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

Supporting Information

Rh(III)-Catalyzed Cascade Annulation to Produce *N*-acetyl Chain of Spiropyrroloisoquinoline Derivatives

Yuan He, Jing Zheng and Lin Dong*

Key Laboratory of Drug-Targeting and Drug Delivery System of the Education Ministry and Sichuan Province, Sichuan Engineering Laboratory for Plant-Sourced Drug and Sichuan Research Center for Drug Precision Industrial Technology, West China School of Pharmacy, Sichuan University, Chengdu 610041, China

dongl@scu.edu.cn

Table of Contents

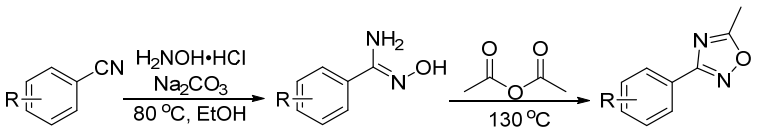
1. General Information

All reactions were carried out in high-pressure reaction tube. Column chromatography was performed with silica gel (200–300 mesh). High-resolution mass spectra (HRMS) were obtained with a Waters-Q-TOF-Premier (ESI). ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker 400 MHz and 100MHz instrument. Spectra were reported relative to Me_4Si (δ 0.0 ppm), $CDCl_3$ (δ 7.26 ppm). ^{13}C NMR were reported relative to $CDCl_3$ (δ 77.16 ppm). Splitting patterns are designated as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. Compounds were characterized by ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and HRMS.

2. Material

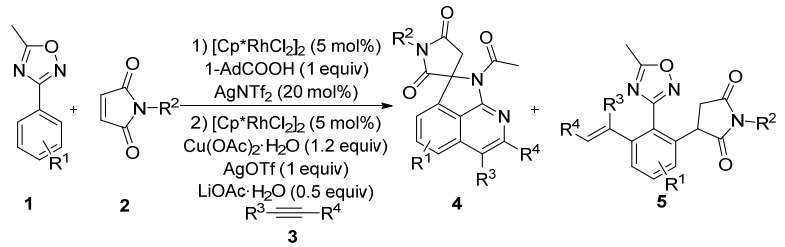
Unless otherwise noted, all reagents were obtained from commercial suppliers and used without further purification. Solvents were dried over sodium (for THF and ether) and CaH_2 (for toluene, DCM and DCE) by refluxing for overnight and freshly distilled prior to use. Alkynes was prepared following literature procedures[1]. Maleimides was prepared following literature procedures[2].

General Procedure for the Synthesis of 3-Aryloxadiazole [3]



A solution with benzonitrile (1.0 equiv, 5.0 mmol), sodium carbonate (2.0 equiv), hydroxylamine hydrochloride (2.0 equiv), and EtOH (7.5 mL) was heated to reflux overnight. After cooling to room temperature, the mixture was filtered over a pad of celite and evaporated to dryness to give crude product benzamidoxime. Then the acetic anhydride (1.1 equiv) was added and the mixture was heated at 130 °C for 1 h. After cooling to room temperature, the mixture solution was extracted with EtOAc (3 × 20 mL), the combined organic layer was washed with saturated brine, then the combined organic layers were dried ($MgSO_4$), filtered, and concentrated in vacuo. Purification of the residue by column chromatography (petroleum ether/ethyl acetate = 30/1) to give the product **1**.

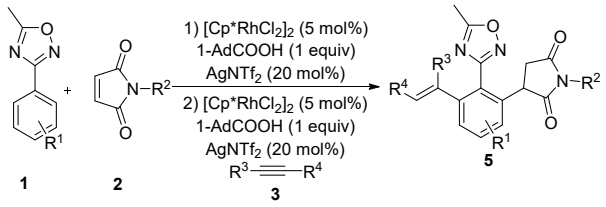
3. General Procedure A for the Synthesis of Products 4 and 5 (Condition A: spiropyrroloisoquinoline 4 as the major product)



A mixture of **1** (0.05 mmol), **2** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $AgNTf_2$ (20 mol%), 1-AdCOOH (1.0 equiv), DCE (0.5 mL) were added to an oven dried high-pressure tube under Ar atmosphere. The reaction mixture was stirred at 100 °C for 5-16 h. Subsequently, **3** (1.2 equiv),

$[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2•H_2O$ (1.2 equiv), AgOTf (1.0 equiv), $LiOAc•2H_2O$ (0.5 equiv) were directly to the mixture, the reaction mixture was stirred at 100 °C for 13 h under Ar. After cooling to room temperature, Na_2CO_3 (2.0 equiv) was added to the tube and stirred until acid disappear (monitored by TLC). Then the mixture was filtered over a pad of celite and the filtered was concentrated in vacuo. Purification of the residue by column chromatography (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1) to give the product **4** and **5**.

4. General Procedure B for the Synthesis of Product 5 (Condition B: 5 as the single product)



A mixture of **1** (0.05 mmol), **2** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $AgNTf_2$ (20 mol%), 1-AdCOOH (1.0 equiv), DCE (0.5 mL) were added to an oven dried high-pressure tube under Ar atmosphere. The reaction mixture was stirred at 100 °C for 16 h. Subsequently, **3** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $AgNTf_2$ (20 mol%), 1-AdCOOH (1.0 equiv) were directly to the mixture, the reaction mixture was stirred at 80 °C for 13 h under Ar. After cooling to room temperature, Na_2CO_3 (3.0 equiv) was added to a tube and stirred until acid disappear (monitored by TLC). Then the mixture was filtered over a pad of celite and the filtered was concentrated in vacuo. Purification of the residue by column chromatography (petroleum ether/ethyl acetate = 2/1) to give the single product **5**.

5. Optimization of the Reaction Conditions

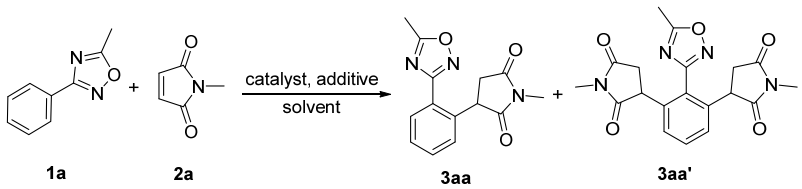


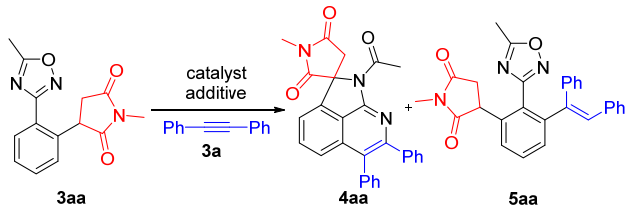
Table S1. The effect of catalysts, additives and solvents on the reaction[a]

Entry	Catalyst	Additive	Solvent	Yield **3aa**[b]	Yield **3aa'**[b]
1	$[RuCl_2(p\text{-cymene})]_2$	PivOH	DCE	Trace	Trace
2	$Cp^*Rh(CH_3CN)_3(SbF_6)_2$	PivOH	DCE	44%	Trace
3	$[Cp^*IrCl_2]_2$	PivOH	DCE	Trace	Trace
4	$Cp^*Co(CO)I_2$	PivOH	DCE	ND	Trace
5	$[Cp^*RhCl_2]_2$	PivOH	DCE	75%	Trace
6	$[Cp^*RhCl_2]_2$	PivOH	Toluene	26%	Trace
7	$[Cp^*RhCl_2]_2$	PivOH	TFE	66%	Trace
8	$[Cp^*RhCl_2]_2$	PivOH	DCM	51%	Trace

9	$[Cp^*RhCl_2]_2$	PivOH	THF	ND	Trace
10	$[Cp^*RhCl_2]_2$	PivOH	CH_3OH	ND	Trace
11	$[Cp^*RhCl_2]_2$	PivOH	1,4-Dioxane	42%	Trace
12	$[Cp^*RhCl_2]_2$	HOAc	DCE	67%	Trace
13	$[Cp^*RhCl_2]_2$	1-AdCOOH	DCE	80%	Trace
14	$[Cp^*RhCl_2]_2$	TFA	DCE	44%	Trace
15	$[Cp^*RhCl_2]_2$	$PhOCH_2COOH$	DCE	60%	Trace
16	$[Cp^*RhCl_2]_2$	PhCOOH	DCE	63%	Trace
17	$[Cp^*RhCl_2]_2$	$LiOAc·H_2O$	DCE	27%	Trace
18	$[Cp^*RhCl_2]_2$	AgOAc	DCE	31%	Trace
19[c]	$[Cp^*RhCl_2]_2$	1-AdCOOH	DCE	63%	Trace
20[d]	$[Cp^*RhCl_2]_2$	1-AdCOOH	DCE	69%	Trace
21[e]	$[Cp^*RhCl_2]_2$	1-AdCOOH	DCE	32%	Trace
22[f]	$[Cp^*RhCl_2]_2$	HOAc	DCE	0%	99%

[a]Reaction conditions: **1a** (0.05 mmol), **2a** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), additive (1.0 equiv), $AgNTf_2$ (20 mol%), DCE (0.5 mL), 100 °C, overnight, under Ar. [b]Isolated yield. [c]$[Cp^*RhCl_2]_2$ (4 mol%), [d]$AgSbF_6$ (20 mol%), [e]AgOTf (20 mol%), [f]**2a** (3 equiv), HOAc (1.5 equiv), 130 °C.

Table S2. The effect of catalyst, additive and solvent on the reaction[a]

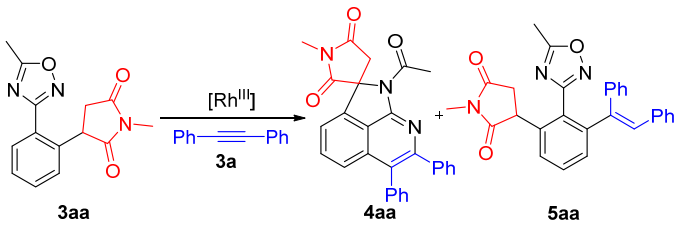


Entry	Catalyst	Additive	Solvent	Yield/ **4aa**[b]	Yield/ **5aa**[b]
1	$[Cp^*RhCl_2]_2$	--	DCE	24%	trace
2	$[Cp^*RhCl_2]_2$	K_2CO_3	DCE	23%	trace
3	$[Cp^*RhCl_2]_2$	LiOAc	DCE	41%	trace
4	$[Cp^*RhCl_2]_2$	NaOAc	DCE	17%	trace
5	$[Cp^*RhCl_2]_2$	Cs_2CO_3	DCE	ND	ND
6	$[Cp^*RhCl_2]_2$	TsOH	DCE	11%	trace
7	$[Cp^*RhCl_2]_2$	1-AdCOOH	DCE	25%	trace
8	$Cp^*(CO)_2I_2$	LiOAc	DCE	Trace	ND
9	$[Cp^*IrCl_2]_2$	LiOAc	DCE	30%	ND
10	$[Ru(p\text{-cymene})Cl_2]_2$	LiOAc	DCE	59%	ND
11	$Cp^*Rh(CH_3CN)_3(SbF_6)_2$	LiOAc	DCE	32%	trace
12	$[Cp^*RhCl_2]_2$	LiOAc	MeOH	ND	ND
13	$[Cp^*RhCl_2]_2$	LiOAc	Toluene	36%	Trace
14	$[Cp^*RhCl_2]_2$	LiOAc	TFE	ND	ND
15	$[Cp^*RhCl_2]$	LiOAc	CH_3CN	ND	ND
16	$[Cp^*RhCl_2]$	LiOAc	THF	ND	ND

[a]Reaction conditions: **3aa** (0.025 mmol), **3a** (1.2 equiv), Catalyst (5 mol%), $Cu(OAc)_2·H_2O$ (1.0 equiv), additive

(0.5 equiv), $AgNTf_2$ (20 mol%), DCE (0.5 mL), 100 °C, 13 h under Ar. [b]Isolated yield.

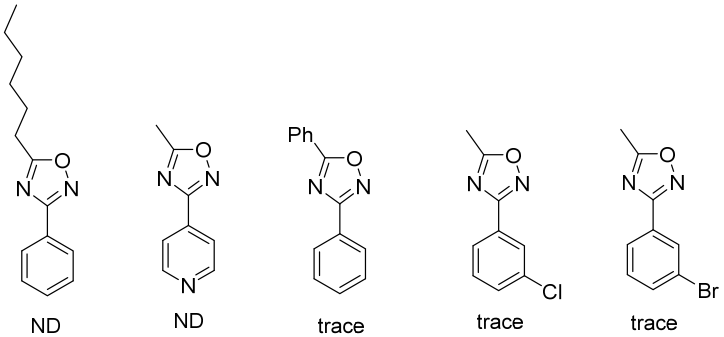
Table S3. The effect of oxidant, Ag salt and temperature on the reaction[a]



Entry	Oxidant	Ag Salt	Temp.	Yield/ **4aa**[b]	Yield/ **5aa**[b]
1	$Cu(OAc)_2·H_2O$	--	100	ND	ND
2	$Cu(OAc)_2·H_2O$	$AgNTf_2$	100	41%	trace
3	$Cu(OAc)_2·H_2O$	$AgSbF_6$	100	26%	trace
4	$Cu(OAc)_2·H_2O$	$AgBF_4$	100	21%	trace
5	$Cu(OAc)_2·H_2O$	AgOTf	100	45%	21%
6	$Cu(OAc)_2·H_2O$	CH_3SO_3Ag	100	35%	trace
7	--	AgOTf	100	ND	trace
8	$Cu(OAc)_2$	AgOTf	100	37%	28%
9	$Cu(acac)_2$	AgOTf	100	Trace	Trace
10	AgOAc	AgOTf	100	19%	trace
11	Ag_2CO_3	AgOTf	100	19%	trace
12	$Zn(OAc)_2·2H_2O$	AgOTf	100	ND	trace
13	$Cu(OAc)_2·H_2O$	AgOTf	80	38%	trace
14	$Cu(OAc)_2·H_2O$	AgOTf	120	37%	trace
15[c]	$Cu(OAc)_2·H_2O$	AgOTf	100	60%	trace

[a]Reaction conditions: **3aa** (0.025 mmol), **3a** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2·H_2O$ (1.0 equiv), LiOAc (0.5 equiv), Ag salt (20 mol%), DCE (0.5 mL), 100 °C, 13 h under Ar. [b]Isolated yield. [c]AgOTf (1.0 equiv).

Table S4. Invalid 3-Aryloxadiazole [a]

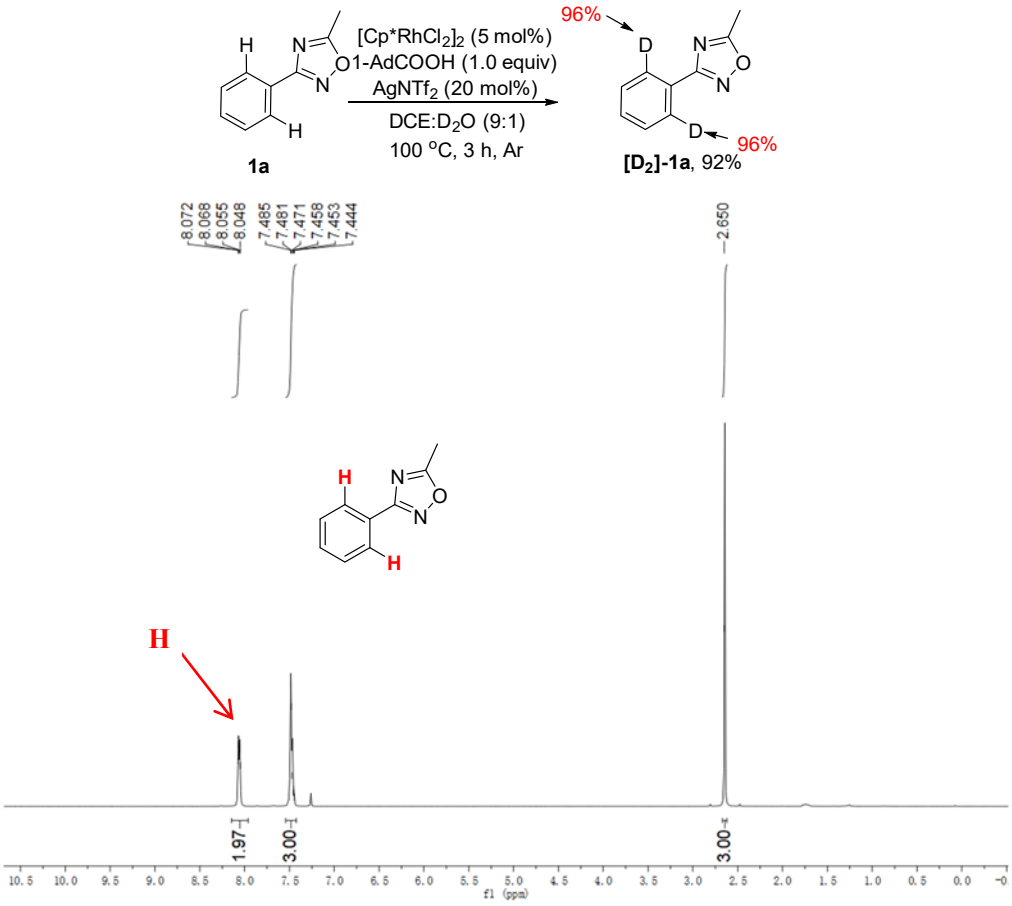


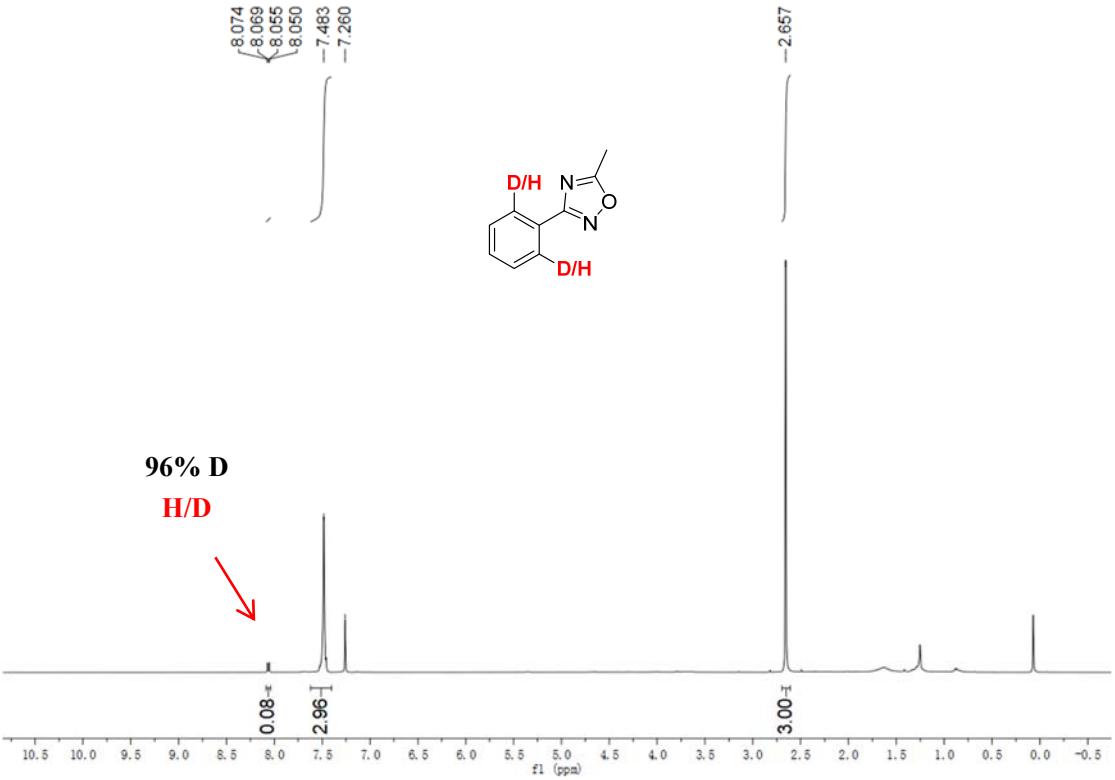
[a]Reaction conditions: **1** (0.05 mmol), **2a** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $AgNTf_2$ (20 mol%), 1-AdCOOH (1.0 equiv), DCE (0.5 mL), 100 °C, under Ar, 5 h. Subsequently, **3a** (1.2 equiv), $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2•H_2O$ (1.2 equiv), AgOTf (1.0 equiv), $LiOAc•2H_2O$ (0.5 equiv) were directly to the mixture, 100 °C, under Ar, 13 h.

6. Mechanism Study

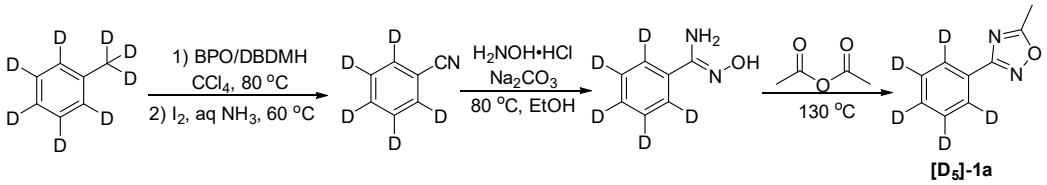
(1) H/D exchange experiments

Deuterium-labeling experiments were performed to study the mechanism of this reaction. **1a** (16.0 mg 0.1 mmol), $[Cp^*RhCl_2]_2$ (3.0 mg, 5 mol%), 1-AdCOOH (18.0 mg, 1.0 quiv), $AgNTf_2$ (7.76 mg, 20 mol%) were stirred in DCE (0.9 mL) and D_2O (0.1 mL) under Ar atmosphere at 100 °C for 3 h. After completion, the reaction mixture was purified by column chromatography (petroleum ether/ethyl acetate =10/1, v/v) to afford the product **1a**+**[D$_2$]-1a**. The deuterium rate (96%) was obtained from ^{1}H NMR. Deuterium was observed at both *ortho*-positions of phenyl ring, which indicated the possibility of the reaction pathway via *ortho* C–H activation.





(2) Preparation of deuterated 5-methyl-3-phenyl-1,2,4-oxadiazole [D_5]-1a substrate[4]

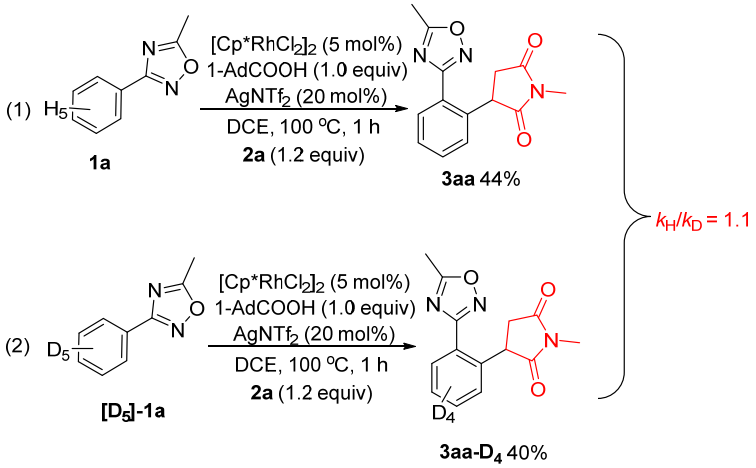


To a solution of toluene-d8 (1.0 g，10 mmol, 99.5% of D, 1 equiv) in dry CCl_4 (10 mL) were added DBDMH (1.57 g, 5.5 mmol, 55 mol %) and benzoyl peroxide (0.32 g, 1 mmol, 10 mol%) at room temperature, and the mixture was stirred for 3 hours at 80 ºC. Then, the mixture was cooled to room temperature, followed by slow addition of aq. NH_3 (concentration: 25%, 30 mL) and I_2 (6.35 g, 25 mmol, 2.7 equiv), and then stirred for 12 hours at 60 ºC. The reaction mixture was quenched by the addition of saturated aq. Na_2SO_3 (30 mL) and extracted with $CHCl_3$ (20 mL×3). The organic layer was dried over Na_2SO_4. After removal of the solvent under reduced pressure, the residue (without purification) reacted with sodium carbonate (3.12g, 20 mmol, 2.0 equiv), hydroxylamine hydrochloride (1.39g, 20 mmol, 2.0 equiv), in EtOH (15 mL). The mixture was stirred at reflux temperature overnight. After cooling to room temperature, the mixture was filterede over a pad of celite and evaporated to dryness to give crude product benzamidoxime. Then the acetic anhydride (1.9 mL, 20 mmol, 2.0 equiv) was added and the mixture was heated at 130 °C for 1 h. After cooling to room temperature, the mixture solution was extracted with EtOAc (3 × 20 mL), the combined organic layer was washed with saturated brine, then the combined organic layers were dried ($MgSO_4$), filtered, and concentrated in vacuo. Purification of the residue by column chromatography (petroleum ether/ethyl acetate = 30/1) to give the product **[D_5]-1a**. ^{1}H NMR (400 MHz, $CDCl_3$): δ =2.65 (s, 3H).

(3) Kinetic isotope experiments

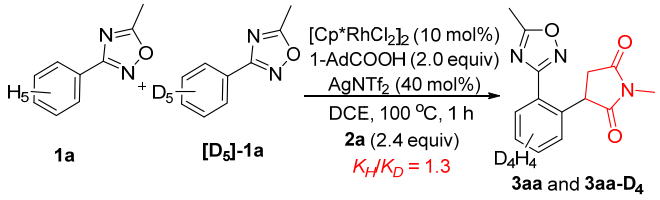
Intermolecular controlled experiment:

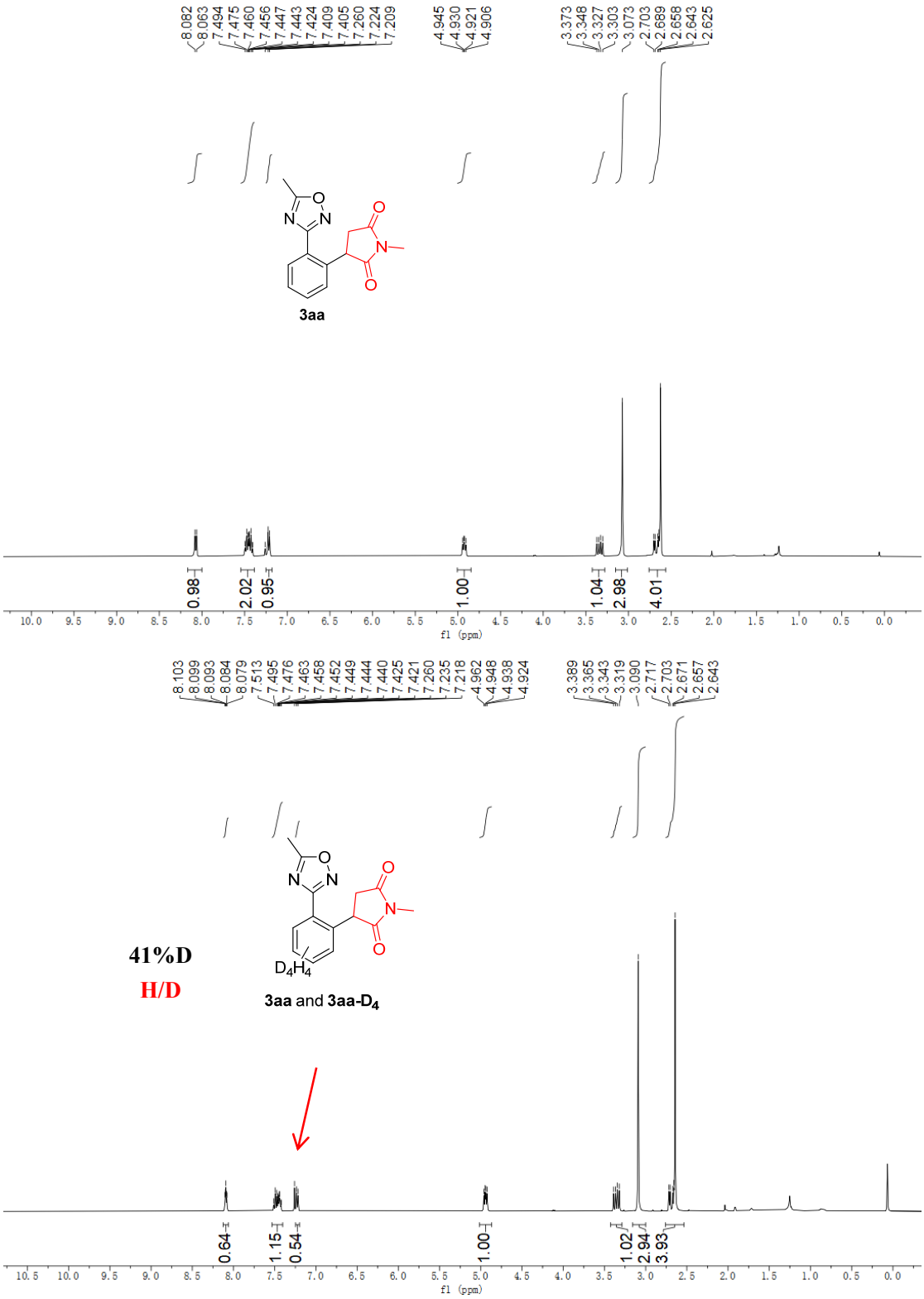
There are twice *ortho* C–H activations, the first *ortho* C–H bond kinetic isotope effect (KIE) study was conducted. Two oven-dried 25 mL tubes were separately charged with **1a** (8.0 mg, 0.05 mmol), or **[D$_5$]-1a** (8.3 mg, 0.05 mmol), and *N*-methylmaleimide **2a** (6.7 mg, 1.2 equiv), [Cp*RhCl$_2$]$_2$ (1.5 mg, 5 mol%), AgNTf$_2$ (3.88 mg, 20 mol%), 1-AdCOOH (9.0 mg, 1.0 equiv), DCE (0.5 mL) were added to an oven dried high-pressure tube under Ar atmosphere. The reaction mixture was stirred at 100 °C for 1 h under Ar. After completion, the reaction mixture was purified by flash chromatography eluting with petroleum ether/ ethyl acetate (3/1) to give **3aa** and **3aa-D$_4$** in 44% and 40% respectively. The KIE value was determined using isolated yields to give kinetic isotopic effect (KIE) k_H/k_D =1.1, thus indicating that the first *ortho* C–H bond cleavage might not be involved in the product determining step.



Intermolecular competition experiment:

In addition, the first *ortho* C–H bond kinetic isotope effect (KIE) study was conducted. An oven-dried 25 mL tube was charged with **1a** (8.0 mg, 0.05 mmol), **[D$_5$]-1a** (8.3 mg, 0.05 mmol), and *N*-methylmaleimide **2a** (13.4 mg, 2.4 equiv), [Cp*RhCl$_2$]$_2$ (3.0 mg, 10 mol%), AgNTf$_2$ (7.76 mg, 40 mol%), 1-AdCOOH (18.0 mg, 2.0 equiv), DCE (1.0 mL) were added to an oven dried high-pressure tube under Ar atmosphere. The reaction mixture was stirred at 100 °C for 1 h under Ar. After completion, the reaction mixture was purified by flash chromatography eluting with petroleum ether/ ethyl acetate (3/1) to give **3aa** and **3aa-D$_4$**. The ratio of two products was determined by ^{1}H NMR integration method to give kinetic isotopic effect (KIE) k_H/k_D =1.3, thus indicating that the first *ortho* C–H bond cleavage might be not involved in the product determining step.

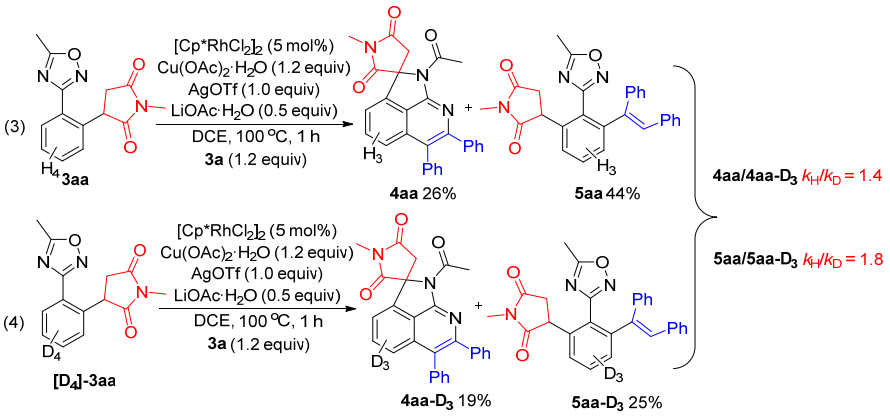




Intermolecular controlled experiment:

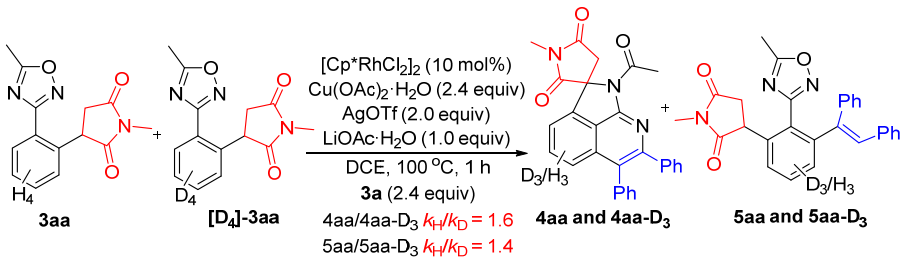
The second *ortho* C–H bond kinetic isotope effect (KIE) study was conducted. Two oven-dried 25 mL tubes were separately charged with **3aa** (6.8 mg, 0.025 mmol), or **[D_4]-3aa** (6.9 mg, 0.025 mmol), and **3a** (5.3 mg, 1.2 equiv), $[Cp^*RhCl_2]_2$ (0.8 mg, 5 mol%), $Cu(OAc)_2•H_2O$ (6.0 mg, 1.2 equiv), AgOTf (6.4 mg, 1.0 equiv), $LiOAc•2H_2O$ (1.3 mg, 0.5 equiv), DCE (0.5 mL) were directly to the mixture, the reaction mixture was stirred at 100 ºC for 1 h under Ar. After completion, the

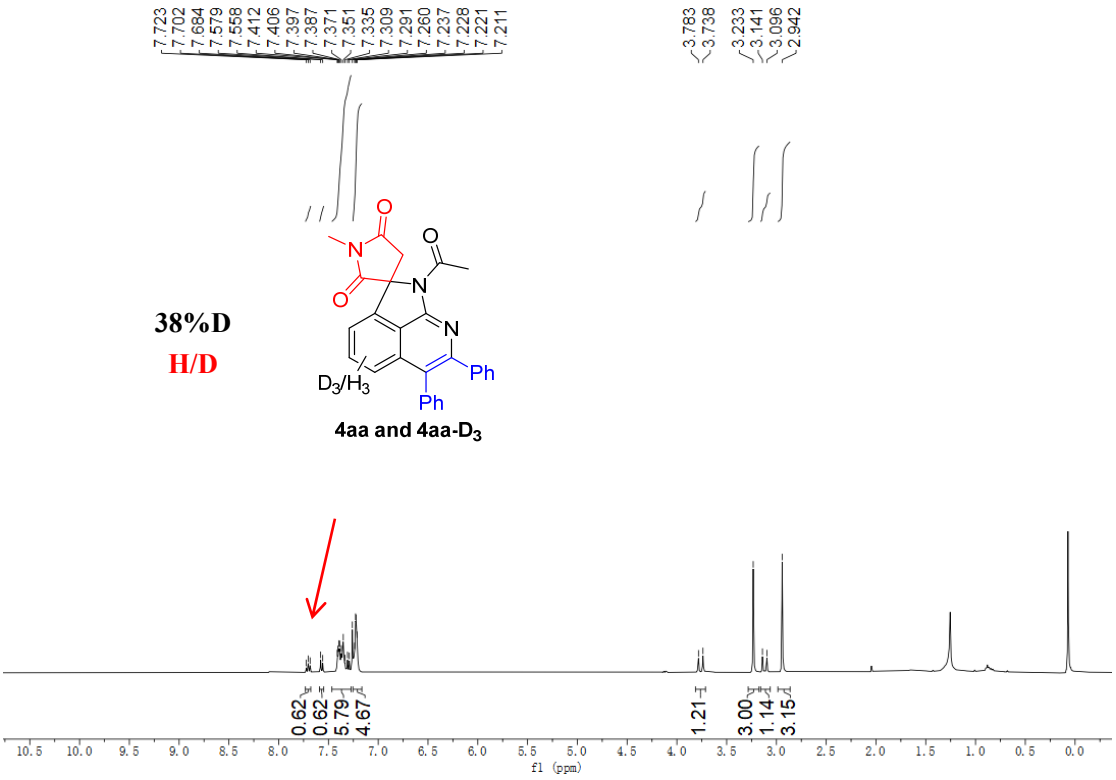
reaction mixture was purified by flash chromatography eluting with petroleum ether/ dichloromethane/ethyl acetate (6/3/1) to give **4aa** and **4aa-D$_3$** in 26% and 19% respectively and **5aa** and **5aa-D$_3$** in 44% and 25% respectively. The KIE value of **4aa** and **4aa-D$_3$** was determined using isolated yields to give kinetic isotopic effect (KIE) k_H/k_D =1.4, thus indicating that the second C-H bond cleavage might not be involved in the product determining step. And the KIE value of **5aa** and **5aa-D$_3$** was determined using isolated yields to give kinetic isotopic effect (KIE) k_H/k_D =1.8, thus indicating that the second C-H bond cleavage might not be involved in the product determining step.



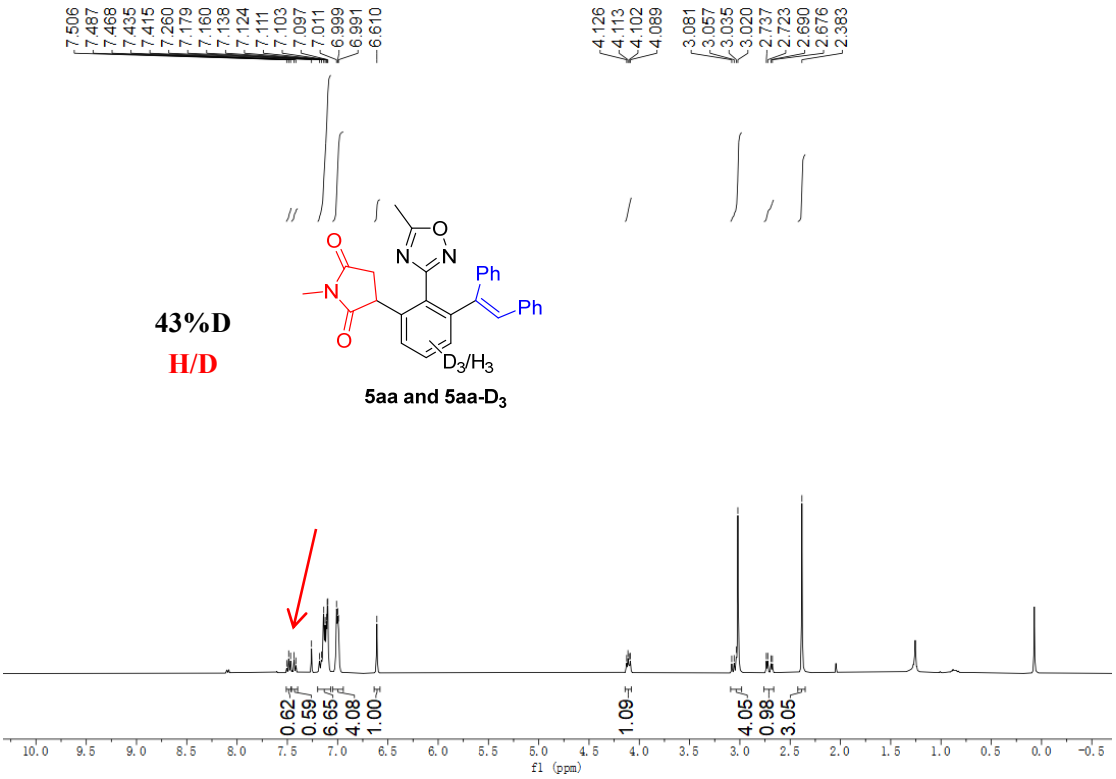
Intermolecular competition experiment:

In addition, the second *ortho* C–H bond kinetic isotope effect (KIE) study was conducted. An oven-dried 25 mL tube was charged with **3aa** (6.8 mg, 0.025 mmol), **[D$_4$]-3aa** (6.9 mg, 0.025 mmol), and **3a** (10.6 mg, 2.4 equiv), $[Cp^*RhCl_2]_2$ (1.5 mg, 10 mol%), $Cu(OAc)_2•H_2O$ (12.0 mg, 2.4 equiv), AgOTf (12.8 mg, 2.0 equiv), $LiOAc•2H_2O$ (2.6 mg, 1.0 equiv), DCE (1.0 mL) were directly to the mixture, the reaction mixture was stirred at 100 °C for 1 h under Ar. After completion, the reaction mixture was purified by flash chromatography eluting with petroleum ether/ dichloromethane/ethyl acetate (6/3/1) to give **4aa**/**4aa-D$_3$** and **5aa**/**5aa-D$_3$** respectively. The ratio of **4aa**/**4aa-D$_3$** was determined by ^{1}H NMR integration method to give kinetic isotopic effect (KIE) k_H/k_D =1.6, thus indicating that the second *ortho* C–H bond cleavage might be not involved in the product determining step. The ratio of **5aa**/**5aa-D$_3$** was determined by ^{1}H NMR integration method to give kinetic isotopic effect (KIE) k_H/k_D =1.4, thus indicating that the second *ortho* C–H bond cleavage might be not involved in the product determining step.



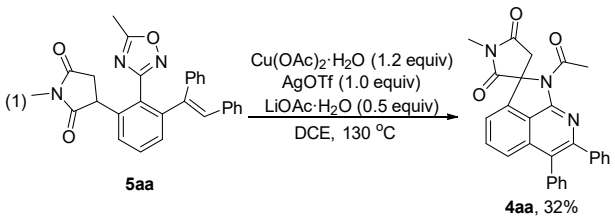


4aa and 4aa-D_3



5aa and 5aa-D_3

(4) Study on Characteristics and Mechanism



To elucidate the role of copper as an oxidant in the reaction, **5aa** could be transformed to spirocyclization **4aa** in absence of $[Cp^*RhCl_2]_2$ (5 mol%), which also means cross coupling product could be the intermediate in the reaction (eq S1).

To further prove the existence of intermediate **VII**, we tried to isolate intermediate **VII**, which was too little to be separated but can be determined by LC-MS and HRMS (Figure S1). LC-MS: Exact Mass $[M+H]^+$: 450.1812, Found $[M+H]^+$: 450.0. HRMS (ESI): Exact Mass $[M+H]^+$: 450.1812, Found $[M+H]^+$: 450.1815.

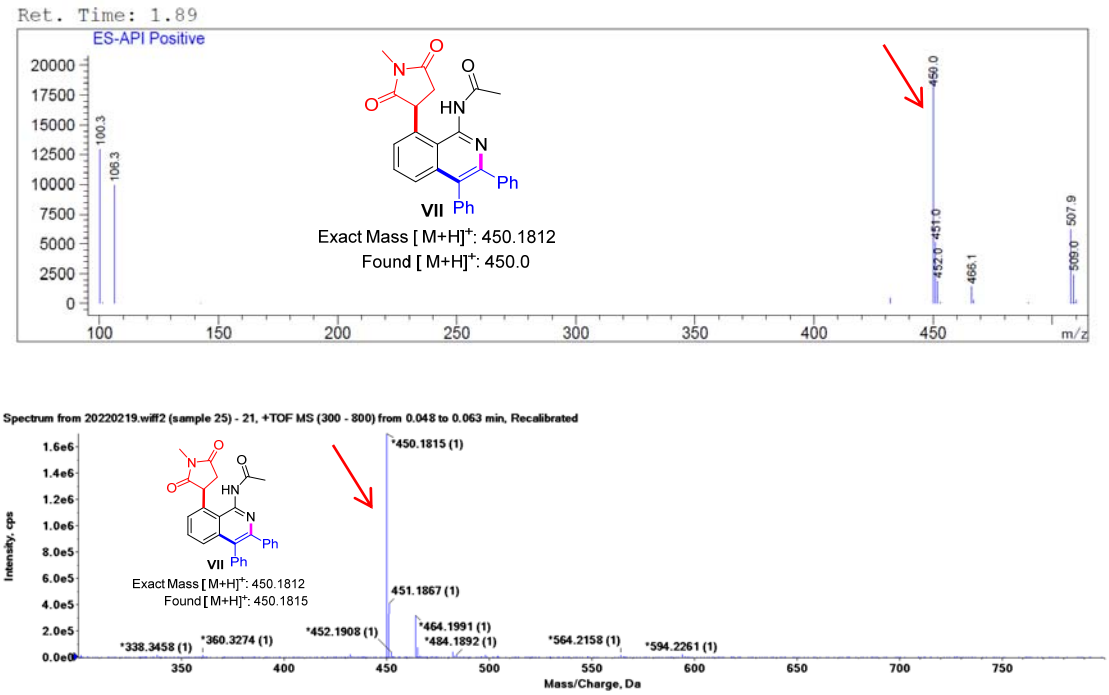
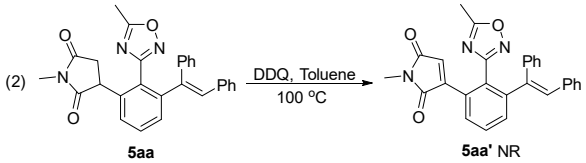
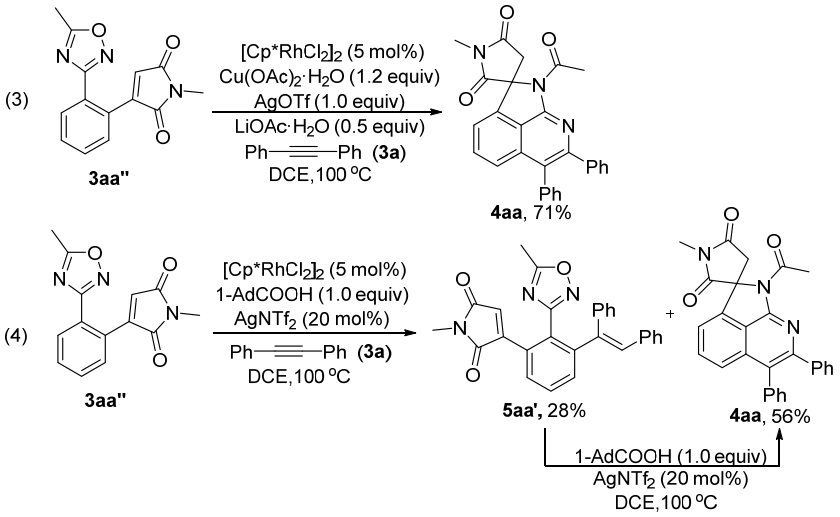


Figure S1 Complex **VII** was Determined by LC-MS and HRMS

To further prove the existence of alkenyl intermediate, a series of reactions were conducted. First, no product **5aa'** was detected when using DDQ as oxidant (eq S2).





Then, we found that **3aa''** could be transformed to **4aa** in 71% yield in the presence of $[Cp^*RhCl_2]_2$ (5 mol%), $Cu(OAc)_2•H_2O$ (1.2 equiv), AgOTf (1.0 equiv), $LiOAc•2H_2O$ (0.5 equiv) and **3a** (eq S3). And we also found that **3aa''** could be transformed to **5aa'** and **4aa** in 28% and 56% yields, respectively in the presence of $[Cp^*RhCl_2]_2$ (5 mol%), $AgNTf_2$ (20 mol%) and 1-AdCOOH (1.0 equiv) (eq S4). **5aa'** and **4aa** have the same polarity and cannot be separated, so the ratio of **5aa'** and **4aa** were determined by ^1H NMR integration method. Next, **5aa''** could be transformed to spirocyclization **4aa** in absence of $[Cp^*RhCl_2]_2$ (5 mol%) and **3a**, suggesting that the aza-Michael addition did not require any rhodium and copper catalyst. The proportion of **5aa'** and **4aa** with time is shown in the Figure S2.

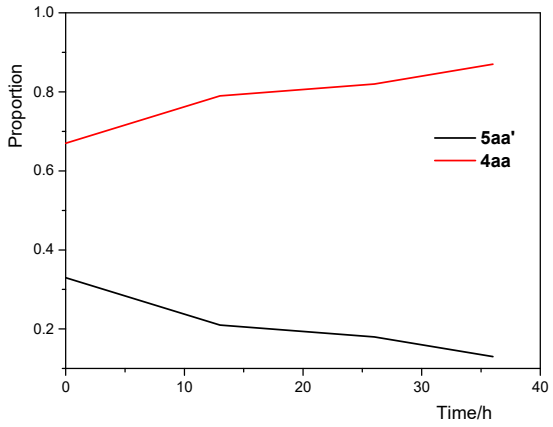
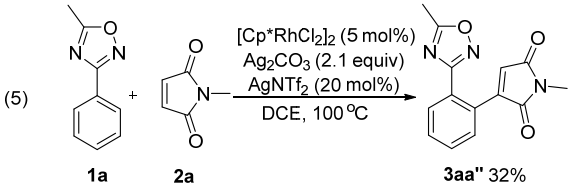


Figure S2 The proportion of **5aa'** and **4aa** with time

In addition, in order to improve the reaction yield, we tried **3aa''** as an intermediate to synthesize the product **4aa** from **1a**. Firstly, we tried some oxidants in the first step, including AgOAc, $Cu(OAc)_2$, $Cu(acac)_2$ and so on, and no product **3aa''** was generated. The desired product **3aa''** could be isolated in 32% yield in the presence of $[Cp^*RhCl_2]_2$, Ag_2CO_3 and $AgNTf_2$.



7. References

[1] Y. Yang, C. Wang, *Chem. Eur. J.* **2019**, 25, 8245–8248.

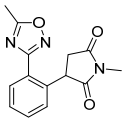
[2] R. Mandal, B. Emayavaramban, B. Sundararaju, *Org. Lett.* **2018**, 20, 2835−2838.

[3] Y. Nishii, A.-K. Bachon, S.-H. Moon, C. Bolm, M. Miura, *Chem. Lett.* **2017**, 46, 1347-1349.

[4] F. Yang, J. J. Yu, Y. Liu and J. Zhu, *Org. Lett*., **2017**, 19, 2885−2888.

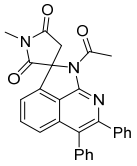
8. Characterization Data and NMR Spectra of *N*-acetyl Chain of Spiropyrroloisoquinoline Derivatives

1-methyl-3-(2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)pyrrolidine-2,5-dione (3aa)



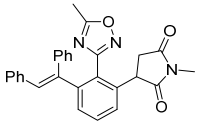
Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 4/1, v/v) afforded 3aa as a white solid (10.8 mg, 80% yield). Melting point: 92.3–93.6 °C; ^{1}H NMR (400 MHz, CDCl3): δ = 8.07 (d, *J* = 7.7 Hz, 1H), 7.52 – 7.38 (m, 2H), 7.22 (d, *J* = 7.0 Hz, 1H), 4.93 (dd, *J* = 9.5, 5.7 Hz, 1H), 3.34 (dd, *J* = 18.4, 9.6 Hz, 1H), 3.07 (s, 3H), 2.72 – 2.60 (m, 4H); ^{13}C NMR (100 MHz, CDCl3): δ = 178.3, 176.4, 176.2, 168.1, 136.9, 131.6, 130.9, 129.3, 128.3, 126.2, 45.0, 38.1, 25.2, 12.4; HRMS (ESI): m/z calcd for $C_{14}H_{13}N_3O_3Na^+$ $[M+Na]^+$: 294.0849, found: 294.0849.

1'-acetyl-1-methyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4aa)



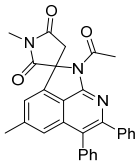
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4aa** as a white solid (11.0 mg, 49% yield). Melting point: 295.5–296.4 °C; ^{1}H NMR (400 MHz, CDCl3): δ = 7.66 (t, *J* = 7.7 Hz, 1H), 7.53 (d, *J* = 8.3 Hz, 1H), 7.43 – 7.27 (m, 6H), 7.24 – 7.14 (m, 5H), 3.72 (d, *J* = 18.0 Hz, 1H), 3.19 (s, 3H), 3.08 (d, *J* = 17.9 Hz, 1H), 2.90 (s, 3H); ^{13}C NMR (100 MHz, CDCl3): δ = 173.9, 173.7, 170.3, 156.0, 152.1, 140.6, 138.6, 136.6, 135.3, 133.6, 131.1, 131.0, 130.7, 128.8, 128.6, 127.7, 127.6, 127.5, 125.1, 124.0, 121.2, 117.0, 71.9, 42.4, 25.9, 25.3; HRMS (ESI): m/z calcd for $C_{28}H_{21}N_3O_3Na^+$ $[M+Na]^+$: 470.1475, found: 470.1475.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5aa)



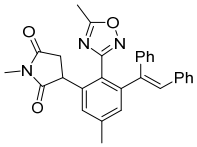
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5aa** as a white solid (11.9 mg, 53% yield). Melting point: 160.8–161.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ =7.48 (t, *J* = 7.7 Hz, 1H), 7.45 – 7.40 (m, 1H), 7.20 – 7.08 (m, 7H), 7.00 (m, 4H), 6.61 (s, 1H), 4.11 (dd, *J* = 9.8, 5.5 Hz, 1H), 3.01 (s, 4H), 2.71 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.5, 176.0, 176.0, 167.6, 146.8, 141.4, 139.7, 138.1, 137.1, 131.7, 130.8, 130.4, 130.3, 129.4, 128.0, 128.0, 127.2, 127.0, 126.9, 126.8, 44.3, 38.4, 25.2, 12.2. HRMS (ESI): m/z calcd for $C_{28}H_{23}N_3O_3Na^+$ $[M+Na]^+$: 472.1632, found: 472.1635.

1'-acetyl-1,4'-dimethyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ba)



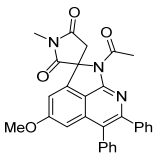
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ba** as a white solid (8.1 mg, 35% yield). Melting point: 268.5–269.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.42 – 7.33 (m, 5H), 7.32 (s, 1H), 7.26 – 7.16 (m, 5H), 7.12 (s, 1H), 3.75 (d, *J* = 17.9 Hz, 1H), 3.24 (s, 3H), 3.10 (d, *J* = 17.9 Hz, 1H), 2.93 (s, 3H), 2.49 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.0, 173.9, 170.4, 155.8, 152.3, 144.9, 140.7, 138.7, 136.8, 135.3, 131.2, 131.1, 130.7, 128.8, 128.6, 127.7, 127.5, 127.5, 124.8, 123.3, 119.7, 118.7, 71.7, 42.4, 25.9, 25.2, 23.1. HRMS (ESI): m/z calcd for $C_{29}H_{24}N_3O_3^+$ $[M+H]^+$: 462.1812, found: 462.1814.

(*E*)-3-(3-(1,2-diphenylvinyl)-5-methyl-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5ba)



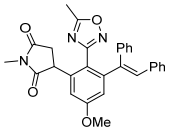
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ba** as a colorless oil (12.3 mg, 53% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.23 (s, 1H), 7.16 – 7.08 (m, 6H), 7.04 – 6.97 (m, 4H), 6.96 (s, 1H), 6.59 (s, 1H), 4.08 (dd, *J* = 9.7, 5.5 Hz, 1H), 3.11 – 2.98 (m, 4H), 2.69 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.38 (d, *J* = 6.5 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.8, 176.2, 175.9, 167.7, 146.7, 141.6, 141.1, 139.8, 137.9, 137.2, 131.5, 131.1, 130.5, 129.5, 128.1, 128.0, 127.6, 127.2, 127.0, 124.0, 44.2, 38.5, 25.3, 21.5, 12.2. HRMS (ESI): m/z calcd for $C_{29}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 486.1788, found: 486.1786.

1'-acetyl-4'-methoxy-1-methyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ca)



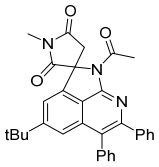
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ca** as a white solid (8.1 mg, 34% yield). Melting point: 208.5–209.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.43 – 7.30 (m, 5H), 7.25 – 7.16 (m, 5H), 6.89 (d, *J* = 1.7 Hz, 1H), 6.83 (d, *J* = 1.7 Hz, 1H), 3.79 (s, 3H), 3.73 (d, *J* = 18.0 Hz, 1H), 3.22 (s, 3H), 3.09 (d, *J* = 18.0 Hz, 1H), 2.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.7, 173.7, 170.3, 165.0, 155.5, 152.9, 140.8, 140.3, 136.9, 136.7, 131.1, 130.9, 130.6, 128.9, 128.7, 127.7, 127.6, 127.5, 124.7, 116.4, 109.0, 103.6, 71.5, 56.2, 42.4, 25.9, 25.1. HRMS (ESI): m/z calcd for $C_{29}H_{24}N_3O_4^+$ $[M+H]^+$: 478.1761, found: 478.1761.

(*E*)-3-(3-(1,2-diphenylvinyl)-5-methoxy-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5ca)



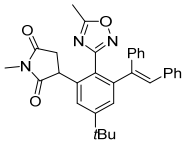
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ca** as a white solid (9.1 mg, 38% yield). Melting point: 162.9–163.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.17 – 7.08 (m, 6H), 7.04 – 6.98 (m, 4H), 6.94 (d, *J* = 2.6 Hz, 1H), 6.68 (d, *J* = 2.4 Hz, 1H), 6.63 (s, 1H), 4.10 (dd, *J* = 9.7, 5.6 Hz, 1H), 3.83 (s, 3H), 3.08 – 2.97 (m, 4H), 2.70 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.5, 176.0, 175.9, 167.6, 161.0, 148.5, 141.7, 139.5, 139.5, 137.1, 131.6, 130.4, 129.5, 128.1, 127.2, 127.1, 119.1, 115.3, 113.2, 55.7, 44.4, 38.3, 25.3, 12.2. HRMS (ESI): m/z calcd for $C_{29}H_{26}N_3O_4^+$ $[M+H]^+$: 480.1918, found: 480.1915.

1'-acetyl-4'-(*tert*-butyl)-1-methyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4da)



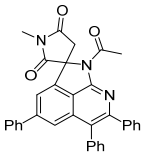
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4da** as a white solid (10.3 mg, 41% yield). Melting point: 261.4–263.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.55 (s, 1H), 7.44 – 7.29 (m, 6H), 7.26 – 7.14 (m, 5H), 3.74 (d, *J* = 18.0 Hz, 1H), 3.25 (s, 3H), 3.13 (d, *J* = 18.0 Hz, 1H), 2.93 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.2, 174.1, 170.4, 158.4, 155.7, 152.2, 140.8, 138.4, 136.7, 134.9, 131.2, 131.0, 130.7, 128.7, 128.6, 127.7, 127.5, 127.5, 125.2, 119.8, 119.7, 115.3, 72.0, 42.7, 36.4, 31.6, 26.0, 25.2. HRMS (ESI): m/z calcd for $C_{32}H_{30}N_3O_3^+$ $[M+H]^+$: 504.2282, found: 504.2286.

(*E*)-3-(5-(*tert*-butyl)-3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5da)



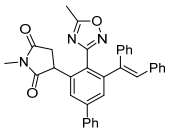
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5da** as a white solid (11.9 mg, 47% yield). Melting point: 103.7–105.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46 (d, *J* = 2.0 Hz, 1H), 7.15 (d, *J* = 2.0 Hz, 1H), 7.14 – 7.07 (m, 6H), 7.05 – 7.00 (m, 2H), 7.00 – 6.95 (m, 2H), 6.64 (s, 1H), 4.10 (dd, *J* = 9.7, 5.7 Hz, 1H), 3.08 – 2.96 (m, 4H), 2.72 (dd, *J* = 18.5, 5.6 Hz, 1H), 2.35 (s, 3H), 1.34 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.7, 176.2, 175.8, 167.7, 154.1, 146.5, 142.2, 139.7, 137.4, 137.3, 131.4, 130.5, 129.5, 128.0, 128.0, 127.6, 127.1, 127.0, 124.3, 123.9, 44.8, 38.4, 35.1, 31.3, 25.2, 12.2. HRMS (ESI): m/z calcd for $C_{32}H_{31}N_3O_3Na^+$ $[M+Na]^+$: 528.2258, found: 528.2260.

1'-acetyl-1-methyl-4',6',7'-triphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ea)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ea** as a white solid (10.2 mg, 39% yield). Melting point: 271.6–272.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.70 (s, 1H), 7.53 – 7.48 (m, 2H), 7.48 – 7.39 (m, 6H), 7.39 – 7.31 (m, 3H), 7.30 – 7.25 (m, 2H), 7.25 – 7.20 (m, 3H), 3.80 (d, *J* = 18.0 Hz, 1H), 3.25 (s, 3H), 3.19 (d, *J* = 18.0 Hz, 1H), 2.96 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 173.8, 170.3, 156.0, 152.7, 147.9, 140.7, 140.6, 139.3, 136.6, 135.4, 131.2, 131.1, 130.7, 129.2, 128.9, 128.7, 128.6, 128.1, 127.8, 127.6, 127.6, 125.2, 122.6, 120.4, 117.0, 72.0, 42.5, 26.0, 25.3. HRMS (ESI): m/z calcd for $C_{34}H_{26}N_3O_3^+$ $[M+H]^+$: 524.1968, found: 524.1963.

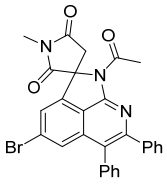
(*E*)-3-(5-(1,2-diphenylvinyl)-4-(5-methyl-1,2,4-oxadiazol-3-yl)-[1,1'-biphenyl]-3-yl)-1-methylpyrrolidine-2,5-dione (5ea)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ea** as a white solid (12.1 mg, 46% yield). Melting point: 182.6–183.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.65 (d, *J* = 1.8 Hz, 1H), 7.59 (dd, *J* = 6.9, 1.7 Hz, 2H), 7.49 – 7.42 (m, 2H), 7.41 – 7.34 (m, 2H), 7.17 – 7.09 (m, 6H), 7.08 – 7.00 (m, 4H), 6.70 (s, 1H), 4.19 (dd, *J* =

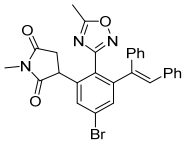
9.7, 5.6 Hz, 1H), 3.14 – 3.00 (m, 4H), 2.78 (dd, *J* = 18.5, 5.6 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.6, 176.0, 176.0, 167.6, 147.4, 143.9, 141.6, 139.7, 139.6, 138.5, 137.2, 131.9, 130.5, 129.5, 129.1, 129.1, 128.4, 128.1, 128.1, 127.5, 127.3, 127.2, 125.8, 125.6, 44.5, 38.5, 25.3, 12.2. HRMS (ESI): m/z calcd for $C_{34}H_{27}N_3O_3Na^+$ $[M+Na]^+$: 548.1945, found: 548.1941.

1'-acetyl-4'-bromo-1-methyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4fa)



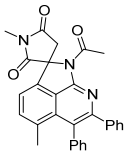
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4fa** as a white solid (7.9 mg, 30% yield). Melting point: 197.9–199.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.71 (s, 1H), 7.40 (s, 1H), 7.40 – 7.33 (m, 5H), 7.25 – 7.17 (m, 5H), 3.74 (d, *J* = 18.0 Hz, 1H), 3.24 (s, 3H), 3.11 (d, *J* = 18.0 Hz, 1H), 2.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.3, 173.3, 170.2, 155.8, 153.5, 140.3, 140.2, 136.3, 136.0, 131.1, 130.9, 130.6, 129.0, 128.9, 128.5, 127.9, 127.8, 127.8, 126.6, 124.2, 120.8, 119.8, 71.5, 42.2, 26.1, 25.3. HRMS (ESI): m/z calcd for $C_{28}H_{21}BrN_3O_3^+$ $[M+H]^+$: 526.0761, found: 526.0759.

(*E*)-3-(5-bromo-3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5fa)



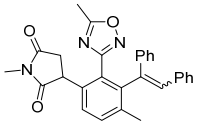
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5fa** as a colorless oil (10.8 mg, 41% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.59 (d, *J* = 2.0 Hz, 1H), 7.32 (d, *J* = 2.0 Hz, 1H), 7.19 – 7.08 (m, 6H), 7.03 – 6.95 (m, 4H), 6.61 (s, 1H), 4.08 (dd, *J* = 9.7, 5.6 Hz, 1H), 3.08 – 2.98 (m, 4H), 2.69 (dd, *J* = 18.5, 5.6 Hz, 1H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.9, 176.3, 175.5, 167.1, 148.6, 140.2, 139.9, 139.1, 136.7, 133.2, 132.6, 130.4, 130.0, 129.5, 128.2, 128.1, 127.5, 127.4, 126.0, 125.1, 44.1, 38.2, 25.4, 12.2. HRMS (ESI): m/z calcd for $C_{28}H_{22}BrN_3O_3Na^+$ $[M+Na]^+$: 550.0737, found: 550.0743.

1'-acetyl-1,5'-dimethyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ga)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ga** as a white solid (11.1 mg, 48% yield). Melting point: 259.9–260.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.45 (d, *J* = 7.2 Hz, 1H), 7.31 – 7.23 (m, 5H), 7.23 – 7.11 (m, 6H), 3.73 (d, *J* = 17.9 Hz, 1H), 3.22 (s, 3H), 3.07 (d, *J* = 18.0 Hz, 1H), 2.88 (s, 3H), 1.88 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.2, 173.9, 170.4, 156.3, 153.4, 141.3, 139.0, 136.9, 136.1, 135.6, 133.7, 131.9, 130.3, 127.9, 127.8, 127.6, 127.4, 127.1, 125.8, 121.7, 117.1, 71.0, 42.6, 25.9, 25.4, 22.3. HRMS (ESI): m/z calcd for $C_{29}H_{24}N_3O_3^+$ $[M+H]^+$: 462.1812, found: 462.1813.

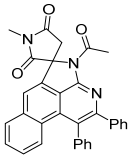
(Z/*E*)-3-(3-(1,2-diphenylvinyl)-4-methyl-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5ga)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ga** (Z/E = 1:1.2

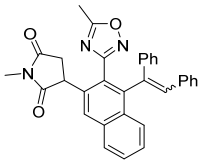
and cannot be separated) as a colorless oil (12.3 mg, 53% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.32 (t, *J* = 8.1 Hz, 1H), 7.20 – 7.04 (m, 9H), 7.00 (q, *J* = 4.7 Hz, 2H), 6.42 (d, *J* = 47.6 Hz, 1H), 4.10 – 4.01 (m, 1H), 3.22 – 3.06 (m, 1H), 3.02 (d, *J* = 14.4 Hz, 3H), 2.85– 2.65 (m, 1H), 2.41 (d, *J* = 5.3 Hz, 3H), 2.14 (d, *J* = 30.9 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.9, 177.7, 176.2, 176.2, 176.1, 176.0, 168.3, 168.2, 145.3, 145.1, 139.9, 139.3, 139.0, 139.0, 137.5, 137.4, 137.3, 137.2, 135.3, 135.2, 133.1, 133.0, 132.4, 131.7, 130.7, 130.4, 129.2, 129.2, 128.1, 127.9, 127.2, 127.2, 127.0, 126.9, 126.8, 44.7, 44.5, 38.7, 38.6, 25.3, 25.2, 20.6, 20.5, 12.3, 12.2. HRMS (ESI): m/z calcd for $C_{29}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 486.1788, found: 486.1784.

4-acetyl-1'-methyl-1,2-diphenyl-4*H*-spiro[benzo[*f*]pyrrolo[4,3,2-ij]isoquinoline-5,3'-pyrrolidine]-2',5'-dione (4ha)



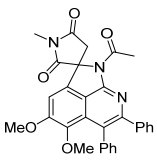
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ha** as a white solid (11.9 mg, 48% yield). Melting point: 279.8–281.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.90 (d, *J* = 8.2 Hz, 1H), 7.61 (s, 1H), 7.57 (t, *J* = 7.5 Hz, 1H), 7.43 – 7.36 (m, 4H), 7.32 – 7.27 (m, 3H), 7.25 – 7.18 (m, 4H), 3.82 (d, *J* = 17.9 Hz, 1H), 3.28 (s, 3H), 3.19 (d, *J* = 17.9 Hz, 1H), 2.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.3, 174.1, 170.5, 155.9, 155.4, 141.2, 139.2, 136.8, 135.2, 133.2, 131.3, 131.2, 130.3, 130.1, 129.3, 129.1, 129.0, 128.5, 128.0, 127.6, 127.5, 127.2, 127.1, 126.9, 119.0, 119.0, 70.7, 43.1, 25.9, 25.4. HRMS (ESI): m/z calcd for $C_{32}H_{24}N_3O_3^+$ $[M+H]^+$: 498.1812, found: 498.1816.

(Z/*E*)-3-(4-(1,2-diphenylvinyl)-3-(5-methyl-1,2,4-oxadiazol-3-yl)naphthalen-2-yl)-1-methylpyrrolidine-2,5-dione (5ha)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ha** (Z/E = 1:1.1 and cannot be separated) as a colorless oil (16.2 mg, 65% yield). ^{1} H NMR (400 MHz, $CDCl_3$): δ = 8.11 (dd, *J* = 17.1, 8.1 Hz, 1H), 7.84 (d, *J* = 8.2 Hz, 1H), 7.72 (s, 1H), 7.56 – 7.49 (m, 1H), 7.48 – 7.40 (m, 1H), 7.21 – 7.06 (m, 10H), 6.65 (d, *J* = 23.4 Hz, 1H), 4.31 – 4.20 (m, 1H), 3.16 – 3.03 (m, 4H), 2.94 – 2.77 (m, 1H), 2.45 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.7, 177.6, 176.2, 176.1, 176.0, 168.1, 168.1, 144.7, 144.7, 139.7, 139.6, 138.3, 137.9, 137.2, 137.1, 134.4, 134.0, 133.9, 133.5, 131.7, 131.6, 130.2, 130.1, 129.3, 129.3, 128.2, 128.1, 127.7, 127.4, 127.3, 127.2, 127.2, 124.8, 124.8, 45.0, 44.9, 38.5, 38.5, 25.3, 25.3, 12.3, 12.2. HRMS (ESI): m/z calcd for $C_{32}H_{26}N_3O_3^+$ $[M+H]^+$: 500.1969, found: 500.1967.

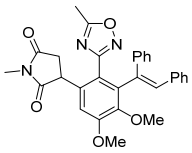
1'-acetyl-4',5'-dimethoxy-1-methyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ia)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ia** as a white solid (8.4 mg, 33% yield). Melting point: 279.2–280.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.34 – 7.28 (m, 3H), 7.26 – 7.14 (m, 7H), 7.01 (s, 1H), 3.95 (s, 3H), 3.73 (d, *J* = 18.0 Hz, 1H), 3.24 (s, 3H), 3.11 (d, *J* = 18.1 Hz, 1H), 3.06 (s, 3H), 2.89 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.1, 173.9, 170.4, 157.6, 155.8, 153.4, 144.3, 141.1, 138.3, 134.9, 131.8, 131.5, 130.6, 129.5, 127.5, 127.3, 127.2, 127.1, 126.8, 123.0, 117.1, 105.0,

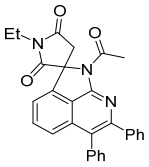
71.2, 60.8, 57.2, 42.5, 26.0, 25.2. HRMS (ESI): m/z calcd for $C_{30}H_{25}N_3O_5Na^+$ $[M+Na]^+$: 530.1686, found: 530.1684.

(*E*)-3-(3-(1,2-diphenylvinyl)-4,5-dimethoxy-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5ia)



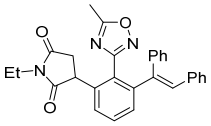
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ia** as a colorless oil (18.8 mg, 74% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.30 – 7.20 (m, 2H), 7.20 – 7.05 (m, 6H), 7.00 – 6.92 (m, 2H), 6.69 (s, 1H), 6.35 (s, 1H), 4.21 – 4.08 (m, 1H), 3.87 (s, 3H), 3.40 – 3.23 (m, 3H), 3.14 – 2.94 (m, 4H), 2.90 – 2.68 (m, 1H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.1, 176.0, 167.8, 154.7, 146.8, 140.3, 137.2, 133.4, 130.3, 129.3, 128.0, 127.9, 127.0, 126.9, 60.1, 56.1, 44.9, 38.5, 25.3, 12.3. HRMS (ESI): m/z calcd for $C_{30}H_{27}N_3O_5Na^+$ $[M+Na]^+$: 532.1843, found: 532.1850.

1'-acetyl-1-ethyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ab)



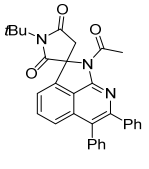
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ab** as a white solid (8.3 mg, 36% yield). Melting point: 284.5–286.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.70 (t, *J* = 7.7 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.44 – 7.31 (m, 5H), 7.30 – 7.18 (m, 6H), 3.85 – 3.70 (m, 3H), 3.08 (d, *J* = 17.9 Hz, 1H), 2.95 (s, 3H), 1.33 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.5, 170.3, 156.1, 152.1, 140.6, 138.8, 136.6, 135.3, 133.6, 131.1, 130.7, 128.7, 127.8, 127.6, 127.5, 125.1, 124.0, 121.3, 116.8, 71.9, 42.4, 34.9, 25.3, 12.9. HRMS (ESI): m/z calcd for $C_{29}H_{23}N_3O_3Na^+$ $[M+Na]^+$: 484.1632, found: 484.1641.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-ethylpyrrolidine-2,5-dione (5ab)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ab** as a white solid (11.3 mg, 49% yield). Melting point: 192.5–194.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49 (t, *J* = 7.7 Hz, 1H), 7.42 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.16 – 7.08 (m, 7H), 7.04 – 6.97 (m, 4H), 6.61 (s, 1H), 4.07 (dd, *J* = 9.7, 5.4 Hz, 1H), 3.59 (q, *J* = 7.2 Hz, 2H), 3.03 (dd, *J* = 18.6, 9.7 Hz, 1H), 2.69 (dd, *J* = 18.5, 5.4 Hz, 1H), 2.38 (s, 3H), 1.19 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.4, 176.0, 175.8, 167.7, 146.8, 141.5, 139.8, 138.4, 137.2, 131.8, 130.9, 130.5, 130.3, 129.5, 128.1, 128.1, 127.2, 127.1, 126.9, 126.6, 44.1, 38.6, 34.2, 13.2, 12.3. HRMS (ESI): m/z calcd for $C_{29}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 486.1788, found: 486.1803.

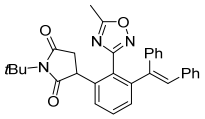
1'-acetyl-1-(*tert*-butyl)-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ac)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ac** as a colorless oil (6.4 mg, 26% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.70 (dd, *J*

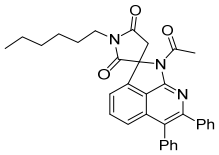
= 8.4, 7.0 Hz, 1H), 7.55 (d, *J* = 8.3 Hz, 1H), 7.43 – 7.32 (m, 5H), 7.29 (d, *J* = 7.1 Hz, 1H), 7.26 – 7.17 (m, 5H), 3.70 (d, *J* = 17.6 Hz, 1H), 2.99 (d, *J* = 17.7 Hz, 1H), 2.94 (s, 3H), 1.70 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.6, 174.3, 170.2, 156.3, 152.1, 140.7, 139.4, 136.7, 135.3, 133.6, 131.2, 130.7, 128.8, 127.7, 127.6, 127.5, 124.9, 123.9, 121.3, 116.4, 71.7, 59.7, 42.3, 28.4, 25.4. HRMS (ESI): m/z calcd for $C_{31}H_{28}N_3O_3^+$ $[M+H]^+$: 490.2125, found: 490.2118.

(*E*)-1-(*tert*-butyl)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)pyrrolidine-2,5-dione (5ac)



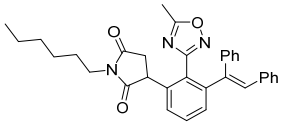
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ac** as a colorless oil (14.2 mg, 58% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49 (t, *J* = 7.7 Hz, 1H), 7.40 (d, *J* = 6.5 Hz, 1H), 7.18 – 7.08 (m, 7H), 7.04– 6.97 (m, 4H), 6.60 (s, 1H), 3.93 (dd, *J* = 10.0, 5.7 Hz, 1H), 2.92 (dd, *J* = 18.2, 10.0 Hz, 1H), 2.62 (dd, *J* = 18.3, 5.8 Hz, 1H), 2.38 (s, 3H), 1.59 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 178.5, 177.0, 175.9, 167.7, 146.7, 141.5, 139.8, 139.1, 137.2, 131.7, 130.9, 130.5, 130.1, 129.5, 128.1, 128.0, 127.2, 127.1, 127.0, 126.3, 58.9 44.0, 38.9, 28.5, 12.3. HRMS (ESI): m/z calcd for $C_{31}H_{30}N_3O_3^+$ $[M+H]^+$: 492.2282, found: 492.2286.

1'-acetyl-1-hexyl-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ad)



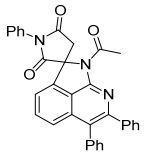
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ad** as colorless oil (6.2 mg, 24% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.70 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.56 (d, *J* = 8.3 Hz, 1H), 7.43 – 7.31 (m, 5H), 7.29 – 7.18 (m, 6H), 3.77 (d, *J* = 17.9 Hz, 1H), 3.71 (t, *J* = 7.5 Hz, 2H), 3.08 (d, *J* = 17.9 Hz, 1H), 2.94 (s, 3H), 1.80 – 1.68 (m, 2H), 1.45 – 1.31 (m, 6H), 0.94 – 0.87 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.7, 173.7, 170.2, 156.1, 152.1, 140.6, 138.9, 136.7, 135.3, 133.6, 130.7, 128.8, 127.8, 127.6, 127.5, 125.0, 124.0, 121.3, 116.7, 71.9, 42.3, 40.0, 31.4, 27.6, 26.6, 25.3, 22.7, 14.2. HRMS (ESI): m/z calcd for $C_{33}H_{32}N_3O_3^+$ $[M+H]^+$: 518.2438, found: 518.2440.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-hexylpyrrolidine-2,5-dione (5ad)



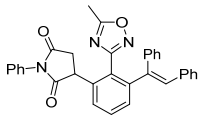
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ad** as colorless oil (11.7 mg, 45% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48 (t, *J* = 7.8 Hz, 1H), 7.42 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.17 – 7.08 (m, 7H), 7.04 – 6.96 (m, 4H), 6.61 (s, 1H), 4.08 (dd, *J* = 9.7, 5.4 Hz, 1H), 3.52 (t, *J* = 7.5 Hz, 2H), 3.02 (dd, *J* = 18.5, 9.7 Hz, 1H), 2.68 (dd, *J* = 18.5, 5.4 Hz, 1H), 2.38 (s, 3H), 1.62 – 1.54 (m, 2H), 1.34 – 1.27 (m, 6H), 0.91 – 0.85 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.5, 176.0, 176.0, 167.7, 146.8, 141.5, 139.8, 138.4, 137.2, 131.7, 130.9, 130.5, 130.3, 129.5, 128.1, 128.1, 127.2, 127.1, 127.0, 126.5, 44.0, 39.3, 38.5, 31.4, 27.8, 26.7, 22.6, 14.1, 12.3. HRMS (ESI): m/z calcd for $C_{33}H_{33}N_3O_3Na^+$ $[M+Na]^+$: 542.2414, found: 542.2419.

1'-acetyl-1,6',7'-triphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ae)



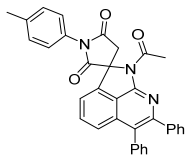
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ae** as a white solid (9.4 mg, 37% yield). Melting point: 283.1–284.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.61 (d, *J* = 8.3 Hz, 1H), 7.54 (t, *J* = 7.5 Hz, 2H), 7.50 – 7.32 (m, 9H), 7.30 – 7.19 (m, 5H), 3.93 (d, *J* = 18.1 Hz, 1H), 3.29 (d, *J* = 18.1 Hz, 1H), 2.99 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.8, 170.4, 156.0, 152.2, 140.6, 138.7, 136.6, 135.4, 133.7, 132.1, 131.2, 131.0, 130.7, 129.5, 129.2, 128.8, 128.7, 127.8, 127.6, 127.6, 126.9, 125.2, 124.2, 121.4, 117.0, 71.9, 42.5, 25.2. HRMS (ESI): m/z calcd for $C_{33}H_{24}N_3O_3^+$ $[M+H]^+$: 510.1812, found: 510.1817.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-phenylpyrrolidine-2, 5-dione (5ae)



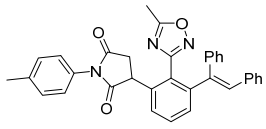
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ae** as a colorless oil (12.0 mg, 47% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.56 – 7.43 (m, 4H), 7.39 (t, *J* = 7.4 Hz, 1H), 7.36 – 7.28 (m, 3H), 7.20 – 7.08 (m, 6H), 7.07 – 6.98 (m, 4H), 6.63 (s, 1H), 4.30 (dd, *J* = 9.9, 5.9 Hz, 1H), 3.22 (dd, *J* = 18.6, 9.9 Hz, 1H), 2.90 (dd, *J* = 18.6, 5.9 Hz, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.4, 176.1, 174.9, 167.7, 147.0, 141.4, 139.7, 138.0, 137.2, 132.0, 131.8, 130.9, 130.5, 129.4, 129.2, 128.7, 128.1, 128.1, 127.4, 127.2, 127.1, 126.8, 126.5, 44.7, 38.4, 12.2. HRMS (ESI): m/z calcd for $C_{33}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 534.1788, found: 534.1783.

1'-acetyl-6',7'-diphenyl-1-(*p*-tolyl)-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2, 5-dione (4af)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4af** as a colorless oil (7.8 mg, 30% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.60 (d, *J* = 7.8 Hz, 1H), 7.47 – 7.31 (m, 10H), 7.29 – 7.18 (m, 5H), 3.91 (d, *J* = 18.1 Hz, 1H), 3.27 (d, *J* = 18.1 Hz, 1H), 2.98 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.0, 172.9, 170.4, 156.0, 152.2, 140.6, 139.4, 138.8, 136.6, 135.4, 133.7, 131.1, 130.7, 130.1, 129.4, 128.7, 127.8, 127.6, 127.6, 126.7, 125.1, 124.2, 121.4, 116.9, 71.9, 42.5, 25.3, 21.4. HRMS (ESI): m/z calcd for $C_{34}H_{26}N_3O_3^+$ $[M+H]^+$: 524.1969, found: 524.1964.

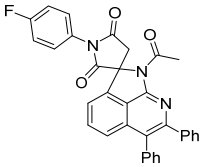
(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-(p-tolyl)pyrrolidine-2 ,5-dione (5af)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5af** as a colorless oil (14.4 mg, 55% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52 (t, *J* = 7.7 Hz, 1H), 7.44 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.33 – 7.24 (m, 3H), 7.21 – 7.09 (m, 8H), 7.06 – 6.98 (m, 4H), 6.62 (s, 1H), 4.28 (dd, *J* = 9.8, 5.8 Hz, 1H), 3.20 (dd, *J* = 18.6, 9.8 Hz, 1H), 2.88 (dd, *J* = 18.6, 5.7 Hz, 1H), 2.37 (d, *J* = 6.1 Hz, 6H).^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.5, 176.1, 175.0, 167.7, 147.0, 141.4, 139.7, 138.8, 138.1, 137.2, 131.8, 130.9, 130.5, 130.4, 129.9, 129.4, 129.4, 128.1, 128.0, 127.3, 127.2, 127.1, 126.8, 126.3,

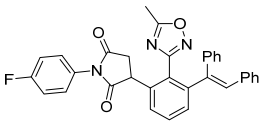
44.6, 38.4, 21.3, 12.2. HRMS (ESI): m/z calcd for $C_{34}H_{28}N_3O_3^+$ $[M+H]^+$: 526.2125, found: 526.2123.

1'-acetyl-1-(4-fluorophenyl)-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ag)



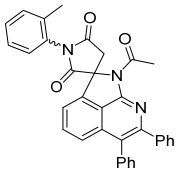
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ag** as a white solid (7.4 mg, 28% yield). Melting point: 240.3–242.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (t, *J* = 7.7 Hz, 1H), 7.61 (d, *J* = 8.3 Hz, 1H), 7.49 – 7.32 (m, 8H), 7.29 – 7.17 (m, 7H), 3.90 (d, *J* = 18.1 Hz, 1H), 3.29 (d, *J* = 18.2 Hz, 1H), 2.98 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.9, 172.8, 170.5, 162.7 (*J* = 247.6 Hz), 155.9, 152.2, 140.5, 138.5, 136.6, 135.4, 133.7, 131.1, 130.7, 128.8 (*J* = 8.8 Hz), 127.9 (d, *J* = 3.1 Hz), 127.8, 127.6 (*J* = 7 Hz), 125.2, 124.3, 121.4, 117.0, 116.5 (*J* = 23.0 Hz), 71.8, 42.5, 25.2. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -111.6. (ESI): m/z calcd for $C_{33}H_{22}FN_3O_3Na^+$ $[M+Na]^+$: 550.1537, found: 550.1536.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-(4-fluorophenyl)pyrrolidine-2,5-dione (5ag)



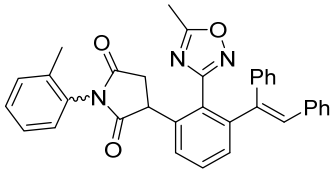
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ag** as a colorless oil (15.9 mg, 60% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52 (t, *J* = 7.7 Hz, 1H), 7.46 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.35 – 7.28 (m, 3H), 7.20 – 7.10 (m, 8H), 7.07 – 6.99 (m, 4H), 6.62 (s, 1H), 4.30 (dd, *J* = 10.0, 5.8 Hz, 1H), 3.22 (dd, *J* = 18.6, 9.9 Hz, 1H), 2.89 (dd, *J* = 18.7, 5.9 Hz, 1H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.3, 176.2, 174.8, 167.7, 162.3 (*J* = 247.1 Hz), 147.1, 141.4, 139.7, 137.7, 137.1, 131.9, 130.7 (*J* = 34.8 Hz), 130.5, 129.4, 128.3 (*J* = 8.7 Hz), 128.1 (*J* = 4.4 Hz), 127.9 (*J* = 3.2 Hz), 127.5, 127.2 (*J* = 14.1 Hz), 126.7, 116.2 (*J* = 22.8 Hz), 44.7, 38.3, 12.2. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -112.2. HRMS (ESI): m/z calcd for $C_{33}H_{24}FN_3O_3Na^+$ $[M+Na]^+$: 552.1694, found: 552.1698.

1'-acetyl-6',7'-diphenyl-1-(*o*-tolyl)-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ah)



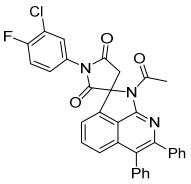
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ah** (rotameric products = 1:1.2 and cannot be separated) as a colorless oil (5.5 mg, 21% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.77 (dd, *J* = 8.4, 7.1 Hz, 1H), 7.61 (d, *J* = 8.3 Hz, 1H), 7.51 – 7.29 (m, 10H), 7.29 – 7.19 (m, 5H), 4.00 (dd, *J* = 61.3, 18.0 Hz, 1H), 3.29 (dd, *J* = 29.6, 18.0 Hz, 1H), 2.99 (d, *J* = 3.9 Hz, 3H), 2.39 (d, *J* = 47.7 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.8, 172.7, 172.6, 172.6, 170.5, 170.2, 156.1, 156.0, 152.2, 140.6, 139.0, 138.8, 137.5, 136.6, 135.5, 135.4, 135.3, 133.7, 133.7, 131.8, 131.2, 131.1, 130.9, 130.7, 130.1, 130.0, 128.8, 128.4, 127.9, 127.8, 127.7, 127.6, 127.5, 126.9, 125.2, 125.1, 124.2, 124.2, 121.5, 121.2, 116.9, 116.6, 72.2, 72.1, 42.8, 42.3, 25.3, 25.3, 18.0, 18.0. HRMS (ESI): m/z calcd for $C_{34}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 546.1788, found: 546.1789.

(*E*)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-(*o*-tolyl)pyrrolidine-2,5-dione (5ah)



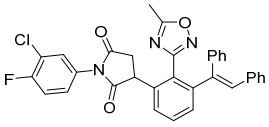
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ah** (rotameric products = 1:1.0 and cannot be separated) as a colorless oil (14.7 mg, 56% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.54 (td, *J* = 7.8, 5.5 Hz, 1H), 7.46 (t, *J* = 6.3 Hz, 1H), 7.38 – 7.27 (m, 4H), 7.19 – 6.97 (m, 11H), 6.63 (d, *J* = 13.1 Hz, 1H), 4.34 (td, *J* = 9.5, 5.7 Hz, 1H), 3.25 (dd, *J* = 19.5, 10.6 Hz, 1H), 2.95 – 2.84 (m, 1H), 2.41 (d, *J* = 6.5 Hz, 3H), 2.20 (d, *J* = 56.9 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.4, 176.3, 176.2, 176.1, 174.9, 174.9, 167.8, 167.7, 147.0, 146.9, 141.5, 141.5, 139.8, 139.7, 138.4, 138.0, 137.2, 137.2, 135.7, 135.6, 131.8, 131.4, 131.3, 131.2, 131.2, 131.1, 131.0, 130.6, 130.5, 130.4, 129.8, 129.7, 129.5, 129.5, 128.1, 128.1, 127.3, 127.3, 127.3, 127.2, 127.1, 127.1, 127.1, 125.8, 44.8, 44.2, 38.9, 38.7, 18.2, 18.0, 12.3. HRMS (ESI): m/z calcd for $C_{34}H_{28}N_3O_3^+$ $[M+H]^+$: 526.2125, found: 526.2129.

1'-acetyl-1-(3-chloro-4-fluorophenyl)-6',7'-diphenyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ai)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ai** as a white solid (7.6 mg, 27% yield). Melting point: 251.2–252.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.61 (d, *J* = 8.3 Hz, 1H), 7.56 (dd, *J* = 6.4, 2.5 Hz, 1H), 7.45 – 7.33 (m, 7H), 7.29 (d, *J* = 8.6 Hz, 1H), 7.26 – 7.18 (m, 5H), 3.88 (d, *J* = 18.2 Hz, 1H), 3.28 (d, *J* = 18.2 Hz, 1H), 2.97 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 172.6, 172.4, 170.6, 158.3 (*J* = 250.3 Hz), 155.8, 152.3, 140.5, 138.3, 136.5, 135.4, 133.7, 131.0, 130.7, 129.4, 128.8, 128.4 (*J* = 3.8 Hz), 127.8, 127.7 (*J* = 7.2 Hz), 127.0 (*J* = 7.8 Hz), 125.3, 124.4, 122.0 (*J* = 18.9 Hz), 121.3, 117.3 (*J* = 22.4 Hz), 117.0, 71.7, 42.5, 25.2. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -113.7. HRMS (ESI): m/z calcd for $C_{33}H_{22}ClFN_3O_3^+$ $[M+H]^+$: 562.1328, found: 562.1321.

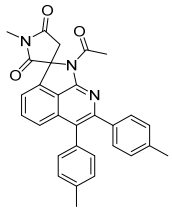
(*E*)-1-(3-chloro-4-fluorophenyl)-3-(3-(1,2-diphenylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)pyrrolidine-2,5-dione (5ai)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ai** as a colorless oil (17.7 mg, 63% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.53 (t, *J* = 7.7 Hz, 1H), 7.49 – 7.41 (m, 2H), 7.31 – 7.22 (m, 3H), 7.17 – 7.09 (m, 6H), 7.05 – 6.98 (m, 4H), 6.61 (s, 1H), 4.30 (dd, *J* = 10.0, 5.9 Hz, 1H), 3.22 (dd, *J* = 18.7, 9.9 Hz, 1H), 2.91 (dd, *J* = 18.7, 5.9 Hz, 1H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.3, 176.0, 174.4, 167.8, 157.8 (*J* = 249.9 Hz), 147.2, 141.3, 139.7, 137.3 (*J* = 28.4 Hz), 131.9, 130.8 (*J* = 23.9 Hz), 130.5, 129.5, 128.9, 128.4 (*J* = 3.8 Hz), 128.1 (*J* = 4.3 Hz), 127.8, 127.2 (*J* = 14.4 Hz), 126.6, 126.4 (*J* = 7.6 Hz), 121.8 (*J* = 18.9 Hz), 117.1 (*J* = 22.3 Hz), 44.8, 38.2, 12.2. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -114.4. HRMS (ESI): m/z calcd for $C_{33}H_{23}ClFN_3O_3Na^+$ $[M+Na]^+$: 586.1304, found: 586.1310.

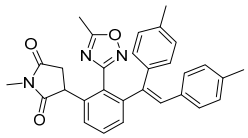
1'-acetyl-1-methyl-6',7'-di-p-tolyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,

5-dione (4aj)



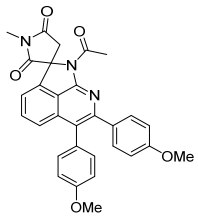
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4aj** as a white solid (10.2 mg, 43% yield). Melting point: 230.1–233.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.66 (dd, *J* = 8.3, 7.1 Hz, 1H), 7.54 (d, *J* = 8.2 Hz, 1H), 7.30 (d, *J* = 8.2 Hz, 2H), 7.24 (s, 1H), 7.17 (d, *J* = 8.3 Hz, 2H), 7.14 – 7.07 (m, 2H) 7.02 (d, *J* = 7.9 Hz, 2H), 3.73 (d, *J* = 18.0 Hz, 1H), 3.21 (s, 3H), 3.09 (d, *J* = 18.0 Hz, 1H), 2.92 (s, 3H), 2.34 (d, *J* = 32.9 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 173.8, 170.3, 155.8, 152.0, 138.6, 137.9, 137.4, 137.2, 135.6, 133.7, 133.4, 130.9, 130.6, 129.5, 128.5, 124.8, 124.1, 121.2, 116.7, 71.9, 42.4, 25.9, 25.3, 21.5, 21.4. HRMS (ESI): m/z calcd for $C_{30}H_{25}N_3O_3Na^+$ $[M+Na]^+$: 498.1788, found: 498.1790.

(*E*)-3-(3-(1,2-di-p-tolylvinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2, 5-dione (5aj)



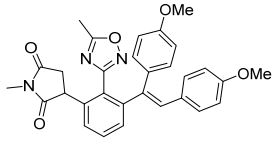
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5aj** as a colorless oil (9.8 mg, 41% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ =7.46 (t, *J* = 7.8 Hz, 1H), 7.39 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.14 (dd, *J* = 7.7, 1.3 Hz, 1H), 6.99 – 6.86 (m, 8H), 6.52 (s, 1H), 4.09 (dd, *J* = 9.6, 5.4 Hz, 1H), 3.09 – 2.98 (m, 4H), 2.70 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.38 (s, 3H), 2.27 (t, *J* = 14.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.6, 176.1, 175.9, 167.7, 147.3, 140.5, 138.0, 137.0, 136.8, 136.8, 134.4, 131.4, 130.8, 130.3, 130.3, 129.3, 128.8, 128.7, 126.8, 126.6, 44.3, 38.5, 25.3, 21.4, 21.3, 12.2. HRMS (ESI): m/z calcd for $C_{30}H_{27}N_3O_3Na^+$ $[M+Na]^+$: 500.1945, found: 500.1954.

1'-acetyl-6',7'-bis(4-methoxyphenyl)-1-methyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]iso quinoline]-2,5-dione (4ak)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1) afforded **4ak** as a white solid (14.7 mg, 58% yield). Melting point: 218.5–219.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.69 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.57 (d, *J* = 8.2 Hz, 1H), 7.38 (d, *J* = 8.9 Hz, 2H), 7.27 (d, *J* = 2.1 Hz, 1H), 7.17 (d, *J* = 7.5 Hz, 2H), 6.94 (d, *J* = 8.9 Hz, 2H), 6.78 (d, *J* = 8.9 Hz, 2H), 3.87 (s, 3H), 3.80 (s, 3H), 3.76 (d, *J* = 17.9 Hz, 1H), 3.24 (s, 3H), 3.11 (d, *J* = 18.0 Hz, 1H), 2.95 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 173.8, 170.3, 159.1, 159.0, 155.7, 151.7, 138.6, 135.7, 133.5, 133.2, 132.0, 129.0, 124.0, 124.0, 121.1, 116.6, 114.3, 113.3, 71.9, 55.4, 55.3, 42.4, 25.9, 25.3. HRMS (ESI): m/z calcd for $C_{30}H_{26}N_3O_5^+$ $[M+H]^+$: 508.1867, found: 508.1863.

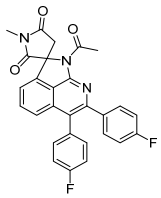
(*E*)-3-(3-(1,2-bis(4-methoxyphenyl)vinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylp yrrolidine-2,5-dione (5ak)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ak** as a colorless oil (6.6 mg, 26% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46 (t, *J* = 7.7 Hz, 1H), 7.39 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.14 (dd, *J* = 7.8, 1.3 Hz, 1H), 6.94 (t, *J* = 8.3 Hz, 4H), 6.66 (t, *J* = 9.0 Hz, 4H), 6.47 (s, 1H), 4.10 (dd, *J*

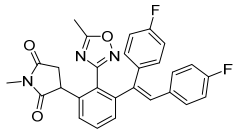
= 9.7, 5.5 Hz, 1H), 3.76 (d, *J* = 11.1 Hz, 6H), 3.08 – 2.98 (m, 4H), 2.70 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.7, 176.1, 176.0, 167.7, 158.7, 158.6, 147.4, 139.2, 138.0, 132.5, 132.4, 131.7, 130.8, 130.7, 130.7, 130.3, 130.0, 126.8, 126.6, 113.5, 113.5, 55.3, 44.3, 38.5, 25.3, 12.2. HRMS (ESI): m/z calcd for $C_{30}H_{27}N_3O_5Na^+$ $[M+Na]^+$: 532.1843, found: 532.1850.

1'-acetyl-6',7'-bis(4-fluorophenyl)-1-methyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4al)



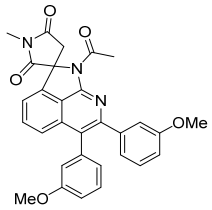
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4al** as a colorless oil (9.4 mg, 39% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.73 (dd, *J* = 8.3, 7.1 Hz, 1H), 7.53 (d, *J* = 8.3 Hz, 1H), 7.40 – 7.29 (m, 3H), 7.19 (s, 2H), 7.09 (t, *J* = 8.8 Hz, 2H), 6.97 – 6.89 (m, 2H), 3.75 (d, *J* = 18.0 Hz, 1H), 3.23 (s, 3H), 3.11 (d, *J* = 18.0 Hz, 1H), 2.92 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.8, 173.7, 170.2, 162.3 (*J* = 245.2 Hz), 156.2, 151.3, 138.8, 136.5 (*J* = 3.2 Hz), 135.2, 133.9, 132.6, 132.4 (*J* = 7.8 Hz), 123.9, 123.7, 121.3, 117.2, 116.2, 115.9, 114.9 (*J* = 21.4 Hz), 72.0, 42.4, 25.9, 25.3. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -113.9, -114.0. HRMS (ESI): m/z calcd for $C_{28}H_{20}F_2N_3O_3^+$ $[M+H]^+$: 484.1467, found: 484.1466.

(*E*)-3-(3-(1,2-bis(4-fluorophenyl)vinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5al)



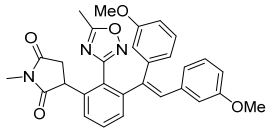
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5al** as a colorless oil (11.6 mg, 48% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49 (t, *J* = 7.8 Hz, 1H), 7.38 (d, *J* = 6.6 Hz, 1H), 7.18 (d, *J* = 7.8 Hz, 1H), 7.01 – 6.90 (m, 4H), 6.82 (q, *J* = 8.6 Hz, 4H), 6.54 (s, 1H), 4.11 (dd, *J* = 9.7, 5.5 Hz, 1H), 3.11 – 2.97 (m, 4H), 2.70 (dd, *J* = 18.4, 5.6 Hz, 1H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.6, 176.2, 175.9, 167.6, 163.2 (*J* = 21.5 Hz), 160. 7 (*J* = 21.6 Hz), 146.4, 140.3 (*J* = 1.5 Hz), 138.2, 135.5 (*J* = 3.4 Hz), 133.0 (*J* = 3.4 Hz), 132.2 (*J* = 7.9 Hz), 131.1, 131.0 (*J* = 2.5 Hz), 130.8, 130.2, 127.2, 126.8, 115.3 (*J* = 6.9 Hz), 115.1 (*J* = 7.1 Hz), 44.3, 38.4, 25.3, 12.2. ^{19}F NMR (376 MHz, $CDCl_3$): δ = -114.1. HRMS (ESI): m/z calcd for $C_{28}H_{21}F_2N_3O_3Na^+$ $[M+Na]^+$: 508.1443, found: 508.1440.

1'-acetyl-6',7'-bis(3-methoxyphenyl)-1-methyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4am)



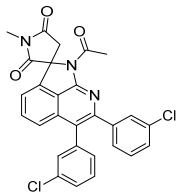
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4am** as a white solid (10.1 mg, 40% yield). Melting point: 218.2–220.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.71 (dd, *J* = 8.4, 7.0 Hz, 1H), 7.60 (d, *J* = 8.3 Hz, 1H), 7.34 – 7.27 (m, 2H), 7.15 (t, *J* = 7.9 Hz, 1H), 7.05 (d, *J* = 7.8 Hz, 1H), 7.01 – 6.95 (m, 1H), 6.92 – 6.73 (m, 4H), 3.81 – 3.68 (m, 4H), 3.63 (s, 3H), 3.23 (s, 3H), 3.11 (d, *J* = 18.0 Hz, 1H), 2.94 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 173.8, 170.3, 159.0, 156.0, 151.8, 141.9, 138.6, 138.1, 135.2, 133.7, 128.8, 125.0, 124.2, 123.1, 121.3, 117.0, 115.7, 114.1, 71.9, 55.4, 55.2, 42.4, 25.9, 25.3. HRMS (ESI): m/z calcd for $C_{30}H_{26}N_3O_5^+$ $[M+H]^+$: 508.1867, found: 508.1870.

(*E*)-3-(3-(1,2-bis(3-methoxyphenyl)vinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5am)



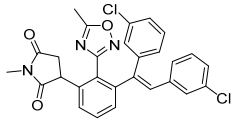
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5am** as a colorless oil (8.7 mg, 34% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52 – 7.40 (m, 2H), 7.16 (d, *J* = 6.1 Hz, 1H), 7.05 (dt, *J* = 17.7, 7.9 Hz, 2H), 6.68 (ddd, *J* = 17.1, 8.3, 2.9 Hz, 2H), 6.62 (d, *J* = 7.7 Hz, 2H), 6.59 – 6.52 (m, 3H), 4.09 (dd, *J* = 9.7, 5.6 Hz, 1H), 3.58 (d, *J* = 29.8 Hz, 6H), 3.01 (s, 4H), 2.70 (dd, *J* = 18.5, 5.4 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.6, 176.0, 176.0, 167.6, 159.3, 159.1, 146.6, 141.5, 141.1, 138.3, 138.1, 131.8, 130.9, 130.1, 129.2, 129.0, 126.9, 126.8, 122.8, 122.2, 115.5, 114.0, 113.6, 113.3, 55.3, 55.0, 44.3, 38.4, 25.2, 12.1. HRMS (ESI): m/z calcd for $C_{30}H_{27}N_3O_5Na^+$ $[M+Na]^+$: 532.1843, found: 532.1843.

1'-acetyl-6',7'-bis(3-chlorophenyl)-1-methyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4an)



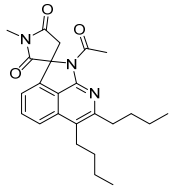
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4an** as a colorless oil (6.2 mg, 24% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.75 (dd, *J* = 8.4, 7.1 Hz, 1H), 7.54 (d, *J* = 8.3 Hz, 1H), 7.45 (t, *J* = 1.9 Hz, 1H), 7.39 – 7.29 (m, 3H), 7.28 – 7.21 (m, 2H), 7.20 – 7.06 (m, 3H), 3.76 (d, *J* = 18.0 Hz, 1H), 3.23 (s, 3H), 3.12 (d, *J* = 18.2 Hz, 1H), 2.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.6, 170.3, 156.4, 150.9, 142.0, 138.8, 138.1, 134.9, 134.1, 133.9, 130.8, 130.6, 129.4, 129.1, 128.7, 128.1, 128.0, 124.0, 123.8, 121.4, 117.6, 72.0, 42.3, 26.0, 25.4. HRMS (ESI): m/z calcd for $C_{28}H_{20}Cl_2N_3O_3^+$ $[M+H]^+$: 516.0876, found: 516.0870.

(*E*)-3-(3-(1,2-bis(3-chlorophenyl)vinyl)-2-(5-methyl-1,2,4-oxadiazol-3-yl)phenyl)-1-methylpyrrolidine-2,5-dione (5an)



According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5an** as a colorless oil (16.8 mg, 65% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50 (t, *J* = 7.8 Hz, 1H), 7.39 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.21 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.17 – 7.01 (m, 4H), 6.97 (d, *J* = 12.7 Hz, 2H), 6.88 (d, *J* = 7.5 Hz, 1H), 6.83 (d, *J* = 7.7 Hz, 1H), 6.56 (s, 1H), 4.12 (dd, *J* = 9.6, 5.6 Hz, 1H), 3.02 (s, 4H), 2.70 (dd, *J* = 18.5, 5.5 Hz, 1H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.5, 176.3, 175.9, 167.4, 145.6, 141.5, 141.1, 138.4, 138.3, 134.1, 134.0, 131.1, 131.0, 130.2, 130.2, 129.6, 129.4, 129.4, 128.5, 127.7, 127.5, 127.5, 127.4, 126.8, 44.3, 38.4, 25.3, 12.1. HRMS (ESI): m/z calcd for $C_{28}H_{22}Cl_2N_3O_3^+$ $[M+H]^+$: 518.1033, found: 518.1019.

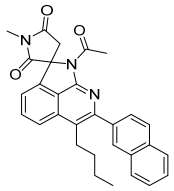
1'-acetyl-6',7'-dibutyl-1-methyl-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ao)



According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ao** as a colorless oil (10.0 mg, 49% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ =

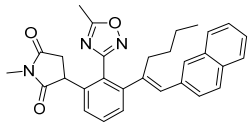
7.77 – 7.67 (m, 2H), 7.18 (d, *J* = 6.6 Hz, 1H), 3.68 (d, *J* = 18.0 Hz, 1H), 3.19 (s, 3H), 3.02 (d, *J* = 17.9 Hz, 1H), 2.96 – 2.84 (m, 7H), 1.83 – 1.72 (m, 2H), 1.63 – 1.53 (m, 2H), 1.52 – 1.40 (m, 4H), 0.99 (td, *J* = 7.3, 2.4 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 174.0, 173.9, 170.2, 154.8, 154.7, 139.0, 134.9, 132.9, 122.5, 121.9, 121.0, 115.6, 71.5, 42.5, 34.8, 33.0, 32.1, 27.3, 25.8, 25.0, 23.2, 22.9, 14.2, 14.1. HRMS (ESI): m/z calcd for $C_{24}H_{30}N_3O_3^+$ $[M+H]^+$: 408.2282, found: 408.2275.

1'-acetyl-6'-butyl-1-methyl-7'-(naphthalen-2-yl)-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4ap)



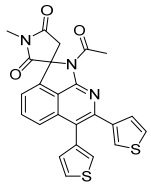
According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4ap** as a colorless oil (11.7 mg, 49% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.02 – 7.86 (m, 5H), 7.85 – 7.78 (m, 1H), 7.69 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.58 – 7.51 (m, 2H), 7.32 (d, *J* = 7.0 Hz, 1H), 3.73 (d, *J* = 18.0 Hz, 1H), 3.23 (s, 3H), 3.09 (d, *J* = 18.0 Hz, 1H), 3.01 (dd, *J* = 9.5, 6.7 Hz, 2H), 2.84 (s, 3H), 1.72 – 1.64 (m, 2H), 1.40 – 1.29 (m, 2H), 0.86 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.9, 173.8, 170.3, 154.8, 152.8, 139.2, 138.8, 135.1, 133.3, 133.1, 132.9, 128.4, 127.9, 127.8, 126.4, 126.4, 124.2, 122.8, 121.7, 116.7, 71.7, 42.4, 33.4, 28.2, 25.9, 25.1, 23.0, 13.9. HRMS (ESI): m/z calcd for $C_{30}H_{27}N_3O_3Na^+$ $[M+Na]^+$: 500.1945, found: 500.1943.

(*E*)-1-methyl-3-(2-(5-methyl-1,2,4-oxadiazol-3-yl)-3-(1-(naphthalen-2-yl)hex-1-en-2-yl)phenyl)pyrrolidine-2,5-dione (5ap)



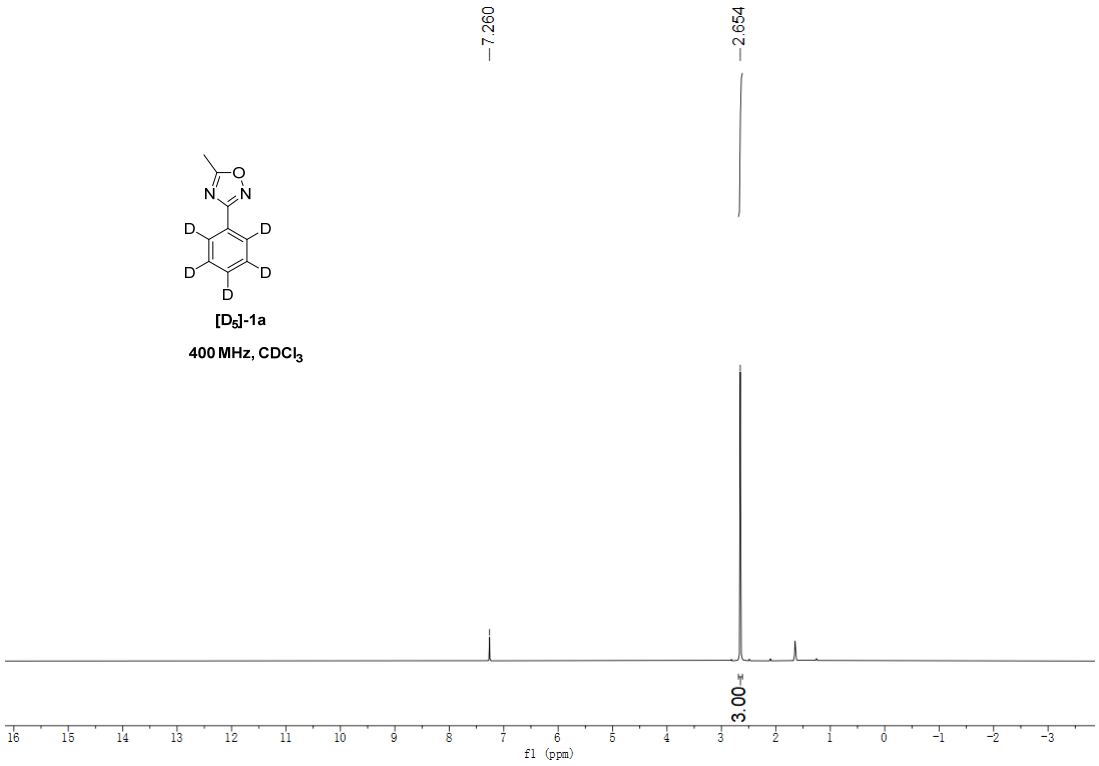
According to general procedure B, purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 2/1, v/v) afforded **5ap** as a colorless oil (7.2 mg, 30% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.84 – 7.75 (m, 3H), 7.60 (s, 1H), 7.54 – 7.39 (m, 4H), 7.30 – 7.26 (m, 1H), 7.17 (d, *J* = 7.7 Hz, 1H), 6.42 (s, 1H), 4.15 (dd, *J* = 9.7, 5.5 Hz, 1H), 3.18 – 3.03 (m, 4H), 2.76 (dd, *J* = 18.6, 5.5 Hz, 1H), 2.59 (s, 3H), 2.52 – 2.35 (m, 2H), 1.47 – 1.36 (m, 2H), 1.26 – 1.21 (m, 2H), 0.83 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 177.8, 176.4, 176.1, 167.9, 146.5, 142.6, 138.1, 135.3, 133.4, 132.3, 131.2, 130.7, 128.8, 128.0, 127.8, 127.7, 127.3, 127.1, 126.6, 126.2, 126.2, 125.9, 44.7, 38.6, 32.4, 30.4, 25.3, 23.0, 14.0, 12.5. HRMS (ESI): m/z calcd for $C_{30}H_{29}N_3O_3Na^+$ $[M+Na]^+$: 502.2101, found: 502.2102.

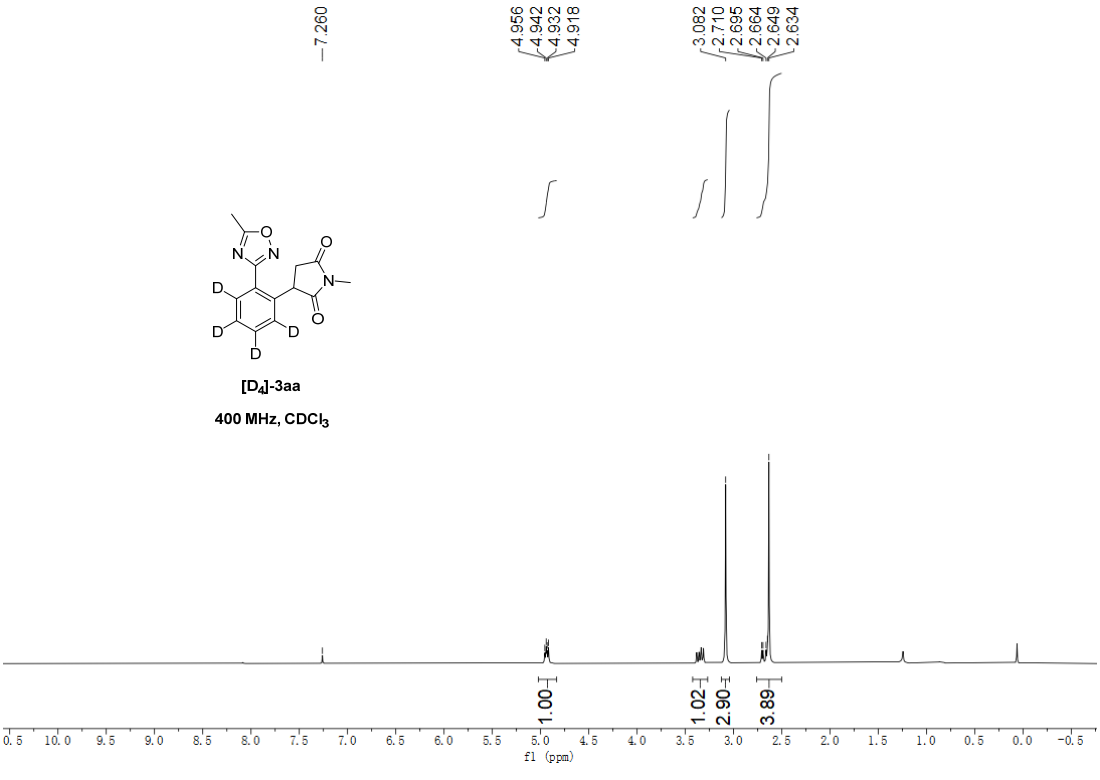
1'-acetyl-1-methyl-6',7'-di(thiophen-3-yl)-1'*H*-spiro[pyrrolidine-3,2'-pyrrolo[4,3,2-*ij*]isoquinoline]-2,5-dione (4aq)

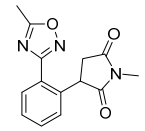


According to general procedure A, purification by column chromatography on silica gel (petroleum ether/ dichloromethane/ethyl acetate = 6/3/1, v/v) afforded **4aq** as a white solid (7.1 mg, 31% yield). Melting point: 181.4–183.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.69 (dd, *J* = 8.3, 7.1 Hz, 1H), 7.56 – 7.47 (m, 2H), 7.30 (dd, *J* = 3.1, 1.3 Hz, 1H), 7.28 – 7.25 (m, 2H), 7.17 (dd, *J* = 5.1, 3.0 Hz, 1H), 7.11 (dd, *J* = 5.1, 1.3 Hz, 1H), 7.00 (dd, *J* = 4.9, 1.2 Hz, 1H), 3.74 (d, *J* = 18.0 Hz, 1H), 3.22 (s, 3H), 3.10 (d, *J* = 17.9 Hz, 1H), 2.97 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 173.8, 173.7, 170.2, 156.0, 147.4, 141.8, 138.5, 136.7, 135.9, 133.8, 129.7, 129.0, 126.8, 126.6, 124.9, 124.4, 124.0, 121.1, 119.0, 116.8, 72.0, 42.3, 25.9, 25.3. HRMS (ESI): m/z calcd for $C_{24}H_{18}N_3O_3S_2^+$ $[M+H]^+$: 460.0784, found: 460.0784.

9. ^{1}H , ^{13}C and ^{19}F NMR spectra

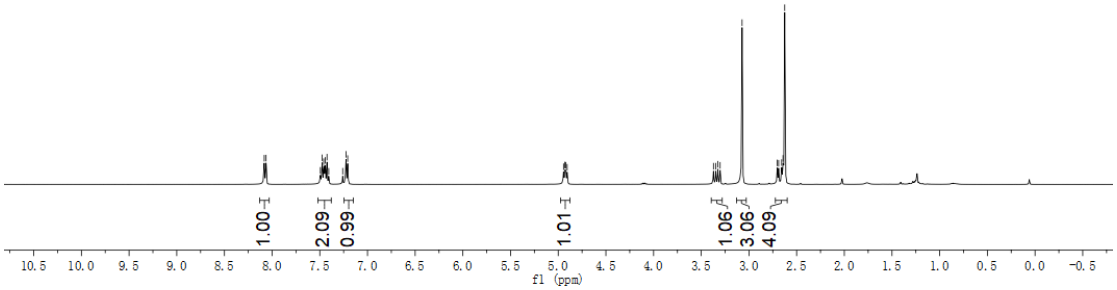


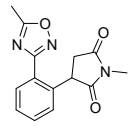




3aa

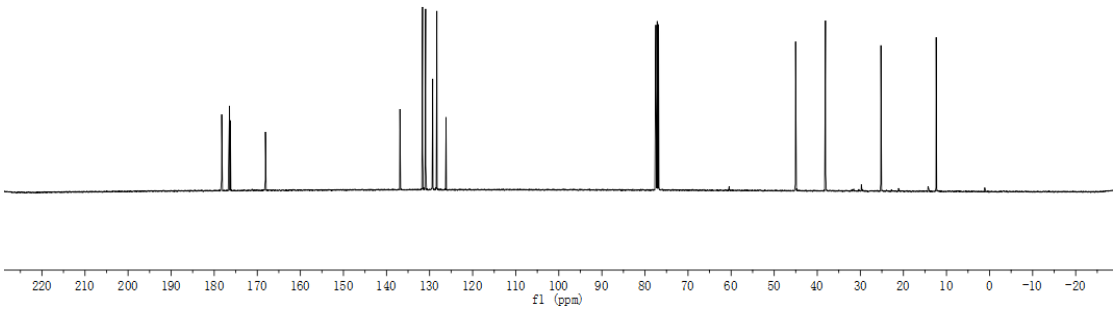
400 MHz, $CDCl_3$

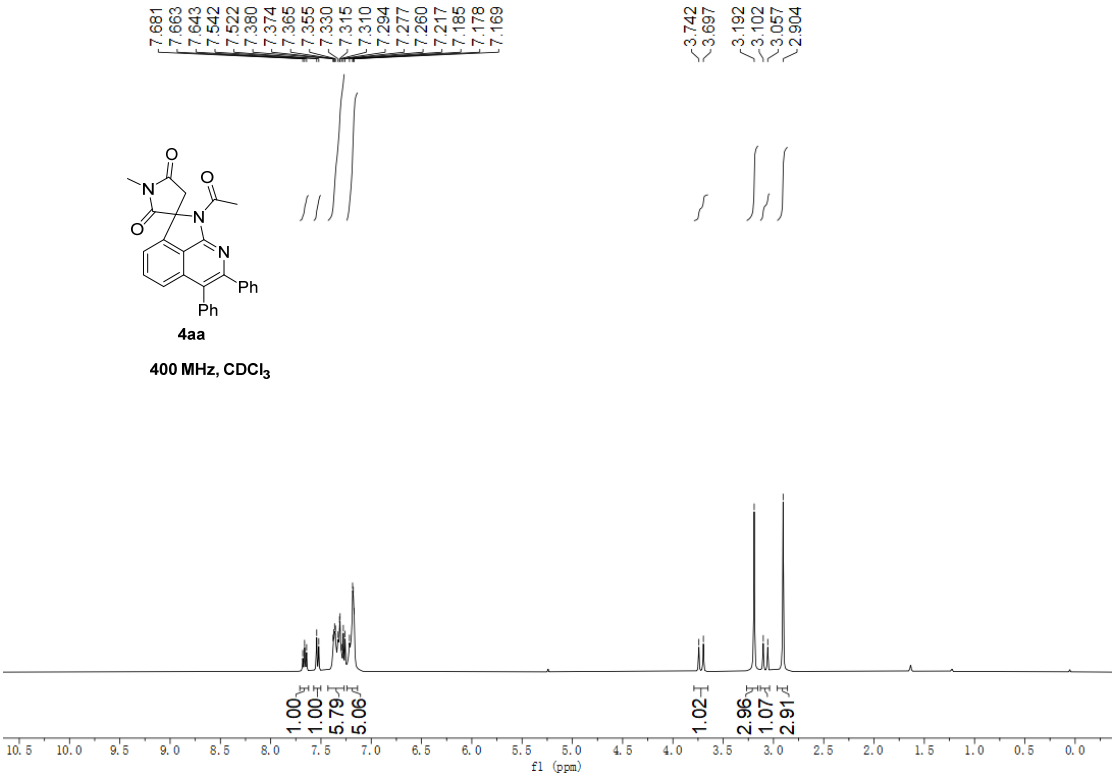




3aa

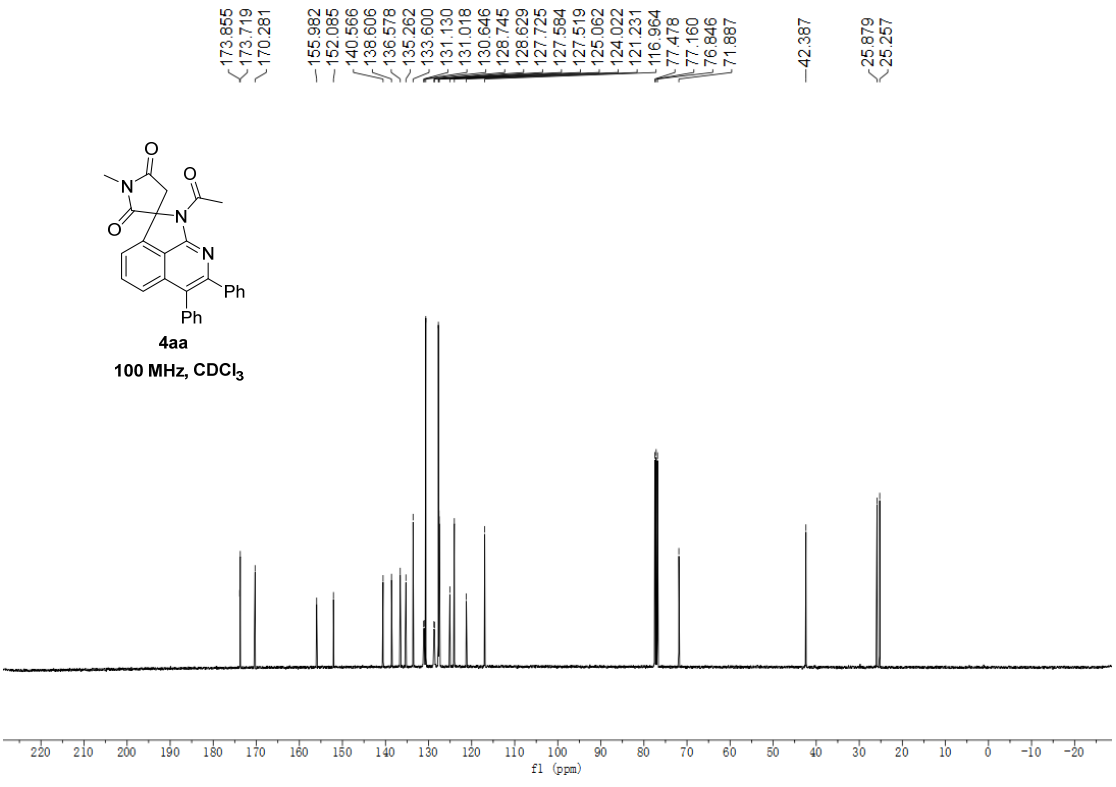
100 MHz, $CDCl_3$





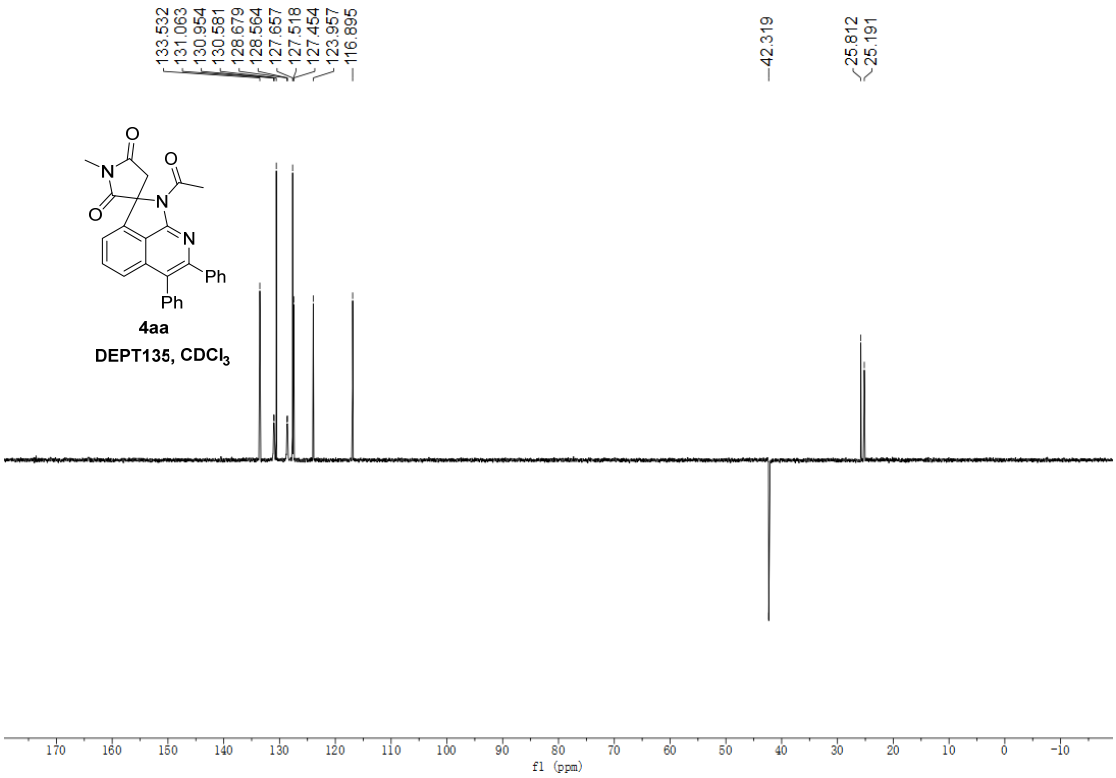
4aa

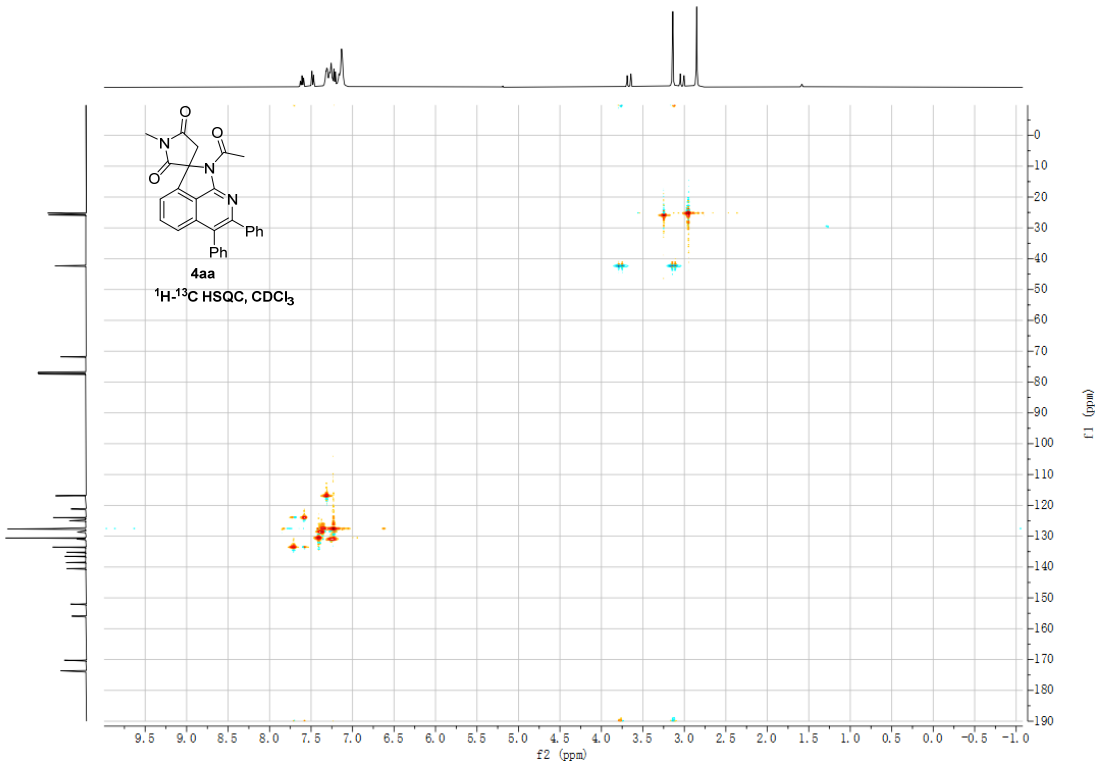
400 MHz, $CDCl_3$

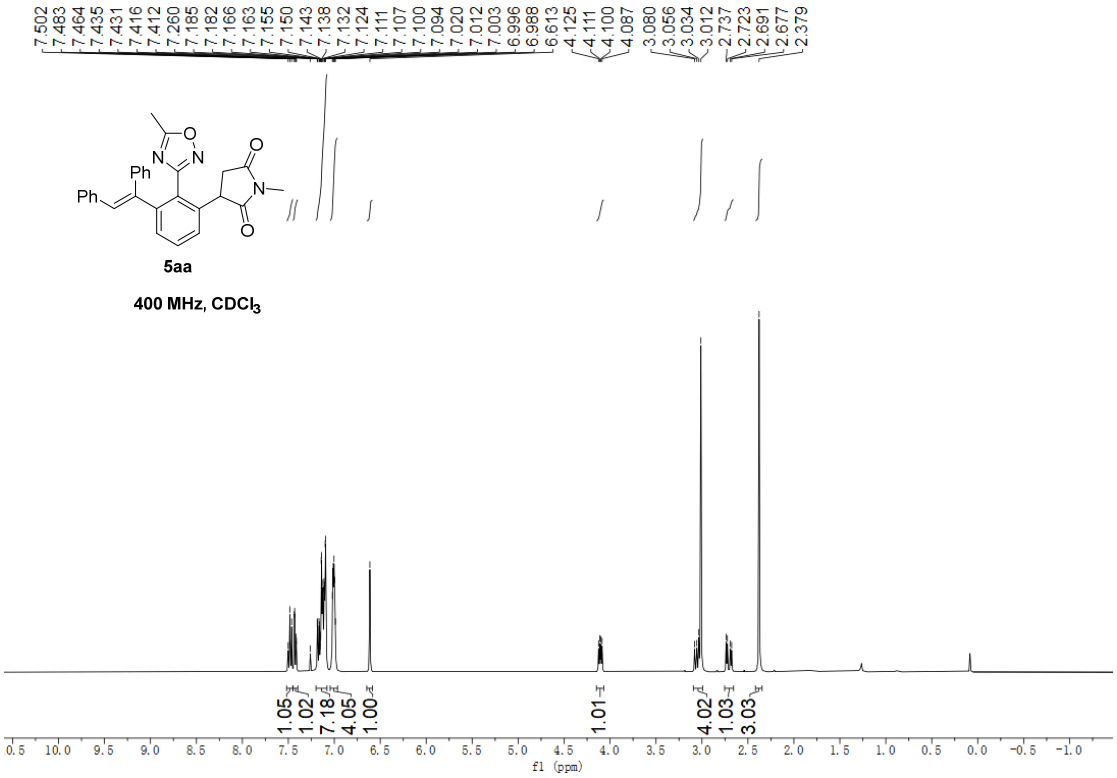


4aa

100 MHz, $CDCl_3$

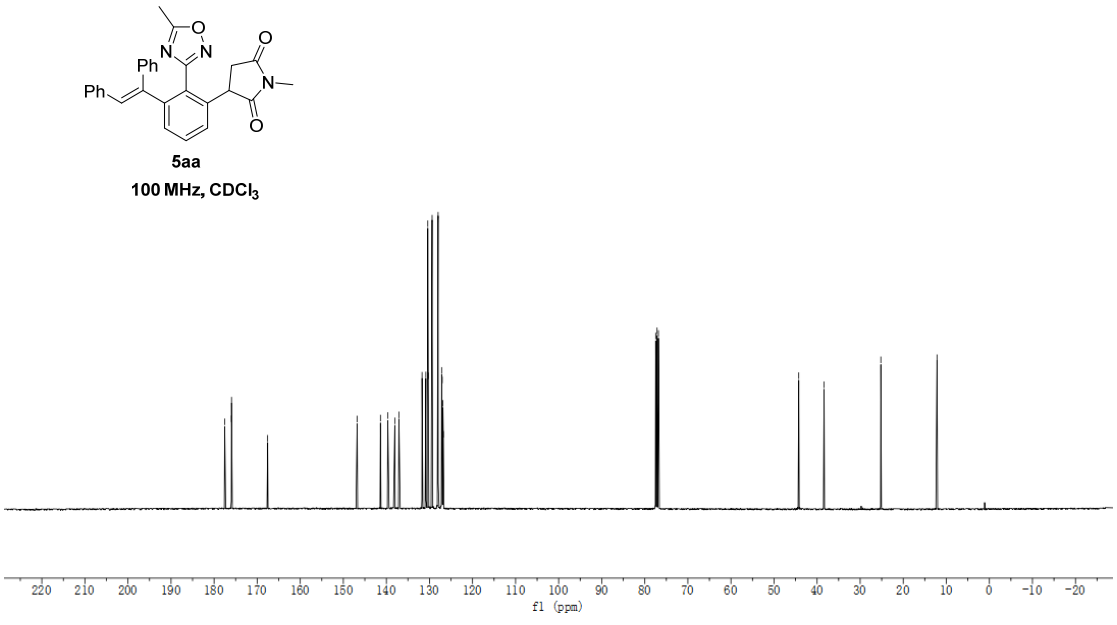

133.532
131.063
130.954
130.581
128.679
128.564
127.657
127.518
127.454
123.957
116.895
42.319
25.812
25.191
4aa
DEPT135, CDCl3
f1 (ppm)


4aa
1H-13C HSQC, CDCl3
f2 (ppm)
f1 (ppm)



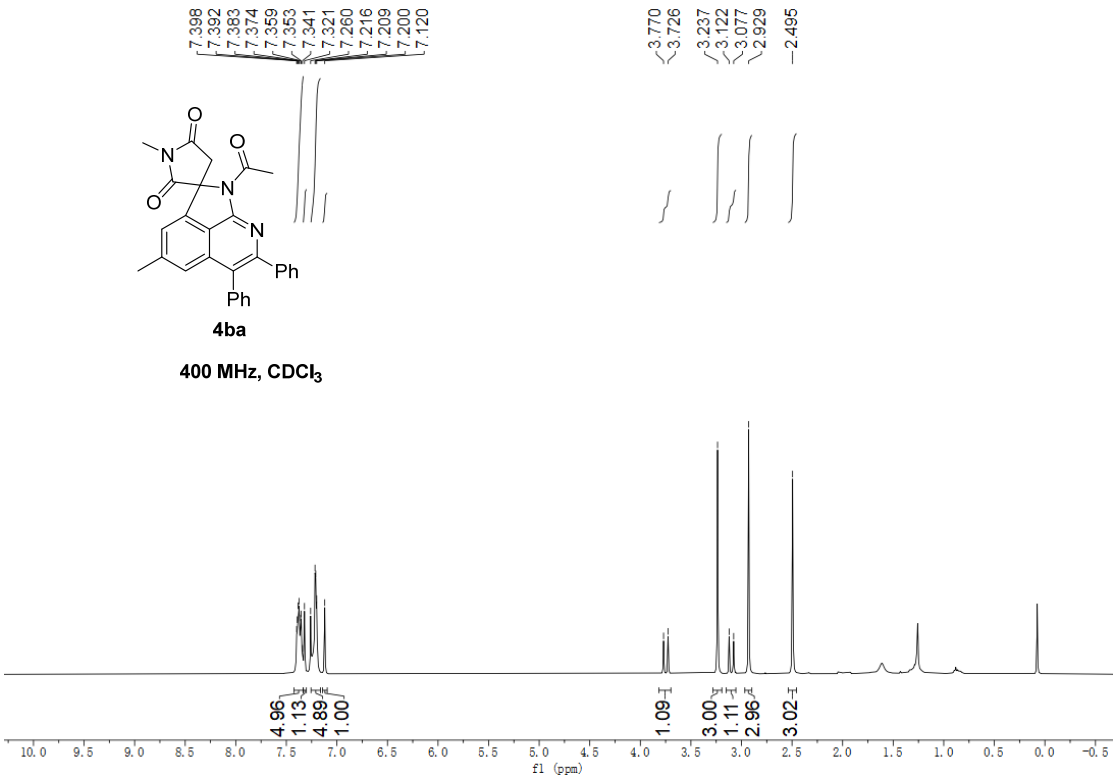
5aa

400 MHz, $CDCl_3$



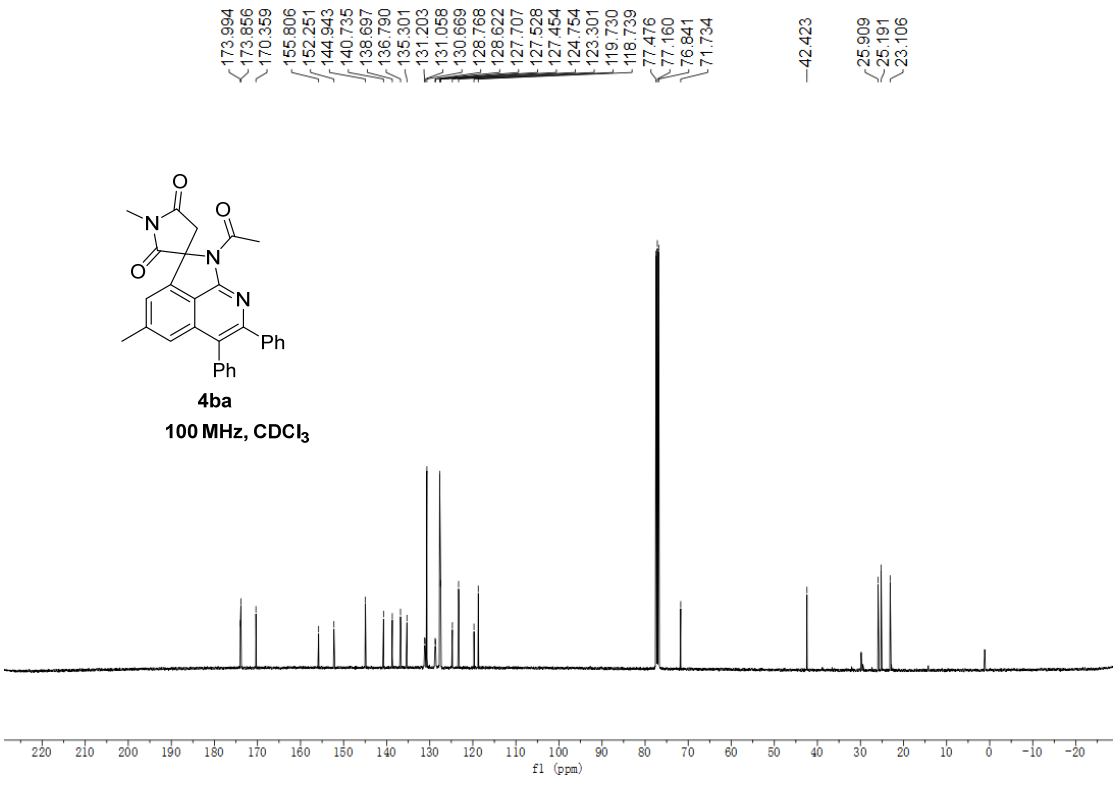
5aa

100 MHz, $CDCl_3$



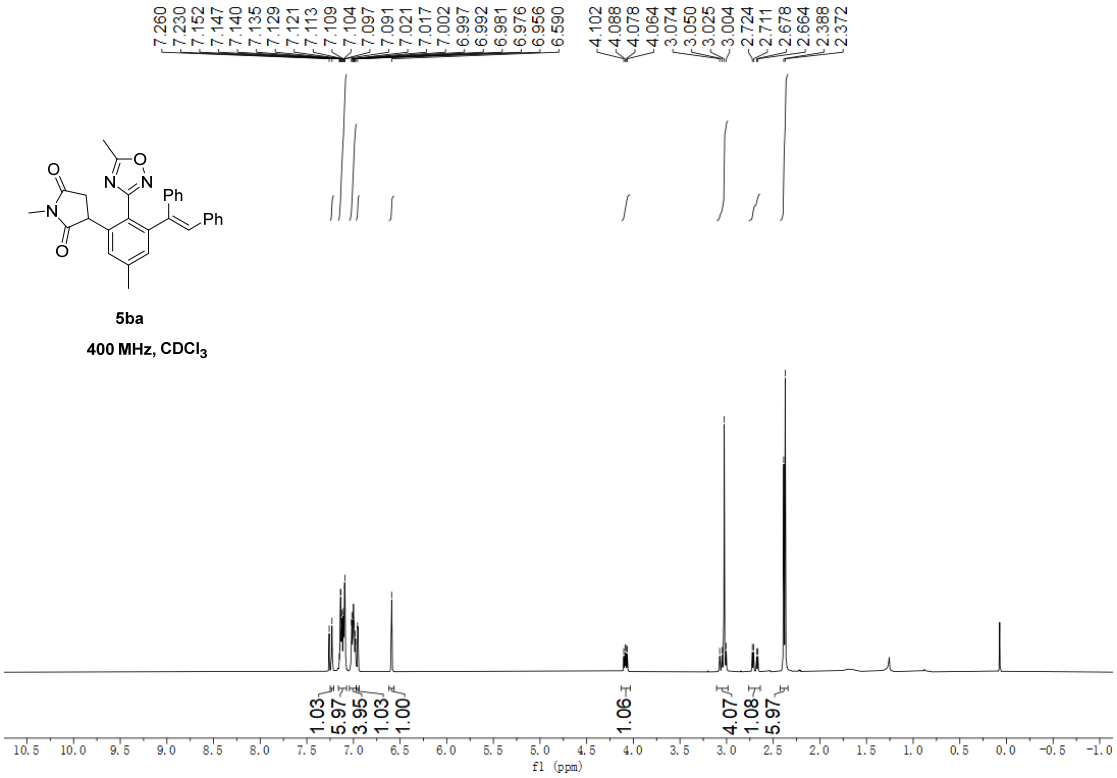
4ba

400 MHz, $CDCl_3$



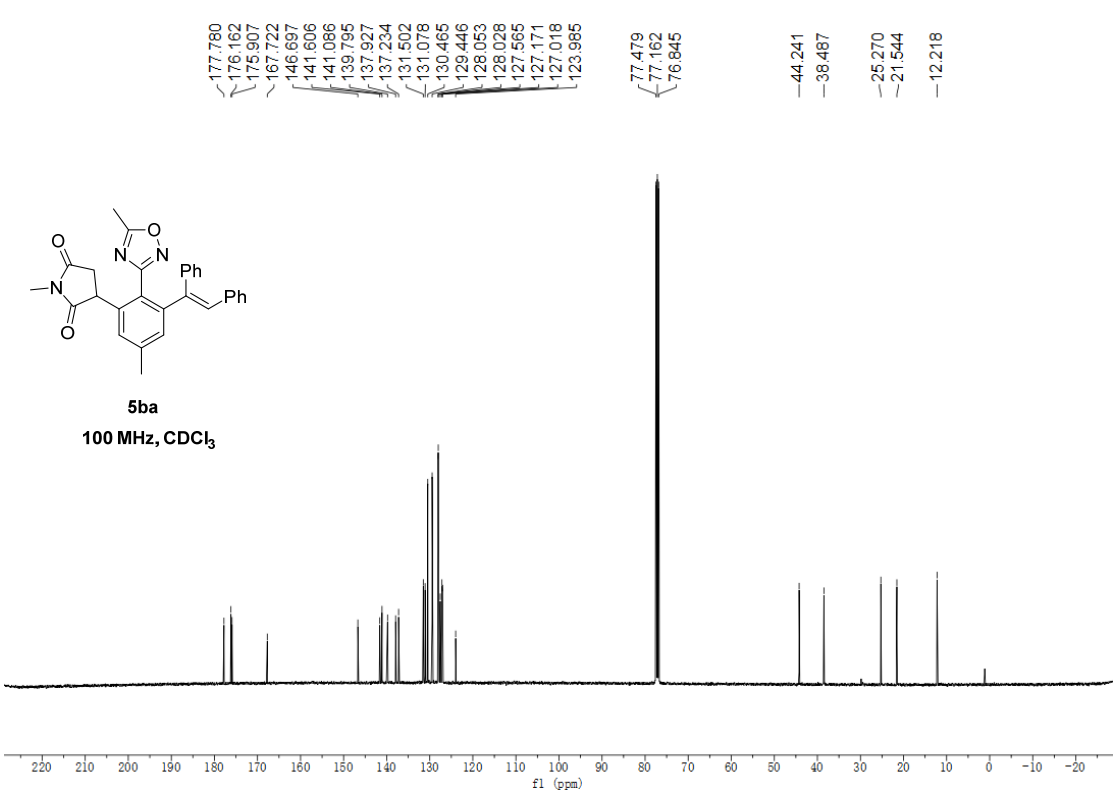
4ba

100 MHz, $CDCl_3$



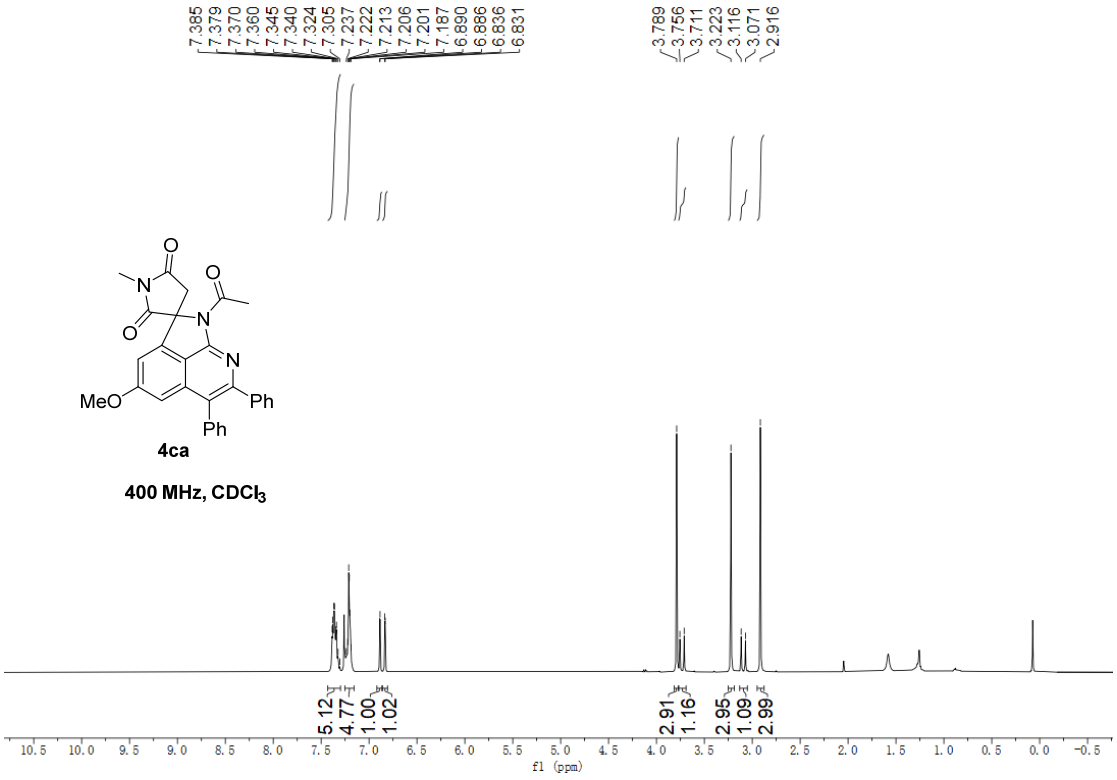
5ba

400 MHz, $CDCl_3$



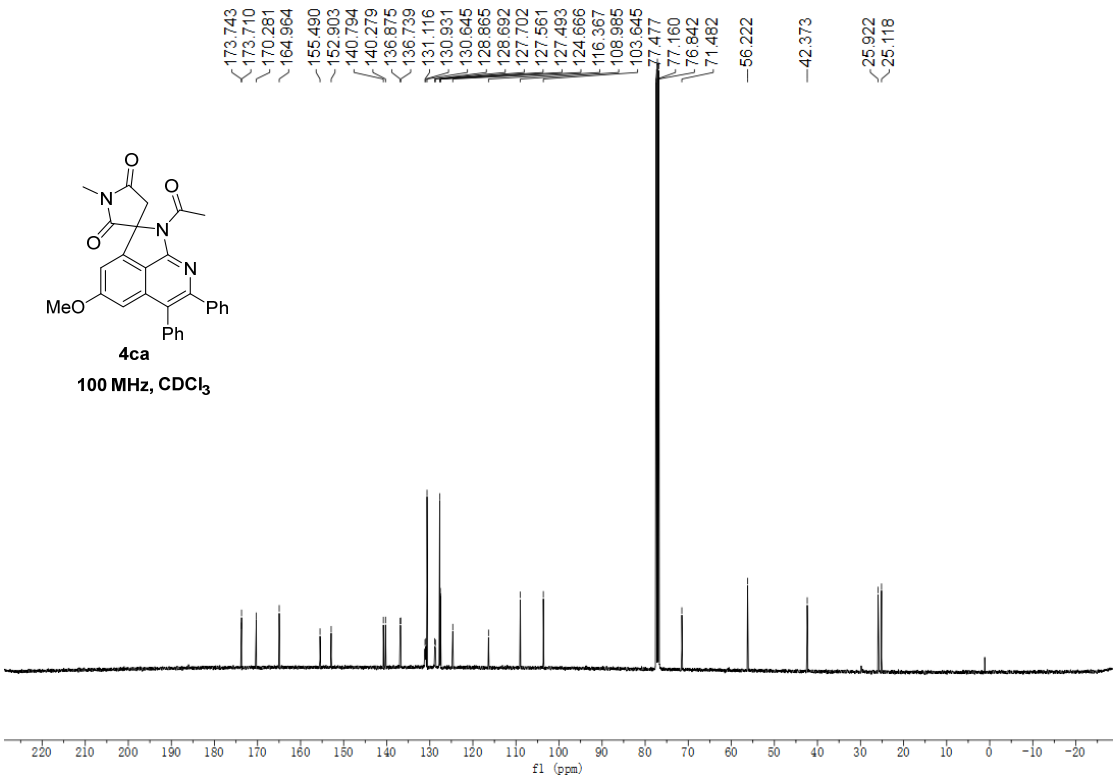
5ba

100 MHz, $CDCl_3$



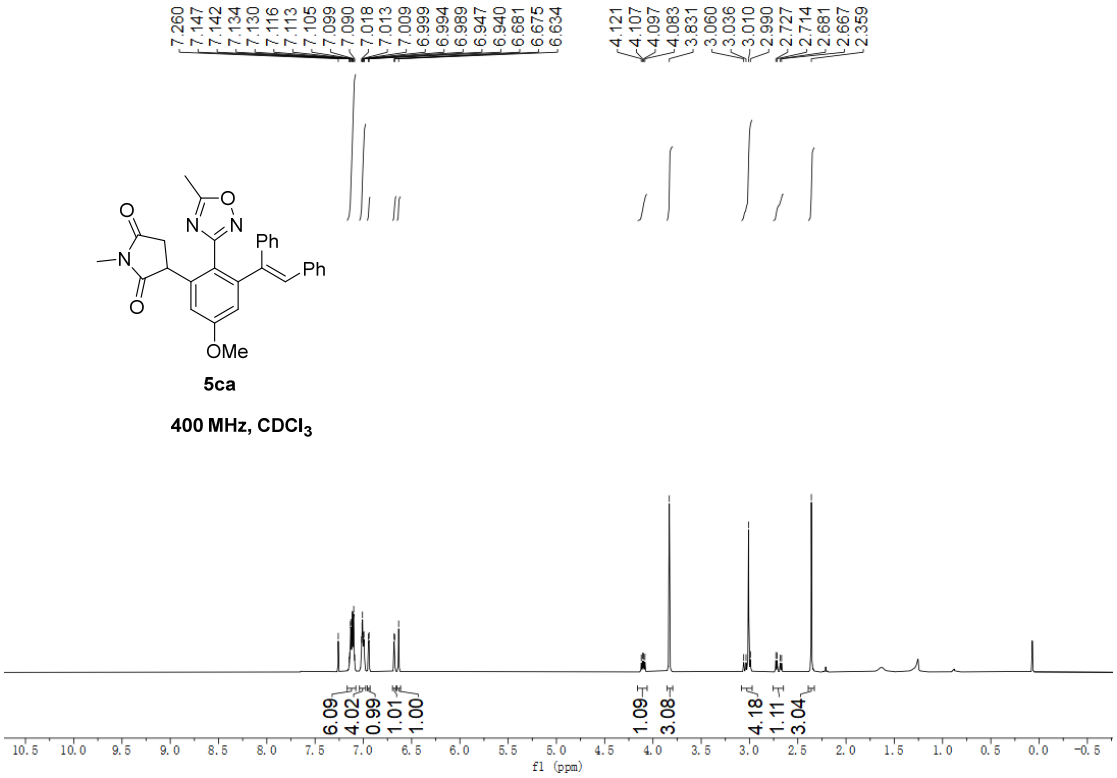
4ca

400 MHz, $CDCl_3$



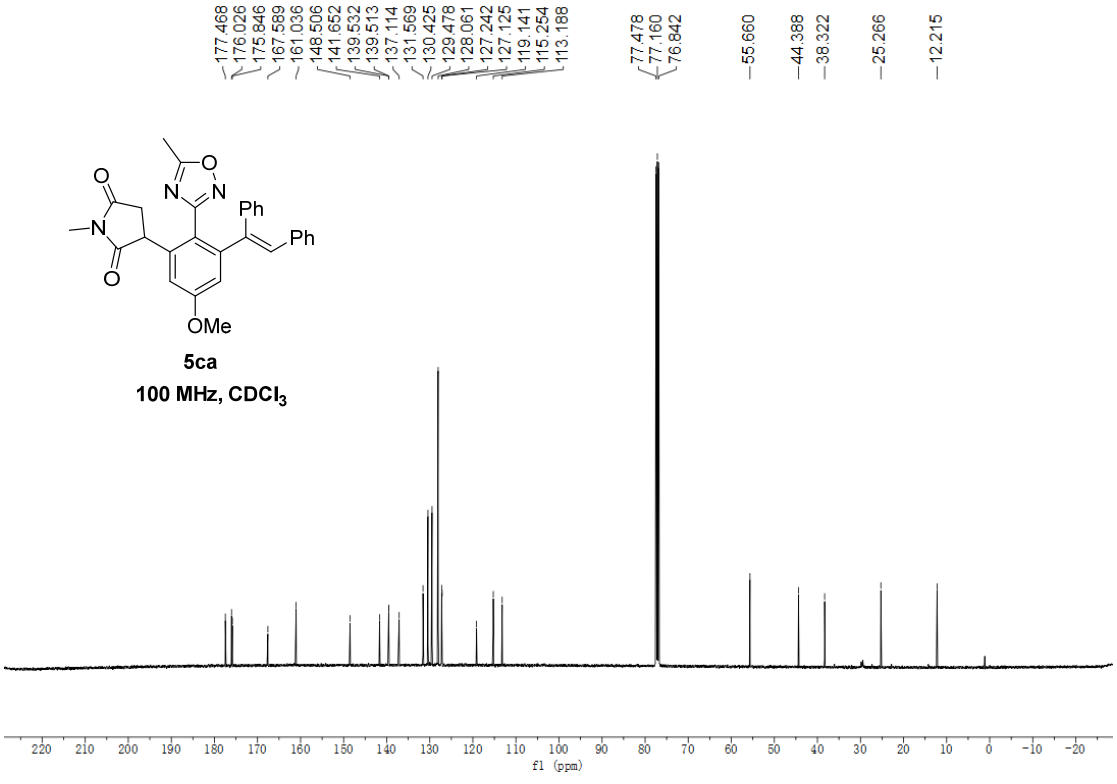
4ca

100 MHz, $CDCl_3$



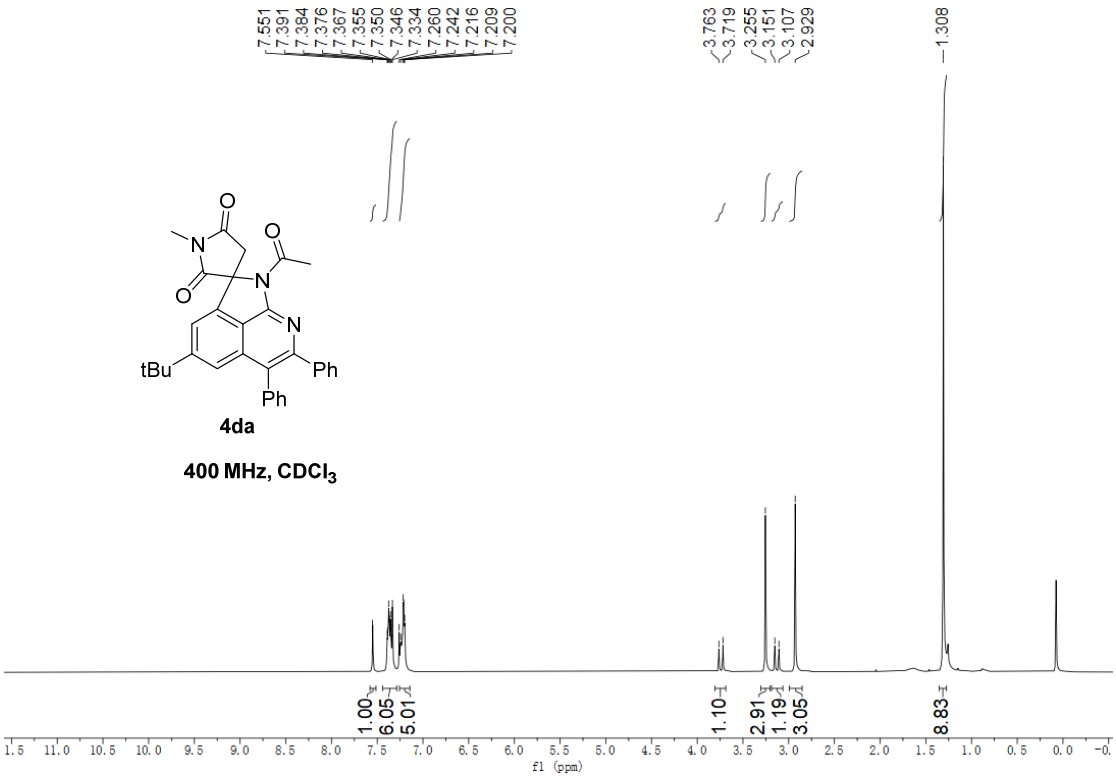
5ca

400 MHz, $CDCl_3$



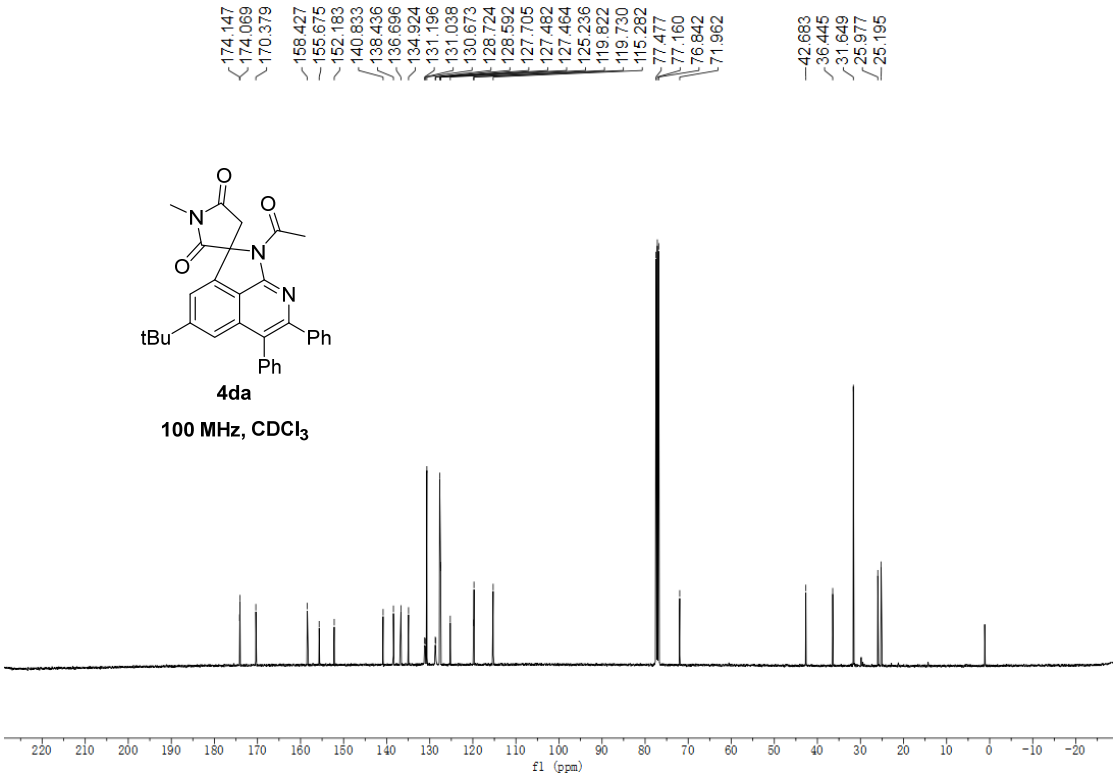
5ca

100 MHz, $CDCl_3$



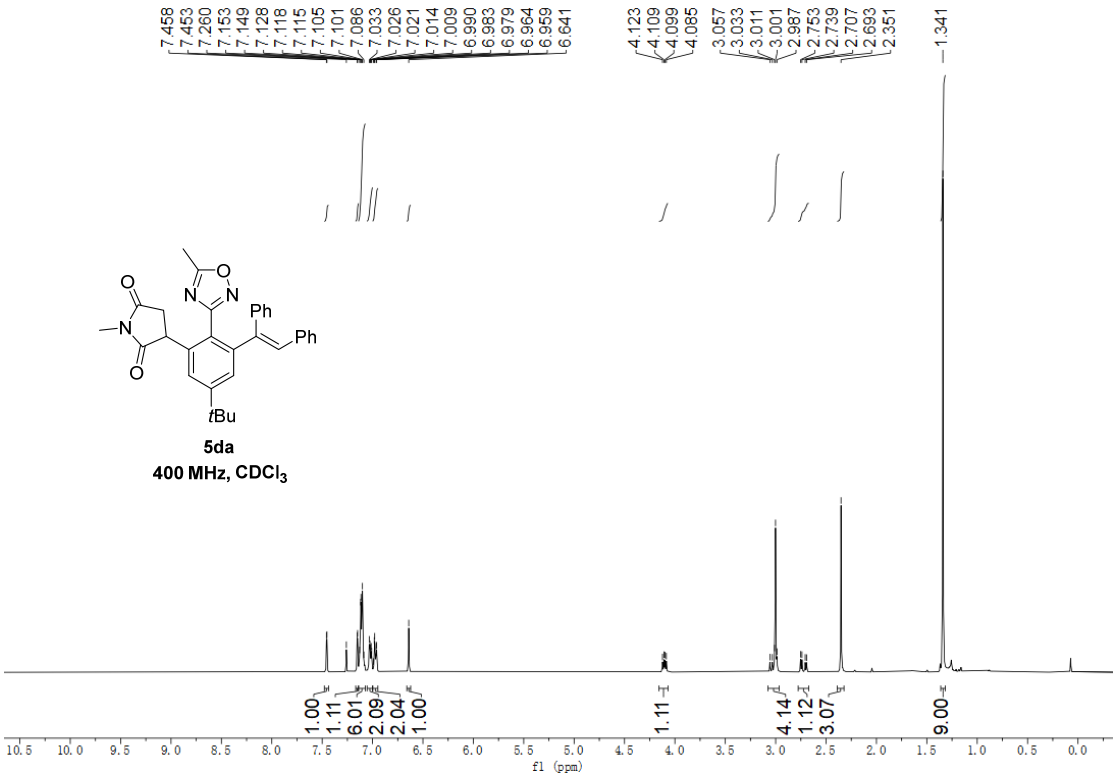
4da

400 MHz, $CDCl_3$



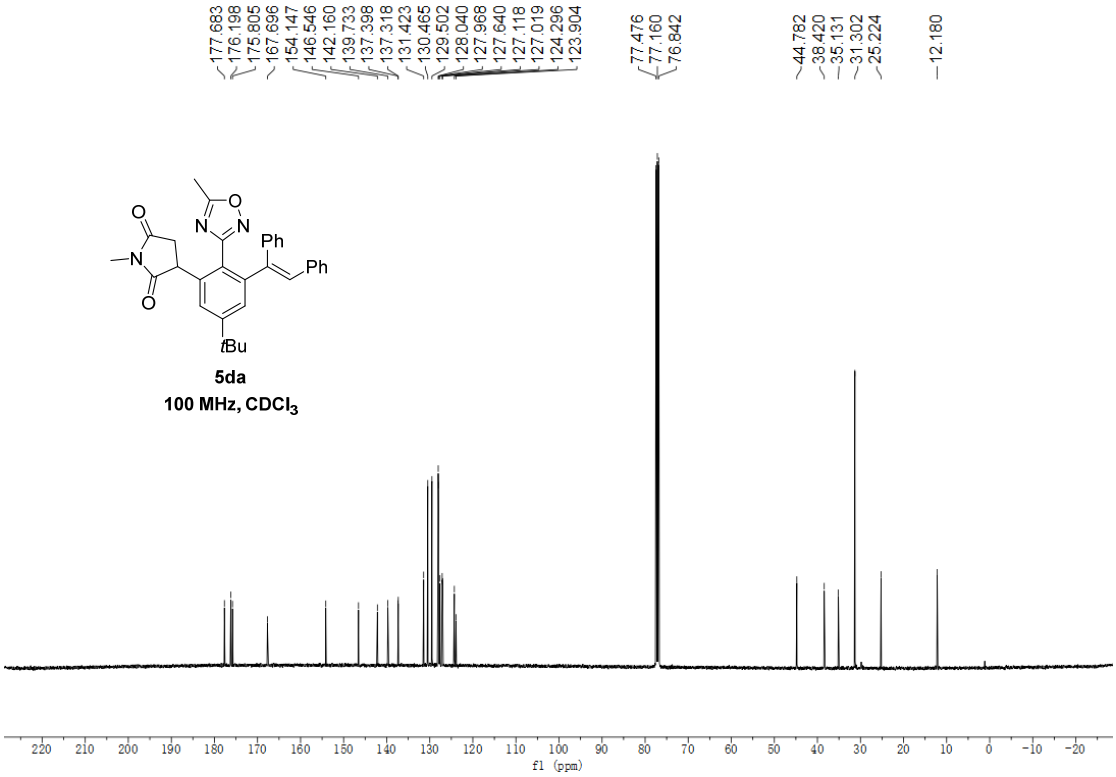
4da

100 MHz, $CDCl_3$



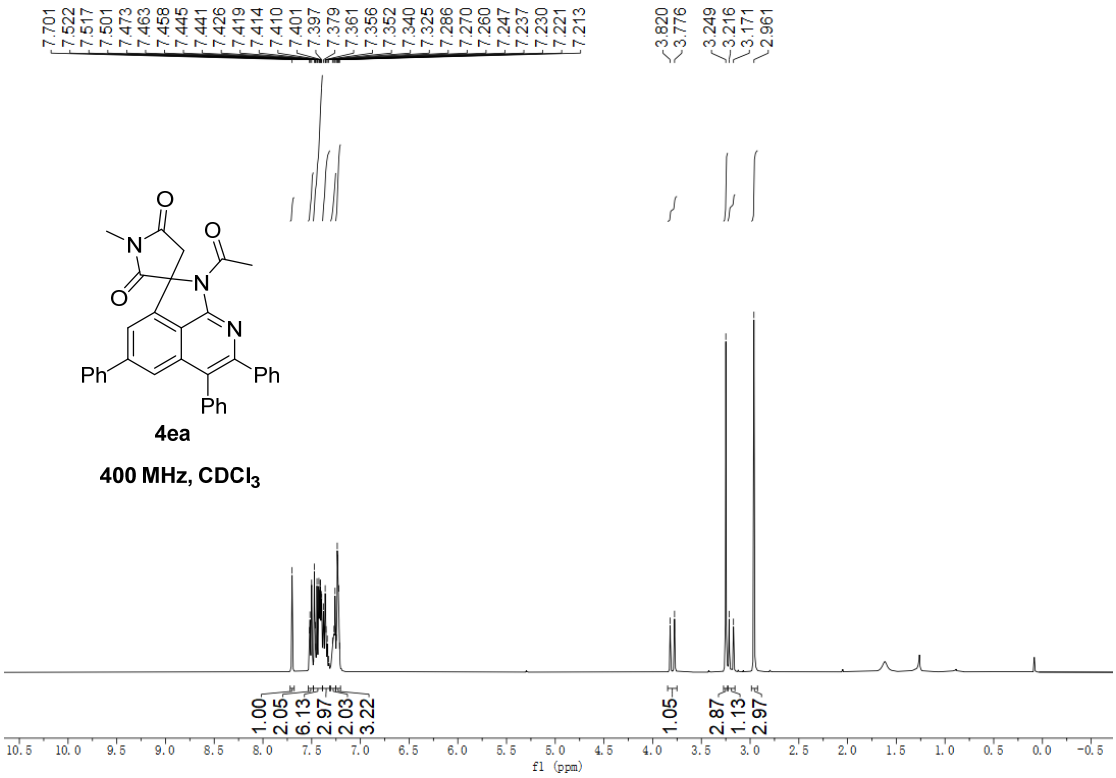
5da

400 MHz, $CDCl_3$



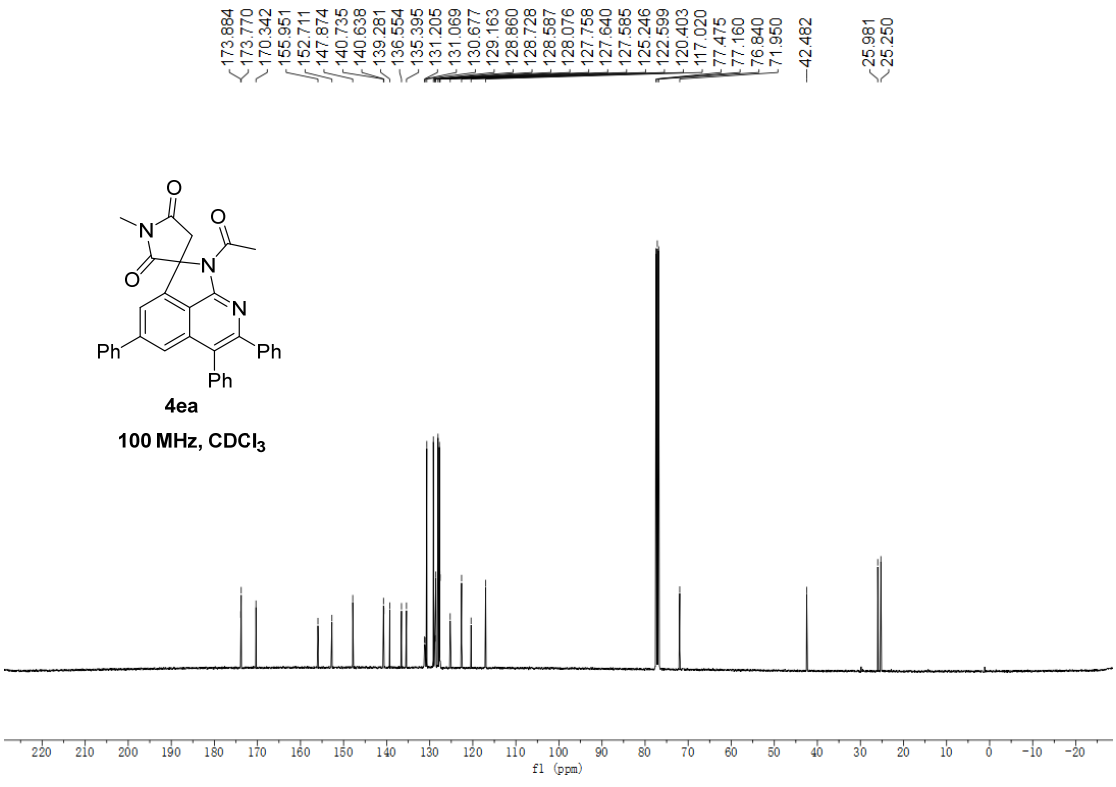
5da

100 MHz, $CDCl_3$



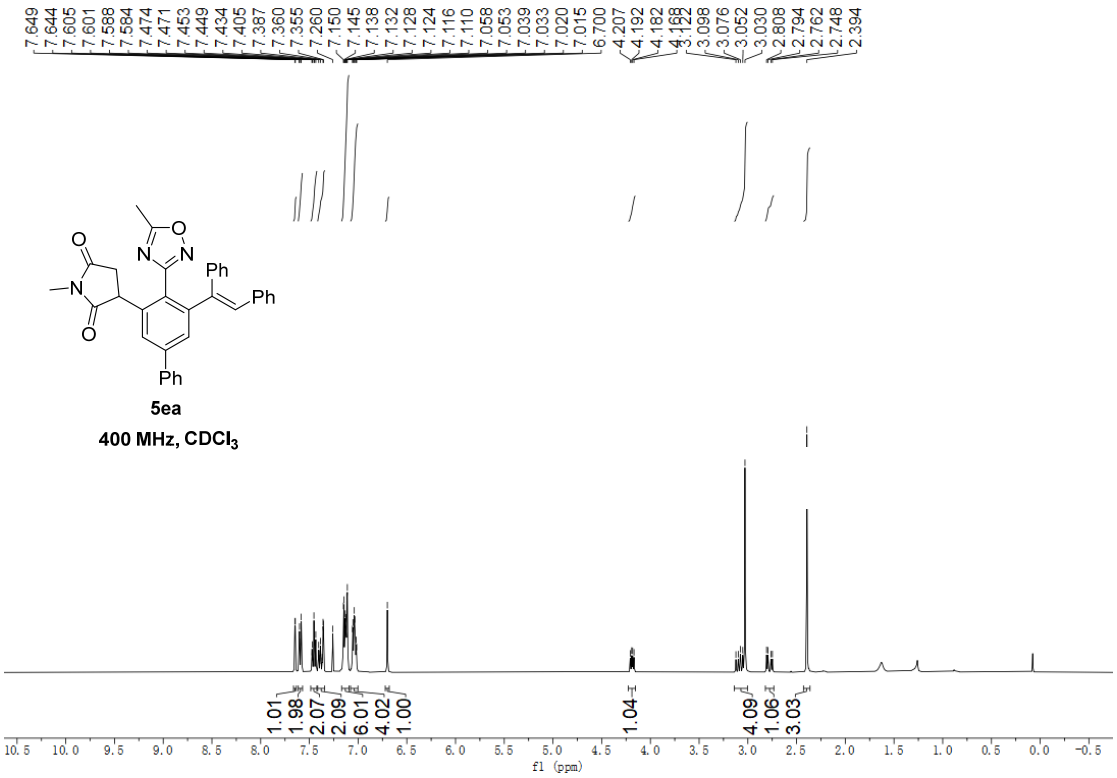
4ea

400 MHz, $CDCl_3$



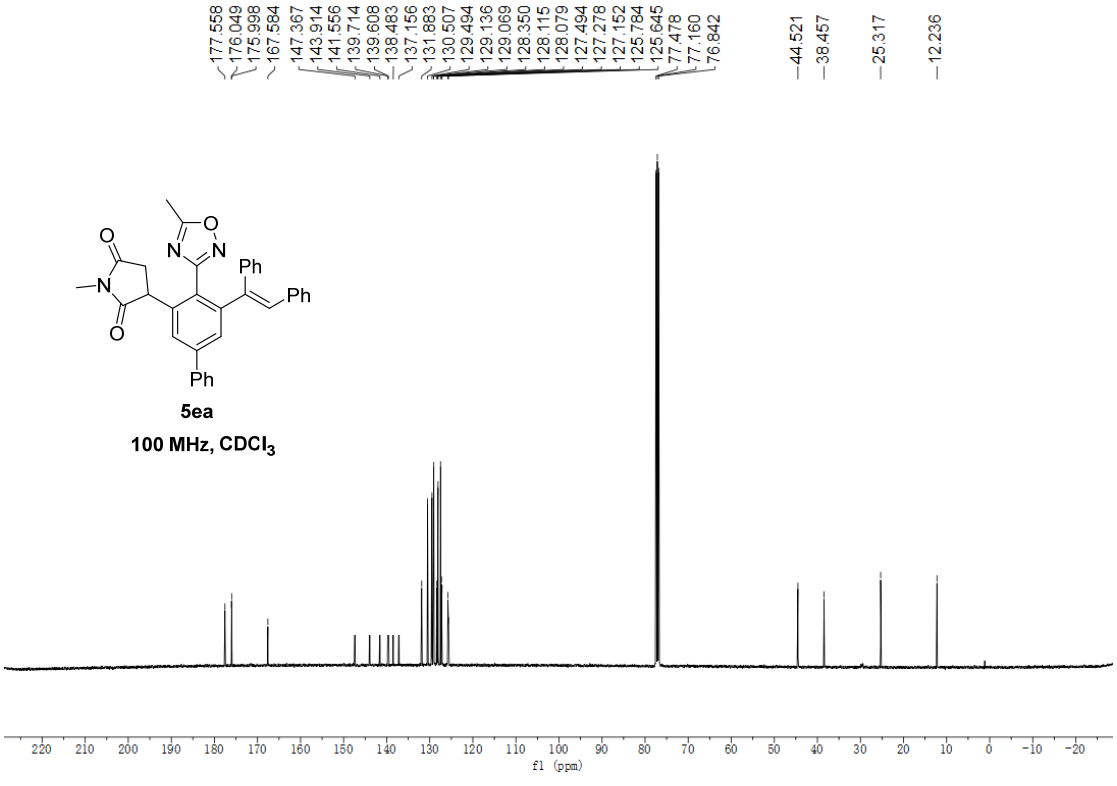
4ea

100 MHz, $CDCl_3$



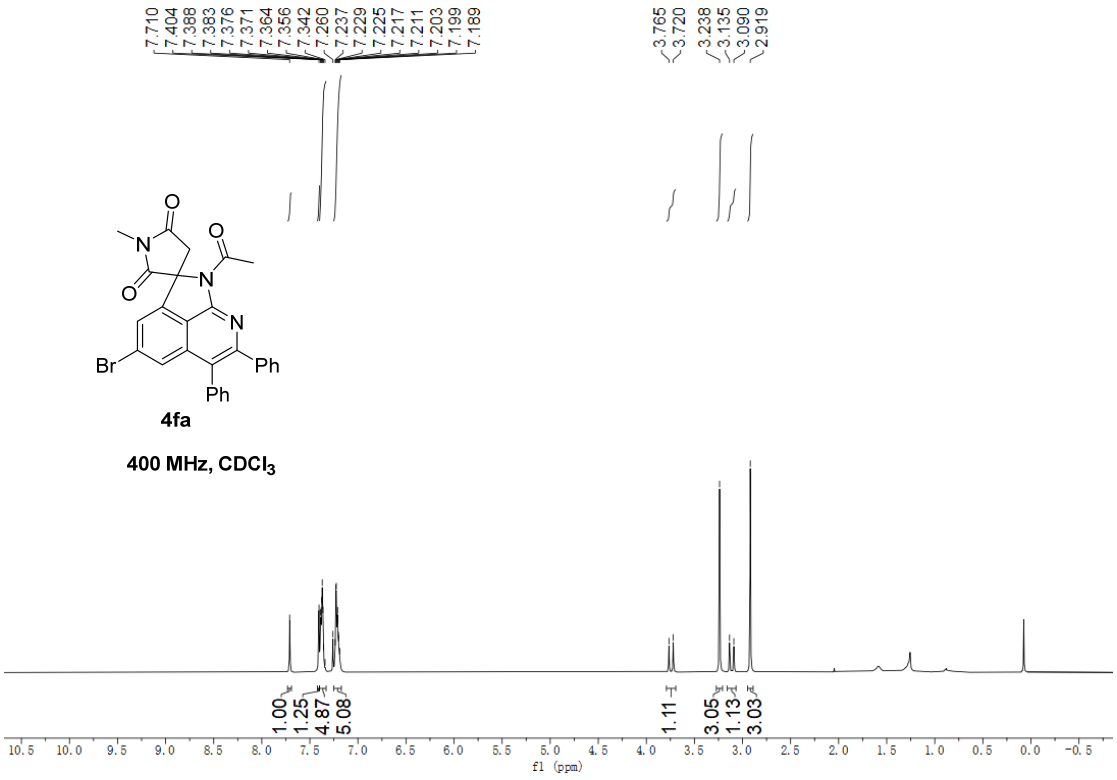
5ea

400 MHz, $CDCl_3$



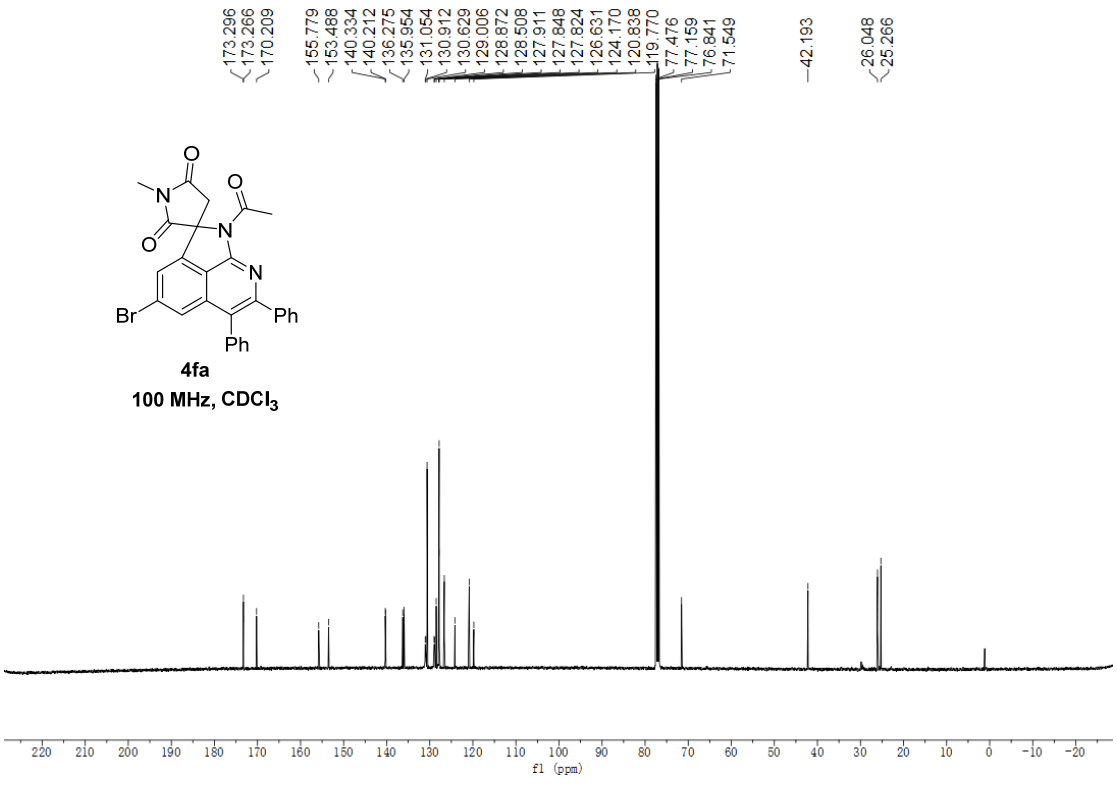
5ea

100 MHz, $CDCl_3$



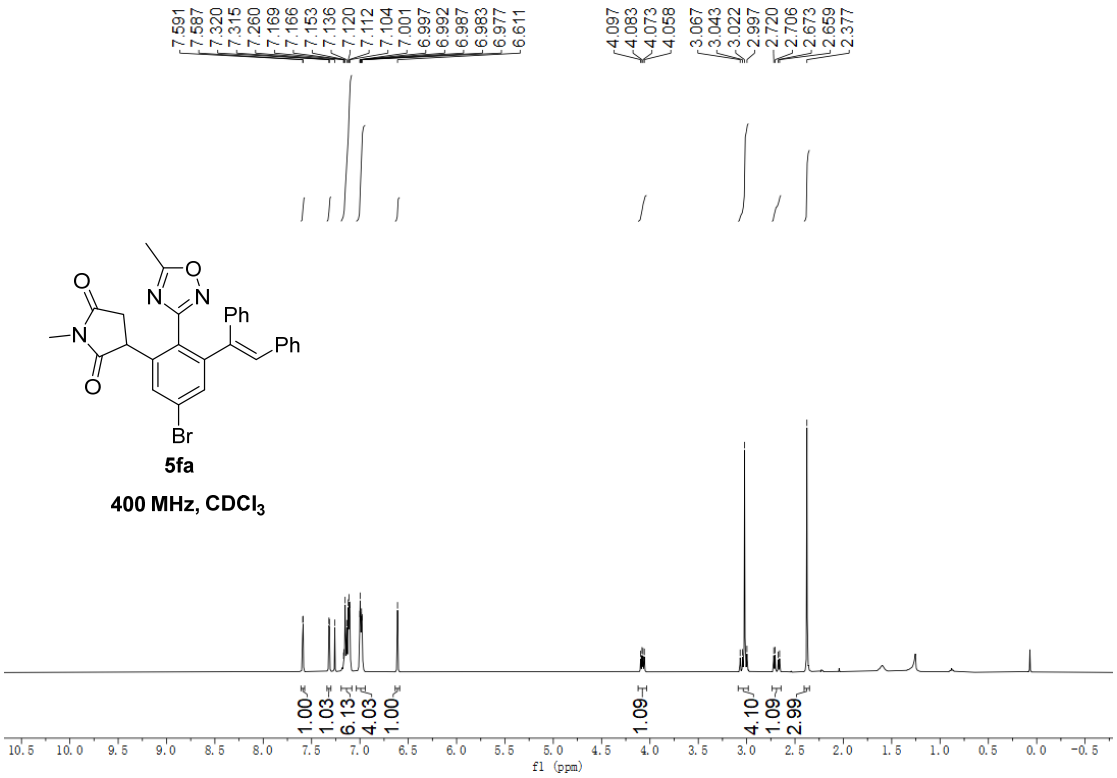
4fa

400 MHz, $CDCl_3$



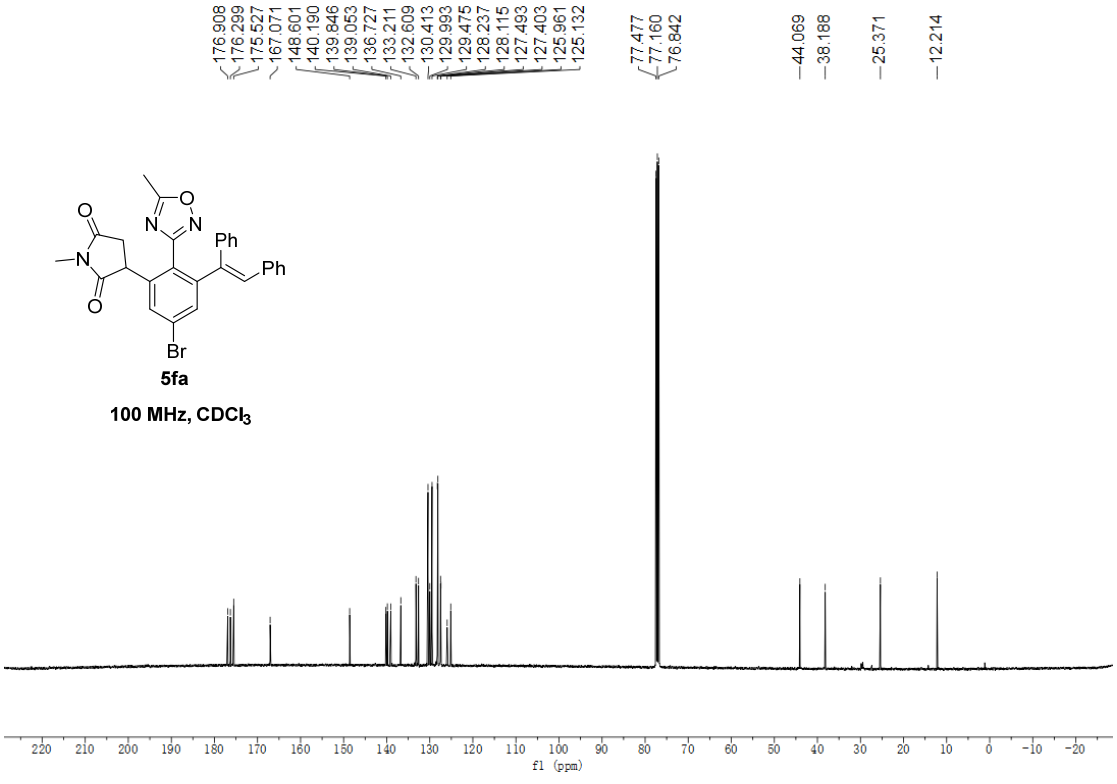
4fa

100 MHz, $CDCl_3$



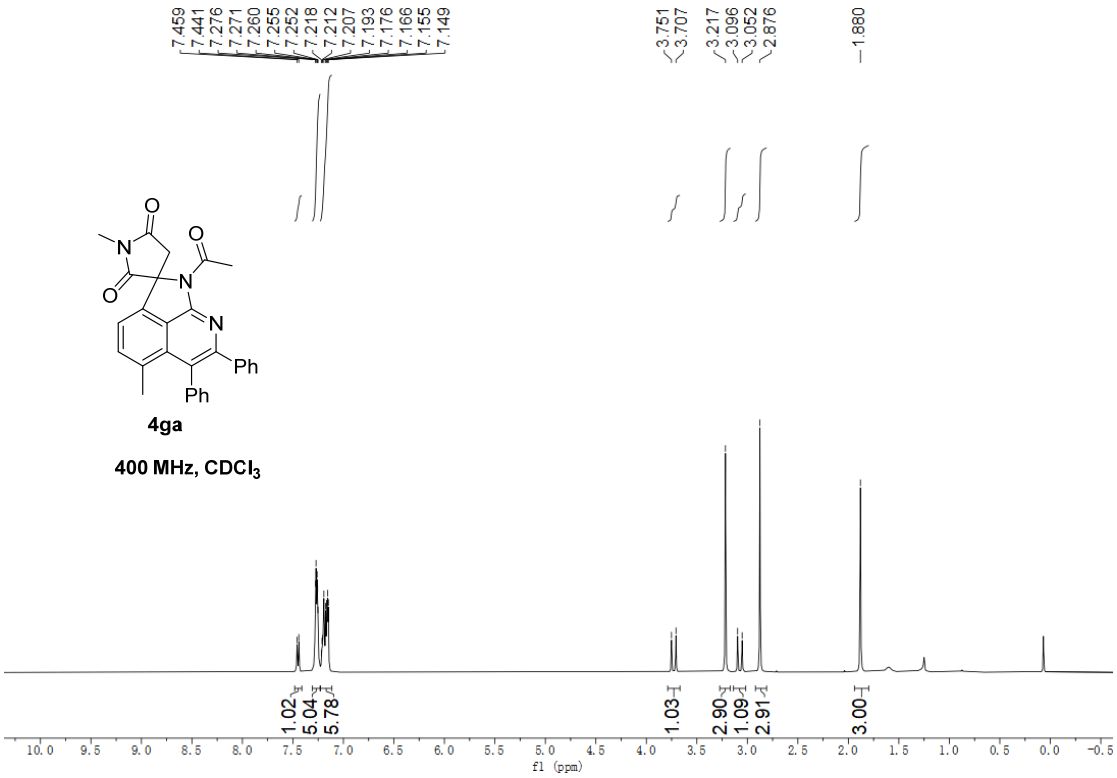
5fa

400 MHz, $CDCl_3$



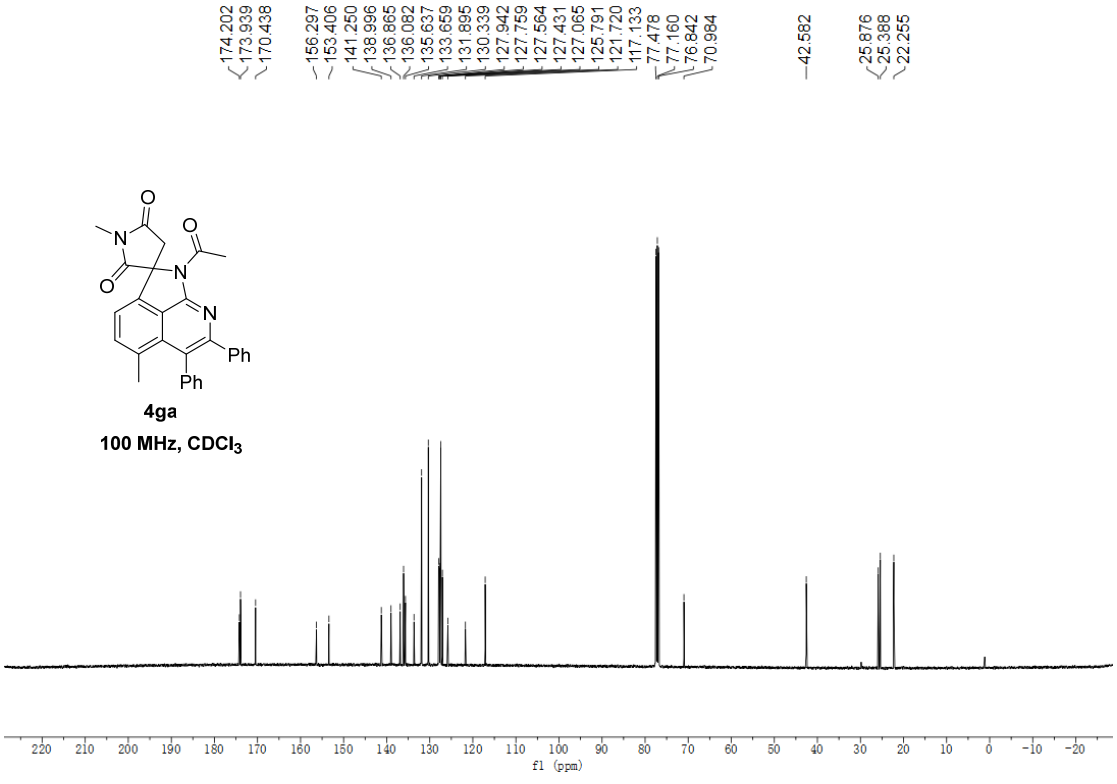
5fa

100 MHz, $CDCl_3$



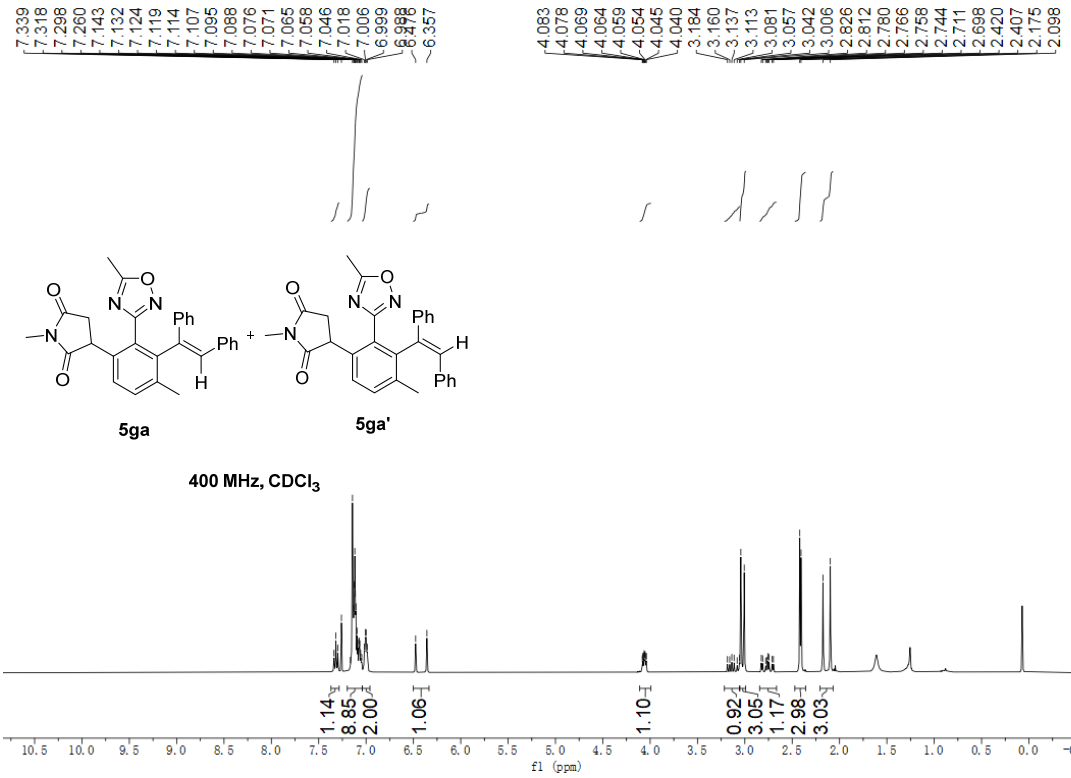
4ga

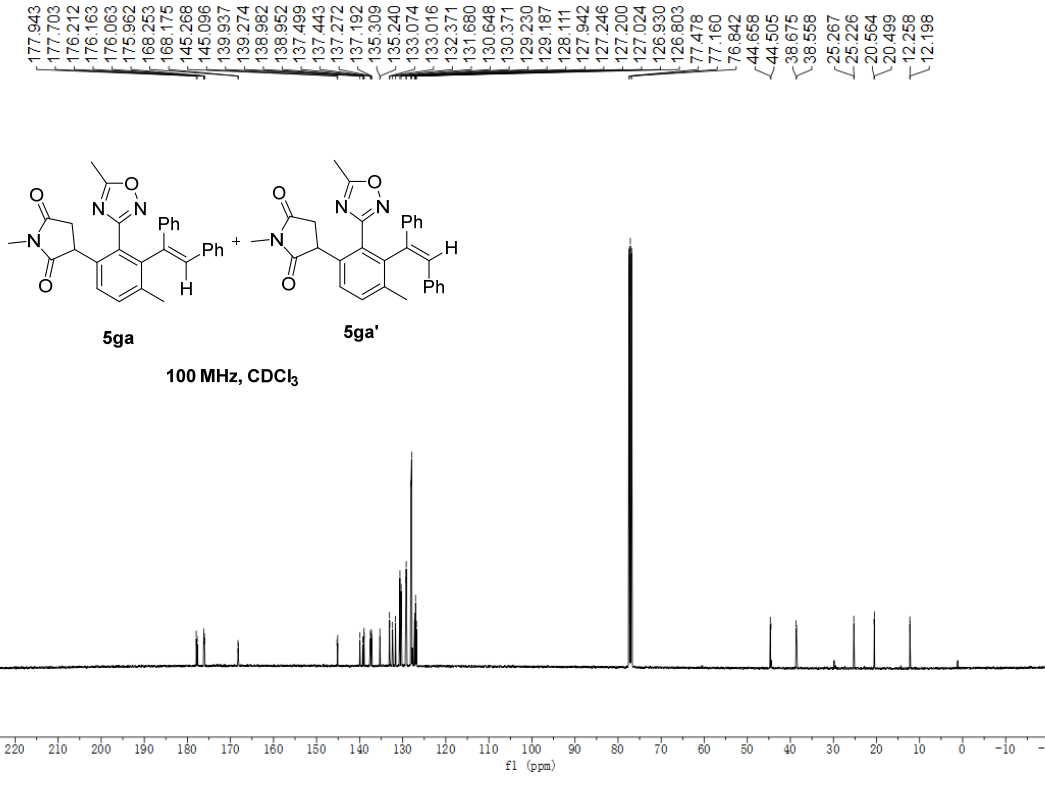
400 MHz, $CDCl_3$

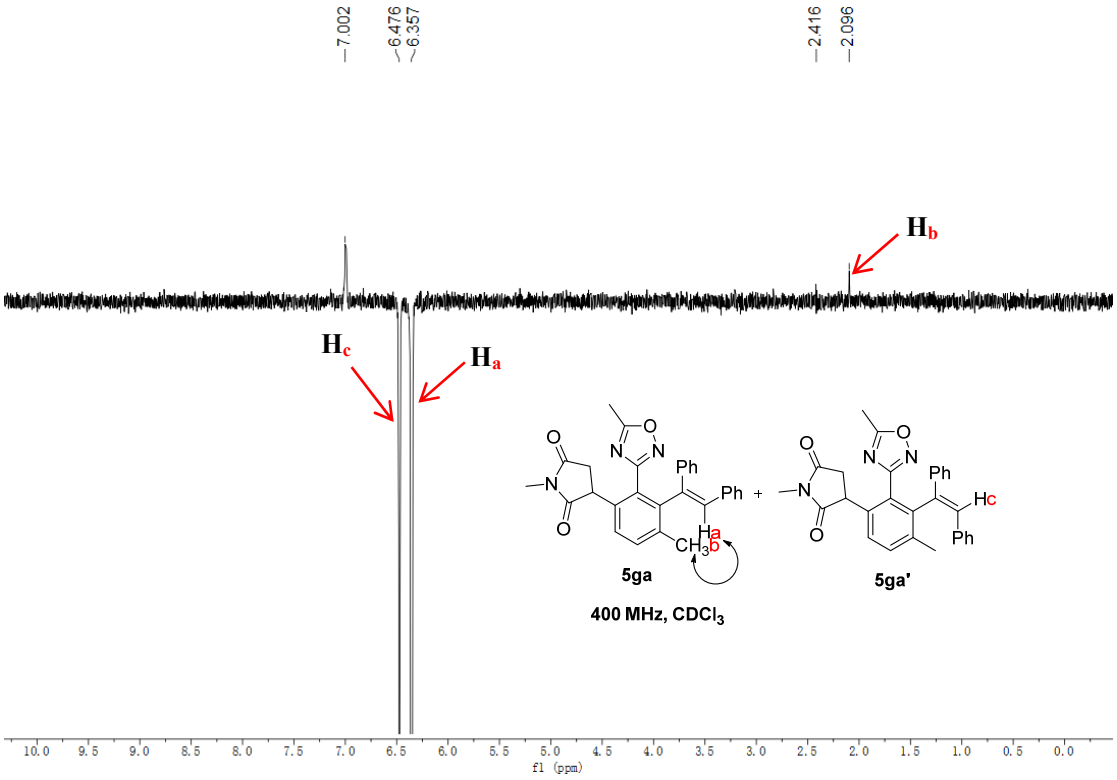


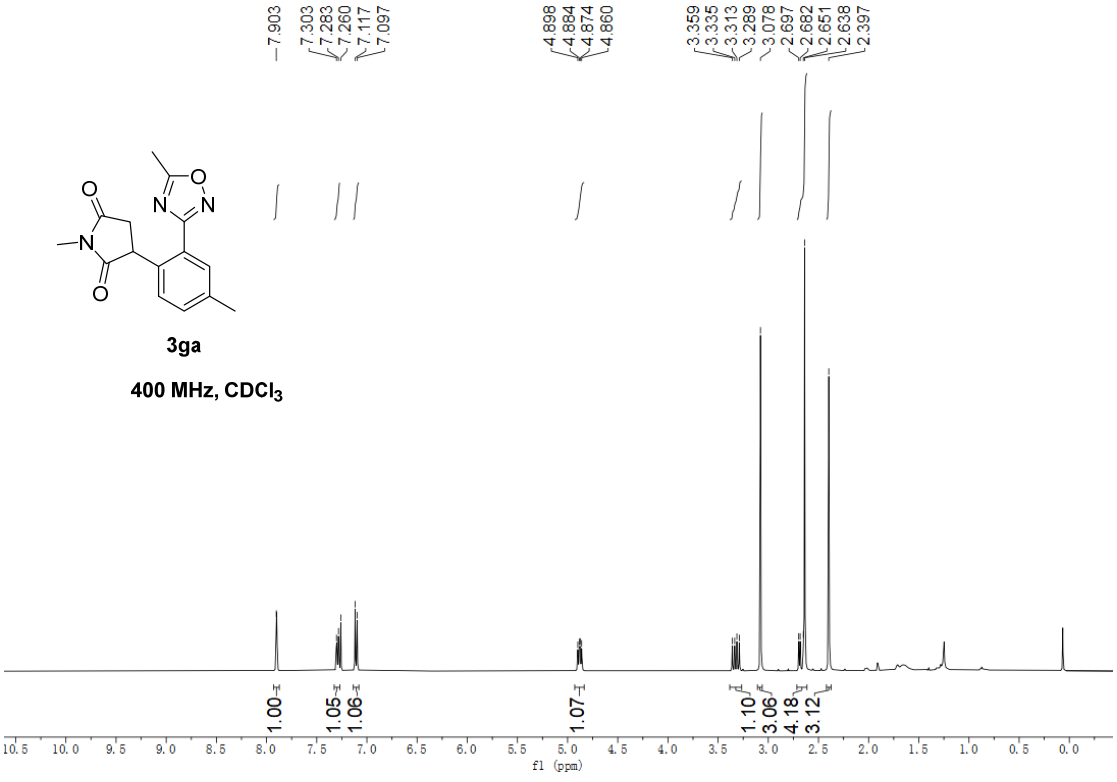
4ga

100 MHz, $CDCl_3$


7.339
7.318
7.298
7.260
7.143
7.132
7.124
7.119
7.114
7.107
7.095
7.088
7.076
7.071
7.065
7.058
7.046
7.018
7.006
6.999
6.988
6.475
6.357
4.083
4.078
4.069
4.064
4.059
4.054
4.045
4.040
3.184
3.160
3.137
3.113
3.081
3.057
3.042
3.006
2.826
2.812
2.780
2.766
2.758
2.744
2.711
2.698
2.420
2.407
2.175
2.098
Ph
Ph
H
Ph
Ph
H
5ga
5ga'
400 MHz, CDCl3
1.14
8.85
2.00
1.06
1.10
0.92
3.05
1.17
2.98
3.03
f1 (ppm)

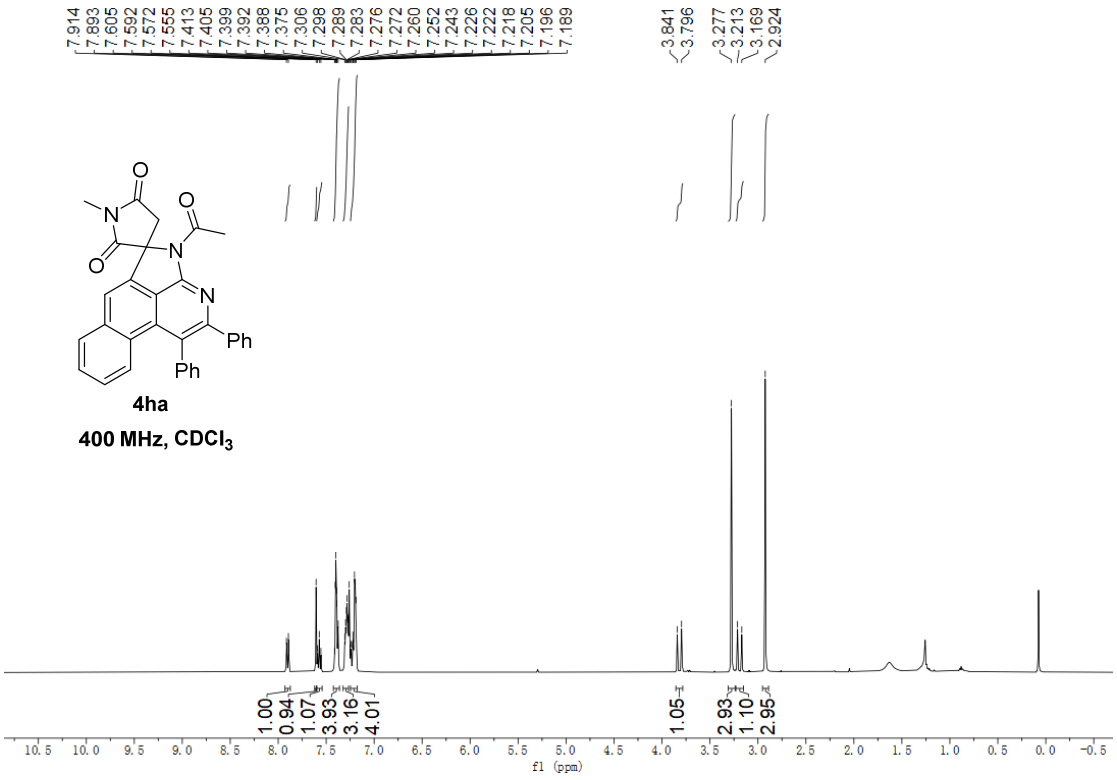

177.943
177.703
176.212
176.163
176.063
175.962
168.253
168.175
145.268
145.096
139.937
139.274
138.982
138.952
137.499
137.443
137.272
137.192
135.309
135.240
133.074
133.016
132.371
131.680
130.648
130.371
129.230
129.187
128.111
127.942
127.246
127.200
127.024
126.930
126.803
77.478
77.160
76.842
44.658
44.505
38.675
38.558
25.267
25.226
20.564
20.499
12.258
12.198
Ph
Ph
H
Ph
Ph
H
5ga
5ga'
100 MHz, CDCl3
f1 (ppm)





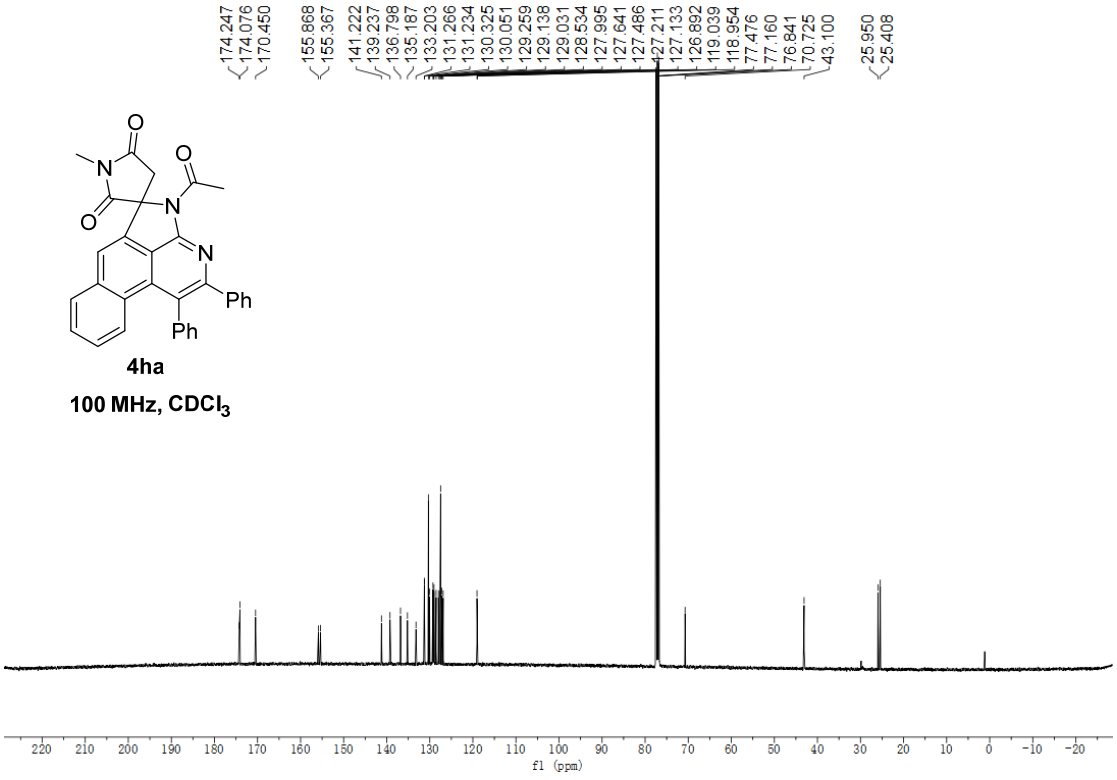
3ga

400 MHz, $CDCl_3$



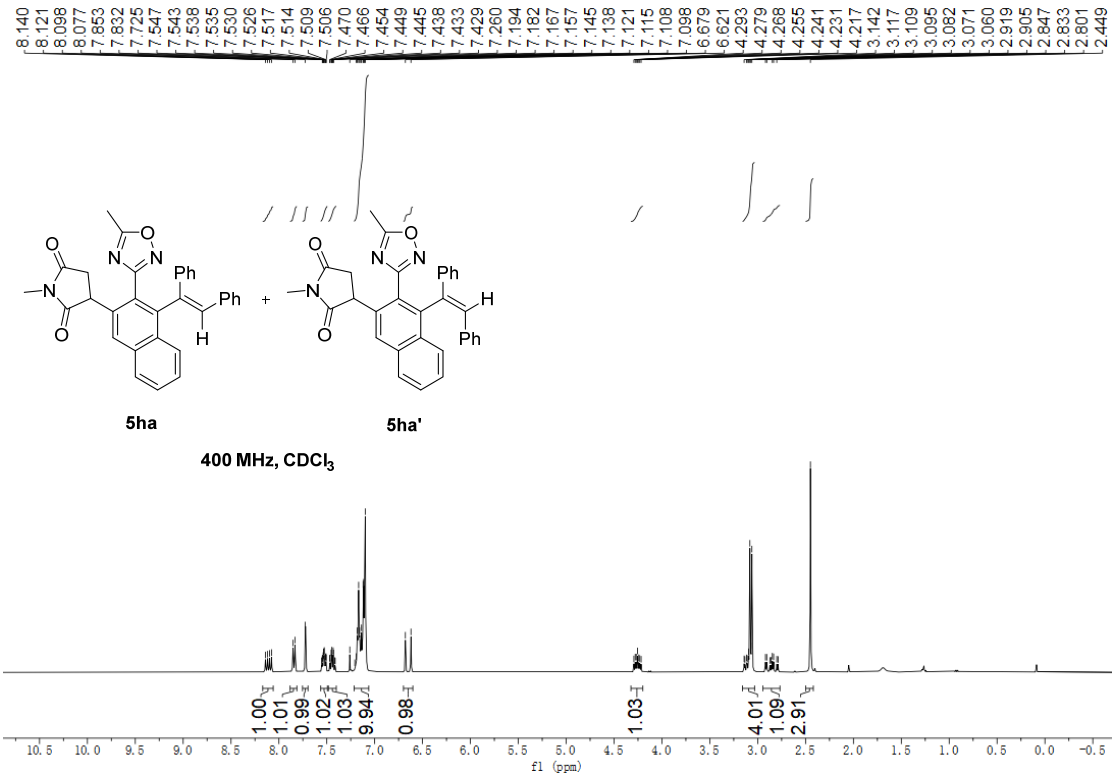
4ha

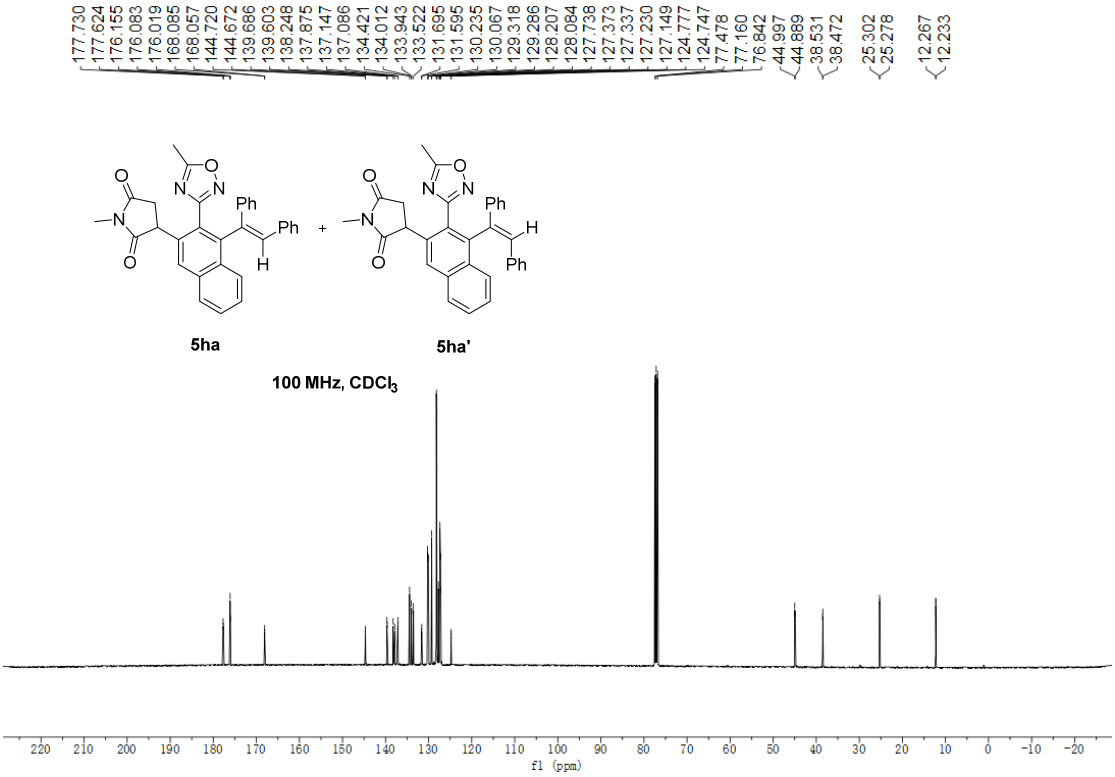
400 MHz, $CDCl_3$

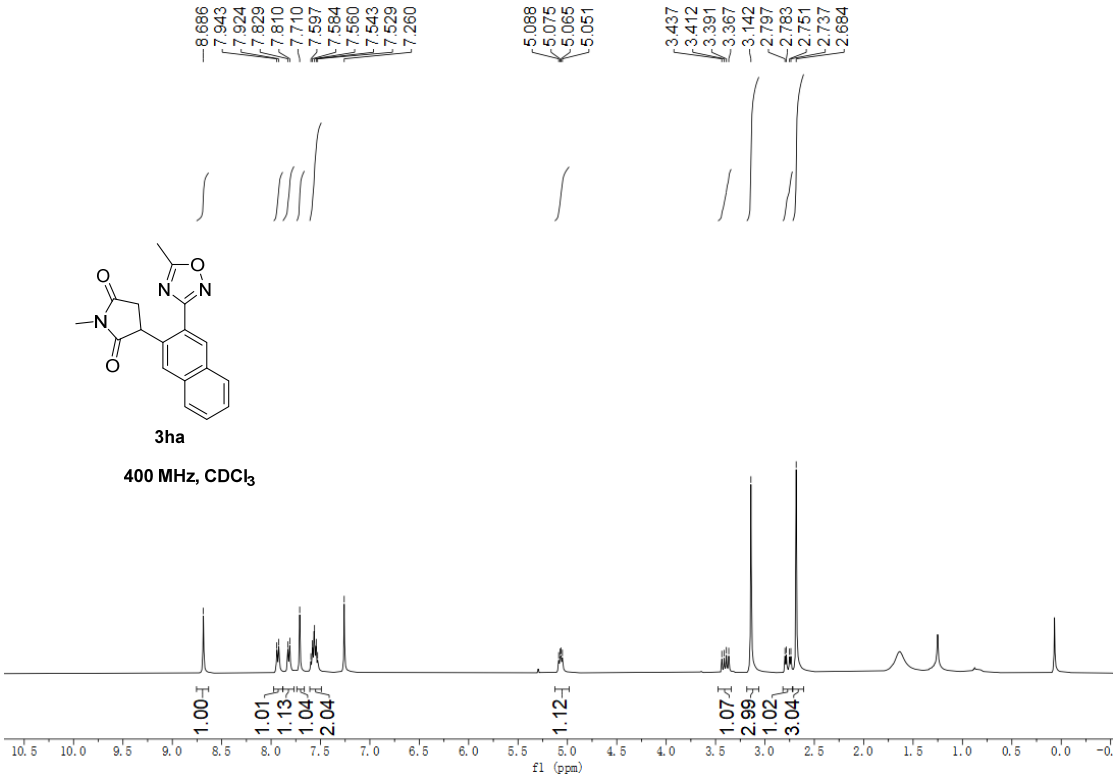


4ha

100 MHz, $CDCl_3$

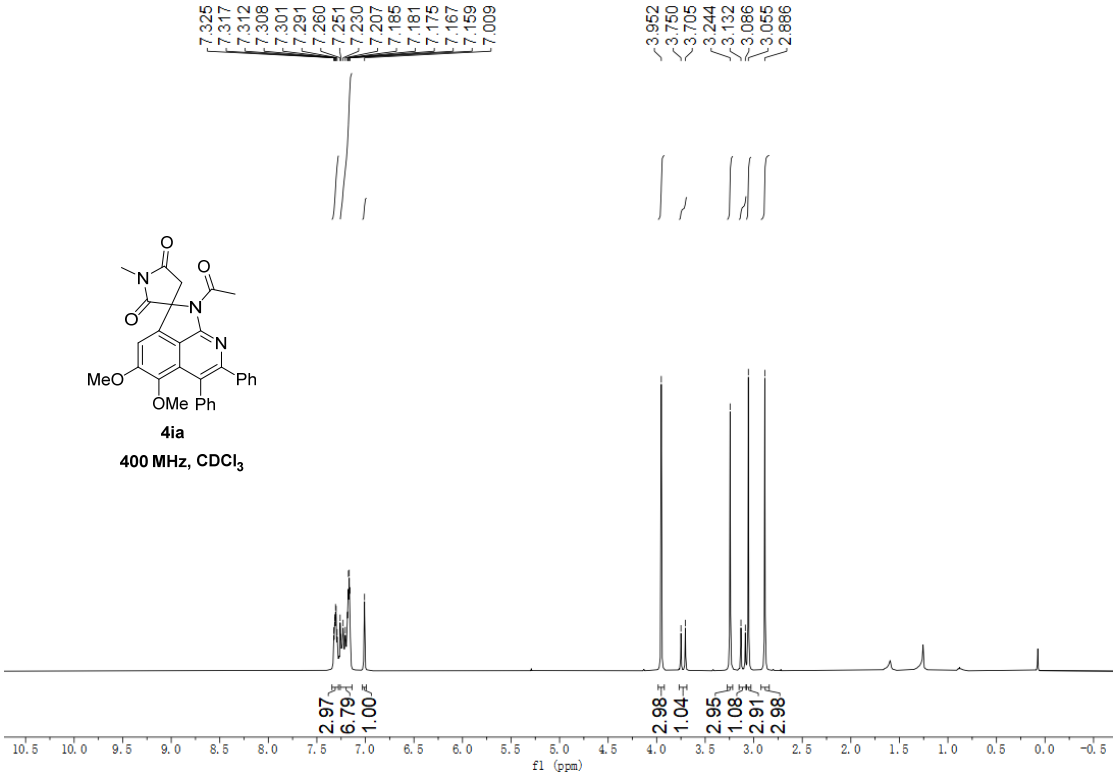

8.140
8.121
8.098
8.077
7.853
7.832
7.725
7.547
7.543
7.538
7.535
7.530
7.526
7.517
7.514
7.509
7.506
7.470
7.466
7.454
7.449
7.445
7.438
7.433
7.429
7.260
7.194
7.182
7.167
7.157
7.145
7.138
7.121
7.115
7.108
7.098
6.679
6.621
4.293
4.279
4.268
4.255
4.241
4.231
4.217
3.142
3.117
3.109
3.095
3.082
3.071
3.060
2.919
2.905
2.847
2.833
2.801
2.449
5ha
5ha'
400 MHz, CDCl3
1.00
1.01
0.99
1.02
1.03
9.94
0.98
1.03
4.01
1.09
2.91
f1 (ppm)


177.730
177.624
176.155
176.083
176.019
168.085
168.057
144.720
144.672
139.686
139.603
138.248
137.875
137.147
137.086
134.421
134.012
133.943
133.522
131.695
131.595
130.235
130.067
129.318
129.286
128.207
128.084
127.738
127.373
127.337
127.230
127.149
124.777
124.747
77.478
77.160
76.842
44.997
44.889
38.531
38.472
25.302
25.278
12.267
12.233
5ha
5ha'
100 MHz, CDCl3
f1 (ppm)



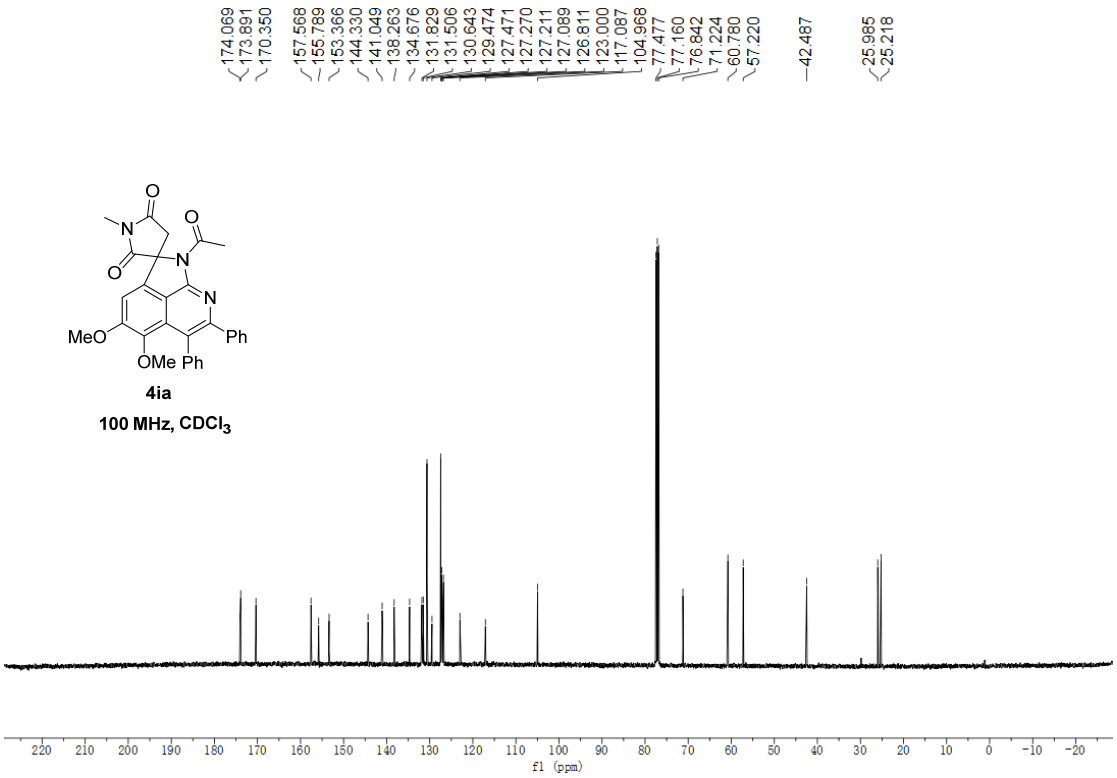
3ha

400 MHz, $CDCl_3$



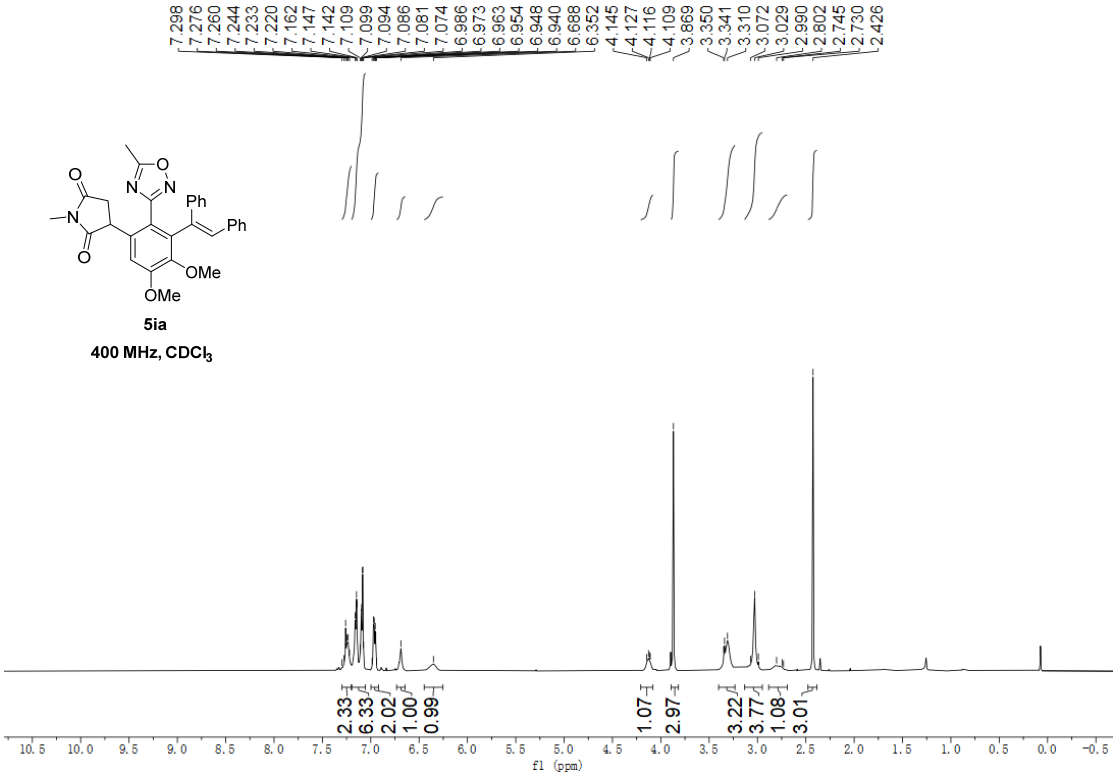
4ia

400 MHz, $CDCl_3$



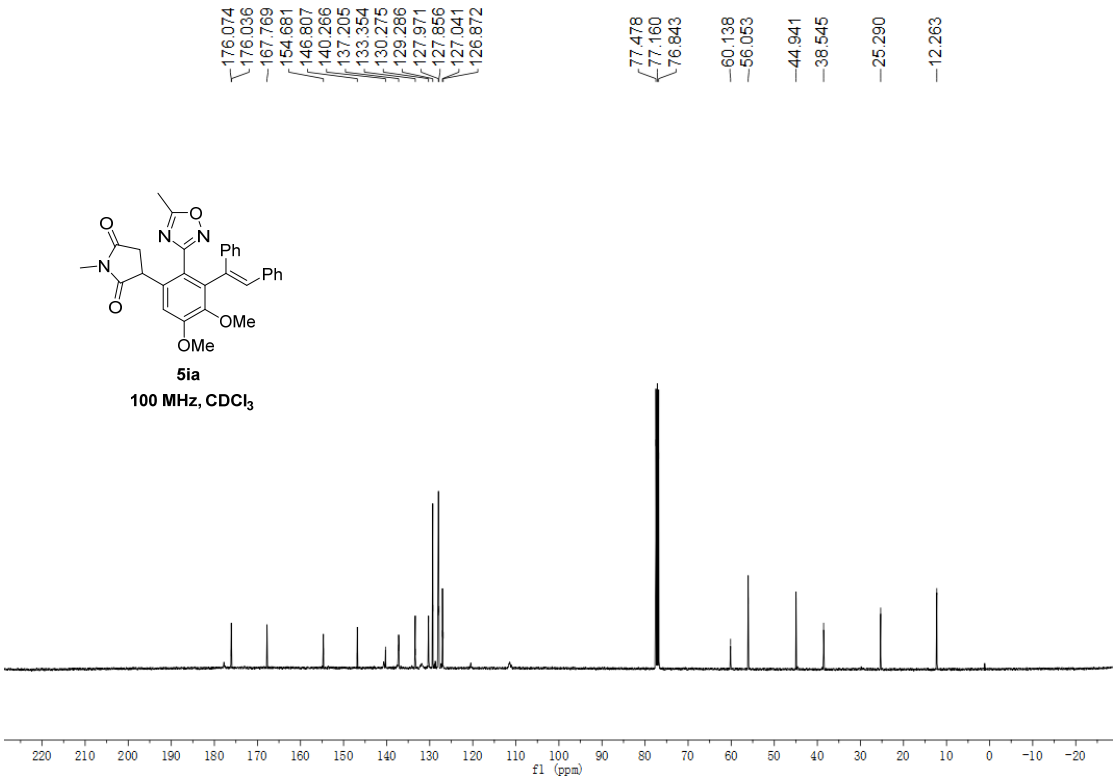
4ia

100 MHz, $CDCl_3$



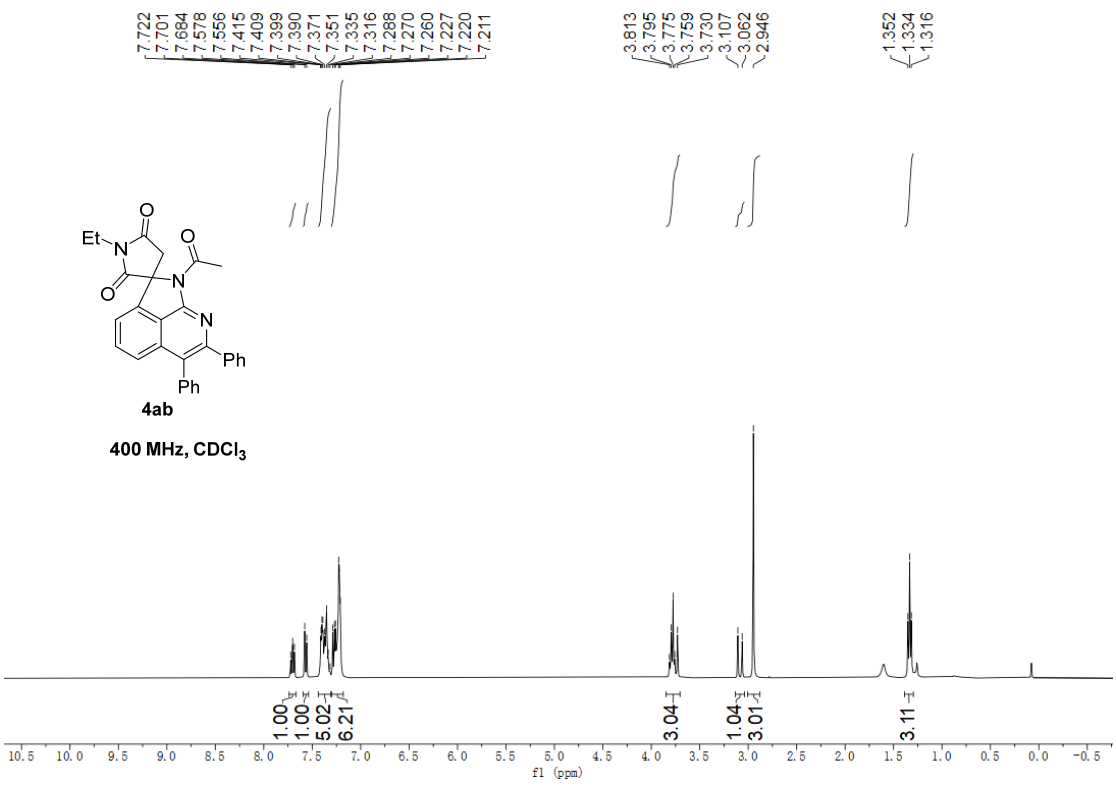
5ia

400 MHz, $CDCl_3$



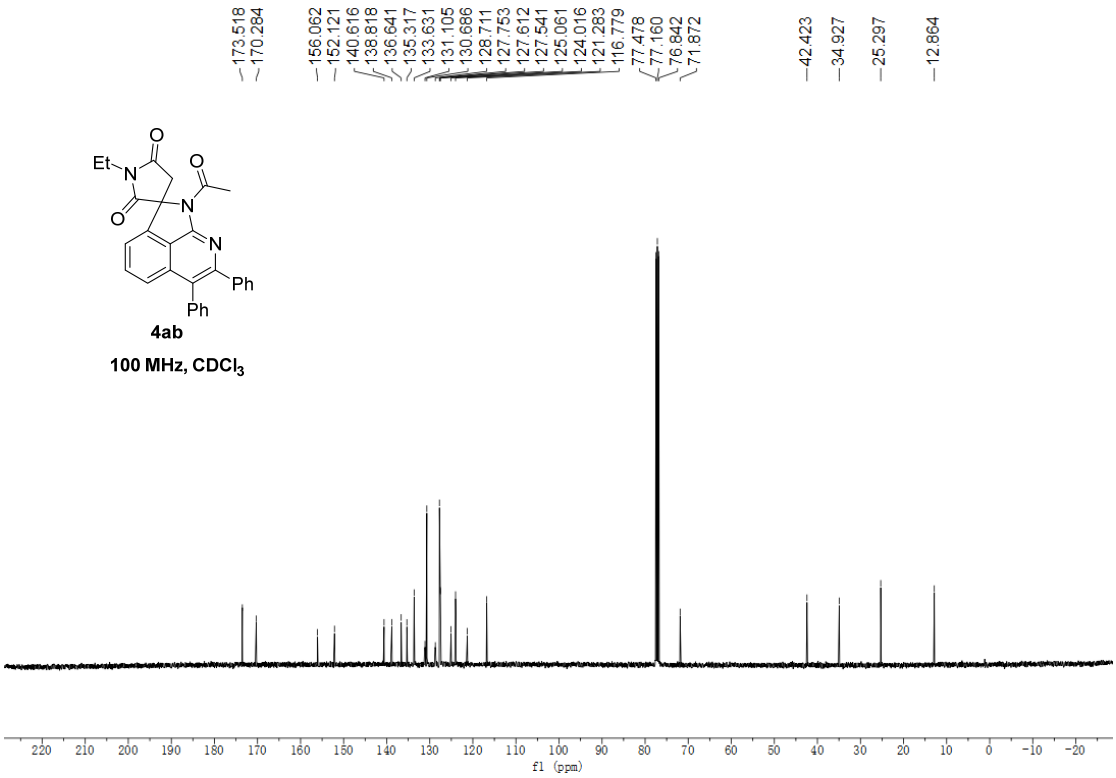
5ia

100 MHz, $CDCl_3$



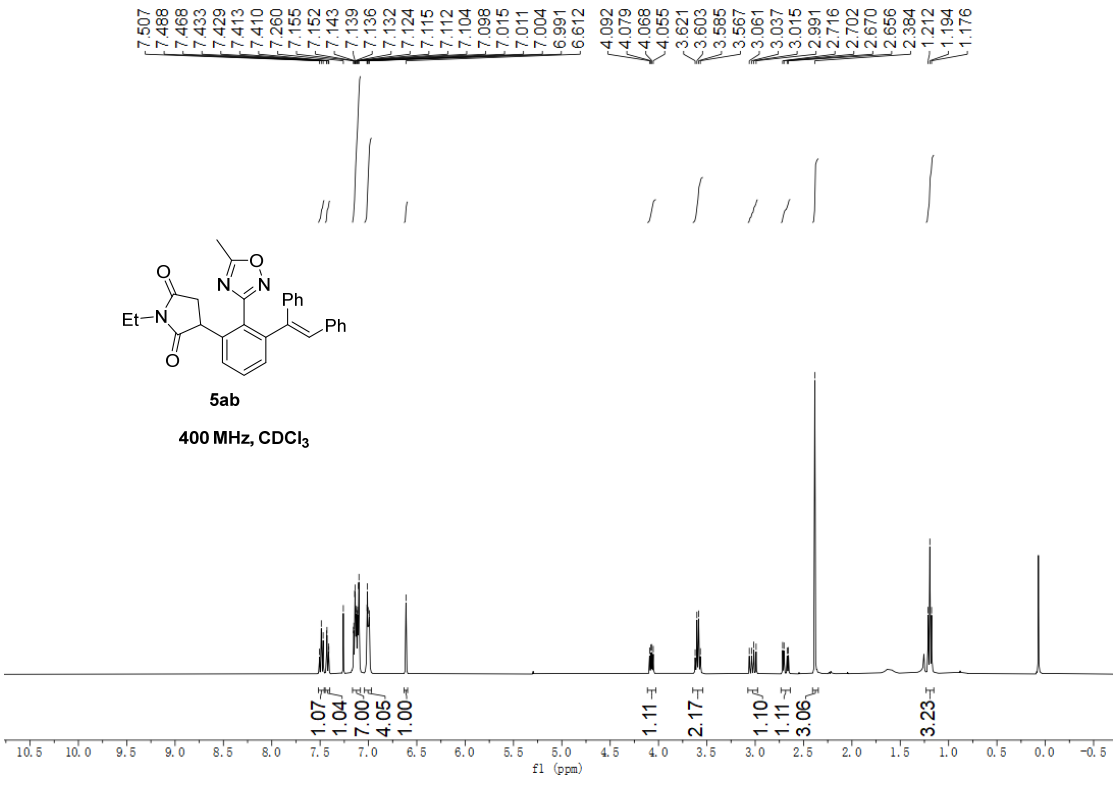
4ab

400 MHz, $CDCl_3$



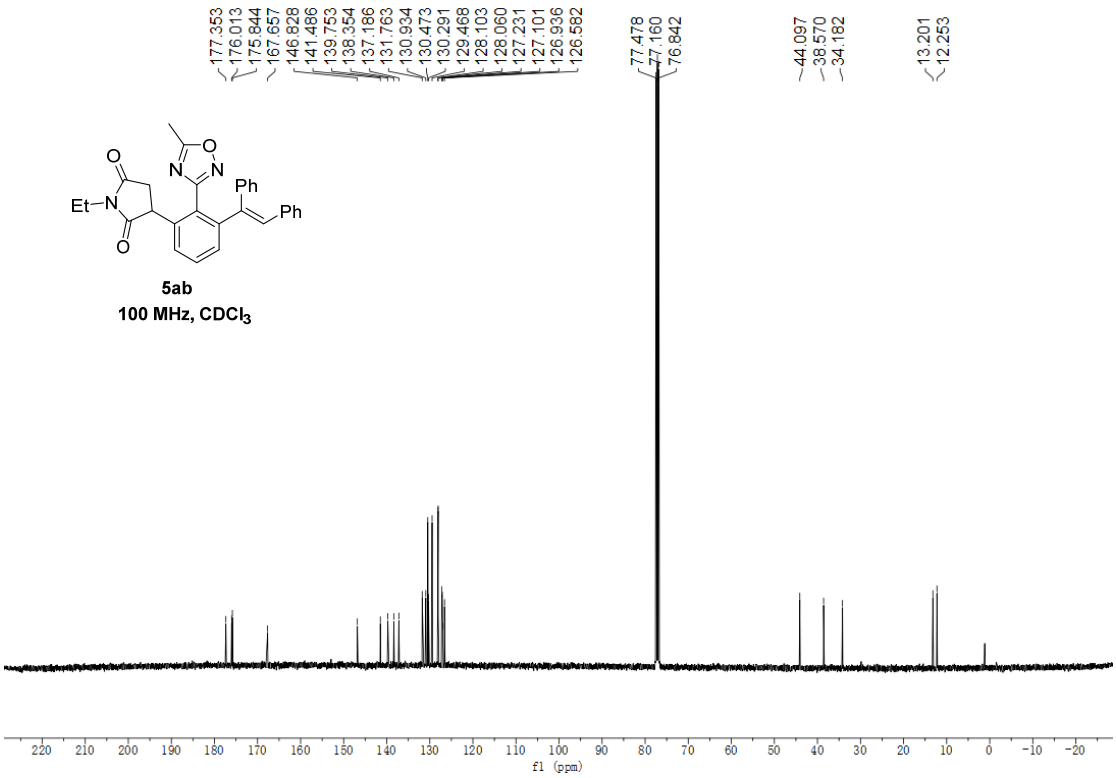
4ab

100 MHz, $CDCl_3$



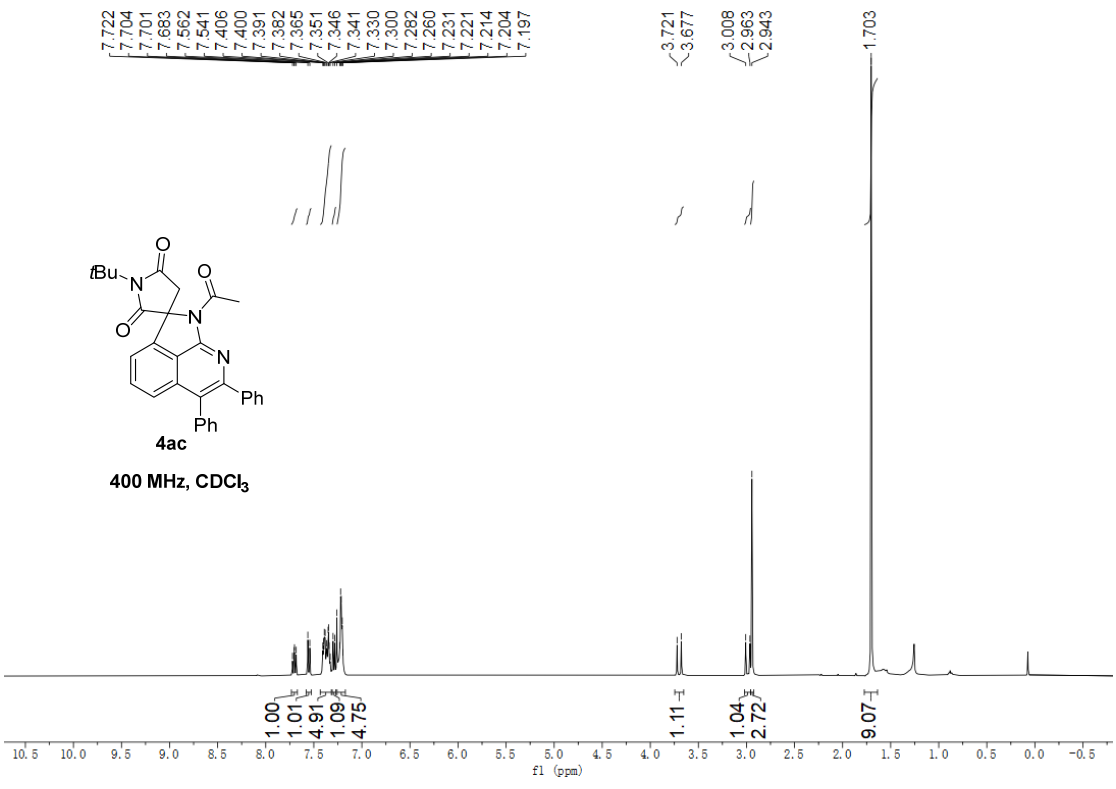
5ab

400 MHz, $CDCl_3$



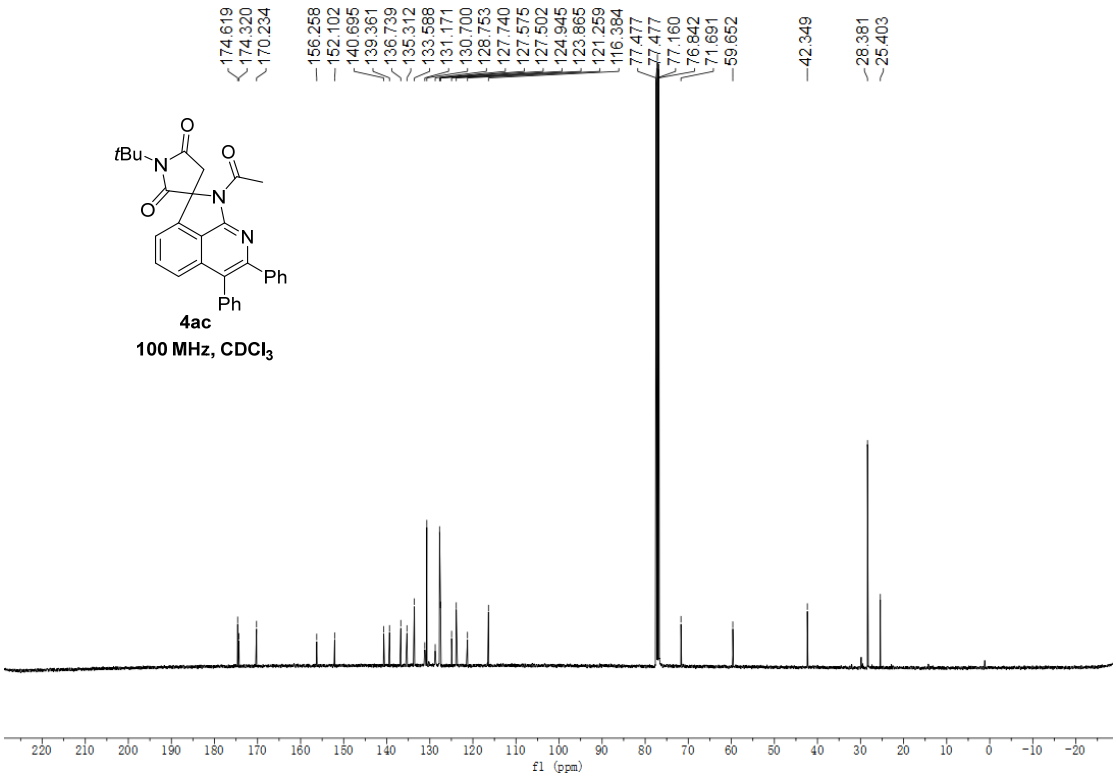
5ab

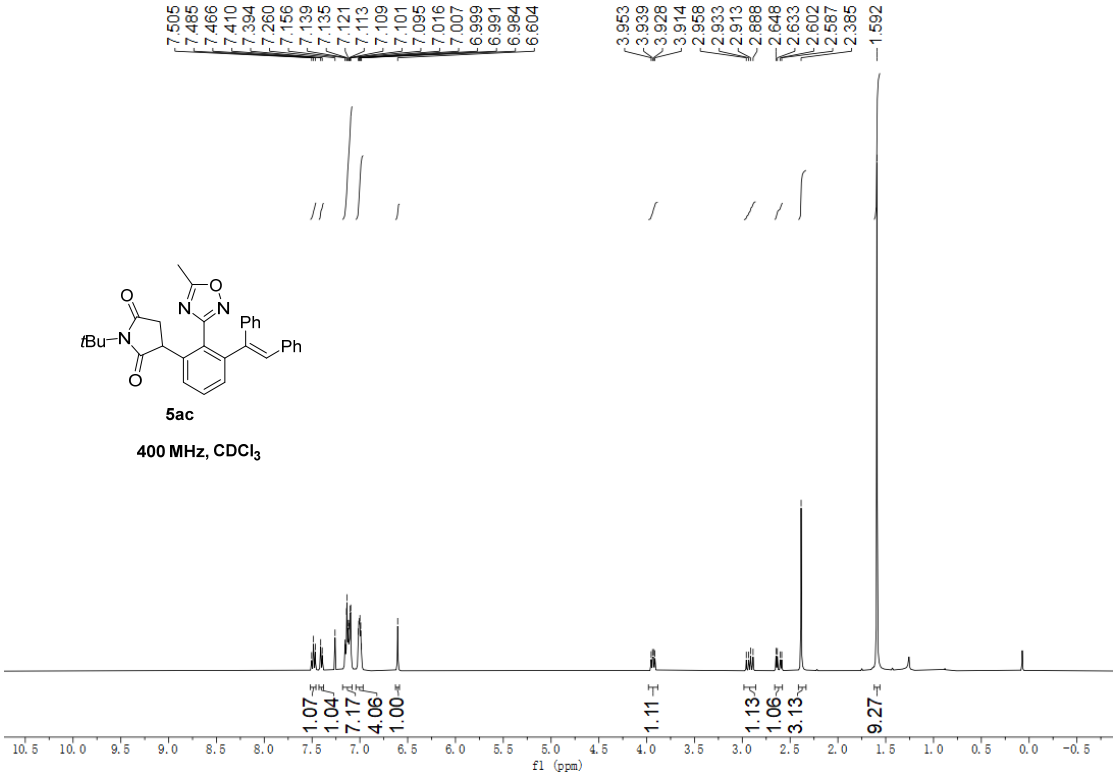
100 MHz, $CDCl_3$

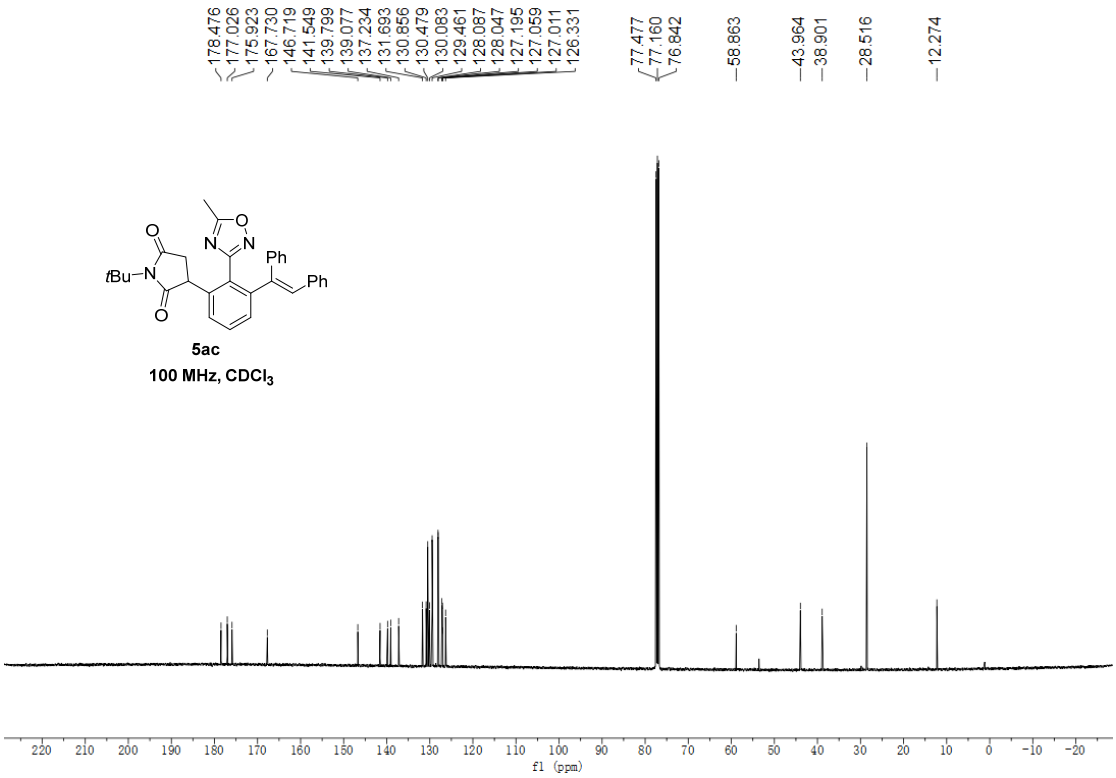


4ac

400 MHz, $CDCl_3$

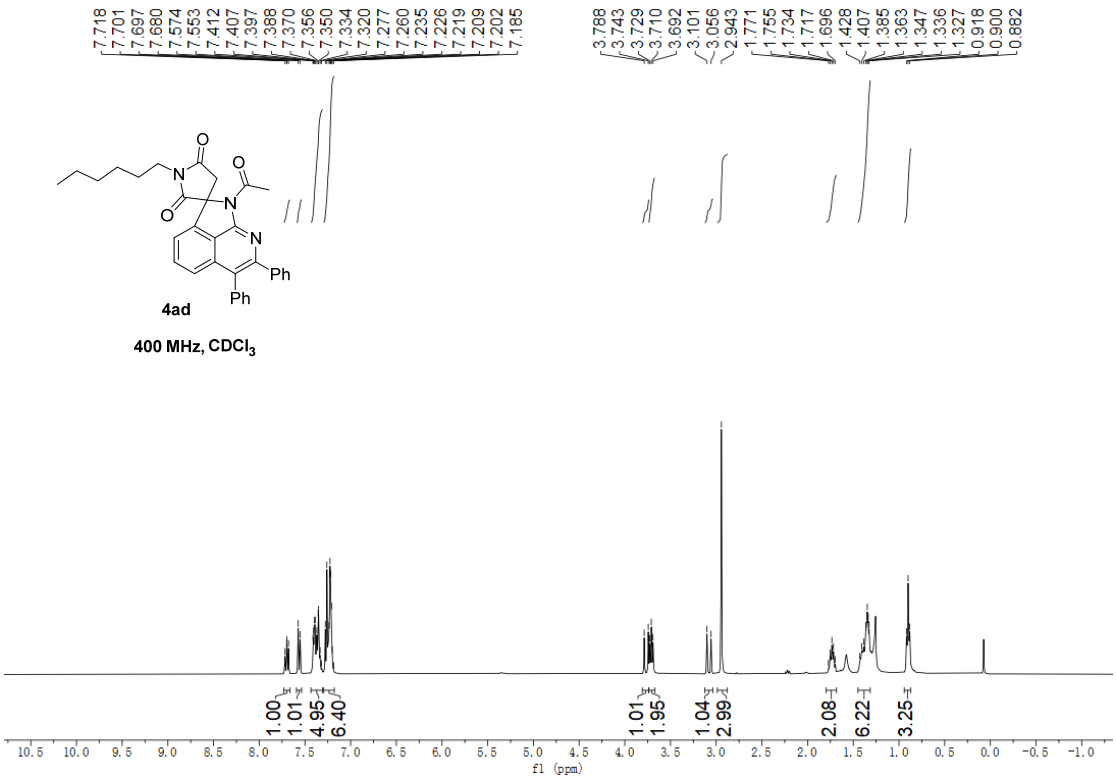

174.619
174.320
170.234
156.258
152.102
140.695
139.361
136.739
135.312
133.588
131.171
130.700
128.753
127.740
127.575
127.502
124.945
123.865
121.259
116.384
77.477
77.477
77.160
76.842
71.691
59.652
42.349
28.381
25.403
tBu
N
O
O
O
N
N
Ph
Ph
4ac
100 MHz, CDCl3
f1 (ppm)


7.505
7.485
7.466
7.410
7.394
7.260
7.156
7.139
7.135
7.121
7.113
7.109
7.101
7.095
7.016
7.007
6.999
6.991
6.984
6.604
3.953
3.939
3.928
3.914
2.958
2.933
2.913
2.888
2.648
2.633
2.602
2.587
2.385
1.592
1.07
1.04
7.17
4.06
1.00
1.11
1.13
1.06
3.13
9.27
tBu
N
O
O
O
N
O
N
Ph
Ph
5ac
400 MHz, CDCl3
f1 (ppm)



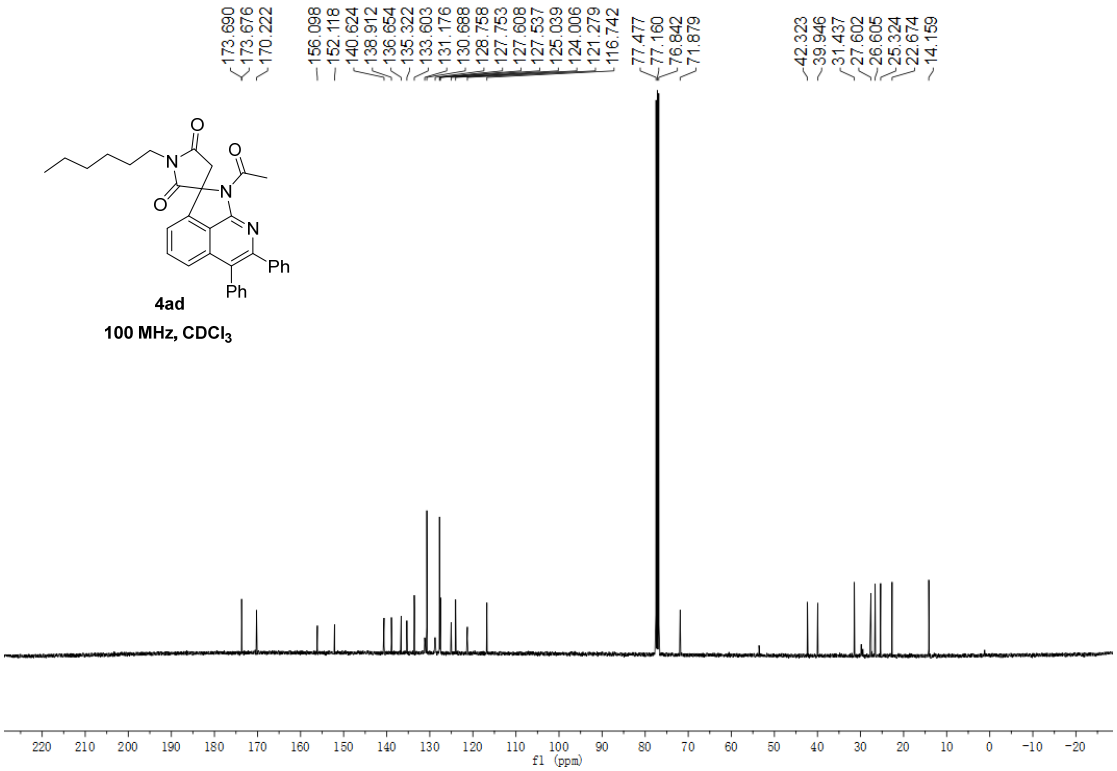
5ac

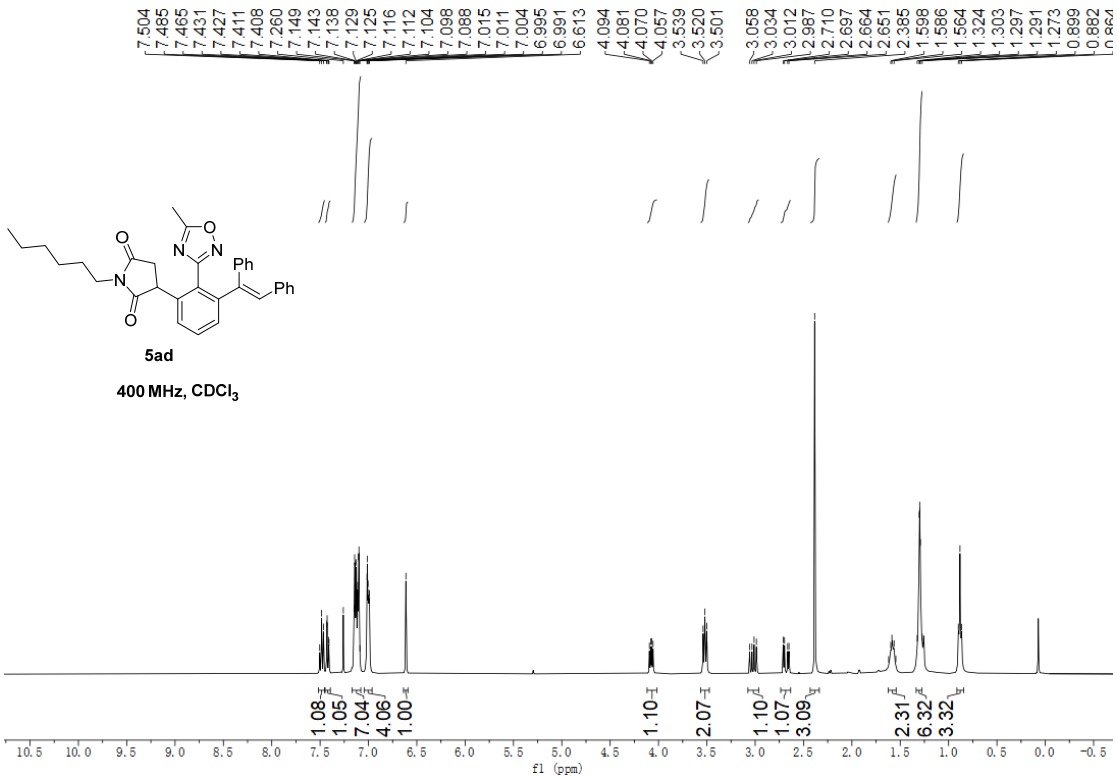
100 MHz, $CDCl_3$

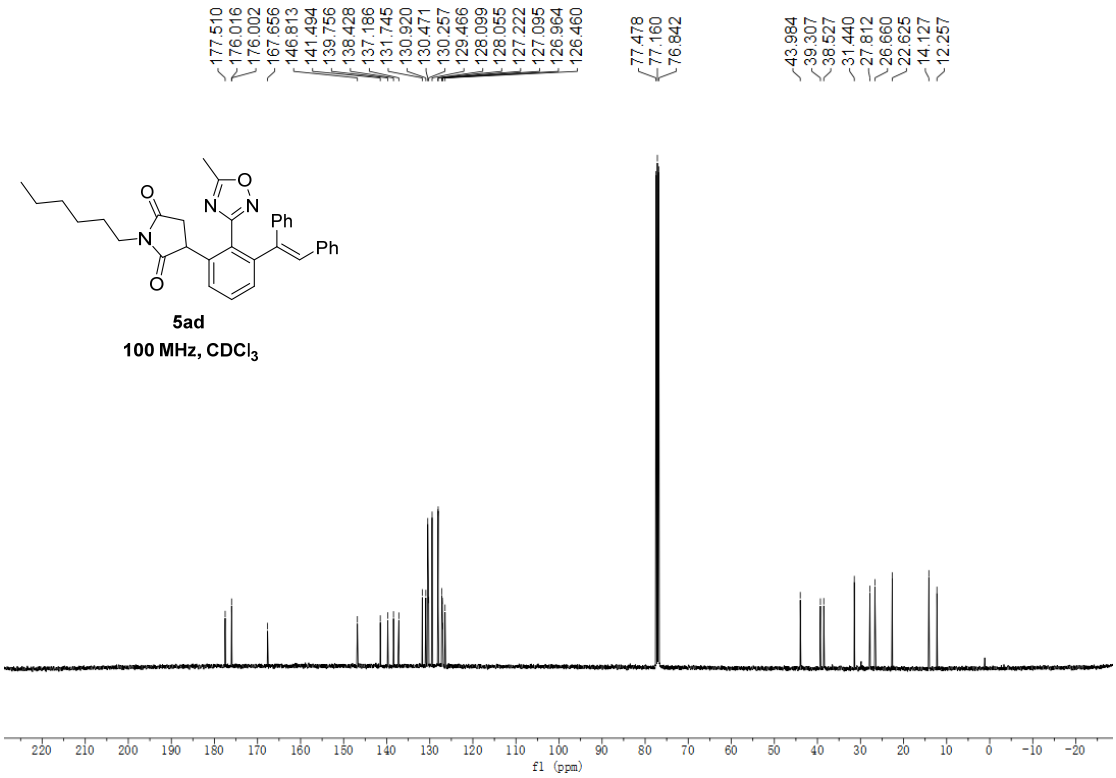


4ad

400 MHz, $CDCl_3$

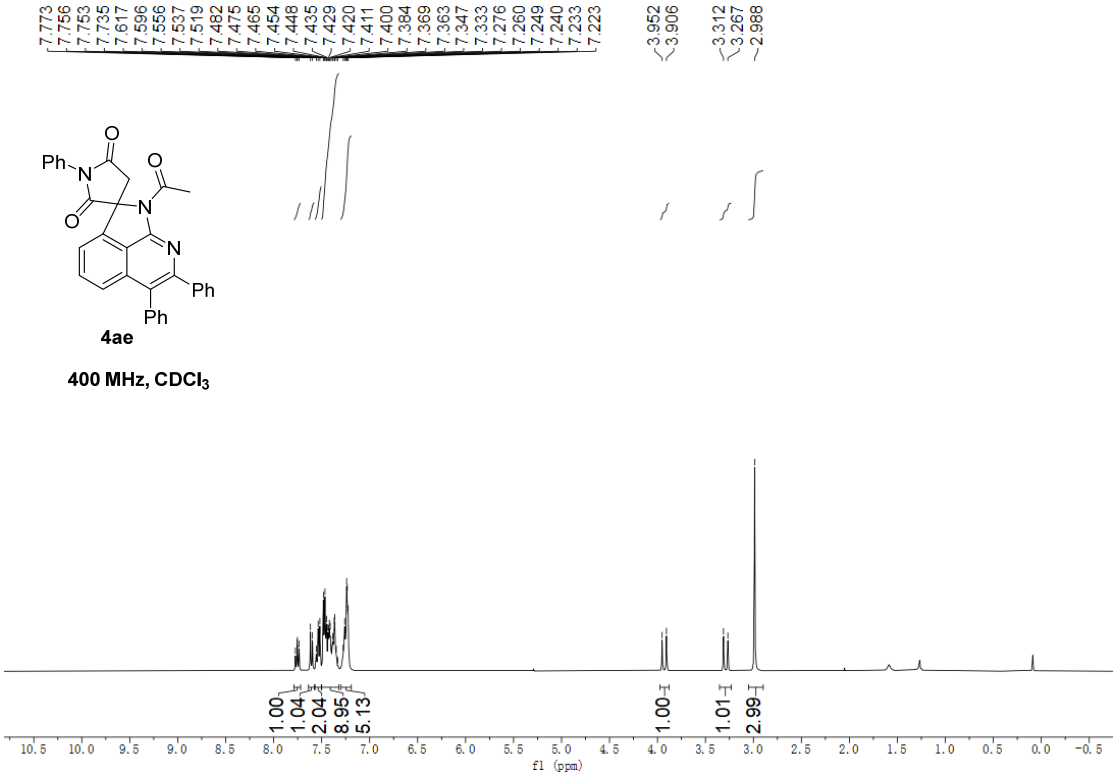

173.690
173.676
170.222
156.098
152.118
140.624
138.912
136.654
135.322
133.603
131.176
130.688
128.758
127.753
127.608
127.537
125.039
124.006
121.279
116.742
77.477
77.160
76.842
71.879
42.323
39.946
31.437
27.602
26.605
25.324
22.674
14.159
Ph
Ph
4ad
100 MHz, CDCl3
f1 (ppm)


7.504
7.485
7.465
7.431
7.427
7.411
7.408
7.260
7.149
7.143
7.138
7.129
7.125
7.116
7.112
7.104
7.098
7.088
7.015
7.011
7.004
6.995
6.991
6.613
4.094
4.081
4.070
4.057
3.539
3.520
3.501
3.058
3.034
3.012
2.987
2.710
2.697
2.664
2.651
2.385
1.598
1.586
1.564
1.324
1.303
1.297
1.291
1.273
0.899
0.882
Ph
Ph
5ad
400 MHz, CDCl3
1.08
1.05
7.04
4.06
1.00
1.10
2.07
1.10
1.07
3.09
2.31
6.32
3.32
f1 (ppm)



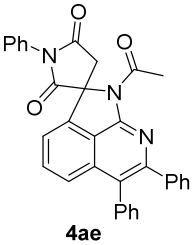
5ad

100 MHz, $CDCl_3$



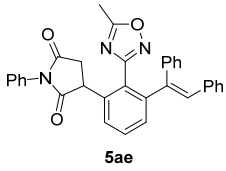
4ae

400 MHz, $CDCl_3$



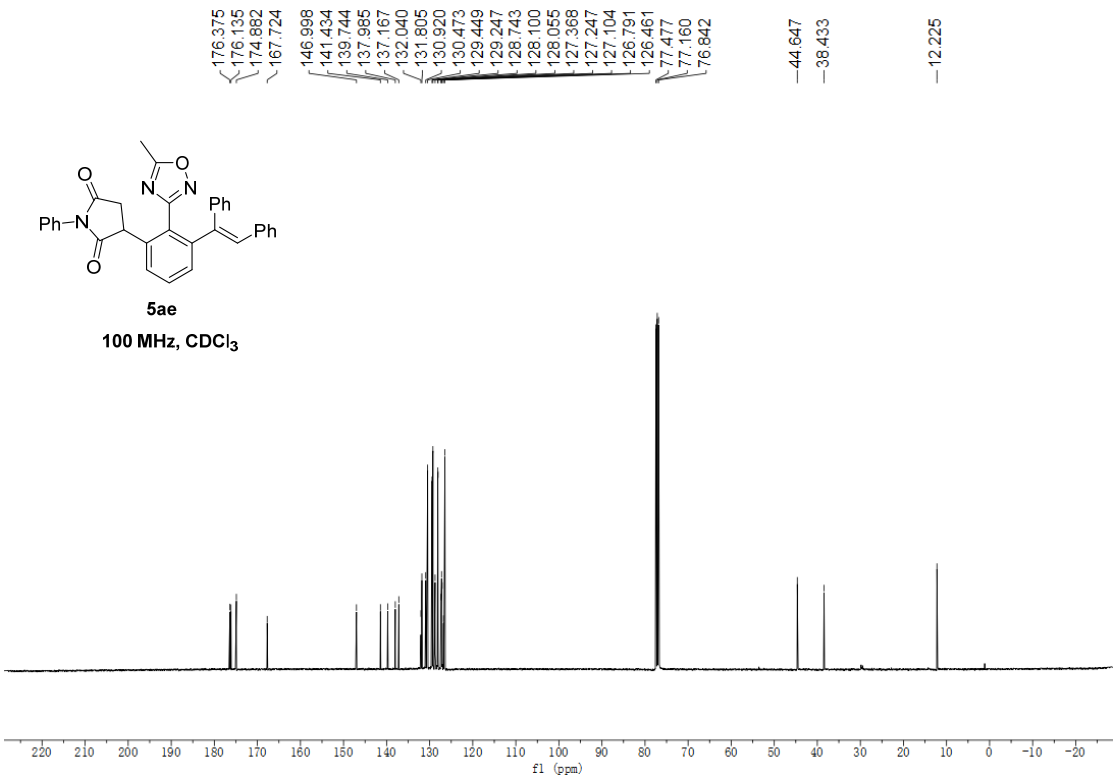
4ae

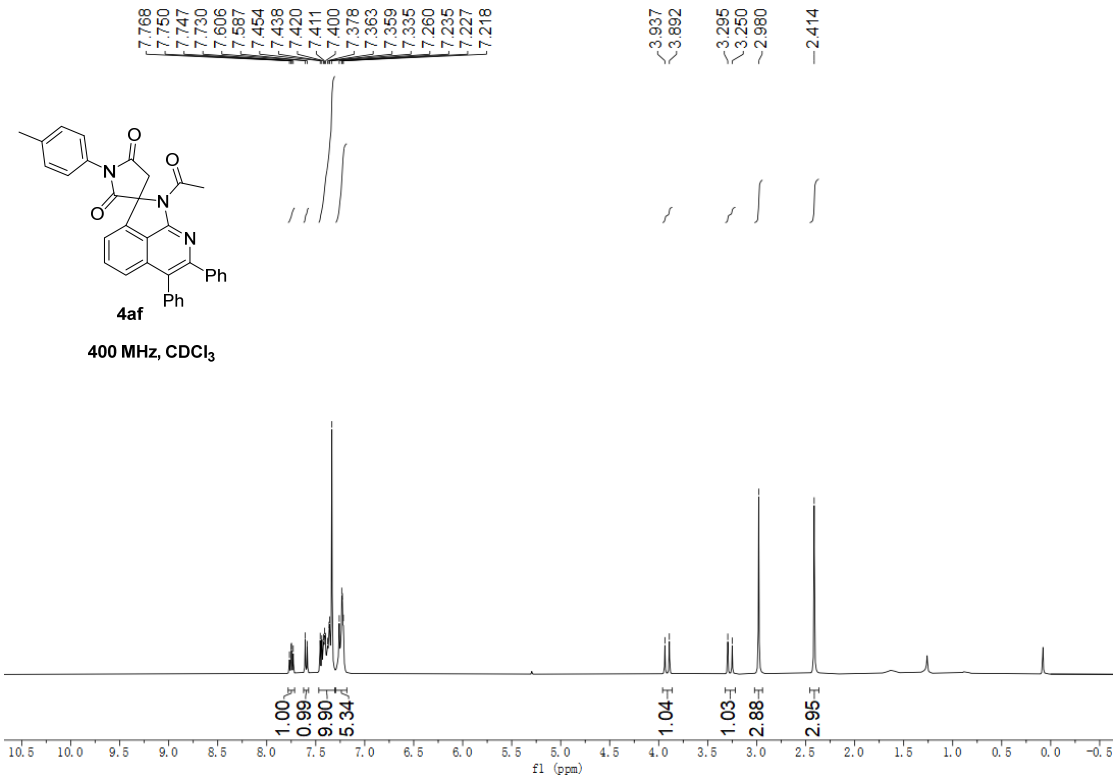
100 MHz, $CDCl_3$

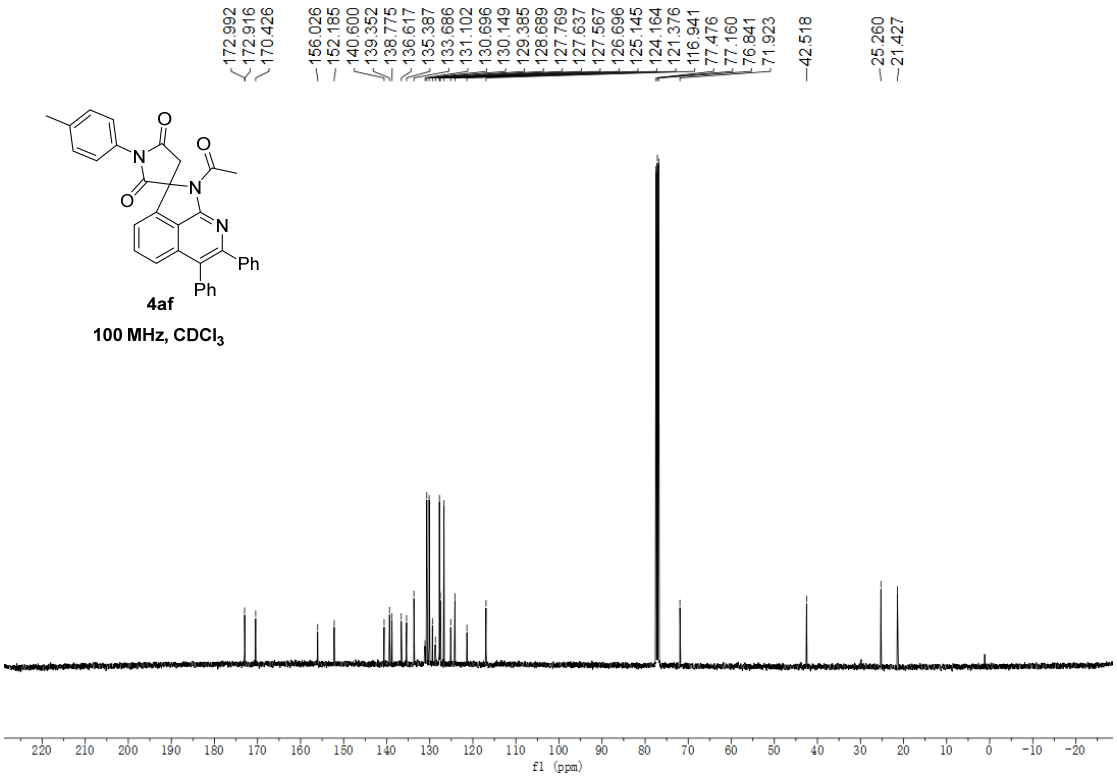


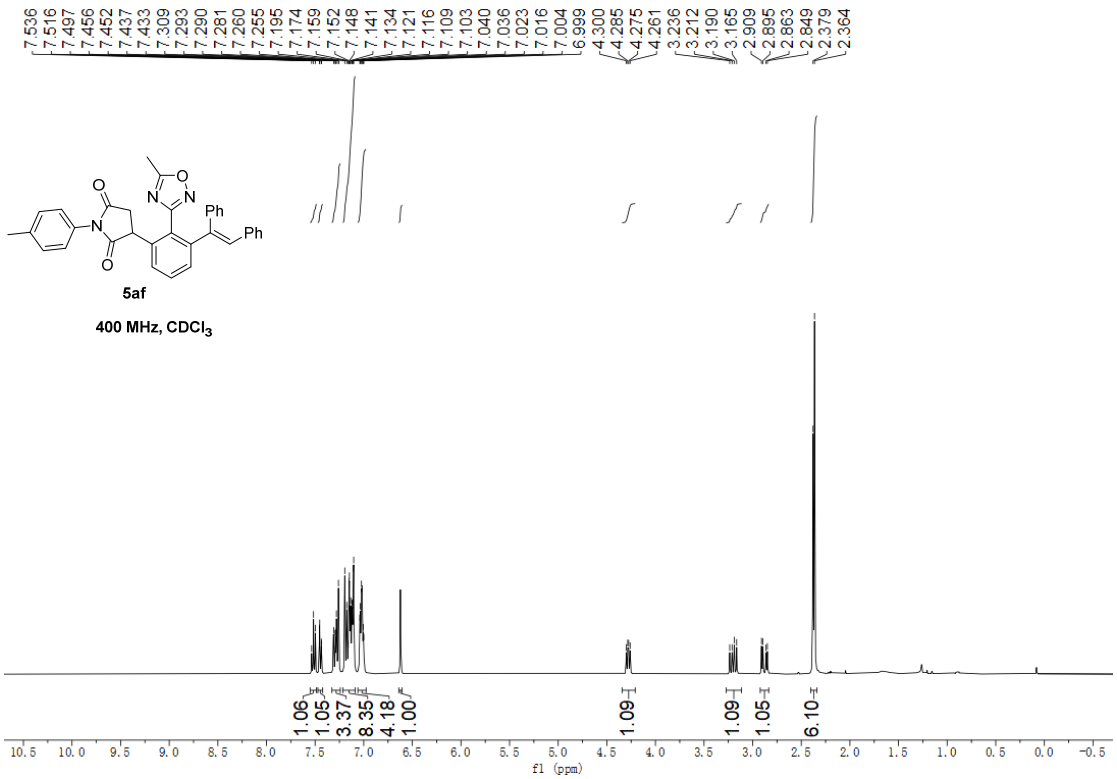
5ae

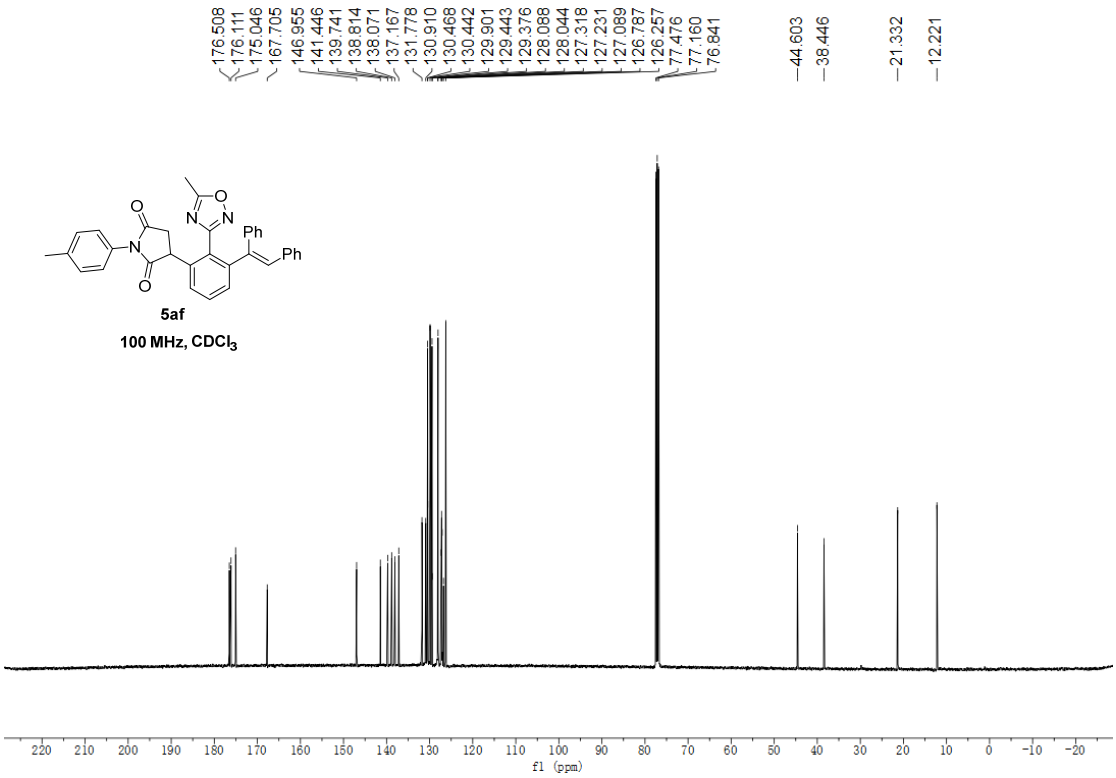
400 MHz, $CDCl_3$

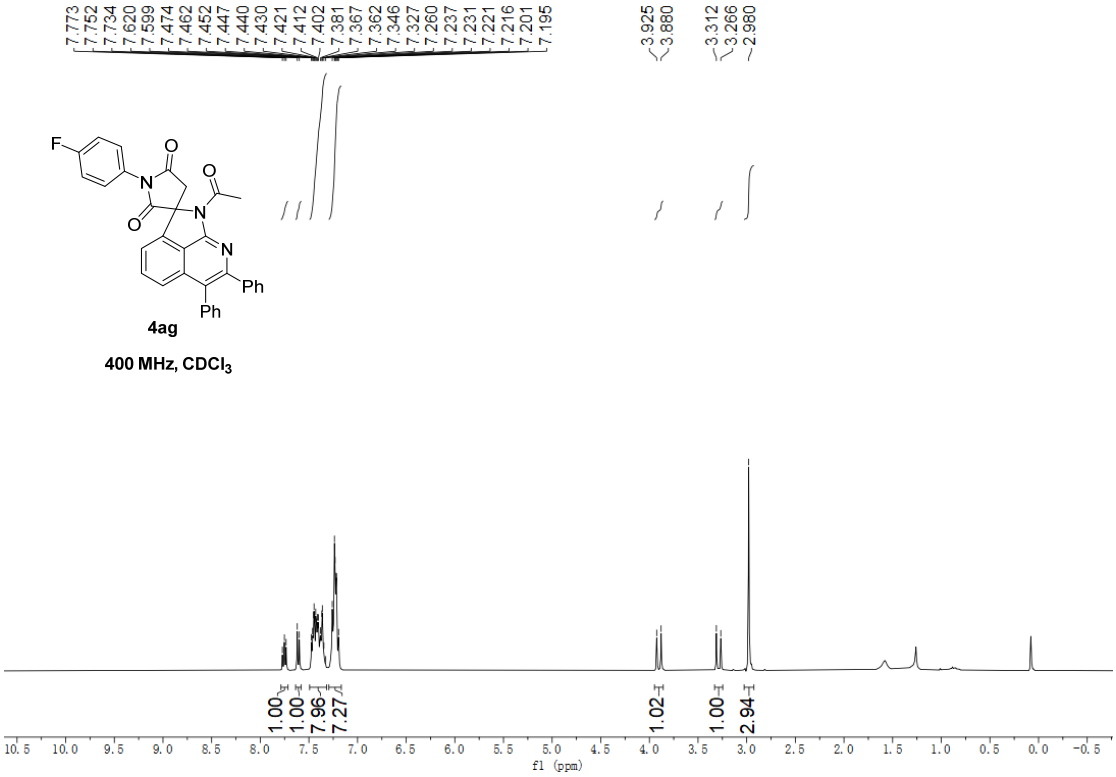

176.375
176.135
174.882
167.724
146.998
141.434
139.744
137.985
137.167
132.040
131.805
130.920
130.473
129.449
129.247
128.743
128.100
128.055
127.368
127.247
127.104
126.791
126.461
77.477
77.160
76.842
44.647
38.433
12.225
Ph
Ph
Ph
5ae
100 MHz, CDCl3
f1 (ppm)

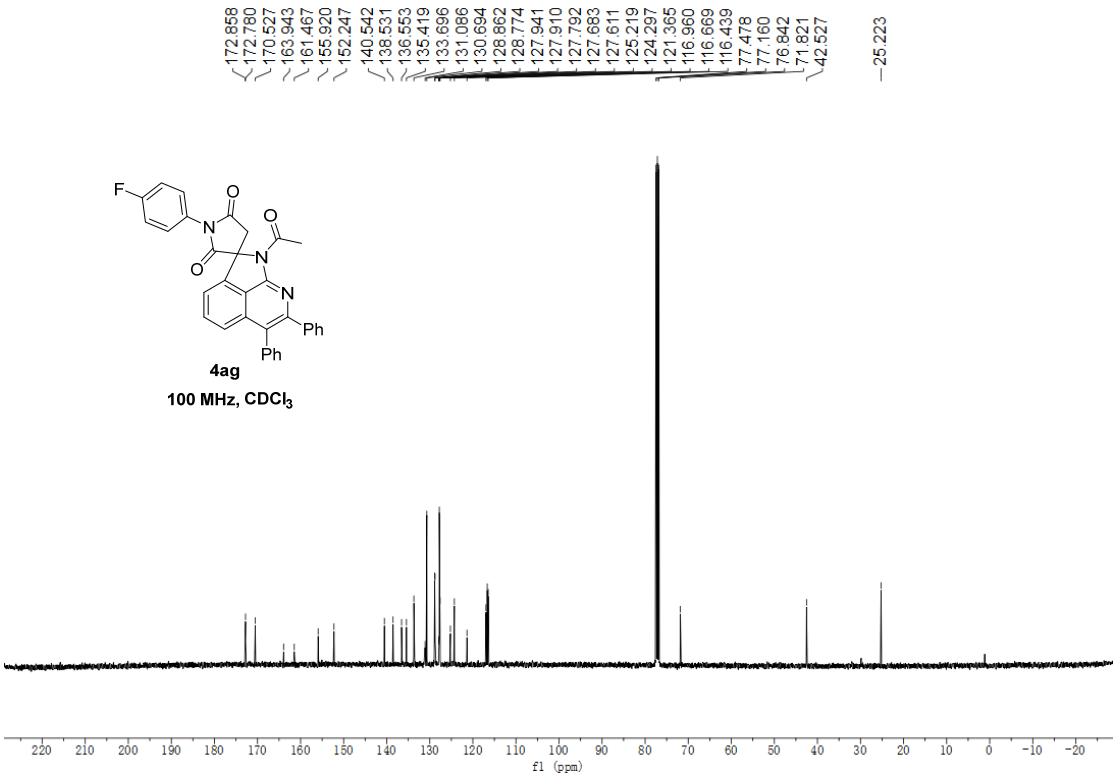

7.768
7.750
7.747
7.730
7.606
7.587
7.454
7.438
7.420
7.411
7.400
7.378
7.363
7.359
7.335
7.260
7.235
7.227
7.218
3.937
3.892
3.295
3.250
2.960
2.414
Ph
Ph
4af
400 MHz, CDCl3
1.00
0.99
9.90
5.34
1.04
1.03
2.88
2.95
f1 (ppm)


172.992
172.916
170.426
156.026
152.185
140.600
139.352
138.775
136.617
135.387
133.686
131.102
130.696
130.149
129.385
128.689
127.769
127.637
127.567
126.696
125.145
124.164
121.376
116.941
77.476
77.160
76.841
71.923
42.518
25.260
21.427
O
N
O
N
O
N
Ph
Ph
4af
100 MHz, CDCl3
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


7.536
7.516
7.497
7.456
7.452
7.437
7.433
7.309
7.293
7.290
7.281
7.260
7.255
7.195
7.174
7.159
7.152
7.148
7.141
7.134
7.121
7.116
7.109
7.103
7.040
7.036
7.023
7.016
7.004
6.999
4.300
4.285
4.275
4.261
3.236
3.212
3.190
3.165
2.909
2.895
2.863
2.849
2.379
2.364
O
N
O
N
Ph
Ph
O
5af
400 MHz, CDCl3
1.06
1.05
3.37
8.35
4.18
1.00
1.09
1.09
1.05
6.10
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

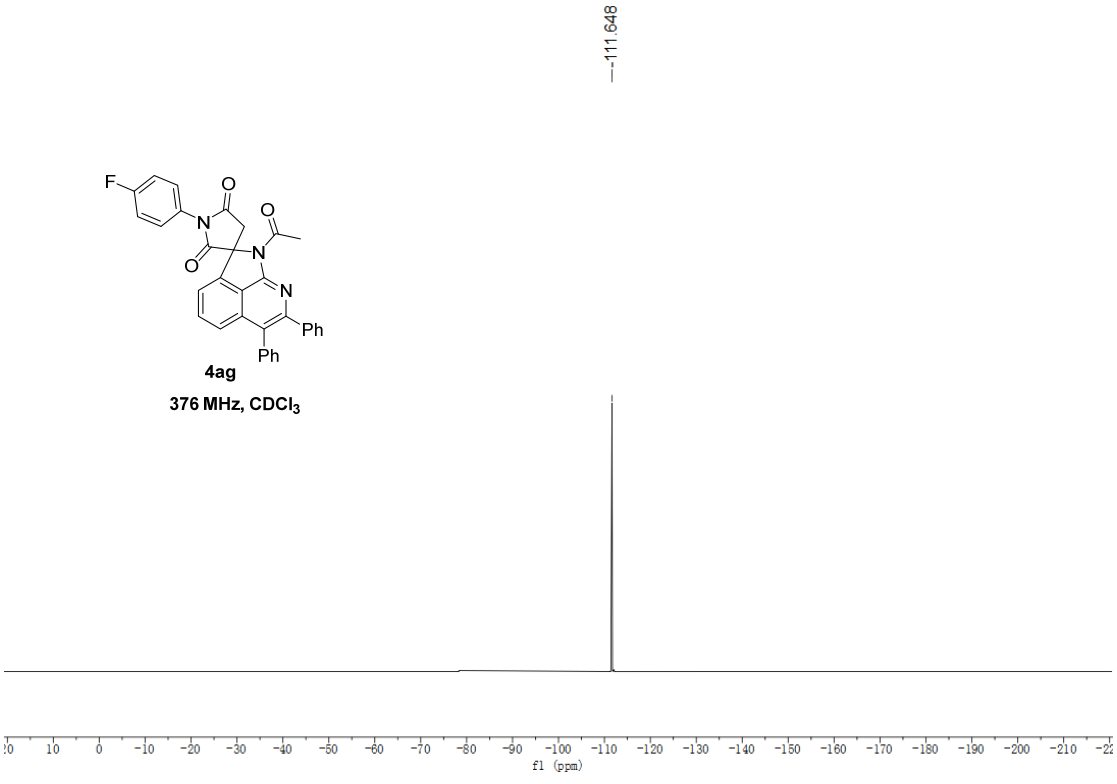

176.508
176.111
175.046
167.705
146.955
141.446
139.741
138.814
138.071
137.167
131.778
130.910
130.468
130.442
129.901
129.443
129.376
128.088
128.044
127.318
127.231
127.089
126.787
126.257
77.476
77.160
76.841
44.603
38.446
21.332
12.221
Ph
Ph
5af
100 MHz, CDCl3
f1 (ppm)


7.773
7.752
7.734
7.620
7.599
7.474
7.462
7.452
7.447
7.440
7.430
7.421
7.412
7.402
7.381
7.367
7.362
7.346
7.327
7.260
7.237
7.231
7.221
7.216
7.201
7.195
3.925
3.880
3.312
3.266
2.980
F
Ph
Ph
4ag
400 MHz, CDCl3
1.00
1.00
7.96
7.27
1.02
1.00
2.94
f1 (ppm)



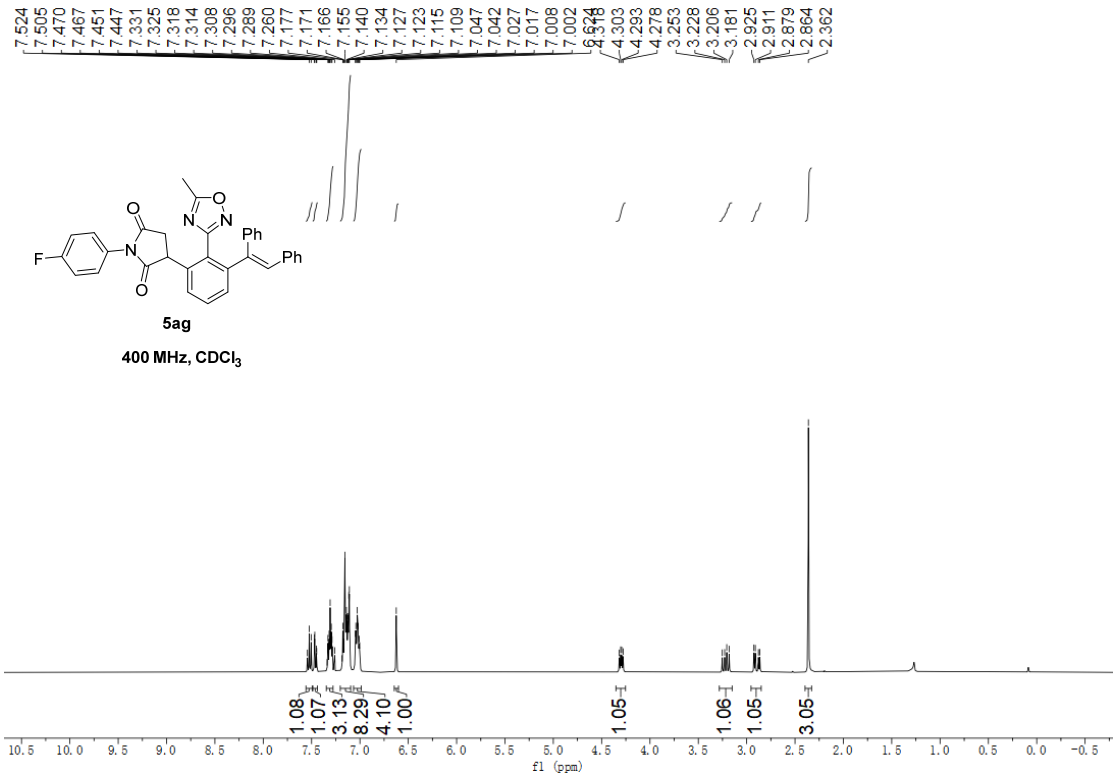
4ag

100 MHz, $CDCl_3$



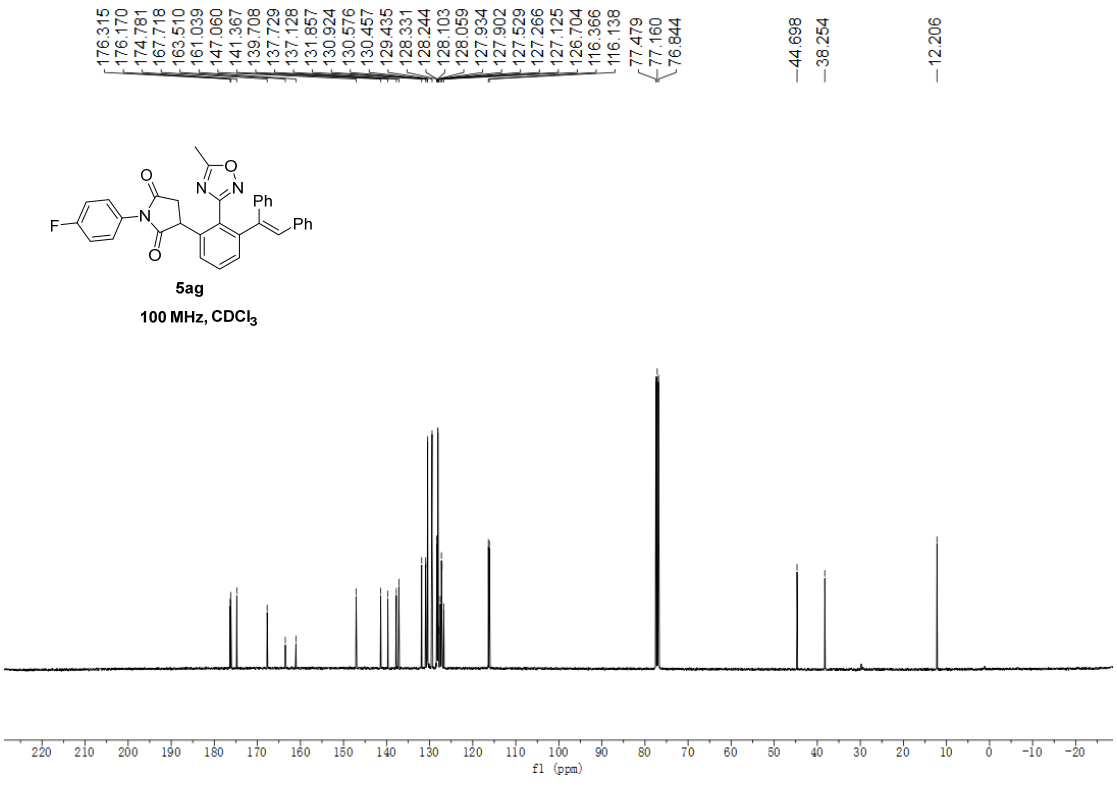
4ag

376 MHz, $CDCl_3$



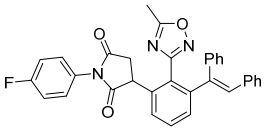
5ag

400 MHz, $CDCl_3$



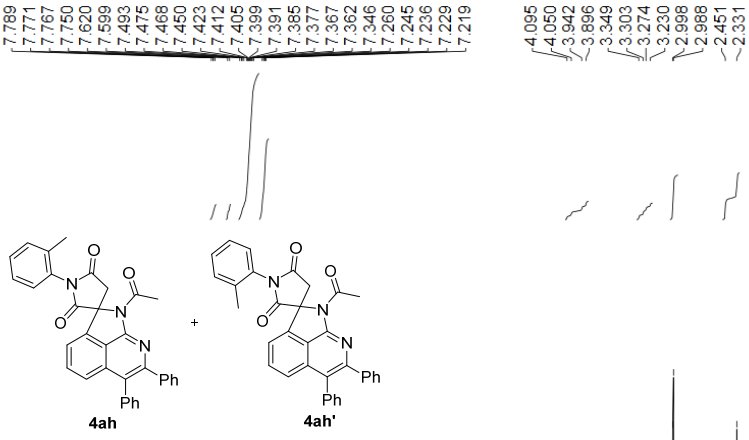
5ag

100 MHz, $CDCl_3$



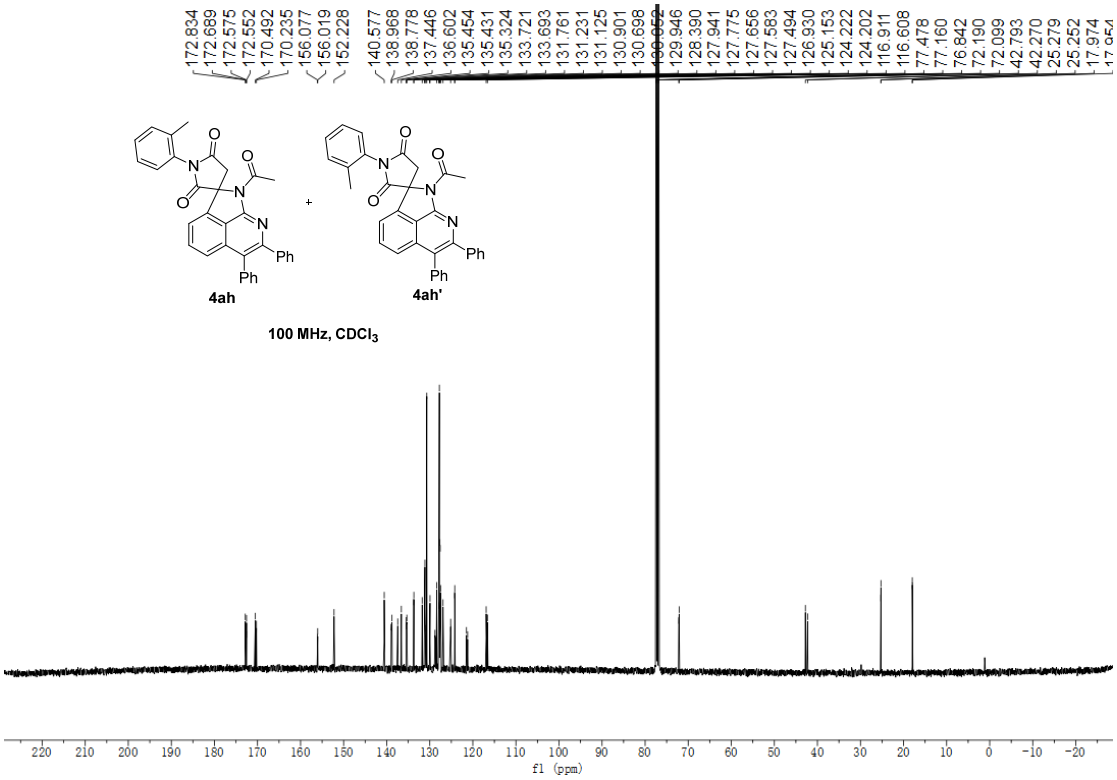
5ag

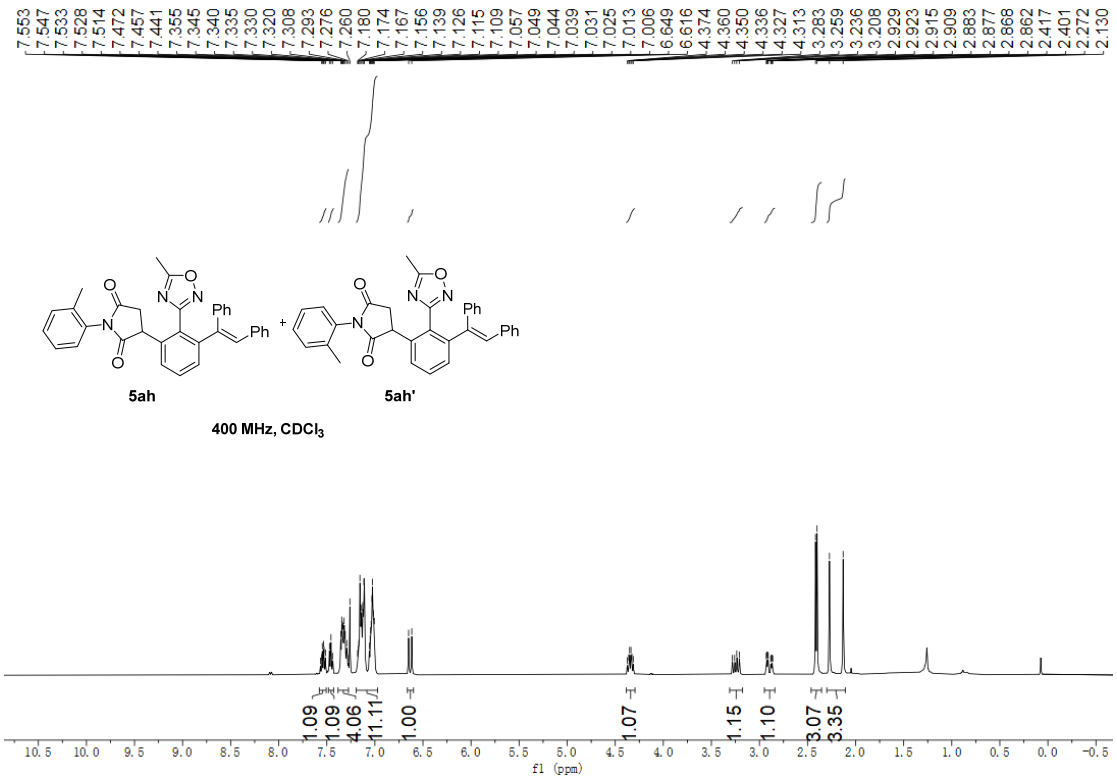
376 MHz, $CDCl_3$

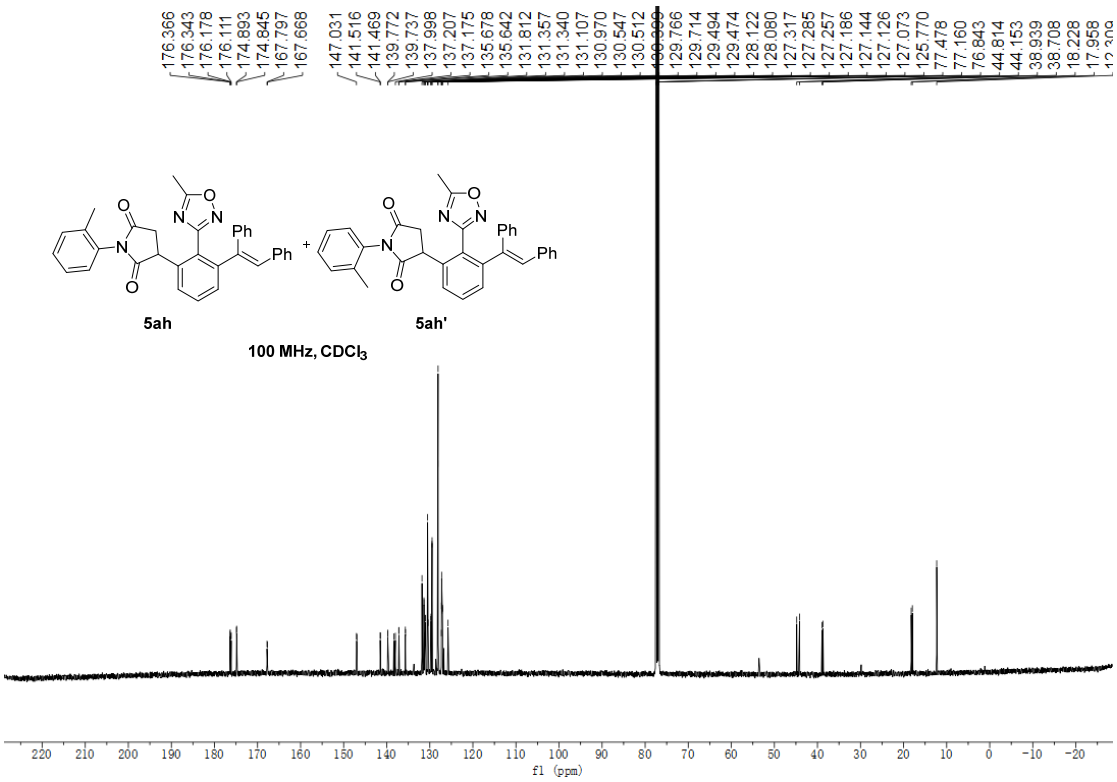


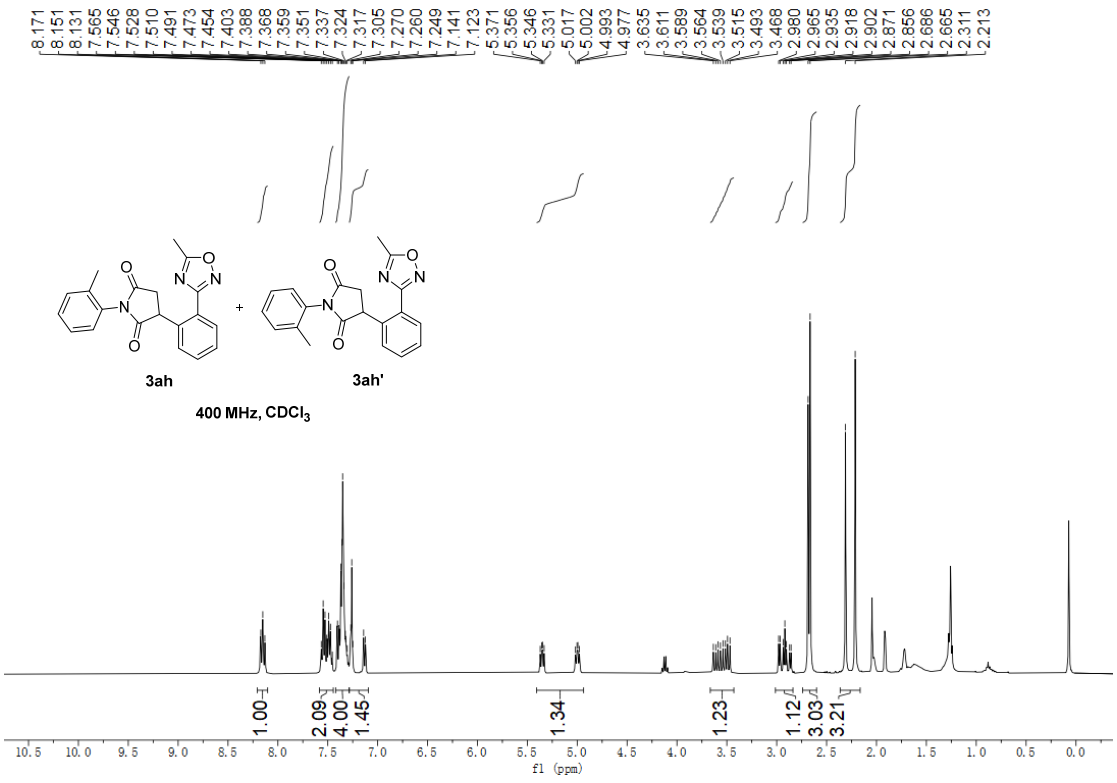
4ah **4ah'**

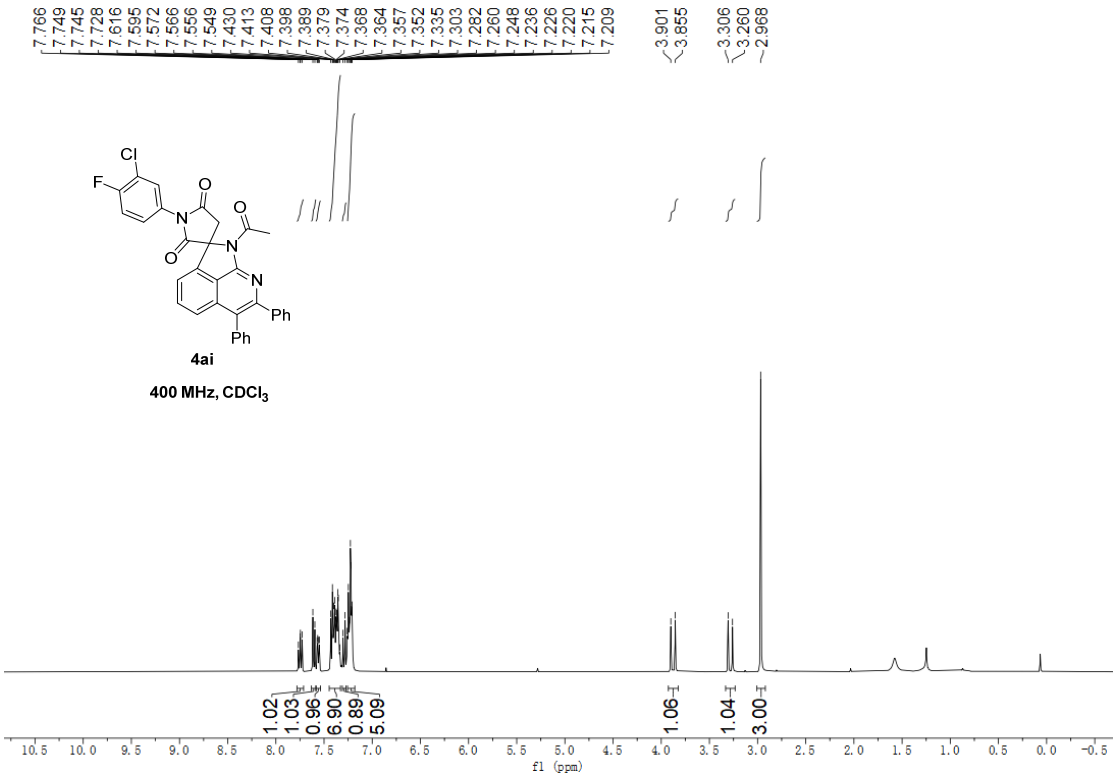
400 MHz, $CDCl_3$


172.834
172.689
172.575
172.552
170.492
170.235
156.077
156.019
152.228
140.577
138.968
138.778
137.446
136.602
135.454
135.431
135.324
133.721
133.693
131.761
131.231
131.125
130.901
130.698
129.946
128.390
127.941
127.775
127.656
127.583
127.494
126.930
125.153
124.222
124.202
116.911
116.608
77.478
77.160
76.842
72.190
72.099
42.793
42.270
25.279
25.252
17.974
Ph
Ph
Ph
Ph
4ah
4ah'
100 MHz, CDCl3
f1 (ppm)


7.553
7.547
7.533
7.528
7.514
7.472
7.457
7.441
7.355
7.345
7.340
7.335
7.330
7.320
7.308
7.293
7.276
7.260
7.180
7.174
7.167
7.156
7.139
7.126
7.115
7.109
7.057
7.049
7.044
7.039
7.031
7.025
7.013
7.006
6.649
6.616
4.374
4.360
4.350
4.336
4.327
4.313
3.283
3.259
3.236
3.208
2.929
2.923
2.915
2.909
2.883
2.877
2.868
2.862
2.417
2.401
2.272
2.130
Ph
Ph
Ph
Ph
5ah
5ah'
400 MHz, CDCl3
1.09
1.09
4.06
11.11
1.00
1.07
1.15
1.10
3.07
3.35
f1 (ppm)

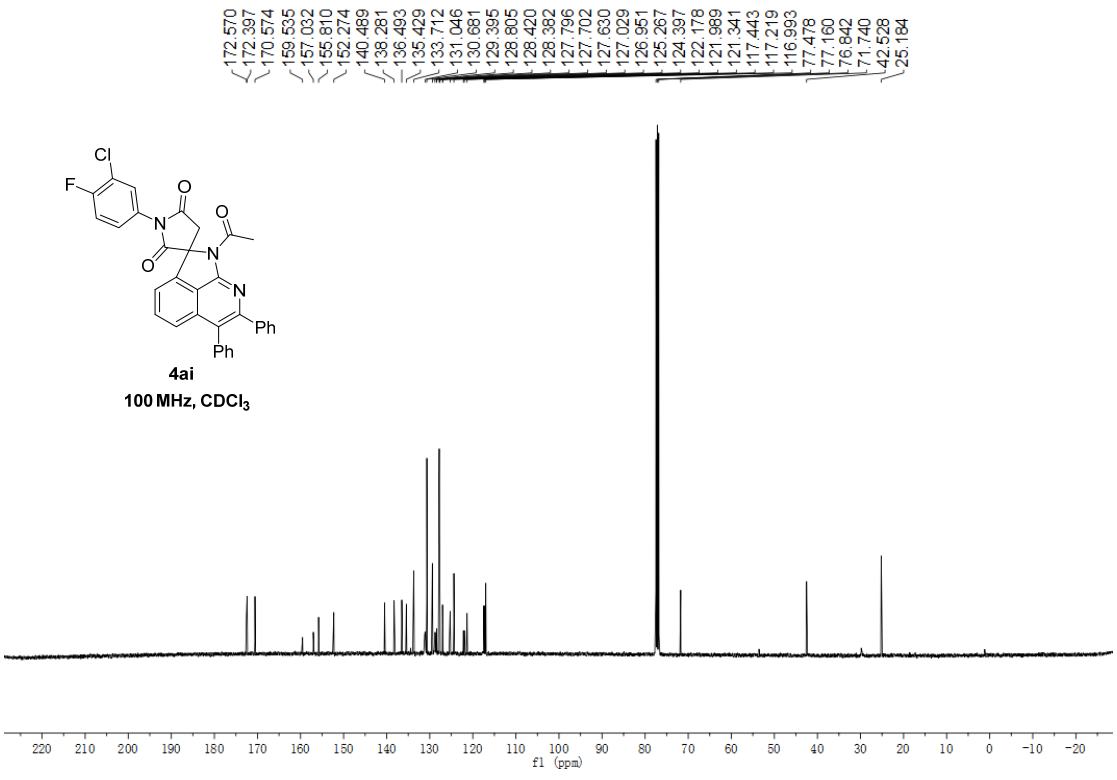

5ah
5ah'
100 MHz, CDCl3
f1 (ppm)


3ah
3ah'
400 MHz, CDCl3
f1 (ppm)



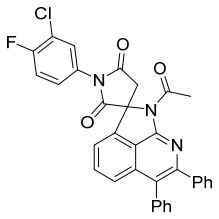
4ai

400 MHz, $CDCl_3$



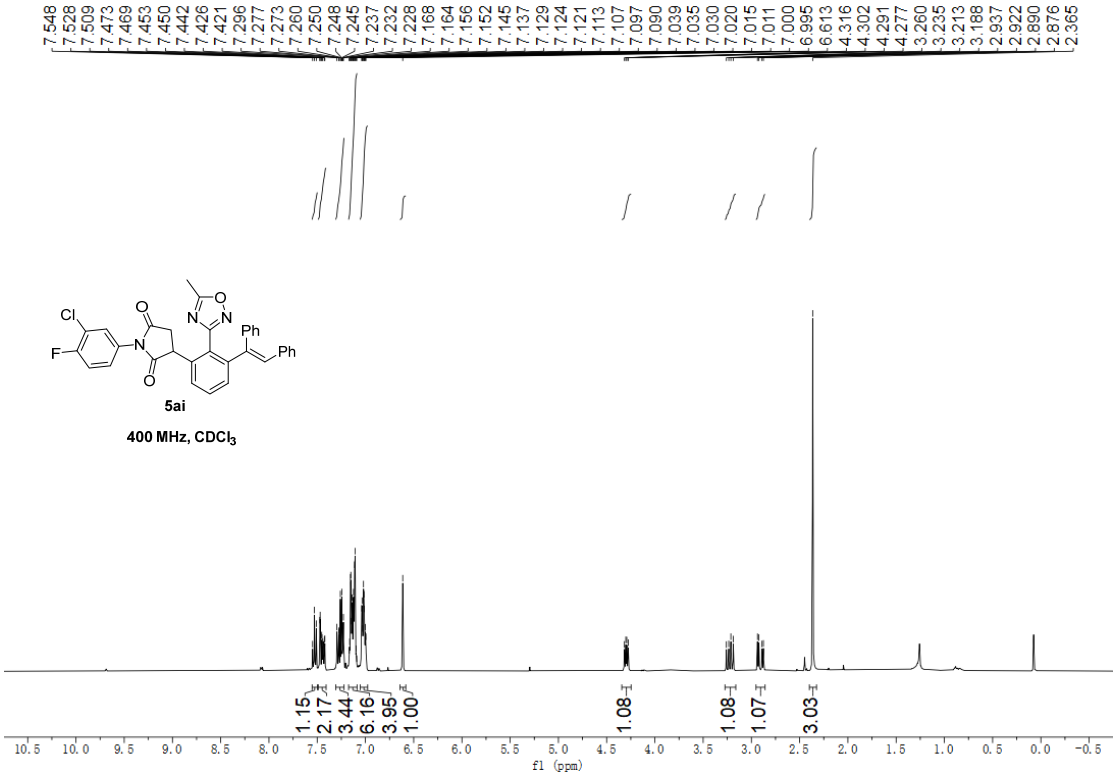
4ai

100 MHz, $CDCl_3$



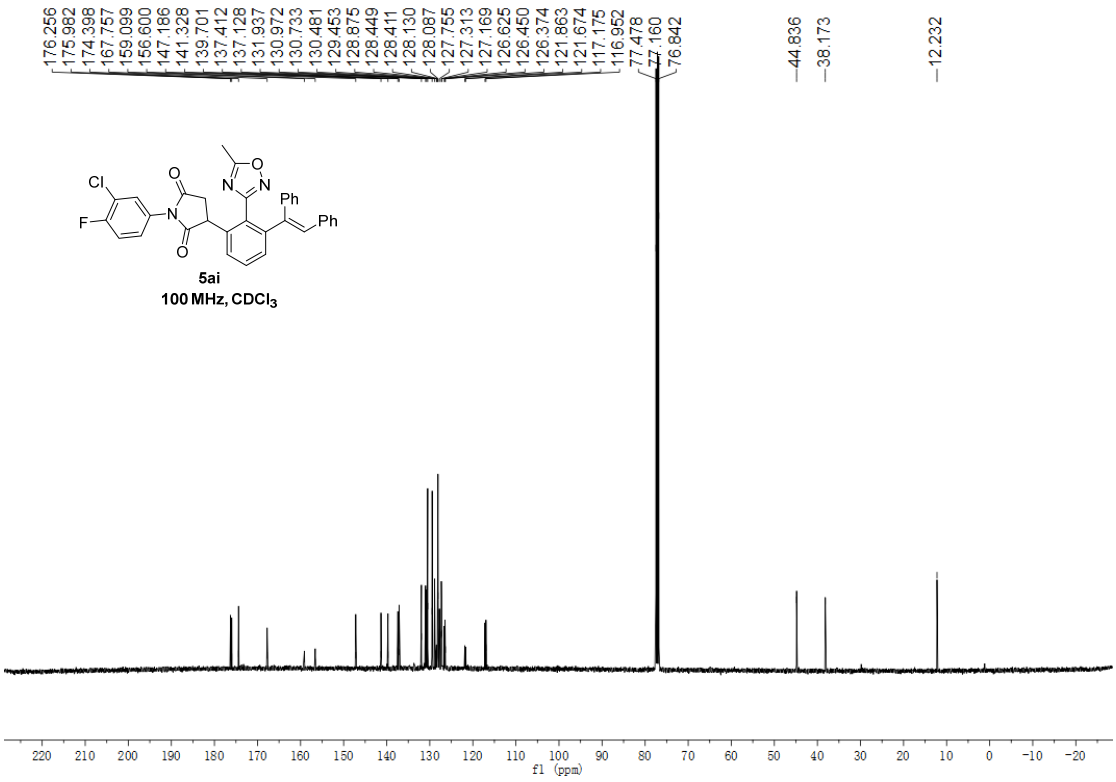
4ai

376 MHz, $CDCl_3$

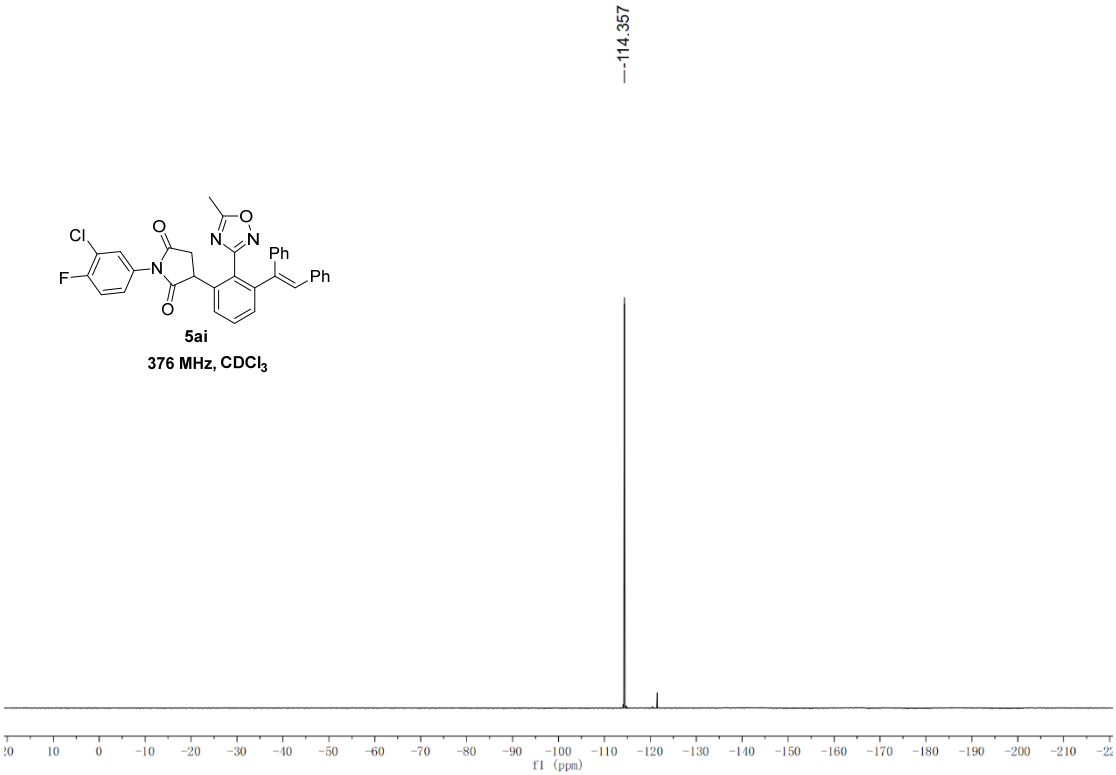


5ai

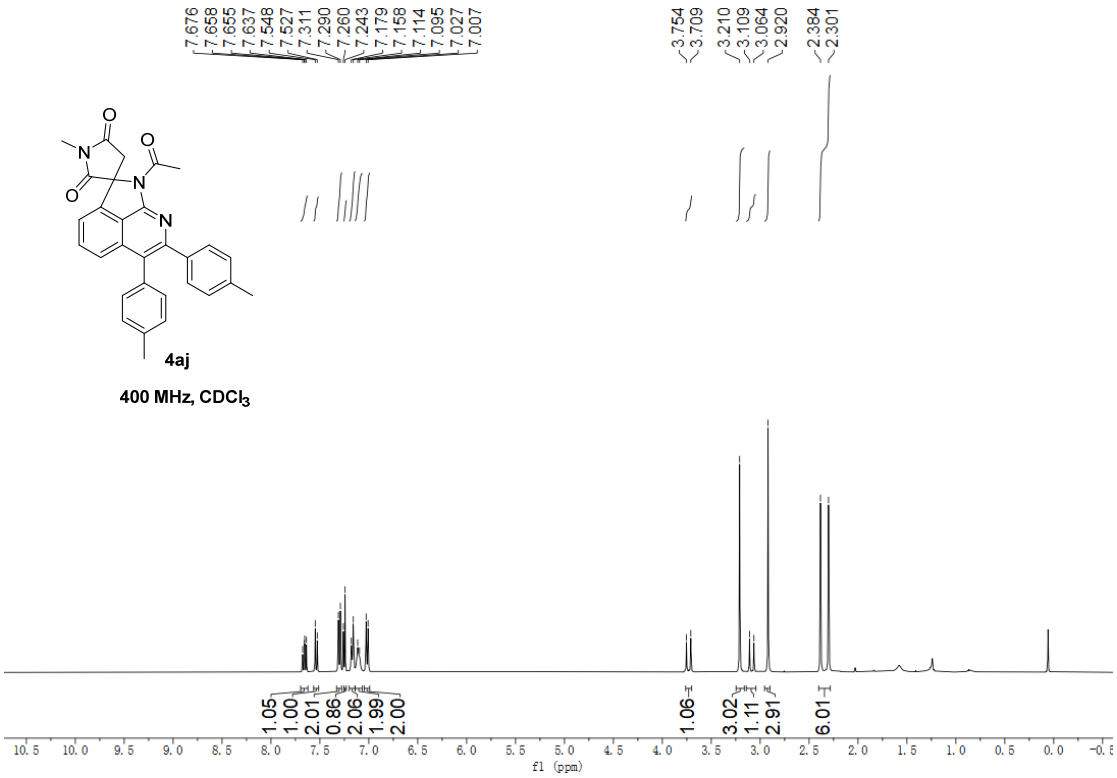
400 MHz, $CDCl_3$



5ai
100 MHz, $CDCl_3$

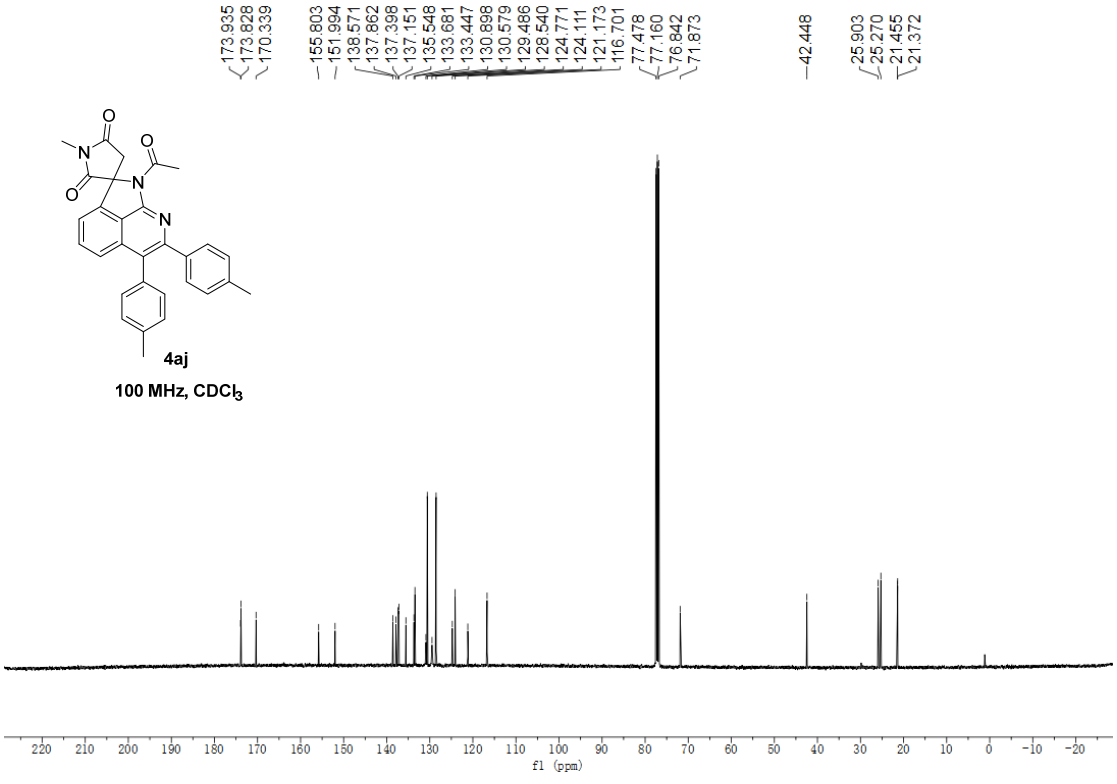


5ai
376 MHz, $CDCl_3$



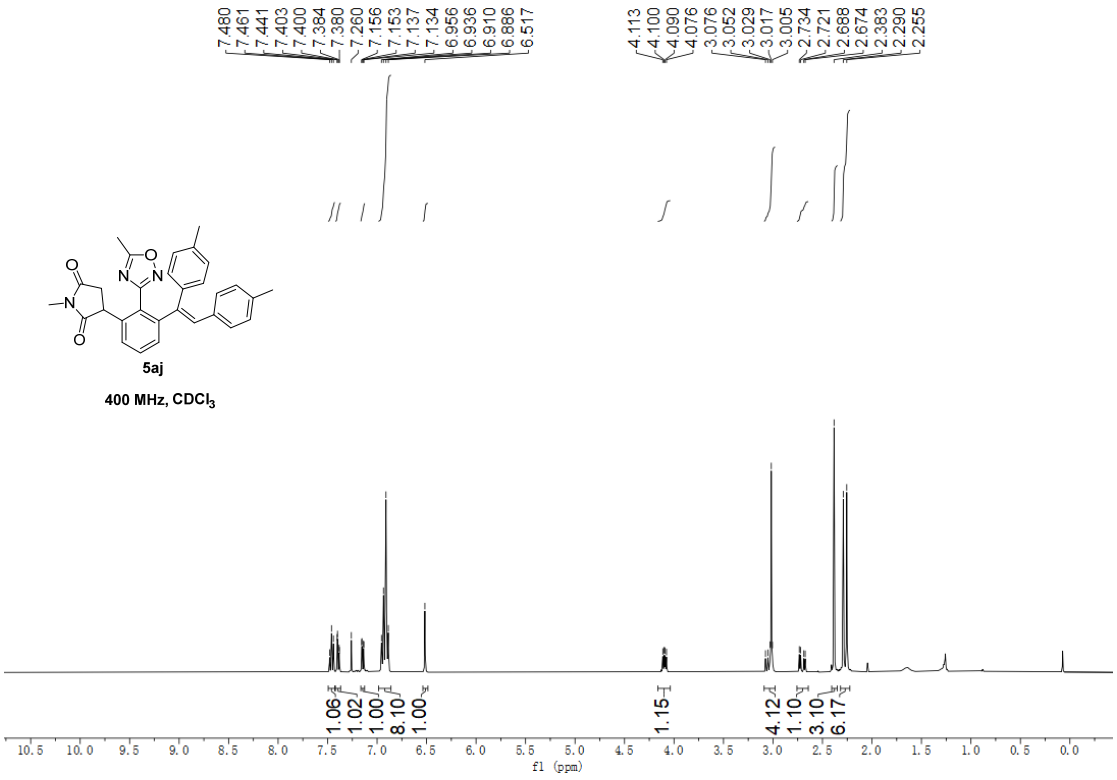
4aj

400 MHz, $CDCl_3$



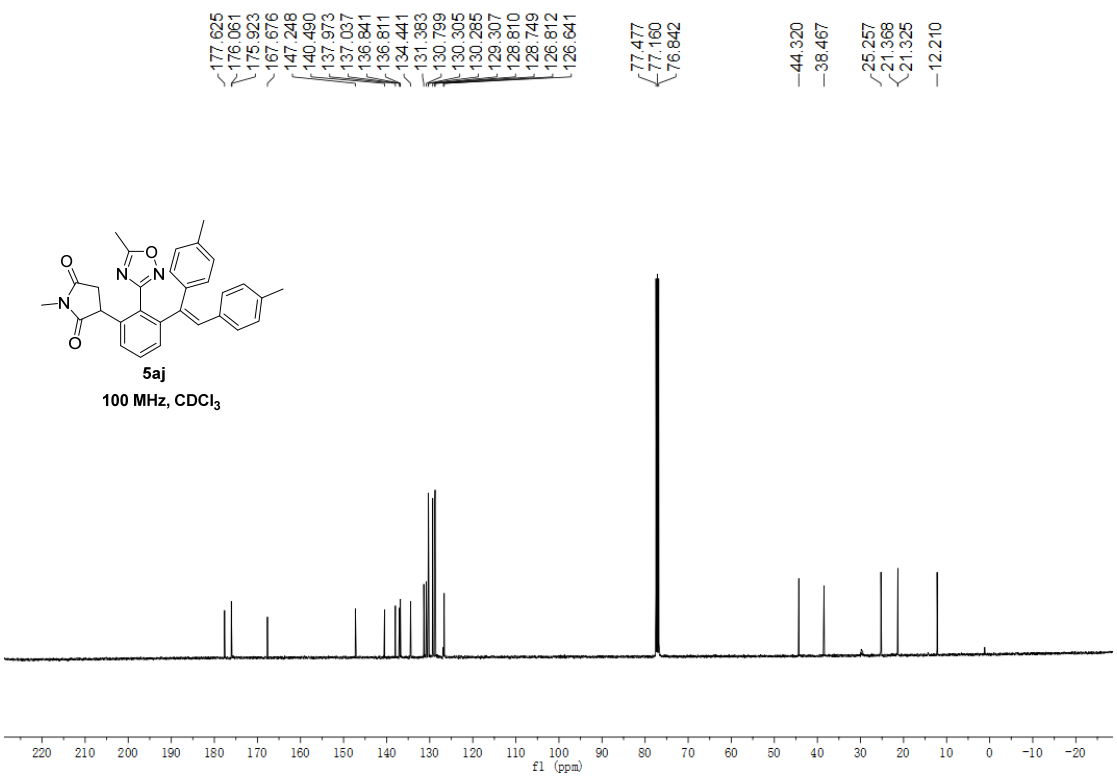
4aj

100 MHz, $CDCl_3$



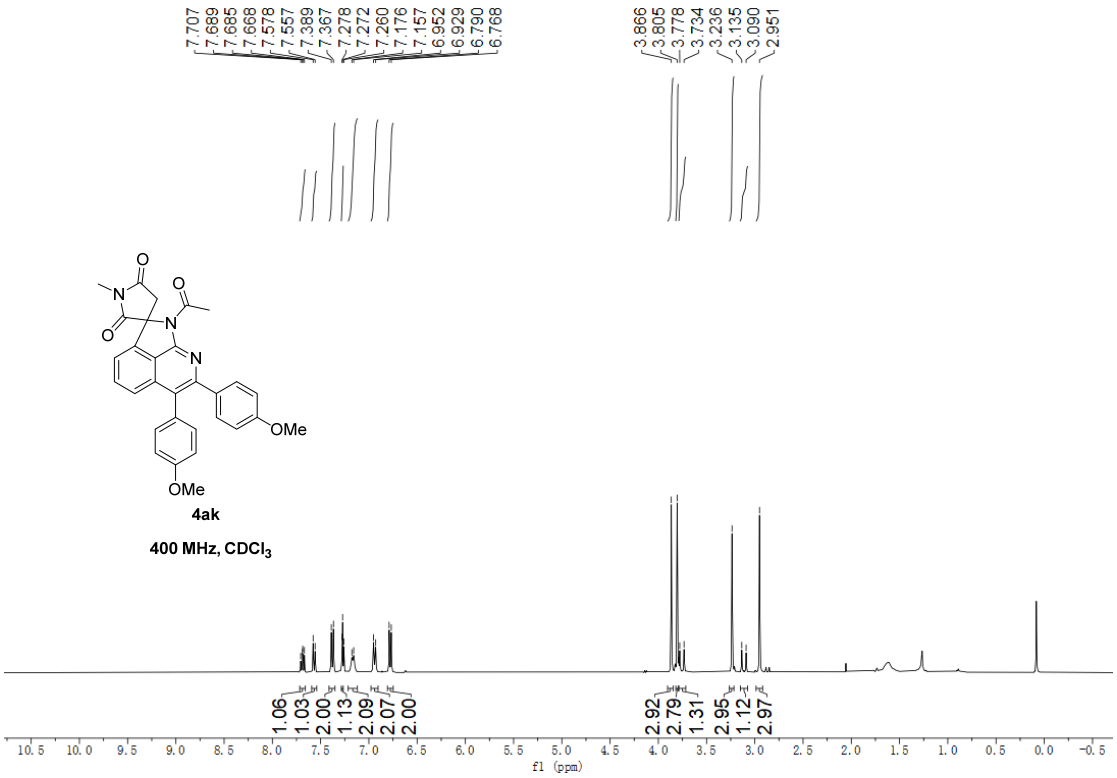
5aj

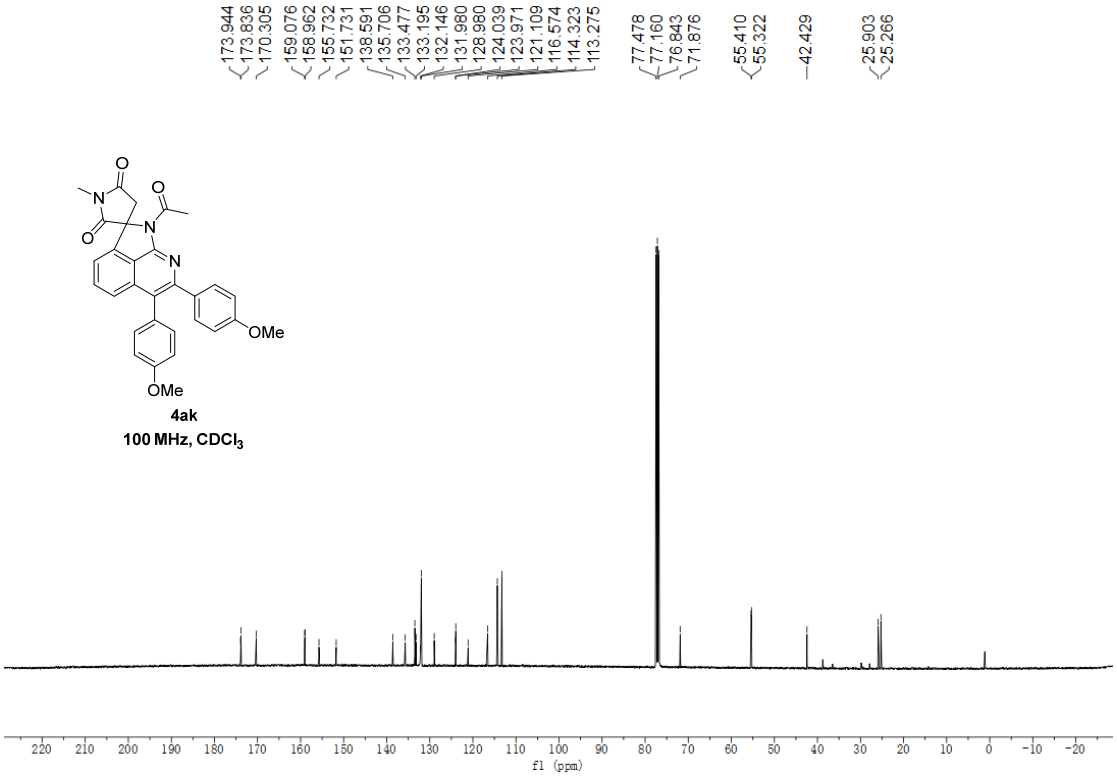
400 MHz, $CDCl_3$

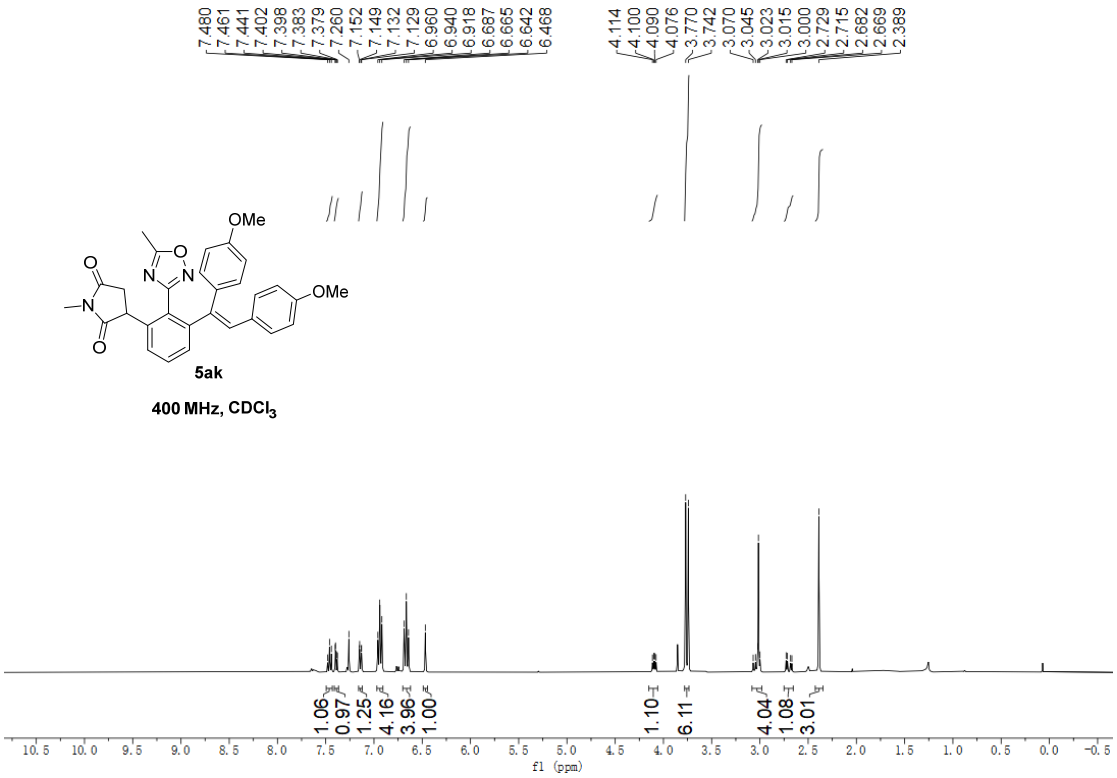


5aj

100 MHz, $CDCl_3$

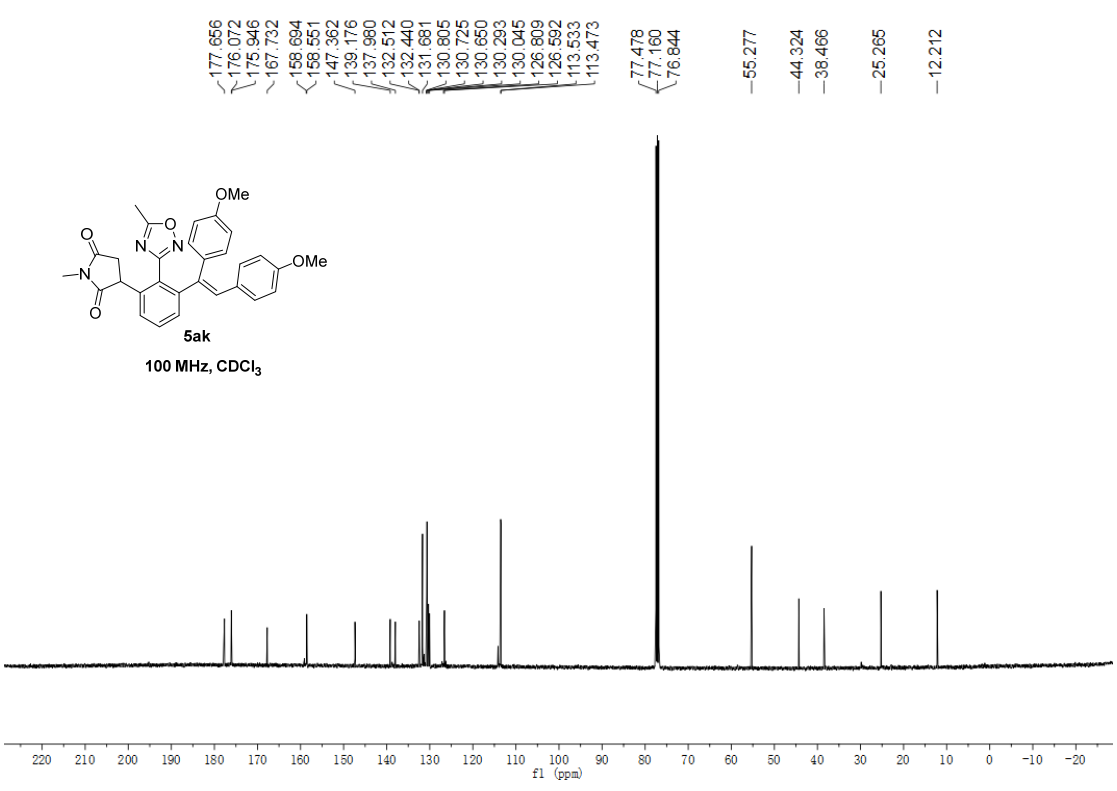

7.707
7.689
7.685
7.668
7.578
7.557
7.389
7.367
7.278
7.272
7.260
7.176
7.157
6.952
6.929
6.790
6.768
3.866
3.805
3.778
3.734
3.236
3.135
3.090
2.951
OMe
OMe
4ak
400 MHz, CDCl3
1.06
1.03
2.00
1.13
2.09
2.07
2.00
2.92
2.79
1.31
2.95
1.12
2.97
f1 (ppm)


173.944
173.836
170.305
159.076
158.962
155.732
151.731
138.591
135.706
133.477
133.195
132.146
131.980
128.980
124.039
123.971
121.109
116.574
114.323
113.275
77.478
77.160
76.843
71.876
55.410
55.322
42.429
25.903
25.266
OMe
OMe
4ak
100 MHz, CDCl3
f1 (ppm)



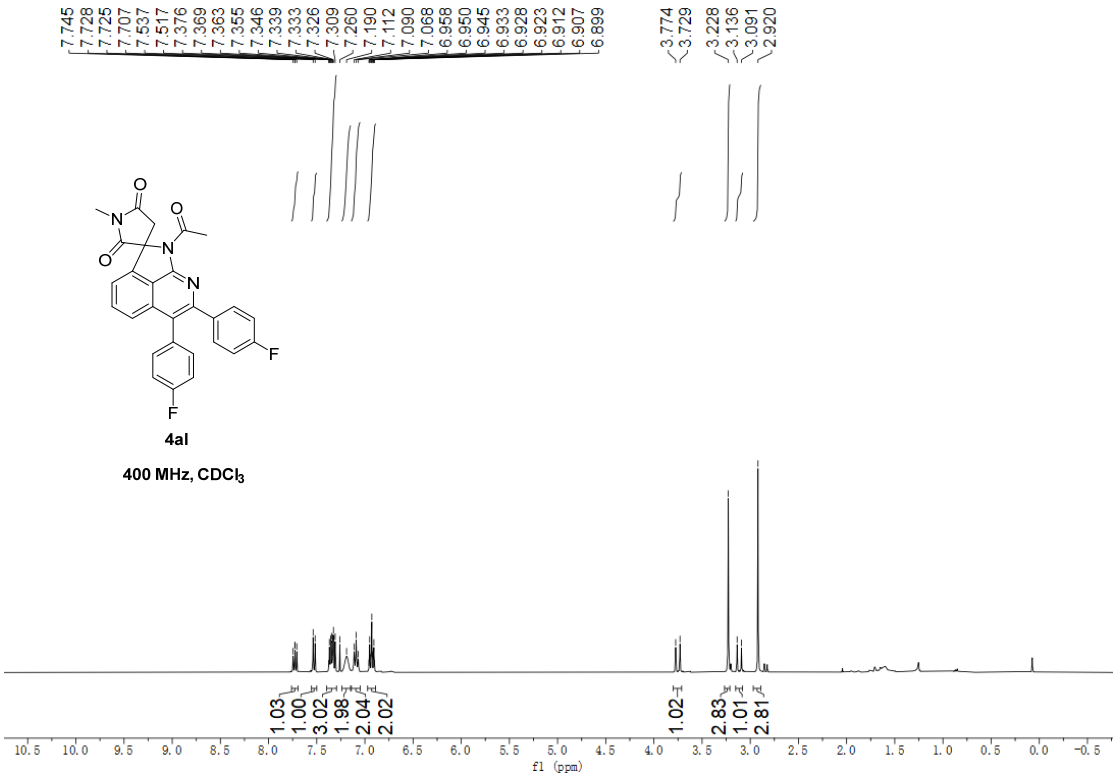
5ak

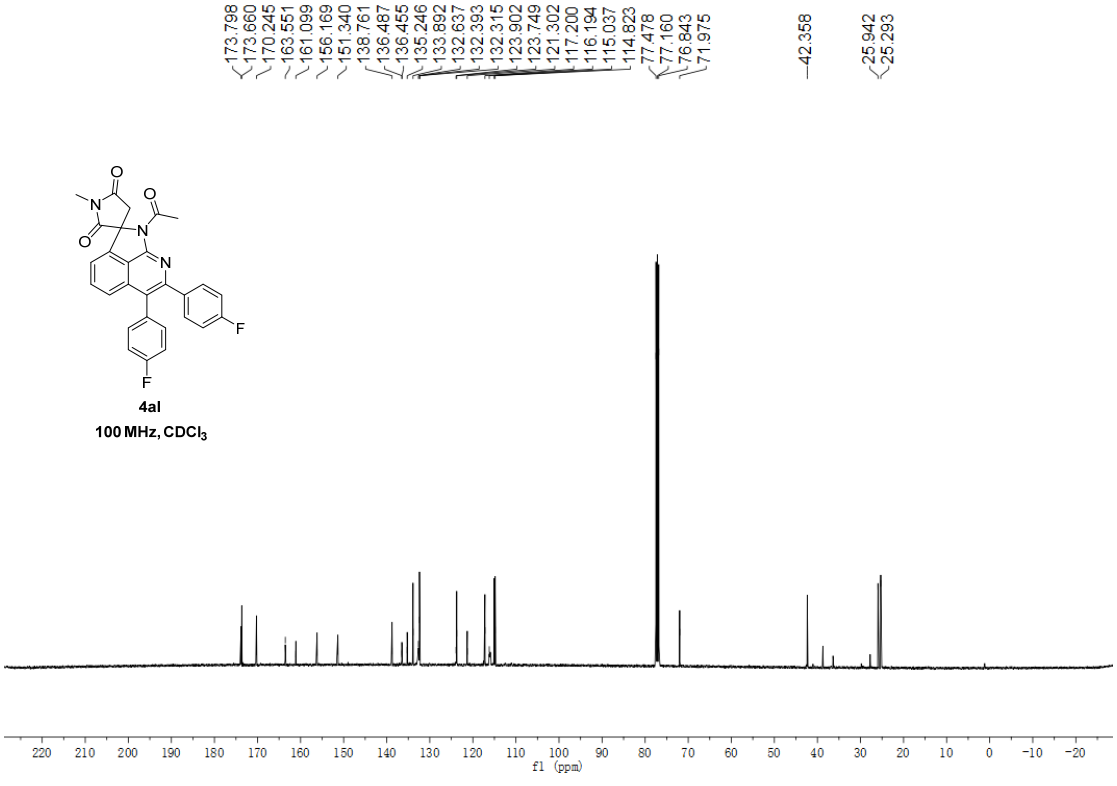
400 MHz, $CDCl_3$

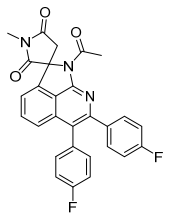


5ak

100 MHz, $CDCl_3$

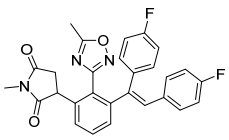

7.745
7.728
7.725
7.707
7.537
7.517
7.376
7.369
7.363
7.355
7.346
7.339
7.333
7.326
7.309
7.260
7.190
7.112
7.090
7.068
6.958
6.950
6.945
6.933
6.928
6.923
6.912
6.907
6.899
3.774
3.729
3.228
3.136
3.091
2.920
O
N
O
O
N
N
F
F
4aI
400 MHz, CDCl3
1.03
1.00
3.02
1.98
2.04
2.02
1.02
2.83
1.01
2.81
f1 (ppm)


173.798
173.660
170.245
163.551
161.099
156.169
151.340
138.761
136.487
136.455
135.246
133.892
132.637
132.393
132.315
123.902
123.749
121.302
117.200
116.194
115.037
114.823
77.478
77.160
76.843
71.975
42.358
25.942
25.293
O
N
O
O
N
N
F
F
4aI
100 MHz, CDCl3
f1 (ppm)



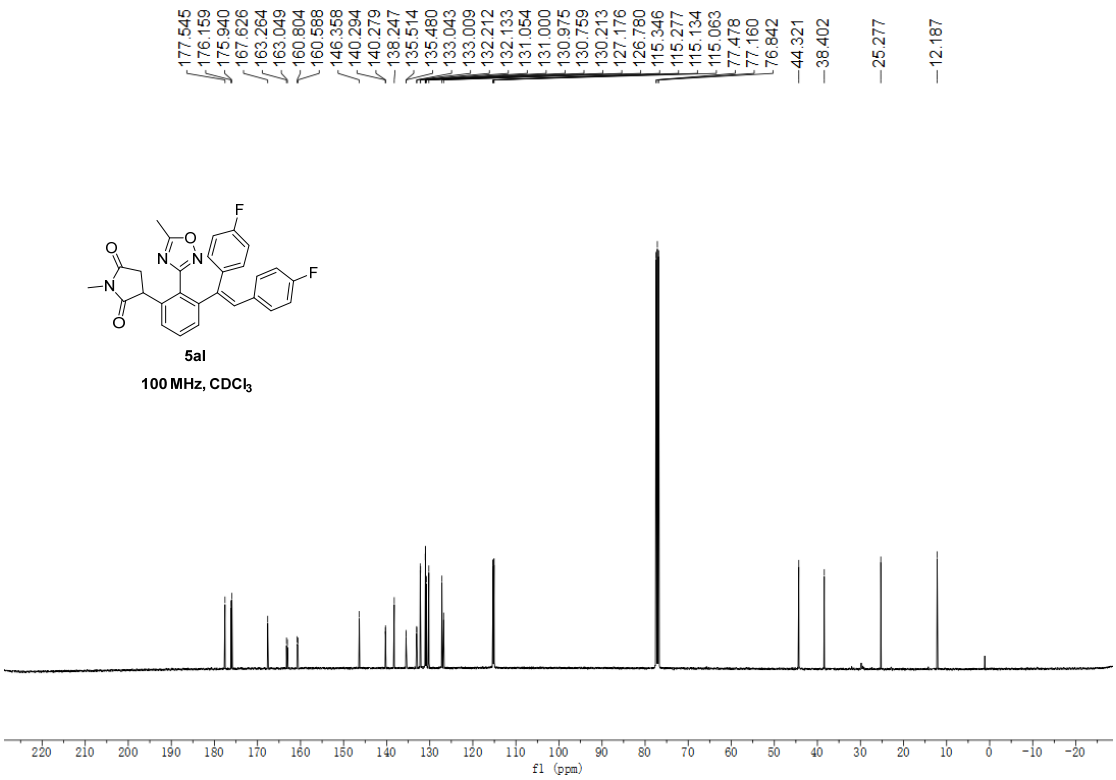
4al

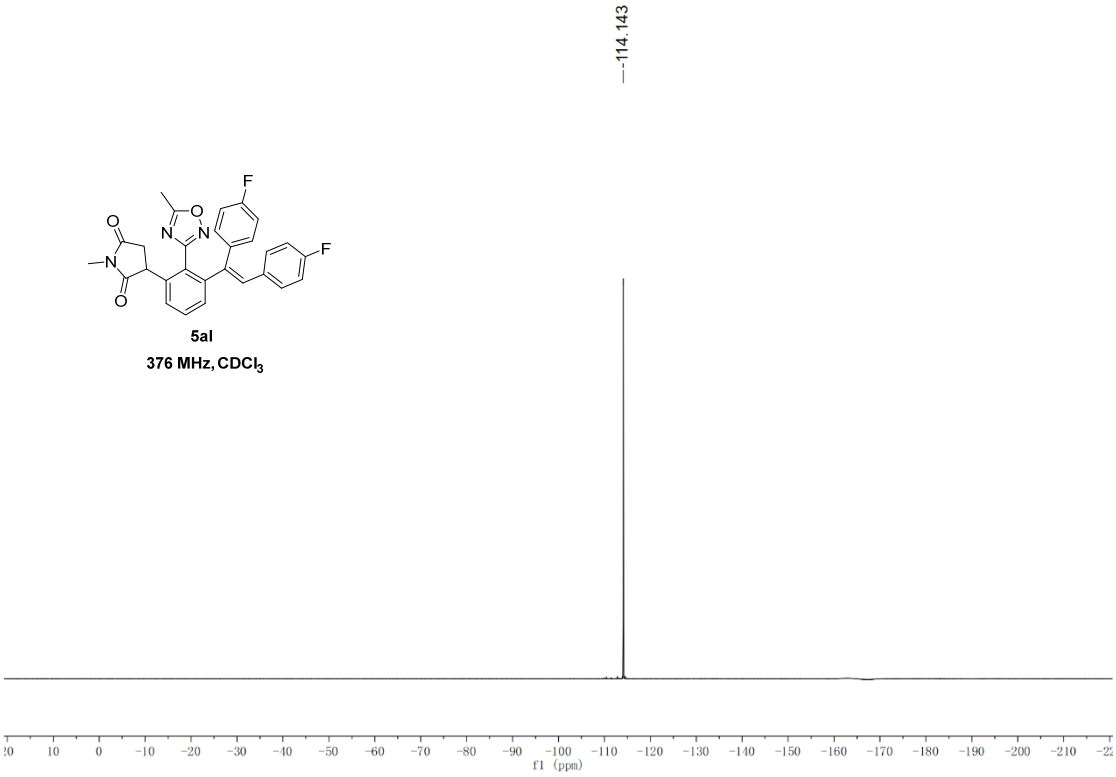
376 MHz, $CDCl_3$

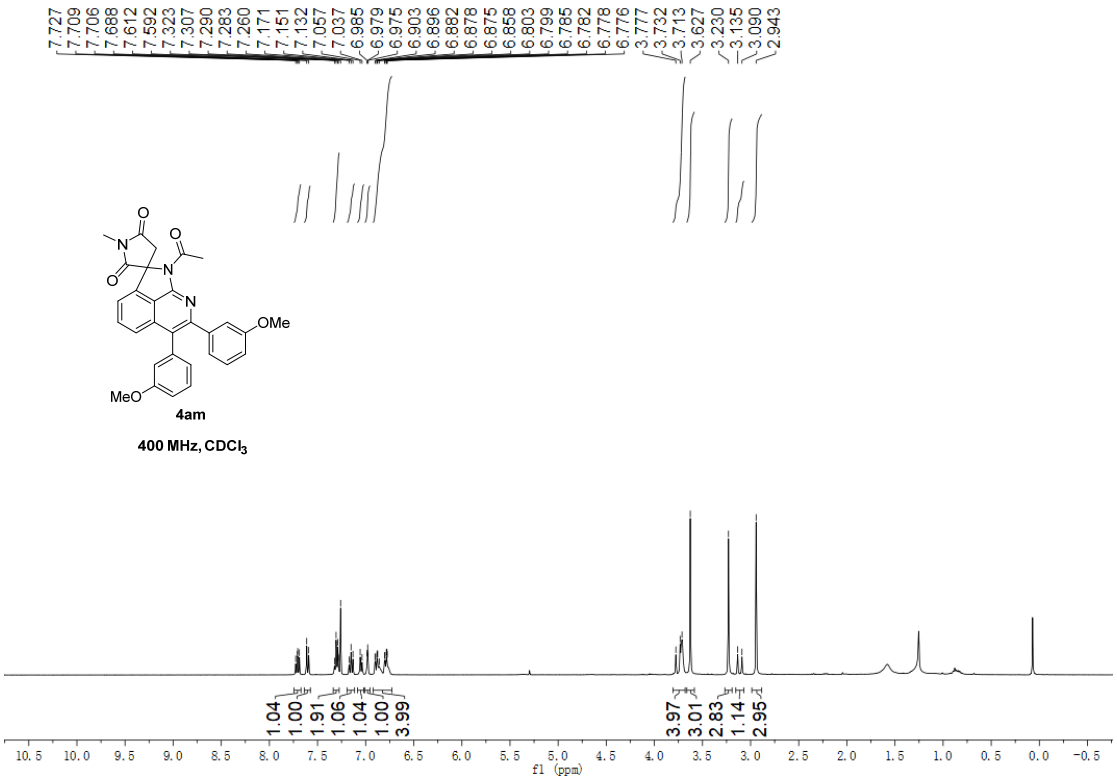


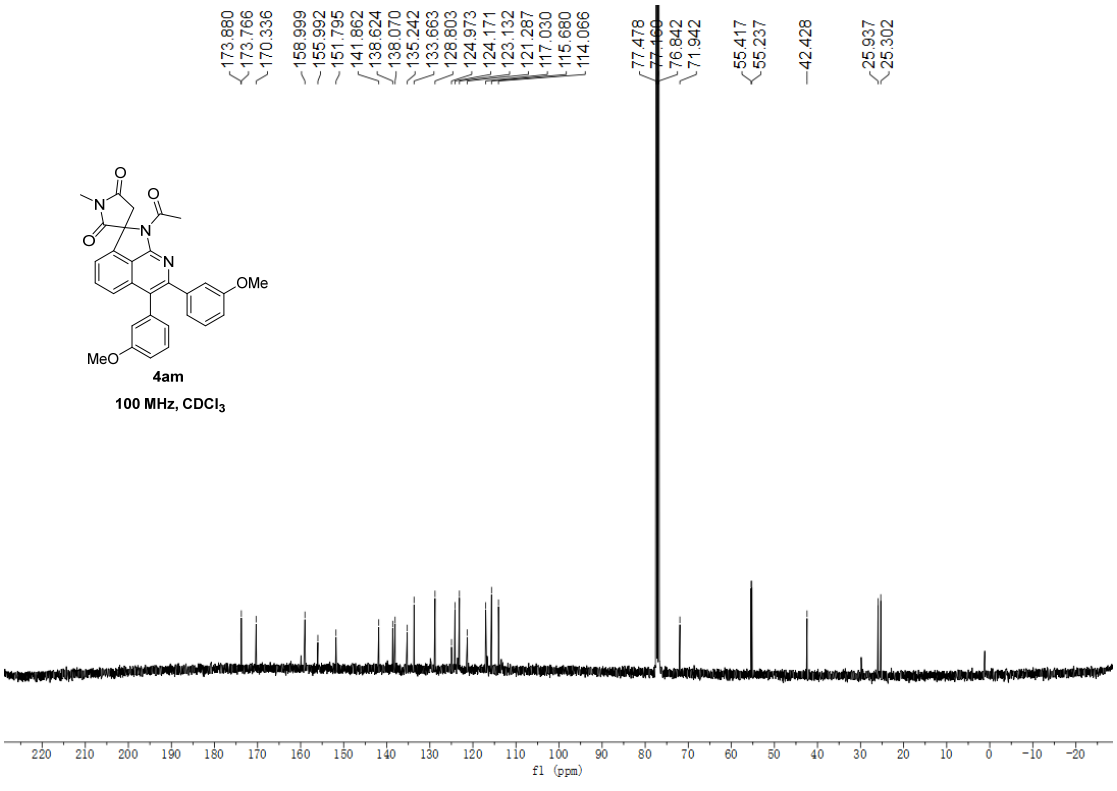
5al

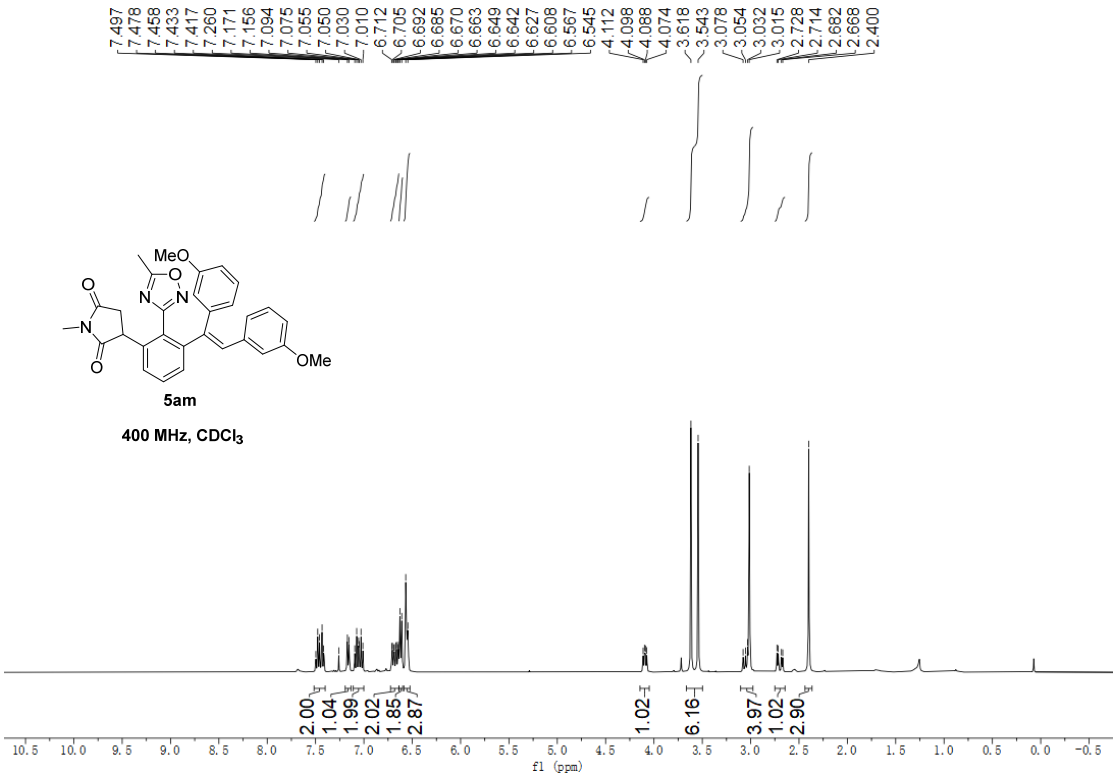
400 MHz, $CDCl_3$


177.545
176.159
175.940
167.626
163.264
163.049
160.804
160.588
146.358
140.294
140.279
138.247
135.514
135.480
133.043
133.009
132.212
132.133
131.054
131.000
130.975
130.759
130.213
127.176
126.780
115.346
115.277
115.134
115.063
77.478
77.160
76.842
44.321
38.402
25.277
12.187
F
F
O
O
N
O
N
N
O
5al
100 MHz, CDCl3
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


-114.143
F
F
O
O
N
O
N
N
O
5al
376 MHz, CDCl3
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

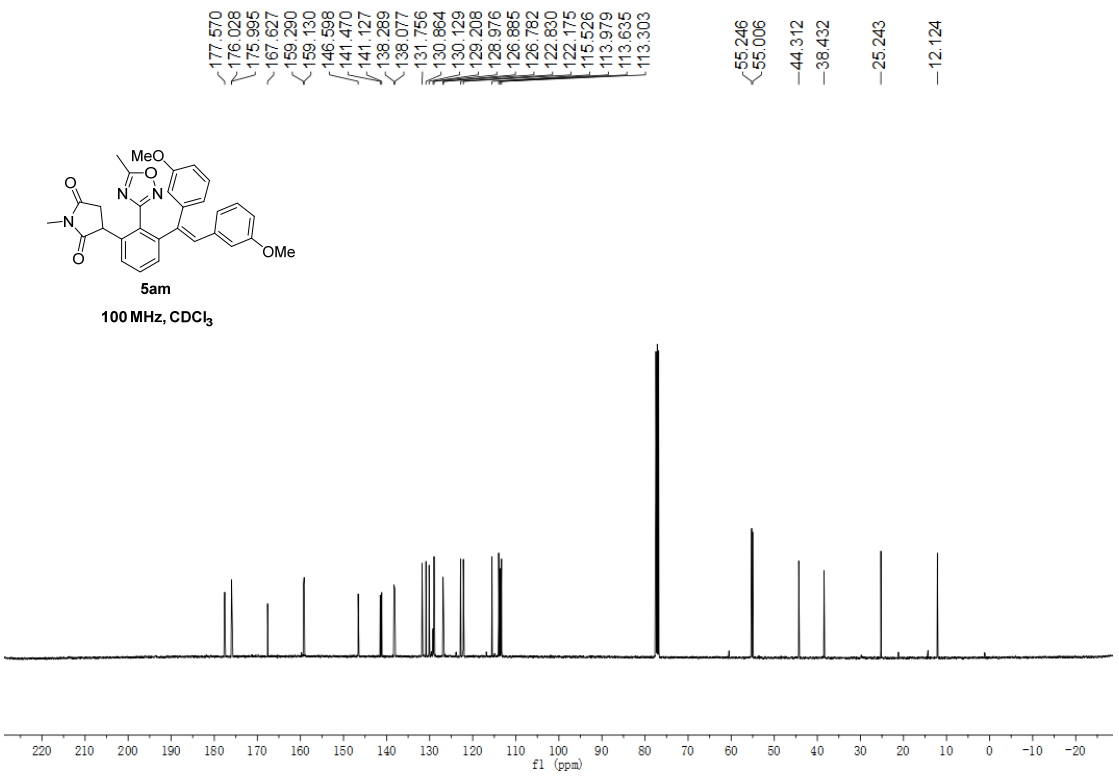

7.727
7.709
7.706
7.688
7.612
7.592
7.323
7.307
7.290
7.283
7.260
7.171
7.151
7.132
7.057
7.037
6.985
6.979
6.975
6.903
6.896
6.882
6.878
6.875
6.858
6.803
6.799
6.785
6.782
6.778
6.776
3.777
3.732
3.713
3.627
3.230
3.135
3.090
2.943
OMe
MeO
4am
400 MHz, CDCl3
1.04
1.00
1.91
1.06
1.04
1.00
3.99
3.97
3.01
2.83
1.14
2.95
f1 (ppm)


173.880
173.766
170.336
158.999
155.992
151.795
141.862
138.624
138.070
135.242
133.663
128.803
124.973
124.171
123.132
121.287
117.030
115.680
114.066
77.478
77.160
76.842
71.942
55.417
55.237
42.428
25.937
25.302
OMe
MeO
4am
100 MHz, CDCl3
f1 (ppm)



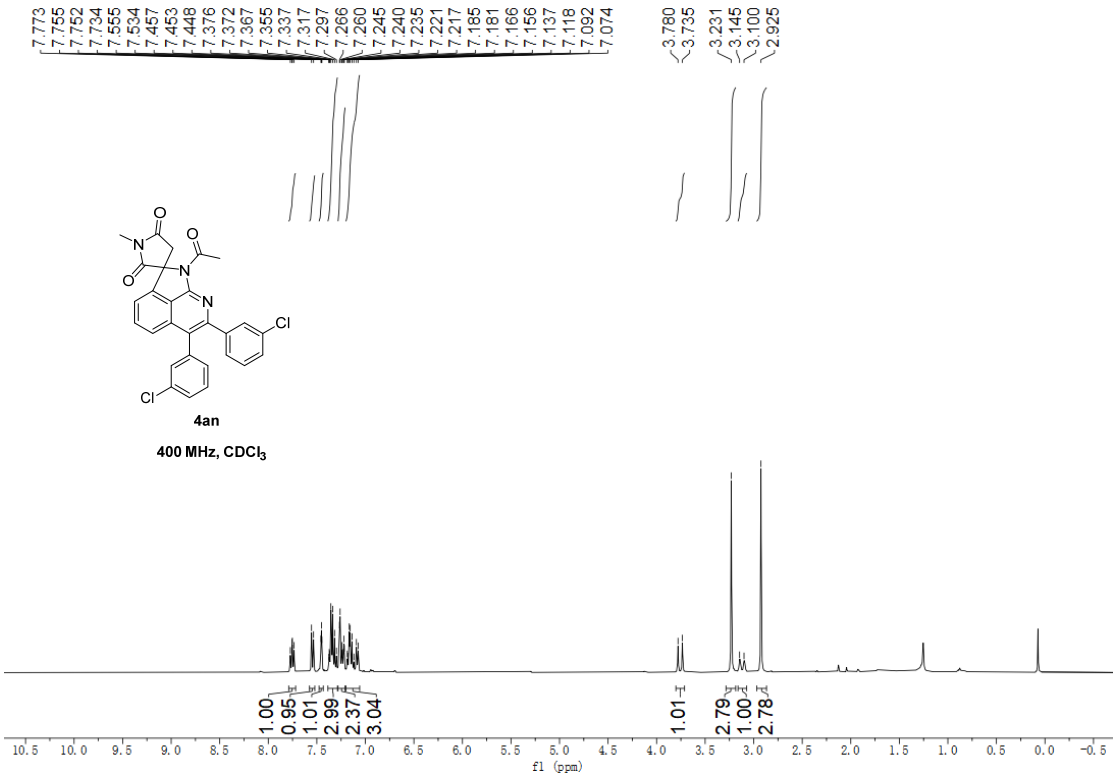
5am

400 MHz, $CDCl_3$



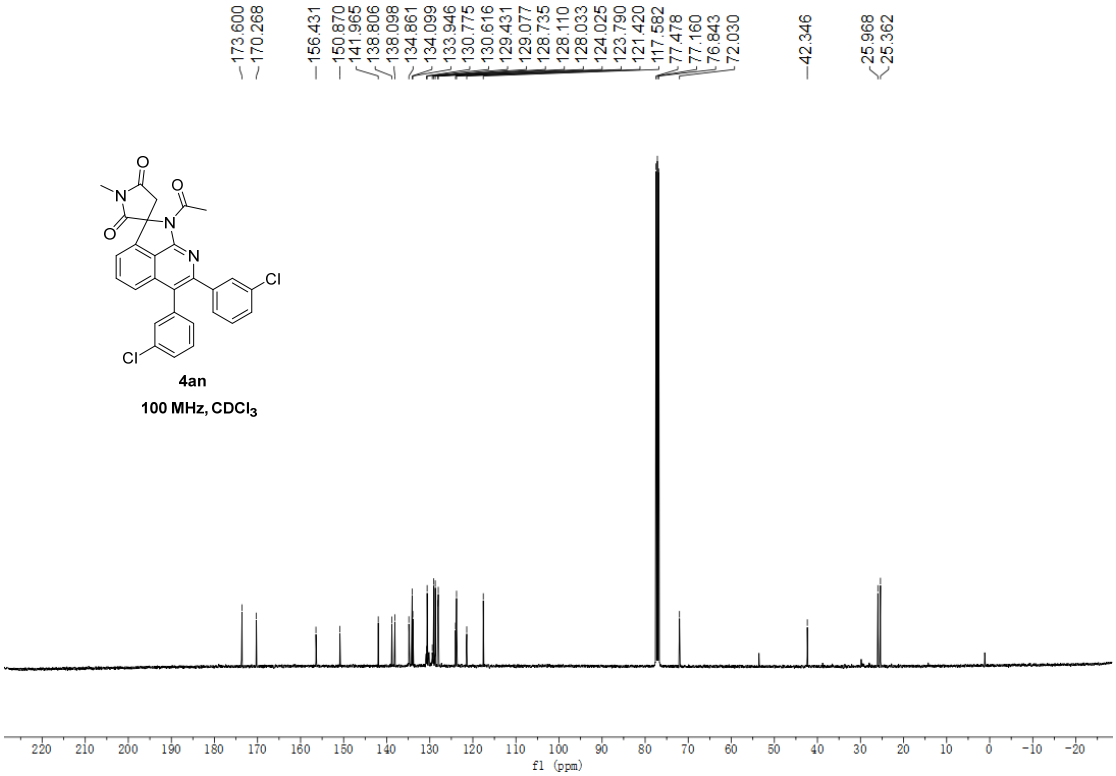
5am

100 MHz, $CDCl_3$



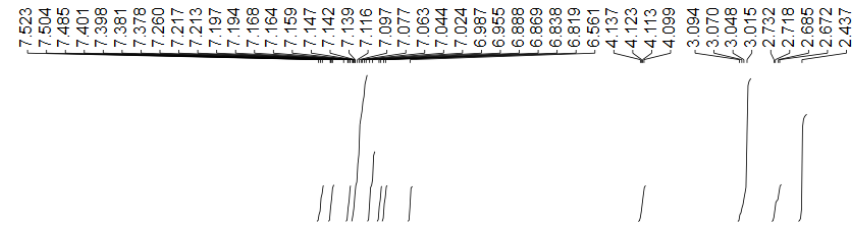
4an

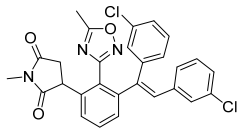
400 MHz, $CDCl_3$



4an

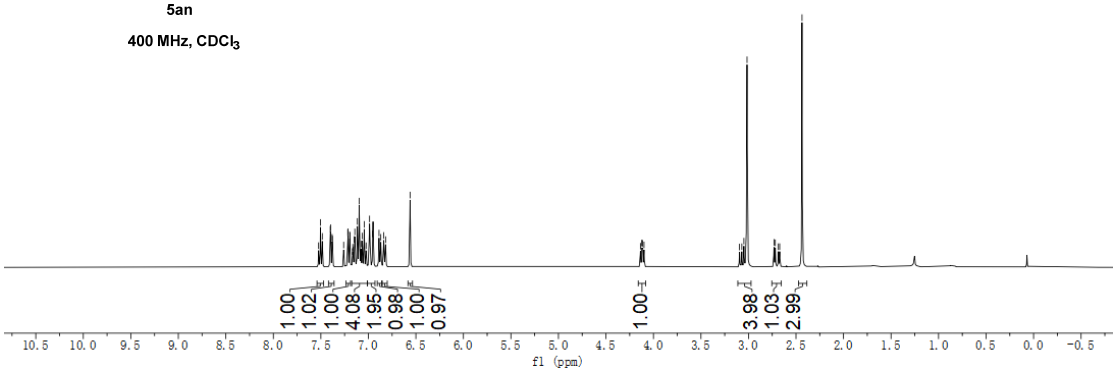
100 MHz, $CDCl_3$

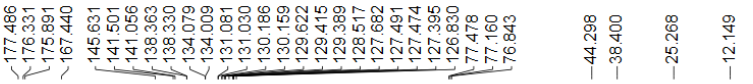


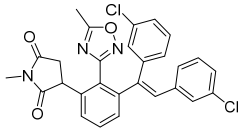


5an

400 MHz, $CDCl_3$

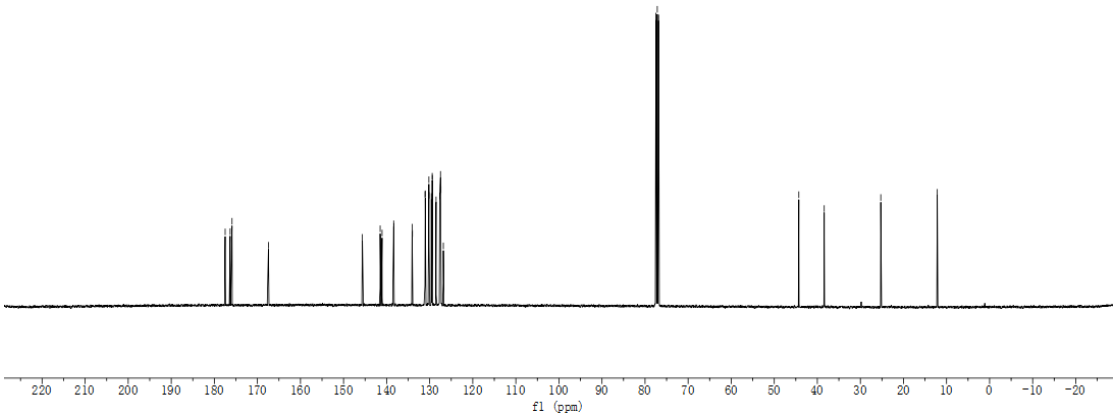


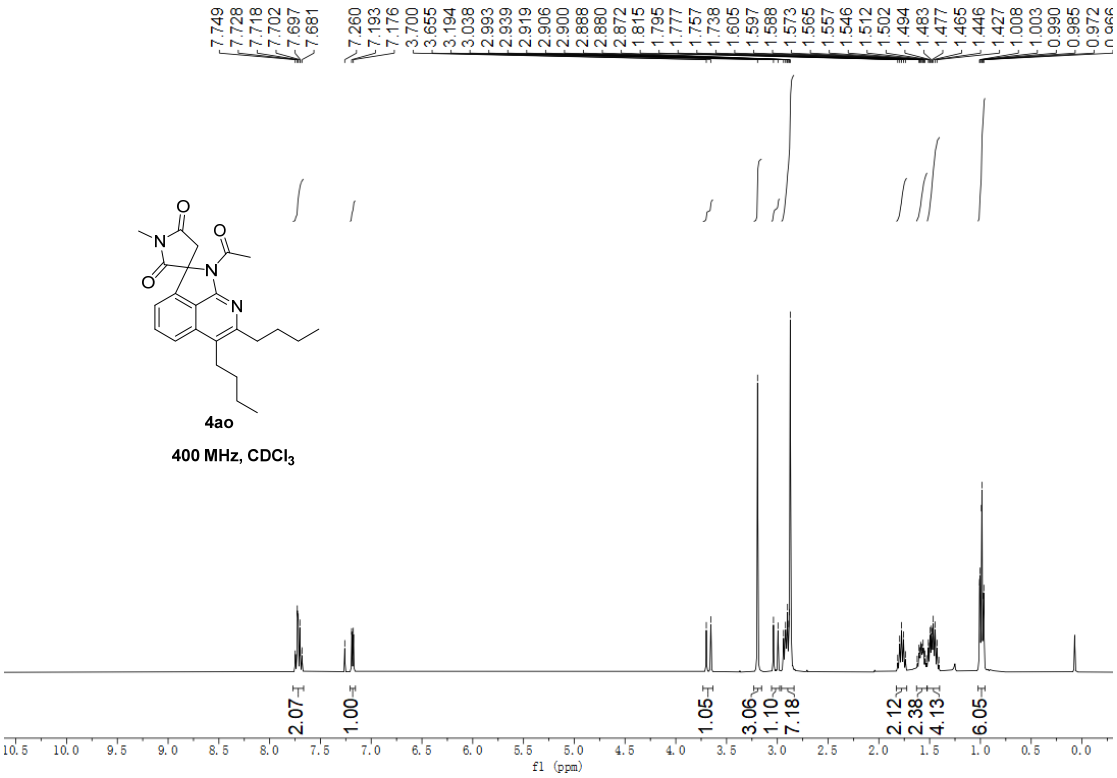




5an

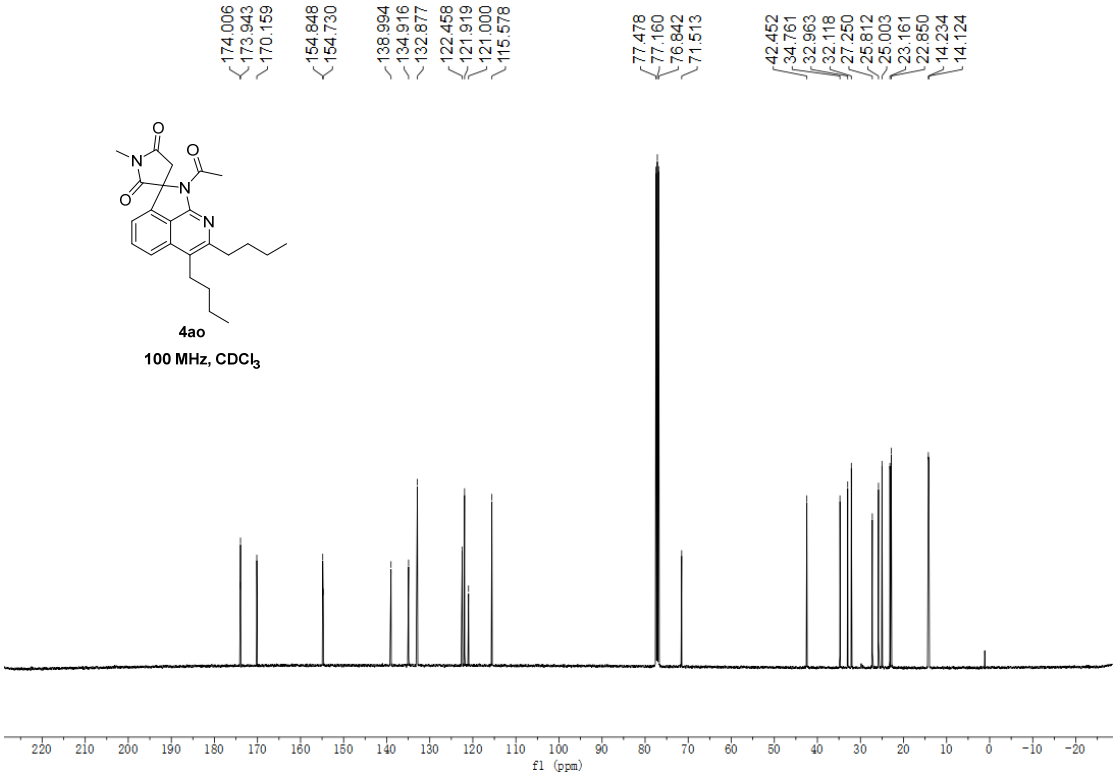
100 MHz, $CDCl_3$





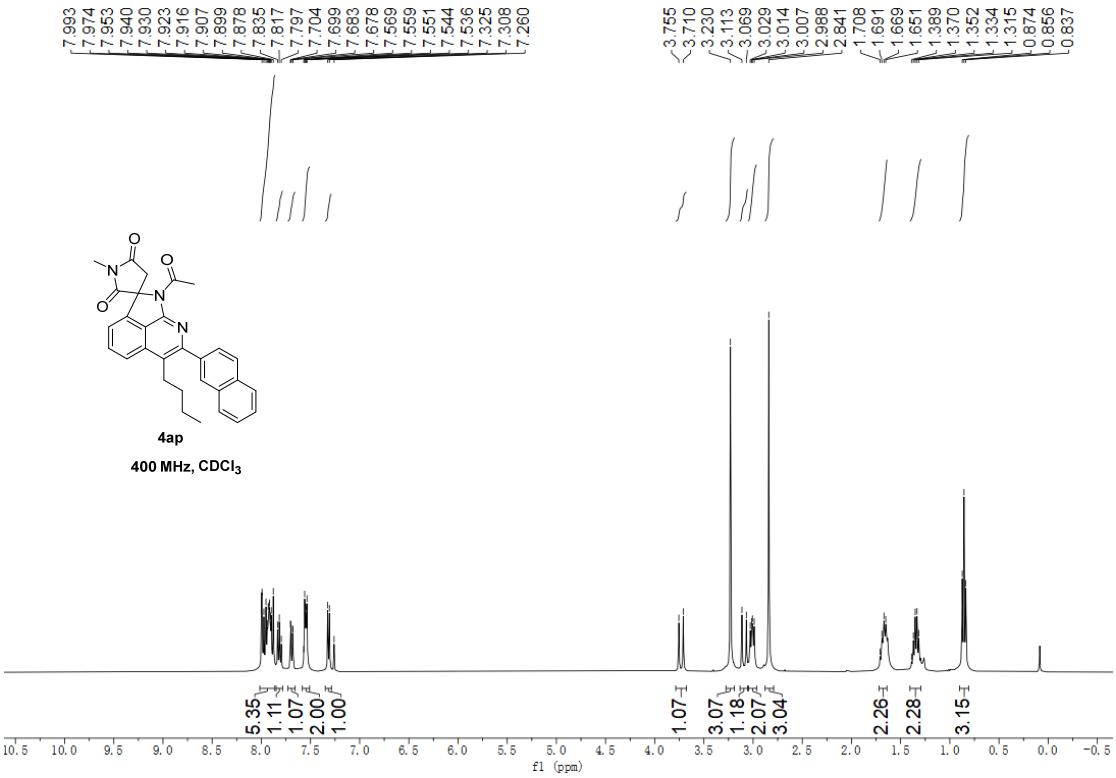
4ao

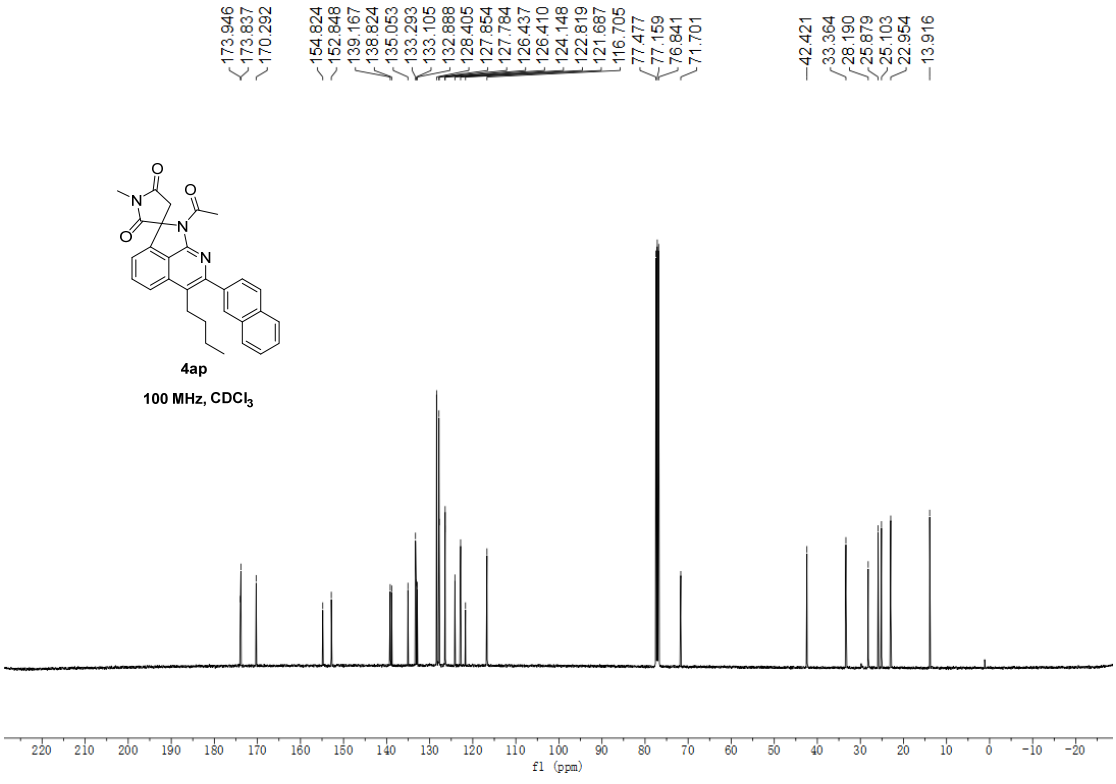
400 MHz, $CDCl_3$

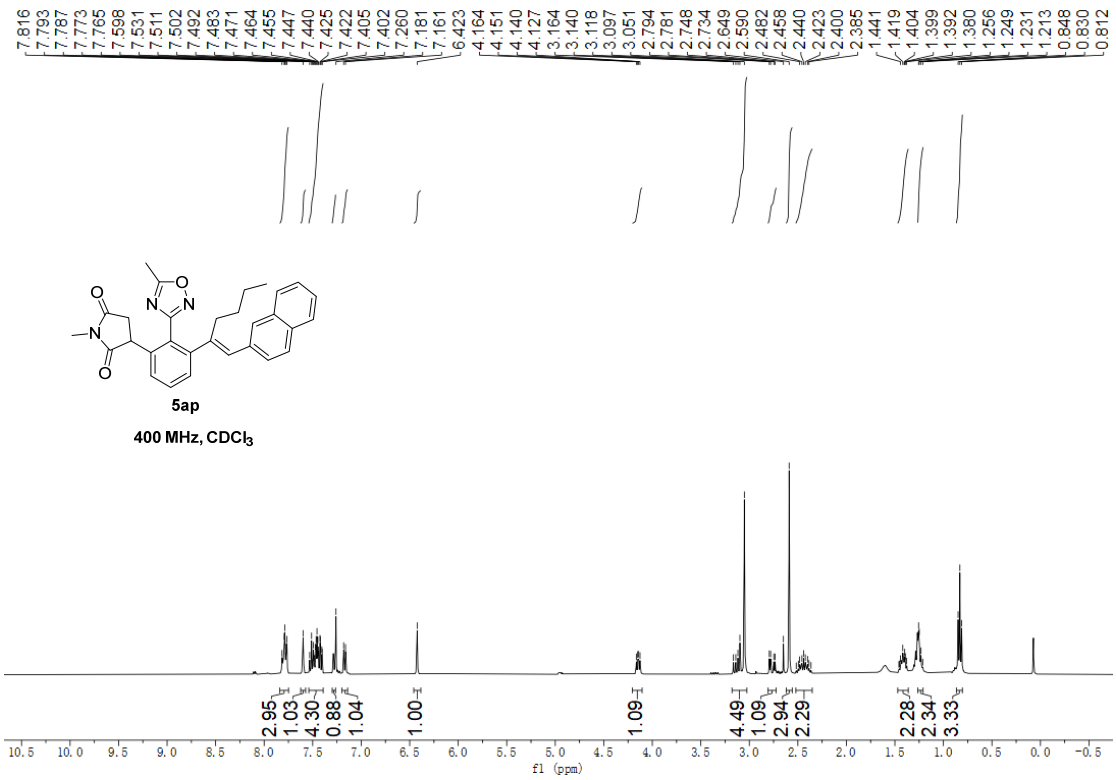


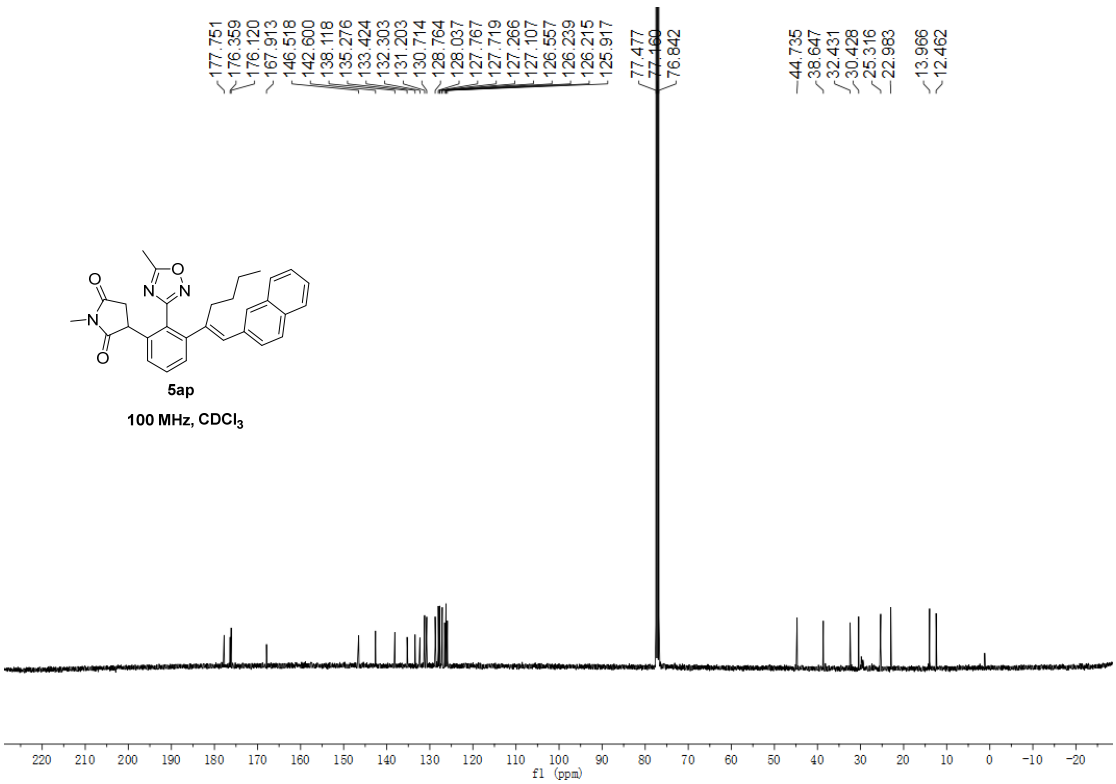
4ao

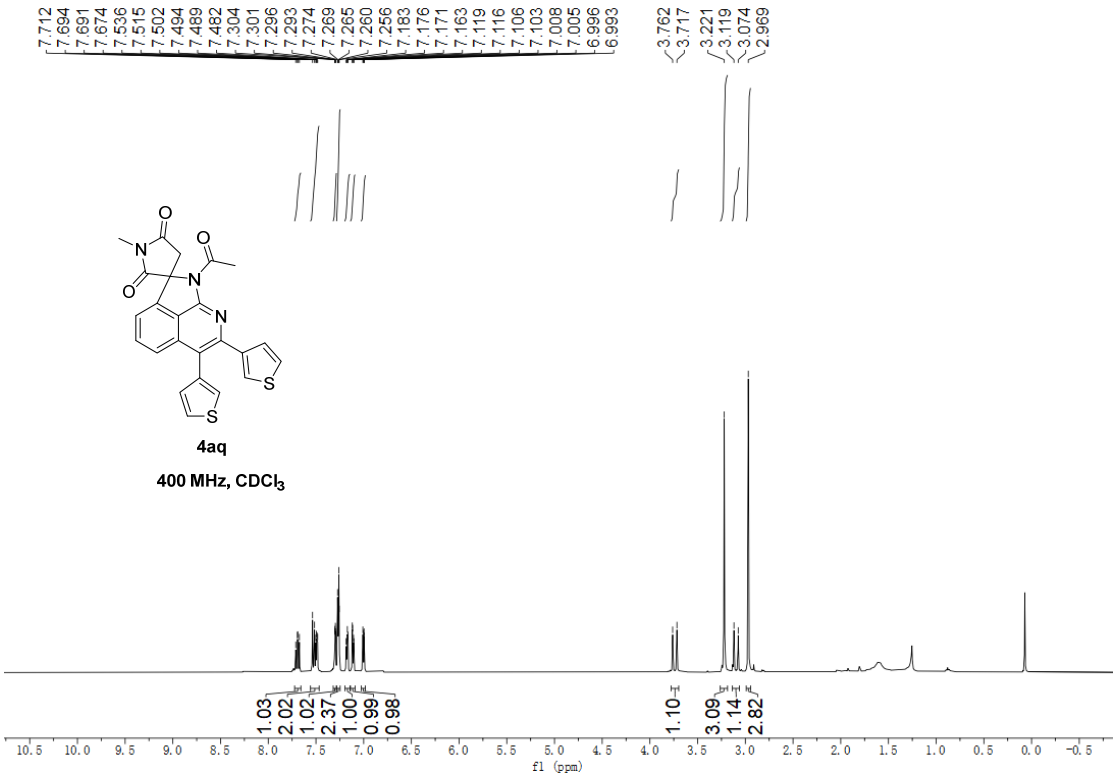
100 MHz, $CDCl_3$


7.993
7.974
7.953
7.940
7.930
7.923
7.916
7.907
7.899
7.878
7.835
7.817
7.797
7.704
7.699
7.683
7.678
7.569
7.559
7.551
7.544
7.536
7.325
7.308
7.260
3.755
3.710
3.230
3.113
3.069
3.029
3.014
3.007
2.988
2.841
1.708
1.691
1.669
1.651
1.389
1.370
1.352
1.334
1.315
0.874
0.856
0.837
4ap
400 MHz, CDCl3
5.35
1.11
1.07
2.00
1.00
1.07
3.07
1.18
2.07
3.04
2.26
2.28
3.15
f1 (ppm)


173.946
173.837
170.292
154.824
152.848
139.167
138.824
135.053
133.293
133.105
132.888
128.405
127.854
127.784
126.437
126.410
124.148
122.819
121.687
116.705
77.477
77.159
76.841
71.701
42.421
33.364
28.190
25.879
25.103
22.954
13.916
4ap
100 MHz, CDCl3
f1 (ppm)

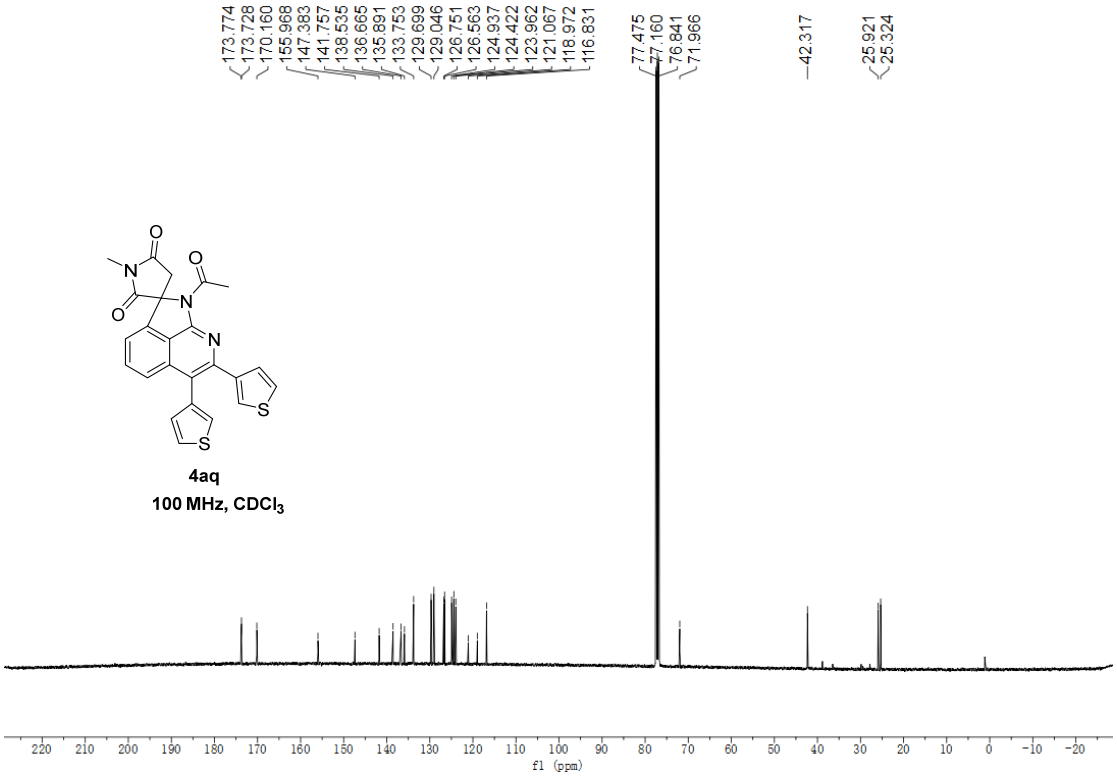

7.816
7.793
7.787
7.773
7.765
7.598
7.531
7.511
7.502
7.492
7.483
7.471
7.464
7.455
7.447
7.440
7.425
7.422
7.405
7.402
7.260
7.181
7.161
6.423
4.164
4.151
4.140
4.127
3.164
3.140
3.118
3.097
3.051
2.794
2.781
2.748
2.734
2.649
2.590
2.482
2.458
2.440
2.423
2.400
2.385
1.441
1.419
1.404
1.399
1.392
1.380
1.256
1.249
1.231
1.213
0.848
0.830
0.812
5ap
400 MHz, CDCl3
2.95
1.03
4.30
0.88
1.04
1.00
1.09
4.49
1.09
2.94
2.29
2.28
2.34
3.33
f1 (ppm)


177.751
176.359
176.120
167.913
146.518
142.600
138.118
135.276
133.424
132.303
131.203
130.714
128.764
128.037
127.767
127.719
127.266
127.107
126.557
126.239
126.215
125.917
77.477
77.160
76.842
44.735
38.647
32.431
30.428
25.316
22.983
13.966
12.462
5ap
100 MHz, CDCl3
f1 (ppm)



4aq

400 MHz, $CDCl_3$



4aq

100 MHz, $CDCl_3$