Electronic Supplementary Information

for

Dual Roles of Ethyl Bromodifluoroacetate in the Formation of Fluorine-containing Heteroaromatic Compounds a

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Table of Contents

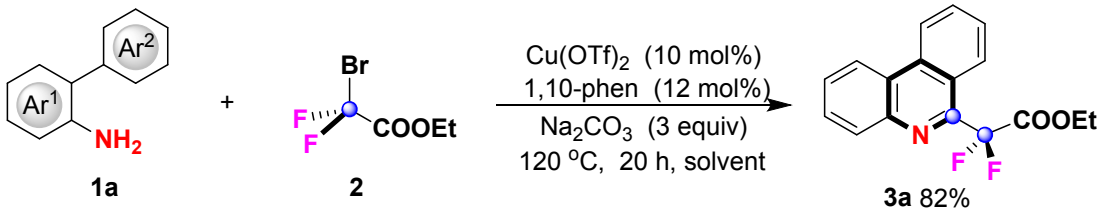
1. General information

All chemicals were purchased from Adamas Reagent, energy chemical company ($BrCF_2COOEt$, $BrCF_2COOH$, $ClCF_2COONa$), J&K Scientific Ltd, Bide Pharmatech Ltd and Tansoole, Shuya company ($BrCF_2PO(OEt)_2$). Unless otherwise stated, all experiments were conducted in a sealed tube under N_2 atmosphere. Reactions were monitored by TLC or GC-MS analysis. Flash column chromatography was performed over silica gel (200-300 mesh).

^{1}H-NMR and ^{13}C-NMR spectra were recorded in $CDCl_3$ on a Bruker Avance 500 spectrometer (500 MHz ^{1}H, 125 MHz ^{13}C, 470 MHz ^{9}F) at room temperature. Chemical shifts were reported in ppm on the scale relative to $CDCl_3$ (δ = 7.26 for ^{1}H-NMR , δ = 77.00 for ^{13}C-NMR) as an internal reference. Coupling constants (*J*) were reported in Hertz (Hz).

2. Optimization of experiment conditions for 3a

Table S1. The reaction of without the additive compared with additive



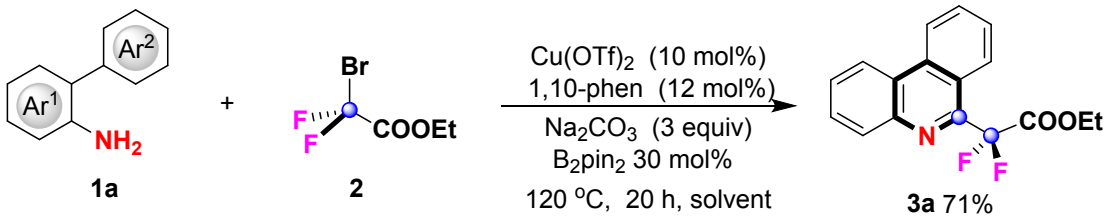
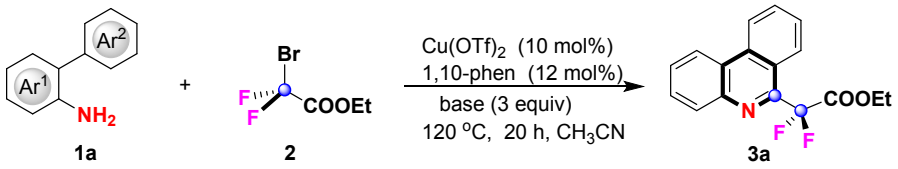


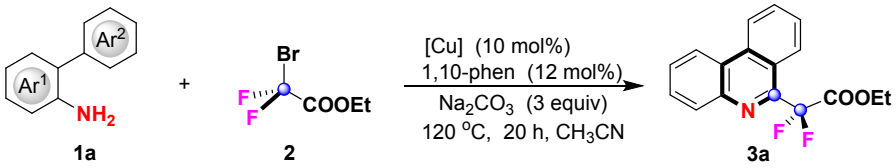
Table S2. Optimization of the bases



entry	base	yield (%)
1	K_2CO_3	78%
2	Na_2CO_3	86% ([b] 82%)
3	$NaHCO_3$	73%
4	K_3PO_4	67%
5	Na_3PO_4	80%
6	Cs_2CO_3	57%
7	NaOAc	63%
8	Li_2CO_3	49%

Reaction condition:, **1a** (0.2 mmol), **2** (3 equiv), $Cu(OTf)_2$ (10 mol%), 1,10-phen (12 mol%), base (3 equiv), GC yield. [b] isolated yield

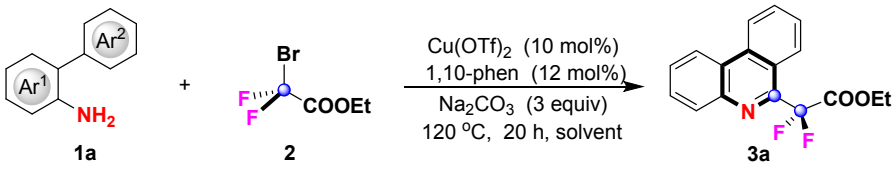
Table S3. Optimization of the Cu salt for reaction



entry	[Cu]	yield (%)
1	$CuSO_4$	67%
2	$Cu(OTf)_2$	86% ([b] 82%)
3	$Cu(OAc)_2$	68%
4	$CuCl_2$	60%
5	$Cu(NO_3)_2$	73%
6	$Cu(acac)_2$	70%
7	CuCN	47%
8	CuCl	58%
9	CuBr	54%
10	CuI	66%

Reaction condition:, **1a** (0.2 mmol), **2** (3 equiv), Cu salt (10 mol%), 1,10-phen (12 mol%), Na_2CO_3 (3 equiv), GC yield. [b] isolated yield

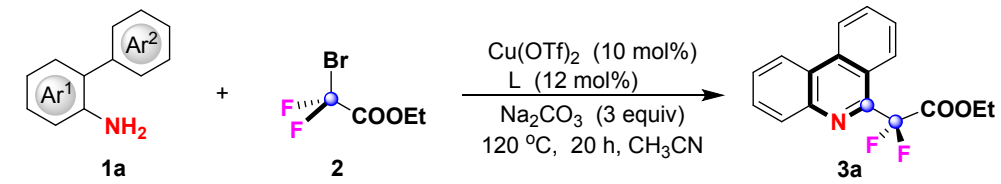
Table S4. Optimization of the solvent for reaction

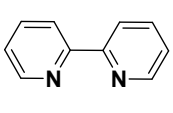


entry	solvent	yield (%)
1	dioxane	77%
2	CH_3CN	86% ([b] 82%)
3	toluene	trace
4	THF	79%
5	acetone	68%
6	DCE	70%
7	DMF	33%
8	DMSO	trace
9	CH_3OH	61%
10	DMOE	42%

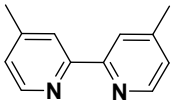
Reaction condition:, **1a** (0.2 mmol), **2** (3 equiv), Cu salt (10 mol%), 1,10-phen (12 mol%), Na_2CO_3 (3 equiv), GC yield. [b] isolated yield, DMOE=1,2-Dimethoxyethane

Table S5. Optimization of the ligand for reaction





L1



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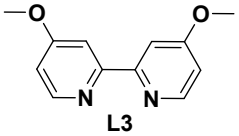

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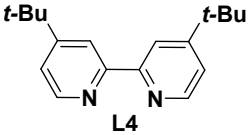
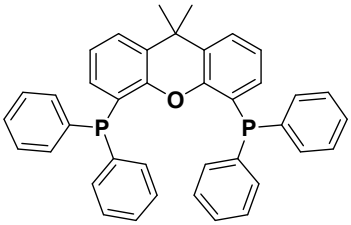


L4



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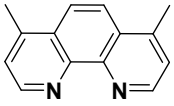

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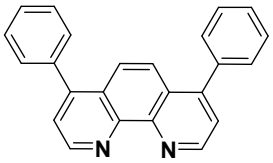
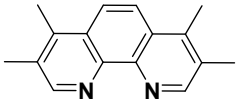
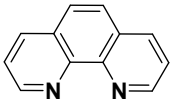


L7



L8

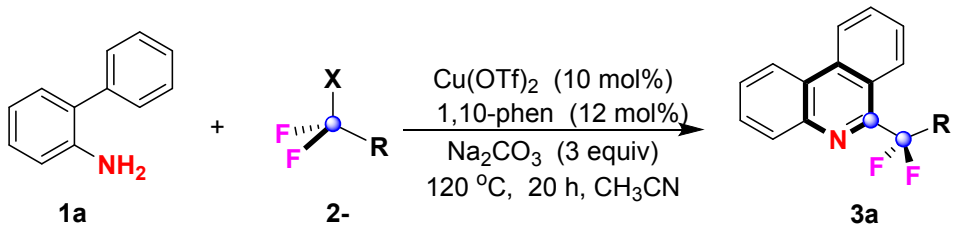


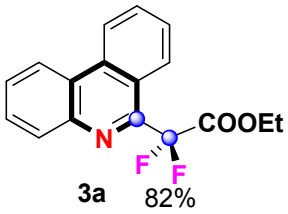
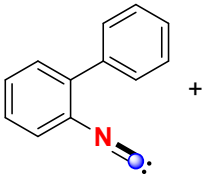
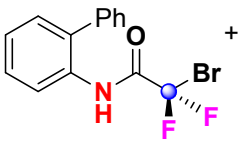
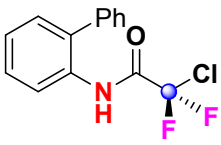
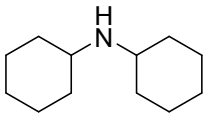
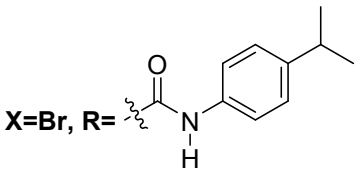
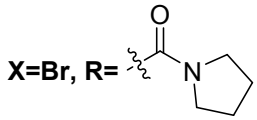
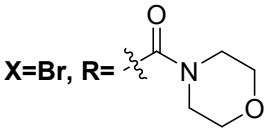
L9

entry	ligand	yield (%)
1	**L1**	69%
2	**L2**	61%
3	**L3**	66%
4	**L4**	68%
5	**L5**	77%
6	**L6**	74%
7	**L7**	71%
8	**L8**	78%
9	**L9**	86% ([b] 82%)

Reaction condition:, **1a** (0.2 mmol), **2** (3 equiv), $Cu(OTf)_2$ (10 mol%), ligand (12 mol%), Na_2CO_3 (3 equiv), GC yield. [b] isolated yield,

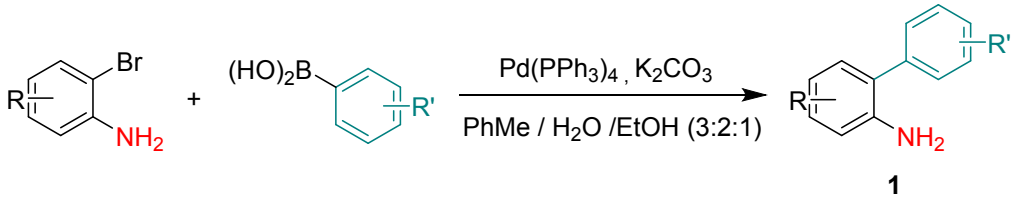
Table S6. Screening of the different diflouromethyl compounds



substrate	products
X=Br, R=COOEt **2** $0.32/g	 **3a** 82%
X=Br, R=COOH **2-COOH** $3.04/g	 **6**, trace +  68% (iso.) + **3-COOH** not detected
X=Br, R=P(O)(OEt)$_2$ **7** $2.29/g	**6** 43% (iso.) + **3a** 31% (iso.) + **3-P(O)(OEt)$_2$** not detected
X=Cl, R=COONa **2-COONa** $0.52/g	 35% GC yield + **3-COONa** not detected
X=Br, R=C(O)NCy$_2$ **2-amide** prepared	**6** 69% (GC) +  detected by GCMS + **3-C(O)(NCy)$_2$** not detected
X=Br, R=  **2-amide** prepared	**6** trace + **3-C(O)NH-iprPh** not detected
X=Br, R=  **2-amide** prepared	**6** trace + **3-C(O)N(CH$_2$)$_4$** not detected
X=Br, R=  **2-amide** prepared	**6** trace + **3-C(O)morpholine** not detected

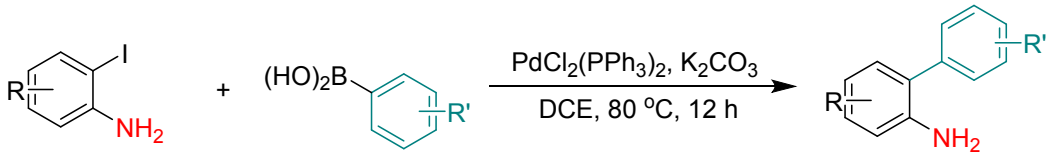
3. General procedure for starting materials

(1). General experimental procedures for substrates 1



1

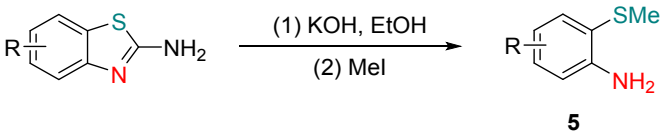
GP-I: In a dry 50 mL round bottom flask, phenylboronic acid (1.3 eq.), K_2CO_3 (4.0 eq.) and $Pd(PPh_3)_4$ (0.1 eq.) were dissolved in a mixture of toluene / water / ethanol (3:2:1, 0.1 M). 2-Bromoaniline (1.0 eq.) was added and the resulting mixture was heated to 95 °C for 20 hours. After cooling to room temperature, the biphasic solution was diluted with saturated aqueous NH_4Cl and CH_2Cl_2 and the phases were separated. The aqueous phase was extracted twice with CH_2Cl_2 (50 mL) and the combined organic phases were washed with water (1 x 50 mL) and saturated aqueous $NaHCO_3$ (1 x 50 mL). The organic phases were dried over Na_2SO_4 and filtered. The filtrate was concentrated in vacuo to afford the crude product. Purification by column chromatography on silica gel (petroleum ether / ethyl acetate) afforded the corresponding products.[1]



1

GP-II 2-Iodoaniline (10 mmol, 1.0 equiv), p-tolylboronic acid (12 mmol, 1.2 equiv) were added to a dry Schlenk flask. The flask was evacuated and backfilled with pure N_2 for 3 times. DME (10 mL) and aqueous solution of K_2CO_3 (2 M, 20 mL) were added with syringe and the mixture was stirred for 30 min at room temperature under N_2 atmosphere. To the stirred mixture, $PdCl_2(PPh_3)_2$ (0.2 mmol, 140 mg, 0.02 equiv) in DME (10 mL) was added with syringe at room temperature and the mixture was stirred at 80 °C for 12 h under N_2 atmosphere (monitored by TLC). After the reaction was complete, the mixture was then cooled to room temperature and diluted with EtOAc (20 mL). The aqueous layer was extracted with EtOAc for 3 times (20 mL × 3). Then the organic phase was combinated and dried over anhydrous $MgSO_4$. The solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel by using a 30:1 mixture of petroleum ether/EtOAc as an eluent to provide amine .[2]

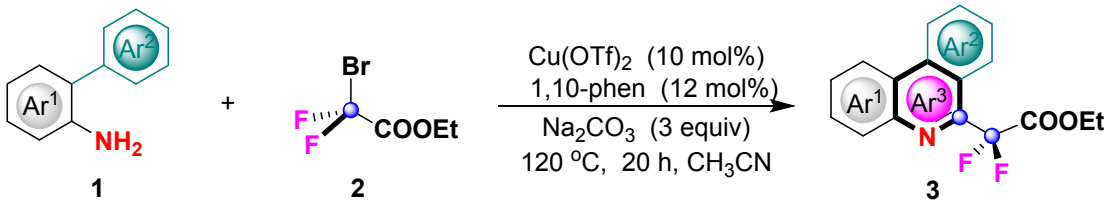
(2). General experimental procedures for substrates 5



5

To the stirred solution of KOH (6 g) in 24 mL of water, benzothioazole (3 mmol) was added and refluxed for 17 h. After cooling to room temperature, MeI (3 mmol) was added drop wise and stirring was continued for an additional 1 h. The resultant reaction mixture extracted with diethyl ether (3 x 25 mL) combined organic layers dried over Na_2SO_4, filtered and concentrated in vacuum. Purification of the crude product was achieved by flash column chromatography using petrol ether/ethyl acetate (15:1) as eluent.

4. General process for the synthesis of B

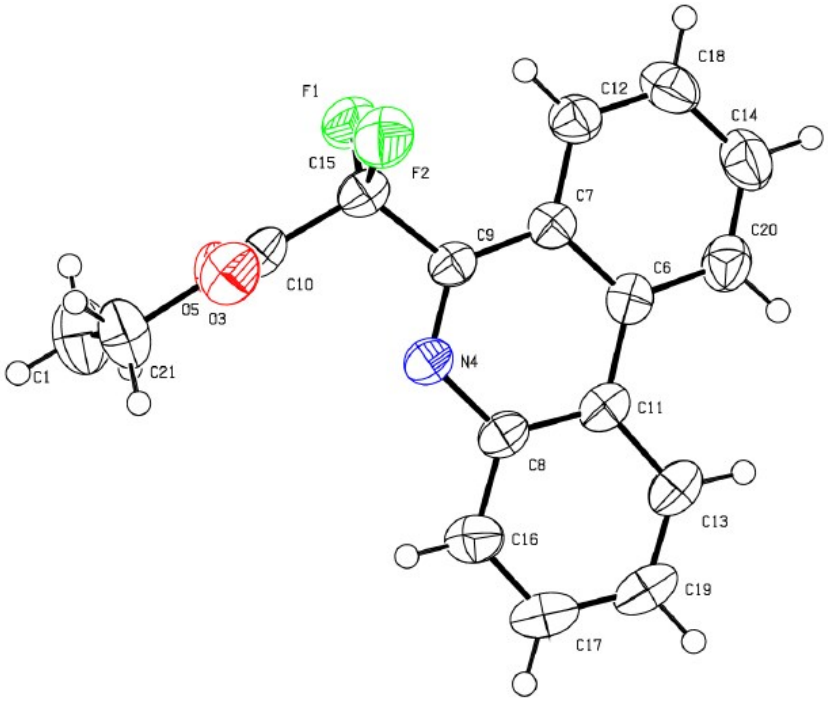


1 **2** **3**

In a dried Schlenk tube were placed **1** (0.2 mol, 1 equiv), Na_2CO_3 (0.6 mol, 3 equiv), $Cu(OTf)_2$ (0.02 mmol 0.1 equiv), 1,10-phen (0.024 mmol 0.12 equiv). **2** (0.6 mmol, 3 equiv) and solvent is added the mixture under N_2 atmosphere. The resulting mixture was stirred at 120 °C for 20 h. Upon completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 100:1, v/v) to give the desired product **3**.

5. Crystal data of 3a

Crystallographic data for compound **3a** (CCDC-1820711) has been deposited with the Cambridge Crystallographic Data Centre, Copies of the data can be obtained, free of charge, on application to CCDC (Email:deposit@ccdc.cam.ac.uk).



Bond precision: C-C = 0.0031 A Wavelength=0.71073

Cell:	a=8.3324(7)	b=18.0049(15)	c=18.9382(19)
	alpha=90	beta=90	gamma=90
Temperature:	296 K		

	Calculated	Reported
Volume	2841.2(4)	2841.2(4)
Space group	P b c a	P b c a
Hall group	-P 2ac 2ab	-P 2ac 2ab
Moiety formula	C17 H13 F2 N O2	C17 H13 F2 N O2
Sum formula	C17 H13 F2 N O2	C17 H13 F2 N O2
Mr	301.28	301.29
Dx,g cm-3	1.409	1.409
Z	8	8
Mu (mm-1)	0.110	0.110
F000	1248.0	1248.8
F000'	1248.76	
h,k,lmax	9,21,22	9,21,22
Nref	2494	2487
Tmin,Tmax		0.419,1.000
Tmin'		

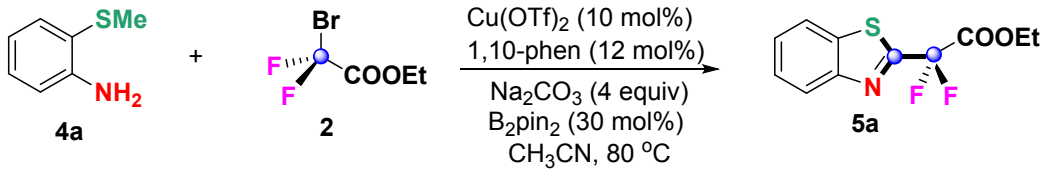
Correction method= # Reported T Limits: Tmin=0.419 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 0.997 Theta(max)= 24.990

R(reflections)= 0.0445(1797) wR2(reflections)= 0.1237(2487

S = 1.061 Npar= 199

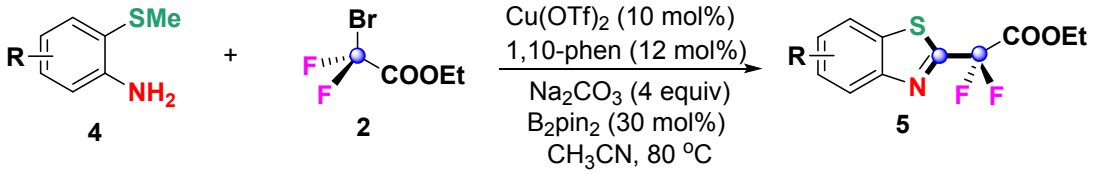
6. Optimization of experiment conditions for 5



entry	[Cu]	ligand	additive	base	solvent	yield (%)
1	$Cu(OTf)_2$	1,10-phen	----	Na_2CO_3	CH_3CN	74
2	$Cu(OTf)_2$	1,10-phen	B_2pin_2	Na_2CO_3	CH_3CN	83 (78)[b]
3	$Cu(OTf)_2$	1,10-phen	B_2pin_2	Na_2CO_3	THF	67
4	$CuSO_4$	1,10-phen	B_2pin_2	Na_2CO_3	CH_3CN	47
5	$Cu(OTf)_2$	Xantphos	B_2pin_2	Na_2CO_3	CH_3CN	60
6	$Cu(OTf)_2$	1,10-phen	B_2pin_2	K_2CO_3	CH_3CN	69
7	$Cu(OTf)_2$	1,10-phen	B_2pin_2	DBU	CH_3CN	23
8[c]	$Cu(OTf)_2$	1,10-phen	B_2pin_2	Na_2CO_3	CH_3CN	54

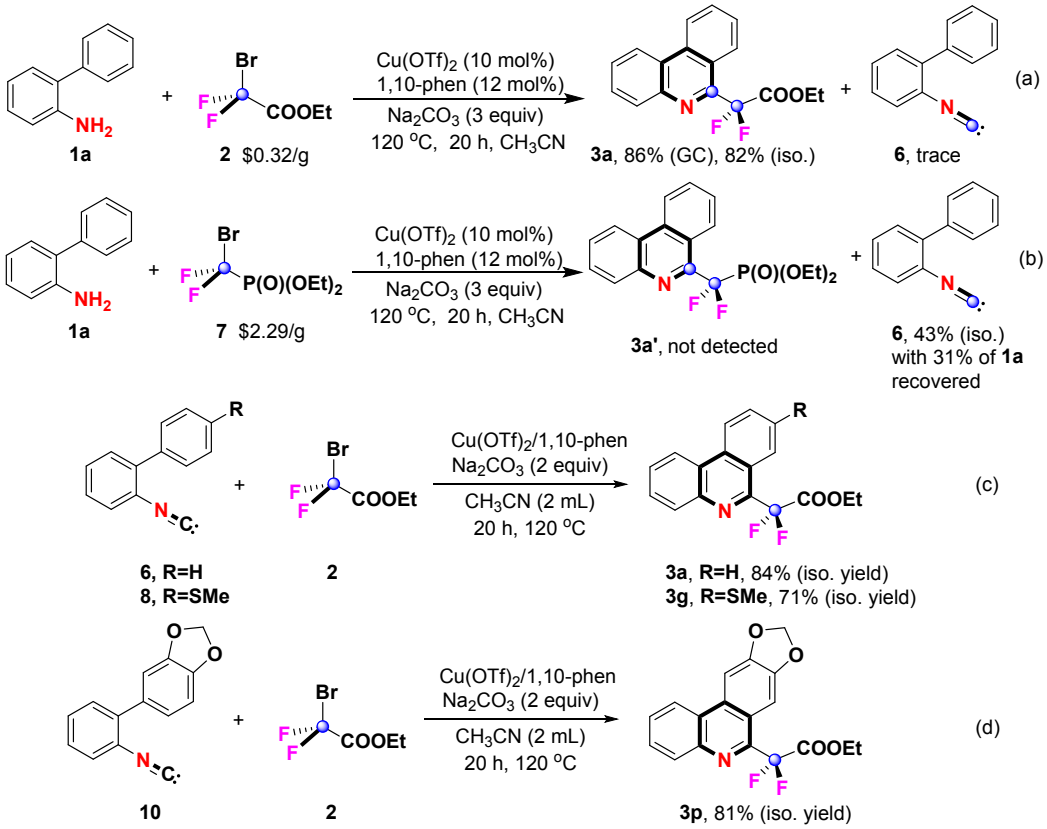
[a] Reaction conditions: **4a** (0.2 mmol), ethyl bromodifluoroacetate (**2**) (3 equiv), [Cu] (10 mol%), ligand (12 mol%), B_2pin_2 (30 mol%), base (4 equiv), CH_3CN (2 mL) under N_2 atmosphere at 80 °C for 24 h. GC yields. [b] Isolated yields. [c] 12 h

7. General process for the synthesis of 5

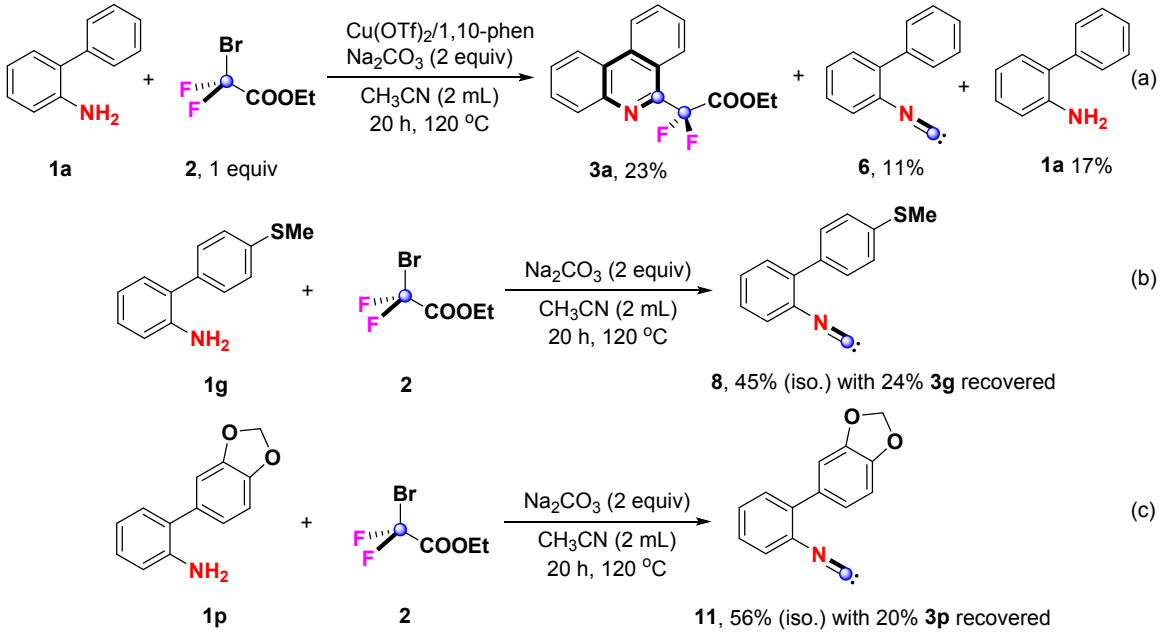


In a dried Schlenk tube were placed **4** (0.2 mol, 1 equiv), Na_2CO_3 (0.8 mol, 4 equiv), $Cu(OTf)_2$ (0.02 mmol 0.1 equiv), 1,10-phen (0.024 mmol 0.12 equiv). **2** (0.6 mmol, 3 equiv), B_2pin_2 (0.06 mmol 0.3 equiv) and solvent CH_3CN is added the mixture under N_2 atmosphere. The resulting mixture was stirred at 80 °C for 24 h. Upon completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 100:1, v/v) to give the desired product **5**.

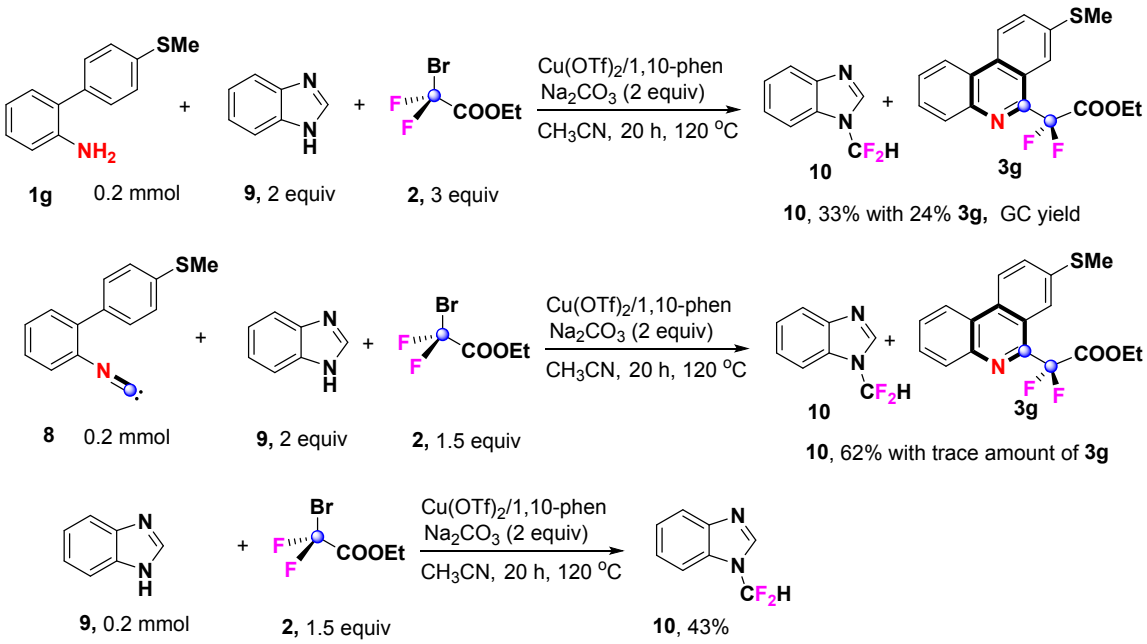
8. Control experiments to figure out the key intermediate for this transformation



9. Control experiments to figure out the formation of isocyanides from amines



10. Control experiments and radical trapping experiments.



11. Computation

Computational Methods

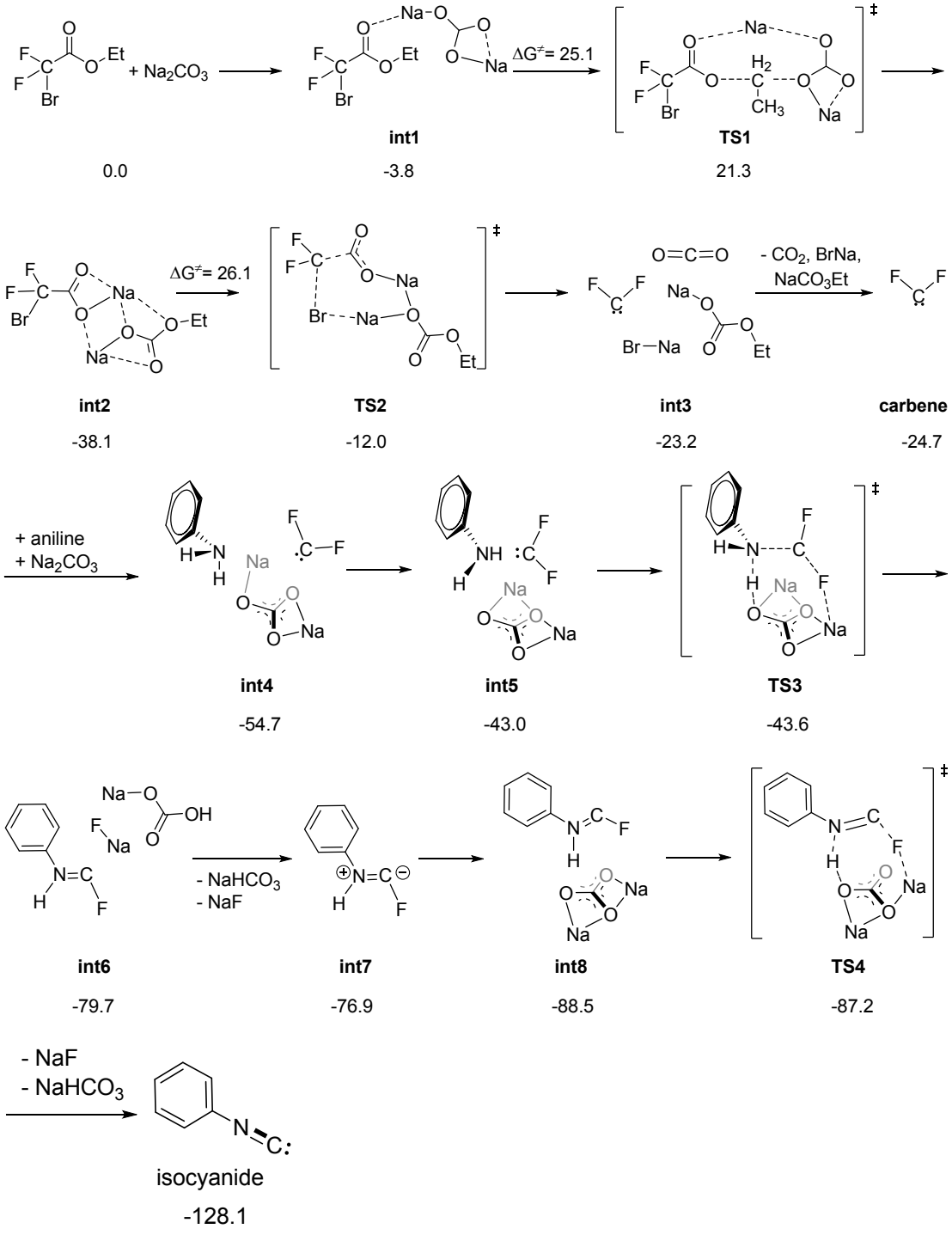
All calculations were carried out with the Gaussian 09 program. Geometries were optimized using the B3LYP density functional with the LANL2DZ basis set for Br and the 6-31G basis set for other atoms. Harmonic frequency analysis was conducted at the same level of theory to verify the stationary points to be real minima or saddle points and to obtain the thermal corrections at 298.15 K. Intrinsic reaction coordinate (IRC) calculations were carried out to ensure that the transition states connect the correct reactants and products. Single-point energies were calculated at optimized gas-phase geometries at the M06-2X/6-311G(d,p) level and solvent effects were introduced with the SMD approach. In the single-point calculations, thermal corrections were added to obtain Gibbs free energies (kcal/mol).

Gaussian 09, Revision D.01, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, J. A., Jr.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, N. J.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Zakrzewski, V. G.; Voth,

G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, Ö.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; Fox, D. J. Gaussian, Inc., Wallingford CT, 2010.

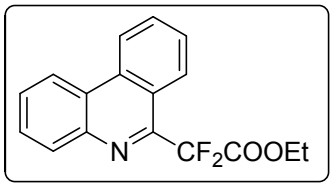
Computational Results

Aniline was used as model molecule of amine substrate for computational study. Free energies are given in kcal/mol.



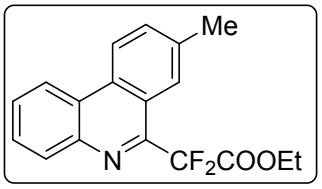
12. Characterization data for products

ethyl 2,2-difluoro-2-(phenanthridin-6-yl)acetate (3a)[3]



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (49.3 mg 82%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.67 (d, *J* = 8.4 Hz, 1H), 8.61 – 8.53 (m, 2H), 8.12 (dd, *J* = 5.9, 3.6 Hz, 1H), 7.94 – 7.87 (m, 1H), 7.78 – 7.71 (m, 3H), 4.57 (q, *J* = 7.1 Hz, 2H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.7 (t, *J* = 31.3 Hz), 150.15 (t, *J* = 28.8 Hz), 141.7, 133.8, 131.2, 130.8, 129.0, 128.9, 127.8, 126.23 (t, *J* = 4.8 Hz), 124.8, 122.5, 122.3 (t, *J* = 2.5 Hz), 122.0, 115.81 (t, *J* = 252.5 Hz), 63.0, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.8.

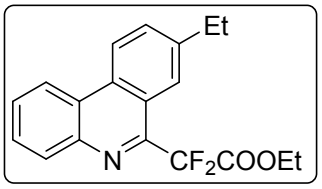
ethyl 2,2-difluoro-2-(8-methylphenanthridin-6-yl)acetate (3b)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (82%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 – 8.50 (m, 2H), 8.32 (d, *J* = 0.7 Hz, 1H), 8.15 – 8.05 (m, 1H), 7.77 – 7.68 (m, 3H), 4.57 (q, *J* = 7.1 Hz, 2H), 2.62 (s, 3H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) 163.7 (t, *J* = 30 Hz), 149.9 (t, *J* = 30 Hz), 141.5, 138.0, 133.1, 131.8, 130.8, 128.8, 128.5, 125.5 (t, *J* = 3.8 Hz), 125.0, 125.0 (t, *J* = 2.5 Hz), 122.4 121.9, 116.0 (t, *J* = 252.5 Hz), 63.0, 21.9, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.9.

HRMS (ESI, m/z) calcd for $C_{18}H_{16}F_2NO_2[M+H]^+$: 316.1149; found: 316.1145.

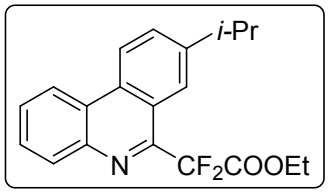
ethyl 2-(8-ethylphenanthridin-6-yl)-2,2-difluoroacetate (3c)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (83%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.62 (d, *J* = 8.5 Hz, 1H), 8.60 – 8.50 (m, 1H), 8.36 (d, *J* = 1.1 Hz, 1H), 8.16 – 8.09 (m, 1H), 7.83 – 7.71 (m, 3H), 4.59 (q, *J* = 7.1 Hz, 2H), 2.95 (q, *J* = 7.6 Hz, 2H), 1.50 (t, *J* = 7.1 Hz, 3H), 1.41 (t, *J* = 7.6 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8 (t, *J* = 31.3 Hz), 150.0 (t, *J* = 28.8 Hz), 144.2, 141.5, 132.0, 132.0, 130.8, 128.8, 128.5, 125.0, 124.40 (t, *J* = 5.0 Hz), 122.6 (t, *J* = 2.5 Hz), 122.5, 121.9, 115.9 (t, *J* = 251.3 Hz), 63.0, 29.2, 15.5, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.0.

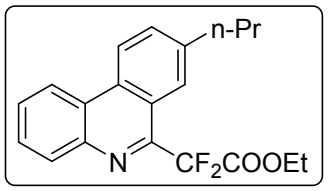
HRMS (ESI, m/z) calcd for $C_{19}H_{18}F_2NO_2[M+H]^+$: 330.1306; found: 330.1302.

ethyl 2,2-difluoro-2-(8-isopropylphenanthridin-6-yl)acetate (3d)



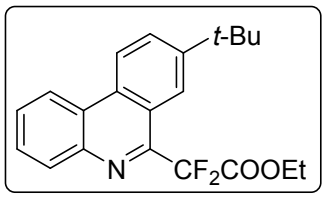
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (83%).
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.61 (d, *J* = 8.6 Hz, 1H), 8.58 – 8.52 (m, 1H), 8.37 (d, *J* = 1.8 Hz, 1H), 8.16 – 8.07 (m, 1H), 7.81 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.76 – 7.63 (m, 2H), 4.56 (q, *J* = 7.1 Hz, 2H), 3.19 (dt, *J* = 13.8, 6.9 Hz, 1H), 1.47 (t, *J* = 7.1 Hz, 3H), 1.40 (d, *J* = 6.9 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8 (t, *J* = 31.3 Hz), 150.0 (t, *J* = 28.8 Hz), 148.8, 141.5, 132.2, 130.8, 130.5, 128.8, 128.5, 125.0, 123.10 (t, *J* = 5.0 Hz), 122.6 (t, *J* = 5 Hz), 122.6, 121.9, 115.9 (t, *J* = 252.5 Hz), 63.0, 34.4, 23.9, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.1.
HRMS (ESI, m/z) calcd for $C_{20}H_{20}F_2NO_2[M+H]^+$: 344.1462; found: 344.1460.

ethyl 2,2-difluoro-2-(8-propylphenanthridin-6-yl)acetate (3e)



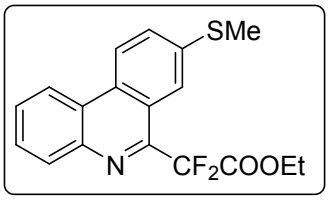
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a yellow oil (77%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.58 (d, *J* = 8.5 Hz, 1H), 8.56 – 8.51 (m, 1H), 8.32 (d, *J* = 1.5 Hz, 1H), 8.22 – 8.01 (m, 1H), 7.79 – 7.65 (m, 3H), 4.57 (q, *J* = 7.1 Hz, 2H), 2.93 – 2.80 (m, 2H), 1.84 – 1.73 (m, 2H), 1.48 (t, *J* = 7.1 Hz, 3H), 1.01 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8 (t, *J* = 30 Hz), 149.94 (t, *J* = 28.8 Hz), 142.7, 141.5, 132.4, 132.0, 130.8, 128.8, 128.5, 125.1 (t, *J* = 6.3 Hz), 125.0, 122.5 (t, *J* = 2.5 Hz), 122.4, 121.9, 115.9 (t, *J* = 252.5 Hz), 63.0, 38.2, 24.5, 14.1, 13.8. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.1.
HRMS (ESI, m/z) calcd for $C_{20}H_{20}F_2NO_2[M+H]^+$: 344.1462; found: 344.1458.

ethyl 2-(8-(tert-butyl)phenanthridin-6-yl)-2,2-difluoroacetate (3f)



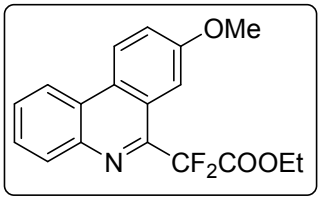
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a yellow oil (76%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.60 (d, *J* = 8.8 Hz, 1H), 8.54 (dd, *J* = 5.7, 3.7 Hz, 2H), 8.16 – 8.07 (m, 1H), 7.98 (dd, *J* = 8.8, 1.9 Hz, 1H), 7.76 – 7.68 (m, 2H), 4.56 (q, *J* = 7.1 Hz, 2H), 1.52 – 1.43 (m, 12H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.6 (t, *J* = 30 Hz), 151.0, 150.2 (t, *J* = 28.8 Hz), 141.6, 131.8, 130.8, 129.7, 128.8, 128.6, 124.9, 122.4 (t, *J* = 1.3 Hz), 122.3, 121.9, 121.8 (t, *J* = 5.0 Hz), 115.84 (t, *J* = 252.5 Hz), 63.0, 35.3, 31.2, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.2.
HRMS (ESI, m/z) calcd for $C_{21}H_{22}F_2NO_2[M+H]^+$: 358.1619; found: 358.1615.

Ethyl 2,2-difluoro-2-(8-(methylthio)phenanthridin-6-yl)acetate (3g)



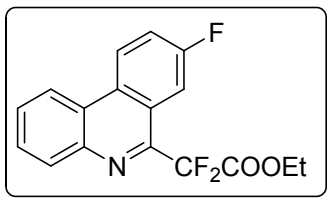
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.65 – 8.39 (m, 2H), 8.25 (d, *J* = 1.9 Hz, 1H), 8.16 – 8.01 (m, 1H), 7.72 (ddt, *J* = 14.3, 6.8, 3.4 Hz, 3H), 4.56 (q, *J* = 7.1 Hz, 2H), 2.64 (s, 3H), 1.47 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.60 (t, *J* = 31.3 Hz), 149.08 (t, *J* = 28.8 Hz), 141.4, 139.6, 131.1, 130.9, 130.0, 129.1, 128.7, 124.8, 122.9 (t, *J* = 17.5 Hz), 122.7, 121.7, 121.1 (t, *J* = 5.0 Hz), 115.8, 63.1, 15.4, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.33 (s).
HRMS (ESI, m/z) calcd for $C_{18}H_{16}F_2NO_2S[M+H]^+$: 348.0870; found: 348.0876.

ethyl 2,2-difluoro-2-(8-methoxyphenanthridin-6-yl)acetate (3h)[4]



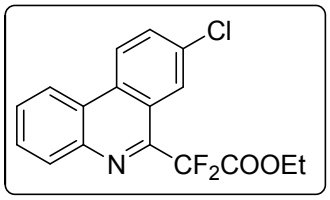
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (58.3 mg, 88%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.55 (d, *J* = 9.2 Hz, 1H), 8.49 – 8.44 (m, 1H), 8.08 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.89 – 7.83 (m, 1H), 7.74 – 7.64 (m, 2H), 7.51 (dd, *J* = 9.1, 2.6 Hz, 1H), 4.57 (q, *J* = 7.1 Hz, 2H), 3.99 (s, 3H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.7 (t, *J* = 31.3 Hz), 158.8, 148.1 (t, *J* = 28.8 Hz), 140.9, 130.7, 128.9, 128.3, 127.9, 125.0, 124.0, 123.6 (t, *J* = 2.5 Hz), 122.3, 121.5, 115.9 (t, *J* =251.3 Hz), 105.7 (t, *J* = 5 Hz), 63.0, 55.5, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.9.

ethyl 2,2-difluoro-2-(8-fluorophenanthridin-6-yl)acetate (3i)



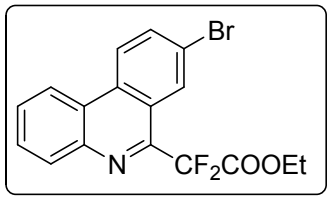
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (47 mg, 74%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.63 (dd, *J* = 9.2, 5.3 Hz, 1H), 8.52 – 8.42 (m, 1H), 8.17 (ddd, *J* = 9.7, 4.3, 2.0 Hz, 1H), 8.12 – 7.96 (m, 1H), 7.79 – 7.69 (m, 2H), 7.63 (ddd, *J* = 9.1, 8.0, 2.6 Hz, 1H), 4.58 (q, *J* = 7.1 Hz, 2H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.37 (t, J = 31.3 Hz), 162.3, 160.4, 149.4 (t, *J* =28.8 Hz), 149.3 (t, *J* = 30.0 Hz), 141.4, 130.9, 130.6, 129.4, 128.9, 125.1 (d, *J* = 7.5 Hz), 124.4, 123.4 (t, *J* = 1.25 Hz), 123.3 (t, *J* = 1.25 Hz), 121.8, 120.8 (d, *J* = 23.8 Hz), 115.6 (t, *J* = 252.5 Hz), 111.2 (t, *J* = 5 Hz), 111.0(t, *J* = 5 Hz) 63.1, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.3, -110.3.
HRMS (ESI, m/z) calcd for $C_{17}H_{13}F_3NO_2[M+H]^+$: 320.0898; found: 320.0894.

ethyl 2-(8-chlorophenanthridin-6-yl)-2,2-difluoroacetate (3j)[4]



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (77%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (d, *J* = 8.9 Hz, 1H), 8.55 – 8.43 (m, 2H), 8.09 (dd, *J* = 5.9, 3.6 Hz, 1H), 7.83 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.80 – 7.71 (m, 2H), 4.58 (q, *J* = 7.1 Hz, 2H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.33 (t, *J* = 30.0 Hz), 149.2 (t, *J* = 28.8 Hz), 141.6, 134.1, 132.2, 131.9, 131.0, 129.4, 129.4, 125.6 (t, *J* = 5 Hz), 124.3, 124.2, 123.1 (t, *J* =1.25 Hz), 121.9, 115.6 (t, *J* = 252.5 Hz), 63.1, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.8.

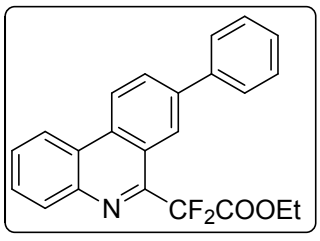
ethyl 2-(8-bromophenanthridin-6-yl)-2,2-difluoroacetate (3k)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (72%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.65 (dd, *J* = 3.7, 1.8 Hz, 1H), 8.55 – 8.40 (m, 2H), 8.24 – 8.01 (m, 1H), 7.93 (dd, *J* = 8.9, 2.0 Hz, 1H), 7.74 (dt, *J* = 5.5, 3.2 Hz, 2H), 4.58 (q, *J* = 7.1 Hz, 2H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.32 (t, *J* = 30.0 Hz), 149.00 (t, *J* = 31.3 Hz), 141.6, 134.5, 132.5, 130.9, 129.4, 129.4, 128.6 (t, *J* = 5 Hz), 124.2, 123.34 (t, *J* = 2.5 Hz), 122.2, 121.9, 115.6(t, *J* = 252.5 Hz), 63.2, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.6.

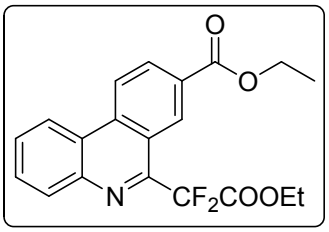
HRMS (ESI, m/z) calcd for $C_{17}H_{13}BrF_2NO_2[M+H]^+$: 380.0098; found: 380.0093.

ethyl 2,2-difluoro-2-(8-phenylphenanthridin-6-yl)acetate (3l)[4]



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a yellow oil (73%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.77 (dd, *J* = 7.7, 5.4 Hz, 2H), 8.67 – 8.59 (m, 1H), 8.23 – 8.11 (m, 2H), 7.84 – 7.76 (m, 4H), 7.61 – 7.54 (m, 2H), 7.51 – 7.44 (m, 1H), 4.61 (q, *J* = 7.1 Hz, 2H), 1.51 (t, *J* = 7.1 Hz, 3H). 13C NMR (125 MHz, $CDCl_3$) δ 163.7 (t, *J* = 31.3 Hz), 150.24 (t, *J* = 28.8 Hz), 141.7, 140.6, 139.9, 132.9, 130.9, 130.5, 129.2, 129.0, 129.0, 128.1, 127.5, 124.7, 124.09 (t, *J* = 4.8 Hz), 123.1, 122.7 (t, *J* = 1.7 Hz), 122.1, 115.9 (t, *J* = 253.8 Hz), 63.1, 14.2. 19F NMR (470 MHz, $CDCl_3$) δ -98.8.

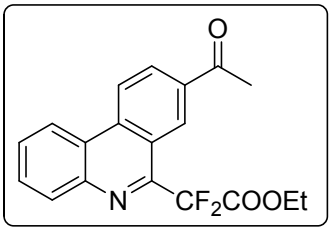
Ethyl 6-(2-ethoxy-1,1-difluoro-2-oxoethyl)phenanthridine-8-carboxylate (3m)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (72%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.26 (d, *J* = 1.6 Hz, 1H), 8.71 (d, *J* = 8.7 Hz, 1H), 8.60 (dd, *J* = 7.0, 2.5 Hz, 1H), 8.51 (dd, *J* = 8.7, 1.5 Hz, 1H), 8.17 – 8.07 (m, 1H), 7.81 (pd, *J* = 7.1, 3.5 Hz, 2H), 4.61 (q, *J* = 7.1 Hz, 2H), 4.52 (q, *J* = 7.1 Hz, 2H), 1.51 (td, *J* = 7.1, 3.8 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.7, 163.41 (t, *J* = 30.0 Hz), 150.6 (t, *J* = 30 Hz), 142.4, 136.6, 131.1, 130.9, 130.1, 129.7, 129.3, 128.4 (t, *J* = 5.0 Hz), 124.2, 122.8, 122.6, 121.8 (t, *J* = 1.25 Hz), 115.6 (t, *J* = 252.5 Hz), 63.1, 61.7, 14.4, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.3.

HRMS (ESI, m/z) calcd for $C_{20}H_{18}F_2NO_4[M+H]^+$: 374.1204; found: 374.1199.

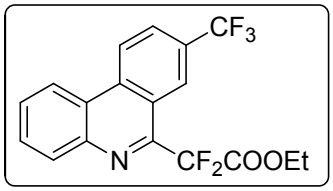
Ethyl2-(8-acetylphenanthridin-6-yl)-2,2-difluoroacetate(3n)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (76%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.05 (d, *J* = 1.6 Hz, 1H), 8.63 (d, *J* = 8.7 Hz, 1H), 8.52 (dd, *J* = 8.1, 1.4 Hz, 1H), 8.38 (dd, *J* = 8.7, 1.7 Hz, 1H), 8.13 – 8.00 (m, 1H), 7.76 (pd, *J* = 7.1, 1.6 Hz, 2H), 4.58 (q, *J* = 7.1 Hz, 2H), 2.76 (s, 3H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 197.0,163.3 (t, *J* = 30 Hz), 150.4 (t, *J* = 28.8 Hz), 142.4, 136.6, 135.7, 130.9, 130.2, 129.4, 129.4, 127.37 (t, *J* = 5.0 Hz), 124.0, 123.1, 122.6, 121.7 (t, *J* = 1.3 Hz), 115.59 (t, *J* = 252.5 Hz), 63.2, 26.6, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.1.

HRMS (ESI, m/z) calcd for $C_{19}H_{16}F_2NO_3[M+H]^+$: 344.1094; found: 344.1098.

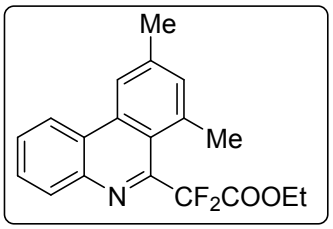
ethyl 2,2-difluoro-2-(8-(trifluoromethyl)phenanthridin-6-yl)acetate (3o)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (71%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.83 (s, 1H), 8.79 (d, *J* = 8.8 Hz, 1H), 8.59 (dd, *J* = 6.7, 2.8 Hz, 1H), 8.18 – 8.11 (m, 1H), 8.09 (dd, *J* = 8.7, 1.5 Hz, 1H), 7.86 – 7.77 (m, 2H), 4.58 (q, *J* = 7.1 Hz, 2H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.2 (t, *J* = 30 Hz), 150.1 (t, *J* = 28.8 Hz), 142.3, 136.0, 131.1, 130.3, 129.9, 129.6, 127.14 (dd, *J* = 2.5 Hz), 124.8 (t, *J* = 1.3 Hz), 123.9 (q, *J* = 3.8

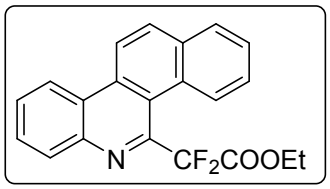
Hz), 123.6, 122.7, 122.4, 121.6 (t, J = 2.5 Hz), 115.5 (t, J = 252.5 Hz), 63.2, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -62.4, -98.3.
HRMS (ESI, m/z) calcd for $C_{18}H_{13}F_5NO_2[M+H]^+$: 370.0866; found: 370.0862.

ethyl 2-(7,9-dimethylphenanthridin-6-yl)-2,2-difluoroacetate (3p)



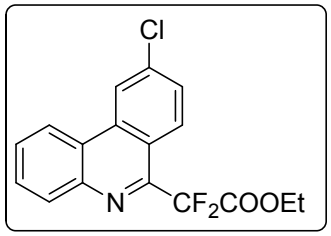
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.51 (dd, J = 4.9, 3.8 Hz, 1H), 8.31 (s, 1H), 8.07 – 7.93 (m, 1H), 7.77 – 7.62 (m, 2H), 7.40 (s, 1H), 4.54 (q, J = 7.1 Hz, 2H), 2.95 (t, J = 2.9 Hz, 3H), 2.56 (s, 3H), 1.46 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 164.7 (t, J = 32.5 Hz), 149.16 (t, J = 32.5 Hz), 140.9, 140.5, 136.2, 135.8, 134.3, 130.0, 128.7, 128.7 125.1, 122.3, 121.0, 120.4, 117.14 (t, J = 256.3 Hz), 62.6, 23.9 (t, J = 12.5 Hz), 21.8, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -96.1.
HRMS (ESI, m/z) calcd for $C_{19}H_{18}F_2NO_2[M+H]^+$: 330.1306; found: 330.1300.

ethyl 2-(benzo[i]phenanthridin-5-yl)-2,2-difluoroacetate (3q)[4]



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (63%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.11 (d, J = 8.5 Hz, 1H), 8.67 – 8.54 (m, 2H), 8.20 (d, J = 8.9 Hz, 1H), 8.17 – 8.10 (m, 1H), 8.00 (dd, J = 7.9, 1.3 Hz, 1H), 7.83 – 7.68 (m, 4H), 4.46 (q, J = 7.1 Hz, 2H), 1.35 (t, J = 7.1 Hz, 3H). 13C NMR (125 MHz, $CDCl_3$) δ 164.29 (t, J = 32.5 Hz), 148.20 (t, J = 30.0 Hz), 142.0, 135.2, 133.1, 132.9, 129.9, 129.4, 128.8, 128.4 (t, J = 16.3 Hz), 128.4, 128.2, 127.4, 127.3, 124.7, 122.7, 120.8, 119.8, 117.1 (t, J = 257.5 Hz), 62.7, 14.0. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.4.

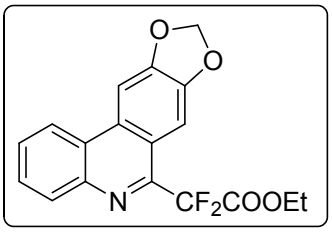
ethyl 2-(9-chlorophenanthridin-6-yl)-2,2-difluoroacetate (3r)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (74%).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.63 (d, J = 2.0 Hz, 1H), 8.54 – 8.44 (m, 2H), 8.19 – 8.02 (m, 1H), 7.86 – 7.75 (m, 2H), 7.71 (dd, J = 8.9, 2.1 Hz, 1H), 4.57 (q, J = 7.1 Hz, 2H), 1.48 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4 (t, J = 30 Hz),149.8 (t, H = 10.0 Hz), 142.1, 138.0,

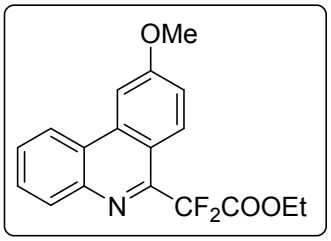
135.3, 131.0, 129.7, 129.2, 128.6, 127.9 (t, J = 6.3 Hz), 123.8, 122.3, 122.1, 120.6 (t, J = 1.3 Hz), 115.6 (t, J = 252.5 Hz), 63.1, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.6.
HRMS (ESI, m/z) calcd for $C_{17}H_{13}ClF_2NO_2[M+H]^+$: 336.0603; found: 336.0595.

Ethyl 2-([1,3]dioxolo[4,5-j]phenanthridin-6-yl)-2,2-difluoroacetate (3s)



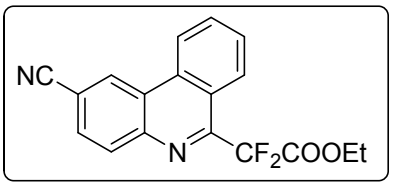
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (84%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (dd, J = 6.2, 3.5 Hz, 1H), 8.06 (dd, J = 6.2, 3.4 Hz, 1H), 7.94 (s, 1H), 7.85 (s, 1H), 7.68 (dd, J = 6.3, 3.3 Hz, 2H), 6.19 (s, 2H), 4.56 (q, J = 7.1 Hz, 2H), 1.48 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.69 (t, J = 31.3 Hz), 151.5, 148.6 (t, J = 12.5 Hz), 141.5, 132.2, 130.7, 128.5, 128.4, 125.0, 121.9, 118.9 (t, J = 1.3 Hz), 116.0 (t, J = 252.5 Hz), 103.5 (t, J = 5.0 Hz), 102.3, 100.3, 63.0, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.1.
HRMS (ESI, m/z) calcd for $C_{18}H_{14}F_2NO_4[M+H]^+$: 346.0891; found: 346.0886.

ethyl 2,2-difluoro-2-(9-methoxyphenanthridin-6-yl)acetate (3t)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (85%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.51 – 8.41 (m, 2H), 8.08 (d, J = 7.7 Hz, 1H), 7.93 (d, J = 2.0 Hz, 1H), 7.77 – 7.65 (m, 2H), 7.32 (dd, J = 9.2, 2.5 Hz, 1H), 4.56 (q, J = 7.1 Hz, 2H), 4.04 (s, 3H), 1.47 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.75 (t, J = 31.3 Hz), 161.6, 149.5 (t, J =28.8 Hz), 142.1, 136.3, 130.8, 129.1, 128.3, 128.1 (t, J = 5 Hz), 124.6, 122.1, 118.2, 117.12 (t, J = 1.3 Hz), 115.8 (t, J = 252.5 Hz), 103.1, 63.0, 55.6, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.6.
HRMS (ESI, m/z) calcd for $C_{18}H_{16}F_2NO_3[M+H]^+$: 332.1098; found: 332.1098.

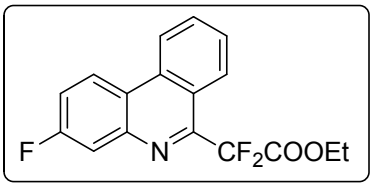
ethyl 2-(2-cyanophenanthridin-6-yl)-2,2-difluoroacetate (3u)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (71%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.90 (d, J = 1.5 Hz, 1H), 8.61 (dd, J = 19.9, 8.3 Hz, 2H), 8.18 (d, J = 8.4 Hz, 1H), 8.05 – 7.97 (m, 1H), 7.92 (dd, J = 8.4, 1.7 Hz, 1H), 7.89 – 7.81 (m, 1H), 4.57 (q, J = 7.1 Hz, 2H), 1.47 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.1 (t, J = 31.3 Hz), 153.1 (t, J = 28.8 Hz), 143.2, 132.9, 132.5, 132.0, 130.6, 129.3, 127.8, 126.7 (t, J = 5.0 Hz), 125.0,

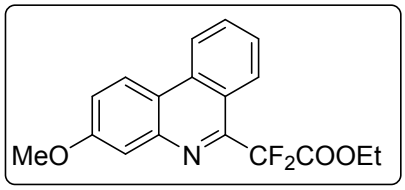
122.6 (t, J = 2.5 Hz), 122.5, 118.5, 115.2 (t, J = 253.8 Hz), 112.4, 63.3, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.9.
HRMS (ESI, m/z) calcd for $C_{18}H_{13}F_2N_2O_2[M+H]^+$: 327.0945; found: 327.0942.

ethyl 2,2-difluoro-2-(3-fluorophenanthridin-6-yl)acetate (3v)



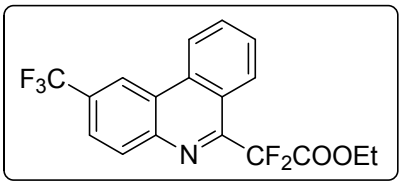
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (86%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.50 (t, J = 7.2 Hz, 2H), 8.45 (dd, J = 9.1, 5.7 Hz, 1H), 7.84 (ddd, J = 8.3, 7.1, 1.1 Hz, 1H), 7.77 – 7.61 (m, 2H), 7.45 (ddd, J = 9.0, 8.1, 2.7 Hz, 1H), 4.58 (q, J = 7.1 Hz, 2H), 1.48 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.6, 163.5 (t, J = 15.4 Hz), 161.6, 151.4 (t, J = 28.8 Hz), 142.9 (d, J = 11.3 Hz), 133.6, 131.6, 127.7, 126.3 (t, J = 5.0 Hz), 124.1 (d, J = 8.8 Hz) 122.2, 121.8, 121.5 (d, J = 2.5 Hz), 118.1(d, J = 23.8 Hz), 115.7 (t, J = 253.8 Hz), 115.1 (d, J = 21.3 Hz), 63.1, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.7, -111.2.
HRMS (ESI, m/z) calcd for $C_{17}H_{13}F_3NO_2[M+H]^+$: 320.0898; found: 320.0896.

ethyl 2,2-difluoro-2-(3-methoxyphenanthridin-6-yl)acetate (3w)[5]



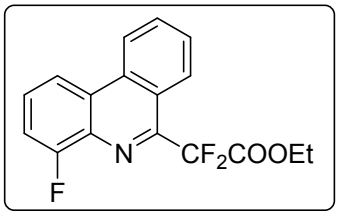
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.56 (d, J = 8.4 Hz, 1H), 8.51 (d, J = 8.2 Hz, 1H), 8.45 (d, J = 9.1 Hz, 1H), 7.85 (ddd, J = 8.3, 7.1, 1.1 Hz, 1H), 7.67 (ddd, J = 8.2, 7.0, 1.1 Hz, 1H), 7.49 (d, J = 2.7 Hz, 1H), 7.37 (dd, J = 9.0, 2.7 Hz, 1H), 4.56 (q, J = 7.1 Hz, 2H), 3.97 (s, 3H), 1.46 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.8 (t, J = 31.3 Hz), 160.3, 150.5 (t, J = 27.5 Hz), 143.5, 134.1, 131.2, 126.8, 126.2 (t, J = 5.0 Hz), 123.2, 122.0, 121.4 (t, J = 1.3 Hz), 120.1, 119.0, 115.7 (t, J = 252.5 Hz), 110.4, 63.0, 55.7, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.8.
HRMS (ESI, m/z) calcd for $C_{10}H_{14}N_3O_2[M+H]^+$: 208.1081; found: 208.1080.

ethyl 2,2-difluoro-2-(2-(trifluoromethyl)phenanthridin-6-yl)acetate (3x)



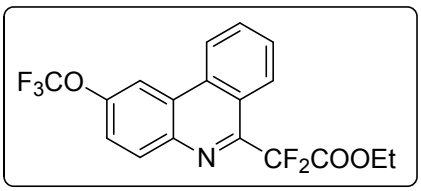
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (79%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.85 (s, 1H), 8.70 (d, *J* = 8.4 Hz, 1H), 8.60 (d, *J* = 8.3 Hz, 1H), 8.23 (d, *J* = 8.5 Hz, 1H), 8.04 – 7.89 (m, 2H), 7.83 (ddd, *J* = 8.2, 7.1, 1.0 Hz, 1H), 4.57 (q, *J* = 7.1 Hz, 2H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.3 (t, *J* = 30 Hz),152.4 (t, *J* = 28.8 Hz), 143.1, 133.6, 132.0, 131.8, 130.6 (dd, *J* = 32.5 Hz), 128.8, 126.61 (t, *J* = 5.0 Hz), 125.1 (m, *J* = 2.5 Hz), 124.6, 122.9, 122.6, 120.8 (t, *J* = 3.8 Hz), 119.9 (q, *J* = 5 Hz), 115.4 (t, *J* = 253.8 Hz), 63.2, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -62.1, -98.9.
HRMS (ESI, m/z) calcd for $C_{18}H_{13}F_5NO_2[M+H]^+$: 370.0866; found: 370.0859.

ethyl 2,2-difluoro-2-(4-fluorophenanthridin-6-yl)acetate (3y)



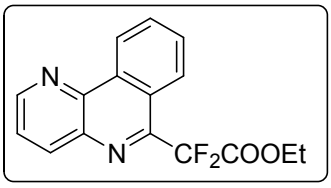
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (86%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.63 – 8.54 (m, 2H), 8.29 (d, *J* = 8.4 Hz, 1H), 7.90 (ddd, *J* = 8.3, 7.1, 1.2 Hz, 1H), 7.77 (ddd, *J* = 8.3, 7.1, 1.1 Hz, 1H), 7.66 (td, *J* = 8.1, 5.2 Hz, 1H), 7.40 (ddd, *J* = 9.3, 7.9, 1.0 Hz, 1H), 4.60 (q, *J* = 7.2 Hz, 2H), 1.50 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.5 (t, *J* = 30.0 Hz), 160.0, 157.9, 150.3 (t, *J* = 31.3 Hz), 133.3, 131.7, 131.5 (d, *J* = 10.0 Hz), 129.1 (d, *J* = 8.8 Hz) 128.5, 126.7, 126.4 (t, *J* = 5.0 Hz), 122.9, 122.4 (t, *J* = 2.5 Hz), 117.5 (d, *J* = 3.8 Hz), 115.8 (t, *J* = 252.5 Hz), 114.1 (d, *J* = 18.8 Hz), 63.3, 14.0. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.7, -122.3.
HRMS (ESI, m/z) calcd for $C_{17}H_{13}F_3NO_2[M+H]^+$: 320.0898; found: 320.0891.

ethyl 2,2-difluoro-2-(2-(trifluoromethoxy)phenanthridin-6-yl)acetate (3z)



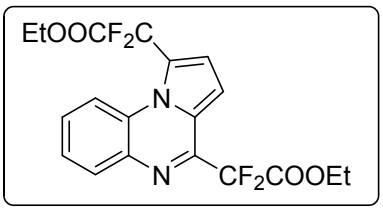
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (76%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.68 – 8.55 (m, 2H), 8.39 (d, *J* = 1.8 Hz, 1H), 8.18 (d, *J* = 8.9 Hz, 1H), 8.05 – 7.91 (m, 1H), 7.89 – 7.79 (m, 1H), 7.63 (dd, *J* = 8.9, 1.5 Hz, 1H), 4.59 (q, *J* = 7.1 Hz, 2H), 1.50 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4 (t, *J* = 30.0 Hz), 150.7 (t, *J* = 28.8 Hz), 149.1, 140.0, 133.3, 132.9, 131.6, 128.8, 126.49 (t, *J* = 5.0 Hz), 126.0, 122.6, 122.4 (t, *J* = 1.3 Hz), 122.3, 121.6, 117.6 (t, *J* = 252.5 Hz), 113.6, 63.1, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -57.6, -98.9.
HRMS (ESI, m/z) calcd for $C_{18}H_{13}F_5NO_3[M+H]^+$: 386.0816; found: 386.0812.

ethyl 2-(benzo[c][1,5]naphthyridin-6-yl)-2,2-difluoroacetate (3aa)



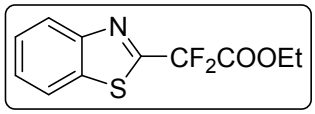
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (77%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.36 – 9.27 (m, 1H), 9.07 (dd, *J* = 4.3, 1.7 Hz, 1H), 8.58 (d, *J* = 8.3 Hz, 1H), 8.41 (dd, *J* = 8.3, 1.7 Hz, 1H), 8.01 (ddd, *J* = 8.2, 7.1, 1.0 Hz, 1H), 7.88 (ddd, *J* = 8.4, 7.1, 1.3 Hz, 1H), 7.70 (dd, *J* = 8.3, 4.3 Hz, 1H), 4.58 (q, *J* = 7.1 Hz, 2H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4 (t, *J* = 30.0 Hz), 151.2, 151.1 (t, *J* = 28.8 Hz), 141.5, 137.8, 136.6, 134.8, 131.8, 129.6, 125.6 (t, *J* = 5.0 Hz), 124.35 (t, *J* = 1.3 Hz), 124.2, 124.1, 115.3 (t, *J* = 252.5 Hz), 63.2, 14.1. ^{19}F NMR (470 MHz, $CDCl_3$) δ -99.0.
HRMS (ESI, m/z) calcd for $C_{16}H_{13}F_2N_2O_2[M+H]^+$: 303.0945; found: 303.0942.

Diethyl 2,2'-(pyrrolo[1,2-a]quinoxaline-1,4-diyl)bis(2,2-difluoroacetate) (3ab)



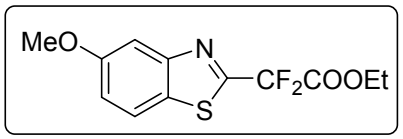
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (73%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.6 Hz, 1H), 8.03 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.64 (ddd, *J* = 8.7, 7.3, 1.6 Hz, 1H), 7.58 – 7.51 (m, 1H), 7.31 – 7.22 (m, 2H), 4.48 (q, *J* = 7.1 Hz, 2H), 4.37 (q, *J* = 7.1 Hz, 2H), 1.40 (t, *J* = 7.1 Hz, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 162.9 (t, *J* = 33.8 Hz), 162.6 (t, *J* = 31.3 Hz), 135.1, 131.5, 130.1, 128.0, 126.4, 125.7, 122.4 (t, *J* = 31.3 Hz), 118.7 (t, *J* = 6.3 Hz), 116.8 (t, *J* = 7.5 Hz), 115.1, 113.1, 111.1 (t, *J* = 246.3 Hz), 107.34 (t, *J* = 3.8 Hz), 64.0, 63.4, 14.0, 13.8. ^{19}F NMR (470 MHz, $CDCl_3$) δ -92.7, -105.1.
HRMS (ESI, m/z) calcd for $C_{19}H_{17}F_4N_2O_4[M+H]^+$: 413.1124; found: 413.1117.

ethyl 2-(benzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5a)



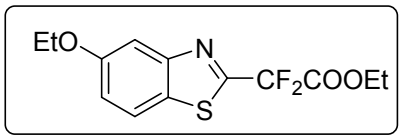
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.8 Hz, 1H), 8.02 – 7.96 (m, 1H), 7.58 (ddd, *J* = 8.3, 7.3, 1.3 Hz, 1H), 7.55 – 7.50 (m, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 1.37 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.7 (t, *J* = 32.5 Hz), 160.3 (t, *J* = 32.5 Hz), 152.5, 135.1, 127.0, 127.0, 124.8, 122.0, 110.3 (t, *J* = 251.3 Hz), 64.0, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.4.
HRMS (ESI, m/z) calcd for $C_{11}H_{10}F_2NO_2S[M+H]^+$: 258.0400; found: 258.0396.

ethyl 2,2-difluoro-2-(5-methoxybenzo[*d*]thiazol-2-yl)acetate (5b)



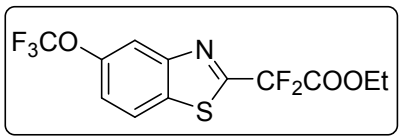
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (77%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, *J* = 9.0 Hz, 1H), 7.37 (d, *J* = 2.5 Hz, 1H), 7.16 (dd, *J* = 9.1, 2.5 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 3.90 (s, 3H), 1.37 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.9 (t, *J* = 31.3 Hz), 159.0, 157.3 (t, *J* = 32.5 Hz), 147.0, 136.8, 125.3, 117.0, 110.3 (t, *J* = 25.3 Hz), 103.6, 63.9, 55.9, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.0.
HRMS (ESI, m/z) calcd for $C_{12}H_{12}F_2NO_3S[M+H]^+$: 288.0506; found: 288.0502.

ethyl 2-(5-ethoxybenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5c)



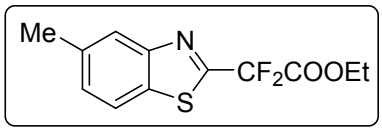
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (82%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 (d, *J* = 9.0 Hz, 1H), 7.36 (d, *J* = 2.5 Hz, 1H), 7.15 (dd, *J* = 9.0, 2.5 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 4.11 (q, *J* = 7.0 Hz, 2H), 1.47 (t, *J* = 7.0 Hz, 3H), 1.37 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.9 (t, *J* = 32.5 Hz), 158.4, 157.1 (t, *J* = 32.5Hz), 146.9, 136.8, 125.3, 117.4, 108.3 (t, *J* = 251.3 Hz), 64.2, 63.9, 14.7, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.0.
HRMS (ESI, m/z) calcd for $C_{13}H_{14}F_2NO_3S[M+H]^+$: 302.0662; found: 302.0658.

ethyl 2,2-difluoro-2-(5-(trifluoromethoxy)benzo[*d*]thiazol-2-yl)acetate (5d)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (85%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 9.0 Hz, 1H), 7.85 (d, *J* = 1.2 Hz, 1H), 7.45 (dd, *J* = 9.0, 1.6 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.5 (t, *J* = 32.5 Hz), 161.4 (t, *J* = 31.3 Hz), 150.8, 147.8, 136.1, 125.8, 121.1, 114.3, 109.9 (t, *J* = 252.5 Hz), 64.1, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -58.0, -98.5.
HRMS (ESI, m/z) calcd for $C_{12}H_9F_5NO_3S[M+H]^+$: 342.0223; found: 342.0220.

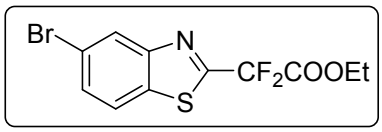
ethyl 2,2-difluoro-2-(5-methylbenzo[*d*]thiazol-2-yl)acetate (5e)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (79%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.4 Hz, 1H), 7.75 (s, 1H), 7.37 (dd, *J* = 8.4, 1.5 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 2.52 (s, 3H), 1.37 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.8 (t, *J* = 31.3 Hz), 159.1 (t, *J* = 32.5 Hz), 150.6, 137.5, 135.4, 128.7, 124.2, 121.5, 110.3 (t, *J* = 251.3 Hz), 63.9, 21.7, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.3.

HRMS (ESI, m/z) calcd for $C_{12}H_{12}F_2NO_2S[M+H]^+$: 272.0557; found: 272.0556.

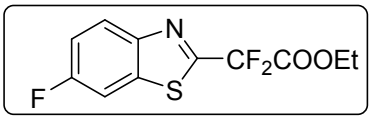
ethyl 2-(5-bromobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5f)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a white solid (67%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (d, *J* = 1.8 Hz, 1H), 8.00 (d, *J* = 8.8 Hz, 1H), 7.68 (dd, *J* = 8.8, 1.9 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 1.37 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.5 (t, *J* = 32.5 Hz), 160.8 (t, *J* = 32.5 Hz), 151.3, 136.7, 130.7, 125.8, 124.7, 121.0, 110.0 (t, *J* = 252.5 Hz), 64.1, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.43 (s).

HRMS (ESI, m/z) calcd for $C_{11}H_{10}BrF_2NO_2S[M+H]^+$: 335.9505; found: 335.9507.

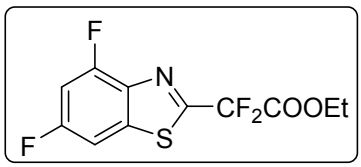
ethyl 2-(6-chlorobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5g)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a yiellow oil (75%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 8.9, 5.0 Hz, 1H), 7.83 (dd, *J* = 9.1, 2.5 Hz, 1H), 7.31 (td, *J* = 8.8, 2.5 Hz, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.0, 162.7 (t, *J* = 32.5 Hz), 161.5 (t, *J* = 31.3 Hz), 161.0, 153.4 (d, *J* = 12.2 Hz), 130.6, 122.9 (d, *J* = 9.9 Hz), 116.3 (d, *J* = 25 Hz), 110.82 (d, *J* = 23.8 Hz), 110.00 (t, *J* = 251.3 Hz), 64.1, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -98.6, -114.0.

HRMS (ESI, m/z) calcd for $C_{11}H_9F_3NO_2S[M+H]^+$: 276.0301; found: 276.0303.

ethyl 2-(4,6-difluorobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5h)

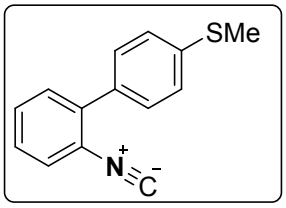


The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 100:1, v/v) to give the product as a yiellow oil (75%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.48 (ddd, *J* = 7.5, 2.3, 1.3 Hz, 1H), 7.09 (ddd, *J* = 9.9, 9.2, 2.3 Hz, 1H), 4.45 (q, *J* = 7.1 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.63 – 160.16 (m), 138.1,109.8 (t, J = 250 Hz), 104.14 (d, *J* = 5.0 Hz), 104.03 (dd, *J* = 26.8, 5.0 Hz), 104.28 – 103.46 (m), 64.2, 13.9. ^{19}F NMR (470 MHz, $CDCl_3$) δ -97.9, -108.45 (d, *J* = 7.0 Hz), -114.71 (d, *J* = 7.1 Hz).

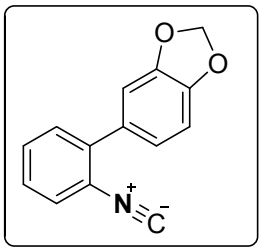
HRMS (ESI, m/z) calcd for $C_{11}H_8F_4NO_2S[M+H]^+$: 294.0212; found: 294.0208.

(2'-isocyano-[1,1'-biphenyl]-4-yl)(methyl)sulfane (8)

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.51 – 7.32 (m, 8H), 2.54 (s, 3H). ^{13}C NMR (125MHz, $CDCl_3$) δ 166.5, 139.3, 138.2, 133.5, 130.4 129.6, 129.3, 128.0, 126.2, 15.5.



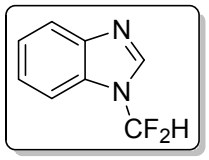
(2'-isocyano-[1,1'-biphenyl]-4-yl)(methyl)sulfane (11)



^{1}H NMR (500 MHz, $CDCl_3$) δ 7.49 – 7.31 (m, 4H), 7.01 – 6.95 (m, 2H), 6.92 (t, *J* = 5.0 Hz, 1H), 6.03 (s, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.5, 147.5, 138.5, 130.8, 130.5, 129.5, 127.9, 122.9, 109.5, 108.5, 101.4.

1-(difluoromethyl)-1H-benzo[d]imidazole (10)

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12 (s, 1H), 7.93 – 7.76 (m, 1H), 7.61 (dd, *J* = 5.4, 3.6 Hz, 1H), 7.37 (ddd, *J* = 85.8, 55.8, 43.2 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 143.9, 139.1, 130.6, 124.8, 124.2, 121.0, 111.1, 109.0 (t, *J* = 248.8 Hz) ^{19}F NMR (470 MHz, $CDCl_3$) δ -93.7.

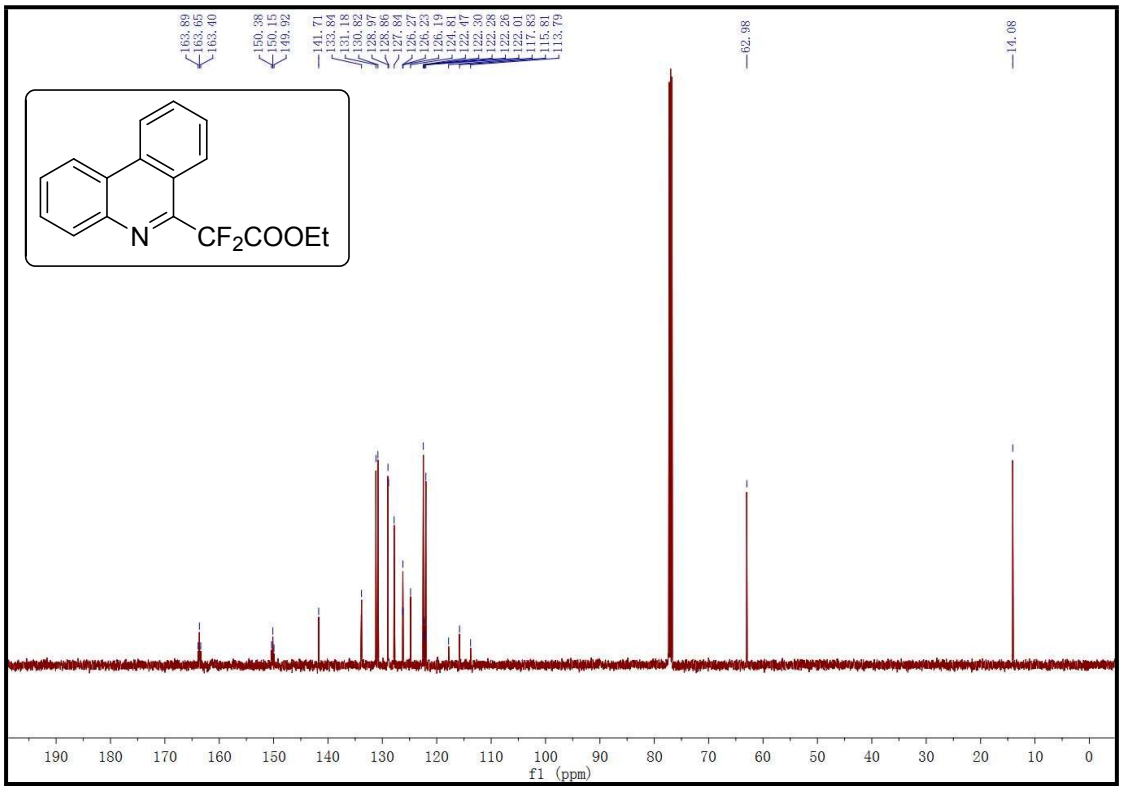


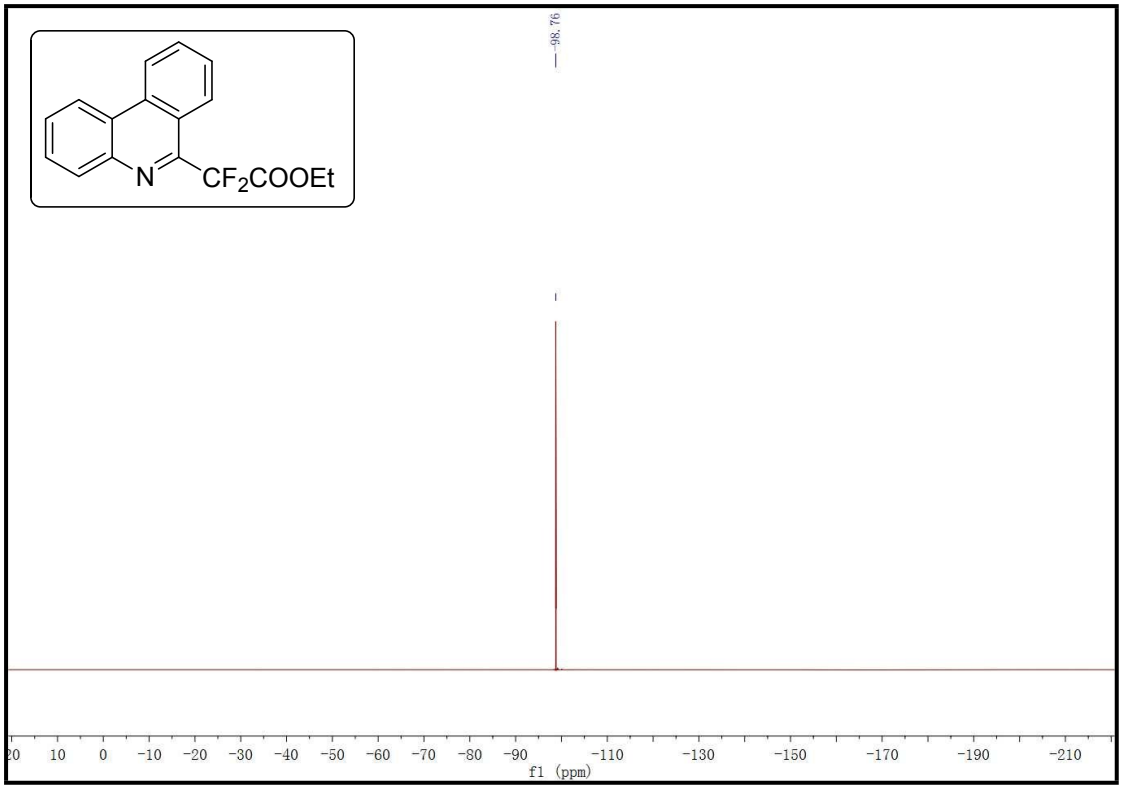
13. References:

1 I. T. Alt, B. Plietker, *Angew. Chem. Int. Ed*. 2016, **55**, 1519-1522.
2 *J. Rong, L. Deng, P. Tan, C. Ni, Y. Gu, Hu, J. Angew. Chem. Int. Ed.* 2016, **55**, 2743-2747.
3 J.-W. Gu, X. Zhang, *Org. Lett.* **2015**, *17*, 5384-5387.
4 X. Sun, S.Yu, *Org. Lett.* **2014**, *16*, 2938-2941.

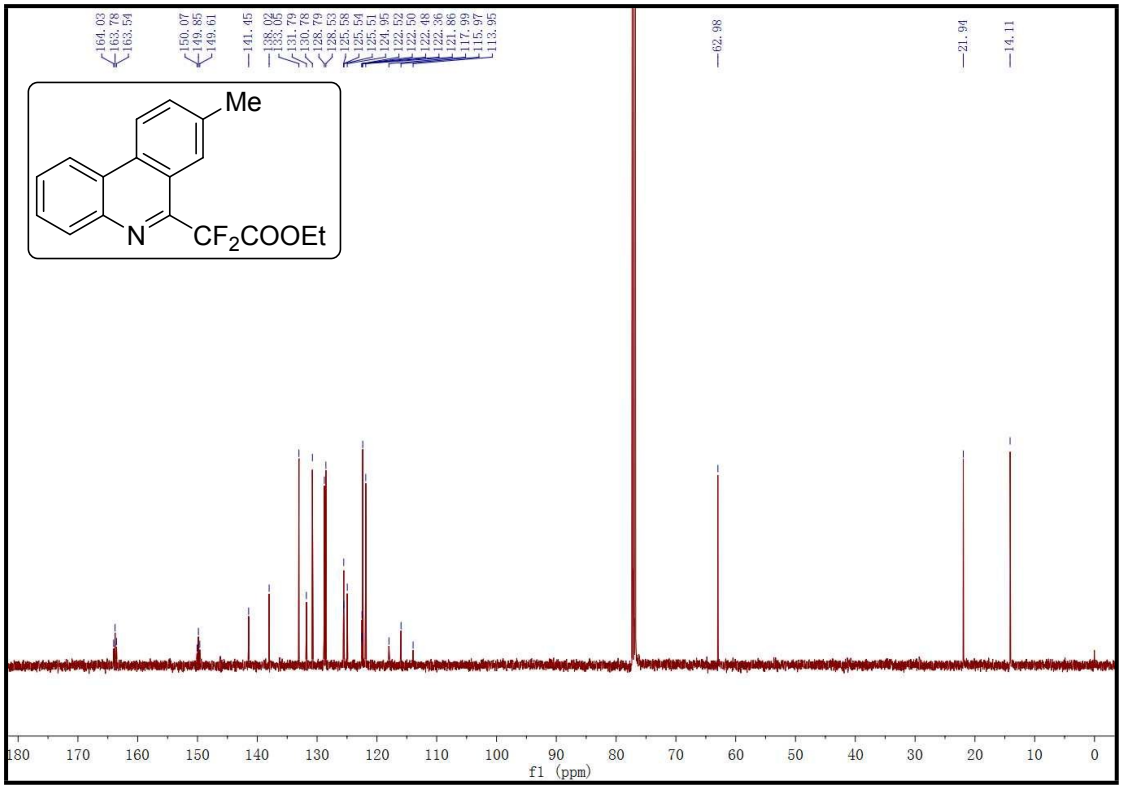
14. NMR spectroscopic data

ethyl 2,2-difluoro-2-(phenanthridin-6-yl)acetate (3a)





ethyl 2,2-difluoro-2-(8-methylphenanthridin-6-yl)acetate (3b)


164.03
163.78
163.54
150.07
149.85
149.61
141.45
138.02
133.05
131.79
130.78
128.79
128.53
125.58
125.54
125.51
124.95
122.52
122.50
122.48
122.36
121.86
117.99
115.97
113.95
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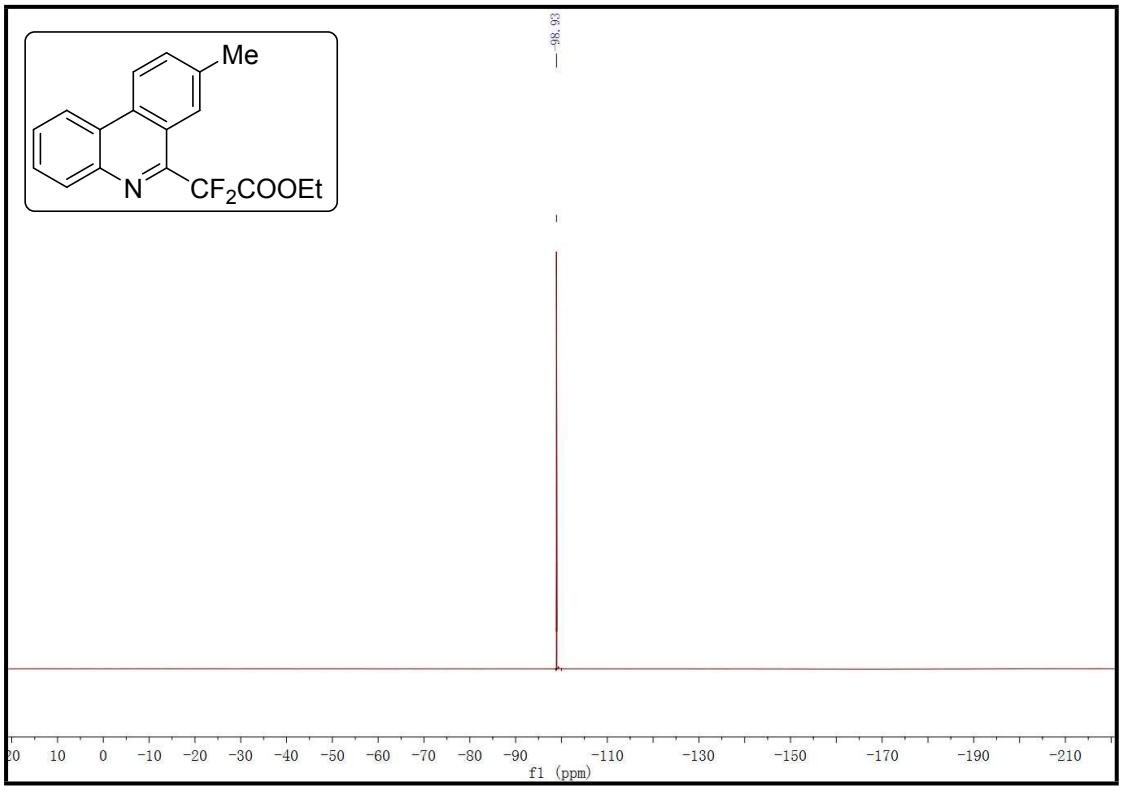
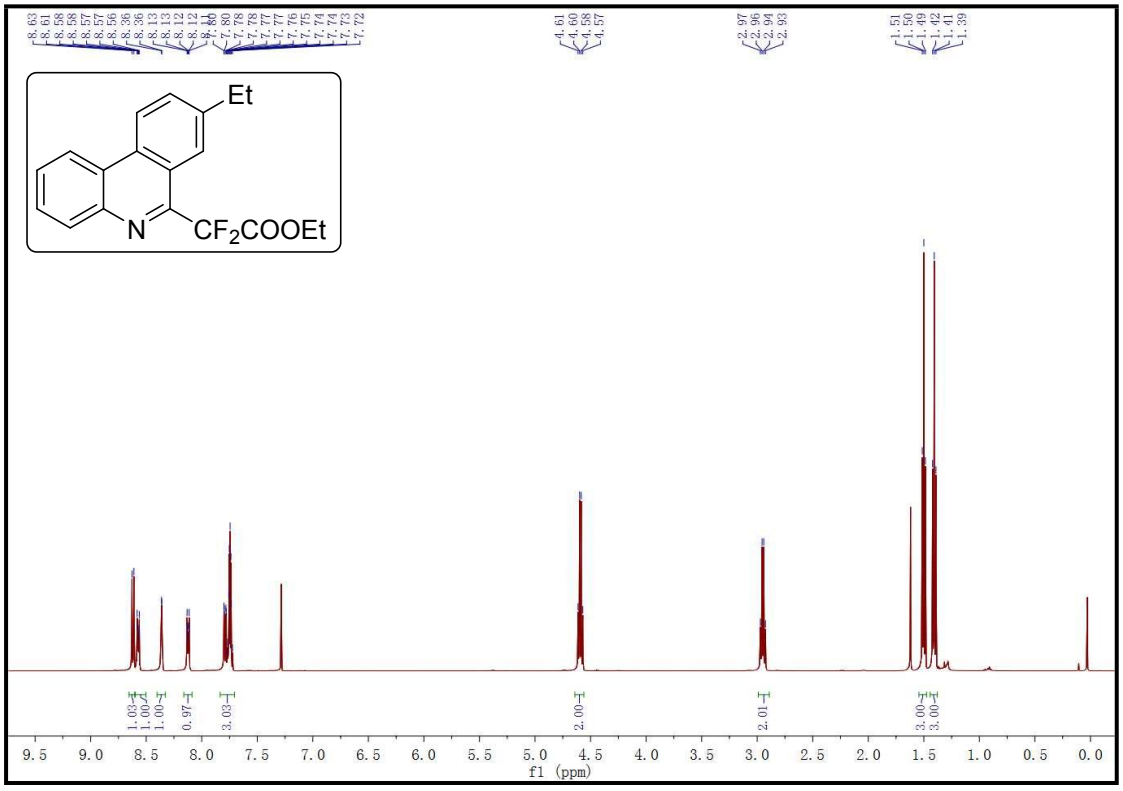
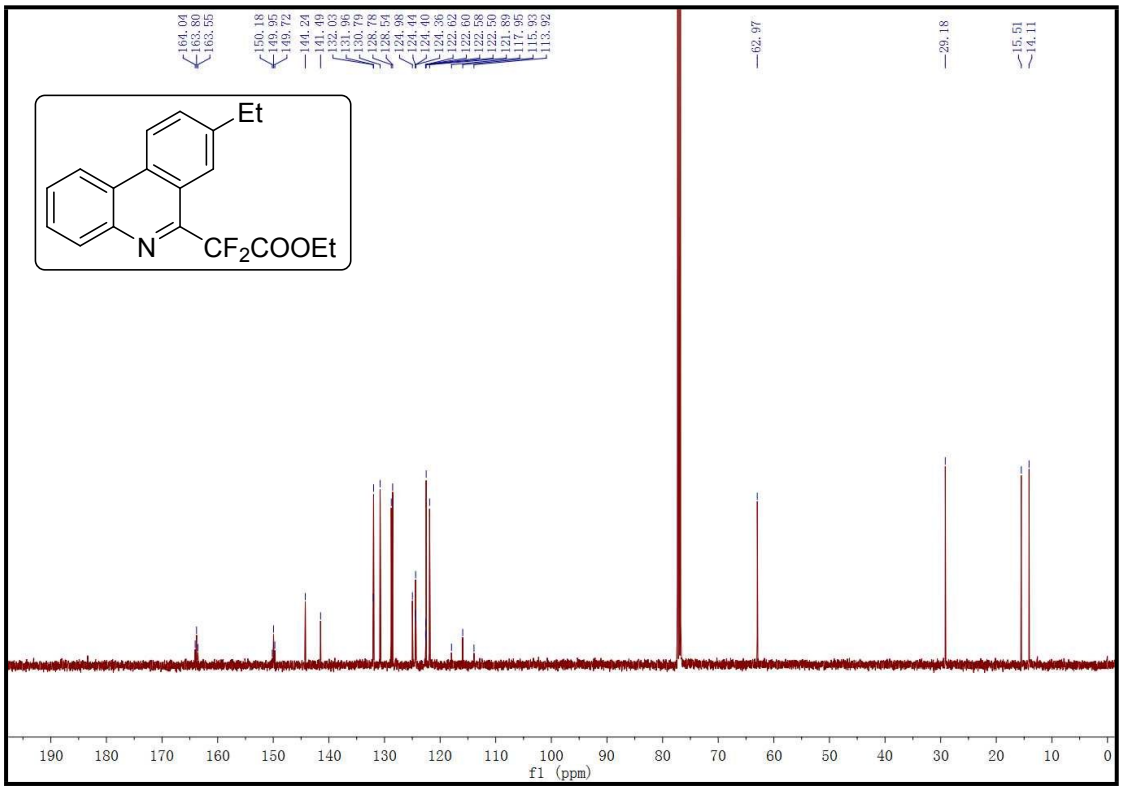
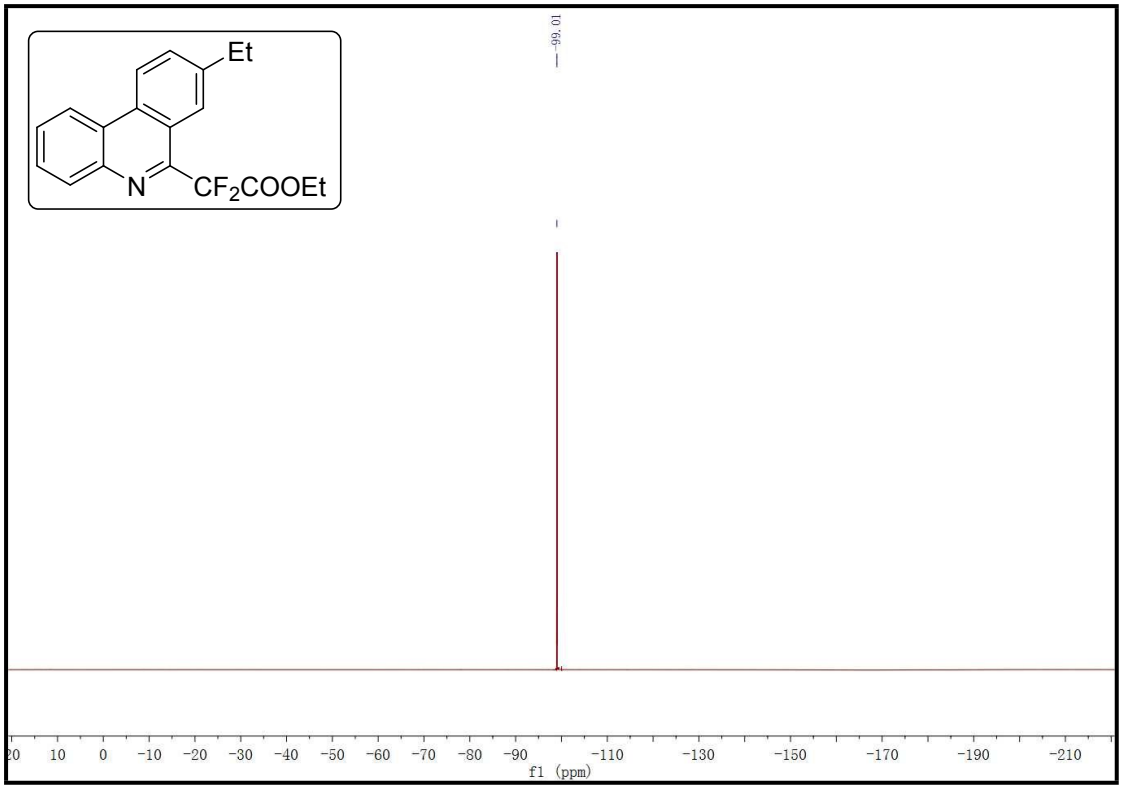
14.11
Me
N
CF2COOEt
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.93
Me
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

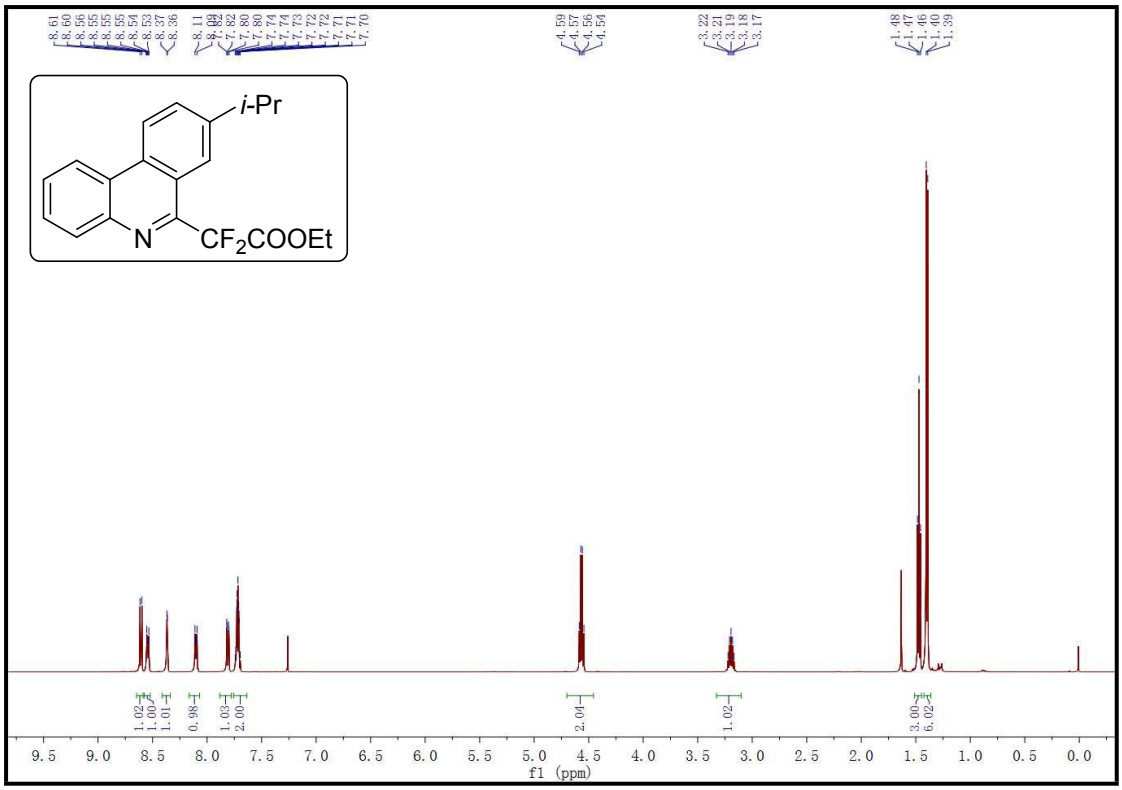
ethyl 2-(8-ethylphenanthridin-6-yl)-2,2-difluoroacetate (3c)

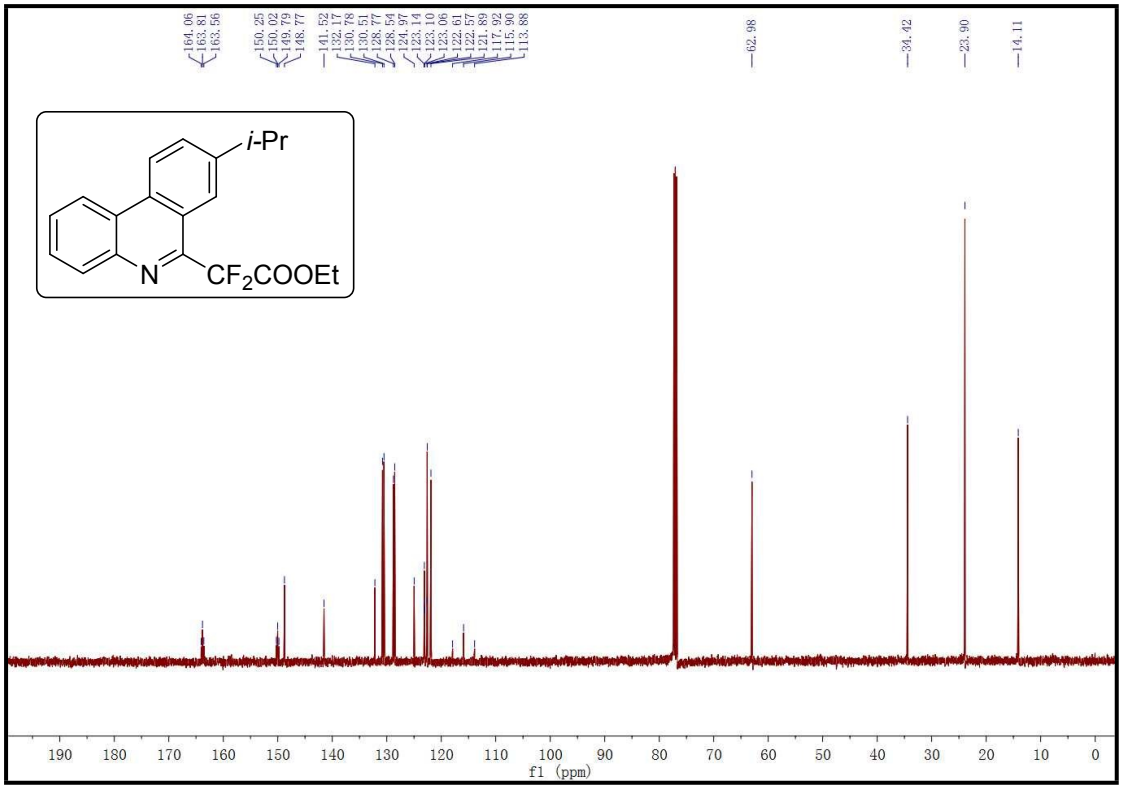


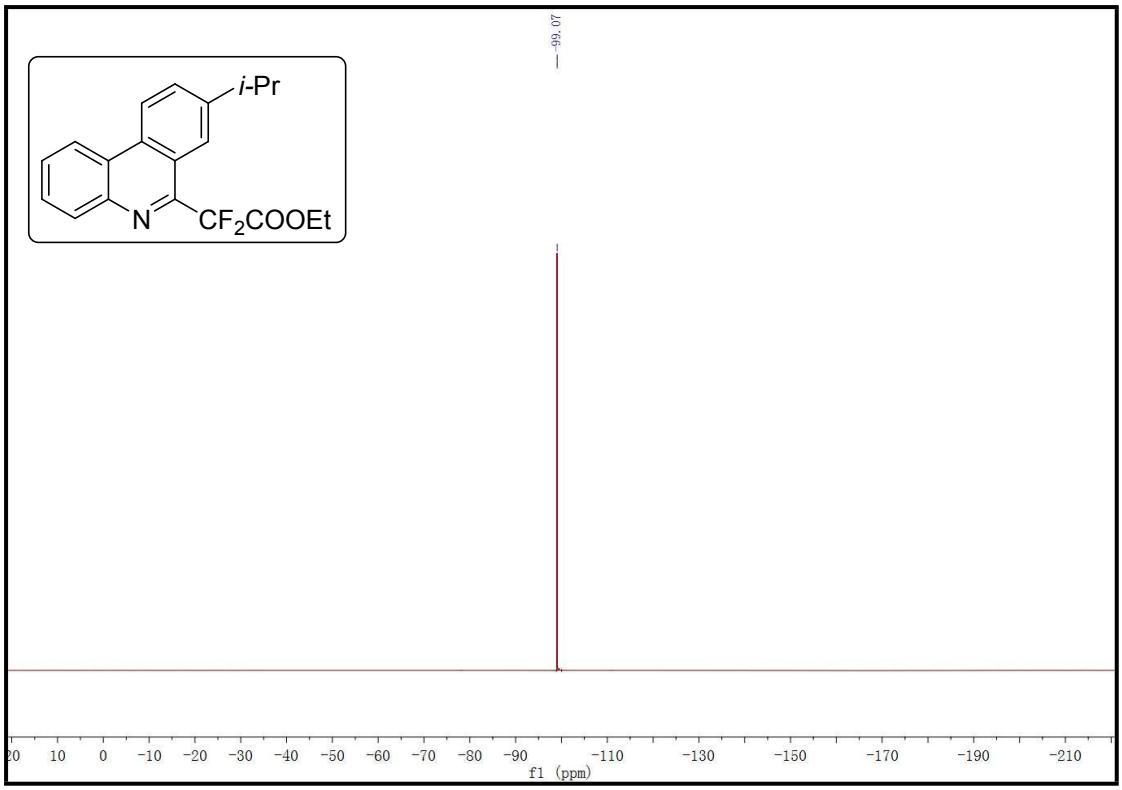




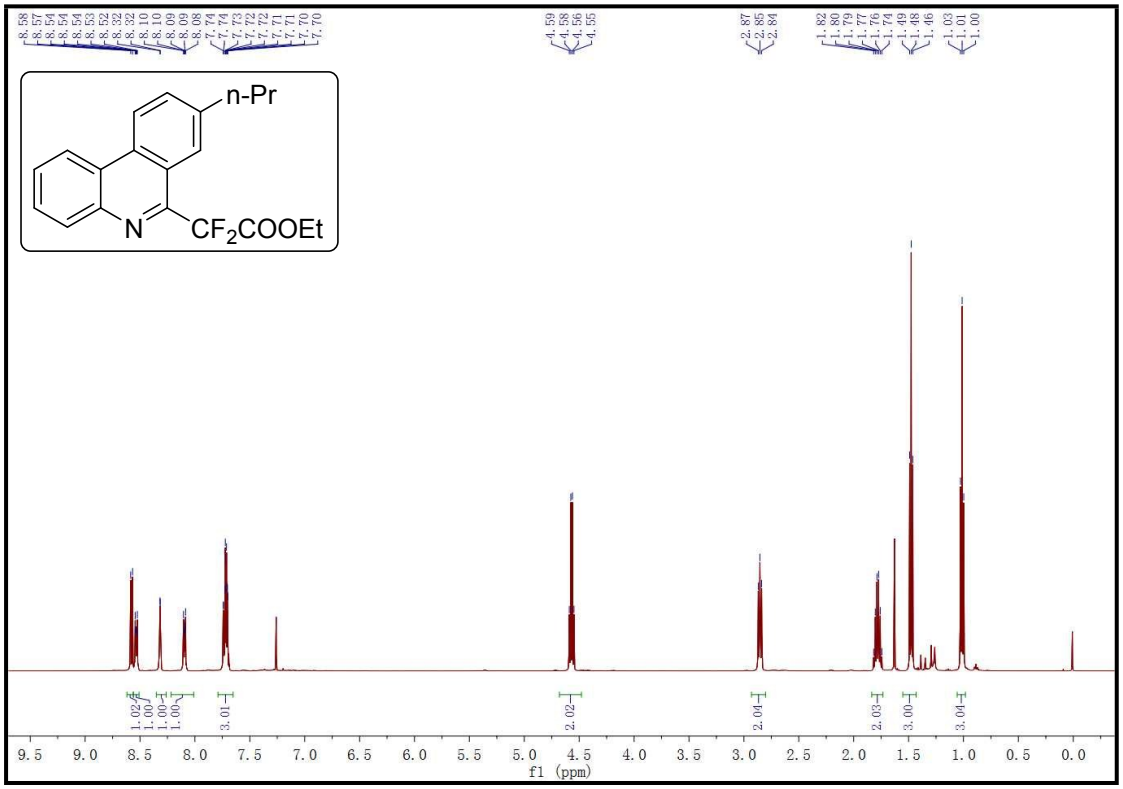
ethyl 2,2-difluoro-2-(8-isopropylphenanthridin-6-yl)acetate (3d)

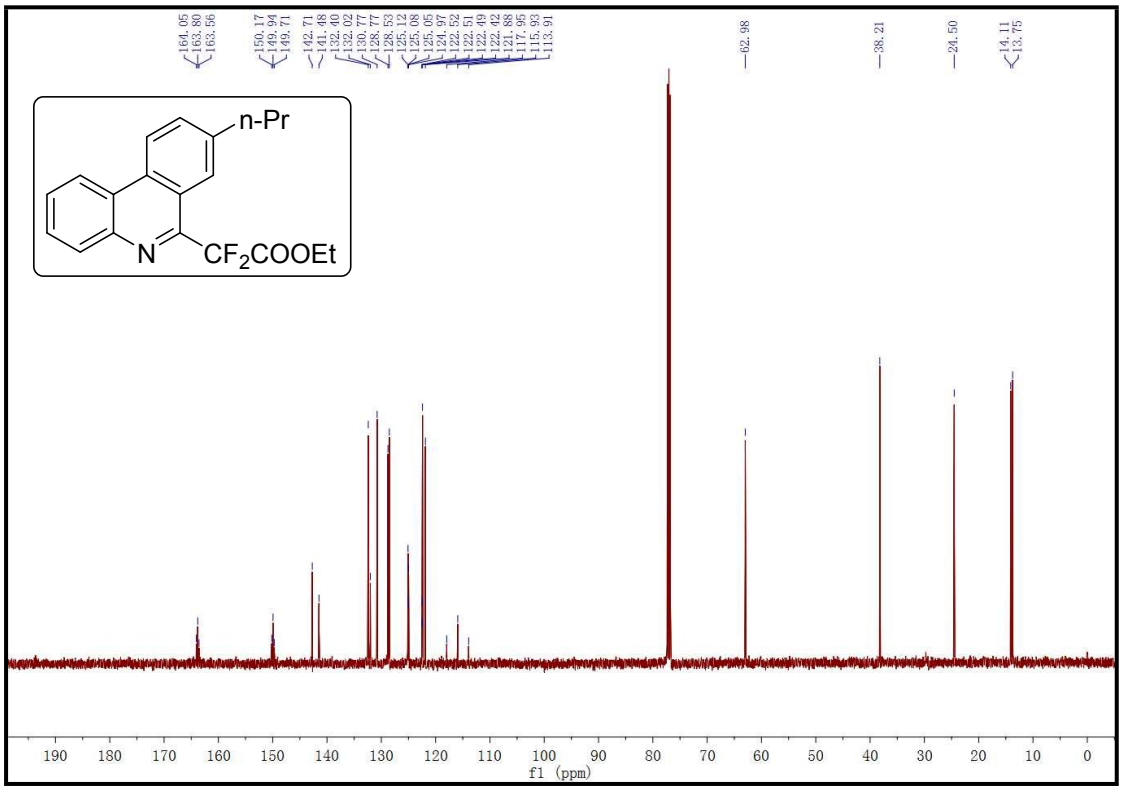


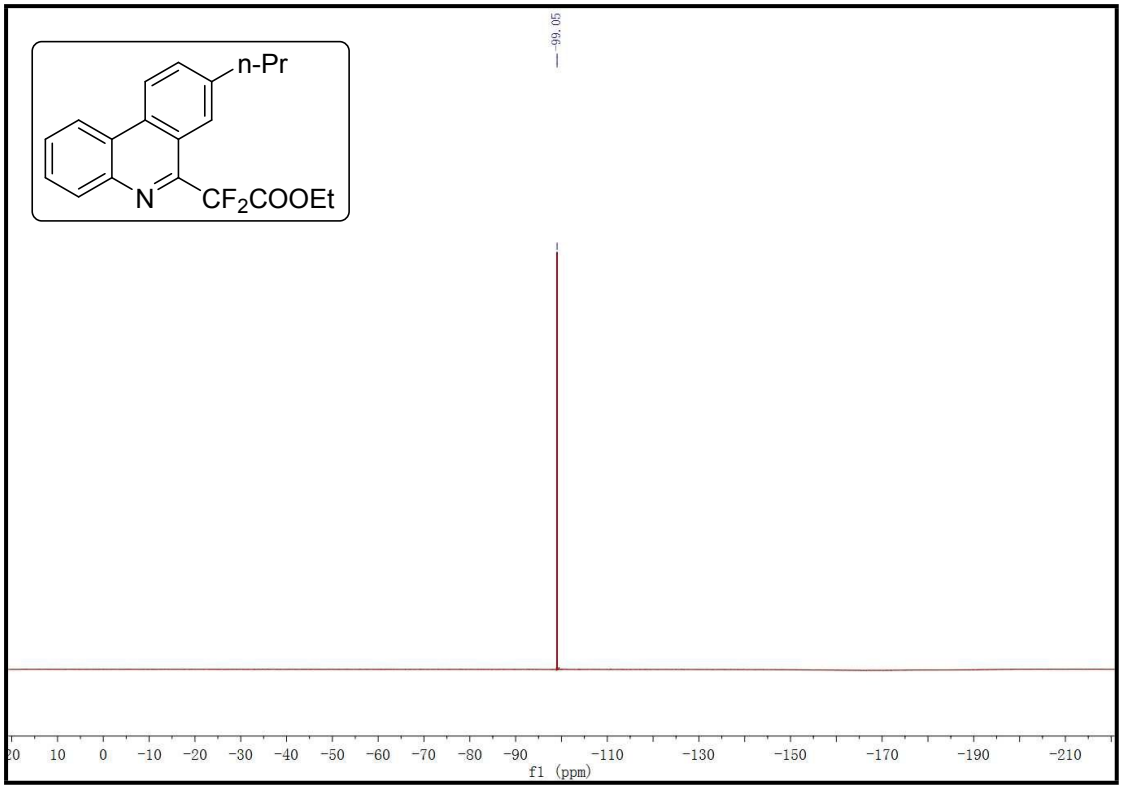

164.06
163.81
163.56
150.25
150.02
149.79
148.77
141.52
132.17
130.78
130.51
128.77
128.54
124.97
123.14
123.10
123.06
122.61
122.57
121.89
117.92
115.90
113.88
62.98
34.42
23.90
14.11
i-Pr
N
CF2COOEt
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-99.07
i-Pr
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

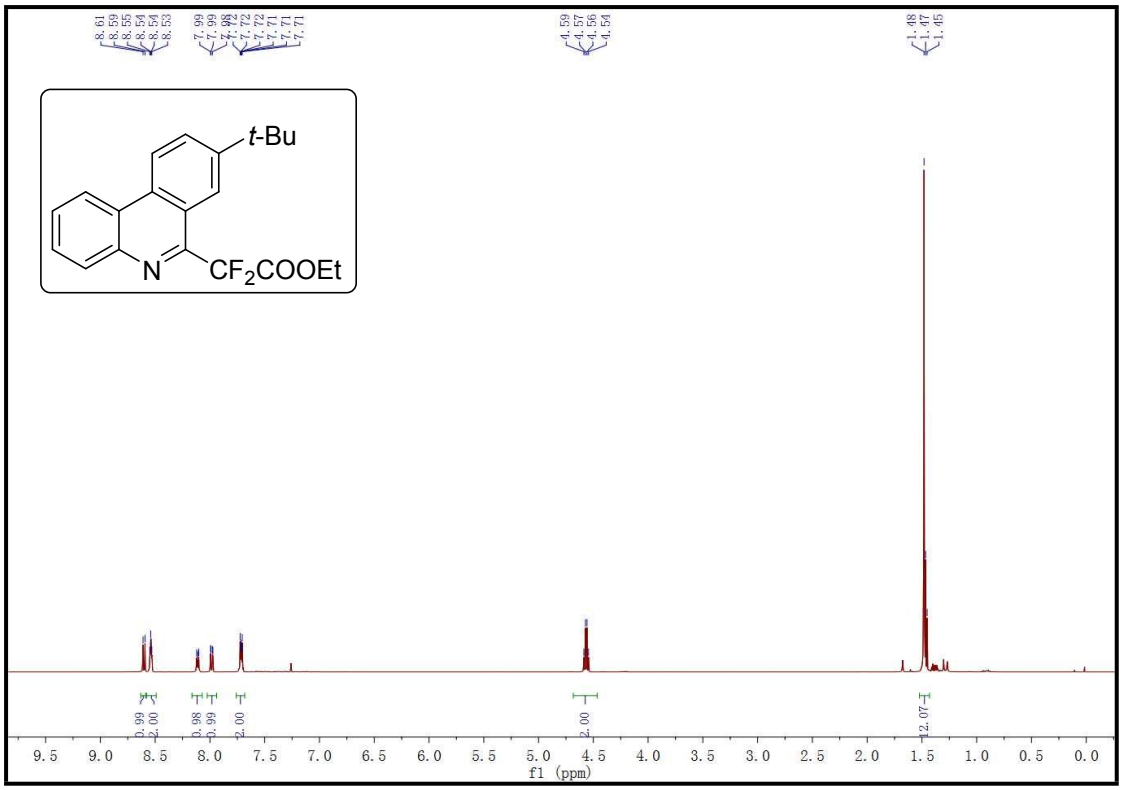
ethyl 2,2-difluoro-2-(8-propylphenanthridin-6-yl)acetate (3e)

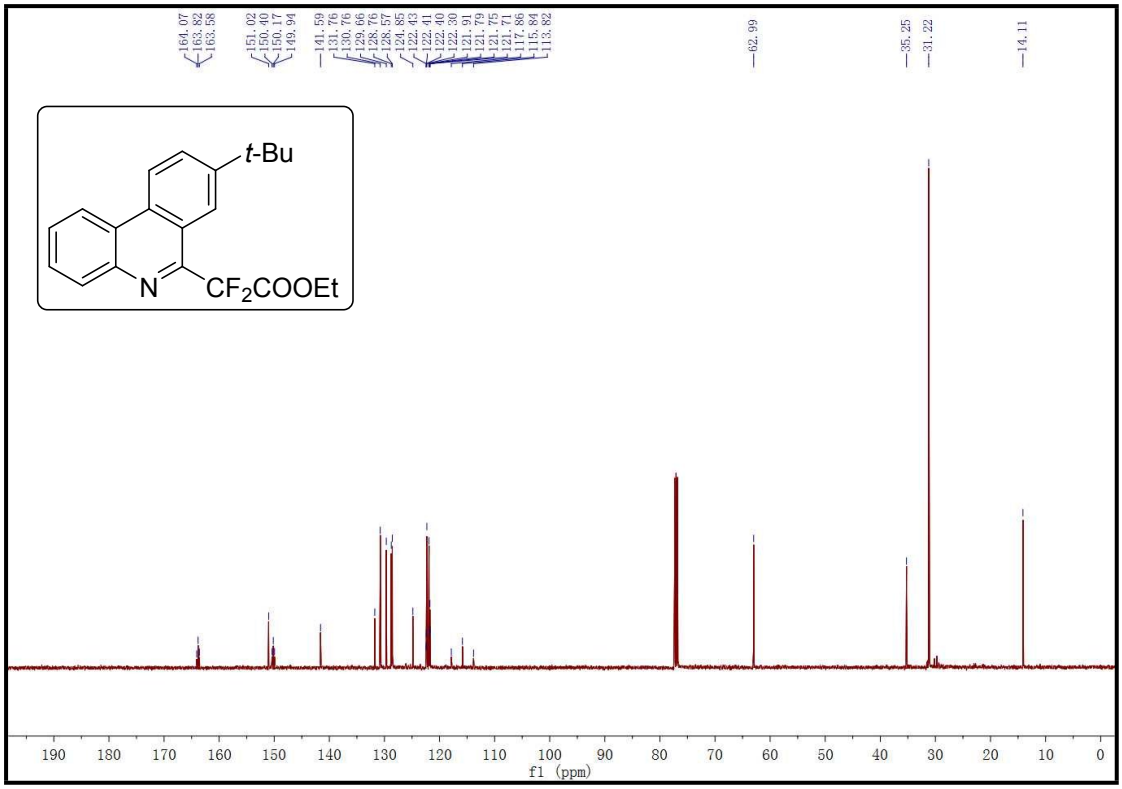


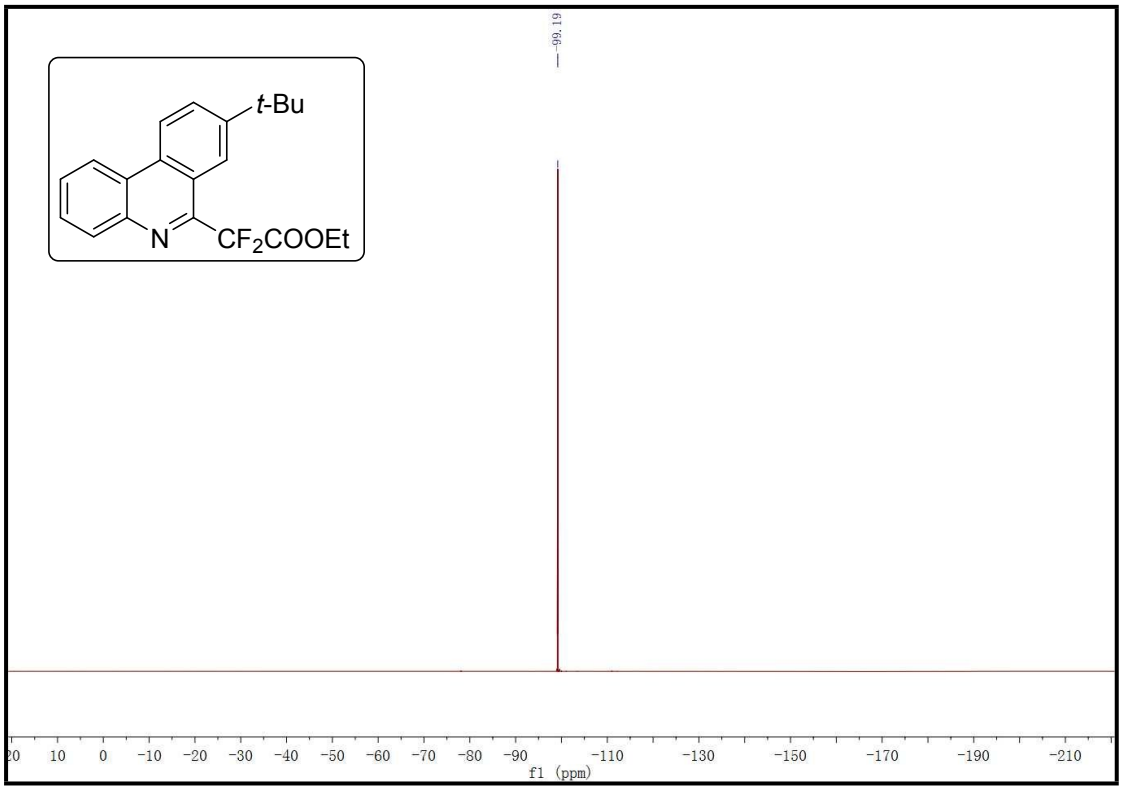




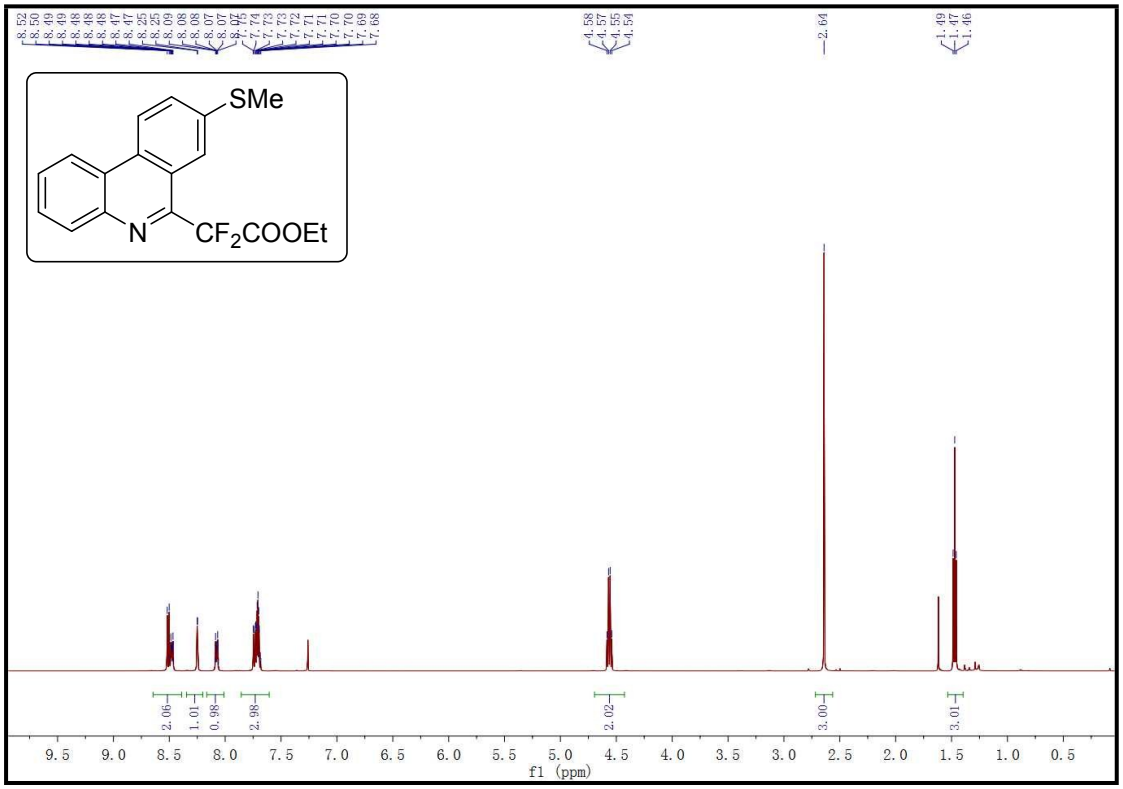
ethyl 2-(8-(tert-butyl)phenanthridin-6-yl)-2,2-difluoroacetate (3f)

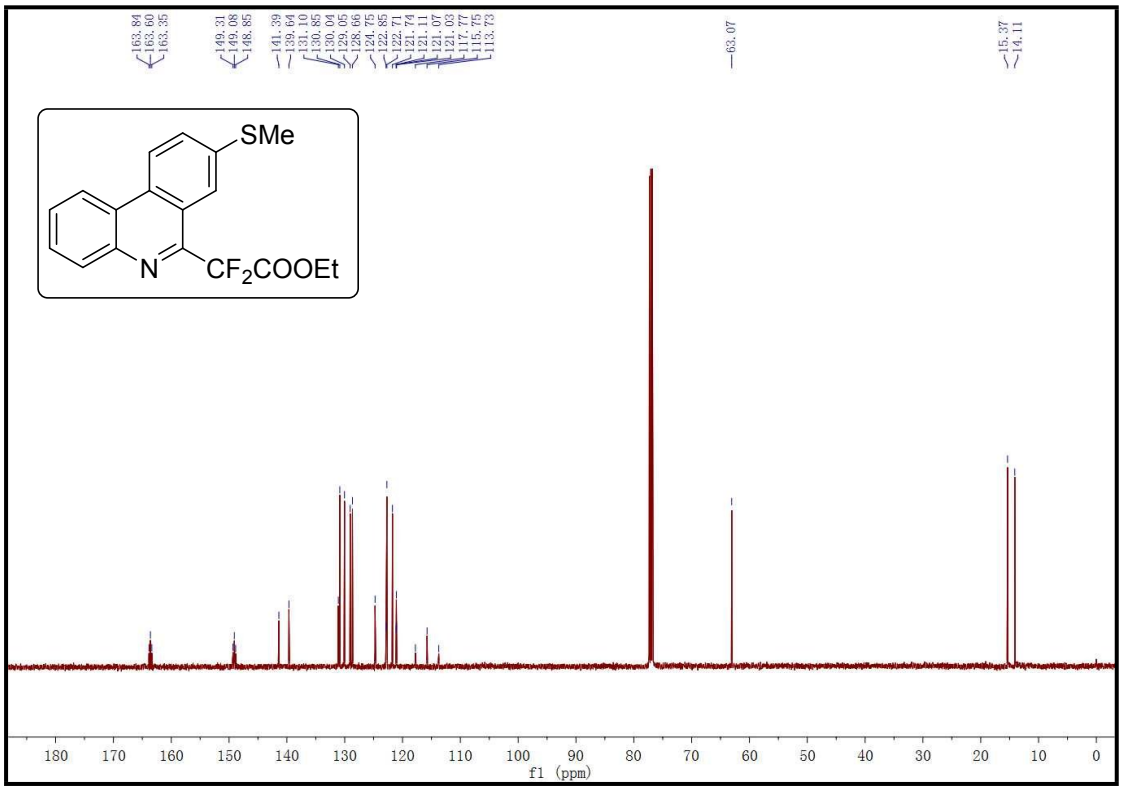


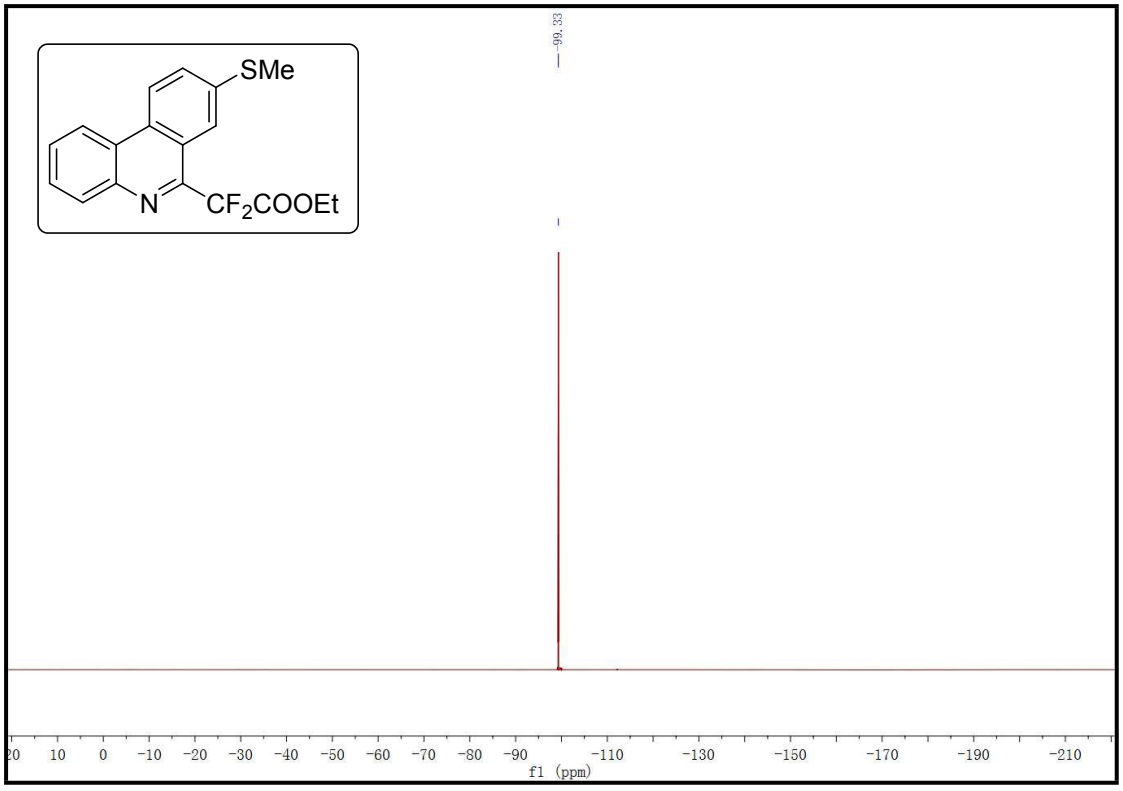

164.07
163.82
163.58
151.02
150.40
150.17
149.94
141.59
131.76
130.76
129.66
128.76
128.57
124.85
122.43
122.41
122.40
122.30
121.91
121.79
121.75
121.71
117.86
115.84
113.82
62.99
35.25
31.22
14.11
t-Bu
N
CF2COOEt
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-99.19
t-Bu
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

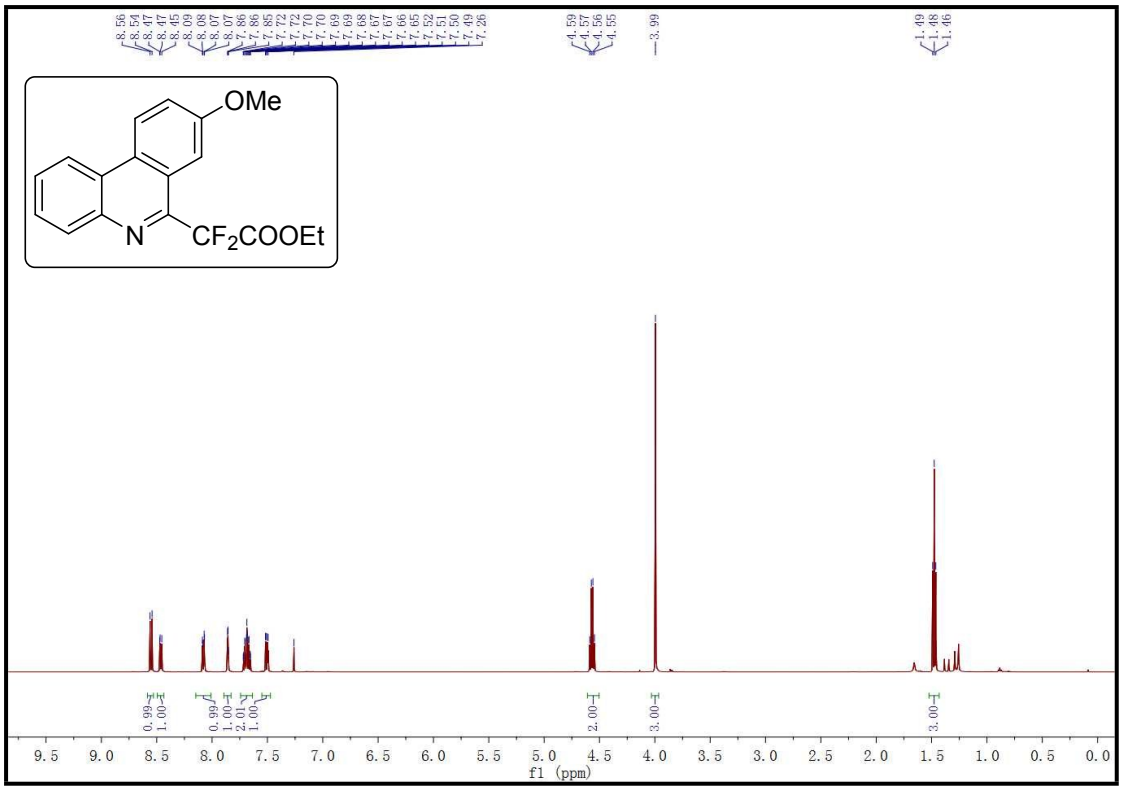
ethyl 2,2-difluoro-2-(8-(methylthio)phenanthridin-6-yl)acetate (3g)

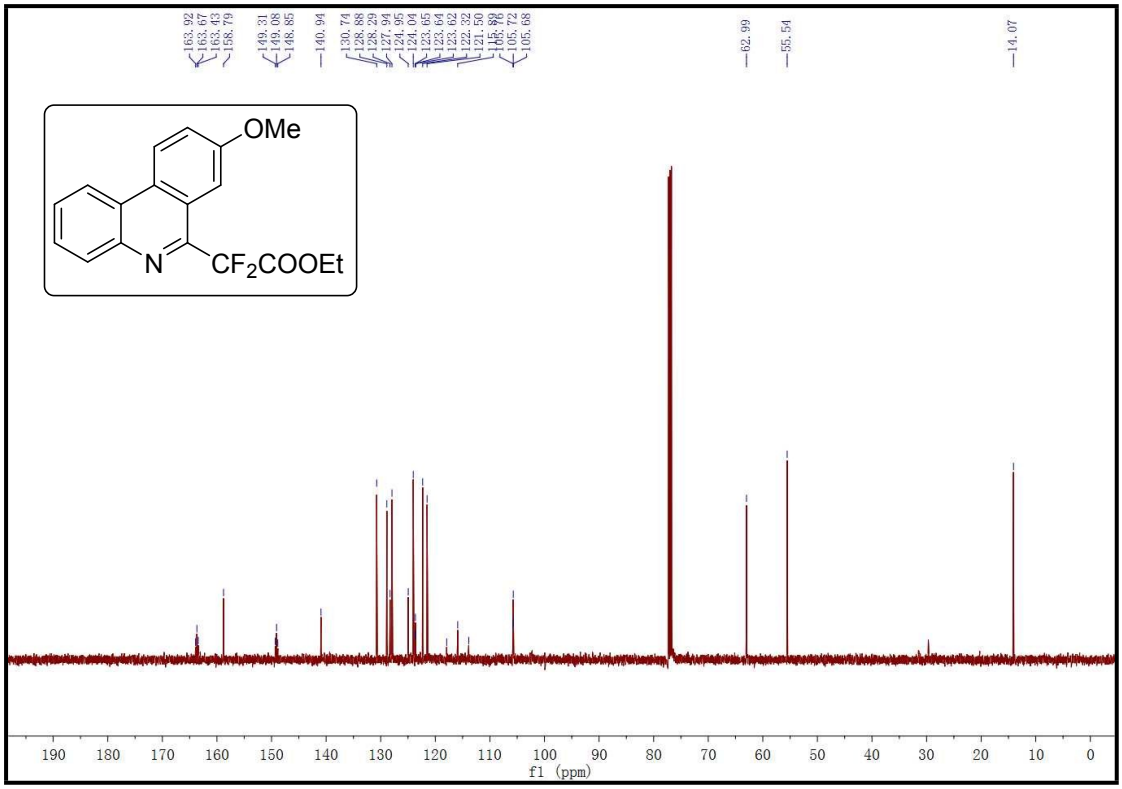






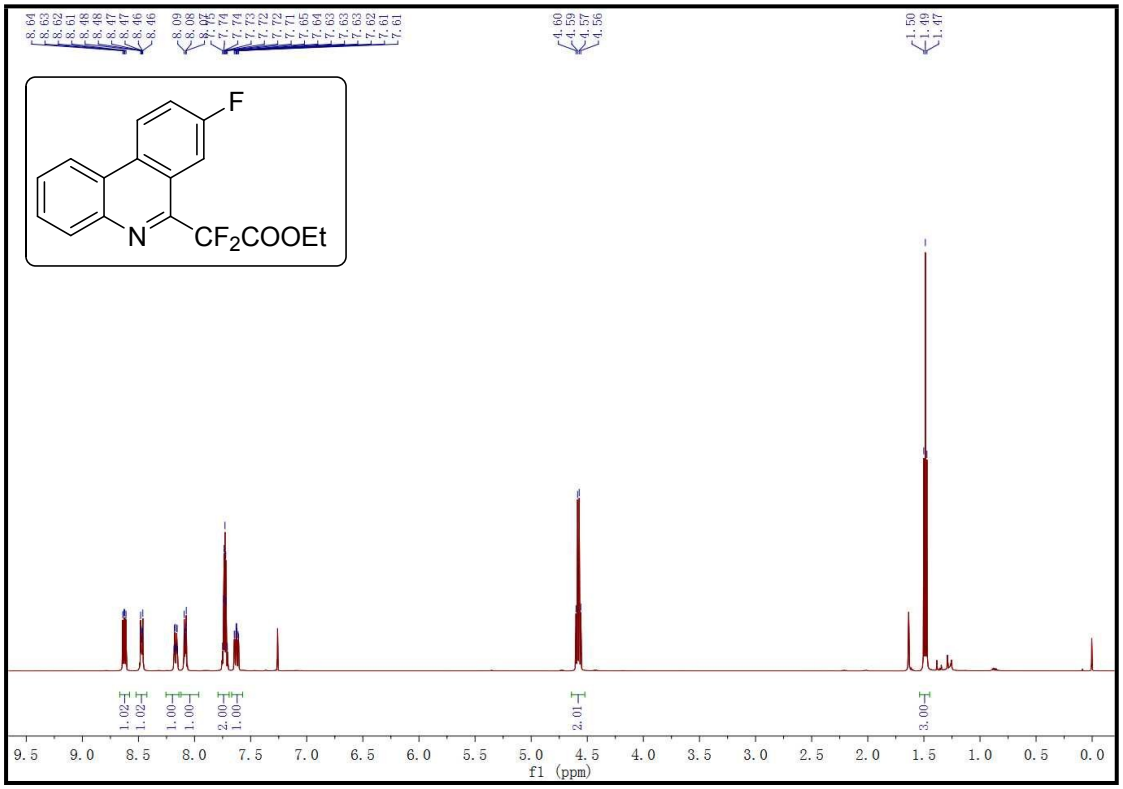
ethyl 2,2-difluoro-2-(8-methoxyphenanthridin-6-yl)acetate (3h)

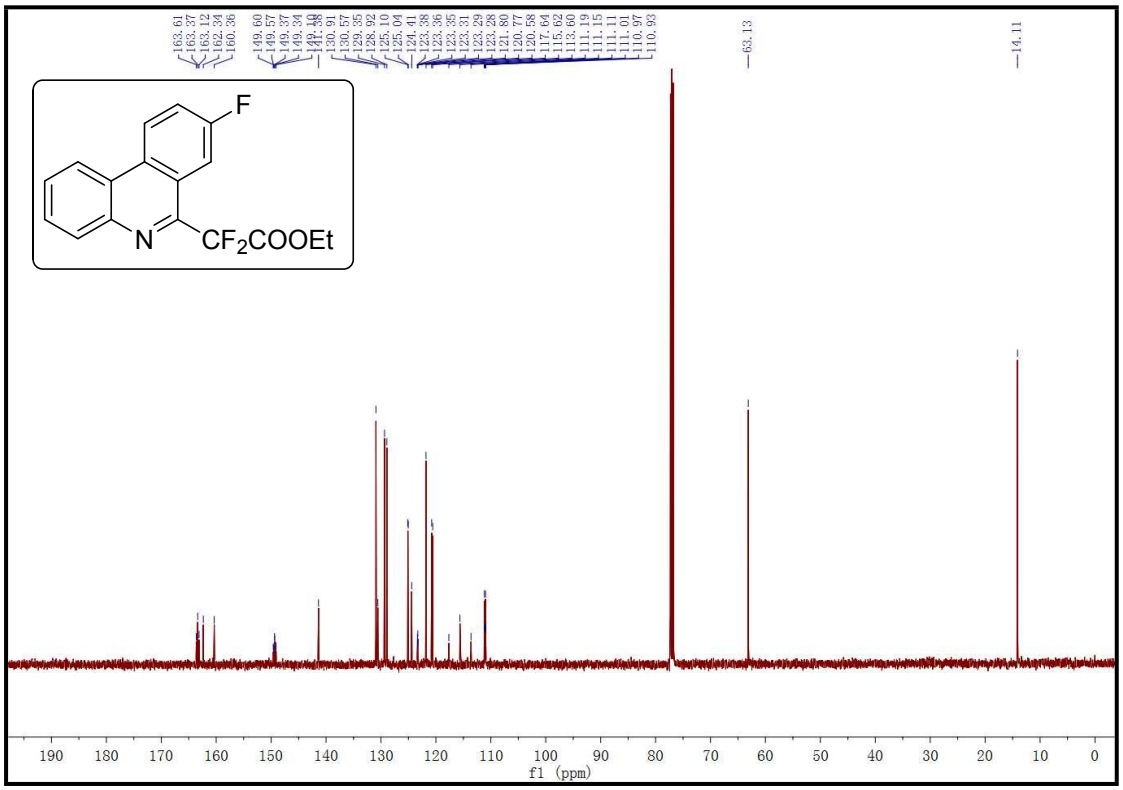


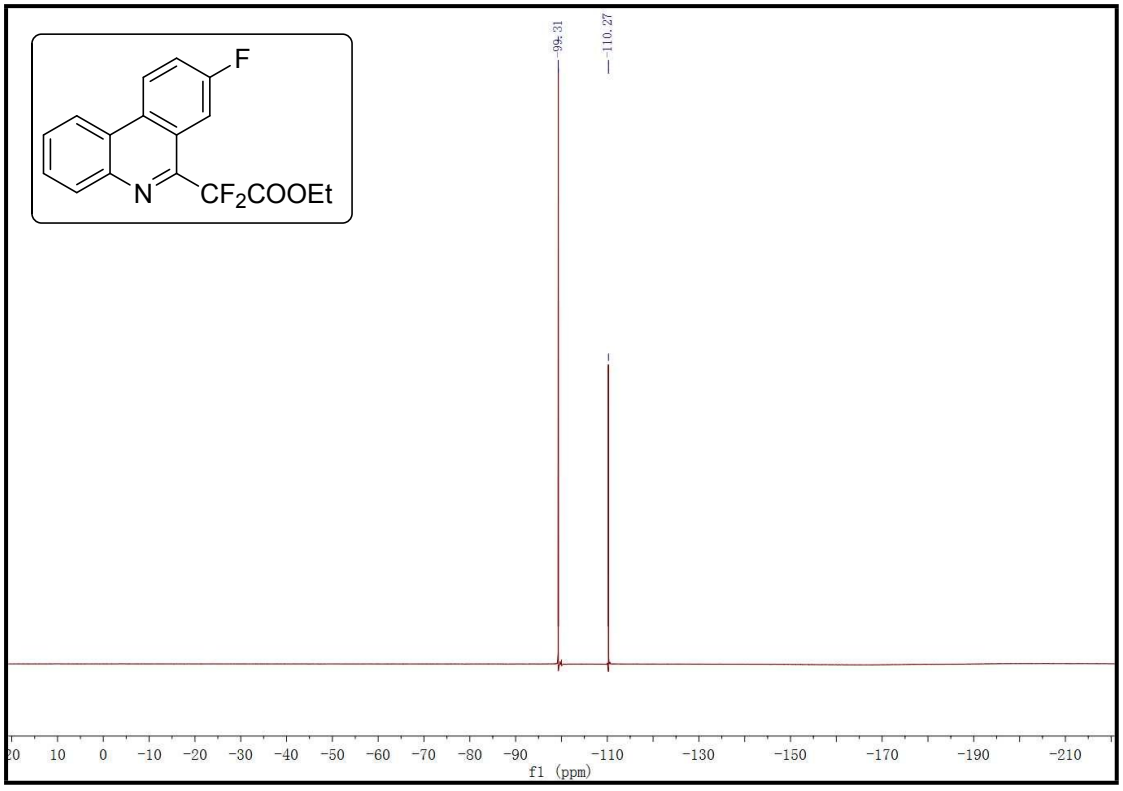

163.92
163.67
163.43
158.79
149.31
149.08
148.85
140.94
130.74
128.88
128.29
127.94
124.95
124.04
123.65
123.64
123.62
122.32
121.50
105.72
105.68
62.99
55.54
14.07
OMe
N
CF2COOEt
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-99.92
OMe
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

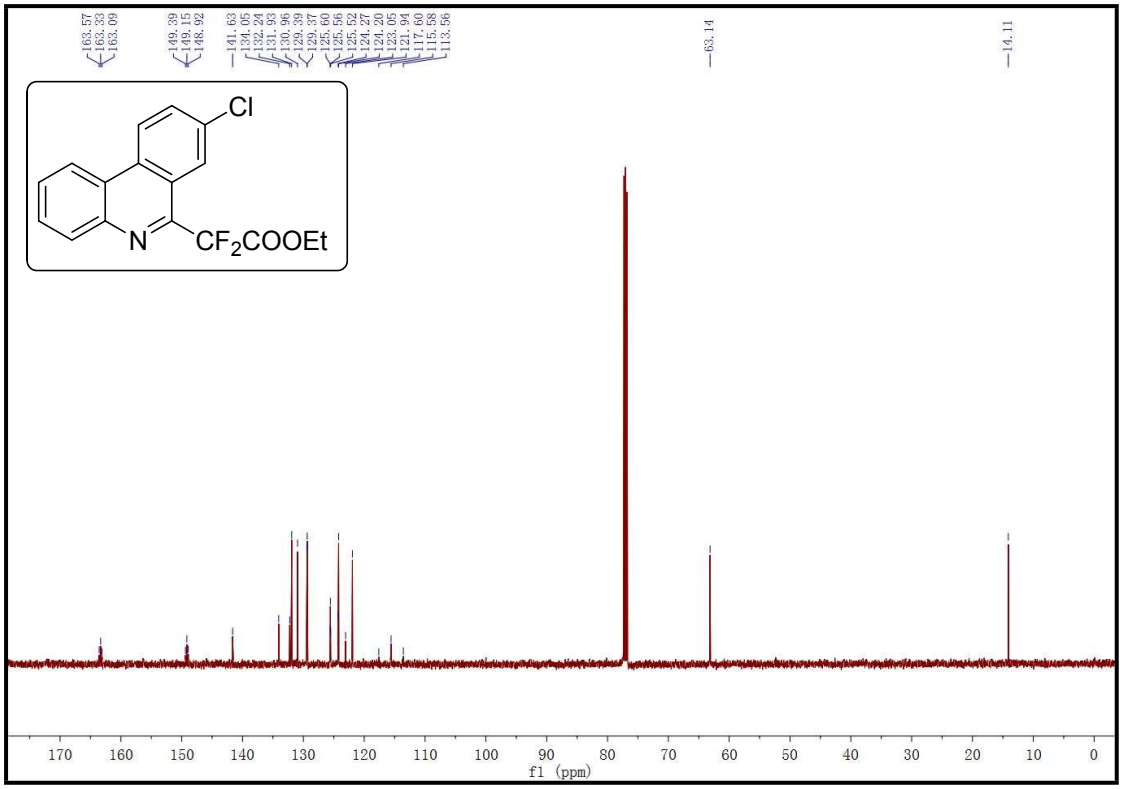
ethyl 2,2-difluoro-2-(8-fluorophenanthridin-6-yl)acetate (3i)

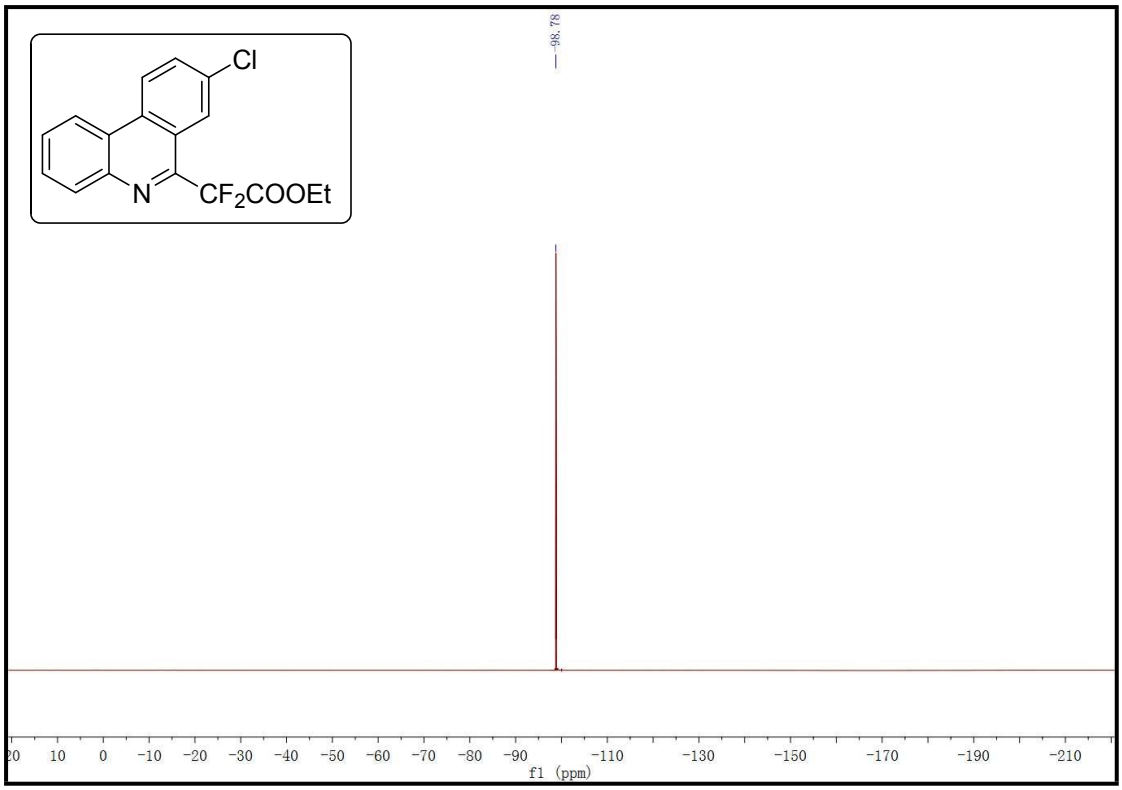




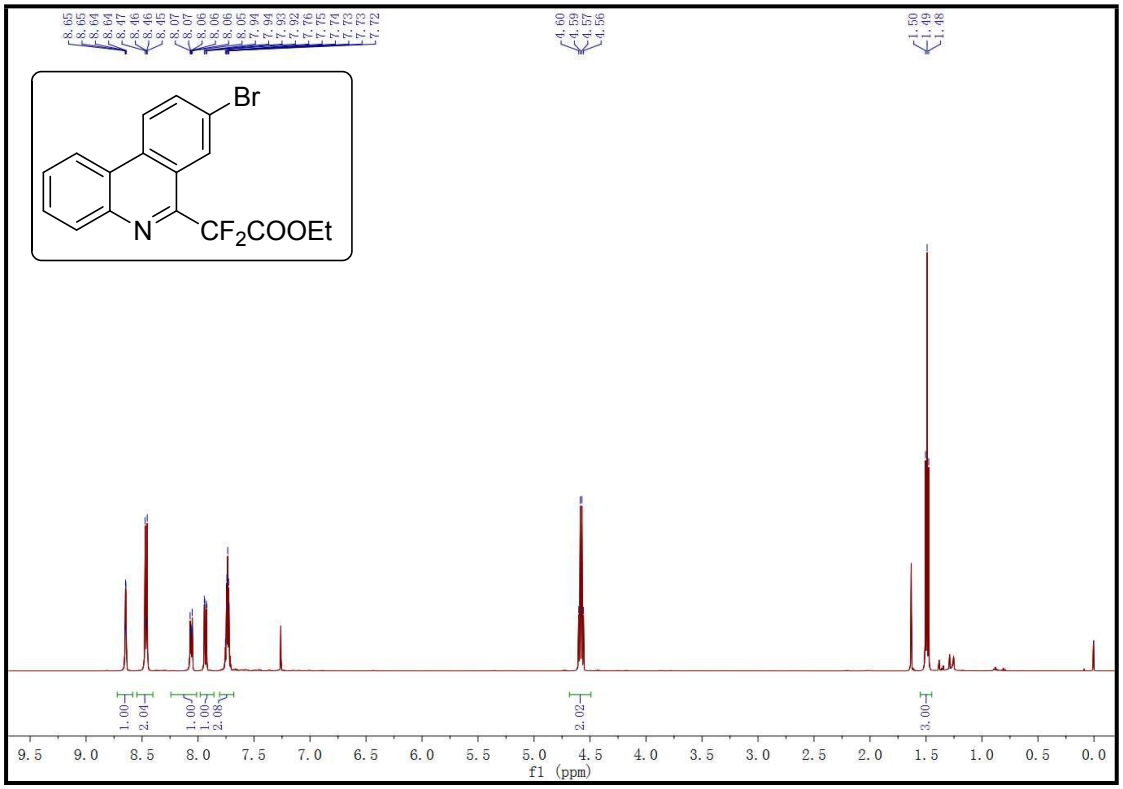


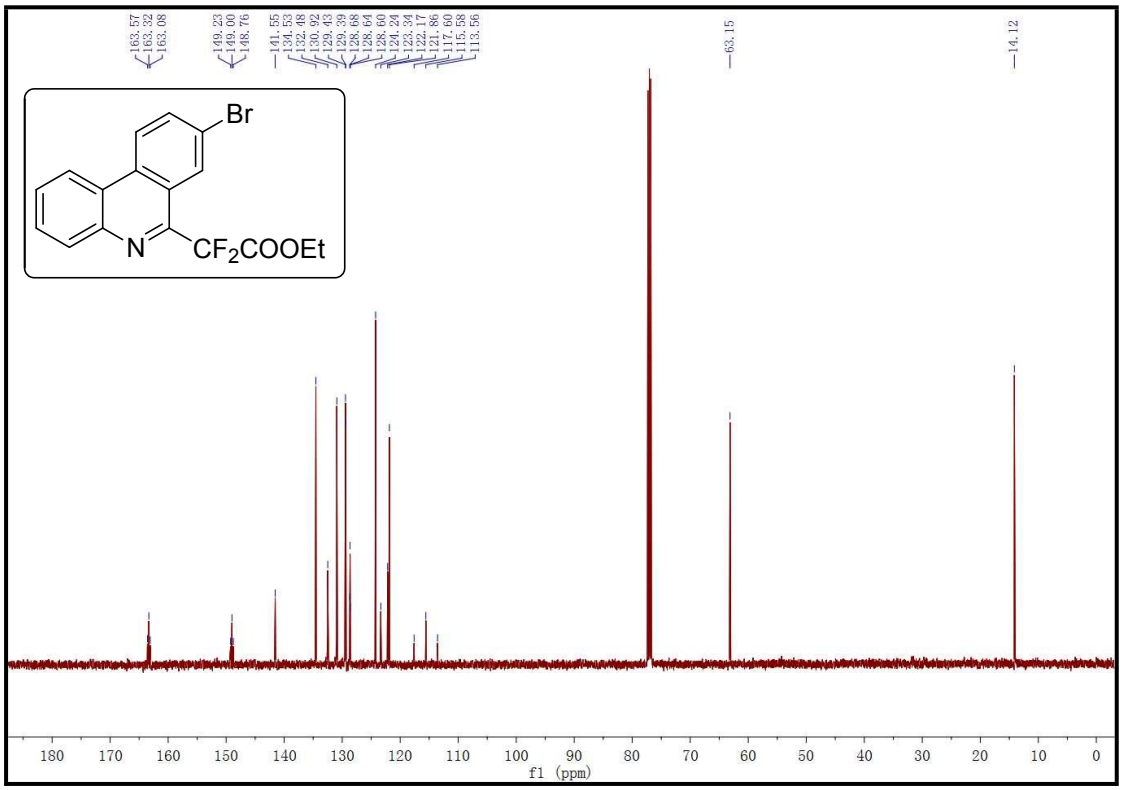
ethyl 2-(8-chlorophenanthridin-6-yl)-2,2-difluoroacetate (3j)

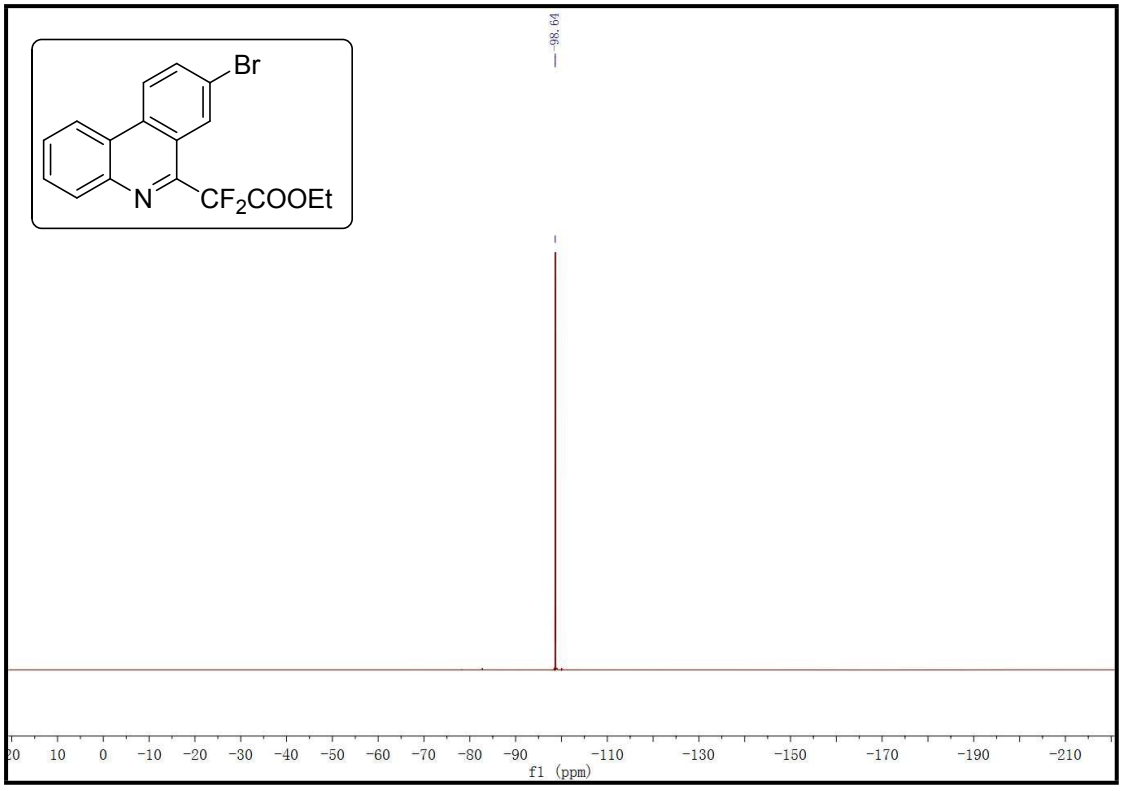

163.57
163.33
163.09
149.39
149.15
148.92
141.63
134.05
132.24
131.93
130.96
129.39
129.37
125.60
125.56
125.52
124.27
123.05
121.93
117.60
115.58
113.56
63.14
14.11
Cl
N
CF2COOEt
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.78
Cl
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

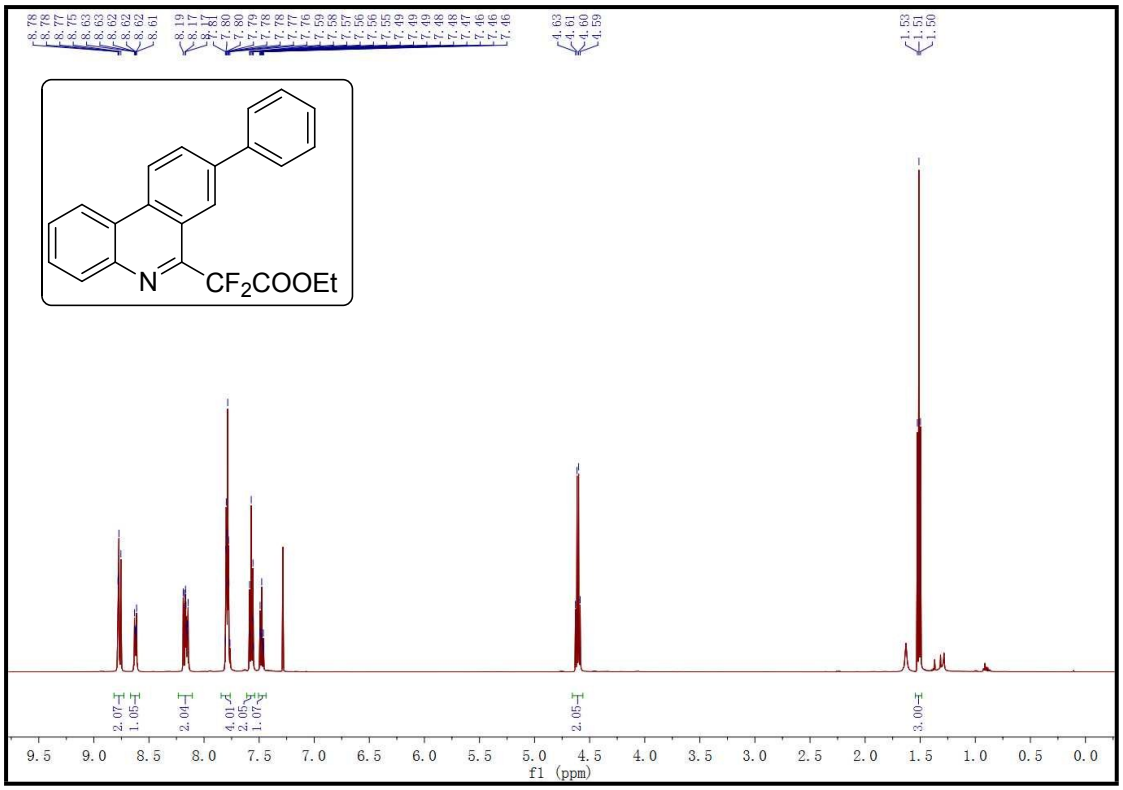
ethyl 2-(8-bromophenanthridin-6-yl)-2,2-difluoroacetate (3k)

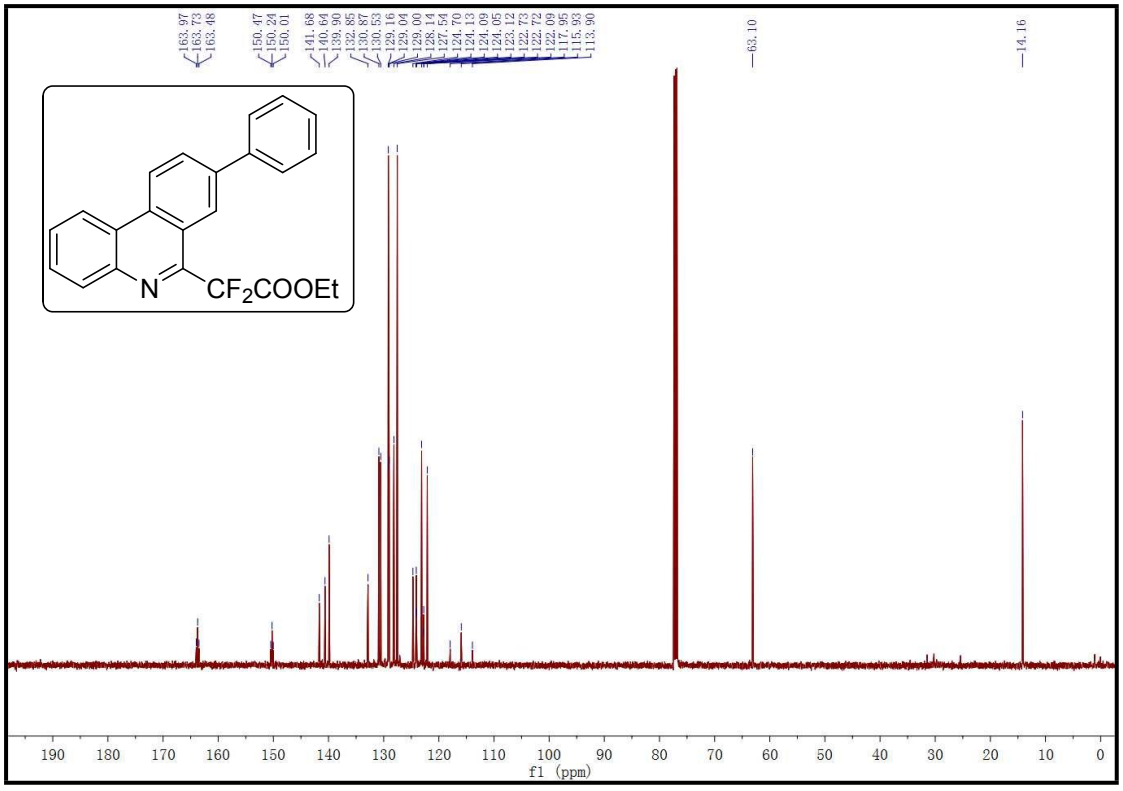






ethyl 2,2-difluoro-2-(8-phenylphenanthridin-6-yl)acetate (3l)

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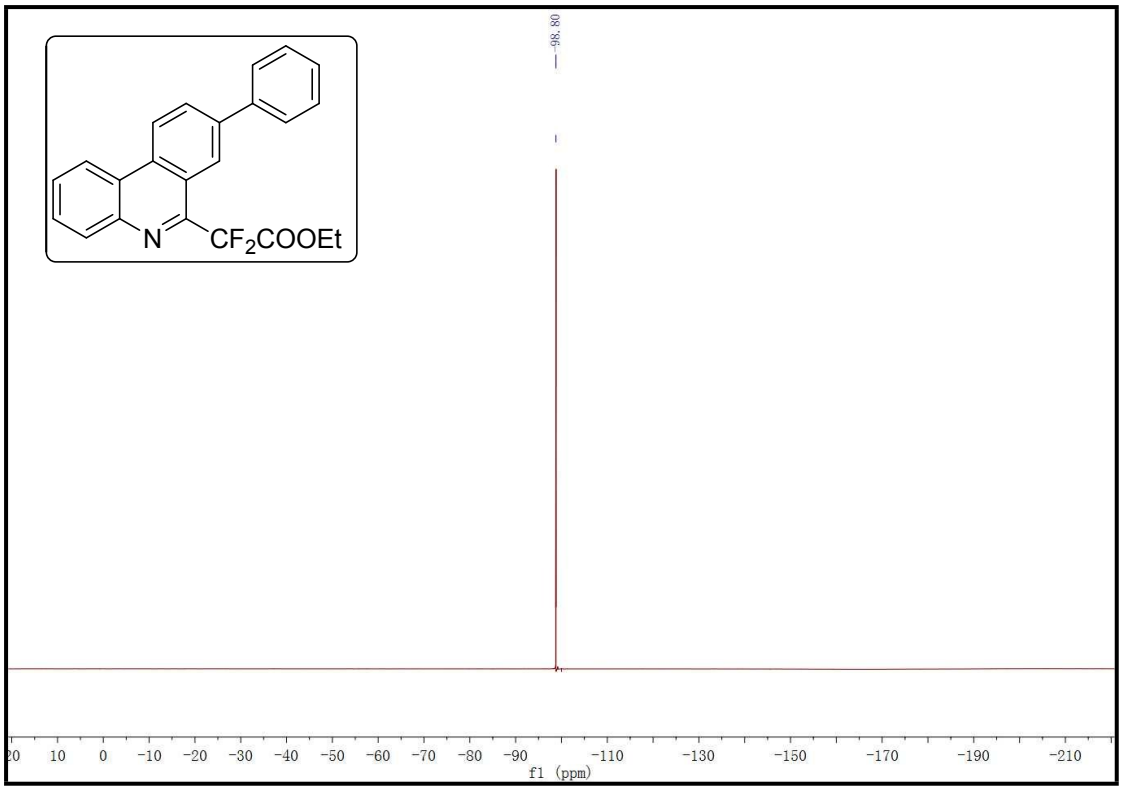
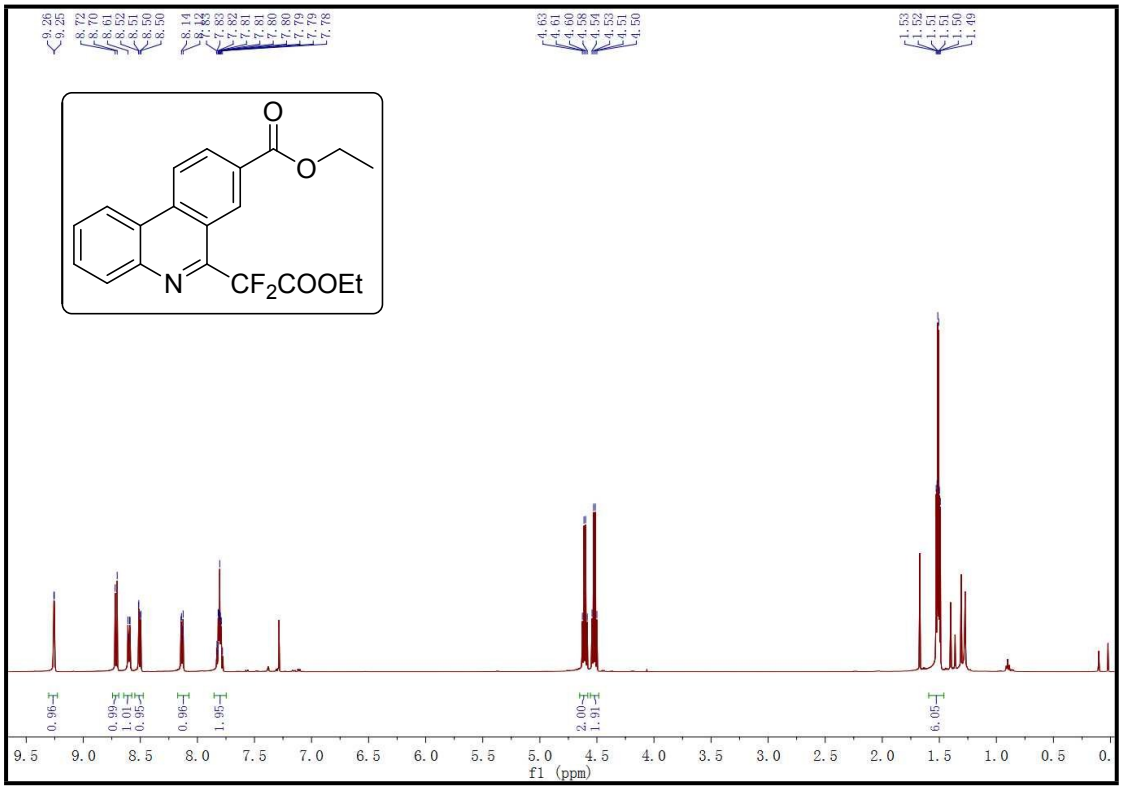
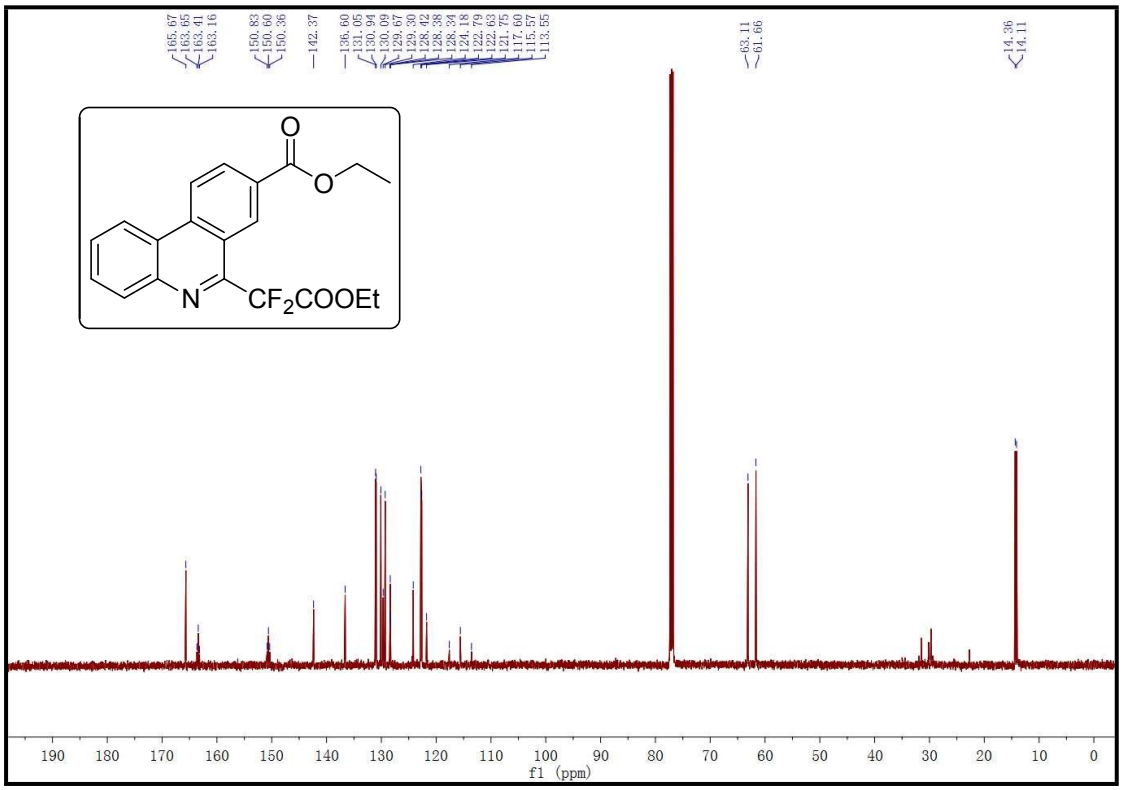
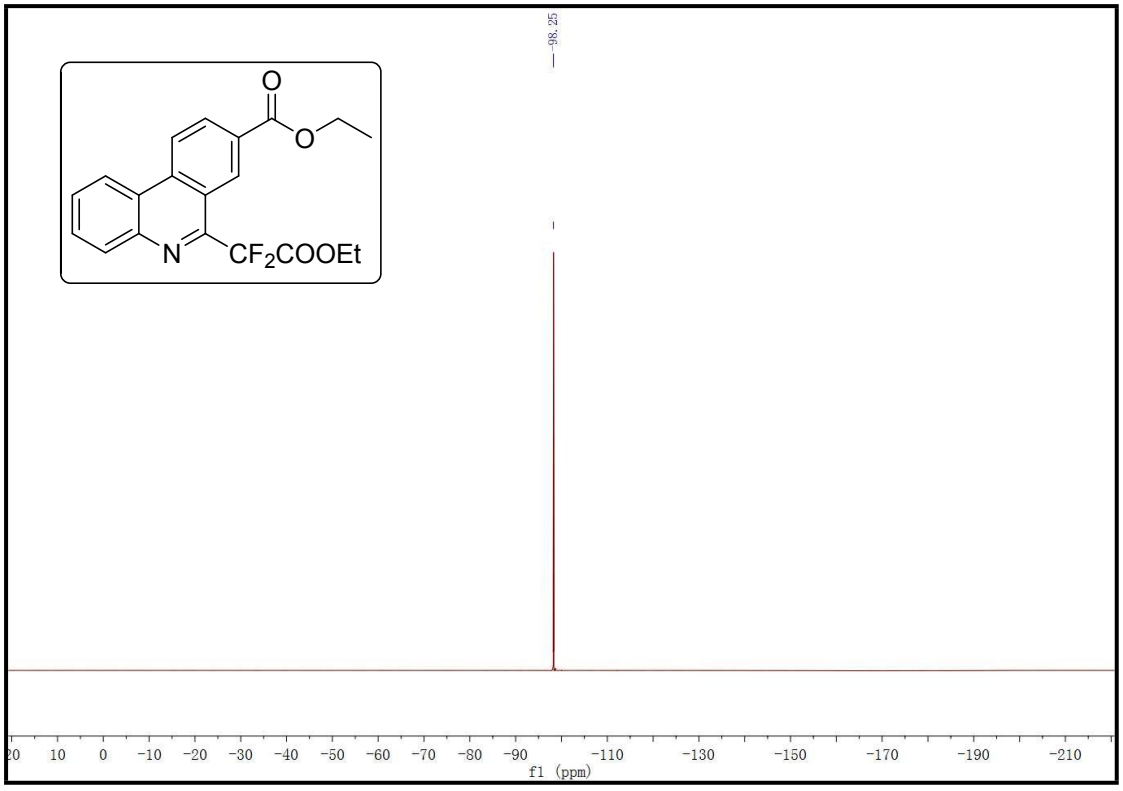
163.73
163.48
150.47
150.24
150.01
141.68
140.64
139.96
132.85
130.87
130.53
129.16
129.04
129.00
128.14
127.54
124.70
124.13
124.09
124.05
123.12
122.73
122.72
122.09
117.95
115.93
113.90
63.10
14.16
N
CF2COOEt
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.80
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

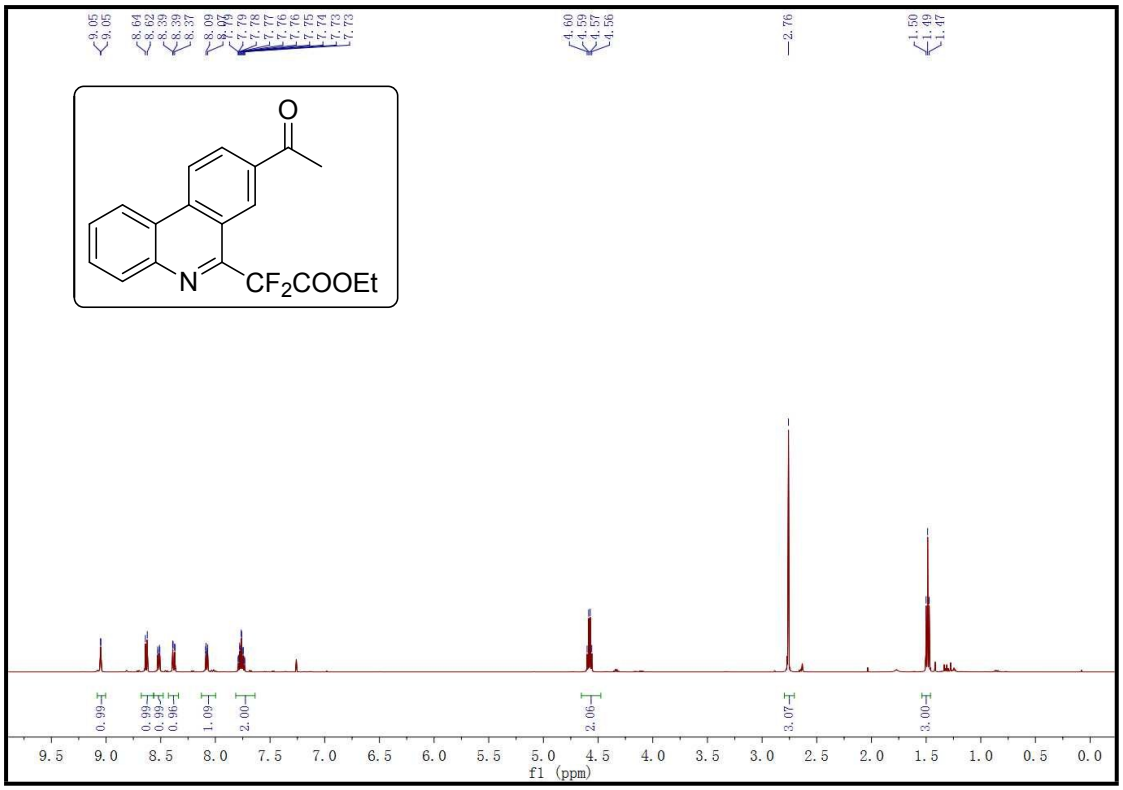
Ethyl 6-(2-ethoxy-1,1-difluoro-2-oxoethyl)phenanthridine-8-carboxylate (3m)

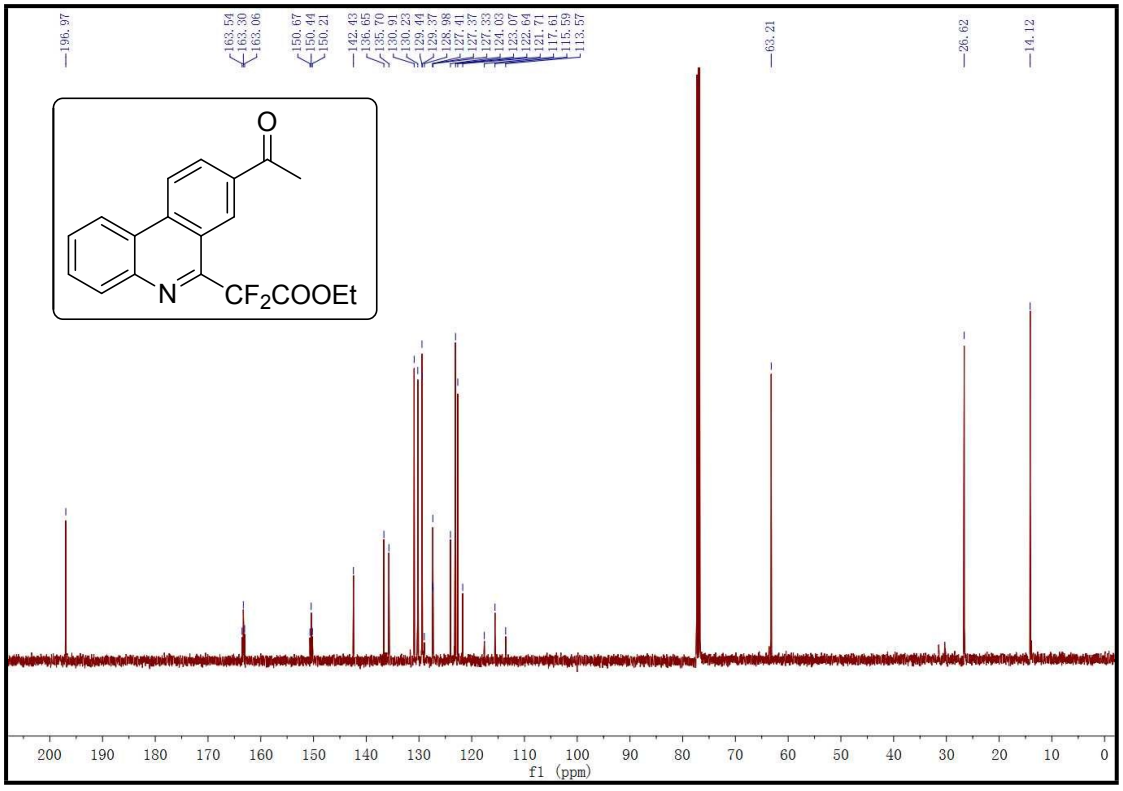


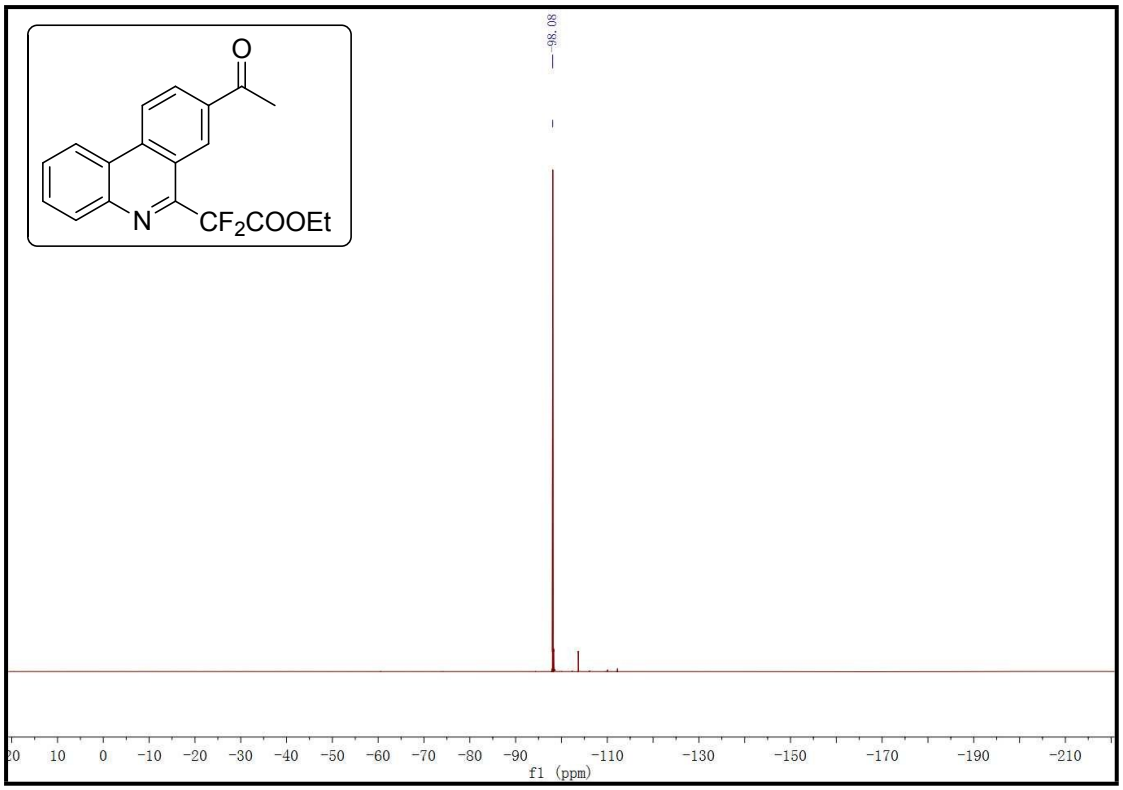




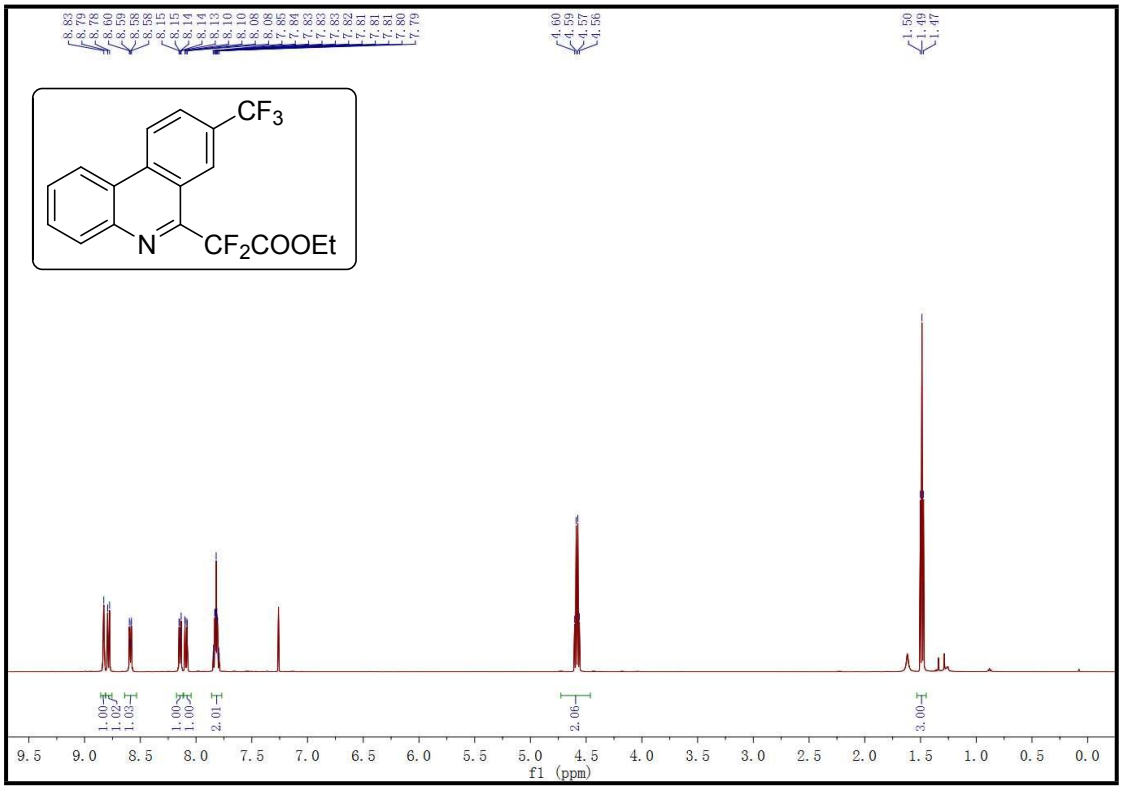
ethyl 2-(8-acetylphenanthridin-6-yl)-2,2-difluoroacetate(3n)

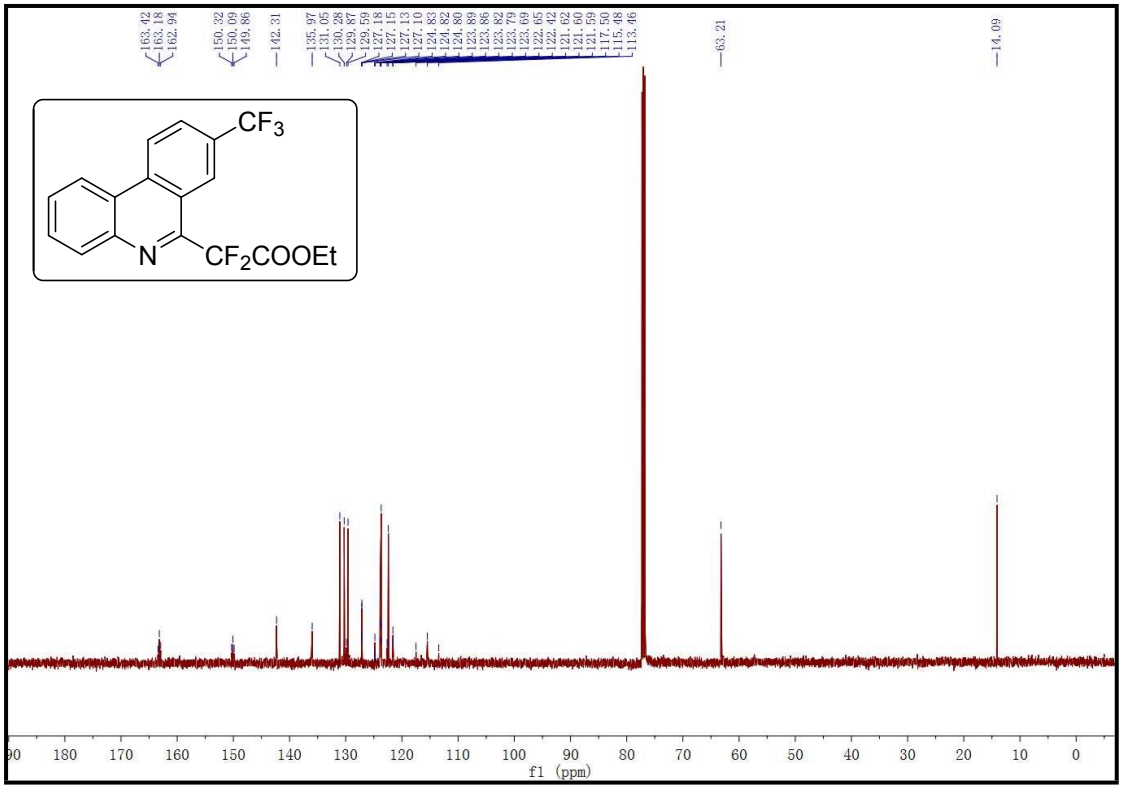


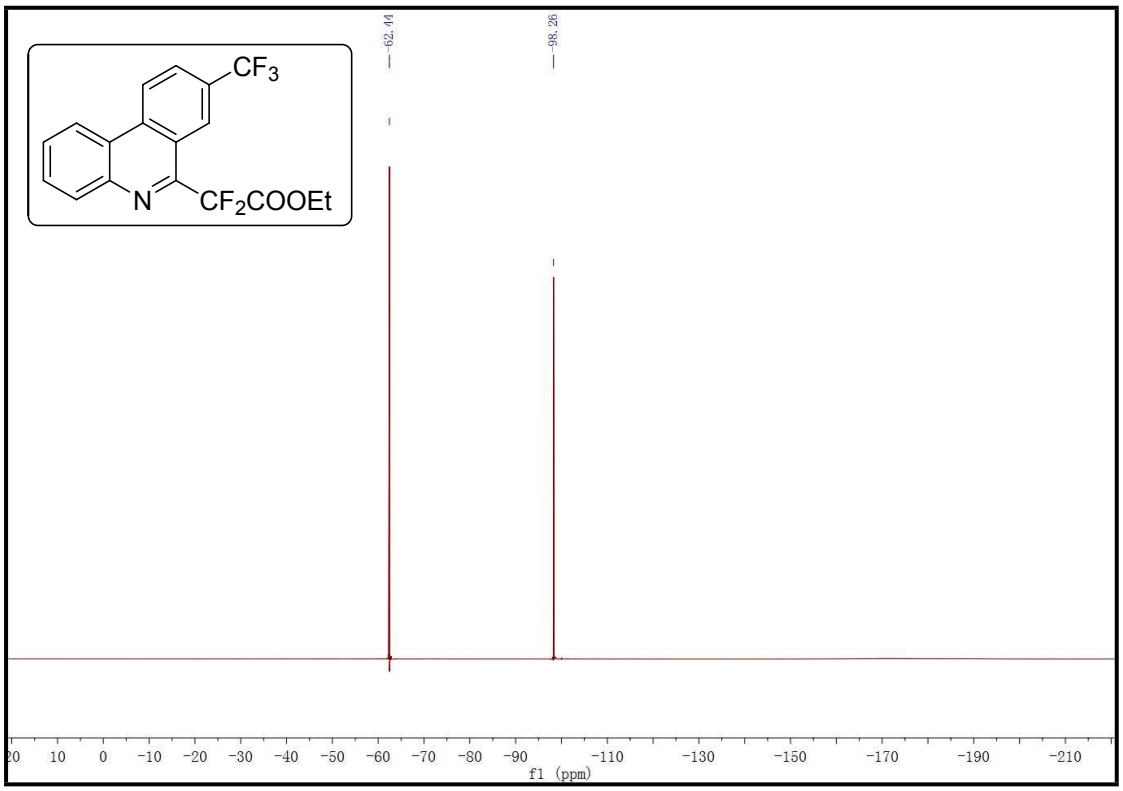

196.97
163.54
163.30
163.06
150.67
150.44
150.21
142.43
136.65
135.70
130.91
130.23
129.44
129.37
128.98
127.41
127.37
127.33
124.03
123.07
122.64
121.71
117.61
115.59
113.57
63.21
26.62
14.12
O
N
CF2COOEt
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.08
O
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

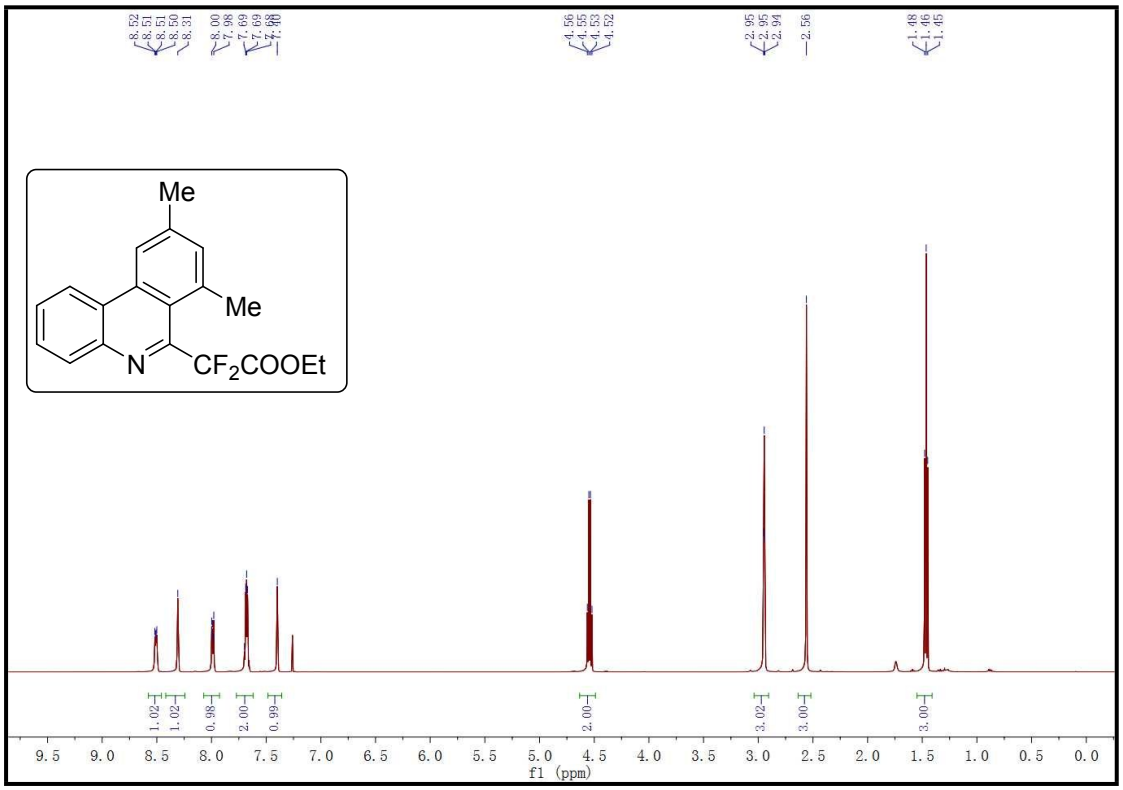
ethyl 2,2-difluoro-2-(8-(trifluoromethyl)phenanthridin-6-yl)acetate (3o)

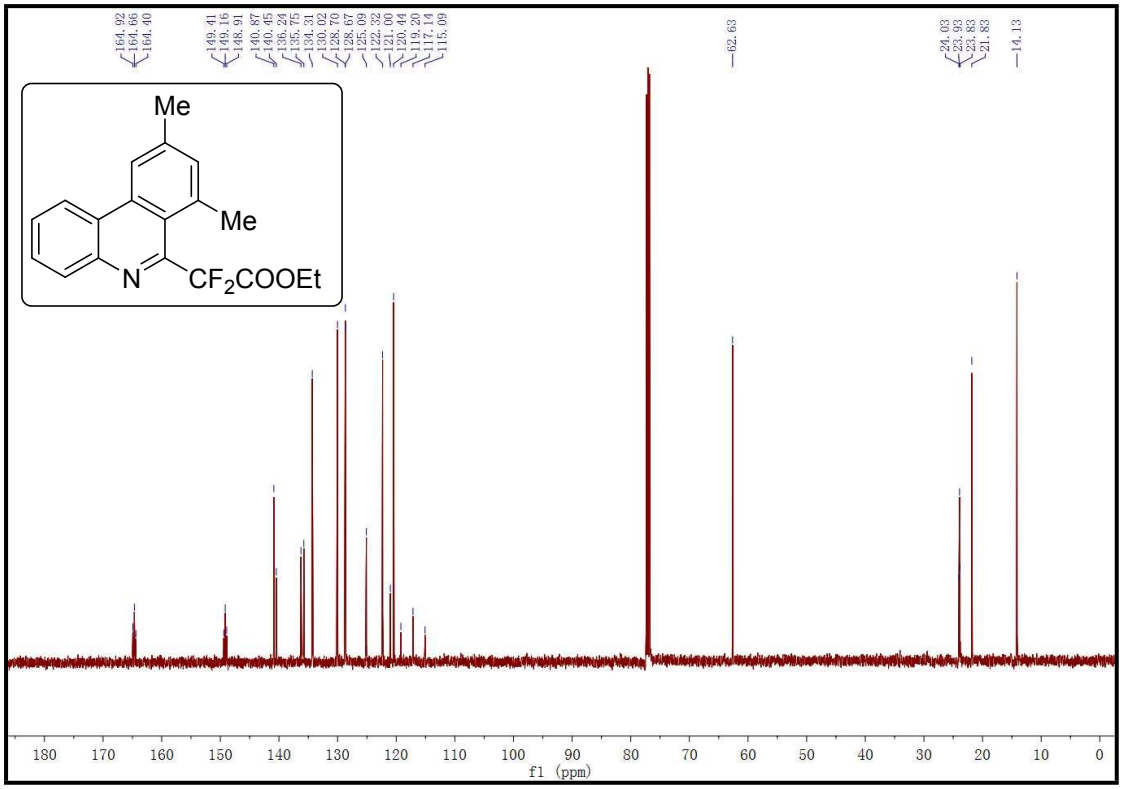


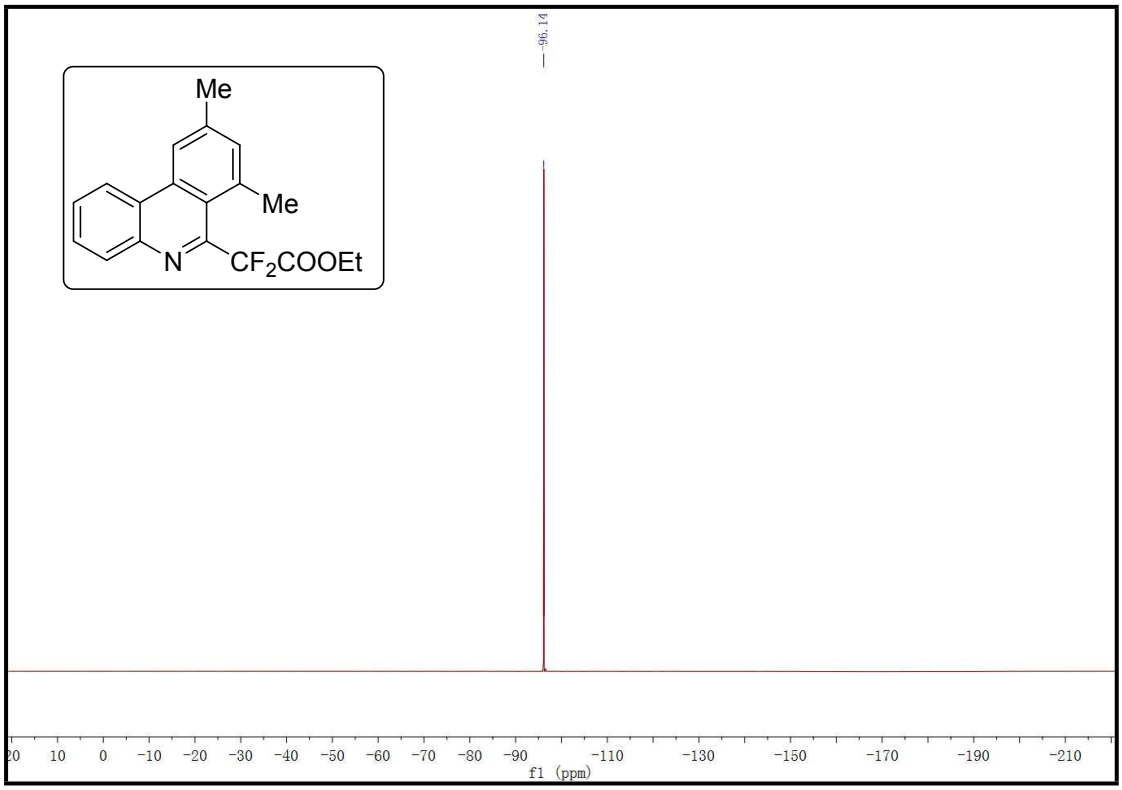




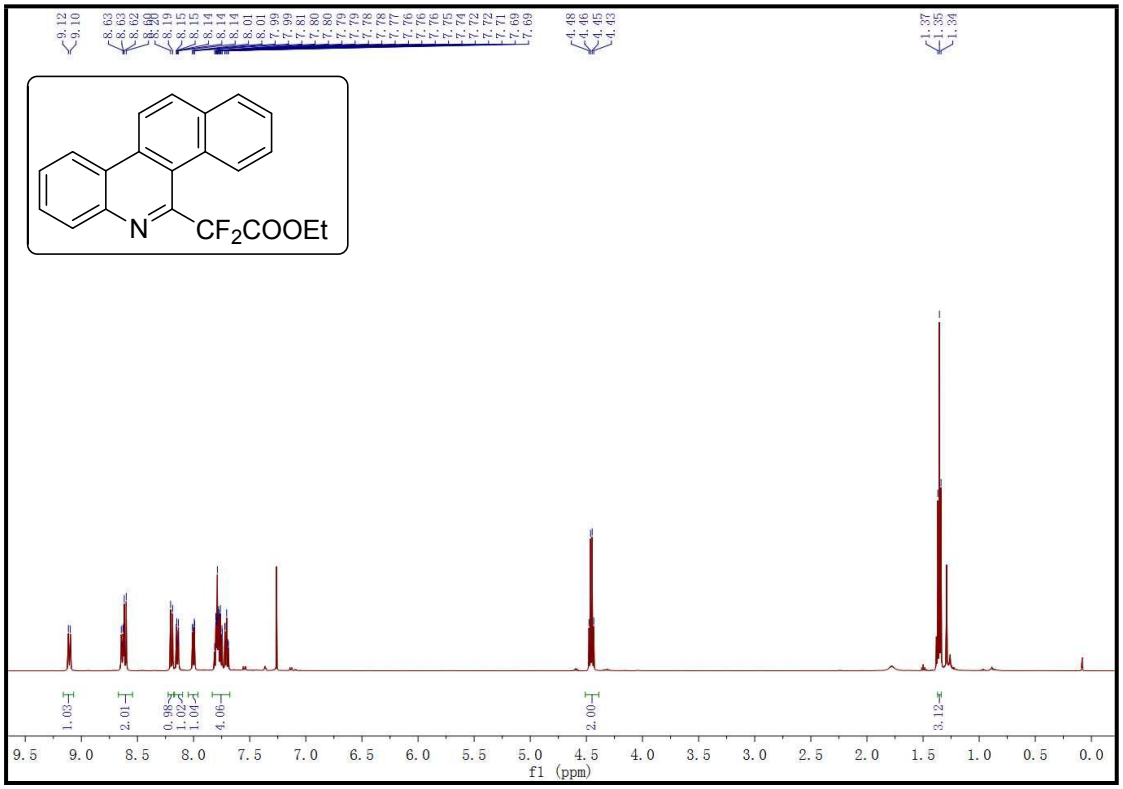
ethyl 2-(7,9-dimethylphenanthridin-6-yl)-2,2-difluoroacetate (3p)

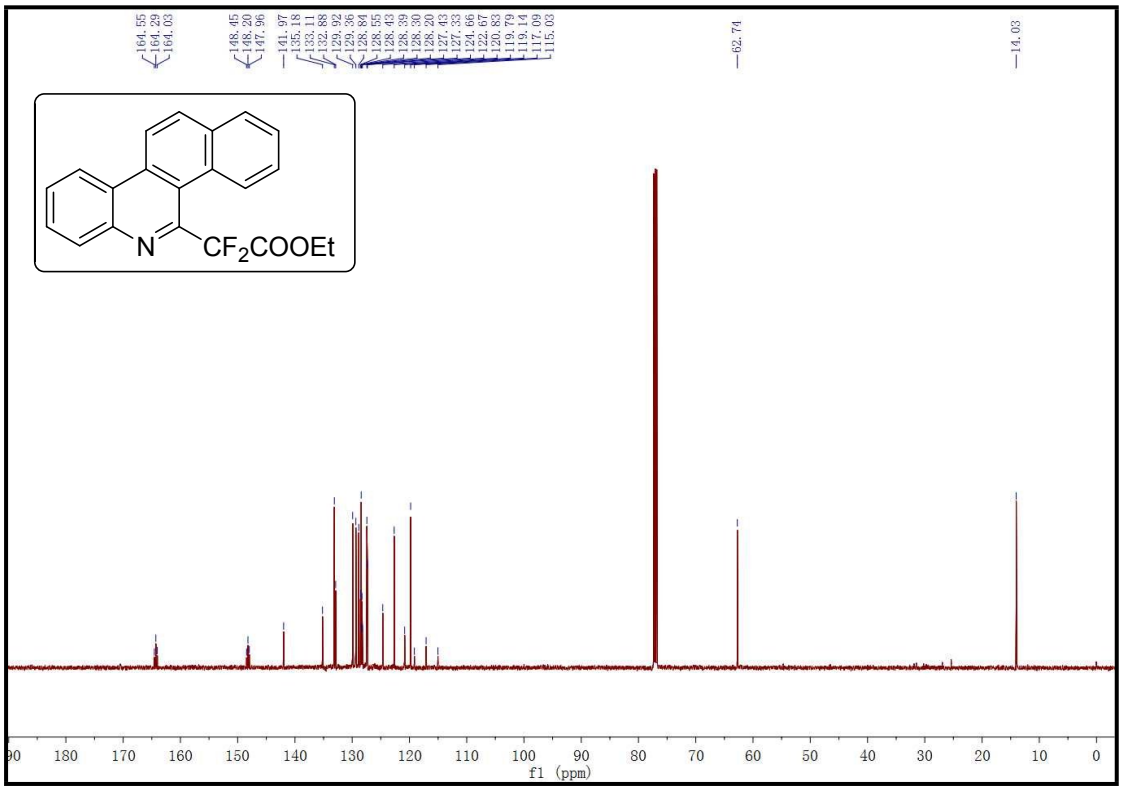


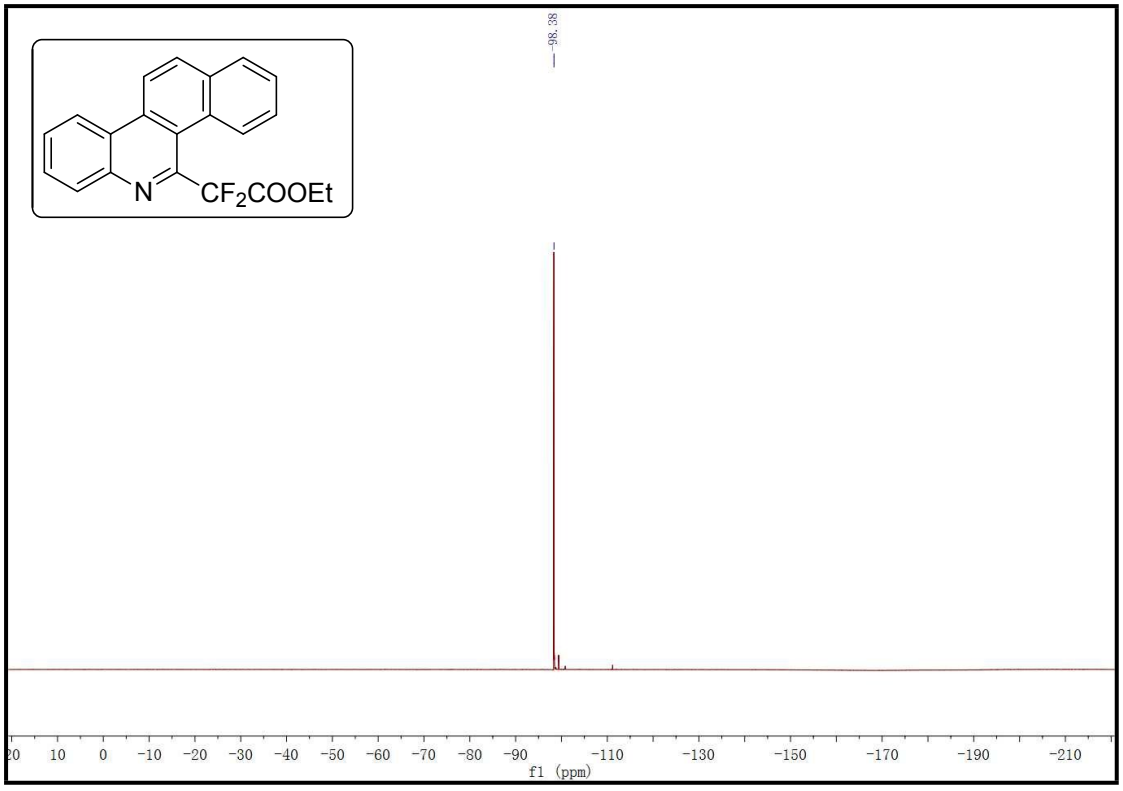

164.92
164.66
164.40
149.41
149.16
148.91
140.87
140.45
135.24
134.31
130.02
128.76
128.67
125.09
122.32
121.06
120.44
119.20
117.14
115.09
62.63
24.03
23.93
23.83
21.83
14.13
Me
Me
N
CF2COOEt
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-96.14
Me
Me
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

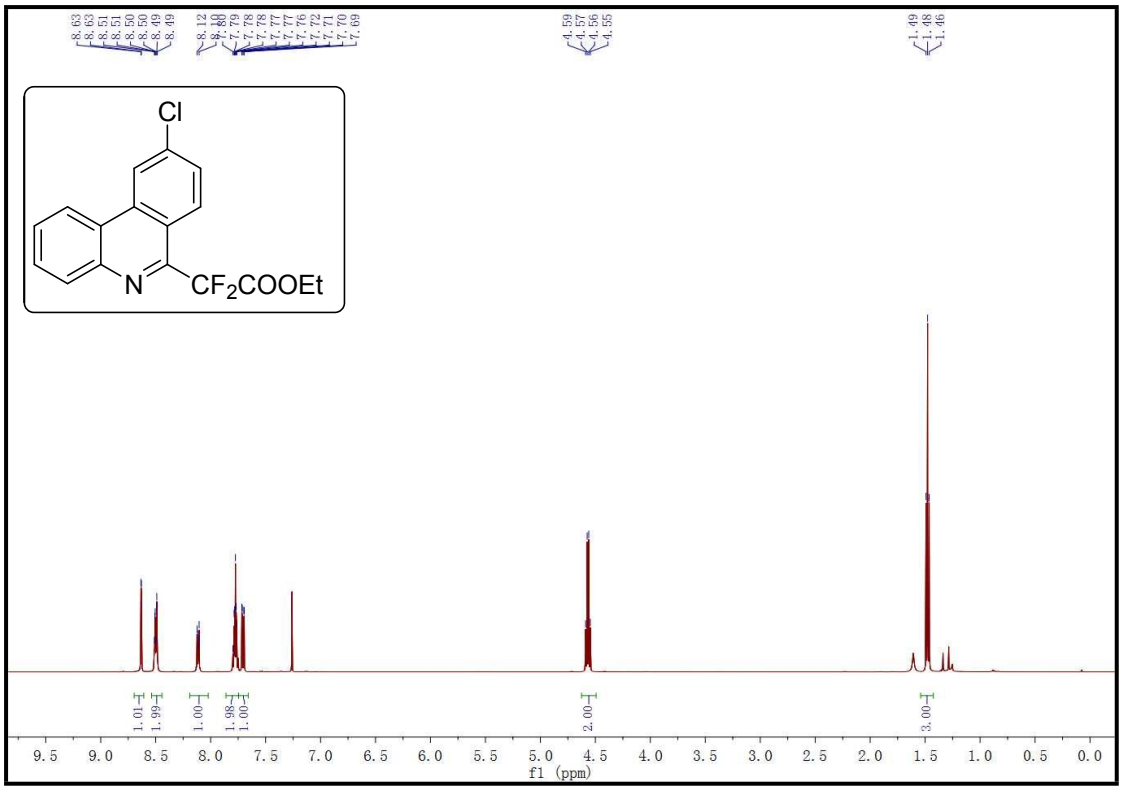
ethyl 2-(benzo[i]phenanthridin-5-yl)-2,2-difluoroacetate (3q)

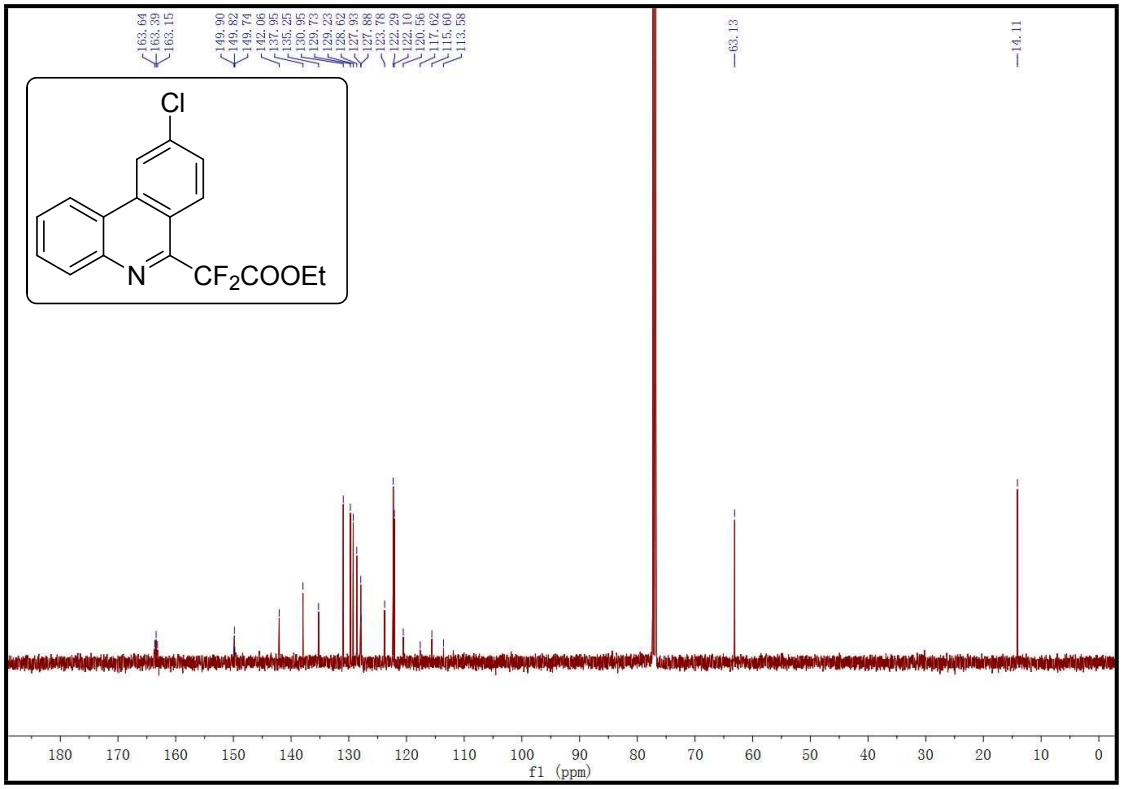


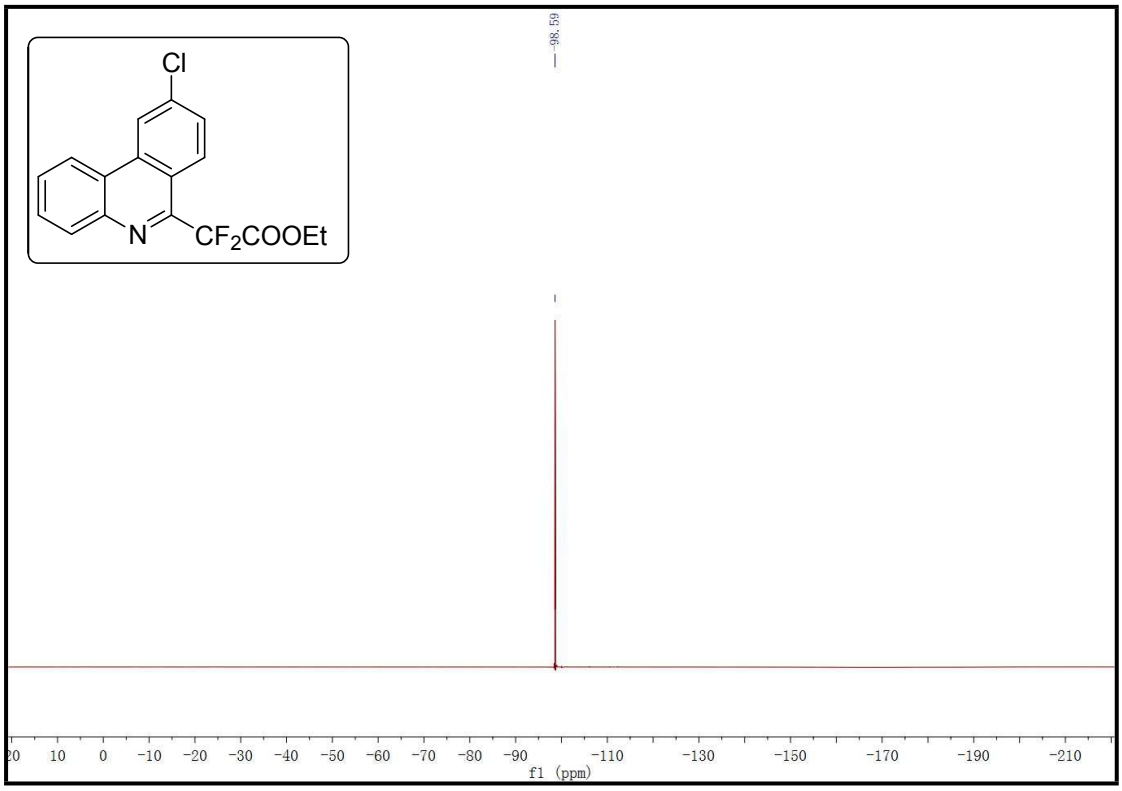




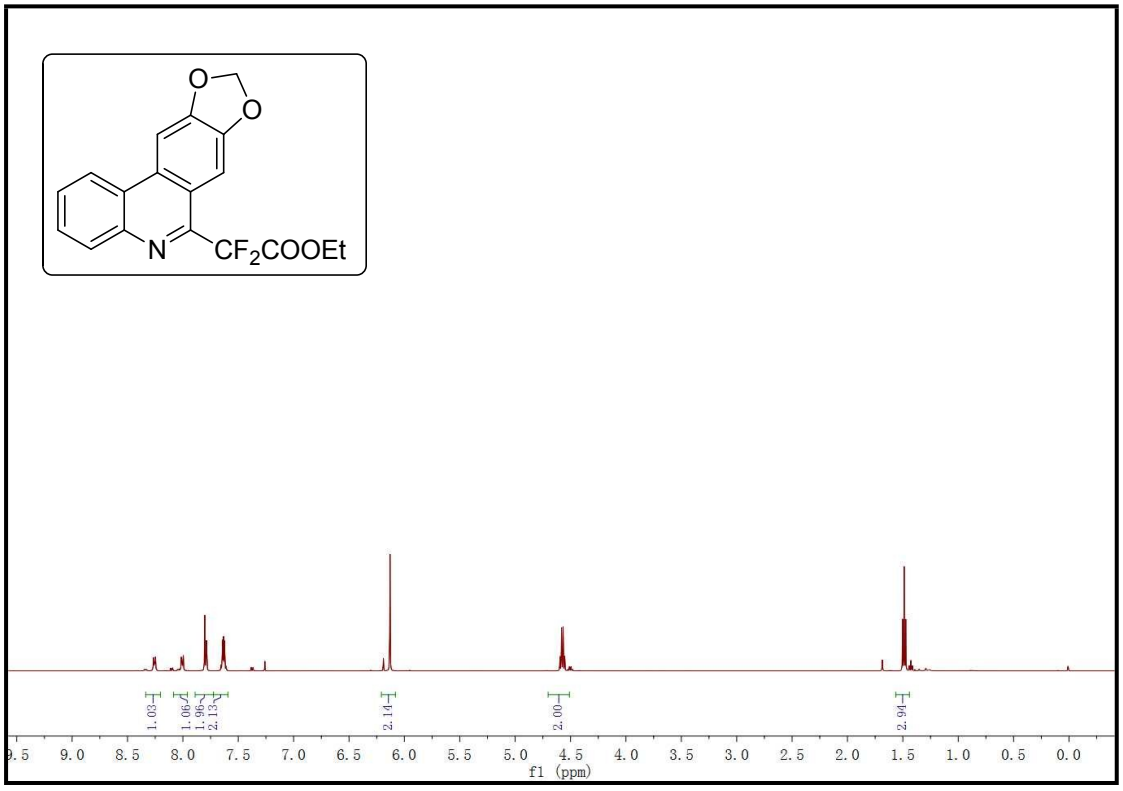
ethyl 2-(9-chlorophenanthridin-6-yl)-2,2-difluoroacetate (3r)

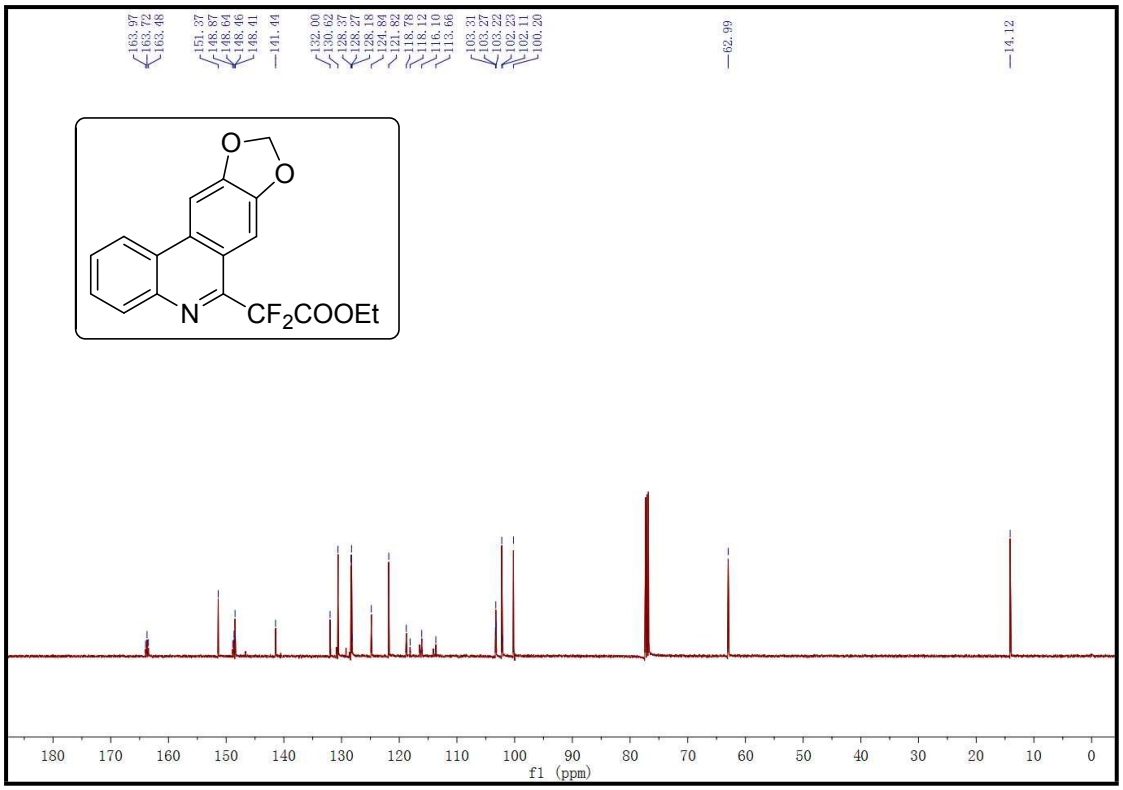


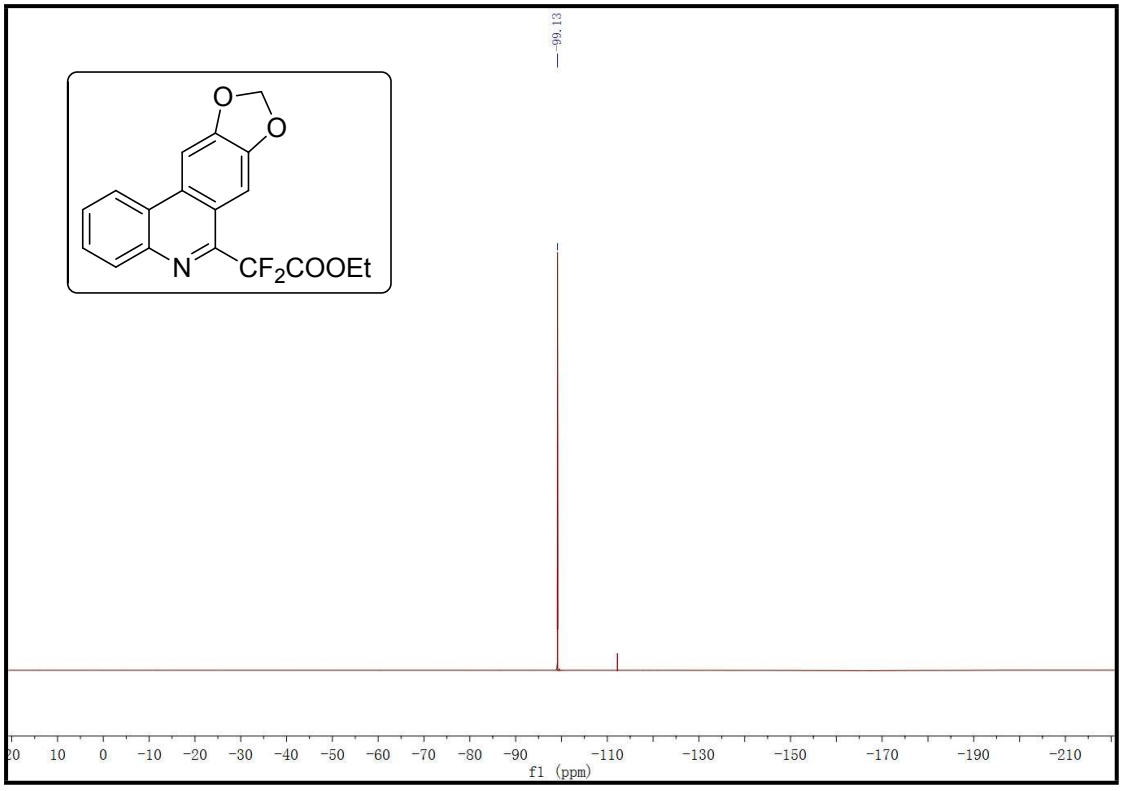

163.64
163.39
163.15
149.90
149.82
149.74
142.06
137.95
135.25
130.95
129.73
129.23
128.62
127.93
127.88
123.78
122.29
122.10
120.56
117.62
115.66
113.58
63.13
14.11
Cl
N
CF2COOEt
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.59
Cl
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

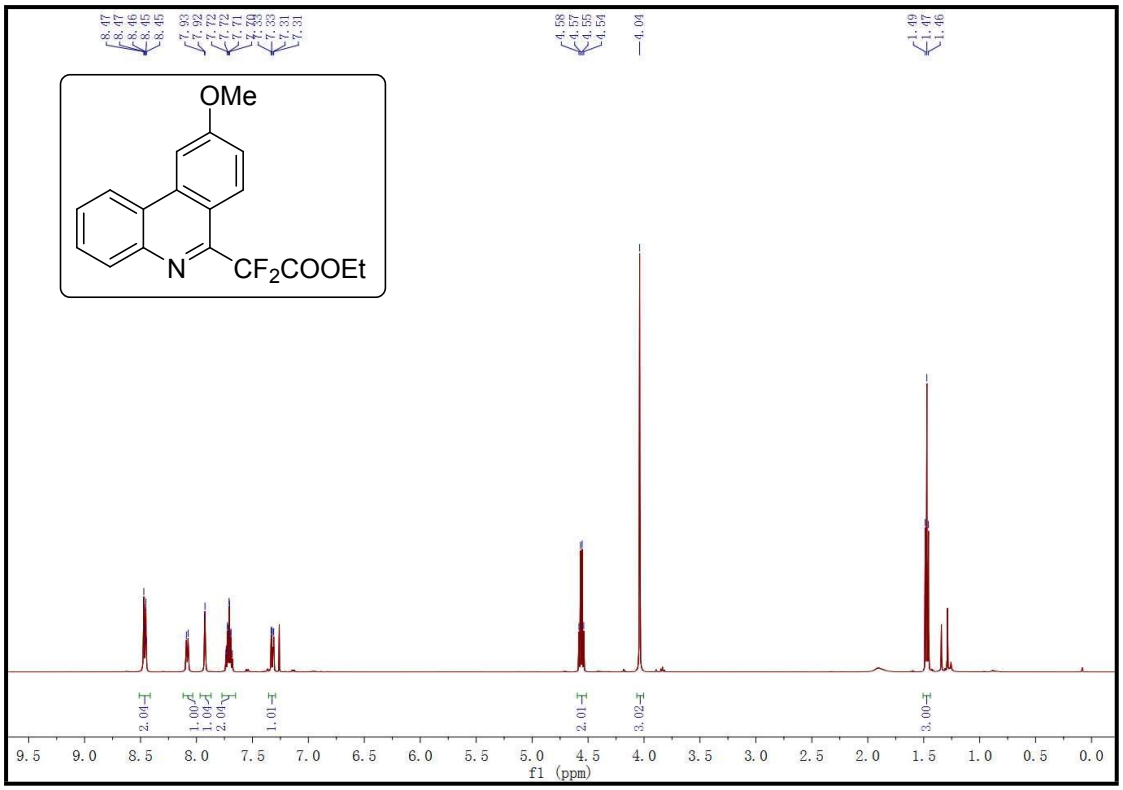
Ethyl 2-([1,3]dioxolo[4,5-j]phenanthridin-6-yl)-2,2-difluoroacetate (3s)

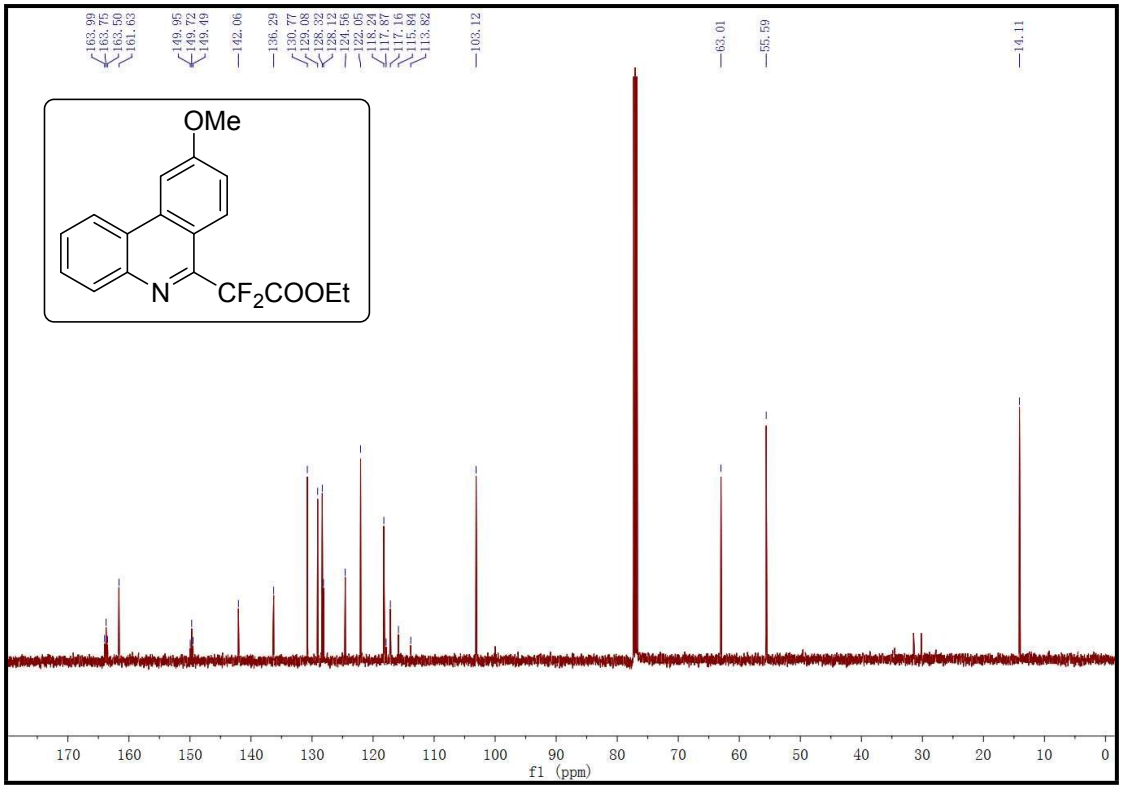


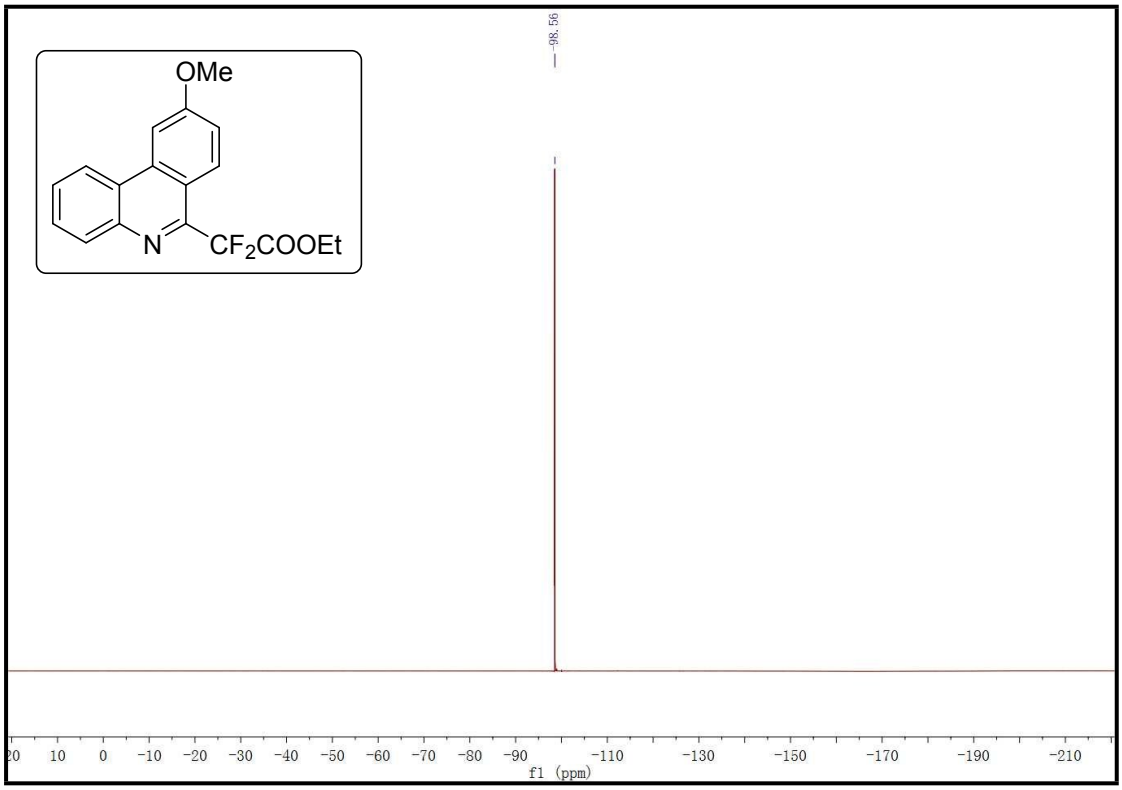




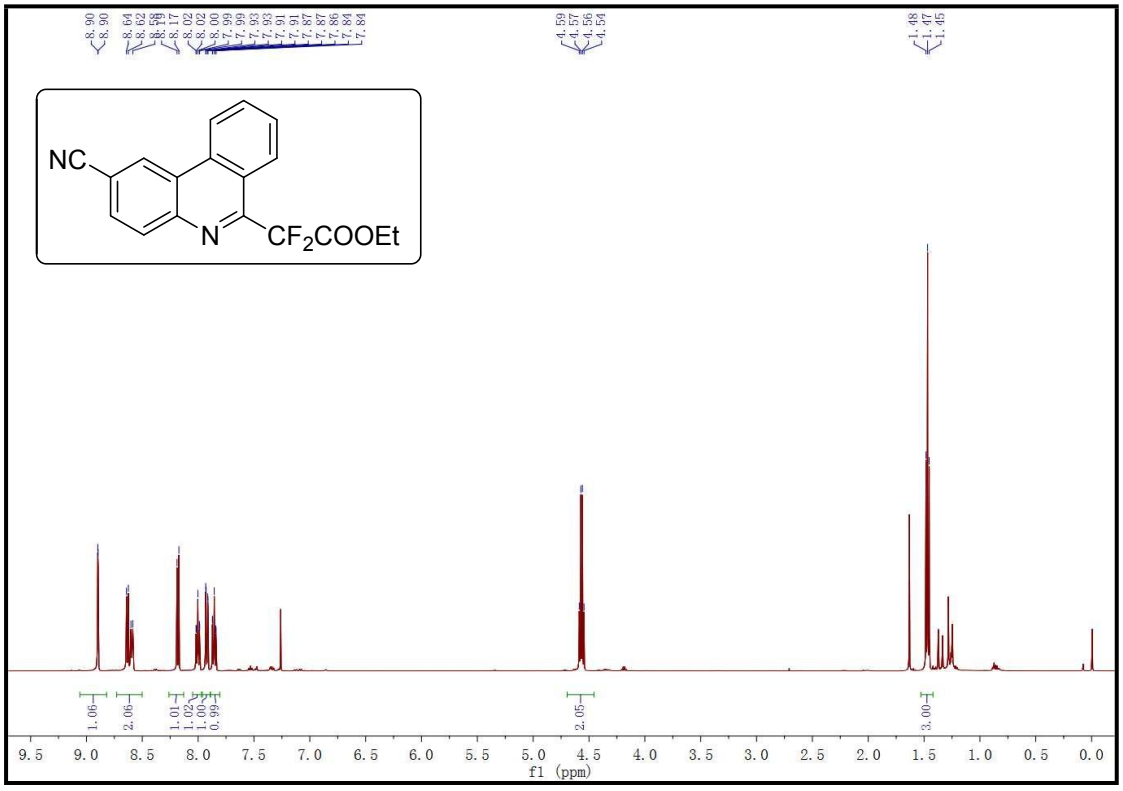
ethyl 2,2-difluoro-2-(9-methoxyphenanthridin-6-yl)acetate (3t)

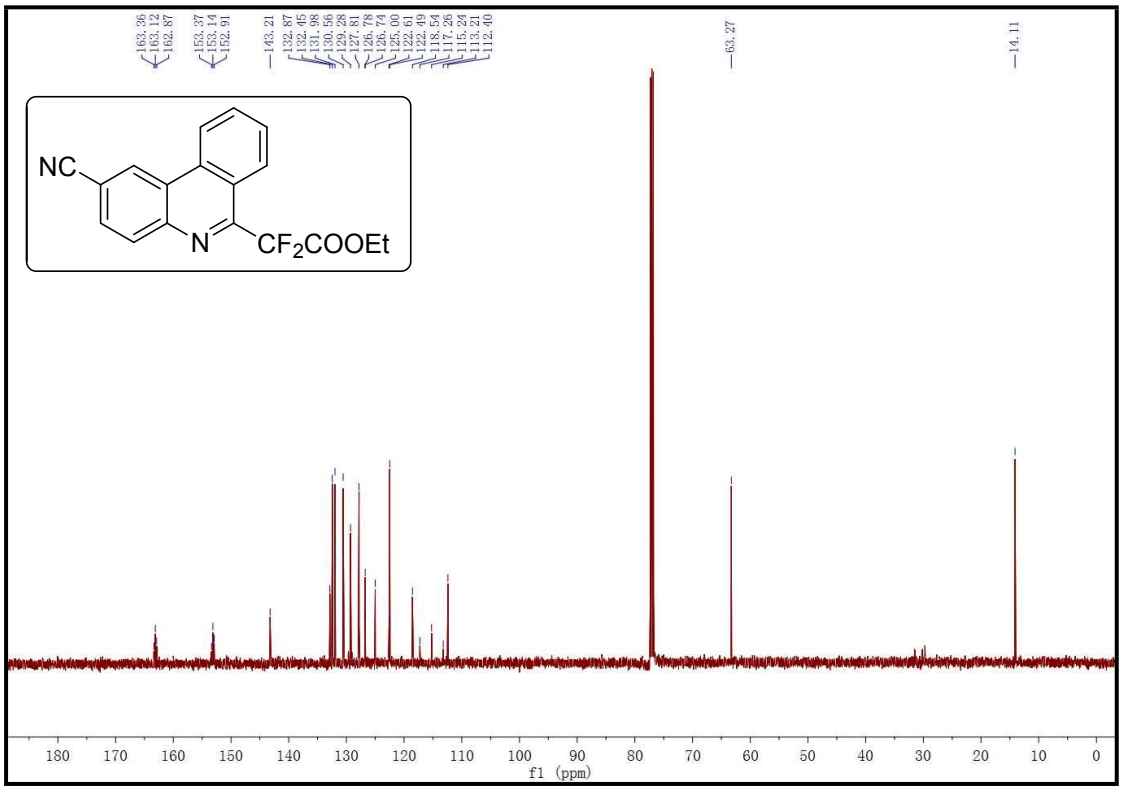


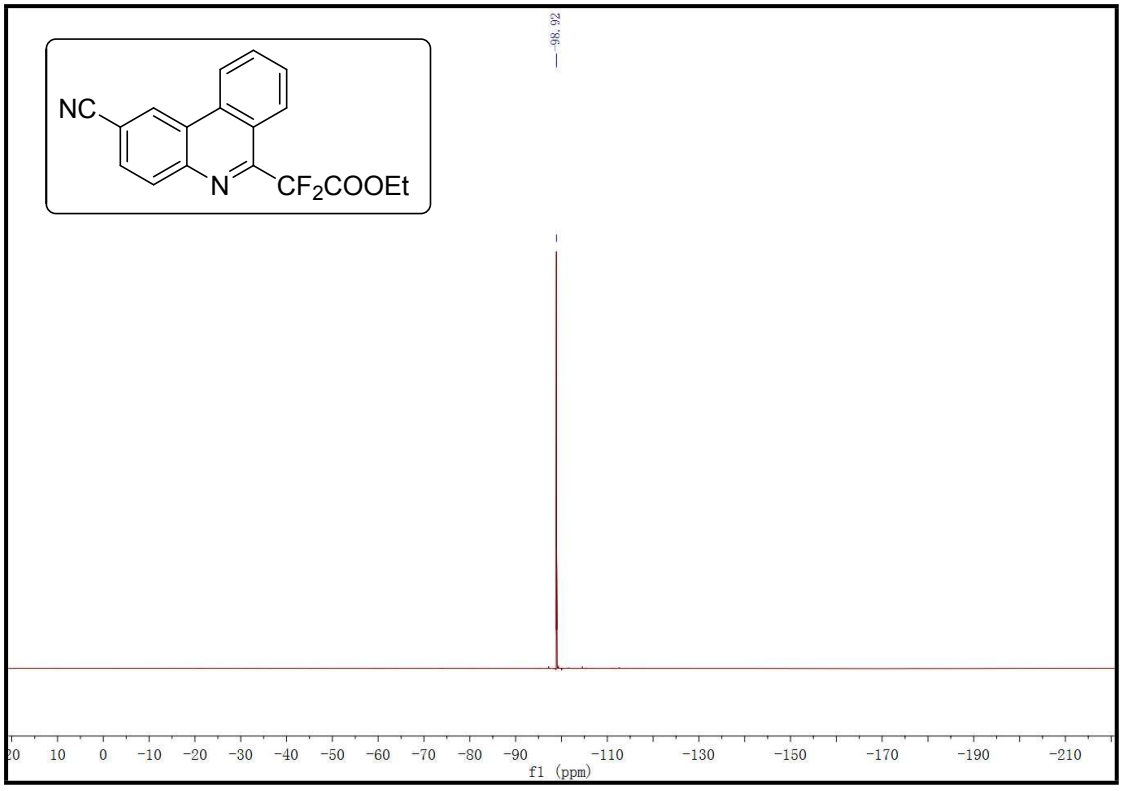

163.99
163.75
163.50
161.63
149.95
149.72
149.49
142.06
136.29
130.77
129.08
128.32
128.12
124.56
122.05
118.24
117.87
117.16
115.84
113.82
103.12
63.01
55.59
14.11
OMe
N
CF2COOEt
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.56
OMe
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

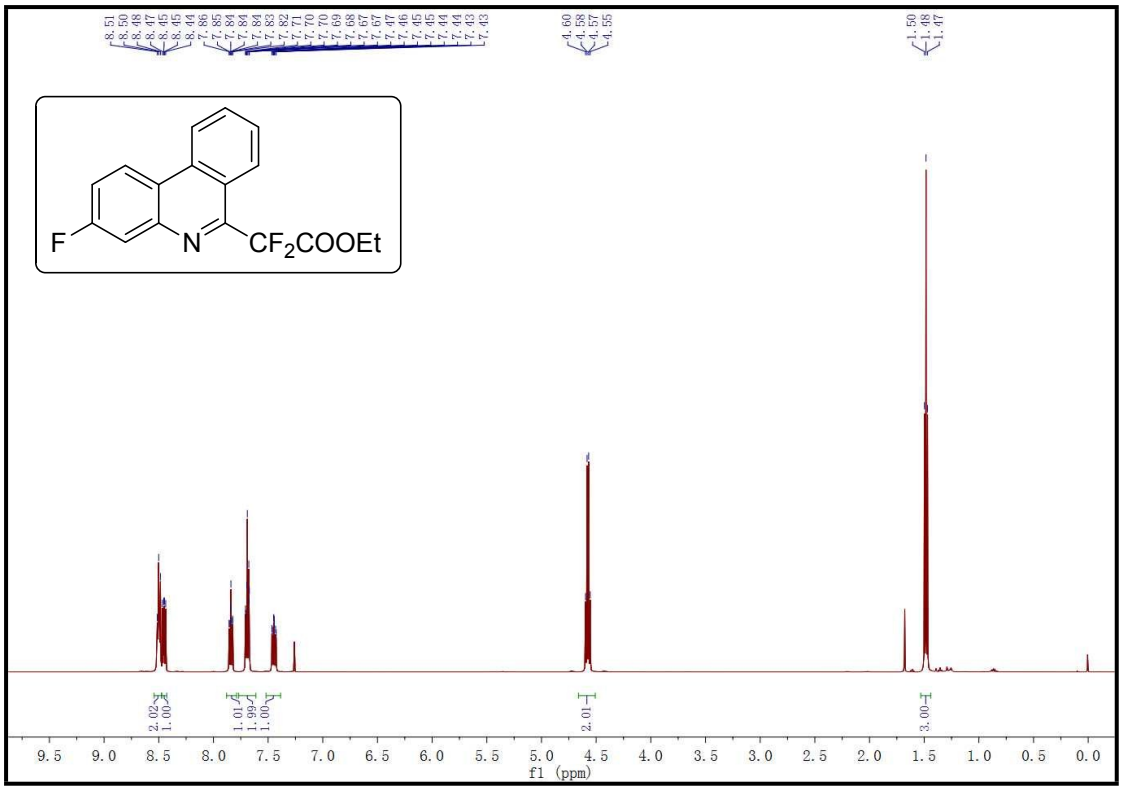
ethyl 2-(2-cyanophenanthridin-6-yl)-2,2-difluoroacetate (3u)

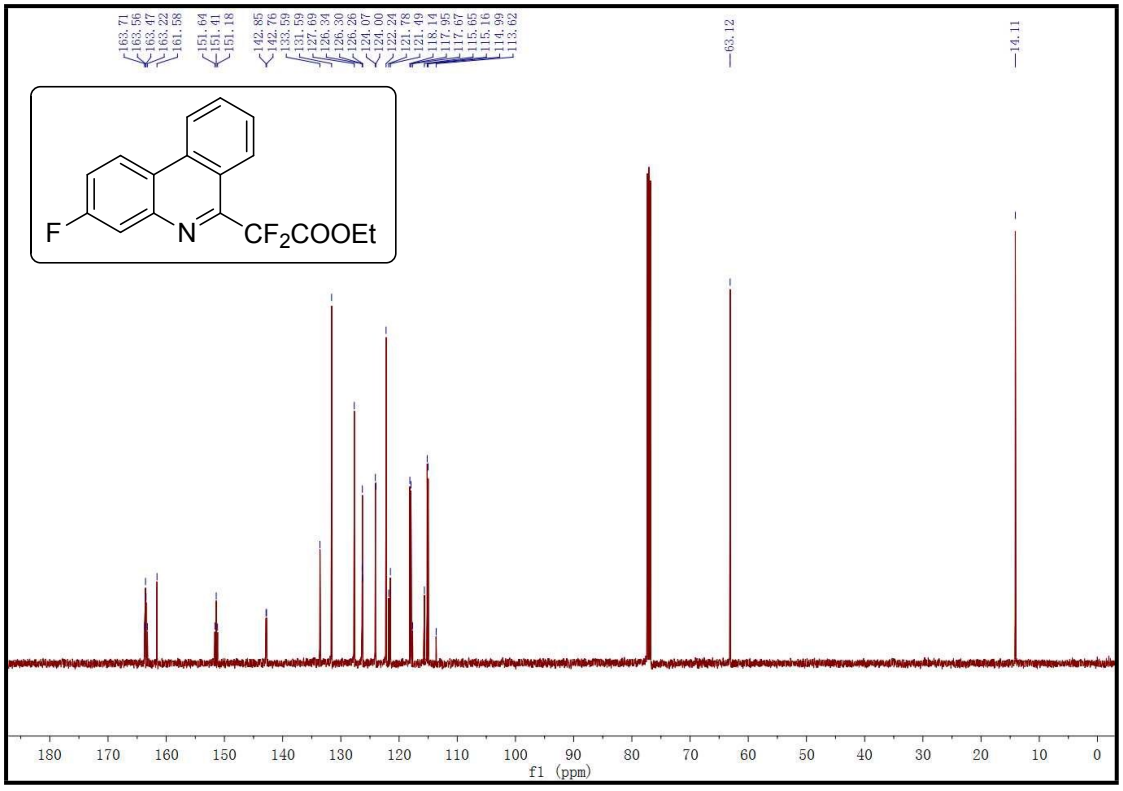


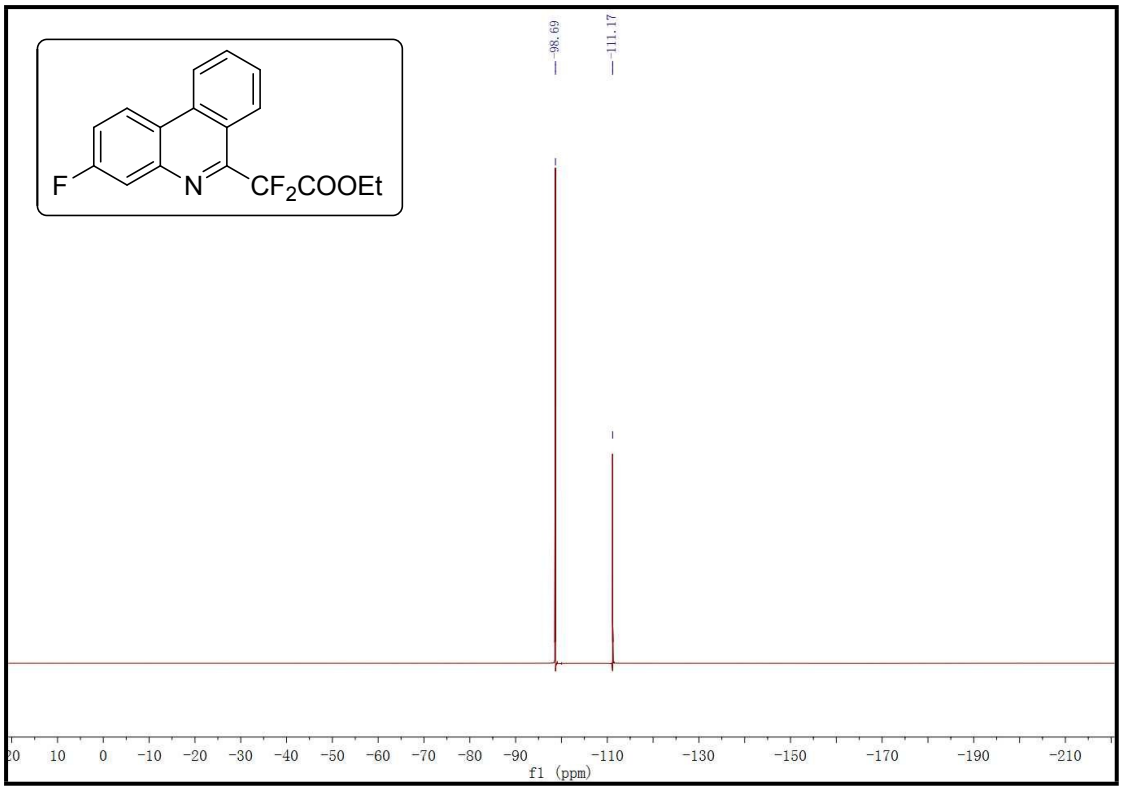




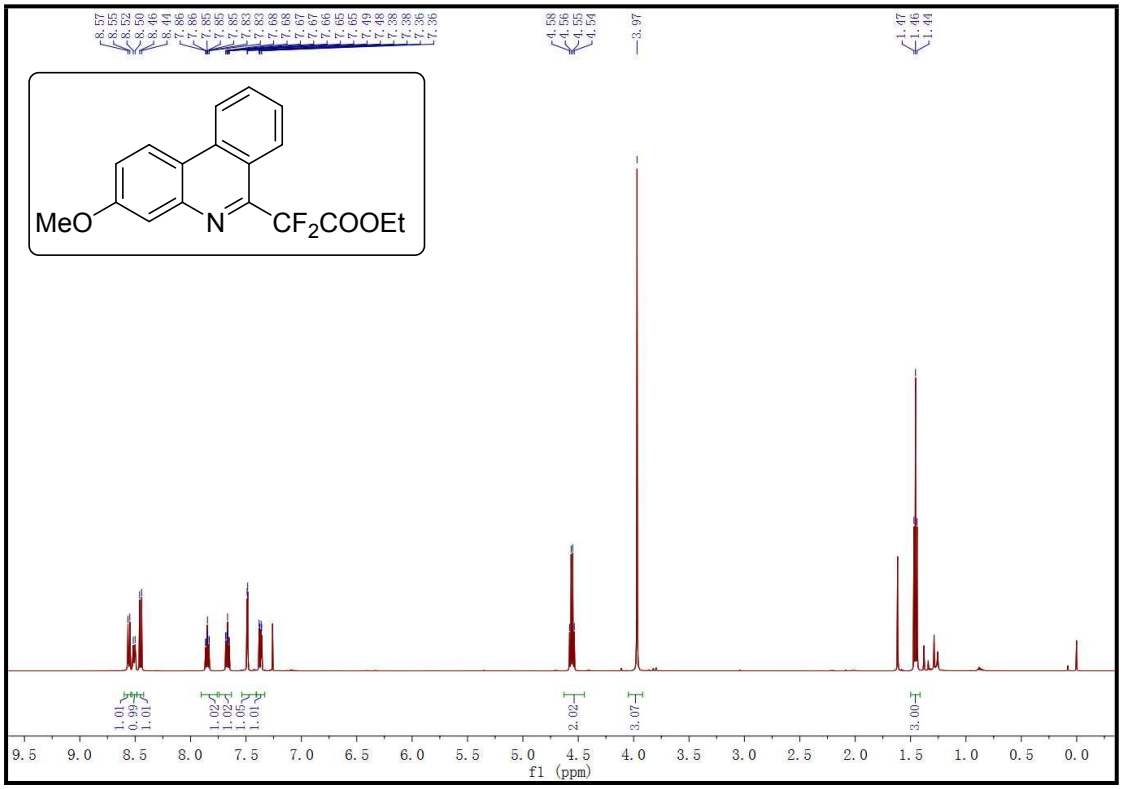
ethyl 2,2-difluoro-2-(3-fluorophenanthridin-6-yl)acetate (3v)

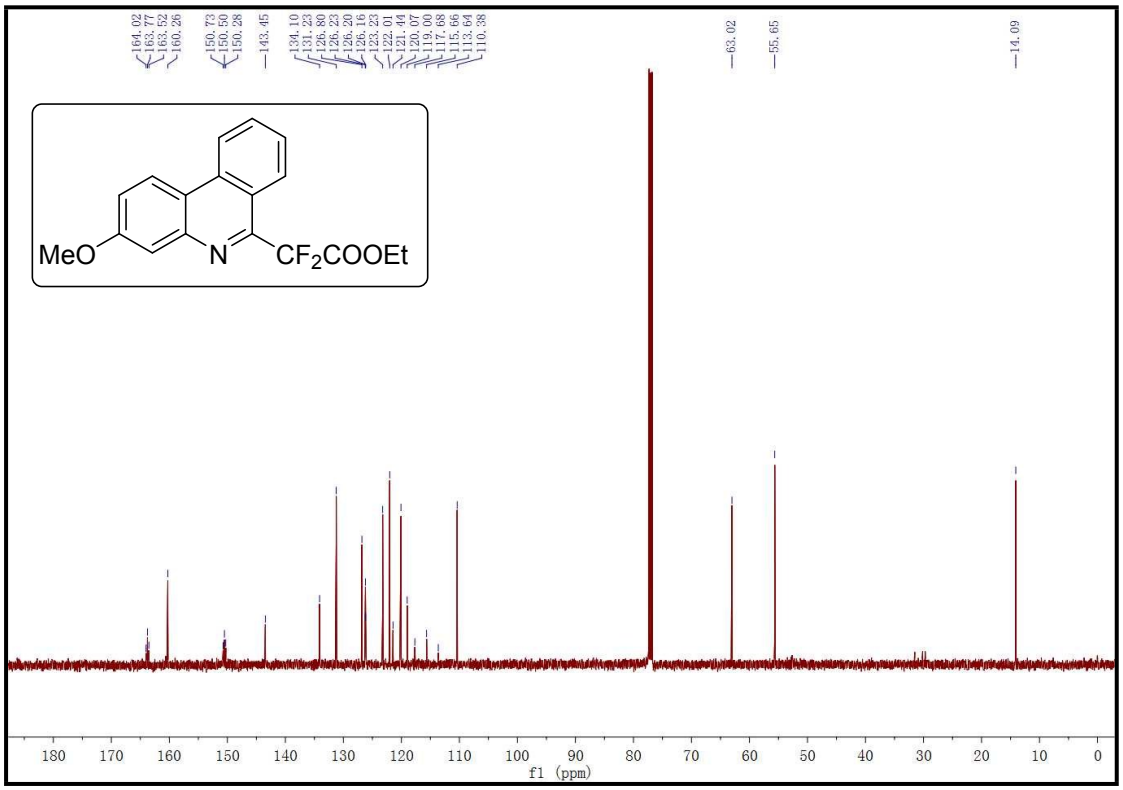


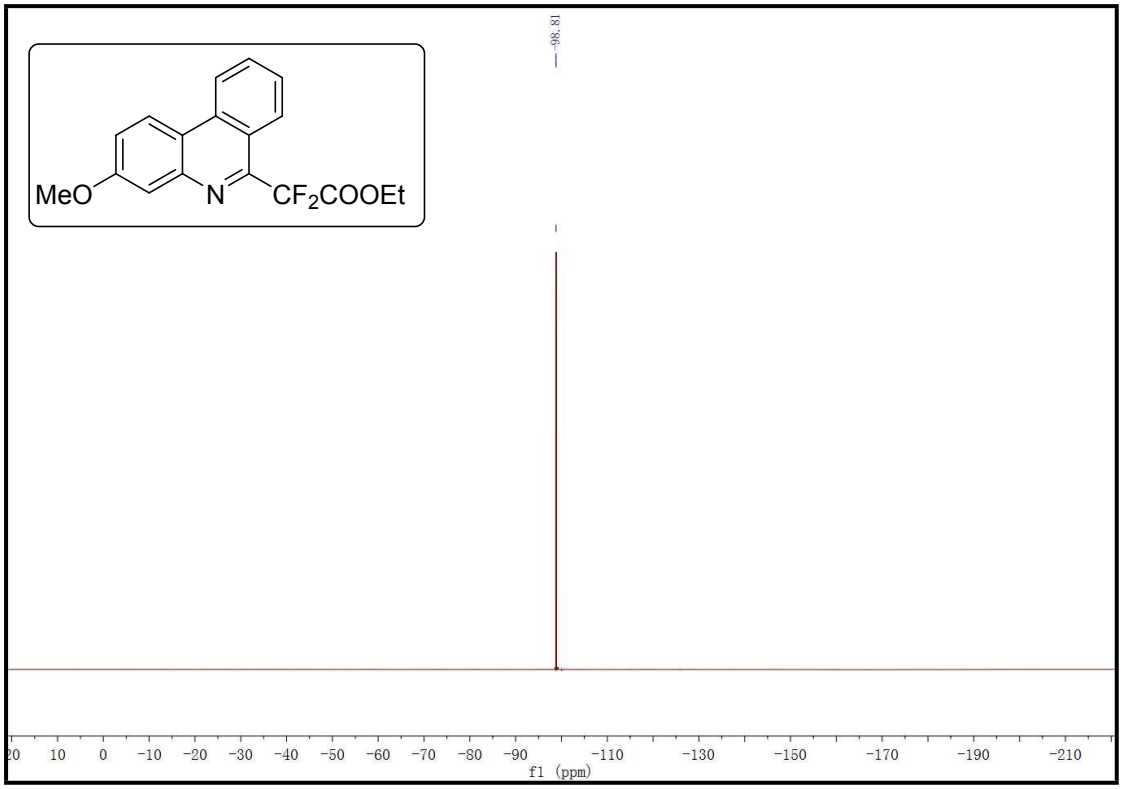

163.71
163.56
163.47
163.22
161.58
151.64
151.41
151.18
142.85
142.76
133.59
131.59
127.69
126.34
126.30
126.26
124.07
124.00
122.24
121.78
121.49
118.14
117.95
117.67
115.65
115.16
114.99
113.62
63.12
14.11
F
N
CF2COOEt
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.69
-111.17
F
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

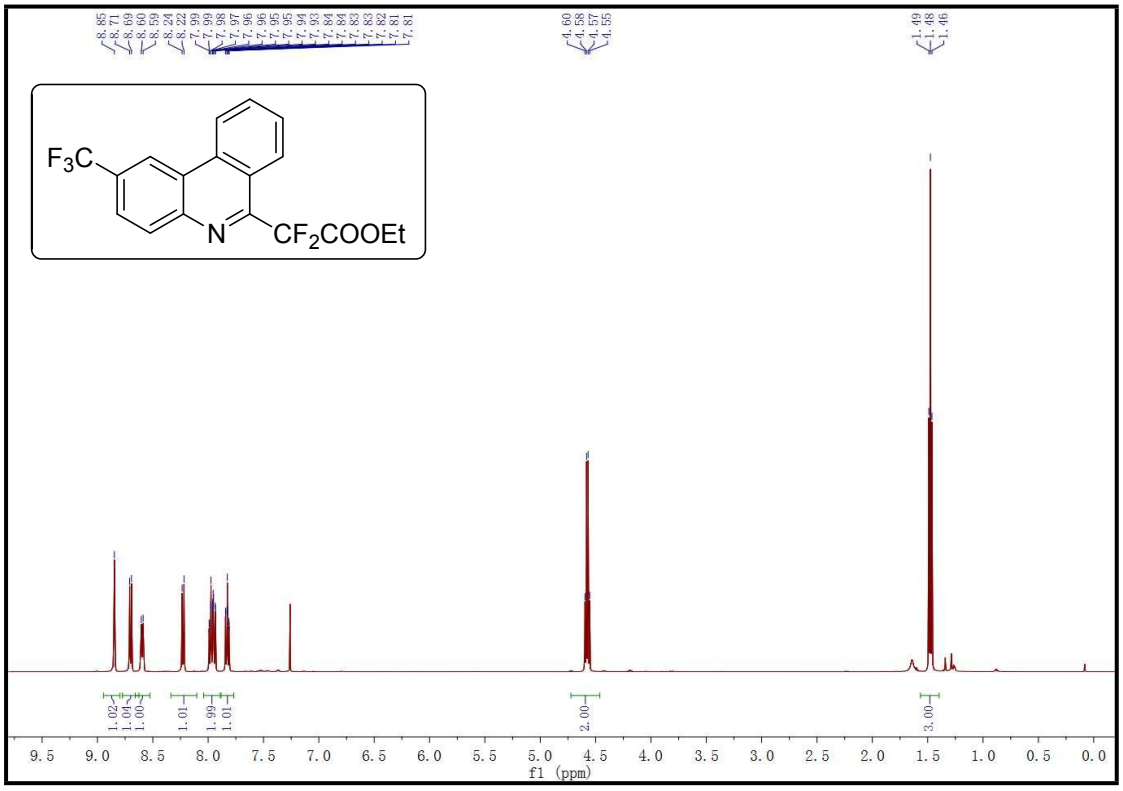
ethyl 2,2-difluoro-2-(3-methoxyphenanthridin-6-yl)acetate (3w)

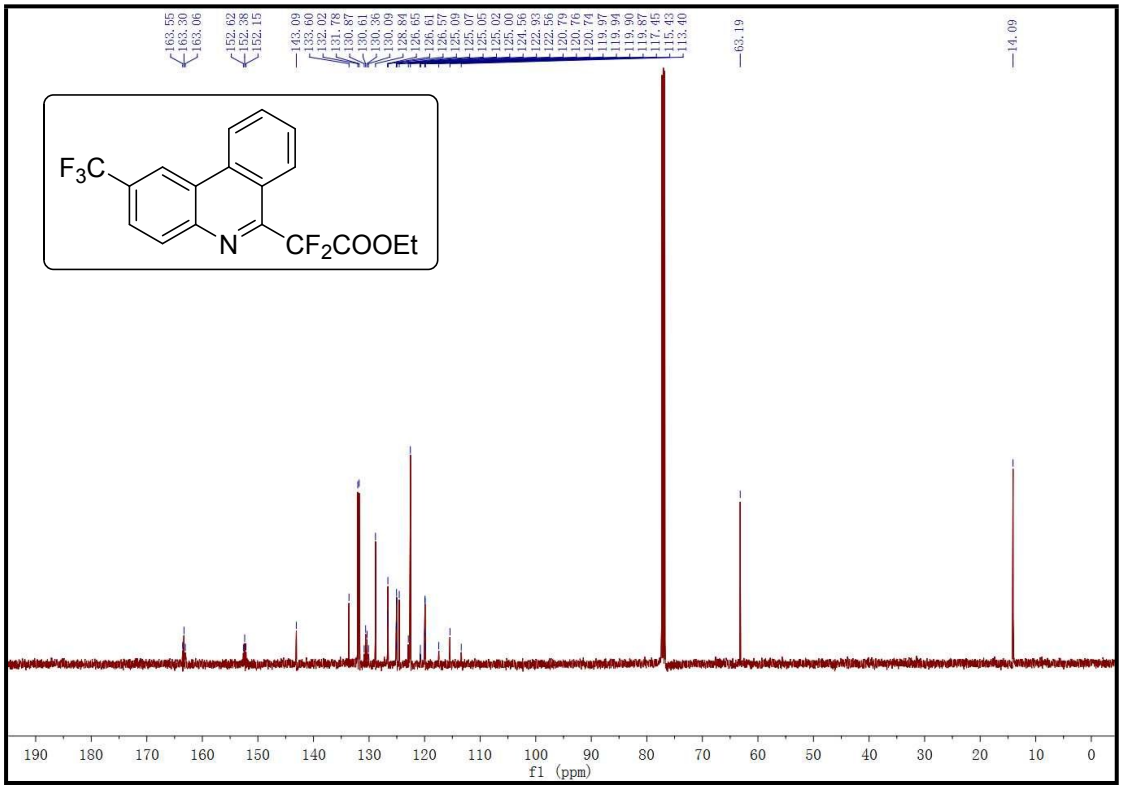


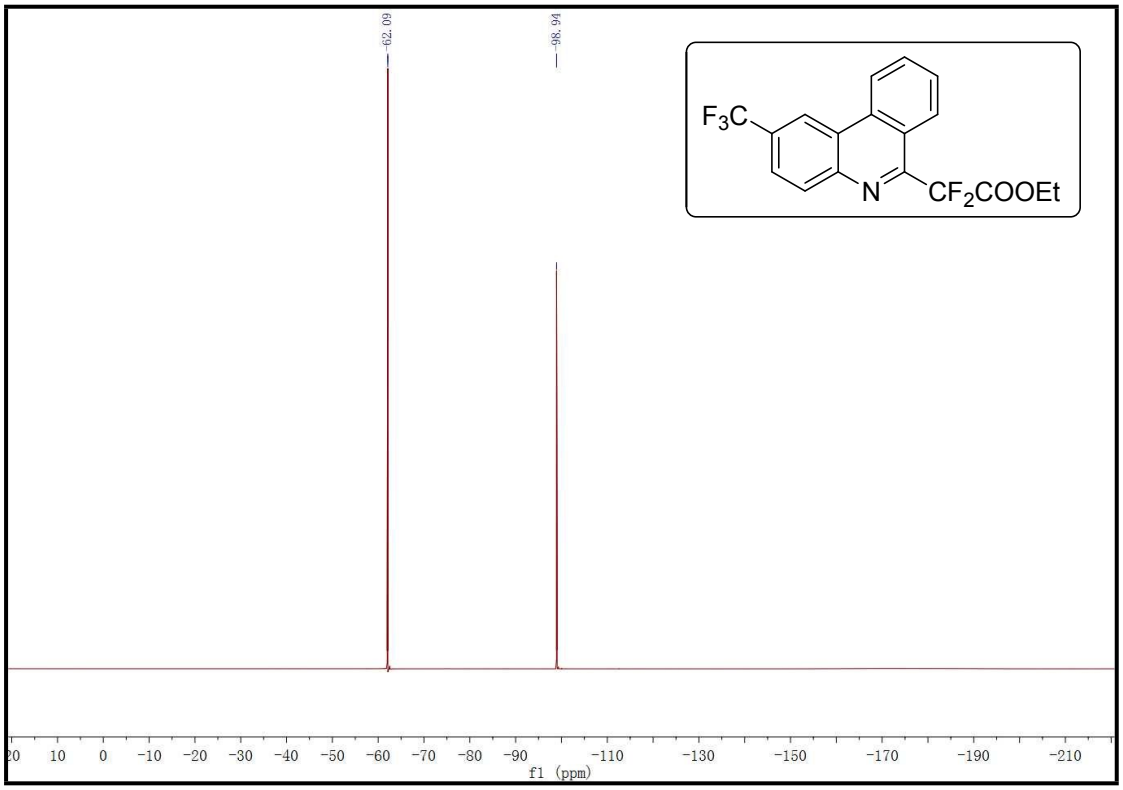




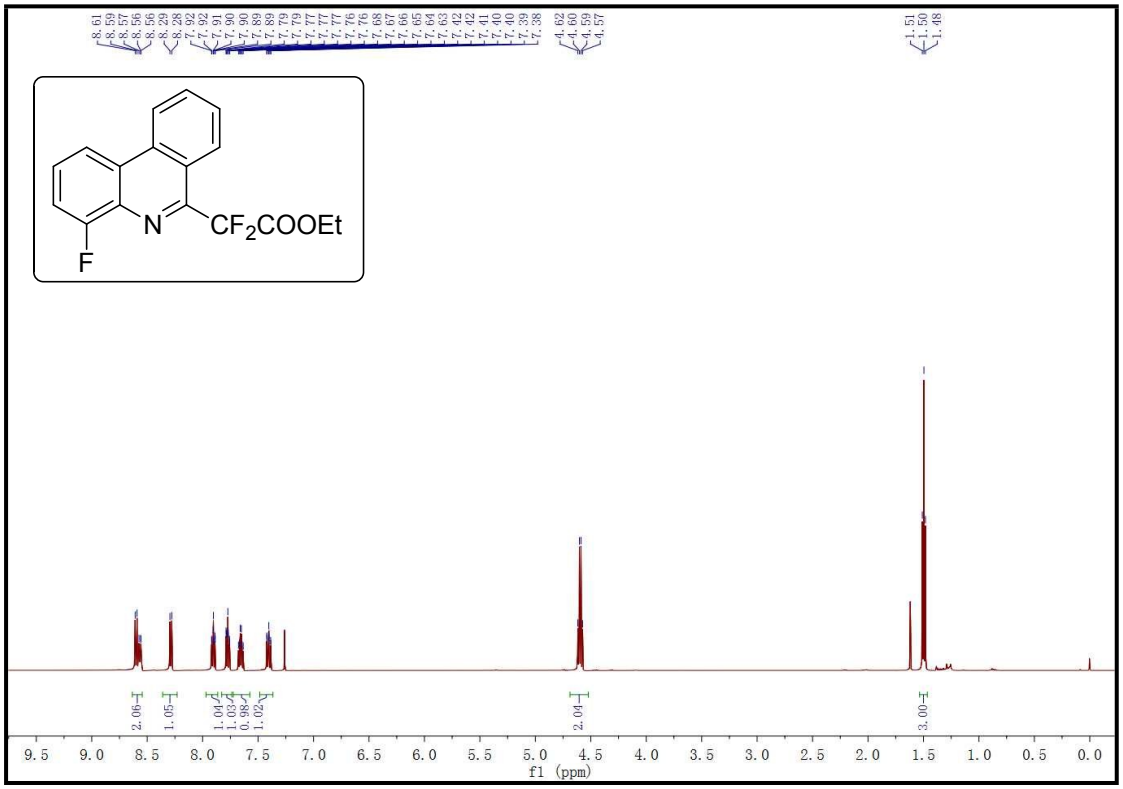
ethyl 2,2-difluoro-2-(2-(trifluoromethyl)phenanthridin-6-yl)acetate (3x)

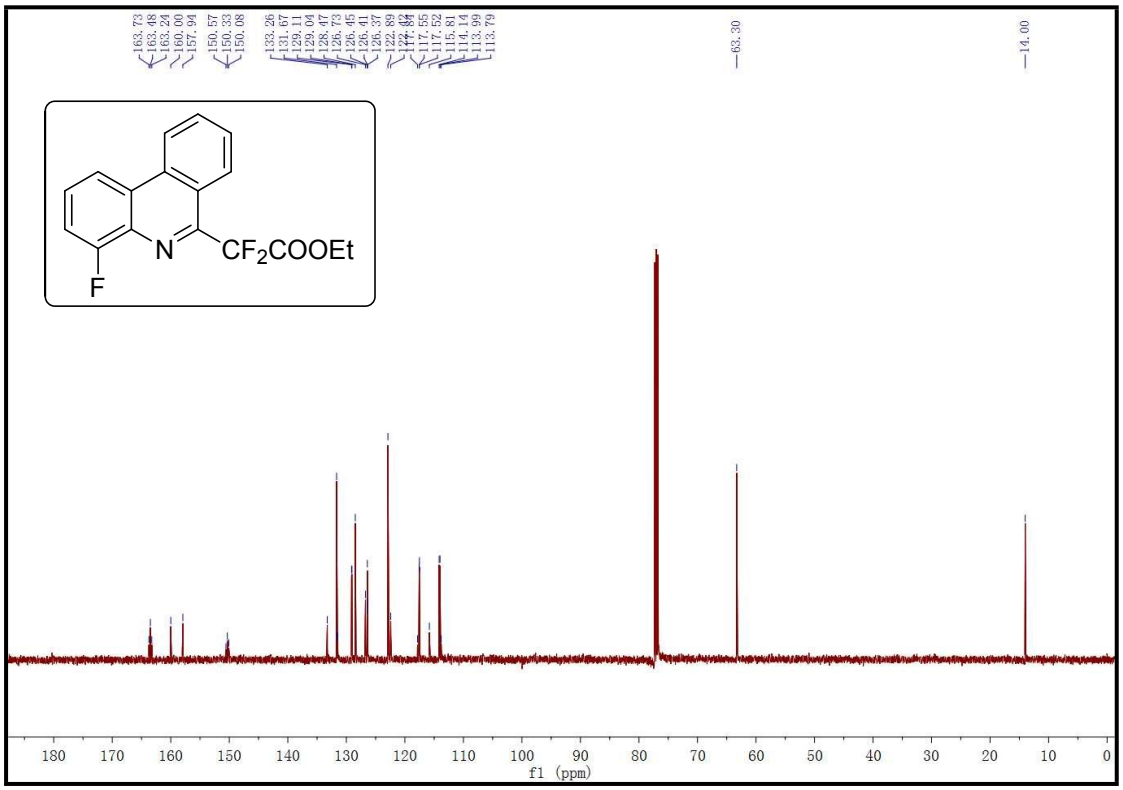


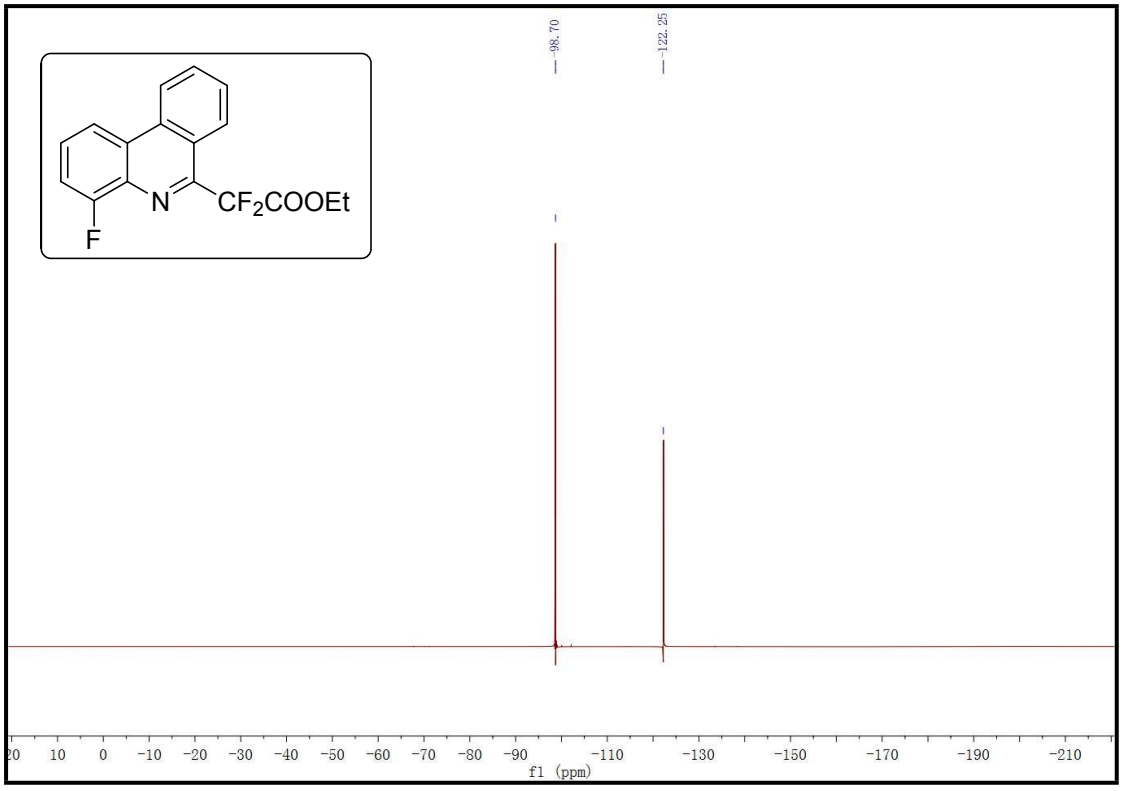

163.55
163.30
163.06
152.62
152.38
152.15
143.09
133.60
132.02
131.78
130.87
130.61
130.36
130.09
128.84
126.65
126.61
126.57
125.09
125.07
125.05
125.02
125.00
124.56
122.93
122.56
120.79
120.76
120.74
119.97
119.94
119.90
119.87
117.45
115.43
113.40
63.19
14.09
F3C
N
CF2COOEt
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-62.09
-98.94
F3C
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

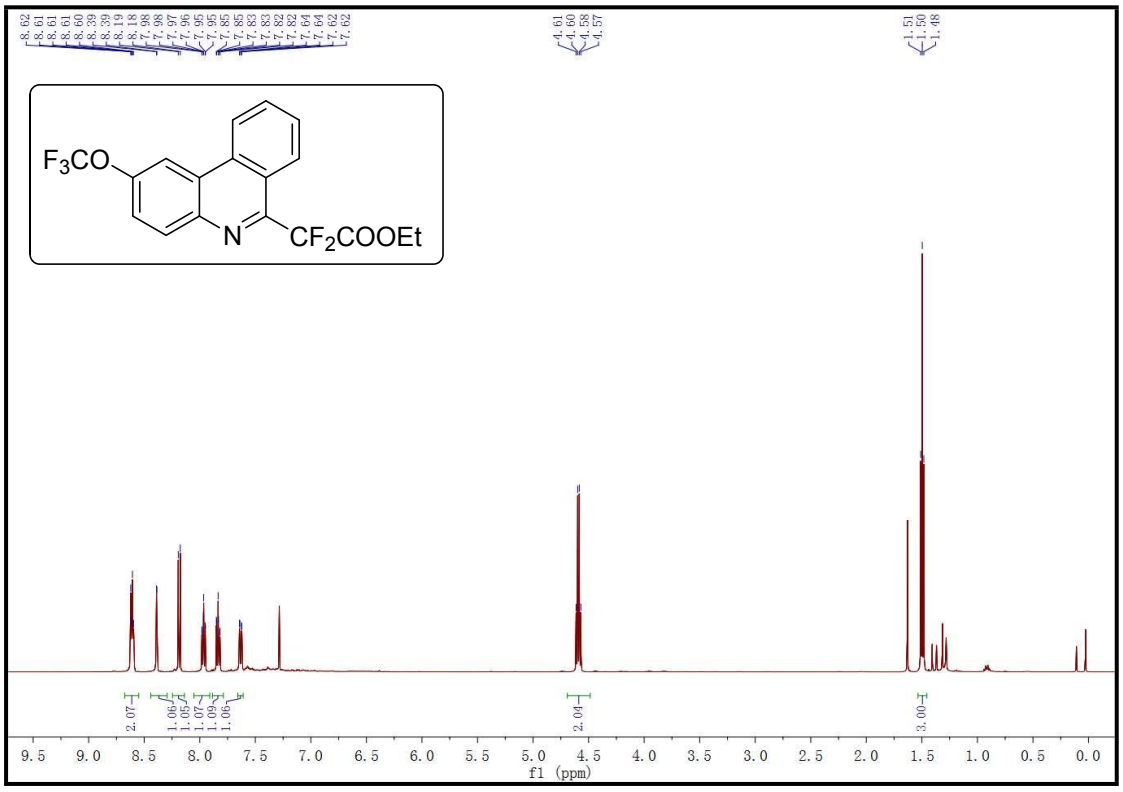
ethyl 2,2-difluoro-2-(4-fluorophenanthridin-6-yl)acetate (3y)

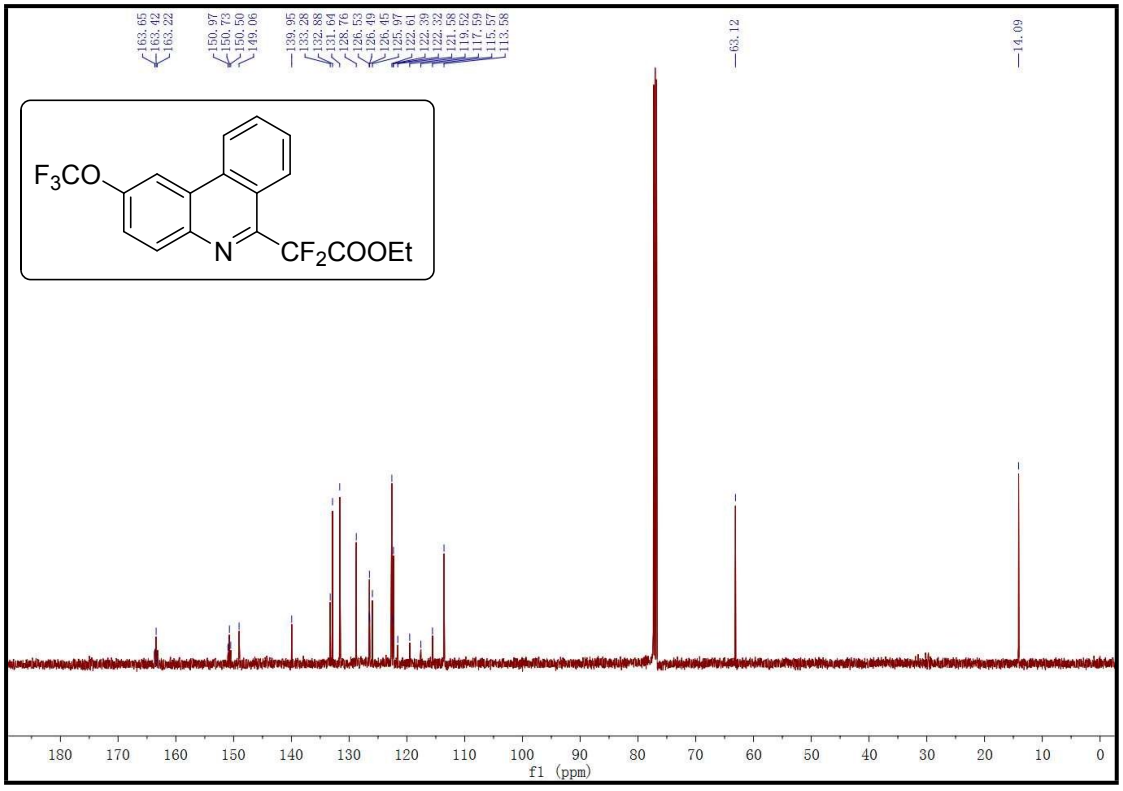


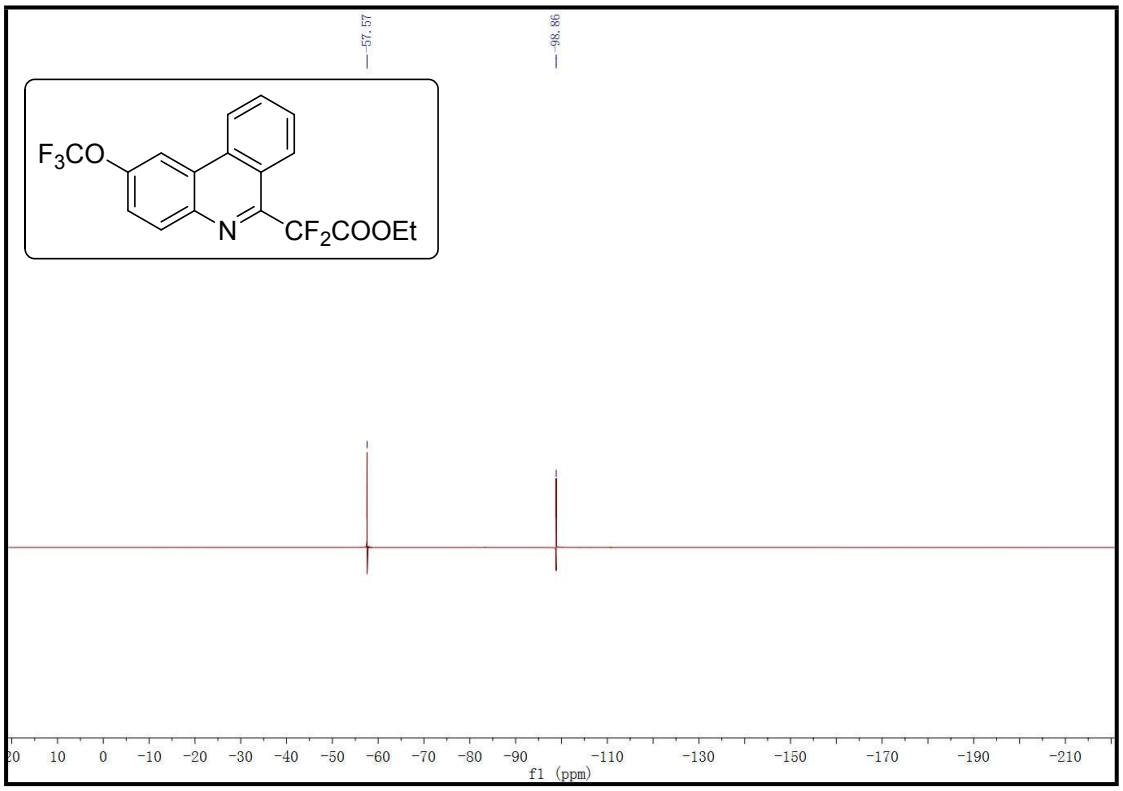




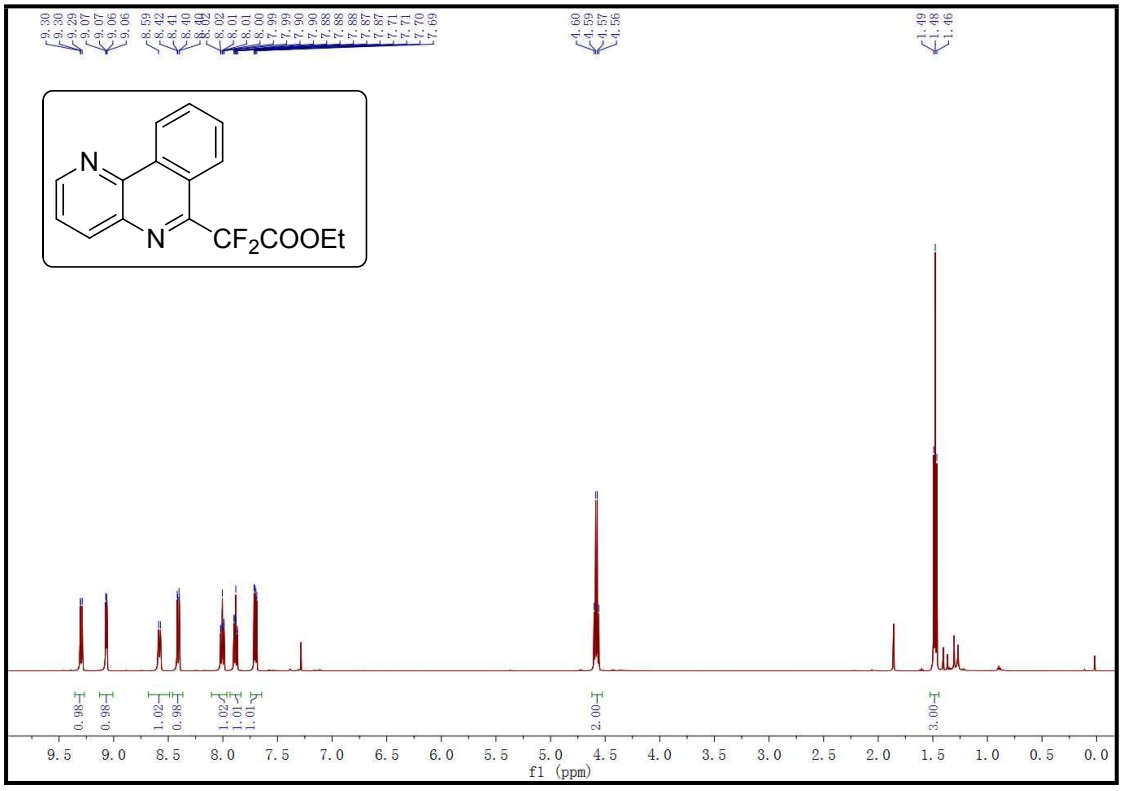
ethyl 2,2-difluoro-2-(2-(trifluoromethoxy)phenanthridin-6-yl)acetate (3z)

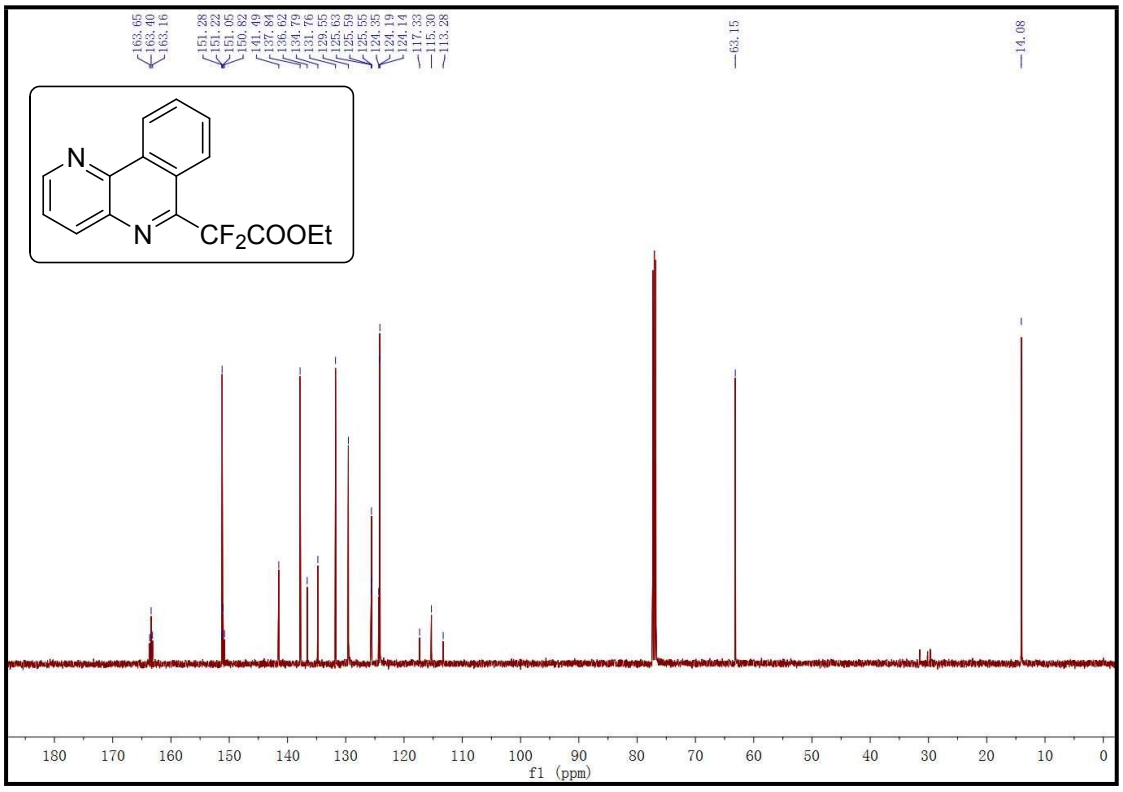


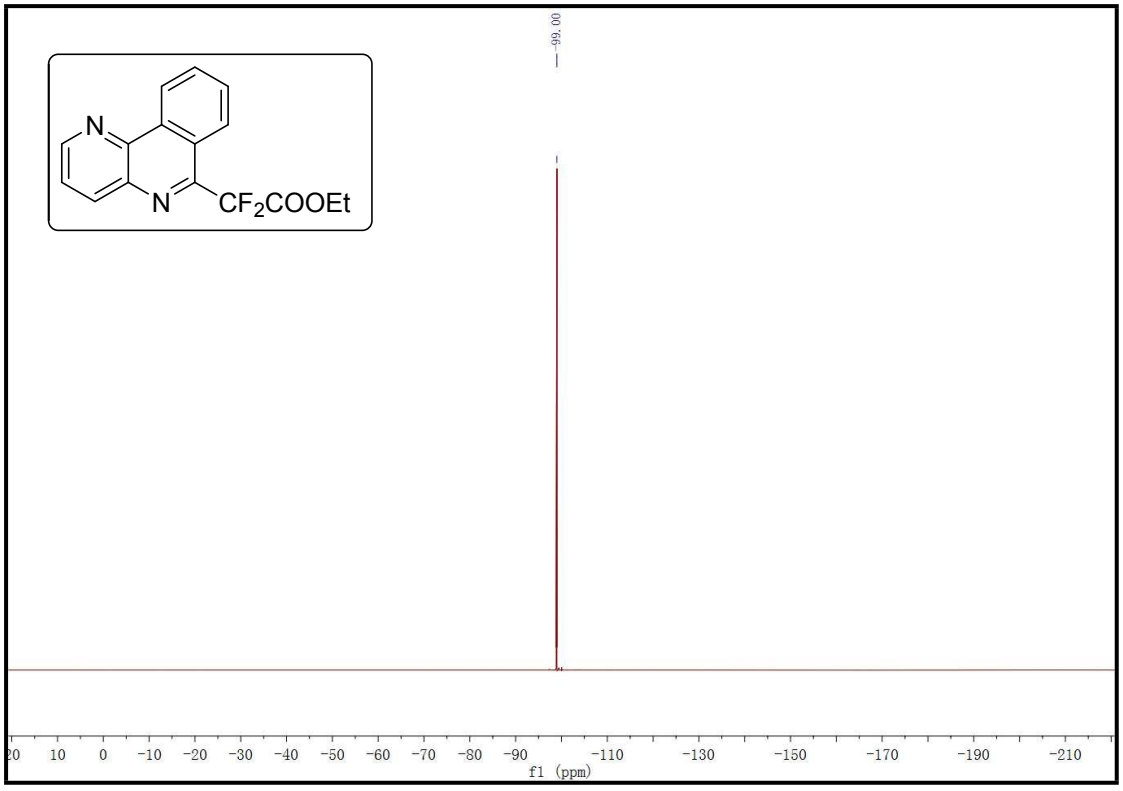

163.65
163.42
163.22
150.97
150.73
150.50
149.06
139.95
133.28
132.88
131.64
128.76
126.53
126.49
126.45
125.97
122.61
122.39
122.32
121.58
119.52
117.59
115.57
113.58
63.12
14.09
F3CO
N
CF2COOEt
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-57.57
-98.86
F3CO
N
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

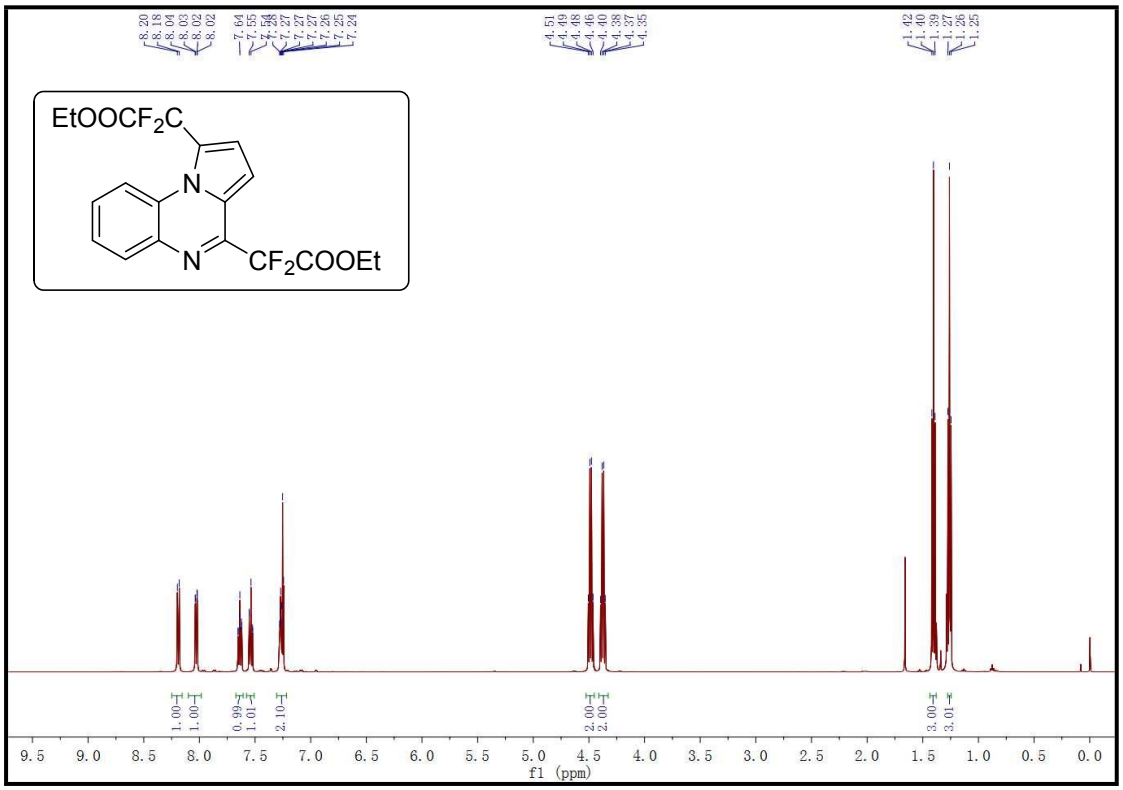
ethyl 2-(benzo[c][1,5]naphthyridin-6-yl)-2,2-difluoroacetate (3aa)

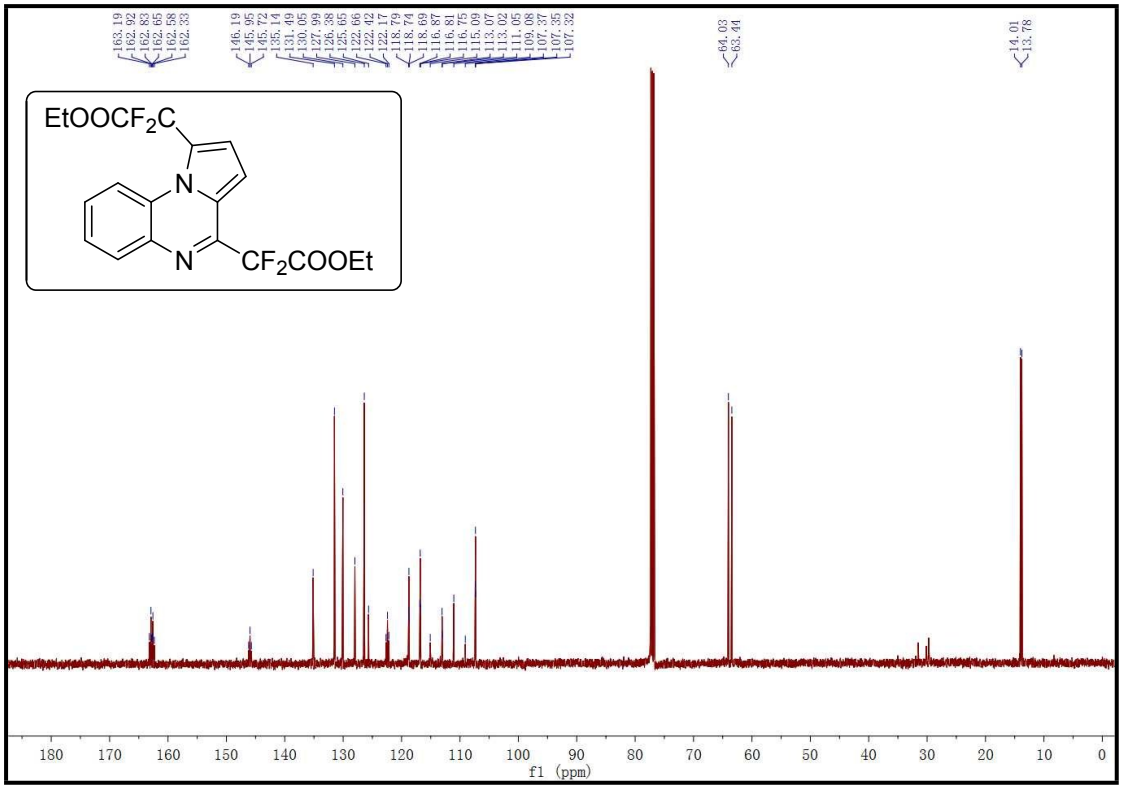


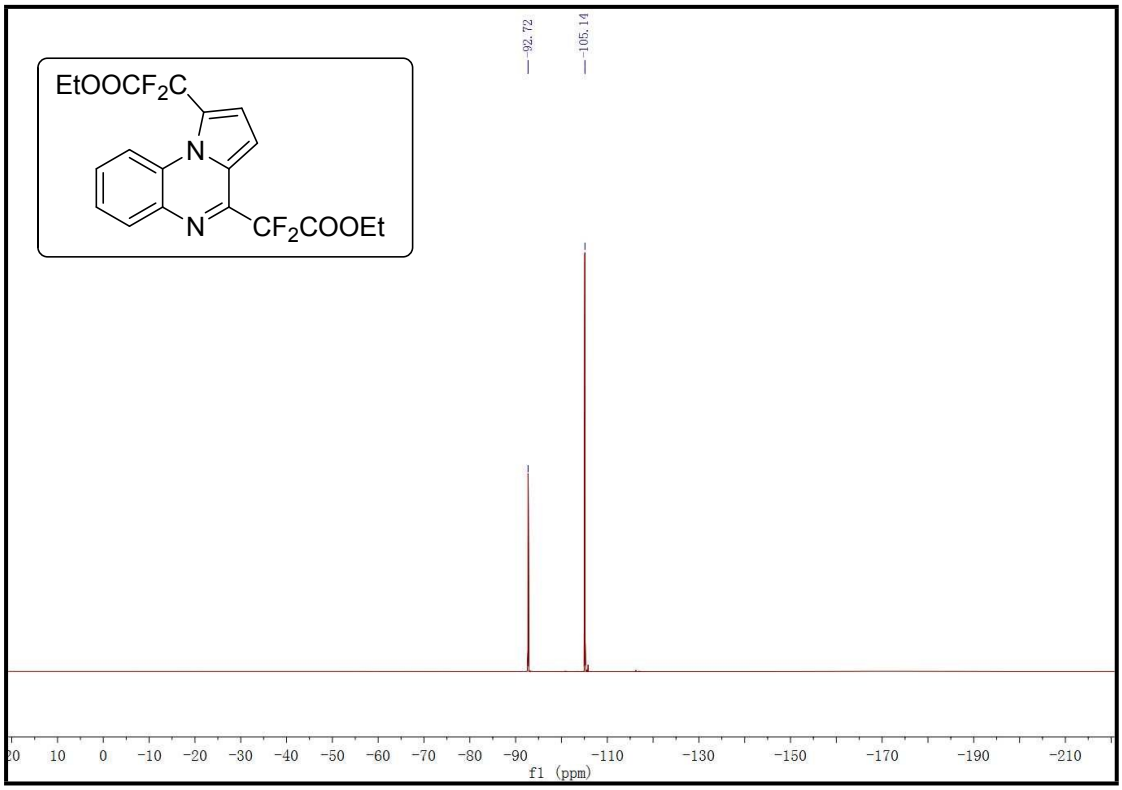




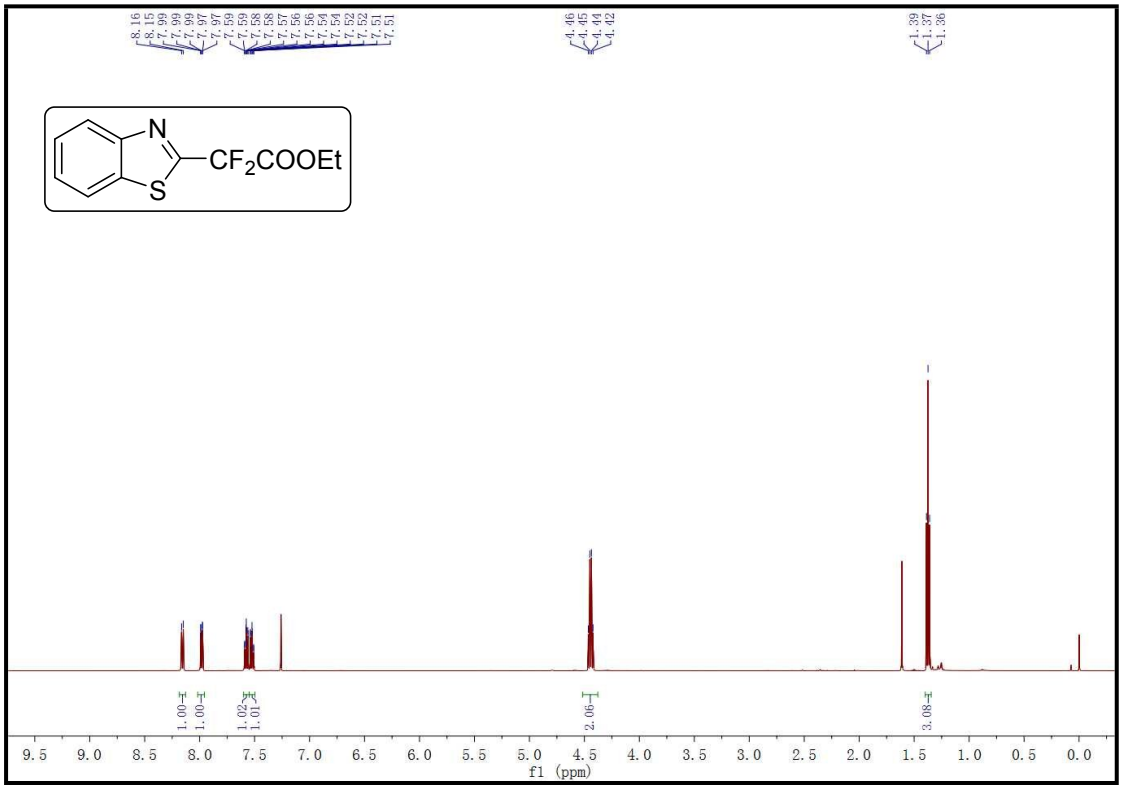
diethyl2,2'-(pyrrolo[1,2-a]quinoxaline-1,4-diyl)bis(2,2-difluoroacetate) (3ab)

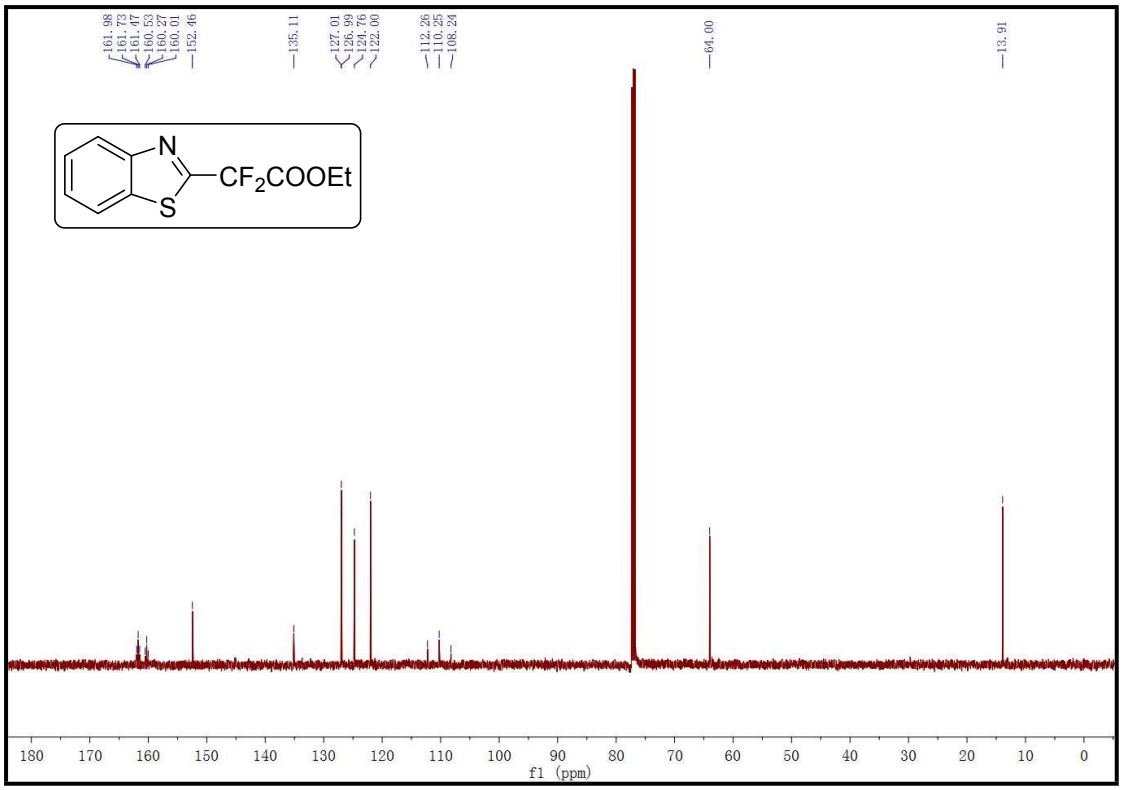


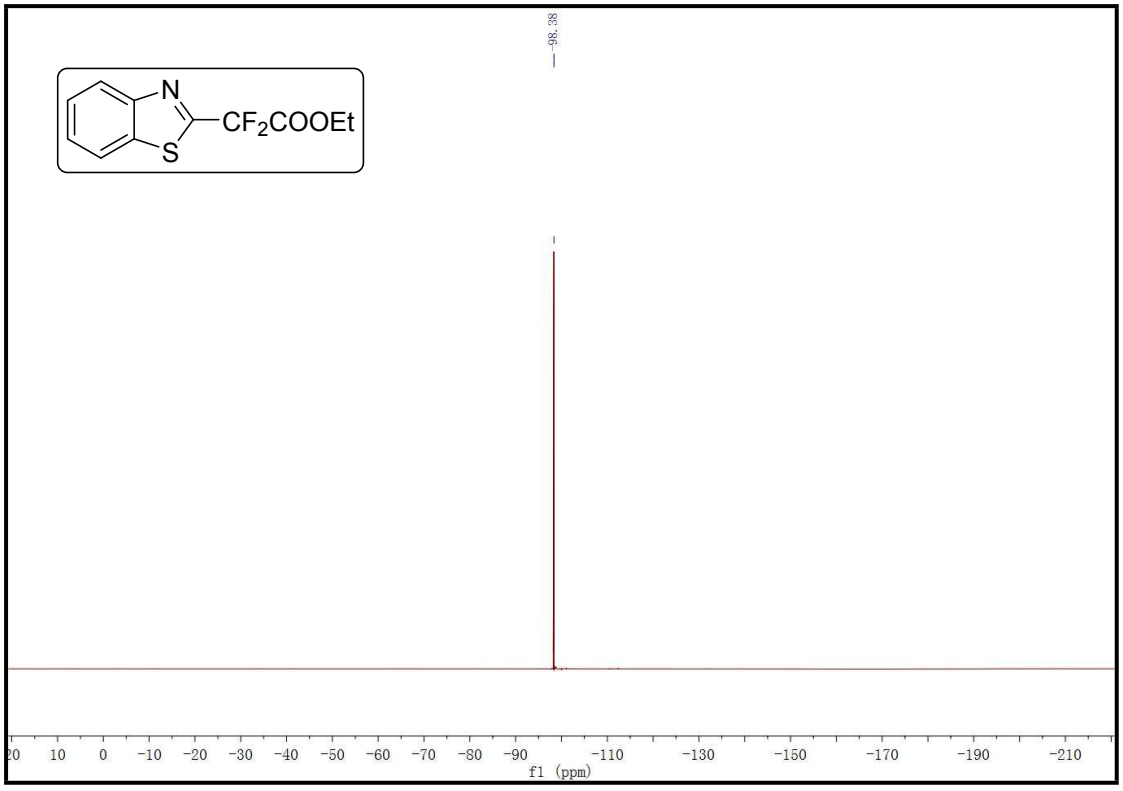

163.19
162.92
162.83
162.65
162.58
162.33
146.19
145.95
145.72
135.14
131.49
130.05
127.99
126.38
125.65
122.66
122.42
122.17
118.79
118.74
118.69
116.87
116.81
116.75
115.09
113.07
113.02
111.05
109.08
107.37
107.35
107.32
64.03
63.44
14.01
13.78
EtOOCF2C
N
N
CF2COOEt
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-92.72
-105.14
EtOOCF2C
N
N
CF2COOEt
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)

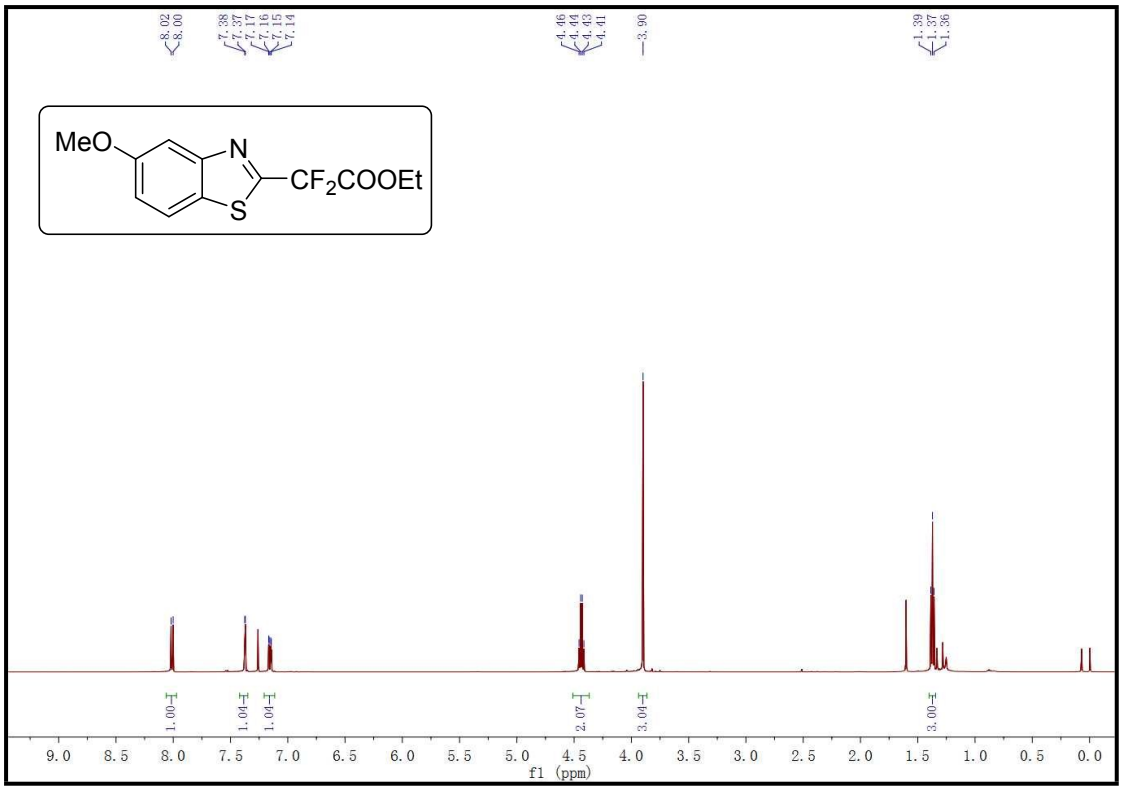
ethyl 2-(benzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5a)

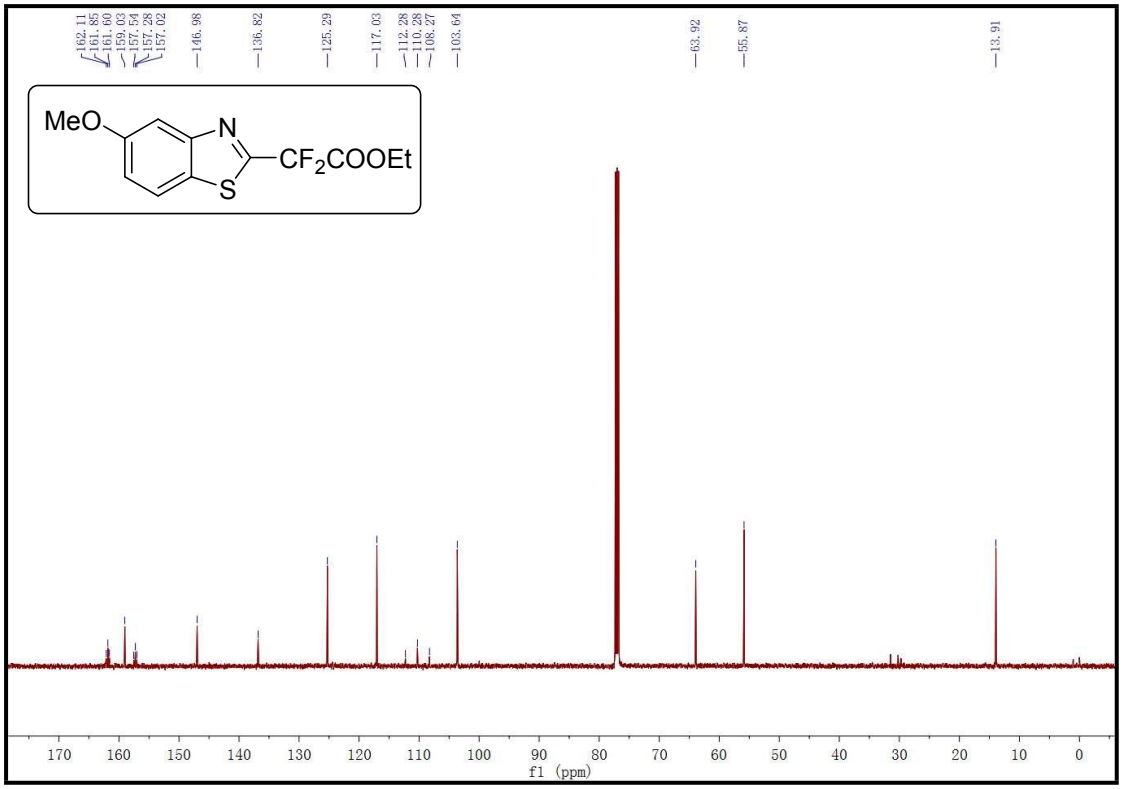


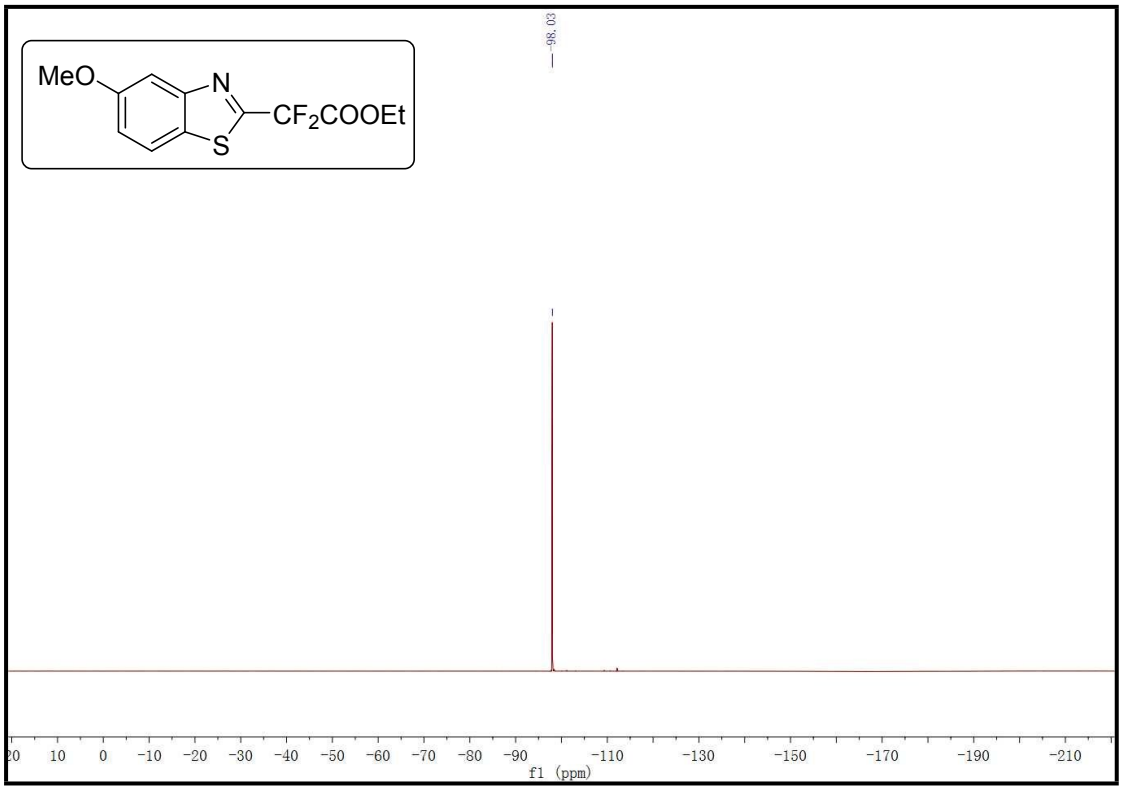




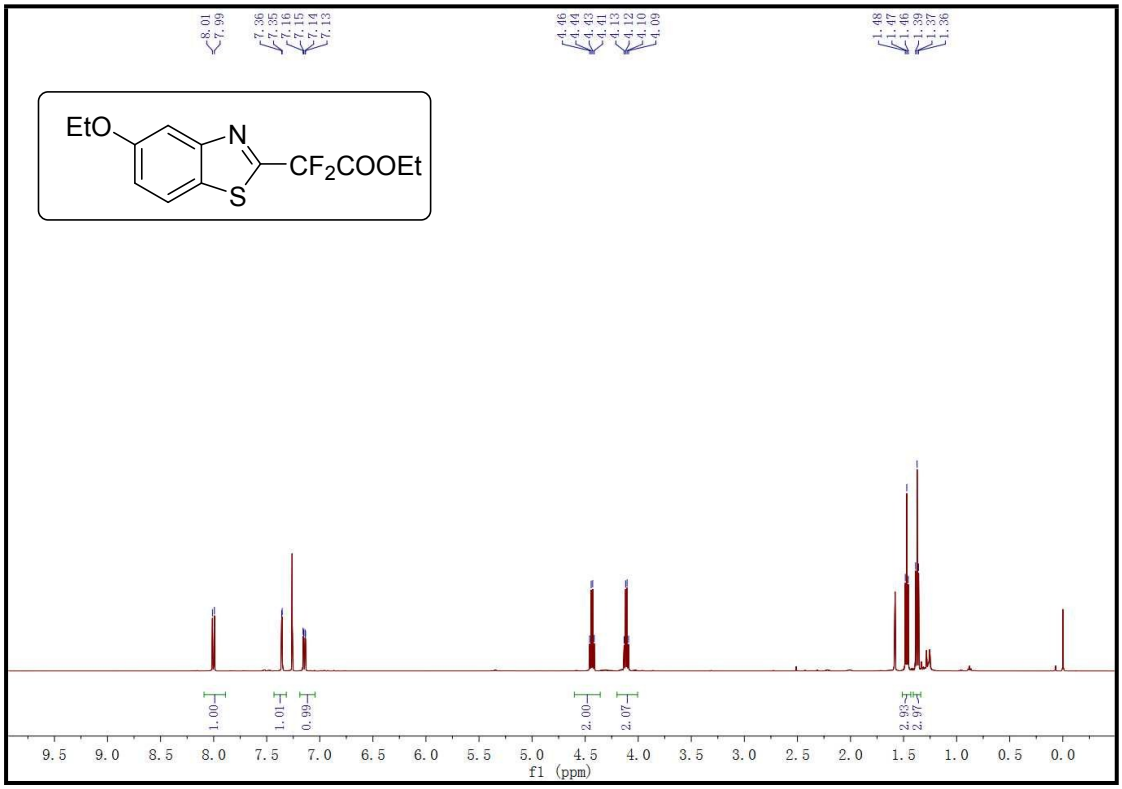
ethyl 2,2-difluoro-2-(5-methoxybenzo[*d*]thiazol-2-yl)acetate (5b)

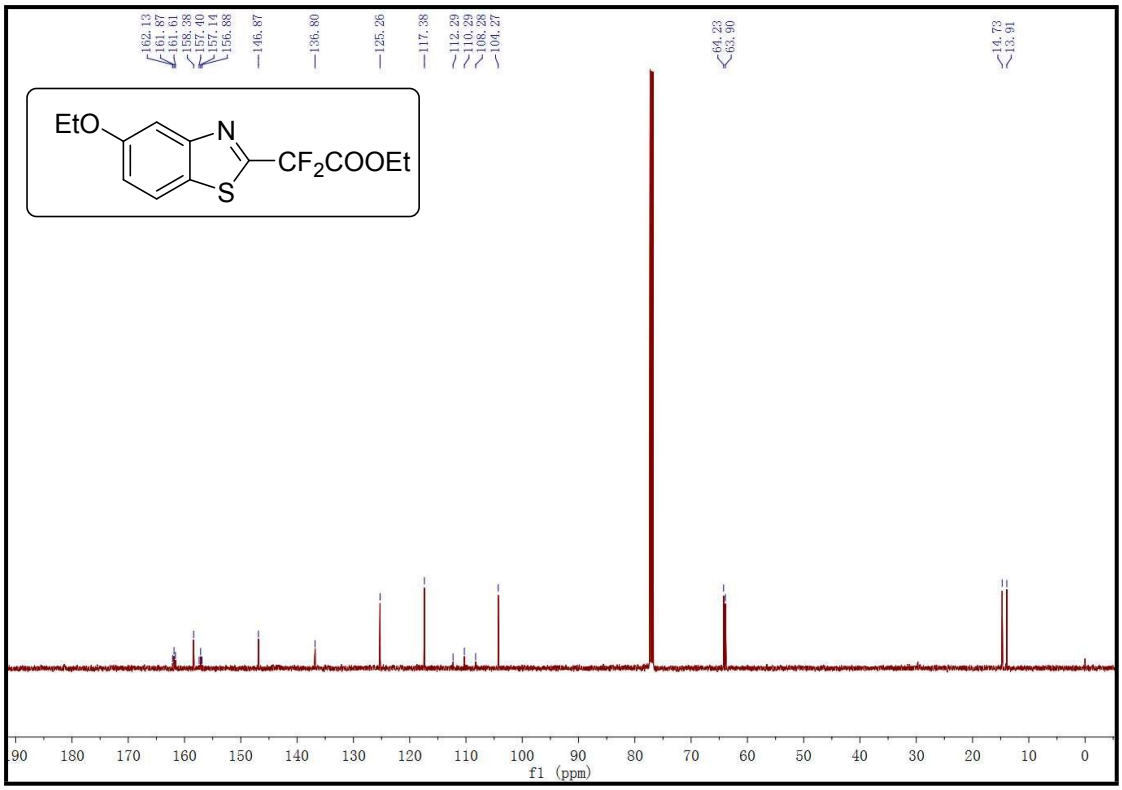


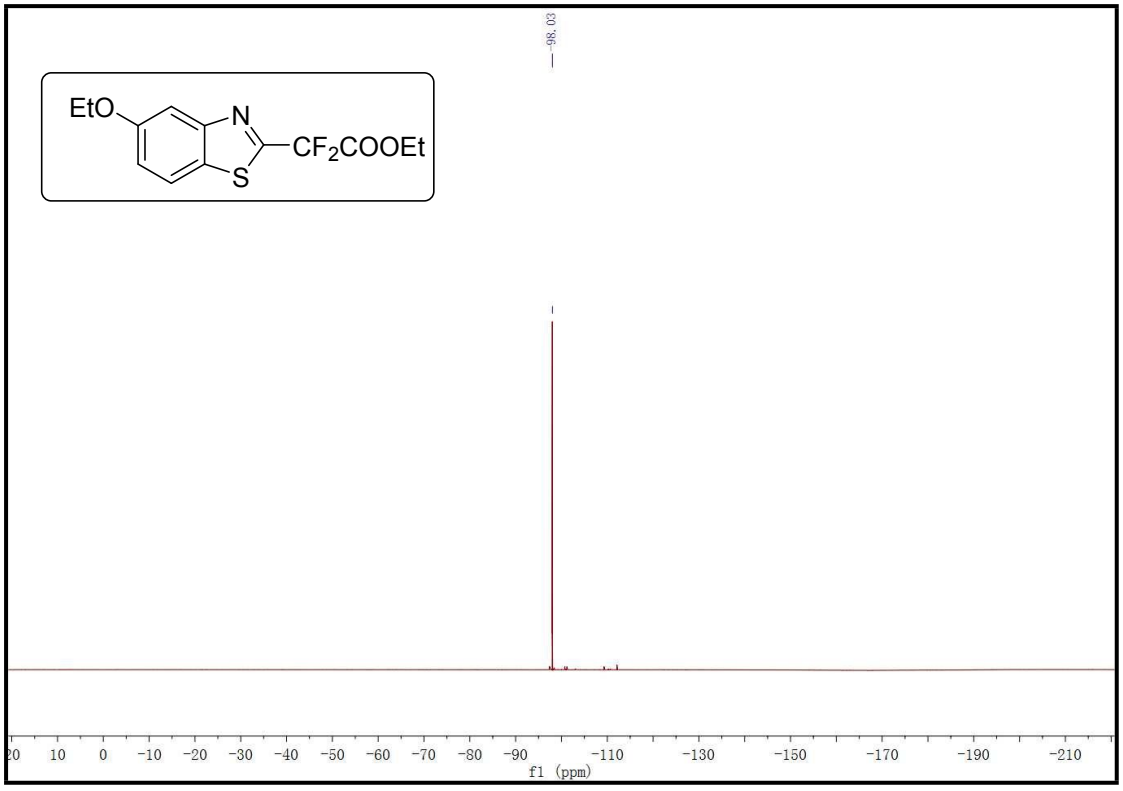

162.11
161.85
161.60
159.03
157.54
157.28
157.02
146.98
136.82
125.29
117.03
112.28
110.28
108.27
103.64
63.92
55.87
13.91
MeO
N
S
CF2COOEt
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


-98.03
MeO
N
S
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

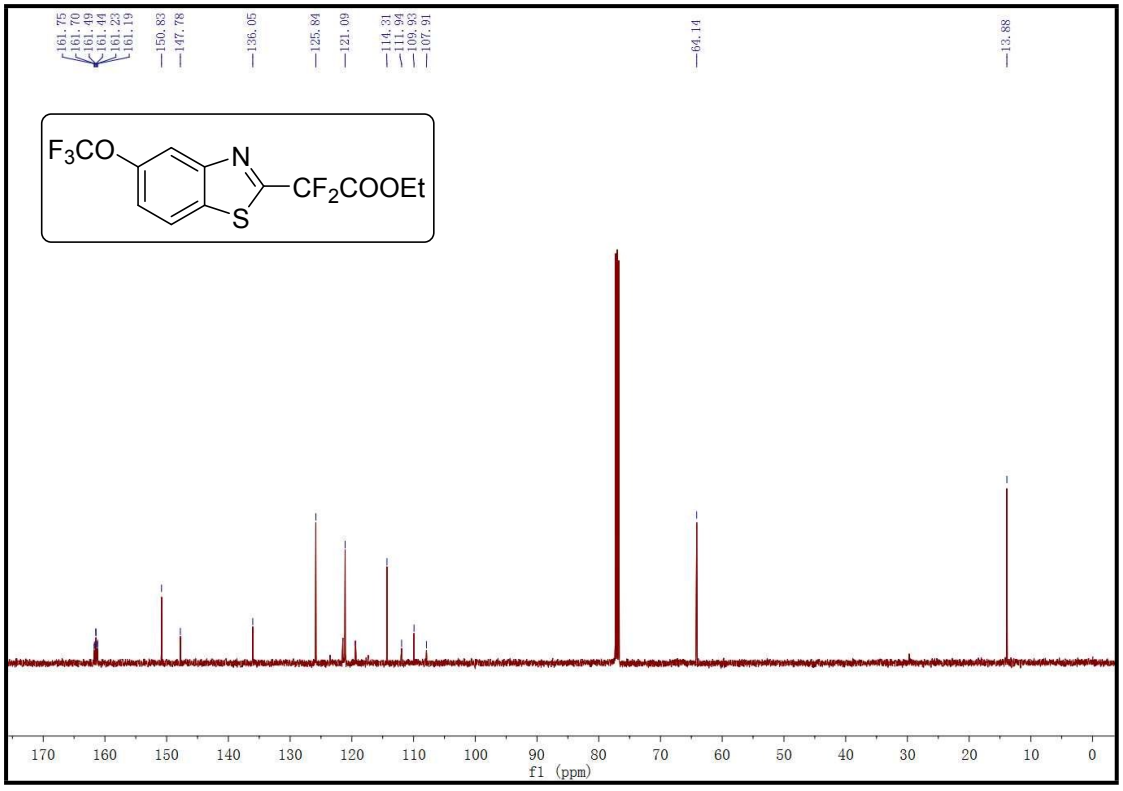
ethyl 2-(5-ethoxybenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5c)

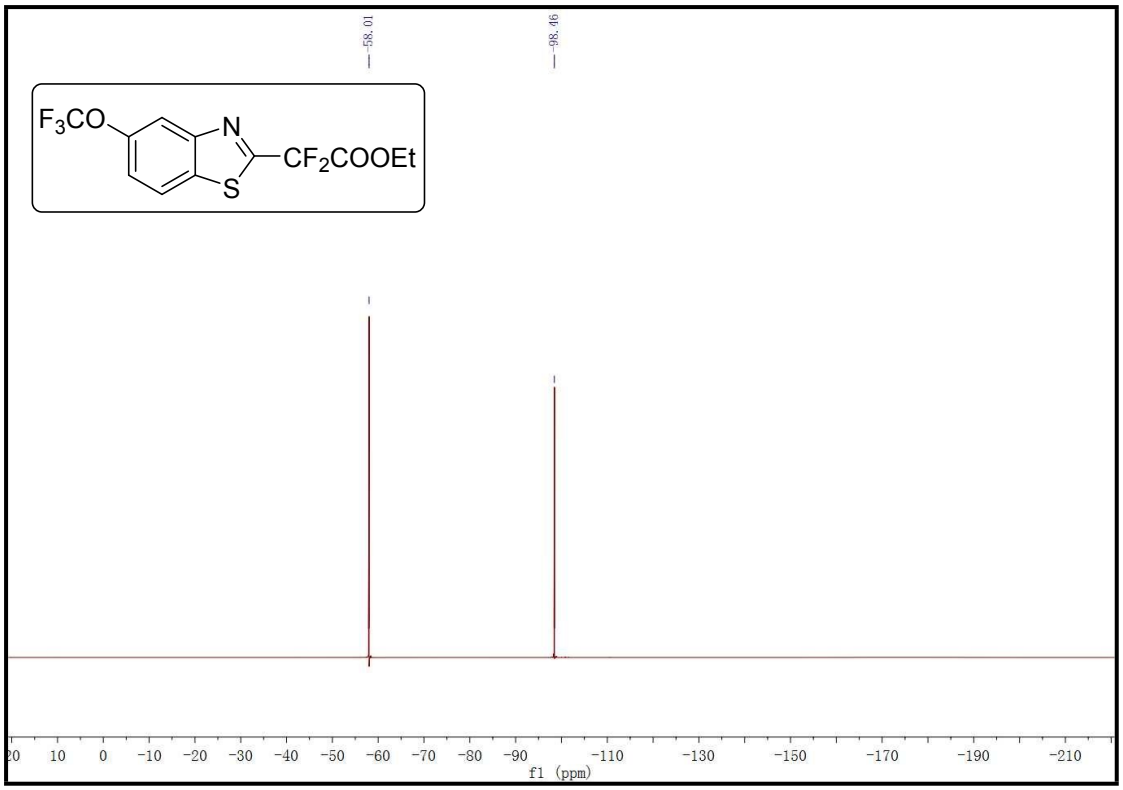




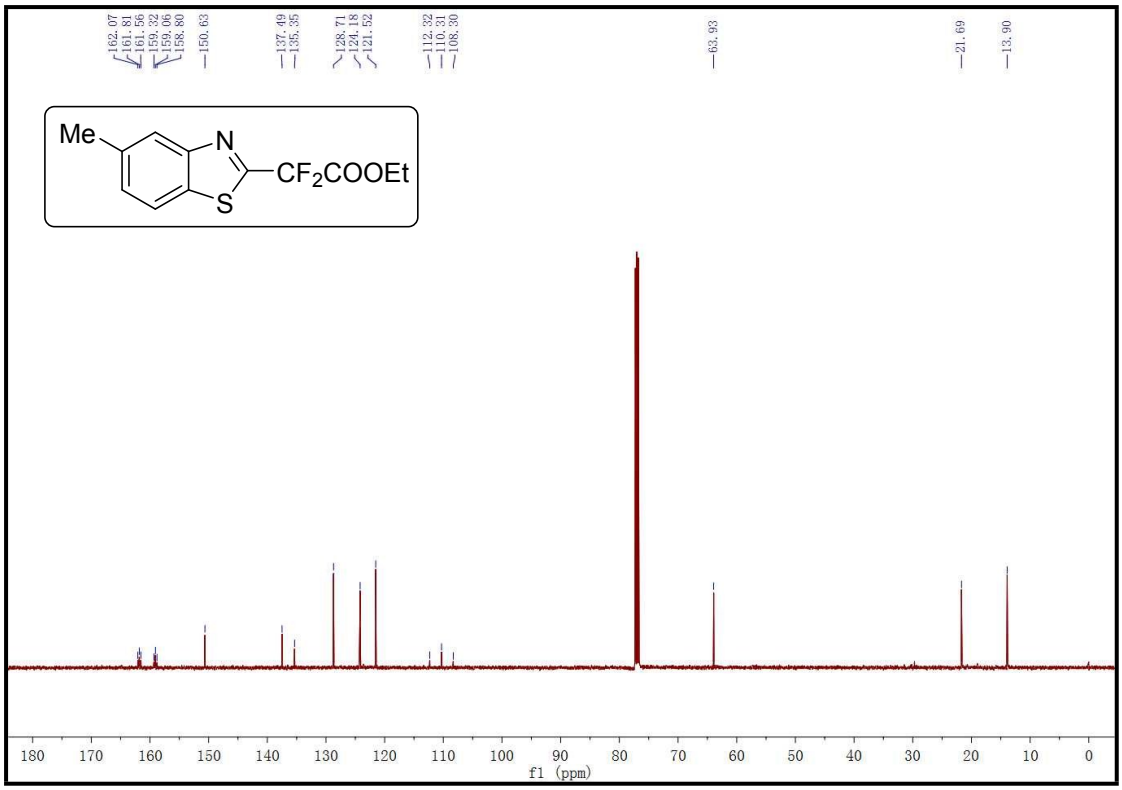


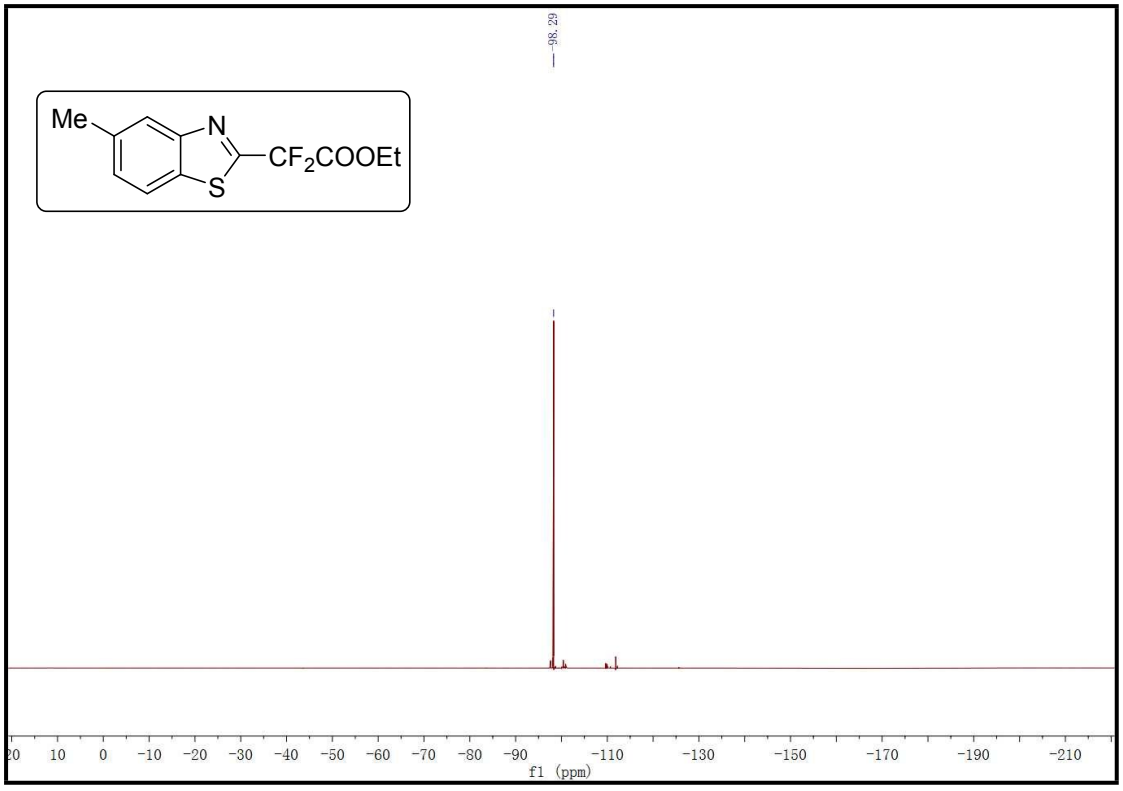
ethyl 2,2-difluoro-2-(5-(trifluoromethoxy)benzo[*d*]thiazol-2-yl)acetate (5d)


161.75
161.70
161.49
161.44
161.23
161.19
150.83
147.78
136.05
125.84
121.09
114.31
111.94
109.93
107.91
64.14
13.88
F3CO
N
S
CF2COOEt
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

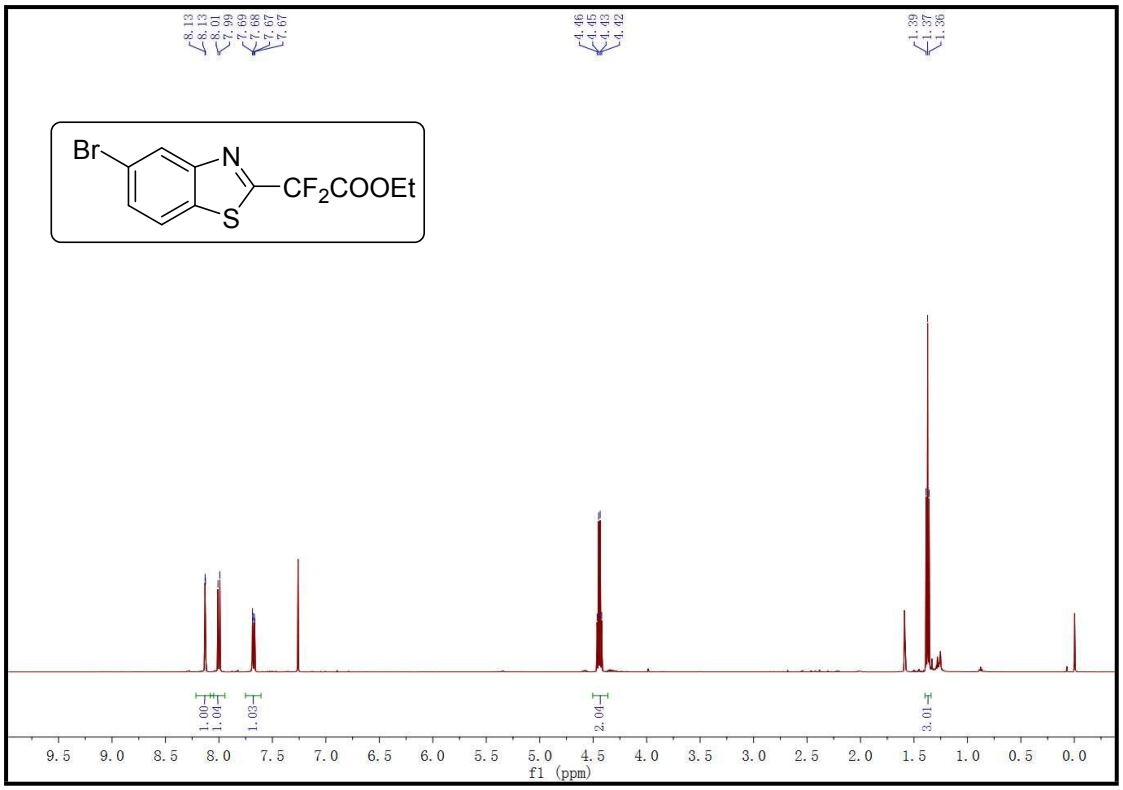

-58.01
-98.46
F3CO
N
S
CF2COOEt
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

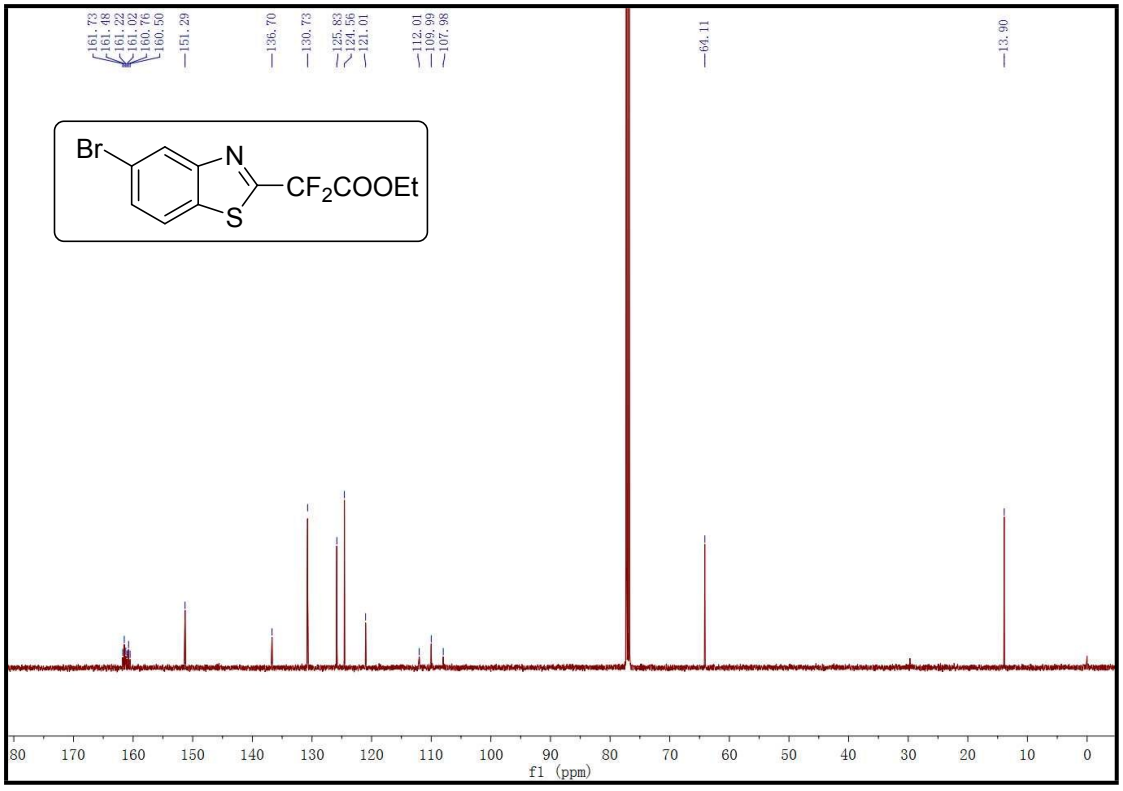
ethyl 2,2-difluoro-2-(5-methylbenzo[*d*]thiazol-2-yl)acetate (5e)

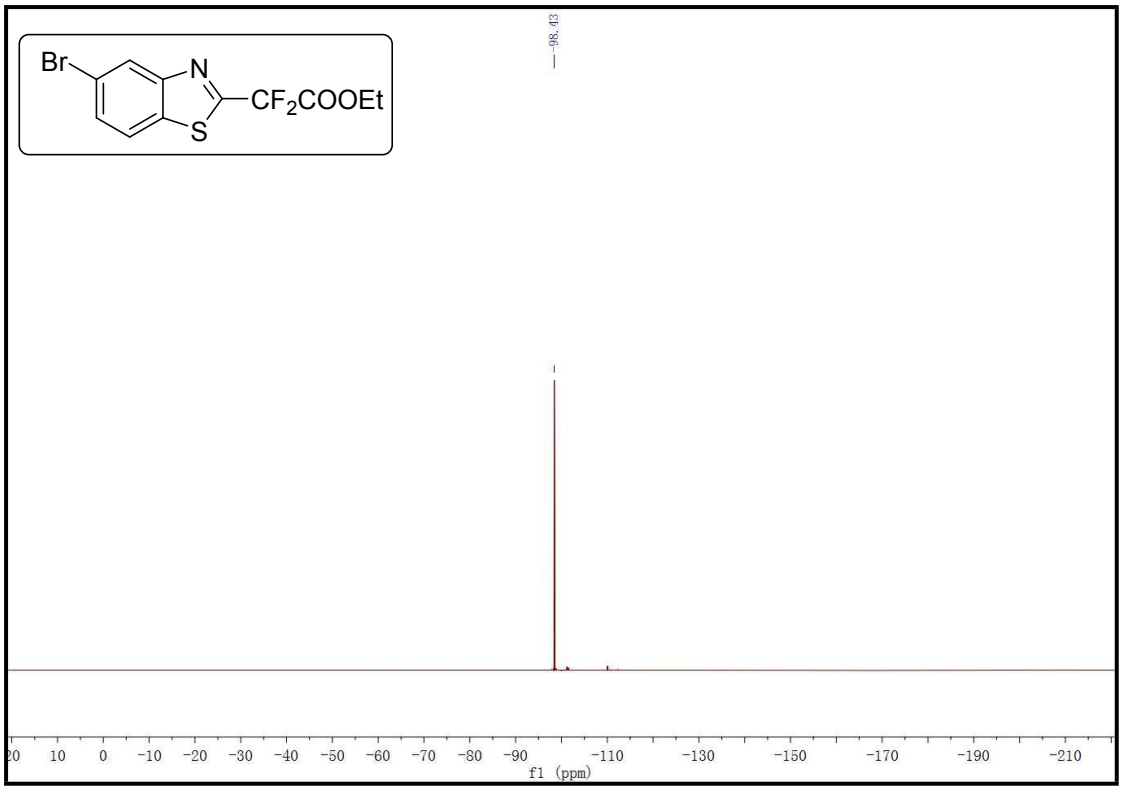




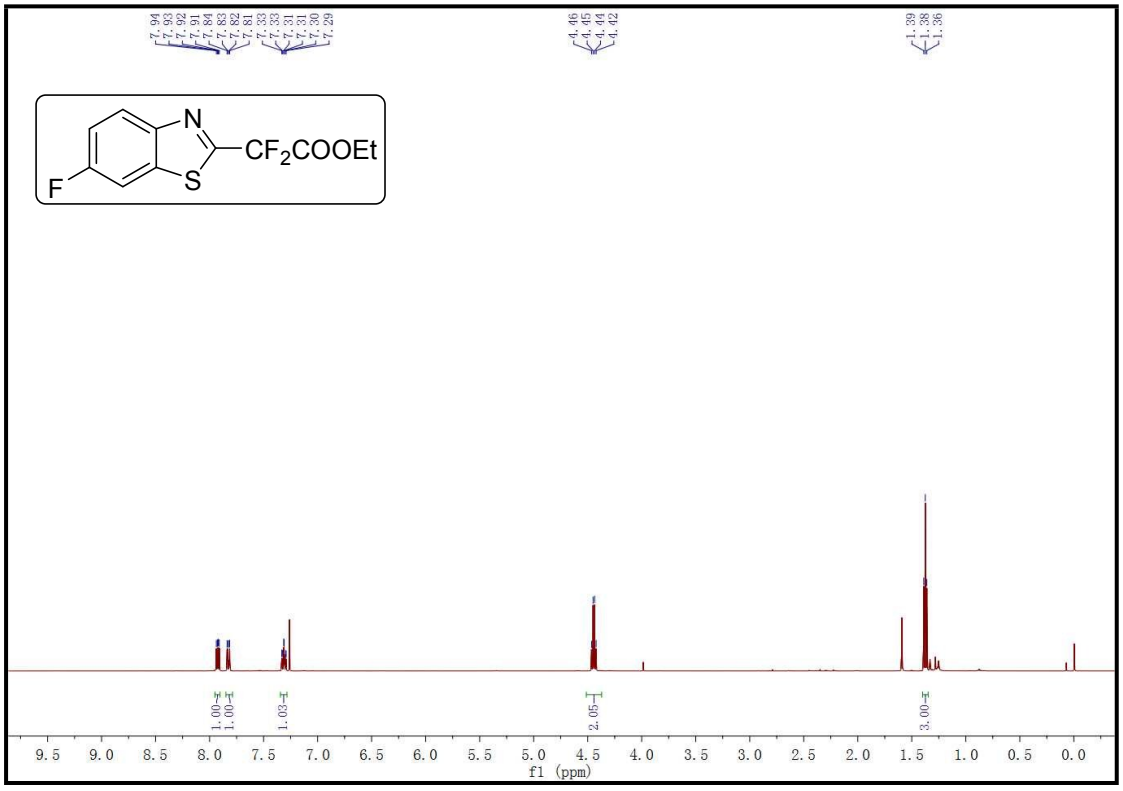
ethyl 2-(5-bromobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5f)

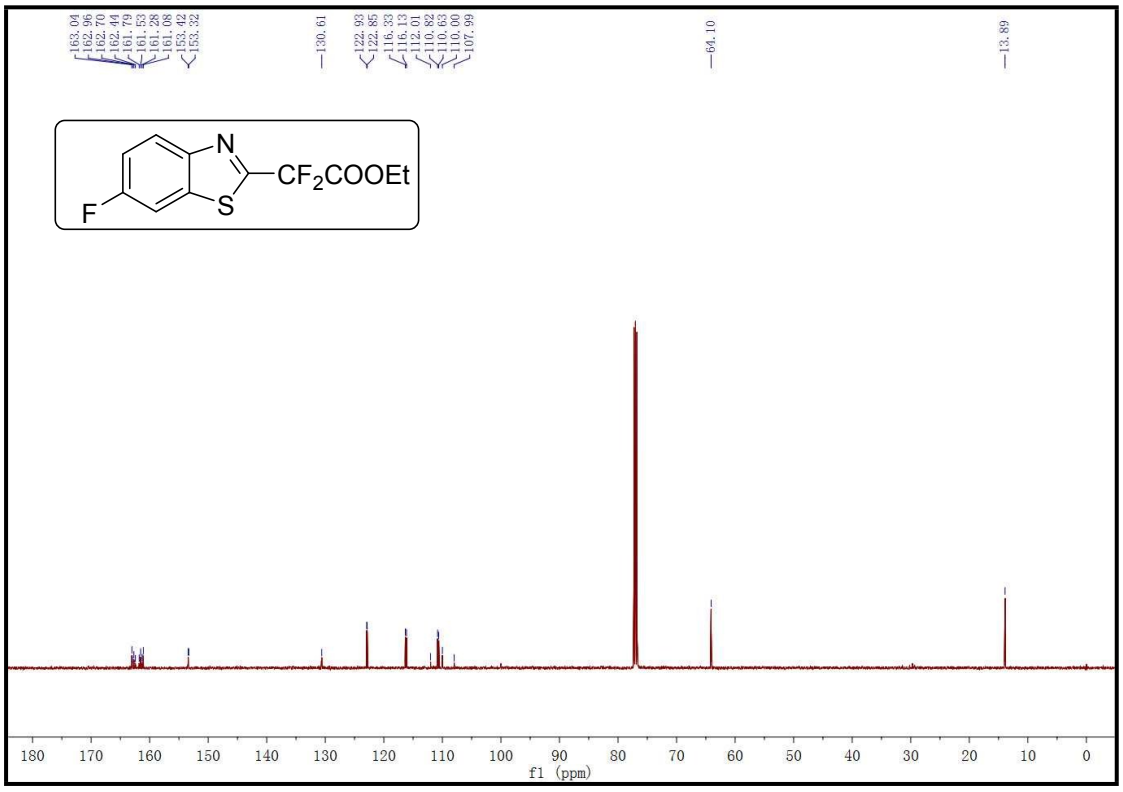


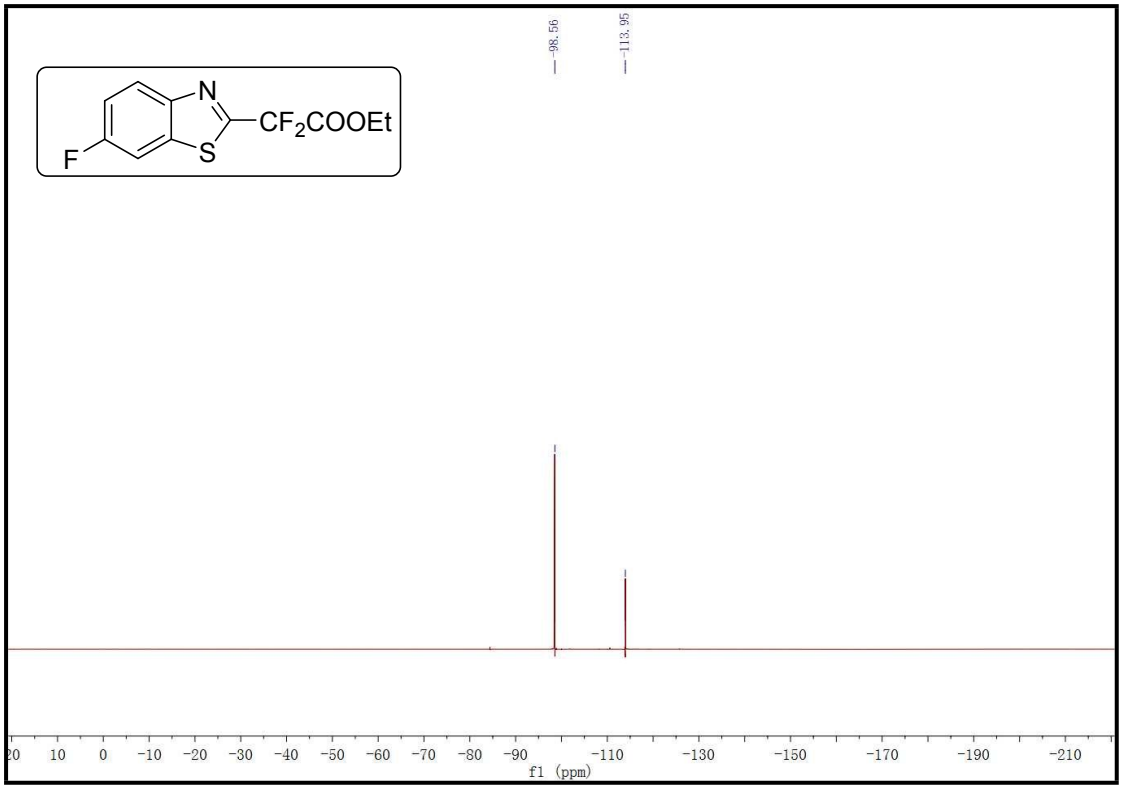

161.73
161.48
161.22
161.02
160.76
160.50
151.29
136.70
130.73
125.83
124.56
121.01
112.01
109.99
107.98
64.11
13.90
Br
N
S
CF2COOEt
f1 (ppm)


-98.43
Br
N
S
CF2COOEt
f1 (ppm)

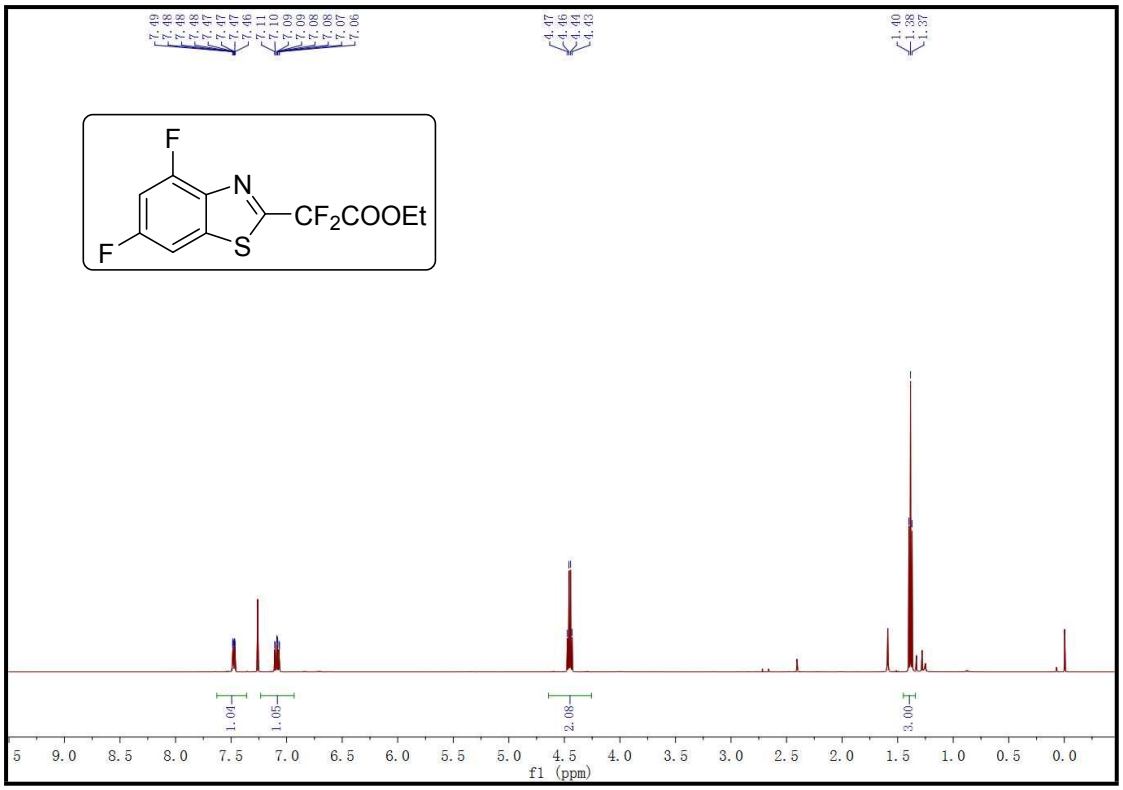
ethyl 2-(6-chlorobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5g)

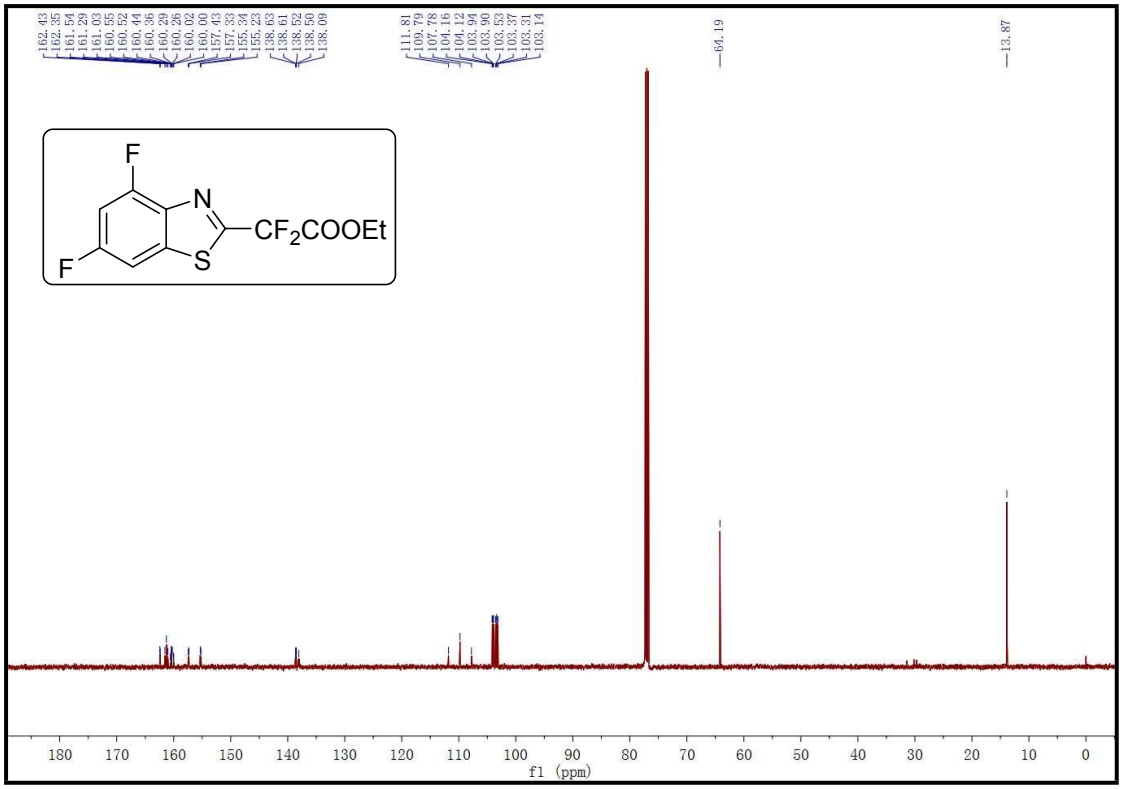


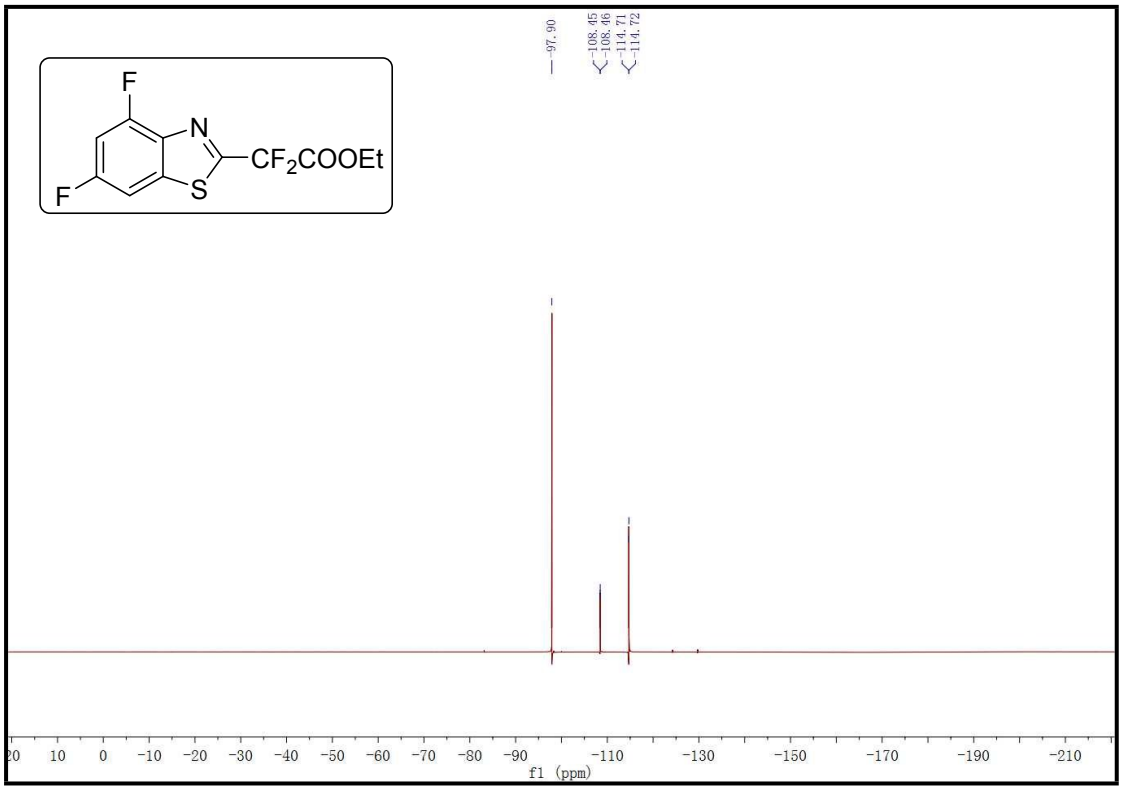




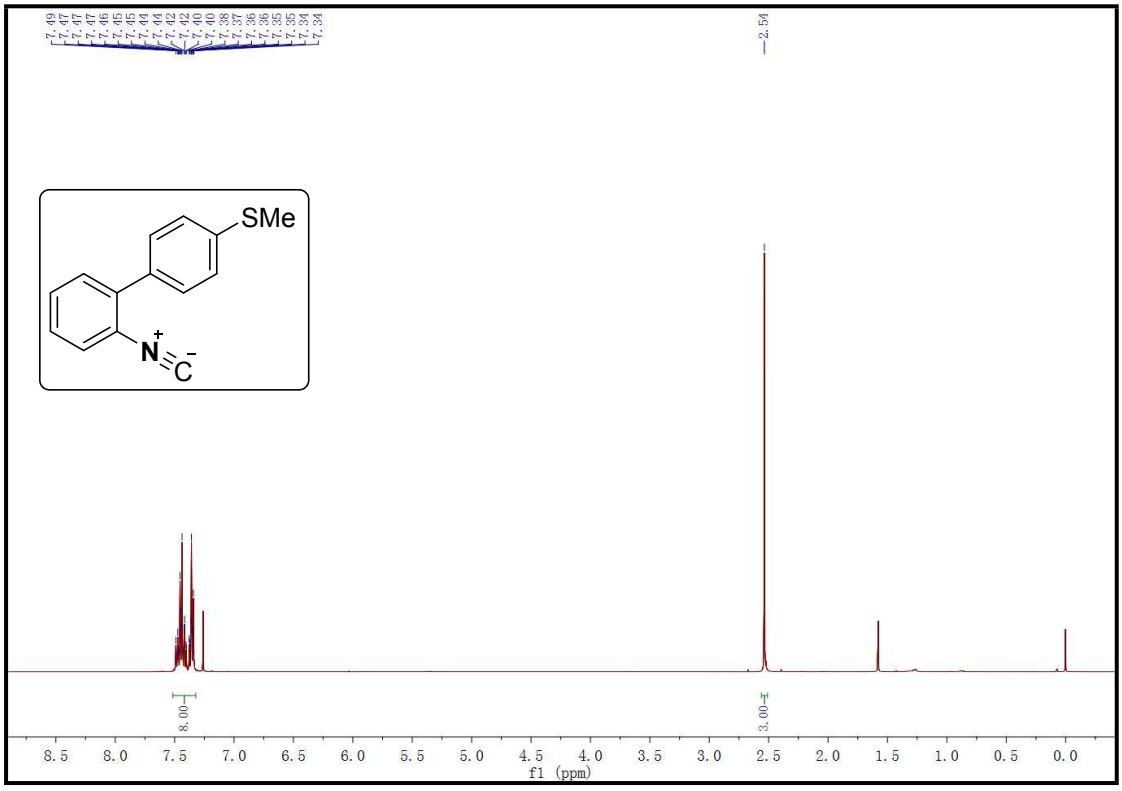
ethyl 2-(4,6-difluorobenzo[*d*]thiazol-2-yl)-2,2-difluoroacetate (5h)

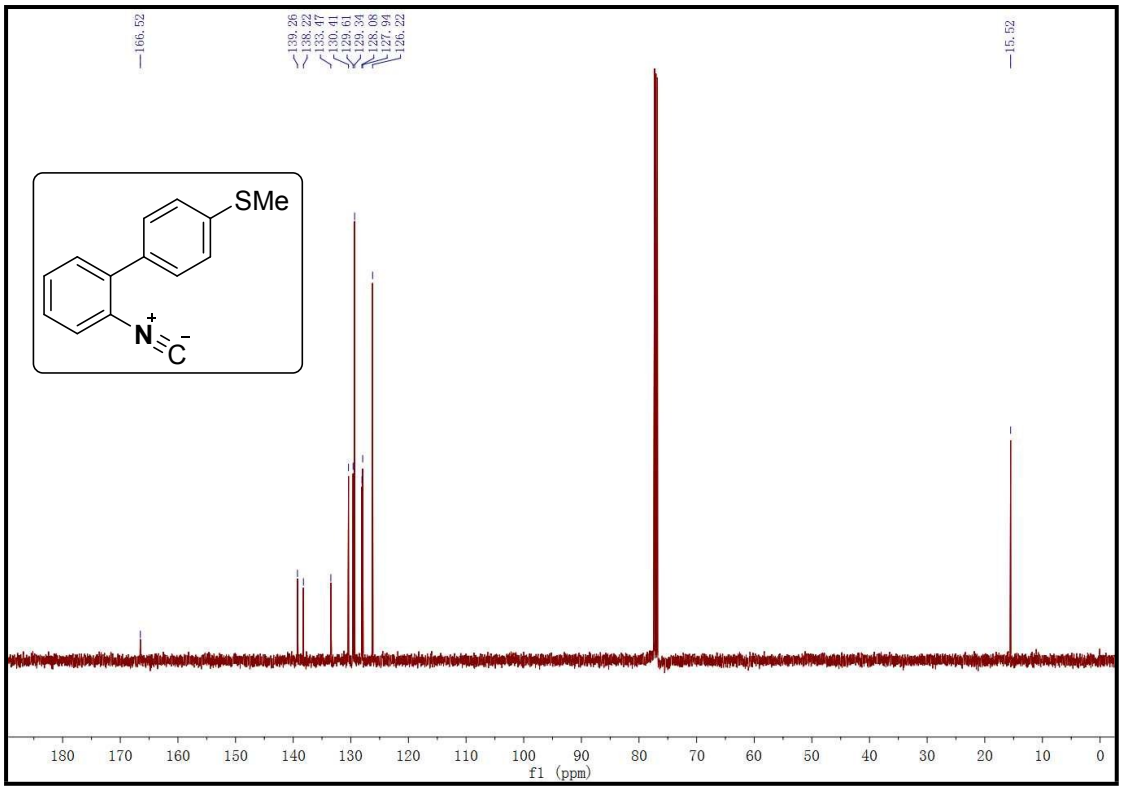



F
N
CF2COOEt
S
F
f1 (ppm)

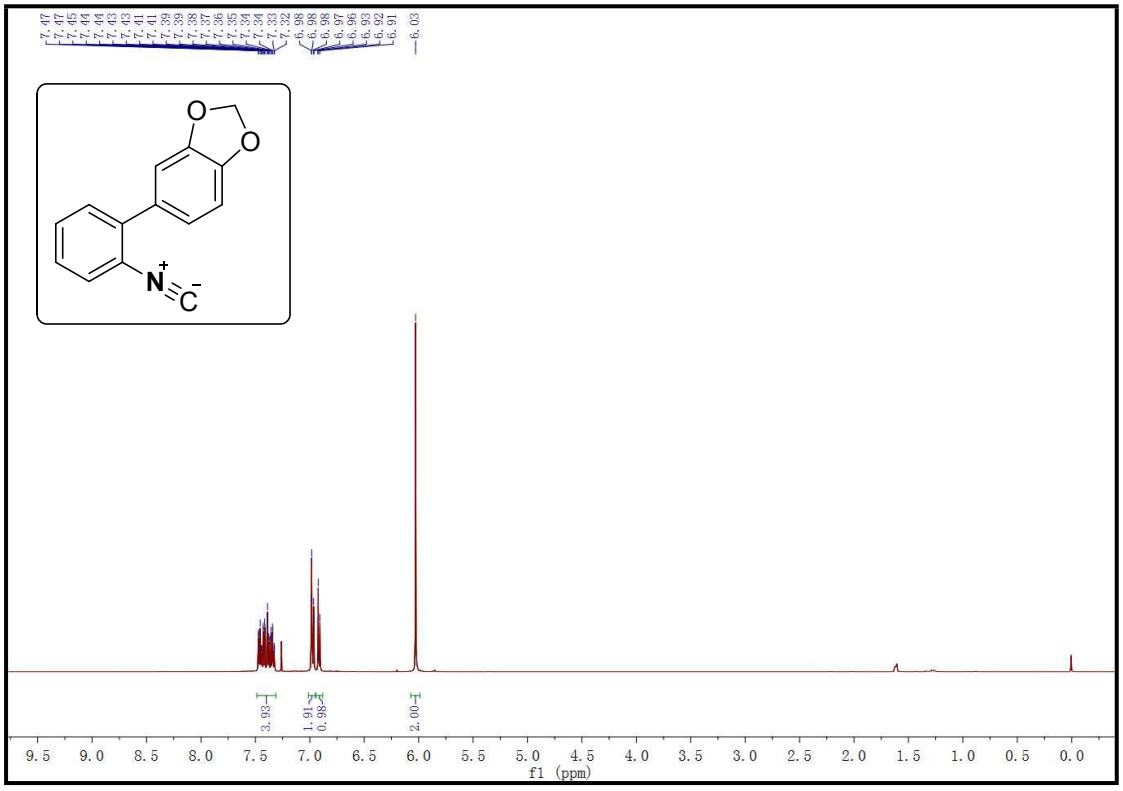

F
N
CF2COOEt
S
F
f1 (ppm)

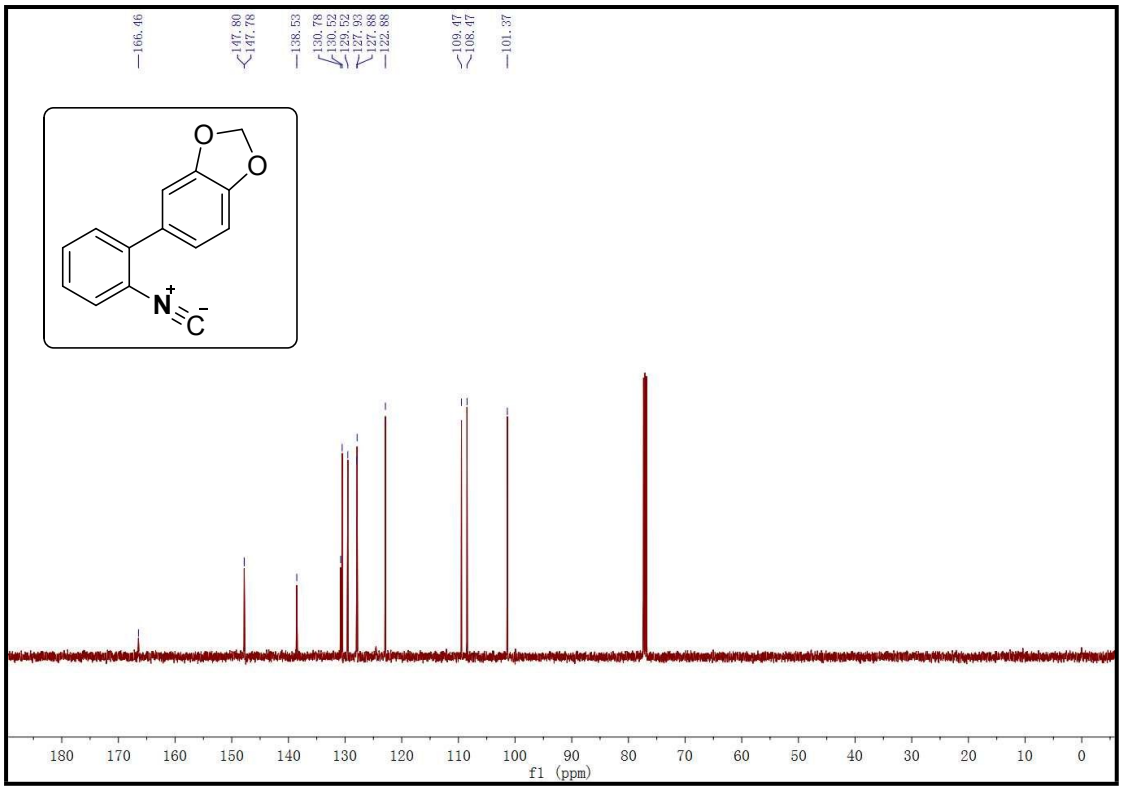
(2'-isocyano-[1,1'-biphenyl]-4-yl)(methyl)sulfane (8)



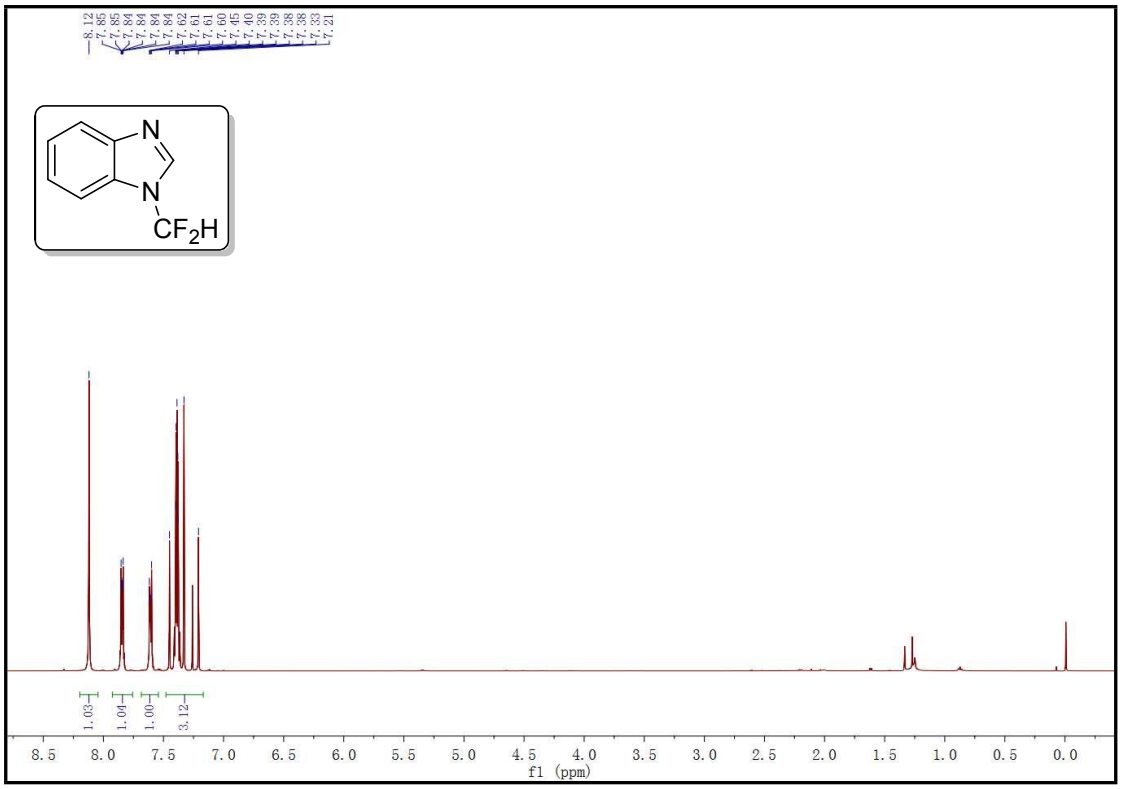


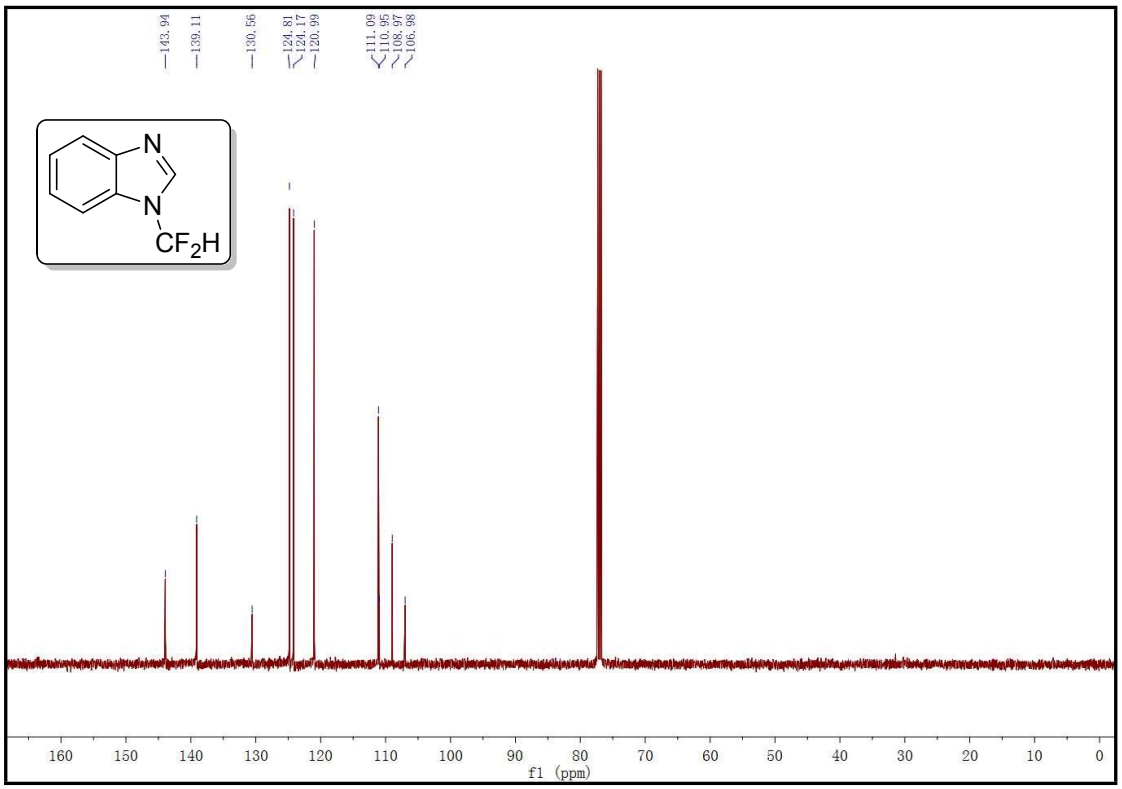
(2'-isocyano-[1,1'-biphenyl]-4-yl)(methyl)sulfane (11)

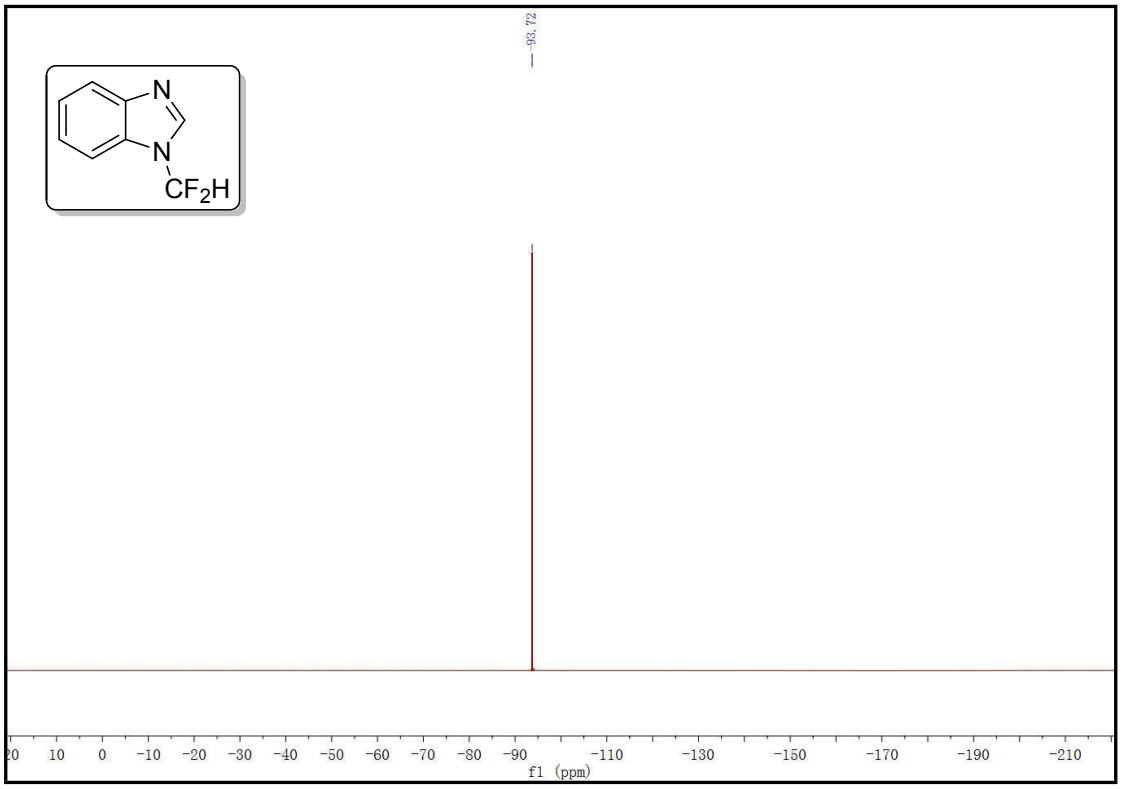




1-(difluoromethyl)-1*H*-benzo[*d*]imidazole (10)






-93.72
N
N
CF2H
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)