Supporting Information

Metal- and photocatalyst-free CF_3-modification of *N*-containing fusion skeletons in photo-flow chemistry

Ting Lv, [†] Chenxi Gu, [†] Yuchen Zhu, [†] Yali He, [†] Wen Lin, [†] Wenjian Wang, [†] Xingyi Zhu, [†*] and Jianjun Li [†,‡*]

[†] Zhejiang Key Laboratory of Green Manufacturing Technology for Chemical Drugs, College of Pharmaceutical Sciences, Zhejiang University of Technology, Hangzhou 310014, P. R. China

[‡] State Key Laboratory of Green Chemical Synthesis and Conversion, Zhejiang University of Technology, Hangzhou 310014, P. R. China

* Corresponding Author.

E-mail: lijianjun@zjut.edu.cn

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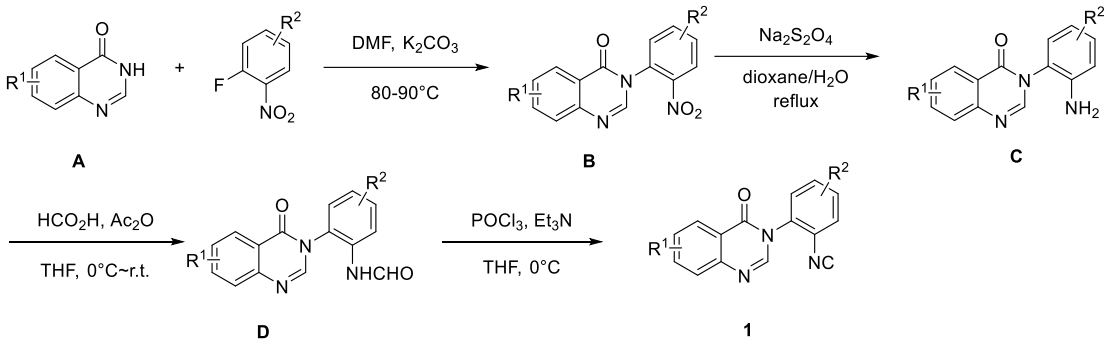
1. General information

Unless otherwise specified, all reagents are obtained from commercial sources and can be used without further purification. Chromatographic purification of products was performed by flash column chromatography on silica gel (200-300 meshes). Thin-layer chromatography (TLC) was carried out on silica plates (TLC Silica GF254). The compounds were visualized by projecting UV light onto the developed plates. The experiments were conducted in a 10 mL of sealed tube or a 100 mL of round bottom flask for gram-scale synthesis. The 450-460 nm light irradiation experiments were performed using a 25 W JG LED lamp from Xuzhou Ai Jia Electronic Technology Co., Ltd. The distance from the light source to the irradiation vessel was approximately 1 cm, and no filter was used in our study. When using LED, a fan was employed to ensure reactions remained at or near room temperature. ^{1}H NMR (400/600 MHz), ^{13}C NMR (101/151 MHz), and ^{19}F NMR (376/565 MHz) spectra were recorded on a Varian and Bruker spectrometers with $CDCl_3$ or DMSO-d_6 as solvent and tetramethylsilane (TMS) as internal standards. Data are reported as follows: Chemical shift (number of protons, multiplicity, coupling constants). Coupling constants were quoted to the nearest 0.1 Hz and multiplicity reported according to the following convention: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublets, ddd = doublet of double doublets, td = triplet of doublets, pd = pentalet of doublets. HRMS spectra were recorded on a Bruker Impact II UHR-QTOF spectrometer using ESI on a TOF mass analysis. The ^{13}C CP/MAS NMR spectra were recorded by Bruker 400 MHz. FT-IR spectra of the samples were recorded by Nicolet iS 10. Gas sorption isotherms were obtained with Micromeritics ASAP 2460 2.01 accelerated surface area and porosimetry analyzers at certain temperatures. Surface areas were calculated from the adsorption data using Brunauer-Emmett-Teller (BET) methods. The pore-size-distribution curves were obtained from the adsorption branches using the non-local density functional theory (NLDFT) method.

2. General Synthetic Procedures

2.1. General procedure for the synthesis of substrates 1



Scheme S1 Synthesis of substrates 1

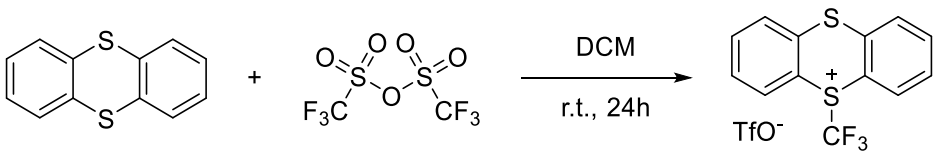
To begin with, a mixture of quinazolin-4(3*H*)-one **A** (10.0 mmol) in 25 mL of *N*,*N*-dimethylformamide (DMF) were added K_2CO_3 (15.0 mmol, 1.5 equiv.) and 1-fluoro-2-nitrobenzene (12 mmol, 1.2 equiv.) sequentially. The mixture was refluxed at 80-90 ℃ for 8 h in a flask equipped with a guard tube. The reaction was quenched with H_2O and extracted with ethyl acetate (25 × 3 mL). The combined organic layers were washed several times with saturated brine, dried over anhydrous Na_2SO_4, and concentrated under vacuum. Crude product was used directly in the next step.

Then, a solution of $Na_2S_2O_4$ (40.0 mmol, 5.0 equiv.) in H_2O (40 mL) was added to the solution of **B** (8.0 mmol) in dioxane (40 mL). The reaction mixture was stirred at reflux temperature for 4 h then cooled to room temperature and was poured into water. The resulting precipitate was filtered off, washed with water (50 mL × 2) and dried in an oven to give **C**.

Next, acetic formic anhydride (24.0 mmol), which was newly prepared from the reaction of acetic anhydride (2.3 mL, 24.0 mmol) with formic acid (1.1 mL, 27.0 mmol) at 55 °C for 2 h, was added dropwise to a mixture of **C** (4.0 mmol) in 6.0 mL THF at 0 °C. The mixture was warmed to room temperature and stirred for another 3 h. Then, the reaction was quenched by saturated $NaHCO_3$ and extracted with ethyl acetate. The combined organic layers were washed with saturated brine, dried over anhydrous Na_2SO_4 and concentrated in vacuum to give the products **D**. These formamides were used for the subsequent dehydration reaction without further purification.

$POCl_3$ (1.1 mL, 12.0 mmol) was added *via* syringe pump to a mixture of Et_3N (5.1 mL, 36.0 mmol) and **D** (4.0 mmol) in THF (6 mL) at 0 °C within 2 h. After that, the resulting mixture was stirred at 0 °C for another 2 hours. Then, the mixture was quenched with $NaHCO_3$ and extracted with DCM. The combined organic layer was washed with saturated brine, dried over anhydrous Na_2SO_4 and concentrated in vacuum. The residue was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the substrates **1** in 25-50% yield.[1]

2.2. General procedure for the synthesis of substrates 2

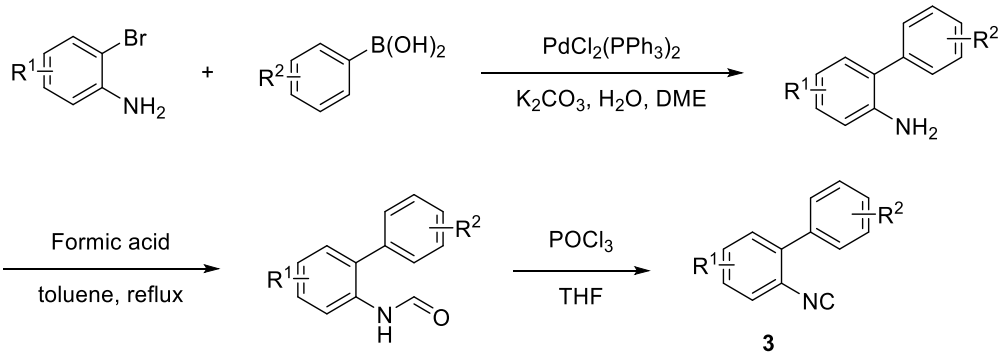


2

Scheme S2 Synthesis of substrates 2

In a 250 mL two-neck round-bottom flask with a magnetic stir bar, thianthrene (5.76 g, 1 equiv.) was dissolved in DCM (60 mL) and triflic anhydride (5 mL, 1.1 equiv.) was added at room temperature. A color change to light purple was observed followed by darkening, and ultimately solid particle formation. The reaction mixture was stirred at room temperature for 24 hours. The reaction mixture was quenched with a saturated $NaHCO_3$ solution (40 mL), extracted with DCM, and dried over Na_2SO_4. The organic layer was evaporated under reduced pressure, resulting in a light brown residue. The crude product was recrystallized by using a mixture of DCM and n-pentane to give the pure substrates **2**.[2]

2.3. General procedure for the synthesis of substrates 3



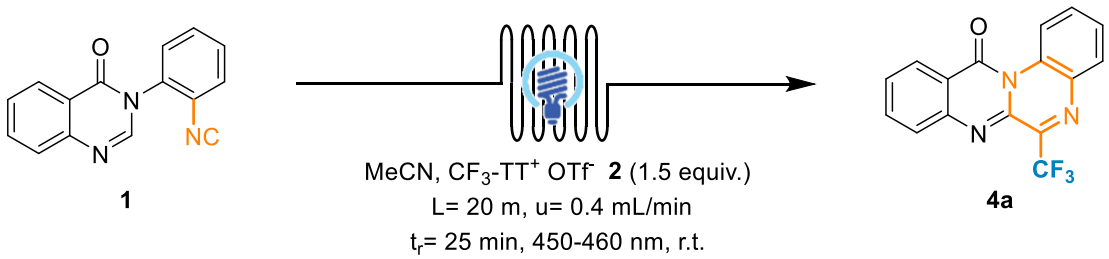
3

Scheme S3 Synthesis of substrates 3

2-Bromo-aniline (1.72 g, 10 mmol, 1.0 equiv.), boronic acid (1.34 g, 11.0 mmol, 1.1 equiv.) and an aqueous solution of K_2CO_3 (2 M, 25 mL) were placed in a three-necked flask under N_2. Then, DME (25 mL) was added and the mixture was stirred for 10-30 min. To the stirred mixture, $PdCl_2(PPh_3)_2$ (71.1 mg, 0.1mmol, 0.01 equiv.) was added and the mixture was stirred at 80 °C for 6 h. The mixture was then cooled to room temperature and diluted with ethyl acetate. The organic layer was washed with water and dried over anhydrous sodium sulfate. The solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate = 20/1) to provide 2-phenylaniline as a white solid (1.44 g, 84%).

A solution of 2-phenylaniline (1.70 g, 10 mmol) and formic acid (0.9 mL) in toluene (15 mL) was refluxed under N_2 atmosphere. The reaction was monitored by TLC. After the reaction was completed, volatile materials were evaporated under reduced pressure. The crude product was purified by flash column chromatography on silica gel to afford pure 2-phenylformanilide (1.88 g, 95%). A THF solution (20 mL) of 2-phenylformanilide (1.88 g, 9.5 mmol) and NEt_3 (7 mL, 50 mmol) was cooled to 0 °C. Then, $POCl_3$ (1.2 mL, 11 mmol) was added dropwise and the mixture was stirred at 0 °C for 1 h. After the reaction was completed, the mixture was quenched by aqueous saturated Na_2CO_3 solution and stirred for 0.5 h. The mixture was extracted with ethyl acetate (20 mL × 3). The combined organic layer was dried over anhydrous sodium sulfate. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate = 50/1) to provide pure isocyanide product as a pale oil (1.50 g, 88%).[3]

2.4. General procedure for the synthesis of product 4a

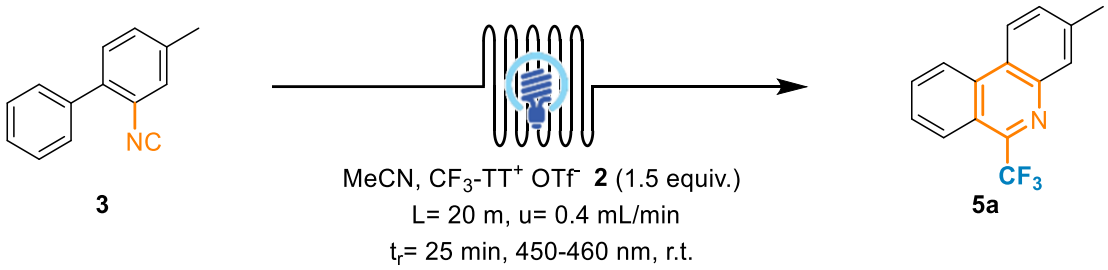


Scheme S4 Synthesis of product 4a

To an oven-dried vial were added reactants **1** (2.0 mmol) and **2** (3.0 mmol, 1.5 equiv.) which were

dissolved in 20 mL of MeCN, and the reaction solution was passed into a 1/16-inch tube using a feed pump, the reaction tube was than irradiated with 450-460 nm blue light at a controlled flow rate of 0.4 mL/min. After 1 hour, take 5 mL of the reaction mixture from the collection flask. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The residue was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the final products **4a**.

2.5. General procedure for the synthesis of product 5a



Scheme S5 Synthesis of substrates 5a

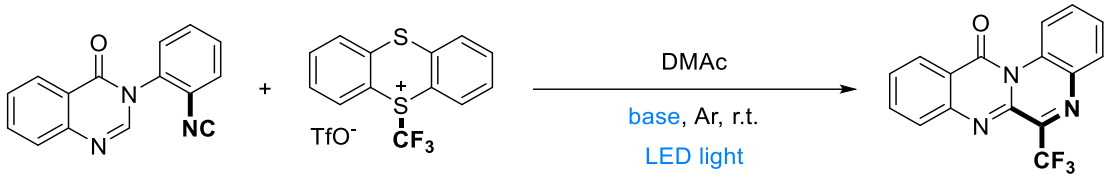
To an oven-dried vial were added reactants **3** (2.0 mmol) and **2** (3.0 mmol, 1.5 equiv.) which were dissolved in 20 mL of MeCN, and the reaction solution was passed into a 1/16-inch tube using a feed pump, the reaction tube was than irradiated with 450-460 nm blue light at a controlled flow rate of 0.4 mL/min. After 1 hour, take 5 mL of the reaction mixture from the collection flask. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The residue was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the final products **5a**.

Figure S1 Continuous flow photoreactor

3. Experimental procedures

3.1. Optimization of reaction condition

Table S1 Optimization of base and light source [a]

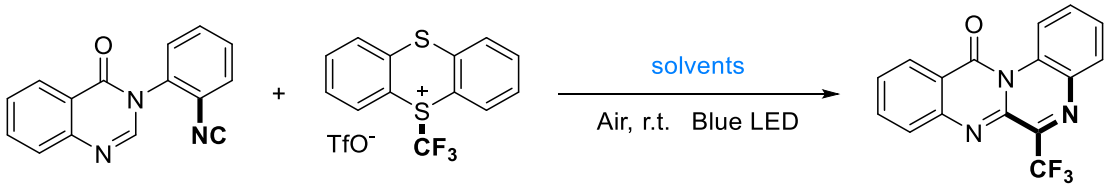


1 **2** **4a**

Entry	**Base**	**λ (nm)**	Yield (%)[b]
1	Na_2HPO_4	390-400	63
2	NaOAc	390-400	54
3	Na_2HPO_4	410-420	63
4	Na_2HPO_4	430-440	65
5	Na_2HPO_4	450-460	70
6[c]	Na_2HPO_4	450-460	68
7	NaOAc	450-460	56
8	K_2HPO_4	450-460	63
9	Et_3N	450-460	45
10	DIPEA	450-460	43
11	TMEDA	450-460	37
12	without base	450-460	78
13	without base	530-540	trace
14	without base	400-800	25

[a] Reaction conditions: **1** (0.5 mmol), **2** (0.5 mmol, 1.0 equiv.), base (0.4 mmol, 2.0 equiv.), DMAc (5 mL), 25-30 °C, under argon atmosphere, in batch, 6 h. [b] Isolated yield based on **1**. [c] Under air.

Table S2 Optimization of solvents [a]

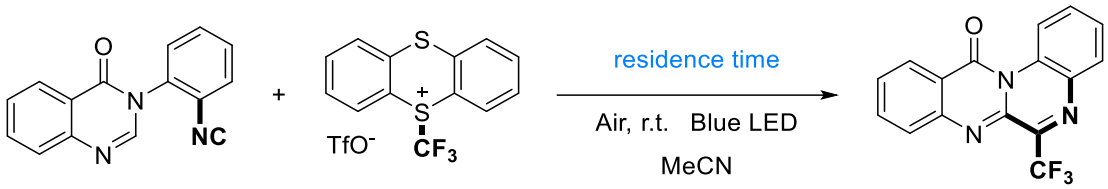


1 **2** **4a**

Entry	**Solvents**	Yield (%)[b]
1	DMAc	72
2[c]	DMAc	44
3	DMF	69
4	MeCN	79
5[c]	MeCN	25
6	MeOH	n.d.
7	DCM	trace
8	EtOAc	trace
9	dixoane	n.d.
10	acetone	n.d.

[a] Reaction conditions: **1** (2.0 mmol), **2** (3 mmol, 1.0 equiv.), solvents (20 mL), 25-30 °C, 1 h, irradiated by 450-460 nm Blue LEDs. [b] Isolated yield based on **1**. [c] Reacted in sealed tubes for 1 h.

Table S3 Optimization of residence time [a]

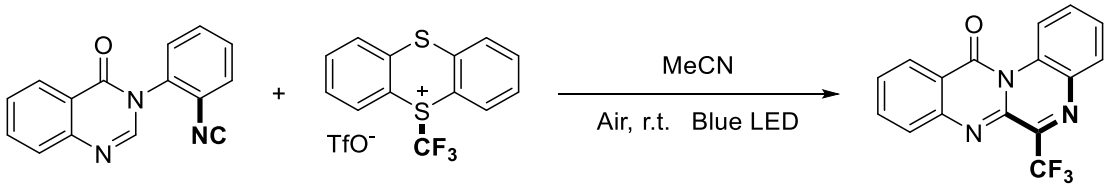


1 **2** **4a**

Entry	Residence time (min)	Yield (%)[b]
1	15	60
2	25	84
3	30	78
4	40	77
5	50	79

[a] Reaction conditions: **1** (2.0 mmol), **2** (3.0 mmol, 1.0 equiv.), solvents (20 mL), 25-30 °C, irradiated by 450-460 nm Blue LEDs. [b] Isolated yield based on **1**.

Table S4 Optimization of equivalent of 2 [a]

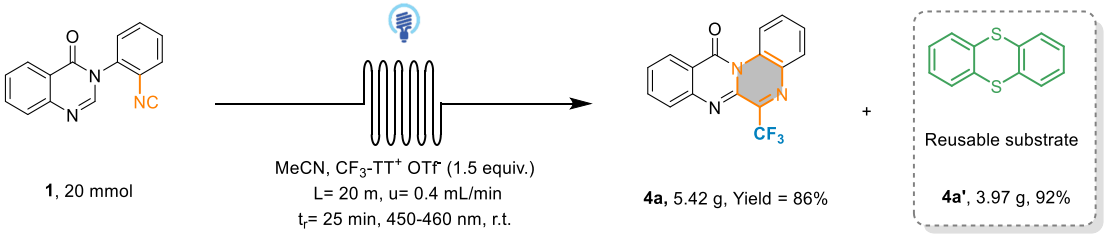


1 **2** **4a**

Entry	Equivalent of **2**	Yield (%)[b]
1	1.0 equiv.	84
2	1.5 equiv.	93
3	2.0 equiv.	90

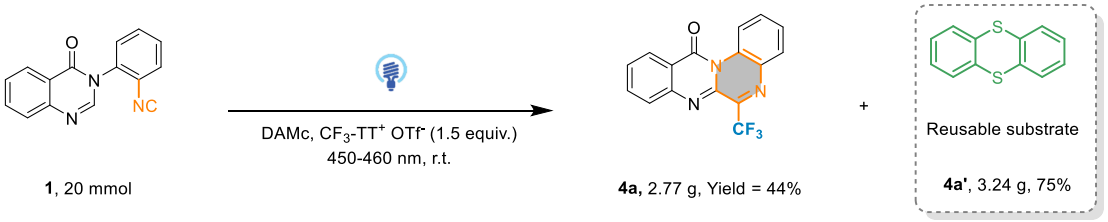
[a] Reaction conditions: **1** (2.0 mmol), **2** (x mmol, n equiv.), MeCN (20 mL), 25-30 °C, t_r = 25 min, irradiated by 450-460 nm Blue LEDs. [b] Isolated yield based on **1**.

3.2. Gram-scale synthesis



Scheme S6 Gram-scale synthesis of the product 4a (in flow)

To an oven-dried vial were added reactants **1** (20 mmol) and **2** (30 mmol, 1.5 equiv.) which were dissolved in 200 mL of MeCN, and the reaction solution was passed into a 1/16-inch tube using a feed pump, the reaction tube was than irradiated with 450-460 nm blue light at a controlled flow rate of 0.4 mL/min. After 10 h, take all the reaction mixture from the collection flask. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The residue was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the product **4a** (5.42 g, 86%) and thianthrene **4a'** (3.97 g, 92%).



Scheme S7 Gram-scale synthesis of the product 4a (in batch)

Since MeCN was found to be less effective than DMAc as a solvent under batch reaction conditions, DMAc was selected as the optimal reaction solvent for batch reactions. To an oven-dried vial round-bottomed flask with magnetic stirring were added reactants **1** (20 mmol) and **2** (30 mmol, 1.5 equiv.) which were dissolved in 200 mL of DMAc. The reaction was excited using two 25 w blue LED lamps of 450-460 nm and stirred for 36 h at room temperature. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The residue was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the product **4a** (2.77 g, 44%) and thianthrene **4a'** (3.24 g, 75%).

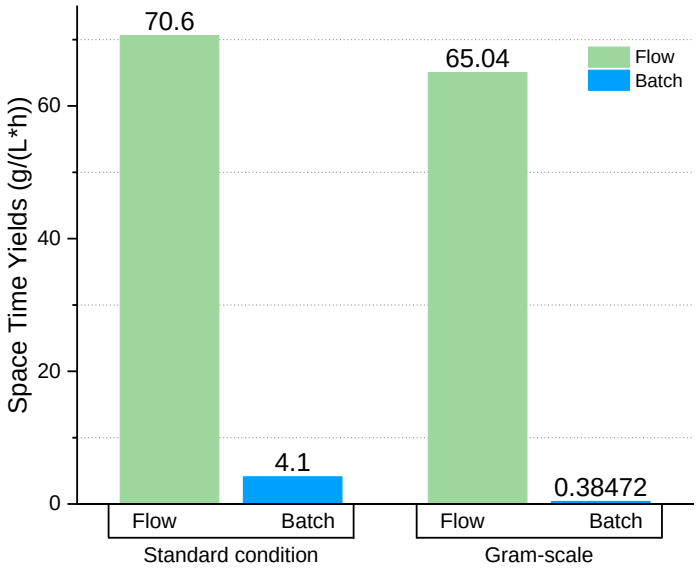
3.3. Space Time Yields Calculation

For reactions in batch:

$$STY = \frac{Mass\ of\ product}{Reaction\ time \times Reactor\ volume}$$

For reaction in flow:

$$STY = \frac{Product\ concentration \times u(Reaction\ liquid\ flow\ rate)}{Reactor\ volume}$$

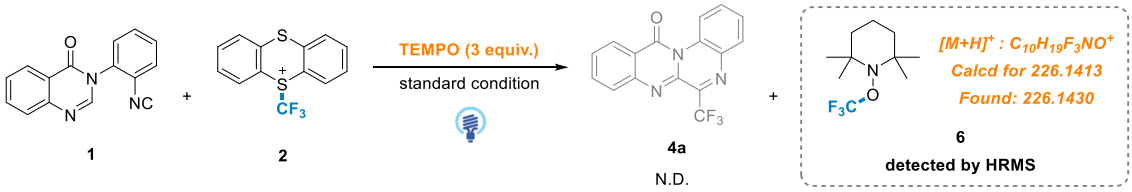


[a] The continuous flow reaction parameters are as follows: Effective length of pipe L = 20 m; Pipe inner diameter d = 0.8 mm; Reaction liquid flow rate u = 0.4 mL/min.

Figure S2 Space time yields calculation comparisons

4. Mechanism study experiments

4.1. Radical capture experiments



Following the standard experimental procedure described above, TEMPO (3 equiv.) were added after the addition of substrates **1** and **2**. After 30 min of reaction, the reaction tube was rinsed with 20 mL of MeCN and the reaction solution obtained was examined by HRMS and it was found that the target molecule **3** could not be detected. The intermediate **6** is detected by HRMS.

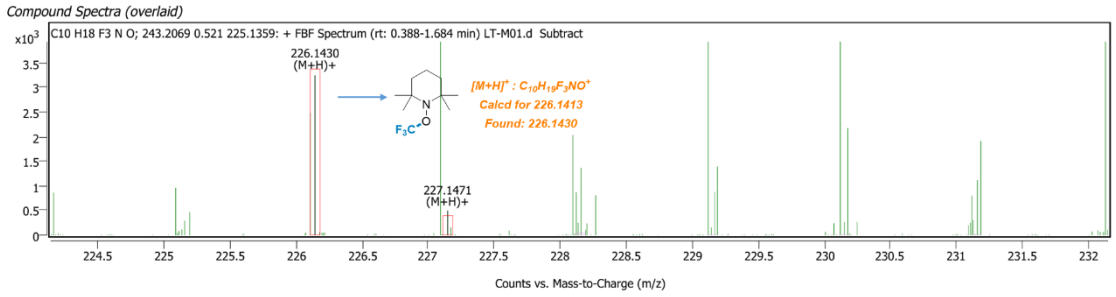
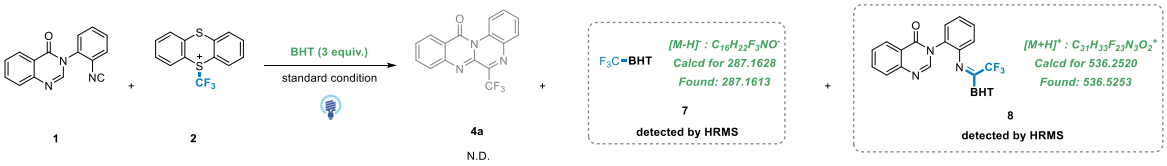


Figure S3 Characterization of HRMS data (TEMPO)



Following the standard experimental procedure described above, BHT (3 equiv.) were added after the addition of substrates **1** and **2**. After 30 min of reaction, the reaction tube was rinsed with 20 ml of MeCN and the reaction solution obtained was examined by HRMS and it was found that the target molecule **3** could not be detected. The intermediate **7**&**8** was detected by HRMS.

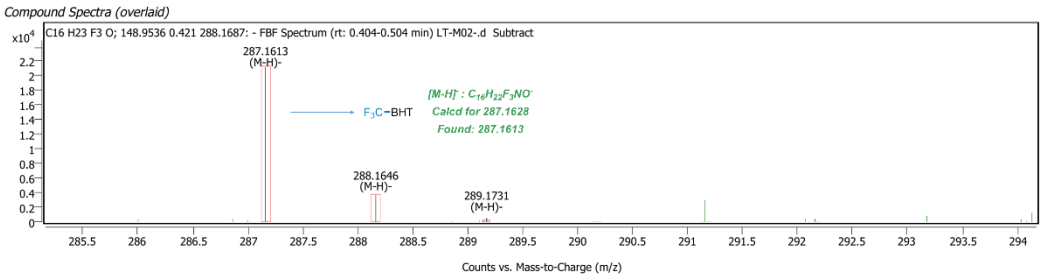


Figure S4-1 Characterization of HRMS data (BHT)

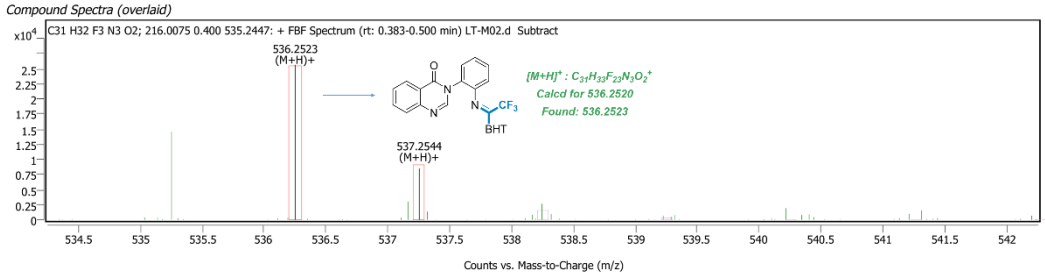
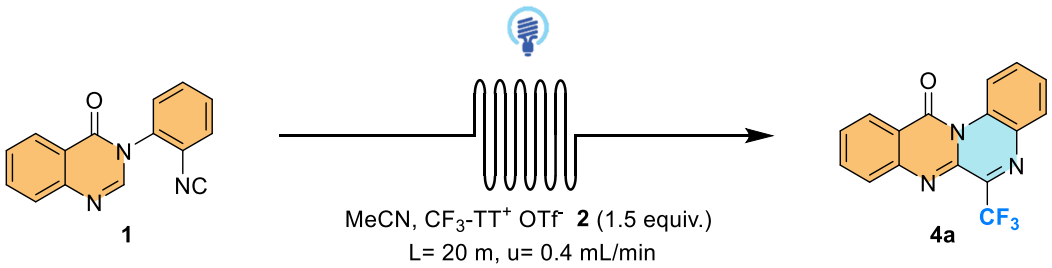


Figure S4-2 Characterization of HRMS data (BHT)

4.2. Control experiments

Table S5 Control experiments [a]



Entry	Variation from standard conditions	Yield (%) [b]
1	None	93
2	Without light	N.R.
3 [b]	CF_3COONa, Togni reagent instead of **2**	N.D.

[a] Reaction conditions: **1** (2.0 mmol) and **2** (3.0 mmol, 1.5 equiv.) dissolved in 20 mL of MeCN, effective length of pipe L = 20 m; pipe inner diameter d = 0.8 mm; reaction liquid flow rate u = 0.4 mL/min, residence time t_r = 25 min. [b] Performed in batch, reaction time = 6 h.

4.3. UV-Vis spectroscopic investigation

Preparation. Firstly, two substrate solutions were configured in beakers, Beaker A was configured

with 0.1 M MeCN solution of substrate **1** (247 mg, 1 mmol, 10 mL MeCN); Beaker B was configured with 0.15 M MeCN solution of substrate **2** (651 mg, 1.5 mmol, 10 mL MeCN). After configuration, three 10 mL volumetric flasks were taken, and 1 mL of the configured MeCN solution of substrate **1** was added to the volumetric flasks with a pipette, and then diluted to 10 mL with acetonitrile (volumetric flask 1). The same procedure was done to configure another 0.01 M solution of substrate **2** (volumetric flask 2). Finally, 1 mL of MeCN solution of substrate **1** and 1 mL of MeCN solution of substrate **2** were pipetted into a volumetric flask 3 and diluted to 10 mL, resulting in a mixture of substrate **1** and substrate **2** (0.01 M+0.015 M).

UV-Vis spectrometric experiments. A quartz cuvette (1 cm × 1 cm × 3.5 cm) was filled with 2 mL of the abovementioned 0.01 M solutions from volumetric flasks 1-3 to perform the UV-vis experiment (300 nm to 800 nm). The resulting spectra are shown in Figure S5.

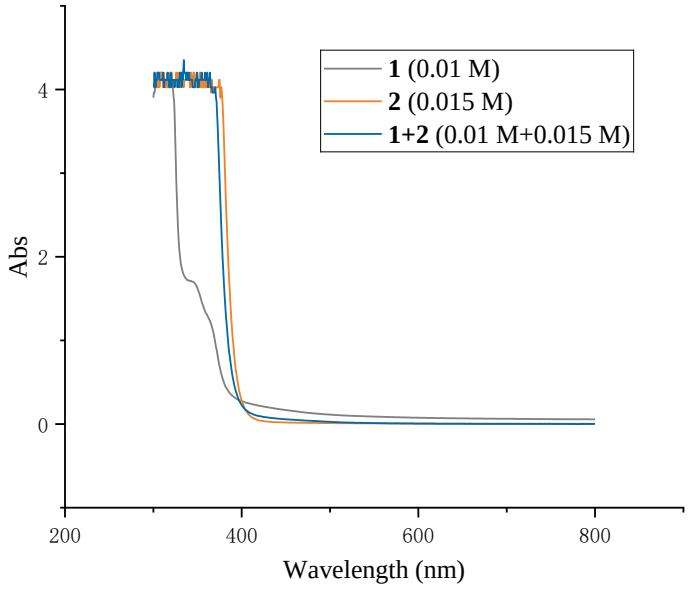


Figure S5 UV-Vis spectrometric experiments

4.4. Stern-Volmer plot

The method of configuring the solution was the same as in **4.3 (UV-Vis spectroscopic investigation)**, and the assay was performed with the addition of substrate **2** with concentration of the substrate **1** was 0.01 M. All the fluorescence spectra were obtained at 450 nm exciting wavelength.

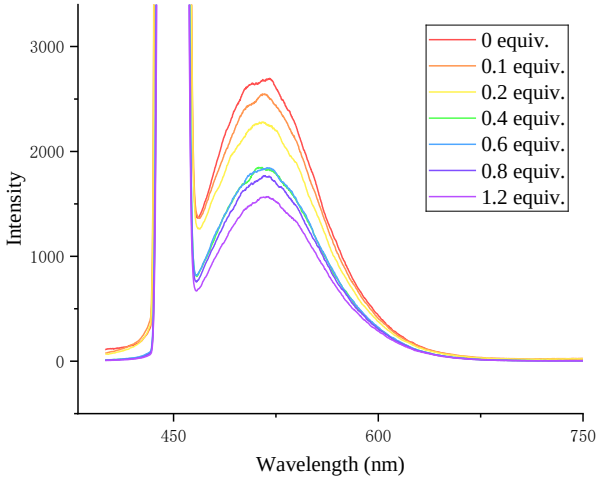


Figure S6 Fluorescence quenching of substrate 2

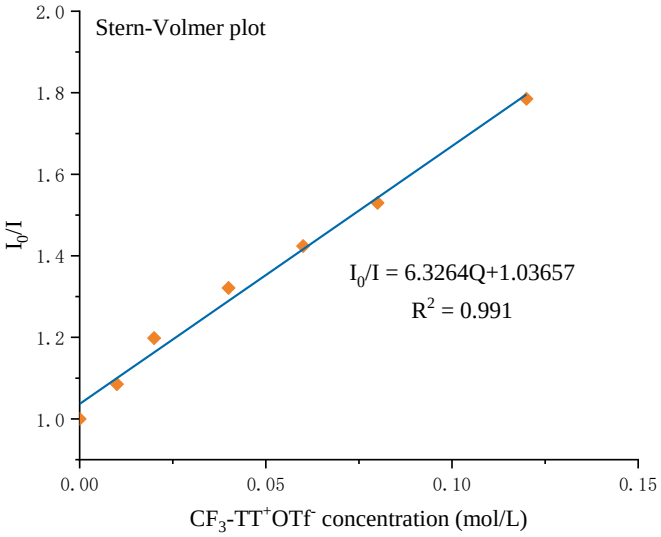


Figure S7 Stern-Volmer analysis

4.5. Light on/off experiment

To an oven-dried sealed tube with magnetic stirring were added reactants **1** (2.0 mmol) and **2** (3/0 mmol, 1.5 equiv.) which were dissolved in 20 mL of DMAc. The mixture was subjected to sequential periods of stirring under visible light irradiation (25 W × 2, 450-460 nm LEDs) followed by stirring in the absence of light. At the end of each period, a small portion (about 0.5 mL) of the reacting solution was taken. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The crude sample was taken for ^{19}F NMR analysis (with 4,4'-Difluorobenzophenone as internal standards) without further purification.

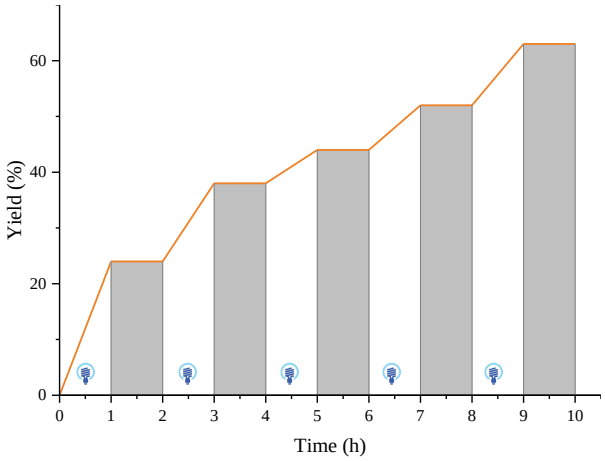


Figure S8 Light on/off experiment

4.6. Quantum Yield calculation

According to the procedure of Yoon[4], the photon flux of the LED (λ_{max} = 458 nm) was determined by standard ferrioxalate actinometry. A 0.15 M solution of ferrioxalate was prepared by dissolving potassium ferrioxalate hydrate (0.737 g) in H_2SO_4 (10 mL of 0.05 M solution). A buffered solution of 1,10-phenanthroline was prepared by dissolving 1,10-phenanthroline (5.0 mg) and sodium acetate (1.13 g) in H_2SO_4 (5.0 mL of 0.5 M solution). Both solutions were stored in the dark. To determine the photon flux of the LED, the ferrioxalate solution (3.0 mL) was placed in a cuvette and irradiated for 90 seconds at λ_{max} = 458 nm. After irradiation, the phenanthroline solution (0.525 mL) was added to the cuvette and the mixture was allowed to stir in the dark for 1 h to allow the ferrous ions to completely coordinate to the phenanthroline. The absorbance of the solution was measured at 510 nm. A nonirradiated sample was also prepared and the absorbance at 510 nm was

measured. Conversion was calculated using eq 1.

	No-irrad	Irrad
$A_{510\ nm}$	2.478	3.806

$$\textbf{mol } Fe^{2+} = (V \times \Delta A)/ (l \times \varepsilon) \quad (1)$$

$$\textbf{mol } Fe^{2+} = [3.525\times10^{-3}\ L \times (3.806-2.478)] / (1\ cm \times 11100\ L\ mol^{-1}cm^{-1}) = 4.216 \times 10^{-7}$$

V is the total volume (3.525×10^{-3} L) of the solution after addition of phenanthroline; **ΔA** is the difference in absorbance at 510 nm between the irradiated and non-irradiated solutions; **l** is the path length (1.00 cm), and **ε** is the molar absorptivity of the ferrioxalate actinometer at 510 nm (11100 L $mol^{-1}cm^{-1}$)[3]. The photon flux can be calculated using eq 2.

$$\textbf{photo flux} = \textbf{mol } Fe^{2+}/ (\Phi \times t \times f) \quad (2)$$

$$\textbf{photo flux} = 4.216\times10^{-7} / (0.845 \times 90 \times 0.9999) = 5.545 \times 10^{-9}\ \textbf{einstein}\ s^{-1}$$

Where **Φ** is the quantum yield for the ferrioxalate actinometer (0.845 for a 0.15 M solution at λ = 458 nm), **t** is the time (90.0 s), and **f** (0.9998) is the fraction of light absorbed at 405 nm by the ferrioxalate actinometer. This value is calculated using eq 3 where A458nm (3.7569) is the absorbance of the ferrioxalate solution at 458 nm. The photon flux was calculated (average of three experiments) to be 9.213×10^{-9} einstein s^{-1}.

$$f = 1 - 10^{-A458\ nm} \quad (3)$$

$$f = 1 - 10^{-3.9024} = 0.9999$$

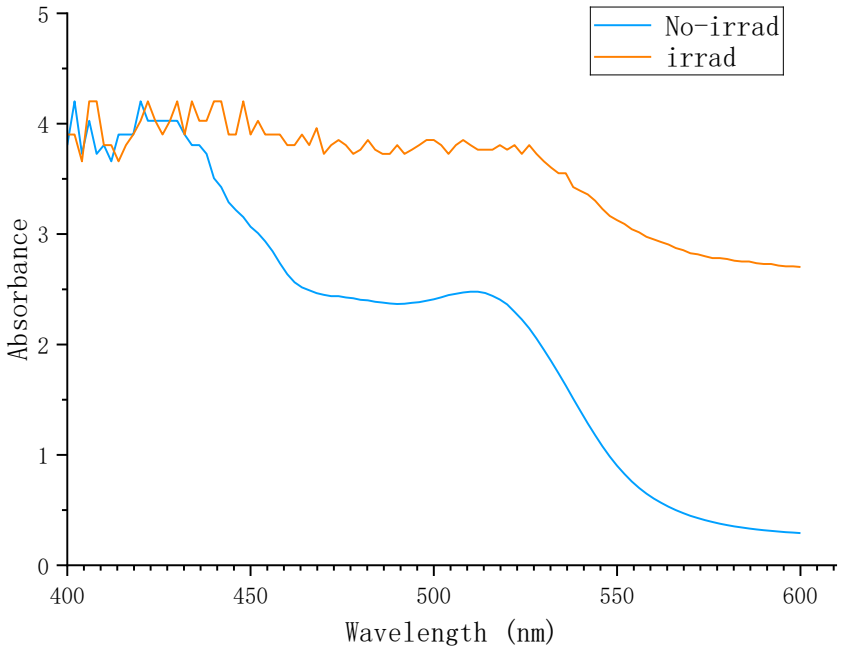
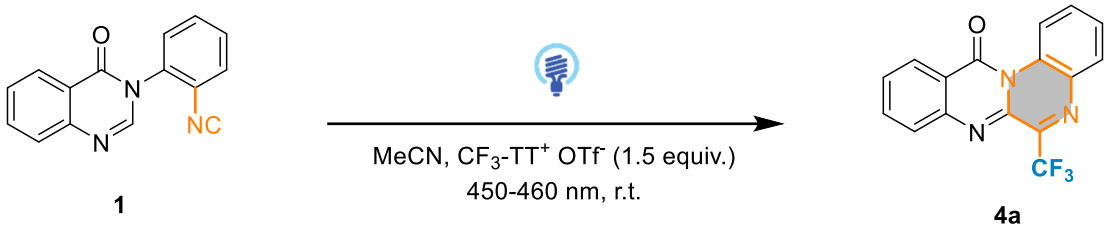


Figure S9. Absorption spectra of three irradiation experiments and non-irradiation experiment

Determination of the reaction quantum yield



1 **4a**

The reaction mixture was stirred and irradiated by blue LED (λ_{max} = 458 nm) for 3600 s. The yield of product was determined by ^{19}F NMR analysis using 4,4'-Difluorobenzophenone as internal standards. The yield of **4a** was determined to be 24% (1.2×10^{-4} mol of **4a**). The reaction quantum yield (Φ) was determined using eq 4 where the photon flux is 9.213×10^{-9} einsteins s^{-1} (determined by actinometry as described above), **t** is the reaction time (3600 s) and **f** is the fraction of incident light absorbed by the catalyst, determined using eq 3.

$$\textbf{Quantum Yield = moles of product formed/ (flux} \times \textbf{f} \times \textbf{t)} \quad (4)$$

$$= 1.2 \times 10^{-4} / (5.545 \times 10^{-9} \times 0.9999 \times 3600) = 6.01\%$$

4.7. ^{19}F NMR analysis

Two sealed tubes were prepared, both added with CF_3-TT^{+-}OTf (0.3 mmol), and 2 mL MeCN. Substrate **1** (0.2 mmol) was added to one of sealed tube. The tubes were irradiated with 450-460 nm LEDs for 6 h at room temperature. Then the reaction solution was extracted with ethyl acetate, and dried over Na_2SO_4 and concentrated in vacuum. The crude sample was taken for ^{19}F NMR analysis without further purification.

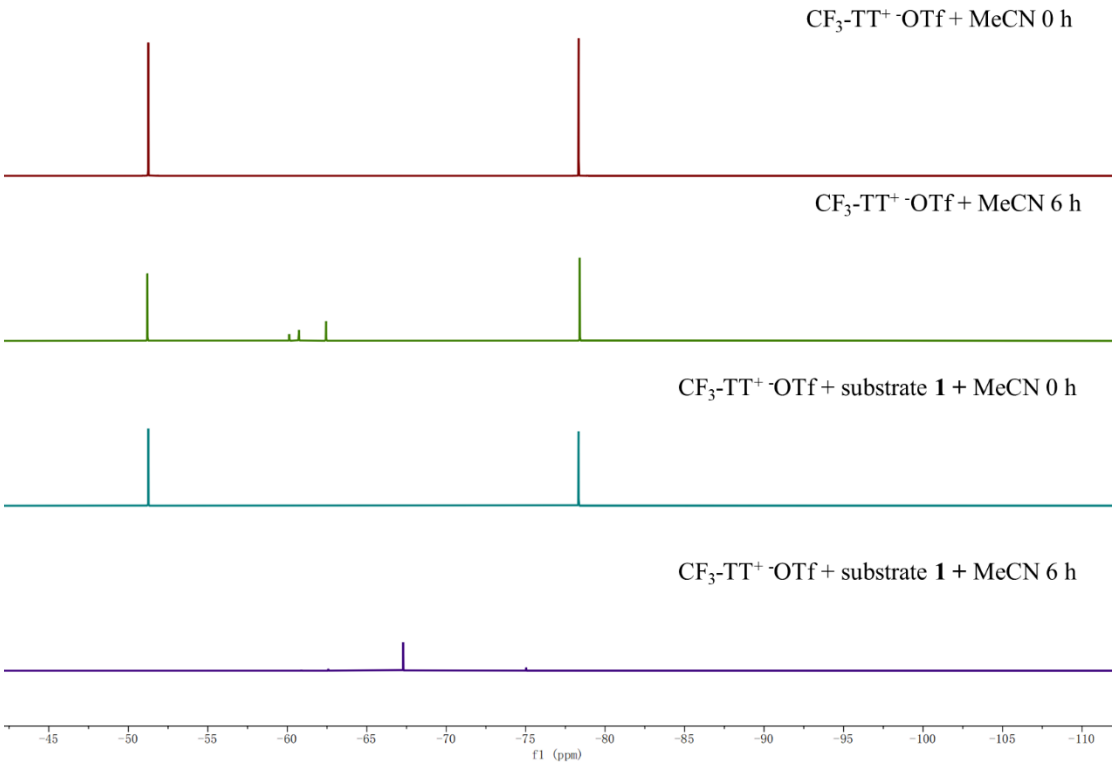


Figure S10 ^{19}F NMR analysis

4.8. Electrochemical measurements

Electrochemical measurements were collected using a CH Instruments model CHI600E electrochemical workstation in an Ar-filled glovebox. A standard three-electrode setup was employed for all measurements to determine the reductive potentials of the thianthrene via cyclic voltammetry in acetonitrile solutions at a scan rate of 100 mV/s, using 0.1 M $TBAPF_6$ as the supporting electrolyte, a glassy carbon working electrode, an Ag wire pseudo-reference electrode, and a Pt wire counter electrode. The plotting of the voltammetric curve adheres to IUPAC guidelines. Specific parameters are provided in the subsequent table.

(1) Electrodes: a glassy carbon working electrode; an Ag wire pseudo-reference electrode; a Pt wire counter electrode;

(2) Electrolyte: 0.1 M $TBAPF_6$;

(3) Solution: dry CH_3CN;

(4) Scan rate: 100 mV/s;

(5) Thianthrene concentration: 0.1 M;

(6) Substrate concentration: 0.1 M

Oxidation potential of substrate **1**: E_{pa} = 0.488 V vs. SCE

Reduction potential of substrate **1**: E_{pc} = -1.28 V vs. SCE

Reduction potential of thianthrene: $E_{1/2}(TT/TT^{+\cdot})$ = -0.936 V vs. SCE

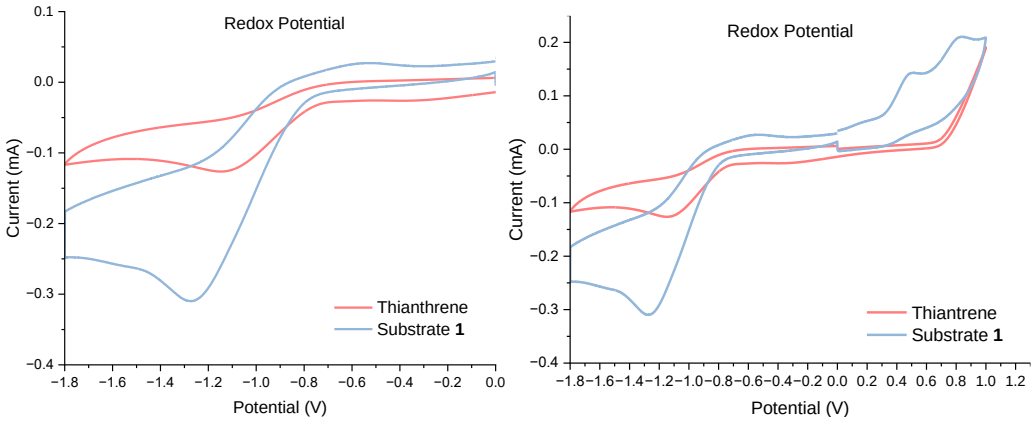


Figure S11 Cyclic voltammetry using 0.1 M $TBAPF_6$ at 100 mV/s

4.9. Proposed mechanism

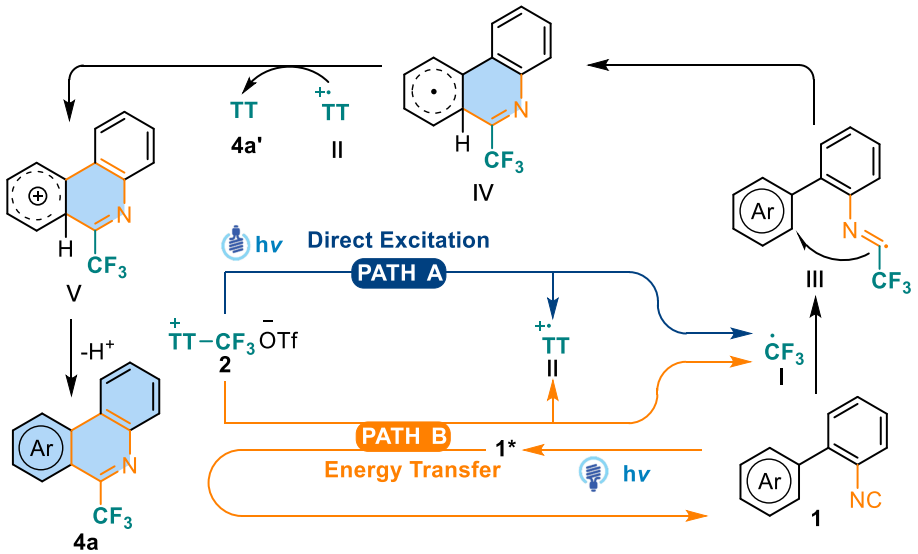


Figure S12 Proposed mechanism

5. References

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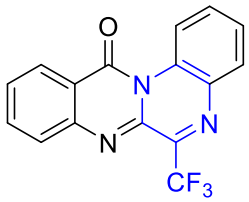
6. Characterization data for the products



6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4a)

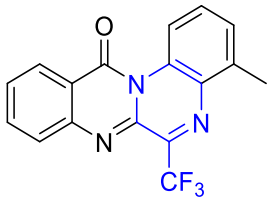
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 30/1). Yellow solid (146.6 mg, 93% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (d, *J* = 8.8 Hz, 1H), 8.49 (d, *J* = 8.0 Hz, 1H), 8.04 (d, *J* = 7.8 Hz, 1H), 7.93 (dt, *J* = 15.0, 8.0 Hz, 2H), 7.79-7.58 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5, 146.9 (q, *J* = 34.3 Hz), 144.9, 136.3, 135.3, 133.3, 132.4, 131.3, 129.2, 128.9, 128.6, 127.8, 127.4, 121.4, 120.7, 120.0 (q, *J* = 277.7 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.28.

HRMS Calcd for $C_{16}H_9F_3N_3O[M+H]^+$: 316.0653, found: 316.0658.



4-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4b)

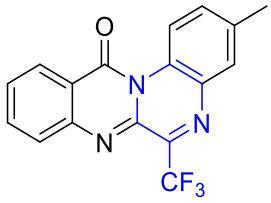
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (146.5 mg, 89% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.44 (d, *J* = 9.2 Hz, 1H), 8.48 (d, *J* = 8.0 Hz, 1H), 7.95 (dd, *J* = 8.3, 1.2 Hz, 1H), 7.91 (dd, *J* = 6.9, 1.5 Hz, 1H), 7.66 (ddd, *J* = 8.1, 7.0, 1.3 Hz, 1H), 7.62-7.57 (m, 1H), 7.47 (d, *J* = 7.4 Hz, 1H), 2.76 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 161.6, 145.0, 144.9 (q, *J* = 33. 2 Hz), 140.1, 136.3, 135.6, 135.1, 131.8, 129.1, 128.7, 128.6, 128.5, 127.4, 121.4, 120.1 (q, *J* = 276.33 Hz), 118.3, 17.8.

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.26.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0818.



3-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4c)

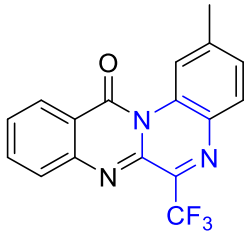
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (156.4 mg, 95% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.54 (d, *J* = 8.9 Hz, 1H), 8.49 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.97-7.94 (m, 1H), 7.93-7.89 (m, 1H), 7.84 (d, *J* = 1.6 Hz, 1H), 7.67 (ddd, *J* = 8.1, 6.9, 1.3 Hz, 1H), 7.54 (dd, *J* = 8.9, 2.2 Hz, 1H), 2.52 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.4, 146.7 (q, *J* = 34.5 Hz), 144.9, 138.1, 136.3, 135.1, 133.4, 133.2, 131.2, 128.8, 128.6, 127.3, 126.9, 121.3, 120.4, 120.0 (q, *J* = 277.7 Hz), 20.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.23.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0817.



2-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4d)

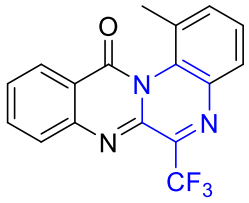
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (153.1 mg, 93% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.49 (s, 1H), 8.48 (d, *J* = 8.0 Hz, 1H), 7.95 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.94-7.88 (m, 2H), 7.67 (t, *J* = 8.1 Hz, 1H), 7.43 (dd, *J* = 8.0, 1.3 Hz, 1H), 2.59 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 161.6, 145.6 (q, *J* = 32.7 Hz), 145.0, 143.7, 136.5, 135.2, 131.4, 130.9, 129.0, 128.8, 128.7, 128.6, 127.3, 121.4, 120.9, 120.1 (q, *J* = 274.8 Hz), 22.6.

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.17.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0819.



1-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4e)

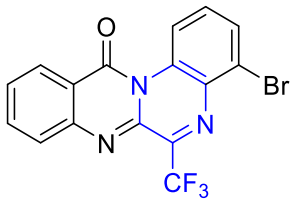
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (139.9 mg, 85% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 7.9, 1.2 Hz, 1H), 7.97-7.93 (m, 1H), 7.90 (ddd, *J* = 8.3, 7.0, 1.5 Hz, 1H), 7.83 (dd, *J* = 6.8, 2.6 Hz, 1H), 7.65 (ddd, *J* = 8.1, 7.0, 1.3 Hz, 1H), 7.56-7.49 (m, 2H), 2.31 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.1, 146.4 (q, *J*=34.3 Hz), 145.5, 137.9, 135.2, 135.0, 134.9, 132.0, 128.7, 128.5, 127.8, 127.6, 126.8, 126.0, 121.2, 119.8 (q, *J*=276.8 Hz), 22.2.

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.32.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0816.



4-bromo-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4f)

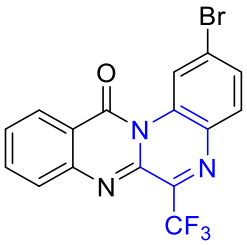
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 30/1). Yellow solid (127.5 mg, 65% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.61 (d, *J* = 8.8 Hz, 1H), 8.49 (d, *J* = 8.1 Hz, 1H), 8.01-7.87 (m, 3H), 7.76-7.66 (m, 1H), 7.56 (t, *J* = 8.3 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.4, 147.4 (q, *J* = 34.3 Hz), 144.9, 135.9, 135.5, 132.5, 132.1, 131.4, 130.8, 129.2, 128.8, 127.5, 126.9, 121.4, 119.9, 119.8 (q, *J* = 276.6 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.26.

HRMS Calcd for $C_{16}H_8BrF_3N_3O[M+H]^+$: 393.9704, found: 393.9711.



2-bromo-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4g)

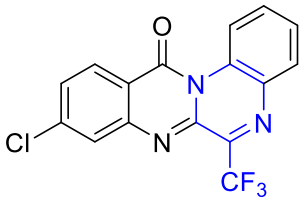
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 30/1). Yellow solid (139.9 mg, 71% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.78 (d, *J* = 2.2 Hz, 1H), 8.50 (dd, *J* = 8.1, 1.4 Hz, 1H), 8.01-7.90 (m, 3H), 7.71 (ddd, *J* = 8.2, 6.5, 1.8 Hz, 1H), 7.60 (dd, *J* = 8.5, 2.2 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.3, 147.00 (q, *J* = 35.35 Hz), 144.8, 138.6, 135.8, 135.6, 132.0, 131.9, 129.8, 129.2, 128.8, 128.2, 127.5, 121.3, 121.0, 119.4 (q, *J* = 277.8 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.33.

HRMS Calcd for $C_{16}H_8BrF_3N_3O[M+H]^+$: 393.9704, found: 393.9709.



9-chloro-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4h)

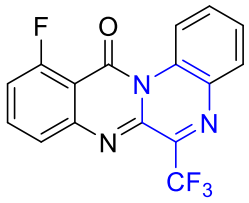
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 30/1). Yellow solid (99.6 mg, 57% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (dd, *J* = 8.8, 1.3 Hz, 1H), 8.43 (d, *J* = 8.7 Hz, 1H), 8.07 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.98 (d, *J* = 2.0 Hz, 1H), 7.78 (ddd, *J* = 8.9, 7.3, 1.8 Hz, 1H), 7.74-7.59 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.9, 146.6 (q, *J* = 34.3 Hz), 141.8, 137.2, 132.7, 131.5, 129.5, 129.03, 128.9, 128.7, 128.0, 127.9, 127.7, 120.7, 119.9 (q, *J* = 277.7 Hz), 119.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.30.

HRMS Calcd for $C_{16}H_8ClF_3N_3O[M+H]^+$: 351.0200, found: 351.0207.



11-fluoro-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4i)

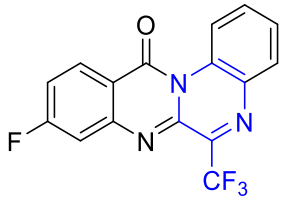
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (109.8 mg, 66% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.51-9.50 (d, *J* = 8.7 Hz, 1H), 8.05-8.04 (d, *J*=7.9 Hz, 1H), 7.87-7.83 (m, 1H), 7.77-7.73 (m, 2H), 7.65-7.62 (t, *J* = 7.6 Hz, 1H), 7.34-7.30 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 161.3 (d, *J* = 268.4 Hz), 158.3 (d, *J* = 4.7 Hz), 146.8, 146.5 (q, *J* = 33.7 Hz), 137.0, 135.6 (d, *J* = 10.5 Hz), 133.3, 132.6, 131.4, 128.7, 127.9, 124.5 (d, *J* = 4.4 Hz), 120.5, 119.9 (q, *J* = 277.8 Hz), 115.2 (d, *J* = 21.0 Hz), 110.9 (d, *J* = 5.3 Hz).

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.39, -109.48.

HRMS Calcd for $C_{16}H_8F_4N_3O[M+H]^+$: 334.0559, found: 334.0563.



9-fluoro-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4j)

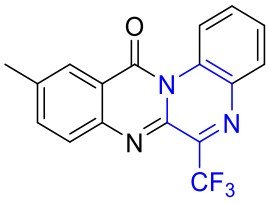
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 20/1). Yellow solid (121.5 mg, 73% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.62 (d, *J* = 8.8 Hz, 1H), 8.50 (dd, *J* = 8.9, 5.9 Hz, 1H), 8.05 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.78-7.72 (m, 1H), 7.67-7.61 (m, 1H), 7.59 (dd, *J* = 9.1, 2.5 Hz, 1H), 7.41-7.35 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.9 (d, *J* = 257.3 Hz), 160.8, 147.1 (d, *J* = 13.4 Hz), 146.6 (q, *J* = 34.9 Hz), 137.3, 135.6, 132.6, 131.4, 130.3 (d, *J* = 10.6 Hz), 128.7, 127.9, 127.7, 120.7, 119.9 (q, *J* = 276.3 Hz), 117.9 (d, *J* = 23.8 Hz), 113.6 (d, *J* = 22.1 Hz).

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.30, -100.87.

HRMS Calcd for $C_{16}H_8F_4N_3O[M+H]^+$: 334.0559, found: 334.0566.



10-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4k)

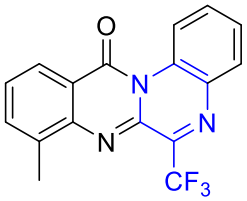
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 25/1). Yellow solid (151.4 mg, 92% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.66-9.64 (d, *J* = 8.7 Hz, 1H), 8.28 (s, 1H), 8.03-8.02 (d, *J* = 7.9 Hz, 1H), 7.87-7.85 (d, *J* = 8.3 Hz, 1H), 7.74-7.71 (m, 2H), 7.62-7.60 (t, *J* = 7.6 Hz, 1H), 2.59 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 161.5, 146.9 (q, *J* =34.5 Hz), 142.9, 139.7, 136.9, 135.7, 133.3, 132.2, 131.2, 129.4, 128.5, 127.6, 127.7, 121.2, 120.7, 120.4 (q, *J* = 277.8 Hz), 21.7.

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.27.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0813.



8-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4l)

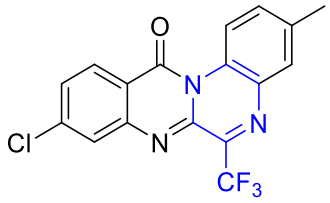
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 25/1). Yellow solid (139.8 mg, 85% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.68 (dd, *J* = 8.8, 1.3 Hz, 1H), 8.34 (d, *J* = 8.1 Hz, 1H), 8.04 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.80-7.70 (m, 2H), 7.66-7.50 (m, 2H), 2.74 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.8, 146.0 (q, *J* = 35.4 Hz), 143.5, 137.7, 135.7, 135.3, 133.4, 132.3, 131.3, 129.3, 128.6, 127.7, 124.9, 121.51, 120.7, 119.5 (q, *J* = 278.76Hz), 16.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.53.

HRMS Calcd for $C_{17}H_{11}F_3N_3O[M+H]^+$: 330.0810, found: 330.0815.



9-chloro-3-methyl-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4m)

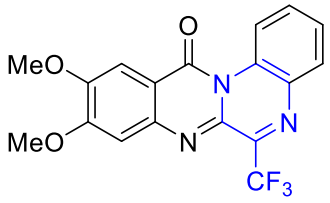
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 25/1). Yellow solid (112.7 mg, 62% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (d, *J* = 8.9 Hz, 1H), 8.43 (d, *J* = 8.6 Hz, 1H), 7.98 (s, 1H), 7.88 (s, 1H), 7.60 (dd, *J* = 15.7, 9.1 Hz, 2H), 2.55 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.8, 147.6 (q, *J* = 34.3 Hz), 145.8, 141.6, 138.4, 133.6, 133.3, 131.4, 129.3, 128.8, 127.9, 126.7, 124.5, 120.4, 119.9 (q, *J* = 278.8 Hz), 119.6, 20.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -67.26.

HRMS Calcd for $C_{17}H_{10}ClF_3N_3O$ $[M+H]^+$: 365.0357, found: 365.0359.



9,10-dimethoxy-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4n)

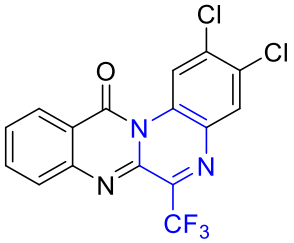
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 15/1). Yellow solid (155.7 mg, 83% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.72 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 7.7 Hz, 1H), 7.77 (s, 1H), 7.71 (t, *J* = 8.0 Hz, 1H), 7.60 (t, *J* = 7.5 Hz, 1H), 7.29 (s, 1H), 4.08 (d, *J* = 5.9 Hz, 6H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 160.6, 156.0, 151.1, 146.6 (q, *J* = 33.5 Hz), 141.4, 135.4, 133.5, 132.0, 131.1, 129.5, 127.6, 120.8, 120.1 (q, *J* = 276.3 Hz), 115.4, 108.4, 105.8, 56.6, 56.5.

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.10.

HRMS Calcd for $C_{18}H_{13}F_3N_3O_3$ $[M+H]^+$: 376.0864, found: 376.0868.



2,3-dichloro-6-(trifluoromethyl)-12H-quinoxalino[2,1-b]quinazolin-12-one (4o)

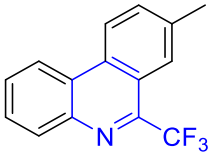
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 30/1). Yellow solid (97.6 mg, 51% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 9.89 (s, 1H), 8.48-8.43 (m, 1H), 8.10 (s, 1H), 7.97-7.93 (m, 2H), 7.70 (ddd, *J* = 8.3, 6.4, 1.9 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 161.1, 148.1 (q, *J* = 34.7 Hz), 144.6, 136.6, 135.7, 135.4, 132.6, 131.7, 131.6, 129.5, 128.9, 127.9, 127.4, 122.4, 121.1, 119.7 (q, *J* = 277.84 Hz).

^{19}F NMR (565 MHz, $CDCl_3$) δ -67.26.

HRMS Calcd for $C_{16}H_7Cl_2F_3N_3O$ $[M+H]^+$: 384.9811, found: 384.9818.



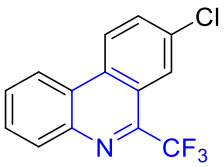
8-methyl-6-(trifluoromethyl)phenanthridine (5a)[5]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 80/1). White solid (112.3 mg, 86% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61-8.55 (m, 2H), 8.31-8.24 (m, 1H), 8.14 (s, 1H), 7.86-7.66 (m, 3H), 2.63 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 146.2 (q, *J* = 32.5 Hz), 141.5, 138.3, 133.2, 131.9, 131.1, 129.1, 128.9, 125.3 (q, *J* = 3.2 Hz), 122.4, 122.0, 121.9 (q, *J* = 277.8 Hz), 121.9, 21.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.48.



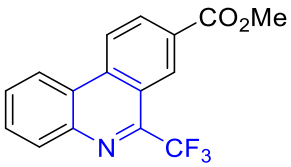
8-chloro-6-(trifluoromethyl)phenanthridine (5b)[6]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 60/1). Pale yellow solid (98.4 mg, 70% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.63 (d, *J* = 8.9 Hz, 1H), 8.55 (dd, *J* = 7.3, 2.3 Hz, 1H), 8.34 (t, *J* = 1.9 Hz, 1H), 8.29 (dd, *J* = 7.3, 2.2 Hz, 1H), 7.87 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.82 (pd, *J* = 7.0, 1.7 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 145.5 (q, *J* = 33.3 Hz), 141.7, 134.3, 132.4, 132.1, 131.3, 129.7, 125.2 (q, *J* = 3.5 Hz), 124.6, 124.3, 122.6, 121.7 (q, *J* = 277.8 Hz), 121.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.62.



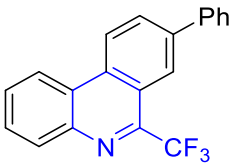
methyl 6-(trifluoromethyl)phenanthridine-8-carboxylate (5c)[7]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 80/1). White solid (94.6 mg, 62% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.09 (s, 1H), 8.79 (d, *J* = 8.7 Hz, 1H), 8.67 (dd, *J* = 7.9, 2.0 Hz, 1H), 8.56 (dd, *J* = 8.7, 1.6 Hz, 1H), 8.34 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.99-7.80 (m, 2H), 4.07 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 146.9 (q, *J* = 33.2 Hz), 142.5, 136.8, 131.3, 131.2, 130.5, 129.7, 129.6, 128.1 (q, *J* = 3.5 Hz), 124.5, 122.9, 122.7, 121.7 (q, *J* = 277.8 Hz), 121.3, 52.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.19.



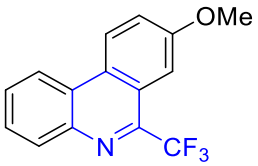
8-phenyl-6-(trifluoromethyl)phenanthridine (5d)[7]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 100/1). White solid (134.04 mg, 83% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.73 (dd, *J* = 9.0, 3.9 Hz, 1H), 8.60 (dt, *J* = 6.5, 3.1 Hz, 1H), 8.56 (s, 1H), 8.30 (d, *J* = 7.2 Hz, 1H), 8.15 (d, *J* = 8.5 Hz, 1H), 7.86-7.77 (m, 2H), 7.75 (d, *J* = 7.6 Hz, 2H), 7.55 (t, *J* = 7.6 Hz, 2H), 7.46 (t, *J* = 7.4 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 146.6 (q, *J* = 32.8 Hz), 141.7, 140.9, 139.1, 132.9, 131.2, 130.7, 129.3, 129.3, 129.2, 128.2, 127.5, 125.0, 123.7 (q, *J* = 3.3 Hz), 123.1, 122.2, 122.1, 122.0 (q, *J* = 277.2 Hz).

^{19}F NMR (565 MHz, $CDCl_3$) δ -63.31.



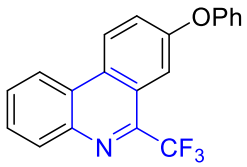
8-methoxy-6-(trifluoromethyl)phenanthridine (5e)[5]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 100/1). White solid (126.03 mg, 91% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60 (d, *J* = 9.1 Hz, 1H), 8.55-8.48 (m, 1H), 8.30-8.23 (m, 1H), 7.75 (hept, *J* = 4.8 Hz, 2H), 7.68 (p, *J* = 2.0 Hz, 1H), 7.55 (dd, *J* = 9.1, 2.6 Hz, 1H), 4.01 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 145.6 (q, *J* = 32.7 Hz), 141.0, 131.1, 129.3, 128.3, 127.7, 125.3, 124.2, 122.5, 122.1 (q, *J* = 277.8 Hz), 121.6, 114.2, 105.5 (q, *J* = 3.5 Hz), 55.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ -64.09.



8-phenoxy-6-(trifluoromethyl)phenanthridine (5f)

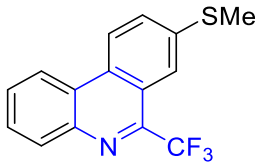
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 100/1). White solid (148.8 mg, 88% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.69 (d, *J* = 9.1 Hz, 1H), 8.58-8.52 (m, 1H), 8.32-8.24 (m, 1H), 7.90 (t, *J* = 2.1 Hz, 1H), 7.83-7.73 (m, 2H), 7.64 (dd, *J* = 9.1, 2.5 Hz, 1H), 7.43 (dd, *J* = 8.5, 7.4 Hz, 2H), 7.23 (t, *J* = 7.4 Hz, 1H), 7.15-7.11 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.0, 156.1, 145.8 (q, *J* = 32.3 Hz), 141.3, 131.2, 130.9, 130.2, 129.8, 129.5, 128.8, 128.2, 125.1, 124.6, 124.4, 123.8, 123.1 (q, *J* = 9.2 Hz), 121.8, 121.8 (q, *J* = 277.8 Hz), 119.4, 112.9 (q, *J* = 4.0 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -64.07.

HRMS Calcd for $C_{20}H_{13}F_3NO$ $[M+H]^+$: 340.0905, found: 340.0911.



8-(methylthio)-6-(trifluoromethyl)phenanthridine (5g)

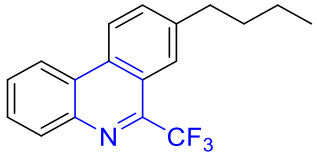
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 80/1). Pale yellow solid (130.4 mg, 89% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60-8.49 (m, 2H), 8.31-8.21 (m, 1H), 8.08 (t, *J* = 2.0 Hz, 1H), 7.80-7.76 (m, 3H), 2.65 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 145.4 (q, *J* = 33.2 Hz), 141.4, 139.9, 131.2, 131.2, 130.2, 129.4, 129.0, 125.0, 122.8, 122.3, 121.9 (q, *J* = 277.8 Hz), 121.8, 120.8 (q, *J* = 3.4 Hz), 15.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.69.

HRMS Calcd for $C_{15}H_{11}F_3NS$ $[M+H]^+$: 294.0520, found: 294.0528.



8-butyl-6-(trifluoromethyl)phenanthridine (5h)

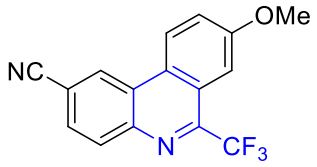
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 100/1). White solid (137.9 mg, 91% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67-8.49 (m, 2H), 8.31-8.22 (m, 1H), 8.14 (t, *J* = 2.2 Hz, 1H), 7.85-7.67 (m, 3H), 2.96-2.80 (m, 2H), 1.73 (p, *J* = 7.6 Hz, 2H), 1.43 (dq, *J* = 14.8, 7.4 Hz, 2H), 0.98 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 146.3 (q, *J* = 32.6 Hz), 143.2, 141.5, 132.6, 132.1, 131.0, 129.1, 128.9, 125.3, 124.7 (q, *J* = 3.4 Hz), 122.5, 122.0 (q, *J* = 278.8 Hz), 121.9, 121.9, 35.9, 33.5, 22.3, 13.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.45.

HRMS Calcd for $C_{18}H_{17}F_3N$ $[M+H]^+$: 304.1268, found: 304.1272.



8-methoxy-6-(trifluoromethyl)phenanthridine-2-carbonitrile (5i)

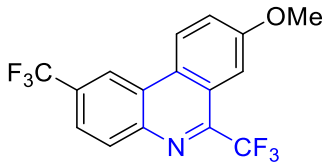
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 60/1). White solid (81.5 mg, 54% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (d, *J* = 1.7 Hz, 1H), 8.59 (d, *J* = 9.1 Hz, 1H), 8.35 (d, *J* = 8.5 Hz, 1H), 7.96-7.90 (m, 1H), 7.72 (q, *J* = 2.1 Hz, 1H), 7.68-7.61 (m, 1H), 4.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.0, 148.0 (q, *J* = 34.3 Hz), 132.3, 129.9, 129.7, 129.0, 128.4, 127.4, 125.4, 124.5, 124.2, 123.6, 121.6 (q, *J* = 278.8 Hz), 112.8, 106.1 (q, *J* = 3.4 Hz), 55.8.

^{19}F NMR (376 MHz, $CDCl_3$) δ -64.42.

HRMS Calcd for $C_{16}H_{10}F_3N_2O$ $[M+H]^+$: 303.0701, found: 303.0703.



8-methoxy-2,6-bis(trifluoromethyl)phenanthridine (5j)

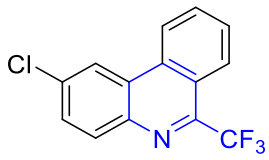
The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 50/1). White solid (106.5 mg, 62% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.76 (s, 1H), 8.59 (d, *J* = 9.2 Hz, 1H), 8.34 (d, *J* = 8.6 Hz, 1H), 7.92 (dd, *J* = 8.6, 1.8 Hz, 1H), 7.70-7.65 (m, 1H), 7.58 (dd, *J* = 9.2, 2.4 Hz, 1H), 4.01 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 159.7, 147.6 (q, *J* = 33.1 Hz), 142.2, 132.0, 130.8 (q, *J* = 32.5 Hz), 128.2, 127.7, 124.2, 124.0 (q, *J* = 273.72 Hz), 123.5, 123.2, 121.7 (q, *J* = 278.8 Hz), 119.4 (q, *J* = 4.3 Hz), 114.2, 105.8 (q, *J* = 3.6 Hz), 55.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ -62.20, -64.36.

HRMS Calcd for $C_{16}H_{10}F_6NO$ $[M+H]^+$: 346.0622, found: 346.0626.



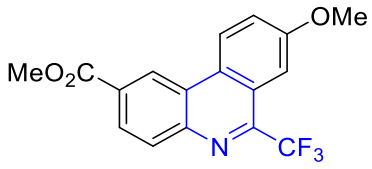
2-chloro-6-(trifluoromethyl)phenanthridine (5k)[5]

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 50/1). Pale yellow solid (98.4 mg, 70% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 (d, *J* = 8.4 Hz, 1H), 8.51 (d, *J* = 2.2 Hz, 1H), 8.37 (dt, *J* = 8.5, 1.9 Hz, 1H), 8.20 (d, *J* = 8.7 Hz, 1H), 7.92 (ddd, *J* = 8.4, 7.0, 1.2 Hz, 1H), 7.79 (ddd, *J* = 8.3, 7.1, 1.2 Hz, 1H), 7.73 (dd, *J* = 8.8, 2.2 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 146.7 (q, *J* = 33.2 Hz), 140.1, 135.4, 132.9, 132.5, 131.7, 129.9, 128.8, 126.1, 125.9 (q, *J* = 3.4 Hz), 122.5, 121.9, 121.8 (q, *J* = 277.8 Hz), 121.8.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.52.



methyl 8-methoxy-6-(trifluoromethyl)phenanthridine-2-carboxylate (5l)

The product was isolated by column chromatography (eluent: petroleum ether/ethyl acetate = 50/1). White solid (113.9 mg, 68% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.24 (d, *J* = 1.8 Hz, 1H), 8.69 (d, *J* = 9.2 Hz, 1H), 8.40-8.24 (m, 2H), 7.95 (dd, *J* = 7.7, 1.4 Hz, 2H), 4.06 (s, 3H), 4.03 (s, 3H).

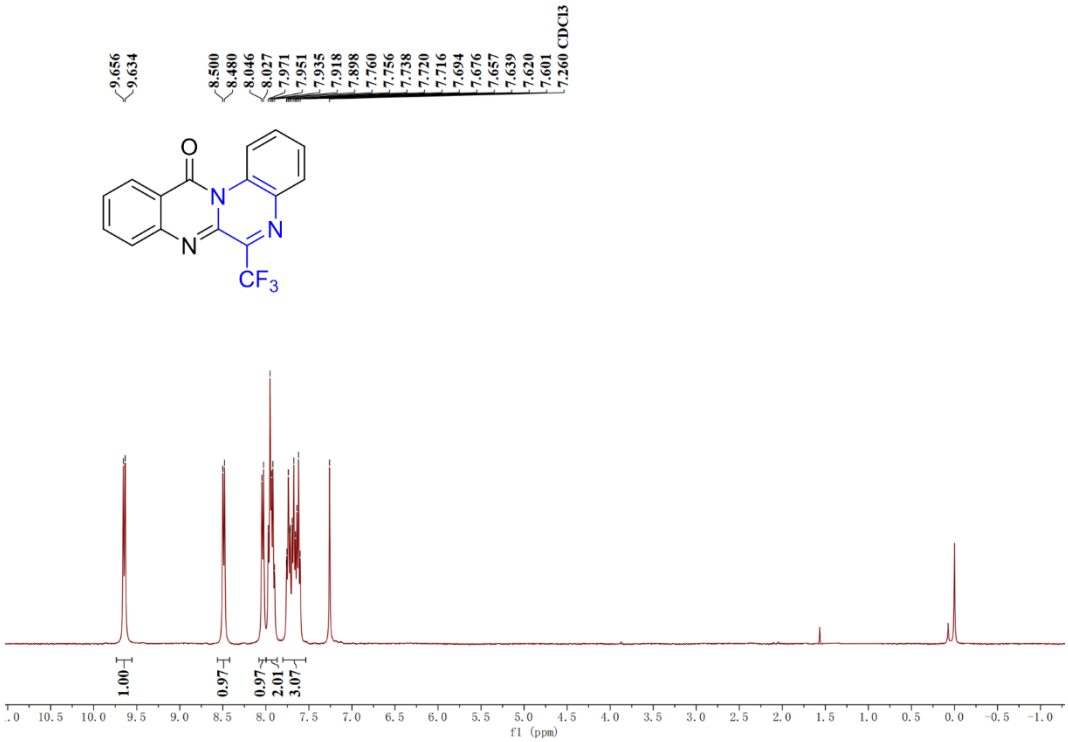
^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 159.4, 147.4 (q, *J* = 33.0 Hz), 141.4, 131.2, 130.2, 129.9, 129.0, 128.4, 128.1, 124.5, 124.4, 124.2, 121.8 (q, *J* = 277.8 Hz), 105.7 (q, *J* = 3.3 Hz), 55.6, 52.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ -64.26.

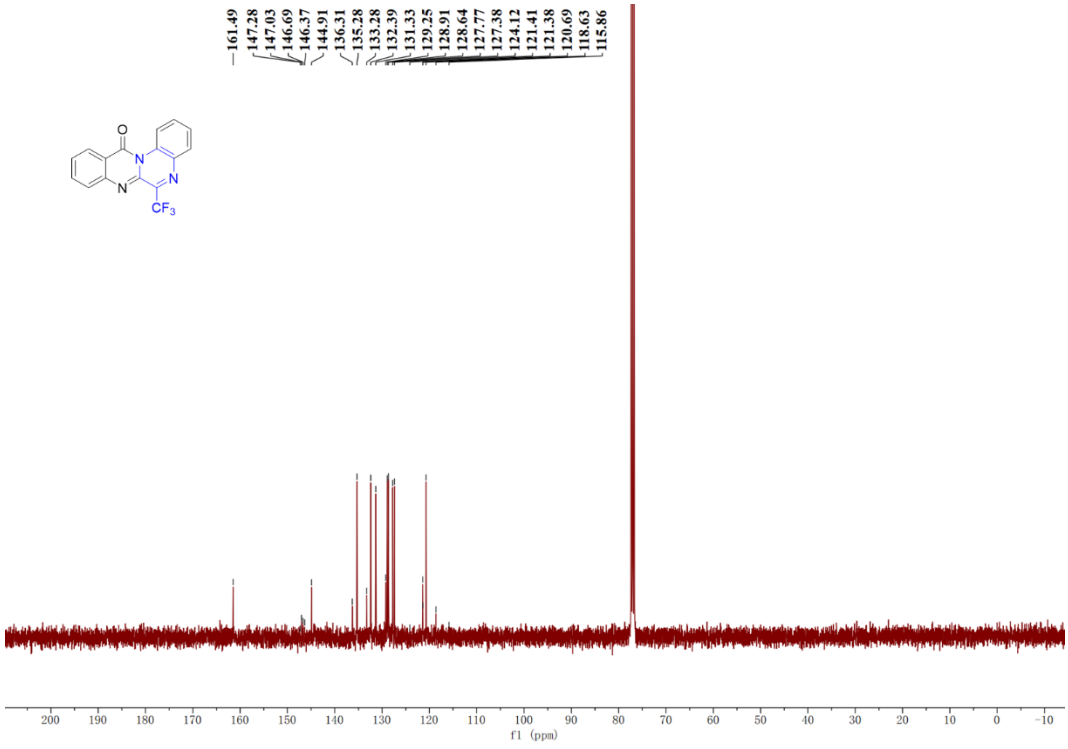
HRMS Calcd for $C_{17}H_{13}F_3NO_3$ $[M+H]^+$: 336.0803, found: 336.0808.

7. ^{1}H, ^{13}C and ^{19}F NMR spectra for products

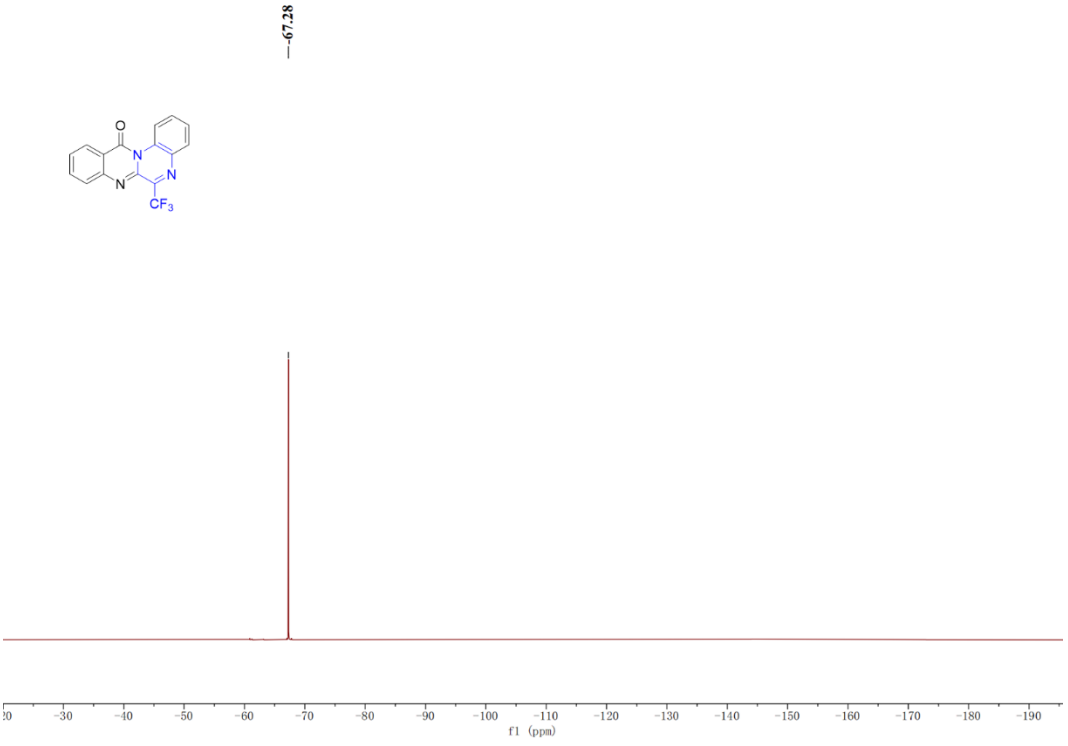
^{1}H NMR spectrum of 4a ($CDCl_3$, 400 MHz)



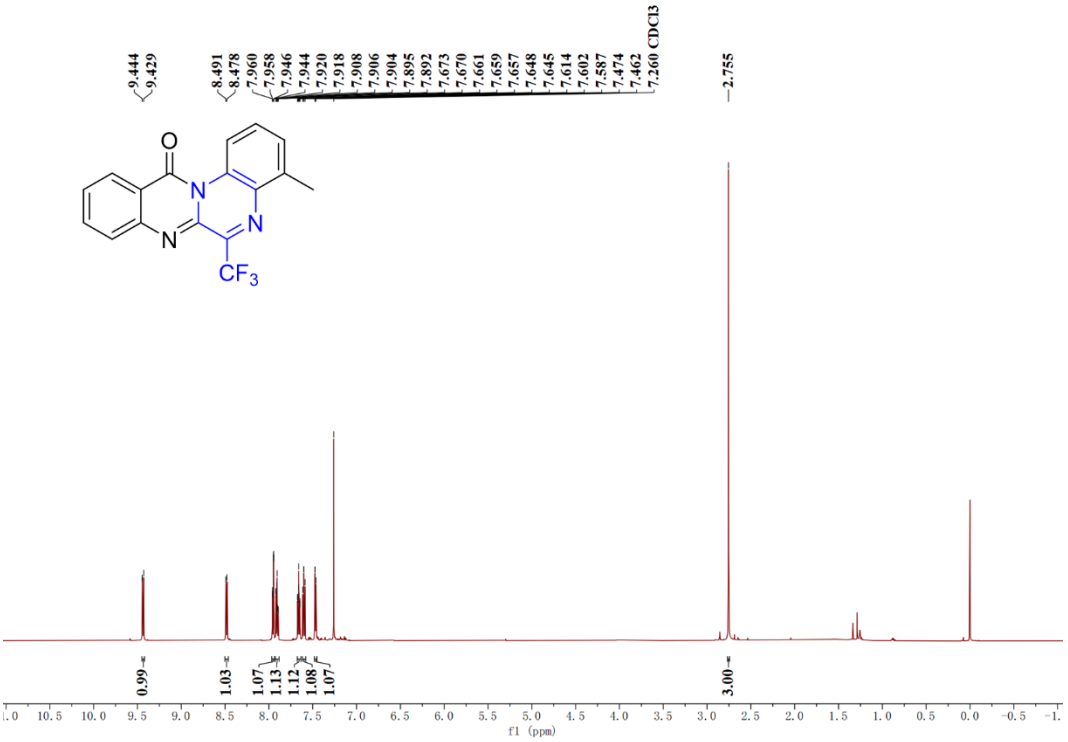
^{13}C NMR spectrum of 4a (101 MHz, $CDCl_3$)



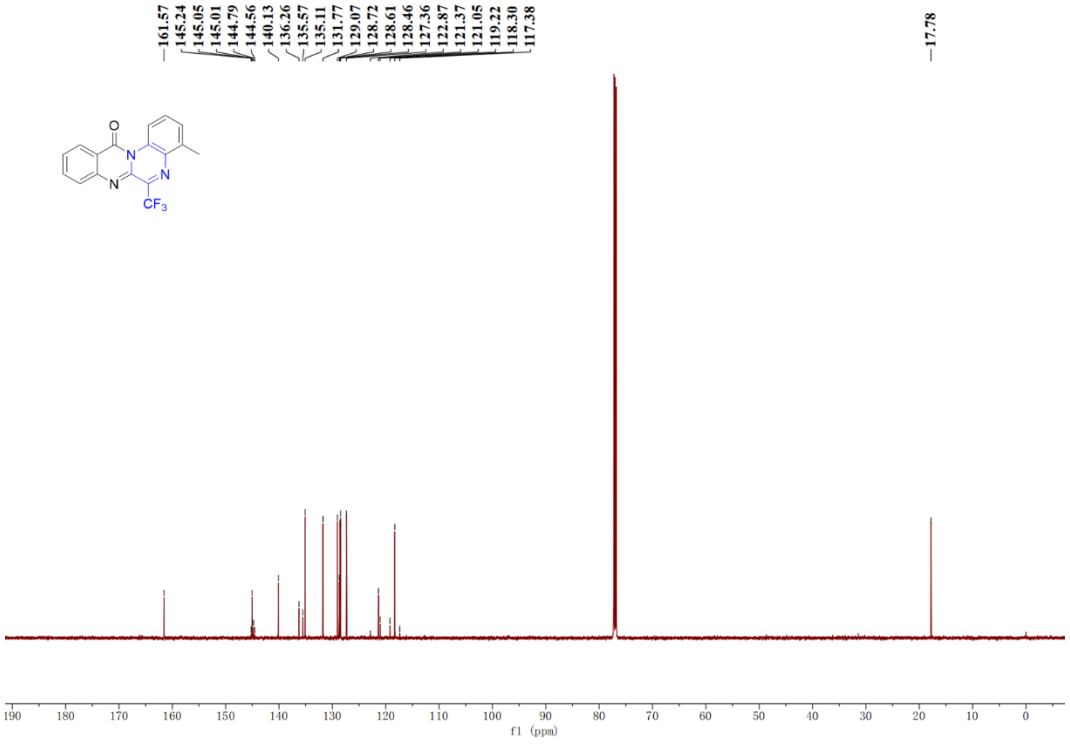
^{19}F NMR spectrum of 4a (376 MHz, $CDCl_3$)



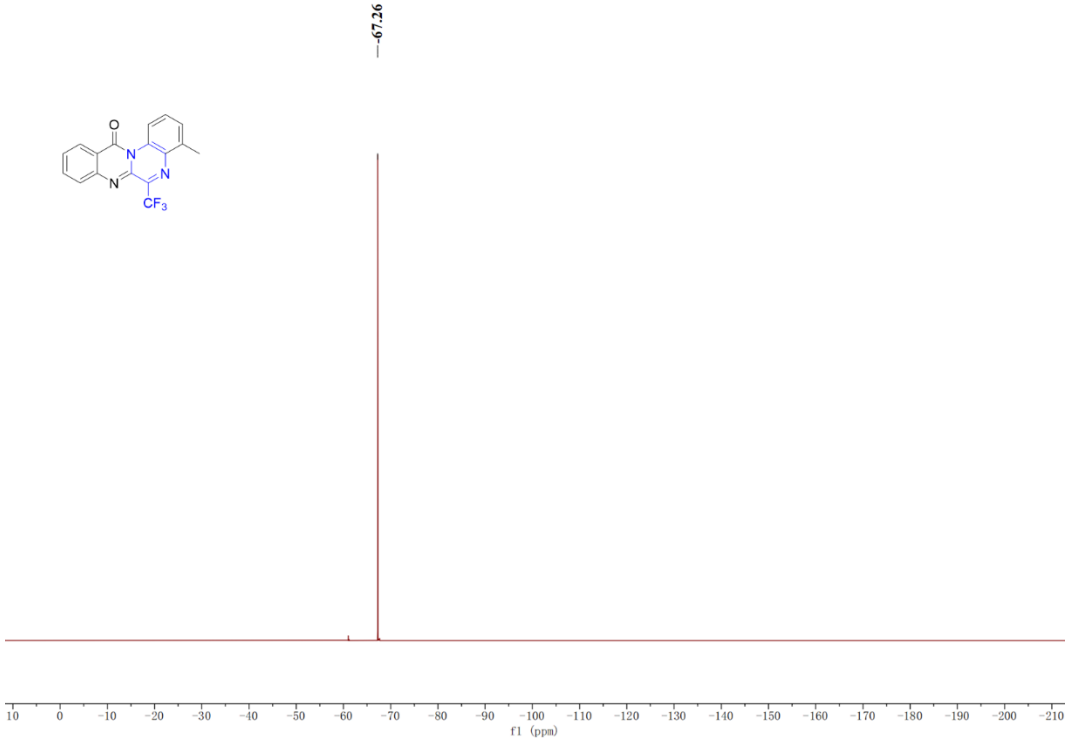
^{1}H NMR spectrum of 4b (600 MHz, $CDCl_3$)



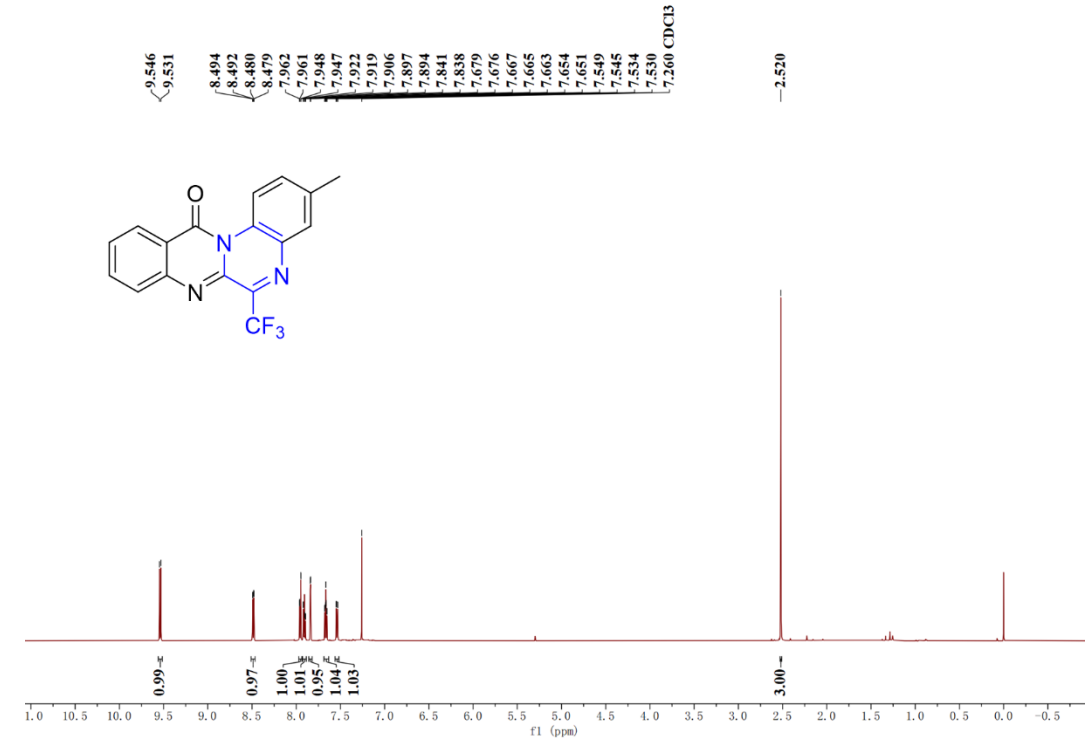
^{13}C NMR spectrum of 4b (151 MHz, $CDCl_3$)



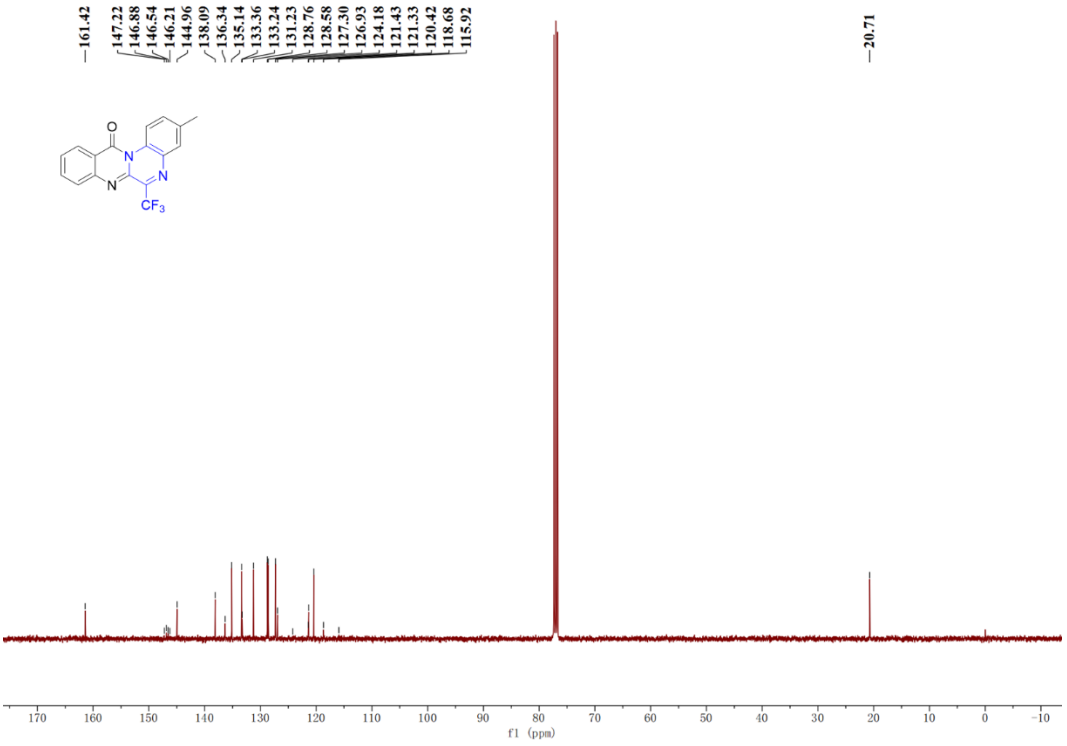
^{19}F NMR spectrum of 4b (565 MHz, $CDCl_3$)



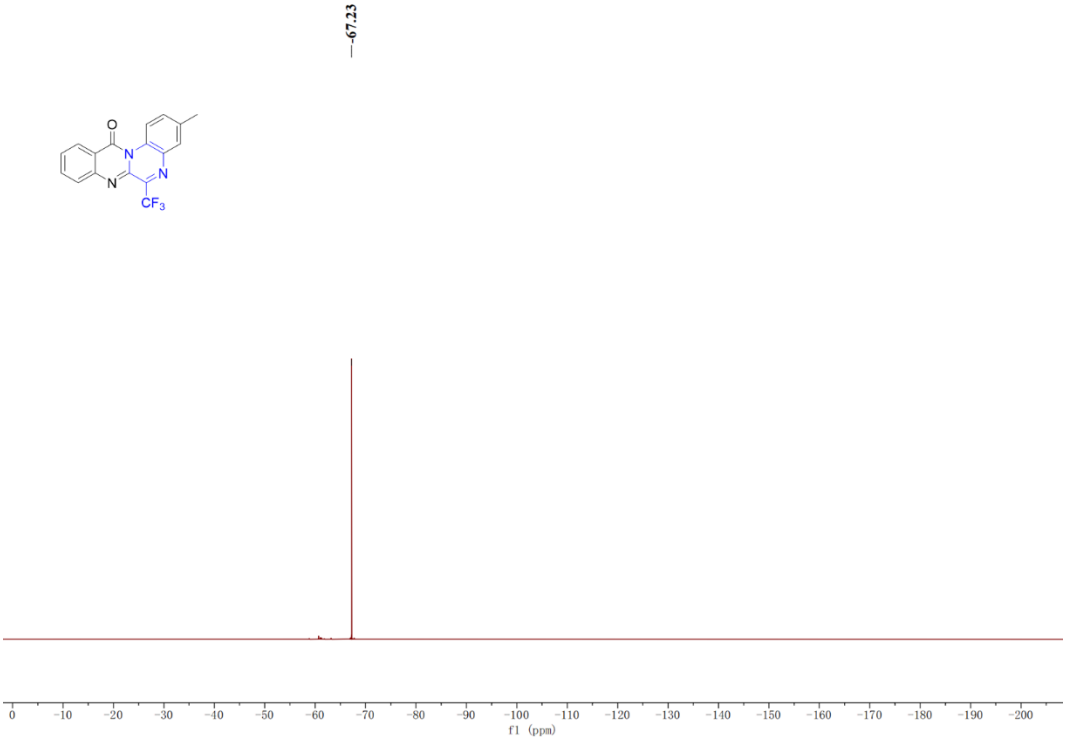
^{1}H NMR spectrum of 4c (600 MHz, $CDCl_3$)



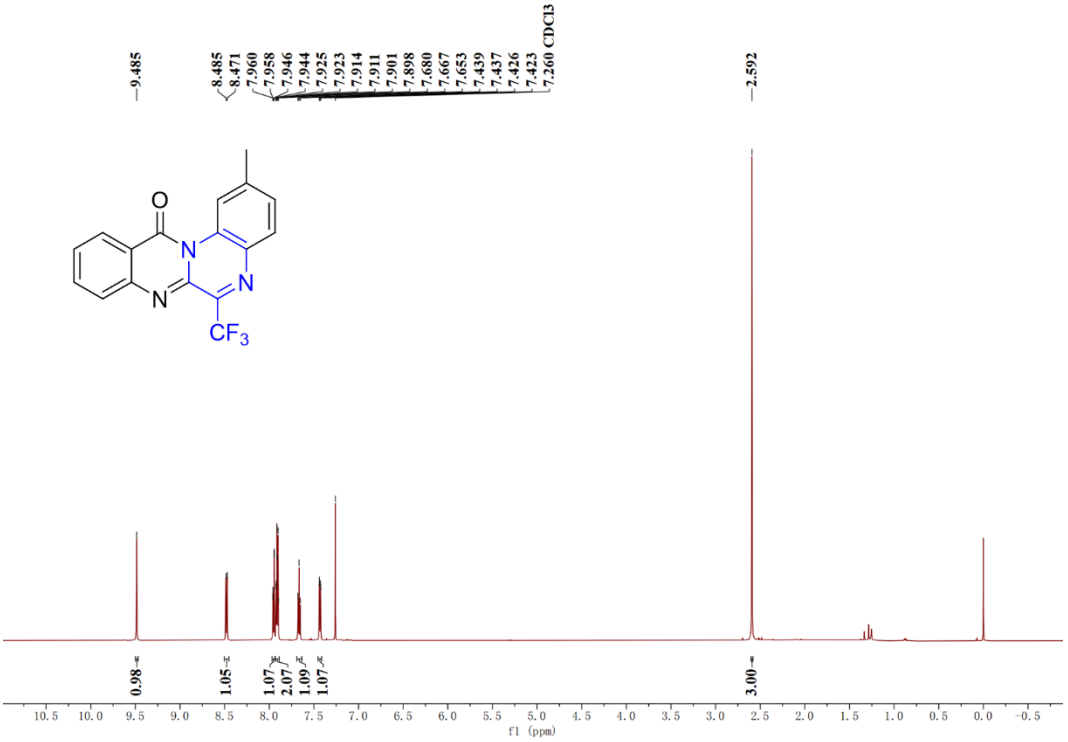
^{13}C NMR spectrum of 4c (101 MHz, $CDCl_3$)



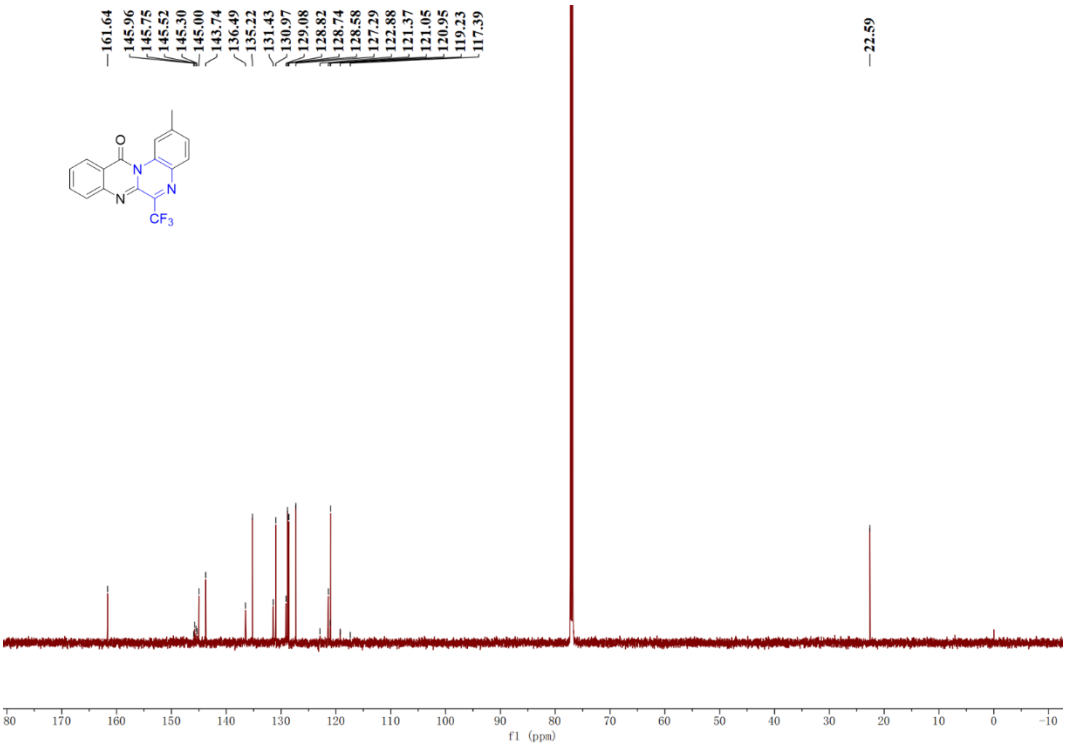
^{19}F NMR spectrum of 4c (376 MHz, $CDCl_3$)



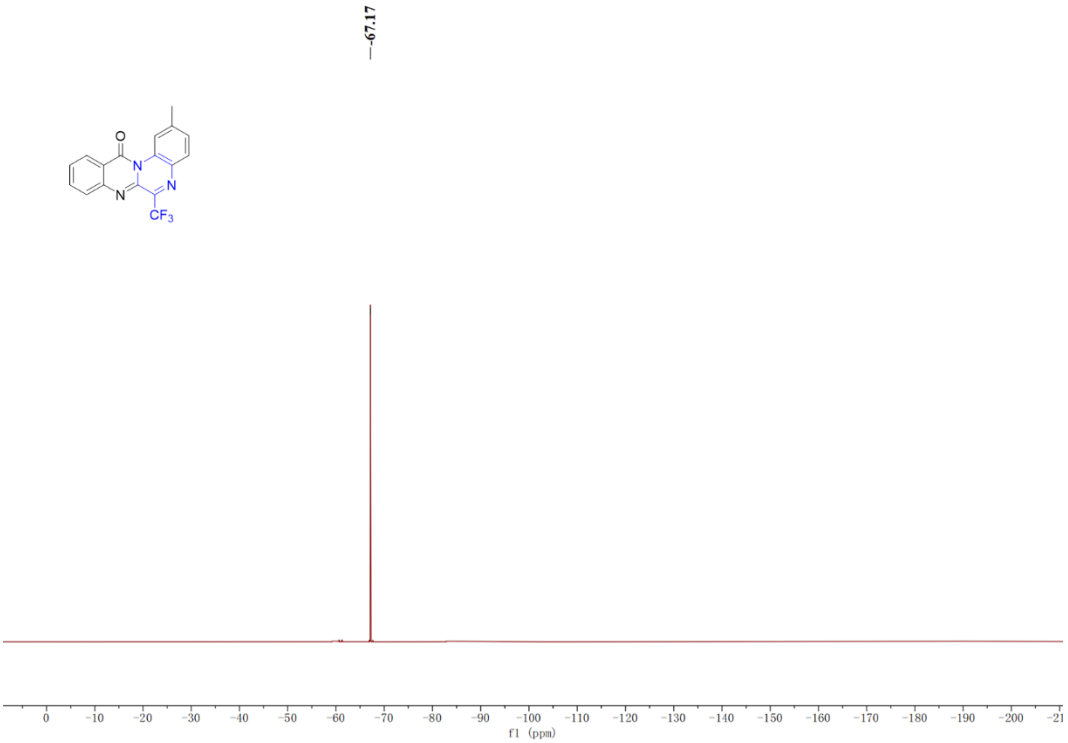
^{1}H NMR spectrum of 4d (600 MHz, $CDCl_3$)



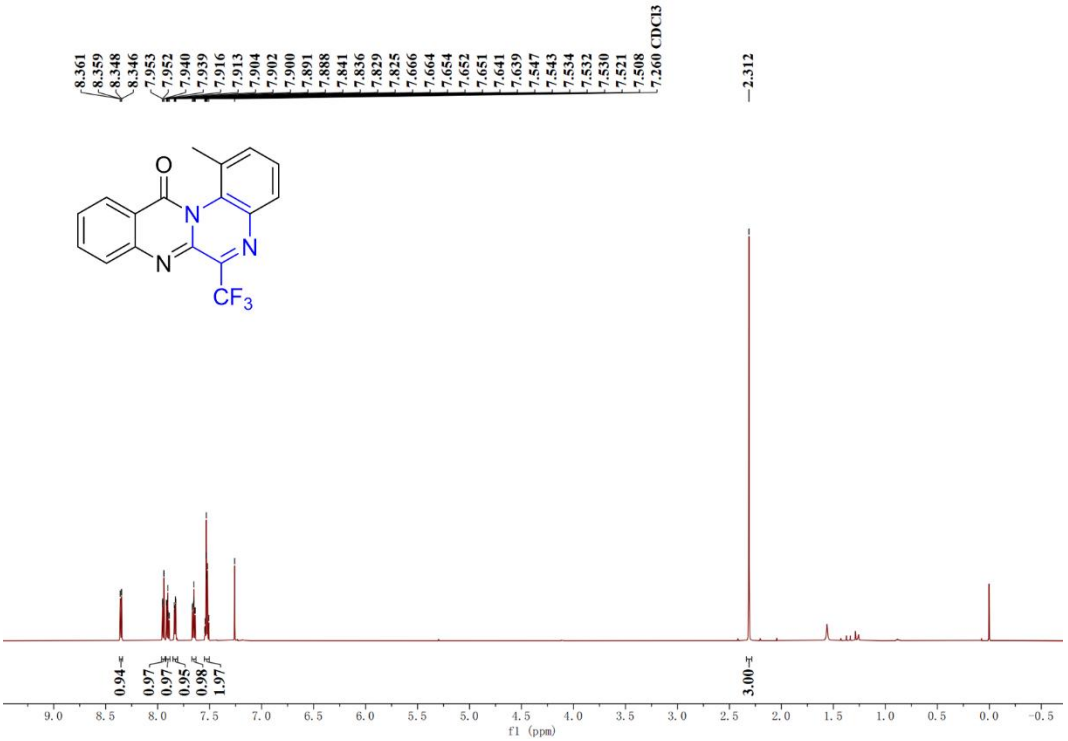
^{13}C NMR spectrum of 4d (151 MHz, $CDCl_3$)



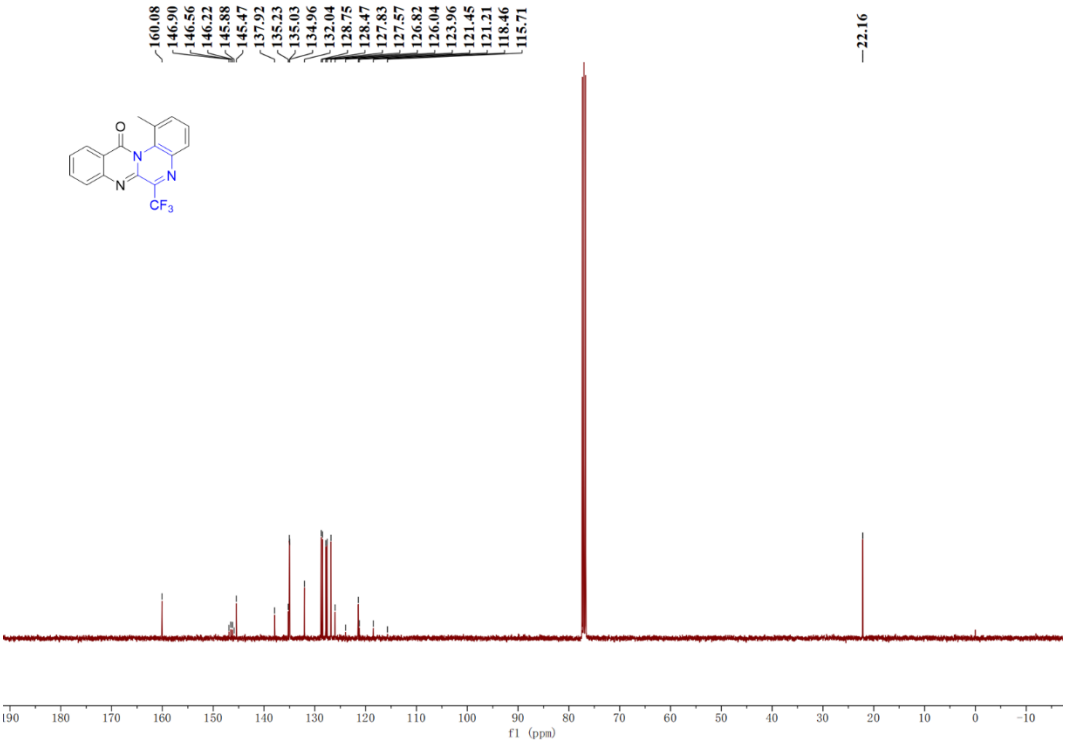
^{19}F NMR spectrum of 4d (565 MHz, $CDCl_3$)



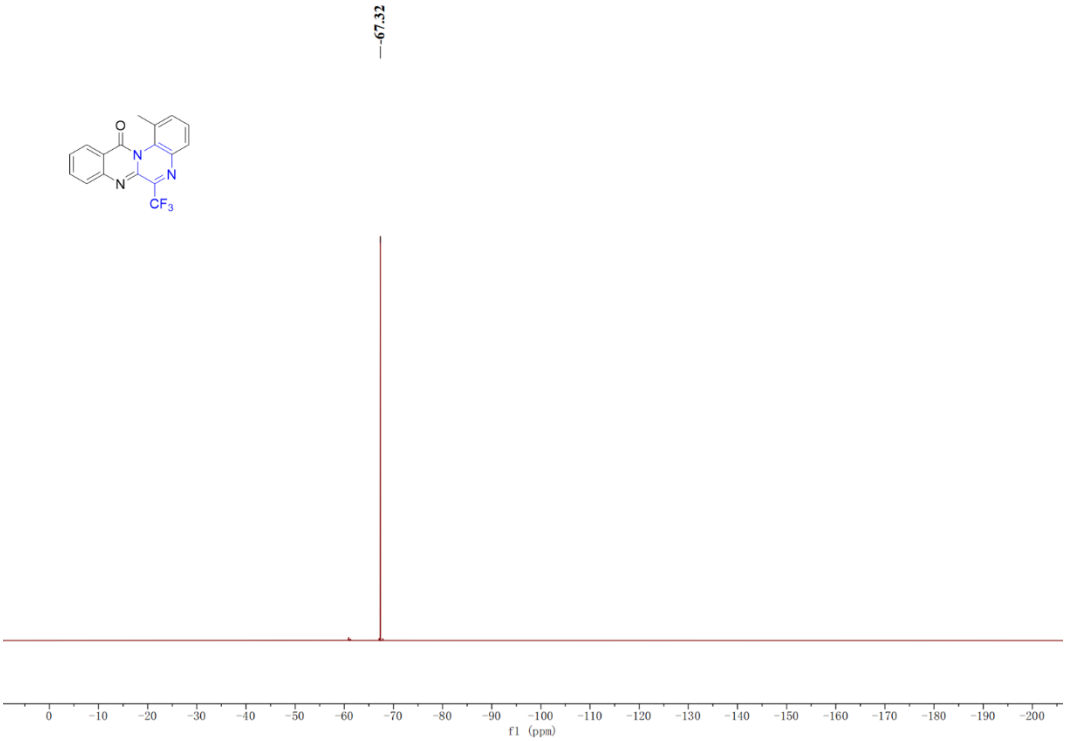
^{1}H NMR spectrum of 4e (600 MHz, $CDCl_3$)



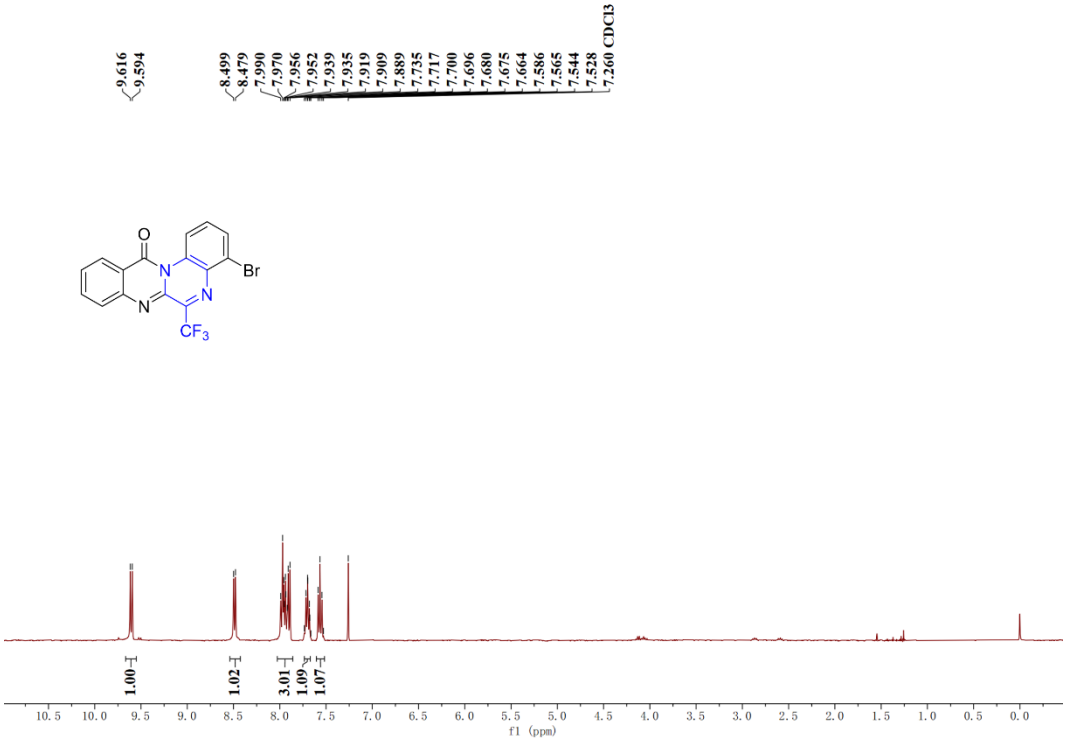
^{13}C NMR spectrum of 4e (101 MHz, $CDCl_3$)



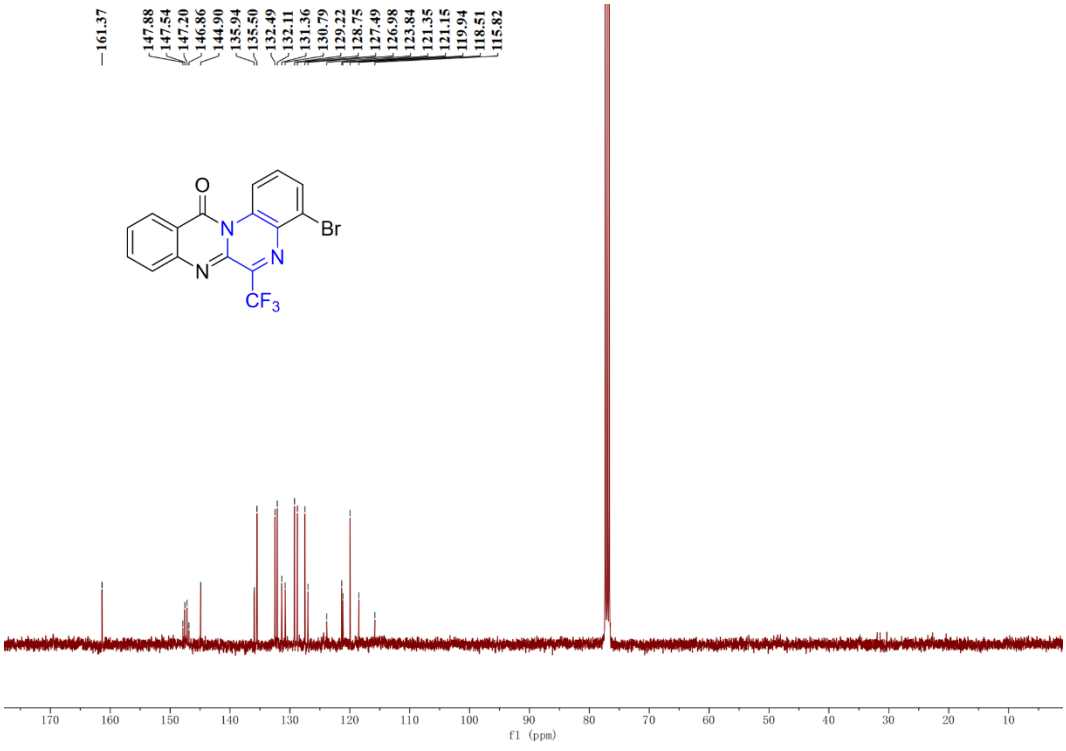
^{19}F NMR spectrum of 4e (376 MHz, $CDCl_3$)



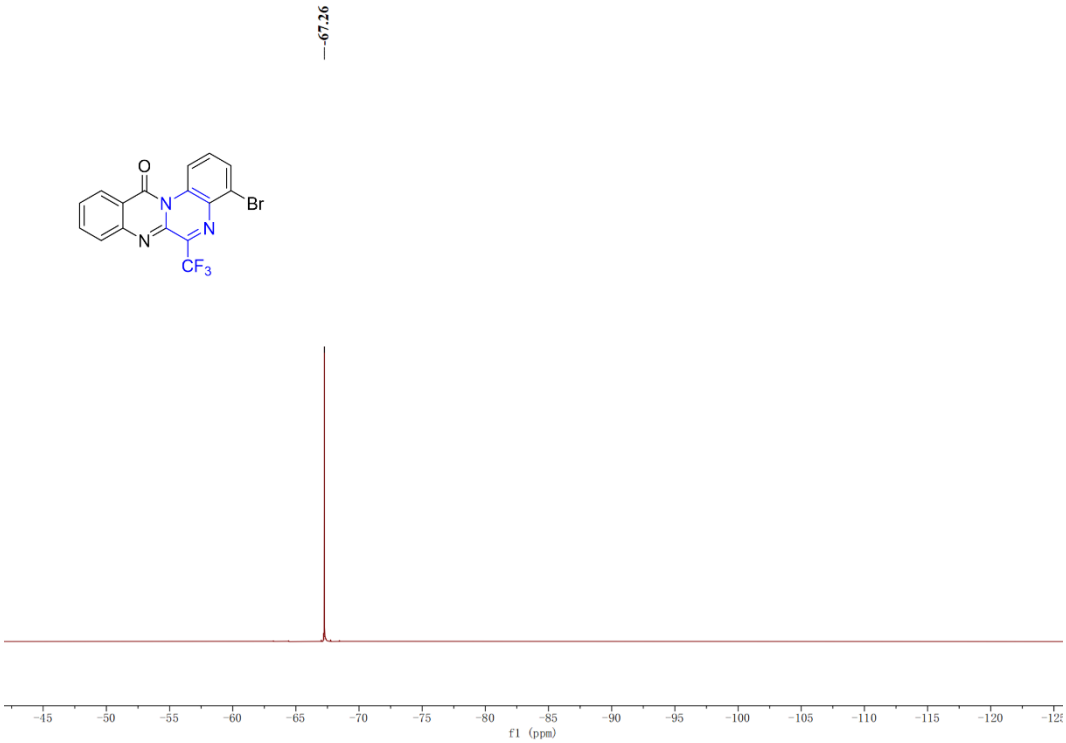
^{1}H NMR spectrum of 4f (400 MHz, $CDCl_3$)



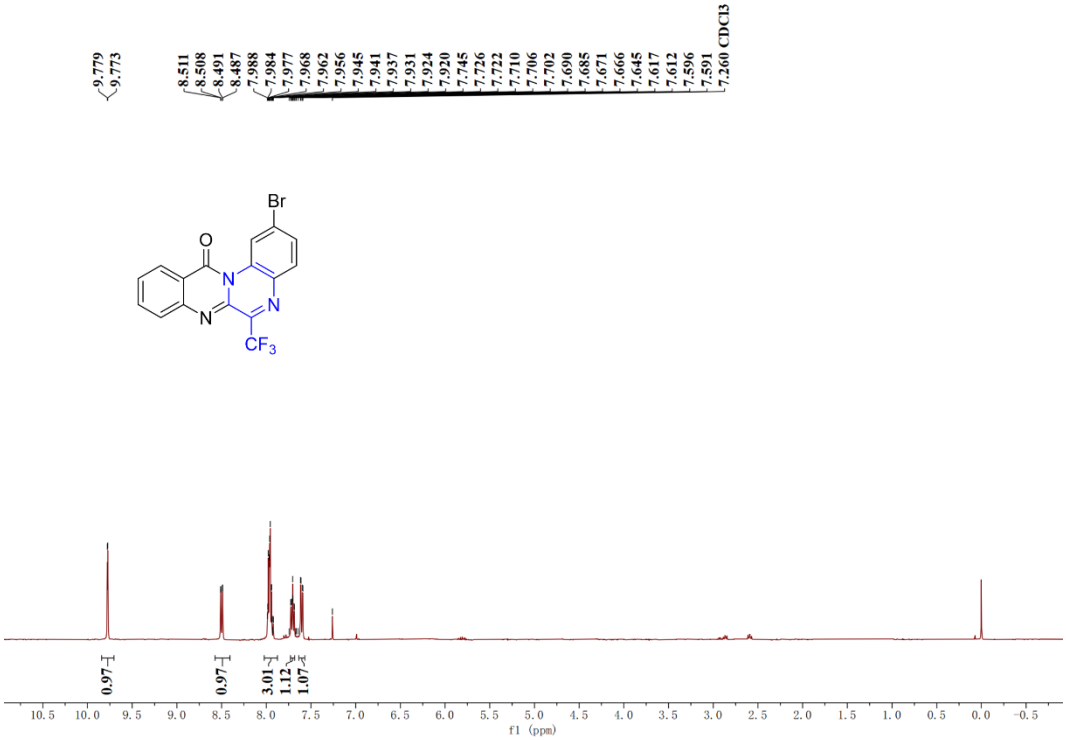
^{13}C NMR spectrum of 4f (101 MHz, $CDCl_3$)



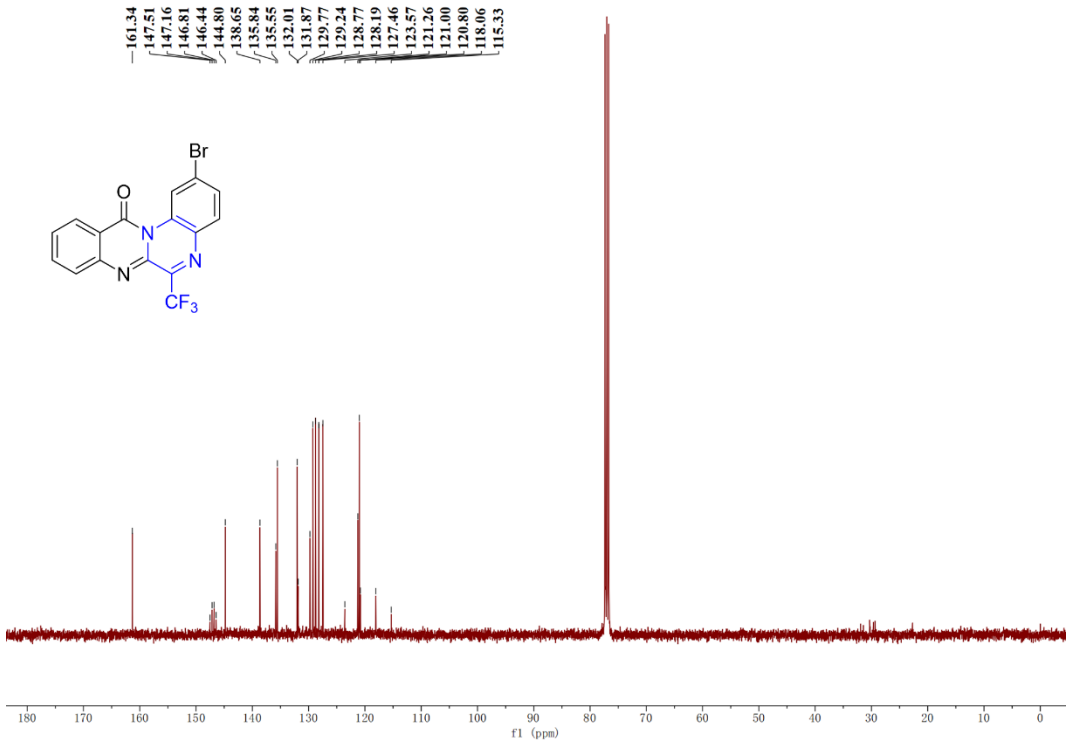
^{19}F NMR spectrum of 4f (376 MHz, $CDCl_3$)



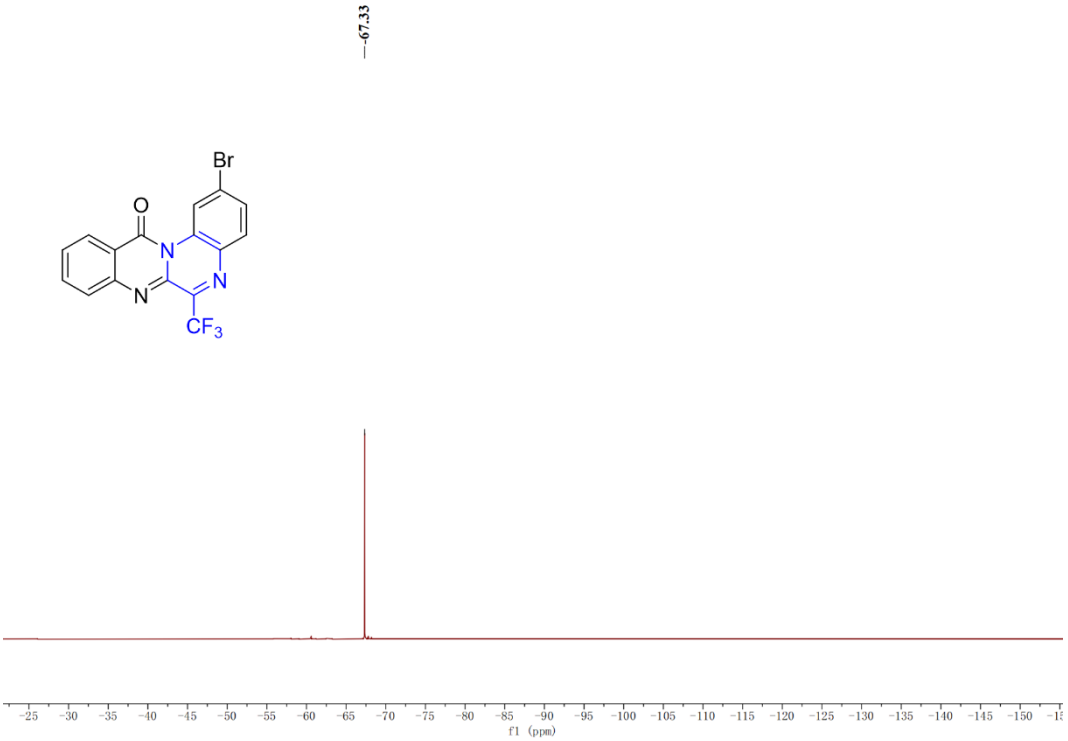
^{1}H NMR spectrum of 4g (400 MHz, $CDCl_3$)



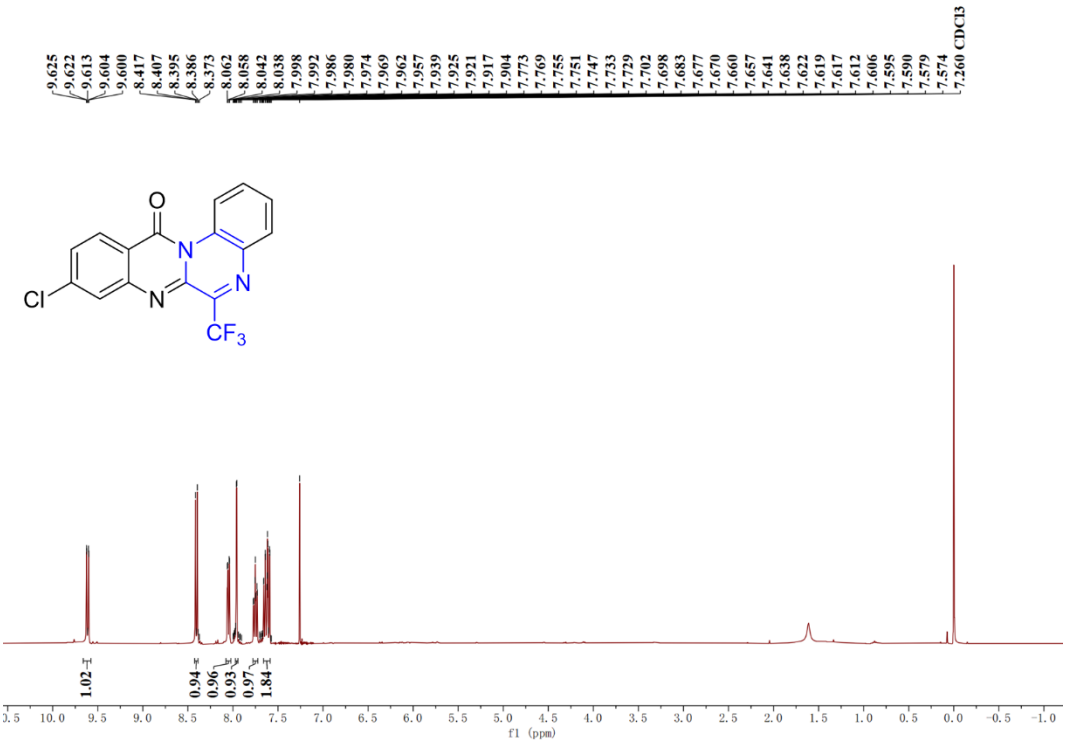
^{13}C NMR spectrum of 4g (101 MHz, $CDCl_3$)



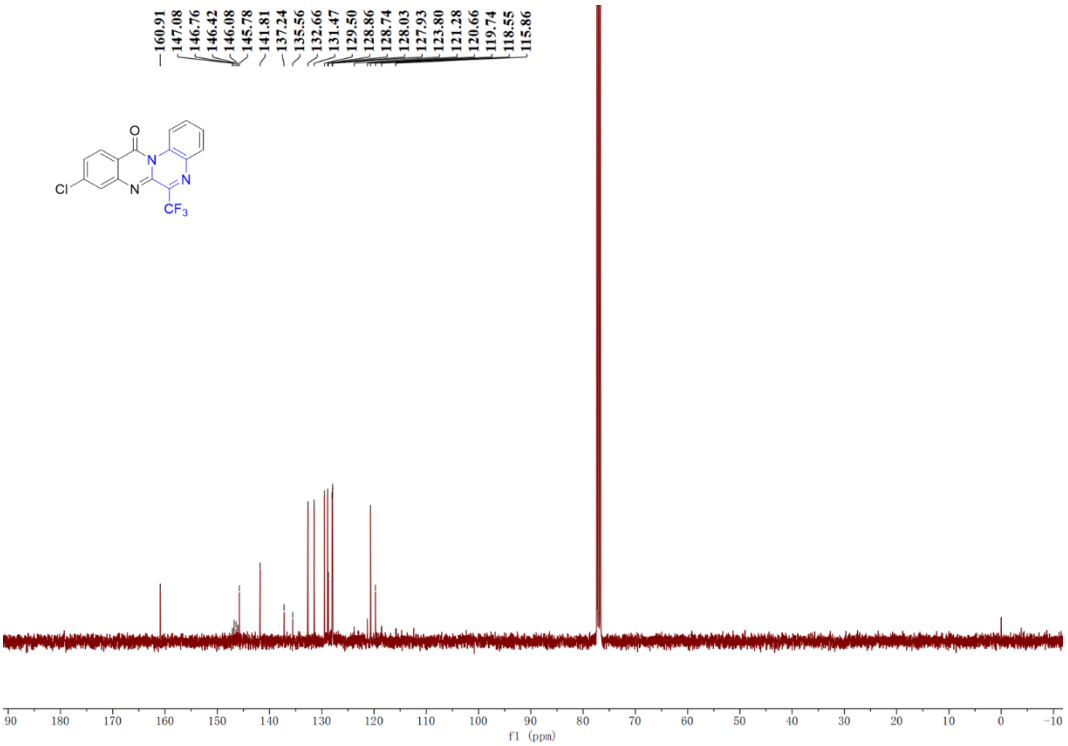
^{19}F NMR spectrum of 4g (376 MHz, $CDCl_3$)



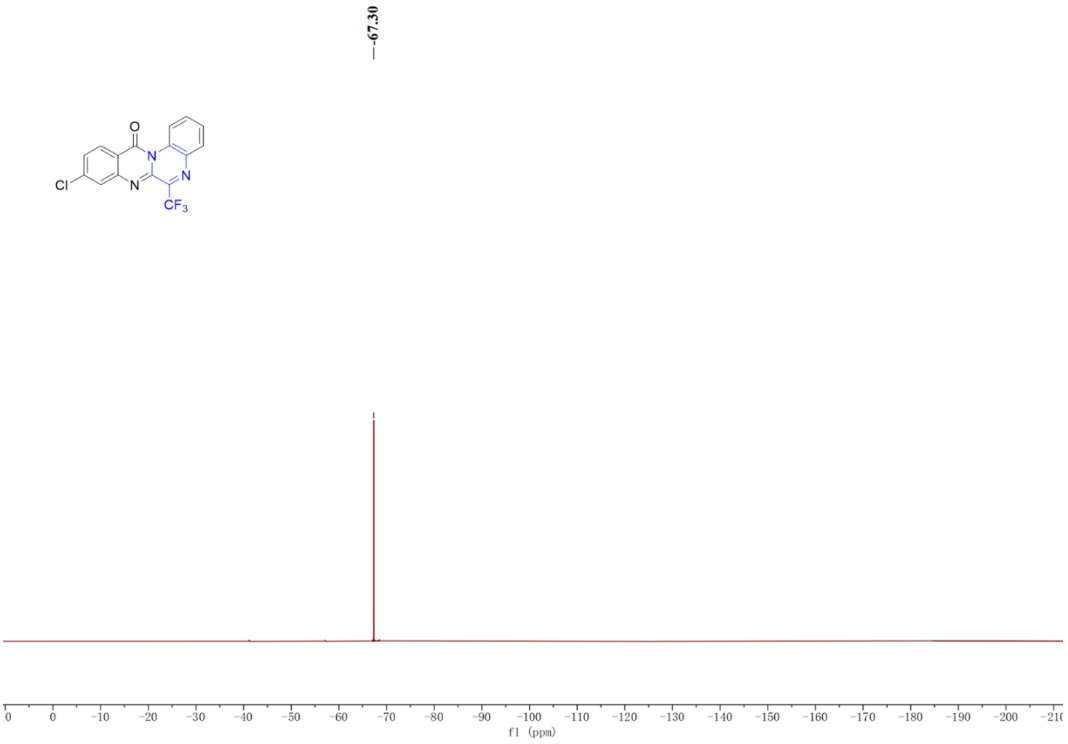
^{1}H NMR spectrum of 4h (400 MHz, $CDCl_3$)



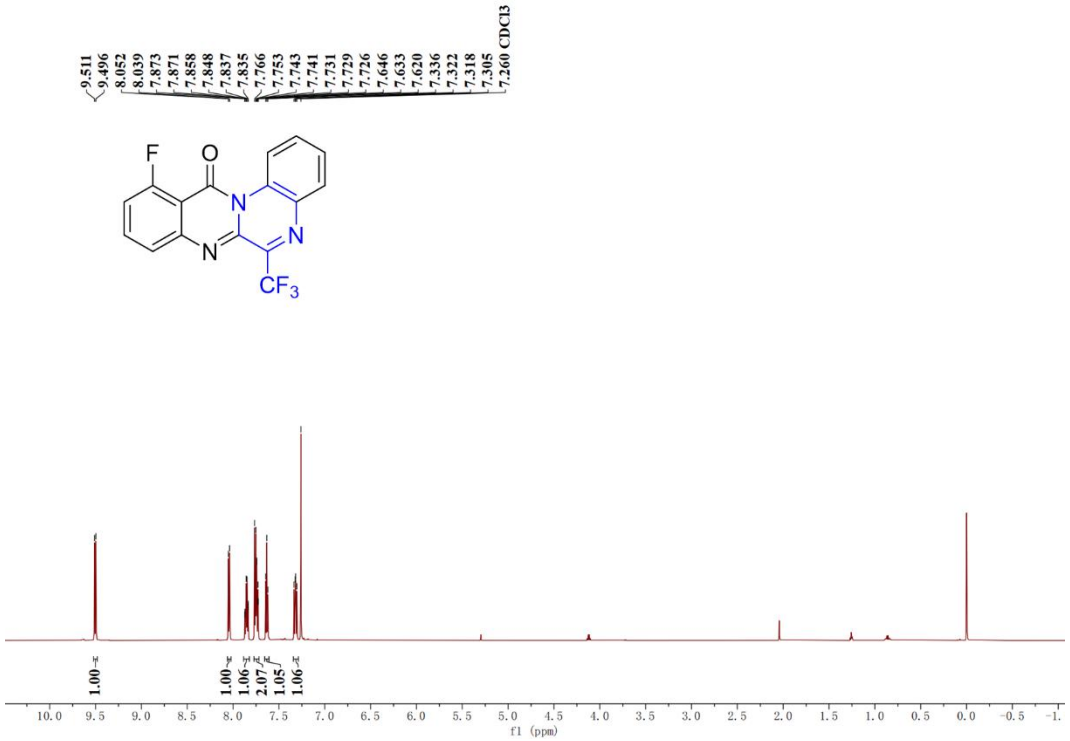
^{13}C NMR spectrum of 4h (101 MHz, $CDCl_3$)



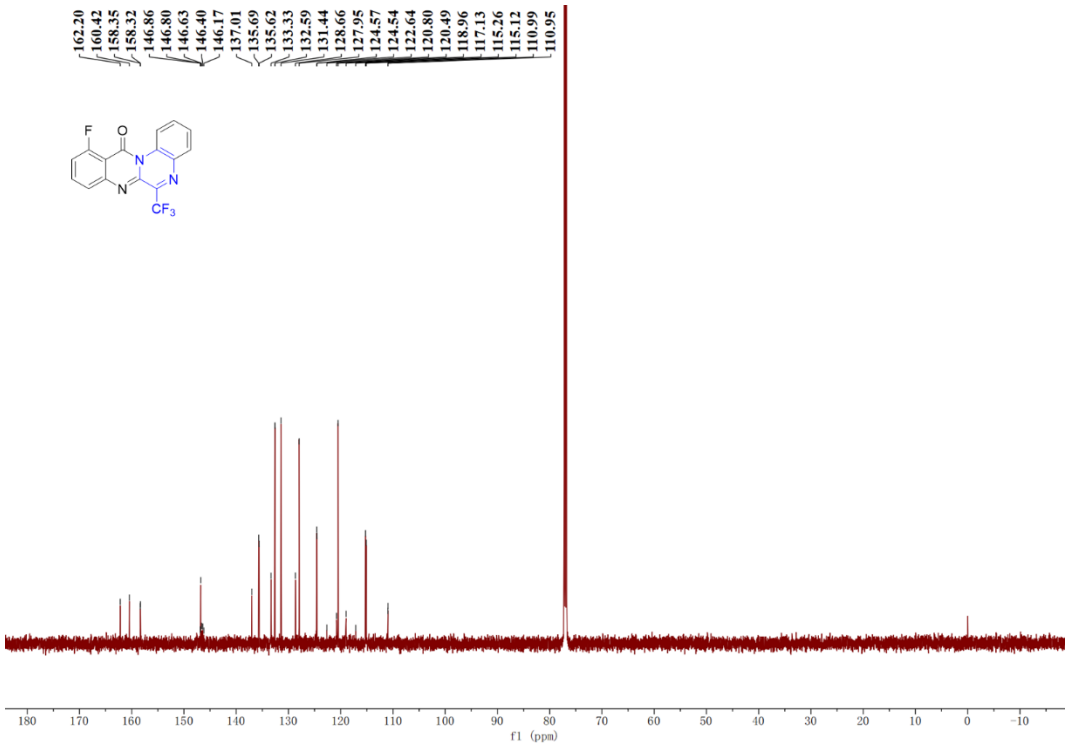
^{19}F NMR spectrum of 4h (376 MHz, $CDCl_3$)



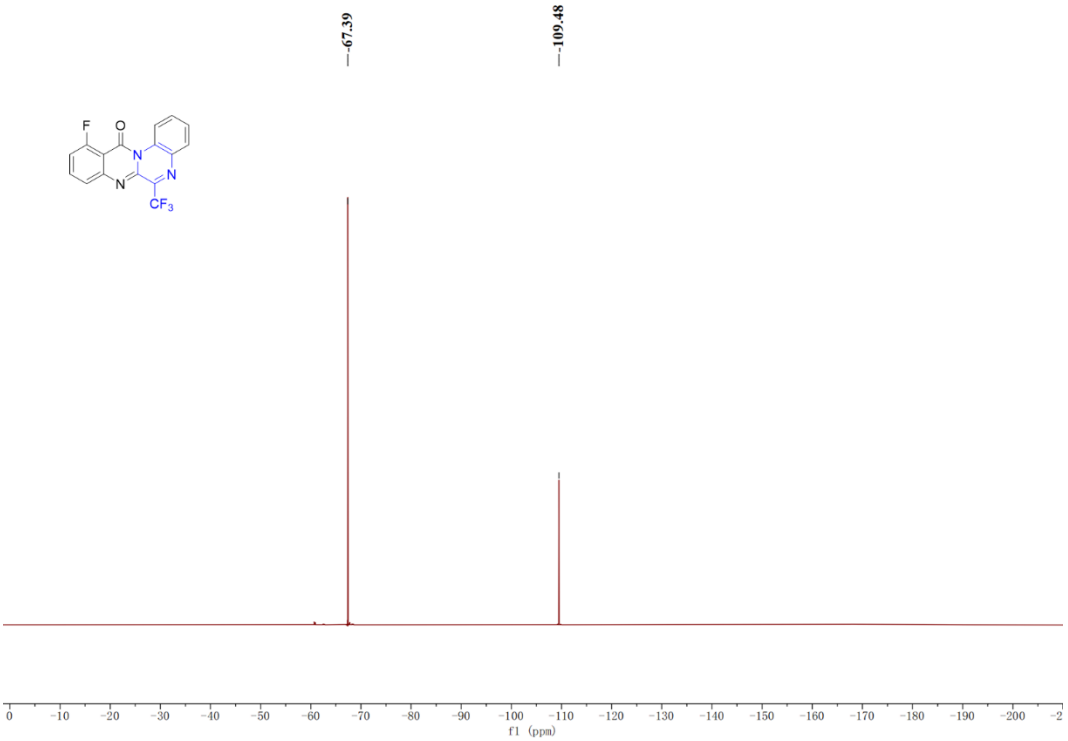
^{1}H NMR spectrum of 4i (600 MHz, $CDCl_3$)



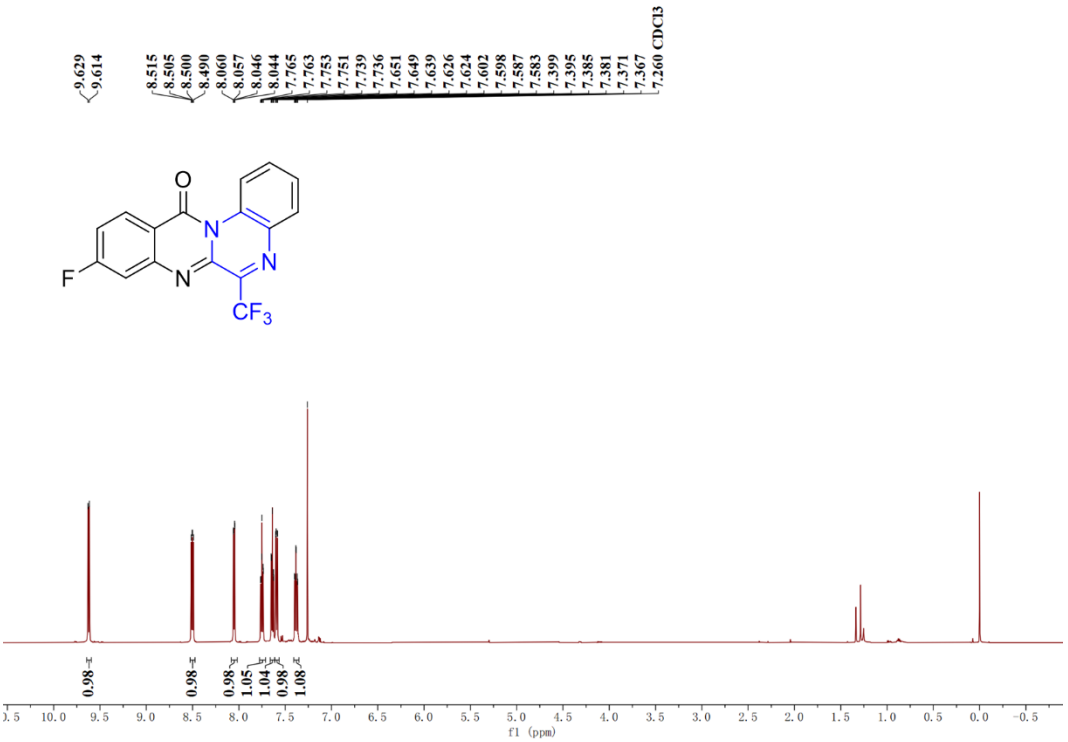
^{13}C NMR spectrum of 4i (151 MHz, $CDCl_3$)



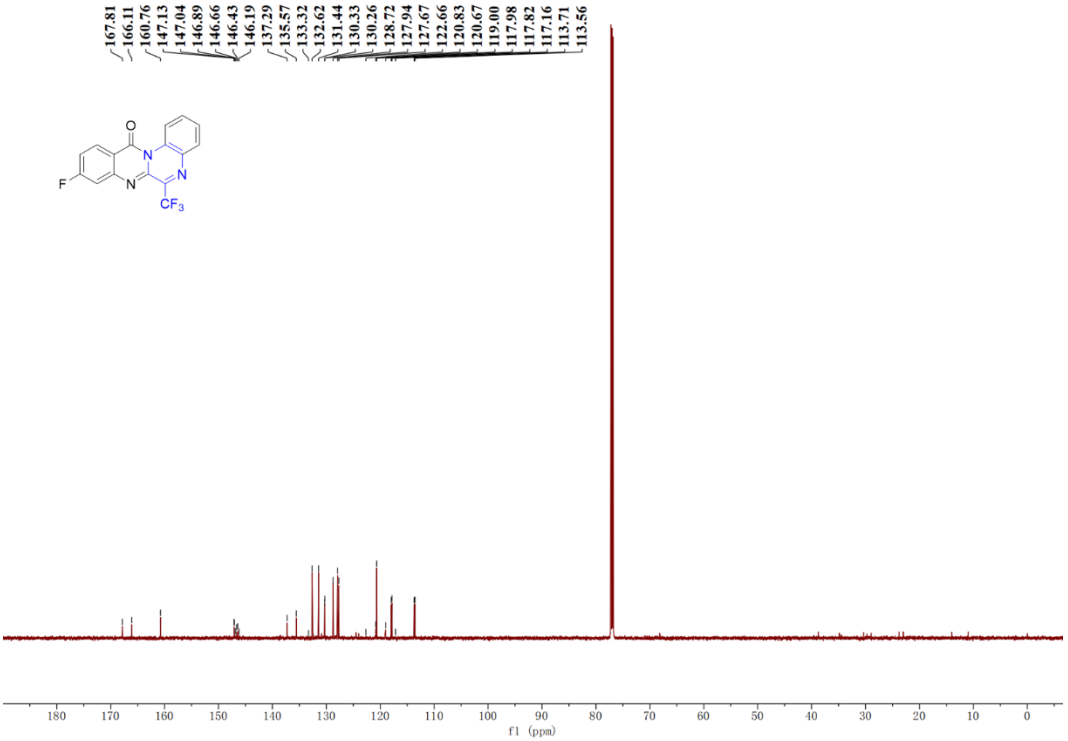
^{19}F NMR spectrum of 4i (565 MHz, $CDCl_3$)



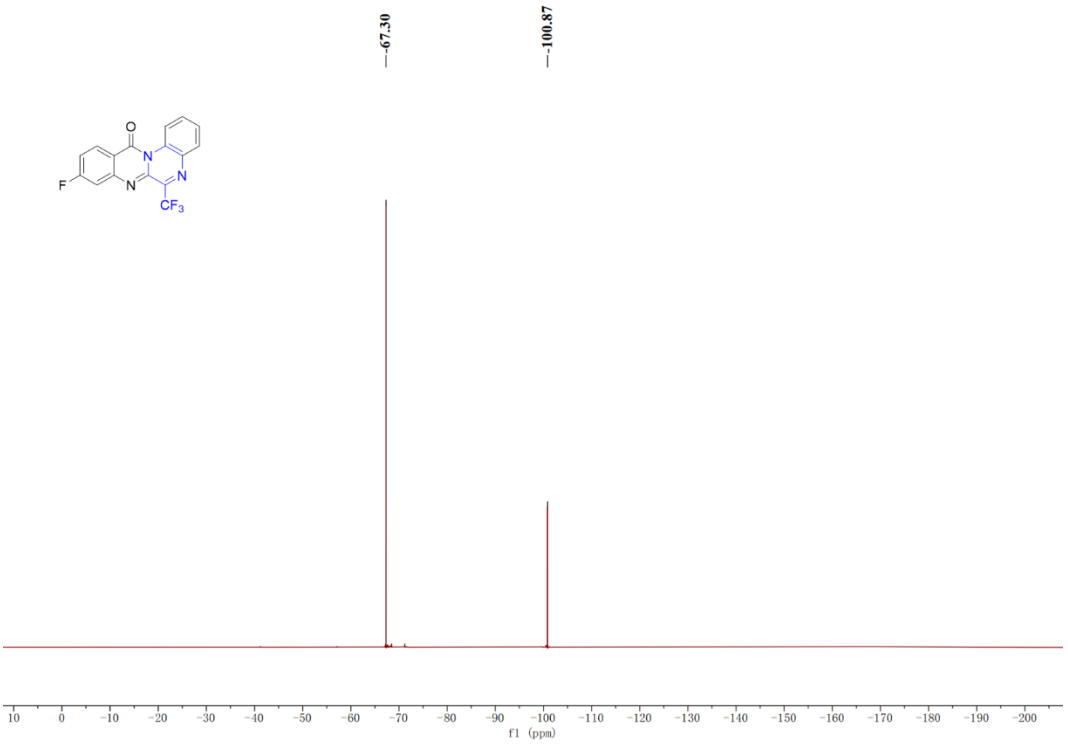
^{1}H NMR spectrum of 4j (600 MHz, $CDCl_3$)



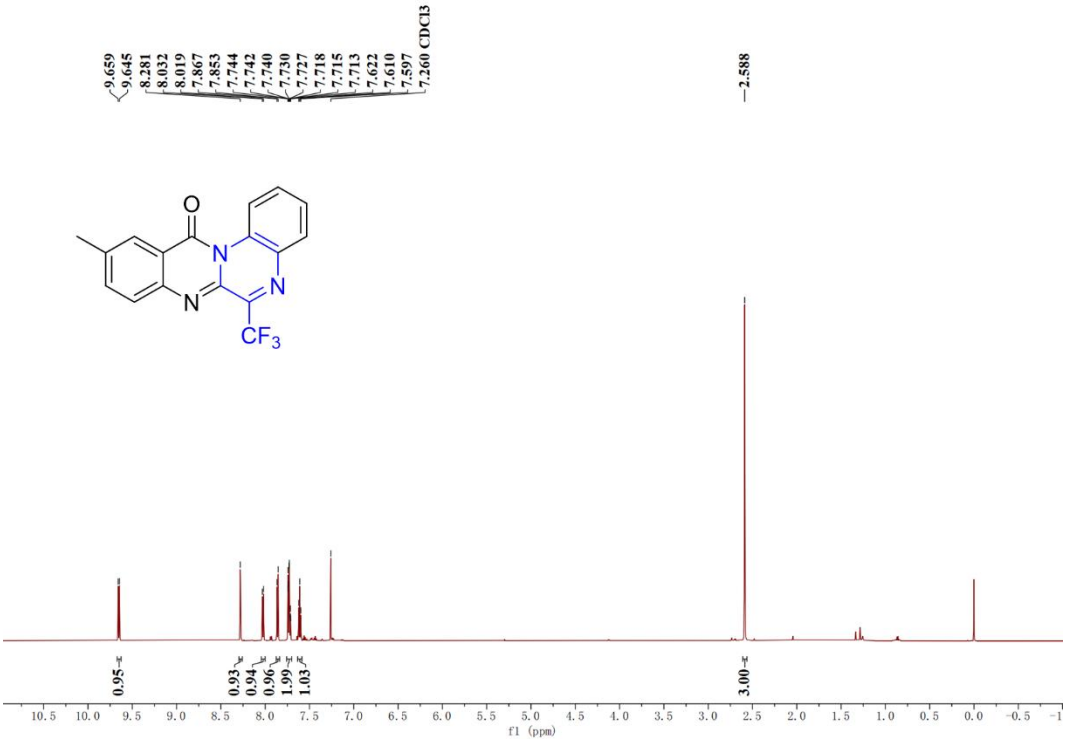
^{13}C NMR spectrum of 4j (151 MHz, $CDCl_3$)



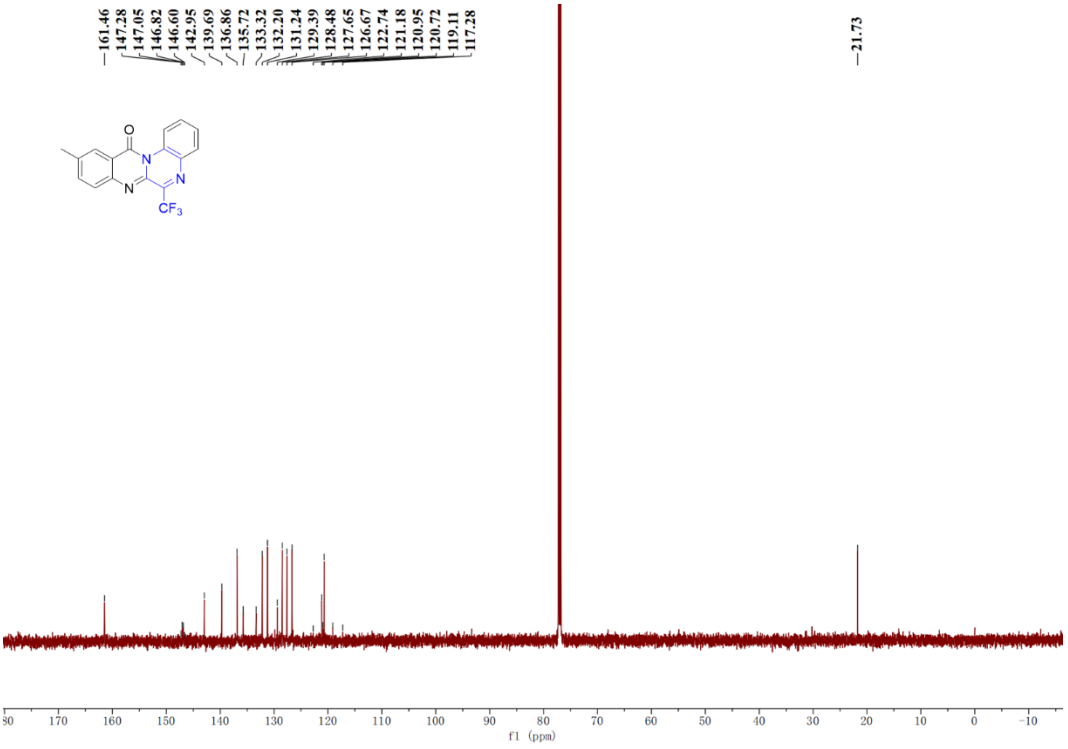
^{19}F NMR spectrum of 4j (565 MHz, $CDCl_3$)



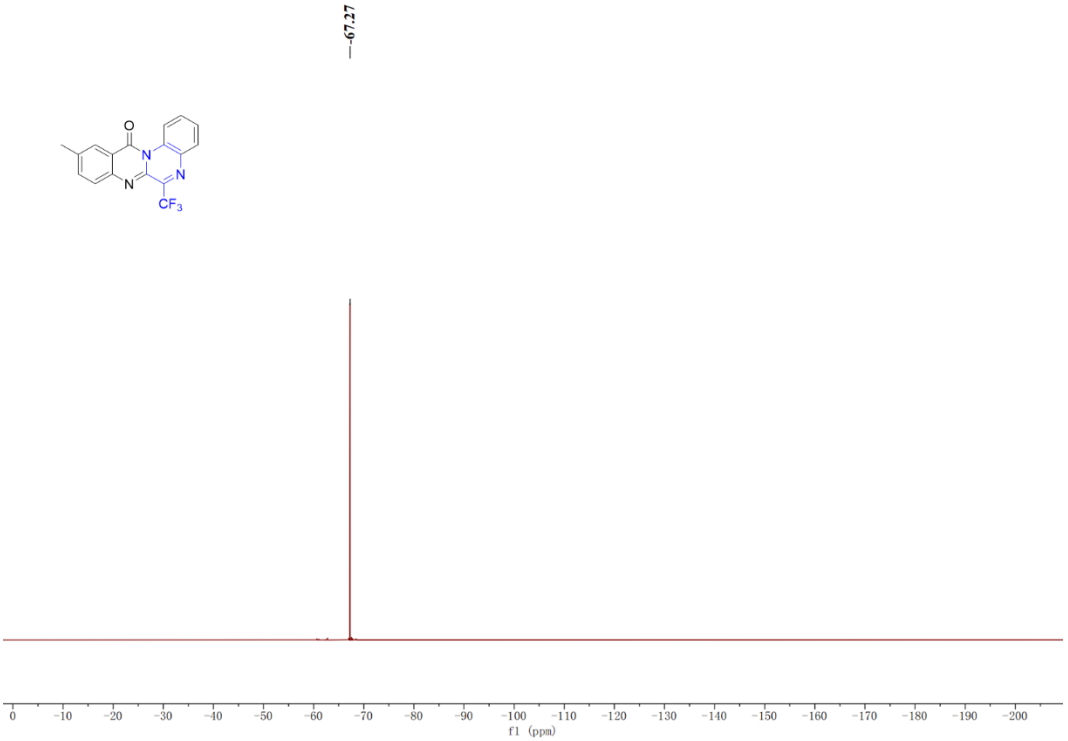
^{1}H NMR spectrum of 4k (600 MHz, $CDCl_3$)



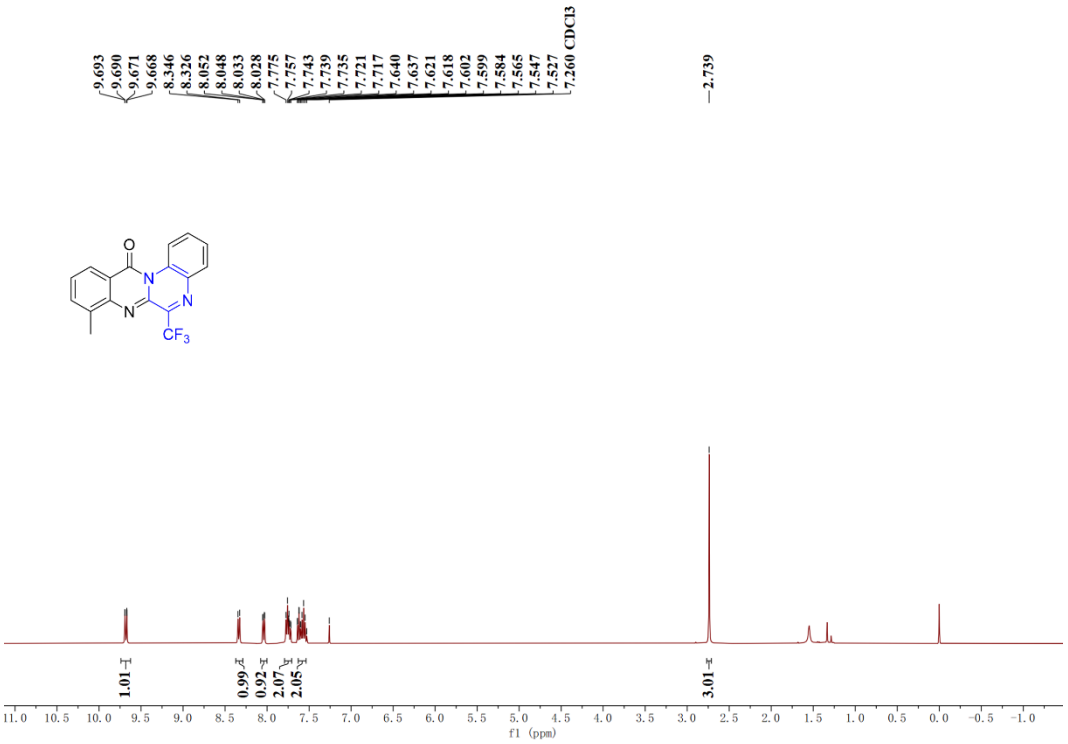
^{13}C NMR spectrum of 4k (151 MHz, $CDCl_3$)



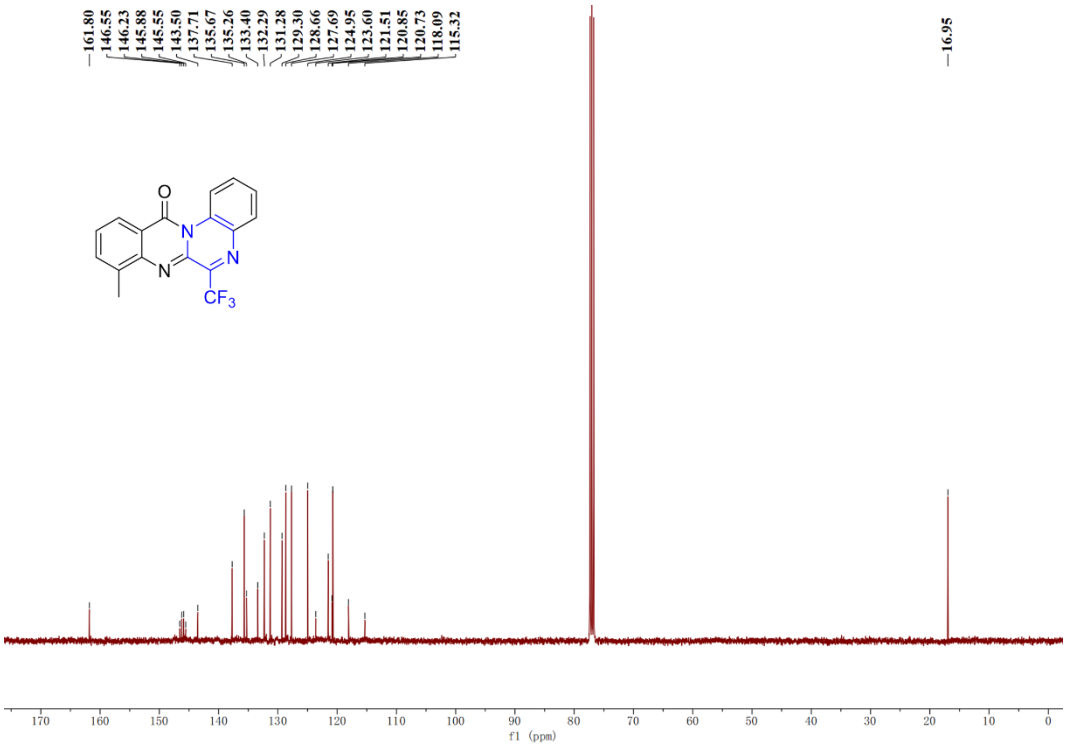
^{19}F NMR spectrum of 4k (565 MHz, $CDCl_3$)



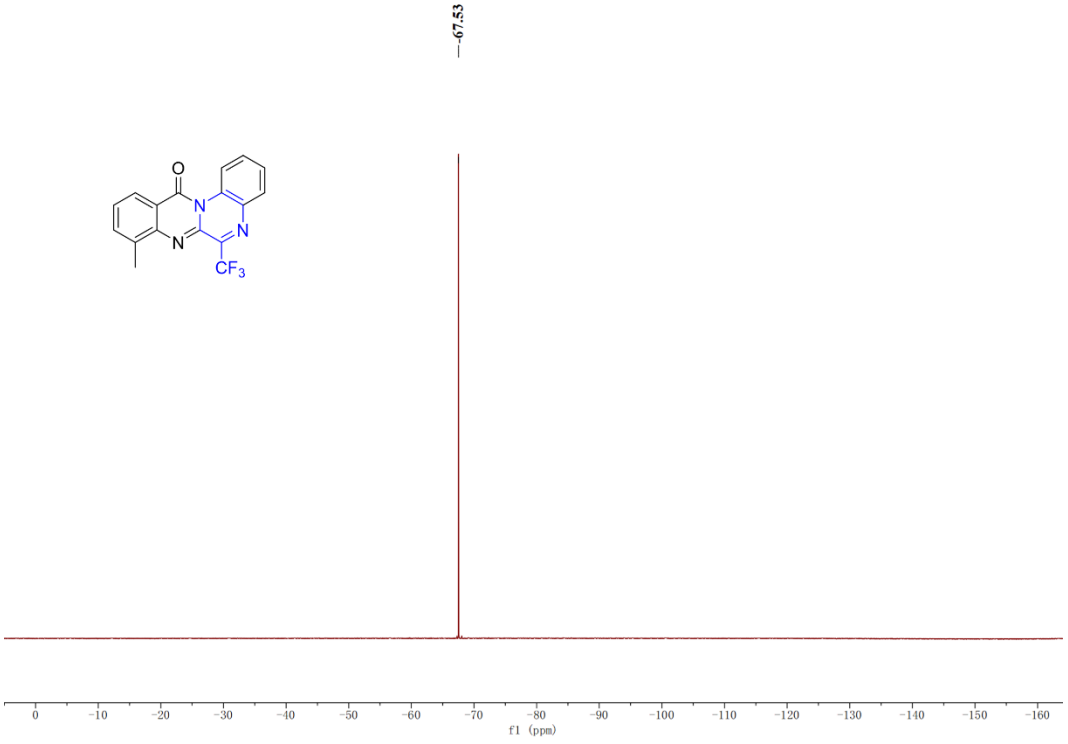
^{1}H NMR spectrum of 4l (400 MHz, $CDCl_3$)



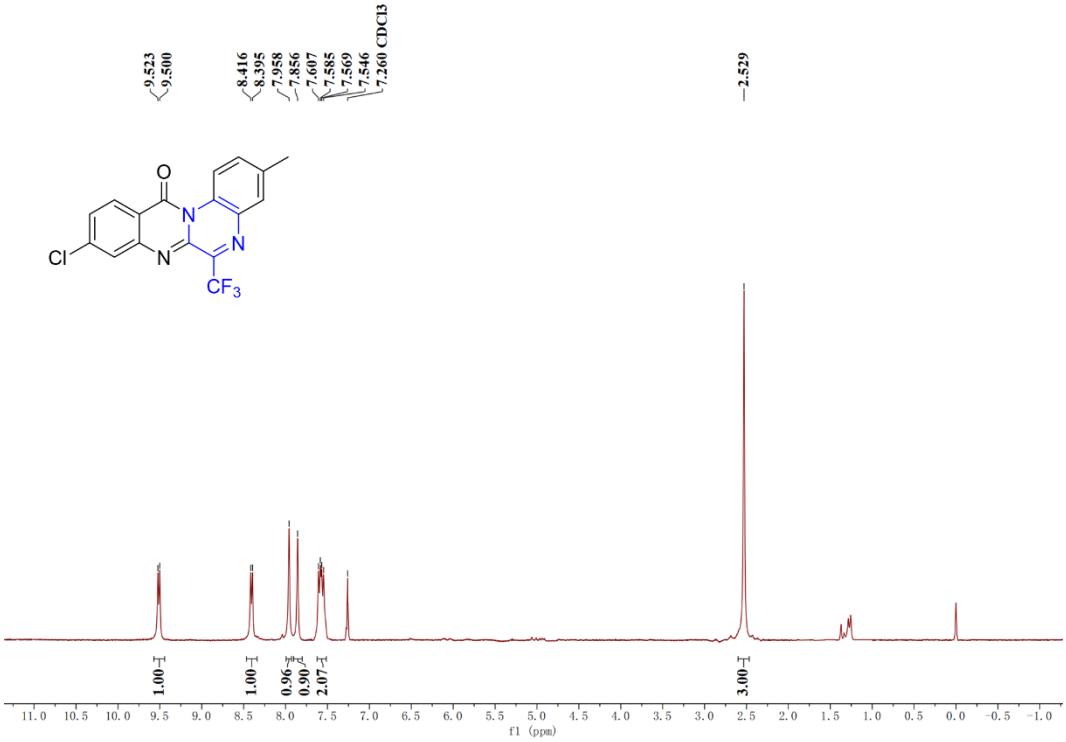
^{13}C NMR spectrum of 4l (101 MHz, $CDCl_3$)



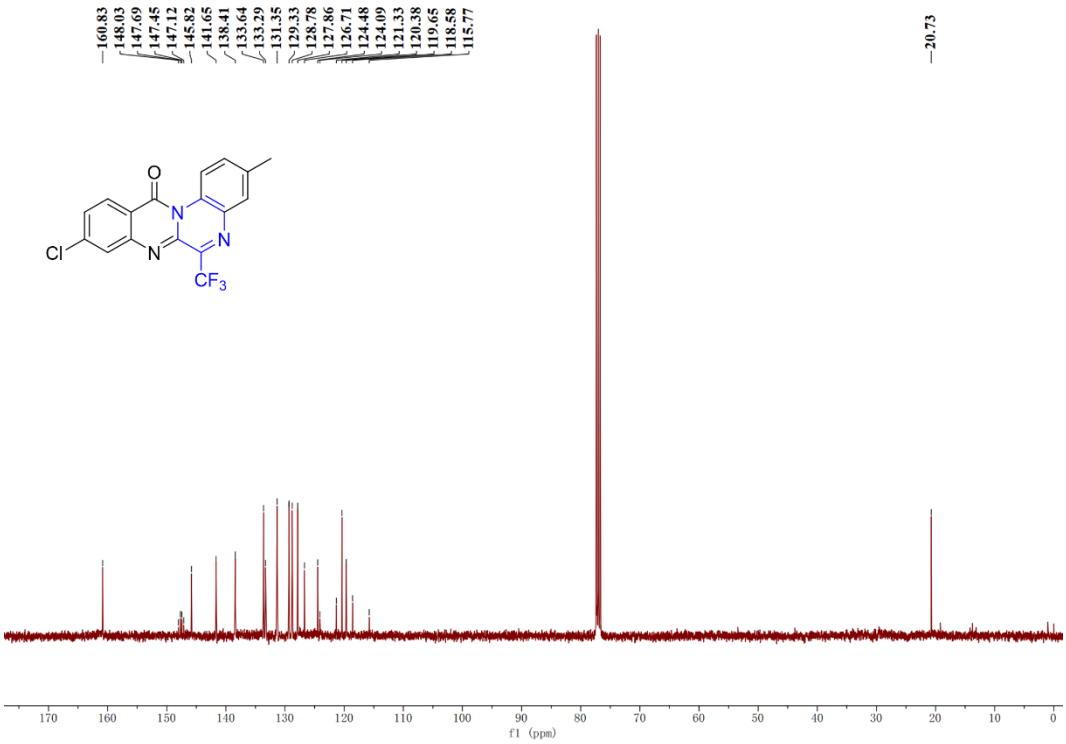
^{19}F NMR spectrum of 4l (376 MHz, $CDCl_3$)



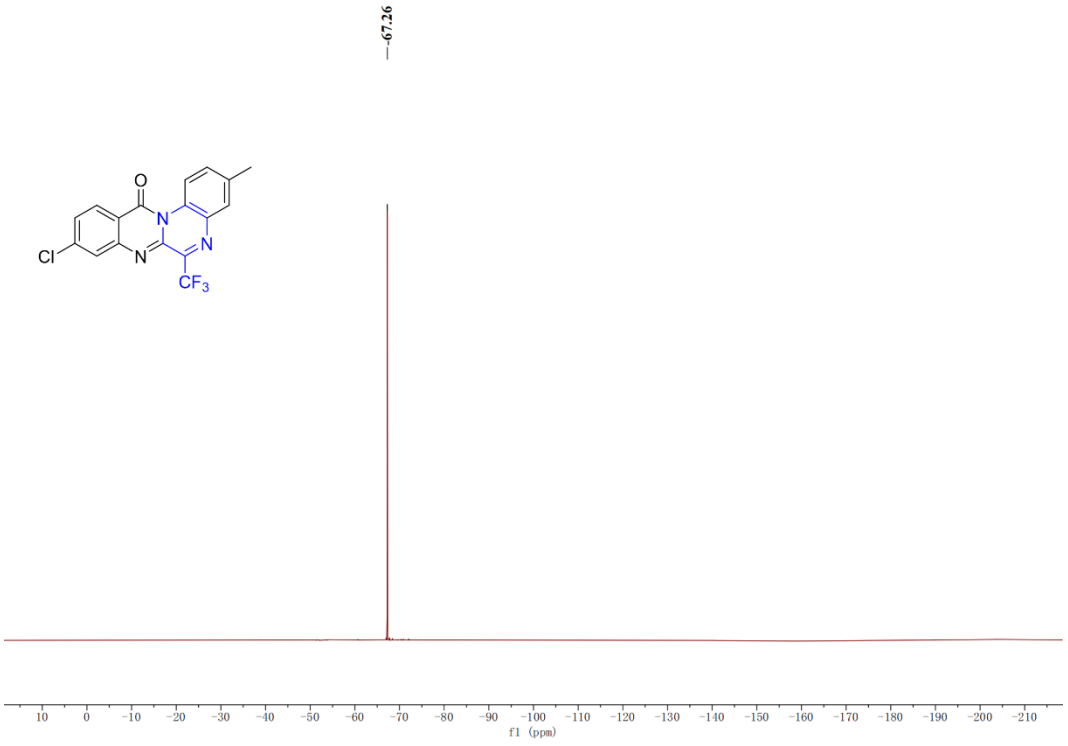
^{1}H NMR spectrum of 4m (400 MHz, $CDCl_3$)



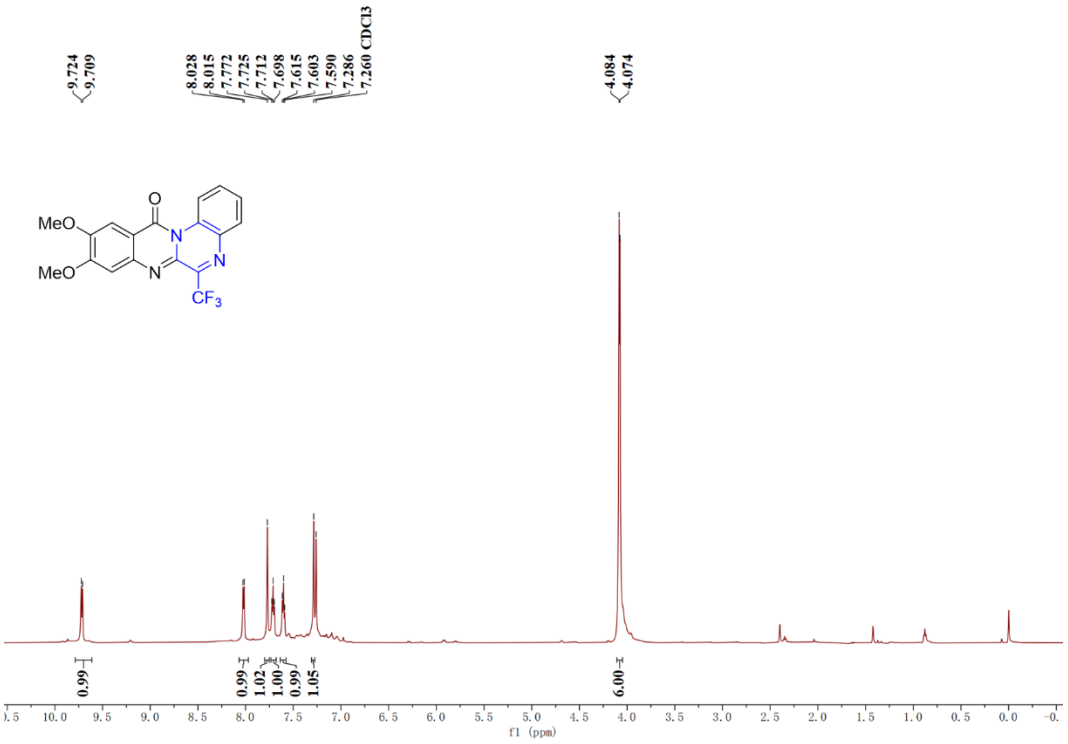
^{13}C NMR spectrum of 4m (101 MHz, $CDCl_3$)



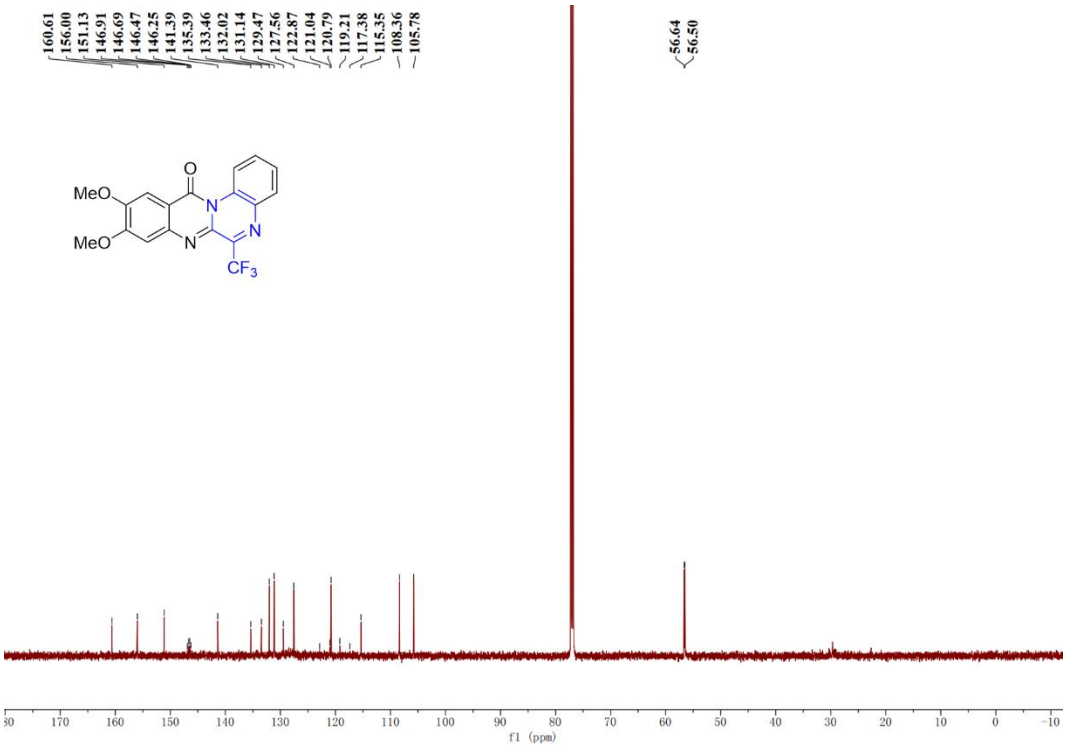
^{19}F NMR spectrum of 4m (376 MHz, $CDCl_3$)



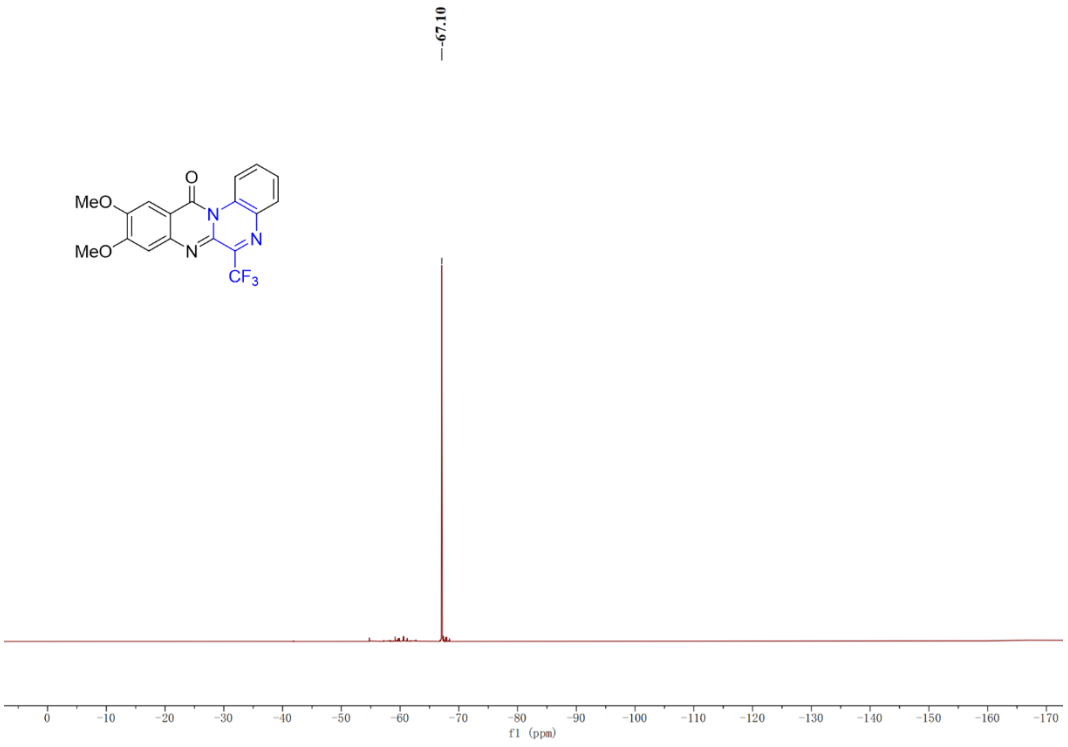
^{1}H NMR spectrum of 4n (600 MHz, $CDCl_3$)



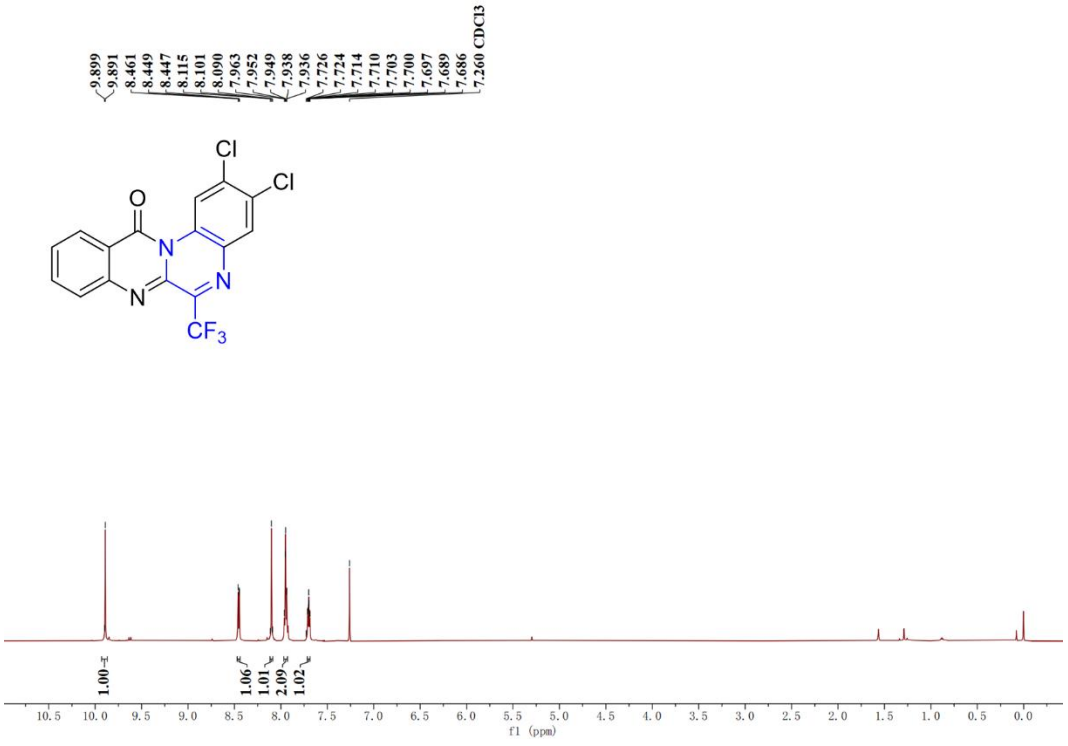
^{13}C NMR spectrum of 4n (151 MHz, $CDCl_3$)



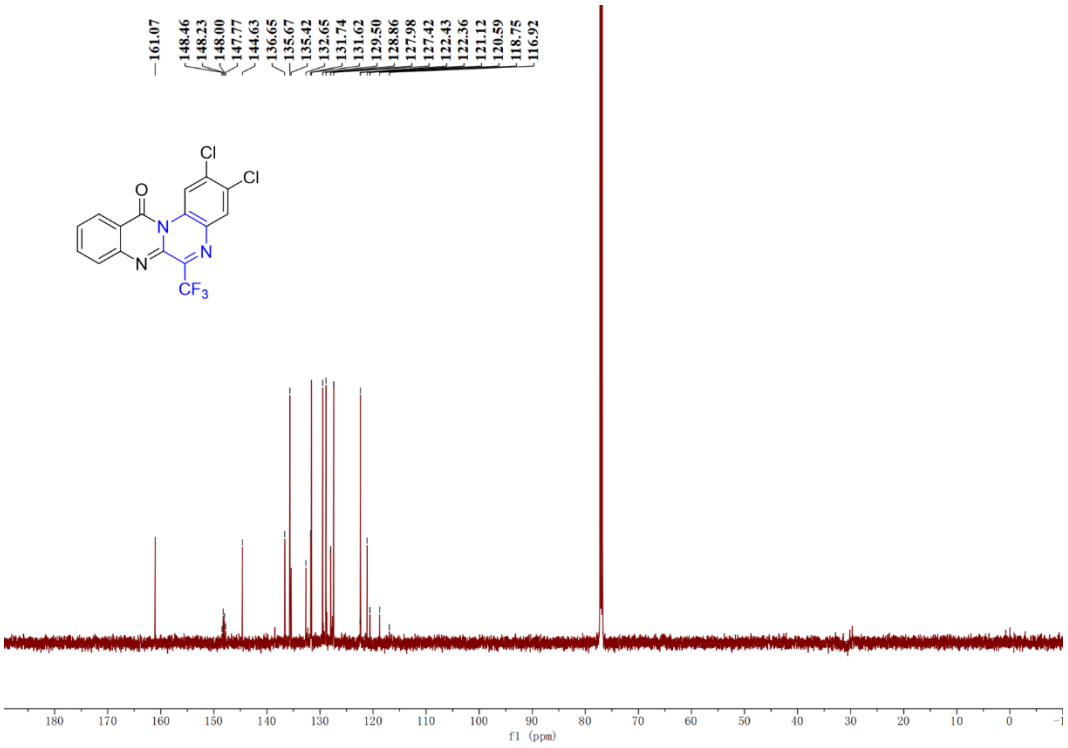
^{19}F NMR spectrum of 4n (565 MHz, $CDCl_3$)



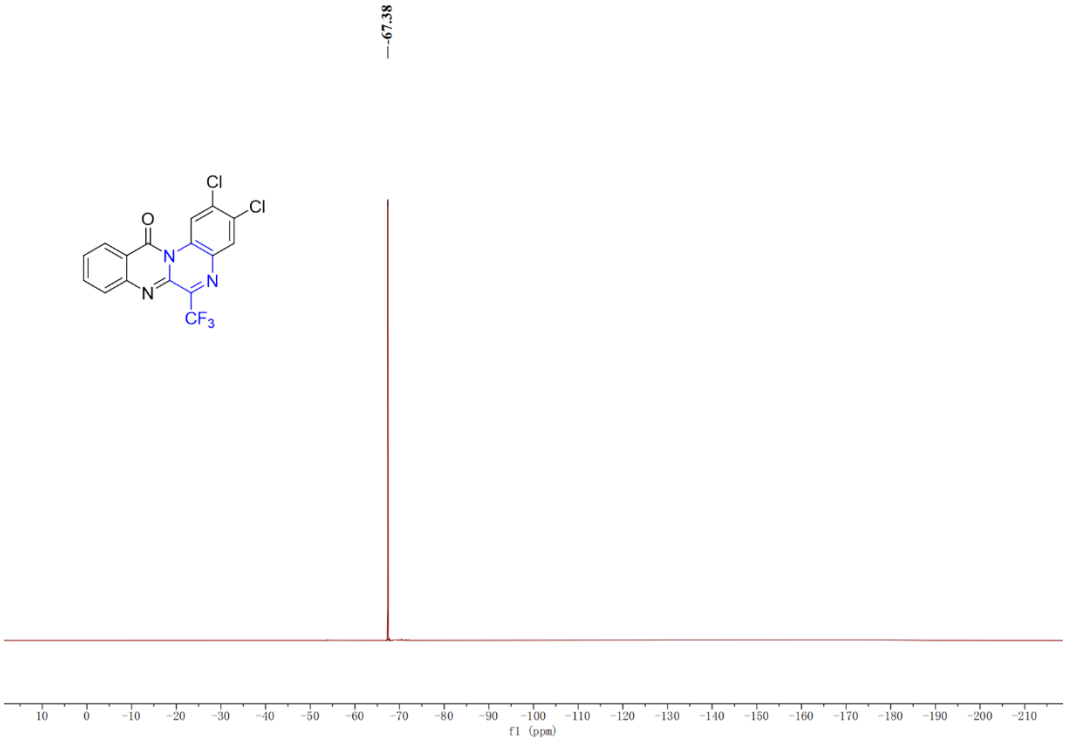
^{1}H NMR spectrum of 4o (600 MHz, $CDCl_3$)



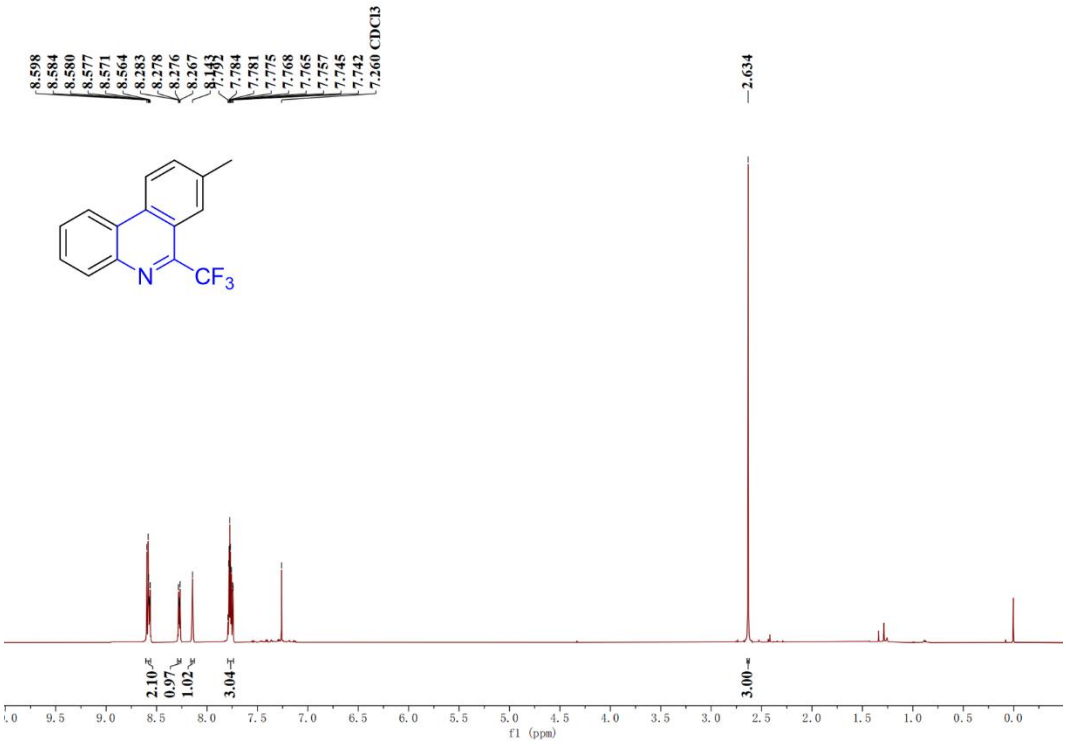
^{13}C NMR spectrum of 4o (151 MHz, $CDCl_3$)



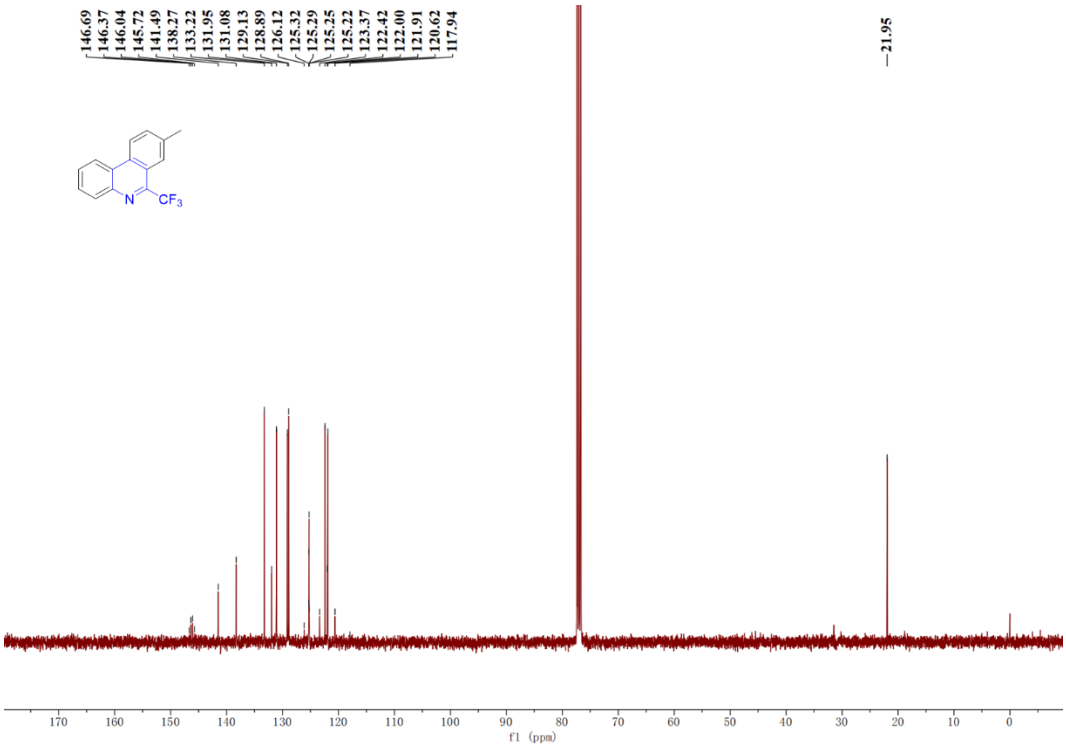
^{19}F NMR spectrum of 4o (565 MHz, $CDCl_3$)



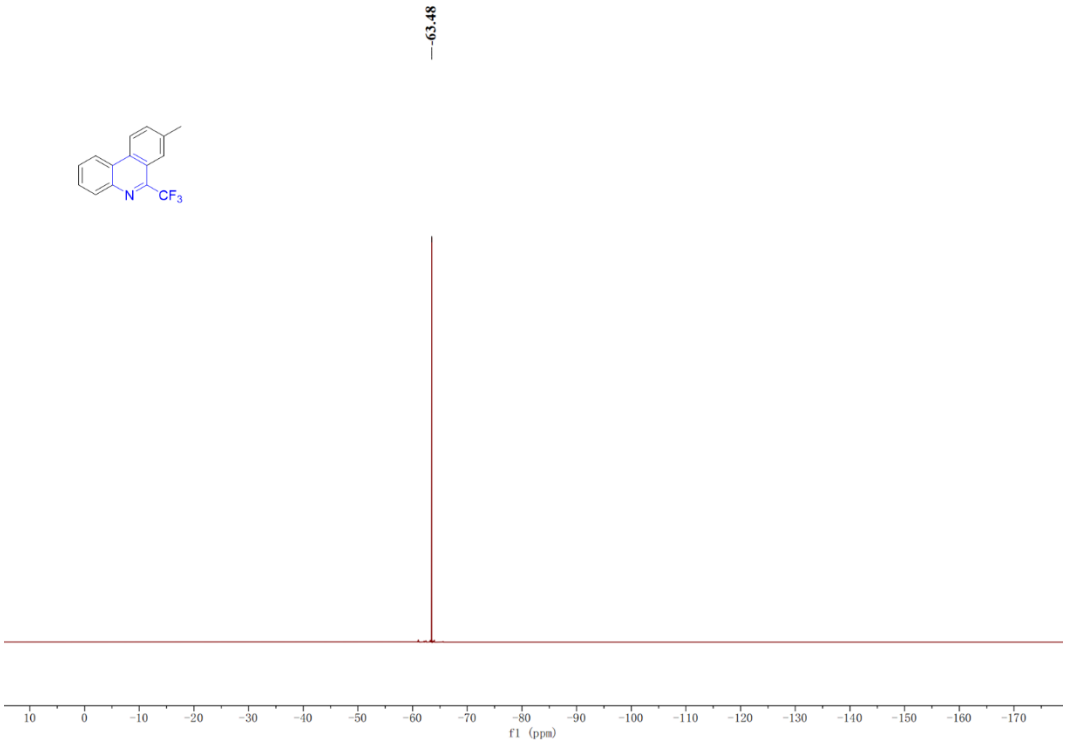
^{1}H NMR spectrum of 5a (600 MHz, $CDCl_3$)



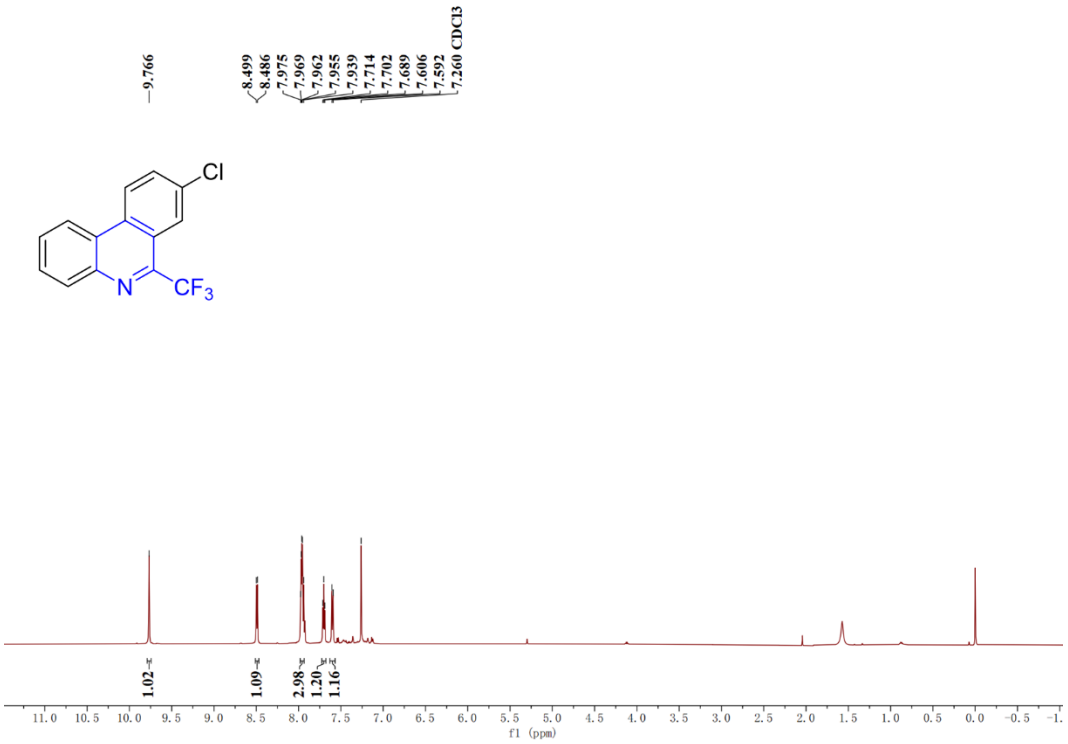
^{13}C NMR spectrum of 5a (101 MHz, $CDCl_3$)



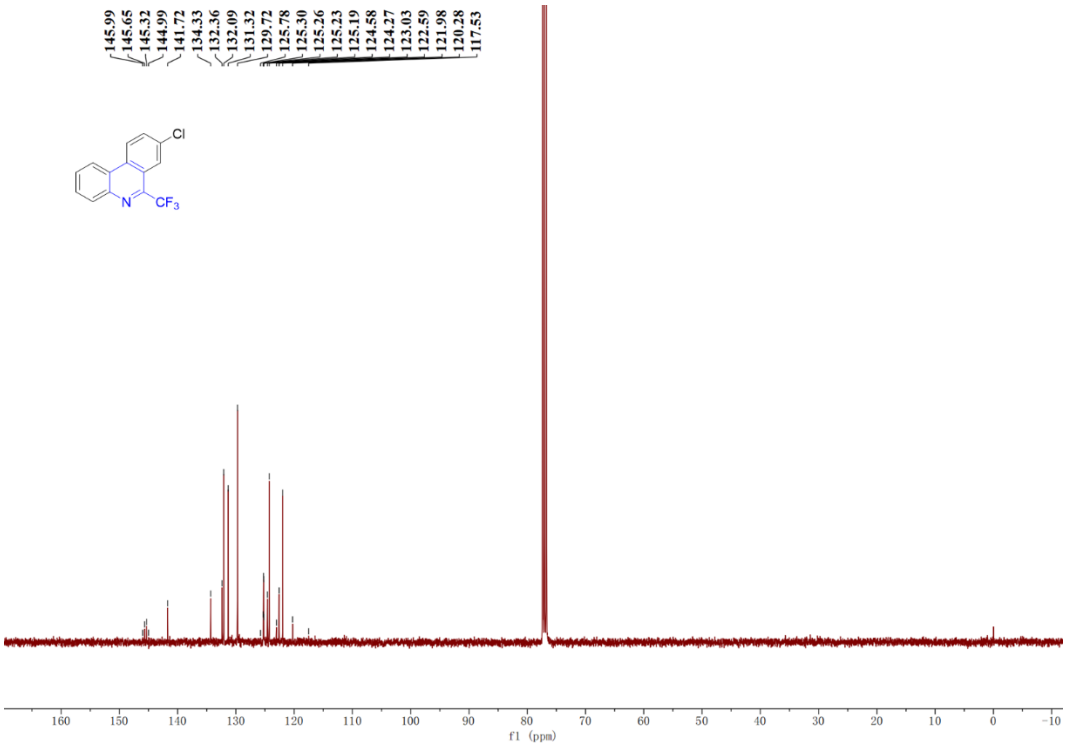
^{19}F NMR spectrum of 5a (376 MHz, $CDCl_3$)



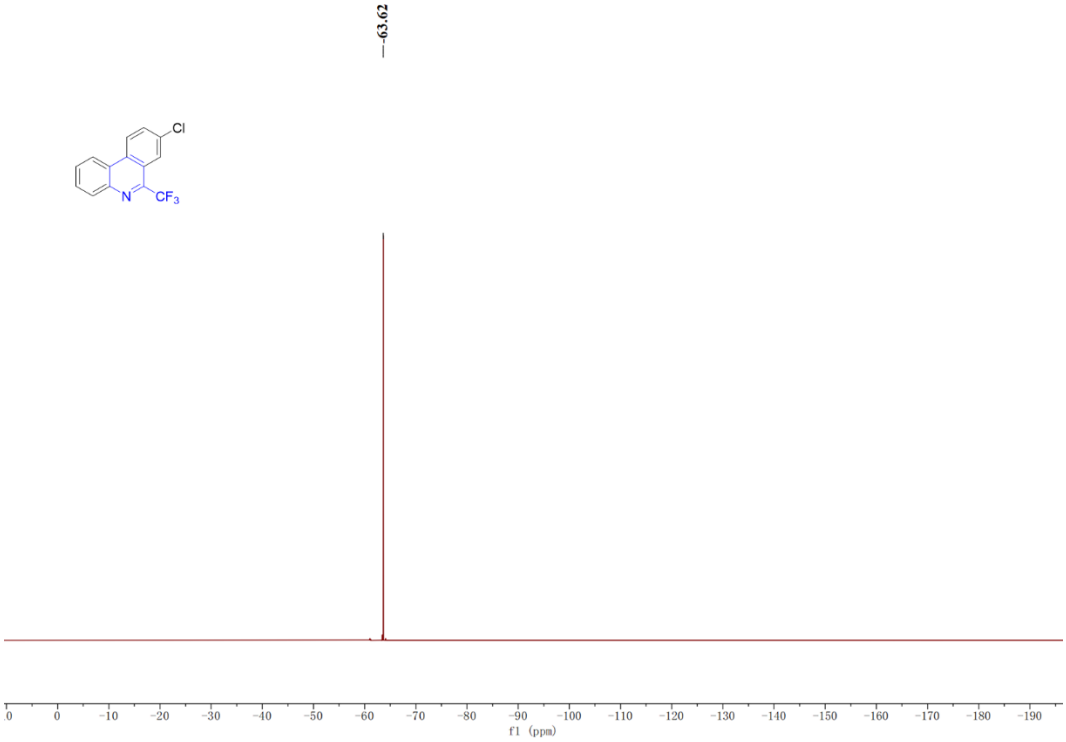
^{1}H NMR spectrum of 5b (600 MHz, $CDCl_3$)



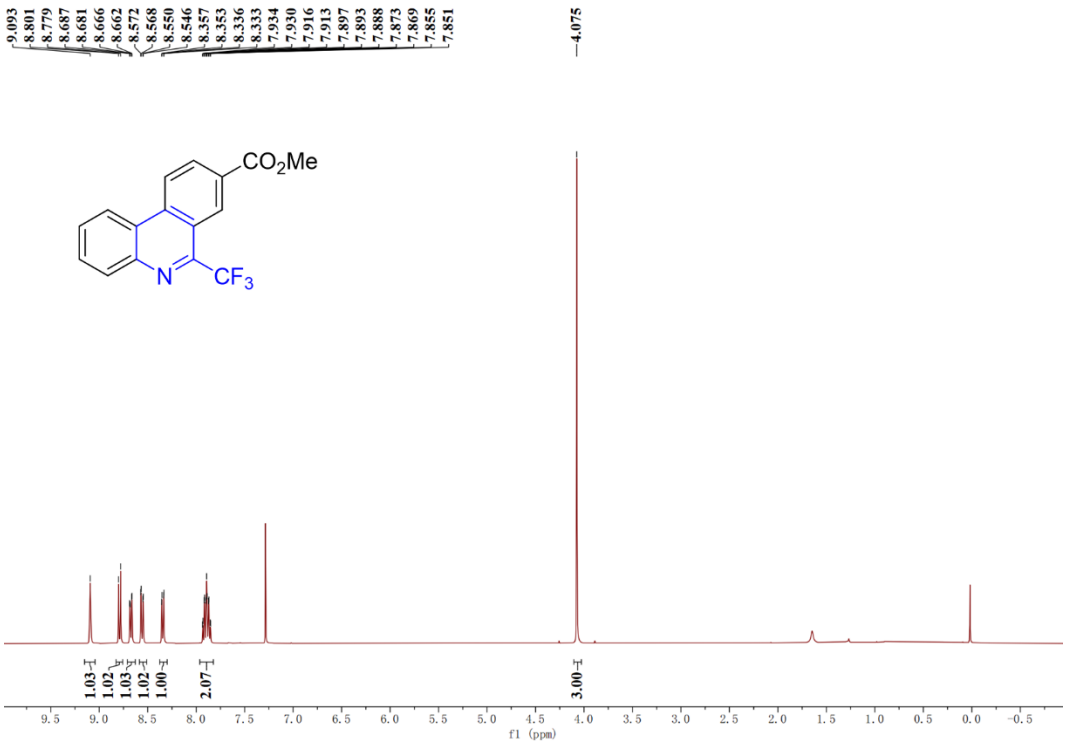
^{13}C NMR spectrum of 5b (101 MHz, $CDCl_3$)



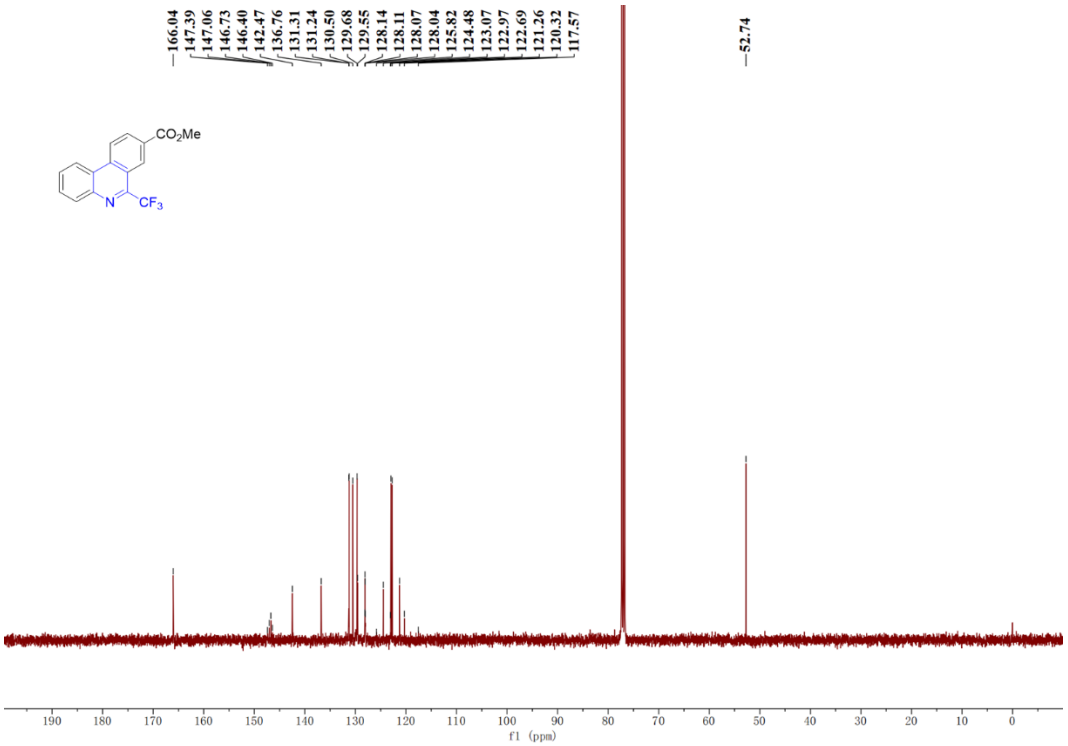
^{19}F NMR spectrum of 5b (376 MHz, $CDCl_3$)



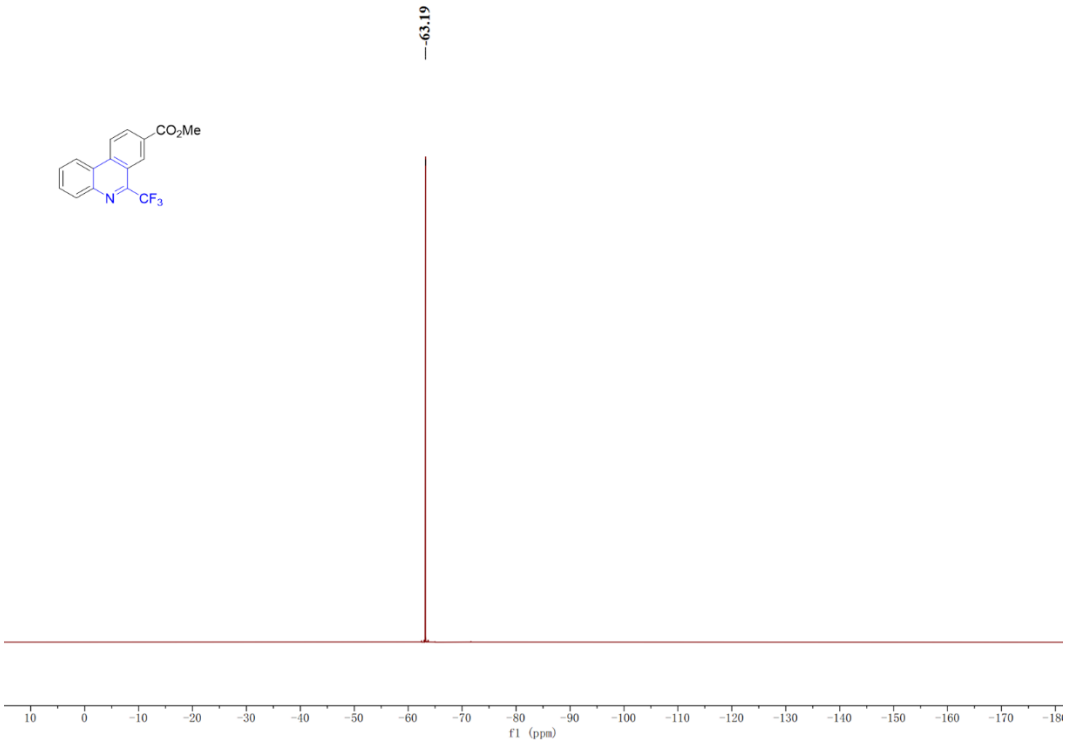
^{1}H NMR spectrum of 5c (400 MHz, $CDCl_3$)



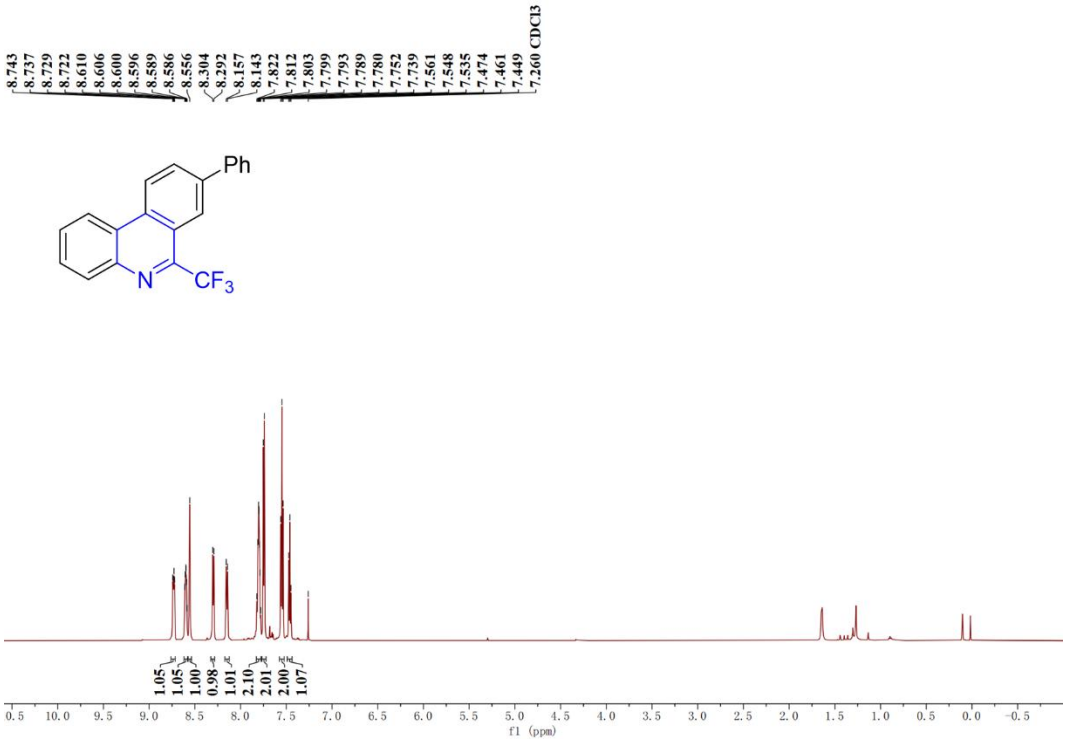
^{13}C NMR spectrum of 5c (101 MHz, $CDCl_3$)



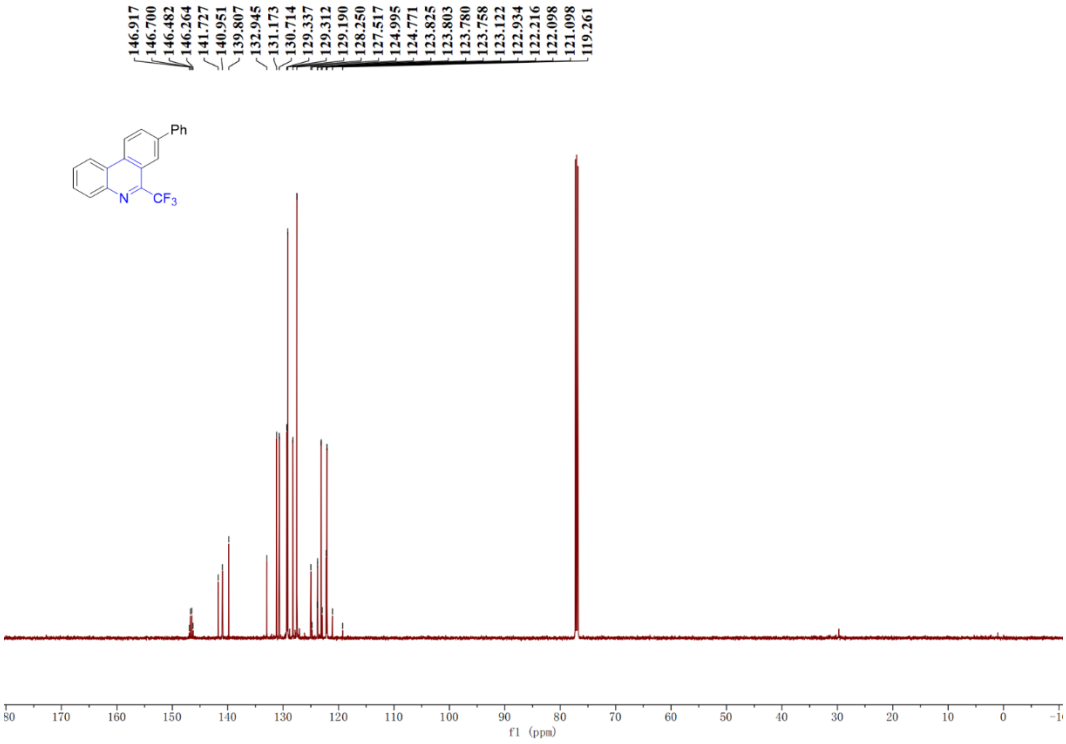
^{19}F NMR spectrum of 5c (376 MHz, $CDCl_3$)



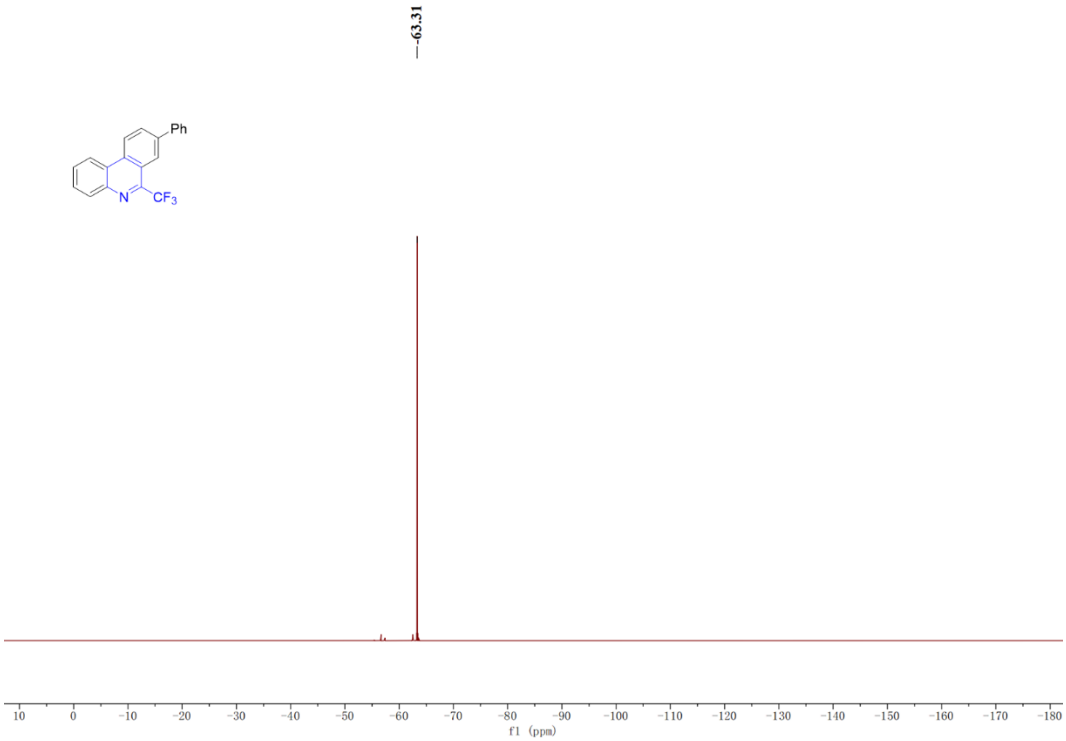
^{1}H NMR spectrum of 5d (600 MHz, $CDCl_3$)



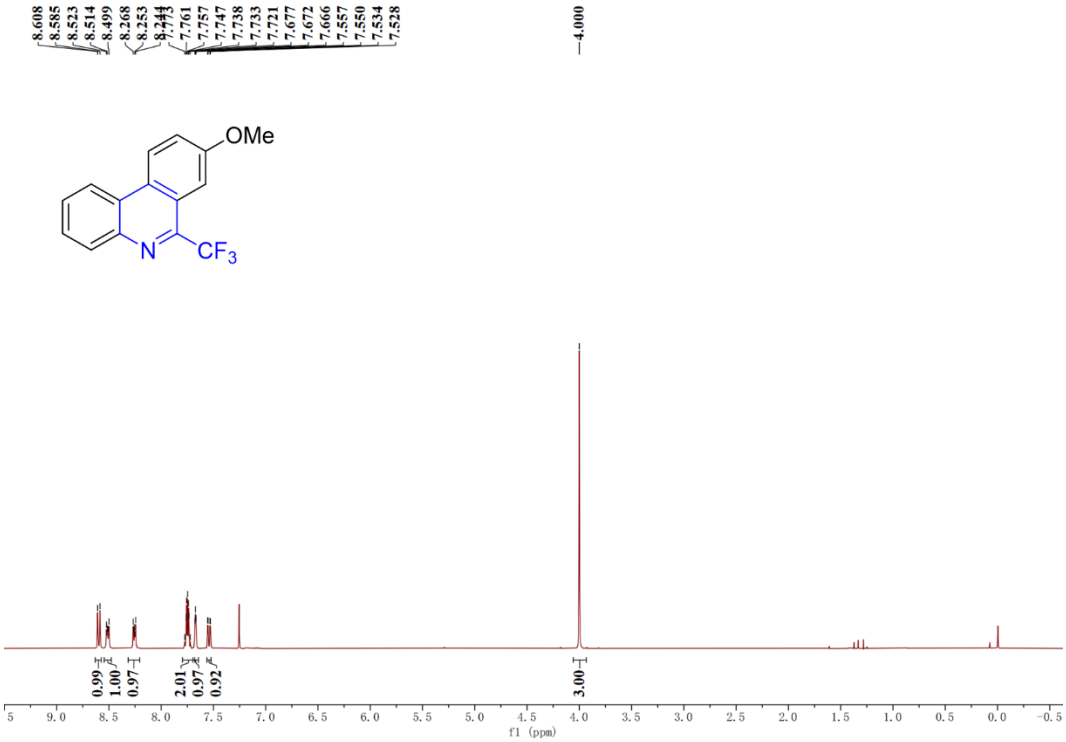
^{13}C NMR spectrum of 5d (151 MHz, $CDCl_3$)



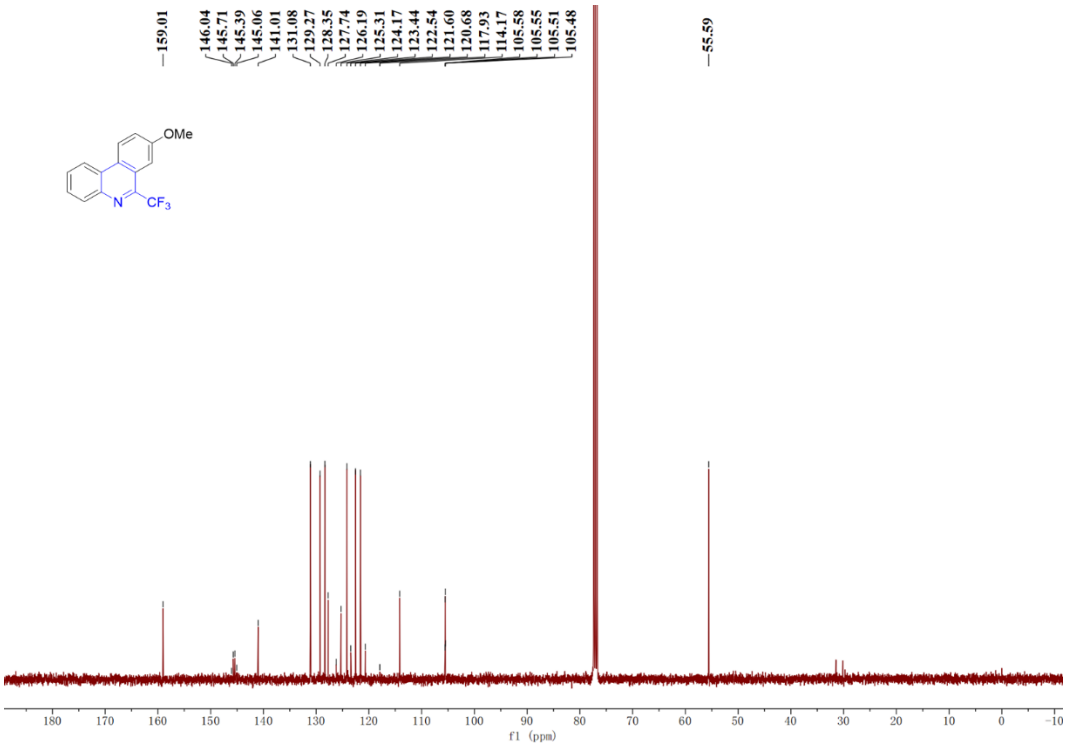
^{19}F NMR spectrum of 5d (565 MHz, $CDCl_3$)



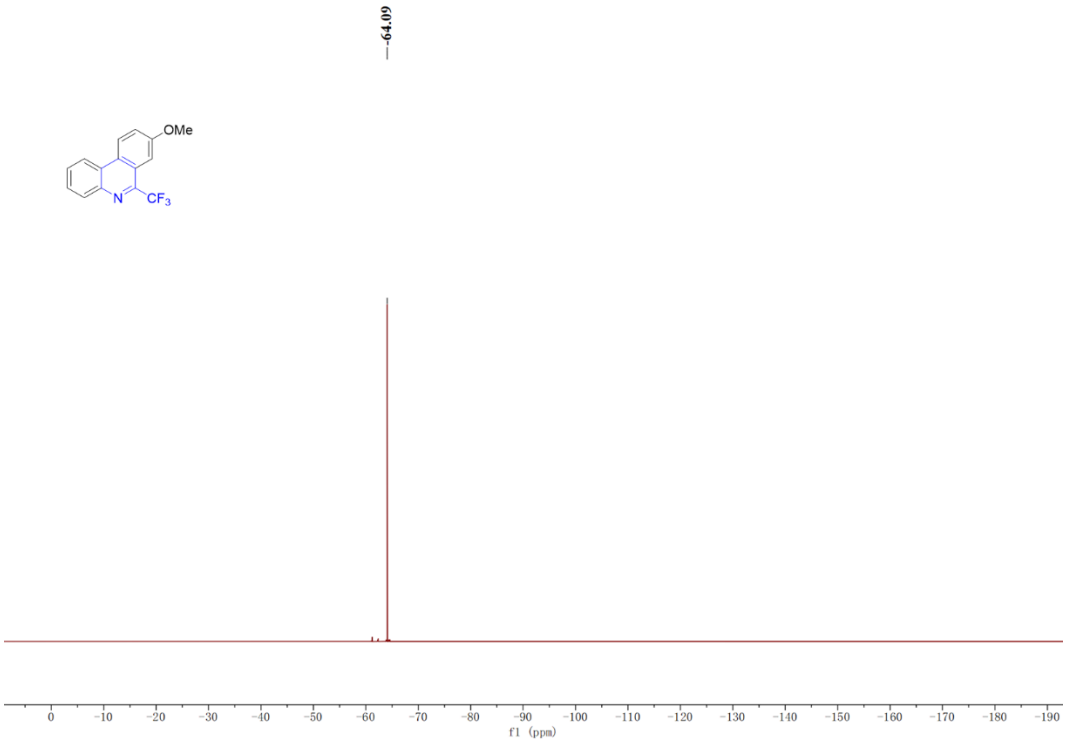
^{1}H NMR spectrum of 5e (400 MHz, $CDCl_3$)



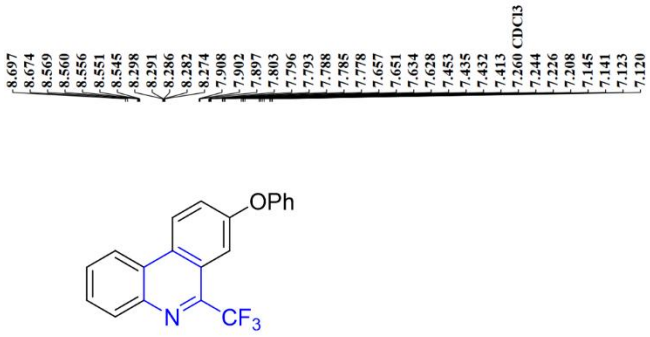
^{13}C NMR spectrum of 5e (101 MHz, $CDCl_3$)

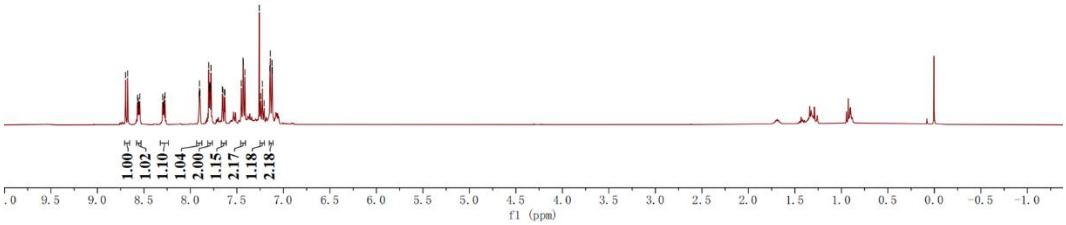


^{19}F NMR spectrum of 5e (376 MHz, $CDCl_3$)

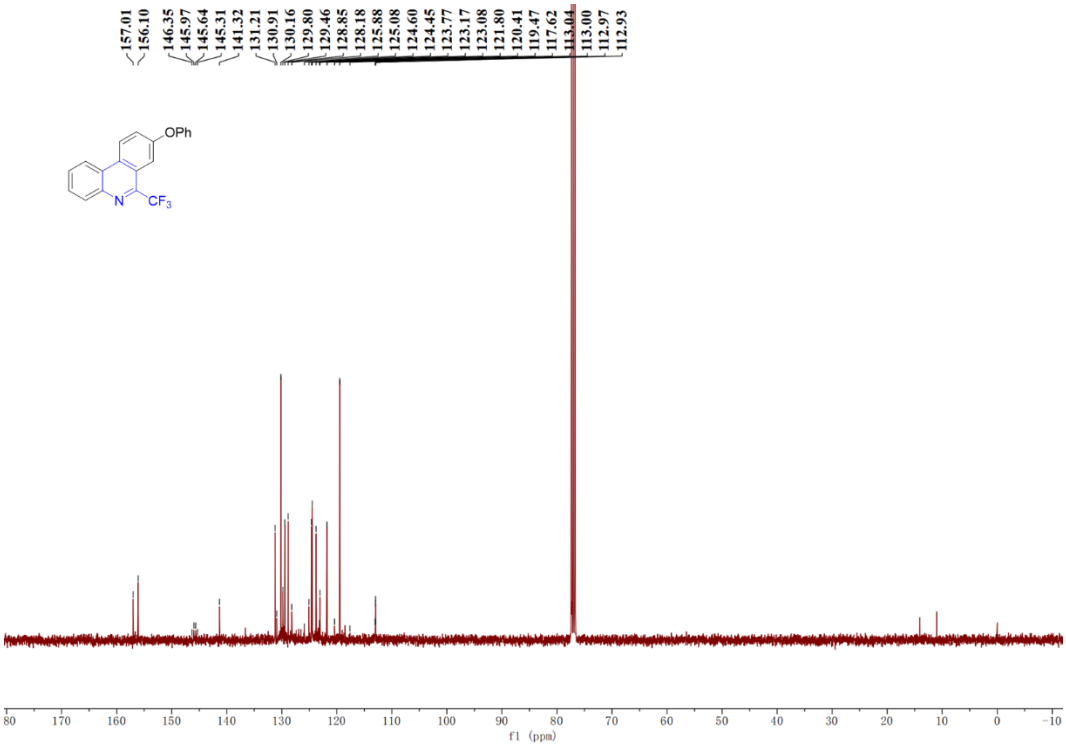


^{1}H NMR spectrum of 5f (400 MHz, $CDCl_3$)

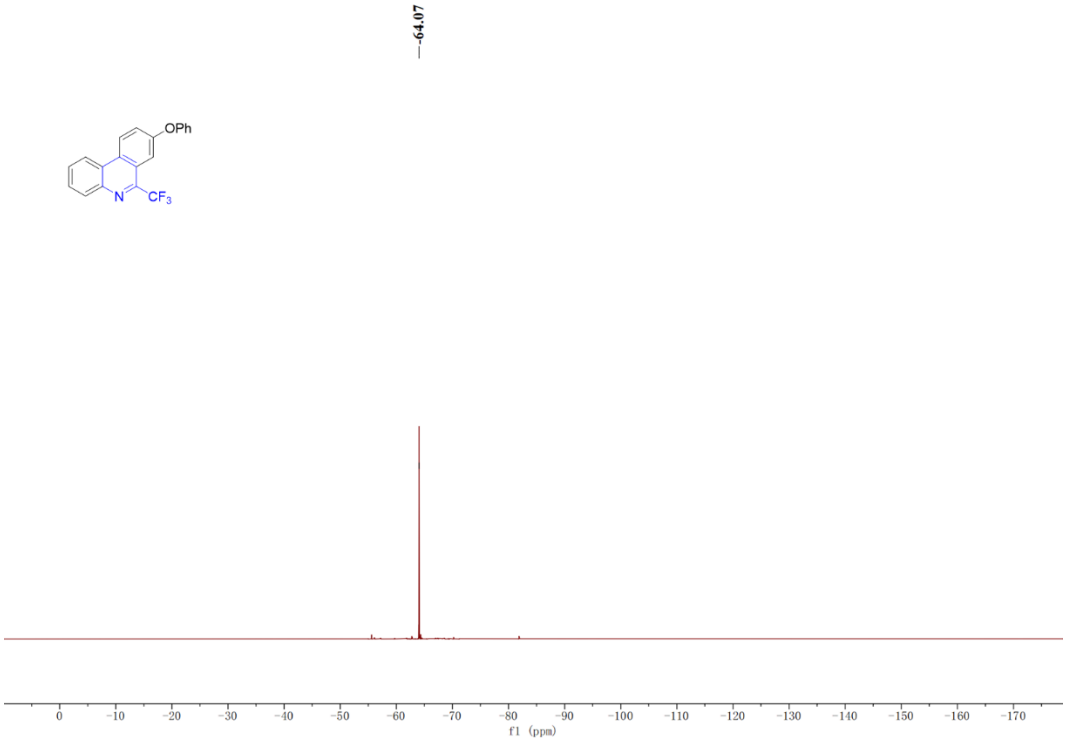




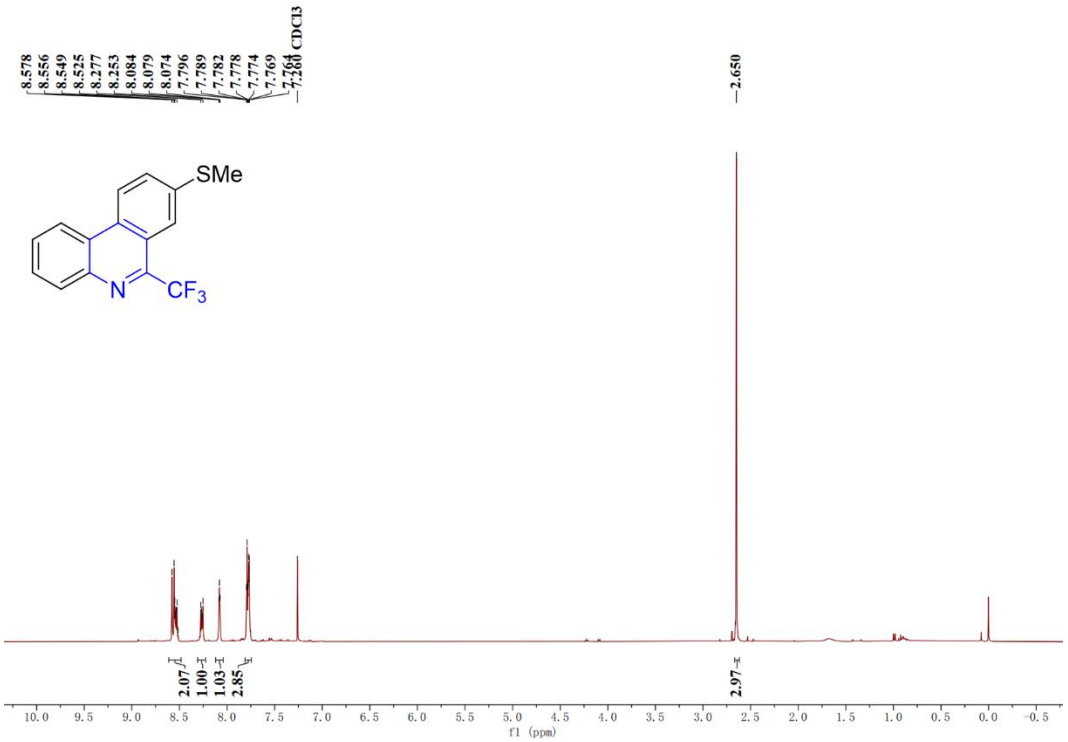
^{13}C NMR spectrum of 5f (101 MHz, $CDCl_3$)



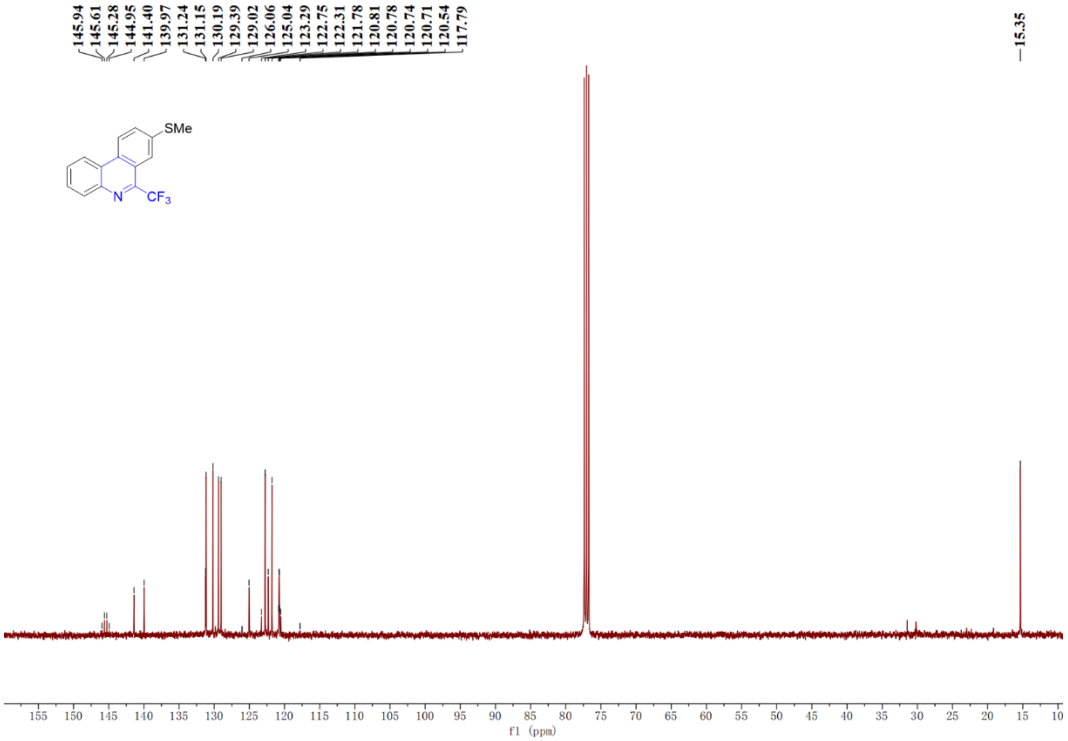
^{19}F NMR spectrum of 5f (376 MHz, $CDCl_3$)



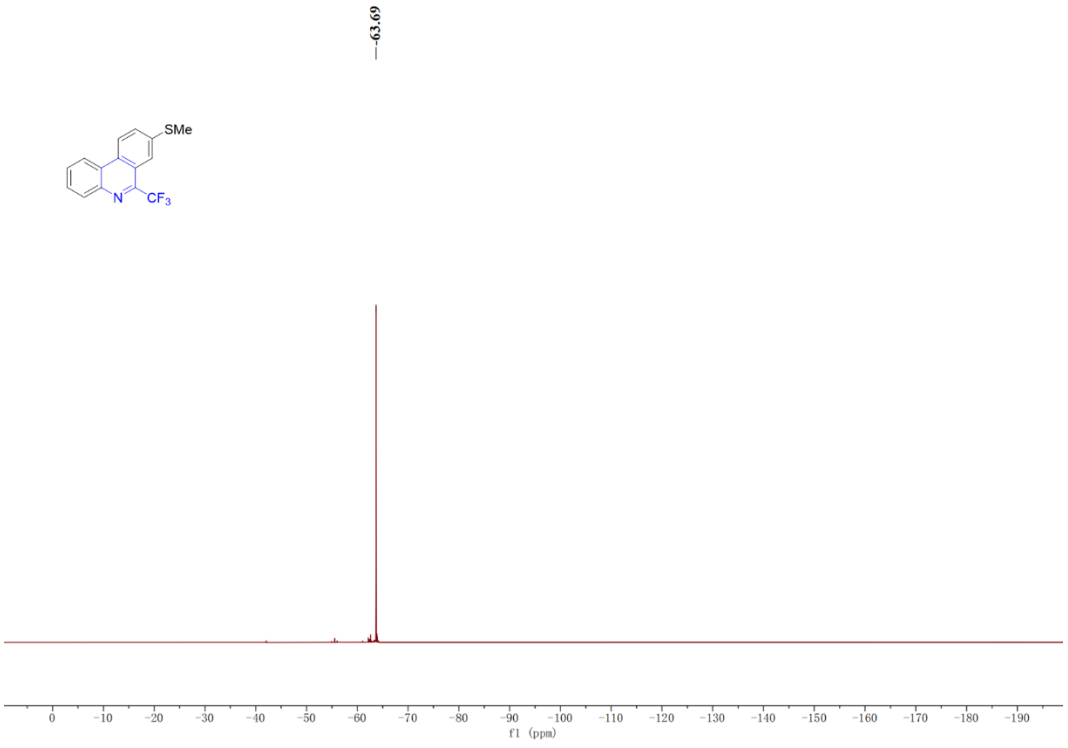
^{1}H NMR spectrum of 5g (400 MHz, $CDCl_3$)



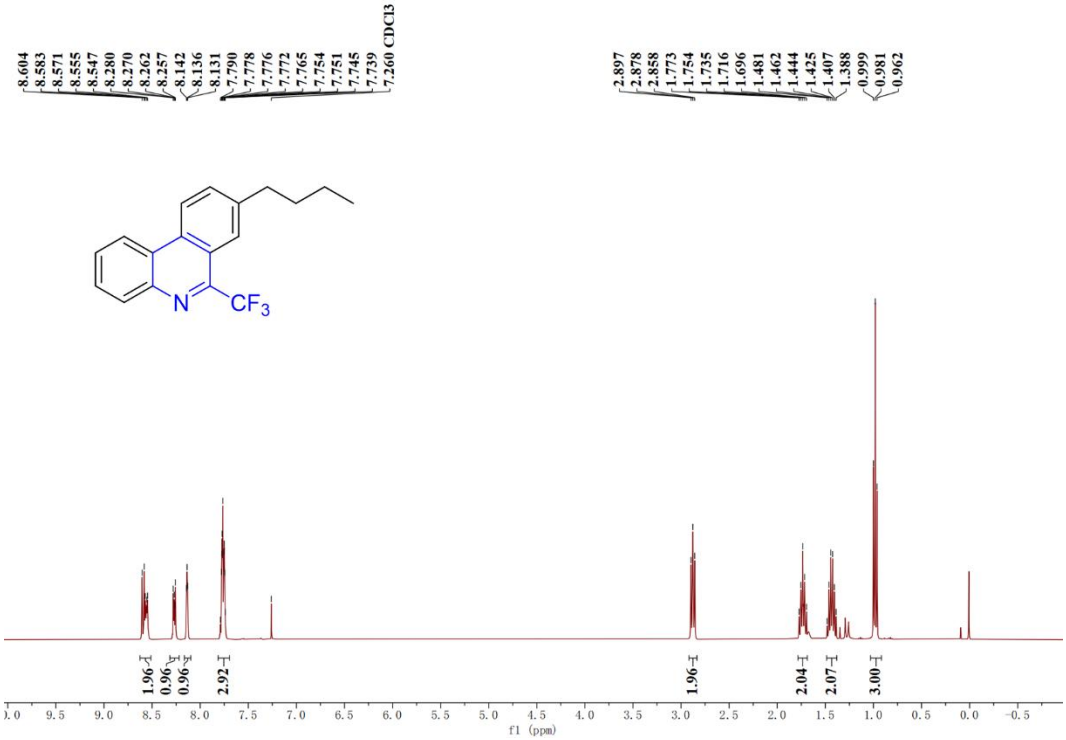
^{13}C NMR spectrum of 5g (101 MHz, $CDCl_3$)



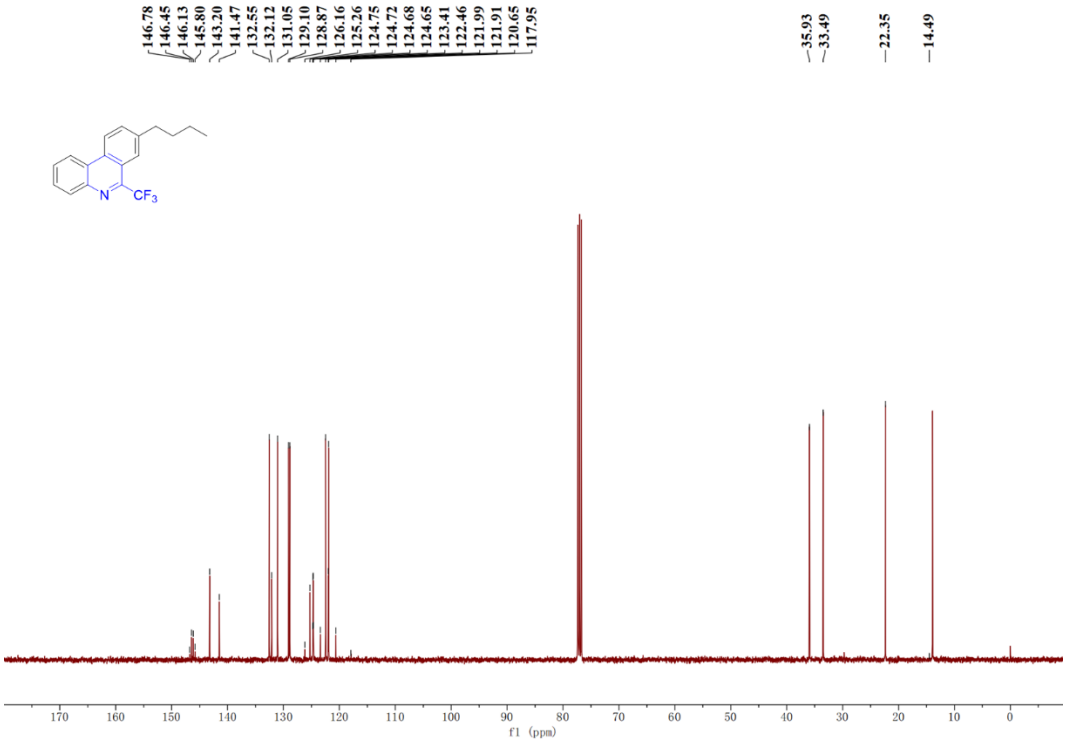
^{19}F NMR spectrum of 5g (376 MHz, $CDCl_3$)



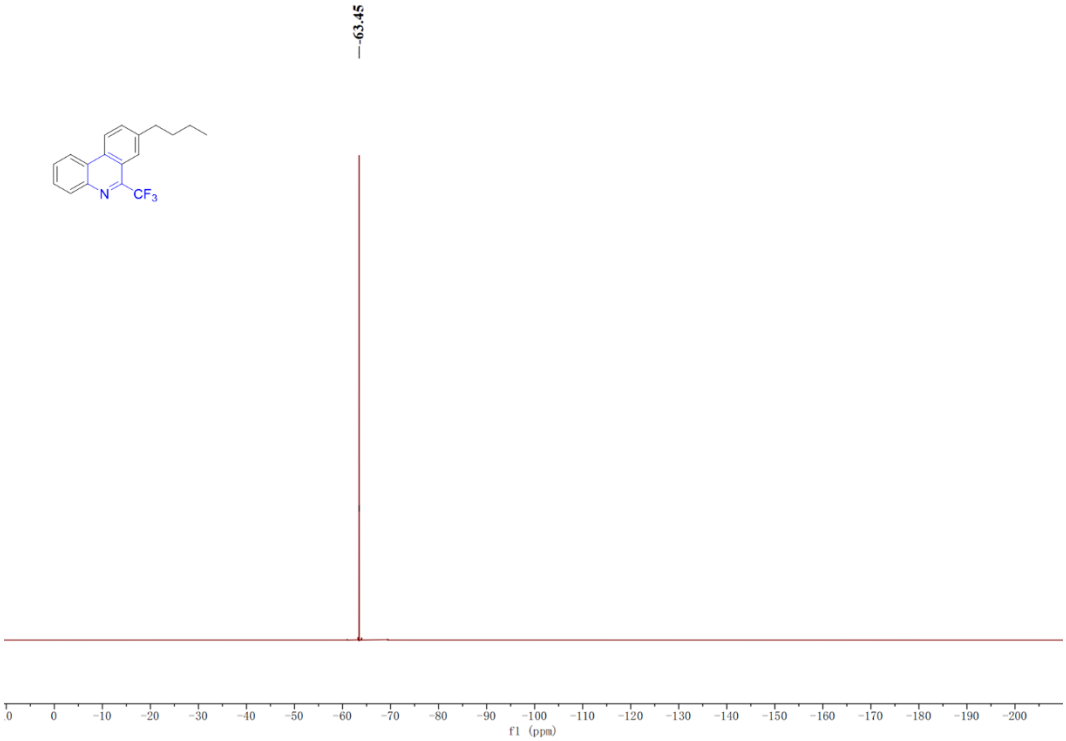
^{1}H NMR spectrum of 5h (400 MHz, $CDCl_3$)



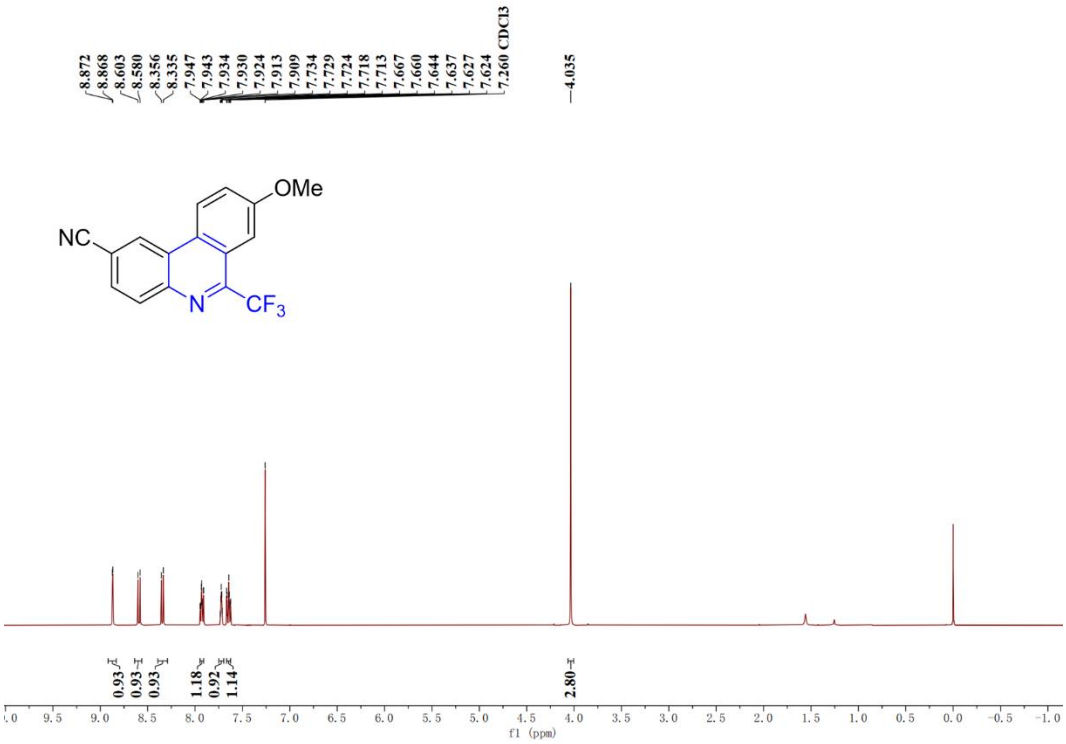
^{13}C NMR spectrum of 5h (101 MHz, $CDCl_3$)



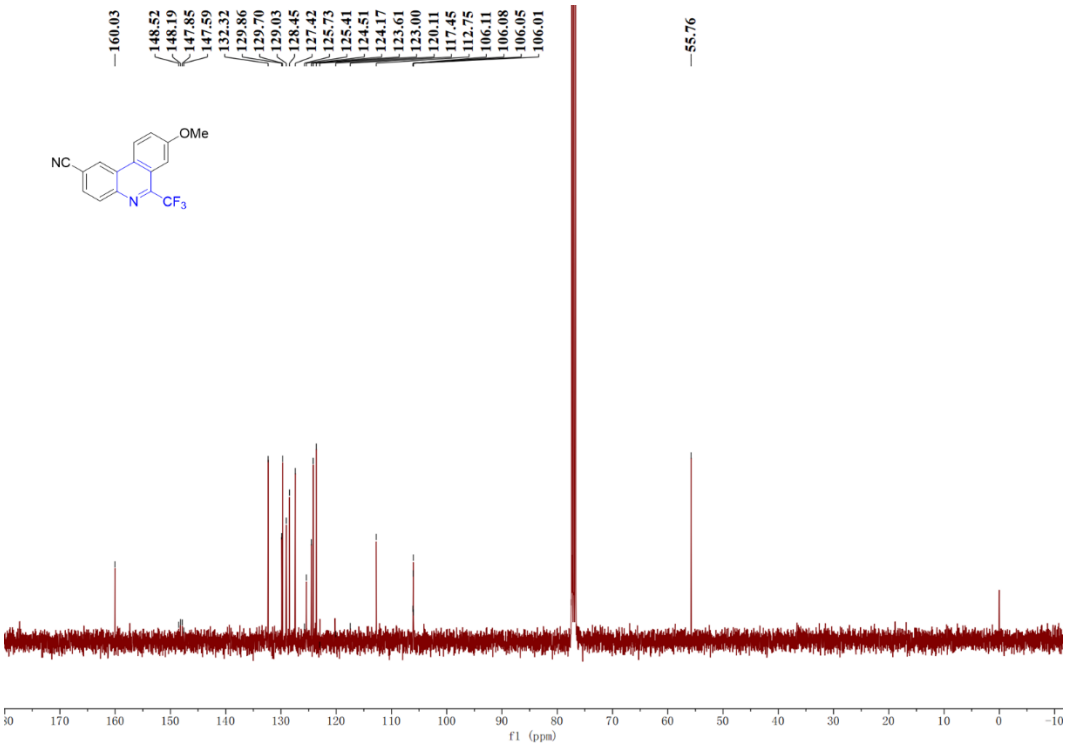
^{19}F NMR spectrum of 5h (376 MHz, $CDCl_3$)



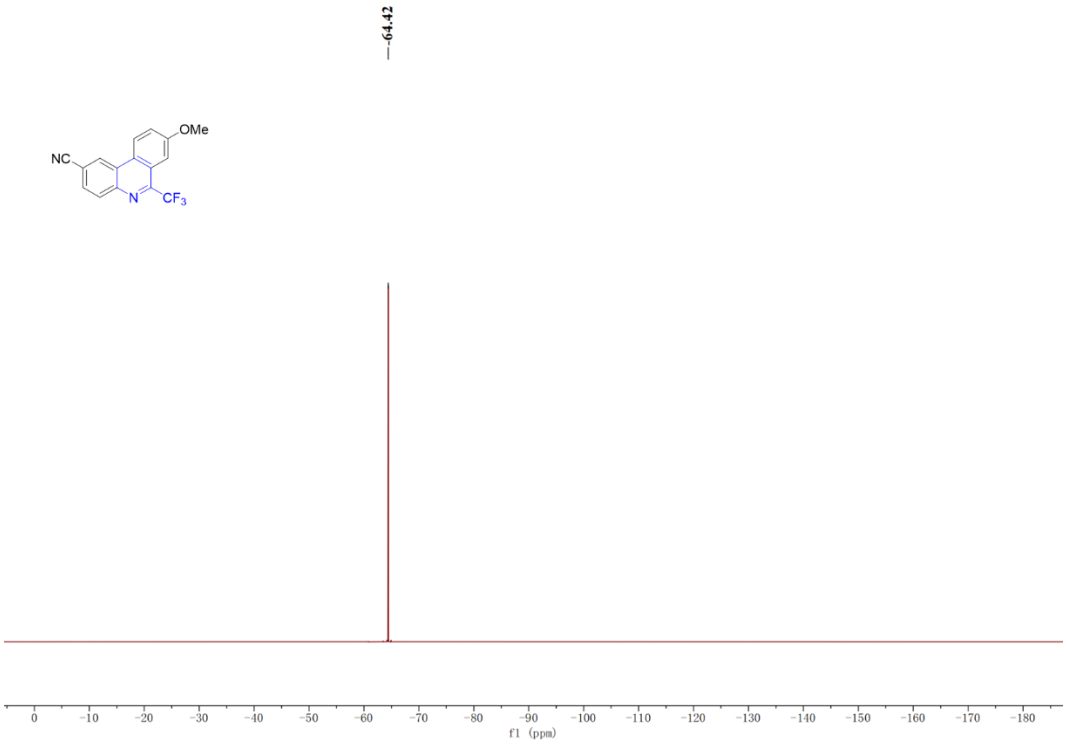
^{1}H NMR spectrum of 5i (400 MHz, $CDCl_3$)



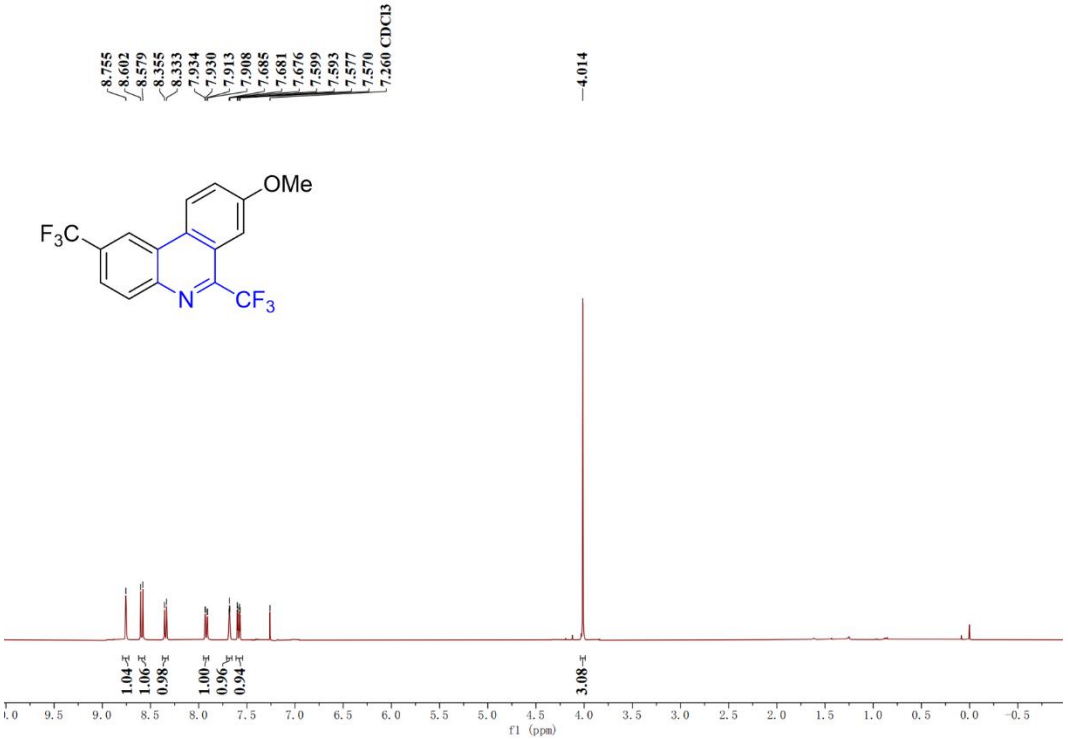
^{13}C NMR spectrum of 5i (101 MHz, $CDCl_3$)



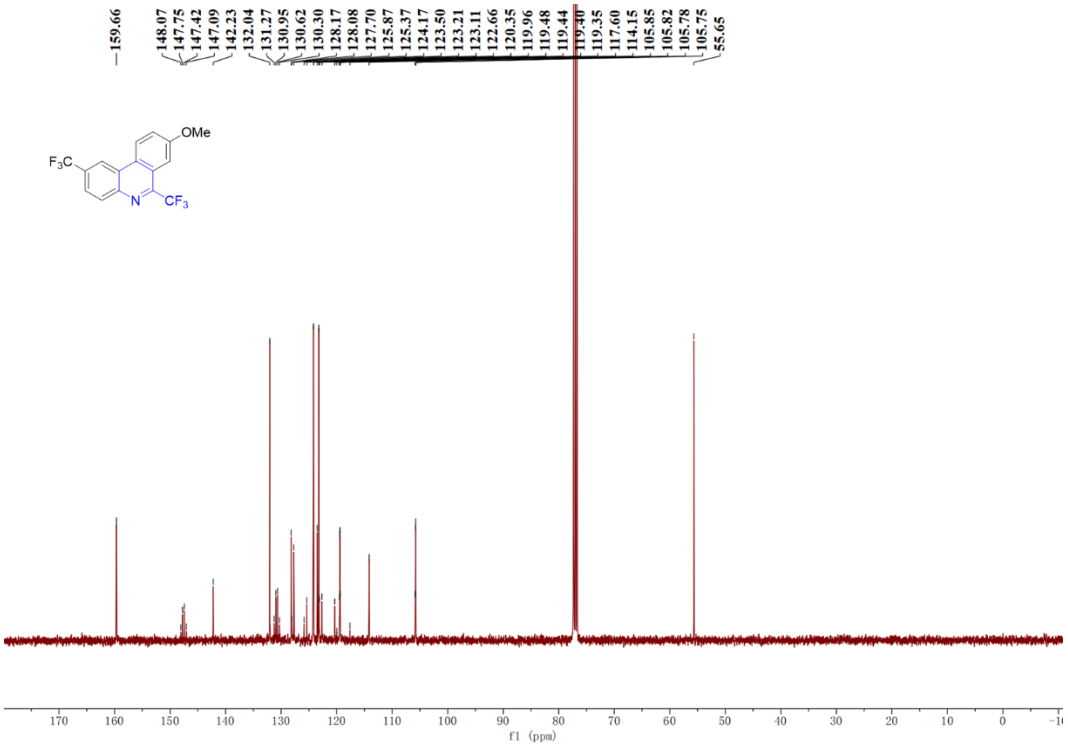
^{19}F NMR spectrum of 5i (376 MHz, $CDCl_3$)



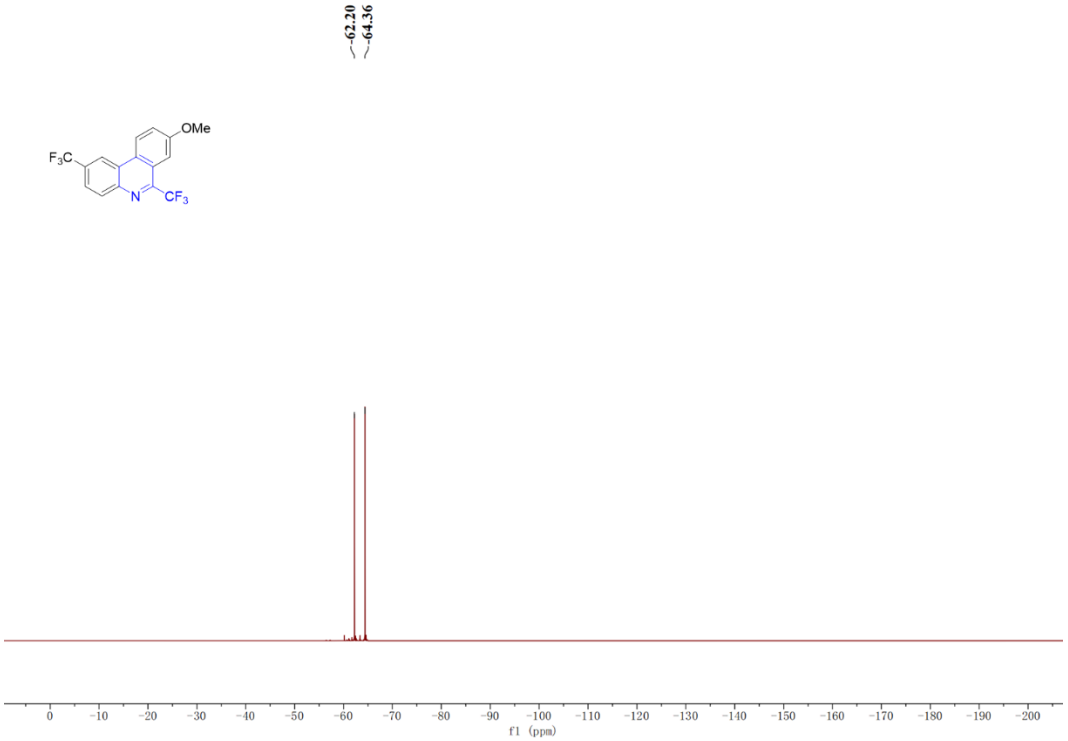
^{1}H NMR spectrum of 5j (400 MHz, $CDCl_3$)



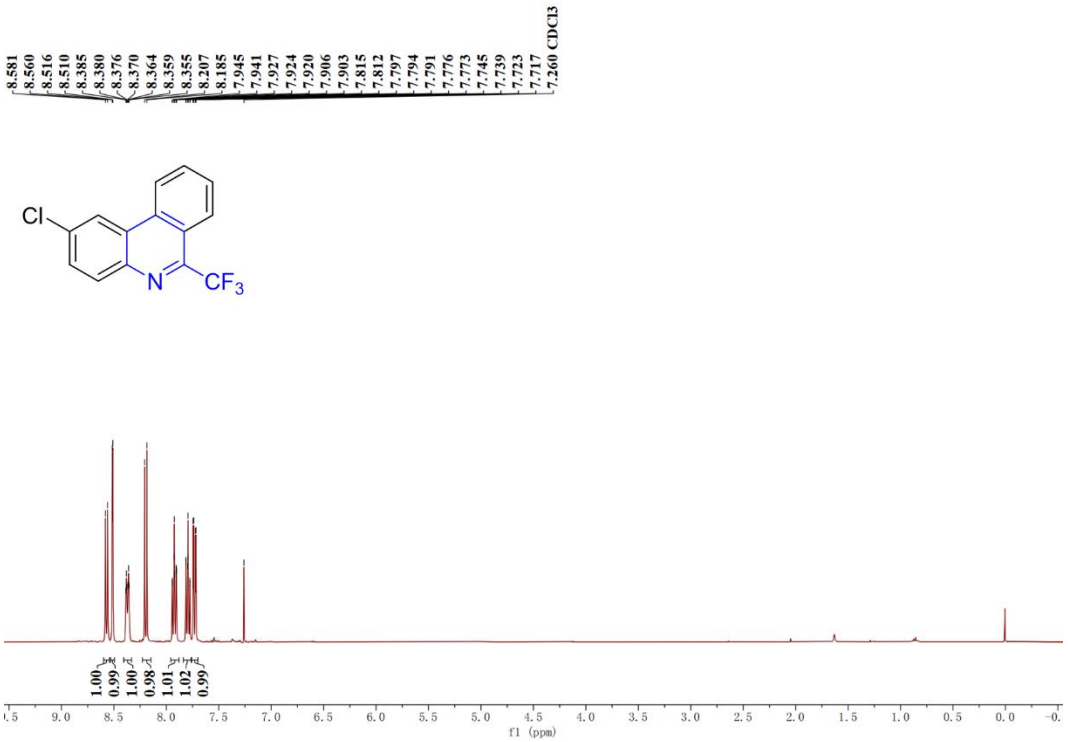
^{13}C NMR spectrum of 5j (101 MHz, $CDCl_3$)



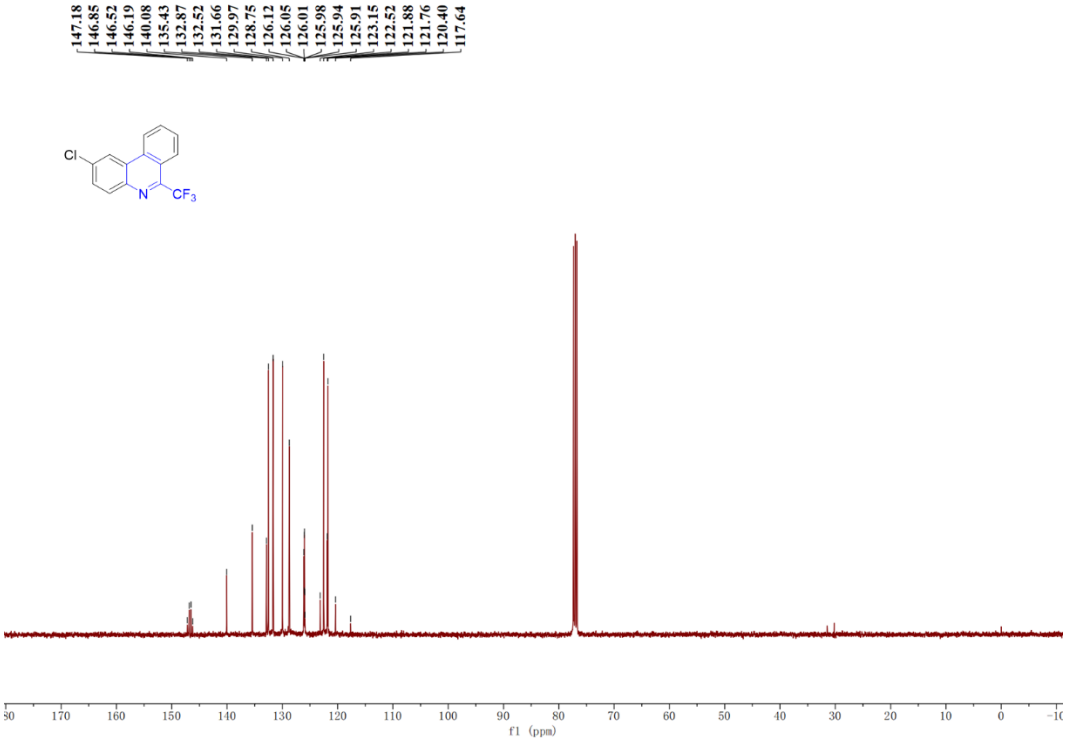
^{19}F NMR spectrum of 5j (376 MHz, $CDCl_3$)



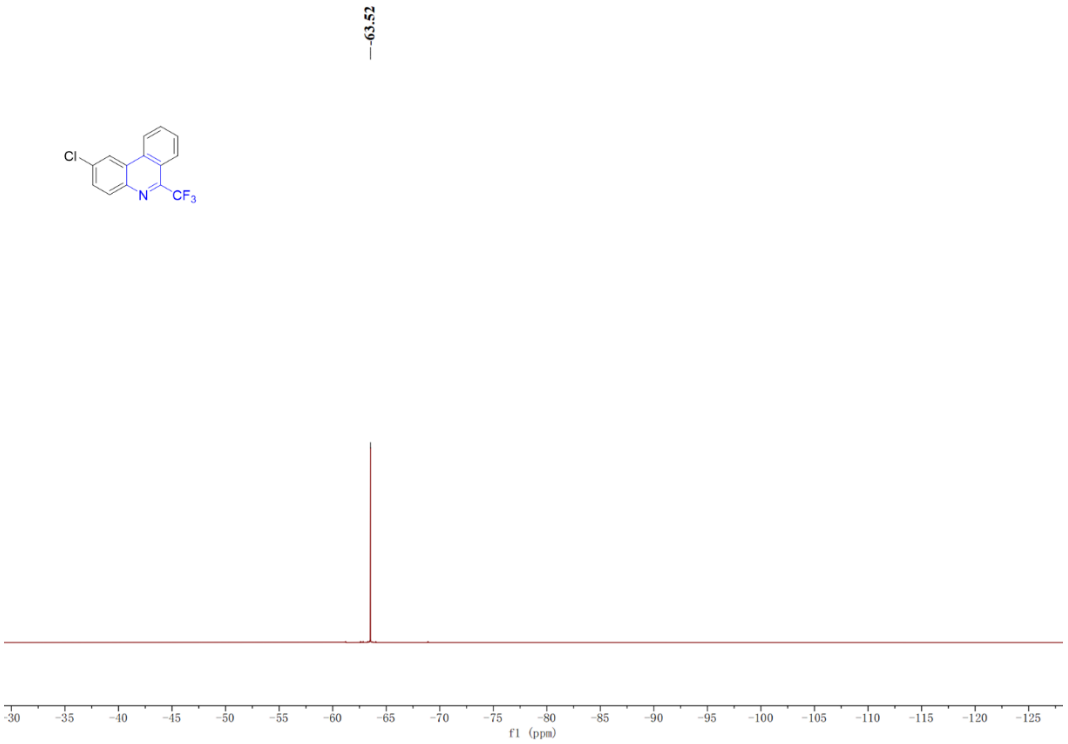
^{1}H NMR spectrum of 5k (400 MHz, $CDCl_3$)



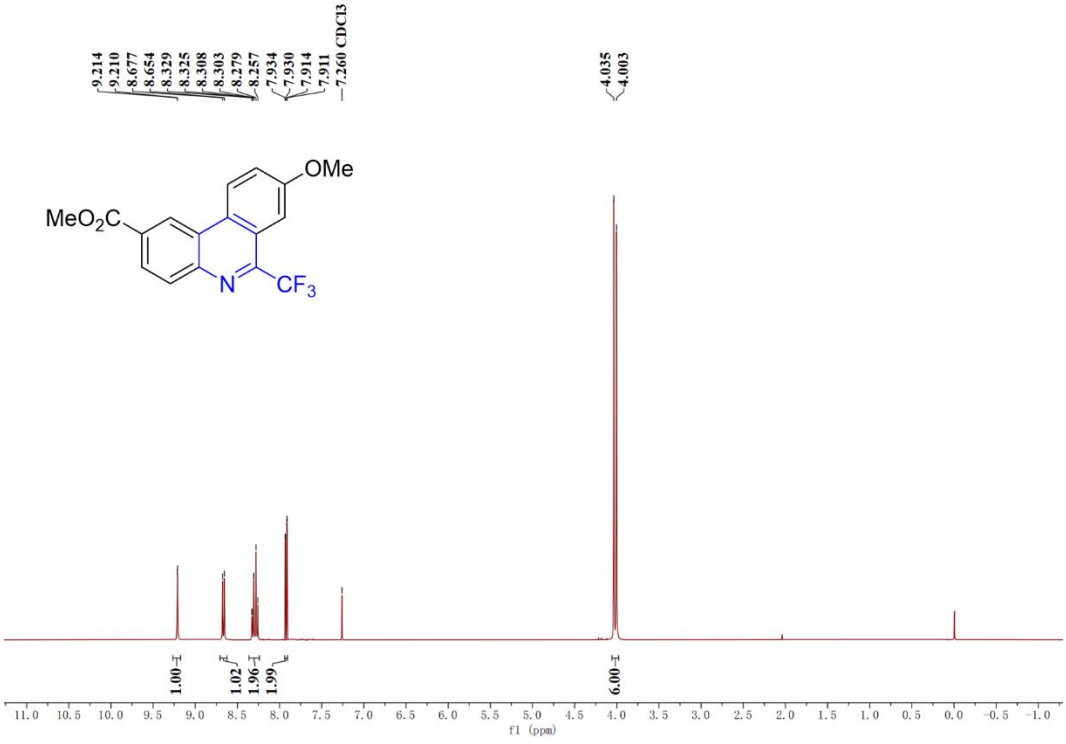
^{13}C NMR spectrum of 5k (101 MHz, $CDCl_3$)



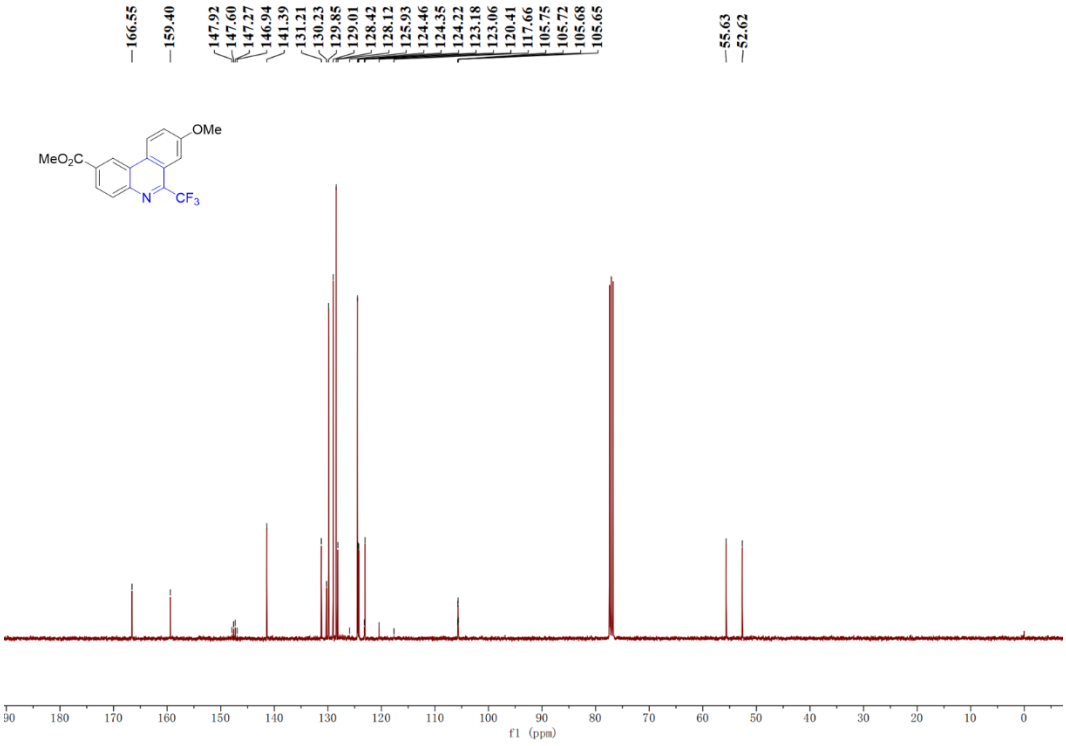
^{19}F NMR spectrum of 5k (376 MHz, $CDCl_3$)



^{1}H NMR spectrum of 5l (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of 5l (101 MHz, $CDCl_3$)



^{19}F NMR spectrum of 5l (376 MHz, $CDCl_3$)