Supporting Information

Photocatalytically switchable chemoselective difluoramidation of olefins for the synthesis of diversified difluoro-γ-lactams

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1. General information

Materials and General Experimental: Ethyl bromodifluoroacetate was purchased from Shanghai Shaoyuan Co. Sodium iodide and ammonium bromide were purchased from Maclean's. *fac*-Ir(ppy)$_3$ was purchased from Bidepharm. Unless otherwise stated, commercially available solvents and reagents were obtained from commercial suppliers without further purification. In addition, petroleum ether (b.p. 60-90 °C) used for column chromatography was distilled before use. Non-commercial starting materials were prepared as described below or according to literature procedures. Analytical thin layer chromatography (TLC) was performed using precoated silica gel HF254 glass plates. Column chromatography was performed using silica gel (200-300 mesh).
Instrumentation: Nuclear magnetic resonance (NMR) spectra were recorded on Bruker Advance 400 MHz and 500 MHz spectrometer at ambient temperature using the non or partly deuterated solvent as internal standard (^{1}H: δ 7.26 ppm and ^{13}C{1H}: δ 77.0 ppm for $CDCl_3$, ^{1}H: δ 2.50 ppm and ^{13}C{1H}: δ 40.0 ppm for DMSO-d_6). Chemical shifts (δ) are reported in ppm, relative to the internal standard of tetramethylsilane (TMS). The coupling constants (J) are quoted in hertz (Hz). Resonances are described as s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br (broad) or combinations thereof. High resolution mass spectra were obtained on Thermo Scientific Q-Exactive (ESI mode, Q-Exactive Orbitrap MS system). Melting points were determined using SGW X-4 apparatus and not corrected. The X-ray diffraction data for the crystallized compound were collected on a Bruker Smart APEX CCD area detector diffractometer (graphite monochromator, Mo Kα radiation, λ = 0.71073 Å) at 296(2) K.

2. Experimental Procedures

2.1 General procedure for the catalytic process

2.1.1 General synthesis steps for product series 2. (2a as an example)

The following ingredients should be added to the 25 mL Schlenk tube: Na_2CO_3 (63.6 mg, 0.6 mmol, 3.0 equiv), NaI (89.9 mg, 0.6 mmol, 3.0 equiv), and *fac*-Ir(ppy)$_3$ (1.2 mg, 0.002 mmol, 1% mmol). After vacuuming and backfilling three times with argon, DMSO (2.0 mL) was added through a 5 mL syringe. Through a 100 μL microinjector, *N*-vinyl bromodifluoroacetamide (57.6 mg, 0.2 mmol, 1.0 equiv) was added to the reaction mixture. Under the irradiation of a 460 nm 30 W blue LED, the mixture was stirred at room temperature for 24 hours. After the reaction was complete (TLC monitoring), 50 mL water was added and then extracted three times with 3×50 mL ethyl acetate. The organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the crude product by column chromatography (silica gel 200-300 mesh, petroleum ether/ethyl acetate = 10:1-5:1) led to the corresponding product **2a** being obtained.

2.1.2 General synthesis steps for product series 3. (3a as an example)

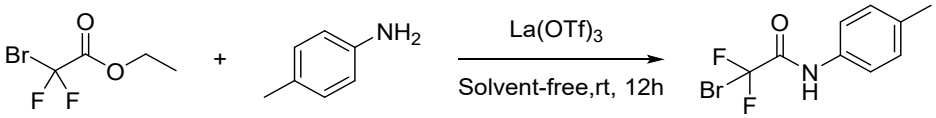
The following ingredients should be added to the 25 mL Schlenk tube: 4DPAIPN (1.6 mg, 0.002 mmol, 1% mmol). After vacuuming and backfilling three times with argon, THF (2.0 mL) was added through a 5mL syringe. Through a 100μL microinjector, *N*-vinyl bromodifluoroacetamide (57.6 mg, 0.2 mmol, 1.0 equiv.) was added to the reaction mixture. Under the irradiation of a 460 nm 30 W blue LED, the mixture was stirred at room temperature for 24 hours. After the reaction was complete (TLC monitoring), 50 mL water was added and then extracted three times with 3×50 mL ethyl acetate. The organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the crude product by column chromatography (silica gel 200-300 mesh, petroleum ether/ethyl acetate = 10:1-5:1) led to the corresponding product **3a** being obtained.

2.1.3 General synthesis steps for product series 4 and 5. (4a as an example)

The following ingredients should be added to the 25 mL Schlenk tube: NaI (74.9 mg, 0.5 mmol, 2.5 equiv) and *fac*-Ir(ppy)$_3$ (1.2 mg, 0.002 mmol, 1% mmol). After vacuuming and backfilling three times with argon, MeCN (2.0 mL) was added through a 5mL syringe. Through a 100μL microinjector, *N*-vinyl bromodifluoroacetamide (57.6 mg, 0.2 mmol, 1.0 equivalent) was added to the reaction mixture. Under the irradiation of a 460 nm 30 W blue LED, the mixture was stirred at room temperature for 24 hours. After the reaction was complete (TLC monitoring), 50 mL water was added and then extracted three times with 3×50 mL ethyl acetate. The organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. Purification of the crude product by column chromatography (silica gel 200-300 mesh, petroleum ether/ethyl acetate = 10:1-5:1) led to the corresponding product **4a** being obtained.

2.2 Synthesis of starting materials

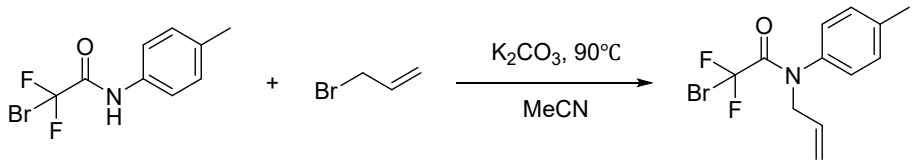
Preparation of the *N*-substituted-2-bromo-2,2-difluoroacetamide



Ethyl dibromofluoroacetate (1212 mg, 6.0 mmol, 1.2 equiv), lanthanum trifluoromethanate La(OTf)$_3$ (147mg, 0.25mmol, 5mol%), and p-toluidine (535mg, 5.0 mmol,1.0 equiv) were dissolved in 25 mL dry Schlenk tubes. Vacuum backfill with argon three times. The mixture was stirred at room temperature and monitored by thin layer chromatography. After the amine was consumed, 50 mL of water is added and the ethyl acetate is extracted three times. The organic phase is dried by anhydrous Na_2SO_4, filtered and condensed under reduced pressure. The crude product was purified by

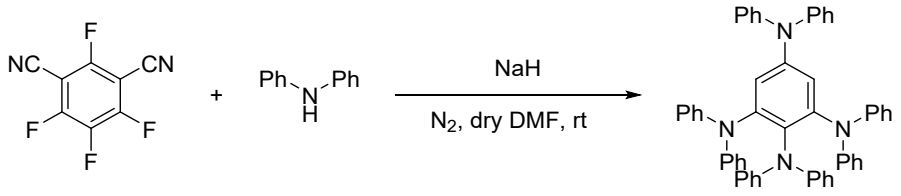
column chromatography (silica gel 200-300 mesh, petroleum ether/ethyl acetate = 10:1) to obtain the corresponding product.[1]

Preparation of *N*-allyl-2-bromo-2,2-difluoro-*N*-arylacetamide



To a solution of 2-bromo-2, 2-difluoro-*N*-phenylacetamide (1.25 g, 5.0 mmol, 1.0 equiv) in CH_3CN, K_2CO_3 (2.07 g, 15 mmol, 3.0 equiv) and 3-bromopropene (1.21 g, 10 mmol, 2.0 equiv) were added. The reaction was stirred at 90℃ for 12h. Extraction was carried out with ethyl acetate/water after the reaction. The organic phase was dried by anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. In order to obtain the corresponding product, the crude product was purified by column chromatography (silica gel 200-300 mesh, petroleum ether/ethyl acetate = 25:1).[2]

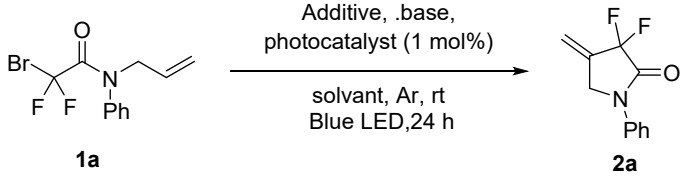
Synthesis of 2,4,5,6-tetrakis(diphenylamino)-isophthalonitrile (4DPAIPN)



Under Nitrogen atmosphere, a 25 mL heat-gun dried two-necked round-bottom flask was filled with dry DMF (5 mL) and diphenylamine (2.8 mmol, 474 mg, 6.0 equiv.) under inert atmosphere. NaH (60% suspension in mineral oil, 3.75 mmol, 150 mg, 8.0 eq.) was slowly added and the mixture was stirred at 60 °C for 5 hours. 2,4,5,6-tetrafluoroisophthalonitrile (0.45 mmol, 93.5 mg, 1 equiv.) was added and the reaction mixture was stirred at 90 °C for 8 hours. After that, the solution was cooled to 0°C and water (3 mL) was slowly added to quench the reaction. A yellow precipitate appeared upon addition of MeOH (10 mL) and was collected by filtration. The solid was redissolved in DCM (10 mL) and reprecipitated by the addition of MeOH (10 mL) to afford the desired clean product.[3]

2.3 Reaction Optimization

Table S1 Optimization of reaction conditions for preparation 2a[a, b]

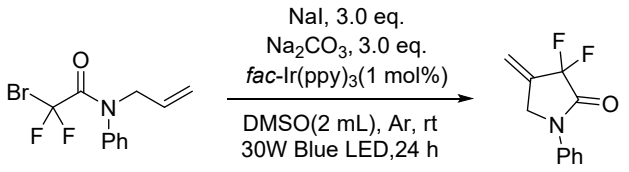


1a **2a**

Entry	Photocatalysts	Blue LED	Solvent	Base	Atmosphere	Additive	Yield **2a**
1	***fac*-Ir(ppy)$_3$**	**30W**	**DMSO**	**Na_2CO_3**	**Ar**	**NaI**	**78%**
2	4CziPN	30W	DMSO	Na_2CO_3	Ar	NaI	48%
3	[Acr^+-Mes][ClO_4^-]	30W	DMSO	Na_2CO_3	Ar	NaI	NR
4	Eosion Y	30W	DMSO	Na_2CO_3	Ar	NaI	53%
5	Rh-6G	30W	DMSO	Na_2CO_3	Ar	NaI	NR
6	methylene blue	30W	DMSO	Na_2CO_3	Ar	NaI	NR
7	*fac*-Ir(ppy)$_3$	6W	DMSO	Na_2CO_3	Ar	NaI	62%
8	*fac*-Ir(ppy)$_3$	8W	DMSO	Na_2CO_3	Ar	NaI	70%
7	*fac*-Ir(ppy)$_3$	30W	DMAC	Na_2CO_3	Ar	NaI	46%
9	*fac*-Ir(ppy)$_3$	30W	DCE	Na_2CO_3	Ar	NaI	trace
10	*fac*-Ir(ppy)$_3$	30W	MeCN	Na_2CO_3	Ar	NaI	N.D.
11	*fac*-Ir(ppy)$_3$	30W	1,4-Dioxane	Na_2CO_3	Ar	NaI	N.D.
12	*fac*-Ir(ppy)$_3$	30W	THF	Na_2CO_3	Ar	NaI	N.D.
13	*fac*-Ir(ppy)$_3$	30W	DCM	Na_2CO_3	Ar	NaI	N.D.
14	*fac*-Ir(ppy)$_3$	30W	DMSO	Et_3N	Ar	NaI	45%
15	*fac*-Ir(ppy)$_3$	30W	DMSO	DIPEA	Ar	NaI	60%
16	*fac*-Ir(ppy)$_3$	30W	DMSO	PMDETA	Ar	NaI	48%
17	*fac*-Ir(ppy)$_3$	30W	DMSO	$NaHCO_3$	Ar	NaI	53%
18	*fac*-Ir(ppy)$_3$	30W	DMSO	K_2CO_3	Ar	NaI	70%
19	*fac*-Ir(ppy)$_3$	30W	DMSO	K_3PO_4	Ar	NaI	43%
20	*fac*-Ir(ppy)$_3$	30W	DMSO	Na_2CO_3	Ar	TBAI	53%
21	*fac*-Ir(ppy)$_3$	30W	DMSO	Na_2CO_3	Ar	KI	29%
22	*fac*-Ir(ppy)$_3$	30W	DMSO	Na_2CO_3	Ar	NH_4I	20%
23	*fac*-Ir(ppy)$_3$	30W	DMSO	Na_2CO_3	Ar	NIS	NR
24	*fac*-Ir(ppy)$_3$	30W	DMSO	Na_2CO_3	O_2	NaI	13%

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), additive (0.6 mmol, 3.0 equiv.), base (0.6 mmol, 3.0 equiv.), Photocatalysts (1 mol%), solvent (2.0 mL), room temperature ,blue LEDs, 24 h. [b] Isolated yields. Et_3N: triethylamine; DIPEA: *N*,*N*-diisopropylethylamine; PMDETA: *N,N,N′,N′,N″*-pentamethyldiethylenetriamine. N.D.: Not Detected.

Table S2 Control experiments [a, b]

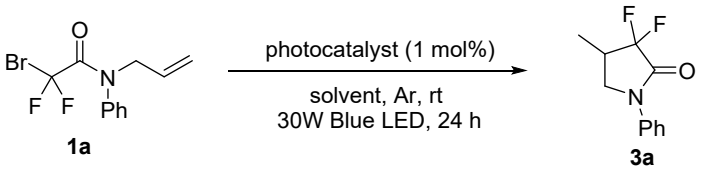


1a **2a**

Entry	[Ir]	NaI	Na_2CO_3	Ar	light	Yield **2a**
1	-	+	+	+	+	NR
2	+	-	+	+	+	NR
3	+	+	-	+	+	NR
4	+	+	+	-	+	23%
5	+	+	+	+	-	NR

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), NaI (0.6 mmol, 3.0 equiv.), Na_2CO_3 (0.6 mmol, 3.0 equiv.), *fac*-Ir(ppy)$_3$ (1 mol%), DMSO (2.0 mL), room temperature, argon atmosphere, blue LEDs 30W , 24 h. [b] Isolated yields.

Table S3 Optimization of reaction conditions for preparation 3a[a, b]

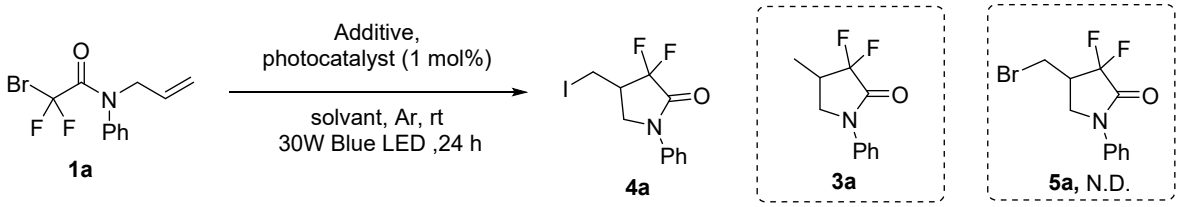


1a **3a**

Entry	Photocatalysts	Solvent	Yield **3a** (%)
1	*fac*-Ir(ppy)$_3$	MeCN:H_2O=2:1	46
2	*fac*-Ir(ppy)$_3$	MeCN:H_2O=1:1	23
4	*fac*-Ir(ppy)$_3$	THF	80
5	*fac*-Ir(ppy)$_3$	Isopropanol	35
6	*fac*-Ir(ppy)$_3$	EtOH	N.D.
7	Eosin Y	THF	65
8	Na_2Eosin Y	THF	71
9	Rh-6G	THF	80
10	**4DPAIPN**	**THF**	**85**
11	DCQ	THF	57
12	*fac*-Ir(ppy)$_3$	THF	80
13	4CziPN	THF	71
14	[Acr$^+$-Mes][ClO_4^-]	THF	59

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.) . Photocatalysts (1 mol %), solvent (2.0 mL), room temperature, argon atmosphere, blue LEDs 30W, 24 h. [b] Isolated yields. N.D.: Not Detected.

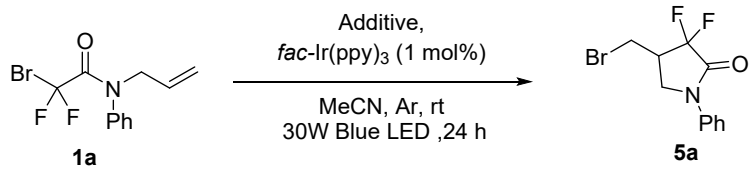
Table S4 Optimization of reaction conditions for preparation 4a[a, b]



Entry	Photocatalysts (1%)	Solvent (0.1M)	Additive (2.5 eq)	Yield **3a** (%)	Yield **4a** (%)
1	*fac*-Ir(ppy)$_3$	DMSO	NaI	N.D.	65
2	Eosin Y	DMSO	NaI	N.D.	N.D.
3	4CziPN	DMSO	NaI	N.D.	25
4	[Ir{dFCF$_3$ppy}$_2$(bpy)]PF$_6$	DMSO	NaI	N.D.	N.D.
5	EosinY Na	DMSO	NaI	N.D.	N.D.
6	Rh-6G	DMSO	NaI	N.D.	N.D.
7	Methylene Blue	DMSO	NaI	N.D.	N.D.
8	Mes-Acr+ClO$_4$-	DMSO	NaI	N.D.	N.D.
7	*fac*-Ir(ppy)$_3$	DMSO	KI	N.D.	60
9	*fac*-Ir(ppy)$_3$	DMSO	NH$_4$I	N.D.	17
10	*fac*-Ir(ppy)$_3$	DMSO	TBAI	N.D.	20
11	*fac*-Ir(ppy)$_3$	DMSO	NIS	N.D.	N.D.
12	*fac*-Ir(ppy)$_3$	DMSO	NaI	N.D.	65
13	*fac*-Ir(ppy)$_3$	DMSO	NaI	N.D.	65%
14	*fac*-Ir(ppy)$_3$	DMF	NaI	17%	53%
15	***fac*-Ir(ppy)$_3$**	**MeCN**	**NaI**	**N.D.**	**72%**
16	*fac*-Ir(ppy)$_3$	MeOH	NaI	N.D.	30%
17	*fac*-Ir(ppy)$_3$	DCM	NaI	16%	25%
18	*fac*-Ir(ppy)$_3$	MeCN [c]	NaI	N.D.	40
19	*fac*-Ir(ppy)$_3$	MeCN[d]	NaI	N.D.	58
20	*fac*-Ir(ppy)$_3$	MeCN	NaI [e]	N.D.	72
21	*fac*-Ir(ppy)$_3$	MeCN	NaI [f]	N.D.	67
22	*fac*-Ir(ppy)$_3$	MeCN	NaI [g]	N.D.	69
23 [h]	*fac*-Ir(ppy)$_3$	MeCN	NaI	47%	N.D.
24 [I]	*fac*-Ir(ppy)$_3$	MeCN	NaI	55%	N.D.
25 [j]	*fac*-Ir(ppy)$_3$	MeCN	NaI	42%	trace

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), additive (0.5 mmol, 2.5 equiv.), Photocatalysts (1 mol %), solvent (2.0 mL), room temperature, argon atmosphere ,blue LEDs 30W , 24 h. [b] Isolated yields .[c] solvent 3.0 mL . [d] solvent 4.0 mL. [e] additive (3.0 equiv.), [f] additive (3.5 equiv.), [g] additive (4.0 equiv.), [h] *N,N,N′,N′*-Tetramethylethylenediamine with 1.0 eq added, [I] Pentamethyldiethylenetriamine with 1.0 eq added, [j] DBU with 1.0 eq added. N.D.: Not Detected.

Table S5 Optimization of reaction conditions for preparation 5a[a, b]



Entry	Photocatalysts	Blue LED	Solvent	Additive	Yield **5a** (%)
1	*fac*-Ir(ppy)$_3$	30W	MeCN	NaBr	63
2	*fac*-Ir(ppy)$_3$	30W	MeCN	LiBr	46
3	*fac*-Ir(ppy)$_3$	30W	MeCN	KBr	29
4	***fac*-Ir(ppy)$_3$**	**30W**	**MeCN**	**NH_4Br**	**73**
5	*fac*-Ir(ppy)$_3$	30W	MeCN	TBAB	40
6	*fac*-Ir(ppy)$_3$	30W	MeCN	NBS	N.D.
7	*fac*-Ir(ppy)$_3$	30W	MeCN	-	45

[a]Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), additive (0.5 mmol, 2.5 equiv.), *fac*-Ir(ppy)$_3$ (1 mol %), MeCN (2.0 mL), room temperature, argon atmosphere ,blue LEDs 30W , 24 h. [b] Isolated yields . N.D.: Not Detected.

3. X-Ray Crystal Structure and Crystallographic Data

The purified compound **2d** is dissolved in dichloromethane and petroleum ether, and placed in a dark cabinet to slowly evaporate. After several days, a yellow bulk crystal is obtained. The X-ray crystal-structure determinations were obtained on a Bruker Smart APEX CCD area detector diffractometer at 296(2) K.

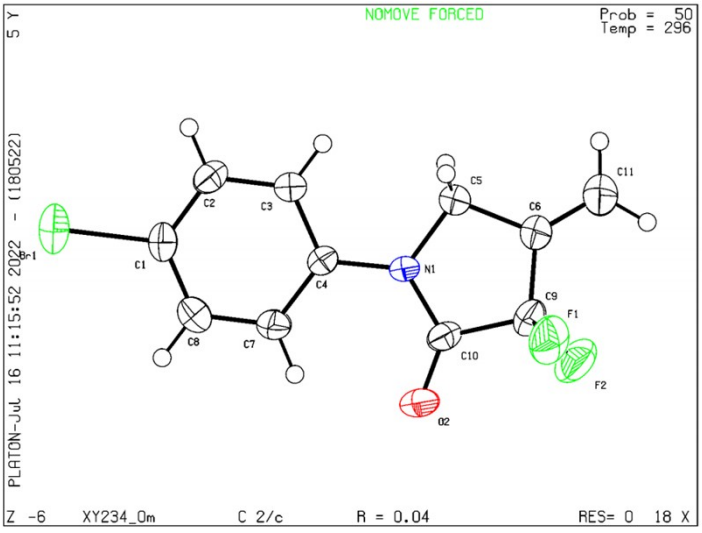


Table S6. Crystal data and structure refinement for compound 2d.

Identification code	CCDC: 2412290
Empirical formula	$C_{11}H_8BrF_2NO$
Formula weight	286.97
Temperature/K	296 (2)
Crystal system	monoclinic
Space group	C2/c
a/Å	23.396(10)
b/Å	6.177(3)
c/Å	16.234(7)
α/°	90
β/°	111.845(6)
γ/°	90
Mr	288.08
Volume/Å^3	2177.6(17)
Z	8
Dx,g /cm^3	1.758
Mu/mm^{-1}	3.779
F (000)	1136.0
F000'	1134.37
h,k,lmax	30,8,21
Nref	2509
Tmin,Tmax	0.493,0.546
Tmin'	0.483
Data completeness	0.992
Theta(max)	27.556
R(reflections)	0.0442(1787)
wR2(reflections)	0.1137(2490)
S	1.091
Npar	145

4. Emission quenching experiments (Stern-Volmer Studies)

All fluorescence measurements were recorded using a Hitachi FL-7000 Fluorometer. All fluorescein solution were irradiated 282nm approximately and the emission intensity from 350 nm to 650 nm was recorded by F-7000 FL Spectrophotometer. In this section, a 4 mL solution of *fac*-Ir(ppy)$_3$ in DMSO (0.002 mmol/mL) was added **1a** (0.04 mmol, 0.08 mmol, 0.16 mmol,

0.32 mmol in turn) 、NaI (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn)、Na_2CO_3 (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn). Then the emission intensity was collected and the results were presented in Figure S1-S4

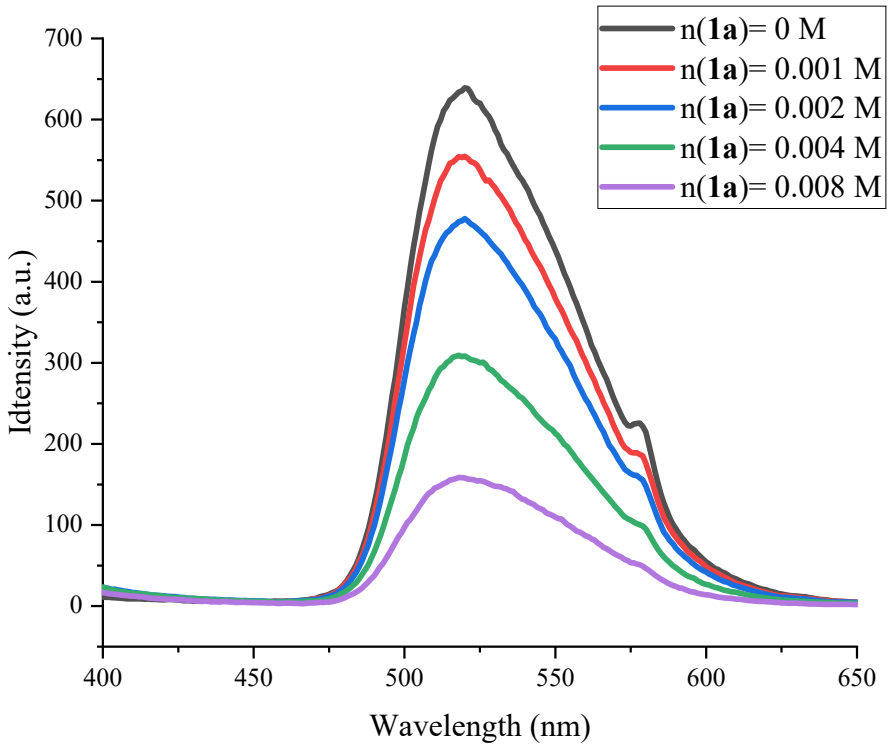


Figure S1: Fluorescence quenching of *fac*-Ir(ppy)$_3$ in DMSO by **1a**

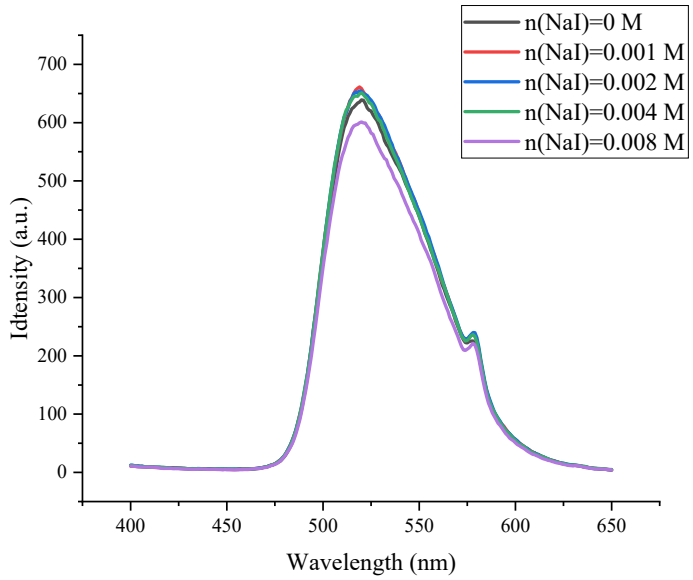


Figure S2:Fluorescence quenching of *fac*-Ir(ppy)$_3$ in DMSO by NaI

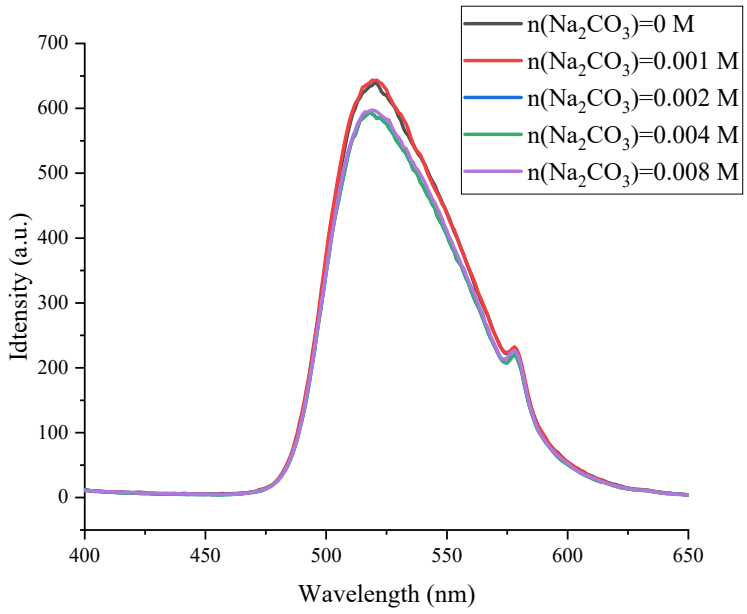


Figure S3: Fluorescence quenching of *fac*-Ir(ppy)$_3$ in DMSO by Na_2CO_3

An indeed fluorescence quenching phenomenon of fluorescein under various concentrations of **1a** or NaI or Na_2CO_3 was demonstrated in a curve of [I0/I] vs [Concentration], as shown in Figure S4.

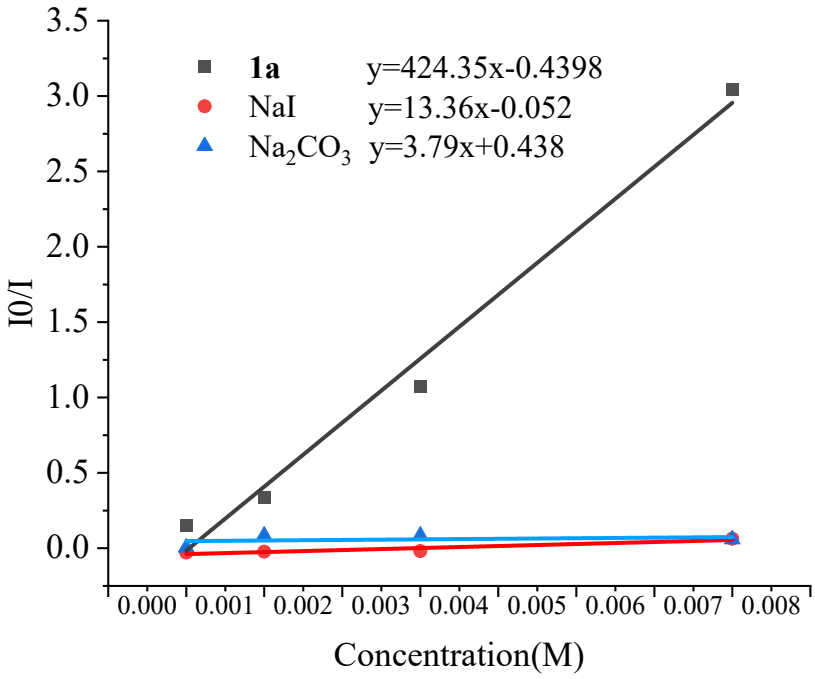


Figure S4: Stern-Volmer plot of Fluorescein in DMSO by **1a**, NaI or Na_2CO_3

In this section, a 4 mL solution of *fac*-Ir(ppy)$_3$ in MeCN (0.002 mmol/mL) was added **1a** (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn) 、NaI (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn)、NH_4Br (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn). Then the emission

intensity was collected and the results were presented in Figure S5-S8

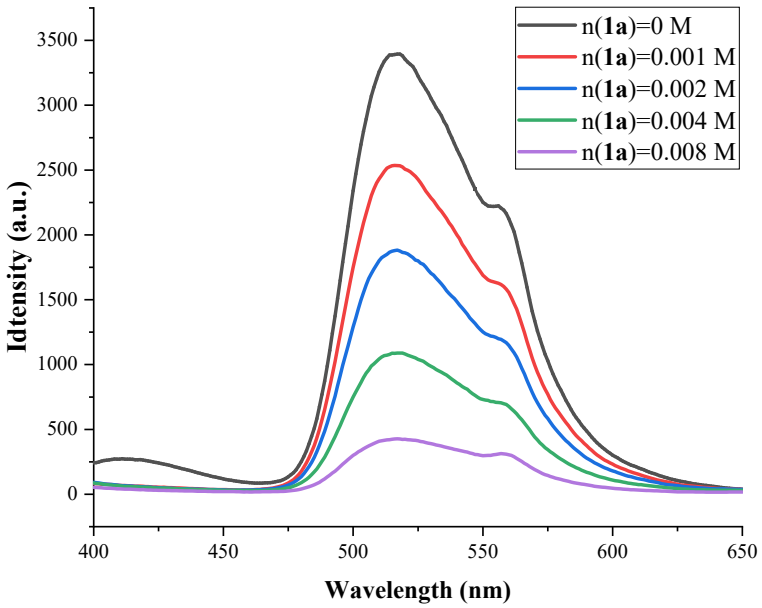


Figure S5: Fluorescence quenching of *fac*-Ir(ppy)$_3$ in MeCN by **1a**

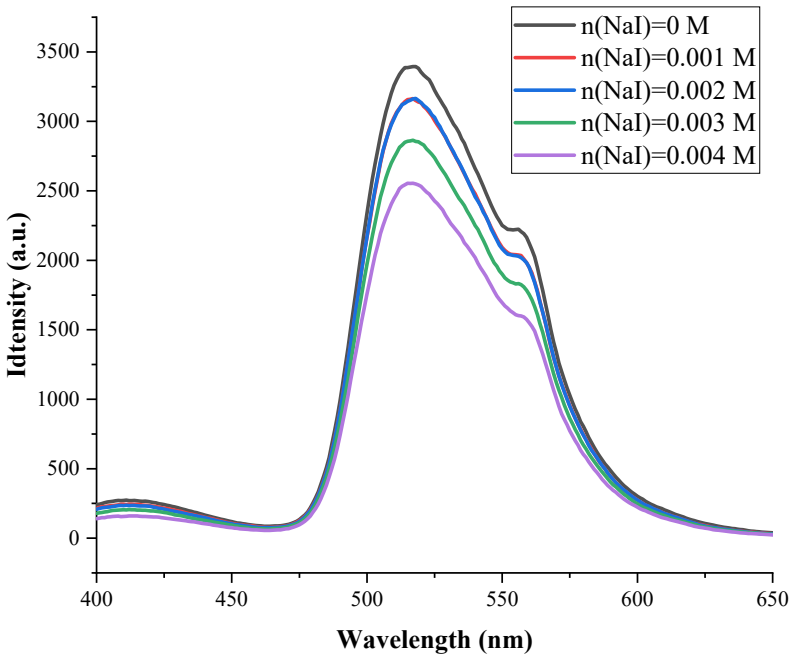


Figure S6: Fluorescence quenching of *fac*-Ir(ppy)$_3$ in MeCN by NaI

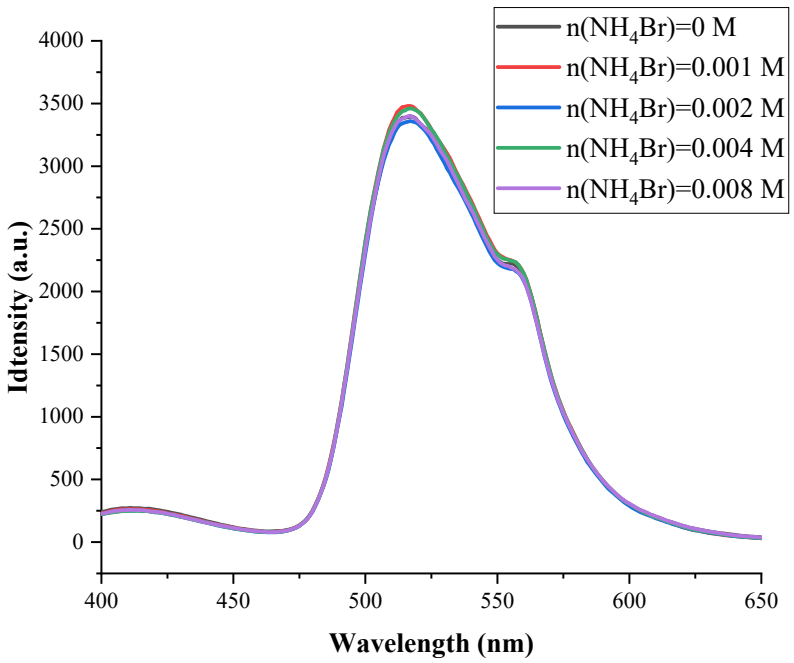


Figure S7: Fluorescence quenching of *fac*-Ir(ppy)$_3$ in MeCN by NH_4Br

An indeed fluorescence quenching phenomenon of fluorescein under various concentrations of **1a** or NaI or NH_4Br was demonstrated in a curve of [I0/I] vs [Concentration], as shown in Figure S8.

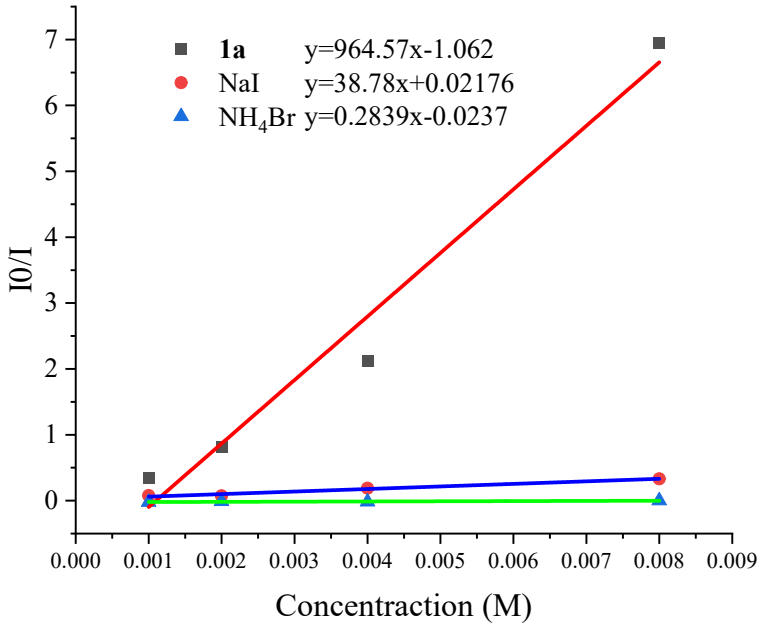


Figure S8: Stern-Volmer plot of Fluorescein in MeCN by **1a**, NaI or NH_4Br

In this section, a 4 mL solution of 4DPAIPN in THF (0.002 mmol/mL) was added **1a** (0.04 mmol, 0.08 mmol, 0.16 mmol, 0.32 mmol in turn). Then the emission intensity was collected and

the results were presented in Figure S9-S10

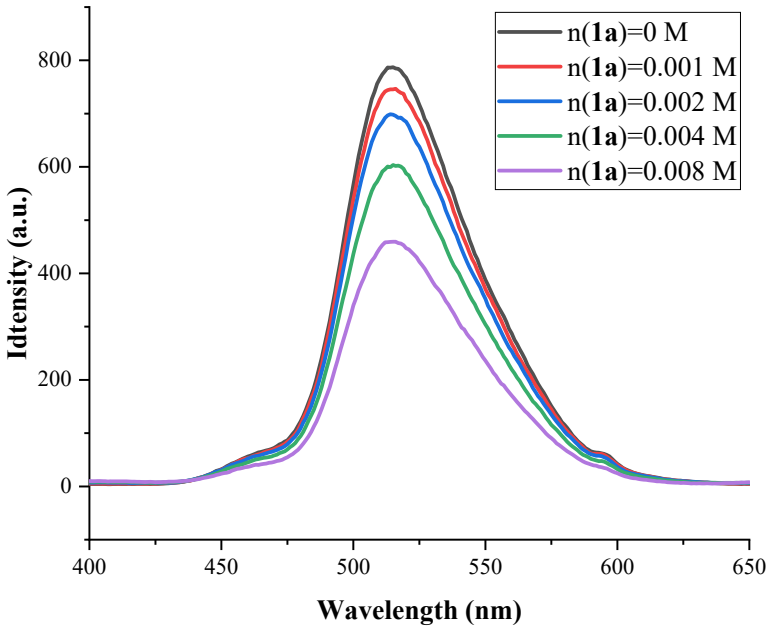


Figure S9: Fluorescence quenching of 4DPAIPN in THF by **1a**

An indeed fluorescence quenching phenomenon of fluorescein under various concentrations of **1a** was demonstrated in a curve of [I0/I] vs [Concentration], as shown in Figure S10.

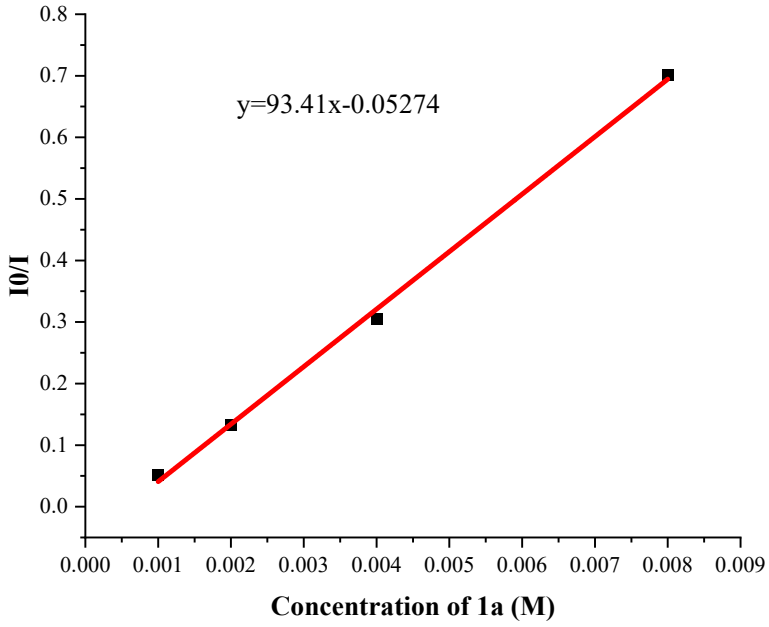


Figure S10: Stern-Volmer plot of Fluorescein in THF by **1a**

5. Cyclic Voltametric experiments

Cyclic Voltametric experiments were conducted on a "**IKA ElectraSyn 2.0 pro Package**" in a three-electrode cell at room temperature (25 ± 2ºC) using Glassy carbon electrode working electrode, Ag/AgCl electrode (3M KCl) as reference electrode, a platinum electrode as the counter electrode. Prior to the measurement, the solution was purged with Ar, and the glassy carbon electrode was rotated to homogenize the probe solution. The testing solution was prepared by dissolving the sample (**1a**, 0.05 mmol) into MeCN (5 mL) with 0.1 M tetrabutylammonium hexafluorophosphate ($TBAPF_6$) for CV study. The potential was scanned back and forward linearly between -2.5 and 2.5 V at a 100 mV/s scan rate. Throughout the measurement process, the solution was shielded by a positive N_2 stream [4]. The CV experiments of all the forms of the substrates were carried out following the aforementioned procedure and the diagrams are depicted as follows:

Cyclic voltammetry studies showed that the reduction of *N*-allyl difluorobromoacetamide **1a** occurs at -1.40 V with a significant peak current. The above experimental data show that the excited photocatalysts *Ir(III) (E^*_{red} = -1.73 V, VS. SCE) and *4DPAIPN (E^*_{red} = -1.52 V, vs. SCE) can undergo a single electron transfer process with reactant **1a** (E^*_{red} = -1.40 V vs. SCE in MeCN).

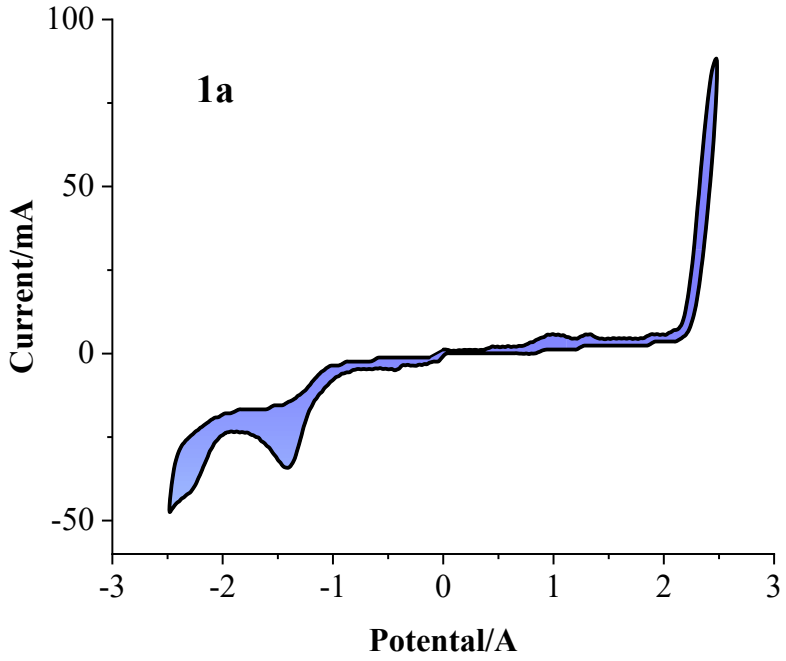
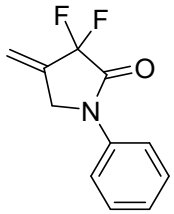


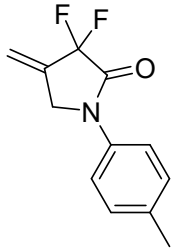
Figure S11. Cyclic voltammogram of **1a** (0.1 mmol vs $Ag/AgNO_3$), scan rate 100 mV/s.

6. Characterization of Products



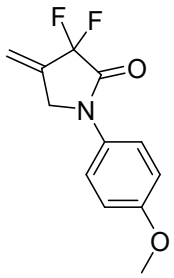
2a

3,3-Difluoro-4-methylene-1-phenylpyrrolidin-2-one (2a), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 36mg 78%, white solid, m.p.: 120-121 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.69 (m, 2H), 7.46 – 7.41 (m, 2H), 7.29 – 7.24 (m, 1H), 6.08 – 6.04 (m, 1H), 5.78 – 5.75 (m, 1H), 4.50 (t, *J* = 2.1 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.94 (t, *J* = 30.5 Hz), 137.54, 132.65 (t, *J* = 19.9 Hz), 129.29, 126.42, 120.08, 118.27, 110.80 (t, *J* = 246.6 Hz), 48.37. HRMS (ESI): m/z $[M+Na]^+$ calcd for $C_{11}H_9F_2NNaO$:232.0544; found:232.0540.



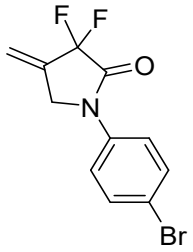
2b

3,3-Difluoro-4-methylene-1-(*p*-tolyl)pyrrolidin-2-one (2b), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 36ng 73%, white solid, m.p.: 128-129 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 – 7.54 (m, 3H), 7.26 – 7.20 (m, 4H), 6.05 (ddd, *J* = 4.4, 2.1, 1.0 Hz, 1H), 5.77 – 5.72 (m, 1H), 4.47 (t, *J* = 2.1 Hz, 2H), 2.36 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.77 (t, *J* = 30.8 Hz), 136.34, 135.03, 132.80 (t, *J* = 19.9 Hz), 129.79, 120.07, 118.13, 110.87 (t, *J* = 246.2 Hz), 48.46, 20.94. HRMS (ESI): m/z $[M+Na]^+$ calcd for $C_{12}H_{11}F_2NNaO$:246.0701; found: 246.0697.



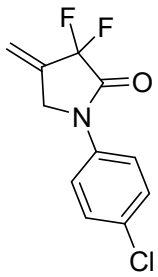
2c

3,3-Difluoro-1-(4-methoxyphenyl)-4-methylenepyrrolidin-2-one (2c), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 38 mg, 72%, white solid, m.p.: 122.5-123.7 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 (d, *J* = 9.1 Hz, 2H), 6.95 (d, *J* = 9.1 Hz, 2H), 6.05 (s, 1H), 5.74 (s, 1H), 4.45 (t, *J* = 2.0 Hz, 2H), 3.82 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.63 (t, *J* = 30.7 Hz), 157.82, 132.83 (t, *J* = 20.1 Hz), 130.58, 121.85, 118.08 (t, *J* = 2.3 Hz), 114.41, 110.89 (t, *J* = 246.3 Hz), 55.49, 48.72.HRMS (ESI): m/z $[M+Na]^+$ calcd for $C_{12}H_{11}F_2NNaO_2$: 262.0650; found: 262.0645.



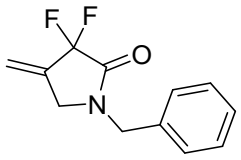
2d

1-(4-Bromophenyl)-3,3-difluoro-4-methylenepyrrolidin-2-one (2d), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 42mg 68%, white solid, m.p.: 147-149 °C.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.60 (m, 2H), 7.57 – 7.53 (m, 2H), 6.10 – 6.06 (m, 1H), 5.80 – 5.76 (m, 1H), 4.47 (t, *J* = 2.1 Hz, 2H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.95 (t, *J* = 31.3 Hz), 136.60, 132.32, 121.40, 119.51, 118.65 (t, *J* = 3.2 Hz), 110.61 (t, *J* = 246.3 Hz), 48.21. HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_8BrF_2NNaO$ calcd for:309.9650; found: 309.9644.



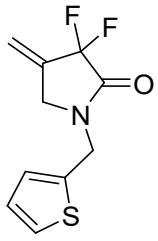
2e

1-(4-Chlorophenyl)-3,3-difluoro-4-methylenepyrrolidin-2-one (2e), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 37mg 70%, white solid, m.p. : 143-145 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 – 7.66 (m, 2H), 7.43 – 7.38 (m, 2H), 6.09 – 6.06 (m, 1H), 5.80 – 5.77 (m, 1H), 4.48 (t, *J* = 2.1 Hz, 2H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.94 (t, *J* = 31.0 Hz), 136.10, 132.23 (t, *J* = 20.2 Hz), 131.72, 129.36, 121.14, 118.62, 110.62 (t, *J* = 246.7 Hz), 48.29 (t, *J* = 2.8 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_8ClF_2NNaO$ calcd for:266.0155; found: 266.0148.



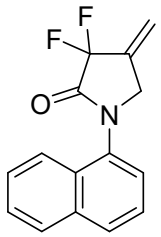
2f

1-Benzyl-3,3-difluoro-4-methylenepyrrolidin-2-one (2f), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 26mg 52%,white solid, m.p.: 127-126 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39 – 7.31 (m, 3H), 7.25 (d, *J* = 7.0 Hz, 2H), 5.97 – 5.90 (m, 1H), 5.60 – 5.54 (m, 1H), 4.59 (s, 2H), 3.88 (t, *J* = 2.1 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 162.99 (t, *J* = 30.3 Hz), 134.13, 133.36 (t, *J* = 20.2 Hz), 129.04, 128.38, 117.94, 111.05 (t, *J* = 247.3 Hz), 47.11, 46.51. HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{11}F_2NNaO$ calcd for:246.0701; found: 246.0694



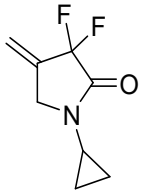
2g

3,3-Difluoro-4-methylene-1-(thiophen-2-ylmethyl)pyrrolidin-2-one (2g), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 28mg 55%, white solid, m.p.: 80-82 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (dd, *J* = 5.1, 1.1 Hz, 1H), 7.03 (d, *J* = 3.3 Hz, 1H), 6.99 (dd, *J* = 5.1, 3.5 Hz, 1H), 5.96 (s, 1H), 5.60 (s, 1H), 4.76 (s, 2H), 3.97 (t, *J* = 2.1 Hz, 2H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.59 (t, *J* = 30.3 Hz), 135.93, 133.29 (t, *J* = 20.2 Hz), 127.92, 127.24, 126.48, 118.10 (t, *J* = 2.6 Hz), 110.94 (t, *J* = 247.4 Hz), 46.38, 41.37.HRMS (ESI): m/z $[M+Na]^+$ $C_{10}H_9F_2NNaOS$ calcd for:252.0265; found: 252.0257



2h

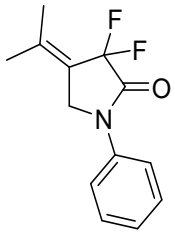
3,3-Difluoro-4-methylene-1-(naphthalen-1-yl)pyrrolidin-2-one (2h), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 20mg 40%, yellow solid, m.p.: 133-134 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12 (dd, *J* = 14.6, 7.8 Hz, 2H), 7.75 (t, *J* = 7.7 Hz, 1H), 7.70 (d, *J* = 8.3 Hz, 1H), 7.54 (t, *J* = 8.0 Hz, 1H), 7.22 (d, *J* = 7.7 Hz, 1H), 6.01 – 5.93 (m, 1H), 5.31 (d, *J* = 2.5 Hz, 1H), 5.28 (d, *J* = 2.6 Hz, 1H), 4.88 (d, *J* = 5.0 Hz, 2H).^{13}C NMR (126 MHz, $CDCl_3$)δ 160.26 – 159.90 (m) 132.73, 131.83 (t, *J* = 2.6 Hz), 130.91, 127.03 (t, *J* = 2.6 Hz), 126.84, 126.14 (t), 124.08, 117.78, 112.35, 45.04. HRMS (ESI): m/z $[M+H]^+$ $C_{15}H_{12}F_2NO$ calcd for:260.0881; found: 260.0676



2i

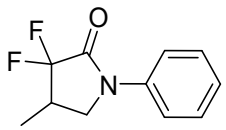
1-Cyclopropyl-3,3-difluoro-4-methylenepyrrolidin-2-one (2i), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 24mg 62%, Light yellow oil, ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.95 – 5.92 (m, 1H), 5.63 – 5.59 (m, 1H),

3.95 (t, *J* = 2.1 Hz, 2H), 2.82 – 2.76 (m, 1H), 0.91 – 0.86 (m, 2H), 0.85 – 0.80 (m, 2H).^{13}C NMR (126 MHz, $CDCl_3$) δ 163.94 (t, *J* = 30.1 Hz), 133.59 (t, *J* = 20.1 Hz), 117.72 (t, *J* = 2.6 Hz), 111.20 (t, *J* = 246.8 Hz), 47.50 (t, *J* = 2.0 Hz), 26.00, 5.03. HRMS (ESI): m/z $[M+Na]^+$ $C_8H_9F_2NNaO$ calcd for:196.0544; found: 196.0542



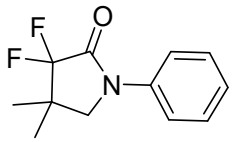
2j

3,3-Difluoro-1-phenyl-4-(propan-2-ylidene)pyrrolidin-2-one (2j), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 32mg 62%, white solid, m.p.: 142-145 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.74 (d, *J* = 7.8 Hz, 2H), 7.43 (t, *J* = 8.0 Hz, 2H), 7.25 (d, *J* = 9.1 Hz, 1H), 4.39 (s, 2H), 2.10 (s, 3H), 1.87 (t, *J* = 4.0 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.84 (t, *J* = 31.4 Hz), 143.58, 137.77, 129.21, 126.24, 120.22, 116.91 (t, *J* = 18.5 Hz), 112.56 (t, *J* = 243.7 Hz), 47.79, 21.23, 20.57.HRMS (ESI): m/z [M+Na]+ $C_{13}H_{13}F_2NNaO$ calcd for: 260.0857; found: 260.0853



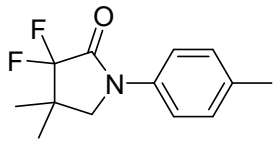
3a

3,3-Difluoro-4-methyl-1-phenylpyrrolidin-2-one (3a), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 40 mg 85%, white solid, m.p.: 86-87 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.9 Hz, 2H), 7.42 (t, *J* = 8.0 Hz, 2H), 7.24 (d, *J* = 7.4 Hz, 1H), 3.95 (t, *J* = 8.8 Hz, 1H), 3.50 (t, *J* = 8.7 Hz, 1H), 2.80 – 2.69 (m, 1H), 1.32 (d, *J* = 7.0 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.54 (t, *J* = 31.7 Hz), 138.01, 129.17, 126.07, 119.85, 119.73 – 115.46 (m), 49.83 (d, *J* = 6.4 Hz), 34.74 (t, *J* = 21.9 Hz), 10.00 (d, *J* = 8.2 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_{11}F_2NNaO$ calcd for: 234.0701 found: 234.0695.



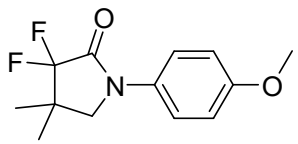
3b

3,3-Difluoro-4,4-dimethyl-1-phenylpyrrolidin-2-one (3b), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 40mg 80%, white solid, m.p.: 52-54 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.61 (m, 2H), 7.45 – 7.39 (m, 2H), 7.26 – 7.21 (m, 1H), 3.59 (t, *J* = 0.9 Hz, 2H), 1.30 (t, *J* = 1.2 Hz, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.52 (t, *J* = 31.9 Hz), 138.14, 129.11, 125.90, 119.73, 118.47 (t, *J* = 254.6 Hz), 56.58, 38.28 (t, *J* = 19.9 Hz), 19.62 (t, *J* = 4.5 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{13}F_2NNaO$ calcd for: 248.0857, found: 248.0852.



3c

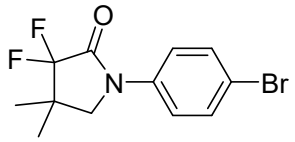
3,3-Difluoro-4,4-dimethyl-1-(p-tolyl)pyrrolidin-2-one (3c), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 38mg 72%, white solid, m.p.: 49-51 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.2 Hz, 2H), 3.56 (s, 2H), 2.35 (s, 3H), 1.28 (s, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.38 (t, *J* = 31.7 Hz), 135.82, 135.70, 129.66, 119.78, 118.54 (t, *J* = 254.4 Hz), 56.79, 38.36 (t, *J* = 20.0 Hz), 20.89, 19.72 (t, *J* = 4.6 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{13}H_{15}F_2NNaO$ calcd for: 262.1014 found: 262.1011.



3d

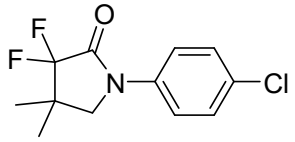
3,3-Difluoro-1-(4-methoxyphenyl)-4,4-dimethylpyrrolidin-2-one (3d), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 40mg 73%,

yellow solid, m.p.: 45-46 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 – 7.47 (m, 2H), 7.02 – 6.87 (m, 2H), 3.82 (s, 3H), 3.55 (s, 2H), 1.29 (s, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.26 (t, *J* = 31.5 Hz), 157.55, 131.31, 121.53, 118.58 (t, *J* = 253.26 Hz), 114.34, 57.12, 55.51, 38.45 (t, *J* = 20.2 Hz), 19.78 (t, *J* = 4.6 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{13}H_{15}F_2NNaO_2$ calcd for: 278.0963, found: 278.0960.



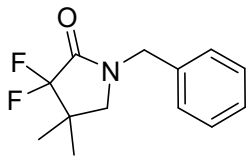
3e

1-(4-Bromophenyl)-3,3-difluoro-4,4-dimethylpyrrolidin-2-one (3e), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 52mg 81%, white solid, m.p.: 60-61 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (dd, *J* = 8.7, 3.8 Hz, 4H), 3.56 (s, 2H), 1.29 (s, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.59 (t, *J* = 32.0 Hz), 137.25, 132.19, 121.12, 118.97, 118.27 (t, *J* = 254.7 Hz), 56.50, 38.31 (t, *J* = 19.8 Hz), 19.69 (t, *J* = 4.3 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{12}BrF_2NNaO$ calcd for: 325.9963, found: 325.9959.



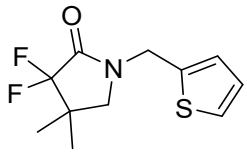
3f

1-(4-Chlorophenyl)-3,3-difluoro-4,4-dimethylpyrrolidin-2-one (3f), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 44mg 79%, white solid, m.p.: 73-76 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 (d, *J* = 8.9 Hz, 2H), 7.37 (d, *J* = 8.9 Hz, 2H), 3.56 (s, 2H), 1.29 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 162.58 (t, *J* = 32.0 Hz), 136.75, 131.23, 129.23, 120.84, 118.28 (t, *J* = 254.7 Hz), 56.58, 38.33 (t, *J* = 19.9 Hz), 19.69 (t, *J* = 4.5 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{12}ClF_2NNaO$ calcd for: 282.0468 found: 282.0461.



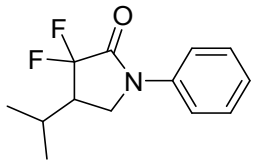
3g

1-Benzyl-3,3-difluoro-4,4-dimethylpyrrolidin-2-one (3g), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 39mg 75%, yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39 – 7.30 (m, 3H), 7.23 (d, *J* = 7.8 Hz, 2H), 4.51 (s, 2H), 2.97 (s, 2H), 1.12 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.70 (t, *J* = 31.5 Hz), 134.65, 128.95, 128.33, 128.19, 118.92 (t, *J* = 255.1 Hz), 54.99, 47.18, 38.62 (t, *J* = 20.2 Hz), 19.71 (t, *J* = 4.6 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{13}H_{15}F_2NNaO$ calcd for: 262.1014, found: 262.1007.



3h

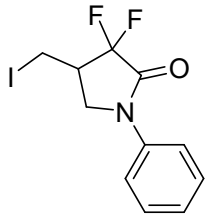
3,3-Difluoro-4,4-dimethyl-1-(thiophen-2-ylmethyl)pyrrolidin-2-one (3h), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 22mg 42%, white solid, m.p.: 63-66 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 (d, *J* = 4.9 Hz, 1H), 6.97 (dd, *J* = 8.7, 3.7 Hz, 2H), 4.69 (s, 2H), 3.05 (s, 2H), 1.13 (s, 6H).^{13}C NMR (126 MHz, $CDCl_3$) δ 163.28 (t, *J* = 31.2 Hz), 136.53, 127.61, 127.09, 126.27, 118.80 (t, *J* = 255.5 Hz), 54.70, 41.49, 38.70 (t, *J* = 20.1 Hz), 19.62 (t, *J* = 4.7 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_{13}F_2NNa$ calcd for: 268.0578, found: 268.0572



3i

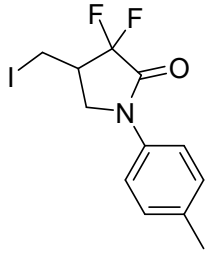
3,3-Difluoro-4,4-dimethyl-1-phenylpyrrolidin-2-one (3i), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 36mg 65%, white solid, m.p.: 119-121 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 2H), 7.42 (t, *J* = 8.0 Hz, 2H), 7.31 – 7.21 (m, 1H), 3.88 (t, *J* = 9.0 Hz, 1H), 3.57 (t, *J* = 9.2 Hz, 1H), 2.35 – 2.21

(m, 1H), 2.16 – 2.05 (m, 1H), 1.19 (d, *J* = 6.6 Hz, 3H), 1.03 (d, *J* = 6.9 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 162.83 (t *J* = 31.5 Hz), 137.97, 129.15, 126.09, 119.96, 117.67 (dd, *J* = 254.6, 249.1 Hz), 47.78 (d, *J* = 7.4 Hz), 46.67 – 45.73 (m), 26.17 (d, *J* = 5.5 Hz), 20.64, 20.04.HRMS (ESI): m/z $[M+Na]^+$ $C_{13}H_{15}F_2NNa$ cacled for:262.1014, found: 262.1009.



4a

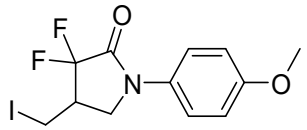
3,3-Difluoro-4-(iodomethyl)-1-phenylpyrrolidin-2-one (4a), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 50mg 70%, yellow solid, m.p.: 86-88 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 9.8 Hz, 2H), 7.44 (t, *J* = 8.1 Hz, 2H), 7.27 (t, *J* = 7.5 Hz, 1H), 4.09 (t, *J* = 9.0 Hz, 1H), 3.61 (t, *J* = 7.7 Hz, 1H), 3.51 (dd, *J* = 10.5, 4.5 Hz, 1H), 3.23 (t, *J* = 10.7 Hz, 1H), 3.14 – 2.97 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.71 (t, *J* = 31.3 Hz), 137.54, 129.26, 126.46, 120.06, 116.06 (dd, *J* = 256.5, 250.9 Hz), 50.28, 42.71 (t, *J* = 21.1 Hz).HRMS (ESI): m/z [M+Na]+ : $C_{11}H_{10}F_2INNaO$ calcd for:359.9667; found: 359.9663.



4b

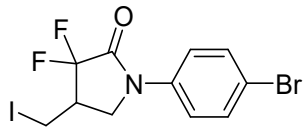
3,3-Difluoro-4-(iodomethyl)-1-(p-tolyl)pyrrolidin-2-one (4b), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 48mg 65%, yellow solid, m.p.: 123-124 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.5 Hz, 2H), 7.23 (d, *J* = 8.3 Hz, 2H), 4.10 – 4.02 (m, 1H), 3.59 (t, *J* = 7.7 Hz, 1H), 3.50 (dd, *J* = 10.5, 4.5 Hz, 1H), 3.23 (t, *J* = 10.6 Hz, 1H), 3.12 – 2.99 (m, 1H), 2.36 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.57 (t, *J* = 30.8 Hz), 136.39, 135.05, 129.81, 120.05, 116.14 (dd, *J*

= 256.5, 250.9 Hz), 50.41 (d, *J* = 5.5 Hz), 42.74 (t, *J* = 21.1 Hz), 29.68, 20.95. HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{12}F_2INNaO$ calcd for: 373.9824; found: 373.9816.



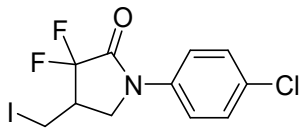
4c

3,3-Difluoro-4-(iodomethyl)-1-(4-methoxyphenyl)pyrrolidin-2-one (4c), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 50mg 64%, white solid, m.p.: 94-96 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 – 7.51 (m, 2H), 6.98 – 6.91 (m, 2H), 4.04 (t, *J* = 9.8 Hz, 1H), 3.82 (s, 3H), 3.57 (t, *J* = 7.7 Hz, 1H), 3.50 (dd, *J* = 10.5, 4.5 Hz, 1H), 3.22 (t, *J* = 10.7 Hz, 1H), 3.13 – 2.98 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.45 (t, *J* = 30.24 Hz), 157.86, 130.58, 121.81, 116.19 (dd, *J* = 256.5, 250.9 Hz), 114.40, 55.50, 50.69 (d, *J* = 5.5 Hz), 42.76 (t, *J* = 21.1 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{12}F_2INO_2$ calcd for:389.9773; found: 389.9767.



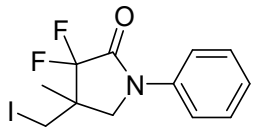
4d

1-(4-Bromophenyl)-3,3-difluoro-4-(iodomethyl)pyrrolidin-2-one (4d), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 62mg 71%, yellow solid, m.p.: 105-109 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 – 7.53 (m, 4H), 4.06 (t, *J* = 8.9 Hz, 1H), 3.58 (t, *J* = 8.8 Hz, 1H), 3.50 (dd, *J* = 10.4, 4.5 Hz, 1H), 3.24 (d, *J* = 10.7 Hz, 1H), 3.14 – 2.99 (m, 1H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.73 (t, *J* = 30.8 Hz), 136.58, 132.31, 121.39, 119.57, 115.87 (dd, *J* = 256.9, 250.5 Hz), 50.16 (d, *J* = 5.5 Hz), 42.57 (t, *J* = 21.1 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_9BrF_2INNaO$ calcd for:437.8722 found: 437.8767.



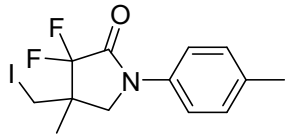
4e

1-(4-Chlorophenyl)-3,3-difluoro-4-(iodomethyl)pyrrolidin-2-one (4e), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1).58mg 74%, yellow oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 9.0 Hz, 2H), 7.39 (d, *J* = 9.0 Hz, 2H), 4.06 (t, *J* = 9.7 Hz, 1H), 3.58 (t, *J* = 8.9 Hz, 1H), 3.50 (dd, *J* = 10.4, 4.6 Hz, 1H), 3.22 (t, *J* = 10.5 Hz, 1H), 3.15 – 2.95 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.77 (t, *J* = 31.3 Hz), 136.13, 131.82, 129.38, 121.18, 115.94 (dd, *J* = 256.9, 250.5 Hz), 50.29, 42.61 (t, *J*=21.1 Hz).HRMS (ESI): m/z [M+Na]+ $C_{11}H_9ClF_2INNaO$ calcd for:393.9278 found: 393.9269.



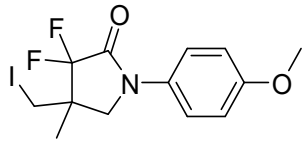
4f

3,3-Difluoro-4-(iodomethyl)-4-methyl-1-phenylpyrrolidin-2-one (4f), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 53mg 72%, yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.61 (m, 2H), 7.46 – 7.40 (m, 2H), 7.29 – 7.24 (m, 1H), 3.82 – 3.78 (m, 1H), 3.58 – 3.50 (m, 2H), 3.31 (d, *J* = 10.6 Hz, 1H), 1.42 (d, *J* = 2.6 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.82 (t, *J* = 32.76 Hz), 137.69, 129.25, 126.32, 119.96, 116.28 (dd, *J* = 261.3, 253.1 Hz), 56.63 (d, *J* = 2.6 Hz), 42.09 (t, *J* = 18.8 Hz), 19.78 (d, *J* = 7.9 Hz), 6.90 (d, *J* = 9.6 Hz). HRMS (ESI): m/z [M+Na]+ $C_{12}H_{12}F_2INNaO$ calcd for:373.9824 found: 373.9817.



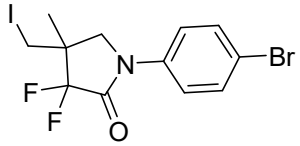
4g

3,3-Difluoro-4-(iodomethyl)-4-methyl-1-(p-tolyl)pyrrolidin-2-one (4g), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 54mg 70%, colorless oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.5 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 3.77 (d, *J* = 10.1 Hz, 1H), 3.52 (d, *J* = 11.9 Hz, 2H), 3.30 (d, *J* = 10.5 Hz, 1H), 2.36 (s, 3H), 1.41 (d, *J* = 2.7 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.68 (t, *J* = 30.24 Hz), 136.26, 135.21, 129.77, 119.98, 116.36 (dd, *J* = 261.5, 253.2 Hz), 56.76, 42.12 (t, *J* = 18.4 Hz), 20.93, 19.80 (d, *J* = 7.4 Hz), 7.02 (d, *J* = 9.2 Hz). HRMS (ESI): m/z [M+Na]+ $C_{13}H_{14}F_2INNaO$ calcd for:387.9980 found: 387.9971.



4h

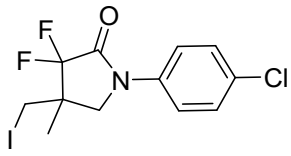
3,3-Difluoro-4-(iodomethyl)-1-(4-methoxyphenyl)-4-methylpyrrolidin-2-one (4h), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), yellow oil. 56mg 73%,^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (d, *J* = 9.0 Hz, 2H), 6.94 (d, *J* = 9.0 Hz, 2H), 3.81 (s, 3H), 3.76 (d, *J* = 10.0 Hz, 1H), 3.53 – 3.48 (m, 2H), 3.30 (d, *J* = 10.5 Hz, 1H), 1.41 (d, *J* = 2.2 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 1 161.55 (t, *J* = 31.5 Hz), 157.82, 121.75, 118.56 – 116.02 (m), 114.42, 57.09, 55.52, 42.18 (t, *J* = 18.8 Hz), 19.81 (d, *J* = 7.4 Hz), 7.07 (d, *J* = 9.2 Hz). HRMS (ESI): m/z [M+Na]+ $C_{13}H_{14}F_2INNaO$ calcd for:387.9980 found: 387.9971.



4i

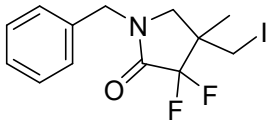
1-(4-Bromophenyl)-3,3-difluoro-4-(iodomethyl)-4-methylpyrrolidin-2-one (4i), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 67mg 75%, white solid, m.p.: 85-89 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (s, 4H), 3.77 (d, *J* = 9.9 Hz, 1H), 3.54 – 3.50 (m, 2H), 3.30 (d, *J* = 10.6 Hz, 1H), 1.42 (d, *J* =

2.3 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.86 (t, *J* = 31.3 Hz), 136.74, 132.30, 121.31, 119.42, 116.10 (dd, *J* = 261.6, 253.2 Hz), 56.51, 42.05 (t, *J* = 18.8 Hz), 19.76 (d, *J* = 6.3 Hz), 6.68 (d, *J* = 9.3 Hz).HRMS (ESI): m/z [M+Na]+ $C_{12}H_{11}BrF_2INNaO$ calcd for:451.8929 found: 451.8921.



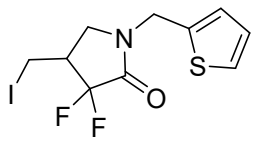
4j

1-(4-Chlorophenyl)-3,3-difluoro-4-(iodomethyl)-4-methylpyrrolidin-2-one (4j), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 61mg 76%, white solid, m.p.: 66-68 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 – 7.58 (m, 2H), 7.41 – 7.37 (m, 2H), 3.77 (dd, *J* = 9.9, 1.1 Hz, 1H), 3.55 – 3.49 (m, 2H), 3.30 (d, *J* = 10.6 Hz, 1H), 1.41 (d, *J* = 2.6 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.84 (t, *J* = 31.6 Hz), 136.22, 131.64, 129.32, 121.04, 116.11 (dd, *J* = 261.4, 253.2 Hz), 56.56 (d, *J* = 2.4 Hz), 42.05 (t, *J* = 18.8 Hz), 19.75 (d, *J* = 6.3 Hz), 6.68 (d, *J* = 9.6 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{11}ClF_2INNaO$ calcd for: 407.9434 found: 407.9427.



4k

1-Benzyl-3,3-difluoro-4-(iodomethyl)-4-methylpyrrolidin-2-one (4k), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 53mg 69%, white solid, m.p.: 85-86 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 – 7.32 (m, 3H), 7.24 (d, *J* = 6.6 Hz, 2H), 4.57 (d, *J* = 14.6 Hz, 1H), 4.47 (d, *J* = 14.6 Hz, 1H), 3.35 (d, *J* = 10.3 Hz, 1H), 3.23 – 3.17 (m, 2H), 2.93 (d, *J* = 10.3 Hz, 1H), 1.24 (d, *J* = 2.5 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 163.06 (t, *J* = 30.24 Hz), 134.29, 129.08, 128.37, 128.30, 116.82 (dd, *J* = 262.9, 253.7 Hz), 54.85, 47.26, 42.48 (t, *J* = 18.8 Hz), 19.69 (d, *J* = 7.4 Hz), 7.19 (d, *J* = 10.1 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{13}H_{14}F_2INNaO$ calcd for:387.9980 found: 387.9971.

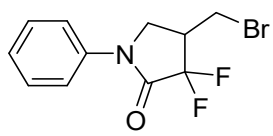


4l

3,3-Difluoro-4-(iodomethyl)-1-(thiophen-2-ylmethyl)pyrrolidin-2-one (4l), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 32mg 43%, yellow oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (dd, *J* = 5.0, 1.4 Hz, 1H), 7.05 – 7.00 (m, 1H), 7.01 – 6.98 (m, 1H), 4.76 – 4.67 (m, 2H), 3.60 – 3.55 (m, 1H), 3.40 (dd, *J* = 10.5, 4.7 Hz, 1H), 3.10 – 3.05 (m, 2H), 2.95 – 2.83 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.56 (t, *J* = 30.8 Hz), 136.01, 127.84, 127.27, 126.49, 116.41 (dd, *J* = 256.9, 251.4 Hz), 48.41 (d, *J* = 6.4 Hz), 43.13 (dd, *J* = 22.5, 20.7 Hz), 41.70.HRMS (ESI): m/z $[M+Na]^+$ $C_{10}H_{10}F_2INNaOS$ calcd for:379.9388 found: 379.9381.

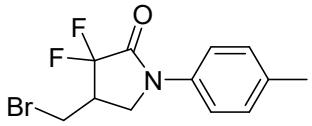
4m

3,3-Difluoro-4-(iodomethyl)-4-methyl-1-(thiophen-2-ylmethyl)pyrrolidin-2-one (4m), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 33mg 43%, yellow oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31 – 7.28 (m, 1H), 7.03 – 6.96 (m, 2H), 4.82 – 4.59 (m, 2H), 3.31 (dd, *J* = 38.9, 10.4 Hz, 2H), 3.11 (dd, *J* = 84.1, 11.4 Hz, 2H), 1.24 (d, *J* = 2.9 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.61 (t, *J* = 30.8 Hz), 136.07, 127.82, 127.18, 126.50, 116.68 (dd, *J* = 262.4, 254.2 Hz), 54.54 (d, *J* = 3.7 Hz), 42.55 (t, *J* = 18.8 Hz), 41.53, 19.54 (d, *J* = 7.4 Hz), 7.13 (d, *J* = 10.1 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{11}H_{12}F_2INNaOS$ calcd for:393.9545 found: 393.9540.



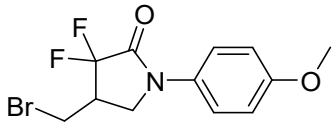
5a

4-(Bromomethyl)-3,3-difluoro-1-phenylpyrrolidin-2-one (5a), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 37mg 65%, yellow solid, m.p.: 56-58 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.8 Hz, 2H), 7.44 (t, *J* = 8.0 Hz, 2H), 7.28 (d, *J* = 7.4 Hz, 1H), 4.12 (t, *J* = 9.1 Hz, 1H), 3.79 – 3.70 (m, 2H), 3.50 (t, *J* = 10.5 Hz, 1H), 3.20 – 3.07 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.46 (t, *J* = 30.8 Hz), 137.54, 129.28, 126.49, 120.05, 116.24 (dd, *J* = 256.2, 251.2 Hz), 48.43 (d, *J* = 4.6 Hz), 43.74 – 40.71 (m), 25.62 (d, *J* = 9.2 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{11}H_{11}BrF_2NO$ calcd for: 289.9987 found: 289.9985.



5b

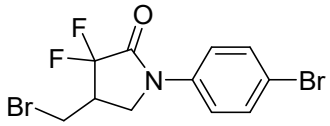
4-(Bromomethyl)-3,3-difluoro-1-(*p*-tolyl)pyrrolidin-2-one (5b), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 37mg 62%, yellow solid, m.p.: 136-137 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.5 Hz, 2H), 7.23 (d, *J* = 8.7 Hz, 2H), 4.08 (t, *J* = 9.1 Hz, 1H), 3.75 (dd, *J* = 10.7, 4.7 Hz, 1H), 3.69 (t, *J* = 8.7 Hz, 1H), 3.49 (t, *J* = 10.5 Hz, 1H), 3.21 – 3.04 (m, 1H), 2.36 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.31 (t *J* =23.94 Hz), 136.42, 135.04, 129.78, 120.03, 116.31 (dd, *J* = 255.6, 250.9 Hz), 48.53 (d, *J* = 5.5 Hz), 42.06 (dd, *J* = 22.5, 19.8 Hz), 25.71 (d, *J* = 10.1 Hz), 20.94. HRMS (ESI): m/z $[M+H]^+$ $C_{12}H_{13}BrF_2NO$ calcd for: 304.0143 found: 304.0137.



5c

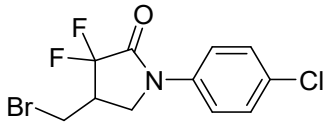
4-(Bromomethyl)-3,3-difluoro-1-(4-methoxyphenyl)pyrrolidin-2-one (5c), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 38mg 60%, yellow solid, m.p.: 94-96 °C.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 – 7.50 (m, 2H), 6.98 – 6.91 (m, 2H), 4.10 – 4.03 (m, 1H), 3.82 (s, 3H), 3.76 (dd, *J* = 10.6, 4.7 Hz, 1H), 3.71 – 3.64 (m, 1H), 3.49 (t, *J* = 10.8 Hz, 1H), 3.26 – 3.01 (m, 1H).^{13}C NMR (126

MHz, $CDCl_3$) δ 161.20 (t, *J* = 30.24 Hz), 157.89, 130.58, 121.82, 118.83 – 114.29 (m), 114.41, 55.51, 48.82 (d, *J* = 5.5 Hz), 42.10 (dd, *J* = 22.5, 19.8 Hz), 25.76 (d, *J* = 10.1 Hz).HRMS (ESI): m/z $[M+H]^+$ $C_{12}H_{13}BrF_2NO_2$ calcd for: 320.0092 found: 320.0088.



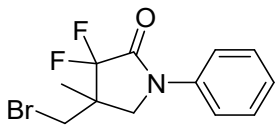
5d

4-(Bromomethyl)-1-(4-bromophenyl)-3,3-difluoropyrrolidin-2-one (5d), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 52mg 71%, white solid, m.p.: 115-117 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 – 7.52 (m, 4H), 4.14 – 4.03 (m, 1H), 3.78 – 3.72 (m, 1H), 3.69 (t, *J* = 7.6 Hz, 1H), 3.49 (t, *J* = 10.5 Hz, 1H), 3.21 – 3.04 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.46 (t, *J* = 31.3 Hz), 136.58, 132.30, 121.38, 119.59, 116.04 (dd, *J* = 256.5, 250.9 Hz), 48.27 (d, *J* = 5.5 Hz), 41.87 (dd, *J* = 22.1, 19.3 Hz), 25.46 (d, *J* = 10.1 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{11}H_{10}Br_2F_2NO$ calcd for: 367.0692; found: 367.0688.



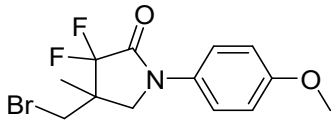
5e

4-(Bromomethyl)-1-(4-chlorophenyl)-3,3-difluoropyrrolidin-2-one (5e), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 48mg 75%, white solid, m.p.: 111-113 °C.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.56 (m, 2H), 7.47 – 7.33 (m, 2H), 4.14 – 4.03 (m, 1H), 3.76 (dd, *J* = 10.7, 4.7 Hz, 1H), 3.73 – 3.66 (m, 1H), 3.50 (t, *J* = 10.5 Hz, 1H), 3.23 – 3.04 (m, 1H).^{13}C NMR (101 MHz, $CDCl_3$) δ 161.48 (t, *J* = 31.31 Hz), 136.10, 131.85, 129.37, 121.15, 116.06 (dd, *J* = 256.2, 250.9 Hz), 48.37 (d, *J* = 5.8 Hz), 41.94 (dd, *J* = 22.4, 19.5 Hz), 25.49 (d, *J* = 10.1 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{11}H_{10}BrClF_2NO$ calcd for: 323.9597 found: 323.9588.



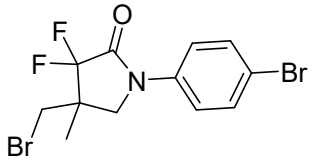
5f

4-(Bromomethyl)-3,3-difluoro-4-methyl-1-phenylpyrrolidin-2-one (5f), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 46mg, 76%, yellow solid, m.p.: 56-58 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.8 Hz, 2H), 7.43 (t, *J* = 8.0 Hz, 2H), 7.27 (t, *J* = 7.4 Hz, 1H), 3.90 (d, *J* = 10.1 Hz, 1H), 3.68 (d, *J* = 10.8 Hz, 1H), 3.60 (d, *J* = 9.6 Hz, 1H), 3.53 (d, *J* = 10.8 Hz, 1H), 1.45 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.53 (t, *J* = 30.8 Hz), 137.66, 129.23, 126.32, 119.94, 117.23 (dd, *J* = 258.8, 255.1 Hz), 54.61, 42.71 (t, *J* = 18.8 Hz), 33.95 (dd, *J* = 7.8, 3.2 Hz), 17.69 (dd, *J* = 6.0, 3.2 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{12}H_{13}BrF_2NO$ calcd for: 304.0143; found: 304.0140.



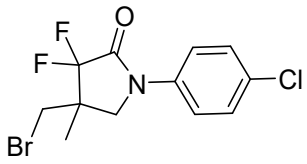
5g

4-(Bromomethyl)-3,3-difluoro-1-(4-methoxyphenyl)-4-methylpyrrolidin-2-one (5g), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 40mg 60%, yellow oil.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 – 7.48 (m, 2H), 6.98 – 6.89 (m, 2H), 3.86 (d, *J* = 10.1 Hz, 1H), 3.82 (d, *J* = 2.3 Hz, 4H), 3.68 (d, *J* = 10.7 Hz, 1H), 3.57 – 3.52 (m, 2H), 1.44 (d, *J* = 2.0 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.28 (t, *J* = 32.76 Hz), 157.82, 130.73, 121.75, 119.57 – 115.07 (m), 114.41, 55.51, 55.07, 42.85 (t, *J* = 18.4 Hz), 34.12 (d, *J* = 8.3 Hz), 17.75 (dd, *J* = 6.4, 2.8 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{13}H_{15}BrF_2NO_2$ calcd for: 334.0249 found: 332.0243.



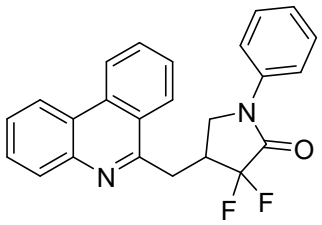
5h

4-(Bromomethyl)-1-(4-bromophenyl)-3,3-difluoro-4-methylpyrrolidin-2-one (5h), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 62mg 77%, white solid, m.p.: 68-73 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55 (s, 4H), 3.87 (d, *J* = 10.1 Hz, 1H), 3.67 (d, *J* = 10.8 Hz, 1H), 3.57 (d, *J* = 10.1 Hz, 1H), 3.51 (d, *J* = 10.8 Hz, 1H), 1.44 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.58 (t, *J* = 31.5 Hz), 136.75, 132.30, 121.30, 119.45, 117.04 (dd, *J* = 259.2, 255.5 Hz), 54.51, 42.71 (t, *J* = 18.8 Hz), 33.86 (dd, *J* = 8.3, 2.8 Hz), 17.72 (dd, *J* = 6.0, 3.2 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{11}Br_2F_2NNaO$ calcd for: 403.9068 found: 403.9059.



5i

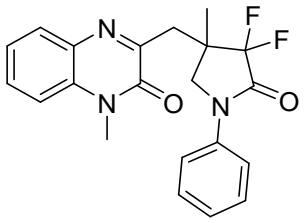
4-(Bromomethyl)-1-(4-chlorophenyl)-3,3-difluoro-4-methylpyrrolidin-2-one (5i), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 53mg 75%, yellow solid, m.p.: 38-40 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 (d, *J* = 9.0 Hz, 2H), 7.39 (d, *J* = 9.0 Hz, 2H), 3.87 (d, *J* = 10.1 Hz, 1H), 3.67 (d, *J* = 10.8 Hz, 1H), 3.57 (d, *J* = 11.3 Hz, 1H), 3.51 (d, *J* = 10.8 Hz, 1H), 1.44 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.57 (t, *J* = 31.3 Hz), 136.24, 131.67, 129.33, 121.05, 117.05 (dd, *J* = 259.2, 255.5 Hz), 54.59, 42.72 (t, *J* = 18.4 Hz), 33.86 (dd, *J* = 8.3, 2.8 Hz), 17.71 (dd, *J* = 6.4, 2.8 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{11}BrClF_2NNaO$ calcd for: 359.9573 found: 359.9565.



6a

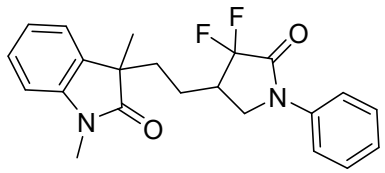
3,3-Difluoro-4-(phenanthridin-6-ylmethyl)-1-phenylpyrrolidin-2-one (6a), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 32mg

40%， white solid, m.p.: 164-166 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 8.67 (d, *J* = 8.2 Hz, 1H), 8.57 (d, *J* = 9.8 Hz, 1H), 8.26 (d, *J* = 8.1 Hz, 1H), 8.09 (d, *J* = 8.1 Hz, 1H), 7.89 (t, *J* = 7.7 Hz, 1H), 7.78 – 7.65 (m, 5H), 7.43 – 7.38 (m, 2H), 7.23 (t, *J* = 7.4 Hz, 2H), 4.50 (t, *J* = 9.6 Hz, 1H), 4.02 (dd, *J* = 16.9, 3.1 Hz, 1H), 3.90 – 3.79 (m, 1H), 3.74 (t, *J* = 8.6 Hz, 1H), 3.63 (dd, *J* = 16.9, 11.1 Hz, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.86 – 162.17 (m), 156.38, 143.24, 138.17, 132.69, 130.79, 129.81, 129.11, 127.75, 126.95, 126.00, 125.22, 123.75, 122.63, 122.04, 119.96, 120.75 – 115.98 (m), 49.63 (d, *J* = 6.4 Hz), 39.30 – 35.49 (m), 31.02 (d, *J* = 6.4 Hz).HRMS (ESI): m/z $[M+Na]^+$ $C_{24}H_{18}F_2N_2NaO$ calcd for: 411.1279; found: 411.1270.



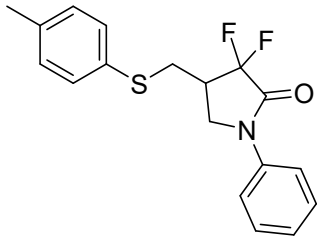
6b

3-((4,4-Difluoro-3-methyl-5-oxo-1-phenylpyrrolidin-3-yl)methyl)-1-methylquinoxalin-2(1H)-one (6b), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 51mg 67%, yellow solid, m.p.: 163-164 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.9 Hz, 1H), 7.63 (d, *J* = 7.9 Hz, 2H), 7.58 (t, *J* = 7.8 Hz, 1H), 7.42 – 7.30 (m, 4H), 7.23 (t, *J* = 7.4 Hz, 1H), 4.29 (d, *J* = 10.2 Hz, 1H), 3.84 (d, *J* = 10.2 Hz, 1H), 3.68 (s, 3H), 3.49 (d, *J* = 15.8 Hz, 1H), 3.30 (d, *J* = 15.8 Hz, 1H), 1.38 (d, *J* = 2.3 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.84 – 161.82 (m), 156.62, 155.02, 138.24, 133.06, 132.24, 130.50, 129.98, 129.08, 125.87, 123.84, 119.97, 120.69 – 117.96 (m), 113.71, 55.02, 41.86 (t, *J* = 18.8 Hz), 34.74 (d, *J* = 8.4 Hz), 29.27, 17.92 (d, *J* = 7.3 Hz).HRMS (ESI): m/z $[M+H]^+$ $C_{21}H_{20}F_2N_3O_2$ calcd for: 384.1518; found: 384.1510.



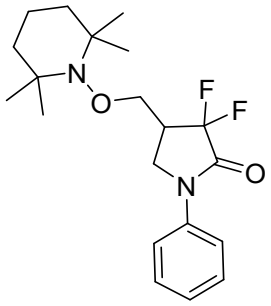
6c

3-(2-(4,4-Difluoro-5-oxo-1-phenylpyrrolidin-3-yl)ethyl)-1,3-dimethylindolin-2-one (6c), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1),47mg 62%, white solid, m.p.: 139-144 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.5 Hz, 2H), 7.41 – 7.37 (m, 2H), 7.31 (t, *J* = 7.8 Hz, 1H), 7.24 – 7.21 (m, 2H), 7.12 (t, *J* = 6.9 Hz, 1H), 6.88 (d, *J* = 7.8 Hz, 1H), 3.85 – 3.81 (m, 1H), 3.41 (t, *J* = 8.9 Hz, 1H), 3.24 (s, 3H), 2.55 – 2.44 (m, 1H), 2.08 – 1.98 (m, 2H), 1.40 (s, 3H), 1.37 – 1.30 (m, 1H), 1.24 – 1.15 (m, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 180.07, 143.17, 137.80, 132.88, 129.16, 128.14, 126.15, 122.96, 122.52, 119.90, 108.24, 48.45 (d, *J* = 7.2 Hz), 48.33, 40.06 – 39.20 (m), 35.21, 26.23, 24.31, 21.04 (d, *J* = 6.7 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{22}H_{23}F_2N_2O$ calcd for: 385.1722; found: 385.1720.



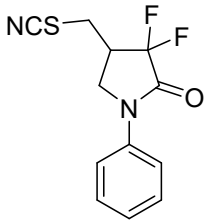
6d

3,3-Difluoro-1-phenyl-4-((p-tolylthio)methyl)pyrrolidin-2-one (6d), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 45mg 68%, yellow solid, m.p.: 99-102 °C.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, *J* = 7.7 Hz, 2H), 7.42 (t, *J* = 8.0 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.24 (d, *J* = 7.5 Hz, 1H), 7.16 (d, *J* = 8.0 Hz, 2H), 4.01 – 3.97 (m, 1H), 3.70 (d, *J* = 15.1 Hz, 1H), 3.45 (dd, *J* = 13.8, 4.2 Hz, 1H), 2.95 (dd, *J* = 13.6, 10.8 Hz, 1H), 2.86 – 2.74 (m, 1H), 2.34 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 137.90, 137.81, 131.43, 130.22, 129.77, 129.20, 126.24, 119.90, 119.29 – 114.63 (m), 48.02 (d, *J* = 6.4 Hz), 39.26 (t, *J* = 21.1 Hz), 30.82 (d, *J* = 7.4 Hz), 21.07. HRMS (ESI): m/z $[M+H]^+$ $C_{18}H_{18}F_2NOS$ calcd for: 334.1072; found: 334.1066.



6e

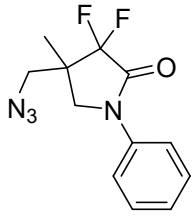
3,3-Difluoro-1-phenyl-4-(((2,2,6,6-tetramethylpiperidin-1-yl)oxy)methyl)pyrrolidin-2-one (6e), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), yellow solid, m.p.: 120-124 °C. 19mg 25%,^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.1 Hz, 2H), 7.43 (t, *J* = 7.9 Hz, 2H), 7.24 (d, *J* = 7.3 Hz, 1H), 4.13 (dd, *J* = 9.2, 5.4 Hz, 1H), 4.06 – 3.99 (m, 2H), 3.80 (dd, *J* = 9.3, 6.2 Hz, 1H), 3.01 – 2.88 (m, 1H), 1.54 – 1.41 (m, 5H), 1.32 (d, *J* = 12.2 Hz, 1H), 1.17 (d, *J* = 5.3 Hz, 6H), 1.09 (s, 3H), 1.02 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 162.22 (t, *J* = 31.2 Hz), 138.00, 129.17, 126.10, 119.94, 118.16 (d, *J* = 252.3 Hz), 71.72 – 71.48 (m), 60.08, 46.98 – 46.29 (m), 39.64, 39.45 – 38.94 (m), 33.07, 19.94 (d, *J* = 13.8 Hz), 16.94. HRMS (ESI): m/z $[M+Na]^+$ $C_{20}H_{28}F_2N_2NaO_2$ calcd for: 389.2011; found: 389.2004.



6f

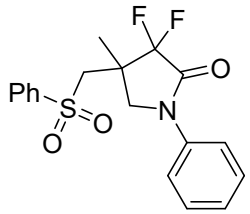
3,3-Difluoro-1-phenyl-4-(thiocyanatomethyl)pyrrolidin-2-one (6f), (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1-5:1), 43mg 75%, white solid, m.p.: 100-102 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 – 7.61 (m, 2H), 7.44 (t, *J* = 8.0 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 1H), 4.21 – 4.15 (m, 1H), 3.80 – 3.73 (m, 1H), 3.53 – 3.44 (m, 1H), 3.26 – 3.09 (m, 2H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.77 – 160.07 (m), 137.27, 129.34, 126.70, 120.10, 116.14 (dd, *J* = 257.4, 250.1 Hz), 110.51,

47.34 (d, *J* = 5.5 Hz), 41.85 – 38.81 (m), 29.51 (d, *J* = 8.7 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{12}H_{10}F_2N_2NaOS$ calcd for: 291.0374; found: 291.0372.



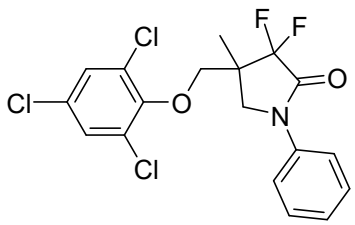
6g

4-(Azidomethyl)-3,3-difluoro-4-methyl-1-phenylpyrrolidin-2-one (6g) (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 10:1, 45mg 85%, yellow oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.5 Hz, 2H), 7.43 (t, *J* = 8.1 Hz, 2H), 7.30 – 7.23 (m, 1H), 3.82 (d, *J* = 10.2 Hz, 1H), 3.60 (d, *J* = 2.6 Hz, 2H), 3.56 (d, *J* = 10.2 Hz, 1H), 1.36 (d, *J* = 2.6 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.56 (t, *J* = 31.3 Hz), 137.75, 129.24, 126.29, 119.91, 119.62 – 115.01 (m), 53.53 (d, *J* = 8.7 Hz), 53.05, 42.38 – 41.99 (m), 16.26 (d, *J* = 8.2 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{12}H_{14}F_2N_4O$ calcd for:267.1052; found: 267.1054.



6h

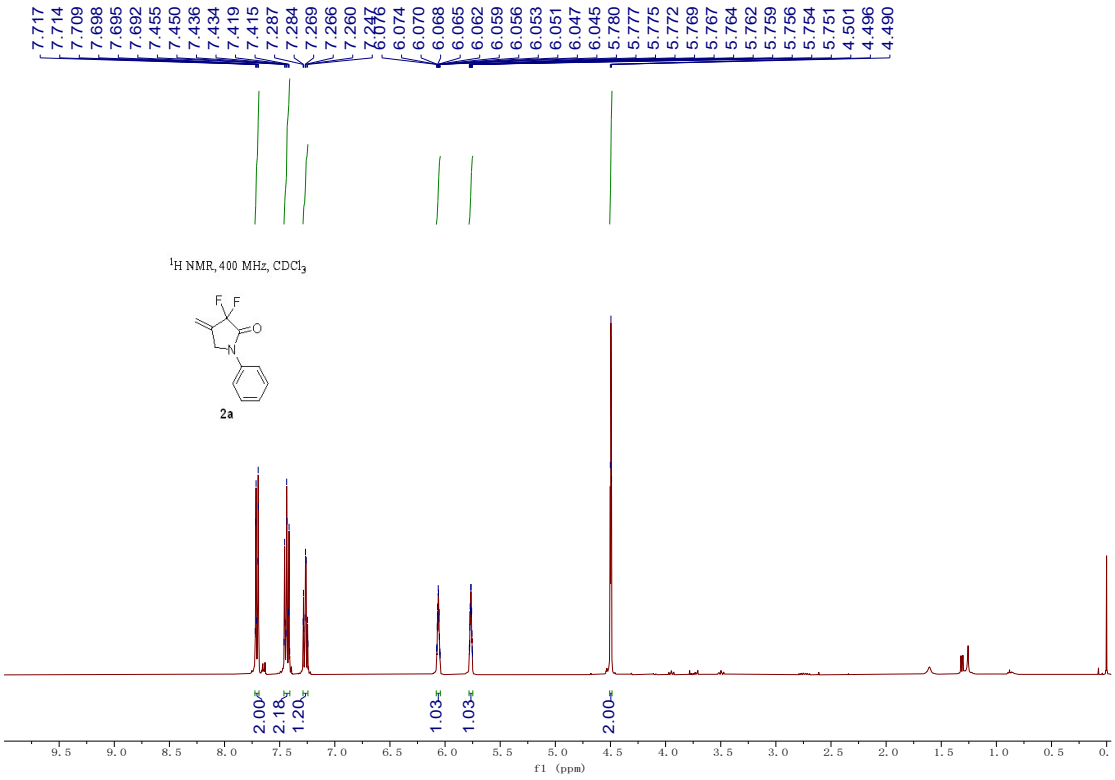
3,3-Difluoro-4-methyl-1-phenyl-4-((2,4,6-trichlorophenoxy)methyl)pyrrolidin-2-one (6h) (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 5:1, 19mg 27%, yellow oil.^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, *J* = 7.0 Hz, 2H), 7.75 – 7.69 (m, 1H), 7.67 (d, *J* = 9.9 Hz, 2H), 7.63 (d, *J* = 8.2 Hz, 2H), 7.48 – 7.41 (m, 2H), 7.31 – 7.23 (m, 1H), 4.34 (d, *J* = 10.7 Hz, 1H), 4.00 (dd, *J* = 10.7, 2.4 Hz, 1H), 3.60 – 3.33 (m, 2H), 1.64 (d, *J* = 2.9 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 160.98 – 159.90 (m), 140.41, 137.67, 134.38, 129.66, 129.27, 127.60, 126.39, 120.02, 119.71 – 115.33 (m), 57.07 (d, *J* = 9.2 Hz), 54.23, 41.23 (t, *J* = 18.8 Hz), 29.67, 18.12 (d, *J* = 6.4 Hz). HRMS (ESI): m/z $[M+H]^+$ $C_{18}H_{18}F_2NO_3S$ calcd for: 366.0970; found: 366.0977.

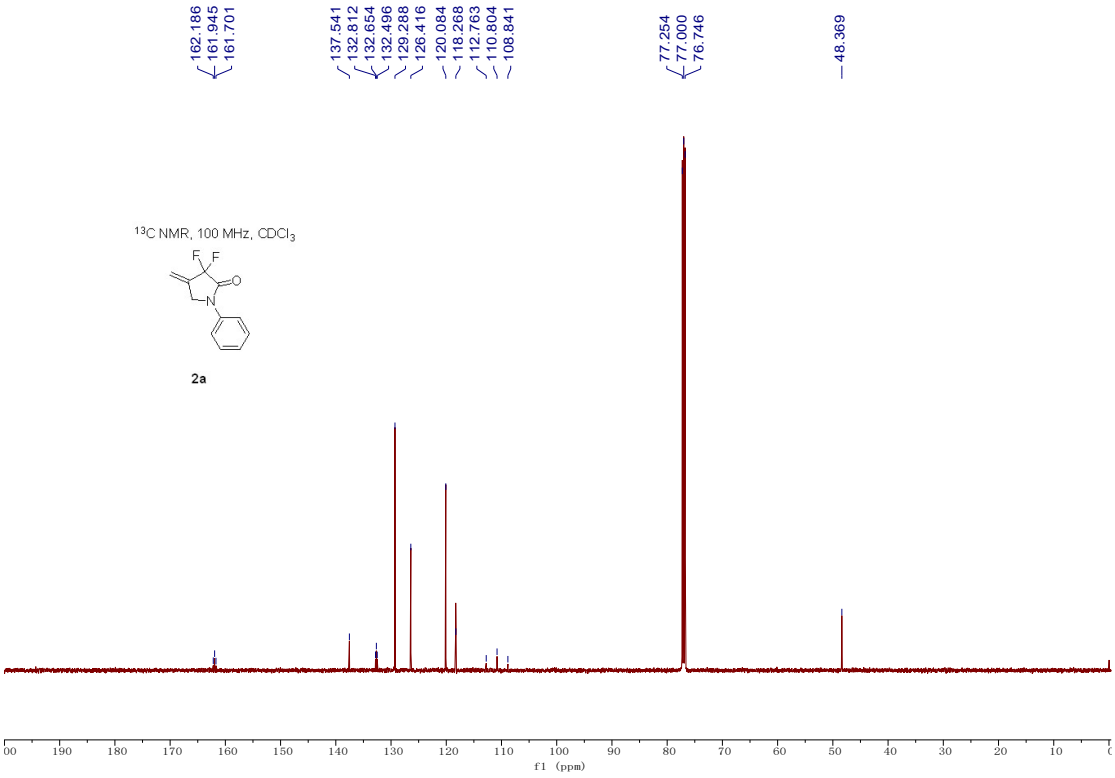


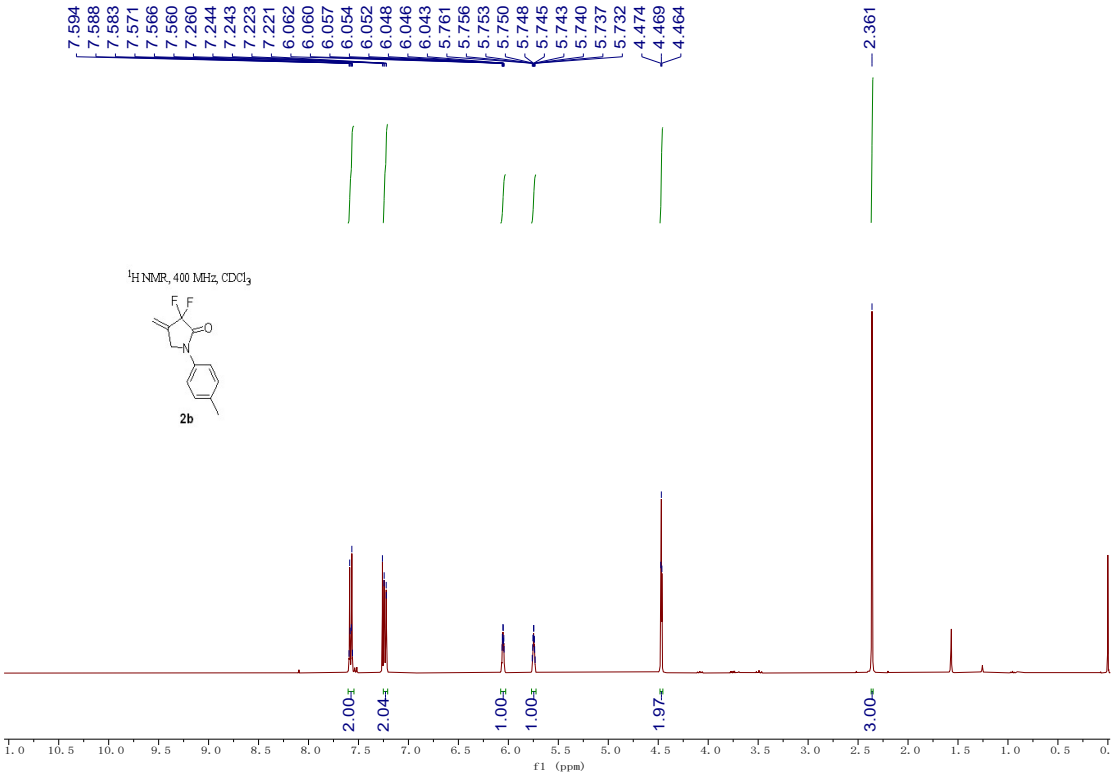
6i

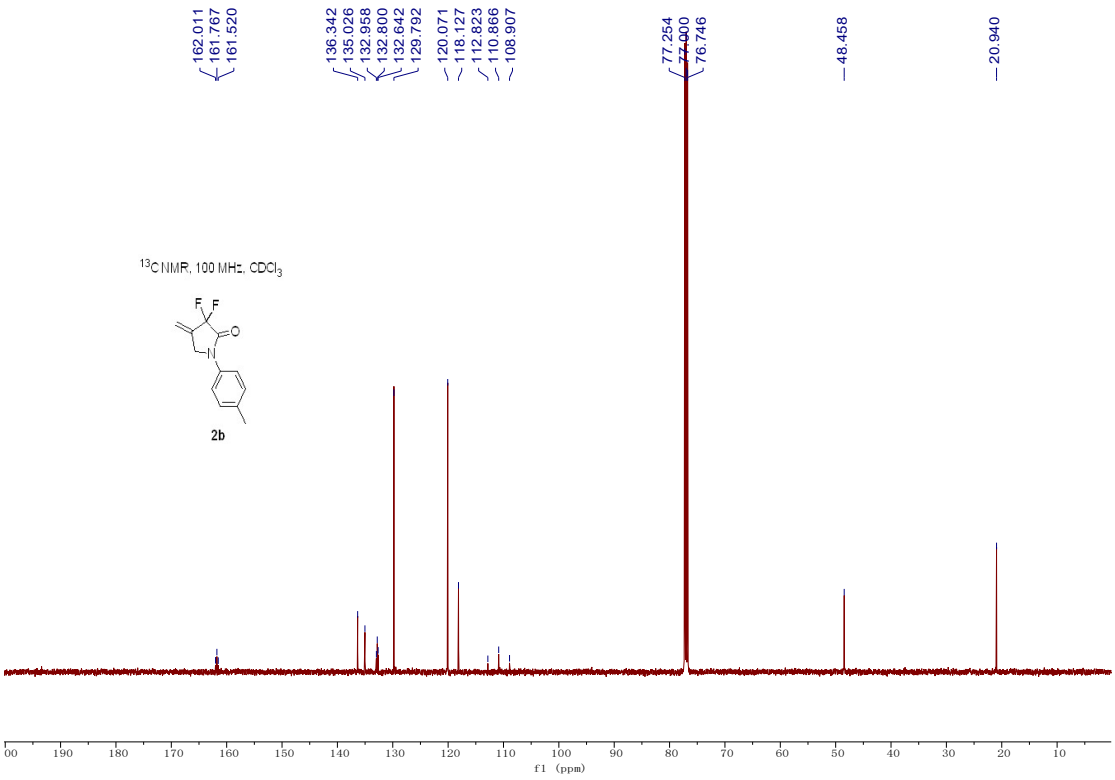
3,3-Difluoro-4-methyl-1-phenyl-4-((2,4,6-trichlorophenoxy)methyl)pyrrolidin-2-one (6i) (silica gel: 200−300 mesh, solvent system: petroleum ether/ethyl acetate = 5:1, 59mg 71%, coloerless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, J = 8.7 Hz, 2H), 7.46 – 7.41 (m, 1H), 7.30 (s, 2H), 7.28 – 7.23 (m, 1H), 4.37 (dd, J = 10.2, 1.5 Hz, 1H), 4.11 (d, J = 8.7 Hz, 1H), 4.04 (d, J = 8.7 Hz, 1H), 3.71 (d, J = 10.6 Hz, 1H), 1.58 (d, J = 2.4 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 161.83 (t, J = 31.3 Hz), 148.83, 137.93, 130.53, 129.95, 129.21, 128.98, 126.16, 119.95, 117.43 (t, J = 256.0 Hz), 72.15 (d, J = 9.3 Hz), 52.33 (d, J = 2.8 Hz), 42.98 (dd, J = 20.3, 17.5 Hz), 15.16 (d, J = 8.3 Hz). HRMS (ESI): m/z $[M+Na]^+$ $C_{18}H_{15}Cl_3F_2NO_2$ calcd for: 420.0131; found: 420.0130.

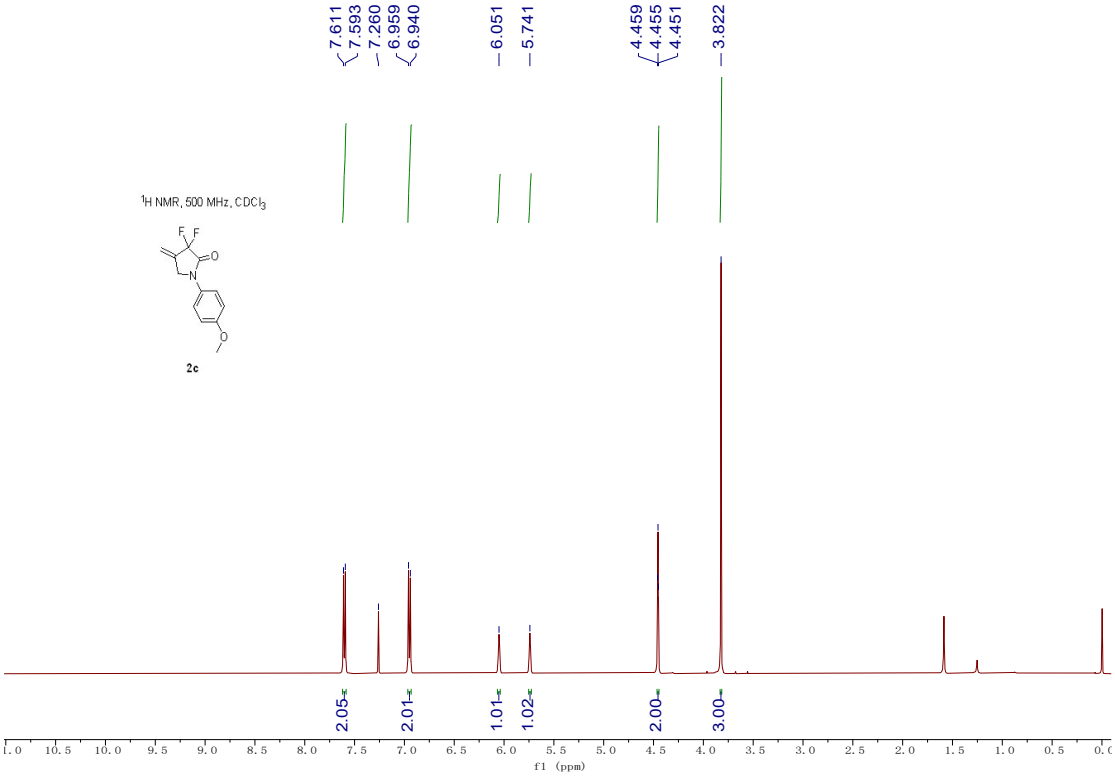
7. ^{1}H-NMR and ^{13}C-NMR Spectra of Products

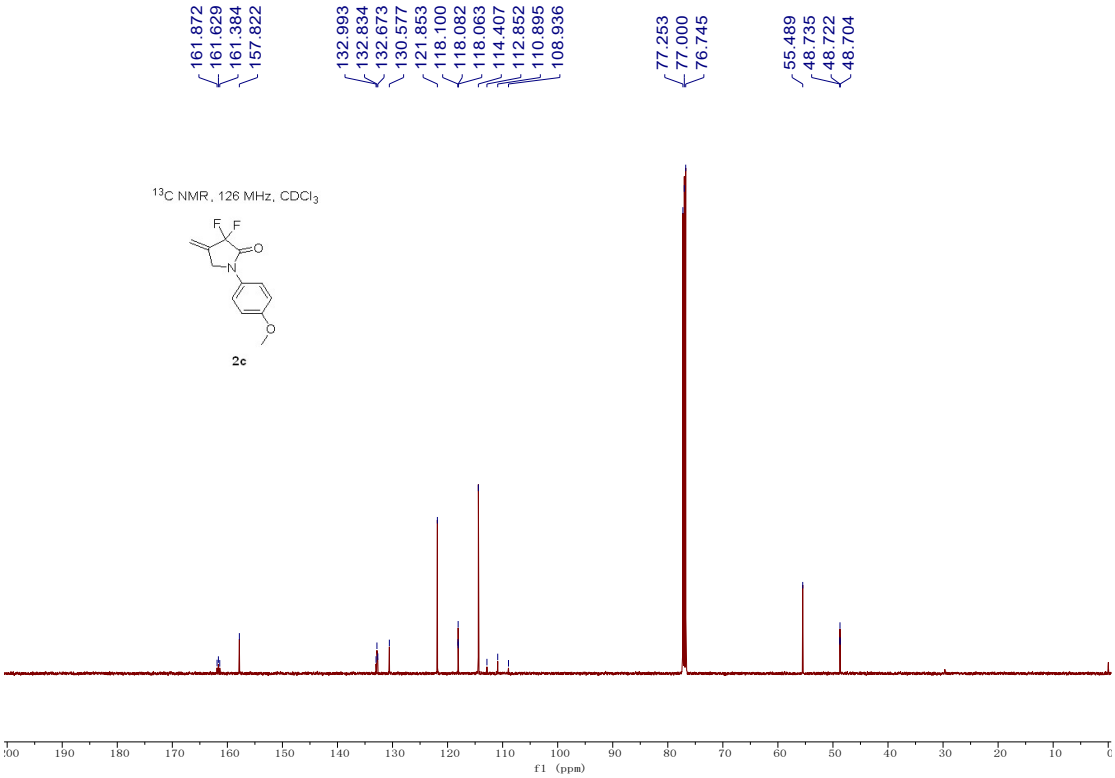


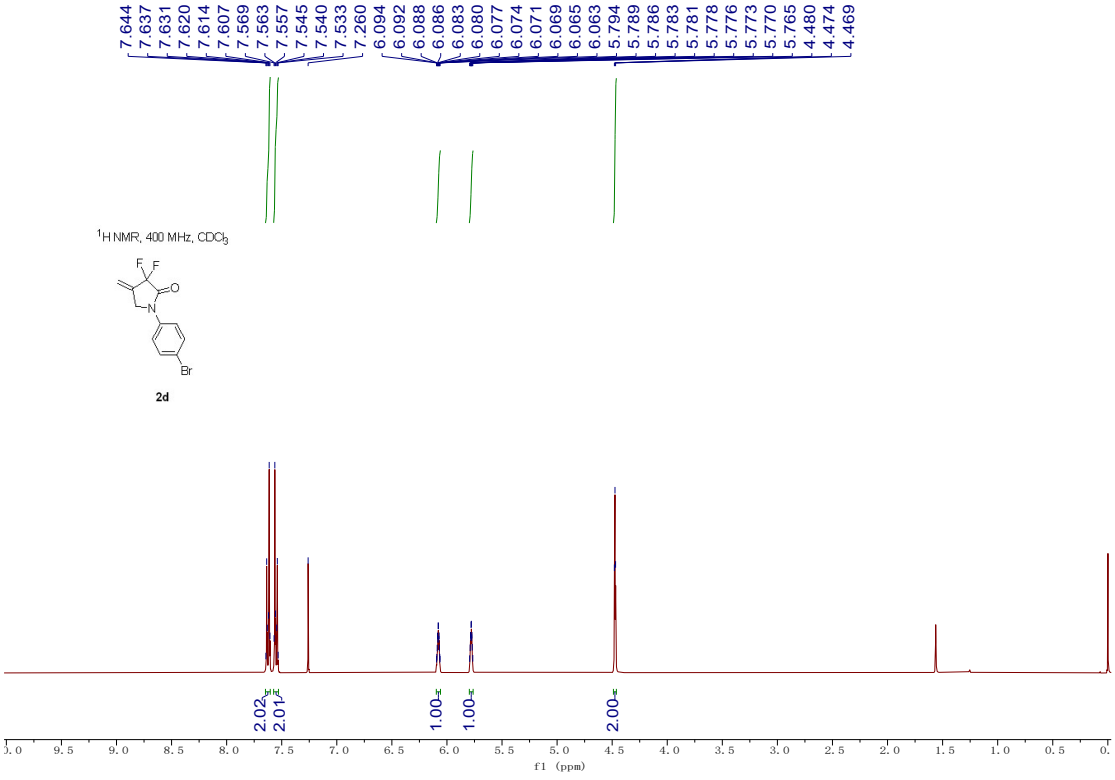

162.186
161.945
161.701
137.541
132.812
132.654
132.496
129.288
128.416
120.084
118.268
112.763
110.804
108.841
77.254
77.000
76.746
48.369
13C NMR, 100 MHz, CDCl3
F
F
O
N
2a
f1 (ppm)

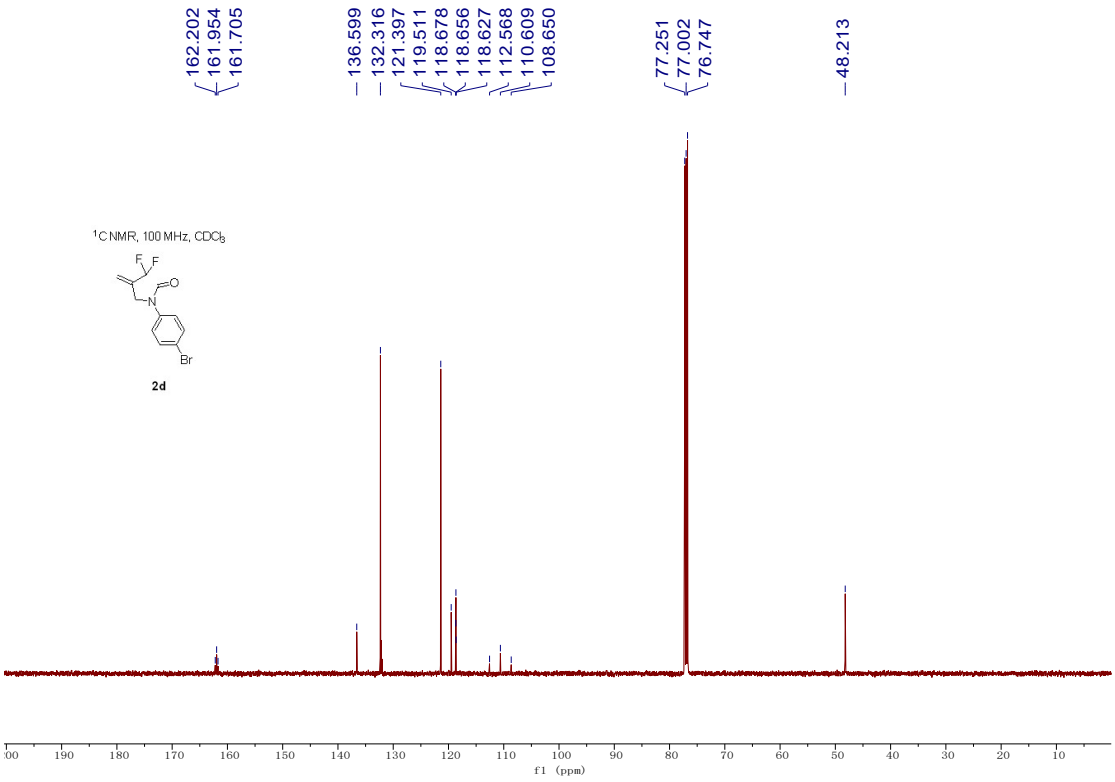

7.594
7.588
7.583
7.571
7.566
7.560
7.260
7.244
7.243
7.223
7.221
6.062
6.060
6.057
6.054
6.052
6.048
6.046
6.043
5.761
5.756
5.753
5.750
5.748
5.745
5.743
5.740
5.737
5.732
4.474
4.469
4.464
2.361
1H NMR, 400 MHz, CDCl3
F
F
O
N
2b
2.00
2.04
1.00
1.00
1.97
3.00
f1 (ppm)

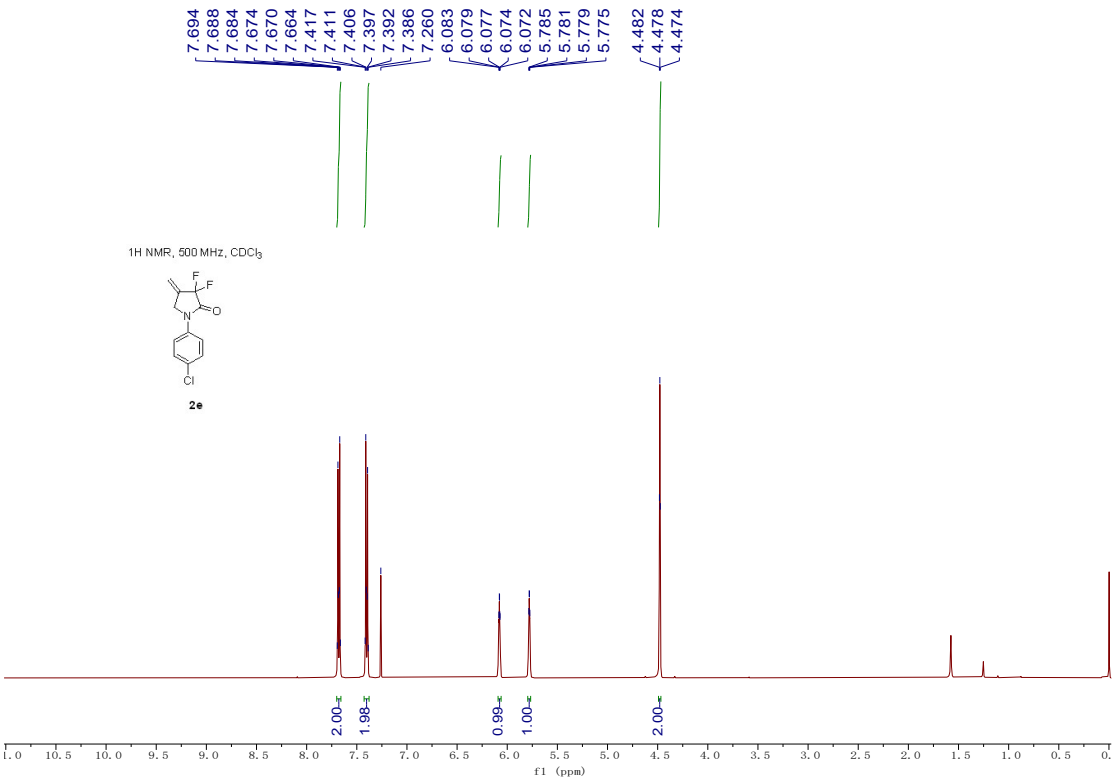

162.011
161.767
161.520
136.342
135.026
132.958
132.800
132.642
129.792
120.071
118.127
112.823
110.866
108.907
77.254
77.000
76.746
48.458
20.940
13C NMR, 100 MHz, CDCl3
F F
O
N
2b
f1 (ppm)

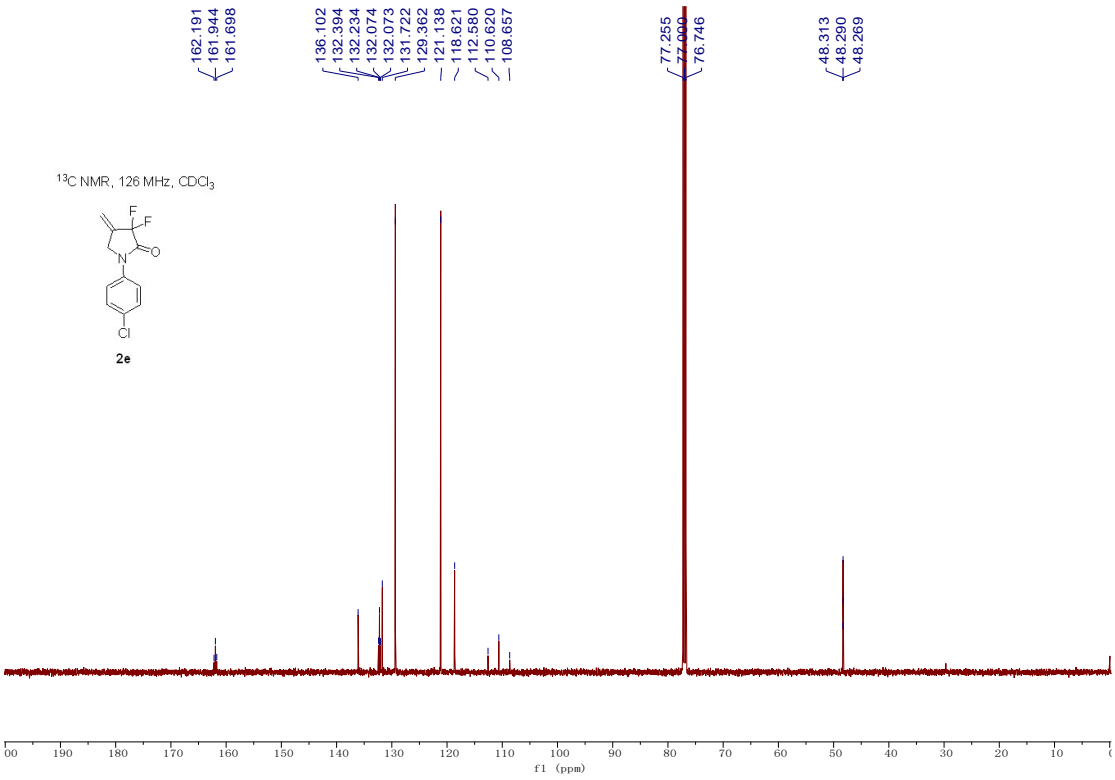

7.611
7.593
7.260
6.959
6.940
6.051
5.741
4.459
4.455
4.451
3.822
1H NMR, 500 MHz, CDCl3
F F
O
N
O
2c
2.05
2.01
1.01
1.02
2.00
3.00
f1 (ppm)

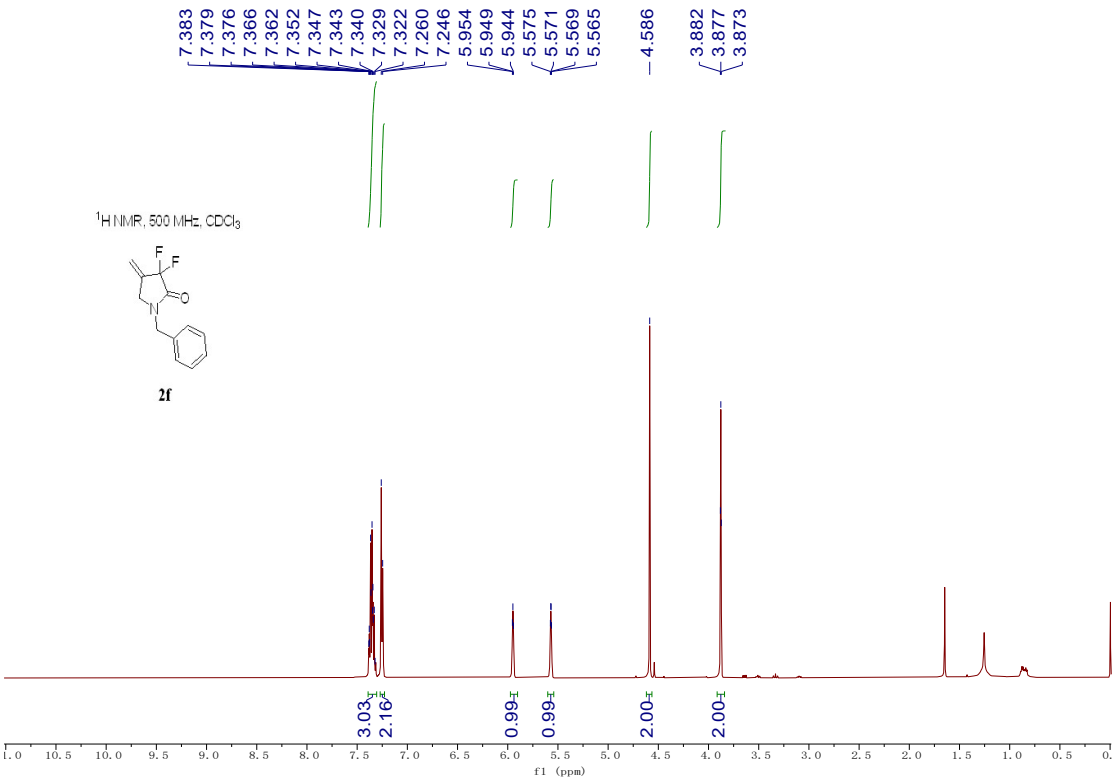

161.872
161.629
161.384
157.822
132.993
132.834
132.673
130.577
121.853
118.100
118.082
118.063
114.407
112.852
110.895
108.936
77.253
77.000
76.745
55.489
48.735
48.722
48.704
13C NMR, 126 MHz, CDCl3
F
F
O
N
O
2c
f1 (ppm)

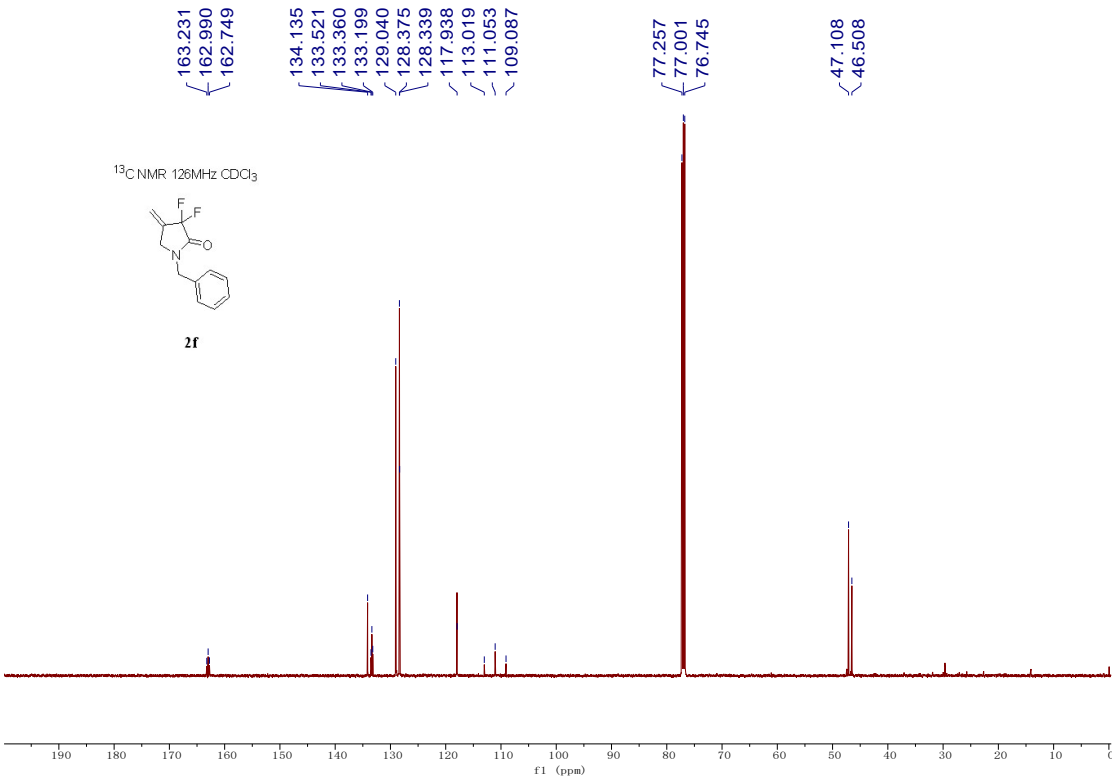

7.644
7.637
7.631
7.620
7.614
7.607
7.569
7.563
7.557
7.545
7.540
7.533
7.260
6.094
6.092
6.088
6.086
6.083
6.080
6.077
6.074
6.071
6.069
6.065
6.063
5.794
5.789
5.786
5.783
5.781
5.778
5.776
5.773
5.770
5.765
4.480
4.474
4.469
1H NMR, 400 MHz, CDCl3
F
F
O
N
Br
2d
2.02
2.01
1.00
1.00
2.00
f1 (ppm)

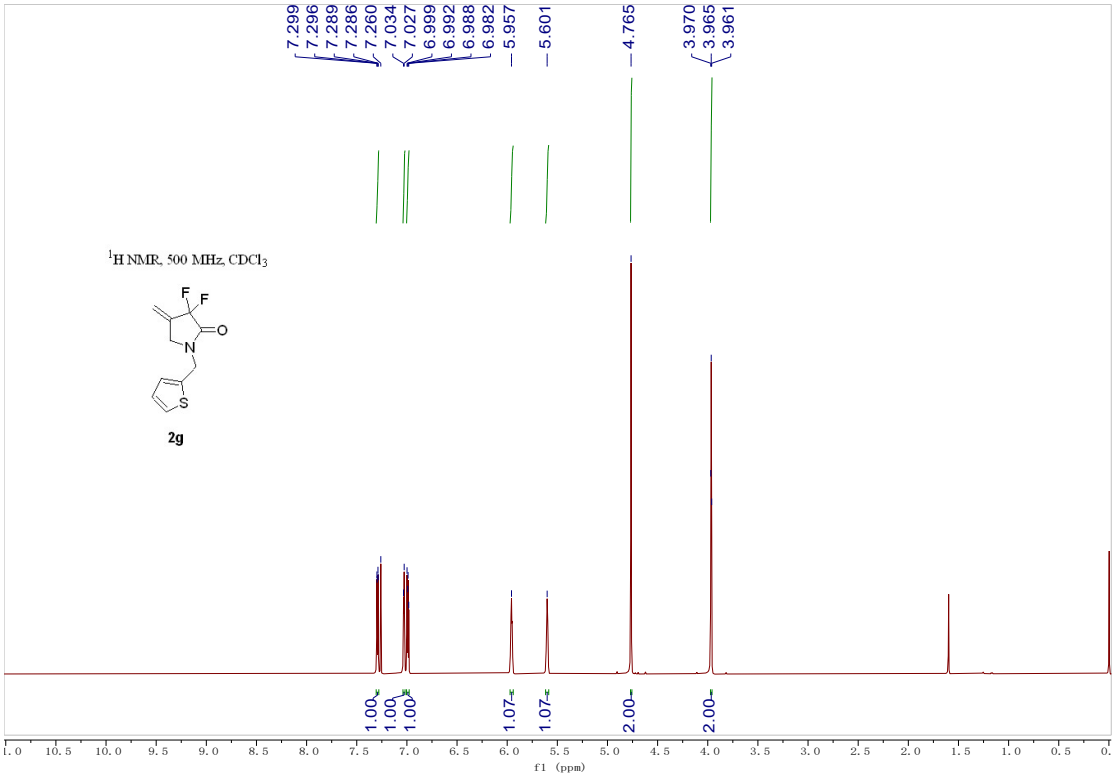

162.202
161.954
161.705
136.599
132.316
121.397
119.511
118.678
118.656
118.627
112.568
110.609
108.650
77.251
77.002
76.747
48.213
^{1}C NMR, 100 MHz, CDCl$_3$
F
F
O
N
Br
2d
f1 (ppm)

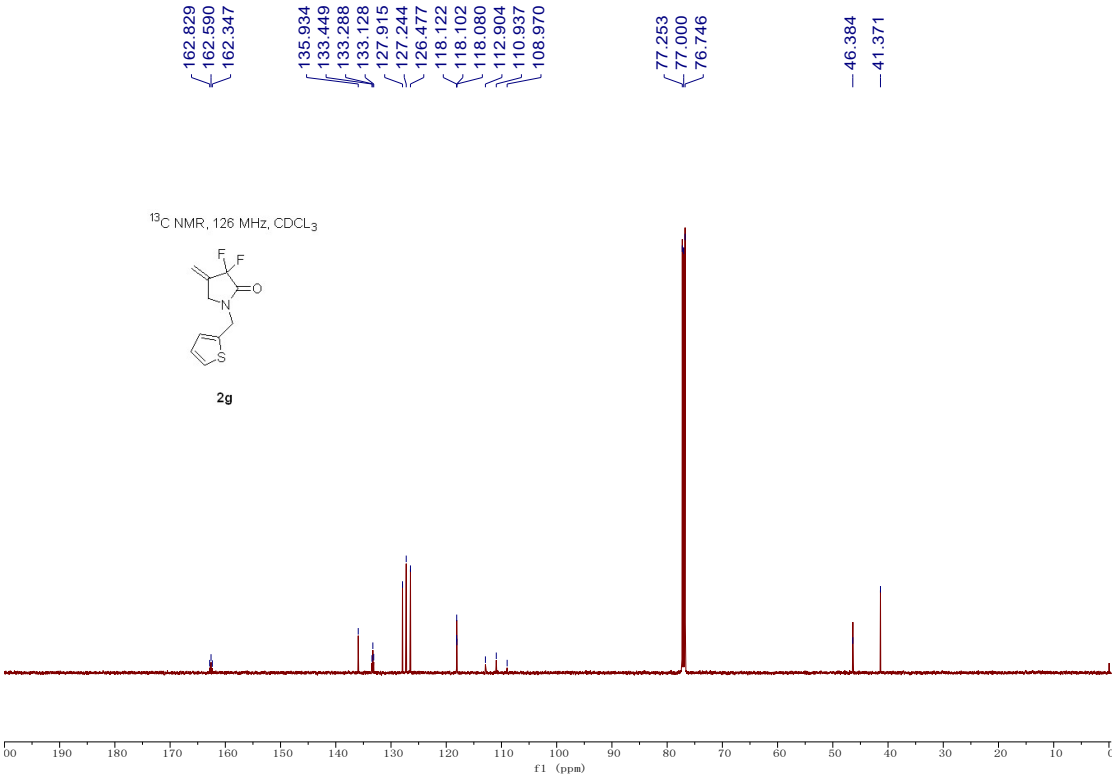

7.694
7.688
7.684
7.674
7.670
7.664
7.417
7.411
7.406
7.397
7.392
7.386
7.260
6.083
6.079
6.077
6.074
6.072
5.785
5.781
5.779
5.775
4.482
4.478
4.474
1H NMR, 500 MHz, CDCl$_3$
F
F
O
N
Cl
2e
2.00
1.98
0.99
1.00
2.00
f1 (ppm)

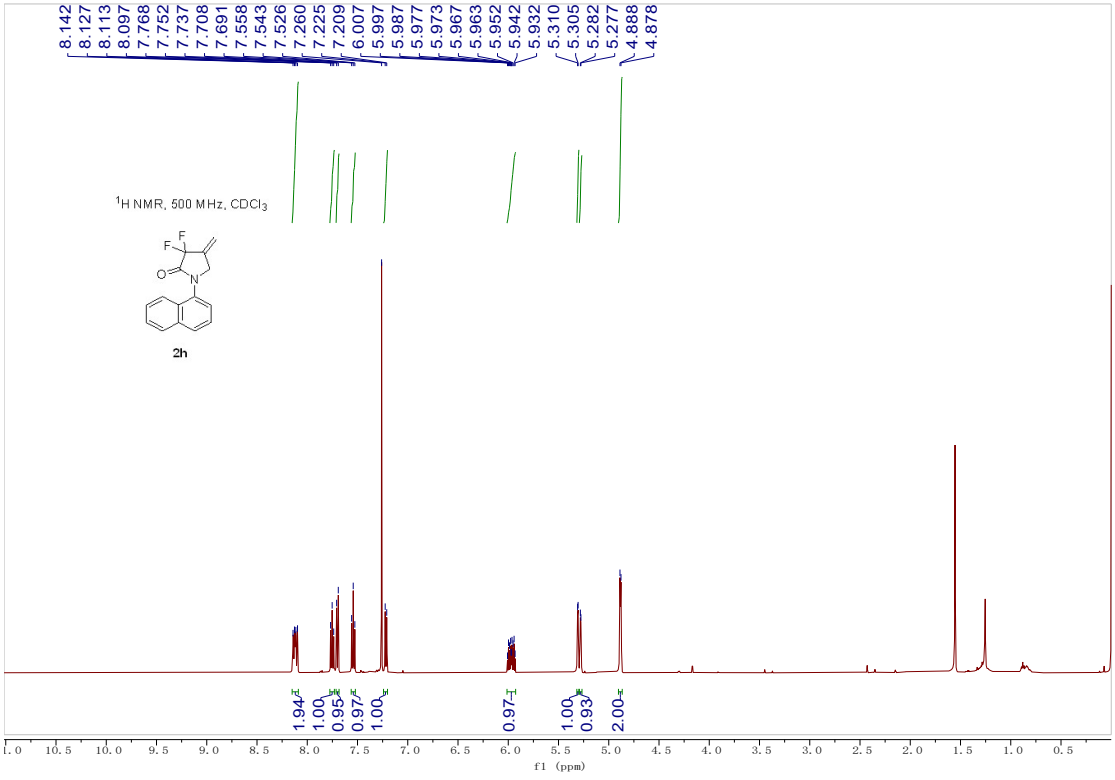

162.191
161.944
161.698
136.102
132.394
132.234
132.074
132.073
131.722
129.362
121.138
118.621
112.580
110.620
108.657
77.255
77.000
76.746
48.313
48.290
48.269
13C NMR, 126 MHz, CDCl3
F
F
O
N
Cl
2e
f1 (ppm)

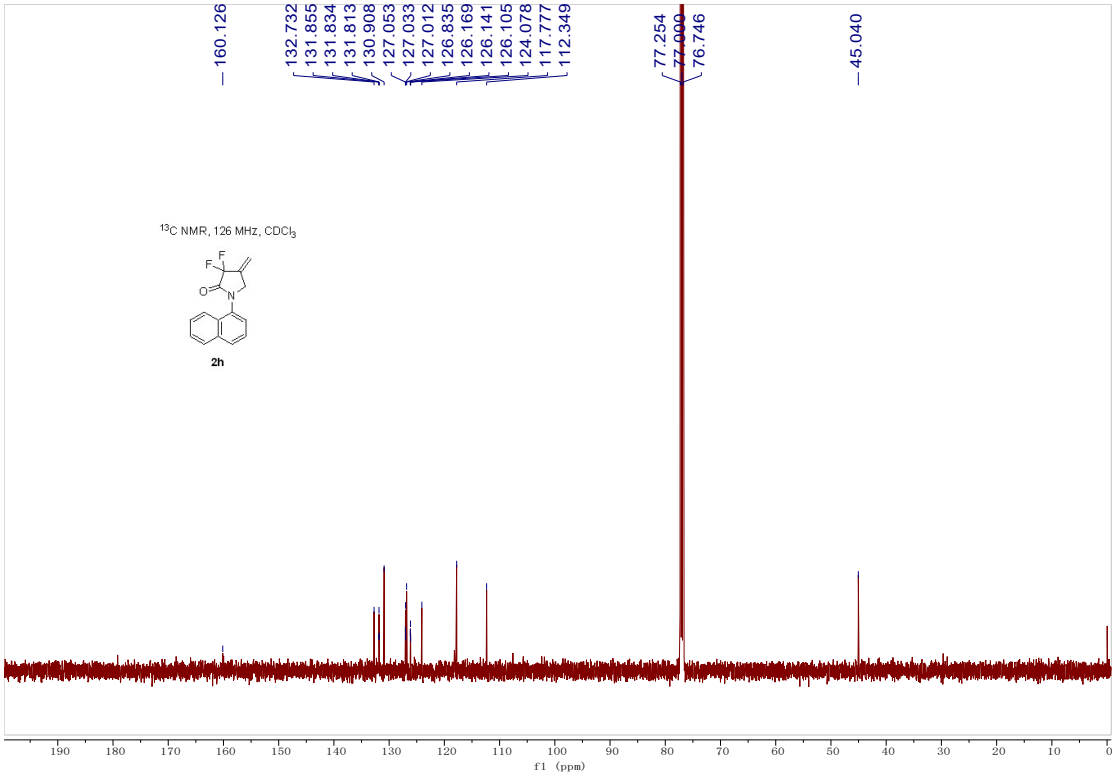

7.383
7.379
7.376
7.366
7.362
7.352
7.347
7.343
7.340
7.329
7.322
7.260
7.246
5.954
5.949
5.944
5.575
5.571
5.569
5.565
4.586
3.882
3.877
3.873
1H NMR, 500 MHz, CDCl3
F
F
O
N
2f
3.03
2.16
0.99
0.99
2.00
2.00
f1 (ppm)

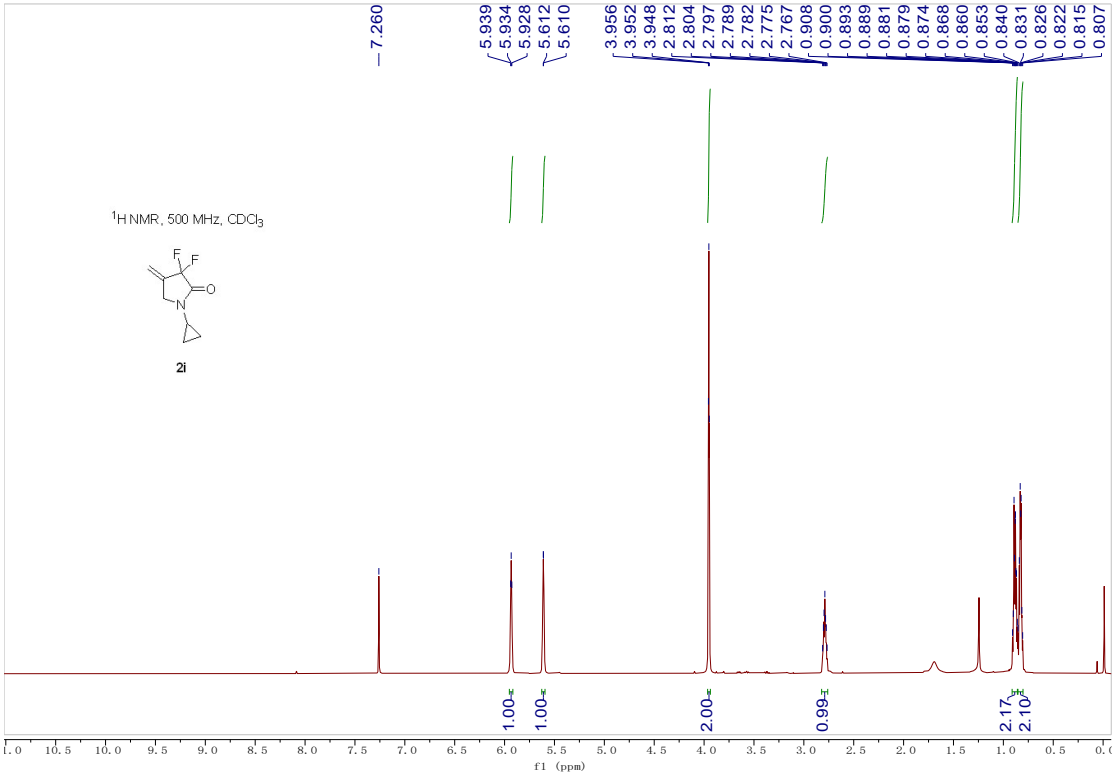

163.231
162.990
162.749
134.135
133.521
133.360
133.199
129.040
128.375
128.339
117.938
113.019
111.053
109.087
77.257
77.001
76.745
47.108
46.508
13C NMR 126MHz CDCl3
F
F
O
N
2f
f1 (ppm)

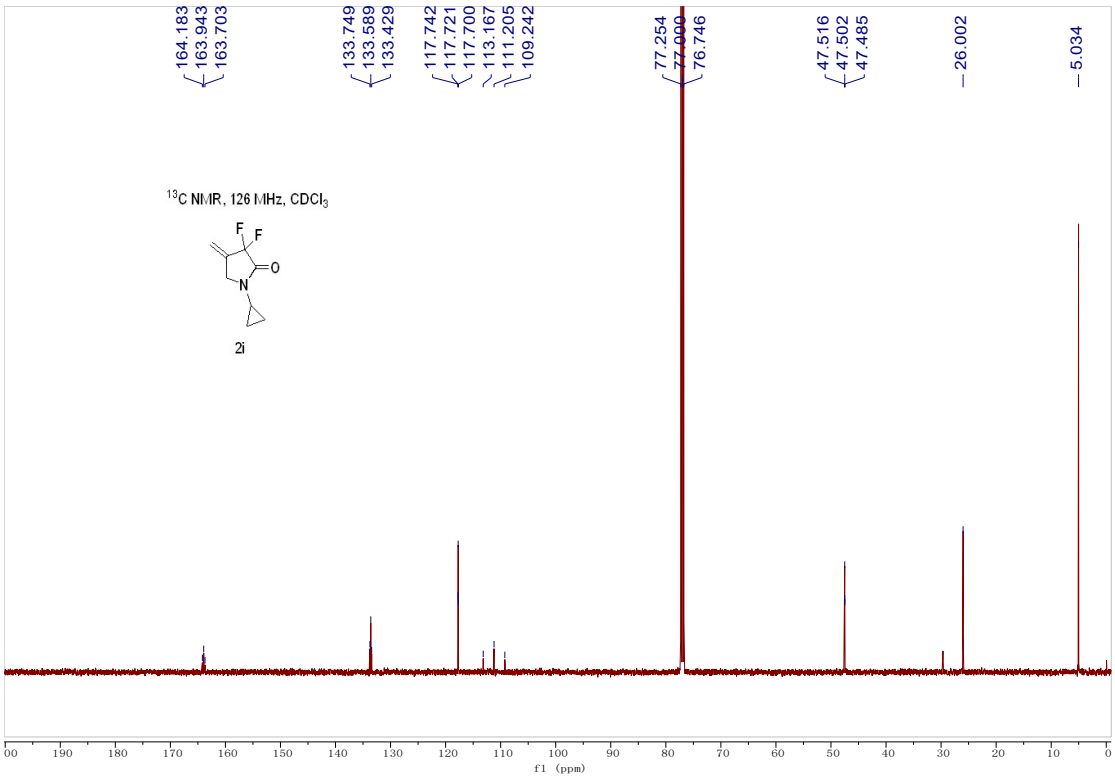

7.299
7.296
7.289
7.286
7.260
7.034
7.027
6.999
6.992
6.988
6.982
5.957
5.601
4.765
3.970
3.965
3.961
1H NMR, 500 MHz, CDCl3
F
F
O
N
S
2g
1.00
1.00
1.00
1.07
1.07
2.00
2.00
f1 (ppm)

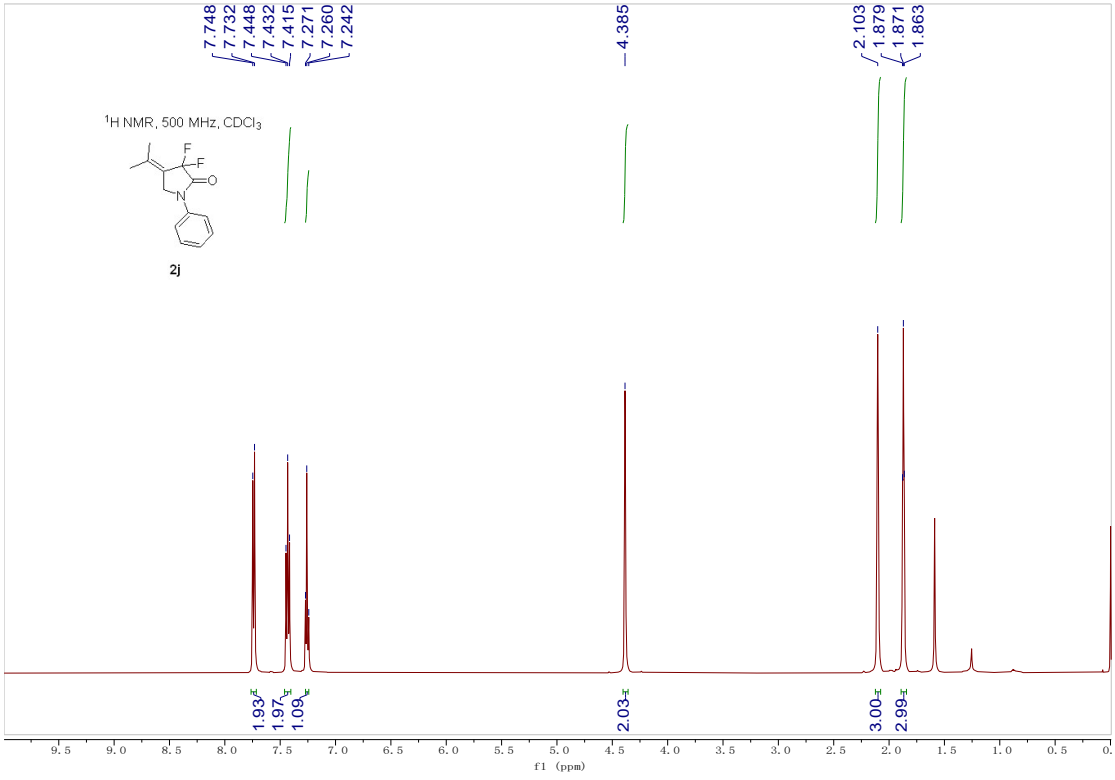

162.829
162.590
162.347
135.934
133.449
133.288
133.128
127.915
127.244
126.477
118.122
118.102
118.080
112.904
110.937
108.970
77.253
77.000
76.746
46.384
41.371
13C NMR, 126 MHz, CDCL3
F
F
O
N
S
2g
f1 (ppm)

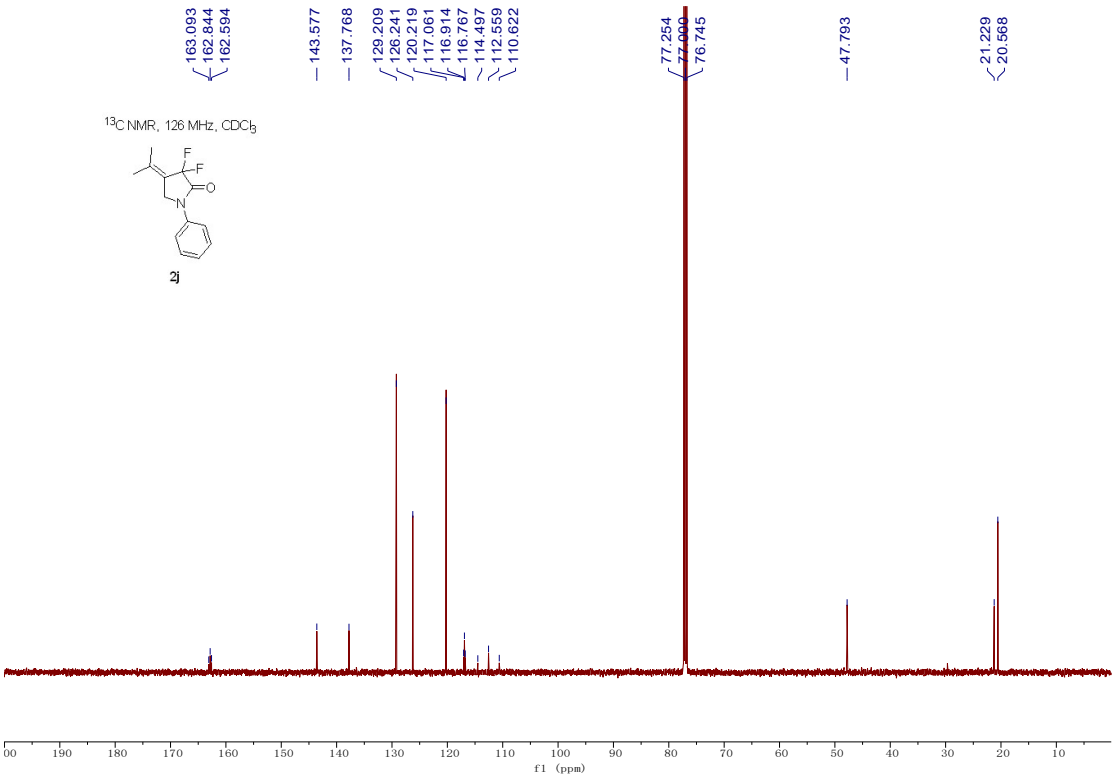

8.142
8.127
8.113
8.097
7.768
7.752
7.737
7.708
7.691
7.558
7.543
7.526
7.260
7.225
7.209
6.007
5.997
5.987
5.977
5.973
5.967
5.963
5.952
5.942
5.932
5.310
5.305
5.282
5.277
4.888
4.878
1H NMR, 500 MHz, CDCl3
F
F
O
N
2h
1.94
1.00
0.95
0.97
1.00
0.97
1.00
0.93
2.00
f1 (ppm)


160.126
132.732
131.855
131.834
131.813
130.908
127.053
127.033
127.012
126.835
126.169
126.141
126.105
124.078
117.777
112.349
77.254
77.000
76.746
45.040
13C NMR, 126 MHz, CDCl3
2h
f1 (ppm)


7.260
5.939
5.934
5.928
5.612
5.610
3.956
3.952
3.948
2.812
2.804
2.797
2.789
2.782
2.775
2.767
0.908
0.900
0.893
0.889
0.881
0.879
0.874
0.868
0.860
0.853
0.840
0.831
0.826
0.822
0.815
0.807
1H NMR, 500 MHz, CDCl3
2i
1.00
1.00
2.00
0.99
2.17
2.10
f1 (ppm)


164.183
163.943
163.703
133.749
133.589
133.429
117.742
117.721
117.700
113.167
111.205
109.242
77.254
77.000
76.746
47.516
47.502
47.485
26.002
5.034
13C NMR, 126 MHz, CDCl3
F
F
O
N
2i
f1 (ppm)


7.748
7.732
7.448
7.432
7.415
7.271
7.260
7.242
4.385
2.103
1.879
1.871
1.863
1H NMR, 500 MHz, CDCl3
F
F
O
N
2j
1.93
1.97
1.09
2.03
3.00
2.99
f1 (ppm)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162.594
143.577
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120.219
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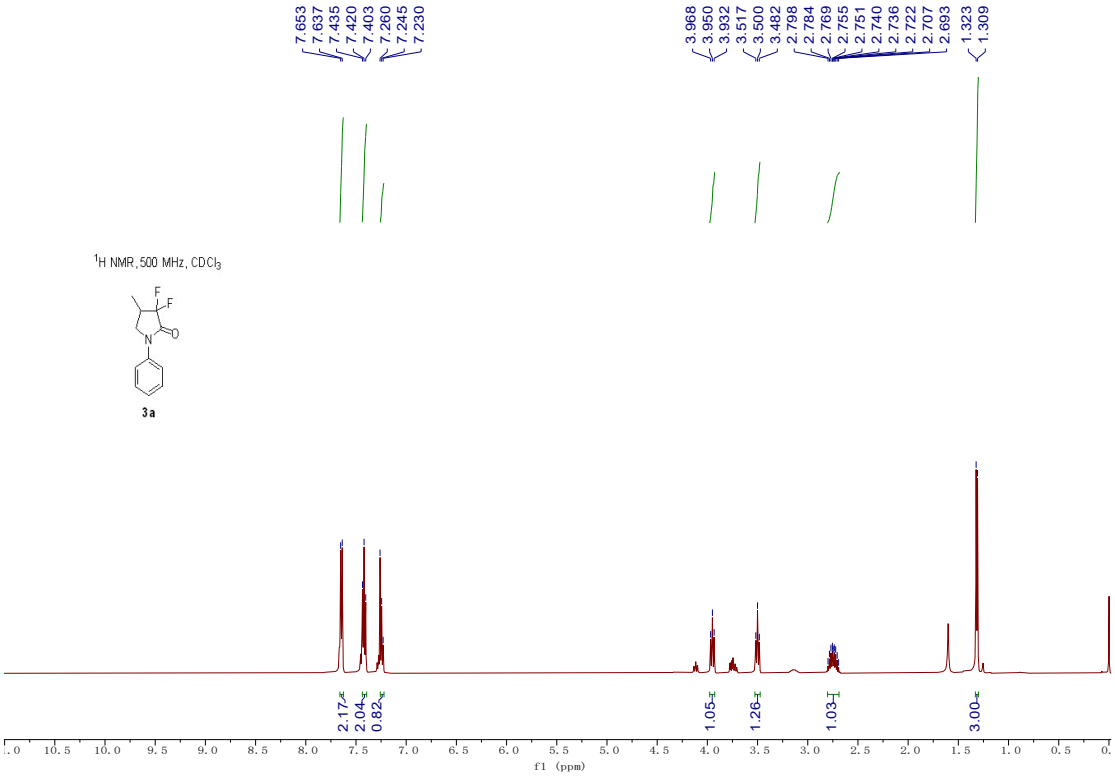
116.914
116.767
114.497
112.559
110.622
77.254
77.000
76.745
47.793
21.229
20.568
13C NMR, 126 MHz, CDCl3
F
F
O
N
2j
f1 (ppm)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7.637
7.435
7.420
7.403
7.260
7.245
7.230
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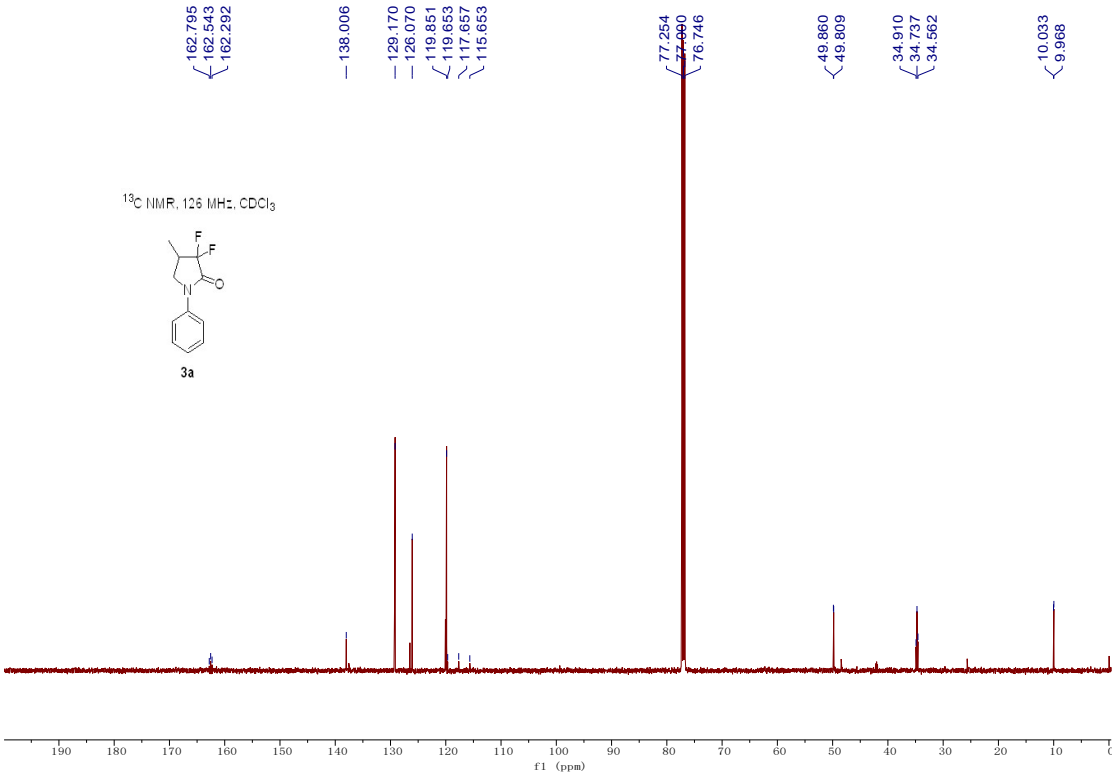
3.950
3.932
3.517
3.500
3.482
2.798
2.784
2.769
2.755
2.751
2.740
2.736
2.722
2.707
2.693
1.323
1.309
1H NMR, 500 MHz, CDCl3
F
F
O
N
3a
2.17
2.04
0.82
1.05
1.26
1.03
3.00
f1 (ppm)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119.653
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115.653
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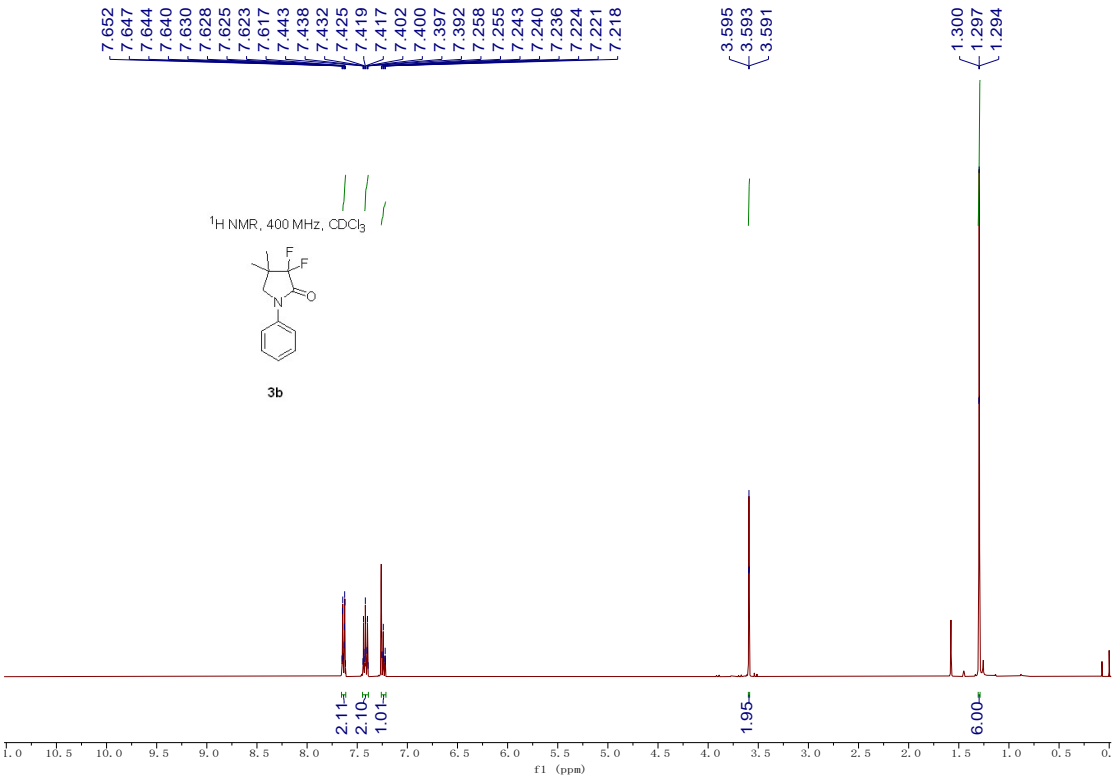
77.000
76.746
49.860
49.809
34.910
34.737
34.562
10.033
9.968
13C NMR, 126 MHz, CDCl3
F
F
O
N
3a
f1 (ppm)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7.647
7.644
7.640
7.630
7.628
7.625
7.623
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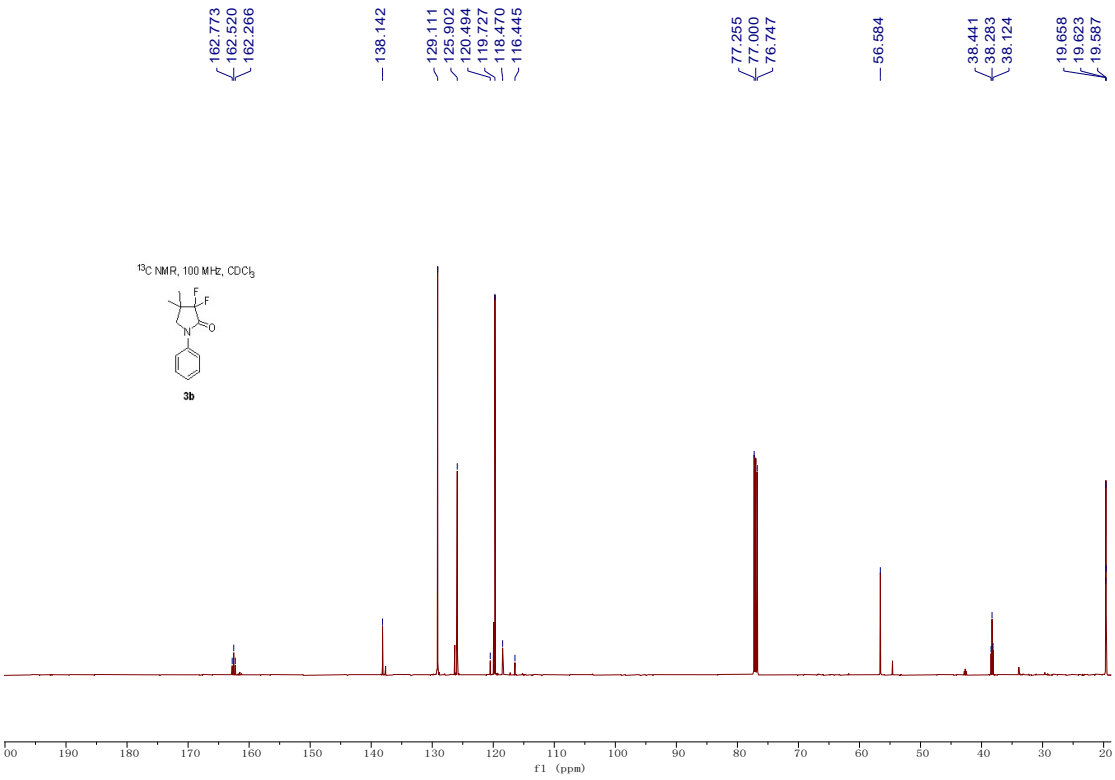
7.438
7.432
7.425
7.419
7.417
7.402
7.400
7.397
7.392
7.258
7.255
7.243
7.240
7.236
7.224
7.221
7.218
3.595
3.593
3.591
1.300
1.297
1.294
1H NMR, 400 MHz, CDCl3
F
F
O
N
3b
2.11
2.10
1.01
1.95
6.00
f1 (ppm)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119.727
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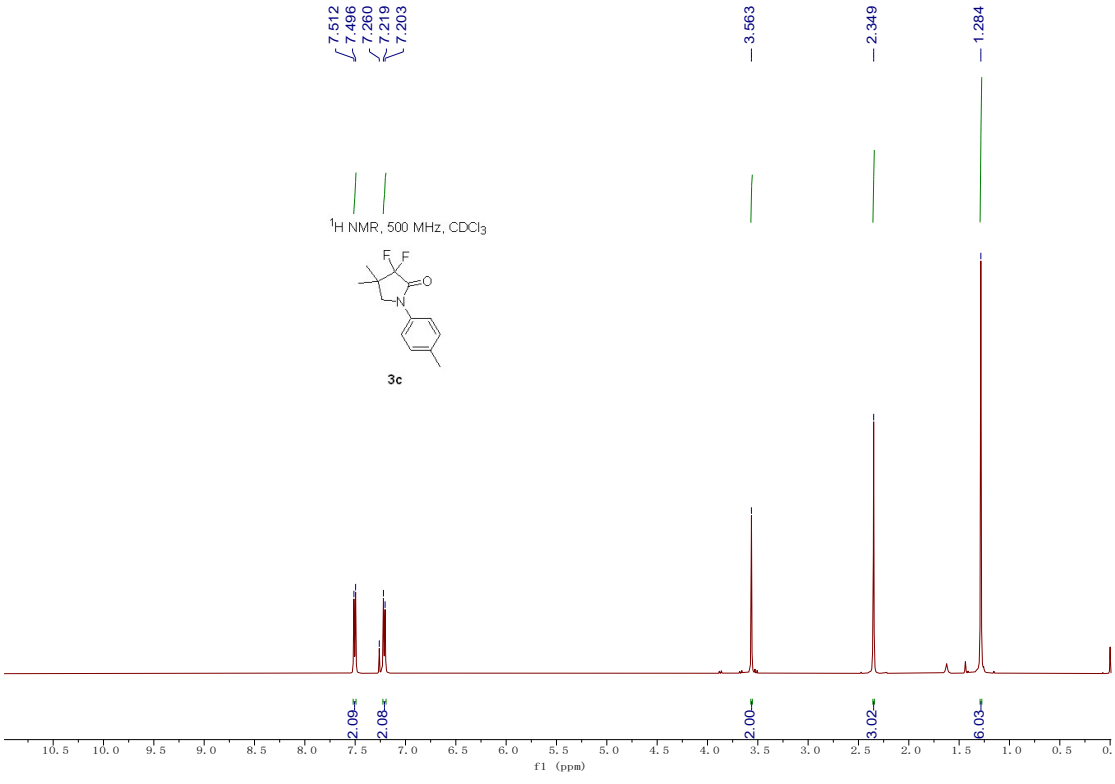
116.445
77.255
77.000
76.747
56.584
38.441
38.283
38.124
19.658
19.623
19.587
13C NMR, 100 MHz, CDCl3
3b
f1 (ppm)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7.496
7.260
7.219
7.203
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2.349
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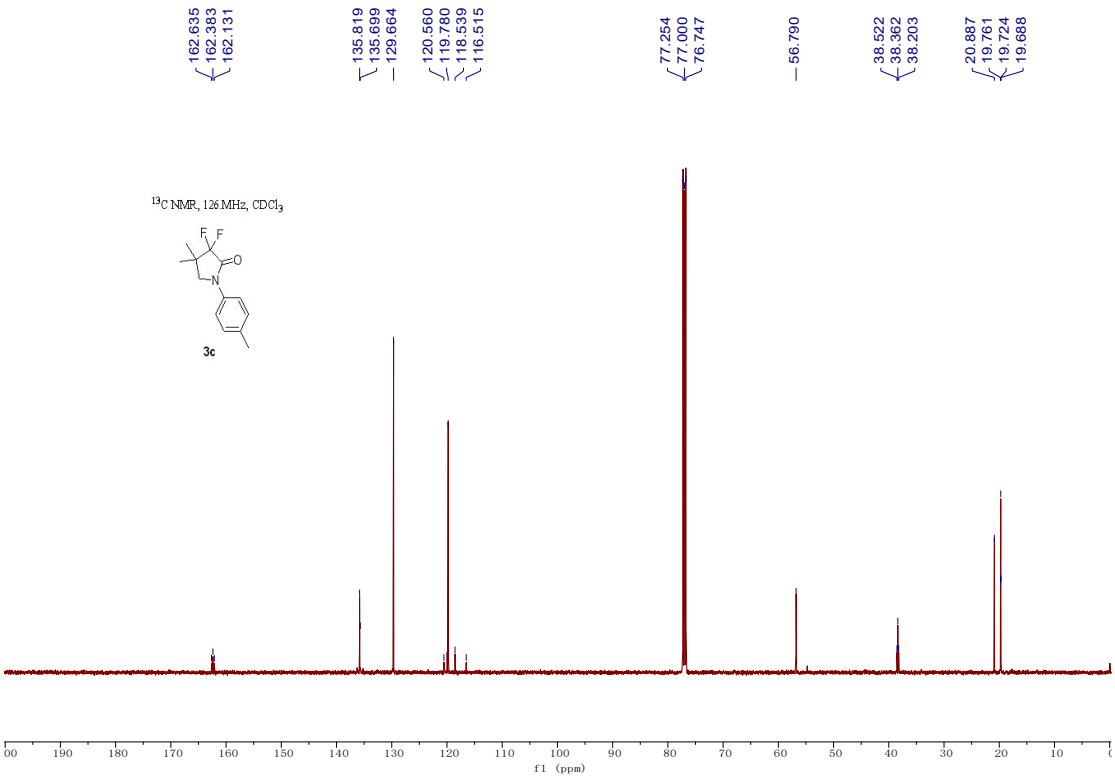
1H NMR, 500 MHz, CDCl3
3c
2.09
2.08
2.00
3.02
6.03
f1 (ppm)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119.780
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116.515
77.254
77.000
76.747
56.790
38.522
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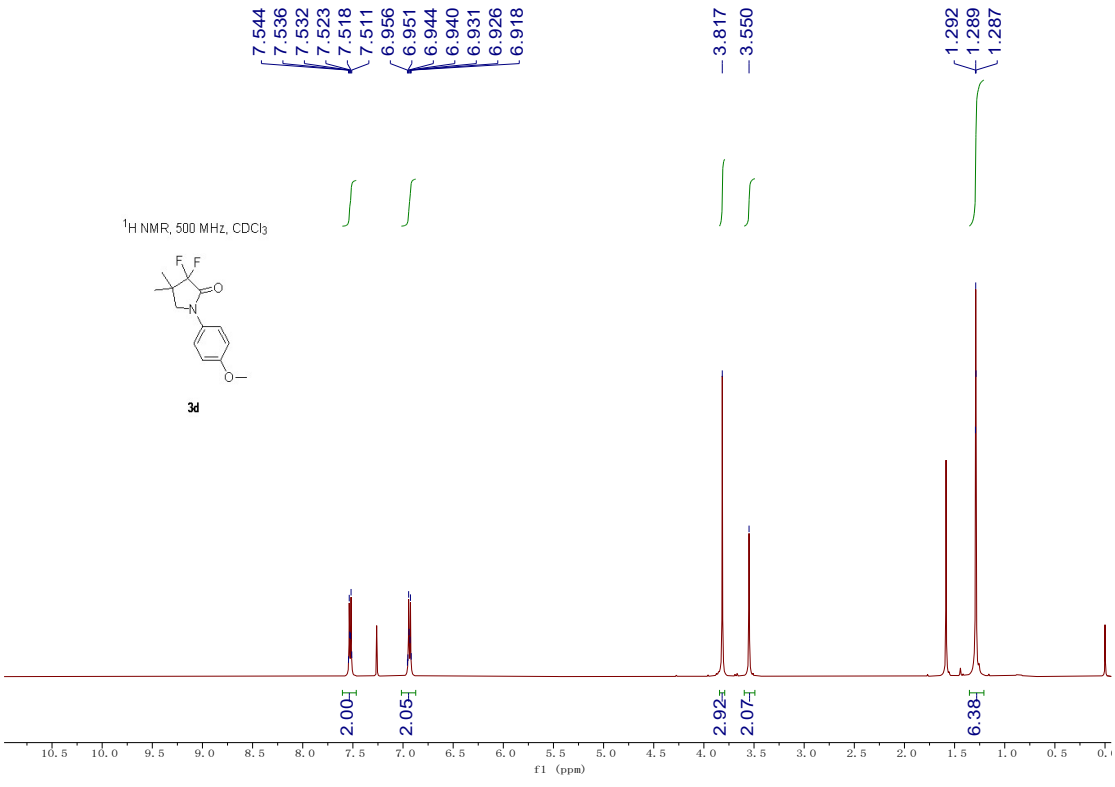
38.203
20.887
19.761
19.724
19.688
13C NMR, 126 MHz, CDCl3
3c
f1 (ppm)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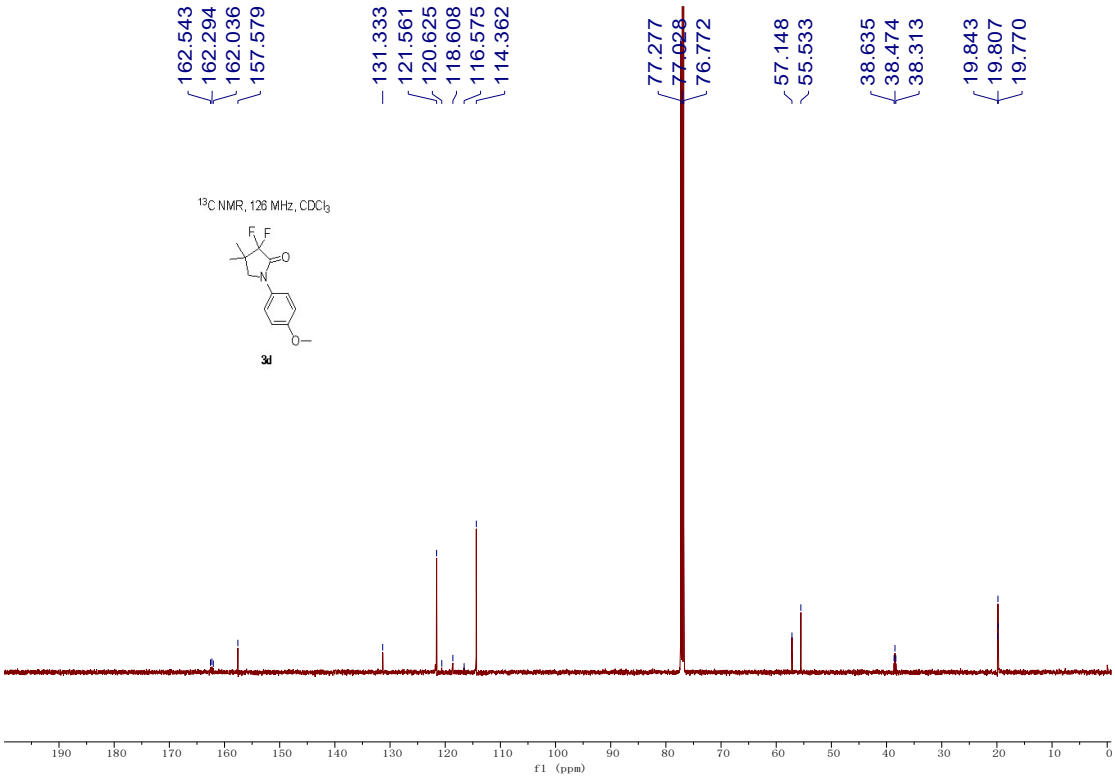
7.536
7.532
7.523
7.518
7.511
6.956
6.951
6.944
6.940
6.931
6.926
6.918
3.817
3.550
1.292
1.289
1.287
1H NMR, 500 MHz, CDCl3
3d
2.00
2.05
2.92
2.07
6.38
f1 (ppm)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120.625
118.608
116.575
114.362
77.277
77.028
76.772
57.148
55.533
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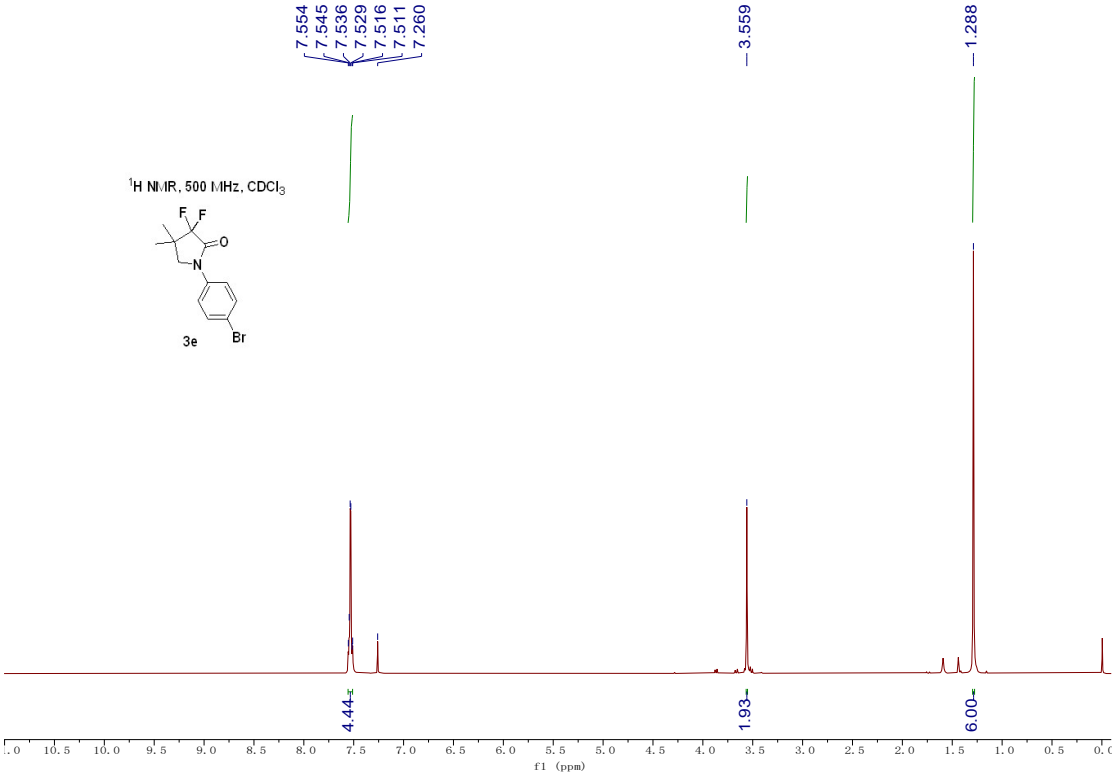
38.474
38.313
19.843
19.807
19.770
13C NMR, 126 MHz, CDCl3
3d
f1 (ppm)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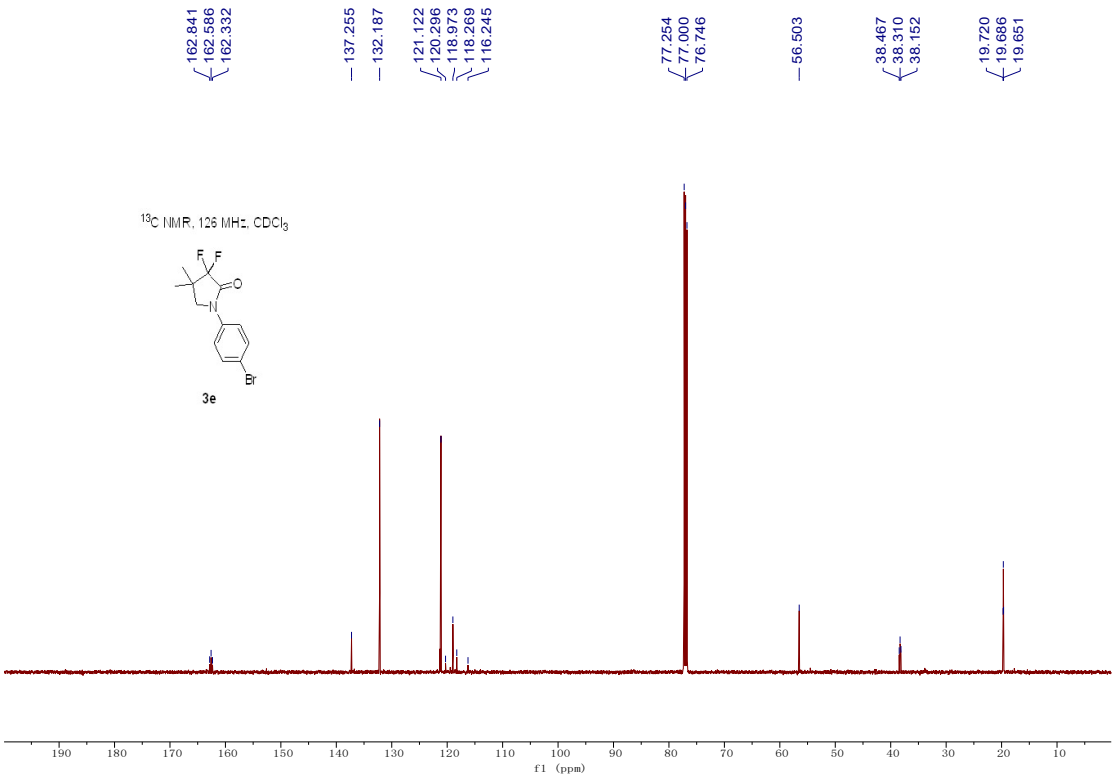
7.545
7.536
7.529
7.516
7.511
7.260
3.559
1.288
1H NMR, 500 MHz, CDCl3
3e
Br
4.44
1.93
6.00
f1 (ppm)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120.296
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116.245
77.254
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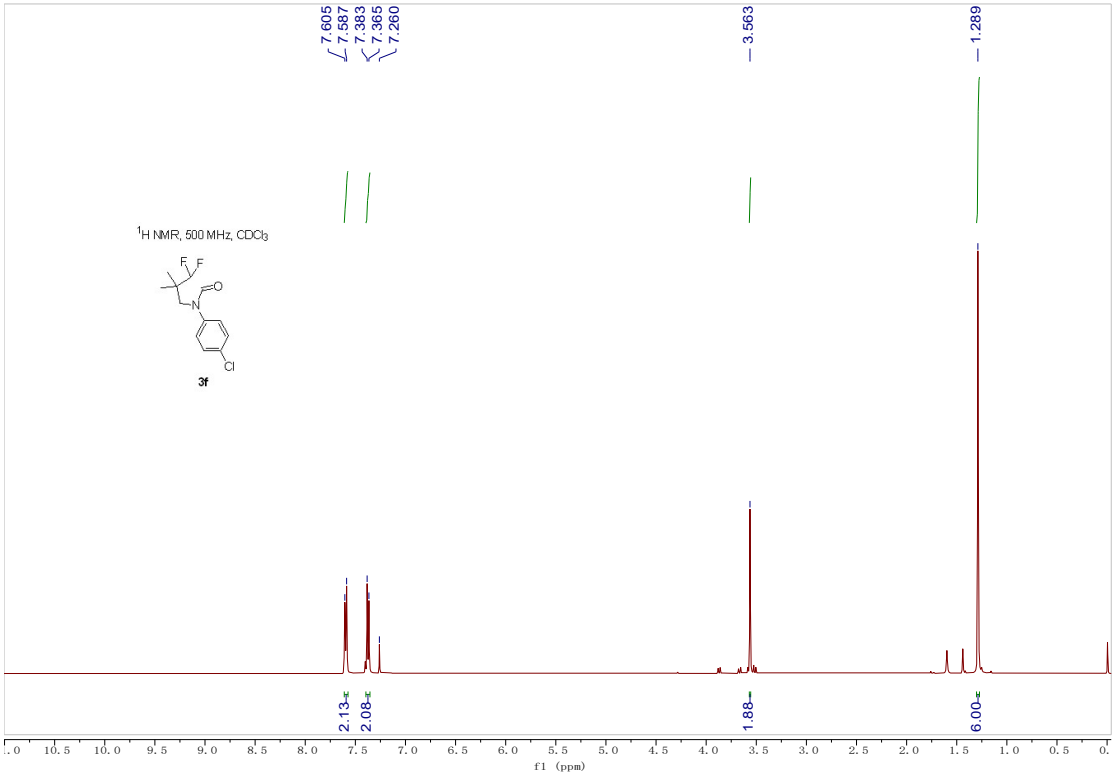
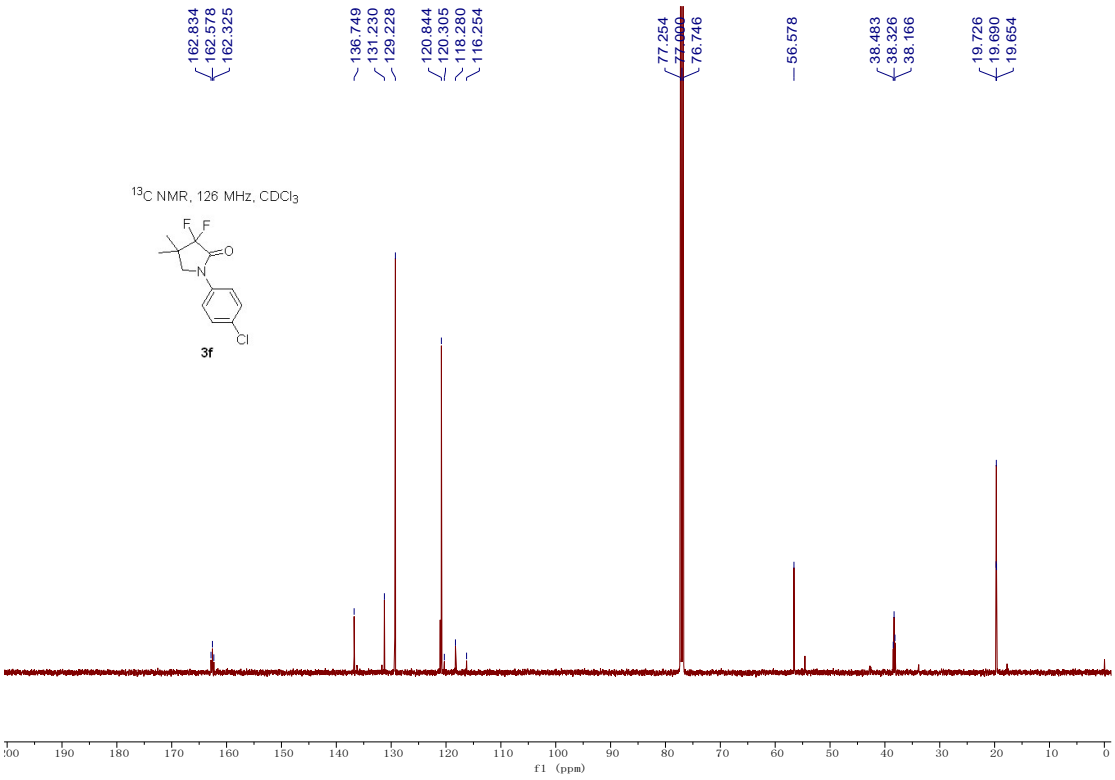
76.746
56.503
38.467
38.310
38.152
19.720
19.686
19.651
13C NMR, 126 MHz, CDCl3
F F
O
N
Br
3e
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.605
7.587
7.383
7.365
7.260
3.563
1.289
1H NMR, 500 MHz, CDCl3
F F
O
N
Cl
3f
2.13
2.08
1.88
6.00
f1 (ppm)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136.749
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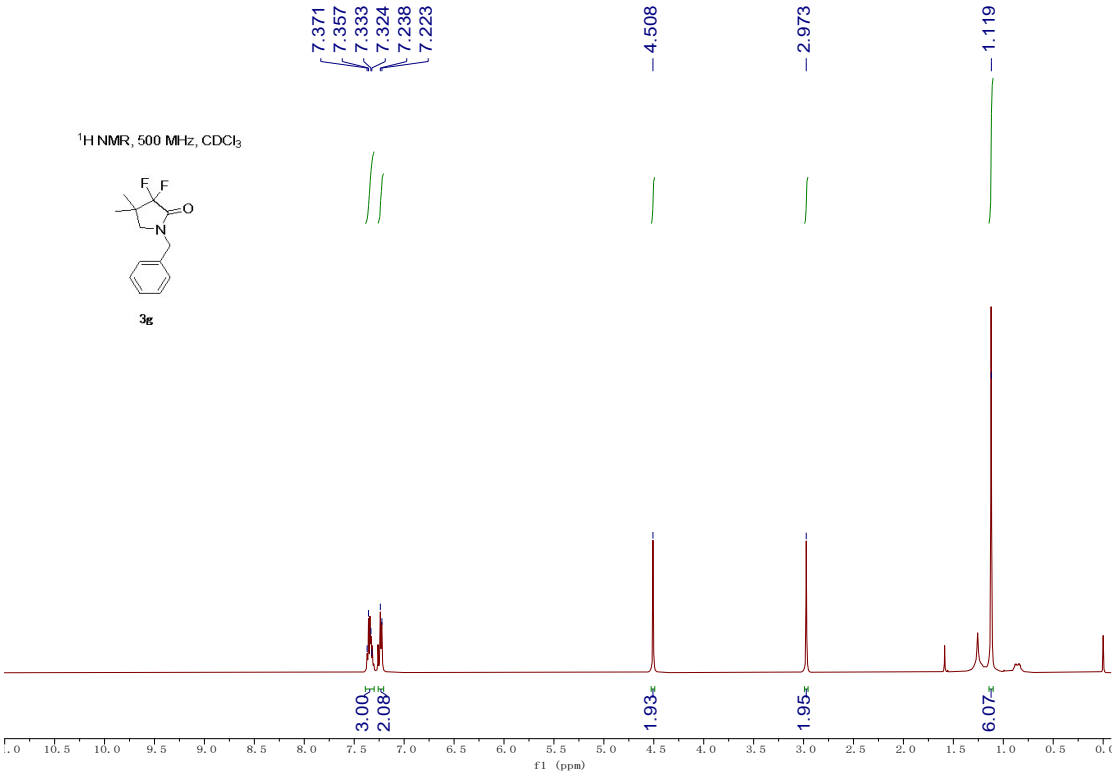
129.228
120.844
120.305
118.280
116.254
77.254
77.000
76.746
56.578
38.483
38.326
38.166
19.726
19.690
19.654
13C NMR, 126 MHz, CDCl3
F F
O
N
Cl
3f
f1 (ppm)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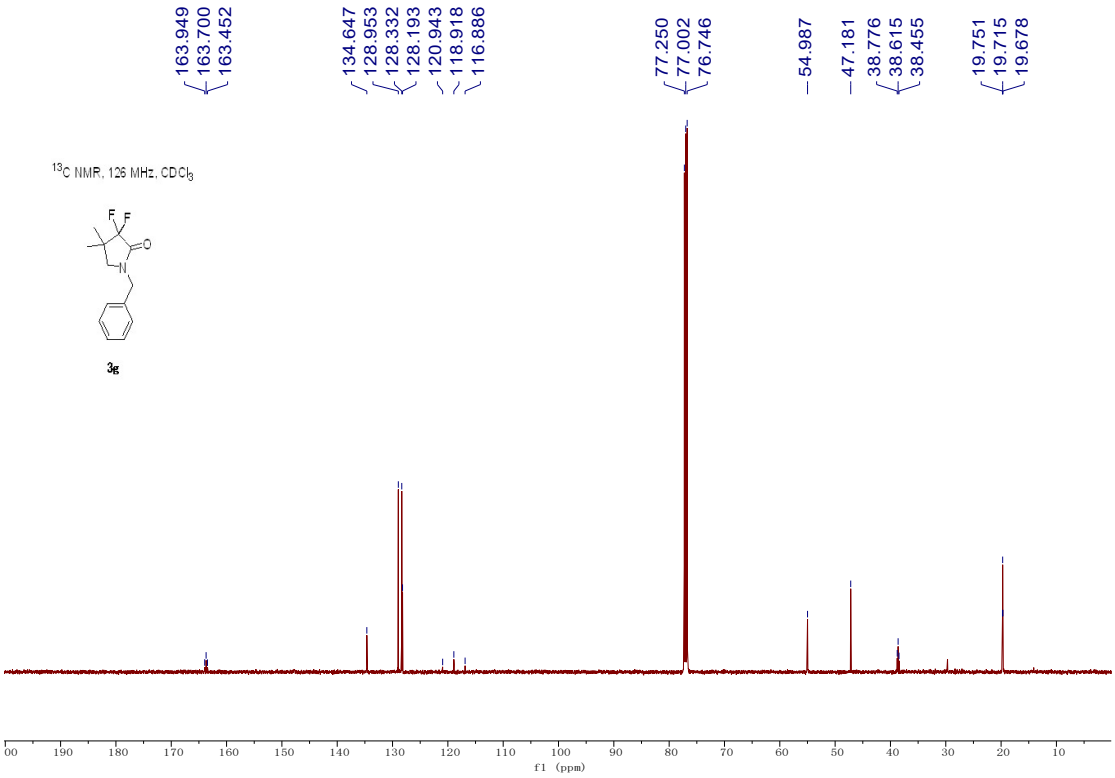
7.357
7.333
7.324
7.238
7.223
4.508
2.973
1.119
1H NMR, 500 MHz, CDCl3
F F
O
N
3g
3.00
2.08
1.93
1.95
6.07
f1 (ppm)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128.193
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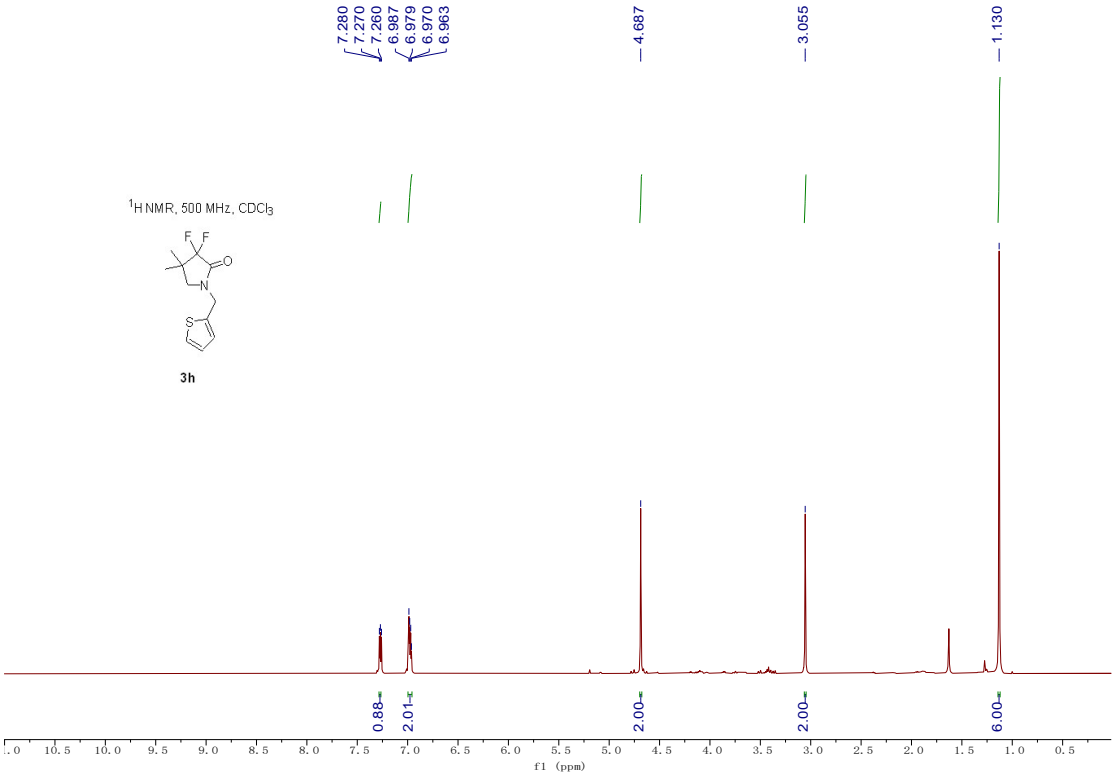
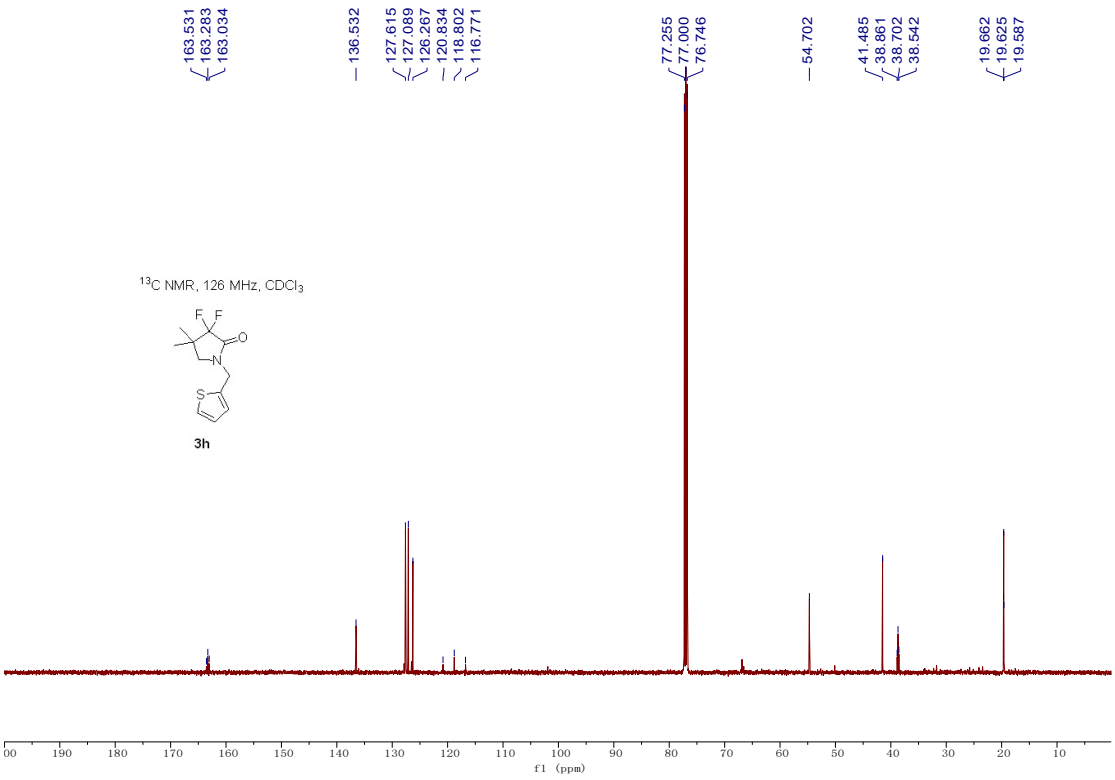
116.886
77.250
77.002
76.746
54.987
47.181
38.776
38.615
38.455
19.751
19.715
19.678
13C NMR, 126 MHz, CDCl3
F F
O
N
3g
f1 (ppm)


7.280
7.270
7.260
6.987
6.979
6.970
6.963
4.687
3.055
1.130
1H NMR, 500 MHz, CDCl3
F F
O
N
S
3h
0.88
2.01
2.00
2.00
6.00
f1 (ppm)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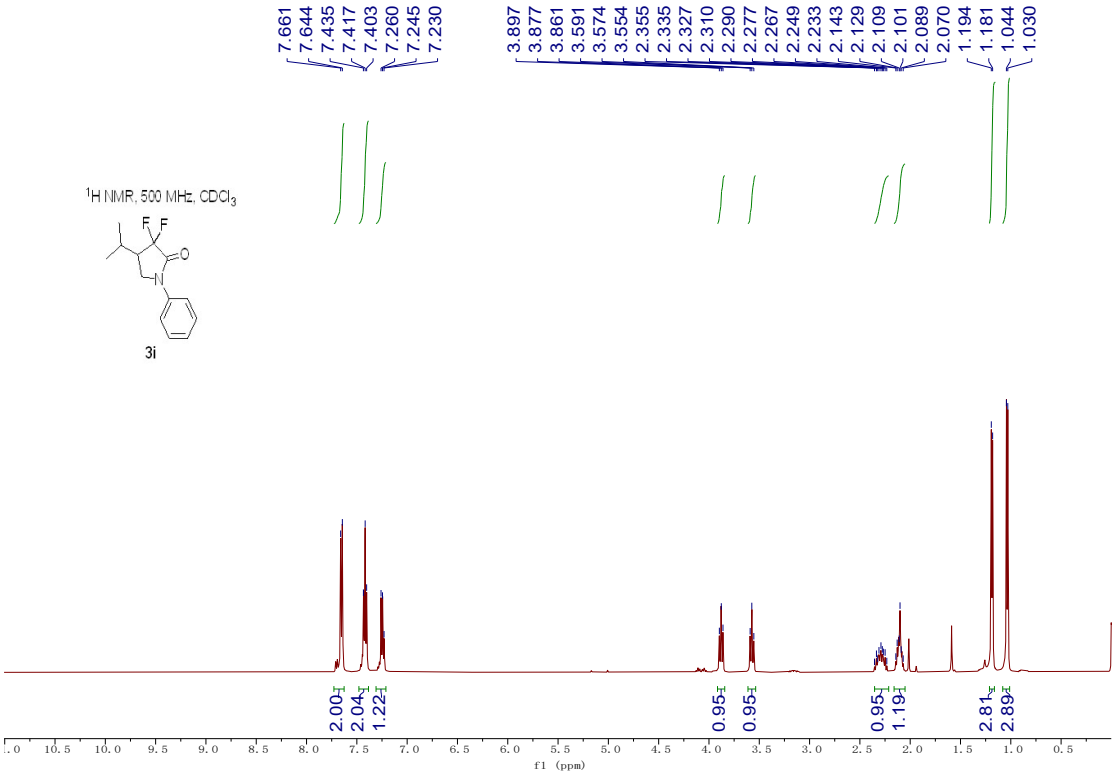
136.532
127.615
127.089
126.267
120.834
118.802
116.771
77.255
77.000
76.746
54.702
41.485
38.861
38.702
38.542
19.662
19.625
19.587
13C NMR, 126 MHz, CDCl3
F F
O
N
S
3h
f1 (ppm)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7.403
7.260
7.245
7.230
3.897
3.877
3.861
3.591
3.574
3.554
2.355
2.335
2.327
2.310
2.290
2.277
2.267
2.249
2.233
2.143
2.129
2.109
2.101
2.089
2.070
1.194
1.181
1.044
1.030
1H NMR, 500 MHz, CDCl3
F F
O
N
3i
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0.95
0.95
0.95
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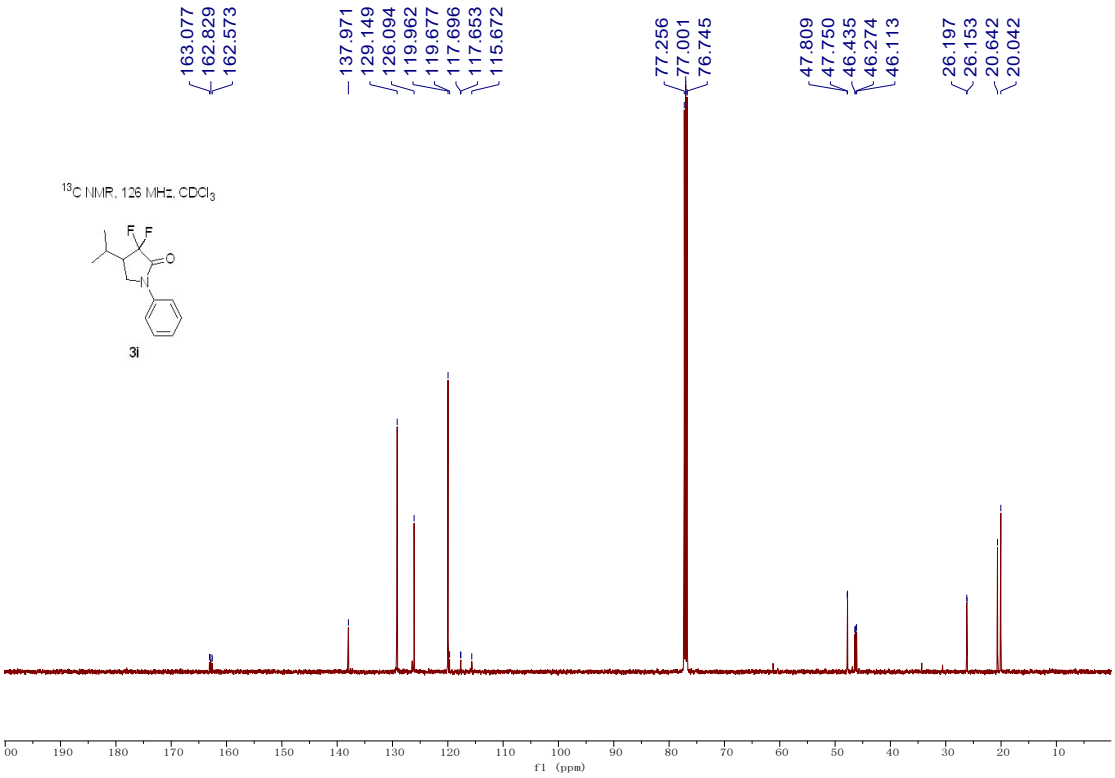
2.81
2.89
f1 (ppm)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77.001
76.745
47.809
47.750
46.435
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46.113
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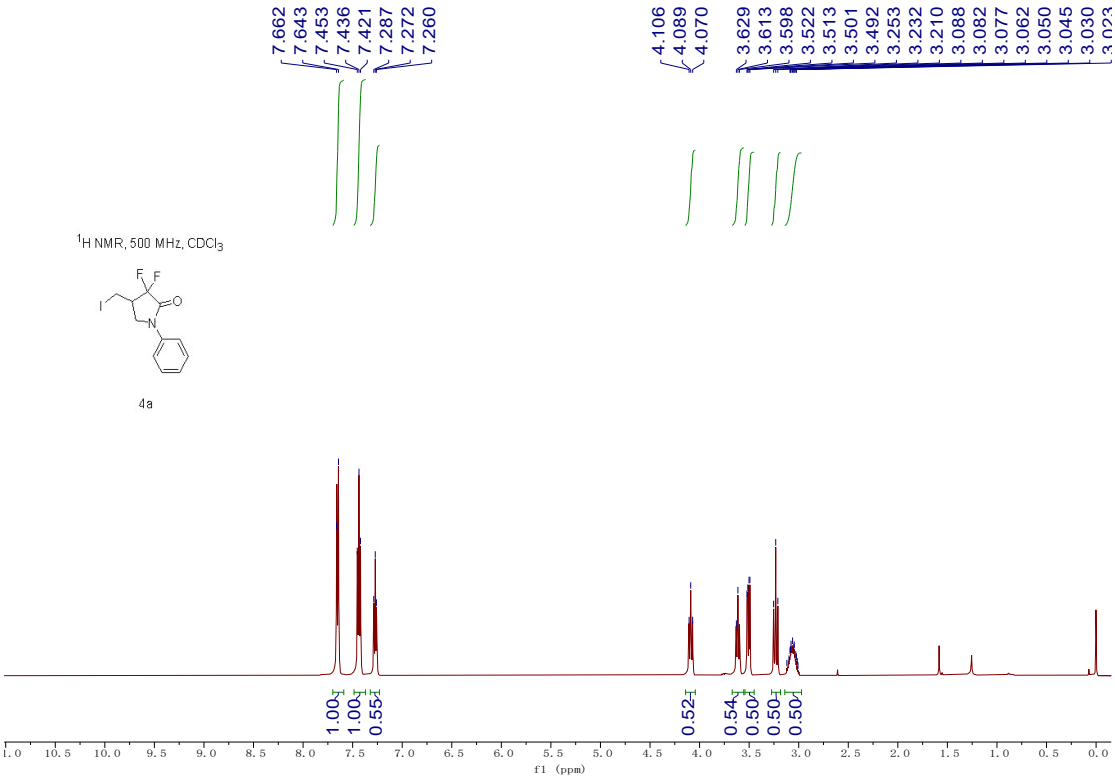
26.153
20.642
20.042
13C NMR, 126 MHz, CDCl3
F F
O
N
3l
f1 (ppm)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7.260
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4.070
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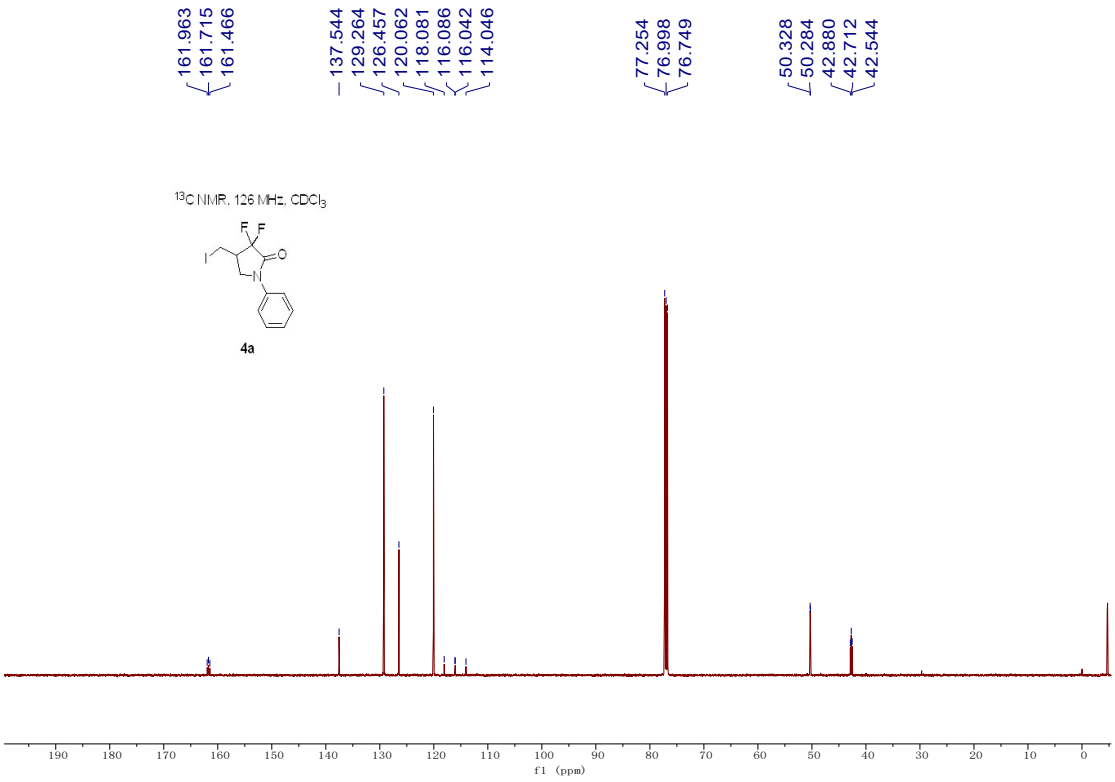
3.613
3.598
3.522
3.513
3.501
3.492
3.253
3.232
3.210
3.088
3.082
3.077
3.062
3.050
3.045
3.030
1H NMR, 500 MHz, CDCl3
F F
I
O
N
4a
1.00
1.00
0.55
0.52
0.54
0.50
0.50
0.50
f1 (ppm)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114.046
77.254
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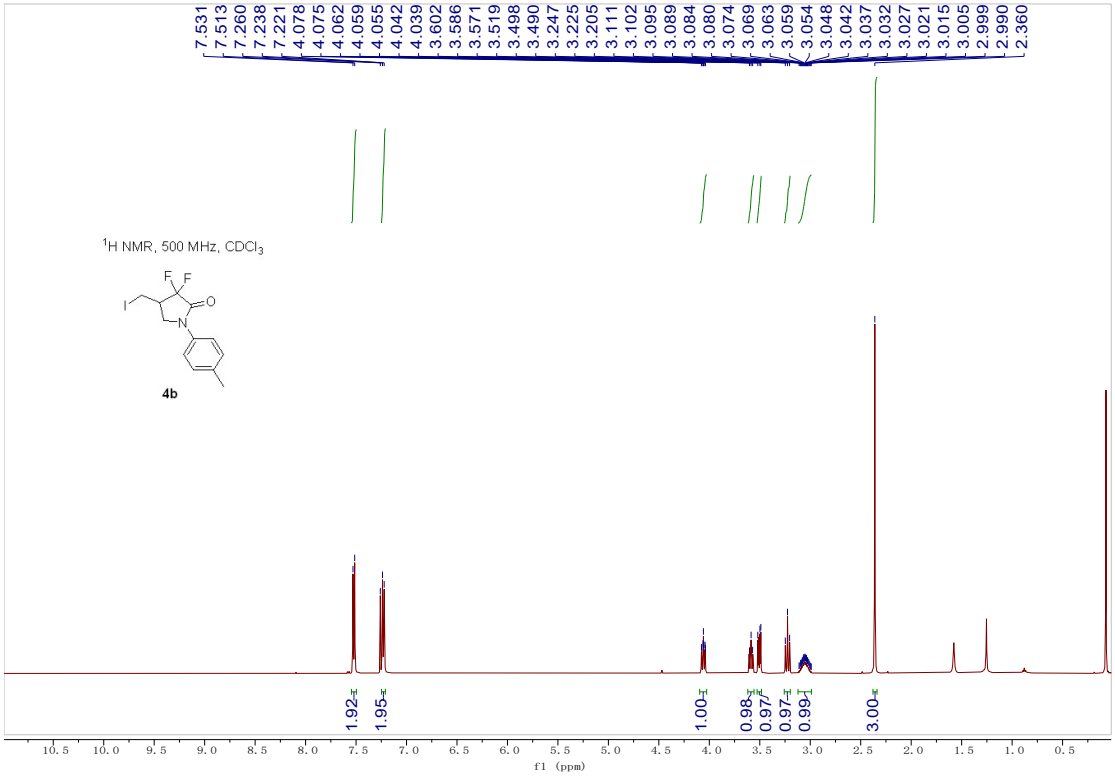
50.328
50.284
42.880
42.712
42.544
13C NMR, 126 MHz, CDCl3
4a
f1 (ppm)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7.238
7.221
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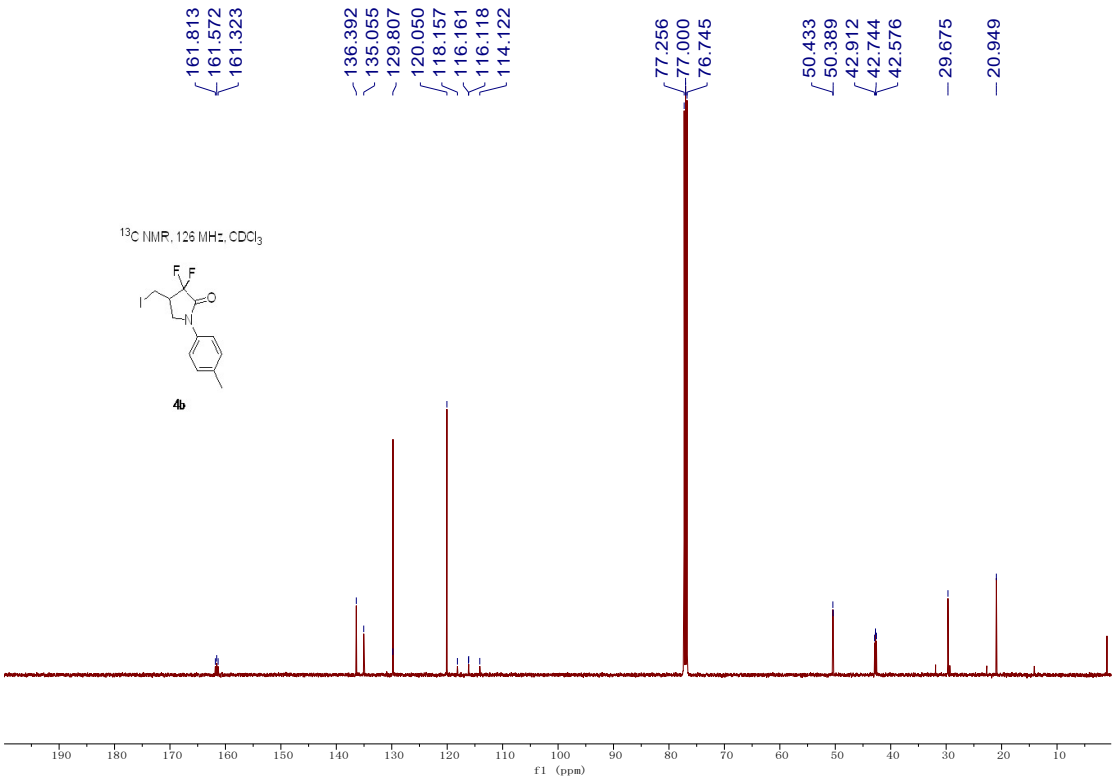
4.075
4.062
4.059
4.055
4.042
4.039
3.602
3.586
3.571
3.519
3.498
3.490
3.247
3.225
3.205
3.111
3.102
3.095
3.089
3.084
3.080
3.074
3.069
3.063
3.059
3.054
3.048
3.042
3.037
3.032
3.027
3.021
3.015
3.005
2.999
2.990
2.360
1H NMR, 500 MHz, CDCl3
4b
1.92
1.95
1.00
0.98
0.97
0.97
0.99
3.00
f1 (ppm)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129.807
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116.161
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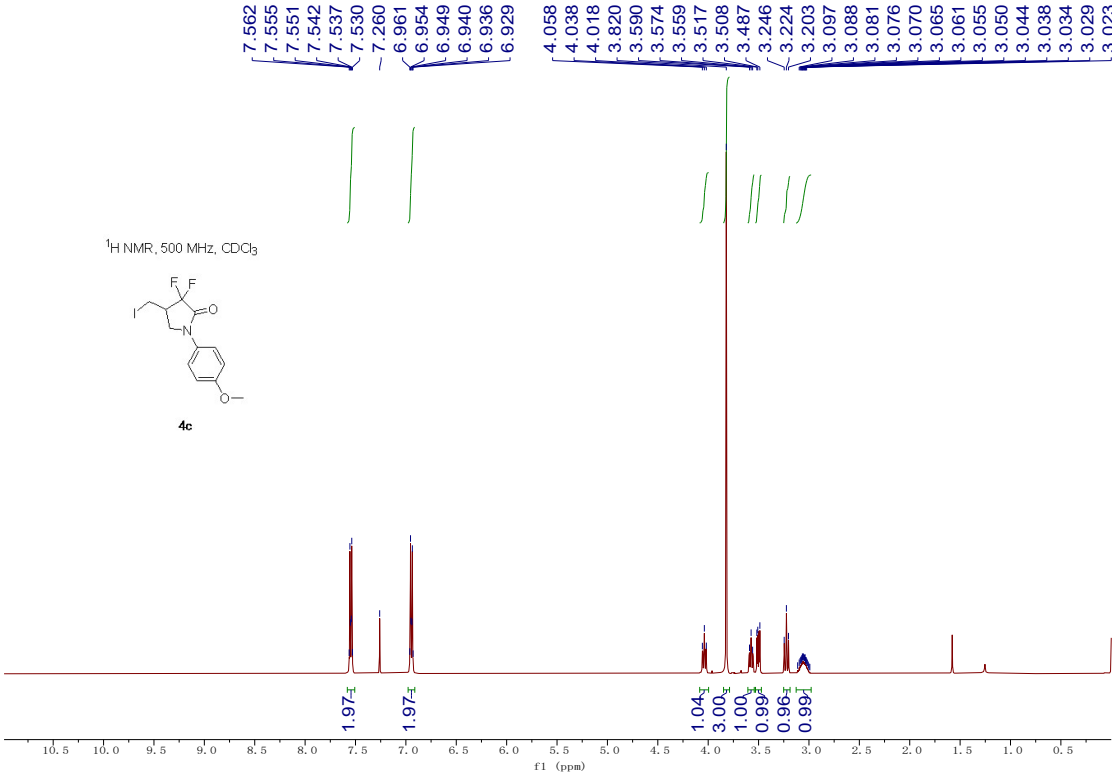
114.122
77.256
77.000
76.745
50.433
50.389
42.912
42.744
42.576
29.675
20.949
13C NMR, 126 MHz, CDCl3
4b
f1 (ppm)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7.530
7.260
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6.954
6.949
6.940
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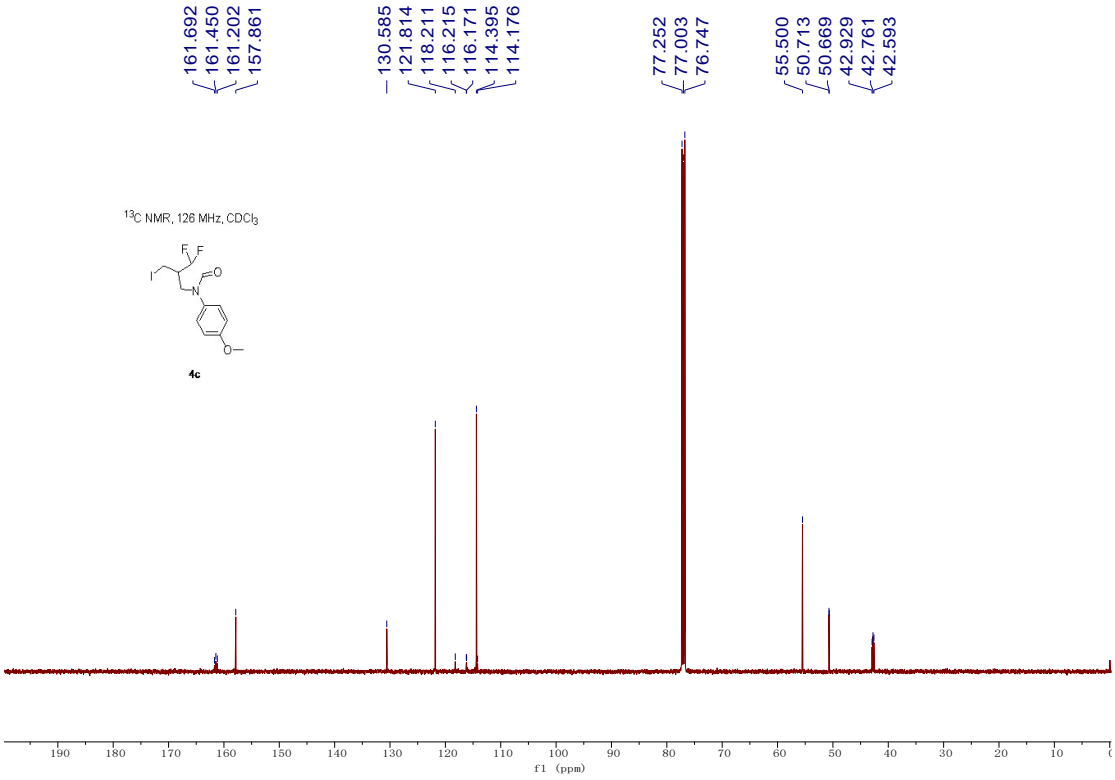
6.929
4.058
4.038
4.018
3.820
3.590
3.574
3.559
3.517
3.508
3.487
3.246
3.224
3.203
3.097
3.088
3.081
3.076
3.070
3.065
3.061
3.055
3.050
3.044
3.038
3.034
3.029
1H NMR, 500 MHz, CDCl3
4c
1.97
1.97
1.04
3.00
1.00
0.99
0.96
0.99
f1 (ppm)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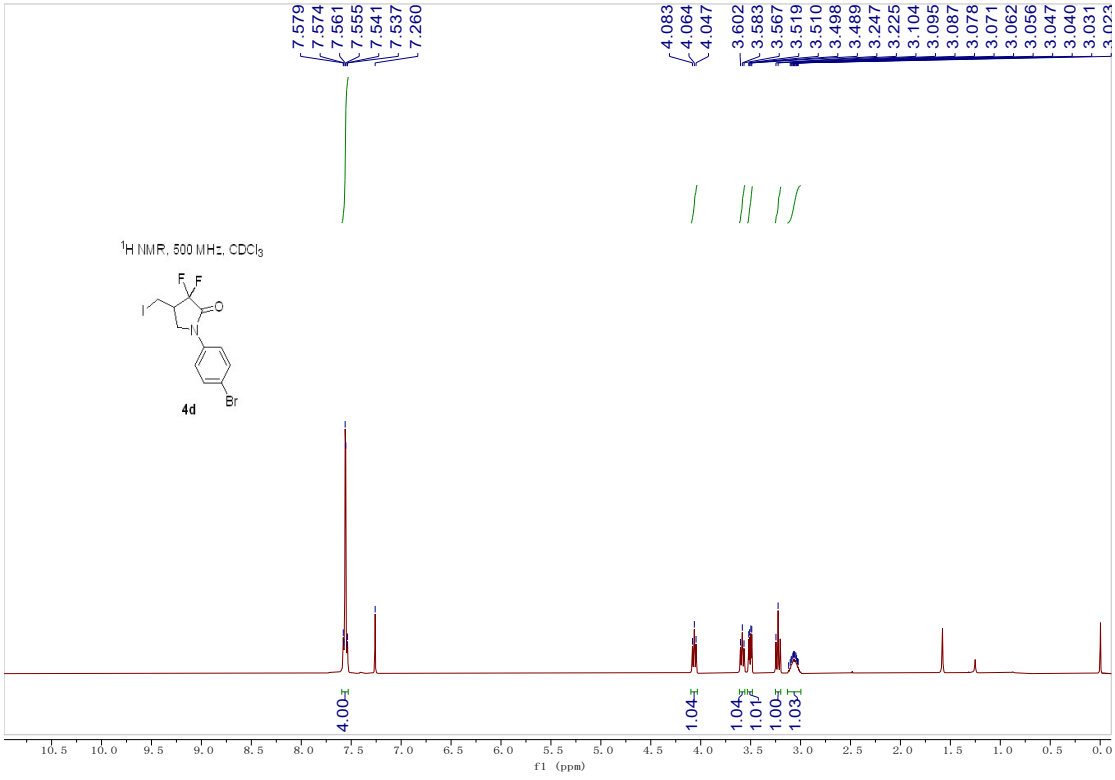
114.176
77.252
77.003
76.747
55.500
50.713
50.669
42.929
42.761
42.593
13C NMR, 126 MHz, CDCl3
4c
f1 (ppm)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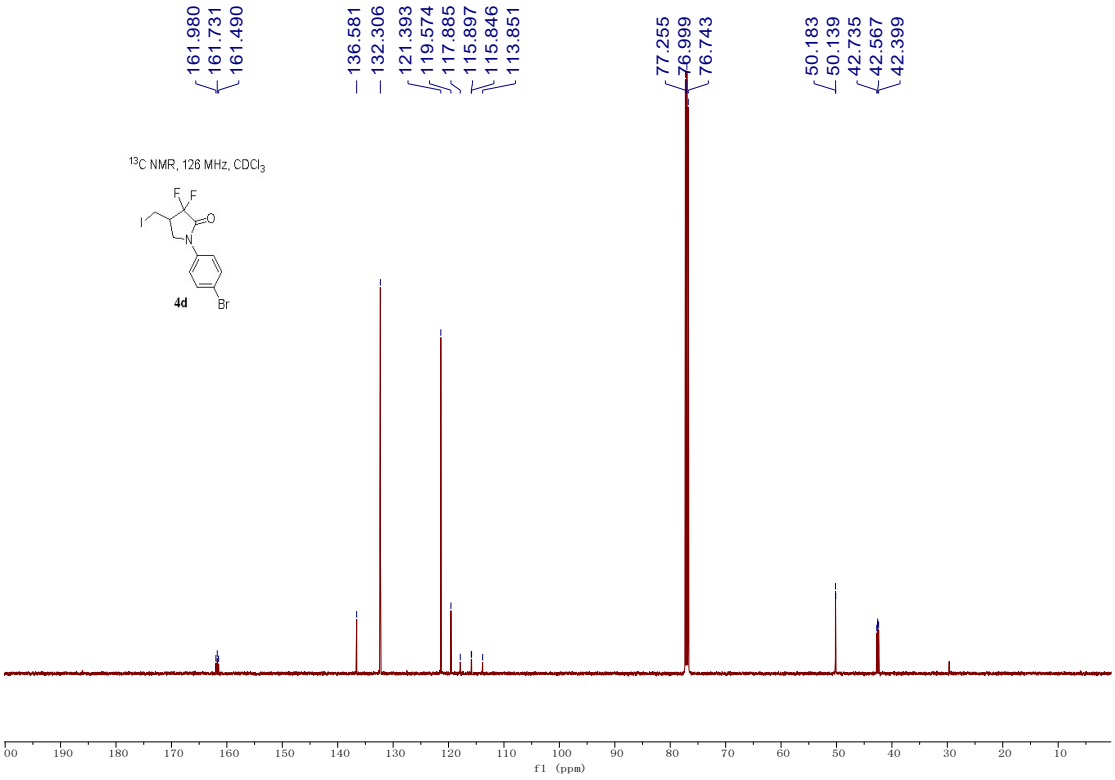
7.555
7.541
7.537
7.260
4.083
4.064
4.047
3.602
3.583
3.567
3.519
3.510
3.498
3.489
3.247
3.225
3.104
3.095
3.087
3.078
3.071
3.062
3.056
3.047
3.040
3.031
1H NMR, 500 MHz, CDCl3
4d
4.00
1.04
1.04
1.01
1.00
1.03
f1 (ppm)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132.306
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117.885
115.897
115.846
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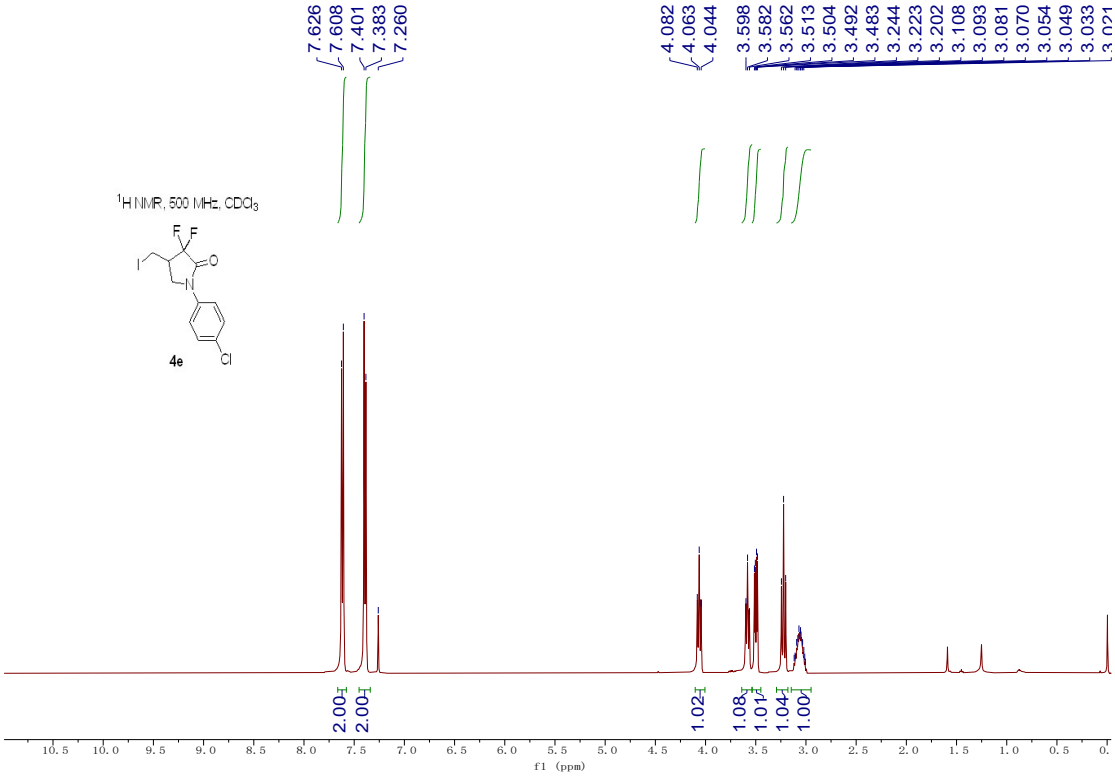
77.255
76.999
76.743
50.183
50.139
42.735
42.567
42.399
13C NMR, 126 MHz, CDCl3
4d
Br
f1 (ppm)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7.608
7.401
7.383
7.260
4.082
4.063
4.044
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3.582
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3.513
3.504
3.492
3.483
3.244
3.223
3.202
3.108
3.093
3.081
3.070
3.054
3.049
3.033
1H NMR, 500 MHz, CDCl3
4e
Cl
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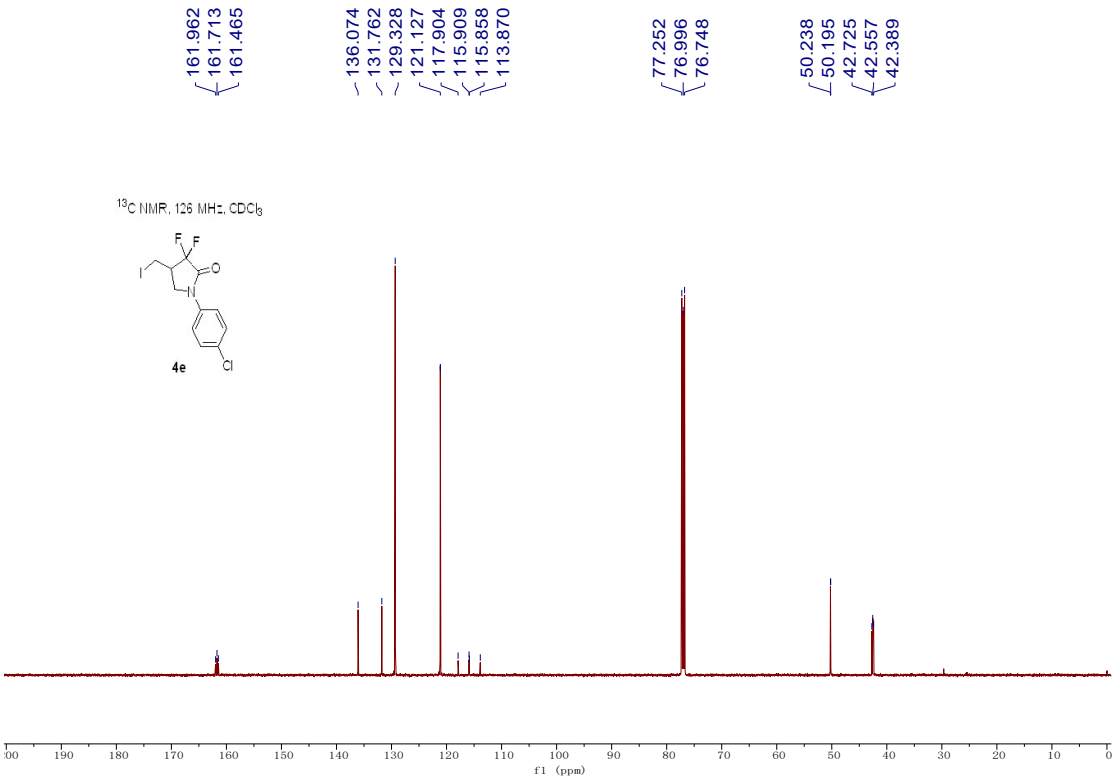
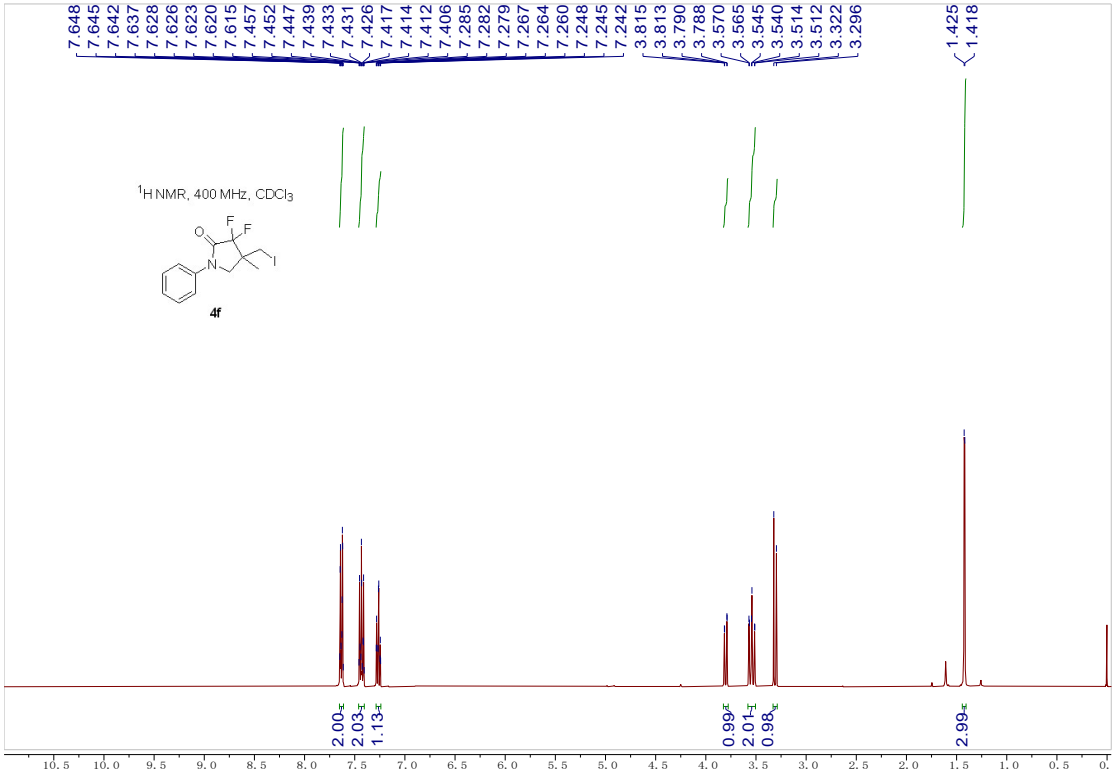
2.00
1.02
1.08
1.01
1.04
1.00
f1 (ppm)


161.962
161.713
161.465
136.074
131.762
129.328
121.127
117.904
115.909
115.858
113.870
77.252
76.996
76.748
50.238
50.195
42.725
42.557
42.389
13C NMR, 126 MHz, CDCl3
4e
f1 (ppm)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7.642
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7.623
7.620
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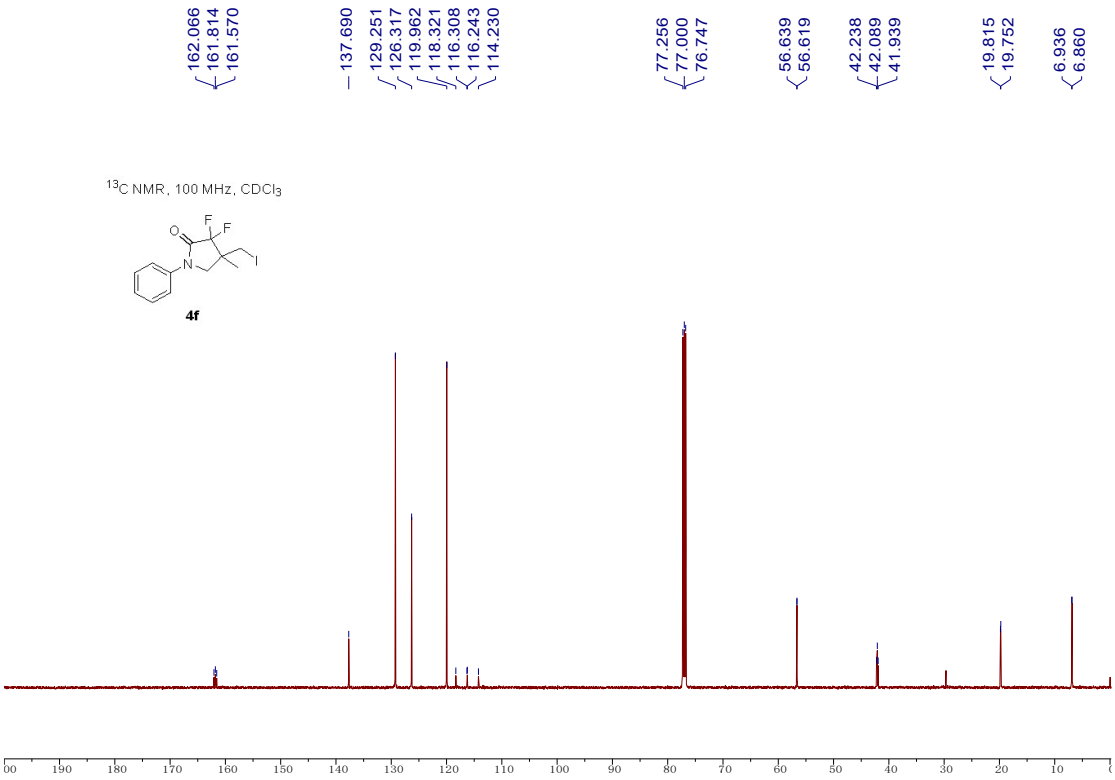
7.439
7.433
7.431
7.426
7.417
7.414
7.412
7.406
7.285
7.282
7.279
7.267
7.264
7.260
7.248
7.245
7.242
3.815
3.813
3.790
3.788
3.570
3.565
3.545
3.540
3.514
3.512
3.322
3.296
1.425
1.418
1H NMR, 400 MHz, CDCl3
4f
2.00
2.03
1.13
0.99
2.01
0.98
2.99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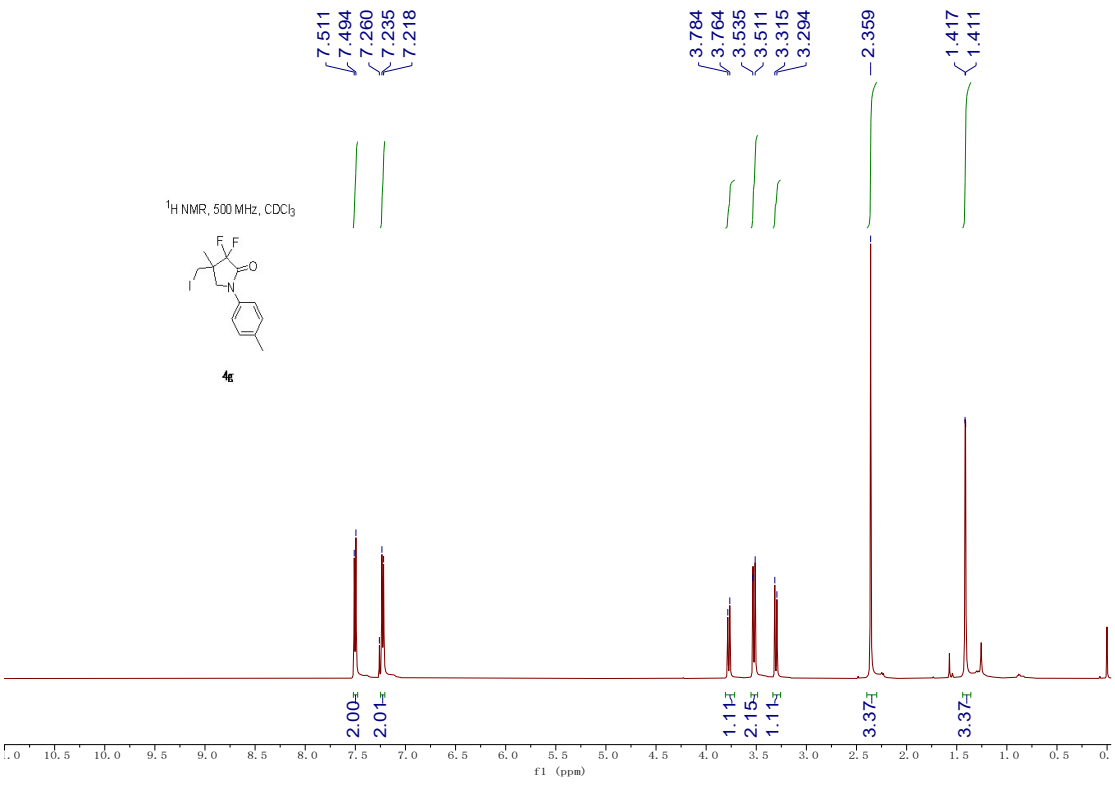
161.570
137.690
129.251
126.317
119.962
118.321
116.308
116.243
114.230
77.256
77.000
76.747
56.639
56.619
42.238
42.089
41.939
19.815
19.752
6.936
6.860
13C NMR, 100 MHz, CDCl3
4f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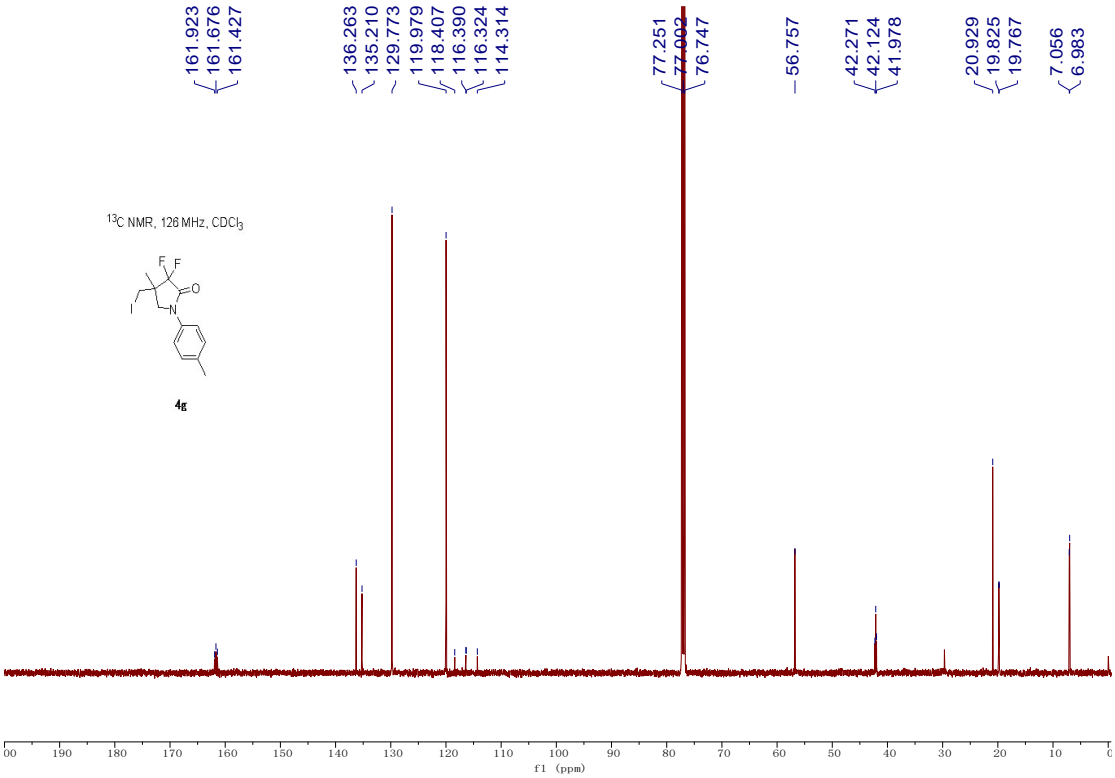
7.494
7.260
7.235
7.218
3.784
3.764
3.535
3.511
3.315
3.294
2.359
1.417
1.411
1H NMR, 500 MHz, CDCl3
4g
2.00
2.01
1.11
2.15
1.11
3.37
3.37
f1 (ppm)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118.407
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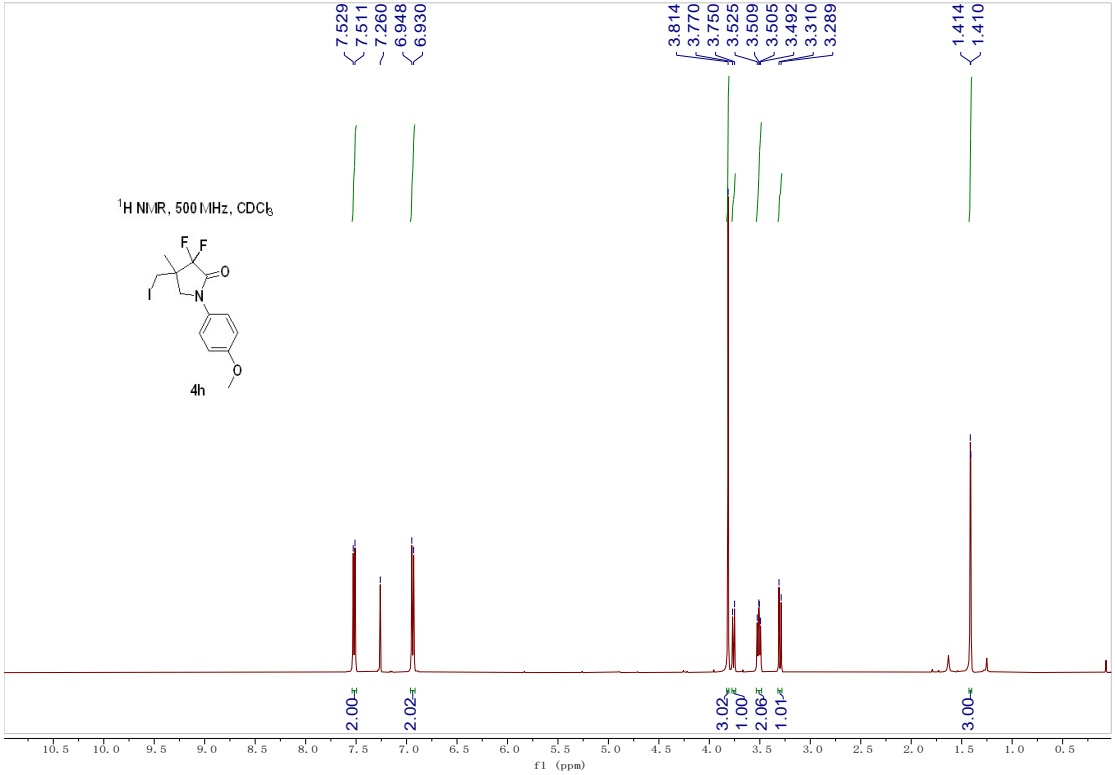
116.324
114.314
77.251
77.002
76.747
56.757
42.271
42.124
41.978
20.929
19.825
19.767
7.056
6.983
13C NMR, 126 MHz, CDCl3
4g
f1 (ppm)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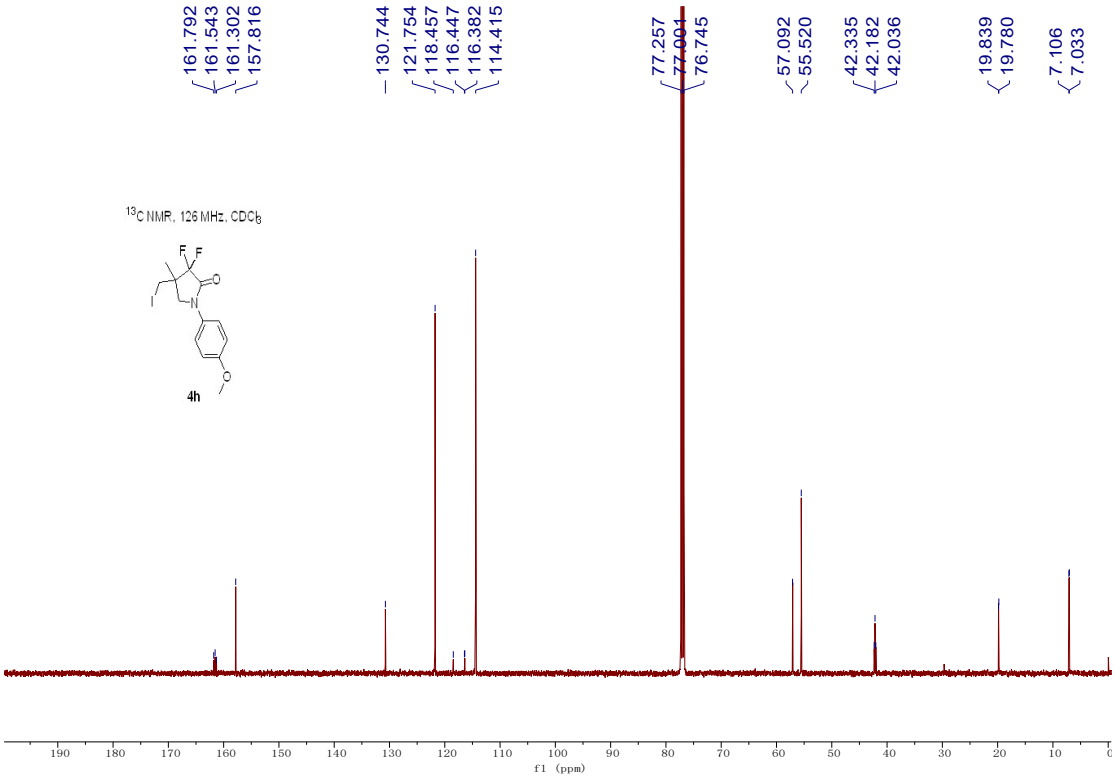
7.511
7.260
6.948
6.930
3.814
3.770
3.750
3.525
3.509
3.505
3.492
3.310
3.289
1.414
1.410
1H NMR, 500 MHz, CDCl3
4h
2.00
2.02
3.02
1.00
2.06
1.01
3.00
f1 (ppm)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118.457
116.447
116.382
114.415
77.257
77.001
76.745
57.092
55.520
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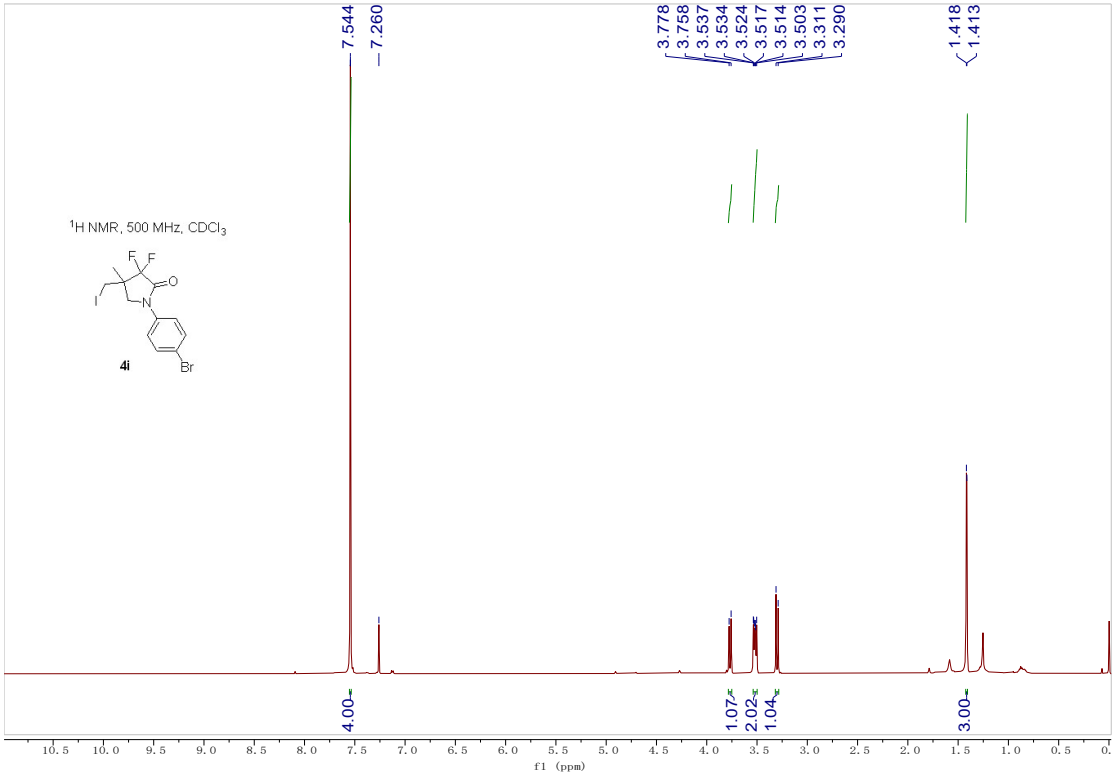
42.182
42.036
19.839
19.780
7.106
7.033
13C NMR, 126 MHz, CDCl3
4h
f1 (ppm)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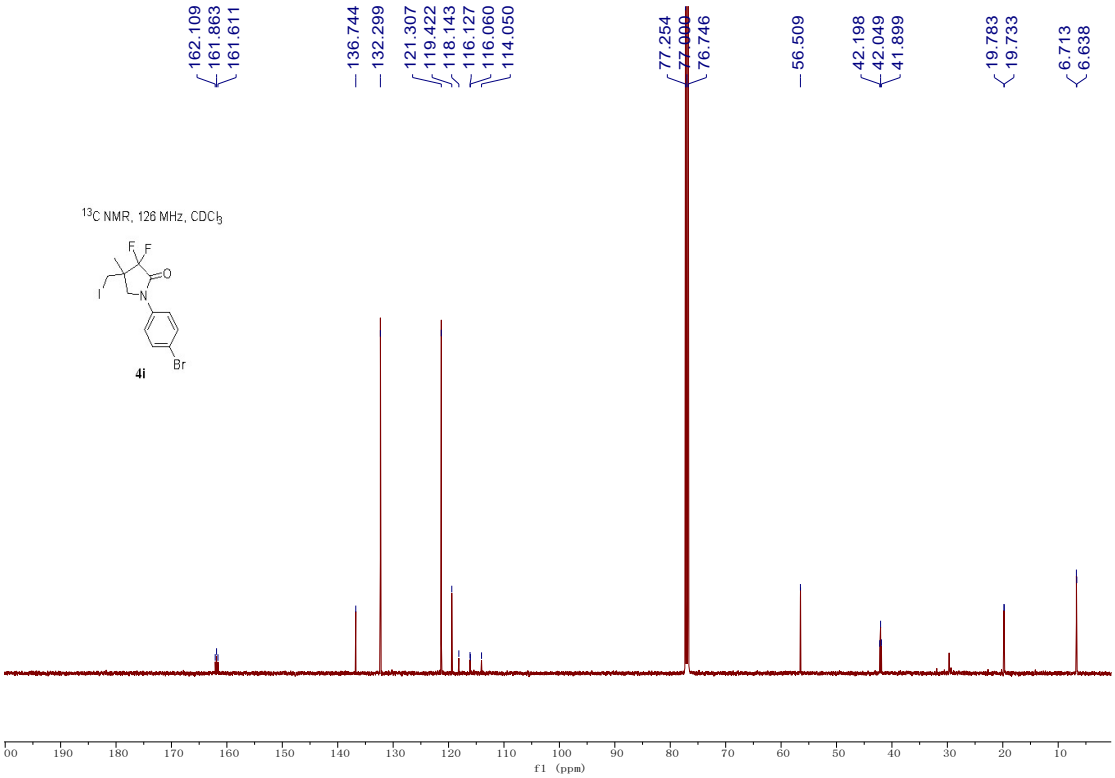
7.260
3.778
3.758
3.537
3.534
3.524
3.517
3.514
3.503
3.311
3.290
1.418
1.413
1H NMR, 500 MHz, CDCl3
4i
4.00
1.07
2.02
1.04
3.00
f1 (ppm)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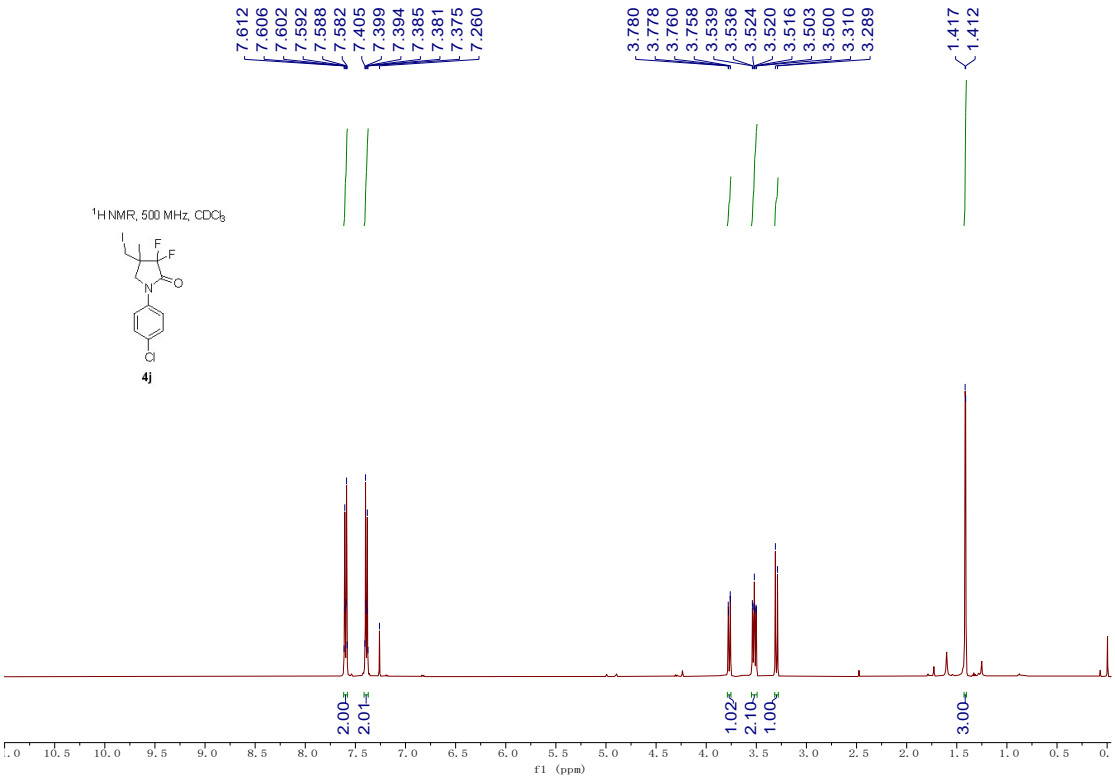
132.299
121.307
119.422
118.143
116.127
116.060
114.050
77.254
77.000
76.746
56.509
42.198
42.049
41.899
19.783
19.733
6.713
6.638
13C NMR, 126 MHz, CDCl3
F F
O
I
N
Br
4i
f1 (ppm)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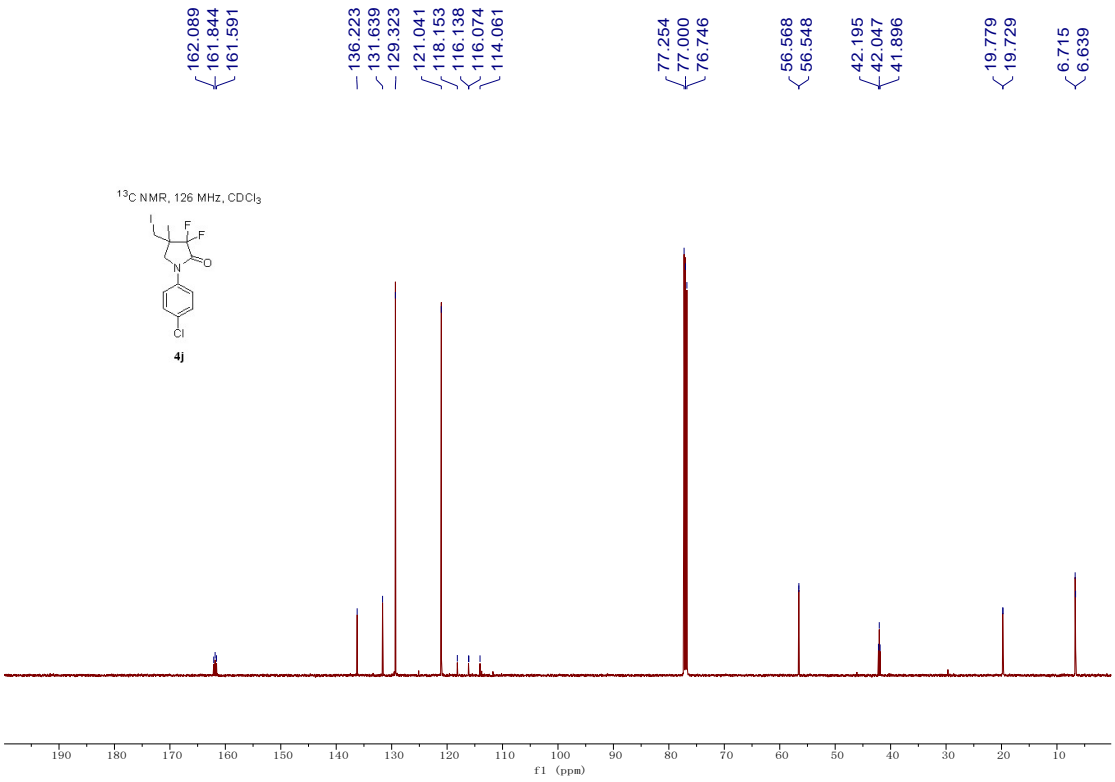
7.606
7.602
7.592
7.588
7.582
7.405
7.399
7.394
7.385
7.381
7.375
7.260
3.780
3.778
3.760
3.758
3.539
3.536
3.524
3.520
3.516
3.503
3.500
3.310
3.289
1.417
1.412
1H NMR, 500 MHz, CDCl3
I
F
F
O
N
Cl
4j
2.00
2.01
1.02
2.10
1.00
3.00
f1 (ppm)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161.591
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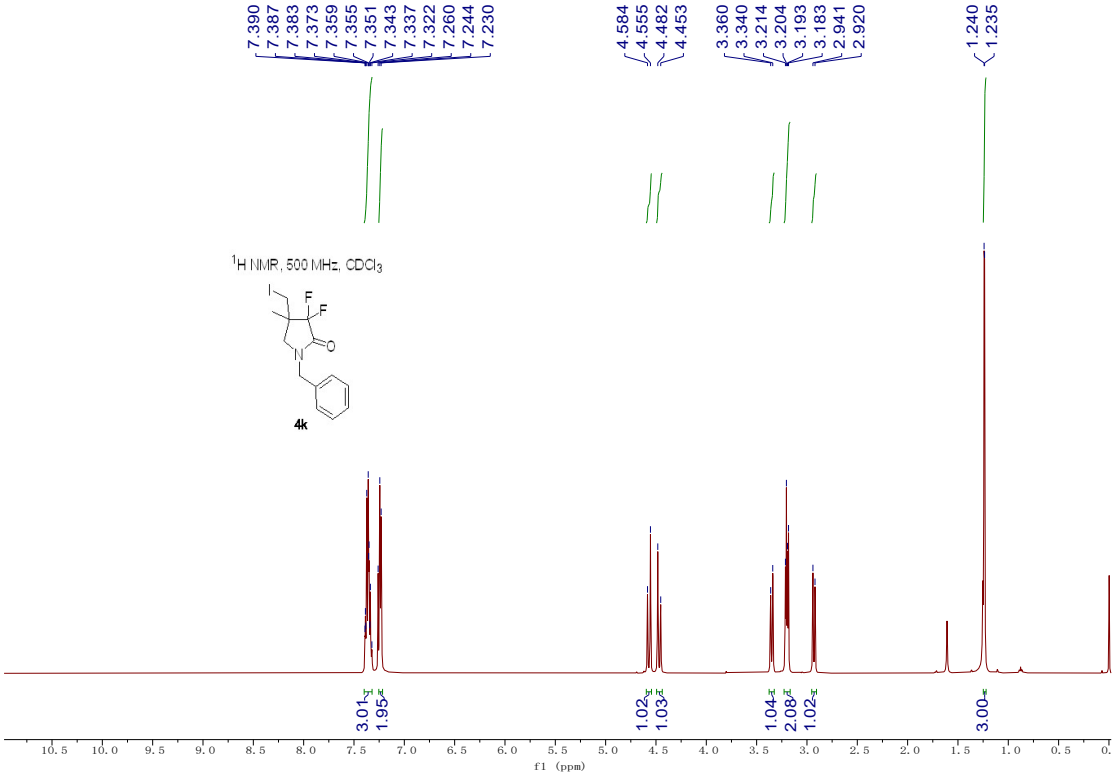
131.639
129.323
121.041
118.153
116.138
116.074
114.061
77.254
77.000
76.746
56.568
56.548
42.195
42.047
41.896
19.779
19.729
6.715
6.639
13C NMR, 126 MHz, CDCl3
4j
f1 (ppm)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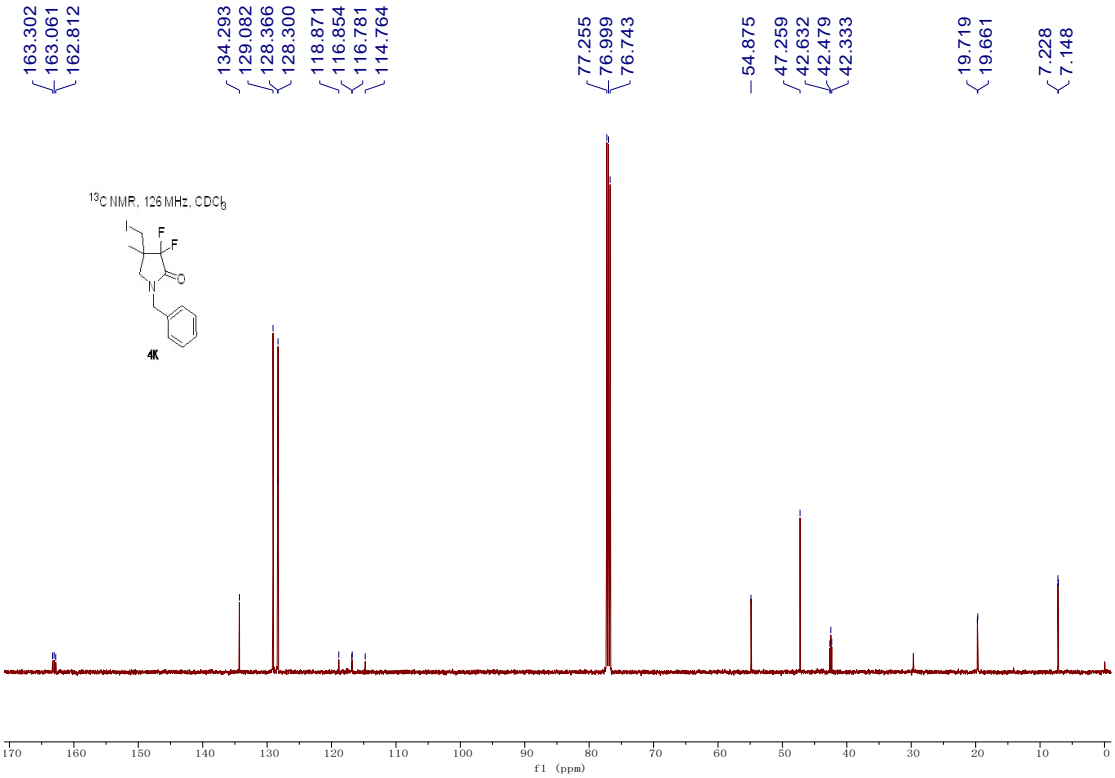
7.387
7.383
7.373
7.359
7.355
7.351
7.343
7.337
7.322
7.260
7.244
7.230
4.584
4.555
4.482
4.453
3.360
3.340
3.214
3.204
3.193
3.183
2.941
2.920
1.240
1.235
1H NMR, 500 MHz, CDCl3
4k
3.01
1.95
1.02
1.03
1.04
2.08
1.02
3.00
f1 (ppm)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163.061
162.812
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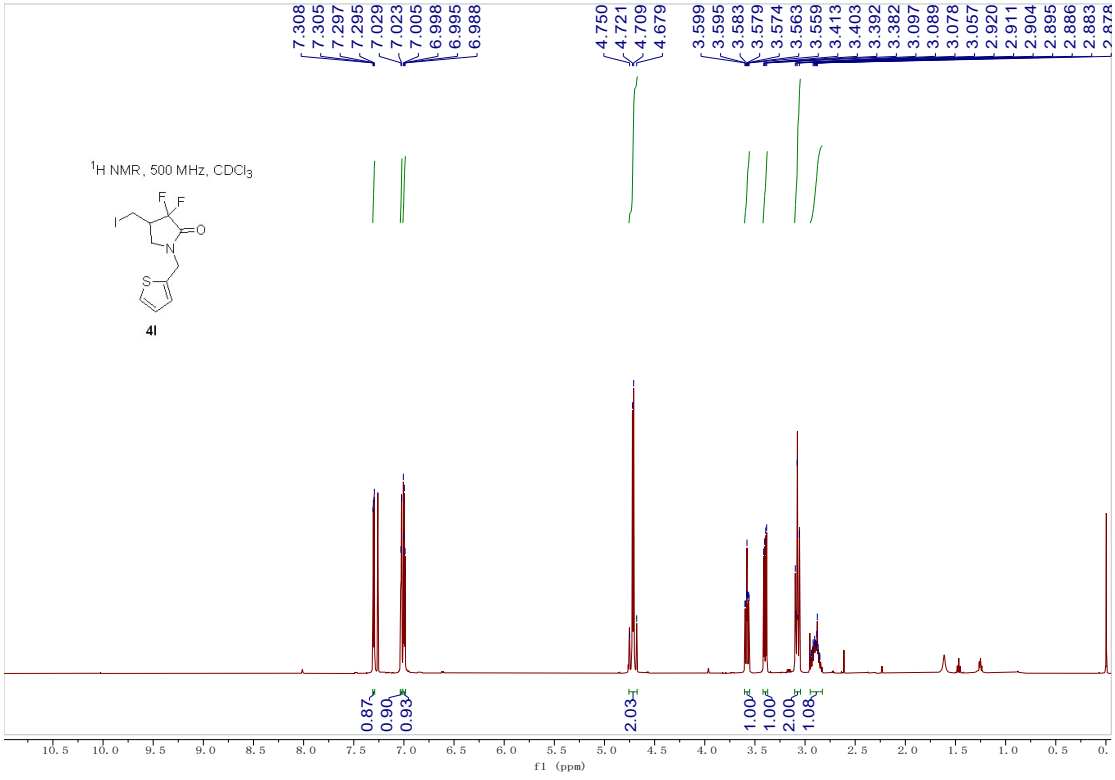
128.366
128.300
118.871
116.854
116.781
114.764
77.255
76.999
76.743
54.875
47.259
42.632
42.479
42.333
19.719
19.661
7.228
7.148
13C NMR, 126 MHz, CDCl3
4K
f1 (ppm)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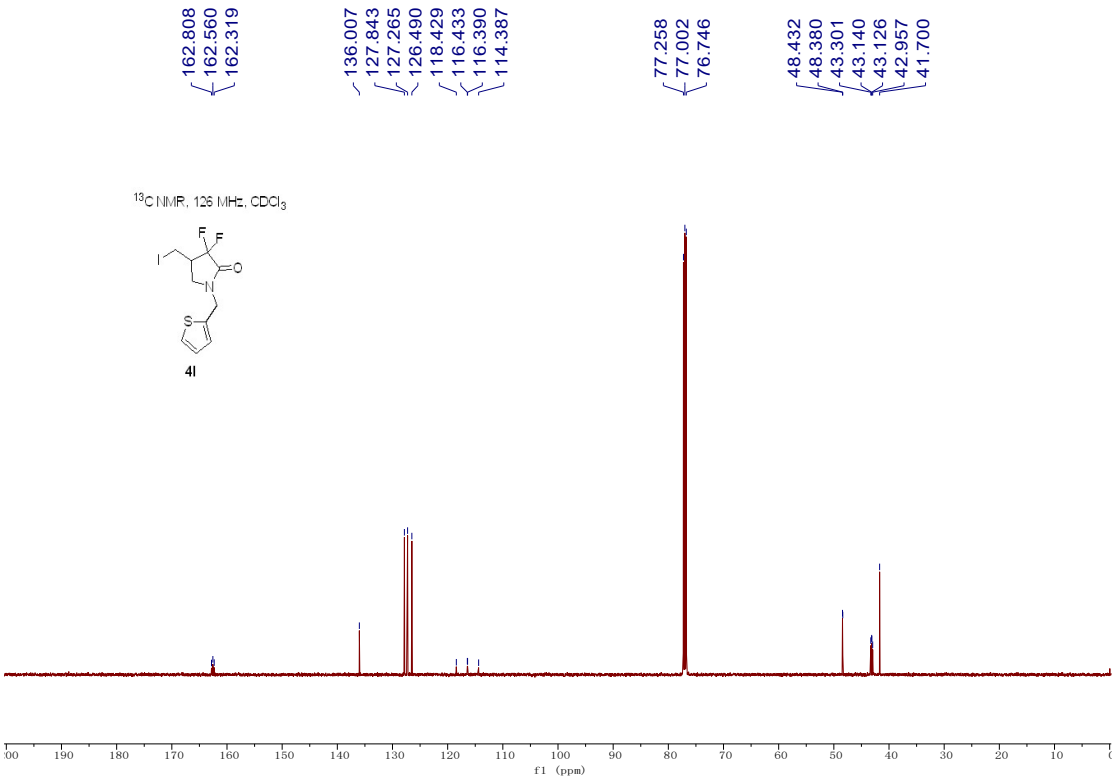
7.305
7.297
7.295
7.029
7.023
7.005
6.998
6.995
6.988
4.750
4.721
4.709
4.679
3.599
3.595
3.583
3.579
3.574
3.563
3.559
3.413
3.403
3.392
3.382
3.097
3.089
3.078
3.057
2.920
2.911
2.904
2.895
2.886
2.883
1H NMR, 500 MHz, CDCl3
4I
0.87
0.90
0.93
2.03
1.00
1.00
2.00
1.08
f1 (ppm)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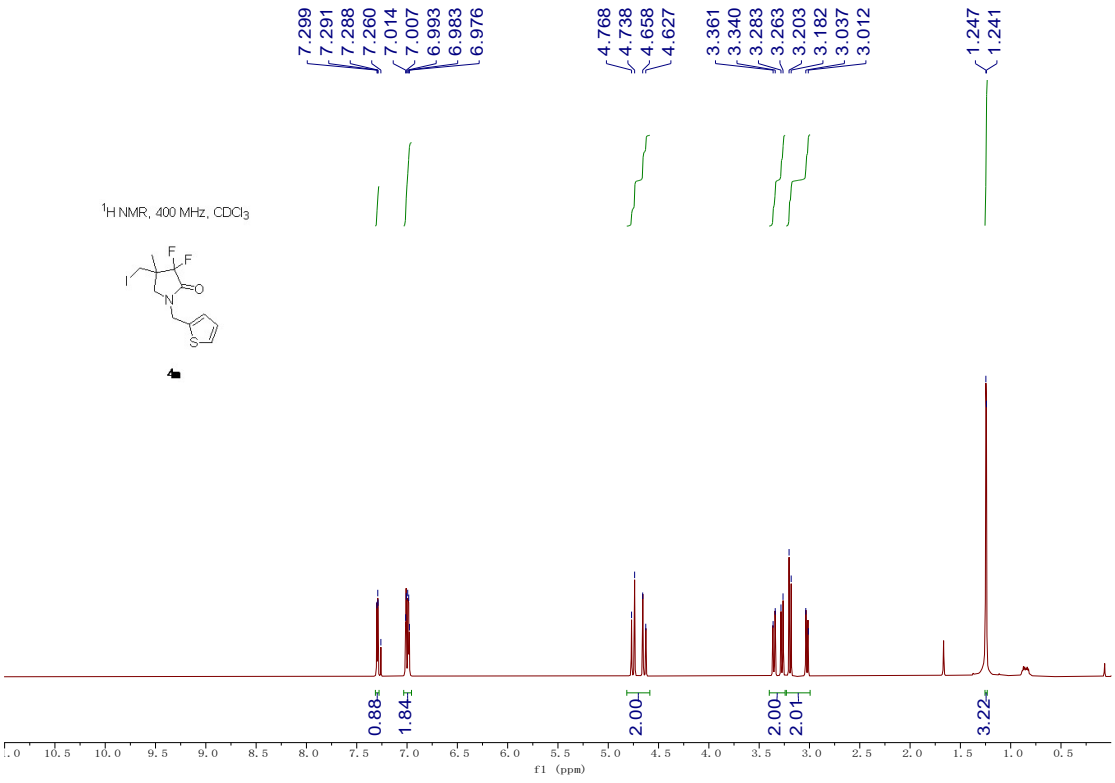
116.390
114.387
77.258
77.002
76.746
48.432
48.380
43.301
43.140
43.126
42.957
41.700
13C NMR, 126 MHz, CDCl3
4l
f1 (ppm)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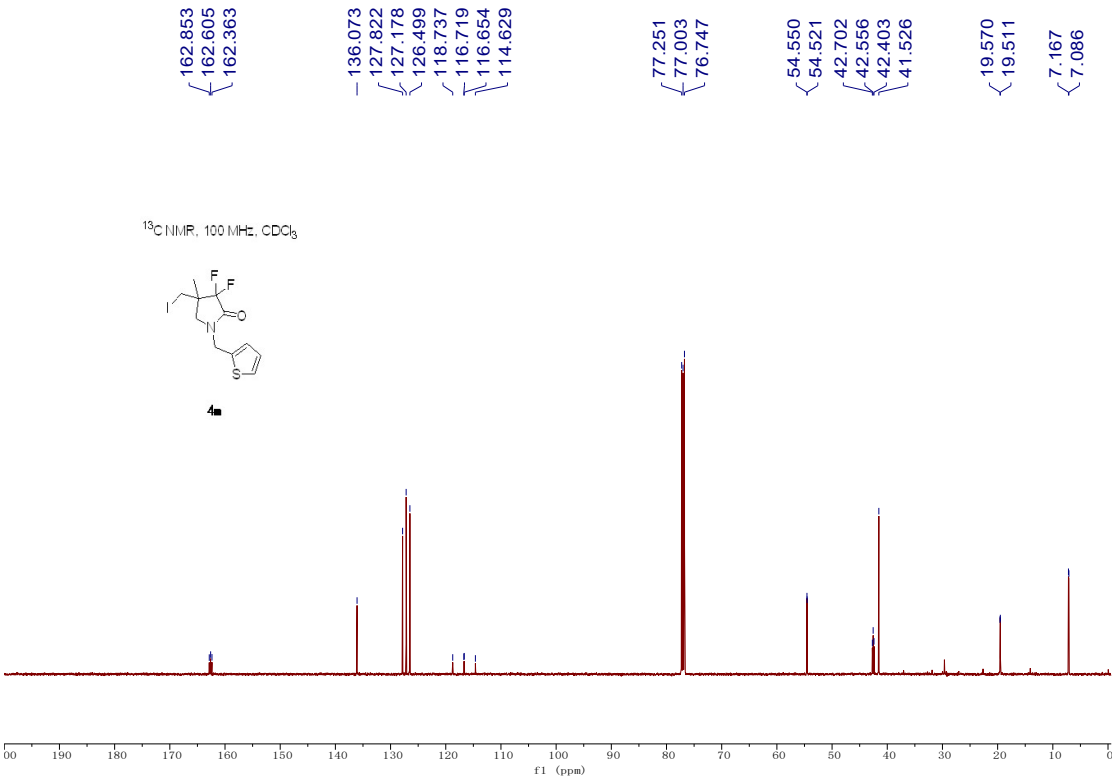
7.291
7.288
7.260
7.014
7.007
6.993
6.983
6.976
4.768
4.738
4.658
4.627
3.361
3.340
3.283
3.263
3.203
3.182
3.037
3.012
1.247
1.241
1H NMR, 400 MHz, CDCl3
0.88
1.84
2.00
2.00
2.01
3.22
f1 (ppm)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127.178
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118.737
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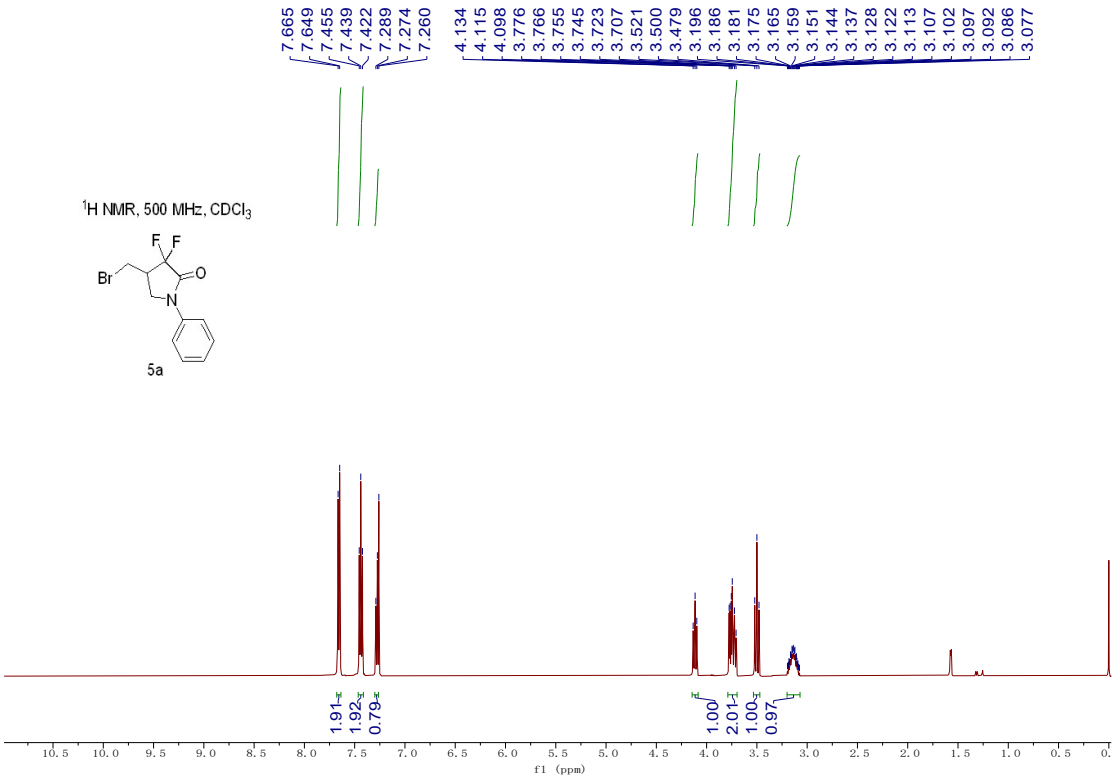
114.629
77.251
77.003
76.747
54.550
54.521
42.702
42.556
42.403
41.526
19.570
19.511
7.167
7.086
13C NMR, 100 MHz, CDCl3
4m
f1 (ppm)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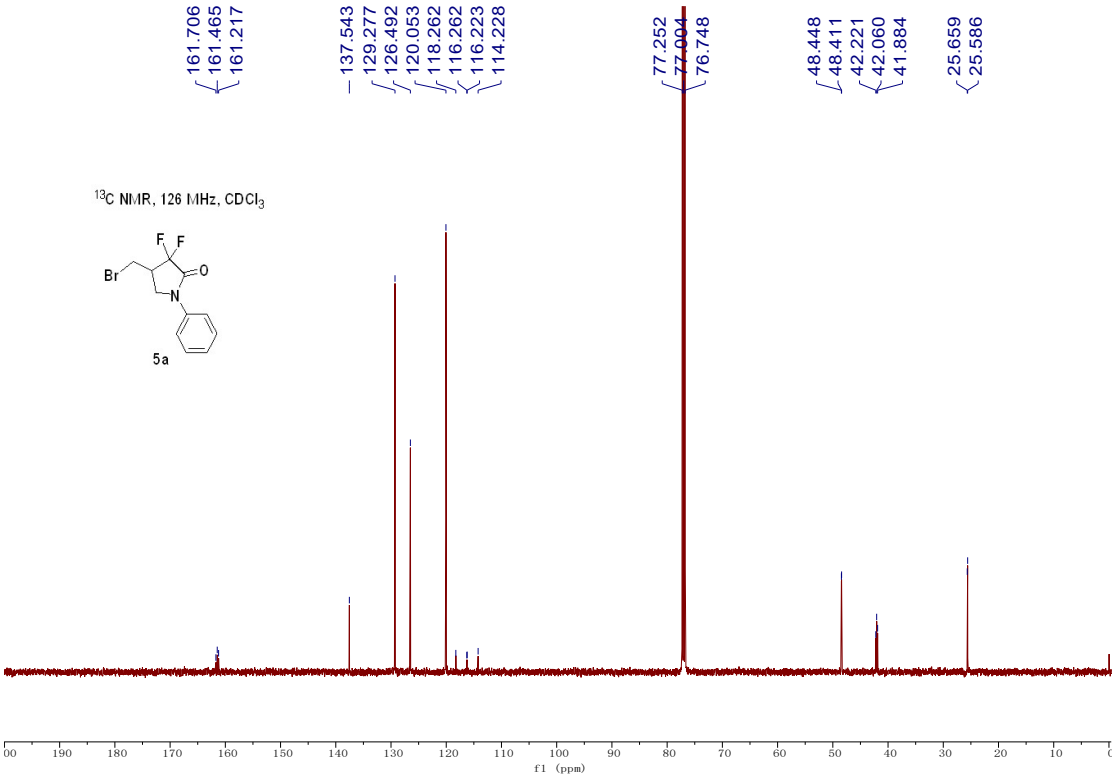
7.274
7.260
4.134
4.115
4.098
3.776
3.766
3.755
3.745
3.723
3.707
3.521
3.500
3.479
3.196
3.186
3.181
3.175
3.165
3.159
3.151
3.144
3.137
3.128
3.122
3.113
3.107
3.102
3.097
3.092
3.086
3.077
1H NMR, 500 MHz, CDCl3
Br
5a
1.91
1.92
0.79
1.00
2.01
1.00
0.97
f1 (ppm)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116.223
114.228
77.252
77.004
76.748
48.448
48.411
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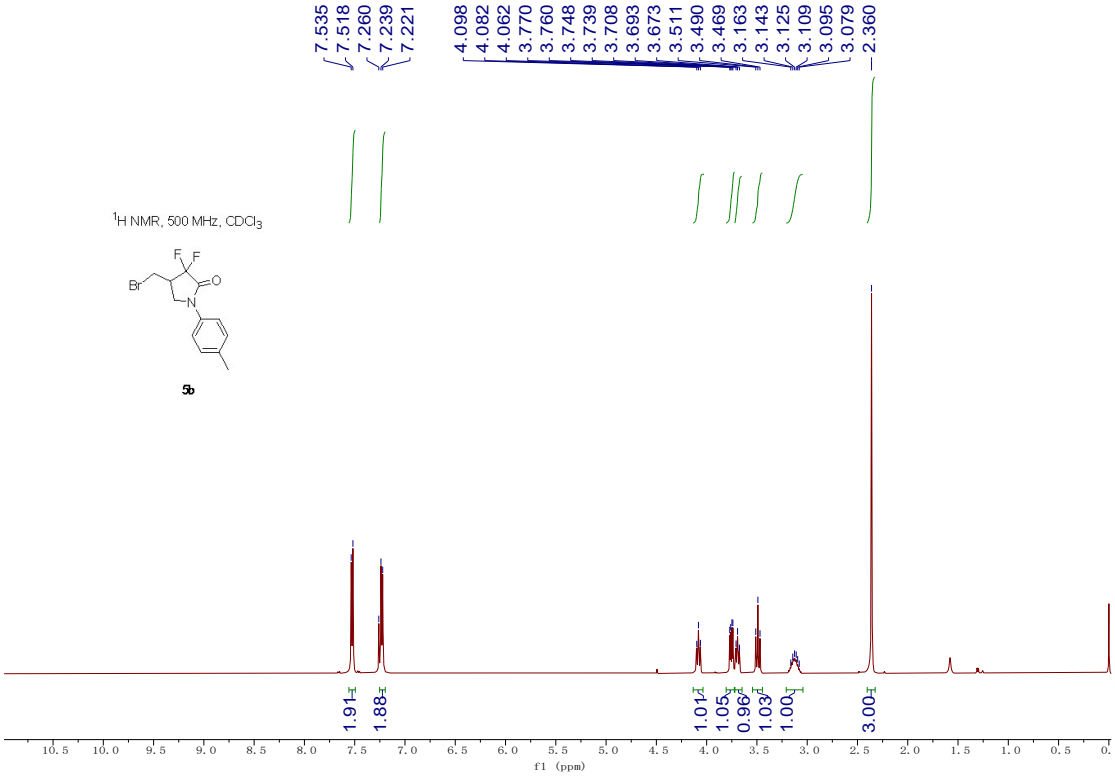
25.659
25.586
13C NMR, 126 MHz, CDCl3
F F
Br
O
N
5a
f1 (ppm)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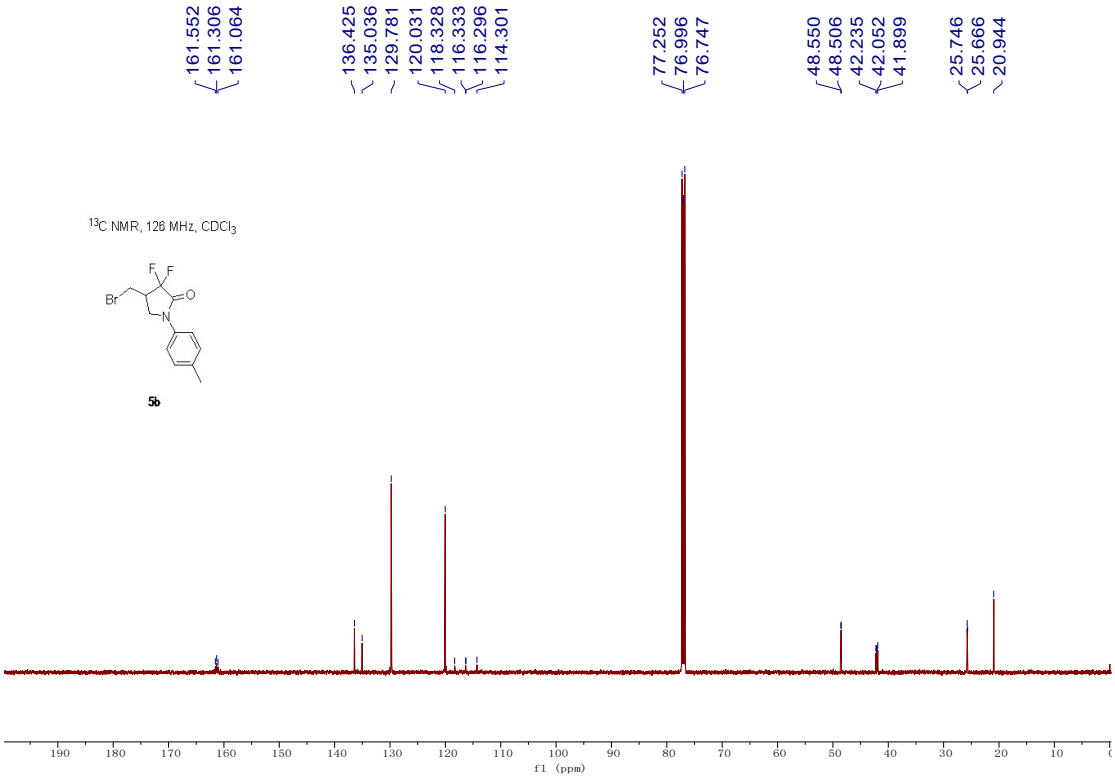
4.082
4.062
3.770
3.760
3.748
3.739
3.708
3.693
3.673
3.511
3.490
3.469
3.163
3.143
3.125
3.109
3.095
3.079
2.360
1H NMR, 500 MHz, CDCl3
F F
Br
O
N
5b
1.91
1.88
1.01
1.05
0.96
1.03
1.00
3.00
f1 (ppm)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114.301
77.252
76.996
76.747
48.550
48.506
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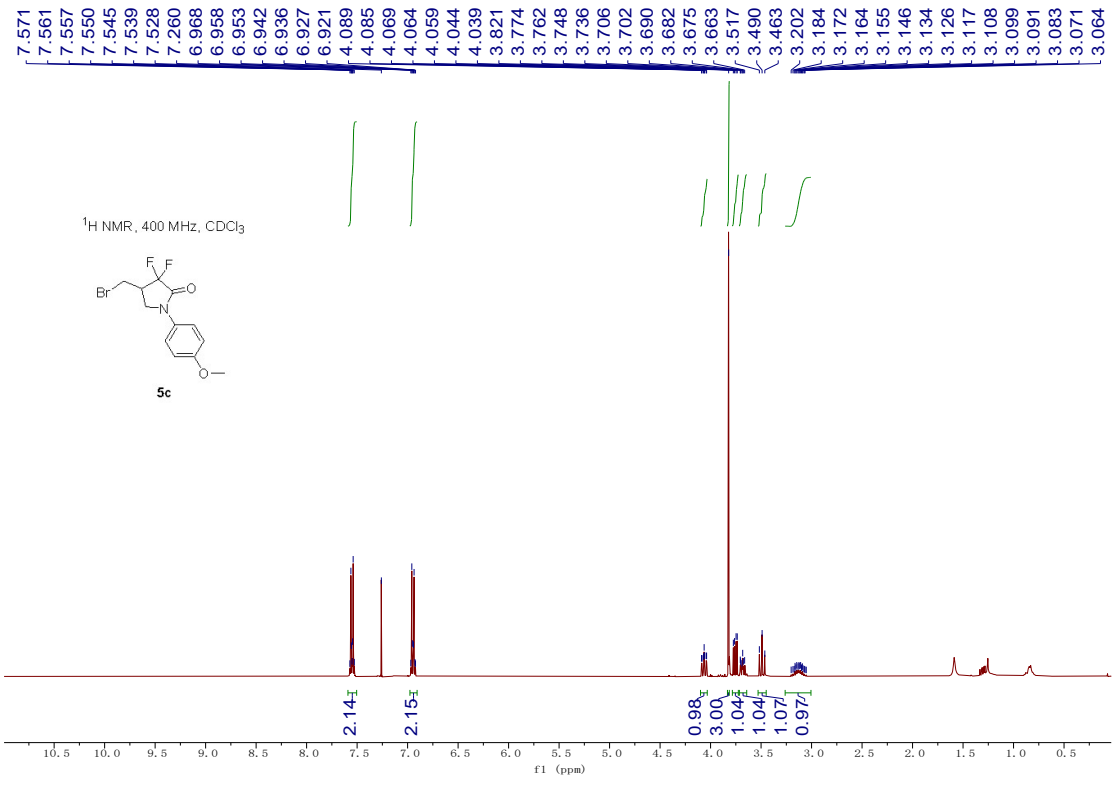
20.944
13C NMR, 126 MHz, CDCl3
5b
f1 (ppm)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7.528
7.260
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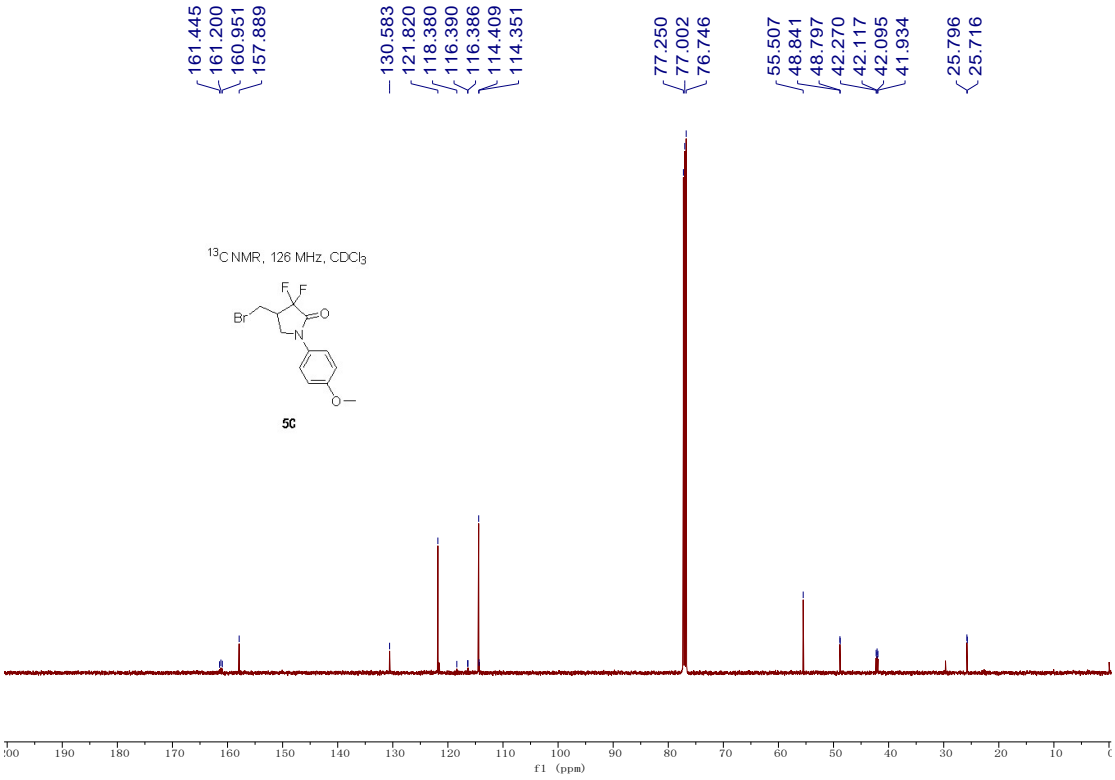
6.958
6.953
6.942
6.936
6.927
6.921
4.089
4.085
4.069
4.064
4.059
4.044
4.039
3.821
3.774
3.762
3.748
3.736
3.706
3.702
3.690
3.682
3.675
3.663
3.517
3.490
3.463
3.202
3.184
3.172
3.164
3.155
3.146
3.134
3.126
3.117
3.108
3.099
3.091
3.083
3.071
3.064
1H NMR, 400 MHz, CDCl3
5c
2.14
2.15
0.98
3.00
1.04
1.04
1.07
0.97
f1 (ppm)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116.390
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114.409
114.351
77.250
77.002
76.746
55.507
48.841
48.797
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42.117
42.095
41.934
25.796
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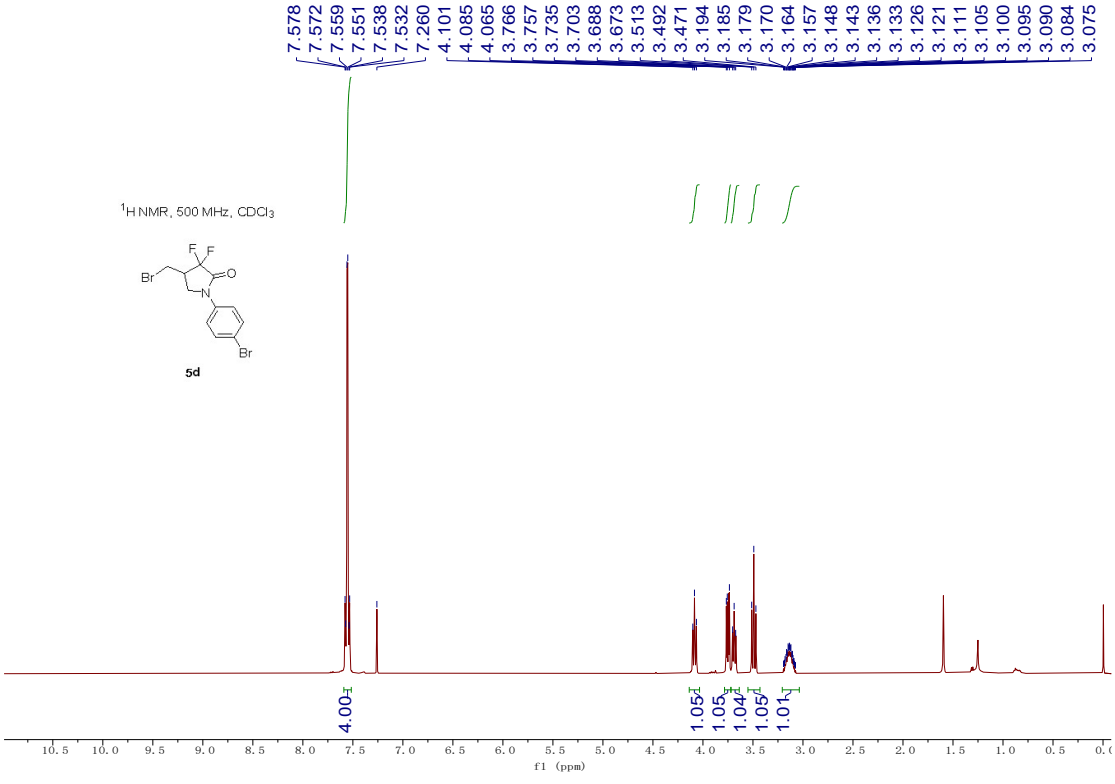
13C NMR, 126 MHz, CDCl3
5c
f1 (ppm)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4.085
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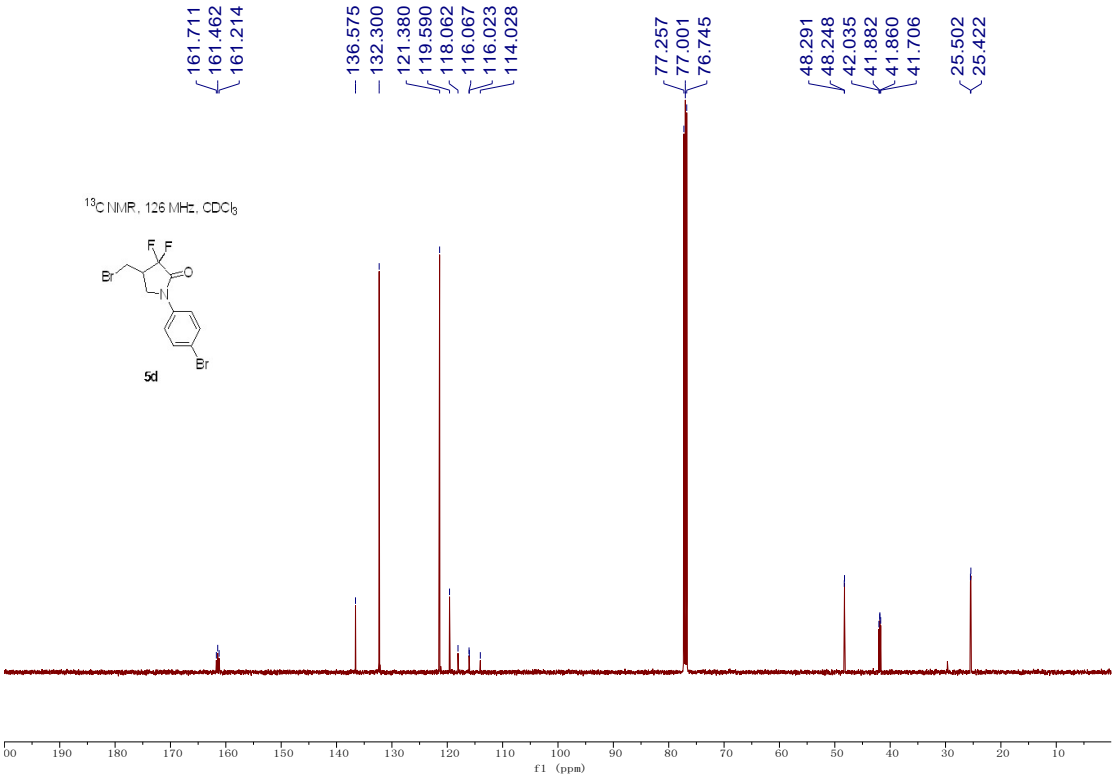
3.735
3.703
3.688
3.673
3.513
3.492
3.471
3.194
3.185
3.179
3.170
3.164
3.157
3.148
3.143
3.136
3.133
3.126
3.121
3.111
3.105
3.100
3.095
3.090
3.084
3.075
1H NMR, 500 MHz, CDCl3
5d
4.00
1.05
1.05
1.04
1.05
1.01
f1 (ppm)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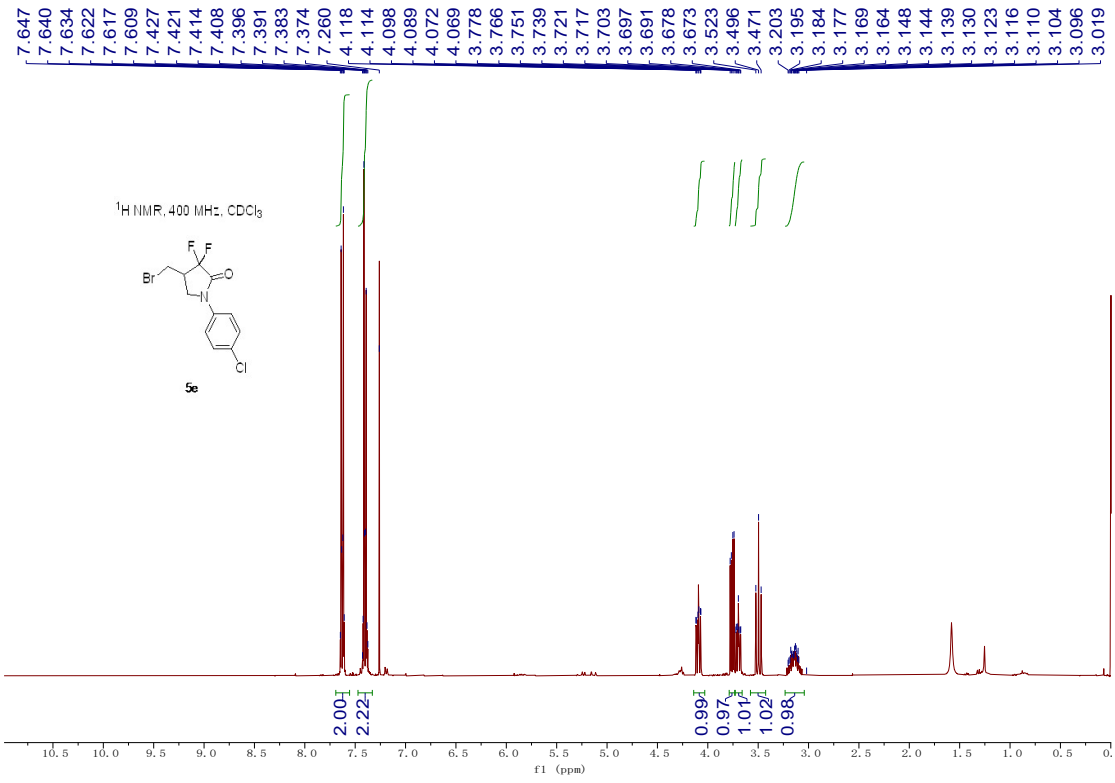
118.062
116.067
116.023
114.028
77.257
77.001
76.745
48.291
48.248
42.035
41.882
41.860
41.706
25.502
25.422
13C NMR, 126 MHz, CDCl3
F F
Br
O
N
Br
5d
f1 (ppm)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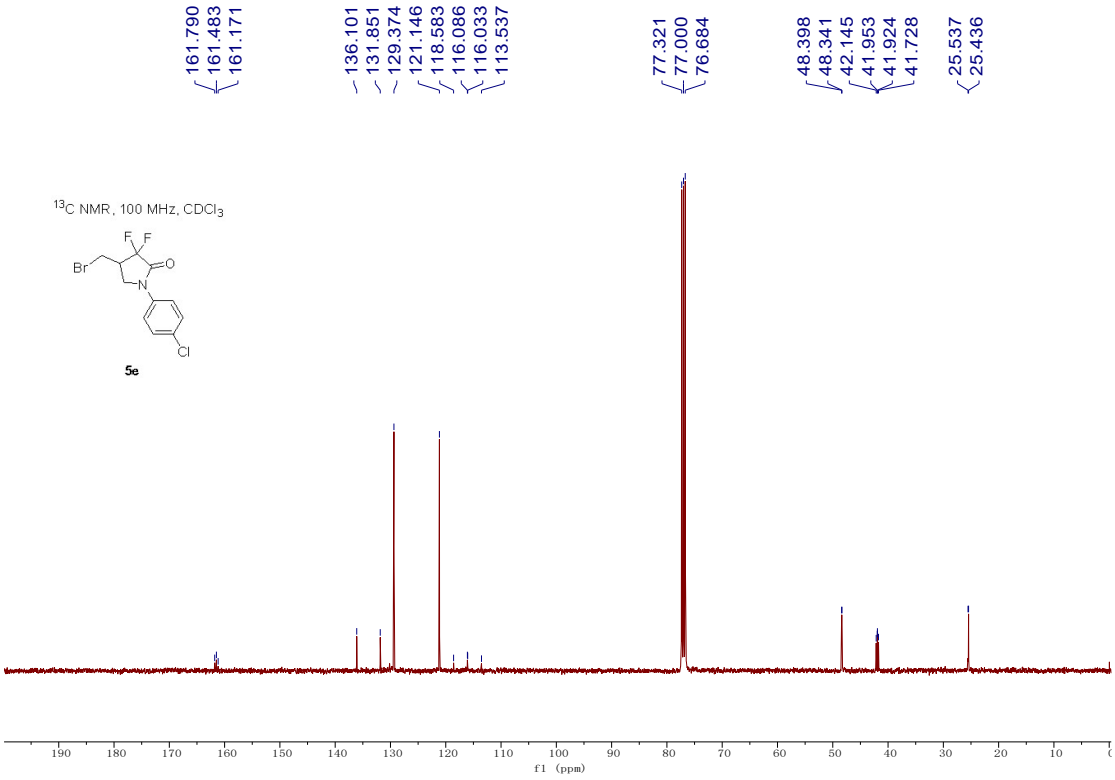
7.383
7.374
7.260
4.118
4.114
4.098
4.089
4.072
4.069
3.778
3.766
3.751
3.739
3.721
3.717
3.703
3.697
3.691
3.678
3.673
3.523
3.496
3.471
3.203
3.195
3.184
3.177
3.169
3.164
3.148
3.144
3.139
3.130
3.123
3.116
3.110
3.104
3.096
3.019
1H NMR, 400 MHz, CDCl3
F F
Br
O
N
Cl
5e
2.00
2.22
0.99
0.97
1.01
1.02
0.98
f1 (ppm)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116.033
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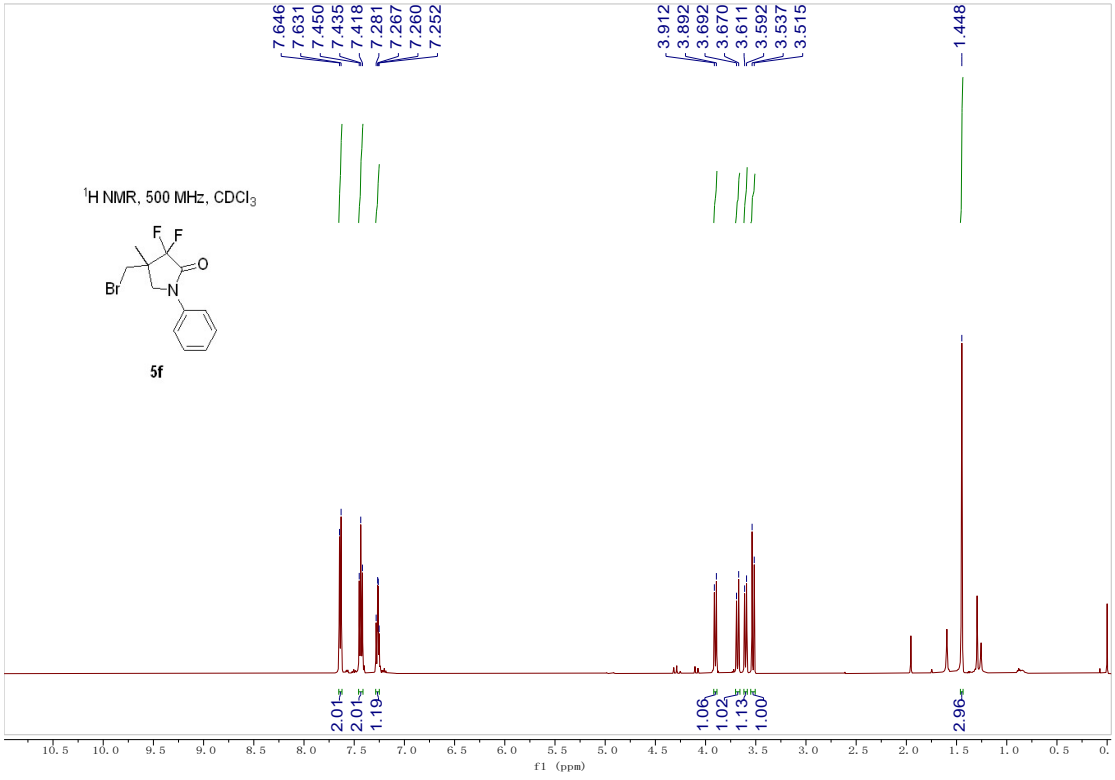
77.000
76.684
48.398
48.341
42.145
41.953
41.924
41.728
25.537
25.436
13C NMR, 100 MHz, CDCl3
F
F
Br
O
N
Cl
5e
f1 (ppm)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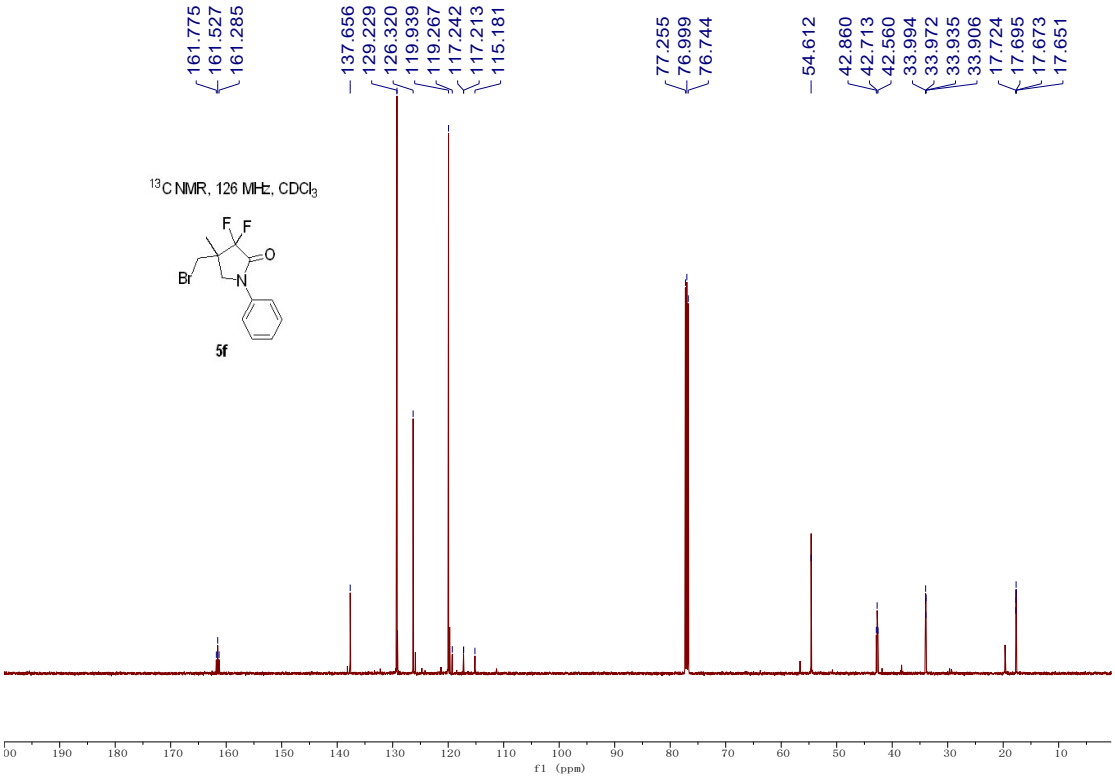
7.631
7.450
7.435
7.418
7.281
7.267
7.260
7.252
3.912
3.892
3.692
3.670
3.611
3.592
3.537
3.515
1.448
1H NMR, 500 MHz, CDCl3
F
F
Br
O
N
5f
2.01
2.01
1.19
1.06
1.02
1.13
1.00
2.96
f1 (ppm)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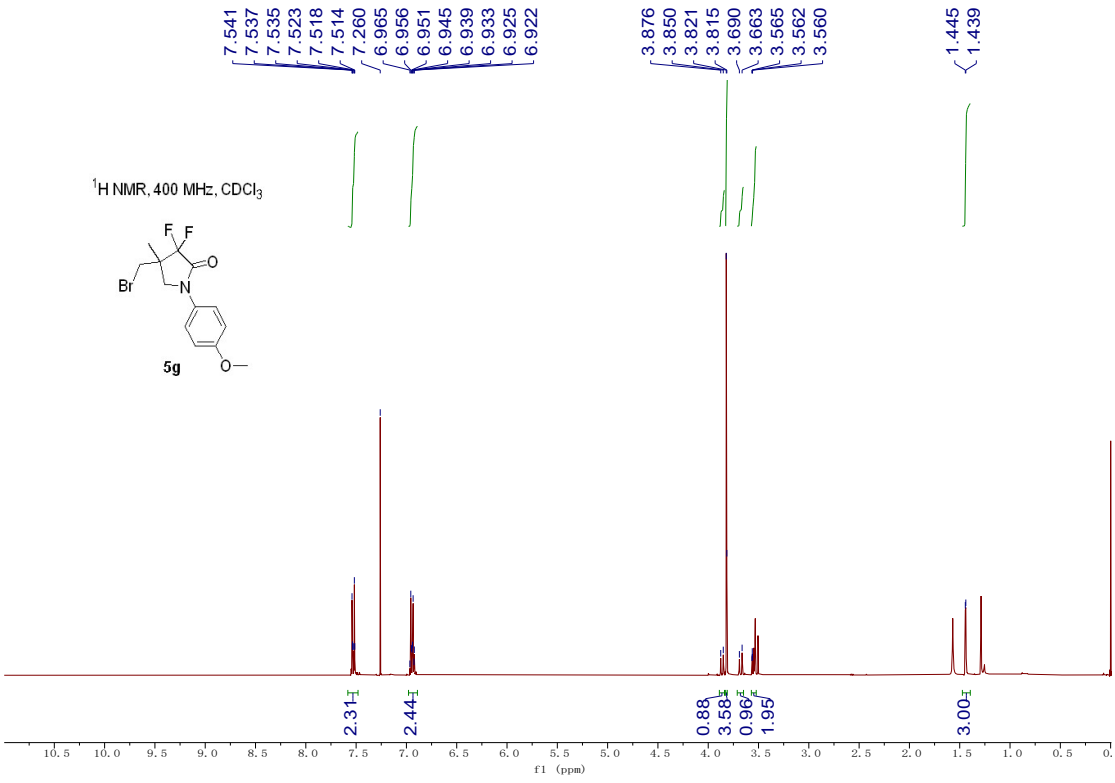
161.527
161.285
137.656
129.229
126.320
119.939
119.267
117.242
117.213
115.181
77.255
76.999
76.744
54.612
42.860
42.713
42.560
33.994
33.972
33.935
33.906
17.724
17.695
17.673
17.651
13C NMR, 126 MHz, CDCl3
F
F
O
Br
N
5f
f1 (ppm)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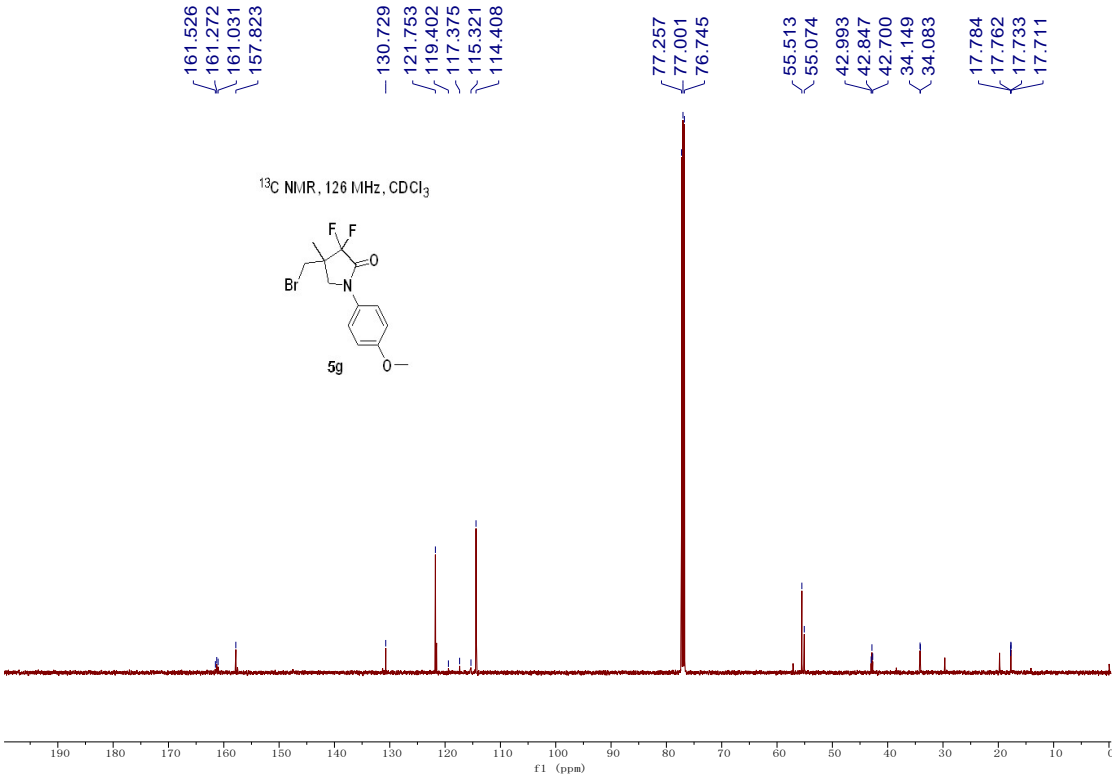
7.537
7.535
7.523
7.518
7.514
7.260
6.965
6.956
6.951
6.945
6.939
6.933
6.925
6.922
3.876
3.850
3.821
3.815
3.690
3.663
3.565
3.562
3.560
1.445
1.439
1H NMR, 400 MHz, CDCl3
F
F
O
Br
N
5g
O
2.31
2.44
0.88
3.58
0.96
1.95
3.00
f1 (ppm)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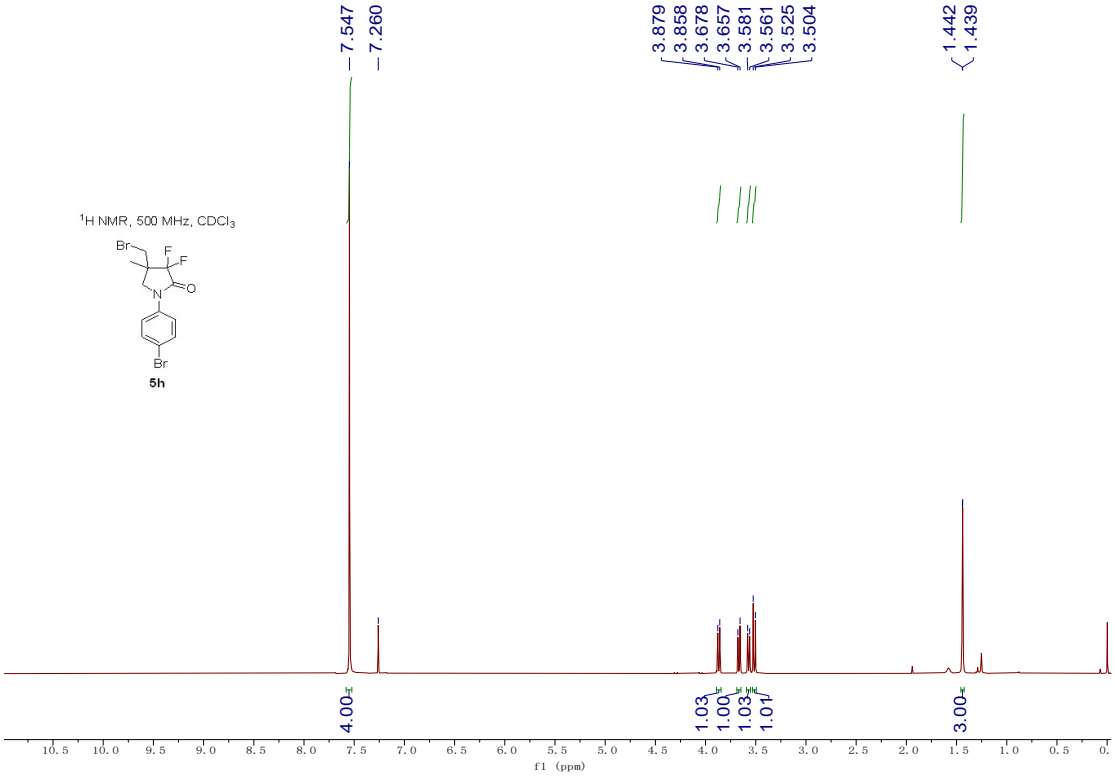
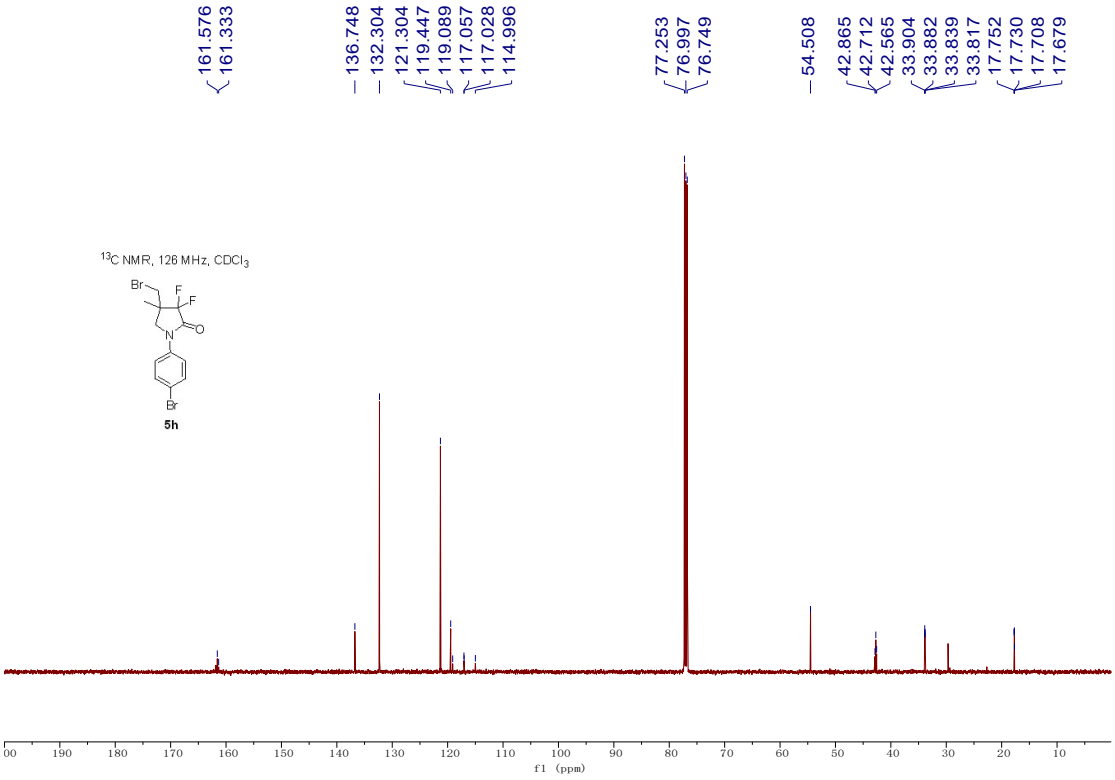
161.272
161.031
157.823
130.729
121.753
119.402
117.375
115.321
114.408
77.257
77.001
76.745
55.513
55.074
42.993
42.847
42.700
34.149
34.083
17.784
17.762
17.733
17.711
13C NMR, 126 MHz, CDCl3
F F
O
Br
N
5g
O
f1 (ppm)


7.547
7.260
3.879
3.858
3.678
3.657
3.581
3.561
3.525
3.504
1.442
1.439
1H NMR, 500 MHz, CDCl3
Br
F
F
O
N
Br
5h
4.00
1.03
1.00
1.03
1.01
3.00
f1 (ppm)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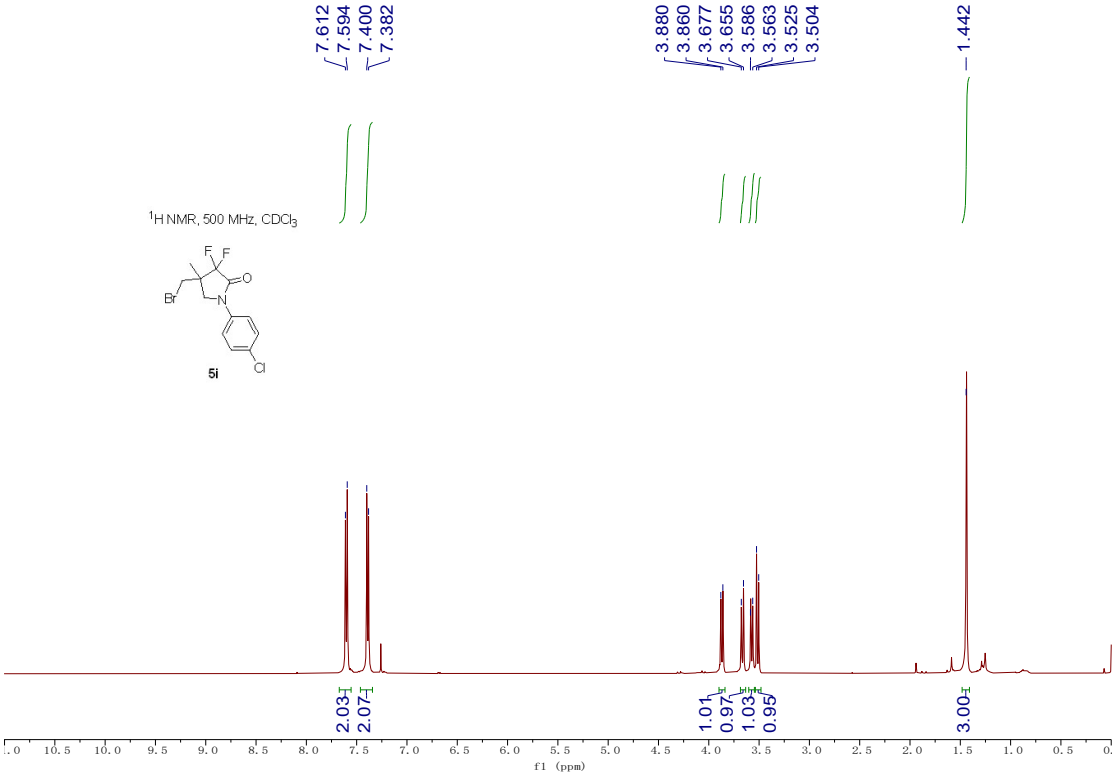
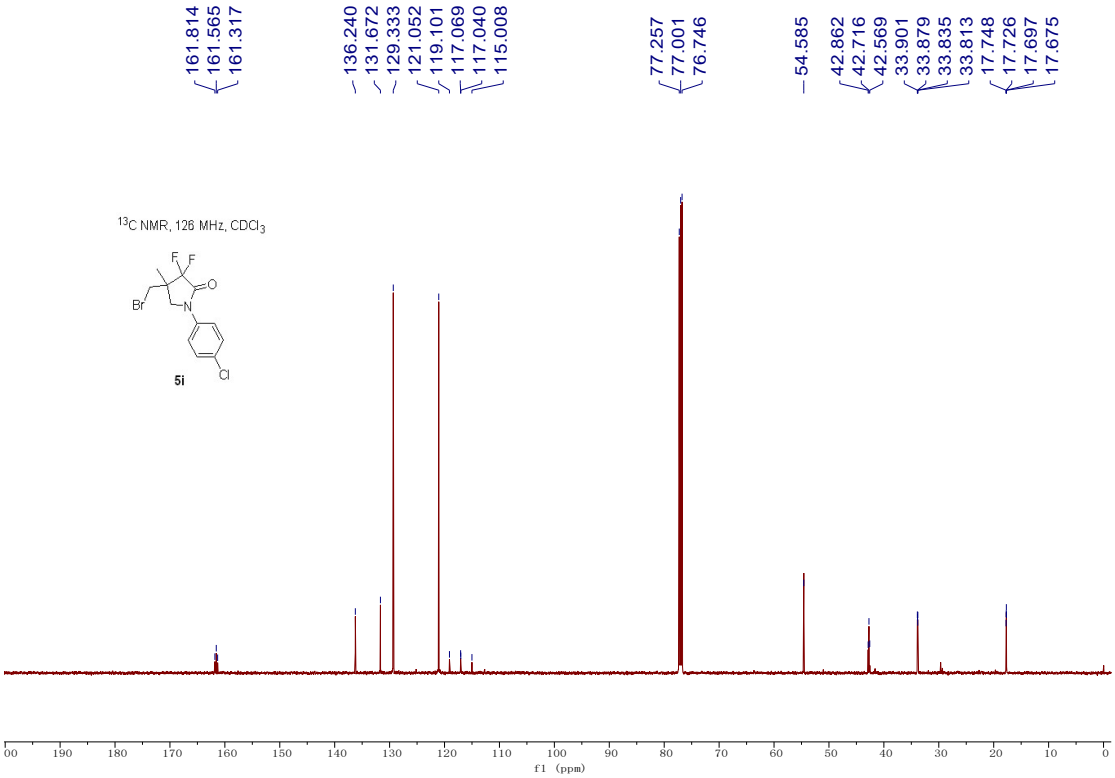
161.333
136.748
132.304
121.304
119.447
119.089
117.057
117.028
114.996
77.253
76.997
76.749
54.508
42.865
42.712
42.565
33.904
33.882
33.839
33.817
17.752
17.730
17.708
17.679
13C NMR, 126 MHz, CDCl3
Br
F
F
O
N
Br
5h
f1 (ppm)


7.612
7.594
7.400
7.382
3.880
3.860
3.677
3.655
3.586
3.563
3.525
3.504
1.442
1H NMR, 500 MHz, CDCl3
F
F
O
Br
N
Cl
5i
2.03
2.07
1.01
0.97
1.03
0.95
3.00
f1 (ppm)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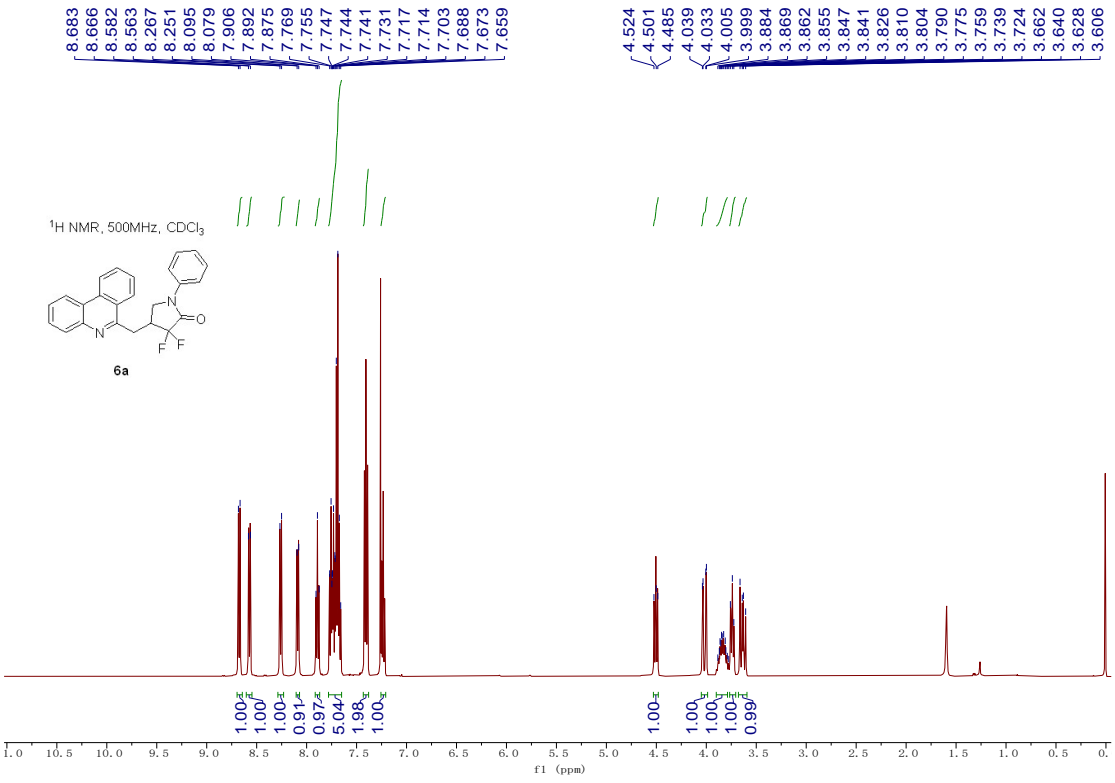
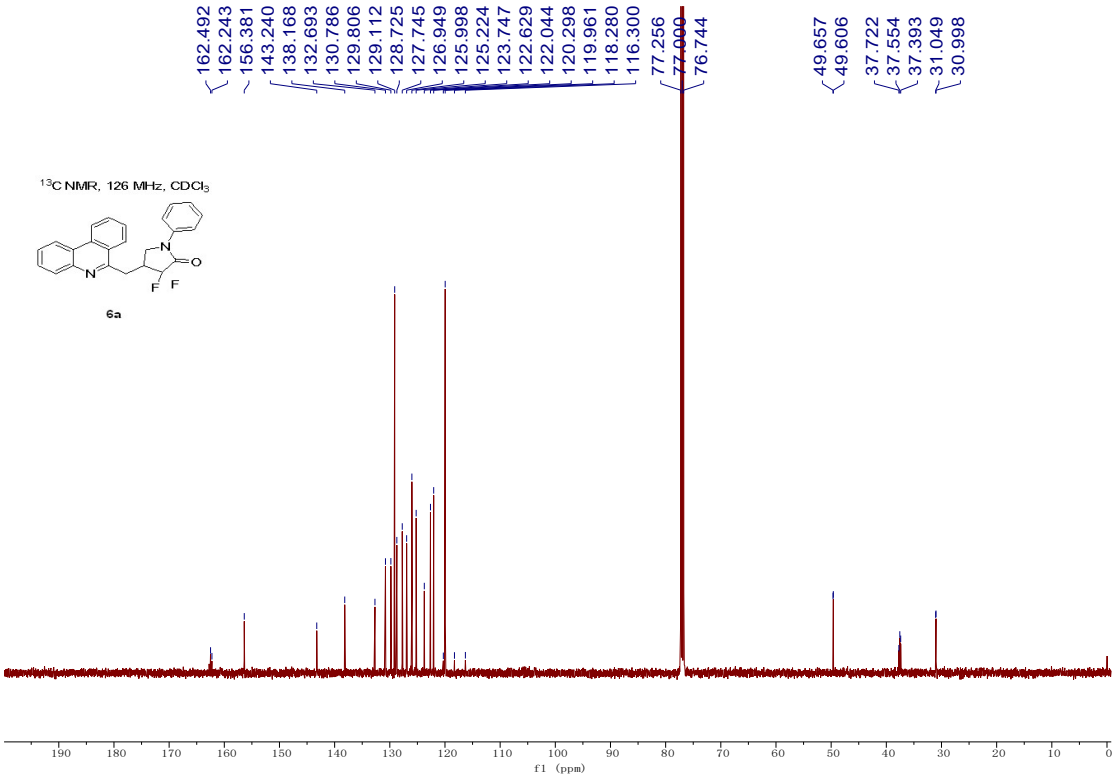
161.565
161.317
136.240
131.672
129.333
121.052
119.101
117.069
117.040
115.008
77.257
77.001
76.746
54.585
42.862
42.716
42.569
33.901
33.879
33.835
33.813
17.748
17.726
17.697
17.675
13C NMR, 126 MHz, CDCl3
5i
f1 (ppm)


8.683
8.666
8.582
8.563
8.267
8.251
8.095
8.079
7.906
7.892
7.875
7.769
7.755
7.747
7.744
7.741
7.731
7.717
7.714
7.703
7.688
7.673
7.659
4.524
4.501
4.485
4.039
4.033
4.005
3.999
3.884
3.869
3.862
3.855
3.847
3.841
3.826
3.810
3.804
3.790
3.775
3.759
3.739
3.724
3.662
3.640
3.628
3.606
1H NMR, 500MHz, CDCl3
6a
1.00
1.00
1.00
0.91
0.97
5.04
1.98
1.00
1.00
1.00
1.00
1.00
0.99
f1 (ppm)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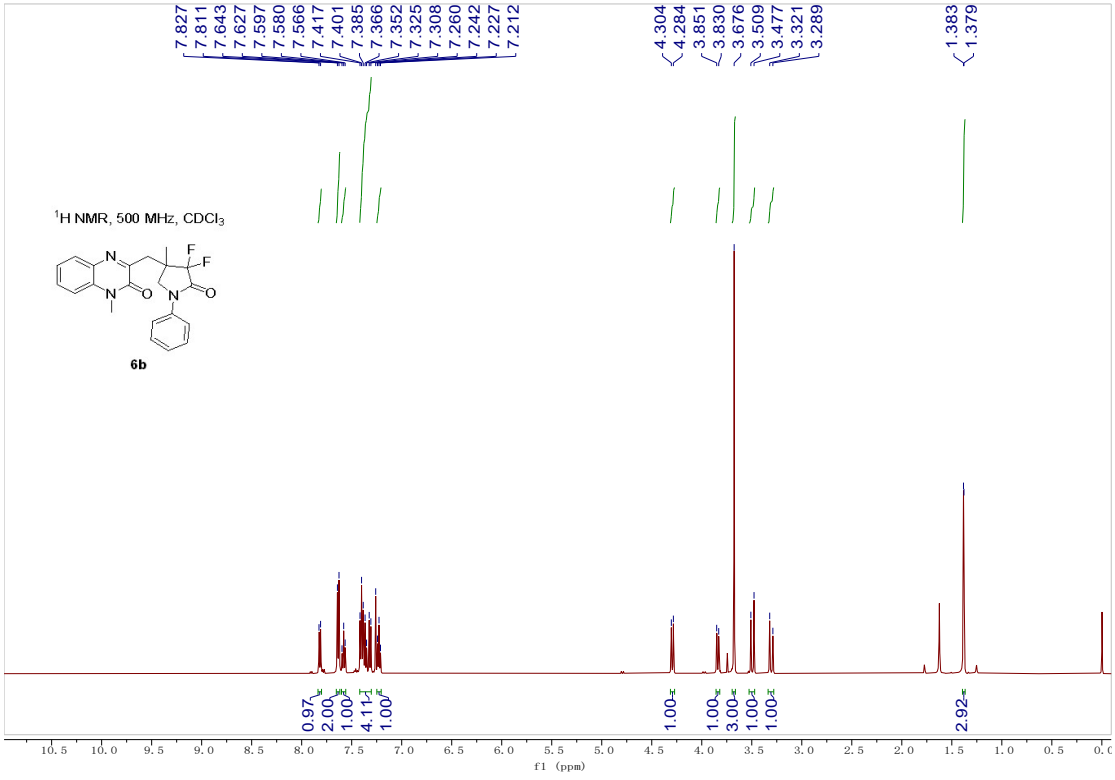
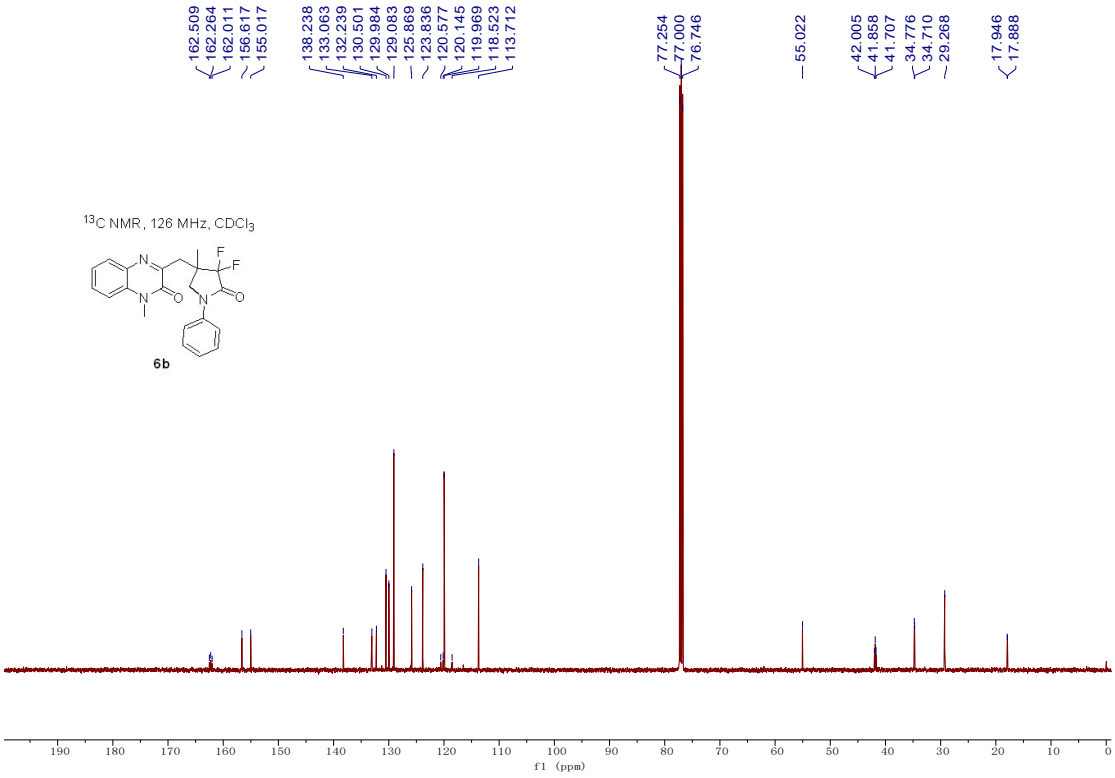
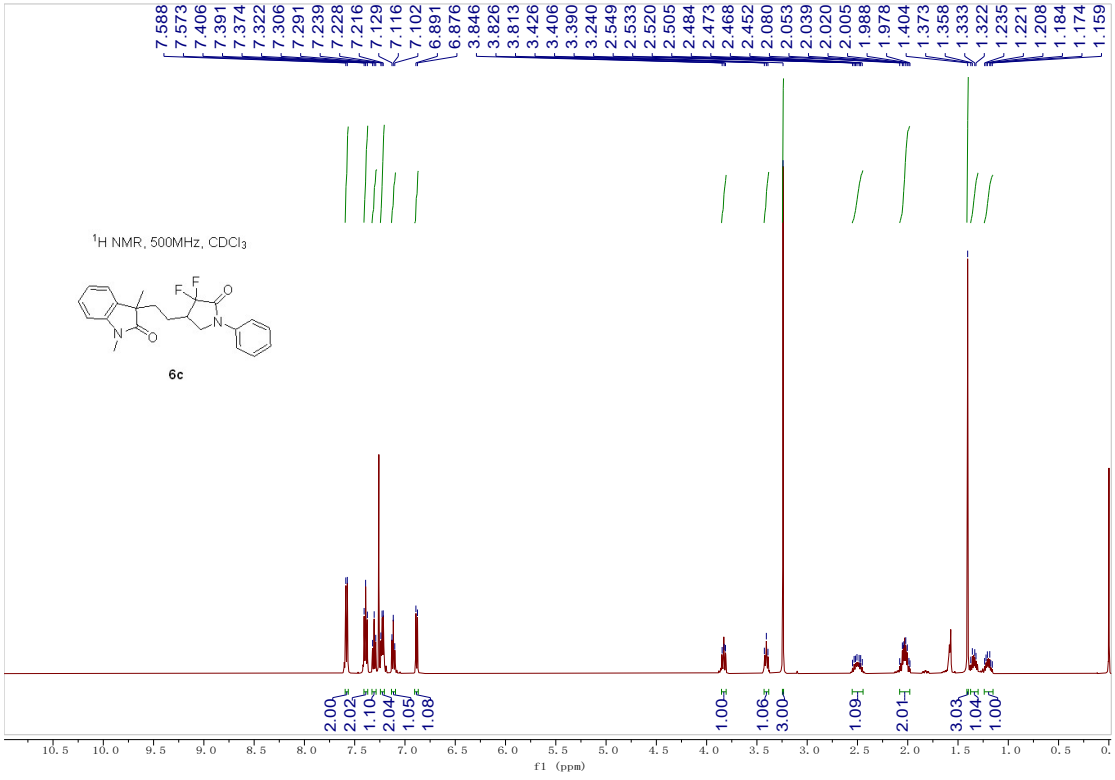
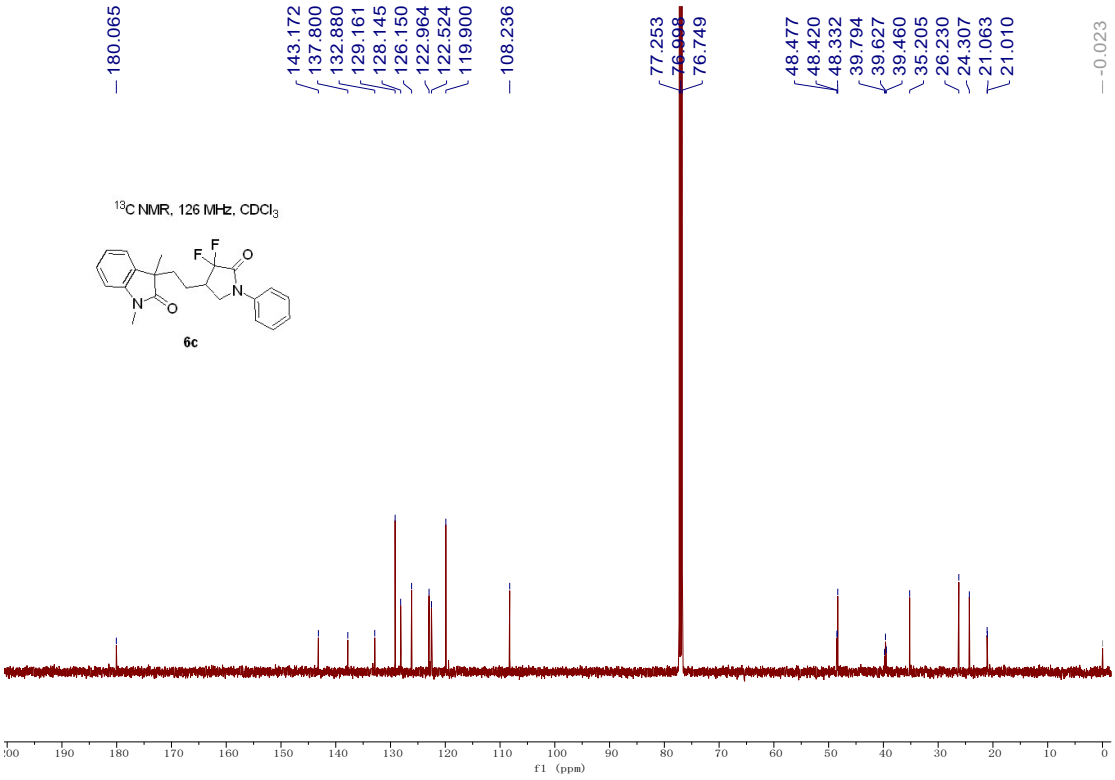
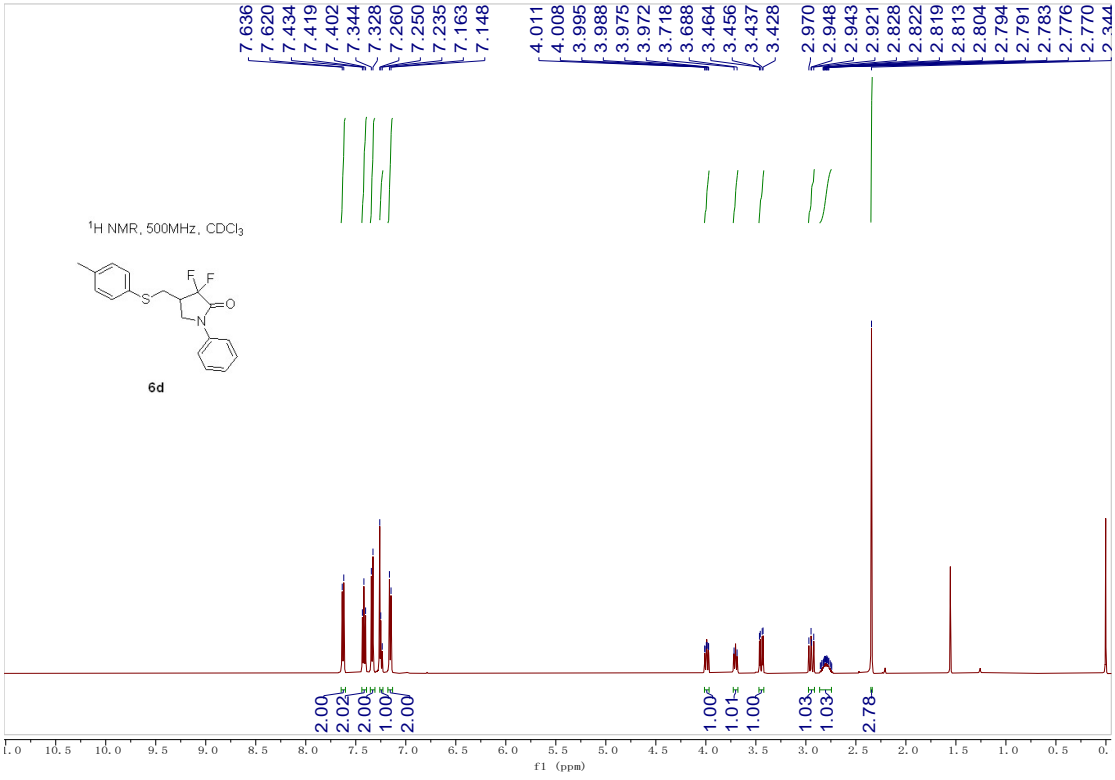
156.381
143.240
138.168
132.693
130.786
129.806
129.112
128.725
127.745
126.949
125.998
125.224
123.747
122.629
122.044
120.298
119.961
118.280
116.300
77.256
77.000
76.744
49.657
49.606
37.722
37.554
37.393
31.049
30.998
13C NMR, 126 MHz, CDCl3
6a
f1 (ppm)


7.827
7.811
7.643
7.627
7.597
7.580
7.566
7.417
7.401
7.385
7.366
7.352
7.325
7.308
7.260
7.242
7.227
7.212
4.304
4.284
3.851
3.830
3.676
3.509
3.477
3.321
3.289
1.383
1.379
1H NMR, 500 MHz, CDCl3
6b
0.97
2.00
1.00
4.11
1.00
1.00
1.00
3.00
1.00
1.00
2.92
f1 (ppm)


162.509
162.264
162.011
156.617
155.017
138.238
133.063
132.239
130.501
129.984
129.083
125.869
123.836
120.577
120.145
119.969
118.523
113.712
77.254
77.000
76.746
55.022
42.005
41.858
41.707
34.776
34.710
29.268
17.946
17.888
13C NMR, 126 MHz, CDCl3
6b
f1 (ppm)


7.588
7.573
7.406
7.391
7.374
7.322
7.306
7.291
7.239
7.228
7.216
7.129
7.116
7.102
6.891
6.876
3.846
3.826
3.813
3.426
3.406
3.390
3.240
2.549
2.533
2.520
2.505
2.484
2.473
2.468
2.452
2.080
2.053
2.039
2.020
2.005
1.988
1.978
1.404
1.373
1.358
1.333
1.322
1.235
1.221
1.208
1.184
1.174
1.159
1H NMR, 500MHz, CDCl3
6c
2.00
2.02
1.10
2.04
1.05
1.08
1.00
1.06
3.00
1.09
2.01
3.03
1.04
1.00
f1 (ppm)


180.065
143.172
137.800
132.880
129.161
128.145
126.150
122.964
122.524
119.900
108.236
77.253
76.998
76.749
48.477
48.420
48.332
39.794
39.627
39.460
35.205
26.230
24.307
21.063
21.010
-0.023
13C NMR, 126 MHz, CDCl3
F
F
O
N
O
N
6c
f1 (ppm)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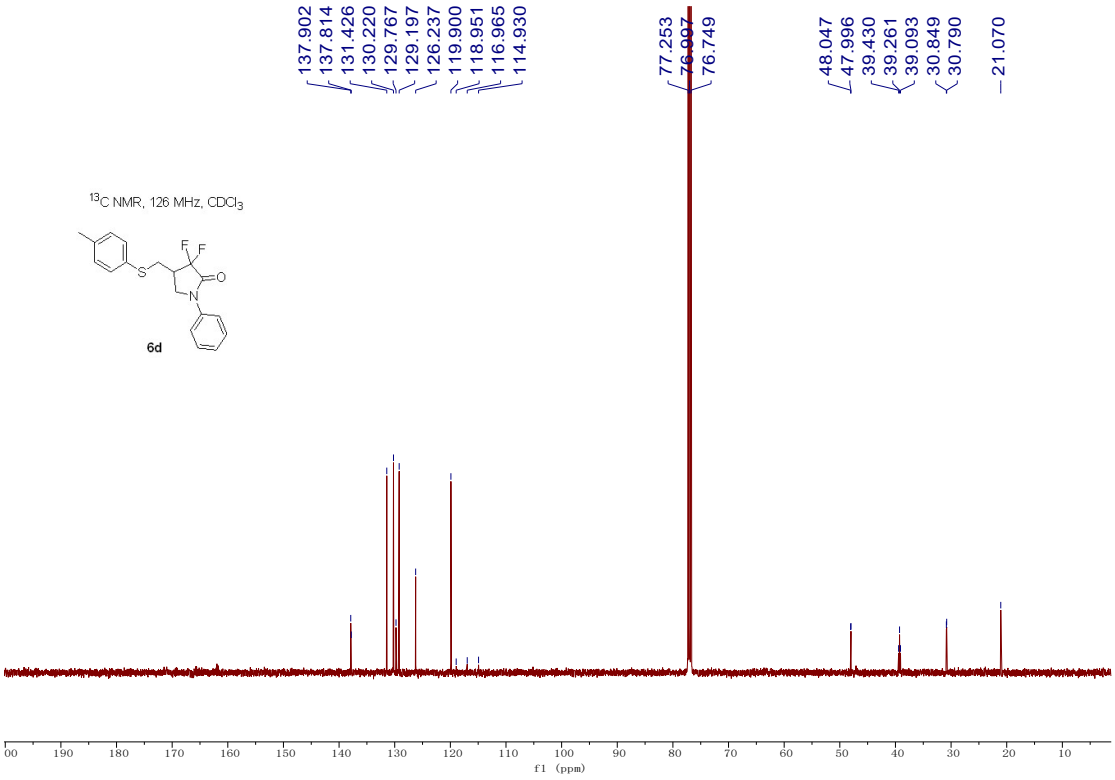
7.620
7.434
7.419
7.402
7.344
7.328
7.260
7.250
7.235
7.163
7.148
4.011
4.008
3.995
3.988
3.975
3.972
3.718
3.688
3.464
3.456
3.437
3.428
2.970
2.948
2.943
2.921
2.828
2.822
2.819
2.813
2.804
2.794
2.791
2.783
2.776
2.770
1H NMR, 500MHz, CDCl3
F
F
S
N
O
6d
2.00
2.02
2.00
1.00
2.00
1.00
1.01
1.00
1.03
1.03
2.78
f1 (ppm)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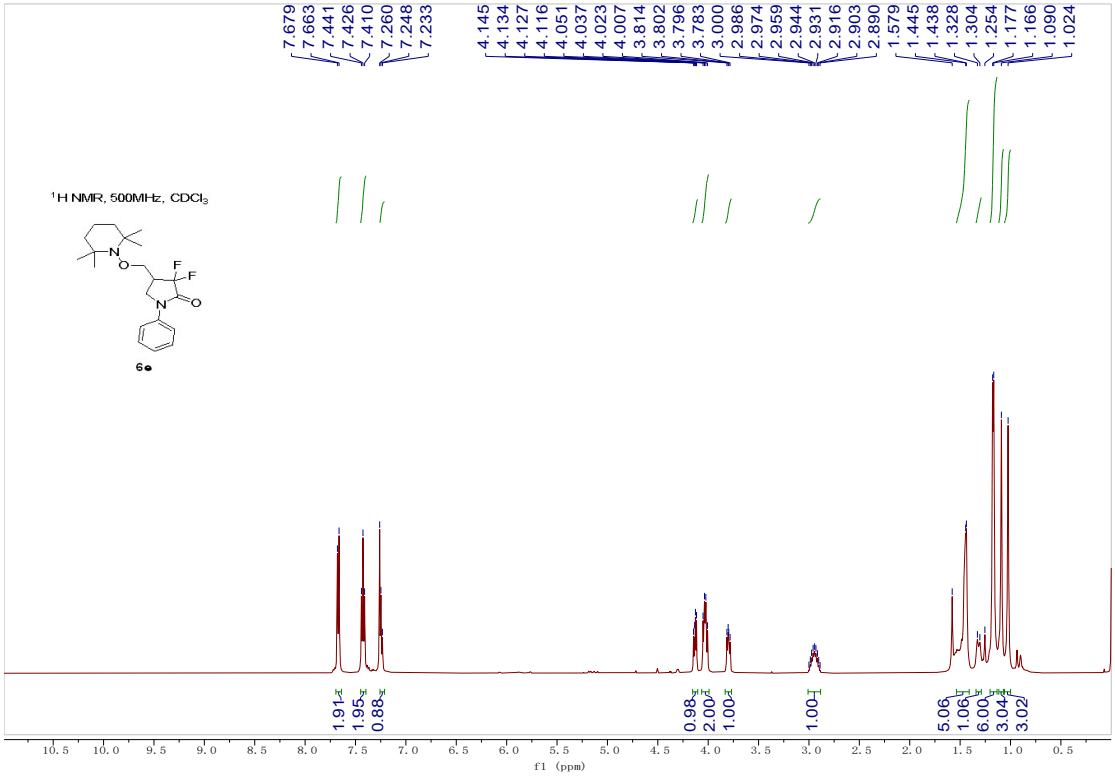
137.814
131.426
130.220
129.767
129.197
126.237
119.900
118.951
116.965
114.930
77.253
76.997
76.749
48.047
47.996
39.430
39.261
39.093
30.849
30.790
21.070
13C NMR, 126 MHz, CDCl3
6d
f1 (ppm)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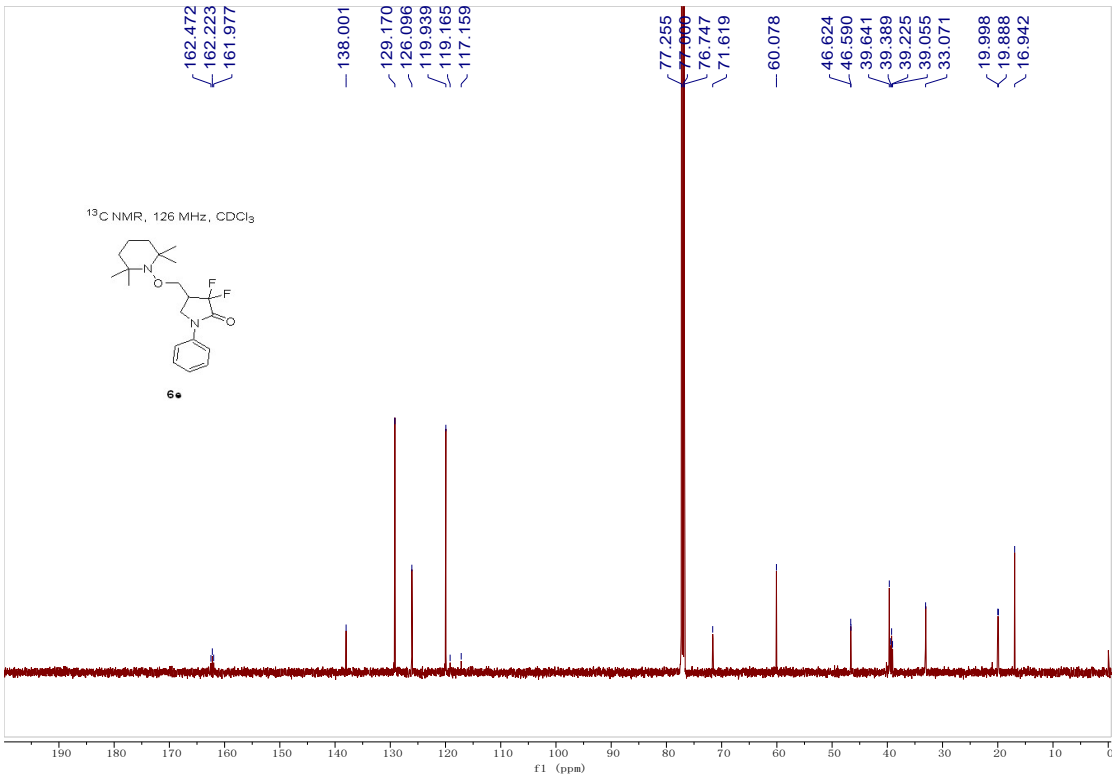
7.663
7.441
7.426
7.410
7.260
7.248
7.233
4.145
4.134
4.127
4.116
4.051
4.037
4.023
4.007
3.814
3.802
3.796
3.783
3.000
2.986
2.974
2.959
2.944
2.931
2.916
2.903
2.890
1.579
1.445
1.438
1.328
1.304
1.254
1.177
1.166
1.090
1.024
1H NMR, 500MHz, CDCl3
6e
1.91
1.95
0.88
0.98
2.00
1.00
1.00
5.06
1.06
6.00
3.04
3.02
f1 (ppm)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162.223
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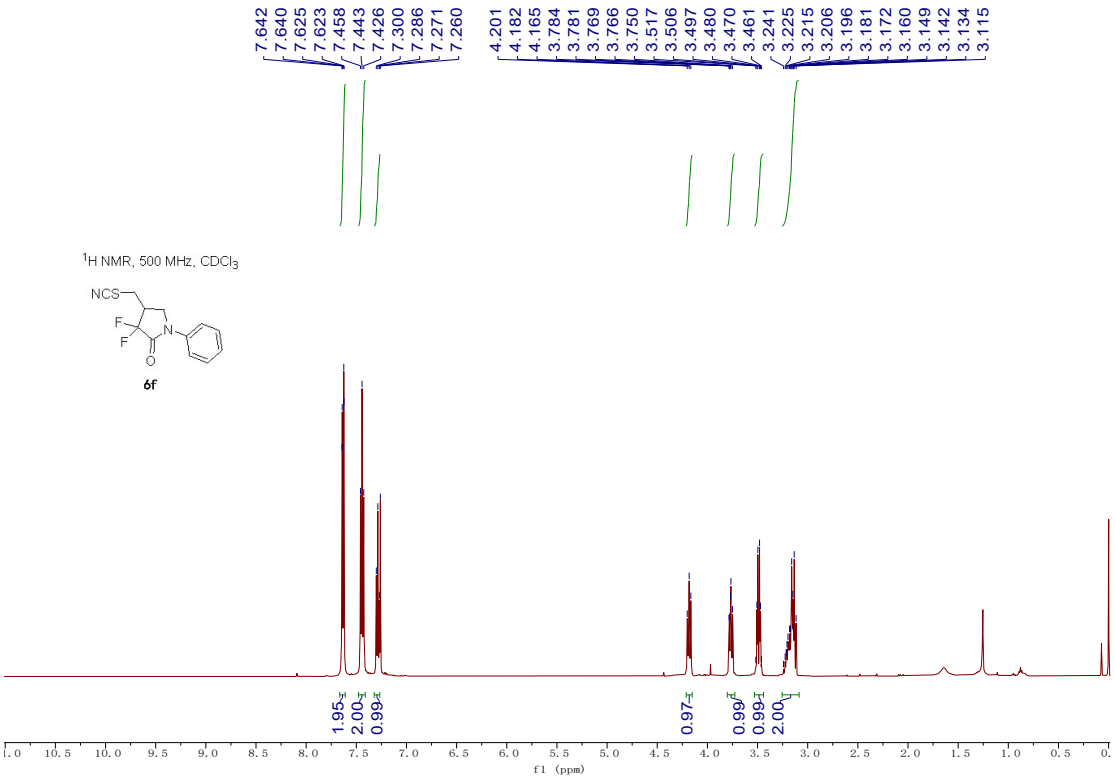
138.001
129.170
126.096
119.939
119.165
117.159
77.255
77.000
76.747
71.619
60.078
46.624
46.590
39.641
39.389
39.225
39.055
33.071
19.998
19.888
16.942
13C NMR, 126 MHz, CDCl3
6e
f1 (ppm)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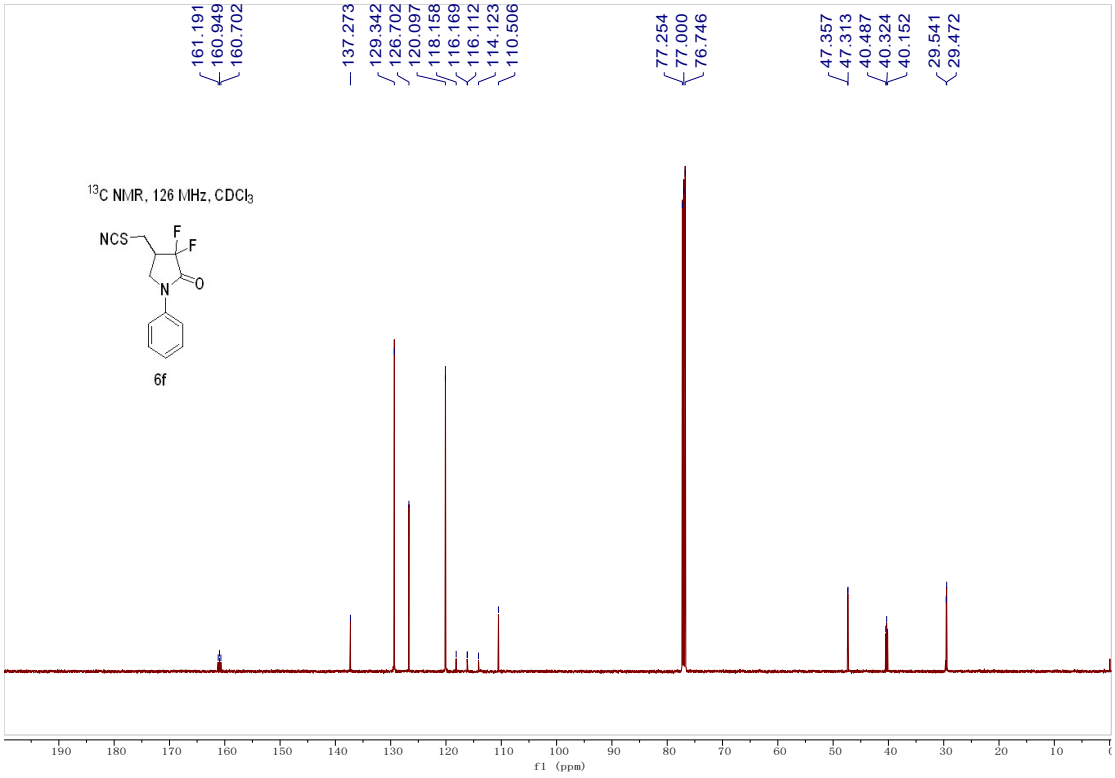
7.640
7.625
7.623
7.458
7.443
7.426
7.300
7.286
7.271
7.260
4.201
4.182
4.165
3.784
3.781
3.769
3.766
3.750
3.517
3.506
3.497
3.480
3.470
3.461
3.241
3.225
3.215
3.206
3.196
3.181
3.172
3.160
3.149
3.142
3.134
3.115
1H NMR, 500 MHz, CDCl3
NCS
F
F
N
O
6f
1.95
2.00
0.99
0.97
0.99
0.99
2.00
f1 (ppm)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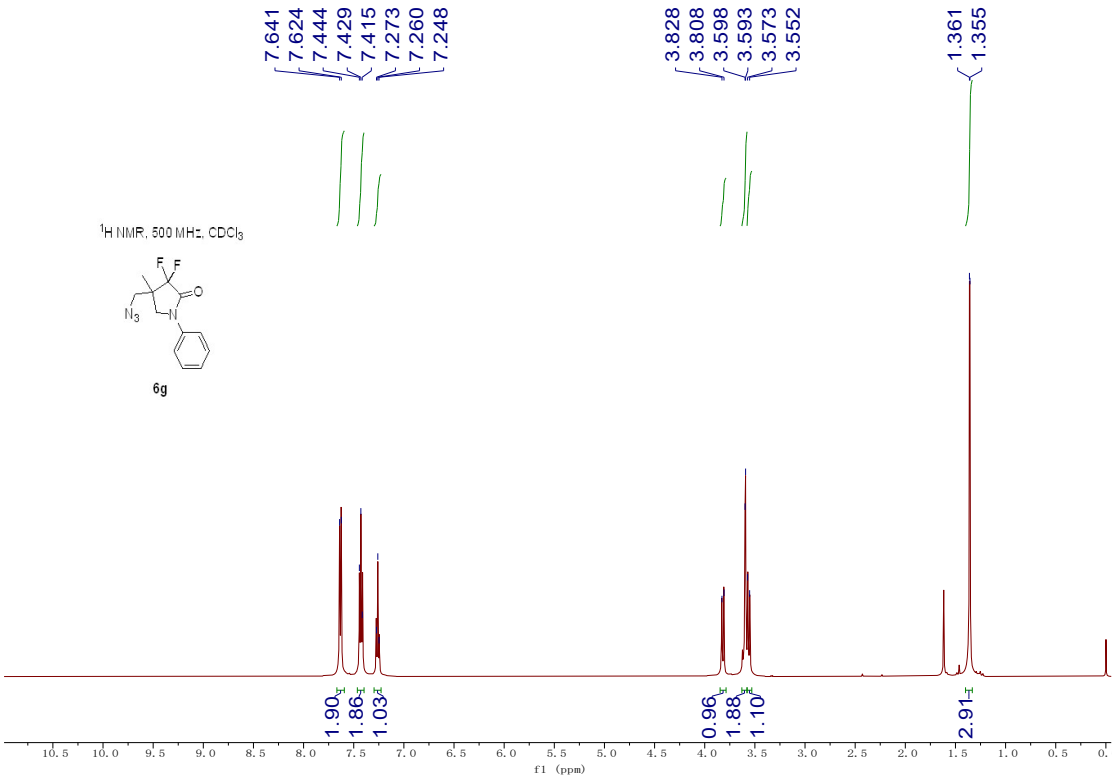
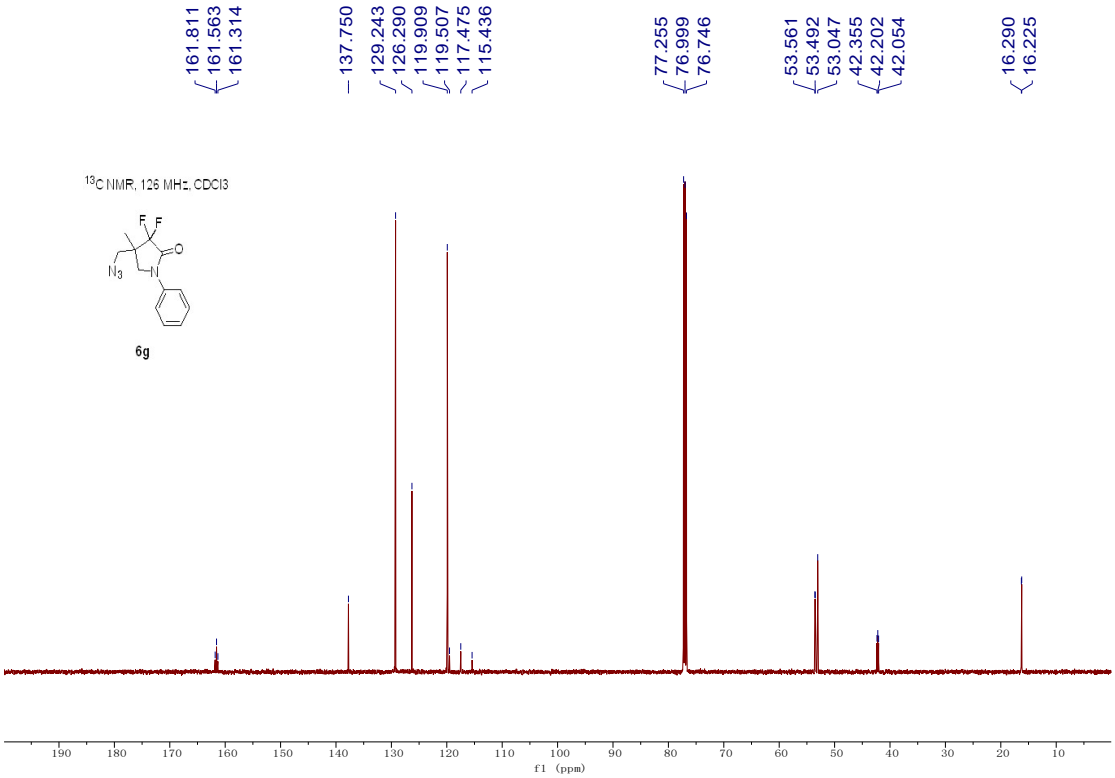
160.949
160.702
137.273
129.342
126.702
120.097
118.158
116.169
116.112
114.123
110.506
77.254
77.000
76.746
47.357
47.313
40.487
40.324
40.152
29.541
29.472
13C NMR, 126 MHz, CDCl3
NCS
F
F
O
N
6f
f1 (ppm)


7.641
7.624
7.444
7.429
7.415
7.273
7.260
7.248
3.828
3.808
3.598
3.593
3.573
3.552
1.361
1.355
1H NMR, 500 MHz, CDCl3
F
F
O
N3
N
6g
1.90
1.86
1.03
0.96
1.88
1.10
2.91
f1 (ppm)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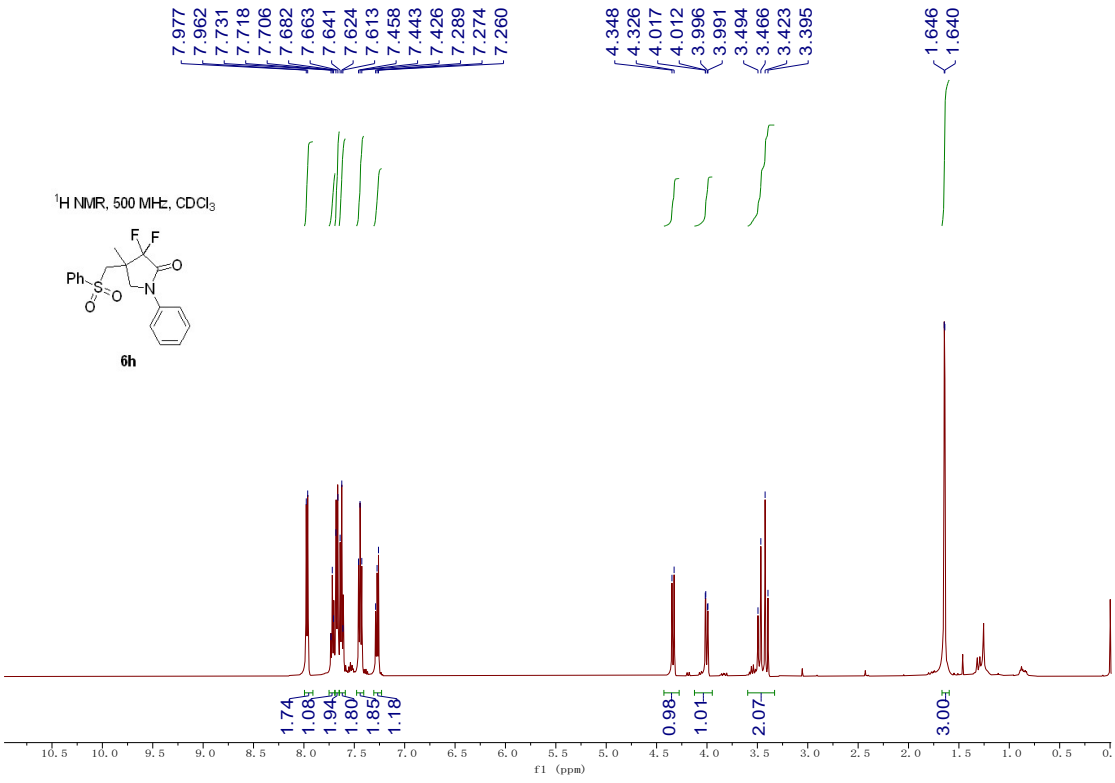
161.563
161.314
137.750
129.243
126.290
119.909
119.507
117.475
115.436
77.255
76.999
76.746
53.561
53.492
53.047
42.355
42.202
42.054
16.290
16.225
13C NMR, 126 MHz, CDCl3
6g
f1 (ppm)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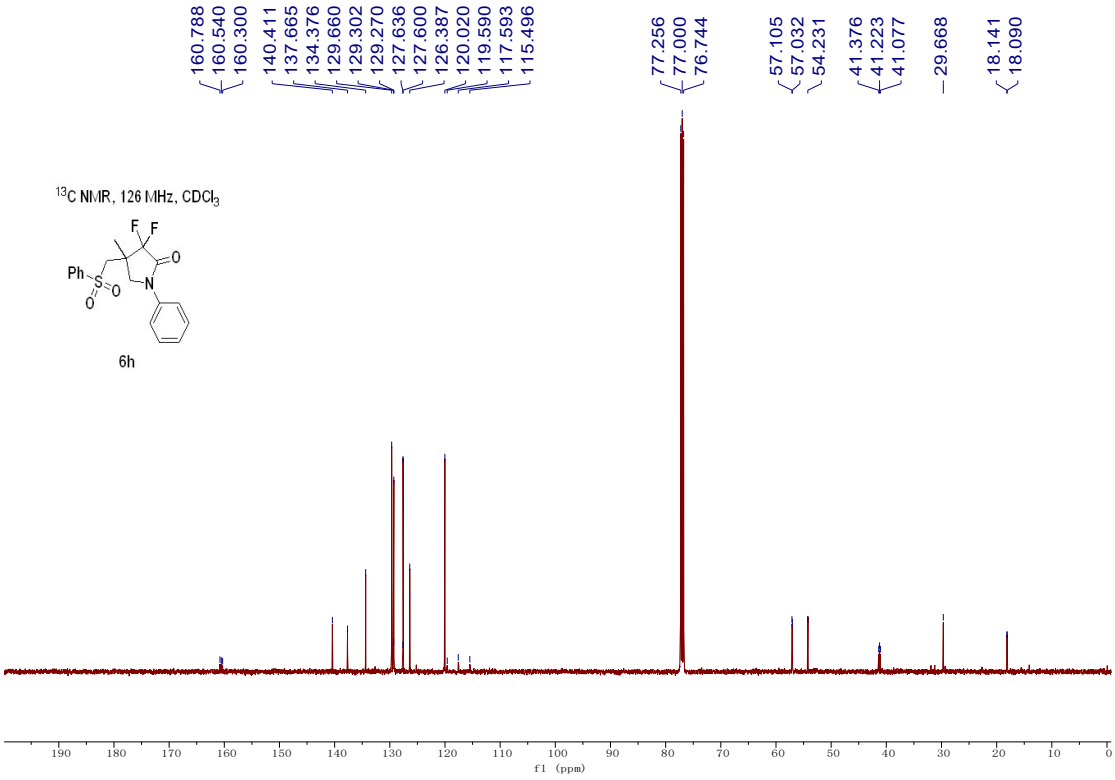
7.962
7.731
7.718
7.706
7.682
7.663
7.641
7.624
7.613
7.458
7.443
7.426
7.289
7.274
7.260
4.348
4.326
4.017
4.012
3.996
3.991
3.494
3.466
3.423
3.395
1.646
1.640
1H NMR, 500 MHz, CDCl3
6h
1.74
1.08
1.94
1.80
1.85
1.18
0.98
1.01
2.07
3.00
f1 (ppm)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160.300
140.411
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134.376
129.660
129.302
129.270
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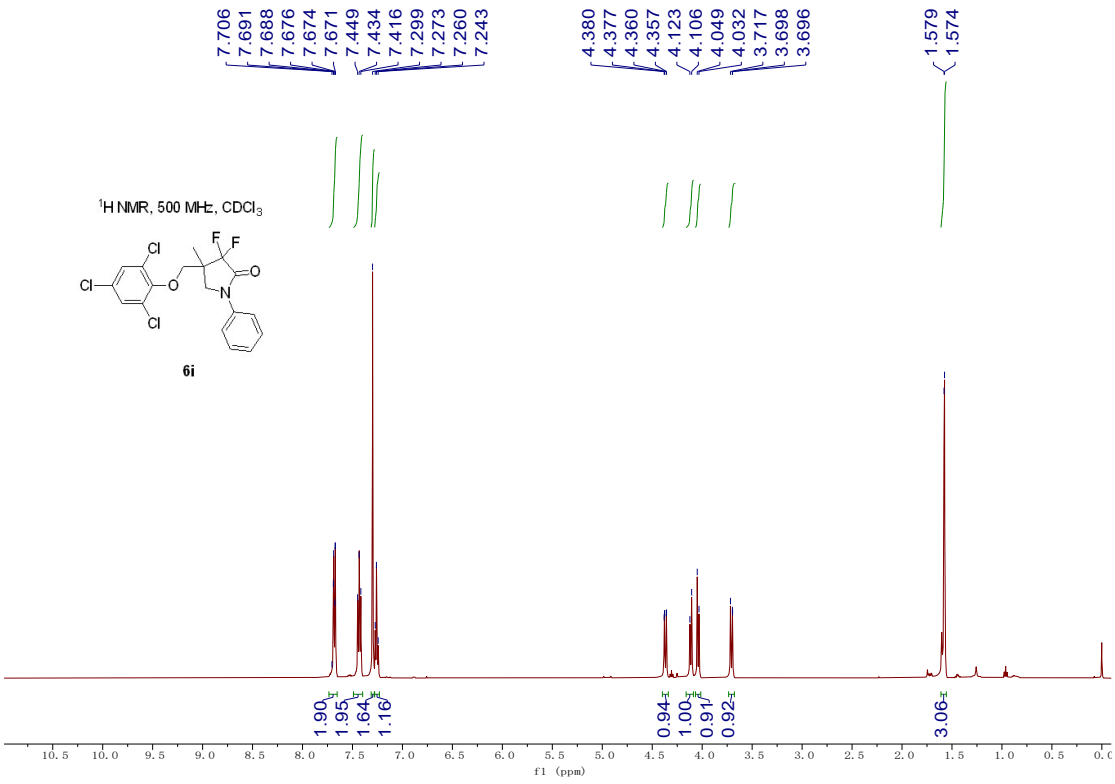
127.600
126.387
120.020
119.590
117.593
115.496
77.256
77.000
76.744
57.105
57.032
54.231
41.376
41.223
41.077
29.668
18.141
18.090
13C NMR, 126 MHz, CDCl3
F
F
Ph
S
O
O
O
N
6h
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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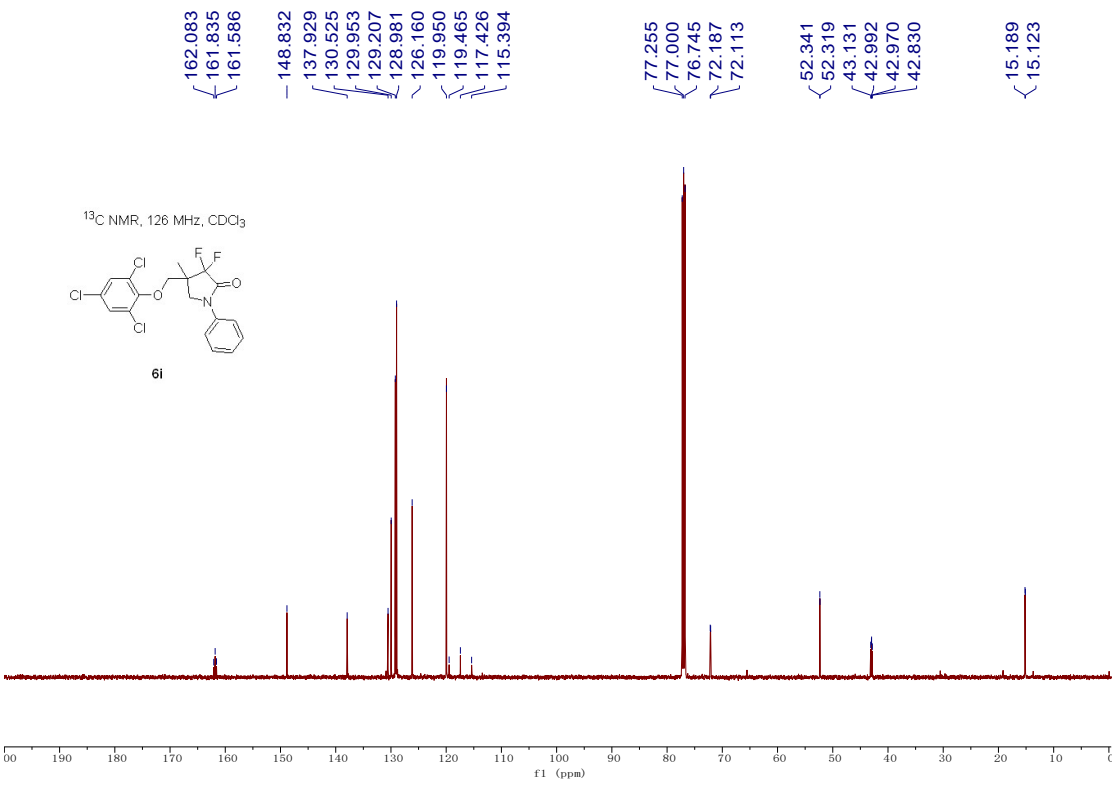
7.691
7.688
7.676
7.674
7.671
7.449
7.434
7.416
7.299
7.273
7.260
7.243
4.380
4.377
4.360
4.357
4.123
4.106
4.049
4.032
3.717
3.698
3.696
1.579
1.574
1H NMR, 500 MHz, CDCl3
Cl
Cl
Cl
O
F
F
O
N
6i
1.90
1.95
1.64
1.16
0.94
1.00
0.91
0.92
3.06
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)



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