Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Sequential Visible-Light-Mediated Wolff Rearrangement and Staudinger Cycloaddition Enabling Assembly of Spiro-Pyrazolone-β-Lactams

Jie Tang, Zhen-Hui Yan, Gu Zhan,* Qian-Qian Yang, Ying-Ying Chen, Xiang Li,* Wei Huang*

State Key Laboratory of Southwestern Chinese Medicine Resources, Hospital of Chengdu University of Traditional Chinese Medicine, School of Pharmacy, Chengdu University of Traditional Chinese Medicine, Chengdu 611137

Supporting Information

1. General information

Nuclear magnetic resonance (NMR) spectra were recorded in Chloroform-*d* on Bruker 600, 700 MHz, or JEOL 600 NMR instrument (at 400, 600 or 700 MHz for ^{1}H, and at 100, 150, or 175 MHz for ^{13}C). Proton chemical shifts are reported in parts per million (δ scale). The ^{1}H NMR chemical shifts are reported in ppm with the internal TMS signal at 0.0 ppm as standard. The ^{13}C NMR chemical shifts were given using Chloroform-*d* or DMSO-d_6 as the internal standard (Chloroform-*d*: δ = 77.00 ppm, DMSO-d_6: δ = 39.50 ppm). Data are reported as follows: chemical shift [multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br s = broad singlet), coupling constant(s) (Hz), integration]. High-resolution mass spectra (HRMS) were obtained using Agilent P/N G1969-90010 or Waters/Acquity UPLC-Synapt G2HDMS. High-resolution mass spectra were reported for the molecular ion $[M+Na]^{+}$. X-ray diffraction experiment was carried out on an Agilent Gemini and the data obtained were deposited at the Cambridge Crystallographic Data Centre. UV detection was performed at 254 nm. Column chromatography was performed on silica gel (200-300 mesh) using an eluent of ethyl acetate (EA) and petroleum ether (PE). TLC was performed on glass-backed silica plates; products were visualized using UV light. All reagents and solvents were obtained from commercial sources and used without further purification. pyrazolone-derived phenyl ketimines **1**,[1] α-diazoketones **2**,[2] arylalkylketenes[3] and other ketimines[4] were prepared according to the literature procedures. Six position parallel photocatalytic reactor were used as the reaction instrument. Melting points were recorded on BUCHI Melting Point M-565 instrument.

Reference

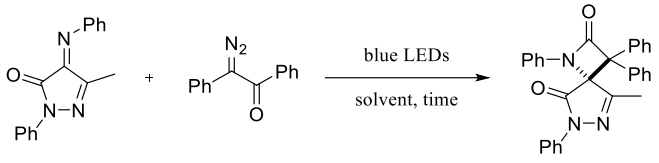
1. P. Chauhan, S. Mahajan, U. Kaya, A. Peuronen, K. Rissanen, D. Enders, Asymmetric Synthesis of Amino-Bis-Pyrazolone Derivatives via an Organocatalytic Mannich Reaction. *J. Org. Chem.* 2017, **82**, 7050-7058.

2. J. R. Denton, H. M. L. Davies, Enantioselective Reactions of Donor/Acceptor Carbenoids Derived from α-Aryl-α-Diazoketones. *Org. Lett*. 2009, **11**, 787-790.

3. L. M. Baigrie, H. R. Seiklay, T. T. Tidwell, Stereospecific formation of enolates from reaction of unsymmetrical ketenes and organolithium reagents. *J. Am. Chem. Soc.* 1985, **107**, 5391-5396.

4. T. Niwa, H. Yorimitsu, K. Oshima, Palladium-Catalyzed Benzylic Arylation of N-Benzylxanthone Imine. *Org. Lett.* 2008, **10**, 4689-4691.

2. Optimization of the model reaction (Table S1)

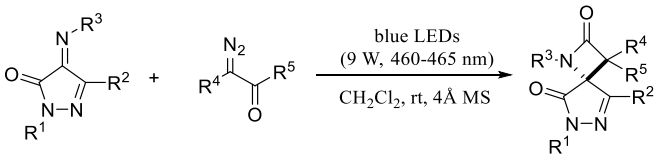


1a **2a** **3a**

Entry	Wave length (nm)	Wattage (W)	solvent	Time (h)	Yield (%)[b]
1	410-415	6	DCM	2	78
2	460-465	6	DCM	1	82
3	520-525	6	DCM	24	70
4	590-595	6	DCM	48	60
5	620-625	6	DCM	48	65
6	460-465	3	DCM	2	82
7	460-465	9	DCM	1	84
8	460-465	12	DCM	1	82
9	460-465	9	THF	2	61
10	460-465	9	Toluene	1.5	65
11	460-465	9	CH_3CN	2	79
12	460-465	9	EA	2	74
13	460-465	9	Et_2O	2.5	66
14[c]	460-465	9	DCM	1	84
15[d]	460-465	9	DCM	1	81
16[e]	460-465	9	DCM	1	85
17[f]	460-465	9	DCM	1	88

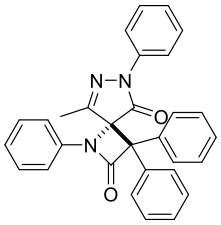
[a]Unless otherwise noted, for the reaction, a mixture of **1a** (0.1 mmol) and **2a** (0.15 mmol) in 1.0 mL of solvent was irradiated at room temperature under LEDs light. [b]Isolated yields. [c]The ratio of **1a**/**2a** was 1.0:2.0. [d]The ratio of **1a**/**2a** was 1.0:2.5. [e]With $MgSO_4$. [f]With 4 Å molecular sieves. DCM: dichloromethane; THF: tetrahydrofuran; EA: ethyl acetate; Et_2O: diethyl ether

3.General procedure for the synthesis of products 3

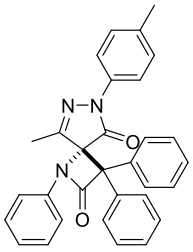


1 **2** **3**

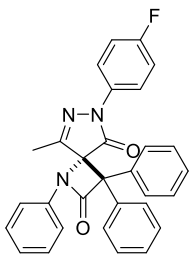
Pyrazolone-derived phenyl ketimines **1** (0.1 mmol) and α-diazoketones **2** (0.2 mmol, 2.0 equiv.) were dissolved in CH_2Cl_2 (1.0 mL). At room temperature, the reaction mixture was then irradiated under blue LEDs for hours until the complete consumption of **1** (monitored by TLC). The reaction mixture was concentrated and the residue was purified by flash chromatography on silica gel (PE/EA = 80/1) to give the pure products **3**.



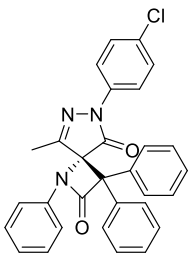
***8-methyl-1,3,3,6-tetraphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3a)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3a** as a white solid in 88% yield (40.2 mg), m. p. 183.4 – 184.4 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.81 (dd, *J* = 8.4, 0.7 Hz, 2H), 7.59 (d, *J* = 7.7 Hz, 2H), 7.54 – 7.50 (m, 2H), 7.40 – 7.35 (m, 2H), 7.29 (t, *J* = 7.7 Hz, 2H), 7.26 – 7.19 (m, 6H), 7.18 – 7.15 (m, 3H), 7.06 – 7.02 (m, 1H), 1.37 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.8, 164.6, 158.6, 137.8, 136.7, 136.6, 136.2, 129.7, 129.17, 129.15, 128.6, 128.4, 128.2, 127.3, 127.0, 125.6, 125.4, 118.4, 116.6, 77.3, 72.8, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{23}N_3O_2Na$ 480.1683; found 480.1682.



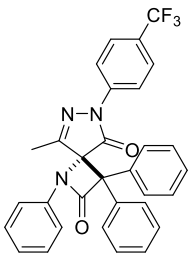
***8-methyl-1,3,3-triphenyl-6-(p-tolyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3b)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3b** as a white solid in 86% yield (40.5 mg), m. p. 190.0 – 191.2 ℃. ^{1}H NMR (600 MHz, Chloroform-*d)* δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 7.2 Hz, 2H), 7.53 – 7.49 (m, 2H), 7.29 (t, *J* = 7.8 Hz, 2H), 7.26 – 7.19 (m, 6H), 7.19 – 7.14 (m, 4H), 7.04 (t, *J* = 7.8 Hz, 1H), 2.31 (s, 3H), 1.36 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.6, 164.6, 158.5, 136.8, 136.6, 136.3, 135.4, 135.3, 129.7, 129.6, 129.2, 128.6, 128.4, 128.2, 127.3, 127.0, 125.4, 118.4, 116.6, 77.2, 72.7, 21.0, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{25}N_3O_2Na$ 494.1839; found 494.1849.



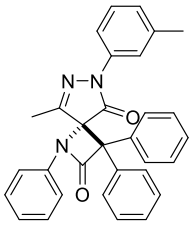
***6-(4-fluorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3c)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3c** as a white solid in 68% yield (32.2 mg), m. p. 195.6 – 197.6 ℃; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.81 – 7.76 (m, 2H), 7.59 (d, *J* = 7.2 Hz, 2H), 7.53 – 7.48 (m, 2H), 7.30 (t, *J* = 8.4 Hz, 2H), 7.26 – 7.19 (m, 6H), 7.17 – 7.15 (dd, *J* = 9.0, 1.2 Hz, 2H), 7.08 – 7.03 (m, 3H), 1.37 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.7, 164.5, 160.1 (d, $J_{C,F}$ = 246.1 Hz), 158.9, 136.58, 136.56, 136.1, 134.0 (d, $J_{C,F}$ = 1.5 Hz), 129.7, 129.2, 128.6, 128.5, 128.3, 127.2, 127.0, 125.5, 120.2 (d, $J_{C,F}$ = 7.5 Hz), 116.5, 115.9 (d, $J_{C,F}$ = 22.5 Hz), 77.4, 72.7, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}FN_3O_2Na$ 498.1589; found 498.1581.



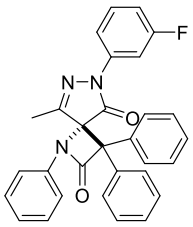
***6-(4-chlorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3d)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3d** as a white solid in 85% yield (41.6 mg), m. p. 185.0 – 188.7 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.80 – 7.75 (m, 2H), 7.58 (d, *J* = 7.7 Hz, 2H), 7.49 (d, *J* = 7.0 Hz, 2H), 7.35 – 7.30 (m, 2H), 7.30 (t, *J* = 7.7 Hz, 2H), 7.27 – 7.18 (m, 6H), 7.16 – 7.14 (m, 2H), 7.05 (t, *J* = 8.4 Hz, 1H), 1.37 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.8, 164.5, 159.1, 136.5, 136.3, 136.1, 130.7, 129.7, 129.21, 129.18, 128.6, 128.5, 128.3, 127.2, 127.0, 125.5, 119.5, 116.5, 77.5, 72.8, 15.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{30}H_{22}ClN_3O_2Na$ 514.1293; found 514.1300.



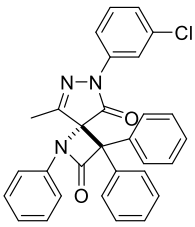
***8-methyl-1,3,3-triphenyl-6-(4-(trifluoromethyl)phenyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3e)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3e** as a white solid in 85% yield (44.7 mg), m. p. 151.1 – 152.3 °C. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.97 (d, *J* = 8.4 Hz, 2H), 7.62 (d, *J* = 8.4 Hz, 2H), 7.58 (d, *J* = 6.3 Hz, 2H), 7.49 (d, *J* = 7.0 Hz, 2H), 7.31 (t, *J* = 7.7 Hz, 2H), 7.28 – 7.18 (m, 6H), 7.15 (d, *J* = 8.4 Hz, 2H), 7.06 (t, *J* = 7.7 Hz, 1H), 1.40 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.2, 164.4, 159.5, 140.4, 136.5, 136.4, 136.0, 129.8, 129.2, 128.7, 128.6, 128.4, 127.2, 127.0, 127.2 (q, $J_{C,F}$ = 31.6 Hz), 126.4, 125.6, 124.0 (q, $J_{C,F}$ = 271.0 Hz), 118.0, 116.5, 77.8, 72.9, 15.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{22}F_3N_3O_2Na$ 548.1557; found 548.1562.



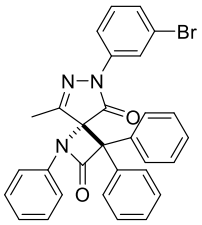
***8-methyl-1,3,3-triphenyl-6-(m-tolyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3f)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3f** as a white solid in 81% yield (38.0 mg), m. p. 178.1 – 180.0 °C. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.64 (s, 1H), 7.62 (d, *J* = 7.7 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.54 – 7.49 (m, 2H), 7.31 – 7.27 (m, 2H), 7.25 – 7.21 (m, 5H), 7.21 – 7.15 (m, 4H), 7.06 – 7.02 (m, 1H), 7.00 (d, *J* = 6.3 Hz, 1H), 2.34 (s, 3H), 1.37 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.7, 164.6, 158.5, 139.2, 137.8, 136.8, 136.6, 136.2, 129.7, 129.2, 129.0, 128.6, 128.4, 128.2, 127.3, 127.0, 126.4, 125.4, 119.0, 116.6, 115.7, 77.3, 72.8, 21.7, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{25}N_3O_2Na$ 494.1839; found 494.1844.



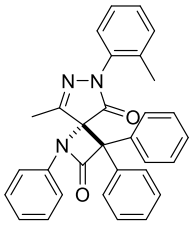
***6-(3-fluorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3g)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3g** as a white solid in 87% yield (41.4 mg), m. p. 130.6 – 132.7 °C. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.66 – 7.62 (m, 1H), 7.62 – 7.54 (m, 3H), 7.51 – 7.47 (m, 2H), 7.34 – 7.27 (m, 3H), 7.27 – 7.19 (m, 6H), 7.15 (dd, *J* = 9.1, 1.4 Hz, 2H), 7.05 (t, *J* = 7.0 Hz, 1H), 6.90 – 6.84 (m, 1H), 1.38 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.9, 164.5, 163.0 (d, $J_{C,F}$ = 244.6 Hz), 159.1, 139.1 (d, $J_{C,F}$ = 10.5 Hz), 136.5, 136.0, 130.5 (d, $J_{C,F}$ = 8.8 Hz), 129.7, 129.2, 128.6, 128.5, 128.3, 127.2, 127.0, 125.5, 116.5, 113.7, 112.3, 112.2, 105.9 (d, $J_{C,F}$ = 28.1 Hz), 77.6, 72.89, 15.4; HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}FN_3O_2Na$ 498.1589; found 498.1592.



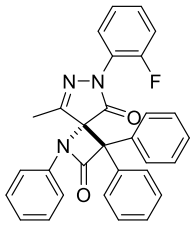
***6-(3-chlorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3h)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3h** as a white solid in 93% yield (45.8 mg), m. p. 147.6 – 149.1 °C. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.86 (s, 1H), 7.77 – 7.73 (m, 1H), 7.58 (d, *J* = 7.7 Hz, 2H), 7.49 (d, *J* = 7.7 Hz,2H), 7.32 – 7.25 (m, 3H), 7.27 – 7.18 (m, 6H), 7.15 (d, *J* = 7.7 Hz, 3H), 7.05 (t, *J* = 7.0 Hz, 1H), 1.38 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.9, 164.5, 159.2, 138.8, 136.5, 136.0, 135.0, 130.2, 129.8, 129.2, 128.6, 128.5, 128.4, 127.2, 127.0, 125.54, 125.50, 125.47, 118.3, 116.5, 116.3, 77.6, 72.8, 15.4. HRMS (ESI-TOF) m/z: [M + Na]$^+$ Calcd for $C_{30}H_{22}ClN_3O_2Na$ 514.1293; found 514.1303.



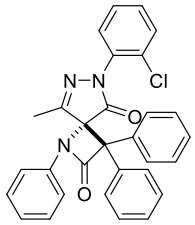
***6-(3-bromophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3i)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3i** as a white solid in 68% yield (36.5 mg); m. p. 154.2 – 158.4 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 8.01 (t, *J* = 2.1 Hz, 1H), 7.80 (dd, *J* = 7.7, 0.7 Hz, 1H), 7.58 (d, *J* = 7.7 Hz, 2H), 7.49 (d, *J* = 7.0 Hz, 2H), 7.32 – 7.27 (m, 3H), 7.27 – 7.19 (m, 7H), 7.15 (d, *J* = 7.7 Hz, 2H), 7.05 (t, *J* = 7.7 Hz, 1H), 1.38 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.9, 164.5, 159.2, 138.9, 136.5, 136.0, 130.5, 129.8, 129.2, 128.6, 128.5, 128.43, 128.41, 128.35, 127.2, 127.0, 125.6, 122.9, 121.2, 116.7, 116.5, 77.6, 72.8, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}BrN_3O_2Na$ 558.0788; found 558.0795.



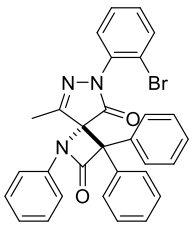
***8-methyl-1,3,3-triphenyl-6-(o-tolyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3j)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3j** as a white solid in 92% yield (43.4 mg), m. p. 178.7 – 180.2 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.64 (d, *J* = 7.7 Hz, 2H), 7.55 – 7.50 (m, 2H), 7.34 (t, *J* = 7.7 Hz, 2H), 7.31 – 7.25 (m, 3H), 7.24 – 7.20 (m, 2H), 7.19 – 7.16 (m, 6H), 7.20 – 7.15 (m, 1H), 7.08 (m, 1H), 2.16 (s, 3H), 1.38 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.3, 164.9, 158.7, 136.7, 136.2, 135.9, 135.2, 134.6, 131.4, 129.7, 129.1, 128.6, 128.5, 128.4, 128.1, 127.3, 126.8, 125.5, 125.3, 116.6, 77.0, 71.8, 18.7, 15.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{25}N_3O_2Na$ 494.1839; found 494.1846.



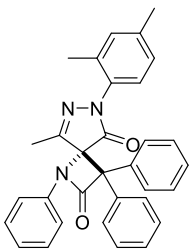
***6-(2-fluorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3k)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3k** as a white solid in 79% yield (37.6 mg), m. p. 185.8 – 187.8 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 7.7 Hz, 2H), 7.59 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.48 – 7.42 (m, 1H), 7.33 – 7.28 (m, 3H), 7.27 – 7.21 (m, 7H), 7.19 – 7.14 (m, 3H), 7.07 (t, *J* = 7.0 Hz, 1H), 1.36 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.6, 164.6, 159.1, 156.8 (d, $J_{C,F}$ = 253.4 Hz), 136.6, 135.8, 129.9, 129.8, 129.7, 129.1, 128.5, 128.4, 128.3, 127.5, 127.0, 126.6, 125.5, 124.8 (d, $J_{C,F}$ = 12.3 Hz), 124.6, 117.0 (d, $J_{C,F}$ = 19.3 Hz), 116.6, 77.2, 71.7, 15.40. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}FN_3NaO_2Na$ 498.1589; found 498.1596.



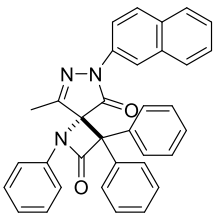
***6-(2-chlorophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3l)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3l** as a white solid in 67% yield (33.1 mg), m. p. 159.2 – 163.4 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.68 (d, *J* = 7.2 Hz, 2H), 7.59 (d, *J* = 7.2 Hz, 2H), 7.48 – 7.43 (m, 1H), 7.38 (dd, *J* = 7.2, 1.8 Hz, 1H), 7.33 (t, *J* = 7.2 Hz, 2H), 7.28 (m, 7H), 7.22 (t, *J* = 7.2 Hz, 2H), 7.17 (d, *J* = 8.4 Hz, 1H), 7.08 (m, 1H), 1.37 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 166.8, 163.1, 157.1, 135.0, 134.7, 133.7, 132.7, 130.0, 129.1, 128.4, 128.0, 127.5, 126.81, 126.78, 126.74, 126.66, 126.2, 126.1, 125.6, 123.9, 115.0, 75.6, 70.0, 13.8. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}ClN_3O_2Na$ 514.1293; found 514.1298.



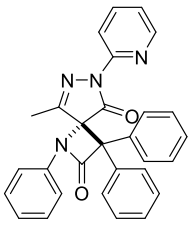
***6-(2-bromophenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3m)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3m** as a white solid in 82% yield (44.2 mg), m. p. 197.5 – 199.5 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.70 (d, *J* = 1.4 Hz, 2H), 7.65 (d, *J* = 7.0 Hz, 1H), 7.63 – 7.58 (m, 2H), 7.37 – 7.31 (m, 4H), 7.31 – 7.25 (m, 5H), 7.25 – 7.18 (m, 3H), 7.16 (t, *J* = 7.0 Hz, 1H), 7.11 – 7.06 (m, 1H), 1.37 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.4, 164.8, 158.7, 136.6, 136.3, 135.9, 135.3, 134.0, 130.3, 129.7, 129.1, 128.73, 128.66, 128.44, 128.41, 128.38, 128.0, 127.3, 125.5, 121.3, 116.6, 77.4, 71.7, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}BrN_3O_2$ 558.0788; found 558.0792.



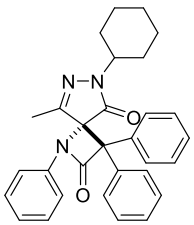
***6-(2,4-dimethylphenyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3n)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3n** as a white solid in 87% yield (42.1 mg), m. p. = 192.5 – 194.2 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.64 (d, *J* = 7.7 Hz, 2H), 7.52 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.33 (t, *J* =7.7 Hz, 2H), 7.29 – 7.19 (m, 7H), 7.19 – 7.14 (m, 2H), 7.10 – 7.05 (m, 1H), 7.01 (d, *J* = 5.6 Hz, 2H), 2.26 (s, 3H), 2.14 (s, 3H), 1.37 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.4, 164.9, 158.5, 138.6, 136.7, 136.3, 135.3, 134.4, 133.3, 132.0, 129.6, 129.1, 128.4, 128.0, 127.4, 127.3, 125.44, 125.35, 125.3, 116.6, 76.9, 71.7, 21.1, 18.6, 15.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{32}H_{27}N_3O_2Na$ 508.1996; found 508.2003.



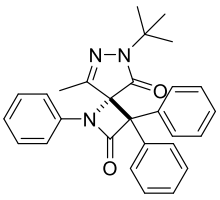
***8-methyl-6-(naphthalen-2-yl)-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione（3o）*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3o** as a white solid in 80% yield (40.4 mg), m. p. 170.6 – 173.7 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.34 (d, *J* = 1.8 Hz, 1H), 8.07 (dd, *J* = 9.0, 1.8 Hz, 1H), 7.91 (d, *J* = 9.0 Hz, 1H), 7.87 – 7.82 (t, *J* = 7.2 Hz, 2H), 7.68 (d, *J* = 7.2 Hz, 2H), 7.61 (d, *J* = 7.2 Hz, 2H), 7.52 – 7.43 (m, 2H), 7.37 (t, *J* = 7.8 Hz, 2H), 7.34 – 7.24 (m, 8H), 7.11 (t, *J* = 7.2 Hz, 1H), 1.48 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) 168.0, 164.6, 158.9, 136.7, 136.6, 136.2, 135.4, 133.5, 131.2, 129.7, 129.2, 129.1, 128.6, 128.5, 128.3, 128.1, 127.7, 127.3, 127.1, 126.8, 125.7, 125.5, 117.8, 116.6, 115.6, 77.4, 72.9, 15.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{34}H_{25}N_3O_2Na$ 530.1839; found 530.1831.



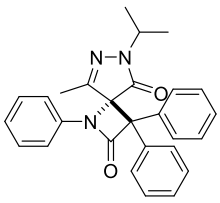
***8-methyl-1,3,3-triphenyl-6-(pyridin-2-yl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3p)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 20/1) giving the product **3p** as a white solid in 95% yield (43.5 mg), m. p. 162.7 – 165.0 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.55 (dd, *J* = 4.8, 1.2 Hz, 1H), 7.79 (d, *J* = 8.4 Hz, 1H), 7.72 – 7.66 (m, 1H), 7.61 (d, *J* = 6.6 Hz, 2H), 7.51 (d, *J* = 7.2 Hz, 2H), 7.28 (t, *J* = 7.2 Hz, 2H), 7.25 – 7.18 (m, 8H), 7.14 (dd, *J* = 7.2, 4.8 Hz, 1H), 7.04 (t, *J* = 7.2 Hz, 1H), 1.45 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.6, 164.4, 160.0, 149.2, 148.9, 138.6, 136.5, 136.3, 136.1, 129.7, 129.2, 128.64, 128.57, 128.3, 127.2, 127.1, 125.5, 121.4, 116.5, 114.0, 77.8, 73.0, 15.7. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{29}H_{22}N_4O_2Na$ 481.1635; found 481.1629.



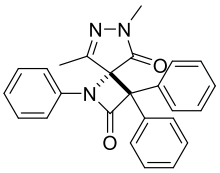
***6-cyclohexyl-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3q)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 100/1) giving the product **3q** as a white solid in 82% yield (37.8 mg), m. p. 209.3 – 211.0 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.58 (d, *J* = 7.2 Hz, 2H), 7.52 (d, *J* = 7.8 Hz, 2H), 7.34 (t, *J* = 7.2 Hz, 2H), 7.28 (q, *J* = 7.2 Hz, 5H), 7.23 (d, 6.6Hz, 1H), 7.16 (d, *J* = 8.4 Hz, 2H), 7.09 (t, *J* = 7.2 Hz, 1H), 4.11 – 4.03 (m, 1H), 2.00 – 1.95 (m, 1H), 1.91 (d, *J* = 10.2 Hz, 2H), 1.89 – 1.78 (m, 3H), 1.70 (d, *J* = 11.4 Hz, 1H), 1.45 – 1.34 (m, 2H), 1.31 (s, 3H), 1.28 – 1.19 (m, 1H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.8, 164.8, 157.0, 136.9, 136.8, 136.2, 129.5, 129.0, 128.4, 128.2, 128.1, 127.3, 127.0, 125.2, 116.4, 76.1, 71.9, 53.4, 31.1, 30.4, 25.5, 25.4, 25.2, 15.3. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{29}N_3O_2Na$ 486.2152; found 486.2144.



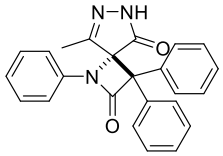
***6-(tert-butyl)-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3r)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3r** as a white solid in 80% yield (36.4 mg), m. p. 160.7 – 161.6 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.54 (d, *J* = 6.6 Hz, 2H), 7.51 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.27 (t, *J* = 7.2 Hz, 2H), 7.24 – 7.19 (m, 5H), 7.18 – 7.13 (m, 1H), 7.14 – 7.09 (m, 2H), 7.03 (t, *J* = 7.8 Hz, 1H), 1.48 (s, 9H), 1.24 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 170.2, 164.9, 155.7, 137.2, 136.9, 136.6, 129.5, 129.0, 128.3, 128.2, 128.0, 127.2, 127.0, 125.1, 116.5, 76.0, 72.4, 58.1, 28.0, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{28}H_{27}N_3O_2Na$ 460.1996; found 460.2002.



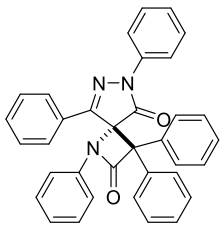
***6-isopropyl-8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3s)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3s** as a white solid in 72% yield (30.5 mg), m. p. 198.4 – 200.6 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.52 (d, *J* = 7.8 Hz, 2H), 7.48 – 7.44 (m, 2H), 7.28 (t, *J* = 7.8 Hz, 2H), 7.25 – 7.20 (m, 5H), 7.18 – 7.15 (m, 1H), 7.10 (d, *J* = 7.8 Hz, 2H), 7.04 (t, *J* = 7.2 Hz, 1H), 4.43 – 4.37(m, 1H), 1.41 (d, *J* = 6.6 Hz, 3H), 1.30 (d, *J* = 6.6 Hz, 3H), 1.27 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.9, 164.8, 157.2, 136.9, 136.8, 136.2, 129.5, 129.1, 128.4, 128.3, 128.1, 127.3, 127.0, 125.2, 116.5, 76.2, 72.0, 46.2, 20.8, 20.2, 15.3. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{27}H_{25}N_3O_2Na$ 446.1839; found 446.1838.



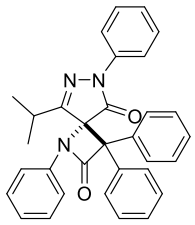
***6,8-dimethyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3t)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3t** as a white solid in 76% yield (30.1 mg), m. p. 167.8 – 169.6 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.62 (d, *J* = 6.3 Hz, 2H), 7.55 – 7.51 (m, 2H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.32 – 7.28 (m, 5H), 7.27 – 7.24 (m, 1H), 7.19 (dd, *J* = 8.4, 1.4 Hz, 2H), 7.12 (t, *J* = 7.7 Hz, 1H), 3.44 (s, 3H), 1.33 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 169.9, 164.8, 157.9, 136.72, 136.68, 136.0, 129.6, 129.1, 128.5, 128.3, 128.2, 127.4, 127.1, 125.3, 116.5, 76.4, 71.4, 32.3, 15.2. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{25}H_{21}N_3O_2Na$ 418.1526; found 418.1534.



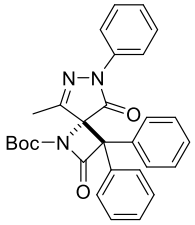
***8-methyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3u)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3u** as a white solid in 87% yield (33.2 mg), m. p. 173.2 – 177.9 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.67 (s, 1H), 7.66 (d, *J* = 7.2 Hz, 2H), 7.63 (d, *J* = 7.2 Hz, 2H), 7.39 (t, *J* = 7.8 Hz, 2H), 7.37 – 7.32 (m, 5H), 7.30 – 7.25 (m, 3H), 7.16 (t, *J* = 7.2 Hz, 1H), 1.36 (s, 3H).^{13}C NMR (150 MHz, Chloroform-*d*) δ 172.5, 164.7, 159.1, 136.59, 136.56, 135.8, 129.7, 129.1, 128.5, 128.4, 128.2, 127.4, 127.0, 125.4, 116.5, 76.7, 70.5, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{25}H_{19}N_3O_2Na$ 404.1370; found 404.1376.



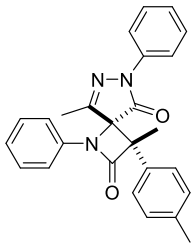
***1,3,3,6,8-pentaphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3v)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3v** as a white solid in 95% yield (49.5 mg), m. p. 203.8-205.0 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.98 – 7.92 (t, *J* = 7.0 Hz, 2H), 7.66 (t, *J* = 7.0 Hz, 2H), 7.52 (t, *J* = 6.3 Hz, 2H), 7.47 (d, *J* = 8.4 Hz, 4H), 7.35 (t, *J* = 6.3 Hz, 2H), 7.33 – 7.27 (m, 3H), 7.27 – 7.24 (m, 3H), 7.14 – 7.09 (t, *J* = 7.0 Hz, 1H), 7.10 – 7.05 (t, *J* = 7.0 Hz, 1H), 7.02 (t, *J* = 7.7 Hz, 2H), 6.94 (m, 2H), 6.89 (t, *J* = 7.7 Hz, 1H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.3, 164.7, 155.0, 137.7, 137.2, 136.6, 136.0, 130.9, 123.0, 129.7, 129.2, 128.6, 128.4, 128.2, 128.1, 127.8, 127.3, 126.9, 126.4, 125.8, 125.5, 118.7, 117.1, 78.8, 72.7. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{35}H_{25}N_3O_2Na$ 542.1839; found 542.1845.



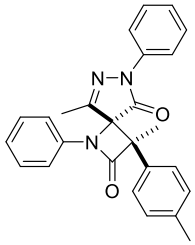
***8-isopropyl-1,3,3-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3x)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3x** as a white solid in 93% yield (45.4 mg), m. p. 165.1 – 167.3 ℃, ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.85 (d, *J* = 8.4 Hz, 2H), 7.59 (s, 2H), 7.52 – 7.47 (m, 2H), 7.38 (t, *J* = 7.8 Hz, 2H), 7.28 (t, *J* = 7.2 Hz, 2H), 7.24 – 7.13 (m, 9H), 7.02 (t, *J* = 7.8 Hz, 1H), 1.65 – 1.56 (m, 1H). 0.88 (d, *J* = 6.6 Hz, 3H), 0.63 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.9, 165.3, 164.9, 138.0, 137.2, 136.8, 136.7, 129.4, 129.13, 129.10, 128.5, 128.4, 128.1, 127.2, 127.1, 125.5, 125.3, 118.4, 117.1, 77.4, 73.1, 29.7, 22.2, 19.3. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{32}H_{27}N_3O_2Na$ 508.1996; found 508.1991.



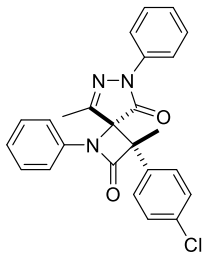
***tert-butyl5-methyl-2,8-dioxo-3,3,7-triphenyl-1,6,7-triazaspiro[3.4]oct-5-ene-1-carboxylate (3y)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3y** as a white solid in 23% yield (11.2 mg), m. p. 153.4 – 156.1 ℃. ^{1}H NMR (600 MHz, DMSO-d_6) δ 7.71 (d, *J* = 7.2 Hz, 2H), 7.54 (d, *J* = 7.2 Hz, 4H), 7.50 (t, *J* = 7.8 Hz, 2H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.39 (t, *J* = 7.2 Hz, 2H), 7.35 (t, *J* = 7.8 Hz, 2H), 7.30 (q, *J* = 7.2 Hz, 2H), 1.40 (s, 3H), 1.31 (s, 9H). ^{1}H NMR (600 MHz, Chloroform-d_6) δ 7.73 (d, *J* = 7.2 Hz, 2H), 7.48 (d, *J* = 7.2 Hz, 2H), 7.44 (d, *J* = 7.2 Hz, 2H), 7.34 (t, *J* = 7.8 Hz, 2H), 7.28 (t, *J* = 7.8 Hz, 2H), 7.23 (t, *J* = 7.8 Hz, 3H), 7.20 (d, *J* = 7.2 Hz, 1H), 7.15 (t, *J* = 7.2 Hz, 1H), 1.40 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (150 MHz, DMSO-*d*) δ 168.6, 157.1, 137.6, 136.4, 136.3, 130.0, 129.7, 129.3, 129.2, 128.6, 126.9, 126.7, 126.2, 118.9, 85.8, 76.2, 71.2, 27.6, 14.9. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{29}H_{27}N_3O_4Na$ 504.1894, found 504.1900.



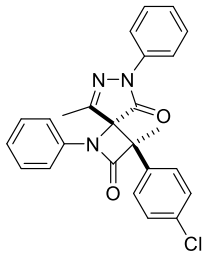
***3,8-dimethyl-1,6-diphenyl-3-(p-tolyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3z)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3z** as a white solid in 45% yield (18.6 mg), m. p. 133.2 – 135.4 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.02 (dd, *J* = 7.8, 1.2 Hz, 2H), 7.50 – 7.45 (m, 3H), 7.30 – 7.25 (m, 3H), 7.19 – 7.13 (m, 4H), 7.10 (t, *J* = 7.2 Hz, 2H), 2.34 (s, 3H), 1.91 (s, 3H), 1.28 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.3, 166.7, 159.6, 138.4, 138.1, 136.8, 134.7, 129.8, 129.7, 129.2, 125.9, 125.7, 125.3, 118.7, 116.3, 71.8, 68.9, 21.5, 21.3, 14.9. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{26}H_{23}N_3O_2Na$ 432.1683, found 432.1687.



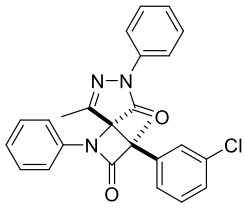
***3,8-dimethyl-1,6-diphenyl-3-(p-tolyl)-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3z')*:** The residue was purified by a silica gel flash chromatography (PE/EA = 60/1) giving the product **3z'** as a white solid in 35% yield (14.2 mg), m. p. 172.3 – 176.4 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.67 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.40 – 7.35 (m, 2H), 7.30 (t, *J* = 7.8 Hz, 2H), 7.25 – 7.15 (m, 5H), 7.13 – 7.07 (m, 3H), 2.36 (s, 3H), 2.32 (s, 3H), 1.94 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.3, 167.0, 157.0, 138.1, 137.6, 136.8, 134.4, 129.7, 129.5, 129.1, 125.9, 125.5, 125.2, 118.6, 116.5, 72.8, 70.5, 22.9, 21.3, 16.9. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{26}H_{23}N_3O_2Na$ 432.1683; found 432.1692.



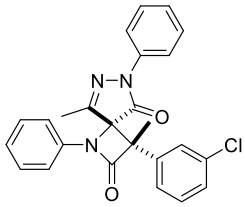
***3-(4-chlorophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3aa)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3aa** as a white solid in 54% yield (23.2 mg), m. p. 153.9 – 155.1 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.59 (dd, *J* = 8.4, 0.7 Hz, 2H), 7.34 – 7.29 (m, 2H), 7.27 – 7.16 (m, 6H), 7.13 (t, *J* = 7.0 Hz, 1H), 7.11 – 7.07 (m, 2H), 7.05 (t, *J* = 7.0 Hz, 1H), 2.28 (s, 3H), 1.86 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 168.0, 166.3, 156.7, 137.4, 136.5, 135.9, 134.3, 129.73, 129.70, 129.1, 128.9, 125.6, 125.4, 118.4, 116.4, 72.5, 69.7, 22.7, 16.9. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{25}H_{20}N_3O_2Na$ 452.1137; found 452.1143.



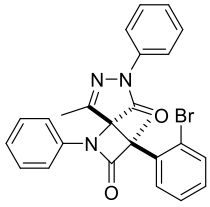
***3-(4-chlorophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3aa')*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3aa'** as a white solid in 42% yield (18.1 mg), m. p. 166.0 – 167.3 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 7.7 Hz, 2H), 7.45 – 7.39 (m, 3H), 7.30 (d, *J* = 9.1 Hz, 2H), 7.25 – 7.19 (m, 3H), 7.09 (d, *J* = 8.4 Hz, 2H), 7.05 (t, *J* = 7.7 Hz, 2H), 1.84 (s, 3H), 1.27 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 167.9, 166.0, 159.0, 137.9, 136.5, 136.2, 134.5, 129.7, 129.5, 129.2, 127.4, 125.8, 125.4, 118.6, 116.3, 71.5, 68.0, 21.6, 14.8. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{25}H_{20}N_3O_2Na$ 452.1137; found 452.1135.



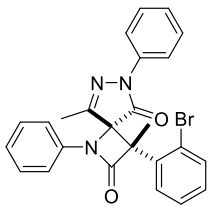
***3-(3-chlorophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3bb)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3bb** as a white solid in 56% yield (24.1 mg), m. p. 173.2 – 177.9 ℃. m. p. 142.6 – 144.9 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 8.4 Hz, 2H), 7.38 (t, *J* = 7.8 Hz, 3H), 7.31 – 7.15 (m, 8H), 7.12 (t, *J* = 7.8 Hz, 1H), 2.36 (s, 3H), 1.94 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.0, 166.0, 156.6, 139.3, 137.2, 136.5, 134.7, 130.0, 129.7, 129.0, 128.6, 126.3, 125.7, 125.4, 124.2, 118.6, 116.4, 72.4, 69.7, 22.6, 16.8. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{25}H_{20}ClN_3O_2Na$ 452.1137; found 452.1133.



***3-(3-chlorophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3bb')*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3bb'** as a white solid in 40% yield (17.3 mg), m. p. 190.1 – 192.3 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.02 (d, *J* = 7.8 Hz, 2H), 7.48 (t, *J* = 7.8 Hz, 3H), 7.33 (m, 2H), 7.30 (m, 3H)., 7.16 (d, *J* = 8.4 Hz, 2H), 7.12 (t, *J* = 7.2 Hz, 2H), 1.92 (s, 3H), 1.35 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.9, 165.8, 158.9, 139.7, 138.0, 136.6, 135.4, 130.7, 129.8, 129.3, 128.8, 126.3, 125.9, 125.5, 124.3, 118.8, 116.4, 71.5, 68.1, 21.5, 14.9. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{25}H_{20}ClN_3O_2Na$ 452.1137; found 452.1141.

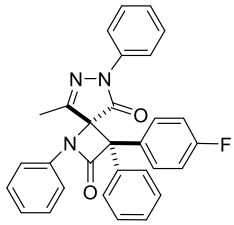


***3-(2-bromophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3cc)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3cc** as a white solid in 38% yield (17.8 mg), m. p. 128.3 – 129.9 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.02 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.97 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.59 (dd, *J* =7.8, 0.6 Hz, 1H), 7.46 (d, *J* = 8.4 Hz, 2H), 7.39 – 7.32 (m, 1H), 7.33 – 7.22 (m, 3H), 7.26 – 7.16 (m, 3H), 7.11 (t, *J* = 7.2 Hz, 1H), 2.17 (s, 3H), 1.40 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.4, 167.1, 157.2, 138.0, 136.6, 134.9, 130.1, 129.8, 129.2, 129.0, 128.2, 125.8, 125.5, 122.0, 119.0, 116.6, 70.3, 68.5, 17.9, 14.4. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{25}H_{20}BrN_3O_2Na$ 496.0632; found 496.0641.

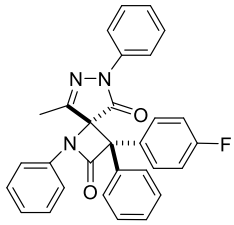


***3-(2-bromophenyl)-3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3cc')*:** The residue was purified by a silica gel flash chromatography (PE/EA = 50/1) giving the product **3cc'** as a white solid in 40% yield (19.2 mg), m. p. 186.0 – 187.5 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.03 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.78 (d, *J* = 7.2 Hz, 2H), 7.47 (d, *J* = 7.2 Hz, 1H), 7.42 – 7.38 (m, 2H), 7.35 (t, *J* = 7.2 Hz, 1H), 7.29 (t, *J* = 7.8 Hz, 2H), 7.22 (d, *J* = 7.2 Hz, 3H), 7.17 – 7.10 (m, 2H), 2.40 (s, 3H), 2.14 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.19, 167.15, 155.6, 137.6, 136.5, 136.2, 134.0, 129.68, 129.65, 129.0, 127.8, 125.6, 125.4, 121.5, 118.8, 116.6, 71.7, 69.7, 20.5, 17.0. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{25}H_{20}BrN_3O_2Na$ 496.0632; found 496.0633.

The isomers **3dd/3dd'** can't be separated neither by flash chromatography nor by HPLC chromatography. The individual yield of **3dd**/**3dd'** was calculated by ^{1}H NMR.

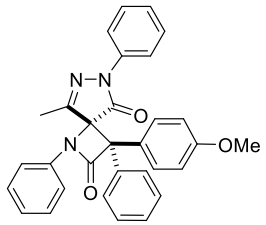


***3-(4-fluorophenyl)-8-methyl-1,3,6-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3dd)*:** The mixture of isomers was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3dd/3dd'** as a white solid in 84% total yield (individual yield was calculated by ^{1}H NMR, **3dd**, 46% yield, 22.1 mg). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.80 (t, *J* = 7.2 Hz, 4H), 7.65 – 7.52 (m, 4H), 7.41 – 7.34 (m, 4H), 7.28 – 7.22 (m, 3H), 7.05 (t, *J* = 7.2 Hz, 2H), 6.92 (t, *J* = 9.0 Hz, 2H), 1.37 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ δ 167.6, 164.4, 162.4 (d, $J_{C,F}$ = 246.8 Hz), 158.7, 137.7, 136.5, 132.6, 131.9, 129.8, 129.3 (d, $J_{C,F}$ = 8.7 Hz), 129.2 (d, $J_{C,F}$ = 4.0 Hz), 128.4, 127.2, 127.0, 125.7, 125.6, 118.4, 116.5, 115.6 (d, $J_{C,F}$ = 21.6 Hz), 76.6, 72.7, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}FN_3O_2Na$ 498.1589; found 498.1589.

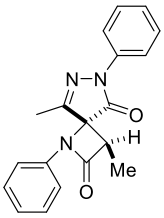


***3-(4-fluorophenyl)-8-methyl-1,3,6-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3dd')*:** The mixture of isomers was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3dd/3dd'** as a white solid in 84% total yield (individual yield was calculated by ^{1}H NMR, **3dd'**, 38% yield, 18.3 mg). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.53 – 7.44 (m, 5H), 7.30 (t, *J* = 7.2 Hz, 3H), 7.18 – 7.14 (m, 9H), 6.99 (t, *J* = 8.4 Hz, 2H), 1.42 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.6, 164.4, 162.5 (d, $J_{C,F}$ = 247.8 Hz), 158.3, 136.5, 136.4, 136.1, 132.6, 131.9, 129.3 (d, $J_{C,F}$ = 2.0 Hz), 129.0, 128.9, 128.6 (d, $J_{C,F}$ = 15.3 Hz), 128.4, 127.2, 125.64, 125.59, 116.5, 116.2 (d, $J_{C,F}$ = 21.6 Hz), 76.6, 72.7, 15.6. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{22}FN_3O_2Na$ 498.1589; found 498.1589.

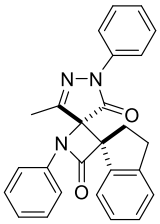
The isomers **3ee/3ee'** can't be separated neither by flash chromatography nor by HPLC chromatography. The individual yield of **3ee**/**3ee'** was calculated by ^{1}H NMR. NMR spectra of **3ee'** can't be obtained due to overlap of NMR signals.



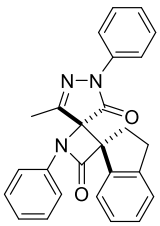
***3-(4-methoxyphenyl)-8-methyl-1,3,6-triphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3ee)*:** The mixture of isomers was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3ee/3ee'** as a white solid in 78% total yield (individual yield was calculated by ^{1}H NMR, **3ee**, 65% yield, 38.5 mg; **3ee'**, 13% yield, 7.7 mg). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.80 (d, *J* = 7.2 Hz, 2H), 7.55 (d, *J* = 6.6 Hz, 2H), 7.48 (d, *J* = 7.2 Hz, 1H), 7.41 (d, *J* = 9.0 Hz, 2H), 7.38 – 7.32 (m, 3H), 7.27 (t, *J* = 7.2 Hz, 2H), 7.23 – 7.18 (m, 4H), 7.02 (t, *J* = 7.2 Hz, 1H), 6.74 (d, *J* = 9.0 Hz, 2H), 3.65 (s, 3H), 1.35 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.7, 164.9, 159.3, 158.9, 137.9, 136.9, 136.6, 129.7, 129.17, 129.16, 128.8, 128.6, 128.38, 128.36, 128.0, 127.1, 127.0, 125.6, 125.4, 77.2, 72.8, 55.2, 15.4. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{25}N_3O_3Na$ 510.1789; found 510.1788.



***3,8-dimethyl-1,6-diphenyl-1,6,7-triazaspiro[3.4]oct-7-ene-2,5-dione (3ff)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 100/1) giving the product **3ff** as a white solid in 75% yield (23.8 mg), m. p. 97.2 – 103.4 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 7.2 Hz, 2H), 7.39 (t, *J* = 7.2 Hz, 2H), 7.24 – 7.18 (m, 3H), 7.03 (t, *J* = 7.8 Hz, 1H), 3.77 (q, *J* = 7.8 Hz, 1H), 2.17 (s, 3H), 1.40 (d, *J* = 7.8 Hz, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 169.1, 165.5, 157.2, 137.7, 136.8, 129.7, 129.1, 125.7, 125.1, 118.5, 115.9, 67.2, 56.7, 15.7, 10.1. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{19}H_{17}N_3O_2Na$ 342.1213; found 342.1220.

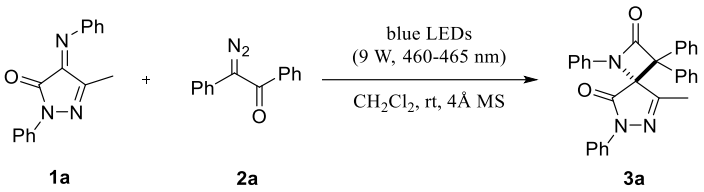


***3''-methyl-1',1''-diphenyl-2,3-dihydrodispiro[indene-1,3'-azetidine-2',4''-pyrazole]-4',5''(1''H)-dione (3gg)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3gg** as a white solid in 64% yield (25.6 mg), m. p. 189.1 – 191.2 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.81 – 7.75 (m, 1H), 7.67 (d, *J* = 7.2 Hz, 2H), 7.37 – 7.31 (m, 4H), 7.30 – 7.26 (m, 2H), 7.24 (d, *J* = 7.8 Hz, 2H), 7.23 – 7.18 (m, 1H), 7.15 (t, *J* = 7.8 Hz, 2H), 3.00 – 2.88 (m, 2H), 2.76 (dt, *J* = 13.8, 9.0 Hz, 1H), 2.68 – 2.62 (m, 1H), 2.33 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.02, 166.96, 157.9, 144.8, 137.7, 136.6, 135.8, 129.7, 129.6, 128.9, 128.0, 126.1, 125.4, 125.3, 124.4, 118.5, 116.5, 77.8, 73.1, 30.9, 30.9, 16.1. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{26}H_{21}N_3O_2Na$ 430.1526; found 430.1536.



***3''-methyl-1',1''-diphenyl-2,3-dihydrodispiro[indene-1,3'-azetidine-2',4''-pyrazole]-4',5''(1''H)-dione (3gg')*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **3gg'** as a white solid in 30% yield (12.2 mg), m. p. 136.9 – 142.7 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.86 (d, *J* = 7.2 Hz, 2H), 7.45 (d, *J* = 7.2 Hz, 1H), 7.41 – 7.34 (t, *J* = 7.2 Hz, 2H), 7.24 (t, *J* = 7.8 Hz, 3H), 7.20 (m, 1H), 7.18 – 7.14 (m, 2H), 7.13 (d, *J* = 7.2 Hz, 2H), 7.06 (t, *J* = 7.2 Hz, 1H), 3.04 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.71 (m, 1H), 2.69 – 2.60 (m, 1H), 2.53 – 2.44 (m, 1H), 1.81 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 169.4, 166.7, 157.8, 146.2, 137.8, 137.4, 136.9, 129.8, 129.7, 129.1, 126.1, 125.8, 125.7, 125.4, 125.2, 118.6, 116.3, 77.9, 77.3, 73.5, 31.8, 30.7, 16.6. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{26}H_{21}N_3O_2Na$ 430.1526; found 430.1530.

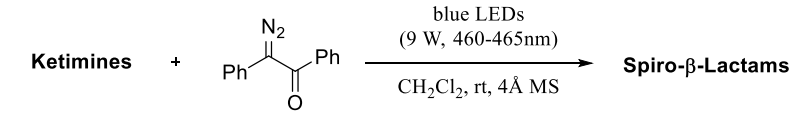
4. Scale-up synthesis of product 3a



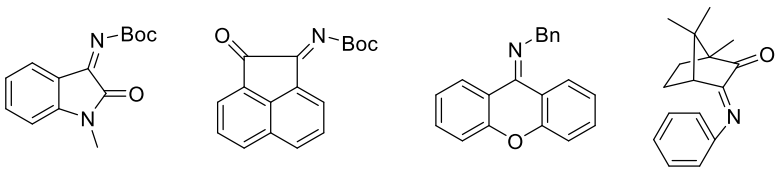
1a **2a** **3a**

Pyrazolone-derived phenyl ketimines **1a** (3.0 mmol, 1.0 equiv.) and α-diazoketones **2a** (6.0 mmol, 2.0 equiv.) were dissolved in CH_2Cl_2 (3 mL). At room temperature, the reaction mixture was then irradiated under blue LEDs for hours until the complete consumption of **1a** (monitored by TLC). The reaction mixture was concentrated and the residue was purified by flash chromatography on silica gel (PE/EA = 80/1) to give the pure product **3a** in 80% (1.1 g) isolated yield.

5. Synthesis of other spiro-β-lactams and deprotection of *N*-Boc group of products 5 and 8

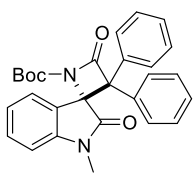


4, 7, 10, 12 **2a** **5, 8, 11, 13**



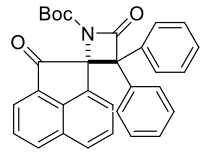
4 **7** **10** **12**

Other ketimines **4, 7, 10 or 12** (0.1 mmol, 1.0 equiv.) and α-diazoketone **2a** (0.2 mmol, 2.0 equiv.) were dissolved in CH_2Cl_2 (1.0 mL). At room temperature, the reaction mixture was then irradiated under blue LEDs for hours until the complete consumption of **4** or **7** (monitored by TLC). The reaction mixture was concentrated and the residue was purified by flash chromatography on silica gel (petroleum ether /ethyl acetate = 80:1) to give the pure products **5, 8, 11 or 13**.

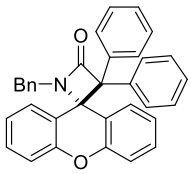


***tert-butyl-1'-methyl-2',4-dioxo-3,3-diphenylspiro[azetidine-2,3'-indoline]-1-carboxylate (5)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 10/1) giving the product **5** as a white solid in 84% yield (38.1 mg), m. p. 178.2 – 179.6 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.44 (d, *J* = 7.2 Hz, 2H), 7.32 – 7.28 (m, 1H), 7.28 – 7.20 (m, 5H), 7.20 – 7.17 (m, 3H). 6.90 (d, *J* = 7.2 Hz, 1H), 6.70 (t, *J* = 7.2 Hz, 1H), 6.12 (d, *J* = 7.2 Hz, 1H). 3.25 (s, 3H), 1.25 (s, 9H). ^{13}C NMR (150 MHz,

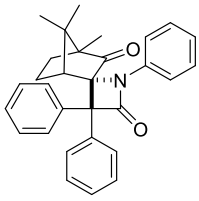
Chloroform-*d*) δ 173.0, 166.3, 144.5, 137.6, 137.1, 130.5, 128.52, 128.49, 128.04, 128.00, 127.7, 126.5, 126.2, 123.4, 122.2, 108.3, 84.2, 75.5, 69.4, 27.8, 26.8. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{28}H_{26}N_2O_4Na$ 477.1785; found 477.1794.



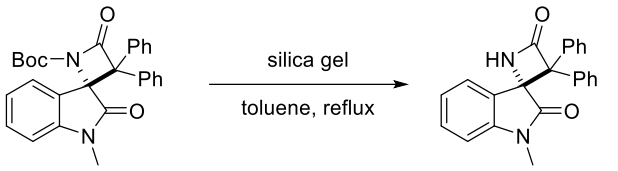
***tert-butyl2,4'-dioxo-3',3'-diphenyl-2H-spiro[acenaphthylene-1,2'-azetidine]-1'-carboxylate (8)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 10/1) giving the product **8** as a white solid in 96% yield (45.6 mg), m. p. 174.1 – 175.6 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.18 (d, *J* = 8.4 Hz, 1H), 8.02 (d, *J* = 7.8 Hz, 1H), 7.87 (d, *J* = 7.8 Hz, 1H), 7.80 (t, *J* = 8.4 Hz, 1H), 7.33 (d, *J* = 7.8 Hz, 3H), 7.20 (m, 3H), 7.16 (m, 5H). 6.45 (d, *J* = 6.6 Hz, 1H), 1.02 (s, 9H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 199.1, 166.7, 142.0, 137.6, 137.5, 133.3, 132.2, 131.9, 130.7, 128.51, 128.47, 128.4, 128.09, 128.05, 128.0, 127.5, 127.2, 126.1, 123.1, 122.2, 84.0, 76.1, 73.4, 27.5. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{31}H_{25}NO_4Na$ 498.1676; found 498.1668.



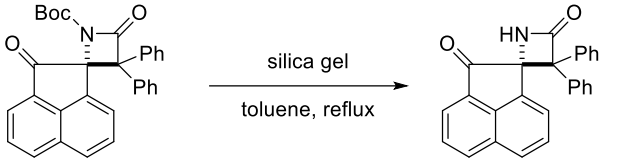
***1-benzyl-3,3-diphenylspiro[azetidine-2,9'-xanthen]-4-one (11)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **11** as a white solid in 74% yield (35.7 mg), m. p. 226.5 – 228.4 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.25 – 7.21 (m, 6H), 7.21 – 7.16 (m, 5H), 7.14 (t, *J* = 7.2 Hz, 2H), 6.98 – 6.91 (m, 6H), 6.54 – 6.46 (m, 4H), 4.44 (s, 2H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 170.4, 152.5, 139.2, 136.2, 129.5, 129.2, 128.5, 128.4, 127.9, 127.6, 127.3, 126.2, 122.4, 119.5, 116.2, 81.9, 68.8, 44.9. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{34}H_{25}NO_2Na$ 502.1778; found 502.1788.



***4',7',7'-trimethyl-1,3,3-triphenylspiro[azetidine-2,2'-bicyclo[2.2.1]heptane]-3',4-dione (13)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 80/1) giving the product **13** as a white solid in 90% yield (39.0 mg), m. p. 215.7 – 218.5 ℃. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.63 (d, *J* = 7.8 Hz, 2H), 7.53 (d, *J* = 6.6 Hz, 2H), 7.43 (t, *J* = 7.8 Hz, 2H), 7.41 (d, *J* = 4.2 Hz, 4H), 7.39 – 7.34 (m, 4H), 7.30 (t, *J* = 7.2 Hz, 1H), 2.89 (d, *J* = 4.8 Hz, 1H), 1.88 – 1.79 (m, 1H), 1.68 – 1.62 (m, 1H), 1.58 – 1.54 (m, 2H), 0.89 (s, 3H), 0.68 (s, 3H), 0.15 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 213.2, 170.4, 138.1, 135.8, 133.9, 130.1, 130.0, 129.4, 129.2, 128.61, 128.58, 128.2, 127.9, 127.7, 83.2, 75.0, 58.5, 49.3, 45.7, 28.2, 24.3, 22.9, 20.1, 9.6. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for $C_{30}H_{29}NO_2Na$ 458.2091; found 458.2083.

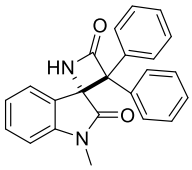


5 **6**

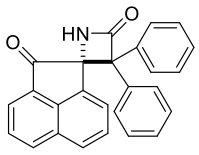


8 **9**

To an oven-dried 25 mL Schlenk tube equipped with a stir bar was charged with cycloadduct **5** or **8** and 1.0 g silica gel (200-300 mesh). To this mixture was added freshly distilled toluene (6 mL) and the reaction mixture was stirred under refluxing. After **5** or **8** was fully consumed, the solvent was removed under reduced pressure and the residue was purified by chromatography on silica gel (petroleum ether /ethyl acetate = 1/4) to give the corresponding product **6** or **9**.

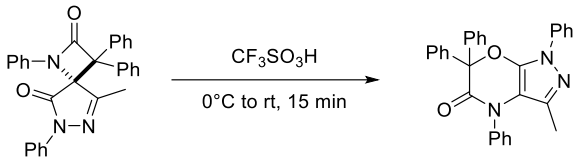


***1'-methyl-3,3-diphenylspiro[azetidine-2,3'-indoline]-2',4-dione (6)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 4/1) giving the product **6** as a white solid in 77% yield (54.3 mg), m. p. 192.4 – 196.6 °C. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.38 (td, *J* = 7.7, 1.4 Hz, 2H), 7.25 – 7.20 (m, 1H), 7.19 – 7.15 (m, 4H), 7.13 – 7.08 (m, 4H), 6.82 (d, *J* = 7.7 Hz, 1H), 6.68 – 6.64 (td, *J* = 7.7, 1.4 Hz, 1H), 6.40 (s, 1H), 6.19 (dd, *J* = 8.4, 2.1 Hz, 1H), 3.15 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 175.5, 169.7, 143.8, 138.5, 138.1, 130.4, 128.32, 128.30, 128.0, 127.6, 127.4, 126.6, 126.4, 124.7, 122.3, 108.3, 78.6, 67.2, 26.8. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{23}H_{18}N_2O_2Na$ 377.1261; found 377.1264.



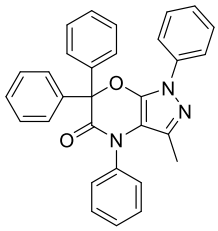
3',3'-diphenyl-2H-spiro[acenaphthylene-1,2'-azetidine]-2,4'-dione (9): The residue was purified by a silica gel flash chromatography (PE/EA = 5/1) giving the product **9** as a white solid in 74% yield (27.6 mg), m. p. 203.7 – 205.5 °C. ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.10 (d, *J* = 8.4 Hz, 1H), 7.89 (d, *J* = 6.6 Hz, 1H), 7.79 (d, *J* = 8.4 Hz, 1H), 7.72 (dd, *J* = 7.8, 7.2 Hz, 1H), 7.30 – 7.25 (m, 3H), 7.14 – 7.08 (m, 4H), 7.06 (d, *J* = 7.2 Hz, 4H), 6.51 (d, *J* = 7.2 Hz, 1H), 6.44 (s, 1H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 201.8, 170.0, 141.4, 138.6, 138.4, 134.3, 132.2, 131.6, 130.5, 128.5, 128.4, 128.3, 128.2, 128.0, 127.6, 127.3, 127.1, 126.0, 123.3, 122.2, 79.2, 71.4. HRMS (ESI-TOF) m/z [M + Na]$^{+}$ Calcd for $C_{26}H_{17}NO_2Na$ 398.1152; found 398.1155.

6. Synthetic transformation of spiro-pyrazolone-β-lactam 3a



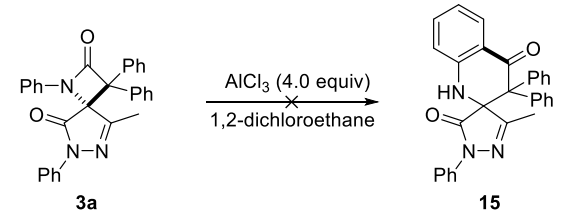
3a **14**

3a (0.1mmol, 45.7 mg) was dissolved in 1,2-dichloroethane (3 mL) and cooled to 0 ℃. Trifluoromethanesulfonic acid (0.1 mmol, 8.9 μL) was then added drop-wise to the stirring solution at 0 ℃. The mixture was warmed to room temperature and stirred for an additional 15 minutes. The reaction was quenched with saturated $NaHCO_3$, extracted with ethyl acetate, dried over anhydrous Na_2SO_4 and concentrated in vacuo to 80% of yield crude product **14** (36.6 mg).

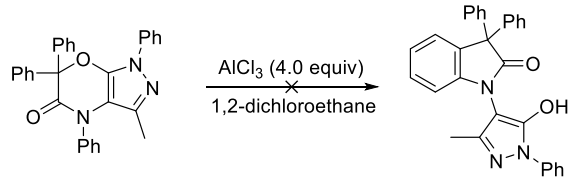


***3-methyl-1,4,6,6-tetraphenyl-1,4-dihydropyrazolo[3,4-b][1,4]oxazin-5(6H)-one (14)*:** The residue was purified by a silica gel flash chromatography (PE/EA = 20/1) giving the product **14** as a white solid in 80% yield (36.6 mg), m. p. 135.1 – 136.7 ℃. ^{1}H NMR (700 MHz, Chloroform-*d*) δ 7.73 (dd, *J* = 9.1, 1.4 Hz, 2H), 7.44 – 7.39 (m, 2H), 7.39 – 7.34 (m, 8H), 7.32 (t, *J* = 7.0 Hz, 1H), 7.28 – 7.24 (m, 6H), 7.20 (t, *J* = 7.7 Hz, 1H), 1.50 (s, 3H). ^{13}C NMR (175 MHz, Chloroform-*d*) δ 163.3, 140.8, 138.7, 138.0, 136.5, 136.4, 129.4, 128.9, 128.4, 128.3, 127.7, 127.5, 126.1, 119.6, 109.4, 91.7, 13.1. HRMS (ESI-TOF) m/z [M + Na]$^+$ Calcd for$C_{30}H_{23}N_3O_2Na$ 480.1683; found 480.1693.

➢ Attempts for synthetic transformation of 3a and 14



3a **15**



14 **16**

7. NOE experiments of products 3aa and 3aa’

The relative configurations of diastereomers **3aa** and **3aa**’ can be determined by the NOE experiments, and the relative configurations of other products **3** were tentatively assigned by analogy.

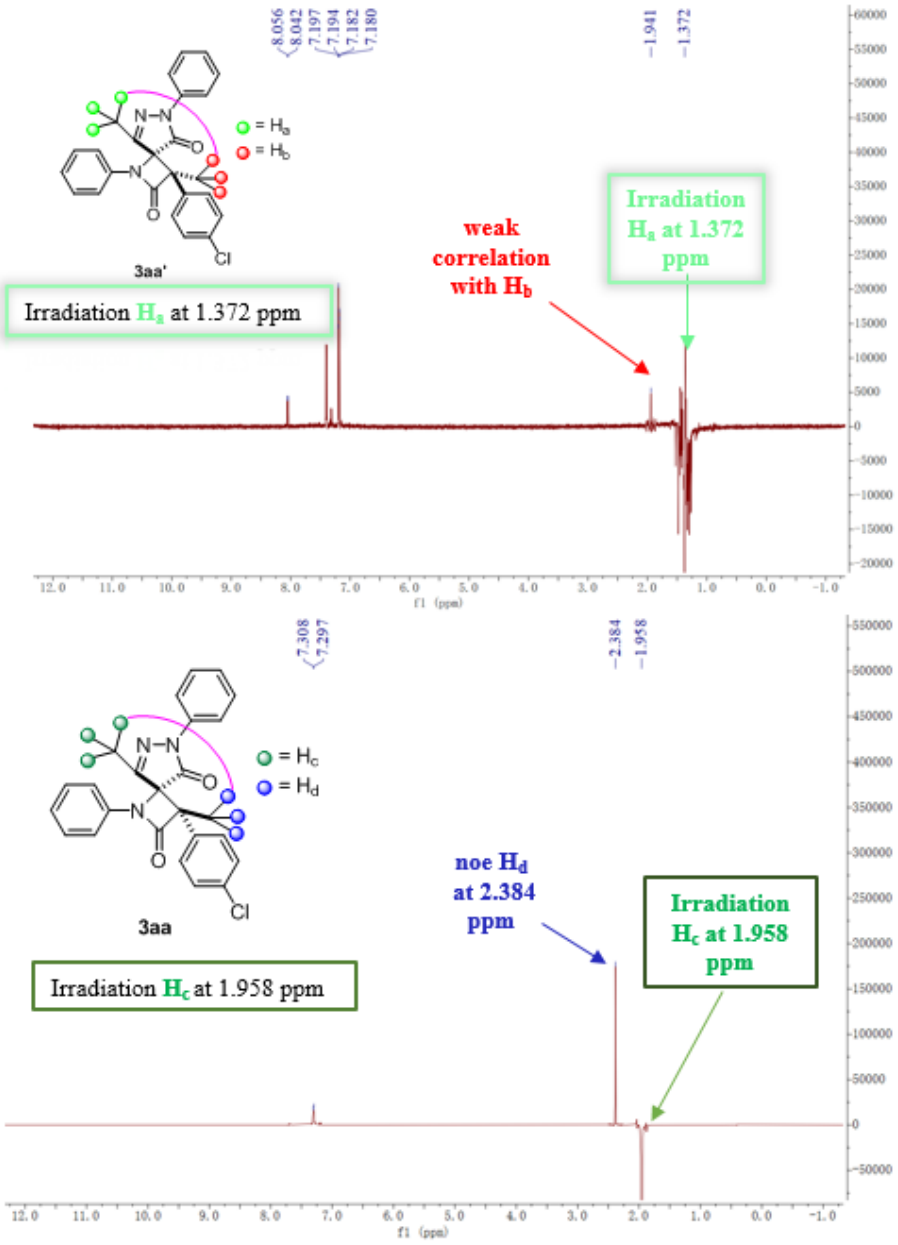
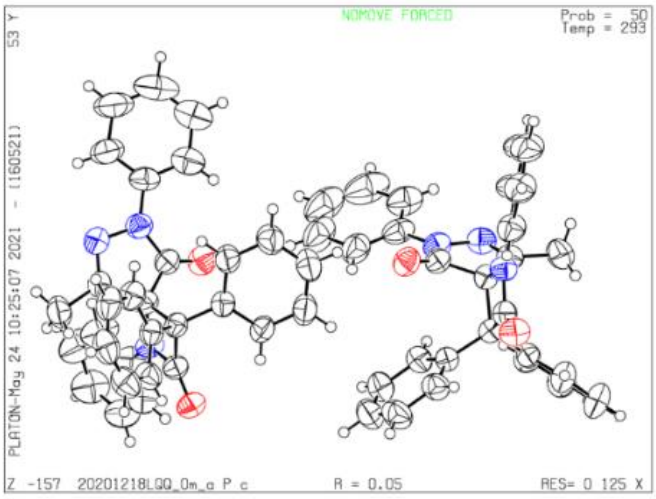


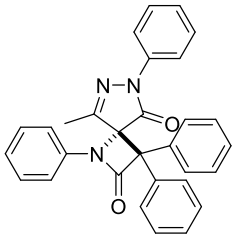
Figure S1. NOE experiments of products **3aa** and **3aa**’

8. X-ray crystal structure of products 3a and 14

To a 10 mL tube containing **3a** (30.0 mg) was added a mixture of solvent (petroleum ether/ethyl acetate/methylene chloride = 1:1:1, v/v/v) (6.0 mL). A clear solution was obtained through ultrasound treatment and was kept at room temperature and the crystals were obtained after the solvent evaporated, which were characterized by X-ray single crystal diffraction. X-ray diffraction experiment was carried out on an Agilent D8 QUEST and the data obtained were deposited at the Cambridge Crystallographic Data Centre.



(Ellipsoid contour probability 50%)

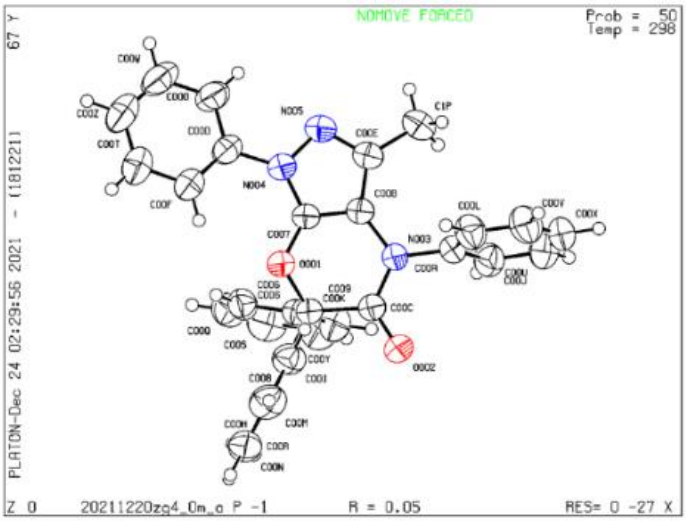


3a, CCDC 2162438

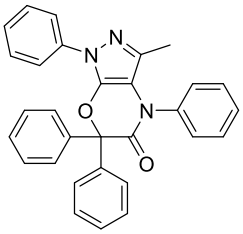
Identification code	20201218LQQ	
Chemical formula	$C_{60}H_{46}N_6O_4$	
Formula weight	915.03 g/mol	
Temperature	293(2) K	
Wavelength	1.54178 Å	
Crystal system	monoclinic	
Space group	P 1 c 1	
Unit cell dimensions	a = 8.6949(2) Å	α = 90°
	b = 11.6143(3) Å	β = 91.655(2)°
	c = 24.1633(7) Å	γ = 90°
Volume	2439.12(11) $Å^3$	
Z	2	
Density (calculated)	1.246 g/cm^3	
Absorption coefficient	0.630 mm^{-1}	
F(000)	960	
Theta range for data collection	3.66 to 68.40°	
Index ranges	-10<=h<=10, -14<=k<=14, -29<=l<=27	
Reflections collected	35837	
Independent reflections	8101 [R(int) = 0.0745]	
Coverage of independent reflections	99.8%	

Absorption correction	Multi-Scan
Structure solution technique	direct methods
Structure solution program	SHELXT 2014/5 (Sheldrick, 2014)
Refinement method	Full-matrix least-squares on F^2
Refinement program	SHELXL-2016/6 (Sheldrick, 2016)
Function minimized	$\Sigma\, w(F_o^2 - F_c^2)^2$
Data / restraints / parameters	8101 / 2 / 634
Goodness-of-fit on F^2	1.033
Final R indices	5764 data; I>2σ(I) R1 = 0.0537, wR2 = 0.1246
	all data R1 = 0.0798, wR2 = 0.1470
Weighting scheme	$w=1/[\sigma^2(F_o^2) +(0.0674P)^2+0.1858P]$
	where $P=(F_o^2+2F_c^2)/3$
Absolute structure parameter	0.5(3)
Extinction coefficient	0.0069(5)
Largest diff. peak and hole	0.188 and -0.155 eÅ^{-3}
R.M.S. deviation from mean	0.046 eÅ^{-3}

To a 10 mL tube containing **14** (30.0 mg) was added a mixture solvent (petroleum ether/ethyl acetate/methylene chloride = 1:1:2, v/v/v) (4 mL). A clear solution was obtained through ultrasound treatment and was kept at room temperature and the crystals were obtained after the solvent evaporated, which were characterized by single crystal X-ray diffraction. X-ray diffraction experiment was carried out on an Agilent D8 QUEST and the data obtained were deposited at the Cambridge Crystallographic Data Centre.



(Ellipsoid contour probability 50%)

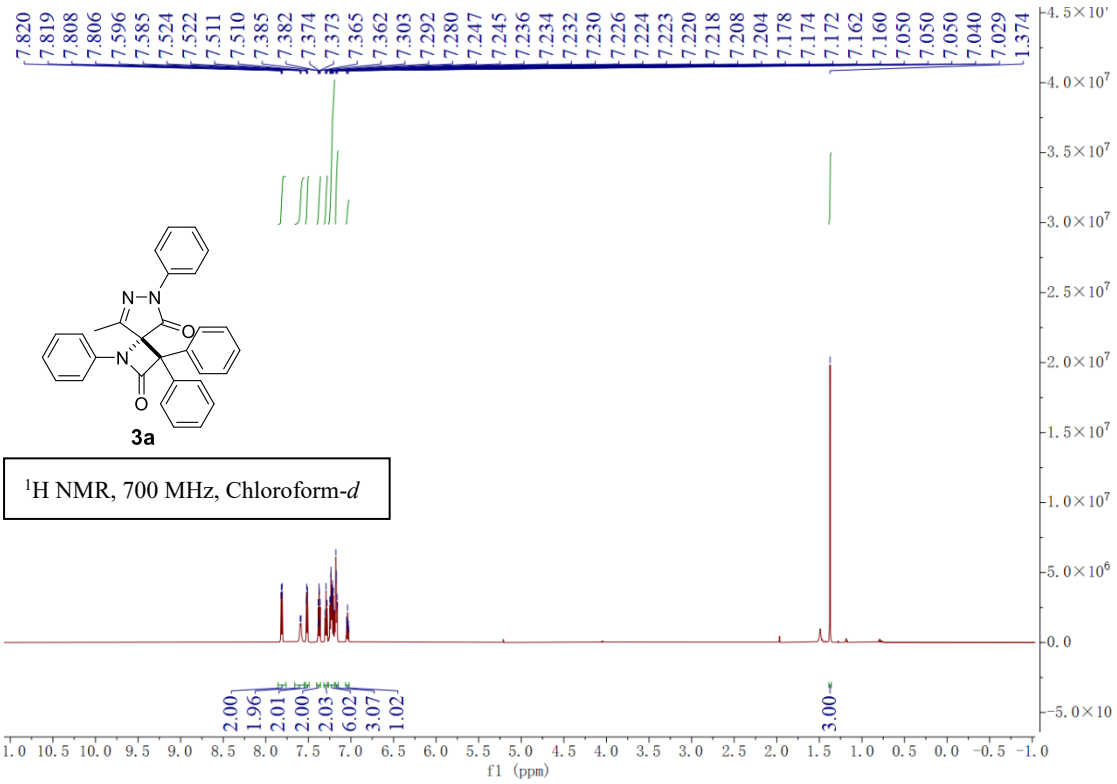


14, CCDC 2162437

Identification code	20211220zg4
Chemical formula	$C_{30}H_{23}N_3O_2$
Formula weight	457.51 g/mol
Temperature	298(2) K

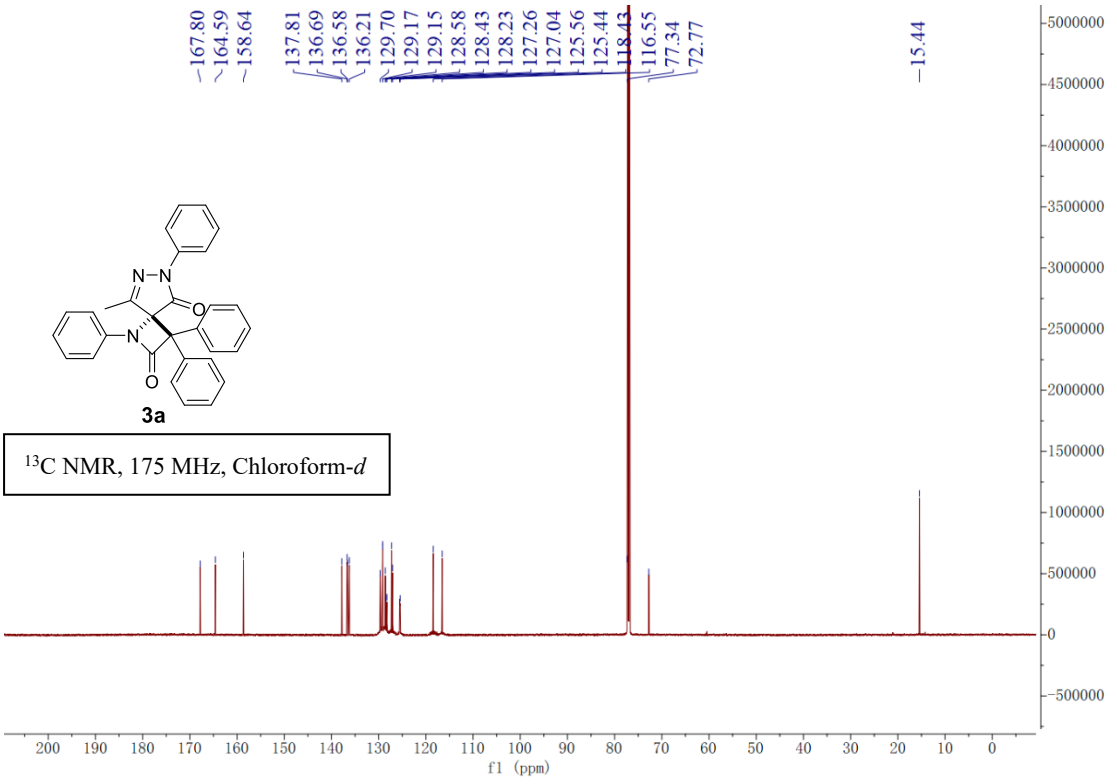
Wavelength	1.54178 Å
Crystal system	triclinic
Space group	P -1
Unit cell dimensions	a = 9.4208(3) Å α = 105.4940(10)°
	b = 11.8769(3) Å β = 94.3980(10)°
	c = 12.1636(3) Å γ = 109.4020(10)°
Volume	1216.38(6) $Å^3$
Z	2
Density (calculated)	1.249 g/cm^3
Absorption coefficient	0.631 mm^{-1}
F(000)	480
Theta range for data collection	3.83 to 68.43°
Index ranges	-11<=h<=11, -14<=k<=14, -14<=l<=14
Reflections collected	34398
Independent reflections	4462 [R(int) = 0.0599]
Structure solution technique	direct methods
Structure solution program	SHELXT 2014/5 (Sheldrick, 2014)
Refinement method	Full-matrix least-squares on F^2
Refinement program	SHELXL-2016/6 (Sheldrick, 2016)
Function minimized	Σ w (F_o2 - F_c^2)2
Data / restraints / parameters	4462 / 0 / 317
Goodness-of-fit on F2	1.043
Final R indices	3390 data; I>2σ(I) R1 = 0.0488, wR2 = 0.1282
	all data R1 = 0.0649, wR2 = 0.1441
Weighting scheme	$w=1/[\sigma^2(F_o^2) + (0.0763P)^2+0.1803P]$
	where $P=(F_o^2+2F_c^2)/3$
Largest diff. peak and hole	0.217 and -0.190 $eÅ^{-3}$
R.M.S. deviation from mean	0.038 $eÅ^{-3}$

9. ^{1}H NMR and ^{13}C NMR spectra



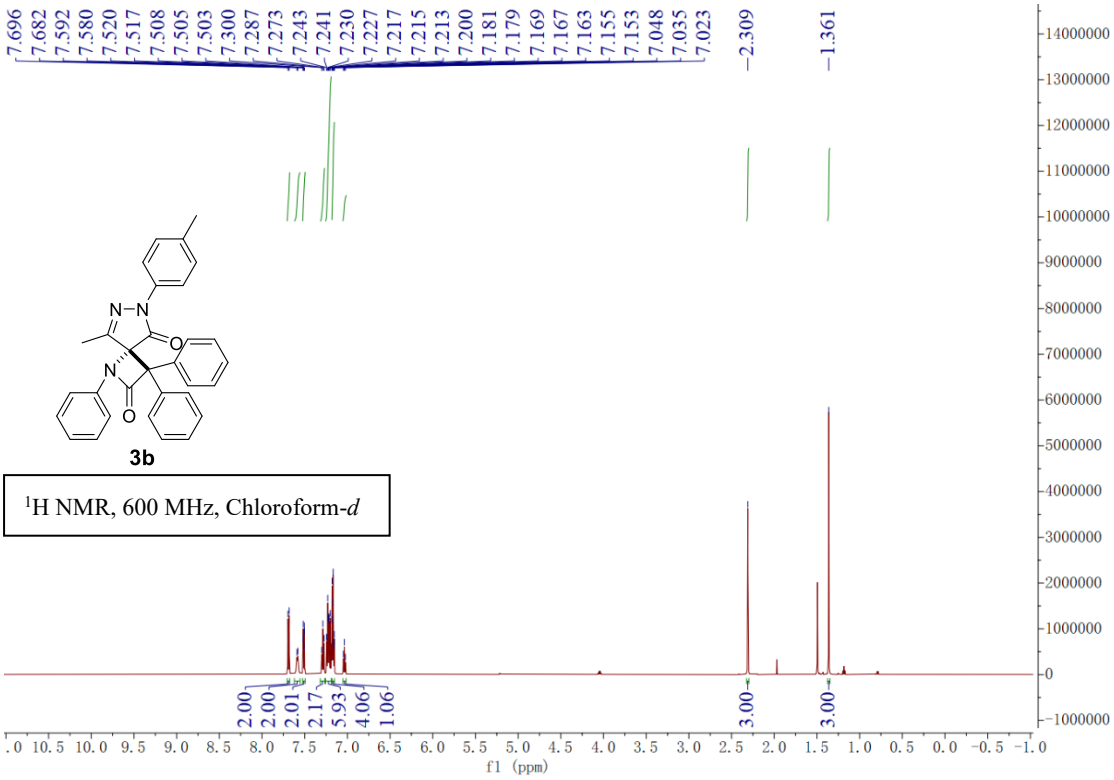
3a

^{1}H NMR, 700 MHz, Chloroform-*d*



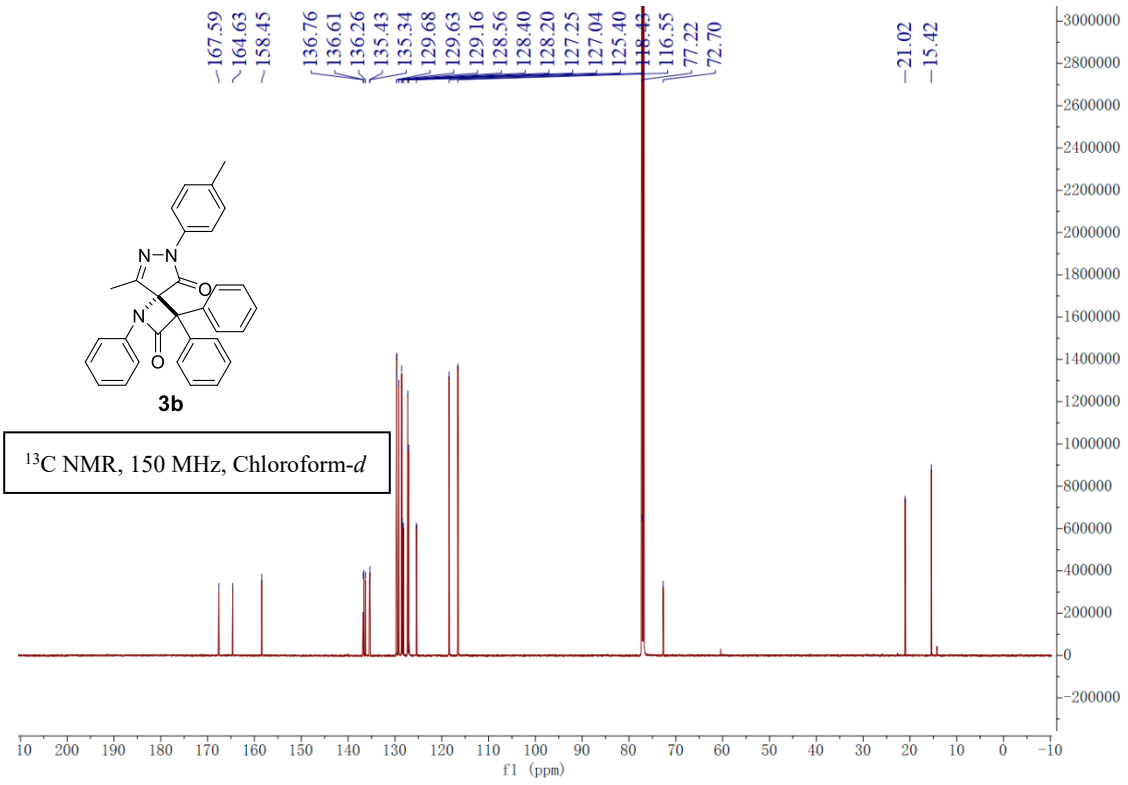
3a

^{13}C NMR, 175 MHz, Chloroform-*d*



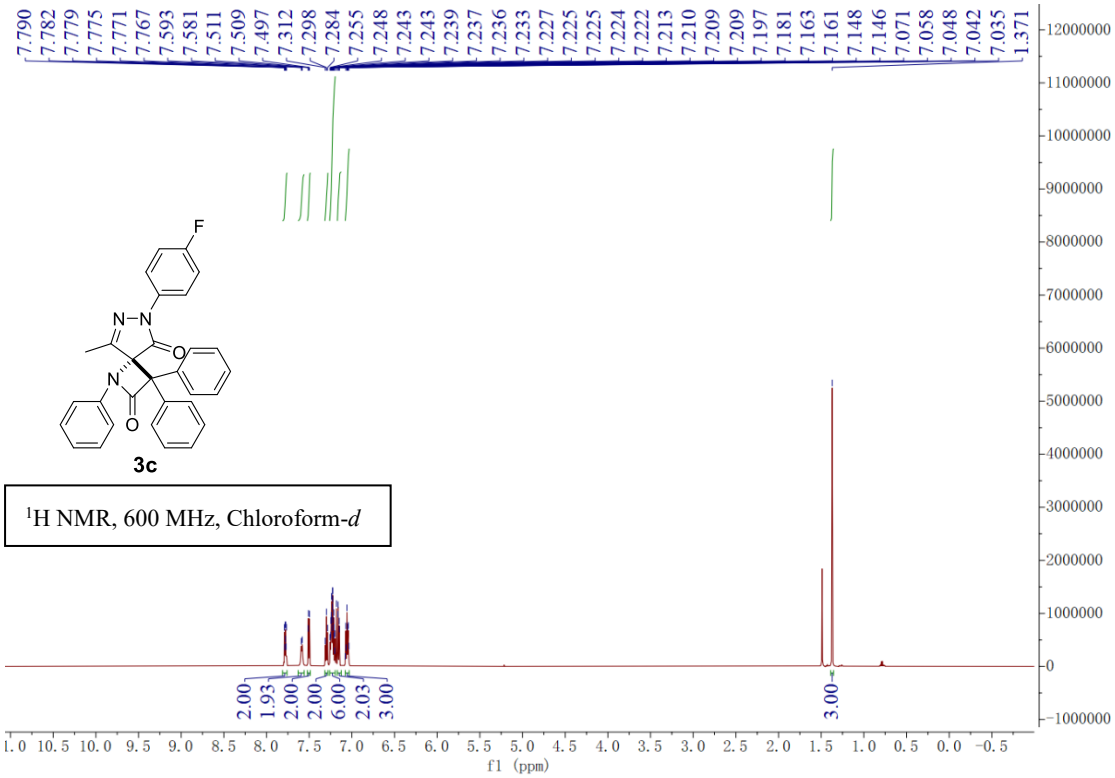
3b

^{1}H NMR, 600 MHz, Chloroform-*d*

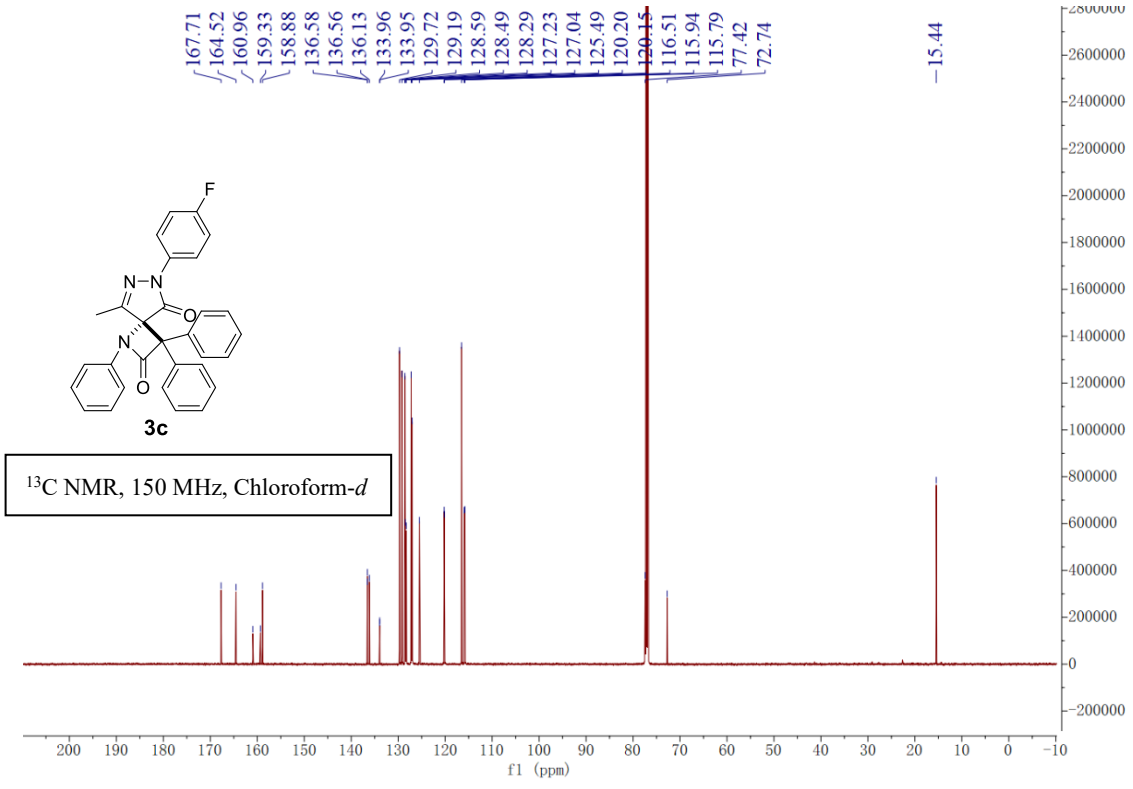


3b

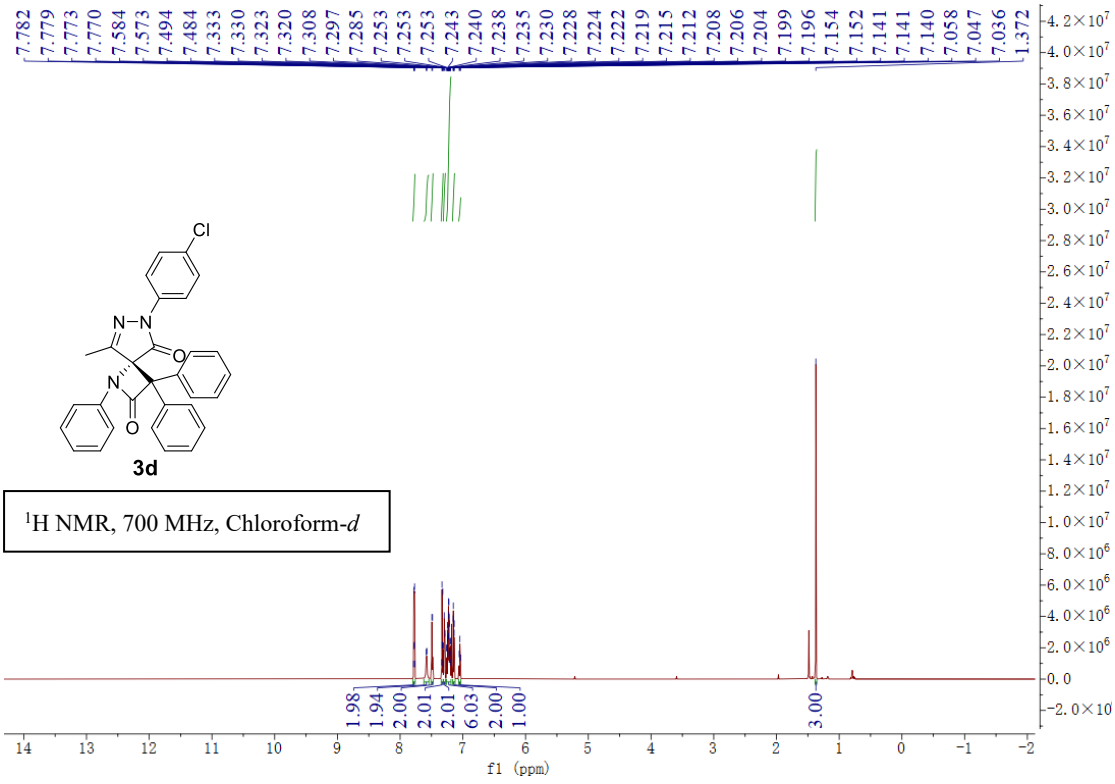
^{13}C NMR, 150 MHz, Chloroform-*d*

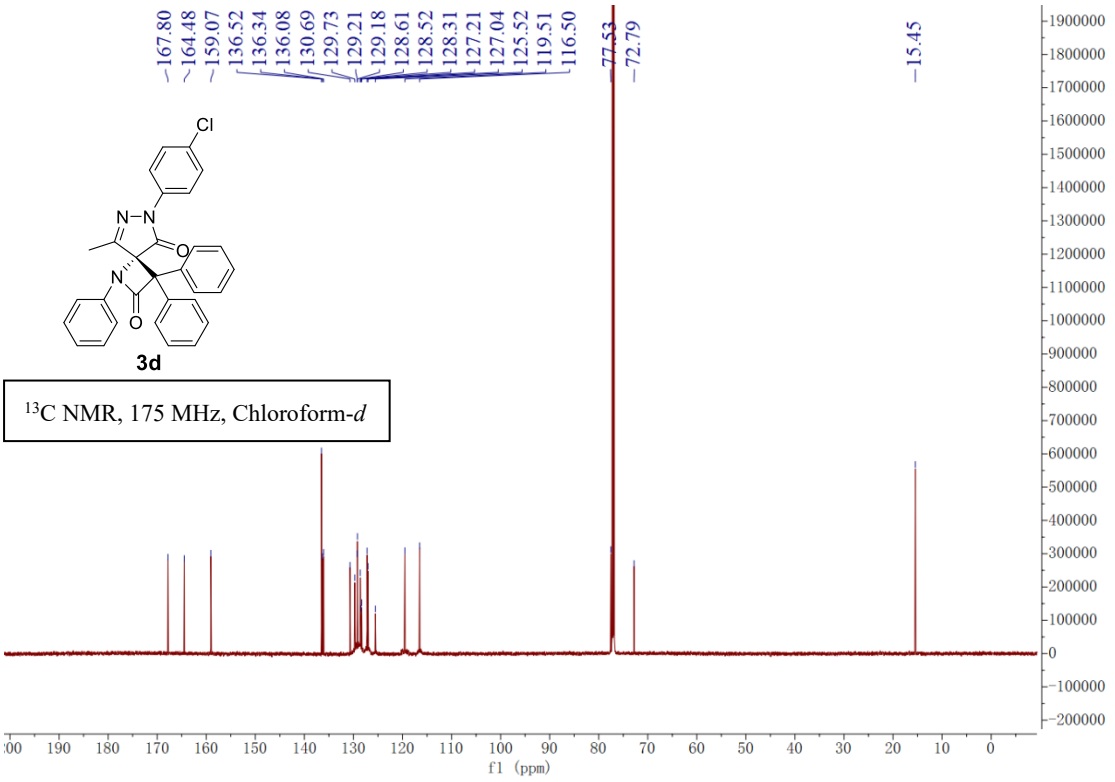


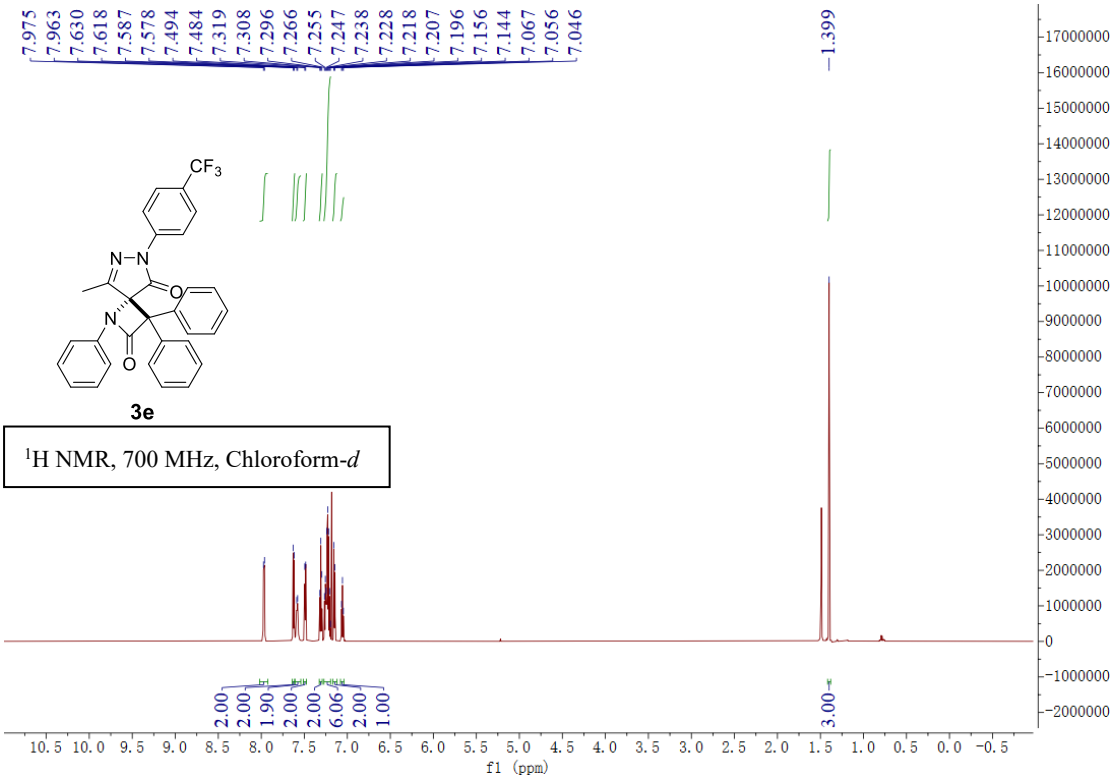
^{1}H NMR, 600 MHz, Chloroform-*d*



^{13}C NMR, 150 MHz, Chloroform-*d*

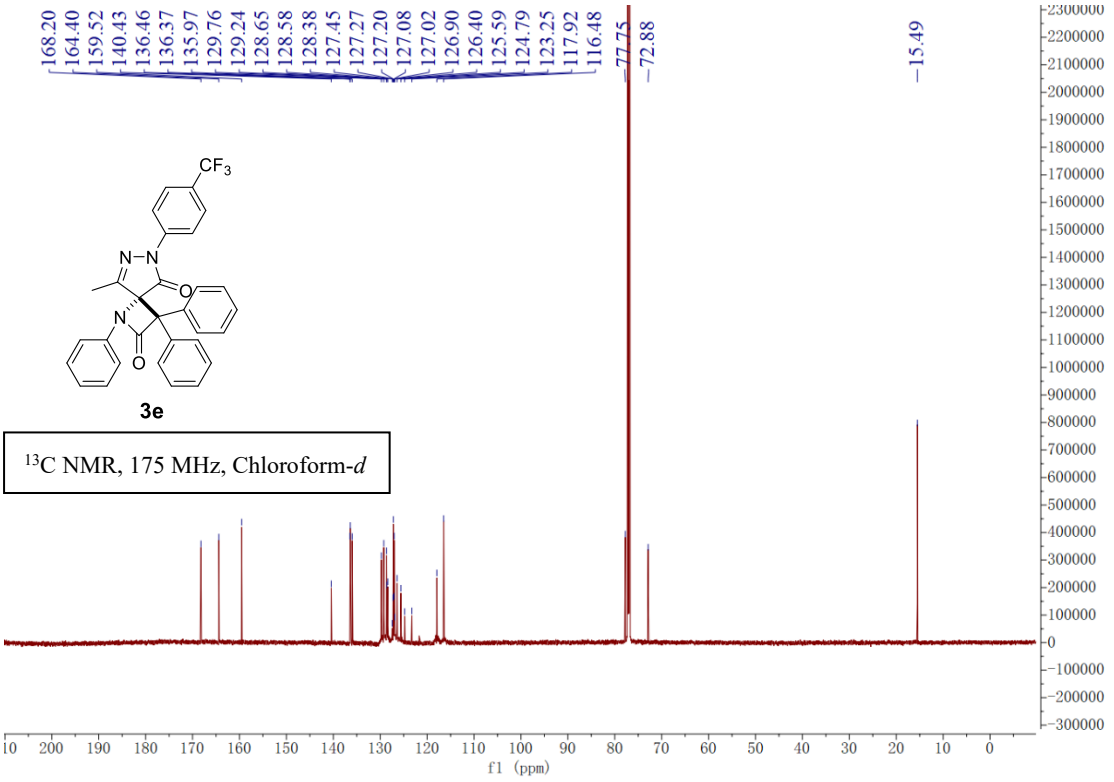

7.782
7.779
7.773
7.770
7.584
7.573
7.494
7.484
7.333
7.330
7.323
7.320
7.308
7.297
7.285
7.253
7.253
7.253
7.243
7.240
7.238
7.235
7.230
7.228
7.224
7.222
7.219
7.215
7.212
7.208
7.206
7.204
7.199
7.196
7.154
7.152
7.141
7.141
7.140
7.058
7.047
7.036
1.372
Cl
N
O
3d
1H NMR, 700 MHz, Chloroform-d
1.98
1.94
2.00
2.01
2.01
6.03
2.00
1.00
3.00
f1 (ppm)


167.80
164.48
159.07
136.52
136.34
136.08
130.69
129.73
129.21
129.18
128.61
128.52
128.31
127.21
127.04
125.52
119.51
116.50
77.53
72.79
15.45
Cl
N
O
3d
13C NMR, 175 MHz, Chloroform-d
f1 (ppm)



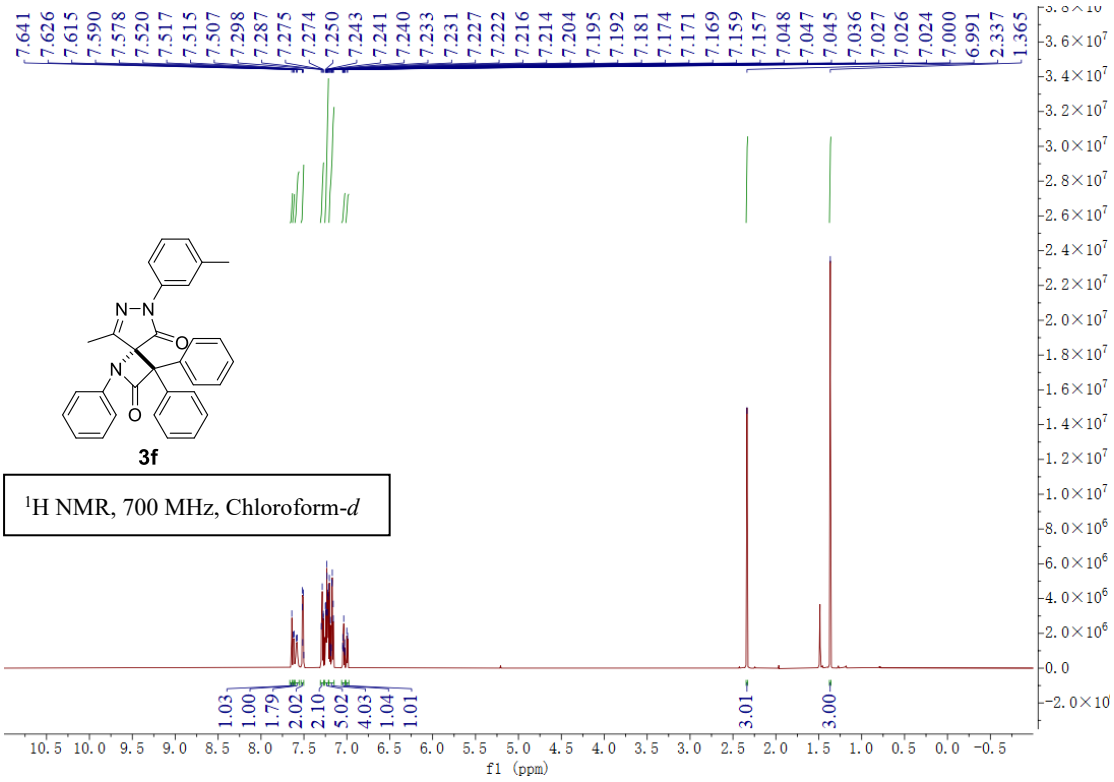
3e

^{1}H NMR, 700 MHz, Chloroform-*d*



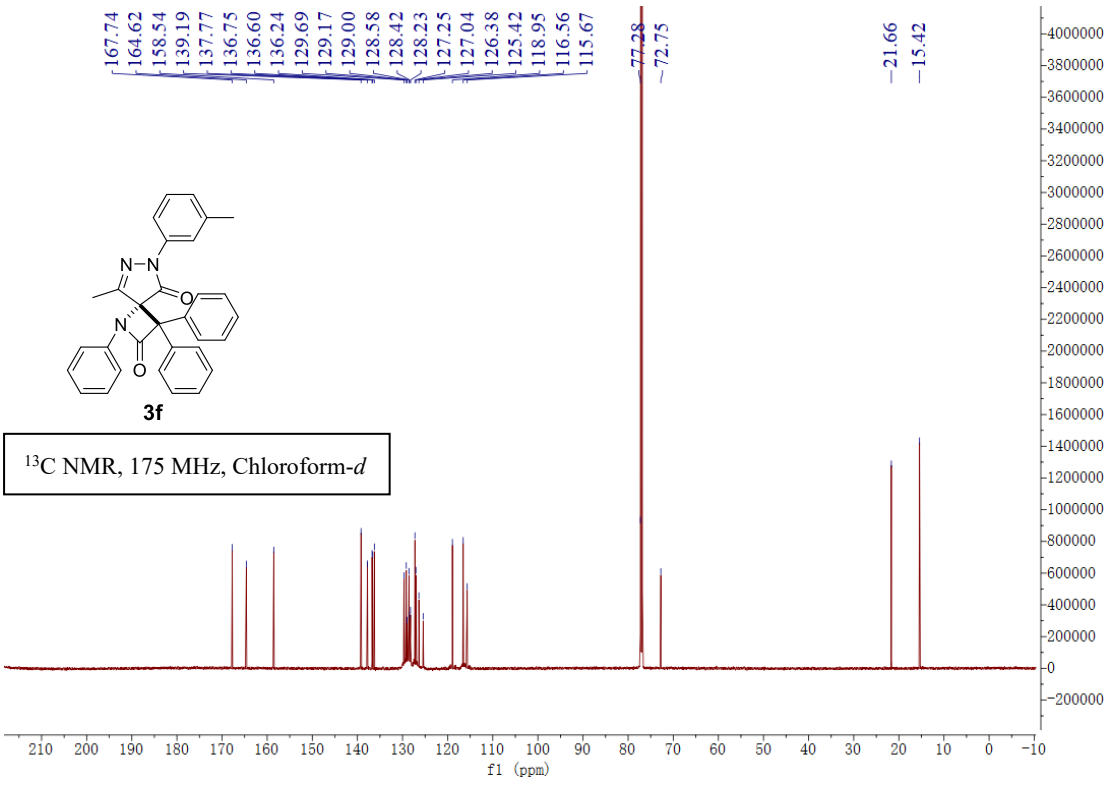
3e

^{13}C NMR, 175 MHz, Chloroform-*d*



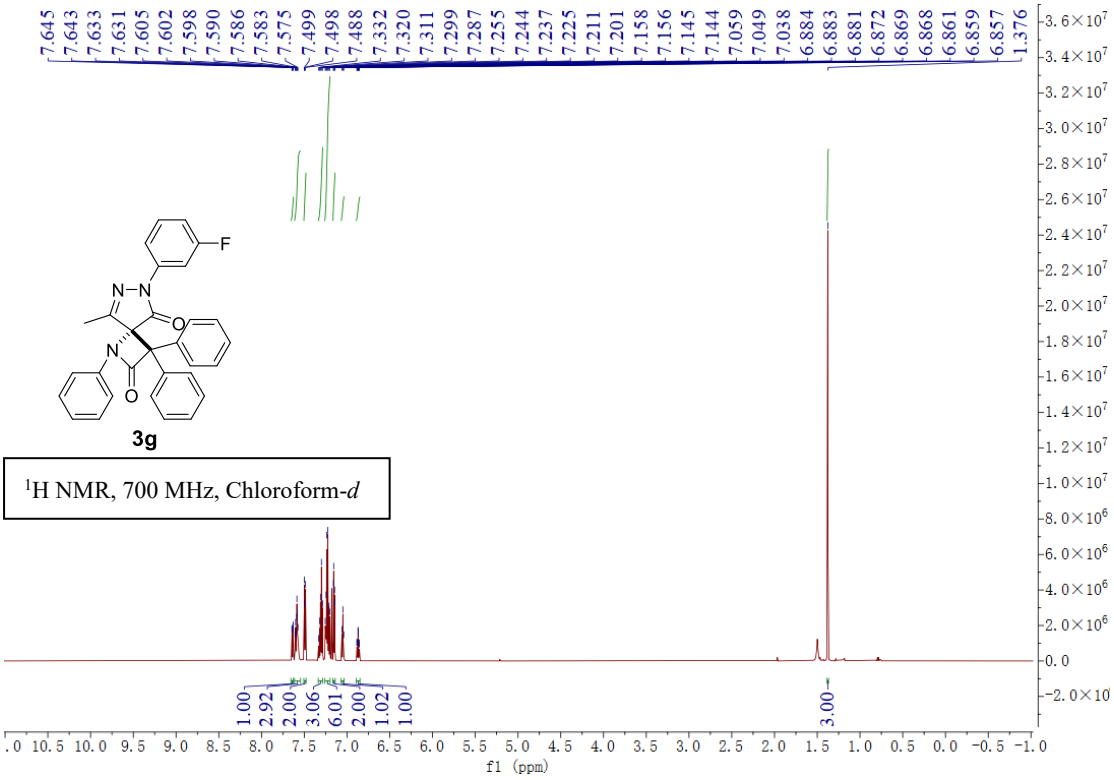
3f

^{1}H NMR, 700 MHz, Chloroform-*d*



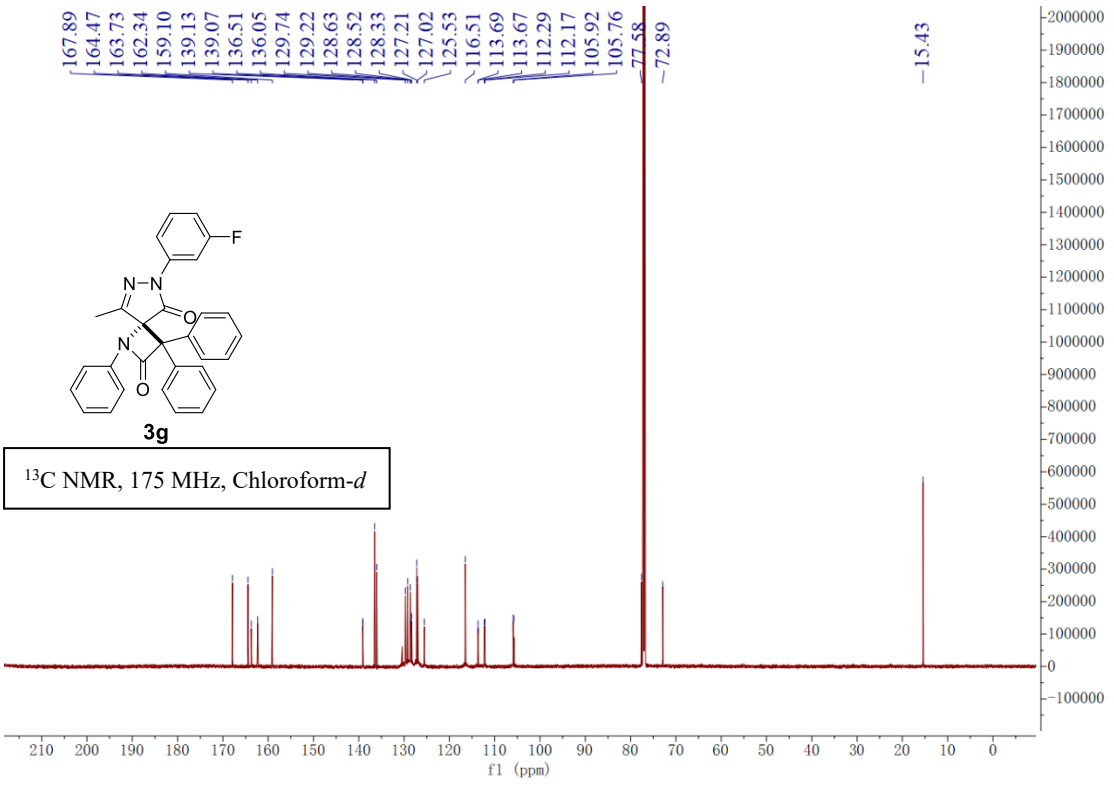
3f

^{13}C NMR, 175 MHz, Chloroform-*d*



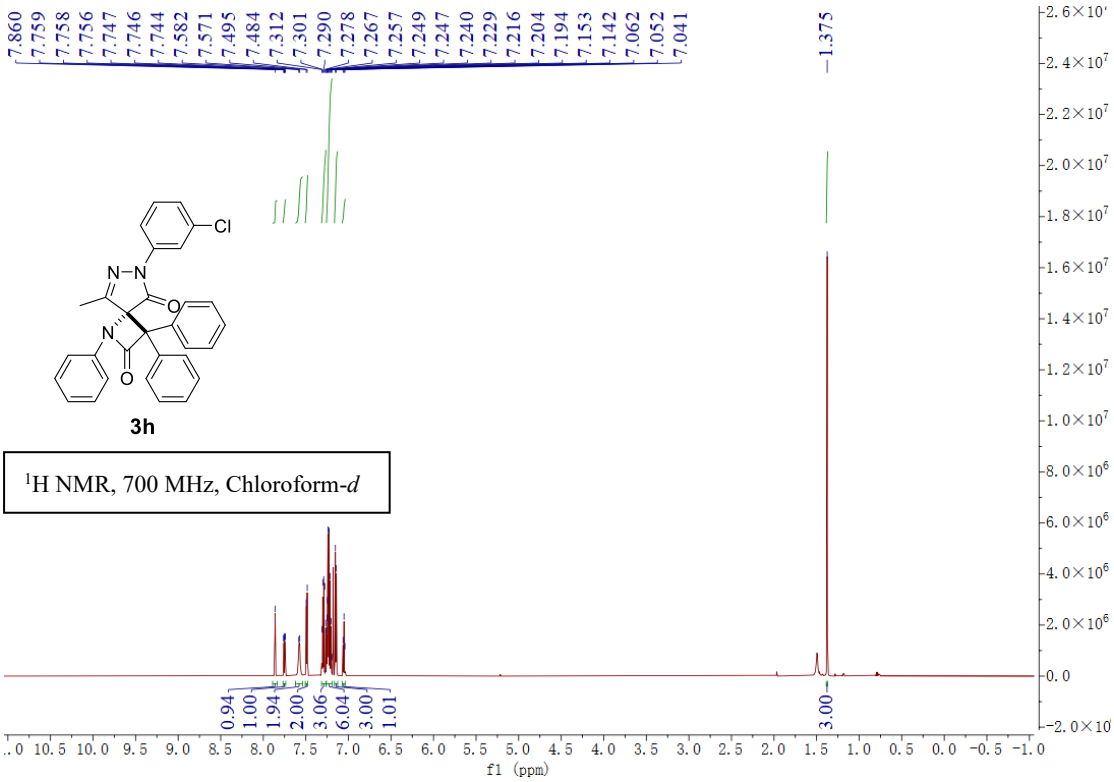
3g

^{1}H NMR, 700 MHz, Chloroform-*d*



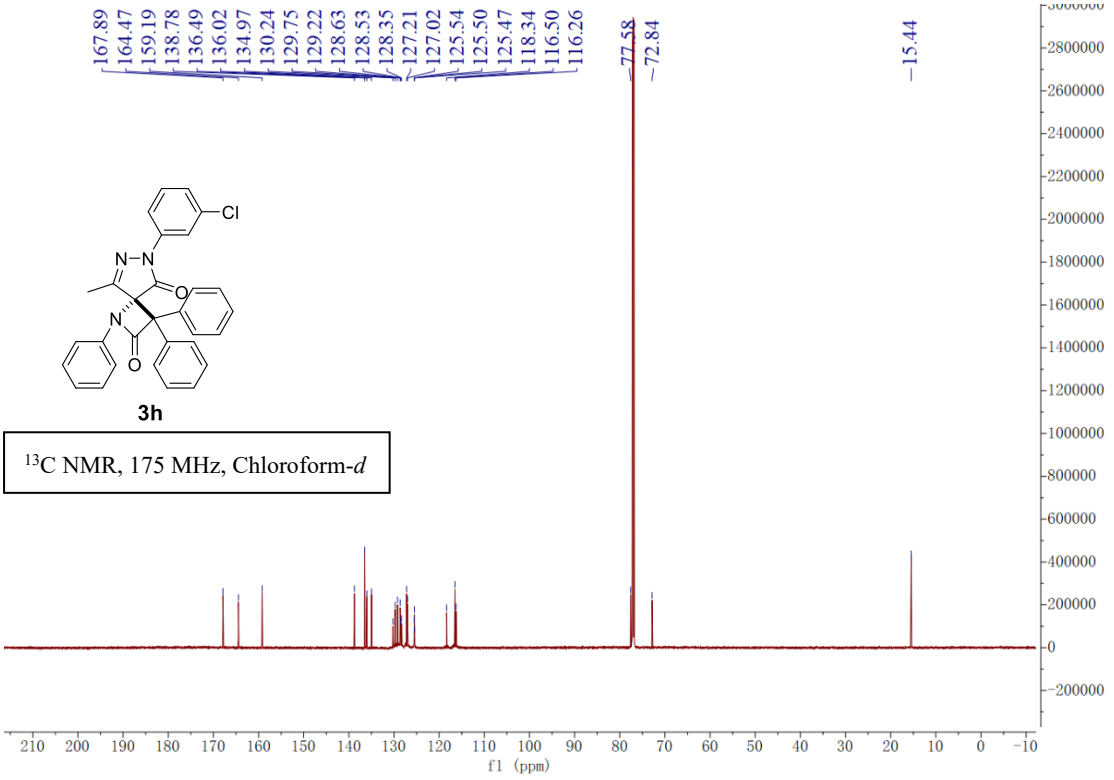
3g

^{13}C NMR, 175 MHz, Chloroform-*d*



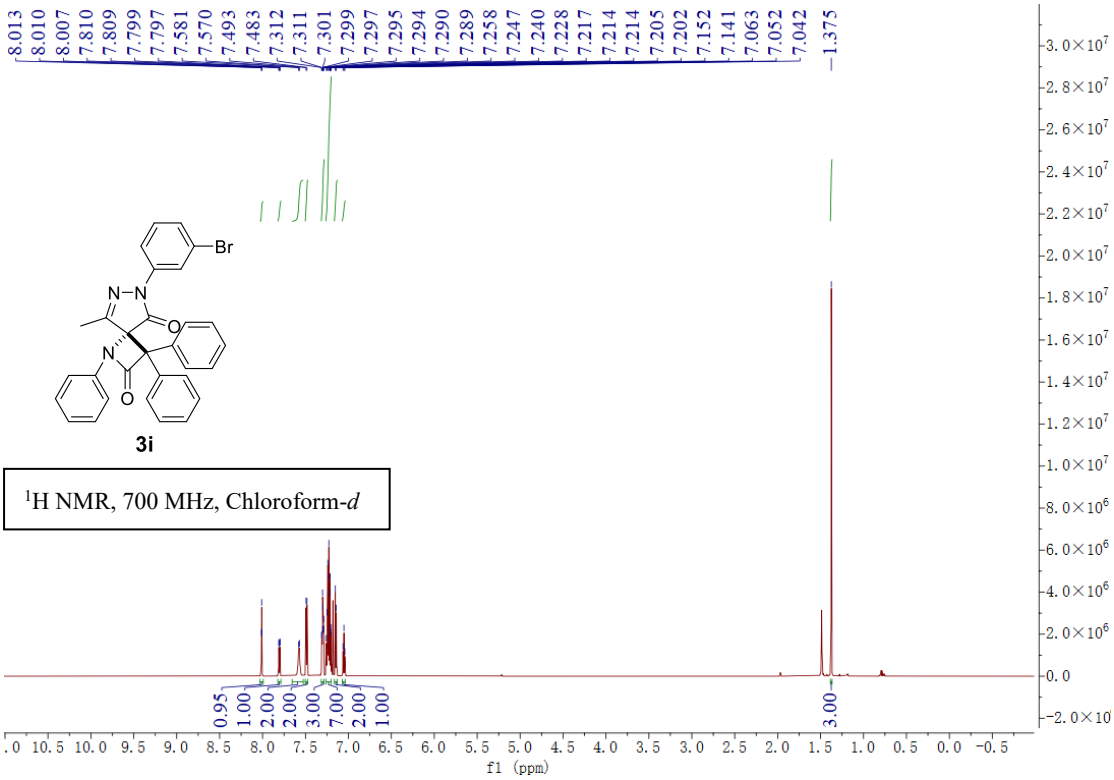
3h

^{1}H NMR, 700 MHz, Chloroform-*d*



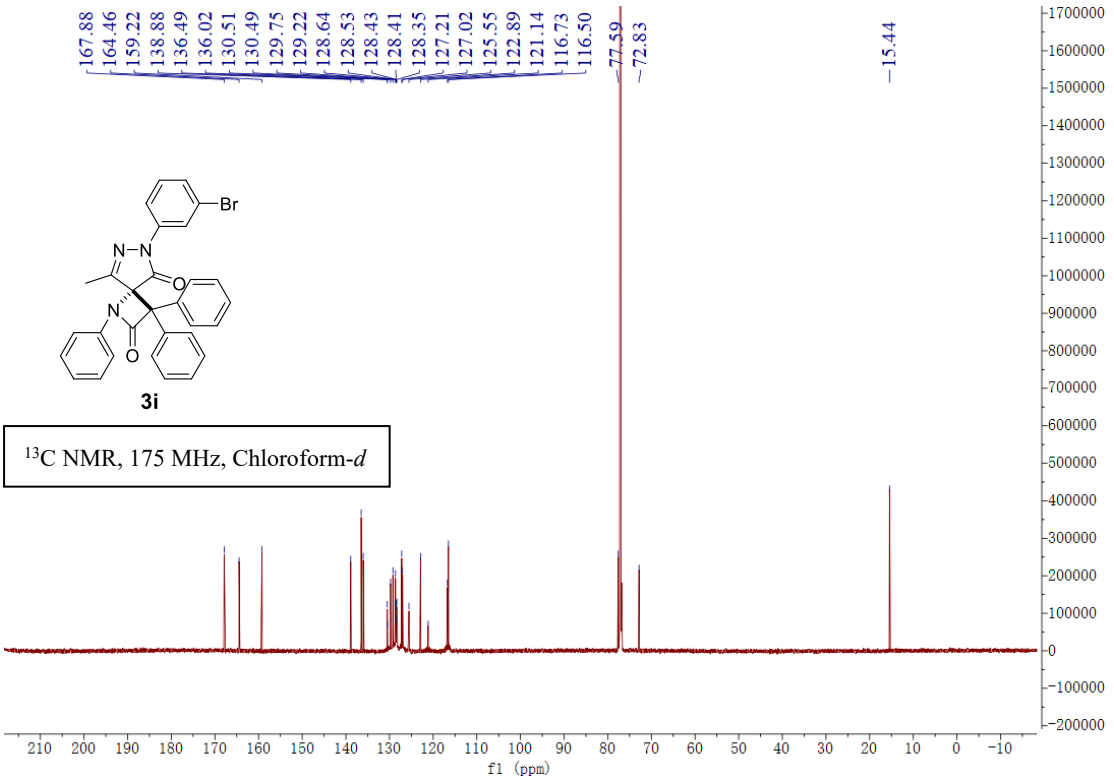
3h

^{13}C NMR, 175 MHz, Chloroform-*d*



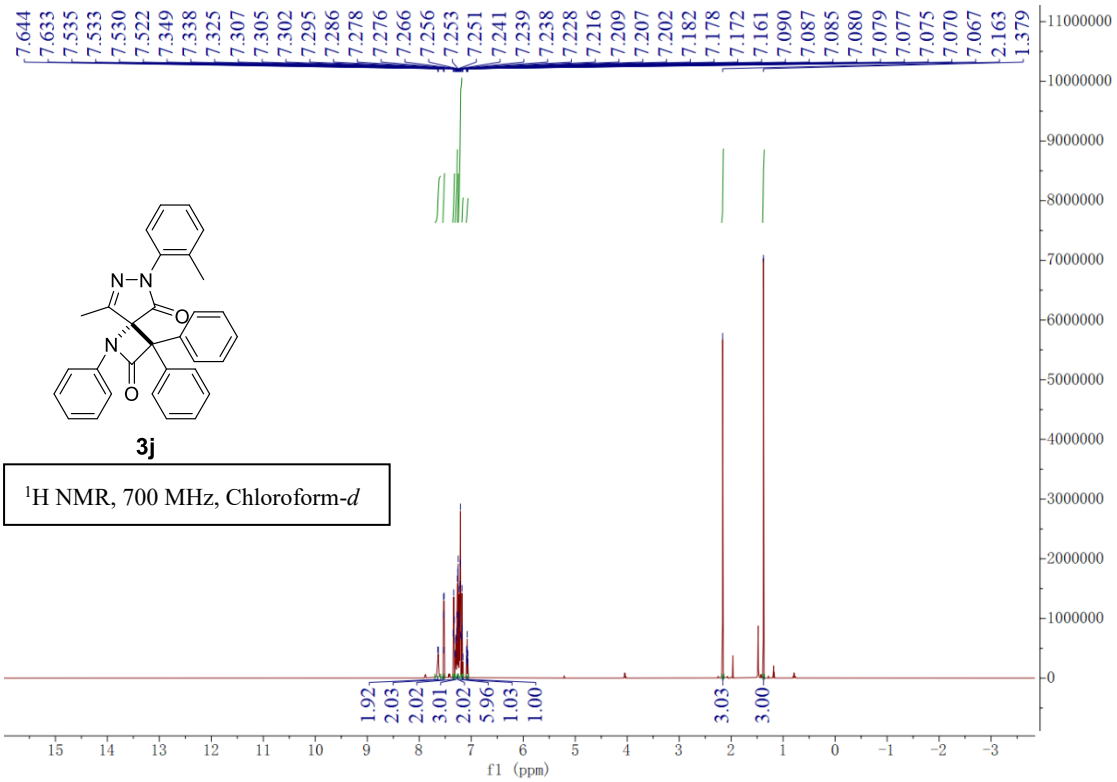
3i

^{1}H NMR, 700 MHz, Chloroform-*d*



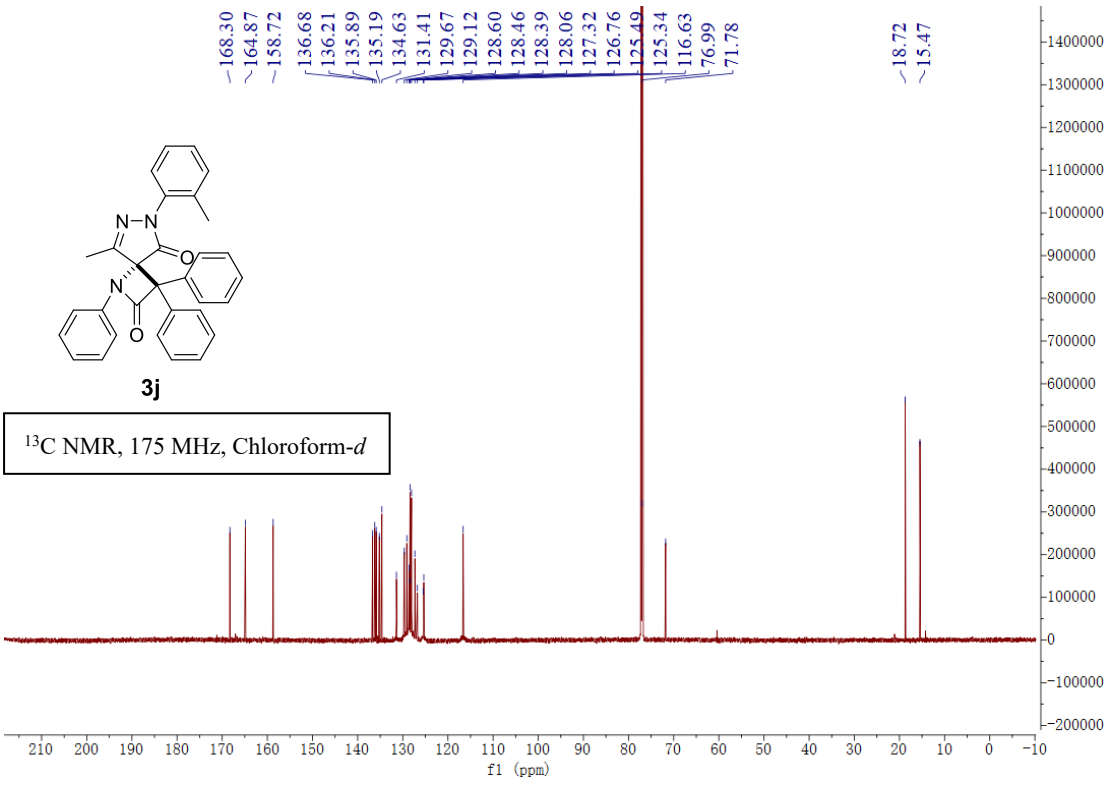
3i

^{13}C NMR, 175 MHz, Chloroform-*d*



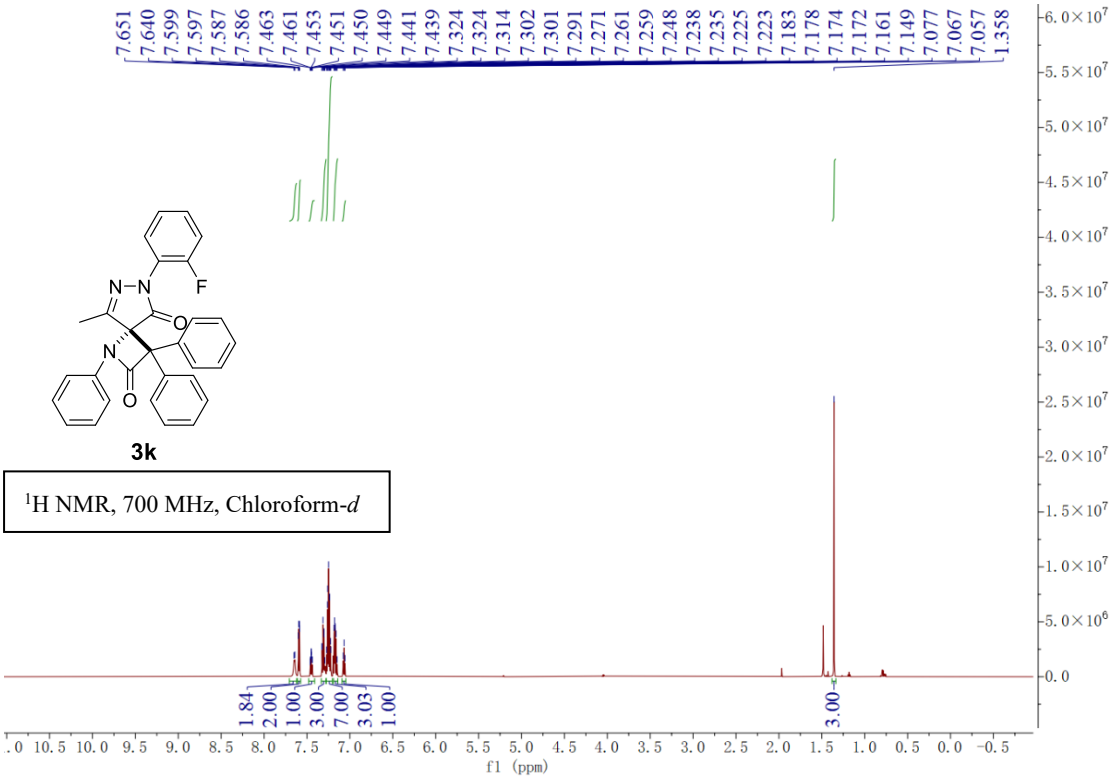
3j

^{1}H NMR, 700 MHz, Chloroform-*d*



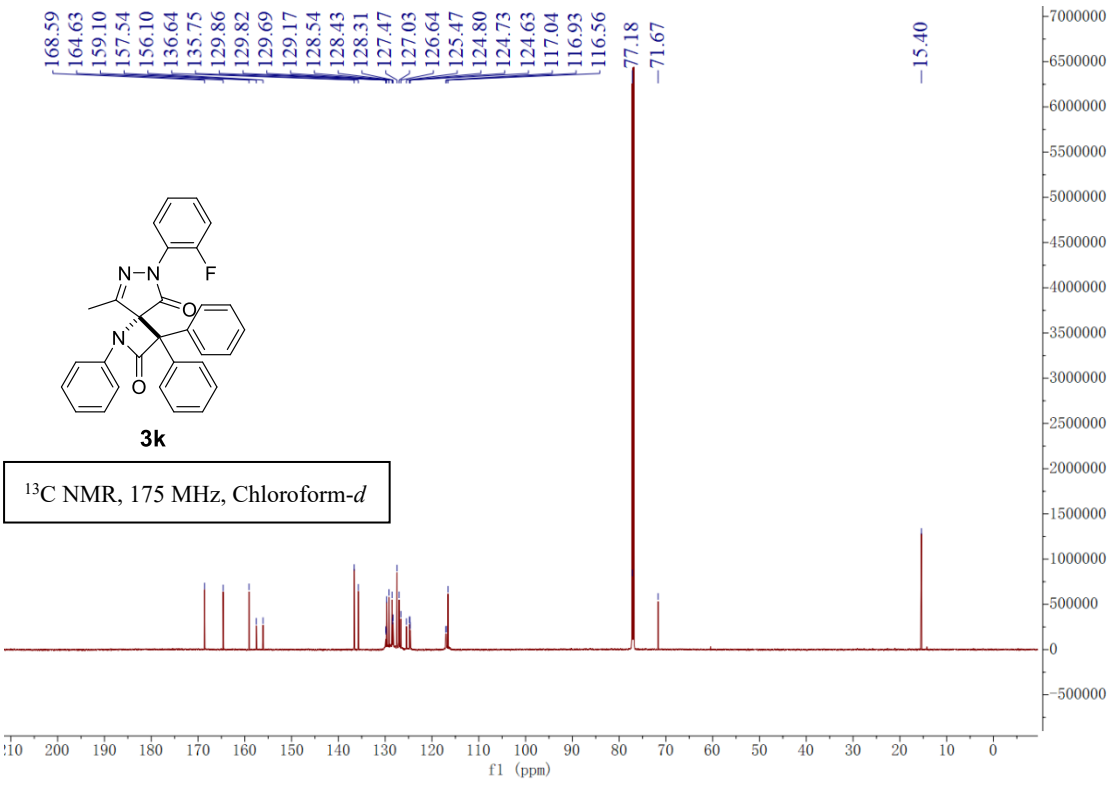
3j

^{13}C NMR, 175 MHz, Chloroform-*d*



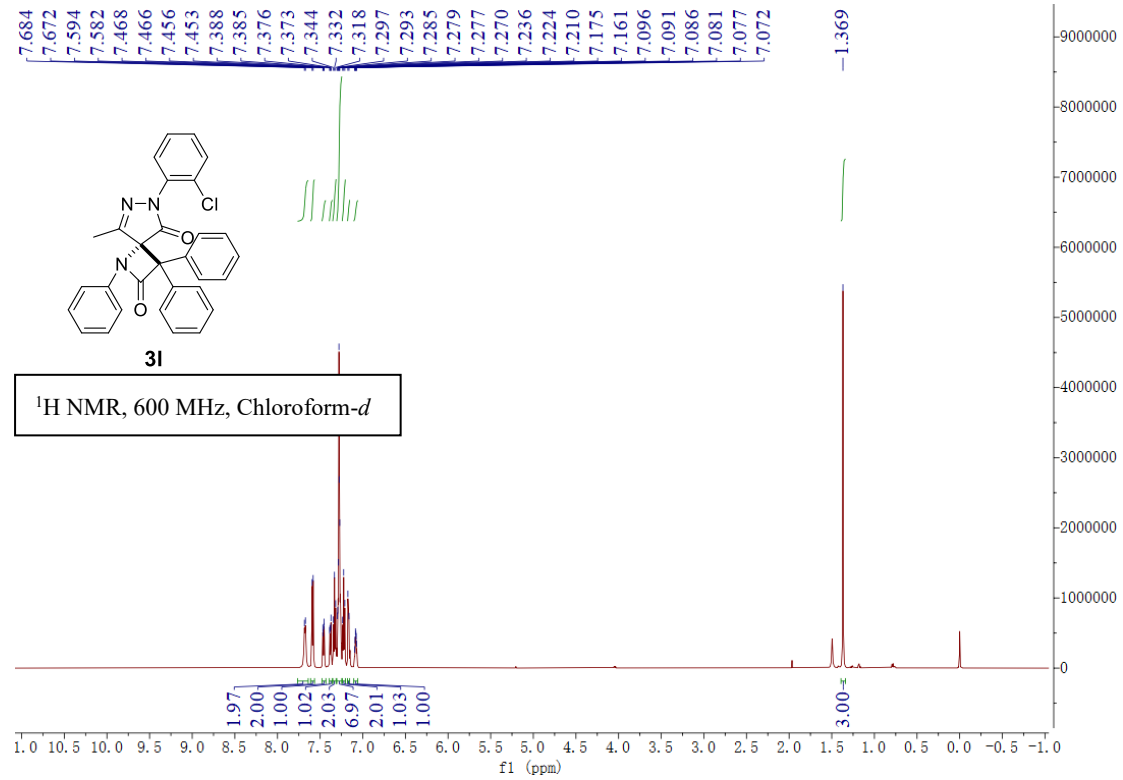
3k

^{1}H NMR, 700 MHz, Chloroform-*d*



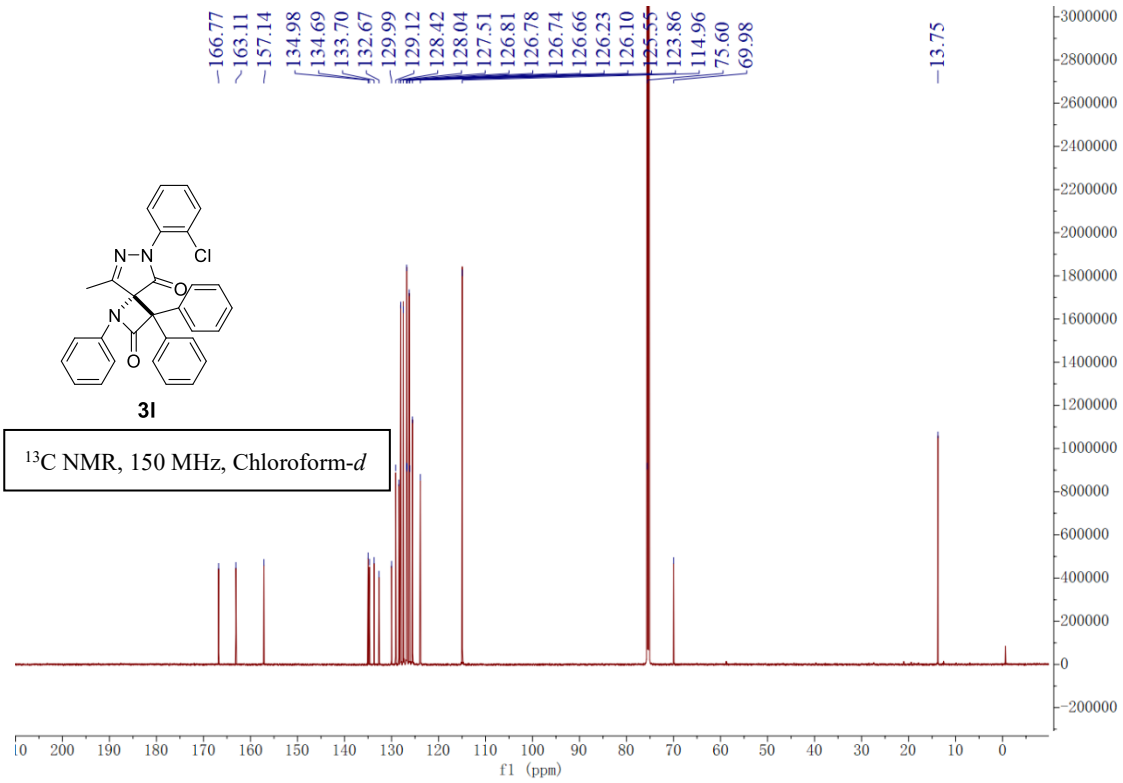
3k

^{13}C NMR, 175 MHz, Chloroform-*d*



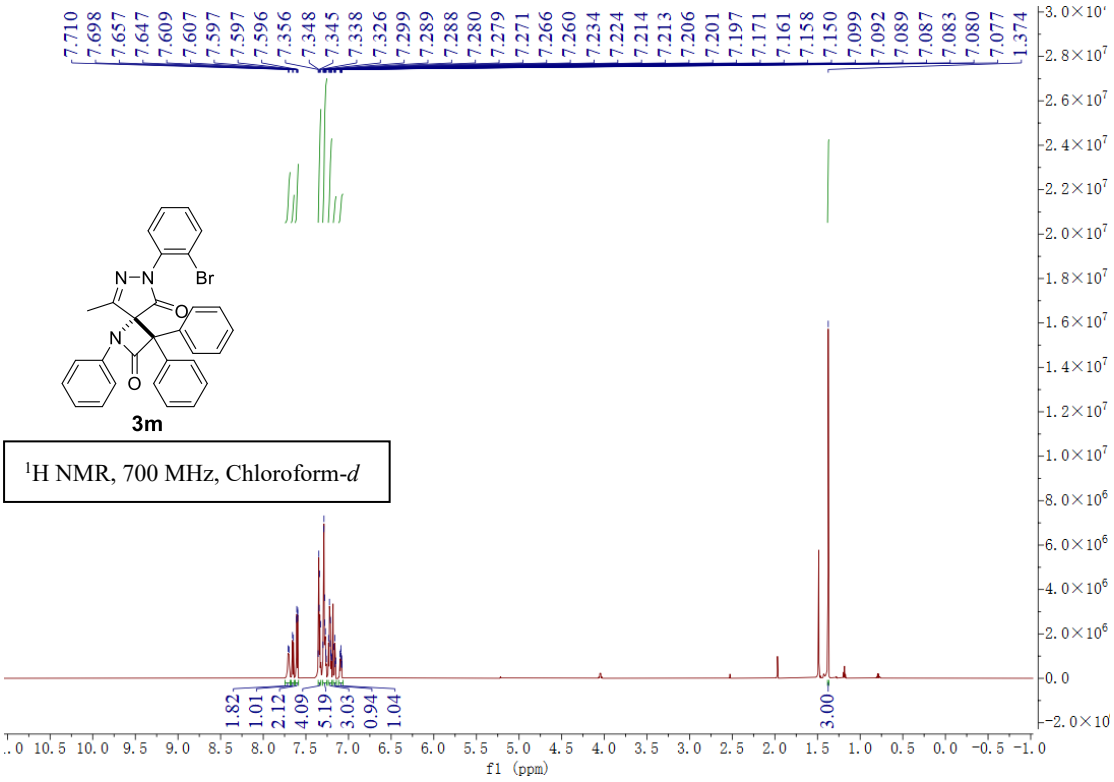
3l

^{1}H NMR, 600 MHz, Chloroform-*d*



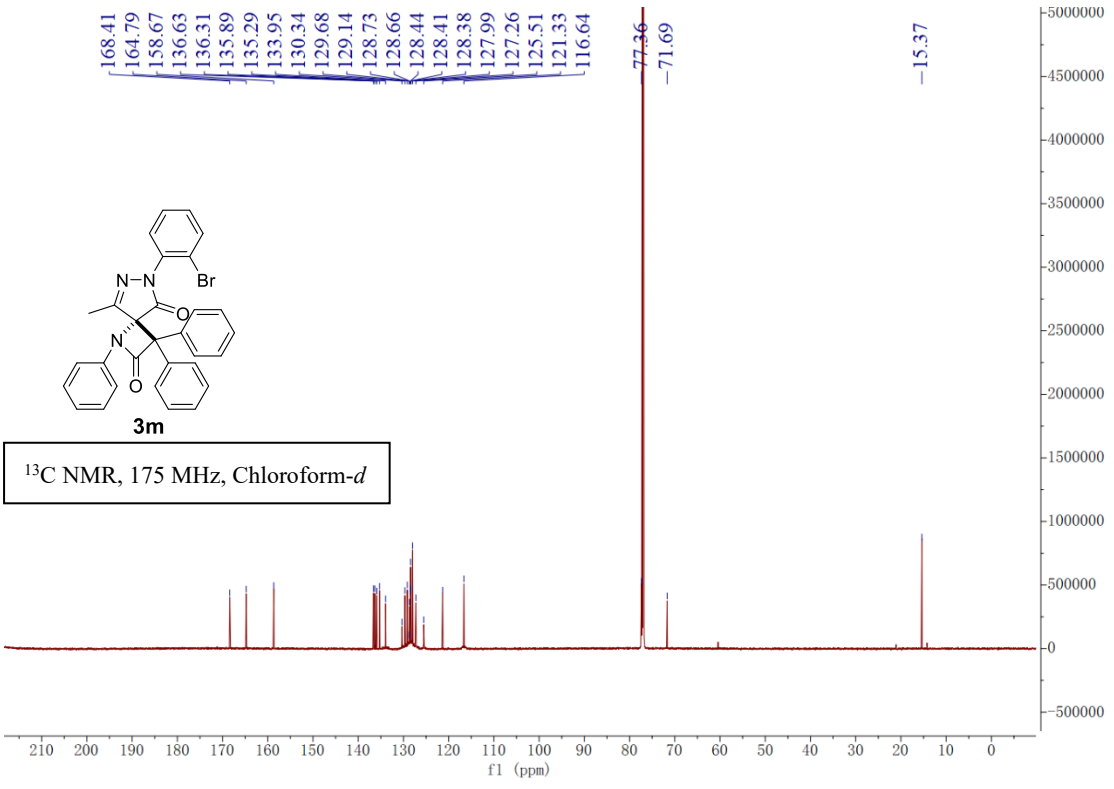
3l

^{13}C NMR, 150 MHz, Chloroform-*d*



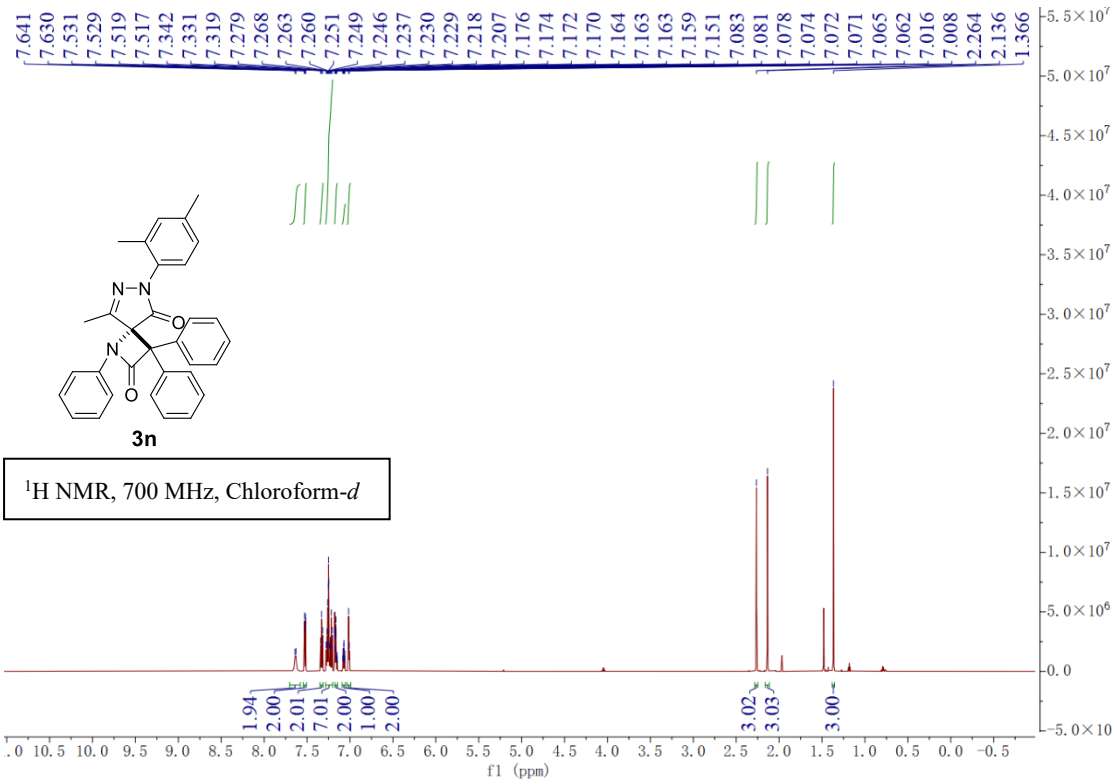
3m

^{1}H NMR, 700 MHz, Chloroform-*d*



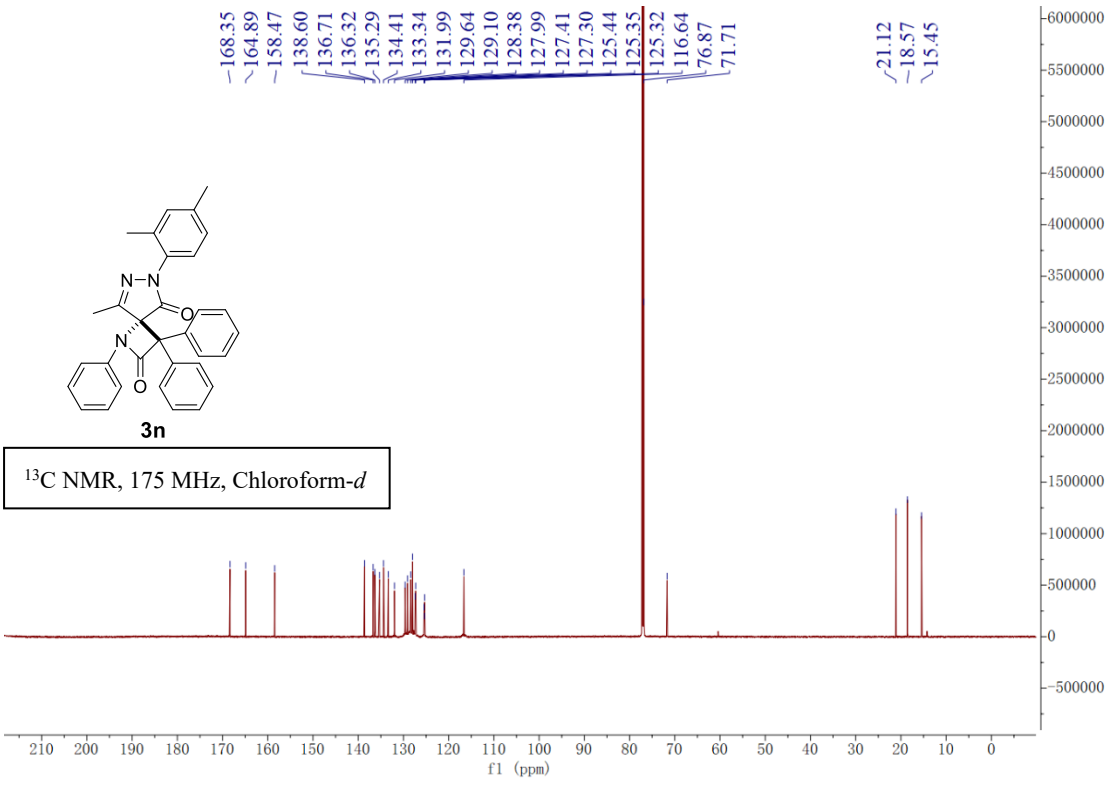
3m

^{13}C NMR, 175 MHz, Chloroform-*d*



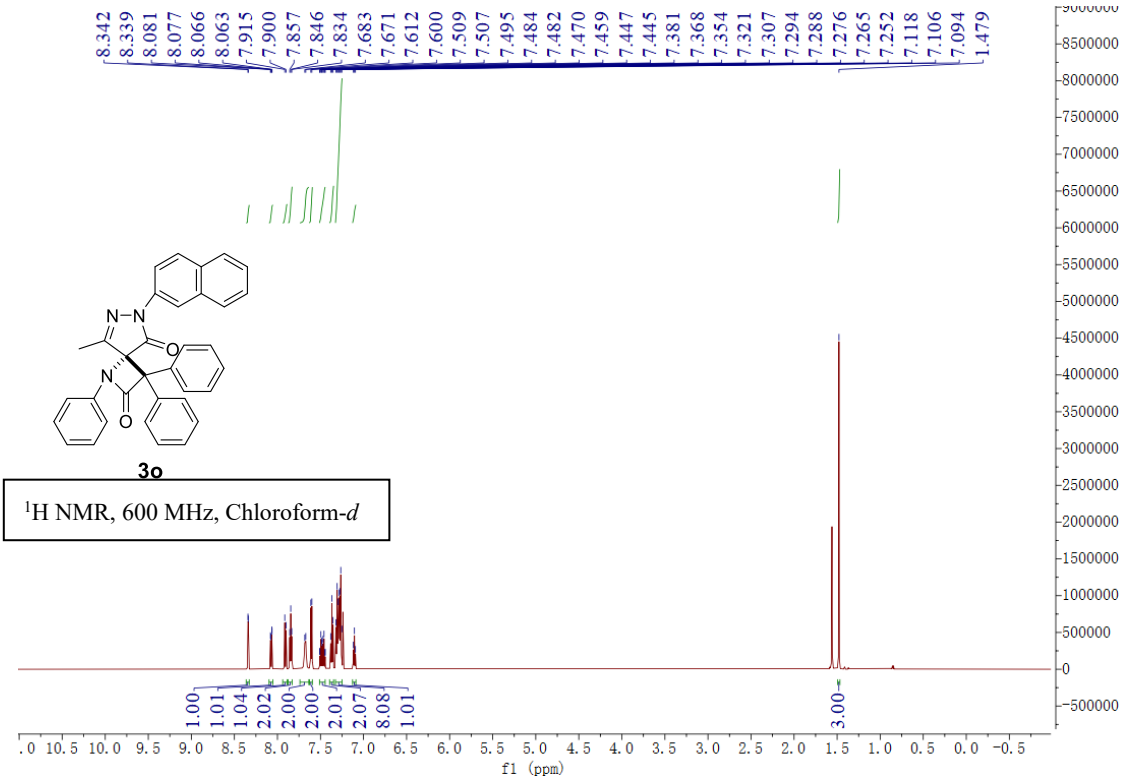
3n

^{1}H NMR, 700 MHz, Chloroform-*d*



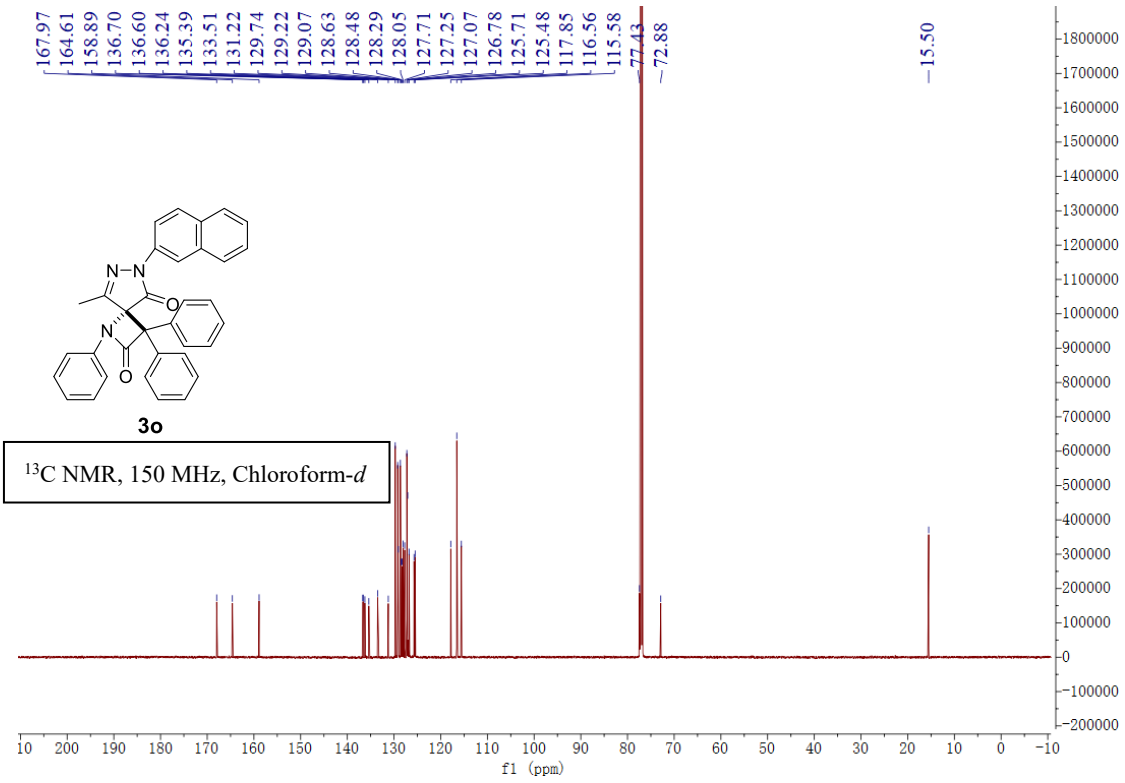
3n

^{13}C NMR, 175 MHz, Chloroform-*d*



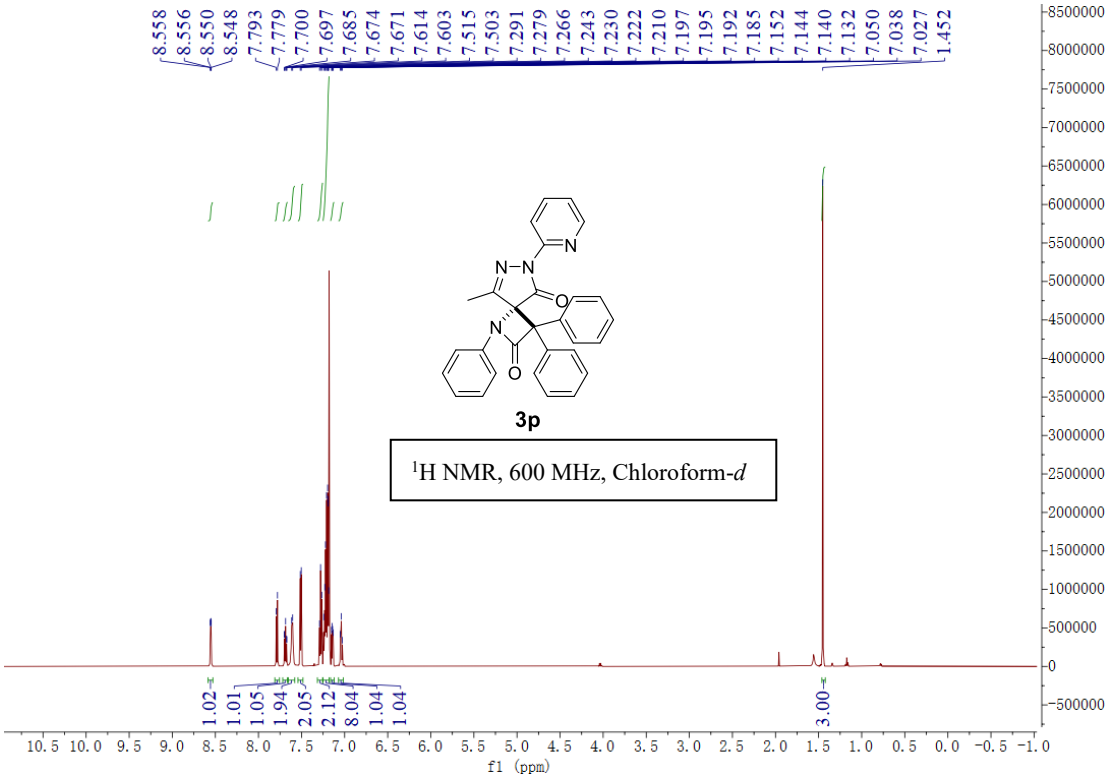
3o

^{1}H NMR, 600 MHz, Chloroform-*d*



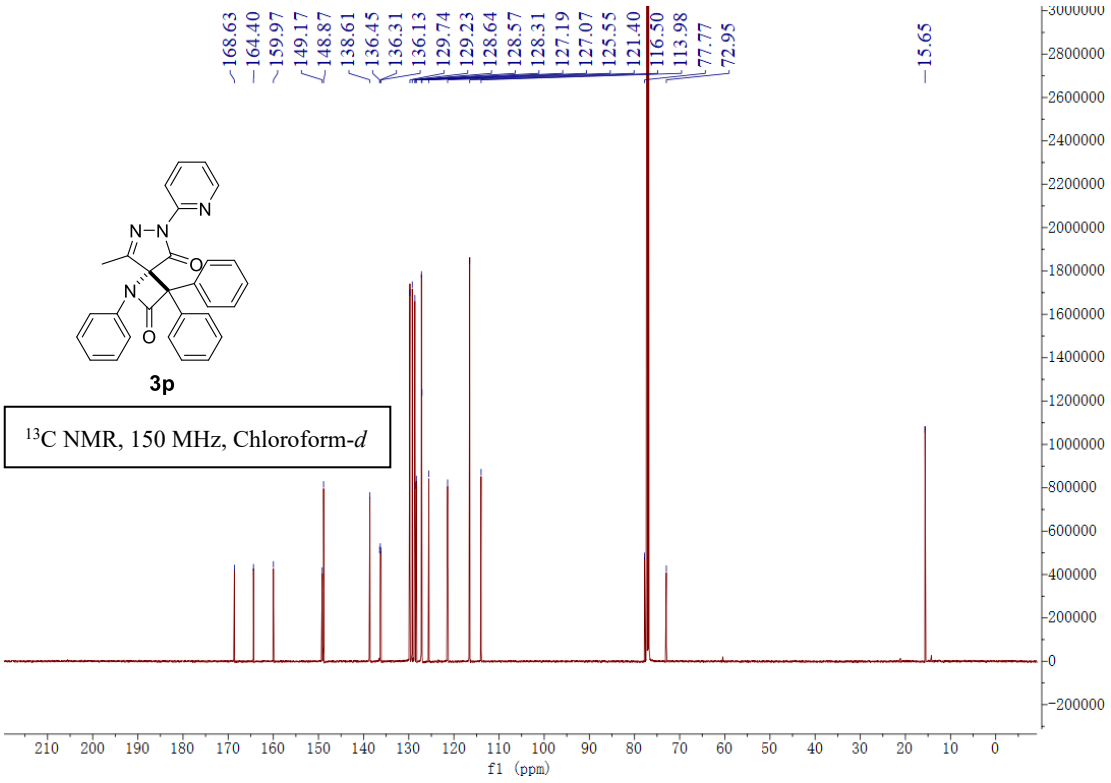
3o

^{13}C NMR, 150 MHz, Chloroform-*d*



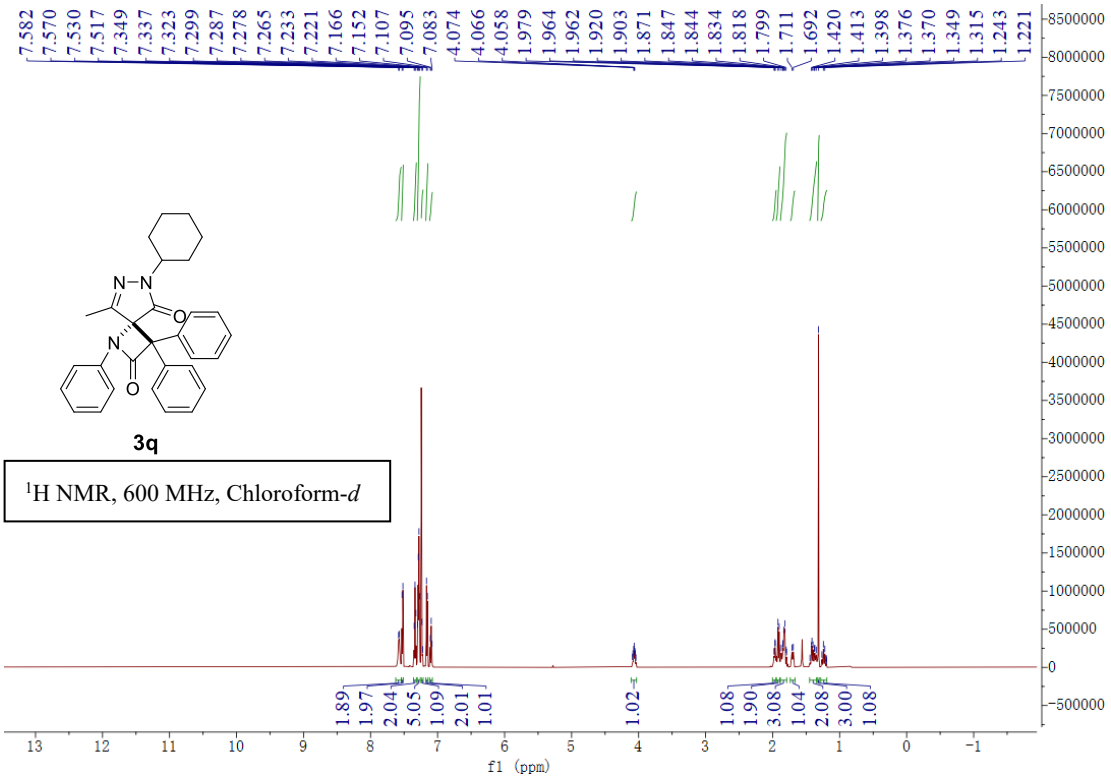
3p

^{1}H NMR, 600 MHz, Chloroform-*d*



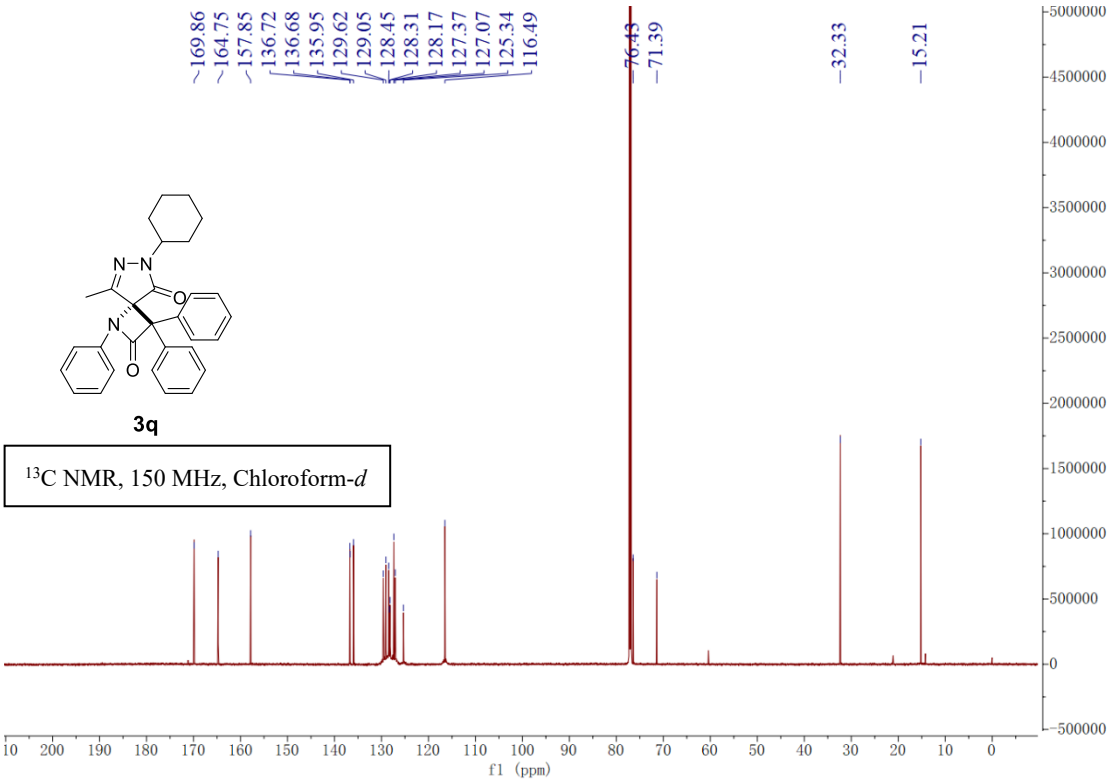
3p

^{13}C NMR, 150 MHz, Chloroform-*d*



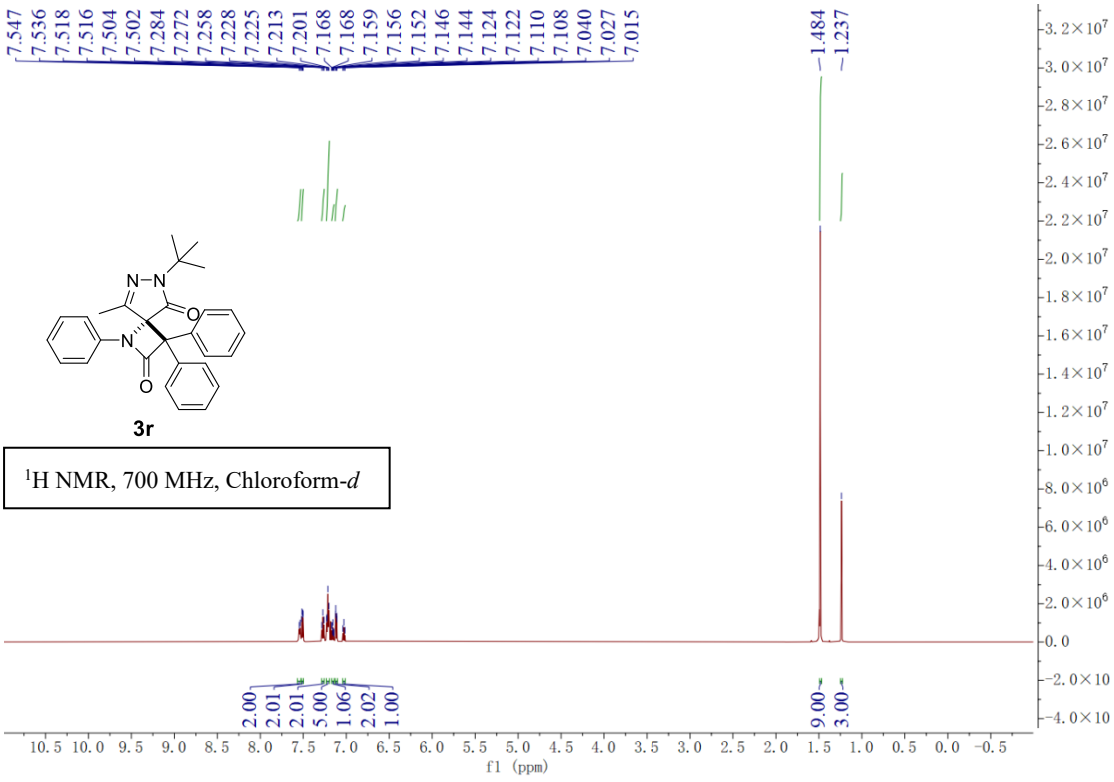
3q

^{1}H NMR, 600 MHz, Chloroform-*d*



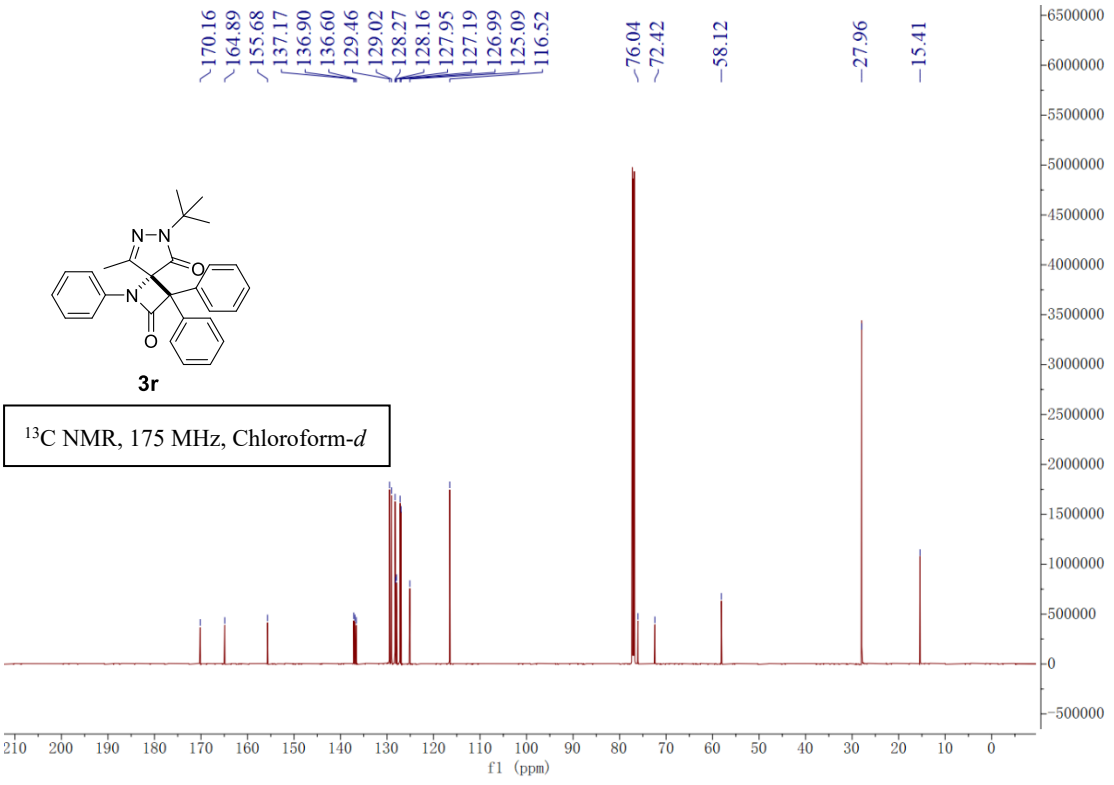
3q

^{13}C NMR, 150 MHz, Chloroform-*d*



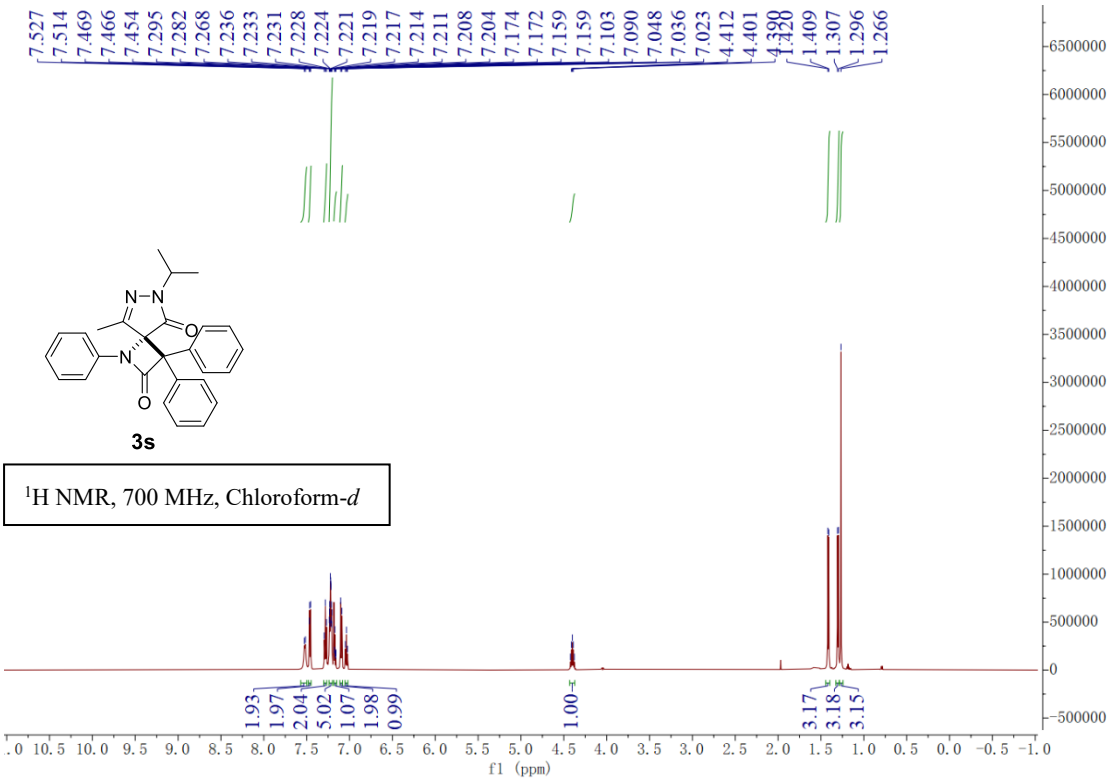
3r

^{1}H NMR, 700 MHz, Chloroform-*d*



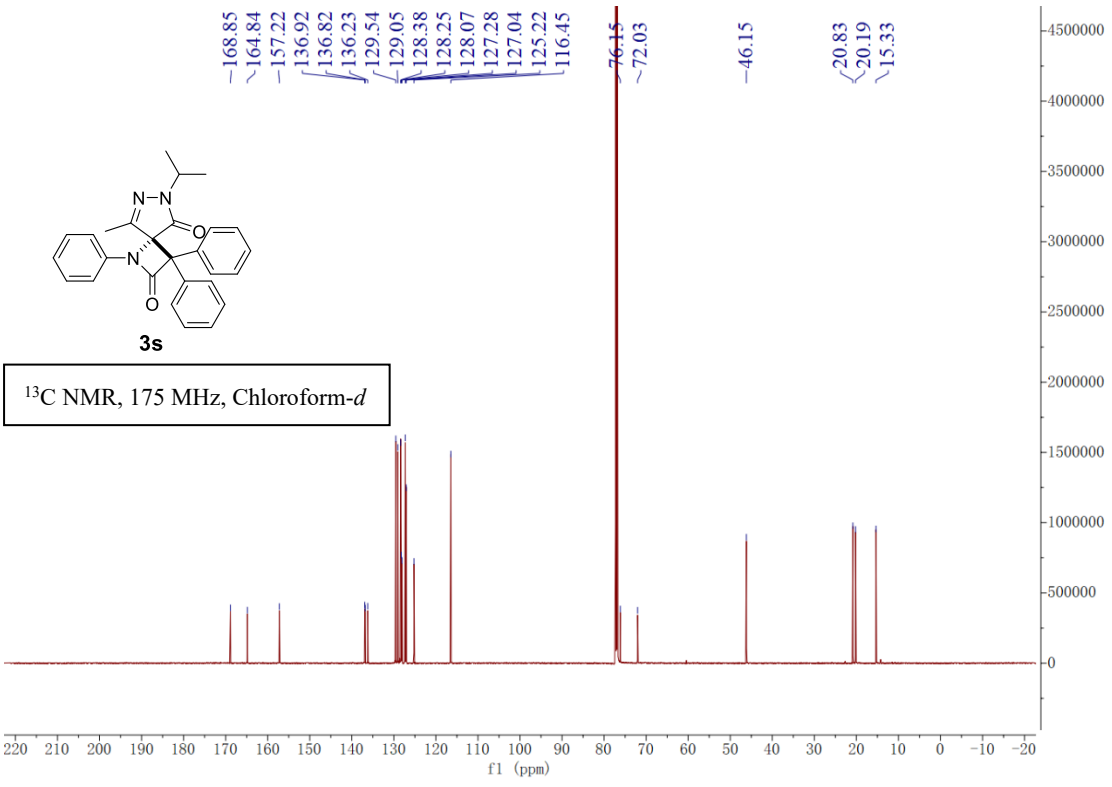
3r

^{13}C NMR, 175 MHz, Chloroform-*d*



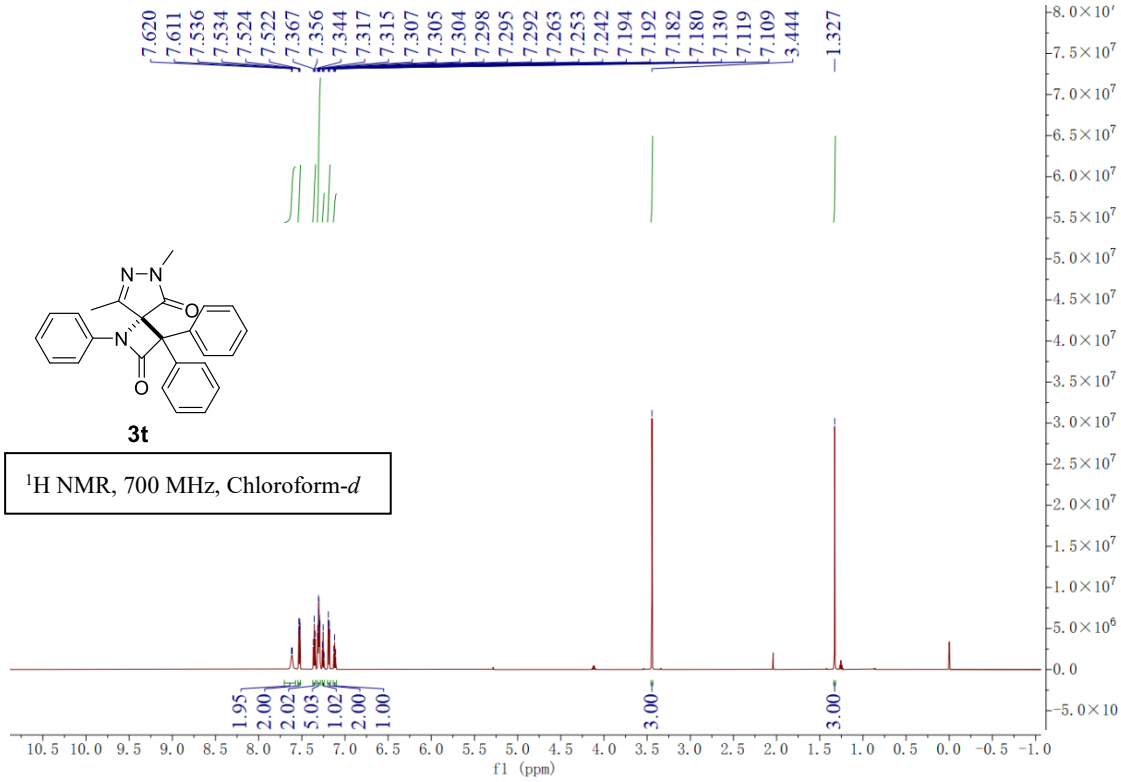
3s

^{1}H NMR, 700 MHz, Chloroform-*d*



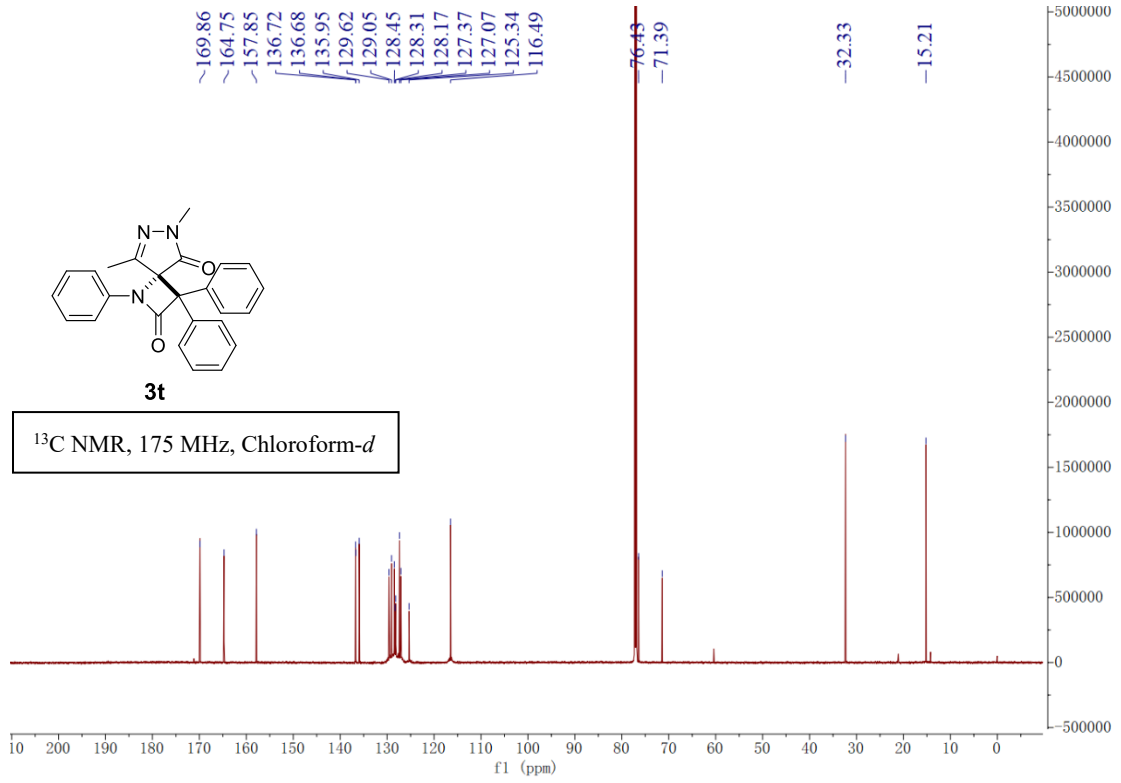
3s

^{13}C NMR, 175 MHz, Chloroform-*d*



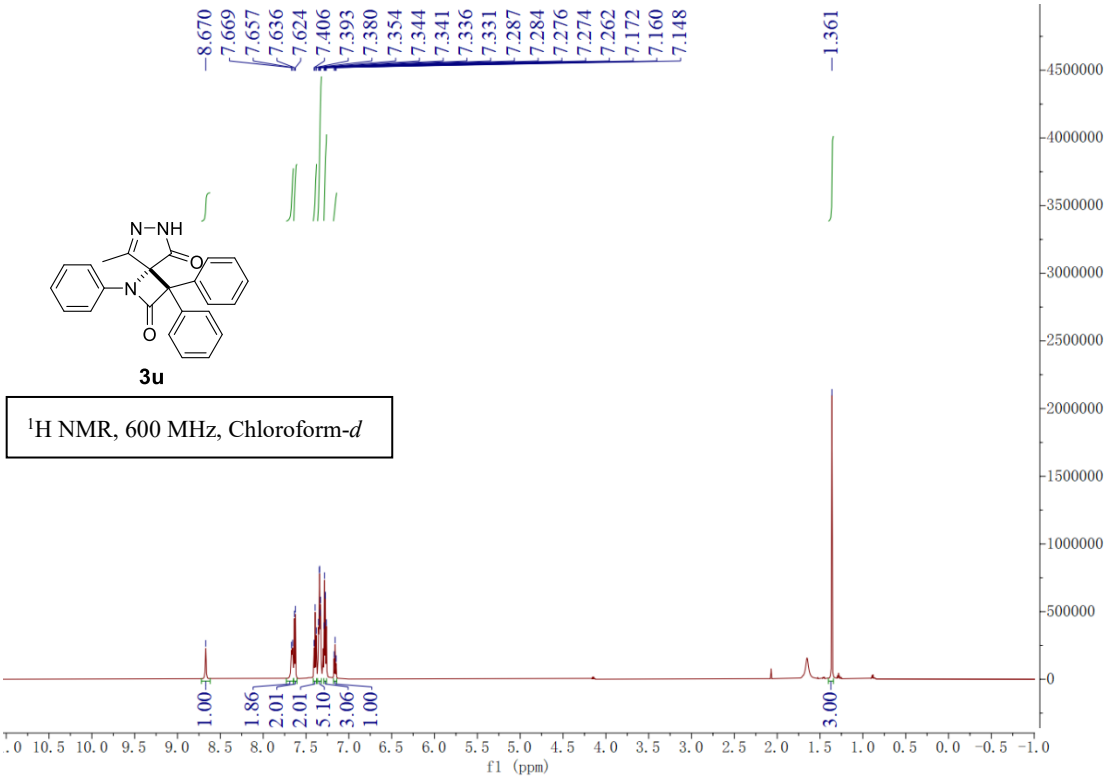
3t

^{1}H NMR, 700 MHz, Chloroform-*d*



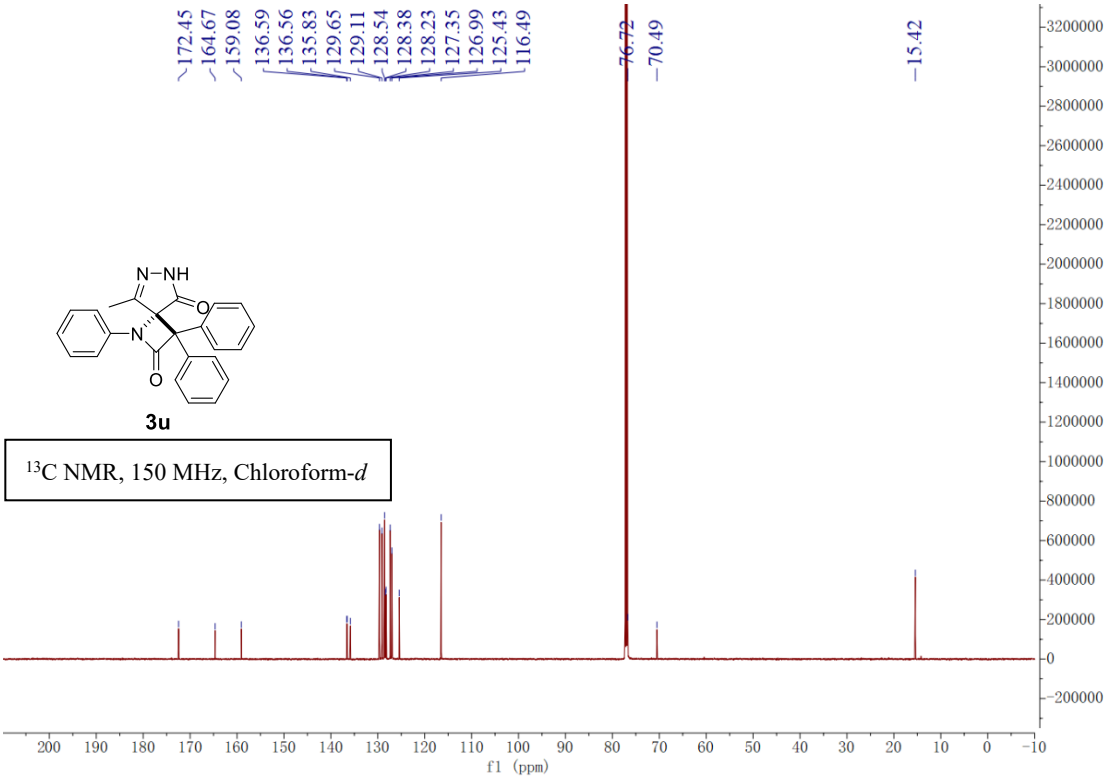
3t

^{13}C NMR, 175 MHz, Chloroform-*d*



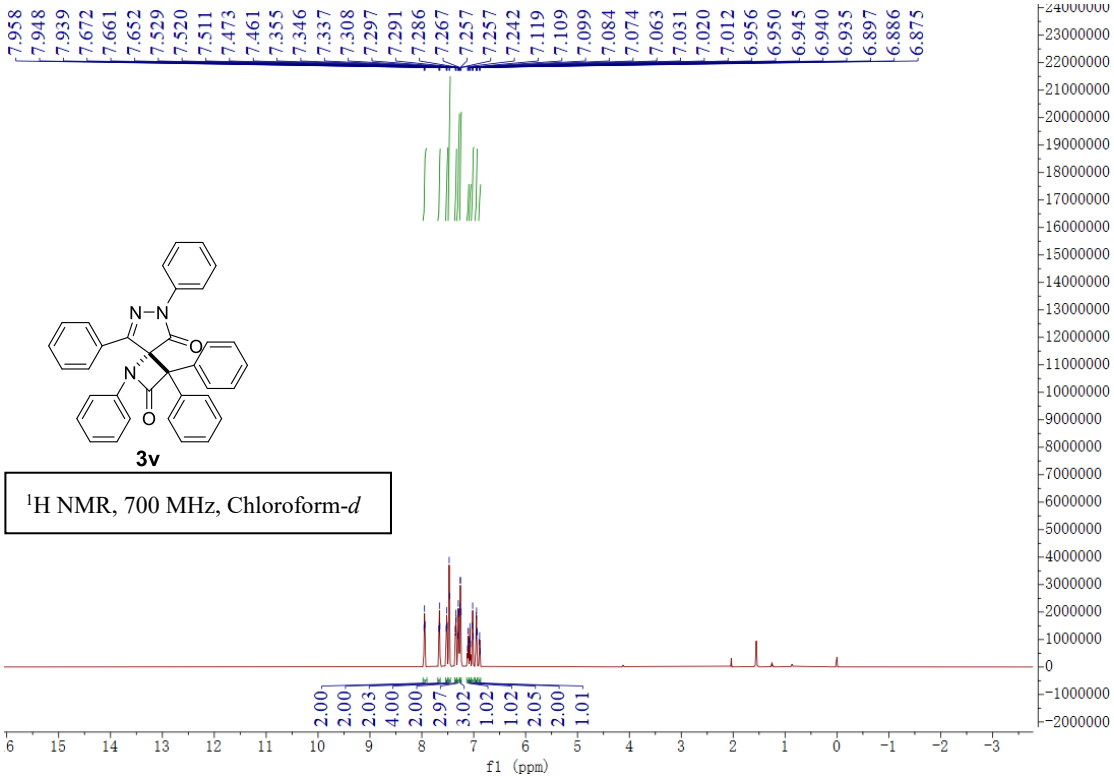
3u

^{1}H NMR, 600 MHz, Chloroform-*d*



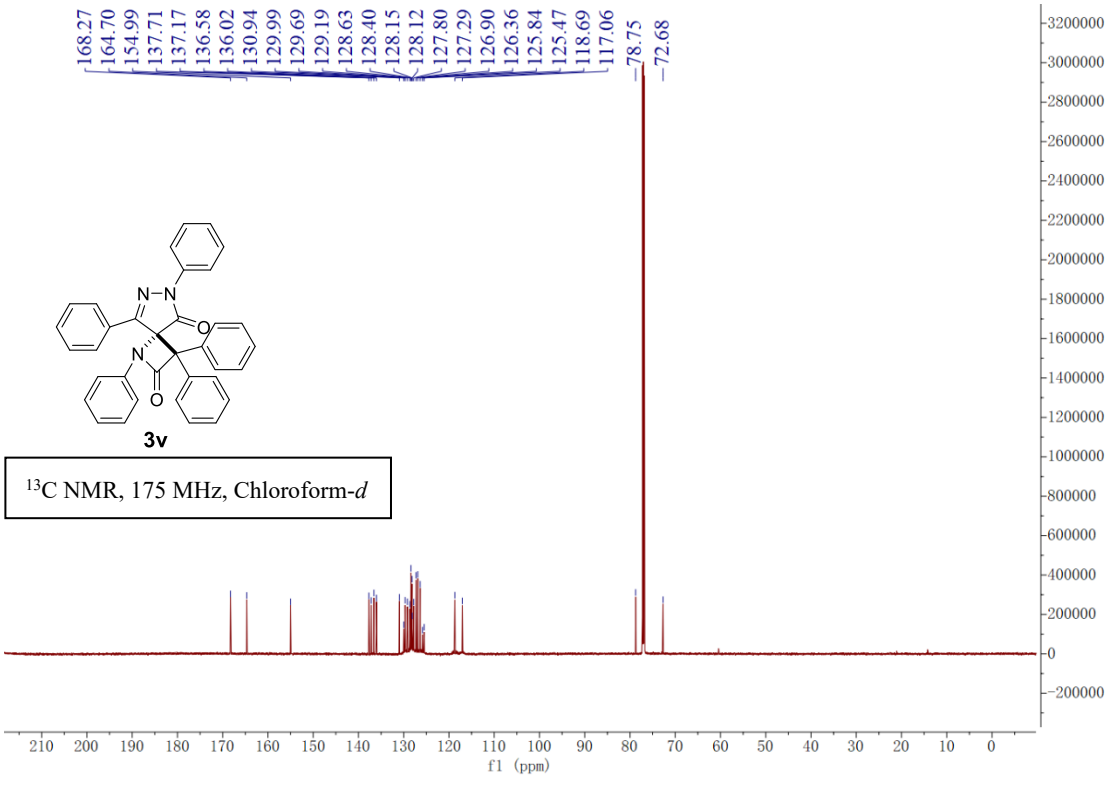
3u

^{13}C NMR, 150 MHz, Chloroform-*d*



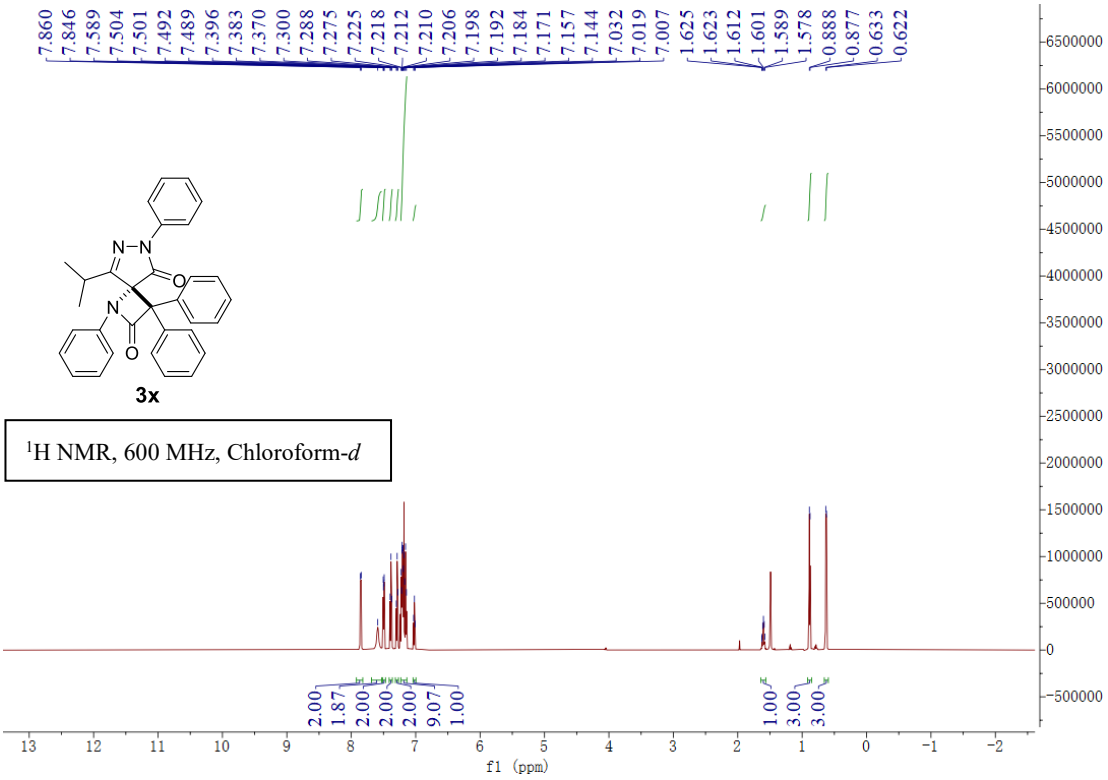
3v

^{1}H NMR, 700 MHz, Chloroform-*d*



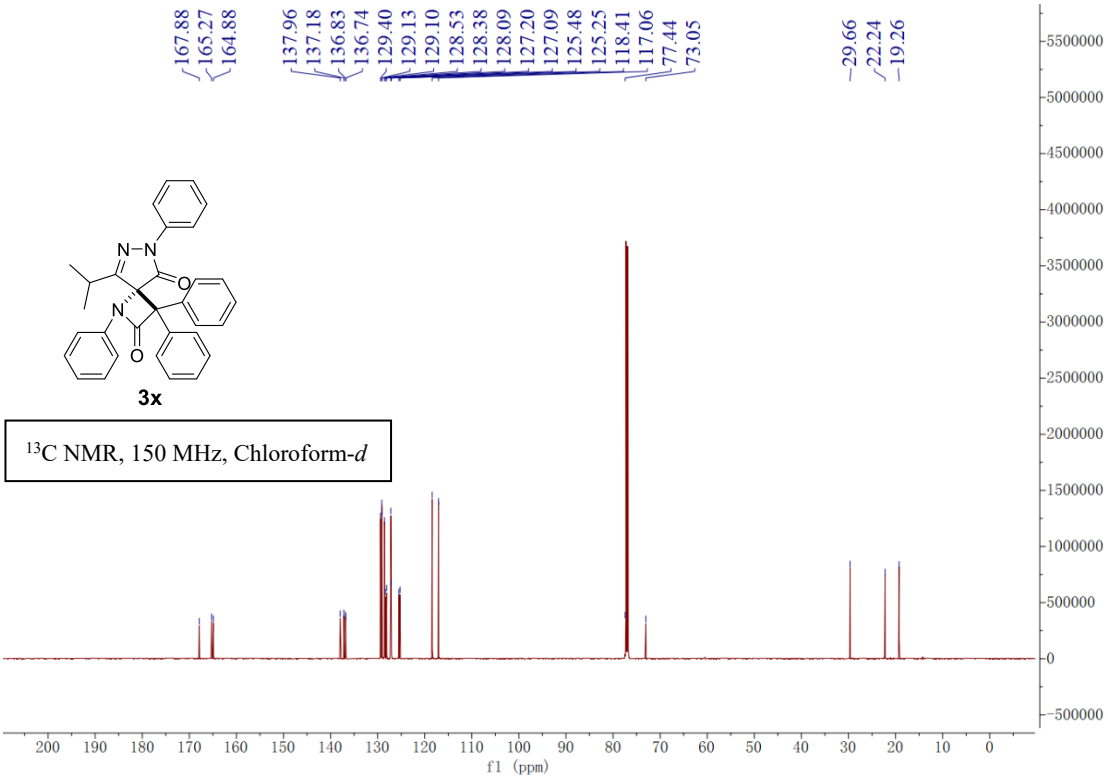
3v

^{13}C NMR, 175 MHz, Chloroform-*d*



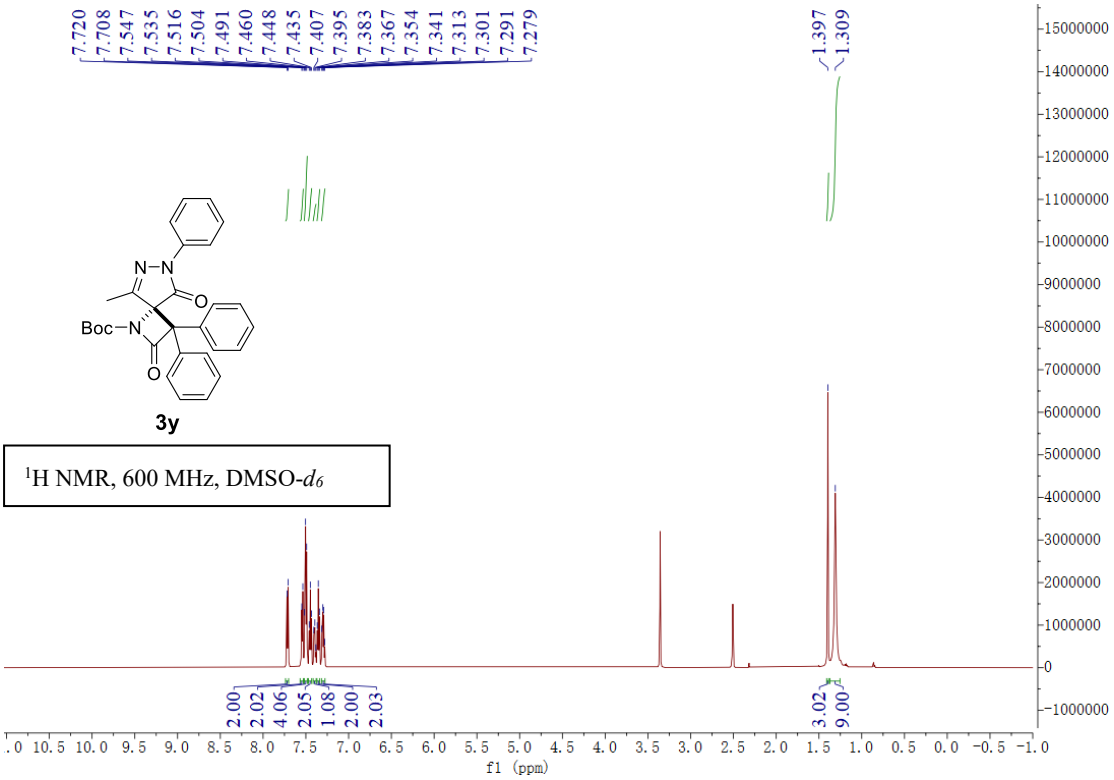
3x

^{1}H NMR, 600 MHz, Chloroform-*d*



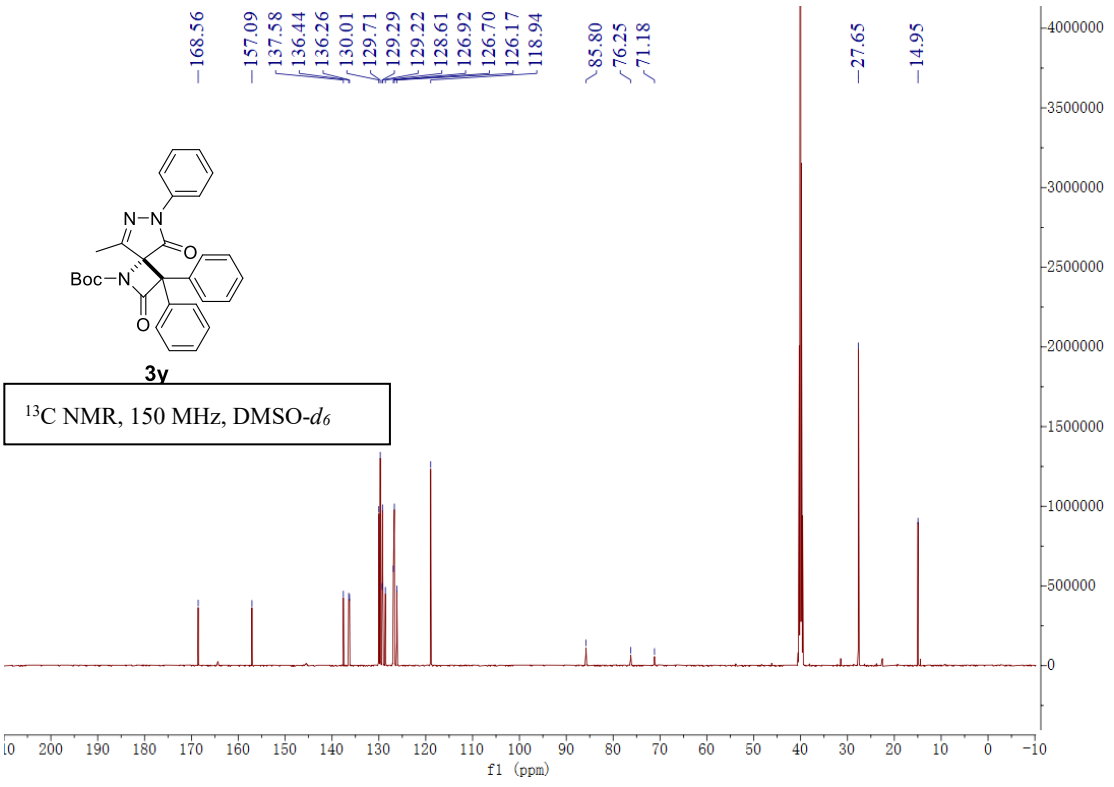
3x

^{13}C NMR, 150 MHz, Chloroform-*d*



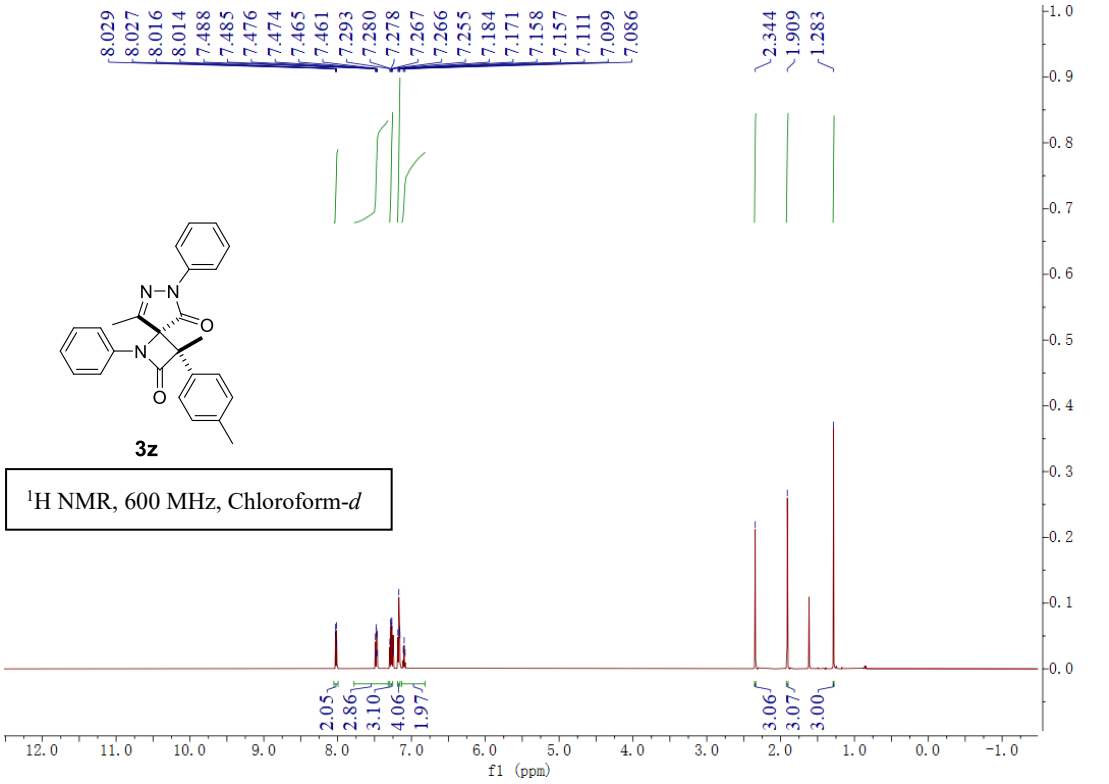
3y

^{1}H NMR, 600 MHz, DMSO-*d*$_6$



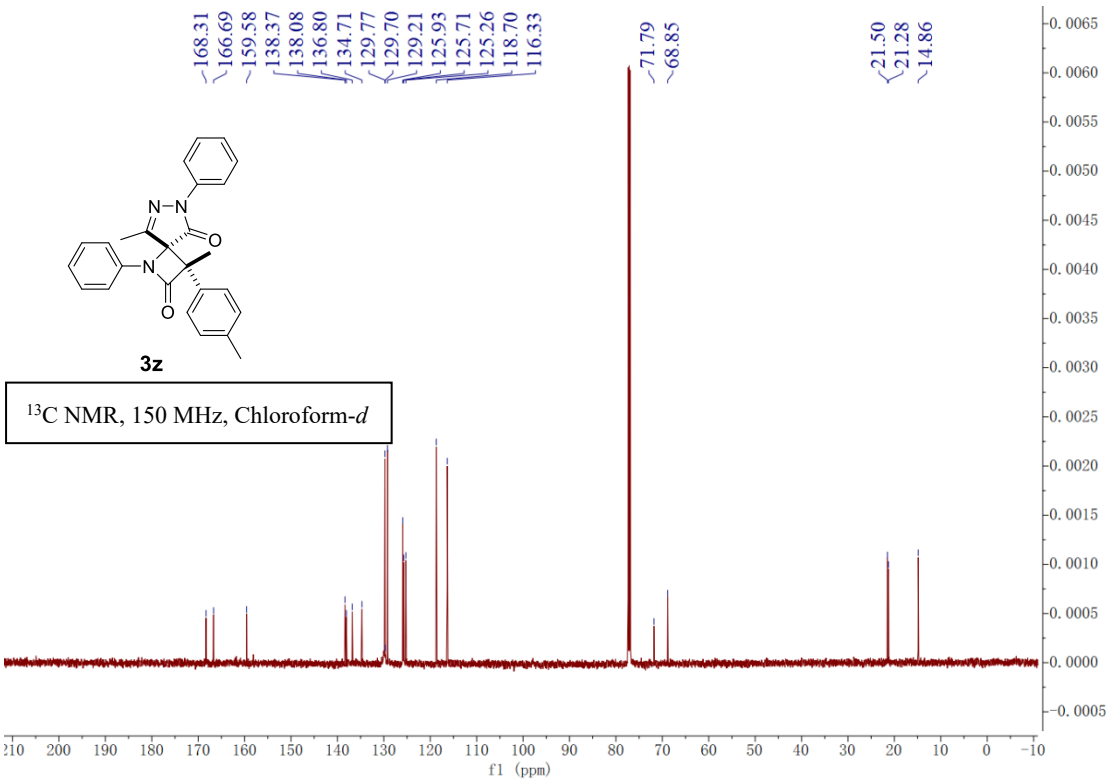
3y

^{13}C NMR, 150 MHz, DMSO-*d*$_6$



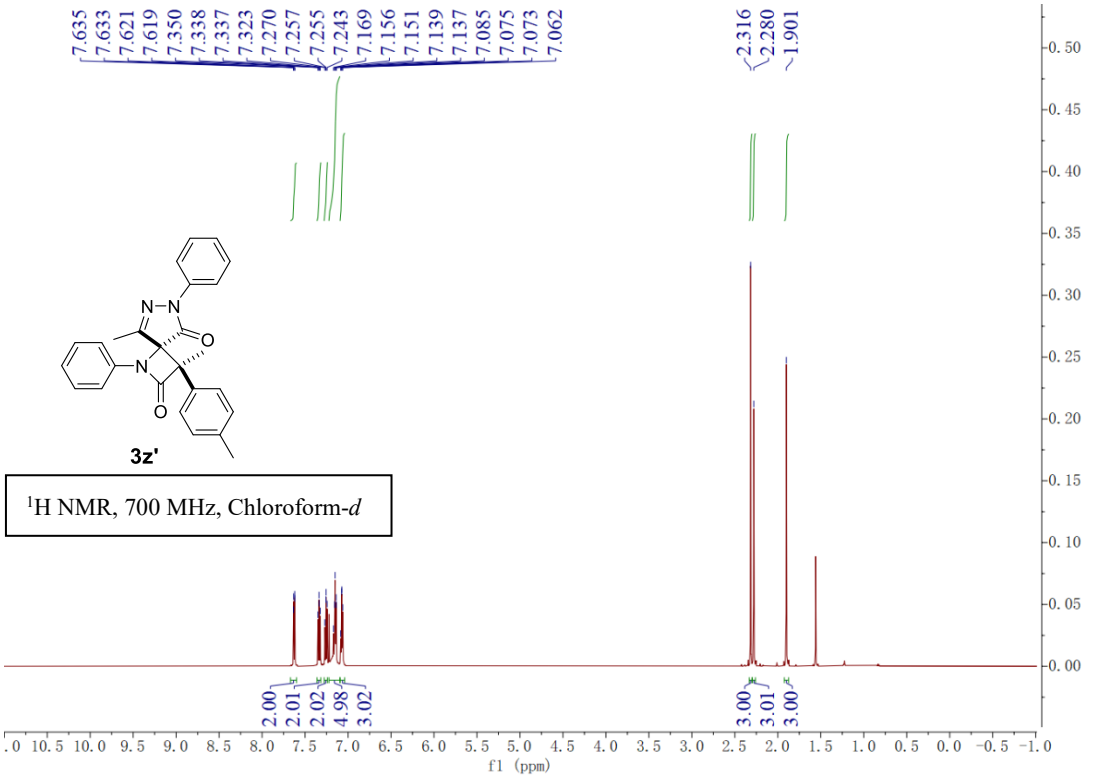
3z

^{1}H NMR, 600 MHz, Chloroform-*d*



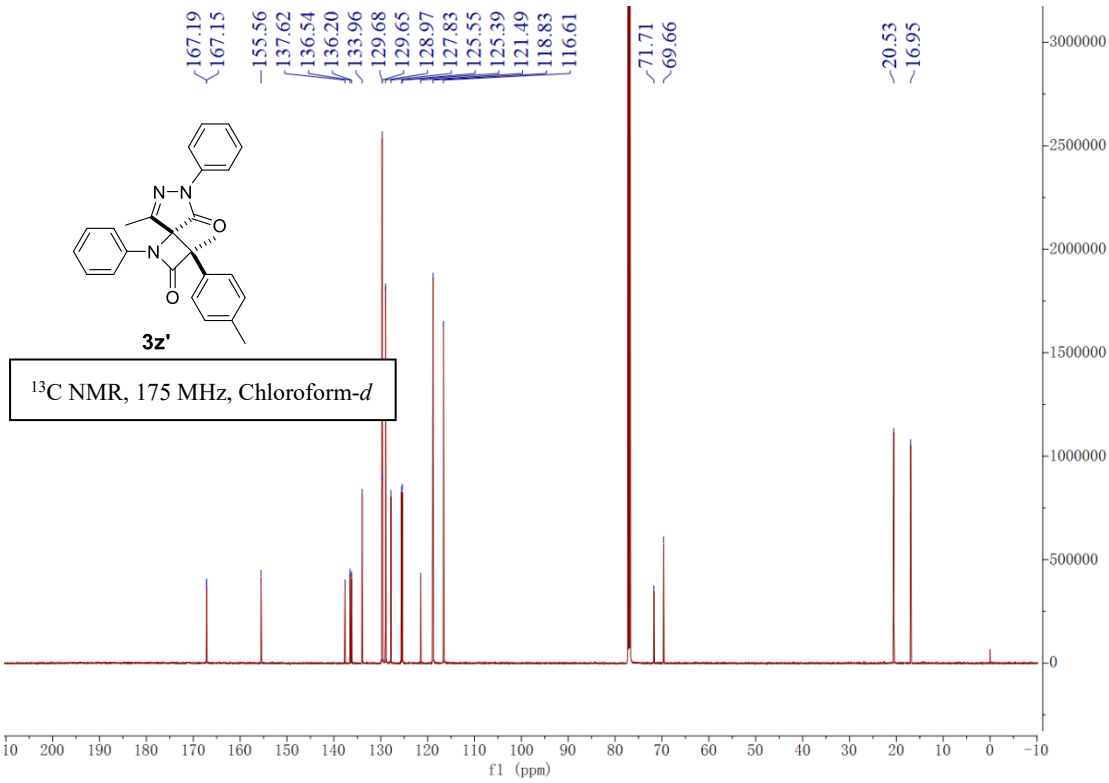
3z

^{13}C NMR, 150 MHz, Chloroform-*d*



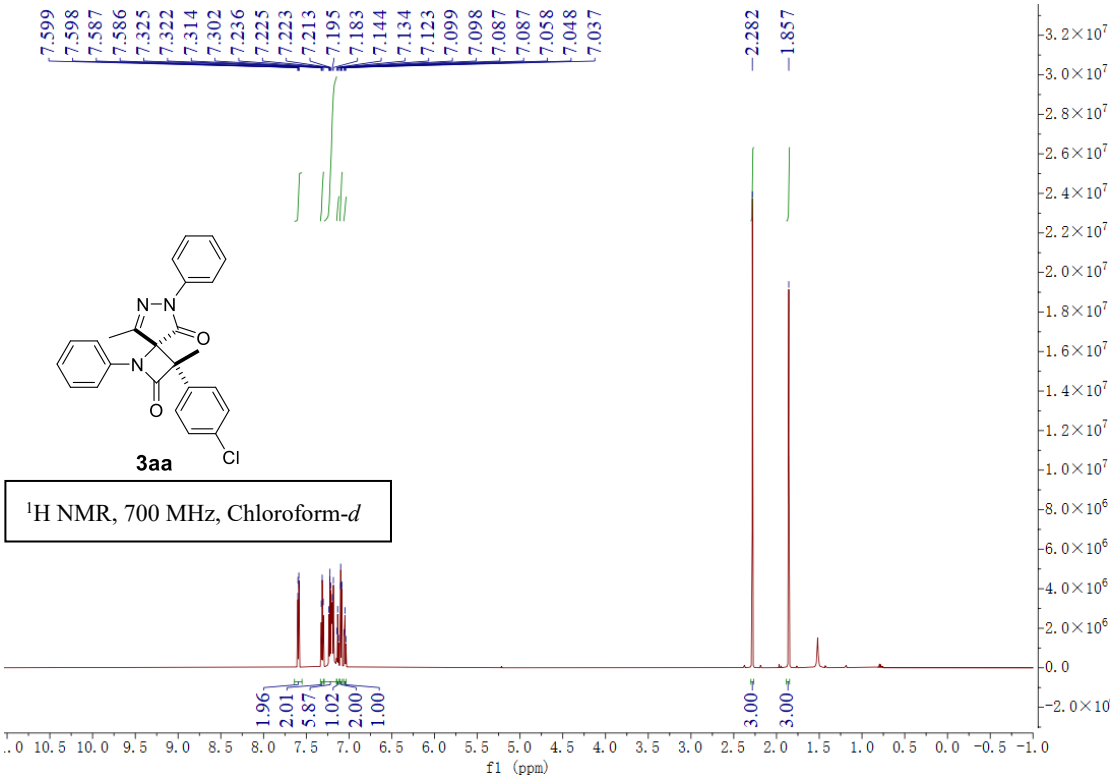
3z'

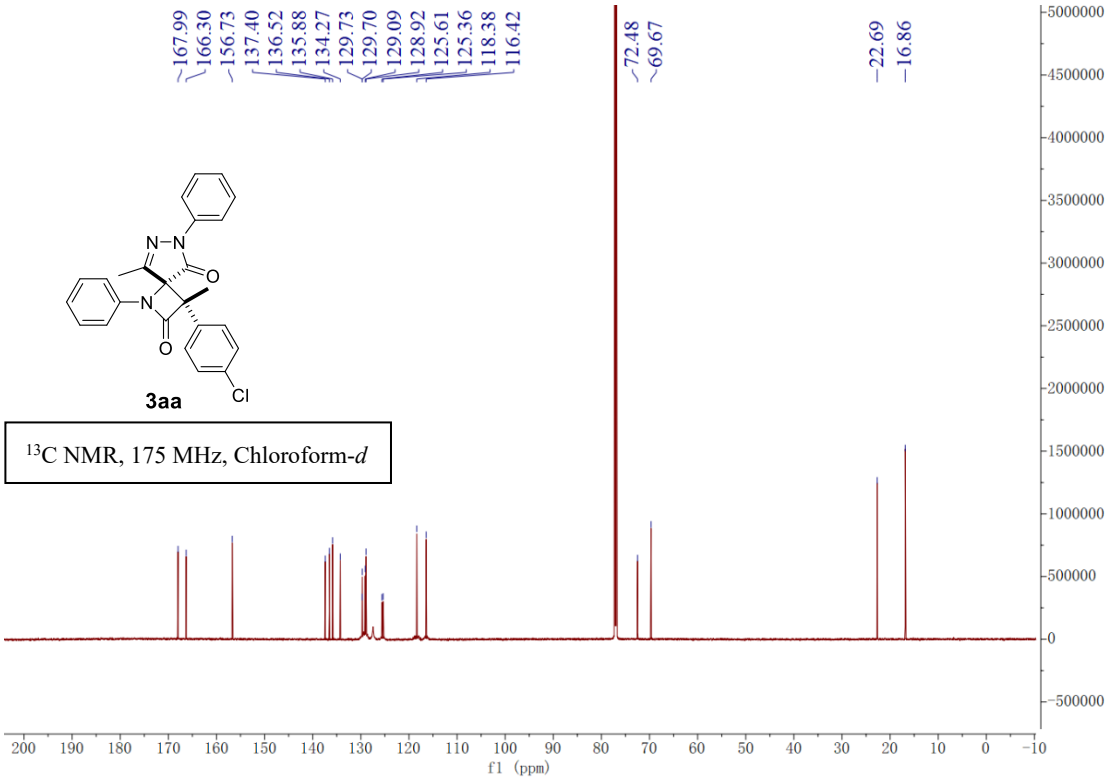
^{1}H NMR, 700 MHz, Chloroform-*d*

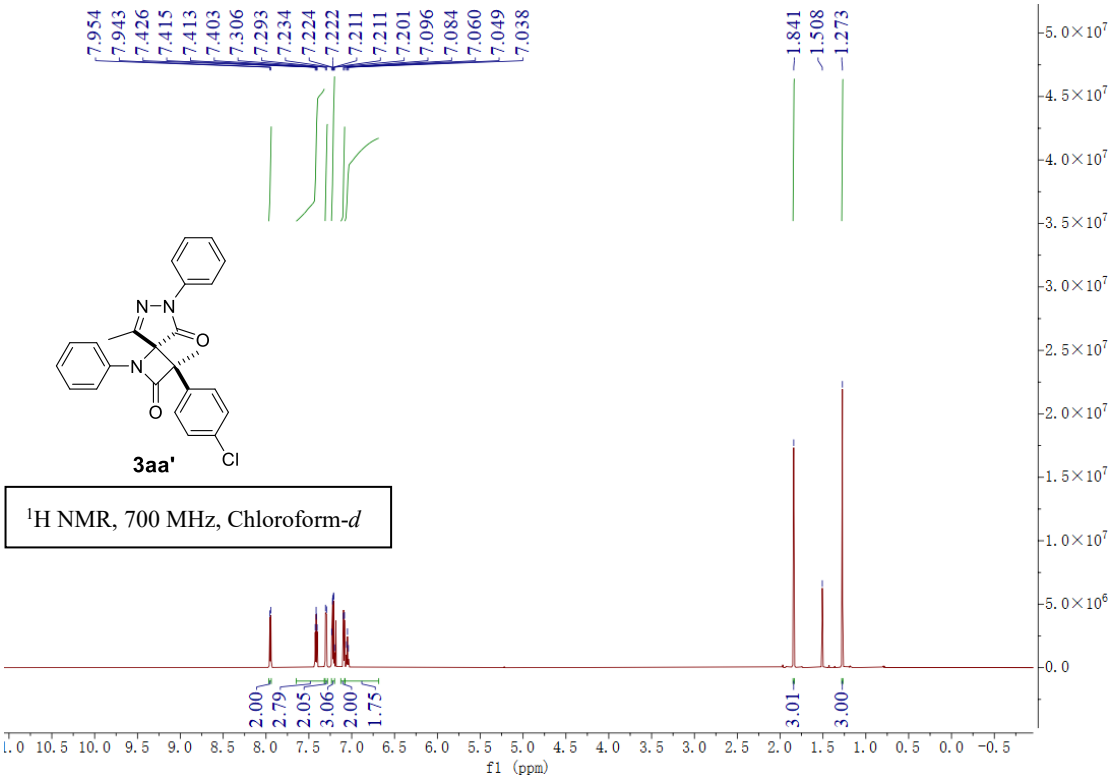


3z'

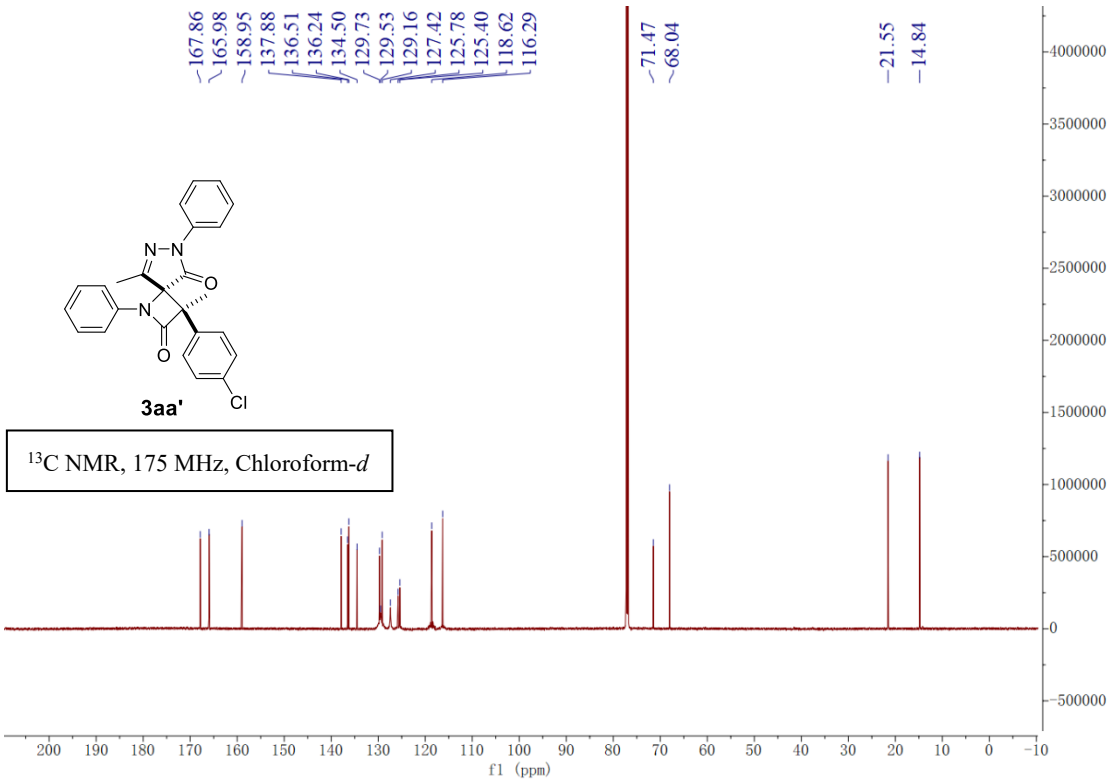
^{13}C NMR, 175 MHz, Chloroform-*d*


7.599
7.598
7.587
7.586
7.325
7.322
7.314
7.302
7.236
7.225
7.223
7.213
7.195
7.183
7.144
7.134
7.123
7.099
7.098
7.087
7.087
7.058
7.048
7.037
2.282
1.857
3aa
1H NMR, 700 MHz, Chloroform-d
1.96
2.01
5.87
1.02
2.00
1.00
3.00
3.00
f1 (ppm)

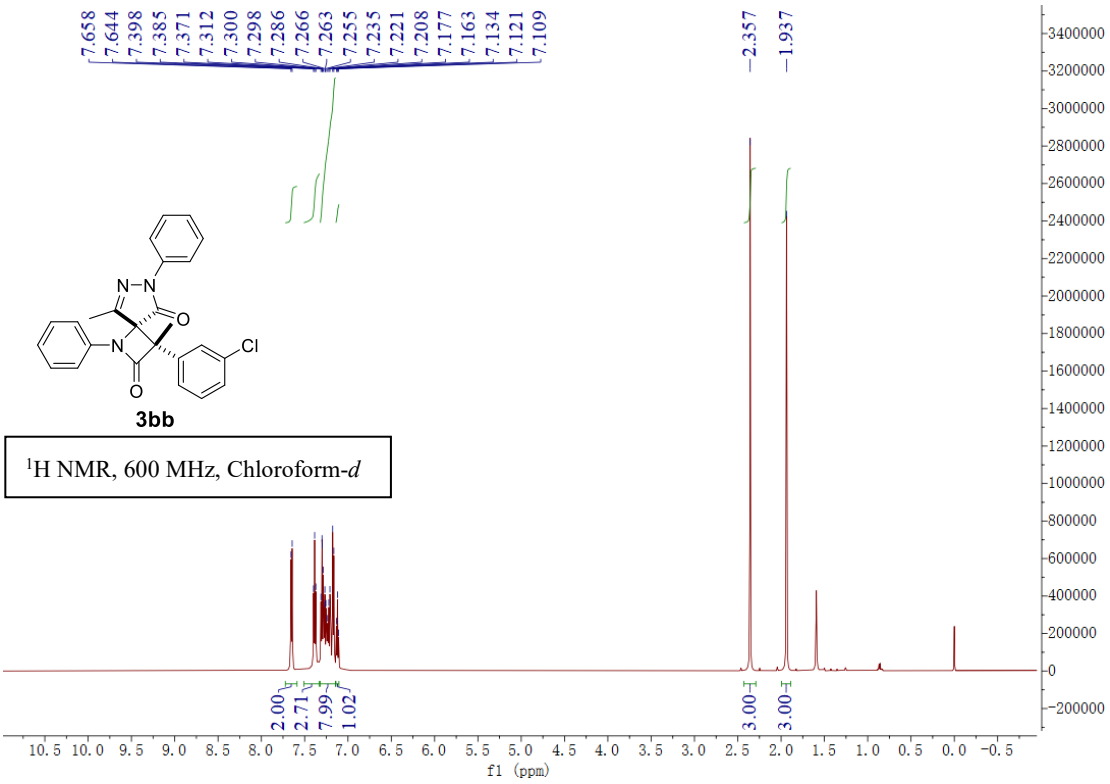

167.99
166.30
156.73
137.40
136.52
135.88
134.27
129.73
129.70
129.09
128.92
125.61
125.36
118.38
116.42
72.48
69.67
22.69
16.86
3aa
13C NMR, 175 MHz, Chloroform-d
f1 (ppm)



^{1}H NMR, 700 MHz, Chloroform-*d*

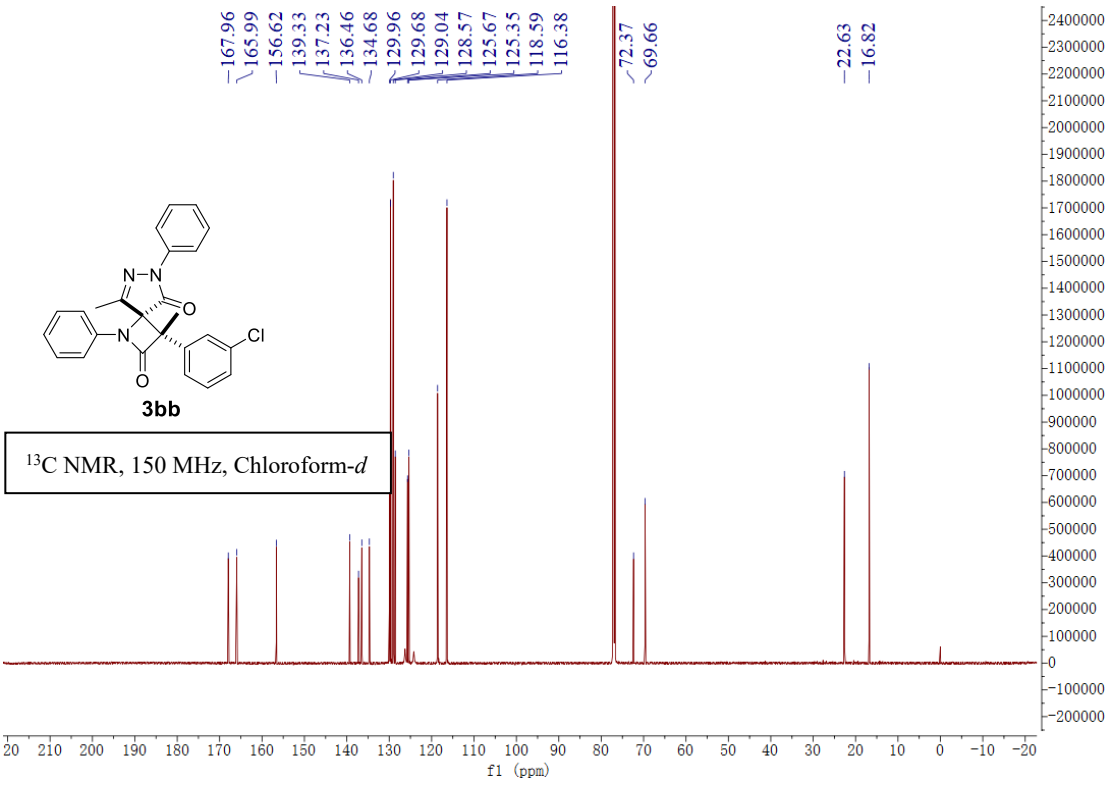


^{13}C NMR, 175 MHz, Chloroform-*d*



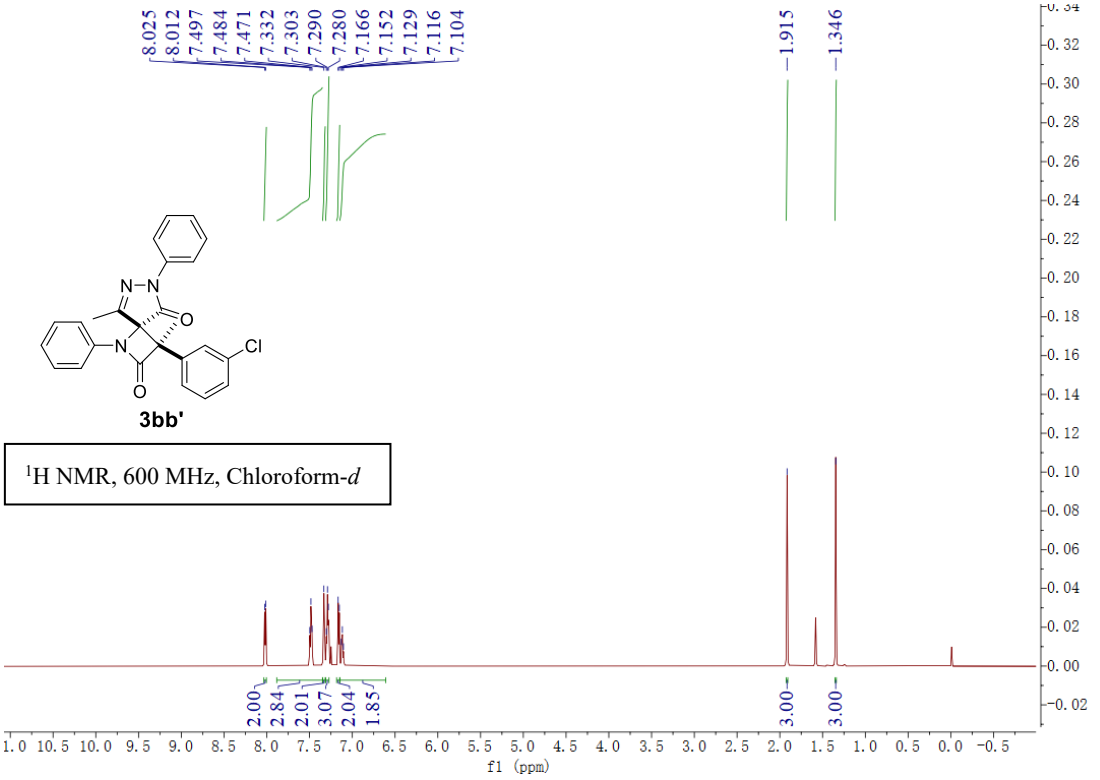
3bb

^{1}H NMR, 600 MHz, Chloroform-*d*



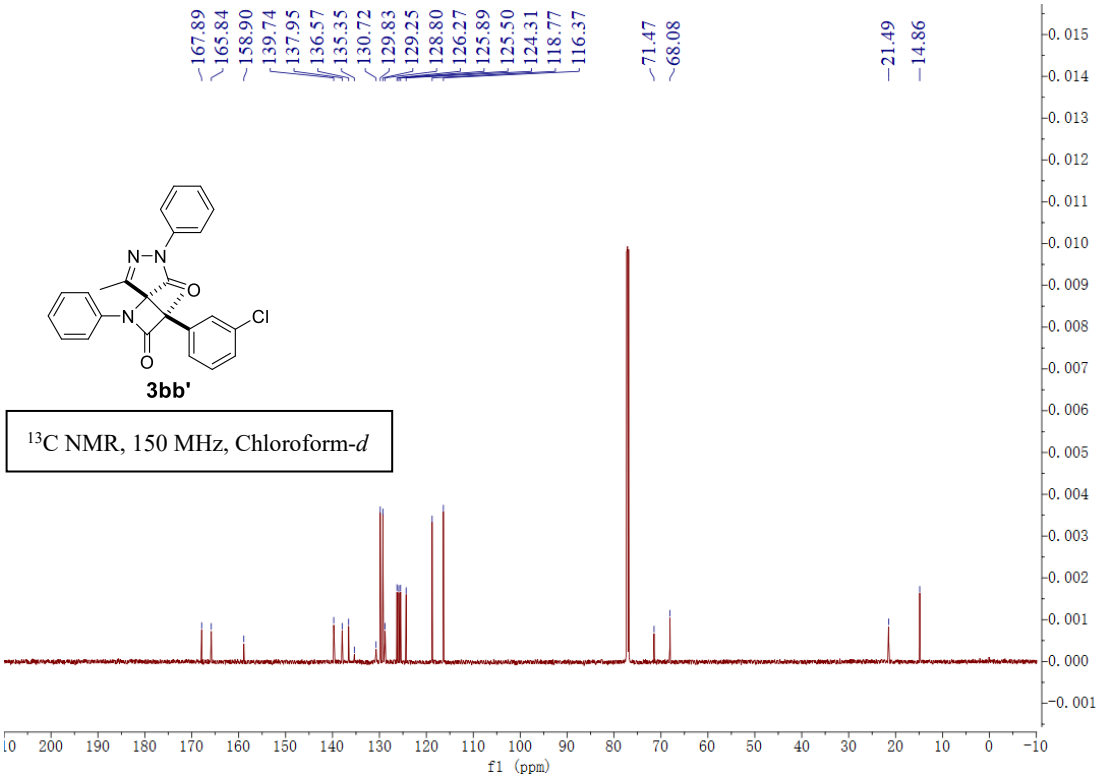
3bb

^{13}C NMR, 150 MHz, Chloroform-*d*



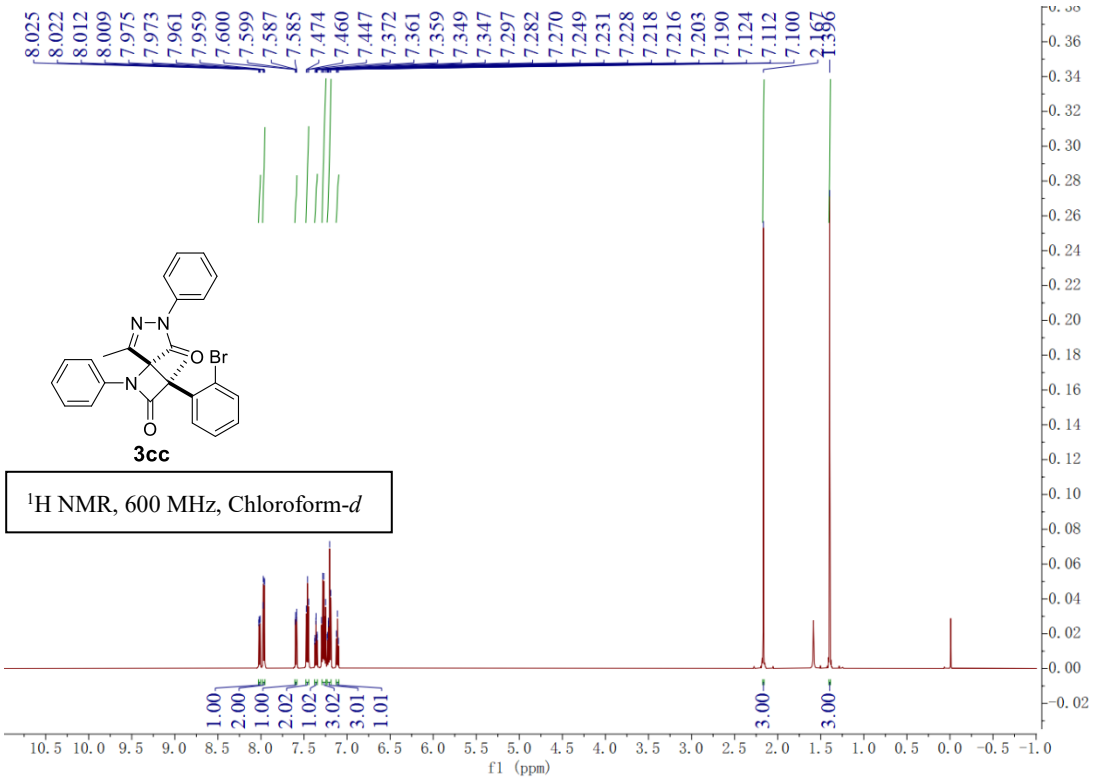
3bb'

^{1}H NMR, 600 MHz, Chloroform-*d*



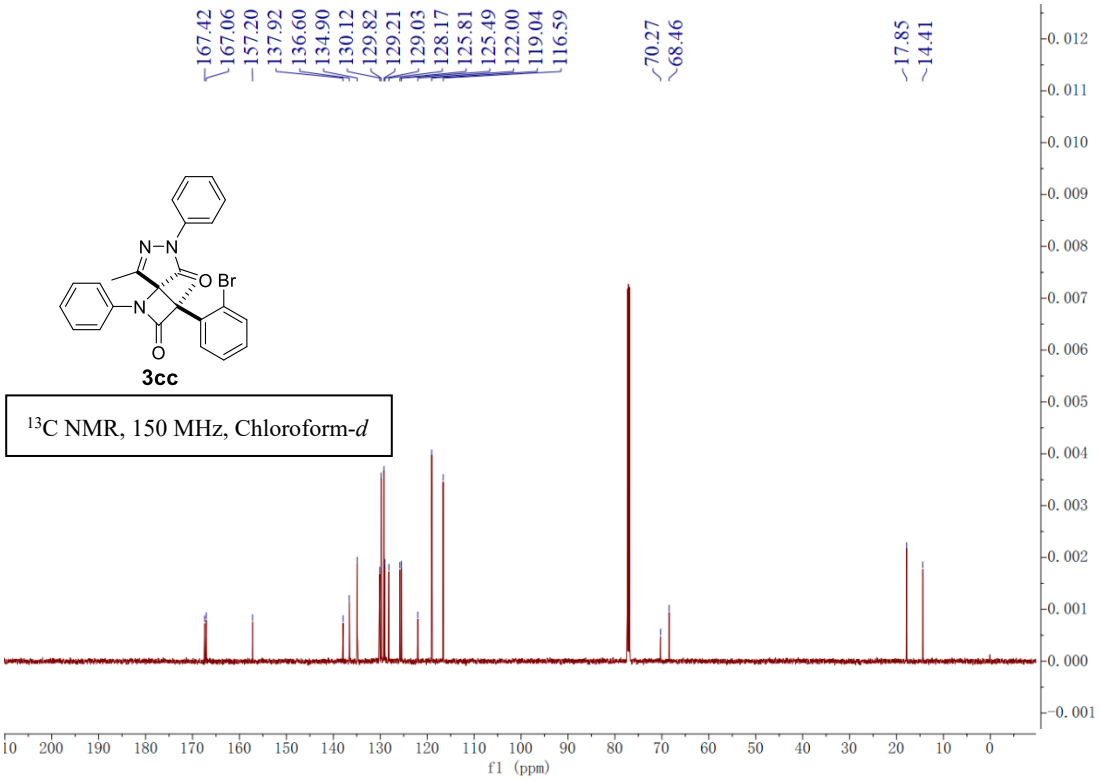
3bb'

^{13}C NMR, 150 MHz, Chloroform-*d*



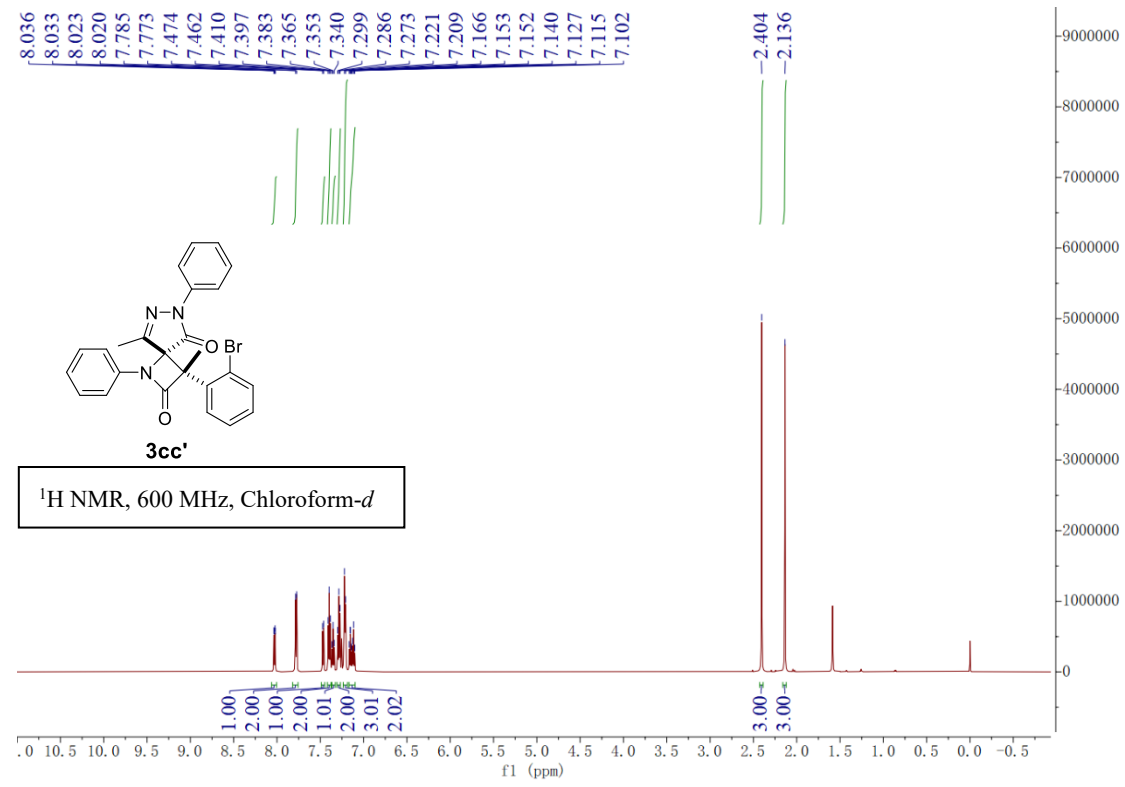
3cc

^{1}H NMR, 600 MHz, Chloroform-*d*



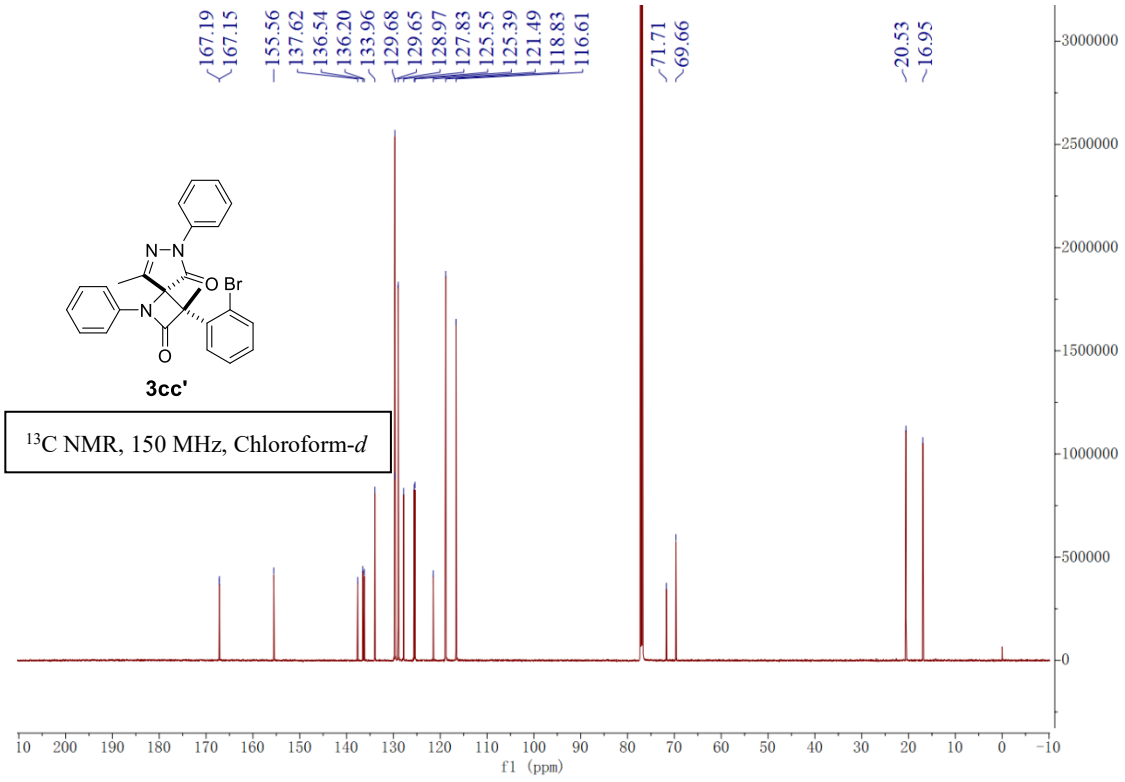
3cc

^{13}C NMR, 150 MHz, Chloroform-*d*



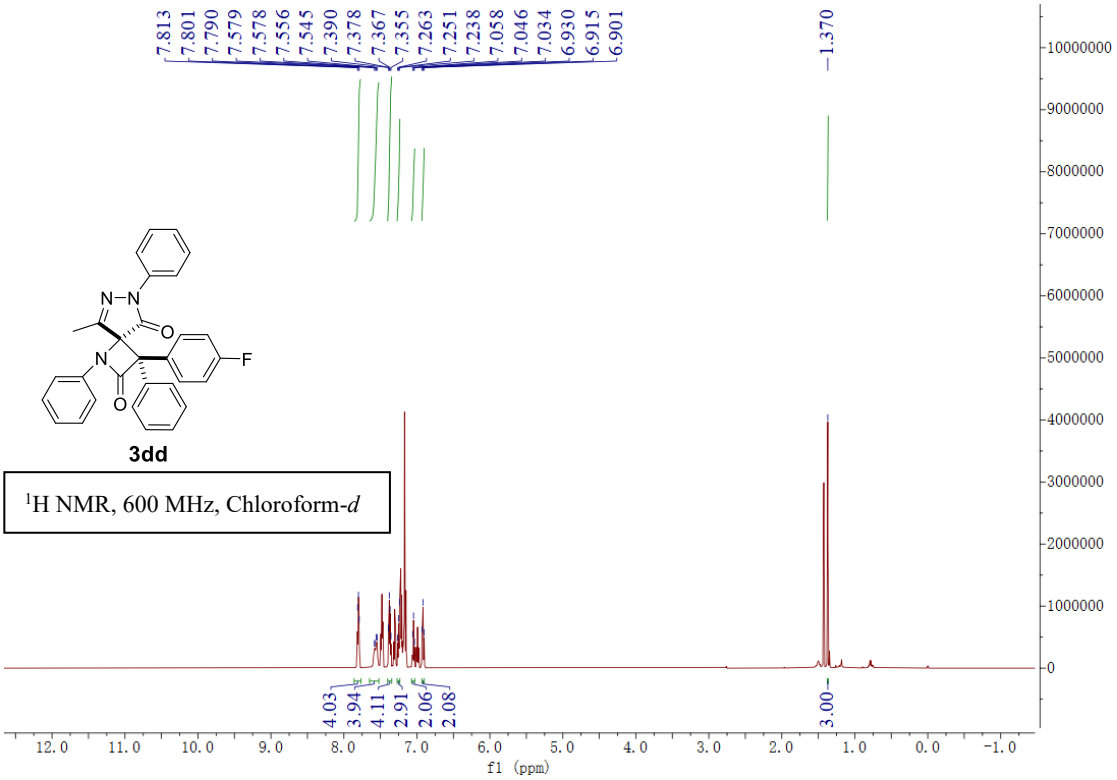
3cc'

^{1}H NMR, 600 MHz, Chloroform-*d*



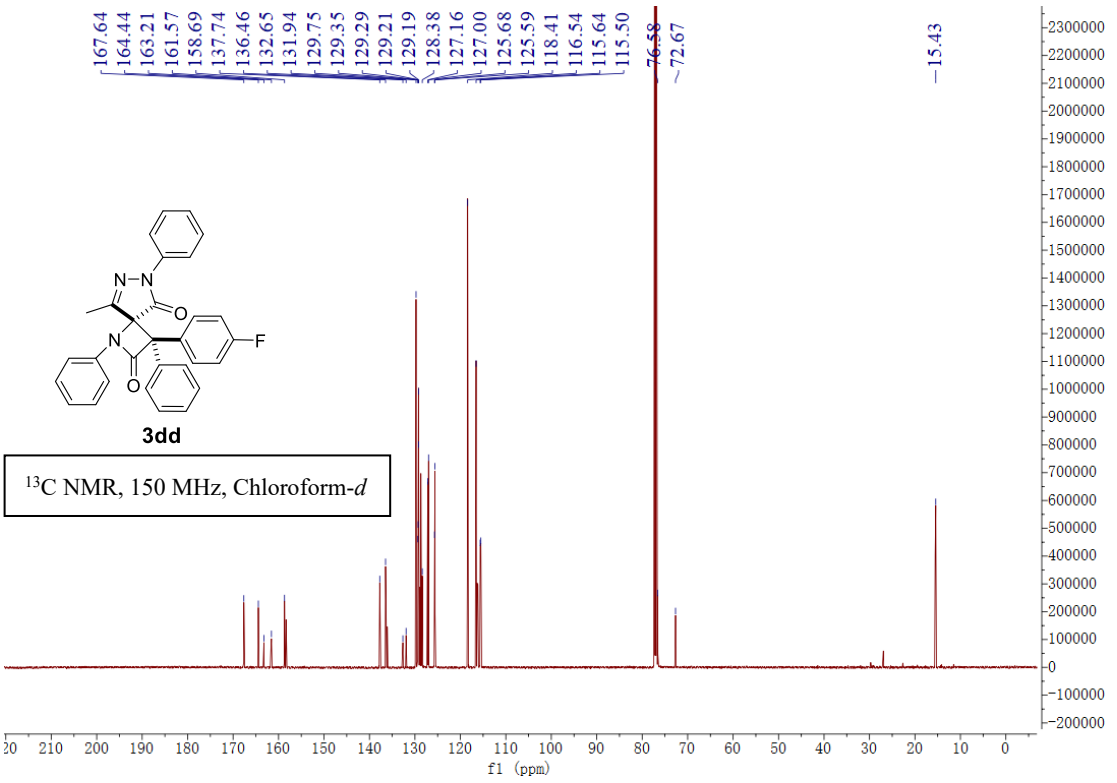
3cc'

^{13}C NMR, 150 MHz, Chloroform-*d*



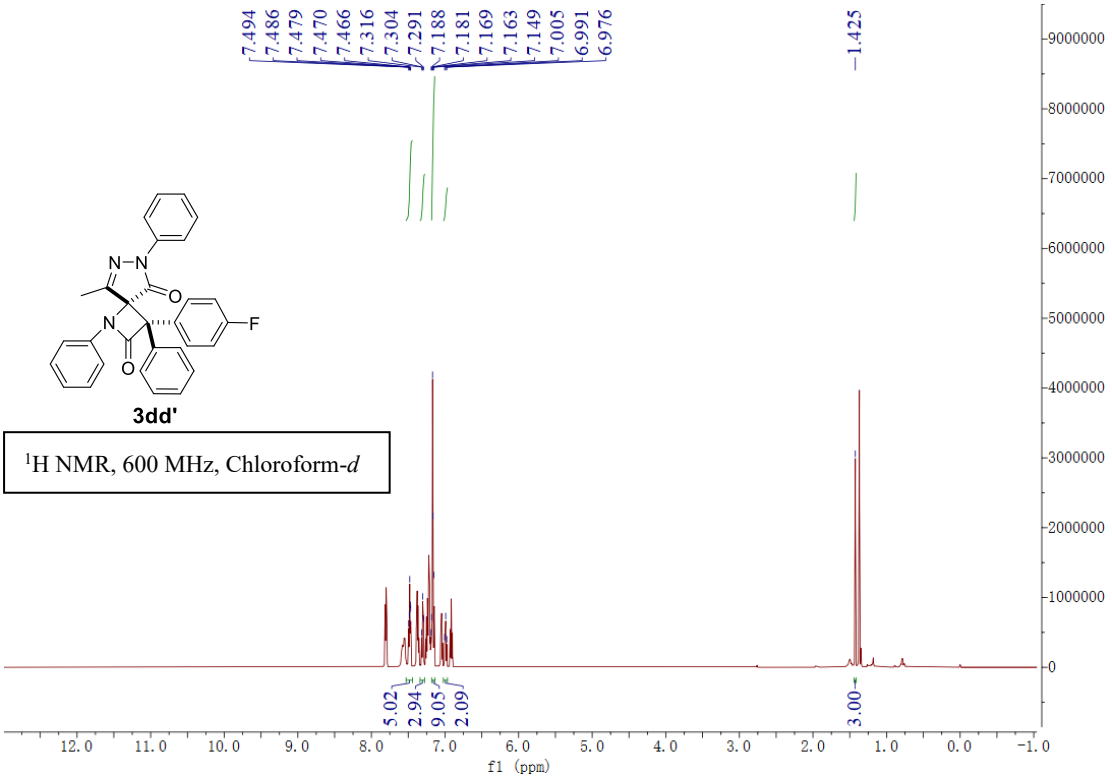
3dd

^{1}H NMR, 600 MHz, Chloroform-*d*



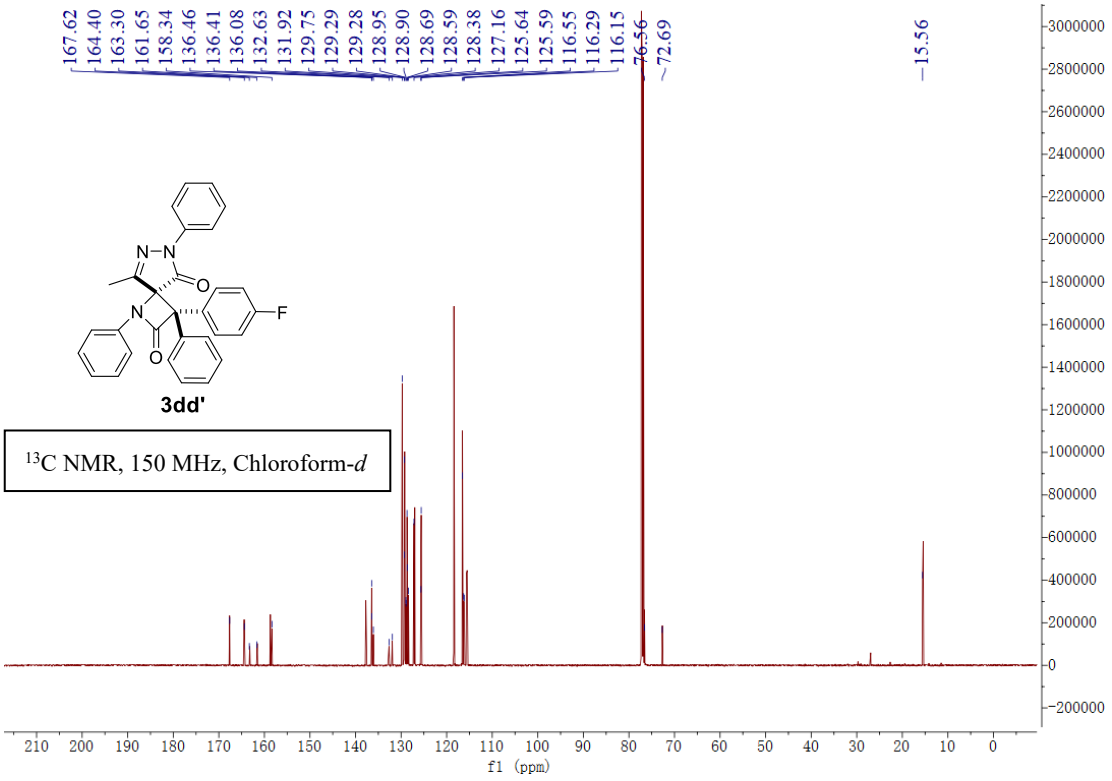
3dd

^{13}C NMR, 150 MHz, Chloroform-*d*



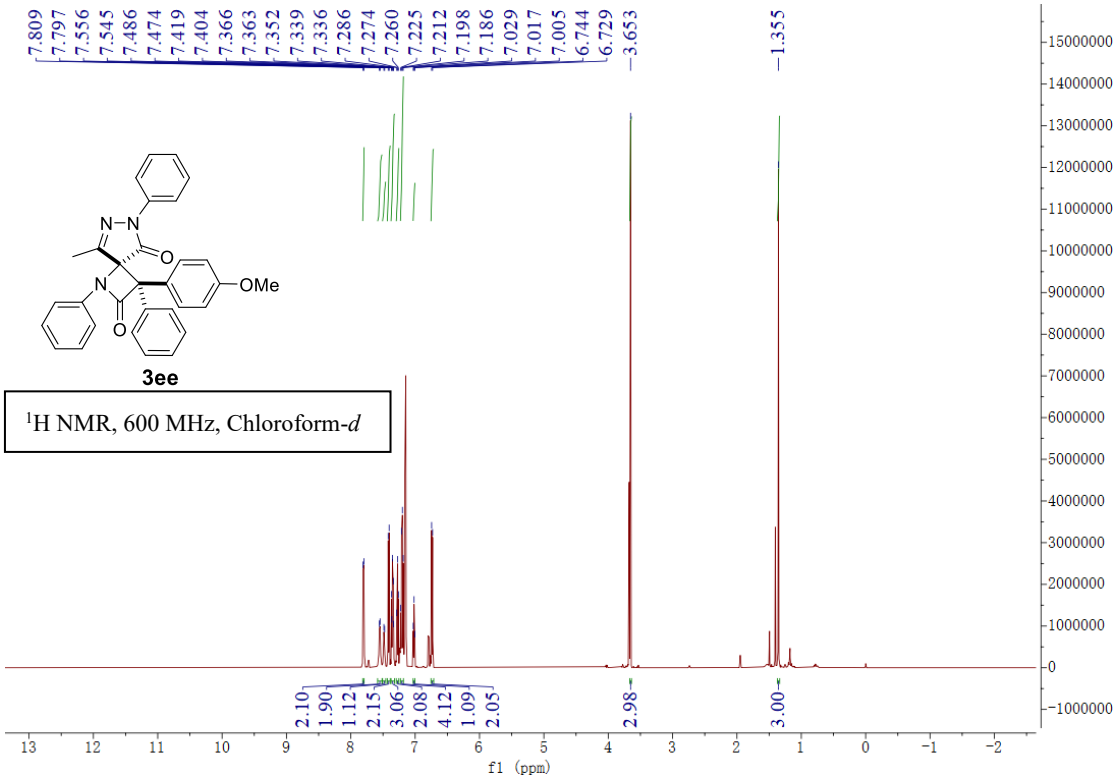
3dd'

^{1}H NMR, 600 MHz, Chloroform-*d*



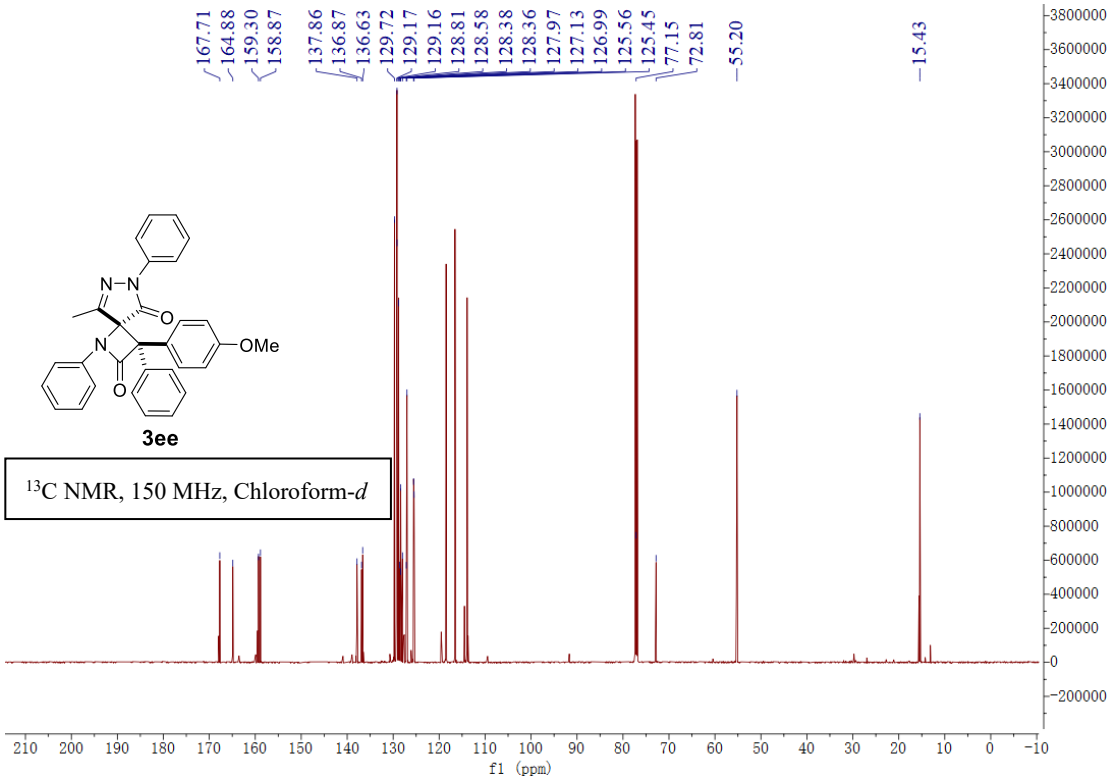
3dd'

^{13}C NMR, 150 MHz, Chloroform-*d*



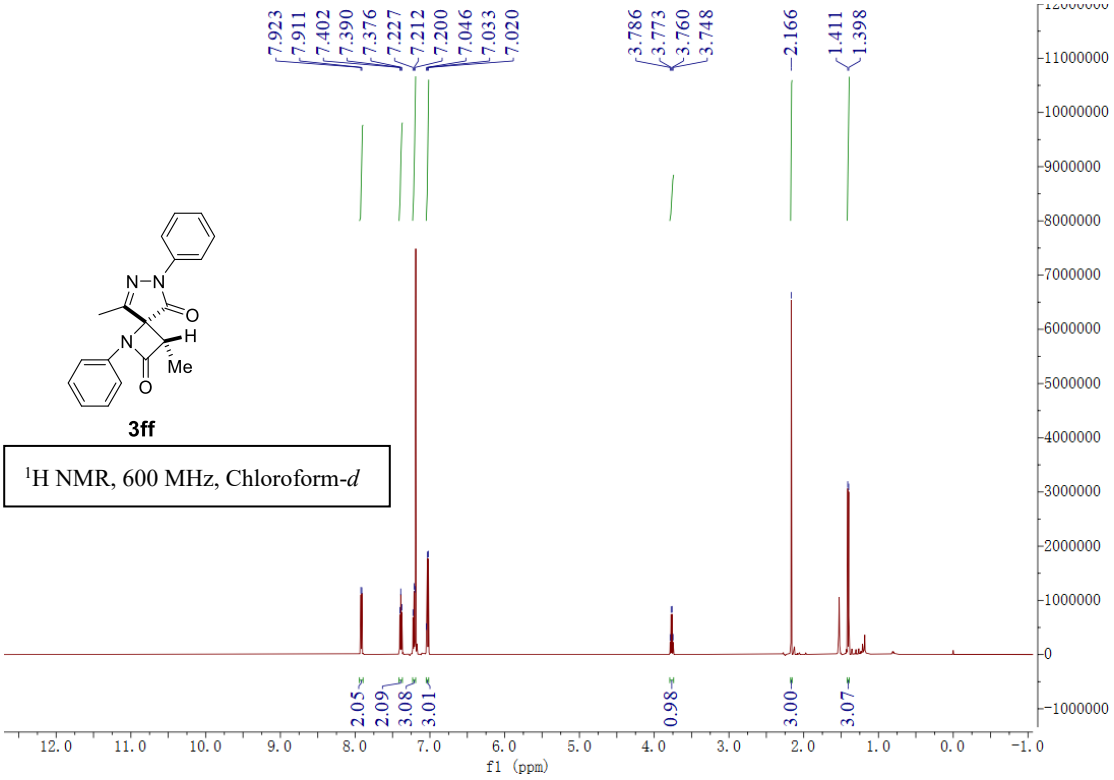
3ee

^{1}H NMR, 600 MHz, Chloroform-*d*



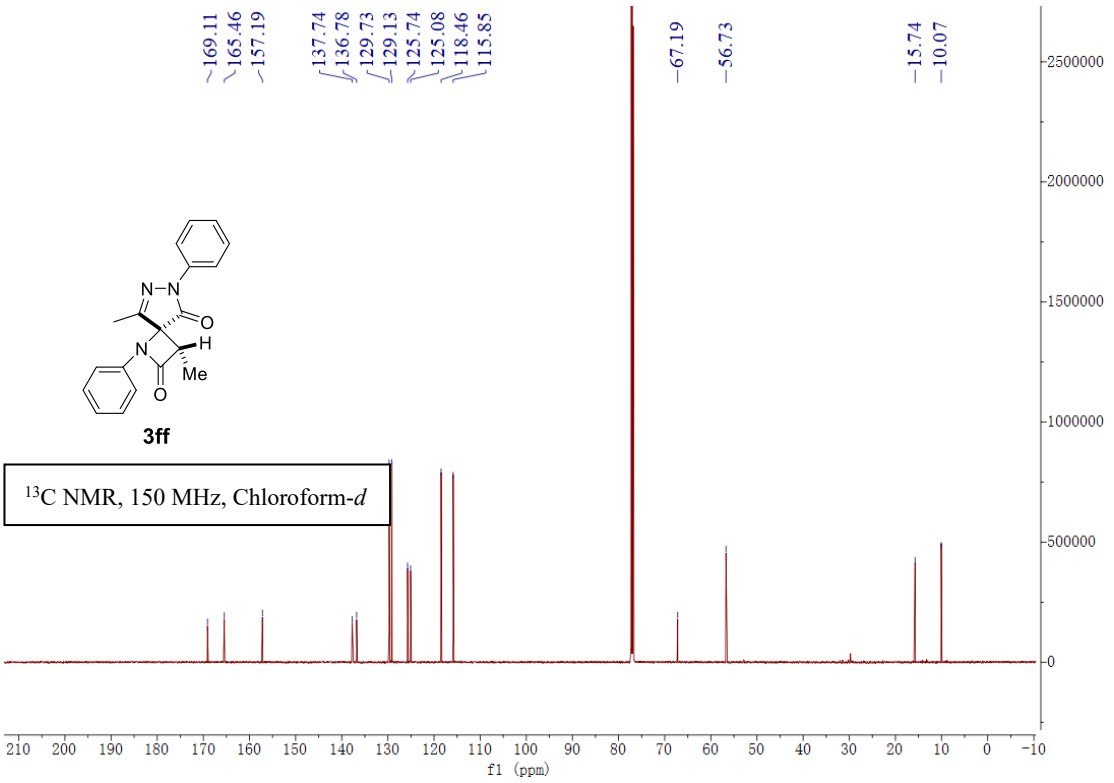
3ee

^{13}C NMR, 150 MHz, Chloroform-*d*



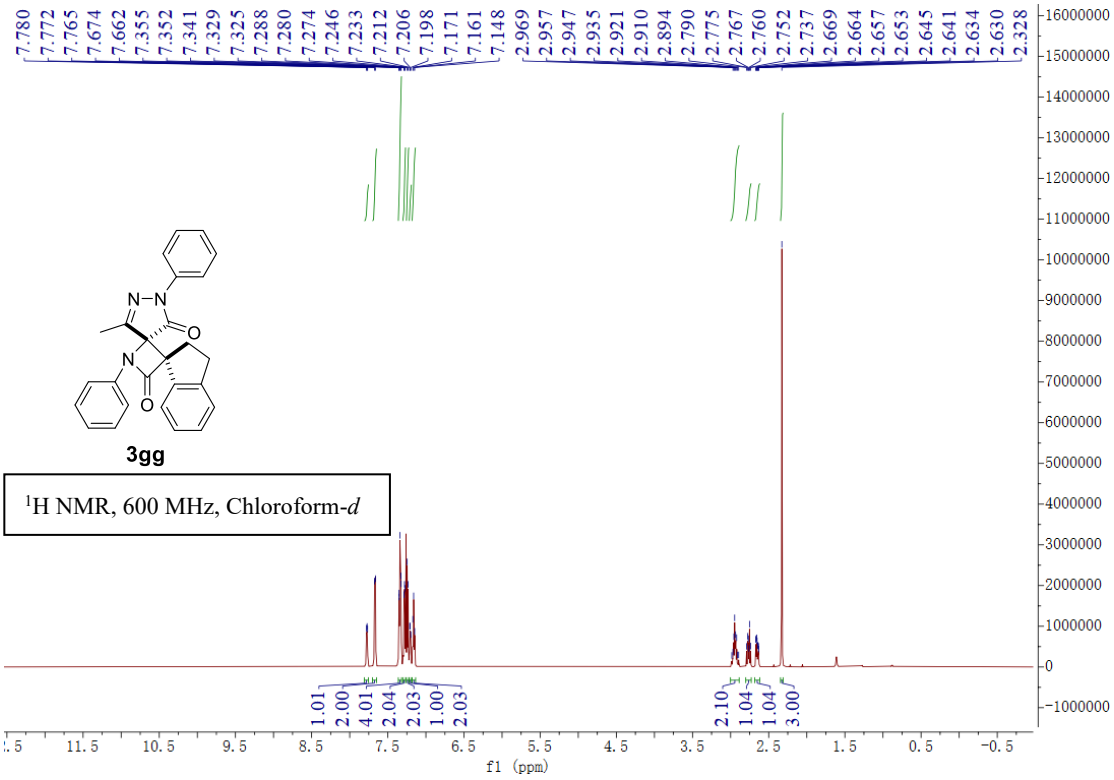
3ff

^{1}H NMR, 600 MHz, Chloroform-*d*



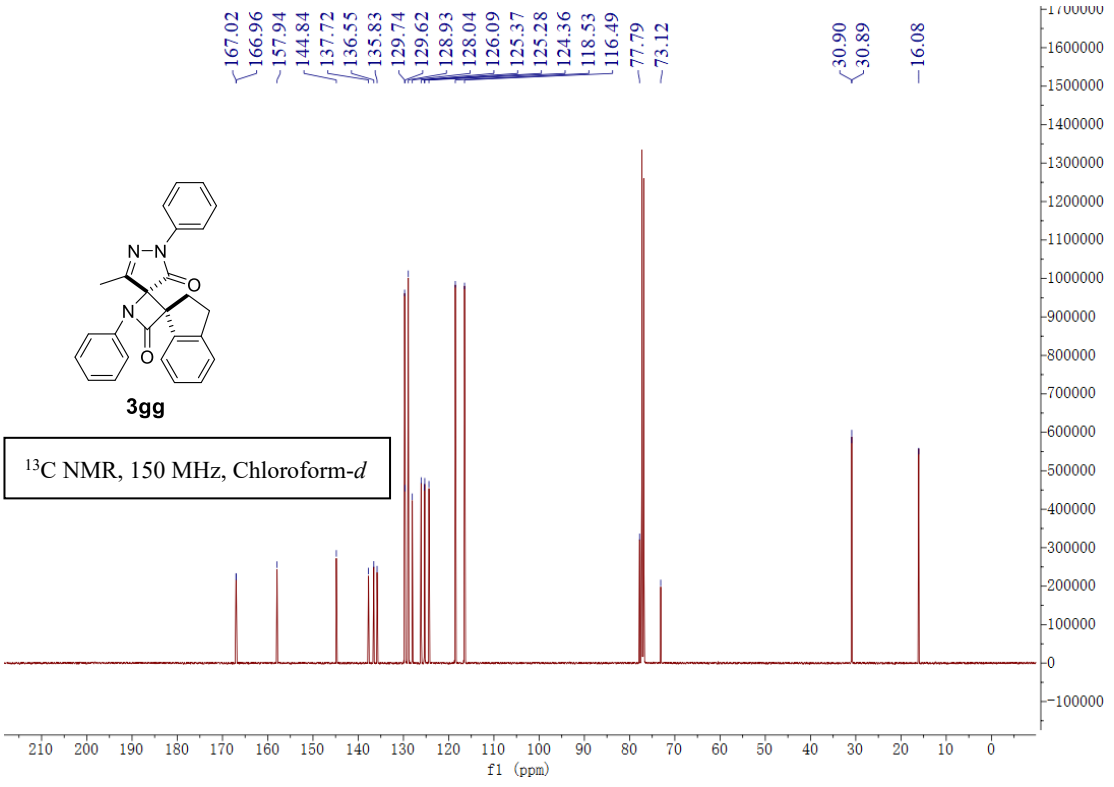
3ff

^{13}C NMR, 150 MHz, Chloroform-*d*



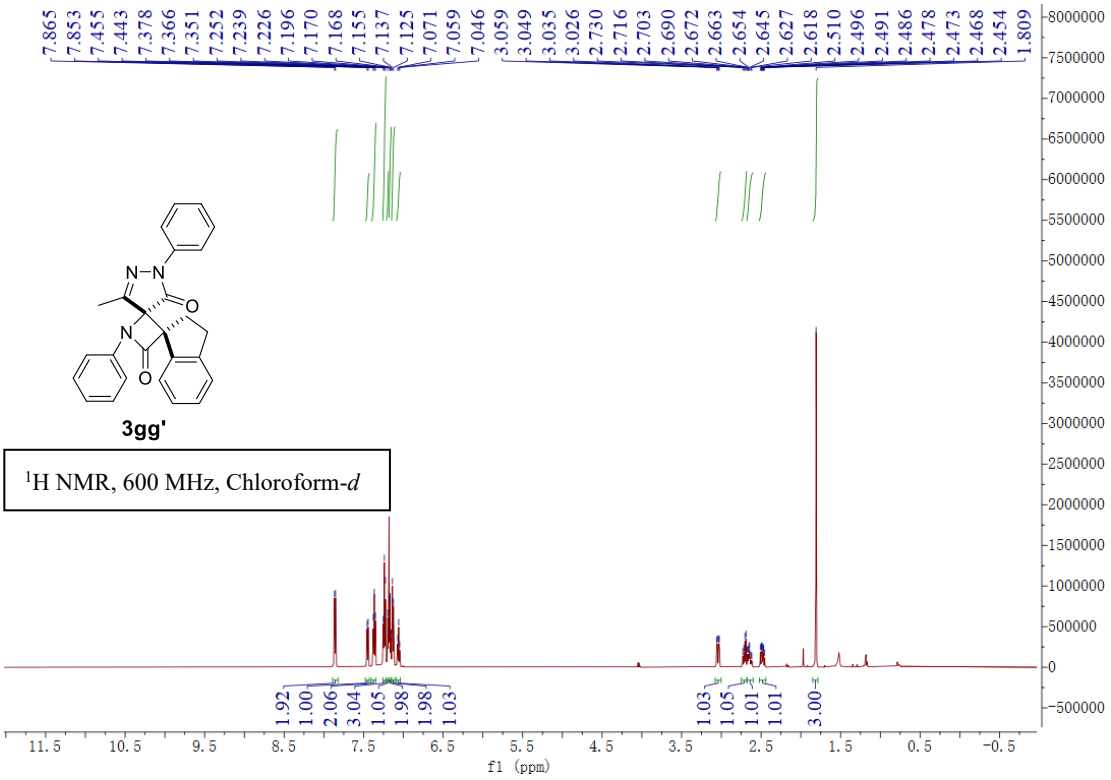
3gg

^{1}H NMR, 600 MHz, Chloroform-*d*



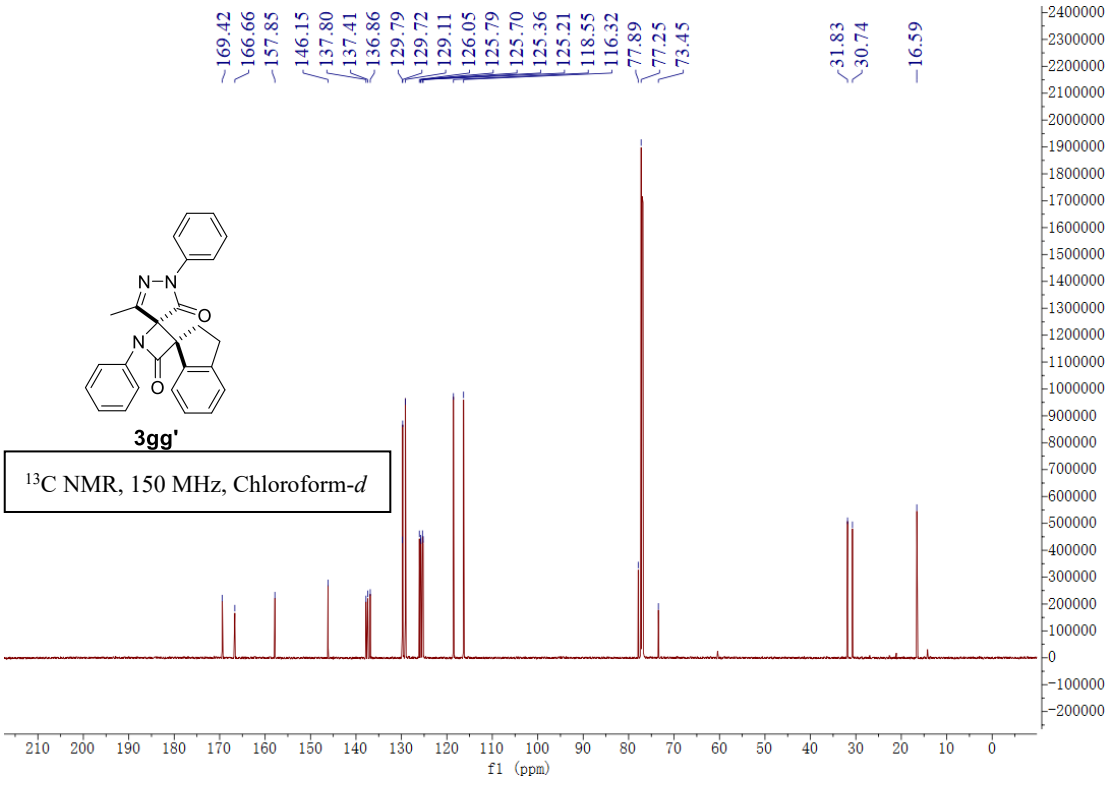
3gg

^{13}C NMR, 150 MHz, Chloroform-*d*



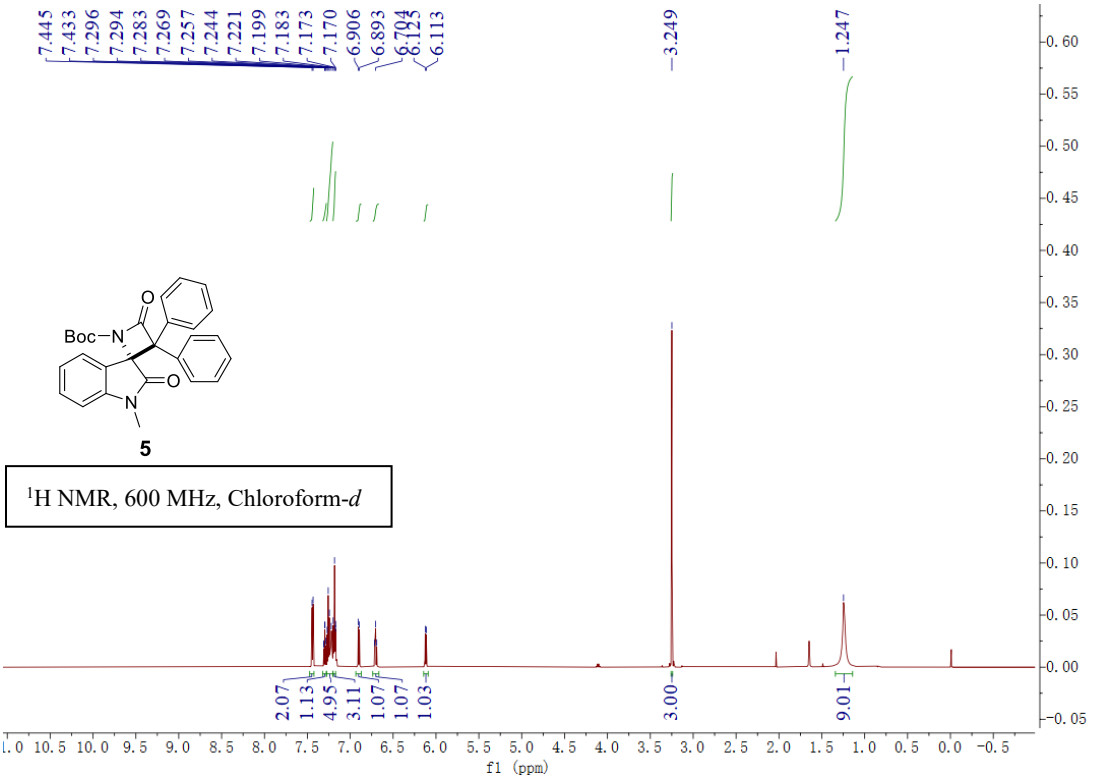
3gg'

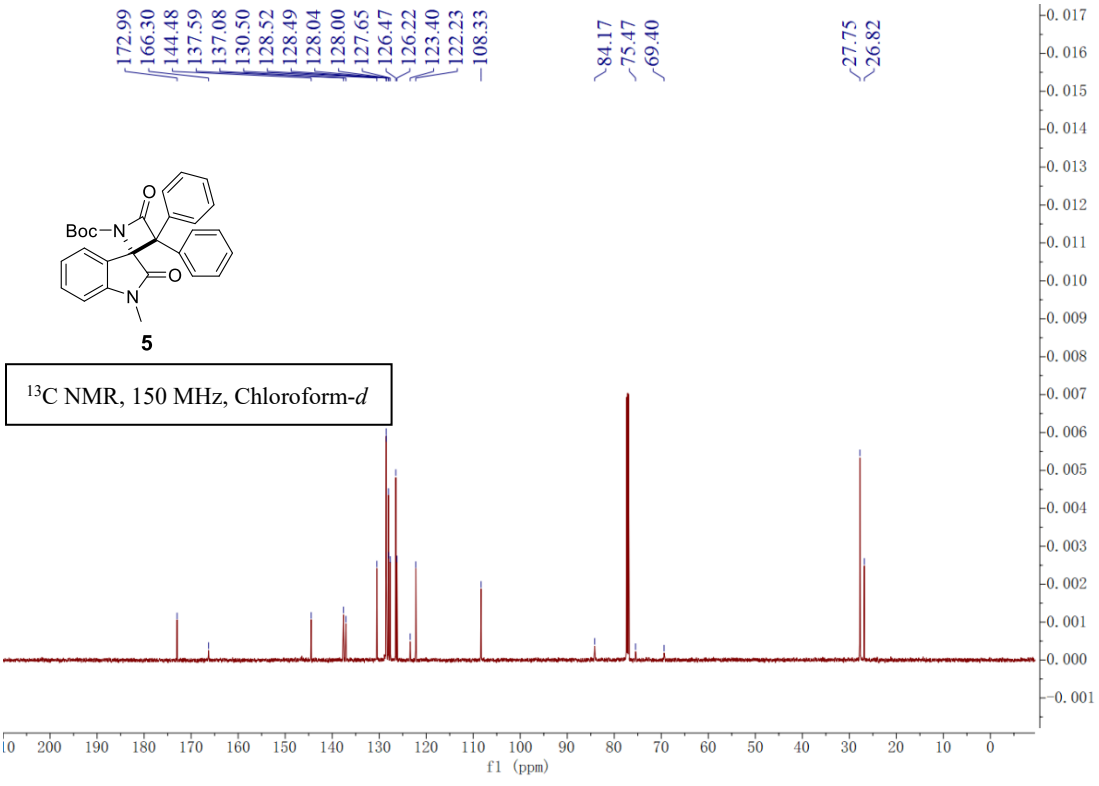
^{1}H NMR, 600 MHz, Chloroform-*d*

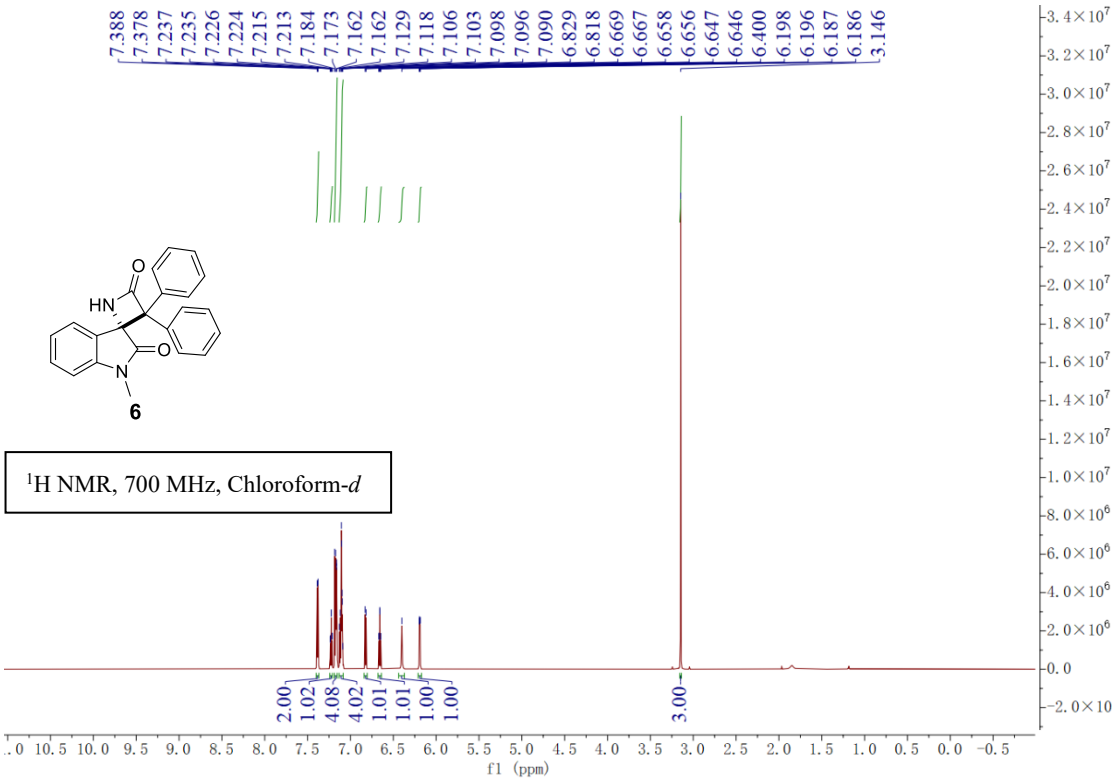


3gg'

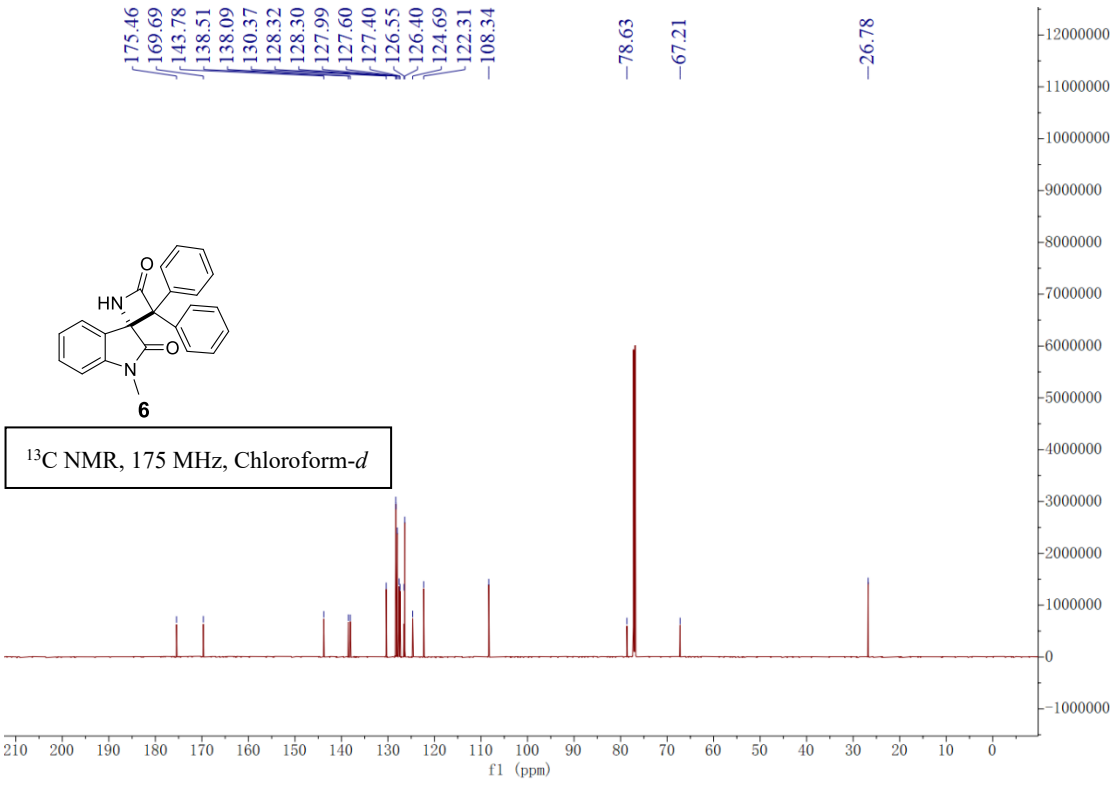
^{13}C NMR, 150 MHz, Chloroform-*d*


7.445
7.433
7.296
7.294
7.283
7.269
7.257
7.244
7.221
7.199
7.183
7.173
7.170
6.906
6.893
6.704
6.125
6.113
3.249
1.247
Boc
N
O
O
N
5
1H NMR, 600 MHz, Chloroform-d
2.07
1.13
4.95
3.11
1.07
1.07
1.03
3.00
9.01
f1 (ppm)

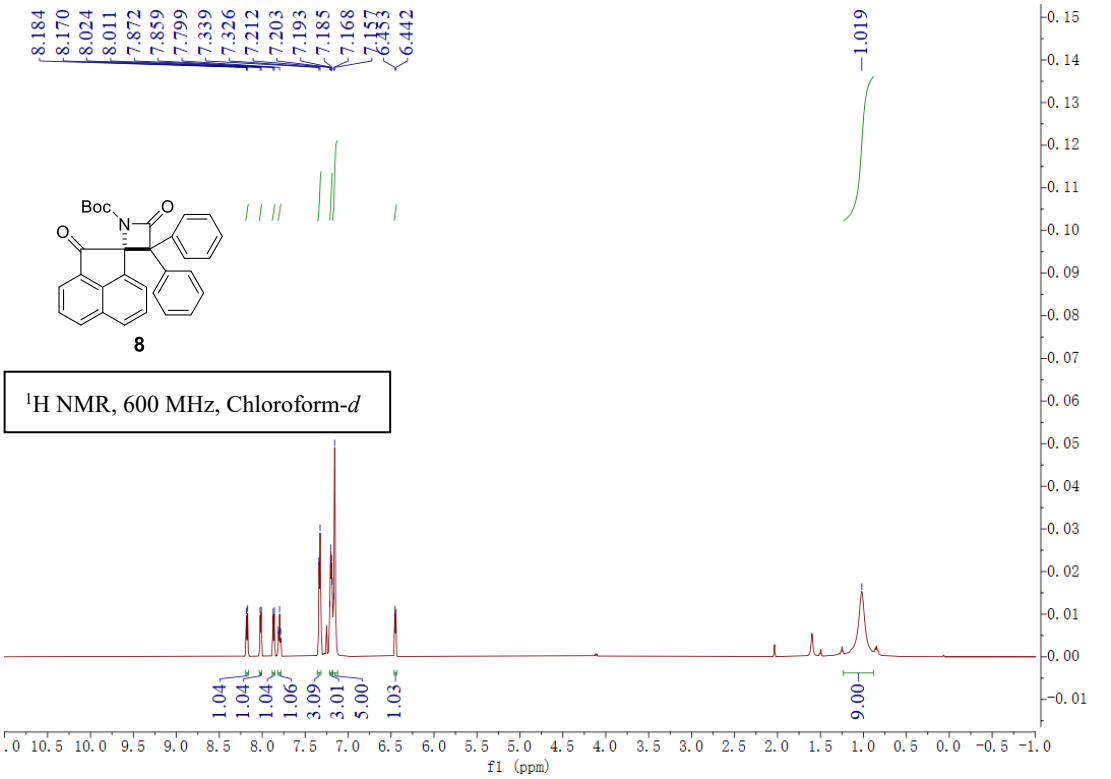

172.99
166.30
144.48
137.59
137.08
130.50
128.52
128.49
128.04
128.00
127.65
126.47
126.22
123.40
122.23
108.33
84.17
75.47
69.40
27.75
26.82
Boc
N
O
O
N
5
13C NMR, 150 MHz, Chloroform-d
f1 (ppm)



^{1}H NMR, 700 MHz, Chloroform-*d*

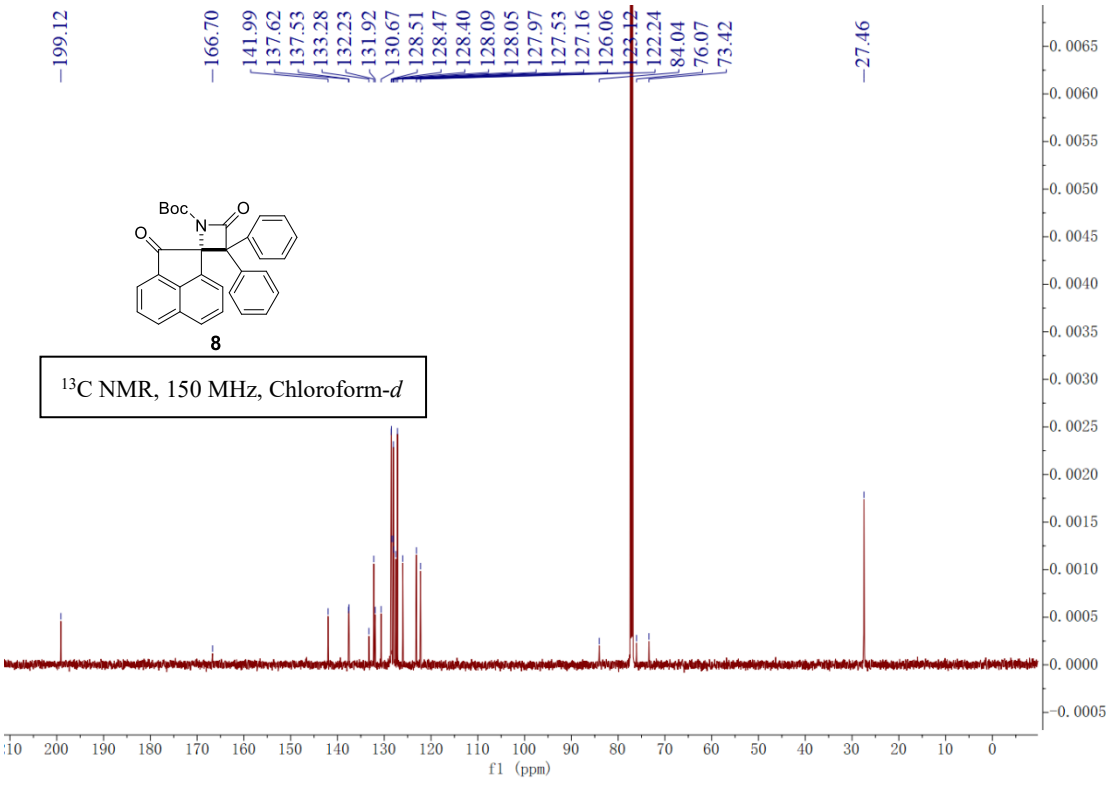


^{13}C NMR, 175 MHz, Chloroform-*d*



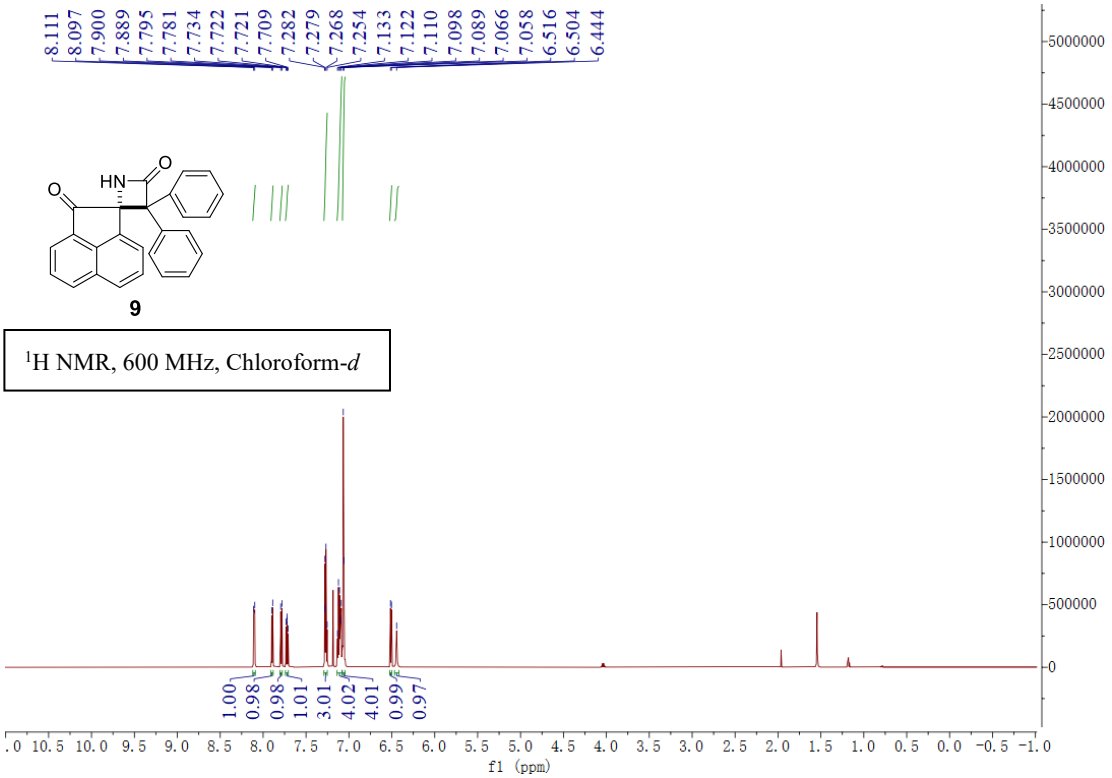
8

^{1}H NMR, 600 MHz, Chloroform-*d*



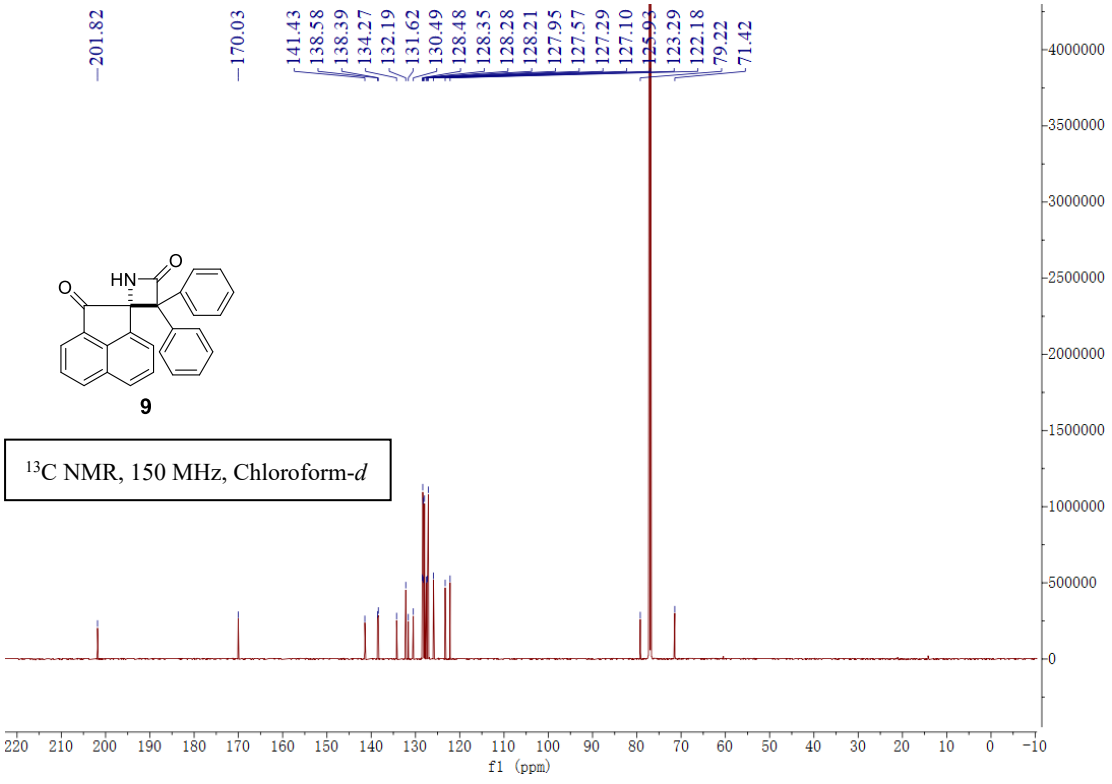
8

^{13}C NMR, 150 MHz, Chloroform-*d*



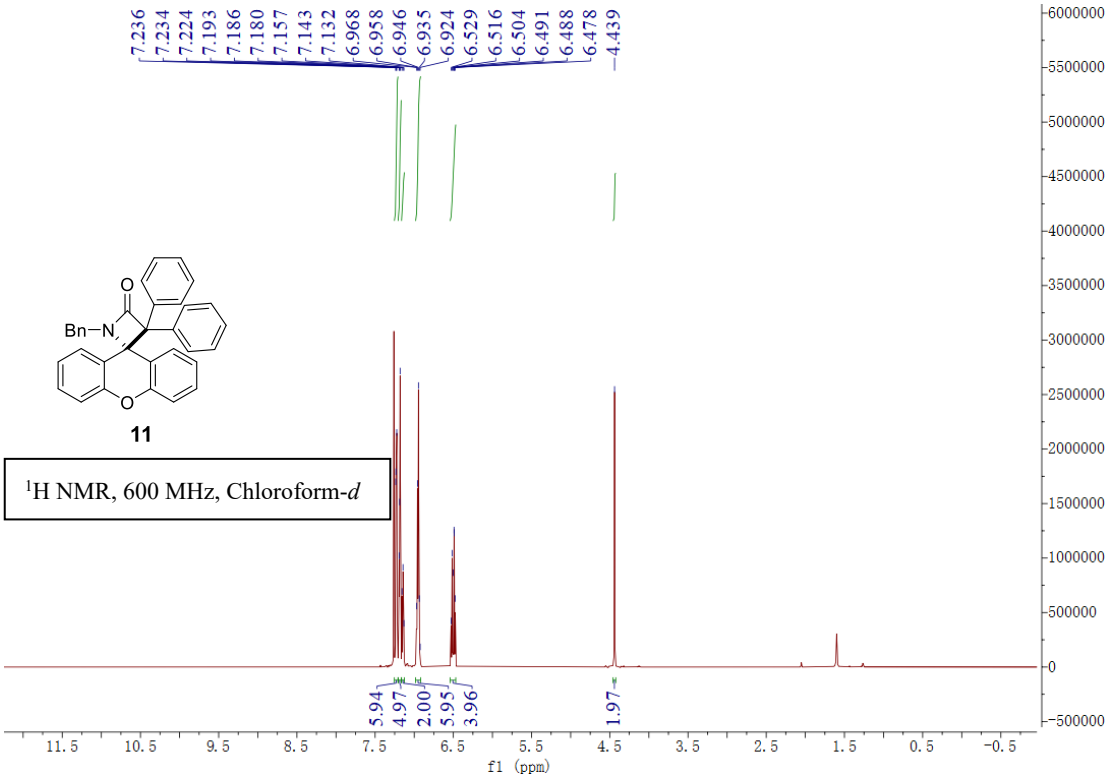
9

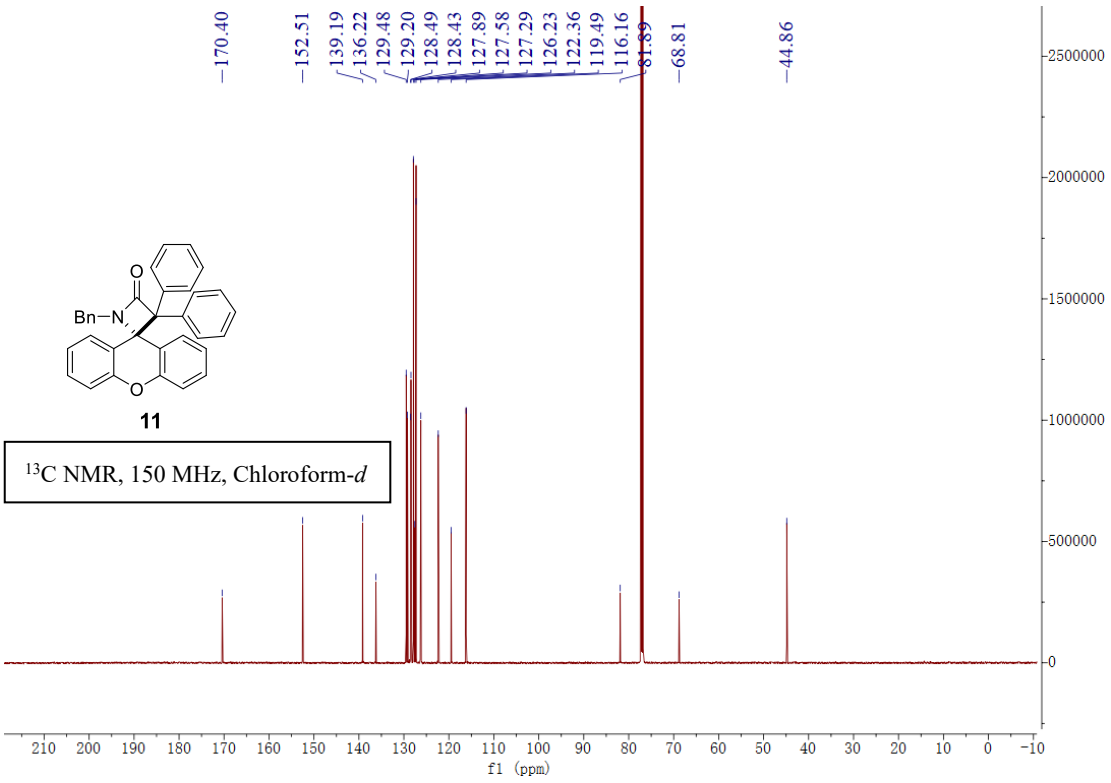
^{1}H NMR, 600 MHz, Chloroform-*d*

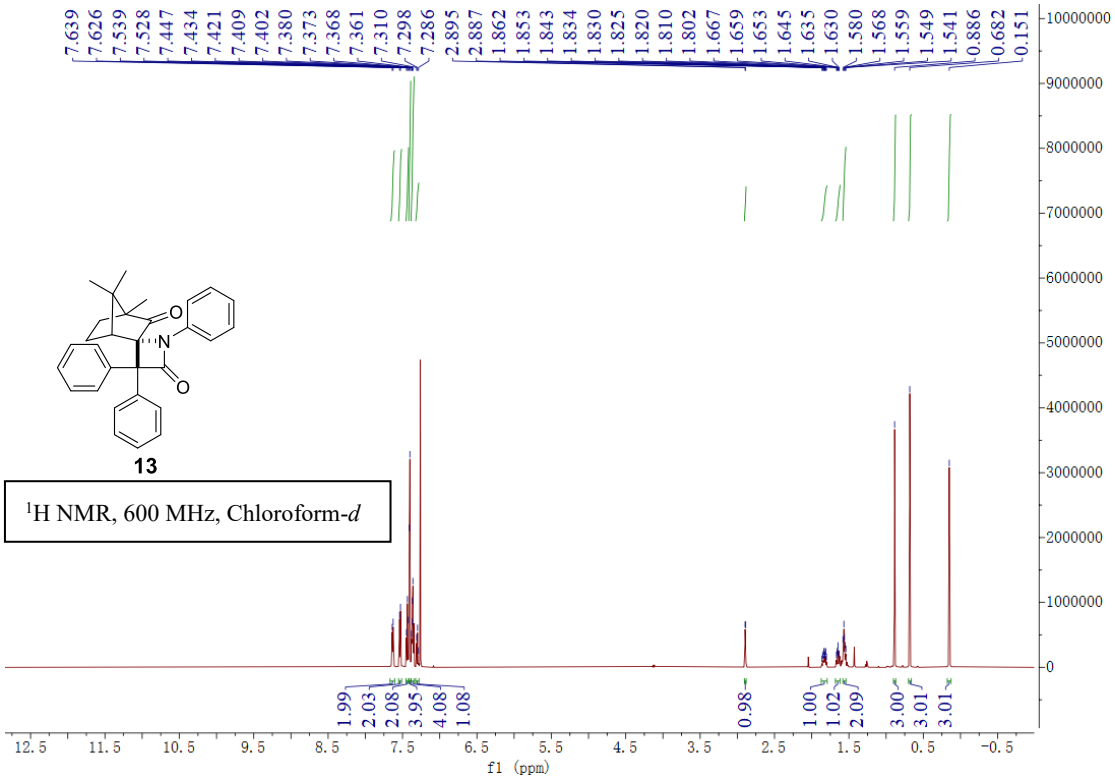


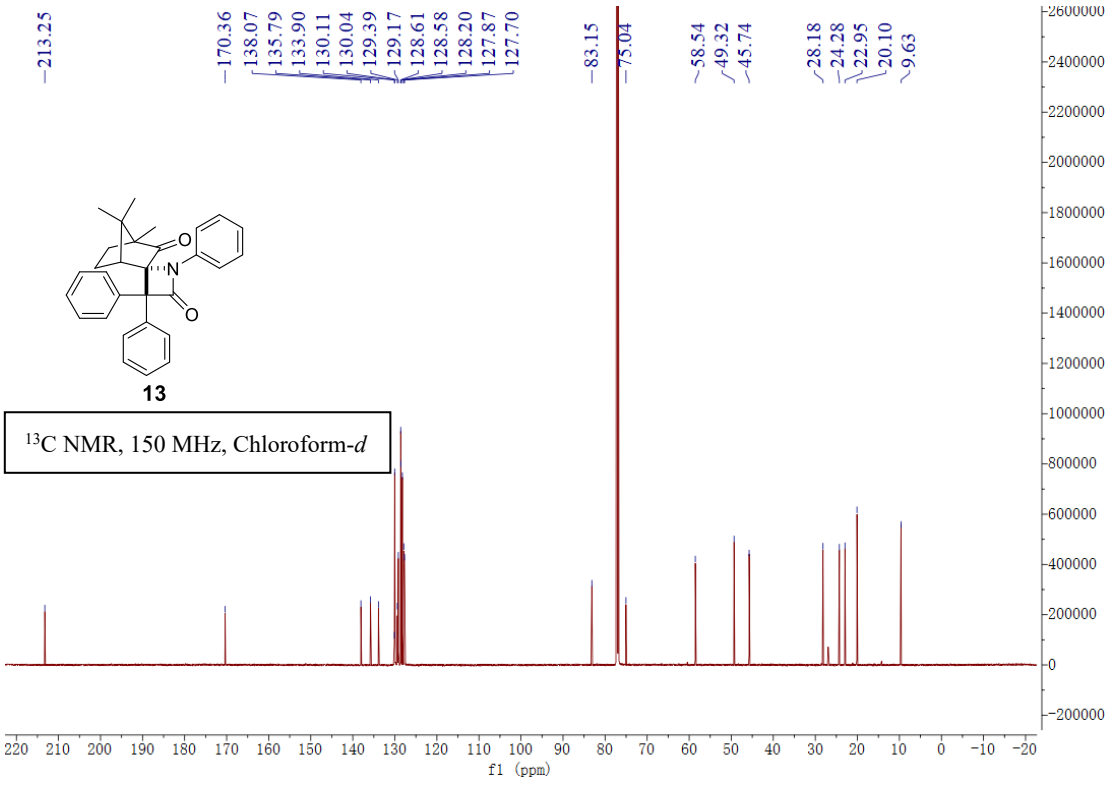
9

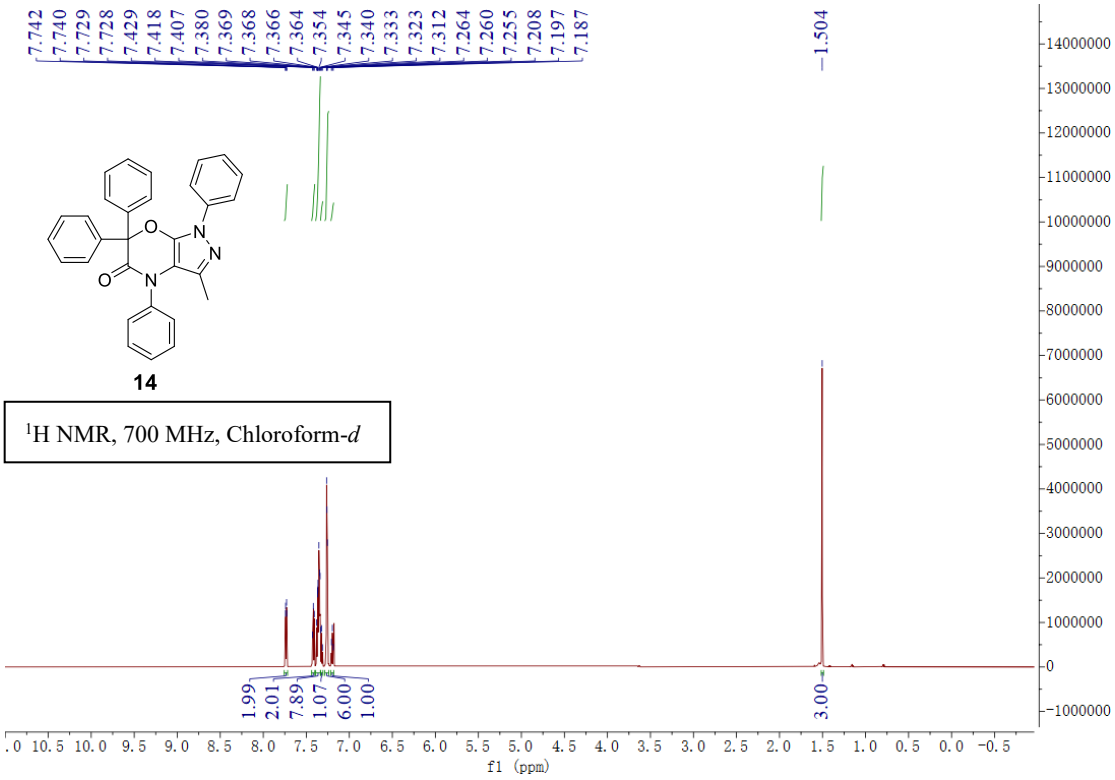
^{13}C NMR, 150 MHz, Chloroform-*d*


7.236
7.234
7.224
7.193
7.186
7.180
7.157
7.143
7.132
6.968
6.958
6.946
6.935
6.924
6.529
6.516
6.504
6.491
6.488
6.478
4.439
Bn—N
O
O
11
[1]H NMR, 600 MHz, Chloroform-d
5.94
4.97
2.00
5.95
3.96
1.97
f1 (ppm)


170.40
152.51
139.19
136.22
129.48
129.20
128.49
128.43
127.89
127.58
127.29
126.23
122.36
119.49
116.16
81.89
68.81
44.86
Bn—N
O
O
11
[13]C NMR, 150 MHz, Chloroform-d
f1 (ppm)

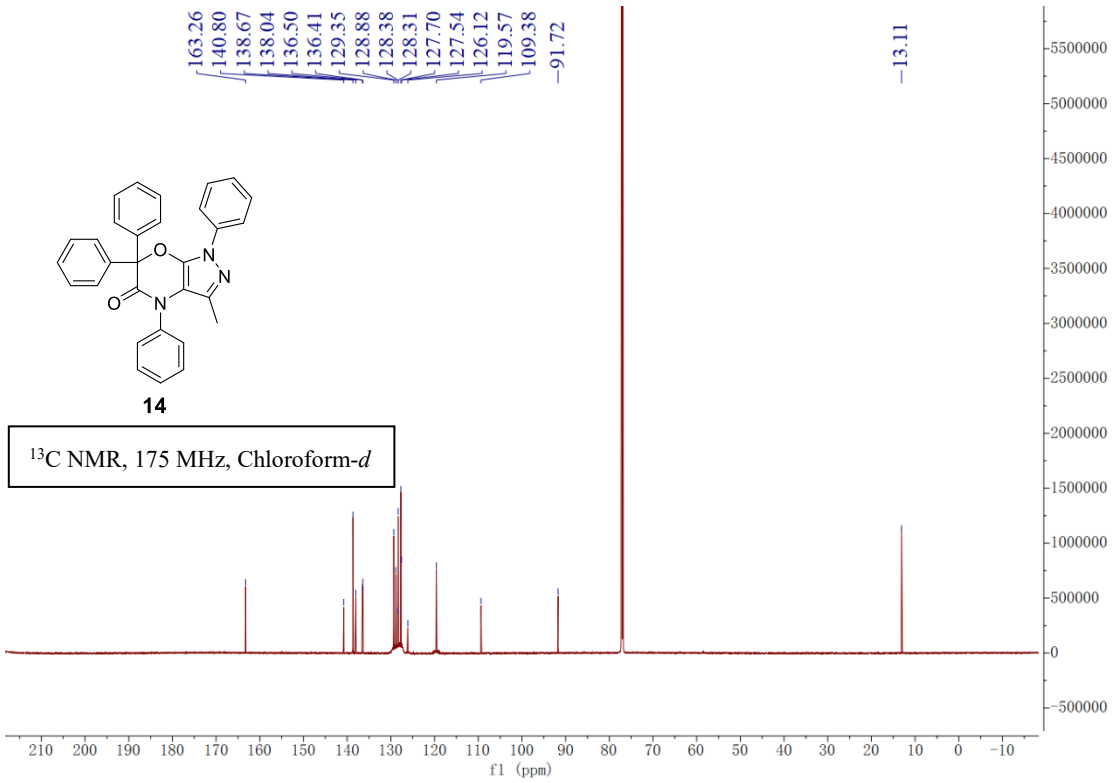

7.639
7.626
7.539
7.528
7.447
7.434
7.421
7.409
7.402
7.380
7.373
7.368
7.361
7.310
7.298
7.286
2.895
2.887
1.862
1.853
1.843
1.834
1.830
1.825
1.820
1.810
1.802
1.667
1.659
1.653
1.645
1.635
1.630
1.580
1.568
1.559
1.549
1.541
0.886
0.682
0.151
O
N
O
13
1H NMR, 600 MHz, Chloroform-d
1.99
2.03
2.08
3.95
4.08
1.08
0.98
1.00
1.02
2.09
3.00
3.01
3.01
f1 (ppm)


213.25
170.36
138.07
135.79
133.90
130.11
130.04
129.39
129.17
128.61
128.58
128.20
127.87
127.70
83.15
75.04
58.54
49.32
45.74
28.18
24.28
22.95
20.10
9.63
O
N
O
13
13C NMR, 150 MHz, Chloroform-d
f1 (ppm)



14

^{1}H NMR, 700 MHz, Chloroform-*d*



14

^{13}C NMR, 175 MHz, Chloroform-*d*