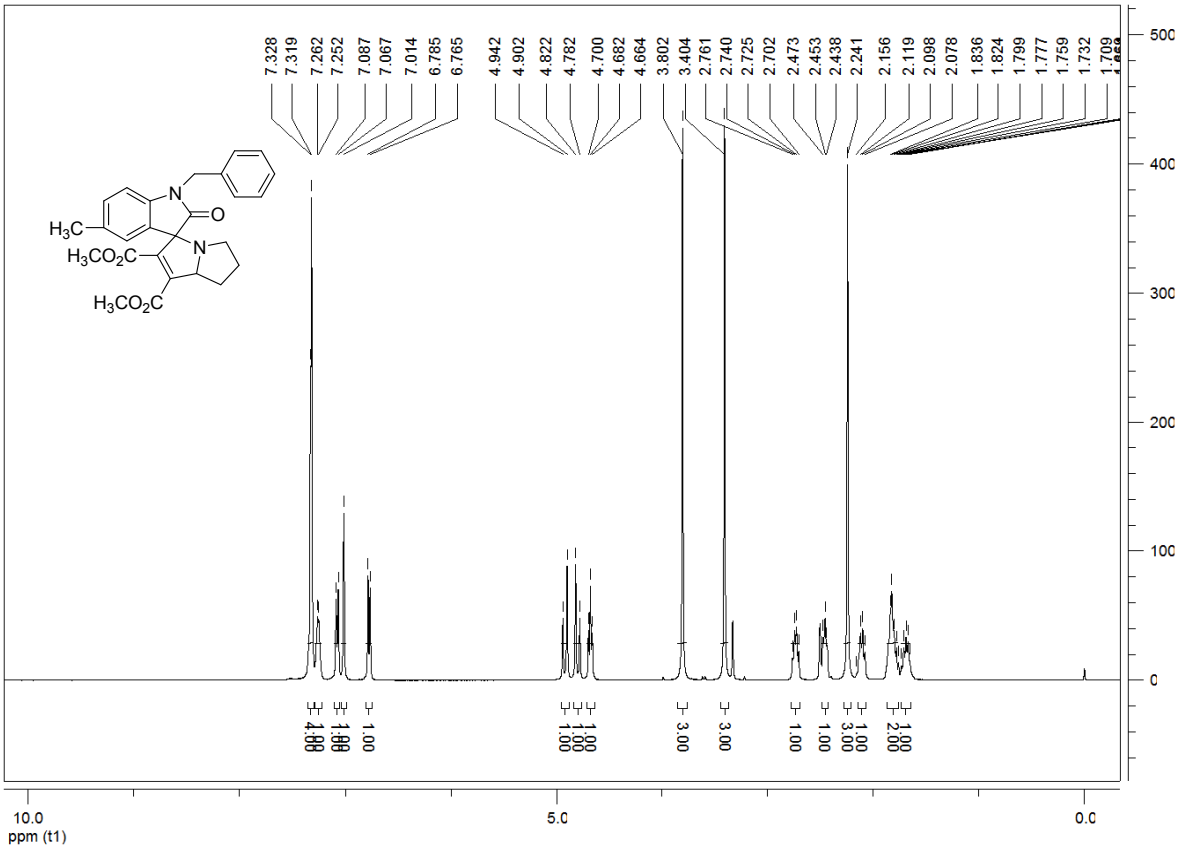
dicarboxylate (1b):

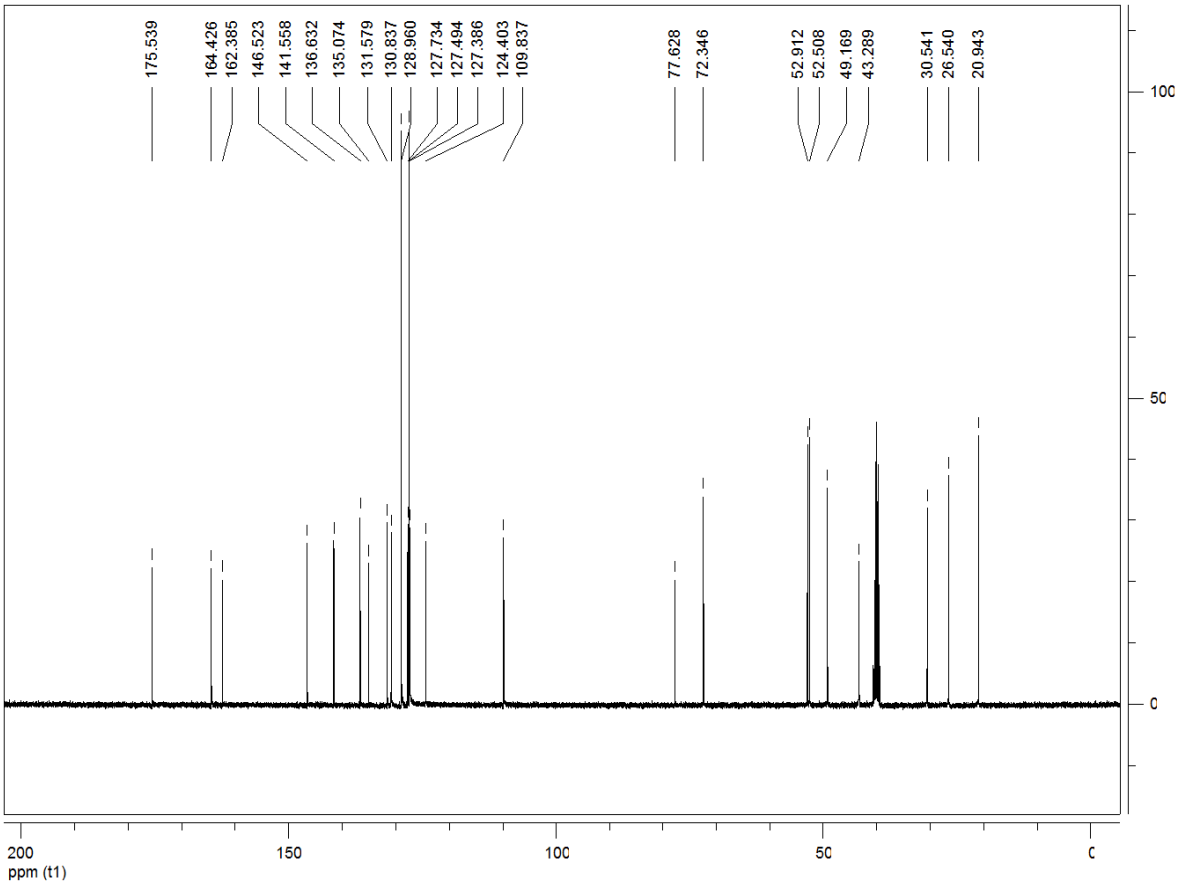




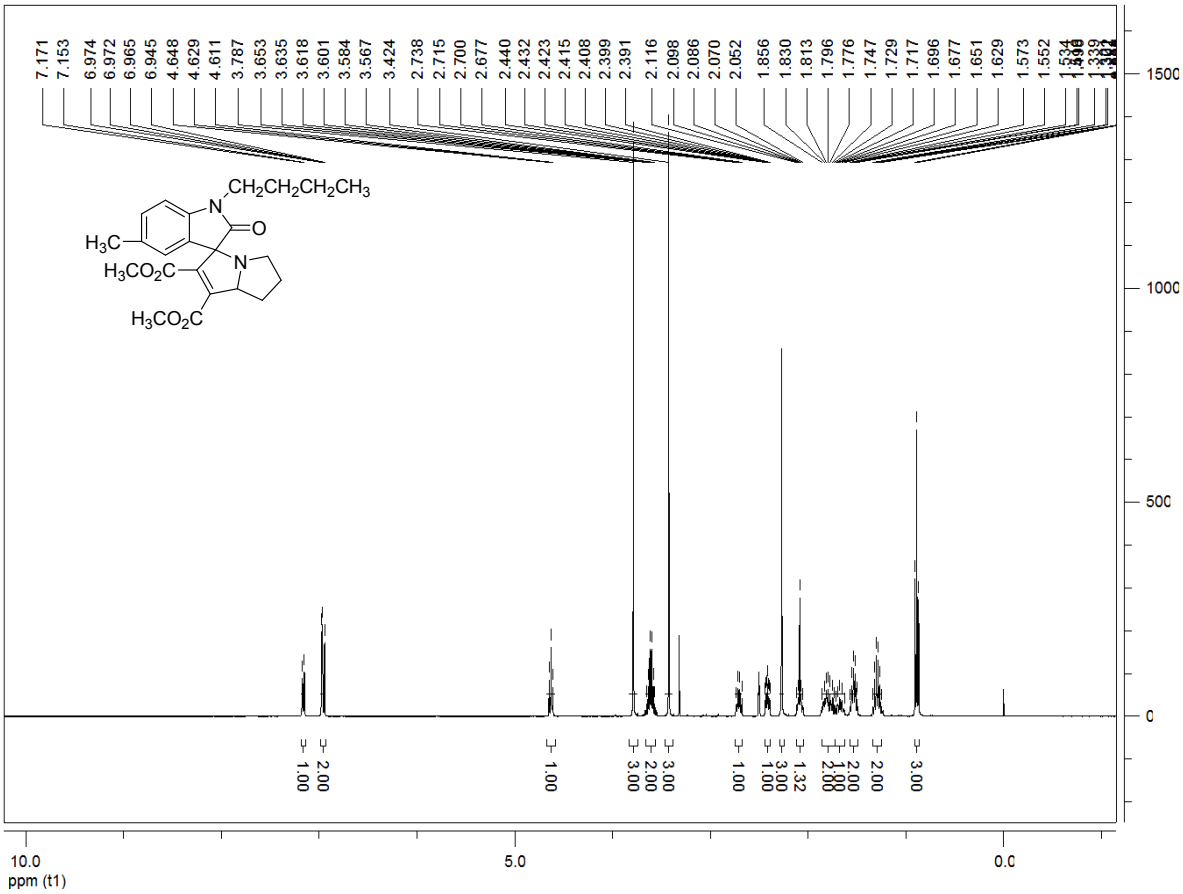
Dimethyl 1-benzyl-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-

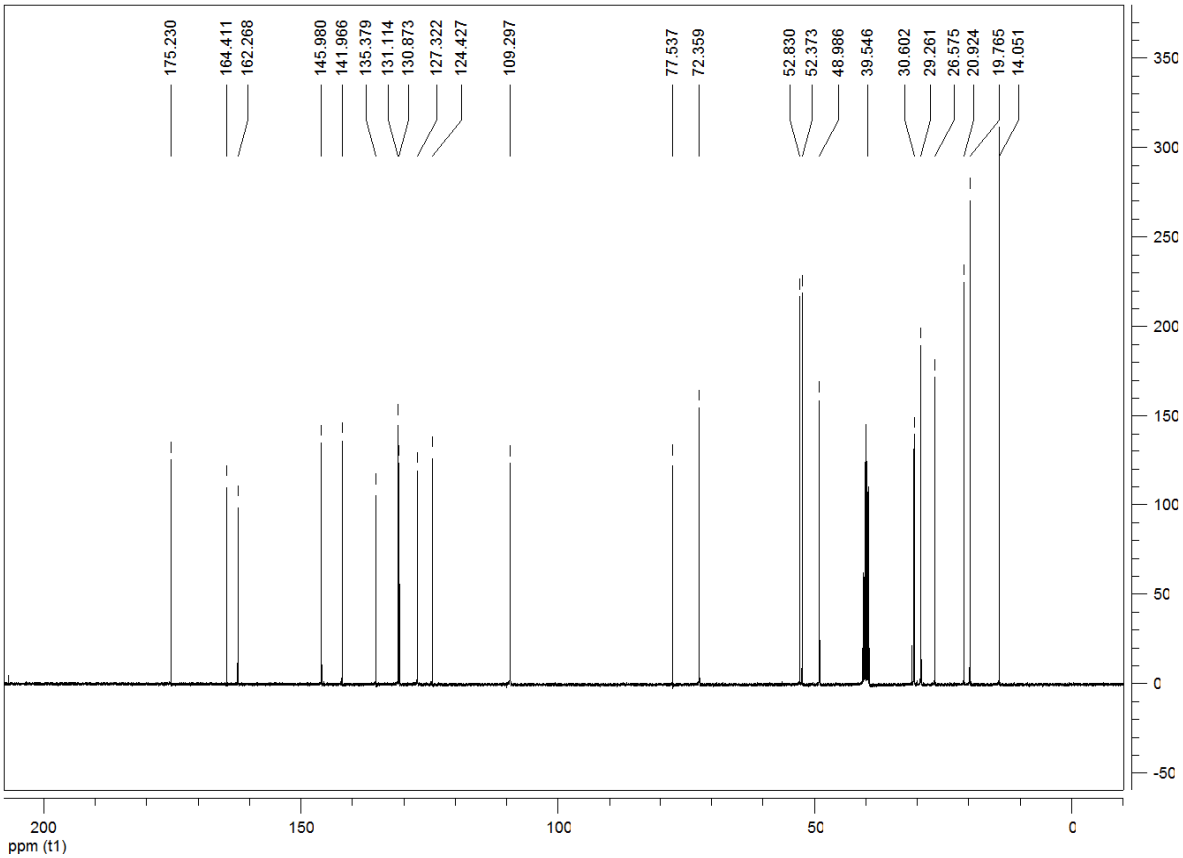
1',2'-dicarboxylate (1c):



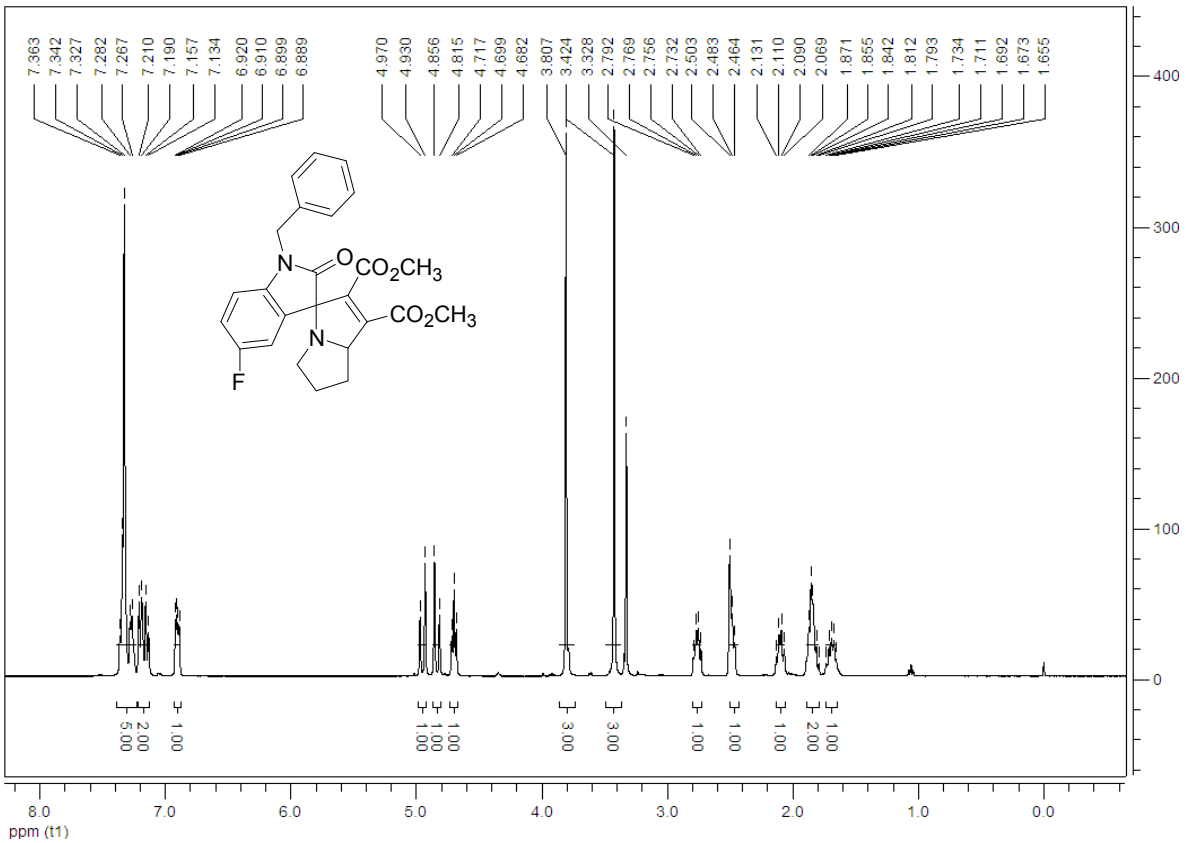


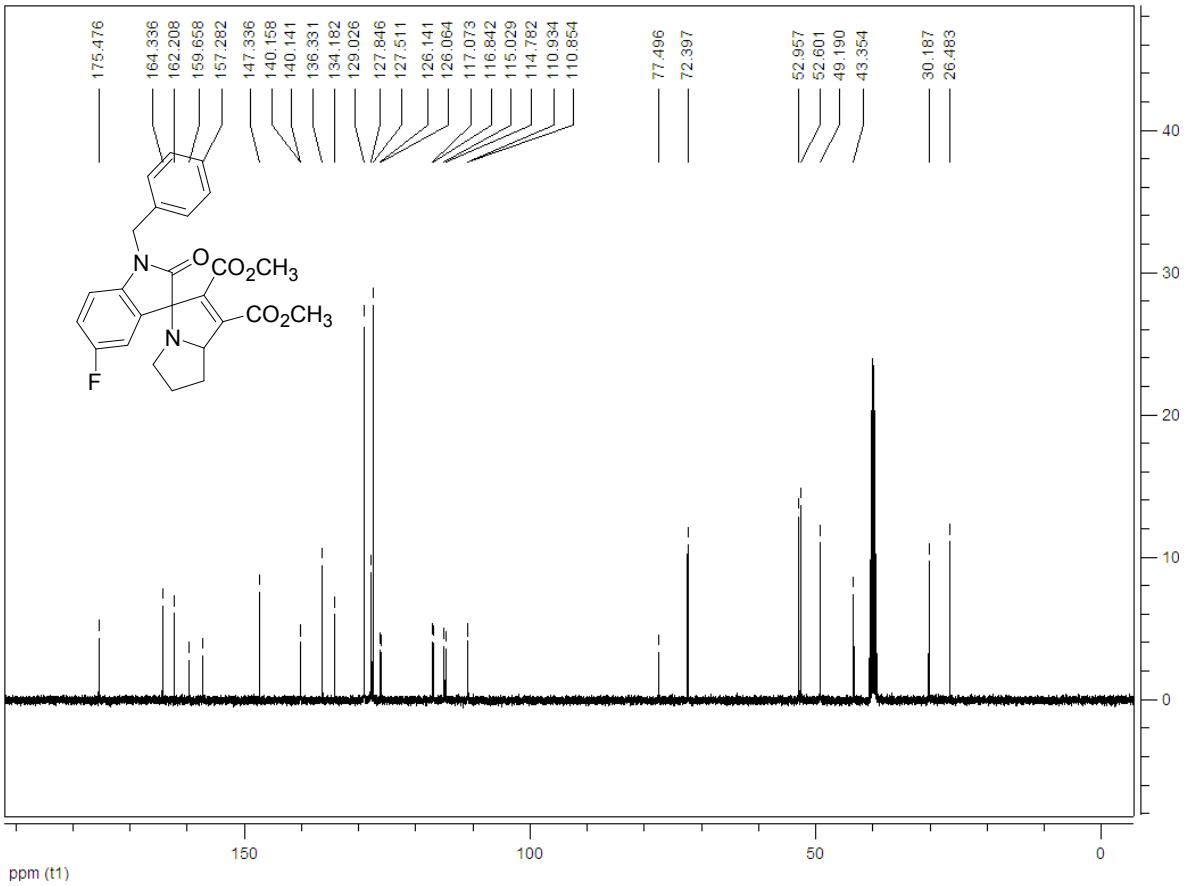
Dimethyl 1-butyl-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (**1d**):



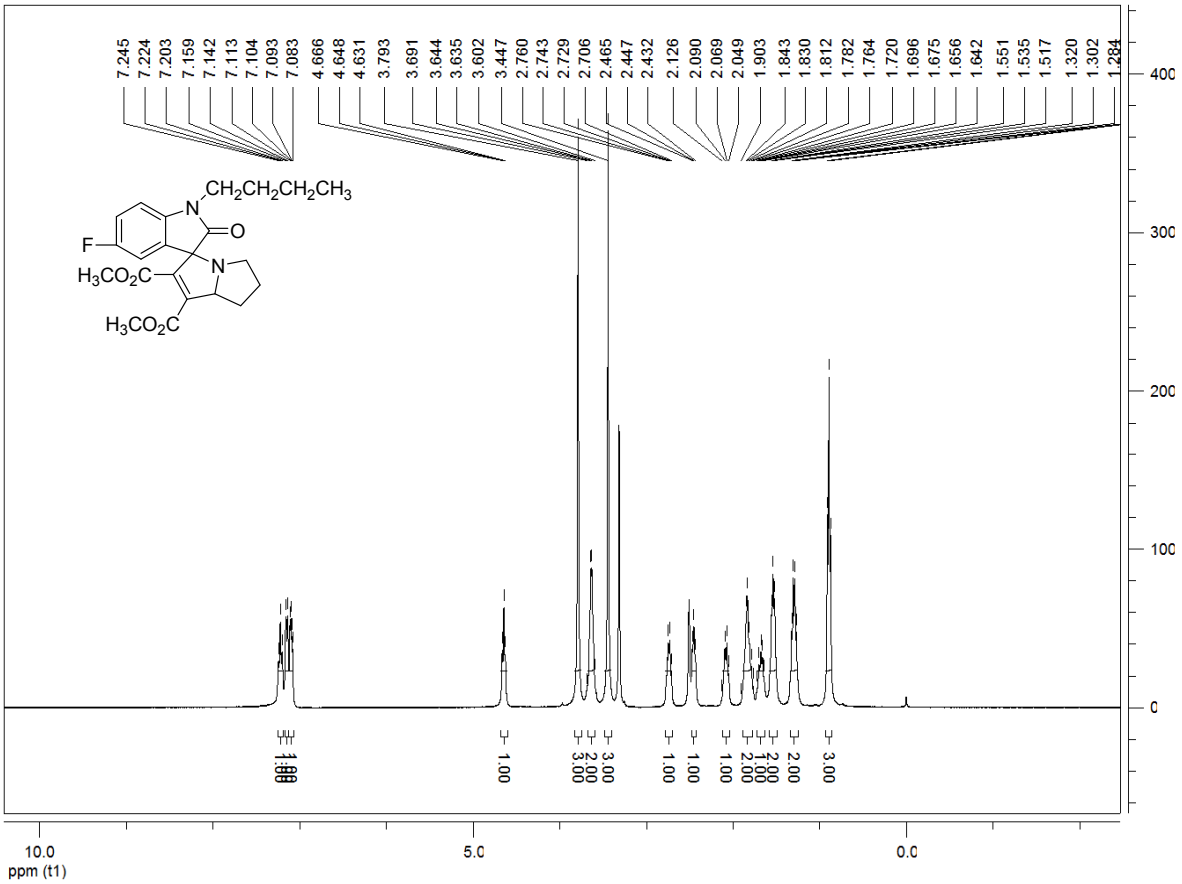


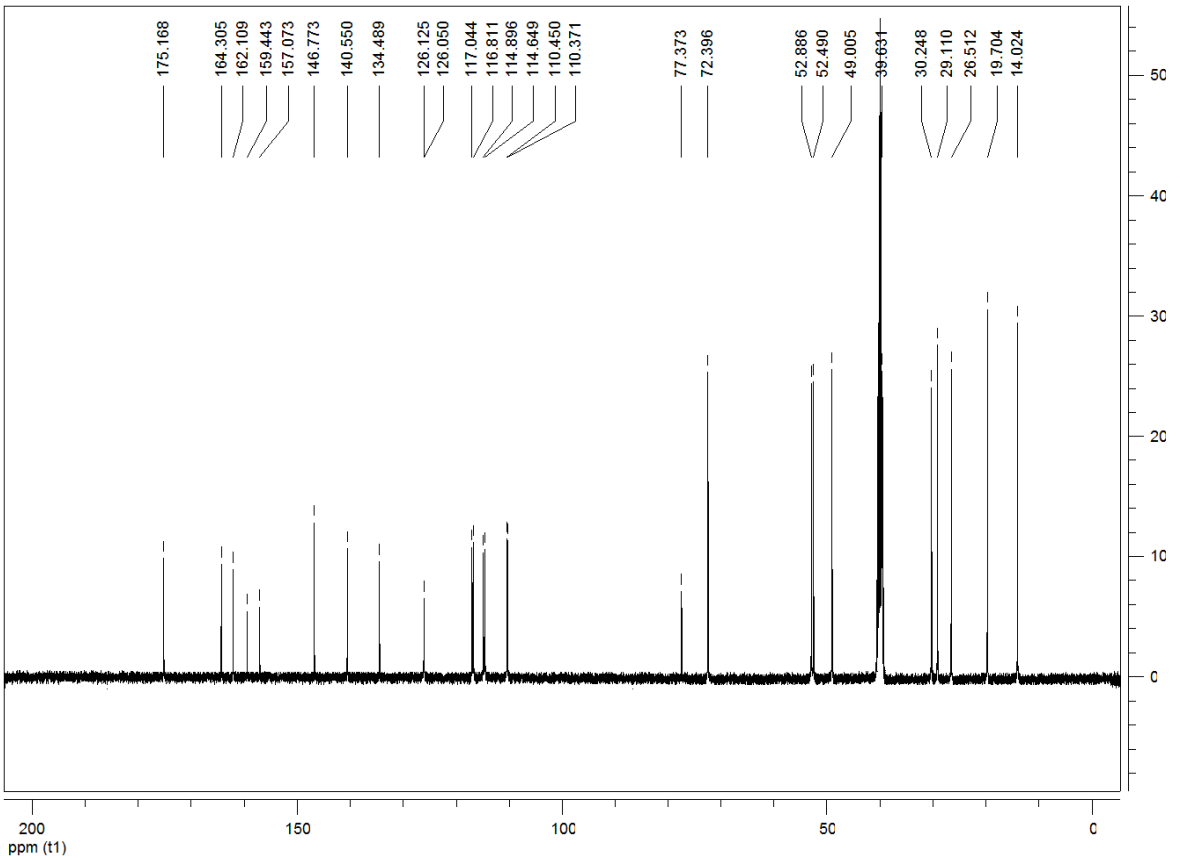
Dimethyl 1-benzyl-5-fluoro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1e):



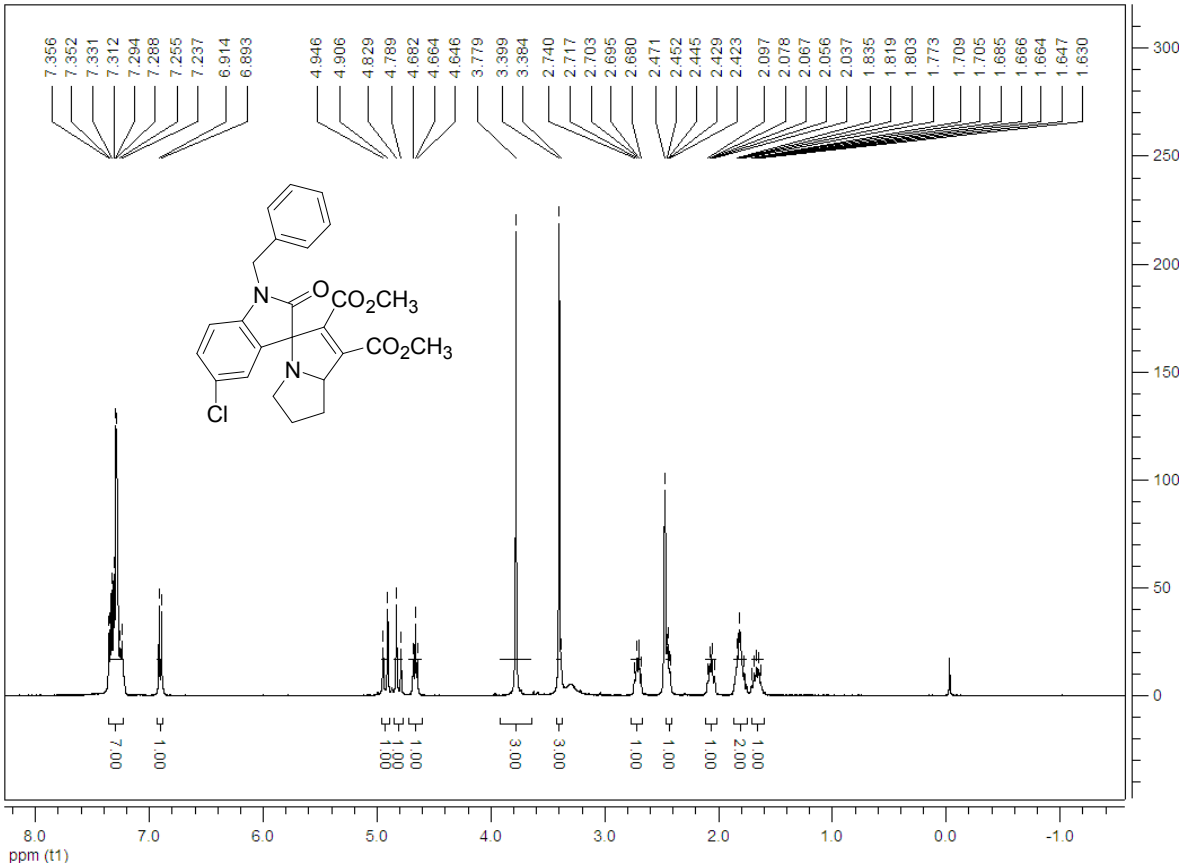


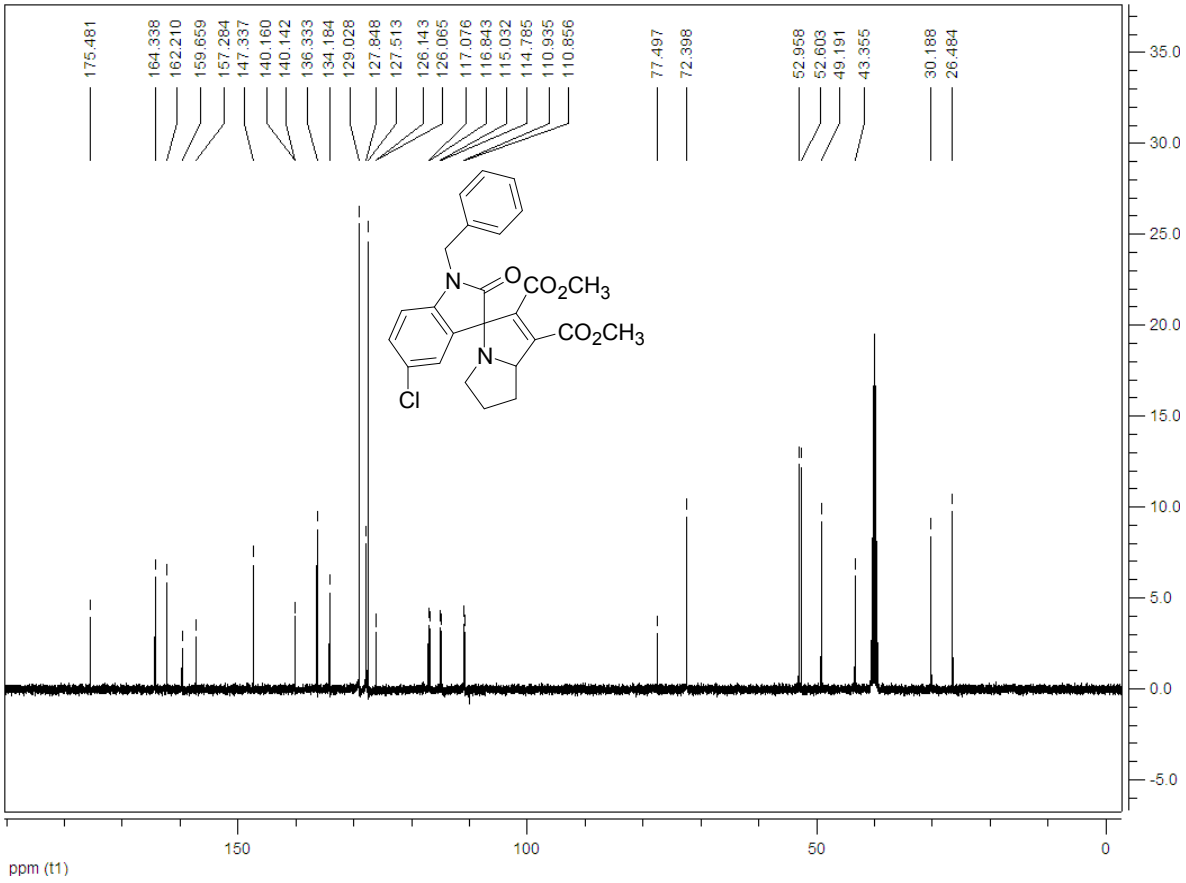
Dimethyl 1-butyl-5-fluoro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1f):



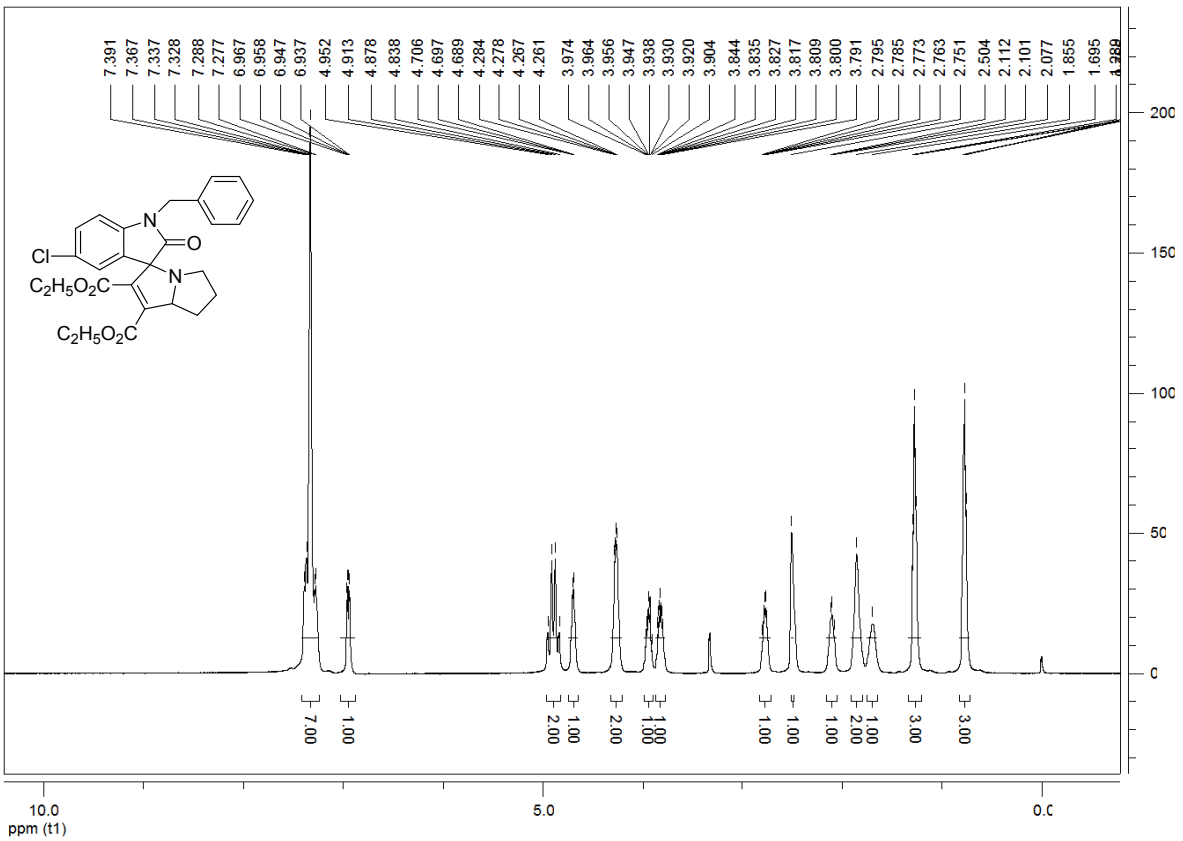


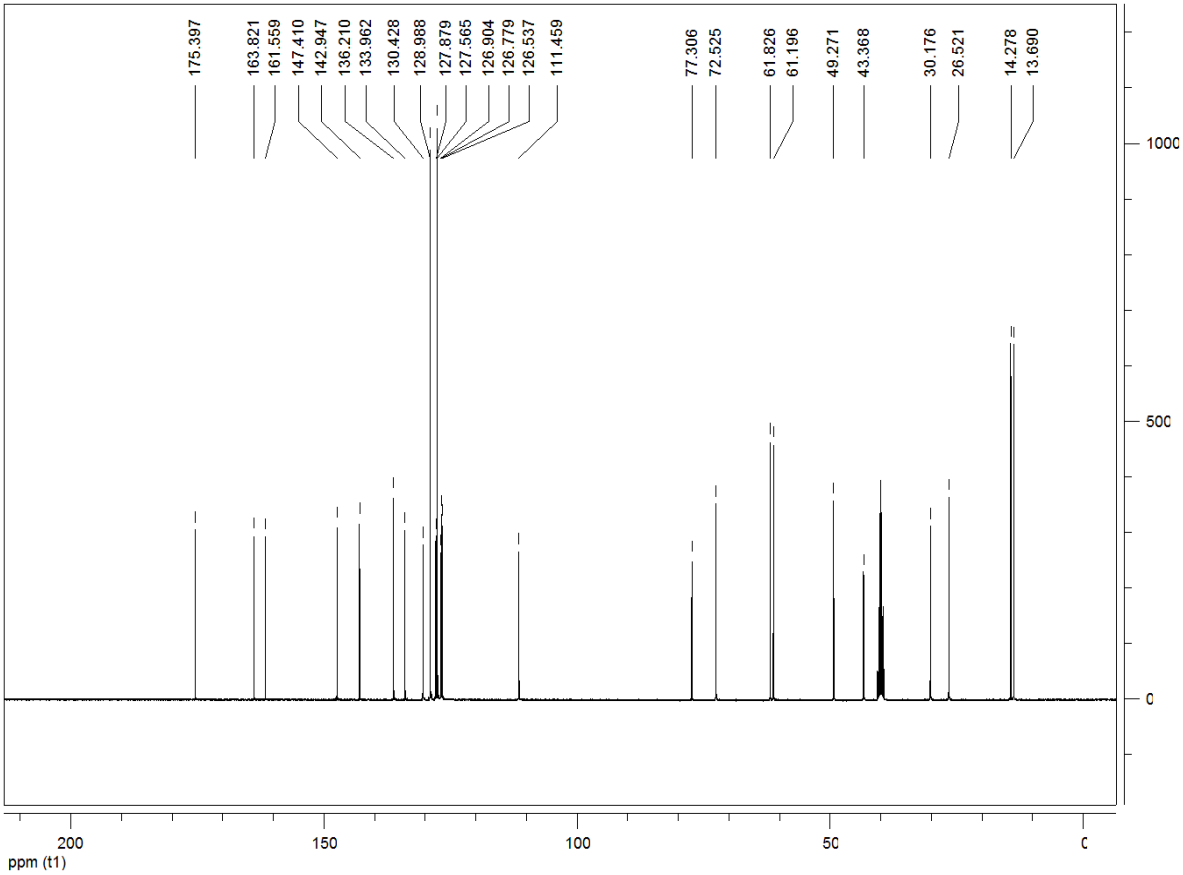
Dimethyl 1-benzyl-5-chloro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1g):



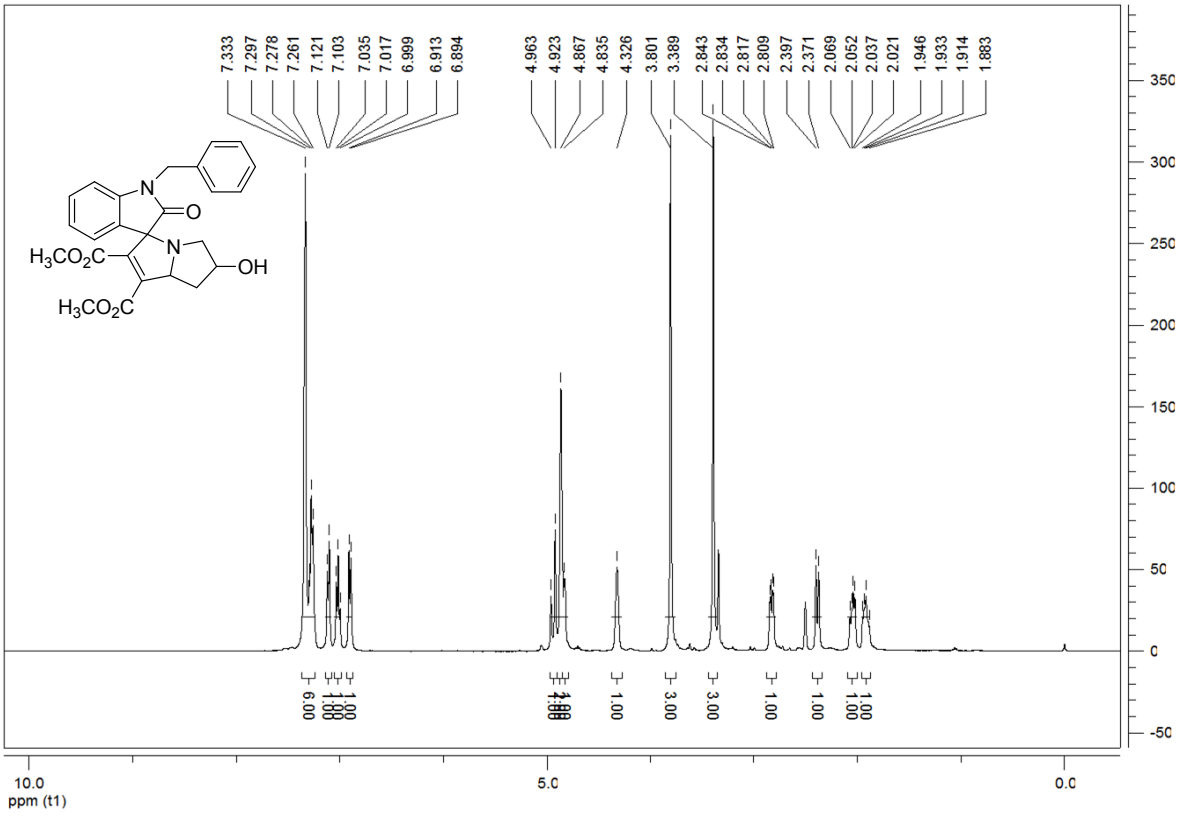


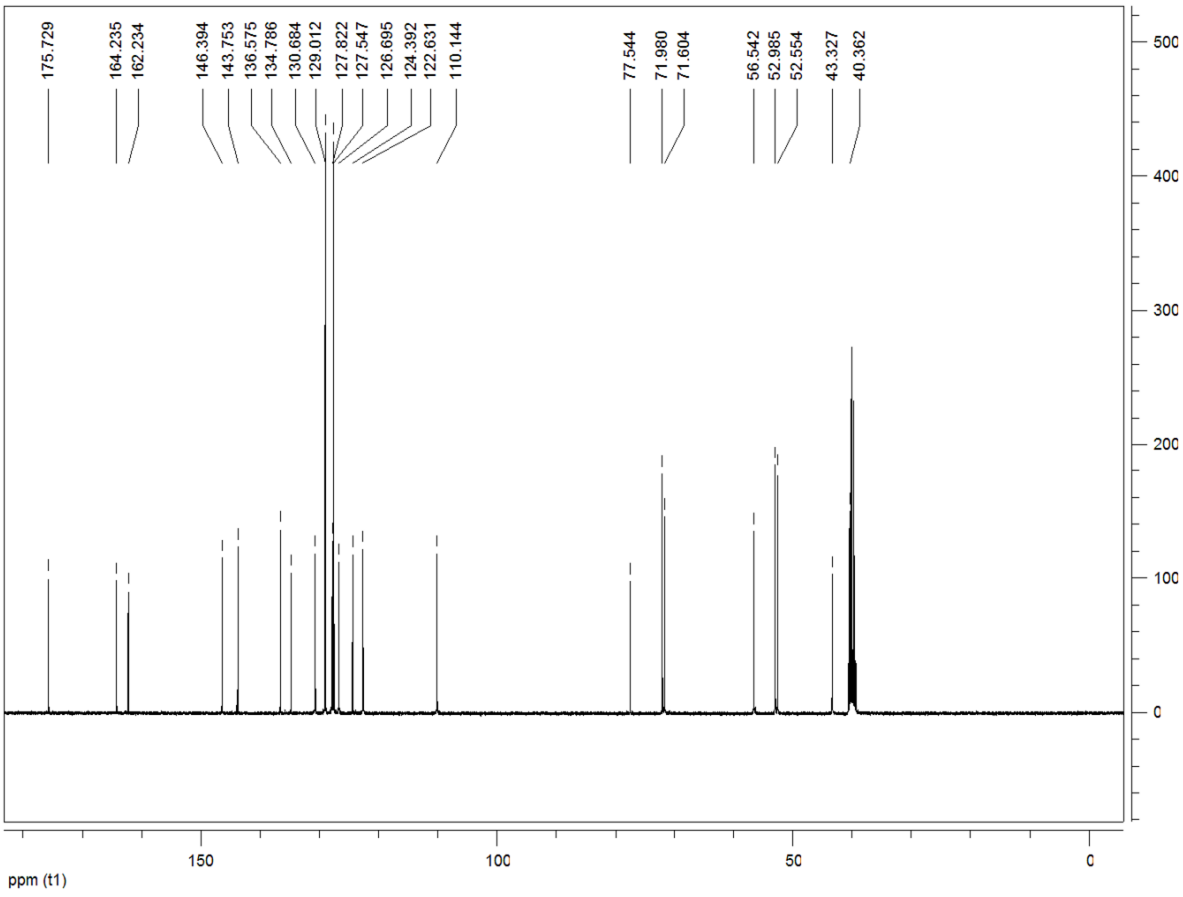
Diethyl 1-benzyl-5-chloro-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1h):



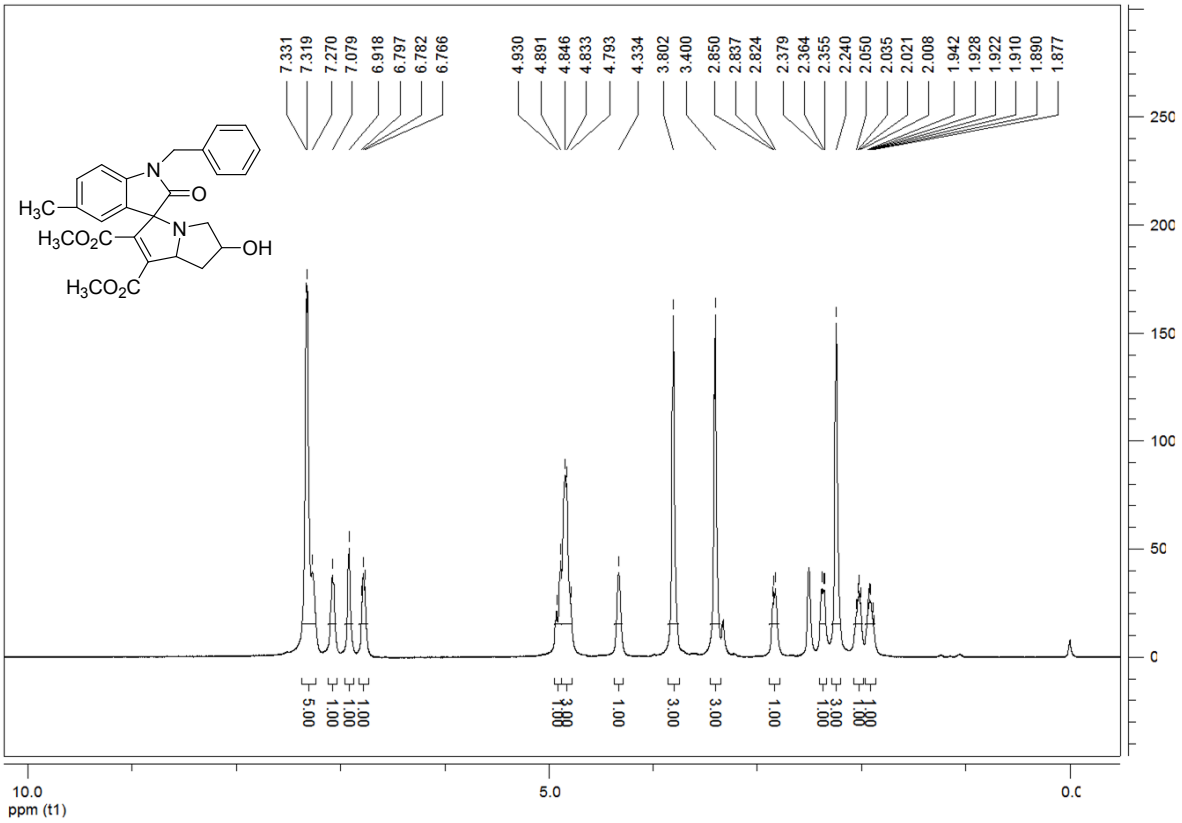


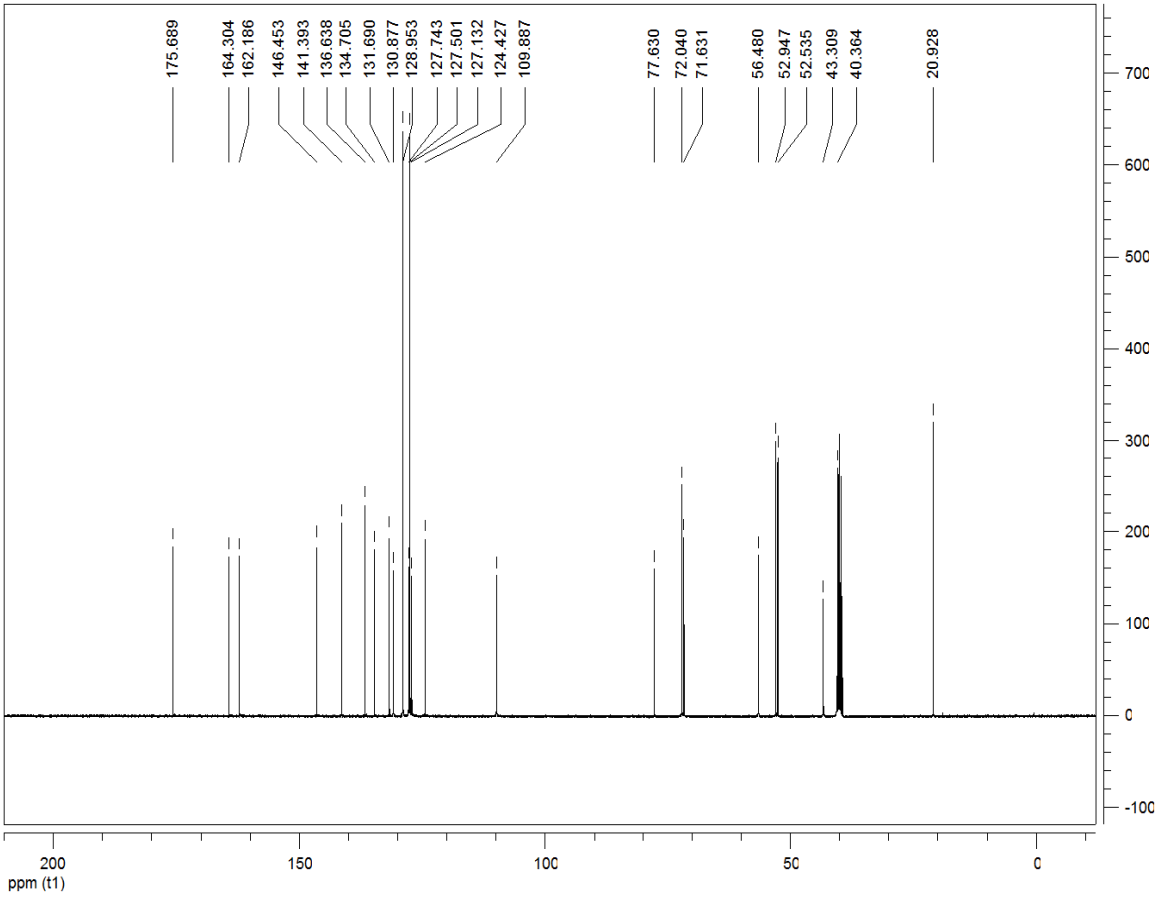
Dimethyl 1-benzyl-6'-hydroxy-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1i):



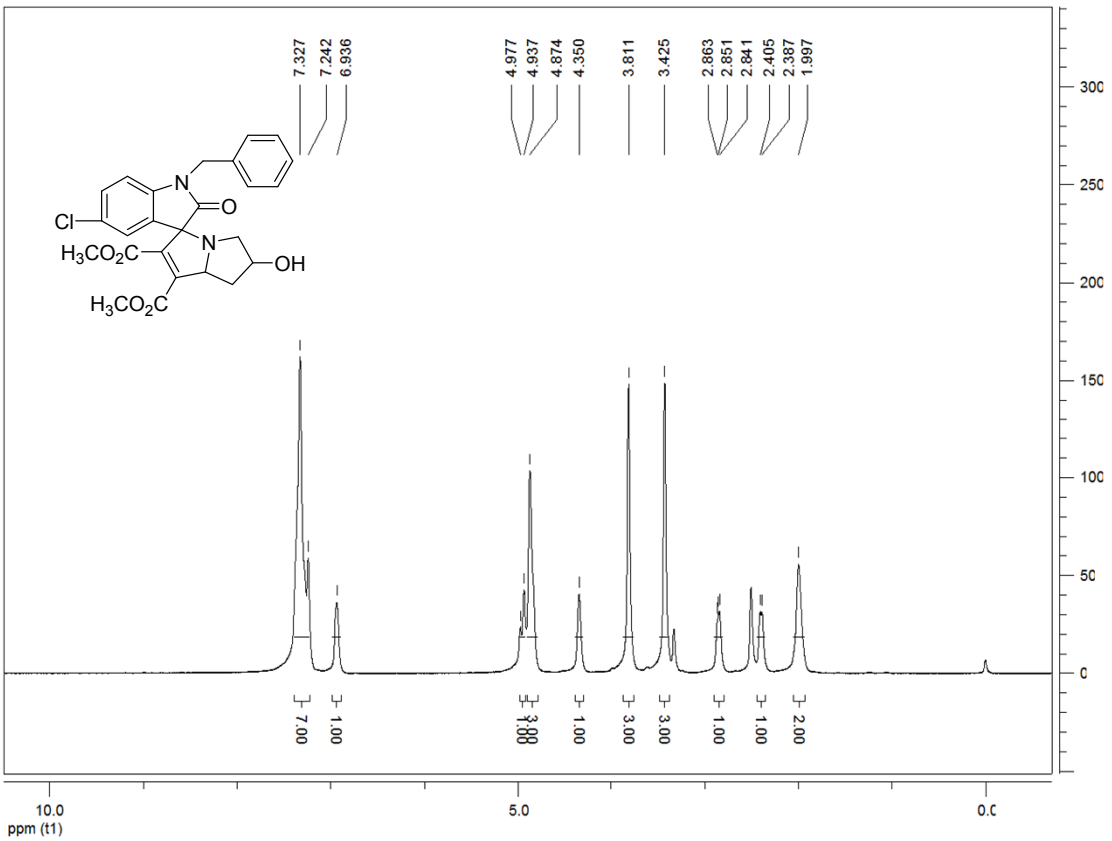


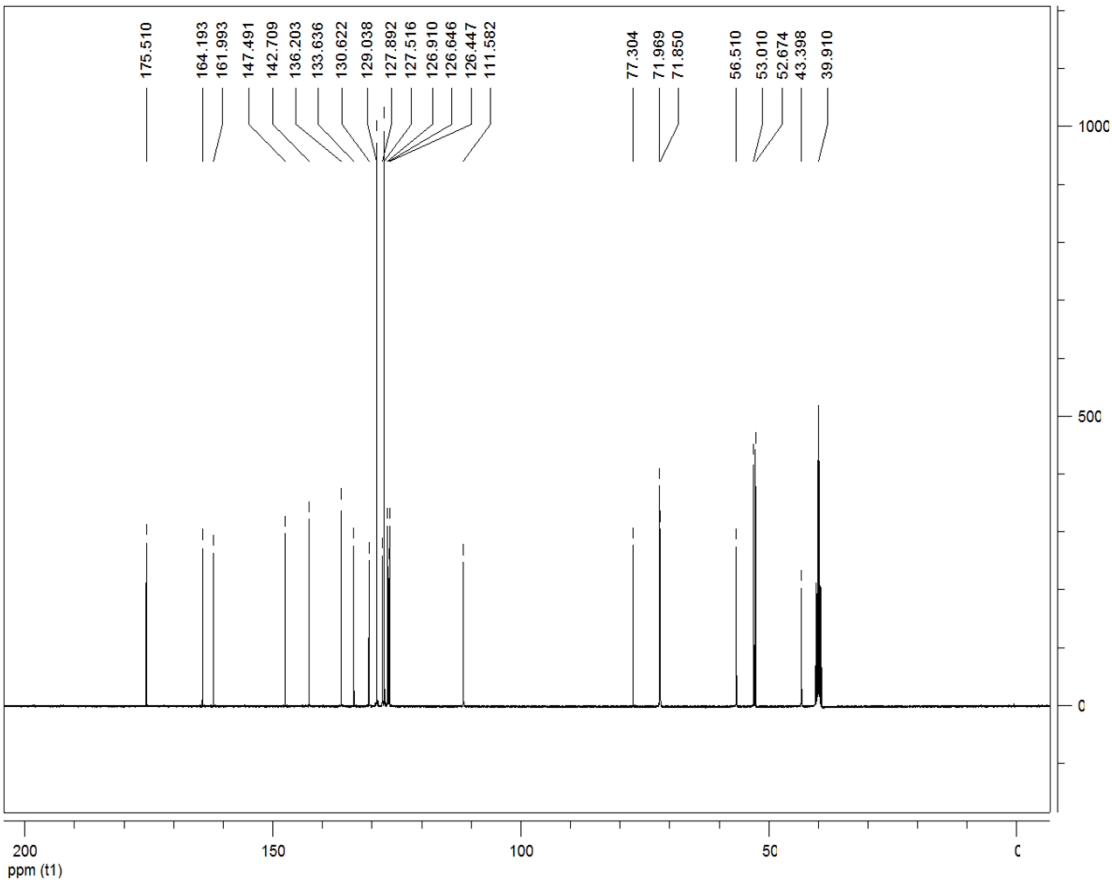
Dimethyl 1-benzyl-6'-hydroxy-5-methyl-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1j):



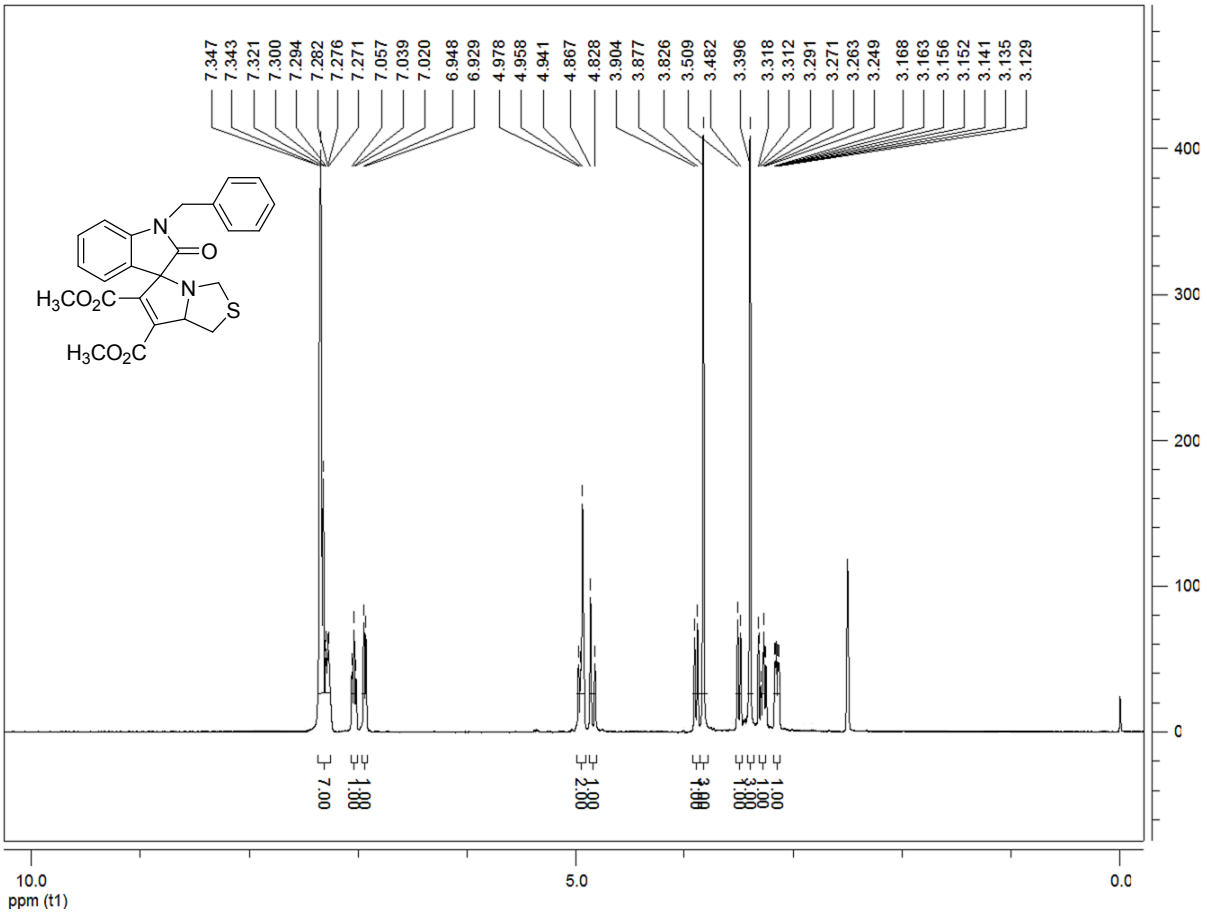


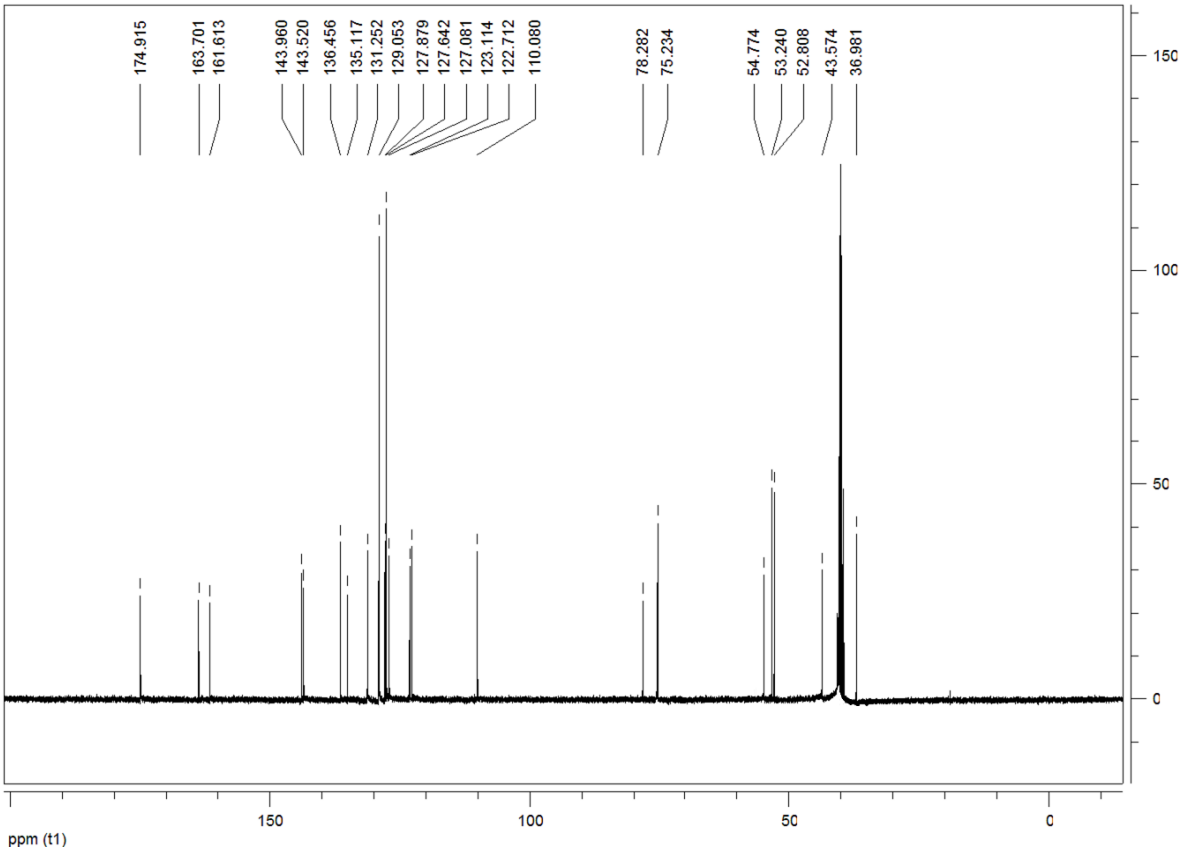
Dimethyl 1-benzyl-5-chloro-6'-hydroxy-2-oxo-5',6',7',7a'-tetrahydrospiro[indoline-3,3'-pyrrolizine]-1',2'-dicarboxylate (1k):



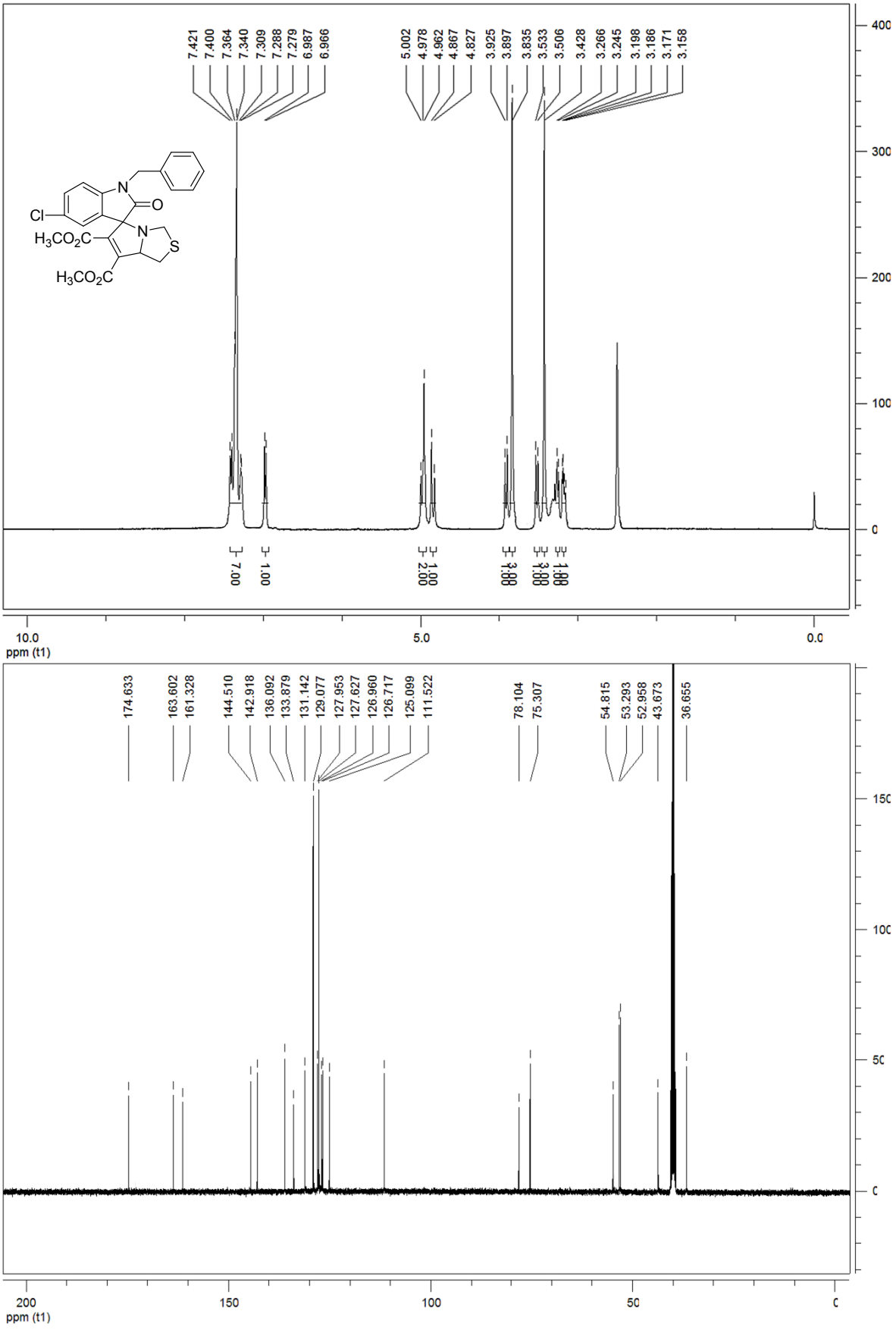


Dimethyl 1-benzyl-2-oxo-3',7a'-dihydro-1'H-spiro[indoline-3,5'-pyrrolo[1,2-c]thiazole]-6',7'-dicarboxylate (1l):

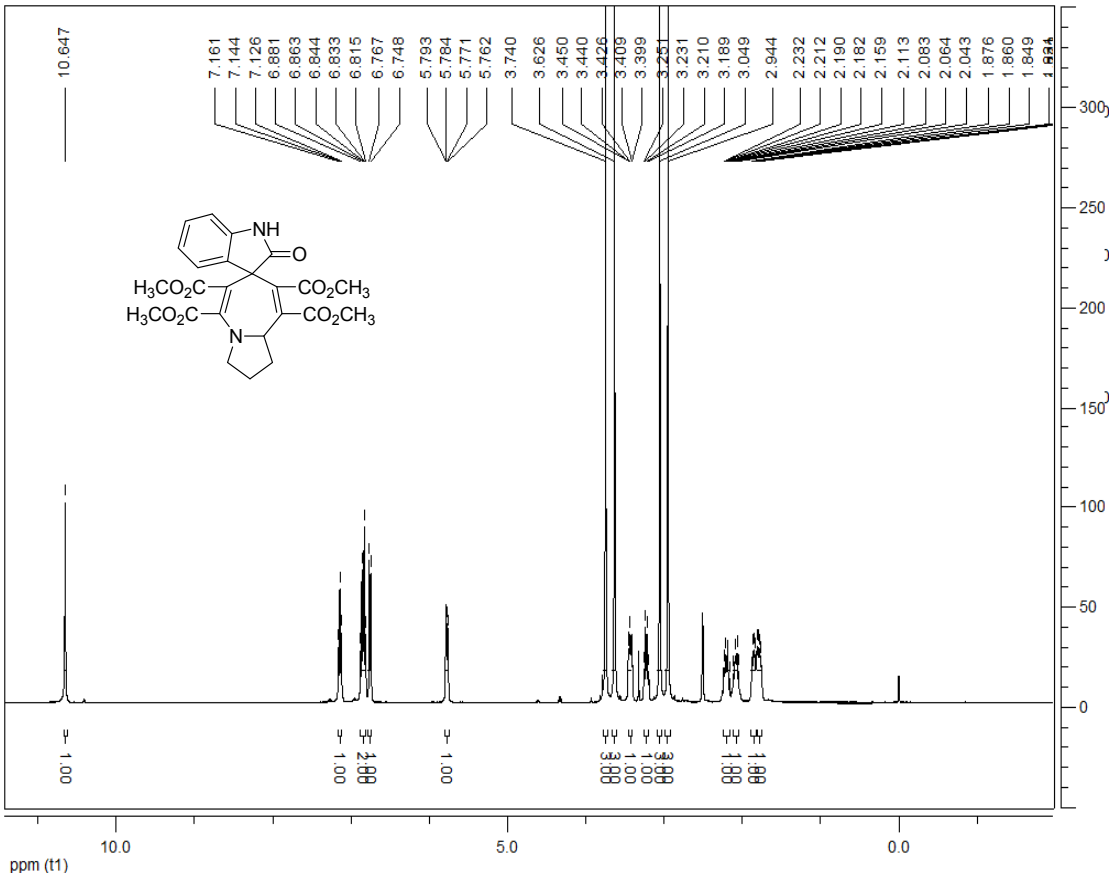


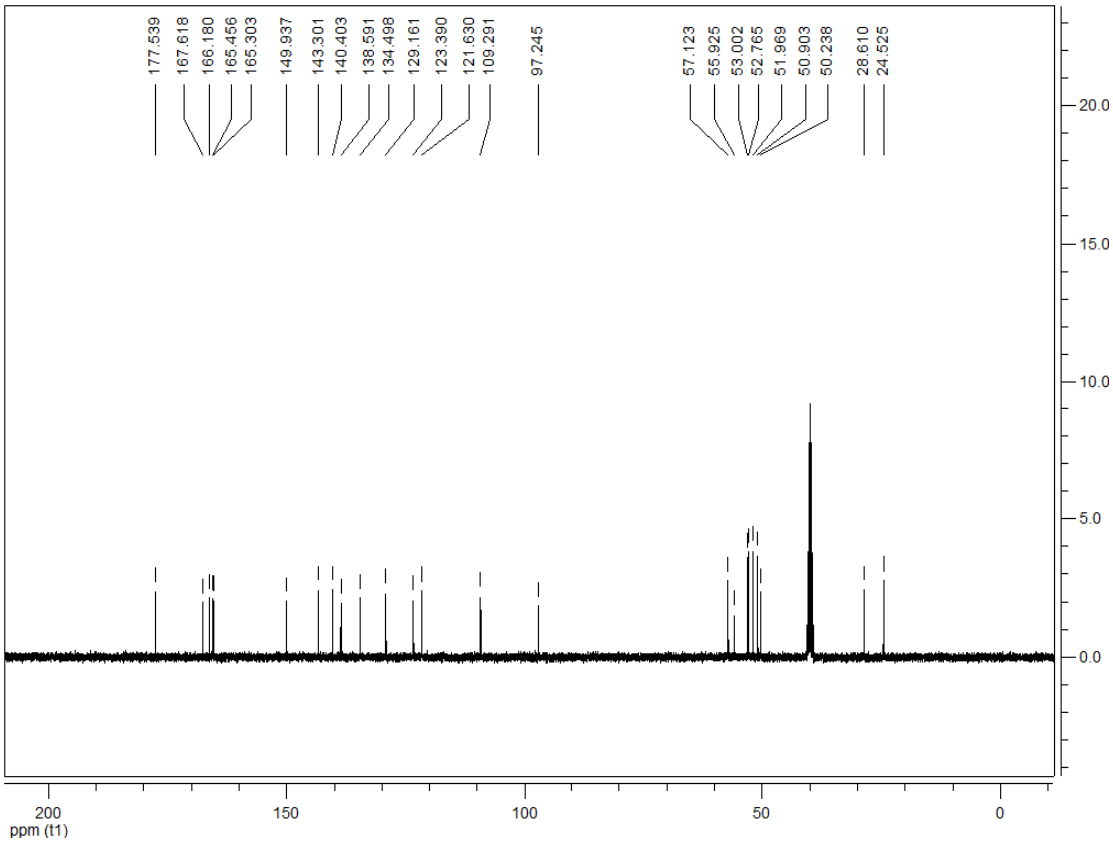


Dimethyl 1-benzyl-5-chloro-2-oxo-3',7a'-dihydro-1'H-spiro[indoline-3,5'-pyrrolo[1,2-c]-thiazole]-6',7'-dicarboxylate (1m):

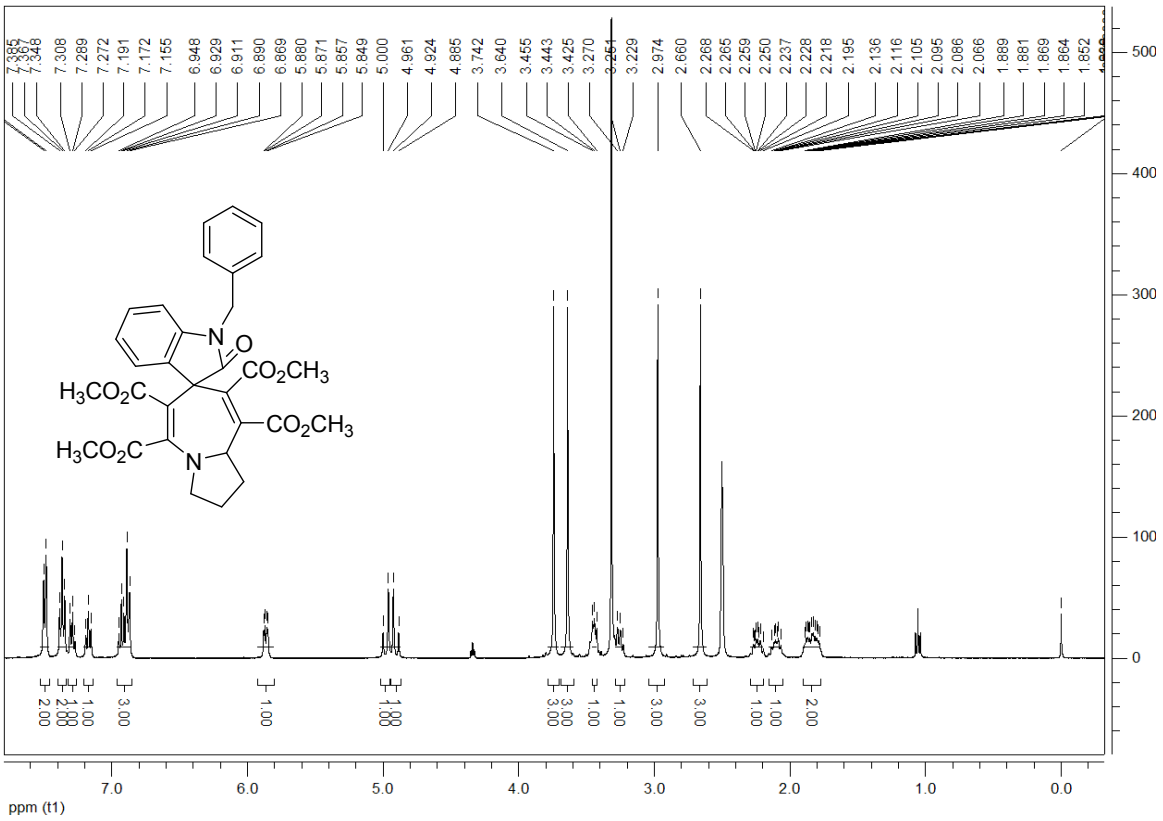


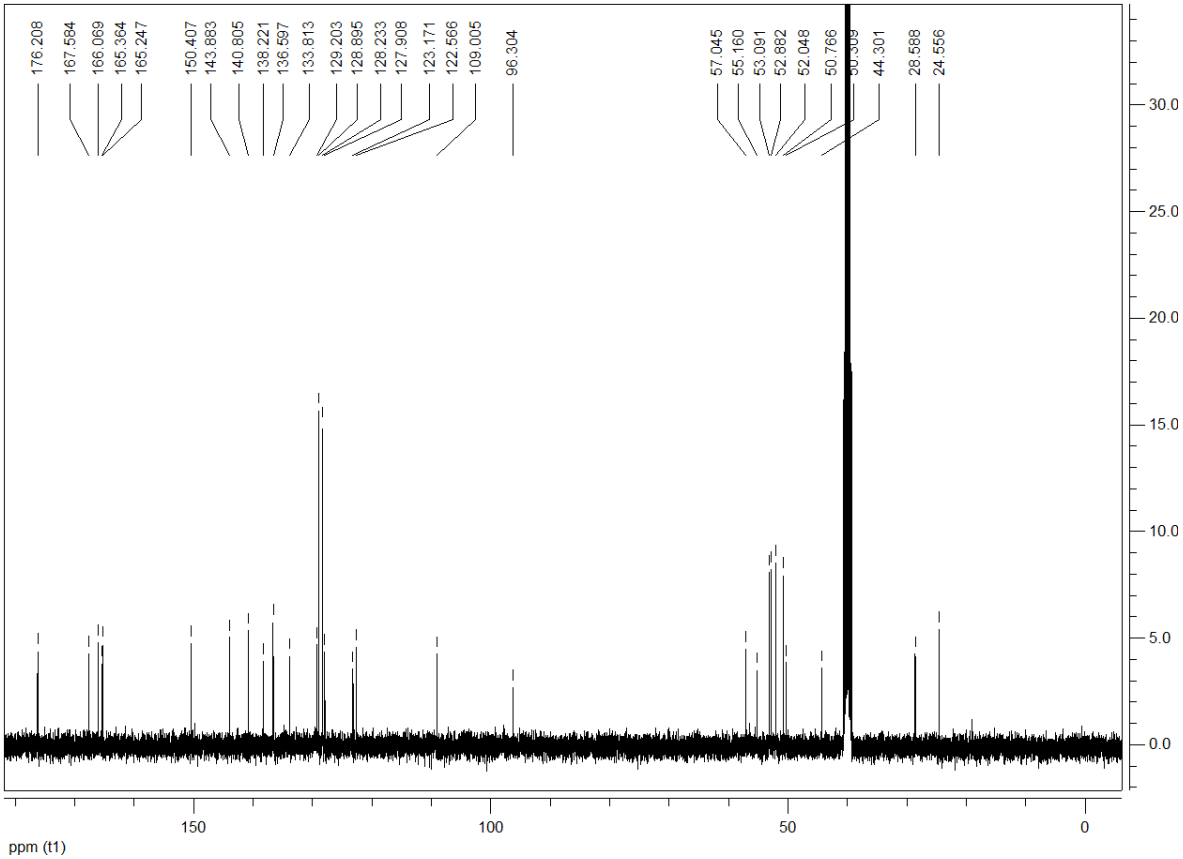
Tetramethyl 2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-Tetracarboxylate (2a):



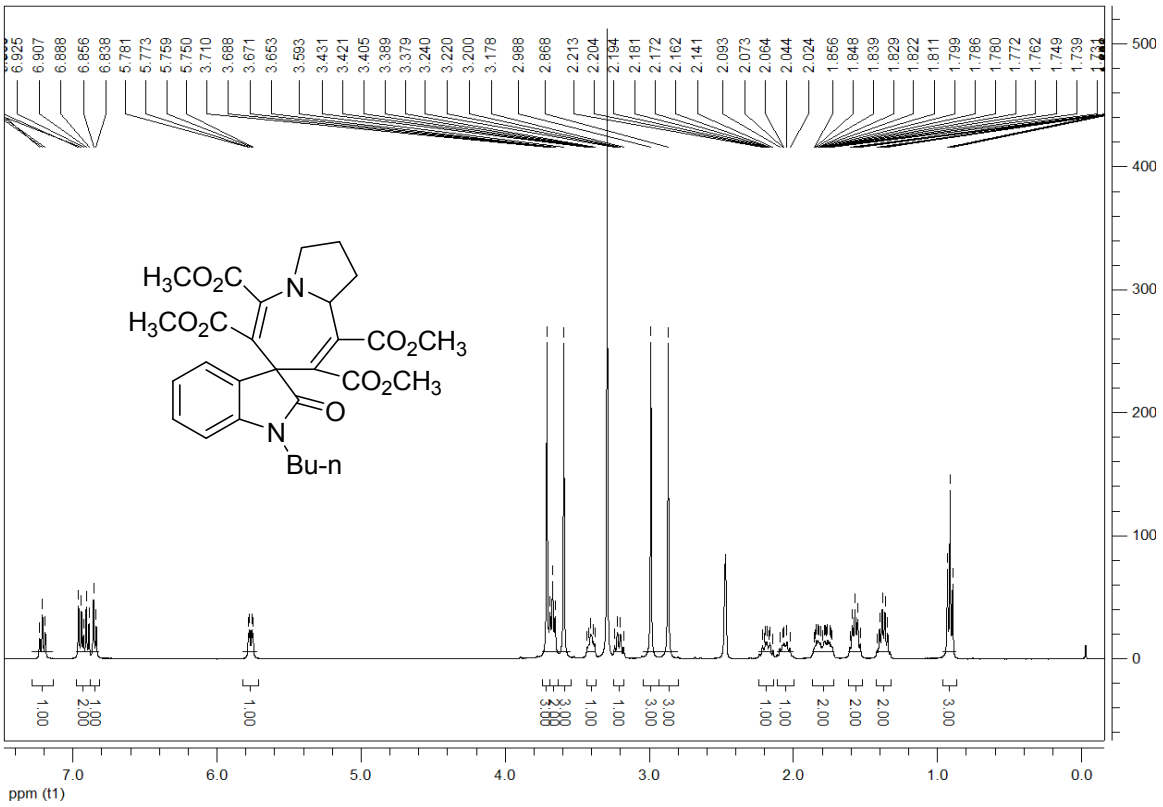


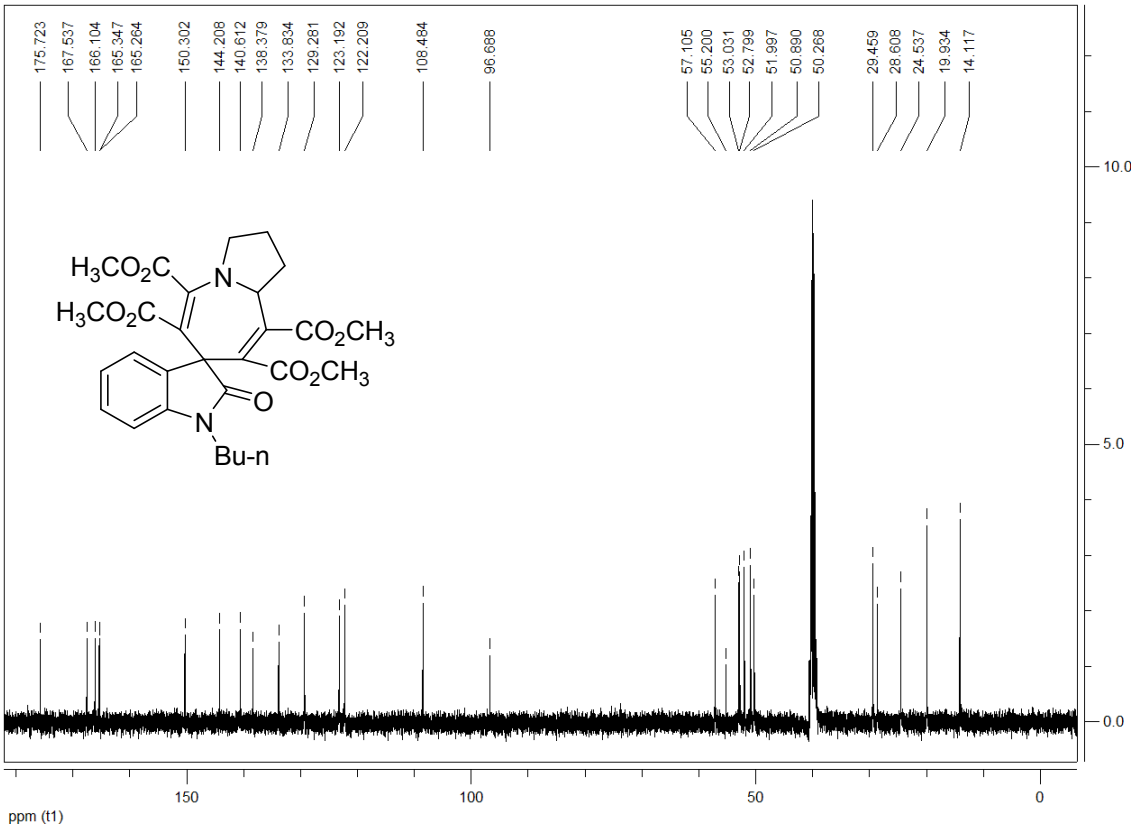
Tetramethyl 1-benzyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2b):



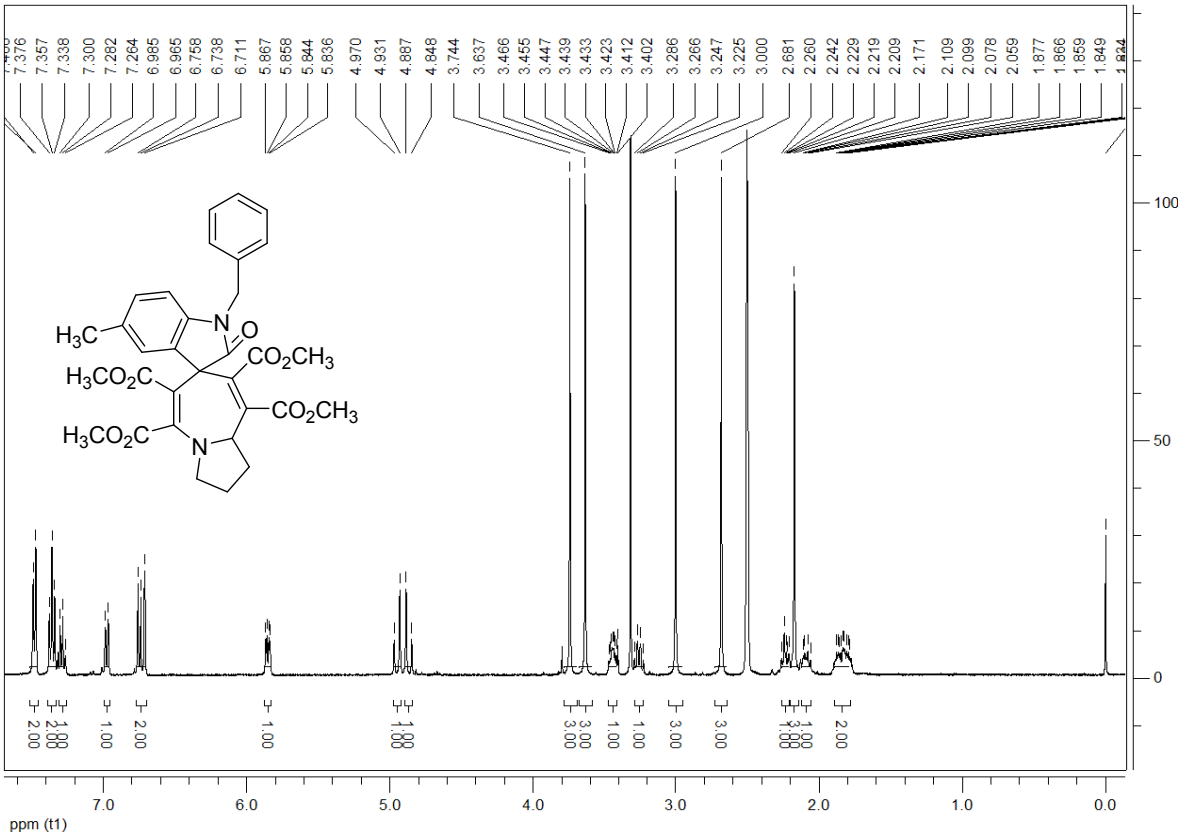


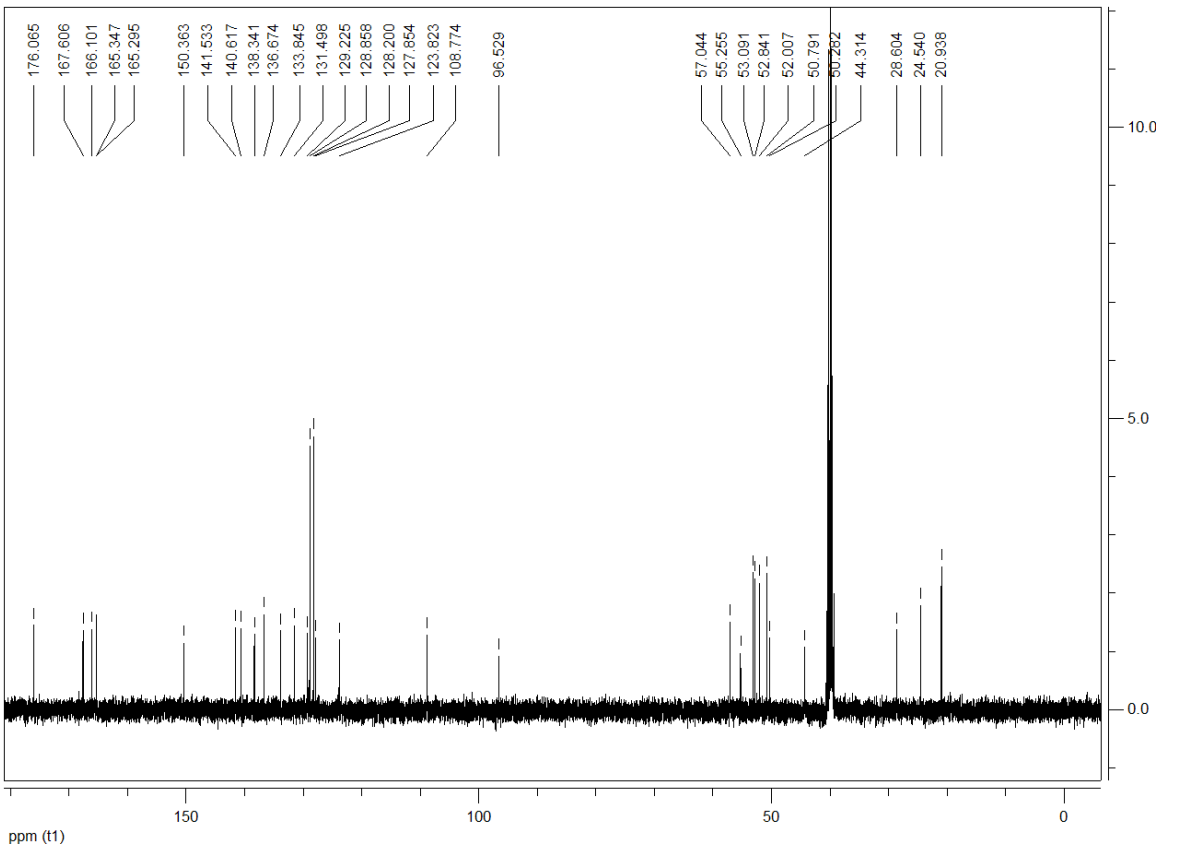
Tetramethyl 1-butyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2c):



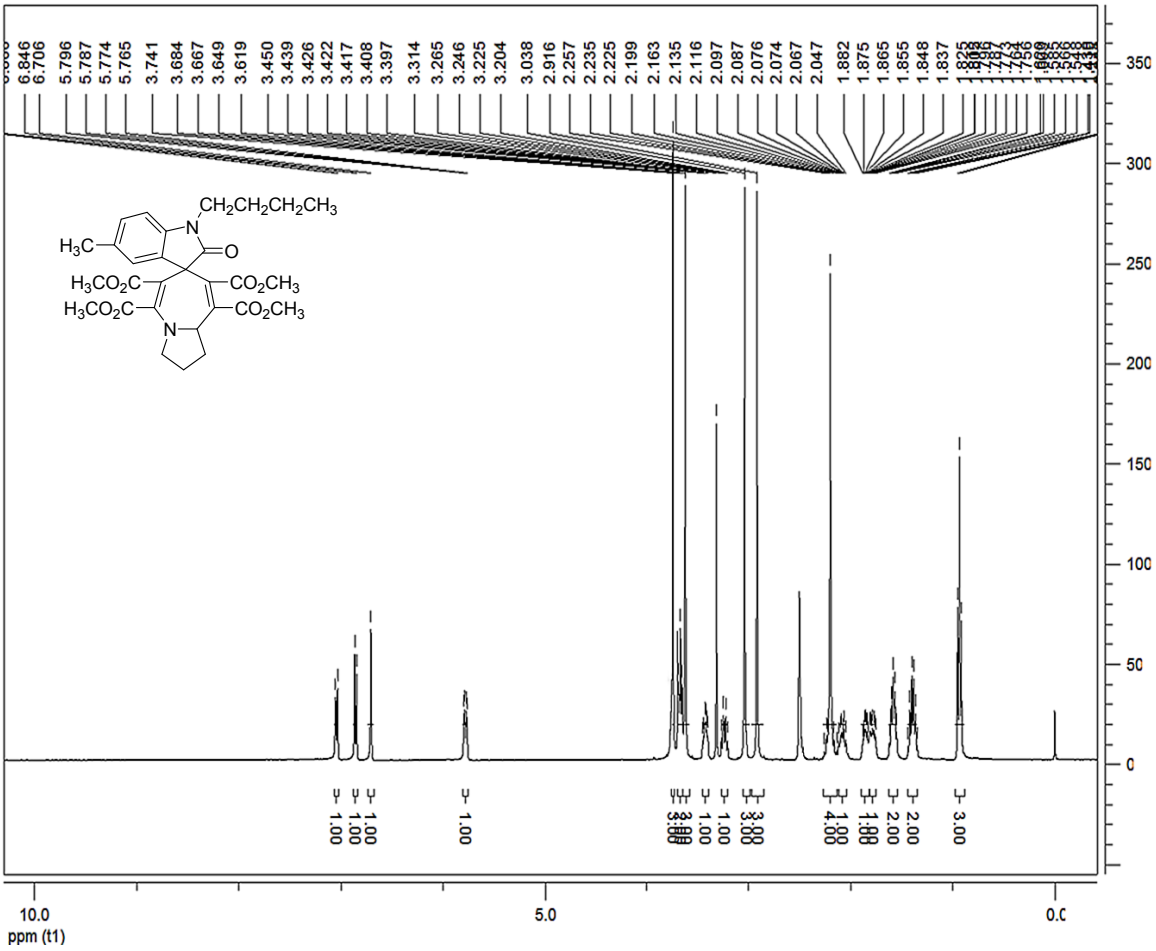


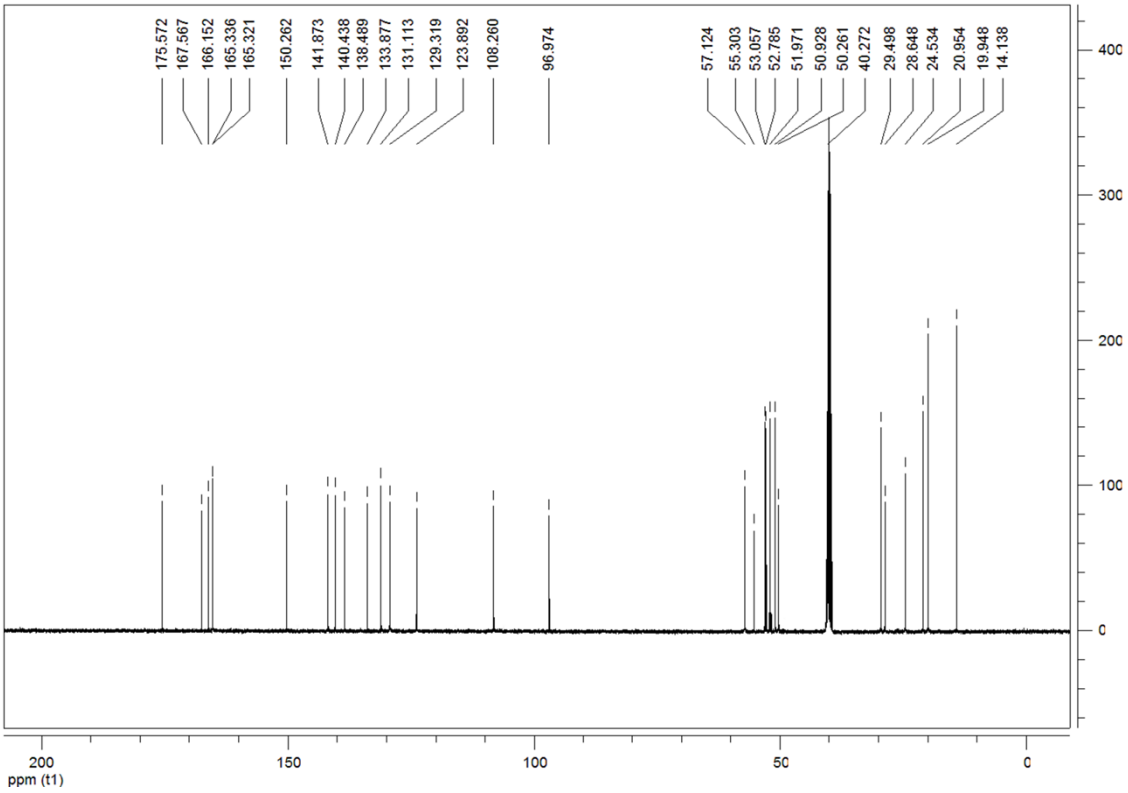
Tetramethyl 1-benzyl-5-methyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2d):



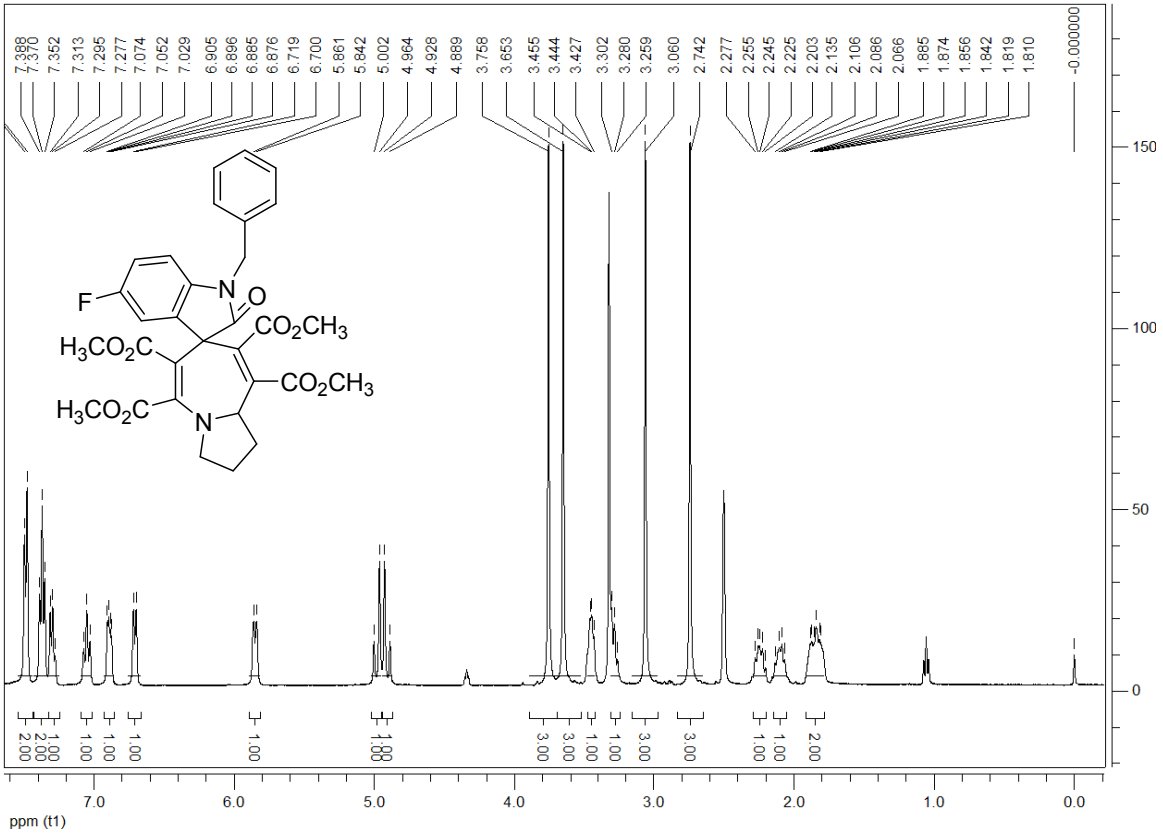


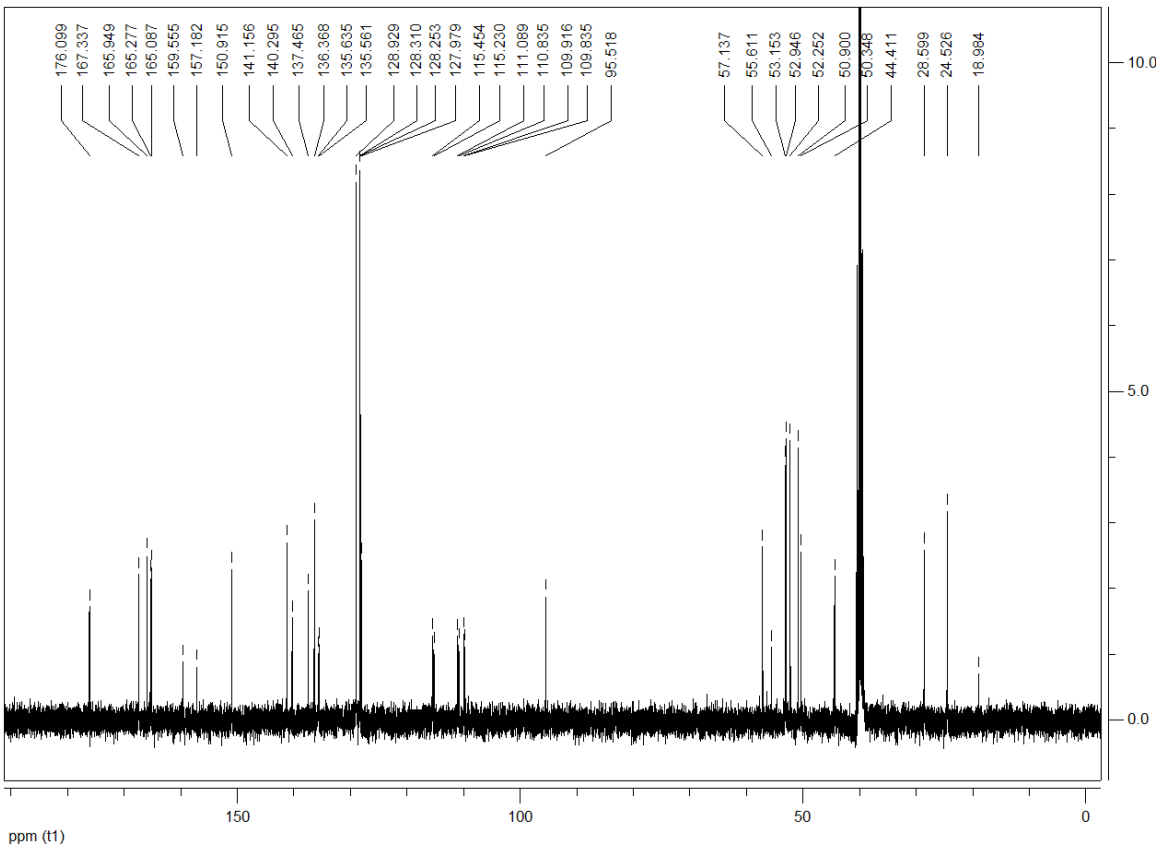
Tetramethyl 1-butyl-5-methyl-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2e):



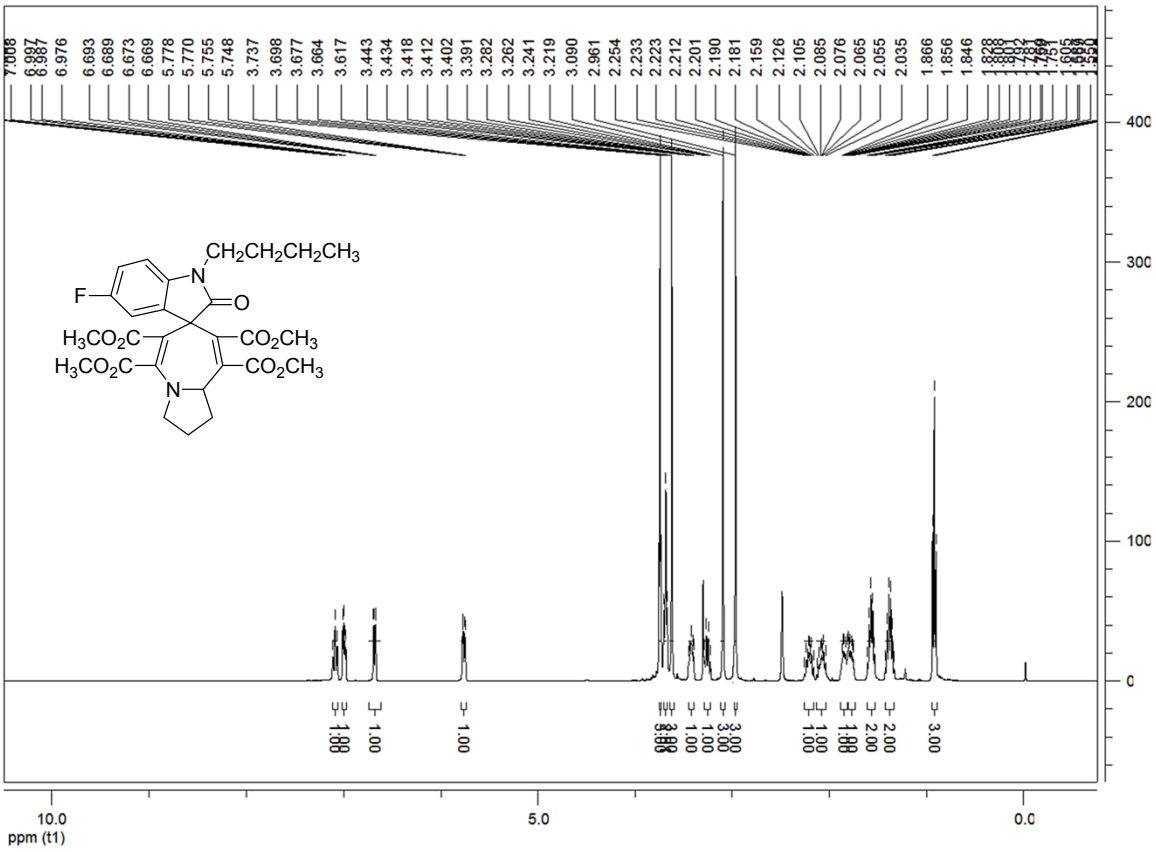


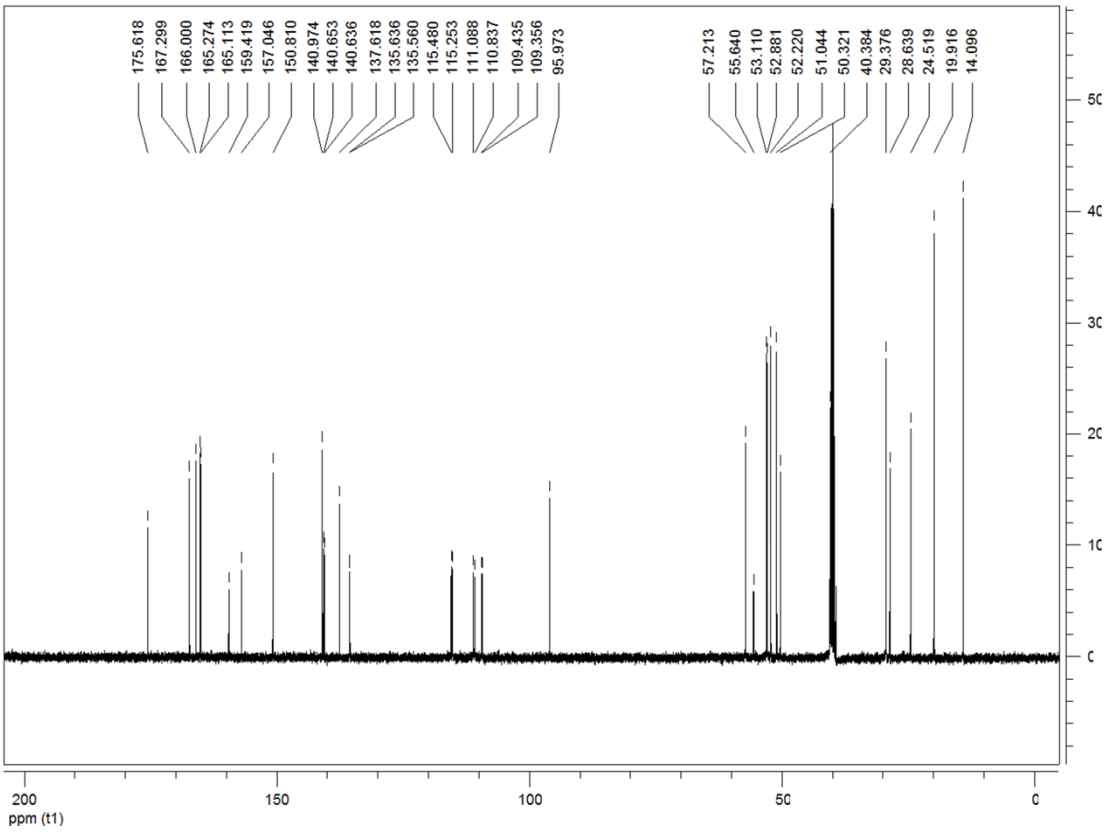
Tetramethyl 1-benzyl-5-fluoro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2f):



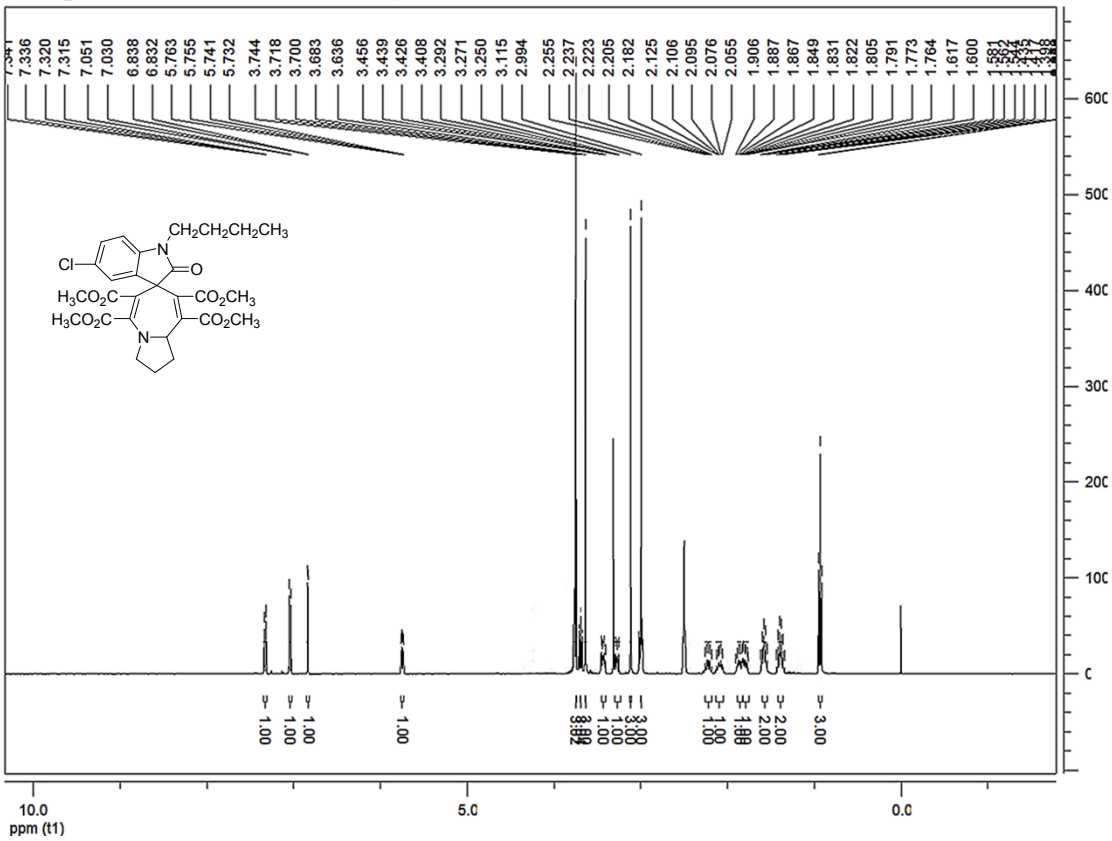


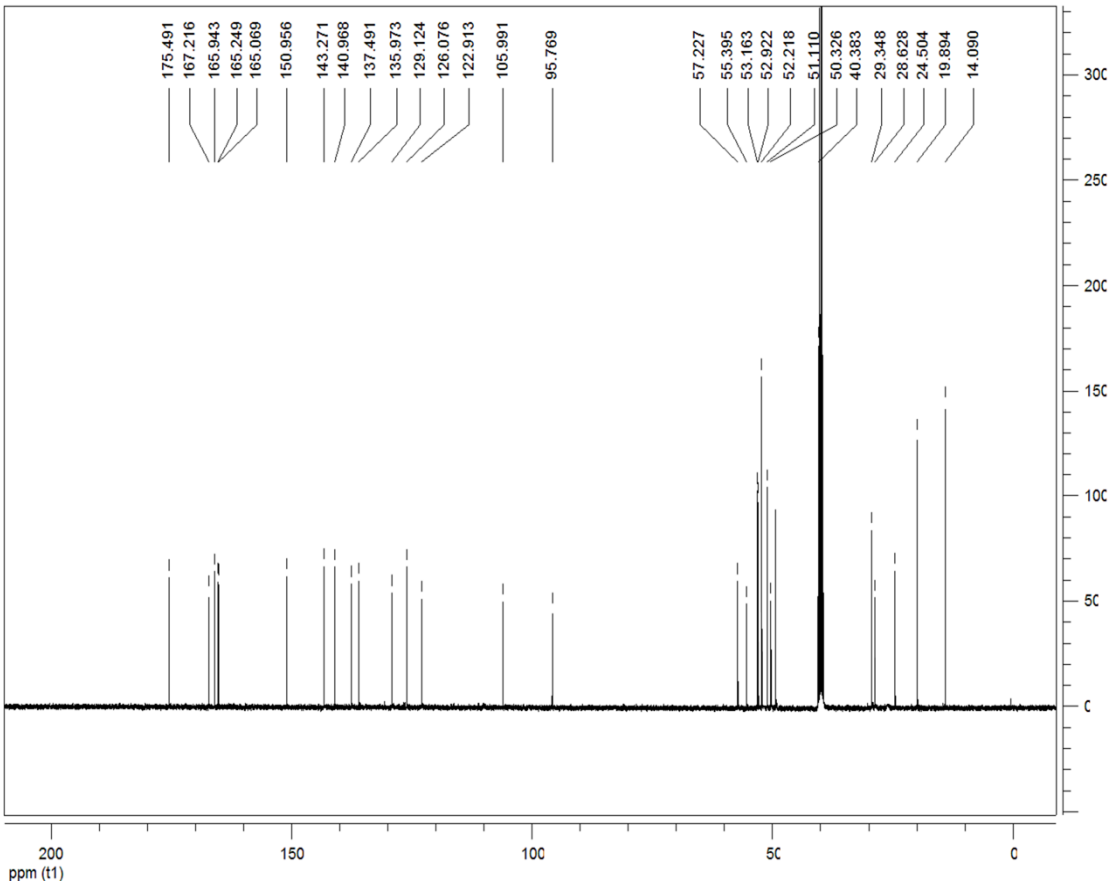
Tetramethyl 1-butyl-5-fluoro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2g):



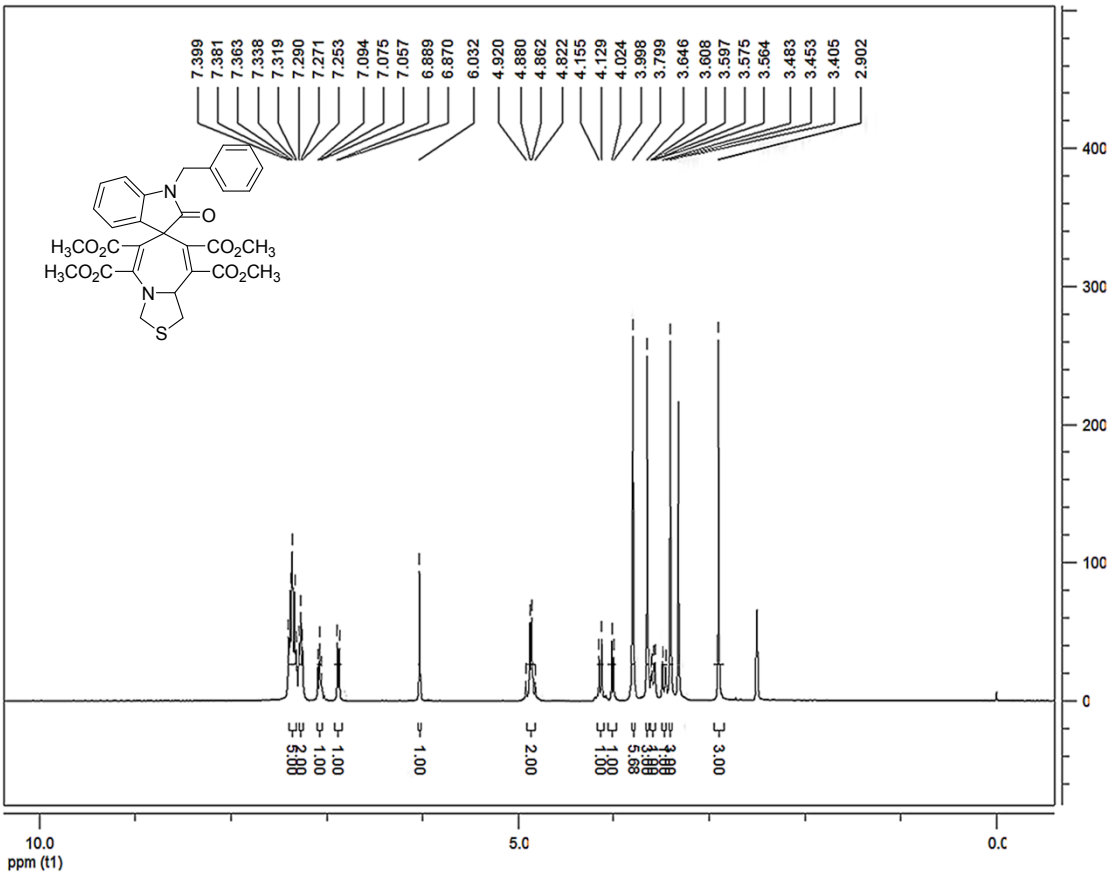


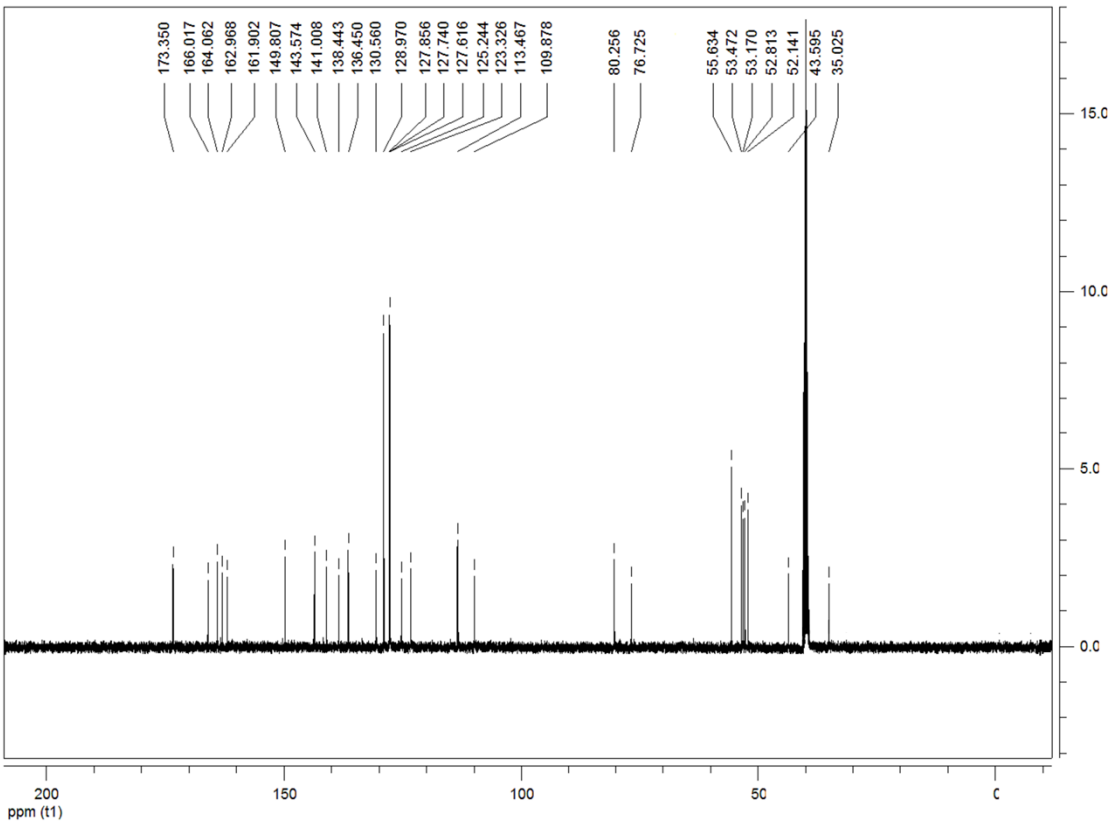
Tetramethyl 1-butyl-5-chloro-2-oxo-1',2',3',9a'-tetrahydrospiro[indoline-3,7'-pyrrolo[1,2-a]azepine]-5',6',8',9'-tetracarboxylate (2h):



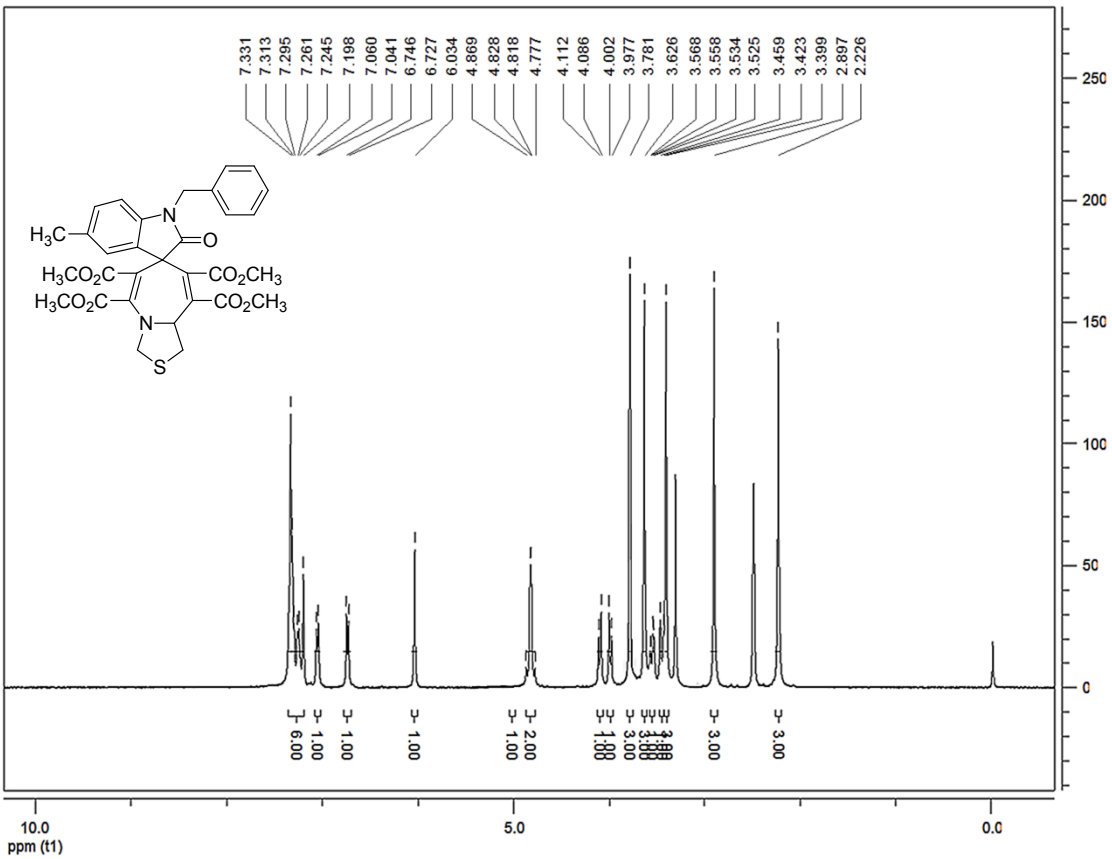


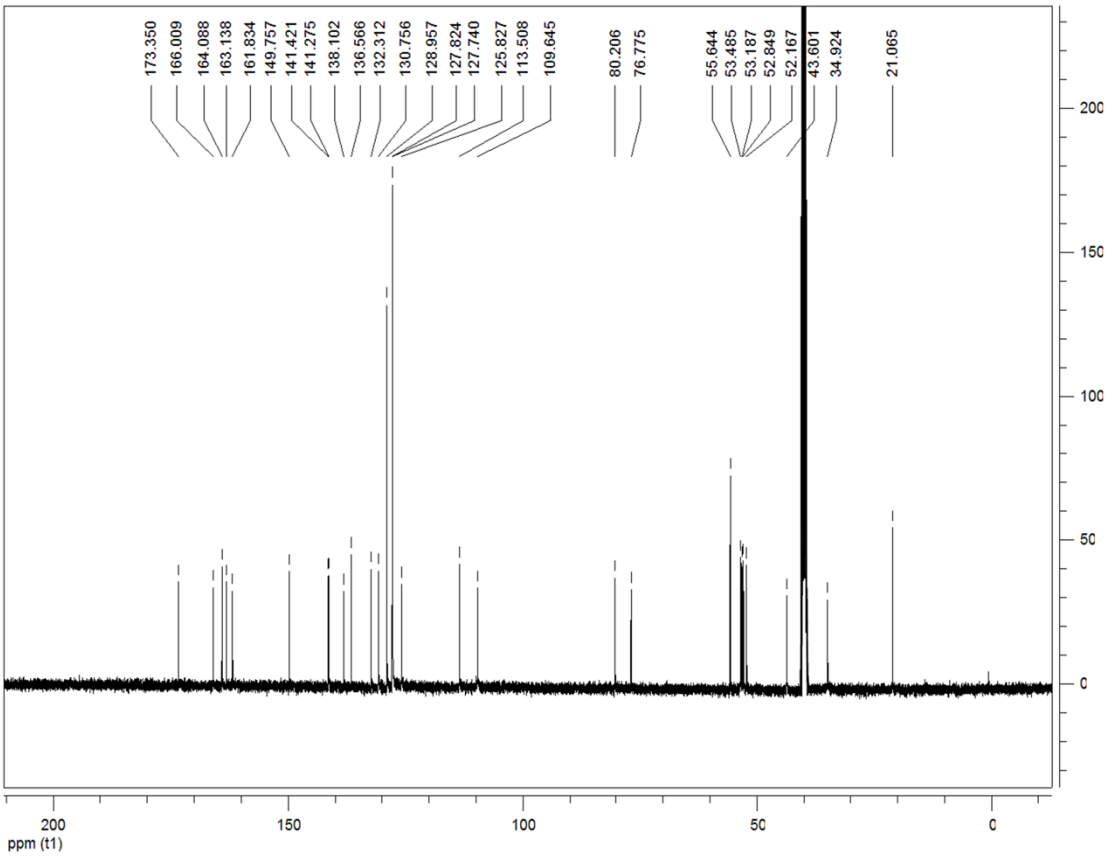
Tetramethyl 1-benzyl-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]azepine]-5',6',8',9'-tetracarboxylate (2i)



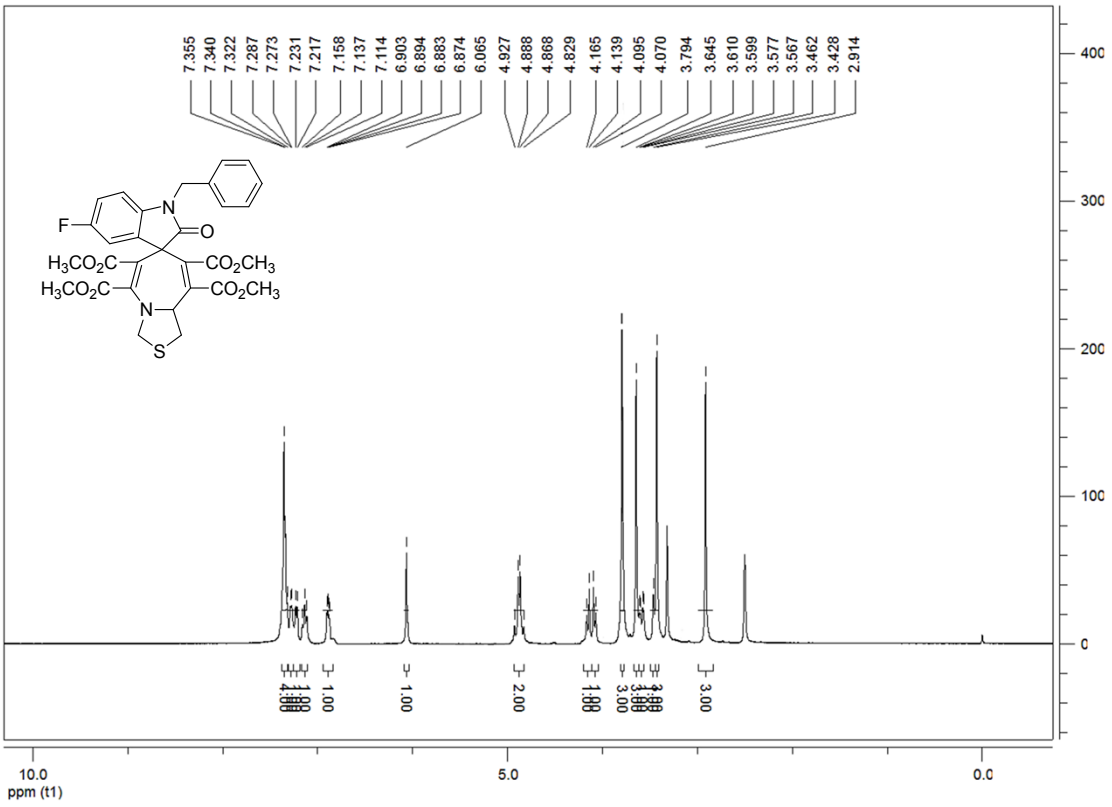


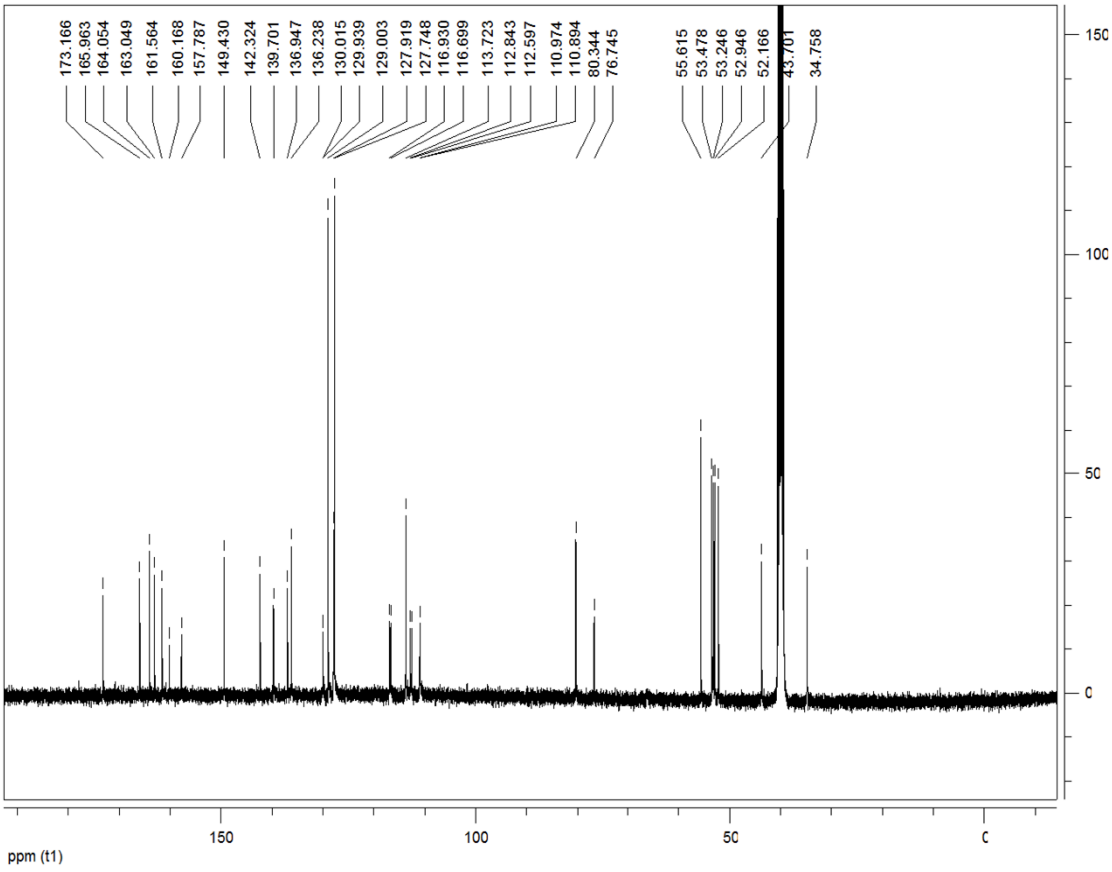
Tetramethyl 1-benzyl-5-methyl-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2j):





Tetramethyl 1-benzyl-5-fluoro-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2k):





Tetramethyl 1-benzyl-5-chloro-2-oxo-3',9a'-dihydro-1'H-spiro[indoline-3,7'-thiazolo[3,4-a]-azepine]-5',6',8',9'-tetracarboxylate (2l):