Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information for

Metal-Free Tandem Reaction Synthesis of Spiro-cyclopropyl Fused Pyrazolin-5-one Derivatives

Man Liu, Chen-Fei Liu, Jing Zhang, Yan-Jun Xu* and Lin Dong*

Table of Contents

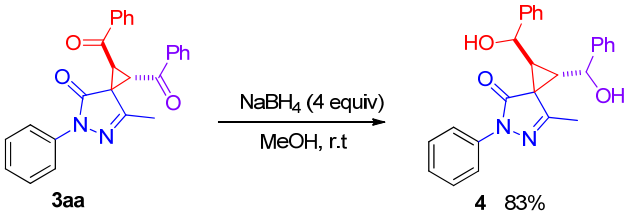
1. General Methods

NMR data were obtained for ^{1}H at 400 MHz or 600 MHz, and for ^{13}C at 100 MHz or 151 MHz. Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard in $CDCl_3$ solution. ESI HRMS was recorded on a Waters SYNAPT G2 and Water XEVO G2 Q-ToF. UV detection was monitored at 220 nm. The UV-vis spectra were recorded on a Shimadzu UV-2450 spectrometer. TLC was performed on glass-backed silica plates. 3-methyl-1-phenyl-1H-pyrazol-5(4H)-one was commercially available, other pyrazolones and sulfoxonium ylides were prepared according to the literature procedures.[1,2] 3-methyl-5-phenyl-1*H*pyrazole-4,5-dione **5** and unsaturated pyrazolone **6** were prepared according to the literature procedures[3,4].

2. General Procedure for Synthesis of Spiropyrazolone Product 3aa

3-methyl-1-phenyl-1*H*-pyrazol-5(4*H*)-one **1a** (8.7 mg, 0.05 mmol) and sulfoxonium ylide **2a** (29.4 mg, 3.0 equiv.) and *p*-nitrobenzoic acid (25.2 mg, 3.0 equiv.) were stirred in toluene (0.5 mL) at 120 °C for 12 h. After completion, the mixture was concentrated under vacuum and purified by flash chromatography eluting with ethyl acetate and petroleum ether (1:10) to give the product **3aa** as light yellow oil (19.0 mg, 93%).

3. Synthetic Application of Spiropyrazolone Product 3aa

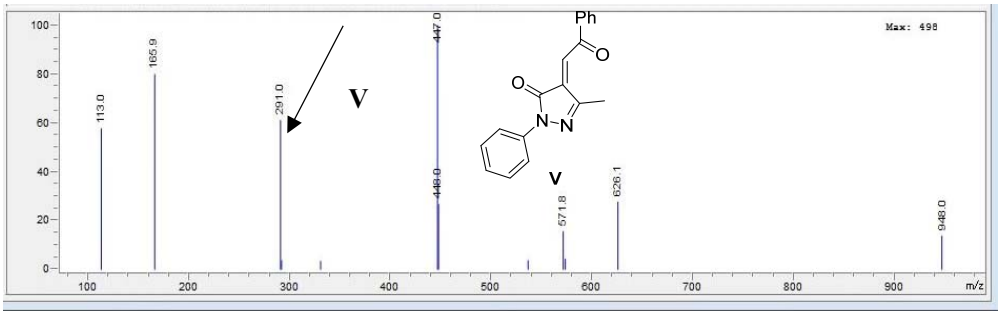


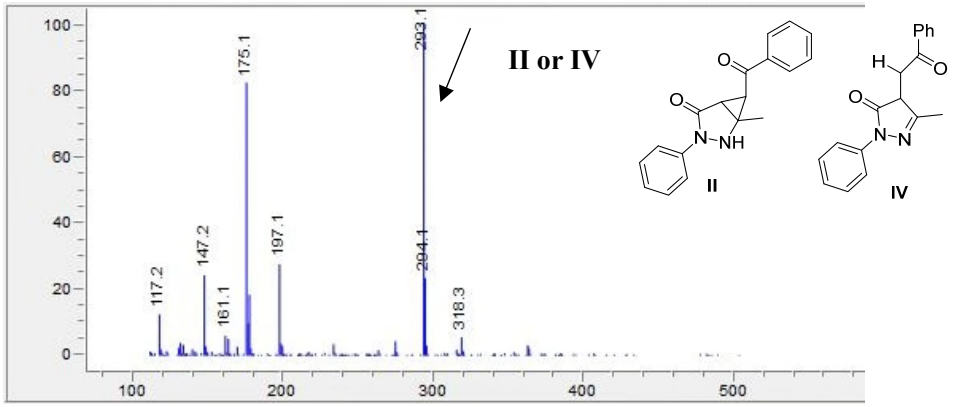
3aa **4** 83%

1,2-bis(hydroxy(phenyl)methyl)-7-methyl-5-phenyl-5,6-diazaspiro[2.4]hept-6-en-4-one **4**: To a solution of the product **3aa** (20.4 mg, 0.05 mmol) in anhydrous MeOH (1 mL) was added $NaBH_4$ (7.6 mg, 4 equiv) in small portions. The resulting solution was stirred at room temperature for 5 min. After completion, the reaction mixture was separated and extracted with ethyl acetate (5 mL × 3). The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. Concentration in vacuo and purification by column chromatography afforded the **4** (17.1 mg, 83%) as a white solid.

4. Determination of Products by LCMS Data

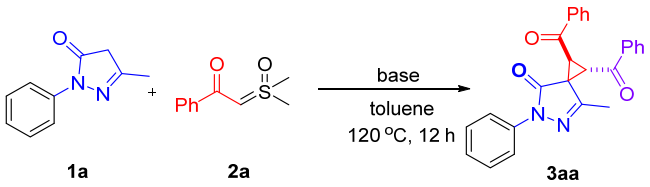
The intermediate **II** (or intermediate **IV**) and **V** could be observed by LCMS when **1a** and **2a** reacted under standard conditions for 1 h.





5. Experimental Section

Table S1. Screening of bases.[a]

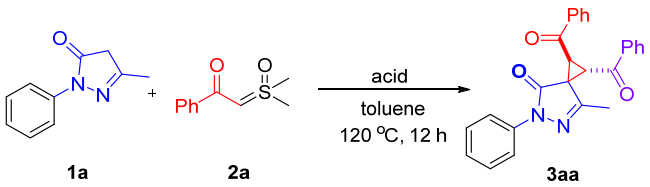


1a **2a** **3aa**

entry	base/equiv	yield (%)[b] **3aa**
1	NaOAc/1	13
2	KOAc/1	ND
3	LiOAc.H_2O/1	ND
4	$Zn(OAc)_2.H_2O$/1	ND
5	t-BuOK/1	ND
6	K_2CO_3/1	ND
7	$Ca(OH)_2$/1	ND

[a] Reaction conditions unless otherwise specified: 0.05 mmol of **1a**, 3.0 equiv. of **2a**, 0.5 mL of toluene, 120 °C, under air, 12 h. [b] Isolated yield

Table S2. Screening of acids.[a]

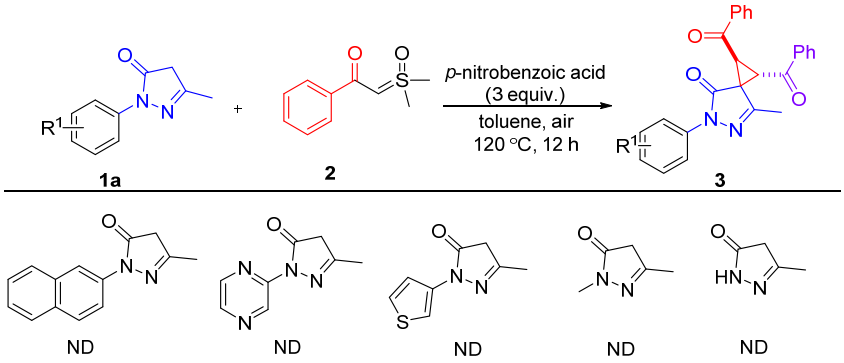


1a **2a** **3aa**

entry	base/equiv	yield (%)[b] **3aa**
1	4-(Trifluoromethyl)benzoic acid/1	62
2	4-Cyanobenzoic acid/1	55
3	Terephthalic acid/1	50
4	2-Nitrophenylacetic acid/1	34
5	3-Hydroxypivalic acid/1	47
6	HOAc/1	39
7	Citric acid/1	48
8	Cyanoacetic acid/1	31

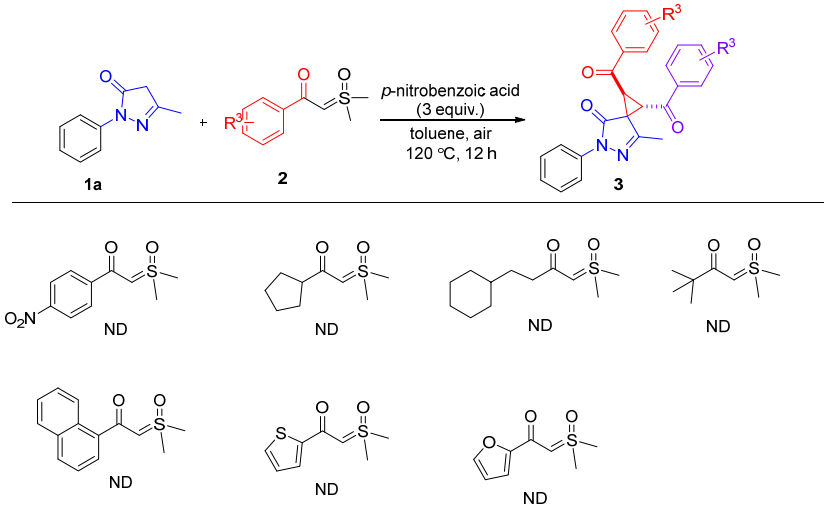
[a] Reaction conditions unless otherwise specified: 0.05 mmol of **1a**, 3.0 equiv. of **2a**, 0.5 mL of toluene, 120 °C, under air, 12 h. [b] Isolated yield

6. The Scope of *N*-arylpyrazol-5-ones[a]



Scheme S1:[a] Unless otherwise mentioned all reactions were performed with 0.05 mmol of **1a**, 3.0 equiv. of **2**, 3.0 equiv. of *p*-nitrobenzoic acid, toluene (0.5 mL), 120 °C, 12 h, under air. Isolated yield

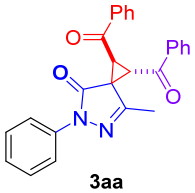
The Scope of Sulfoxonium Ylides[a]



Scheme S2:[a] Unless otherwise mentioned all reactions were performed with 0.05 mmol of **1a**, 3.0 equiv. of **2**, 3.0 equiv. of *p*-nitrobenzoic acid, toluene (0.5 mL), 120 °C, 12 h, under air. Isolated yield

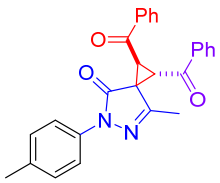
7. Characterization Data for Pyrazolin-5-one Derivatives

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3aa**). Light yellow oil, 12 h, 19.0 mg, 93% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.04-8.02 (s, 1H), 7.79 (dd, J_1 = 8.8 Hz, J_2 = 1.2 Hz, 2H), 7.64 (t, J = 7.6 Hz, 1H), 7.56 (t, J = 7.2 Hz, 1H), 7.50 (t, J = 7.6 Hz, 2H), 7.44 (t, J = 8.0 Hz, 2H), 7.33 (t, J = 8.4 Hz, 2H), 7.29 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.14 (t, J = 7.2 Hz, 1H), 4.35 (d, J = 8.0 Hz, 1H), 4.25 (d, J = 8.0 Hz, 1H), 2.09 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.1, 188.8, 166.8, 155.0, 137.9, 135.7, 135.7, 134.6, 134.0, 129.1, 129.0, 128.8, 128.8, 128.4, 125.2, 118.6, 45.0, 39.2, 38.3, 15.1 ppm. ESI HRMS: calcd. for $C_{26}H_{20}N_2O_3$+H 409.1552, found 409.1555.

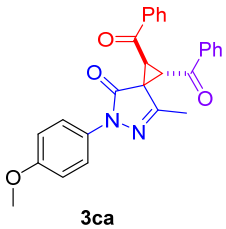


3aa

(4-methyl-7-oxo-6-(p-tolyl)-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ba**). Yellow oil, 12 h, 15.4 mg, 73% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.03 (d, J = 7.8 Hz, 2H), 7.86 (d, J = 7.2 Hz, 2H), 7.65-7.62 (m, 3H), 7.55 (t, J = 7.2 Hz, 1H), 7.50 (t, J = 7.8 Hz, 2H), 7.44 (t, J = 7.2 Hz, 2H), 7.13 (t, J = 8.4 Hz, 2H), 4.33 (d, J = 8.4 Hz, 1H), 4.23 (d, J = 8.4 Hz, 1H), 2.30 (s, 3H), 2.07 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.6, 188.4, 166.9, 155.2, 145.0, 138.0, 133.3, 133.3, 129.8, 129.6, 128.9, 128.8, 128.5, 125.1, 118.6, 44.9, 39.3, 38.4, 21.7, 21.7, 15.1 ppm. ESI HRMS: calcd. for $C_{27}H_{22}N_2O_3$+H 423.1709, found 423.1711.

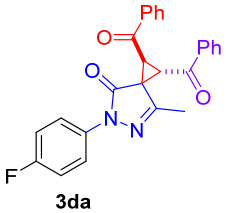


3ba



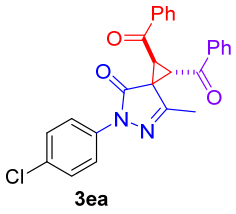
3ca

(6-(4-methoxyphenyl)-4-methyl-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ca**). Yellow oil, 12 h, 7.9 mg, 36% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.97-7.94 (m, 2H), 7.80-7.77 (m, 2H), 7.64 (t, J = 7.6 Hz, 1H), 7.59-7.55 (m, 3H), 7.49 (t, J = 7.6 Hz, 1H), 7.43 (t, J = 7.6 Hz, 2H), 7.37 (t, J = 7.6 Hz, 2H), 6.80-6.76 (m, 2H), 4.26 (d, J = 8.4 Hz, 1H), 4.16 (d, J = 8.4 Hz, 1H), 3.70 (s, 3H), 2.09 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.2, 188.9, 166.4, 157.1, 154.8, 135.7, 134.0, 131.3, 129.1, 128.9, 128.4, 120.5, 113.9, 55.4, 44.9, 39.0, 38.2, 15.1 ppm. ESI HRMS: calcd. for $C_{27}H_{22}N_2O_4$+Na 461.1477, found 461.1476.



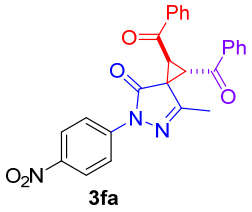
3da

(6-(4-fluorophenyl)-4-methyl-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3da**). Yellow oil, 12 h, 16.0 mg, 75% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.03 (d, J = 7.2 Hz, 2H), 7.86 (d, J = 7.8 Hz, 2H), 7.76-7.74 (m, 2H), 7.64 (t, J = 7.2 Hz, 1H), 7.57 (t, J = 7.2 Hz, 1H), 7.51 (t, J = 7.8 Hz, 2H), 7.45 (t, J = 7.8 Hz, 2H), 7.01 (t, J = 9.0 Hz, 2H), 4.34 (d, J = 7.8 Hz, 1H), 4.25 (d, J = 7.8 Hz, 1H), 2.09 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.0, 188.7, 176.4, 166.7, 159.9 (J_{CF} = 243.4 Hz), 155.2, 135.7 (J_{CF} = 4.1 Hz), 134.6, 134.1, 129.1, 129.0, 128.8, 128.4, 120.5 (J_{CF} = 8.0 Hz), 115.5 (J_{CF} = 22.5 Hz), 44.8, 39.2, 38.4, 15.1 ppm. ESI HRMS: calcd. for $C_{26}H_{19}FN_2O_3$+Na 449.1277, found 449.1277.



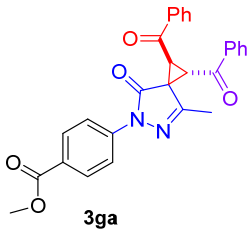
3ea

(6-(4-chlorophenyl)-4-methyl-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ea**). Yellow oil, 12 h, 14.1 mg, 64% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.02 (d, J = 7.8 Hz, 2H), 7.86 (d, J = 7.8 Hz, 2H), 7.77 (d, J = 9.0 Hz, 2H), 7.64 (t, J = 7.2 Hz, 1H), 7.56 (t, J = 7.8 Hz, 1H), 7.50 (t, J = 7.8 Hz, 2H), 7.44 (t, J = 7.8 Hz, 2H), 7.28 (t, J = 9.0 Hz, 2H), 4.34 (d, J = 8.4 Hz, 1H), 4.25 (d, J = 8.4 Hz, 1H), 2.08 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.9, 188.6, 166.8, 155.4, 136.5, 135.7, 135.6, 134.6, 134.1, 130.3, 129.1, 129.0, 128.8, 128.8, 128.4, 119.7, 44.9, 39.3, 38.5, 15.2 ppm. ESI HRMS: calcd. for $C_{26}H_{19}ClN_2O_3$+H 465.0982, found 465.0979.



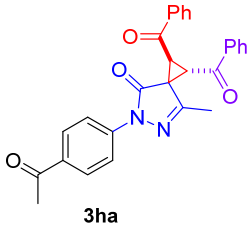
3fa

(4-methyl-6-(4-nitrophenyl)-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3fa**). Yellow oil, 12 h, 14.3 mg, 63% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.21 (d, J = 9.6 Hz, 2H), 8.07 (d, J = 9.0 Hz, 2H), 8.03 (d, J = 7.8 Hz, 2H), 7.88 (d, J = 7.2 Hz, 2H), 7.66 (t, J = 7.8 Hz, 1H), 7.58 (t, J = 7.2 Hz, 1H), 7.52 (t, J = 7.8 Hz, 2H), 7.46 (t, J = 7.8 Hz, 2H), 4.38 (d, J = 8.4 Hz, 1H), 4.31 (d, J = 8.4 Hz, 1H), 2.12 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.6 188.2, 167.5, 156.6, 144.1, 142.8, 135.5, 135.5, 134.8, 134.3, 129.2, 129.1, 128.8, 128.4, 124.8, 117.8, 44.8, 39.8, 38.9, 15.3 ppm. ESI HRMS: calcd. for $C_{26}H_{19}N_3O_5$+H 454.1403, found 454.1404.



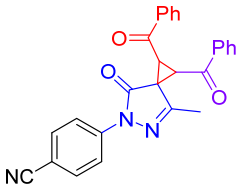
3ga

methyl 4-(1,2-dibenzoyl-7-methyl-4-oxo-5,6-diazaspiro[2.4]hept-6-en-5-yl)benzoate (**3ga**). Yellow oil, 12 h, 14.9 mg, 64% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.02 (t, J = 8.4 Hz, 4H), 7.94 (d, J = 8.4 Hz, 2H), 7.87 (d, J = 7.8 Hz, 2H), 7.65 (t, J = 7.8 Hz, 1H), 7.57 (t, J = 7.2 Hz, 1H), 7.51 (t, J = 7.8 Hz, 2H), 7.45 (t, J = 7.8 Hz, 2H), 4.36 (d, J = 8.4 Hz, 1H), 4.28 (d, J = 8.4 Hz, 1H), 3,88 (s, 3H), 2.10 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.8 188.5, 167.2, 166.5, 155.8, 135.6, 134.7, 134.1, 130.5, 129.2, 129.0, 128.8, 128.4, 117.6, 52.0, 44.9, 39.5, 38.6, 15.2 ppm. ESI HRMS: calcd. for $C_{28}H_{22}N_2O_5$+H 467.1607, found 467.1607.



3ha

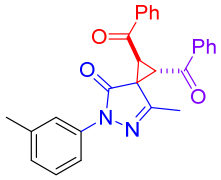
(6-(4-acetylphenyl)-4-methyl-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ha**). Yellow oil, 12 h, 11.5 mg, 51% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.03 (d, J = 7.2 Hz, 2H), 7.97-7.93 (m, 4H), 7.87 (d, J = 7.8 Hz, 2H), 7.65 (t, J = 7.8 Hz, 1H), 7.57 (t, J = 7.2 Hz, 1H), 7.51 (t, J = 7.8 Hz, 2H), 7.45 (t, J = 7.8 Hz, 2H), 4.37 (d, J = 8.4 Hz, 1H), 4.29 (d, J = 8.4 Hz, 1H), 2.56 (s, 3H), 2.11 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 196.9, 190.8 188.5, 167.2, 155.9, 135.6, 134.7, 134.2, 129.4, 129.2, 129.0, 128.8, 128.4, 117.7, 44.9, 39.5, 38.6, 26.4, 15.2 ppm. ESI HRMS: calcd. for $C_{28}H_{22}N_2O_4$+H 451.1658, found 451.1657.



3ia

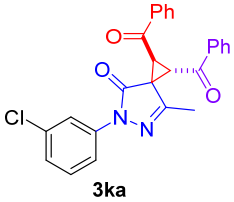
4-(1,2-dibenzoyl-7-methyl-4-oxo-5,6-diazaspiro[2.4]hept-6-en-5-yl) benzonitrile (**3ia**). Yellow oil, 12 h, 16.0 mg, 74% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.03-8.00 (m, 4H), 7.88-7.86 (m, 2H), 7.65-7.61 (m, 3H), 7.57 (d, J = 7.2 Hz, 1H), 7.50 (t, J = 8.0 Hz, 2H), 7.45 (t, J = 7.6 Hz, 2H), 4.36 (d, J = 8.4 Hz, 1H), 4.29 (d, J = 8.4 Hz, 1H), 2.11 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.6 188.3, 167.4, 156.3, 134.8, 134.2, 133.0, 129.2, 129.0, 128.8, 128.4, 118.7, 118.2, 108.1, 44.9, 39.7, 38.8, 15.2 ppm. ESI HRMS: calcd. for $C_{27}H_{19}N_3O_3$+H 434.1505, found 434.1502.

(4-methyl-7-oxo-6-(m-tolyl)-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ja**).



3ja

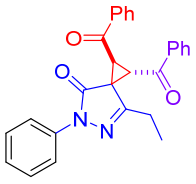
Yellow oil, 12 h, 15.0 mg, 71% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.05 (d, J = 7.6 Hz, 2H), 7.89 (d, J = 7.2 Hz, 2H), 7.68-7.65 (m, 2H), 7.59 (t, J = 7.6 Hz, 2H), 7.53 (t, J = 7.6 Hz, 2H), 7.47 (t, J = 7.6 Hz, 2H), 7.28-7.23 (m, 1H), 6.99 (d, J = 7.6 Hz, 1H), 4.37 (d, J = 8.0 Hz, 1H), 4.28 (d, J = 8.0 Hz, 1H), 2.35 (s, 3H), 2.11 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.1, 188.8, 166.8, 154.9, 138.8, 137.9, 135.7, 135.7, 134.6, 134.0, 129.1, 129.0, 128.8, 128.6, 128.4, 126.1, 119.2, 115.7, 45.0, 39.2, 38.2, 21.5, 15.1ppm. ESI HRMS: calcd. for $C_{27}H_{22}N_2O_3$+Na 445.1528, found 445.1528.



3ka

(6-(3-chlorophenyl)-4-methyl-7-oxo-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ka**). Yellow oil, 12 h, 15.0 mg, 68% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.96-7.93 (m, 2H), 7.82 (t, J = 2.0 Hz, 1H), 7.80-7.78 (m, 2H), 7.69-7.66 (m, 1H), 7.57 (t, J = 7.2 Hz, 1H), 7.50 (t, J = 7.2 Hz, 1H), 7.43 (t, J = 2.0 Hz, 2H), 7.37 (t, J = 7.6 Hz, 2H), 7.19-7.15 (m, 1H), 7.05-7.02 (m, 1H), 4.28 (d, J = 8.4 Hz, 1H), 4.19 (d, J = 8.4 Hz, 1H), 2.01 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.9, 188.5, 166.9, 155.5, 138.9, 135.6, 135.6, 134.7, 134.6, 134.1, 129.9, 129.2, 129.0, 128.8, 128.4, 125.1, 118.5, 116.3, 44.9, 39.4, 38.5, 15.1 ppm. ESI HRMS: calcd. for $C_{26}H_{19}ClN_2O_3$+Na 465.0982, found 465.0988.

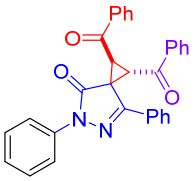
(4-ethyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3ma**).



3ma

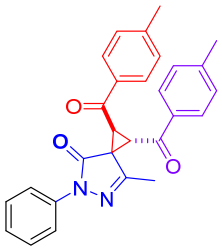
Yellow oil, 12 h, 12.4 mg, 59% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.95-7.93 (m, 2H), 7.84-7.75 (m, 4H), 7.56 (tt, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 748 (tt, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.42 (t, J = 8.0 Hz, 2H), 7.36 (t, J = 8.0 Hz, 2H), 7.29-7.24 (m, 2H), 7.07 (tt, J_1 = 8.4 Hz, J_2 = 1.2 Hz, 1H), 4.24 (d, J = 8.0 Hz, 1H), 4.17 (d, J = 8.0 Hz, 1H), 2.37-2.29 (m, 1H), 2.17-2.07 (m, 1H), 1.20 (t, J = 7.2 Hz, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.2, 188.9, 167.0, 158.8, 138.1, 135.7, 134.6, 134.0, 129.1, 128.9, 128.8, 128.4, 125.2, 118.6, 44.8, 39.4, 38.3, 22.0, 9.9 ppm. ESI HRMS: calcd. for $C_{27}H_{22}N_2O_3$+Na 445.1528, found 445.1525.

(7-oxo-4,6-diphenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(phenylmethanone) (**3na**). Yellow oil, 12 h, 13.4 mg, 57% yield; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.02 (d, J = 7.2 Hz, 2H), 7.92 (d, J = 7.8 Hz, 2H), 7.73 (d, J = 7.2 Hz, 2H), 7.58 (q, J = 7.8 Hz, 2H), 7.48 (t, J = 7.8 Hz, 2H), 7.44 (t, J = 7.2 Hz, 1H), 7.42-7.33 (m, 6H), 7.27 (d, J = 7.2 Hz, 2H), 7.20 (t, J = 7.8 Hz, 1H), 4.55 (d, J = 8.4 Hz, 1H), 4.23 (d, J = 8.4 Hz, 1H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.0, 188.6, 166.8, 160.1, 160.0, 155.0, 137.9, 137.0, 136.9, 130.2, 129.9, 128.8, 125.3, 121.6, 121.4, 121.1, 120.9, 118.6, 112.4, 112.1, 55.5, 55.4, 44.9, 39.4, 38.4, 15.1 ppm. ESI HRMS: calcd. for $C_{31}H_{22}N_2O_3$+H 471.1709, found 471.1709.



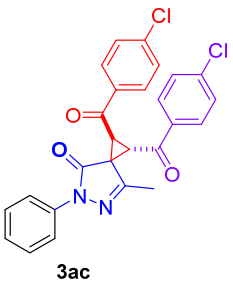
3na

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(p-tolylmethanone) (**3ab**). Yellow oil, 12 h, 16.4 mg, 75% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.92 (d, J = 8.4 Hz, 2H), 7.80 (d, J = 7.6 Hz, 2H), 7.76 (d, J = 8.0 Hz, 2H), 7.33 (t, J = 7.6 Hz, 2H), 7.28 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 7.14 (t, J = 7.6 Hz, 1H), 4.32 (d, J = 8.0 Hz, 1H), 4.22 (d, J = 8.0 Hz, 1H), 2.42 (s, 3H), 2.37 (s, 3H), 2.06 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.6, 188.4, 166.9, 155.2, 145.8, 145.0, 138.0, 133.3, 129.8, 129.6, 128.9, 128.8, 128.5, 125.1, 118.6, 44.9, 39.3, 38.4, 21.8, 21.7, 15.1 ppm. ESI HRMS: calcd. for $C_{28}H_{24}N_2O_3$+H 437.1865, found 437.1859.



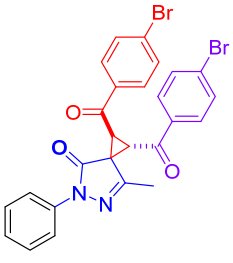
3ab

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(p-tolylmethanone) (**3ac**). Yellow oil, 12 h, 19.3 mg, 81% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.02 (t, J = 1.6 Hz, 1H), 7.89-7.87 (m, 2H), 7.80-7.77 (m, 2H), 7.66-7.61 (m, 2H), 7.55-7.52 (m, 1H), 7.45 (t, J = 8.0 Hz, 1H), 7.40-7.35 (m, 3H), 7.16 (t, J = 7.6 Hz, 1H), 4.27 (d, J = 8.0 Hz, 1H), 4.19 (d, J = 8.0 Hz, 1H), 2.09 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 189.8, 187.5, 166.5, 154.6, 141.4, 140.7, 137.7, 133.9, 133.8, 130.1, 129.6, 129.5, 129.3, 128.8, 125.4, 118.5, 44.8, 38.8, 38.0, 15.1 ppm. ESI HRMS: calcd. for $C_{26}H_{18}Cl_2N_2O_3$+Na 499.0592, found 499.0595.

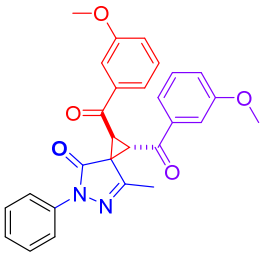


3ac

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis((4-bromophenyl)methanone) (**3ad**). Yellow oil, 12 h, 12.1 mg, 43% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.88 (d, J = 8.4 Hz, 2H), 7.79 (d, J = 8.4 Hz, 2H), 7.71 (d, J = 8.0 Hz, 2H), 7.65 (d, J = 8.4 Hz, 2H), 7.59 (d, J = 8.4 Hz, 2H), 7.35 (t, J = 8.0 Hz, 2H), 7.17 (t, J = 7.6 Hz, 1H), 4.26 (d, J = 8.0 Hz, 1H), 4.19 (d, J = 8.0 Hz, 1H), 2.07 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 190.1, 187.8, 166.5, 154.7, 134.3, 134.3, 132.5, 132.4, 130.3, 130.2, 129.8, 129.7, 129.5, 128.9, 125.4, 118.6, 44,9, 38,9, 125.4, 118.6, 44.9, 38.9, 38.0, 15.1 ppm. ESI HRMS: calcd. for $C_{26}H_{18}Br_2N_2O_3$+Na 586.9582, found 586.9574.

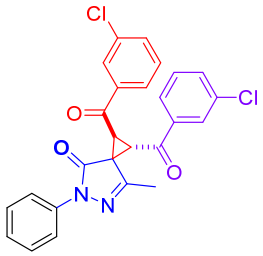


3ad



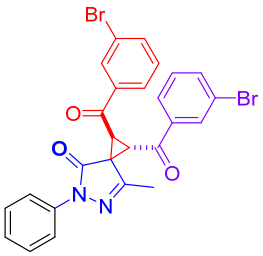
3ae

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(p-tolylmethanone) (**3ae**). Yellow oil, 12 h, 16.6 mg, 71% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.72 (d, J = 7.6 Hz, 2H), 7.52 (d, J = 7.6 Hz, 1H), 7.47-7.46 (m, 1H), 7.38-7.37 (m, 1H), 7.34-7.23 (m, 5H), 7.12-7.03 (m, 3H), 4.24 (d, J = 8.0 Hz, 1H), 4.13 (d, J = 8.0 Hz, 1H), 3.77 (s, 3H), 3.74 (s, 3H), 2.01 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 191.0, 188.6, 166.8, 160.1, 160.0, 155.0, 137.9, 137.0, 136.9, 130.2, 129.9, 128.8, 125.3, 121.6, 121.4, 121.1, 120.9, 118.6, 112.4, 112.1, 55.5, 55.4, 44.9, 39.4, 38.4, 15.1ppm. ESI HRMS: calcd. for $C_{28}H_{24}N_2O_5$+Na 491.1583, found 491.1592.



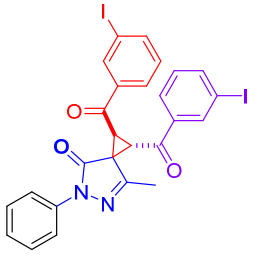
3af

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis((3-chlorophenyl)methanone) (**3af**). Yellow oil, 12 h, 18.1 mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.02 (t, J = 1.6 Hz, 1H), 7.89-7.87 (m, 2H), 7.80-7.77 (m, 2H), 7.66-7.63 (m, 2H), 7.55-7.52 (m, 1H), 7.45 (t, J = 8.0 Hz, 1H), 7.40-7.33 (m, 3H), 7.16 (t, J = 7.6 Hz, 1H) 4.27 (d, J = 8.0 Hz, 1H), 4.19 (d, J = 8.0 Hz, 1H), 2.09 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 189.9, 187.5, 166.4, 163.9, 154.6, 137.7, 137.1, 137.0, 135.7, 135.5, 134.6, 134.1, 130.5, 130.3, 128.9, 128.5, 128.5, 127.0, 126.3, 125.5, 118.7, 45.0, 38.8, 38.0, 15.2 ppm. ESI HRMS: calcd. for $C_{26}H_{18}Cl_2N_2O_3$+H 477.0773, found 477.0774.



3ag

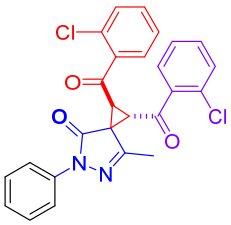
(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis((3-bromophenyl)methanone) (**3ag**). Yellow oil, 12 h, 14.1 mg, 50% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.19 (s, 1H), 8.05 (s, 1H), 7.93 (d, J = 7.6 Hz, 1H), 7.79 (d, J = 7.6 Hz, 3H), 7.69 (d, J = 8.0 Hz, 2H), 7.41-7.26 (m, 4H), 7.17 (t, J = 7.6 Hz, 1H), 4.27 (d, J = 8.4 Hz, 1H), 4.20 (d, J = 8.4 Hz, 1H), 2.10 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 189.9, 187.4, 166.4, 154.6, 137.7, 137.5, 137.3, 137.2, 137.0, 131.5, 131.5, 130.7, 130.5, 128.9, 127.5, 126.7, 125.5, 123.6, 123.5, 118.7, 45.0, 38.7, 38.0, 15.2 ppm. ESI HRMS: calcd. for $C_{26}H_{18}Br_2N_2O_3$+Na 586.9582, found 586.9576.



3ah

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis((3-iodophenyl)methanone) (**3ah**). Yellow oil, 12 h, 17.4 mg, 53% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.38 (s, 1H), 8.24 (s, 1H), 7.96 (t, J = 7.2 Hz, 2H), 7.89 (d, J = 7.6 Hz, 1H), 7.79 (d, J = 8.0 Hz, 2H), 7.72 (d, J = 7.6 Hz, 1H), 7.36 (t, J = 8.0 Hz, 2H), 7.27-7.23 (m, 1H), 7.17 (t, J = 7.6 Hz, 2H), 4.26 (d, J = 8.0 Hz, 1H), 4.18 (d, J = 8.0 Hz, 1H), 2.10 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 189.8, 187.4, 166.5, 154.6, 143.4, 142.8, 137.7, 137.5, 137.4, 137.2, 137.1, 130.7, 130.5, 128.9, 128.1, 127.3, 125.5, 118.7, 94.9, 94.9, 45.0, 38.6, 37.9, 15.2 ppm. ESI HRMS: calcd. for $C_{26}H_{18}I_2N_2O_3$+H 660.9485, found 660.9483.

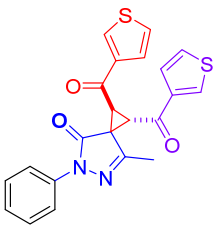
(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis((2-chlorophenyl)methanone)



3aj

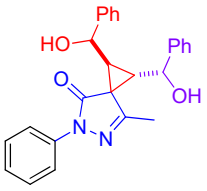
(**3aj**). Yellow oil, 12 h, 9.3 mg, 39% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.80 (d, J = 8.0 Hz, 2H), 7.70 (d, J = 7.2 Hz, 1H), 7.61 (d, J = 7.2 Hz, 1H), 7.44-7.42 (m, 1H), 7.41-7.31 (m, 7H), 7.15 (t, J = 7.2 Hz, 1H), 4.40 (d, J = 8.0 Hz, 1H), 4.05 (d, J = 8.0 Hz, 1H), 2.12 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 193.1, 191.1, 167.1, 155.5, 137.9, 137.2, 137.0, 133.5, 133.2, 132.5, 131.9, 131.7, 131.0, 130.5, 130.4, 128.8, 127.3, 127.3, 125.3, 118.8, 48.0, 43.5, 41.9, 15.4 ppm. ESI HRMS: calcd. for $C_{26}H_{18}Cl_2N_2O_3$+H 477.0773, found 477.0772.

(4-methyl-7-oxo-6-phenyl-5,6-diazaspiro[2.4]hept-4-ene-1,2-diyl)bis(thiophen-3-ylmethanone)



3ak

(**3ak**). Yellow oil, 12 h, 13.9 mg, 66% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.82 (dd, J_1 = 4.0 Hz, J_2 = 1.2 Hz, 1H), 7.76-7.73 (m, 2H), 7.71 (dd, J_1 = 4.8 Hz, J_2 = 1.2 Hz, 1H), 7.59 (dd, J_1 = 5.2 Hz, J_2 = 1.2 Hz, 1H), 7.54 (dd, J_1 = 4.0 Hz, J_2 = 1.2 Hz, 1H), 7.28 (t, J = 7.2 Hz, 2H), 7.12-7.06 (m, 2H), 7.04-7.02 (m, 1H), 4.19 (d, J = 8.0 Hz, 1H), 4.13 (d, J = 8.0 Hz, 1H), 2.07 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 183.3, 181.1, 166.7, 155.1, 143.0, 142.4, 137.9, 136.1, 134.8, 13.4, 132.8, 128.9, 128.8, 128.5, 125.2, 118.6, 45.0, 39.7, 38.8, 15.2 ppm. ESI HRMS: calcd. for $C_{22}H_{16}N_2O_3S_2$+Na 443.0500, found 443.0504



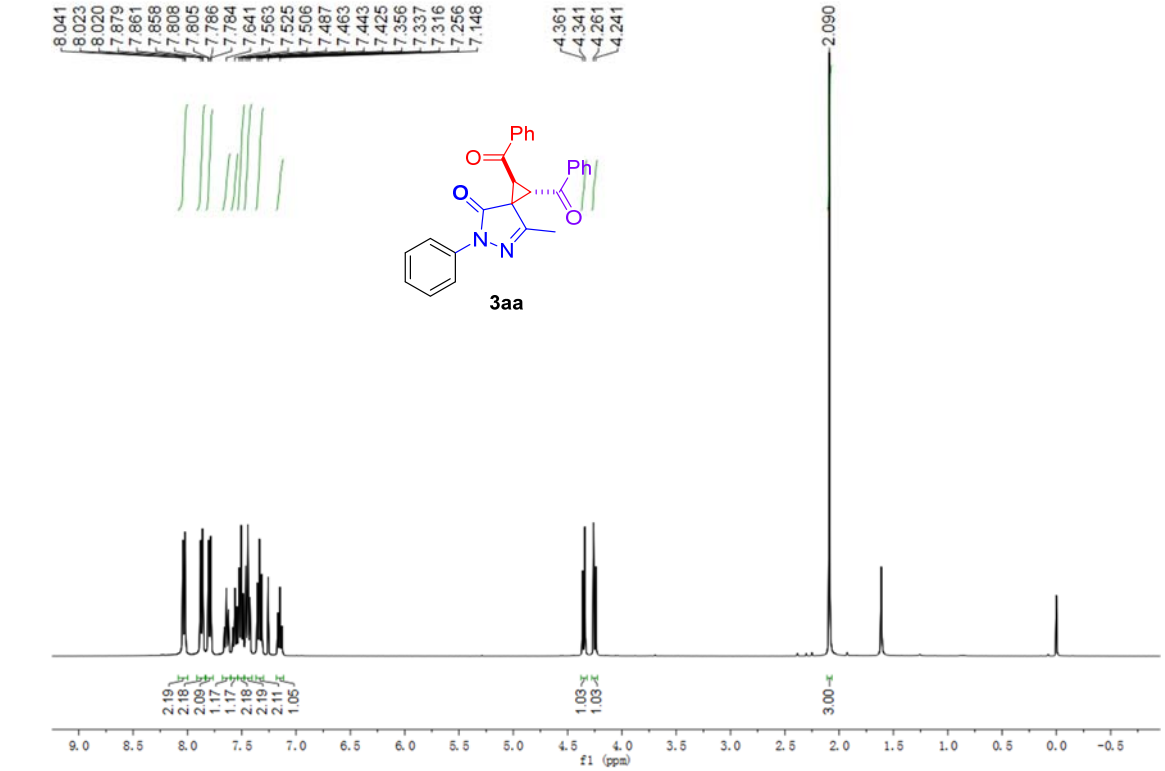
4

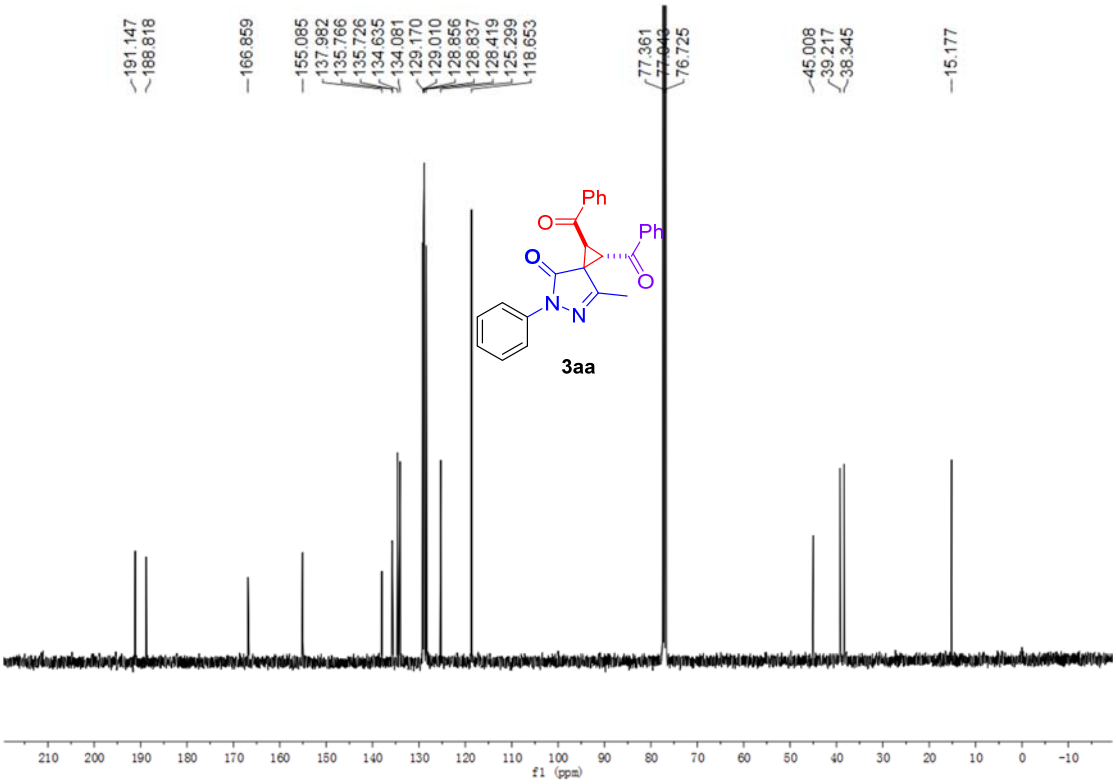
1,2-bis(hydroxy(phenyl)methyl)-7-methyl-5-phenyl-5,6-diazaspiro[2.4]hept-6-en-4-one (**4**). White soild, 5 min, 17.1 mg, 83% yield; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.90 (d, J = 7.6 Hz, 2H), 7.40 (t, J = 8.0 Hz, 2H), 7.25-7.24 (m, 1H), 7.23-7.19 (m, 3H), 7.17-7.15 (m, 2H), 7.13-7.08 (m, 1H), 5.21 (dd, J_1 = 8.4 Hz, J_2 = 4.8 Hz, 1H), 4.56 (d, J_1 = 9.6 Hz, J_2 = 3.2 Hz, 1H), 2.82-2.76 (m, 1H), 2.65-2.61 (m, 1H), 2.26 (s, 3H) ppm. ^{13}C NMR (100 MHz, CDCl3): δ = 171.4, 157.8, 142.2, 141.5, 138.4, 128.8, 128.5, 128.2, 127.6, 125.4, 125.4, 125.1, 119.1, 73.6, 69.2, 46.7, 45.4, 41.8, 15.8 ppm. ESI HRMS: calcd. for $C_{26}H_{24}N_2O_3$+Na 435.1685, found 435.1684.

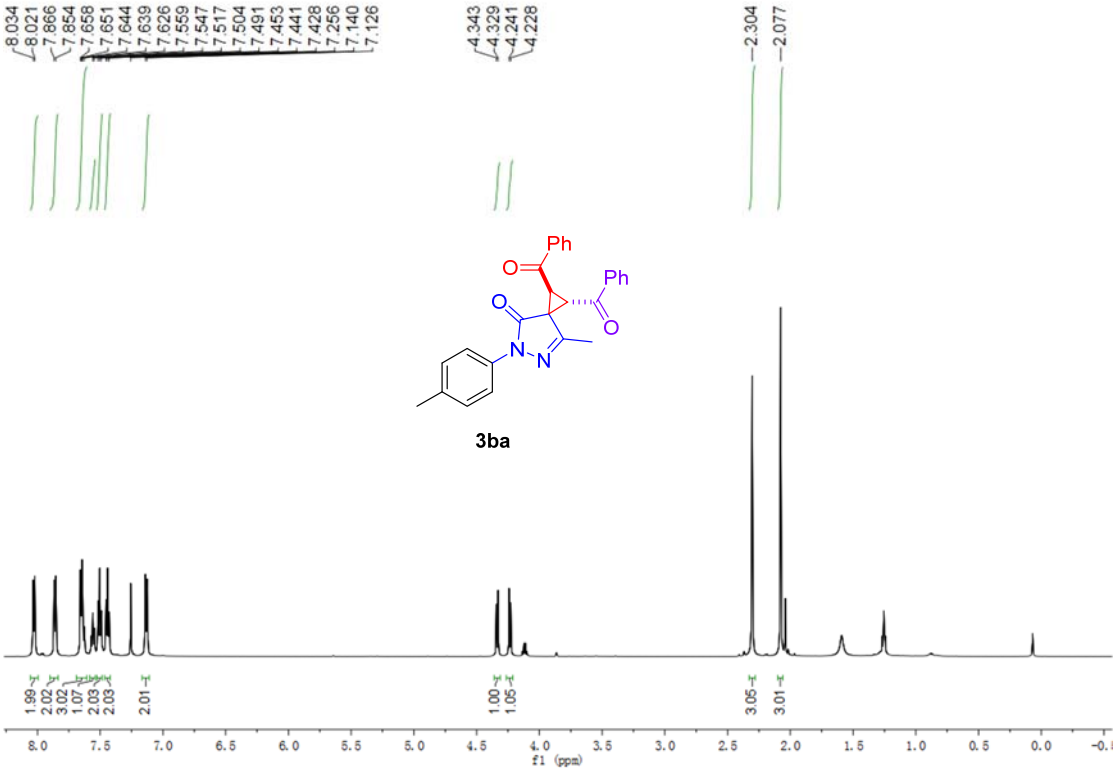
References

1. a) Lai, X.; Zha, G.; Liu, W.; Xu, Y.; Sun, P.; Xia, T.; Shen, Y. *Synlett*., **2016**, *27(13)*, 1983; b) Hadi, V.; Koh, Y. H.; Sanchez, T. W.; Barrios, D.; Neamati, N.; Jung, K. W. *Bioorg. Med. Chem. Lett.* **2010**, *20*, 6854.
2. a) Xu,Y.; Zheng, G.; Yang, X.; Li, X. *Chem. Commun.*, **2018**, *54*, 670; b) Wu, X.; Xiong, H.; Sun, S.; Cheng, J. *Org. Lett.* **2018**, *20*, 1396.
3. Vetica, F.; Chauhan, P.; Mahajan, S.; Raabe, G.; Enders, D. *Synthesis,* **2018**, *50*, 1039.
4. a) Jia, Y.; Tang, X.; Cai, G.; Jia, R.; Wang, B.; Miao, Z. *Eur. J. Org. Chem.* **2015**, 4720; b) Liang, J.; Chen, Q.; Liu, L.; Jiang, X.; Wang, R. *Org. Biomol. Chem*., **2013**, *11*, 1441.

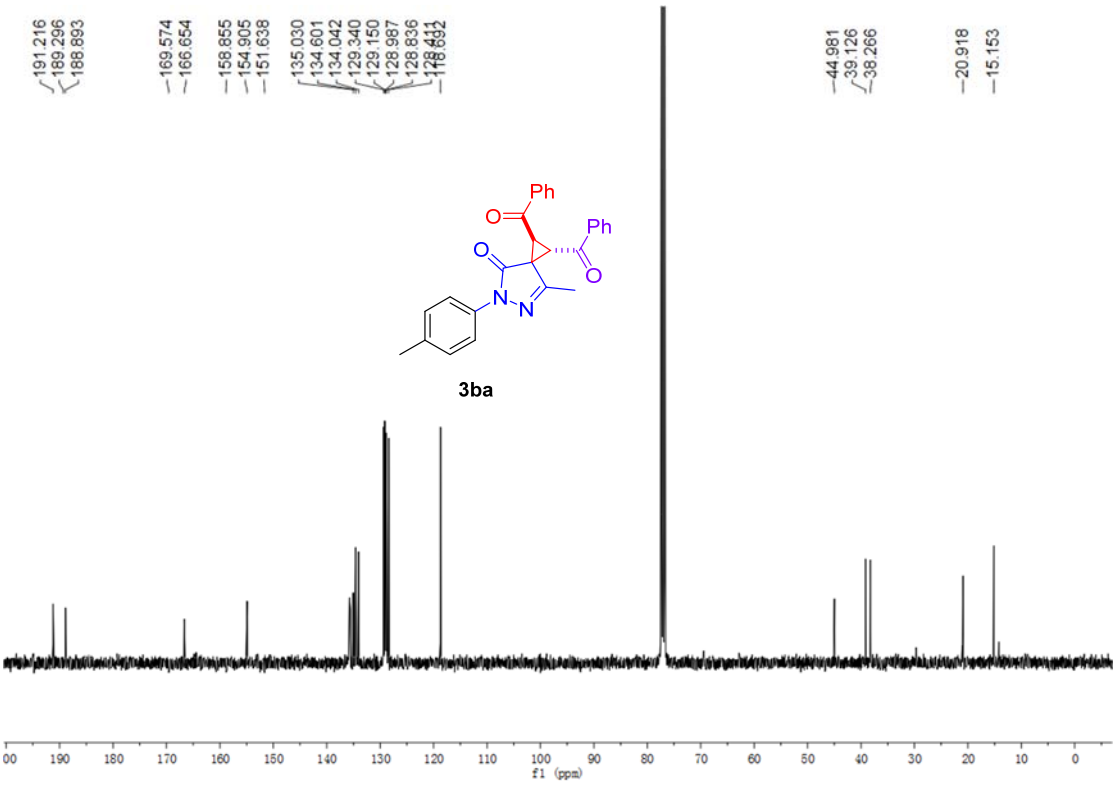
8. NMR Spectra of Pyrazolin-5-one Derivatives



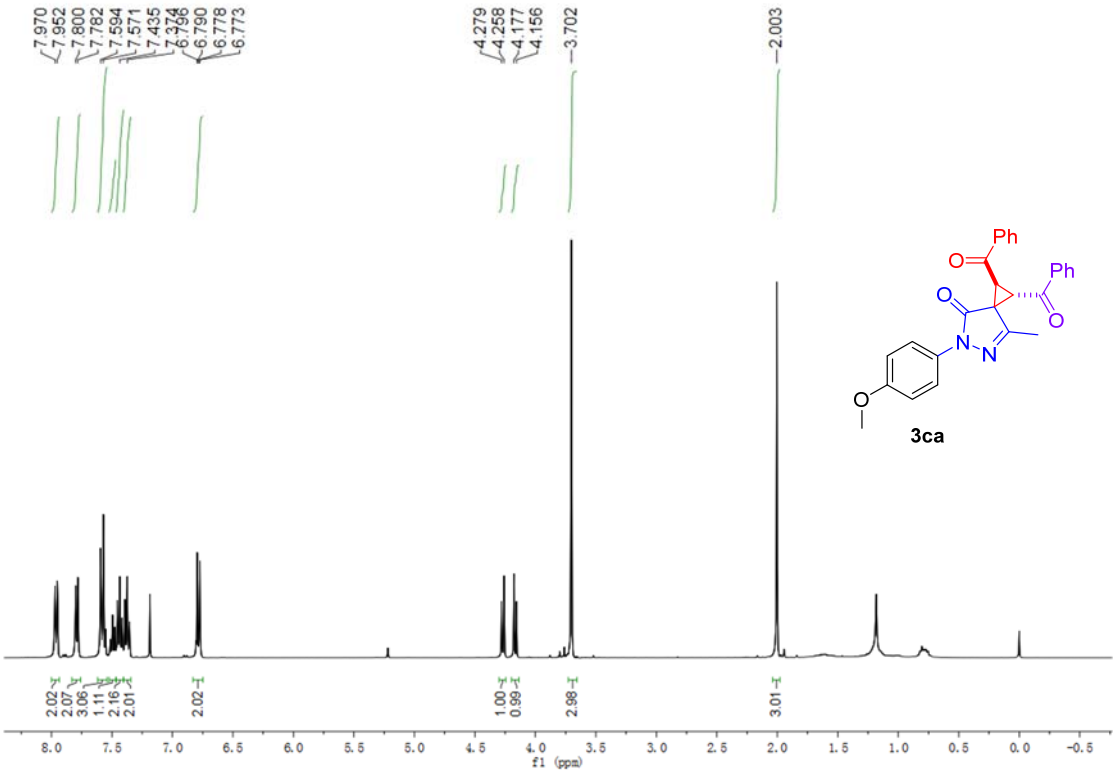


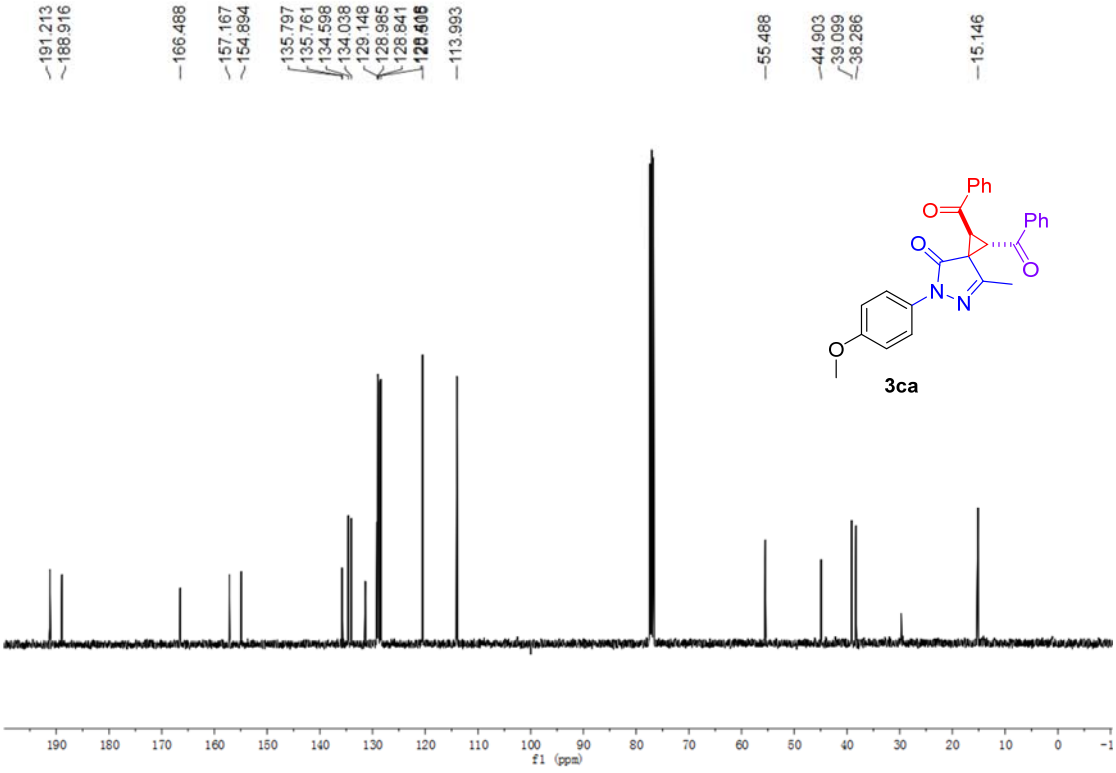

8.034
8.021
7.866
7.854
7.658
7.651
7.644
7.639
7.626
7.559
7.547
7.517
7.504
7.491
7.453
7.441
7.428
7.256
7.140
7.126
4.343
4.329
4.241
4.228
2.304
2.077
Ph
O
Ph
O
O
N
N
1.99
2.02
3.02
1.07
2.03
2.03
2.01
1.00
1.05
3.05
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

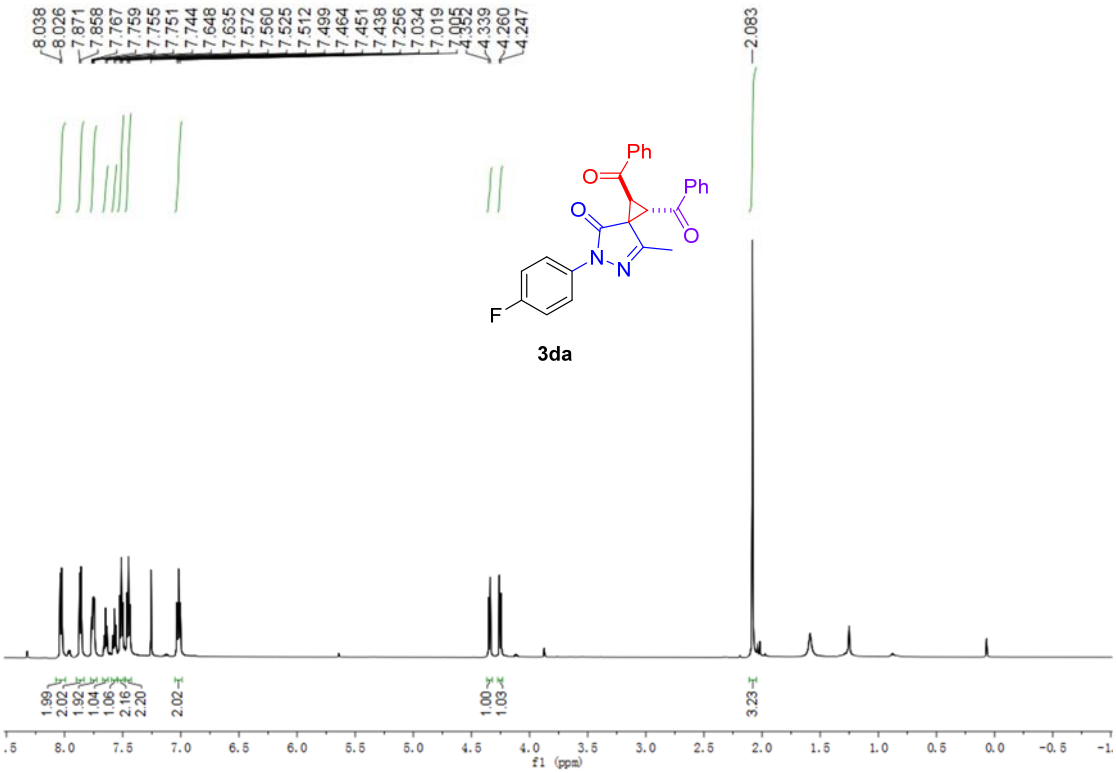
3ba


191.216
189.296
188.893
169.574
166.654
158.855
154.905
151.638
135.030
134.601
134.042
129.340
129.150
128.987
128.836
44.981
39.126
38.266
20.918
15.153
Ph
O
Ph
O
O
N
N
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

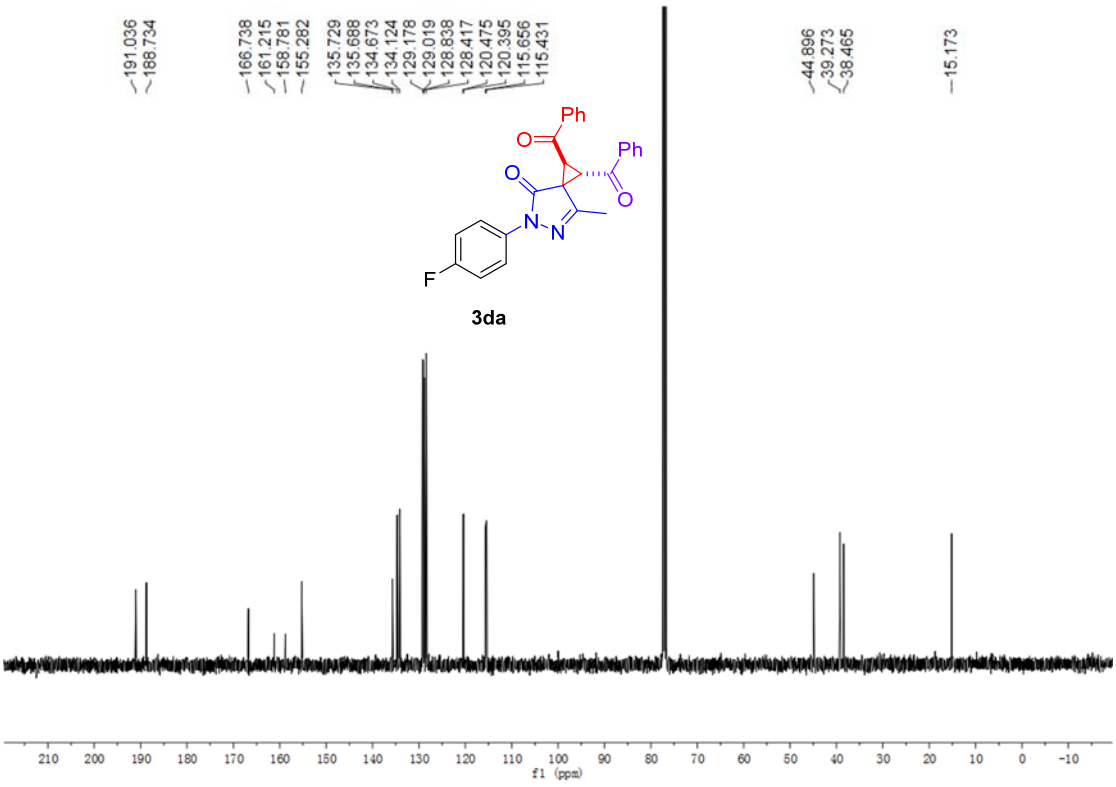
3ba


7.970
7.952
7.800
7.782
7.594
7.571
7.435
6.790
6.778
6.773
4.279
4.258
4.177
4.156
3.702
2.003
Ph
Ph
O
O
O
N
N
O
3ca
f1 (ppm)

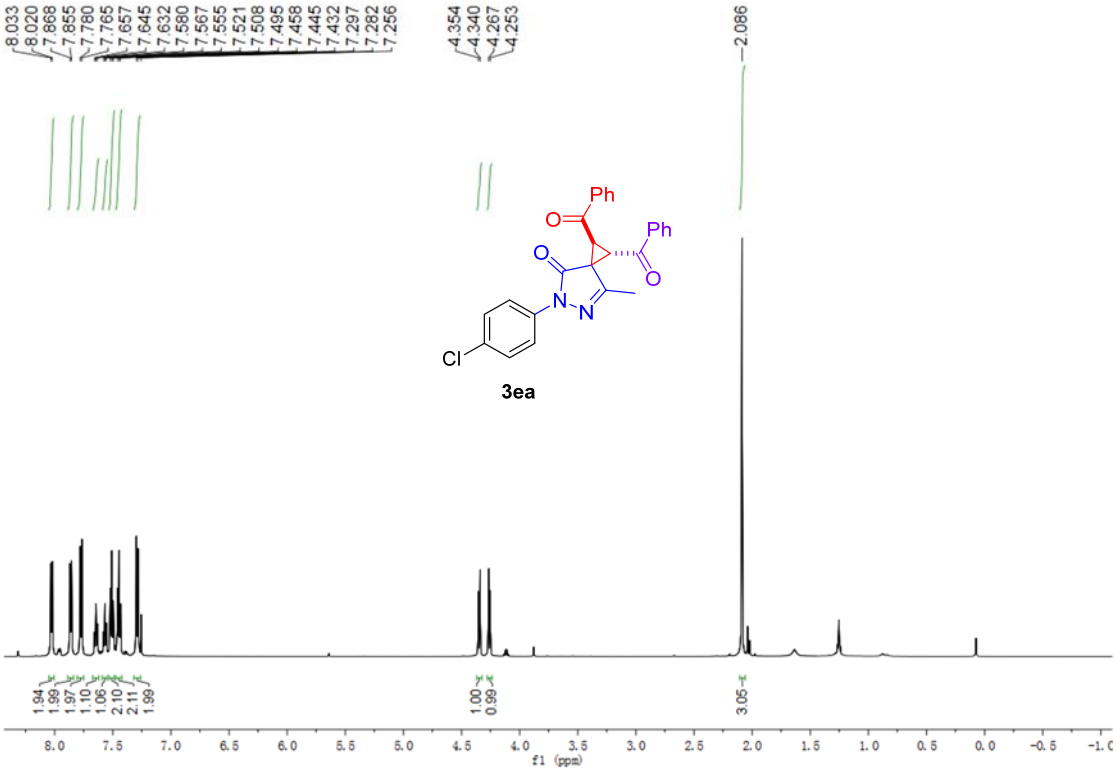

191.213
188.916
166.488
157.167
154.894
135.797
135.761
134.598
134.038
129.148
128.985
128.841
113.993
55.488
44.903
39.099
38.286
15.146
Ph
Ph
O
O
O
N
N
O
3ca
f1 (ppm)

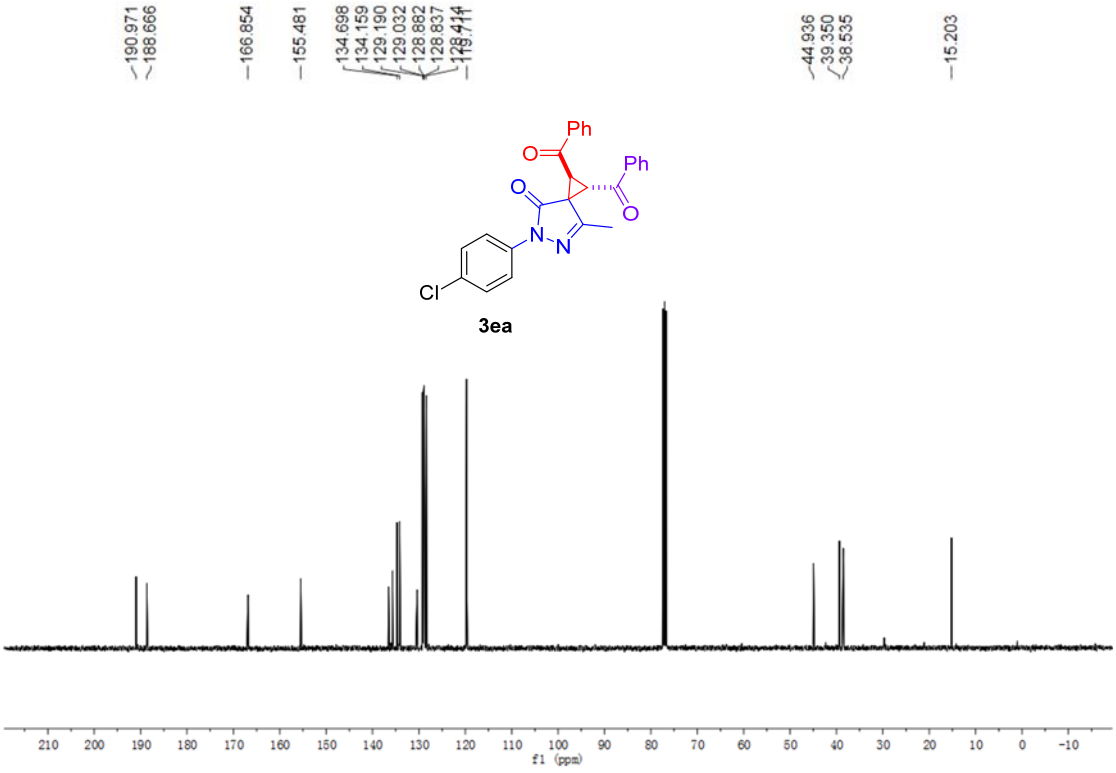

8.038
8.026
7.871
7.858
7.767
7.759
7.755
7.751
7.744
7.648
7.635
7.572
7.560
7.525
7.512
7.499
7.464
7.451
7.438
7.256
7.034
7.019
7.005
4.352
4.339
4.260
4.247
2.083
Ph
O
Ph
O
O
N
N
F
1.99
2.02
1.92
1.04
1.06
2.16
2.20
2.02
1.00
1.03
3.23
f1 (ppm)

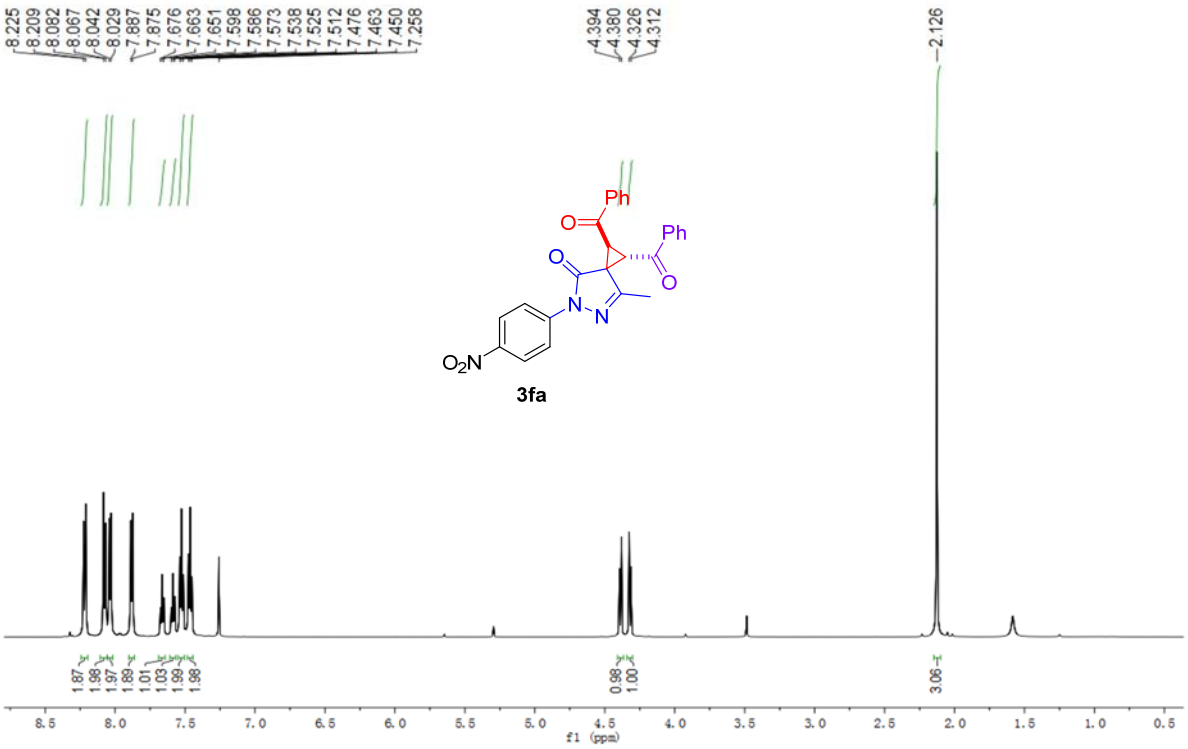
3da


191.036
188.734
166.738
161.215
158.781
155.282
135.729
135.688
134.673
134.124
129.178
129.019
128.838
128.417
120.475
120.395
115.656
115.431
44.896
39.273
38.465
15.173
Ph
O
Ph
O
O
N
N
F
f1 (ppm)

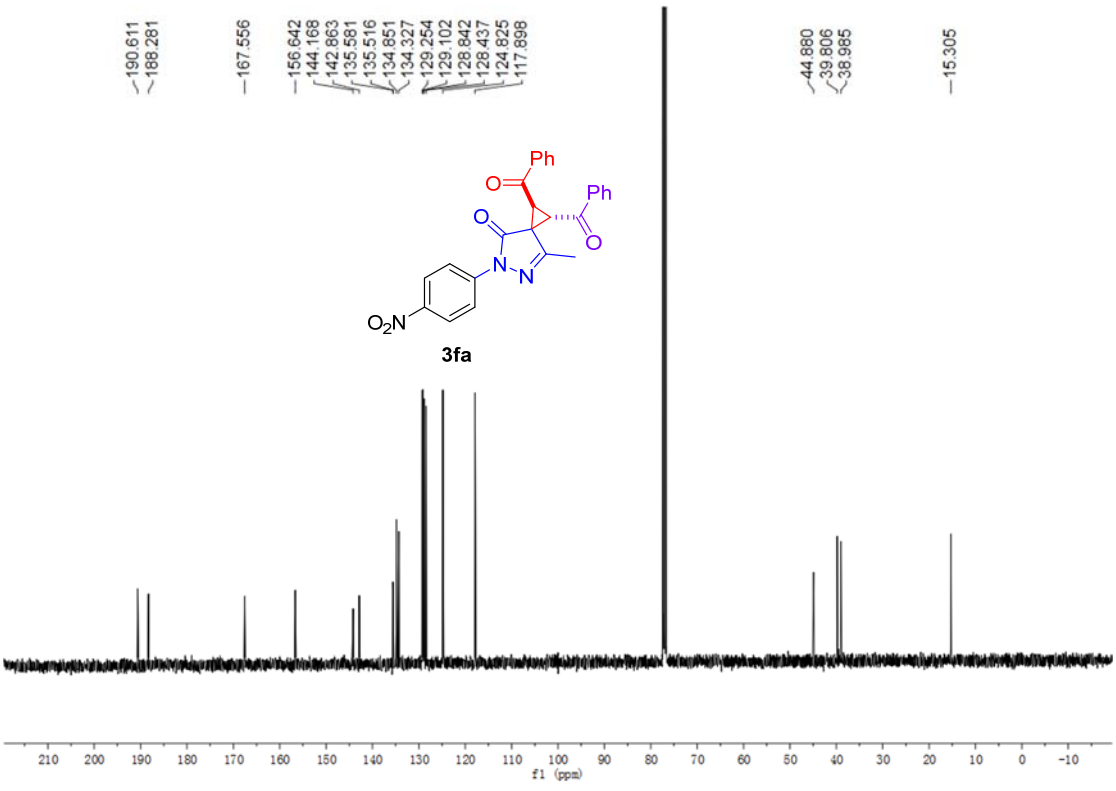
3da


8.033
8.020
7.868
7.855
7.780
7.765
7.657
7.645
7.632
7.580
7.567
7.555
7.521
7.508
7.495
7.458
7.445
7.432
7.297
7.282
7.256
4.354
4.340
4.267
4.253
2.086
Ph
O
Ph
O
O
N
N
Cl
3ea
1.94
1.99
1.97
1.10
1.06
2.10
2.11
1.99
1.00
0.99
3.05
f1 (ppm)

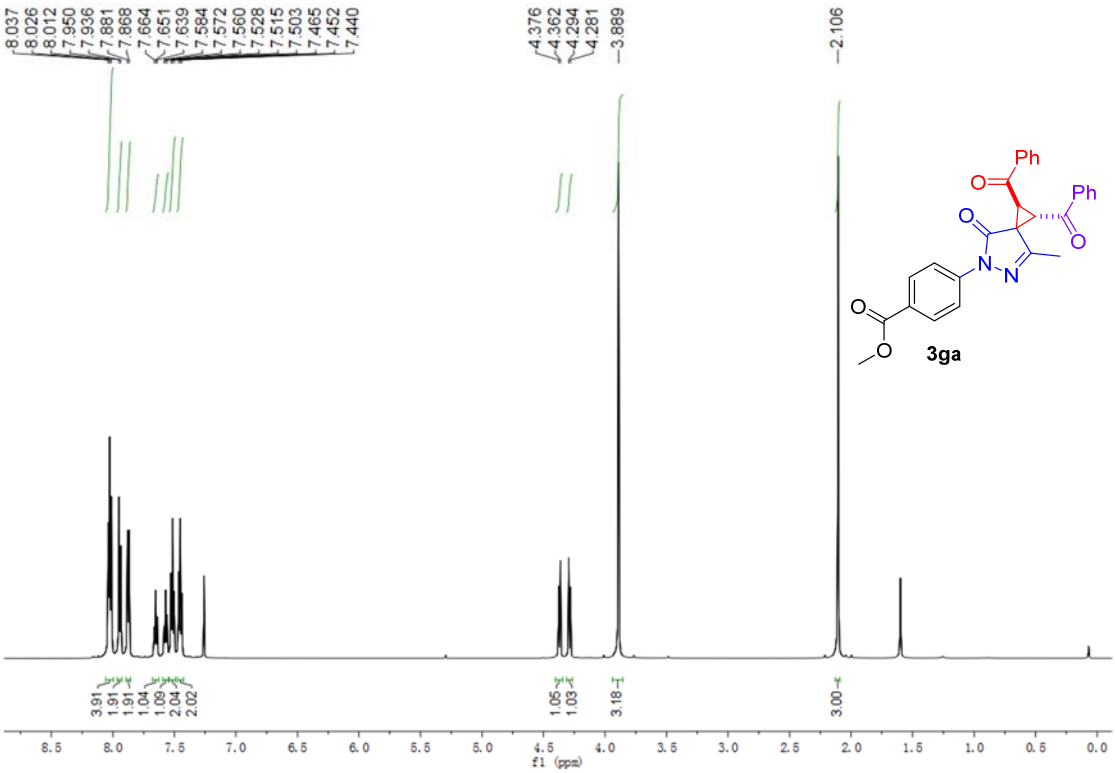

190.971
188.666
166.854
155.481
134.698
134.159
129.190
129.032
128.882
128.837
44.936
39.350
38.535
15.203
Ph
O
Ph
O
O
N
N
Cl
3ea
f1 (ppm)

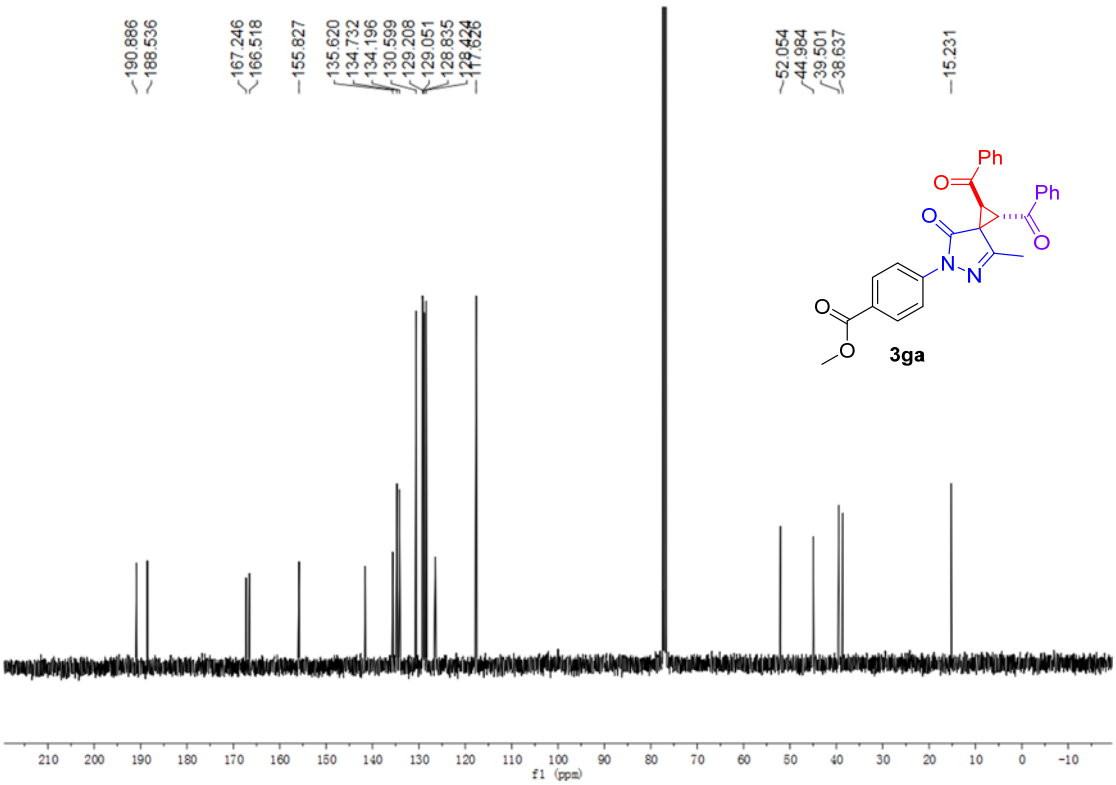

8.225
8.209
8.082
8.067
8.042
8.029
7.887
7.875
7.676
7.663
7.651
7.598
7.586
7.573
7.538
7.525
7.512
7.476
7.463
7.450
7.258
4.394
4.380
4.326
4.312
2.126
Ph
O
Ph
O
O
N
N
O2N
1.87
1.98
1.97
1.89
1.01
1.03
1.99
1.98
0.98
1.00
3.06
f1 (ppm)

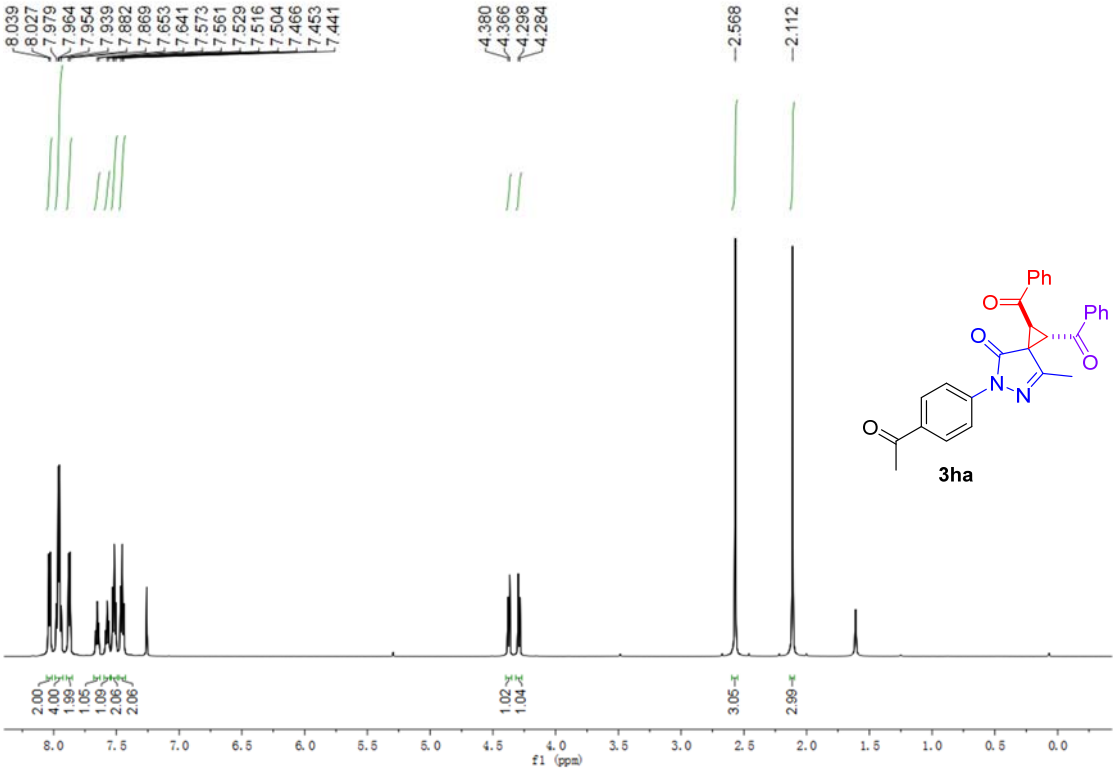
3fa

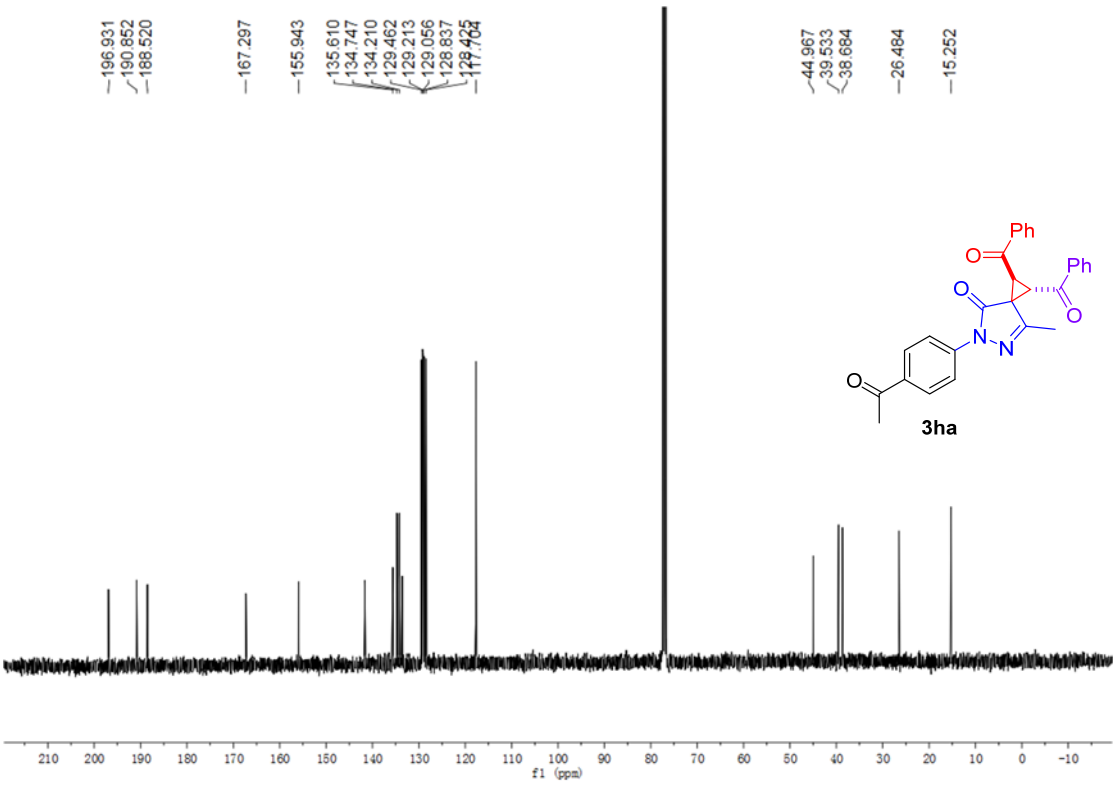

190.611
188.281
167.556
156.642
144.168
142.863
135.581
135.516
134.851
134.327
129.254
129.102
128.842
128.437
124.825
117.898
44.880
39.806
38.985
15.305
Ph
O
Ph
O
O
N
N
O2N
f1 (ppm)

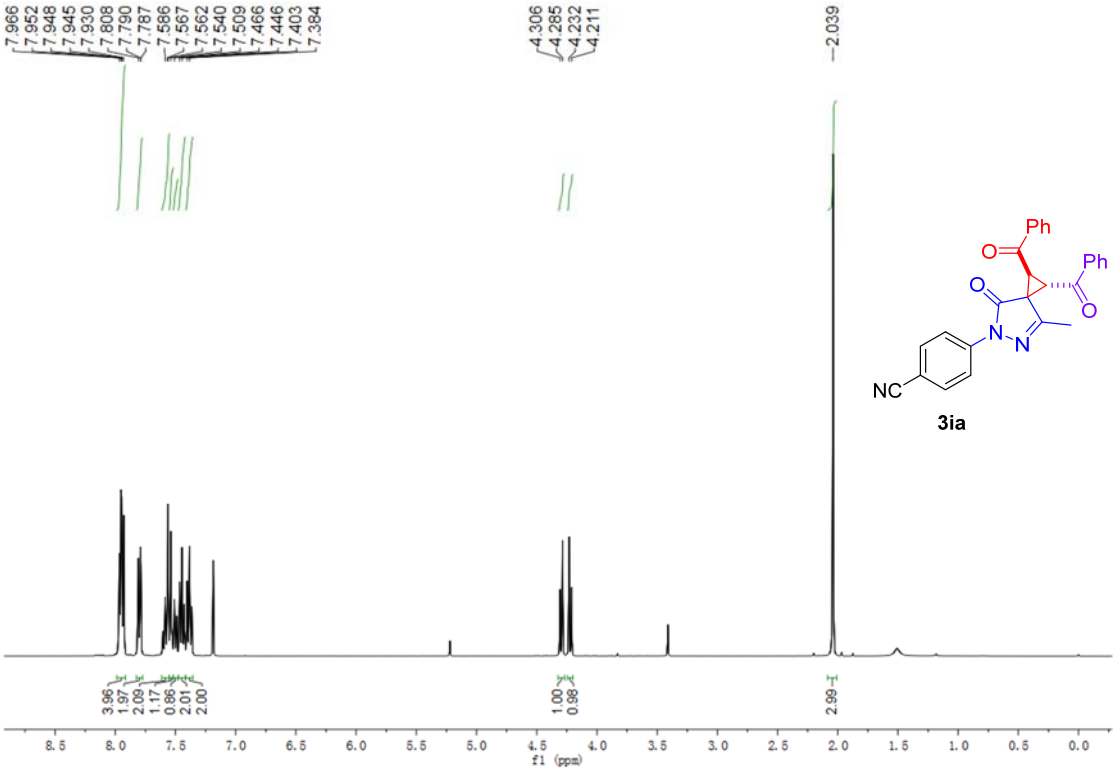
3fa

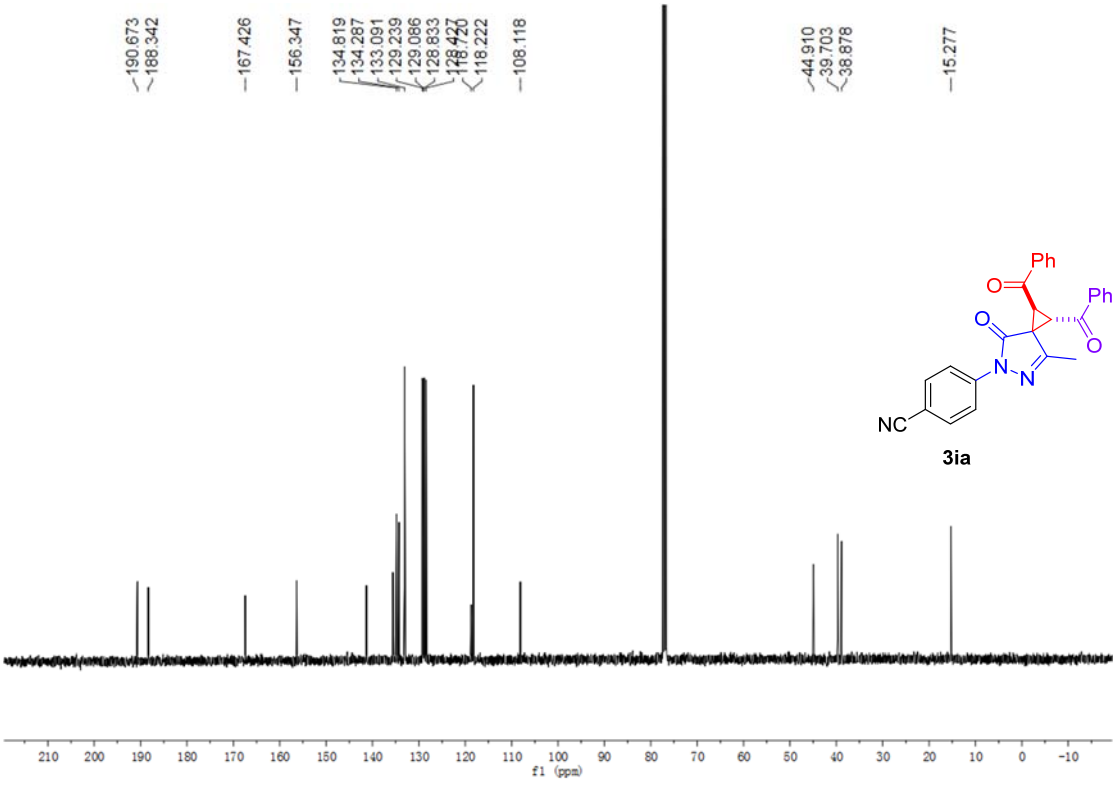

8.037
8.026
8.012
7.950
7.936
7.881
7.868
7.664
7.651
7.639
7.584
7.572
7.560
7.528
7.515
7.503
7.465
7.452
7.440
4.376
4.362
4.294
4.281
3.889
2.106
3.91
1.91
1.91
1.04
1.09
2.04
2.02
1.05
1.03
3.18
3.00
f1 (ppm)
Ph
Ph
3ga

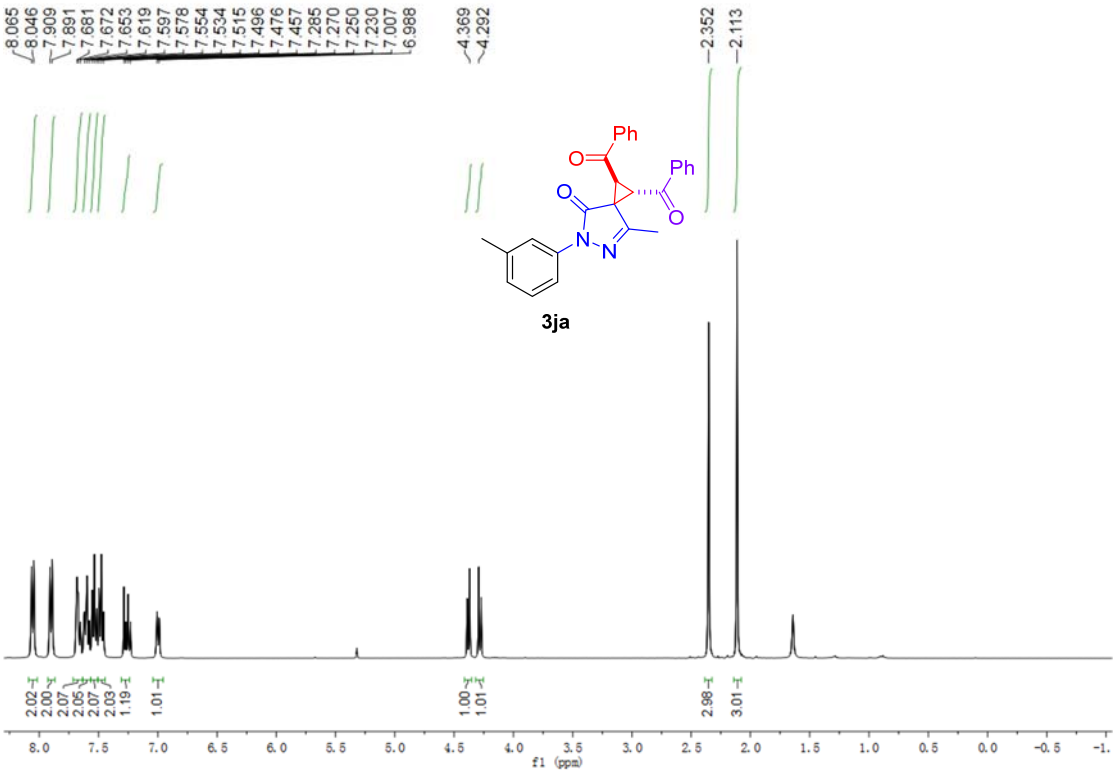

190.886
188.536
167.246
166.518
155.827
135.620
134.732
134.196
130.599
129.208
129.051
128.835
52.054
44.984
39.501
38.637
15.231
f1 (ppm)
Ph
Ph
3ga


8.039
8.027
7.979
7.964
7.954
7.939
7.882
7.869
7.653
7.641
7.573
7.561
7.529
7.516
7.504
7.466
7.453
7.441
4.380
4.366
4.298
4.284
2.568
2.112
2.00
4.00
1.99
1.05
1.09
2.06
2.06
1.02
1.04
3.05
2.99
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
f1 (ppm)
Ph
O
Ph
O
O
N
N
O
3ha

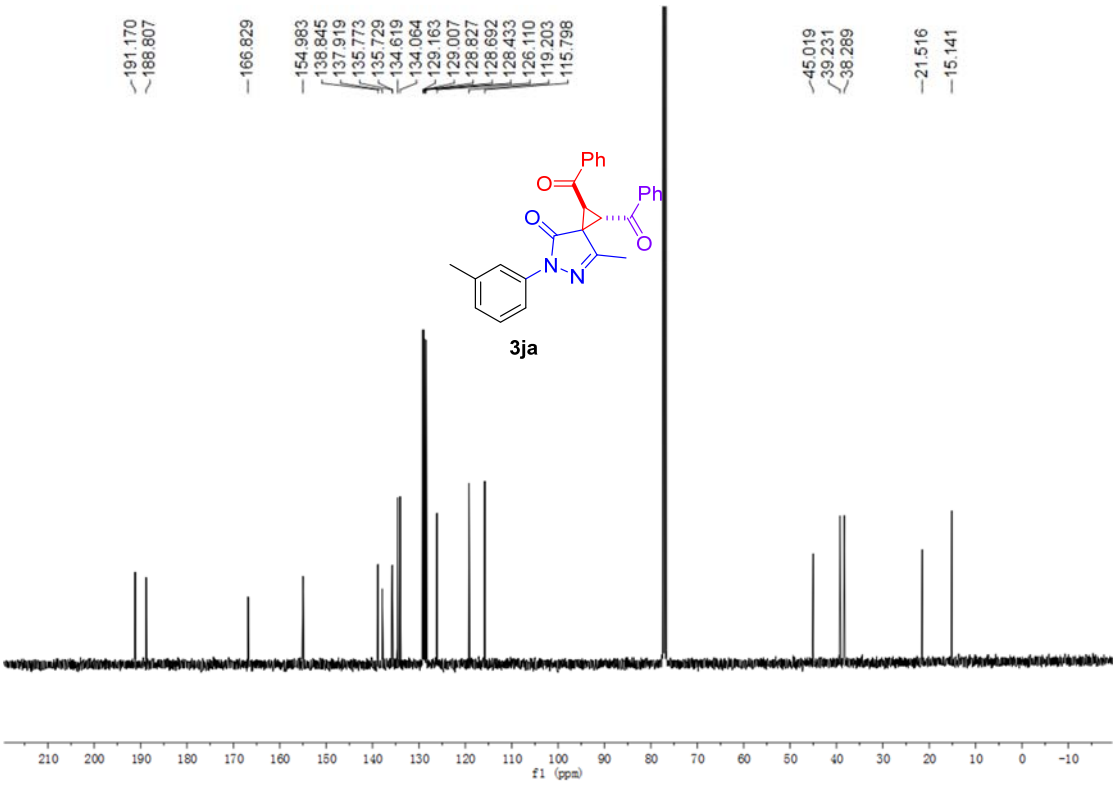

196.931
190.852
188.520
167.297
155.943
135.610
134.747
134.210
129.462
129.213
129.056
128.837
44.967
39.533
38.684
26.484
15.252
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)
Ph
O
Ph
O
O
N
N
O
3ha


7.966
7.952
7.948
7.945
7.930
7.808
7.790
7.787
7.586
7.567
7.562
7.540
7.509
7.466
7.446
7.403
7.384
4.306
4.285
4.232
4.211
2.039
Ph
O
Ph
O
O
N
N
NC
3ia
3.96
1.97
2.09
1.17
0.86
2.01
2.00
1.00
0.98
2.99
f1 (ppm)

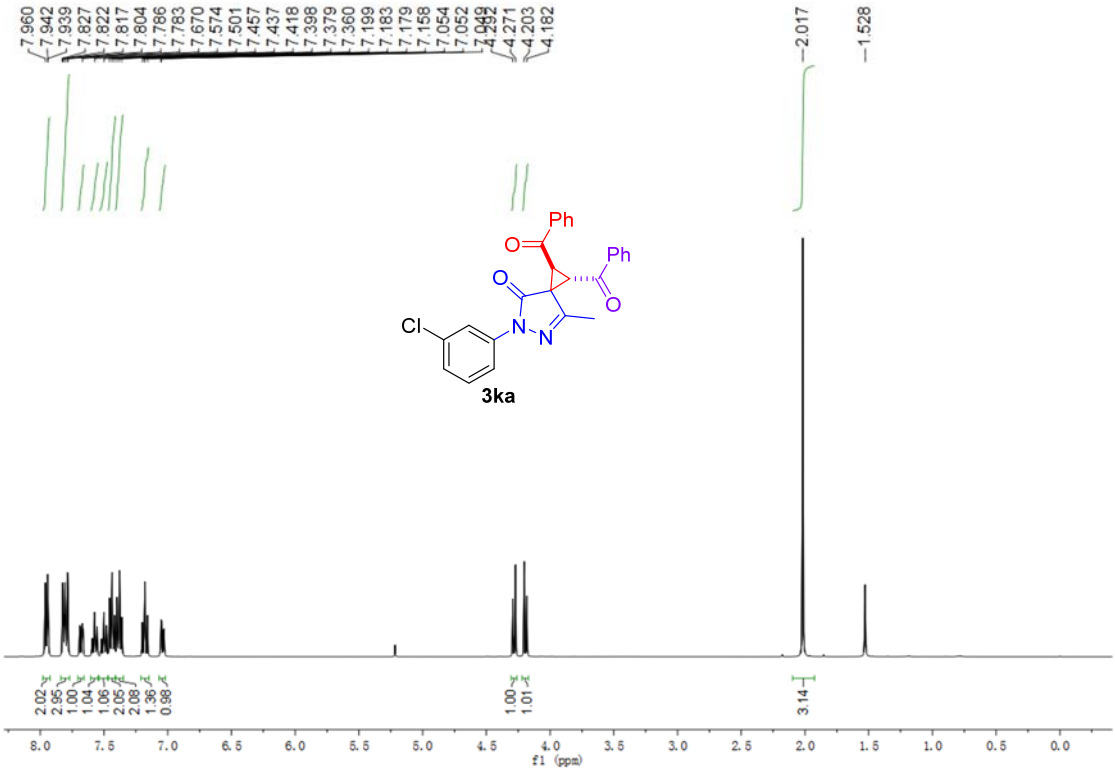

190.673
188.342
167.426
156.347
134.819
134.287
133.091
129.239
129.086
128.833
118.222
108.118
44.910
39.703
38.878
15.277
Ph
O
Ph
O
O
N
N
NC
3ia
f1 (ppm)

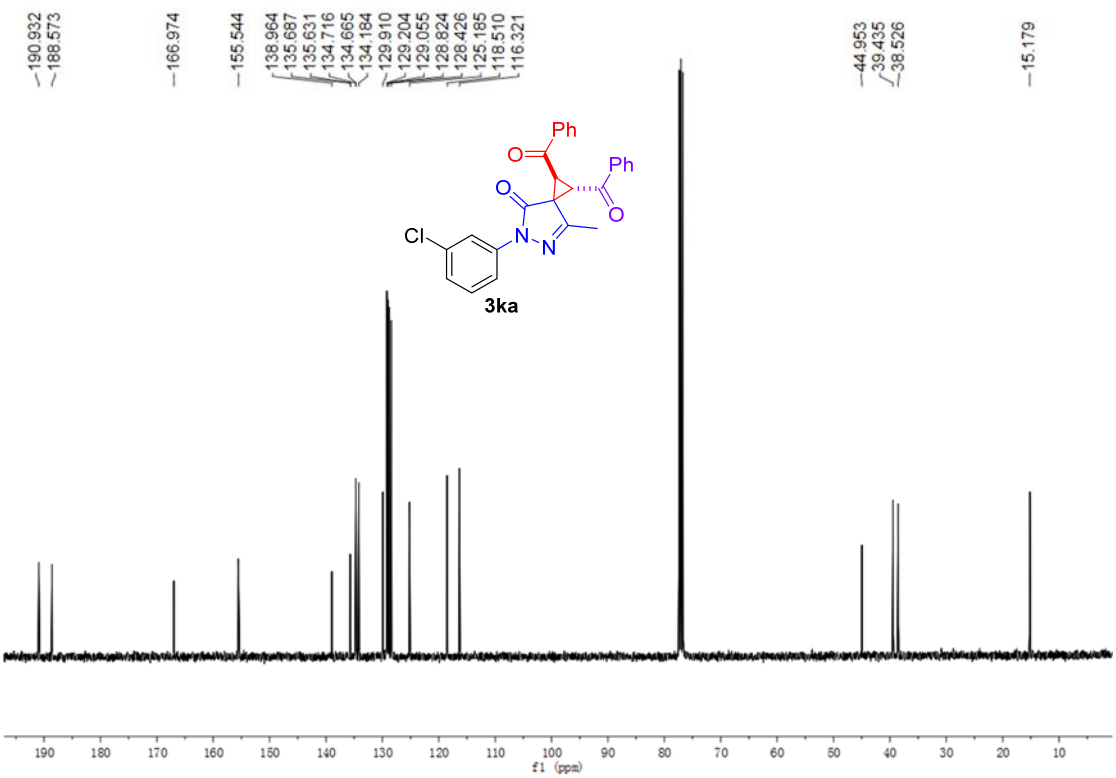

8.065
8.046
7.909
7.891
7.681
7.672
7.653
7.619
7.597
7.578
7.554
7.534
7.515
7.496
7.476
7.457
7.285
7.270
7.250
7.230
7.007
6.988
4.369
4.292
2.352
2.113
Ph
O
Ph
O
O
N
N
2.02
2.00
2.07
2.05
2.07
2.03
1.19
1.01
1.00
1.01
2.98
3.01
f1 (ppm)

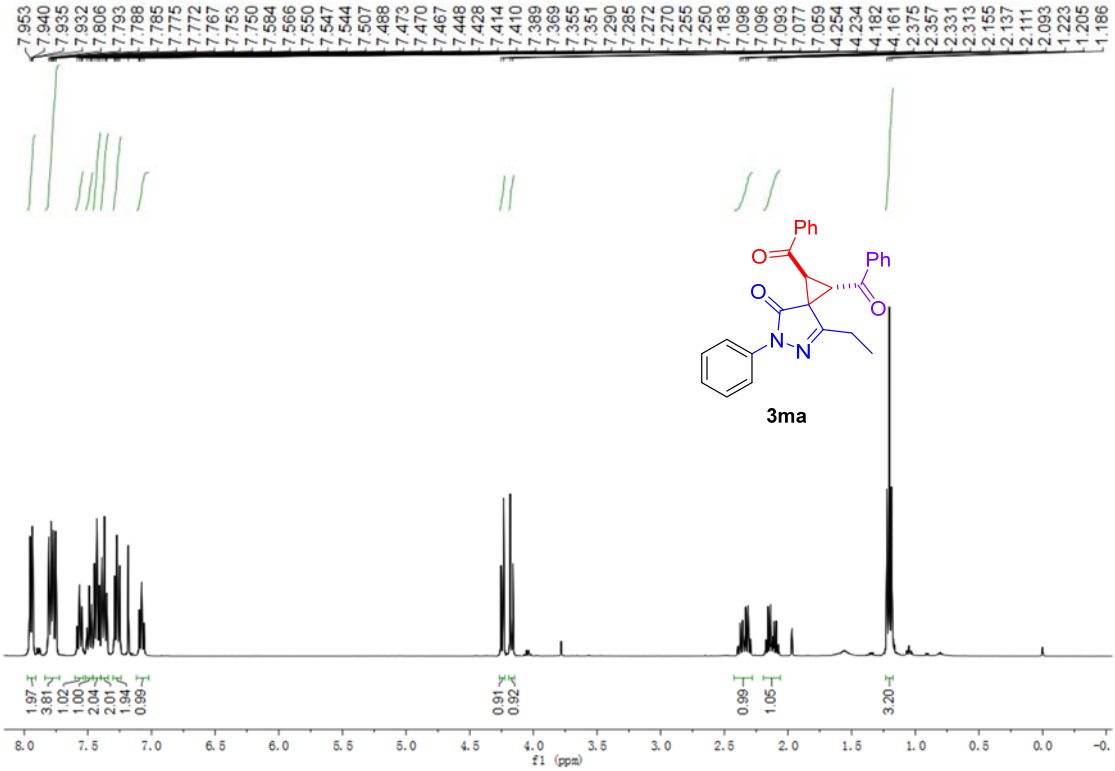
3ja

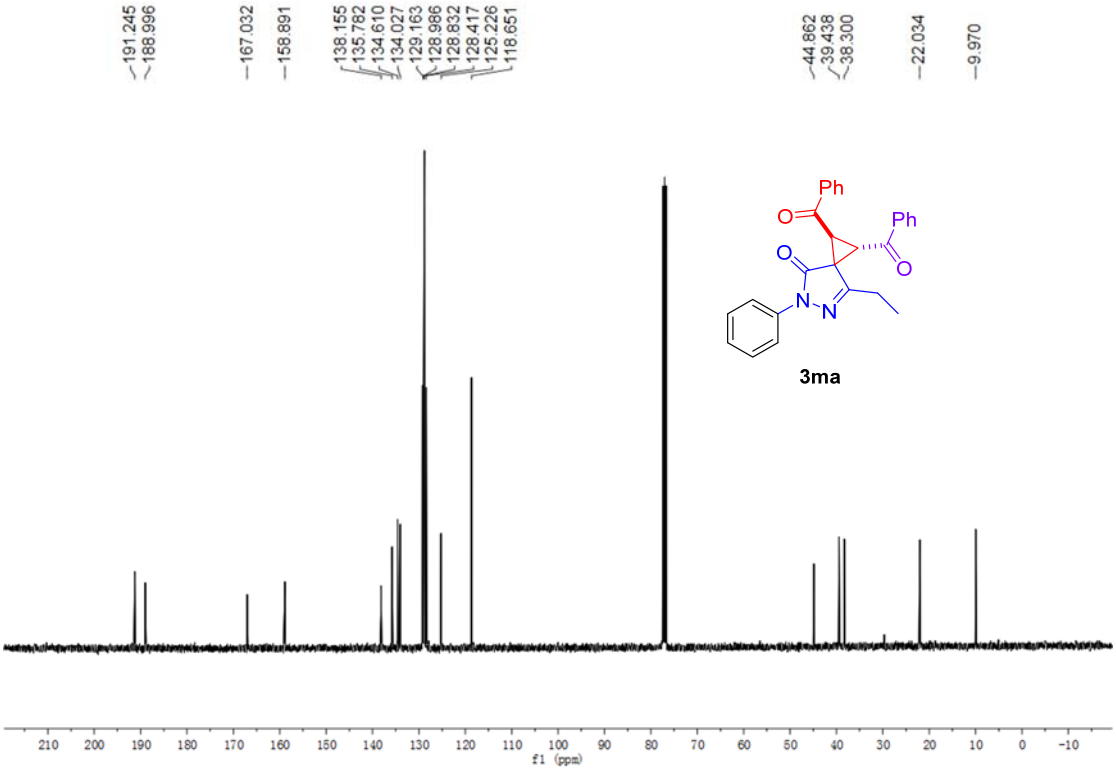

191.170
188.807
166.829
154.983
138.845
137.919
135.773
135.729
134.619
134.064
129.163
129.007
128.827
128.692
128.433
126.110
119.203
115.798
45.019
39.231
38.289
21.516
15.141
Ph
O
Ph
O
O
N
N
f1 (ppm)

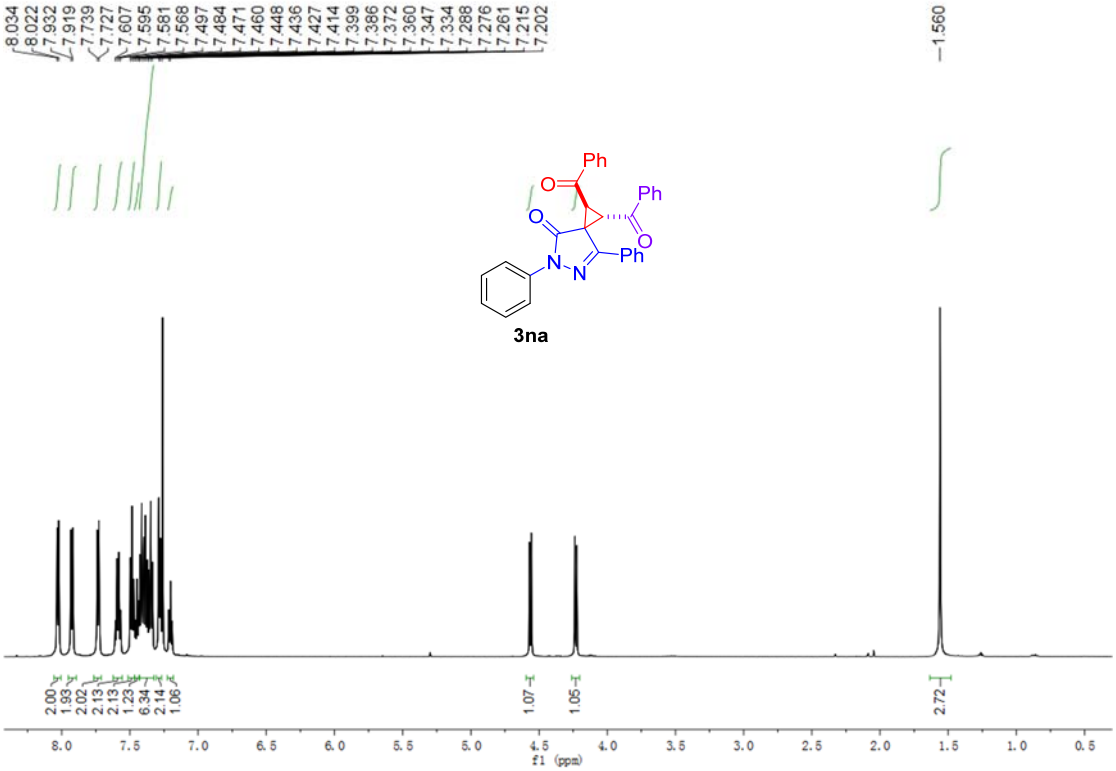
3ja


7.960
7.942
7.939
7.827
7.822
7.817
7.804
7.786
7.783
7.670
7.574
7.501
7.457
7.437
7.418
7.398
7.379
7.360
7.199
7.183
7.179
7.158
7.054
7.052
4.271
4.203
4.182
2.017
1.528
Ph
O
Ph
O
O
N
N
Cl
3ka
2.02
2.95
1.00
1.04
1.06
2.05
2.08
1.36
0.98
1.00
1.01
3.14
f1 (ppm)

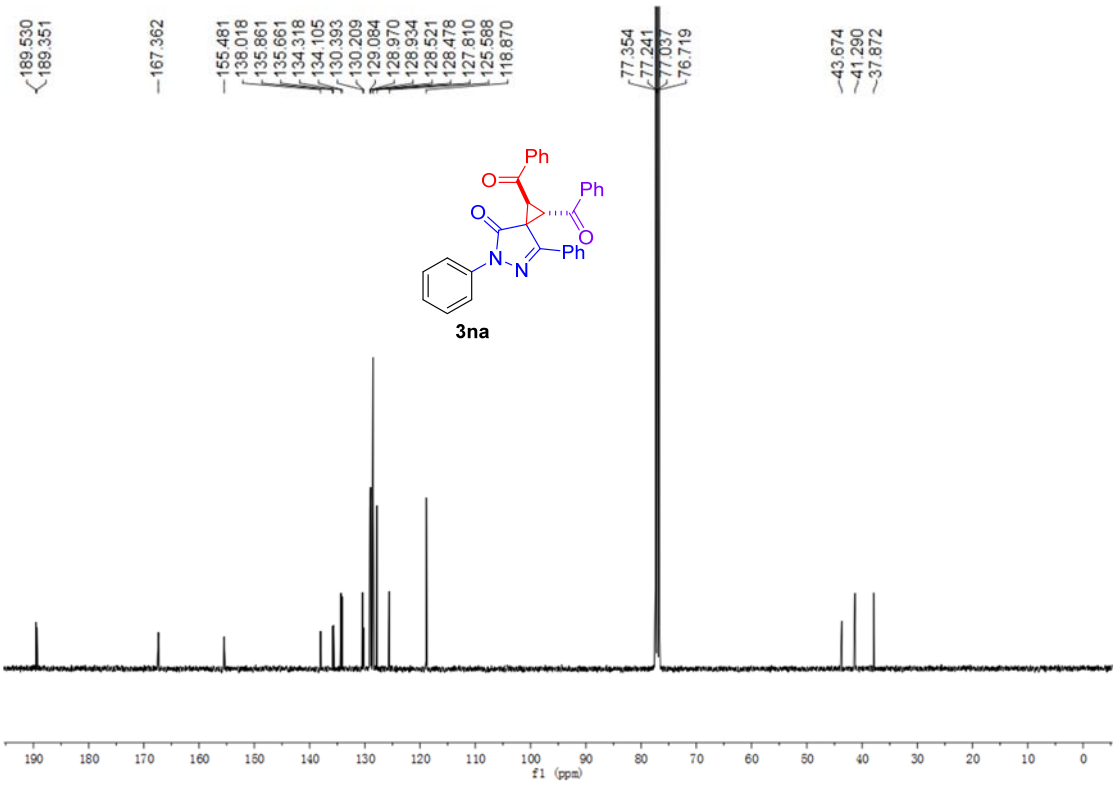

190.932
188.573
166.974
155.544
138.964
135.687
135.631
134.716
134.665
134.184
129.910
129.204
129.055
128.824
128.426
125.185
118.510
116.321
44.953
39.435
38.526
15.179
Ph
O
Ph
O
O
N
N
Cl
3ka
f1 (ppm)


7.953
7.940
7.935
7.932
7.806
7.793
7.788
7.785
7.775
7.772
7.767
7.753
7.750
7.584
7.566
7.550
7.547
7.544
7.507
7.488
7.473
7.470
7.467
7.448
7.428
7.414
7.410
7.389
7.369
7.355
7.351
7.290
7.285
7.272
7.270
7.255
7.250
7.183
7.098
7.096
7.093
7.077
7.059
4.254
4.234
4.182
4.161
2.375
2.357
2.331
2.313
2.155
2.137
2.111
2.093
1.223
1.205
1.186
Ph
O
Ph
O
O
N
N
3ma
1.97
3.81
1.02
1.00
2.04
2.01
1.94
0.99
0.91
0.92
0.99
1.05
3.20
f1 (ppm)

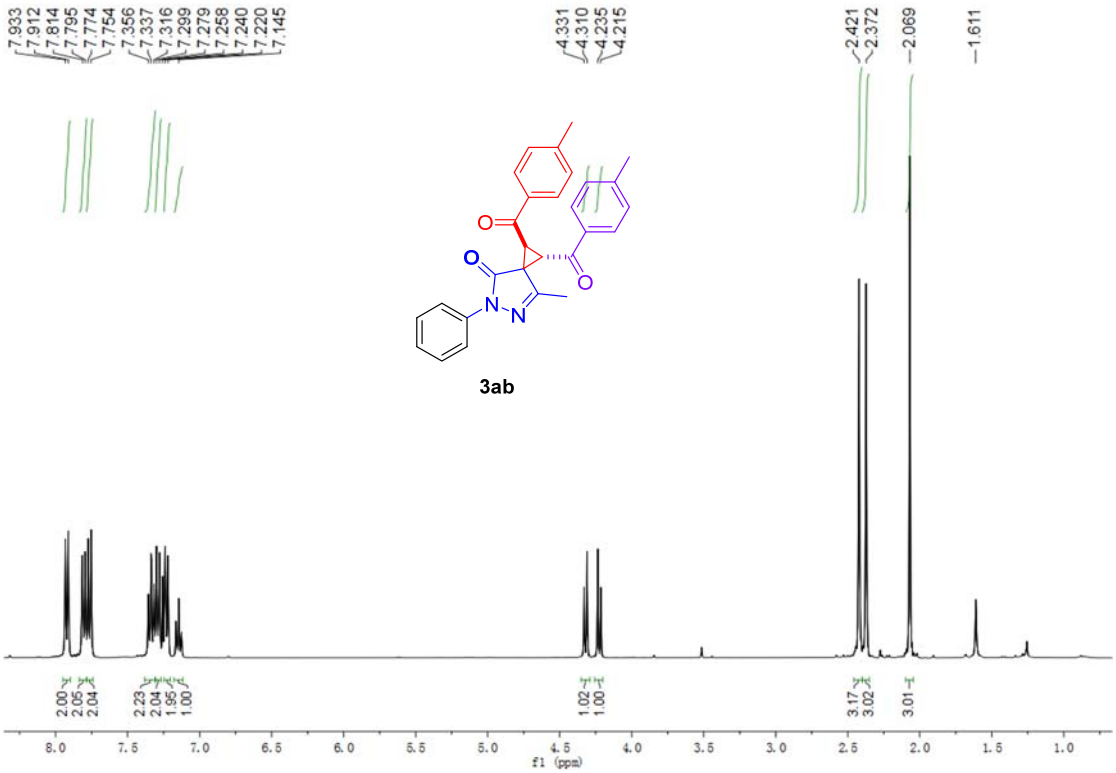

191.245
188.996
167.032
158.891
138.155
135.782
134.610
134.027
129.163
128.986
128.832
128.417
125.226
118.651
44.862
39.438
38.300
22.034
9.970
Ph
O
Ph
O
O
N
N
3ma
f1 (ppm)

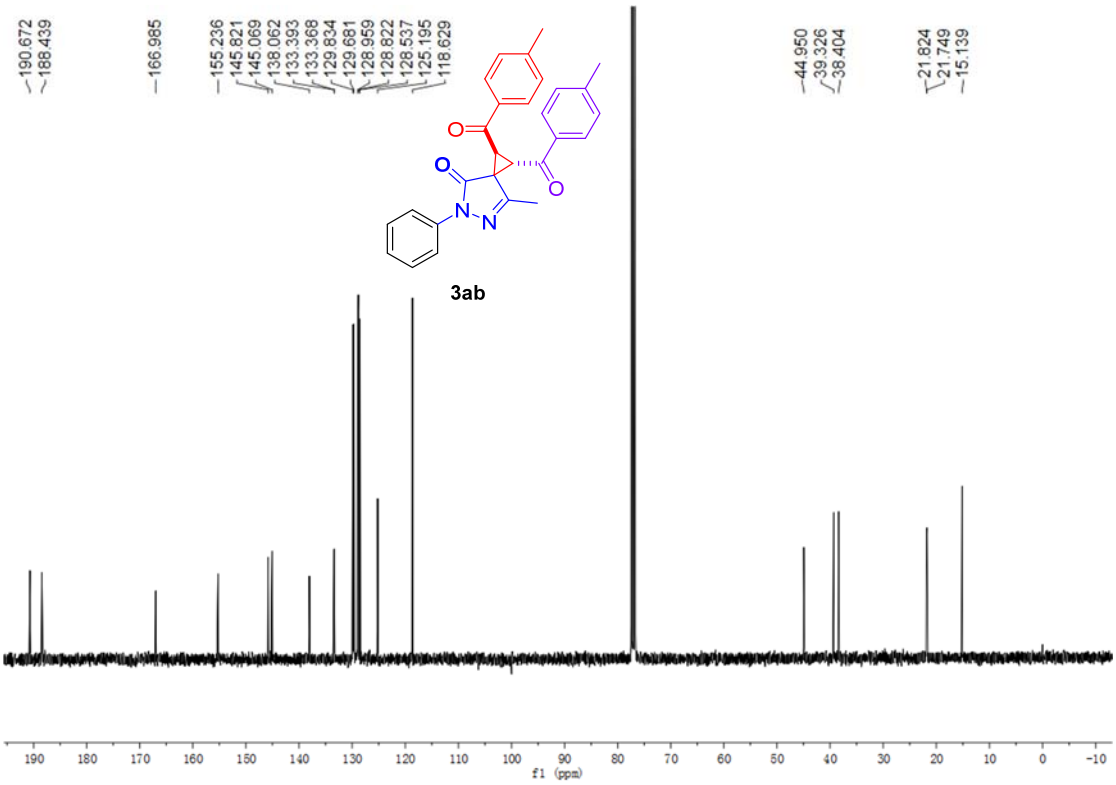

8.034
8.022
7.932
7.919
7.739
7.727
7.607
7.595
7.581
7.568
7.497
7.484
7.471
7.460
7.448
7.436
7.427
7.414
7.399
7.386
7.372
7.360
7.347
7.334
7.288
7.276
7.261
7.215
7.202
1.560
Ph
O
Ph
O
O
N
N
Ph
2.00
1.93
2.02
2.13
2.13
1.23
6.34
2.14
1.06
1.07
1.05
2.72
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

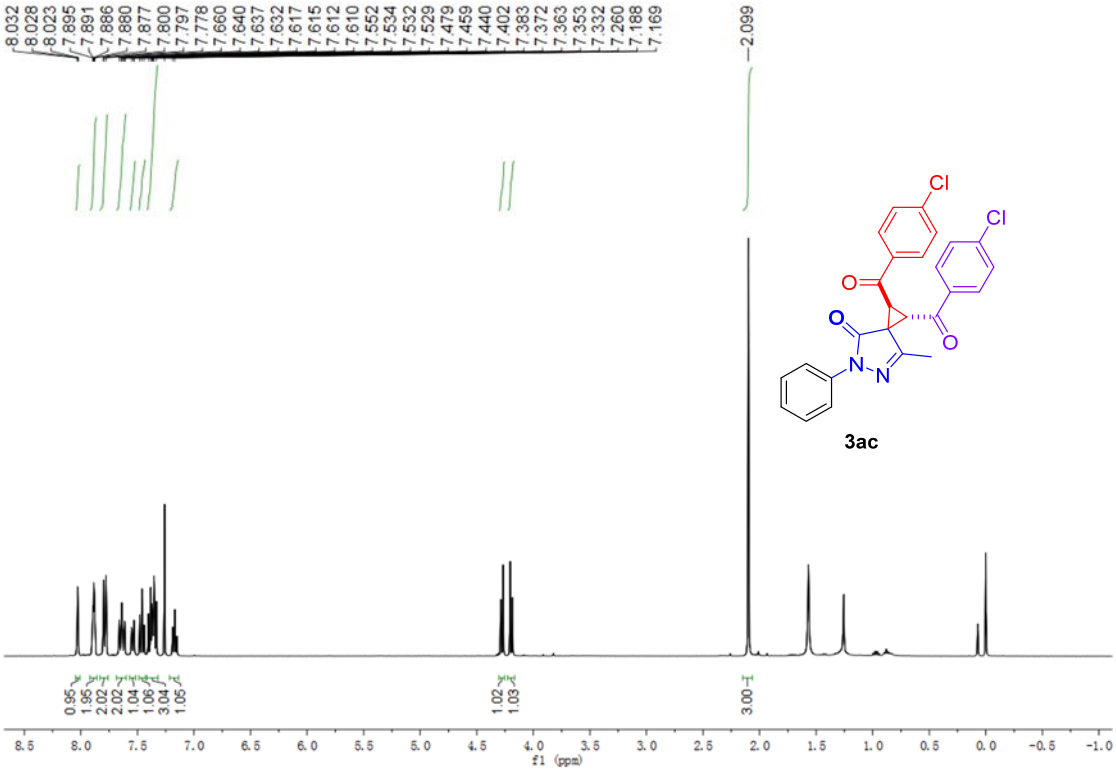
3na

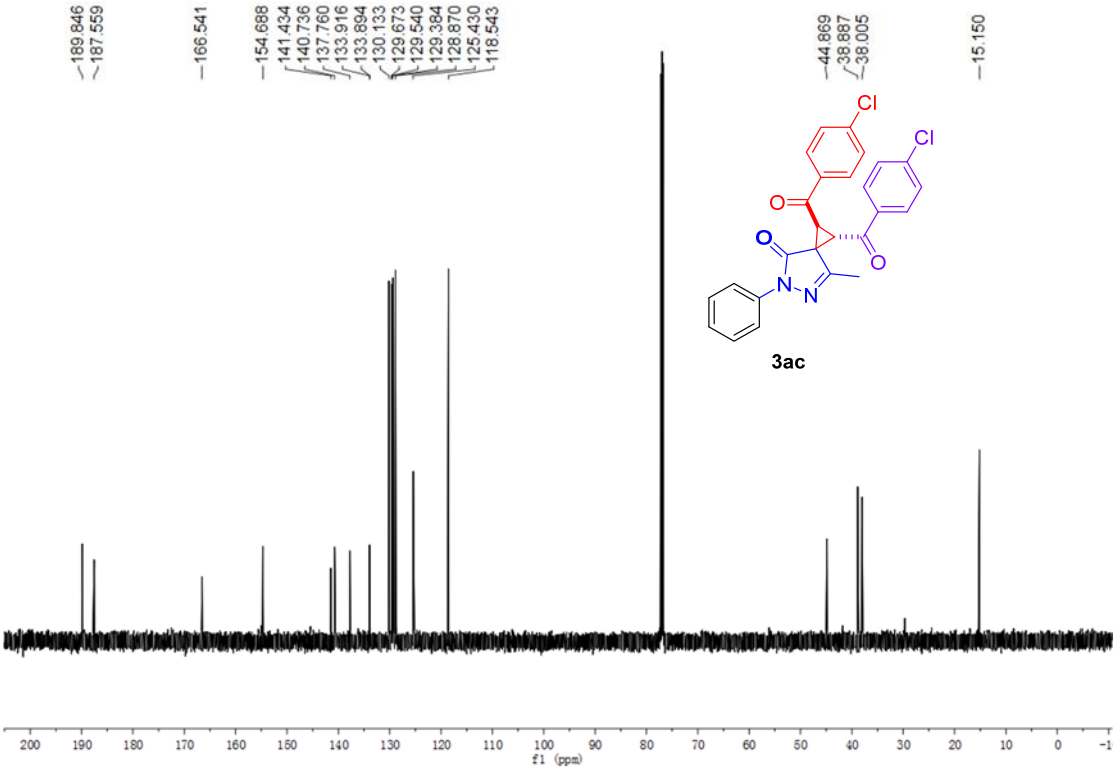

189.530
189.351
167.362
155.481
138.018
135.861
135.661
134.318
134.105
130.393
130.209
129.084
128.970
128.934
128.521
128.478
127.810
125.588
118.870
77.354
77.241
77.037
76.719
43.674
41.290
37.872
Ph
O
Ph
O
O
N
N
Ph
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

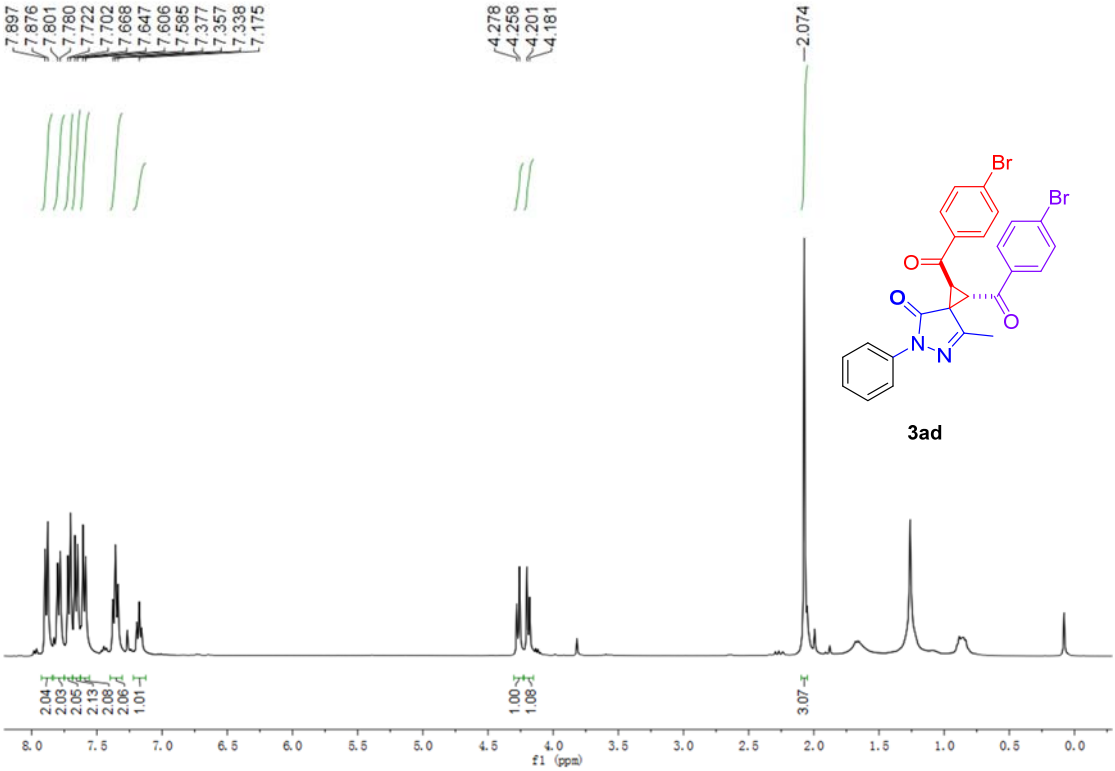
3na

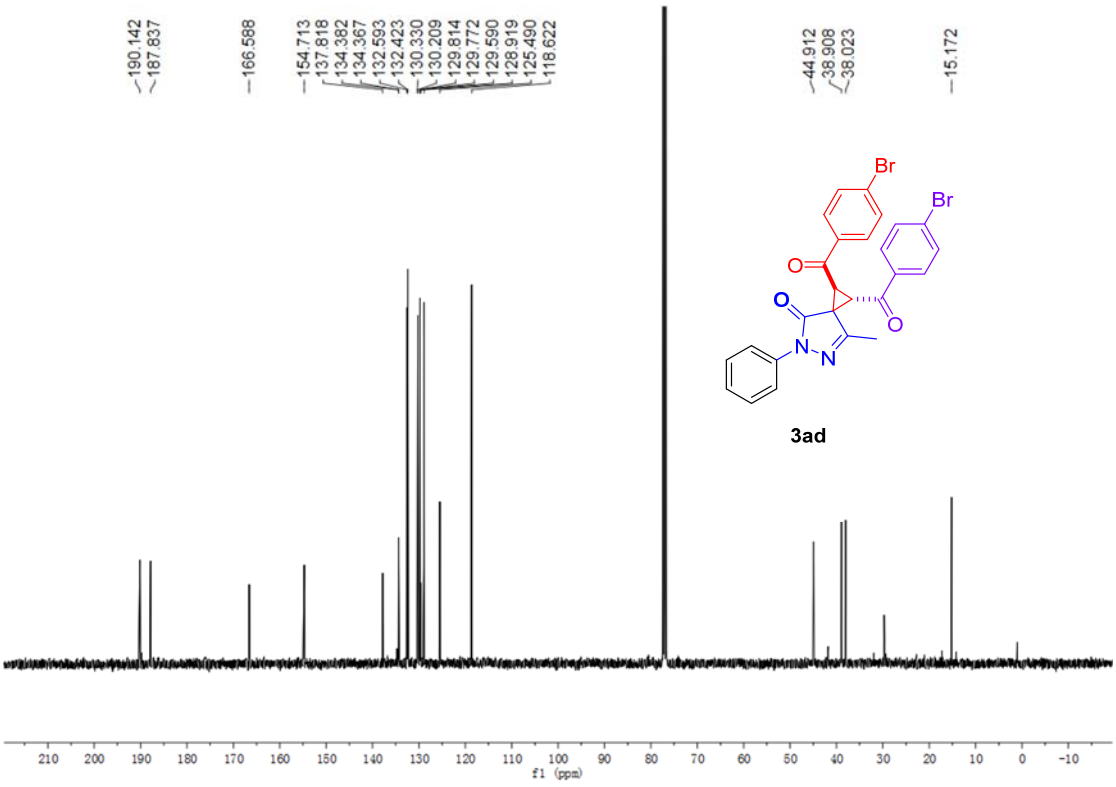

7.933
7.912
7.814
7.795
7.774
7.754
7.356
7.337
7.316
7.299
7.279
7.258
7.240
7.220
7.145
4.331
4.310
4.235
4.215
2.421
2.372
2.069
1.611
3ab

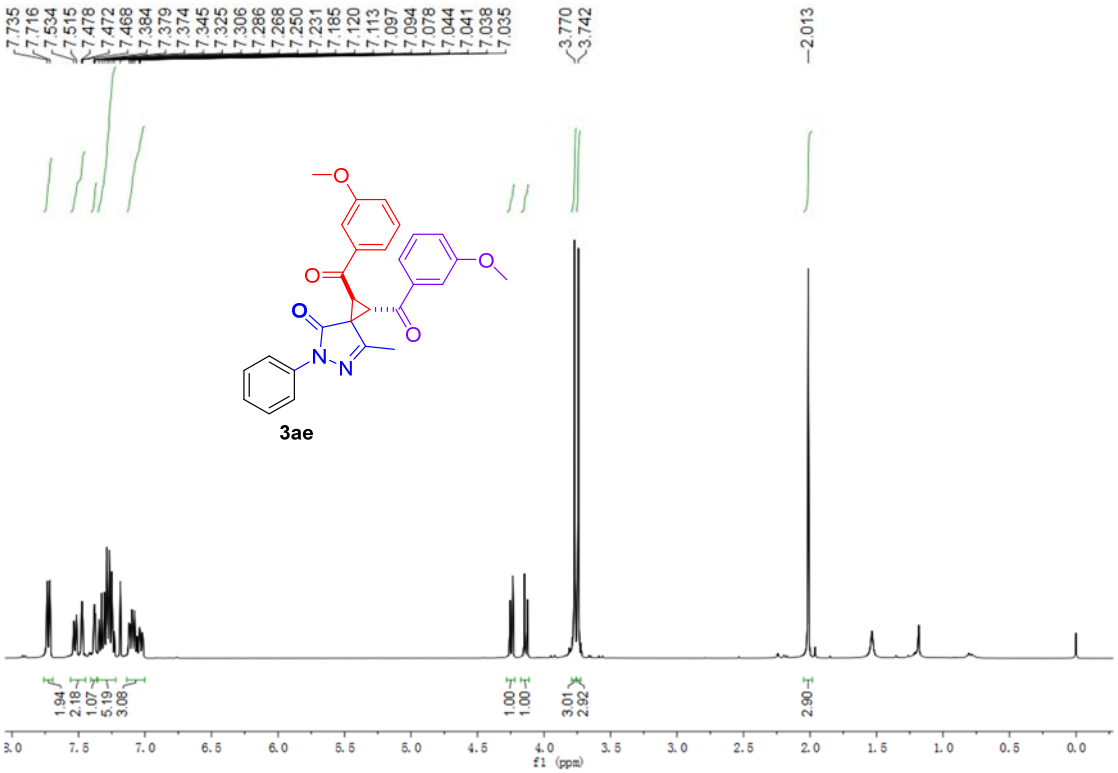

190.672
188.439
166.985
155.236
145.821
145.069
138.062
133.393
133.368
129.834
129.681
128.959
128.822
128.537
125.195
118.629
44.950
39.326
38.404
21.824
21.749
15.139
3ab
f1 (ppm)

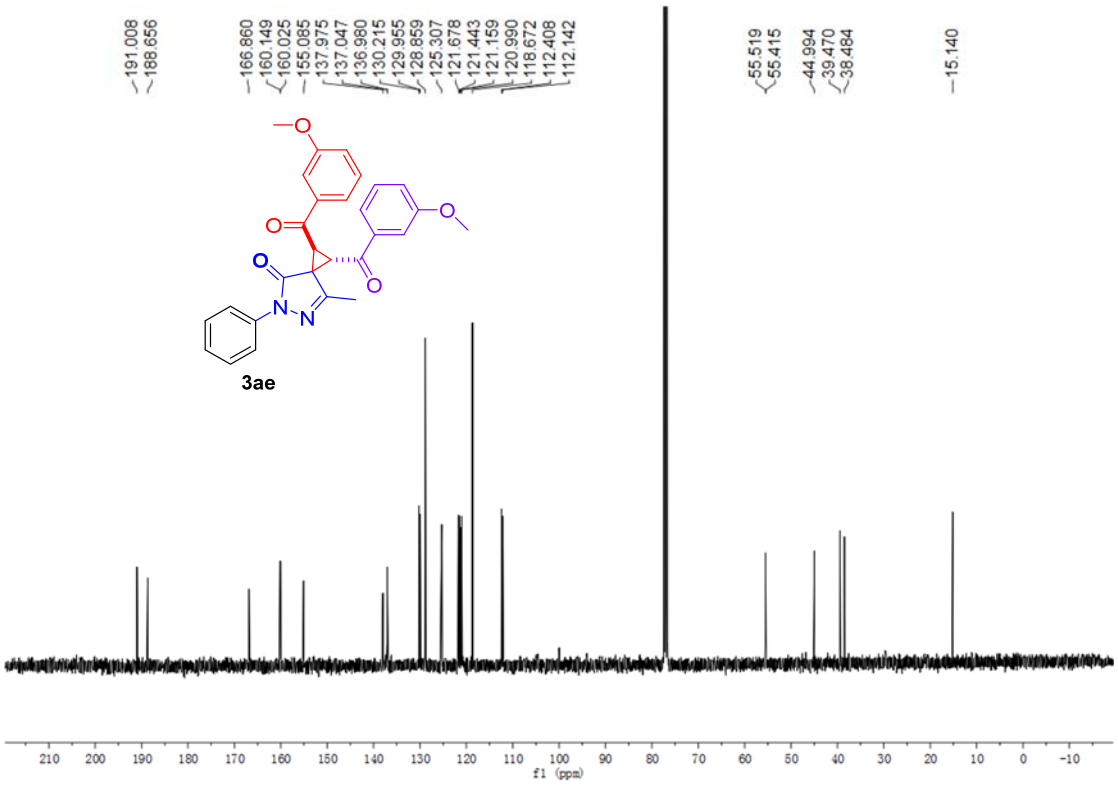

8.032
8.028
8.023
7.895
7.891
7.886
7.880
7.877
7.800
7.797
7.778
7.660
7.640
7.637
7.632
7.617
7.615
7.612
7.610
7.552
7.534
7.532
7.529
7.479
7.459
7.440
7.402
7.383
7.372
7.363
7.353
7.332
7.260
7.188
7.169
2.099
0.95
1.95
2.02
2.02
1.04
1.06
3.04
1.05
1.02
1.03
3.00
f1 (ppm)
Cl
Cl
O
O
O
N
N
3ac

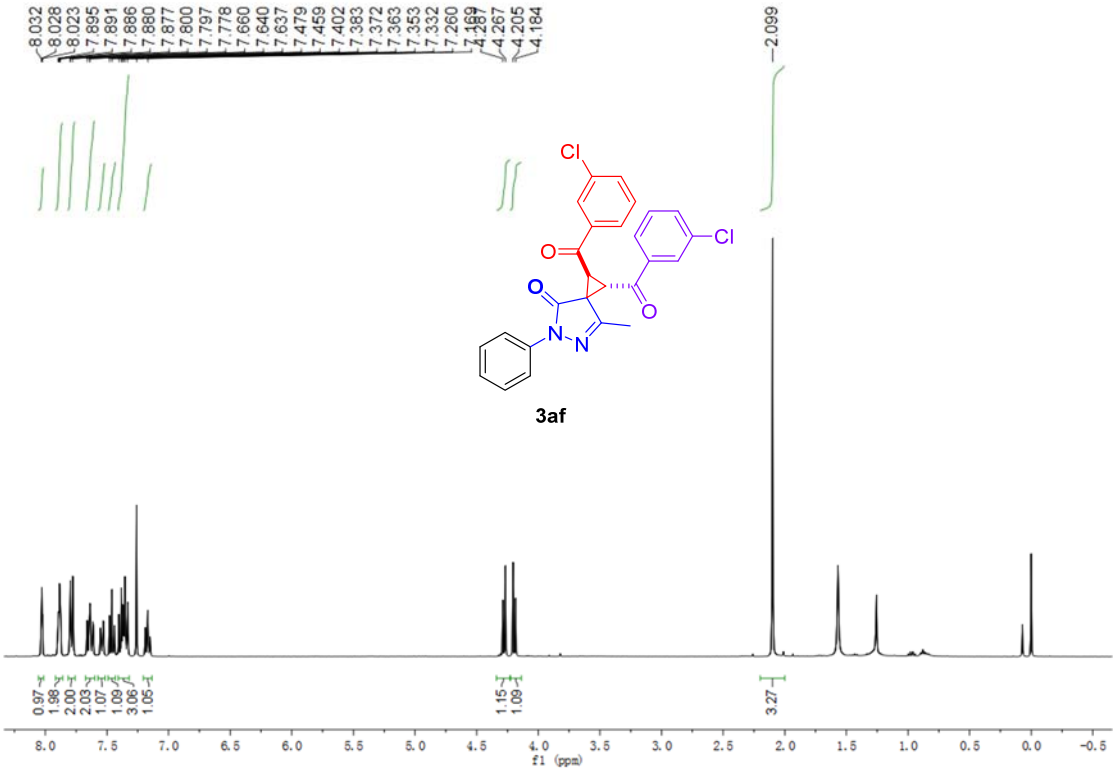

189.846
187.559
166.541
154.688
141.434
140.736
137.760
133.916
133.894
130.133
129.673
129.540
129.384
128.870
125.430
118.543
44.869
38.887
38.005
15.150
f1 (ppm)
Cl
Cl
O
O
O
N
N
3ac

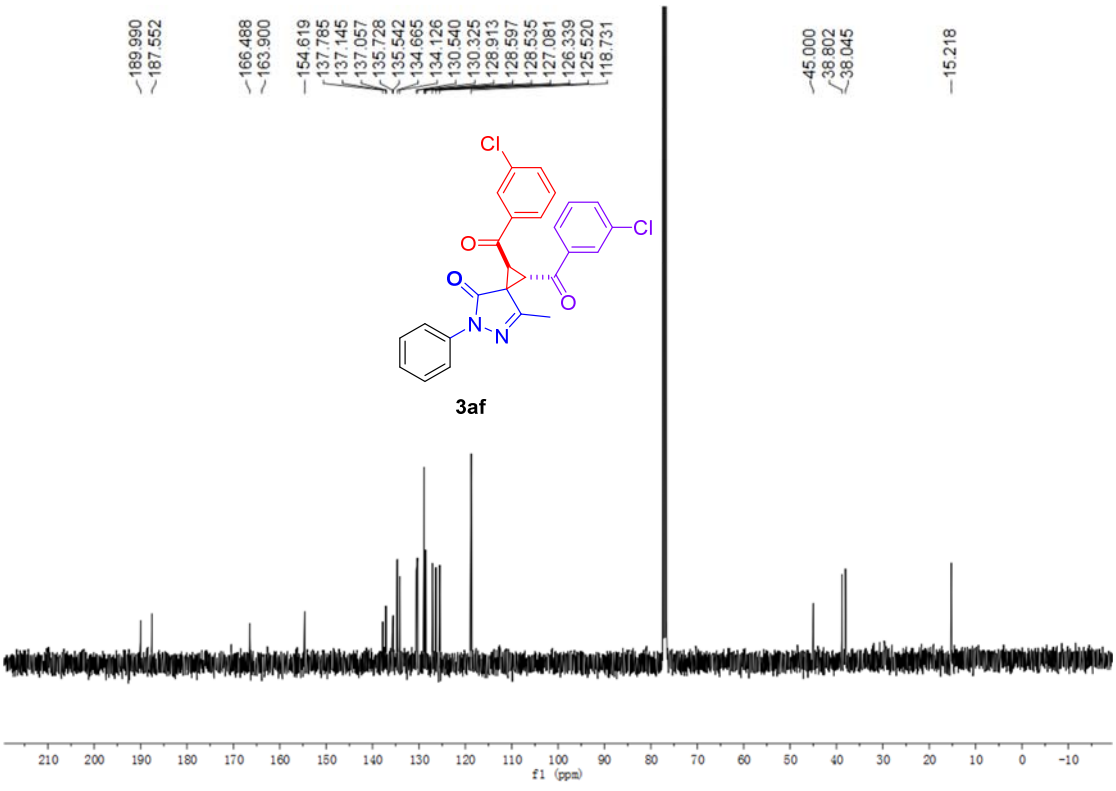

7.897
7.876
7.801
7.780
7.722
7.702
7.668
7.647
7.606
7.585
7.377
7.357
7.338
7.175
4.278
4.258
4.201
4.181
2.074
Br
Br
O
O
O
N
N
3ad
2.04
2.03
2.05
2.13
2.08
2.06
1.01
1.00
1.08
3.07
f1 (ppm)

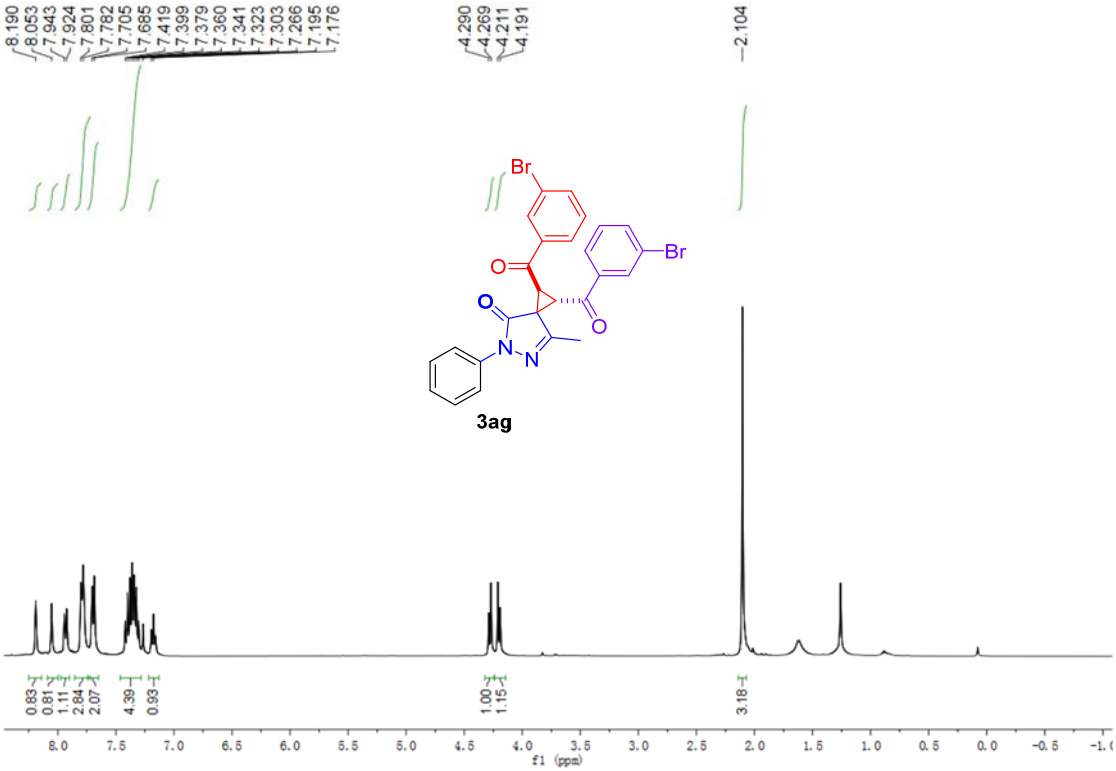

190.142
187.837
166.588
154.713
137.818
134.382
134.367
132.593
132.423
130.330
130.209
129.814
129.772
129.590
128.919
125.490
118.622
44.912
38.908
38.023
15.172
Br
Br
O
O
O
N
N
3ad
f1 (ppm)

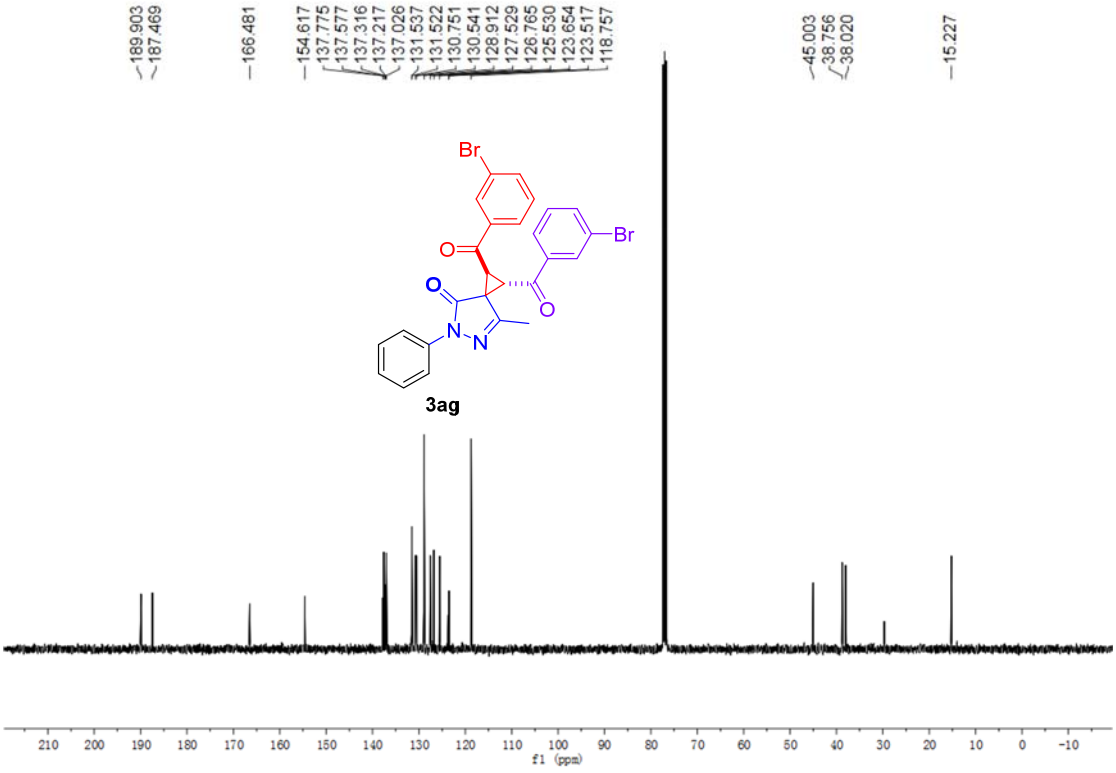

7.735
7.716
7.534
7.515
7.478
7.472
7.468
7.384
7.379
7.374
7.345
7.325
7.306
7.286
7.268
7.250
7.231
7.185
7.120
7.113
7.097
7.094
7.078
7.044
7.041
7.038
7.035
3.770
3.742
2.013
3ae
1.94
2.18
1.07
5.19
3.08
1.00
1.00
3.01
2.92
2.90
f1 (ppm)

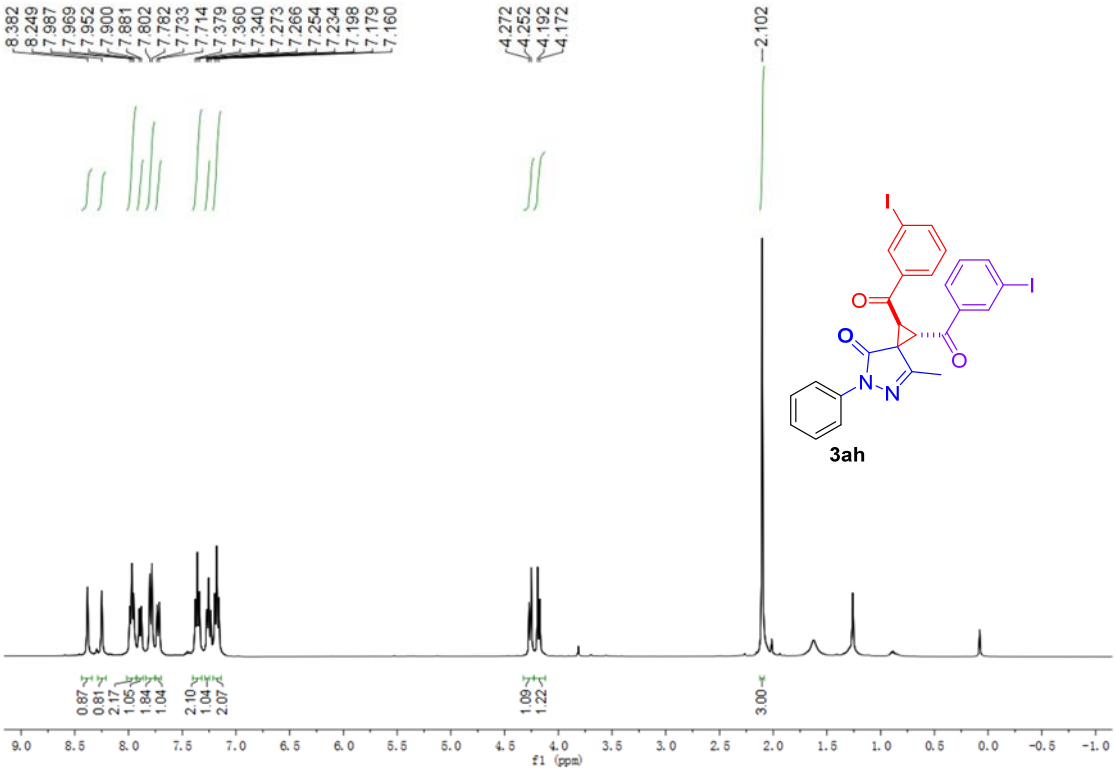

191.008
188.656
166.860
160.149
160.025
155.085
137.975
137.047
136.980
130.215
129.955
128.859
125.307
121.678
121.443
121.159
120.990
118.672
112.408
112.142
55.519
55.415
44.994
39.470
38.484
15.140
3ae
f1 (ppm)

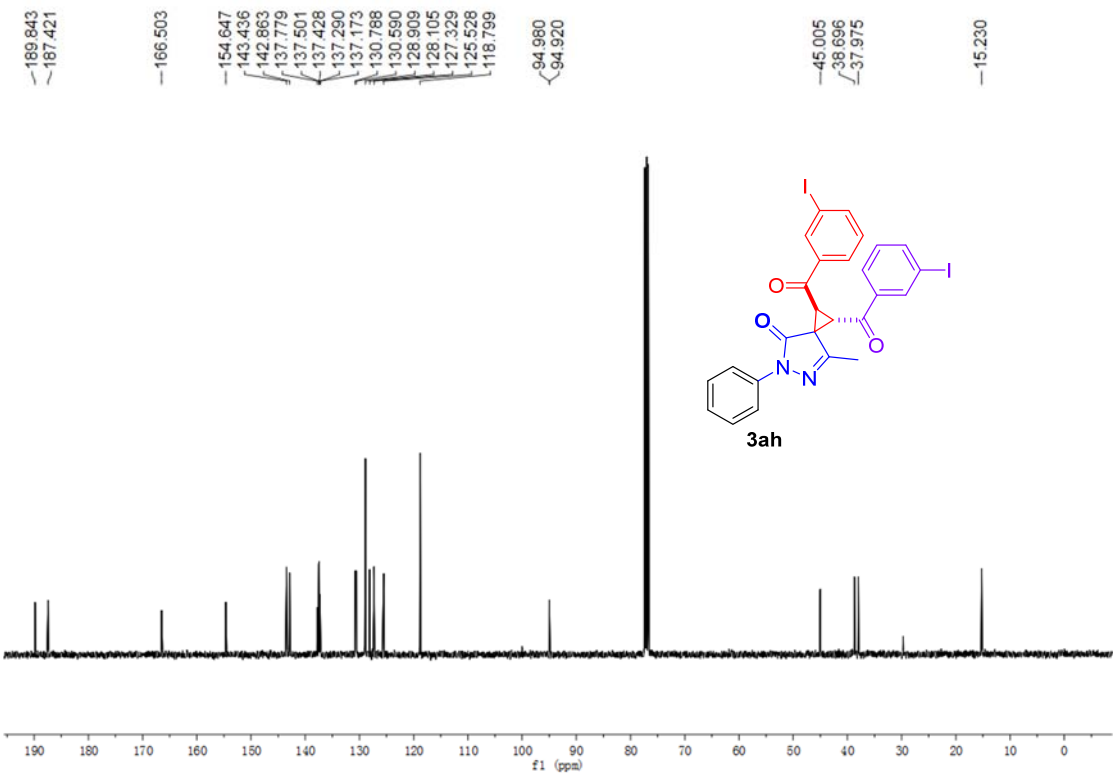

8.032
8.028
8.023
7.895
7.891
7.886
7.880
7.877
7.800
7.797
7.778
7.660
7.640
7.637
7.479
7.459
7.402
7.383
7.372
7.363
7.353
7.332
7.260
7.169
4.287
4.267
4.205
4.184
2.099
Cl
Cl
O
O
O
N
N
3af
0.97
1.98
2.00
2.03
1.07
1.09
3.06
1.05
1.15
1.09
3.27
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

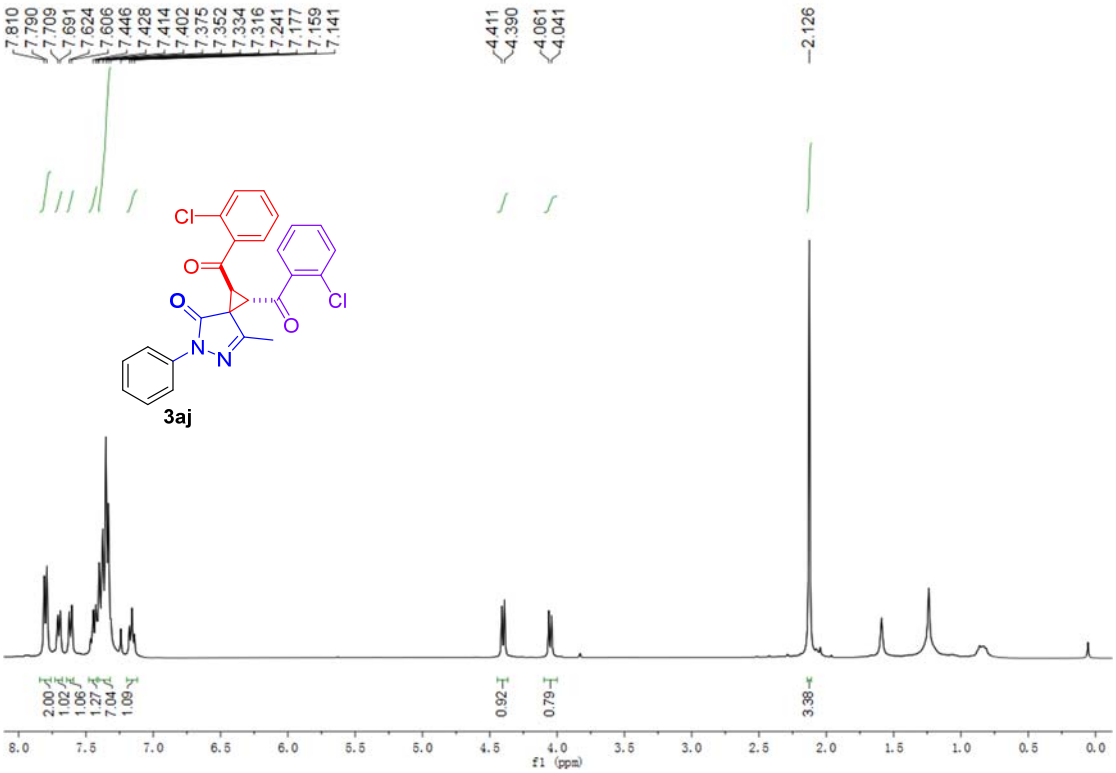

189.990
187.552
166.488
163.900
154.619
137.785
137.145
137.057
135.728
135.542
134.665
134.126
130.540
130.325
128.913
128.597
128.535
127.081
126.339
125.520
118.731
45.000
38.802
38.045
15.218
Cl
Cl
O
O
O
N
N
3af
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

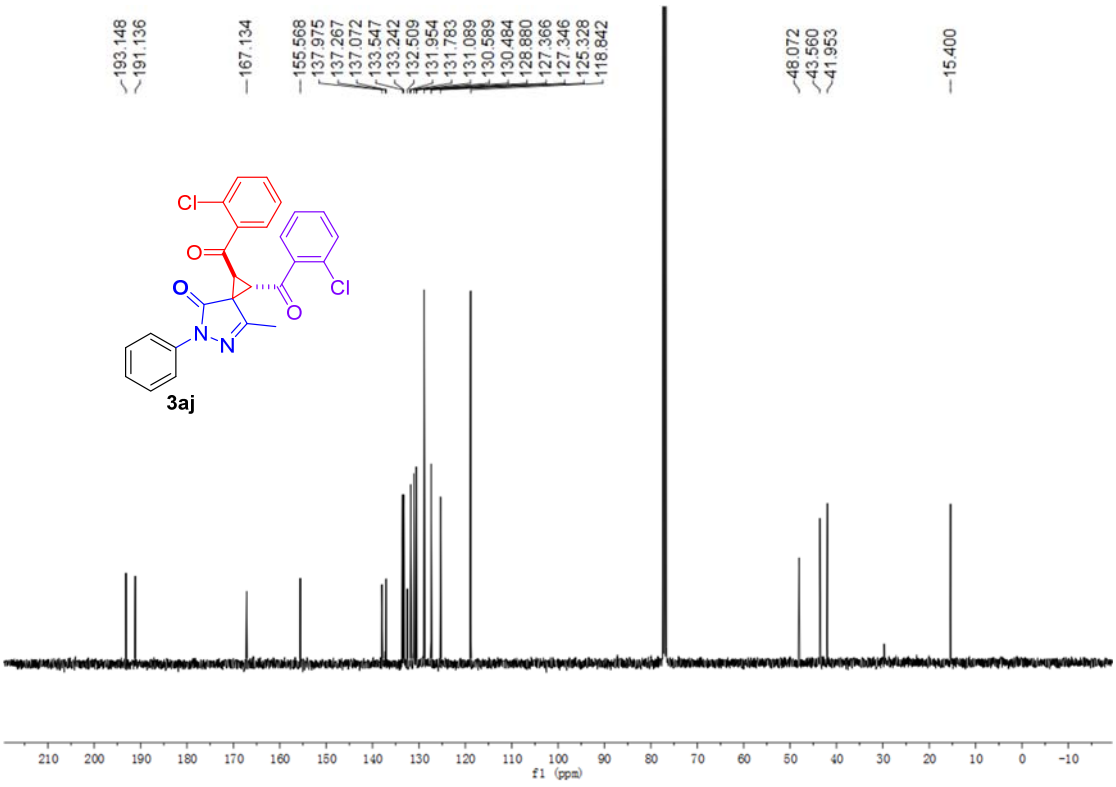

8.190
8.053
7.943
7.924
7.801
7.782
7.705
7.685
7.419
7.399
7.379
7.360
7.341
7.323
7.303
7.266
7.195
7.176
4.290
4.269
4.211
4.191
2.104
Br
Br
O
O
O
N
N
3ag
0.83
0.81
1.11
2.84
2.07
4.39
0.93
1.00
1.15
3.18
f1 (ppm)

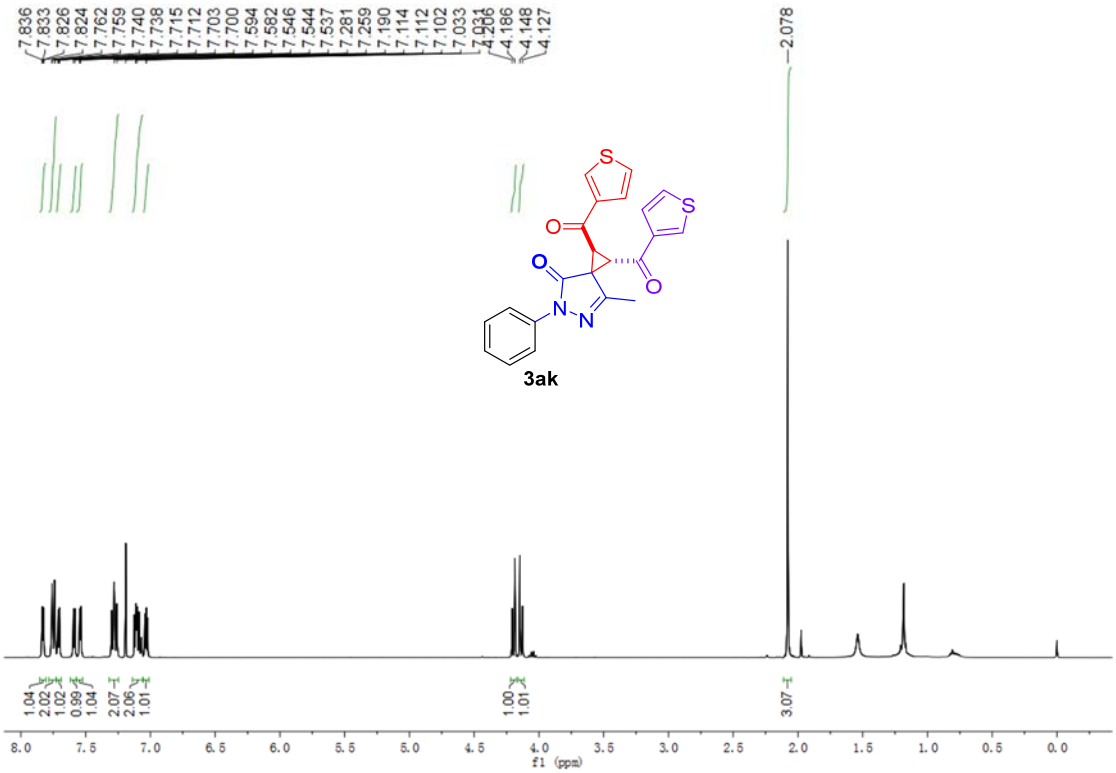

189.903
187.469
166.481
154.617
137.775
137.577
137.316
137.217
137.026
131.537
131.522
130.751
130.541
128.912
127.529
126.765
125.530
123.654
123.517
118.757
45.003
38.756
38.020
15.227
Br
Br
O
O
O
N
N
3ag
f1 (ppm)

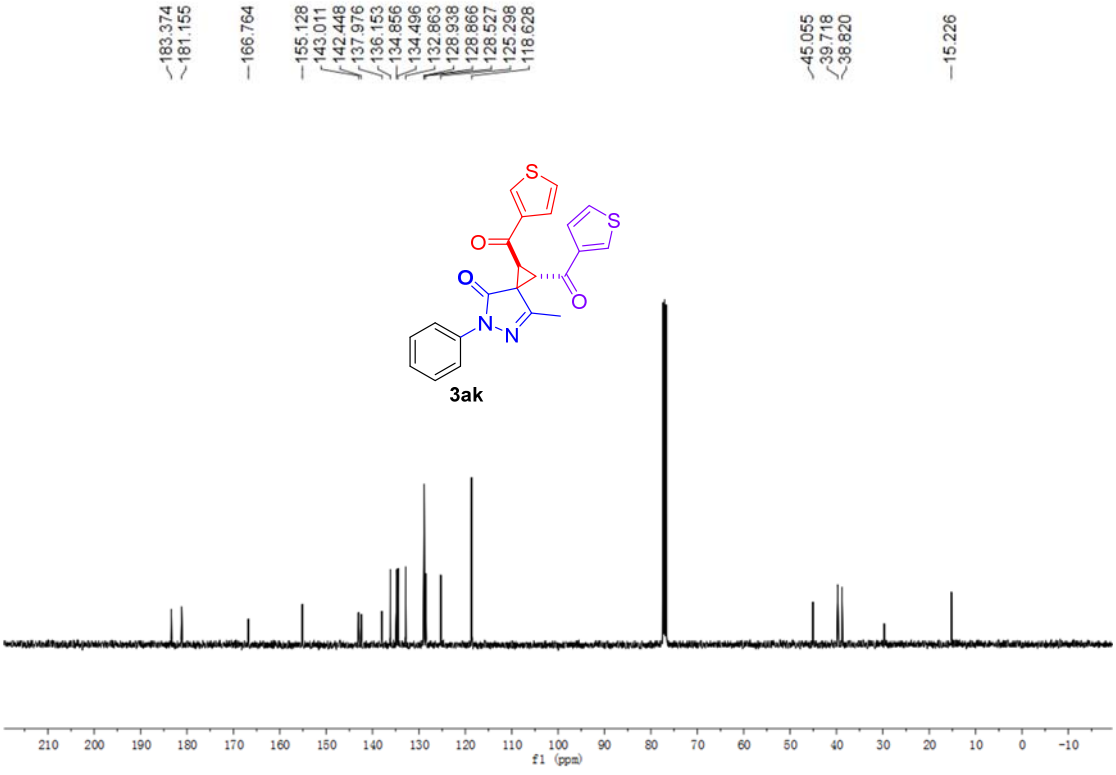

8.382
8.249
7.987
7.969
7.952
7.900
7.881
7.802
7.782
7.733
7.714
7.379
7.360
7.340
7.273
7.266
7.254
7.234
7.198
7.179
7.160
4.272
4.252
4.192
4.172
2.102
0.87
0.81
2.17
1.05
1.84
1.04
2.10
1.04
2.07
1.09
1.22
3.00
f1 (ppm)
3ah

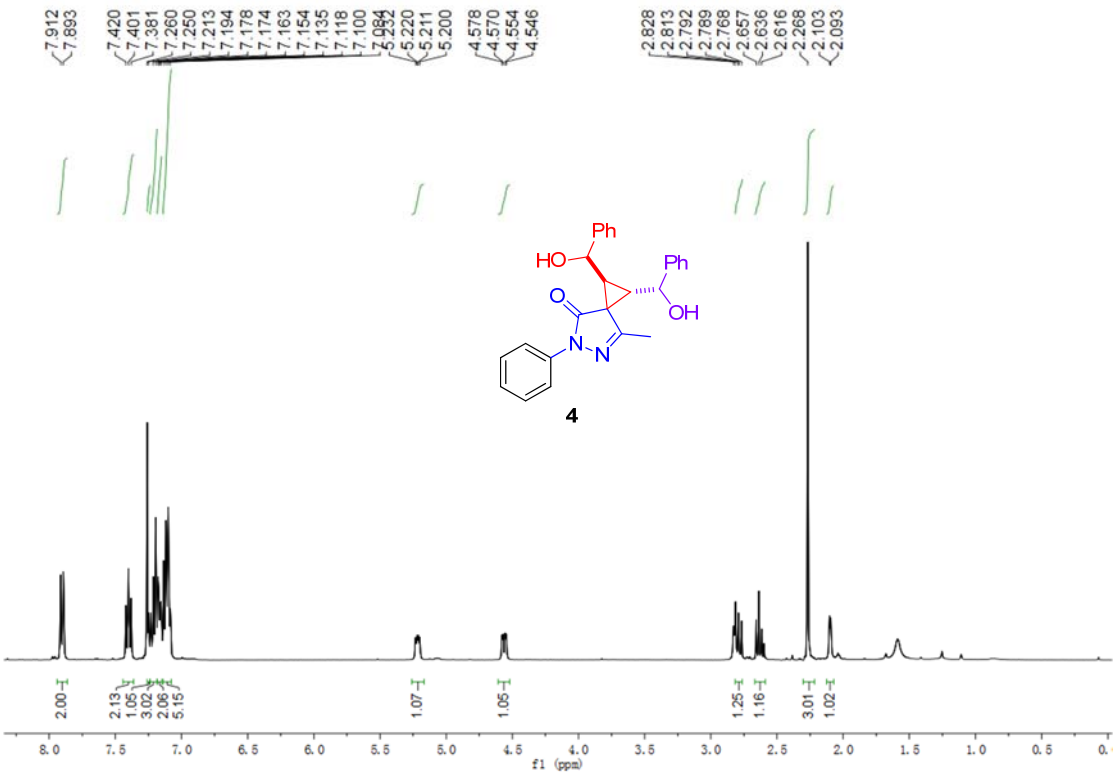

189.843
187.421
166.503
154.647
143.436
142.863
137.779
137.501
137.428
137.290
137.173
130.788
130.590
128.909
128.105
127.329
125.528
118.799
94.980
94.920
45.005
38.696
37.975
15.230
f1 (ppm)
3ah

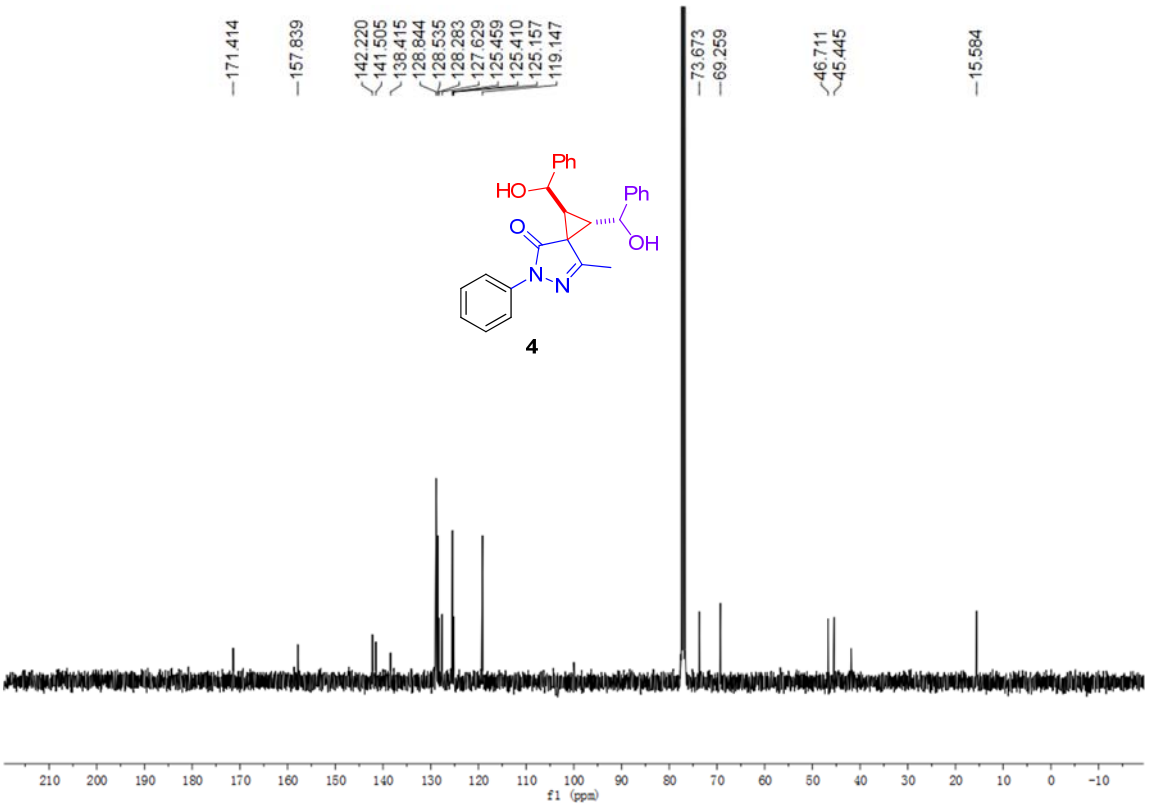

7.810
7.790
7.709
7.691
7.624
7.606
7.446
7.428
7.414
7.402
7.375
7.352
7.334
7.316
7.241
7.177
7.159
7.141
4.411
4.390
4.061
4.041
2.126
Cl
O
O
N
N
O
Cl
3aj
2.00
1.02
1.06
1.27
7.04
1.09
0.92
0.79
3.38
f1 (ppm)


193.148
191.136
167.134
155.568
137.975
137.267
137.072
133.547
133.242
132.509
131.954
131.783
131.089
130.589
130.484
128.880
127.366
127.346
125.328
118.842
48.072
43.560
41.953
15.400
Cl
O
O
N
N
O
Cl
3aj
f1 (ppm)


7.836
7.833
7.826
7.824
7.762
7.759
7.740
7.738
7.715
7.712
7.703
7.700
7.594
7.582
7.546
7.544
7.537
7.281
7.259
7.190
7.114
7.112
7.102
7.033
4.186
4.148
4.127
2.078
S
S
O
O
O
N
N
3ak
1.04
2.02
1.02
0.99
1.04
2.07
2.06
1.01
1.00
1.01
3.07
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
f1 (ppm)


183.374
181.155
166.764
155.128
143.011
142.448
137.976
136.153
134.856
134.496
132.863
128.938
128.866
128.527
125.298
118.628
45.055
39.718
38.820
15.226
S
S
O
O
O
N
N
3ak
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.912
7.893
7.420
7.401
7.381
7.260
7.250
7.213
7.194
7.178
7.174
7.163
7.154
7.135
7.118
7.100
5.220
5.211
5.200
4.578
4.570
4.554
4.546
2.828
2.813
2.792
2.789
2.768
2.657
2.636
2.616
2.268
2.103
2.093
Ph
HO
Ph
OH
O
N
N
4
2.00
2.13
1.05
3.02
2.06
5.15
1.07
1.05
1.25
1.16
3.01
1.02
f1 (ppm)


171.414
157.839
142.220
141.505
138.415
128.844
128.535
128.283
127.629
125.459
125.410
125.157
119.147
73.673
69.259
46.711
45.445
15.584
Ph
HO
Ph
OH
O
N
N
4
f1 (ppm)