Supporting Information

Precise construction of spiro stereocenters via enantioselective radical addition through modulating photocatalysis from redox to energy transfer

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1. General information

Experiments involving moisture and/or air sensitive components were performed under a positive pressure of argon in oven-dried glassware equipped with a rubber septum inlet. Dried solvents and liquid reagents were transferred by oven-dried syringes or hypodermic syringe cooled to ambient temperature in a desiccator. Reaction mixtures were stirred in 10 mL Schlenk tube with Teflon-coated magnetic stirring bars unless otherwise stated. Moisture in non-volatile reagents/compounds was removed in high vacuo by means of an oil pump and subsequent purging with nitrogen. Solvents were removed under vacuum and heated with a water bath at 35−40 °C using rotary evaporator with aspirator. The condenser was cooled with running water at 0 °C.

All experiments were monitored by analytical thin layer chromatography (TLC). TLC was performed with pre-coated TLC plates, *silica gel* 60F-254, layer thickness 0.25 mm. After elution, plate was visualized under UV illumination at 254 nm for UV active material. Further visualization was achieved by staining phosphomolybdic acid solution. For those using the aqueous stains, the TLC plates were heated on a hot plate.

Columns for flash chromatography (FC) contained silica gel 200−300 mesh. Columns were packed as slurry of silica gel in petroleum ether and equilibrated solution using the appropriate solvent system. The elution was assisted by applying pressure of about 2 atm with an air pump.

Instrumentations

NMR: ^{1}H NMR spectra were recorded at room temperature on a Bruker AVANCE NEO 400 (400 MHz) or Bruker AVANCE III HD 600 (600 MHz) spectrometer. ^{13}C NMR spectra were recorded on a Bruker AVANCE NEO 400 (100 MHz) or Bruker AVANCE III HD 600 (151 MHz) with complete proton decoupling. ^{19}F NMR spectra were recorded on a Bruker AVANCE NEO 400 (376 MHz) or Bruker AVANCE III HD 600 (565 MHz) spectrometer. Proton nuclear magnetic resonance (^{1}H NMR) and carbon NMR (^{13}C NMR) were recorded in $CDCl_3$ or CD_3OD. Chemical shifts are reported in parts per million (ppm), using the residual solvent signal as an internal standard: $CDCl_3$ (^{1}H NMR: δ 7.26, singlet; ^{13}C NMR: δ 77.16, triplet), CD_3OD (^{1}H NMR: δ 3.31, multiplets; ^{13}C NMR: δ 48.80, multiplets). Multiplicities were given as: *s* (singlet), *d* (doublet), *t* (triplet), *q* (quartet), *quintet*, *m* (multiplets), *dd* (doublet of doublets), *dt* (doublet of triplets), and *br* (broad). Coupling constants (*J*) were recorded in hertz

(Hz). The number of proton atoms (*n*) for a given resonance was indicated by *n*H. The number of carbon atoms (*n*) for a given resonance was indicated by *n*C. High Resolution Mass Spectrometry (HRMS) analysis was obtained using Electrospray Ionization (ESI) and reported in units of mass of charge ratio (m/z). ESI was acquired using a Bruker Compact (ESI-TOF). Mass samples were dissolved in MeOH (HPLC [High Performance Liquid Chromatography] grade) unless otherwise stated. Optical rotations were determined on a INESA SGW®-2. Optical rotations were recorded on a polarimeter with a sodium lamp of wavelength 589 nm and reported as follows; $[\alpha]_{\lambda}^{T^{\circ}C}$ (*c* = g/100 mL, solvent). Melting points were determined on a melting point apparatus (OptiMelt MPA100). Enantiomeric excesses were determined by chiral HPLC analysis using Thermo Scientific Ultimate 3000. UV detection was monitored at 254 nm and 210 nm at the same time. HPLC samples were dissolved in HPLC grade isopropanol (IPA) unless otherwise stated.

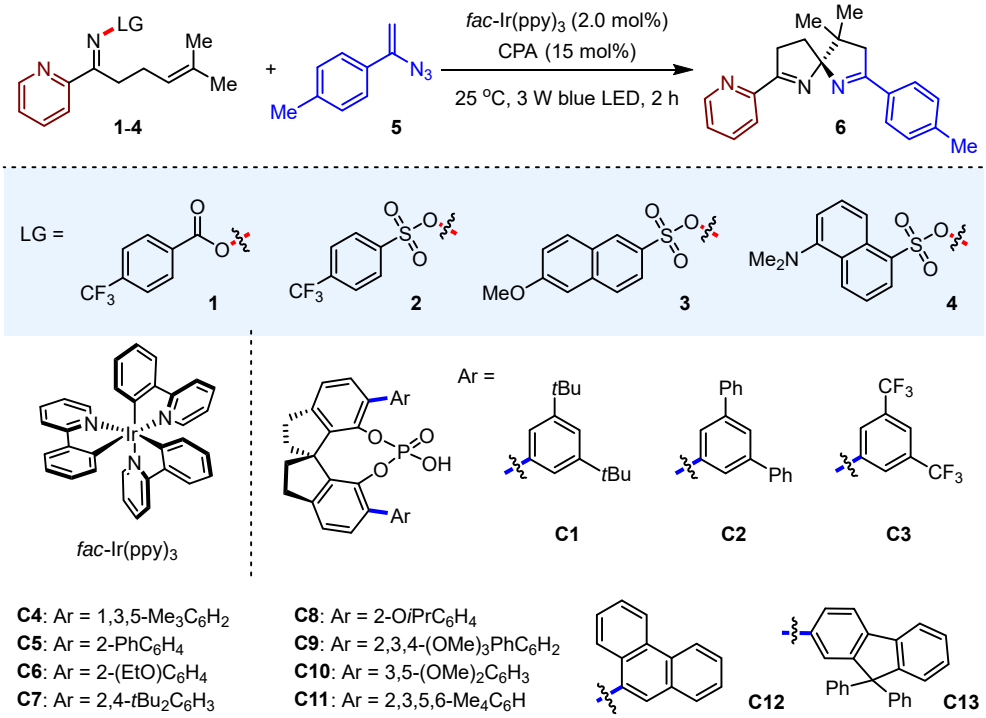
Luminescence Measurements were performed on a Nanolog infrared fluorescence spectrometer (Nanolog FL3-2iHR, US) equipped with a continuous Xe source for steady state measurements and a Xe flashlight source for the observation of phosphorescence spectra. Fluorescence spectra were recorded at ambient conditions in 10×10 mm quartz cuvettes (Hellma, Suprasil). Luminescence spectra at cryogenic conditions (77 K) were recorded in quartz tubes (inner ø = 4 mm) in a small quartz Dewar vessel which was filled with liquid nitrogen. All solutions were handled under dry nitrogen and degassed (15 min in an ultrasound bath) to exclude oxygen as triplet quencher. A longpass filter (Schott Advanced Optics, WG300 or Hebo Spezialglass, UV280) was introduced in the emission-beam path to prevent the scattered excitation light to pass the emission monochromator at higher order wavelengths where necessary.

Materials

All commercial reagents were purchased with the highest purity grade. They were used without further purification unless specified. All solvents used, mainly petroleum ether (PE) and ethyl acetate (EA) were distilled. Anhydrous toluene, $tBuC_6H_5$ and EtC_6H_5 were freshly distilled from sodium/benzophenone before use. All compounds synthesized were stored in a −80 °C freezer and light-sensitive compounds were protected with aluminum foil.

2. Optimization of reaction conditions

Table S1. Optimization of reaction conditions[a]



entry	CPA	1-4	additive	solvent (mL)	base (equiv.)	ee (%)[b]
1	**C1**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	15
2	**C2**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	10
3	**C3**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	8
4	**C4**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	2
5	**C5**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	4
6	**C6**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	0
7	**C7**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	2
8	**C8**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	4
9	**C9**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	2
10	**C10**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	2
11	**C11**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	0
12	**C12**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	8
13	**C13**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	0

14	**C14**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	14
15	**C15**	**1**	-	$CHCl_3$ (0.5)	K_2CO_3 (1.5)	12
16	**C1**	**1**	-	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	-
17	**C1**	**2**	-	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	31
18	**C1**	**3**	-	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	40
19	**C1**	**4**	-	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	61
20	**C1**	**4**	H_2O (5 μL)	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	77
21	**C1**	**4**	H_2O (10 μL)	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	65
22	**C1**	**4**	H_2O (15 μL)	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	75
23	**C1**	**4**	H_2O (20 μL)	$^tBuC_6H_5$ (0.5)	K_2CO_3 (1.5)	73
25	**C1**	**4**	H_2O (5 μL)	$^tBuC_6H_5$ (0.6)	K_2CO_3 (1.5)	79
26	**C1**	**4**	H_2O (5 μL)	$^tBuC_6H_5$ (0.7)	K_2CO_3 (1.5)	71
27	**C1**	**4**	H_2O (5 μL)	$^tBuC_6H_5$ (0.8)	K_2CO_3 (1.5)	77
28	**C1**	**4**	H_2O (5 μL)	$^tBuC_6H_5$ (0.9)	K_2CO_3 (1.5)	73
29	**C1**	**4**	H_2O (5 μL)	$^iPrC_6H_5$ (0.6)	K_2CO_3 (1.5)	25
30	**C1**	**4**	H_2O (5 μL)	Toluene (0.6)	K_2CO_3 (1.5)	77
31	**C1**	**4**	H_2O (5 μL)	1-^{t}Bu-3,5-$Me_2C_6H_3$ (0.6)	K_2CO_3 (1.5)	73
32	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (1.5)	81
33	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	$KHCO_3$ (1.5)	73
34	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_3PO_4 (1.5)	65
35	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2HPO_4 (1.5)	53
36	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	Na_2CO_3 (1.5)	69
37	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	$NaHCO_3$ (1.5)	67
38	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	Na_3PO_4 (1.5)	37
39	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	Na_2HPO_4 (1.5)	49
40	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	Cs_2CO_3 (1.5)	59
41	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (1.0)	70

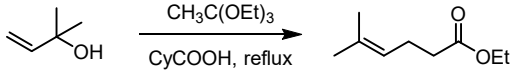
42	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (2.0)	75
43	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (2.5)	79
44	**C1**	**4**	H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (3.0)	73
45	**C1**	**4**	KF (1.0 equiv.) + H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (1.5)	90
46	**C1**	**4**	LiF (1.0 equiv.) + H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (1.5)	87
47	**C1**	**4**	NH_4F (1.0 equiv.) + H_2O (5 μL)	EtC_6H_5 (0.6)	K_2CO_3 (1.5)	21

[a]0.02 mmol scale and irradiation distance = 2.0 cm. [b]Determined by chiral HPLC analysis.

3. Experimental procedures

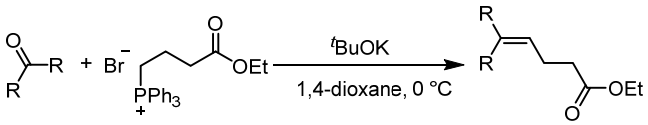
3.1 Synthesis of olefinic sulfonyl oximes

General procedure A



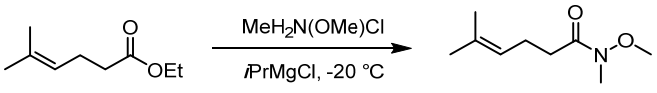
According to a literature procedure:[1] A solution of 1,1-dimethylallyl alcohol (1.0 equiv.), triethyl orthoacetate (10 equiv.) and cyclohexanecarboxylic acid (0.1 equiv.) was stirred under reflux conditions for 3 h. The reaction mixture was then cooled to room temperature and extracted three times with diethyl ether. The combined organic layers were washed with 10 % aqueous HCl, saturated aqueous $NaHCO_3$ solution, water and brine. The organic layer was dried with $MgSO_4$ and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (30:1) as eluent to afford the corresponding ester.

General procedure B



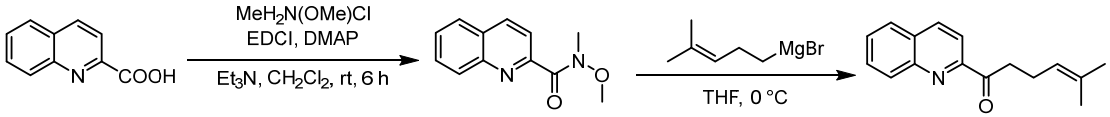
According to a literature procedure:[2] (4-Ethoxy-4-oxobutyl) triphenylphosphonium bromide (1.3 equiv.) was placed in a flame-dried round-bottom flask, and anhydrous THF (0.3 M solution for the ketone) was added under an argon atmosphere. The mixture was cooled to 0 °C and treated with *t*BuOK (1.5 equiv.). After stirring for 1 hour, the ketone (1.0 equiv.) was added dropwise. Upon complete addition, the reaction mixture was gradually warmed to room temperature and stirred for an additional 12 hours. The reaction was then quenched with water and extracted with diethyl ether. The combined organic phase was washed with brine and concentrated under reduced pressure. The residue was purified by silica gel chromatography, eluting with a hexanes/ethyl acetate mixture, to yield the desired product.

General procedure C



According to a literature procedure:[1] to a solution of ester (1.0 equiv.) in dry THF and *N*,*O*-dimethylhydroxylamide hydrochloride (3.0 equiv.) was slowly added a freshly prepared solution of *i*-PrMgCl in THF (1.0 M, 4.0 equiv.) at –20 °C. The mixture was stirred for 30 min at –10 °C and then hydrolyzed with NH_4Cl solution (20 wt % in H_2O, 100 mL), followed by three times extraction with diethyl ether (100 mL). The combined organic layers were dried with $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by flash column chromatography to afford the desired Weinreb amide.

General procedure D

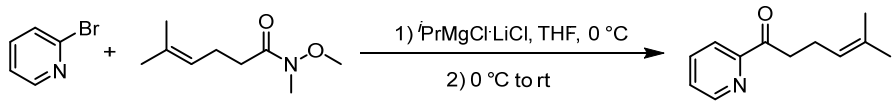


According to a literature procedure:[3,4] Picolinic acid (1.0 equiv.), DMAP (0.02 equiv.), EDCI (1.2 equiv.), and *N*,*O*-dimethyl hydroxylamine hydrochloride (1.1 equiv.) were weighed into a flame-dried round-bottom flask, which was subsequently sealed with a septum. Anhydrous dichloromethane (CH_2Cl_2) was added via syringe, and the resulting solution was cooled to 0 °C using an ice bath. Triethylamine (3.0 equiv.) was then introduced through a syringe, and the mixture was stirred at 0 °C for 15 minutes. The ice bath was removed, and stirring was continued for an additional 6 hours at room temperature. The reaction was quenched by the addition of water. After separating the organic layer, the aqueous phase was neutralized with a saturated aqueous solution of sodium bicarbonate ($NaHCO_3$) until a pH of 7−8 was achieved. The aqueous layer was then washed with CH_2Cl_2. All organic layers were combined and washed successively with saturated aqueous $NaHCO_3$ and saturated aqueous sodium chloride (NaCl), followed by drying over magnesium sulfate ($MgSO_4$). The mixture was filtered and concentrated under reduced pressure to yield the amide as a white solid.

To a flame-dried round-bottom flask equipped with a condenser and stir bar, magnesium turnings and a catalytic amount of 1,2-dibromoethane were added. A solution of 5-bromo-2-methylpent-2-ene (1.2 equiv.) in anhydrous THF was then introduced gradually, first in portions and subsequently dropwise. The reaction mixture was stirred at room temperature for 1 hour. Following this, the reaction was cooled to 0 °C, and a solution of amide (1.0 equiv.) in THF was added dropwise. The mixture was allowed to stir under a nitrogen atmosphere overnight. After completion, the reaction was cooled to 0 °C and quenched with a saturated

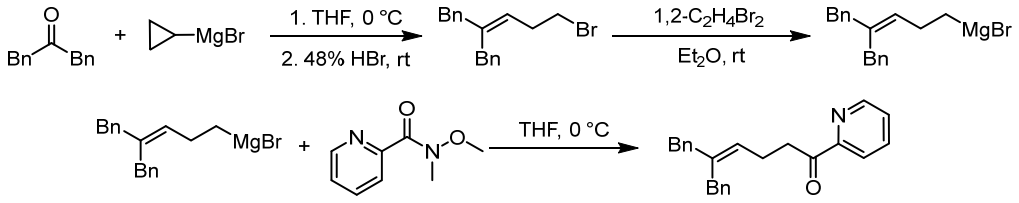
aqueous solution of NH_4Cl. The organic layer was extracted with diethyl ether, washed with saturated aqueous NH_4Cl and brine, and then dried over anhydrous Na_2SO_4. The solvent was removed under reduced pressure to yield a clear oil. The crude product was subsequently purified by silica gel chromatography to afford the desired compound.

General procedure E



According to a literature procedure:[5] A dry Schlenk tube equipped with a stirring bar was charged with 2-bromopyridine (1.0 equiv.) and dry THF. The solution was cooled to 0 °C, and *i*-PrMgCl•LiCl (1 equiv., 1.3 M in THF) was added dropwise. The mixture was stirred at 0 °C for 4 hours, after which a solution of Weinreb amide (1.0 equiv.) in THF was introduced. The reaction was allowed to warm to room temperature and stirred overnight. Subsequently, 5 mL of water and diethyl ether were added to the mixture. The layers were separated, and the aqueous phase was extracted with diethyl ether. The combined organic layers were dried, filtered, and evaporated. Purification by column chromatography on silica gel yielded the ketone as an oil.

General procedure F

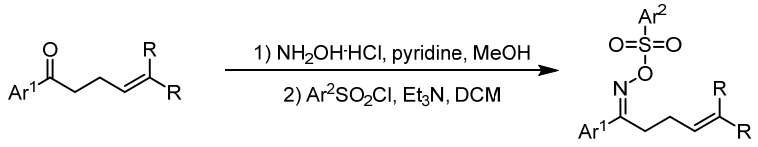


According to a literature procedure:[6] The freshly prepared Grignard reagent was cooled in an ice bath and a solution of 1,3-diphenylpropan-2-one (1.0 equiv) in Et_2O was added dropwise over 10 minutes, which was then stirred overnight at room temperature. After cooling to 0 ºC, it was quenched by saturated NH_4Cl. The separated aqueous layer was extracted with Et_2O, and the combined organic layers were washed with water (10 mL), brine (10 mL), dried over Na_2SO_4, filtered, and concentrated. Crude product was obtained as a pale-yellow oil, which was directly used in next step without further purification.

To the above crude product at room temperature was added dropwise 48% aq HBr (1.6 equiv) over 20 minutes with vigorous stirring, which was then stirred for an additional two hours. Water and Et_2O were added and the resulting mixture was stirred for 5 minutes. The separated aqueous layer was extracted with Et_2O, and the combined organic layers were washed sequentially with water and brine. It was then dried over Na_2SO_4, filtered, concentrated to give crude as a pale-yellow oil, The crude product was purified via silica gel chromatography to give the titled compound.

To a flame-dried 100-mL round bottom flask equipped with stir bar was added magnesium turnings (1.4 equiv.) and a catalytic amount of 1,2-dibromoethane. To the mixture was added (2-(3-bromopropylidene)propane-1,3-diyl)dibenzene (1.2 equiv.) dissolved in anhydrous THF, first portion-wise and then dropwise. The reaction mixture was stirred at rt for 1 hours. The reaction was cooled to room temperature and then 0 ^oC, after which Weinreb amide (1.0 equiv.) dissolved in THF was added dropwise. The reaction was allowed to stir under nitrogen overnight. The reaction was cooled to 0 ^oC and quenched with saturated aqueous NH_4Cl, extracted with Et_2O, washed with saturated aqueous NH_4Cl and brine, dried over anhydrous Na_2SO_4, and concentrated in vacuo to afford a clear oil. The crude product was purified via silica gel chromatography to give the titled compound.

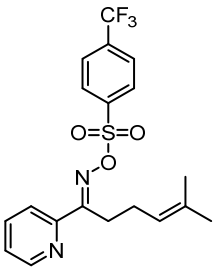
General procedure G



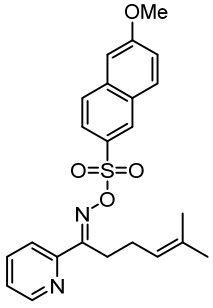
According to a literature procedure:[7] A solution of the ketone (1.0 equiv.), hydroxylamine hydrochloride (1.2 equiv.), and pyridine (1.5 equiv.) in methanol was stirred at room temperature for 6 hours. Following this reaction period, the solvent was removed under reduced pressure, and the residue was dissolved in ethyl acetate for extraction. The organic phase was washed twice with saturated sodium chloride NaCl, dried over Na_2SO_4, and concentrated under vacuum. The resulting residue was then dissolved in dry CH_2Cl_2, and triethylamine (1.5 equiv.) was added. Benzoyl chloride (1.2 equiv.) was introduced dropwise while maintaining the

temperature at 0 °C, and the mixture was stirred at this temperature for an additional 2 hours. Subsequently, the reaction mixture was extracted with CH_2Cl_2. The combined organic phases were dried over Na_2SO_4 and concentrated under vacuum. Further purification was achieved through column chromatography on silica gel, yielding the olefinic sulfonyl oximes.

Characterization data for representative olefinic sulfonyl oximes

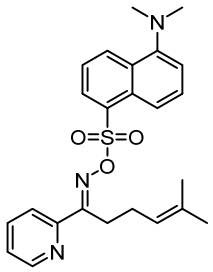


(*E*)-5-methyl-1-(pyridin-2-yl)hex-4-en-1-one *O*-((4-(trifluoromethyl)phenyl)sulfonyl) oxime (2) was synthesized according to general procedure **A, C, E** and **G**. White solid; Mp 95.7−96.5 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.62 (d, *J* = 4.7 Hz, 1H), 8.18 (d, *J* = 8.2 Hz, 2H), 7.83 (d, *J* = 8.3 Hz, 2H), 7.76 – 7.60 (m, 2H), 7.34 (dd, *J* = 8.8, 4.7 Hz, 1H), 5.08 (t, *J* = 7.3 Hz, 1H), 3.05 (t, *J* = 7.7 Hz, 2H), 2.22 (q, *J* = 7.5 Hz, 2H), 1.59 (s, 3H), 1.48 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.3, 151.0, 149.5, 139.4, 136.8, 135.7 (q, *J* = 33.3 Hz), 133.6, 129.6, 126.29 (q, *J* = 3.7 Hz), 125.4, 124.6 (q, *J* = 222.7 Hz), 122.4, 122.2, 26.9, 25.7, 25.2, 17.7; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -63.27; **HRMS (ESI)** 413.1140 m/z (M + H^+), calc. for $C_{19}H_{20}F_3N_2O_3S^+$ 413.1141.

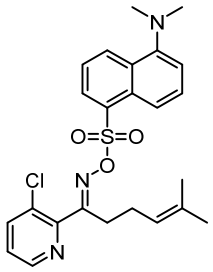


(*E*)-5-methyl-1-(pyridin-2-yl)hex-4-en-1-one *O*-((6-methoxynaphthalen-2-yl)sulfonyl) oxime (3) was synthesized according to general procedure **A**, **C**, **E** and **G**. White solid; Mp 90.5−91.3 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.70 (d, *J* = 4.5 Hz, 1H), 8.64 (s, 1H), 8.06 (dd, *J* = 8.7, 1.5 Hz, 1H), 7.98 (dd, *J* = 13.3, 8.9 Hz, 2H), 7.83 (d, *J* = 7.9 Hz, 1H), 7.77 (dd, *J* = 10.8, 4.5 Hz, 1H), 7.39 (dt, *J* = 11.1, 4.5 Hz, 2H), 7.29 (s, 1H), 5.20 (t, *J* = 7.1 Hz, 1H), 4.06 (s, 3H), 3.15 (t, *J* = 7.8 Hz, 2H), 2.31 (dd, *J* = 15.0, 7.4 Hz, 2H), 1.68 (s, 3H), 1.58 (s, 3H); **^{13}C**

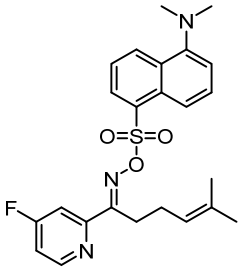
NMR (101 MHz, $CDCl_3$) δ 167.2, 160.5, 151.3, 149.1, 137.4, 136.7, 133.4, 131.0, 130.7, 130.1, 127.8, 127.4, 125.1, 124.2, 122.5, 122.2, 120.8, 105.9, 55.6, 26.7, 25.6, 25.1, 17.6. **HRMS** (ESI) 425.1531 m/z ($M + H^+$), calc. for $C_{23}H_{25}N_2O_4S^+$ 425.1530.



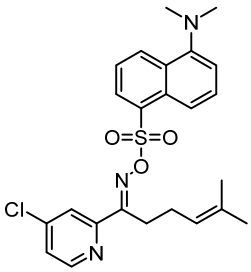
(*E*)-5-methyl-1-(pyridin-2-yl)hex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 89.4−90.2 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.5 Hz, 1H), 8.56 – 8.50 (m, 1H), 8.44 – 8.37 (m, 2H), 7.62 – 7.53 (m, 4H), 7.23 (m, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 5.12 – 5.04 (m, 1H), 3.06 – 3.01 (m, 2H), 2.88 (s, 6H), 2.18 (m, 2H), 1.56 (s, 3H), 1.45 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.2, 151.2, 149.1, 136.3, 133.2, 131.8, 131.4, 130.1, 129.8, 128.7, 124.9, 123.1, 122.6, 122.1, 119.5, 115.5, 45.4, 26.6, 25.5, 25.2, 17.5; **HRMS** (ESI) 438.1844 ($M + H^+$), calc. for $C_{24}H_{28}N_3O_3S^+$ 438.1846.



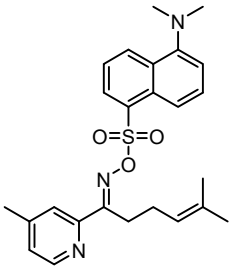
(*E*)-1-(3-chloropyridin-2-yl)-5-methylhex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4a) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 102.5 - 103.4 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.67 (d, *J* = 5.3 Hz, 1H), 8.45 (d, *J* = 7.4 Hz, 1H), 8.43 (d, *J* = 5.3 Hz, 2H), 7.62 (m, 2H), 7.54 (d, *J* = 1.8 Hz, 1H), 7.24 (dd, *J* = 5.2, 1.9 Hz, 1H), 7.22 (d, *J* = 6.6 Hz, 1H), 5.06 (t, *J* = 7.2 Hz, 1H), 3.03 – 2.97 (m, 2H), 2.90 (s, 6H), 2.16 (m, 2H), 1.56 (s, 3H), 1.45 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.4, 152.9, 149.9, 144.6, 133.6, 132.1, 132.0, 131.3, 130.3, 129.8, 128.8, 125.3, 123.4, 122.5, 122.4, 119.8, 115.8, 77.4, 77.2, 76.9, 45.6, 26.7, 25.6, 25.3, 17.6; **HRMS** (ESI) 472.1452 m/z ($M + H^+$), calc. for $C_{24}H_{27}ClN_3O_3S^+$ 472.1456.



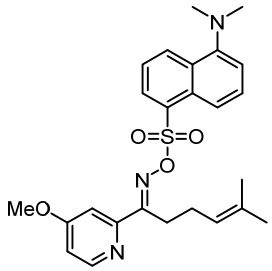
(*E*)-1-(4-fluoropyridin-2-yl)-5-methylhex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4b) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; 96.2 - 97.0 °C; **^{1}H NMR** (400 MHz, CD_3OD) δ 8.69 (d, *J* = 8.5 Hz, 1H), 8.55 (dd, *J* = 7.9, 5.4 Hz, 1H), 8.42 (dd, *J* = 7.4, 1.2 Hz, 1H), 8.37 (d, *J* = 8.7 Hz, 1H), 7.66 (m, 2H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.18 (m, 2H), 5.02 – 4.93 (m, 1H), 3.00 (t, *J* = 7.6 Hz, 2H), 2.87 (s, 6H), 2.14 (q, *J* = 7.5 Hz, 2H), 1.47 (s, 3H), 1.34 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 262.7 Hz), 166.4 (d, *J* = 3.6 Hz), 154.5, 151.5 (d, *J* = 7.1 Hz), 133.5, 132.0, 131.3, 130.2, 129.9, 128.9, 123.4, 122.5, 119.6, 115.7, 113.0 (d, *J* = 16.7 Hz), 109.8 (d, *J* = 18.5 Hz), 45.6, 26.7, 25.6, 25.3, 17.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -101.67. **HRMS** (ESI) 456.1750 m/z (M + H^+), calc. for $C_{24}H_{27}FN_3O_3S^+$ 456.1752.



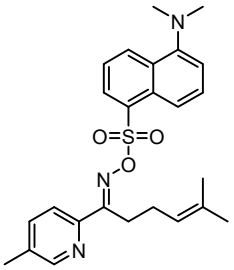
(*E*)-1-(4-chloropyridin-2-yl)-5-methylhex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4c) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 103.3−104.1 °C; **^{1}H NMR (**600 MHz, $CDCl_3$) δ 8.66 (d, *J* = 7.5 Hz, 1H), 8.45 (dd, *J* = 7.4, 1.2 Hz, 1H), 8.43 – 8.36 (m, 2H), 7.61 (m, 2H), 7.56 – 7.52 (m, 1H), 7.24 (dd, *J* = 5.3, 2.0 Hz, 1H), 7.21 (d, *J* = 7.3 Hz, 1H), 5.10 – 4.88 (m, 1H), 3.07 – 2.94 (m, 2H), 2.89 (s, 6H), 2.16 (m, 2H), 1.56 (s, 3H), 1.45 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.4, 152.8, 149.9, 144.5, 133.5, 132.0, 131.2, 130.2, 129.8, 128.8, 125.2, 123.4, 122.4, 122.3, 115.7, 77.3, 77.1, 76.9, 45.6, 26.6, 25.6, 25.2, 17.6; **HRMS** (ESI) 472.1454 m/z (M + H^+), calc. for $C_{24}H_{27}ClN_3O_3S^+$ 472.1456.



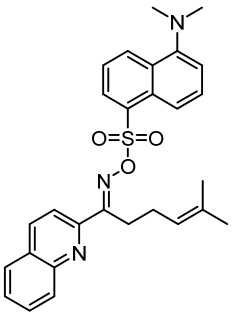
(*E*)-5-methyl-1-(4-methylpyridin-2-yl)hex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4d) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 93.9−94.8 °C; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 7.8 Hz, 1H), 8.47 – 8.39 (m, 2H), 8.38 (d, *J* = 4.9 Hz, 1H), 7.65 – 7.50 (m, 2H), 7.39 – 7.36 (m, 1H), 7.20 (d, *J* = 7.4 Hz, 1H), 7.06 (m, 1H), 5.10 – 5.05 (m, 1H), 3.06 – 2.96 (m, 2H), 2.89 (s, 6H), 2.27 (s, 3H), 2.16 (m, 2H), 1.57 (s, 3H), 1.46 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.5, 151.0, 148.8, 147.6, 133.2, 131.7, 131.5, 130.2, 129.7, 128.6, 125.9, 123.2, 122.9, 122.6, 115.6, 45.5, 26.7, 25.5, 25.2, 20.9, 17.6; **HRMS** (ESI) 452.2001 m/z ($M + H^+$), calc. for $C_{25}H_{30}N_3O_3S^+$ 452.2002.



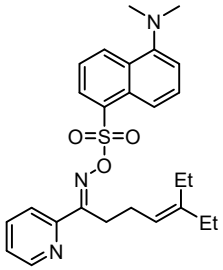
(*E*)-1-(4-methoxypyridin-2-yl)-5-methylhex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4e) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 89.5–90.3 °C; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 8.2 Hz, 1H), 8.47 – 8.37 (m, 2H), 8.34 (d, *J* = 5.7 Hz, 1H), 7.59 (m, 2H), 7.20 (d, *J* = 7.5 Hz, 1H), 7.02 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 5.7, 2.6 Hz, 1H), 5.14 – 5.00 (m, 1H), 3.76 (s, 3H), 3.05 – 2.95 (m, 2H), 2.89 (s, 6H), 2.16 (m, 2H), 1.57 (s, 3H), 1.47 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 165.9, 152.9, 150.3, 133.3, 131.9, 131.8, 131.5, 130.3, 129.9, 128.8, 127.2, 123.2, 122.7, 115.7, 111.7, 107.7, 77.4, 77.2, 76.9, 55.4, 45.6, 26.9, 25.7, 25.3, 17.7; **HRMS** (ESI) 468.1956 m/z ($M + H^+$), calc. for $C_{25}H_{30}N_3O_4S^+$ 468.1952.



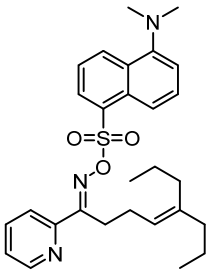
(*E*)-5-methyl-1-(5-methylpyridin-2-yl)hex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4f) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 68.7−69.7 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.4 Hz, 1H), 8.41 (m, 2H), 8.35 (s, 1H), 7.62 – 7.52 (m, 2H), 7.46 (d, *J* = 8.1 Hz, 1H), 7.36 (dd, *J* = 8.1, 1.7 Hz, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 5.09 (t, *J* = 7.2 Hz, 1H), 3.00 (m, 2H), 2.88 (s, 6H), 2.29 (s, 3H), 2.16 (m, 2H), 1.58 (s, 3H), 1.47 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 149.6, 148.6, 136.9, 135.1, 133.3, 131.9, 131.8, 131.6, 130.2, 129.9, 128.8, 123.3, 122.8, 121.7, 115.6, 45.6, 26.7, 25.7, 25.4, 18.5, 17.7; **HRMS** (ESI) 452.2000 m/z (M + H^+), calc. for $C_{25}H_{30}N_3O_3S^+$ 452.2002.



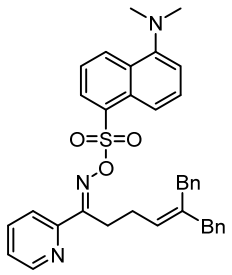
(*E*)-5-methyl-1-(quinolin-2-yl)hex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4g) was synthesized according to general procedure **D** and **G**. Yellow solid; Mp 77.3−78.1 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 7.3 Hz, 1H), 8.47 (m, 2H), 8.00 (m, 2H), 7.81 – 7.48 (m, 6H), 7.19 (d, *J* = 6.7 Hz, 1H), 5.19 (m, 1H), 3.25 – 3.09 (m, 2H), 2.87 (s, 6H), 2.27 (m, 2H), 1.60 (s, 3H), 1.54 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 151.1, 147.6, 136.2, 133.4, 131.9, 131.9, 131.5, 130.2, 130.1, 129.9, 129.8, 128.8, 128.5, 127.7, 127.6, 123.3, 122.9, 119.6, 119.1, 115.6, 45.6, 26.6, 25.7, 25.6, 17.7; **HRMS** (ESI) 488.2004 m/z (M + H^+), calc. for $C_{28}H_{30}N_3O_3S^+$ 488.2002.



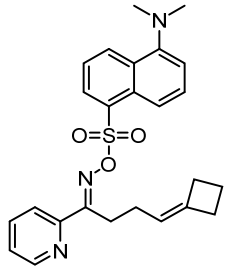
(*E*)-5-ethyl-1-(pyridin-2-yl)hept-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4h) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 82.9−83.7 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.5 Hz, 1H), 8.53 (d, *J* = 4.7 Hz, 1H), 8.47 – 8.32 (m, 2H), 7.61 – 7.57 (m, 2H), 7.57 – 7.52 (m, 2H), 7.23 (m, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 5.03 (t, *J* = 7.2 Hz, 1H), 3.09 – 2.99 (m, 2H), 2.21 (m, 2H), 1.92 – 1.81 (m, 4H), 0.86 (t, *J* = 6.0 Hz, 3H), 0.83 (t, *J* = 6.2 Hz, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.4, 151.4, 149.2, 144.5, 136.4, 131.9, 131.9, 131.5, 130.2, 129.9, 128.8, 125.0, 123.3, 122.2, 120.7, 119.6, 115.6, 45.6, 29.1, 26.98, 24.8, 23.2, 13.3, 12.8; **HRMS** (ESI) 466.2160 m/z (M + H^+), calc. for $C_{26}H_{32}N_3O_3S^+$ 466.2159.



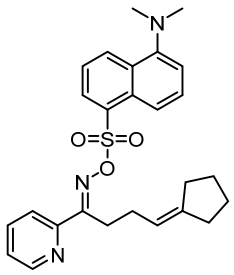
(*E*)-5-propyl-1-(pyridin-2-yl)oct-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4i) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly oil; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.61 (d, *J* = 8.5 Hz, 1H), 8.54 – 8.51 (m, 1H), 8.45 – 8.37 (m, 2H), 7.57 (m, 4H), 7.23 – 7.20 (m, 1H), 7.18 (d, *J* = 7.5 Hz, 1H), 5.11 (t, *J* = 7.2 Hz, 1H), 3.11 – 2.98 (m, 2H), 2.86 (s, 6H), 2.22 (m, 2H), 1.91 – 1.82 (m, 4H), 1.30 (m, 4H), 0.82 (m, 6H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 151.9, 151.3, 149.1, 141.1, 136.4, 131.9, 131.8, 131.5, 130.2, 129.9, 128.8, 125.0, 123.2, 122.8, 122.2, 119.5, 115.6, 45.5, 38.9, 32.1, 27.0, 25.0, 21.6, 21.2, 14.2, 14.0; **HRMS** (ESI) 494.2472 m/z (M + H^+), calc. for $C_{28}H_{36}N_3O_3S^+$ 494.2472.



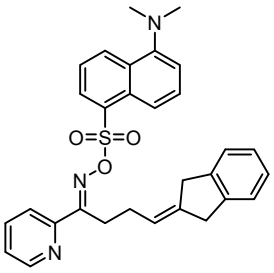
(*E*)-5-benzyl-6-phenyl-1-(pyridin-2-yl)hex-4-en-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4j) was synthesized according to general procedure **F** and **G**. Kelly oil; **^{1}H NMR** (600 MHz, $CDCl_3$) δ8.45 (d, *J* = 8.5 Hz, 1H), 8.35 (d, *J* = 4.8 Hz, 1H), 8.29 (dd, *J* = 7.3, 0.8 Hz, 1H), 8.23 (d, *J* = 8.7 Hz, 1H), 7.46 – 7.35 (m, 3H), 7.33 – 7.27 (m, 1H), 7.13 – 7.02 (m, 7H), 6.95 (d, *J* = 7.5 Hz, 1H), 6.91 (d, *J* = 7.2 Hz, 2H), 6.81 (d, *J* = 6.5 Hz, 2H), 5.20 (t, *J* = 7.3 Hz, 1H), 3.06 – 2.99 (m, 2H), 2.94 (s, 2H), 2.90 (s, 2H), 2.67 (s, 6H), 2.27 (m, 2H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.8, 151.8, 150.9, 149.1, 139.7, 139.7, 139.1, 136.4, 131.9, 131.8, 131.3, 130.1, 129.8, 129.1, 128.8, 128.7, 128.4, 128.2, 126.2, 126.0, 125.9, 125.1, 123.1, 122.1, 119.3, 115.5, 77.4, 77.2, 76.9, 45.4, 42.8, 35.1, 26.6, 25.4; **HRMS** (ESI) 590.2470 m/z (M + H^+), calc. for $C_{36}H_{36}N_3O_3S^+$ 590.2472.



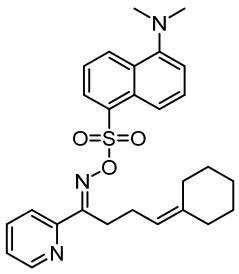
(*E*)-4-cyclobutylidene-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4k) was synthesized according to general procedure **A**, **C**, **E** and **G**. Grayish green solid; Mp 105.3−106.1 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.86 (d, *J* = 8.4 Hz, 1H), 8.76 (d, *J* = 4.7 Hz, 1H), 8.65 (m, 2H), 7.87 – 7.75 (m, 4H), 7.53 – 7.34 (m, 2H), 5.20 (m, 1H), 3.28 (t, *J* = 7.7 Hz, 2H), 2.68 (t, *J* = 7.5 Hz, 2H), 2.61 (t, *J* = 7.6 Hz, 2H), 2.31 (m, 2H), 2.07 – 1.96 (m, 2H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.3, 156.8, 151.4, 149.2, 141.8, 136.4, 131.9, 131.8, 131.5, 130.2, 129.9, 128.8, 125.0, 123.3, 122.2, 119.7, 118.3, 115.6, 45.6, 30.8, 29.1, 26.6, 25.2, 16.9; **HRMS** (ESI) 450.1848 m/z (M + H^+), calc. for $C_{25}H_{28}N_3O_3S^+$ 450.1846.



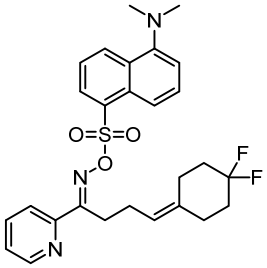
(*E*)-4-cyclopentylidene-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4l) was synthesized according to general procedure **A**, **C**, **E** and **G**. Grayish green solid; Mp 70.3−71.0 °C; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.79 – 8.30 (m, 4H), 7.60 (d, *J* = m, 4H), 7.26 (s, 2H), 5.19 (s, 1H), 3.10 (s, 2H), 2.92 (s, 6H), 2.20 (s, 2H), 2.02 (m, 4H), 1.54 (s, 4H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.4, 151.9, 151.4, 149.2, 145.0, 136.4, 131.9, 131.5, 130.2, 129.9, 128.8, 125.0, 123.2, 122.2, 119.6, 118.1, 115.6, 45.6, 33.5, 28.5, 26.8, 26.5, 26.4, 26.4; **HRMS** (ESI) 464.2000 m/z (M + H^+), calc. for $C_{26}H_{30}N_3O_3S^+$ 464.2002.



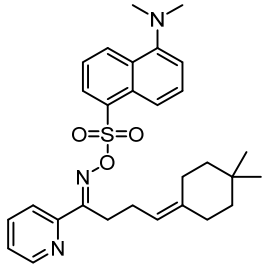
(*E*)-4-(1,3-dihydro-2*H*-inden-2-ylidene)-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamineo)naphthalen-1-yl)sulfonyl) oxime (4m) was synthesized according to general procedure **A**, **C**, **E** and **G**. White solid; Mp 122.0−122.9 °C; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.71 (s, 1H), 8.55 (m, 1H), 8.48 (d, *J* = 7.1 Hz, 1H), 8.45 (d, *J* = 7.3 Hz, 1H), 7.62 (t, *J* = 8.1 Hz, 2H), 7.52 (m, 2H), 7.24 (m, 2H), 7.13 (m, 4H), 5.38 (m, 1H), 3.47 (s, 2H), 3.35 (s, 2H), 3.14 (t, *J* = 7.7 Hz, 2H), 2.93 (s, 6H), 2.30 (m, 2H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.4, 151.3 149.2, 142.2, 142.0, 140.3, 136.5, 132.1, 131.8, 131.5, 130.2, 128.8, 126.4, 126.4, 125.1, 124.8, 124.5, 123.7, 122.2, 121.2, 115.9, 45.8, 39.2, 35.7, 26.8, 26.3; **HRMS** (ESI) 512.2000 m/z (M + H^+), calc. for $C_{30}H_{30}N_3O_3S^+$ 512.2002.



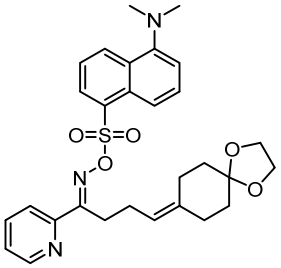
(*E*)-4-cyclohexylidene-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4n) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 64.3−65.1 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 8.1 Hz, 1H), 8.55 – 8.51 (m, 1H), 8.45 – 8.39 (m, 2H), 7.65 – 7.55 (m, 4H), 7.23 (m, 1H), 7.19 (d, *J* = 7.4 Hz, 1H), 5.01 (t, *J* = 7.4 Hz, 1H), 3.05 (t, *J* = 7.7 Hz, 2H), 2.88 (s, 6H), 2.20 (m, 2H), 1.93 – 1.85 (m, 4H), 1.44 (m, 2H), 1.33 (m, 4H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 151.4, 149.1, 141.4, 136.4, 131.9, 131.5, 130.2, 129.9, 128.8, 125.0, 123.3, 122.2, 119.7, 119.3, 115.7, 45.6, 37.0, 28.6, 28.5, 27.8, 26.9, 26.9, 24.4; **HRMS** (ESI) 478.2157 m/z (M + H^+), calc. for $C_{27}H_{32}N_3O_3S^+$ 478.2159.



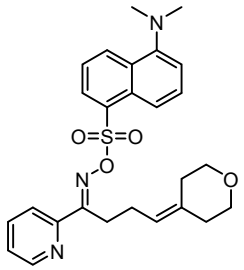
(*E*)-4-(4,4-difluorocyclohexylidene)-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino) naphthalen-1-yl)sulfonyl) oxime (4o) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 103.9−104.8 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.66 (d, *J* = 5.8 Hz, 1H), 8.53 (m, 1H), 8.44 (m, 1H), 8.42 (d, *J* = 8.6 Hz, 1H), 7.63 – 7.58 (m, 4H), 7.26 – 7.24 (m, 1H), 7.21 (d, *J* = 6.8 Hz, 1H), 5.18 (t, *J* = 7.5 Hz, 1H), 3.09 (t, *J* = 7.6 Hz, 2H), 2.90 (s, 6H), 2.27 (m, 2H), 2.05 – 2.01 (m, 2H), 2.01 – 1.97 (m, 2H), 1.69 (m, 2H), 1.61 (m, 2H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.8, 151.2, 149.2, 136.5, 136.0, 132.1, 131.9, 131.4, 130.2, 128.8, 125.2, 123.4 (dd, J=249.1, 232.2 Hz), 122.8, 121.9, 115.7, 45.6, 34.9 (t, *J* = 23.2 Hz), 34.3 (t, *J* = 23.7 Hz), 32.0 (t, *J* = 5.0 Hz), 26.4, 24.8, 23.6 (t, *J* = 5.2 Hz); **^{19}F NMR** (376 MHz, $CDCl_3$) δ -97.32; **HRMS** (ESI) 514.1972 m/z (M + H^+), calc. for $C_{27}H_{30}F_2N_3O_3S^+$ 514.1970.



(*E*)-4-(4,4-dimethylcyclohexylidene)-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino) naphthalen-1-yl)sulfonyl) oxime (4p) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 118.8−119.7 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.3 Hz, 1H), 8.53 (d, *J* = 4.7 Hz, 1H), 8.42 (m, 2H), 7.64 – 7.51 (m, 4H), 7.32 – 7.09 (m, 2H), 5.02 (t, *J* = 7.3 Hz, 1H), 3.05 (t, *J* = 7.7 Hz, 2H), 2.88 (s, 6H), 2.20 (m, 2H), 1.93 – 1.85 (m, 4H), 1.17 – 1.04 (m, 4H), 0.85 (s, 6H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.3, 151.4, 149.1, 141.1, 136.4, 131.9, 131.9, 131.5, 130.2, 129.9, 128.8, 125.0, 123.3, 122.2, 119.6, 119.3, 115.6, 45.6, 40.8, 40.5, 32.7, 30.6, 28.3, 26.9, 24.5, 24.3; **HRMS** (ESI) 506.2467 m/z (M + H^+), calc. for $C_{29}H_{36}N_3O_3S^+$ 506.2472.

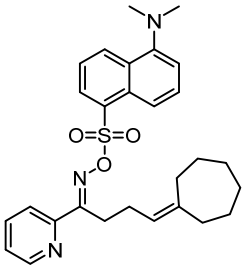


(*E*)-1-(pyridin-2-yl)-4-(1,4-dioxaspiro[4.5]decan-8-ylidene)butan-1-one *O*-((5-(dimethylll amino)naphthalen-1-yl)sulfonyl) oxime (4q) was synthesized according to general procedure **B**, **C**, **E** and **G**. Kelly solid; Mp 116.6−117.5 ºC; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.74 (d, *J* = 8.2 Hz, 1H), 8.63 (d, *J* = 4.2 Hz, 1H), 8.52 (m, 2H), 7.69 (m, 4H), 7.40 – 7.25 (m, 2H), 5.19 (t, *J* = 7.1 Hz, 1H), 4.03 (s, 4H), 3.18 (m, 2H), 2.99 (s, 6H), 2.34 (m, 2H), 2.13 (s, 4H), 1.63 – 1.47 (m, 4H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.1, 151.3, 149.1 138.5, 136.5, 131.95, 131.9, 131.4, 130.2, 129.9, 128.8, 125.1, 123.3, 122.2, 120.9, 119.6, 115.7, 109.0, 64.4, 45.7, 36.1, 35.3, 33.4, 26.7, 24.9, 24.8; **HRMS** (ESI) 536.2213 m/z (M + H^+), calc. for $C_{29}H_{34}N_3O_5S^+$ 536.2214.

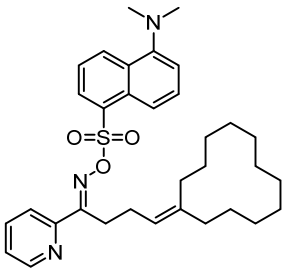


(*E*)-1-(pyridin-2-yl)-4-(tetrahydro-4*H*-pyran-4-ylidene)butan-1-one *O*-((5-(dimethylami neo)naphthalen-1-yl)sulfonyl) oxime (4r) was synthesized according to general procedure **B**, **C**, **E** and **G**. Yellow solid; Mp 74.4−75.1 ºC; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.4

Hz, 1H), 8.53 (d, *J* = 4.5 Hz, 1H), 8.43 (d, *J* = 7.2 Hz, 1H), 8.39 (d, *J* = 8.6 Hz, 1H), 7.65 – 7.53 (m, 4H), 7.25 – 7.21 (m, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 5.12 (t, *J* = 7.4 Hz, 1H), 3.44 (t, *J* = 5.4 Hz, 2H), 3.36 (t, *J* = 5.4 Hz, 2H), 3.08 (t, *J* = 7.5 Hz, 2H), 2.88 (s, 6H), 2.25 (m, 2H), 1.96 (m, 4H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.9, 151.3, 149.2, 136.5, 135.9, 131.9, 131.4, 130.2, 129.9, 129.9, 128.8, 125.1, 123.3, 122.1, 121.3, 119.5, 115.6, 45.6, 36.8, 29.5, 26.6, 24.2; **HRMS** (ESI) 480.1956 m/z ($M + H^+$), calc. for $C_{26}H_{30}N_3O_4S^+$ 480.1952.



(*E*)-4-cycloheptylidene-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4s) was synthesized according to general procedure **A**, **C**, **E** and **G**. Kelly solid; Mp 88.4−89.2 °C; **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 8.3 Hz, 1H), 8.53 (d, *J* = 4.7 Hz, 1H), 8.47 – 8.31 (m, 2H), 7.63 – 7.51 (m, 4H), 7.24 (dd, *J* = 8.8, 4.6 Hz, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 5.07 (t, *J* = 7.1 Hz, 1H), 3.09 – 3.01 (m, 2H), 2.88 (s, 6H), 2.21 – 2.15 (m, 2H), 2.03 (m, 4H), 1.40 (s, 8H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 167.4, 151.4, 149.2, 144.5, 136.4, 131.9, 131.9, 131.9, 130.2, 129.9, 128.8, 125.0, 123.3, 122.2, 120.7, 119.6, 115.6, 45.6, 29.1, 26.9, 24.9, 23.2, 13.3, 12.8; **HRMS** (ESI) 492.2314 m/z ($M + H^+$), calc. for $C_{28}H_{34}N_3O_3S^+$ 492.2315.

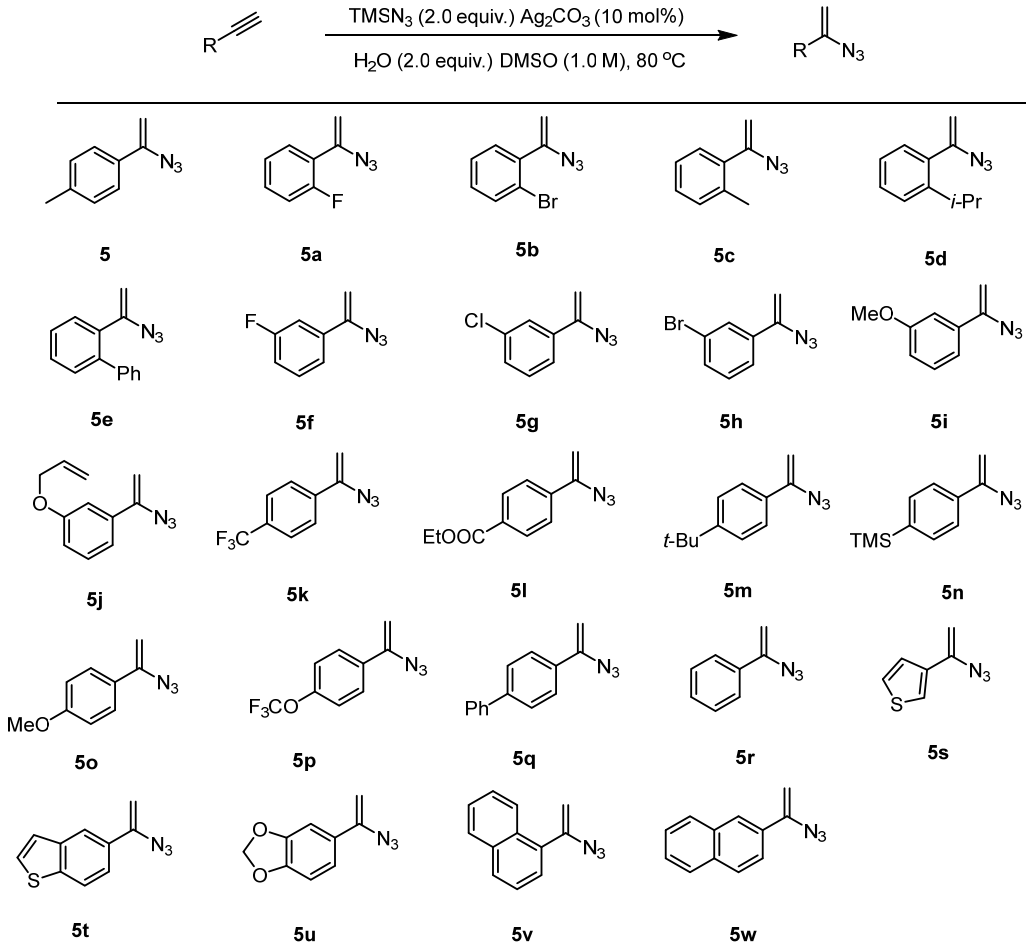


(*E*)-4-cyclododecylidene-1-(pyridin-2-yl)butan-1-one *O*-((5-(dimethylamino)naphthalen-1-yl)sulfonyl) oxime (4t) was synthesized according to general procedure **A**, **C**, **E** and **G**. White solid; Mp 81.9−82.8 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.5 Hz, 1H), 8.53 (m, 1H), 8.42 (m, 2H), 7.58 (m, 4H), 7.24 (m, 1H), 7.19 (d, *J* = 7.6 Hz, 1H), 5.17 (t, *J* = 7.2 Hz, 1H), 3.09 – 2.97 (m, 2H), 2.88 (s, 6H), 2.24 (m, 2H), 1.91 (t, *J* = 6.6 Hz, 4H), 1.41 – 1.18 (m, 18H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 167.4, 151.4, 149.2, 139.2, 136.4, 131.9, 131.5, 130.2, 129.9, 128.8, 125.0, 123.2, 123.2, 122.2, 119.6, 115.6, 45.6, 31.6, 28.6, 26.9, 25.3, 25.2, 24.9, 24.2, 24.2, 24.0, 23.9, 23.5, 23.3, 22.4; **HRMS** (ESI) 584.2920 m/z (M + Na^+), calc. for $C_{33}H_{43}N_3NaO_3S^+$ 584.2917.

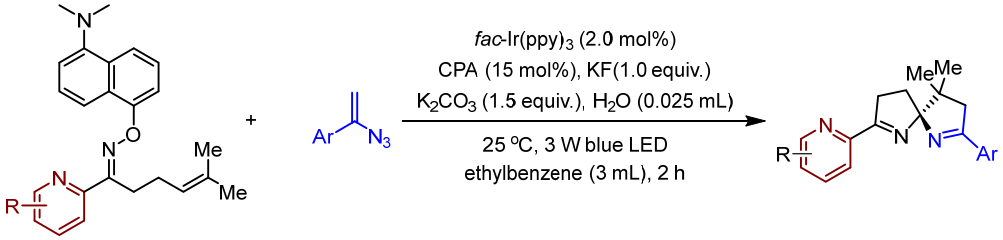
3.2 Synthesis of vinyl azides

Vinyl azides were synthesized following established literature procedures. To a Schlenk flask equipped with a stir bar, terminal alkyne (3.0 mmol, 1.0 equiv.), $TMSN_3$ (6.0 mmol, 2.0 equiv.), and H_2O (6.0 mmol, 2.0 equiv.) were added to 3 mL of dimethyl sulfoxide (DMSO) and heated to 80 °C. Subsequently, Ag_2CO_3 (10 mol%) was introduced into the mixture. After stirring, the reaction was allowed to cool to room temperature, then diluted with water and extracted with ethyl acetate three times. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was further purified by flash column chromatography on silica gel using a petroleum ether/ethyl acetate eluent, yielding the desired vinyl azide.



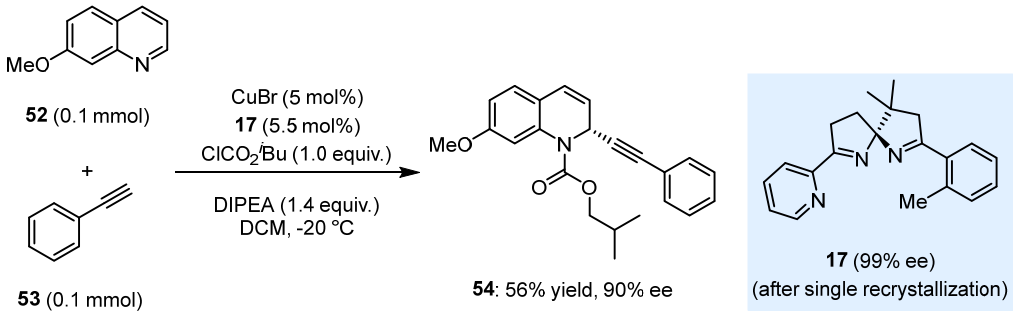
The experimental data are in accordance with the literature reports: **5**[8], **5b**[8], **5k-5r**[8], **5v**[8], **5t**[8], **5v**[8], **5a**[9], **5d**[9], **5f-5j**[9], **5s**[9], **5u**[9], **5c**[10], **5e**[11]

3.3 General experimental procedures for accessing enantioenriched products



An oven-dried Schlenk tube (10 mL) equipped with a stirring bar was charged with olefinic sulfonyl oximes (0.1 mmol), **C**1 (0.015 mmol, 15 mol%), K_2CO_3 (0.015 mmol, 1.5 equiv.), KF (0.1 mmol, 1.0 equiv.), H_2O (0.025 mL), a photocatalyst (2.0 mol%), vinyl azide (0.3 mmol, 3.0 equiv.), and ethylbenzene (3.0 mL). The reaction mixture was degassed three times using the freeze-pump-thaw method. The tube was then positioned approximately 2.0 cm from 3 W blue LEDs and stirred at room temperature for 2 hours. Upon completion, the residue was purified by flash chromatography on silica gel using a gradient elution of petroleum ether/ethyl acetate/tetrahydrofuran (15:1:1 to 10:1:1) to yield the desired product.

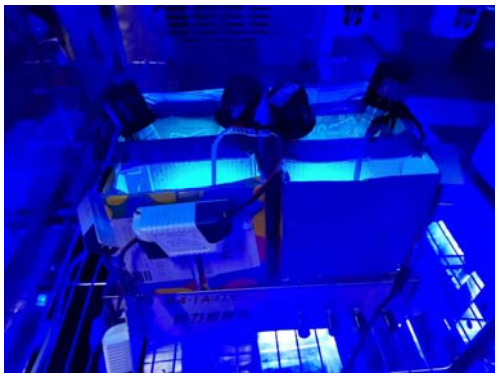
3.4 Application of *N*, *N*, *N*-ligand[12]



CuBr (0.005 mmol, 5 mol%) was added to a flask inside a glove box, which was subsequently fitted with a septum before being removed and placed under a dry nitrogen atmosphere. To this flask, a solution of compound **17** (0.0055 mmol, 5.5 mol%) in dichloromethane (1.0 mL) was added, and the mixture was stirred for 30 minutes at room temperature. Following this, the mixture was cooled to 0 °C, compound **53** (0.1 mmol, 1.0 equiv.) was introduced into the flask. During the stirring period, isobutyl chloroformate (0.1 mmol, 1.0 equiv.) was added to a solution of 7-methoxyquinoline (0.1 mmol, 1.0 equiv.) in DCM (1.0 mL) and stirred for 5 minutes at room temperature. The resulting quinolinium salt was then transferred to the flask

containing the copper catalyst and alkyne, followed by the addition of DIPEA (0.14 mmol, 1.4 equiv.) via syringe, the mixture was cooled to -20℃. The reaction mixture was stirred for the appropriate duration, as monitored by TLC. Upon completion, the reaction mixture was subjected directly to flash column chromatography on silica gel, using an eluent of ethyl acetate/petroleum ether (10:1), to yield the desired product **54**.

4. Experimental equipment



5. Mechanism studies

5.1 UV/Visible absorption spectroscopy

UV-vis absorption spectroscopy was performed on a PERSEE TU-1901 spectrophotometer, equipped with a temperature control unit at 25 °C. The samples were measured in a 3 mL quartz cuvette fitted with a PTFE stopper. **4**, **5**, **C1 and *fac*-Ir(ppy)$_3$** were prepared as a 0.1 mM solution with fresh DCM as the solvent for measurement.

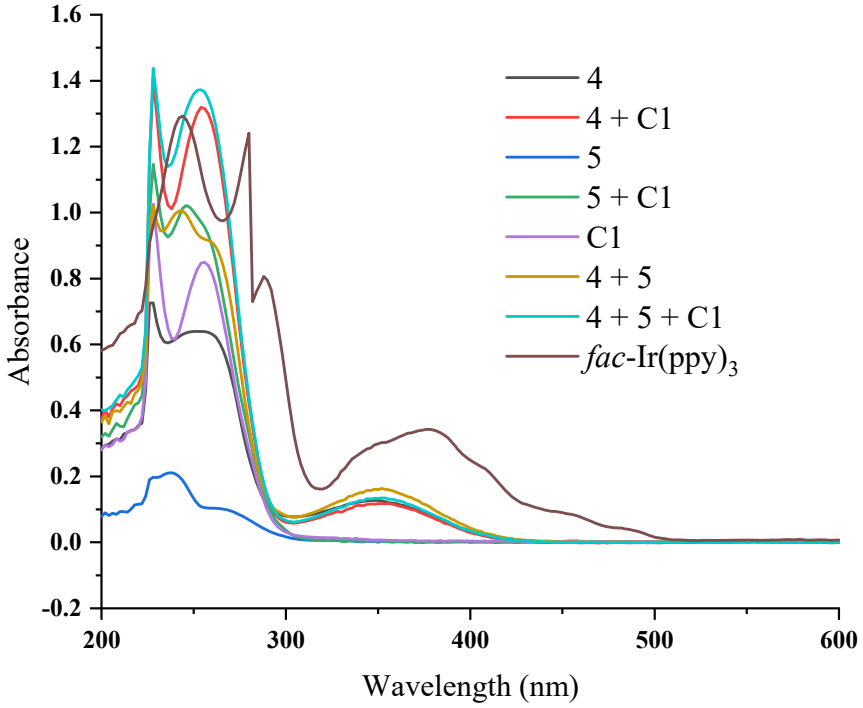


Fig. S1. UV-vis absorption spectra of **4**, **5**, **C1, 4 + C1**, **5 + C1**, **4 + 5**, **4 + 5 + C1 and *fac*-Ir(ppy)$_3$**.

Comments: The results can rule out the production of new photo-sensitive species, such as EDA complexes, in the reaction system.

5.2 Cyclic voltammetry studies

Electrochemical measurements were conducted using a CHI 660E electrochemical analyzer (CH Instruments). Electrochemical potentials were determined under standardized conditions to maintain internal consistency. Cyclic voltammograms were collected with a potentiostat. Samples, consisting of 0.01 mmol of compounds **4**, **5**, **4** + **C1**, and **5** + **C1**, were prepared in 10 mL of 0.1 M tetrabutylammonium hexafluorophosphate dissolved in anhydrous acetonitrile. The measurements utilized a radially configured glassy carbon working electrode, a platinum wire counter electrode, and a saturated KCl silver/silver chloride reference electrode, with all values referenced to Ag/AgCl.

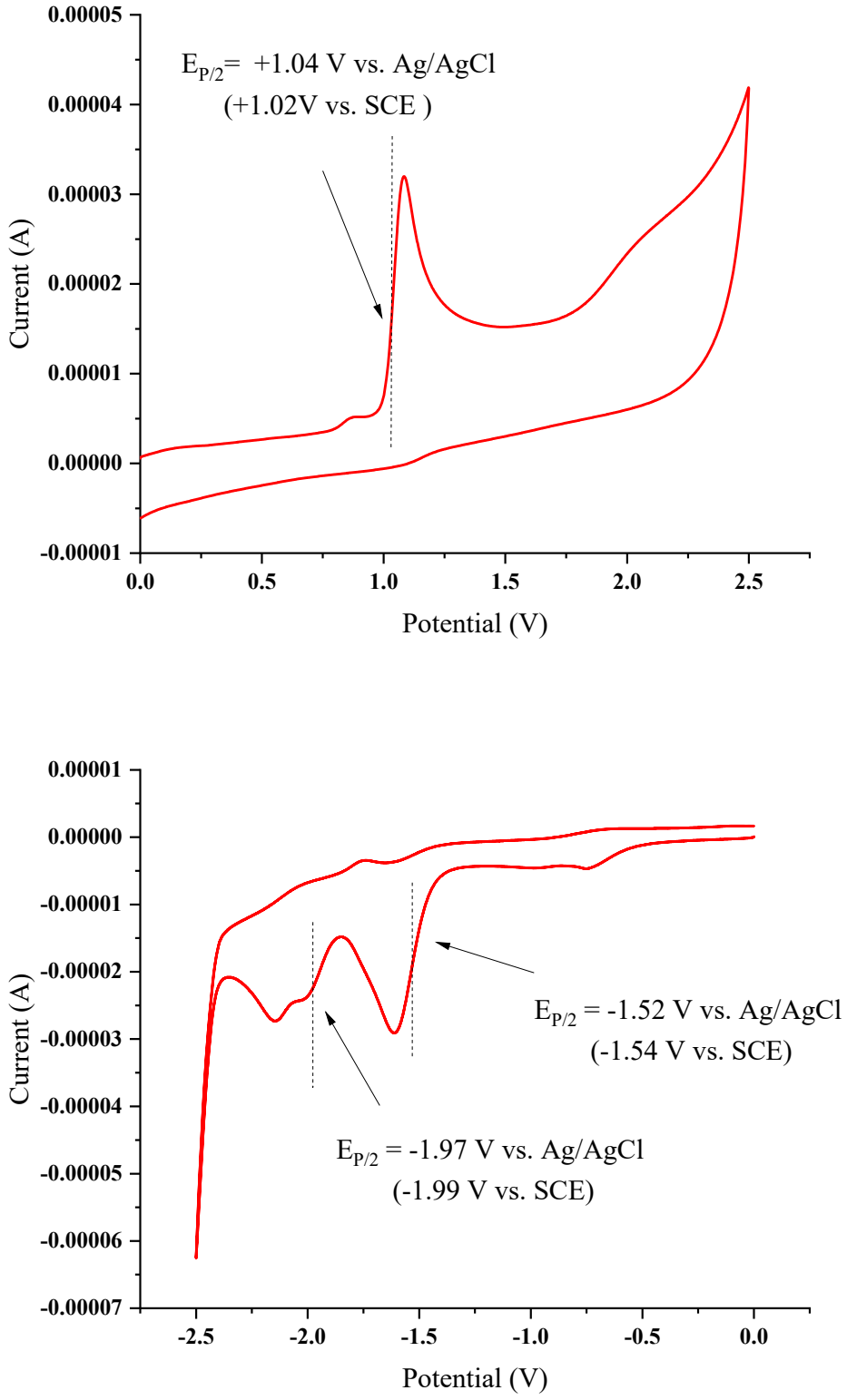


Fig. S2 Cyclic voltammogram of **4** in MeCN.

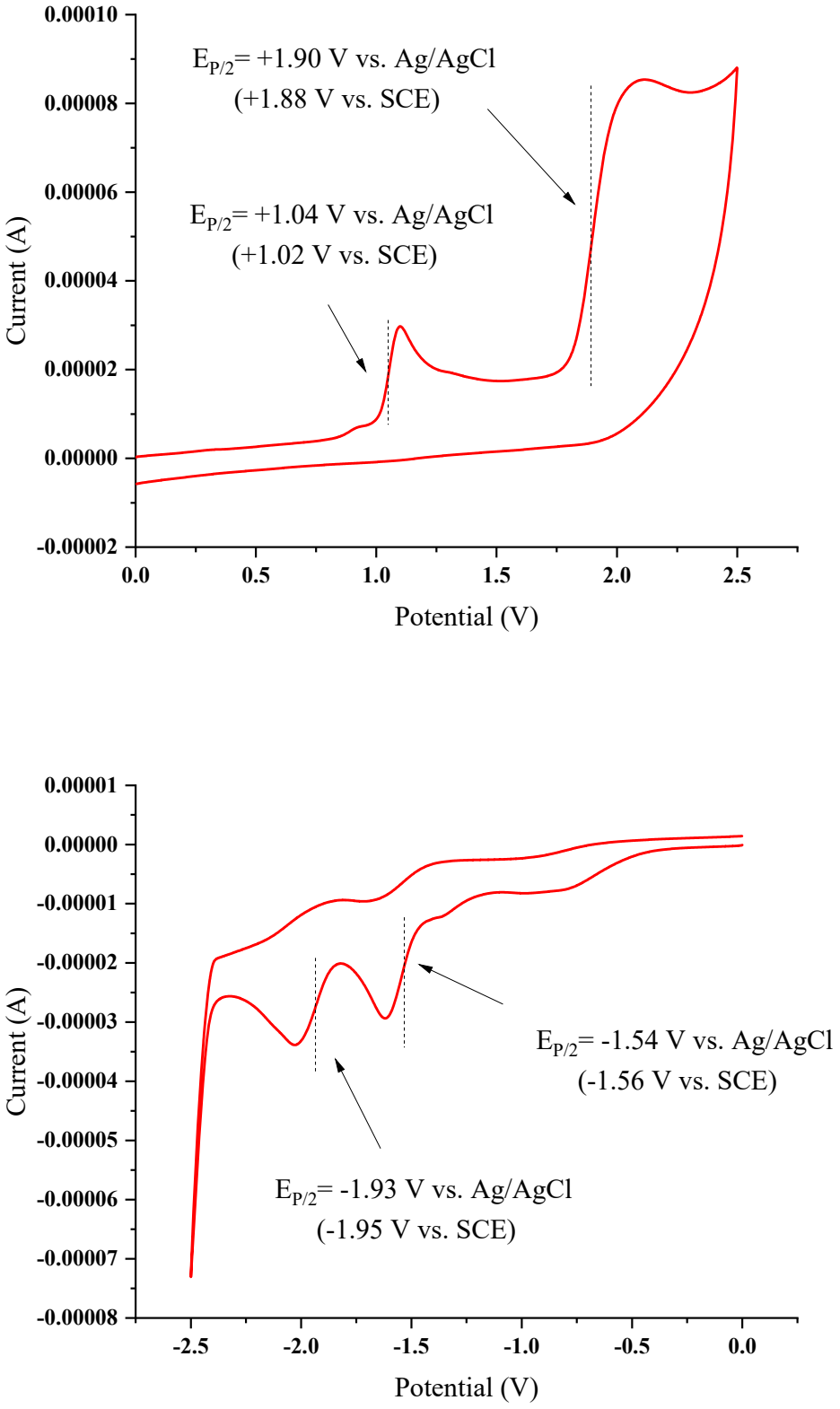


Fig. S3 Cyclic voltammogram of **4** + **C1** in MeCN.

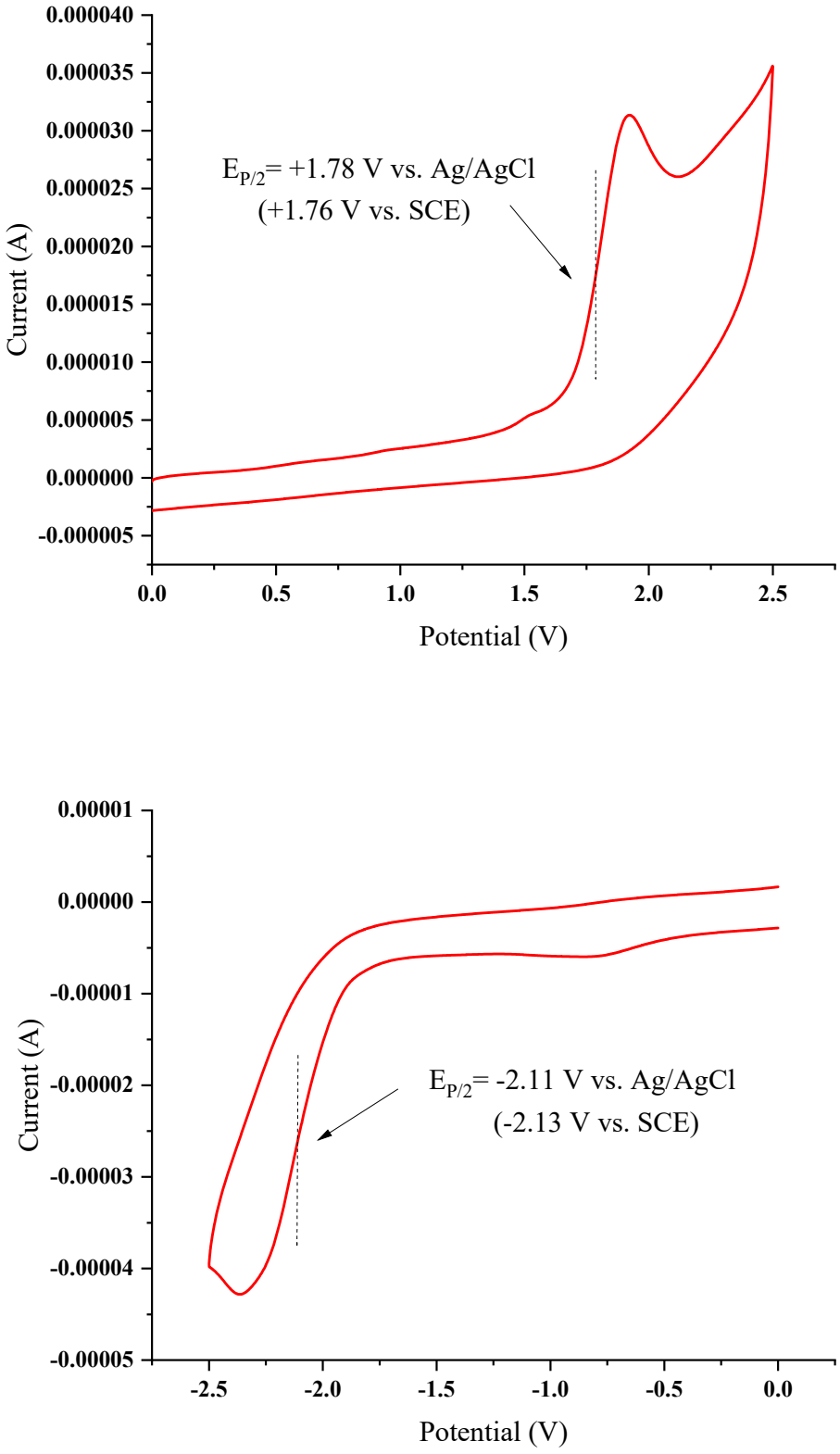
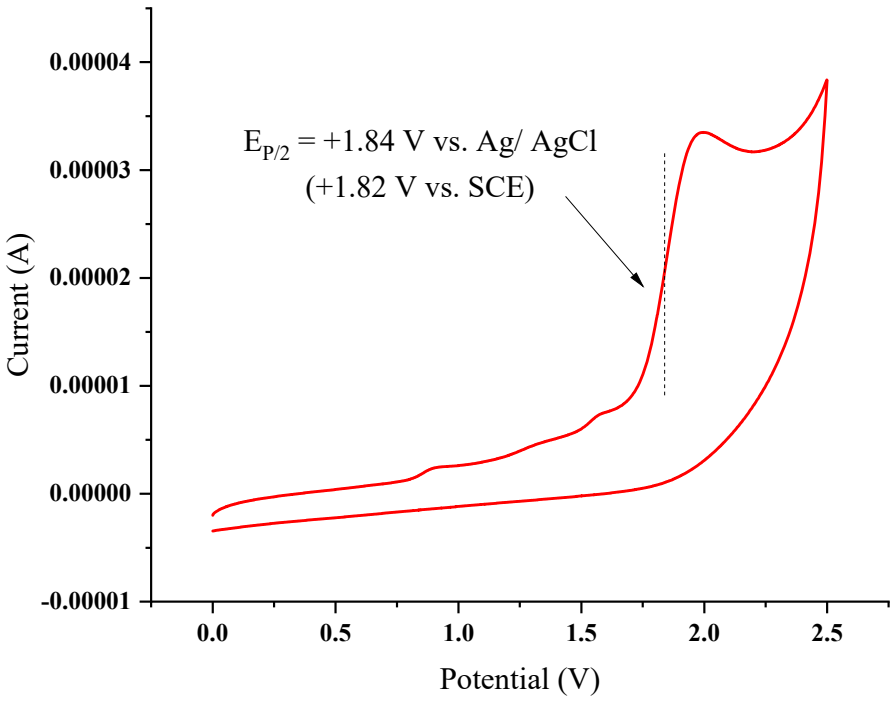


Fig. S4 Cyclic voltammogram of **5** in MeCN.



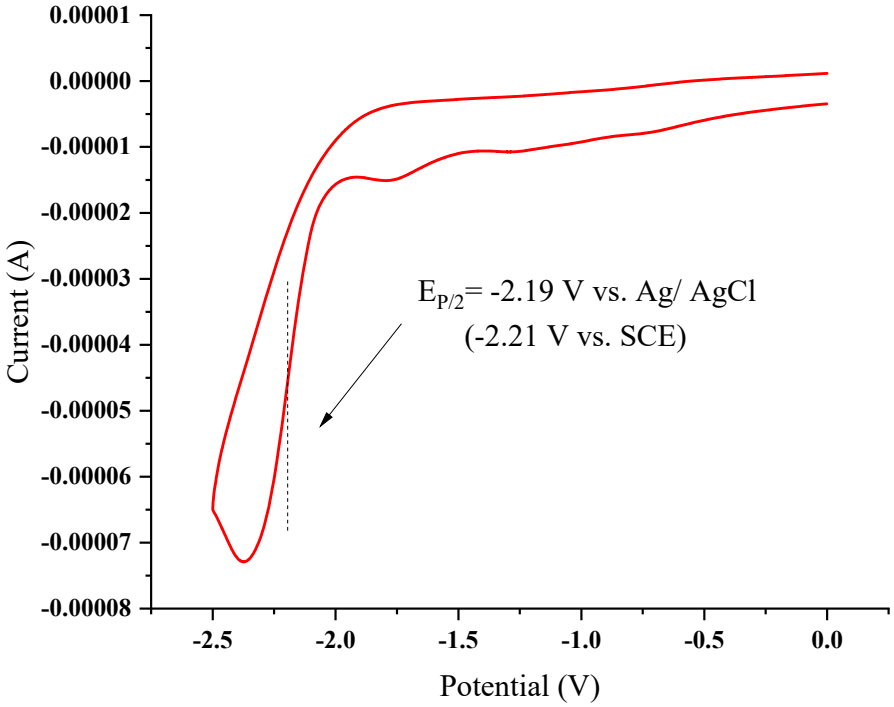


Fig. S5 Cyclic voltammogram of **5** + **C1** in MeCN.

5.3 Phosphorescence emission spectra at 77K of 4

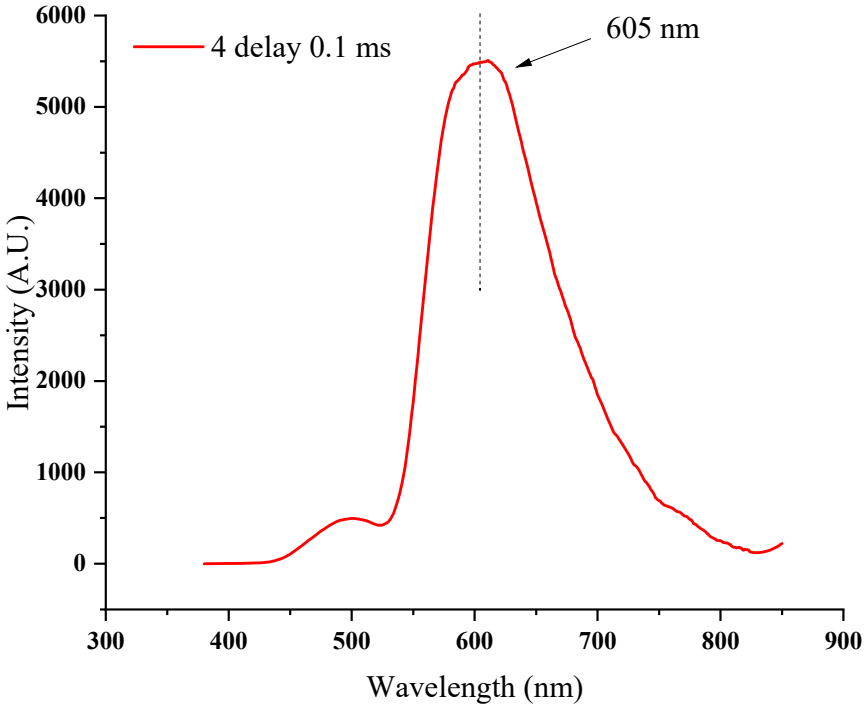


Fig. S6 The phosphorescence emission data for **4** with concentration of 1.0 mM in a DCM matrix at 77 K. The maxima was obtained at 605 nm. E_T = 47.3 kcal/mol.

5.4 Fluorescence emission spectra of 4 and *fac*-Ir(ppy)$_3$

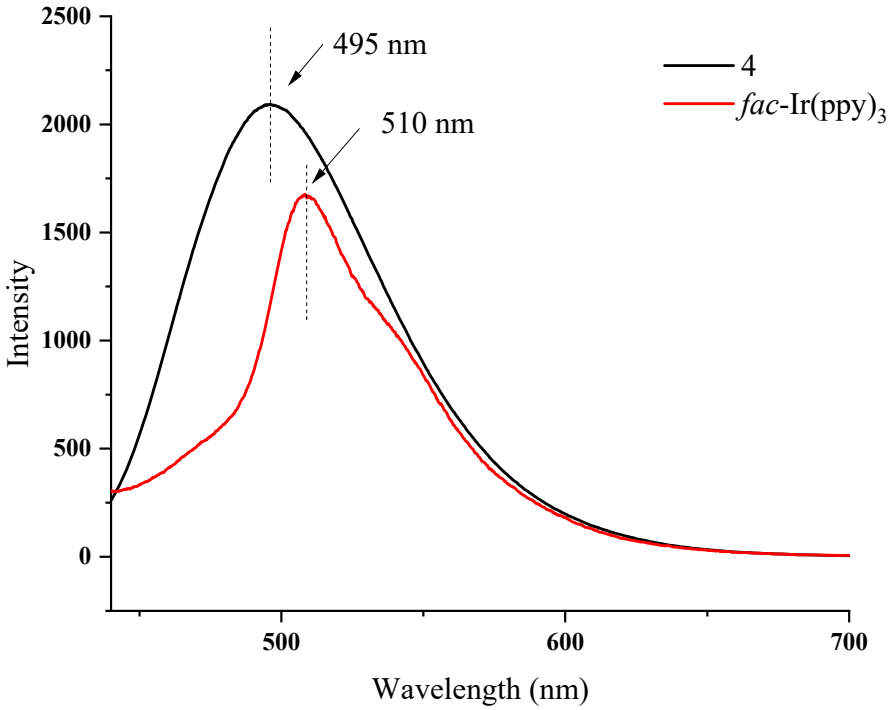


Fig. S7 The fluorescence emission spectrum for **4** and *fac*-Ir(ppy)$_3$ with concentration of 1.0 mM in a DCM, the maxima was obtained at 495 nm and 510 nm, respectively.

5.5 Stern-Volmer fluorescence quenching experiments and grating experiment

Emission intensities were recorded on a spectrofluorometer, *fac*-Ir(ppy)$_3$ solution was excited at 370 nm and the emission intensity at 510 nm was observed. A solution of *fac*-Ir(ppy)$_3$ (1.0×10^{-5} M) in EtPh was added to the appropriate amount of quencher in 3.0 mL volumetric flask under N_2. The solution was transferred to a 3.0 mL quartz cell and the emission spectrum of the sample was collected.

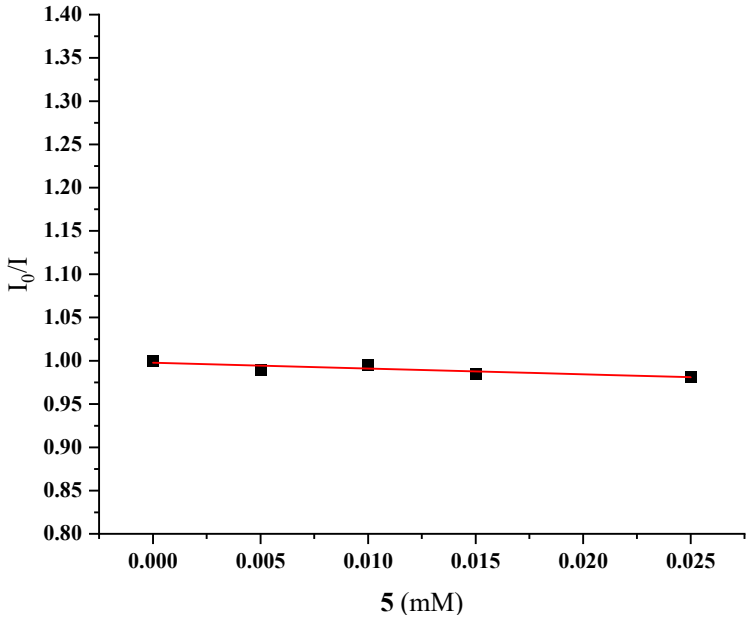
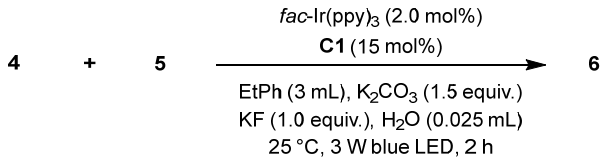


Fig. S8 Luminescence quenching experminent: Stern-Volmer plots of the photosensitizer *fac*-Ir(ppy)$_3$ using varying concentrations of **5** in EtPh.

5.6 Linear effect experiments



The ee value of **C1** was determined by HPLC analysis: CHIRALPAK QD-AX (4.6 mm i.d. x 150 mm); methanol/acetonitrile/acetic acid/triethylamine = 50/50/2/0.2; flow 0.5 mL/min; 25 °C; 254 nm. The ee value of **6** was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 nm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 20 °C, 254 nm.

entry	1	2	3	4	5	6
ee (%) of **C1**	3	27	45	66	81	99
ee (%) of **6**	0	18	40	60	72	90

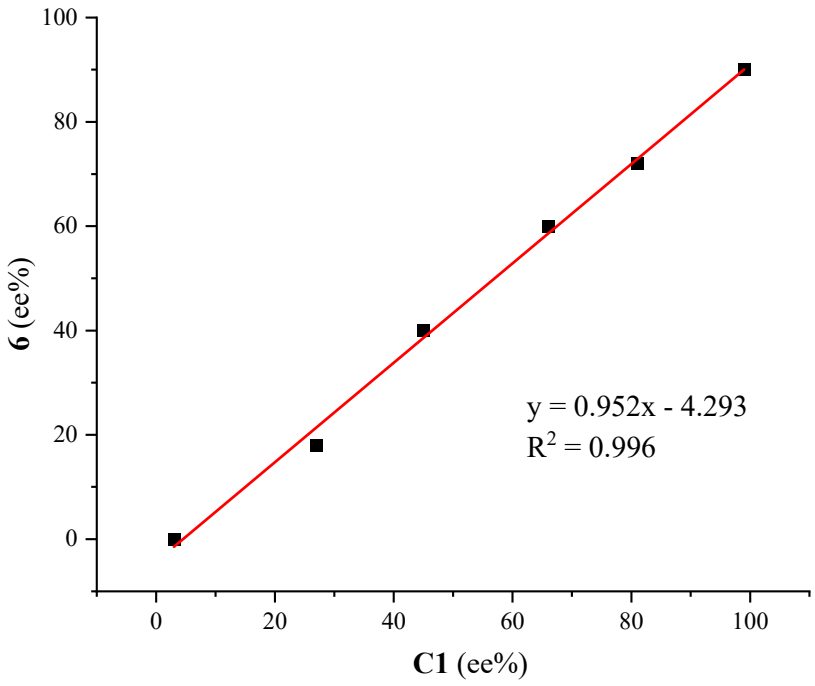
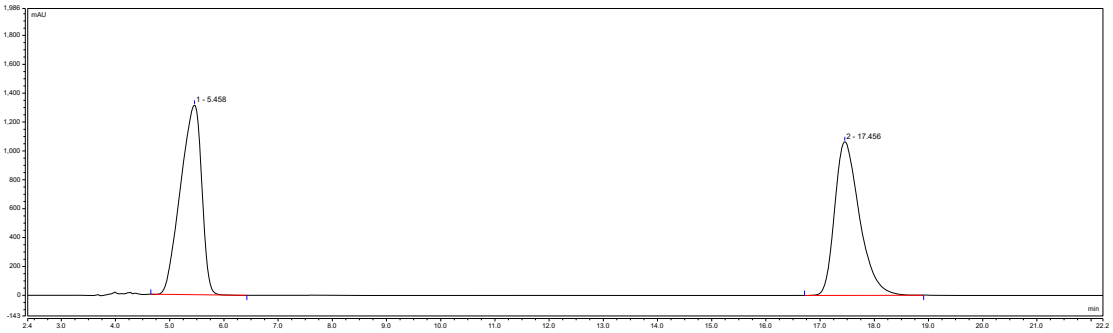


Fig. S9 Relationship between ee values of **C1** and **6.**

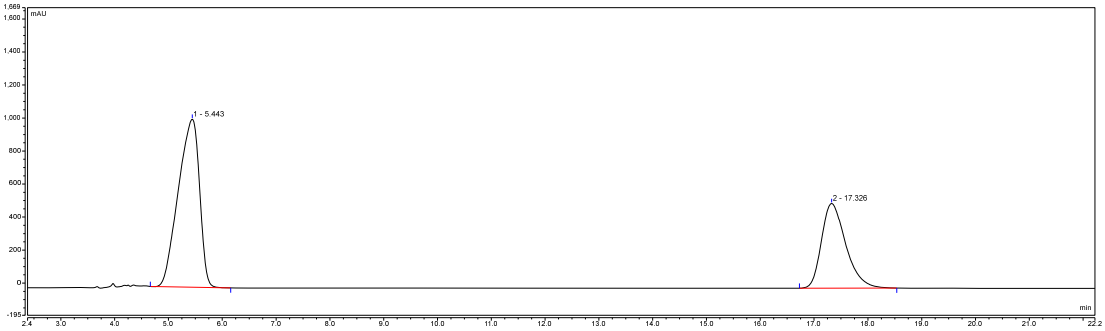
HPLC spectra:

C1: 3% ee



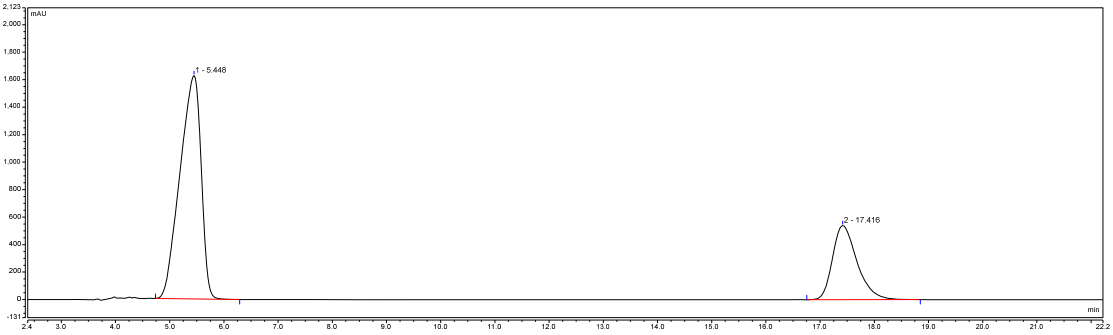
Entry	Retention Time	Area	Height	%Area
1	5.458	594.8593	1313.39	51.36
2	17.456	563.3493	1064.01	48.64

C1: 27% ee



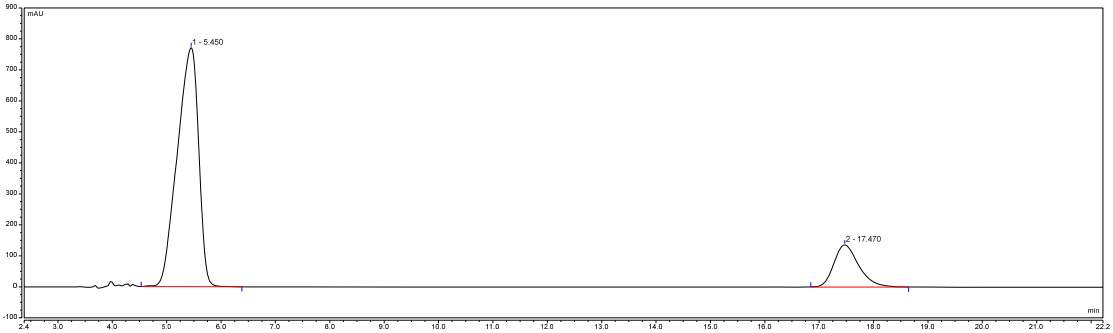
Entry	Retention Time	Area	Height	%Area
1	5.443	465.1247	1017.41	63.51
2	17.326	267.2776	512.38	36.49

C1：45% ee



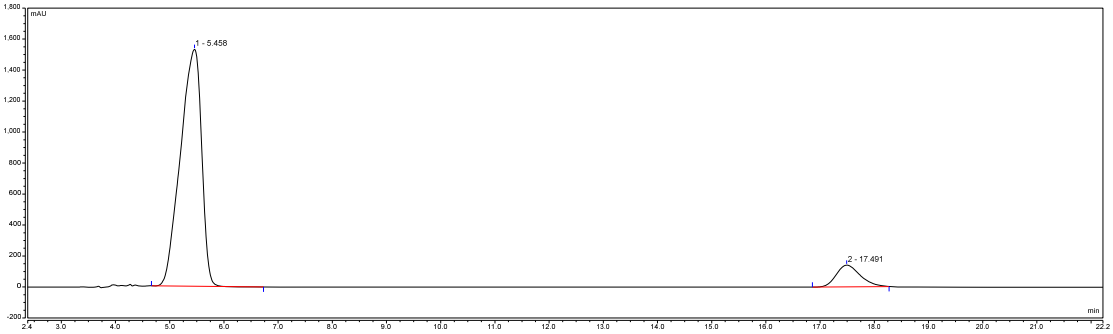
Entry	Retention Time	Area	Height	%Area
1	5.448	734.9608	1624.47	72.28
2	17.416	281.8033	538.59	27.72

C1：66% ee



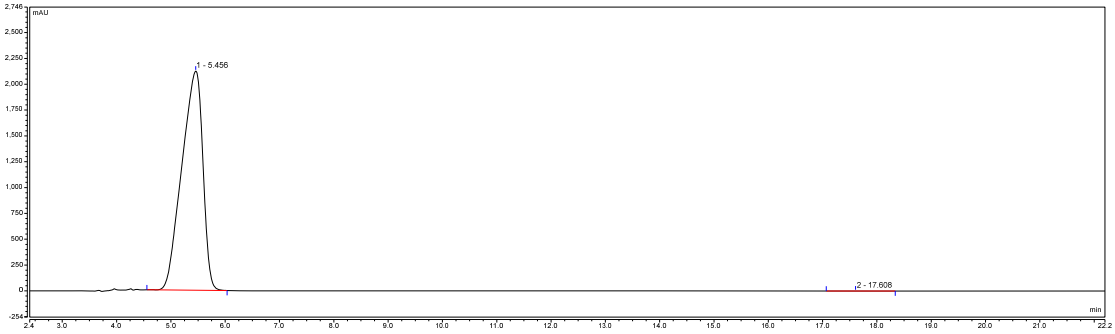
Entry	Retention Time	Area	Height	%Area
1	5.450	350.5317	771.17	82.96
2	17.470	72.0007	135.99	17.04

C1: 81%



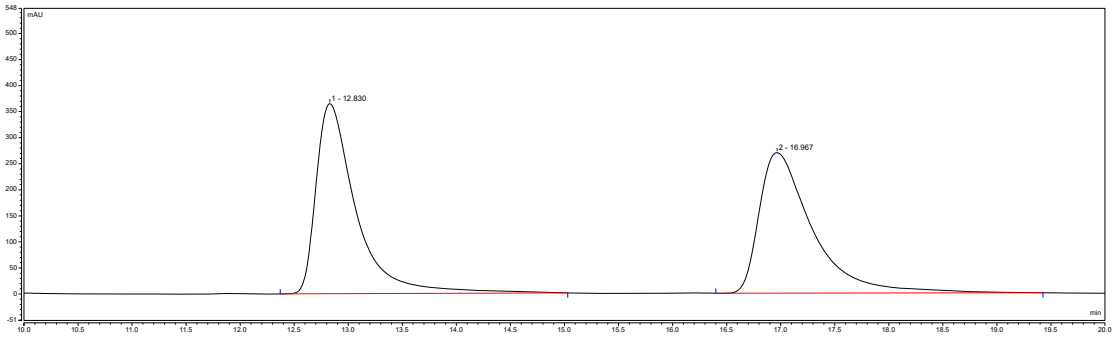
Entry	Retention Time	Area	Height	%Area
1	5.458	691.4495	1528.72	90.58
2	17.491	71.8996	140.24	9.42

C1: 99% ee



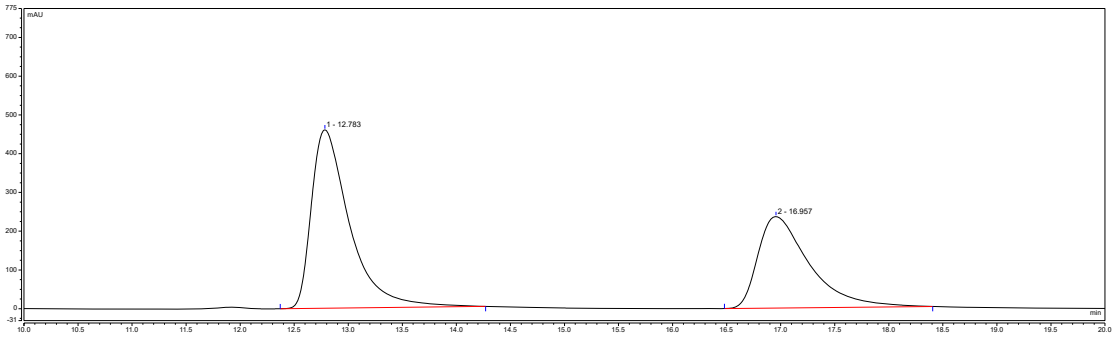
Entry	Retention Time	Area	Height	%Area
1	5.456	950.4685	2122.53	99.99
2	17.608	0.1202	0.25	0.01

6a: 0% ee



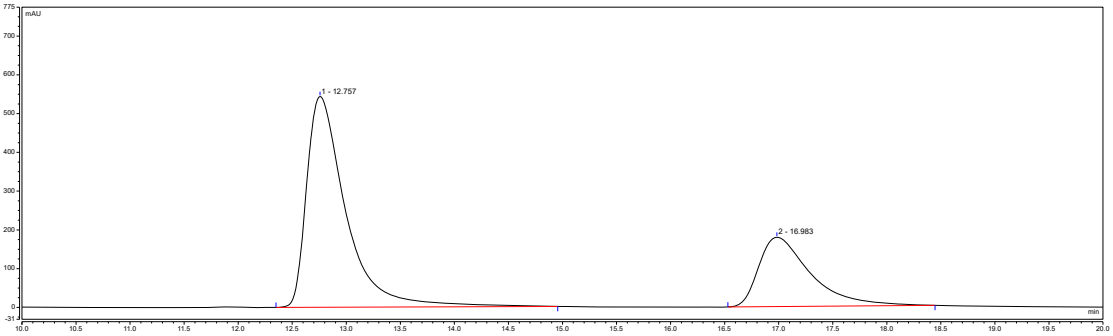
Entry	Retention Time	Area	Height	%Area
1	12.830	156.0018	364.68	50.37
2	16.967	153.7055	269.96	49.63

6a: 18% ee



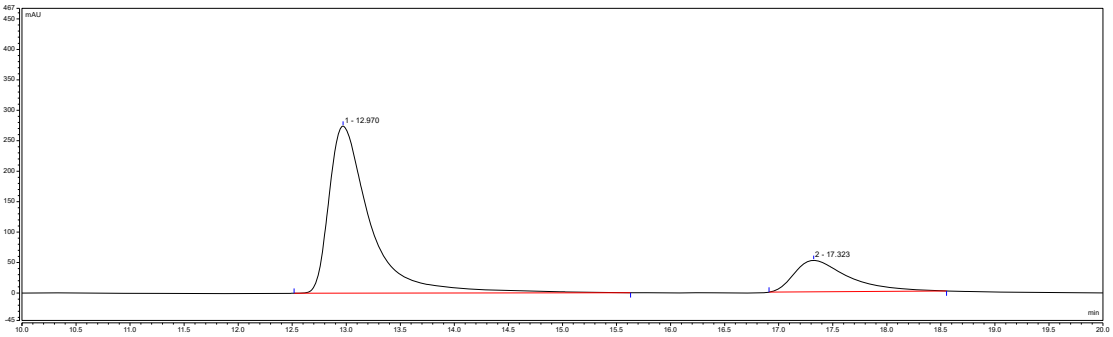
Entry	Retention Time	Area	Height	%Area
1	12.783	188.6594	460.27	59.21
2	16.957	129.9564	236.20	40.79

6a: 40% ee



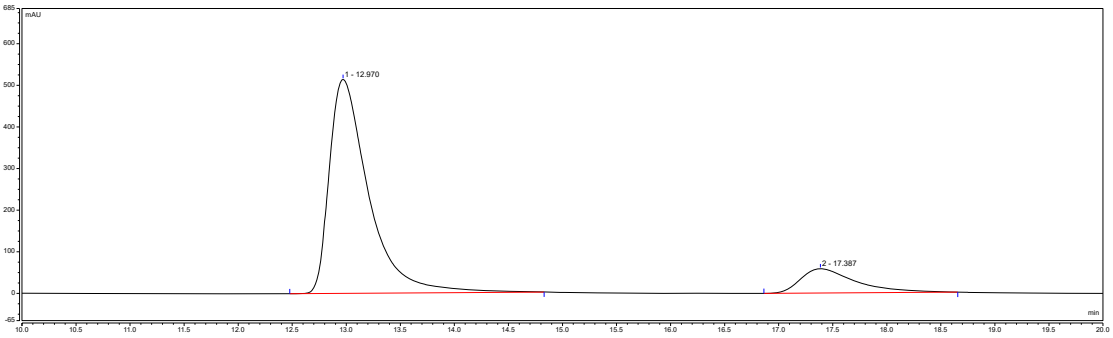
Entry	Retention Time	Area	Height	%Area
1	12.757	227.9025	543.68	69.65
2	16.983	99.3121	179.03	30.35

6a: 60% ee



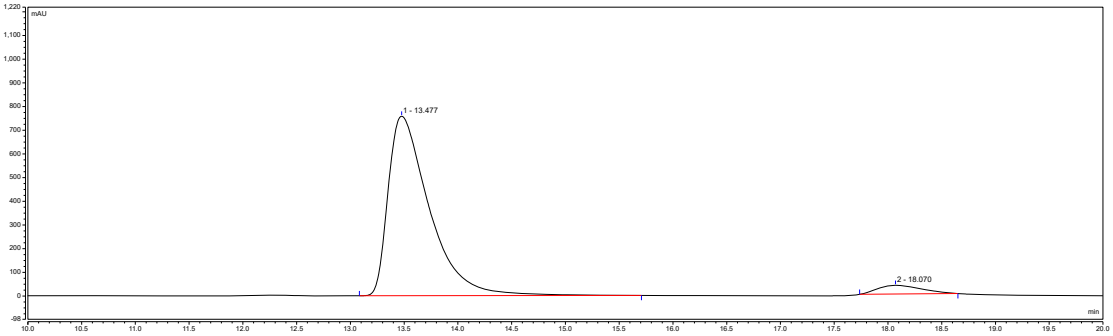
Entry	Retention Time	Area	Height	%Area
1	12.970	121.1727	274.29	80.22
2	17.323	29.8721	51.67	19.78

6a: 72% ee



Entry	Retention Time	Area	Height	%Area
1	12.970	216.3354	514.25	86.25
2	17.387	34.4827	58.49	13.75

6a: 90% ee



Entry	Retention Time	Area	Height	%Area
1	13.477	336.3840	757.81	95.07
2	18.070	17.4559	36.80	4.93

6. Determination of the absolute configurations

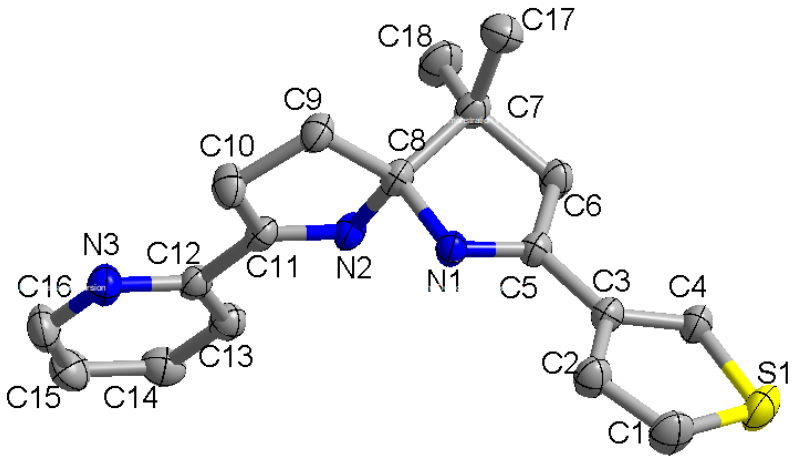


Fig. S10 X-ray single-crystal structure of **29** (CCDC: 2414232).

Table S2 Crystal data and structure refinement for 29.

Identification code	**29**
Empirical formula	$C_{18}H_{19}N_3S$
Formula weight	309.42
Temperature/K	293(2)
Crystal system	monoclinic
Space group	C2
a/Å	20.1236(5)
b/Å	7.0187(3)
c/Å	12.0117(4)
α/°	90
β/°	97.820(3)
γ/°	90
Volume/Å^3	1680.77(9)
Z	4
ρ_{calc}g/cm^3	1.223
μ/mm^{-1}	1.694
F(000)	656.0
Crystal size/mm^3	0.21 × 0.11 × 0.1
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	7.428 to 141.706
Index ranges	-24 ≤ h ≤ 24, -8 ≤ k ≤ 6, -14 ≤ l ≤ 14
Reflections collected	11325
Independent reflections	2804 [R_{int} = 0.0345, R_{sigma} = 0.0285]
Data/restraints/parameters	2804/1/201
Goodness-of-fit on F^2	1.071

Final R indexes [I>=2σ (I)]	R_1 = 0.0419, wR_2 = 0.1138
Final R indexes [all data]	R_1 = 0.0465, wR_2 = 0.1186
Largest diff. peak/hole / e Å^{-3}	0.17/-0.22
Flack parameter	0.025(13)

Table S3. Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for 29. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	*x*	*y*	*z*	U(eq)
S1	7950.3(4)	4541(2)	8455.3(11)	80.9(4)
N1	5498.4(11)	4997(4)	8285(2)	42.9(6)
N2	4655.7(11)	5098(4)	6710(2)	46.7(6)
N3	3185.1(14)	2283(5)	6060(3)	57.7(7)
C1	7516(2)	3026(7)	9190(4)	69.7(11)
C2	6839.2(16)	3466(6)	9045(3)	55.8(8)
C3	6691.9(14)	5054(5)	8331(2)	43.2(7)
C4	7250.2(15)	5776(6)	7953(3)	54.6(8)
C5	6011.9(13)	5818(5)	7994(2)	41.6(7)
C6	5877.3(15)	7582(5)	7294(3)	50.6(8)
C7	5164.9(15)	8098(5)	7529(3)	51.3(8)
C8	4900.8(13)	6082(5)	7777(2)	44.4(7)
C9	4323.2(15)	5963(6)	8495(3)	53.1(8)
C10	3861.8(15)	4445(7)	7923(3)	58.4(9)
C11	4104.8(13)	4269(5)	6795(2)	43.4(7)
C12	3738.4(14)	3180(5)	5847(3)	45.1(7)
C13	3963.2(16)	3135(5)	4806(3)	50.3(8)
C14	3605.7(19)	2088(6)	3951(3)	60.3(9)
C15	3036(2)	1150(7)	4158(3)	67.1(10)
C16	2845.2(18)	1287(7)	5226(4)	68.6(11)
C17	5225(2)	9361(7)	8573(4)	69.1(10)
C18	4739.7(19)	9092(7)	6549(4)	74.0(12)

Table S4 Anisotropic Displacement Parameters (Å^2×10^3) for 29. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
S1	38.1(4)	90.0(9)	114.9(8)	7.7(7)	11.7(4)	12.8(5)
N1	34.7(11)	44.4(16)	49.5(12)	4.1(12)	6.1(9)	-0.9(11)
N2	32.6(11)	59.3(19)	48.3(12)	-3.0(12)	6.2(9)	0.5(11)
N3	45.2(13)	63(2)	65.4(15)	-5.1(15)	10.7(12)	-8.2(13)
C1	59(2)	67(3)	80(2)	19(2)	0.1(17)	15(2)
C2	47.3(16)	58(2)	61.4(17)	10.8(17)	2.9(13)	4.2(16)

C3	35.7(13)	44.5(19)	49.0(14)	-0.8(13)	4.0(10)	1.3(12)
C4	37.3(14)	57(2)	70.2(19)	2.2(18)	10.8(13)	0.8(15)
C5	34.4(13)	46.2(19)	44.1(13)	0.1(13)	4.5(10)	0.7(12)
C6	42.4(15)	51(2)	59.6(17)	13.1(15)	9.8(13)	-1.1(14)
C7	43.2(15)	51(2)	59.9(17)	6.5(16)	8.1(13)	5.9(15)
C8	33.8(13)	51(2)	48.4(14)	0.7(14)	7.0(11)	2.5(13)
C9	39.1(14)	67(2)	54.7(16)	-5.0(16)	11.6(12)	1.2(15)
C10	49.3(15)	73(3)	55.3(16)	-5.5(18)	16.4(13)	-14.7(19)
C11	34.7(12)	48.4(19)	47.4(14)	3.4(13)	6.9(10)	7.2(13)
C12	36.4(12)	46.5(19)	52.1(15)	3.8(14)	4.8(11)	5.2(13)
C13	48.0(15)	50(2)	53.3(16)	3.5(15)	7.2(12)	2.8(15)
C14	72(2)	57(2)	51.6(17)	-1.4(17)	6.1(15)	4.0(19)
C15	67(2)	65(3)	66(2)	-16(2)	-0.9(17)	-6(2)
C16	52.8(19)	74(3)	79(2)	-13(2)	9.8(17)	-24(2)
C17	72(2)	55(3)	83(2)	-8(2)	17.9(18)	-2(2)
C18	56.9(19)	73(3)	90(3)	26(2)	3.4(18)	16(2)

Table S5 Bond Lengths for 29.

Atom	Atom	Length/Å	Atom	Atom	Length/Å
S1	C1	1.698(5)	C6	C7	1.542(4)
S1	C4	1.694(3)	C7	C8	1.555(5)
N1	C5	1.273(4)	C7	C17	1.527(5)
N1	C8	1.483(4)	C7	C18	1.527(5)
N2	C8	1.481(4)	C8	C9	1.541(4)
N2	C11	1.268(4)	C9	C10	1.515(5)
N3	C12	1.334(4)	C10	C11	1.506(4)
N3	C16	1.332(5)	C11	C12	1.482(4)
C1	C2	1.384(5)	C12	C13	1.386(4)
C2	C3	1.412(5)	C13	C14	1.383(5)
C3	C4	1.365(4)	C14	C15	1.374(6)
C3	C5	1.474(4)	C15	C16	1.392(6)
C5	C6	1.501(5)			

Table S6 Bond Angles for 29.

Atom	Atom	Atom	Angle/°	Atom	Atom	Atom	Angle/°
C4	S1	C1	92.50(19)	C18	C7	C17	110.0(4)
C5	N1	C8	107.3(3)	N1	C8	C7	105.5(2)
C11	N2	C8	109.6(2)	N1	C8	C9	111.9(3)
C16	N3	C12	117.4(3)	N2	C8	N1	105.8(2)
C2	C1	S1	111.2(3)	N2	C8	C7	109.9(2)

C1	C2	C3	112.0(3)	N2	C8	C9	105.8(2)
C2	C3	C5	124.3(3)	C9	C8	C7	117.4(3)
C4	C3	C2	112.4(3)	C10	C9	C8	104.3(3)
C4	C3	C5	123.3(3)	C11	C10	C9	102.2(3)
C3	C4	S1	111.9(3)	N2	C11	C10	115.4(3)
N1	C5	C3	121.2(3)	N2	C11	C12	121.6(3)
N1	C5	C6	115.8(3)	C12	C11	C10	123.0(3)
C3	C5	C6	123.0(3)	N3	C12	C11	115.9(3)
C5	C6	C7	101.1(3)	N3	C12	C13	123.1(3)
C6	C7	C8	99.9(3)	C13	C12	C11	121.0(3)
C17	C7	C6	108.4(3)	C14	C13	C12	118.8(3)
C17	C7	C8	111.2(3)	C15	C14	C13	118.9(3)
C18	C7	C6	113.8(3)	C14	C15	C16	118.4(3)
C18	C7	C8	113.2(3)	N3	C16	C15	123.5(4)

Table S7 Torsion Angles for 29.

A	B	C	D	Angle/°	A	B	C	D	Angle/°
S1	C1	C2	C3	-0.2(5)	C7	C8	C9	C10	138.4(3)
N1	C5	C6	C7	18.4(4)	C8	N1	C5	C3	-178.0(3)
N1	C8	C9	C10	-99.3(3)	C8	N1	C5	C6	1.8(4)
N2	C8	C9	C10	15.4(4)	C8	N2	C11	C10	-1.6(4)
N2	C11	C12	N3	176.3(3)	C8	N2	C11	C12	179.5(3)
N2	C11	C12	C13	-4.3(5)	C8	C9	C10	C11	-15.5(4)
N3	C12	C13	C14	-1.1(5)	C9	C10	C11	N2	11.5(4)
C1	S1	C4	C3	-0.1(3)	C9	C10	C11	C12	-169.6(3)
C1	C2	C3	C4	0.1(5)	C10	C11	C12	N3	-2.6(5)
C1	C2	C3	C5	178.1(3)	C10	C11	C12	C13	176.8(3)
C2	C3	C4	S1	0.0(4)	C11	N2	C8	N1	109.9(3)
C2	C3	C5	N1	-4.2(5)	C11	N2	C8	C7	-136.6(3)
C2	C3	C5	C6	176.0(3)	C11	N2	C8	C9	-9.0(4)
C3	C5	C6	C7	-161.8(3)	C11	C12	C13	C14	179.6(3)
C4	S1	C1	C2	0.2(4)	C12	N3	C16	C15	-0.4(6)
C4	C3	C5	N1	173.5(3)	C12	C13	C14	C15	0.8(6)
C4	C3	C5	C6	-6.3(5)	C13	C14	C15	C16	-0.4(6)
C5	N1	C8	N2	95.0(3)	C14	C15	C16	N3	0.1(7)
C5	N1	C8	C7	-21.5(3)	C16	N3	C12	C11	-179.8(3)
C5	N1	C8	C9	-150.3(3)	C16	N3	C12	C13	0.9(6)
C5	C3	C4	S1	-177.9(2)	C17	C7	C8	N1	-83.3(3)
C5	C6	C7	C8	-28.3(3)	C17	C7	C8	N2	163.1(3)
C5	C6	C7	C17	88.2(3)	C17	C7	C8	C9	42.2(4)

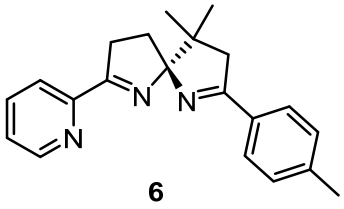
C5	C6	C7	C18	-149.2(3)	C18	C7	C8	N1	152.4(3)
C6	C7	C8	N1	31.0(3)	C18	C7	C8	N2	38.7(4)
C6	C7	C8	N2	-82.6(3)	C18	C7	C8	C9	-82.2(4)
C6	C7	C8	C9	156.5(3)					

Table S8 Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for 29.

Atom	*x*	*y*	*z*	U(eq)
H1	7708	2030	9633	84
H2	6519	2796	9377	67
H4	7246	6820	7476	66
H6A	5887	7322	6503	61
H6B	6196	8584	7538	61
H9A	4489	5599	9262	64
H9B	4092	7175	8503	64
H10A	3910	3252	8333	70
H10B	3397	4847	7844	70
H13	4347	3796	4686	60
H14	3749	2019	3247	72
H15	2784	441	3598	80
H16	2460	650	5365	82
H17A	5510	8754	9175	104
H17B	4788	9556	8791	104
H17C	5414	10569	8409	104
H18A	4940	10295	6408	111
H18B	4296	9299	6733	111
H18C	4716	8308	5890	111

7. Characterization of adducts

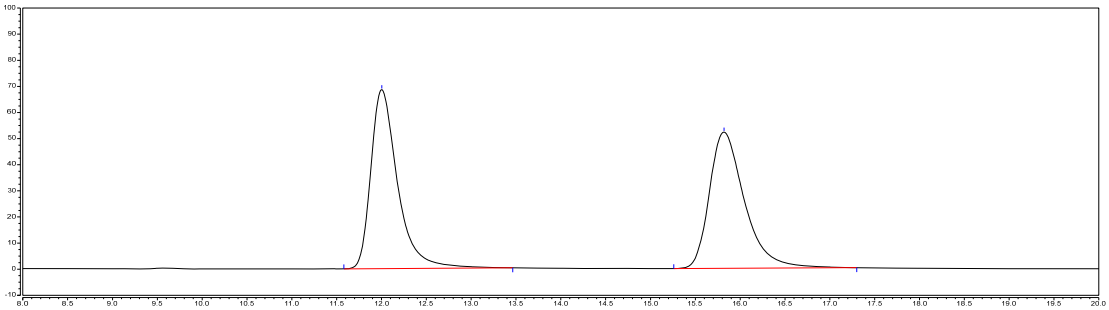
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(*p*-tolyl)-1,6-diazaspiro[4.4]nona-1,6-diene (6)



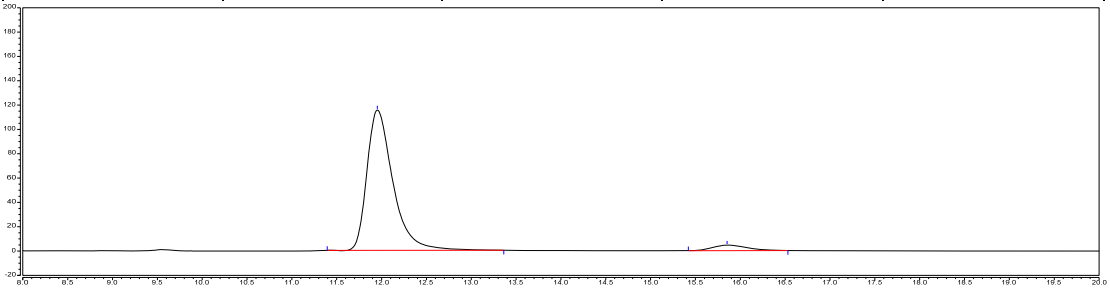
6

White solid; Mp 130.2−131.1 °C; 22.2 mg, 70% yield, 90% ee; $[\alpha]_D^{22}$ –36.1 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.66 – 8.62 (m, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.76 (d, *J* = 8.1 Hz, 2H), 7.70 (td, *J* = 7.7, 1.8 Hz, 1H), 7.30 (m, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 3.39 (m, 1H), 3.22 (m, 2H), 2.87 (d, *J* = 15.9 Hz, 1H), 2.37 (s, 3H), 2.30 (m, 1H), 2.15 (m, 1H), 1.15 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 174.6, 174.4, 153.6, 149.1, 140.9, 136.2, 132.3, 129.1, 127.9, 124.7, 122.7, 111.2, 50.1, 45.0, 35.3, 28.5, 25.1, 22.0, 21.6; **HRMS** (ESI) m/z 317.1892 (M +H^+), calc. for $C_{21}H_{23}N_3^+$ 317.1892.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 12.0 min (major) and 15.8 min (minor).

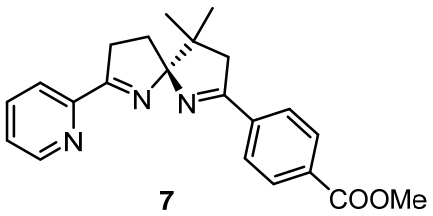


Entry	Retention Time	Area	Height	%Area
1	12.003	23.6889	68.55	50.02
2	15.820	23.6721	52.20	49.98



Entry	Retention Time	Area	Height	%Area
1	11.953	38.6644	115.39	95.00
2	15.853	2.0343	4.55	5.00

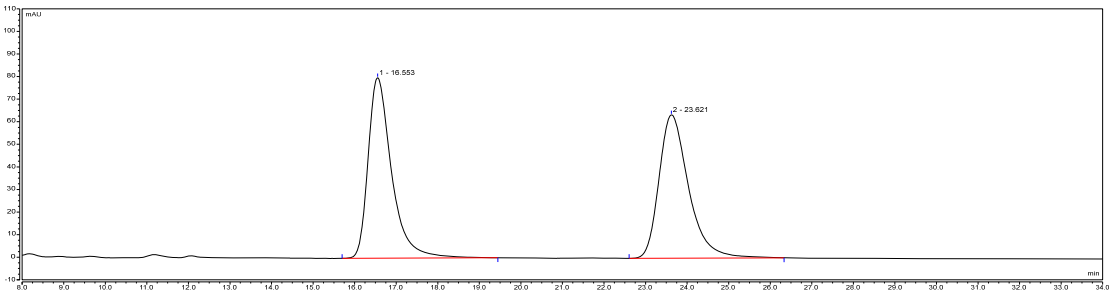
(*R*)-methyl-4-(4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-dien-2-yl) benzoate (7)



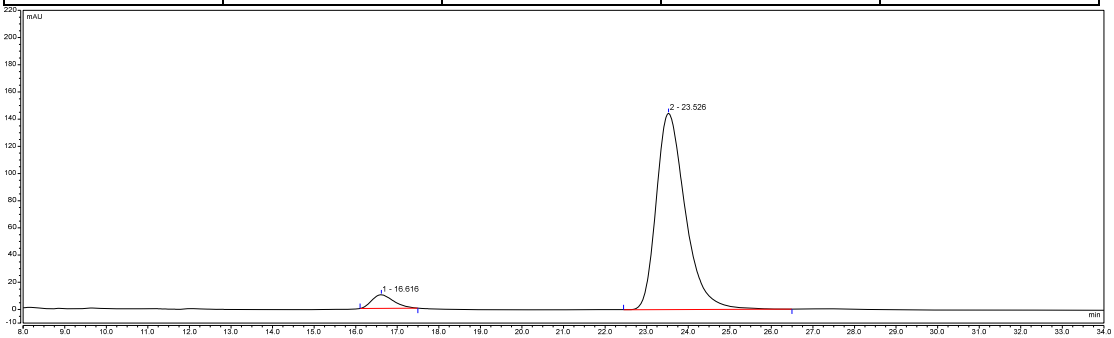
7

Yellow solid; Mp 116.3−117.1 °C; 19.6 mg, 54% yield, 90% ee; $[\alpha]_D^{22}$ +218.9 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_2Cl_2) δ 8.62 (d, *J* = 4.8 Hz, 1H), 8.13 (d, *J* = 7.9 Hz, 1H), 8.05 (d, *J* = 8.4 Hz, 2H), 7.93 (d, *J* = 8.3 Hz, 2H), 7.72 (td, *J* = 7.7, 1.7 Hz, 1H), 7.36 – 7.28 (m, 1H), 3.90 (s, 3H), 3.28 (m, 2H), 3.23 (d, *J* = 15.8 Hz, 1H), 2.90 (d, *J* = 16.1 Hz, 1H), 2.31 – 2.22 (m, 1H), 2.13 (m, 1H), 1.17 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (101 MHz, CD_2Cl_2) δ 170.4, 168.6, 161.8, 148.7, 144.4, 134.3, 131.4, 127.2, 124.8, 123.0, 120.1, 117.4, 106.7, 47.4, 45.2, 40.1, 30.5, 23.6, 20.1, 16.8; **HRMS** (ESI) m/z 362.1862 (M +H^+), calc. for $C_{22}H_{24}N_3O_2^+$ 362.1863.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 16.5 min (minor) and 23.6 min (major).

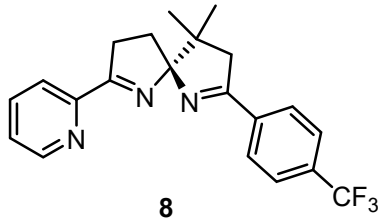


Entry	Retention Time	Area	Height	%Area
1	16.553	79.95	52.3562	50.05
2	23.621	63.52	52.2507	49.95



Entry	Retention Time	Area	Height	%Area
1	16.616	6.0873	10.00	4.97
2	23.526	116.4727	144.26	95.03

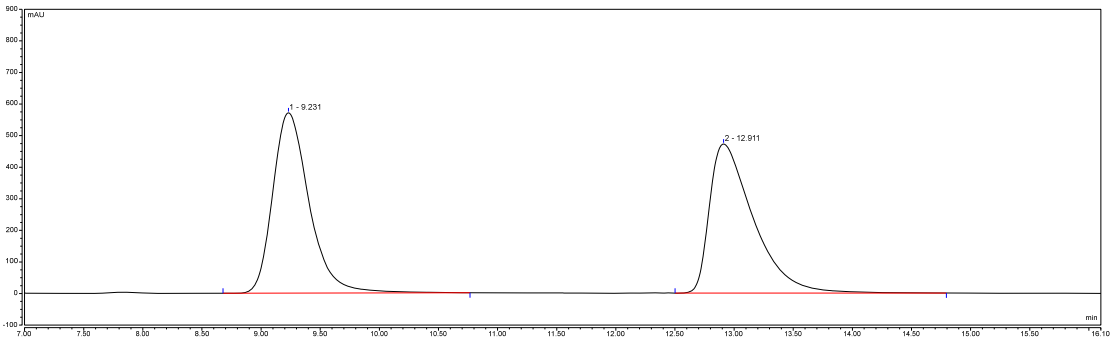
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(4-(trifluoromethyl)phenyl)-1,6-diazaspiro[4.4]nona-1,6-diene (8)



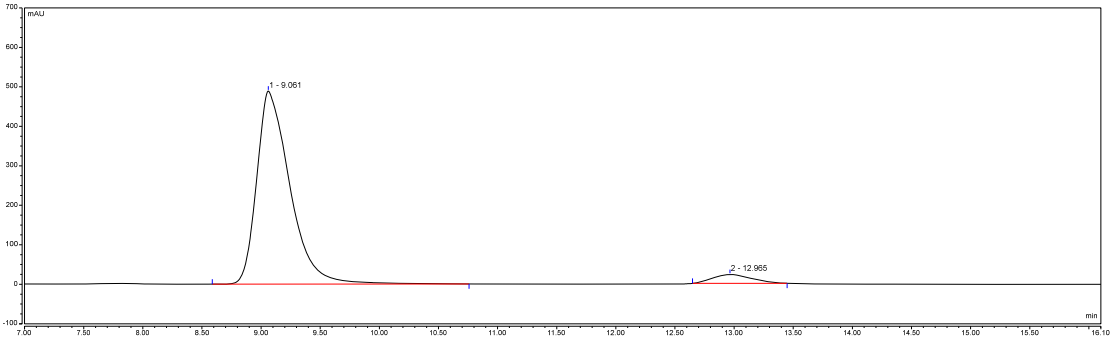
8

Yellow solid; Mp 112.8−113.6 °C; 20.5 mg, 55% yield, 90% ee; $[\alpha]_D^{22}$ −39.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.68 – 8.61 (m, 1H), 8.15 (d, *J* = 7.9 Hz, 1H), 7.97 (d, *J* = 8.1 Hz, 2H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.2 Hz, 2H), 7.30 (m, 1H), 3.40 (m, 1H), 3.32 – 3.20 (m, 2H), 2.87 (d, *J* = 16.1 Hz, 1H), 2.36 – 2.27 (m, 1H), 2.15 (m, 1H), 1.17 (s, 3H), 1.07 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 175.4, 173.6, 153.3, 149.2, 138.3, 136.3, 132.4 (q, *J* = 32.7 Hz), 128.3, 125.4 (q, *J* = 3.6 Hz), 124.9, 124.1 (q, *J* = 270.7 Hz), 111.5, 107.8,50.1, 45.2, 35.4, 28.4, 25.1, 21.8; **^{19}F NMR** (376 MHz, CD_3OD) δ -64.33; **HRMS** (ESI) 372.1680 m/z ($M+H^+$), calc. for $C_{21}H_{21}F_3N_3^+$ 372.1682.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.2 min (major) and 12.9 min (minor).



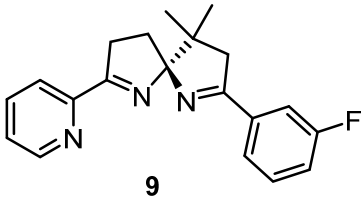
Entry	Retention Time	Area	Height	%Area
1	9.231	203.7416	570.71	50.05
2	12.911	203.3037	472.14	49.95



Entry	Retention Time	Area	Height	%Area

1	9.061	158.7658	489.03	95.00
2	12.965	8.3636	22.14	5.00

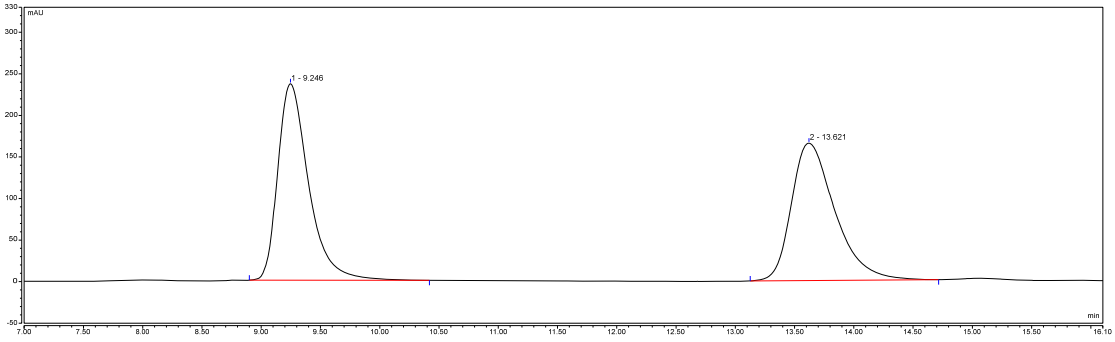
(*R*)-2-(3-fluorophenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (9)



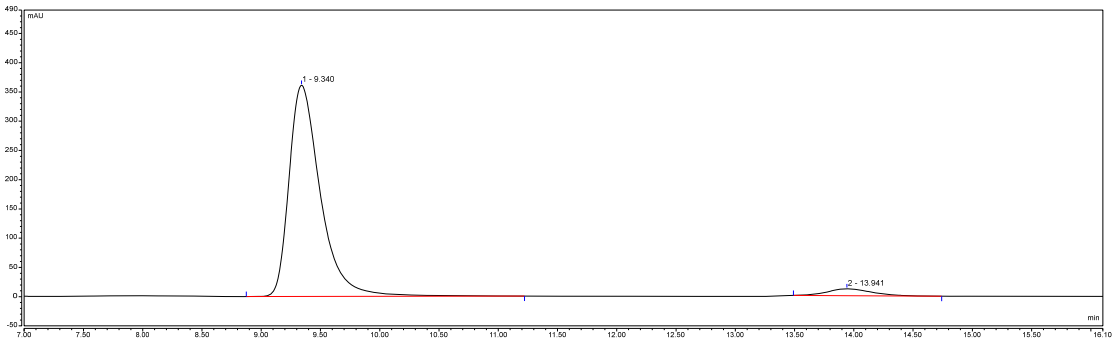
9

Yellow solid; Mp 149.3−150.1 °C; 26.4 mg, 82% yield, 91% ee; $[\alpha]_D^{22}$ +51.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.8 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.70 (td, *J* = 7.8, 1.6 Hz, 1H), 7.60 (m, 2H), 7.35 (m, 1H), 7.33 – 7.27 (m, 1H), 7.11 (td, *J* = 8.3, 2.3 Hz, 1H), 3.38 (m, 1H), 3.29 – 3.20 (m, 2H), 2.84 (d, *J* = 16.0 Hz, 1H), 2.30 (m, 1H), 2.21 – 2.08 (m, 1H), 1.17 (s, 3H), 1.07 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 175.1, 173.6 (d, *J* = 2.6 Hz), 163.7, 162.1, 153.5, 149.2, 137.4 (d, *J* = 7.5 Hz), 136.3, 129.9 (d, *J* = 7.8 Hz), 124.9, 123.7 (d, *J* = 2.3 Hz), 122.7, 117.6 (d, *J* = 21.7 Hz), 114.7 (d, *J* = 22.2 Hz), 111.4, 50.2, 45.2, 35.4, 28.5, 25.2, 21.9; **^{19}F NMR** (376 MHz, CD_3OD) δ -114.24; **HRMS** (ESI) 322.1714 m/z (M +H^+), calc. for $C_{20}H_{21}FN_3^+$ 322.1714.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.2 min (major) and 13.6 min (minor).

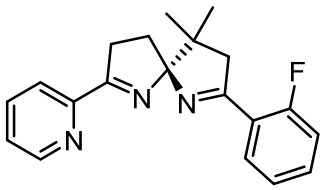


Entry	Retention Time	Area	Height	%Area
1	9.246	71.2050	236.37	50.35
2	13.621	70.2168	165.42	49.65



Entry	Retention Time	Area	Height	%Area
1	9.340	110.5999	360.89	95.63
2	13.941	5.0538	11.71	4.37

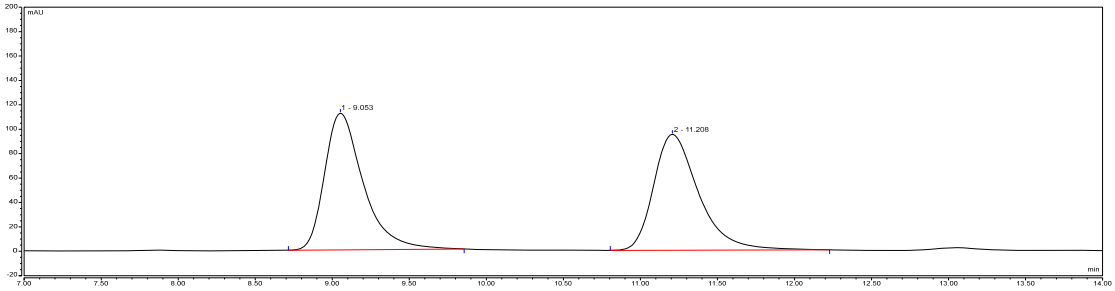
(*R*)-2-(2-fluorophenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (10)



10

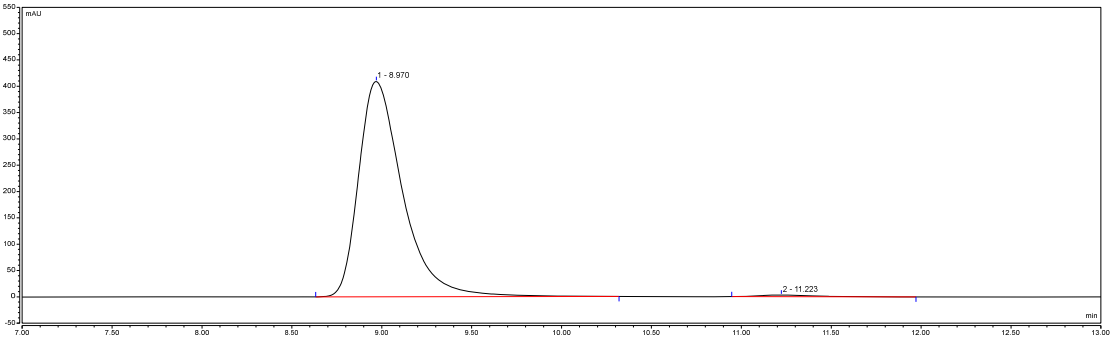
White solid; Mp 145.1−145.9 °C; 20.0 mg, 62% yield, 99% ee; $[\alpha]_D^{22}$ +54.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, J = 4.2 Hz, 1H), 8.18 (d, J = 7.9 Hz, 1H), 7.98 (td, J = 7.7, 1.6 Hz, 1H), 7.73 – 7.65 (m, 1H), 7.40 – 7.33 (m, 1H), 7.31 – 7.26 (m, 1H), 7.13 (t, J = 7.6 Hz, 1H), 7.06 (dd, J = 11.2, 8.4 Hz, 1H), 3.39 – 3.30 (m, 2H), 3.24 (m, 1H), 2.92 (dd, J = 16.7, 3.5 Hz, 1H), 2.28 (m, 1H), 2.15 (m, 1H), 1.15 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 175.0, 172.1 (d, *J* = 1.8 Hz), 161.9 (d, *J* = 252.8 Hz), 153.5, 149.1, 136.2, 132.2 (d, *J* = 8.7 Hz), 130.1 (d, *J* = 3.5 Hz), 124.8, 124.2 (d, *J* = 3.3 Hz), 123.3 (d, *J* = 11.8 Hz), 122.7, 116.2 (d, *J* = 22.6 Hz), 110.2, 53.23 (d, *J* = 6.0 Hz), 45.1 (d, *J* = 1.4 Hz), 35.3, 28.3, 24.9, 21.8; **^{19}F NMR** (565 MHz, $CDCl_3$) δ -112.7; **HRMS** (ESI) 322.1714 m/z ($M + H^+$), calc. for $C_{20}H_{21}FN_3^+$ 322.1714.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.0 min (major) and 11.2 min (minor).



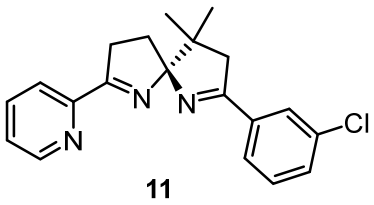
Entry	Retention Time	Area	Height	%Area

1	9.053	32.6268	112.00	50.42
2	11.208	32.0861	94.88	49.58



Entry	Retention Time	Area	Height	%Area
1	8.970	115.8794	408.87	99.07
2	11.223	1.0863	3.19	0.93

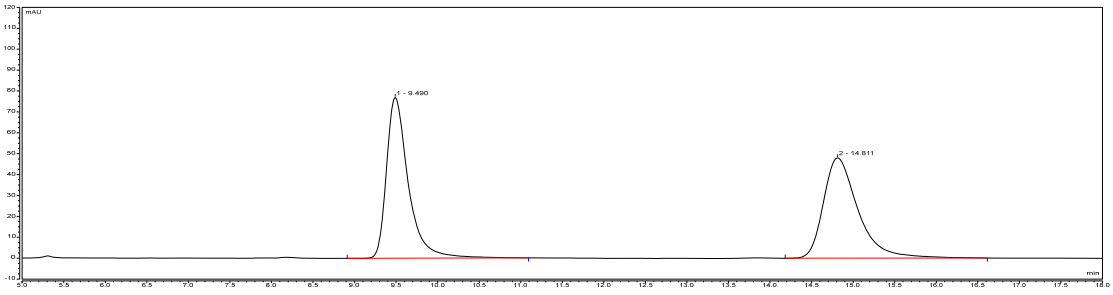
(*R*)-2-(3-chlorophenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (11)



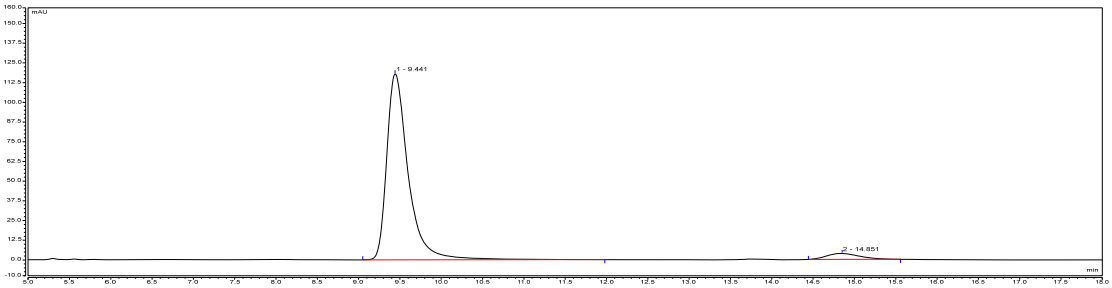
11

Yellow solid; Mp 61.2−62.0 °C; 18.3 mg, 54% yield, 91% ee; $[\alpha]_D^{22}$ +315.5 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.1 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.88 (s, 1H), 7.76 – 7.65 (m, 2H), 7.38 (d, *J* = 7.9 Hz, 1H), 7.33 – 7.27 (m, 2H), 3.38 (dd, *J* = 17.4, 8.7 Hz, 1H), 3.25 (m, 2H), 2.83 (d, *J* = 16.0 Hz, 1H), 2.34 – 2.25 (m, 1H), 2.14 (m, 1H), 1.16 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 175.1, 173.6, 153.5, 149.2, 136.3, 134.6, 130.75, 129.7, 127.9, 126.2, 124.9, 122.7, 111.4, 50.1, 45.2, 35.4, 28.4, 25.2, 21.9; **HRMS** (ESI) 338.1419 m/z (M + H^+), calc. for $C_{20}H_{21}ClN_3^+$ 338.1419.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.5 min (major) and 14.8 min (minor).

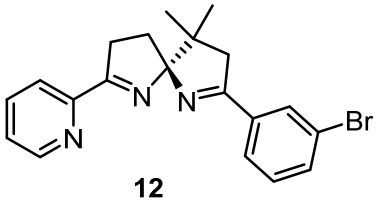


Entry	Retention Time	Area	Height	%Area
1	9.490	23.4172	76.86	50.32
2	14.811	23.1219	47.97	49.68



Entry	Retention Time	Area	Height	%Area
1	9.441	35.5181	118.01	95.35
2	14.851	1.7321	3.78	4.65

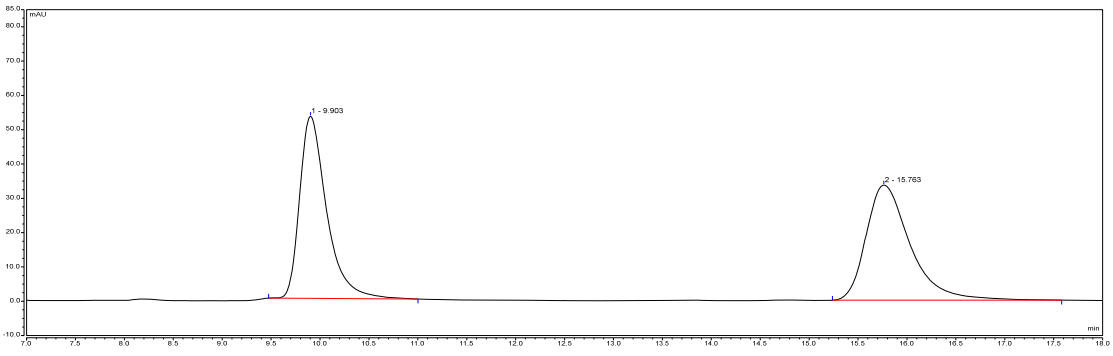
(*R*)-2-(3-bromophenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (12)



12

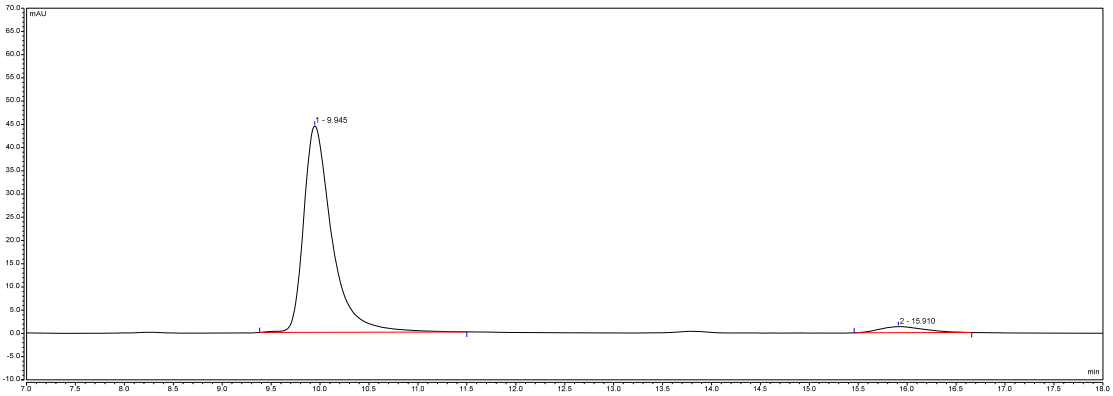
White solid; Mp 140.0−140.9 °C; 20.2 mg, 53% yield, 91% ee; $[\alpha]_D^{22}$ +236.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.66 (d, *J* = 4.4 Hz, 1H), 8.18 (d, *J* = 7.9 Hz, 1H), 8.06 (s, 1H), 7.78 (d, *J* = 7.6 Hz, 1H), 7.71 (td, *J* = 7.8, 1.5 Hz, 1H), 7.56 (d, *J* = 7.9 Hz, 1H), 7.32 (dd, *J* = 6.5, 5.1 Hz, 1H), 7.28 (d, *J* = 7.6 Hz, 1H), 3.41 (m, 1H), 3.31 – 3.21 (m, 2H), 2.85 (d, *J* = 16.0 Hz, 1H), 2.35 – 2.27 (m, 1H), 2.16 (m, 1H), 1.18 (s, 3H), 1.08 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 175.1, 173.4, 153.4, 149.2, 137.1, 136.2, 133.6, 130.8, 129.9, 126.5, 124.8, 122.7, 122.7, 111.3, 50.0, 45.1, 35.3, 28.4, 25.1, 21.9; **HRMS** (ESI) 382.0915 m/z (M + H^+), calc. for $C_{20}H_{21}BrN_3^+$ 382.0913.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.9 min (major) and 15.7 min (minor).



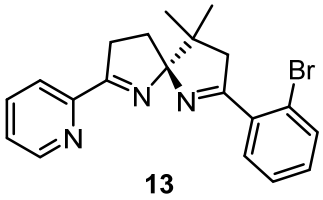
Entry	Retention Time	Area	Height	%Area

1	9.903	16.9639	53.04	49.22
2	15.763	17.4990	33.57	50.78



Entry	Retention Time	Area	Height	%Area
1	9.945	14.8335	44.40	95.58
2	15.910	0.6852	1.31	4.42

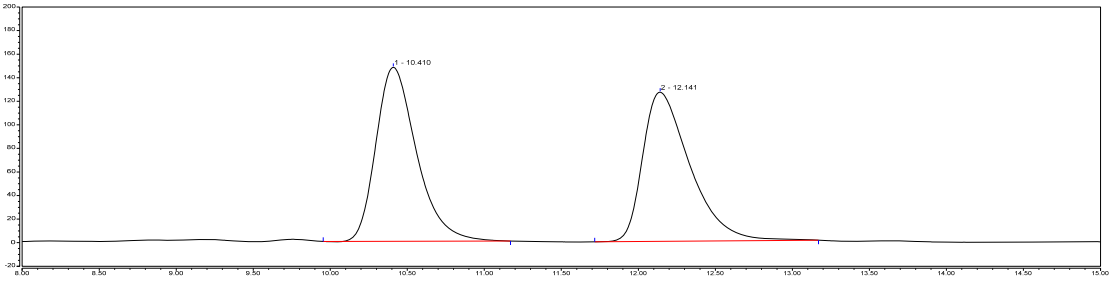
(*R*)-2-(2-bromophenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (13)



13

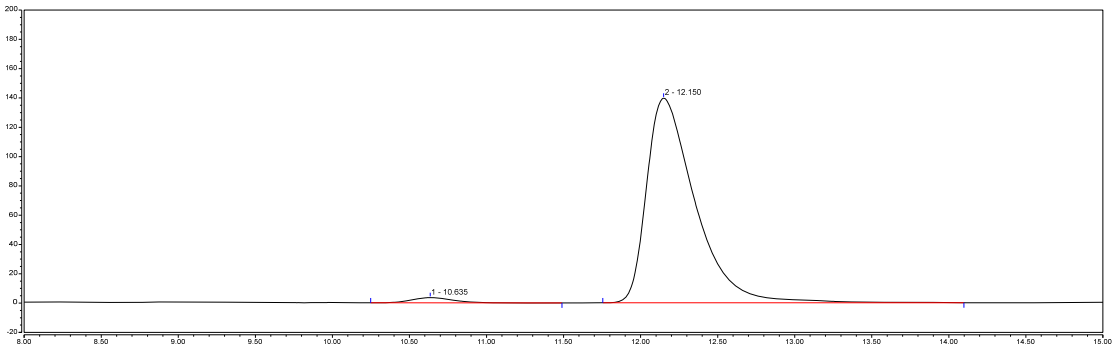
White solid; Mp 128.4−129.2 °C; 30.9 mg, 81% yield, 95% ee; $[\alpha]_D^{22}$ −27.1 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.4 Hz, 1H), 8.21 (d, *J* = 7.9 Hz, 1H), 7.72 (td, *J* = 7.7, 1.6 Hz, 1H), 7.57 (d, *J* = 7.9 Hz, 1H), 7.50 (dd, *J* = 7.6, 1.5 Hz, 1H), 7.34 – 7.26 (m, 2H), 7.20 (td, *J* = 7.8, 1.6 Hz, 1H), 3.40 – 3.27 (m, 3H), 2.98 (d, *J* = 16.4 Hz, 1H), 2.37 – 2.27 (m, 1H), 2.13 (m, 1H), 1.17 (s, 3H), 1.15 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 176.2, 174.3, 152.5, 148.1, 136.9, 135.3, 132.3, 129.6, 129.5, 126.4, 123.8, 121.7, 120.3, 109.9, 76.4, 76.2, 75.9, 52.2, 44.6, 34.2, 27.2, 23.8, 20.7; **HRMS** (ESI) 382.0912 m/z ($M + H^+$), calc. for $C_{20}H_{21}BrN_3^+$ 382.0913.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 10.4 min (minor) and 12.1 min (major).



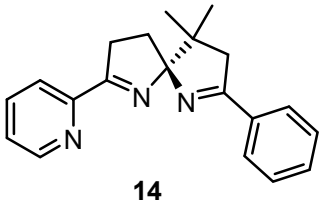
Entry	Retention Time	Area	Height	%Area

1	10.410	45.1504	147.62	50.07
2	12.141	45.0170	126.62	49.93



Entry	Retention Time	Area	Height	%Area
1	10.635	1.1155	3.59	2.14
2	12.150	51.0606	139.65	97.86

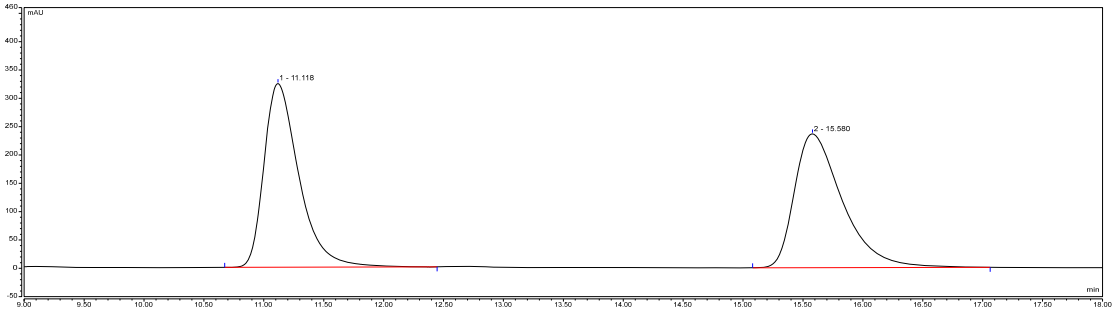
(*R*)-4,4-dimethyl-2-phenyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (14)



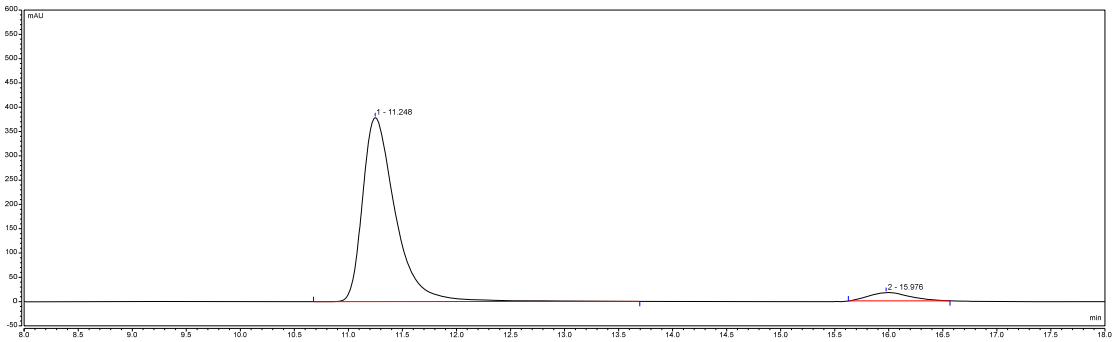
14

White solid; Mp 99.8−100.6 °C; 26.5 mg, 87% yield, 90% ee; $[\alpha]_D^{22}$ +169.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.4 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.87 (d, *J* = 7.0 Hz, 2H), 7.68 (td, *J* = 7.7, 1.7 Hz, 1H), 7.43 – 7.36 (m, 3H), 7.31 – 7.26 (m, 1H), 3.40 (m, 1H), 3.24 (m, 2H), 2.88 (d, *J* = 15.9 Hz, 1H), 2.36 – 2.27 (m, 1H), 2.15 (m, 1H), 1.17 (s, 3H), 1.07 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 174.8, 174., 153.5, 149.1, 136.2, 135.0, 130.7, 128.4, 127.9, 124.7, 122.7, 111.3, 50.1, 45.0, 35.3, 28.5, 25.1, 21.9; **HRMS** (ESI) 304.1808 m/z (M +H^+), calc. for $C_{20}H_{22}N_3^+$ 304.1808.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 11.1 min (major) and 15.6 min (minor).

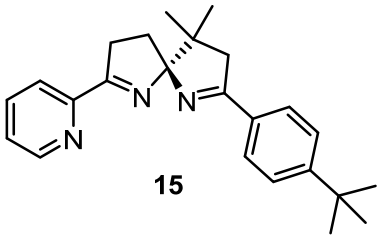


Entry	Retention Time	Area	Height	%Area
1	11.118	109.6161	324.15	50.02
2	15.580	109.5438	236.12	49.98



Entry	Retention Time	Area	Height	%Area
1	11.248	133.0498	378.38	94.72
2	15.976	7.4211	17.13	5.28

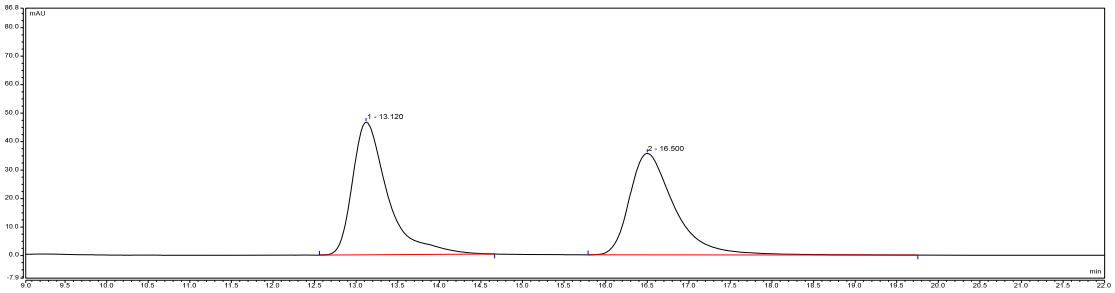
(*R*)-2-(4-(*tert*-butyl)phenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (15)



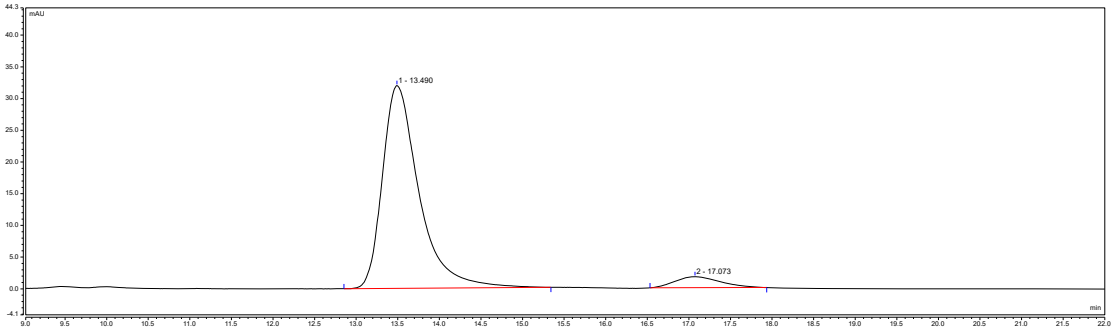
15

Yellow solid; Mp 87.0−87.9 °C; 25.9 mg, 72% yield, 87% ee; $[\alpha]_D^{22}$ +347.9 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.0 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.82 (d, *J* = 8.0 Hz, 2H), 7.68 (t, *J* = 7.1 Hz, 1H), 7.41 (d, *J* = 8.2 Hz, 2H), 7.31 – 7.26 (m, 1H), 3.43 – 3.33 (m, 1H), 3.28 – 3.15 (m, 2H), 2.87 (d, *J* = 15.9 Hz, 1H), 2.33 – 2.26 (m, 1H), 2.15 (m, 1H), 1.32 (s, 9H), 1.16 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 174.6 174.4, 154.2, 153.6, 149.1, 136.2, 132.2, 127.7, 125.4, 124.7, 122.7, 111.2, 50.0, 45.0, 35.3, 34.9, 31.3, 28.4, 25.0, 22.0; **HRMS** (ESI) 360.2434 m/z ($M + H^+$), calc. for $C_{24}H_{30}N_3^+$ 360.2434.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 13.1 min (major) and 16.5 min (minor).

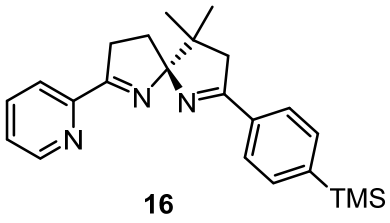


Entry	Retention Time	Area	Height	%Area
1	13.120	22.8950	46.56	50.78
2	16.500	22.1930	35.61	49.22



Entry	Retention Time	Area	Height	%Area
1	13.490	16.3046	31.99	93.73
2	17.073	1.0906	1.75	6.27

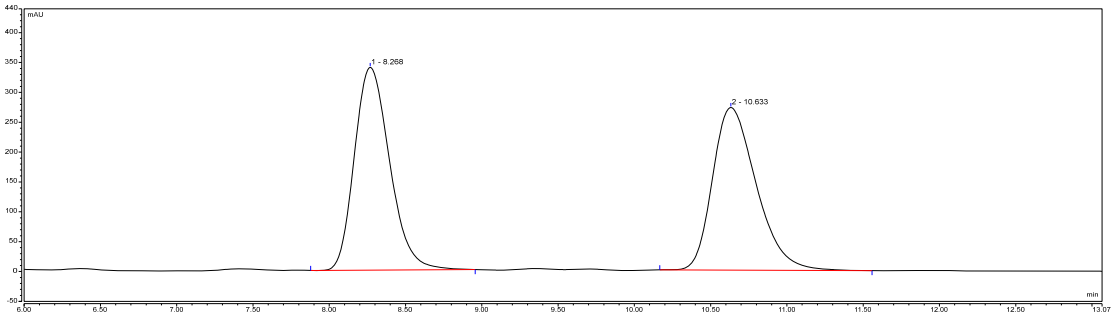
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(4-(trimethylsilyl)phenyl)-1,6-diazaspiro[4.4]nona-1,6-diene (16)



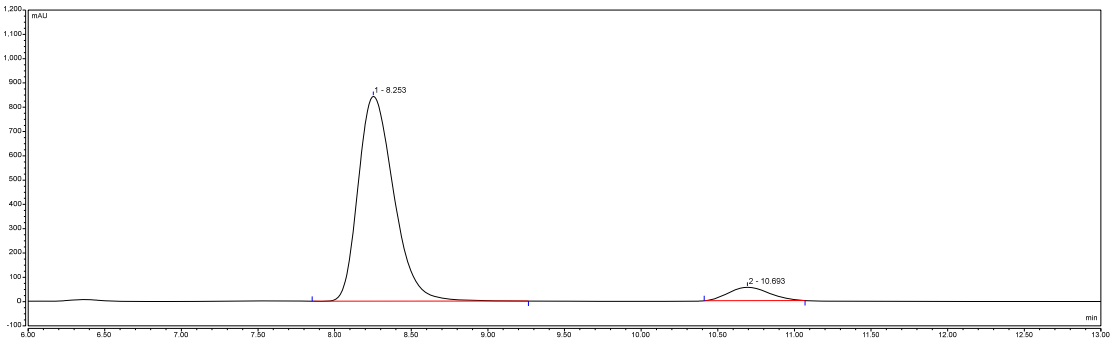
16

Yellow solid; Mp 121.2−122.0 °C; 16.9 mg, 45% yield, 86% ee; $[\alpha]_D^{22}$ +27.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.8 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 2H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.55 (d, *J* = 8.1 Hz, 2H), 7.29 (m, 1H), 3.39 (m, 1H), 3.30 – 3.18 (m, 2H), 2.88 (d, *J* = 15.9 Hz, 1H), 2.30 (m, 1H), 2.16 (m, 1H), 1.16 (s, 4H), 1.06 (s, 4H), 0.27 (s, 9H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 174.8, 174.7, 153.5, 149.1, 144.0, 136.2, 135.2, 133.4, 127.0, 124.8, 122.7, 111.2, 50.0, 45.0, 35.3, 28.4, 25.0, 22.0, -1.1; **HRMS** (ESI) 376.2204 m/z (M + H^+), calc. for $C_{23}H_{30}N_3Si^+$ 376.2204.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 8.3 min (major) and 10.6 min (minor).

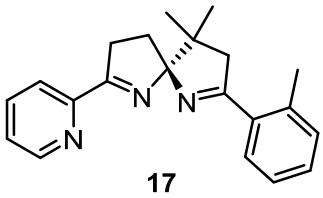


Entry	Retention Time	Area	Height	%Area
1	8.268	90.9800	339.35	50.15
2	10.633	90.4203	272.18	49.85



Entry	Retention Time	Area	Height	%Area
1	8.253	226.2281	842.65	93.08
2	10.693	16.8216	55.07	6.92

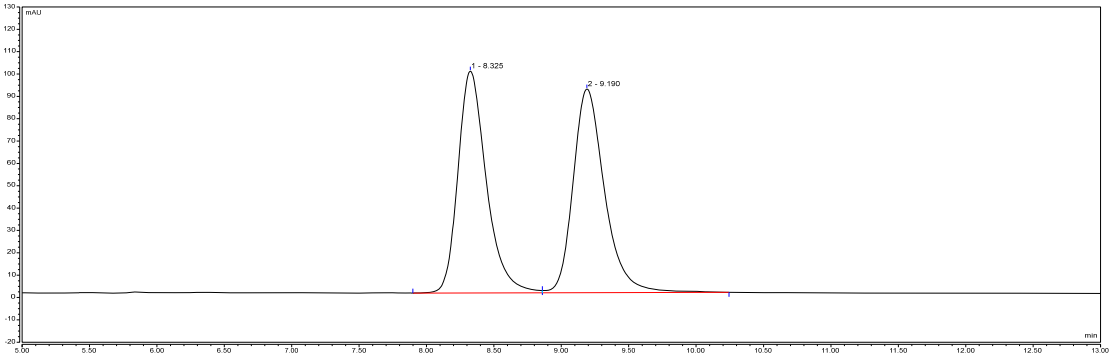
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(*o*-tolyl)-1,6-diazaspiro[4.4]nona-1,6-diene (17)



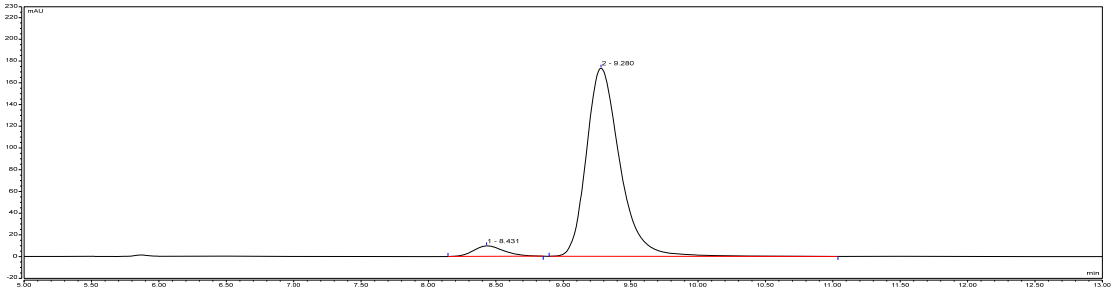
17

White solid; Mp 117.9−118.7 °C; 23.2 mg, 73% yield, 90% ee; $[\alpha]_D^{22}$ −33.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.61 – 8.44 (m, 1H), 8.11 (d, *J* = 7.8 Hz, 1H), 7.63 (td, *J* = 7.7, 1.7 Hz, 1H), 7.37 (d, *J* = 7.4 Hz, 1H), 7.22 (m, 1H), 7.20 – 7.15 (m, 1H), 7.12 (m, 2H), 3.29 – 3.15 (m, 3H), 2.66 (d, *J* = 16.1 Hz, 1H), 2.42 (s, 3H), 2.30 – 2.19 (m, 1H), 2.05 (m, 1H), 1.10 (s, 3H), 1.02 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 177.2, 174.9, 153.7, 149.1, 137.0, 136.2, 135.7, 131.1, 129.2, 128.7, 125.6, 124.8, 122.7, 111.5, 53.7, 44.8, 35.2, 28.5, 25.1, 21.5, 21.2; **HRMS** (ESI) 318.1965 m/z (M + H^+), calc. for $C_{21}H_{24}N_3^+$ 318.1965.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 8.3 min (minor) and 9.2 min (major).

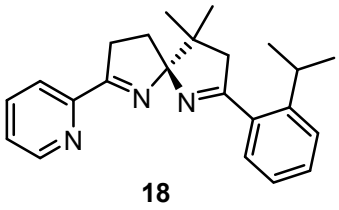


Entry	Retention Time	Area	Height	%Area
1	8.325	24.2549	99.23	49.59
2	9.190	24.6521	91.11	50.41



Entry	Retention Time	Area	Height	%Area
1	8.431	2.5219	9.68	4.83
2	9.280	49.7100	173.08	95.17

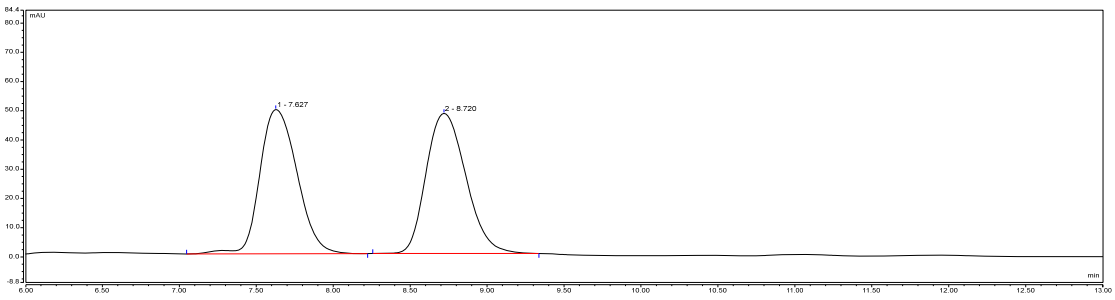
(*R*)-2-(2-isopropylphenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (18)



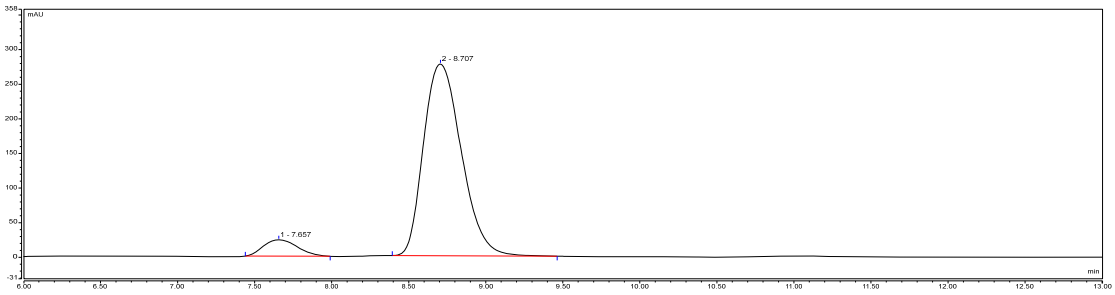
18

White solid; Mp 113.3 - 114.2 °C; 19.4 mg, 56% yield, 86% ee; $[\alpha]_D^{22}$ −32.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.75 – 8.50 (m, 1H), 8.19 (d, *J* = 7.9 Hz, 1H), 7.71 (td, *J* = 7.7, 1.7 Hz, 1H), 7.36 – 7.27 (m, 4H), 7.22 – 7.11 (m, 1H), 3.56 – 3.45 (m, 1H), 3.32 – 3.28 (m, 2H), 2.70 (d, *J* = 16.3 Hz, 1H), 2.33 (m, 1H), 2.11 (m, 1H), 1.24 (d, *J* = 6.9 Hz, 3H), 1.20 (d, *J* = 6.9 Hz, 3H), 1.18 (s, 3H), 1.13 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 177.8, 174.9, 153.7, 149.1, 147.1 136.3, 135.6, 129.3, 128.1, 125.7, 125.5, 124.8, 122.6, 111.6, 54.9, 44.8, 35.1, 29.5, 28.3, 25.0, 24.1, 24.2, 21.5; **HRMS** (ESI) 346.2278 m/z ($M + H^+$), calc. for $C_{23}H_{28}N_3^+$ 346.2278.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 85/15; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 7.6 min (minor) and 8.7 min (major).

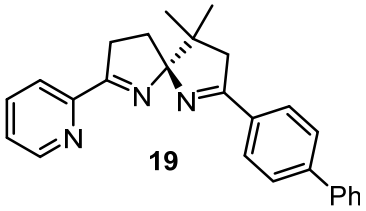


Entry	Retention Time	Area	Height	%Area
1	7.627	13.8441	49.31	49.08
2	8.720	14.3635	47.91	50.92



Entry	Retention Time	Area	Height	%Area
1	7.657	6.0145	23.50	7.10
2	8.707	78.6801	276.98	92.90

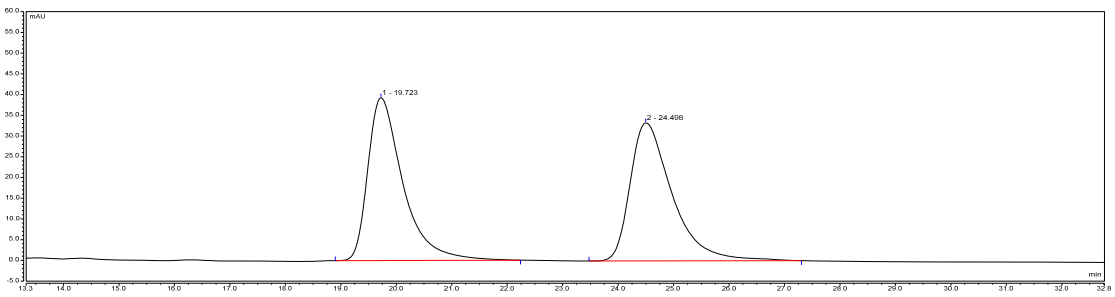
(*R*)-2-([1,1'-biphenyl]-4-yl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (19)



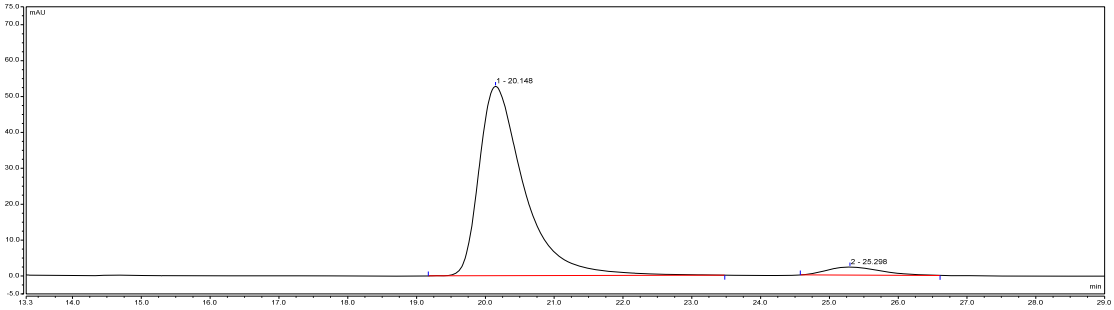
19

White solid; Mp 173.3−174.1 °C; 23.2 mg, 61% yield, 90% ee; $[\alpha]_D^{22}$ +83.2 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.65 (d, *J* = 4.7 Hz, 1H), 8.18 (d, *J* = 7.9 Hz, 1H), 7.95 (d, *J* = 8.3 Hz, 2H), 7.70 (td, *J* = 7.7, 1.7 Hz, 1H), 7.63 (dd, *J* = 10.1, 7.9 Hz, 4H), 7.44 (t, *J* = 7.7 Hz, 2H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.30 (m, 1H), 3.42 (m, 1H), 3.32 – 3.21 (m, 2H), 2.92 (d, *J* = 15.9 Hz, 1H), 2.38 – 2.27 (m, 1H), 2.17 (m, 1H), 1.19 (s, 3H), 1.09 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 174.8, 174.3, 153.5, 149.1, 143.5, 140.5, 136.3, 133.9, 128.9, 128.5, 127.8, 127.2, 127.1, 124.8, 122.7, 111.3, 50.1, 45.1, 35.3, 28.5, 25.2, 22.0; **HRMS** (ESI) 380.2121 ($M + H^+$), calc. for $C_{26}H_{26}N_3^+$ 380.2121.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 19.7 min (major) and 24.5 min (minor).

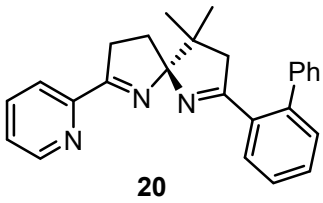


Entry	Retention Time	Area	Height	%Area
1	19.723	28.7281	39.27	49.67
2	24.498	29.1076	33.33	50.33



Entry	Retention Time	Area	Height	%Area
1	20.148	39.9711	52.74	95.17
2	25.298	2.0290	2.28	4.83

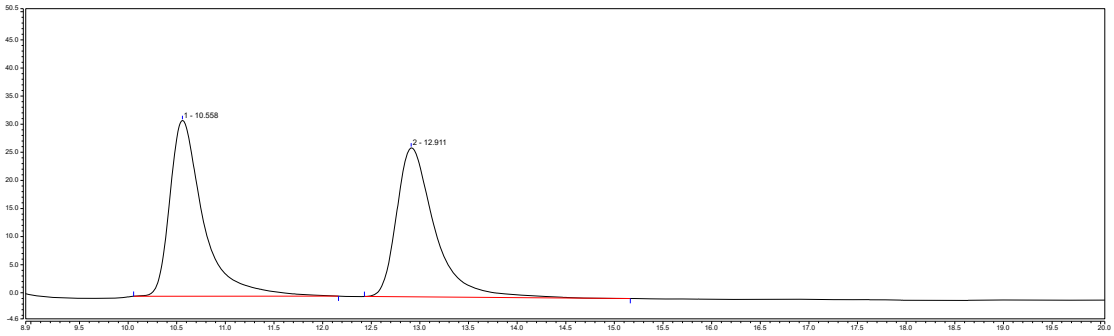
(*R*)-2-([1,1'-biphenyl]-2-yl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro [4.4] nona-1,6-diene (20)



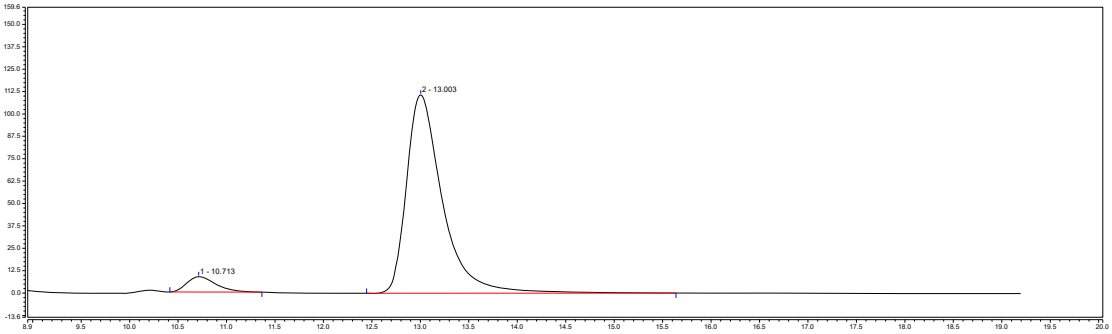
20

White solid; Mp 122.9−123.8 °C; 28.9 mg, 76% yield, 88% ee; $[\alpha]_D^{22}$ +288.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.65 (d, *J* = 4.8 Hz, 1H), 8.22 (d, *J* = 7.9 Hz, 1H), 7.74 (t, *J* = 7.7 Hz, 1H), 7.66 (d, *J* = 7.4 Hz, 1H), 7.45 – 7.31 (m, 9H), 3.38 – 3.17 (m, 2H), 2.58 (d, *J* = 16.5 Hz, 1H), 2.31 – 2.22 (m, 1H), 2.10 – 1.98 (m, 2H), 0.94 (s, 3H), 0.85 (s, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 178.5, 174.7, 153.6, 149.1, 141.2, 141.1, 136.2, 130.1, 129.5, 129.3, 128.3, 127.5, 127.4, 124.8, 122.6, 110.8, 52.8, 45.1, 35.1, 28.2, 24.6, 21.8; **HRMS** (ESI) 380.2121 m/z (M + H^+), calc. for $C_{26}H_{26}N_3^+$ 380.2121.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 10.6 min (minor) and 12.9 min (major).

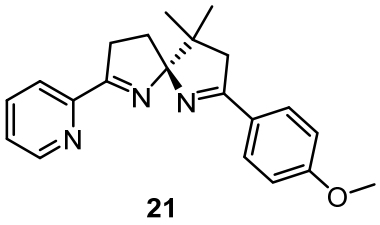


Entry	Retention Time	Area	Height	%Area
1	10.558	12.4890	31.25	50.90
2	12.911	12.0471	26.50	49.10



Entry	Retention Time	Area	Height	%Area
1	10.713	3.0019	8.60	5.93
2	13.003	47.5936	110.74	94.07

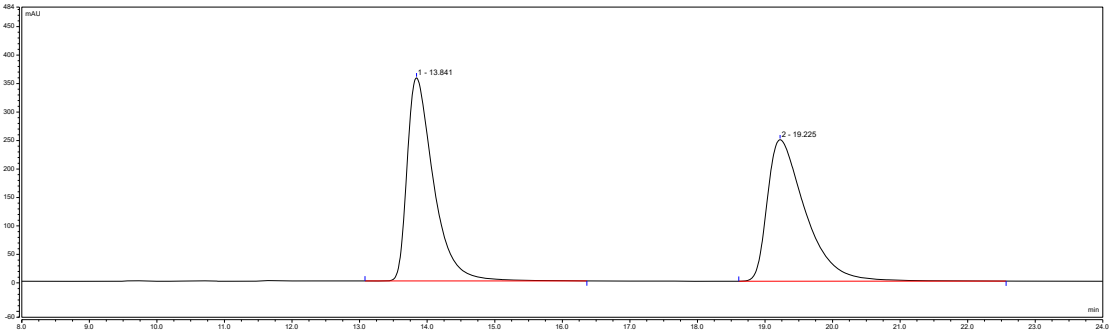
(*R*)-2-(4-methoxyphenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (21)



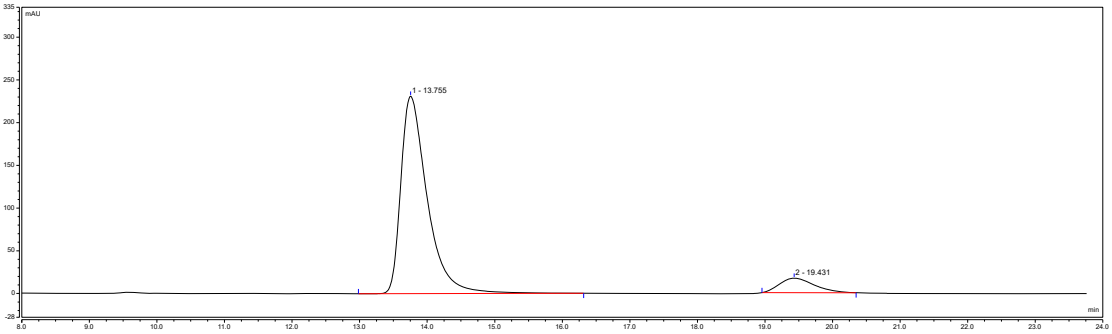
21

White solid; Mp 123.0−123.9 °C; 21.4 mg, 64% yield, 83% ee; $[\alpha]_D^{22}$ −167.4 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.63 (d, *J* = 4.4 Hz, 1H), 8.11 (d, *J* = 7.9 Hz, 1H), 7.87 (d, *J* = 7.7 Hz, 1H), 7.83 (d, *J* = 8.8 Hz, 2H), 7.46 (dd, *J* = 6.7, 5.5 Hz, 1H), 6.98 (d, *J* = 8.8 Hz, 2H), 3.83 (s, 3H), 3.41 (m, 1H), 3.33 – 3.21 (m, 3H), 2.98 (d, *J* = 16.5 Hz, 1H), 2.30 – 2.15 (m, 2H), 1.16 (s, 3H), 1.07 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 177.5, 177.0, 163.7, 153.5, 150.1, 138.0, 130.7, 127.6, 126.5, 123.5, 114.8, 112.1, 55.7, 50.7, 45.3, 36.2, 28.6, 25.3, 21.5; **HRMS** (ESI) 334.1914 m/z (M + H^+), calc. for $C_{21}H_{24}N_3O^+$ 334.1914.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 13.8 min (major) and 19.2 min (minor).

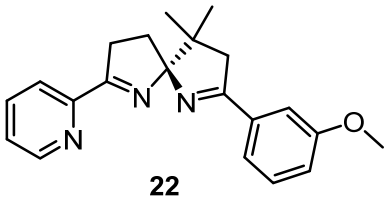


Entry	Retention Time	Area	Height	%Area
1	13.841	161.3460	356.58	49.91
2	19.225	161.9124	248.36	50.09



Entry	Retention Time	Area	Height	%Area
1	13.755	104.4886	231.01	91.20
2	19.431	10.0825	16.98	8.80

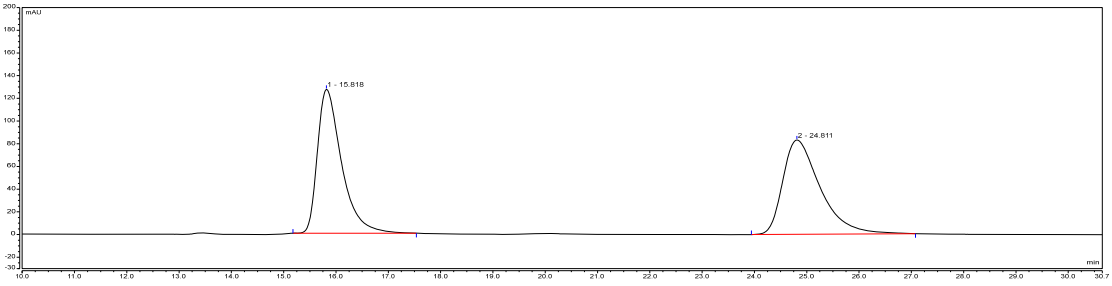
(*R*)-2-(3-methoxyphenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (22)



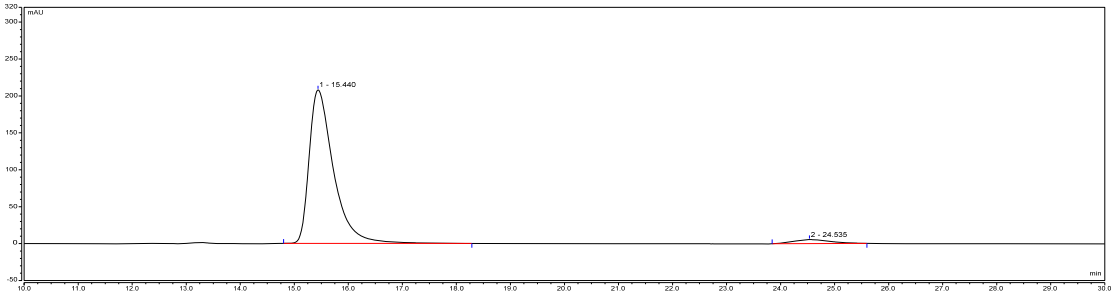
22

White solid; Mp 87.2−88.1 °C; 31.4 mg, 94% yield, 92% ee; $[\alpha]_D^{22}$ −108.4 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.63 (d, *J* = 4.8 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.67 (m, 1H), 7.45 (m, 1H), 7.38 (d, *J* = 7.7 Hz, 1H), 7.31 – 7.25 (m, 2H), 6.96 (dd, *J* = 8.1, 2.5 Hz, 1H), 3.81 (s, 3H), 3.44 – 3.31 (m, 1H), 3.26 – 3.15 (m, 2H), 2.85 (d, *J* = 16.0 Hz, 1H), 2.28 (m, 1H), 2.13 (m, 1H), 1.14 (s, 3H), 1.05 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 174.7, 174.4, 159.6, 153.5, 149.1, 136.5, 136.2, 129.3, 124.7, 122.6, 120.6, 117.2, 112.2, 111.2, 77.5, 77.1, 76.8, 55.4, 50.2, 45.0, 35.2, 28.5, 25.0, 22.0; **HRMS** (ESI) 334.1914 m/z ($M + H^+$), calc. for $C_{21}H_{24}N_3O^+$ 334.1914.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 15.8 min (major) and 24.8 min (minor).

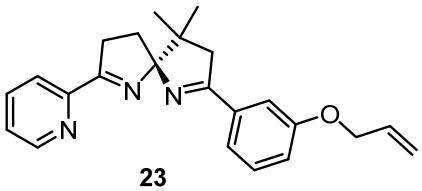


Entry	Retention Time	Area	Height	%Area
1	15.818	67.8241	126.64	49.66
2	24.811	68.7576	83.09	50.34



Entry	Retention Time	Area	Height	%Area
1	15.440	108.1700	207.79	96.30
2	24.535	4.1587	5.38	3.70

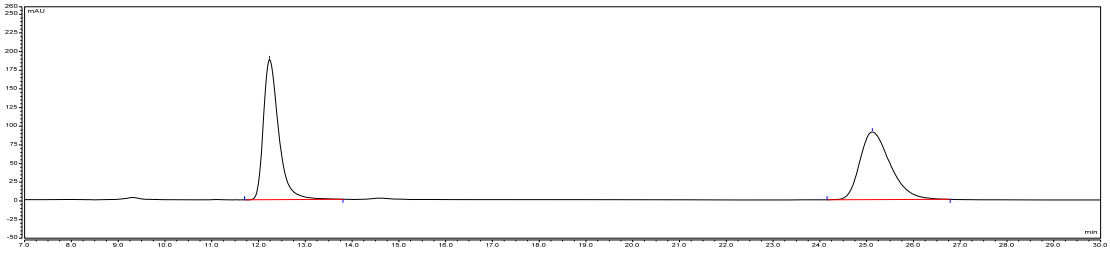
(*R*)-2-(3-(allyloxy)phenyl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (23)



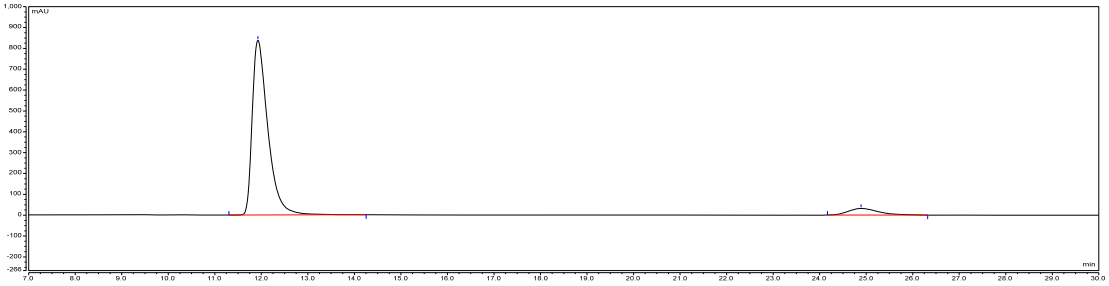
23

White solid; Mp 129.3−130.1 °C; 18.7 mg, 52% yield, 87% ee; $[\alpha]_D^{22}$ −38.1 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 4.8 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.68 (td, *J* = 7.7, 1.7 Hz, 1H), 7.47 (s, 1H), 7.40 (d, *J* = 7.6 Hz, 1H), 7.28 (m, 2H), 6.98 (dd, *J* = 8.1, 2.4 Hz, 1H), 6.04 (m, 1H), 5.40 (dd, *J* = 17.3, 1.5 Hz, 1H), 5.26 (dd, *J* = 10.5, 1.3 Hz, 1H), 4.56 (d, *J* = 5.3 Hz, 2H), 3.38 (m, 1H), 3.23 (m, 2H), 2.85 (d, *J* = 15.9 Hz, 1H), 2.29 (m, 1H), 2.14 (m, 1H), 1.15 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 174.8, 174.5, 158.7, 153.5, 149.1, 136.4, 136.2, 133.2, 129.3, 124.8, 122.7, 120.8, 117.8, 117.7, 113.3, 111.2, 68.9, 50.2, 45.0, 35.3, 28.5, 25.1, 22.0; **HRMS** (ESI) 360.2070 m/z ($M + H^+$), calc. for $C_{23}H_{26}N_3O^+$ 360.2070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 12.2 min (major) and 25.1 min (minor).

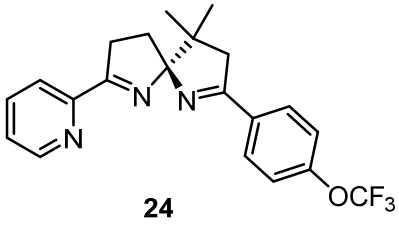


Entry	Retention Time	Area	Height	%Area
1	12.237	70.7692	187.85	50.95
2	25.123	68.1214	90.70	49.05



Entry	Retention Time	Area	Height	%Area
1	11.927	324.5224	838.10	93.79
2	24.890	21.4765	30.67	6.21

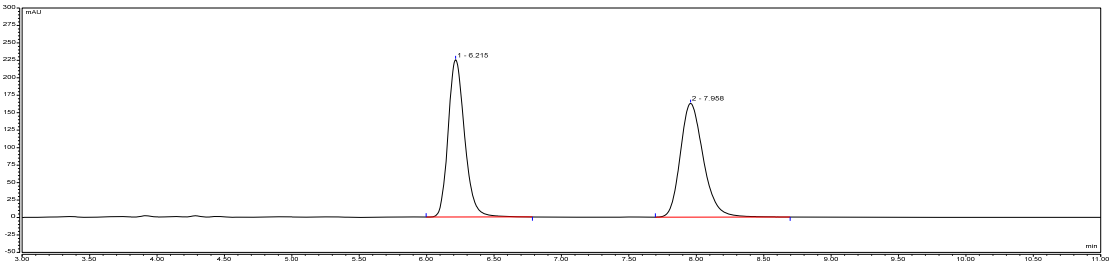
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(4-(trifluoromethoxy)phenyl)-1,6-diazaspiro[4.4] nona-1,6-diene (24)



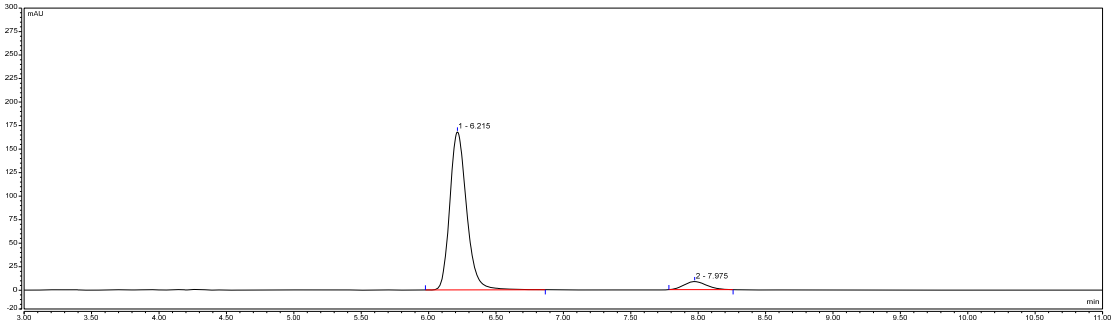
24

White solid; Mp 118.0−119.0 °C; 16.7 mg, 43% yield, 87% ee; $[\alpha]_D^{22}$ +47.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.6 Hz, 1H), 8.15 (d, *J* = 7.9 Hz, 1H), 7.90 (d, *J* = 8.7 Hz, 2H), 7.68 (td, *J* = 7.7, 1.6 Hz, 1H), 7.34 – 7.27 (m, 1H), 7.22 (d, *J* = 8.3 Hz, 2H), 3.38 (m, 1H), 3.29 – 3.16 (m, 2H), 2.84 (d, *J* = 15.9 Hz, 1H), 2.29 (m, 1H), 2.20 – 2.03 (m, 1H), 1.16 (s, 3H), 1.06 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 175.1, 173.3, 153.4, 151.0, 149.2, 136.3, 133.6, 129.6, 124.8, 123.0, 120.64, 120.5 (q, *J* = 257.8 Hz), 111.4, 50.1, 45.2, 35.3, 28.4, 25.1, 21.9; **^{19}F NMR** (565 MHz, $CDCl_3$) δ -57.7; **HRMS** (ESI) 388.1631 m/z ($M + H^+$), calc. for $C_{21}H_{21}F_3N_3O^+$ 388.1631.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 6.2 min (major) and 7.9 min (minor).

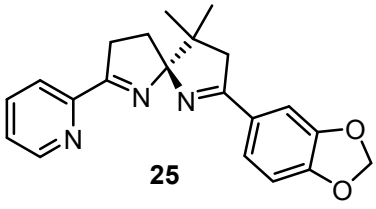


Entry	Retention Time	Area	Height	%Area
1	6.215	31.7399	225.18	49.68
2	7.958	32.1456	162.76	50.32



Entry	Retention Time	Area	Height	%Area
1	6.215	24.2024	167.93	93.73
2	7.975	1.6196	8.47	6.27

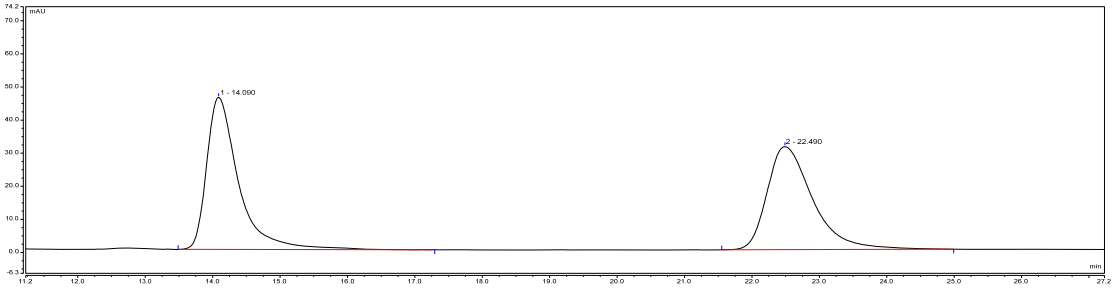
(*R*)-2-(benzo[*d*][1,3]dioxol-5-yl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (25)



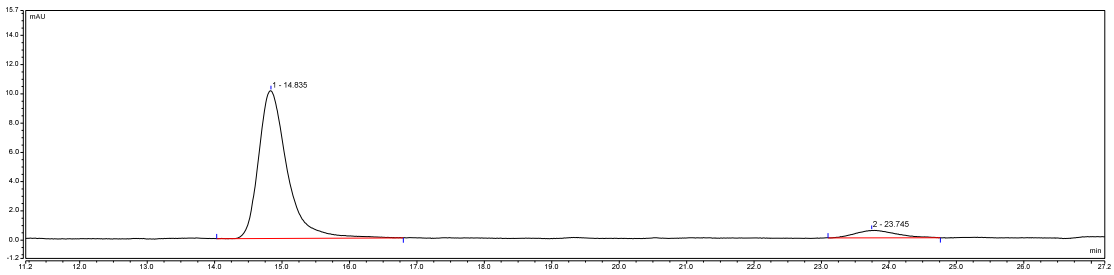
25

White solid; Mp 146.7−147.5 °C; 29.6 mg, 85% yield, 86% ee; $[\alpha]_D^{22}$ −48.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.70 – 8.50 (m, 1H), 8.12 (d, J = 7.9 Hz, 1H), 7.93 – 7.81 (m, 1H), 7.48 (m, 1H), 7.41 (m, 1H), 7.41 – 7.37 (m, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 6.02 (m, 2H), 3.40 (m, 1H), 3.30 (d, *J* = 3.1 Hz, 1H), 3.27 (t, *J* = 5.9 Hz, 1H), 2.97 (d, *J* = 16.5 Hz, 1H), 2.25 (dd, *J* = 8.2, 6.4 Hz, 2H), 1.16 (s, 3H), 1.08 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 177.3, 177.1, 153.5, 151.8, 150.1, 149.4, 138.0, 129.4, 126.5, 124.7, 123.5, 112.1, 108.8, 107.9, 102.9, 50.9, 45.4, 36.2, 28.6, 25.3, 21.5; **HRMS** (ESI) 348.1706 m/z (M +H^+), calc. for $C_{21}H_{21}F_3N_3O^+$ 348.1707.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 70/30; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time:14.1 min (major) and 22.5 min (minor).

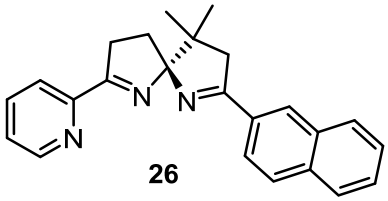


Entry	Retention Time	Area	Height	%Area
1	14.090	25.0992	45.92	50.77
2	22.490	24.3365	31.18	49.23



Entry	Retention Time	Area	Height	%Area
1	14.835	4.9381	10.11	93.22
2	23.745	0.3589	0.52	6.78

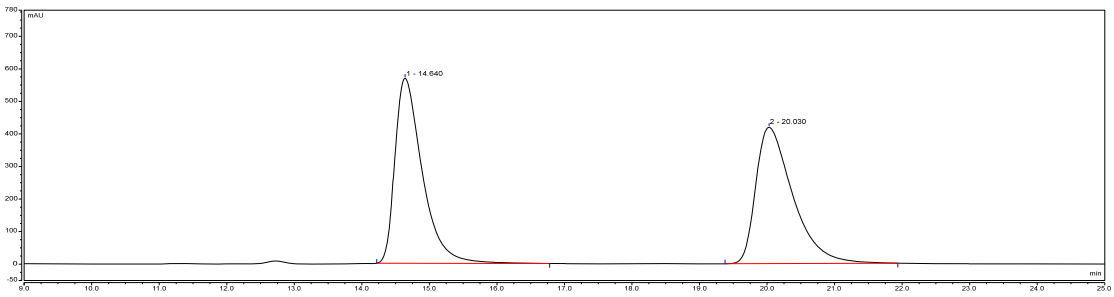
(*R*)-4,4-dimethyl-2-(naphthalen-2-yl)-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (26)



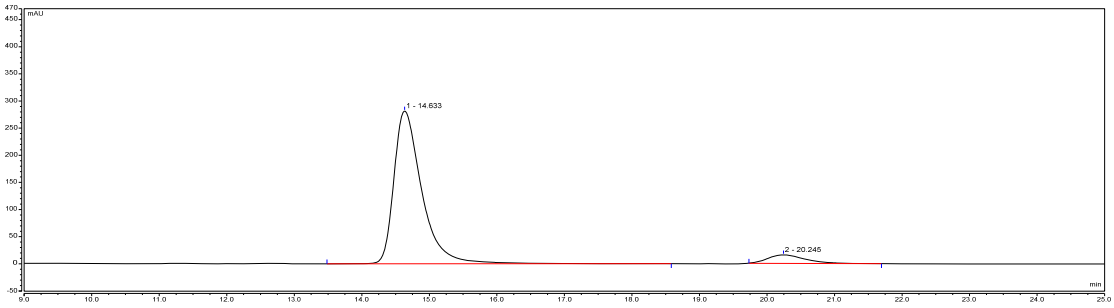
26

White solid; Mp 155.9−156.8 °C; 31.5 mg, 89% yield, 87% ee; $[\alpha]_D^{22}$ −29.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.64 (d, *J* = 4.6 Hz, 1H), 8.34 (s, 1H), 8.13 (d, *J* = 8.0 Hz, 1H), 8.03 (dd, *J* = 8.6, 1.5 Hz, 1H), 7.98 (d, *J* = 7.6 Hz, 1H), 7.92 – 7.88 (m, 2H), 7.86 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.55 (m, 2H), 7.50 – 7.42 (m, 1H), 3.49 – 3.40 (m, 2H), 3.31 – 3.27 (m, 1H), 3.17 (d, *J* = 16.4 Hz, 1H), 2.30 (m, 2H), 1.22 (s, 3H), 1.13 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 178.1, 177.3, 153.5, 150.2, 138.1, 136.1, 134.2, 132.6, 130.3, 129.8, 129.2, 128.6,128.5, 127.6, 126.6, 124.8, 123.5, 112.4, 50.9, 45.4, 36.3, 28.7, 25.3, 21.5; **HRMS** (ESI) 354.1965 m/z (M + H^+), calc. for $C_{24}H_{24}N_3^+$ 354.1965.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 14.6 min (major) and 20.0 min (minor).

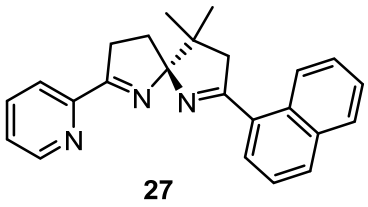


Entry	Retention Time	Area	Height	%Area
1	14.640	266.4490	568.46	50.06
2	20.030	265.8514	418.78	49.94



Entry	Retention Time	Area	Height	%Area
1	14.633	134.8512	281.58	93.13
2	20.245	9.9473	15.63	6.87

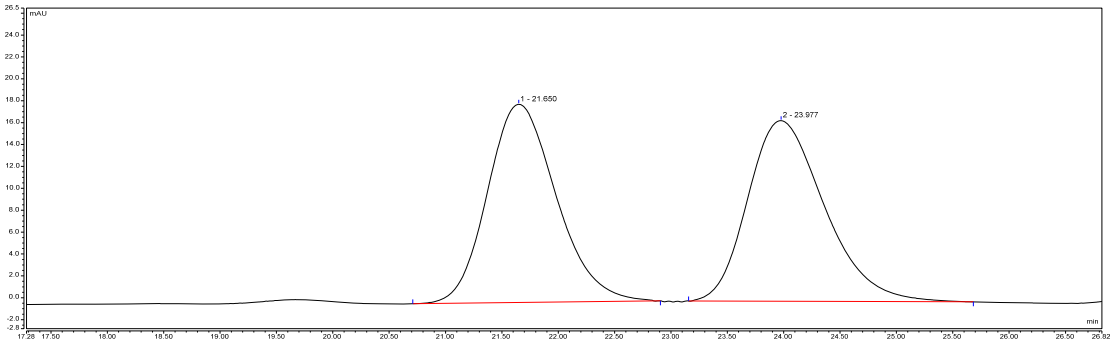
(*R*)-4,4-dimethyl-2-(naphthalen-1-yl)-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (27)



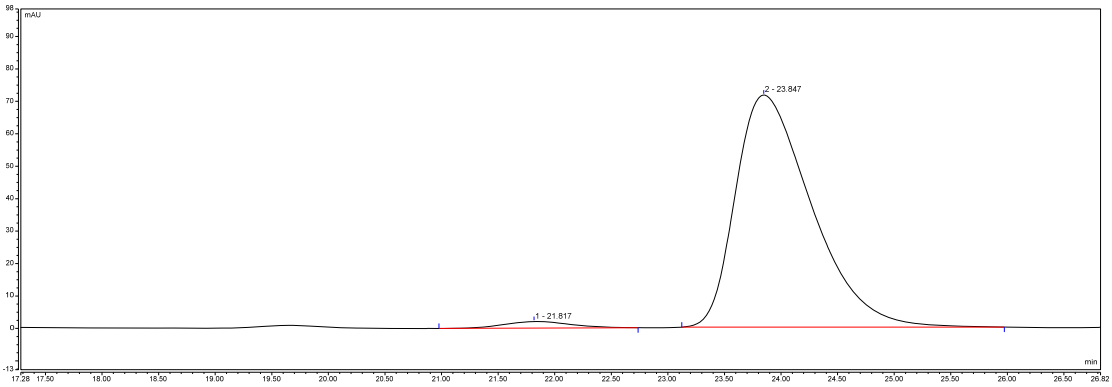
27

White solid; Mp 147.1−147.9 °C; 30.1 mg, 85% yield, 95% ee; $[\alpha]_D^{22}$ −41.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.86 (d, *J* = 8.2 Hz, 1H), 8.66 (dd, *J* = 4.8, 0.7 Hz, 1H), 8.25 (d, *J* = 7.5 Hz, 1H), 7.90 – 7.79 (m, 2H), 7.77 – 7.66 (m, 2H), 7.56 – 7.41 (m, 3H), 7.32 (m, 1H), 3.57 (d, *J* = 16.0 Hz, 1H), 3.48 – 3.29 (m, 2H), 2.93 (d, *J* = 16.0 Hz, 1H), 2.52 – 2.42 (m, 1H), 2.21 (m, 1H), 1.24 (s, 3H), 1.19 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 176.4, 175.1 153.6, 149.2, 136.3, 134.0, 133.0, 131.0, 130.5, 128.3, 127.5, 127.2, 126.5, 126.1, 124.8, 124.8, 122.8, 112.1, 53.9, 44.6, 35.3, 28.6, 25.2, 21.6; **HRMS** (ESI) 354.1965 m/z (M + H^+), calc. for $C_{24}H_{24}N_3^+$ 354.1965.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 95/5; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 21.6 min (minor) and 23.9 min (major).

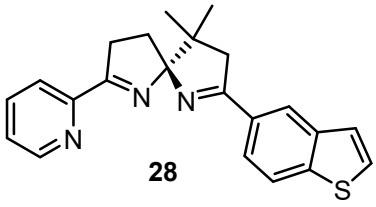


Entry	Retention Time	Area	Height	%Area
1	21.650	12.7943	18.12	49.59
2	23.977	13.0052	16.49	50.41



Entry	Retention Time	Area	Height	%Area
1	21.817	1.3686	2.03	2.40
2	23.847	55.6272	71.54	97.60

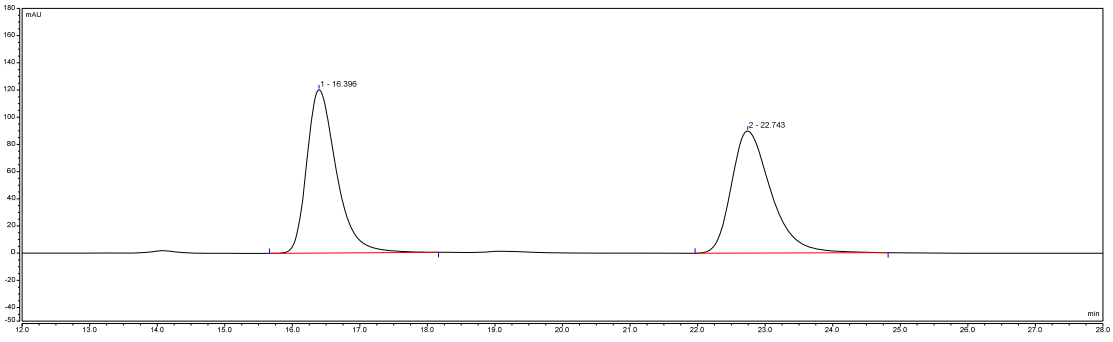
(*R*)-2-(benzo[*b*]thiophen-5-yl)-4,4-dimethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (28)



28

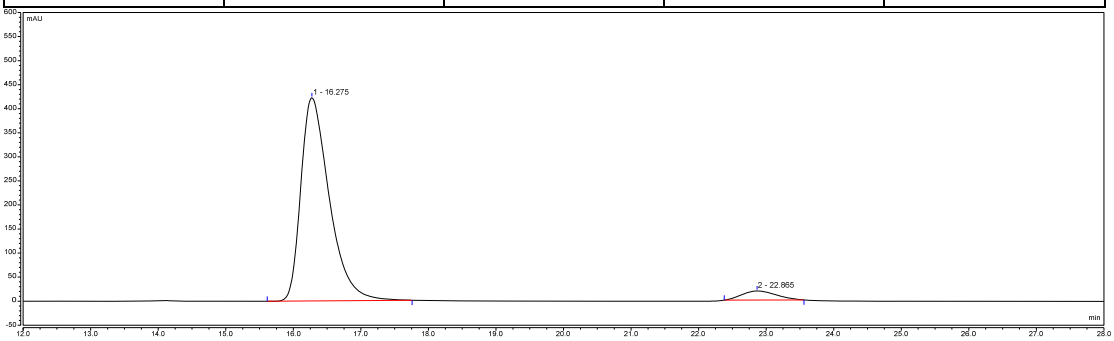
Yellow solid; Mp 117.2−118.0 °C; 20.9 mg, 58% yield, 90% ee; $[\alpha]_D^{22}$ −49.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.68 – 8.60 (m, 1H), 8.33 (s, 1H), 8.12 (dd, *J* = 8.0, 0.9 Hz, 1H), 7.96 (dd, *J* = 8.5, 2.6 Hz, 1H), 7.90 (dd, *J* = 8.5, 1.2 Hz, 1H), 7.89 – 7.83 (m, 1H), 7.64 (dd, *J* = 5.4, 2.6 Hz, 1H), 7.46 (dd, *J* = 5.3, 1.6 Hz, 2H), 3.48 – 3.38 (m, 2H), 3.31 – 3.26 (m, 1H), 3.10 (dd, *J* = 16.4, 4.9 Hz, 1H), 2.28 (m, 2H), 1.20 (s, 3H), 1.11 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 178.3, 177.2, 153.5, 150.2, 143.9, 141.0, 138.0, 131.6, 128.7, 126.6, 125.2, 124.8, 123.9, 123.5, 123.4, 112.3, 51.0, 45.4, 36.2, 28.7, 25.3, 21.5; **HRMS** (ESI) 360.1528 m/z (M + H^+), calc. for $C_{22}H_{22}N_3S^+$ 360.1529.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time:16.4 min (major) and 22.7 min (minor).



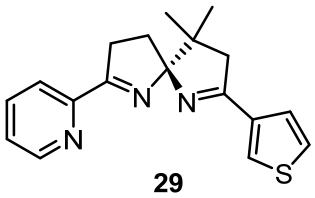
Entry	Retention Time	Area	Height	%Area
1	16.396	60.8735	120.13	50.05

2	22.743	60.7590	89.83	49.95



Entry	Retention Time	Area	Height	%Area
1	16.275	422.31	205.9780	94.88
2	22.865	18.89	11.1160	5.12

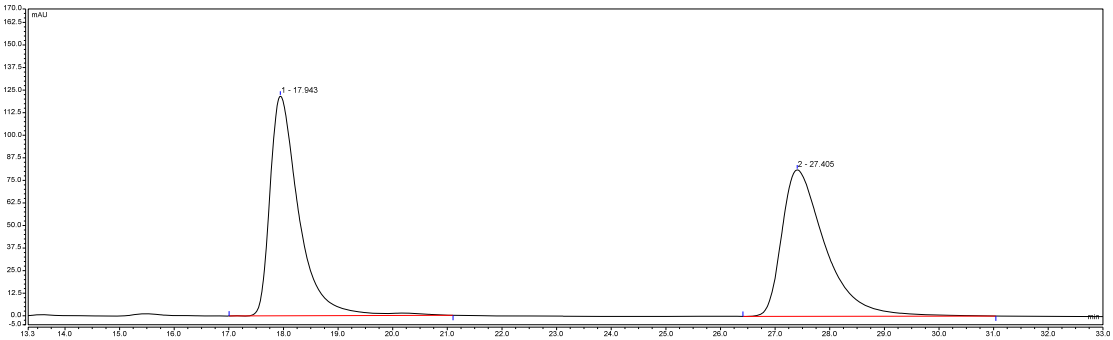
(*R*)-4,4-dimethyl-7-(pyridin-2-yl)-2-(thiophen-3-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (29)



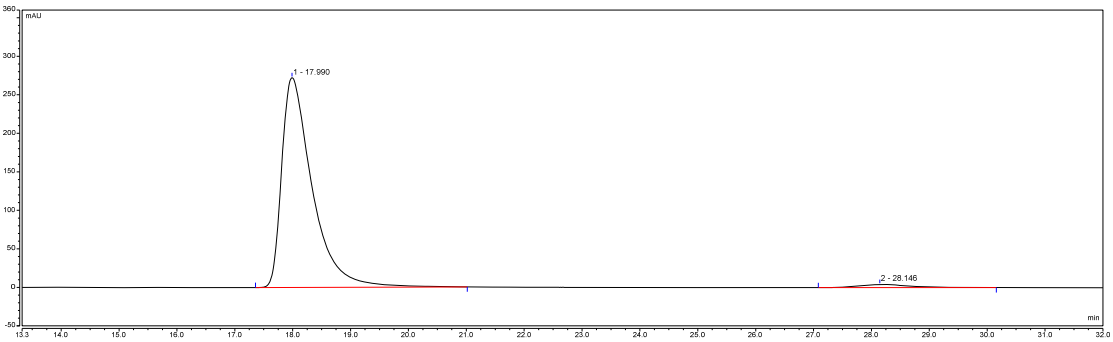
29

White solid; Mp 147.5−148.3 °C; 23.3 mg, 75% yield, 95% ee; $[\alpha]_D^{22}$ −292.0 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 3.8 Hz, 1H), 8.17 (d, *J* = 7.8 Hz, 1H), 7.78 – 7.64 (m, 2H), 7.59 (d, *J* = 4.2 Hz, 1H), 7.30 (m, 2H), 3.37 (m, 1H), 3.22 (d, *J* = 15.7 Hz, 2H), 2.81 (d, *J* = 15.8 Hz, 1H), 2.29 (m, 1H), 2.19 – 2.06 (m, 1H), 1.15 (s, 3H), 1.07 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 175.9, 172.1, 152.3, 148.9, 137.0, 136.8, 129.9, 126.5, 125.8, 125.3, 122.3, 110.9, 50.3, 44.0, 35.0, 27.4, 24.1, 20.2; **HRMS** (ESI) 310.1372 m/z ($M + H^+$), calc. for $C_{18}H_{20}N_3S^+$ 310.1372.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 17.9 min (major) and 27.4 min (minor).

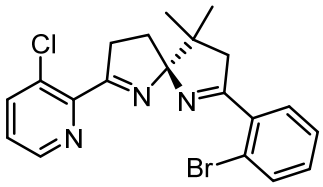


Entry	Retention Time	Area	Height	%Area
1	17.943	74.7485	121.69	50.12
2	27.405	74.3949	81.12	49.88



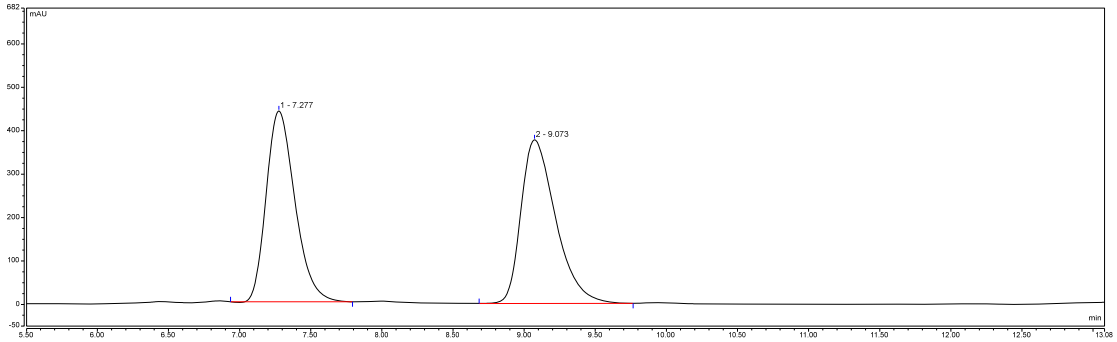
Entry	Retention Time	Area	Height	%Area
1	17.990	272.29	166.2436	97.63
2	28.146	4.01	4.0311	2.37

(*R*)-2-(2-bromophenyl)-7-(3-fluoropyridin-2-yl)-4,4-dimethyl-1,6-diazaspiro[4.4]nona-1,6-diene (30)

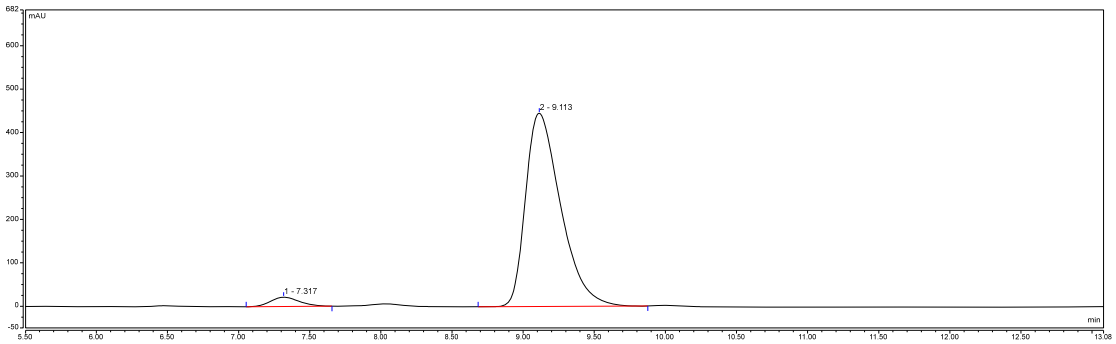


30

Yellow solid; Mp 87.3−88.1 °C; 26.6 mg, 64% yield, 92% ee; $[\alpha]_D^{22}$ –30.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.51 (d, *J* = 5.3 Hz, 1H), 8.18 (dd, *J* = 48.8, 1.9 Hz, 1H), 7.62 – 7.51 (m, 1H), 7.54 – 7.44 (m, 1H), 7.32 – 7.27 (m, 2H), 7.20 (td, *J* = 7.8, 1.7 Hz, 1H), 3.34 (d, *J* = 16.4 Hz, 1H), 3.31 – 3.19 (m, 2H), 2.98 (d, *J* = 16.4 Hz, 1H), 2.32 (m, 1H), 2.11 (m, 1H), 1.16 (s, 3H), 1.14 (s, 3H); ^{13}C **NMR** (151 MHz, $CDCl_3$) δ 177.4, 174.4, 154.9, 149.9, 144.4, 137.8, 133.3, 130.7, 130.4, 127.4, 125.0, 122.9, 121.3, 110.9, 53.3, 45.6, 35.2, 28.2, 24.8, 21.6; **HRMS** (ESI) 416.0521 m/z (M + H^+), calc. for $C_{20}H_{20}BrClN_3^+$ 416.0524. The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 7.3 min (minor) and 9.1 min (major).

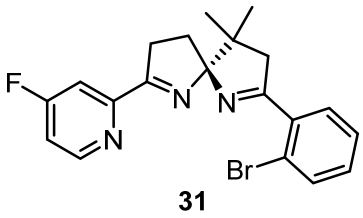


Entry	Retention Time	Area	Height	%Area
1	7.277	102.8317	439.58	49.12
2	9.073	106.5133	376.68	50.88



Entry	Retention Time	Area	Height	%Area
1	7.317	4.9989	21.38	3.79
2	9.113	126.9549	445.04	96.21

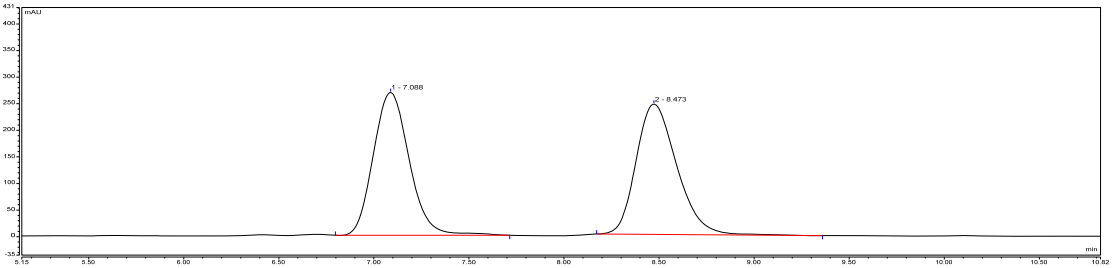
(*R*)-2-(2-bromophenyl)-7-(4-fluoropyridin-2-yl)-4,4-dimethyl-1,6-diazaspiro[4.4]nona-1,6-diene (31)



31

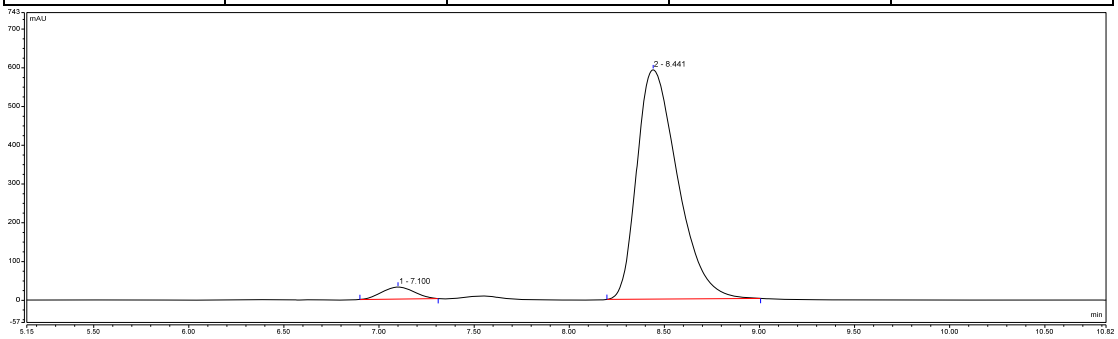
Yellow solid; Mp 120.7−121.5 °C; 22.4 mg, 56% yield, 92% ee; $[\alpha]_D^{22}$ −42.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.66 (dd, *J* = 8.3, 5.7 Hz, 1H), 7.92 (dd, *J* = 9.8, 2.5 Hz, 1H), 7.67 (dd, *J* = 8.0, 0.6 Hz, 1H), 7.46 – 7.39 (m, 2H), 7.36 – 7.34 (m, 1H), 7.33 – 7.29 (m, 1H), 3.37 (d, *J* = 16.9 Hz, 1H), 3.30 (d, *J* = 8.6 Hz, 2H), 3.01 (d, *J* = 16.9 Hz, 1H), 2.28 (t, *J* = 7.3 Hz, 2H), 1.21 (s, 3H), 1.20 (s, 3H); **^{13}C NMR** (101 MHz, CD_3OD) δ 180.5, 176.7(d, *J* = 3.6 Hz), 170.2 (d, *J* = 261.7 Hz), 156.9 (d, *J* = 7.0 Hz), 153.0 (d, *J* = 7.2 Hz), 138.2, 134.2, 132.1, 130.7, 128.6, 121.4, 114.1 (d, *J* = 17.1 Hz), 111.9, 110.8 (d, *J* = 18.4 Hz), 54.3, 46.3, 36.1, 28.6, 24.9, 21.4; **^{19}F NMR** (565 MHz, CD_3OD) δ -103.67; **HRMS** (ESI) 400.0819 m/z ($M + H^+$), calc. for $C_{20}H_{20}BrFN_3^+$ 400.0819.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 7.1 min (minor) and 8.5 min (major).



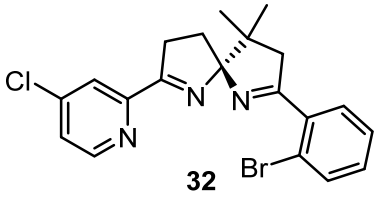
Entry	Retention Time	Area	Height	%Area
1	7.088	58.9000	268.46	49.22

2	8.473	60.7684	245.01	50.78



Entry	Retention Time	Area	Height	%Area
1	7.100	6.1243	30.97	4.00
2	8.441	147.0176	592.42	96.00

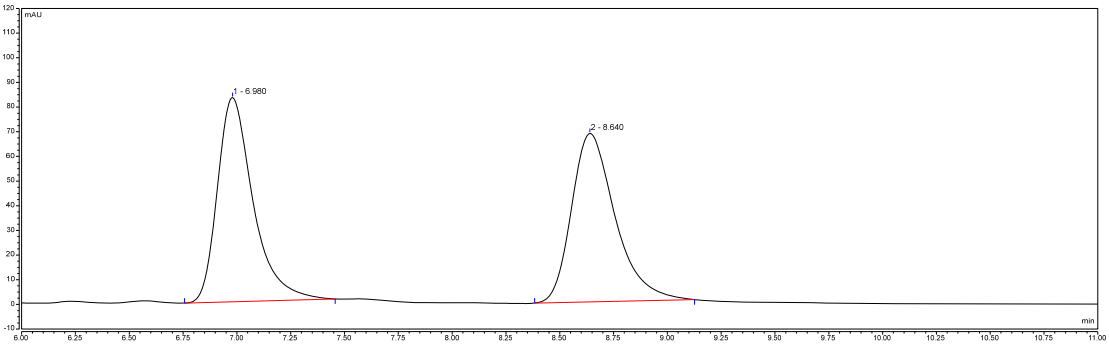
(*R*)-2-(2-bromophenyl)-7-(4-chloropyridin-2-yl)-4,4-dimethyl-1,6-diazaspiro[4.4]nona-1,6-diene (32)



32

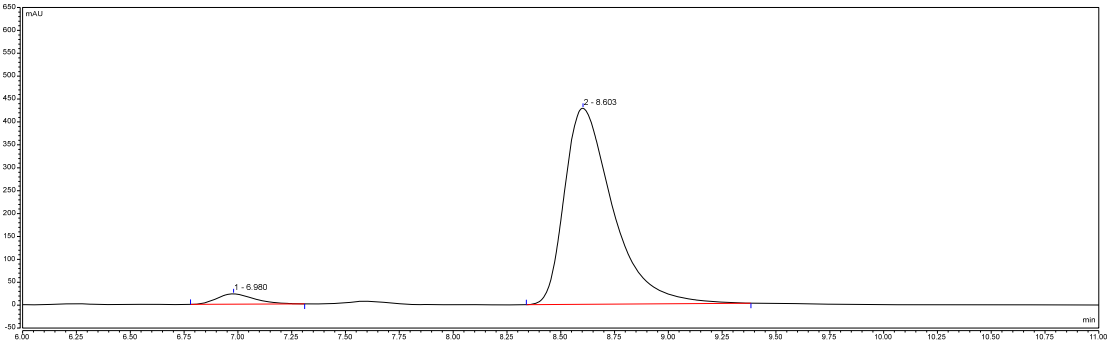
Yellow solid; Mp 126.0−126.8 °C; 29.9 mg, 72% yield, 92% ee; $[\alpha]_D^{22}$ −16.8 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.52 (d, *J* = 5.3 Hz, 1H), 8.23 (d, *J* = 1.9 Hz, 1H), 7.57 (dd, *J* = 7.9, 0.8 Hz, 1H), 7.50 (dd, *J* = 7.6, 1.6 Hz, 1H), 7.35 – 7.27 (m, 2H), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H), 3.39 – 3.32 (m, 1H), 3.26 (m, 2H), 2.99 (d, *J* = 16.4 Hz, 1H), 2.33 (m, 1H), 2.12 (m, 1H), 1.16 (s, 3H), 1.14 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 177.5, 174.4, 154.9, 150.0, 144.5, 137.8, 133.4, 130.7, 130.5, 127.4, 125.0, 122.9, 121.3, 110.9, 53.3, 45.7, 35.2, 28.2, 24.8, 21.6; **HRMS** (ESI) 416.0520 m/z ($M + H^+$), calc. for $C_{20}H_{20}BrClN_3^+$ 416.0524.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 7.0 min (minor) and 8.6 min (major).



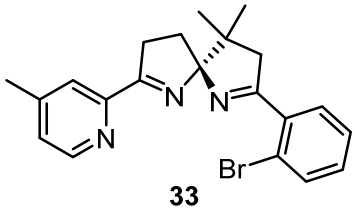
Entry	Retention Time	Area	Height	%Area
1	6.980	15.9218	82.76	49.85

2	8.640	16.0206	68.27	50.15



Entry	Retention Time	Area	Height	%Area
1	6.980	4.5374	22.63	3.91
2	8.603	111.5857	427.89	96.09

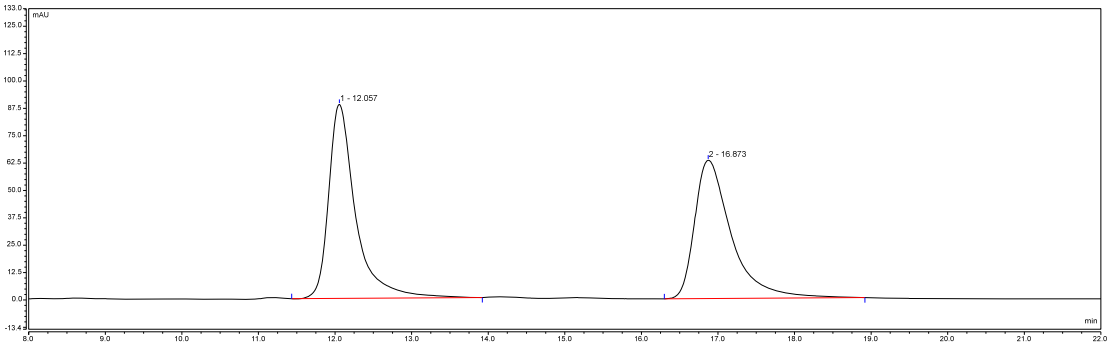
(*R*)-2-(2-bromophenyl)-4,4-dimethyl-7-(4-methylpyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (33)



33

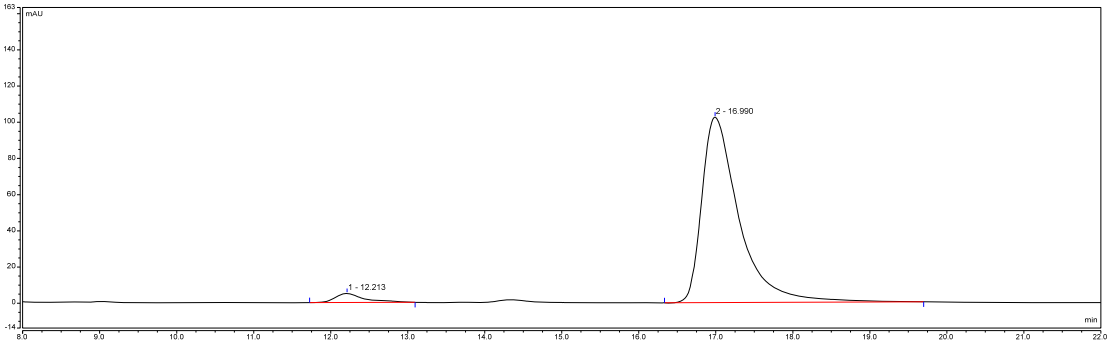
White solid; Mp 96.4−97.2 °C; 28.1 mg, 71% yield, 93% ee; $[\alpha]_D^{22}$ −20.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.49 (d, *J* = 5.0 Hz, 1H), 8.01 (s, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.46 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.42 (m, 1H), 7.34 (m, 2H), 3.37 (d, *J* = 16.9 Hz, 1H), 3.33 – 3.26 (m, 2H), 3.01 (d, *J* = 16.9 Hz, 1H), 2.44 (s, 3H), 2.31 – 2.22 (m, 2H), 1.21 (s, 3H), 1.20 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 180.3, 177.7, 153.3, 149.9, 138.2, 134.2, 132.1, 130.8, 128.5, 127.5, 124.4, 121.4, 111.9, 54.2, 46.2, 36.1, 28.6, 25.0, 21.5, 20.8; **HRMS** (ESI) 396.1070 m/z (M + H^+), calc. for $C_{21}H_{23}BrN_3^+$396.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 12.1 min (minor) and 16.9 min (major).



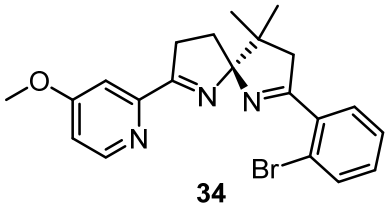
Entry	Retention Time	Area	Height	%Area
1	12.057	36.0942	88.60	50.77

2	16.873	34.9945	63.20	49.23



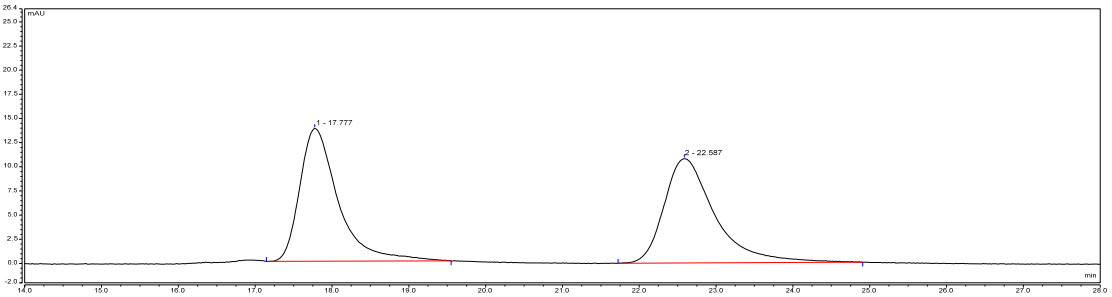
Entry	Retention Time	Area	Height	%Area
1	12.213	2.1926	4.99	3.68
2	16.990	57.3287	102.46	96.32

(*R*)-2-(2-bromophenyl)-7-(4-methoxypyridin-2-yl)-4,4-dimethyl-1,6-diazaspiro[4.4]nona-1,6-diene (34)

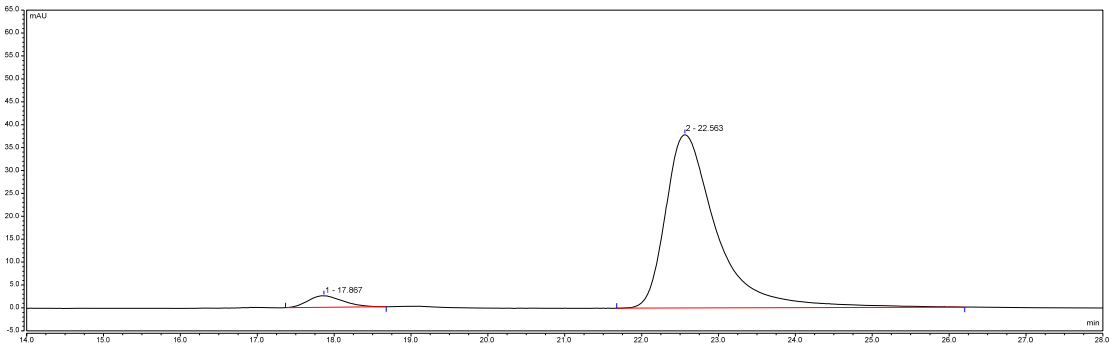


34

White solid; Mp 106.4−107.2 °C; 27.6 mg, 67% yield, 91% ee; $[\alpha]_D^{22}$ −26.5 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.44 (d, *J* = 5.7 Hz, 1H), 7.74 (d, *J* = 2.6 Hz, 1H), 7.57 (dd, *J* = 8.0, 0.9 Hz, 1H), 7.52 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.30 (td, *J* = 7.5, 1.0 Hz, 1H), 7.21 (td, *J* = 7.7, 1.7 Hz, 1H), 6.85 (dd, *J* = 5.7, 2.6 Hz, 1H), 3.89 (s, 3H), 3.34 (d, *J* = 16.4 Hz, 1H), 3.31 – 3.22 (m, 2H), 2.97 (d, *J* = 16.4 Hz, 1H), 2.35 – 2.23 (m, 1H), 2.13 (m, 1H), 1.16 (s, 3H), 1.14 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 177.1, 175.3, 165.9, 155.3, 150.3, 137.9, 133.4 130.7, 130.5, 127.4, 121.3, 111.9, 110.9, 107.87, 55.5, 53.3, 45.8, 35.4, 28.3, 24.8, 21.8; **HRMS** (ESI) 412.1019 m/z ($M + H^+$), calc. for $C_{21}H_{23}BrN_3O^+$ 412.1019. The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 17.8 min (minor) and 22.6 min (major).

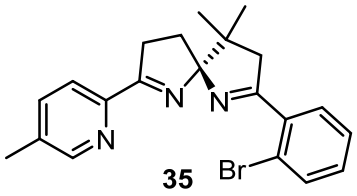


Entry	Retention Time	Area	Height	%Area
1	17.777	7.9726	13.73	49.17
2	22.587	8.2432	10.82	50.83



Entry	Retention Time	Area	Height	%Area
1	17.867	1.3272	2.53	4.36
2	22.563	29.1262	37.86	95.64

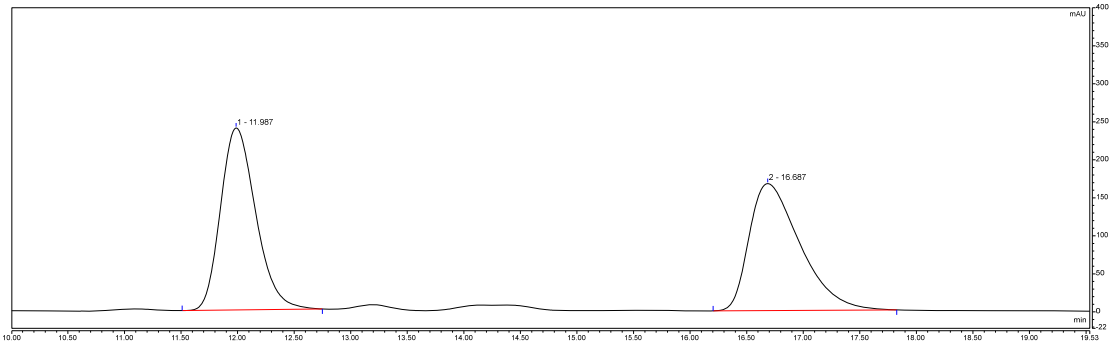
(*R*)-2-(2-bromophenyl)-4,4-dimethyl-7-(5-methylpyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (35)



35

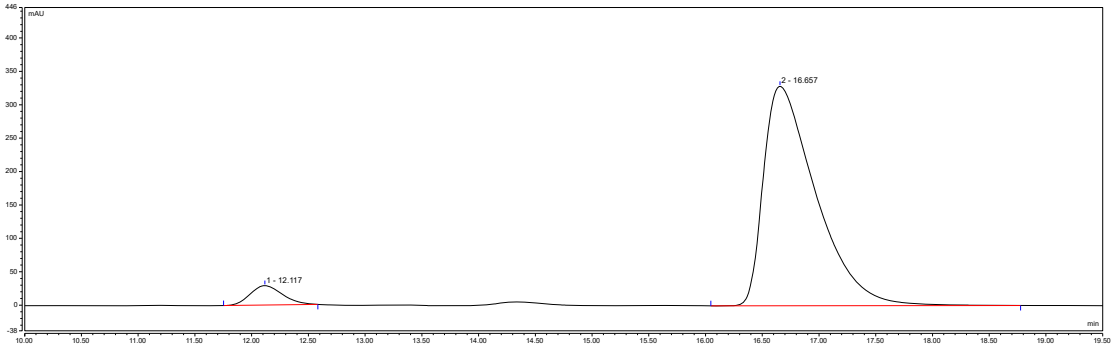
White solid; Mp 96.7−97.5 °C; 29.7 mg, 75% yield, 90% ee; $[\alpha]_D^{22}$ −36.9 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.48 (dd, *J* = 1.4, 0.7 Hz, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.72 (d, *J* = 8.0 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.45 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.41 (td, *J* = 7.5, 1.0 Hz, 1H), 7.33 (m, 1H), 3.35 (d, *J* = 16.9 Hz, 1H), 3.32 – 3.27 (m, 2H), 2.99 (d, *J* = 16.9 Hz, 1H), 2.40 (s, 3H), 2.27 – 2.21 (m, 2H), 1.19 (s, 3H), 1.19 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 178.9, 176.3, 149.7, 149.3, 137.2, 137.1, 136.0, 133.0, 130.8, 129.5, 127.3, 122.1, 120.2, 110.7, 53.0, 45.0, 34.9, 27.4, 23.8, 20.3, 17.0; **HRMS** (ESI) 396.1069 m/z ($M + H^+$), calc. for $C_{21}H_{23}BrN_3^+$ 396.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.0 min (minor) and 11.2 min (major).



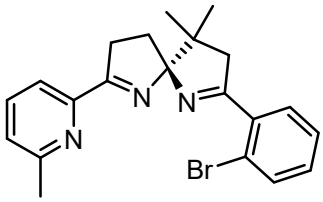
Entry	Retention Time	Area	Height	%Area
1	11.987	86.3239	239.32	49.83

2	16.687	86.9137	167.03	50.17



Entry	Retention Time	Area	Height	%Area
1	12.117	9.6115	29.11	5.19
2	16.657	175.6218	328.41	94.81

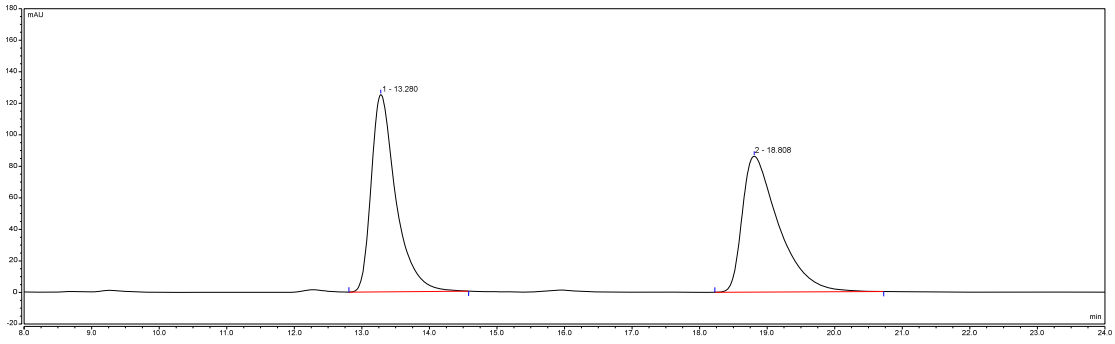
(*R*)-2-(2-bromophenyl)-4,4-dimethyl-7-(6-methylpyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (36)



36

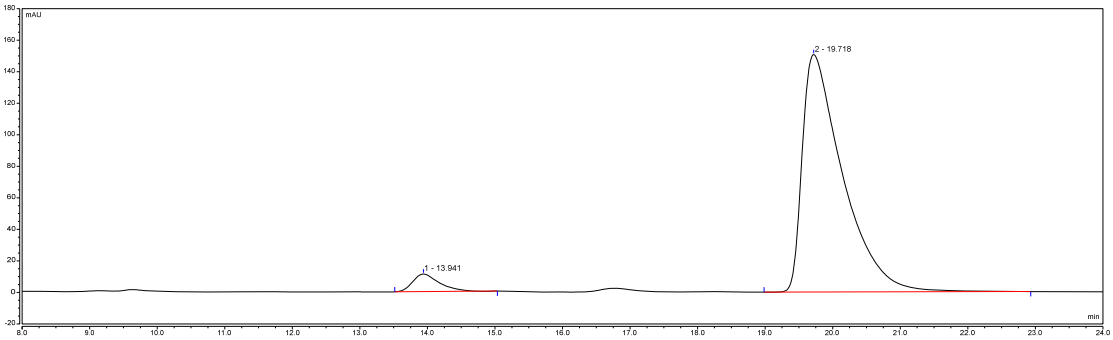
White solid; Mp 98.4−99.3 °C; 25.7 mg, 65% yield, 91% ee; $[\alpha]_D^{22}$ −38.0 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 7.92 (d, *J* = 7.7 Hz, 1H), 7.76 (t, *J* = 7.7 Hz, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.47 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.42 (m, 1H), 7.35 (d, *J* = 7.6 Hz, 2H), 3.36 (d, *J* = 16.9 Hz, 1H), 3.32 – 3.30 (m, 1H), 3.01 (d, *J* = 16.9 Hz, 1H), 2.59 (s, 3H), 2.56 (d, *J* = 5.6 Hz, 1H), 2.26 (t, *J* = 7.0 Hz, 2H), 1.21 (s, 3H), 1.20 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 180.2, 178.3, 159.6, 153.1, 138.3, 138.0, 134.2, 132.1, 130.8, 128.5, 126.0, 121.4, 120.6, 111.9, 54.2, 46.2, 36.2, 28.6, 25.1, 24.0, 21.5; **HRMS** (ESI) 396.1070 m/z ($M + H^+$), calc. for $C_{21}H_{23}BrN_3^+$ 396.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 13.3 min (minor) and 18.8 min (major).



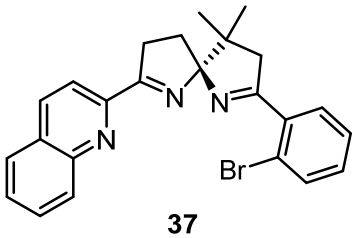
Entry	Retention Time	Area	Height	%Area
1	13.280	52.8715	125.10	49.63

2	18.808	53.6494	86.19	50.37



Entry	Retention Time	Area	Height	%Area
1	13.941	5.0326	11.15	4.60
2	19.718	104.2851	150.57	95.40

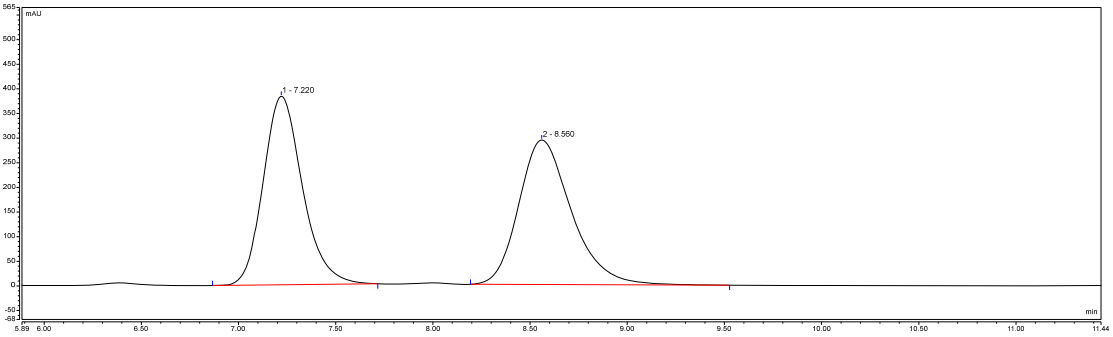
(*R*)-2-(7-(2-bromophenyl)-9,9-dimethyl-1,6-diazaspiro[4.4]nona-1,6-dien-2-yl)quinoline (37)



37

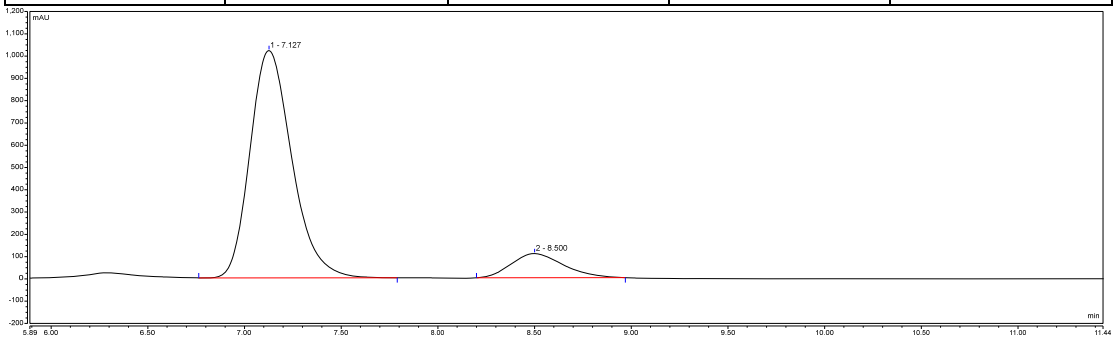
White solid; Mp 96.3−97.1 °C; 29.4 mg, 68% yield, 77% ee; $[\alpha]_D^{22}$ +30.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.34 (d, *J* = 8.5 Hz, 1H), 8.15 (d, *J* = 8.4 Hz, 2H), 7.82 (dd, *J* = 8.1, 1.1 Hz, 1H), 7.72 (m, 1H), 7.62 – 7.50 (m, 3H), 7.31 (td, *J* = 7.5, 1.2 Hz, 1H), 7.25 – 7.18 (m, 1H), 3.55 – 3.42 (m, 2H), 3.42 – 3.33 (m, 1H), 3.01 (d, *J* = 16.4 Hz, 1H), 2.37 (m, 1H), 2.19 (m, 1H), 1.20 (s, 3H), 1.18 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 177.2, 175.9, 153.8, 147.9, 137.9, 135.9, 133.4, 130.6, 130.5, 130.1, 129.5, 128.7, 127.7, 127.4, 127.4, 121.3, 120.2, 111.2, 53.4, 45.8, 35.2, 28.3, 24.8, 21.8; **HRMS** (ESI) 432.1070 m/z (M + H^+), calc. for $C_{24}H_{23}BrN_3^+$ 432.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.0 min (major) and 11.2 min (minor).



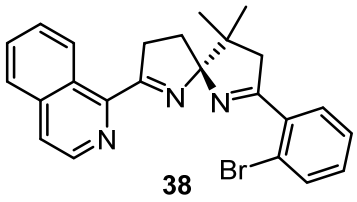
Entry	Retention Time	Area	Height	%Area
1	7.220	89.8899	382.99	49.43

2	8.560	91.9658	293.54	50.57



Entry	Retention Time	Area	Height	%Area
1	7.127	255.8833	1020.00	88.31
2	8.500	33.8698	108.37	11.69

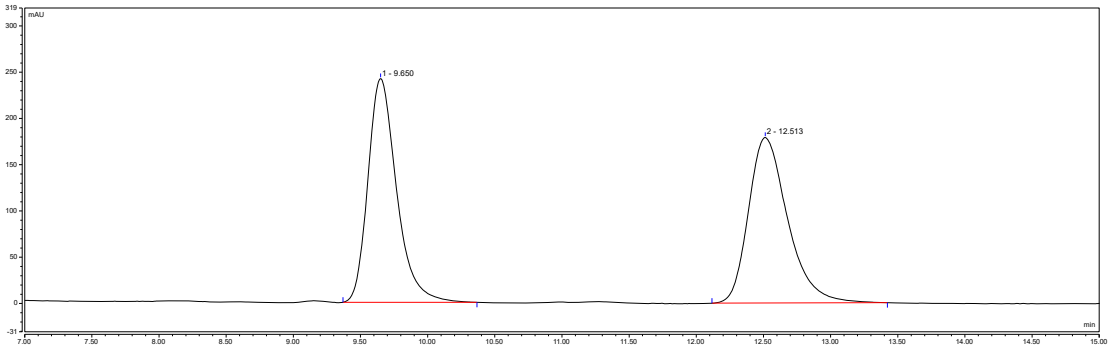
(*R*)-1-(7-(2-bromophenyl)-9,9-dimethyl-1,6-diazaspiro[4.4]nona-1,6-dien-2-yl) isoquinoline (38)



38

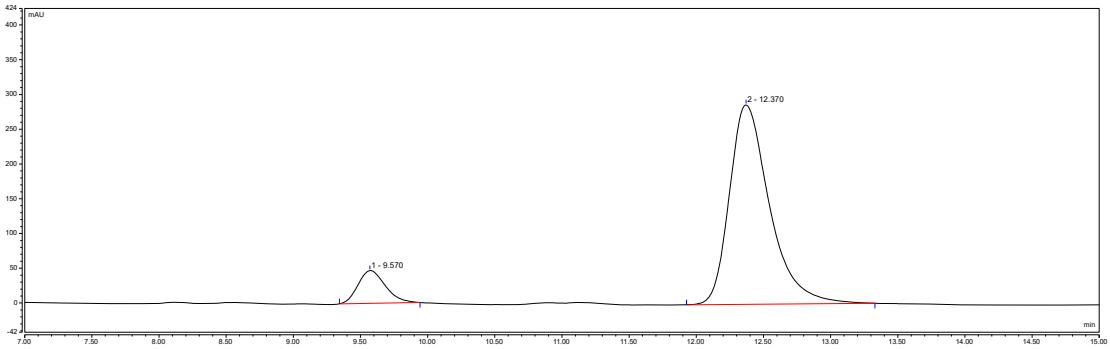
White solid; Mp 132.4−133.2 °C; 26.8 mg, 62% yield, 80% ee; $[\alpha]_D^{22}$ +57.3 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 9.04 (d, *J* = 8.6 Hz, 1H), 8.55 (d, *J* = 5.6 Hz, 1H), 7.97 (d, *J* = 8.2 Hz, 1H), 7.87 (d, *J* = 5.6 Hz, 1H), 7.81 – 7.74 (m, 1H), 7.72 – 7.64 (m, 2H), 7.46 – 7.42 (m, 2H), 7.35 (m, 1H), 3.49 (m, 1H), 3.45 – 3.37 (m, 2H), 3.01 (d, *J* = 17.0 Hz, 1H), 2.35 – 2.28 (m, 2H), 1.31 (s, 3H), 1.27 (s, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 180.7, 178.3, 154.1, 142.2, 138.5, 138.1, 134.2, 132.0, 131.7, 130.5, 129.2, 128.6, 128.4, 127.9, 127.7, 123.7, 121.3, 113.4, 54.4, 46.1, 39.2, 28.2, 24.9, 21.7; **HRMS** (ESI) 432.1069 m/z (M + H^+), calc. for $C_{24}H_{23}BrN_3^+$ 432.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.6 min (minor) and 12.5 min (major).



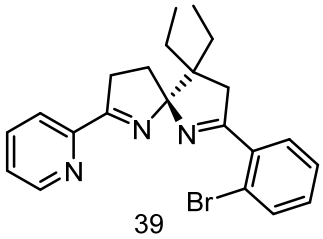
Entry	Retention Time	Area	Height	%Area

1	9.650	59.7291	241.86	49.70
2	12.513	60.4520	178.98	50.30



Entry	Retention Time	Area	Height	%Area
1	9.570	11.0719	47.11	10.03
2	12.370	99.3123	287.15	89.97

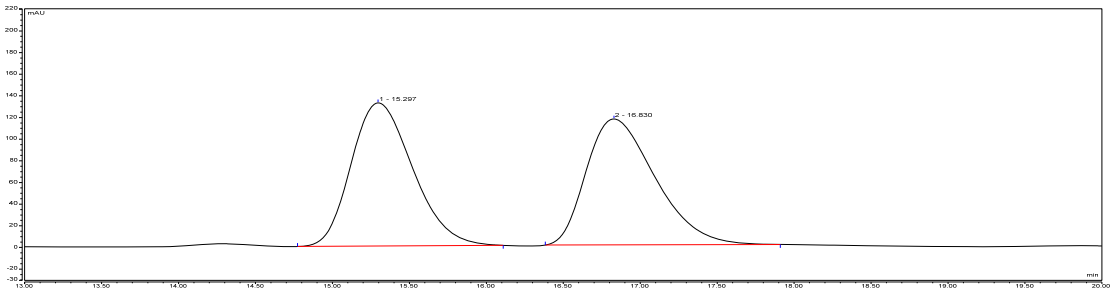
(*R*)-2-(2-bromophenyl)-4,4-diethyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (39)



39

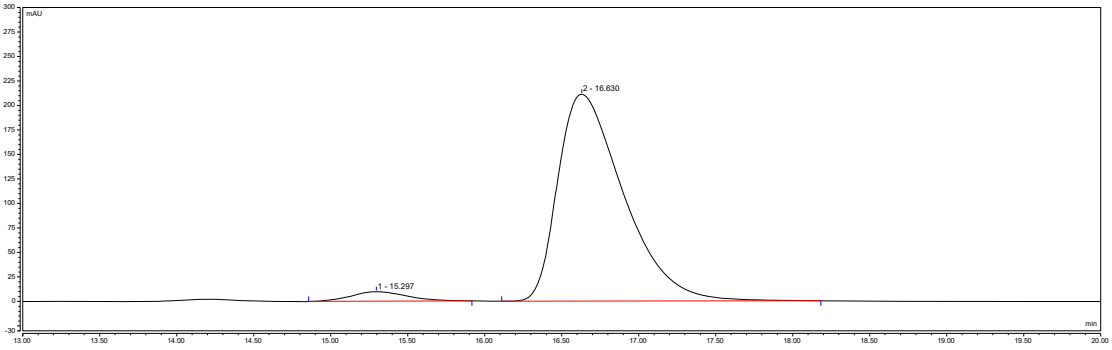
White solid; Mp 89.0−89.9 °C; 22.9 mg, 56% yield, 93% ee; $[\alpha]_D^{22}$ −32.9 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.71 – 8.50 (m, 1H), 8.17 (d, *J* = 7.9 Hz, 1H), 7.94 – 7.80 (m, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.52 – 7.43 (m, 2H), 7.40 (m, 1H), 7.36 – 7.24 (m, 1H), 3.32 (m, 2H), 3.25 (d, *J* = 17.3 Hz, 1H), 3.09 (d, *J* = 17.3 Hz, 1H), 2.38 – 2.26 (m, 2H), 1.84 (m, 1H), 1.79 – 1.71 (m, 2H), 1.59 (m, 1H), 0.93 (t, *J* = 7.4 Hz, 3H), 0.83 (t, *J* = 7.5 Hz, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 179.2, 177.1, 153.6, 150.1, 138.0, 137.9, 134.3, 132.1, 131.0, 128.5, 126.6, 123.6, 121.5, 112.2, 52.7, 50.5, 35.9, 30.1, 26.1, 25.8, 9.6, 9.5; **HRMS** (ESI) 410.1226 m/z (M + H^+), calc. for $C_{22}H_{25}BrN_3^+$ 410.1226.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 90/10; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 15.3 min (minor) and 16.8 min (major).



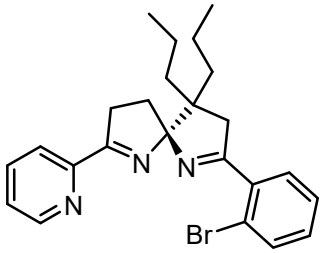
Entry	Retention Time	Area	Height	%Area
1	15.297	61.2781	132.23	50.42

2	16.830	60.2531	116.30	49.58



Entry	Retention Time	Area	Height	%Area
1	15.297	4.0545	9.71	3.74
2	16.630	104.3055	211.15	96.26

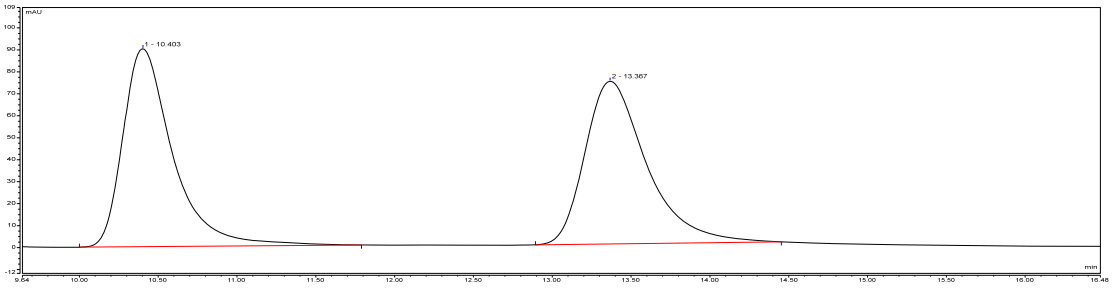
(*R*)-2-(2-bromophenyl)-4,4-dipropyl-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (40)



40

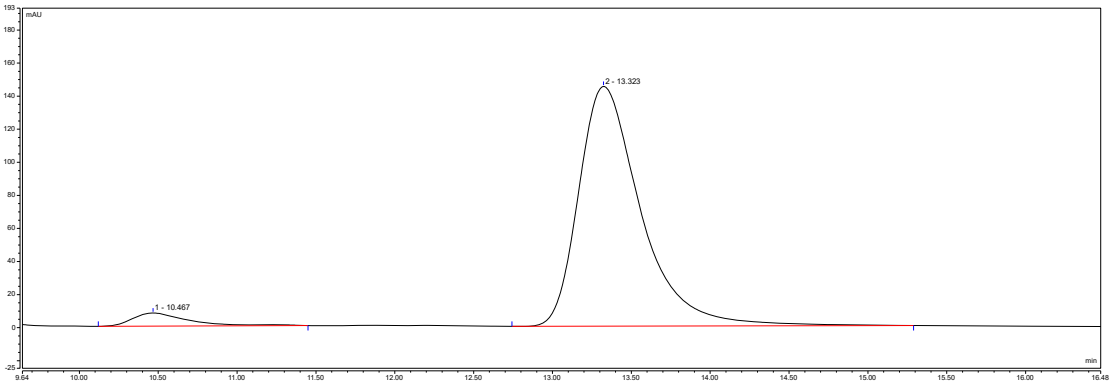
White solid; Mp 109.8−110.6 °C; 26.1 mg, 60% yield, 90% ee; $[\alpha]_D^{22}$ −36.6 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.64 (dd, *J* = 4.8, 0.7 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.90 (m, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.51 – 7.43 (m, 2H), 7.41 (m, 1H), 7.36 – 7.29 (m, 1H), 3.43 – 3.31 (m, 1H), 3.27 (d, *J* = 17.3 Hz, 1H), 3.11 (d, *J* = 17.2 Hz, 1H), 2.42 – 2.29 (m, 2H), 1.79 – 1.62 (m, 3H), 1.56 – 1.46 (m, 1H), 1.38 – 1.24 (m, 3H), 1.22 – 1.11 (m, 1H), 0.96 (t, *J* = 7.2 Hz, 3H), 0.85 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (151 MHz, CD_3OD) δ 179.3, 177.1, 153.6, 150.2, 138.1, 137.9, 134.4, 132.1, 131.1, 128.5, 126.6, 123.6, 121.5, 112.3, 52.5, 51.2, 36.9, 36.8, 35.9, 30.0, 19.4, 19.0, 15.2, 15.2; **HRMS** (ESI) 438.1539 m/z (M + H^+), calc. for $C_{24}H_{29}BrN_3^+$ 438.1539.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 10.4 min (minor) and 13.4 min (major).



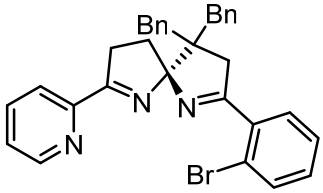
Entry	Retention Time	Area	Height	%Area

1	10.403	33.0103	90.12	49.64
2	13.367	33.4931	74.03	50.36



Entry	Retention Time	Area	Height	%Area
1	10.467	3.2124	7.92	4.63
2	13.323	66.1171	144.97	95.37

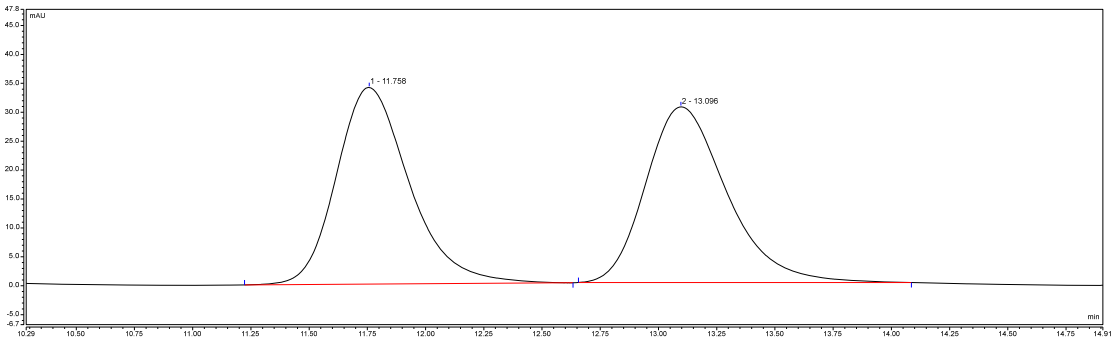
(*R*)-4,4-dibenzyl-2-(2-bromophenyl)-7-(pyridin-2-yl)-1,6-diazaspiro[4.4]nona-1,6-diene (41)



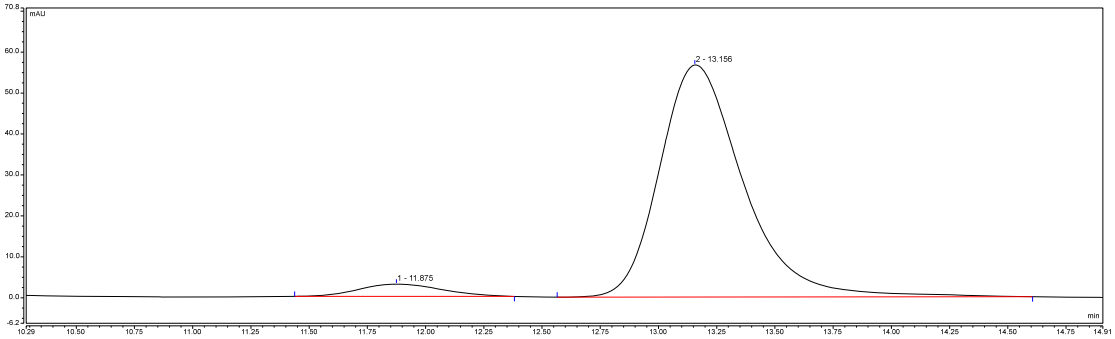
41

Yellow oil; 30.4 mg, 57% yield, 90% ee; $[\alpha]_D^{22}$ +47.2 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.68 – 8.64 (m, 1H), 8.28 (d, *J* = 7.9 Hz, 1H), 7.93 (m, 1H), 7.56 (d, *J* = 8.0 Hz, 1H), 7.54 – 7.49 (m, 1H), 7.28 (d, *J* = 7.7 Hz, 2H), 7.25 – 7.20 (m, 4H), 7.16 – 7.13 (m, 4H), 7.10 (d, *J* = 7.1 Hz, 2H), 6.52 (dd, *J* = 7.7, 1.4 Hz, 1H), 3.84 (d, *J* = 16.8 Hz, 1H), 3.38 – 3.33 (m, 1H), 3.27 (d, *J* = 13.1 Hz, 1H), 3.24 (s, 1H), 3.05 (d, *J* = 16.8 Hz, 1H), 2.93 (d, *J* = 14.0 Hz, 1H), 2.90 – 2.83 (m, 2H), 2.56 – 2.49 (m, 1H), 2.38 – 2.31 (m, 1H); **^{13}C NMR** (151 MHz, CD_3OD) δ 179.1, 176.8, 153.7, 150.2, 140.2, 139.8, 138.1, 137.3, 134.1, 132.0, 131.6, 131.4, 129.2, 128.9, 127.9, 127.2, 126.6, 123.8, 121.3, 112.5, 56.0, 40.9, 40.9, 36.2, 30.7, 29.5; **HRMS** (ESI) 534.1539 m/z (M + H^+), calc. for $C_{32}H_{29}BrN_3^+$ 534.1539.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 11.7 min (minor) and 13.1 min (major).

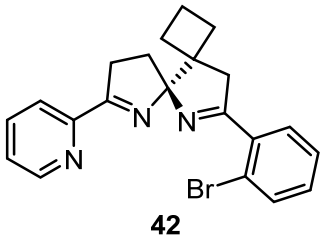


Entry	Retention Time	Area	Height	%Area
1	11.758	12.3496	33.99	50.14
2	13.096	12.2806	30.38	49.86



Entry	Retention Time	Area	Height	%Area
1	11.875	1.2308	3.00	4.96
2	13.156	23.5759	56.66	95.04

(*R*)-11-(2-bromophenyl)-7-(pyridin-2-yl)-6,10-diazadispiro [3.0.4^5.3^4] dodeca-6,10-diene (42)

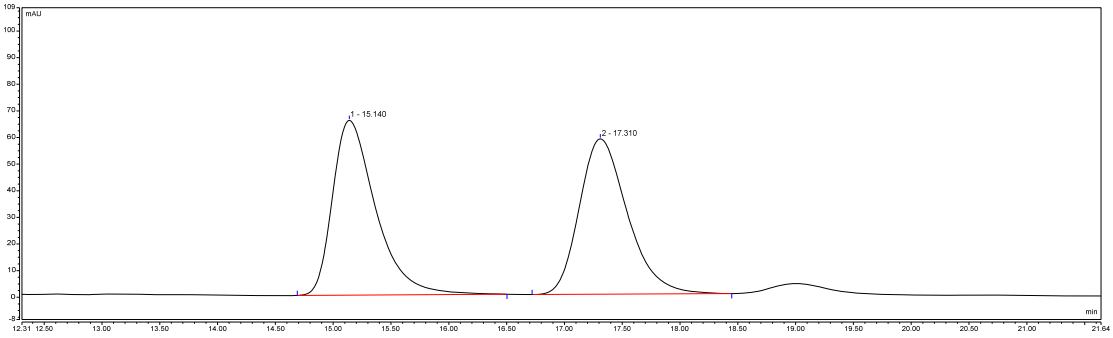


42

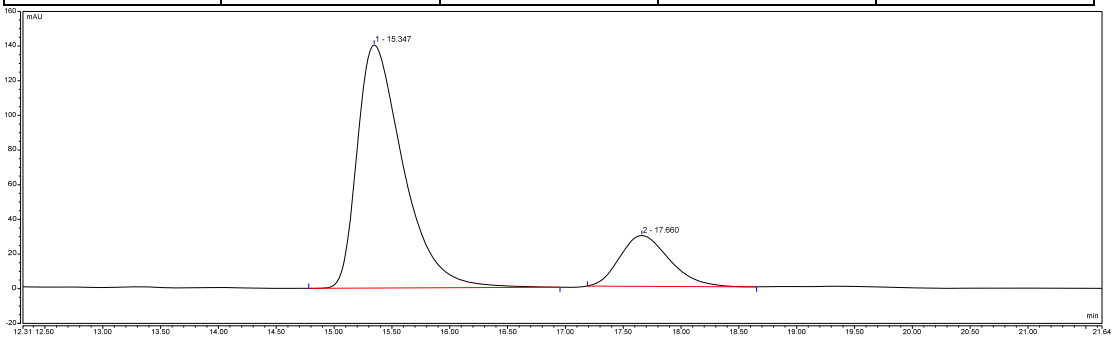
White solid; Mp 102.5−103.3 °C; 24.0 mg, 61% yield, 63% ee; $[\alpha]_D^{22}$ −70.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.66 (dd, *J* = 4.8, 0.6 Hz, 1H), 8.20 (d, *J* = 7.9 Hz, 1H), 7.90 (td, *J* = 7.8, 1.7 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.52 – 7.47 (m, 1H), 7.45 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.42 (m, 1H), 7.33 (td, *J* = 7.9, 1.8 Hz, 1H), 3.54 (d, *J* = 17.2 Hz, 1H), 3.41 (d, *J* = 17.2 Hz, 1H), 3.39 – 3.29 (m, 2H), 2.47 (m, 1H), 2.37 – 2.26 (m, 1H), 2.26 – 2.19 (m, 1H), 2.16 (m, 1H), 2.04 – 1.93 (m, 3H), 1.76 (m, 1H); **^{13}C NMR** (151 MHz, CD_3OD) δ 178.9, 178.7, 153.3, 150.2, 138.2, 138.1, 134.1, 132.1, 130.6, 128.6, 126.7, 123.7, 121.4, 110.7, 53.4, 52.9, 36.5, 30.4, 29.6, 28.5, 16.8; **HRMS** (ESI) 394.0914 m/z ($M + H^+$), calc. for $C_{21}H_{21}BrN_3^+$ 394.0913.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 15.1 min (major) and

17.3 min (minor).

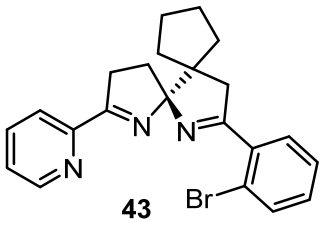


Entry	Retention Time	Area	Height	%Area
1	15.140	28.3819	65.65	50.19
2	17.310	28.1718	58.35	49.81



Entry	Retention Time	Area	Height	%Area
1	15.347	64.4327	140.21	81.58
2	17.660	14.5477	29.29	18.42

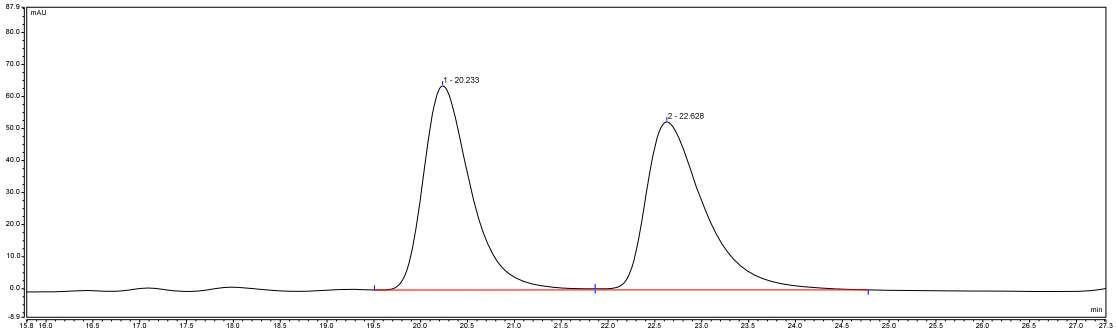
(*R*)-12-(2-bromophenyl)-2-(pyridin-2-yl)-1,13-diazadispiro [4.0.4^6.3^5]trideca-1,12-diene (43)



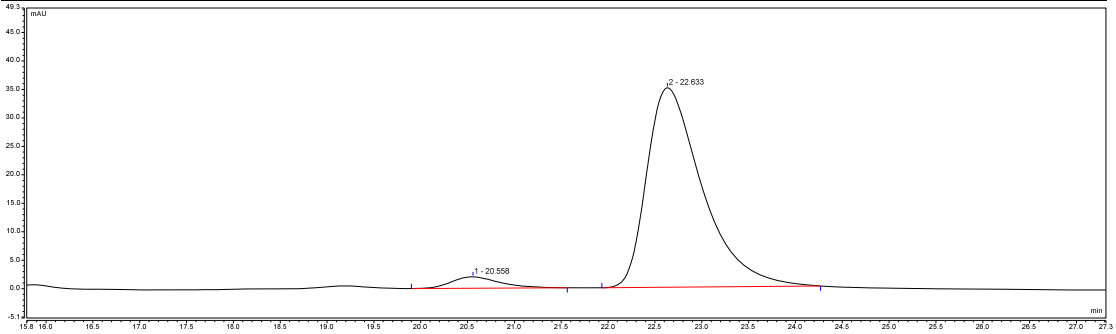
43

White solid; Mp 110.2−111.0 °C; 28.1 mg, 69% yield, 90% ee; $[\alpha]_D^{22}$ −78.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.65 (d, *J* = 4.8 Hz, 1H), 8.15 (d, *J* = 7.9 Hz, 1H), 7.90 (m, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.49 (m, 1H), 7.47 – 7.38 (m, 2H), 7.33 (m, 1H), 3.31 (m, 3H), 3.13 (d, *J* = 16.9 Hz, 1H), 2.35 – 2.17 (m, 2H), 1.76 (m, 8H); **^{13}C NMR** (151 MHz, CD_3OD) δ 180.1, 177.9, 153.5, 150.2, 138.3, 138.1, 134.2, 132.1, 130.7, 128.6, 126.6, 123.7, 121.4, 111.6, 58.5, 53.1, 36.0, 35.3, 33.2, 29.9, 24.9, 24.9; **HRMS** (ESI) 408.1072 m/z (M + H^+), calc. for $C_{22}H_{23}BrN_3^+$ 408.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 85/15; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 20.2 min (minor) and 22.6 min (major).

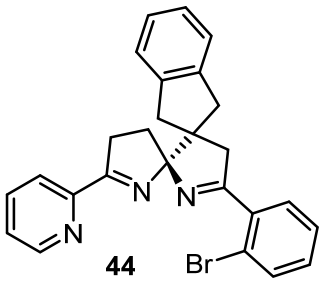


Entry	Retention Time	Area	Height	%Area
1	20.233	37.2799	63.74	49.71
2	22.628	37.7167	52.49	50.29



Entry	Retention Time	Area	Height	%Area
1	20.558	1.1840	2.01	4.69
2	22.633	24.0835	35.05	95.31

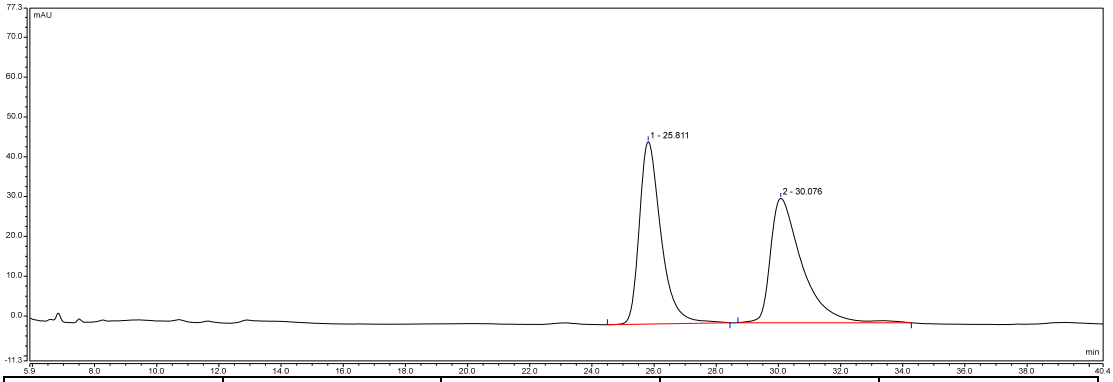
(*R*)-5'-(2-bromophenyl)-5''-(pyridin-2-yl)-1,3,3'',4''-tetrahydro-4'H-dispiro[indene-2,3'-pyrrole-2',2''-pyrrole] (44)



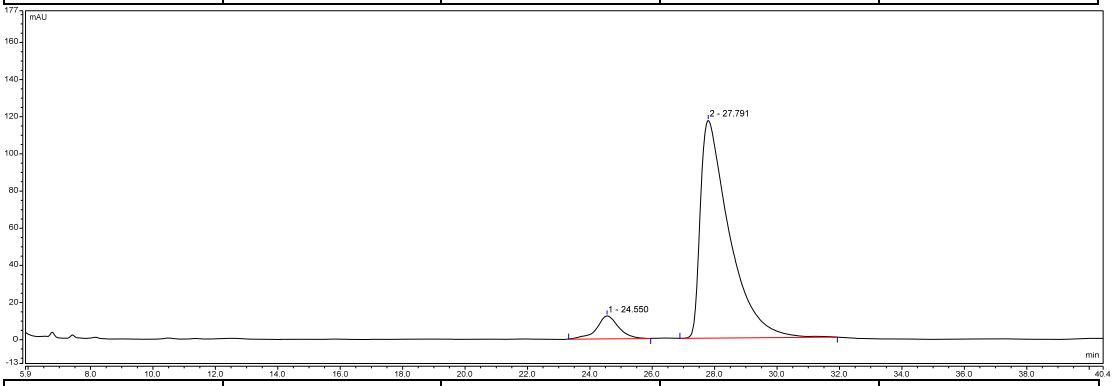
44

White solid; Mp 144.4−145.2 °C; 26.4 mg, 58% yield, 85% ee; $[\alpha]_D^{22}$ −41.0 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.64 (d, *J* = 4.7 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.91 (td, *J* = 7.8, 1.6 Hz, 1H), 7.66 (d, *J* = 7.9 Hz, 1H), 7.53 – 7.46 (m, 2H), 7.43 (t, *J* = 7.1 Hz, 1H), 7.34 (td, *J* = 7.7, 1.8 Hz, 1H), 7.24 – 7.13 (m, 2H), 7.13 – 7.05 (m, 2H), 3.46 (d, *J* = 17.0 Hz, 1H), 3.41 – 3.32 (m, 1H), 3.27 – 3.16 (m, 4H), 3.07 (d, *J* = 16.3 Hz, 1H), 3.02 (d, *J* = 15.8 Hz, 1H), 2.38 – 2.28 (m, 2H); **^{13}C NMR** (101 MHz, CD_3OD) δ 180.2, 178.4, 153.4, 150.2, 143.1, 142.6, 138.1, 134.2, 132.2, 130.8, 128.6, 127.5, 127.4, 126.7, 125.3, 125.3, 123.8, 121.5, 111.1, 59.0, 53.5, 42.6, 39.8, 36.2, 30.2; **HRMS** (ESI) 456.1070 m/z ($M + H^+$), calc. for $C_{26}H_{23}BrN_3^+$ 456.1070.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 85/15; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 25.8 min (minor) and 30.1 min (major).

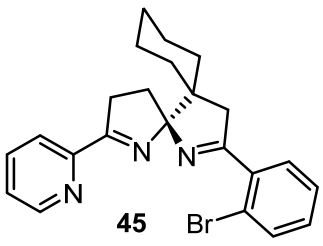


Entry	Retention Time	Area	Height	%Area
1	25.811	36.8749	45.77	50.13
2	30.076	36.6763	31.23	49.87



Entry	Retention Time	Area	Height	%Area
1	24.550	10.0530	12.34	7.40
2	27.791	125.8880	117.19	92.60

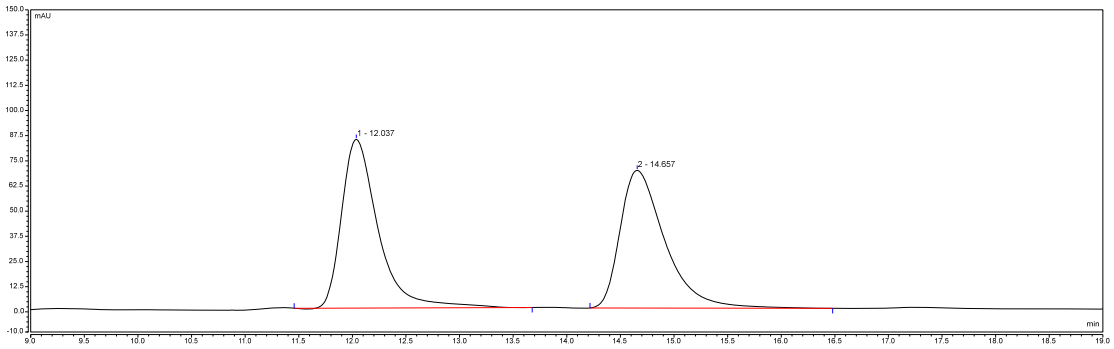
(*R*)-13-(2-bromophenyl)-2-(pyridin-2-yl)-1,14-diazadispiro[4.0.5^6.3^5]tetradeca-1,13-diene (45)



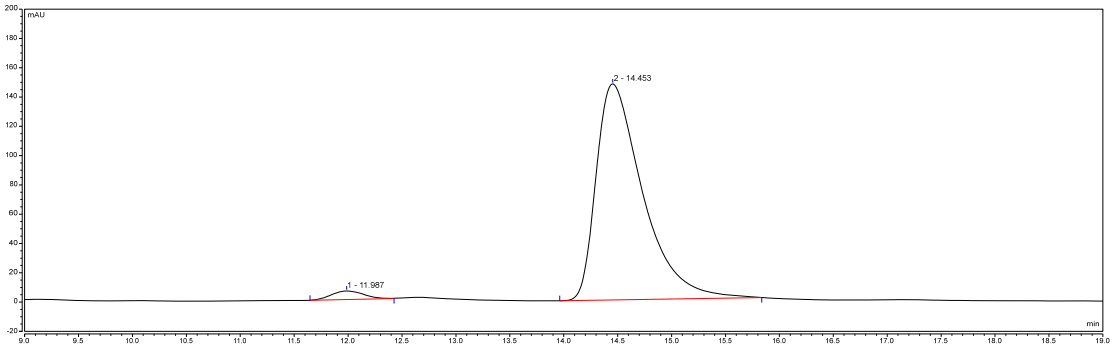
45

White solid; Mp 120.8−121.6 °C; 32.9 mg, 78% yield, 94% ee; $[\alpha]_D^{22}$ −36.0 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.64 (m, 1H), 8.14 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.90 (td, *J* = 7.8, 1.7 Hz, 1H), 7.69 – 7.62 (m, 1H), 7.48 (m, 1H), 7.44 – 7.40 (m, 2H), 7.33 (m, 1H), 3.35 (d, *J* = 17.1 Hz, 1H), 3.30 (m, 2H), 3.19 (dd, *J* = 17.1, 1.1 Hz, 1H), 2.31 (m, 1H), 2.21 (m, 1H), 1.75 – 1.70 (m, 3H), 1.58 – 1.19 (m, 7H); **^{13}C NMR** (151 MHz, CD_3OD) δ 180.2, 177.6, 153.6, 150.2, 138.4, 138.1, 134.2, 132.1, 130.8, 128.6 , 126.6, 123.6, 121.4, 112.5, 50.7, 35.8, 31.8, 31.5, 30.7, 28.7, 27.2, 25.0, 23.7; **HRMS** (ESI) 422.1222 m/z (M + H^+), calc. for $C_{23}H_{25}BrN_3^+$ 422.1226.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 12.0 min (minor) and 14.7 min (major).

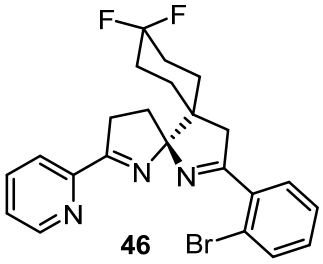


Entry	Retention Time	Area	Height	%Area
1	12.037	33.0808	83.71	50.04
2	14.657	33.0324	68.30	49.96



Entry	Retention Time	Area	Height	%Area
1	11.987	1.9936	5.78	2.64
2	14.453	73.6515	147.46	97.36

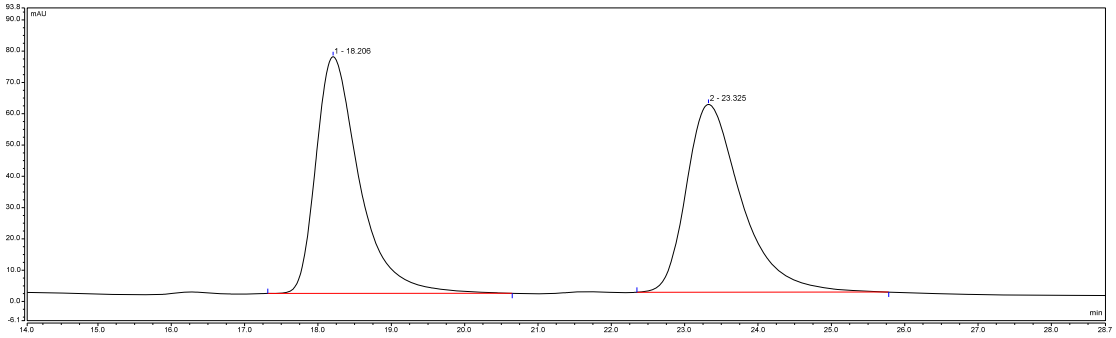
(*R*)-13-(2-bromophenyl)-9,9-difluoro-2-(pyridin-2-yl)-1,14-diazadispiro[4.0.5^6.3^5]tetradeca-1,13-diene (46)



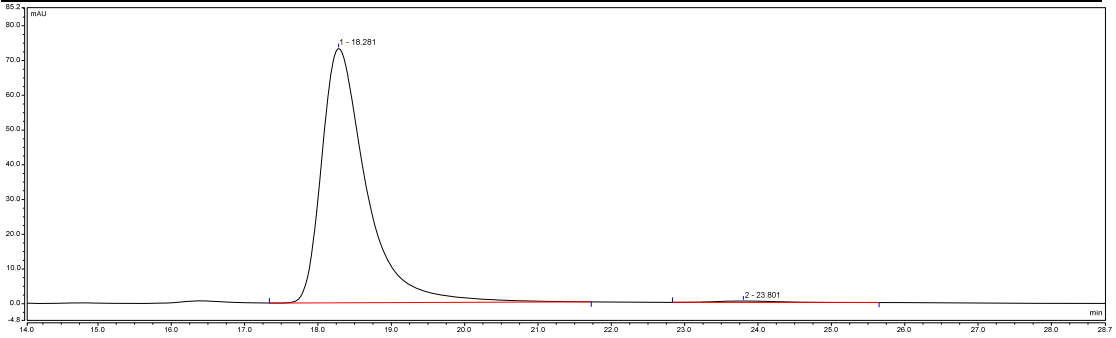
White solid; Mp 131.8−132.6 °C; 20.6 mg, 45% yield, 99% ee; $[\alpha]_D^{22}$ −34.1 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.65 (m, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.72 (td, *J* = 7.7, 1.8 Hz, 1H), 7.58 (dd, *J* = 8.0, 1.0 Hz, 1H), 7.47 (dd, *J* = 7.6, 1.7 Hz, 1H), 7.35 – 7.28 (m, 2H), 7.25 – 7.18 (m, 1H), 3.37 – 3.29 (m, 3H), 3.21 (dd, *J* = 16.5, 1.0 Hz, 1H), 2.32 (m, 1H), 2.15 – 2.11 (m, 2H), 2.09 – 2.04 (m, 1H), 1.92 (m, 1H), 1.79 (m, 2H), 1.71 (m, 2H), 1.57 (td, *J* = 13.8, 3.7 Hz, 1H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 176.4, 175.9 153.3, 149.3, 137.5, 136.3, 133.3, 130.9, 130.6, 127.6, 125.0, 123.5 (dd, *J* = 242.5, 239.4 Hz), 122.7, 121.2), 110.8, 48.6, 46.5, 35.1, 32.3 (dd, *J* = 25.5, 22.4 Hz), 30.9 (dd, *J* = 25.1, 23.3 Hz), 28.5, 27.29 (d, *J* = 9.6 Hz); **^{19}F NMR** (565 MHz, CD_3OD) δ -92.21 (d, *J* =

236.3 Hz), -104.90 (d, J = 236.6 Hz); **HRMS** (ESI) 458.1038 m/z (M + H^+), calc. for $C_{23}H_{23}BrF_2N_3^+$ 458.1038.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 90/10; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 18.2 min (major) and 23.3 min (minor).

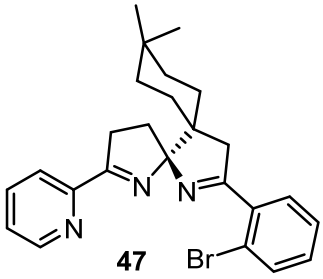


Entry	Retention Time	Area	Height	%Area
1	18.206	51.9119	75.66	49.79
2	23.325	52.3536	60.01	50.21



Entry	Retention Time	Area	Height	%Area
1	18.281	51.5021	73.17	99.36
2	23.801	0.3298	0.38	0.64

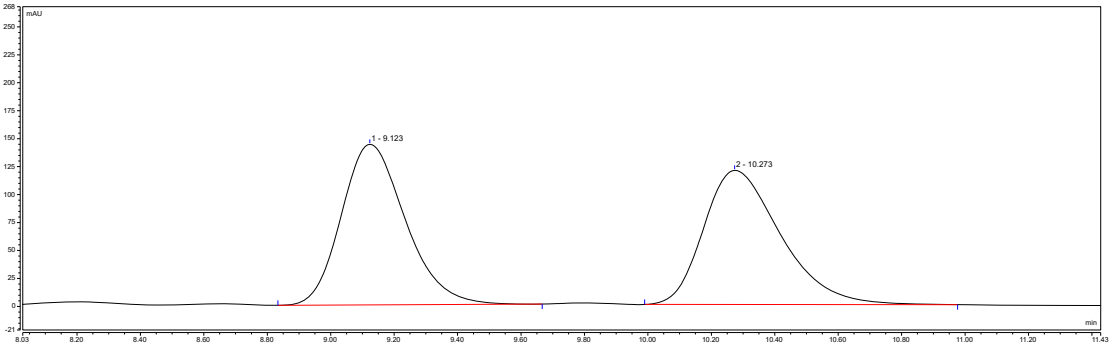
(*R*)-13-(2-bromophenyl)-9,9-dimethyl-2-(pyridin-2-yl)-1,14-diazadispiro[4.0.5^6.3^5]-tetradeca-1,13-diene (47)



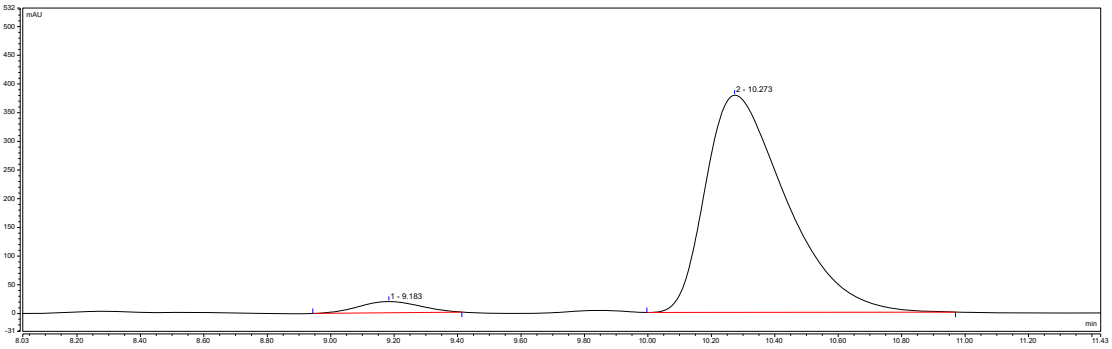
47

White solid; Mp 113.3−114.1 °C; 31.9 mg, 71% yield, 92% ee; $[\alpha]_D^{22}$ −32.9 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, CD_3OD) δ 8.69 – 8.59 (m, 1H), 8.15 (d, J = 7.9 Hz, 1H), 7.91 (t, J = 7.7 Hz, 1H), 7.67 (d, J = 8.0 Hz, 1H), 7.51 – 7.47 (m, 1H), 7.44 – 7.39 (m, 2H), 7.34 (m, 1H), 3.37 – 3.33 (m, 1H), 3.33 – 3.29 (m, 2H), 3.17 (t, J = 16.9 Hz, 1H), 2.36 – 2.29 (m, 1H), 2.28 – 2.20 (m, 1H), 1.80 – 1.72 (m, 1H), 1.67 – 1.62 (m, 1H), 1.59 – 1.54 (m, 1H), 1.54 – 1.47 (m, 2H), 1.43 – 1.37 (m, 2H), 1.34 – 1.29 (m, 1H),

0.95 (s, 3H), 0.94 (s, 3H). **^{13}C NMR** (151 MHz, CD_3OD) δ 180.2, 177.6, 153.6, 150.2, 138.3, 138.1, 134.2, 132.1, 130.8, 128.6, 126.6, 123.6, 121.3, 112.5, 50.5, 37.8, 36.5, 35.9, 33.2, 30.6, 28.9, 27.6, 27.3, 24.0. **HRMS** (ESI) 450.1539 m/z ($M + H^+$), calc. for $C_{25}H_{29}BrN_3^+$ 450.1539. The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.1 min (minor) and 10.3 min (major).

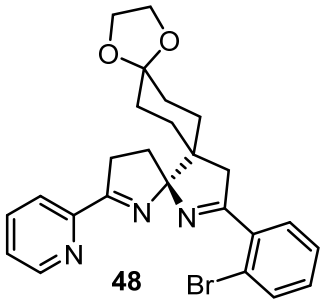


Entry	Retention Time	Area	Height	%Area
1	9.123	33.5631	143.61	49.89
2	10.273	33.7144	119.91	50.11



Entry	Retention Time	Area	Height	%Area
1	9.183	4.3674	19.66	3.77
2	10.273	111.5968	378.55	96.23

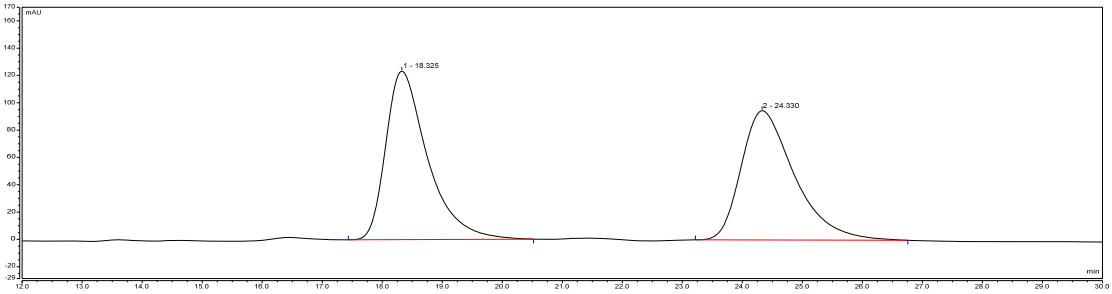
(*R*)-17-(2-bromophenyl)-2-(pyridin-2-yl)-10,13-dioxa-1,18-diazatrispiro[4.0.2.4^9.2^6.3^5]-octadeca-1,17-diene (48)



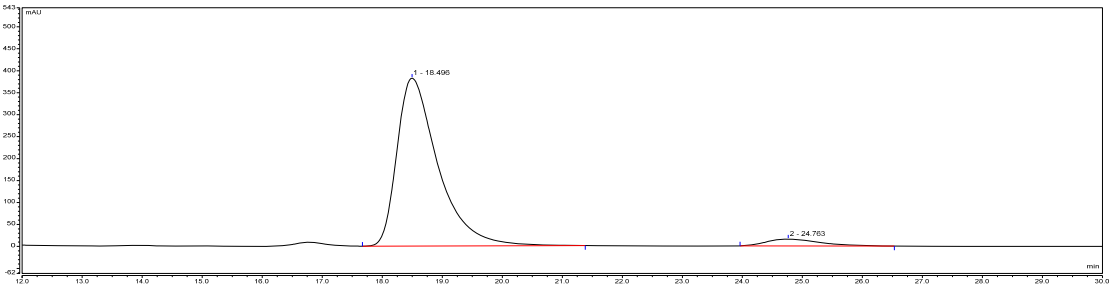
48

White solid; Mp 79.4−80.3 °C; 20.6 mg, 43% yield, 90% ee; $[\alpha]_D^{22}$ +36.7 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.69 – 8.60 (m, 1H), 8.20 – 8.10 (m, 1H), 7.91 (td, *J* = 7.8, 1.6 Hz, 1H), 7.67 (d, *J* = 7.8 Hz, 1H), 7.53 – 7.46 (m, 1H), 7.46 – 7.38 (m, 2H), 7.35 (m, 1H), 3.93 (s, 4H), 3.39 (d, *J* = 17.1 Hz, 1H), 3.32 – 3.28 (m, 2H), 3.23 (d, *J* = 17.1 Hz, 1H), 2.36 – 2.19 (m, 2H), 1.95 (d, *J* = 9.9 Hz, 1H), 1.76 (m, 5H), 1.64 – 1.58 (m, 2H). **^{13}C NMR** (101 MHz, CD_3OD) δ 180.0, 177.7, 153.5, 150.2, 138.2, 138.0, 134.2, 132.2, 130.8, 128.6, 126.6, 123.7, 121.4, 112.1, 109.4, 65.1, 65.1, 35.9, 33.7, 32.4, 29.2, 28.8; **HRMS** (ESI) 480.1281 m/z (M + H^+), calc. for $C_{25}H_{27}BrN_3O_2^+$ 480.1281.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 18.3 min (major) and 24.3 min (minor).

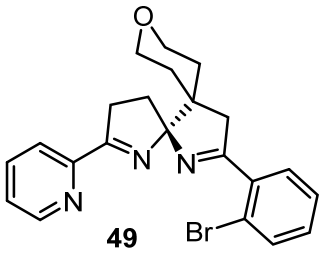


Entry	Retention Time	Area	Height	%Area
1	18.325	99.5481	123.27	50.58
2	24.330	97.2757	94.66	49.42



Entry	Retention Time	Area	Height	%Area
1	18.496	302.8833	382.19	95.04
2	24.763	15.7916	15.72	4.96

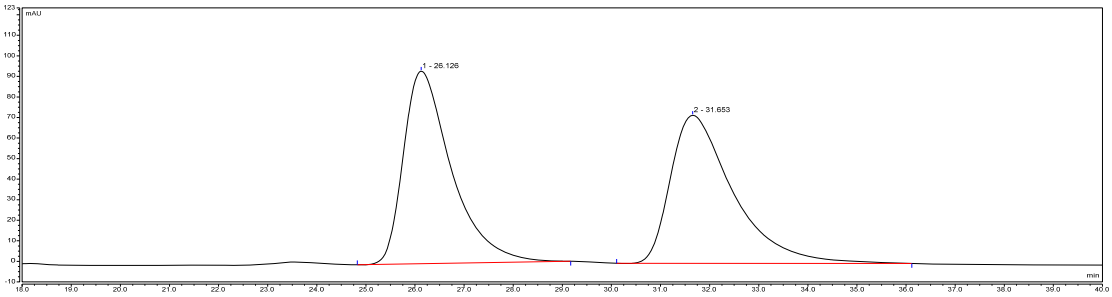
(*R*)-13-(2-bromophenyl)-2-(pyridin-2-yl)-9-oxa-1,14-diazadispiro[4.0.5^6.3^5]tetradeca-1,13-diene (49)



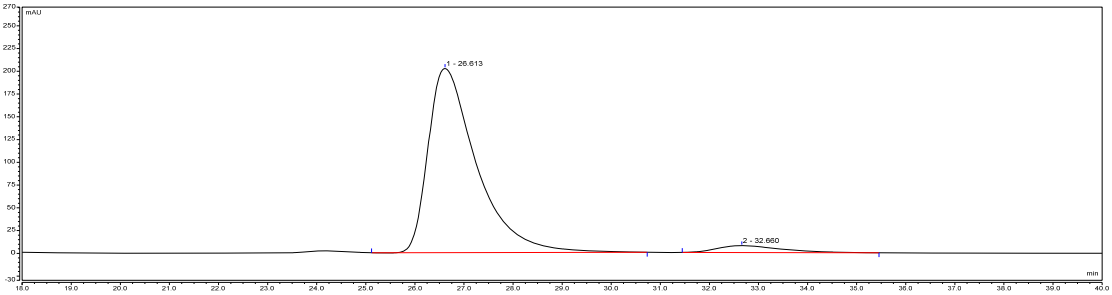
49

White solid; Mp 91.6−92.5 °C; 22.0 mg, 52% yield, 90% ee; $[\alpha]_D^{22}$ −25.0 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.65 (m, 1H), 8.15 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.90 (td, *J* = 7.8, 1.7 Hz, 1H), 7.67 (dd, *J* = 8.0, 0.7 Hz, 1H), 7.49 (m, 1H), 7.47 – 7.39 (m, 2H), 7.35 (m, 1H), 3.92 (m, 2H), 3.73 – 3.63 (m, 1H), 3.58 – 3.45 (m, 2H), 3.36 – 3.30 (m, 3H), 2.34 (m, 1H), 2.29 – 2.18 (m, 1H), 1.82 – 1.75 (m, 2H), 1.72 – 1.56 (m, 2H); **^{13}C NMR** (151 MHz, CD_3OD) δ 179.7, 178.2, 153.4, 150.2, 138.1, 134.2, 132.2, 130.8, 128.6, 126.7, 125.9, 123.7, 121.4, 112.2, 66.8, 65.5, 47.8, 35.9, 32.2, 31.9, 30.7, 28.9; **HRMS** (ESI) 424.1019 m/z (M +H^+), calc. for $C_{22}H_{23}BrN_3O^+$ 424.1019.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 26.1 min (major) and 31.6 min (minor).

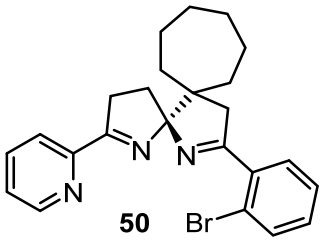


Entry	Retention Time	Area	Height	%Area
1	26.126	106.0119	93.66	49.88
2	31.653	106.5155	72.02	50.12



Entry	Retention Time	Area	Height	%Area
1	26.613	231.0167	202.37	95.23
2	32.660	11.5803	7.64	4.77

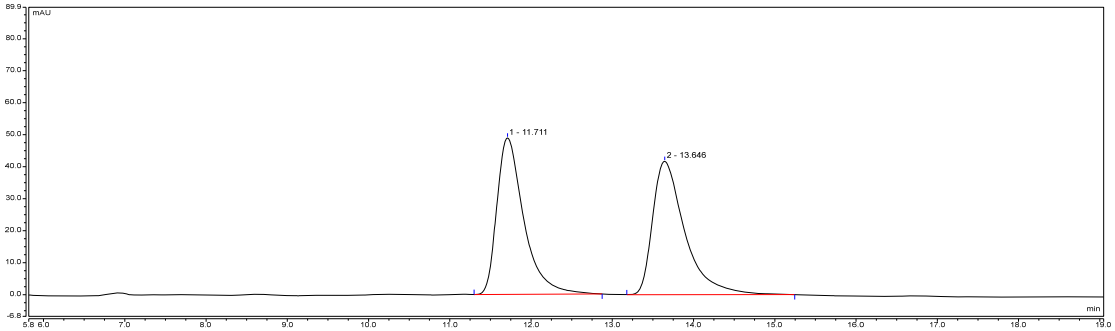
(*R*)-14-(2-bromophenyl)-2-(pyridin-2-yl)-1,15-diazadispiro[4.0.6^6.3^5]pentadeca-1,14-diene (50)



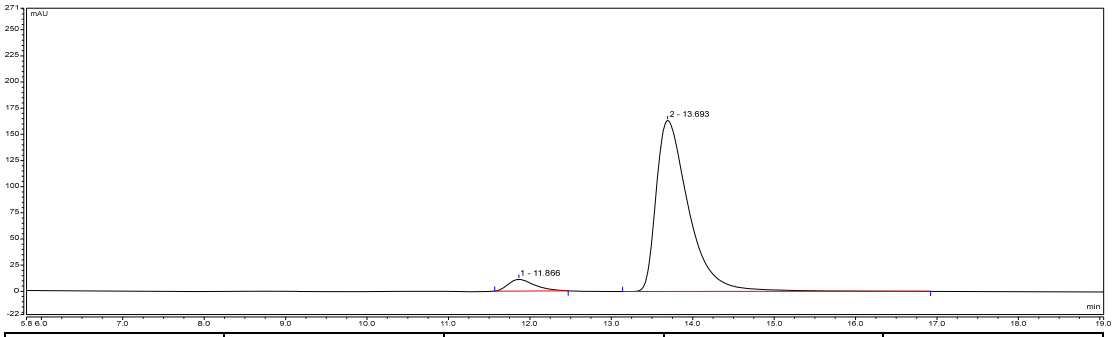
50

White solid; Mp 91.2−92.1 °C; 29.6 mg, 68% yield, 90% ee; $[\alpha]_D^{22}$ −34.8 (*c* 1.0, CH_3OH); **^{1}H NMR** (400 MHz, CD_3OD) δ 8.64 (d, *J* = 4.8 Hz, 1H), 8.16 (d, *J* = 7.9 Hz, 1H), 7.90 (t, *J* = 7.8 Hz, 1H), 7.65 (d, *J* = 7.9 Hz, 1H), 7.52 – 7.45 (m, 1H), 7.43 – 7.38 (m, 2H), 7.36 – 7.29 (m, 1H), 3.28 (dd, *J* = 8.2, 4.2 Hz, 2H), 3.23 (d, *J* = 8.8 Hz, 2H), 2.36 – 2.28 (m, 2H), 1.96 (dd, *J* = 14.0, 7.5 Hz, 1H), 1.83 (dd, *J* = 14.3, 6.5 Hz, 1H), 1.65 (m, 10H); **^{13}C NMR** (101 MHz, CD_3OD) δ 180.1, 177.3, 153.6, 150.2, 138.4, 138.1, 134.2, 132.1, 130.8, 128.5, 126.6, 123.7, 121.3, 113.1, 53.7, 51.6, 36.1, 35.9, 34.1, 30.2, 29.9, 29.4, 25.7, 24.7; **HRMS** (ESI) 436.1383 m/z ($M + H^+$), calc. for $C_{24}H_{27}BrN_3^+$ 436.1383.

The ee was determined by HPLC analysis: CHIRALPAK IE (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 11.7 min (minor) and 13.6 min (major).

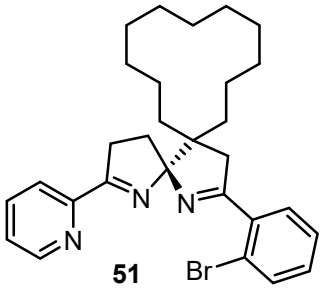


Entry	Retention Time	Area	Height	%Area
1	11.711	18.7634	48.88	49.46
2	13.646	19.1736	41.67	50.54



Entry	Retention Time	Area	Height	%Area
1	11.866	4.1697	11.15	5.25
2	13.693	75.2429	163.39	94.75

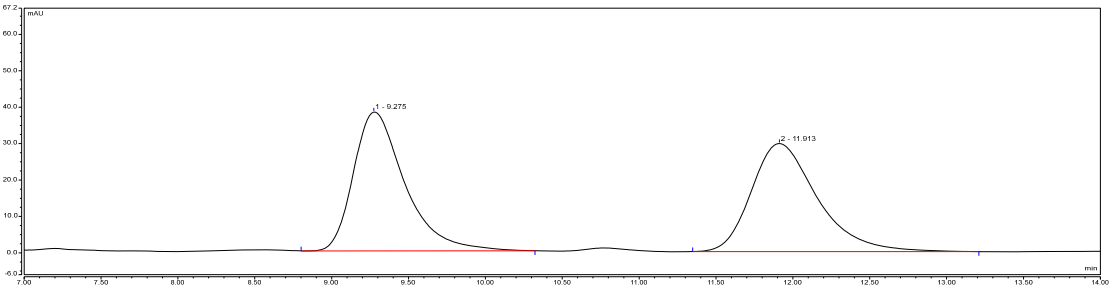
(*R*)-19-(2-bromophenyl)-2-(pyridin-2-yl)-1,20-diazadispiro[4.0.11^6.3^5]icosa-1,19-diene (51)



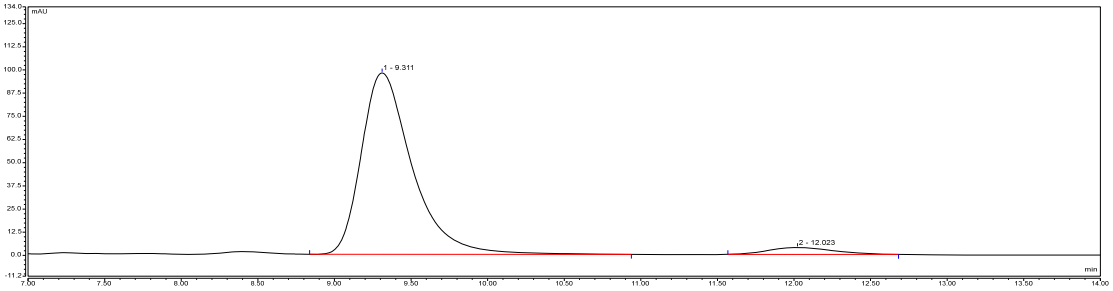
51

White solid; Mp 70.5−71.4 °C; 21.7 mg, 43% yield, 91% ee; $[\alpha]_D^{22}$ −21.6 (*c* 1.0, CH_3OH) ; **^{1}H NMR** (600 MHz, CD_3OD) δ 8.64 (d, *J* = 4.7 Hz, 1H), 8.15 (d, *J* = 7.9 Hz, 1H), 7.96 – 7.78 (m, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.53 – 7.43 (m, 1H), 7.43 – 7.34 (m, 2H), 7.34 – 7.23 (m, 1H), 3.36 – 3.28 (m, 2H), 3.21 (d, *J* = 17.3 Hz, 1H), 3.10 (d, *J* = 17.3 Hz, 1H), 2.32 (dd, *J* = 8.0, 4.3 Hz, 2H), 1.83 (dd, *J* = 11.3, 6.3 Hz, 2H), 1.54 – 1.21 (m, 20H); **^{13}C NMR** (151 MHz, CD_3OD) δ 179.5, 177.6, 153.6, 150.2, 138.2, 138.1, 134.1, 132.0, 130.7, 128.5, 126.6, 123.6, 121.3, 112.6, 52.4, 51.3, 35.4, 30.6, 30.3, 28.8, 27.9, 27.8, 27.0, 23.7, 23.6, 23.3, 22.8, 20.7, 20.4; **HRMS** (ESI) 506.2165 m/z ($M + H^+$), calc. for $C_{29}H_{37}BrN_3^+$ 506.2165.

The ee was determined by HPLC analysis: CHIRALPAK IC (4.6 mm i.d. x 250 mm); hexane/2-propanol = 80/20; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 9.3 min (major) and 11.9 min (minor).

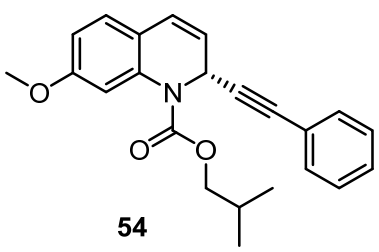


Entry	Retention Time	Area	Height	%Area
1	9.275	14.7538	38.13	50.01
2	11.913	14.7491	29.68	49.99



Entry	Retention Time	Area	Height	%Area
1	9.311	37.6599	97.87	95.38
2	12.023	1.8225	3.77	4.62

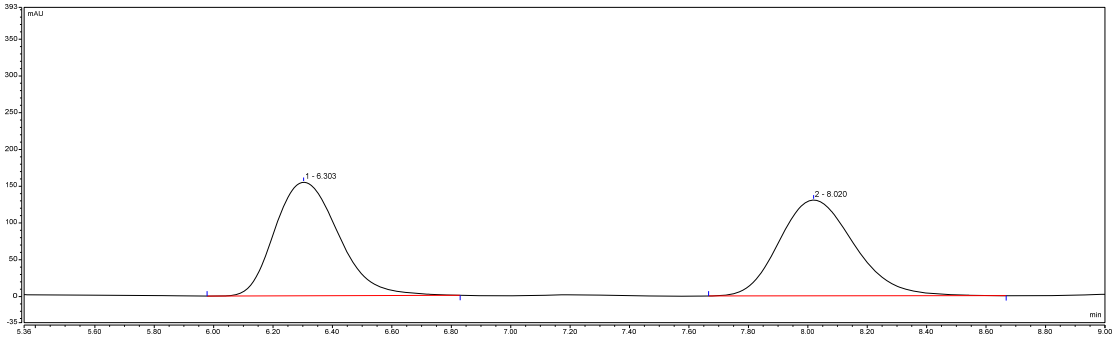
(*R*)-isobutyl-7-methoxy-2-(phenylethynyl)quinoline-1(2H)-carboxylate (54)



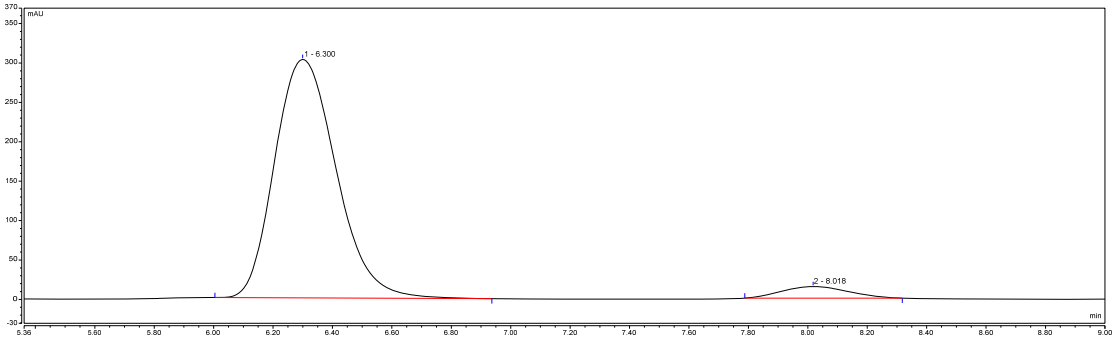
54

Colorless oil; 20.3 mg, 56% yield, 90% ee; $[\alpha]_D^{22}$ −38.8 (*c* 1.0, CH_3OH); **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.35 (s, 1H), 7.33 – 7.29 (m, 2H), 7.23 (m, 3H), 7.05 (d, *J* = 8.4 Hz, 1H), 6.67 (dd, *J* = 8.4, 2.5 Hz, 1H), 6.51 (d, *J* = 9.3 Hz, 1H), 6.08 (d, *J* = 5.5 Hz, 1H), 5.95 (dd, *J* = 9.1, 6.3 Hz, 1H), 4.12 – 3.98 (m, 2H), 3.82 (s, 3H), 2.08 – 1.99 (m, 1H), 1.00 (s, 3H), 0.99 (s, 3H); **^{13}C NMR** (151 MHz, $CDCl_3$) δ 159.4, 135.7, 132.0, 128.41, 128.2, 127.5, 125.7, 122.7), 119.9, 110.6, 86.2, 83.2, 77.3, 77.1, 76.9, 72.8, 55.5, 44.8, 28.0, 19.3; **HRMS** (ESI) 362.1750 m/z (M + H^+), calc. for $C_{23}H_{24}NO_3^+$ 362.1751.

The ee was determined by HPLC analysis: CHIRALPAK ODH (4.6 mm i.d. x 250 mm); hexane/2-propanol = 90/10; flow rate 1.0 mL/min; 25 °C; 254 nm; retention time: 6.3 min (major) and 8.0 min (minor).

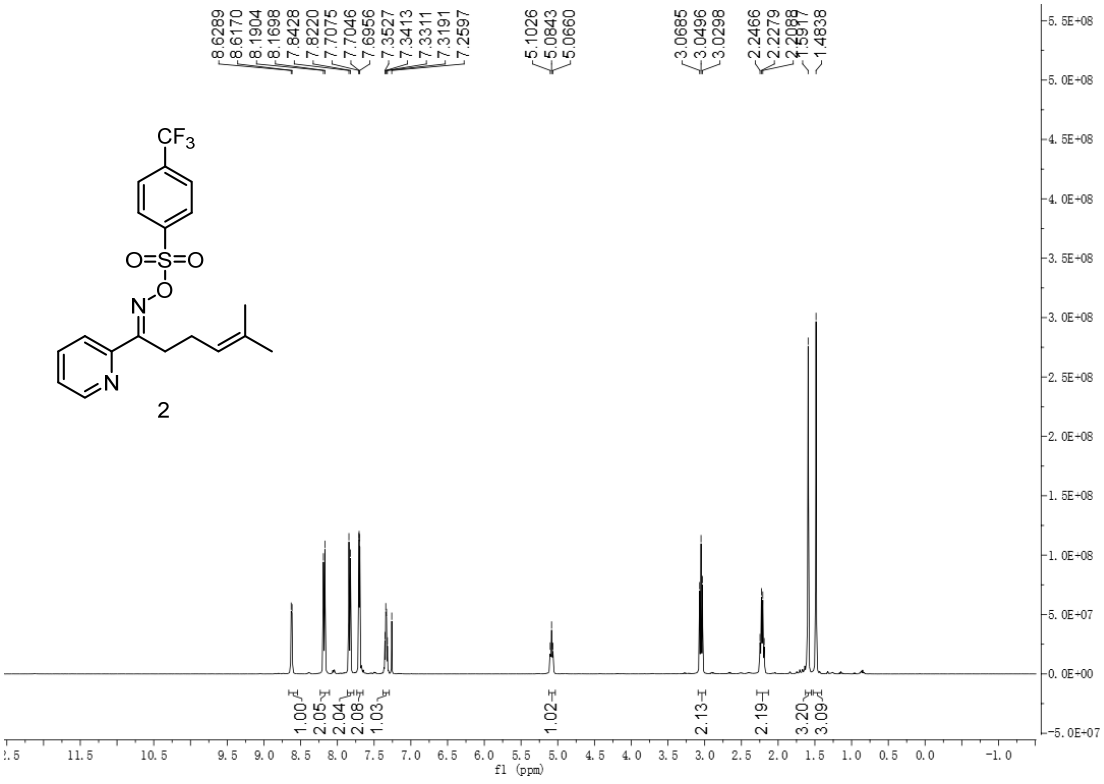


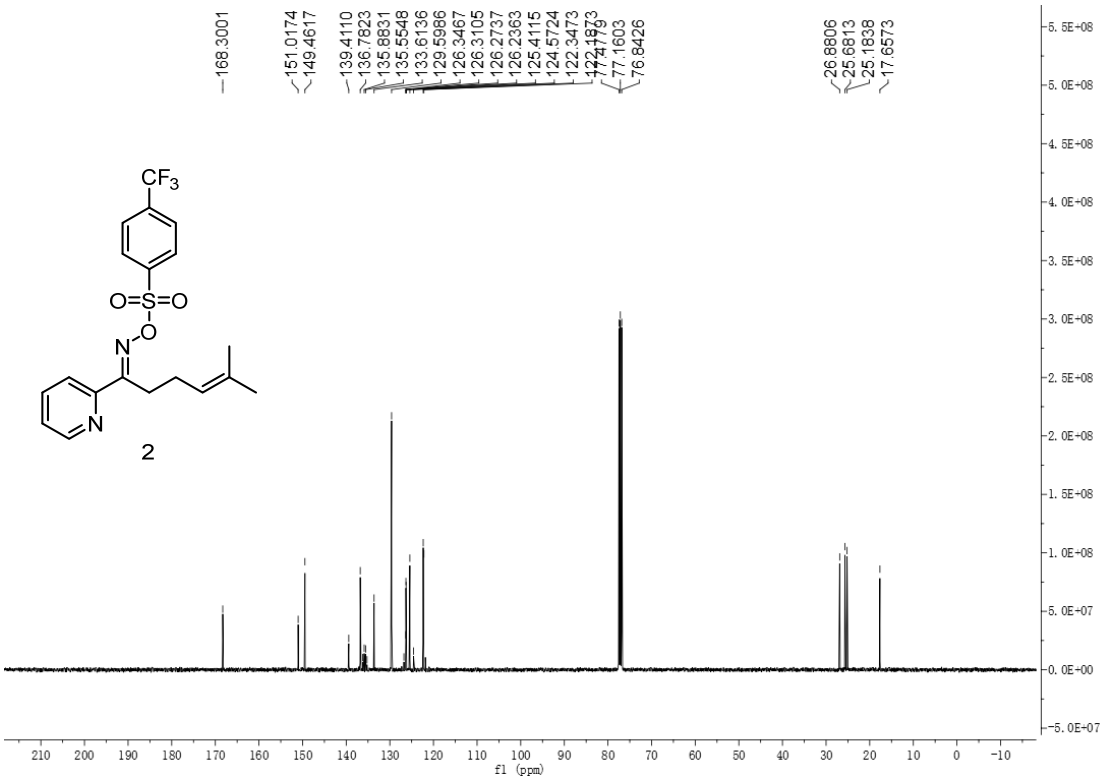
Entry	Retention Time	Area	Height	%Area
1	6.303	38.3051	154.30	50.12
2	8.020	38.1287	130.31	49.88

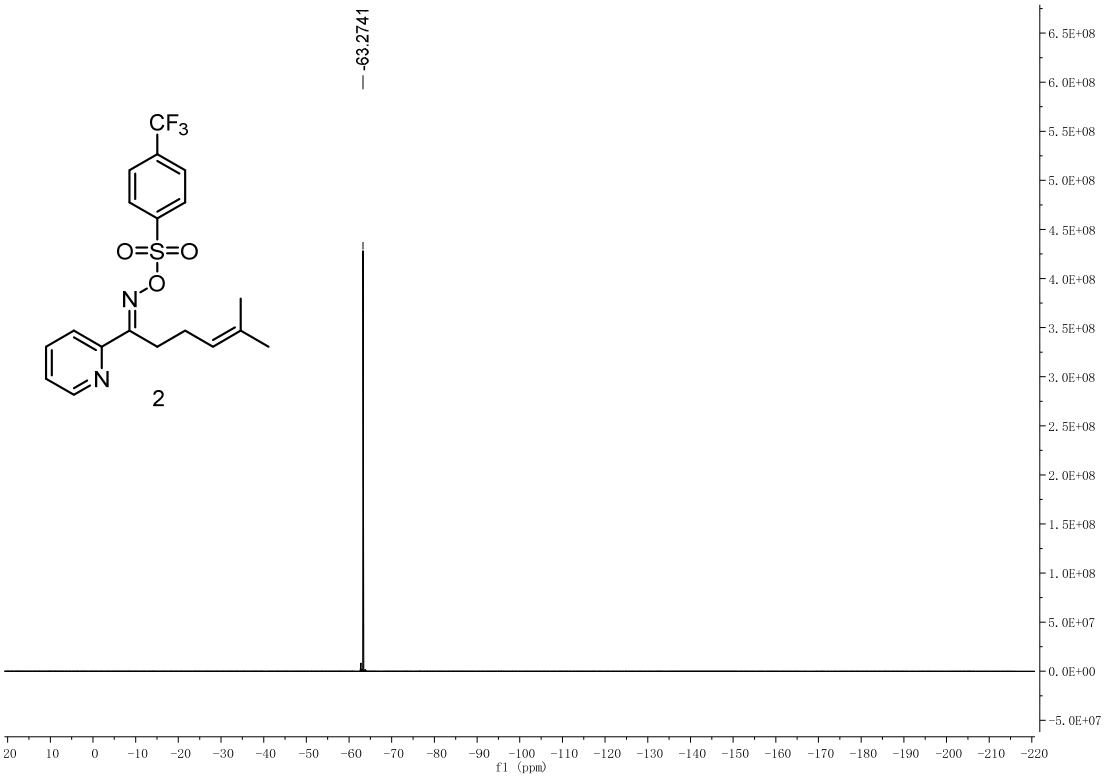


Entry	Retention Time	Area	Height	%Area
1	6.300	72.5252	302.57	95.02
2	8.018	3.8014	14.68	4.98

8. Copies of NMR spectra



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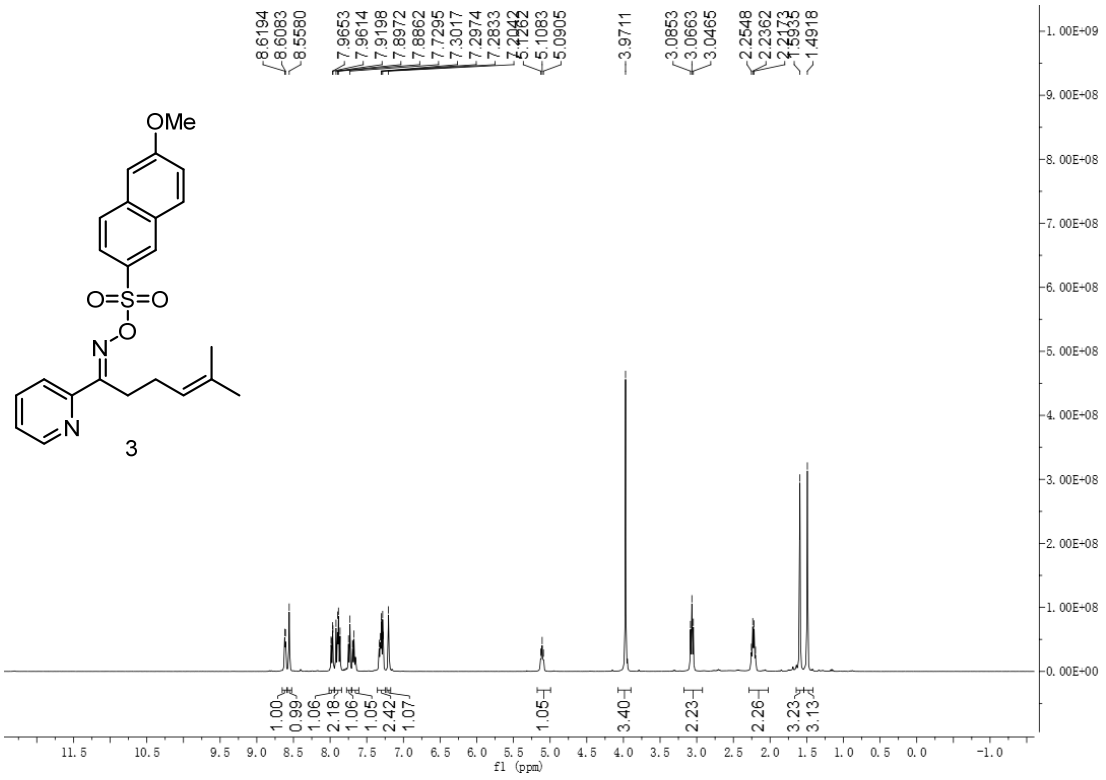
N
O
2
f1 (ppm)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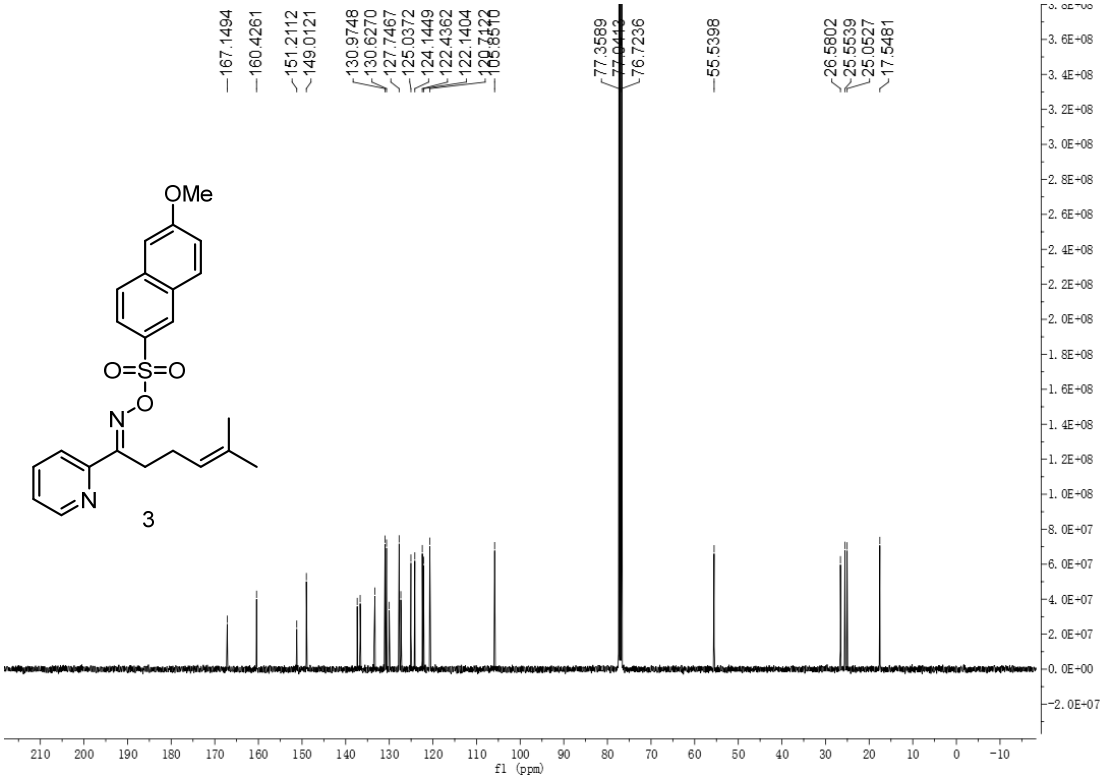
7.9614
7.9198
7.8972
7.8862
7.7295
7.3017
7.2974
7.2833
5.1262
5.1083
5.0905
3.9711
3.0853
3.0663
3.0465
2.2548
2.2362
1.4918
OMe
O=S=O
N
O
3
1.00
0.99
1.06
2.18
1.06
1.05
2.42
1.07
1.05
3.40
2.23
2.26
3.23
3.13
f1 (ppm)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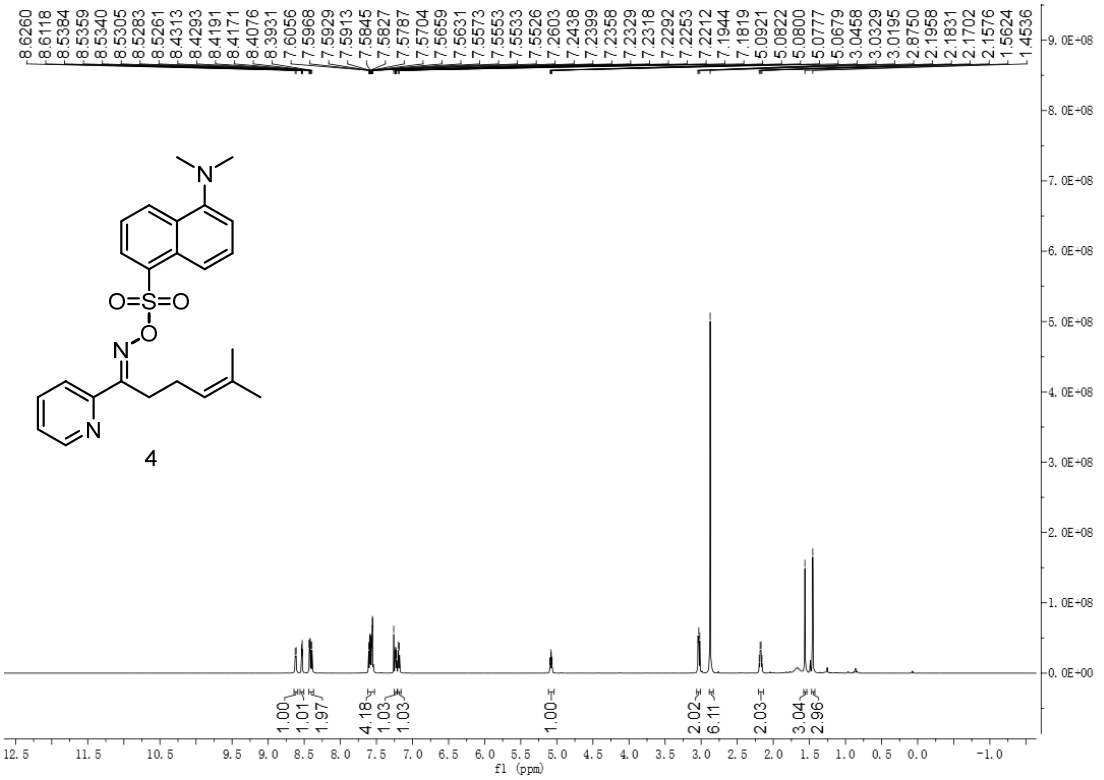
160.4261
151.2112
149.0121
130.9748
130.6270
127.7467
125.0372
124.1449
122.4362
122.1404
105.8510
77.3589
77.0413
76.7236
55.5398
26.5802
25.5539
25.0527
17.5481
OMe
O=S=O
N
O
N
3
f1 (ppm)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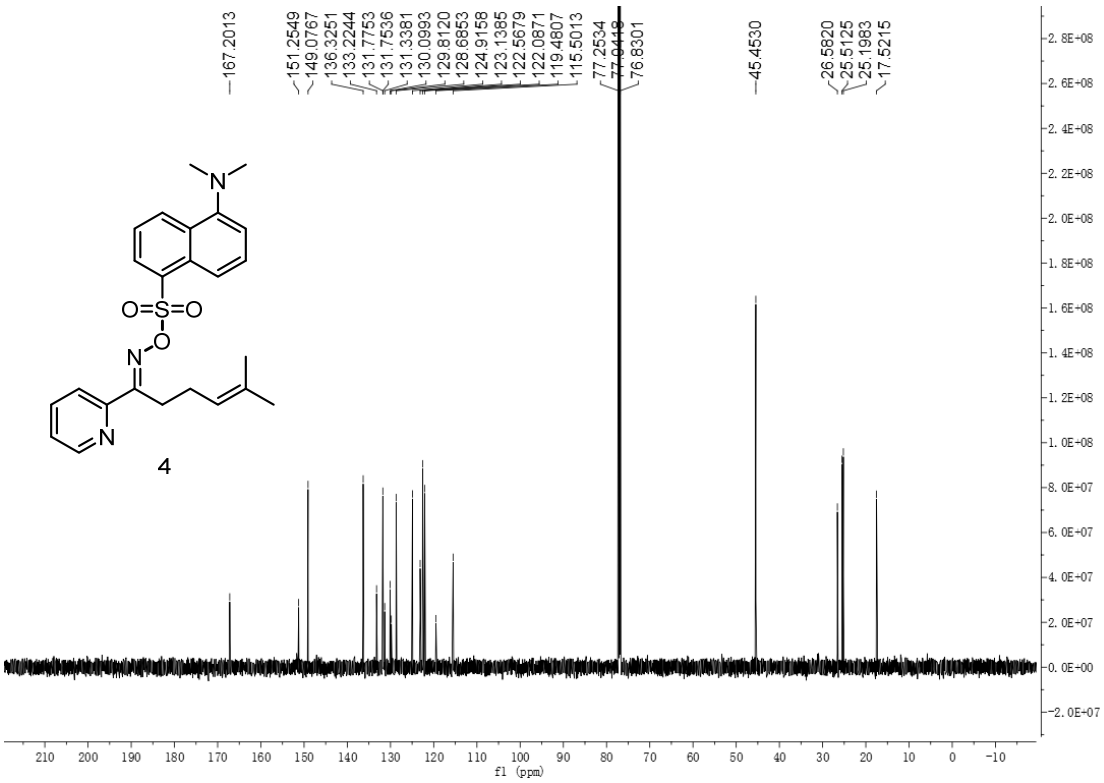
8.6118
8.5384
8.5359
8.5340
8.5305
8.5283
8.5261
8.4313
8.4293
8.4191
8.4171
8.4076
8.3931
7.6056
7.5968
7.5929
7.5913
7.5845
7.5827
7.5787
7.5704
7.5659
7.5631
7.5573
7.5553
7.5533
7.5526
7.2603
7.2438
7.2399
7.2358
7.2329
7.2318
7.2292
7.2253
7.2212
7.1944
7.1819
5.0921
5.0822
5.0800
5.0777
5.0679
3.0458
3.0329
3.0195
2.8750
2.1958
2.1831
2.1702
2.1576
1.5624
1.4536
O=S=O
N
O
N
4
1.00
1.01
1.97
4.18
1.03
1.03
1.00
2.02
6.11
2.03
3.04
2.96
f1 (ppm)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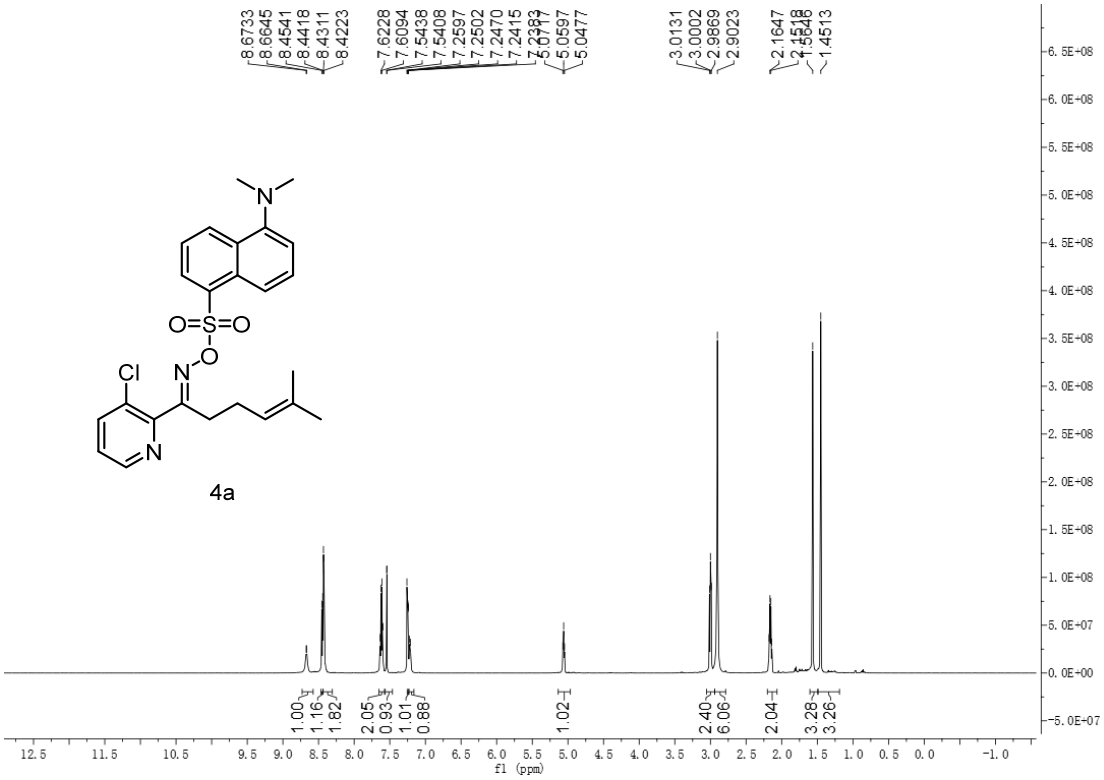
149.0767
136.3251
133.2244
131.7753
131.7536
131.3381
130.0993
129.8120
128.6853
124.9158
123.1385
122.5679
122.0871
119.4807
115.5013
77.2534
77.0448
76.8301
45.4530
26.5820
25.5125
25.1983
17.5215
O=S=O
N
O
N
4
f1 (ppm)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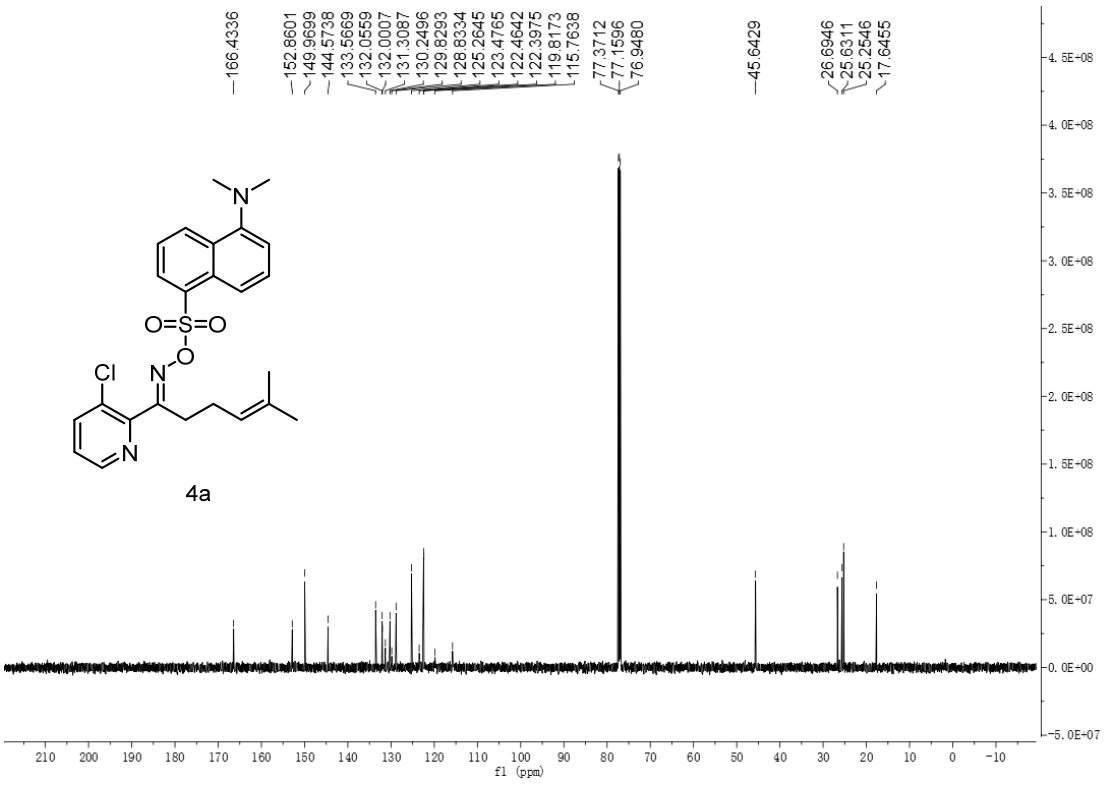
8.6645
8.4541
8.4418
8.4311
8.4223
7.6228
7.6094
7.5438
7.5408
7.2597
7.2502
7.2470
7.2415
5.0597
5.0477
3.0131
3.0002
2.9869
2.9023
2.1647
1.4513
4a
1.00
1.16
1.82
2.05
0.93
1.01
0.88
1.02
2.40
6.06
2.04
3.28
3.26
f1 (ppm)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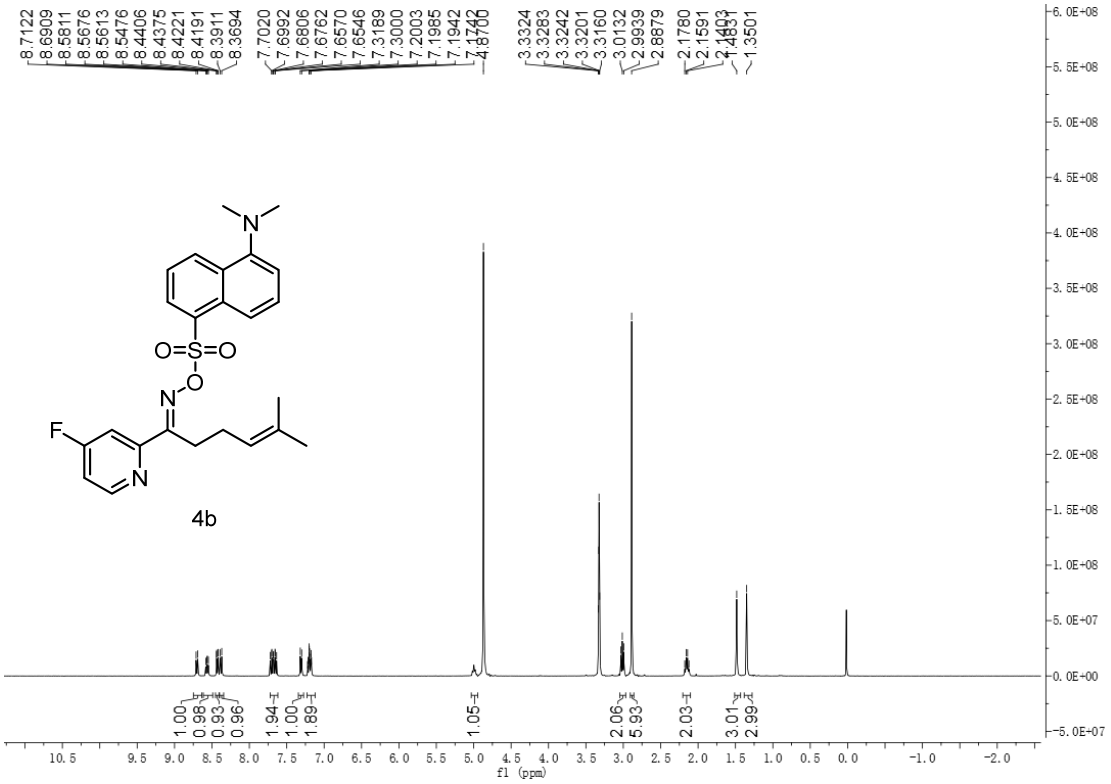
149.9699
144.5738
133.5669
132.0559
132.0007
131.3087
130.2496
129.8293
128.8334
125.2645
123.4765
122.4642
122.3975
119.8173
115.7638
77.3712
77.1596
76.9480
45.6429
26.6946
25.6311
25.2546
17.6455
4a
f1 (ppm)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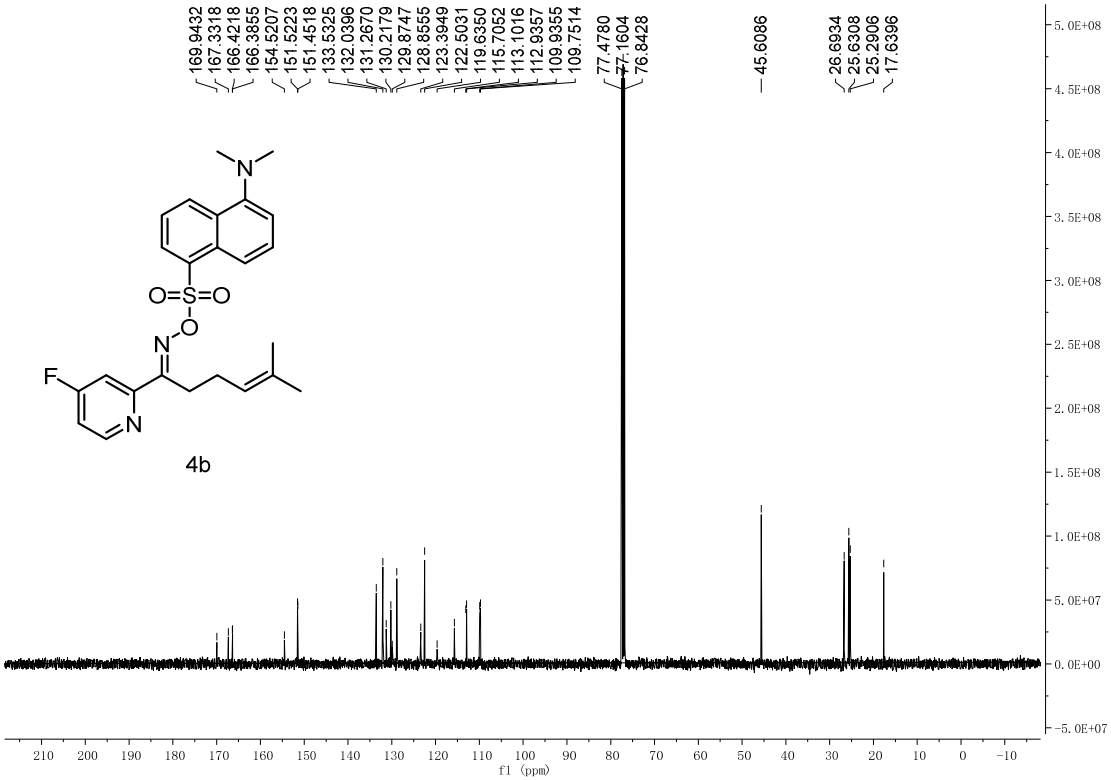
8.4221
8.4191
8.3911
8.3694
7.7020
7.6992
7.6806
7.6762
7.6570
7.6546
7.3189
7.3000
7.2003
7.1985
7.1942
7.1742
7.1700
3.3324
3.3283
3.3242
3.3201
3.3160
3.0132
2.9939
2.8879
2.1780
2.1591
2.1403
1.4831
1.3501
4b
1.00
0.98
0.93
0.96
1.94
1.00
1.89
1.05
2.06
5.93
2.03
3.01
2.99
f1 (ppm)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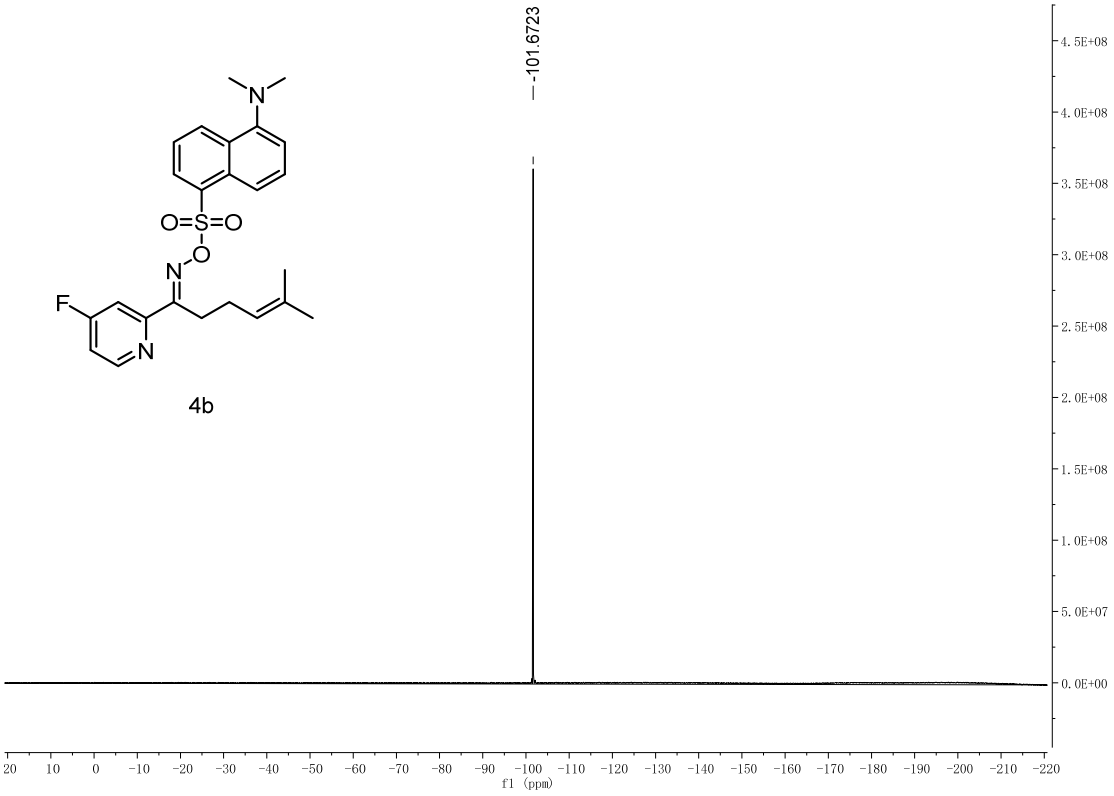
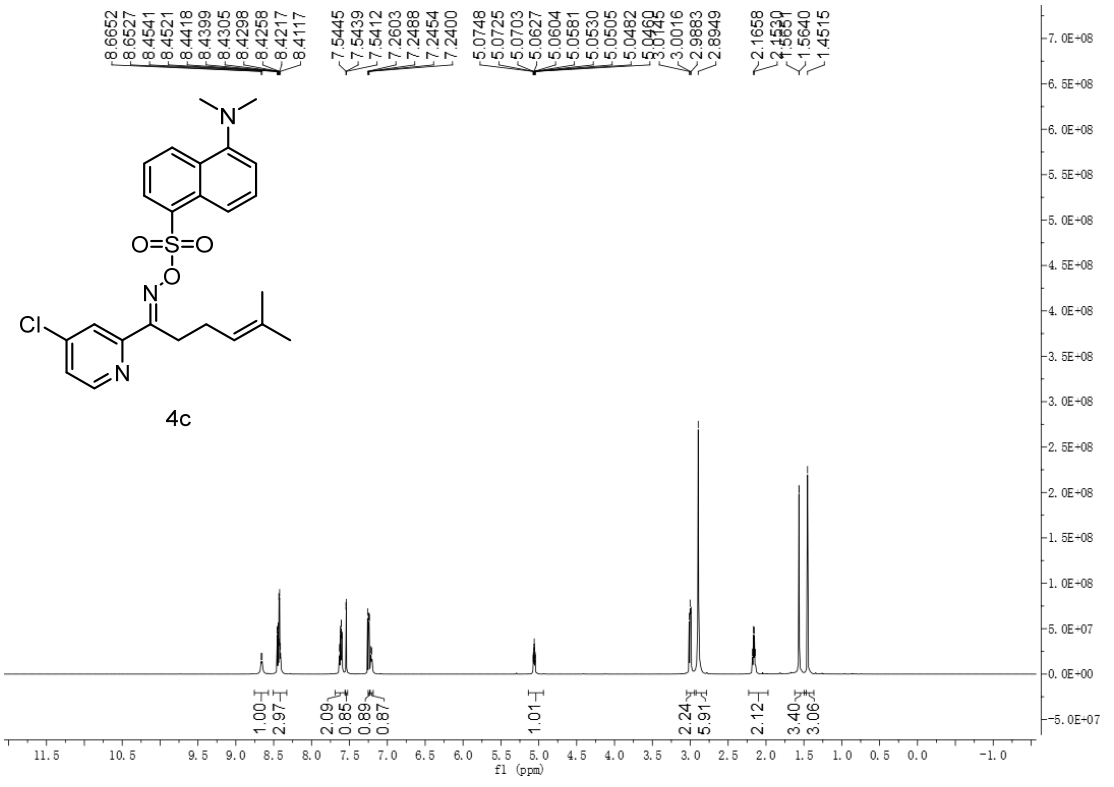
167.3318
166.4218
166.3855
154.5207
151.5223
151.4518
133.5325
132.0396
131.2670
130.2179
129.8747
128.8555
123.3949
122.5031
119.6350
115.7052
113.1016
112.9357
109.9355
109.7514
77.4780
77.1604
76.8428
45.6086
26.6934
25.6308
25.2906
17.6396
4b
f1 (ppm)


-101.6723
f1 (ppm)

4b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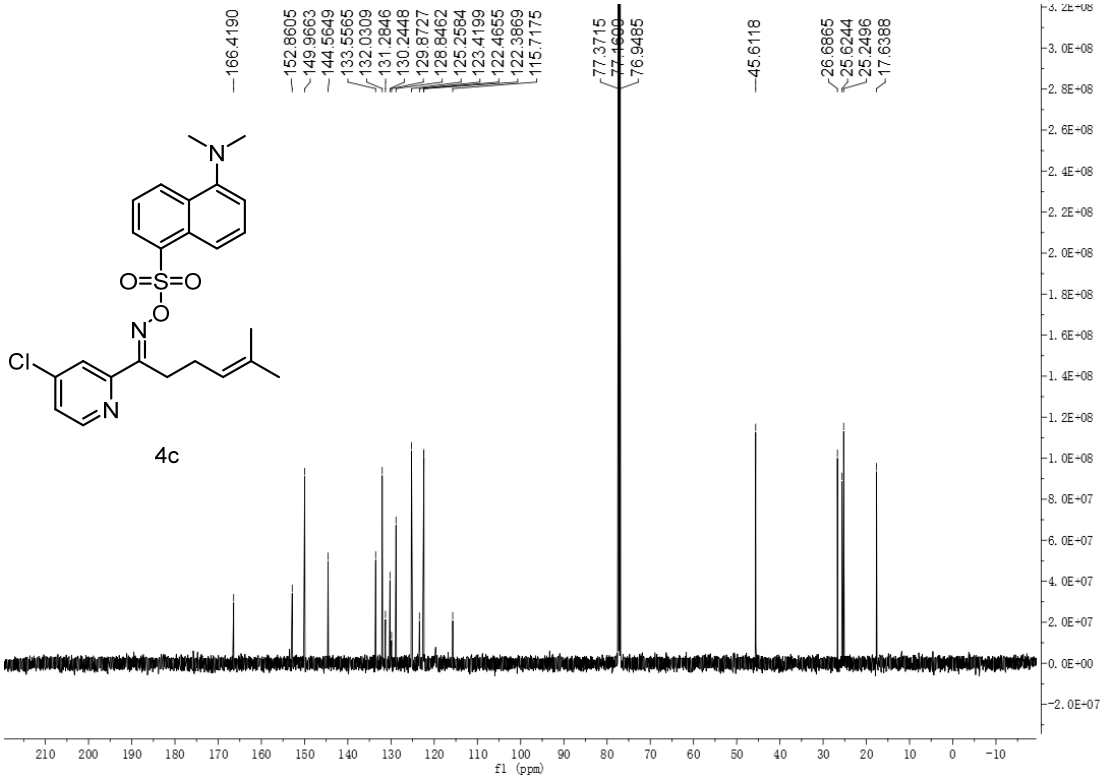
8.4258
8.4217
8.4117
7.5445
7.5439
7.5412
7.2603
7.2488
7.2454
7.2400
5.0748
5.0725
5.0703
5.0627
5.0604
5.0581
5.0530
5.0505
5.0482
3.0016
2.9883
2.8949
2.1658
1.5640
1.4515
1.00
2.97
2.09
0.85
0.89
0.87
1.01
2.24
5.91
2.12
3.40
3.06
f1 (ppm)

4c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133.5565
132.0309
131.2846
130.2448
129.8727
128.8462
125.2584
123.4199
122.4655
122.3869
115.7175
77.3715
77.1600
76.9485
45.6118
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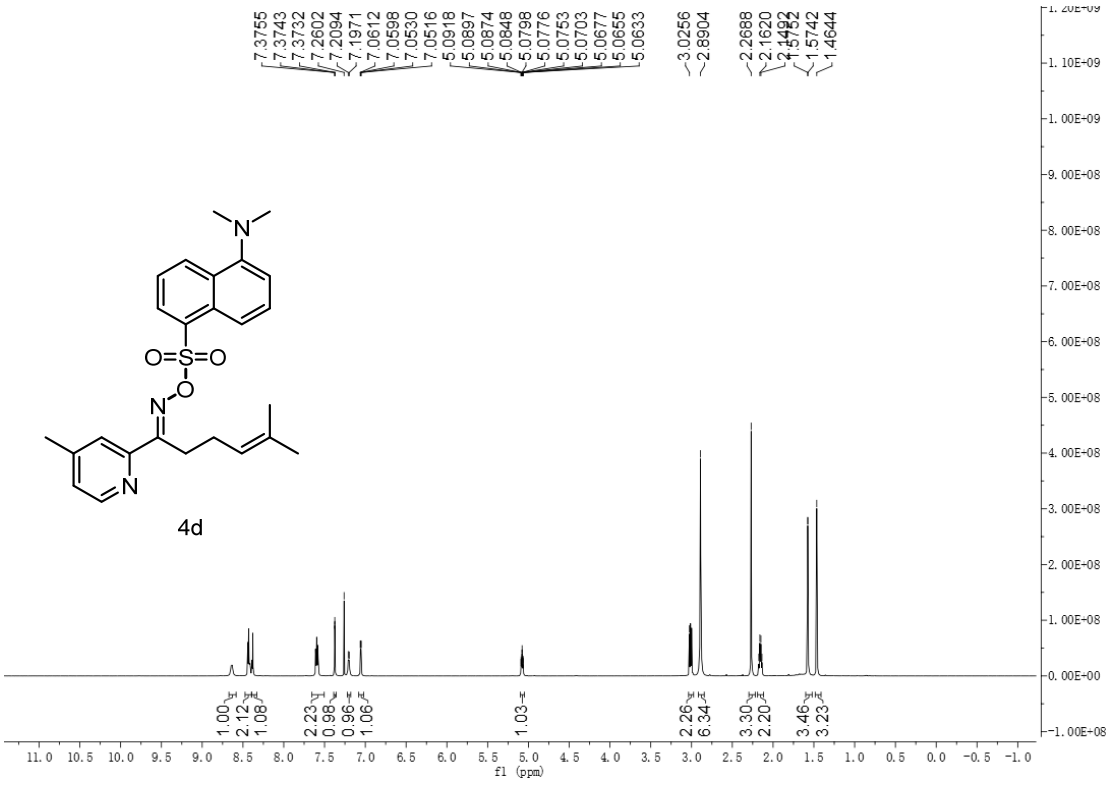
25.6244
25.2496
17.6388
O=S=O
N
O
Cl
N
4c
f1 (ppm)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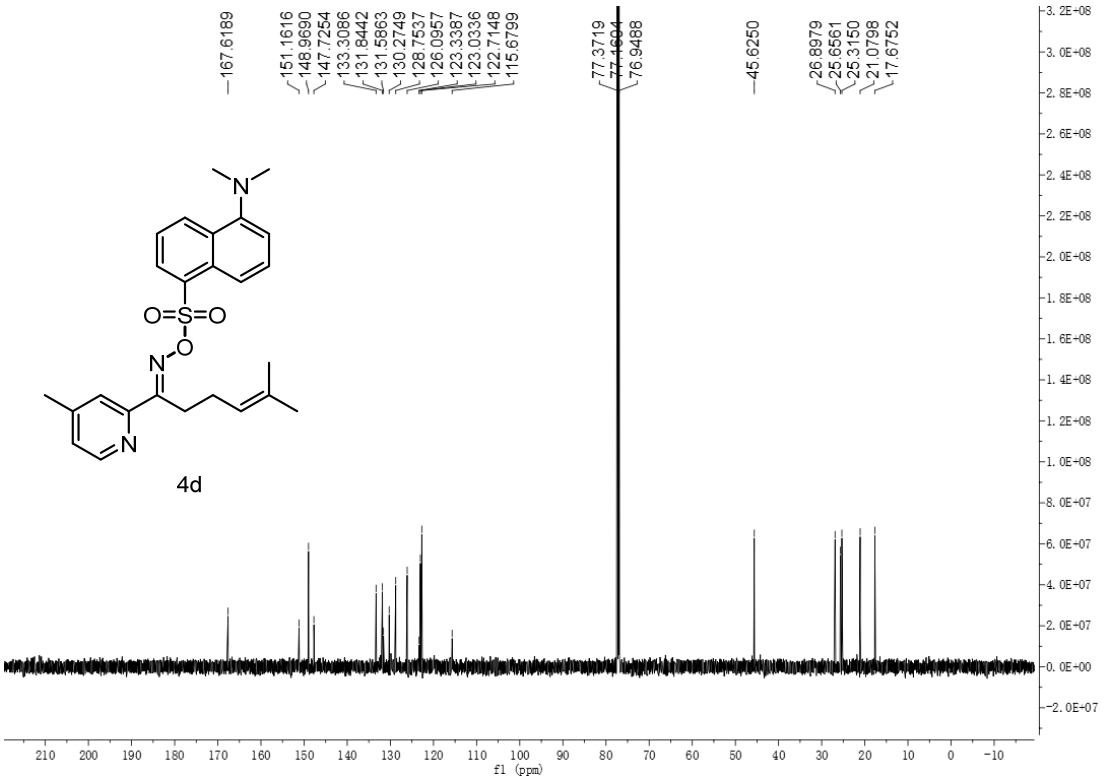
7.3743
7.3732
7.2602
7.2094
7.1971
7.0612
7.0598
7.0530
7.0516
5.0918
5.0897
5.0874
5.0848
5.0798
5.0776
5.0753
5.0703
5.0677
5.0655
5.0633
3.0256
2.8904
2.2688
2.1620
2.1492
1.5752
1.5742
1.4644
O=S=O
N
O
N
4d
1.00
2.12
1.08
2.23
0.98
0.96
1.06
1.03
2.26
6.34
3.30
2.20
3.46
3.23
f1 (ppm)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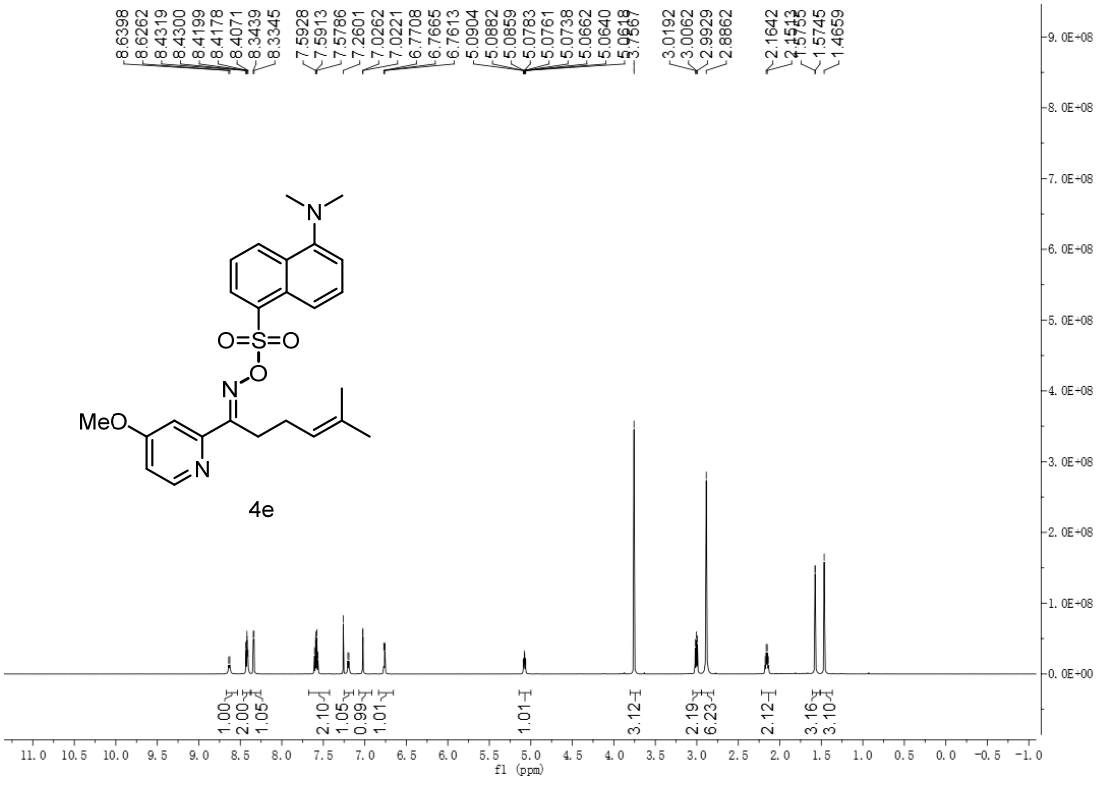
123.0336
122.7148
115.6799
77.3719
77.1604
76.9488
45.6250
26.8979
25.6561
25.3150
21.0798
17.6752
4d
f1 (ppm)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7.5786
7.2601
7.0262
7.0221
6.7708
6.7665
6.7613
5.0904
5.0882
5.0859
5.0783
5.0761
5.0738
5.0662
5.0640
3.7567
3.0192
3.0062
2.9929
2.8862
2.1642
1.5745
1.4659
MeO
4e
1.00
2.00
1.05
2.10
1.05
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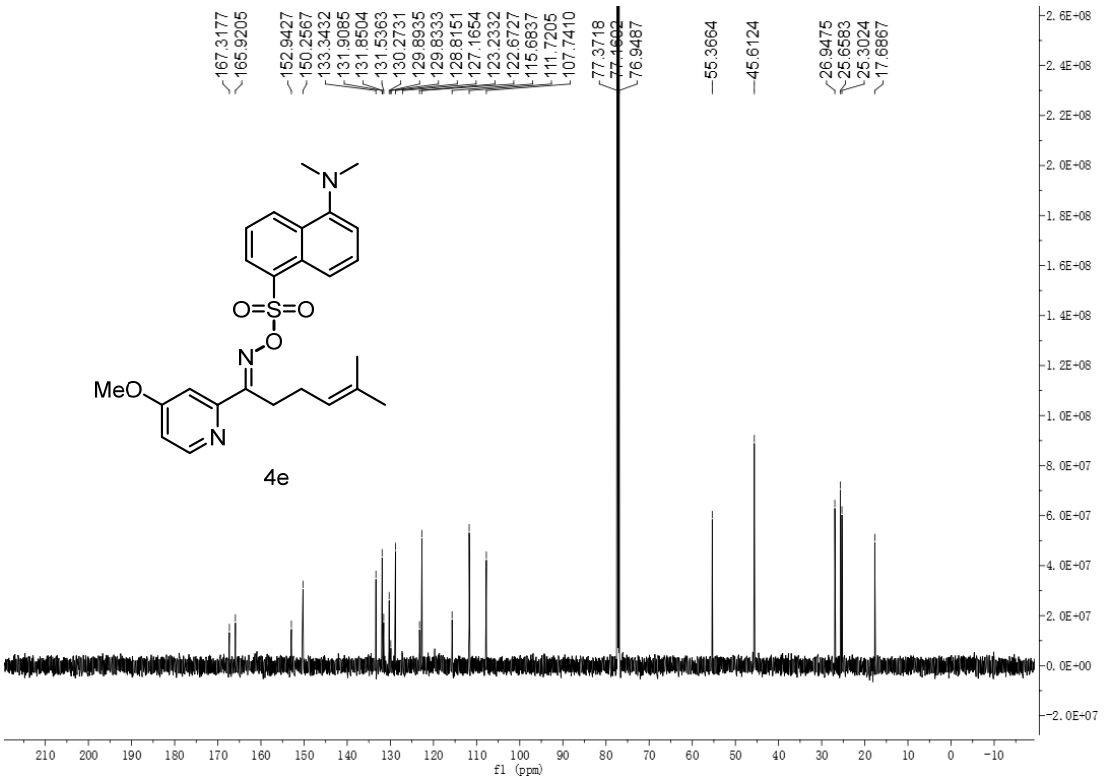
1.01
1.01
3.12
2.19
6.23
2.12
3.16
3.10
f1 (ppm)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127.1654
123.2332
122.6727
115.6837
111.7205
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77.3718
77.1602
76.9487
55.3664
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25.6583
25.3024
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MeO
N
O=S=O
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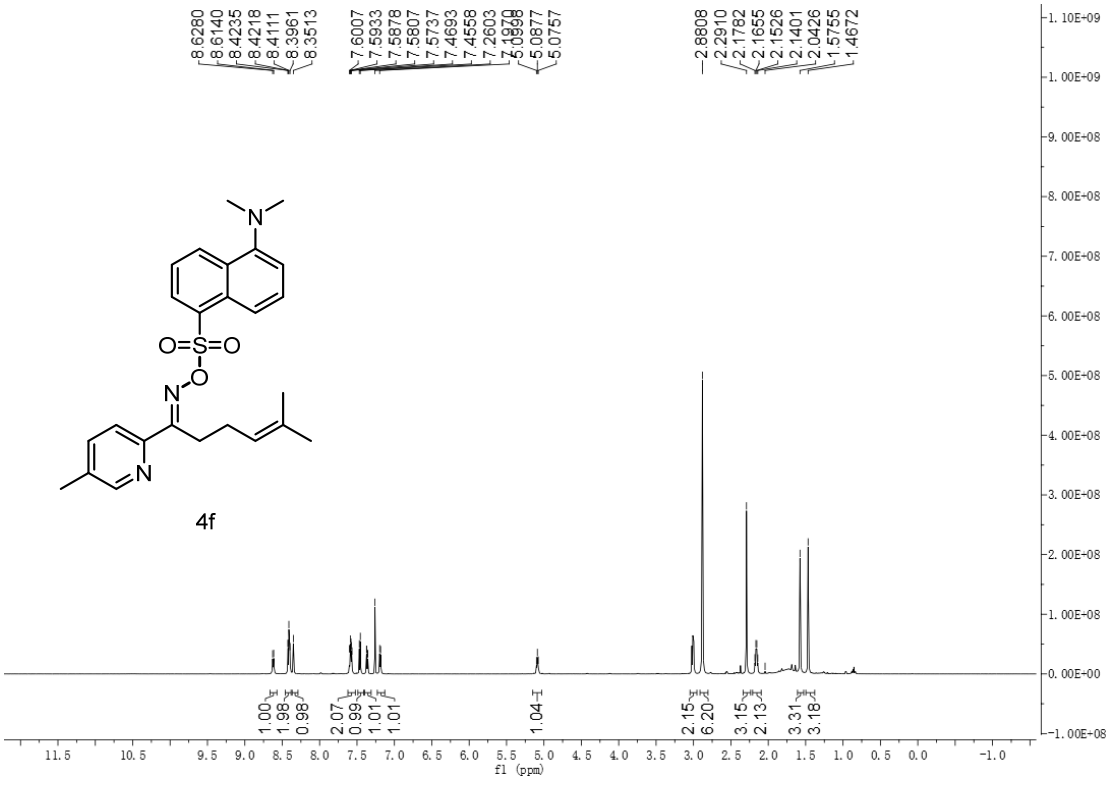
O
4e
f1 (ppm)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7.5737
7.4693
7.4558
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5.0877
5.0757
2.8808
2.2910
2.1782
2.1655
2.1526
2.1401
2.0426
1.5755
1.4672
1.00
1.98
0.98
2.07
0.99
1.01
1.01
1.04
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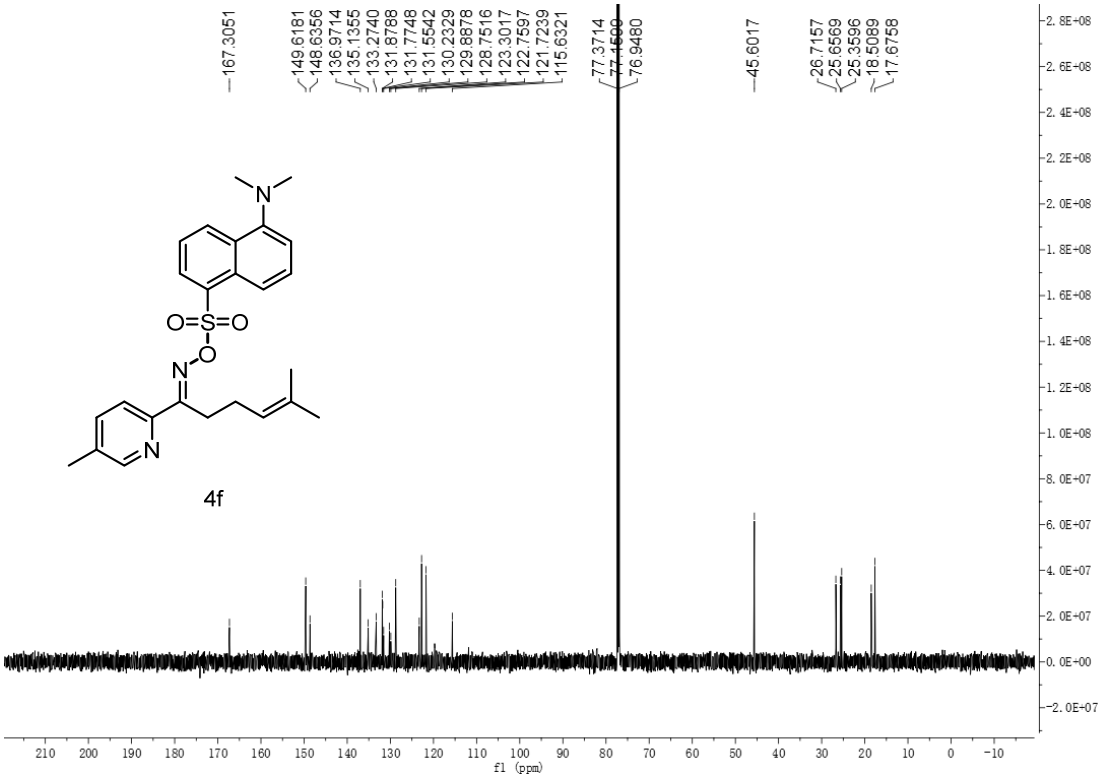
6.20
3.15
2.13
3.31
3.18
4f
f1 (ppm)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121.7239
115.6321
77.3714
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18.5089
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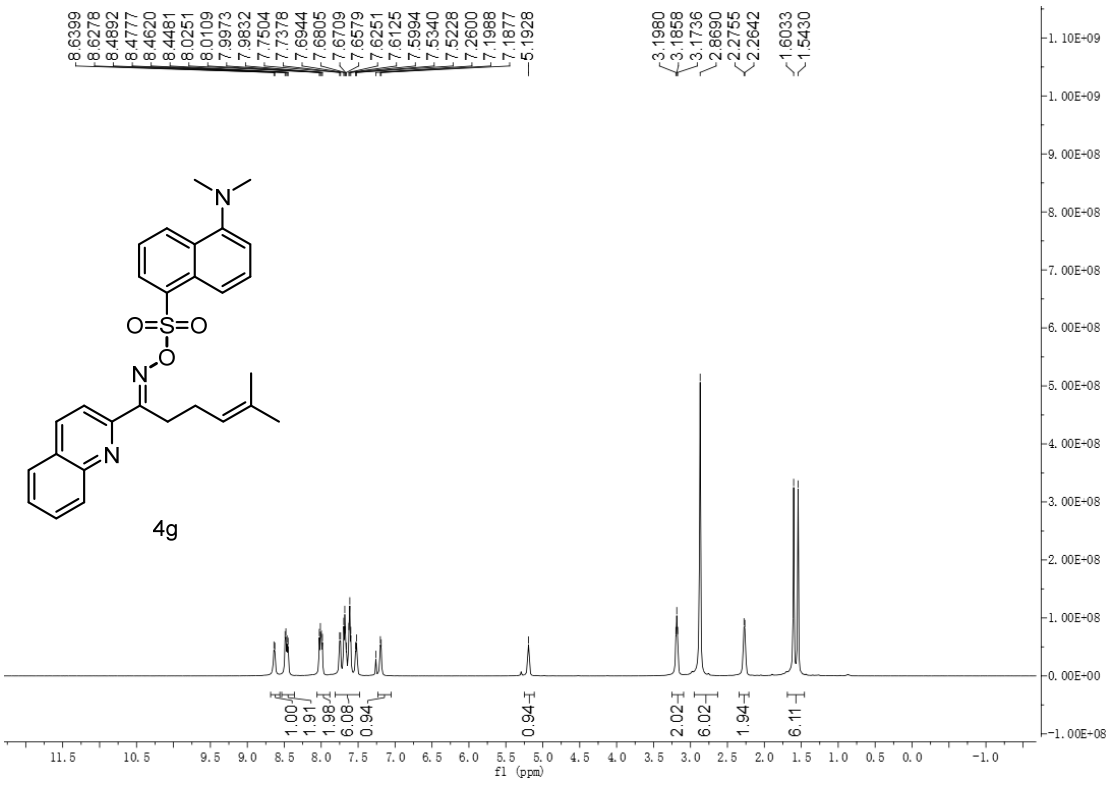
f1 (ppm)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7.6805
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7.6251
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7.5994
7.5340
7.5228
7.2600
7.1988
7.1877
5.1928
3.1980
3.1858
3.1736
2.8690
2.2755
2.2642
1.6033
1.5430
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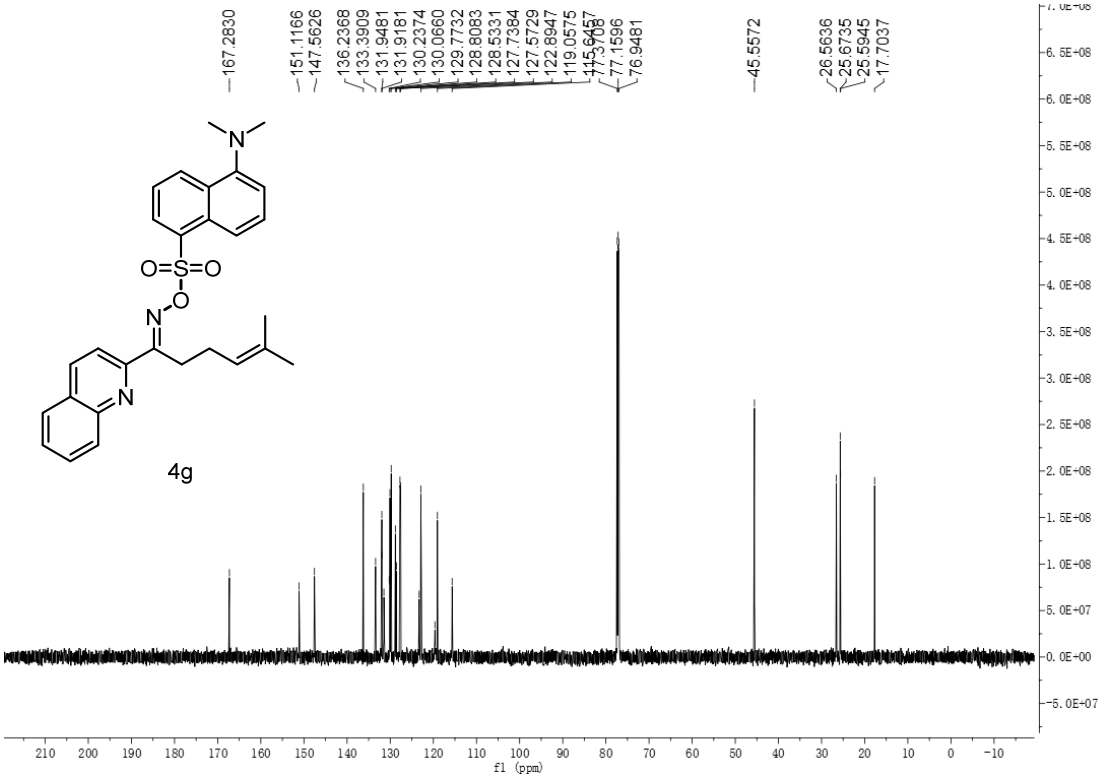
1.91
1.98
6.08
0.94
0.94
2.02
6.02
1.94
6.11
4g
f1 (ppm)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128.8083
128.5331
127.7384
127.5729
122.8947
119.0575
115.6457
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76.9481
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25.5945
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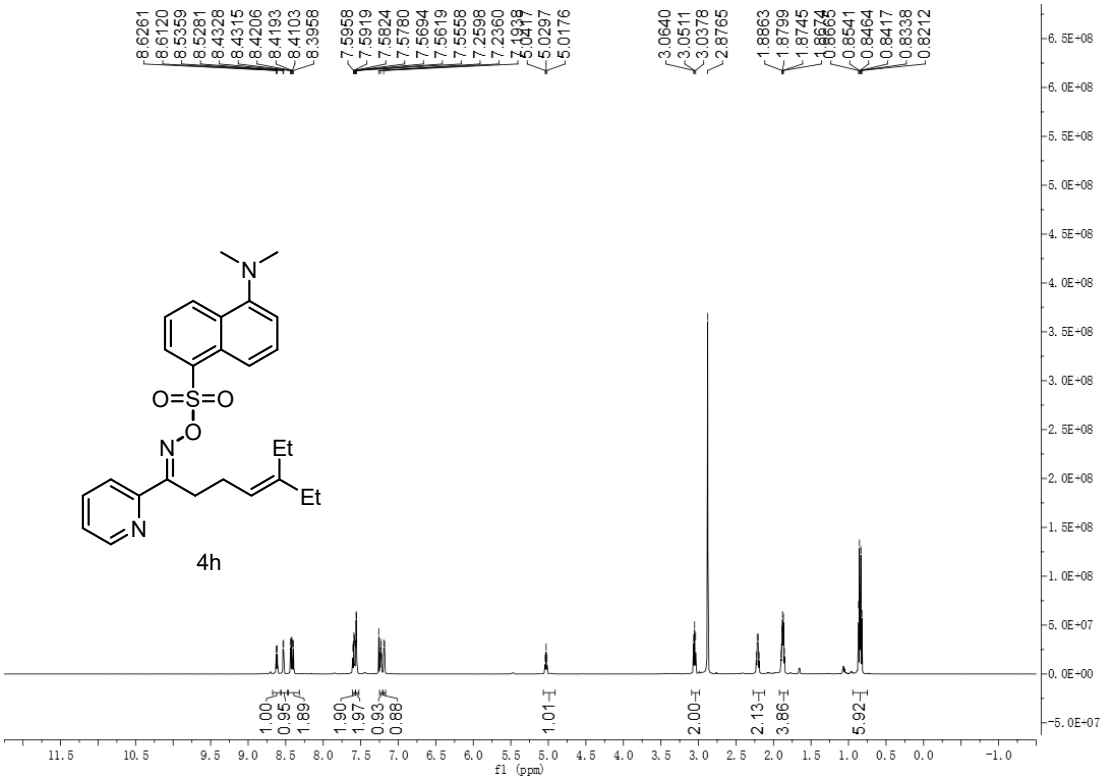
4g
f1 (ppm)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8.3958
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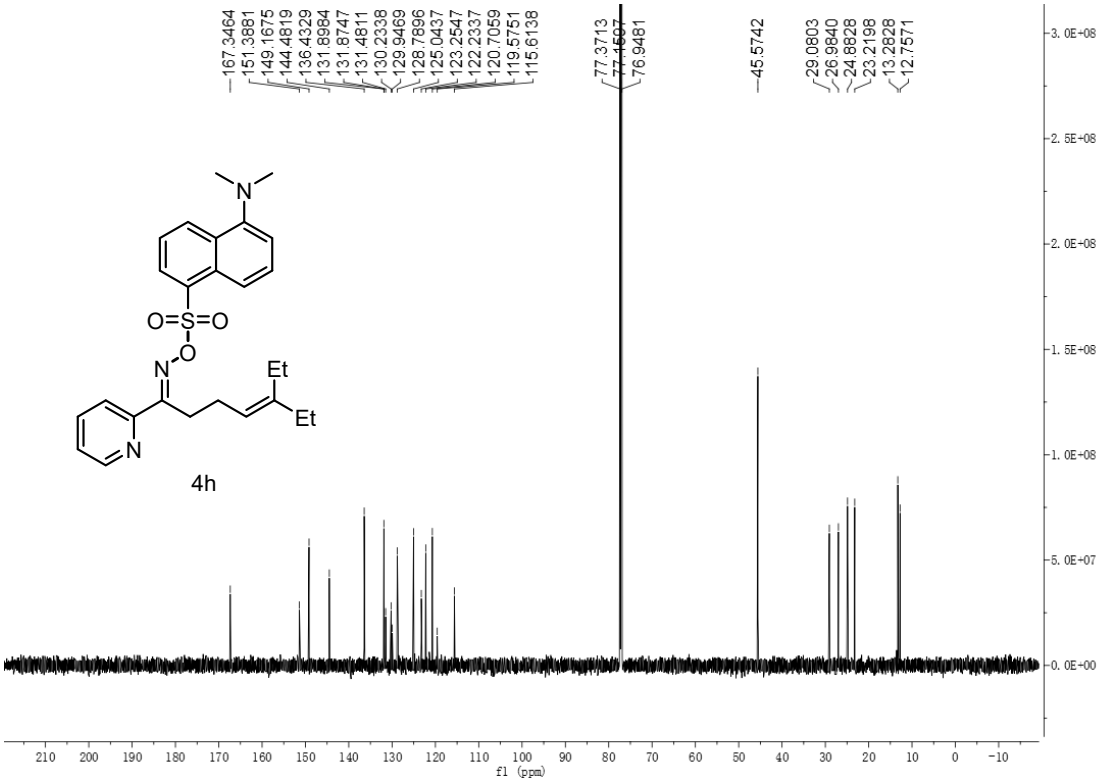
7.5919
7.5824
7.5780
7.5694
7.5619
7.5558
7.2598
7.2360
5.0417
5.0297
5.0176
3.0640
3.0511
3.0378
2.8765
1.8863
1.8799
1.8745
0.8541
0.8464
0.8417
0.8338
0.8212
Et
Et
4h
1.00
0.95
1.89
1.90
1.97
0.93
0.88
1.01
2.00
2.13
3.86
5.92
f1 (ppm)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129.9469
128.7896
125.0437
123.2547
122.2337
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119.5751
115.6138
77.3713
77.1587
76.9481
45.5742
29.0803
26.9840
24.8828
23.2198
13.2828
12.7571
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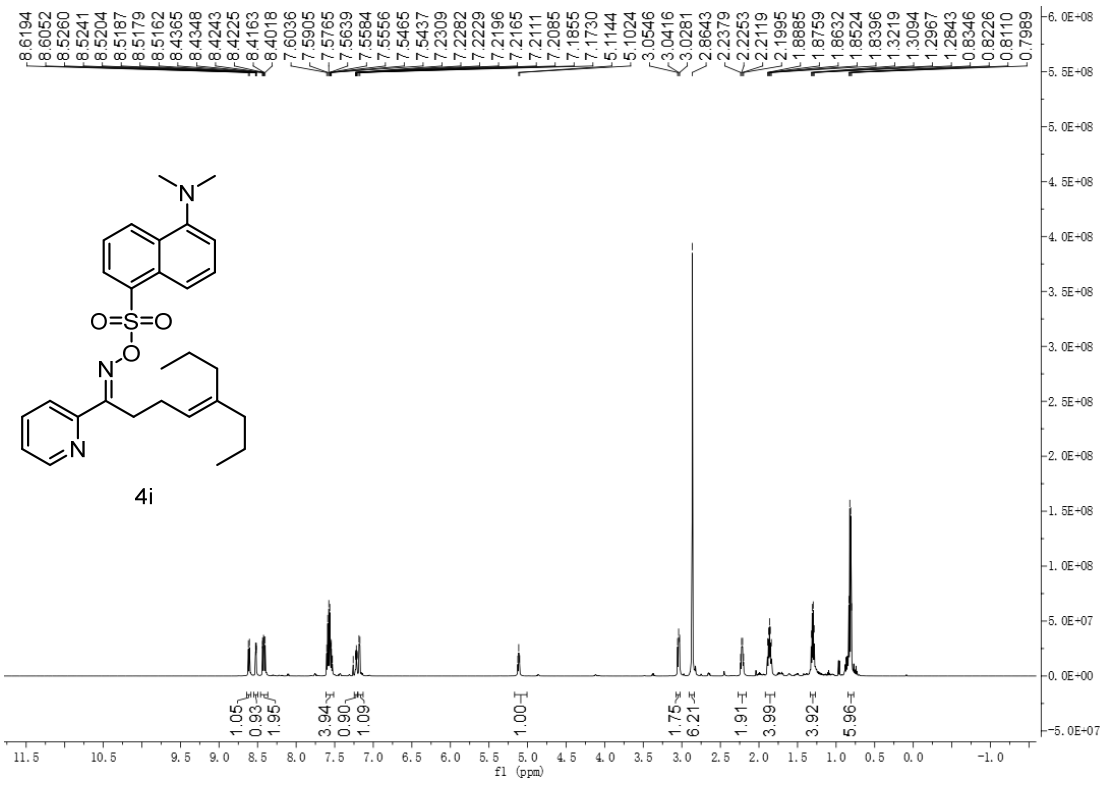
N
Et
Et
4h
f1 (ppm)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8.4225
8.4163
8.4018
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7.5905
7.5765
7.5639
7.5584
7.5556
7.5465
7.5437
7.2309
7.2282
7.2229
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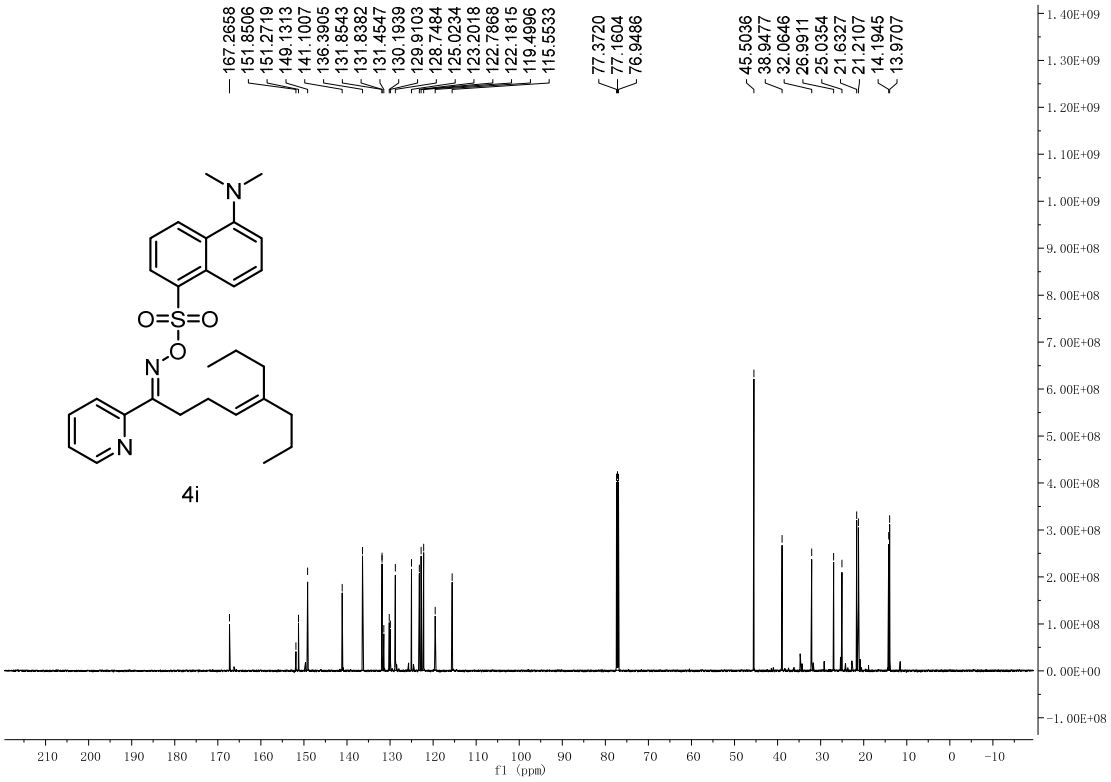
7.2165
7.2111
7.2085
7.1855
7.1730
5.1144
5.1024
3.0546
3.0416
3.0281
2.8643
2.2379
2.2253
2.2119
2.1995
1.8885
1.8759
1.8632
1.8524
1.8396
1.3219
1.3094
1.2967
1.2843
0.8346
0.8226
0.8110
0.7989
O=S=O
N
4i
1.05
0.93
1.95
3.94
0.90
1.09
1.00
1.75
6.21
1.91
3.99
3.92
5.96
f1 (ppm)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131.8382
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129.9103
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125.0234
123.2018
122.7868
122.1815
119.4996
115.5533
77.3720
77.1604
76.9486
45.5036
38.9477
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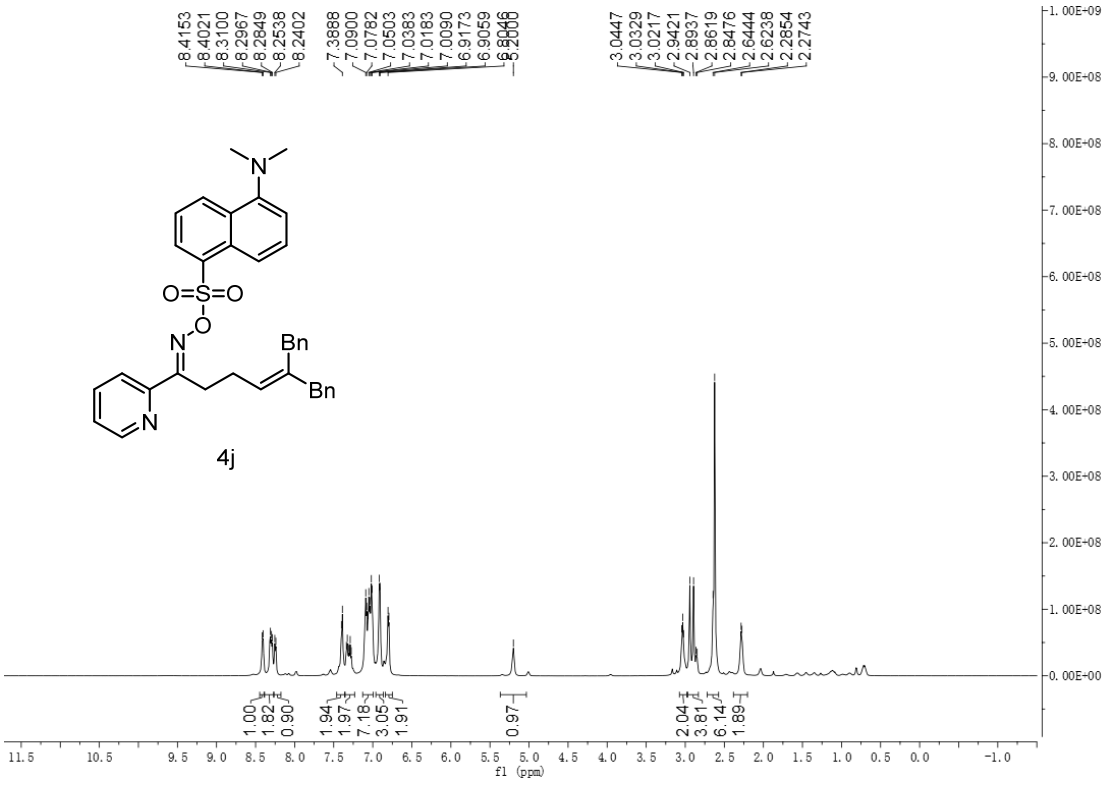
26.9911
25.0354
21.6327
21.2107
14.1945
13.9707
4i
f1 (ppm)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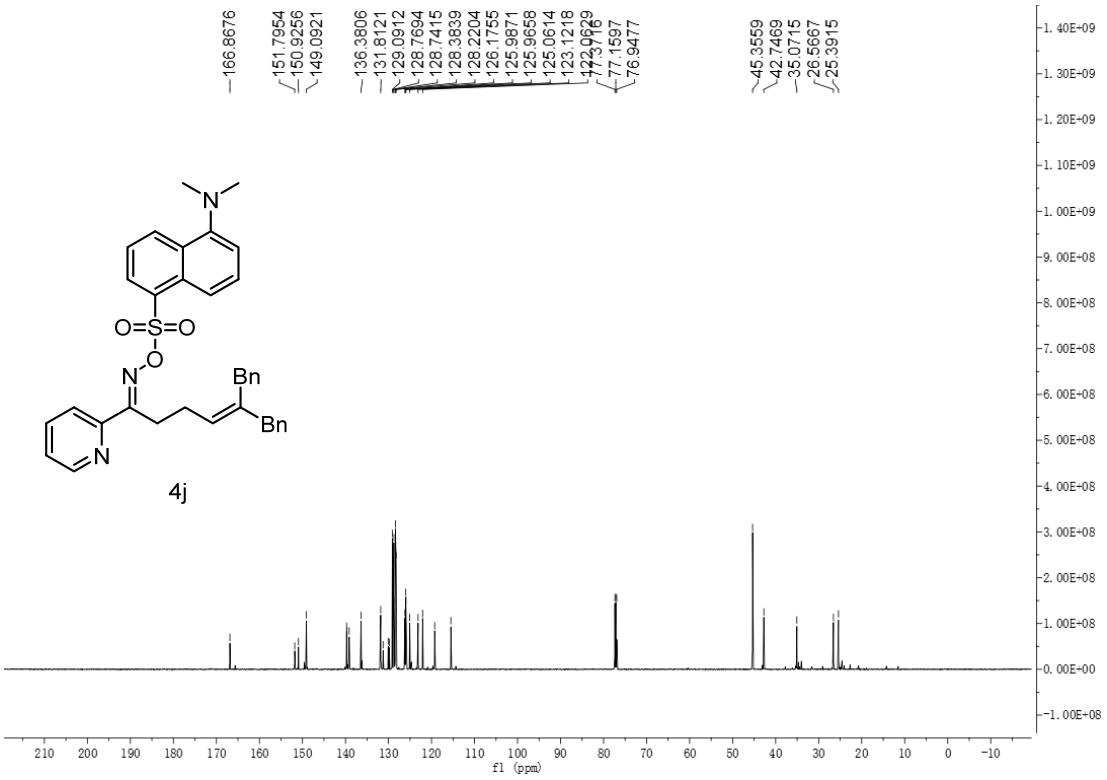
7.0503
7.0383
7.0183
7.0090
6.9173
6.9059
3.0447
3.0329
3.0217
2.9421
2.8937
2.8619
2.8476
2.6444
2.6238
2.2854
2.2743
Bn
Bn
4j
1.00
1.82
0.90
1.94
1.97
7.18
3.05
1.91
0.97
2.04
3.81
6.14
1.89
f1 (ppm)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125.9871
125.9658
125.0614
123.1218
122.0629
77.3716
77.1597
76.9477
45.3559
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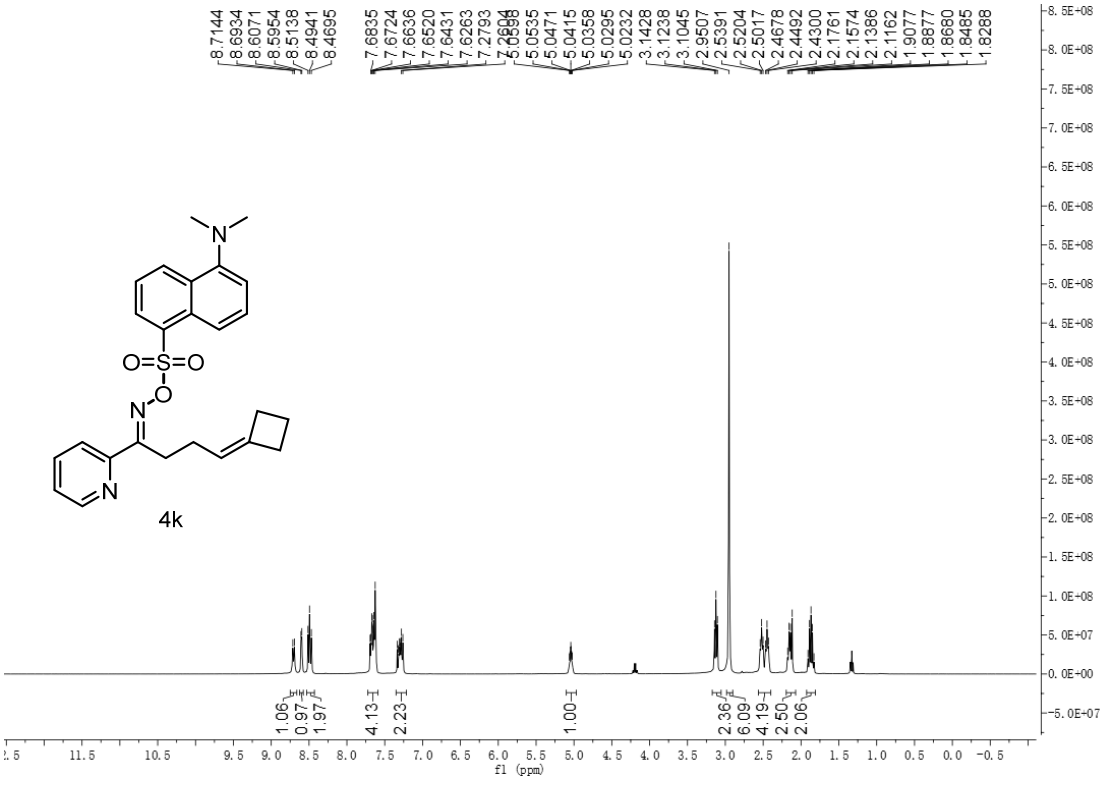
25.3915
O=S=O
N
O
N
Bn
Bn
N
4j
f1 (ppm)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7.6263
7.2793
5.0535
5.0471
5.0415
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5.0232
3.1428
3.1238
3.1045
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2.5204
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2.4300
2.1761
2.1574
2.1386
2.1162
1.9077
1.8877
1.8680
1.8485
1.8288
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0.97
1.97
4.13
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6.09
4.19
2.50
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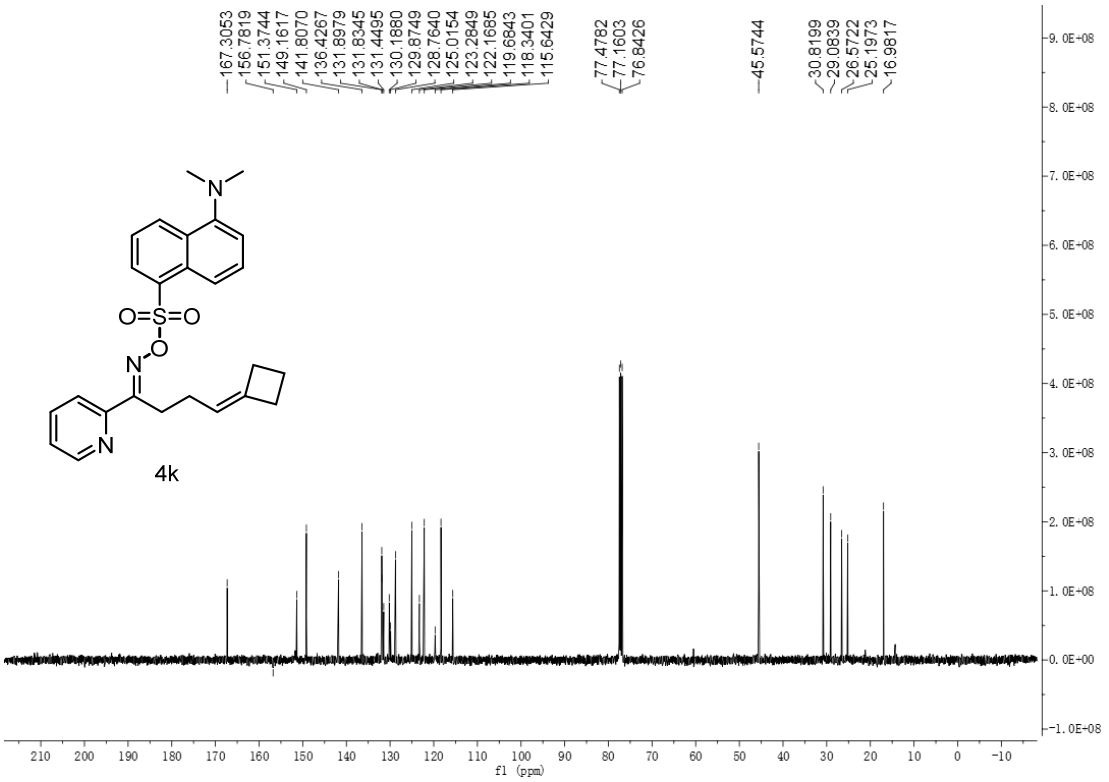
N
O
N
4k
f1 (ppm)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129.8749
128.7640
125.0154
123.2849
122.1685
119.6843
118.3401
115.6429
77.4782
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25.1973
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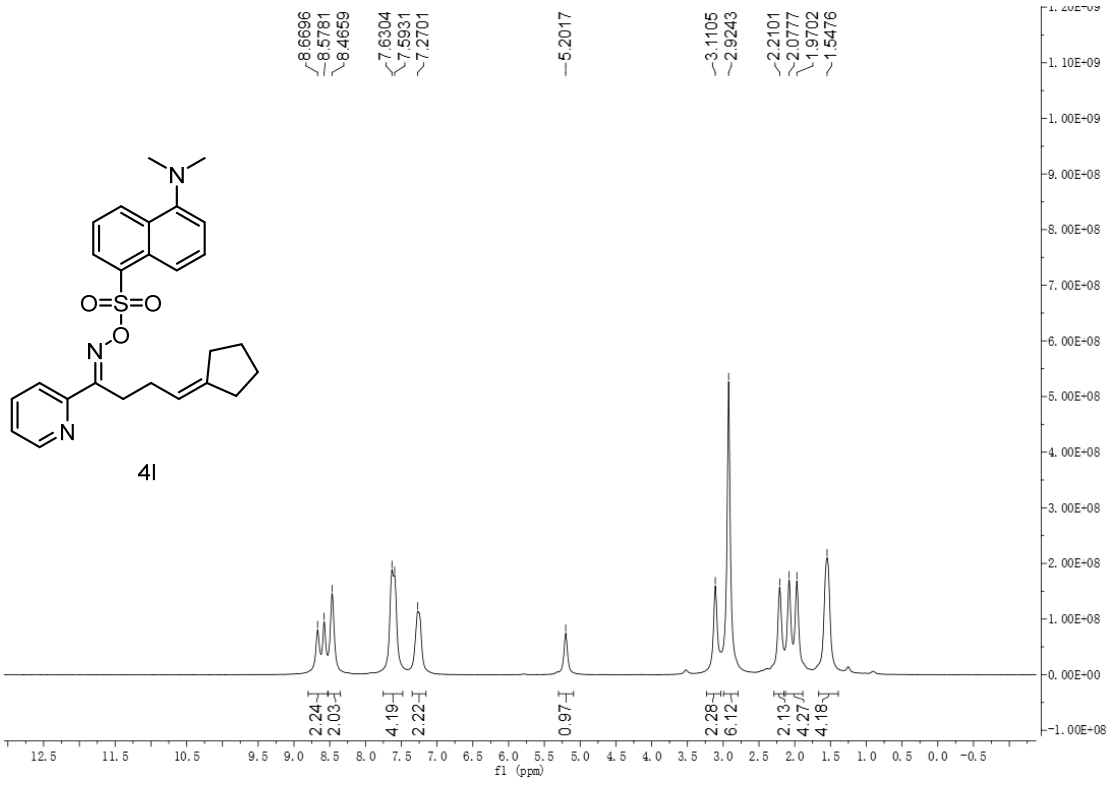
4k
f1 (ppm)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1.9702
1.5476
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2.03
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2.22
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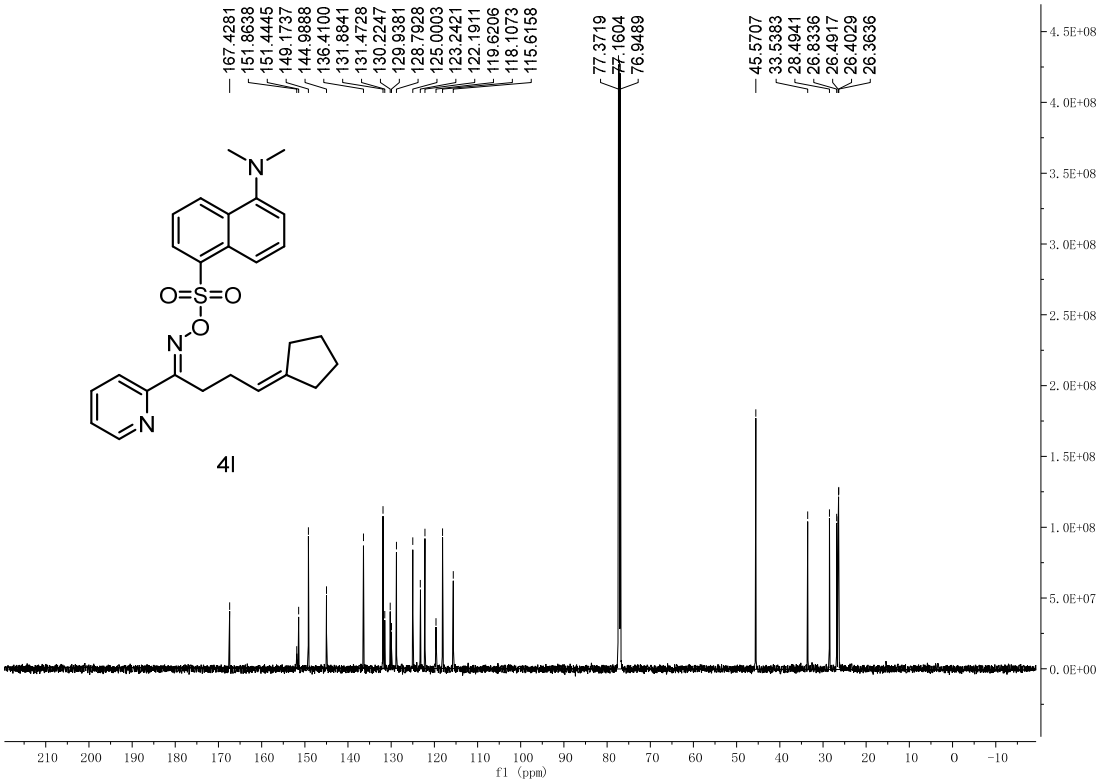
2.28
6.12
2.13
4.27
4.18
4l
f1 (ppm)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77.3719
77.1604
76.9489
45.5707
33.5383
28.4941
26.8336
26.4917
26.4029
26.3636
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
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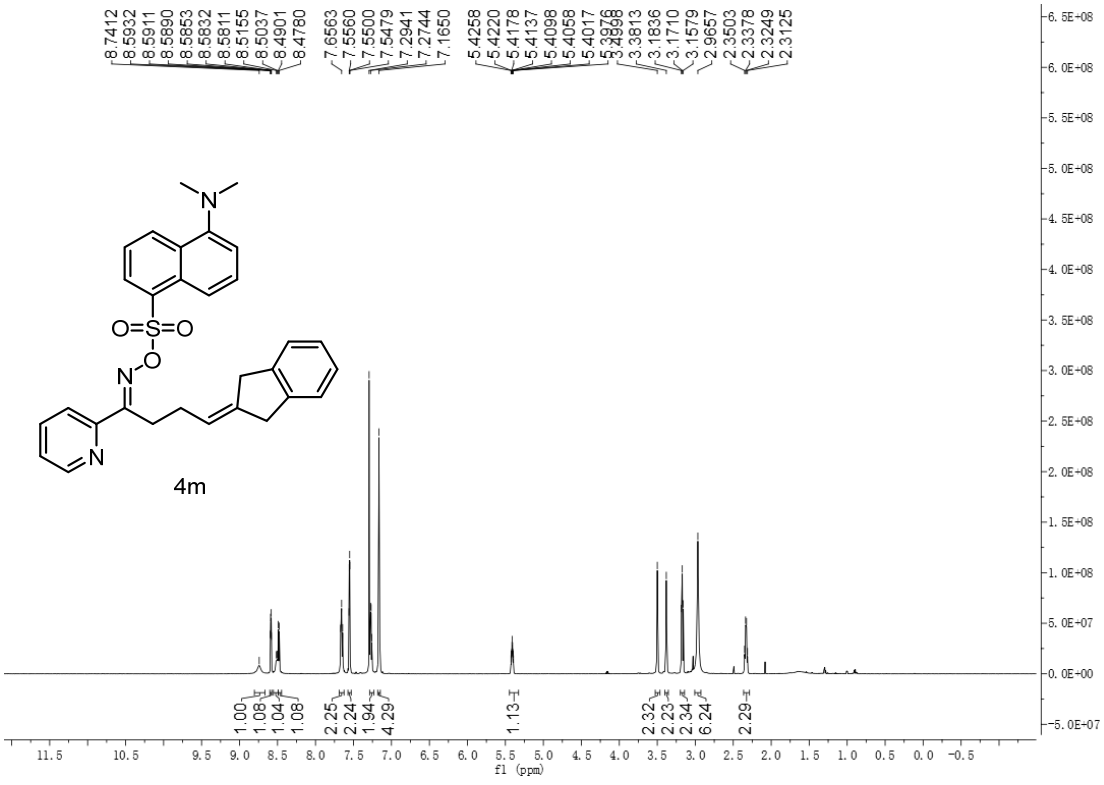
f1 (ppm)
4l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7.5500
7.5479
7.2941
7.2744
7.1650
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5.4220
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5.4098
5.4058
5.4017
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3.1710
3.1579
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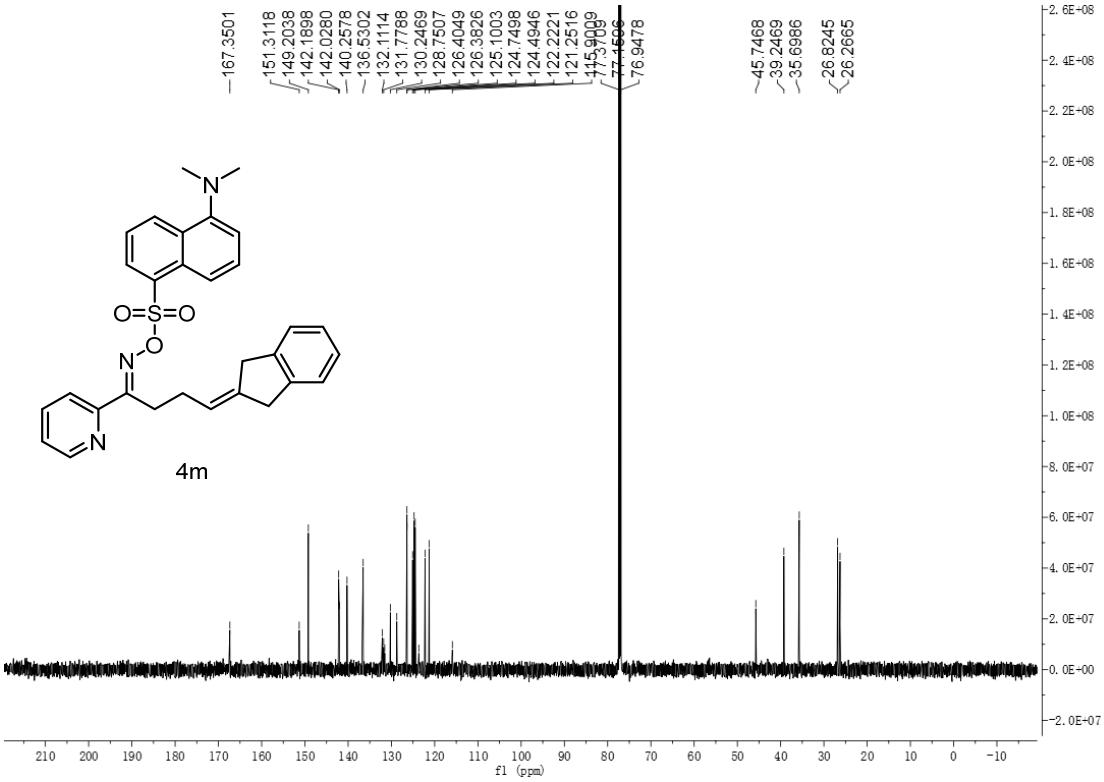
2.3378
2.3249
2.3125
6.5E+08
6.0E+08
5.5E+08
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
1.00
1.08
1.04
1.08
2.25
2.24
1.94
4.29
1.13
2.32
2.23
2.34
6.24
2.29
11.5 10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)
4m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126.4049
126.3826
125.1003
124.7498
124.4946
122.2221
121.2516
115.9009
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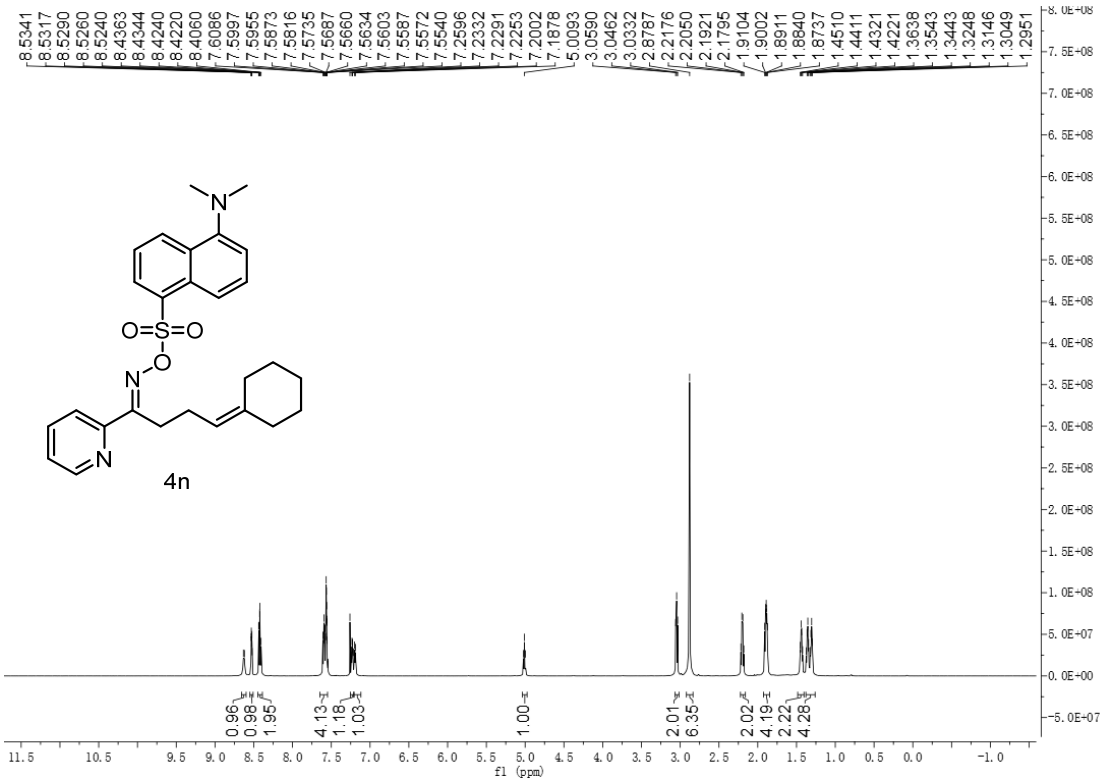
4m
f1 (ppm)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1.8840
1.8737
1.4510
1.4411
1.4321
1.4221
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1.3443
1.3248
1.3146
1.3049
1.2951
4n
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0.98
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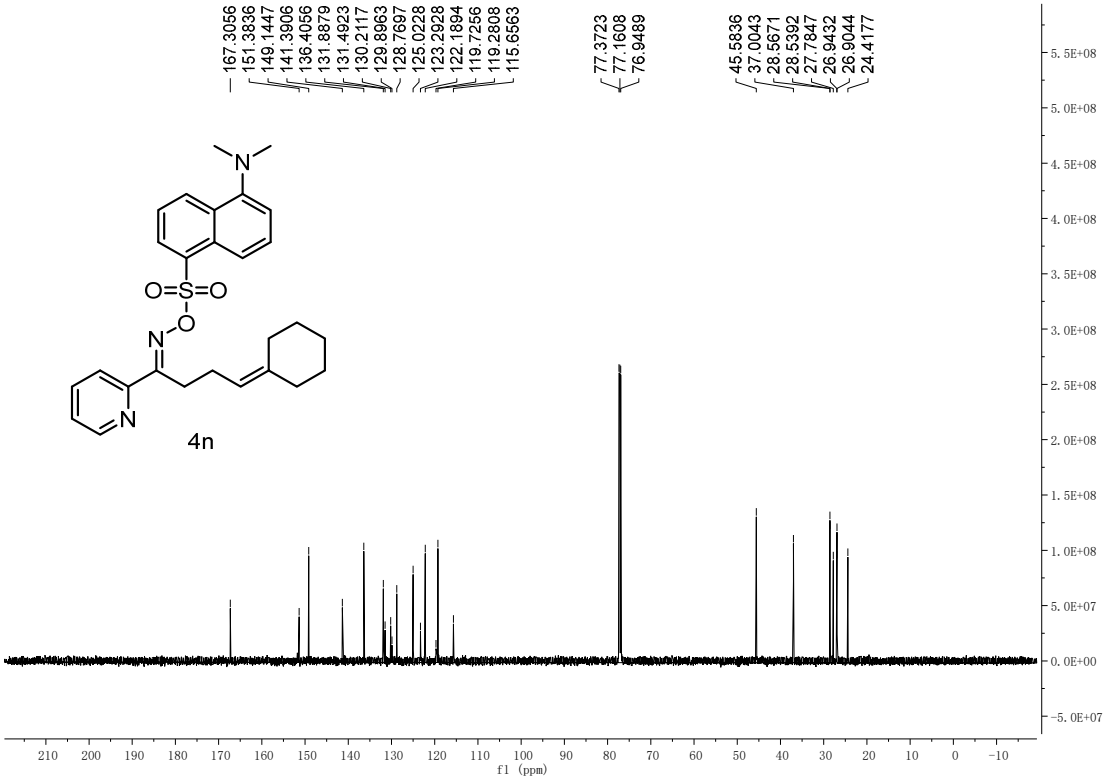
1.00
2.01
6.35
2.02
4.19
2.22
4.28
f1 (ppm)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76.9489
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26.9044
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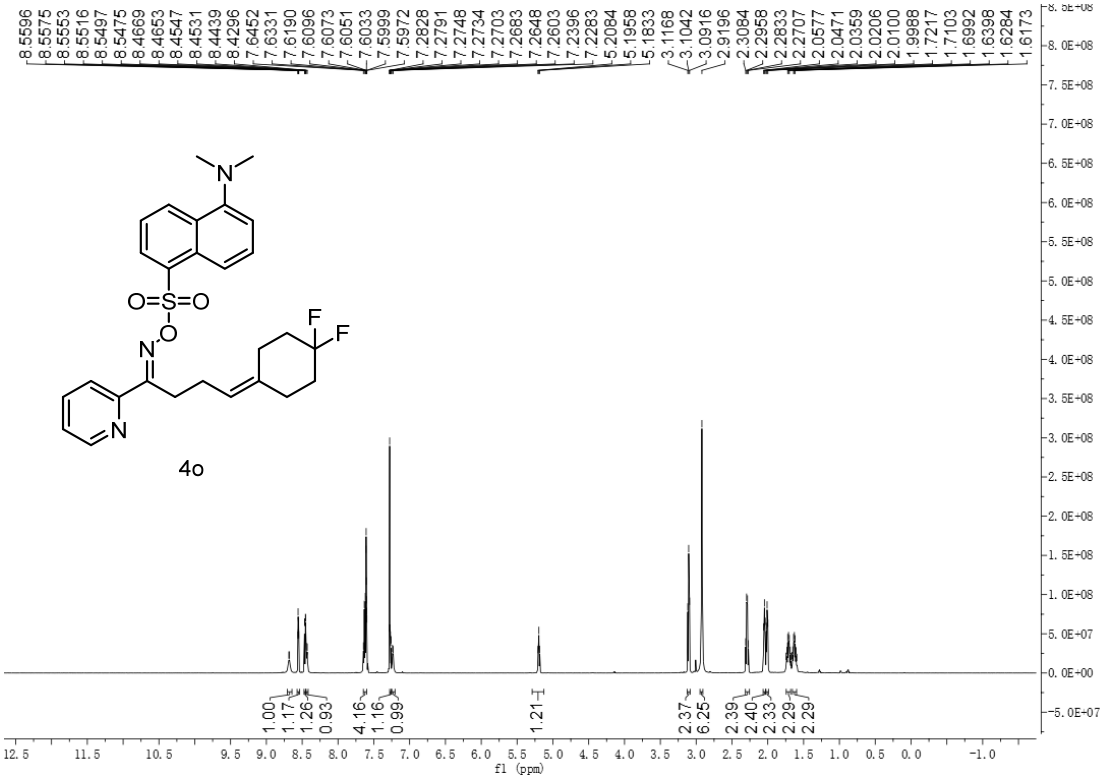
4n
f1 (ppm)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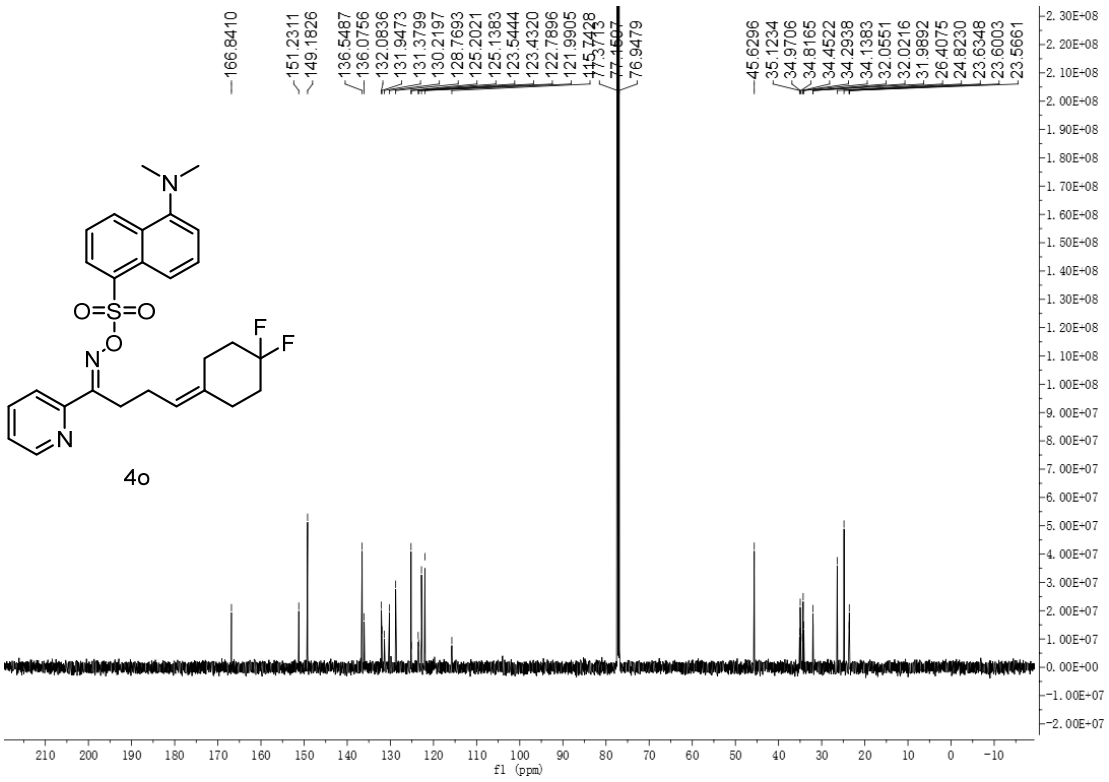
4.16
1.16
0.99
1.21
2.37
6.25
2.39
2.40
2.33
2.29
2.29
f1 (ppm)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125.1383
123.5444
123.4320
122.7896
121.9905
115.7428
77.4607
76.9479
45.6296
35.1234
34.9706
34.8165
34.4522
34.2938
34.1383
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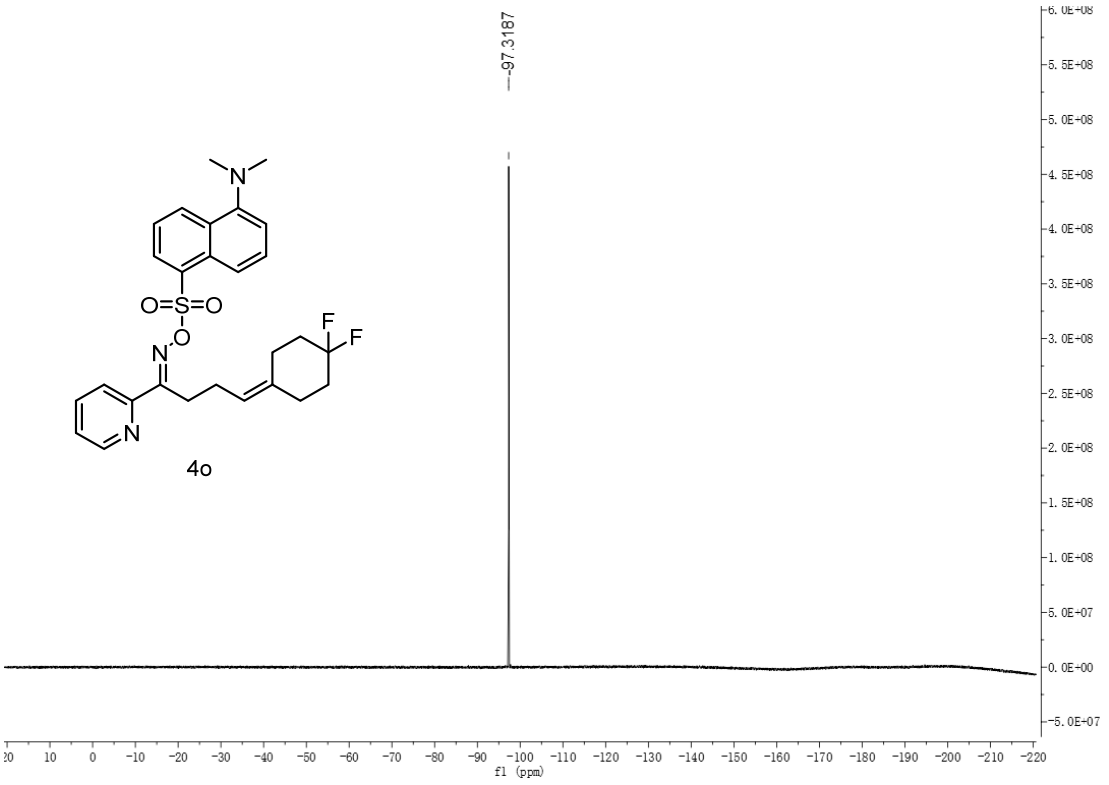
31.9892
26.4075
24.8230
23.6348
23.6003
23.5661
f1 (ppm)

4o


97.3187
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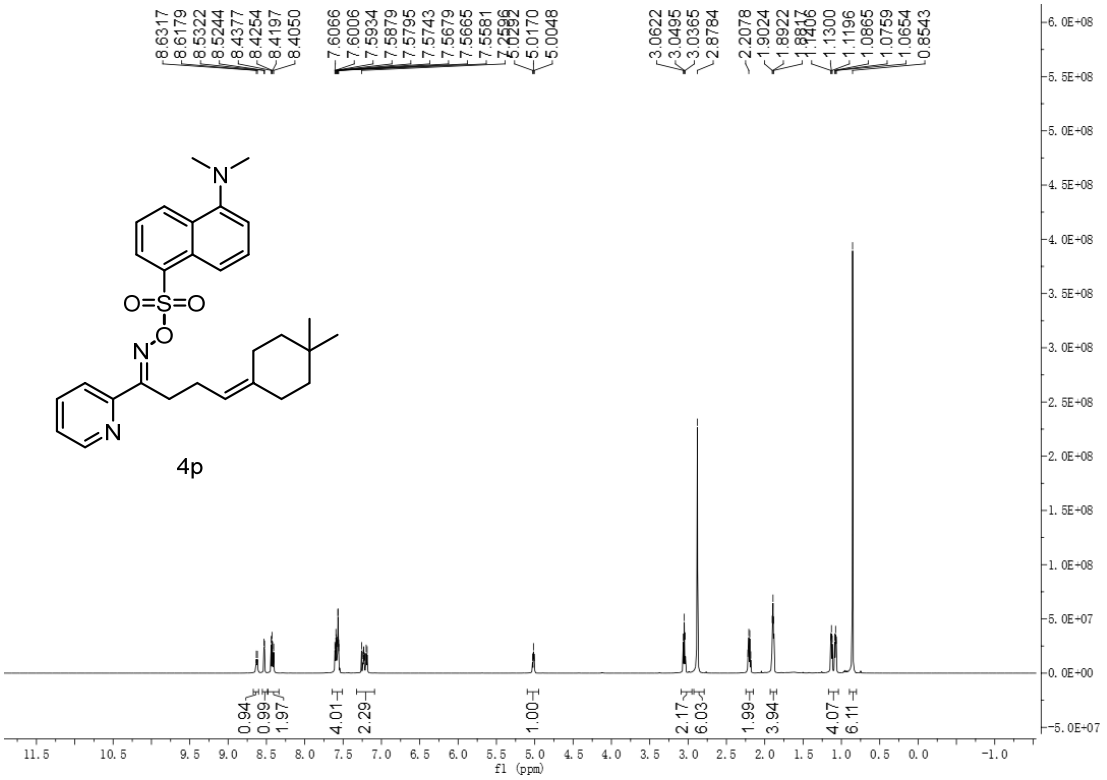
4o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8.4197
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7.6006
7.5934
7.5879
7.5795
7.5743
7.5679
7.5665
7.5581
5.0170
5.0048
3.0622
3.0495
3.0365
2.8784
2.2078
1.9024
1.8922
1.1300
1.1196
1.0865
1.0759
1.0654
0.8543
0.94
0.99
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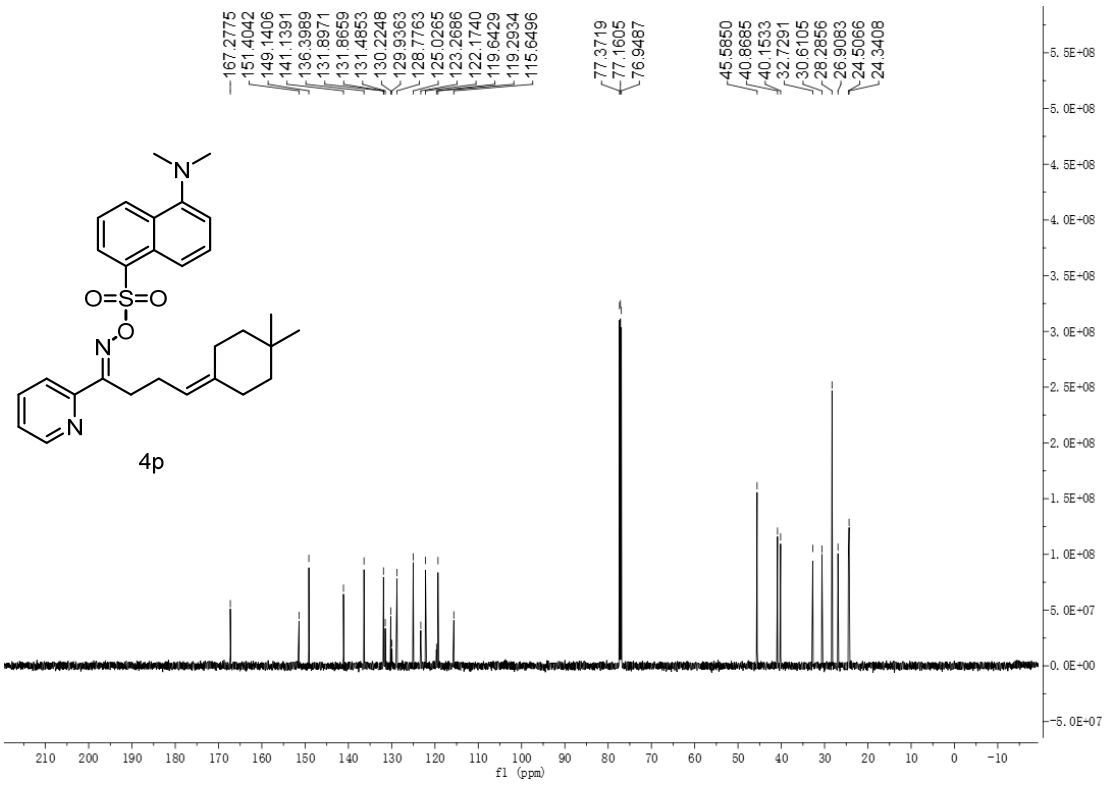
4.01
2.29
1.00
2.17
6.03
1.99
3.94
4.07
6.11
f1 (ppm)
4p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128.7763
125.0265
123.2686
122.1740
119.6429
119.2934
115.6496
77.3719
77.1605
76.9487
45.5850
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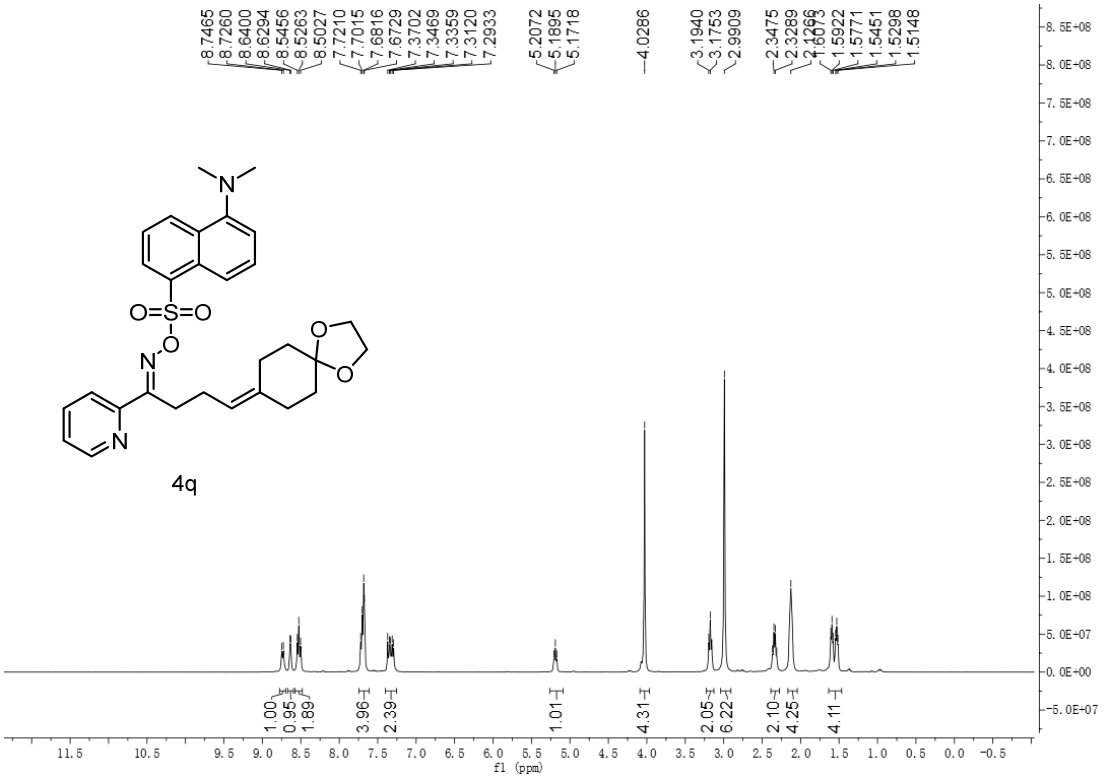
30.6105
28.2856
26.9083
24.5066
24.3408
f1 (ppm)
4p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8.5027
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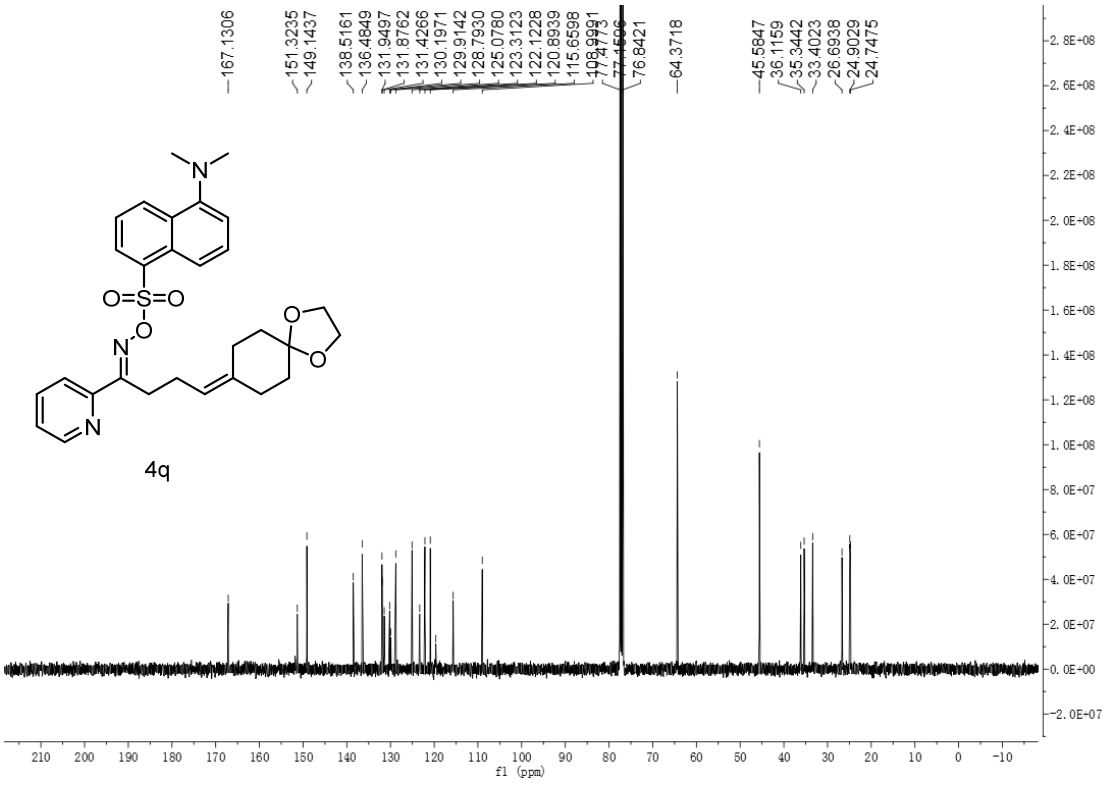
7.7015
7.6816
7.6729
7.3702
7.3469
7.3359
7.3120
7.2933
5.2072
5.1895
5.1718
4.0286
3.1940
3.1753
2.9909
2.3475
2.3289
2.1266
1.6073
1.5922
1.5771
1.5451
1.5298
1.5148
1.00
0.95
1.89
3.96
2.39
1.01
4.31
2.05
6.22
2.10
4.25
4.11
f1 (ppm)
4q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131.8762
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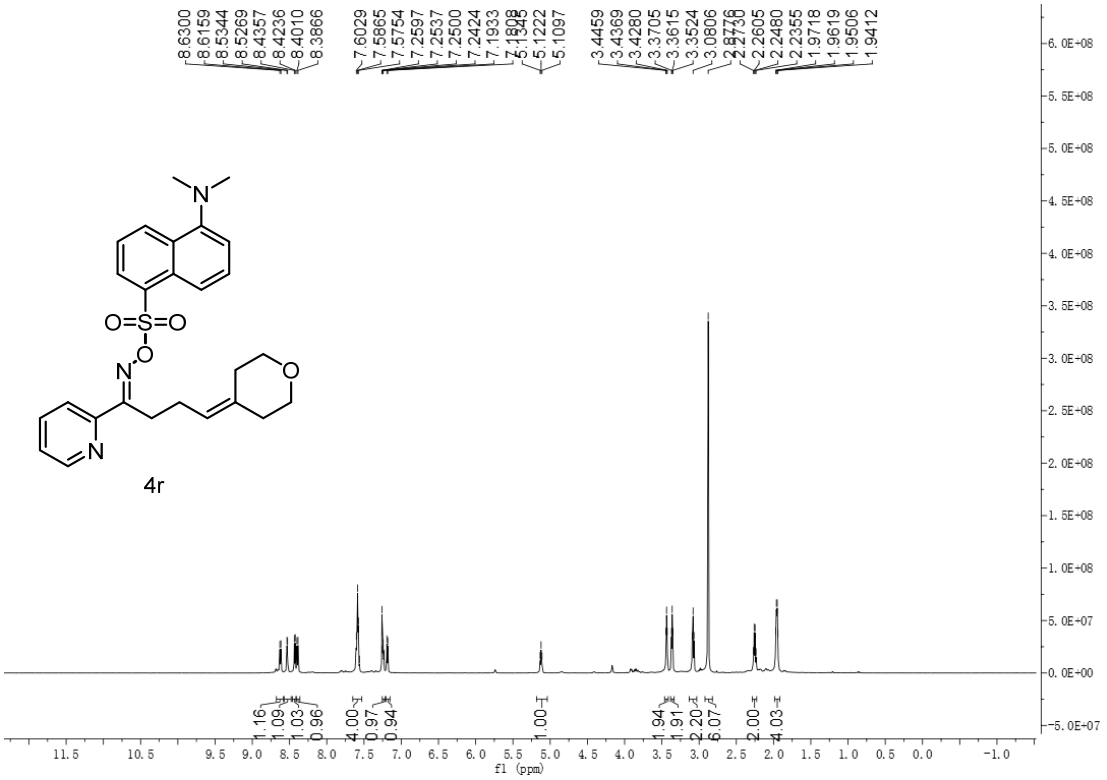
130.1971
129.9142
128.7930
125.0780
123.3123
122.1228
120.8939
115.6598
77.4606
76.8421
64.3718
45.5847
36.1159
35.3442
33.4023
26.6938
24.9029
24.7475
f1 (ppm)
4q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7.2597
7.2537
7.2500
7.2424
7.1933
5.1222
5.1097
3.4459
3.4369
3.4280
3.3705
3.3615
3.3524
3.0806
2.2605
2.2480
2.2355
1.9718
1.9619
1.9506
1.9412
4r
1.16
1.09
1.03
0.96
4.00
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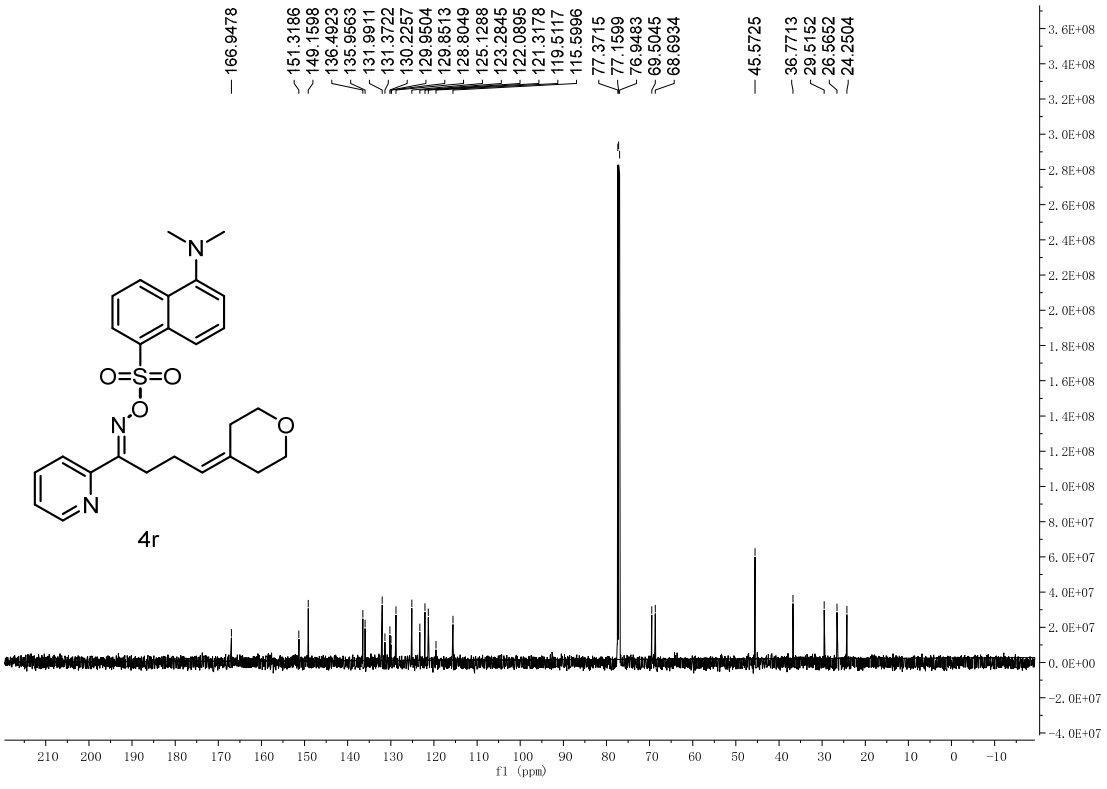
0.94
1.00
1.94
1.91
2.20
6.07
2.00
4.03
f1 (ppm)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128.8049
125.1288
123.2845
122.0895
121.3178
119.5117
115.5996
77.3715
77.1599
76.9483
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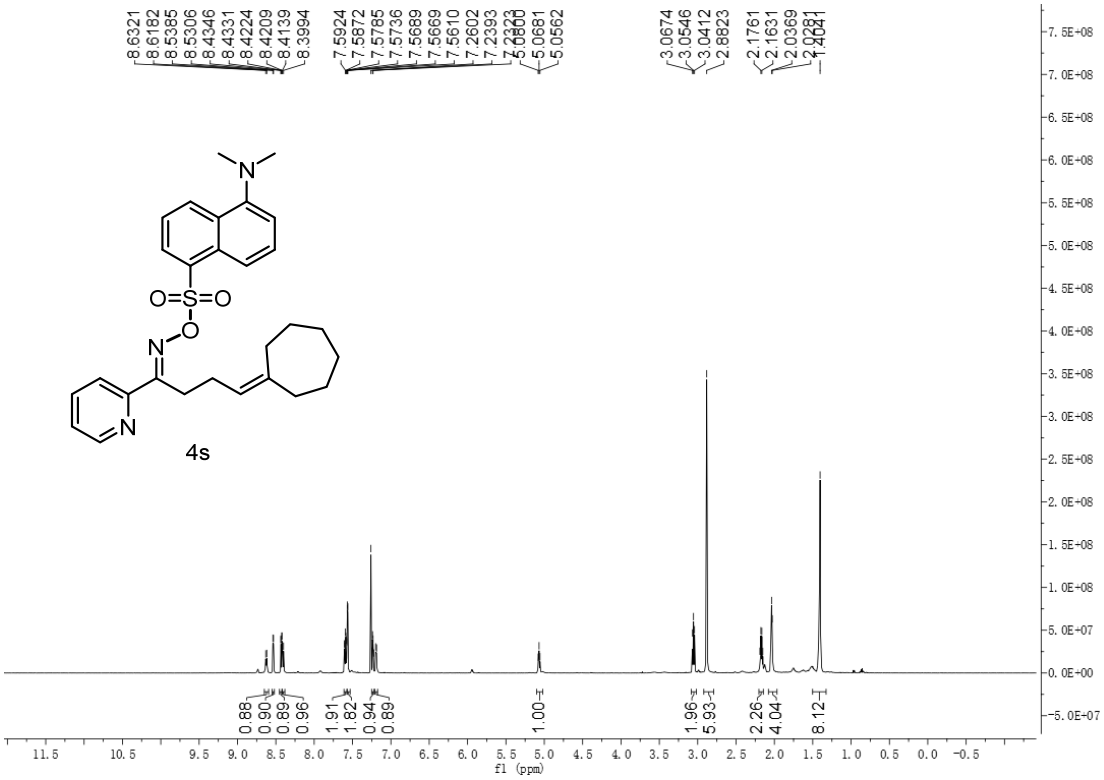
68.6934
45.5725
36.7713
29.5152
26.5652
24.2504
4r
f1 (ppm)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7.5736
7.5689
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7.5610
7.2602
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5.0562
3.0674
3.0546
3.0412
2.8823
2.1761
2.1631
2.0369
2.0281
1.4041
4s
0.88
0.90
0.89
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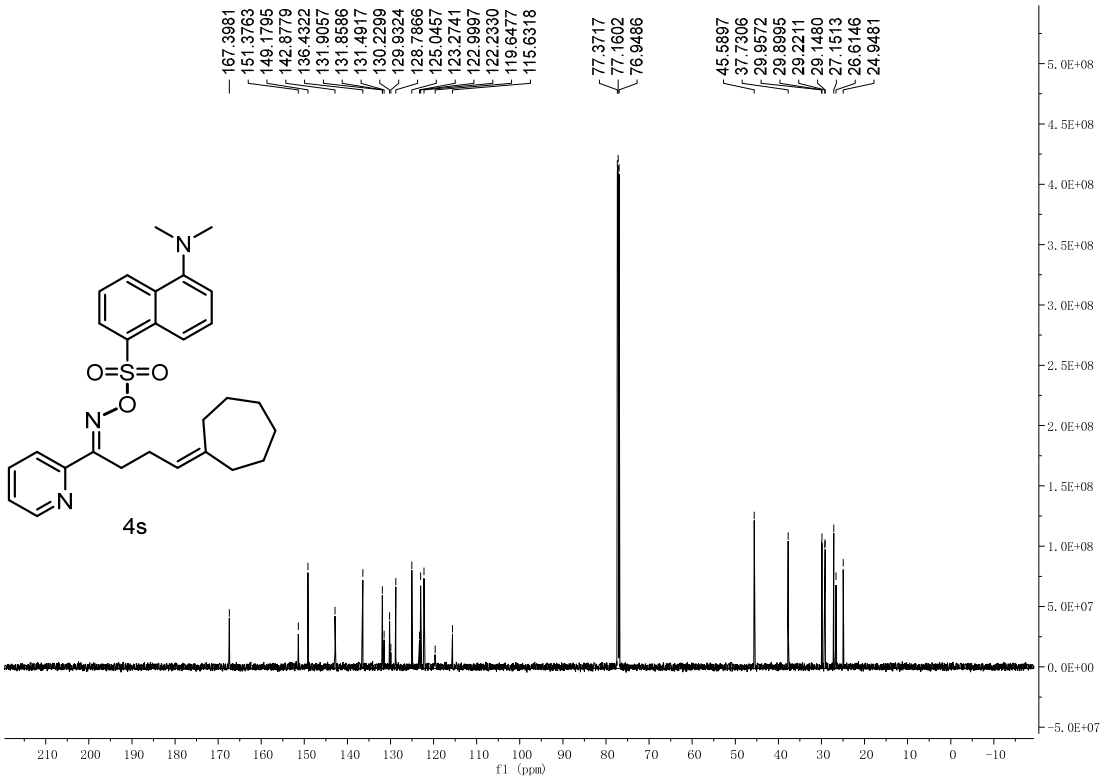
1.91
1.82
0.94
0.89
1.00
1.96
5.93
2.26
4.04
8.12
f1 (ppm)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125.0457
123.2741
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122.2330
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115.6318
77.3717
77.1602
76.9486
45.5897
37.7306
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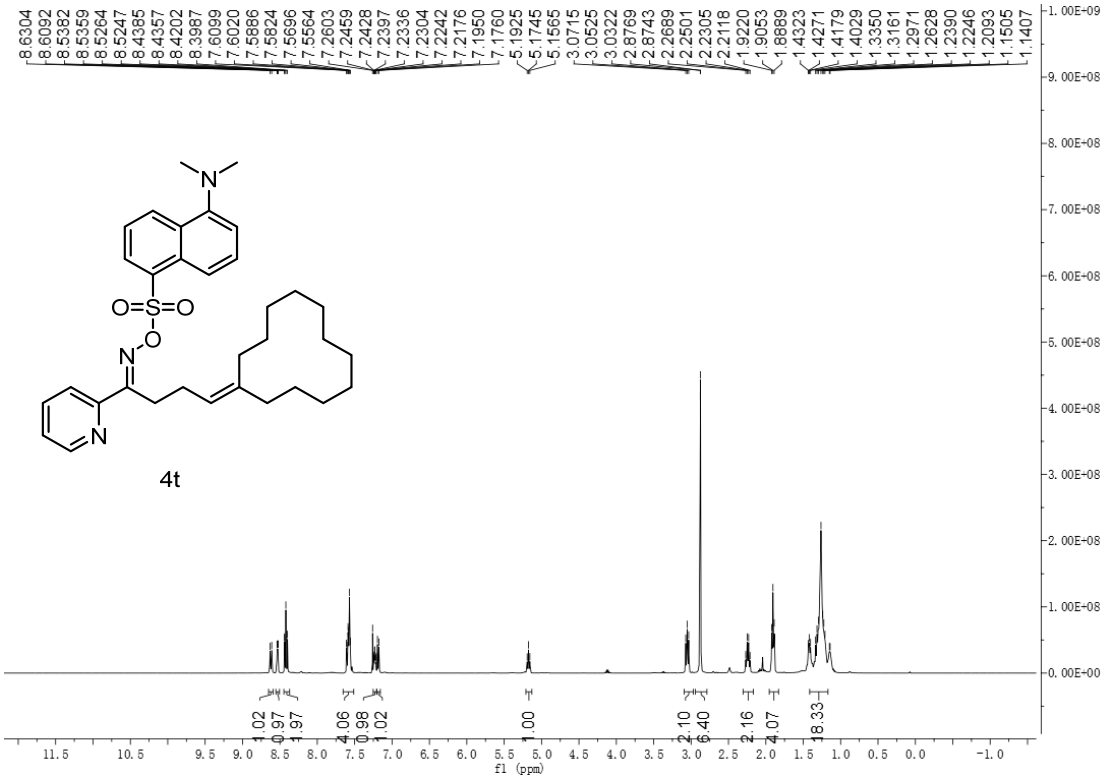
29.8995
29.2211
29.1480
27.1513
26.6146
24.9481
4s
f1 (ppm)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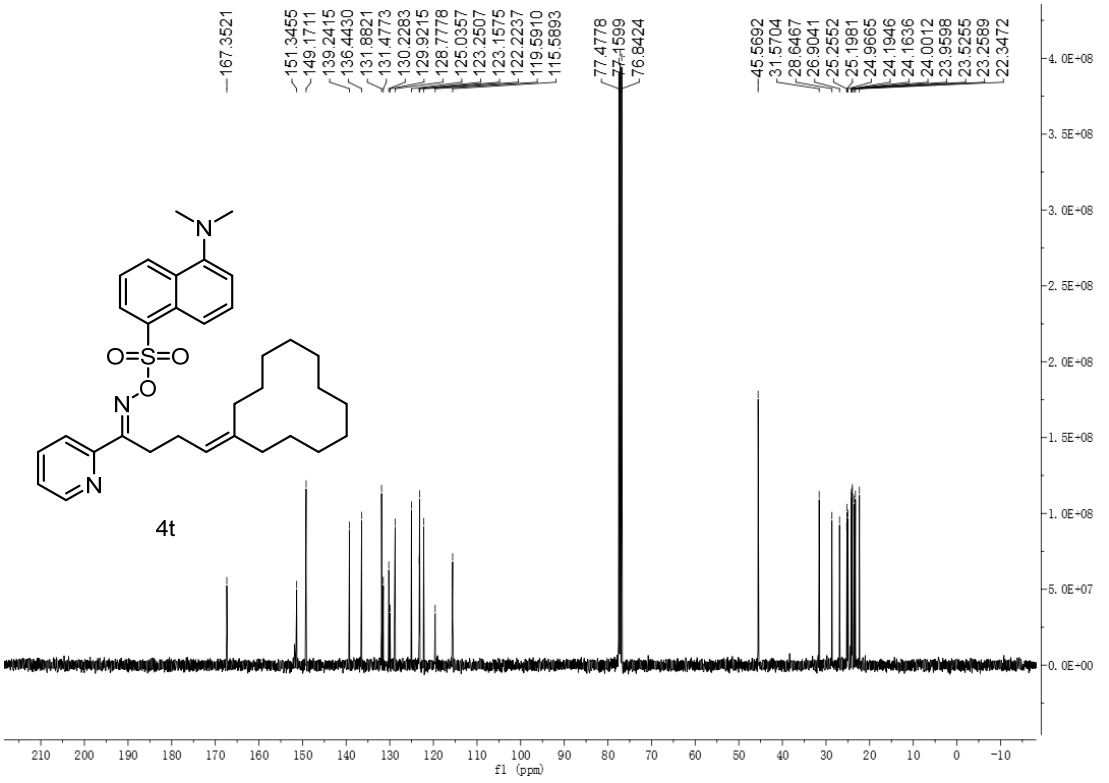
fl (ppm)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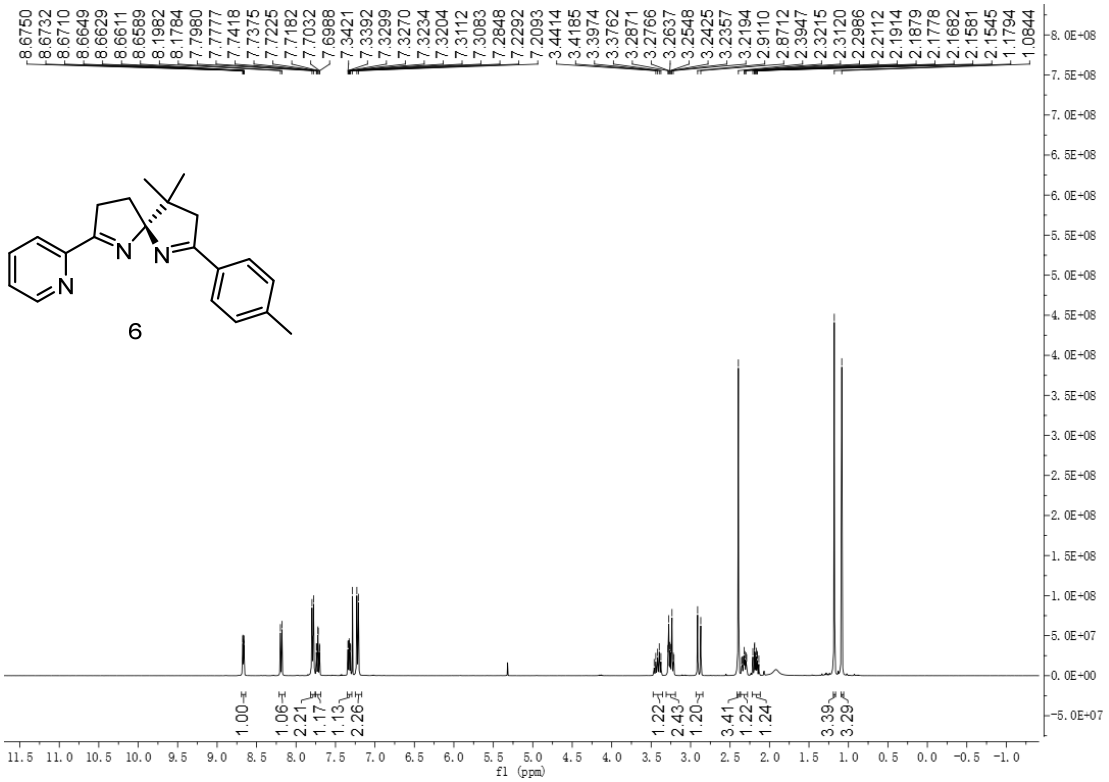
fl (ppm)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8.1784
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7.7777
7.7418
7.7375
7.7225
7.7182
7.7032
7.6988
7.3421
7.3392
7.3299
7.3270
7.3234
7.3204
7.3112
7.3083
7.2848
7.2292
7.2093
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3.4185
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3.3762
3.2871
3.2766
3.2637
3.2548
3.2425
3.2357
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2.3947
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2.3120
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2.2112
2.1914
2.1879
2.1778
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2.1581
2.1545
1.1794
1.0844
6
1.00
1.06
2.21
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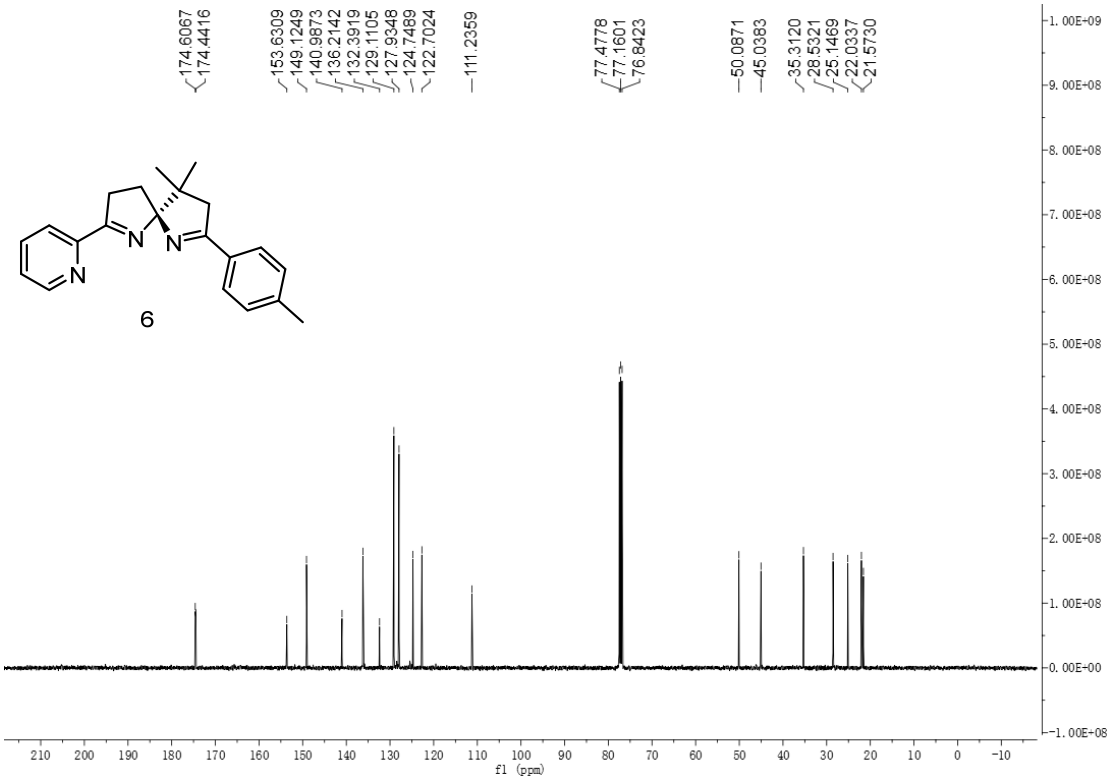
1.22
2.43
1.20
3.41
1.22
1.24
3.39
3.29
f1 (ppm)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77.4778
77.1601
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28.5321
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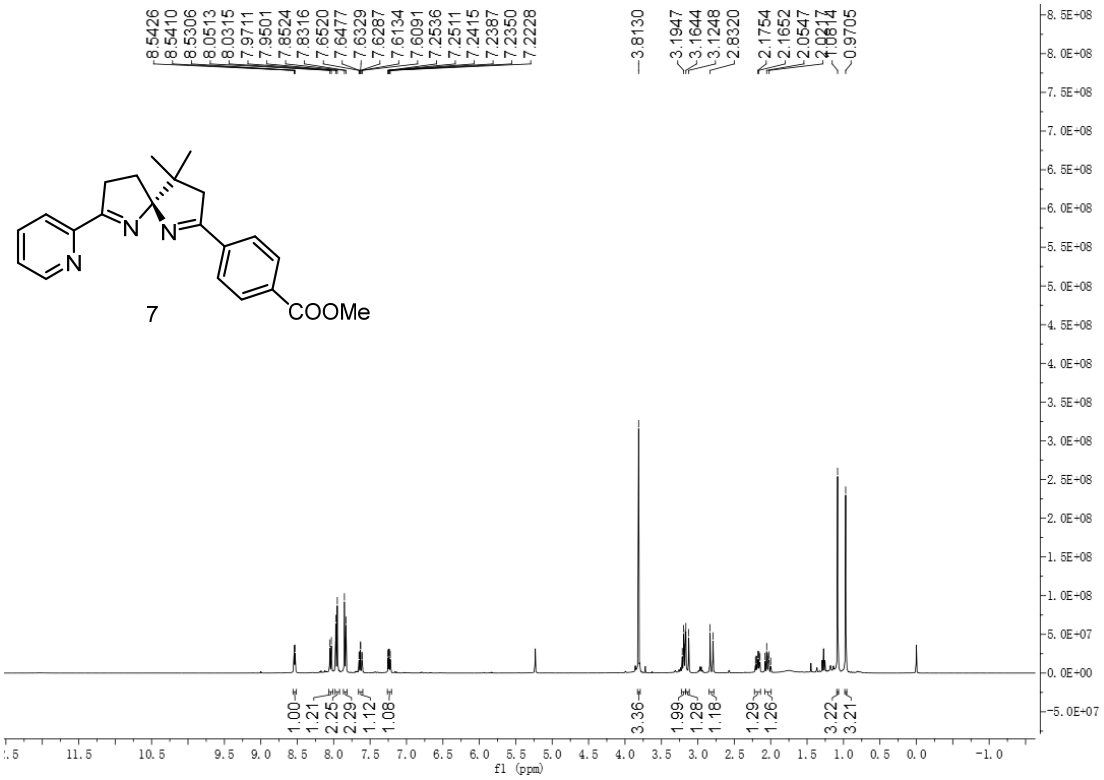
22.0337
21.5730
6
f1 (ppm)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7.9501
7.8524
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7.6520
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7.6329
7.6287
7.6134
7.6091
7.2536
7.2511
7.2415
7.2387
7.2350
7.2228
3.8130
3.1947
3.1644
3.1248
2.8320
2.1754
2.1652
2.0547
2.0217
2.0014
0.9705
7
COOMe
1.00
1.21
2.25
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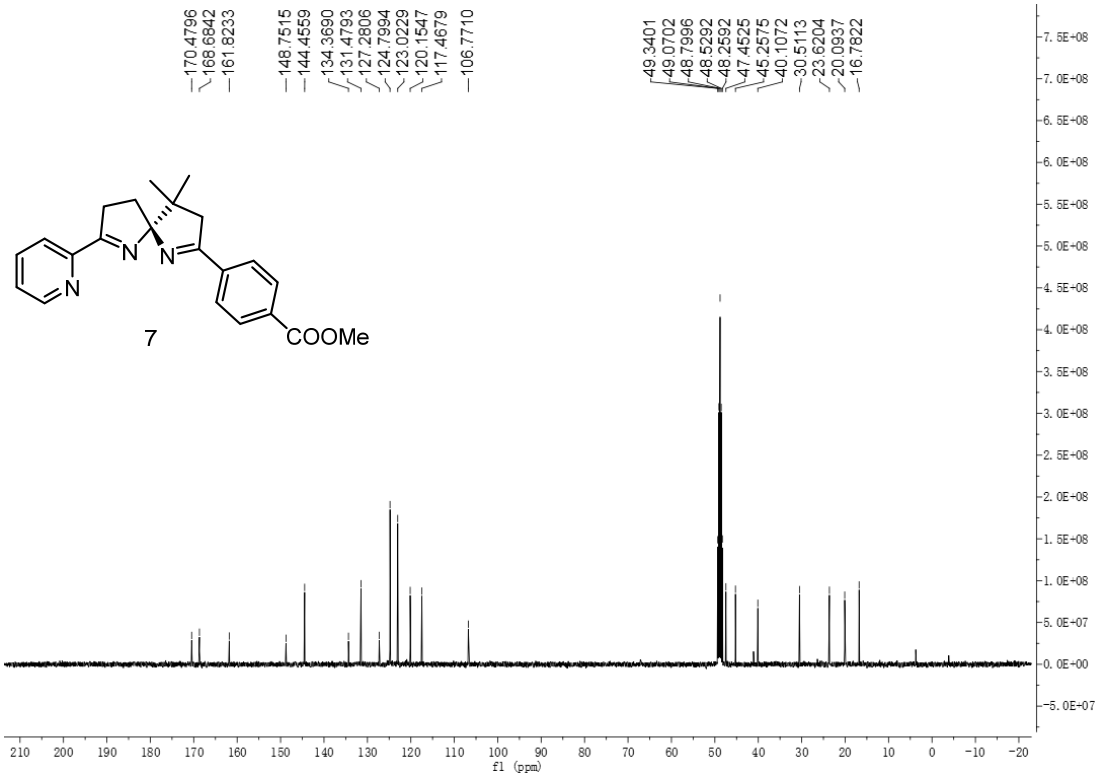
1.08
3.36
1.99
1.28
1.18
1.29
1.26
3.22
3.21
f1 (ppm)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49.3401
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48.5292
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40.1072
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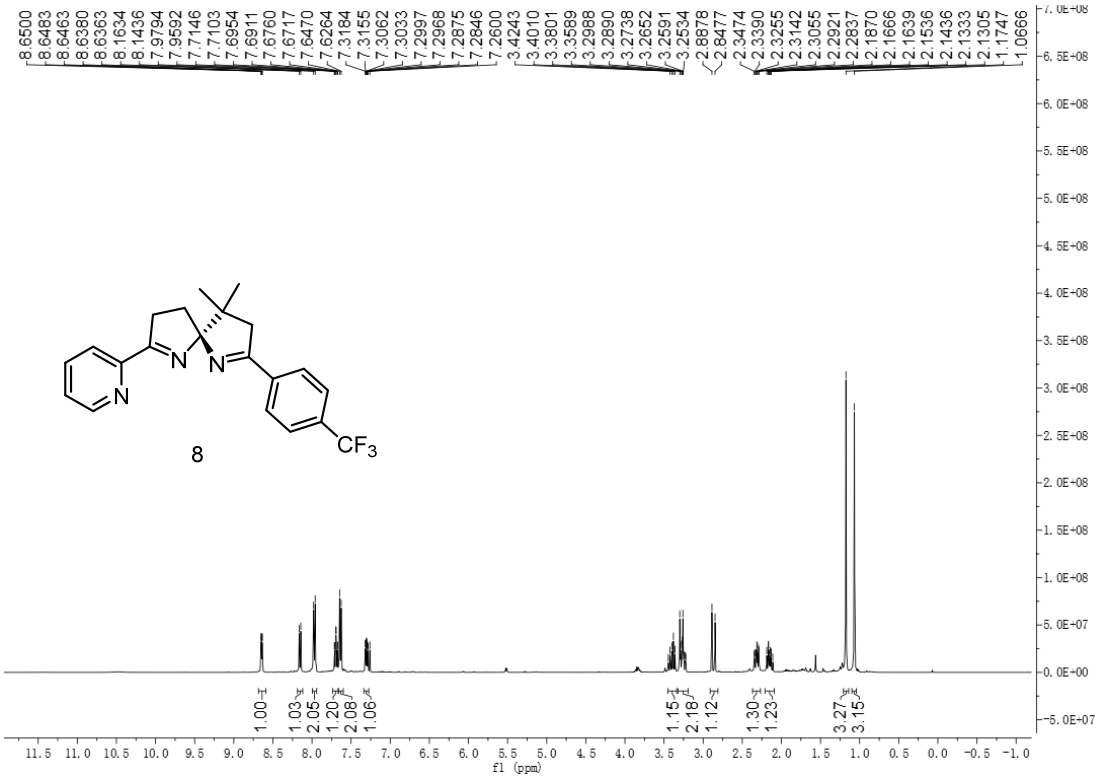
7
COOMe
f1 (ppm)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7.6470
7.6264
7.3184
7.3155
7.3062
7.3033
7.2997
7.2968
7.2875
7.2846
7.2600
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2.1536
2.1436
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1.1747
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1.00
1.03
2.05
1.20
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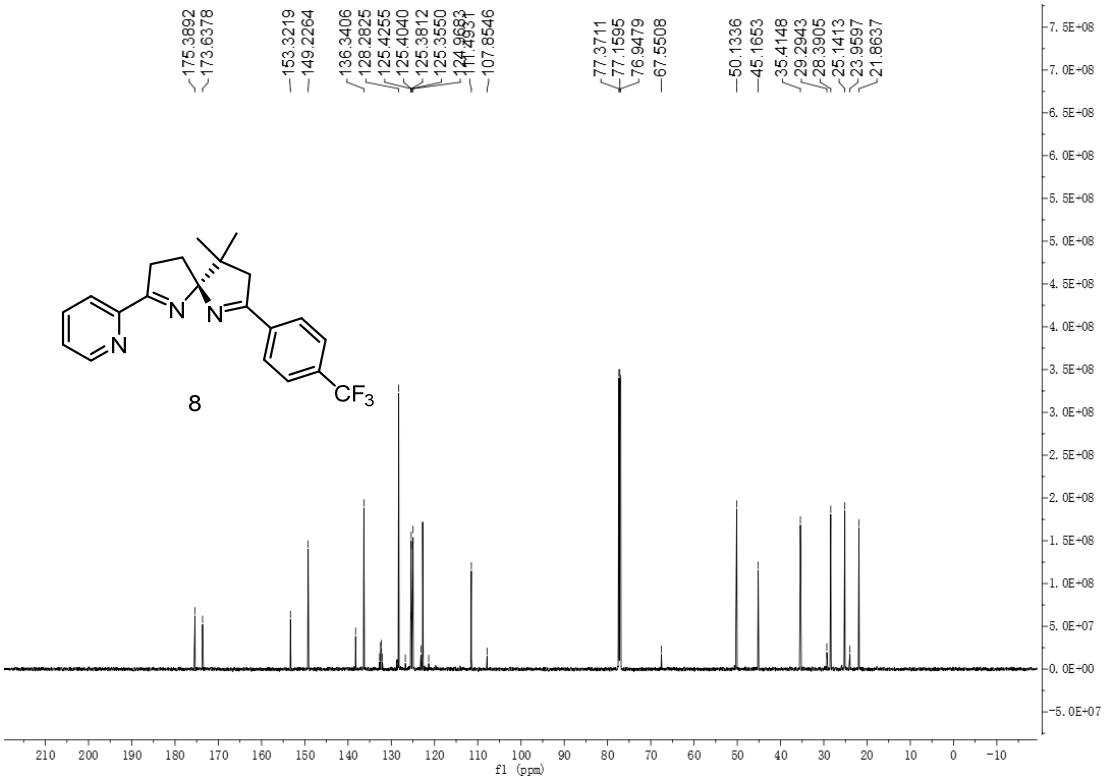
1.15
2.18
1.12
1.30
1.23
3.27
3.15
f1 (ppm)
8
CF3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107.8546
77.3711
77.1595
76.9479
67.5508
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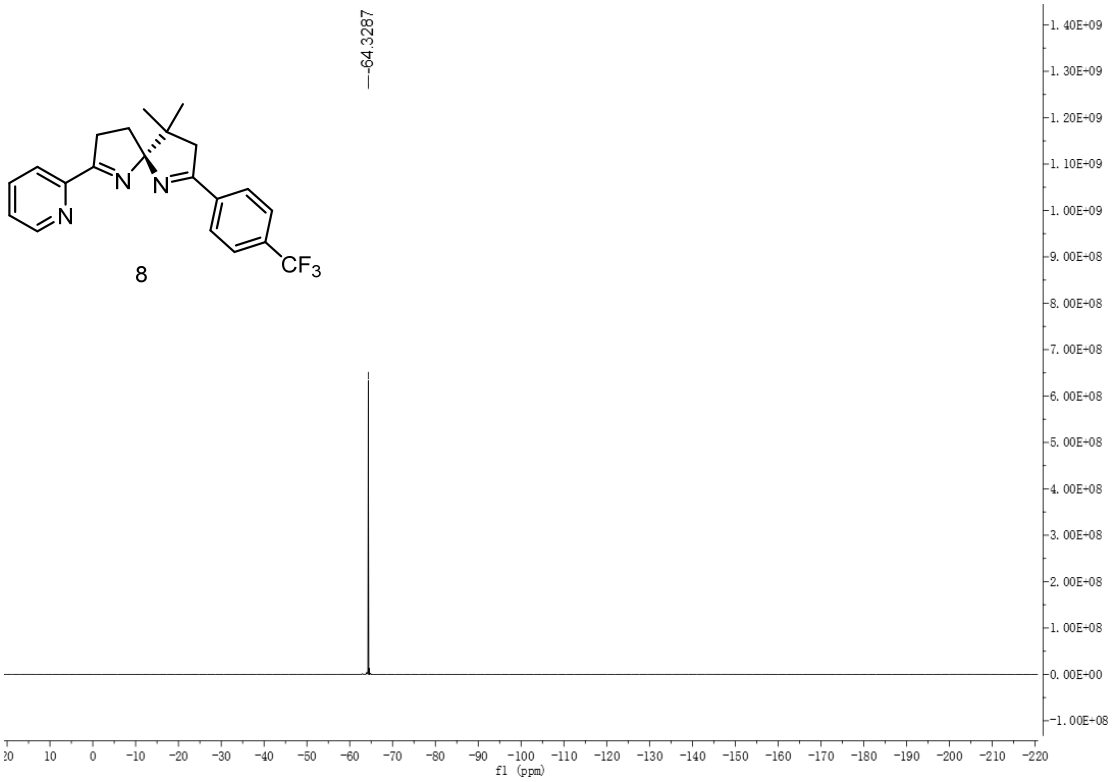
29.2943
28.3905
25.1413
23.9597
21.8637
f1 (ppm)
8
CF3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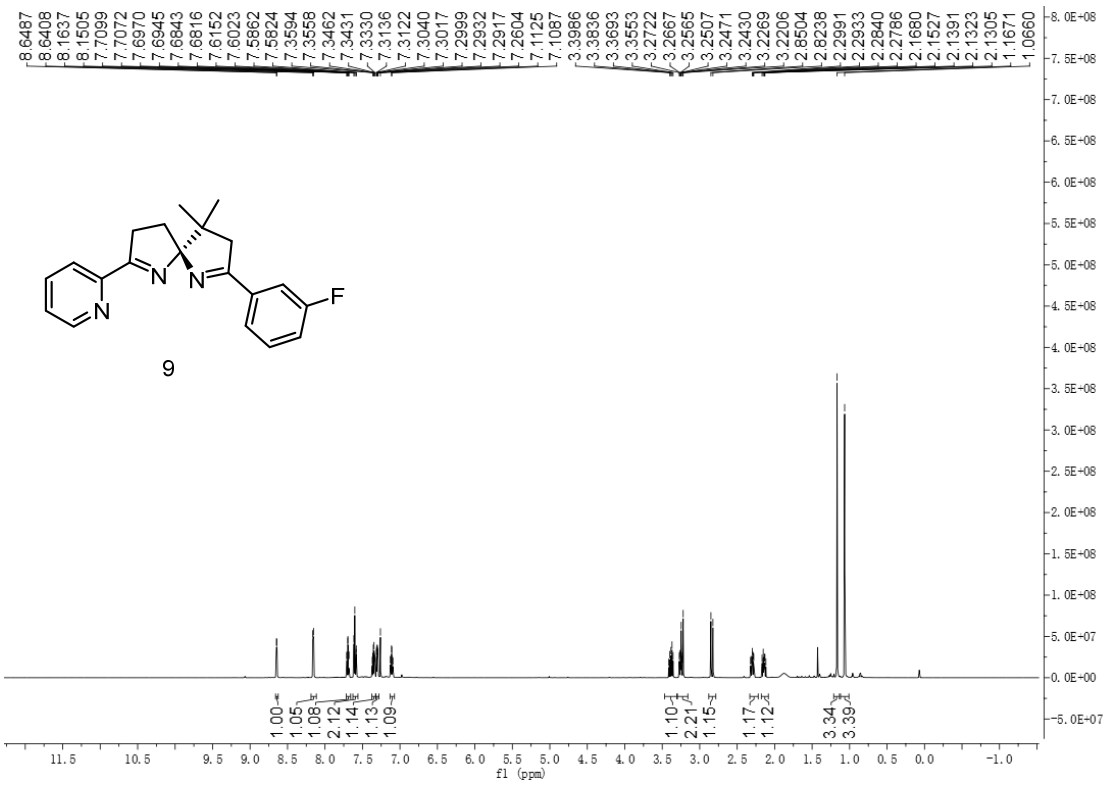
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7.5824
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7.3462
7.3431
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7.3122
7.3040
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7.2999
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F
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1.05
1.08
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1.09
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1.12
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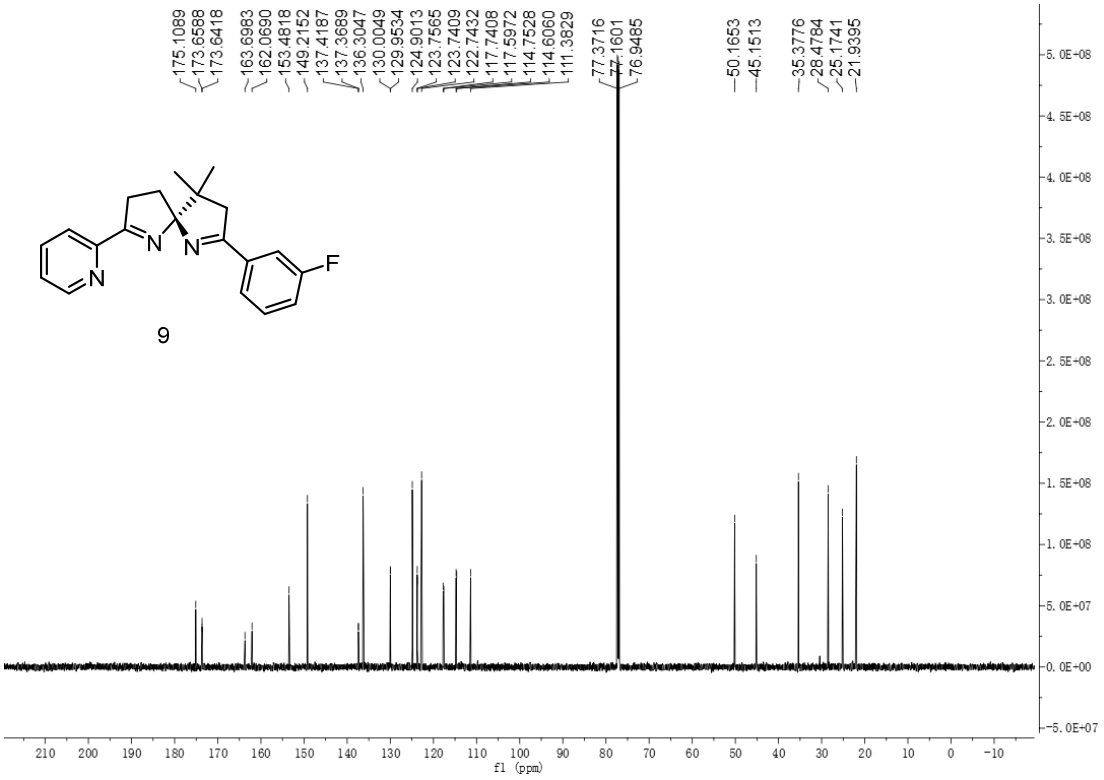
3.39
f1 (ppm)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117.7408
117.5972
114.7528
114.6060
111.3829
77.3716
77.1601
76.9485
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28.4784
25.1741
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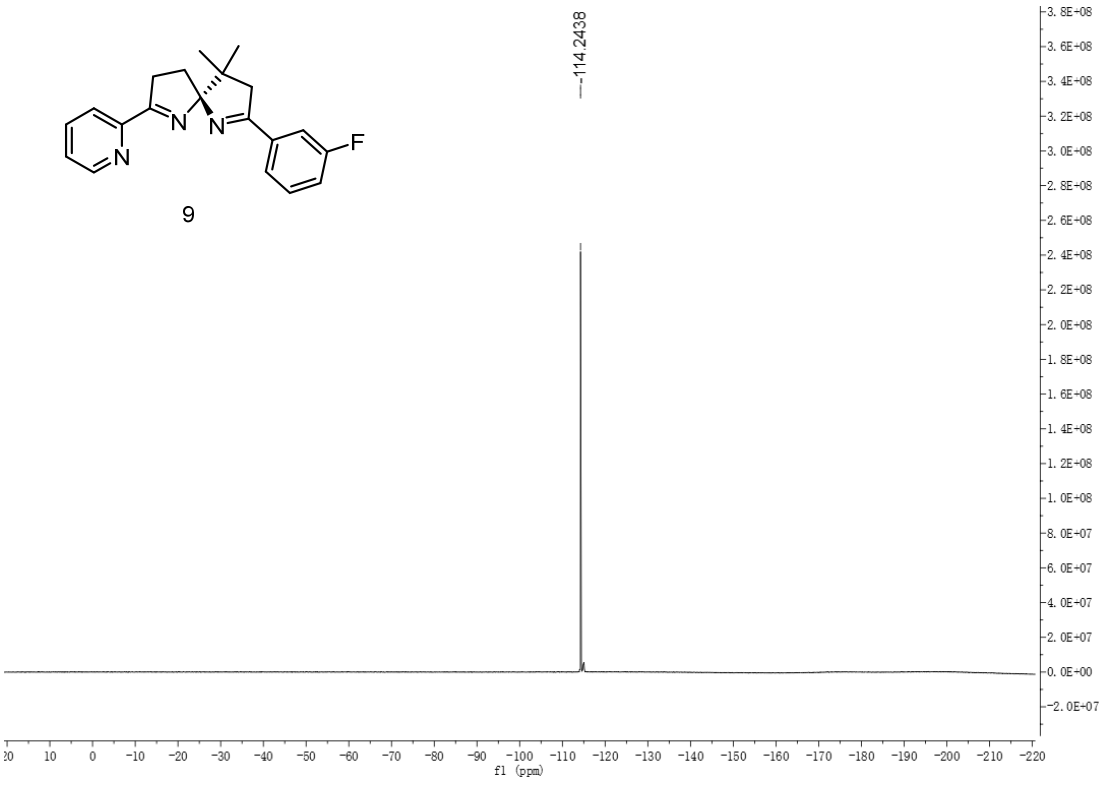
N
N
9
f1 (ppm)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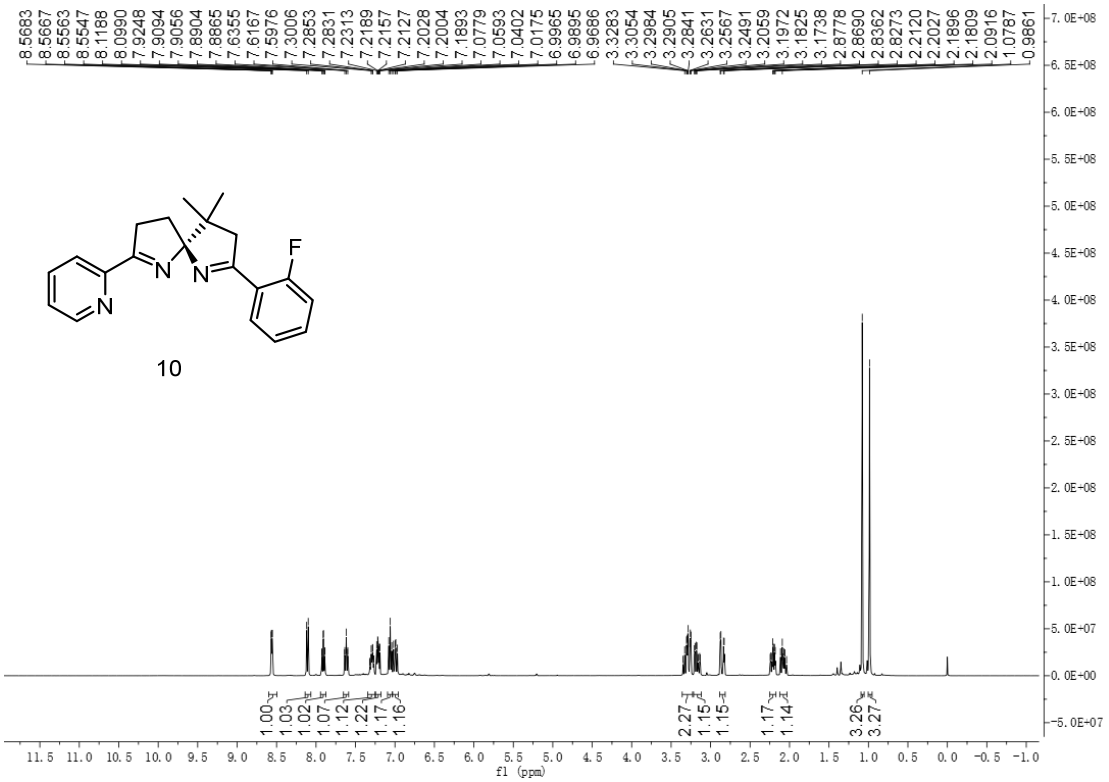
9
f1 (ppm)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7.2313
7.2189
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7.0175
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6.9895
6.9686
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3.2059
3.1972
3.1825
3.1738
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2.8362
2.8273
2.2120
2.2027
2.1896
2.1809
2.0916
1.0787
0.9861
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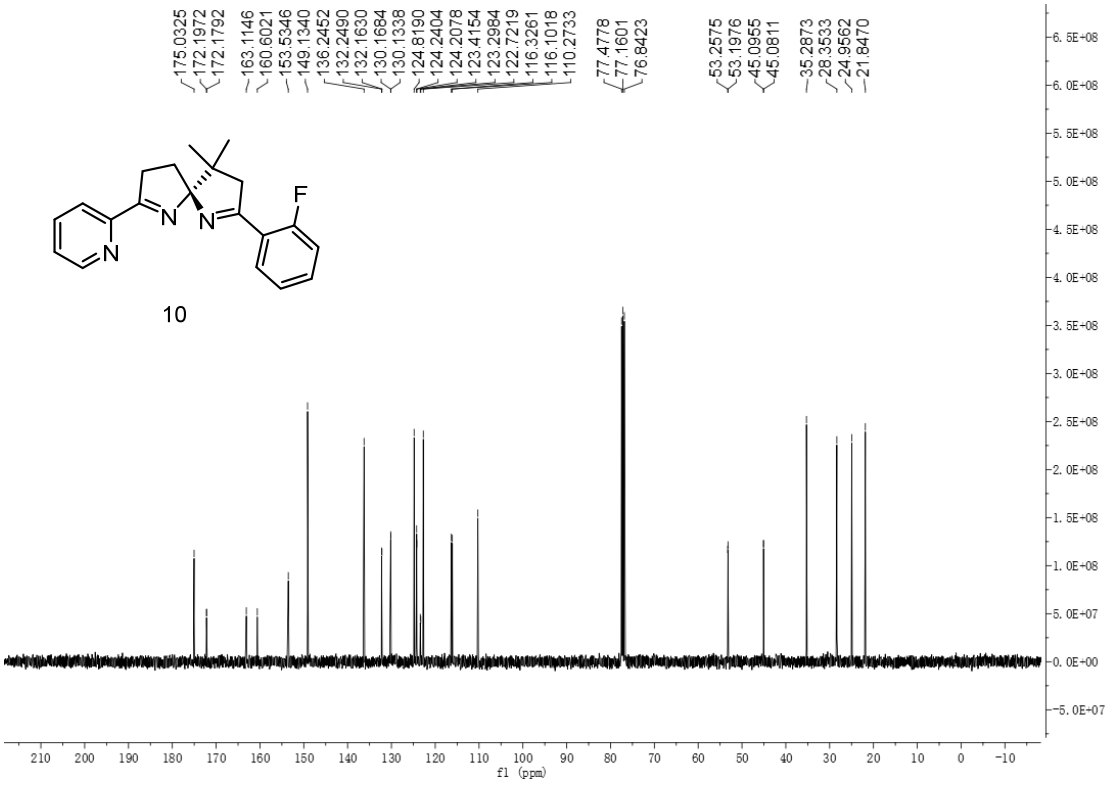
N
N
10
1.00
1.03
1.02
1.07
1.12
1.22
1.17
1.16
2.27
1.15
1.15
1.17
1.14
3.26
3.27
f1 (ppm)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124.2078
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110.2733
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77.1601
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53.2575
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28.3533
24.9562
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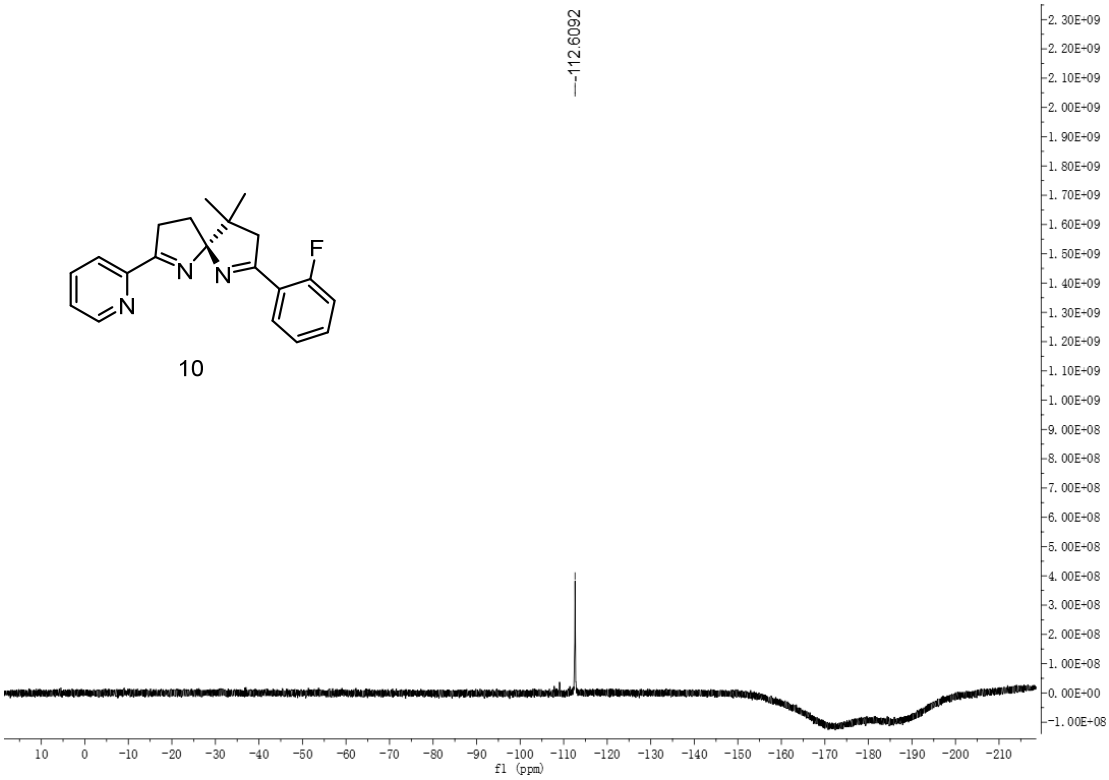
N
10
f1 (ppm)


—112.6092
F
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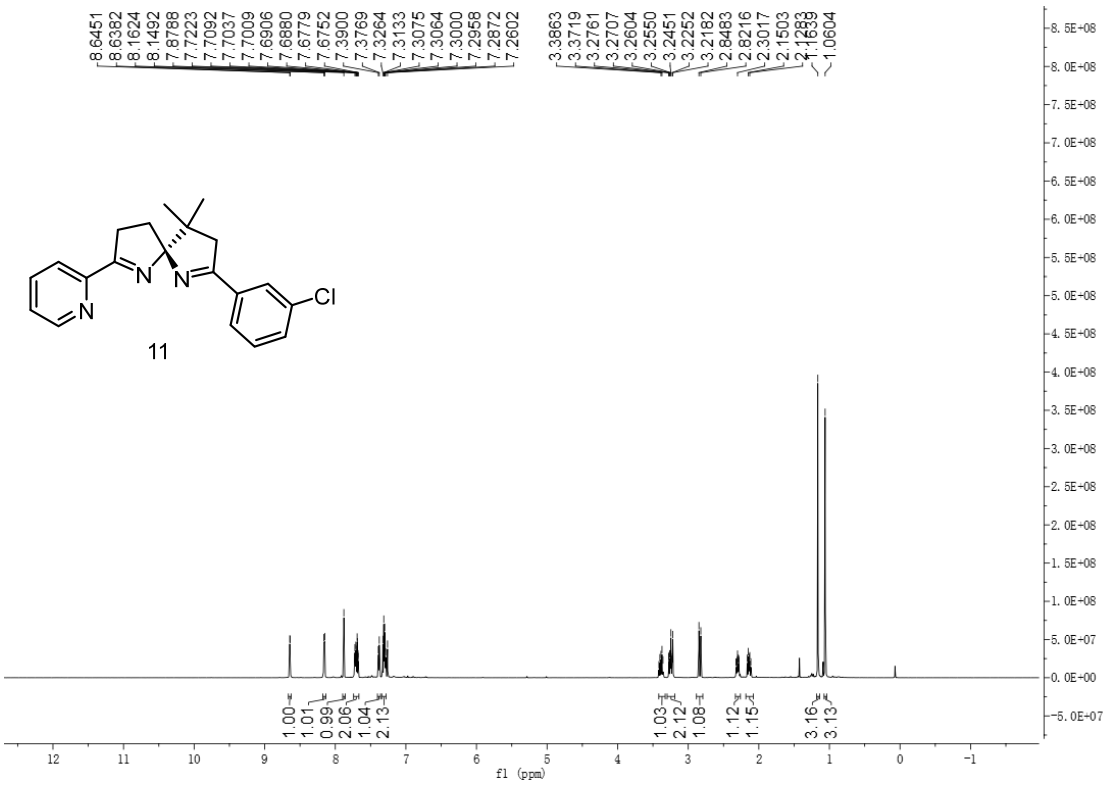
N
N
10
f1 (ppm)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7.6779
7.6752
7.3900
7.3769
7.3264
7.3133
7.3075
7.3064
7.3000
7.2958
7.2872
7.2602
3.3863
3.3719
3.2761
3.2707
3.2604
3.2550
3.2451
3.2252
3.2182
2.8483
2.8216
2.3017
2.1503
1.0604
Cl
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N
N
11
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1.01
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1.03
2.12
1.08
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1.15
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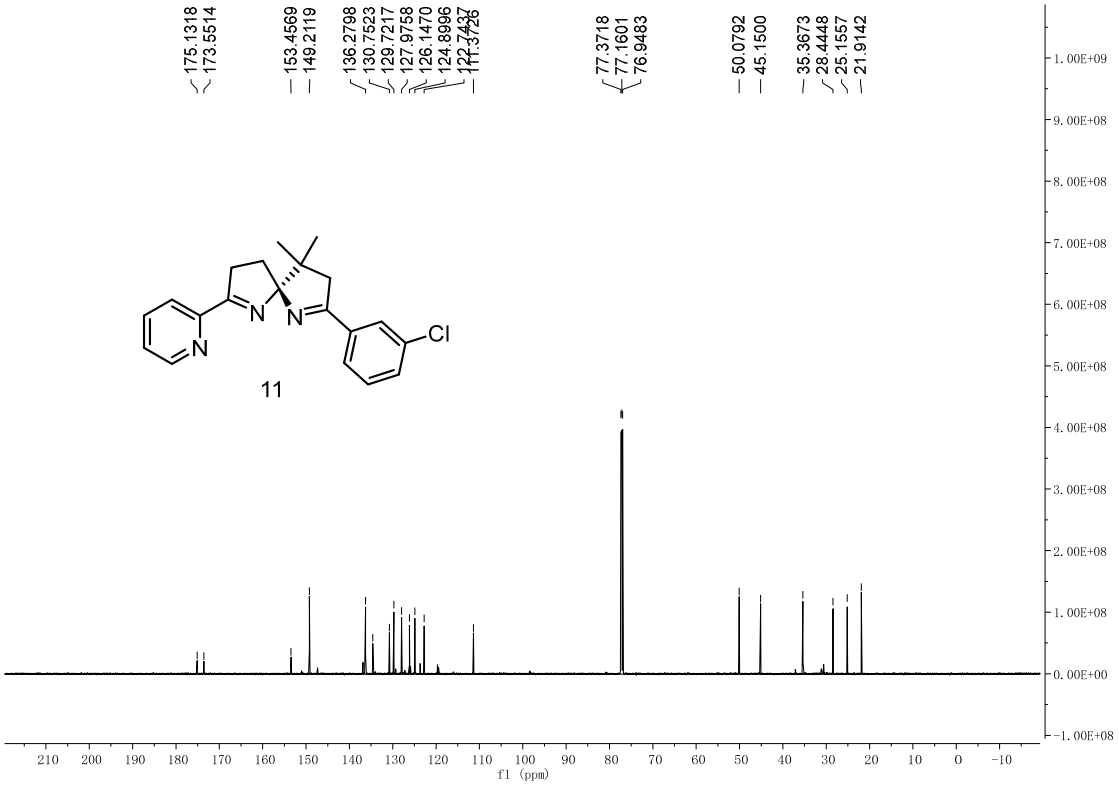
f1 (ppm)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122.7437
111.3726
77.3718
77.1601
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25.1557
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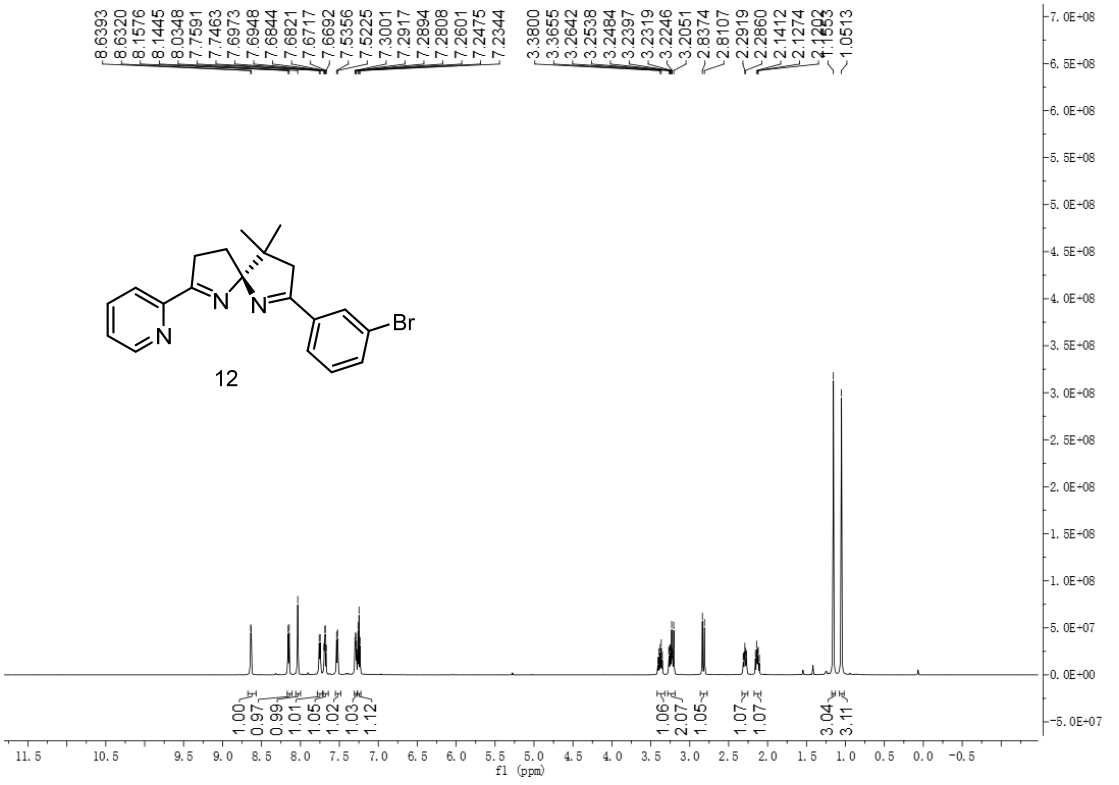
Cl
11
f1 (ppm)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7.2475
7.2344
3.3800
3.3655
3.2642
3.2538
3.2484
3.2397
3.2319
3.2246
3.2051
2.8374
2.8107
2.2919
2.2860
2.1412
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N
N
N
Br
12
1.00
0.97
0.99
1.01
1.05
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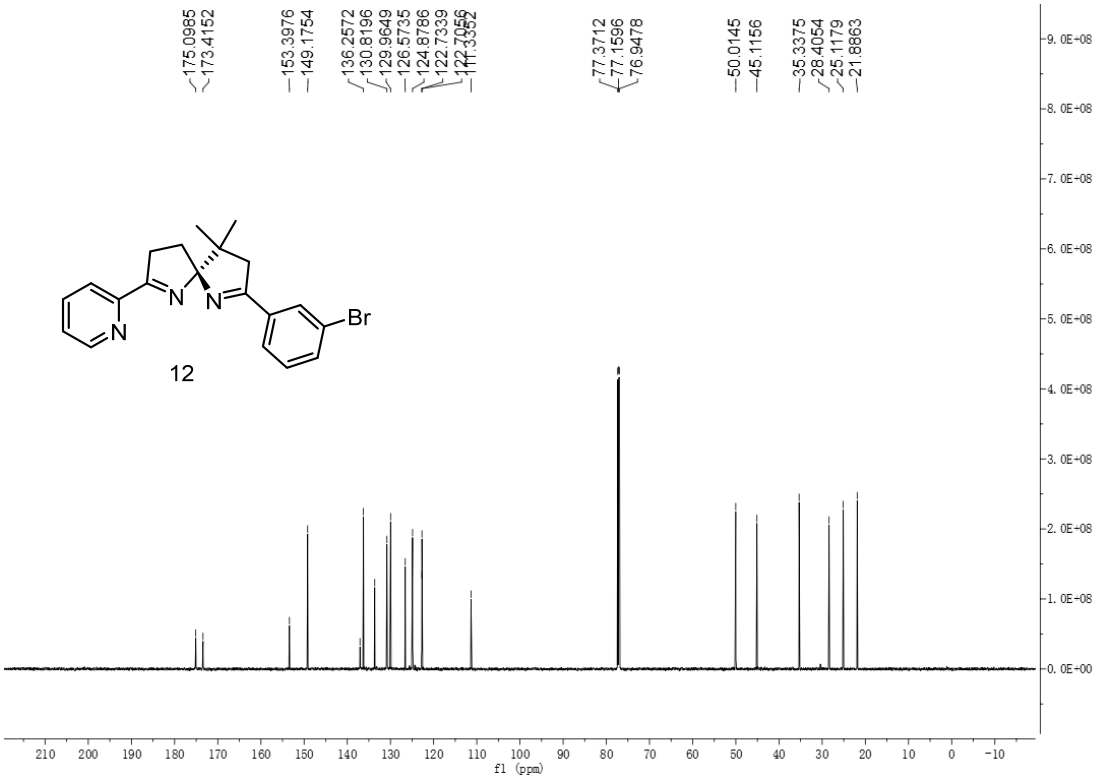
1.12
1.06
2.07
1.05
1.07
1.07
3.04
3.11
f1 (ppm)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76.9478
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25.1179
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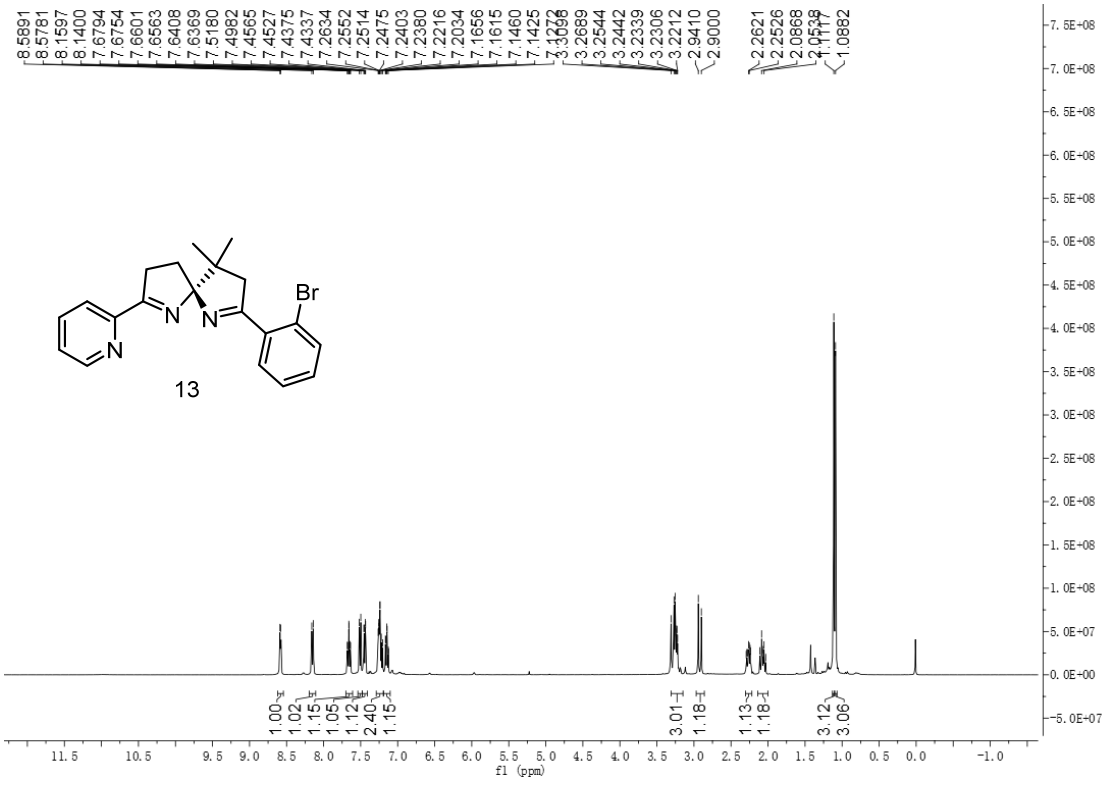
N
12
f1 (ppm)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7.2403
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7.1615
7.1460
7.1425
3.2689
3.2544
3.2442
3.2339
3.2306
3.2212
2.9410
2.9000
2.2621
2.2526
2.0868
2.0538
1.1747
1.0882
1.00
1.02
1.15
1.05
1.12
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1.15
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1.13
1.18
3.12
3.06
Br
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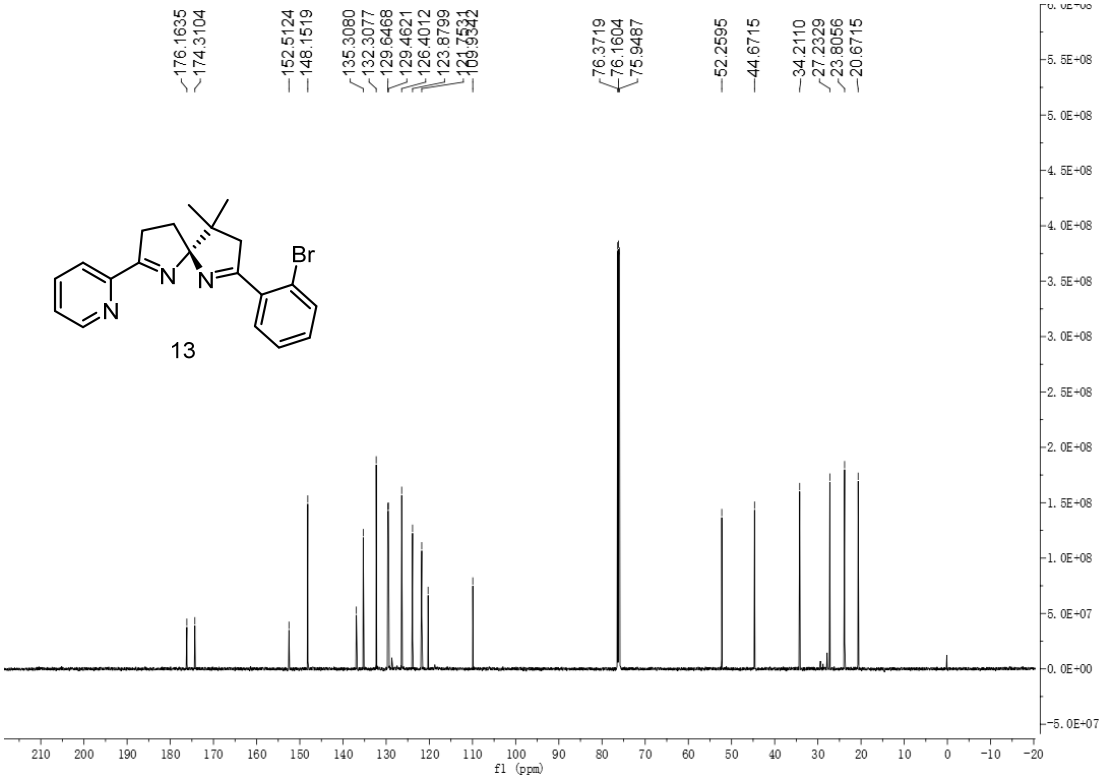
13
f1 (ppm)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123.8799
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76.3719
76.1604
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34.2110
27.2329
23.8056
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Br
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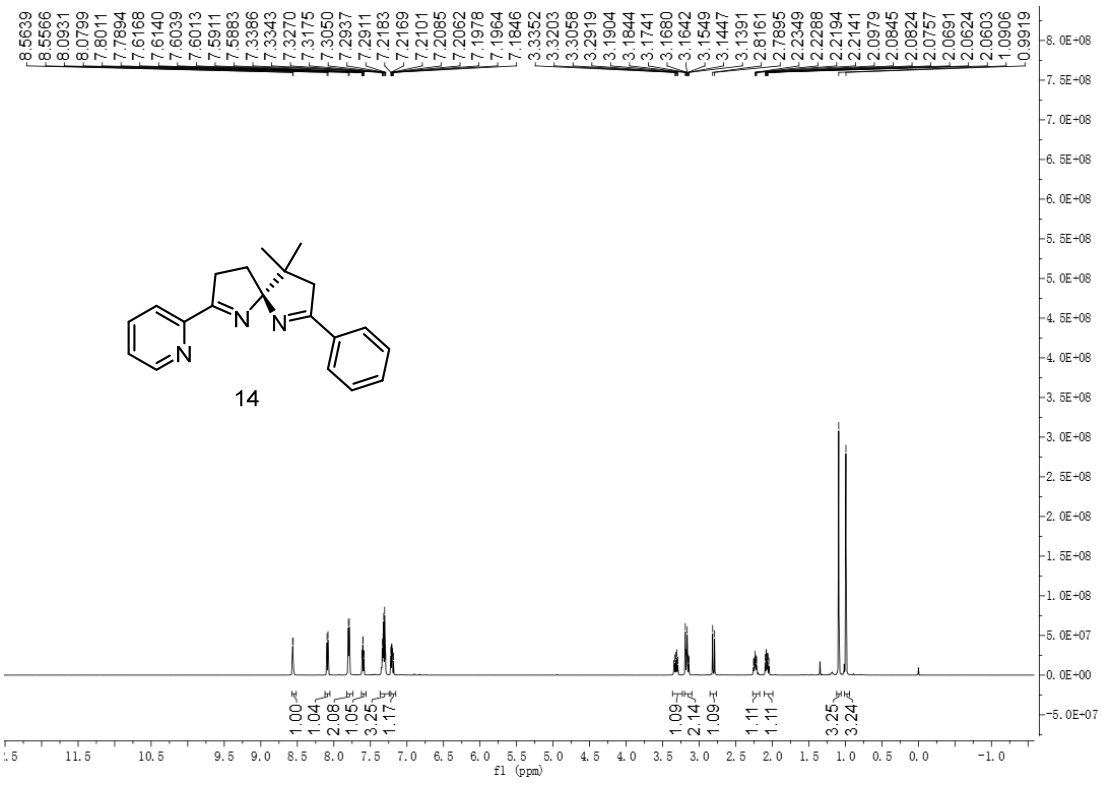
N
N
13
f1 (ppm)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7.5883
7.3386
7.3343
7.3270
7.3175
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7.2937
7.2911
7.2183
7.2169
7.2101
7.2085
7.2062
7.1978
7.1964
7.1846
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3.1904
3.1844
3.1741
3.1680
3.1642
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2.7895
2.2349
2.2288
2.2194
2.2141
2.0979
2.0845
2.0824
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2.0603
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1.04
2.08
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1.09
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3.24
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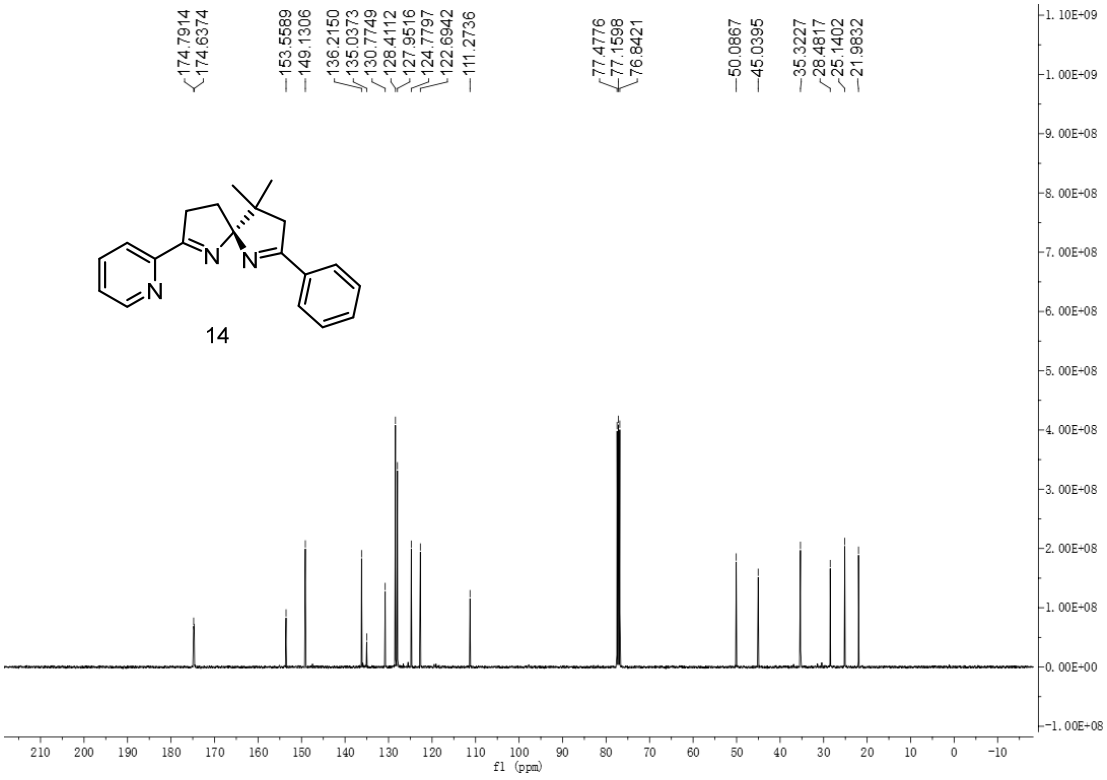
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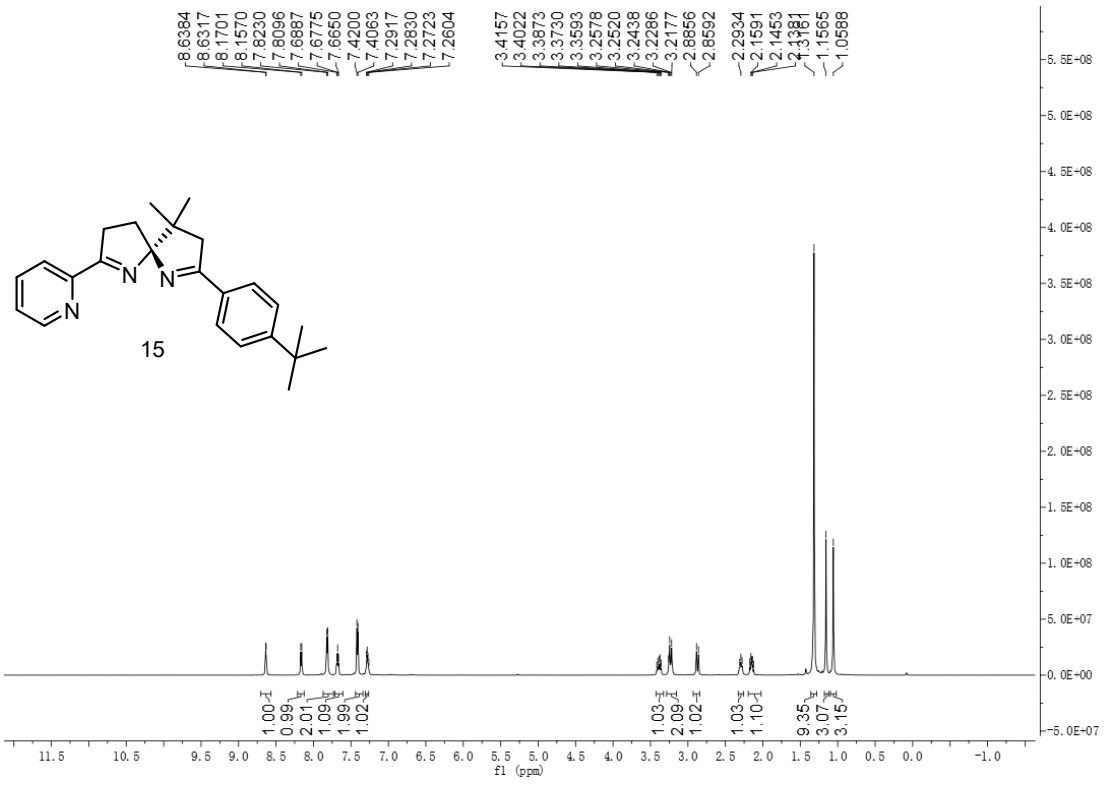
f1 (ppm)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3.3730
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3.2520
3.2438
3.2286
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2.2934
2.1591
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2.1181
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2.01
1.09
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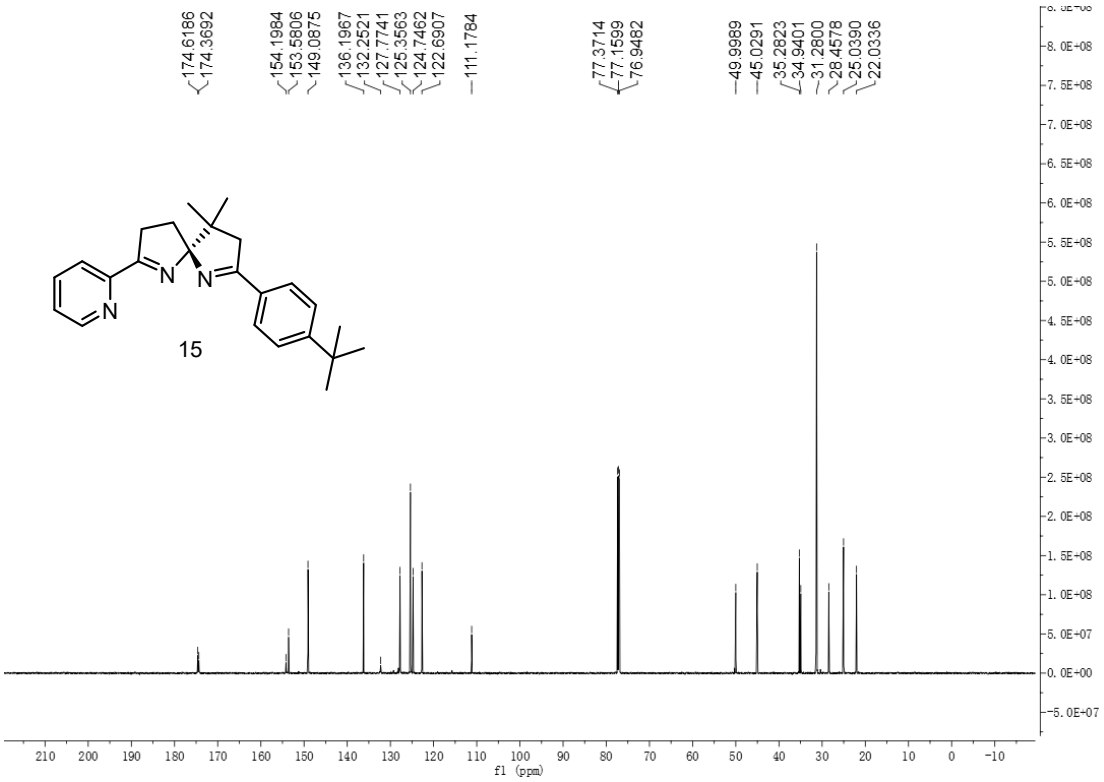
2.09
1.02
1.03
1.10
9.35
3.07
3.15
15
f1 (ppm)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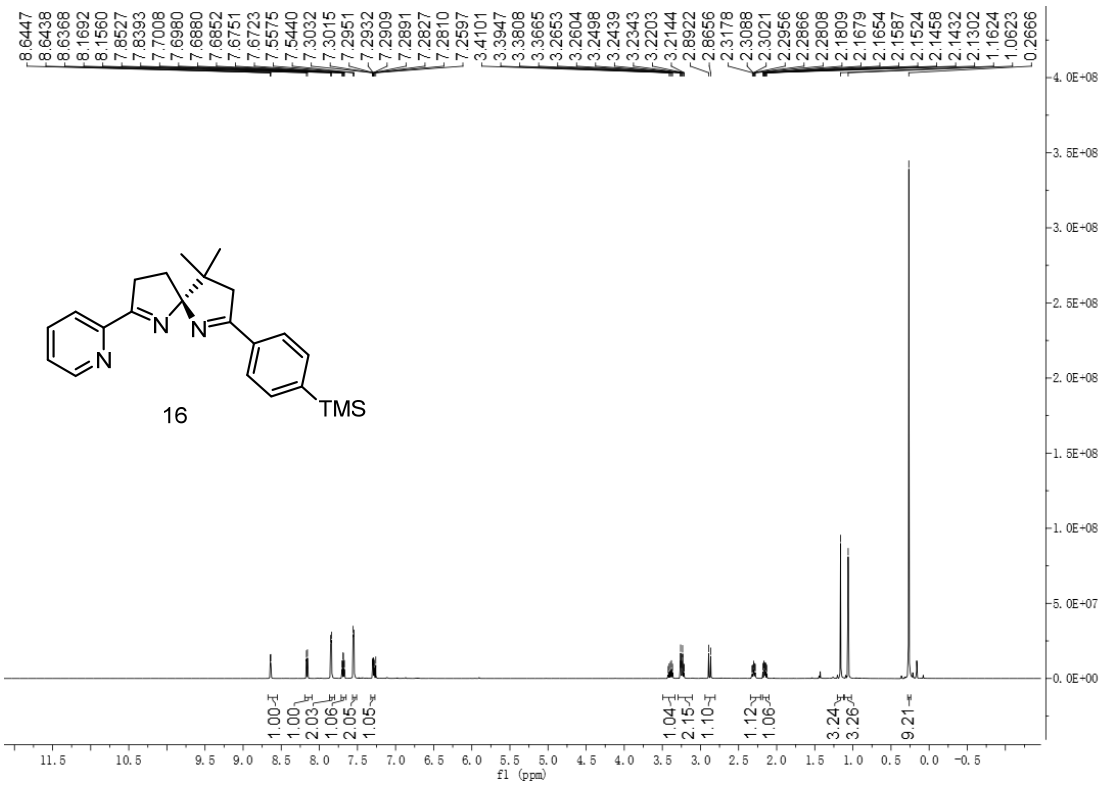
f1 (ppm)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2.1809
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2.1524
2.1458
2.1432
2.1302
1.1624
1.0623
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TMS
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1.00
2.03
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1.04
2.15
1.10
1.12
1.06
3.24
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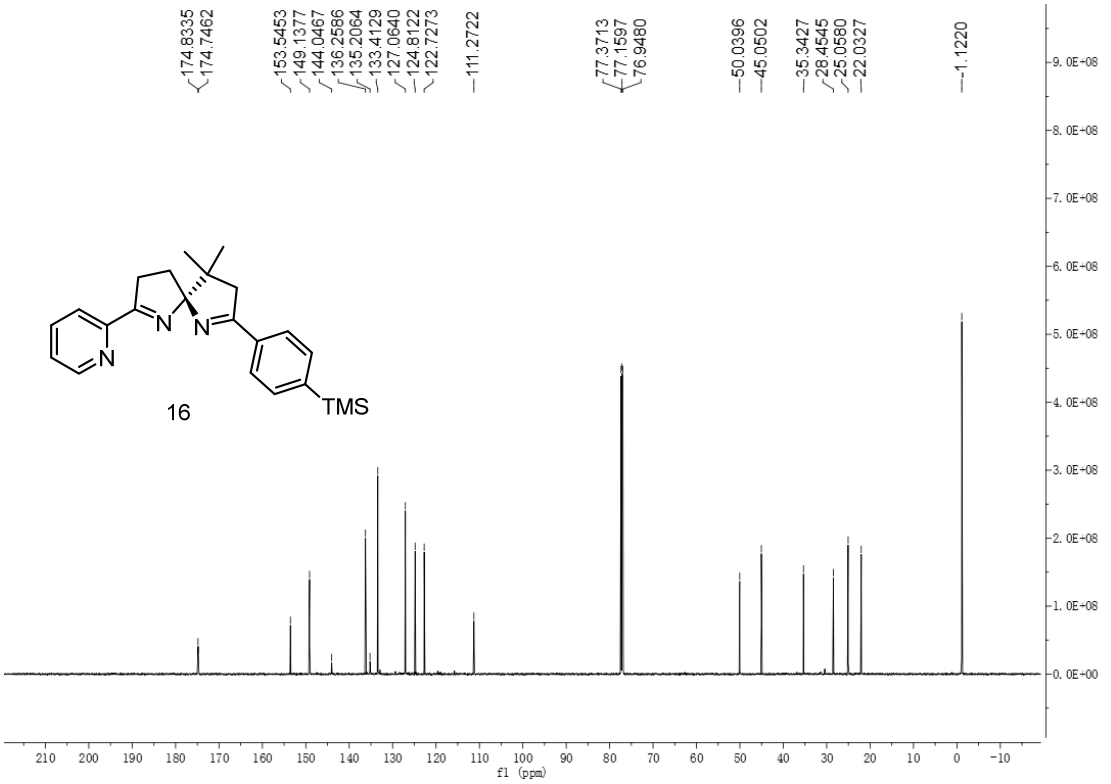
f1 (ppm)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77.1597
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22.0327
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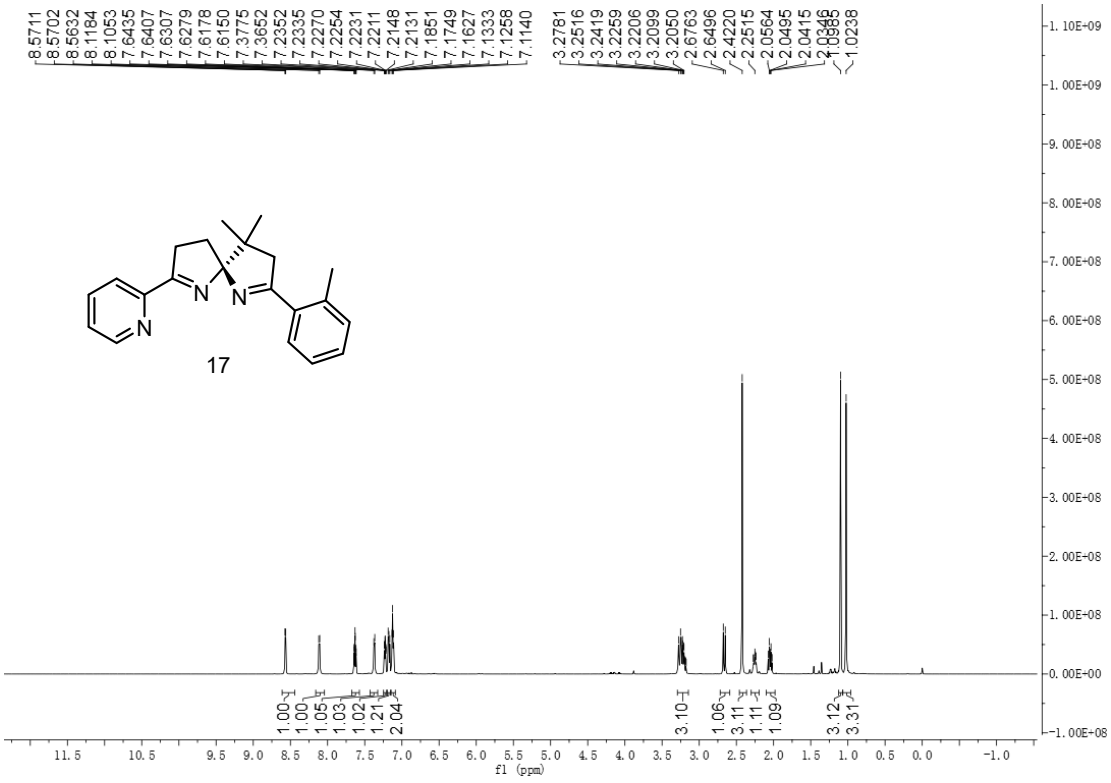
16
TMS
f1 (ppm)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1.00
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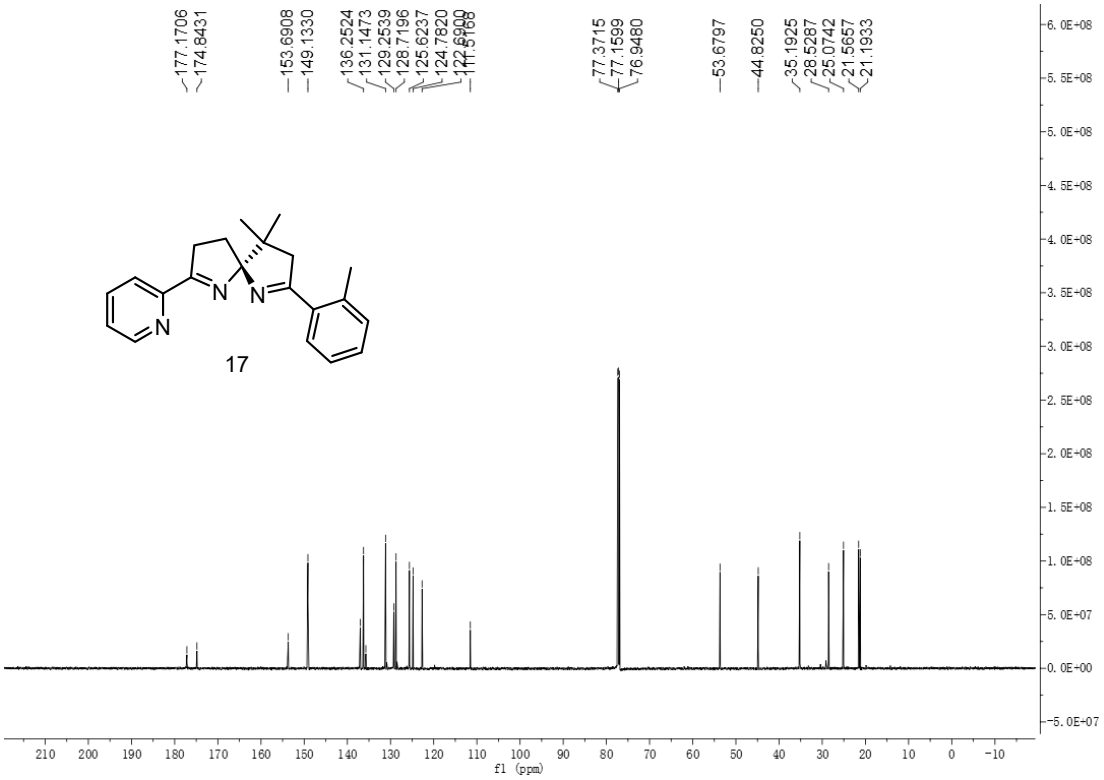
1.11
1.09
3.12
3.31
f1 (ppm)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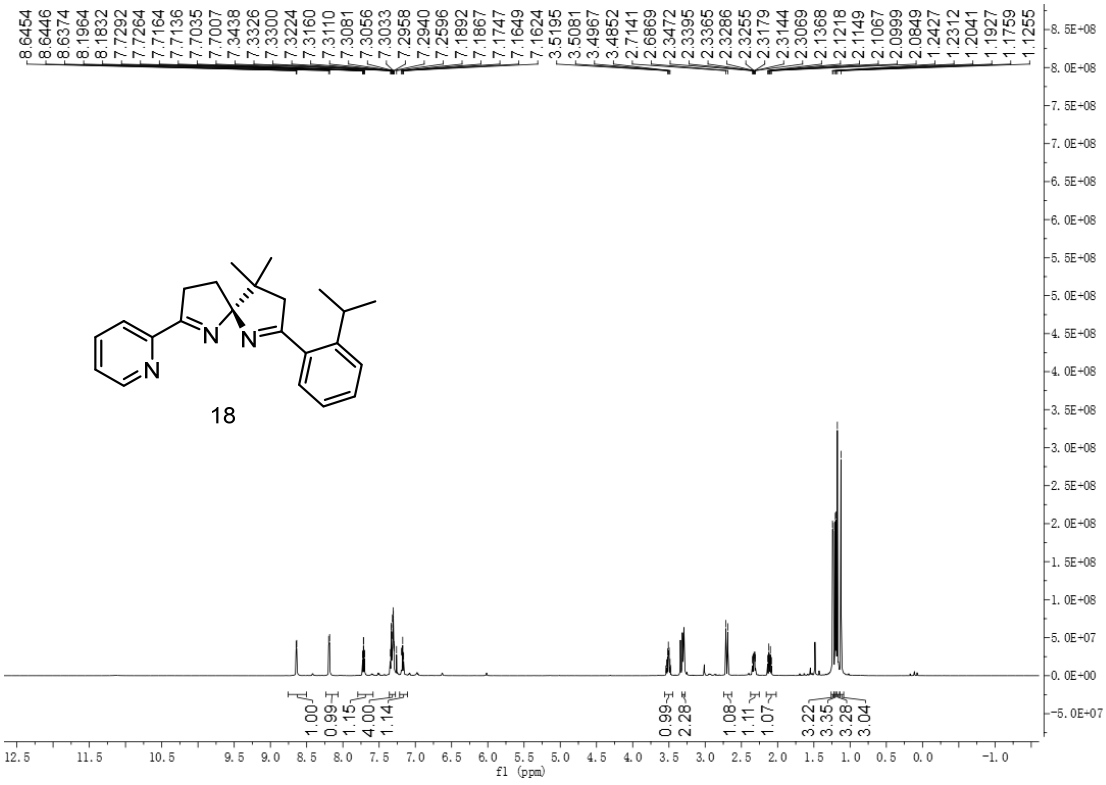
21.1933
17
f1 (ppm)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1.11
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3.35
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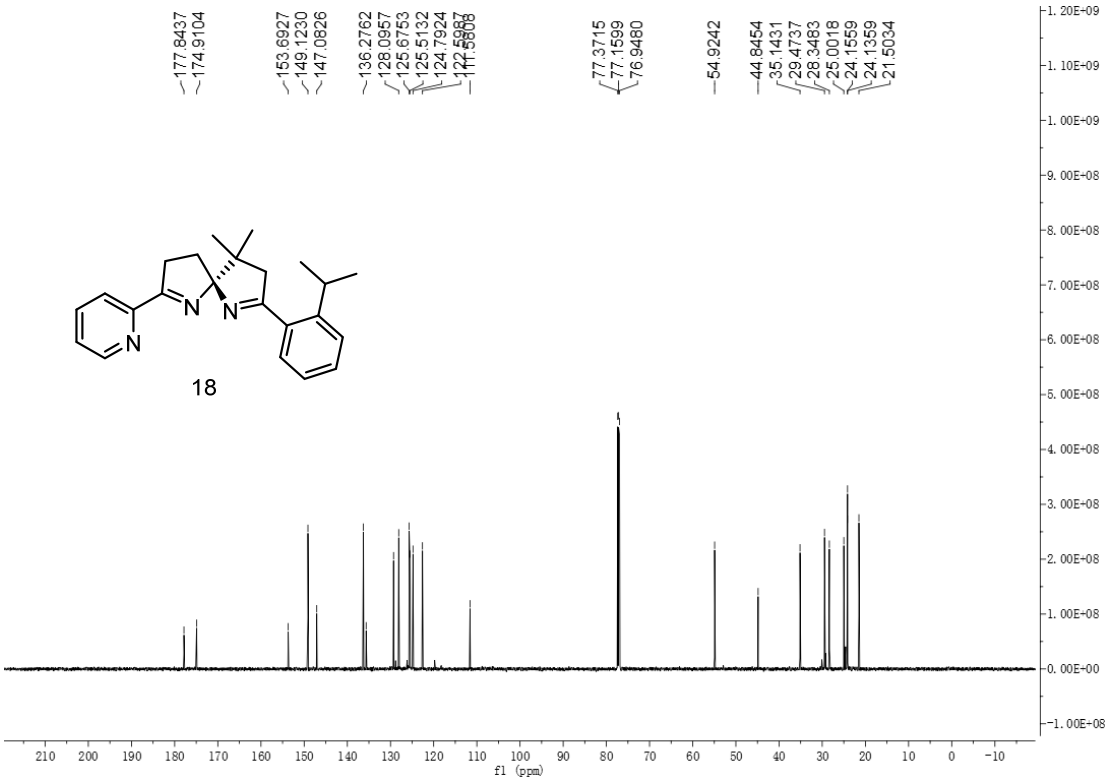
3.04
f1 (ppm)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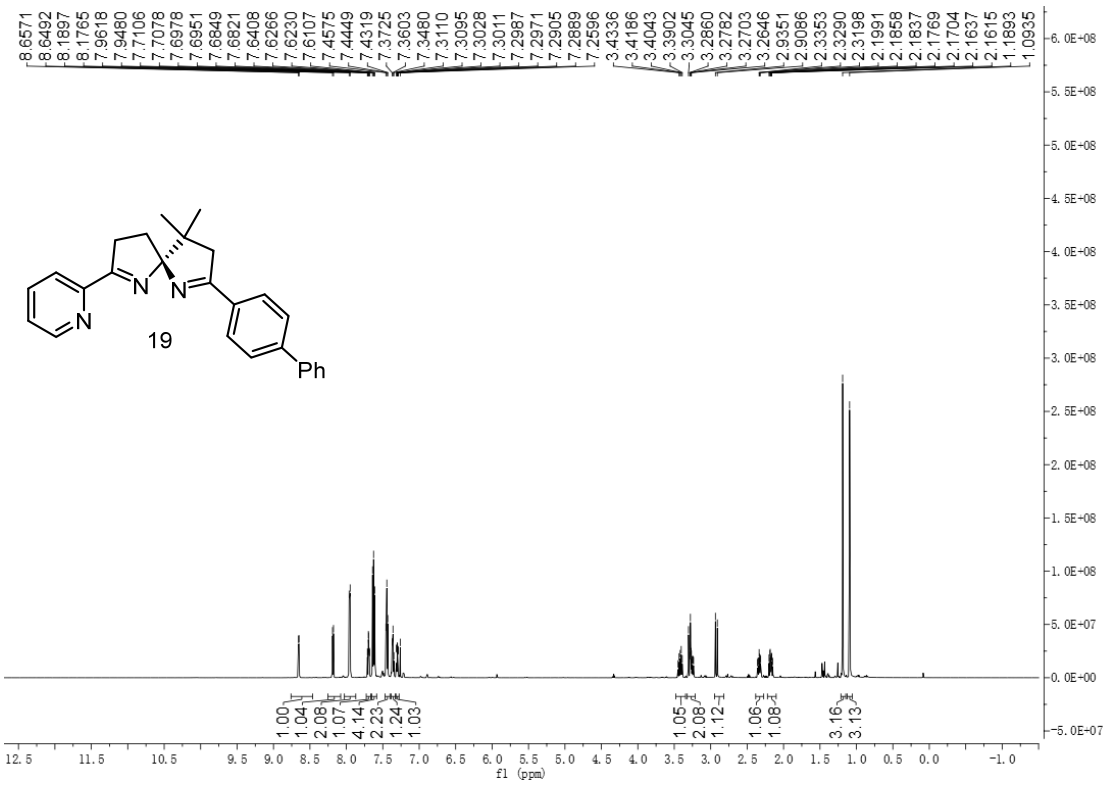
18
f1 (ppm)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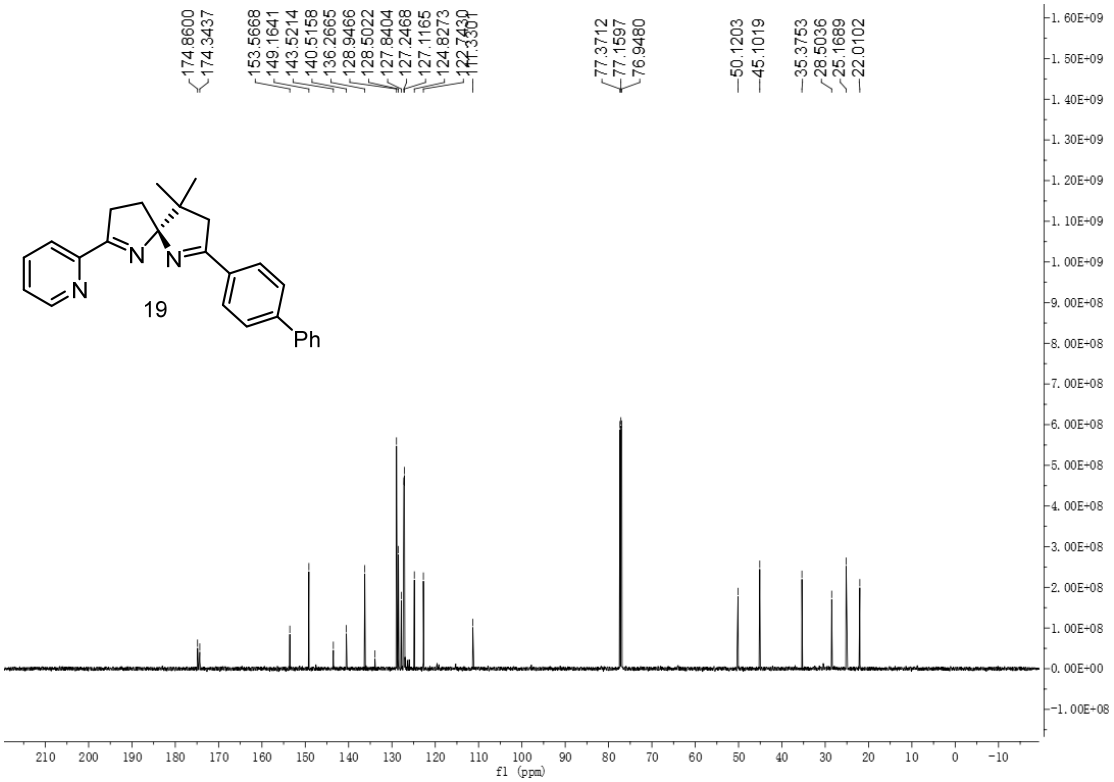
3.13
f1 (ppm)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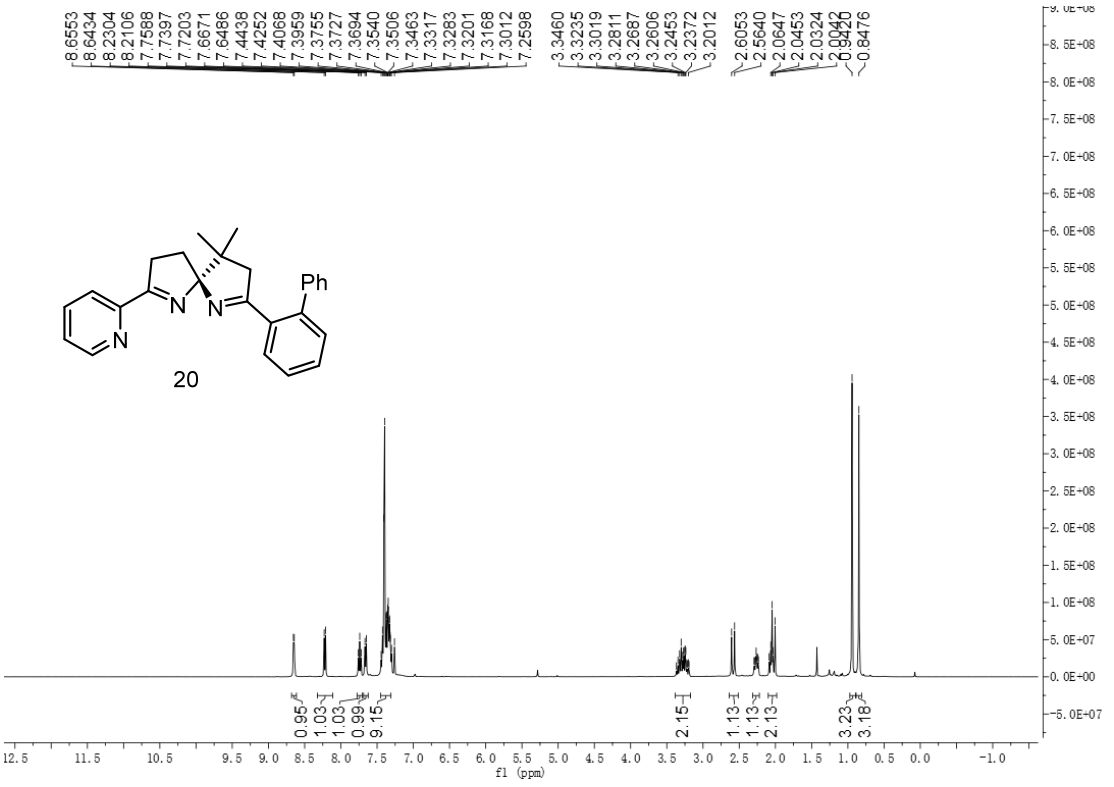
19
Ph
f1 (ppm)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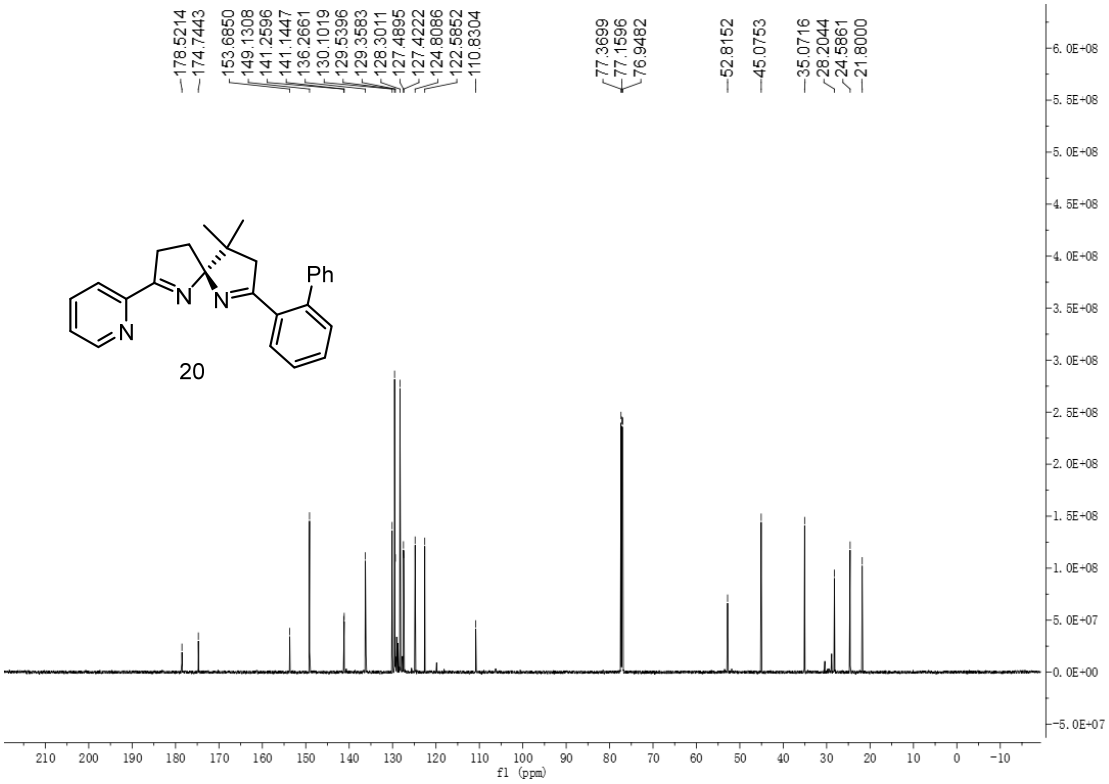
20
Ph
f1 (ppm)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20
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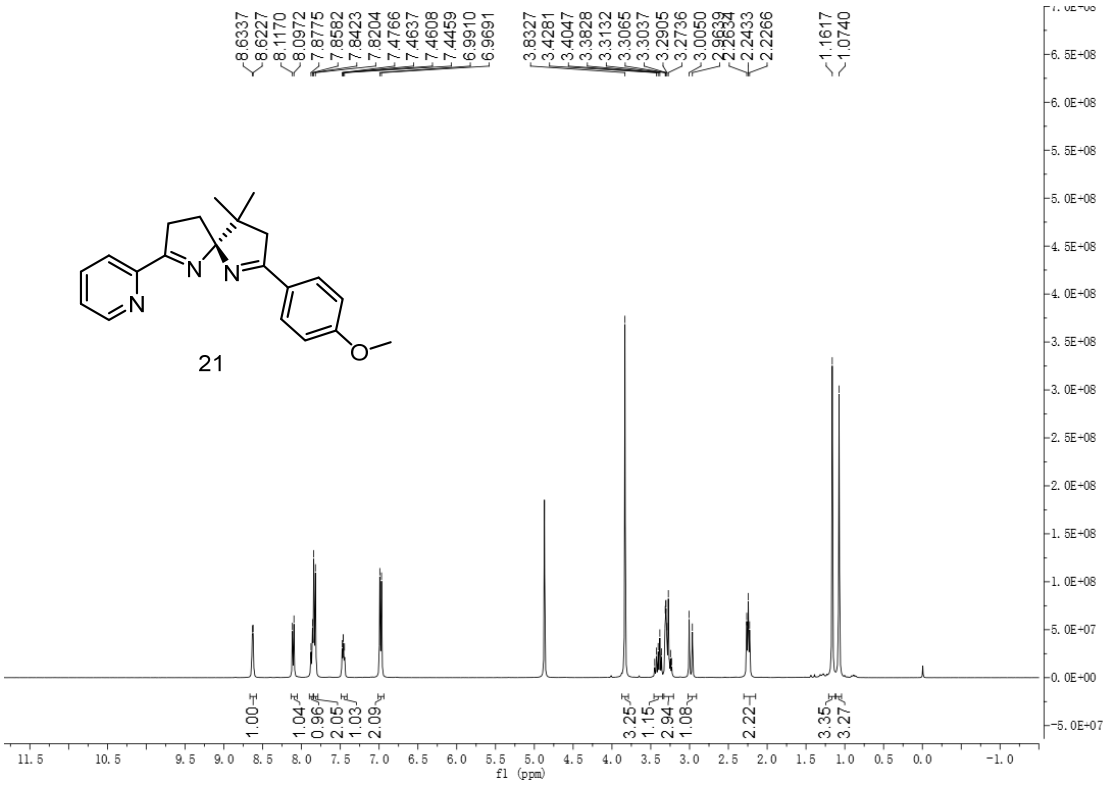
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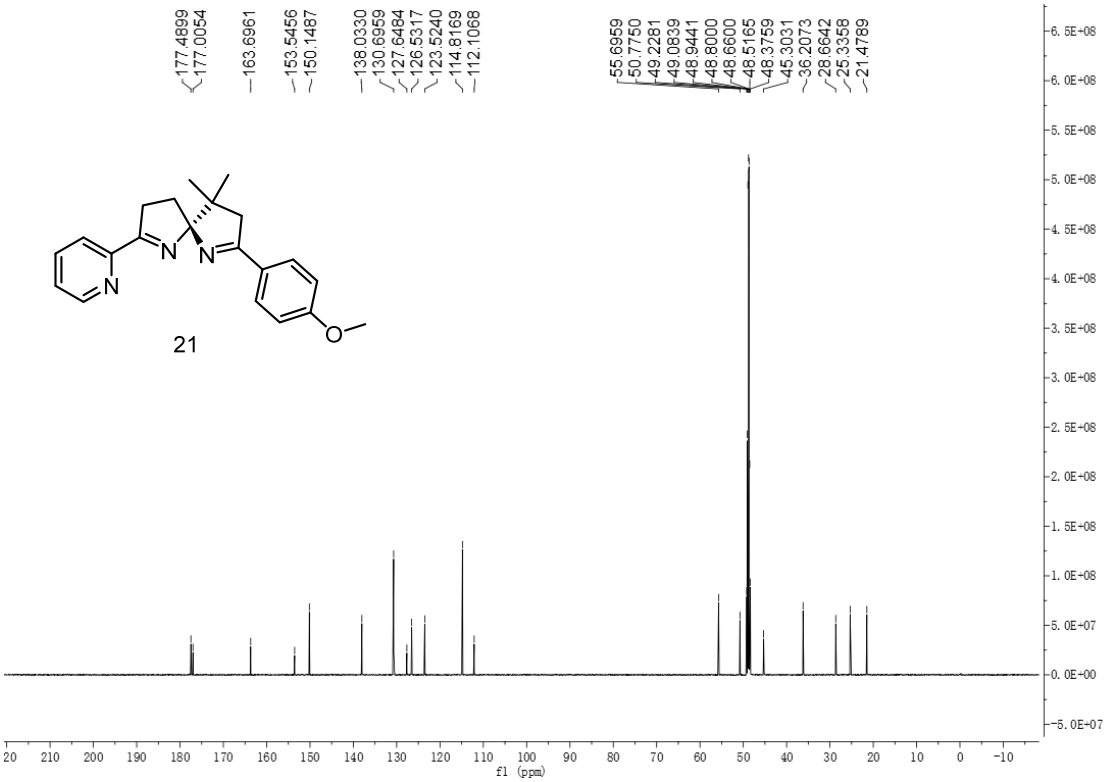
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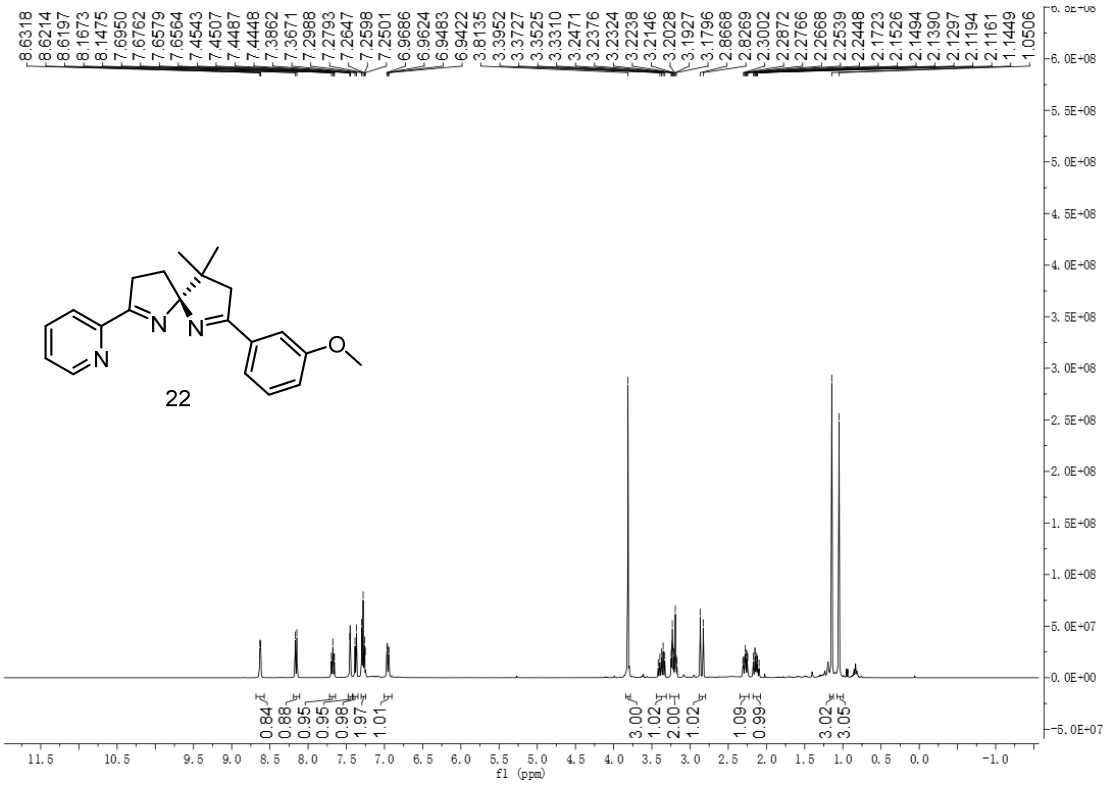
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3.3310
3.2471
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3.2238
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2.8269
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2.1390
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2.1449
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0.95
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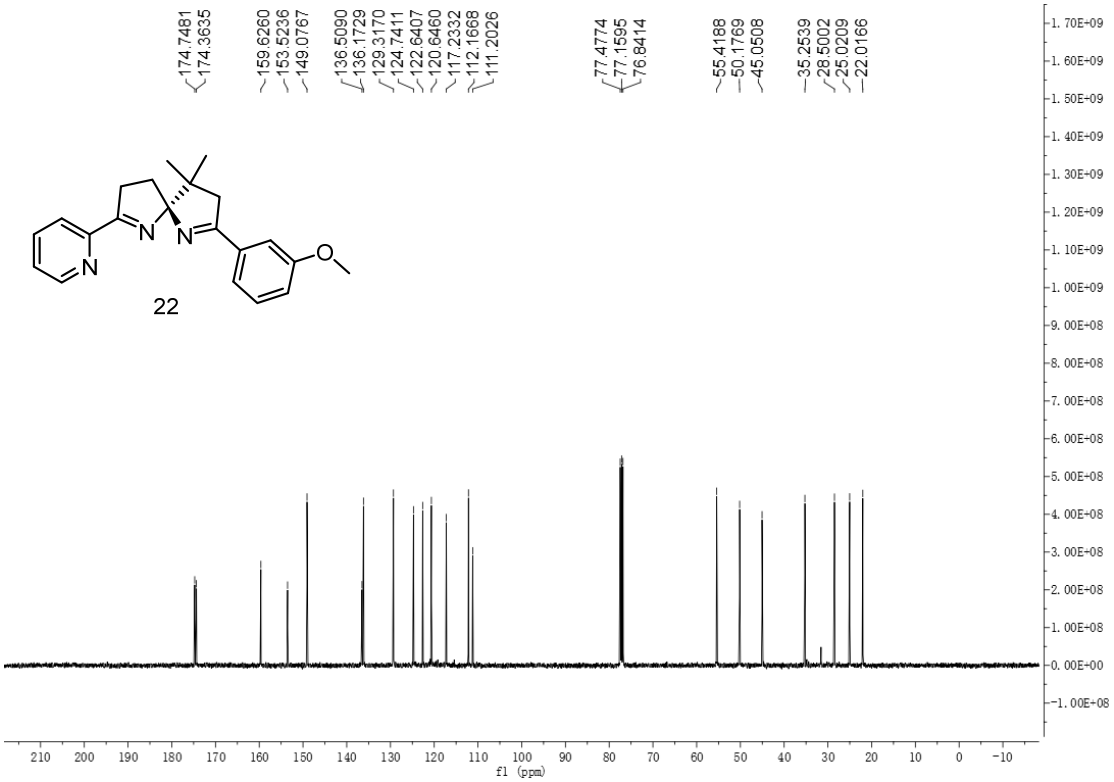
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112.1668
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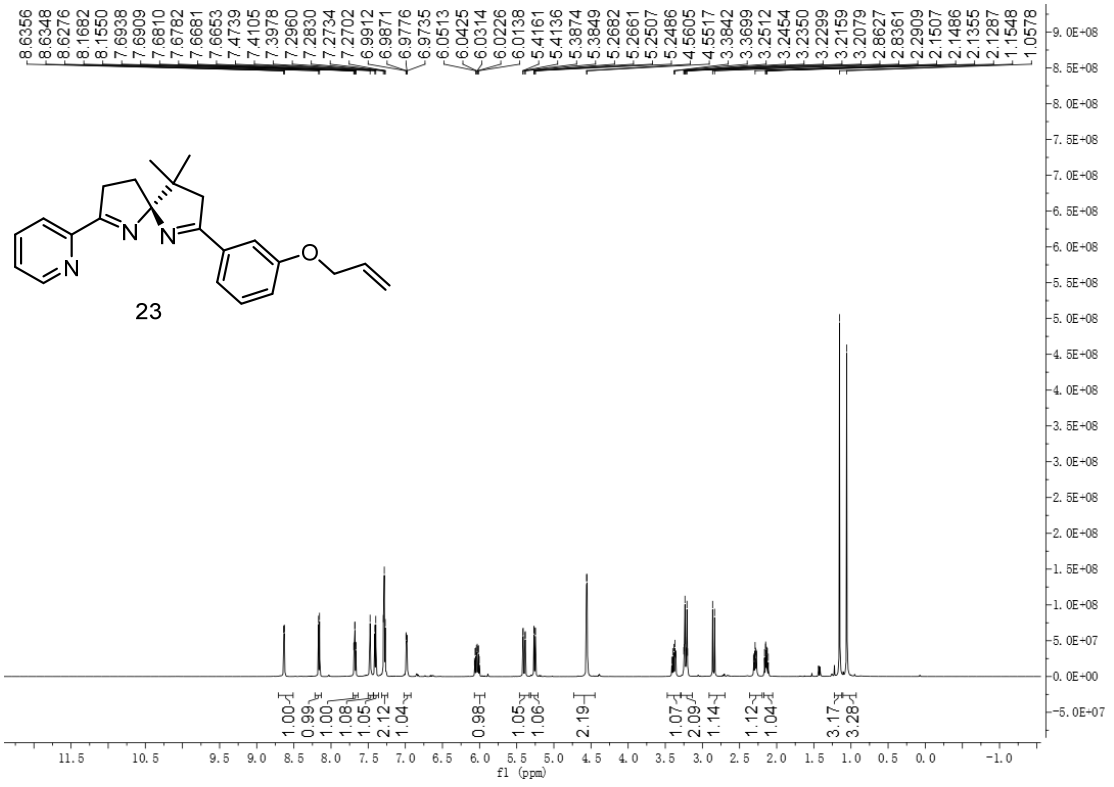
f1 (ppm)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6.9735
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6.0425
6.0314
6.0226
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5.4136
5.3874
5.3849
5.2682
5.2661
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5.2486
4.5605
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3.3842
3.3699
3.2512
3.2454
3.2350
3.2299
3.2159
3.2079
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2.2909
2.1507
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2.1355
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N
O
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2.12
1.04
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1.12
1.04
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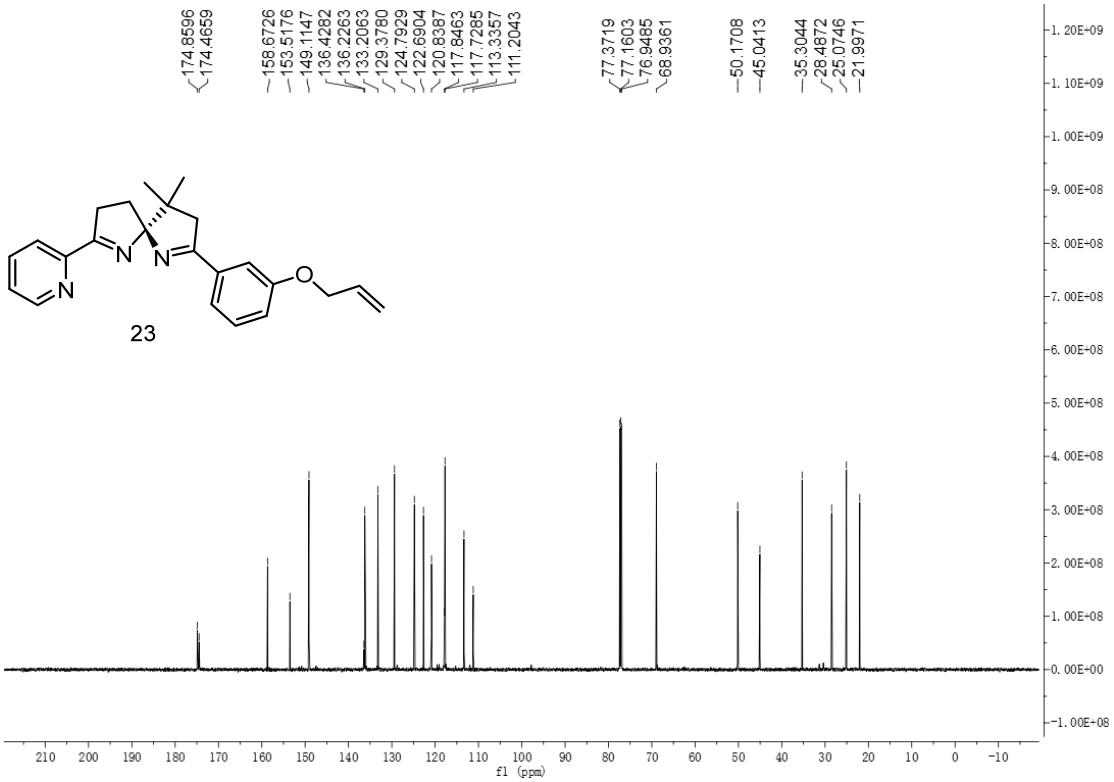
f1 (ppm)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113.3357
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77.1603
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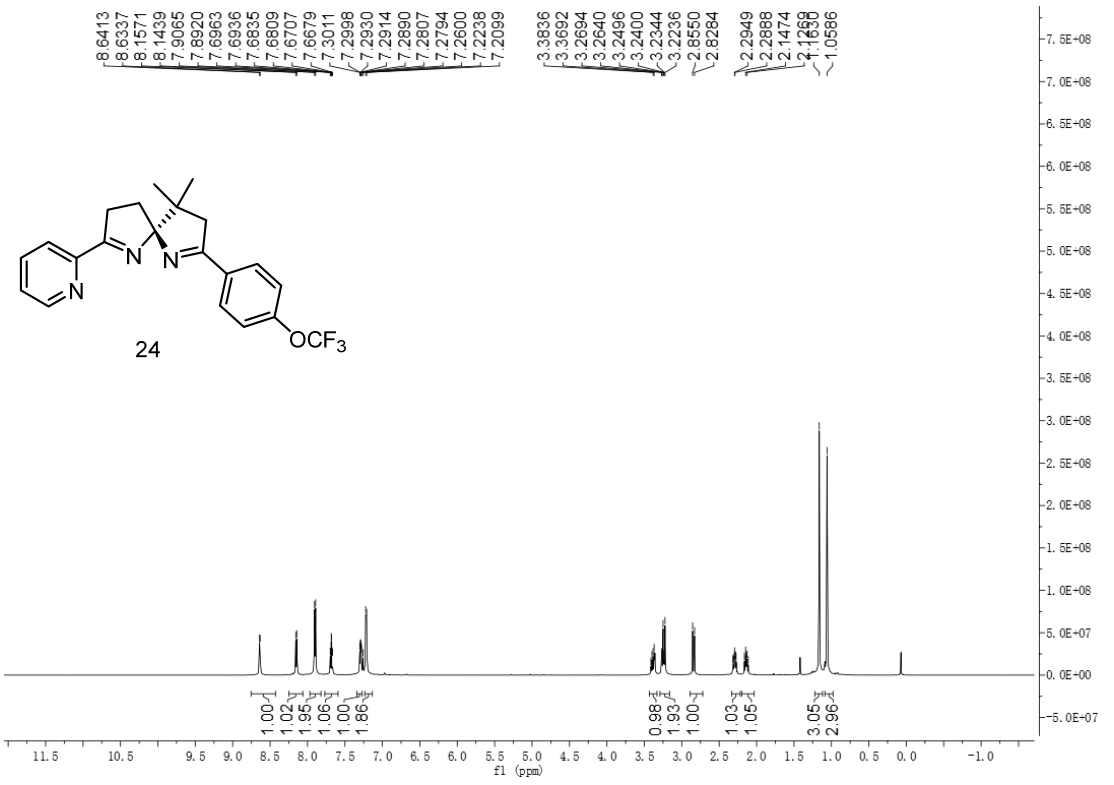
f1 (ppm)

23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7.2099
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3.3692
3.2694
3.2640
3.2496
3.2400
3.2344
3.2236
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2.8284
2.2949
2.2888
2.1474
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1.00
1.02
1.95
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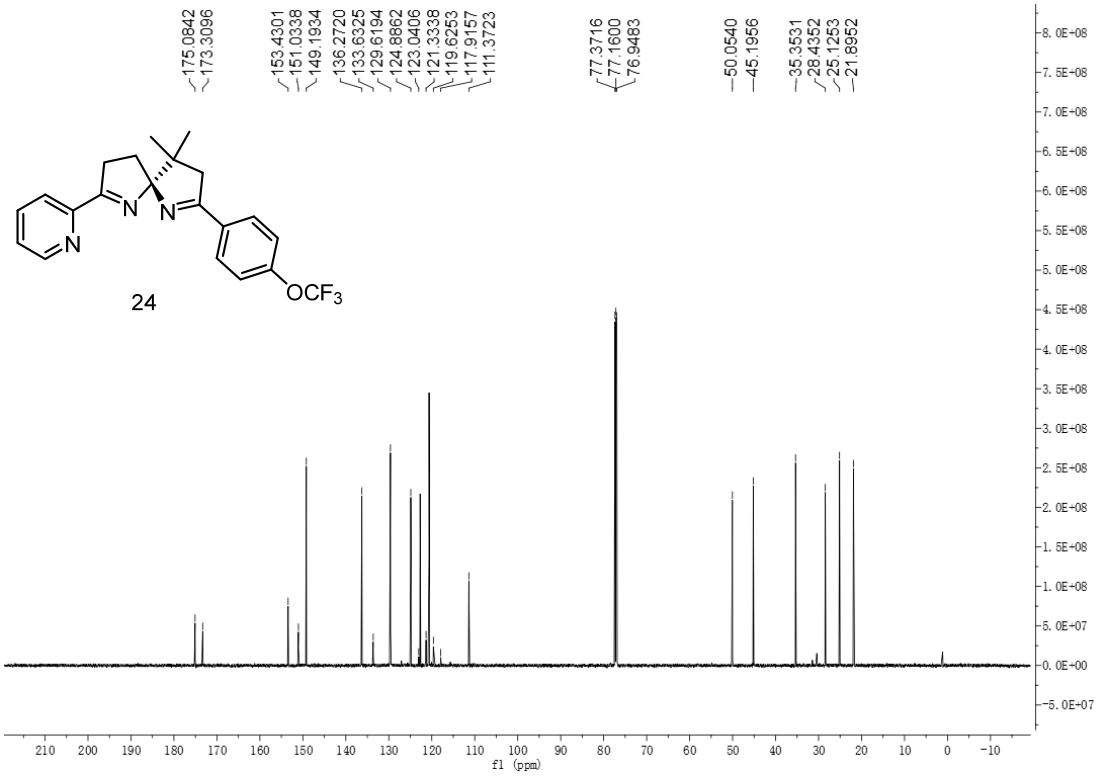
1.03
1.05
3.05
2.96
f1 (ppm)

24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117.9157
111.3723
77.3716
77.1600
76.9483
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21.8952
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N
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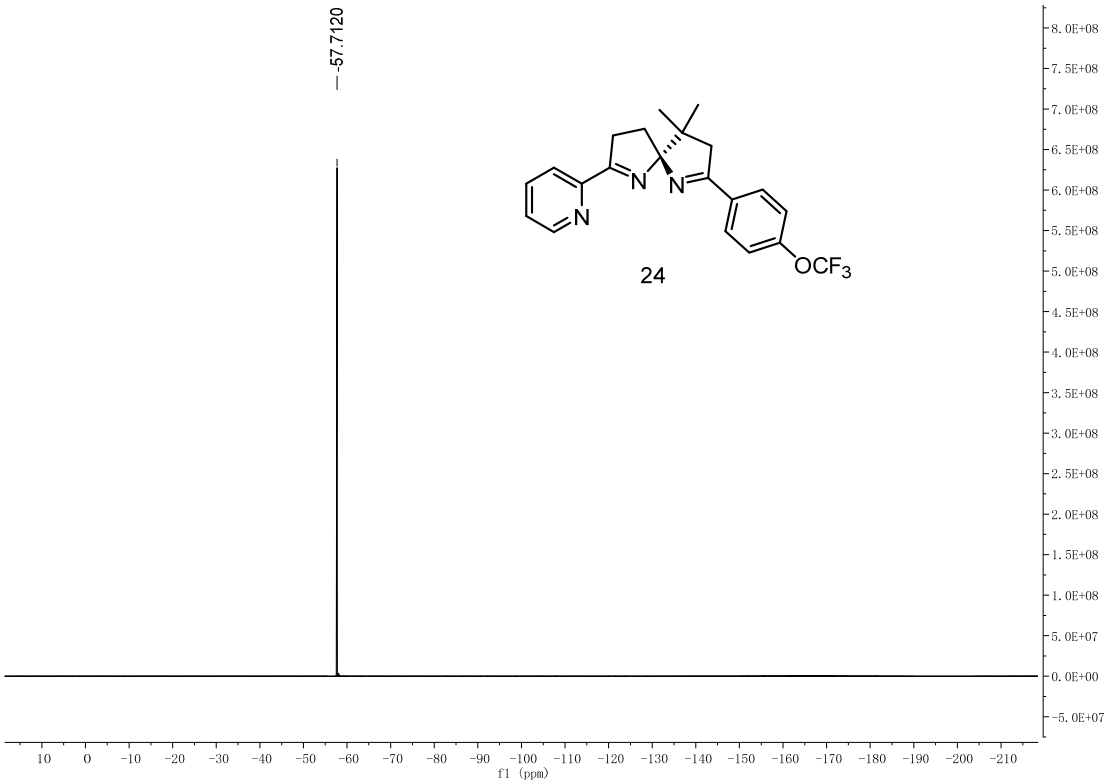
OCF3
24
f1 (ppm)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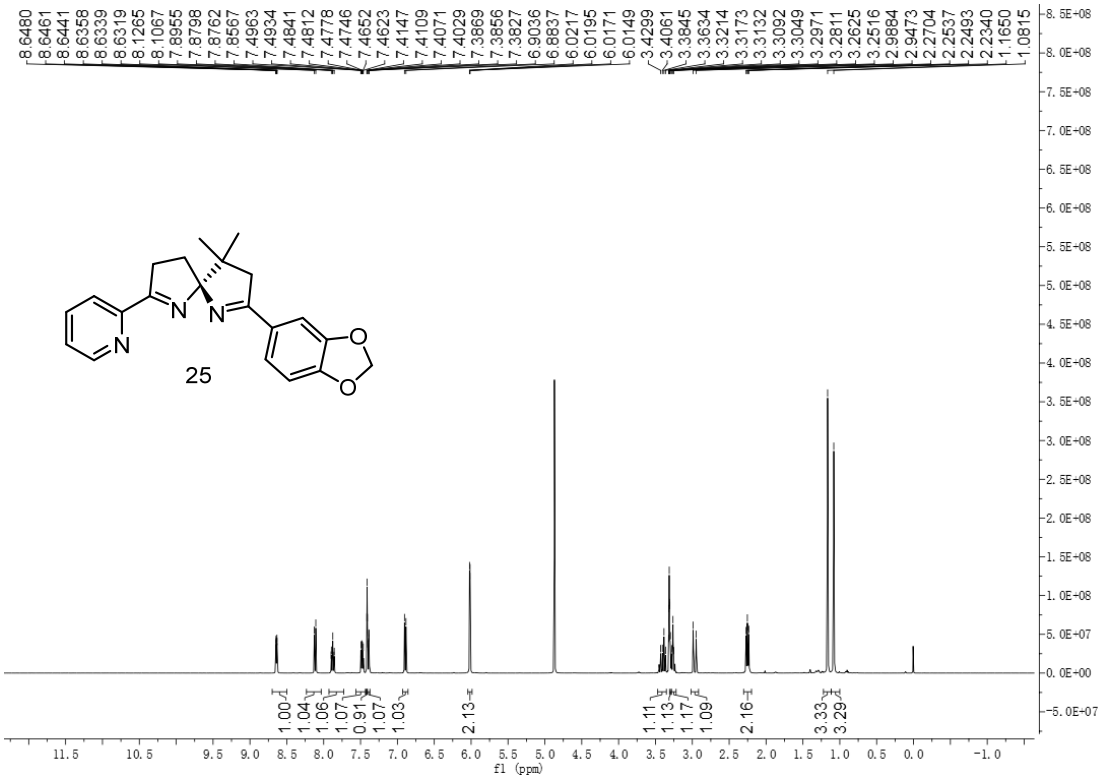
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2.2493
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1.0815
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N
O
O
25
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1.04
1.06
1.07
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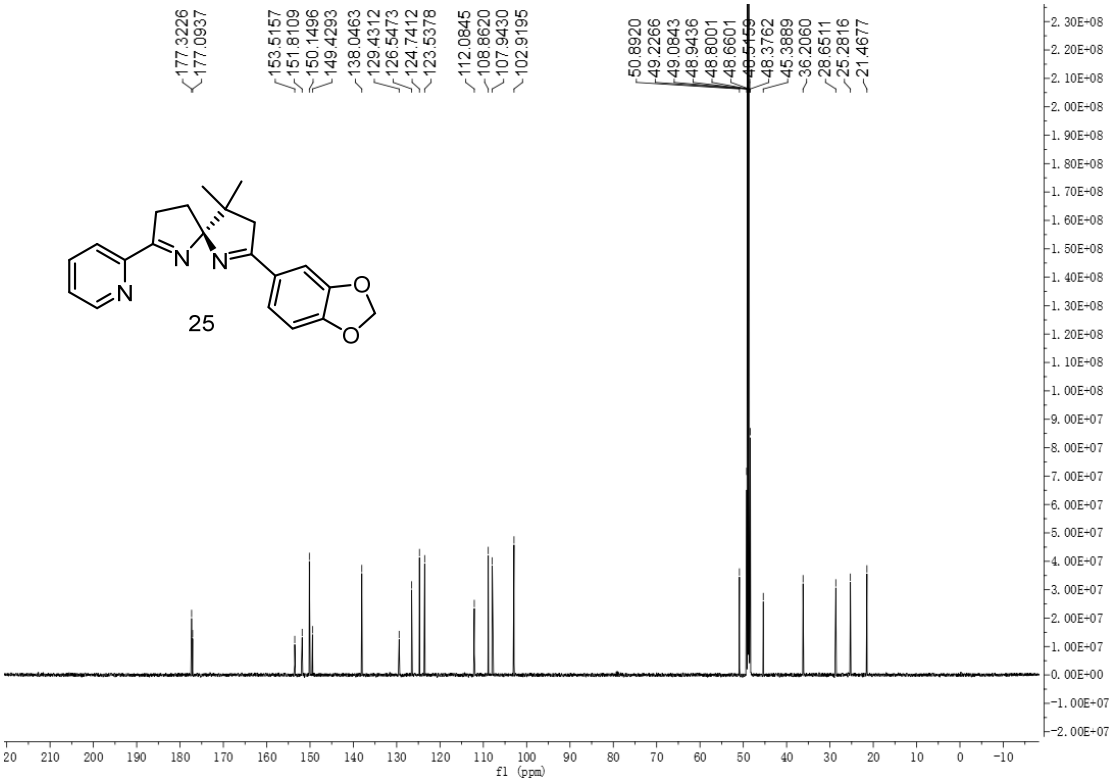
1.13
1.17
1.09
2.16
3.33
3.29
f1 (ppm)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108.8620
107.9430
102.9195
50.8920
49.2266
49.0843
48.9436
48.8001
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48.3762
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36.2060
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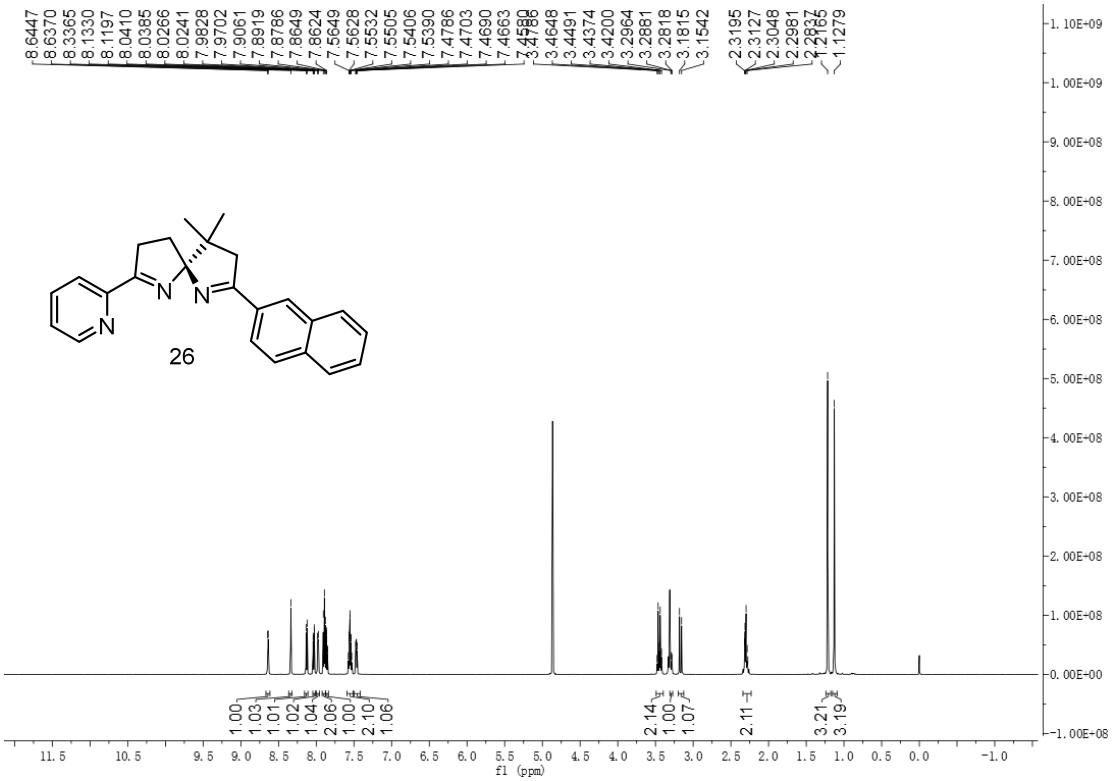
f1 (ppm)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3.1815
3.1542
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1.1279
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1.03
1.01
1.02
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1.07
2.11
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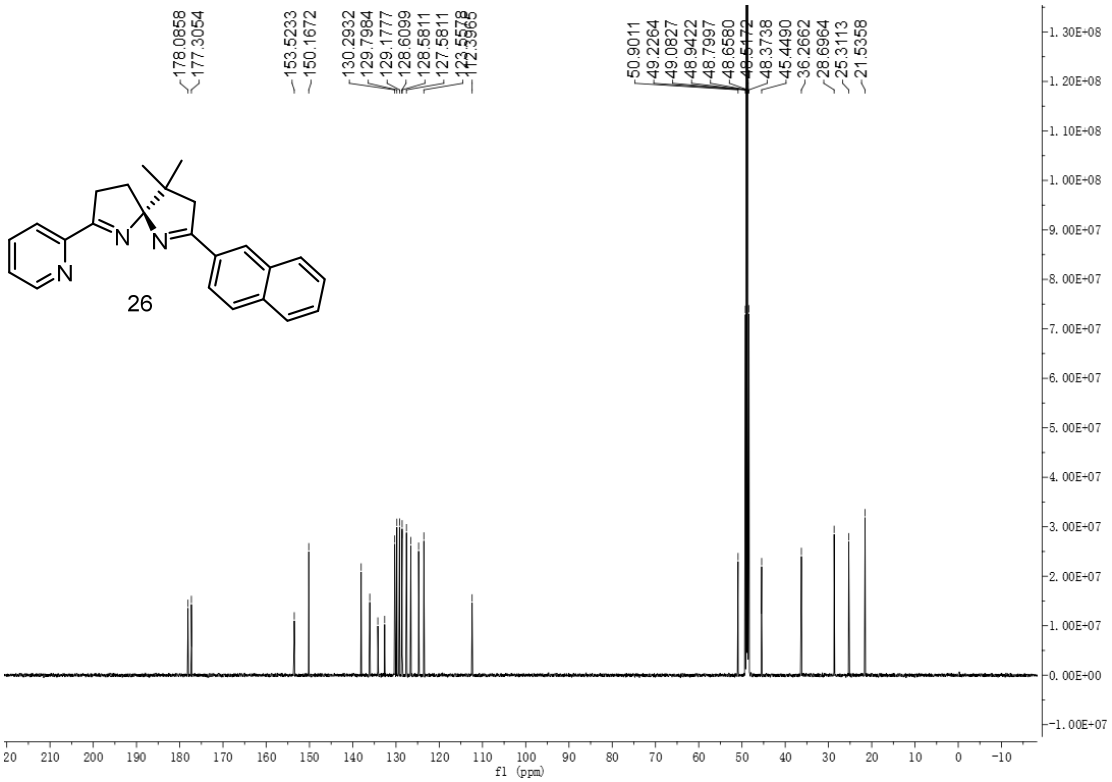
3.19
f1 (ppm)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50.9011
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49.0827
48.9422
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48.3738
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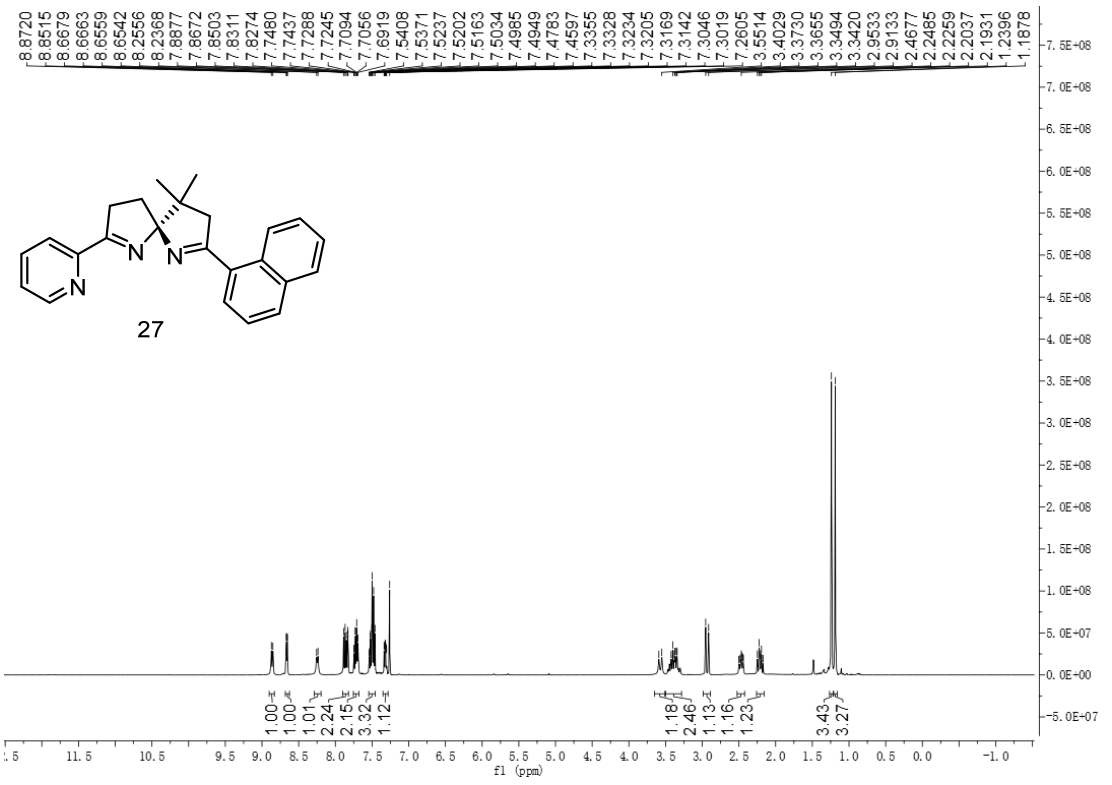
f1 (ppm)

26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7.8311
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7.7437
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7.7094
7.7056
7.6919
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7.5371
7.5237
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7.5163
7.5034
7.4985
7.4949
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7.4597
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7.3328
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7.3205
7.3169
7.3142
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7.3019
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3.3655
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3.3420
2.9533
2.9133
2.4677
2.2485
2.2259
2.2037
2.1931
1.2396
1.1878
1.00
1.00
1.01
2.24
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1.23
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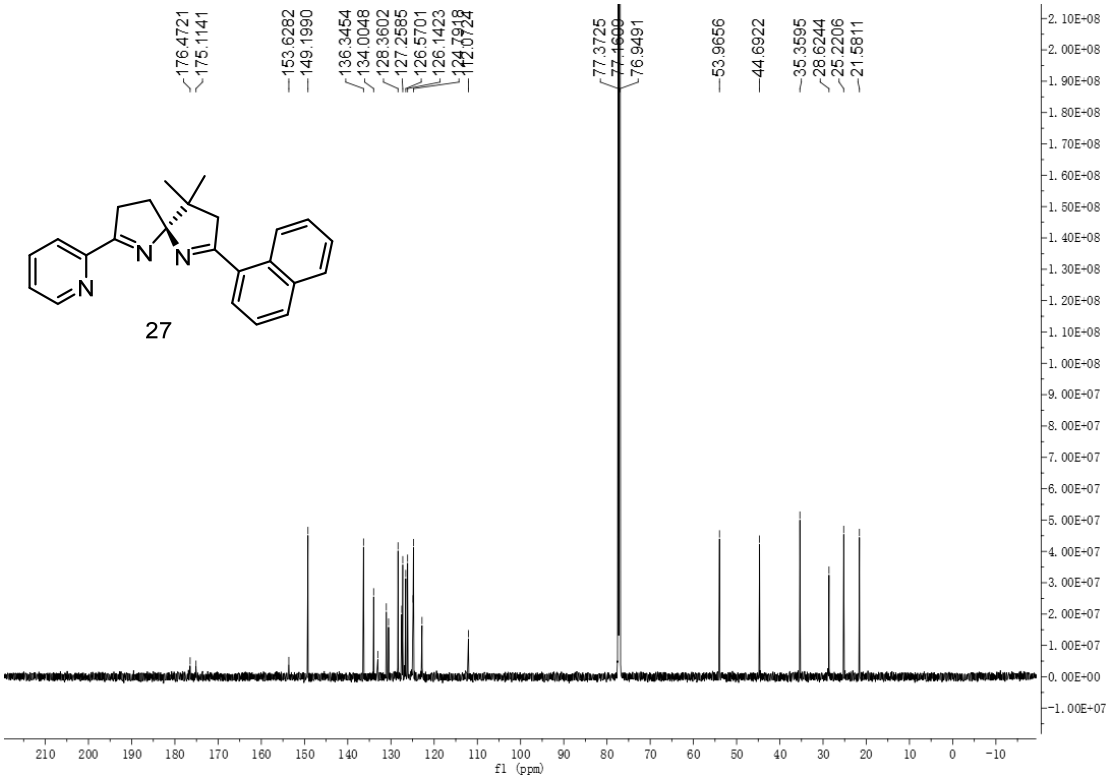
f1 (ppm)

27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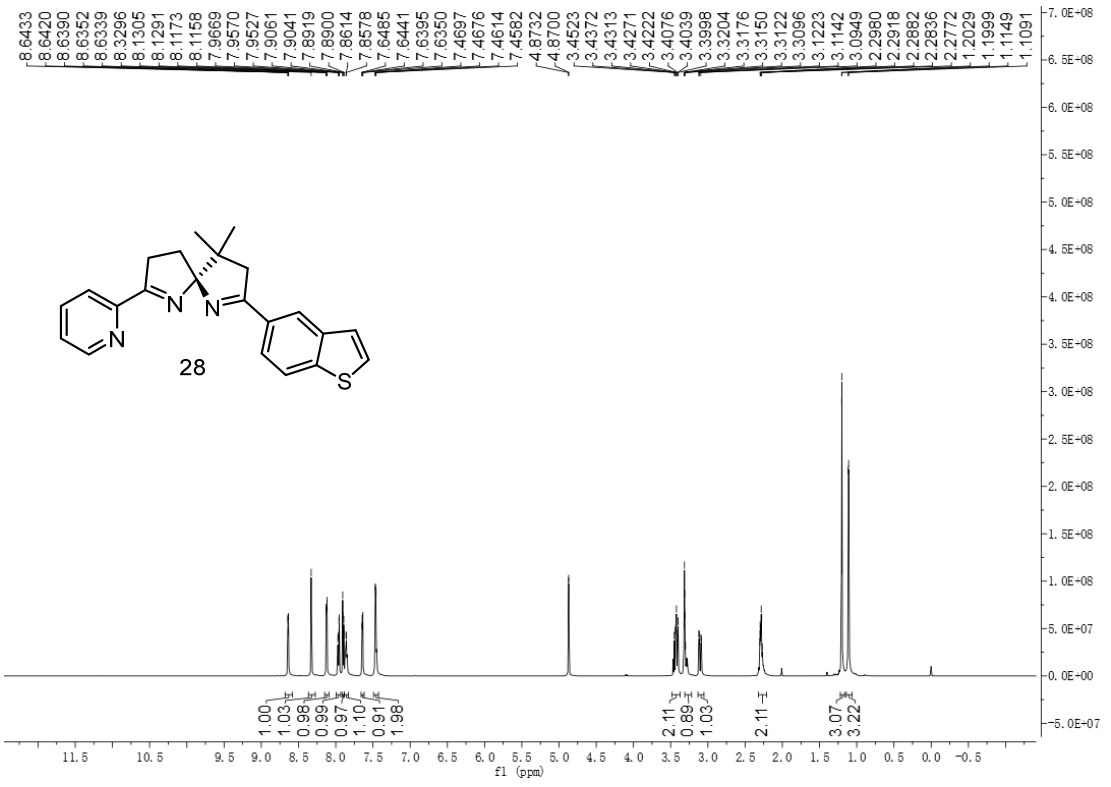
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7.8614
7.8578
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7.6441
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3.4039
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3.3204
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1.00
1.03
0.98
0.99
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1.98
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2.11
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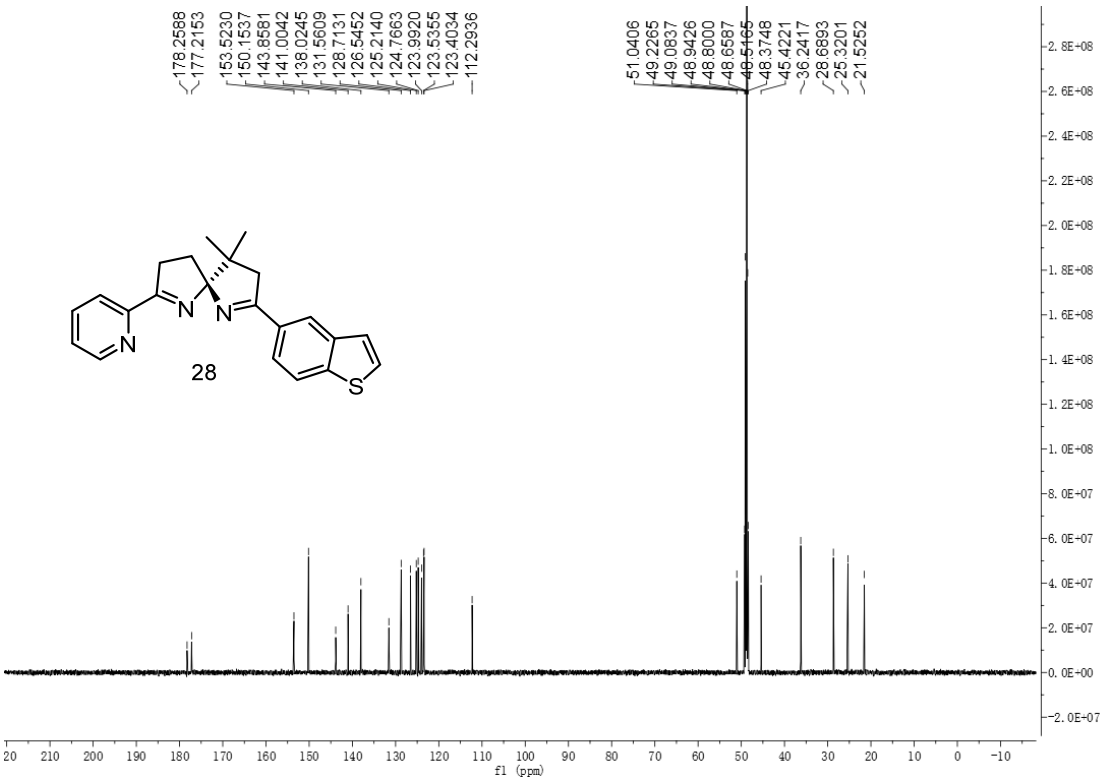
f1 (ppm)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123.4034
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49.0837
48.9426
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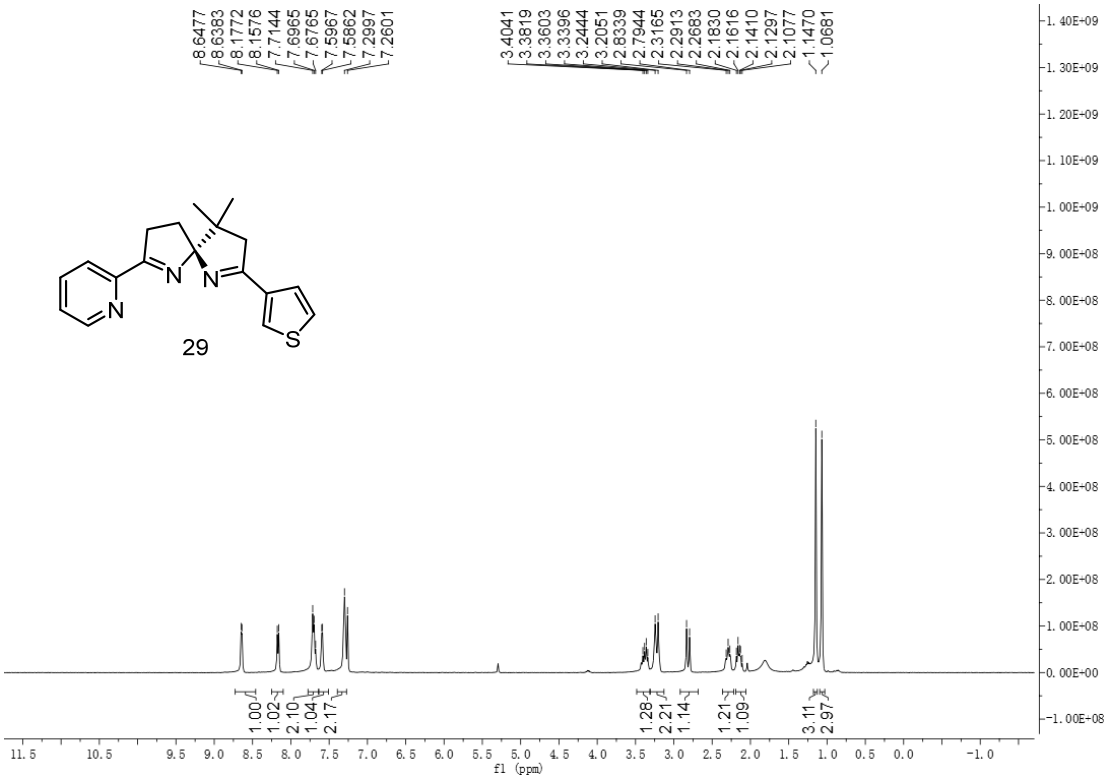
28
f1 (ppm)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3.3396
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2.8339
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2.2683
2.1830
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2.1297
2.1077
1.1470
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1.02
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1.28
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1.14
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1.09
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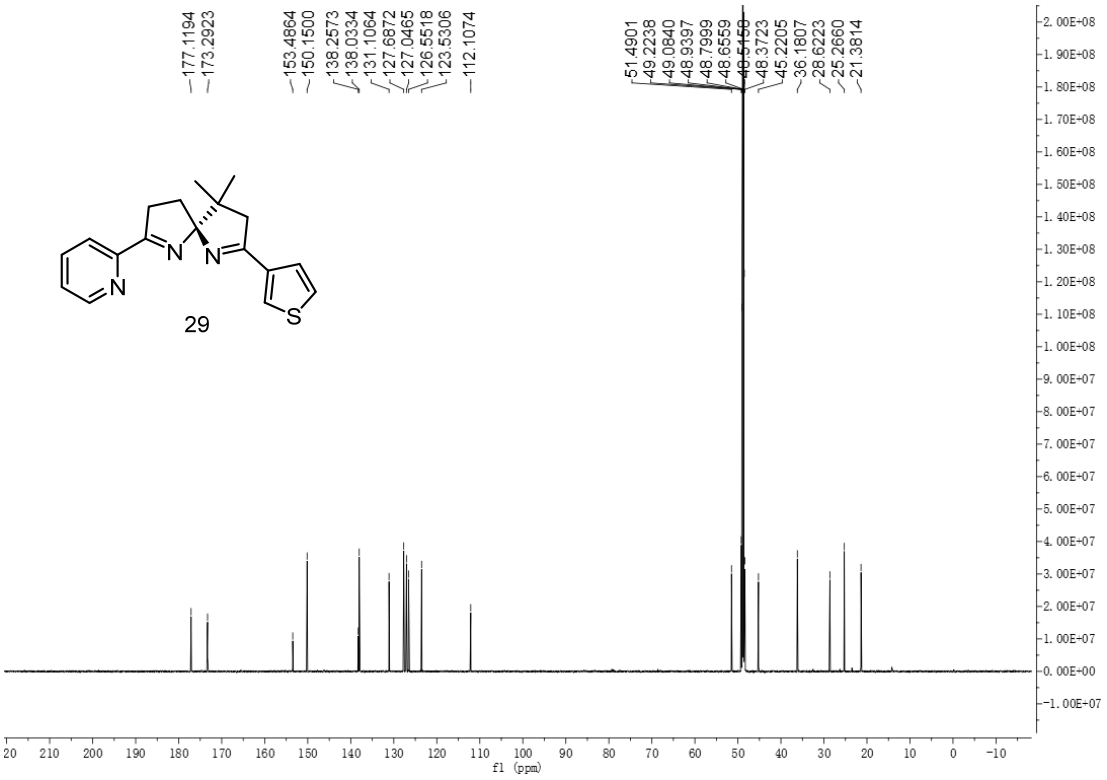
29
f1 (ppm)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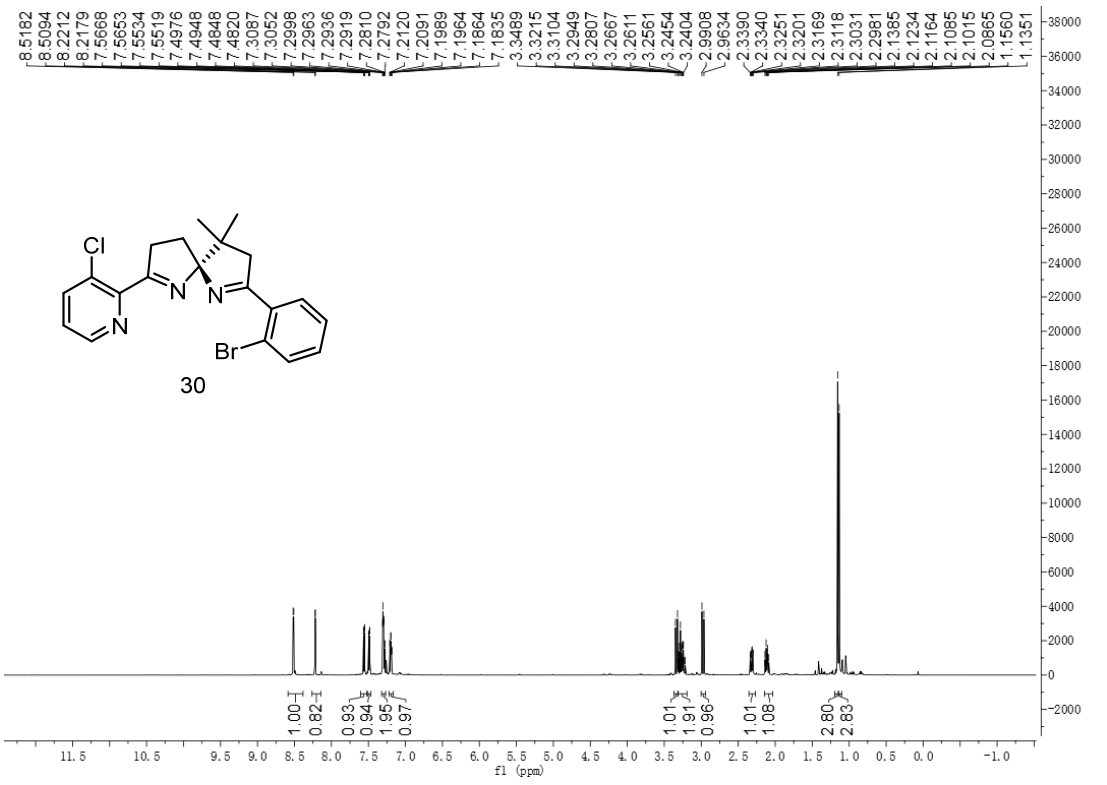
21.3814
f1 (ppm)

29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7.1835
3.3489
3.3215
3.3104
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3.2404
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2.3340
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2.3201
2.3169
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2.3031
2.2981
2.1385
2.1234
2.1164
2.1085
2.1015
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1.1351
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0.93
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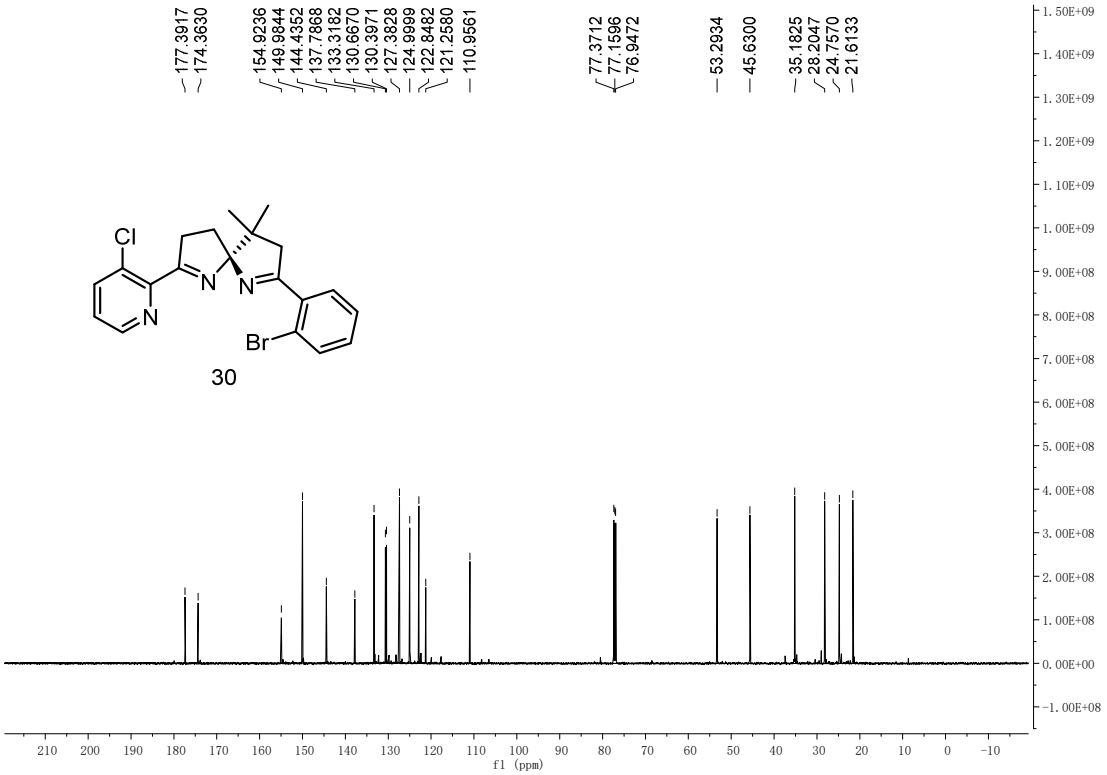
f1 (ppm)

30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110.9561
77.3712
77.1596
76.9472
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Cl
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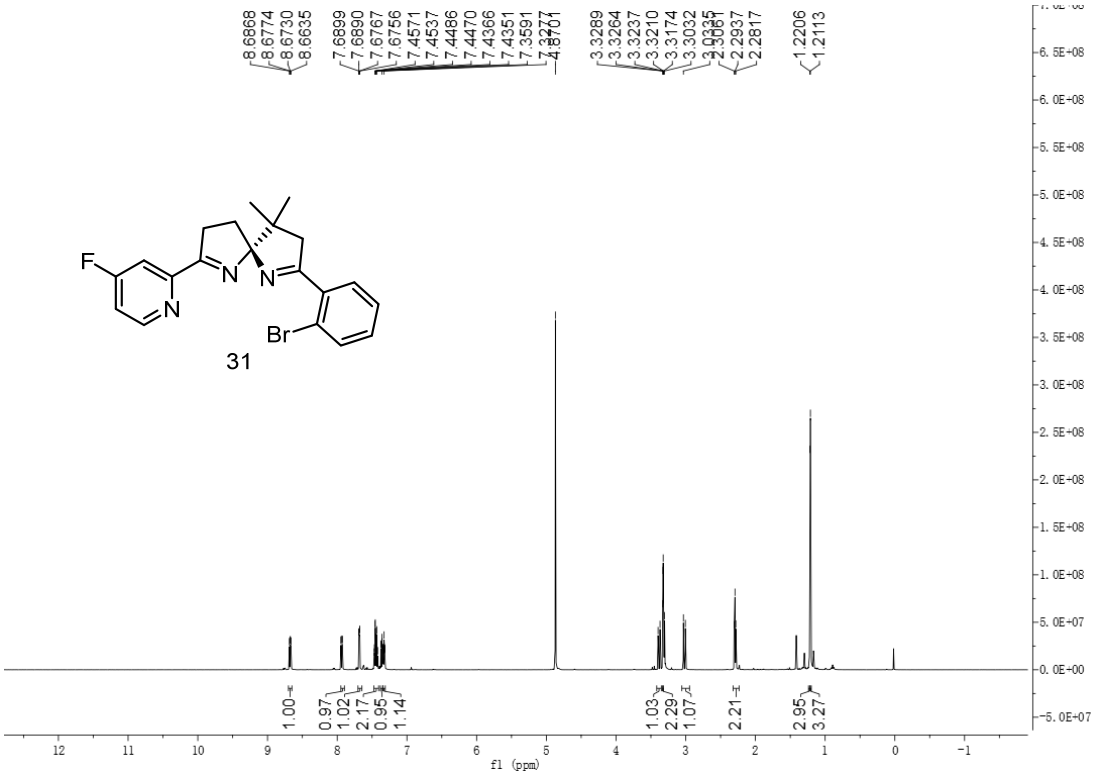
N
Br
30
f1 (ppm)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3.3032
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1.2206
1.2113
F
N
N
N
Br
31
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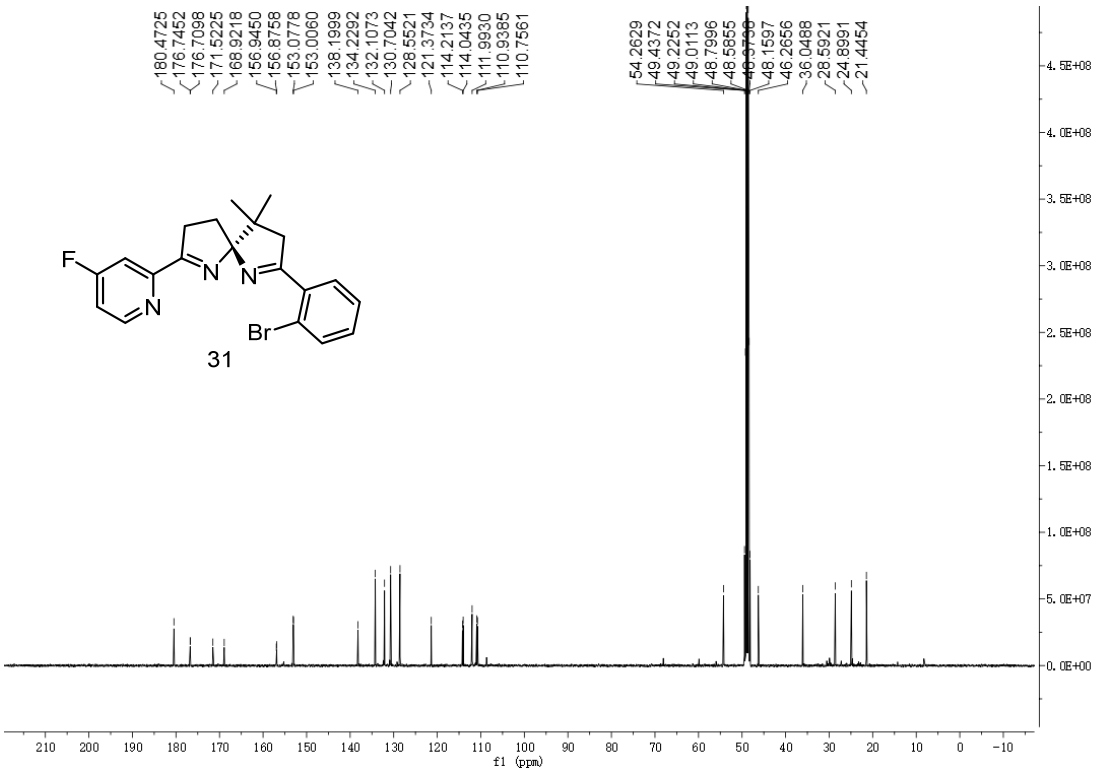
1.07
2.21
2.95
3.27
f1 (ppm)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21.4454
F
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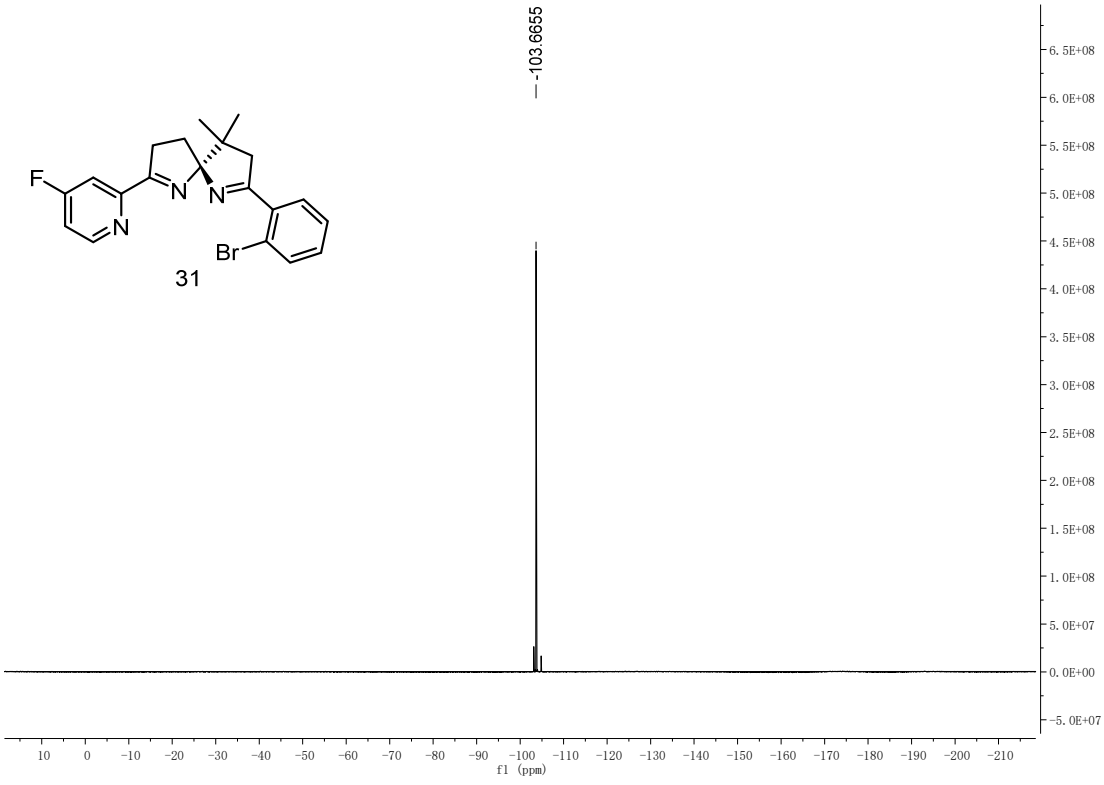
N
Br
31
f1 (ppm)


-103.6655
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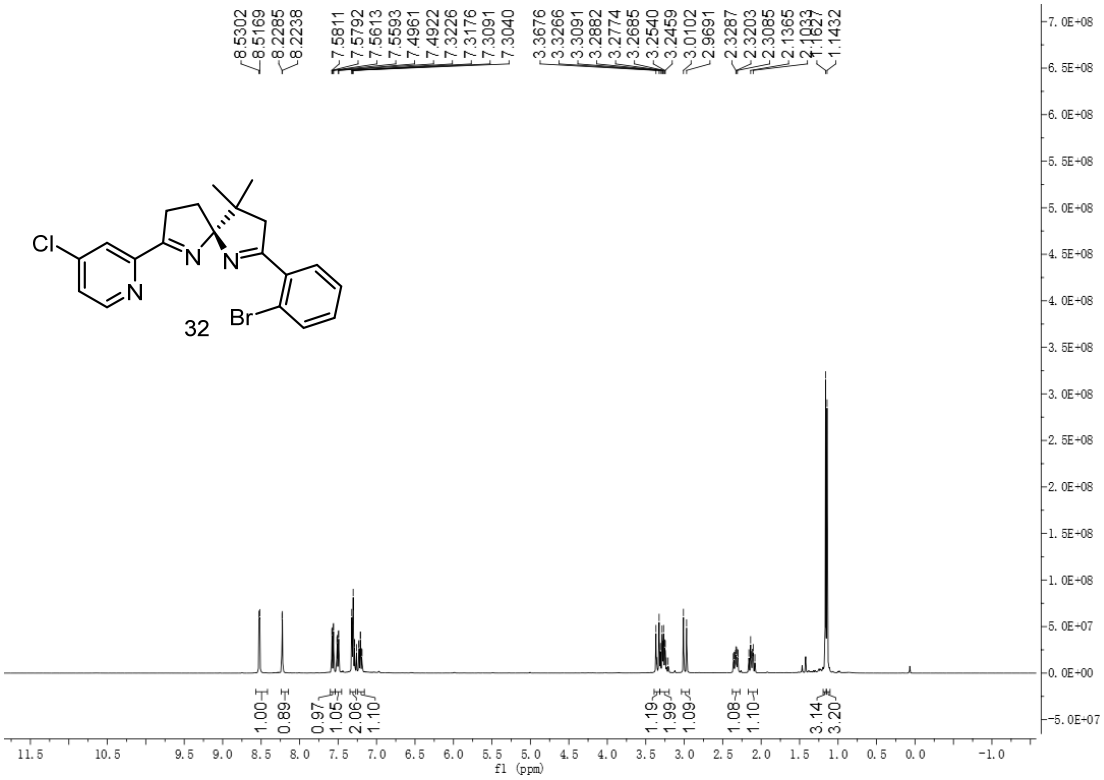
N
N
N
Br
31
f1 (ppm)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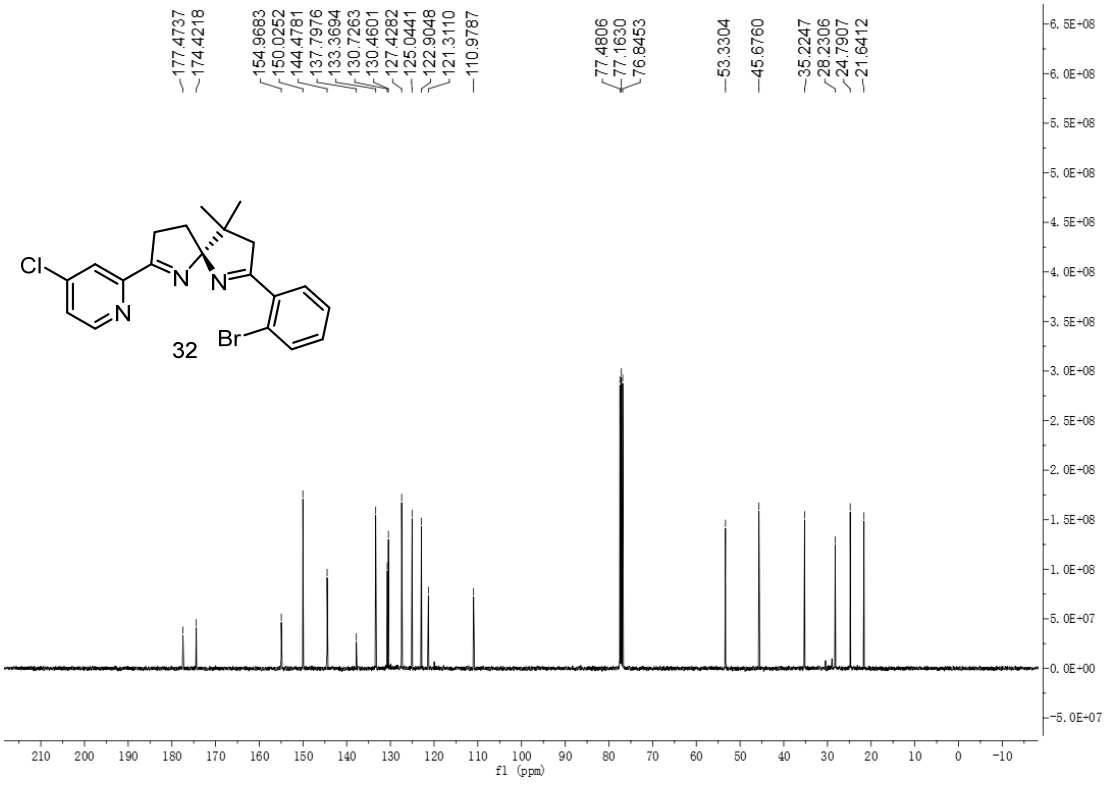
7.5792
7.5613
7.5593
7.4961
7.4922
7.3226
7.3176
7.3091
7.3040
3.3676
3.3266
3.3091
3.2882
3.2774
3.2685
3.2540
3.2459
3.0102
2.9691
2.3287
2.3203
2.3085
2.1365
2.1033
1.1627
1.1432
Cl
N
N
N
Br
32
1.00
0.89
0.97
1.05
2.06
1.10
1.19
1.99
1.09
1.08
1.10
3.14
3.20
f1 (ppm)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154.9683
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144.4781
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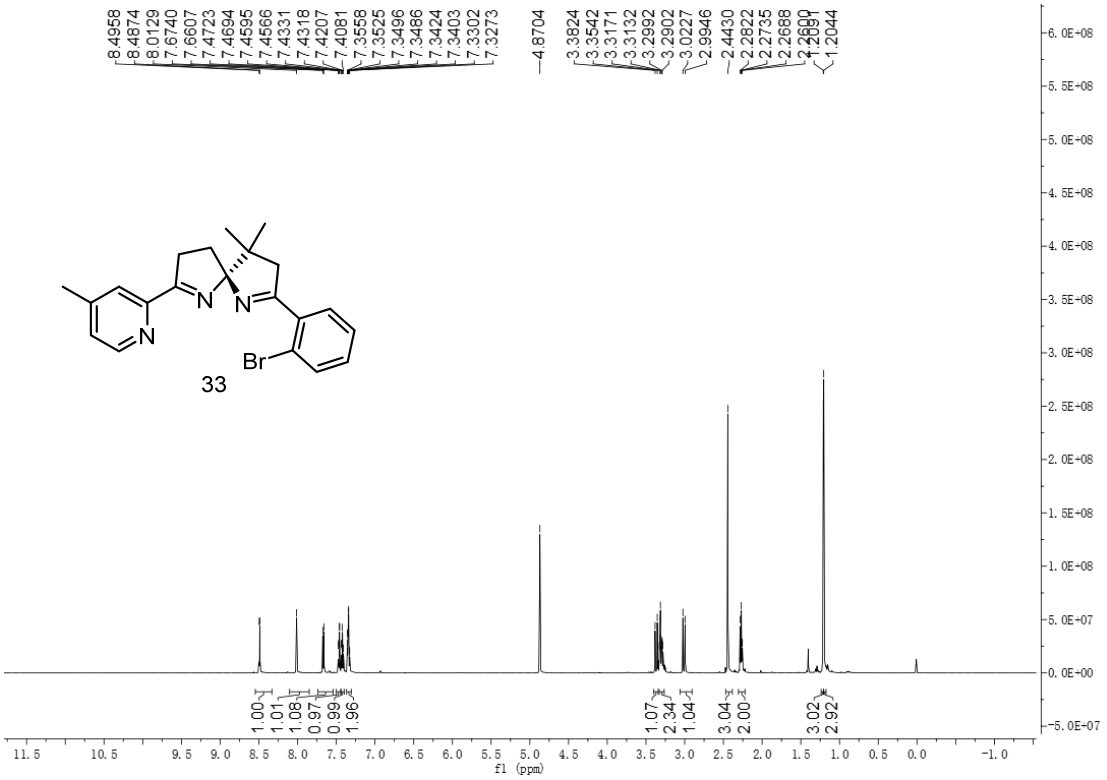
133.3694
130.7263
130.4601
127.4282
125.0441
122.9048
121.3110
110.9787
77.4806
77.1630
76.8453
53.3304
45.6760
35.2247
28.2306
24.7907
21.6412
Cl
N
N
N
Br
32
f1 (ppm)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7.4694
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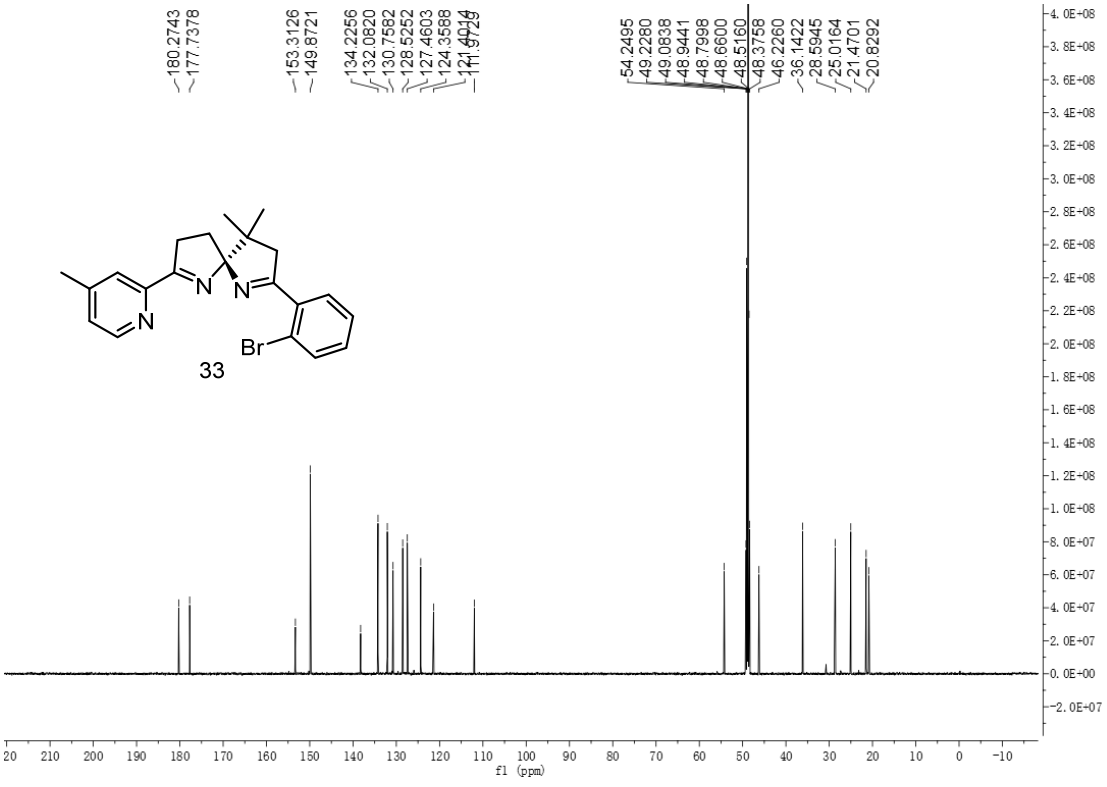
7.4566
7.4331
7.4318
7.4207
7.4081
7.3558
7.3525
7.3496
7.3486
7.3424
7.3403
7.3302
7.3273
4.8704
3.3824
3.3542
3.3171
3.3132
3.2992
3.2902
3.0227
2.9946
2.4430
2.2822
2.2735
2.2688
1.2691
1.2044
Br
33
fl (ppm)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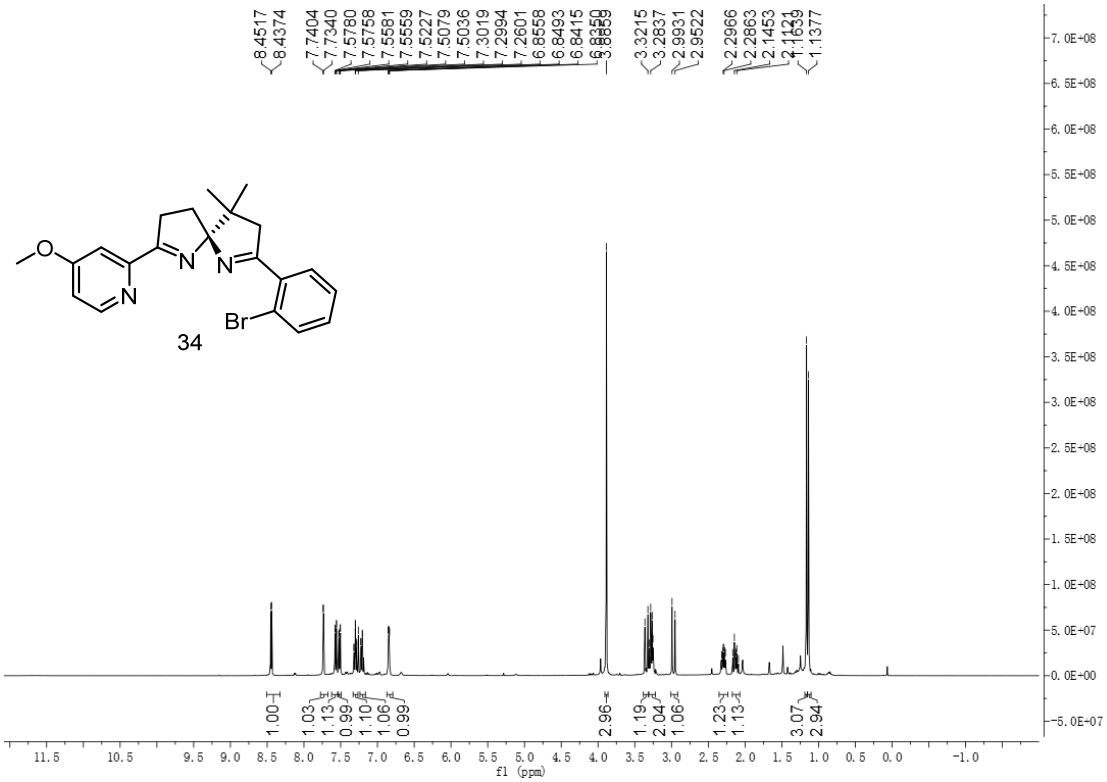
177.7378
153.3126
149.8721
134.2256
132.0820
130.7582
128.5252
127.4603
124.3588
54.2495
49.2280
49.0838
48.9441
48.7998
48.6600
48.5160
48.3758
46.2260
36.1422
28.5945
25.0164
21.4701
20.8292
Br
33
fl (ppm)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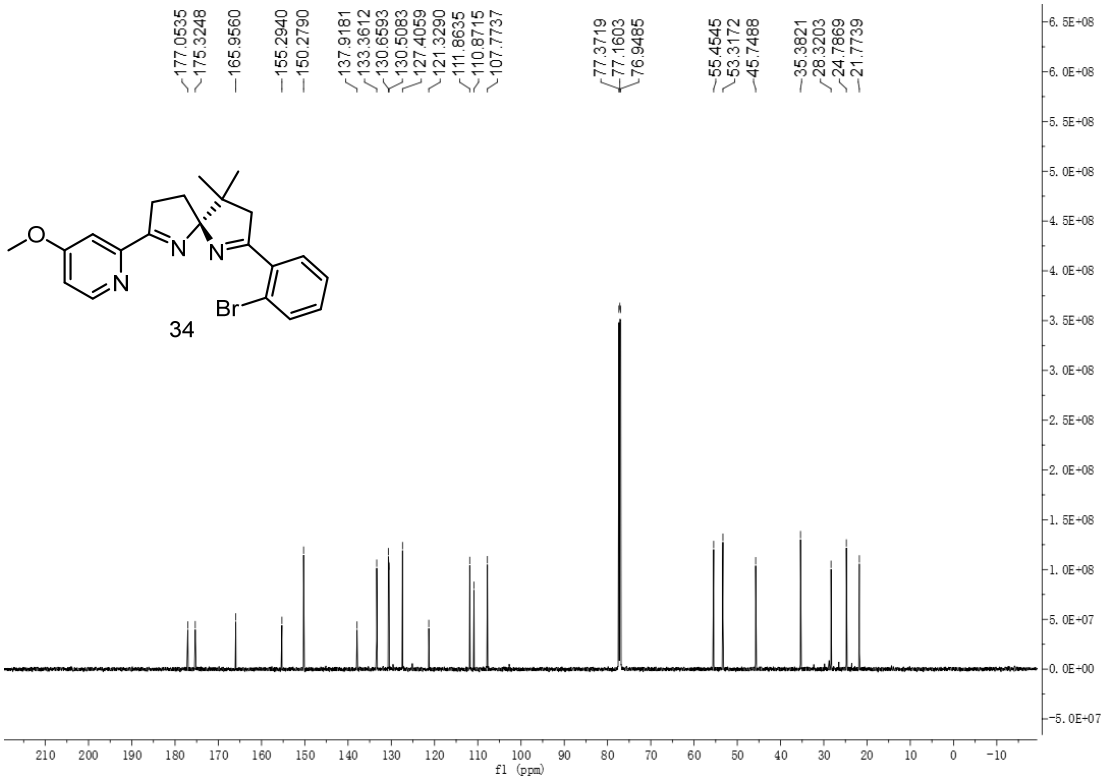
8.4374
7.7404
7.7340
7.5780
7.5758
7.5581
7.5559
7.5227
7.5079
7.5036
7.3019
7.2994
7.2601
6.8558
6.8493
6.8415
3.8859
3.3215
3.2837
2.9931
2.9522
2.2966
2.2863
2.1453
1.1377
1.00
1.03
1.13
0.99
1.10
1.06
0.99
2.96
1.19
2.04
1.06
1.23
1.13
3.07
2.94
f1 (ppm)
O
N
N
N
Br
34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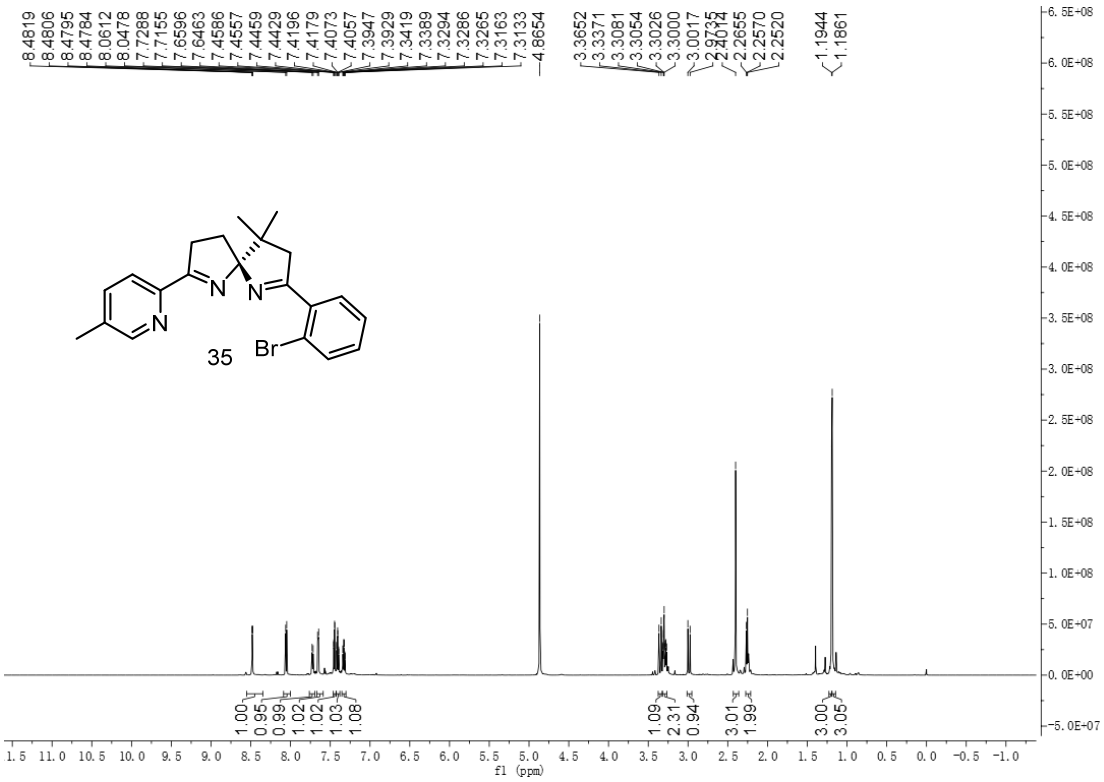
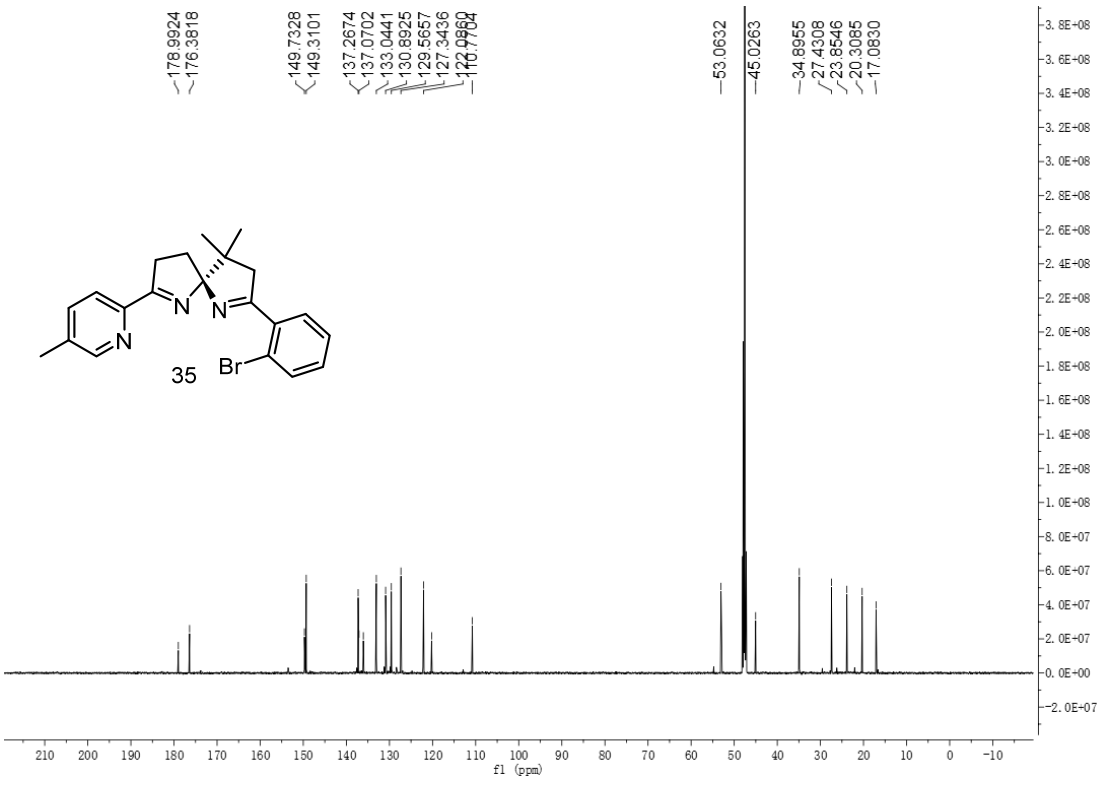
165.9560
155.2940
150.2790
137.9181
133.3612
130.6593
130.5083
127.4059
121.3290
111.8635
110.8715
107.7737
77.3719
77.1603
76.9485
55.4545
53.3172
45.7488
35.3821
28.3203
24.7869
21.7739
f1 (ppm)
O
N
N
N
Br
34


8.4819
8.4806
8.4795
8.4784
8.0612
8.0478
7.7288
7.7155
7.6596
7.6463
7.4586
7.4557
7.4459
7.4429
7.4196
7.4179
7.4073
7.4057
7.3947
7.3929
7.3419
7.3389
7.3294
7.3286
7.3265
7.3163
7.3133
4.8654
3.3652
3.3371
3.3081
3.3054
3.3026
3.3000
3.0017
2.9735
2.4014
2.2655
2.2570
2.2520
1.1944
1.1861
1.00
0.95
0.99
1.02
1.02
1.03
1.08
1.09
2.31
0.94
3.01
1.99
3.00
3.05
f1 (ppm)
35
Br


178.9924
176.3818
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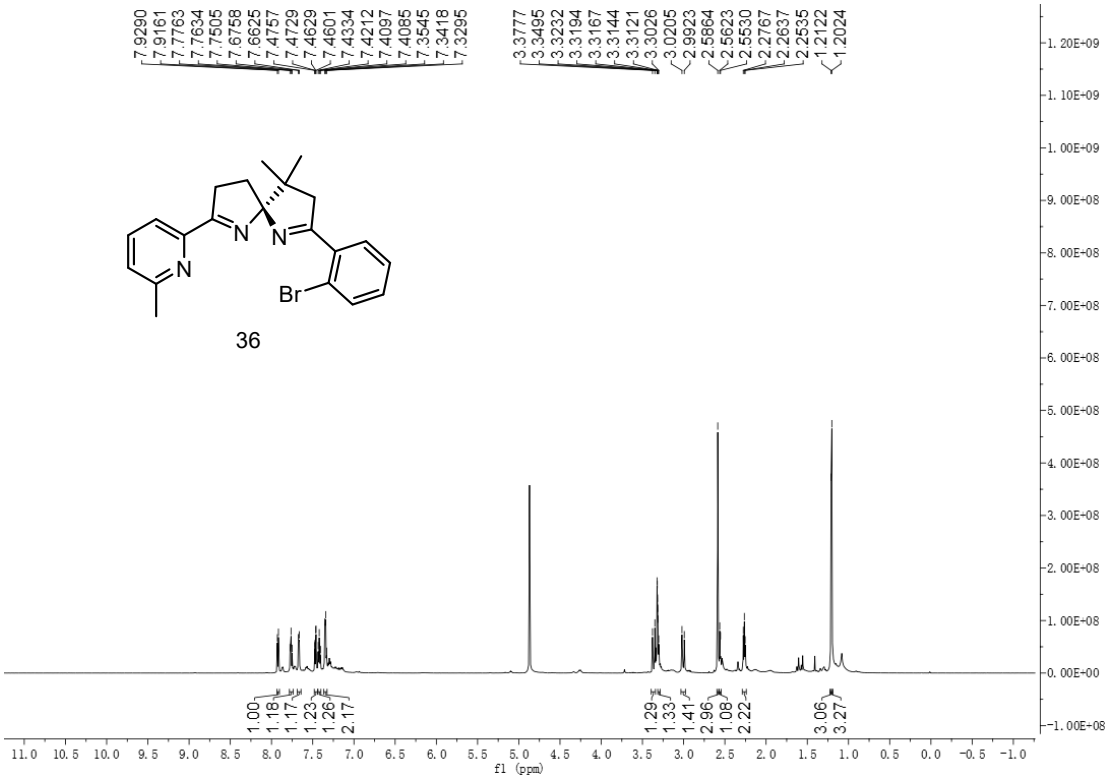
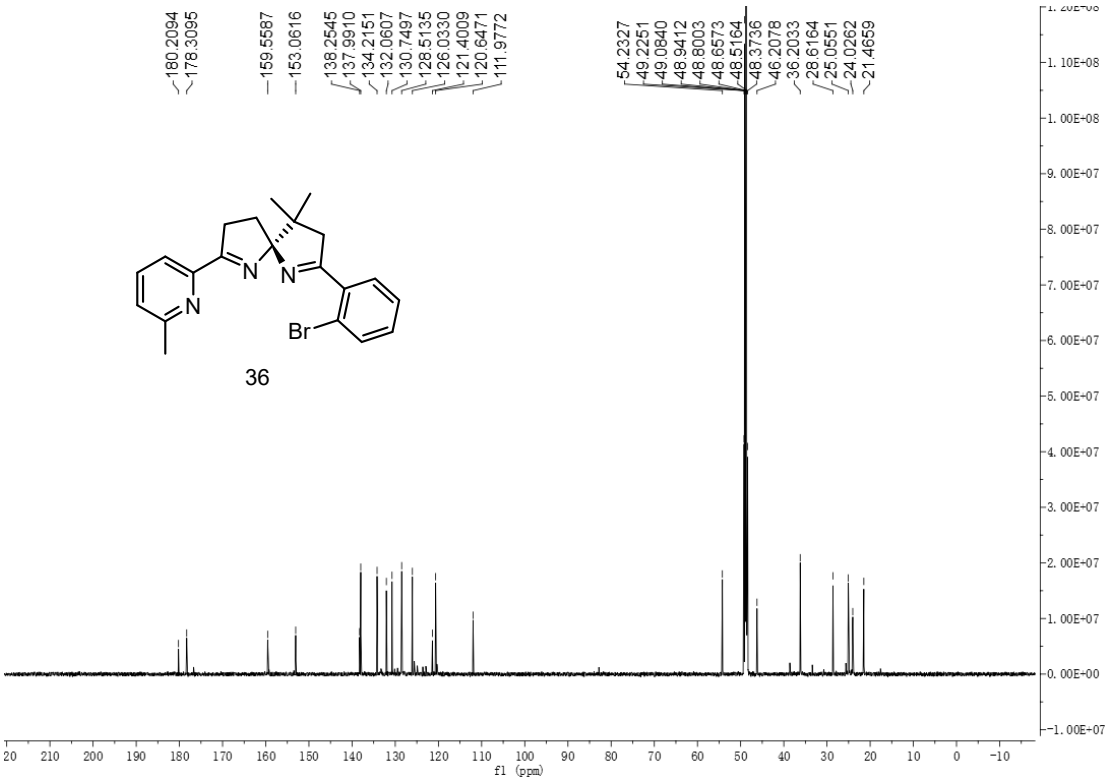
149.3101
137.2674
137.0702
133.0441
130.8925
129.5657
127.3436
122.0860
53.0632
45.0263
34.8955
27.4308
23.8546
20.3085
17.0830
f1 (ppm)
35
Br


7.9290
7.9161
7.7763
7.7634
7.7505
7.6758
7.6625
7.4757
7.4729
7.4629
7.4601
7.4334
7.4212
7.4097
7.4085
7.3545
7.3418
7.3295
3.3777
3.3495
3.3232
3.3194
3.3167
3.3144
3.3121
3.3026
3.0205
2.9923
2.5864
2.5623
2.5530
2.2767
2.2637
2.2535
1.2122
1.2024
N
N
N
Br
36
1.00
1.18
1.17
1.23
1.26
2.17
1.29
1.33
1.41
2.96
1.08
2.22
3.06
3.27
f1 (ppm)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134.2151
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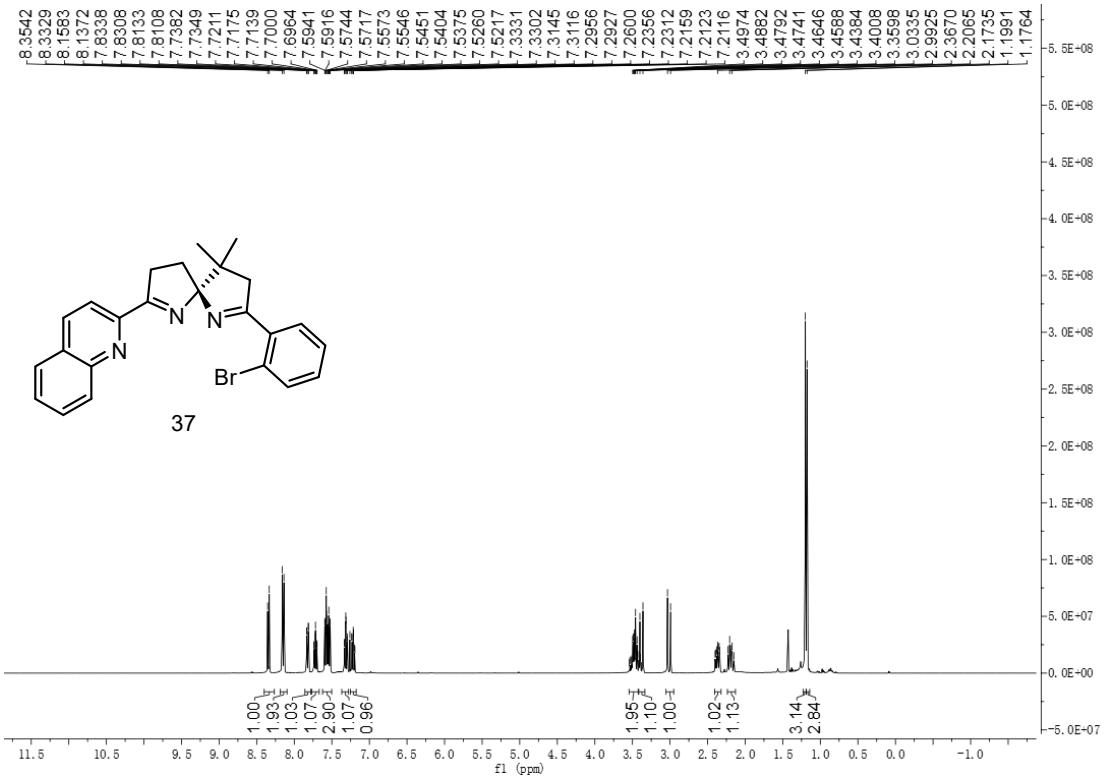
130.7497
128.5135
126.0330
121.4009
120.6471
111.9772
54.2327
49.2251
49.0840
48.9412
48.8003
48.6573
48.5164
48.3736
46.2078
36.2033
28.6164
25.0551
24.0262
21.4659
N
N
N
Br
36
f1 (ppm)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7.8338
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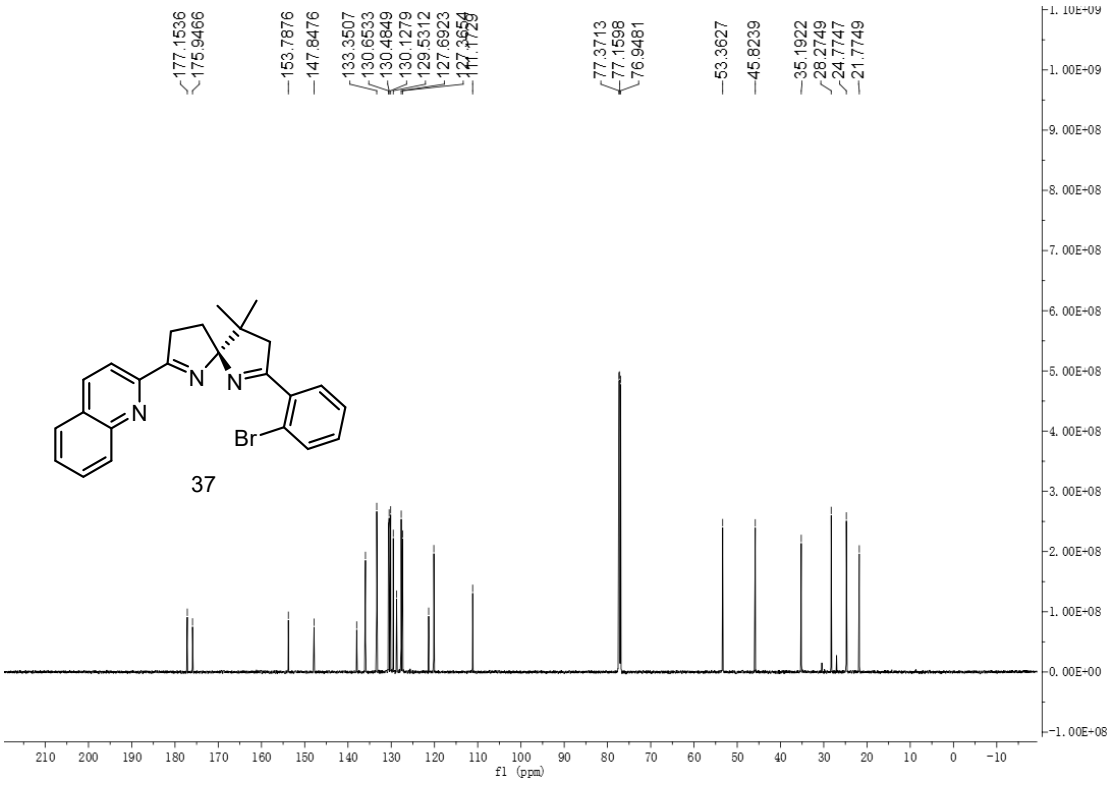
7.8133
7.8108
7.7382
7.7349
7.7211
7.7175
7.7139
7.7000
7.6964
7.5941
7.5916
7.5744
7.5717
7.5573
7.5546
7.5451
7.5404
7.5375
7.5260
7.5217
7.3331
7.3302
7.3145
7.3116
7.2956
7.2927
7.2600
7.2356
7.2312
7.2159
7.2123
7.2116
3.4974
3.4882
3.4792
3.4741
3.4646
3.4588
3.4384
3.4008
3.3598
3.0335
2.9925
2.3670
2.2065
2.1735
1.1991
1.1764
N
N
N
Br
37
1.00
1.93
1.03
1.07
2.90
1.07
0.96
1.95
1.10
1.00
1.02
1.13
3.14
2.84
f1 (ppm)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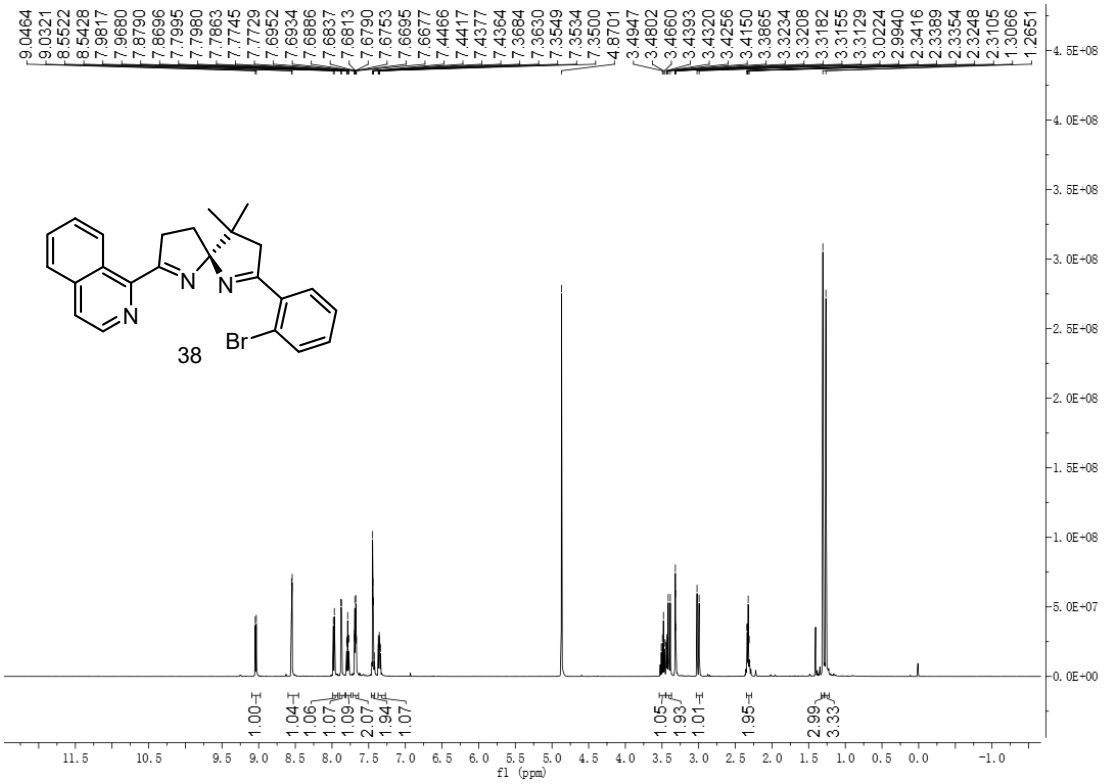
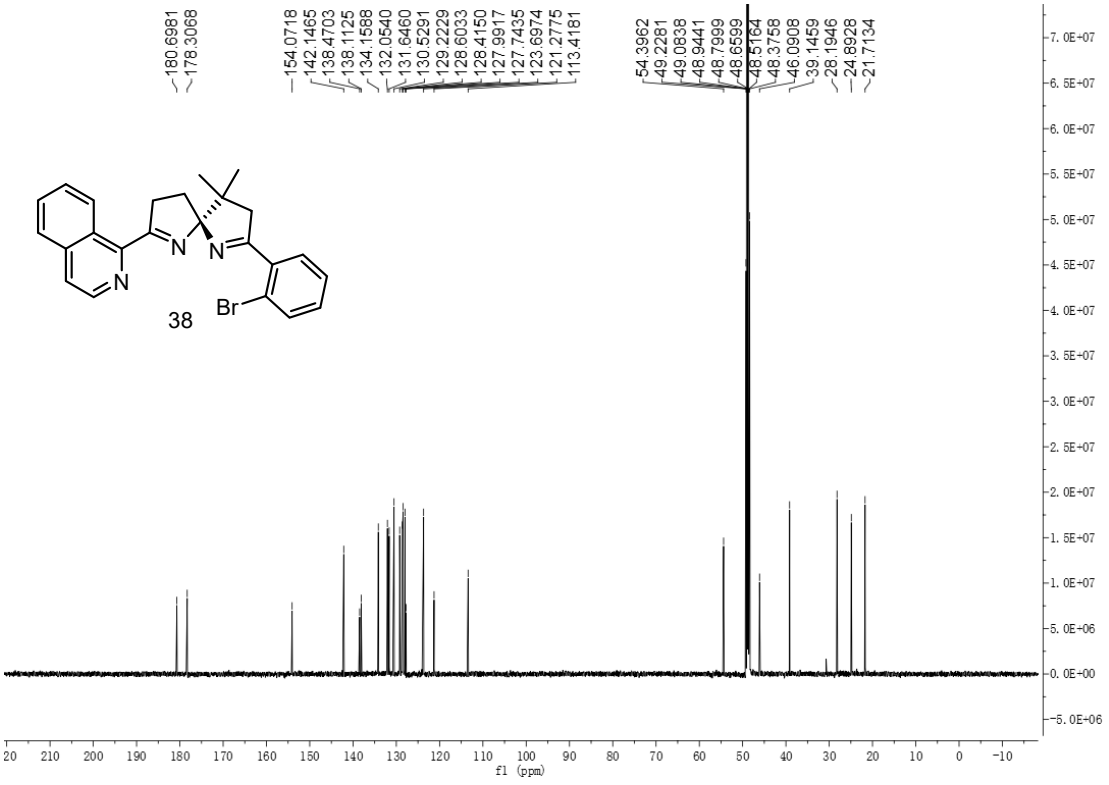
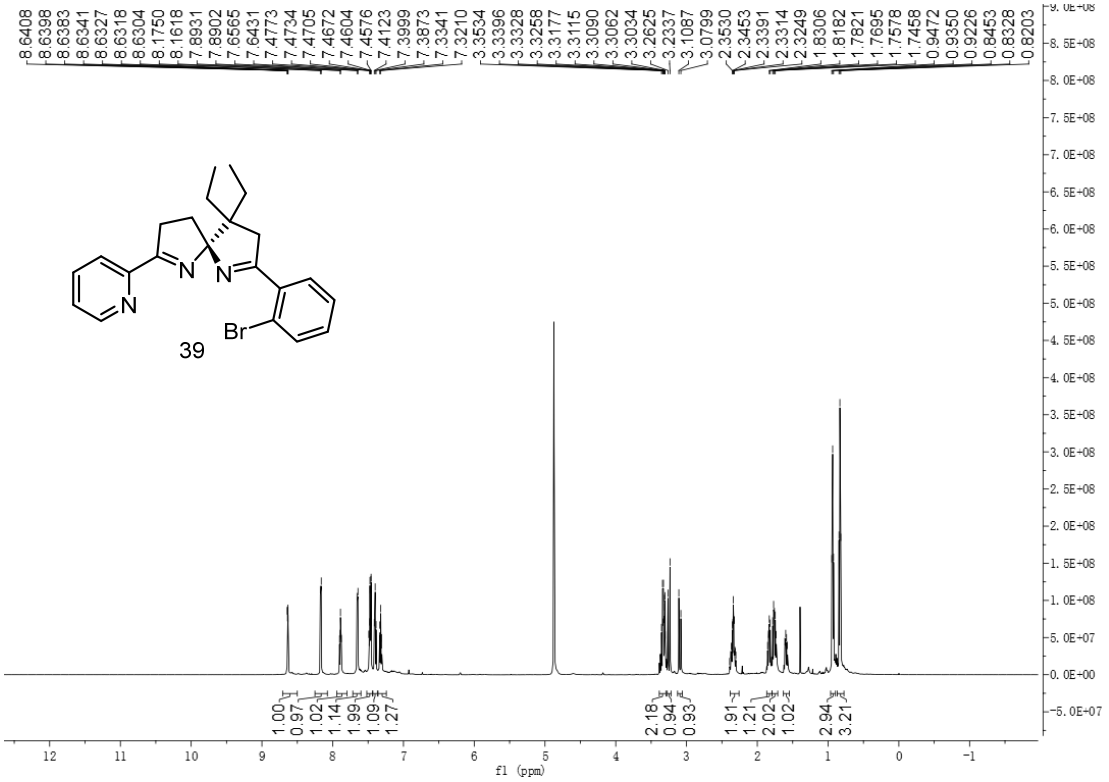
133.3507
130.6533
130.4849
130.1279
129.5312
127.6923
127.3654
111.1729
77.3713
77.1598
76.9481
53.3627
45.8239
35.1922
28.2749
24.7747
21.7749
N
N
N
Br
37
f1 (ppm)


38
Br
f1 (ppm)


38
Br
f1 (ppm)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8.6304
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8.1618
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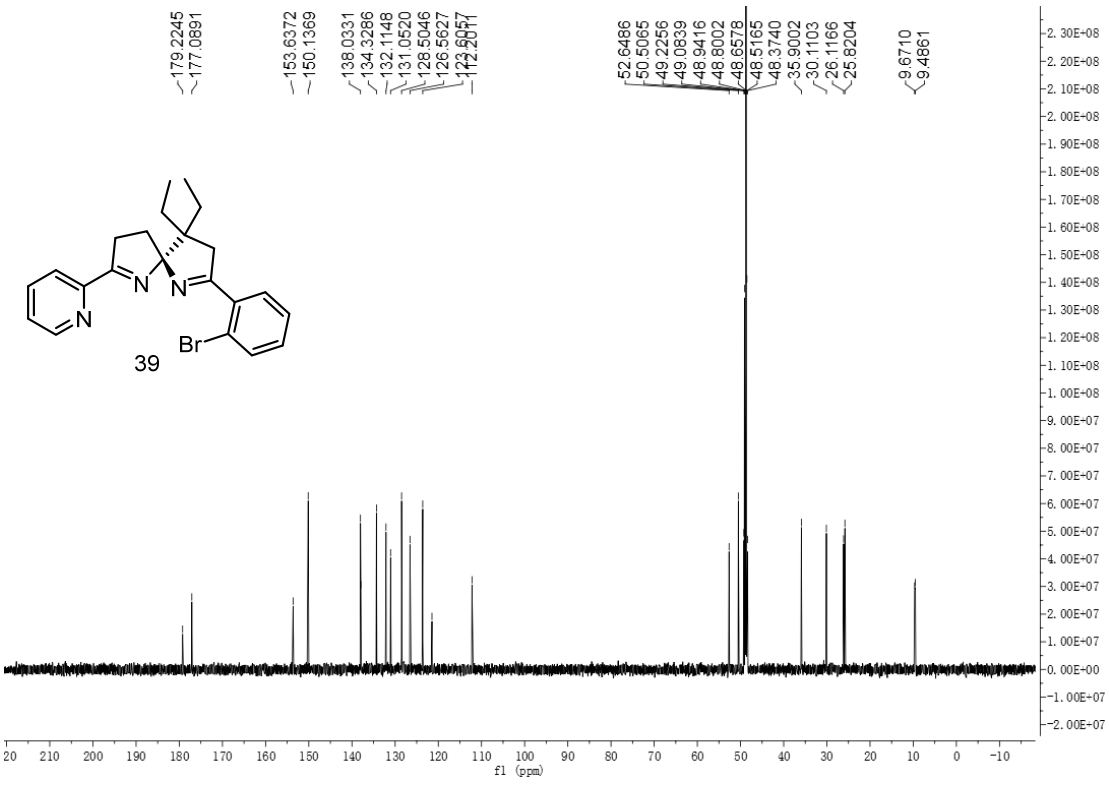
7.8902
7.6565
7.6431
7.4773
7.4734
7.4705
7.4672
7.4604
7.4576
7.4123
7.3999
7.3873
7.3341
7.3210
3.3534
3.3396
3.3328
3.3258
3.3177
3.3115
3.3090
3.3062
3.3034
3.2625
3.2337
3.1087
3.0799
2.3530
2.3453
2.3391
2.3314
2.3249
1.8306
1.8182
1.7821
1.7695
1.7578
1.7458
0.9472
0.9350
0.9226
0.8453
0.8328
0.8203
N
N
N
Br
39
1.00
0.97
1.02
1.14
1.99
1.09
1.27
2.18
0.94
0.93
1.91
1.21
2.02
1.02
2.94
3.21
f1 (ppm)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126.5627
123.6057
112.2011
52.6486
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49.2256
49.0839
48.9416
48.8002
48.6578
48.5165
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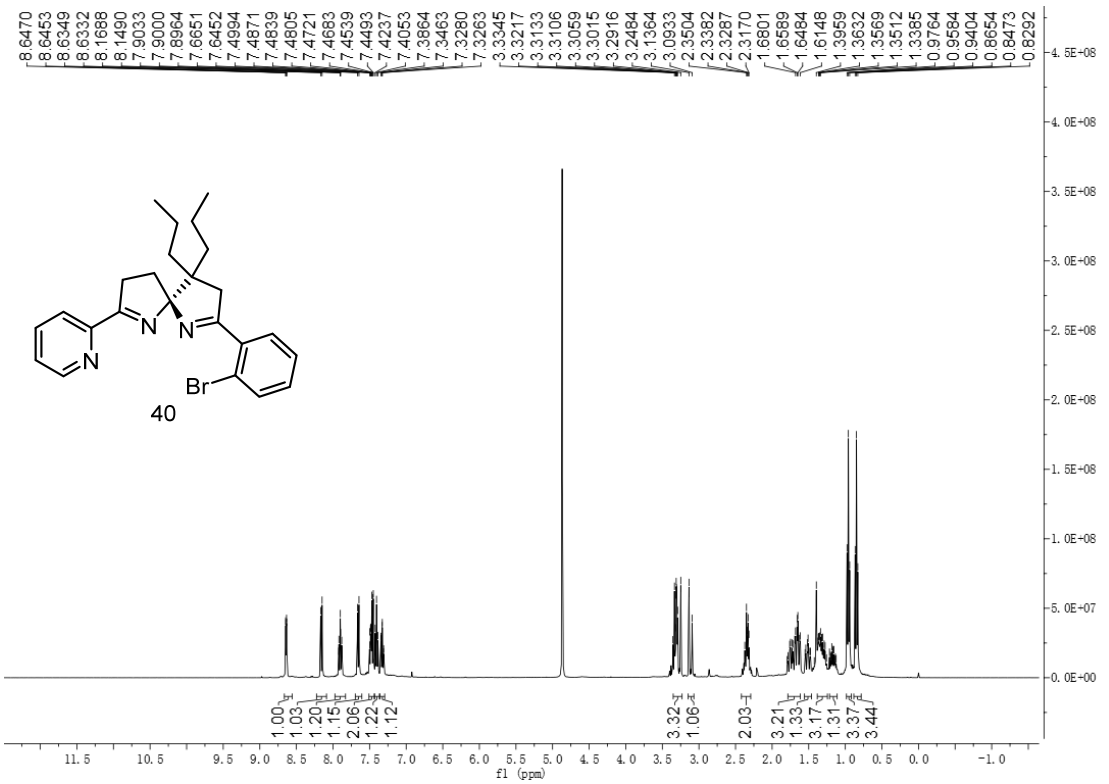
35.9002
30.1103
26.1166
25.8204
9.6710
9.4861
N
N
Br
39
f1 (ppm)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8.1490
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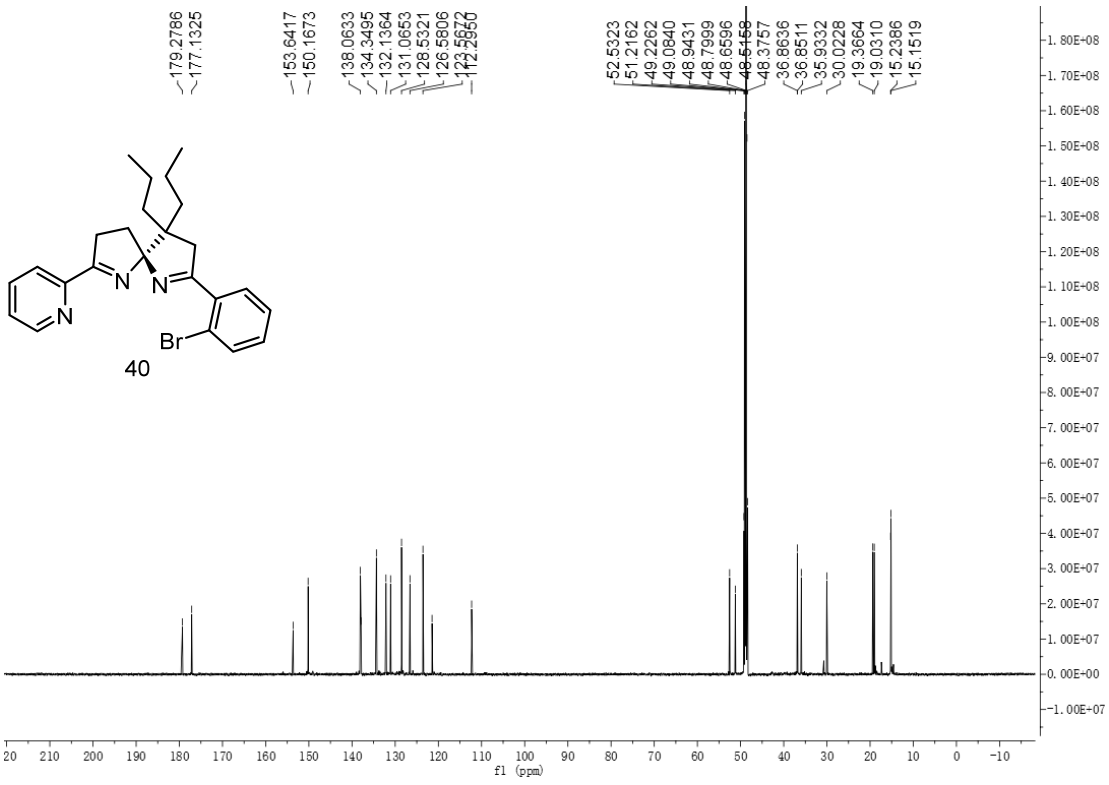
7.4994
7.4871
7.4839
7.4805
7.4721
7.4683
7.4539
7.4493
7.4237
7.4053
7.3864
7.3463
7.3280
7.3263
3.3345
3.3217
3.3133
3.3106
3.3059
3.3015
3.2916
3.2484
3.1364
3.0933
2.3504
2.3382
2.3287
2.3170
1.6801
1.6589
1.6484
1.6148
1.3959
1.3632
1.3569
1.3512
1.3385
0.9764
0.9584
0.9404
0.8654
0.8473
0.8292
Br
40
1.00
1.03
1.20
1.15
2.06
1.22
1.12
3.32
1.06
2.03
3.21
1.33
3.17
1.31
3.37
3.44
f1 (ppm)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132.1364
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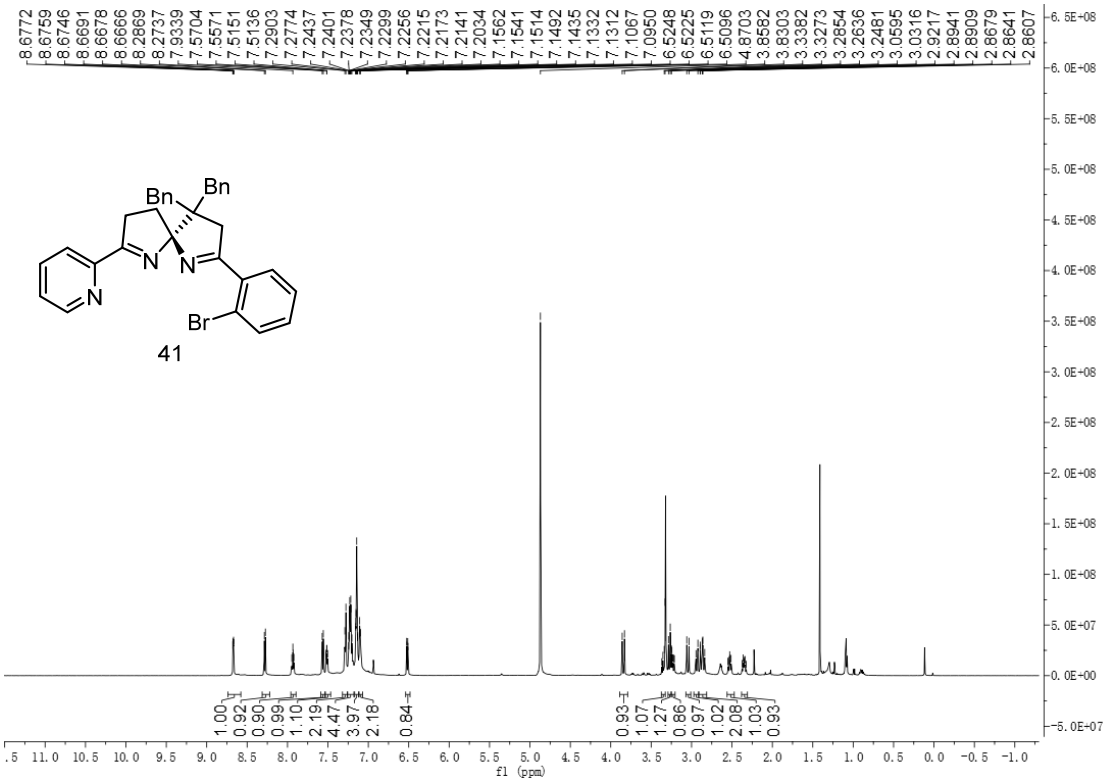
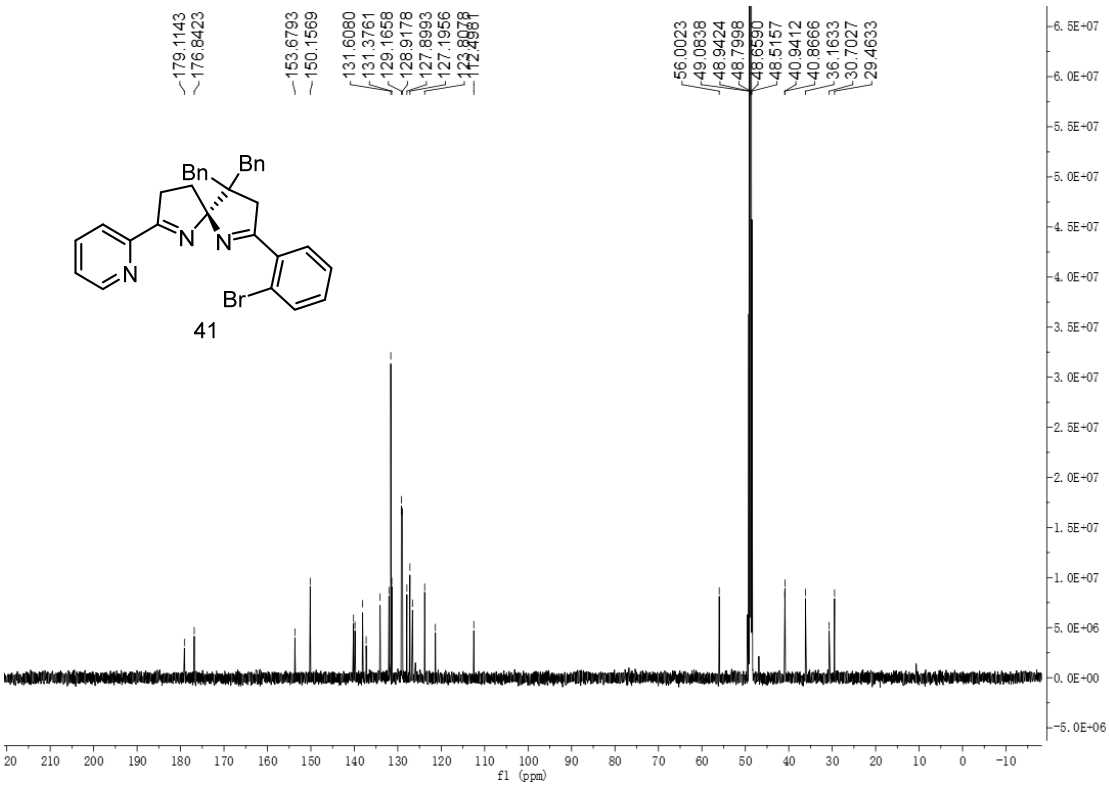
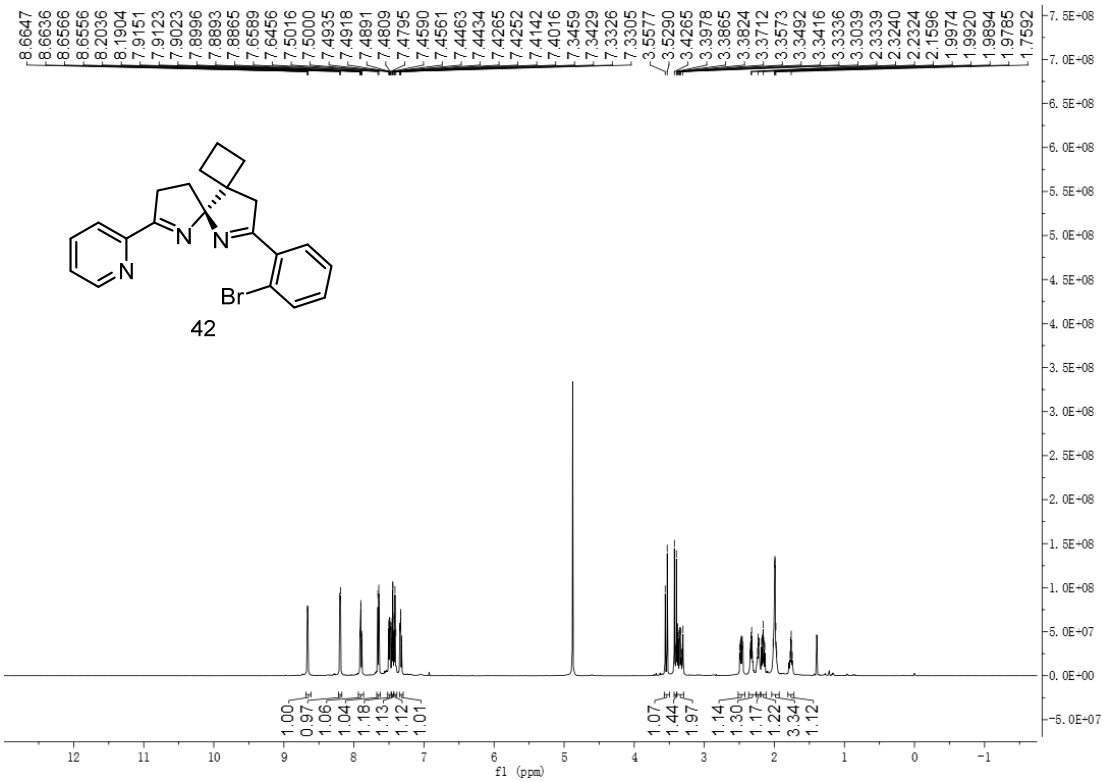
128.5321
126.5806
52.5323
51.2162
49.2262
49.0840
48.9431
48.7999
48.6596
48.5158
48.3757
36.8636
36.8511
35.9332
30.0228
19.3664
19.0310
15.2386
15.1519
Br
40
f1 (ppm)


Bn
Bn
N
N
N
Br
41
f1 (ppm)


Bn
Bn
N
N
N
Br
41
f1 (ppm)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7.8865
7.6589
7.6456
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7.4463
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7.4252
7.4142
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7.3305
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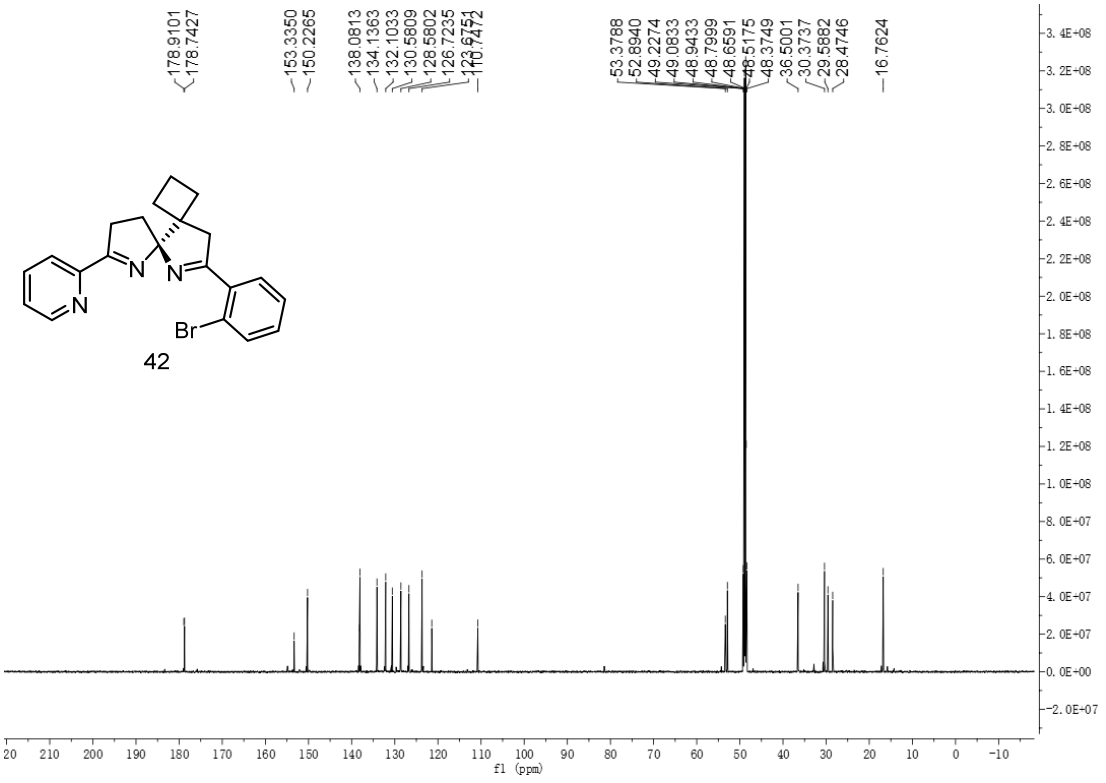
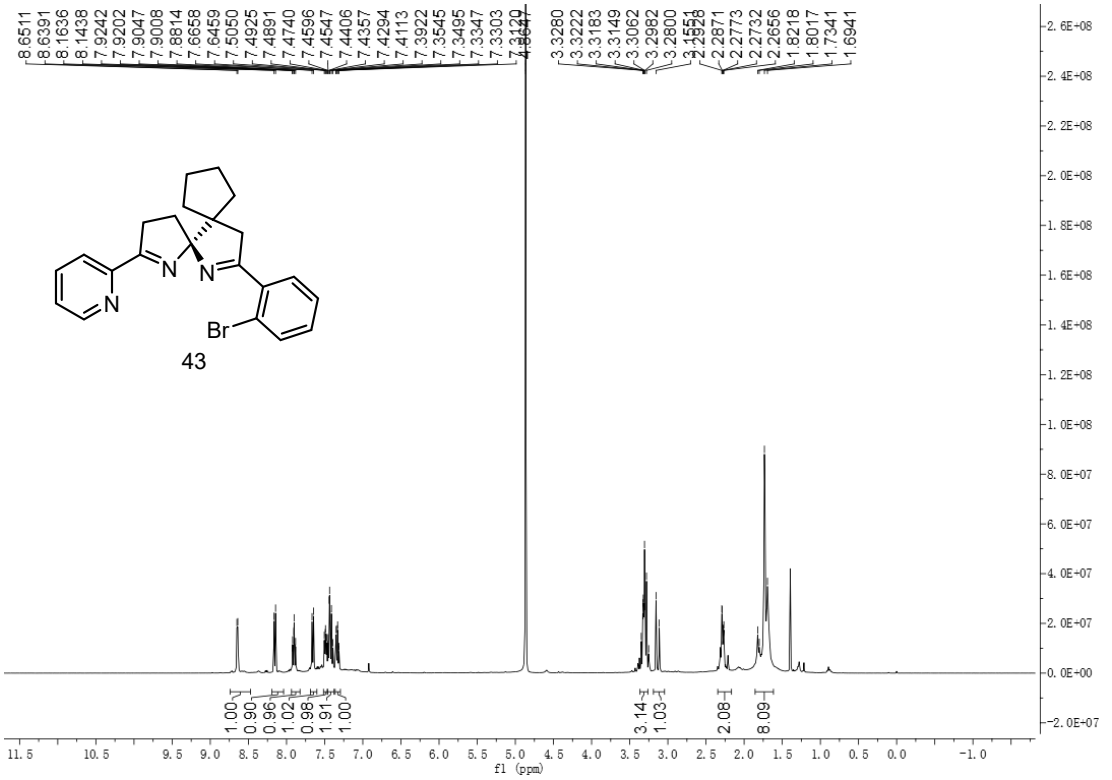
3.5290
3.4265
3.3978
3.3865
3.3824
3.3712
3.3573
3.3492
3.3416
3.3336
3.3039
2.3339
2.3240
2.2324
2.1596
1.9974
1.9920
1.9894
1.9785
1.7592
N
N
N
Br
42
1.00
0.97
1.06
1.04
1.18
1.13
1.12
1.01
1.07
1.44
1.97
1.14
1.30
1.17
1.22
3.34
1.12
f1 (ppm)


178.9101
178.7427
153.3350
150.2265
138.0813
134.1363
132.1033
130.5809
128.5802
126.7235
53.3788
52.8940
49.2274
49.0833
48.9433
48.7999
48.6591
48.5175
48.3749
36.5001
30.3737
29.5882
28.4746
16.7624
N
N
N
Br
42
f1 (ppm)


8.6511
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8.1636
8.1438
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7.9202
7.9047
7.9008
7.8814
7.6658
7.6459
7.5050
7.4925
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7.4740
7.4596
7.4547
7.4406
7.4357
7.4294
7.4113
7.3922
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7.3495
7.3347
7.3303
7.3120
3.3280
3.3222
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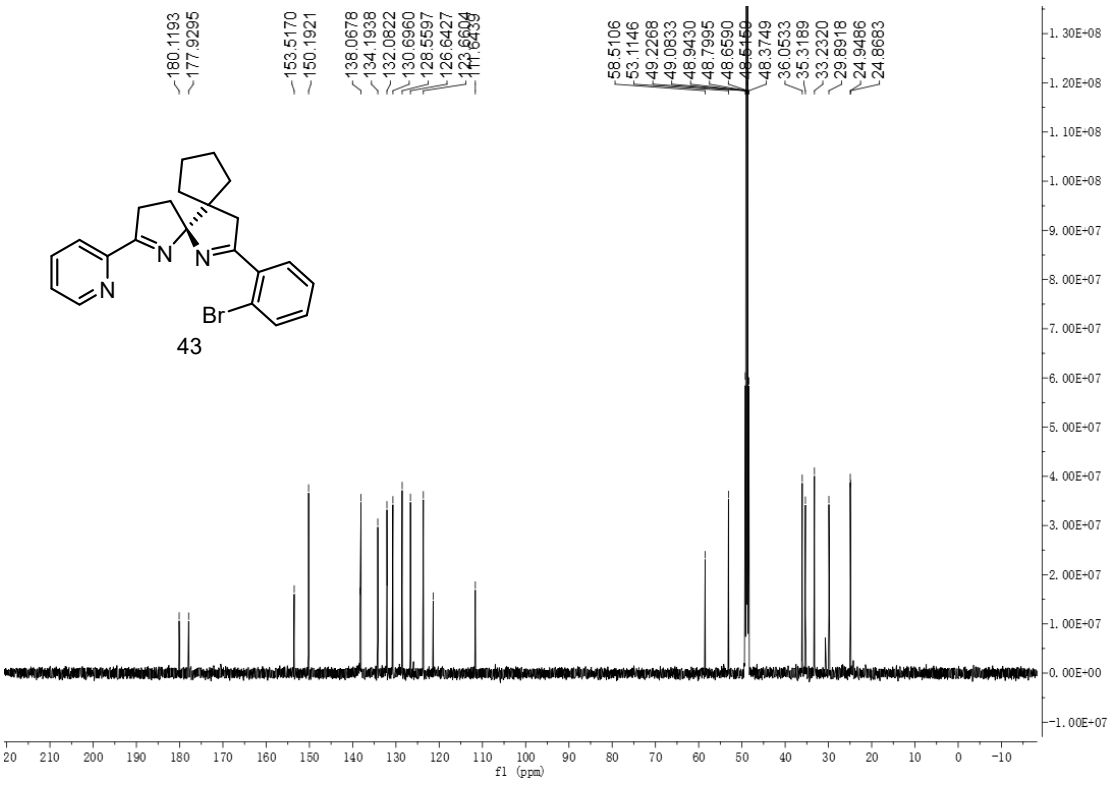
3.3149
3.3062
3.2982
3.2800
2.2871
2.2773
2.2732
2.2656
1.8218
1.8017
1.7341
1.6941
1.00
0.90
0.96
1.02
0.98
1.91
1.00
3.14
1.03
2.08
8.09
N
N
N
Br
43
f1 (ppm)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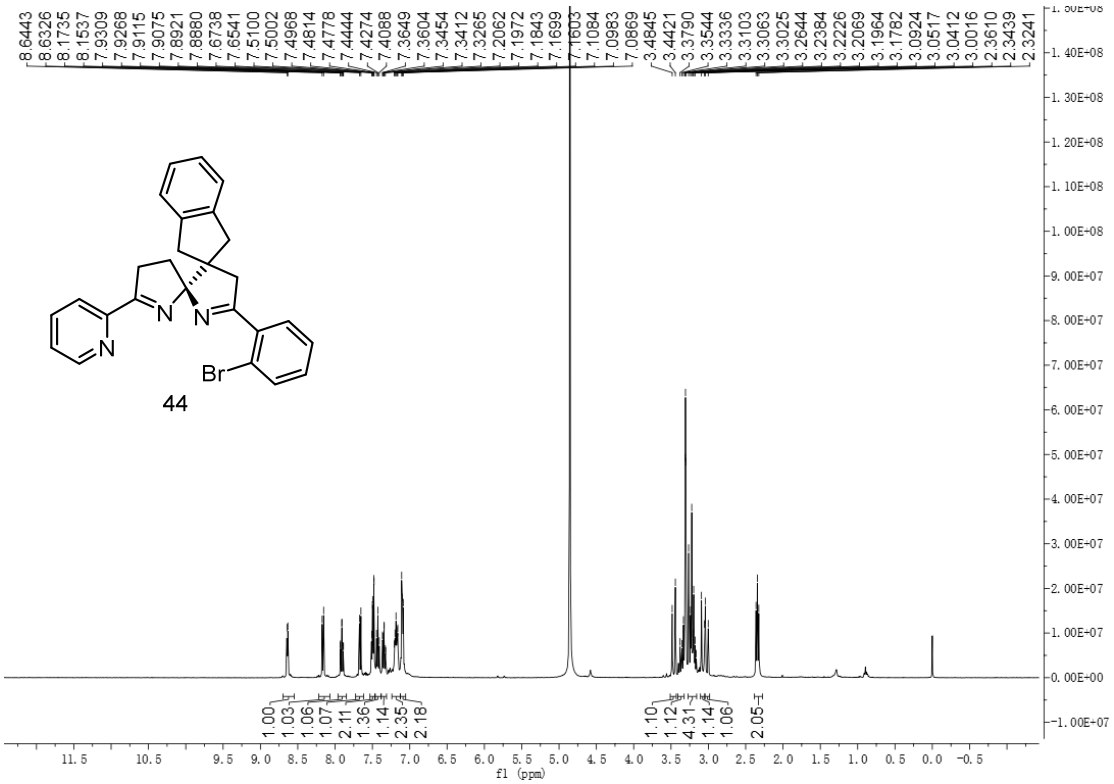
Br
43
f1 (ppm)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7.4088
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7.3604
7.3454
7.3412
7.3265
7.2062
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7.1843
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7.1603
7.1084
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7.0869
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3.4421
3.3790
3.3544
3.3336
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3.3063
3.3025
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3.2384
3.2226
3.2069
3.1964
3.1782
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2.3610
2.3439
2.3241
1.00
1.03
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1.14
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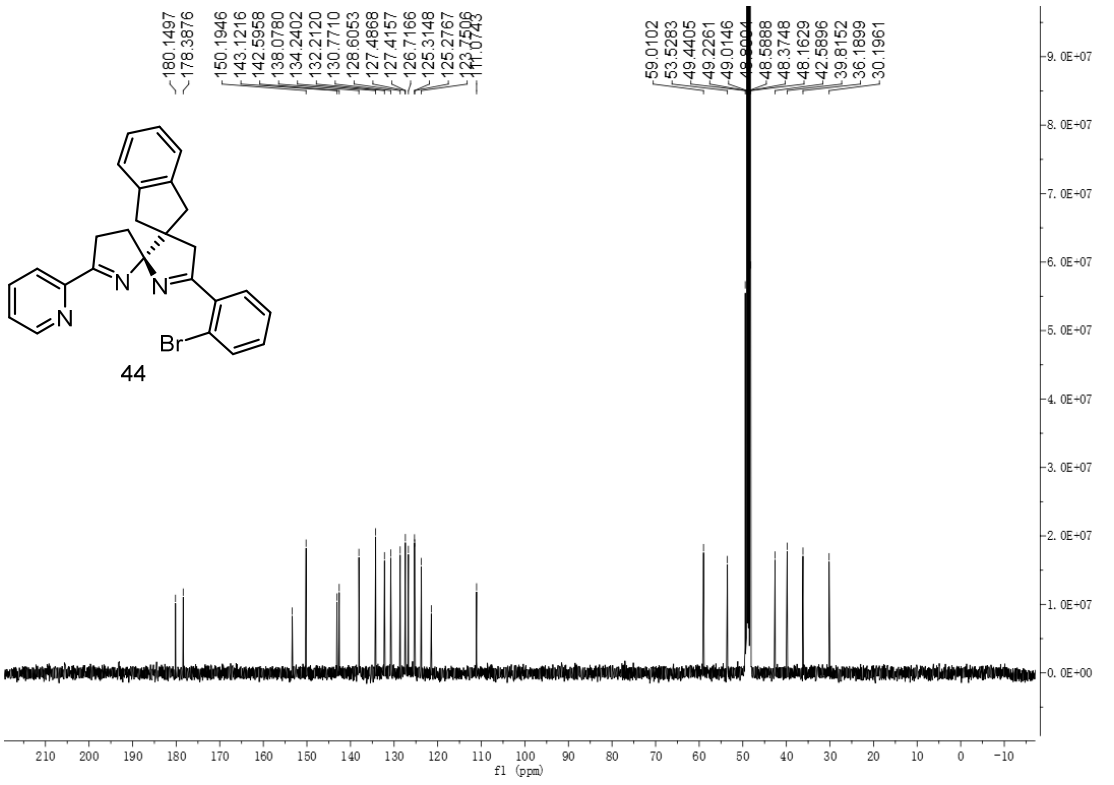
N
Br
44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111.0743
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49.0146
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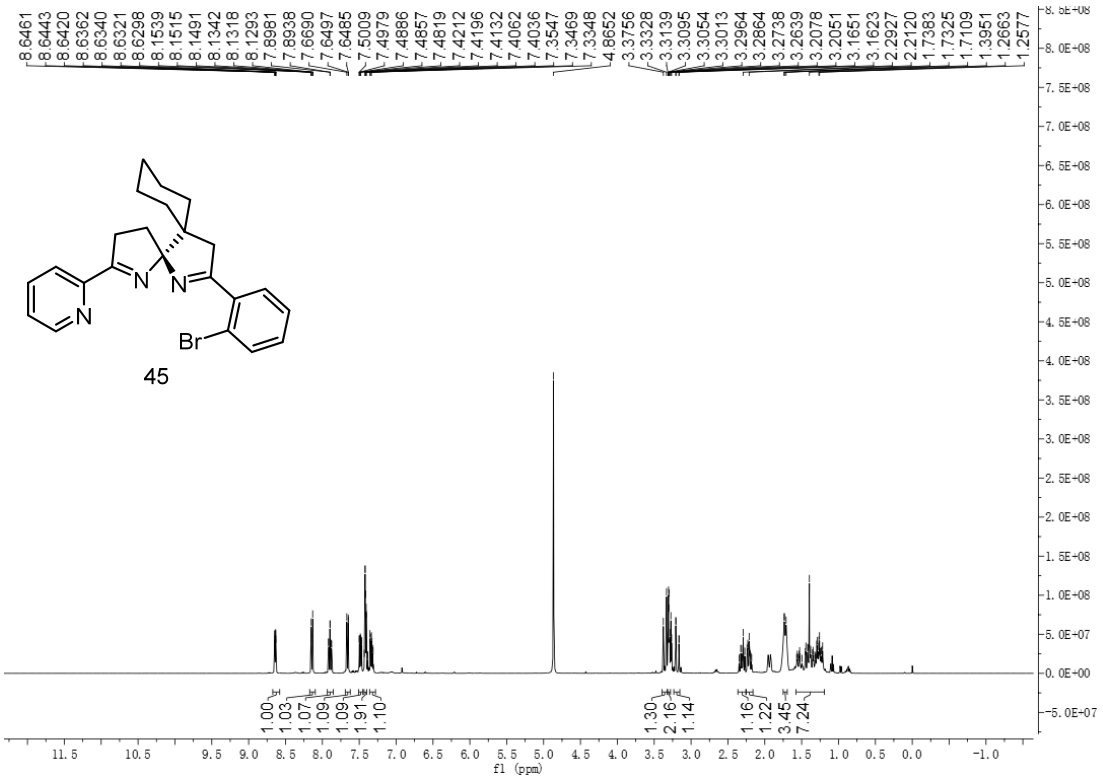
Br
44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1.07
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1.16
1.22
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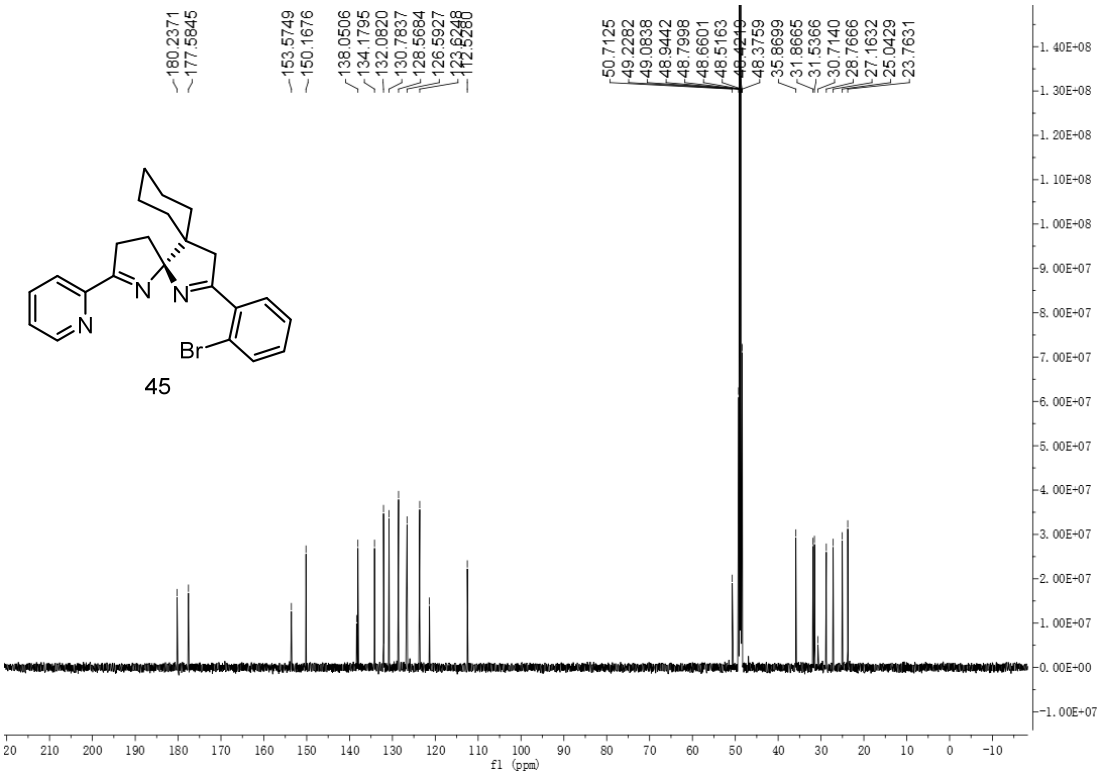
7.24
f1 (ppm)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48.5163
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48.3759
35.8699
31.8665
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Br
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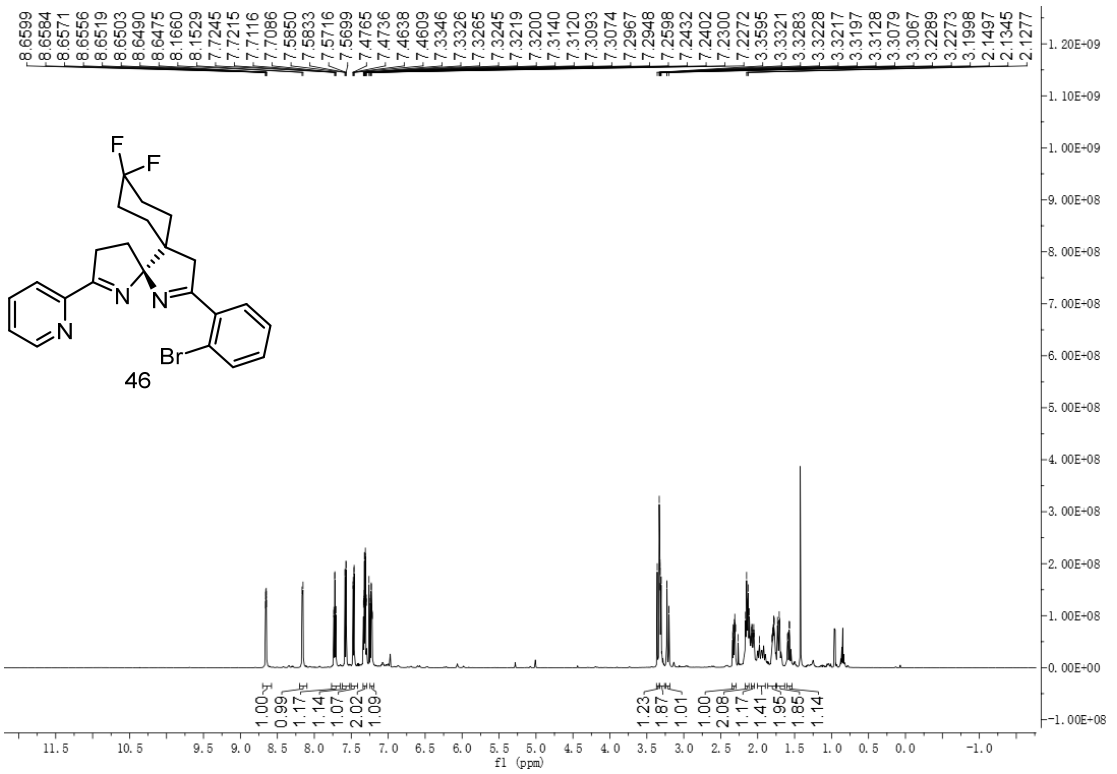
f1 (ppm)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F
N
N
N
Br
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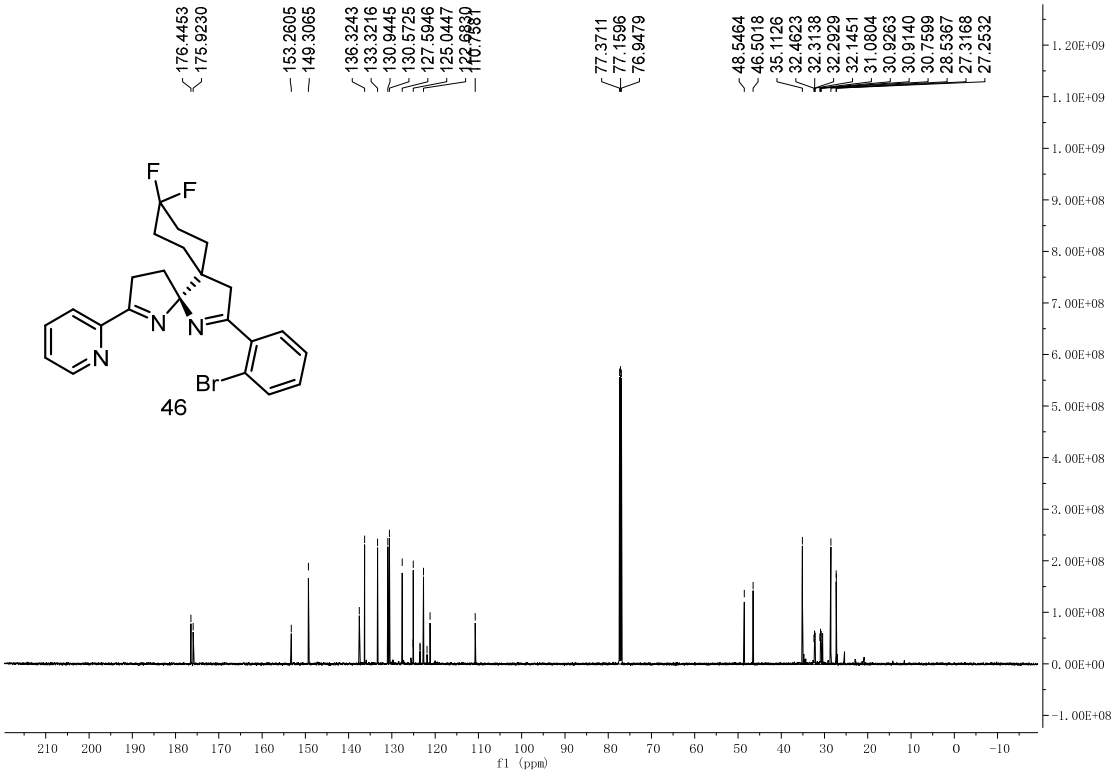
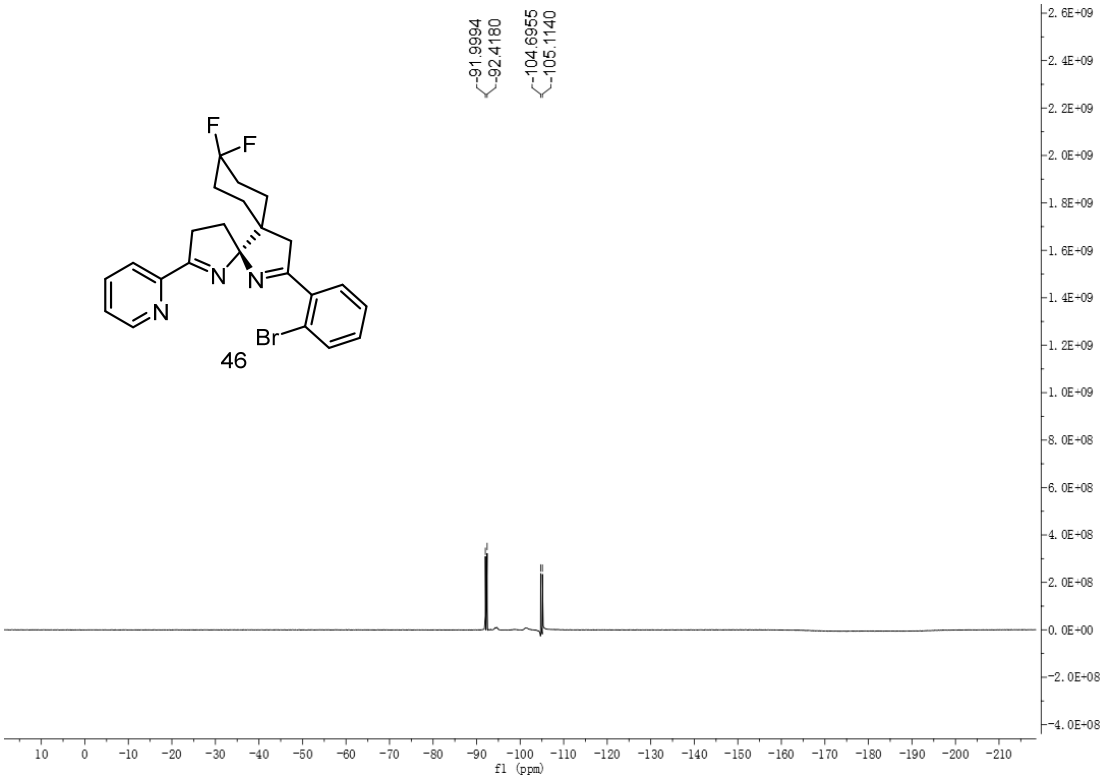
fl (ppm)


F
F
N
N
N
Br
46
fl (ppm)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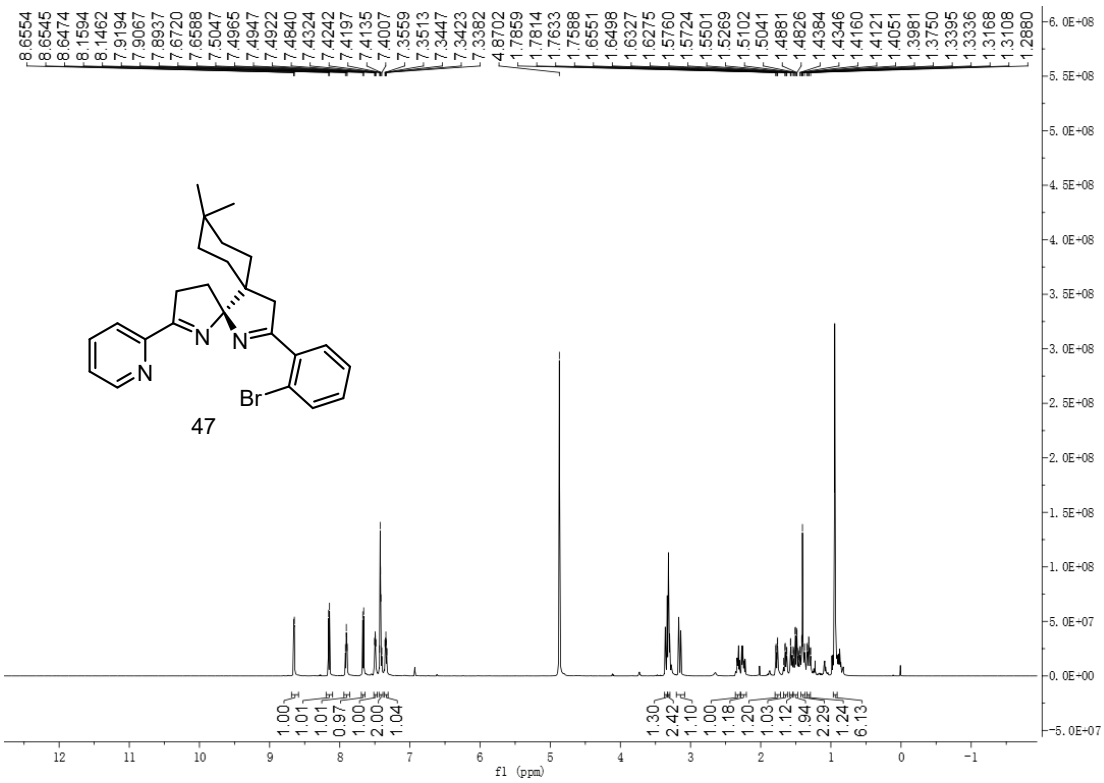
F
N
N
N
Br
f1 (ppm)

46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1.5760
1.5724
1.5501
1.5269
1.5102
1.5041
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1.3336
1.3168
1.3108
1.2880
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1.01
1.01
0.97
1.00
2.00
1.04
1.30
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1.00
1.18
1.20
1.03
1.12
1.94
2.29
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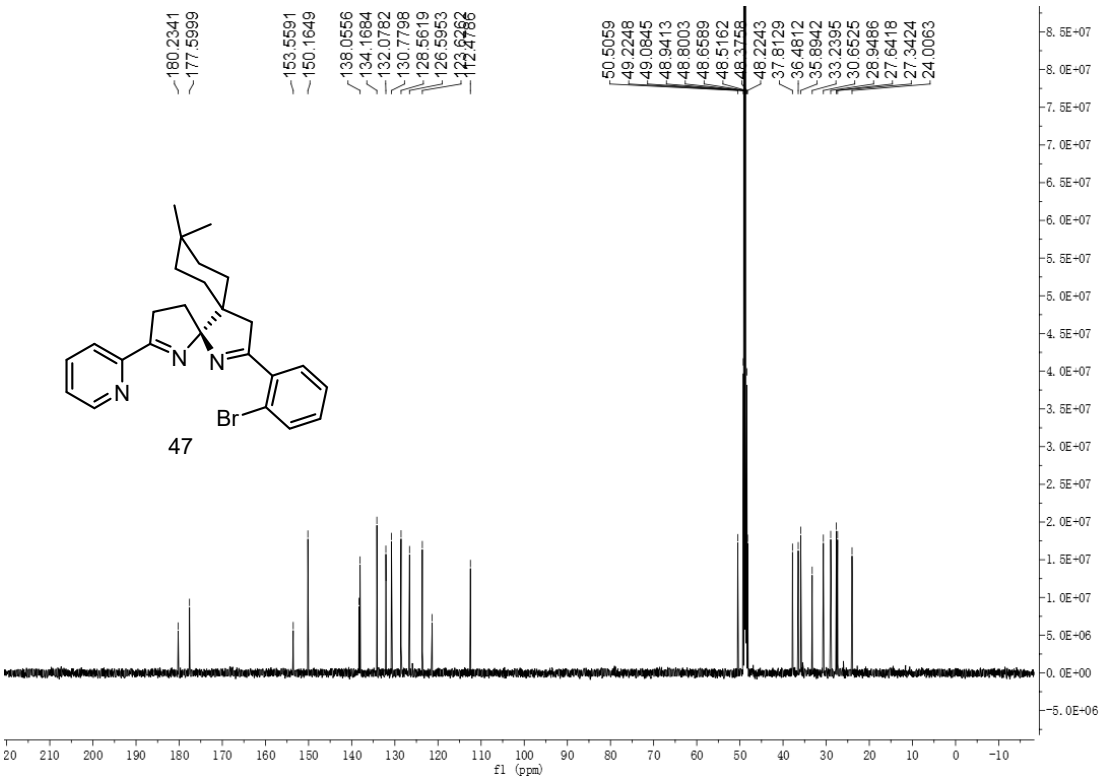
6.13
f1 (ppm)

47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48.2243
37.8129
36.4812
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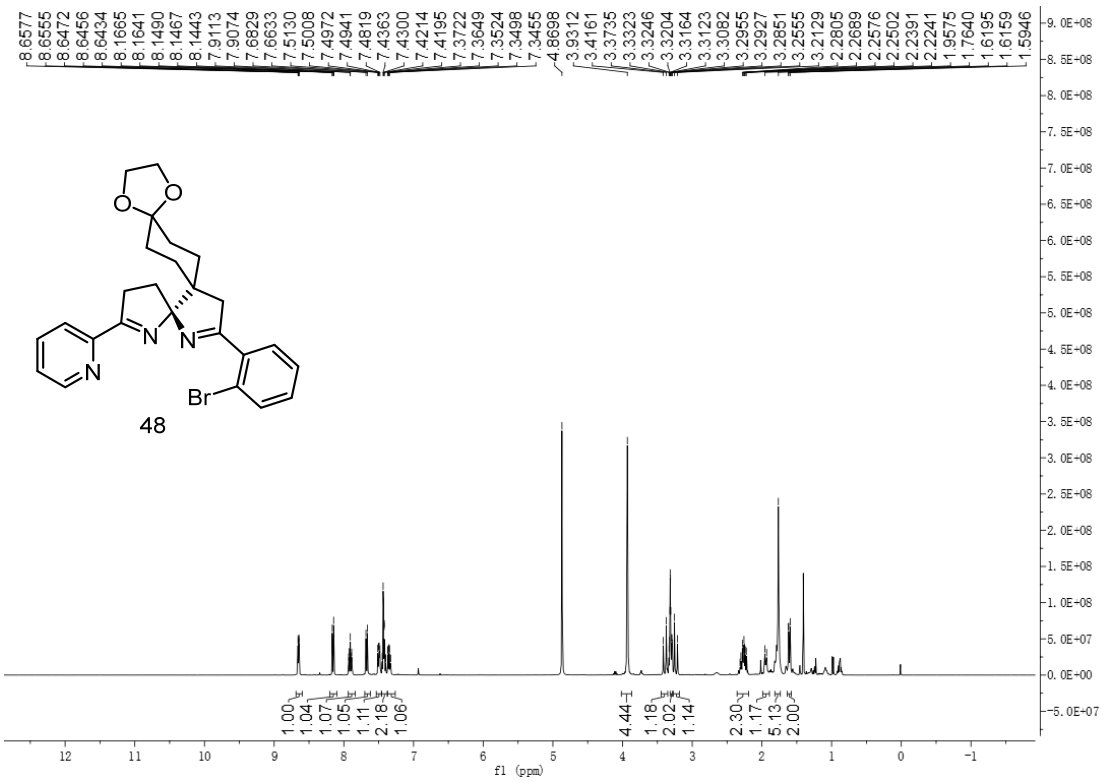
Br
47
f1 (ppm)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7.4300
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2.2502
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1.6159
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N
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N
Br
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1.05
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1.14
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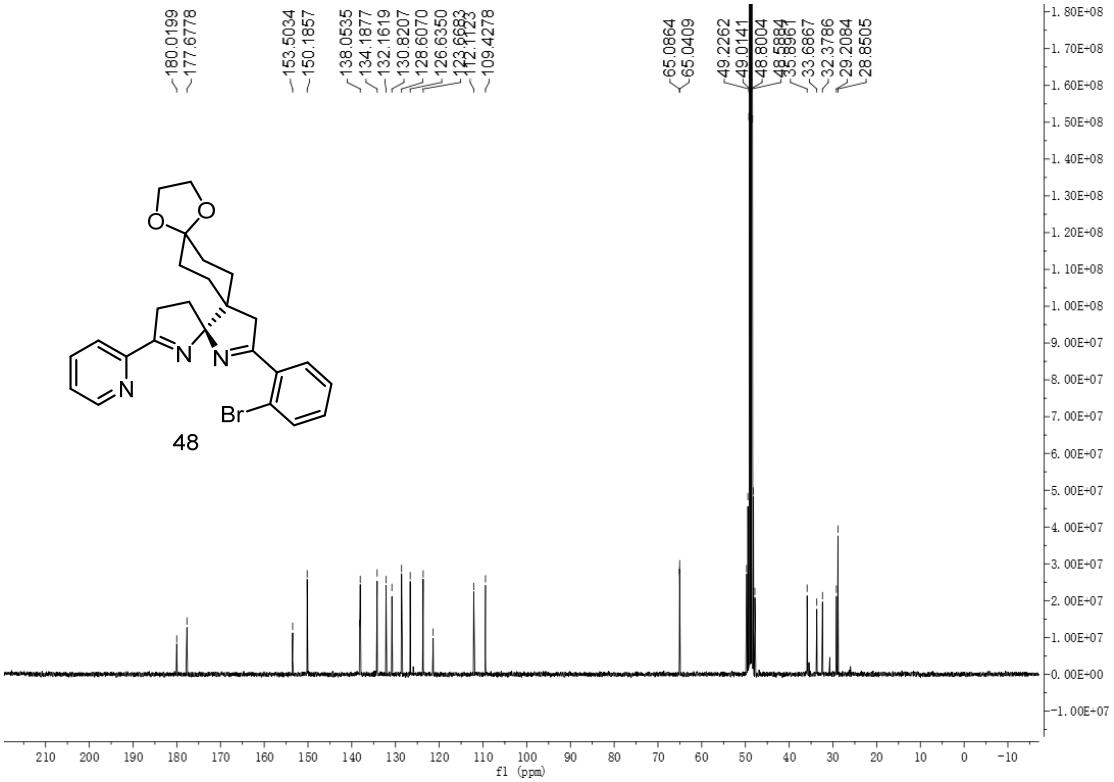
2.00
f1 (ppm)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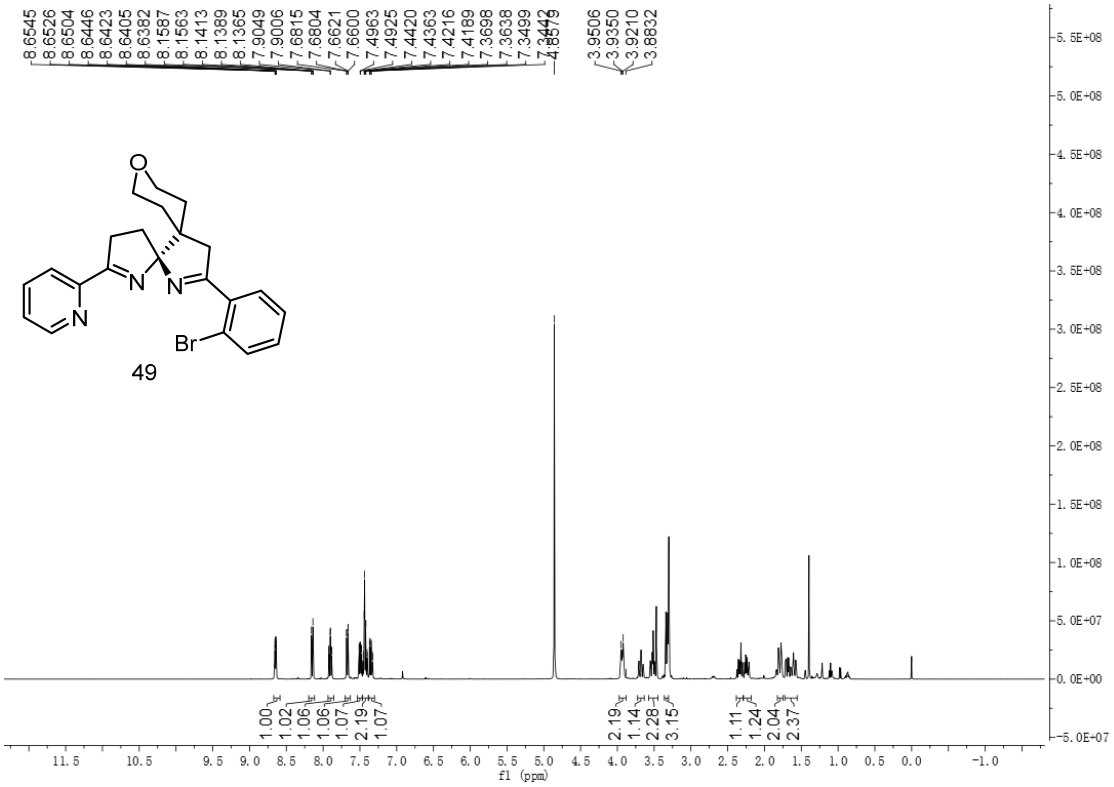
N
N
N
Br
48
f1 (ppm)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8.1365
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7.9006
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7.6600
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7.4925
7.4420
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7.3638
7.3499
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3.8832
1.00
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2.19
1.07
2.19
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1.11
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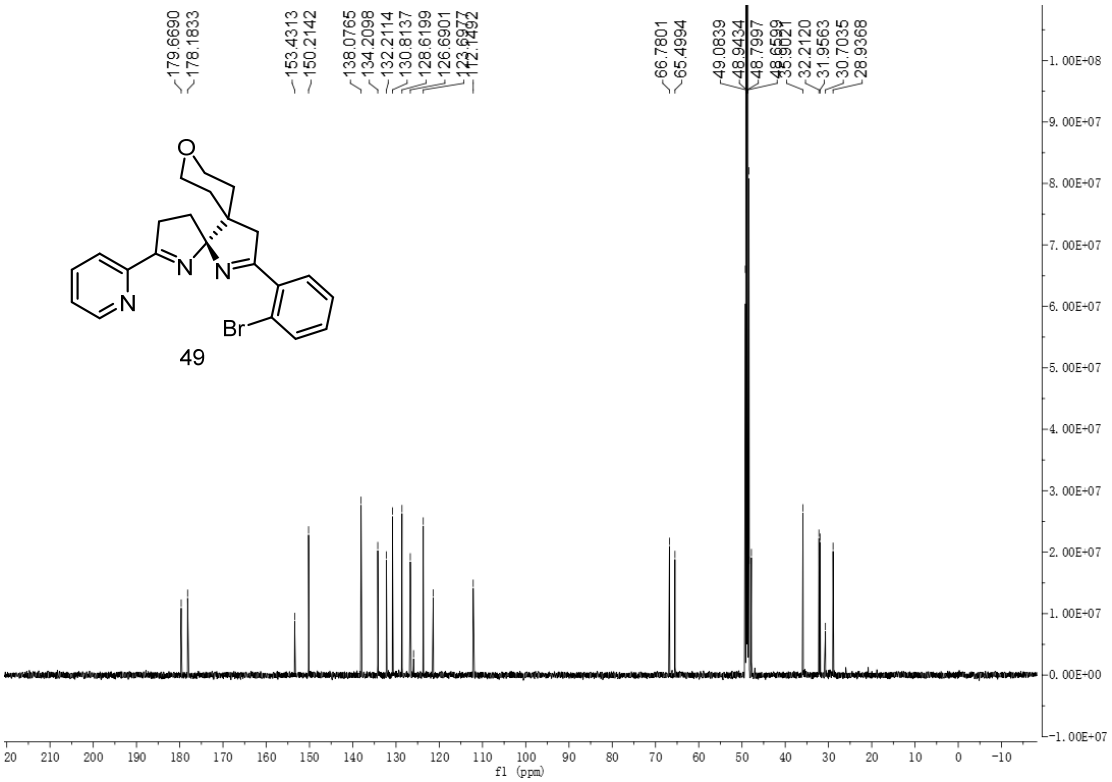
Br
49
f1 (ppm)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N
N
Br
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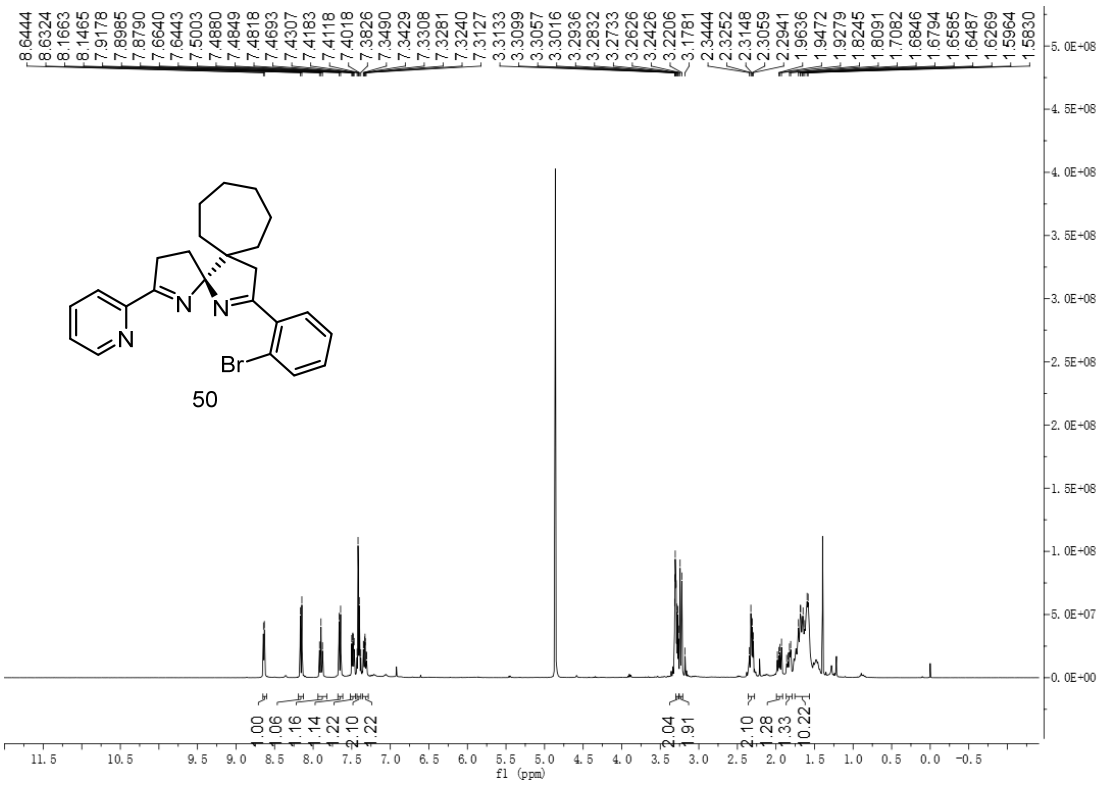
f1 (ppm)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N
Br
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1.00
1.06
1.16
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1.22
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1.28
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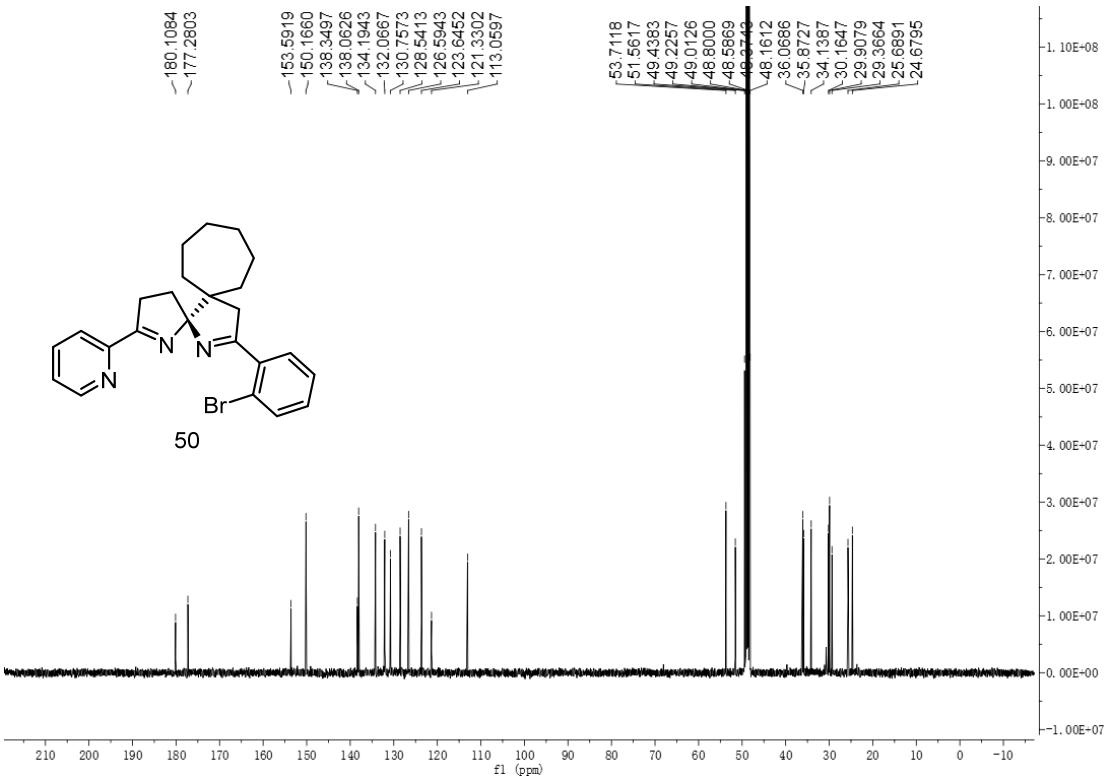
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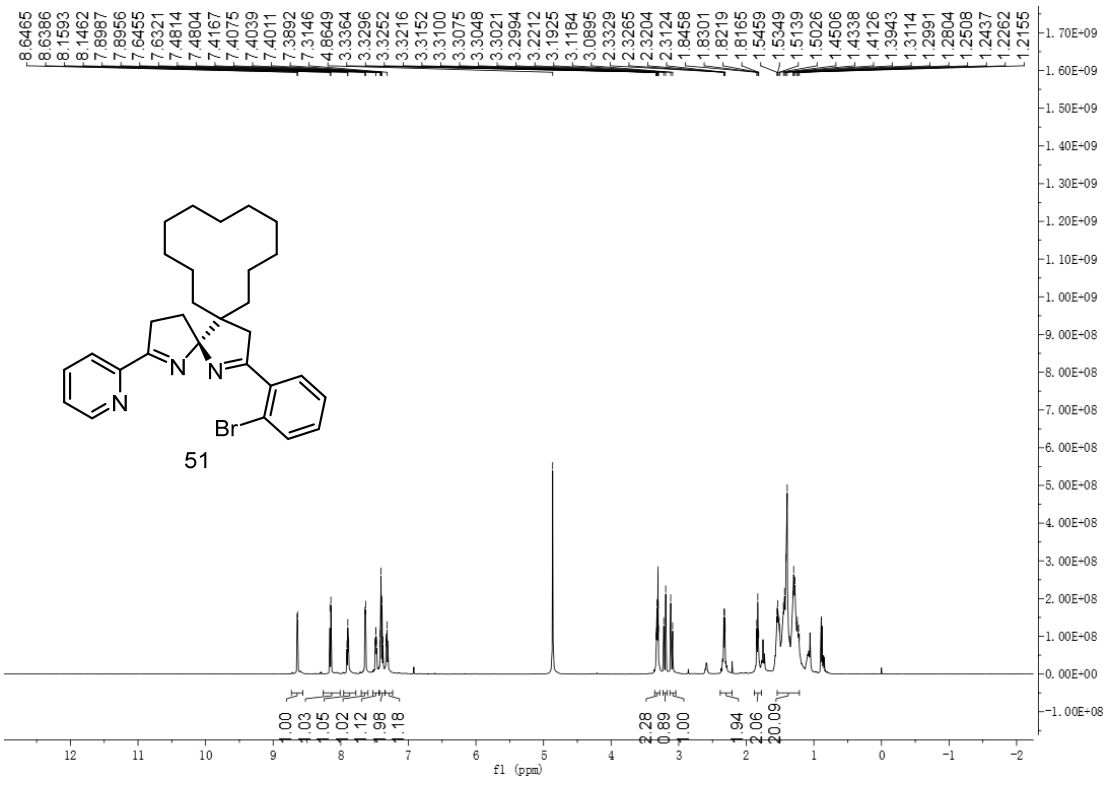
Br
f1 (ppm)

50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1.2508
1.2437
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1.03
1.05
1.02
1.12
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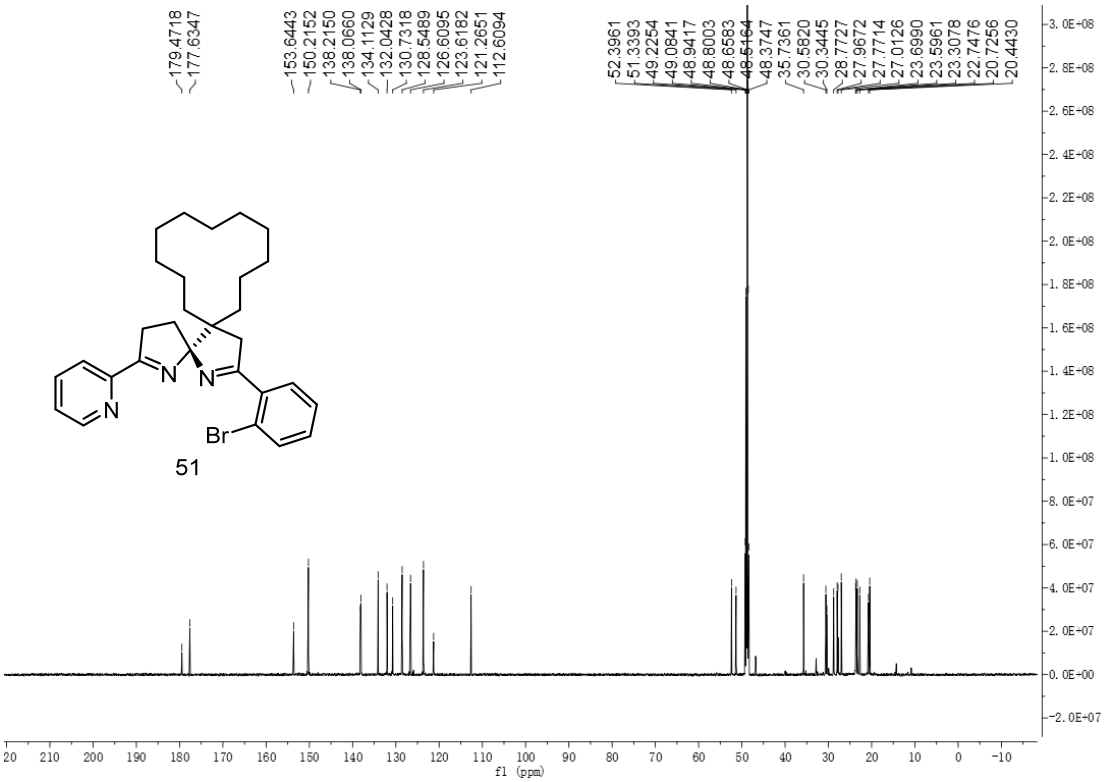
Br
f1 (ppm)

51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51.3393
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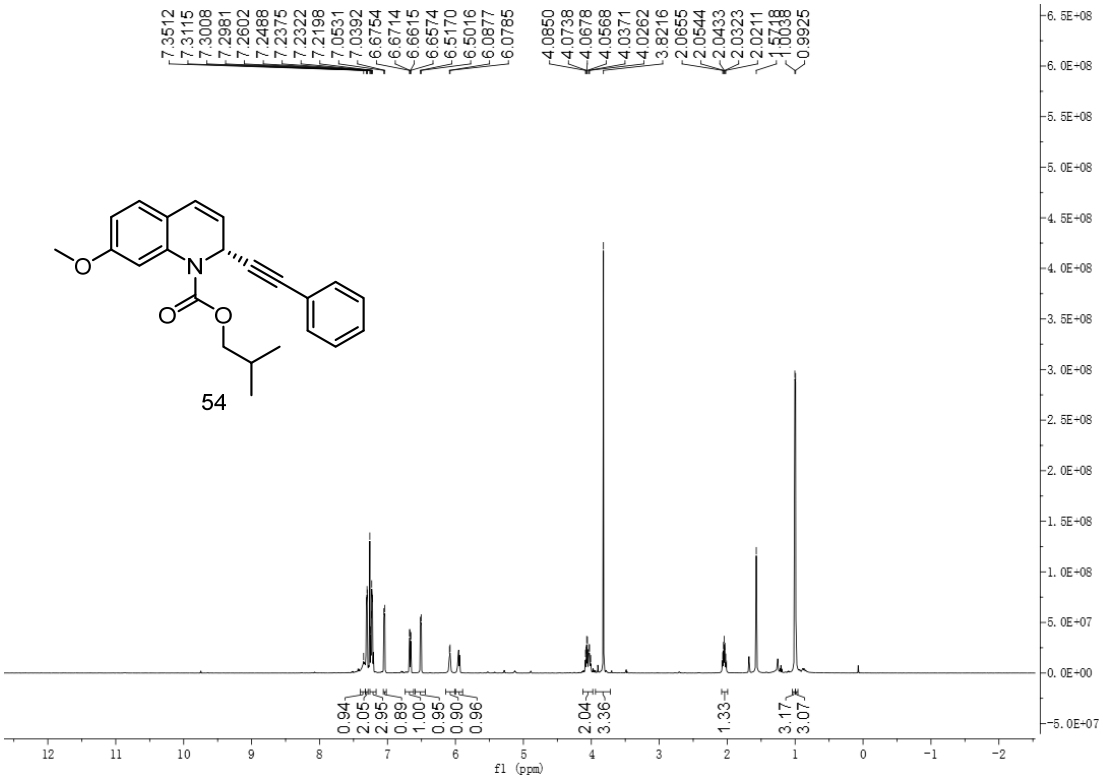
Br
51
f1 (ppm)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2.05
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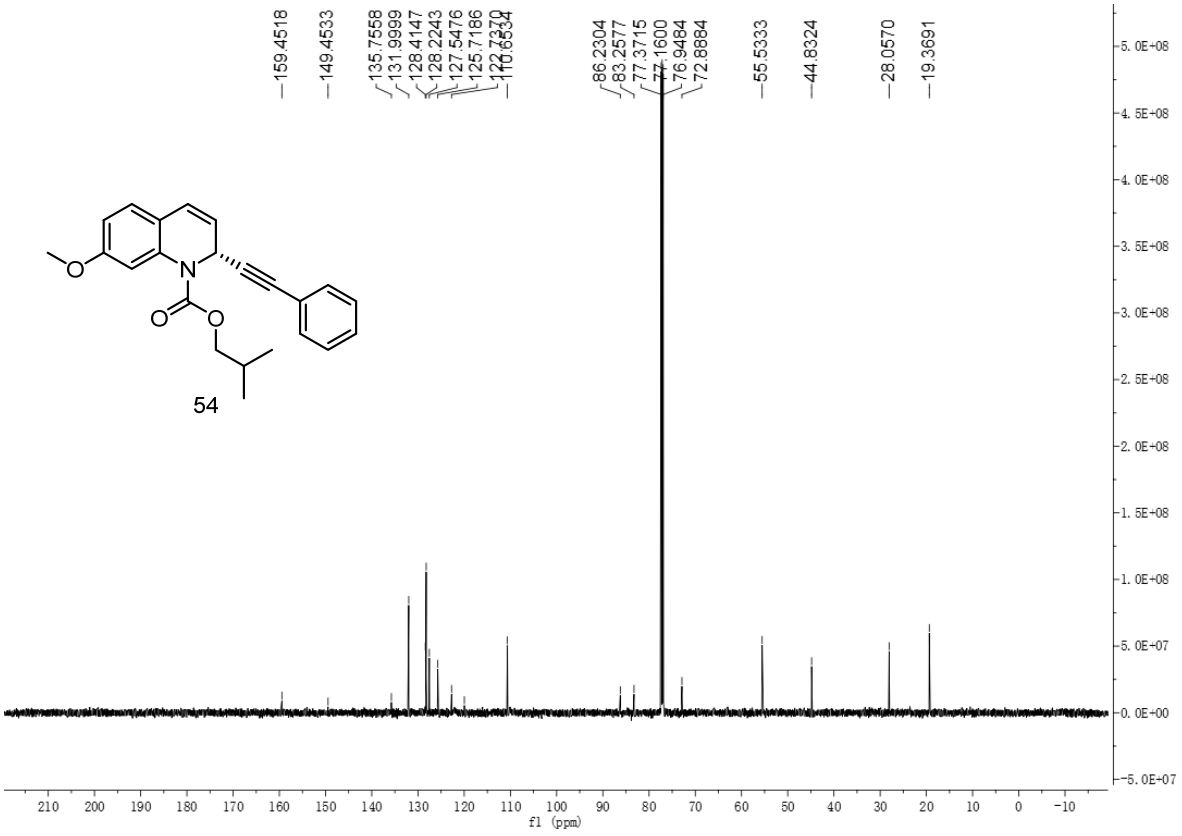
3.07
f1 (ppm)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76.9484
72.8884
55.5333
44.8324
28.0570
19.3691
O
N
O
O
54
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

9. References

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