Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Copper-Catalyzed Oxidative *ipso*-Carboalkylation of Activated Alkynes with Ethers Leading to 3-Etherified Azaspiro[4.5]trienones

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Supporting Information

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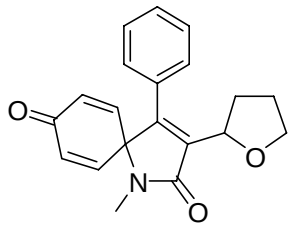
(A) Typical experimental procedure

(a) Typical Experimental Procedure for the Cu-Catalyzed Synthesis of 3-Etherified Azaspiro[4.5]trienones:

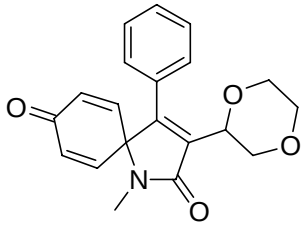
To a Schlenk tube were added *N*-arylpropiolamides **1** (0.3 mmol), ethers **2** (1.5 mmol), CuCl (5 mol%), TBHP (1.2 equiv, 5 M in decane) and ^{n}BuOAc (2 mL). Then the tube was charged with argon, and was stirred at 120 ^{o}C for the indicated time until complete consumption of starting material as monitored by TLC and/or GC-MS analysis. After the reaction was finished, the reaction mixture was washed with brine. The aqueous phase was re-extracted with ethyl acetate. The combined organic extracts were dried over Na_2SO_4, concentrated in vacuum, and the resulting residue was purified by silica gel column chromatography (hexane/ethyl acetate) to afford the desired product.

(B) Analytical data

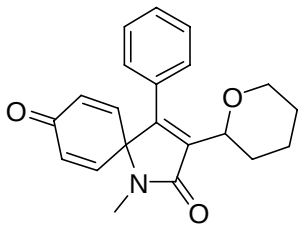


1-Methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3aa): Yellow solid, mp 164.2-165.5 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.35-7.28 (m, 3H), 7.17-7.14 (m, 2H), 6.55-6.49 (m, 2H), 6.45-6.41 (m, 2H), 4.65 (t, *J* = 7.6 Hz, 1H), 3.95-3.89 (m, 1H), 3.82-3.77 (m, 1H), 2.87 (s, 3H), 2.35-2.30 (m, 1H), 2.11-2.05 (m, 2H), 1.92-1.87 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.0, 169.1, 152.1, 145.3, 145.1, 137.3, 133.1 (2), 130.7, 129.3, 128.4, 128.2, 73.1, 69.2, 67.3, 30.2, 27.1, 25.7; IR (KBr, cm^{-1}): 1705, 1668; LRMS

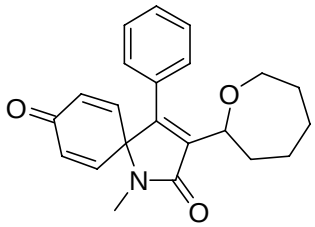
(EI, 70 eV) *m/z* (%): 321 (M^+, 25), 278 (100), 129 (20); HRMS *m/z* (ESI) calcd for $C_{20}H_{20}NO_3$ ($[M+H]^+$) 322.1438, found 322.1422.



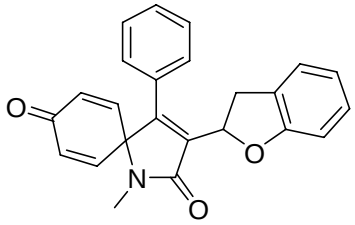
3-(1,4-Dioxan-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ab): Yellow solid, mp 172.3-173.4 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.39-7.32 (m, 3H), 7.16 (d, *J* = 7.2 Hz, 2H), 6.52-6.47 (m, 2H), 6.45-6.41 (m, 2H), 4.50-4.47 (m, 1H), 3.79-3.66 (m, 6H), 2.87 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.8, 168.8, 155.4, 144.7, 144.6, 133.4, 133.3 (2), 130.4, 129.6, 128.3, 128.2, 71.3, 68.0, 67.7, 66.9, 66.1, 25.9; IR (KBr, cm^{-1}): 1703, 1666; LRMS (EI, 70 eV) *m/z* (%): 337 (M^+, 100), 264 (81), 129 (86); HRMS *m/z* (ESI) calcd for $C_{20}H_{20}NO_4$ ($[M+H]^+$) 338.1352, found 338.1358.



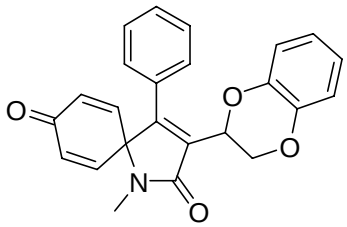
1-Methyl-4-phenyl-3-(tetrahydro-2*H*-pyran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ac): Yellow solid, mp 170.2-171.4 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.37-7.28 (m, 3H), 7.20-7.18 (m, 2H), 6.51 (d, *J* = 10.0 Hz, 2H), 6.44-6.39 (m, 2H), 4.22-4.19 (m, 1H), 4.00-3.96 (m, 1H), 3.44-3.37 (m, 1H), 2.87 (s, 3H), 2.11-2.04 (m, 1H), 1.85 (t, *J* = 8.4 Hz, 1H), 1.62-1.43 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.0, 169.2, 152.4, 145.4, 145.2, 136.9, 133.1, 131.0, 129.2, 128.5, 128.4, 128.1, 73.0, 68.8, 67.3, 28.8, 25.8, 25.4, 23.3; IR (KBr, cm^{-1}): 1708, 1665; LRMS (EI, 70 eV) *m/z* (%): 335 (M^+, 91), 307 (100), 123 (35); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_3$ ($[M+H]^+$) 336.1594, found 336.1579.



1-Methyl-3-(oxepan-2-yl)-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ad): Yellow solid, mp 182.4-183.6 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.35-7.29 (m, 3H), 7.17-7.14 (m, 2H), 6.57-6.48 (m, 2H), 6.42-6.39 (m, 2H), 4.00-3.95 (m, 1H), 3.66-3.63 (m, 1H), 3.55-3.51 (m, 1H), 2.88 (s, 3H), 1.74-1.65 (m, 4H), 1.58-1.41 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.1, 169.7, 150.6, 145.5, 145.2, 138.6, 133.0 (2), 131.0, 129.1, 128.4, 128.1, 74.5, 68.8, 67.5, 32.8, 31.0, 26.8, 26.7, 25.9; IR (KBr, cm^{-1}): 1710, 1672; LRMS (EI, 70 eV) *m/z* (%): 349 (M^+, 41), 321 (100), 165 (46); HRMS *m/z* (ESI) calcd for $C_{22}H_{24}NO_3$ ($[M+H]^+$) 350.1751, found 350.1746.

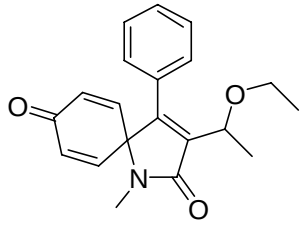


3-(2,3-Dihydrobenzofuran-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ae): Yellow solid, mp 207.5-208.8 ^{o}C (uncorrected); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.34-7.31 (m, 1H), 7.27-7.24 (m, 2H), 7.12-7.10 (m, 3H), 7.09-7.02 (m, 1H), 6.82 (t, *J* = 7.5 Hz, 1H), 6.56-6.53 (m, 2H), 6.50 (d, *J* = 3.0 Hz, 1H), 6.48-6.46 (m, 1H), 6.43-6.40 (m, 1H), 5.56-5.53 (m, 1H), 3.58-3.54 (m, 1H), 3.42-3.37 (m, 1H), 2.88 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.9, 168.8, 159.1, 153.1, 144.9, 144.7, 135.6, 133.4, 133.3, 130.3, 129.5, 128.2 (2), 127.9, 126.3, 124.5, 120.7, 109.2, 76.4, 67.7, 34.6, 25.9; IR (KBr, cm^{-1}): 1714, 1674; LRMS (EI, 70 eV) *m/z* (%): 369 (M^+, 10), 207 (81), 91 (100); HRMS *m/z* (ESI) calcd for $C_{24}H_{20}NO_3$ ($[M+H]^+$) 370.1438, found 370.1423.

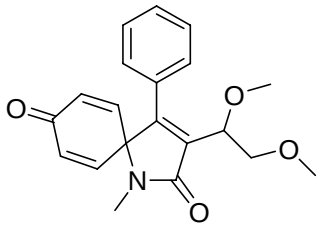


3-(2,3-Dihydrobenzo[*b*][1,4]dioxin-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3af):

Yellow solid, mp 212.2-213.8 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.25 (t, *J* = 6.4 Hz, 2H), 7.09 (t, *J* = 4.4 Hz, 2H), 6.83-6.78 (m, 3H), 6.72-6.57 (m, 1H), 6.55-6.52 (m, 3H), 6.45 (t, *J* = 4.0 Hz, 2H), 5.08-5.06 (m, 1H), 4.63-4.58 (m, 1H), 4.29-4.26 (m, 1H), 2.91 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.8, 168.7, 156.1, 145.8, 144.4, 144.2, 142.9, 133.6, 131.9, 129.9, 129.6, 128.2, 128.1, 121.6, 121.4, 120.2, 117.1, 117.0, 69.5, 68.2, 65.3, 26.1; IR (KBr, cm^{-1}): 1715, 1675; LRMS (EI, 70 eV) *m/z* (%): 385 (M^+, 33), 276 (100), 121 (24); HRMS *m/z* (ESI) calcd for $C_{24}H_{20}NO_4$ ($[M+H]^+$) 386.1387, found 386.1399.

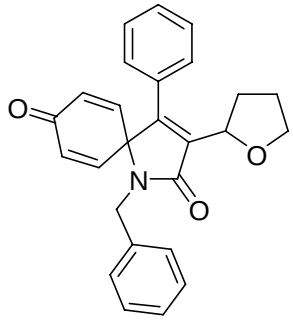


3-(1-Ethoxyethyl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ag): Yellow solid, mp 157.8-158.9 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.35-7.29 (m, 3H), 7.14-7.12 (m, 2H), 6.53-6.48 (m, 2H), 6.44-6.40 (m, 2H), 4.39-4.34 (m, 1H), 3.32-3.26 (m, 2H), 2.90 (s, 3H), 1.46 (d, *J* = 6.4 Hz, 3H), 0.94 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.0, 169.6, 151.3, 145.3 (2), 137.9, 133.2, 133.1, 130.9, 129.2, 128.4, 128.0, 70.4, 67.7, 64.2, 25.9, 20.2, 14.9; IR (KBr, cm^{-1}): 1704, 1667; LRMS (EI, 70 eV) *m/z* (%): 323 (M^+, 2), 279 (100), 165 (14); HRMS *m/z* (ESI) calcd for $C_{20}H_{22}NO_3$ ($[M+H]^+$) 324.1594, found 324.1575.

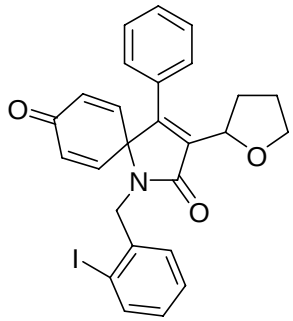


3-(1,2-Dimethoxyethyl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ah): Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.37-7.31 (m, 4H), 7.25-7.17 (m, 2H), 6.57-6.54 (m, 1H), 6.50-6.45 (m, 1H), 6.45-6.38 (m, 1H), 4.29 (t, *J* = 6.0 Hz, 1H), 3.79 (t, *J* = 8.4 Hz, 1H), 3.70 (t, *J* = 4.8 Hz, 1H), 3.35 (s, 3H), 3.21 (s,

3H), 2.90 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.9, 169.3, 154.5, 145.2, 145.0, 133.9, 133.3, 133.1, 130.4, 129.4, 128.4, 128.2, 75.2, 72.8, 67.9, 59.1, 57.4, 25.9; IR (KBr, cm^{-1}): 1701, 1660; LRMS (EI, 70 eV) *m/z* (%): 339 (M^+, 2), 294 (100), 118 (12); HRMS *m/z* (ESI) calcd for $C_{20}H_{22}NO_4$ ($[M+H]^+$) 340.1543, found 340.1532.

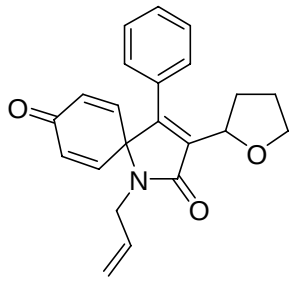


1-Benzyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ba): Yellow solid, mp 147.6-148.8 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.32-7.24 (m, 8H), 7.09-7.06 (m, 2H), 6.38-6.33 (m, 2H), 6.31-6.18 (m, 2H), 4.65 (t, *J* = 8.0 Hz, 1H), 4.53 (d, *J* = 6.8 Hz, 2H), 3.96-3.91 (m, 1H), 3.83-3.78 (m, 1H), 2.37-2.30 (m, 1H), 2.14-2.04 (m, 2H), 1.92-1.86 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.2, 169.2, 152.6, 145.5, 145.3, 137.5, 137.2, 132.2, 131.9, 130.5, 129.2, 128.9, 128.5 (2), 128.1, 127.7, 73.3, 69.3, 67.7, 44.5, 30.4, 27.1; IR (KBr, cm^{-1}): 1721, 1678; LRMS (EI, 70 eV) *m/z* (%): 397 (M^+, 16), 354 (26), 91 (100); HRMS *m/z* (ESI) calcd for $C_{26}H_{24}NO_3$ ($[M+H]^+$) 398.1751, found 398.1757.

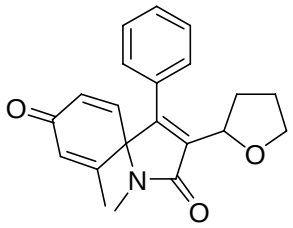


1-(2-Iodobenzyl)-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ca): Yellow solid, mp 156.2-158.0 ^{o}C (uncorrected); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.74 (d, *J* = 7.6 Hz, 1H), 7.37 (d, *J* = 1.2 Hz, 1H), 7.32-7.28 (m, 4H), 7.10-7.07 (m, 2H), 6.98-6.95 (m, 1H), 6.37-6.32 (m, 2H), 6.30-6.15 (m, 2H), 4.74 (t, *J* = 8.8 Hz, 1H), 4.69-4.63 (m, 2H), 3.97-3.91 (m, 1H), 3.83-3.79 (m, 1H), 2.37-2.30 (m, 1H), 2.13-2.09 (m, 2H), 1.93-1.89 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.2, 169.2, 152.9, 144.7, 144.5, 139.8, 139.4, 137.0, 132.7,

132.5, 130.4, 130.1, 129.4, 129.3, 128.5 (2), 128.1, 99.4, 73.3, 69.3, 67.6, 48.8, 30.5, 27.1; IR (KBr, cm^{-1}): 1715, 1670; LRMS (EI, 70 eV) *m/z* (%):524 (M^++H, 8), 523 (M^+, 24), 396 (100), 129 (11); HRMS *m/z* (ESI) calcd for $C_{26}H_{23}INO_3$ ($[M+H]^+$) 524.0717, found 524.0751.

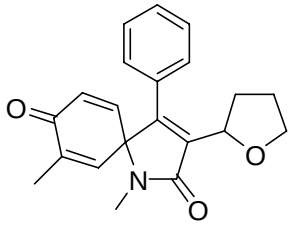


1-Allyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3da): Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.35-7.30 (m, 3H), 7.14-7.12 (m, 2H), 6.52 (d, *J* = 9.6 Hz, 2H), 6.38-6.36 (m, 2H), 5.83-5.77 (m, 1H), 5.16-5.12 (m, 2H), 4.63 (t, *J* = 7.6 Hz, 1H), 3.92 (t, *J* = 4.8 Hz, 3H), 3.82-3.78 (m, 1H), 2.34-2.29 (m, 1H), 2.12-2.04 (m, 2H), 1.91-1.86 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.3, 169.0, 152.5, 145.6, 145.4, 137.4, 133.3, 132.6 (2), 130.6, 129.3, 128.5, 128.2, 118.5, 73.2, 69.3, 67.6, 43.4, 30.3, 27.1; IR (KBr, cm^{-1}): 1718, 1668; LRMS (EI, 70 eV) *m/z* (%): 347 (M^+, 36), 304 (100), 165 (24); HRMS *m/z* (ESI) calcd for $C_{22}H_{22}NO_3$ ($[M+H]^+$) 348.1594, found 348.1583.

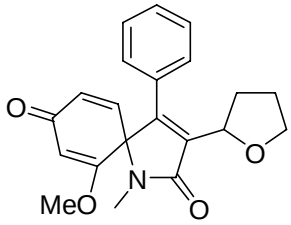


1,6-Dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3fa): Yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.36-7.32(m, 3H), 7.17-7.12 (m, 2H), 6.52-6.42 (m, 2H), 6.32-6.29 (m, 1H), 4.73-4.68 (m, 1H), 3.99-3.95 (m, 1H), 3.84-3.81 (m, 1H), 2.78 (d, *J* = 3.0 Hz, 3H), 2.37-2.32 (m, 1H), 2.16-2.14 (m, 1H), 2.10-2.08 (m, 1H), 1.94-1.90 (m, 1H), 1.78-1.75 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.8, 169.1, 152.6, 152.5, 145.1, 144.9, 140.2, 140.1, 139.9, 136.9, 136.8, 132.8 (2), 130.8, 129.1, 128.3 (2), 128.1 (2), 73.1, 69.2, 69.1, 67.8 (2), 30.2 (2), 27.0

(2), 25.6, 15.7; IR (KBr, cm^{-1}): 1708, 1658; LRMS (EI, 70 eV) *m/z* (%): 335 (M^+, 30), 292 (100), 129 (19); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_3$ ($[M+H]^+$) 336.1594, found 336.1590.

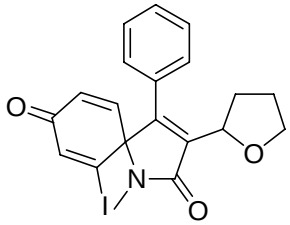


1,7-Dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ga): Yellow solid, mp 161.0-162.0 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.34-7.28 (m, 3H), 7.14-7.11 (m, 2H), 6.48-6.44 (m, 1H), 6.40-6.30 (m, 1H), 6.28-6.27 (m, 1H), 4.66-4.62 (m, 1H), 3.93-3.89 (m, 1H), 3.78 (t, *J* = 4.0 Hz, 1H), 2.85 (s, 3H), 2.33-2.28 (m, 1H), 2.09-2.03 (m, 2H), 1.89 (d, *J* = 7.2 Hz, 3H), 1.87-1.82 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.8, 169.2, 152.6, 152.5, 145.1, 144.9, 140.2, 140.1, 139.9, 137.0, 136.9, 132.9, 132.8, 130.9, 129.1, 128.4, 128.3, 128.1 (2), 73.2, 69.2 (2), 67.8 (2), 30.3, 30.2, 27.1, 27.0, 25.6, 15.7; IR (KBr, cm^{-1}): 1702, 1667; LRMS (EI, 70 eV) *m/z* (%): 335 (M^+, 36), 292 (100), 129 (14); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_3$ ($[M+H]^+$) 336.1594, found 336.1591.

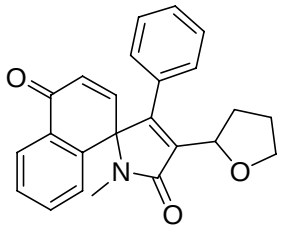


6-Methoxy-1-methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ha): Yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ: 7.34-7.29 (m, 3H), 7.07-7.05 (m, 2H), 6.34-6.28 (m, 2H), 5.71-5.67 (m, 1H), 4.68-4.63 (m, 1H), 3.93-3.88 (m, 1H), 3.80-3.76 (m, 1H), 3.73 (s, 3H), 2.77 (d, *J* = 4.4 Hz, 3H), 2.35-2.30 (m, 1H), 2.08 (t, *J* = 6.8 Hz, 2H), 1.93-1.89 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 186.4, 170.0, 168.6, 151.8, 141.1, 137.6, 132.2, 130.6, 129.2, 128.3, 128.2, 106.2, 73.2, 69.3, 68.7, 56.1, 30.5, 27.0, 25.4; IR (KBr, cm^{-1}): 1720, 1673; LRMS (EI, 70 eV) *m/z* (%): 351 (M^+,

17), 308 (100), 207 (36); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_4$ ($[M+H]^+$) 352.1543, found 352.1524.

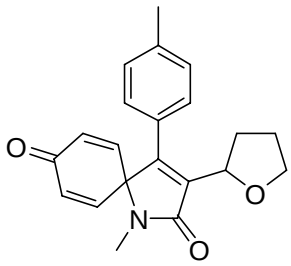


6-Iodo-1-methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ia): Yellow solid, mp 149.0-150.2 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.38-7.32 (m, 3H), 7.23-7.18 (m, 3H), 6.80 (t, *J* = 11.2 Hz, 1H), 6.52 (t, *J* = 8.4 Hz, 1H), 4.77-4.64 (m, 1H), 4.03-3.83 (m, 1H), 3.73-3.67 (m, 1H), 2.82 (d, *J* = 6.4 Hz, 3H), 2.40-2.33 (m, 1H), 2.22-2.12 (m, 2H), 1.92-1.83 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 181.0, 169.2, 151.2, 150.6, 144.8, 144.4, 144.1, 139.6, 139.3, 132.2, 130.1, 129.8, 129.6, 129.3, 128.6, 128.5, 128.4, 128.1, 126.0, 125.6, 73.8, 73.1, 71.9, 71.6, 69.5, 69.1, 30.9, 30.4, 27.1, 26.7, 25.5, 25.4; IR (KBr, cm^{-1}): 1708, 1660; LRMS (EI, 70 eV) *m/z* (%): 447 (M^+, 15), 404 (100), 129 (19); HRMS *m/z* (ESI) calcd for $C_{20}H_{19}INO_3$ ($[M+H]^+$) 448.0368, found 448.0365.

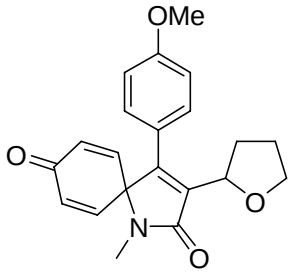


1'-Methyl-3'-phenyl-4'-(tetrahydrofuran-2-yl)-4*H*-spiro[naphthalene-1,2'-pyrrole]-4,5'(1'*H*)-dione(3ja): Yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 8.11 (t, *J* = 8.0 Hz, 1H), 7.64-7.61 (m, 1H), 7.52 (t, *J* = 7.5 Hz, 1H), 7.27 (d, *J* = 6.0 Hz, 1H), 7.22-7.18 (m, 1H), 7.13 (t, *J* = 6.5 Hz, 2H), 6.68-6.62 (m, 2H), 6.60-6.54 (m, 2H), 4.69-4.67 (m, 1H), 3.97-3.92 (m, 1H), 3.83-3.81 (m, 1H), 2.74 (s, 3H), 2.13-2.09 (m, 2H), 1.92-1.87 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.1, 183.0, 169.7, 155.4, 155.2, 145.6, 145.4, 137.2, 137.1, 136.1, 135.9, 133.5, 133.4, 132.8 (2), 132.6, 132.5, 130.6, 129.1, 128.9 (2), 128.3, 128.2, 128.0, 127.9, 127.2, 127.1, 125.9, 125.5, 73.2, 69.2, 69.1,

68.3 (2), 30.4 (2), 27.0 (2), 25.4; IR (KBr, cm^{-1}): 1721, 1668; LRMS (EI, 70 eV) *m/z* (%): 371 (M^+, 25), 328 (100), 129 (18); HRMS *m/z* (ESI) calcd for $C_{24}H_{22}NO_3$ ($[M+H]^+$) 372.1558, found 372.1552.

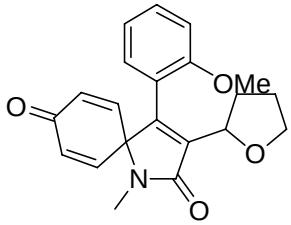


1-Methyl-3-(tetrahydrofuran-2-yl)-4-*p*-tolyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ka): Yellow solid, mp 152.1-154.0 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.11 (t, *J* = 6.4 Hz, 2H), 7.05 (d, *J* = 4.0 Hz, 2H), 6.54-6.47 (m, 2H), 6.45-6.40 (m, 2H), 4.66 (t, *J* = 8.0 Hz, 1H), 3.99-3.94 (m, 1H), 3.83-3.80 (m, 1H), 2.86 (s, 3H), 2.33 (s, 3H), 2.17-2.11 (m, 1H), 2.11-2.03 (m, 2H), 1.92-1.87 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.1, 169.3, 152.4, 145.5, 145.3, 139.4, 136.9, 133.1, 133.0, 129.0, 128.2, 127.7, 73.1, 69.2, 67.3, 30.1, 27.1, 25.6, 21.2; IR (KBr, cm^{-1}): 1722, 1667; LRMS (EI, 70 eV) *m/z* (%): 335 (M^+, 21), 292 (100), 115 (25); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_3$ ($[M+H]^+$) 336.1594, found 336.1593.

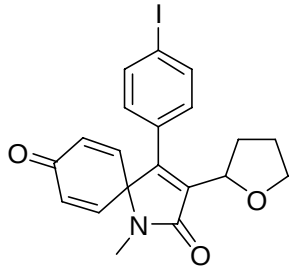


4-(4-Methoxyphenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3la): Yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ: 7.13 (t, *J* = 4.4 Hz, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 6.53-6.44 (m, 4H), 4.68 (t, *J* = 8.0 Hz, 1H), 4.01-3.96 (m, 1H), 3.83-3.80 (m, 1H), 3.80 (s, 3H), 2.86 (s, 3H), 2.38-2.33 (m, 1H), 2.17-2.14 (m, 1H), 2.14-2.03 (m, 1H), 1.94-1.87 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.2, 169.4, 160.3, 152.2, 145.7, 145.5, 136.5, 133.1, 133.0, 129.8, 122.9, 113.8, 73.2, 69.3, 67.3, 55.2, 30.1, 27.2, 25.6; IR (KBr, cm^{-1}): 1719, 1658; LRMS (EI,

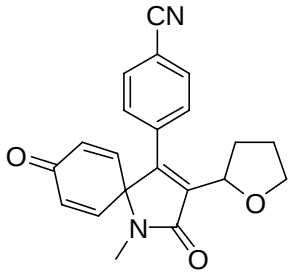
70 eV) *m/z* (%): 351 (M^+, 37), 308 (100), 237 (7); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_4$ ($[M+H]^+$) 352.1543, found 352.1522.



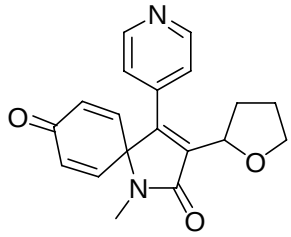
4-(2-Methoxyphenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ma): Yellow solid, mp 151.3-152.3 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.31-7.27 (m, 1H), 6.87 (t, *J* = 4.8 Hz, 3H), 6.59-6.50 (m, 2H), 6.31 (t, *J* = 10.0 Hz, 2H), 4.54 (s, 1H), 3.73 (s, 3H), 3.71 (s, 2H), 2.89 (s, 3H), 2.07-2.04 (m, 2H), 1.85-1.80 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.3, 169.3, 156.4, 148.4, 145.9, 139.3, 130.5, 119.9, 119.3, 110.7, 73.8, 69.0, 68.2, 55.2, 30.3, 26.7, 26.0; IR (KBr, cm^{-1}): 1720, 1659; LRMS (EI, 70 eV) *m/z* (%): 351 (M^+, 36), 308 (100), 131 (11); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_4$ ($[M+H]^+$) 352.1543, found 352.1526.



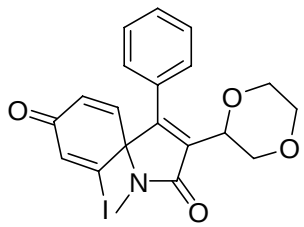
4-(4-Iodophenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3na): Yellow solid, mp 148.2-149.4 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.66 (d, *J* = 4.0 Hz, 2H), 6.90 (d, *J* = 4.0 Hz, 2H), 6.51-6.41 (m, 4H), 4.63 (t, *J* = 7.2 Hz, 1H), 3.89-3.84 (m, 1H), 3.80-3.75 (m, 1H), 2.87 (s, 3H), 2.28-2.23 (m, 1H), 2.09-2.05 (m, 2H), 1.93-1.88 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.7, 168.9, 150.7, 145.0, 144.8, 137.9, 137.4, 133.3 (2), 130.2, 130.0, 95.6, 73.2, 69.2, 67.1, 30.3, 27.0, 25.7; IR (KBr, cm^{-1}): 1705, 1665; LRMS (EI, 70 eV) *m/z* (%): 447 (M^+, 28), 404 (100), 220 (13); HRMS *m/z* (ESI) calcd for $C_{20}H_{19}INO_3$ ($[M+H]^+$) 448.0368, found 448.0362.



4-(1-Methyl-2,8-dioxo-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-trien-4-yl)benzonitrile(3oa): Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.62 (d, *J* = 8.0 Hz, 2H), 7.28 (d, *J* = 6.8 Hz, 2H), 6.51-6.42 (m, 4H), 4.65 (t, *J* = 7.6 Hz, 1H), 3.76-3.68 (m, 2H), 2.89 (s, 3H), 2.19-2.14 (m, 2H), 2.07-2.01 (m, 1H), 1.93-1.86 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.4, 168.5, 149.1, 144.6, 144.4, 139.4, 135.8, 133.6, 133.5, 131.8, 129.4, 118.0, 113.1, 73.6, 69.1, 67.3, 30.8, 26.8, 25.9; IR (KBr, cm^{-1}): 1718, 1660; LRMS (EI, 70 eV) *m/z* (%): 346 (M^+, 16), 303 (100), 154 (16); HRMS *m/z* (ESI) calcd for $C_{21}H_{19}N_2O_3$ ($[M+H]^+$) 347.1390, found 347.1396.

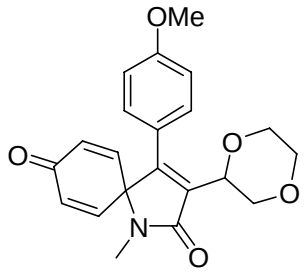


1-Methyl-4-(pyridin-4-yl)-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3qa): Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.62 (s, 2H), 7.09 (s, 2H), 6.52-6.43 (m, 4H), 4.67 (t, *J* = 7.6 Hz, 1H), 3.75-3.72 (m, 2H), 2.89 (s, 3H), 2.19-2.15 (m, 2H), 2.05 (t, *J* = 6.0 Hz, 1H), 1.94-1.89 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.4, 168.5, 149.5, 148.1, 144.4, 144.2, 139.3, 139.2, 133.6, 133.5, 123.2, 73.5, 69.0, 67.0, 30.8, 26.7, 25.8; IR (KBr, cm^{-1}): 1698, 1670; LRMS (EI, 70 eV) *m/z* (%): 322 (M^+, 13), 279 (100), 167 (13); HRMS *m/z* (ESI) calcd for $C_{19}H_{19}N_2O_3$ ($[M+H]^+$) 323.1390, found 323.1392.

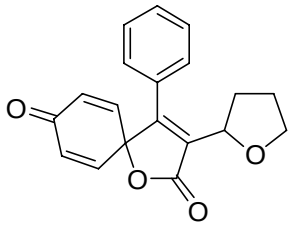


3-(1,4-Dioxan-2-yl)-6-iodo-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ib): Yellow solid, mp 161.2-162.2 ^{o}C (uncorrected); ^{1}H NMR (400 MHz,

$CDCl_3$) δ: 7.39-7.32 (m, 3H), 7.24 (d, *J* = 7.2 Hz, 2H), 7.17 (d, *J* = 1.2 Hz, 1H), 6.77 (d, *J* = 9.6 Hz, 1H), 6.54-6.51 (m, 1H), 4.58-4.54 (m, 1H), 3.92 (t, *J* = 10.8 Hz, 1H), 3.78-3.64 (m, 5H), 2.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 180.4, 168.6, 154.5, 145.0, 143.6, 135.1, 132.4, 130.0, 129.5, 128.5, 128.4, 125.1, 72.0, 71.4, 67.9, 66.8, 66.2, 25.6; IR (KBr, cm^{-1}): 1721, 1668; LRMS (EI, 70 eV) *m/z* (%): 463 (M^+, 100), 419 (28), 205 (20); HRMS *m/z* (ESI) calcd for $C_{20}H_{19}INO_4$ ($[M+H]^+$) 464.0322, found 464.0316.

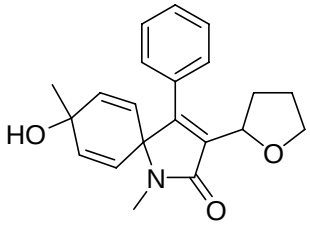


3-(1,4-Dioxan-2-yl)-4-(4-methoxyphenyl)-1-methyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3lb): Yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.15 (d, *J* = 8.8 Hz, 2H), 6.85 (d, *J* = 8.8 Hz, 2H), 6.48-6.45 (m, 4H), 4.52-4.49 (m, 1H), 4.15 (t, *J* = 10.8 Hz, 1H), 3.81 (s, 3H), 3.80-3.65 (m, 5H), 2.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.9, 169.0, 160.6, 155.3, 145.1, 145.0, 133.2 (2), 132.5, 129.6, 122.6, 113.8, 71.3, 67.8, 67.6, 66.9, 66.1, 55.2, 25.8; IR (KBr, cm^{-1}): 1725, 1662; LRMS (EI, 70 eV) *m/z* (%): 367 (M^+, 100), 294 (50), 152 (16); HRMS *m/z* (ESI) calcd for $C_{21}H_{22}NO_5$ ($[M+H]^+$) 368.1450, found 368.1436.

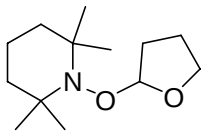


4-Phenyl-3-(tetrahydrofuran-2-yl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ra): Yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.42-7.36 (m, 3H), 7.19 (t, *J* = 4.0 Hz, 2H), 6.68-6.64 (m, 2H), 6.37-6.32 (m, 2H), 4.65 (t, *J* = 7.5 Hz, 1H), 3.96-3.92 (m, 1H), 3.85-3.81 (m, 1H), 2.30-2.26 (m, 1H), 2.15-2.10 (m, 2H), 1.93-1.91 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 183.8, 169.9, 161.5, 142.7, 142.6, 131.8 (2), 131.4, 130.2, 129.1,

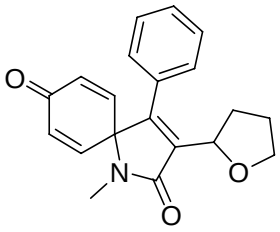
128.6, 127.9, 81.6, 72.5, 69.4, 30.2, 27.0; IR (KBr, cm^{-1}): 1711, 1628; LRMS (EI, 70 eV) *m/z* (%): 308 (M^+, 22), 167 (48), 149 (100); HRMS *m/z* (ESI) calcd for $C_{19}H_{17}O_4$ ($[M+H]^+$) 309.1121, found 309.1142.

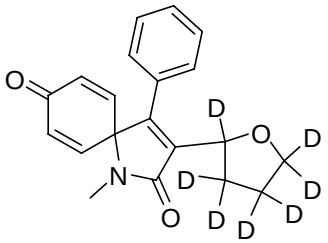


8-Hydroxy-1,8-dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-trien-2-one(3ua): Yellow solid, mp 152.1-154.0 ^oC (uncorrected); ^1H NMR (400 MHz, $CDCl_3$) δ: 7.31-7.28 (m, 3H), 7.14-7.11 (m, 2H), 6.09-6.06 (m, 2H), 5.39-5.33 (m, 2H), 4.58 (t, *J* = 7.6 Hz, 1H), 3.82 (t, *J* = 6.8 Hz, 1H), 3.76-3.71 (m, 1H), 2.83 (s, 3H), 2.28-2.21 (m, 1H), 2.03 (t, *J* = 4.4 Hz, 2H), 1.84 (t, *J* = 6.0 Hz, 1H), 0.76 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 169.2, 155.8, 138.3, 135.2, 132.1, 128.9, 128.4, 127.6, 124.6, 124.4, 73.3, 69.0, 66.6, 65.0, 30.4, 28.0, 27.0, 25.3; IR (KBr, cm^{-1}): 1667; LRMS (EI, 70 eV) *m/z* (%): 337 (M^+, 5), 290 (100), 205 (20) ; HRMS *m/z* (ESI) calcd for $C_{21}H_{24}NO_3$ ($[M+H]^+$) 338.1648, found 338.1652.



2,2,6,6-Tetramethyl-1-(tetrahydrofuran-2-yloxy)piperidine(4): [S1] Yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ: 5.37-5.35 (m, 1H), 3.88-3.81 (m, 2H), 2.01-1.90 (m, 3H), 1.79-1.75 (m, 1H), 1.50-1.43 (m, 6H), 1.22 (s, 3H), 1.11 (s, 3H), 1.07 (s, 3H), 1.04 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 109.5, 66.6, 40.1, 39.6, 33.8, 33.3, 31.2, 23.9, 20.4, 20.0, 17.2; IR (KBr, cm^{-1}): 2870, 1362; LRMS (EI, 70 eV) *m/z* (%): 227 (M^+, 1), 142 (100), 71 (63); HRMS *m/z* (ESI) calcd for $C_{13}H_{26}NO_2$ ($[M+H]^+$) 228.1958, found 228.1965.



and


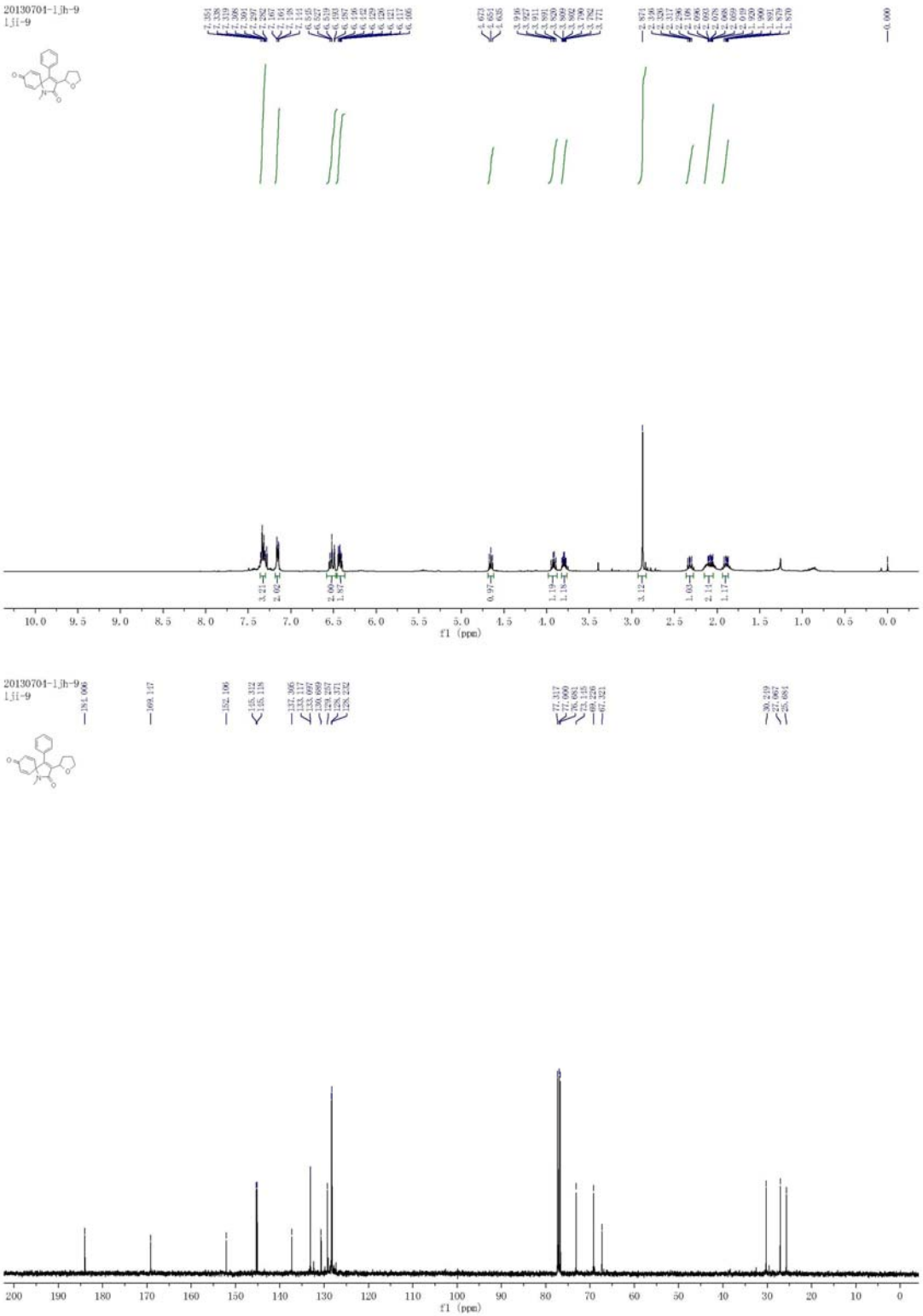
Product 3aa and 3aa-D7: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.36-7.31 (m, 3H), 7.15 (d, *J* = 6.8 Hz, 2H), 6.55-6.49 (m, 2H), 6.49-6.41 (m, 2H), 4.65 (t, *J* = 7.6 Hz, 0.75H), 3.95-3.90 (m, 0.76H), 3.83-3.79 (m, 0.75H), 2.88 (s, 3H), 2.35-2.30 (m, 0.76H), 2.13-2.05 (m, 1.5H), 1.92-1.87 (m, 0.76H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 184.1, 169.2, 152.1, 145.4, 145.2, 137.4, 133.2, 133.1, 130.7, 129.3, 128.4, 128.3, 73.2, 69.3, 67.3, 30.3, 27.1, 25.7.

(C) References

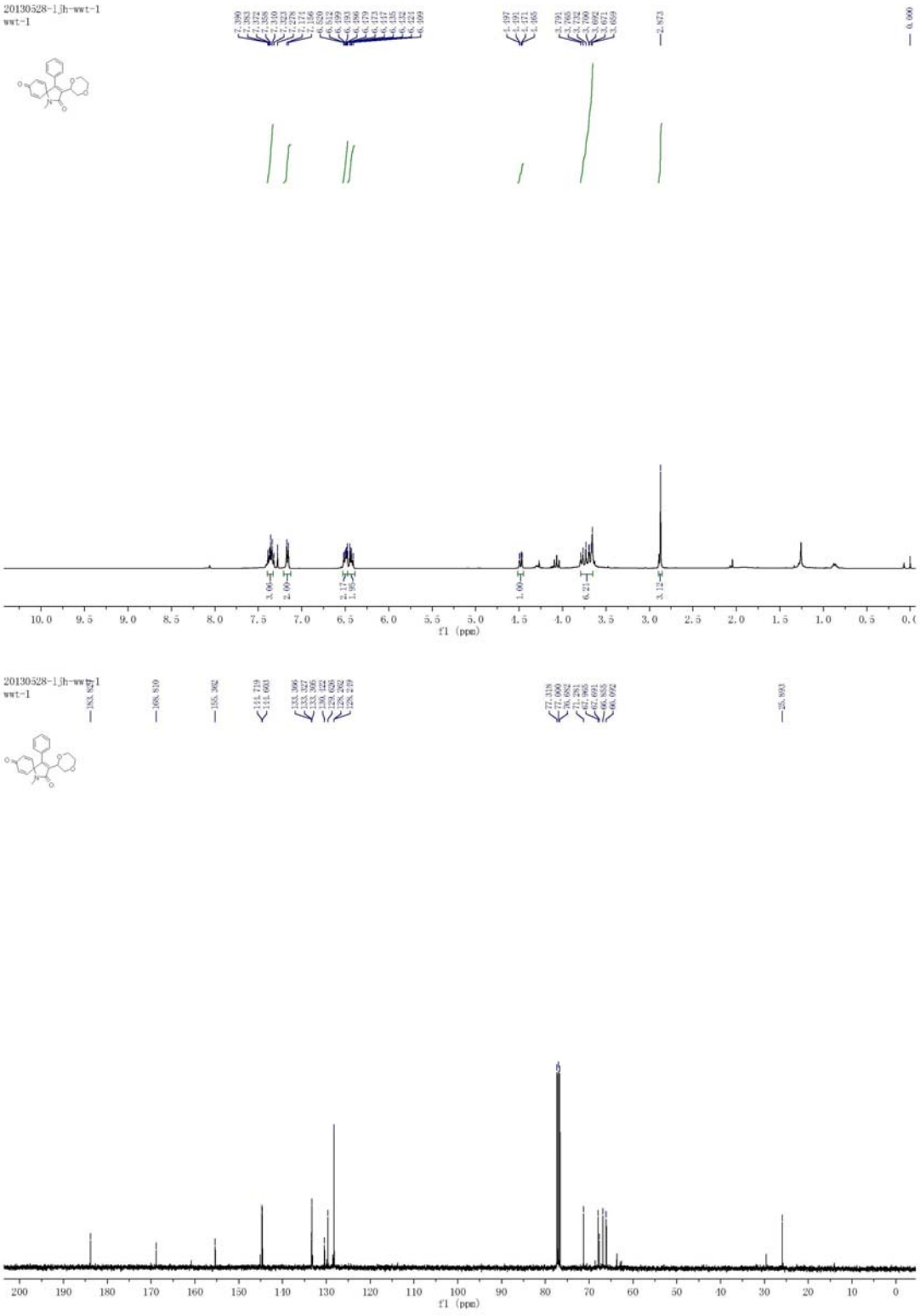
[S1] S.-G. Pan, J.-H. Liu, H.-R. Li, Z.-Y. Wang, X.-W. Guo, Z.-P. Li, *Org*. *Lett*. **2010**, *12*, 1932.

(D) Spectra

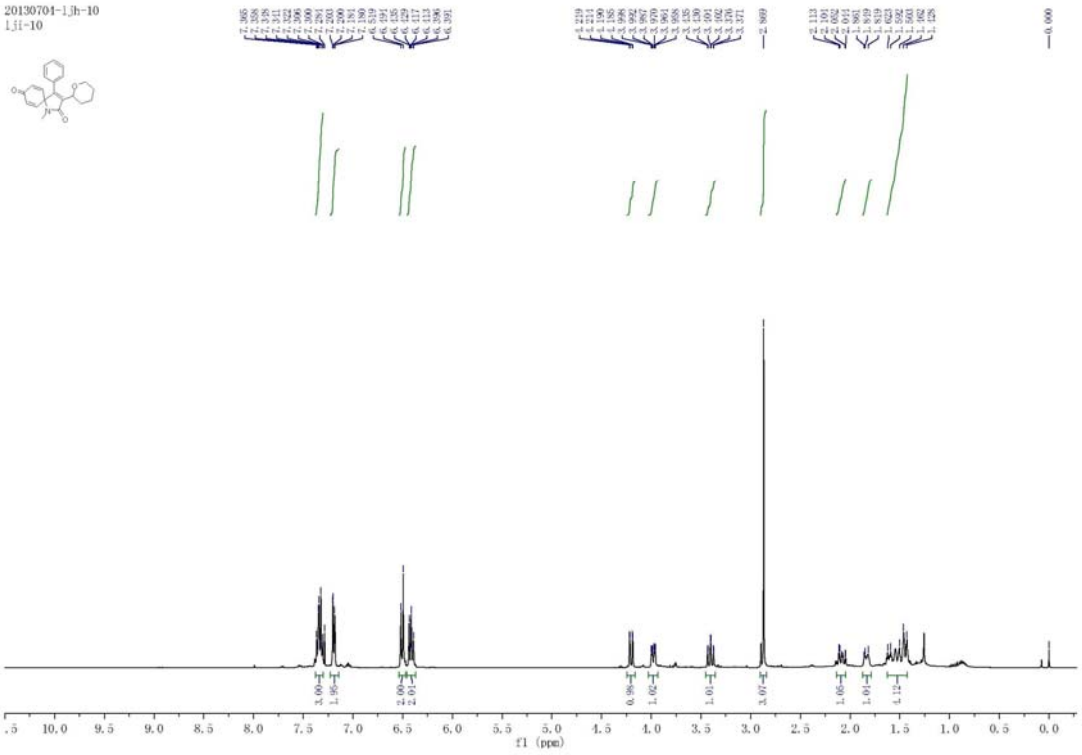
1-Methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3aa)

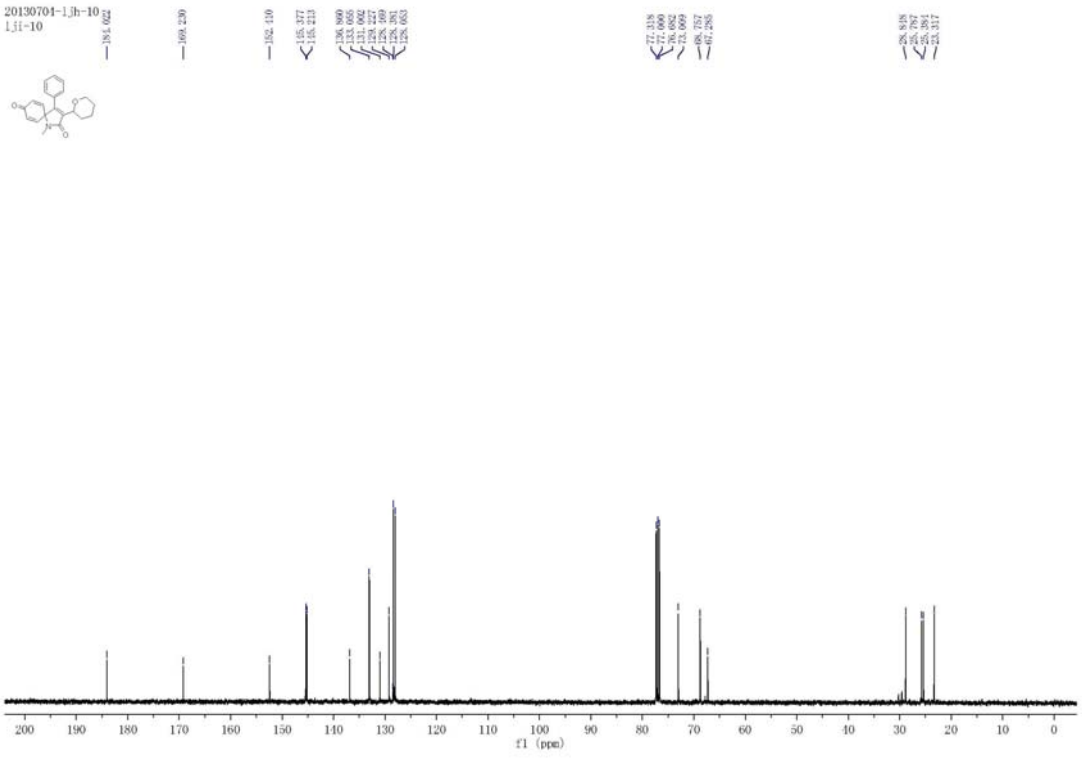


3-(1,4-Dioxan-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ab)

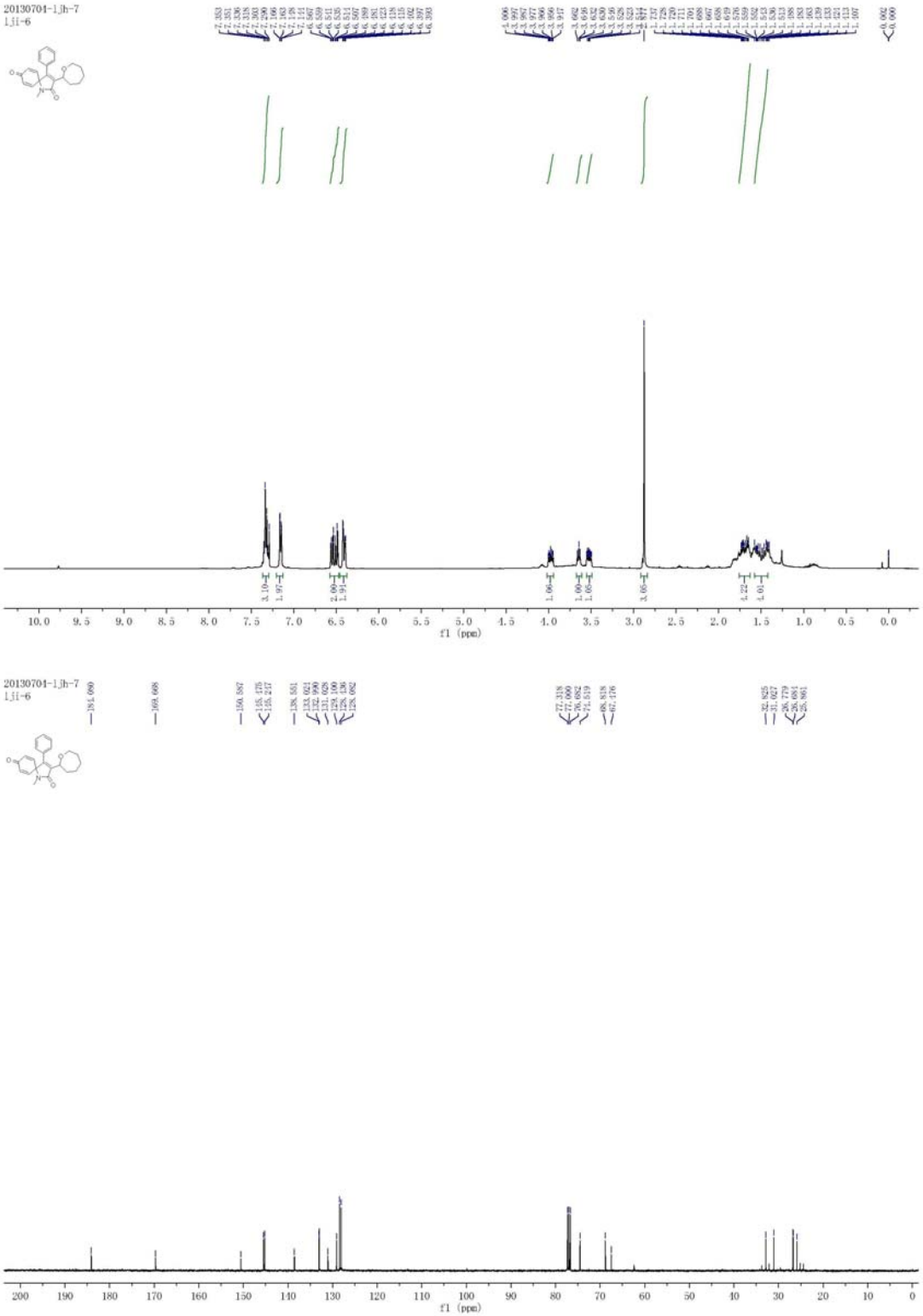


1-Methyl-4-phenyl-3-(tetrahydro-2*H*-pyran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ac)

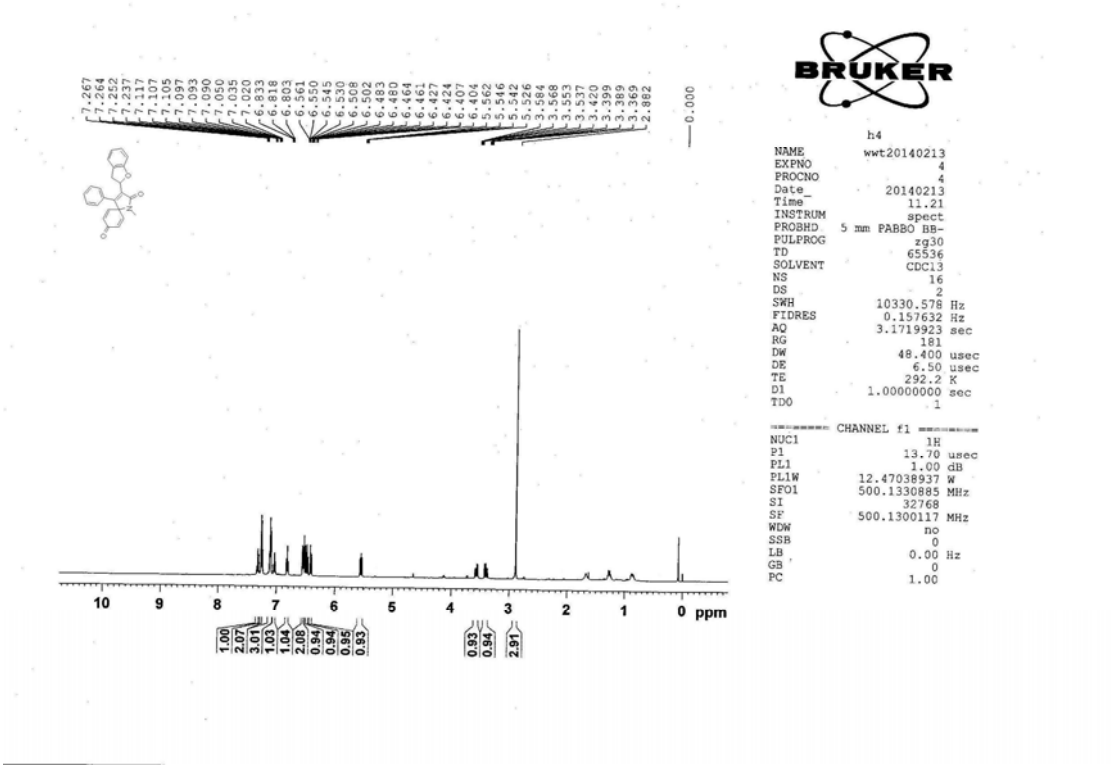


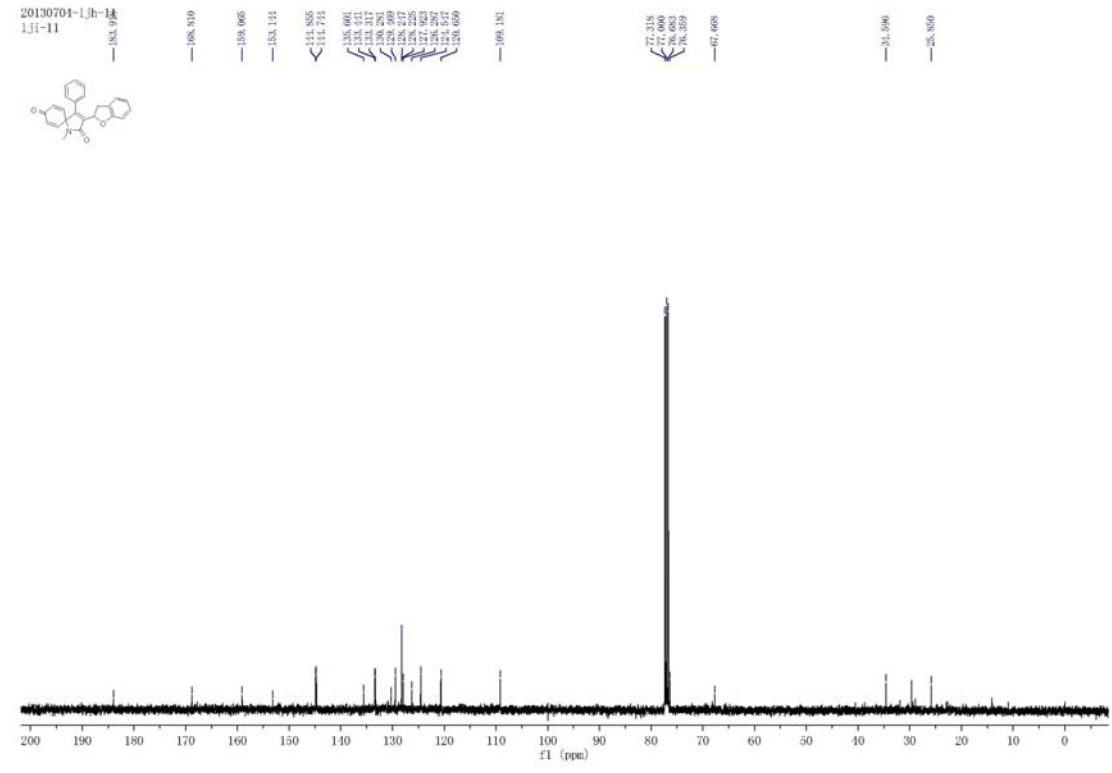


1-Methyl-3-(oxepan-2-yl)-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ad)

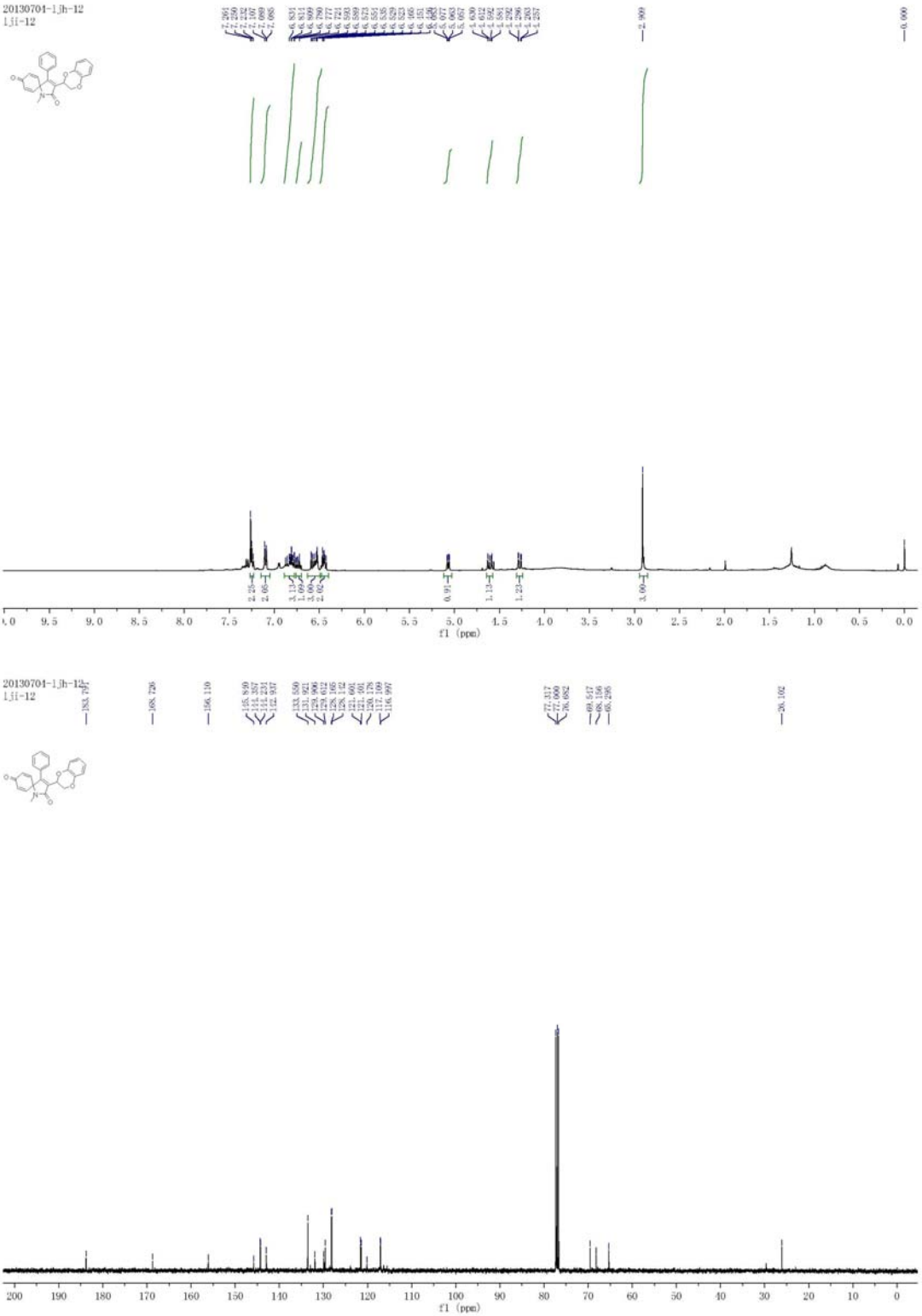


3-(2,3-Dihydrobenzofuran-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ae)

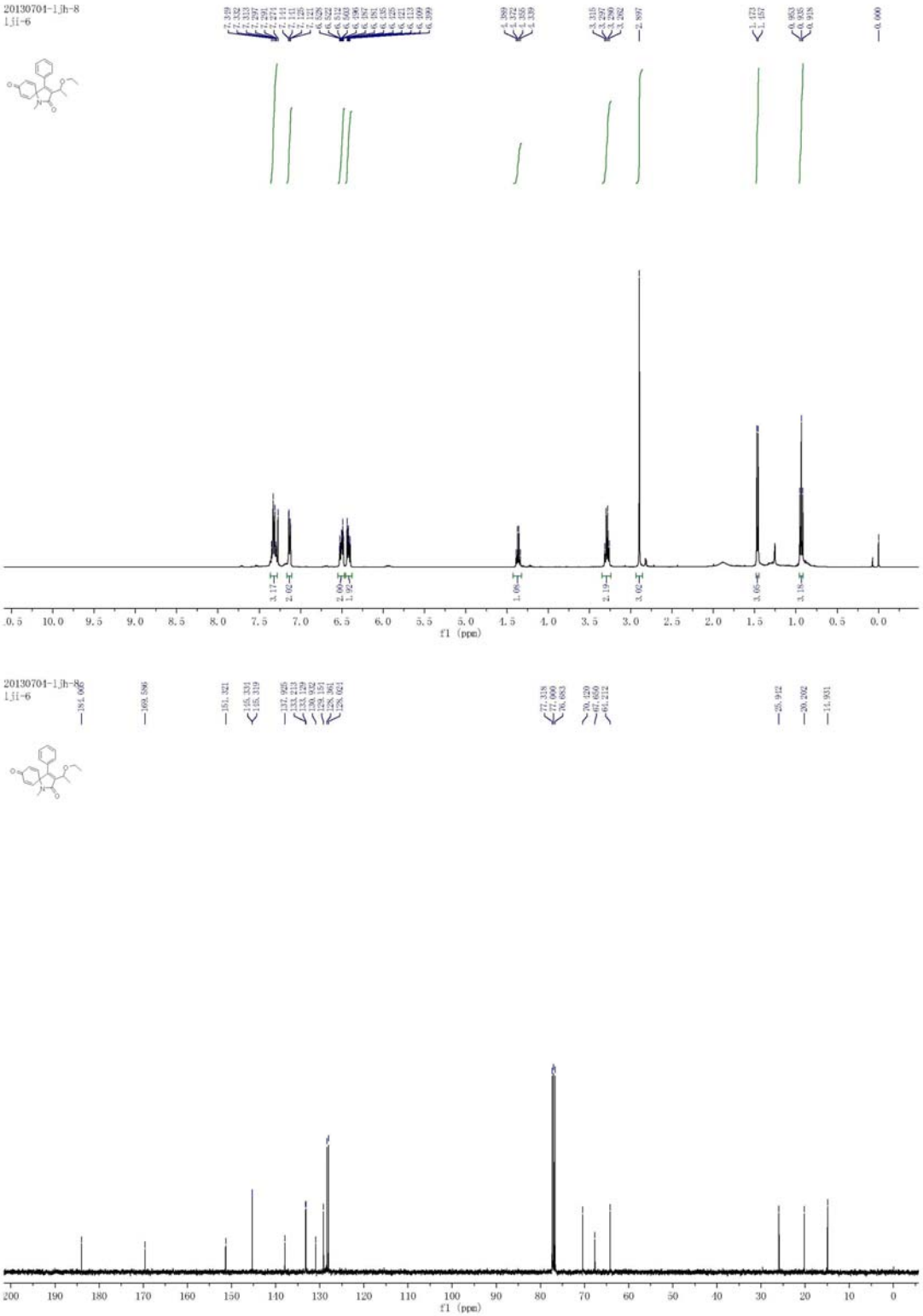




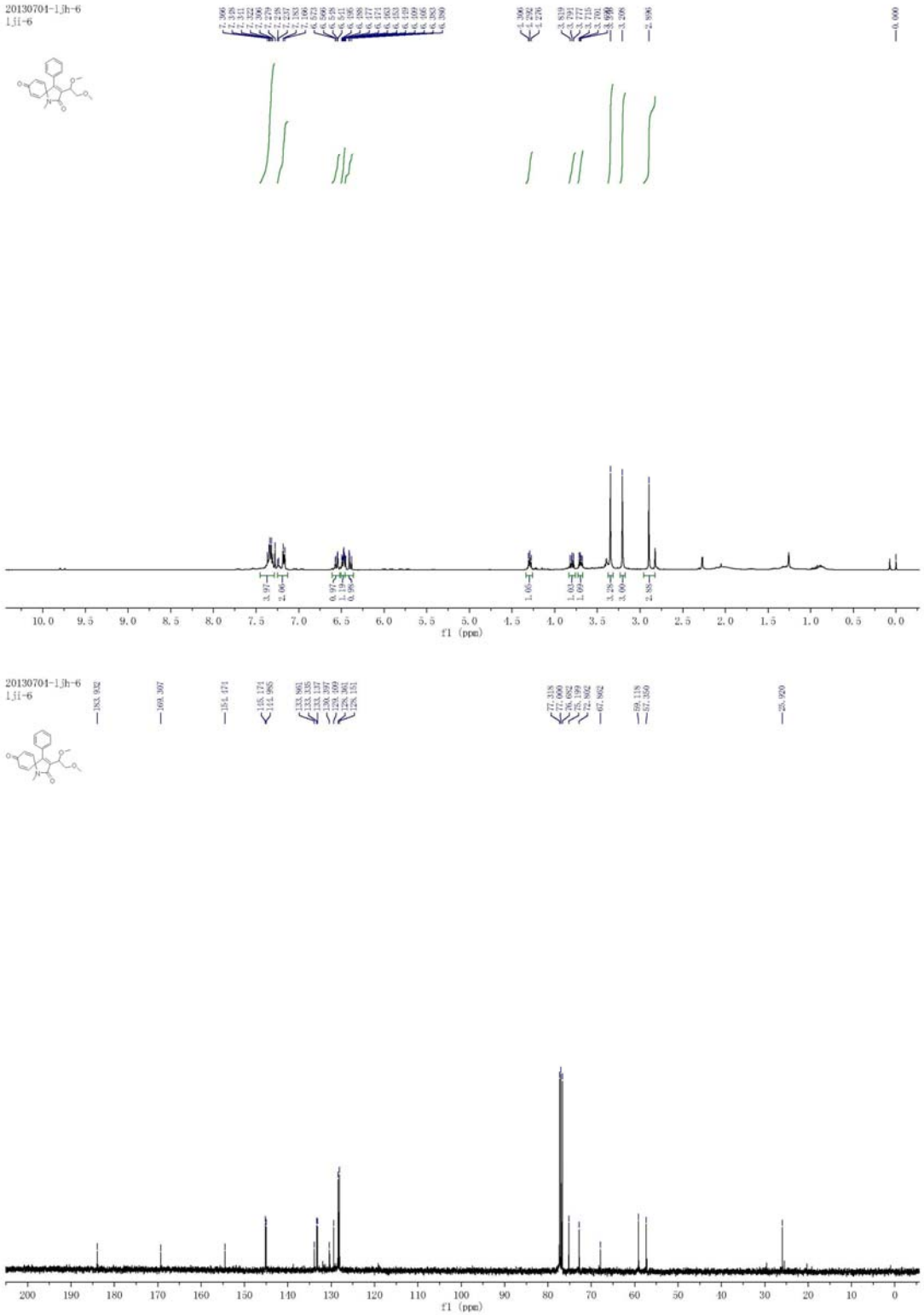
3-(2,3-Dihydrobenzo[*b*][1,4]dioxin-2-yl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3af)



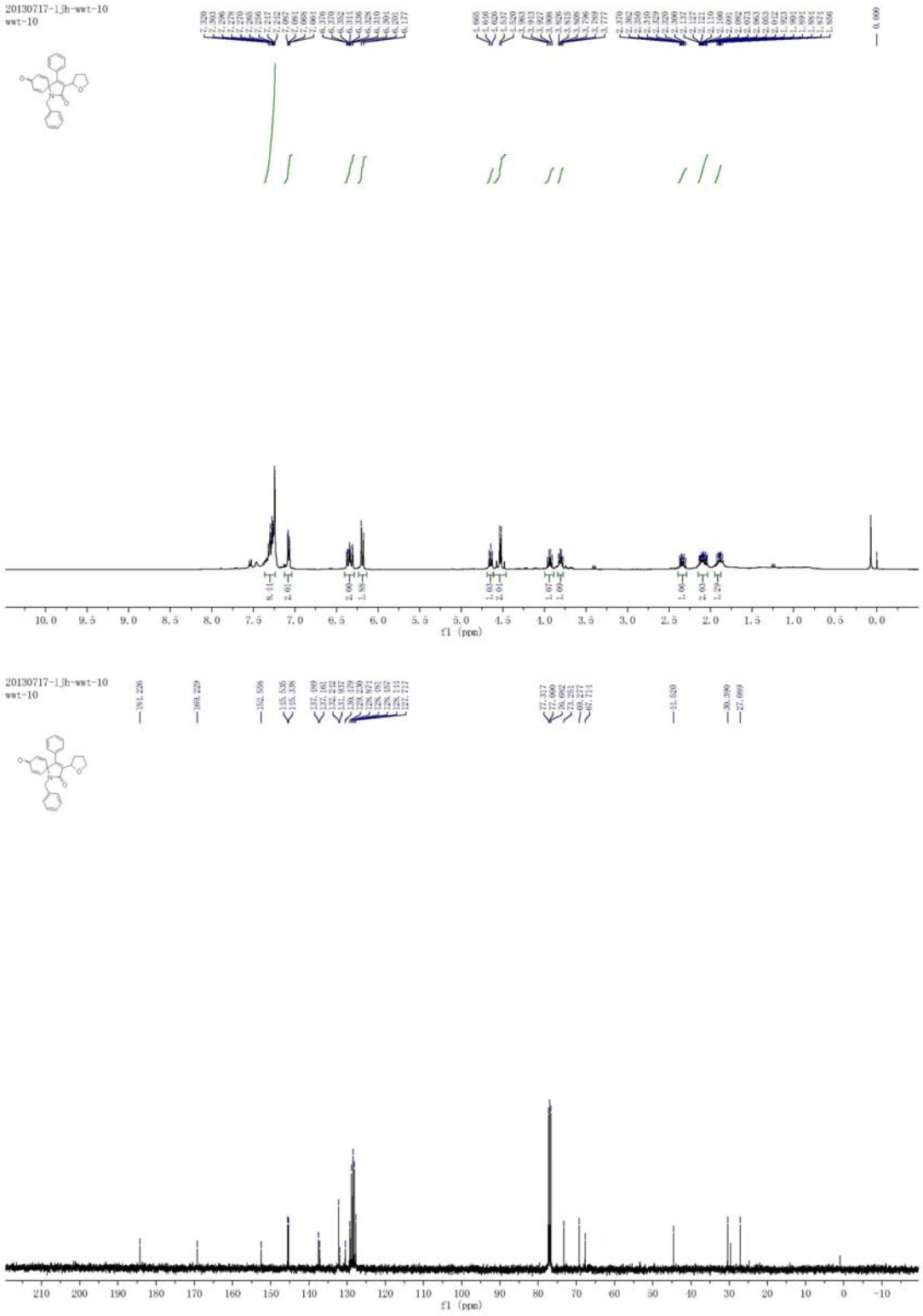
3-(1-Ethoxyethyl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ag)



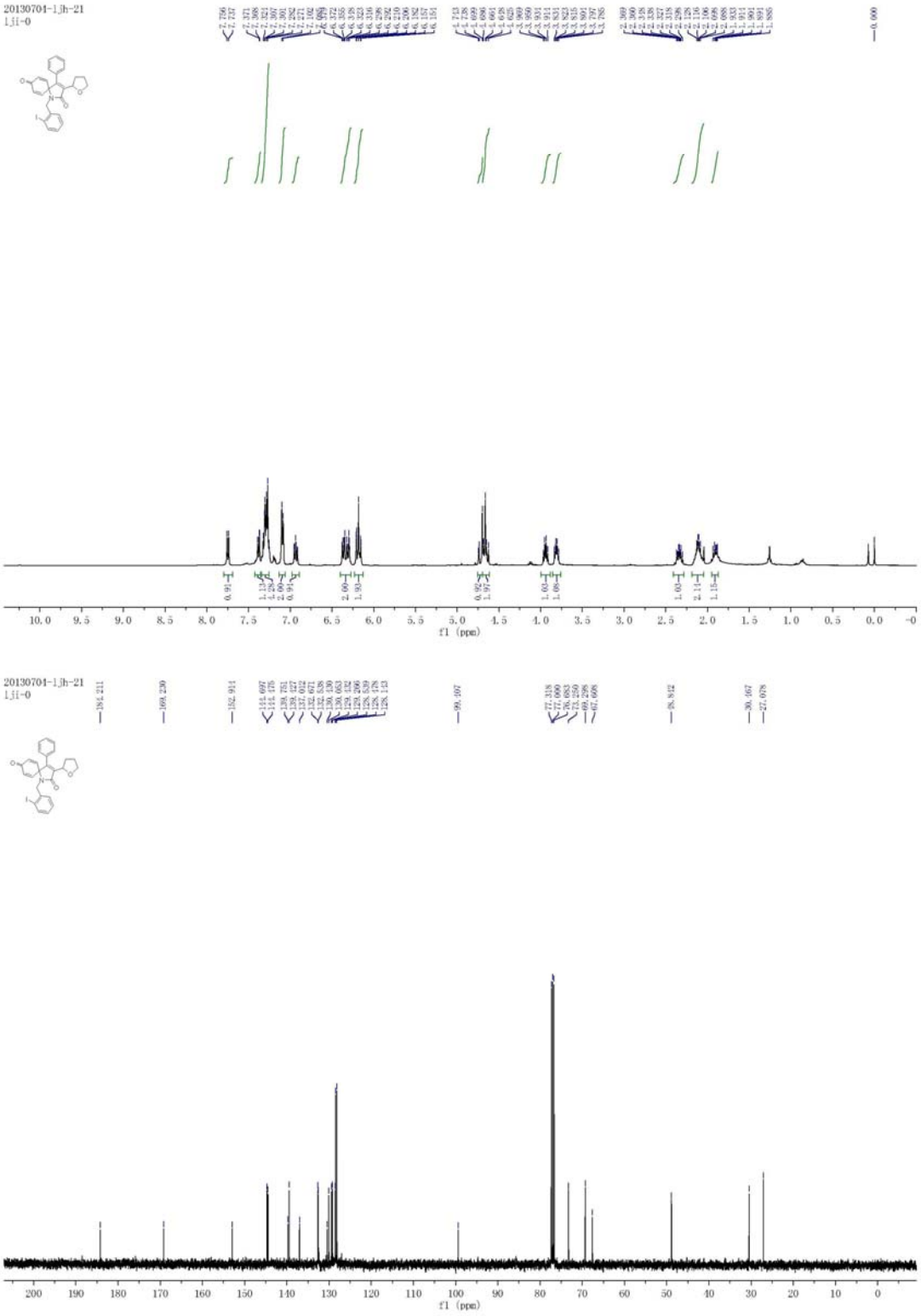
3-(1,2-Dimethoxyethyl)-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ah)



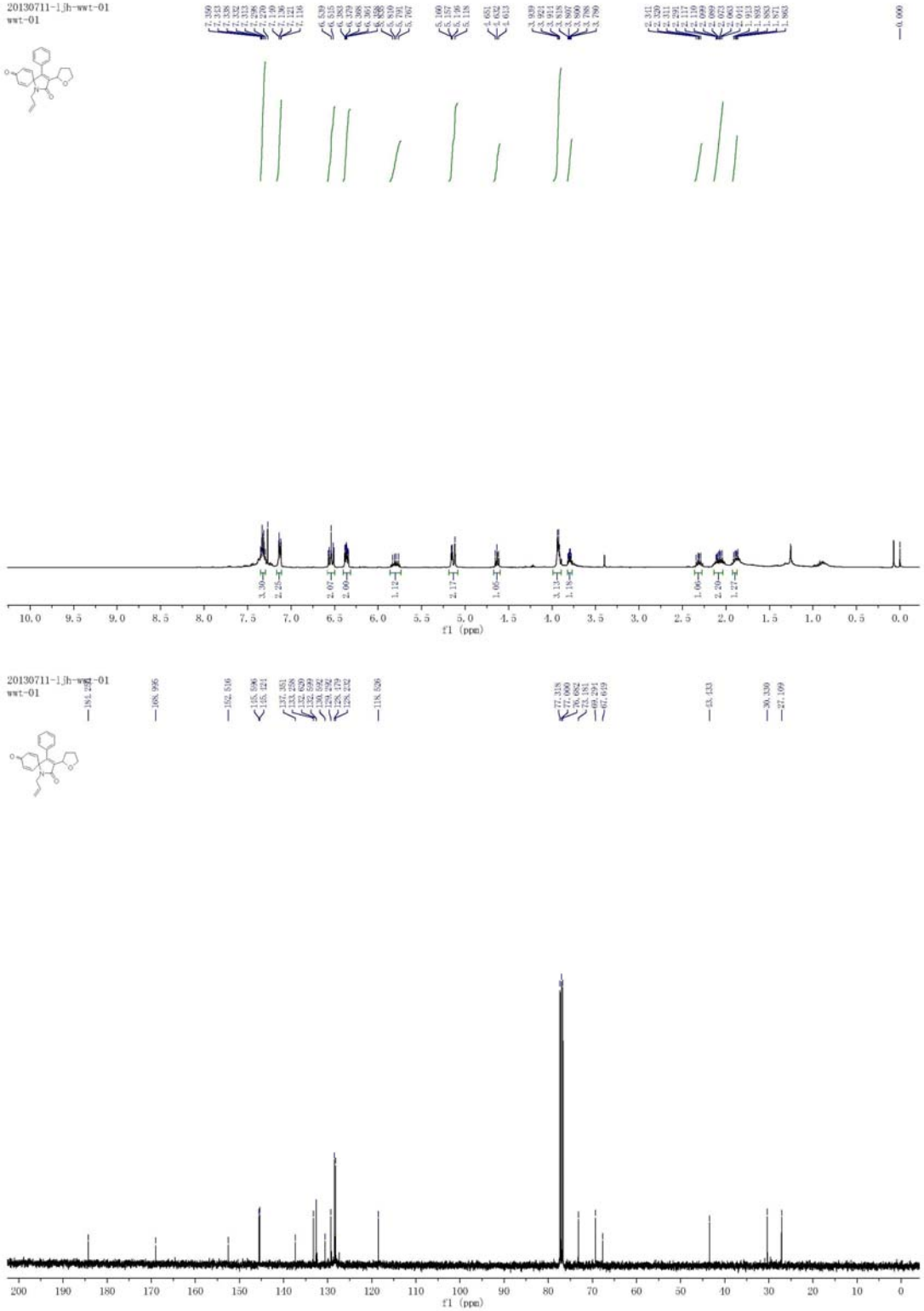
1-Benzyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ba)



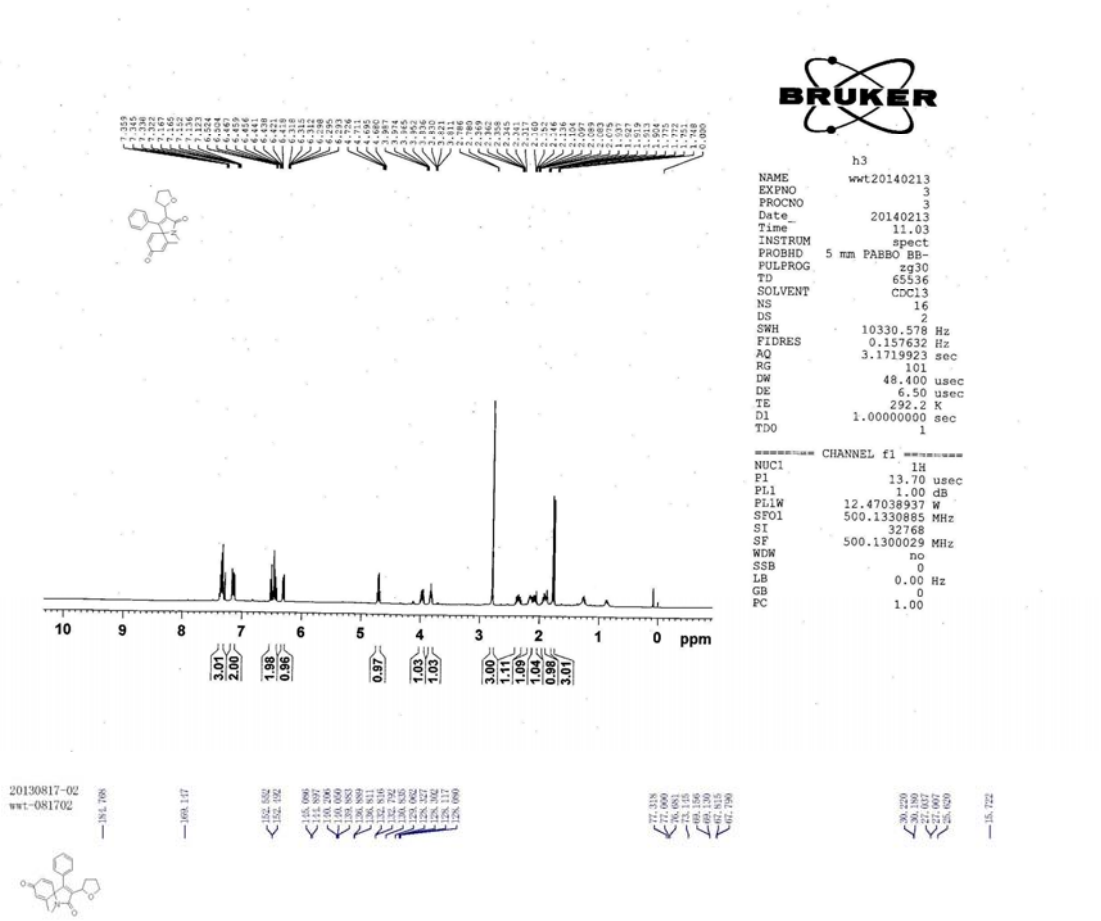
1-(2-Iodobenzyl)-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ca)

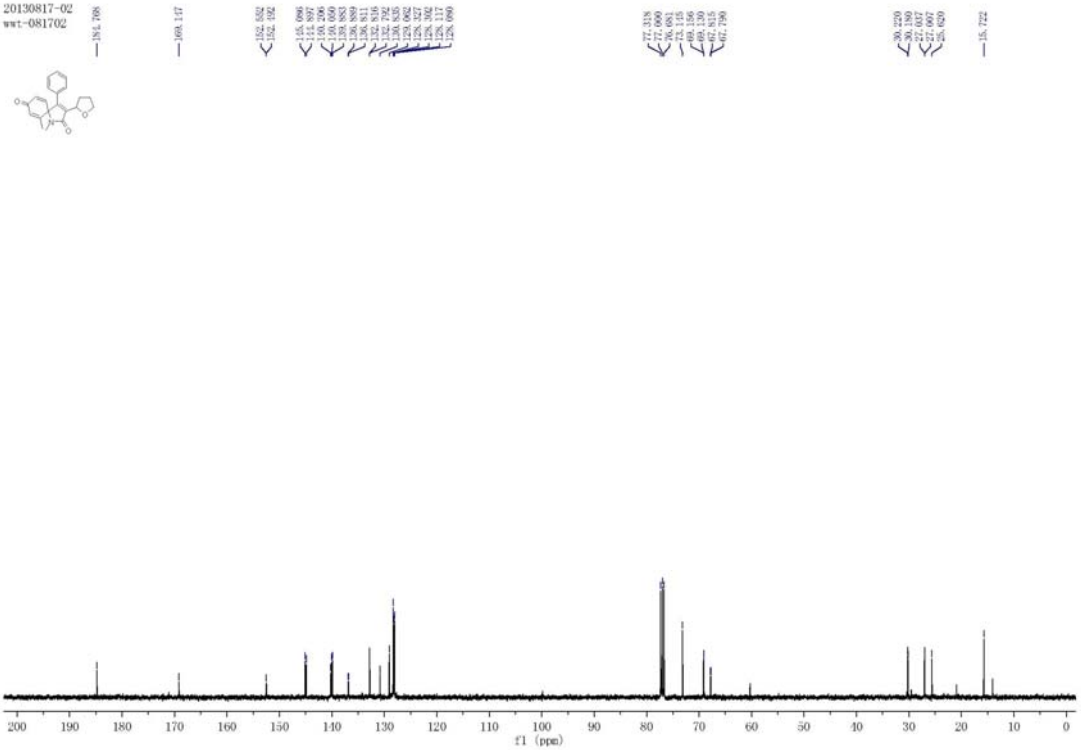


1-Allyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3da)

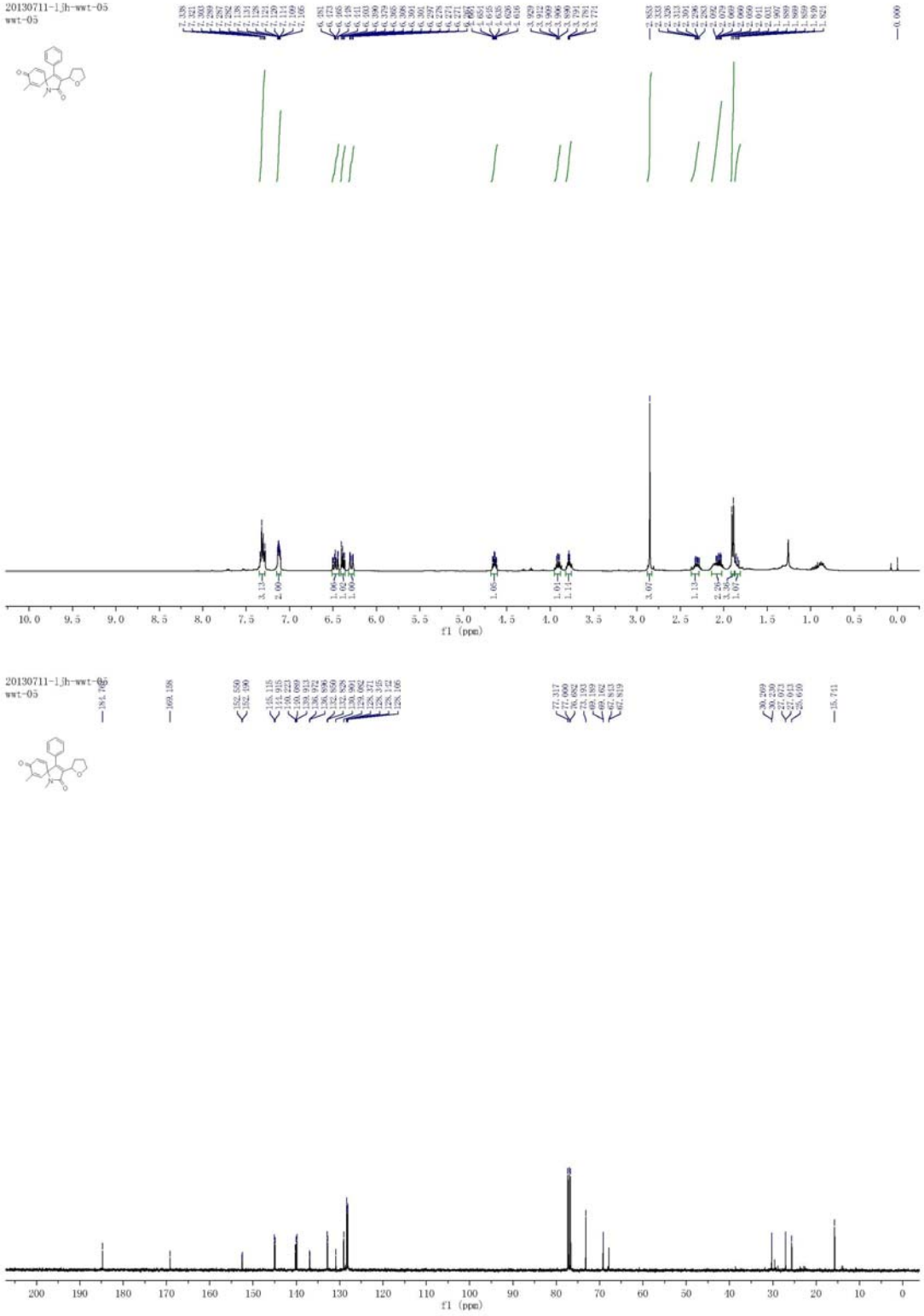


1,6-Dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3fa)

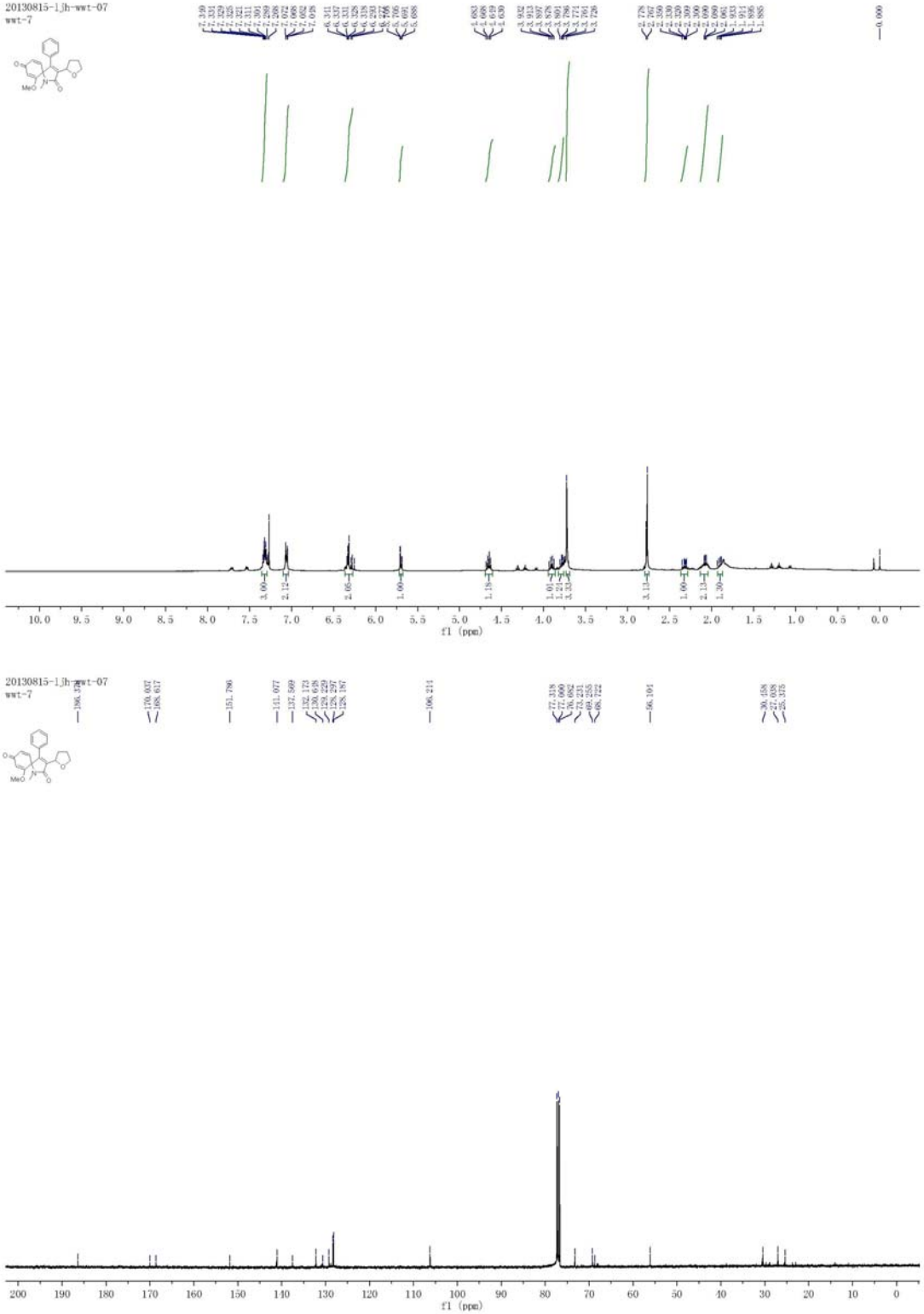




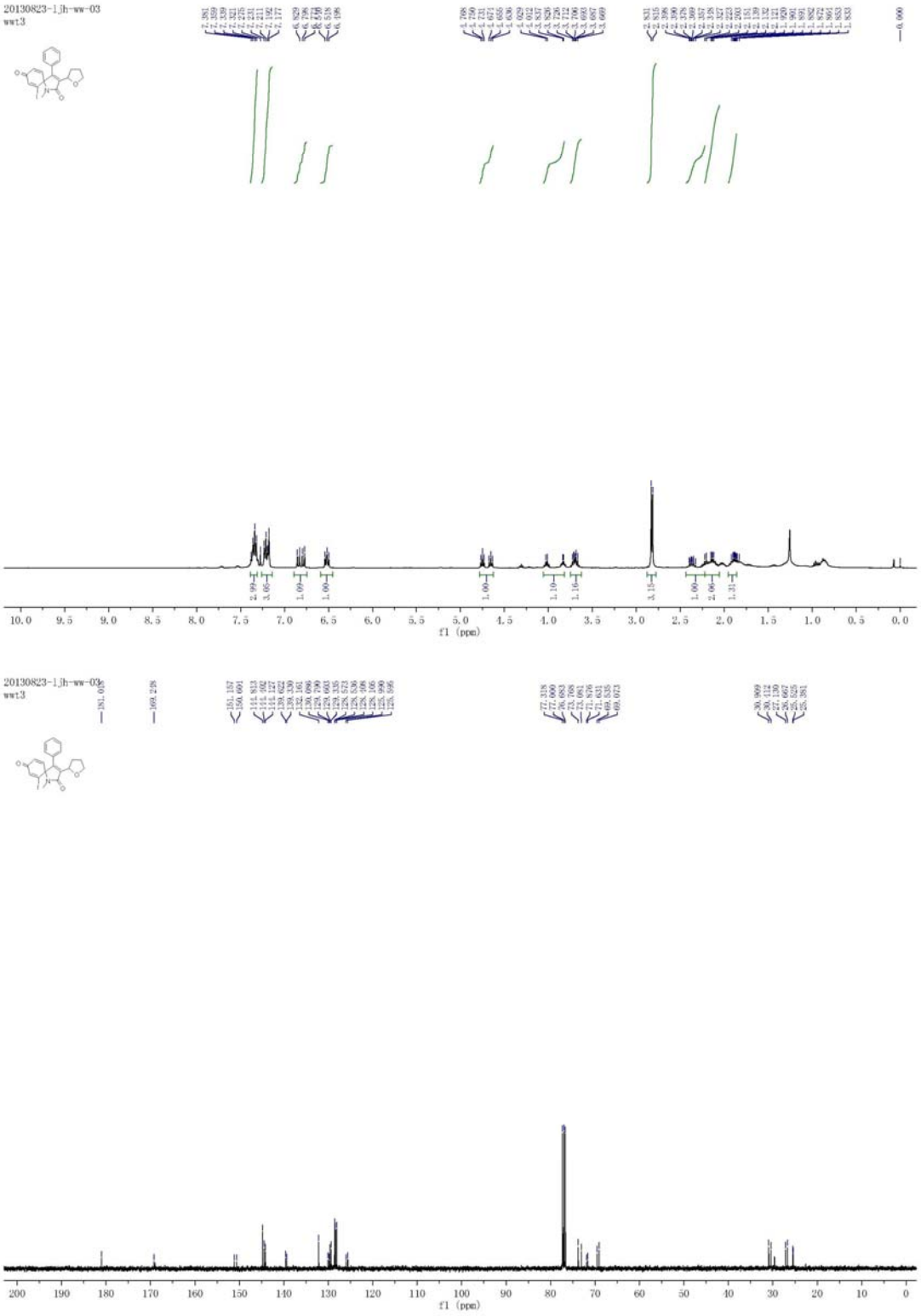
1,7-Dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8dione(3ga)



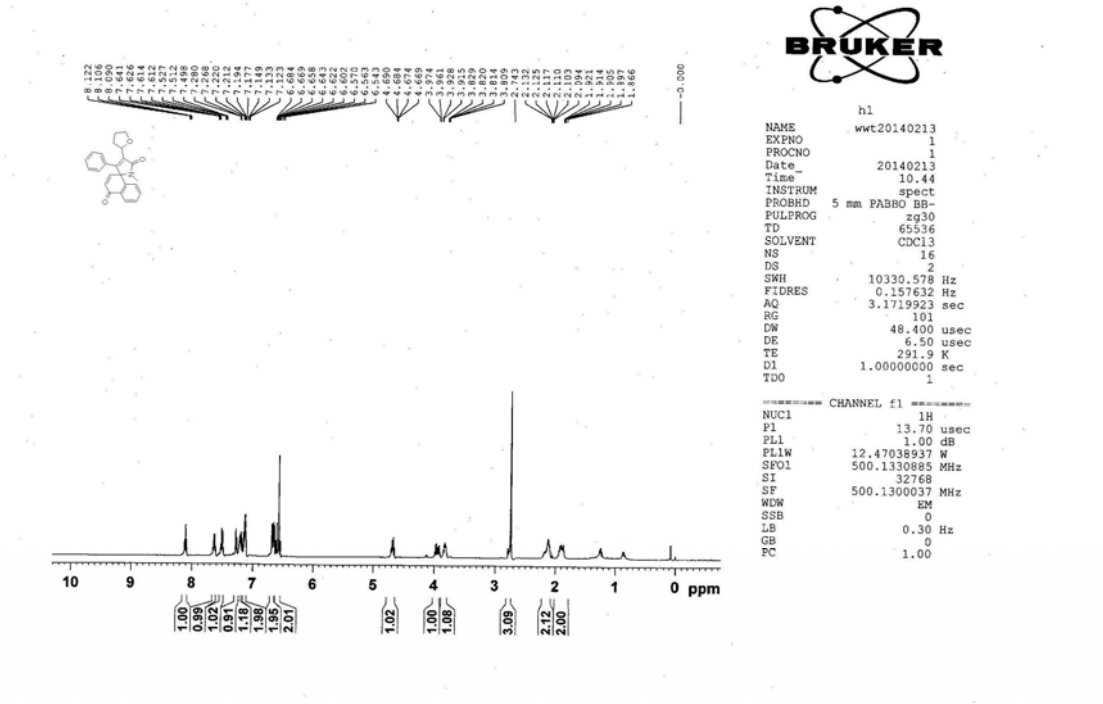
6-Methoxy-1-methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ha)

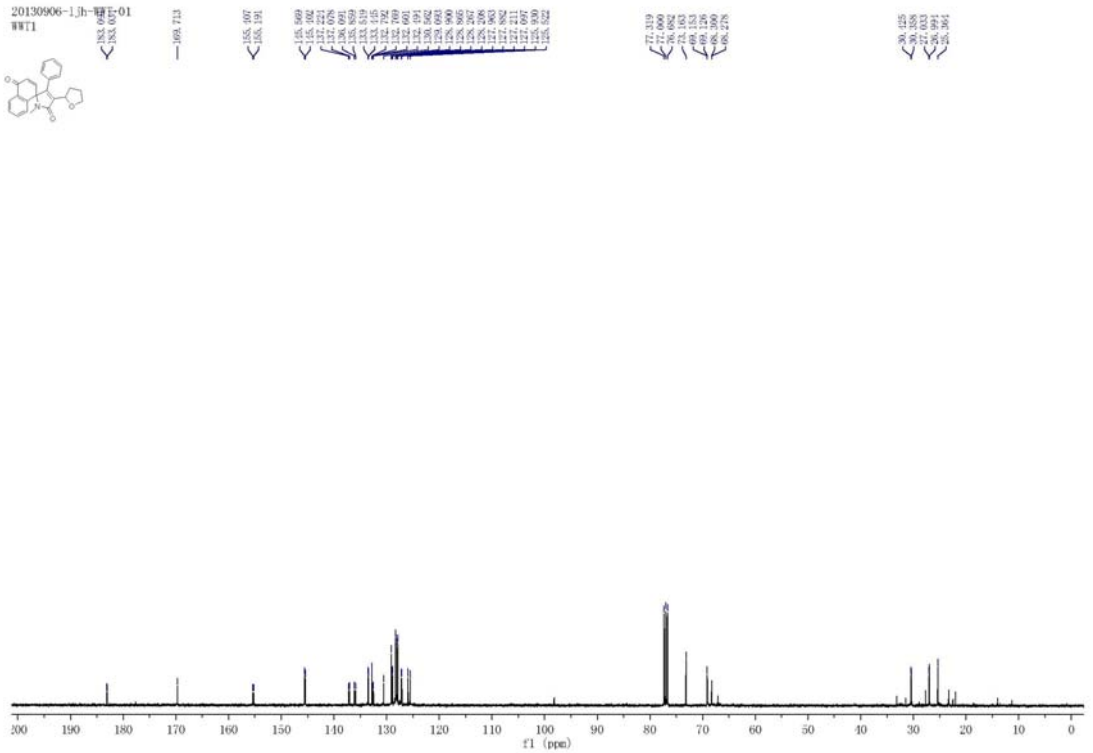


6-Iodo-1-methyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ia)

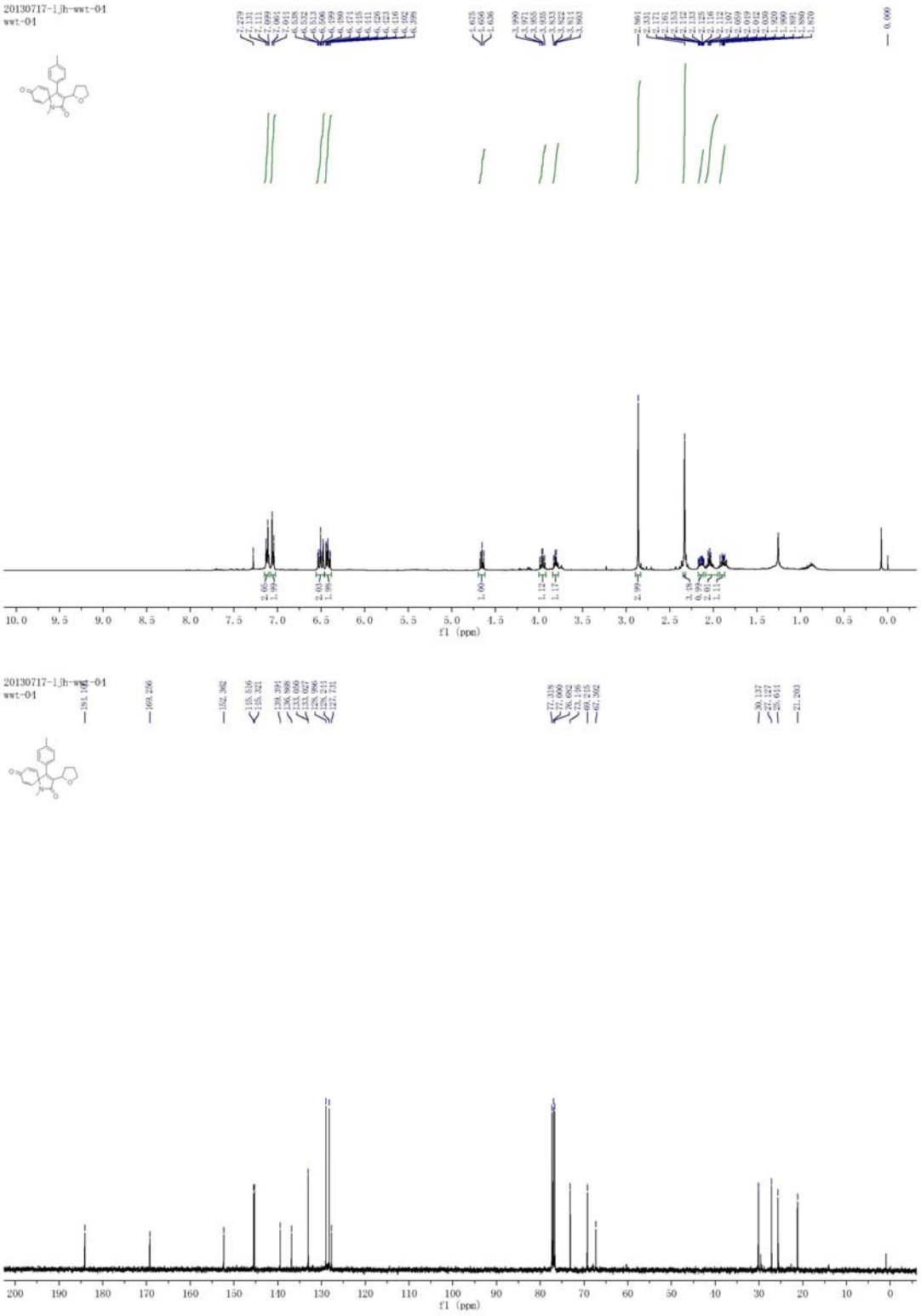


1'-Methyl-3'-phenyl-4'-(tetrahydrofuran-2-yl)-4*H*-spiro[naphthalene-1,2'-pyrrole]-4,5'(1'*H*)-dione(3ja)

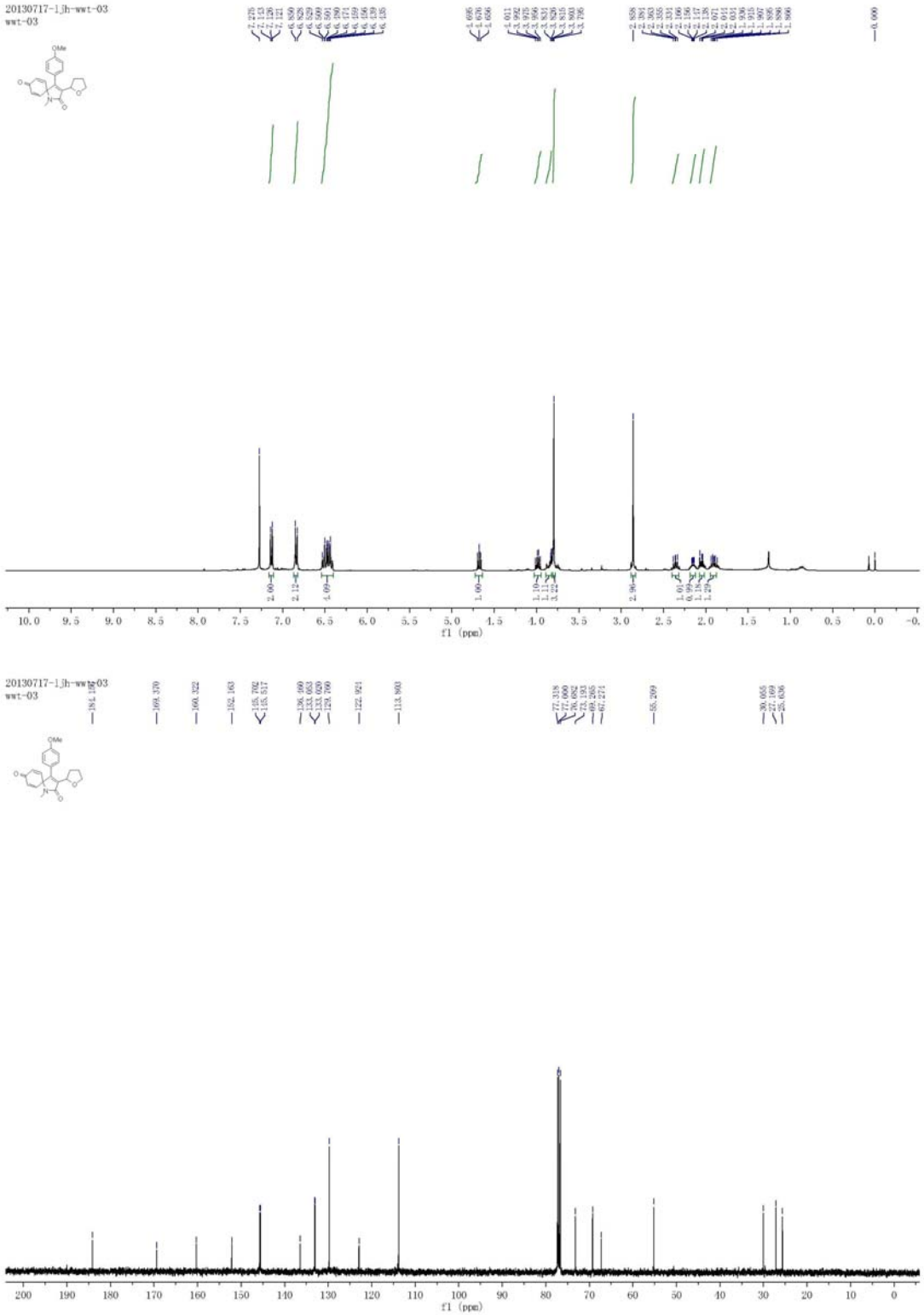




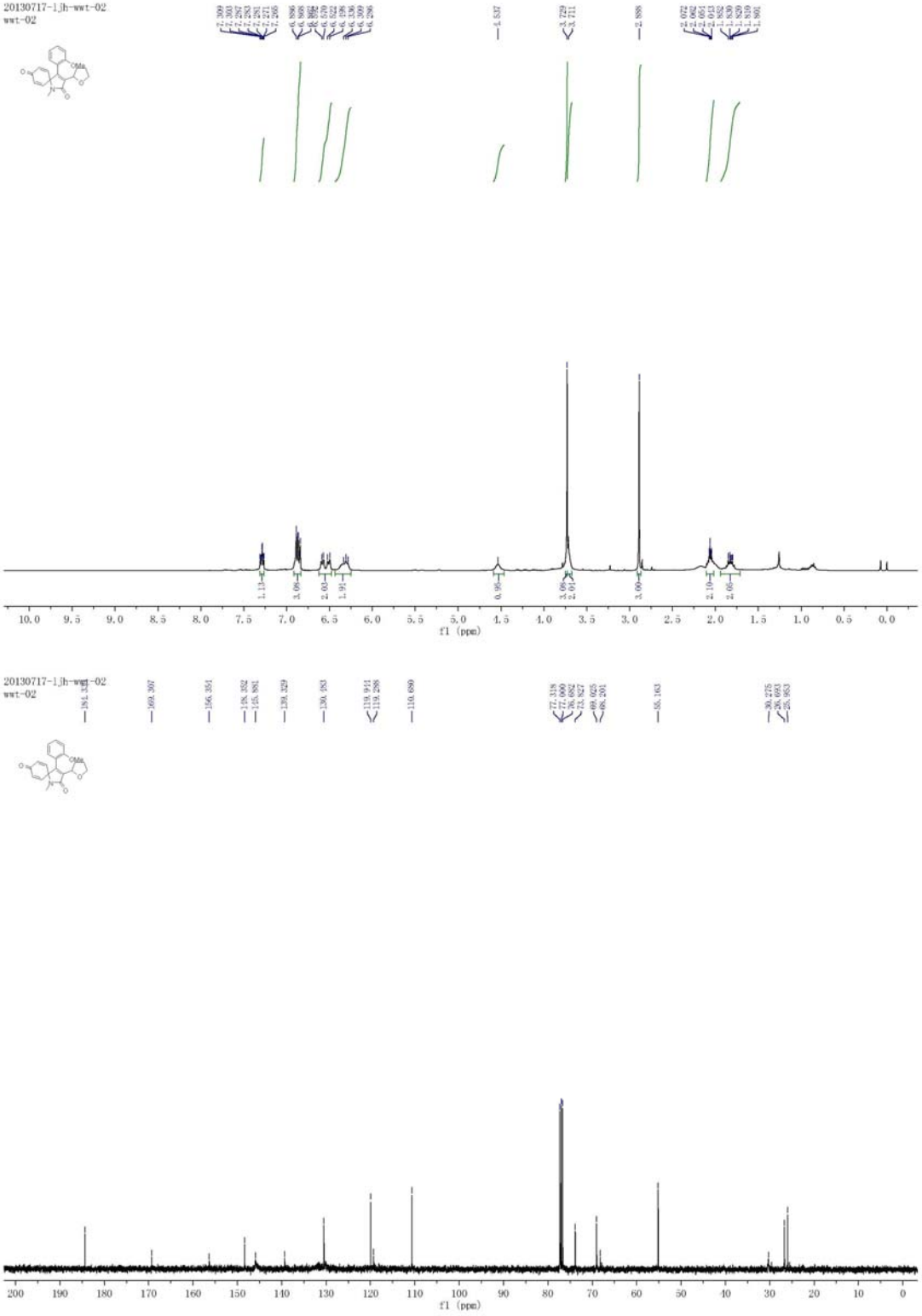
1-Methyl-3-(tetrahydrofuran-2-yl)-4-*p*-tolyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ka)



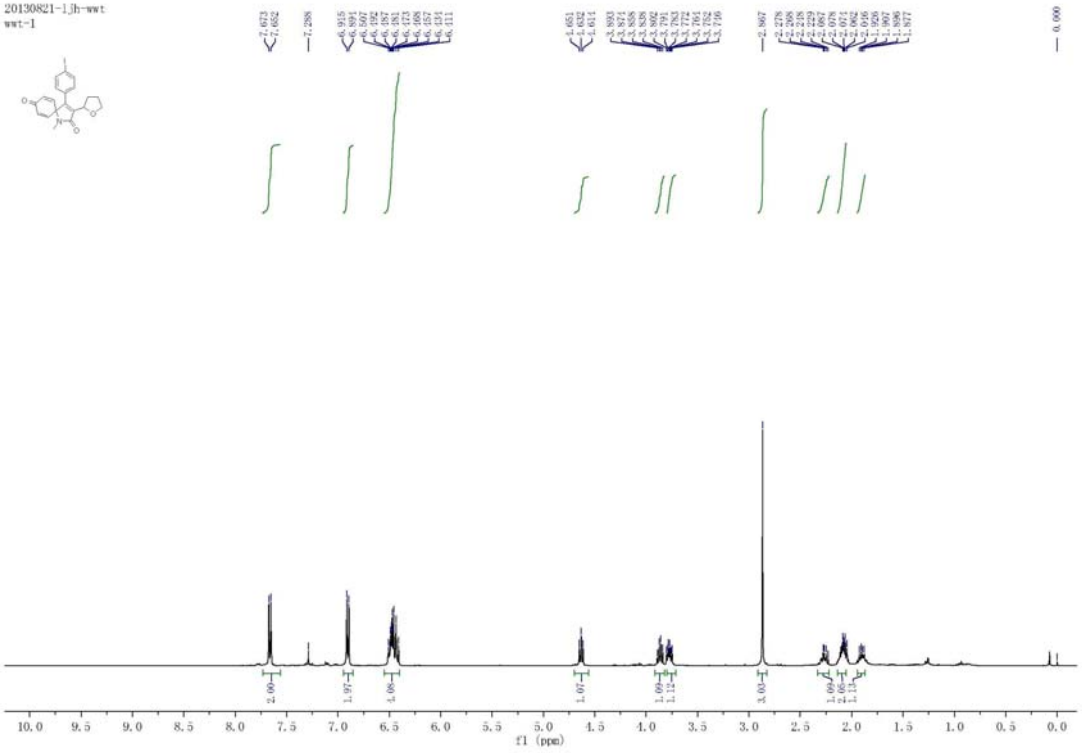
4-(4-Methoxyphenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3la)

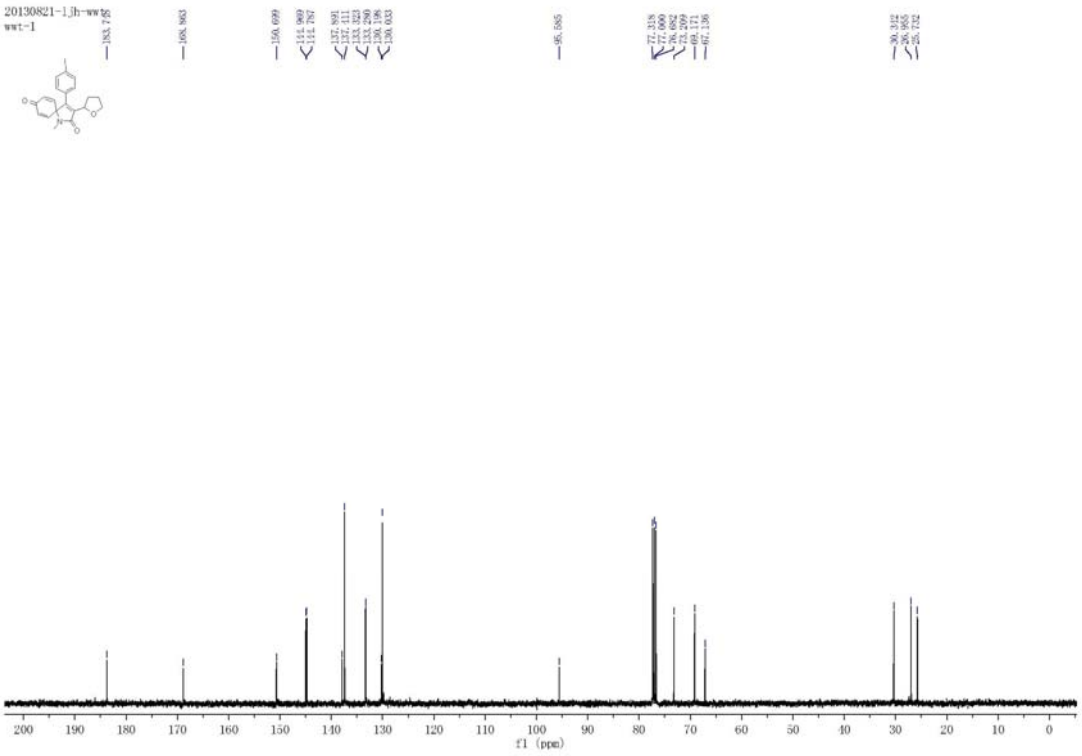


4-(2-Methoxyphenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ma)

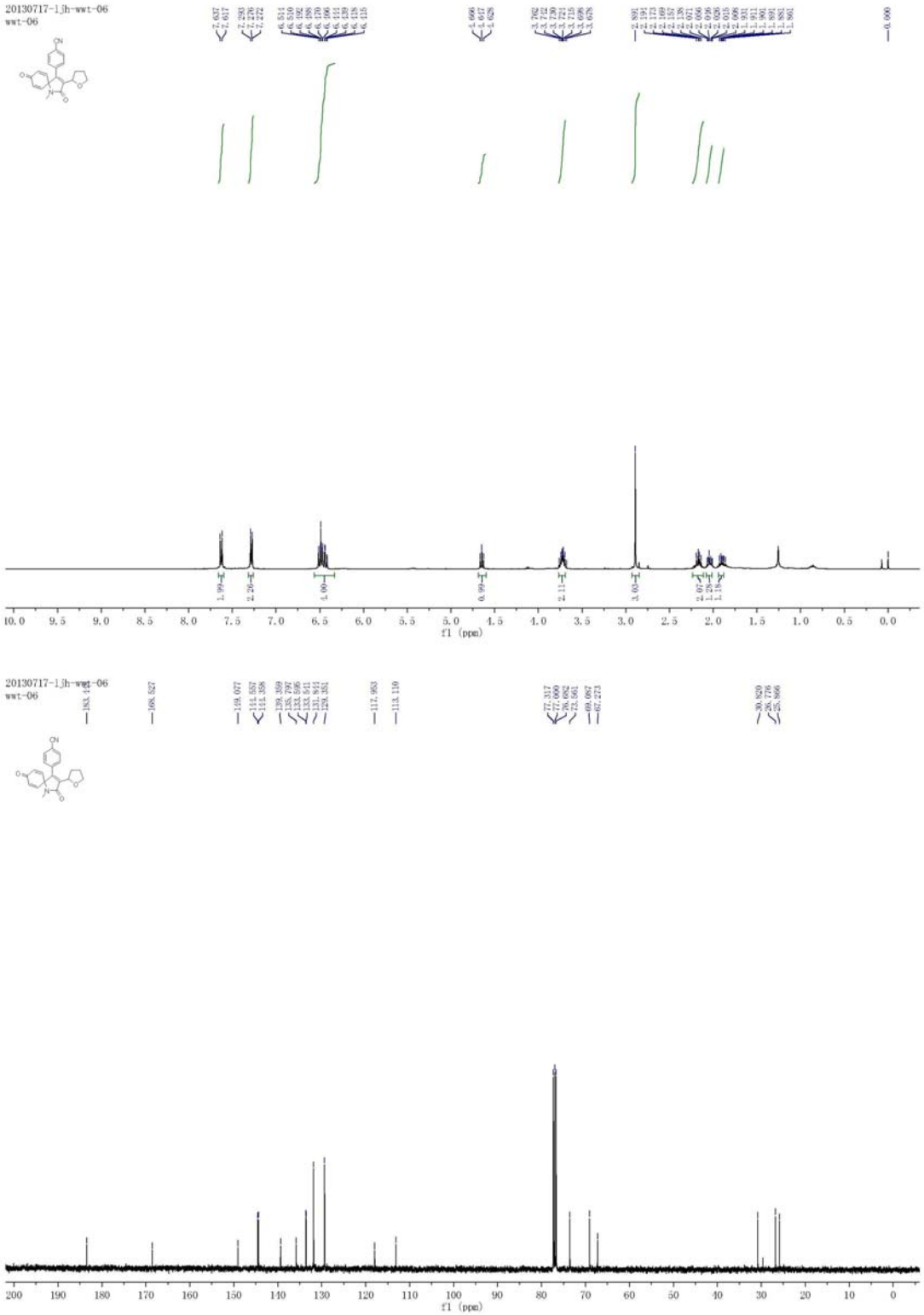


4-(4-Iodophenyl)-1-methyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene2,8dione(3na)

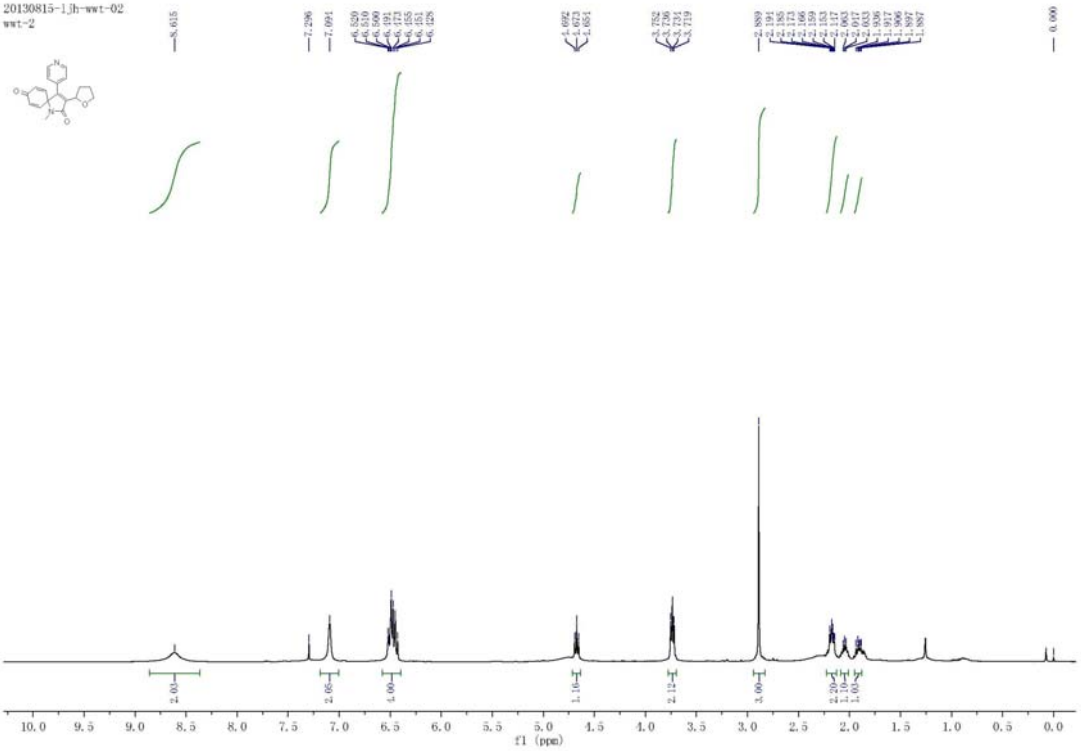


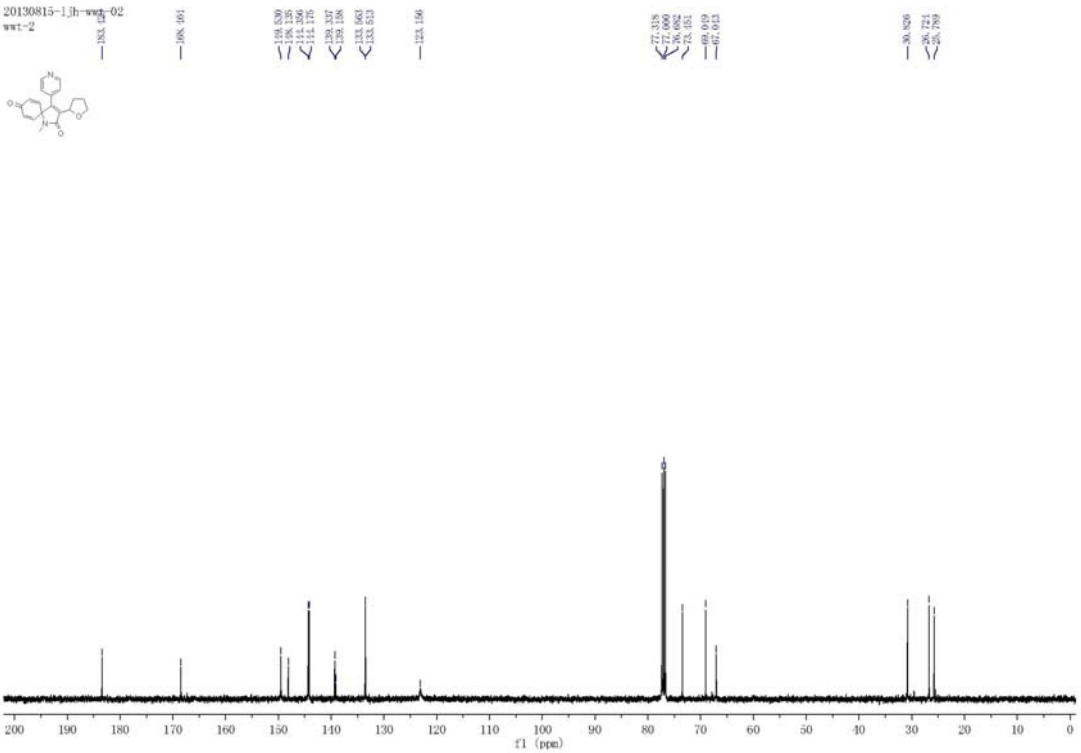


4-(1-Methyl-2,8-dioxo-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-trien-4-yl)benzonitrile(3oa)

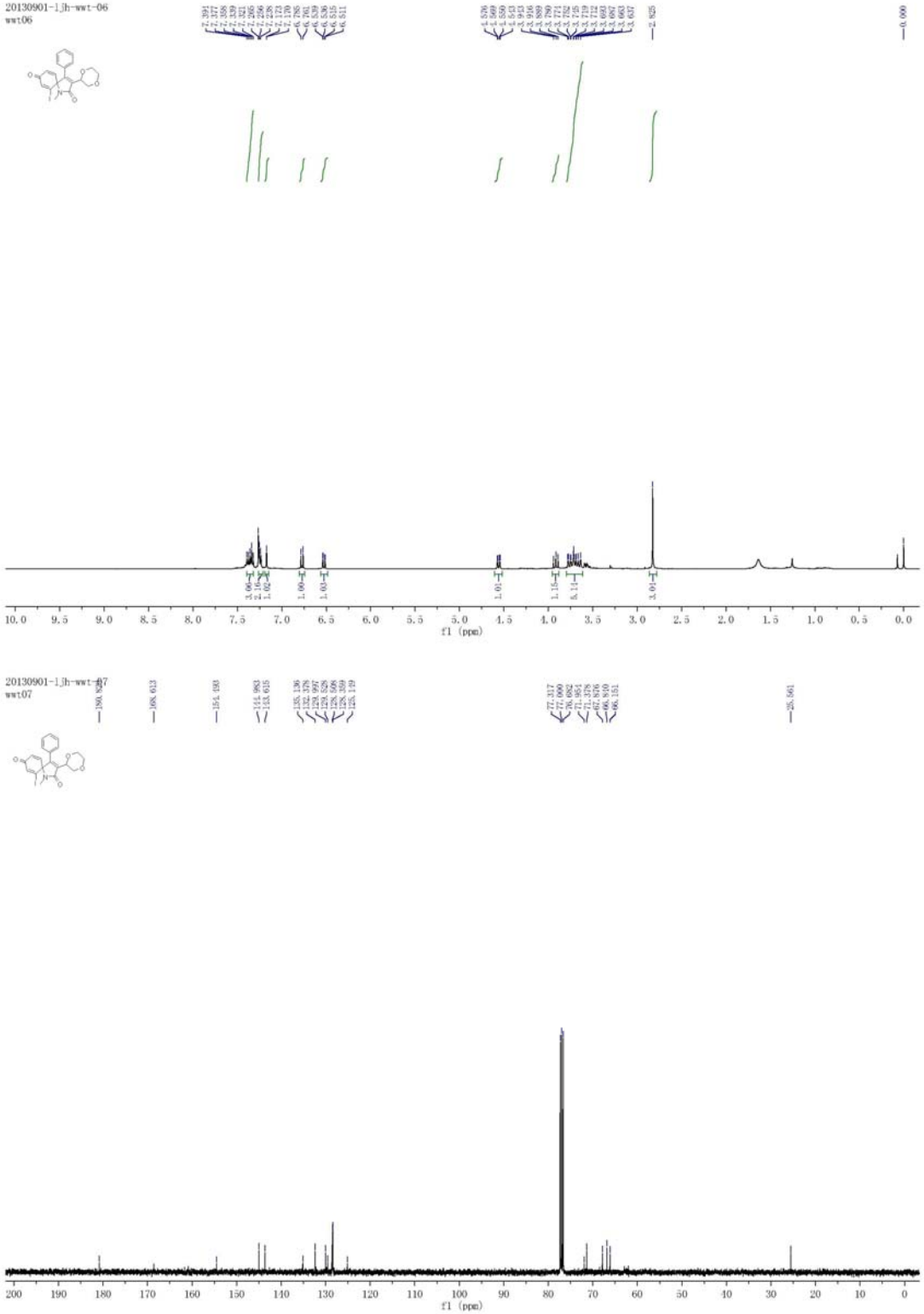


1-Methyl-4-(pyridin-4-yl)-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3qa)

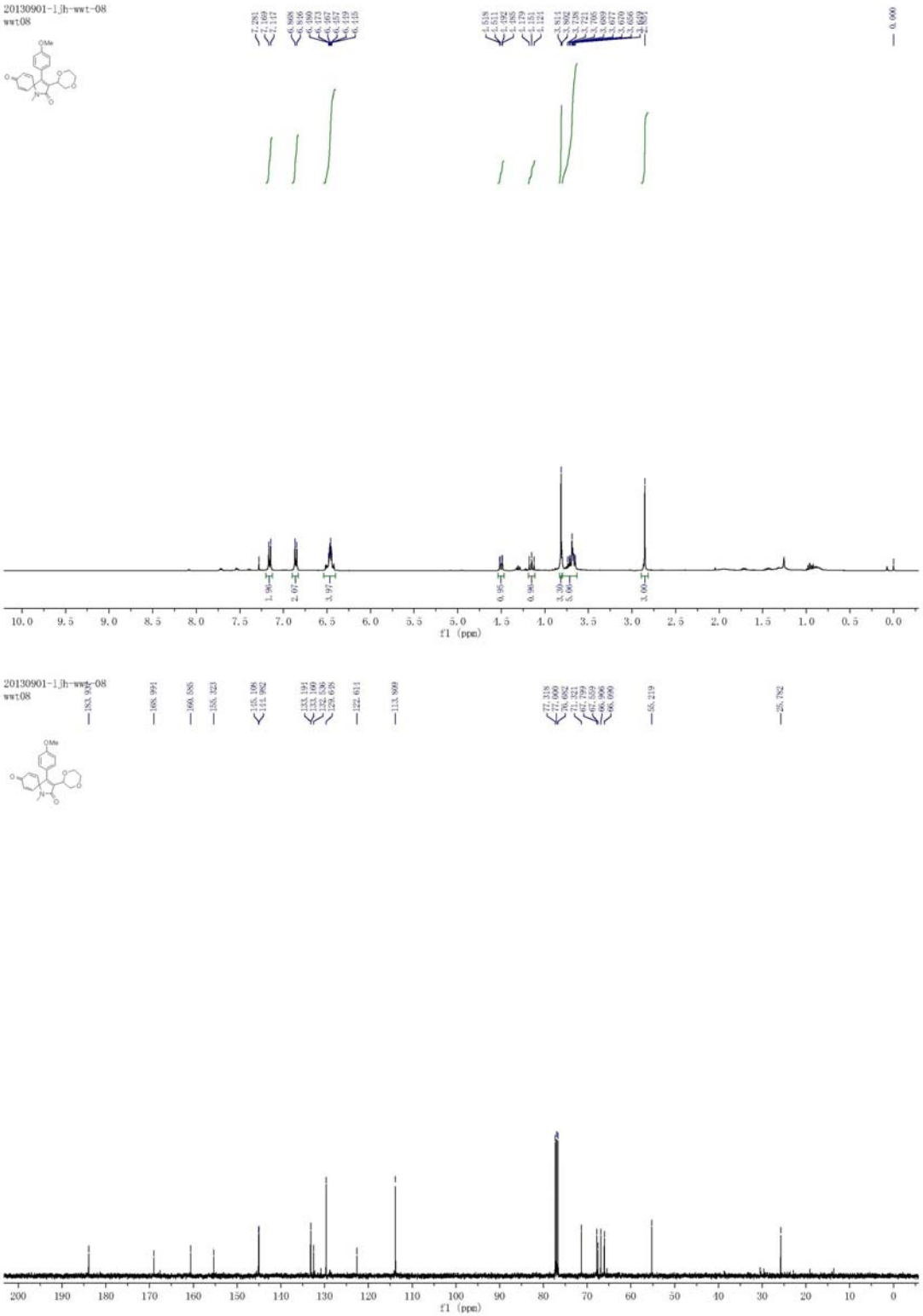




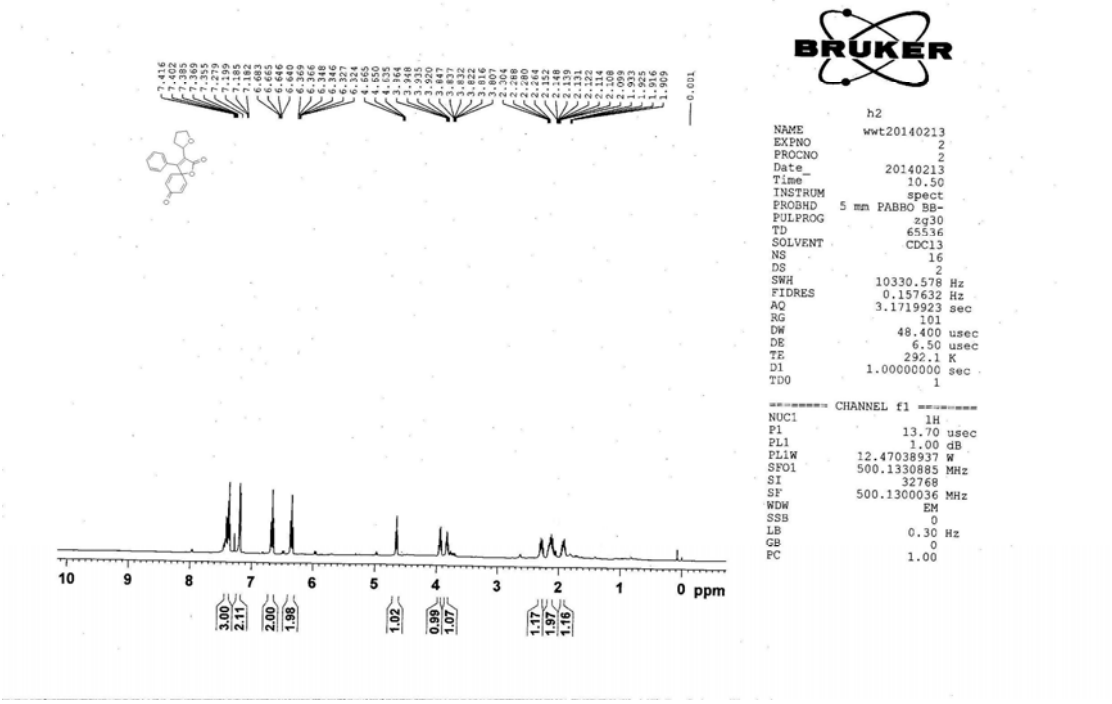
3-(1,4-Dioxan-2-yl)-6-iodo-1-methyl-4-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ib)

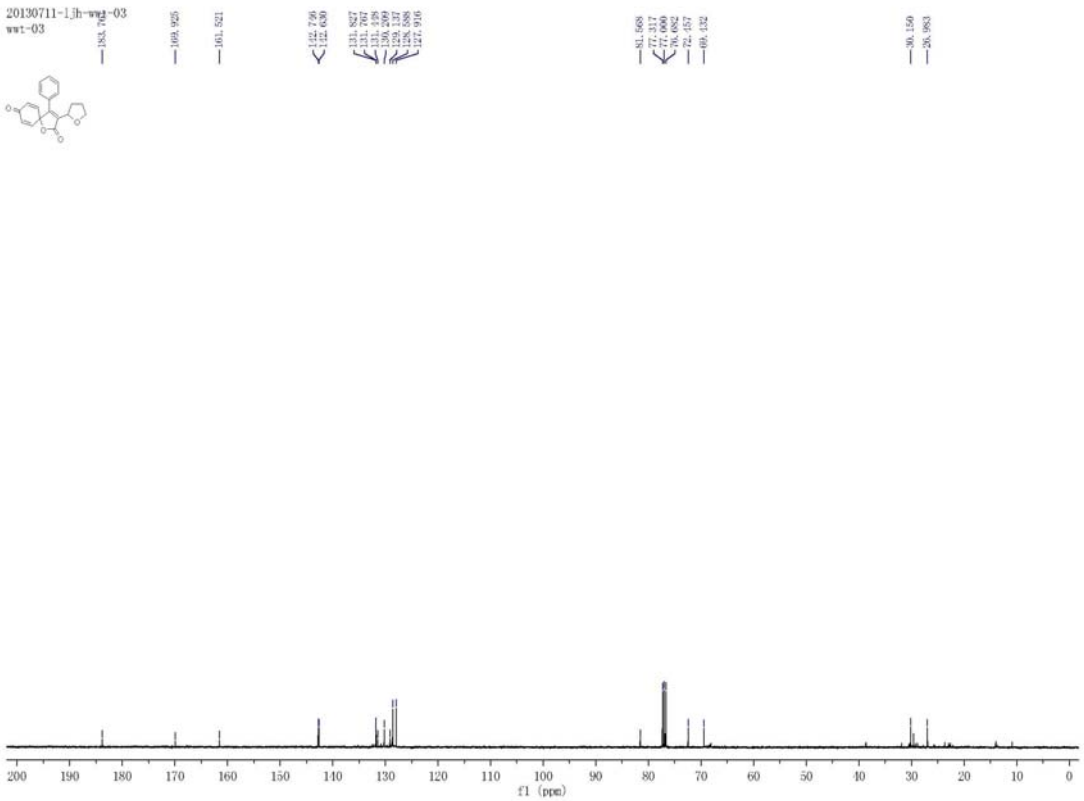


3-(1,4-Dioxan-2-yl)-4-(4-methoxyphenyl)-1-methyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione(3lb)

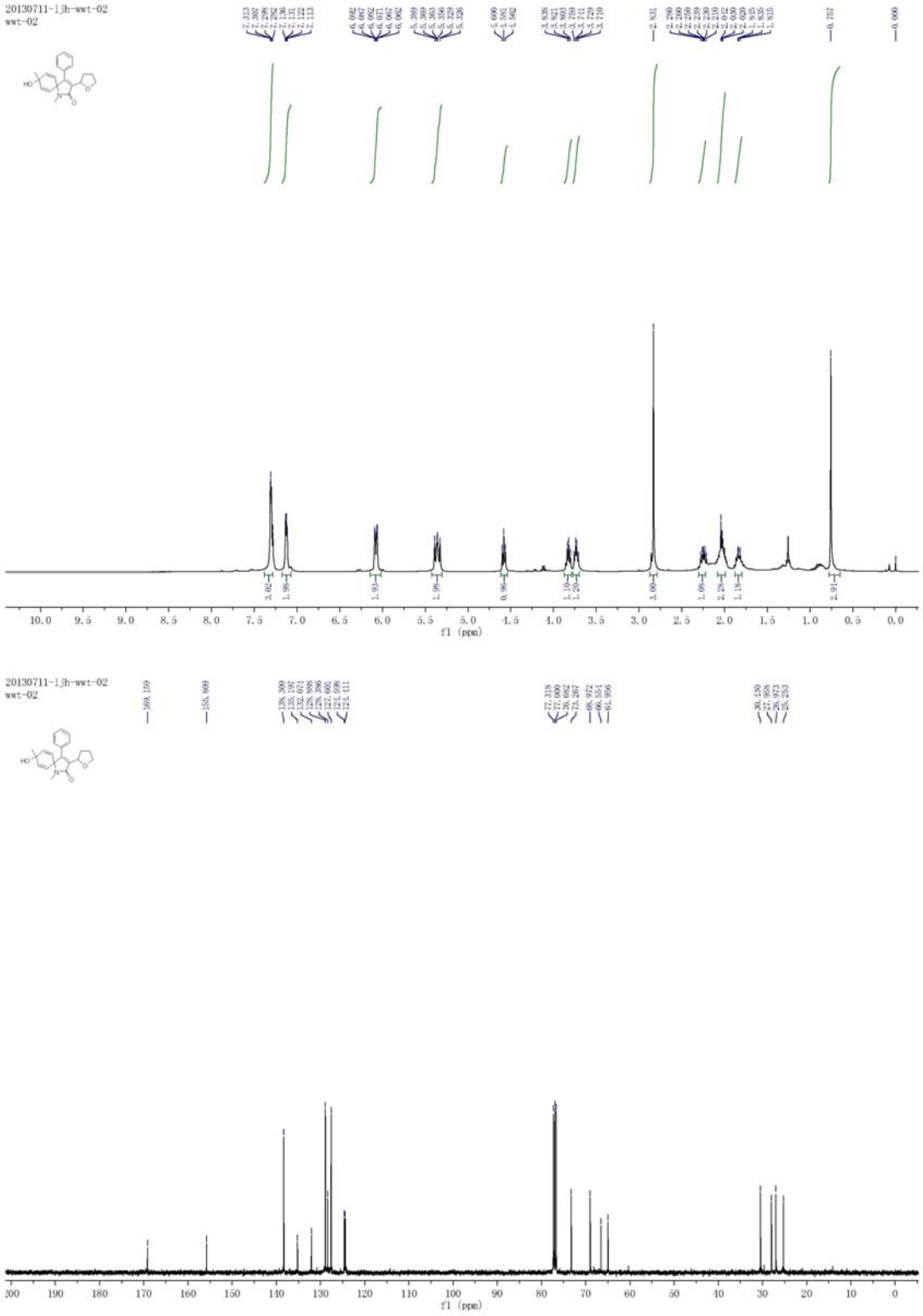


4-Phenyl-3-(tetrahydrofuran-2-yl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione(3ra)

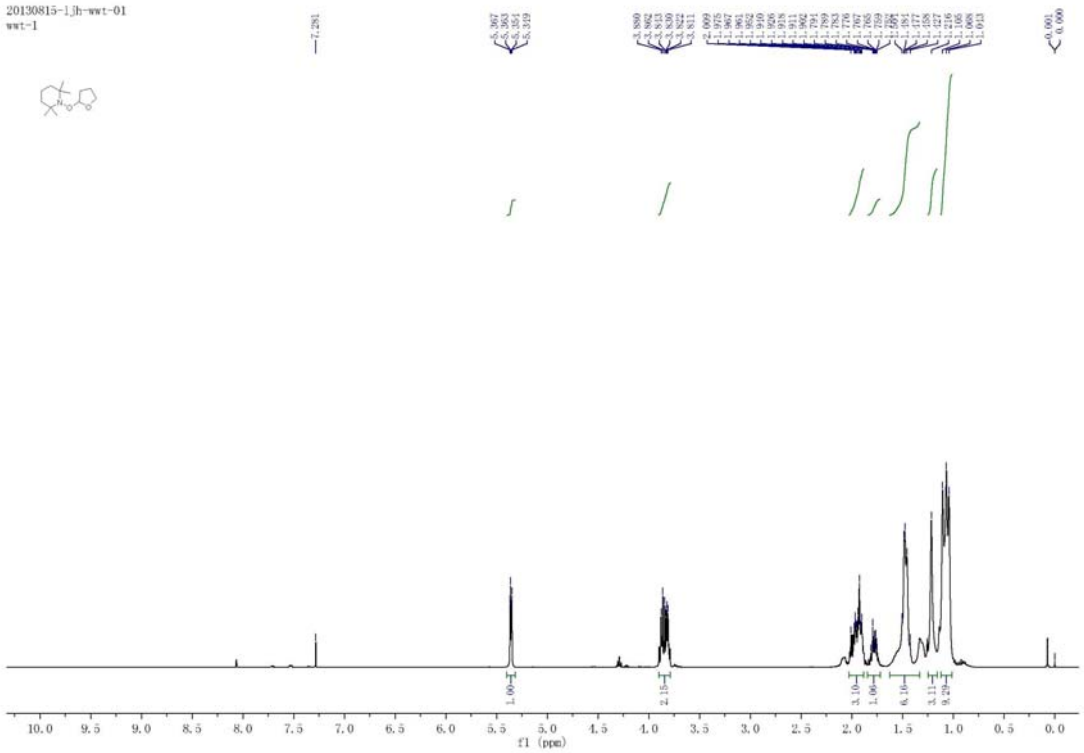


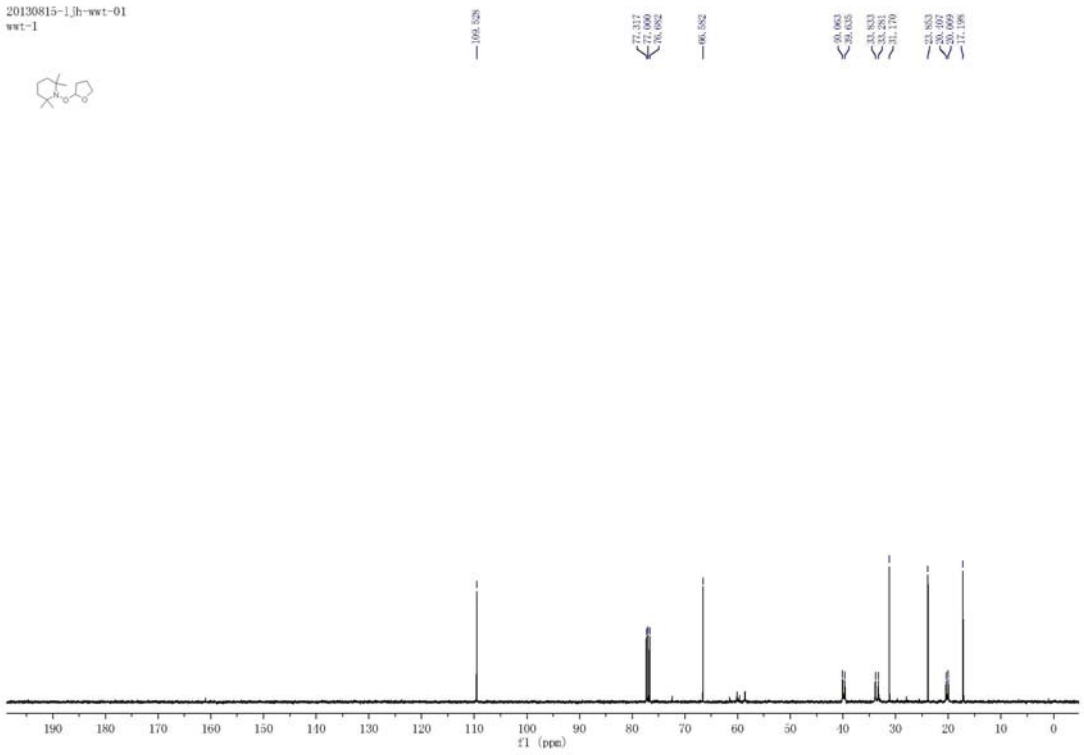


8-Hydroxy-1,8-dimethyl-4-phenyl-3-(tetrahydrofuran-2-yl)-1-azaspiro[4.5]deca-3,6,9-trien-2-one(3ua)



2,2,6,6-Tetramethyl-1-(tetrahydrofuran-2-yloxy)piperidine(4)





Product 3aa and 3aa-D7