Electronic Supplementary Material (ESI) for Chemical Communications.

Asymmetric sequential annulation/aldol process of 4-isothiocyanato pyrazolones and allenones: access to novel spiro[pyrrole-pyrazolones] and spiro[thiopyranopyrrole-pyrazolones]

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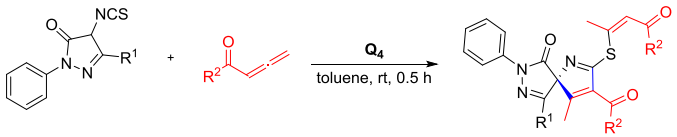
1. General information

Unless otherwise noted, materials were purchased from commercial suppliers and used without further purification. Column chromatography was performed on silica gel (200~300 mesh). Enantiomeric excesses (ee) were determined by HPLC using corresponding commercial chiral columns as stated at 30 ℃ with UV detector at 254 nm. Optical rotations were reported as follows: $[\alpha]_D^T$ (c g/100 mL, solvent). All ^{1}H NMR and ^{19}F NMR spectra were recorded on a Bruker Avance Ⅱ 400 MHz, Bruker Avance Ⅱ 500 MHz and Bruker Avance Ⅲ 600 MHz respectively, ^{13}C NMR spectra were recorded on a Bruker Avance Ⅱ 101 MHz or Bruker Avance Ⅲ 151 MHz with chemical shifts reported as ppm (in $CDCl_3$, TMS as an internal standard). Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, br = broad singlet, dd = double doublet, coupling constants in Hz, integration). HRMS (ESI) was obtained with a HRMS/MS instrument (LTQ Orbitrap XL TM). The absolute configuration of 4 was assigned by the X-ray analysis.

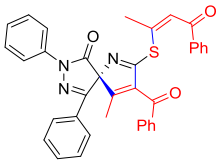
4-isothiocyanato pyrazolones were prepared according to the literature.[1] Allenyl ketones were prepared according to the literature.[2] Catalyst **Q4** and **Q5** were synthesized according to the literature procedure.[3] The racemic products were synthesized using quinine/quinidine = 1:1 as the catalyst.

2. Experimental procedures and characterization of compounds 4, 5



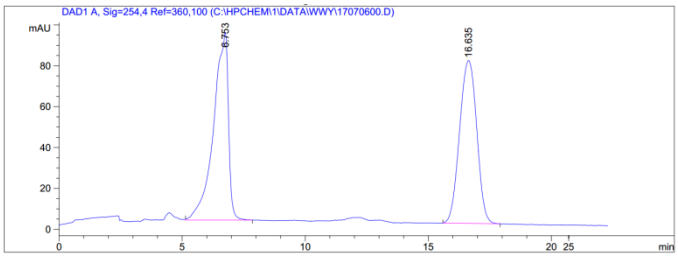
A tube equipped with a magnetic stir bar was charged with 4-isothiocyanato pyrazolone **1** (0.2 mmol), **Q4** (0.02 mmol), and toluene (2 mL). After stirring for 5 min, alkynyl ketone **2** (0.5 mmol) was added in one portion. The reaction was detected by TLC. After 0.5 h, the mixture was purified by column chromatography on silica gel (unless otherwise noticed, petroleum ether/EtOAc = 20:1 was used as the eluent) directly to give the product **4**.

Compound 4aa



4aa

Prepared according to the procedure within 0.5 h as colorless oil (76.7 mg, 66% yield). $[\alpha]_D^{17}$ = -186.79 (*c* 0.41, CH_2Cl_2), ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02 (d, *J* = 7.7 Hz, 2H), 8.00-7.96 (m, 2H), 7.85-7.81 (m, 2H), 7.69-7.61 (m, 2H), 7.58 (d, *J* = 6.2 Hz, 2H), 7.55-7.39 (m, 8H), 7.30 (t, *J* = 7.7 Hz, 3H), 2.51 (d, *J* = 1.4 Hz, 3H), 1.87 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-d) δ 190.6, 189.3, 175.2, 165.2, 162.2, 153.9, 148.3, 140.3, 138.2, 137.7, 136.4, 134.6, 132.8, 131.6, 129.9, 129.8, 129.2, 129.1, 128.5, 128.5, 128.0, 126.2, 125.9, 119.2, 93.79, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{25}H_{17}N_3O_2S$ ($[M+H]^+$) 412.1114, Found 412.1114. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 16.9 min, tminor = 6.8 min).



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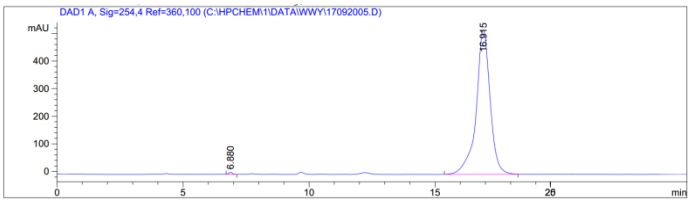
1	6.753	BB	0.5407	3863.63428	91.85115	49.9834
2	16.635	BB	0.6674	3866.19287	79.77332	50.0166



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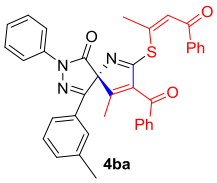
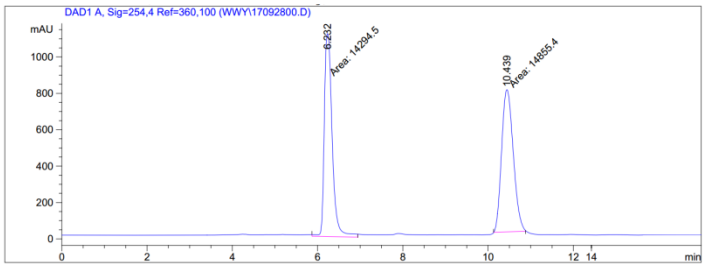
1	6.880	VB	0.1487	71.85115	7.31070	0.3545
2	16.915	BB	0.5763	2.01937e4	523.21265	99.6455

Compound 4ba



Prepared according to the procedure within 0.5 h as colorless oil (86.8 mg, 73% yield); $[\alpha]_D^{17}$ = -110.66 (*c* 0.31, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.03 (d, *J* = 8.7 Hz, 2H), 7.97 (d, *J* = 7.7 Hz, 2H), 7.84 (d, *J* = 7.7 Hz, 2H), 7.65 (s, 2H), 7.56-7.41 (m, 6H), 7.36-7.25 (m, 5H), 7.25 (s, 1H), 2.51 (d, *J* = 1.6 Hz, 3H), 2.39 (s, 3H), 1.87 (s, 3H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.5, 189.3, 175.1, 165.2, 162.2, 154.0, 148.2, 140.4, 138.9, 138.3, 137.71, 136.5, 134.5, 132.8, 132.4, 129.9, 129.8, 129.1, 128.5, 128.5, 127.9, 126.4, 126.1, 123.1, 93.9, 21.8, 21.5, 12.9. HRMS (ESI) m/z Calcd. for $C_{37}H_{29}N_3O_3S$ ([M+H]$^+$) 596.2002, Found 596.1992. Enantiomeric excess was determined to be 95% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.8 min, tminor = 6.3 min).



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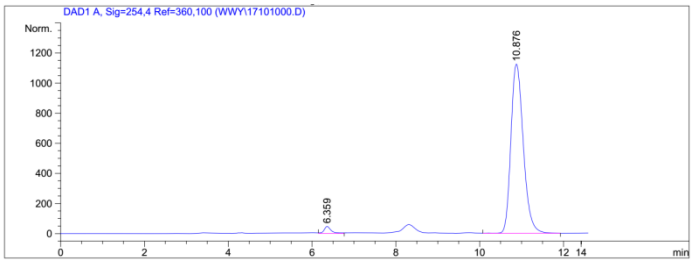
1	6.232	MM	0.2134	1.42945e4	1116.20996	49.0379
2	10.439	MM	0.3165	1.48554e4	782.36310	50.9621



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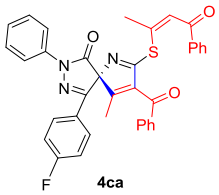
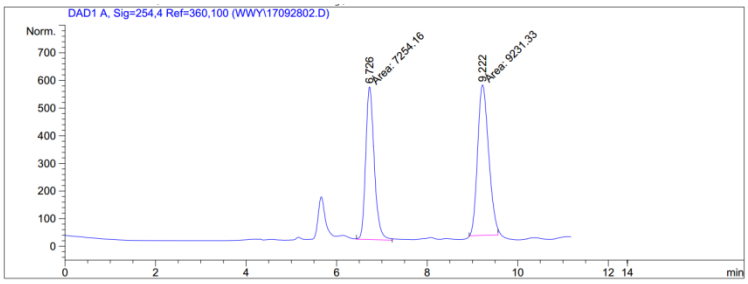
1	6.359	VB	0.1741	550.99896	46.53965	2.3282
2	10.876	VP	0.3179	2.31150e4	1124.17139	97.6718

Compound 4ca



Prepared according to the procedure within 0.5 h as colorless oil (87.6 mg, 73% yield); $[\alpha]_D^{16}$ = -170.63 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.06-7.95 (m,4H), 7.88-7.82 (m, 2H), 7.70-7.61 (m, 2H), 7.60-7.43 (m, 7H), 7.38-7.26 (m, 3H), 7.12 (t, *J* = 8.6 Hz, 2H), 2.52 (d, *J* = 1.3 Hz, 3H), 1.86 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.5, 189.2, 175.4, 165.0, 164.6 (d, *J* = 253.4 Hz), 161.8, 152.9, 148.1, 140.5, 138.2, 137.6, 136.4, 134.6, 132.9, 129.8, 129.1 (d, *J* = 1.4 Hz), 128.5, 128.5, 128.1 (d, *J* = 8.7 Hz), 126.2, 126.2, 119.2, 116.5 (d, *J* = 22.3 Hz), 93.7, 21.8, 12.8; ^{19}F NMR (470 MHz, Chloroform-*d*) δ -106.82 - -107.02 (m). HRMS (ESI) m/z Calcd. for $C_{25}H_{17}N_3O_2S$ ($[M+H]^+$) 412.1114, Found 412.1114. Enantiomeric excess was determined to be 98% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 6.5 min, tminor = 9.2 min).



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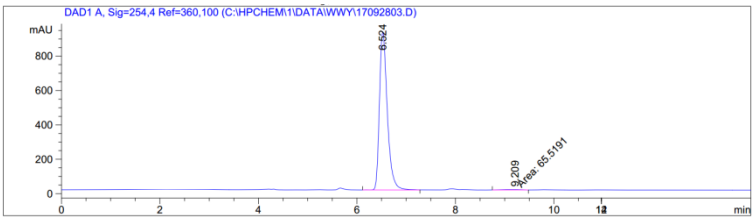
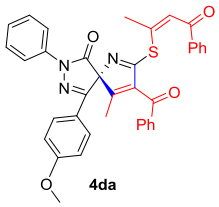
2	9.222	MM	0.2824	9231.32813	544.88361	55.9967

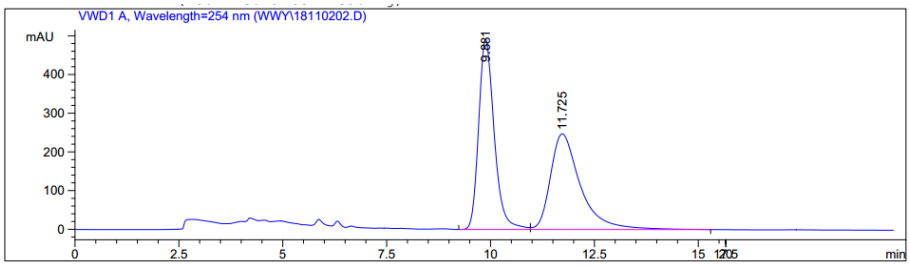


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.524	PB	0.1693	1.02031e4	920.88086	99.3620
2	9.209	MM	0.4906	65.51913	2.22561	0.6380

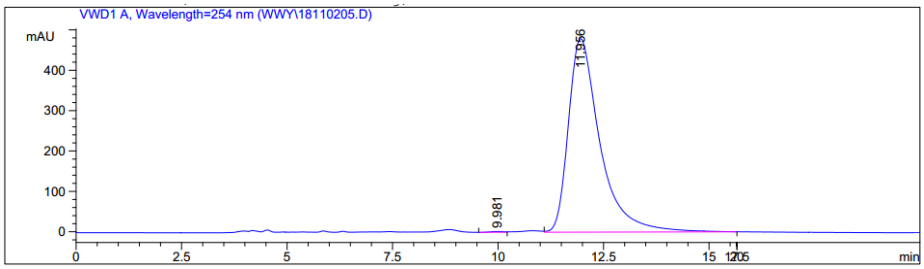
Compound 4da



Prepared according to the procedure within 0.5 h as colorless oil (89.2 mg, 73% yield); $[\alpha]_D^{17}$ = -189.91 (*c* 0.37, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.02 (d, *J* = 7.5 Hz, 2H), 7.98 (d, *J* = 7.0 Hz, 2H), 7.84 (d, *J* = 7.0 Hz, 2H), 7.69-7.61 (m, 2H), 7.56-7.42 (m, 7H), 7.37-7.26 (m, 3H), 6.92 (d, *J* = 8.9 Hz, 2H), 3.83 (s, 3H), 2.52 (d, *J* = 1.3 Hz, 3H), 1.86 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.7, 189.3, 174.9, 165.0, 162.4, 162.2, 153.6, 148.4, 140.2, 138.3, 137.8, 136.5, 134.5, 132.8, 129.8, 129.1, 129.1, 128.5, 128.5, 127.8, 127.6, 125.9, 122.6, 119.2, 114.6, 94.0, 55.5, 21.8, 12.9. HRMS (ESI) m/z Calcd. for $C_{37}H_{30}N_3O_4S$ ($[M+H]^+$) 612.1952, Found 612.1941. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 11.9 min, tminor = 9.9 min).

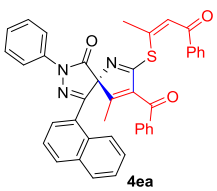


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.881	VV	0.3990	1.28114e4	491.12912	50.7615
2	11.725	VB	0.7502	1.24270e4	247.55083	49.2385

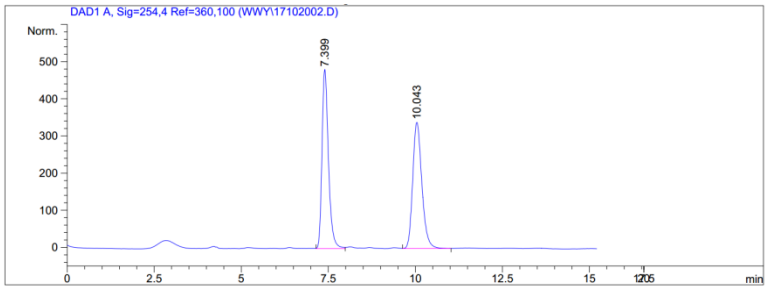


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.981	VV	0.3307	45.24305	2.05804	0.1809
2	11.956	VB	0.7778	2.49598e4	479.41721	99.8191

Compound 4ea



Prepared according to the procedure within 0.5 h as colorless oil (88.3 mg, 70% yield); $[\alpha]_D^{18}$ = -171.66 (*c* 0.44, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 9.27 (d, *J* = 8.6 Hz, 1H), 8.08 (dd, *J* = 8.7, 1.2 Hz, 2H), 7.95 (d, *J* = 8.3 Hz, 1H), 7.91 (m, 3H), 7.85-7.80 (m, 2H), 7.71-7.58 (m, 4H), 7.58-7.40 (m, 7H), 7.33 (t, *J* = 7.4 Hz, 1H), 7.28 (d, *J* = 8.2 Hz, 1H), 7.12 (d, *J* = 6.3 Hz, 1H), 2.50 (d, *J* = 1.3 Hz, 3H), 1.90 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.6, 189.3, 174.9, 164.7, 162.5, 154.6, 148.4, 140.4, 138.2, 137.7, 136.5, 134.5, 134.3, 132.8, 132.3, 130.5, 129.7, 129.2, 129.1, 129.0, 128.5, 128.4, 128.2, 127.8, 127.1, 126.6, 126.2, 126.1, 126.1, 125.1, 119.2, 95.1, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{40}H_{30}N_3O_3S$ ($[M+H]^+$) 632.2002, Found 632.2005. Enantiomeric excess was determined to be 79% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 9.8 min, tminor = 7.3 min).



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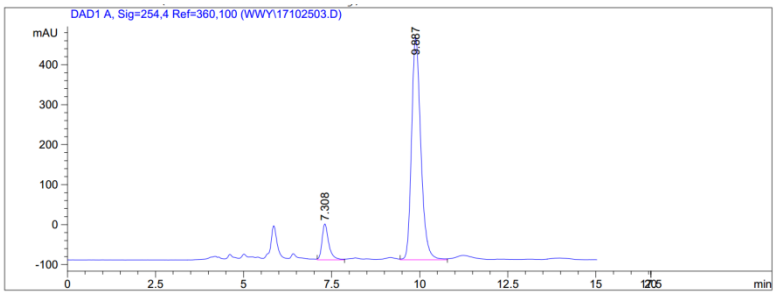
1	7.399	BV	0.1942	6206.65186	481.99774	49.9461
2	10.043	VB	0.2817	6220.06006	339.50171	50.0539



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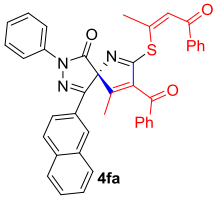
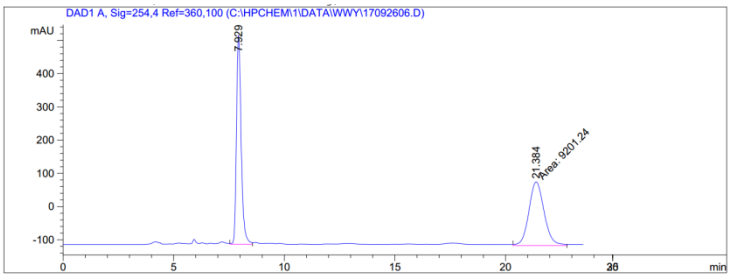
1	7.308	BB	0.1993	1195.61414	89.84445	10.5077
2	9.887	VB	0.2860	1.01829e4	555.11523	89.4923

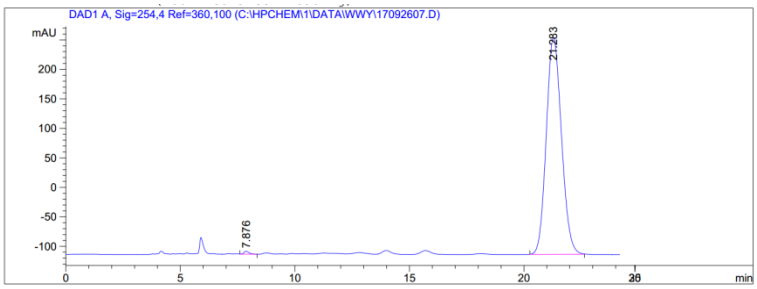
Compound 4fa



Prepared according to the procedure within 0.5 h as colorless oil (84.5 mg, 67% yield); $[\alpha]_D^{16}$ = -120.66 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.09-8.04 (m, 2H), 8.00 (t, *J* = 6.8 Hz, 3H), 7.89 (d, *J* = 8.7 Hz, 1H), 7.86-7.77 (m, 4H), 7.73 (d, *J* = 1.7 Hz, 1H), 7.69-7.60 (m, 2H), 7.56-7.47 (m, 6H), 7.41 (t, *J* = 7.4 Hz, 1H), 7.30 (t, *J* = 7.5 Hz, 1H), 7.25-7.21 (m, 2H), 2.54 (d, *J* = 1.2 Hz, 3H), 1.90 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.6, 189.3, 175.3, 165.2, 162.3, 153.7, 148.2, 140.5, 138.2, 137.7, 136.5, 134.7, 134.6, 132.9, 132.8, 129.8, 129.2, 129.1, 129.0, 128.5, 128.5, 128.2, 127.9, 127.9, 127.5, 127.1, 126.5, 126.2, 122.4, 119.3, 93.8, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{40}H_{30}N_3O_3S$ ([M+H]$^+$) 632.2002, Found 632.1994. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 21.2 min, tminor = 7.8 min).



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.929	VV	0.2266	9304.52637	629.06079	50.2791
2	21.384	MM	0.7996	9201.23633	191.78377	49.7209



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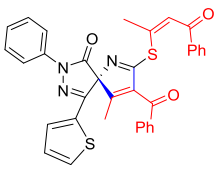
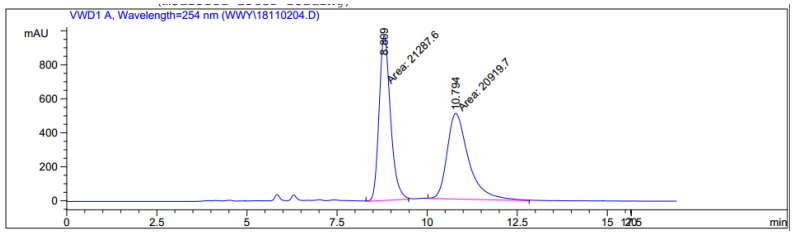
1	7.876	BB	0.2224	77.55614	5.01633	0.4563
2	21.283	BB	0.7050	1.69197e4	367.60971	99.5437

Compound 4ga

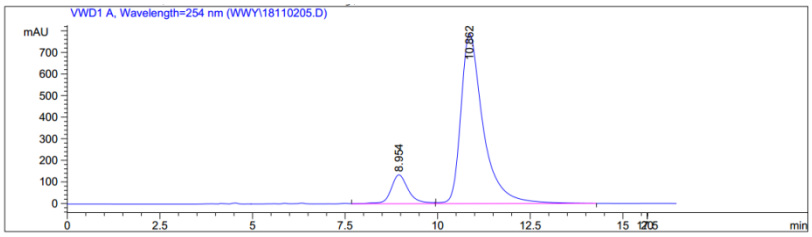


4ga

Prepared according to the procedure within 0.5 h as colorless oil (80.0 mg, 69% yield); $[\alpha]_D^{16}$ = -128.88 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.03-7.93 (m, 4H), 7.85 (d, *J* = 6.9 Hz, 2H), 7.70-7.61 (m, 2H), 7.52 (t, *J* = 7.7 Hz, 2H), 7.49-7.44 (m, 4H), 7.33 (t, *J* = 7.7 Hz, 2H), 7.30-7.23 (m, 1H), 7.13-7.07 (m, 1H), 7.09-7.02 (m, 1H), 2.53 (s, 3H), 1.88 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-d) δ 190.5, 189.3, 175.6, 164.9, 161.5, 149.9, 147.9, 140.2, 138.2, 137.5, 136.4, 134.6, 132.9, 132.5, 129.8, 129.8, 129.2, 129.1, 128.6, 128.5, 128.3, 128.3, 128.2, 126.1, 119.2, 93.6, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{34}H_{26}N_3O_3S_2$ ([M+H]$^+$) 588.1410, Found 588.1406. Enantiomeric excess was determined to be 77% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 16.9 min, tminor = 6.8 min).

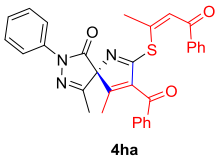


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.809	MM	0.3658	2.12876e4	969.81360	50.4359
2	10.794	MM	0.6914	2.09197e4	504.28552	49.5641



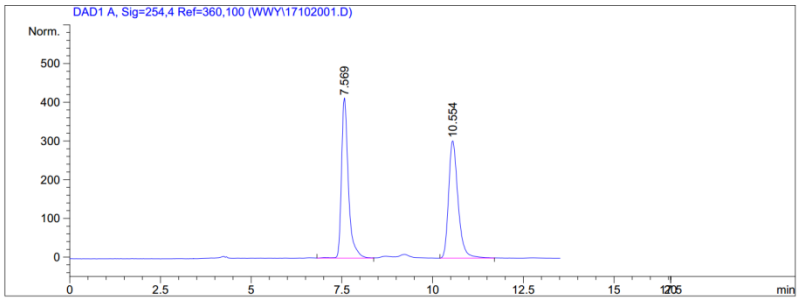
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.954	VB	0.4925	4403.88330	134.04524	11.7893
2	10.862	BB	0.6214	3.29512e4	786.29016	88.2107

Compound 4ha

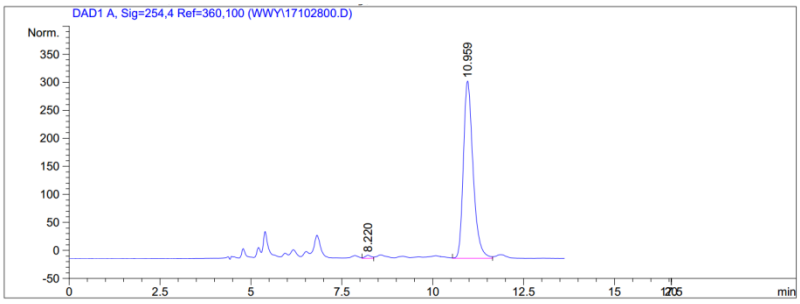


4ha

Prepared according to the procedure within 0.5 h as colorless oil (41.5 mg, 40% yield); $[\alpha]_D^{17}$ = -201.96 (*c* 0.21, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 7.96-7.87 (m, 6H), 7.70-7.61 (m, 2H), 7.52 (td, *J* = 7.7, 5.7 Hz, 3H), 7.42 (dt, *J* = 15.2, 7.3 Hz, 4H), 7.25 (s, *J* = 7.3 Hz 1H), 2.55 (d, *J* = 1.3 Hz, 3H), 1.99 (s, 3H), 1.87 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.5, 189.3, 175.3, 165.6, 159.4, 156.2, 148.1, 140.6, 138.2, 137.6, 136.4, 134.6, 132.9, 129.7, 129.1, 129.0, 128.6, 128.5, 128.3, 125.8, 118.9, 94.5, 21.8, 14.3, 12.6. HRMS (ESI) m/z Calcd. for $C_{31}H_{26}N_3O_3S$ ([M+H]$^+$) 520.1689, Found 520.1681. Enantiomeric excess was determined to be 97% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.9 min, tminor = 8.2 min).

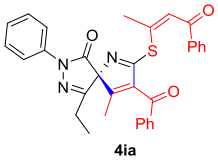


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.569	VB	0.2032	5490.86328	412.85352	50.0525
2	10.554	BB	0.2750	5479.33984	302.98309	49.9475



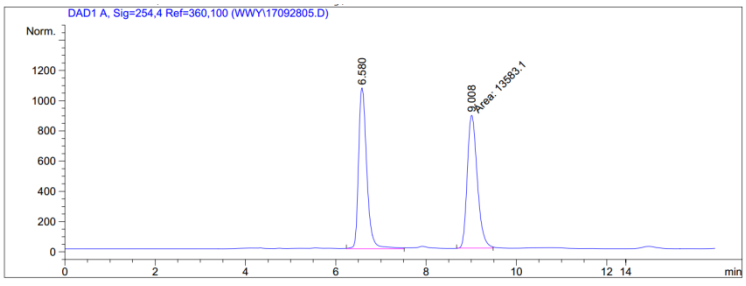
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.220	VV	0.1822	69.04163	5.66425	1.1647
2	10.959	VV	0.2841	5858.82324	316.29837	98.8353

Compound 4ia

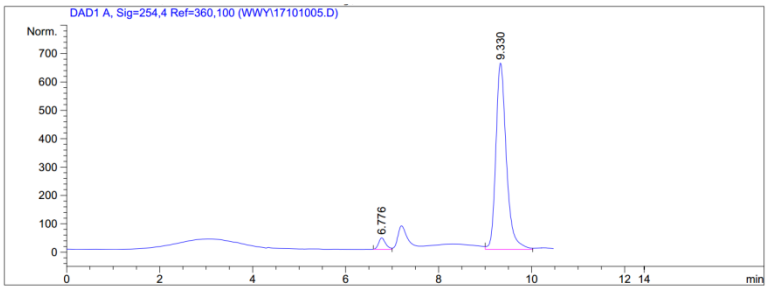


4ia

Prepared according to the procedure within 0.5 h as colorless oil (86.3 mg, 81% yield); $[\alpha]_D^{18}$ = -194.75 (*c* 0.46, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 7.97-7.88 (m, 6H), 7.70-7.61 (m, 2H), 7.56-7.48 (m, 3H), 7.48-7.37 (m, 4H), 7.12 (t, *J* = 10.9 Hz, 1H), 2.54 (s, 3H), 2.40-2.18 (m, 2H), 1.87 (s, 3H), 1.25 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.5, 189.3, 175.1, 165.7, 160.3, 159.8, 148.2, 140.5, 138.3, 137.7, 136.4, 134.5, 132.9, 129.7, 129.1, 129.0, 128.6, 128.5, 128.1, 125.7, 118.9, 94.6, 22.5, 21.8, 12.7, 9.7. HRMS (ESI) m/z Calcd. for $C_{25}H_{17}N_3O_2S$ ($[M+H]^+$) 534.1846, Found 534.1837. Enantiomeric excess was determined to be 92% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 9.3 min, tminor = 6.7 min).

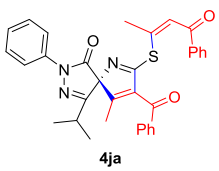


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.580	BB	0.1939	1.34967e4	1064.62646	49.8404
2	9.008	MM	0.2574	1.35831e4	879.51312	50.1596



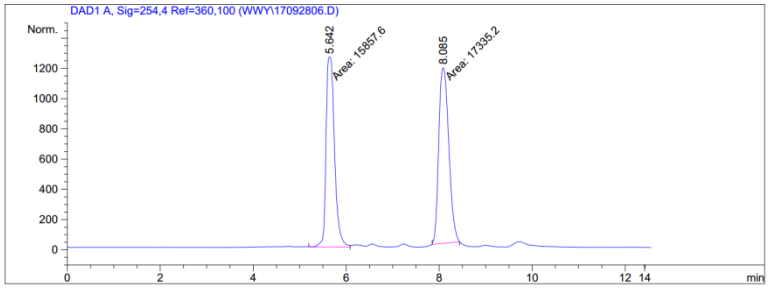
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.776	BV	0.1592	416.90558	40.13433	3.9015
2	9.330	VV	0.2365	1.02687e4	656.35687	96.0985

Compound 4ja

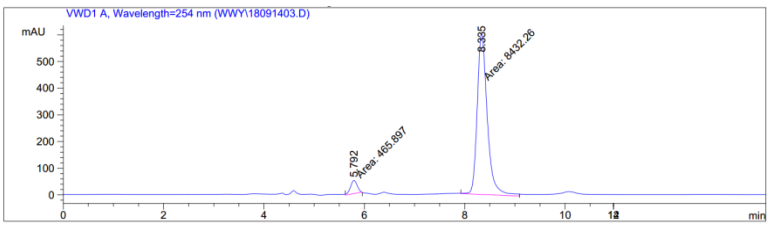


4ja

Prepared according to the procedure within 0.5 h as colorless oil (76.6 mg, 70% yield) ; $[\alpha]_D^{16}$ = -189.12 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 7.93 (m, 6H), 7.68-7.62 (m, 2H), 7.56-7.49 (m, 3H), 7.47-7.38 (m, 4H), 7.23 (t, *J* = 7.4 Hz, 1H), 2.54 (m, 1H), 2.53 (d, *J* = 1.3 Hz, 3H), 1.25 (d, *J* = 6.8 Hz, 3H), 1.22 (d, *J* = 7.0 Hz, 3H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.7, 189.4, 174.8, 165.7, 163.7, 160.3, 148.2, 140.3, 138.2, 137.8, 136.4, 134.5, 132.9, 129.7, 129.1, 129.0, 128.6, 128.5, 128.1, 118.9, 94.8, 30.2, 21.9, 20.2 (d, *J* = 11.2 Hz), 12.78. HRMS (ESI) m/z Calcd. for $C_{33}H_{30}N_3O_3S$ ($[M+H]^+$) 548.2002, Found 548.1994. Enantiomeric excess was determined to be 89% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 8.3 min, tminor = 5.7 min).

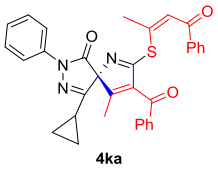


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	5.642	MM	0.2102	1.58576e4	1257.60742	47.7741
2	8.085	MM	0.2486	1.73352e4	1162.07275	52.2259



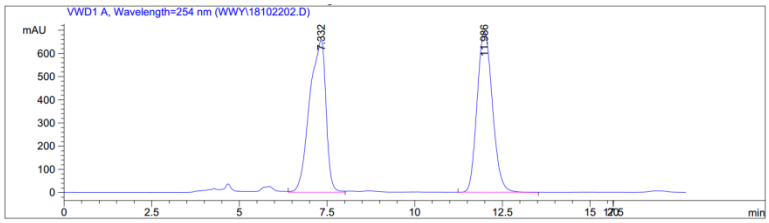
Peak #	RT [min]	Type	Width [min]	Area	Area %	Name
1	5.792	MM	0.160	483.710	5.431	
2	8.335	BB	0.211	8422.038	94.569	

Compound 4ka

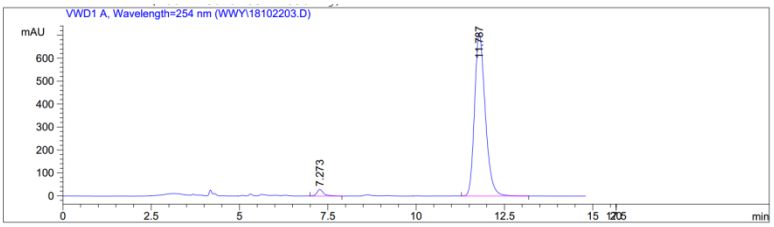


4ka

Prepared according to the procedure within 0.5 h as colorless oil (65.4 mg, 60% yield); $[\alpha]_D^{15}$ = -197.55 (*c* 0.32, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.98-7.85 (m, 6H), 7.70-7.60 (m, 2H), 7.56-7.46 (m, 3H), 7.42 (t, *J* = 8.0 Hz, 4H), 7.21 (d, *J* = 7.4 Hz, 1H), 2.55 (s, 3H), 1.90 (s, 3H), 1.38 (tt, *J* = 8.5, 5.0 Hz, 1H), 1.15-1.05 (m, 2H), 0.98 (dd, *J* = 8.2, 3.2 Hz, 2H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.6, 189.4, 175.1, 165.4, 161.1, 160.2, 148.4, 142.6, 140.4, 138.2, 137.7, 136.4, 134.6, 132.9, 129.7, 129.1, 129.0, 128.6, 128.6, 128.5, 128.1, 127.9, 125.8, 125.7, 118.9, 94.7, 80.8, 29.5, 21.9, 12.8, 9.8, 8.5. HRMS (ESI) m/z Calcd. for $C_{33}H_{28}N_3O_3S$ ($[M+H]^+$) 546.1846, Found 546.1842. Enantiomeric excess was determined to be 95% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 11.7 min, tminor = 7.2 min).

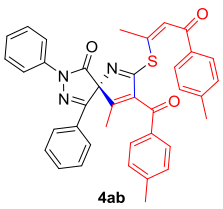


#	Time	Area	Height	Width	Area%	Symmetry
1	7.332	21270.5	658.8	0.4364	50.253	2.237
2	11.986	21056.2	691	0.4807	49.747	0.852



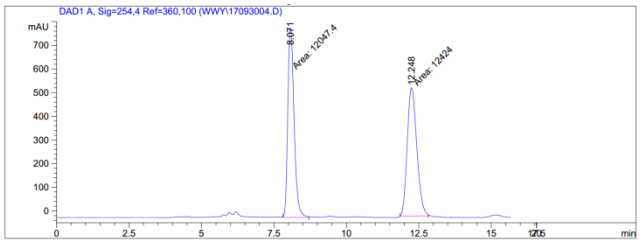
#	Time	Area	Height	Width	Area%	Symmetry
1	7.273	385	28.6	0.2009	2.522	0.725
2	11.787	14880.4	706.9	0.3228	97.478	0.733

Compound 4ab

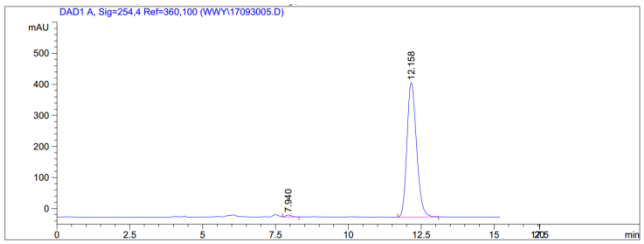


4ab

Prepared according to the procedure within 0.5 h as colorless oil (81.6 mg, 67% yield); $[\alpha]_D^{16}$ = -156.00 (*c* 0.41, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.02 (d, *J* = 8.5 Hz, 2H), 7.88 (d, *J* = 8.2 Hz, 2H), 7.74 (d, *J* = 8.2 Hz, 2H), 7.61 (d, *J* = 1.5 Hz, 1H), 7.60-7.55 (m, 2H), 7.48 (dd, *J* = 8.6, 7.3 Hz, 2H), 7.45-7.39 (m, 3H), 7.31 (d, *J* = 8.1 Hz, 3H), 7.10 (d, *J* = 8.0 Hz, 2H), 2.50 (d, *J* = 1.3 Hz, 3H), 2.44 (s, 3H), 2.33 (s, 3H), 1.86 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.2, 189.0, 175.4, 165.3, 161.4, 153.9, 147.5, 145.8, 143.6, 140.6, 137.7, 135.7, 134.0, 131.5, 129.9, 129.8, 129.2, 129.2, 129.1, 128.6, 128.4, 126.1, 125.9, 119.2, 93.7, 21.9, 21.8, 21.6, 12.8. HRMS (ESI) m/z Calcd. for $C_{38}H_{32}N_3O_3S$ ($[M+H]^+$) 610.2159, Found 610.2148. Enantiomeric excess was determined to be 98% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 12.1 min, tminor = 7.9 min).

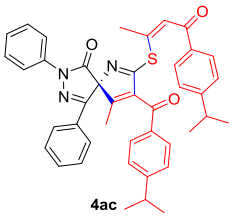


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.071	MM	0.2505	1.20474e4	801.59412	49.2305
2	12.248	MM	0.3812	1.24240e4	543.19574	50.7695

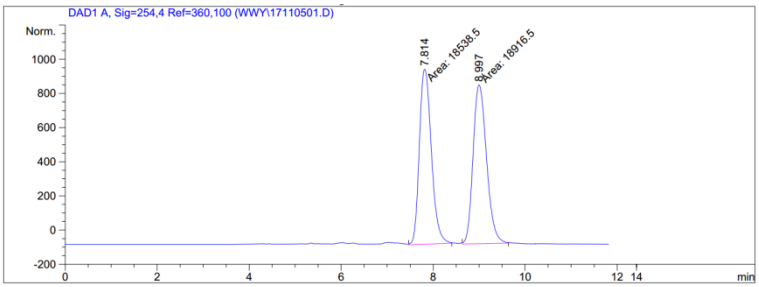


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.940	VB	0.2070	91.05917	6.59800	0.9126
2	12.158	BB	0.3564	9887.28809	432.93488	99.0874

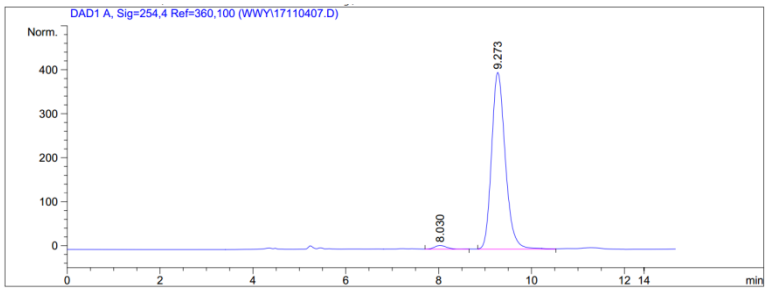
Compound 4ac



Prepared according to the procedure within 0.5 h as colorless oil (79.8 mg, 60% yield); $[\alpha]_D^{13}$ = -187.00 (*c* 0.41, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.04 (d, *J* = 7.5 Hz, 2H), 7.93 (d, *J* = 8.4 Hz, 2H), 7.78 (d, *J* = 8.4 Hz, 2H), 7.65 (d, *J* = 1.4 Hz, 1H), 7.59 (dd, *J* = 8.0, 1.7 Hz, 2H), 7.51-7.40 (m, 5H), 7.36 (d, *J* = 8.3 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 1H), 7.15 (d, *J* = 8.3 Hz, 2H), 2.98 (m, 1H), 2.87 (m, 1H), 2.50 (d, *J* = 1.2 Hz, 3H), 1.87 (s, 3H), 1.27 (d, *J* = 6.9 Hz, 6H), 1.21 (d, *J* = 0.9 Hz, 6H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 190.2, 189.0, 175.4, 165.3, 161.1, 156.4, 154.3, 153.9, 147.3, 140.7, 137.8, 136.1, 134.2, 131.5, 130.2, 130.0, 129.2, 129.1, 128.8, 128.3, 127.3, 126.6, 126.1, 125.9, 119.2, 93.7, 34.4, 34.2, 23.7, 23.6, 23.6, 21.8, 12.8. HRMS (ESI) m/z Calcd. for $C_{42}H_{40}N_3O_3S$ ($[M+H]^+$) 666.2785, Found 666.2774. Enantiomeric excess was determined to be 96% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 9.2 min, tminor = 8.0 min).

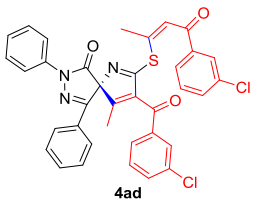


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.814	MM	0.3017	1.85385e4	1024.08740	49.4953
2	8.997	MM	0.3393	1.89165e4	929.23755	50.5047

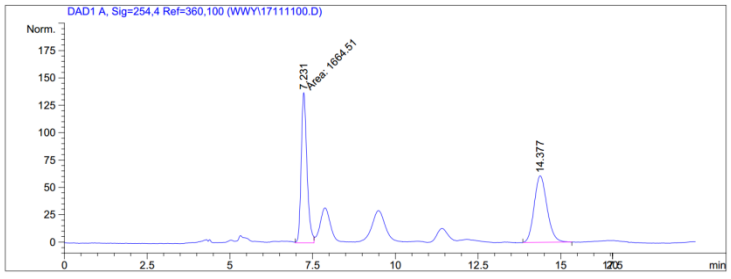


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.030	VB	0.3006	172.08455	8.78162	2.0413
2	9.273	BB	0.3156	8258.23047	402.08234	97.9587

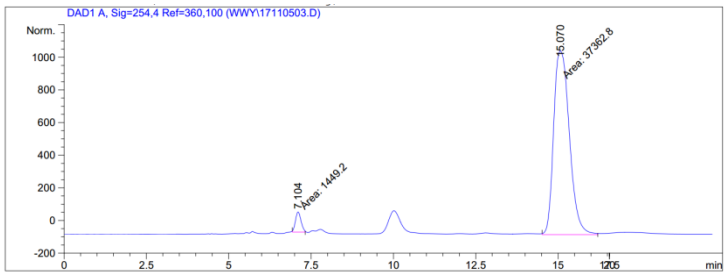
Compound 4ad



Prepared according to the procedure within 0.5 h as colorless oil (65.0 mg, 50% yield); $[\alpha]_D^{15}$ = -201.66 (*c* 0.34, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02 (d, *J* = 8.1 Hz, 2H), 7.95 (s, 1H), 7.86 (s, 1H), 7.83 (d, *J* = 7.8 Hz, 1H), 7.70 (d, *J* = 7.8 Hz, 1H), 7.65 (s, 1H), 7.62 (d, *J* = 8.0 Hz, 1H), 7.55 (d, *J* = 6.9 Hz, 2H), 7.53-7.39 (m, 7H), 7.29 (t, *J* = 7.5 Hz, 1H), 7.23 (d, *J* = 7.9 Hz, 1H), 2.50 (s, 3H), 1.88 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 189.2, 187.8, 174.5, 164.8, 163.0, 153.7, 149.4, 139.9, 139.8, 137.9, 137.6, 135.6, 134.9, 134.4, 132.7, 131.6, 130.5, 129.9, 129.8, 129.2, 129.1, 128.6, 128.2, 126.9, 126.5, 126.2, 125.9, 119.2, 93.9, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{25}H_{17}N_3O_2S$ ($[M+H]^+$) 650.1066, Found 650.1063. Enantiomeric excess was determined to be 92% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 15.0 min, tminor = 7.1 min).

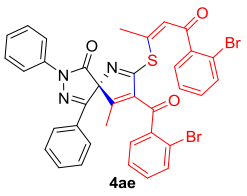


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.231	MM	0.2018	1664.51355	137.50322	50.4197
2	14.377	PP	0.4184	1636.80530	60.74264	49.5803

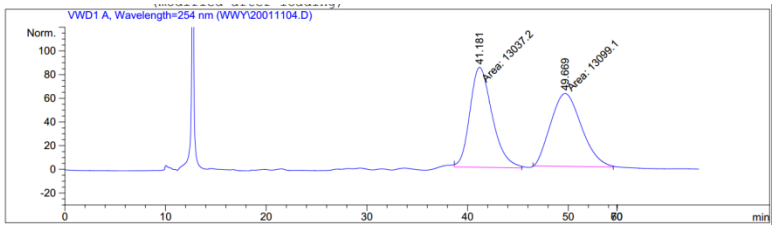


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.104	MM	0.1963	1449.19983	123.06200	3.7339
2	15.070	MM	0.5525	3.73628e4	1127.04346	96.2661

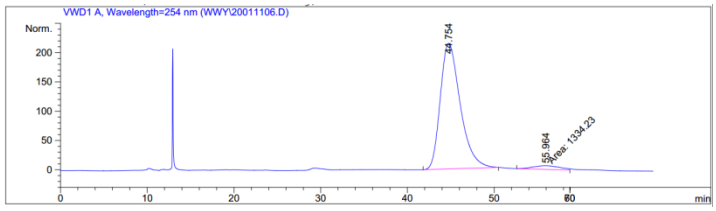
Compound 4ae



Prepared according to the procedure within 0.5 h as colorless oil (91.6 mg, 62% yield); $[\alpha]_D^{17}$ = -55.50 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 7.95 (d, *J* = 7.6 Hz, 2H), 7.62 (d, *J* = 1.1 Hz, 1H), 7.55-7.50 (m, 3H), 7.48-7.47 (m, 1H), 7.46-7.41 (m, 4H), 7.40-7.34 (m, 4H), 7.29-7.26 (m, 2H), 7.25-7.21 (m, 2H), 2.58 (d, *J* = 1.3 Hz, 3H), 1.72 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 191.1, 190.1, 175.3, 167.4, 164.7, 153.6, 150.5, 141.4, 139.8, 139.1, 137.6, 133.7, 132.8, 131.8, 131.5, 130.7, 129.8, 129.8, 129.8, 129.1, 129.0, 128.1, 127.4, 126.1, 126.1, 119.7, 119.7, 119.2, 94.1, 22.2, 12.7. HRMS (ESI) m/z Calcd. for $C_{36}H_{26}N_3O_3SBr_2$ ($[M+H]^+$) 740.0036, Found 740.0022. Enantiomeric excess was determined to be 92% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 44.7 min, tminor = 55.9 min).

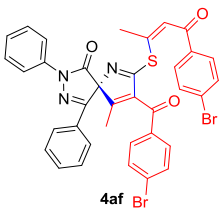


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	41.181	MM	2.5737	1.30372e4	84.42672	49.8815
2	49.669	MM	3.5515	1.30991e4	61.47183	50.1185

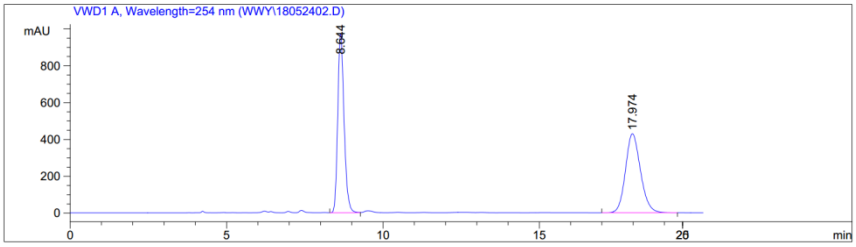


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	44.754	BB	2.3936	3.43049e4	214.59309	96.2563
2	55.964	MM	3.7402	1334.23132	5.94549	3.7437

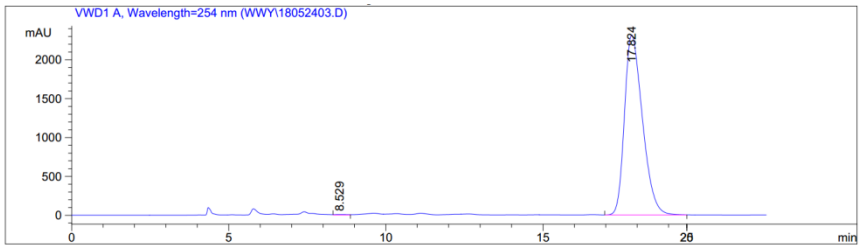
Compound 4af



Prepared according to the procedure within 0.5 h as colorless oil (104.5 mg, 71% yield); $[\alpha]_D^{17}$ = -95.75 (*c* 0.32, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.01 (dd, *J* = 8.7, 1.2 Hz, 2H), 7.83 (d, *J* = 8.6 Hz, 2H), 7.69-7.64 (m, 4H), 7.62 (d, *J* = 1.3 Hz, 1H), 7.57-7.53 (m, 2H), 7.53-7.47 (m, 3H), 7.46-7.39 (m, 4H), 7.34-7.29 (m, 1H), 2.49 (d, *J* = 1.3 Hz, 3H), 1.88 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 189.5, 188.0, 174.7, 164.9, 162.5, 153.8, 149.1, 140.0, 137.6, 137.0, 135.1, 132.5, 131.8, 131.6, 131.2, 130.2, 129.9, 129.8, 129.3, 129.2, 127.9, 126.8, 126.3, 125.9, 119.2, 93.9, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{36}H_{26}N_3O_3SBr_2$ ($[M+H]^+$) 740.0036, Found 740.0030. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 17.8 min, tminor = 8.5 min).

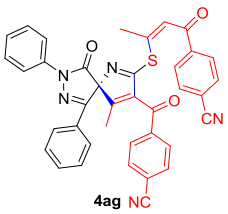


Peak #	RT [min]	Type	Width [min]	Area	Area %	Name
1	8.644	VV	0.214	13632.051	48.865	
2	17.974	BB	0.512	14265.233	51.135	

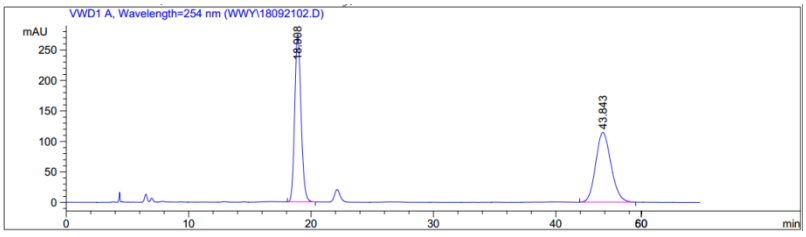


Peak #	RT [min]	Type	Width [min]	Area	Area %	Name
1	8.529	VV	0.391	191.482	0.208	
2	17.824	VB	0.612	91824.516	99.792	

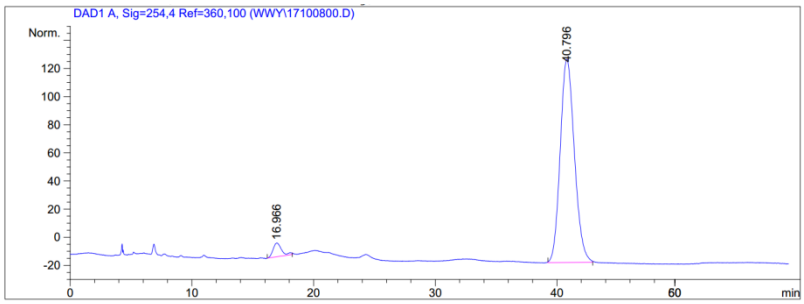
Compound 4ag



Prepared according to the procedure within 0.5 h as colorless oil (95.9 mg, 76% yield); $[\alpha]_D^{21}$ = -164.84 (*c* 0.36, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.09 (d, *J* = 8.4 Hz, 2H), 8.03 (d, *J* = 7.5 Hz, 2H), 7.87 (t, *J* = 8.8 Hz, 4H), 7.82-7.75 (m, 2H), 7.60-7.52 (m, 5H), 7.48-7.45 (m, 2H), 7.41-7.34 (m, 2H), 2.53 (d, *J* = 1.3 Hz, 3H), 1.92 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 189.2, 187.4, 174.0, 164.7, 164.1, 153.6, 150.8, 141.4, 139.5, 139.3, 137.4, 132.9, 132.4, 132.36, 131.8, 130.0, 129.7, 129.3, 129.3, 128.9, 128.7, 126.6, 125.8, 125.5, 119.2, 117.7, 115.9, 94.1, 22.1, 13.1. HRMS (ESI) m/z Calcd. for $C_{38}H_{26}N_5O_3S$ ($[M+H]^+$) 632.1751, Found 632.1753. Enantiomeric excess was determined to be 92% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 40.7 min, tminor = 16.9 min).

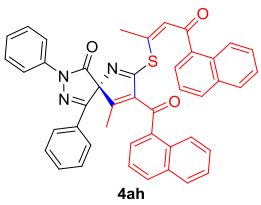


Peak #	RT [min]	Type	Width [min]	Area	Area %	Name
1	18.908	PB	0.562	9883.434	49.766	
2	43.843	BB	1.341	9976.386	50.234	

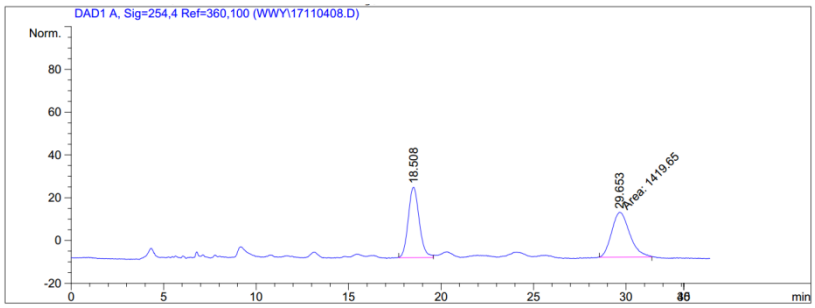


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.966	PB	0.5903	475.43219	9.76063	3.9087
2	40.796	BB	1.1801	1.16881e4	144.44043	96.0913

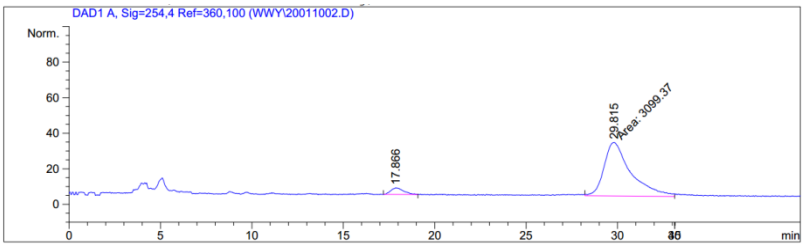
Compound 4ah



Prepared according to the procedure within 0.5 h as colorless oil (95.3 mg, 70% yield); $[\alpha]_D^{15}$ = -90.25 (*c* 0.32, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.71 (dd, *J* = 8.6, 1.1 Hz, 1H), 8.56-8.44 (m, 1H), 8.07 (d, *J* = 8.2 Hz, 1H), 7.99 (dd, *J* = 8.7, 1.2 Hz, 2H), 7.96 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.92-7.87 (m, 2H), 7.83-7.80 (m, 1H), 7.77 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.66 (ddd, *J* = 8.5, 6.9, 1.5 Hz, 1H), 7.57 (dd, *J* = 6.8, 1.6 Hz, 2H), 7.54-7.49 (m, 3H), 7.48-7.38 (m, 8H), 7.31-7.26 (m, 2H), 2.56 (d, *J* = 1.3 Hz, 3H), 1.75 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 192.7, 191.8, 175.8, 165.1, 164.3, 153.9, 148.3, 141.4, 137.7, 136.7, 134.4, 134.1, 133.9, 133.8, 132.5, 132.3, 131.5, 131.4, 130.3, 130.2, 130.0, 129.2, 129.1, 128.7, 128.7, 128.7, 128.4, 127.7, 127.0, 126.4, 126.1, 125.9, 125.7, 125.4, 112.8, 112.5, 119.2, 93.8, 21.9, 12.9. HRMS (ESI) m/z Calcd. for $C_{44}H_{32}N_3O_3S$ ($[M+H]^+$) 682.2159, Found 682.2137. Enantiomeric excess was determined to be 89% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 29.8 min, tminor = 17.8 min).

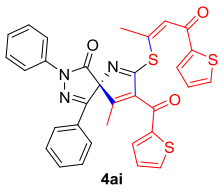


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.508	BB	0.6434	1364.95813	32.94386	49.0180
2	29.653	MM	1.1268	1419.64722	20.99841	50.9820

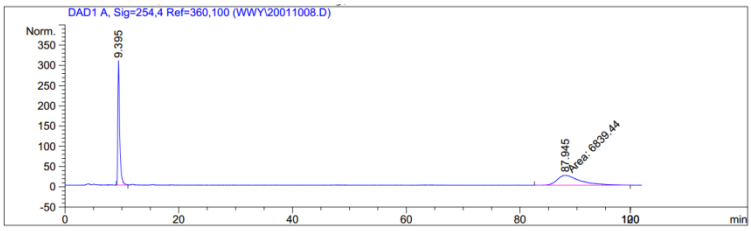


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.866	BB	0.5936	182.09482	3.70359	5.5492
2	29.815	MM	1.7151	3099.36670	30.11760	94.4508

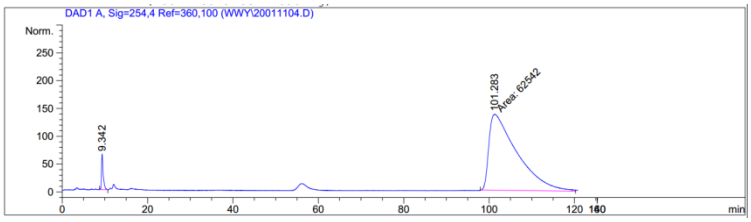
Compound 4ai



Prepared according to the procedure within 0.5 h as colorless oil (86.6 mg, 73% yield); $[\alpha]_D^{16}$ = -112.00 (*c* 0.44, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-d) δ 8.03 (d, *J* = 7.6 Hz, 2H), 7.82 (dd, *J* = 4.9, 1.2 Hz, 1H), 7.78 (dd, *J* = 3.8, 1.2 Hz, 1H), 7.62 (d, *J* = 1.3 Hz, 1H), 7.58 (dd, *J* = 8.1, 1.7 Hz, 2H), 7.55-7.47 (m, 4H), 7.47-7.41 (m, 3H), 7.29 (t, *J* = 7.5 Hz, 1H), 7.16 (dd, *J* = 4.9, 3.9 Hz, 1H), 6.96 (dd, *J* = 4.9, 3.8 Hz, 1H), 2.57 (d, *J* = 1.3 Hz, 3H), 1.98 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 182.0, 181.2, 174.4, 165.1, 161.0, 153.9, 149.0, 146.2, 143.2, 140.5, 137.6, 137.0, 136.7, 133.9, 131.9, 131.6, 129.9, 129.3, 129.1, 128.9, 128.2, 126.3, 126.2, 125.9, 119.2, 93.7, 21.8, 12.9. HRMS (ESI) m/z Calcd. for $C_{32}H_{24}N_3O_3S_3$ ($[M+H]^+$) 594.0974, Found 594.0964. Enantiomeric excess was determined to be 95% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 101.3 min, tminor = 9.3 min).

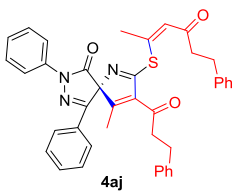


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.395	BB	0.3237	6828.97852	306.79050	49.9617
2	87.945	MM	4.6935	6839.44043	24.28675	50.0383



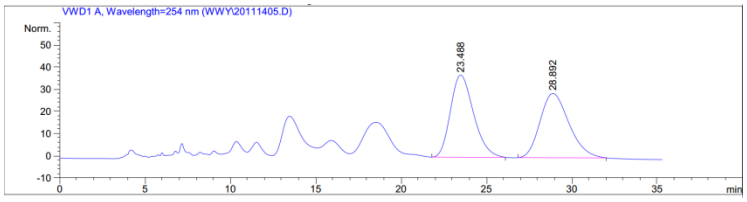
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.342	BB	0.4029	1772.26367	64.02471	2.7556
2	101.283	MM	7.6301	6.25420e4	136.61172	97.2444

Compound 4aj

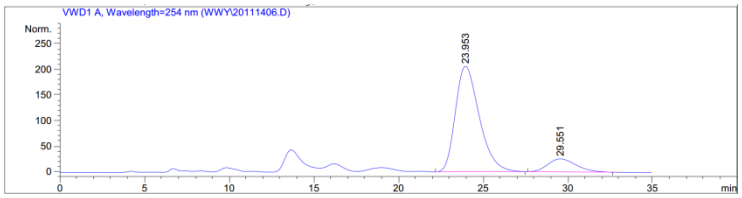


Prepared according to the procedure within 0.5 h as colorless oil (72.6 mg, 57% yield); $[\alpha]_D^{15}$ = -32.00 (*c* 0.14, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.00 (d, *J* = 8.5 Hz, 2H), 7.54 - 7.44 (m, 5H), 7.44 - 7.35 (m, 2H), 7.38 - 7.29 (m, 3H), 7.30 - 7.22 (m, 5H), 7.21 - 7.15 (m 3H), 6.85 (s, 1H), 3.28 - 3.13 (m, 2H), 3.13 - 3.05 (m, 2H), 2.96 - 2.84 (m, 2H), 2.82 - 2.71 (m, 2H), 2.52 (d, *J* = 1.3 Hz, 3H), 2.17 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 198.1, 195.9, 175.8, 165.2, 164.9, 153.5, 148.5, 141.0, 140.3, 139.8, 137.6, 131.5, 131.1, 130.0, 129.1, 128.7, 128.5, 128.4, 126.5, 126.1, 126.1, 125.8, 119.2, 94.1, 46.1, 45.0, 29.8, 29.6, 21.8, 13.6. HRMS (ESI) m/z Calcd. for $C_{40}H_{36}N_3O_3S$ ($[M+H]^+$) 638.2472, Found 638.2471. Enantiomeric excess was determined to be 75% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C,

0.8 mL/min, tmajor = 23.9 min, tminor = 29.5 min).

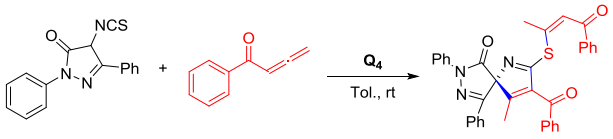


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	23.488	PB	1.4143	3494.99854	37.02643	50.4487
2	28.892	BB	1.6187	3432.82422	29.05483	49.5513



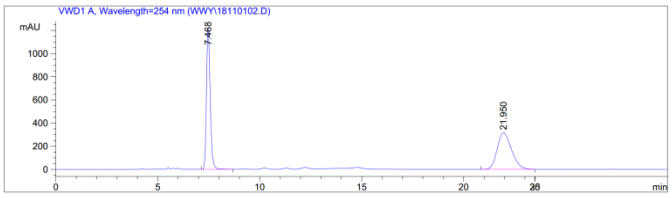
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	23.953	PB	1.4959	2.02675e4	206.24312	87.2671
2	29.551	BB	1.5968	2957.16650	25.45897	12.7329

Gram scale synthesis of the product 3aa

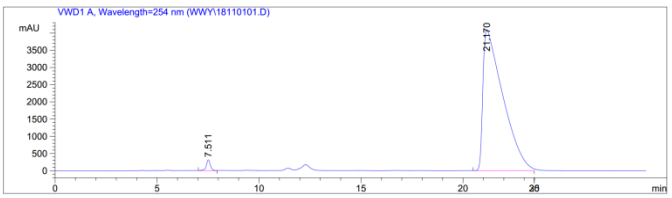


1a, 2.5 mmol **2a**, 6.3 mmol **4aa**, 0.97 g
66% yield, 97% ee

To a tube equipped with a magnetic stir bar was charged with 4-isothiocyanato pyrazolone **1a** (732 mg, 2.5 mmol, 1.0 eq.) and **Q4** (157 mg, 0.25 mmol, 0.1 eq.), followed with toluene (25 mL). After stirred for 5 min, allenyl ketone **2a** (900 mg, 6.3 mmol, 2.5 eq.) was added in one portion. After 0.5 h, the solvent was removed under vacuum, the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 was used as the eluent) to give the product **4aa** 0.97 g as light-yellow oil (yield 66%, ee 97%).

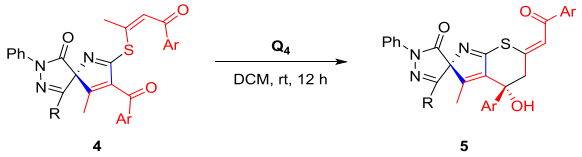


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.468	VB	0.1953	1.54970e4	1215.72229	50.0684
2	21.950	BB	0.7533	1.54547e4	317.21164	49.9316



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.511	VV	0.2155	4600.68115	317.86209	1.6217
2	21.170	VB	0.8705	2.79100e5	4096.65820	98.3783

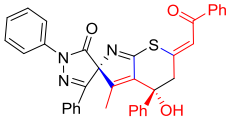
The procedure for the synthesis of compounds 5.



4 5

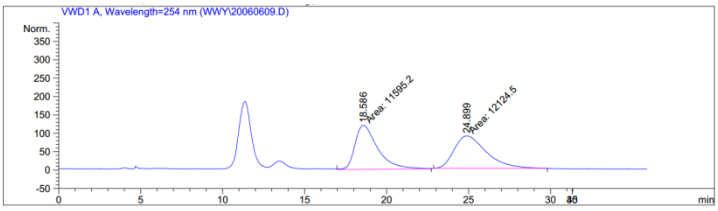
A reaction tube was charged with **4** (0.1 mmol) and DCM (1 mL), then **Q4** (6.3mg, 0.01 mmol, 0.1 eq.) was added at room temperature. After the reaction was stirred for 12 h, the crude product was purified by column chromatography on silica gel to give the product **5**.

Compound 5aa

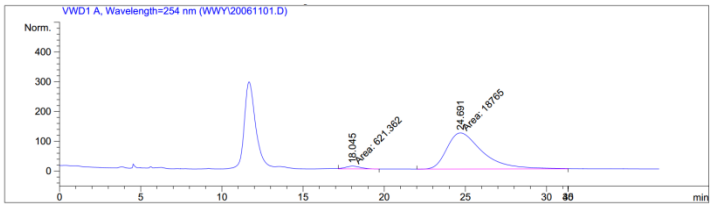


5aa

Prepared according to the procedure within 12 h as white solid (51.7 mg, 89% yield, dr > 20:1). mp 155-157 °C; $[\alpha]_D^{18}$ = 122.00 (*c* 0.32, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 8.1 Hz, 2H), 7.90 (d, *J* = 7.6 Hz, 2H), 7.58 (d, *J* = 7.7 Hz, 2H), 7.48 (d, *J* = 7.6 Hz, 3H), 7.45-7.36 (m, 7H), 7.35-7.27 (m, 4H), 7.13 (s, 1H), 3.55 (d, *J* = 14.5 Hz, 1H), 3.19 (d, *J* = 14.6 Hz, 1H), 2.99 (bs, 1H), 1.38 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.6, 178.7, 165.8, 156.5, 154.5, 150.5, 142.3, 140.2, 137.7, 137.5, 132.9, 131.2, 130.1, 129.0, 128.7, 128.3, 128.2, 125.9, 125.2, 120.6, 119.3, 93.4, 72.4, 51.5, 12.1. HRMS (ESI) m/z Calcd. for $C_{36}H_{28}N_3O_3S$ ($[M+H]^+$) 582.1846, Found 582.1841. Enantiomeric excess was determined to be 93% (determined by HPLC using chiral OD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 12.6 min, tminor = 18.0 min).

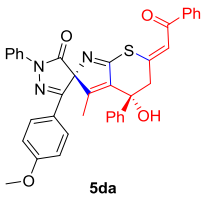


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.586	MM	1.6090	1.15952e4	120.10866	48.8842
2	24.899	MM	2.2865	1.21245e4	88.37763	51.1158



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.045	MM	1.0848	621.36206	9.54624	3.2051
2	24.691	MM	2.5718	1.87650e4	121.60748	96.7949

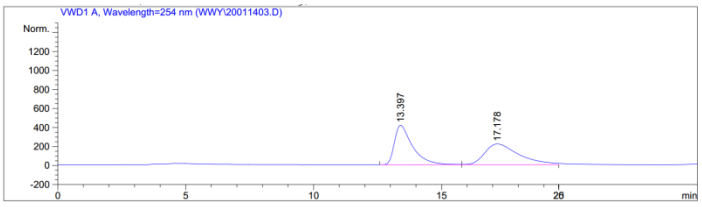
Compound 5da



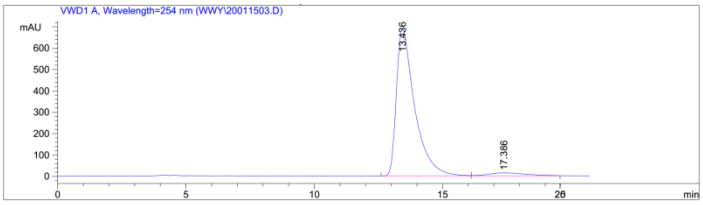
5da

Prepared according to the procedure within 12 h as white solid (55.0 mg, 90% yield, dr = 7.3:1). mp 122.5-125.0 °C; $[\alpha]_D^{17}$ = 71.25 (*c* 0.45, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d:* methanol-*d* = 10:1) δ 7.87 (dt, *J* = 25.0, 7.9 Hz, 4H), 7.55 (q, *J* = 7.8, 6.6 Hz, 3H), 7.46 (q, *J* = 7.5 Hz, 2H), 7.40 (p, *J* = 7.5 Hz, 4H). 7.36-7.27 (m, 4H), 7.23 (t, *J* = 7.8 Hz, 1H), 7.14 (d, *J* = 7.2 Hz, 1H), 3.52 (dd, *J* = 14.7, 7.2 Hz, 1H), 3.38 (s, 1H), 3.33 (s, 3H), 3.22 (dd, *J* = 14.9, 7.3 Hz, 1H), 2.44 (h, *J* = 7.3 Hz, 1H), 1.49 (s, 3H); ^{13}C NMR (151 MHz, Chloroform-*d:* methanol-*d* = 10:1) δ 189.1, 179.2, 166.3, 164.4, 154.5, 151.1, 142.4, 140.4, 137.6, 137.4, 132.9, 128.9, 128.8, 128.7, 128.1, 128.0,

125.6, 125.4, 120.4, 119.1, 94.1, 71.9, 51.3, 29.7, 20.1, 19.9, 11.9. HRMS (ESI) m/z Calcd. for $C_{37}H_{30}N_3O_4S$ ($[M+H]^+$) 612.1952, Found 612.1949. Enantiomeric excess was determined to be 91% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 13.4 min, tminor = 17.3 min).

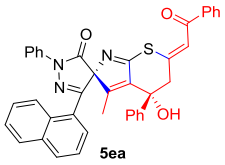


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.397	BB	0.7205	2.03498e4	415.08429	49.4167
2	17.178	BB	1.4082	2.08302e4	217.85573	50.5833



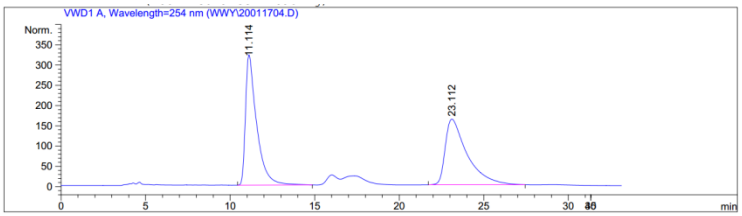
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.436	BB	0.7261	3.40209e4	687.16327	95.5481
2	17.386	BB	1.4628	1585.15601	14.63865	4.4519

Compound 5ea

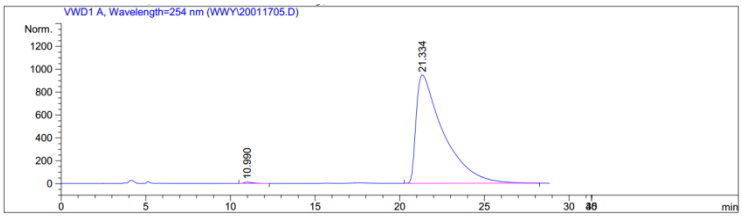


5ea

Prepared according to the procedure within 12 h as white solid (52.4 mg, 83% yield, dr = 4:1). mp 160-162 °C; $[\alpha]_D^{16}$ = 102.73 (*c* 0.28, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform:Methol = 10:1-*d*) δ 9.08 (d, *J* = 8.6 Hz, 1H), 8.00 (d, *J* = 8.0 Hz, 2H), 7.86 (d, *J* = 8.2 Hz, 1H), 7.81 (d, *J* = 8.3 Hz, 3H), 7.59 (t, *J* = 7.8 Hz, 1H), 7.58-7.48 (m, 4H), 7.47 (t, *J* = 7.8 Hz, 2H), 7.38 (q, *J* = 7.6 Hz, 4H), 7.29 (dd, *J* = 14.9, 7.6 Hz, 2H), 7.17 (d, *J* = 7.3 Hz, 3H), 6.93 (s, 1H), 3.47 (d, *J* = 14.4 Hz, 1H), 3.00 (dd, *J* = 14.5, 4.0 Hz, 1H), 2.84 (s, 1H), 1.37 (s, 3H); ^{13}C NMR (151 MHz, Chloroform-*d*) δ 188.6, 178.7, 165.5, 156.5, 154.9, 150.4, 142.2, 140.3, 137.9, 137.7, 137.4, 134.1, 132.9, 131.7, 130.4, 129.1, 129.0, 129.0, 128.8, 128.6, 128.3, 128.2, 128.2, 127.9, 126.9, 126.4, 126.3, 126.0, 125.8, 125.3, 125.3, 125.2, 120.6, 119.2, 94.6, 72.3, 51.3, 21.5, 12.2. HRMS (ESI) m/z Calcd. for $C_{40}H_{30}N_3O_3S$ ($[M+H]^+$) 632.2002, Found 632.2005. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 21.3 min, tminor = 10.9 min).

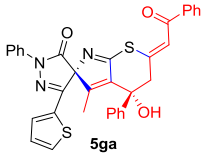


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.114	BB	0.6554	1.47698e4	321.47485	50.2616
2	23.112	BB	1.3033	1.46161e4	162.17950	49.7384



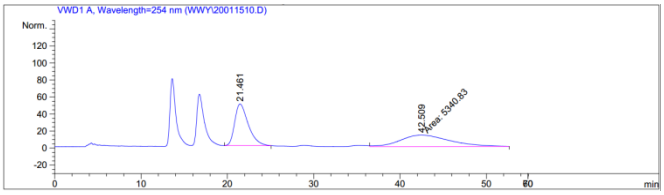
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.990	BB	0.4880	378.81726	11.19394	0.3568
2	21.334	BB	1.5565	1.05781e5	947.00714	99.6432

Compound 5ga

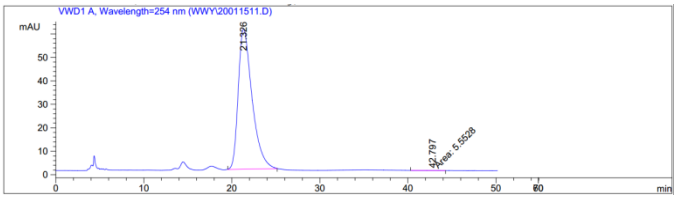


5ga

Prepared according to the procedure within 12 h as yellow solid (47.5 mg, 81% yield, dr = 6:1). mp 225-226 °C; $[\alpha]_D^{17}$ = 30.91 (*c* 0.22, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d:* methanol-*d* = 10:1) δ 7.92 (q, *J* = 6.3 Hz, 4H), 7.58 (q, *J* = 6.8 Hz, 3H), 7.46 (q, *J* = 8.1 Hz, 6H), 7.41 (t, *J* = 7.3 Hz, 1H), 7.32 (d, *J* = 6.9 Hz, 1H), 7.27 (q, *J* = 7.0 Hz, 1H), 7.18 (s, 1H), 7.02 (dd, *J* = 23.1, 4.0 Hz, 2H), 3.55 (d, *J* = 14.6 Hz, 1H), 3.37 (s, 1H), 3.26 (d, *J* = 14.7 Hz, 1H), 1.50 (s, 3H); ^{13}C NMR (151 MHz, Chloroform-*d:* methanol-*d* = 10:1) δ 189.1, 180.2, 165.6, 155.7, 150.9, 150.4, 142.5, 140.5, 137.4, 137.3, 133.0, 132.2, 129.4, 128.9, 128.7, 128.6, 128.4, 128.1, 128.0, 126.0, 125.3, 120.5, 119.3, 92.8, 71.8, 51.2, 11.8. HRMS (ESI) m/z Calcd. for $C_{34}H_{26}N_3O_3S_2$ ([M+H]$^+$) 588.1410, Found 588.1402. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 21.3 min, tminor = 42.7 min).

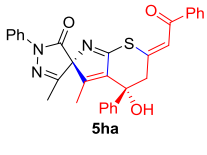


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	21.461	BB	1.6309	5352.28467	48.95086	50.0536
2	42.509	MM	6.5990	5340.83105	13.48909	49.9464



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	21.326	BB	1.5791	6545.97754	59.84095	99.9152
2	42.797	MM	2.0956	5.55280	4.41626e-2	0.0848

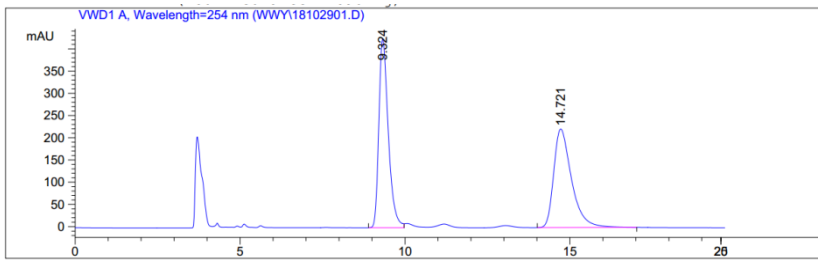
Compound 5ha



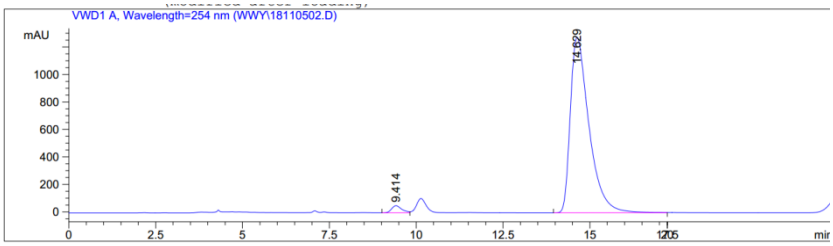
5ha

Prepared according to the procedure within 12 h as white solid (45.6 mg, 88% yield, dr > 20:1). mp 110.2-112.5 °C; $[\alpha]_D^{17}$ = 21.00 (*c* 0.22, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.94-7.76 (m, 2H), 7.58-7.49 (m, 3H), 7.47-7.34 (m, 5H), 7.31 (t, *J* = 7.3 Hz, 1H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.09 (s, 1H), 3.51 (d, *J* = 14.4 Hz, 1H), 3.21 (d, *J* = 14.4 Hz, 1H), 3.10 (s, 1H), 1.87 (s, 3H), 1.49 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.7, 178.9, 166.2, 157.0, 153.9, 150.3, 141.9, 140.7, 137.6, 137.5, 132.9, 129.0,

128.9, 128.7, 128.3, 128.2, 125.6, 125.3, 120.7, 119.0, 94.0, 72.5, 51.4, 13.9, 11.8. HRMS (ESI) m/z Calcd. for $C_{31}H_{26}N_3O_3S$ ([M+H]$^+$) 520.1689, Found 520.1689. Enantiomeric excess was determined to be 95% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 14.6 min, tminor = 9.4 min).

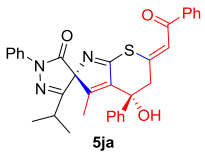


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.324	BV	0.3011	8435.51270	425.59113	50.3756
2	14.721	BB	0.5654	8309.73828	221.72362	49.6244



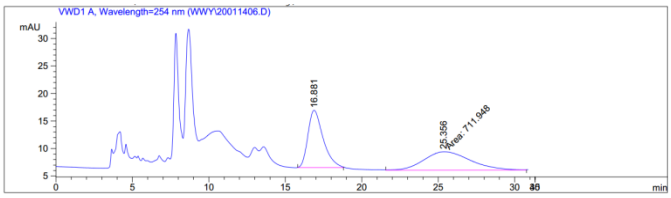
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.414	BV	0.3099	1068.23193	51.93084	2.1772
2	14.629	PB	0.5664	4.79954e4	1277.57483	97.8228

Compound 5ja

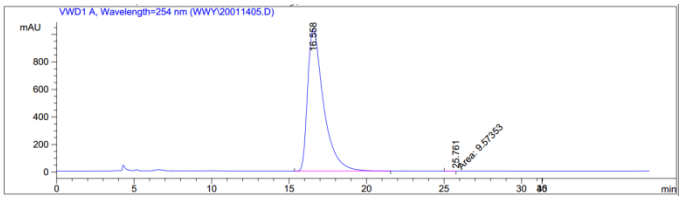


5ja

Prepared according to the procedure within 12 h as white solid (44.3 mg, 81% yield, dr = 3.4:1). mp 172.0-174.1 °C; $[\alpha]_D^{17}$ = 29.37 (*c* 0.12, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.90 (d, *J* = 7.7 Hz, 2H), 7.86 (d, *J* = 8.1 Hz, 2H), 7.55 (d, *J* = 8.0 Hz, 3H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.41 (q, *J* = 8.3 Hz, 4H), 7.33 (t, *J* = 7.4 Hz, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 7.14 (s, 1H), 3.52 (d, *J* = 14.4 Hz, 1H), 3.23 (d, *J* = 14.5 Hz, 1H), 2.47 (s, 1H), 2.46-2.41 (m, 1H), 1.50 (s, 3H), 1.19 (d, *J* = 6.9 Hz, 3H), 1.14 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d:* methanol-*d* = 10:1) δ 188.9, 178.9, 166.3, 164.4, 154.5, 151.0, 142.4, 140.2, 137.6, 137.5, 132.9, 128.9, 128.8, 128.7, 128.1, 128.1, 125.6, 125.4, 120.4, 119.1, 94.1, 71.9, 51.4, 29.8, 20.1, 20.0, 12.0. HRMS (ESI) m/z Calcd. for $C_{33}H_{30}N_3O_3S$ ([M+H]$^+$) 548.2002, Found 548.2000. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 16.5 min, tminor = 25.7 min).

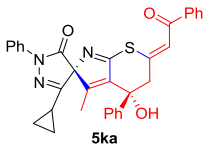


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.881	BB	0.9755	720.17621	10.41609	50.2873
2	25.356	MM	3.5387	711.94775	3.35318	49.7127



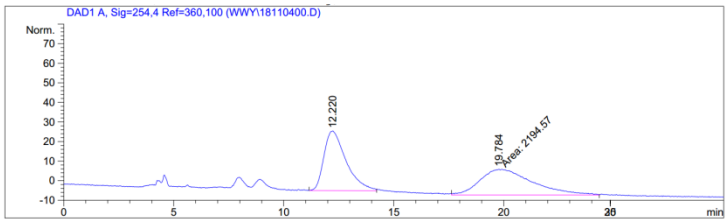
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.558	BB	1.0678	7.37224e4	1030.22559	99.9870
2	25.761	MM	0.7289	9.57353	2.18908e-1	0.0130

Compound 5ka

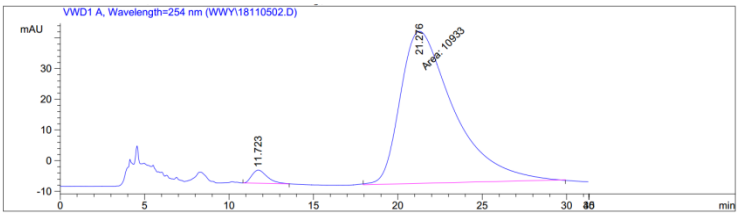


5ka

Prepared according to the procedure within 12 h as white solid (49.1 mg, 90% yield, dr > 20:1). mp 150.5-152.1 °C $[\alpha]_D^{16}$ = 66.36 (*c* 0.21, CH_2Cl_2); ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.96 (d, *J* = 7.7 Hz, 2H), 7.78 (d, *J* = 8.1 Hz, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.53 (dd, *J* = 12.5, 6.0 Hz, 5H), 7.45 (t, *J* = 7.9 Hz, 2H), 7.37 (t, *J* = 7.5 Hz, 2H), 7.26 (dt, *J* = 14.7, 7.4 Hz, 2H), 6.59 (s, 1H), 3.65 (d, *J* = 14.4 Hz, 1H), 3.37 (d, *J* = 14.5 Hz, 1H), 1.50 (p, *J* = 7.0, 6.6 Hz, 1H), 1.07-0.81 (m, 4H); ^{13}C NMR (101 MHz, DMSO-d_6) δ 188.7, 179.0, 166.3, 162.8, 153.1, 152.0, 143.3, 141.8, 137.7, 137.4, 133.7, 129.6, 129.3, 128.7, 128.5, 128.2, 126.3, 126.0, 120.7, 119.1, 93.7, 79.8, 72.3, 50.0, 12.1, 9.9, 9.3, 9.1. HRMS (ESI) m/z Calcd. for $C_{33}H_{28}N_3O_3S$ ($[M+H]^+$) 546.1846, Found 546.1846. Enantiomeric excess was determined to be 95% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 21.3 min, tminor = 11.7 min).

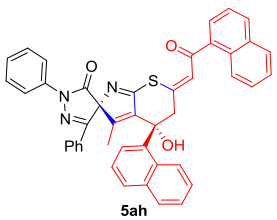


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.220	PB	1.0412	2139.50122	30.54407	49.3647
2	19.784	MM	2.7804	2194.56909	13.15488	50.6353



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.723	PB	0.8059	271.52014	4.28724	2.4233
2	21.276	MM	3.6739	1.09330e4	49.59721	97.5767

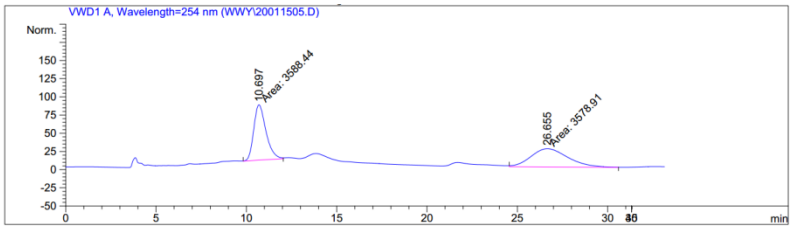
Compound 5ah



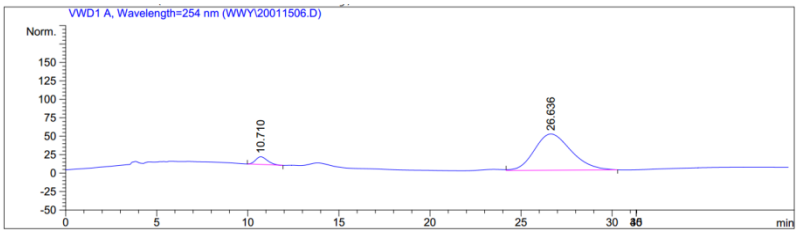
5ah

Prepared according to the procedure within 12 h as yellow solid (63.3 mg, 93% yield, dr = 4.5:1). mp 206.5-209.0 °C; $[\alpha]_D^{16}$ = -33.44 (*c* 0.34, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.54-8.29 (m, 2H), 8.08-7.81 (m, 7H), 7.61 (t, *J* = 8.2 Hz, 2H), 7.59-7.48 (m, 7H), 7.41 (dt, *J* = 16.4, 7.5 Hz, 6H), 7.23 (t, *J* = 7.5 Hz, 1H), 6.85 (s, 1H), 4.17 (d, *J* = 15.0 Hz, 1H), 3.19 (d, *J*

= 14.9 Hz, 1H), 2.81 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 192.2, 178.2, 165.5, 155.8, 154.0, 150.0, 137.8, 136.4, 134.5, 133.8, 132.6, 131.1, 130.3, 130.3, 130.0, 129.4, 129.3, 129.1, 128.9, 128.4, 127.8, 127.1, 126.5, 126.0, 125.9, 125.8, 125.7, 125.4, 125.3, 112.6, 112.3, 119.2, 93.4, 48.8, 11.6. HRMS (ESI) m/z Calcd. for $C_{44}H_{32}N_3O_3S$ ([M+H]$^+$) 682.2159, Found 682.2159. Enantiomeric excess was determined to be 87% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 26.6 min, tminor = 10.7 min).

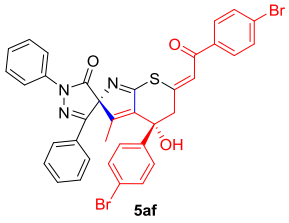


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.697	MM	0.7857	3588.44458	76.11823	50.0665
2	26.655	MM	2.3822	3578.90771	25.03889	49.9335

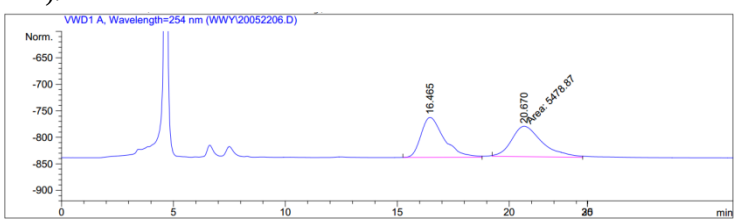


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.710	BP	0.6950	470.93600	10.41508	6.4037
2	26.636	VB	2.0235	6883.16016	49.07932	93.5963

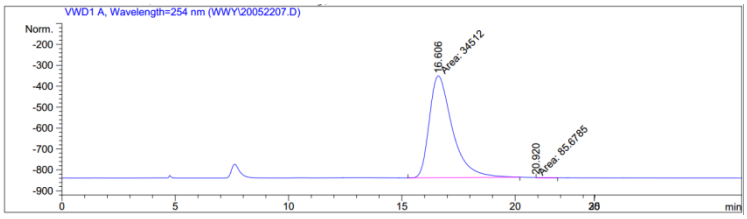
Compound 5af



Prepared according to the procedure within 12 h as light-yellow solid (62.6 mg, 85% yield, dr > 20:1). mp 170.0-173.0 °C; $[\alpha]_D^{16}$ = 112.44 (*c* 0.32, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.89 (d, *J* = 5.7 Hz, 2H), 7.77-7.68 (m, 2H), 7.57-7.48 (m, 2H), 7.50-7.38 (m, 8H), 7.39-7.33 (m, 1H), 7.30 (d, *J* = 7.7 Hz, 2H), 7.23 (s, 1H), 7.03 (s, 1H), 3.43 (d, *J* = 14.4 Hz, 1H), 3.33 (s, 1H), 3.12 (d, *J* = 14.4 Hz, 1H), 1.41-1.36 (m, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 187.4, 178.4, 165.7, 156.9, 154.4, 150.8, 141.5, 139.7, 137.5, 136.0, 132.1, 132.0, 131.3, 130.0, 129.7, 129.1, 129.0, 128.3, 127.1, 126.1, 125.9, 122.4, 120.3, 119.3, 93.4, 72.0, 51.4, 12.3. HRMS (ESI) m/z Calcd. for $C_{36}H_{25}Br_2N_3O_3S$ ([M+H]$^+$) 738.0056, Found 738.0063. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 16.6 min, tminor = 20.9 min).

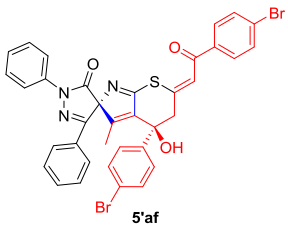


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.465	BB	1.0650	5387.66064	75.28382	49.5803
2	20.670	MM	1.5910	5478.86670	57.39261	50.4197



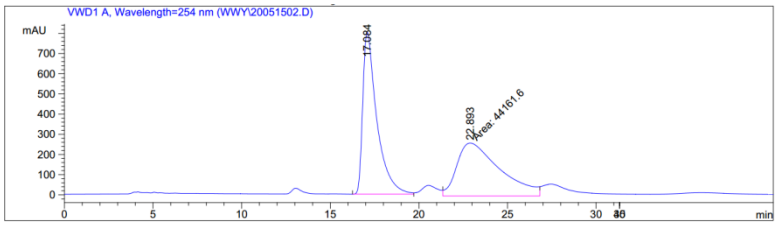
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.606	MM	1.1809	3.45120e4	487.08191	99.7524
2	20.920	MM	0.7228	85.67849	1.97552	0.2476

Compound 5'af

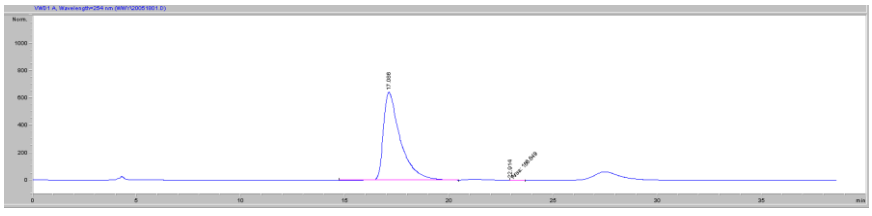


5'af

This diastereoisomer was prepared according to the procedure using DABCO as catalyst within 24 h as yellow solid (62.6 mg, 85% yield, dr = 3:1). mp 215.0-217.5 °C; $[\alpha]_D^{17}$ = -144.40 (*c* 0.23, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.85 (d, *J* = 8.0 Hz, 2H), 7.59 (d, *J* = 7.9 Hz, 2H), 7.55-7.42 (m, 5H), 7.42-7.32 (m, 6H), 7.23 (d, *J* = 9.0 Hz, 3H), 6.92 (s, 1H), 4.69 (s, 1H), 3.44 (d, *J* = 14.1 Hz, 1H), 3.29 (d, *J* = 14.2 Hz, 1H), 1.70 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 187.4, 178.6, 165.8, 156.9, 154.4, 150.9, 141.6, 139.7, 137.4, 135.9, 132.1, 132.0, 131.3, 129.9, 129.7, 129.1, 129.1, 128.3, 127.1, 126.2, 125.9, 122.4, 120.3, 119.3, 93.4, 71.9, 51.3, 12.2. HRMS (ESI) m/z Calcd. for $C_{36}H_{25}Br_2N_3O_3S$ ([M+H]$^+$) 738.0056, Found 738.0063. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 12.5 min, tminor = 17.9 min).

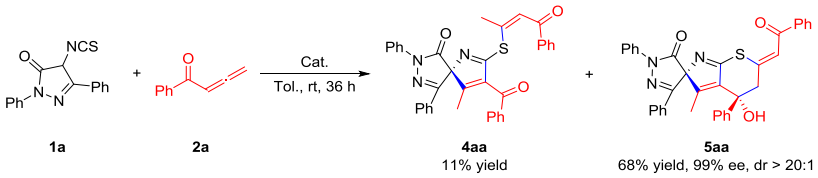


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	17.084	PV	0.8026	4.42749e4	802.20886	50.0641
2	22.893	MM	2.8074	4.41616e4	262.17572	49.9359



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	17.086	BB	0.8304	3.67616e4	644.10669	99.5487
2	22.914	MM	0.5041	166.64861	3.86023	0.4513

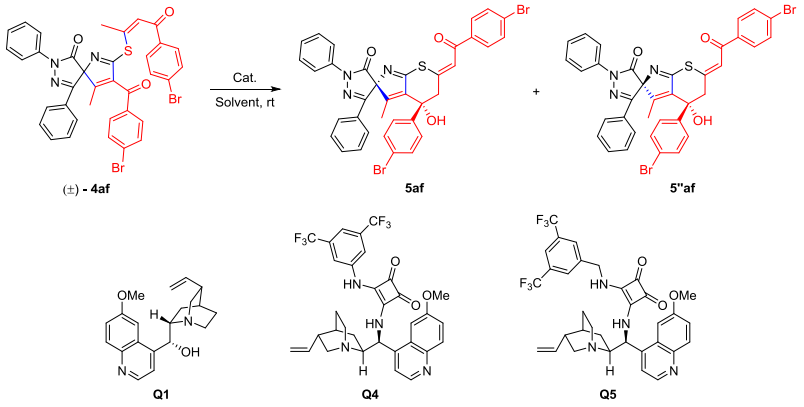
One-pot procedure for the synthesis of compound 5aa from 1a and 2a.



A tube equipped with a magnetic stir bar was charged with 4-isothiocyanato pyrazolone **1a** (0.2 mmol), **Q4** (0.02 mmol), and toluene (2 mL). After stirring for 5 min, alkynyl ketone **2a** (0.5 mmol) was added in one portion. The reaction was detected by TLC. After 36 h, the mixture was purified by column chromatography on silica gel (unless otherwise noticed, petroleum ether/EtOAc = 5:1 was used as the eluent) directly to give the product **5aa**.

Asymmetric aldol reaction of racemic 4 to compound 5.

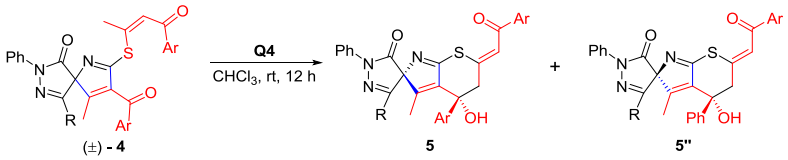
Table S1 Optimization of Reaction Conditions



Entry	Catalyst	Amount of Cat. (X equiv)	Solvent	*t* [h]	Yield[a] [%]		Ee[b] [%]	
					5af	**5"af**	**5af**	**5"af**
1	**Q1**	1	DCM	24	49	45	77	49
2	**Q4**	1	DCM	2	47	50	99	85
3	**Q5**	1	DCM	12	41	42	97	73
4	**Q4**	1	$CHCl_3$	12	41	40	99	87
5	**Q4**	1	THF	12	40	40	95	89
6	**Q4**	1	CH_3CN	12	41	43	97	87
7	**Q4**	1	toluene	12	46	48	93	85
8	**Q4**	0.1	$CHCl_3$	12	45	43	99	91
9	**Q4**	0.05	$CHCl_3$	14	41	40	99	88

The reaction was carried out on a 0.1 mmol scale in 1 mL solvent with catalyst. [a]Isolated yield was given. [b]The ee was determined by chiral HPLC.

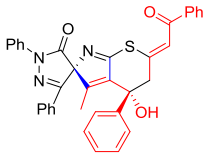
Asymmetric aldol reactions of racemic 4 to compound 5



To a solution of racemic **4** (0.1 mmol, 1.0 eq.) in $CHCl_3$ (1.0 mL) was added **Q4** (6.3 mg, 0.01 mmol, 0.1 eq.). The reaction mixture was stirred at rt for 12 h. The reaction was detected by TLC.

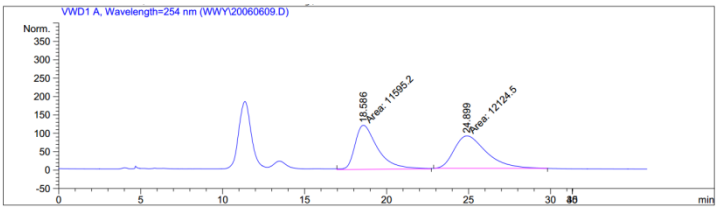
When the reaction finished, the crude mixture was purified by column chromatography on silica gel to give **5**.

Compound 5aa

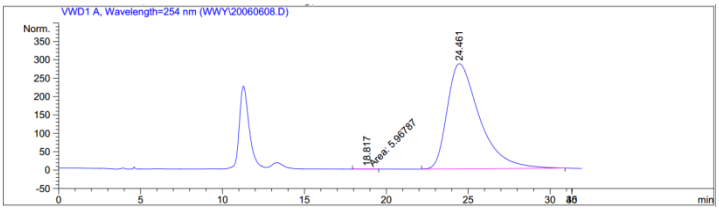


5aa

Prepared according to the procedure within 12 h as white solid (25.0 mg, 43% yield). Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 12.4 min, tminor = 18.8 min).

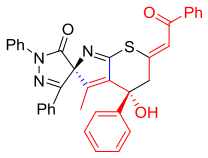


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.586	MM	1.6090	1.15952e4	120.10866	48.8842
2	24.899	MM	2.2865	1.21245e4	88.37763	51.1158



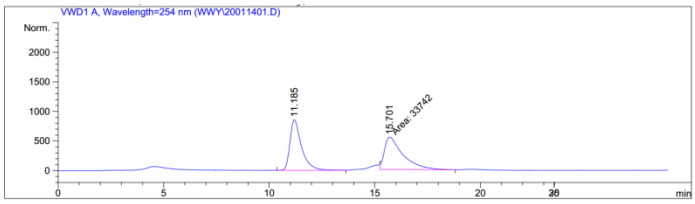
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.817	MM	0.9314	5.96787	1.06793e-1	0.0152
2	24.461	BB	2.0148	3.93021e4	286.08875	99.9848

Compound 5"aa

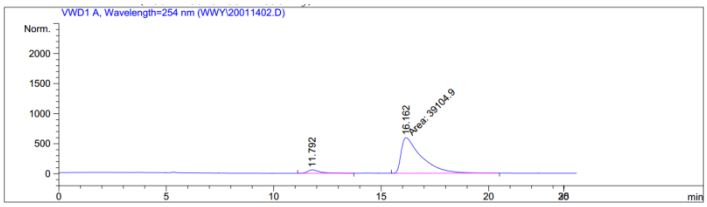


5"aa

Prepared according to the procedure within 12 h as white solid (25.6 mg, 44% yield). mp 190.0-192.0 °C; $[\alpha]_D^{17}$ = -144.40 (*c* 0.31, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 7.5 Hz, 2H), 7.83 (d, *J* = 7.0 Hz, 2H), 7.52 (d, *J* = 8.4 Hz, 3H), 7.47-7.32 (m, 9H), 7.30 (t, *J* = 6.9 Hz, 3H), 7.23 (d, *J* = 7.6 Hz, 1H), 7.03 (s, 1H), 4.39 (s, 1H), 3.47 (d, *J* = 12.8 Hz, 1H), 3.37 (d, *J* = 14.1 Hz, 1H), 1.87 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.8, 179.3, 166.6, 156.3, 154.8, 150.5, 142.2, 142.1, 137.5, 137.5, 132.9, 131.3, 130.0, 129.0, 128.9, 128.6, 128.6, 128.2, 128.1, 126.1, 125.2, 120.7, 119.4, 93.4, 72.4, 51.9, 12.1. HRMS (ESI) m/z Calcd. for $C_{36}H_{28}N_3O_3S$ ($[M+H]^+$) 582.1846, Found 582.1846. Enantiomeric excess was determined to be 89% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 16.1 min, tminor = 11.8 min)

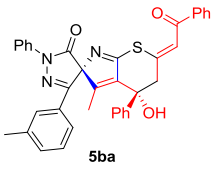


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.185	BB	0.5622	3.25348e4	854.43909	49.0893
2	15.701	MM	1.0236	3.37420e4	549.40326	50.9107



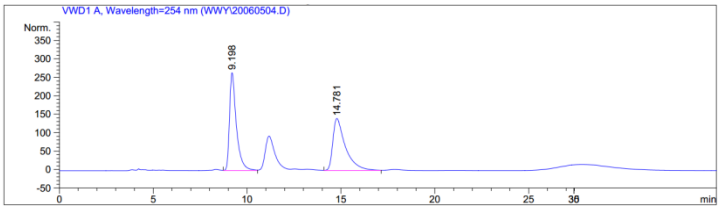
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.792	BB	0.5847	2276.18921	57.07076	5.5005
2	16.162	MM	1.0980	3.91049e4	593.55243	94.4995

Compound 5ba

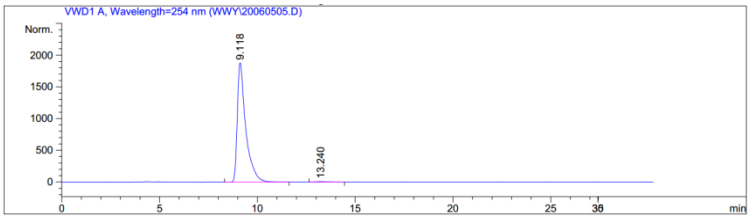


5ba

Prepared according to the procedure within 12 h as white solid (12.4 mg, 41% yield). mp 215.5-217.1 °C; $[\alpha]_D^{15}$ = -77.81 (*c* 0.21, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.91 (d, *J* = 8.1 Hz, 2H), 7.82 (d, *J* = 7.7 Hz, 2H), 7.52 (t, *J* = 7.4 Hz, 1H), 7.41 (q, *J* = 7.5 Hz, 6H), 7.36 (s, 1H), 7.33-7.27 (m, 4H), 7.25-7.20 (m, 3H), 7.02 (s, 1H), 4.21 (s, 1H), 3.46 (d, *J* = 14.1 Hz, 1H), 3.37 (d, *J* = 14.1 Hz, 1H), 2.36 (s, 3H), 1.68 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.7, 179.1, 166.4, 156.5, 154.9, 150.6, 142.2, 141.8, 138.6, 137.6, 137.5, 132.9, 132.2, 130.0, 129.0, 128.8, 128.6, 128.6, 128.2, 128.1, 126.5, 126.0, 125.2, 123.3, 120.6, 119.4, 93.4, 72.6, 51.9, 21.5, 12.2. HRMS (ESI) m/z Calcd. for $C_{37}H_{30}N_3O_3S$ ($[M+H]^+$) 596.2002, Found 596.2001. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 9.1 min, tminor = 13.2 min)

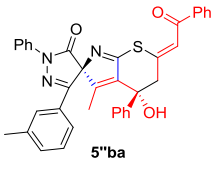


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.198	VV	0.3695	6709.02832	265.12314	50.6082
2	14.781	VB	0.6719	6547.76807	140.86249	49.3918



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.118	BB	0.4354	5.66046e4	1881.55078	99.4529
2	13.240	BB	0.5595	311.37698	8.09267	0.5471

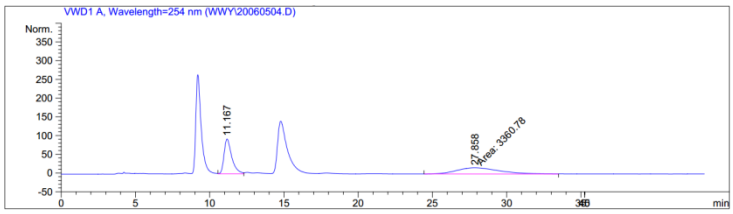
Compound 5"ba



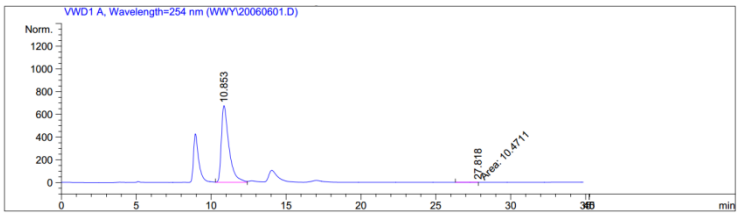
5"ba

Prepared according to the procedure within 12 h as white solid (22.0 mg, 37% yield). mp 140.5-142.8 °C; $[\alpha]_D^{16}$ = 10.00 (*c* 0.11, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 8.1 Hz, 2H), 7.88 (d, *J* = 7.7 Hz, 2H), 7.57 (d, *J* = 7.8 Hz, 2H), 7.50 (t, *J* = 3.4 Hz, 2H), 7.40 (dq, *J* = 15.4, 7.7 Hz, 9H), 7.11 (s, 1H), 3.78 (s, 1H), 3.55 (d, *J* = 14.6 Hz, 1H), 3.21 (d, *J* = 14.6 Hz, 1H), 2.30 (s, 3H), 1.40 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.6, 178.8, 165.9, 156.6, 154.7, 150.7,

142.2, 140.0, 138.6, 137.7, 137.5, 132.9, 132.1, 130.0, 129.0, 128.9, 128.7, 128.6, 128.2, 126.4, 125.9, 125.4, 125.2, 123.2, 120.4, 119.3, 93.4, 72.7, 51.3, 21.5, 12.1. HRMS (ESI) m/z Calcd. for $C_{37}H_{30}N_3O_3S$ ($[M+H]^+$) 596.2002, Found 596.2002. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.8 min, tminor = 27.8 min).

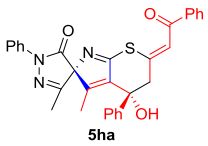


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.167	VV	0.5411	3395.02466	93.28299	50.2535
2	27.858	MM	3.3586	3360.77710	16.67727	49.7465



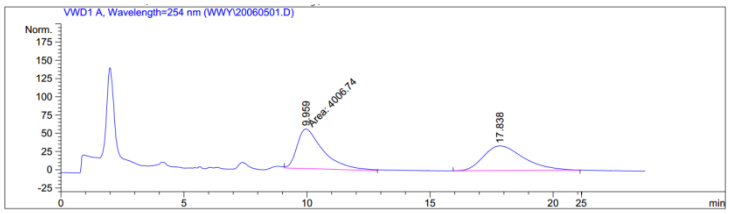
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.853	VV	0.5160	2.38182e4	675.80597	99.9561
2	27.818	MM	1.4117	10.47107	1.23623e-1	0.0439

Compound 5ha

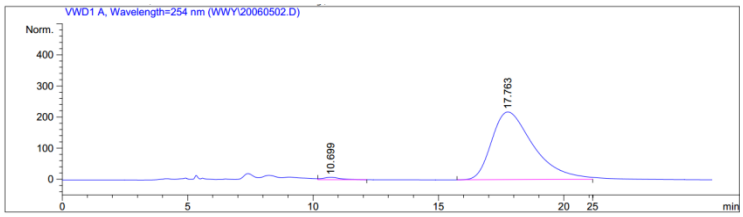


5ha

Prepared according to the procedure within 12 h as white solid (12.4 mg, 47% yield). Enantiomeric excess was determined to be 97% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 17.7 min, tminor = 10.7 min).

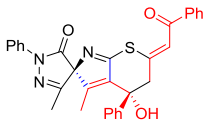


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.959	MM	1.2332	4006.74048	54.14888	50.9973
2	17.838	BB	1.6911	3850.02393	33.77238	49.0027



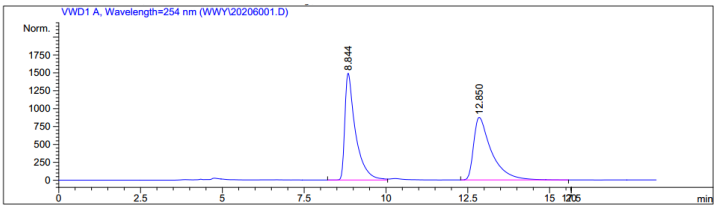
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.699	VB	0.7277	397.22000	7.80447	1.5297
2	17.763	BB	1.7692	2.55696e4	217.71043	98.4703

Compound 5”ha

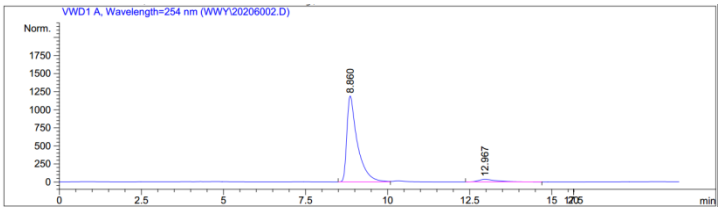


5"ha

Prepared according to the procedure within 12 h as white solid (12.4 mg, 47% yield). mp 117.0-120.0 °C; $[\alpha]_D^{17}$ = -50.63 (*c* 0.21, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.79 (dd, *J* = 6.9, 1.5 Hz, 4H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.45-7.37 (m, 4H), 7.40-7.25 (m, 6H), 7.18 (t, *J* = 7.4 Hz, 1H), 6.98 (s, 1H), 4.50 (s, 1H), 3.43-3.27 (m, 2H), 1.91 (s, 3H), 1.63 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.7, 179.7, 167.0, 157.1, 153.8, 150.3, 142.5, 142.1, 137.5, 137.4, 132.9, 128.9, 128.7, 128.6, 128.2, 128.1, 125.8, 125.2, 120.7, 119.2, 72.5, 51.8, 13.8, 11.8. HRMS (ESI) m/z Calcd. for $C_{31}H_{26}N_3O_3S$ ($[M+H]^+$) 520.1689, Found 520.1688. Enantiomeric excess was determined to be 91% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 8.8 min, tminor = 12.9 min).

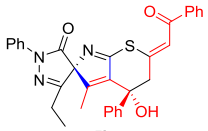


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.844	VV	0.3223	3.37590e4	1491.49707	50.5889
2	12.850	VB	0.5461	3.29731e4	874.75891	49.4111



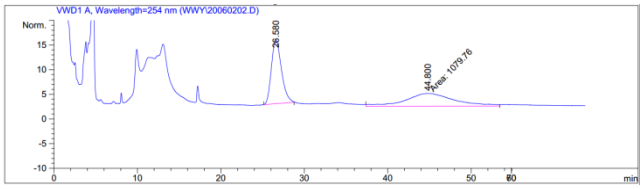
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.860	PV	0.3181	2.64283e4	1186.54785	95.4335
2	12.967	BB	0.5522	1264.58777	33.30036	4.5665

Compound 5ia

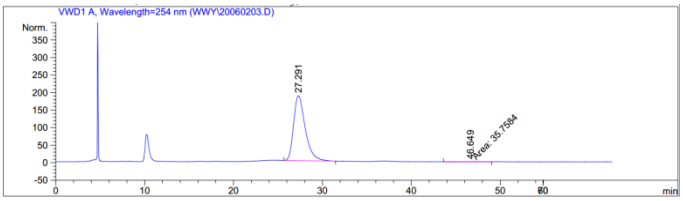


5ia

Prepared according to the procedure within 12 h as white solid (22.9 mg, 43% yield). mp 210.1-212.5 °C; $[\alpha]_D^{15}$ = 30.00 (*c* 0.20, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.88 (t, *J* = 8.3 Hz, 4H), 7.54 (d, *J* = 7.7 Hz, 3H), 7.49-7.36 (m, 6H), 7.33 (d, *J* = 7.3 Hz, 1H), 7.21 (t, *J* = 7.4 Hz, 1H), 7.12 (s, 1H), 3.52 (d, *J* = 14.4 Hz, 1H), 3.23 (d, *J* = 14.5 Hz, 1H), 2.69 (s, 1H), 2.32-2.05 (m, 2H), 1.50 (s, 3H), 1.17 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.6, 178.3, 166.2, 160.9, 154.4, 150.2, 141.8, 140.3, 137.8, 137.5, 133.0, 129.1, 128.9, 128.7, 128.4, 128.2, 125.6, 125.3, 120.7, 119.1, 94.2, 72.6, 51.5, 22.1, 12.0, 9.7. HRMS (ESI) m/z Calcd. for $C_{32}H_{28}N_3O_3S$ ($[M+H]^+$) 534.1846, Found 534.1840. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 27.2 min, tminor = 46.6 min)

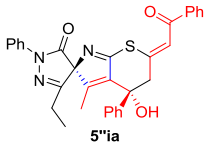


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	26.580	BB	1.1742	1089.03564	12.97706	50.2139
2	44.800	MM	6.9614	1079.75720	2.58510	49.7861



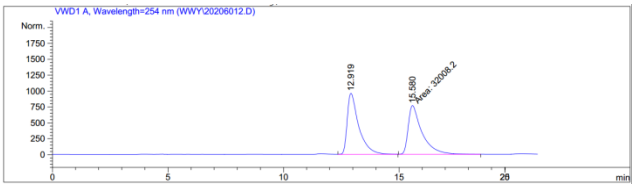
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	27.291	BB	1.3702	1.68408e4	185.08058	99.7881
2	46.649	MM	2.6589	35.75836	2.24145e-1	0.2119

Compound 5”ia

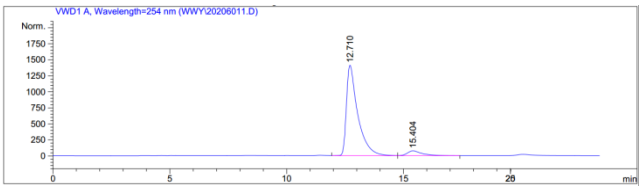


5"ia

Prepared according to the procedure within 12 h as white solid (25.6 mg, 48% yield); $[\alpha]_D^{17}$ = -95.45 (*c* 0.21, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.84-7.74 (m, 4H), 7.50 (t, *J* = 7.9 Hz, 1H), 7.43-7.26 (m, 10H), 7.17 (t, *J* = 7.5 Hz, 1H), 6.98 (s, 1H), 4.48 (s, 1H), 3.50-3.14 (m, 2H), 2.34-2.06 (m, 2H), 1.62 (s, 3H), 1.20 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.7, 179.4, 167.1, 161.2, 154.2, 150.4, 142.5, 141.8, 137.6, 137.5, 132.8, 128.9, 128.7, 128.6, 128.2, 128.0, 125.7, 125.2, 120.7, 119.3, 94.1, 72.5, 51.8, 22.1, 11.9, 9.7. HRMS (ESI) m/z Calcd. for $C_{32}H_{28}N_3O_3S$ ($[M+H]^+$) 534.1846, Found 534.1841. Enantiomeric excess was determined to be 87% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 12.7 min, tminor = 15.4 min)

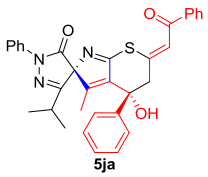


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.919	BV	0.5059	3.33652e4	960.15509	51.0379
2	15.580	MM	0.6951	3.20082e4	767.47906	48.9621



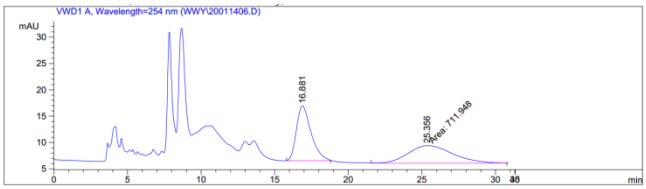
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.710	VV	0.4817	4.75162e4	1410.82031	93.4251
2	15.404	VB	0.6425	3344.02271	75.85223	6.5749

Compound 5ja

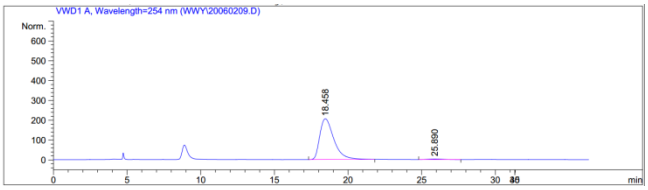


5ja

Prepared according to the procedure within 12 h as white solid (22.4 mg, 41% yield). Enantiomeric excess was determined to be 97% (determined by HPLC using chiral AD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 18.4 min, tminor = 25.8 min).

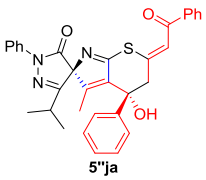


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.881	BB	0.9755	720.17621	10.41609	50.2873
2	25.356	MM	3.5387	711.94775	3.35318	49.7127



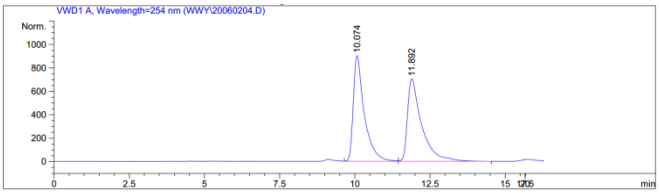
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.458	BB	1.0257	1.36831e4	205.91396	98.5628
2	25.890	BP	0.8667	199.52203	2.84346	1.4372

Compound 5”ja

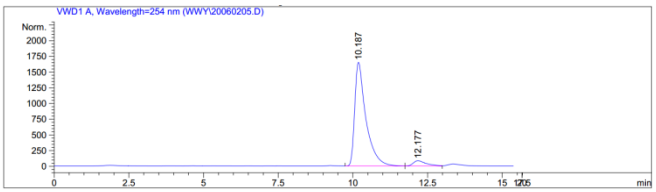


5"ja

Prepared according to the procedure within 12 h as white solid (25.2 mg, 46%); $[\alpha]_D^{17}$ = -45.65 (*c* 0.18, CH_2Cl_2); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.85-7.76 (m, 4H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.46-7.36 (m, 4H), 7.40-7.30 (m, 4H), 7.33-7.25 (m, 1H), 7.18 (t, *J* = 7.4 Hz, 1H), 6.98 (s, 1H), 4.99-4.50 (m, 1H), 3.39 (d, *J* = 13.1 Hz, 1H), 3.30 (d, *J* = 13.8 Hz, 1H), 2.44 (hept, *J* = 6.9 Hz, 1H), 1.62 (s, 3H), 1.21 (d, *J* = 6.9 Hz, 3H), 1.13 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 188.7, 179.1, 167.1, 164.5, 154.6, 150.6, 142.6, 141.7, 137.6, 137.5, 132.8, 128.9, 128.6, 128.6, 128.2, 128.0, 125.8, 125.2, 120.7, 119.3, 94.2, 72.3, 51.8, 29.9, 20.1, 20.1, 12.1. HRMS (ESI) m/z Calcd. for $C_{33}H_{30}N_3O_3S$ ($[M+H]^+$) 548.2002, Found 548.1999. Enantiomeric excess was determined to be 89% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.1 min, tminor = 12.1 min).

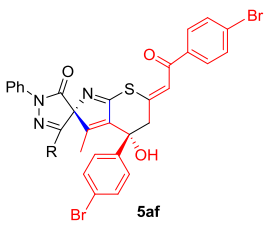


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.074	VV	0.3641	2.28609e4	902.03802	49.9216
2	11.892	VB	0.4651	2.29327e4	702.79700	50.0784



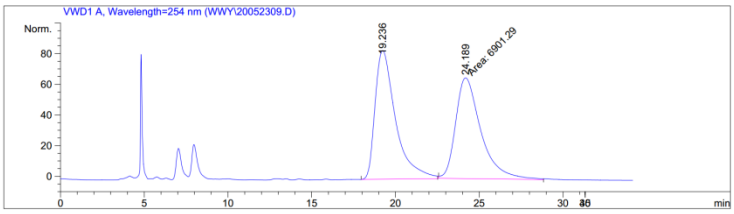
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.187	VV	0.3758	4.31372e4	1653.03088	94.1296
2	12.177	VV	0.4530	2690.27319	86.19263	5.8704

Compound 5af

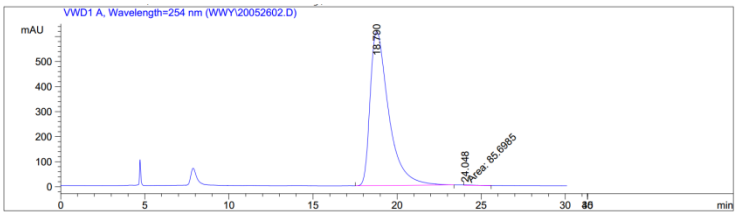


5af

Prepared according to the procedure within 12 h as yellow solid (33.2 mg, 45% yield). Enantiomeric excess was determined to be 99% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 18.7 min, tminor = 12.0 min).

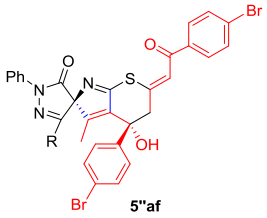


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	19.236	BB	1.2638	7142.44043	83.91729	50.8586
2	24.189	MM	1.7495	6901.29004	65.74348	49.1414



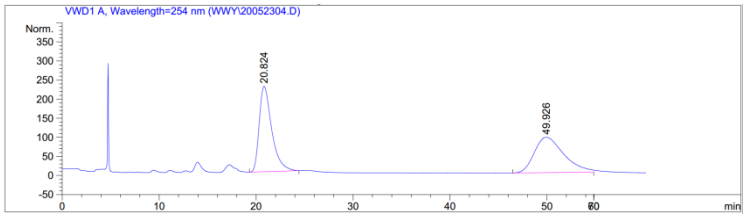
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.790	PB	1.1531	4.71063e4	614.80127	99.8184
2	24.048	MM	0.9664	85.69849	1.47800	0.1816

Compound 5”af

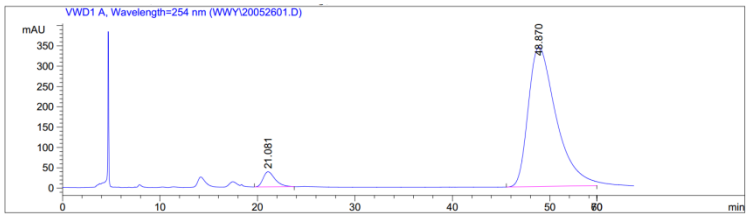


5"af

Prepared according to the procedure within 12 h as yellow solid (31.8 mg, 43% yield). Enantiomeric excess was determined to be 91% (determined by HPLC using chiral IC-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 48.8 min, tminor = 21.0 min).

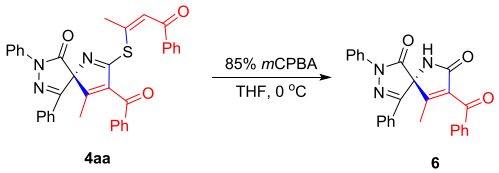


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	20.824	PB	1.3558	2.00852e4	223.79175	50.0028
2	49.926	BB	2.8964	2.00830e4	92.89378	49.9972



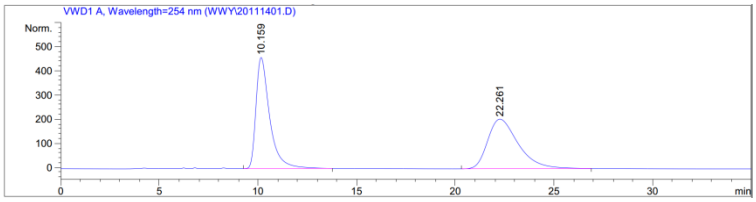
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	21.081	PB	1.2695	3168.61621	37.12518	4.3693
2	48.870	BB	2.9657	6.93518e4	343.47601	95.6307

Synthesis of compound 6 and 7

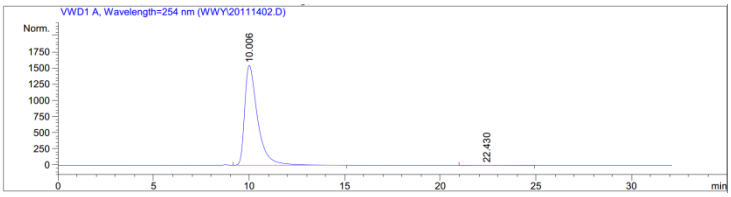


4aa **6**

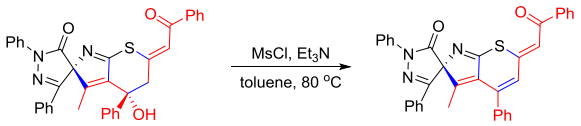
To a solution of **4aa** (58.1 mg, 0.1 mmol, 1.0 equiv) in THF (1.0 mL) was added 85% *m*CPBA (42.6 mg, 0.21 mmol, 2.1 equiv) at 0 °C. The reaction mixture was stirred at 0 °C for 2 h. And then the mixture was diluted with EtOAc (10 mL) and quenched with saturated $NaHCO_3$ aqueous (5 mL). The organic phase was separated and washed with saturated $NaHCO_3$ aqueous and brine, dried over Na_2SO_4, concentrated. The crude mixture was purified by column chromatography on silica gel (EtOAc/petroleum ether = 1/5) to give **6** as light-yellow oil (32.6 mg, 81% yield). $[\alpha]_D^{16}$ = -37.00 (*c* 0.12, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.91 (d, *J* = 8.0 Hz, 2H), 7.88 - 7.80 (m, 2H), 7.74 - 7.66 (m, 2H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.44 - 7.29 (m, 8H), 7.21 (t, *J* = 7.5 Hz, 1H), 1.78 (s, 3H); ^{13}C NMR (151 MHz, Chloroform-*d*) δ 190.2, 171.5, 167.3, 157.3, 153.6, 137.4, 136.1, 134.6, 134.3, 131.8, 129.8, 129.4, 129.2, 128.9, 128.8, 126.3, 126.1, 74.5, 12.0. HRMS (ESI) m/z Calcd. for $C_{26}H_{20}N_3O_3$ ($[M+H]^+$) 422.1499, Found 422.1498. Enantiomeric excess was determined to be 99% (determined by HPLC using chiral OD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.0 min, tminor = 22.4 min).



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.159	VB	0.7226	2.22356e4	460.00241	50.1360
2	22.261	BB	1.6363	2.21150e4	205.37311	49.8640

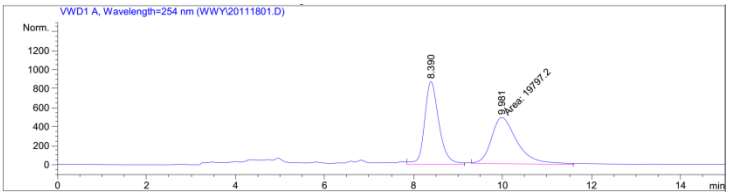


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.006	VB	0.7030	7.28335e4	1544.61096	99.5775
2	22.430	BB	1.2104	309.05127	3.00423	0.4225



5aa **7**

Methanesulfonyl chloride (12.5 mg, 0.11 mmol) and then triethylamine (11.1 mg, 0.11 mmol) were added to a solution of **5aa** (58.1 mg 0.1 mmol) in toluene (2 mL). This mixture was refluxed for 2 h and then poured into saturated aqueous ammonium chloride (5 mL). After separation of the organic layer, the aqueous phase was extracted with ethyl acetate. The combined organic phase was dried over magnesium sulfate. After evaporation of the solvents, the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 was used as the eluent) to give **7** as yellow solid (44 mg, 1.17 mmol). mp 115.0 - 117.5 °C; $[\alpha]_D^{16}$ = 215.70 (*c* 0.14, CH_2Cl_2); ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.00 (d, *J* = 7.7 Hz, 2H), 7.96 (d, *J* = 8.0 Hz, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.50 (dd, *J* = 8.0, 3.8 Hz, 4H), 7.44 (t, *J* = 8.0 Hz, 3H), 7.42 (d, *J* = 6.2 Hz, 3H), 7.37 (t, *J* = 7.6 Hz, 3H), 7.33 (s, 1H), 7.29 (s, 1H), 7.24 (d, *J* = 7.7 Hz, 1H), 6.64 (s, 1H), 1.43 (s, 3H); ^{13}C NMR (151 MHz, Chloroform-*d*) δ 189.1, 177.7, 165.6, 155.8, 154.1, 147.8, 140.9, 138.1, 137.8, 137.7, 132.9, 131.2, 131.1, 130.2, 129.3, 129.0, 129.0, 128.8, 128.7, 128.1, 125.9, 119.8, 119.2, 94.0, 13.2. HRMS (ESI) m/z Calcd. for $C_{36}H_{26}N_3O_2S$ ($[M+H]^+$) 564.1740, Found 564.1741. Enantiomeric excess was determined to be 96% (determined by HPLC using chiral OD-H column, hexane/2-propanol = 7/3, λ = 254 nm, 30 °C, 0.8 mL/min, tmajor = 10.4 min, tminor = 9.4 min).



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
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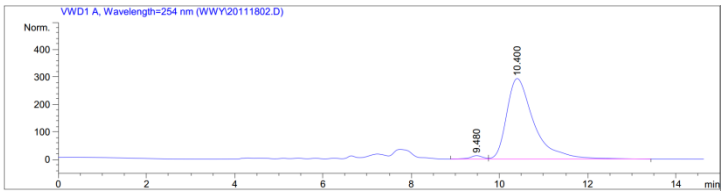
2	9.981	MM	0.6765	1.97972e4	487.70041	50.1405



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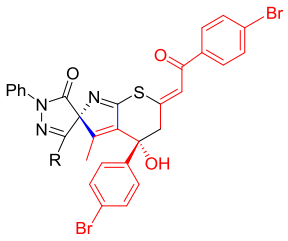
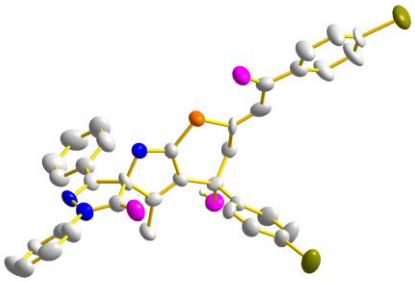
2	10.400	VB	0.6398	1.25356e4	293.32022	98.0062

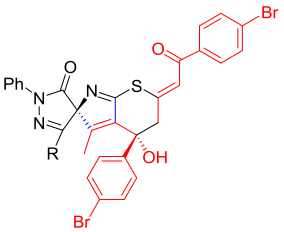
3. X-ray structures of 5af and 5”af



5af

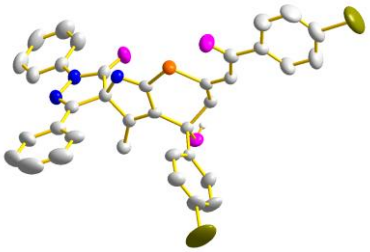
≡





5"af

≡



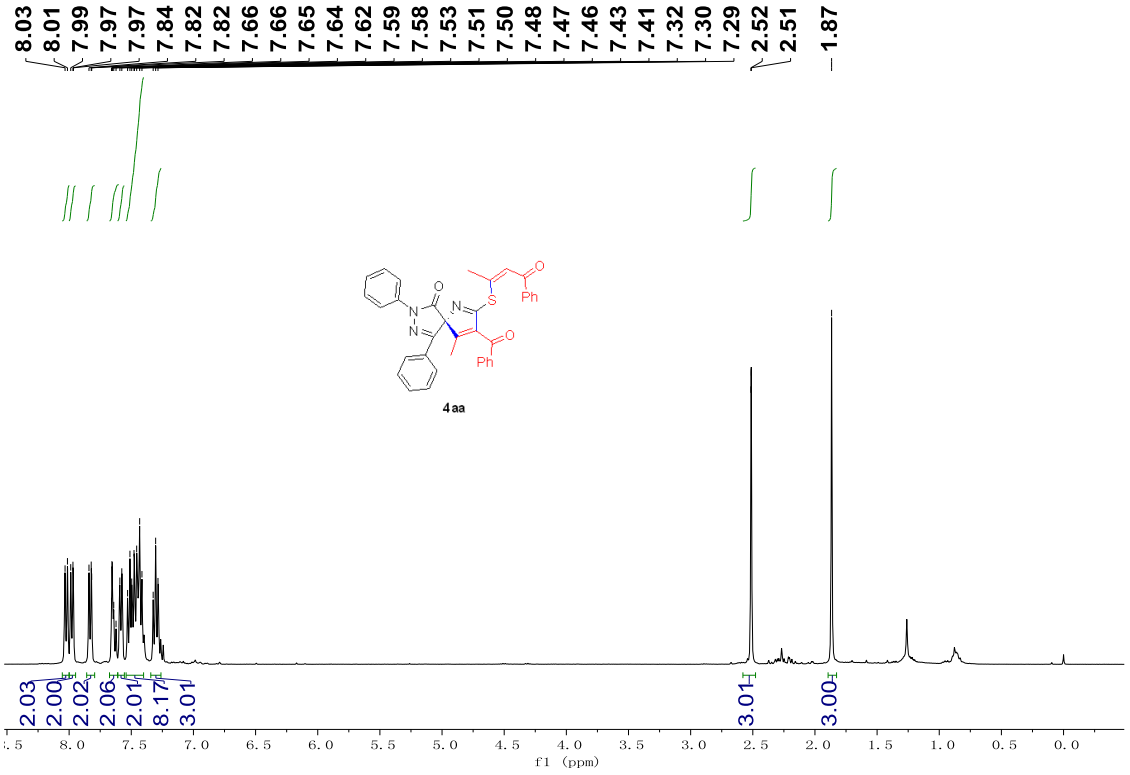
4. References

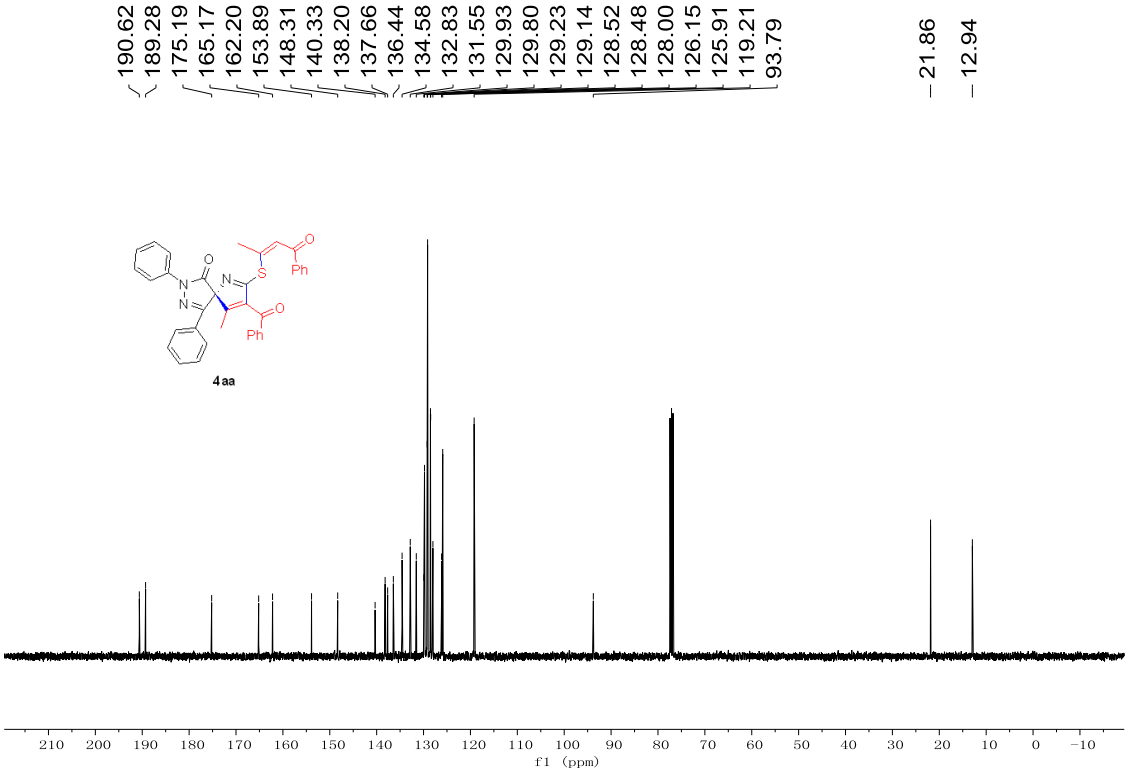
(1) X. Bao, S. Wei, X. Qian, J. Qu, B. Wang, L. Zou and G. Ge, Asymmetric Construction of a Multi-Pharmacophore-Containing Dispirotriheterocyclic Scaffold and Identification of a Human Carboxylesterase 1 Inhibitor. *Org. Lett.* 2018, **20**, 3394-3398.

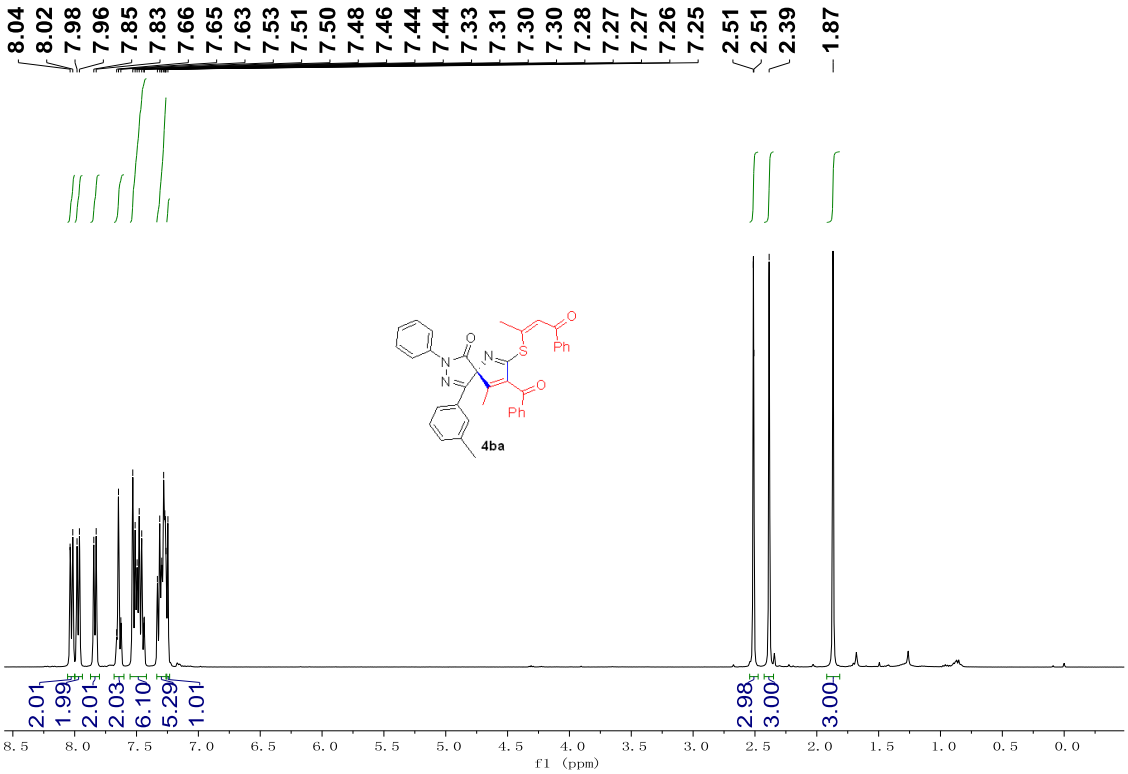
(2) (a) X. Zhang, X. Jia, L. Fang, N. Liu, J. Wang and X. Fan, Tandem Reactions of 1,2-Allenic Ketones Leading to Substituted Benzenes and α,β-Unsaturated Nitriles. *Org. Lett.* 2011, **13**, 5024-5027; (b) H. Xu, X. Zhang, Y. He, S. Guo and X. Fan, Tandem reaction of 3-hydroxyhexa-4,5-allenic esters: a novel access to diversely substituted 2H-pyran-2-ones and indenes. *Chem. Commun*. 2012, **48,** 3121-3123.

(3) (a) W. Yang and D.-M. Du, Highly Enantioselective Michael Addition of Nitroalkanes to Chalcones Using Chiral Squaramides as Hydrogen Bonding Organocatalysts. *Org. Lett.* 2010, **12**, 5450-5453; (b) J. P. Malerich, K. Hagihara and V. H. Rawal, Chiral Squaramide Derivatives are Excellent Hydrogen Bond Donor Catalysts. *J. Am. Chem. Soc*. 2008, **130**, 14416-14417.

5. NMR spectra for compounds



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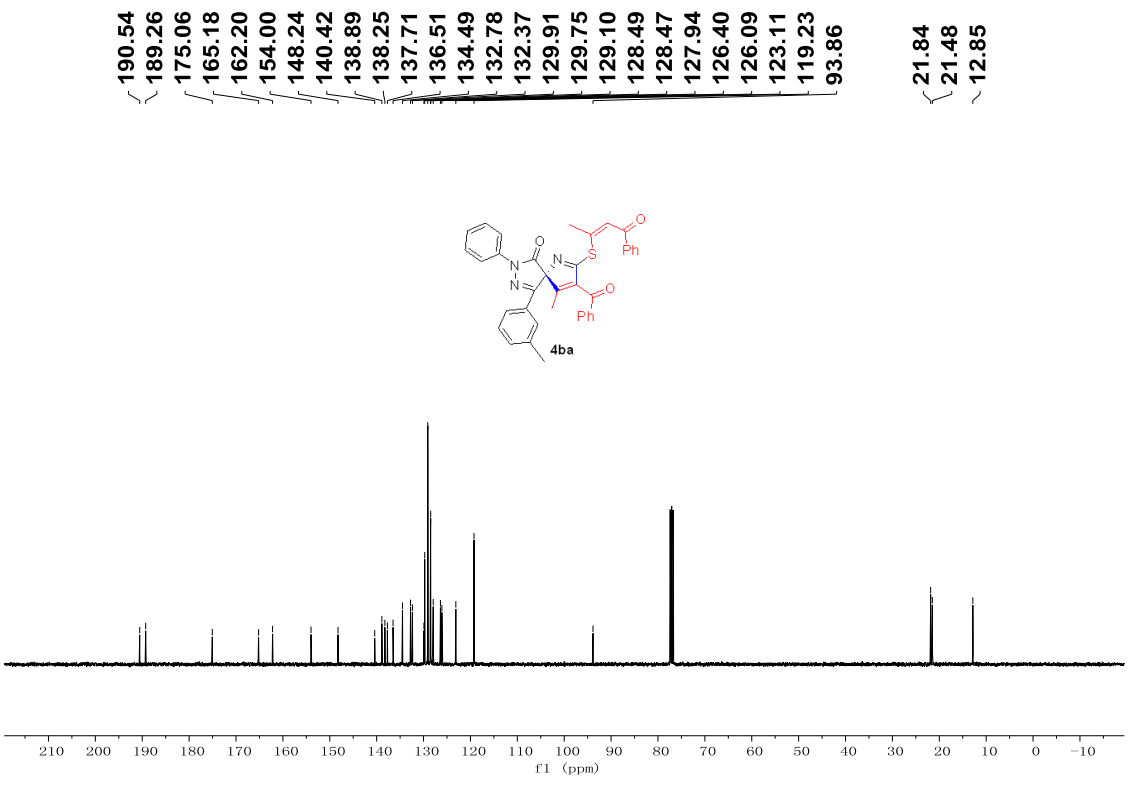
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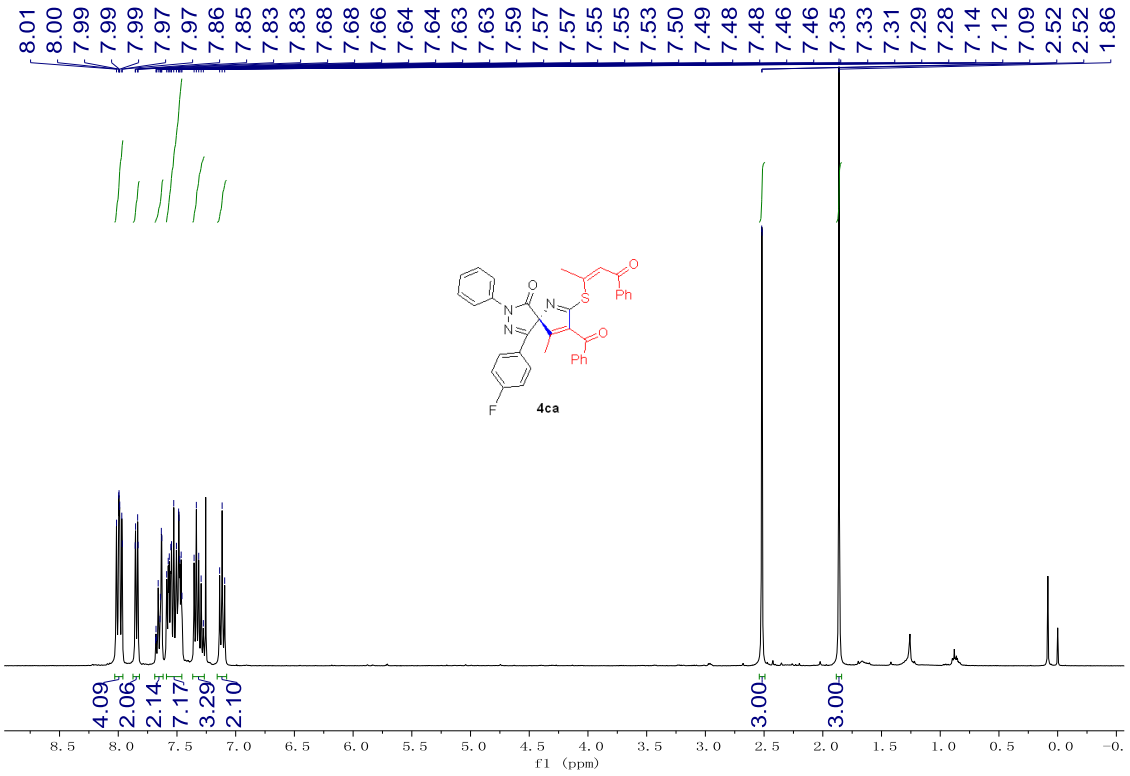
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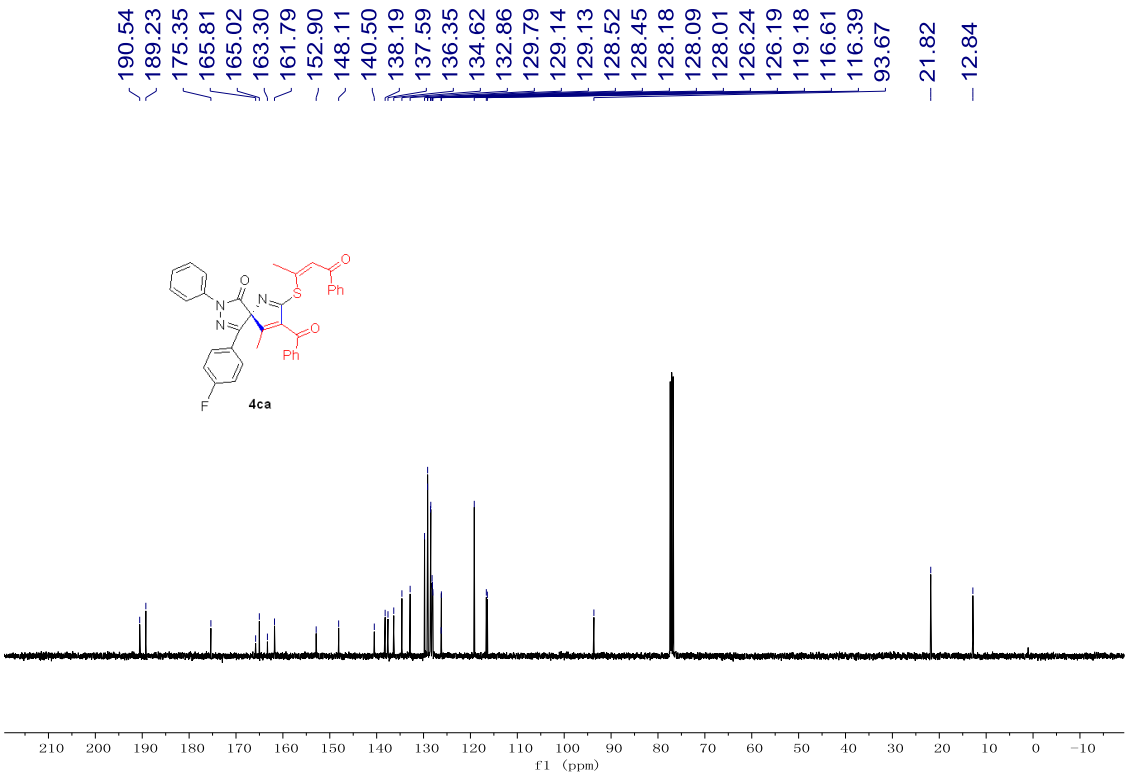
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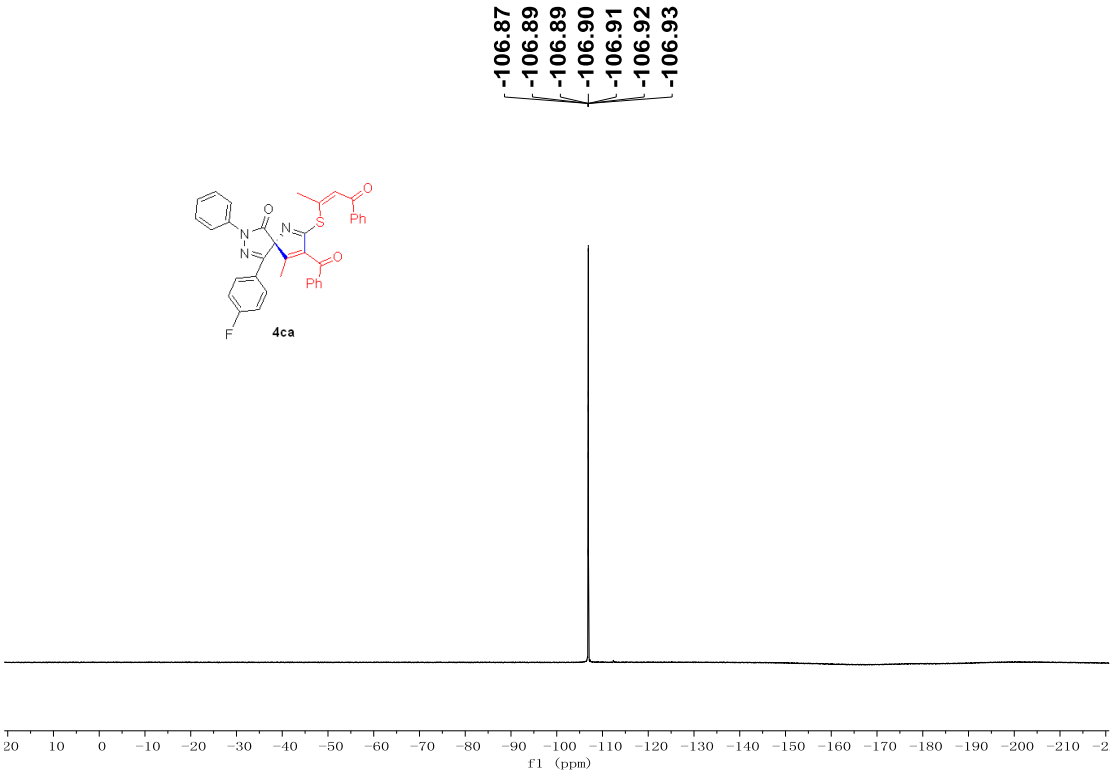
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O
Ph
F
4ca
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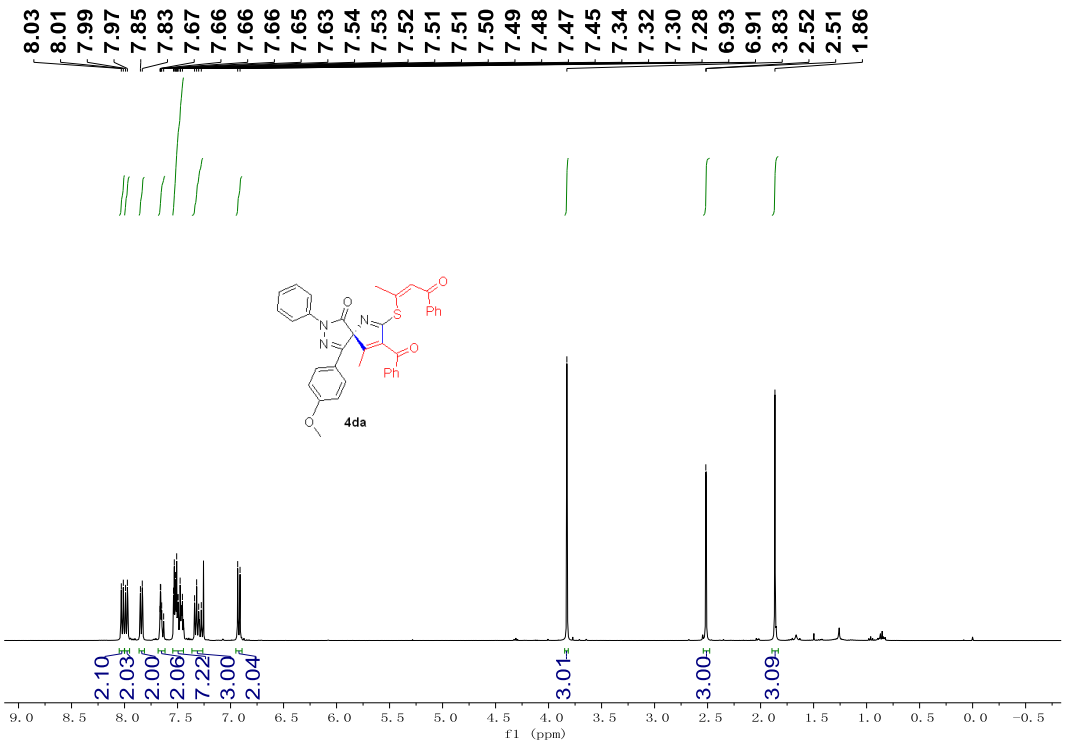
f1 (ppm)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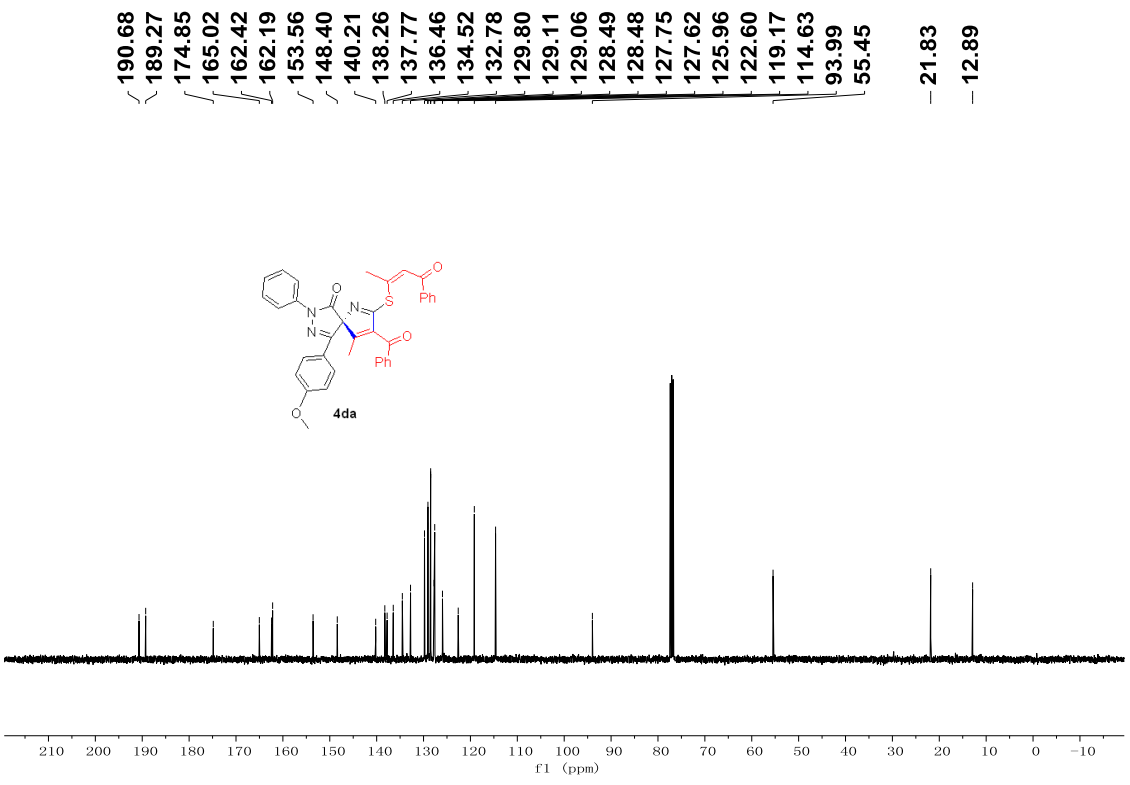
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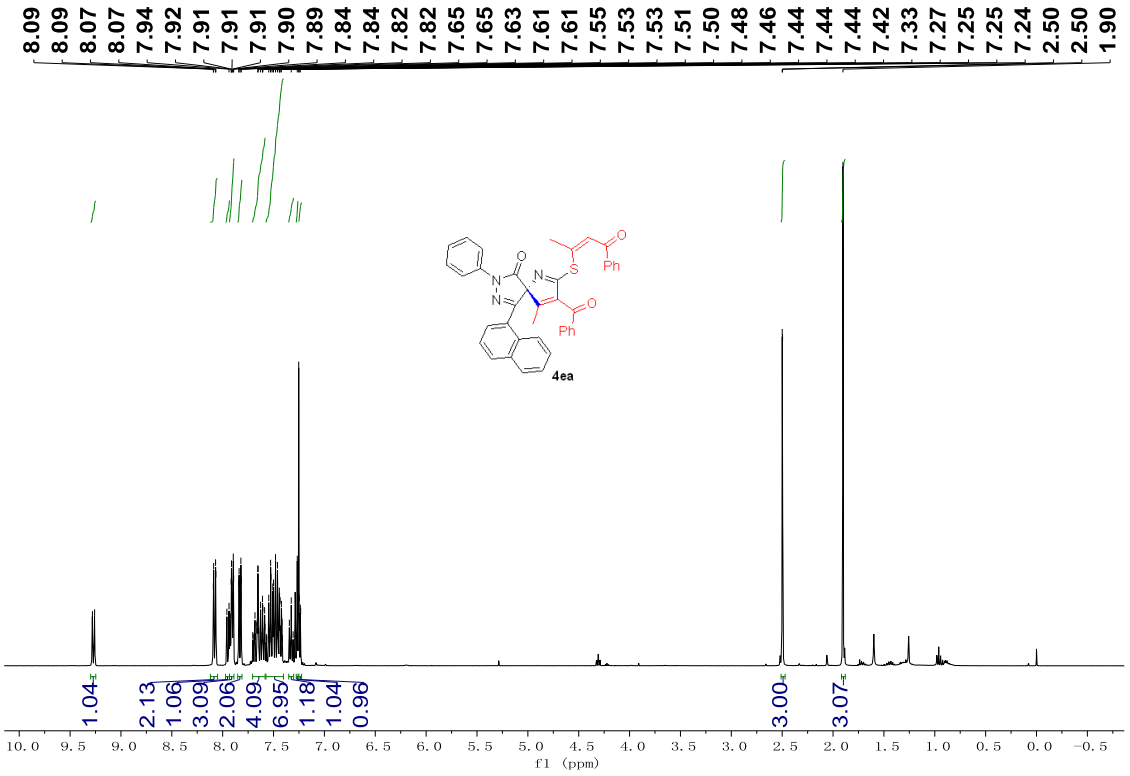
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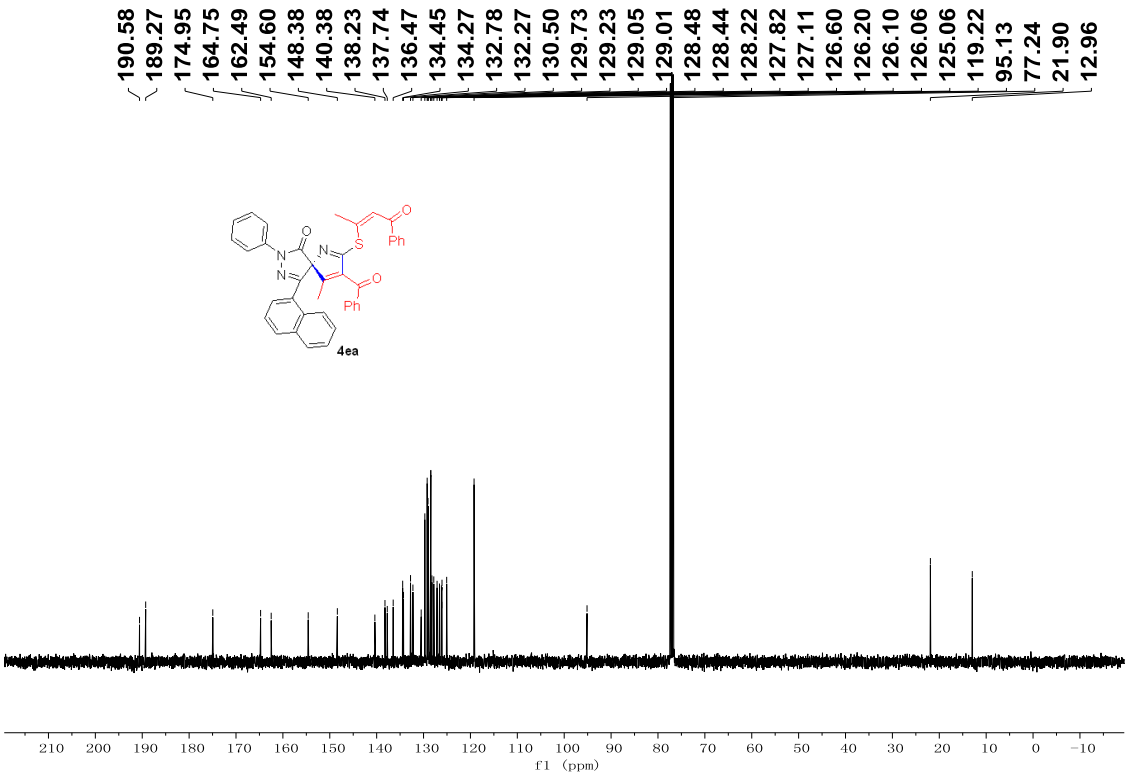
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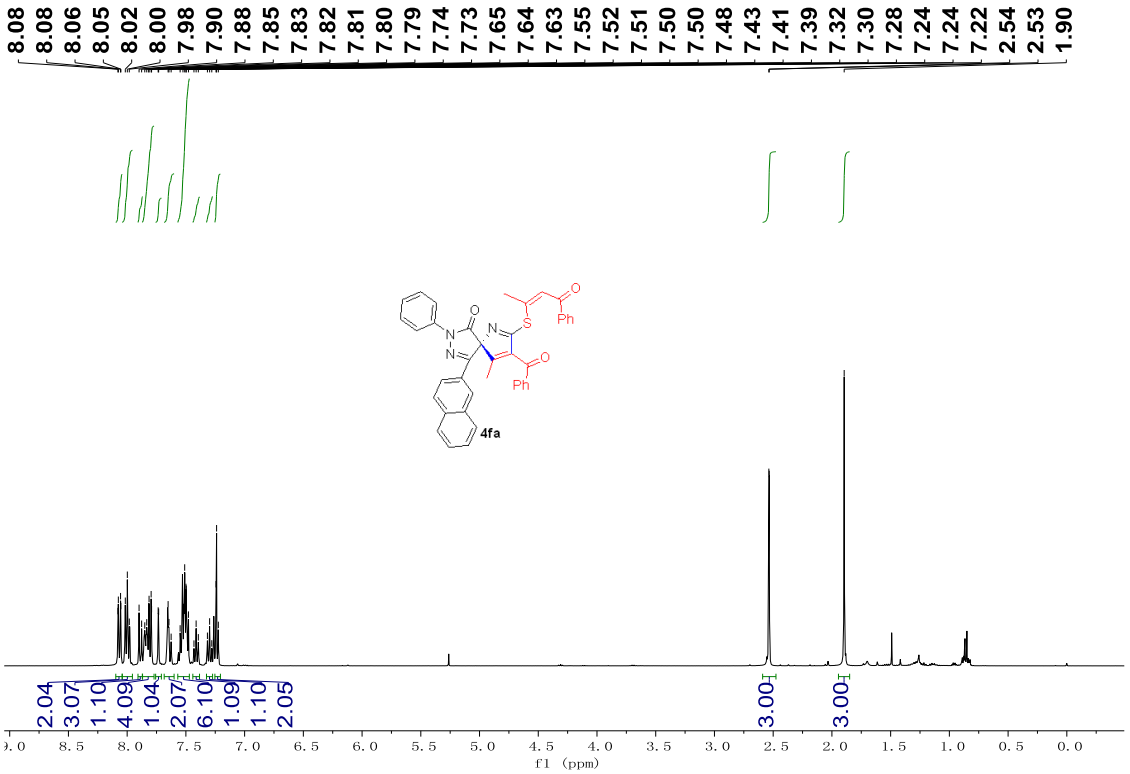
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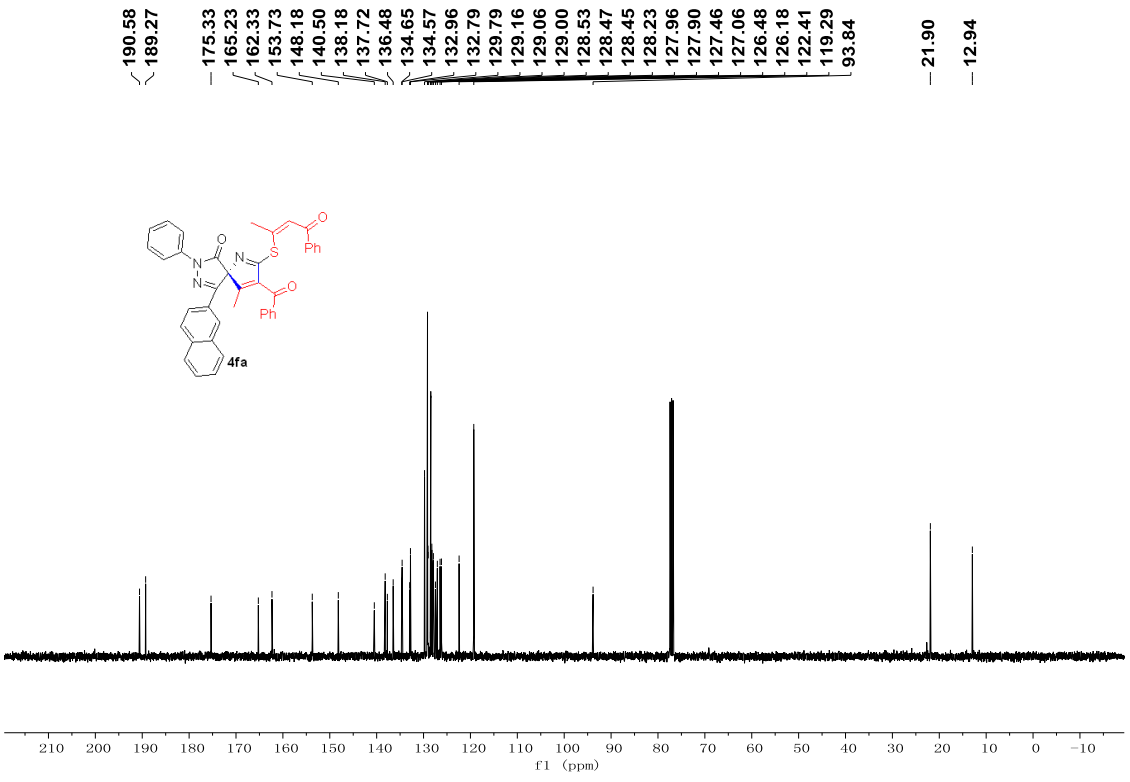
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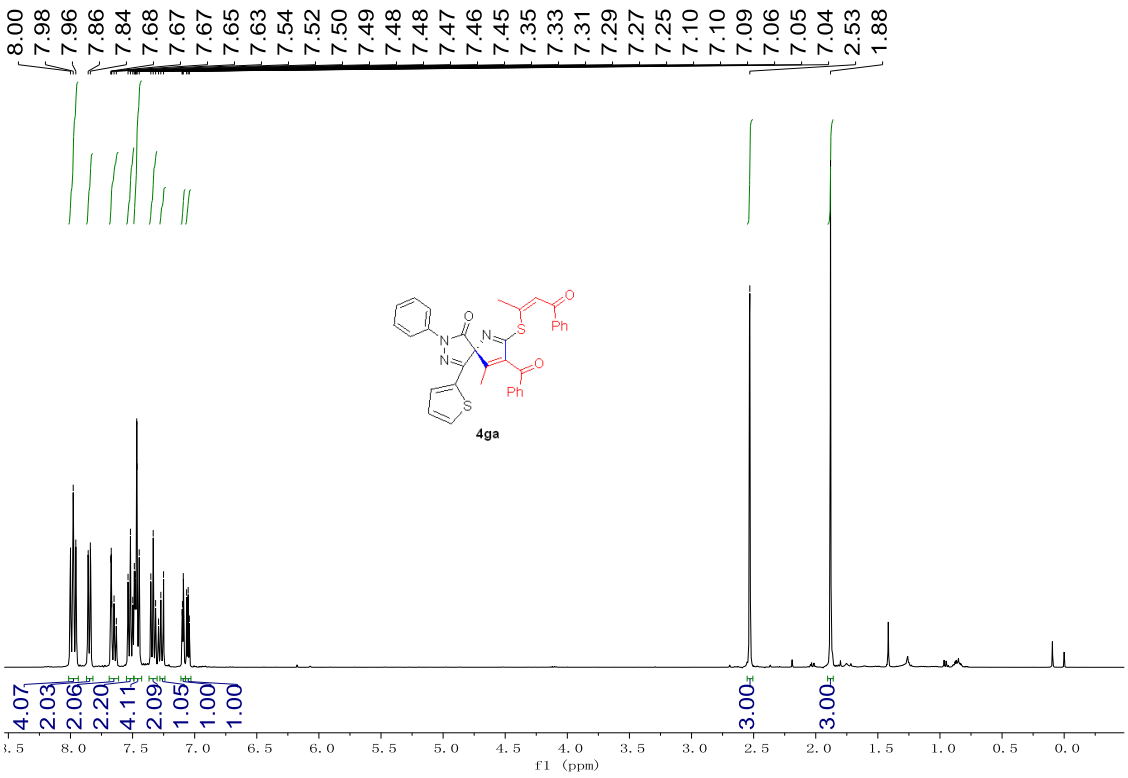
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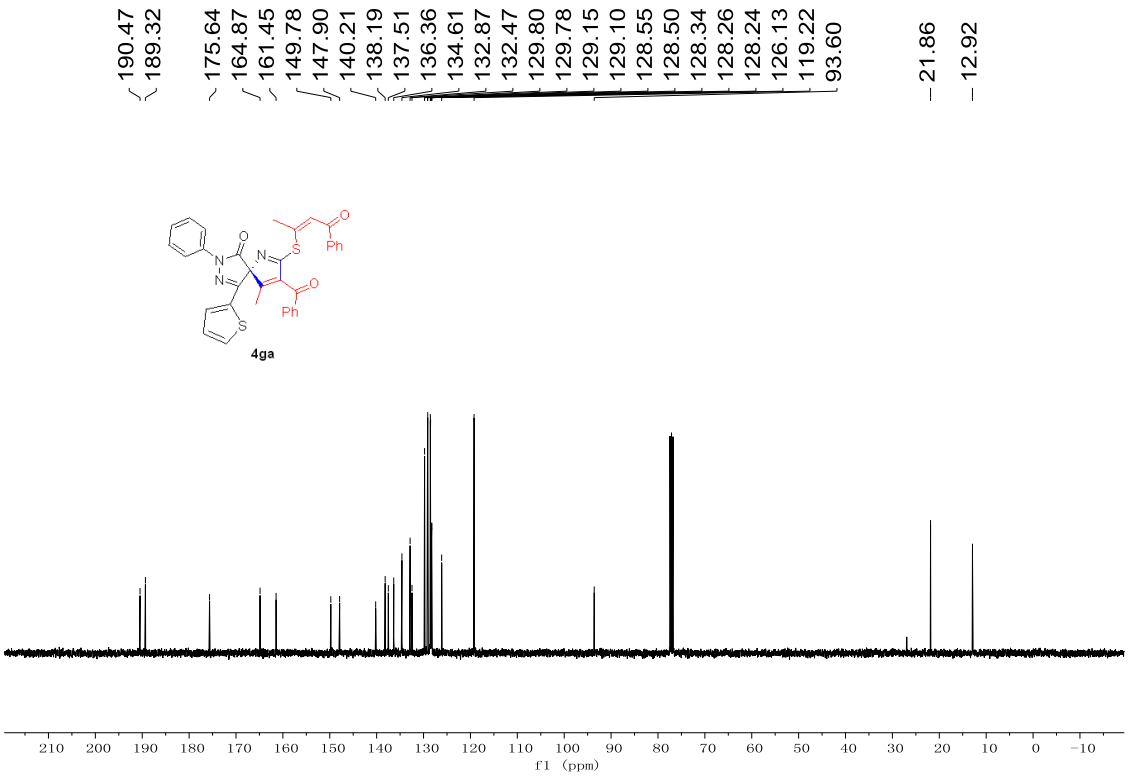
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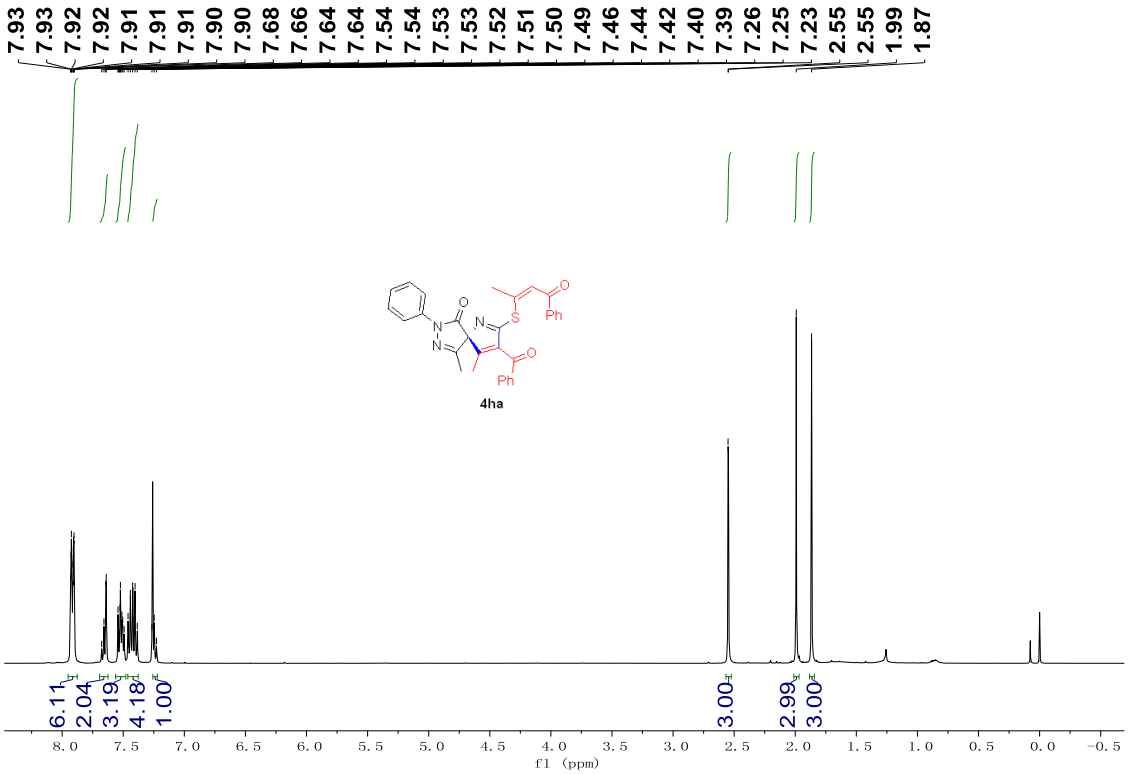
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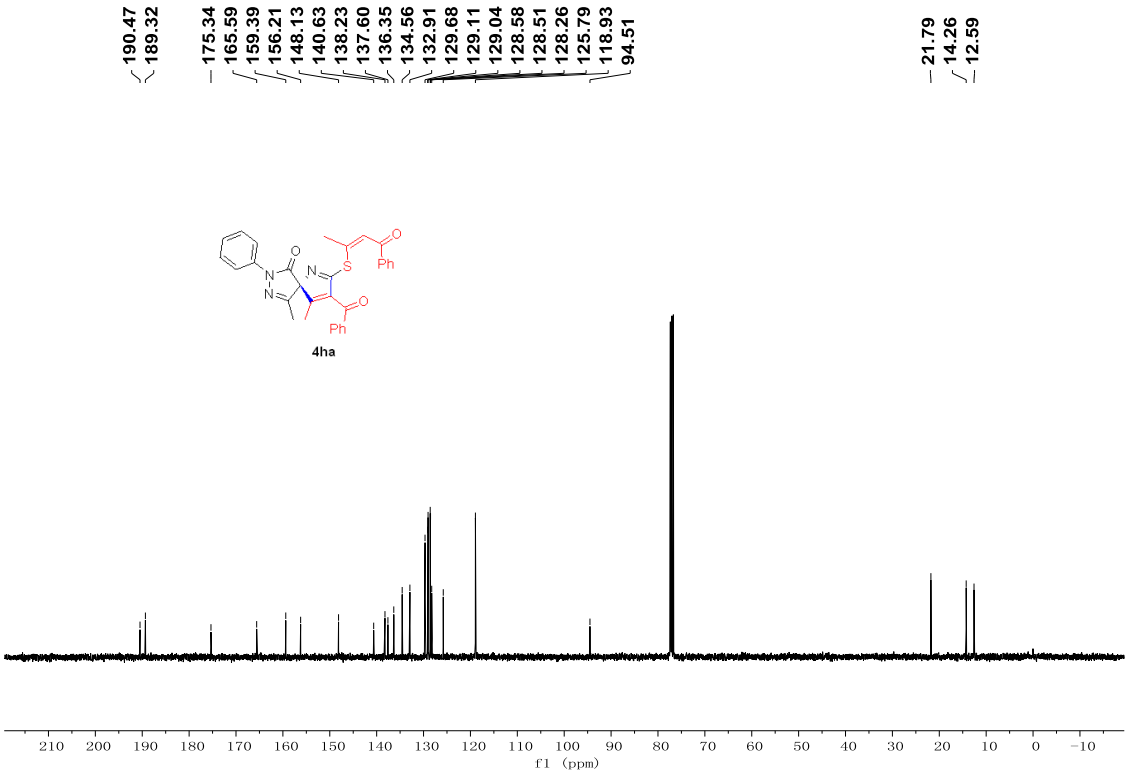
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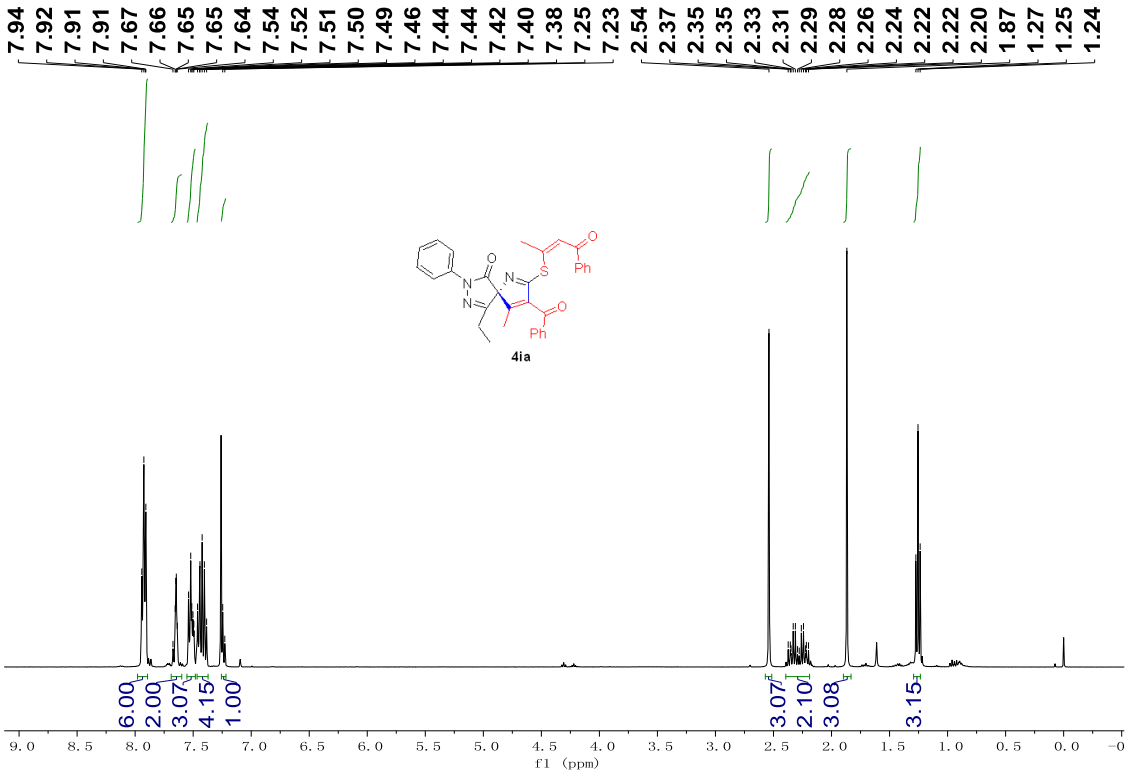
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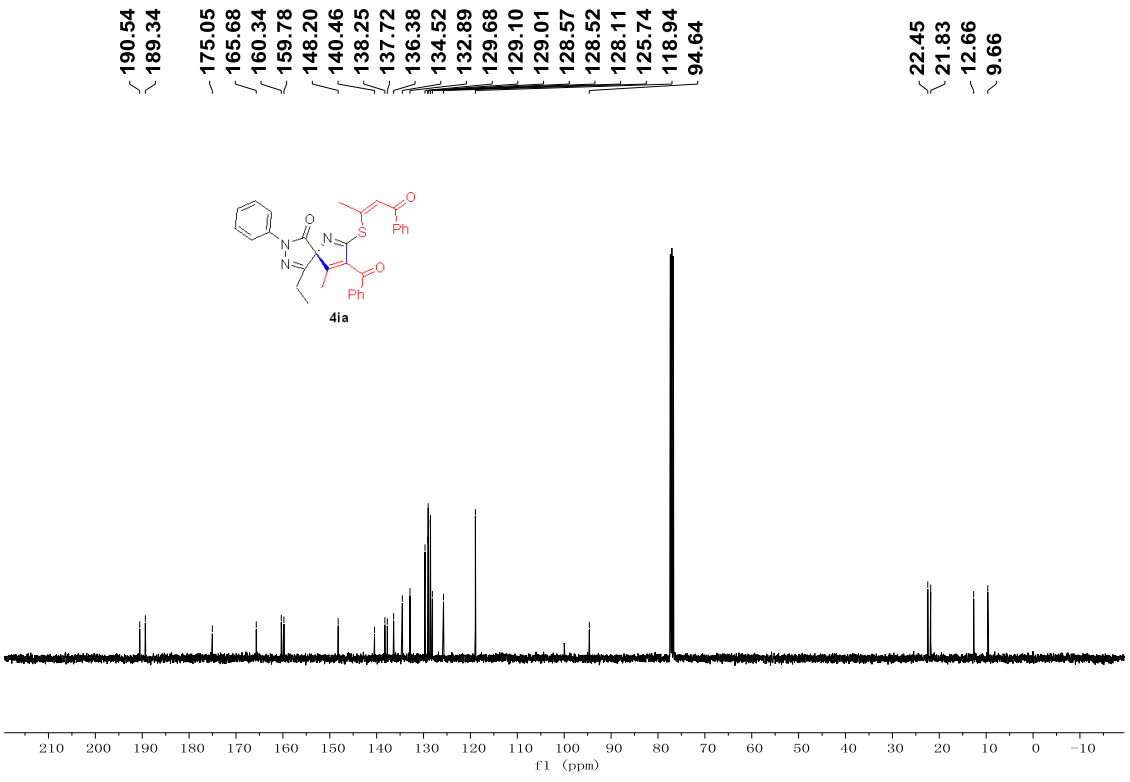
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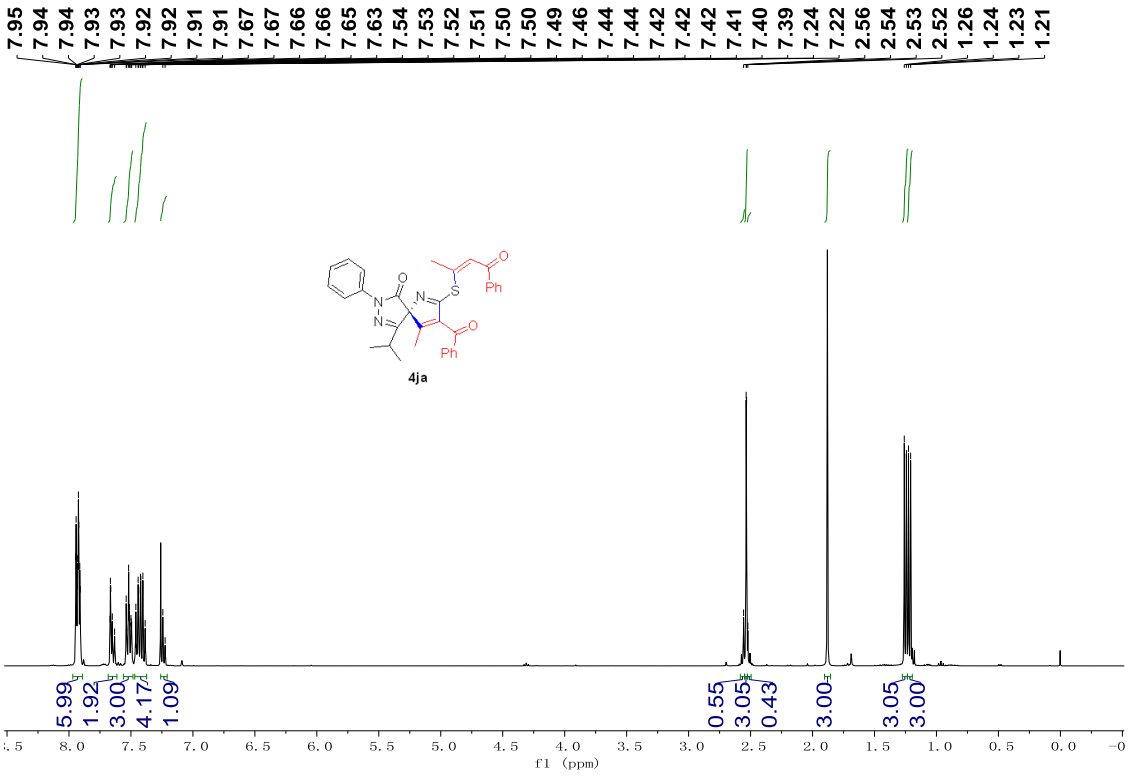
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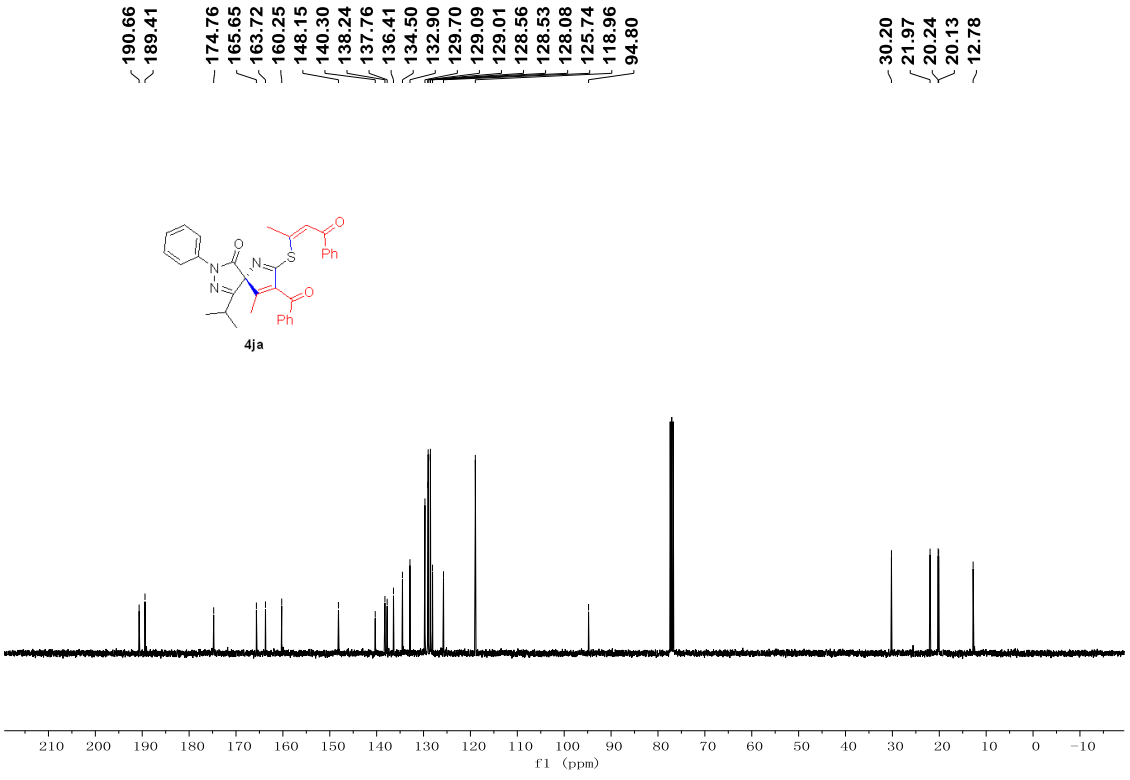
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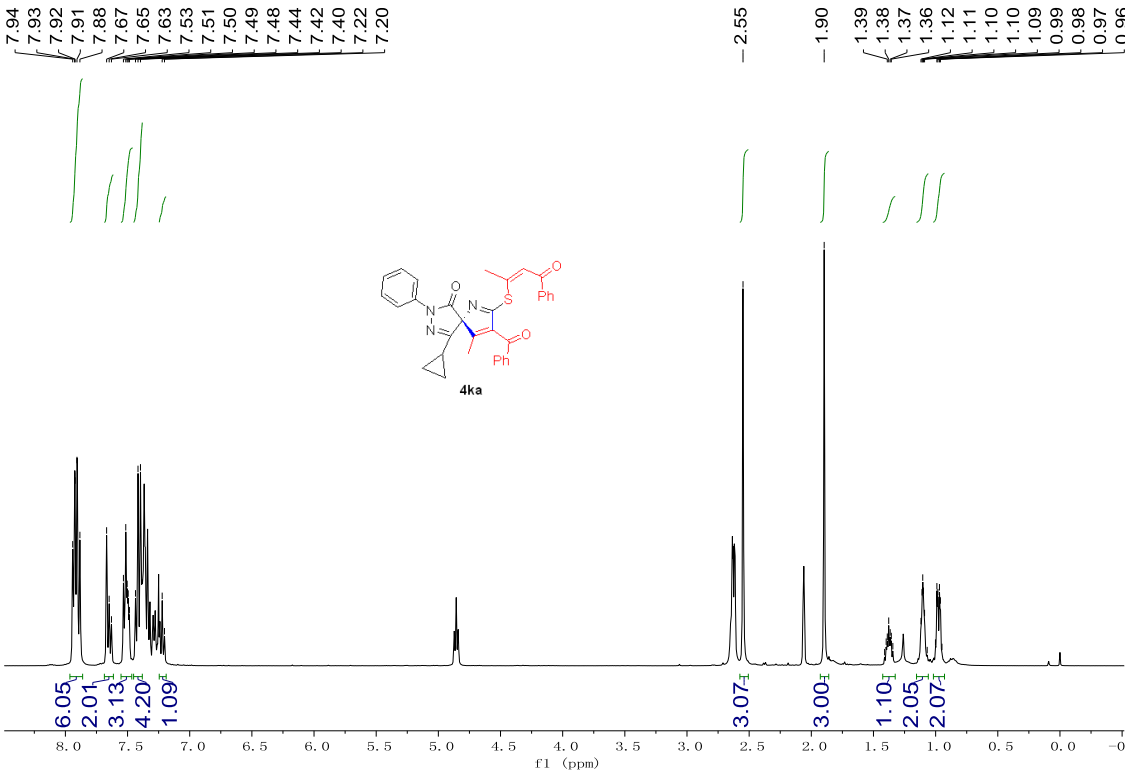
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7.44
7.42
7.40
7.22
7.20
2.55
1.90
1.39
1.38
1.37
1.36
1.12
1.11
1.10
1.10
1.09
0.99
0.98
0.97
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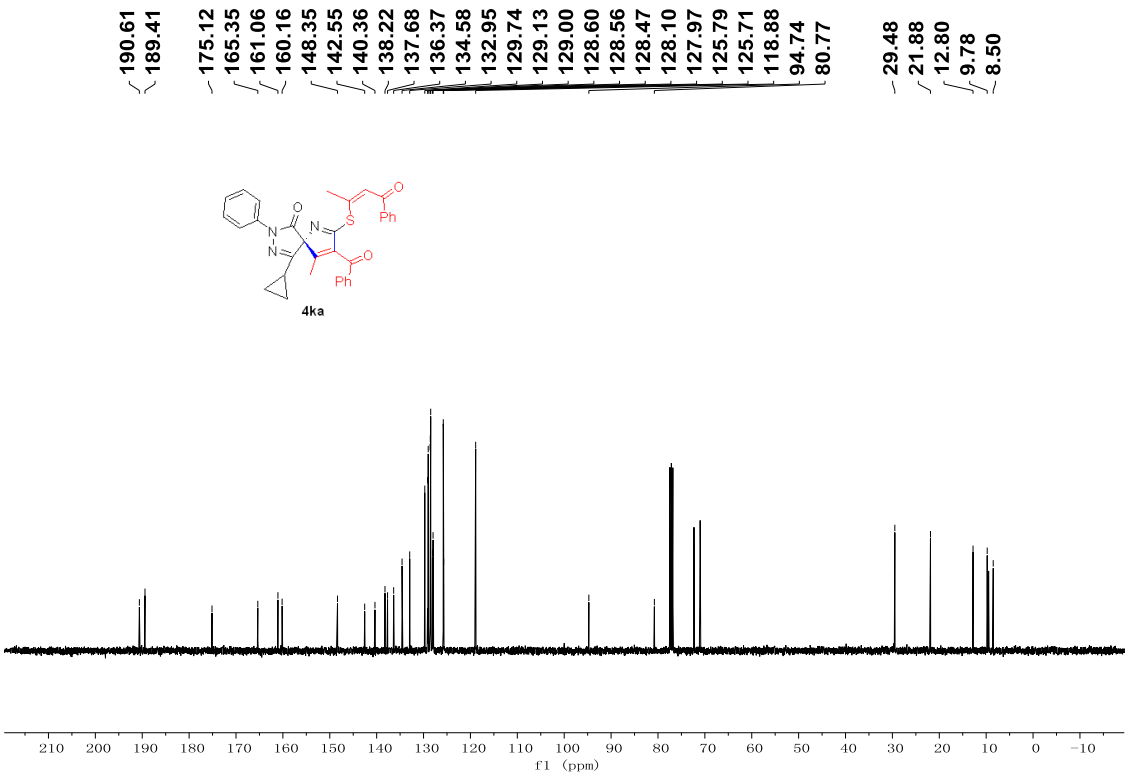
3.13
4.20
1.09
3.07
3.00
1.10
2.05
2.07
f1 (ppm)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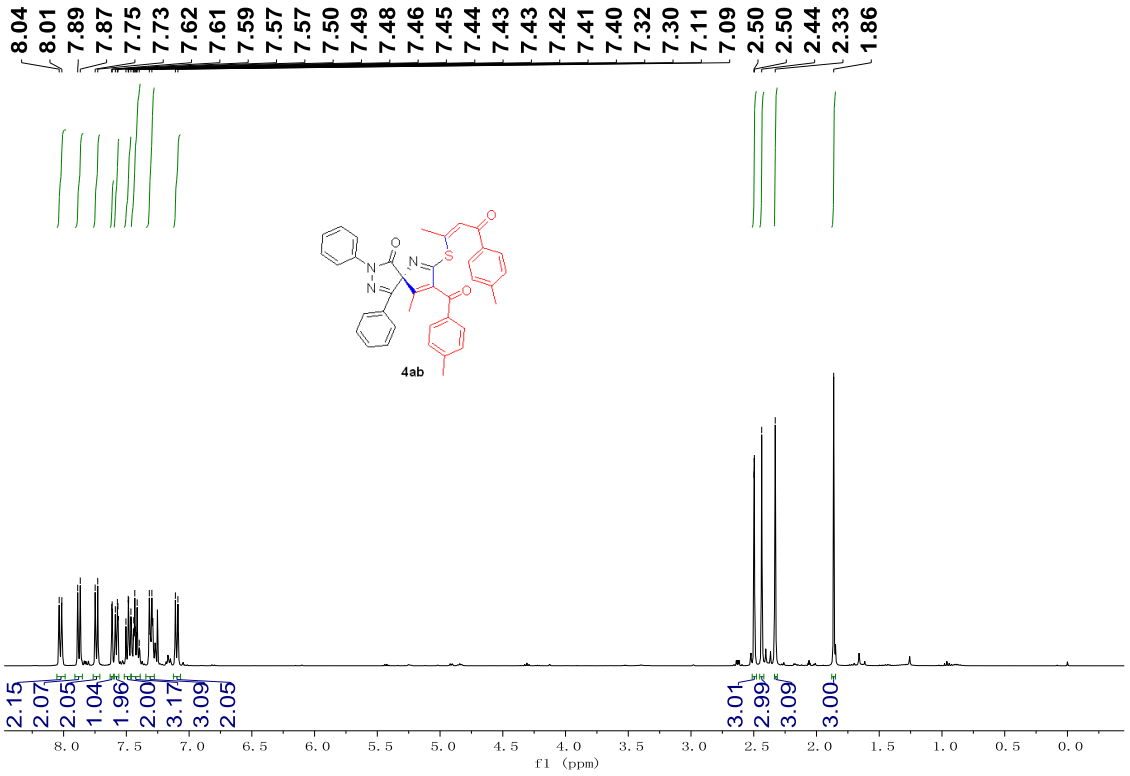
f1 (ppm)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2.33
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2.07
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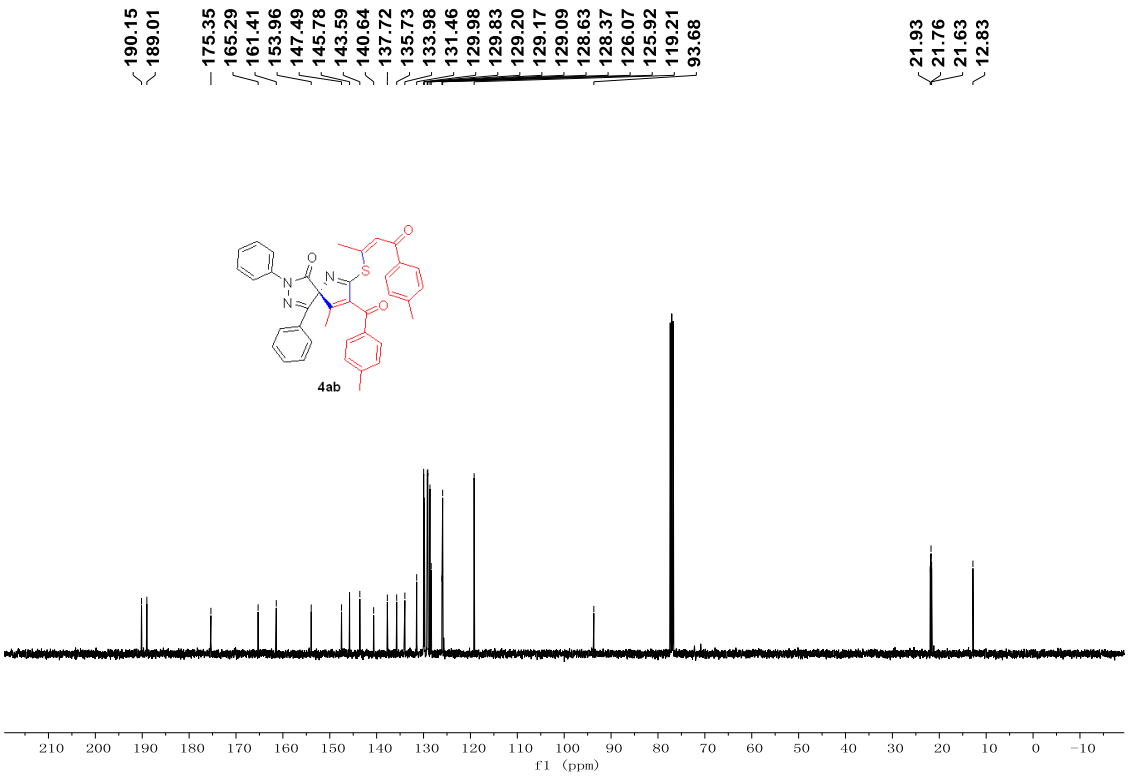
3.00
f1 (ppm)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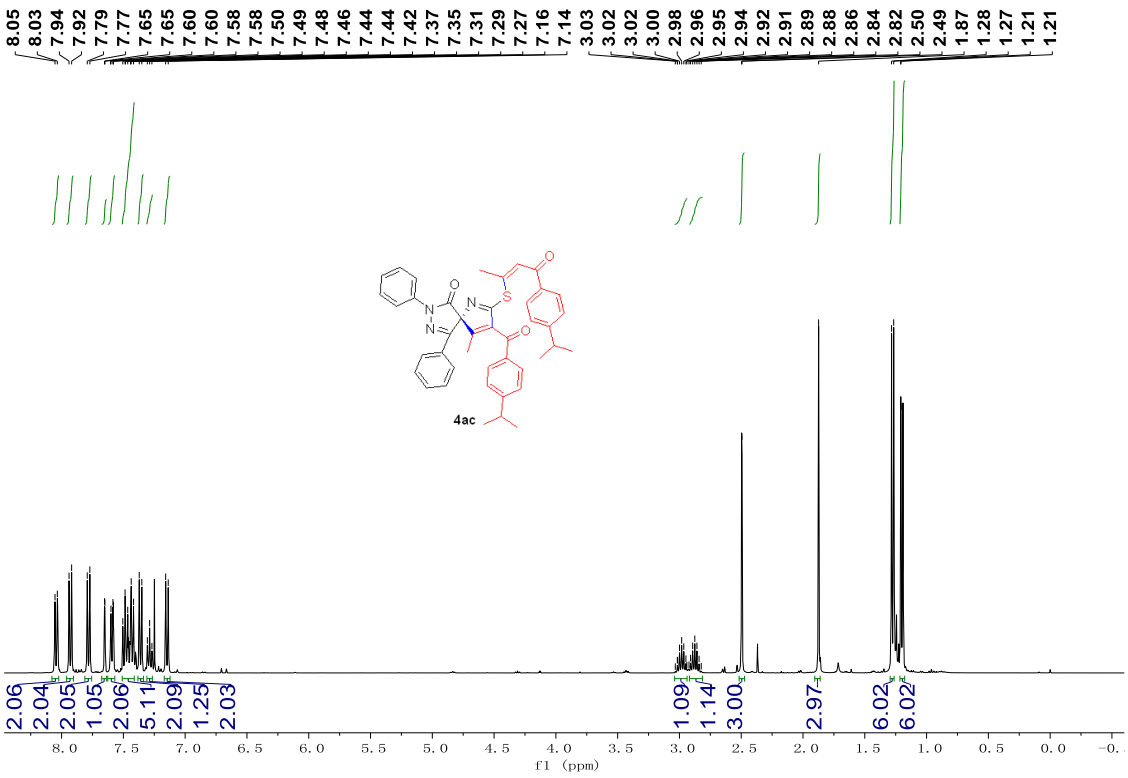
4ab
f1 (ppm)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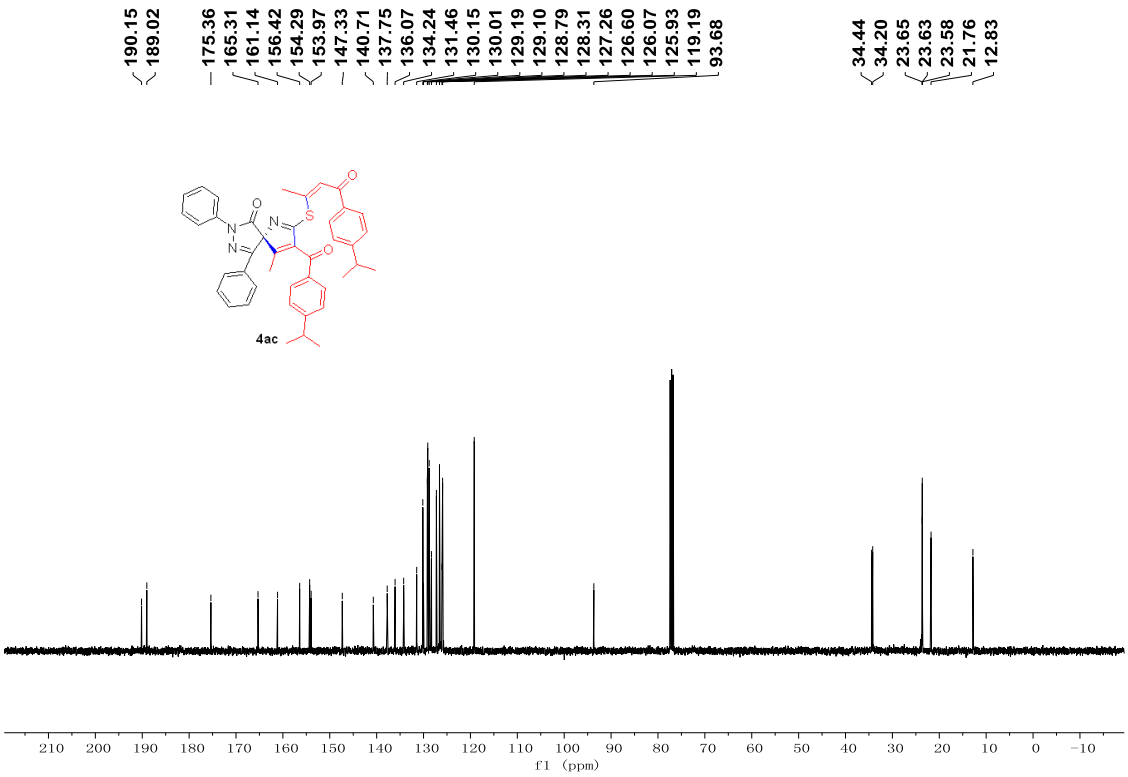
f1 (ppm)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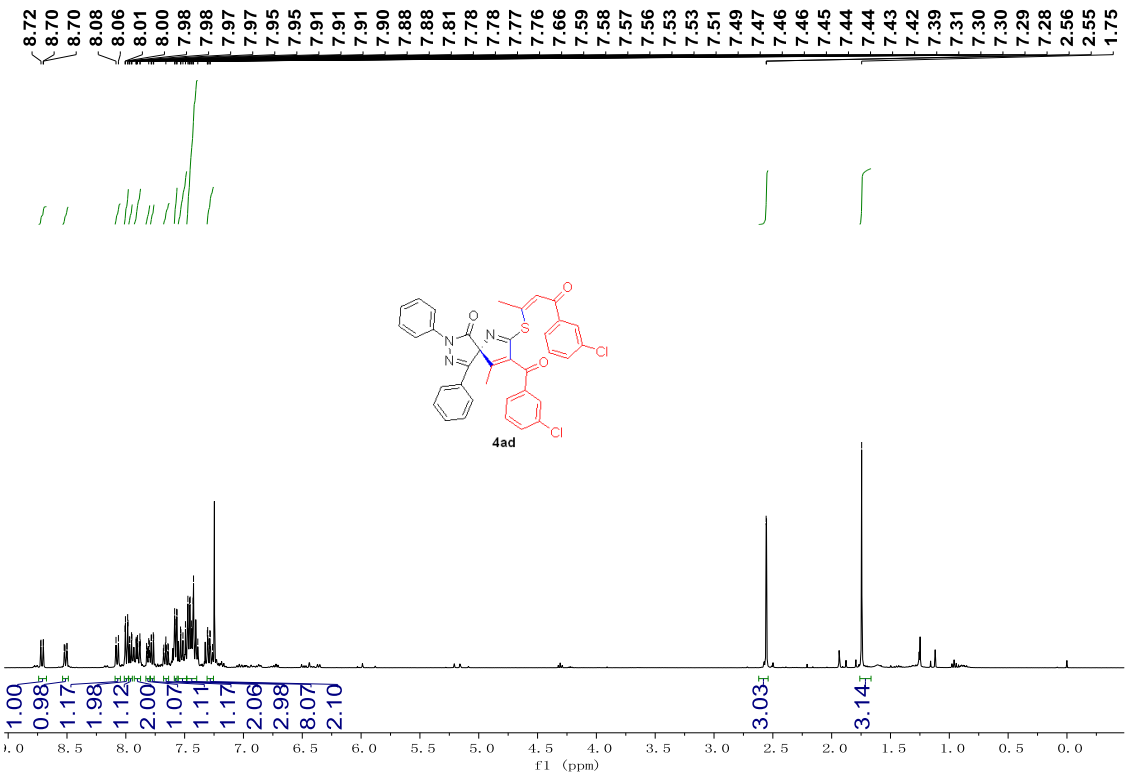
4ac
f1 (ppm)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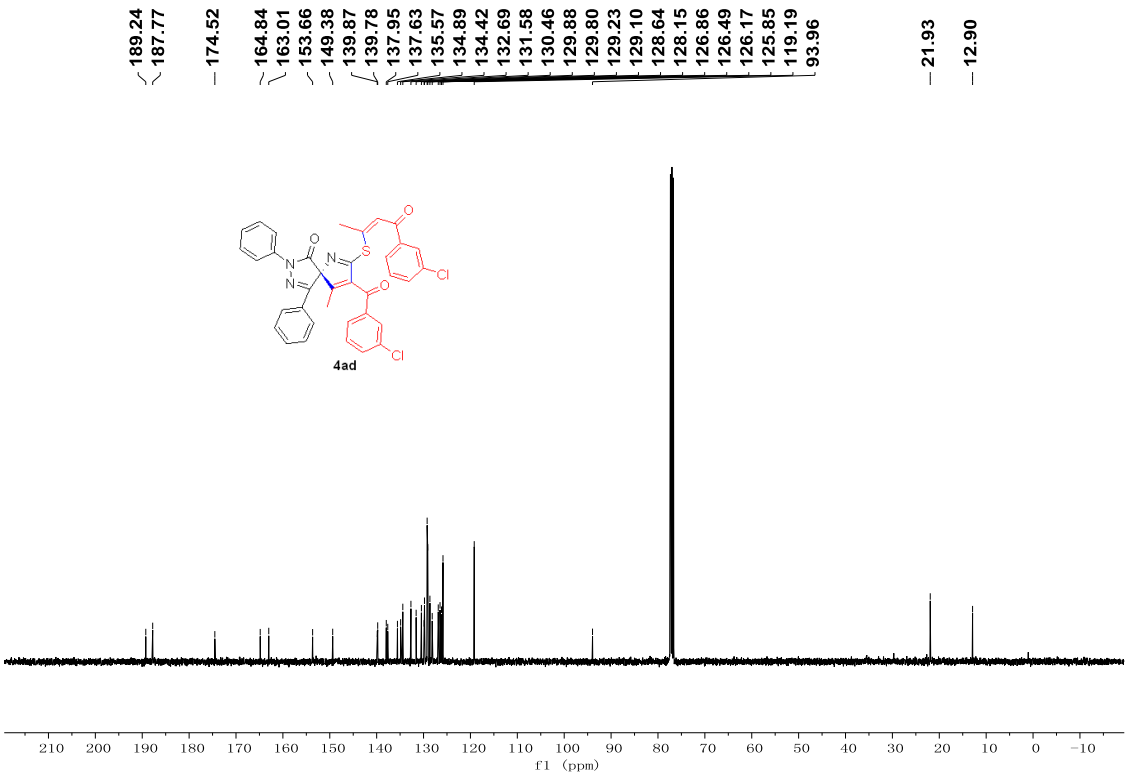
f1 (ppm)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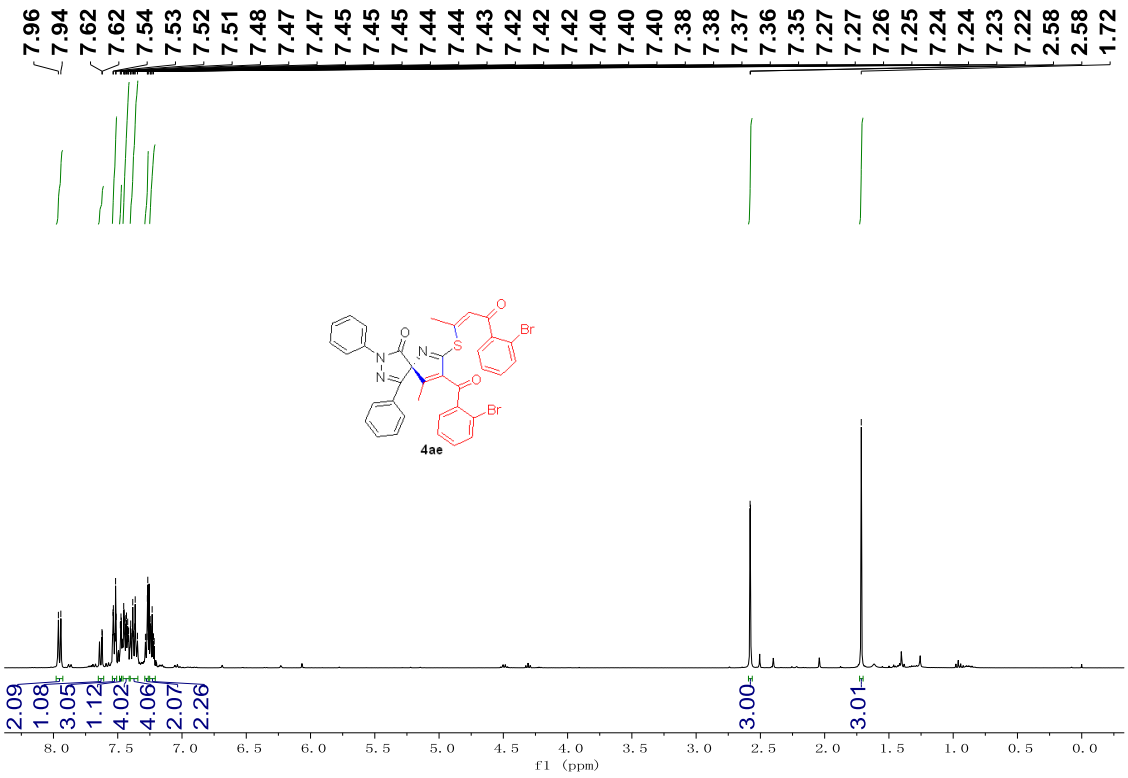
4ad
f1 (ppm)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7.45
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7.36
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7.27
7.27
7.26
7.25
7.24
7.24
7.23
7.22
2.58
2.58
1.72
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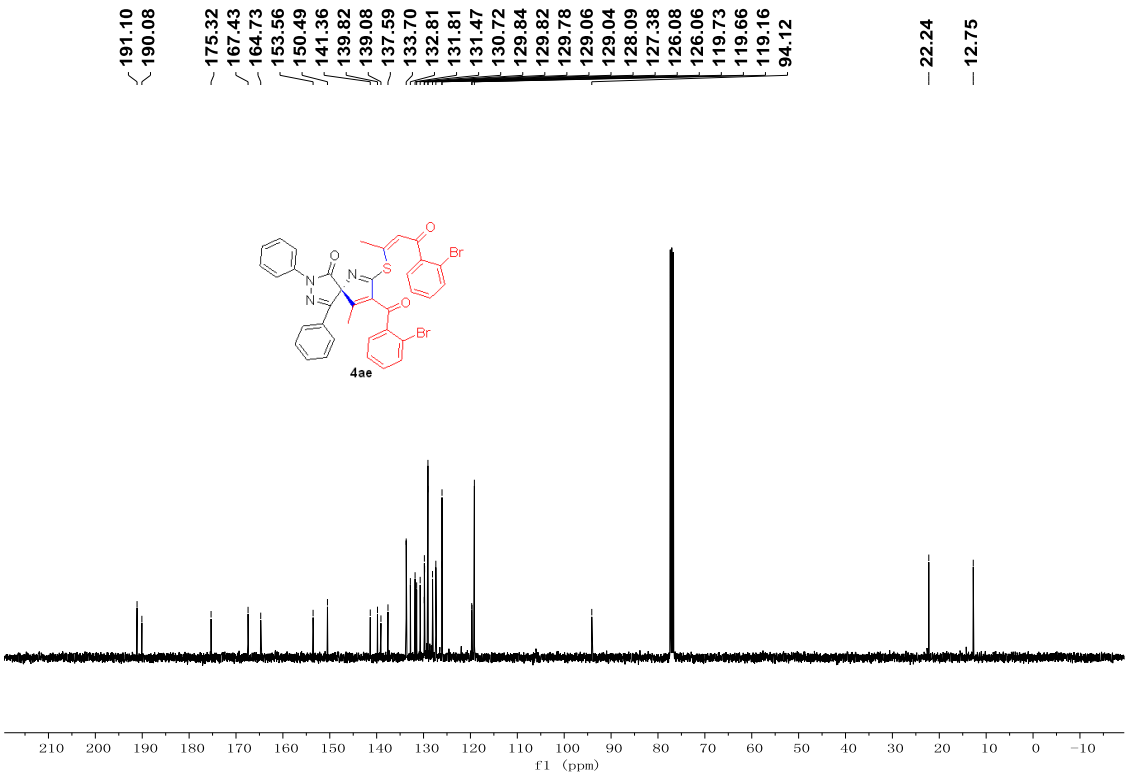
3.01
f1 (ppm)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131.81
131.47
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129.84
129.82
129.78
129.06
129.04
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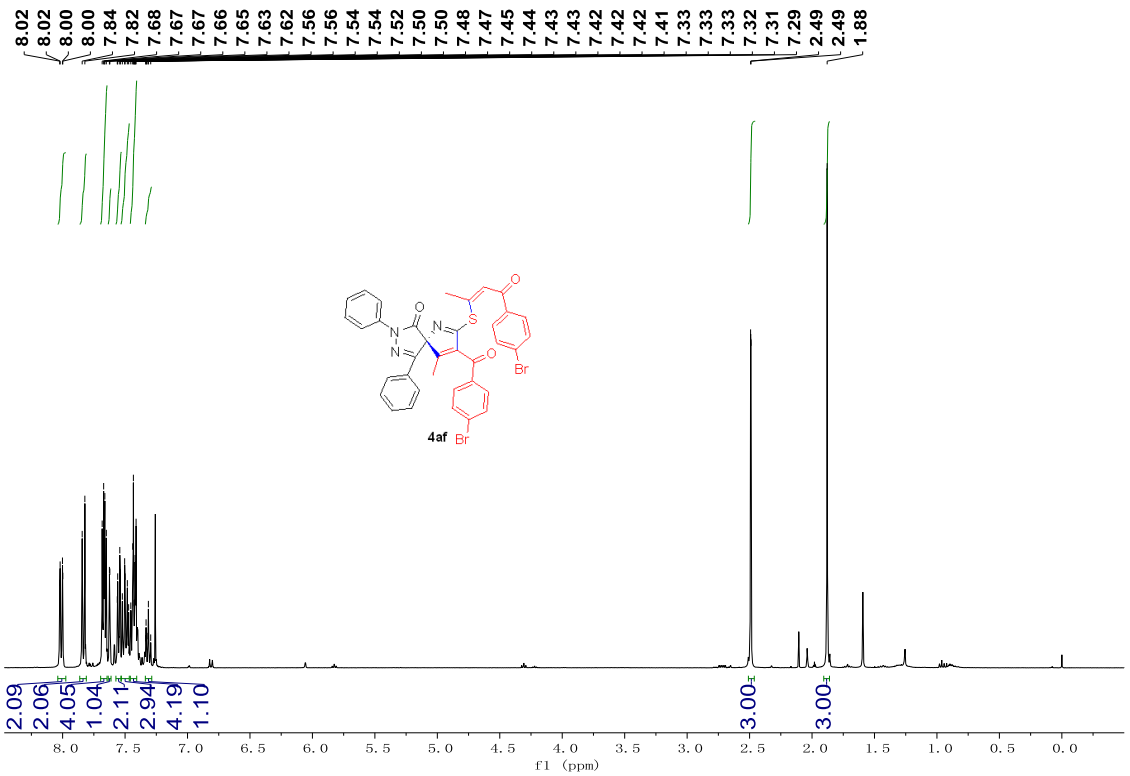
94.12
22.24
12.75
4ae
f1 (ppm)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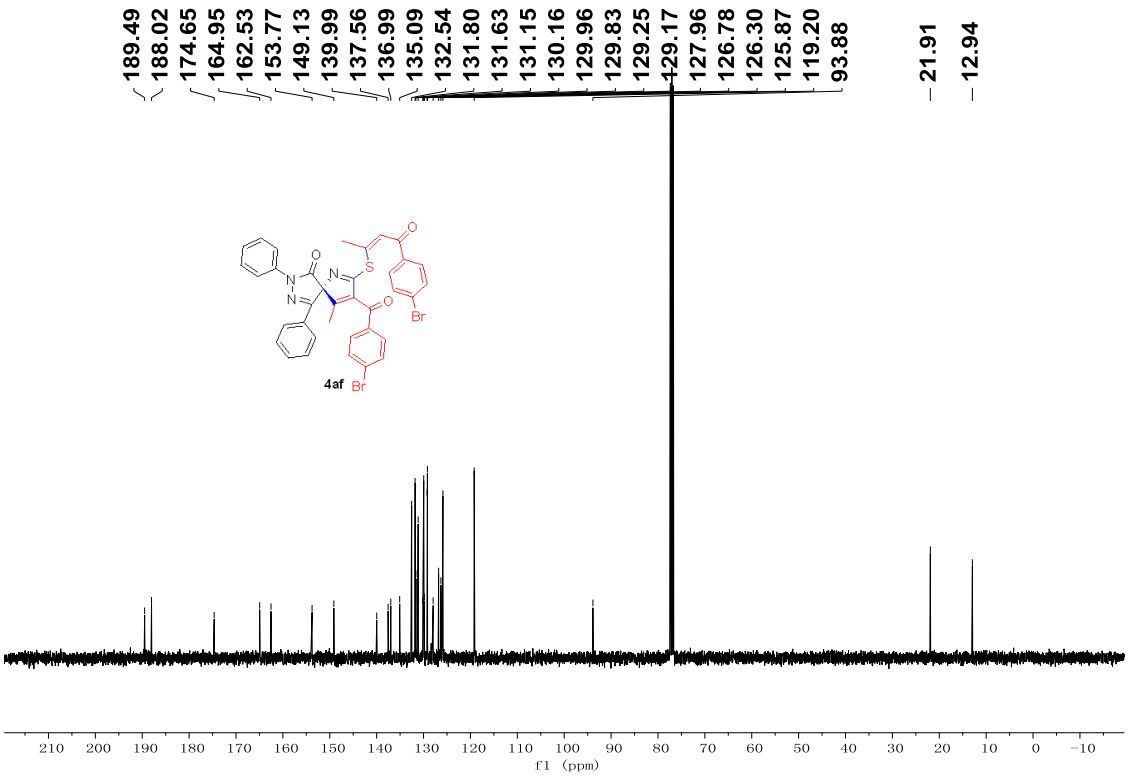
4af Br
2.09 2.06 4.05 1.04 2.11 2.94 4.19 1.10 3.00 3.00
f1 (ppm)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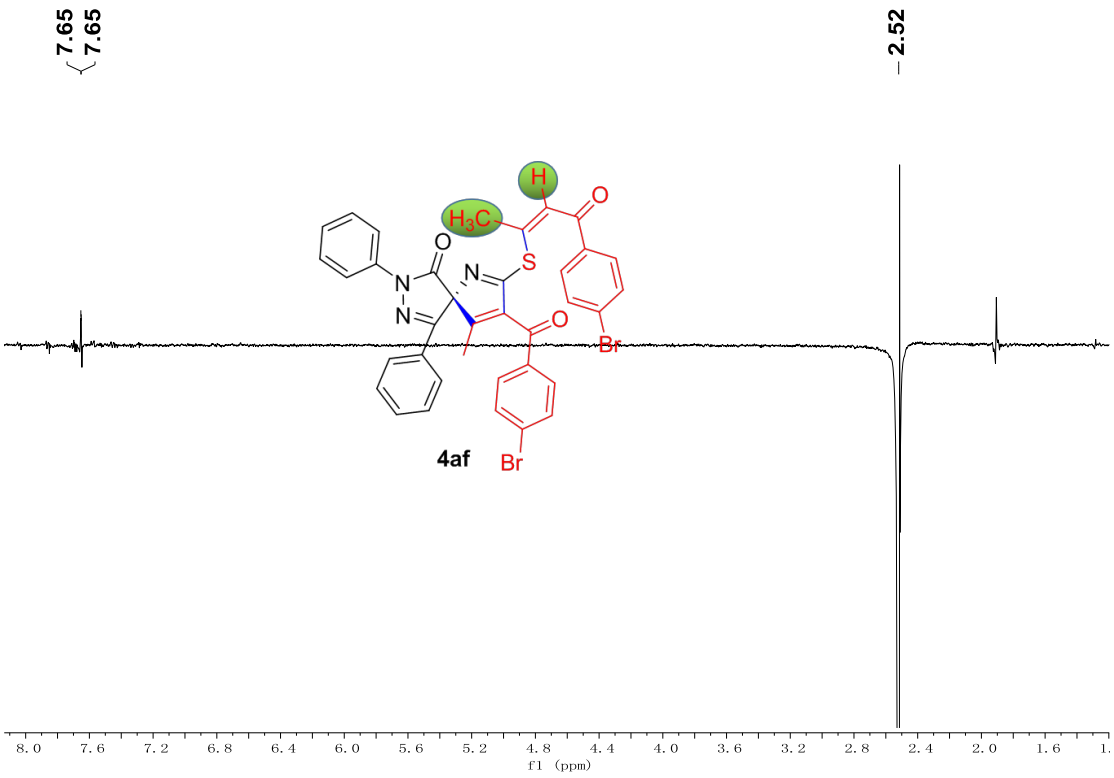
4af Br
f1 (ppm)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N
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O
Br
4af
Br
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7.2
6.8
6.4
6.0
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4.4
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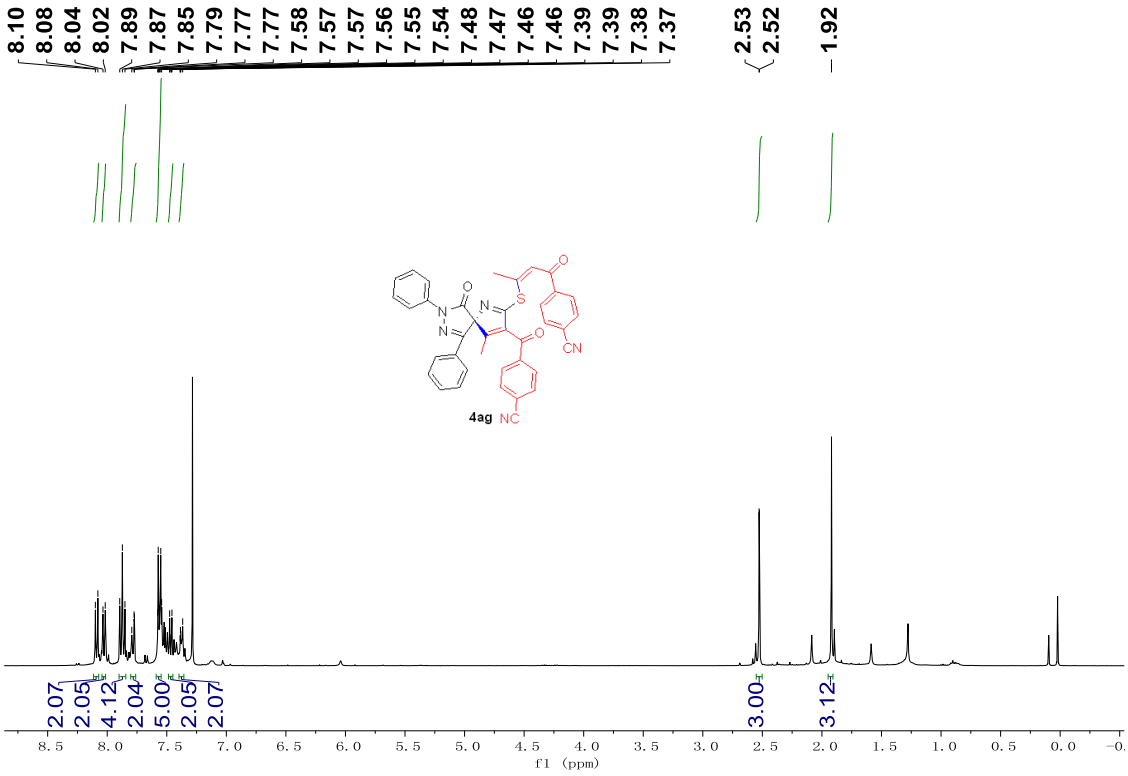
3.6
3.2
2.8
2.4
2.0
1.6
f1 (ppm)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7.56
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7.54
7.48
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7.46
7.46
7.39
7.39
7.38
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2.52
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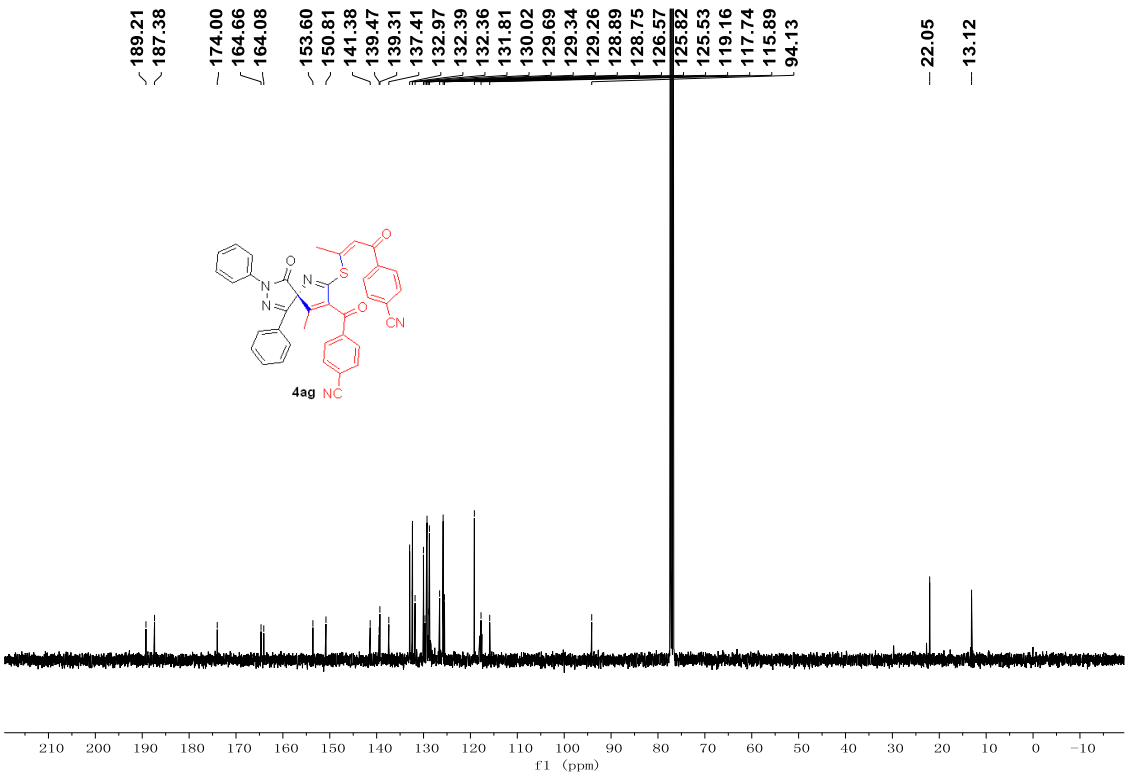
4.12
2.04
5.00
2.05
2.07
3.00
3.12
f1 (ppm)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119.16
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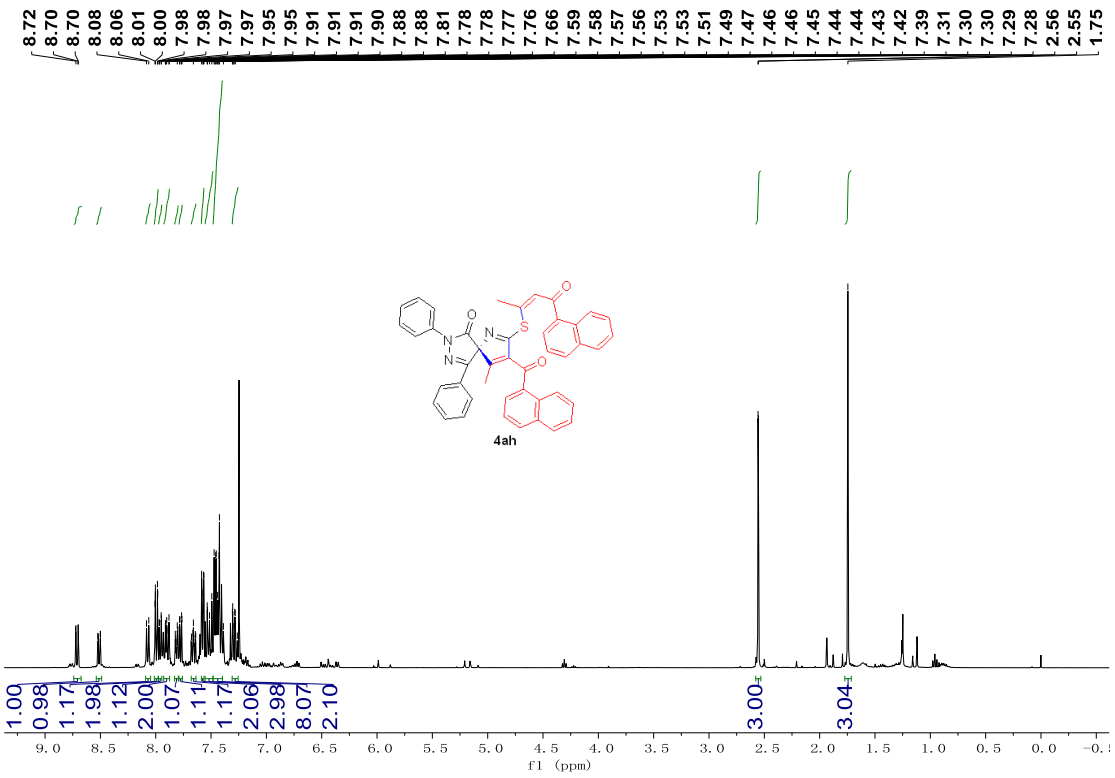
22.05
13.12
4ag NC
f1 (ppm)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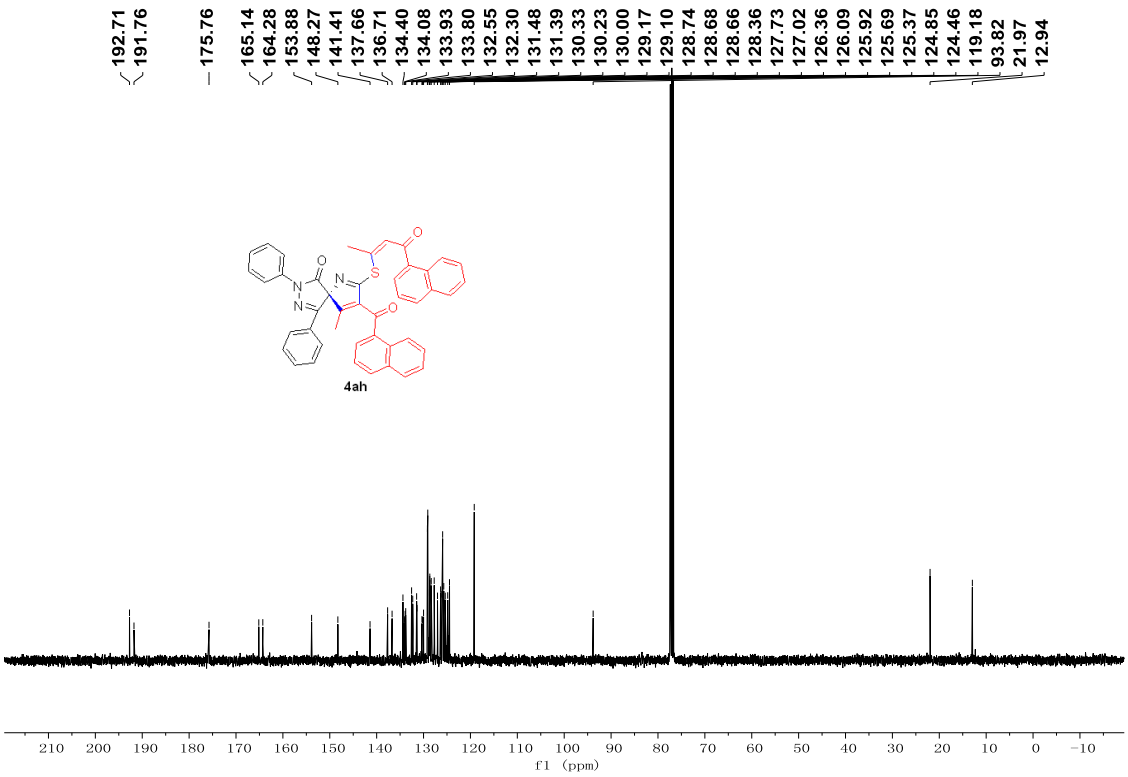
f1 (ppm)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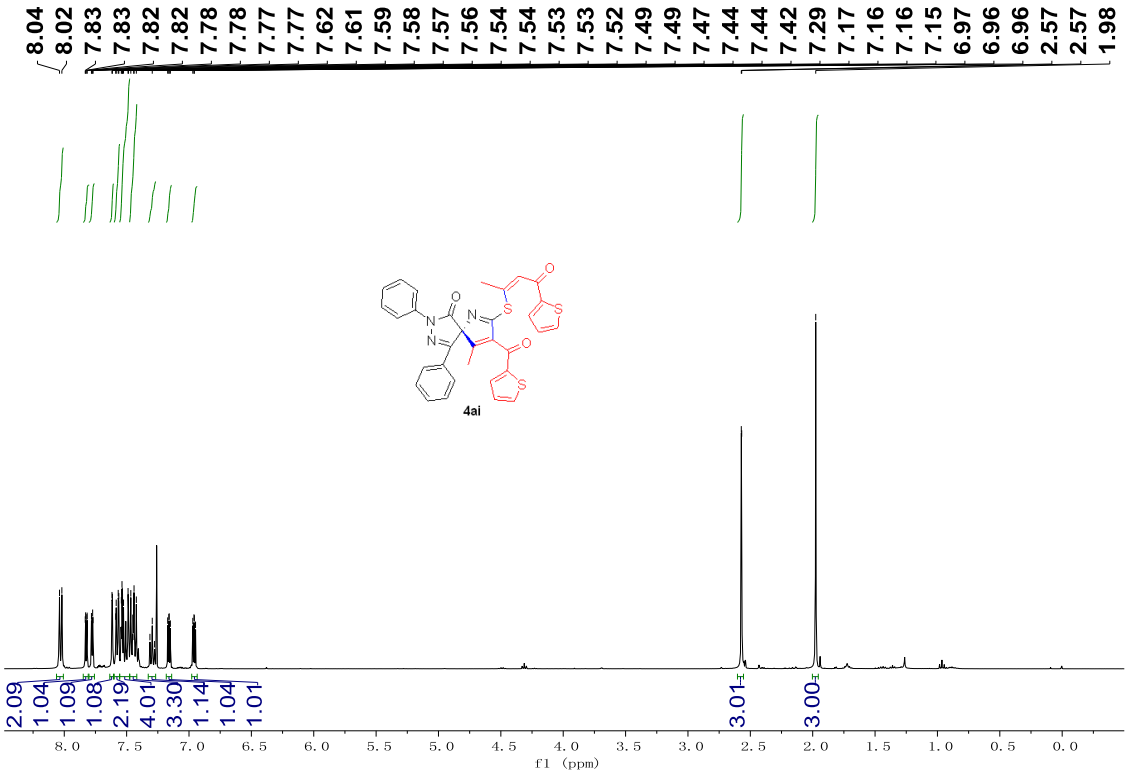
4ah
f1 (ppm)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6.97
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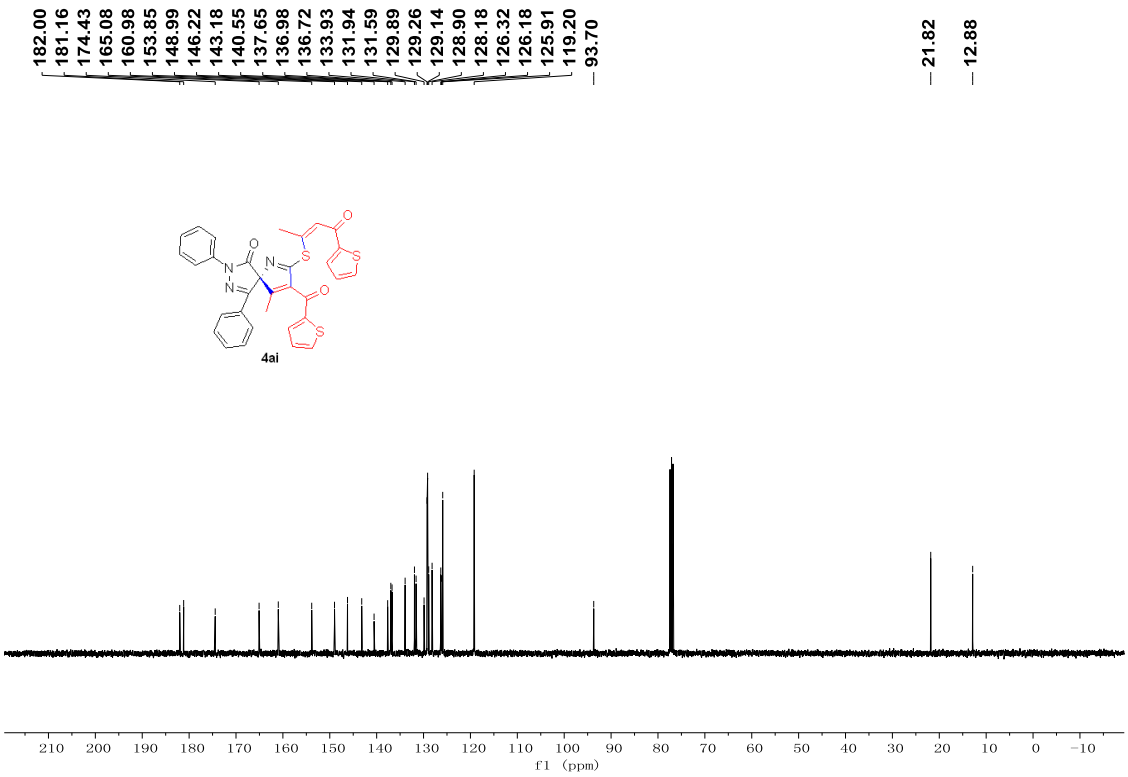
3.00
f1 (ppm)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131.94
131.59
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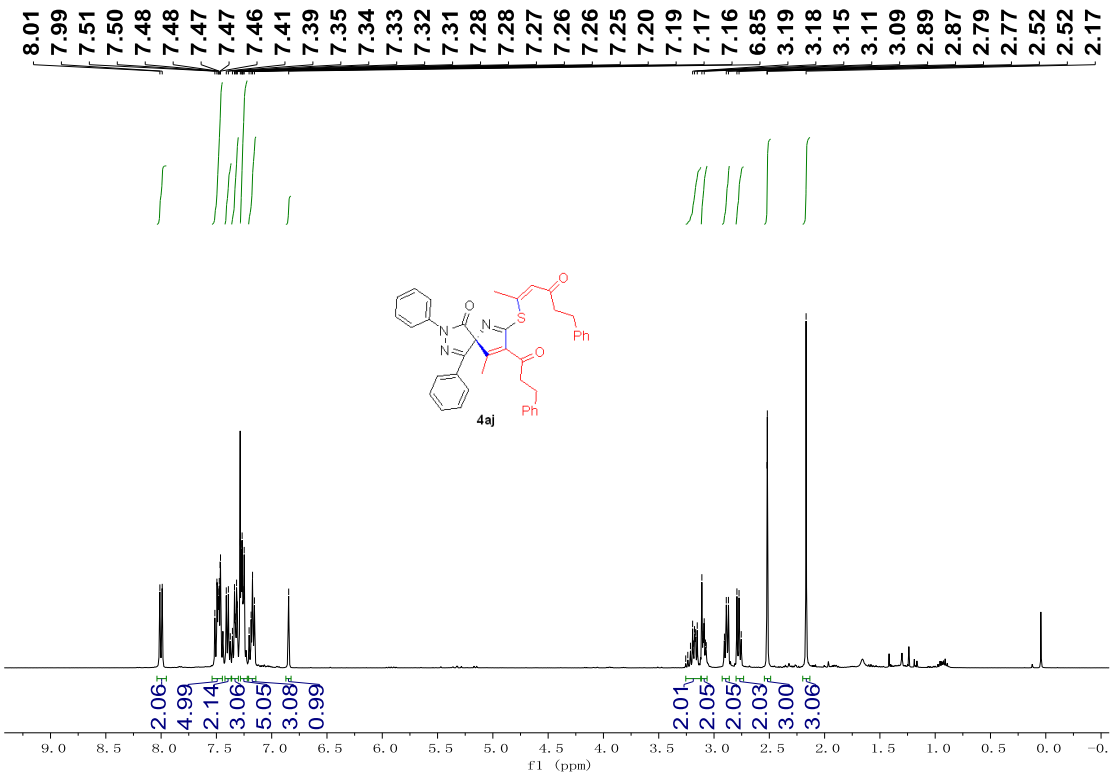
93.70
21.82
12.88
4ai
f1 (ppm)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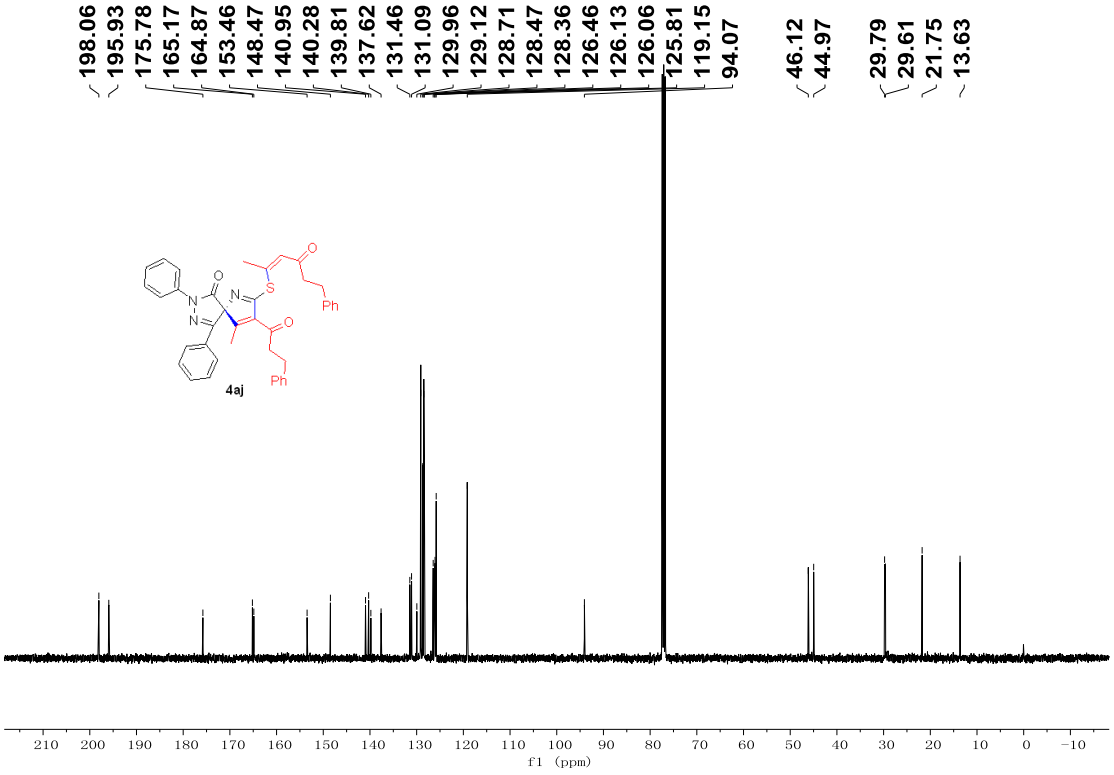
2.06 4.99 2.14 3.06 5.05 3.08 0.99
2.01 2.05 2.05 2.03 3.00 3.06
f1 (ppm)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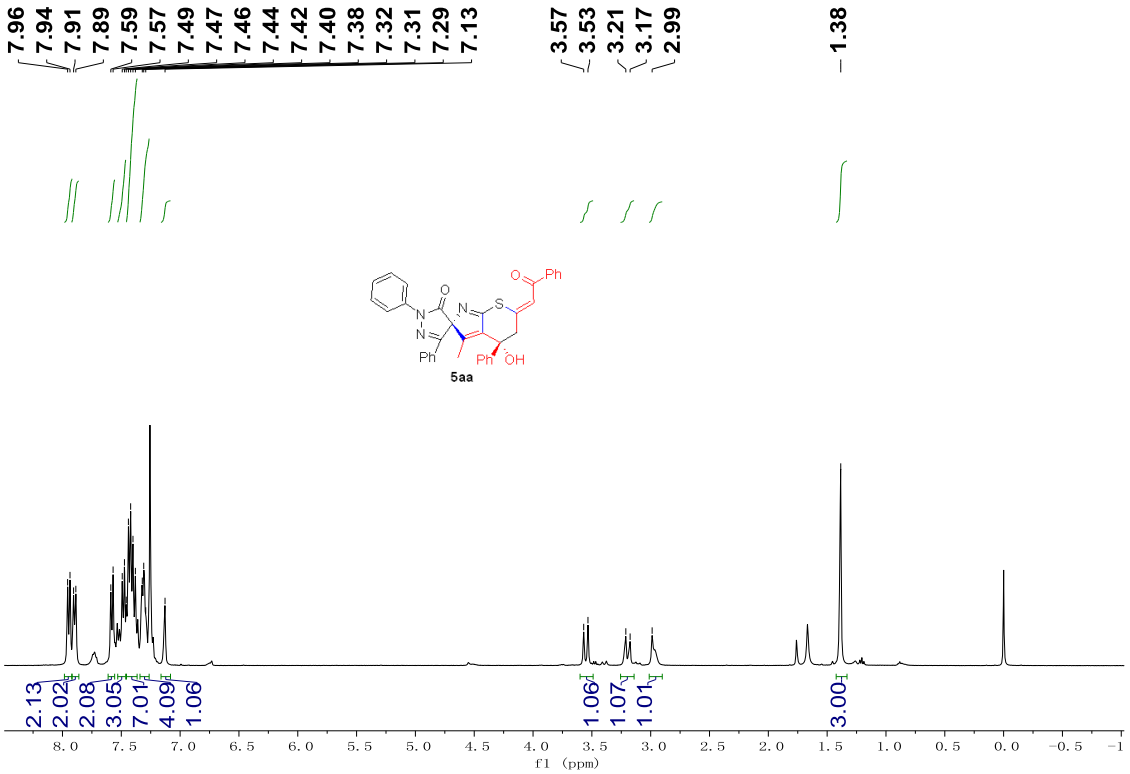
f1 (ppm)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3.17
2.99
1.38
5aa
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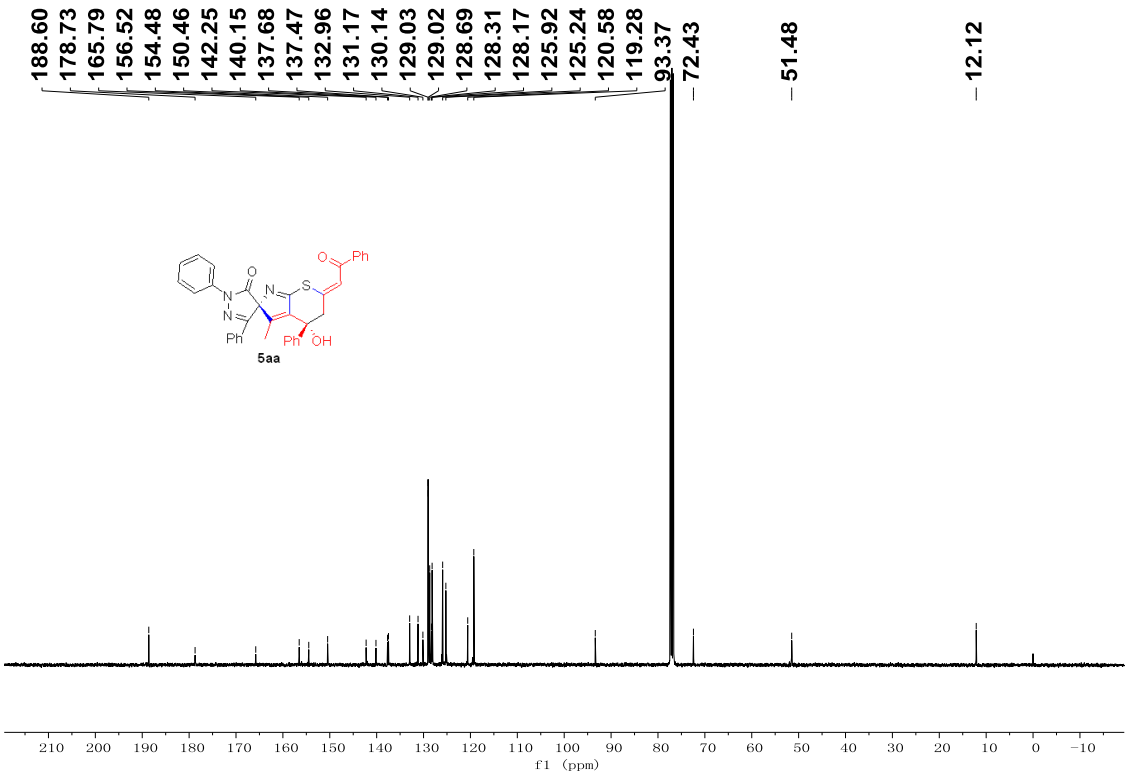
3.00
f1 (ppm)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72.43
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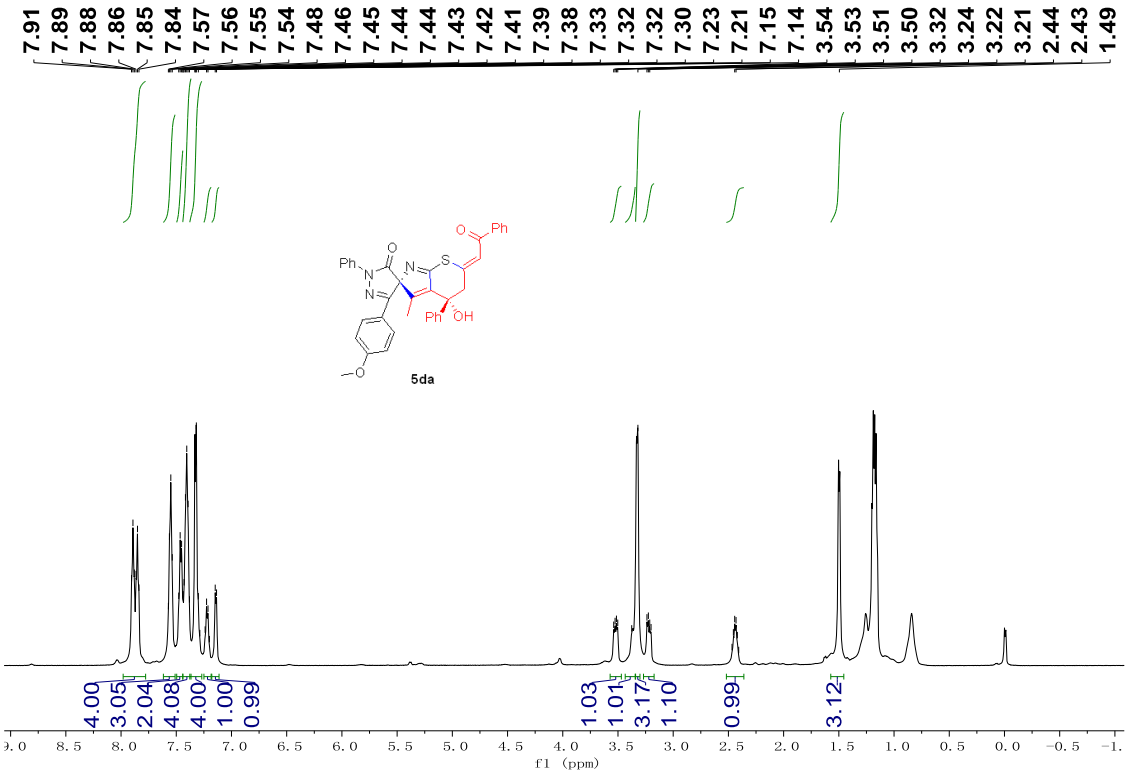
12.12
5aa
f1 (ppm)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1.01
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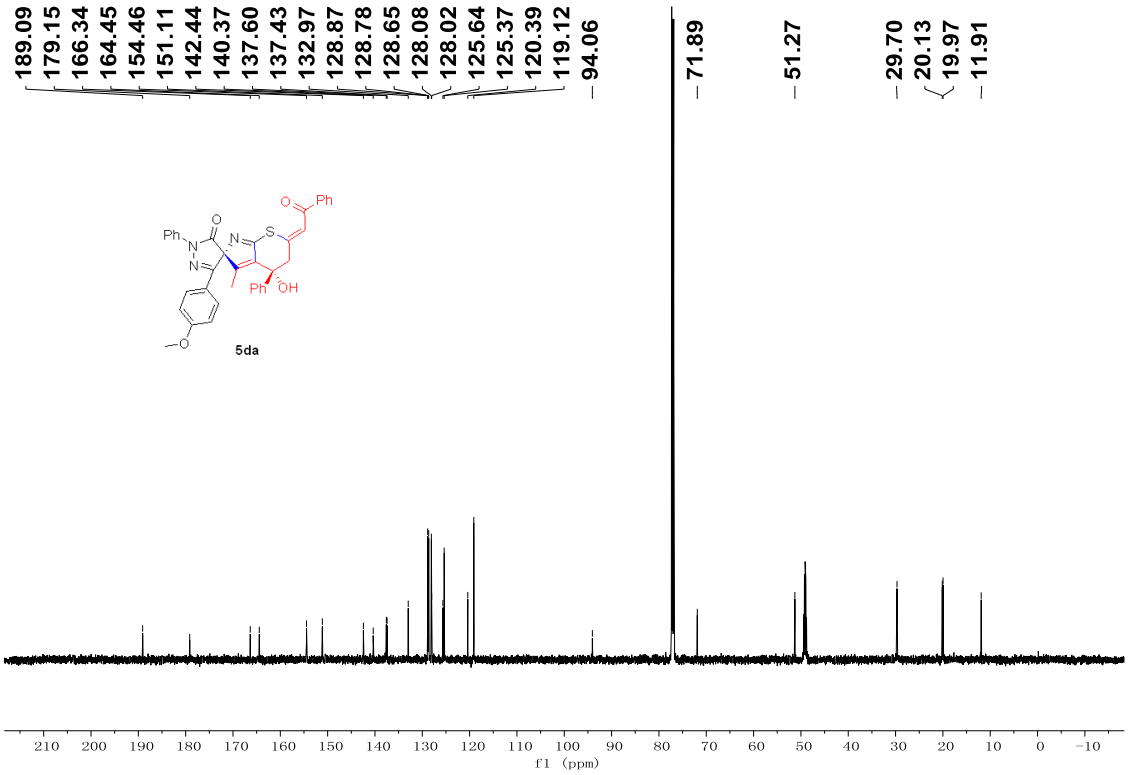
3.12
f1 (ppm)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132.97
128.87
128.78
128.65
128.08
128.02
125.64
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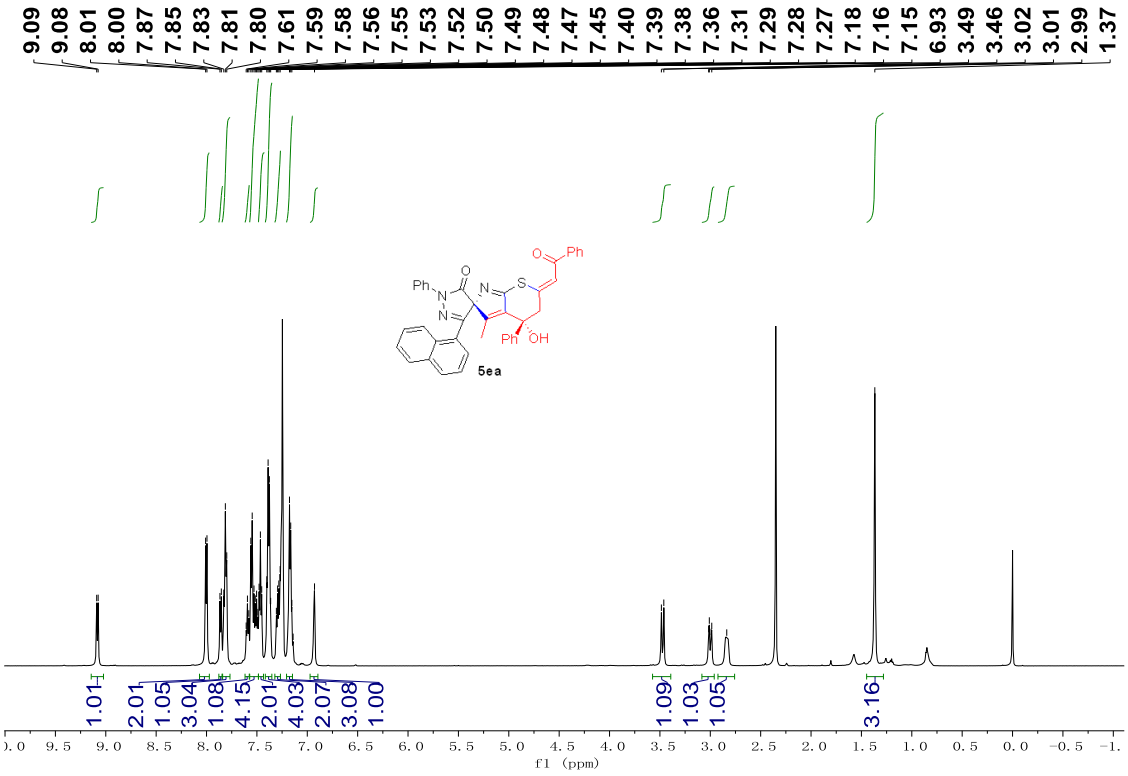
51.27
29.70
20.13
19.97
11.91
5da
f1 (ppm)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5ea
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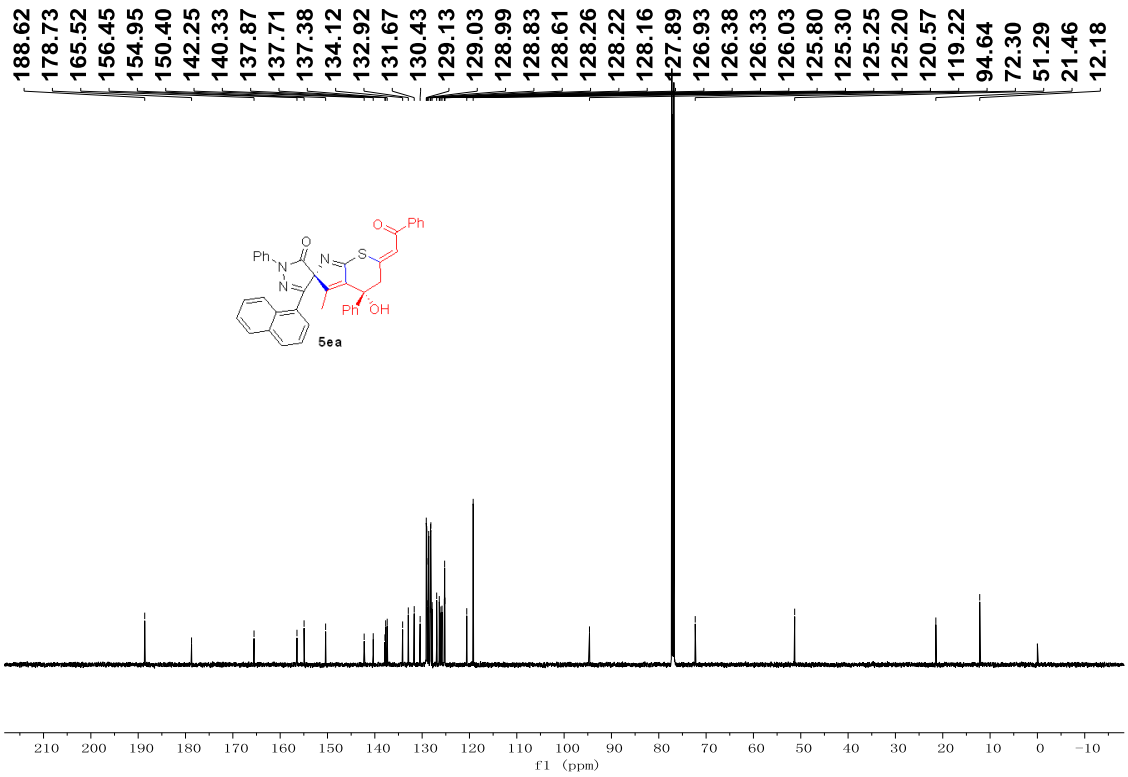
f1 (ppm)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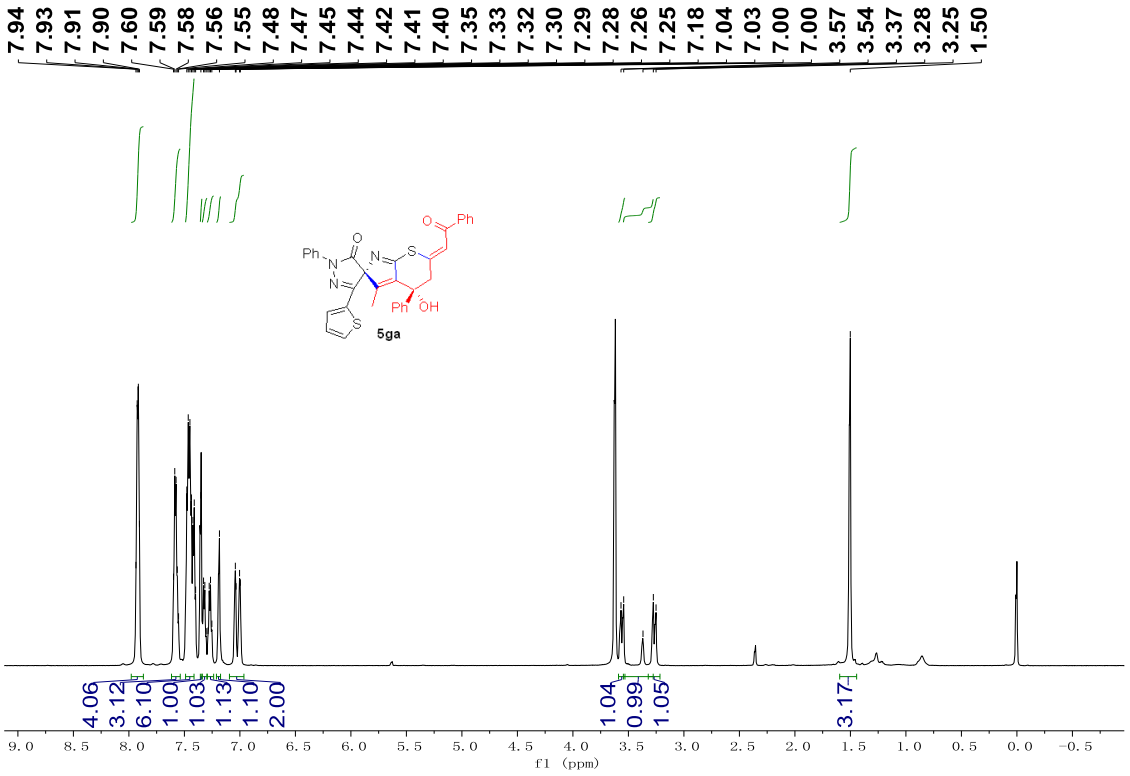
5ea
f1 (ppm)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7.42
7.41
7.40
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7.33
7.32
7.30
7.29
7.28
7.26
7.25
7.18
7.04
7.03
7.00
7.00
3.57
3.54
3.37
3.28
3.25
1.50
5ga
4.06
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1.10
2.00
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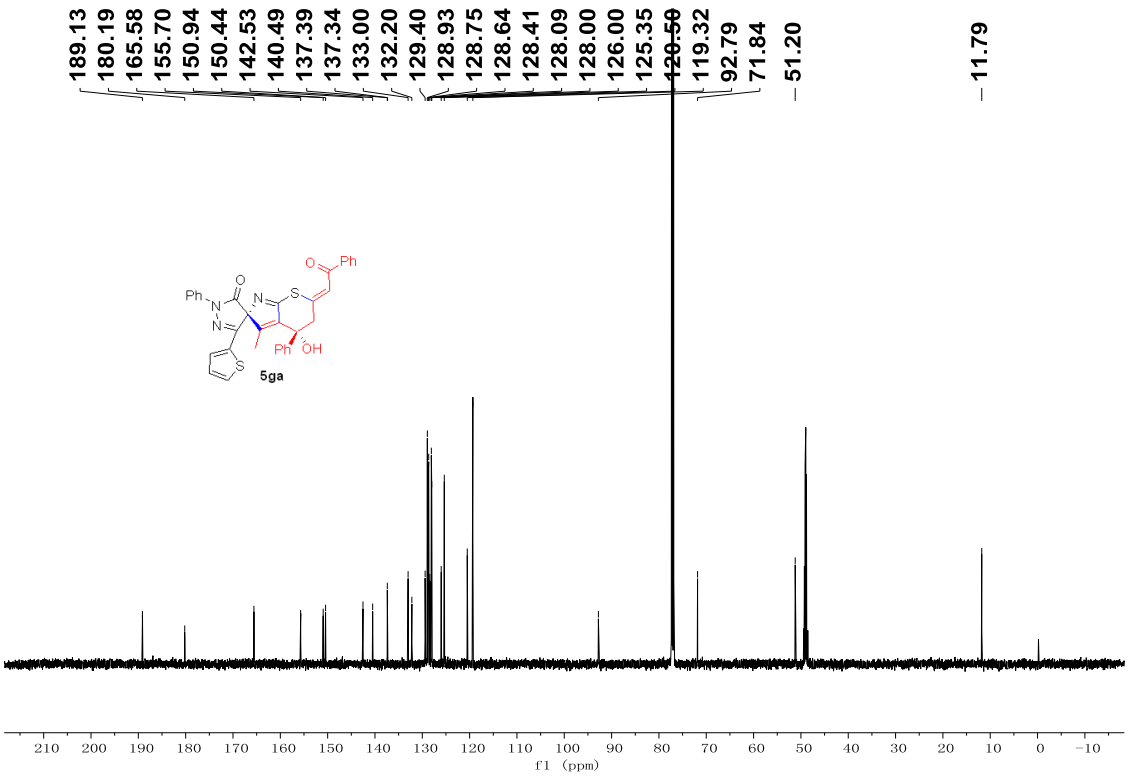
3.17
f1 (ppm)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128.64
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119.32
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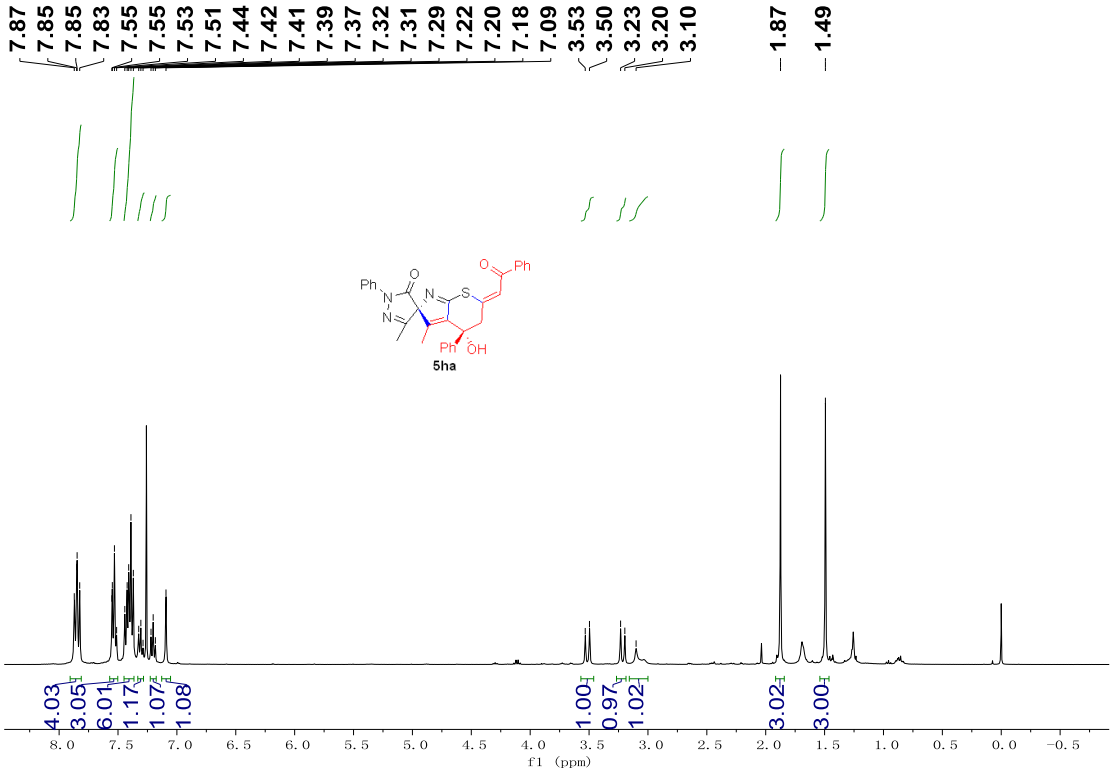
71.84
51.20
11.79
5ga
f1 (ppm)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7.37
7.32
7.31
7.29
7.22
7.20
7.18
7.09
3.53
3.50
3.23
3.20
3.10
1.87
1.49
5ha
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3.05
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1.07
1.08
1.00
0.97
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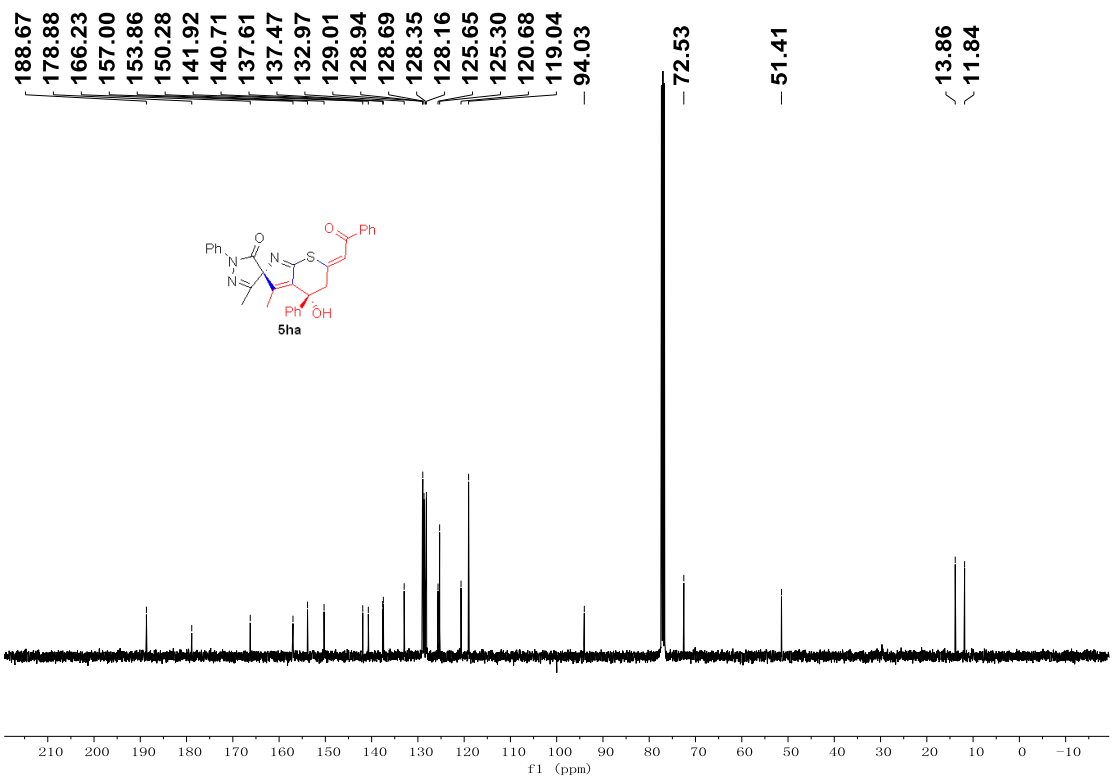
3.02
3.00
f1 (ppm)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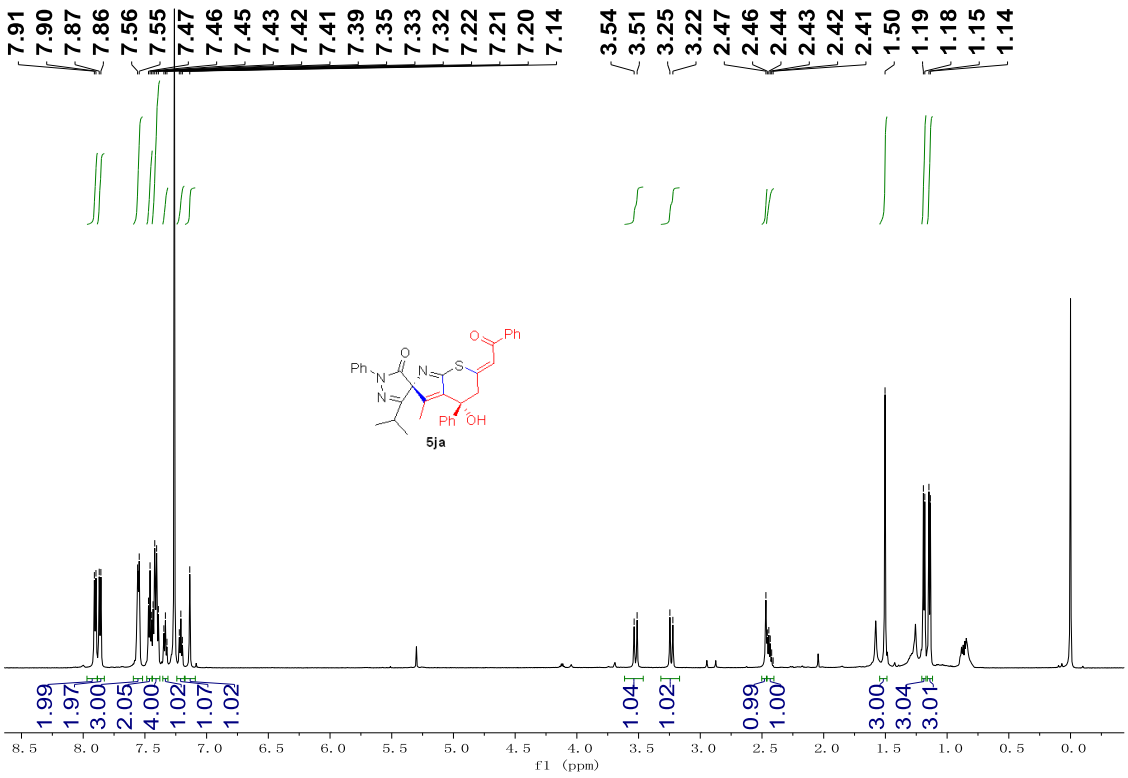
11.84
5ha
f1 (ppm)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7.14
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3.51
3.25
3.22
2.47
2.46
2.44
2.43
2.42
2.41
1.50
1.19
1.18
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1.14
5ja
1.99
1.97
3.00
2.05
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1.02
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3.00
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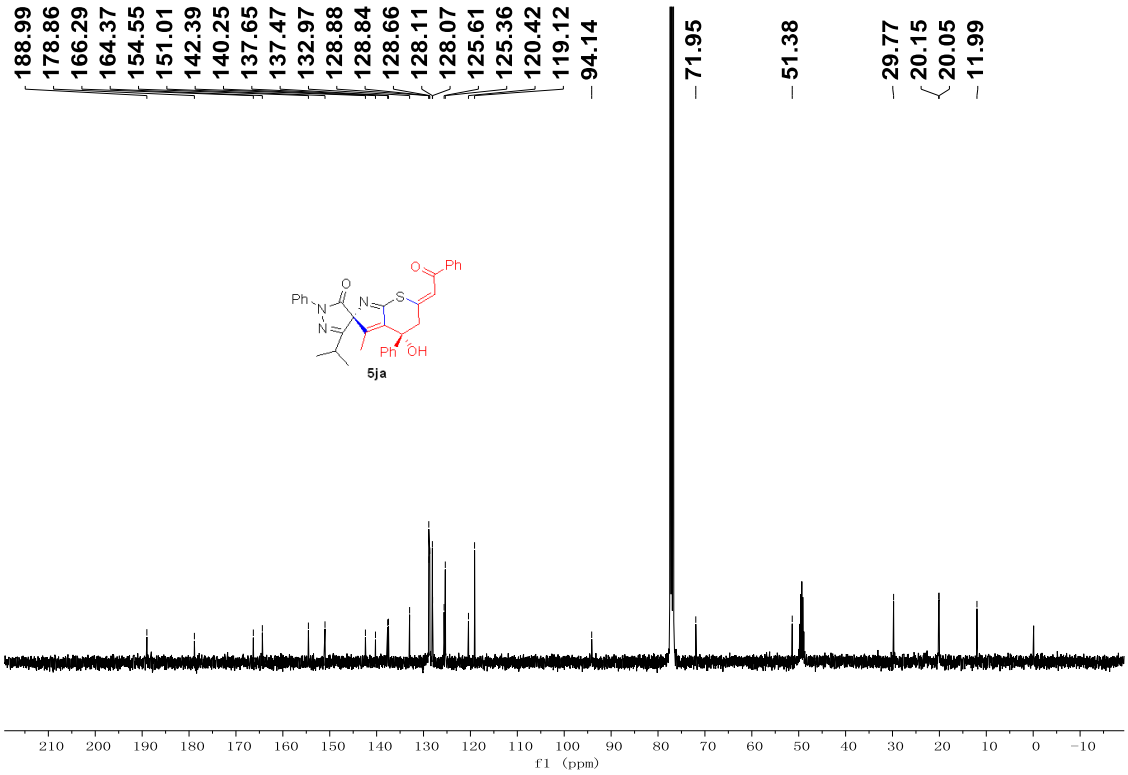
3.01
f1 (ppm)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128.11
128.07
125.61
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51.38
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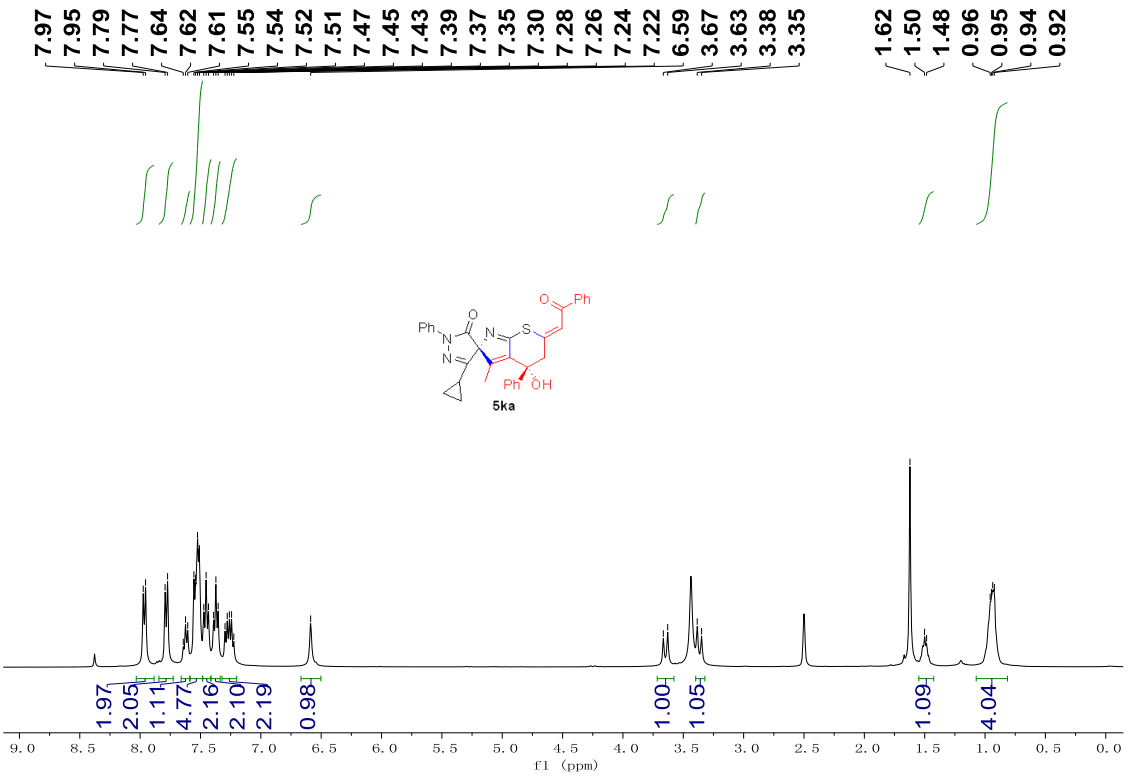
20.15
20.05
11.99
5ja
f1 (ppm)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7.43
7.39
7.37
7.35
7.30
7.28
7.26
7.24
7.22
6.59
3.67
3.63
3.38
3.35
1.62
1.50
1.48
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0.95
0.94
0.92
5ka
1.97
2.05
1.11
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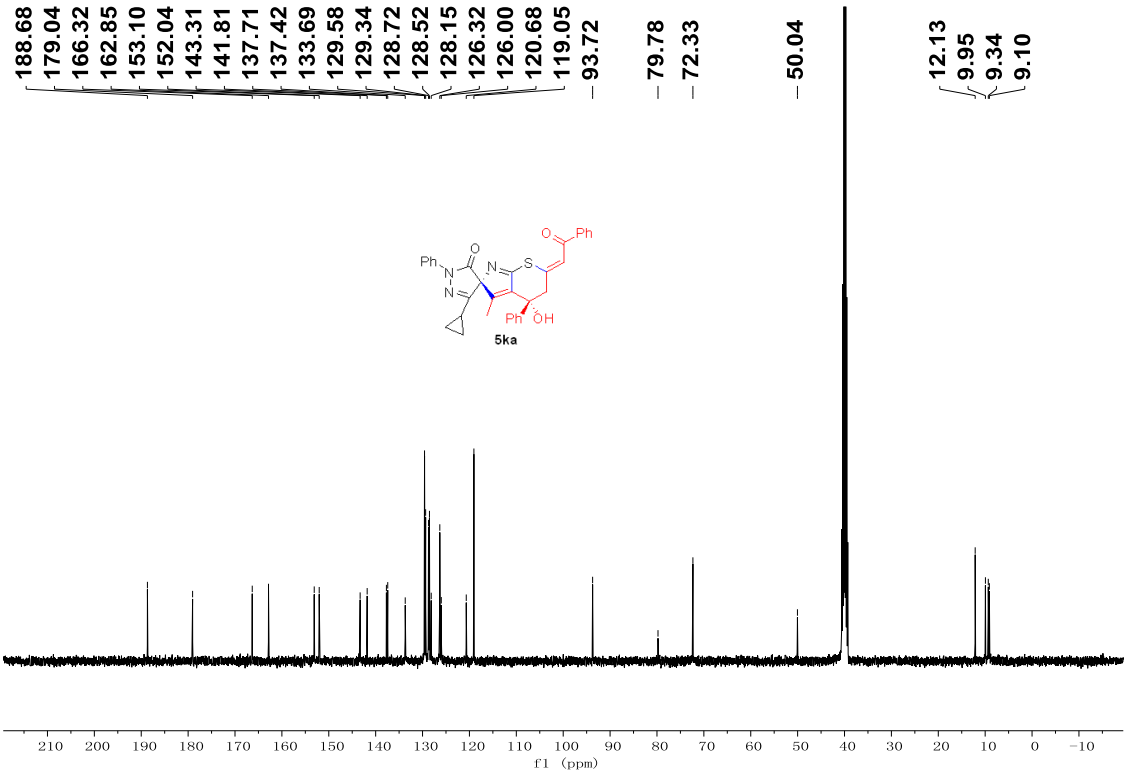
2.16
2.10
2.19
0.98
1.00
1.05
1.09
4.04
f1 (ppm)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128.52
128.15
126.32
126.00
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9.95
9.34
9.10
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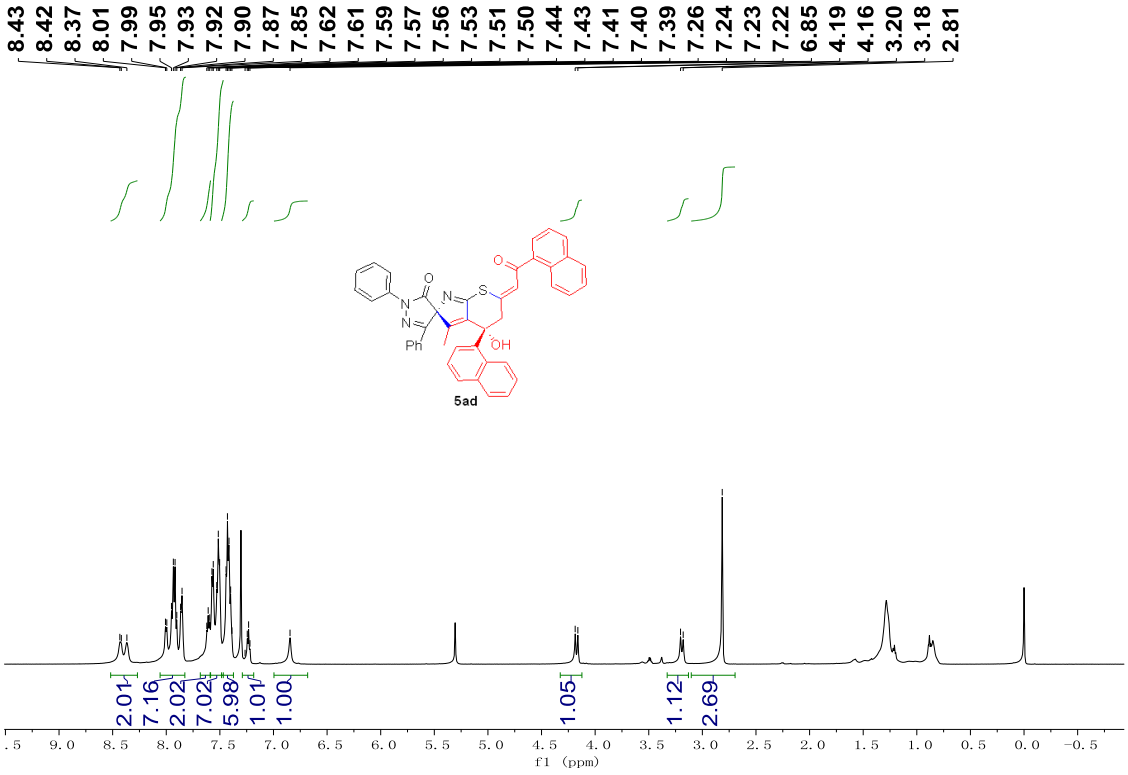
f1 (ppm)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7.85
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7.61
7.59
7.57
7.56
7.53
7.51
7.50
7.44
7.43
7.41
7.40
7.39
7.26
7.24
7.23
7.22
6.85
4.19
4.16
3.20
3.18
2.81
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2.02
7.02
5.98
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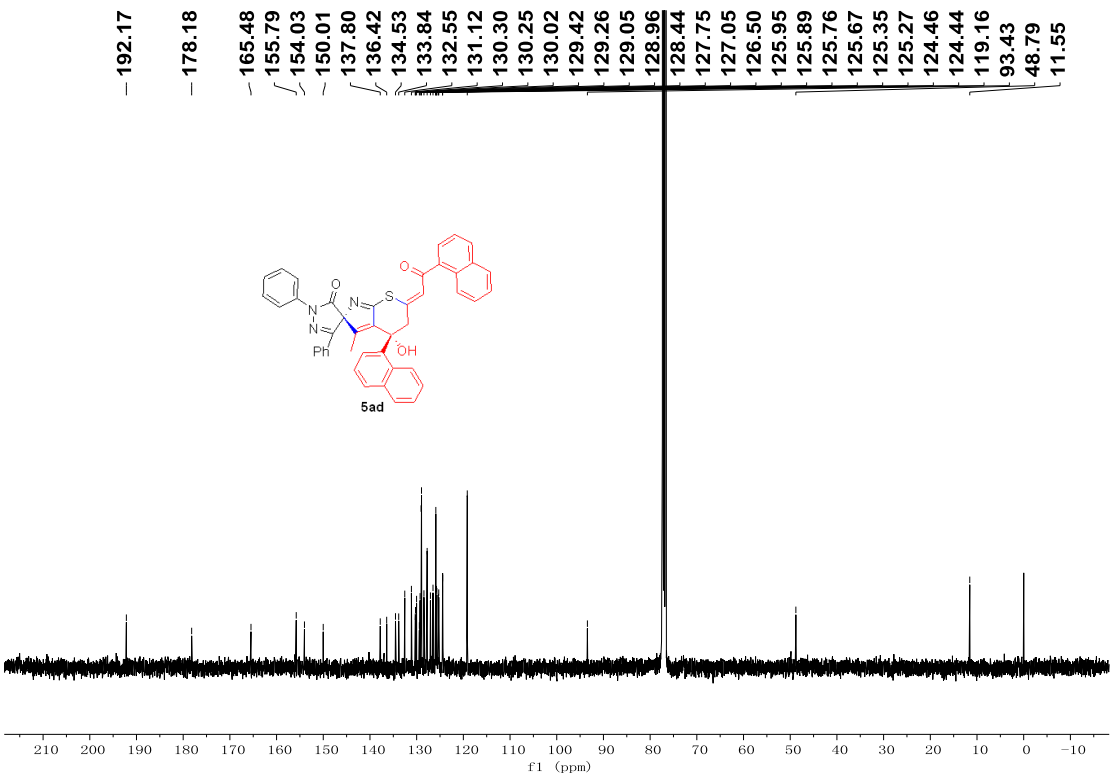
1.00
1.05
1.12
2.69
f1 (ppm)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130.25
130.02
129.42
129.26
129.05
128.96
128.44
127.75
127.05
126.50
125.95
125.89
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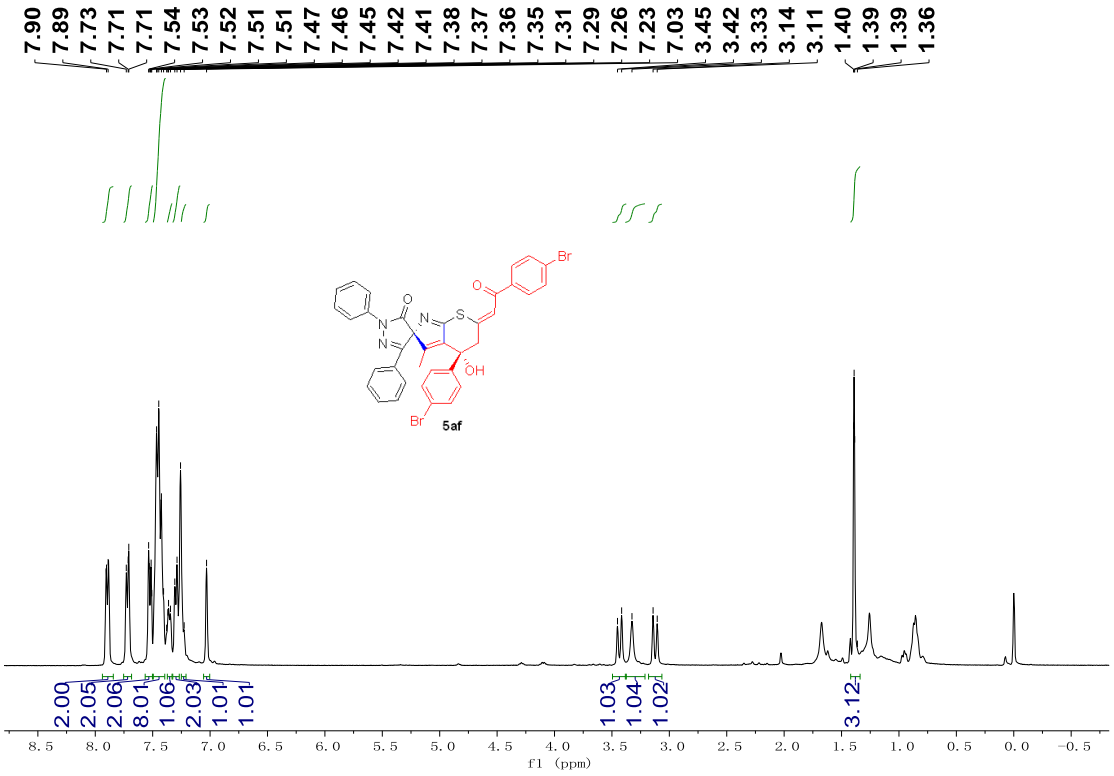
48.79
11.55
5ad
f1 (ppm)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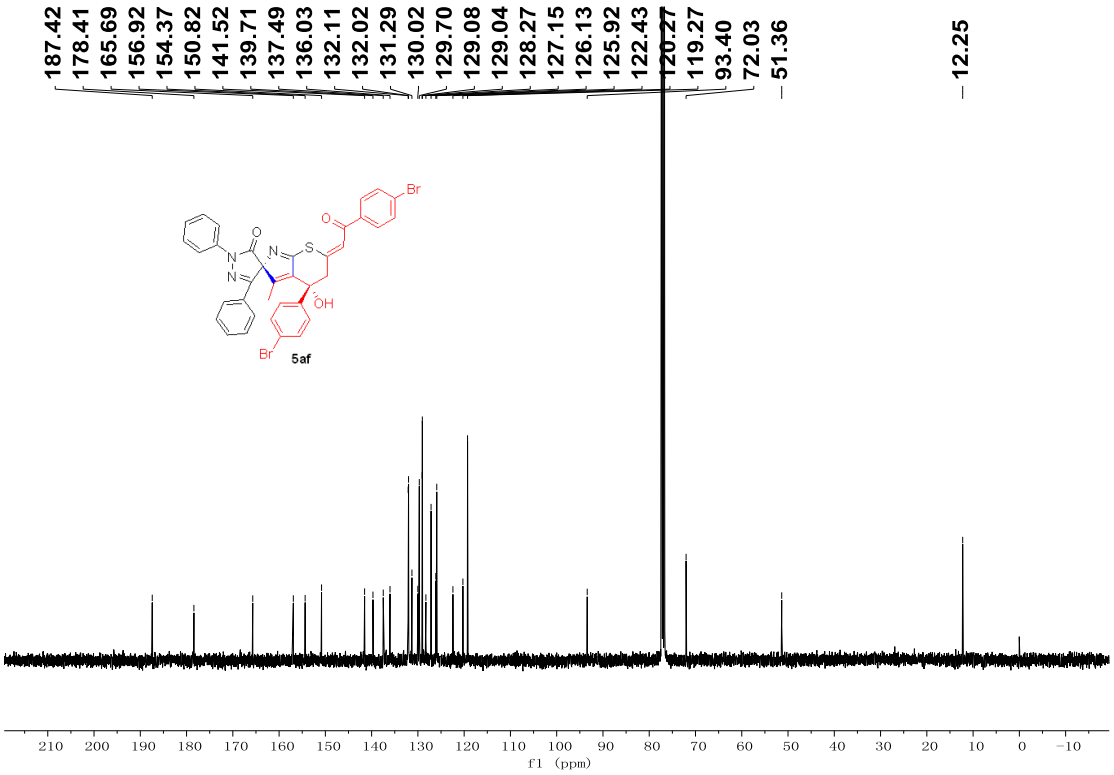
1.03
1.04
1.02
3.12
f1 (ppm)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130.02
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129.08
129.04
128.27
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122.43
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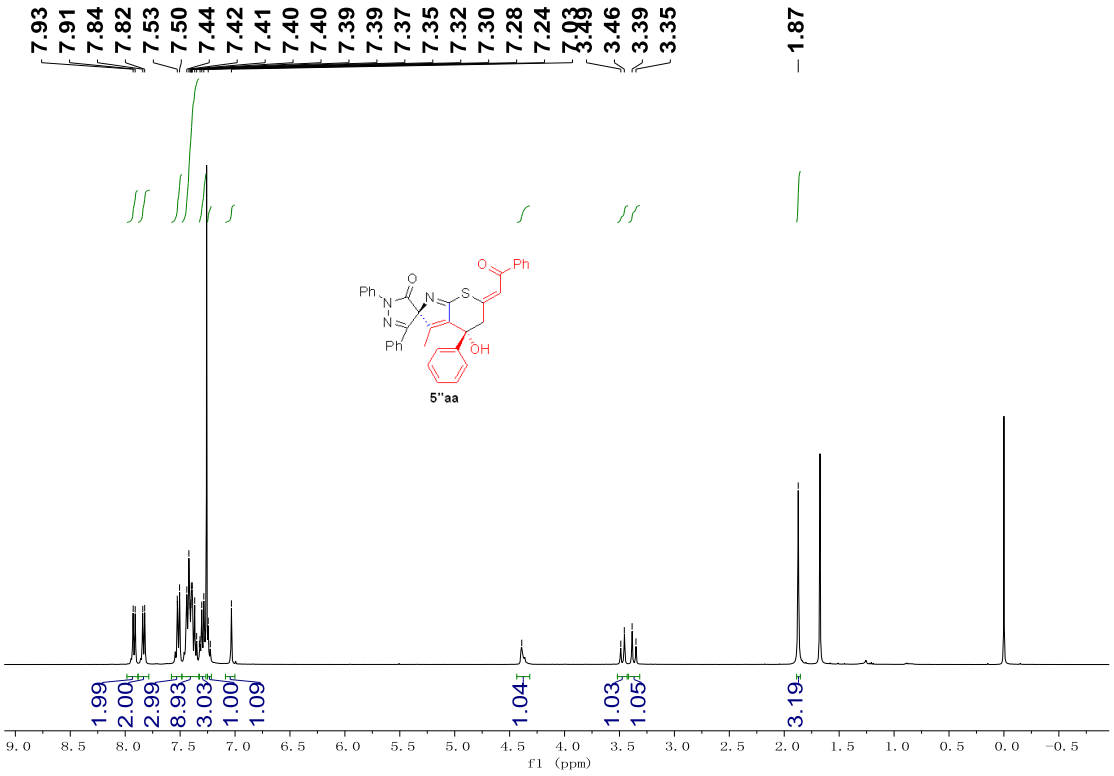
119.27
93.40
72.03
51.36
12.25
5af
f1 (ppm)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7.39
7.37
7.35
7.32
7.30
7.28
7.24
7.03
3.49
3.46
3.39
3.35
1.87
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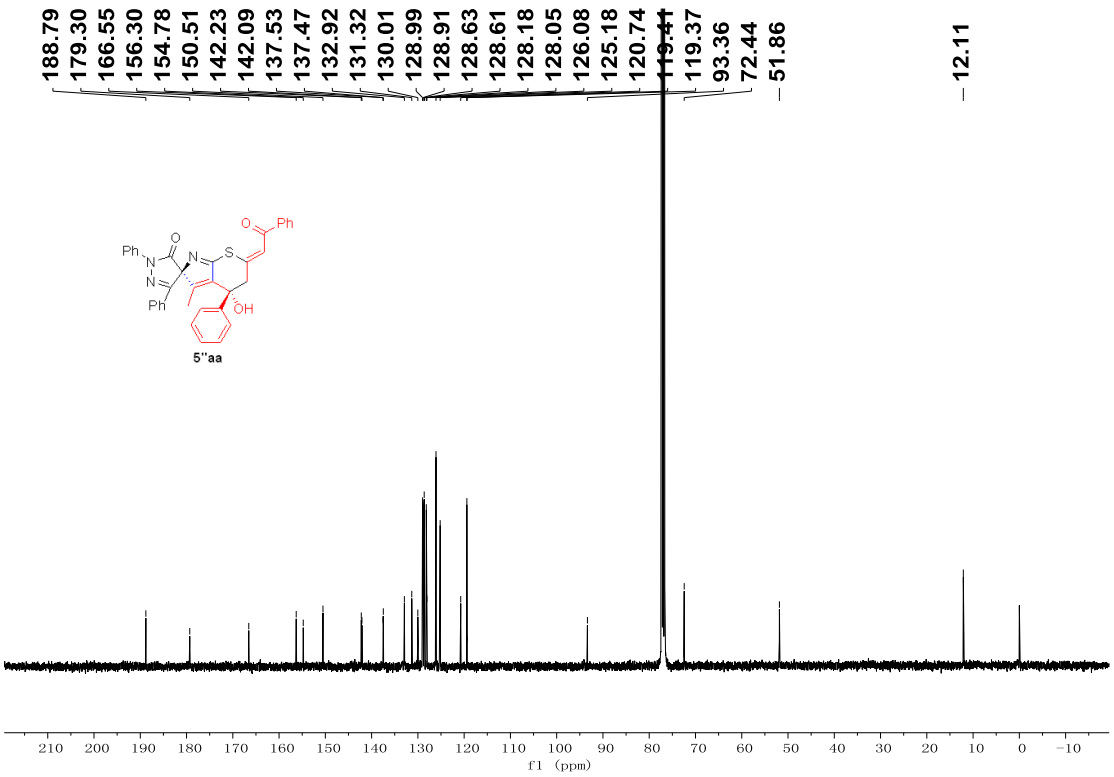
1.04
1.03
1.05
3.19
f1 (ppm)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128.99
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128.63
128.61
128.18
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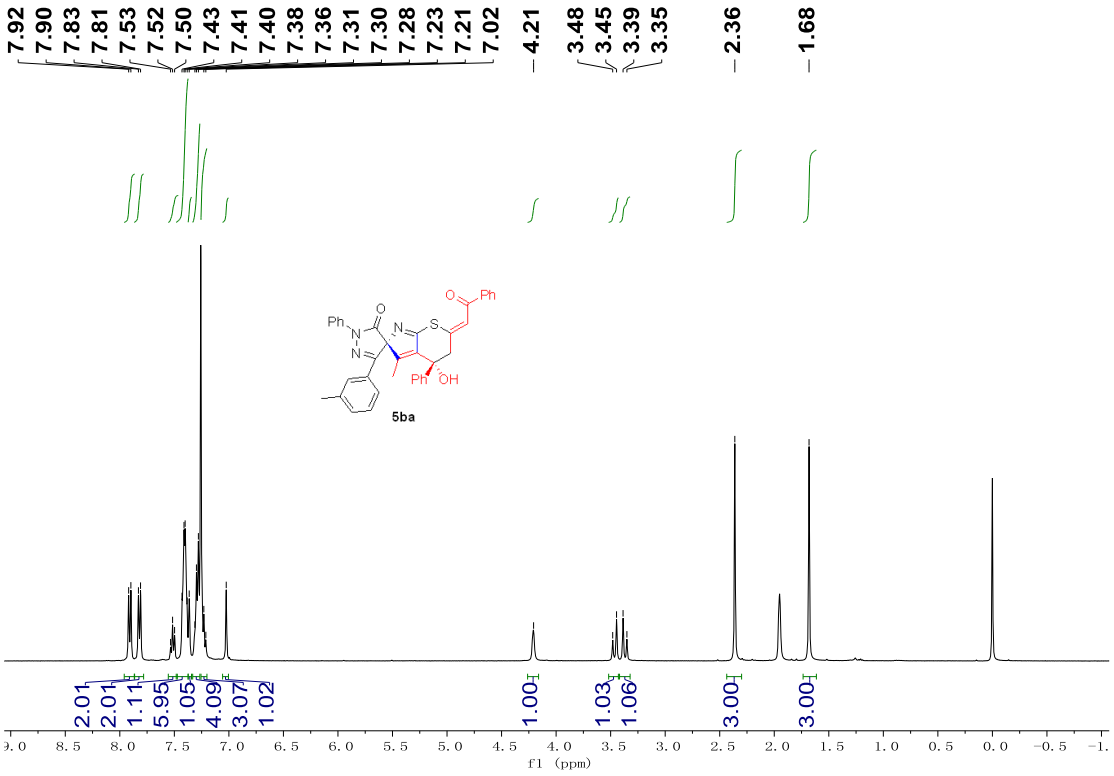
51.86
12.11
5''aa
f1 (ppm)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7.30
7.28
7.23
7.21
7.02
4.21
3.48
3.45
3.39
3.35
2.36
1.68
5ba
2.01
2.01
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4.09
3.07
1.02
1.00
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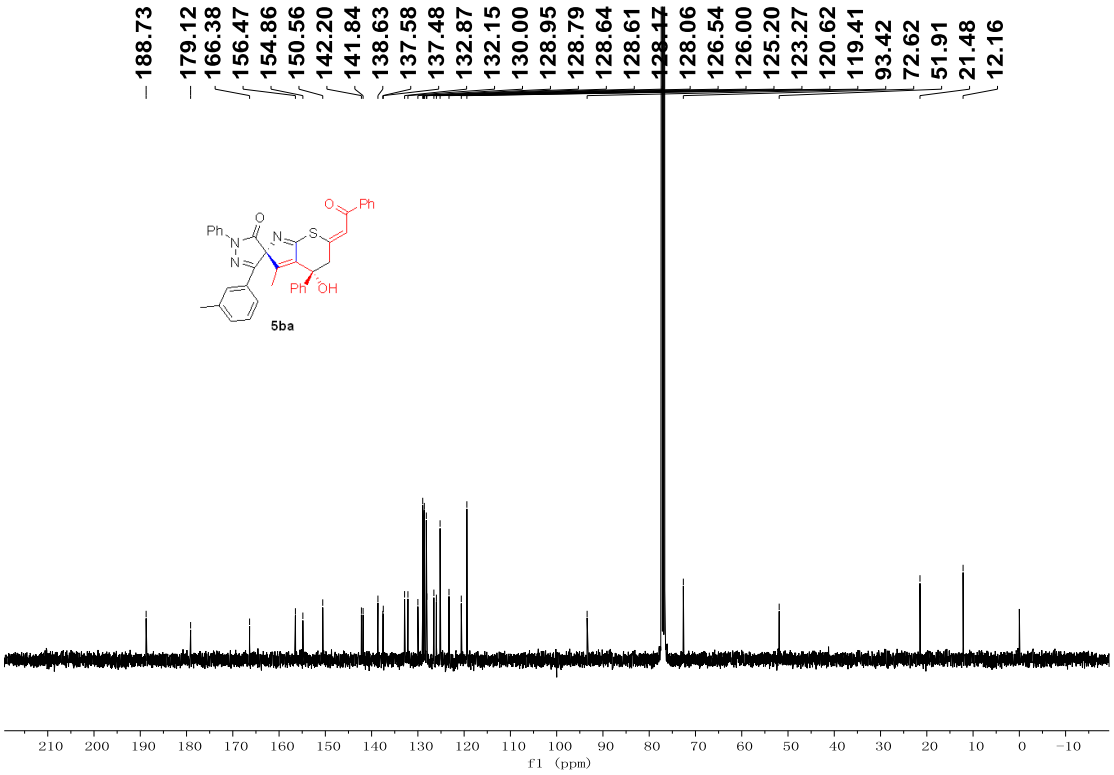
1.06
3.00
3.00
f1 (ppm)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128.79
128.64
128.61
128.17
128.06
126.54
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120.62
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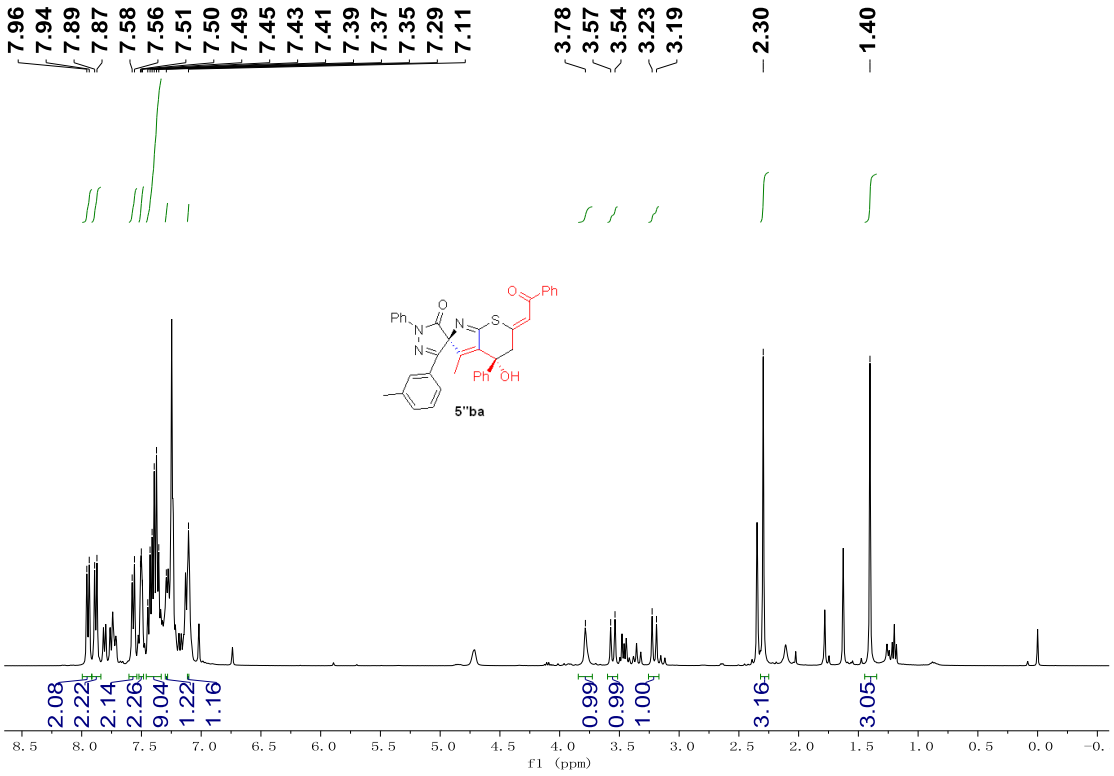
93.42
72.62
51.91
21.48
12.16
5ba
f1 (ppm)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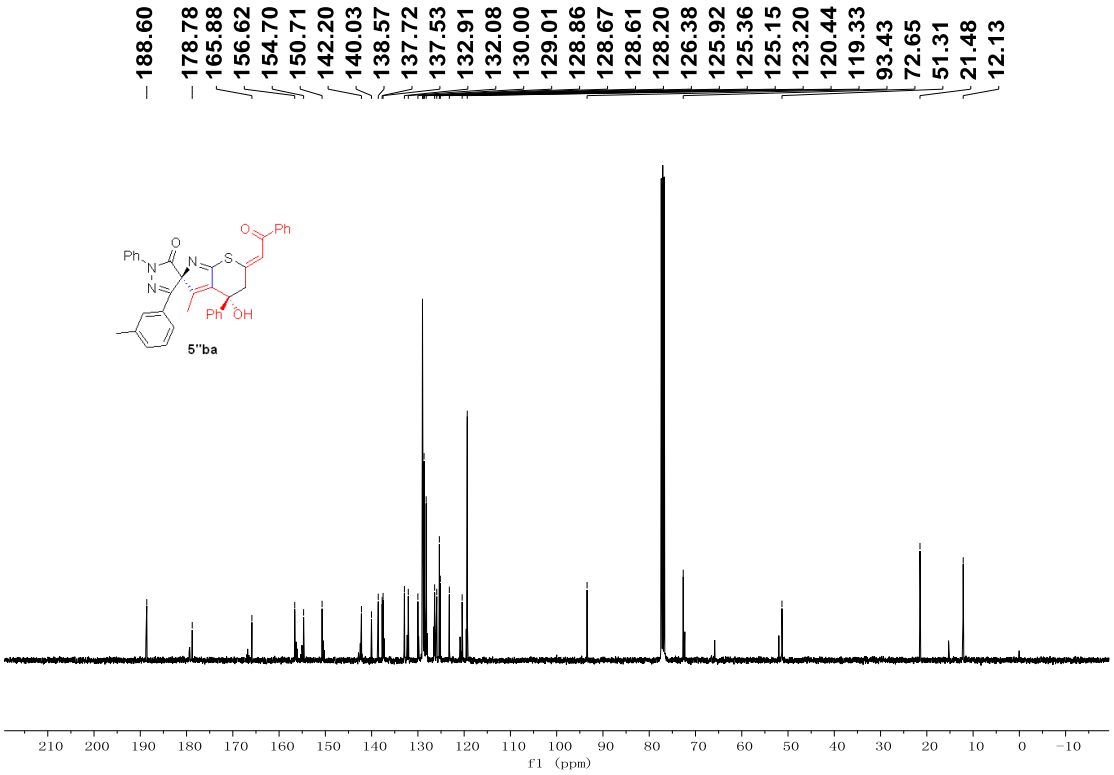
7.41
7.39
7.37
7.35
7.29
7.11
3.78
3.57
3.54
3.23
3.19
2.30
1.40
5''ba
2.08
2.22
2.14
2.26
9.04
1.22
1.16
0.99
0.99
1.00
3.16
3.05
f1 (ppm)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137.72
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132.91
132.08
130.00
129.01
128.86
128.67
128.61
128.20
126.38
125.92
125.36
125.15
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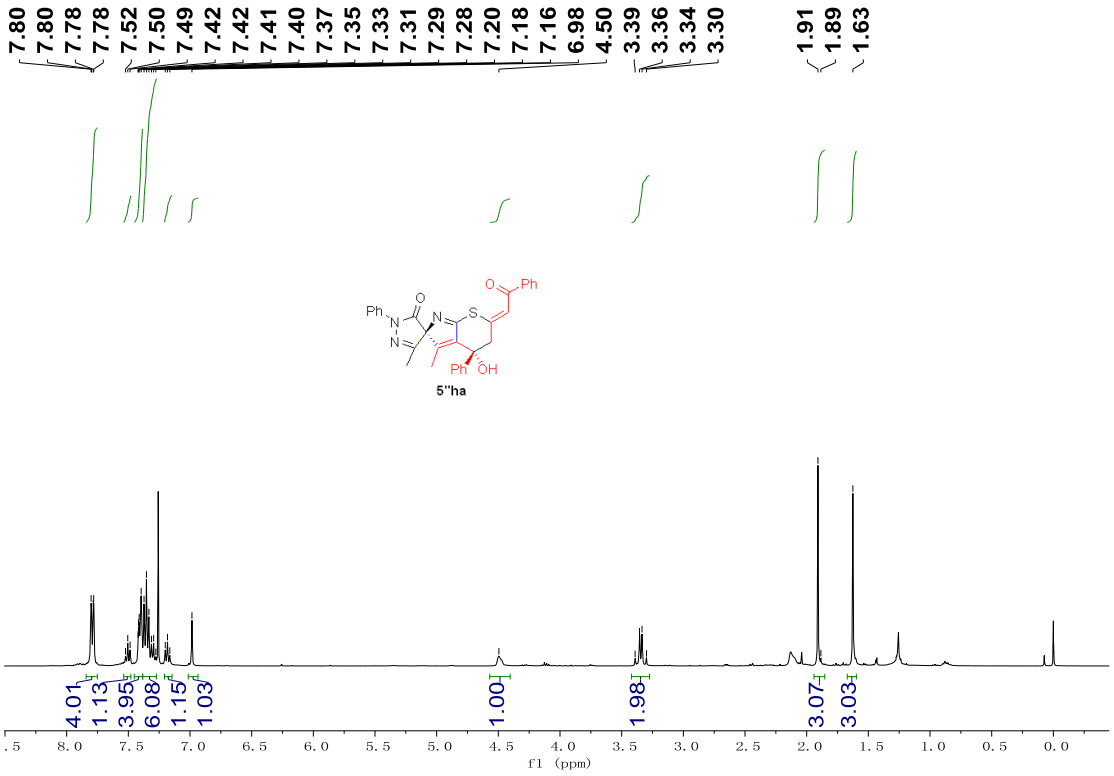
120.44
119.33
93.43
72.65
51.31
21.48
12.13
5''ba
f1 (ppm)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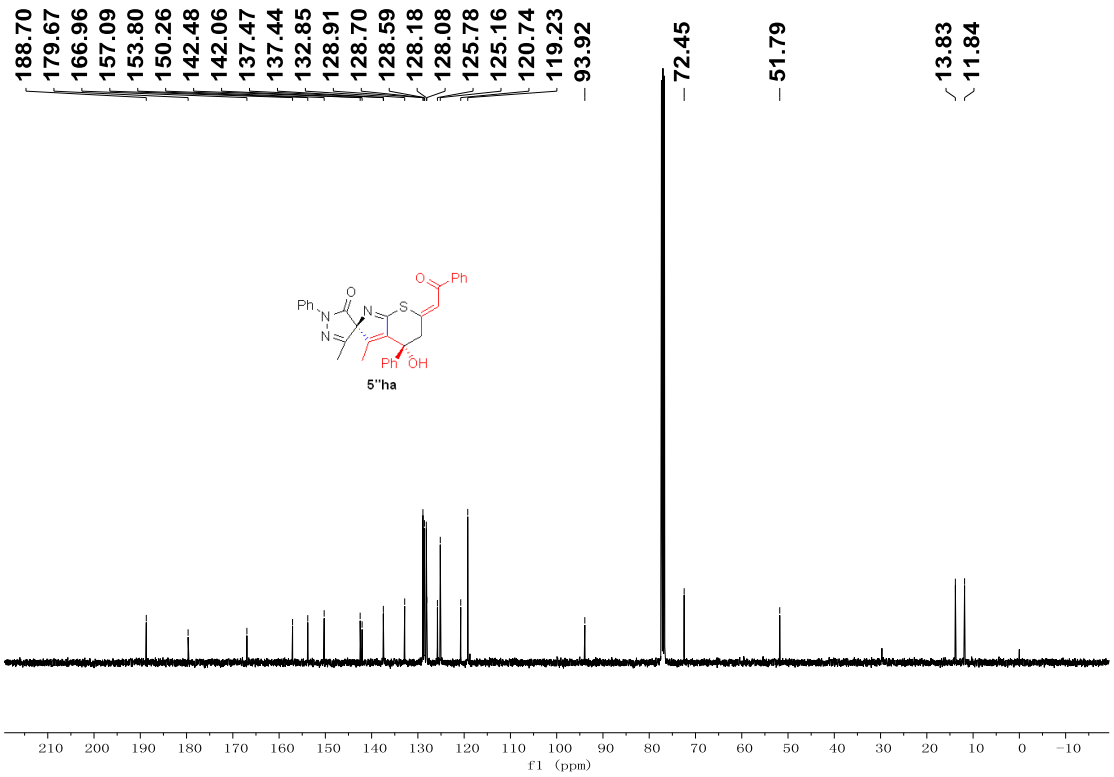
7.31
7.29
7.28
7.20
7.18
7.16
6.98
4.50
3.39
3.36
3.34
3.30
1.91
1.89
1.63
5"ha
4.01
1.13
3.95
6.08
1.15
1.03
1.00
1.98
3.07
3.03
f1 (ppm)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128.59
128.18
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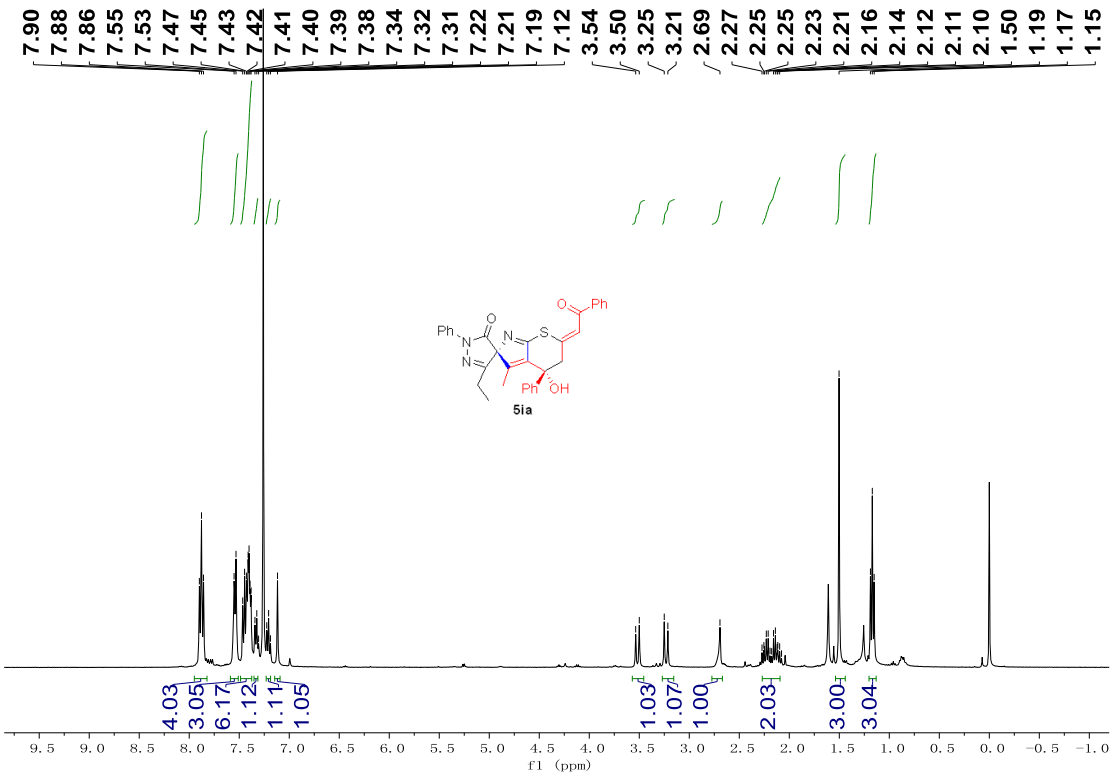
120.74
119.23
93.92
72.45
51.79
13.83
11.84
5"ha
f1 (ppm)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2.23
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2.14
2.12
2.11
2.10
1.50
1.19
1.17
1.15
5ia
4.03
3.05
6.17
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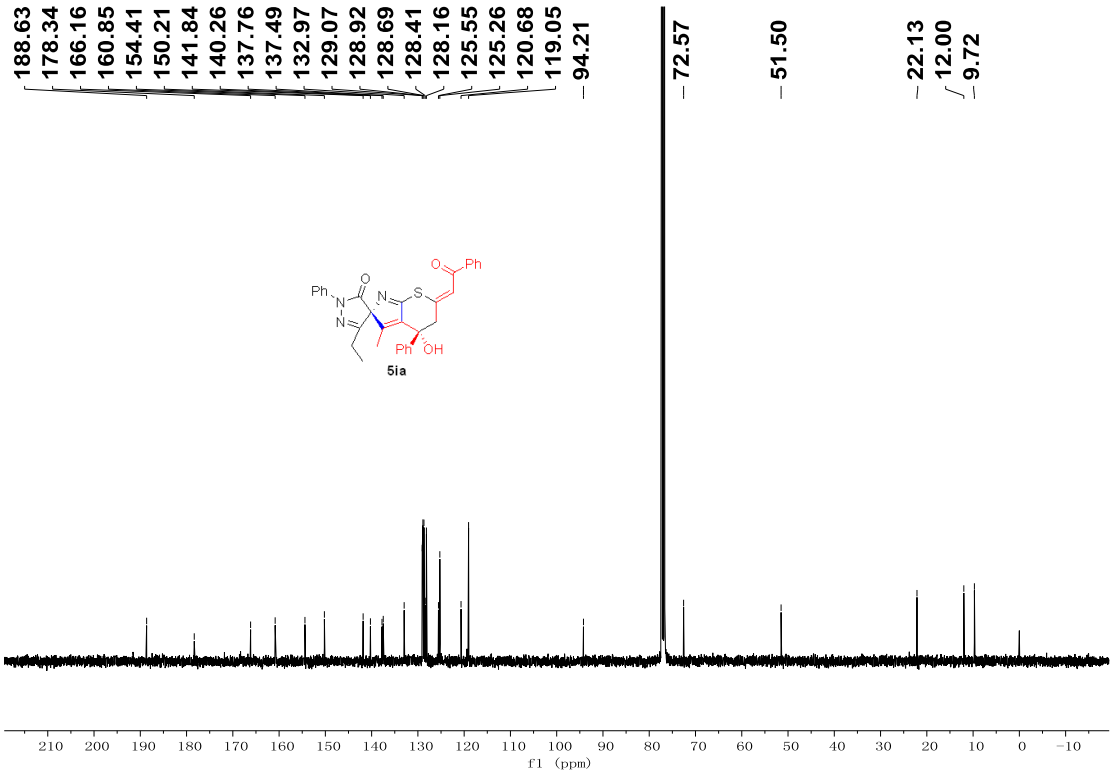
1.11
1.05
1.03
1.07
1.00
2.03
3.00
3.04
f1 (ppm)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132.97
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128.92
128.69
128.41
128.16
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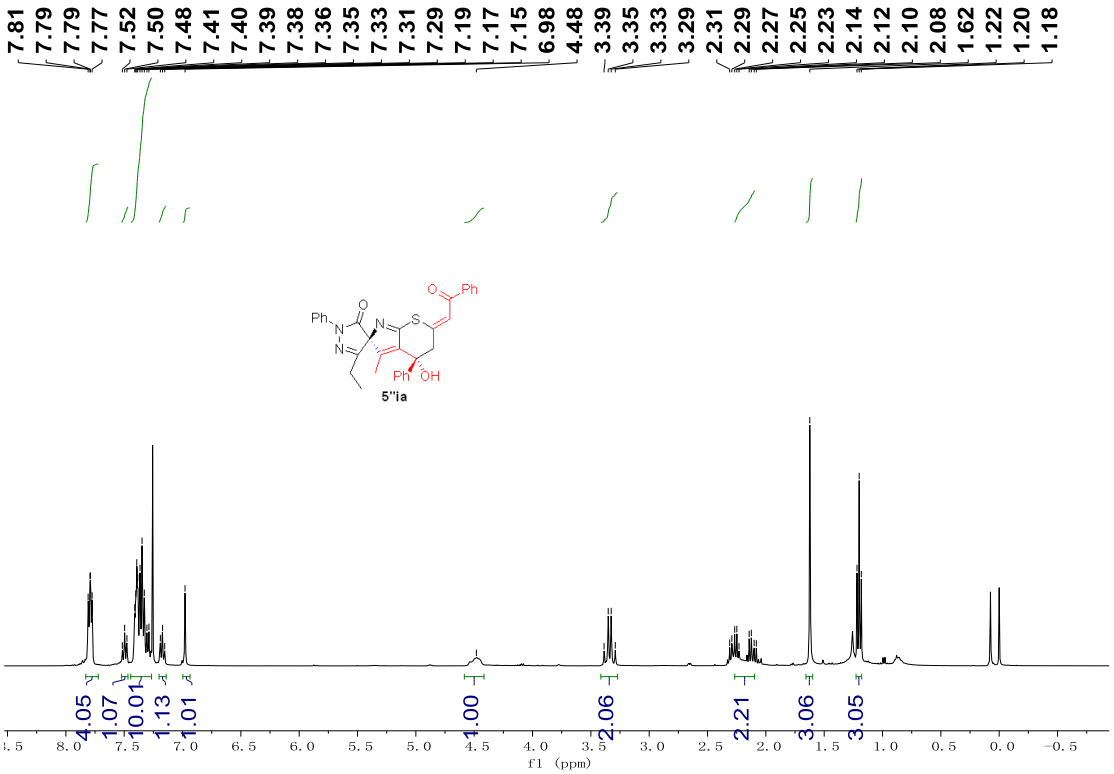
94.21
72.57
51.50
22.13
12.00
9.72
5ia
f1 (ppm)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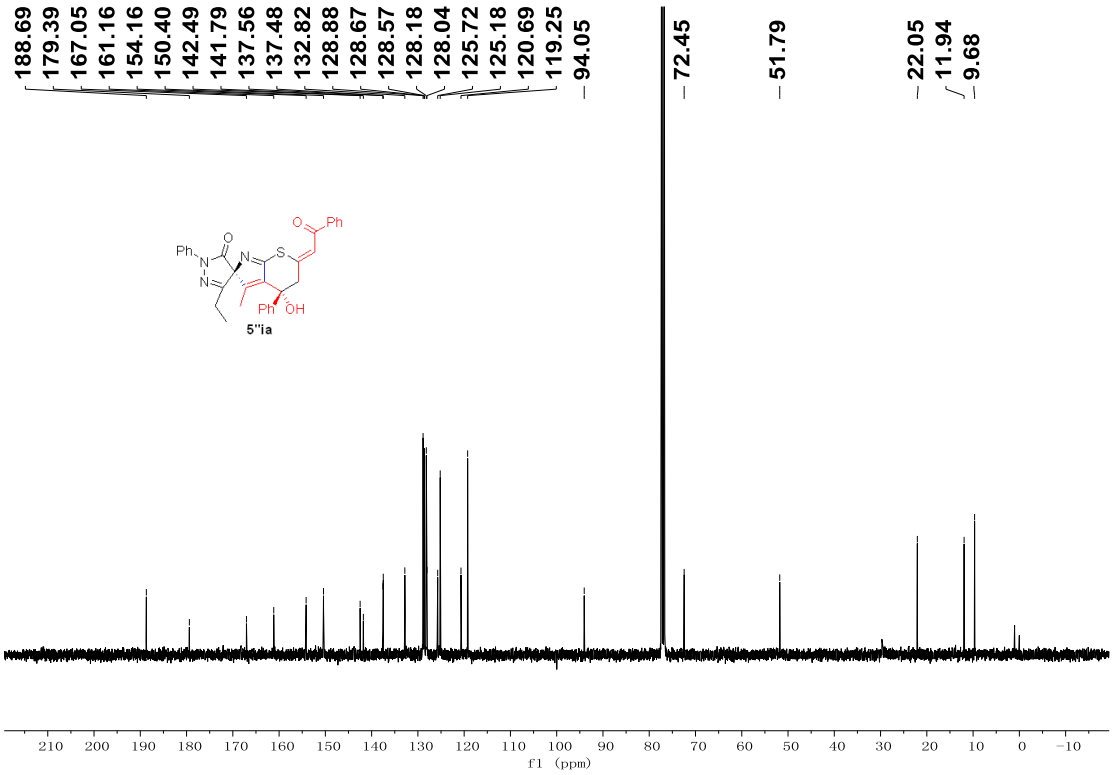
5"ia
4.05 1.07 10.01 1.13 1.01 1.00 2.06 2.21 3.06 3.05
f1 (ppm)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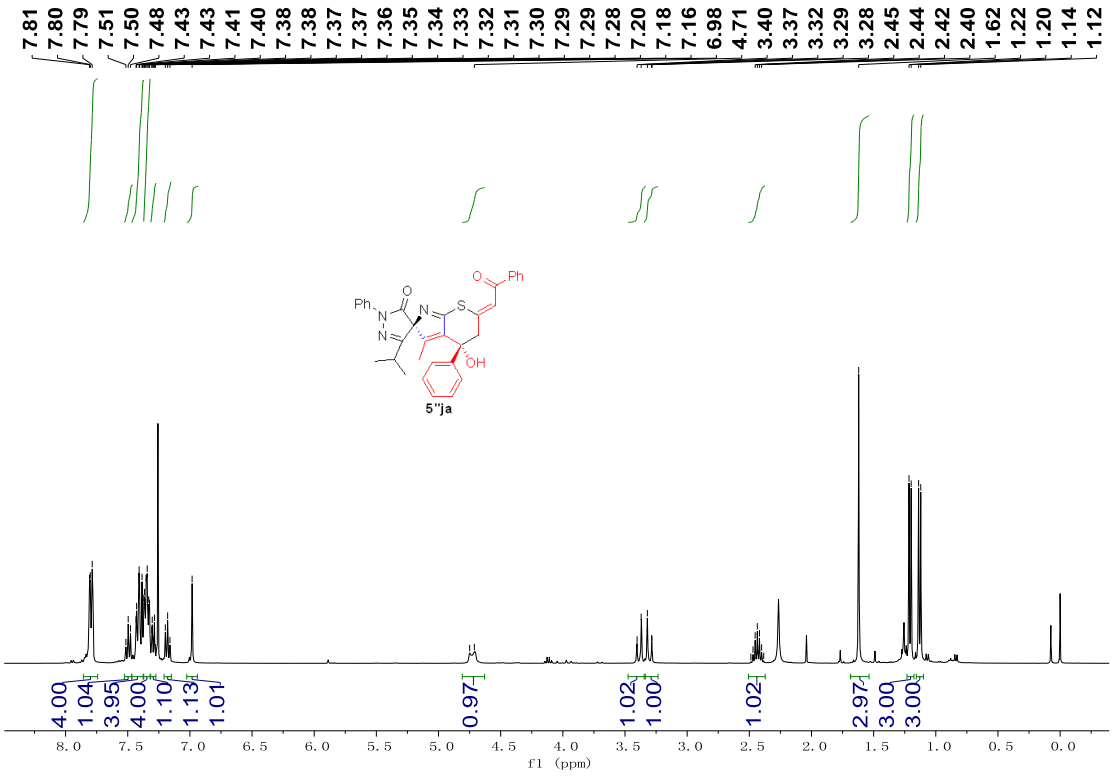
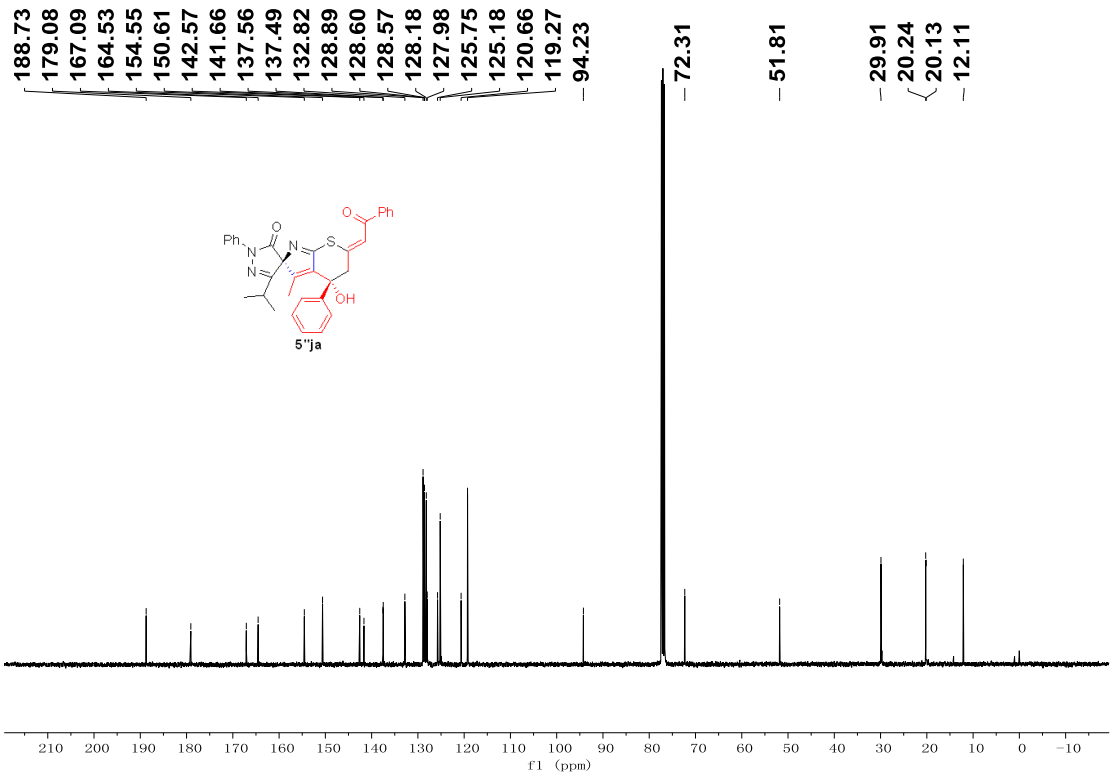
5"ia
f1 (ppm)


7.81 7.80 7.79 7.51 7.50 7.48 7.43 7.43 7.41 7.40 7.38 7.38 7.37 7.37 7.36 7.35 7.34 7.33 7.32 7.31 7.30 7.29 7.29 7.28 7.20 7.18 7.16 6.98 4.71 3.40 3.37 3.32 3.29 3.28 2.45 2.44 2.42 2.40 1.62 1.22 1.20 1.14 1.12
5"ja
4.00 1.04 3.95 4.00 1.10 1.13 1.01 0.97 1.02 1.00 1.02 2.97 3.00 3.00
f1 (ppm)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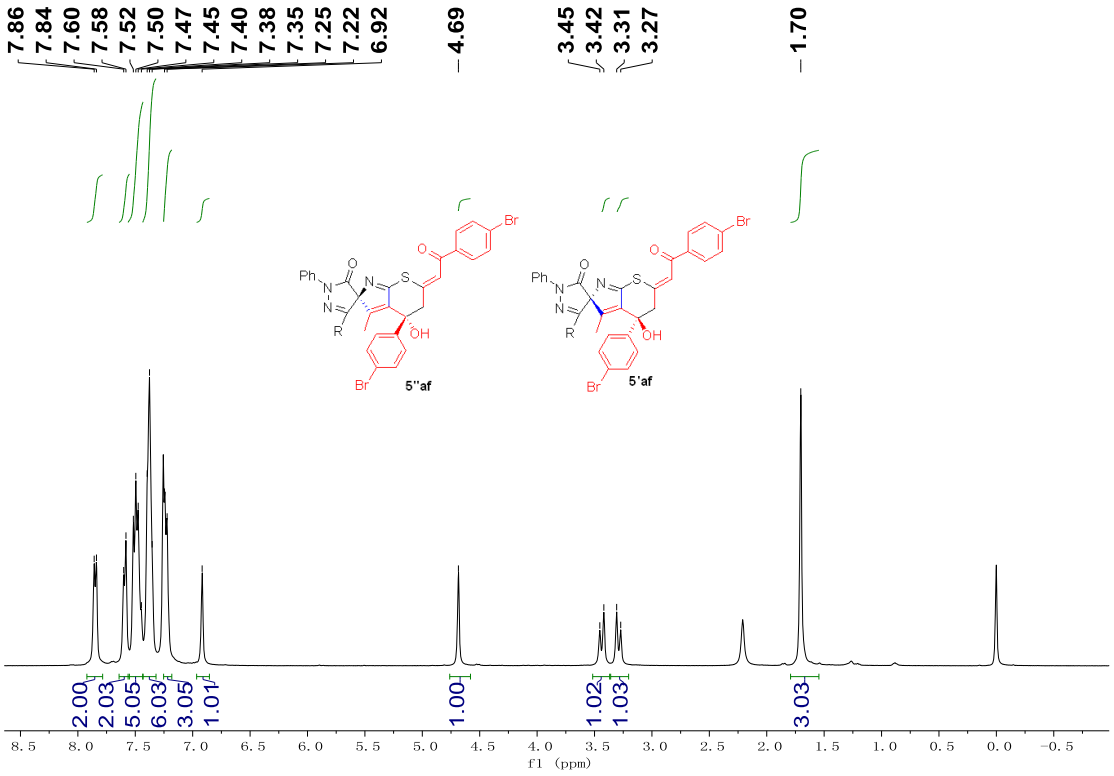
f1 (ppm)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7.60
7.58
7.52
7.50
7.47
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7.40
7.38
7.35
7.25
7.22
6.92
4.69
3.45
3.42
3.31
3.27
1.70
5"af
5'af
2.00
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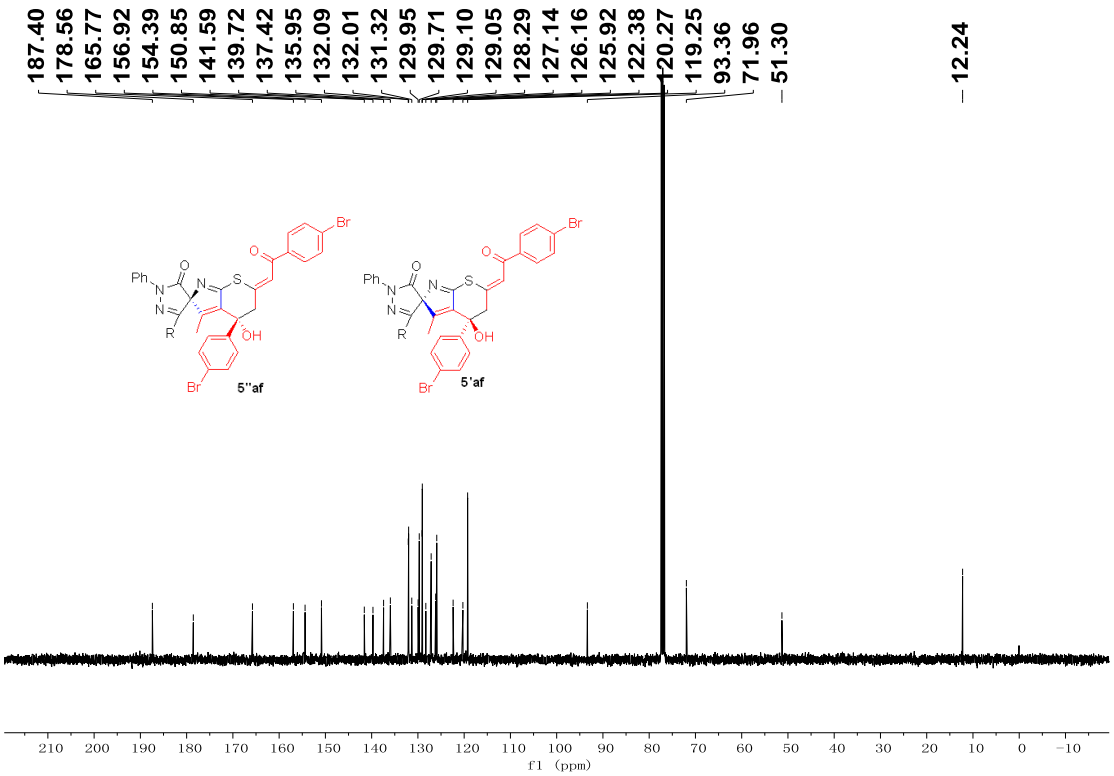
5.05
6.03
3.05
1.01
1.00
1.02
1.03
3.03
f1 (ppm)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154.39
150.85
141.59
139.72
137.42
135.95
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132.01
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129.95
129.71
129.10
129.05
128.29
127.14
126.16
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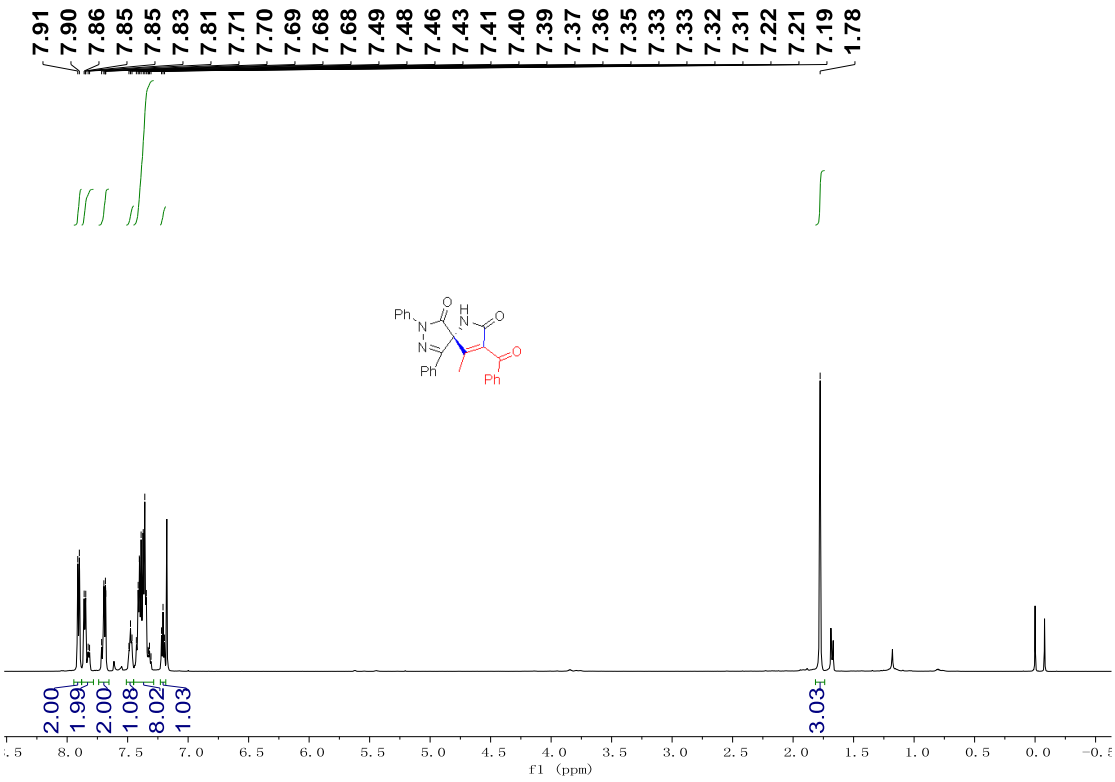
120.27
119.25
93.36
71.96
51.30
12.24
5"af
5'af
f1 (ppm)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7.48
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7.43
7.41
7.40
7.39
7.37
7.36
7.35
7.33
7.33
7.32
7.31
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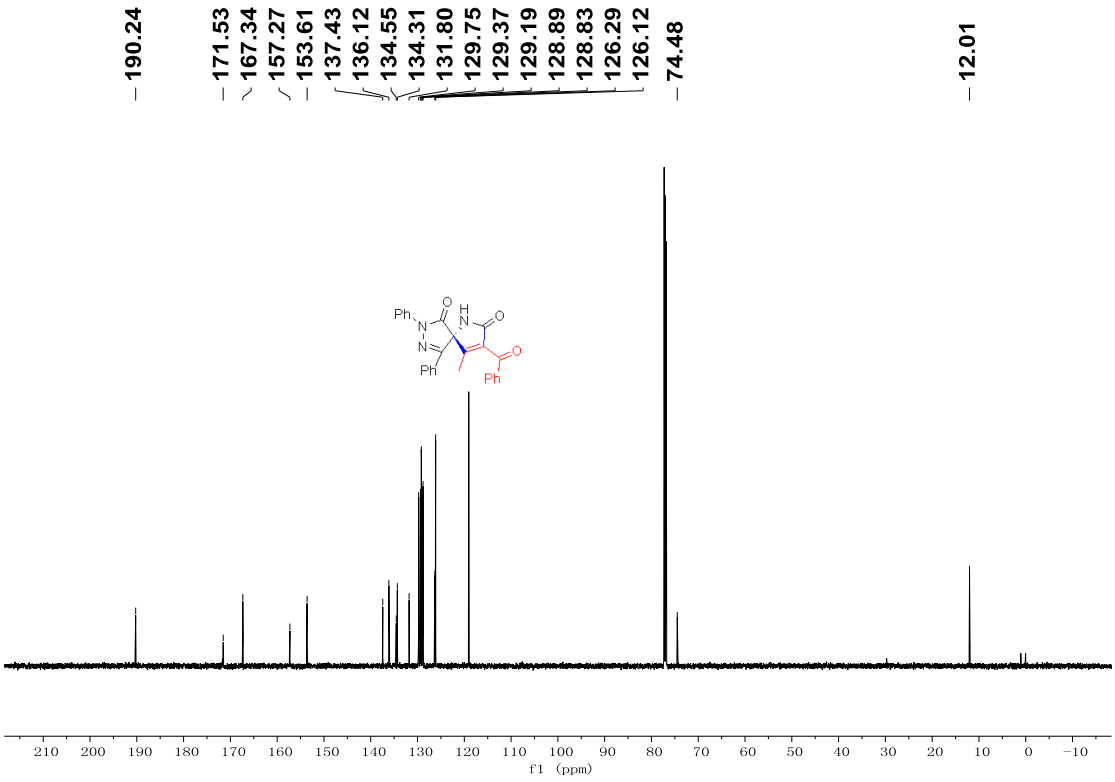
2.00
1.99
2.00
1.08
8.02
1.03
3.03
f1 (ppm)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167.34
157.27
153.61
137.43
136.12
134.55
134.31
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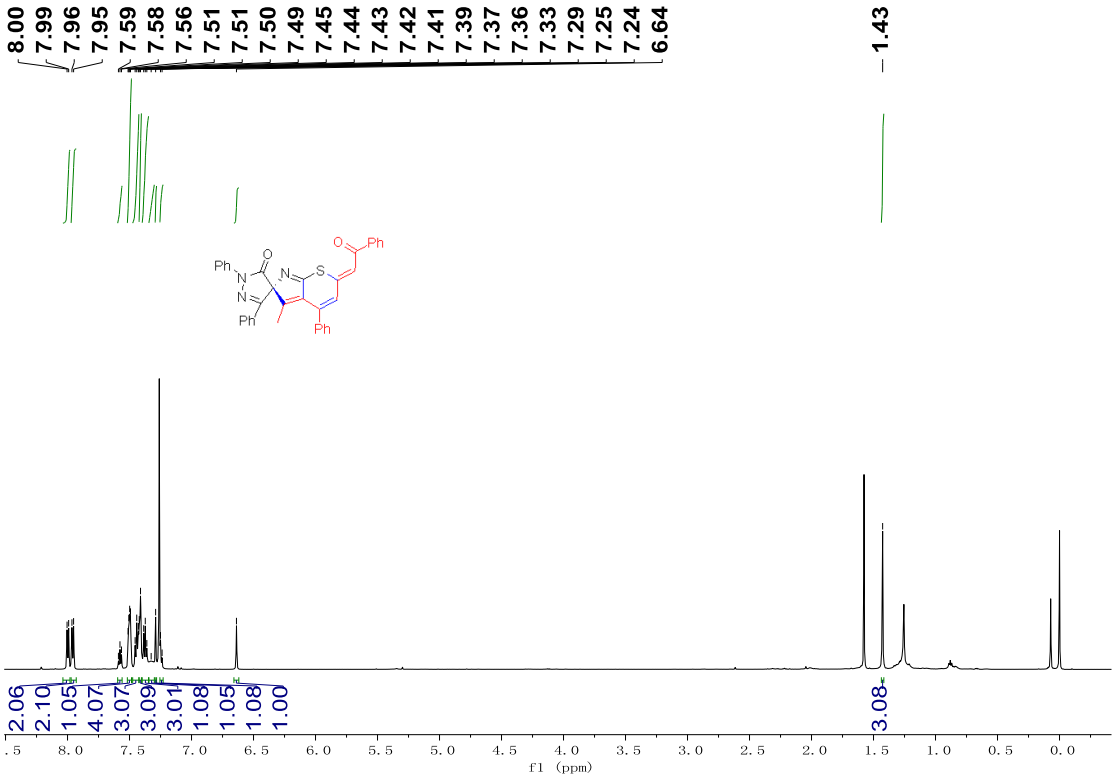
126.12
74.48
12.01
f1 (ppm)


8.00
7.99
7.96
7.95
7.59
7.58
7.56
7.51
7.51
7.50
7.49
7.45
7.44
7.43
7.42
7.41
7.39
7.37
7.36
7.33
7.29
7.25
7.24
6.64
1.43
2.06
2.10
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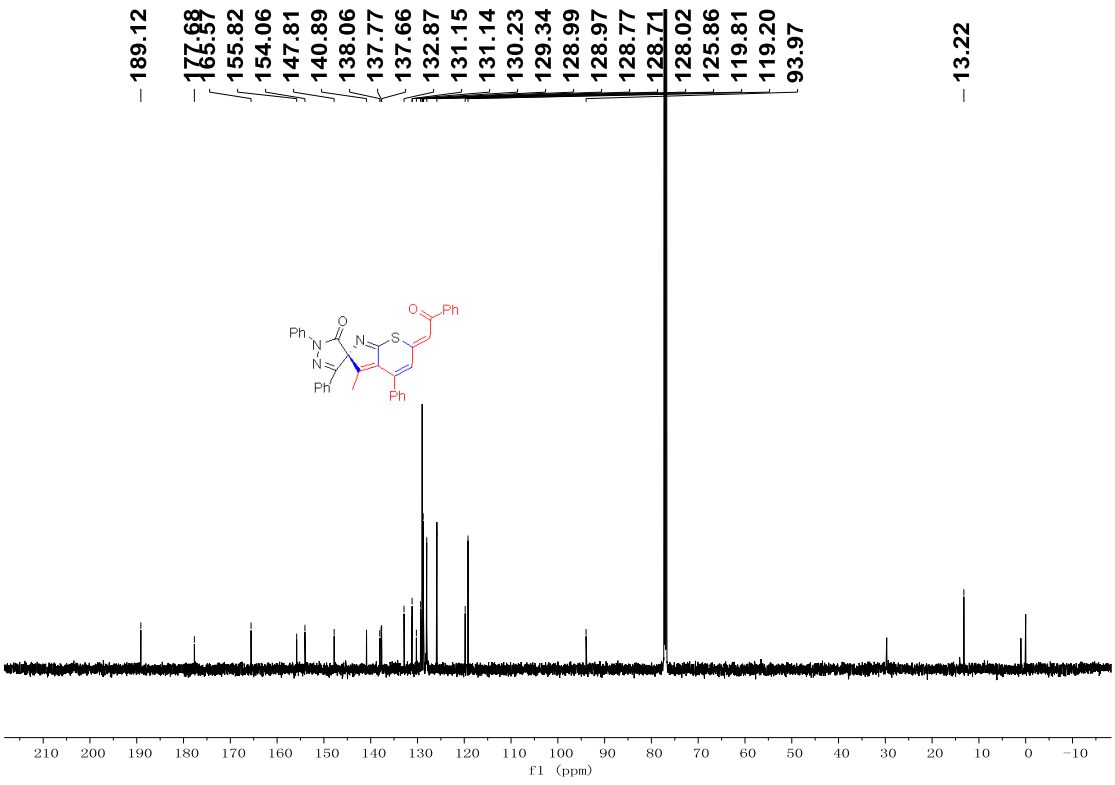
3.07
3.09
3.01
1.08
1.05
1.08
1.00
3.08
f1 (ppm)


189.12
177.68
165.57
155.82
154.06
147.81
140.89
138.06
137.77
137.66
132.87
131.15
131.14
130.23
129.34
128.99
128.97
128.77
128.71
128.02
125.86
119.81
119.20
93.97
13.22
f1 (ppm)