Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

SUPPORTING INFORMATION

Highly Stereoselective Construction of Novel Dispirooxindole-heterocycles *via* Self-1,3-dipolar Cycloaddition

Yan-Hua Sun,[a,§] Yu Xiong,[a,§] Chu-Qin Peng,[a] Wu Li,[a] Jun-An Xiao,[a] and Hua Yang*[a]

[a] College of Chemistry and Chemical Engineering, Central South University,

Changsha 410083, P. R. China

Contents

1. <u>Supplementary Experiment</u>

Visualization of the reversibility for self-1,3-dipolar cycloaddition. The cycloadduct --3-benzyl-5-phenyl-imidazolino(spiro-[2,3']-oxindole)-spiro-[4,3'']-oxindole **3a** (*ca.* 10 mg) was added to 5 mL sample tube. Then, DCM (2 mL) and additive were added to it respectively. After 4 hours, pictures of these tubes were taken and the image is shown as below. It should be mentioned that **3a** is white powder and isatin is reddish solid. Therefore, the solution of **3a** should be colorless. The yellowish or brown color in tube **2** and **3** came from the reversibility of this reaction to generate isatin in the presence of silica gel. It turned out that basic or neutral conditions can significantly diminish the reversibility of this reaction. Therefore, aluminum oxide column was chosen to purify the corresponding cycloadduct.

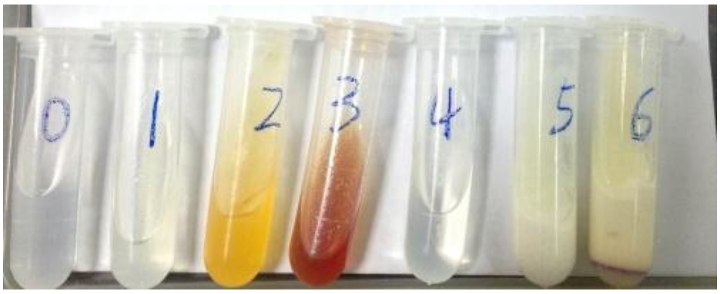


Image 1

Additive in each tube:

0: no additive;

1: 3,5-dinitrobezoic acid;

2: silica gel;

3: 3,5-dinitrobenzoic acid and silica gel;

4: Et_3N;

5: neutral aluminum oxide;

6: neutral aluminum oxide and 3,5-dinitrobenzoic acid.

2. Experimental Section

General

Unless otherwise noted, all the reagents were purchased from commercial suppliers and used without further purification. ^{1}H NMR spectra were recorded at 400 or 500 MHz. The chemical shifts were recorded in ppm relative to tetramethylsilane and with the solvent resonance as the internal standard. Data were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), integration. ^{13}C NMR data were collected at 100 MHz with complete proton decoupling. Chemical shifts were reported in ppm from the tetramethylsilane with the solvent resonance as internal standard. Infrared spectra (IR) were measured by FT-IR apparatus. High resolution mass spectroscopy (HRMS) were recorded on TOF MS ES+ mass spectrometer and acetonitrile and dichloromethane were used to dissolve the sample. Column chromatography was carried out on aluminum oxide (200-300 mesh).

Typical procedure for synthesis of dispirooxindole-imidazolidine 3:

N-substituted isatin (0.40 mmol), benzylamine (0.48 mmol, 1.2 eq), and 3,5-dinitrobenzonic acid (127 mg, 0.6 mmol, 1.5 eq) were dissolved in THF (4 mL). After completion of the reaction (monitored by TLC), organic solvent was removed *in vacuo*. Then the residue was purified *via* flash chromatography to yield the corresponding product.

Dispirooxindole 3a:

White solid (89.1 mg, yield 89%, single stereoisomer obtained); m.p. 208-210 ℃; IR (KBr) *v* 3431, 3051, 2926, 1715, 1610, 1469, 1347, 1113, 751, 695 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.07 (d, *J* = 6.8 Hz, 1H), 7.85 (d, *J* = 7.2 Hz, 1 H), 7.33-7.41 (m, 2H), 7.22-7.30 (m, 2H), 7.12-7.19 (m, 3H), 6.93-7.01 (m, 3H), 6.88 (d, *J* = 7.2 Hz, 2H), 6.81 (d, *J* = 7.6 Hz, 1H), 6.76 (d, *J* = 7.6 Hz, 1H), 6.53 (d, *J* = 6.8 Hz, 2H), 5.33 (d, *J* = 12.0 Hz, 1H), 4.15 (d, *J* = 12.0 Hz, 1H), 3.58 (d, *J* = 13.6 Hz, 1H), 3.27 (d, *J* = 13.6 Hz, 1H), 2.84 (s, 3H), 2.51 (s, 3H); ^{13}C NMR (DMSO-d_6, 100MHz) δ 177.4, 176.2, 144.9, 144.6, 137.2, 134.9, 130.9, 129.9, 128.7, 128.2, 127.7, 127.4, 127.0, 126.6, 126.4, 126.2, 124.5, 123.1, 122.8, 109.0, 108.9, 81.1, 74.7, 69.8, 49.3, 25.96, 25.77; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{29}N_4O_2$ 501.2291, found 501.2268.

Dispirooxindole 3c:

White solid (55.9 mg, yield 50%, single stereoisomer obtained); m.p. 151-153 ℃; IR (KBr) *v* 3433, 2932, 1728, 1614, 1487, 1185, 1077, 911, 746, 689 cm^{-1}; ^{1}H NMR (DMSO-d_6, 500 MHz) δ 8.10 (d, *J* = 7.5 Hz, 1H), 7.90-7.92 (m, 1H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.30-7.37 (m, 3H), 7.13-7.18 (m, 3H), 6.93-7.01 (m, 6H), 6.78-6.80 (m, 1H), 6.52 (d, *J* = 7.5 Hz, 2H), 5.37 (d, *J* = 11.5 Hz, 1H), 4.92 (d, *J* = 11.0 Hz, 1H), 4.71 (d, *J* = 11.0 Hz, 1H), 4.59 (d, *J* = 11.0 Hz, 1H), 4.38 (dd, *J* = 11.0, 5.0 Hz, 2H), 3.62 (d, *J* = 14.0 Hz, 1H), 3.31 (d, *J* = 14.0 Hz, 1H), 3.14 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 178.1, 177.0, 143.4, 143.1, 137.1, 134.7, 131.01, 129.99, 128.7, 128.3, 127.8, 127.2, 126.83, 126.77, 126.7, 125.0, 123.6, 123.5, 110.1, 109.9, 81.7, 74.7, 71.2, 70.9, 70.2, 56.1, 54.9, 49.2; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{32}N_4O_4Na$ 583.2321, found 583.2343.

Dispirooxindole 3d:

White solid (62.1 mg, yield 48%, single stereoisomer obtained); m.p. 192-193 ℃; IR (KBr) *ν* 3443, 2920, 1729, 1696, 1608, 1179, 963, 756, 694 cm^{-1}; ^{1}H NMR (DMSO-d_6, 500 MHz) *δ* 8.13 (d, *J* = 7.0 Hz, 1H), 7.94 (d, *J* = 7.0 Hz, 1H), 6.98-7.34 (m, 21H), 6.75 (d, *J* = 8.0 Hz, 1H), 6.62 (d, *J* = 7.5 Hz, 2H), 6.38-6.40 (m, 3H), 5.47 (d, *J* = 12.0 Hz, 1H), 4.84 (d, *J* = 16.0 Hz, 1H), 4.67 (d, *J* = 16.0 Hz, 1H), 4.52 (d, *J* = 16.0 Hz, 1H), 4.43 (d, *J* = 12.0 Hz, 1H), 3.99 (d, *J* = 16.0 Hz, 1H), 3.73 (d, *J* = 13.5 Hz, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.6, 176.5, 143.9, 143.7, 137.3, 136.7, 136.0, 134.5, 130.9, 129.8, 129.1, 128.8, 128.6, 128.54, 128.48, 127.9, 127.8, 127.6, 127.3, 127.2, 127.1, 127.0, 126.7, 125.0, 123.11, 123.06, 109.7, 109.4, 81.7, 74.3, 70.1, 49.4, 43.0, 42.9; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{44}H_{36}N_4O_2Na$ 675.2736, found 675.2755.

Dispirooxindole 3e:

White solid (99.5 mg, yield 94%, single stereoisomer obtained); m.p. 224-225 ℃; IR (KBr) *ν* 3433, 2920, 1725, 1703, 1497, 1091, 974, 748, 697 cm^{-1}; ^{1}H NMR (DMSO-d_6, 500 MHz) *δ* 7.88 (s, 1H), 7.66 (s, 1H), 7.12-7.20 (m, 5H), 6.94-7.00 (m, 3H), 6.87 (d, *J* = 7.0 Hz, 2H), 6.70 (d, *J* = 8.0 Hz, 1H), 6.65 (d, *J* = 7.5 Hz, 1H), 6.55 (d, *J* = 7.5 Hz, 2H), 5.29 (d, *J* = 12.0 Hz, 1H), 4.08 (d, *J* = 12.5 Hz, 1H), 3.60 (d, *J* = 14.0 Hz, 1H), 3.26 (d, *J* = 13.5 Hz, 1H), 2.83 (s, 3H), 2.56 (s, 3H), 2.46 (s, 3H), 2.43 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.3, 176.2, 142.6, 142.3, 137.4, 135.0, 132.0, 131.8, 130.9, 130.0, 128.7, 128.2, 127.7, 127.5, 126.9, 126.8, 126.7, 126.4, 125.2, 108.7, 108.6, 81.3, 74.7, 69.7, 49.4, 26.0, 25.81, 25.76, 21.4; HRMS(TOF-ES+) m/z: $[M+H]^+$calcd for $C_{34}H_{33}N_4O_2$ 529.2604, found 529.2603.

Dispirooxindole 3f:

White solid (100.7 mg, yield 94%, single stereoisomer obtained); m.p. 191-193 ℃; IR (KBr) *ν* 3294, 2883, 1712, 1618, 1492, 1269, 1111, 979, 817, 794, 748, 699 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 7.91 (dd, *J* = 8.0, 2.8 Hz, 1H), 7.60 (dd, *J* = 8.0, 2.8 Hz, 1H), 7.14-7.27 (m, 5H), 6.96-7.03 (m, 5H), 6.82 (dd, *J* = 8.4, 4.0 Hz, 1H), 6.77 (dd, *J* = 8.4, 4.0 Hz, 1H), 6.61 (d, *J* = 6.4 Hz, 2H), 5.27 (d, *J* = 11.2 Hz, 1H), 4.39 (d, *J* = 10.8 Hz, 1H), 3.58 (d, *J* = 13.6 Hz, 1H), 3.32 (d, *J* = 12.4 Hz, 1H), 2.84 (s, 3H), 2.57 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.5, 175.8, 160.3, 160.1, 157.9, 157.8, 141.1, 140.8, 136.8, 134.5, 129.44, 129.36, 128.8, 128.5, 128.42, 128.39, 128.2, 127.8, 127.2, 126.8, 117.1, 116.9, 116.2, 116.0, 114.5, 114.3, 112.2, 112.0, 109.93, 109.85, 81.22, 75.2, 70.4, 49.6, 26.2, 26.0; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{27}N_4O_2F_2$ 537.2102, found 537.2115.

Dispirooxindole 3g:

White solid (66.5 mg, yield 59%, single stereoisomer obtained); m.p. 289-291 ℃; IR (KBr) *ν* 3429, 2927, 1718, 1609, 1487, 1456, 1097, 975, 808, 747, 696 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400MHz) *δ* 8.09 (d, *J* = 2.4 Hz, 1H), 7.78 (d, *J* = 2.0 Hz, 1H), 7.45 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.40 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.14-7.22 (m, 3H), 6.94-7.01 (m, 5H), 6.85 (d, *J* = 8.0 Hz, 1H), 6.78 (d, *J* = 8.4 Hz, 1H), 6.57-6.59 (m, 2H), 5.26 (d, *J* = 10.8 Hz, 1H), 4.46 (d, *J* = 10.8 Hz, 1H), 3.55 (d, *J* = 13.6 Hz, 1H), 3.34 (d, *J* = 12.0 Hz, 1H), 2.86 (s, 3H), 2.56 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.4, 175.6, 143.8, 143.5, 136.7, 134.5, 130.6, 129.7, 129.6, 128.7, 128.6, 128.5, 128.2, 127.9, 127.3, 127.1, 126.9, 126.8, 124.4, 110.5, 110.4, 81.1, 75.0, 70.5, 49.7, 26.2, 25.9; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{32}H_{26}N_4O_2Cl_2Na$ 591.1331, found 591.1328.

Dispirooxindole 3h:

White solid (120.1 mg, yield 92%, single stereoisomer obtained); m.p. 245-246 ℃; IR (KBr) *ν* 3327, 3029, 1717, 1609, 1487, 1456, 1098, 975, 747, 696 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 8.09 (d, *J* = 2.0 Hz, 1H), 7.78 (d, *J* = 2.4 Hz, 1H), 7.45 (dd, *J* = 8.4, 2.4 Hz, 1H), 7.40 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.14-7.25 (m, 3H), 6.96-7.06 (m, 5H), 6.85 (d, *J* = 8.4 Hz, 1H), 6.78 (d, *J* = 8.4 Hz, 1H), 6.57-6.59 (m, 2H), 5.26 (d, *J* = 10.8 Hz, 1H), 4.46 (d, *J* = 10.8 Hz, 1H), 3.55 (d, *J* = 13.6 Hz, 1H), 3.34 (d, *J* = 10.8 Hz, 1H), 2.86 (s, 3H), 2.56 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.4, 175.6, 143.8, 143.5, 136.7, 134.5, 130.6, 129.7, 129.6, 128.7, 128.6, 128.5, 128.2, 127.9, 127.3, 127.1, 126.9, 126.8, 124.4, 110.5, 110.4, 81.1, 75.0, 70.4, 49.7, 26.2, 26.0; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{27}N_4O_2Br_2$ 657.0501, found 657.0470.

Dispirooxindole 3i:

White solid (103.9 mg, yield 91%, single stereoisomer obtained); m.p. 187-188 ℃; IR (KBr) *ν* 3444, 2923, 1724, 1609, 1368, 1070, 898, 743, 697 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 8.04 (d, *J* = 8.0 Hz, 1H), 7.81 (d, *J* = 7.6 Hz, 1H), 7.28-7.34 (m, 2H), 7.15-7.22 (m, 3H), 6.91-7.05 (m, 7H), 6.58 (d, *J* = 6.8 Hz, 2H), 5.28 (d, *J* = 11.2 Hz, 1H), 4.29 (d, *J* = 11.2 Hz, 1H), 3.53 (d, *J* = 13.6 Hz, 1H), 3.31 (d, *J* = 13.6 Hz, 1H), 2.84 (s, 3H), 2.57 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.6, 176.0, 146.4, 146.0, 136.8, 135.4, 134.6, 134.4, 128.7, 128.4, 128.3, 127.9, 127.8, 127.2, 126.6, 126.2, 125.9, 125.4, 122.7, 122.4, 109.5, 109.4, 80.7, 74.5, 69.9, 49.4, 26.2, 26.0; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{27}N_4O_2Cl_2$ 569.1511, found 569.1537.

Dispirooxindole 3j:

White solid (81.7 mg, yield 62%, single stereoisomer obtained); m.p. 208-210 ℃; IR (KBr) *ν* 3287, 2879, 1739, 1713, 1605, 1368, 1091, 976, 813, 751, 700 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 7.98 (d, *J* = 7.6 Hz, 1H), 7.75 (d, *J* = 8.4 Hz, 1H), 7.43-7.48 (m, 2H), 7.15-7.20 (m, 3H), 6.93-7.08 (m, 7H), 6.57 (d, *J* = 7.2 Hz, 2H), 5.28 (d, *J* = 11.2 Hz, 1H), 4.29 (d, *J* = 10.8 Hz, 1H), 3.53 (d, *J* = 13.6 Hz, 1H), 3.31 (d, *J* = 13.6 Hz, 1H), 2.84 (s, 3H), 2.56 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 177.5, 175.9, 146.5, 146.1, 136.8, 134.6, 128.7, 128.4, 128.3, 128.2, 127.8, 127.2, 126.6, 126.3, 125.9, 125.7, 125.4, 123.8, 122.7, 112.2, 112.1, 80.8, 74.5, 69.9, 49.5, 26.2, 26.0; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{27}N_4O_2Br_2$ 657.0501, found 657.0476.

Dispirooxindole 3k:

White solid (83.4 mg, yield 73%, single stereoisomer obtained); m.p. 204-206 ℃; IR (KBr) *ν* 3427, 2948, 1719, 1712, 1608, 1464, 1108, 972, 781, 752, 699 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 8.11 (dd, *J* = 7.2, 0.8 Hz, 1H), 7.85 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.16-7.40 (m, 7H), 7.00-7.09 (m, 3H), 6.92 (d, *J* = 7.2 Hz, 2H), 6.53 (d, *J* = 6.8 Hz, 2H), 5.27 (d, *J* = 10.4 Hz, 1H), 4.32 (d, *J* = 10.8 Hz, 1H), 3.51 (d, *J* = 13.2 Hz, 1H), 3.33 (d, *J* = 13.6 Hz, 1H), 3.14 (s, 3H), 2.86 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ* 178.1, 176.3, 140.5, 140.1, 136.7, 134.5, 132.8, 131.9, 130.7, 129.9, 128.9, 128.6, 128.3, 127.8, 127.3, 126.6, 125.8, 124.5, 124.1, 123.7, 114.9, 114.7, 80.2, 74.6, 70.5, 49.5, 29.2, 28.9; HRMS (TOF-ES+) m/z: $[M+H]^+$ calcd for $C_{32}H_{27}N_4O_2Cl_2$ 569.1511, found 569.1515.

Dispirooxindole 3l:

White solid (100.6 mg, yield 94%, single stereoisomer obtained); m.p. 87-89 ℃; IR (KBr) *ν* 3419, 2928, 1715, 1611, 1506, 1101, 835, 754 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) *δ* 8.07 (d, *J* = 7.2 Hz, 1H), 7.84 (d, J = 6.8 Hz, 1H), 7.22–7.42 (m, 4H), 6.92-7.01 (m, 4H), 6.85 (d, *J* = 7.6 Hz, 1H), 6.77-6.81 (m, 3H), 6.52-6.55 (m, 2H), 5.31 (d, *J* = 11.2 Hz, 1H), 4.24 (d, *J* = 11.2 Hz, 1H), 3.58 (d, *J* = 13.6 Hz, 1H), 3.23 (d, *J* = 13.6 Hz, 1H), 2.88 (s, 3H), 2.62 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 177.5, 176.0, 163.3, 162.6, 160.8, 160.1, 144.8, 144.5, 133.4, 131.18, 131.15, 130.9, 130.6, 130.5, 130.0, 128.7, 128.6, 127.2, 126.6, 126.4, 124.6, 123.1, 122.8, 115.1, 114.9, 114.5, 114.3, 109.0, 108.9, 81.1, 74.6, 69.2, 48.6, 26.0, 25.8; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{32}H_{26}N_4O_2F_2Na$ 559.1922, found 559.1908.

Dispirooxindole 3m:

White solid (102.4 mg, yield 89%, single stereoisomer obtained); m.p. 162-165 ℃; IR (KBr) *v* 3331, 3069, 2926, 1720, 1612, 1491, 1271, 1102, 966, 849, 750 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.07 (d, *J* = 7.2 Hz, 1H), 7.77 (d, *J* = 7.6 Hz, 1H), 7.68-7.74 (m, 1H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.28 (t, *J* = 8.0 Hz, 1H), 7.15-7.23 (m, 2H), 6.93-7.04 (m, 2H), 6.89 (d, *J* = 7.6 Hz, 1H), 6.60-6.79 (m, 4H), 5.61 (d, *J* = 10.8 Hz, 1H), 4.35 (d, *J* = 10.4 Hz, 1H), 3.77 (d, *J* = 14.0 Hz, 1H), 3.16 (d, *J* = 14.0 Hz, 1H), 2.94 (s, 3H), 2.68 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 177.5, 176.0, 144.8, 144.1, 131.0, 129.9, 126.9, 126.6, 126.3, 125.3, 122.9, 109.0, 108.6, 81.1, 74.4, 62.2, 26.1, 25.9; HRMS (TOF-ES+) m/z: [M+Na]+ calcd for $C_{32}H_{24}N_4O_2F_4Na$ 595.1733, found 595.1738.

Dispirooxindole 3n:

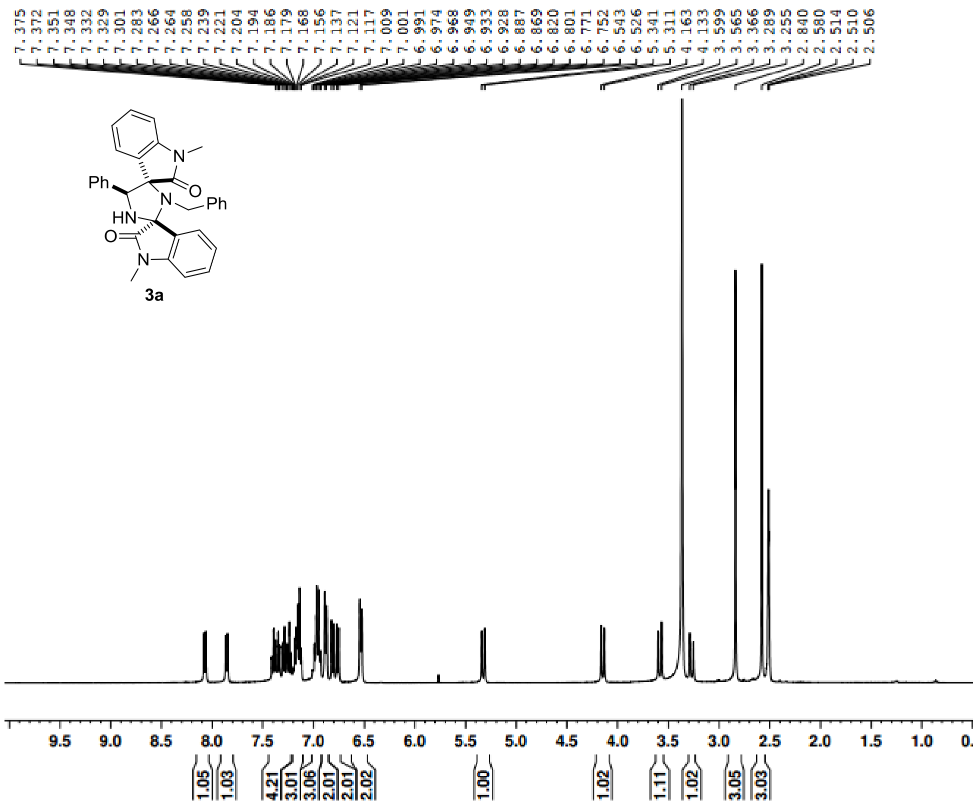
White solid (88.7 mg, yield 78%, single stereoisomer obtained); m.p. 204-205 ℃; IR (KBr) *v* 3851, 3673, 3667, 3585, 3456, 2358, 1660, 1614, 970, 808, 757 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.05 (d, *J* = 7.2 Hz, 1H), 7.84 (d, *J* = 6.8 Hz, 1H), 7.21-7.42 (m, 6H), 7.01 (d, *J* = 8.4 Hz, 2H), 6.93 (d, *J* = 8.4 Hz, 2H), 6.85 (d, *J* = 7.6 Hz, 1H), 6.79 (d, *J* = 8.0 Hz, 1H), 6.51 (d, *J* = 8.0 Hz, 2H), 5.31 (d, *J* = 11.2 Hz, 1H), 4.28 (d, *J* = 11.2 Hz, 1H), 3.56 (d, *J* = 13.6 Hz, 1H), 3.23 (d, *J* = 13.6 Hz, 1H), 2.88 (s, 3H), 2.61 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 177.4, 175.9, 144.8, 144.5, 136.3, 134.1, 132.9, 131.6, 131.0, 130.5, 130.1, 128.5, 128.2, 127.6, 126.9, 126.5, 124.7, 123.2, 122.8, 109.0, 81.1, 74.4, 69.2, 48.7, 31.4, 26.0, 25.9, 22.5, 14.4; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{32}H_{26}N_4O_2Cl_2Na$ 591.1331, found 591.1310.

Dispirooxindole 3o:

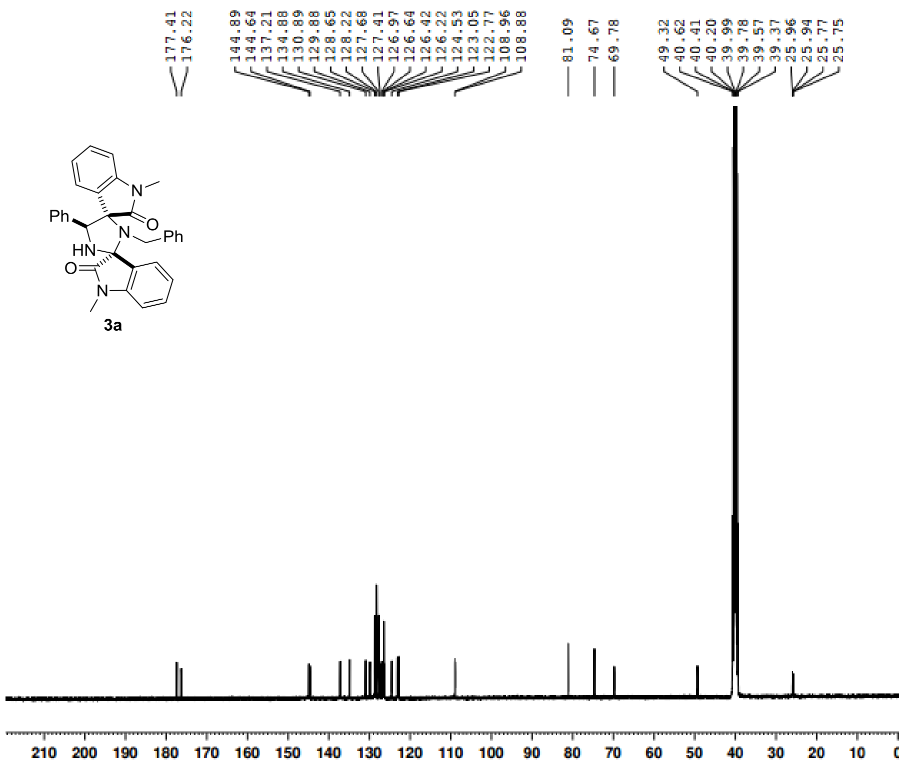
White solid (84.3 mg, yield 74%, single stereoisomer obtained); m.p. 210-211 ℃; IR (KBr) *v* 3913, 3451, 2360, 2342, 1722, 1612, 1469, 1371, 755, 669 cm^{-1}; ^{1}H NMR (DMSO-d_6, 400 MHz) δ 8.13 (d, *J* = 7.2 Hz, 1H), 7.85 (t, *J* = 7.8 Hz, 2H), 6.97-7.37 (m, 11H), 6.84 (d, *J* = 7.6 Hz, 1H), 6.69 (d, *J* = 7.6 Hz, 1H), 5.98 (d, *J* = 9.6 Hz, 1H), 4.28 (d, *J* = 9.6 Hz, 1H), 4.06 (d, *J* = 14.8 Hz, 1H), 3.21 (d, *J* = 14.8 Hz, 1H), 2.95 (s, 3H), 2.68 (s, 3H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 177.8, 176.0, 144.7, 144.0, 134.8, 133.6, 132.6, 131.1, 130.9, 130.4, 130.0, 129.7, 129.4, 128.9, 128.7, 126.9, 126.8, 126.4, 126.3, 122.9, 122.6, 108.9, 108.6, 81.3, 75.0, 64.5, 46.6, 26.1; HRMS (TOF-ES+) m/z: $[M+Na]^+$ calcd for $C_{32}H_{26}N_4O_2Cl_2Na$ 591.1331, found 591.1389.

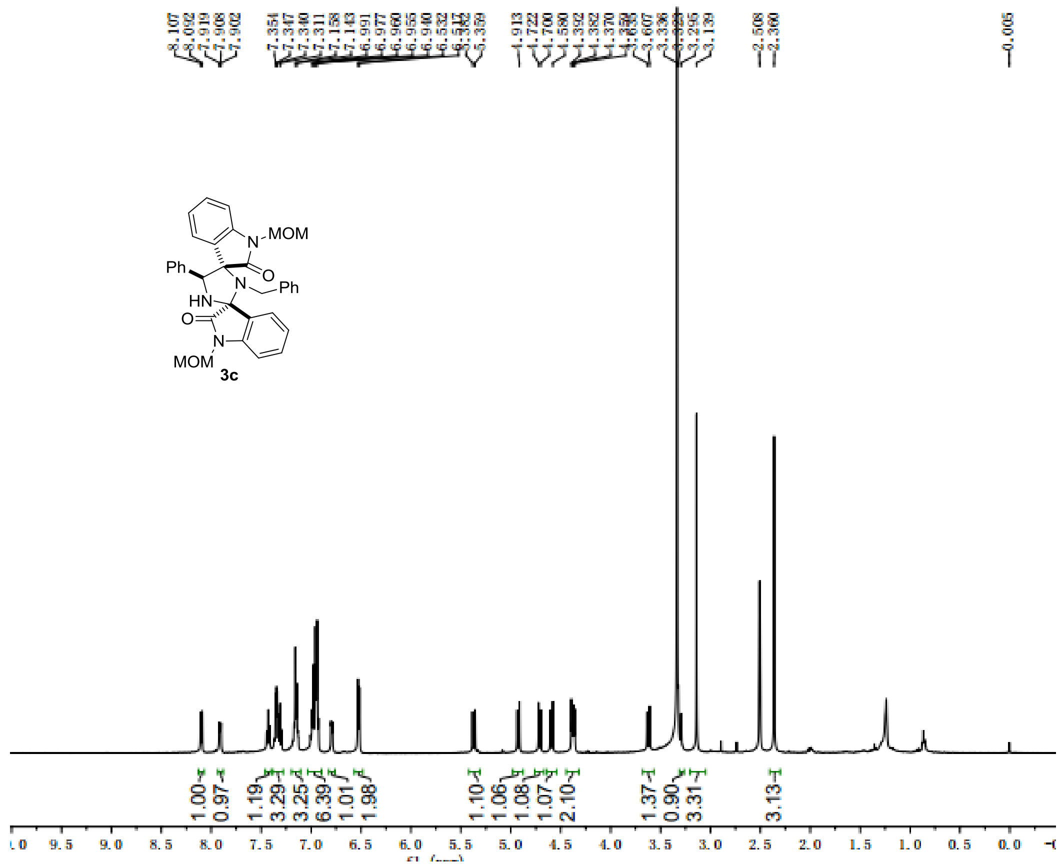
3. NMR Spectra of New Compounds

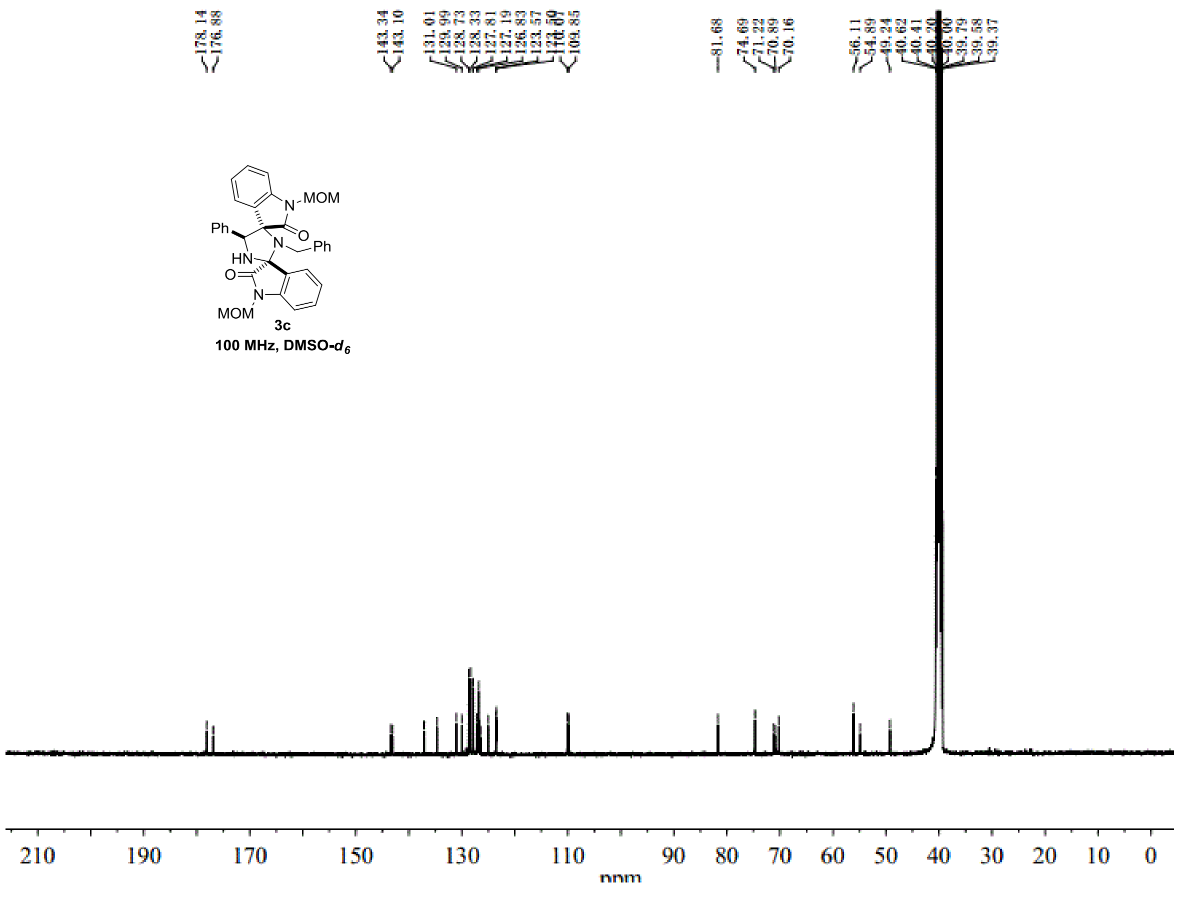
NA-3

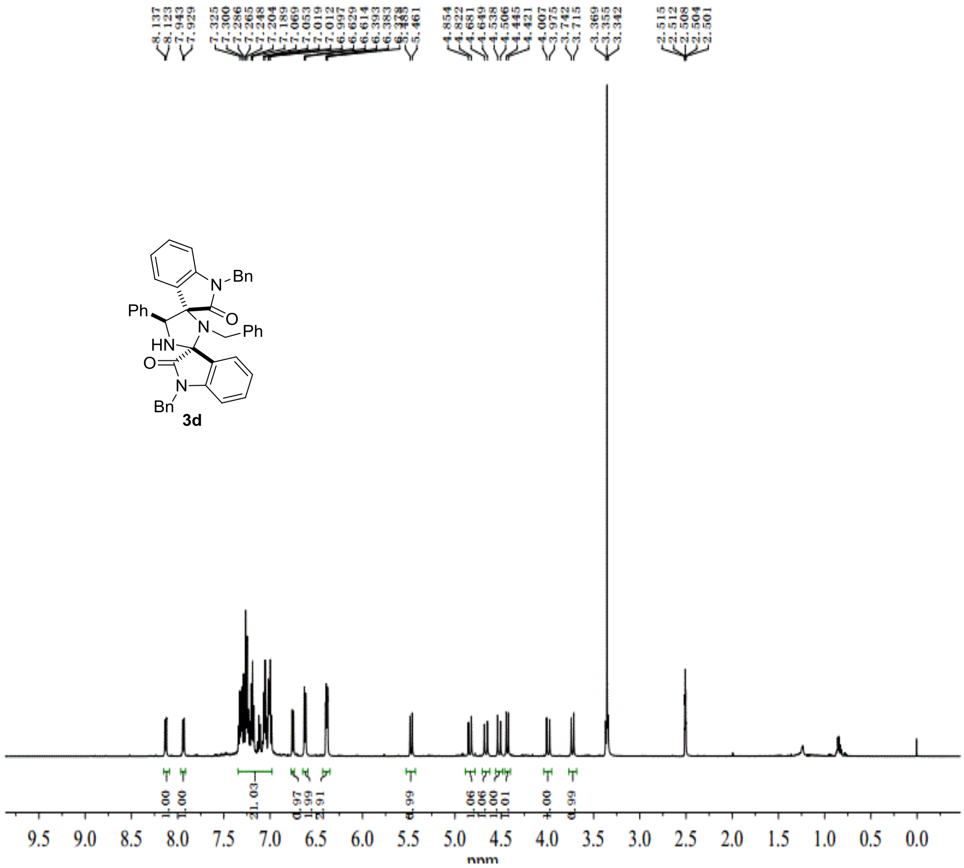


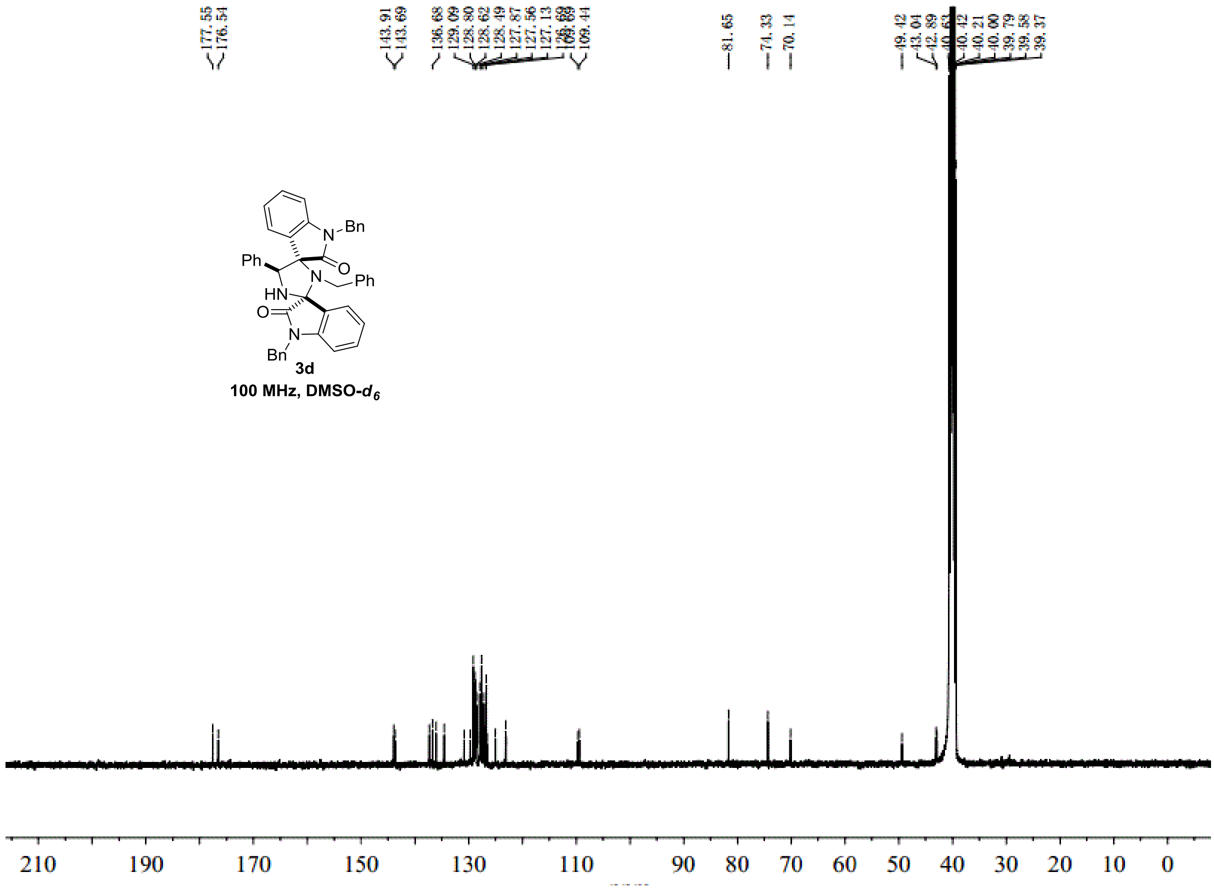
NA-3



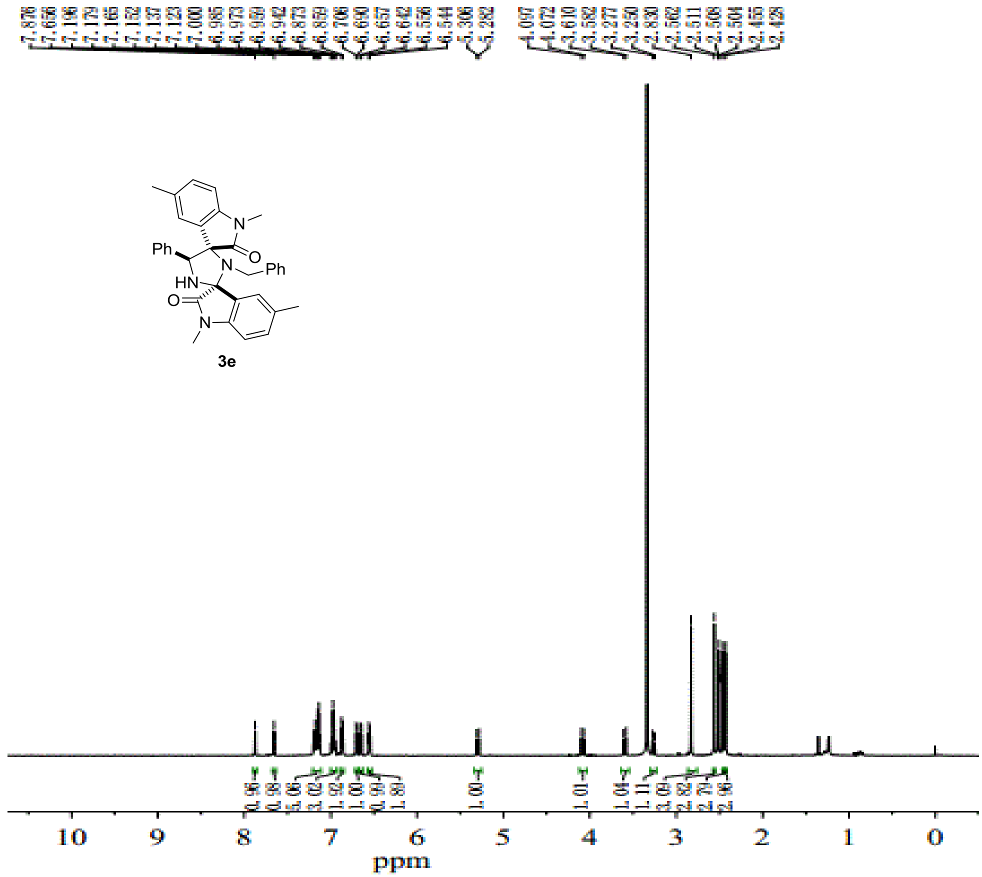

N-MOM
O
Ph
N
Ph
HN
O
MOM
3c
1.00
0.97
1.19
3.29
3.25
6.39
1.01
1.98
1.10
1.06
1.08
1.07
2.10
1.37
0.90
3.31
3.13
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

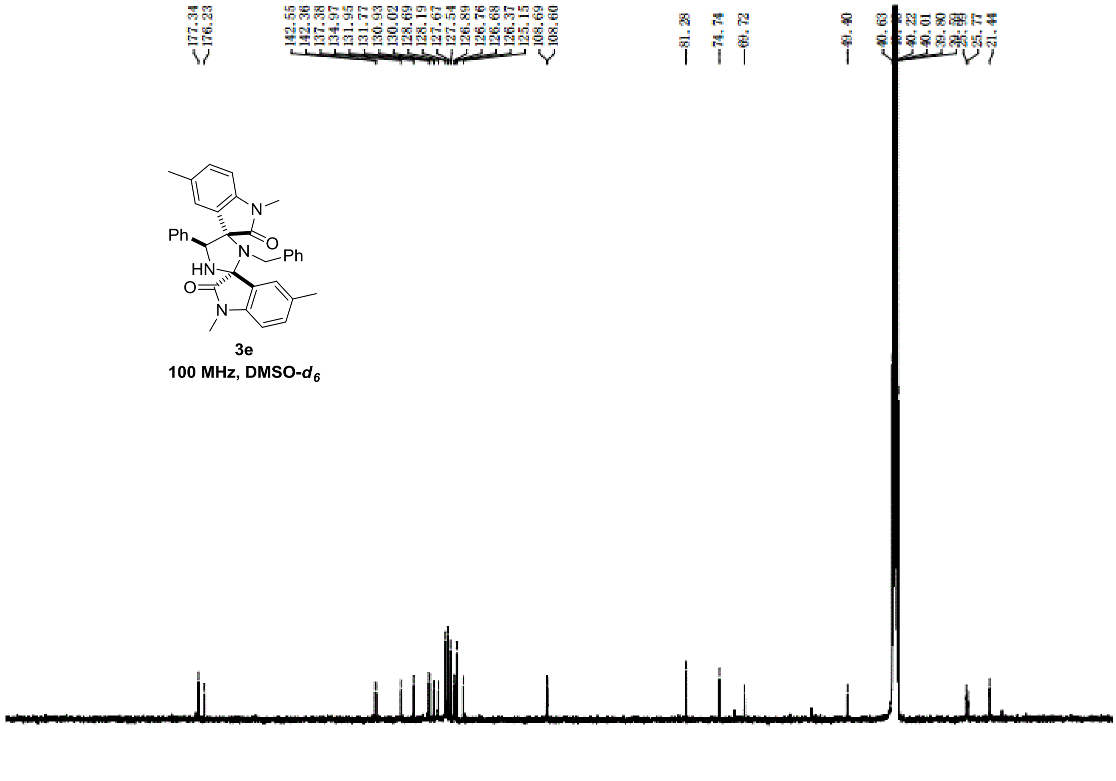

N-MOM
O
Ph
N
Ph
HN
O
MOM
3c
100 MHz, DMSO-d6
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
ppm

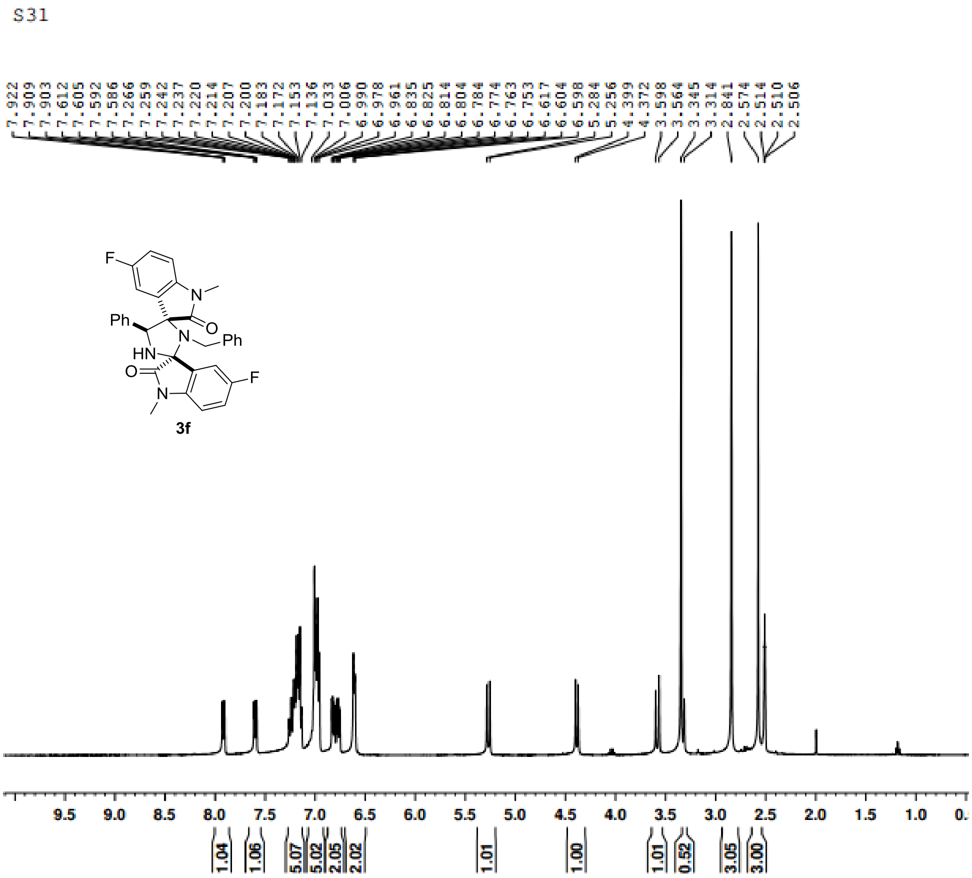


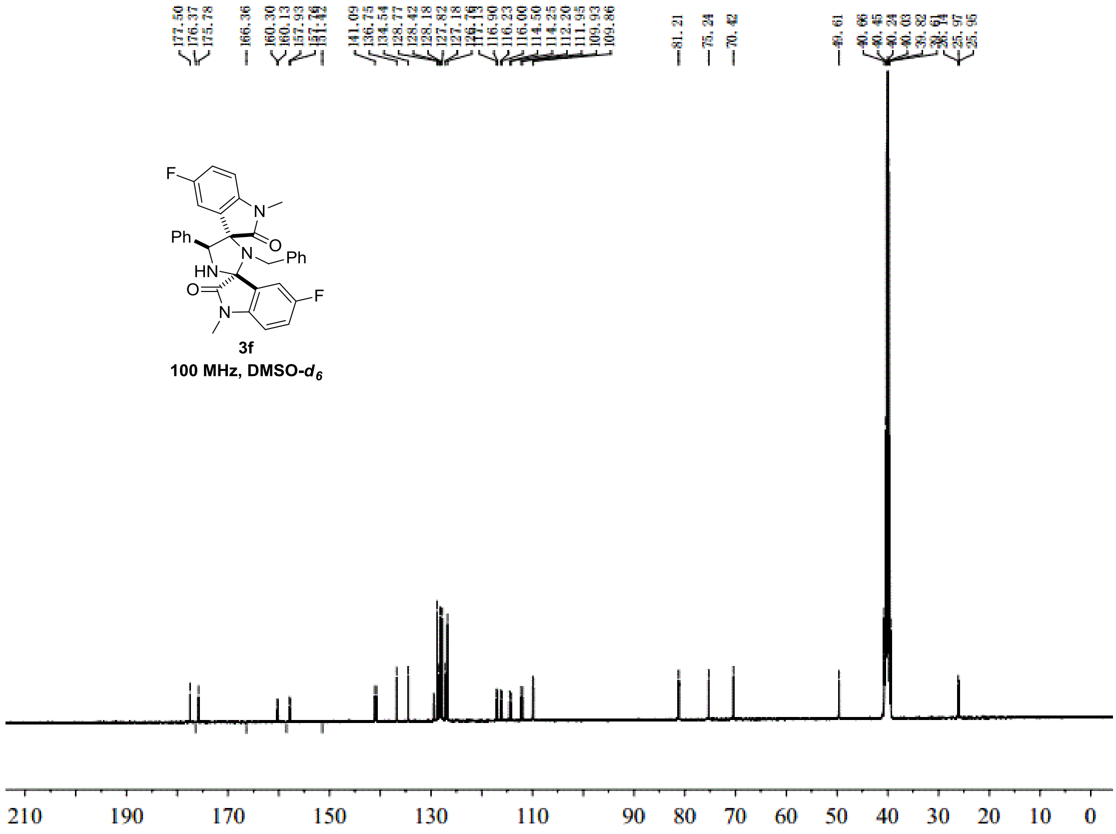


100 MHz, DMSO-d_6

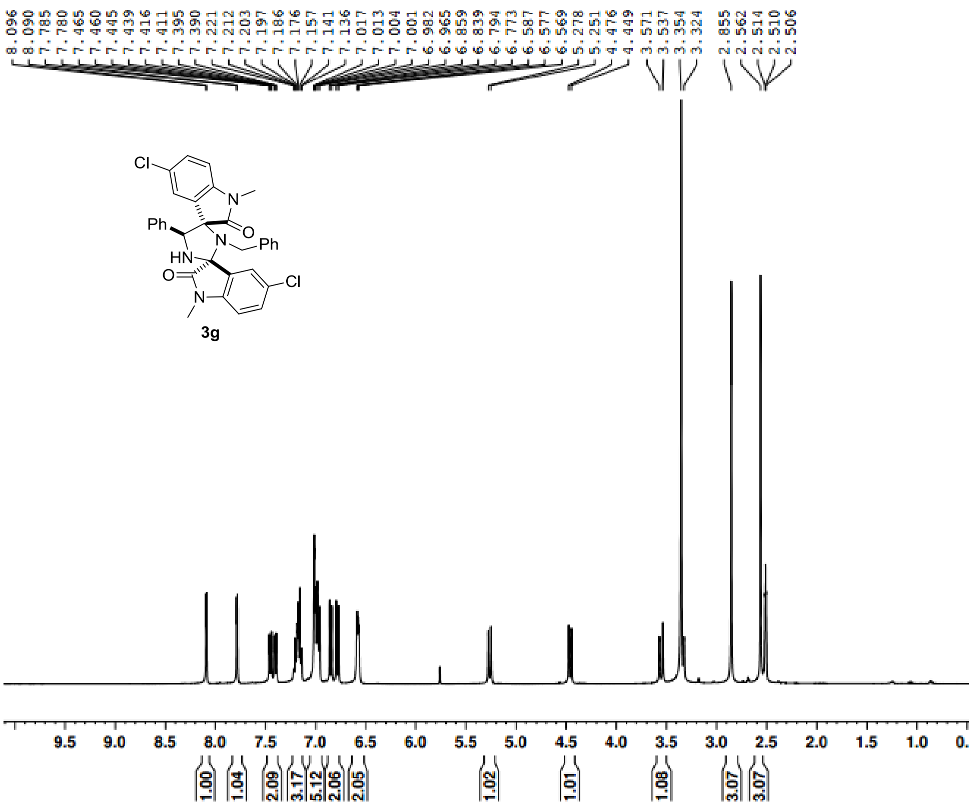




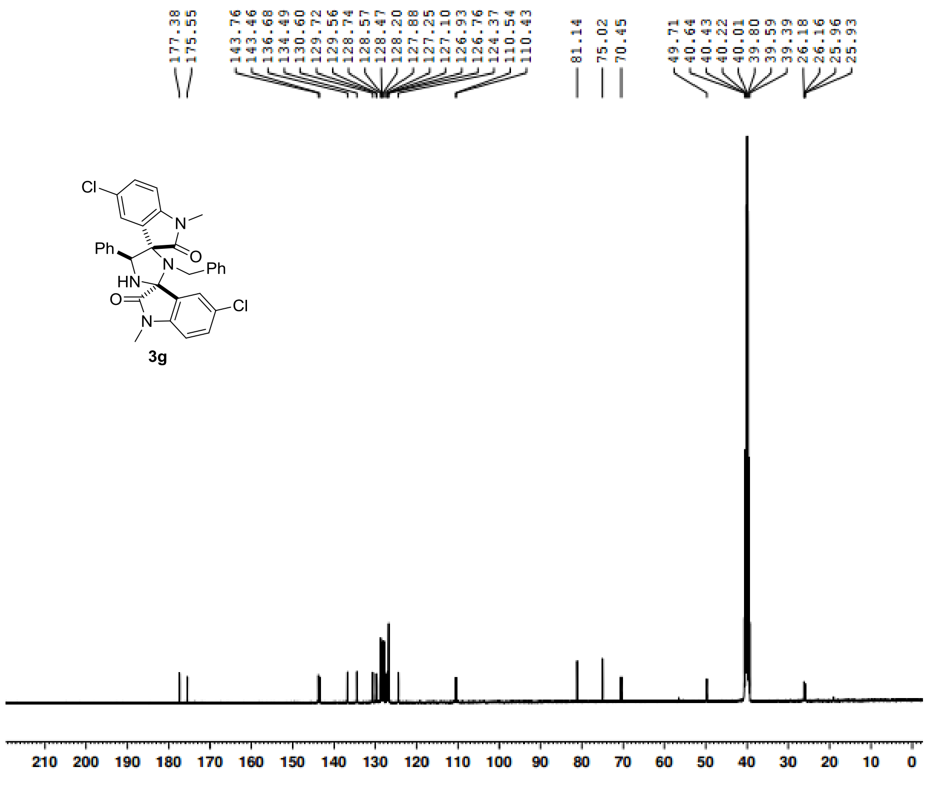

S31
3f
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
1.04 1.06 5.07 5.02 2.05 2.02 1.01 1.00 1.01 0.52 3.05 3.00


3f
100 MHz, DMSO-d_6
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0

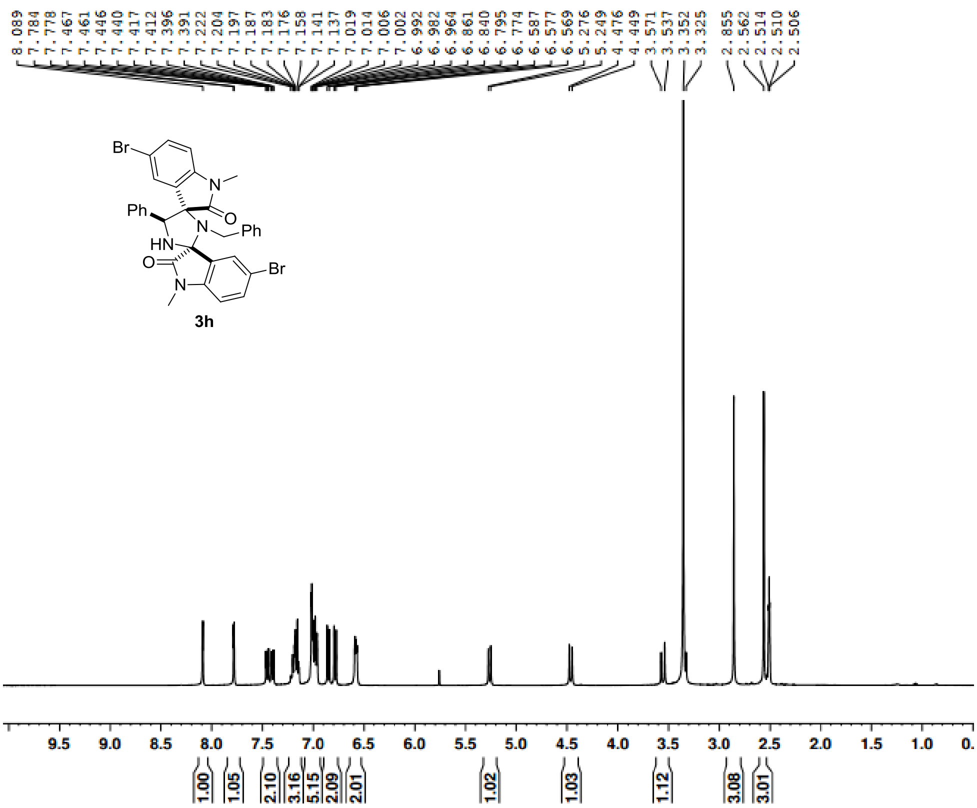
S-28



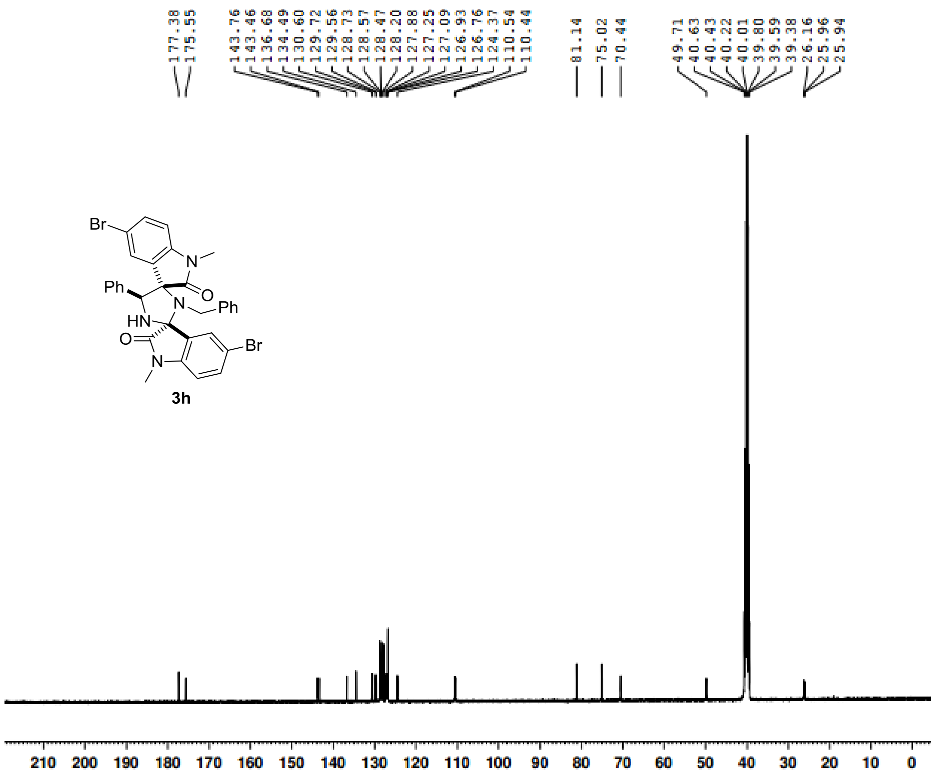
S28



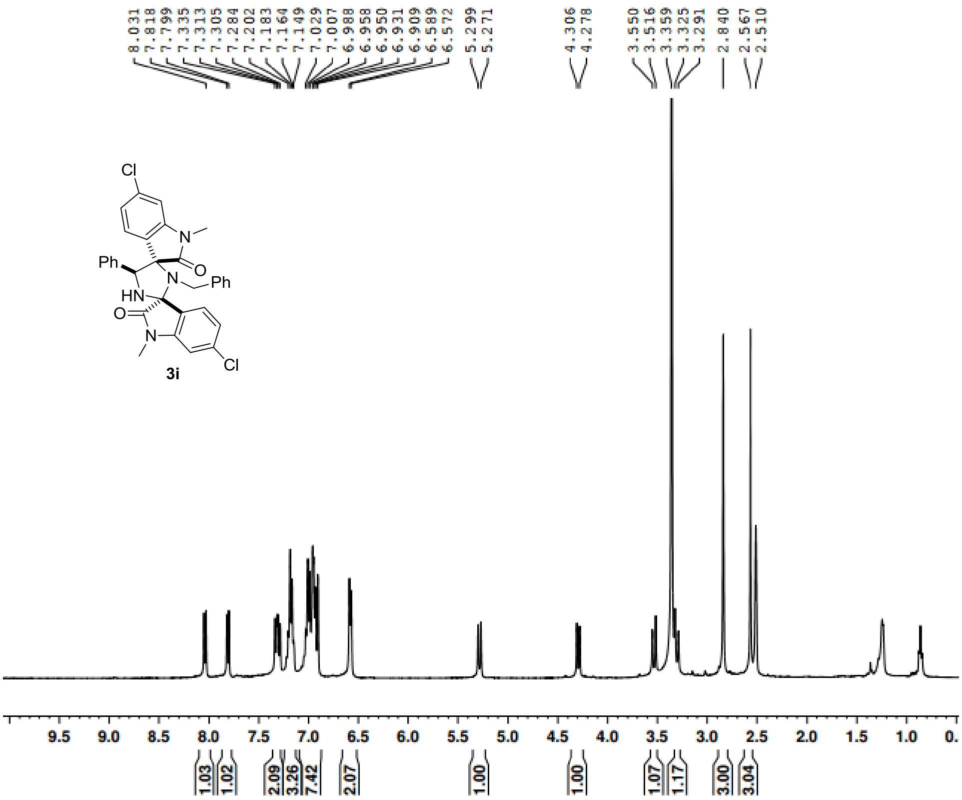
S-30



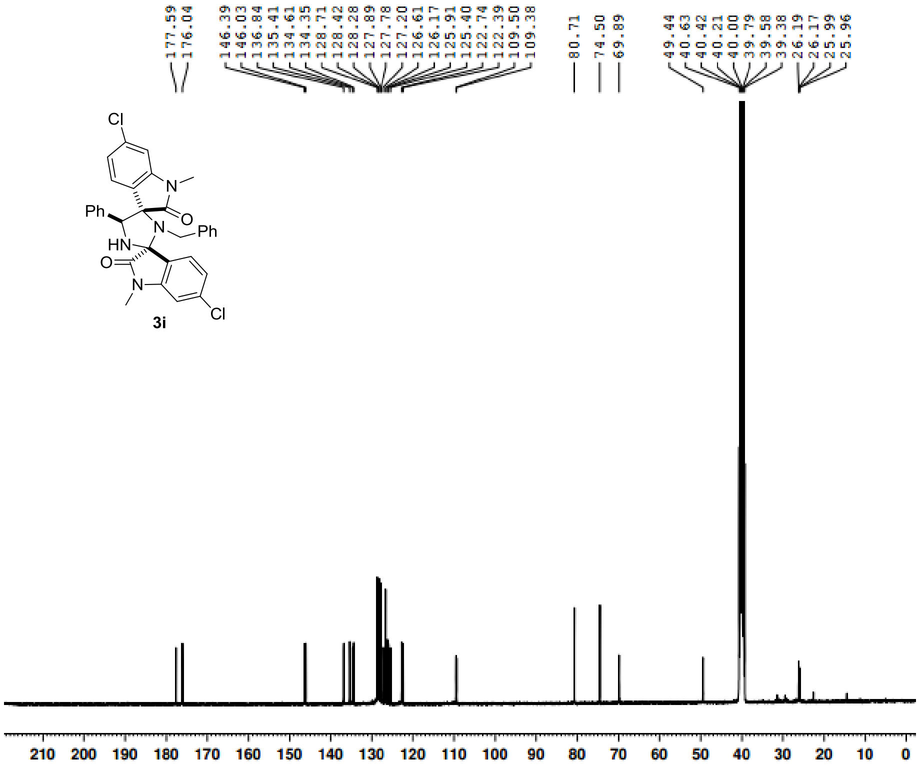
S-30



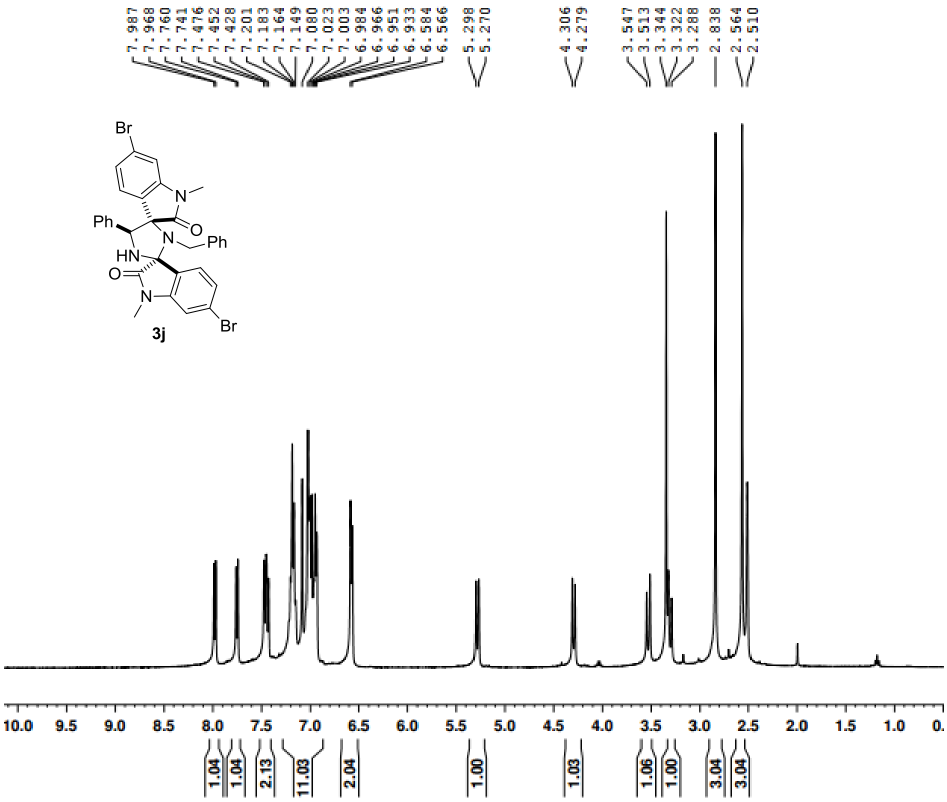
S32


8.031
7.818
7.799
7.335
7.313
7.305
7.284
7.202
7.183
7.164
7.149
7.029
7.007
6.988
6.958
6.950
6.931
6.909
6.589
6.572
5.299
5.271
4.306
4.278
3.550
3.516
3.359
3.325
3.291
2.840
2.567
2.510
Cl
N
Ph
O
N
Ph
HN
O
N
Cl
3i
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.
1.03
1.02
2.09
3.26
7.42
2.07
1.00
1.00
1.07
1.17
3.00
3.04

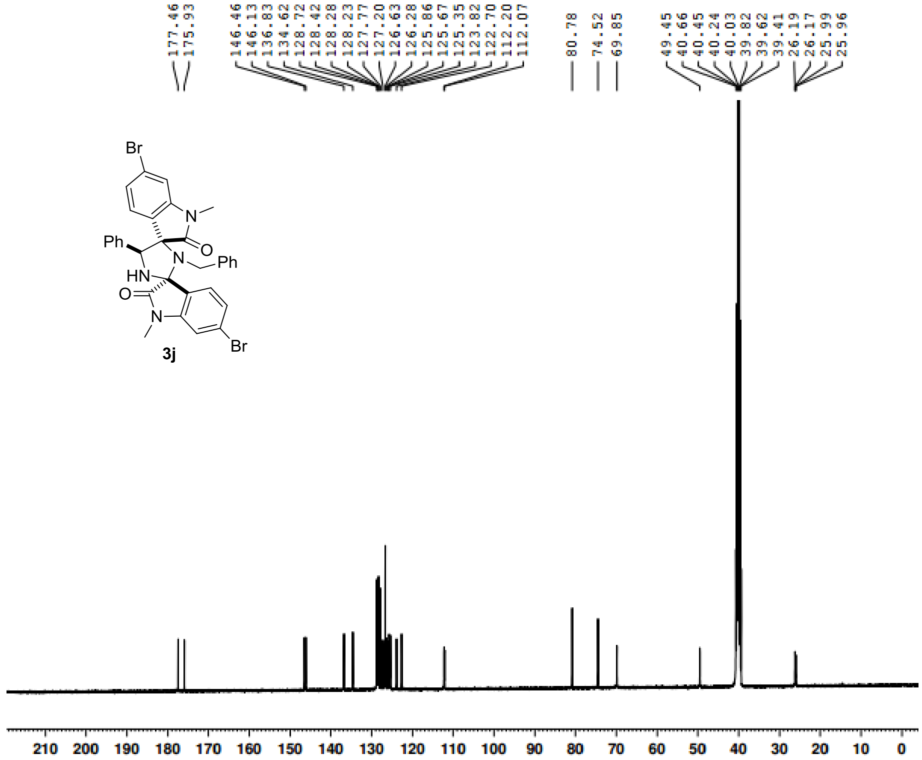
S32


177.59
176.04
146.39
146.03
136.84
135.41
134.61
134.35
128.71
128.42
128.28
127.89
127.78
127.20
126.61
126.17
125.91
125.40
122.74
122.39
109.50
109.38
80.71
74.50
69.89
49.44
40.63
40.42
40.21
40.00
39.79
39.58
39.38
26.19
26.17
25.99
25.96
Cl
N
Ph
O
N
Ph
HN
O
N
Cl
3i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

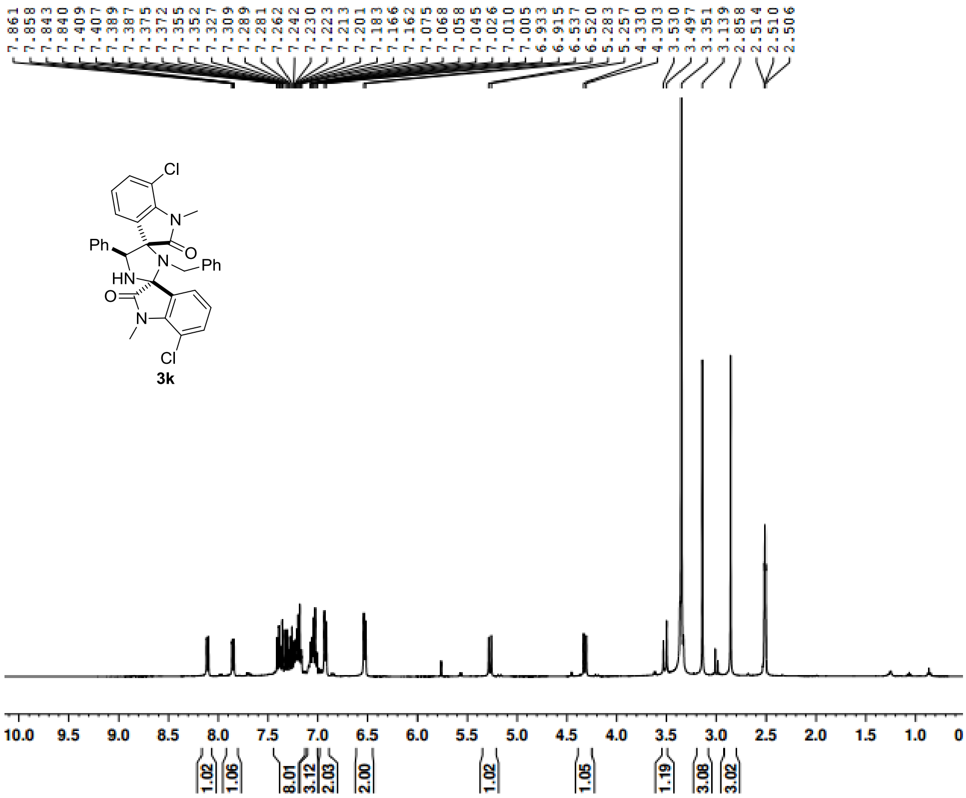
S33


7.987
7.968
7.760
7.741
7.476
7.452
7.428
7.201
7.183
7.164
7.149
7.080
7.023
7.003
6.984
6.966
6.951
6.933
6.584
6.566
5.298
5.270
4.306
4.279
3.547
3.513
3.344
3.322
3.288
2.838
2.564
2.510
Br
Ph
N
O
HN
Ph
O
N
Br
3j
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.
1.04
1.04
2.13
11.03
2.04
1.00
1.03
1.06
1.00
3.04
3.04

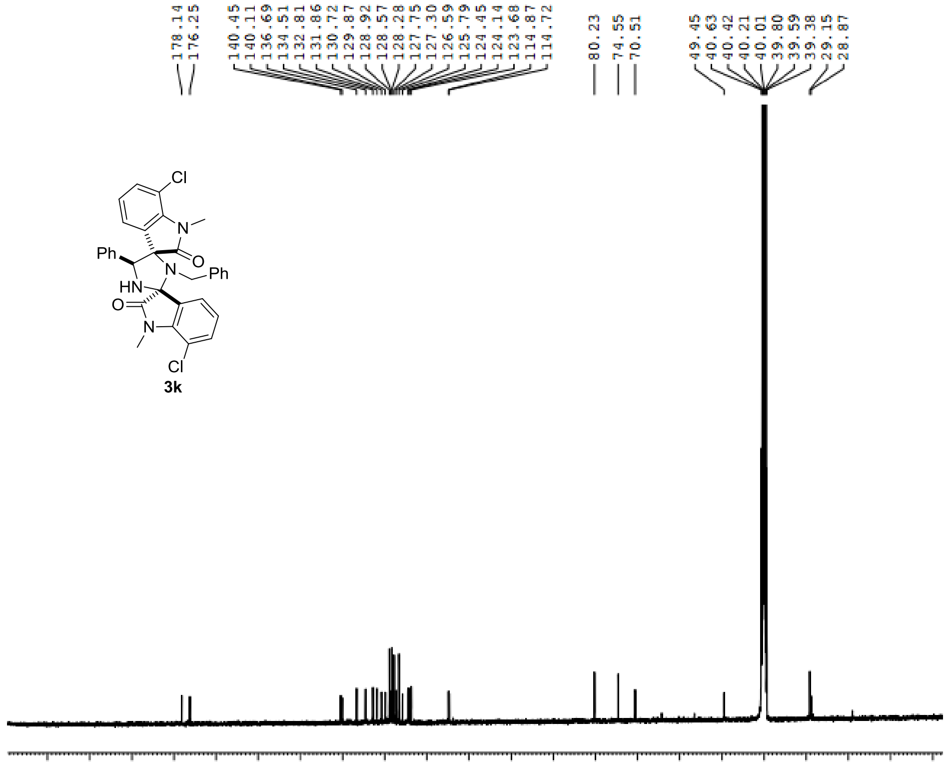
S33

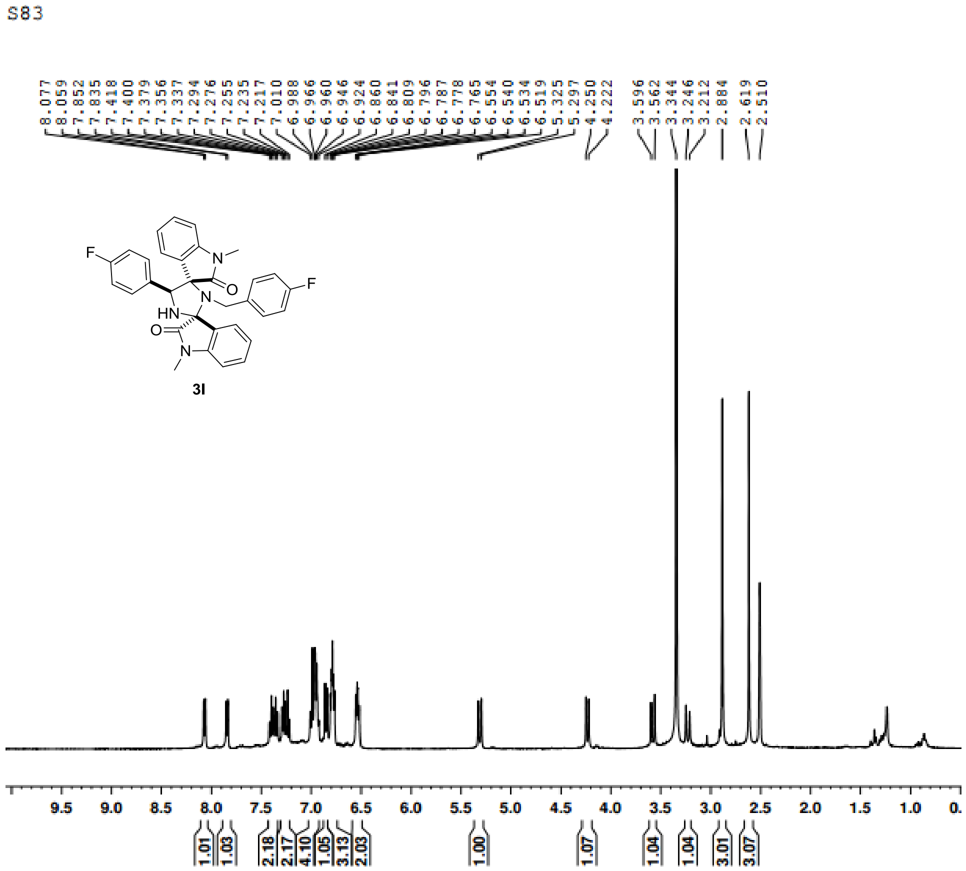

177.46
175.93
146.46
146.13
136.83
134.62
128.72
128.42
128.28
128.23
127.77
127.20
126.63
126.28
125.86
125.67
125.35
123.82
122.70
122.20
112.07
80.78
74.52
69.85
49.45
40.66
40.45
40.24
40.03
39.82
39.62
39.41
26.19
26.17
25.99
25.96
Br
Ph
N
O
HN
Ph
O
N
Br
3j
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

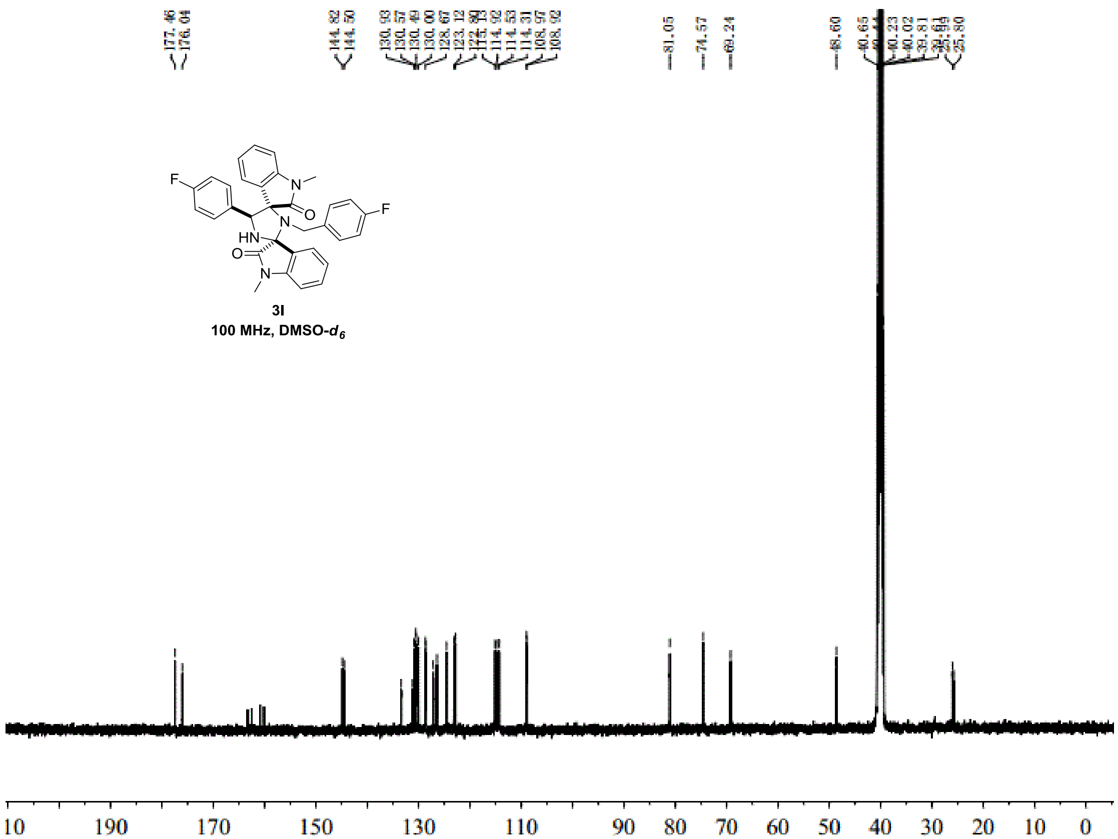
S-34



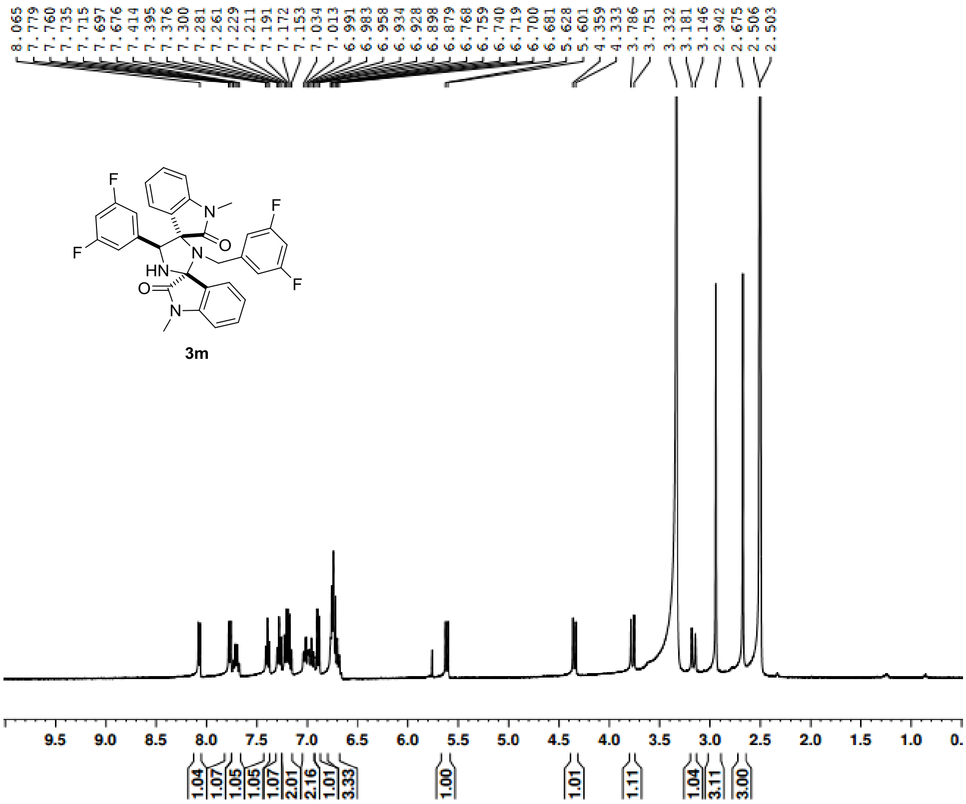
S-34

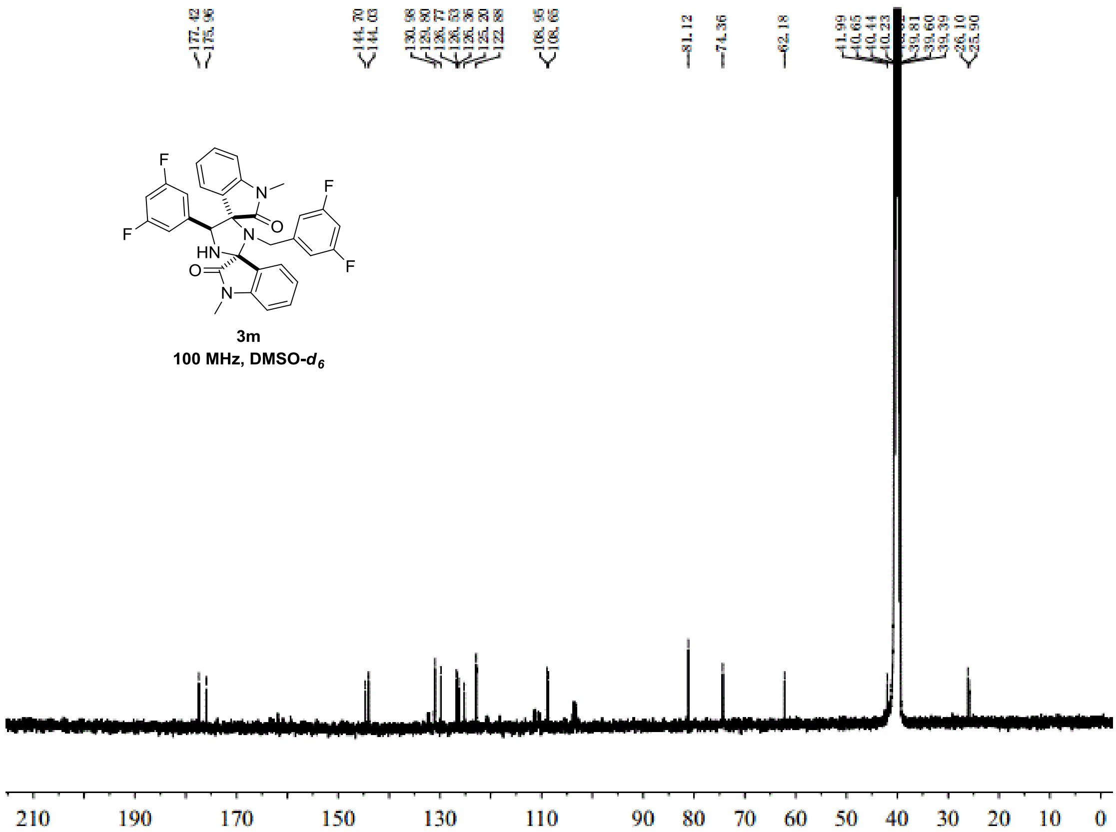



S83
8.077
8.059
7.852
7.835
7.418
7.400
7.379
7.356
7.337
7.294
7.276
7.255
7.235
7.217
7.010
6.988
6.966
6.960
6.946
6.924
6.860
6.841
6.809
6.796
6.787
6.778
6.765
6.554
6.540
6.534
6.519
5.325
5.297
4.250
4.222
3.596
3.562
3.344
3.246
3.212
2.884
2.619
2.510
F
N
O
F
HN
N
O
N
3l
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.
1.01
1.03
2.18
2.17
4.10
1.05
3.13
2.03
1.00
1.07
1.04
1.04
3.01
3.07

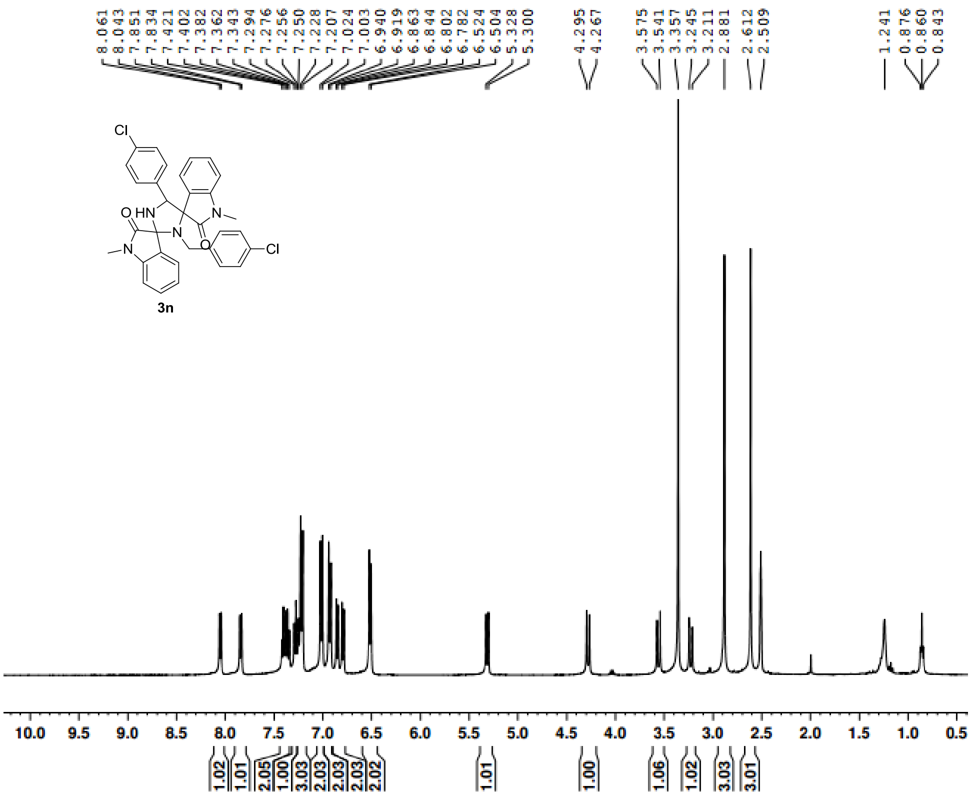

177.46
176.04
144.82
144.50
130.93
130.57
130.49
130.00
128.67
123.12
114.92
114.53
114.31
108.97
108.92
81.05
74.57
69.24
48.60
40.65
40.23
40.02
39.81
25.80
F
N
O
F
HN
N
O
N
3l
100 MHz, DMSO-d6
10 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0

S85

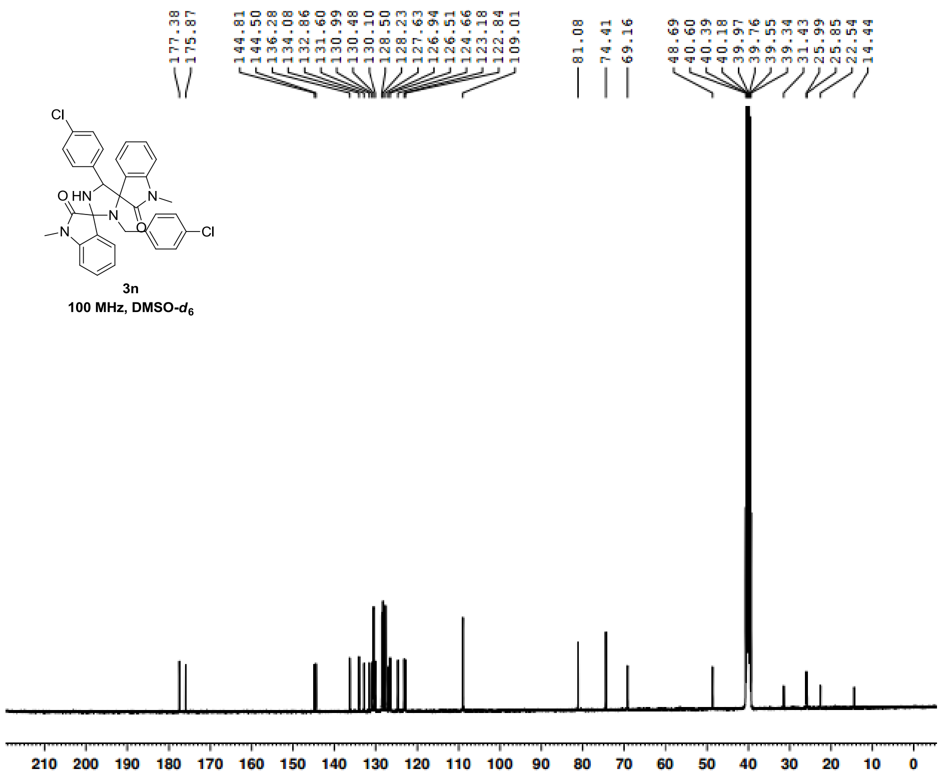

8.065
7.779
7.760
7.735
7.715
7.697
7.676
7.414
7.395
7.376
7.300
7.281
7.261
7.229
7.211
7.191
7.172
7.153
7.034
7.013
6.991
6.983
6.958
6.934
6.928
6.898
6.879
6.768
6.759
6.740
6.719
6.700
6.681
5.628
5.601
4.359
4.333
3.786
3.751
3.332
3.181
3.146
2.942
2.675
2.506
2.503
3m
1.04
1.07
1.05
1.05
1.07
2.01
2.16
1.01
3.33
1.00
1.01
1.11
1.04
3.11
3.00


177.42
175.96
144.70
144.03
130.98
129.80
126.77
126.53
126.36
125.20
122.88
108.95
108.65
81.12
74.36
62.18
39.81
39.60
39.39
26.10
25.90
3m
100 MHz, DMSO-d6

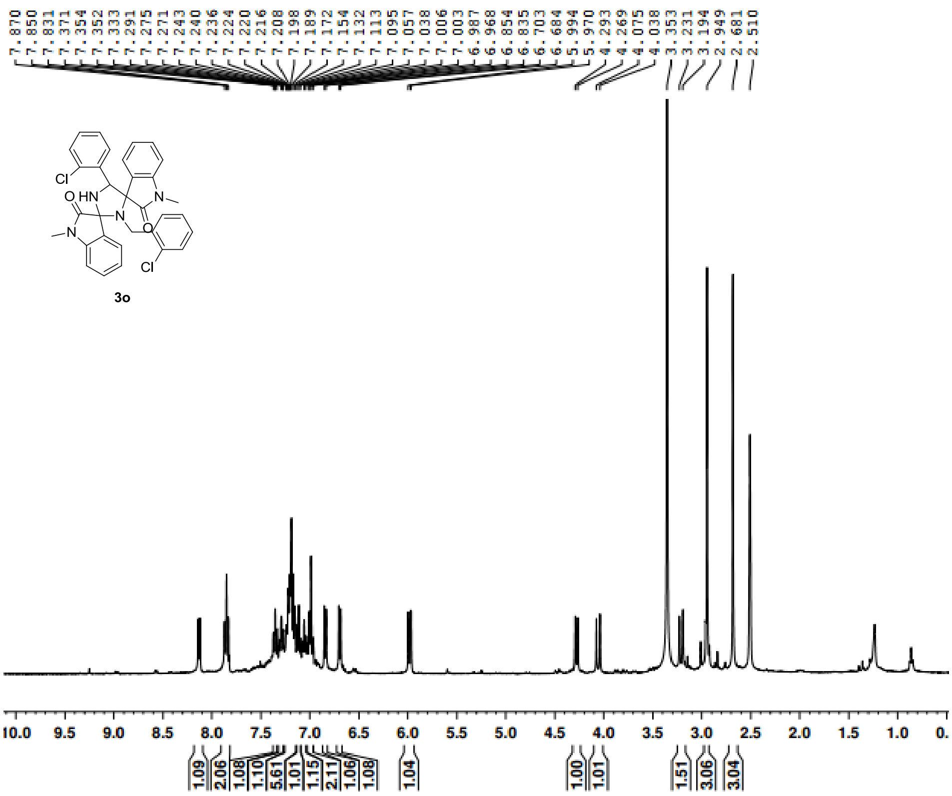
H140


8.061 8.043 7.851 7.834 7.421 7.402 7.382 7.362 7.343 7.294 7.276 7.256 7.250 7.228 7.207 7.024 7.003 6.940 6.919 6.863 6.844 6.802 6.782 6.524 6.504 5.328 5.300 4.295 4.267 3.575 3.541 3.357 3.245 3.211 2.881 2.612 2.509 1.241 0.876 0.860 0.843
Cl
HN
O
N
N
O
Cl
3n
1.02 1.01 2.05 1.00 3.03 2.03 2.03 2.03 2.02 1.01 1.00 1.06 1.02 3.03 3.01
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

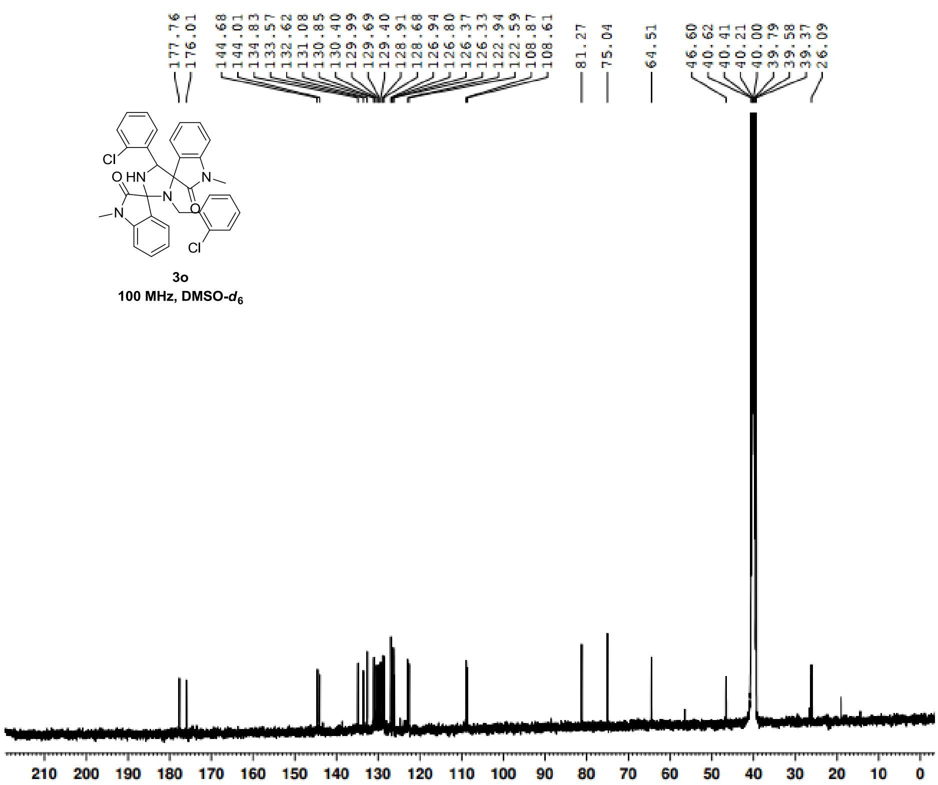
H140


177.38 175.87 144.81 144.50 136.28 134.08 132.86 131.60 130.99 130.48 130.10 128.50 128.23 127.63 126.94 126.51 124.66 123.18 122.84 109.01 81.08 74.41 69.16 48.69 40.60 40.39 40.18 39.97 39.76 39.55 39.34 31.43 25.99 25.85 22.54 14.44
Cl
HN
O
N
N
O
Cl
3n
100 MHz, DMSO-d6
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

H141


7.870 7.850 7.831 7.371 7.354 7.352 7.333 7.291 7.275 7.271 7.243 7.240 7.236 7.224 7.220 7.216 7.208 7.198 7.189 7.172 7.154 7.132 7.113 7.095 7.057 7.038 7.006 7.003 6.987 6.968 6.854 6.835 6.703 6.684 5.994 5.970 4.293 4.269 4.075 4.038 3.353 3.231 3.194 2.949 2.681 2.510
3o

H141


177.76 176.01 144.68 144.01 134.83 133.57 132.62 131.08 130.85 130.40 129.99 129.69 129.40 128.91 128.68 126.94 126.80 126.37 126.33 122.94 122.59 108.87 108.61 81.27 75.04 64.51 46.60 40.62 40.41 40.21 40.00 39.79 39.58 39.37 26.09
3o
100 MHz, DMSO-d_6