Supporting Information

Base-controlled Selective Cleavage of C-F Bonds of Difluorocarbene for the Divergent Assembly of Indolizines

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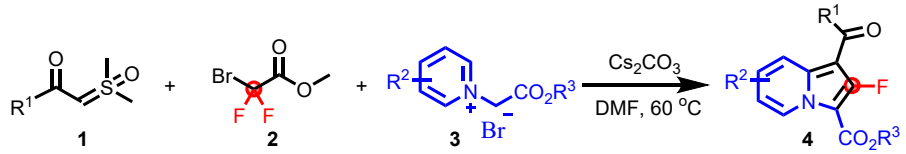
Table of Contents **page**

1.General information

All substrates and reagents were commercially available and used without further purification. TLC analysis was performed using pre-coated glass plates. Column chromatography was performed using silica gel (200–300 mesh). ^{1}H spectra were recorded in $CDCl_3$ on 600/400 MHz NMR spectrometers and resonances (δ) are given in parts per million relative to tetramethylsilane. Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet), coupling constants (Hz) and integration. ^{13}C spectra were recorded in $CDCl_3$ on 150/100 MHz NMR spectrometers and resonances (δ) are given in ppm. HRMS were obtained on a Bruker 7-tesla FT-ICR MS equipped with an electrospray source. The X-ray crystal-structure determinations were obtained on a Bruker SMART APEX CCD system. Sulfoxonium ylides **1** and pyridinium salt **3** were known compounds, and prepared according to the reported procedures.[1] $BrCF_2COOMe$ was commercially available and used without further purification.

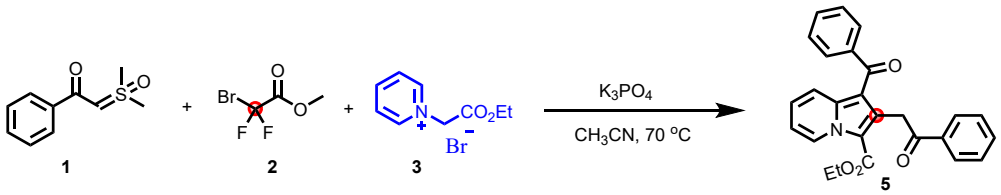
2.General procedure for the synthesis of 4



A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1** (1 mmol), $BrCF_2COOMe$ (1.5 mmol), **3** (1.5 mmol), Cs_2CO_3 (2 mmol) in DMF (10 mL). The mixture was stirred at 60 °C for 5 hours. After cooling to room temperature, the mixture was quenched with water (100 mL), extracted with EtOAc (3 × 150 mL), the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (eluent: PE/EtOAc) to afford the products.

3. Optimization of the reaction conditions for the synthesis of 5

Table S1. Screening the reaction conditions of :**CF_2** as C source

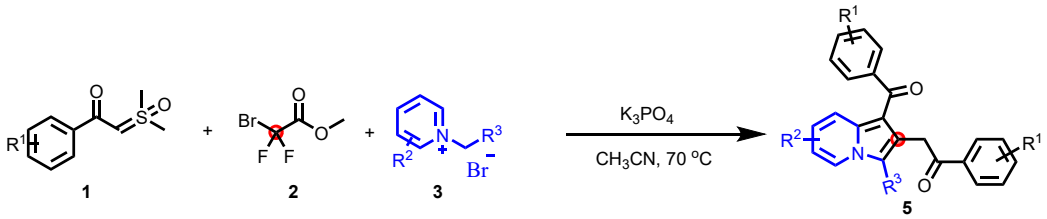


Entry	variation from the standard conditions [a]	Yield (%) [b]
1	none	61
2	$BrCF_2CO_2Et$	47
3	$ClCF_2CO_2Et$	<10
4	THF	<10
5	DMSO	trace
6	DMC	52
7	DMF	43
8	K_2CO_3	55
9	Na_2CO_3	<10

10	Cs_2CO_3	N.D.
11	Et_3N	trace

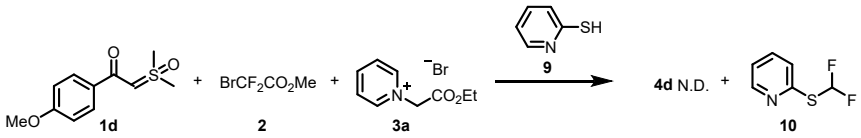
[a]Standard conditions: reactions were carried out with **1** (2 equiv.), **2** (1 equiv.) **3** (1 equiv.) and K_3PO_4 (2 equiv.) in CH_3CN (0.1 M) at 70 ℃ for 5 h. [b]Isolated yields.

4.General procedure for the synthesis of 5



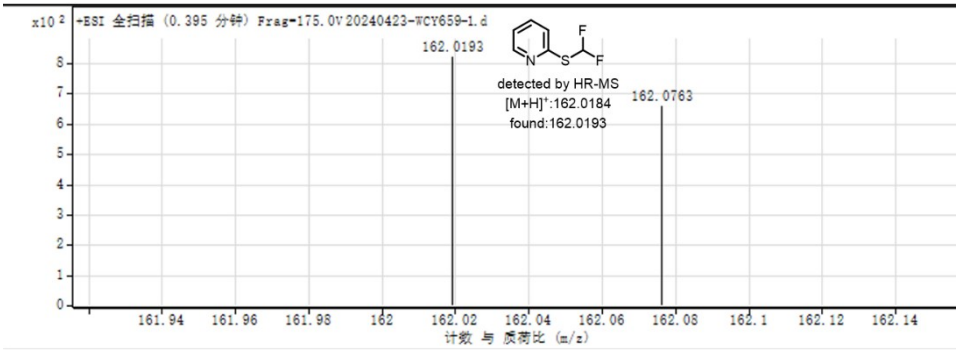
A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1** (2 mmol), $BrCF_2COOMe$ (1 mmol), **3** (1 mmol), K_3PO_4 (2 mmol) in CH_3CN (10 mL). The mixture was stirred at 70 °C for 5 hours. After cooling to room temperature, the mixture was quenched with water (100 mL), extracted with EtOAc (3 × 150 mL), the combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (eluent: PE/EtOAc) to afford the products.

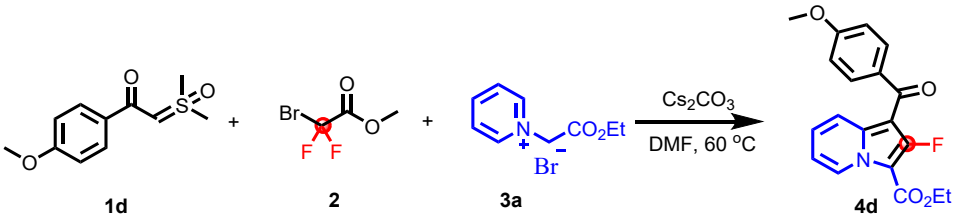
5. Mechanistic study



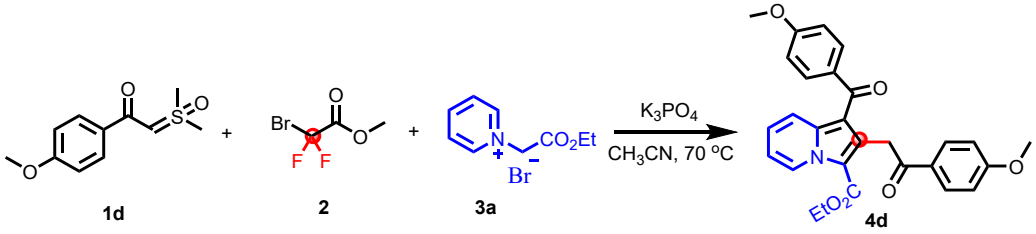
A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1d** (1 mmol), $BrCF_2COOMe$ (1.5 mmol), **3** (1.5 mmol), Cs_2CO_3 (2 mmol), **9** (3 equiv.), in DMF (10 mL). The mixture was stirred at 60 °C for 20 mins. The mixture was stirred at 60 °C for 5 h. After cooling to room temperature, Then, the 0.5 mL of the reaction solution was diluted with 1.5 mL of EtOAc. The samples were immediately monitored by HPLC-MS.

A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1** (2 mmol), $BrCF_2COOMe$ (1 mmol), **3** (1 mmol), K_3PO_4(2 mmol), **9** (3 equiv.), in CH_3CN (10 mL). After cooling to room temperature, Then, the 0.5 mL of the reaction solution was diluted with 1.5 mL of EtOAc. The samples were immediately monitored by HPLC-MS.



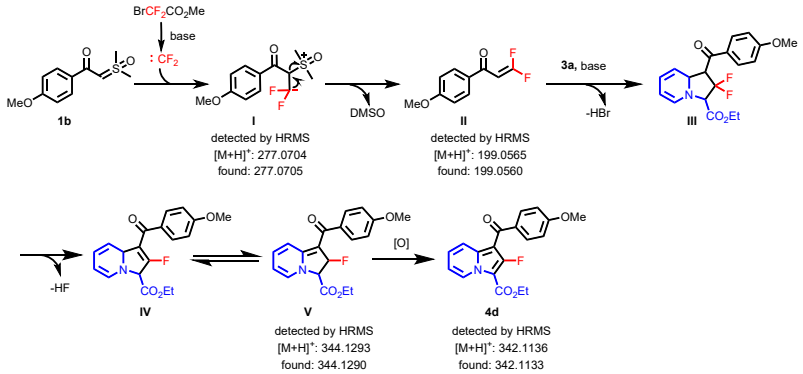


A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1d** (1 mmol), $BrCF_2COOMe$ (1.5 mmol), **3a** (1.5 mmol), Cs_2CO_3 (2 mmol) in DMF (10 mL). The mixture was stirred at 60 °C for 20 mins. After cooling to room temperature, Then, the 0.5 mL of the reaction solution was diluted with 1.5 mL of EtOAc. The samples were immediately monitored by HPLC-MS.

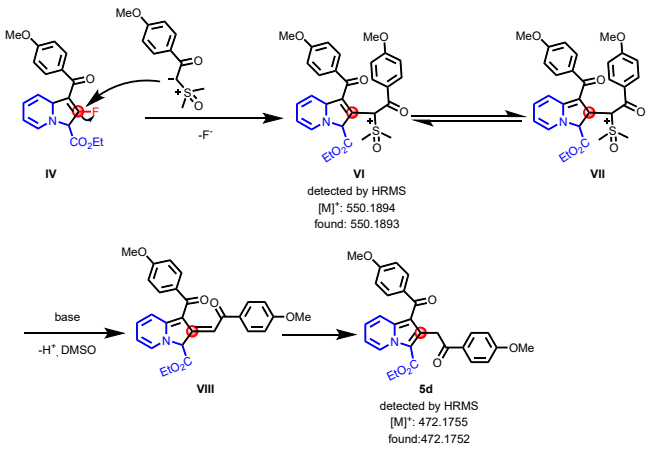


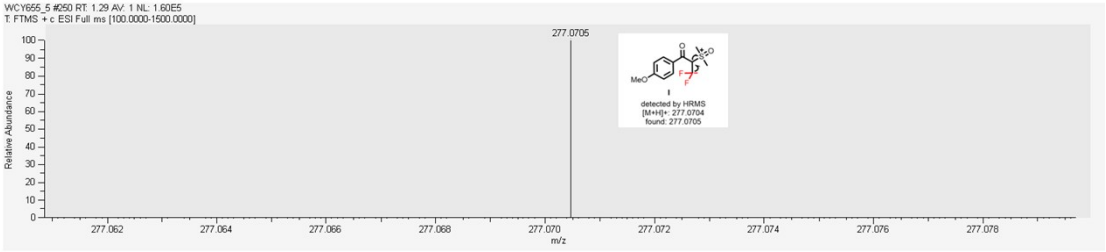
A 35 mL sealed tube equipped with a magnetic stir bar was charged with the mixture of **1d** (2 mmol), $BrCF_2COOMe$ (1 mmol), **3a** (1 mmol), K_3PO_4 (2 mmol) in CH_3CN (10 mL). The mixture was stirred at 70 °C for 20 mins. After cooling to room temperature, Then, the 0.5 mL of the reaction solution was diluted with 1.5 mL of EtOAc. The samples were immediately monitored by HPLC-MS.

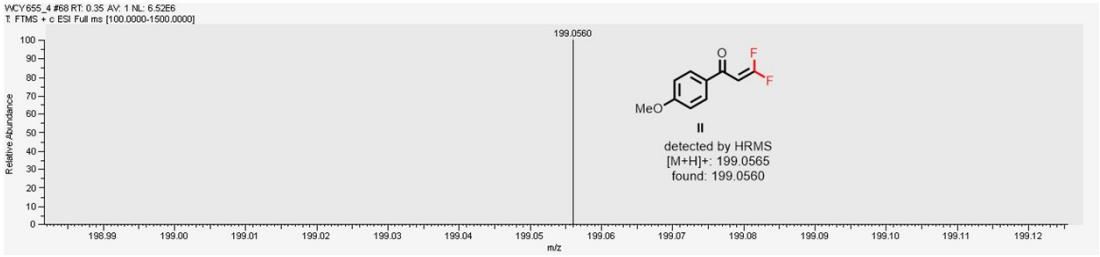
The possible process for the CF source reaction

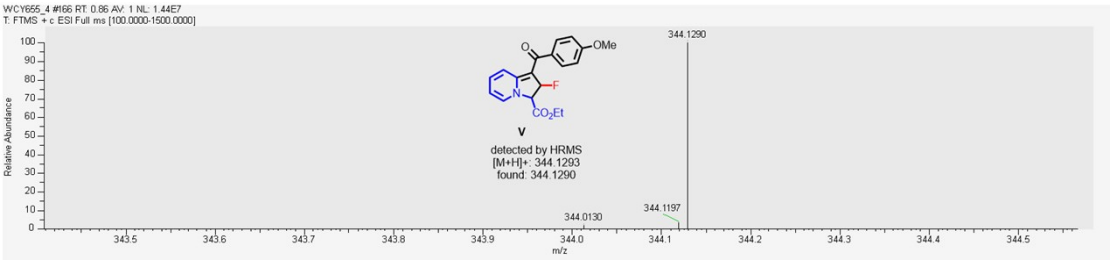


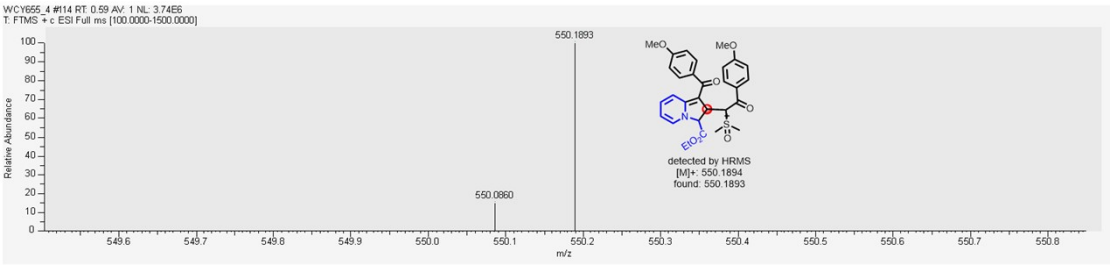
The possible process for the C source reaction



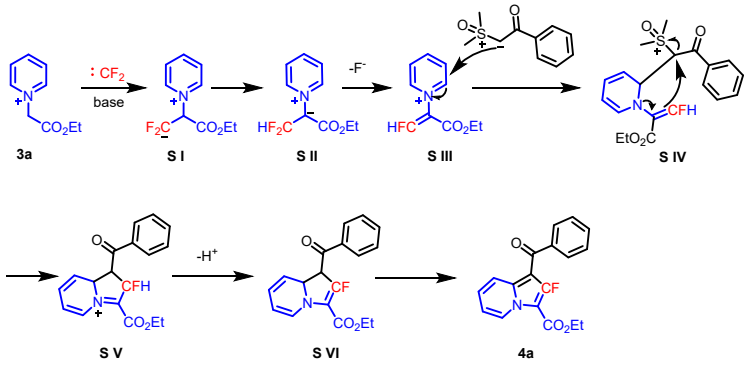




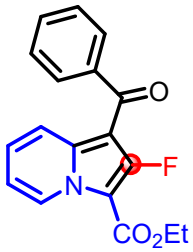




Another pathway

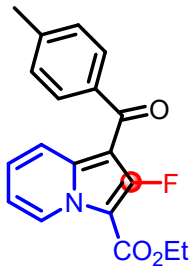


6. Characterization data for compounds



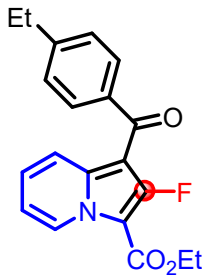
ethyl 1-benzoyl-2-fluoroindolizine-3-carboxylate (4a):

Yield 60%; 37.2 mg; yellow soild; mp 117-119 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, J = 6.8 Hz, 1H), 8.44 (d, J = 8.8 Hz, 1H), 7.82 (d, J = 6.8 Hz, 2H), 7.4-7.6 (m, 4H), 7.10 (t, J = 6.8 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.67(d, J = 4.0 Hz, J_{CF}), 160.6(d, J = 5.0 Hz, J_{CF}), 156.7(d, J = 270.0 Hz, J_{CF}), 139.9, 136.5, 131.9, 128.69(d, J = 2.0 Hz, J_{CF}), 128.1, 127.93, 127.87, 119.6(d, J = 4.0 Hz, J_{CF}), 115.6, 101.7(d, J = 21.0 Hz, J_{CF}), 101.1(d, J = 10.0 Hz, J_{CF}), 60.5, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.31. HRMS (ESI) m/z calcd for $C_{18}H_{14}FNO_3Na^+$ $(M+Na)^+$ 334.08499, found 334.08472.



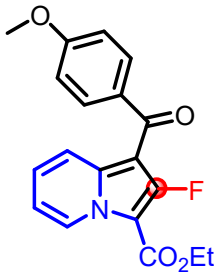
ethyl 2-fluoro-1-(4-methylbenzoyl)indolizine-3-carboxylate (4b):

Yield 61%; 39.6 mg; yellow soild; mp 78-80 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.56 (d, J = 7.2 Hz, 1H), 8.40 (d, J = 8.8 Hz, 1H), 7.74 (dd, J = 8.0, 2.8 Hz, 2H), 7.48–7.39 (m, 1H), 7.34–7.19 (m, 3H), 7.0-7.1 (m, 1H), 4.41 (q, J = 7.2 Hz, 2H), 2.44 (s, 3H), 1.39 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.3(d, J = 3.0 Hz, J_{CF}), 160.60(d, J = 4.0 Hz, J_{CF}), 156.5(d, J = 269.0 Hz, J_{CF}), 142.7, 137.1, 136.4(d, J = 5.0 Hz, J_{CF}), 129. (d, J = 2.0 Hz, J_{CF}), 128.8, 127.8, 127.7, 119.56(d, J = 4.0 Hz, J_{CF}), 115.4, 101.6(d, J = 19.0 Hz, J_{CF}), 101.25(d, J = 10.0 Hz, J_{CF}), 60.5, 21.6, 14.4.^{19}F NMR (376 MHz, $CDCl_3$) δ -129.53. HRMS (ESI) m/z calcd for $C_{19}H_{16}FNO_3Na^+$ $(M+Na)^+$ 348.10064, found 348.10068.



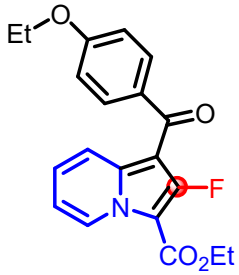
ethyl 1-(4-ethylbenzoyl)-2-fluoroindolizine-3-carboxylate (4c):

Yield 60%; 41 mg; yellow soild; mp 102-104 °C; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.56 (t, J = 8.4 Hz, 1H), 8.41 (t, J = 9.2 Hz, 1H), 7.78 (t, J = 7.6 Hz, 2H), 7.44 (dd, J = 16.4, 9.2 Hz, 1H), 7.32 (dd, J = 15.6, 7.2 Hz, 2H), 7.09 (dd, J = 16.0, 7.2 Hz, 1H), 4.52–4.33 (m, 2H), 2.89–2.65 (m, 2H), 1.43–1.37 (m, 3H), 1.33–1.26 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.4(d, J = 3.0 Hz, J_{CF}), 160.6(d, J = 4.0 Hz, J_{CF}), 156.5(d, J = 269.0 Hz, J_{CF}), 148.9, 137.3, 136.4, 129.1, 127.8, 127.6, 119.6, 115.4, 101.6(d, J = 22.0 Hz, J_{CF}), 101.15(d, J = 11.0 Hz, J_{CF}), 60.5, 28.9, 15.2, 14.4.^{19}F NMR (376 MHz, $CDCl_3$) δ -129.53. HRMS (ESI) m/z calcd for $C_{20}H_{19}FNO_3^+$ $(M+H)^+$ 340.1343, found 340.1336.



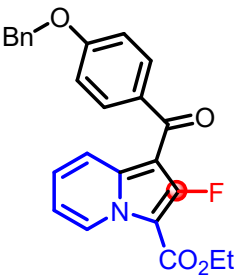
ethyl 2-fluoro-1-(4-methoxybenzoyl)indolizine-3-carboxylate (4d):

Yield 63%; 42.8 mg; white soild; mp 140-142 °C; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (d, J = 7.2 Hz, 1H), 8.35 (d, J = 8.8 Hz, 1H), 7.85 (dd, J = 8.8, 2.8 Hz, 2H), 7.48–7.36 (m, 1H), 7.07 (t, J = 6.8 Hz, 1H), 6.98 (d, J = 8.8 Hz, 2H), 4.41 (q, J = 7.2 Hz, 2H), 3.89 (s, 3H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.2(d, J = 3.0 Hz, J_{CF}), 162.9, 160.59(d, J = 4.0 Hz, J_{CF}), 156.3(d, J = 268.0 Hz, $^1J_{CF}$), 136.36(d, J = 5.0 Hz, J_{CF}), 132.3, 131.22(d, J = 3.0 Hz, J_{CF}), 127.7, 127.4, 119.5(d, J = 5.0 Hz, J_{CF}), 115.29(d, J = 2.0 Hz, J_{CF}), 113.4, 101.5(d, J = 22.0 Hz, J_{CF}), 101.2 (d, J = 11.0 Hz, J_{CF}), 60.5, 55.4, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.00. HRMS (ESI) m/z calcd for $C_{19}H_{16}FNO_4Na^+$ $(M+Na)^+$ 364.09556, found 364.09534.



ethyl 1-(4-ethoxybenzoyl)-2-fluoroindolizine-3-carboxylate (4e):

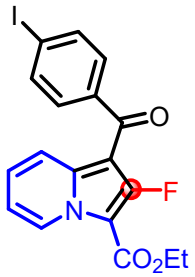
Yield 62%; 44.0 mg; white soild; mp 117-119 °C; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (d, J = 7.2 Hz, 1H), 8.34 (d, J = 8.8 Hz, 1H), 7.83 (dd, J = 8.8, 3.2 Hz, 2H), 7.46–7.32 (m, 1H), 7.07 (td, J = 7.2, 1.2 Hz, 1H), 6.97 (d, J = 8.8 Hz, 2H), 4.41 (d, J = 7.2 Hz, 2H), 4.12 (d, J = 7.2 Hz, 2H), 1.45 (dd, J = 14.0, 7.2 Hz, 3H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.25(d, J = 4.0 Hz, J_{CF}), 162.4, 160.6(d, J = 5.0 Hz, J_{CF}), 156.3(d, J = 268.0 Hz, J_{CF}), 136.35(d, J = 5.0 Hz, J_{CF}), 132.1, 131.25(d, J = 2.0 Hz, J_{CF}), 127.7,



127.4, 119.48(d, J = 4.0 Hz, J_{CF}), 115.3, 113.9, 101.5(d, J = 22.0 Hz, J_{CF}), 101.25(d, J = 10.0 Hz, J_{CF}), 63.6, 60.5, 14.7, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.00. HRMS (ESI) m/z calcd for $C_{20}H_{19}FNO_4^+$ $(M+H)^+$ 356.1293, found 356.1286.

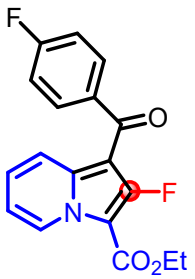
ethyl 1-(4-(benzyloxy)benzoyl)-2-fluoroindolizine-3-carboxylate (4f):

Yield 59%; 49.2 mg; white soild; mp 157-158 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (d, J = 7.2 Hz, 1H), 8.35 (d, J = 8.8 Hz, 1H), 7.85 (dd, J = 8.8, 2.8 Hz, 2H), 7.55–7.30 (m, 6H), 7.07 (t, J = 7.6 Hz, 3H), 5.15 (s, 2H), 4.41 (q, J = 7.2 Hz, 2H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.22(d, J = 4.0 Hz, J_{CF}), 162.1, 160.6(d, J = 5.0 Hz, J_{CF}), 156.3(d, J = 268.0 Hz, J_{CF}), 136.30, 132.5, 131.3(d, J = 3.0 Hz, J_{CF}), 128.6, 128.2, 127.8, 127.50, 127.47, 119.5(d, J = 4.0 Hz, J_{CF}), 115.33, 115.31, 114.3, 101.5, (d, J = 21.0 Hz, J_{CF}), 101.25(d, J = 13.0 Hz, J_{CF}), 99.9, 70.1, 60.5, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.91. HRMS (ESI) m/z calcd for $C_{16}H_{12}FNO_4Na^+$ $(M+Na)^+$ 324.0643, found 324.0636.



ethyl 2-fluoro-1-(4-iodobenzoyl)indolizine-3-carboxylate (4g):

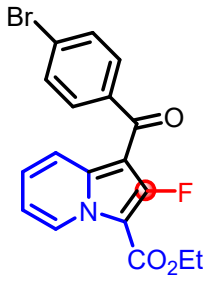
Yield 54%; 47.0 mg; yellow soild; mp 153-155 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, J = 7.2 Hz, 1H), 8.43 (d, J = 8.8 Hz, 1H), 7.84 (d, J = 8.4 Hz, 2H), 7.59–7.41 (m, 3H), 7.12 (t, J = 7.2 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H).; ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.58(d, J = 3.0 Hz, J_{CF}), 160.45(d, J = 4.0 Hz, J_{CF}), 156.58(d, J = 269.0 Hz, J_{CF}), 139.2, 137.4, 136.41(d, J = 5.0 Hz, J_{CF}), 130.17(d, J = 3.0 Hz, J_{CF}), 128.2, 128.0, 119.6(d, J = 4.0 Hz, J_{CF}), 115.8, 101.8(d, J = 21.0 Hz, J_{CF}), 100.65(d, J = 10.0 Hz, J_{CF}), 99.3, 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.25. HRMS (ESI) m/z calcd for $C_{18}H_{14}FINO_3Na^+$ $(M+H)^+$ 437.9997, found 437.9993.



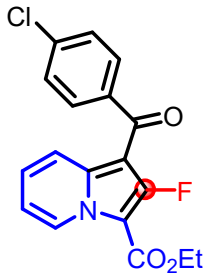
ethyl 2-fluoro-1-(4-fluorobenzoyl)indolizine-3-carboxylate (4h):

Yield 56%; 36.8 mg; yellow solid; mp 134-136 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, J = 7.2 Hz, 1H), 8.42 (d, J = 8.8 Hz, 1H), 7.82-7.87 (m, 2H), 7.47 (dd, J = 8.4, 7.6 Hz, 1H), 7.1-7.3 (m, 3H), 4.41 (q, J = 7.2 Hz, 2H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C

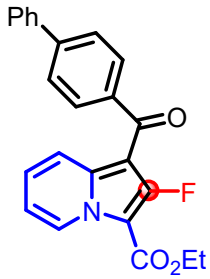
NMR (100 MHz, $CDCl_3$) δ 187.03(d, J = 3.0 Hz, J_{CF}), 165.1(d, J = 251.0 Hz, J_{CF}), 160.5(d, J = 4.0 Hz, J_{CF}), 156.5(d, J = 269.0 Hz, J_{CF}), 136.42(d, J = 4.0 Hz, J_{CF}), 136.0, 131.30(d, J = 3.0 Hz, J_{CF}), 131.21(d, J = 3.0 Hz, J_{CF}), 128.0, 127.9, 119.52(d, J = 5.0 Hz, J_{CF}), 115.63(d, J = 2.0 Hz, J_{CF}), 115.4, 115.2, 101.7(d, J = 22.0 Hz, J_{CF}), 100.75(d, J = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -107.03, -129.60. HRMS (ESI) m/z calcd for $C_{18}H_{13}F_2NO_3Na^+$ $(M+Na)^+$ 352.07557, found 352.07532.



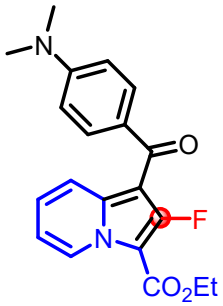
ethyl 1-(4-bromobenzoyl)-2-fluoroindolizine-3-carboxylate (4i):
Yield 49%; 38.0 mg; yellow solid; mp 125-127 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, J = 7.2 Hz, 1H), 8.44 (d, J = 8.8 Hz, 1H), 7.68 (dd, J = 8.4, 2.4 Hz, 2H), 7.63 (d, J = 8.4 Hz, 2H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.4(d, J = 3.0 Hz, J_{CF}), 160.46(d, J = 4.0 Hz, J_{CF}), 156.6(d, J = 269.0 Hz, J_{CF}), 138.64(d, J = 2.0 Hz, J_{CF}), 136.43(d, J = 5.0 Hz, J_{CF}), 131.4, 130.26(d, J = 3.0 Hz, J_{CF}), 128.2, 128.0, 126.7, 119.55(d, J = 5.0 Hz, J_{CF}), 115.8, 101.8(d, J = 21.0 Hz, J_{CF}), 100.65(d, J = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.31. HRMS (ESI) m/z calcd for $C_{18}H_{13}BrFNO_3Na^+$ $(M+Na)^+$ 411.99551, found 411.99551.



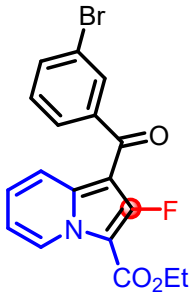
ethyl 1-(4-chlorobenzoyl)-2-fluoroindolizine-3-carboxylate (4j):
Yield 47%; 32.4 mg; yellow solid; mp 119-120 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, J = 7.2 Hz, 1H), 8.43 (d, J = 8.8 Hz, 1H), 7.76 (dd, J = 8.4, 2.8 Hz, 2H), 7.48 (t, J = 8.8 Hz, 3H), 7.12 (t, J = 7.2 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H).; ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.26(d, J = 3.0 Hz, J_{CF}), 160.49(d, J = 4.0 Hz, J_{CF}), 156.6(d, J = 270.0 Hz, J_{CF}), 138.21(d, J = 2.0 Hz, J_{CF}), 138.18, 136.45(d, J = 5.0 Hz, J_{CF}), 130.15(d, J = 3.0 Hz, J_{CF}), 128.5, 128.2, 128.0, 119.56(d, J = 4.0 Hz, J_{CF}), 115.74(d, J = 4.0 Hz, J_{CF}), 101.8(d, J = 21.0 Hz, J_{CF}), 100.75(d, J = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.39. HRMS (ESI) m/z calcd for $C_{18}H_{13}ClFNO_3Na^+$ $(M+Na)^+$ 368.04602, found 368.04590.



ethyl 1-([1,1'-biphenyl]-4-carbonyl)-2-fluoroindolizine-3-carboxylate (4k):
Yield 51%; 39.6 mg; yellow solid; mp 166-167 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (d, *J* = 7.2 Hz, 1H), 8.45 (d, *J* = 8.8 Hz, 1H), 7.91 (dd, *J* = 8.4, 2.8 Hz, 2H), 7.72 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.2 Hz, 2H), 7.46 (dd, *J* = 14.0, 6.4 Hz, 3H), 7.40 (d, *J* = 7.2 Hz, 1H), 7.13–7.06 (m, 1H), 4.42 (q, *J* = 7.2 Hz, 2H), 1.39 (t, *J* = 7.2 Hz, 3H).; ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.21(d, *J* = 3.0 Hz, J_{CF}), 160.64(d, *J* = 4.0 Hz, J_{CF}), 156.7(d, *J* = 269.0 Hz, J_{CF}), 144.8, 140.2, 138.6, 136.54(d, *J* = 5.0 Hz, J_{CF}), 129.47(d, *J* = 3.0 Hz, J_{CF}), 128.9, 128.01, 127.96, 127.3, 126.9, 119.66(d, *J* = 5.0 Hz, J_{CF}), 115.6, 101.8(d, *J* = 21.0 Hz, J_{CF}), 101.2(d, *J* = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.30. HRMS (ESI) m/z calcd for $C_{24}H_{19}FNO_3^+$ $(M+H)^+$ 388.1343, found 388.1351.

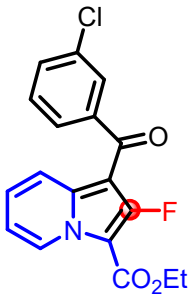


ethyl 1-(4-(dimethylamino)benzoyl)-2-fluoroindolizine-3-carboxylate (4l):
Yield 53%; 37.4 mg; yellow solid; mp 192-193 ℃; TLC (PE:EtOAc, 8:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.52 (d, *J* = 7.2 Hz, 1H), 8.26 (d, *J* = 8.8 Hz, 1H), 7.83 (dd, *J* = 8.8, 2.8 Hz, 2H), 7.40–7.32 (m, 1H), 7.03 (t, *J* = 6.8 Hz, 1H), 6.72 (d, *J* = 8.8 Hz, 2H), 4.42 (q, *J* = 7.2 Hz, 2H), 3.08 (s, 6H), 1.40 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.63(d, *J* = 4.0 Hz, J_{CF}), 160.78(d, *J* = 5.0 Hz, J_{CF}), 155.9 (d, *J* = 267.0 Hz, J_{CF}), 153.3, 136.15(d, *J* = 5.0 Hz, J_{CF}), 131.63, 131.53(d, *J* = 2.0 Hz, J_{CF}), 127.6, 126.7, 119.46(d, *J* = 4.0 Hz, J_{CF}), 114.9, 110.7, 101.7(d, *J* = 11.0 Hz, J_{CF}), 101.2(d, *J* = 22.0 Hz, J_{CF}), 60.4, 40.0, 14.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.72. HRMS (ESI) m/z calcd for $C_{20}H_{19}FN_2O_3Na^+$ $(M+Na)^+$ 377.1272, found 377.1271.



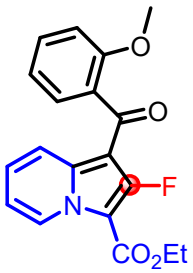
ethyl 1-(3-bromobenzoyl)-2-fluoroindolizine-3-carboxylate (4m):

Yield 49%; 38.0 mg; yellow solid; mp 147-150 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (d, J = 7.2 Hz, 1H), 8.45 (d, J = 8.8 Hz, 1H), 7.93 (s, 1H), 7.70 (t, J = 8.4 Hz, 2H), 7.49 (t, J = 8.0 Hz, 1H), 7.37 (t, J = 8.0 Hz, 1H), 7.13 (t, J = 6.8 Hz, 1H), 4.42 (q, J = 7.2 Hz, 2H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.95(d, J = 3.0 Hz, J_{CF}), 160.47(d, J = 4.0 Hz, J_{CF}), 156.7 (d, J = 271.0 Hz, J_{CF}), 141.8, 136.45(d, J = 5.0 Hz, J_{CF}), 134.7, 131.42(d, J = 2.0 Hz, J_{CF}), 129.7, 128.4, 128.0, 127.2(d, J = 3.0 Hz, J_{CF}), 122.3, 119.57(d, J = 4.0 Hz, J_{CF}), 115.84(d, J = 2.0 Hz, J_{CF}), 101.9(d, J = 22.0 Hz, J_{CF}), 100.55(d, J = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.31. HRMS (ESI) m/z calcd for $C_{18}H_{13}BrFNO_3Na^+$ $(M+Na)^+$ 411.9955, found 411.9954.

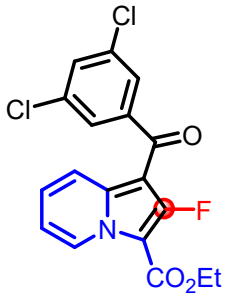


ethyl 1-(3-chlorobenzoyl)-2-fluoroindolizine-3-carboxylate (4n):

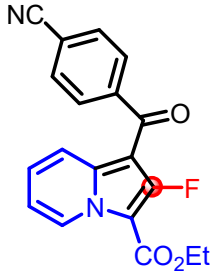
Yield 48%; 30.3 mg; yellow solid; mp 125-127 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (d, J = 6.8 Hz, 1H), 8.45 (d, J = 8.8 Hz, 1H), 7.77 (s, 1H), 7.67 (d, J = 6.8 Hz, 1H), 7.41-7.54 (m, 3H), 7.13 (t, J = 6.8 Hz, 1H), 4.42 (q, J = 7.2 Hz, 2H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.05(d, J = 4.0 Hz, J_{CF}), 160.47(d, J = 4.0 Hz, J_{CF}), 156.72(d, J = 270.0 Hz, J_{CF}), 141.6, 136.5, 134.3, 131.8, 129.5, 128.55(d, J = 2.0 Hz, J_{CF}), 128.3, 128.0, 126.74(d, J = 4.0 Hz, J_{CF}), 119.56(d, J = 5.0 Hz, J_{CF}), 115.8, 101.9(d, J = 21.0 Hz, J_{CF}), 100.6(d, J = 10.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.33. HRMS (ESI) m/z calcd for $C_{18}H_{13}ClFNO_3Na^+$ $(M+Na)^+$ 368.04602, found 368.04593.



ethyl 2-fluoro-1-(2-methoxybenzoyl)indolizine-3-carboxylate (4o):
Yield 53%; 38.0 mg; white solid; mp 148-150 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (d, J = 7.2 Hz, 1H), 8.63 (d, J = 8.8 Hz, 1H), 7.51–7.40 (m, 3H), 7.10 (t, J = 7.2 Hz, 1H), 7.04 (t, J = 7.6 Hz, 1H), 6.99 (d, J = 8.4 Hz, 1H), 4.37 (q, J = 7.2 Hz, 2H), 3.80 (s, 3H), 1.35 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.7(d, J = 3.0 Hz, J_{CF}), 160.67(d, J = 4.0 Hz, J_{CF}), 159.3, 157.93 (d, J = 271.0 Hz, J_{CF}), 157.0, 136.0 (d, J = 4.0 Hz, J_{CF}), 131.5, 131.1, 128.7, 128.4, 127.9, 120.5, 120.0 (d, J = 5.0 Hz, J_{CF}), 115.68 (d, J = 2.0 Hz, J_{CF}), 111.1, 102.55 (d, J = 9.0 Hz, J_{CF}), 101.9 (d, J = 21.0 Hz, J_{CF}), 60.5, 55.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -32.06. HRMS (ESI) m/z calcd for $C_{18}H_{13}ClFNO_3Na^+$ $(M+Na)^+$ 342.1146, found 342.1134.

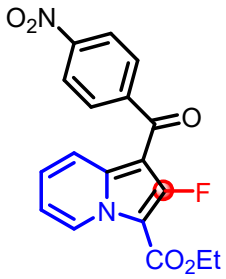


ethyl 1-(3,5-dichlorobenzoyl)-2-fluoroindolizine-3-carboxylate (4p):
Yield 37%; 24.0 mg; white solid; mp 178-180 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.59 (d, J = 7.2 Hz, 1H), 8.46 (d, J = 8.8 Hz, 1H), 7.63 (s, 2H), 7.57–7.44 (m, 2H), 7.15 (t, J = 6.8 Hz, 1H), 4.43 (q, J = 7.2 Hz, 2H), 1.41 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.5(d, J = 3.0 Hz, J_{CF}), 160.38(d, J = 5.0 Hz, J_{CF}), 156.7(d, J = 270.0 Hz, J_{CF}), 142.7, 136.4, 134.9, 131.4, 128.7, 128.2, 126.84(d, J = 3.0 Hz, J_{CF}), 119.56(d, J = 5.0 Hz, J_{CF}), 116.1, 102.1(d, J = 21.0 Hz, J_{CF}), 100.25(d, J = 10.0 Hz, J_{CF}), 60.8, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.38. HRMS (ESI) m/z calcd for $C_{18}H_{13}Cl_2FNO_3^+$ $(M+H)^+$ 380.0251, found 380.0256.

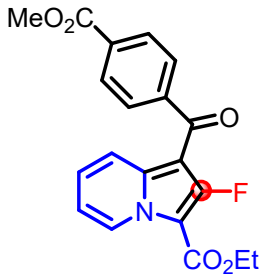


ethyl 1-(4-cyanobenzoyl)-2-fluoroindolizine-3-carboxylate (4q):

Yield 33%; 22.0 mg; white solid; mp 202-203 °C; TLC (PE:EtOAc, 7:1 v/v);^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (d, J = 7.2 Hz, 1H), 8.52 (d, J = 8.8 Hz, 1H), 7.86 (dd, J = 8.4, 2.0 Hz, 2H), 7.79 (d, J = 8.0 Hz, 2H), 7.59–7.47 (m, 1H), 7.17 (t, J = 7.2 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.7(d, J = 3.0 Hz, J_{CF}), 160.32(d, J = 4.0 Hz, J_{CF}), 156.8(d, J = 270.0 Hz, J_{CF}), 143.7, 136.47(d, J = 5.0 Hz, J_{CF}), 132.1, 128.91, 128.88, 128.2, 119.59(d, J = 4.0 Hz, J_{CF}), 118.3, 116.16(d, J = 3.0 Hz, J_{CF}), 114.9, 102.1(d, J = 21.0 Hz, J_{CF}), 100.15(d, J = 10.0 Hz, J_{CF}), 60.7, 14.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.23. HRMS (ESI) m/z calcd for $C_{19}H_{13}FN_2O_3Na^+$ $(M+Na)^+$ 359.0802, found 359.0800.

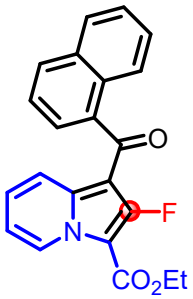


ethyl 2-fluoro-1-(4-nitrobenzoyl)indolizine-3-carboxylate (4r):
Yield 31%; 22.0 mg; yellow solid; mp 154-156 °C; TLC (PE:EtOAc, 7:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.61 (d, J = 7.2 Hz, 1H), 8.54 (d, J = 8.8 Hz, 1H), 8.35 (d, J = 8.8 Hz, 2H), 7.92 (dd, J = 8.8, 2.4 Hz, 2H), 7.56 (t, J = 8.0 Hz, 1H), 7.19 (t, J = 6.8 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 186.46(d, J = 3.0 Hz, J_{CF}), 160.31(d, J = 4.0 Hz, J_{CF}), 156.8 (d, J = 270.0 Hz, J_{CF}), 149.4, 145.4, 136.46(d, J = 5.0 Hz, J_{CF}), 129.3(d, J = 3.0 Hz, J_{CF}), 129.0, 128.2, 123.5, 119.63(d, J = 4.0 Hz, J_{CF}), 116.3, 102.2(d, J = 21.0 Hz, J_{CF}), 100.35(d, J = 10.0 Hz, J_{CF}), 60.8, 14.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.17. HRMS (ESI) m/z calcd for $C_{18}H_{13}FN_2O_5Na^+$ $(M+Na)^+$ 379.07007, found 379.06992.



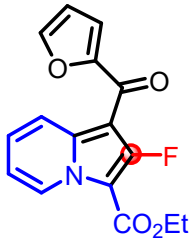
ethyl 2-fluoro-1-(4-(methoxycarbonyl)benzoyl)indolizine-3-carboxylate (4s):
Yield 34%; 25.0 mg; yellow solid; mp 152-153 °C; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.59 (d, J = 7.2 Hz, 1H), 8.49 (d, J = 8.8 Hz, 1H), 8.16 (d, J = 8.0 Hz, 2H), 7.84 (dd, J = 8.0, 2.0 Hz, 2H), 7.60–7.45 (m, 1H), 7.14 (t, J = 7.2 Hz, 1H), 4.41 (q, J = 7.2 Hz, 2H), 3.97 (s, 3H), 1.38 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.9(d, J = 3.0 Hz, J_{CF}), 166.5, 160.45(d, J = 5.0 Hz, J_{CF}), 156.8(d, J = 270.0 Hz, J_{CF}), 143.8, 136.45(d, J = 5.0 Hz, J_{CF}), 132.7, 129.4, 128.5, 128.40(d, J = 3.0 Hz, J_{CF}), 128.0, 119.6(d, J = 5f.0 Hz, J_{CF}), 115.9,

101.9(d, J = 22.0 Hz, J_{CF}), 100.75(d, J = 10.0 Hz, J_{CF}), 60.6, 52.4, 14.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.05. HRMS (ESI) m/z calcd for $C_{20}H_{16}FNO_5Na^+$ $(M+Na)^+$ 392.0905, found 392.0903.



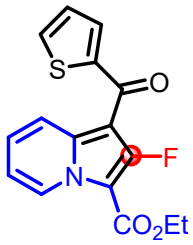
ethyl 1-(1-naphthoyl)-2-fluoroindolizine-3-carboxylate (4t):

Yield 43 %; 31.0 mg; yellow solid; mp 105-107 °C; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (d, J = 7.2 Hz, 1H), 8.66 (d, J = 8.8 Hz, 1H), 8.16 (d, J = 7.6 Hz, 1H), 7.99 (d, J = 8.4 Hz, 1H), 7.95–7.88 (m, 1H), 7.67 (d, J = 6.0 Hz, 1H), 7.58–7.45 (m, 4H), 7.15 (t, J = 7.2 Hz, 1H), 4.34 (q, J = 7.2 Hz, 2H), 1.31 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 189.76(d, J = 3.0 Hz, J_{CF}), 160.52(d, J = 5.0 Hz, J_{CF}), 157.6(d, J = 272.0 Hz, J_{CF}), 138.58(d, J = 2.0 Hz, J_{CF}), 136.3(d, J = 4.0 Hz, J_{CF}), 133.6, 130.6, 130.2, 128.6, 128.3, 128.1, 127.0, 126.2, 125.8(d, J = 3.0 Hz, J_{CF}), 125.1, 124.7, 119.89(d, J = 4.0 Hz, J_{CF}), 115.9, 102.48(d, J = 8.0 Hz, J_{CF}), 102.1(d, J = 21.0 Hz, J_{CF}), 60.5, 14.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -129.36. HRMS (ESI) m/z calcd for $C_{22}H_{16}FNO_3Na^+$ $(M+Na)^+$ 384.1006, found 384.1004.

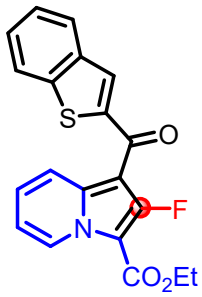


ethyl 2-fluoro-1-(furan-2-carbonyl)indolizine-3-carboxylate (4u):

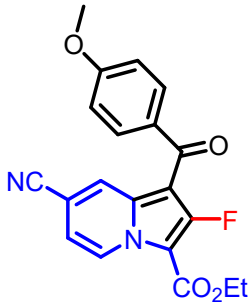
Yield 55%; 33.0 mg; yellow solid; mp 99-100 °C; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (d, J = 7.2 Hz, 1H), 8.40 (d, J = 8.8 Hz, 1H), 7.69 (s, 1H), 7.50–7.38 (m, 1H), 7.34 (t, J = 3.2 Hz, 1H), 7.08 (t, J = 7.2 Hz, 1H), 6.60 (dd, J = 3.2, 1.6 Hz, 1H), 4.45 (q, J = 7.2 Hz, 2H), 1.44 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.36(d, J = 3.0 Hz, J_{CF}), 160.55(d, J = 5.0 Hz, J_{CF}), 155.95(d, J = 269.0 Hz, J_{CF}), 152.6, 146.4, 136.45(d, J = 6.0 Hz, J_{CF}), 127.8, 127.7, 119.6(d, J = 4.0 Hz, J_{CF}), 118.3, 118.2, 115.49(d, J = 2.0 Hz, J_{CF}), 112.0, 101.8(d, J = 21.0 Hz, J_{CF}), 100.36(d, J = 11.0 Hz, J_{CF}), 60.6, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.23. HRMS (ESI) m/z calcd for $C_{16}H_{12}FNO_4Na^+$ $(M+Na)^+$ 324.0643, found 324.0636.



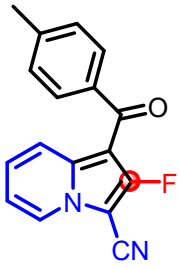
ethyl 2-fluoro-1-(thiophene-2-carbonyl)indolizine-3-carboxylate (4v):
Yield 56%; 35.4 mg; yellow solid; mp 115-153 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (d, J = 7.2 Hz, 1H), 8.35 (d, J = 8.8 Hz, 1H), 7.80 (t, J = 4.4 Hz, 1H), 7.68 (d, J = 4.8 Hz, 1H), 7.53–7.34 (m, 1H), 7.17 (t, J = 4.4 Hz, 1H), 7.08 (t, J = 6.8 Hz, 1H), 4.44 (q, J = 7.2 Hz, 2H), 1.43 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.37(d, J = 3.0 Hz, J_{CF}), 160.52(d, J = 4.0 Hz, J_{CF}), 155.8(d, J = 268.0 Hz, J_{CF}), 145.2, 136.3(d, J = 5.0 Hz, J_{CF}), 133.2, 132.7, 132.6, 127.8, 127.6, 119.55(d, J = 4.0 Hz, J_{CF}), 115.45(d, J = 2.0 Hz, J_{CF}), 101.7(d, J = 22.0 Hz, J_{CF}), 100.8(d, J = 11.0 Hz, J_{CF}), 60.5, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.60. HRMS (ESI) m/z calcd for $C_{16}H_{12}FNO_3SNa^+$ $(M+Na)^+$ 340.0414, found 340.0412.



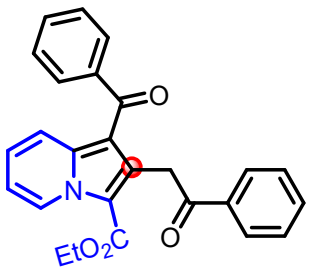
ethyl 1-(benzo[b]thiophene-2-carbonyl)-2-fluoroindolizine-3-carboxylate (4w):
Yield 52%;38.0 mg; white solid; mp 173-174 ℃; TLC (PE:EtOAc, 10:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (d, J = 5.6 Hz, 1H), 8.41 (d, J = 8.4 Hz, 1H), 8.04 (s, 1H), 7.92 (d, J = 7.6 Hz, 2H), 7.45 (dd, J = 14.0, 6.0 Hz, 3H), 7.12 (t, J = 5.6 Hz, 1H), 4.46 (d, J = 7.2 Hz, 2H), 1.49–1.37 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.62(d, J = 3.0 Hz, J_{CF}), 160.52(d, J = 4.0 Hz, J_{CF}), 155.93(d, J = 269.0 Hz, J_{CF}), 144.5, 142.2, 139.2, 136.4, 129.7, 129.6, 127.94, 127.90, 127.0, 126.0, 124.8, 122.8, 119.6(d, J = 4.0 Hz, J_{CF}), 115.7, 101.8(d, J = 22.0 Hz, J_{CF}), 100.75(d, J = 11.0 Hz, J_{CF}), 60.7, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -130.39. HRMS (ESI) m/z calcd for $C_{20}H_{15}FO_3N^+$ $(M+H)^+$ 368.0751, found 368.0741.



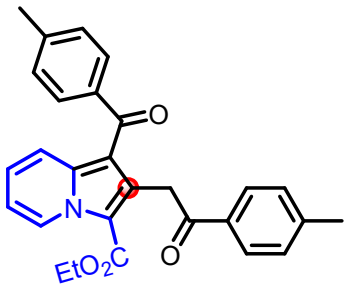
ethyl 7-cyano-2-fluoro-1-(4-methoxybenzoyl)indolizine-3-carboxylate (4x):
Yield 35%; 25.6 mg; white solid; mp 167-168 ℃; TLC (PE:EtOAc, 5:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (d, *J* = 7.2 Hz, 1H), 8.72 (s, 1H), 7.75 (dd, *J* = 8.0, 2.4 Hz, 2H), 7.32 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 6.4 Hz, 1H), 4.44 (d, *J* = 7.2 Hz, 2H), 2.46 (s, 3H), 1.41 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.8(d, *J* = 4.0 Hz, J_{CF}), 160.1(d, *J* = 4.0 Hz, J_{CF}), 156.06(d, *J* = 271.0 Hz, J_{CF}), 143.8, 136.1, 133.7, 129.19, 129.16, 128.1, 125.42(d, *J* = 5.0 Hz, J_{CF}), 117.1, 115.2, 109.8, 104.3, 104.1(d, *J* = 21.0 Hz, J_{CF}), 103.94(d, *J* = 10.0 Hz, J_{CF}), 61.3, 21.8, 14.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -127.52. HRMS (ESI) m/z calcd for $C_{20}H_{16}FN_2O_4^+$ $(M+H)^+$ 367.1089, found 367.1095.



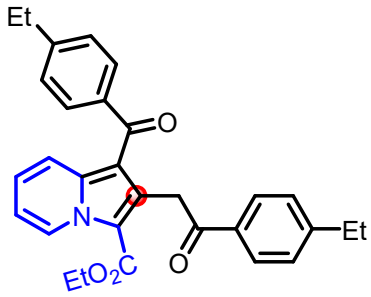
2-fluoro-1-(4-methylbenzoyl)indolizine-3-carbonitrile (4y):
Yield 41%; 22.8 mg; white solid; mp 174-176 ℃; TLC (PE:EtOAc, 8:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.39 (d, *J* = 9.2 Hz, 1H), 8.30 (d, *J* = 6.8 Hz, 1H), 7.72 (dd, *J* = 8.0, 3.2 Hz, 2H), 7.54–7.41 (m, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.14-7.18 (m, 1H), 2.45 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.2(d, *J* = 3.0 Hz, J_{CF}), 157.61(d, *J* = 268.0 Hz, J_{CF}), 143.4, 136.3, 136.1, 129.04, 128.97, 128.0, 125.7, 120.72(d, *J* = 4.0 Hz, J_{CF}), 116.2, 109.88(d, *J* = 4.0 Hz, J_{CF}), 101.1(d, *J* = 9.0 Hz, J_{CF}), 85.4(d, *J* = 27.0 Hz, J_{CF}), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -133.78. HRMS (ESI) m/z calcd for $C_{17}H_{12}FN_2O^+$ $(M+H)^+$ 279.0928, found 279.0933.



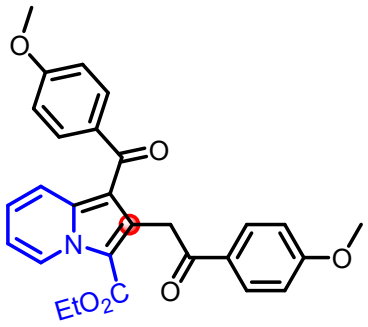
ethyl 1-benzoyl-2-(2-oxo-2-phenylethyl)indolizine-3-carboxylate (5a):
Yield 61%; 50.8 mg; yellow solid; mp 128-130 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.69–9.61 (m, 1H), 8.01–7.93 (m, 1H), 7.76–7.66 (m, 1H), 7.57 (s, 1H), 7.49 (s, 1H), 7.38 (dt, *J* = 7.2, 2.4 Hz, 1H), 7.16–7.09 (m, 1H), 6.96–6.89 (m, 1H), 4.96–4.88 (m, 1H), 4.27–4.18 (m, 1H), 1.12–1.03 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.4, 192.1, 161.6, 140.8, 138.7, 137.0, 133.4, 132.9, 131.9, 128.9, 128.4, 128.1, 127.9, 125.3, 118.8, 114.8, 114.1, 60.3, 37.7, 14.0. HRMS (ESI) m/z calcd for $C_{26}H_{22}NO_4^+$ $(M+H)^+$ 412.1543, found 412.1541.



ethyl 1-(4-methylbenzoyl)-2-(2-oxo-2-(p-tolyl)ethyl)indolizine-3-carboxylate (5b):
Yield 60%; 52.6 mg; yellow solid; mp 120-121 ℃; TLC (PE:EtOAc, 6:1 v/v);^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, *J* = 7.2 Hz, 1H), 7.87 (d, *J* = 8.0 Hz, 2H), 7.63 (d, *J* = 8.0 Hz, 2H), 7.40 (d, *J* = 8.8 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.14–7.07 (m, 1H), 6.91 (t, *J* = 6.8 Hz, 1H), 4.88 (s, 2H), 4.22 (q, *J* = 7.2 Hz, 2H), 2.41 (s, 3H), 2.34 (s, 3H), 1.07 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 192.0, 161.6, 143.5, 142.6, 138.5, 138.1, 134.6, 133.3, 129.2, 129.12, 129.09, 128.1, 128.0, 125.0, 118.9, 115.2, 114.8, 114.0, 60.2, 37.5, 21.6, 21.5, 14.1. HRMS (ESI) m/z calcd for $C_{28}H_{26}NO_4^+$ $(M+H)^+$ 440.1856, found 440.1856.

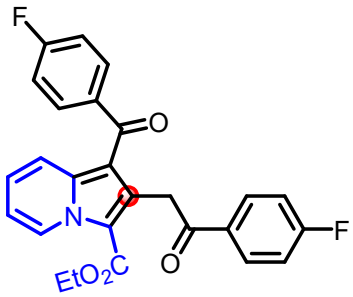


ethyl 1-(4-ethylbenzoyl)-2-(2-(4-ethylphenyl)-2-oxoethyl)indolizine-3-carboxylate (5c):
Yield 62%; 57.8 mg; white solid; mp 125-126 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (d, *J* = 7.2 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 2H), 7.64 (d, *J* = 8.0 Hz, 2H), 7.49 (d, *J* = 8.8 Hz, 1H), 7.26 (d, *J* = 7.6 Hz, 2H), 7.19–7.11 (m, 3H), 6.92 (t, *J* = 6.8 Hz, 1H), 4.84 (s, 2H), 4.23 (q, *J* = 7.2 Hz, 2H), 2.70 (q, *J* = 7.6 Hz, 2H), 2.62 (q, *J* = 7.6 Hz, 2H), 1.25 (d, *J* = 7.6 Hz, 3H), 1.15 (t, *J* = 7.6 Hz, 3H), 1.07 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.0, 192.0, 161.7, 149.7, 148.8, 138.6, 138.3, 134.8, 133.3, 129.3, 128.1, 128.0, 127.93, 127.90, 125.1, 118.9, 115.2, 114.8, 114.0, 60.2, 37.6, 28.9, 28.8, 15.20, 15.15, 14.1. HRMS (ESI) m/z calcd for $C_{30}H_{30}NO_4^+$ $(M+H)^+$ 468.2169, found 468.2166.



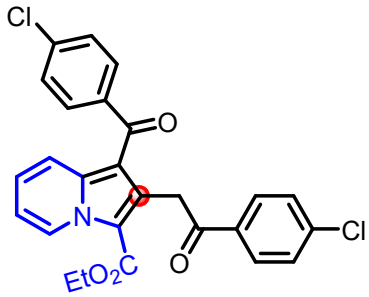
ethyl 1-(4-methoxybenzoyl)-2-(2-(4-methoxyphenyl)-2-oxoethyl)indolizine-3-carboxylate (5d):

Yield 65%; 61.2 mg; white solid; mp 136-137 ℃; TLC (PE:EtOAc, 4:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.62 (d, *J* = 7.2 Hz, 1H), 7.98 (d, *J* = 8.4 Hz, 2H), 7.74 (d, *J* = 8.4 Hz, 2H), 7.42 (d, *J* = 9.2 Hz, 1H), 7.14–7.05 (m, 1H), 6.96–6.83 (m, 5H), 4.86 (s, 2H), 4.21 (q, *J* = 7.2 Hz, 2H), 3.85 (s, 3H), 3.78 (s, 3H), 1.06 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 190.8, 163.2, 162.8, 161.5, 138.2, 133.1, 131.4, 130.1, 127.9, 124.7, 118.7, 115.3, 114.5, 113.8, 113.6, 113.5, 60.1, 55.31, 55.26, 37.2, 14.0. HRMS (ESI) m/z calcd for $C_{28}H_{26}NO_6^+$ $(M+H)^+$ 472.1755, found 472.1752.



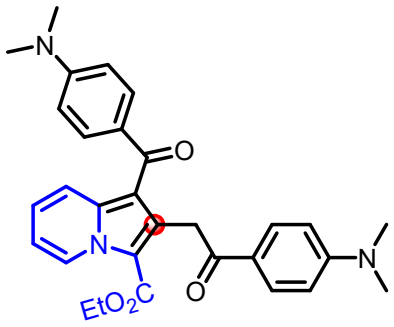
ethyl 1-(4-fluorobenzoyl)-2-(2-(4-fluorophenyl)-2-oxoethyl)indolizine-3-carboxylate (5e):

Yield 51%; 45.6 mg; white solid; mp 189-191 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, *J* = 7.2 Hz, 1H), 8.04 (dd, *J* = 8.4, 5.6 Hz, 2H), 7.76 (dd, *J* = 8.4, 5.6 Hz, 2H), 7.32 (d, *J* = 9.2 Hz, 1H), 7.15 (dd, *J* = 12.0, 5.6 Hz, 3H), 7.08 (t, *J* = 8.4 Hz, 2H), 6.94 (t, *J* = 6.8 Hz, 1H), 4.92 (s, 2H), 4.25 (q, *J* = 7.2 Hz, 2H), 1.10 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.8, 190.5, 165.64(d, *J* = 253.0 Hz, J_{CF}), 165.1(d, *J* = 252.0 Hz, J_{CF}), 161.4, 138.5, 136.9, 136.8, 133.3, 133.1, 131.6(d, *J* = 9.0 Hz, J_{CF}), 130.55(d, *J* = 9.0 Hz, J_{CF}), 128.2, 125.4, 118.6, 115.71(d, *J* = 4.0 Hz, J_{CF}), 115.49(d, *J* = 4.0 Hz, J_{CF}), 115.0, 114.6, 114.2, 60.4, 37.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -105.37, 106.54. HRMS (ESI) m/z calcd for $C_{26}H_{20}F_2ON^+$ $(M+H)^+$ 448.1355, found 448.1350.



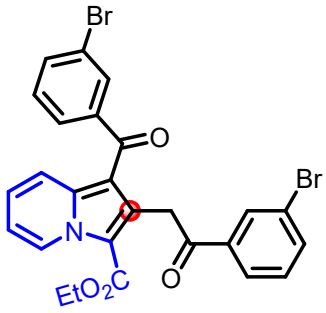
ethyl 1-(4-chlorobenzoyl)-2-(2-(4-chlorophenyl)-2-oxoethyl)indolizine-3-carboxylate (5f):

Yield 43%; 41.2 mg; white solid; mp 177-179 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, *J* = 7.2 Hz, 1H), 7.95 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 8.4 Hz, 2H), 7.45 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 9.2 Hz, 1H), 7.19–7.10 (m, 1H), 6.93-6.97 (m, 1H), 4.92 (s, 2H), 4.25 (d, *J* = 7.2 Hz, 2H), 1.11 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.2, 190.7, 161.4, 139.4, 139.0, 138.5, 138.3, 135.2, 133.2, 130.5, 129.4, 128.9, 128.8, 128.3, 125.6, 118.6, 115.1, 114.4, 114.3, 60.4, 37.5, 14.1. HRMS (ESI) m/z calcd for $C_{26}H_{20}Cl_2NO_4^+$ $(M+H)^+$ 480.0764, found 480.0773.



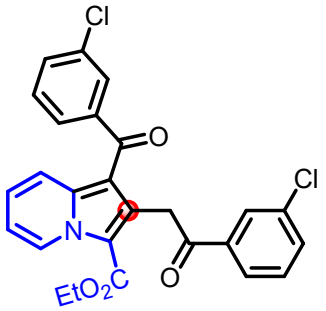
ethyl 1-(4-(dimethylamino)benzoyl)-2-(2-(4-(dimethylamino)phenyl)-2-oxoethyl)indolizine-3-carboxylate (5g):

Yield 56%; 55.6 mg; white solid; mp 204-206 ℃ ; TLC (PE:EtOAc, 4:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (d, *J* = 7.2 Hz, 1H), 7.90 (d, *J* = 8.8 Hz, 2H), 7.74 (d, *J* = 8.8 Hz, 2H), 7.47 (d, *J* = 8.8 Hz, 1H), 7.05 (t, *J* = 8.0 Hz, 1H), 6.84 (t, *J* = 6.8 Hz, 1H), 6.62 (d, *J* = 8.8 Hz, 2H), 6.57 (d, *J* = 8.8 Hz, 2H), 4.81 (s, 2H), 4.19 (q, *J* = 7.2 Hz, 2H), 3.01 (s, 6H), 2.97 (s, 6H), 1.05 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.5, 190.4, 161.7, 153.0, 137.7, 133.1, 131.8, 130.0, 127.6, 125.2, 123.9, 118.7, 116.2, 114.1, 113.3, 110.6, 110.4, 59.9, 39.9, 36.7, 14.0. HRMS (ESI) m/z calcd for $C_{30}H_{32}N_3O_4^+$ $(M+H)^+$ 498.2387, found 498.2382.



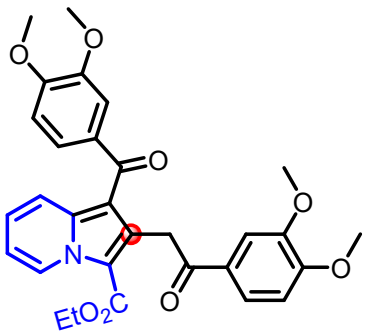
ethyl 1-(3-bromobenzoyl)-2-(2-(3-bromophenyl)-2-oxoethyl)indolizine-3-carboxylate (5h):

Yield 42%; 47.6 mg; white solid; mp 150-152 ℃; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (d, *J* = 7.2 Hz, 1H), 8.12 (s, 1H), 7.93 (d, *J* = 8.0 Hz, 1H), 7.82 (s, 1H), 7.71 (dd, *J* = 8.0, 0.8 Hz, 1H), 7.64–7.57 (m, 2H), 7.43–7.32 (m, 2H), 7.27 (s, 1H), 7.23–7.15 (m, 1H), 6.97 (t, *J* = 7.2 Hz, 1H), 4.89 (s, 2H), 4.27 (d, *J* = 7.2 Hz, 2H), 1.14 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 190.3, 161.4, 142.6, 138.8, 138.6, 135.9, 134.8, 133.0, 131.8, 131.1, 130.2, 130.1, 128.3, 127.4, 126.5, 125.9, 122.9, 122.8, 118.7, 115.3, 114.5, 114.1, 60.5, 37.7, 14.2. HRMS (ESI) m/z calcd for $C_{26}H_{20}Br_2NO_4^+$ $(M+H)^+$ 567.9754, found 567.9746.



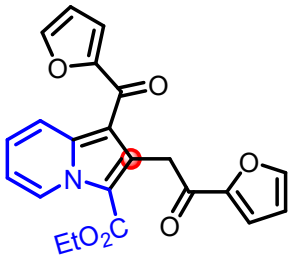
ethyl 1-(3-chlorobenzoyl)-2-(2-(3-chlorophenyl)-2-oxoethyl)indolizine-3-carboxylate (5i):

Yield 39%; 35.2 mg; yellow solid; mp 138-140 ℃; TLC (PE:EtOAc, 4:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (d, *J* = 7.2 Hz, 1H), 7.97 (s, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.67 (s, 1H), 7.56 (t, *J* = 7.6 Hz, 2H), 7.43 (dd, *J* = 16.4, 8.4 Hz, 2H), 7.39–7.30 (m, 2H), 7.22–7.13 (m, 1H), 6.97 (t, *J* = 6.8 Hz, 1H), 4.90 (s, 2H), 4.27 (q, *J* = 7.2 Hz, 2H), 1.14 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.0, 190.4, 161.4, 142.4, 138.8, 138.4, 134.9, 134.7, 133.1, 133.0, 131.9, 129.9, 128.9, 128.3, 128.1, 127.0, 126.1, 125.9, 118.7, 115.3, 114.5, 114.2, 60.5, 37.7, 14.2. HRMS (ESI) m/z calcd for $C_{26}H_{20}Cl_2NO_4^+$ $(M+H)^+$ 480.0764, found 480.0765.



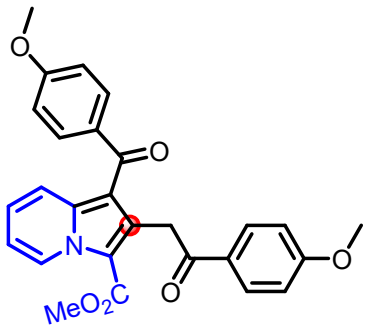
ethyl 1-(3,4-dimethoxybenzoyl)-2-(2-(3,4-dimethoxyphenyl)-2-oxoethyl)indolizine-3-carboxylate (5j):

Yield 59%; 62.6 mg; yellow solid; mp 150-152 °C; TLC (PE:EtOAc, 3:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (d, *J* = 7.2 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.55 (s, 1H), 7.49 (d, *J* = 8.8 Hz, 1H), 7.37 (d, *J* = 7.2 Hz, 2H), 7.20–7.08 (m, 1H), 6.91 (dd, *J* = 15.2, 7.6 Hz, 2H), 6.81 (d, *J* = 8.8 Hz, 1H), 4.86 (s, 2H), 4.24 (q, *J* = 7.2 Hz, 2H), 3.94 (d, *J* = 9.2 Hz, 6H), 3.87 (s, 6H), 1.09 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 190.8, 161.4, 152.9, 152.4, 148.70, 148.65, 138.2, 133.2, 133.0, 130.1, 127.8, 124.7, 123.8, 122.3, 118.7, 115.1, 114.5, 113.8, 111.2, 110.0, 109.8, 60.1, 55.9, 55.81, 55.78, 55.75, 37.1, 14.0. HRMS (ESI) m/z calcd for $C_{30}H_{30}NO_8^+$ $(M+H)^+$ 532.1966, found 532.1963.



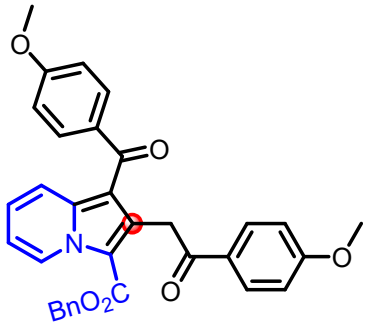
ethyl 1-(furan-2-carbonyl)-2-(2-(furan-2-yl)-2-oxoethyl)indolizine-3-carboxylate (5k):

Yield 52%; 40.6 mg; black solid; mp 110-112°C; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.62 (d, *J* = 7.2 Hz, 1H), 7.66 (d, *J* = 8.8 Hz, 1H), 7.57 (d, *J* = 14.8 Hz, 2H), 7.27–7.14 (m, 3H), 6.95 (s, 1H), 6.54 (dd, *J* = 12.0, 1.2 Hz, 2H), 4.78 (s, 2H), 4.25 (d, *J* = 6.4 Hz, 2H), 1.12 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.6, 178.2, 161.4, 153.6, 152.6, 146.3, 145.9, 138.1, 131.2, 128.1, 125.2, 118.8, 118.6, 116.6, 114.8, 114.7, 114.2, 112.3, 112.2, 60.4, 37.2, 13.8. HRMS (ESI) m/z calcd for $C_{22}H_{18}NO_6^+$ $(M+H)^+$ 392.1129, found 392.1127.



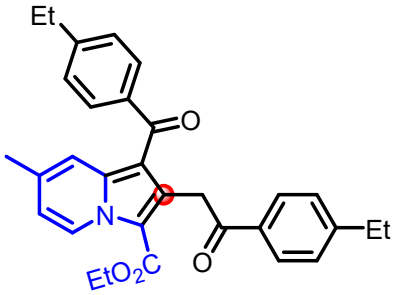
methyl 1-(4-methoxybenzoyl)-2-(2-(4-methoxyphenyl)-2-oxoethyl)indolizine-3-carboxylate (5l):

Yield 54%; 49.2 mg; gray solid; mp 168-169 ℃; TLC (PE:EtOAc, 3:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (d, *J* = 7.2 Hz, 1H), 7.98 (d, *J* = 8.8 Hz, 2H), 7.75 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 9.2 Hz, 1H), 7.16–7.04 (m, 1H), 6.95–6.83 (m, 5H), 4.83 (s, 2H), 3.85 (s, 3H), 3.79 (s, 3H), 3.69 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.2, 190.8, 163.1, 162.8, 161.8, 138.2, 133.4, 133.0, 131.4, 130.11, 130.06, 127.8, 124.8, 118.7, 115.3, 114.3, 113.8, 113.53, 113.48, 55.30, 55.25, 51.0, 36.9. HRMS (ESI) m/z calcd for $C_{27}H_{24}NO_6^+$ $(M+H)^+$ 458.1598, found 458.1592.



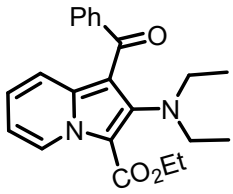
2-(benzo[d]oxazol-2-yl)-1-(4-methoxyphenyl)ethan-1-one (5m):

Yield 51%; 54.2 mg; white solid; mp 155-157℃; TLC (PE:EtOAc, 3:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (d, *J* = 7.2 Hz, 1H), 7.81 (d, *J* = 8.8 Hz, 2H), 7.72 (d, *J* = 8.8 Hz, 2H), 7.40 (d, *J* = 9.2 Hz, 1H), 7.20–7.08 (m, 6H), 6.89 (dd, *J* = 10.0, 4.0 Hz, 1H), 6.85 (dd, *J* = 8.8, 2.0 Hz, 4H), 5.18 (s, 2H), 4.80 (s, 2H), 3.86 (s, 3H), 3.78 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.9, 190.9, 163.1, 162.9, 161.4, 138.4, 135.4, 133.5, 133.1, 131.5, 130.1, 130.0, 128.33, 128.29, 128.0, 124.9, 118.8, 115.5, 114.3, 113.9, 113.6, 113.5, 66.2, 55.4, 55.3, 37.2. HRMS (ESI) m/z calcd for $C_{33}H_{28}NO_6^+$ $(M+H)^+$ 534.1911, found 534.1909.



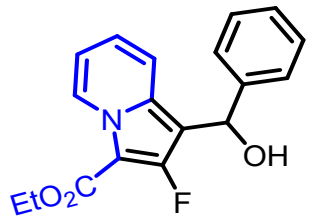
ethyl 1-(4-ethylbenzoyl)-2-(2-(4-ethylphenyl)-2-oxoethyl)-7-methylindolizine-3-carboxylate (5n):

Yield 48%; 46.0 mg; white solid; mp 150-152 °C; TLC (PE:EtOAc, 4:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.51 (d, *J* = 7.2 Hz, 1H), 7.83 (d, *J* = 7.6 Hz, 2H), 7.62 (d, *J* = 7.6 Hz, 2H), 7.40 (s, 1H), 7.25 (t, *J* = 7.2 Hz, 2H), 7.15 (d, *J* = 7.6 Hz, 2H), 6.77 (d, *J* = 7.2 Hz, 1H), 4.73 (s, 2H), 4.20 (q, *J* = 6.8 Hz, 2H), 2.69 (d, *J* = 7.6 Hz, 2H), 2.58 (d, *J* = 7.6 Hz, 2H), 2.31 (s, 3H), 1.25 (t, *J* = 7.2 Hz, 3H), 1.11 (t, *J* = 7.6 Hz, 3H), 1.06 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.9, 192.1, 161.6, 149.6, 148.5, 139.2, 138.5, 136.6, 134.8, 133.2, 129.1, 128.0, 127.8, 127.4, 117.7, 116.6, 114.22, 114.15, 60.0, 37.8, 28.83, 28.77, 21.3, 15.2, 14.0. HRMS (ESI) m/z calcd for $C_{31}H_{32}NO_4^+$ $(M+H)^+$ 482.2326, found 482.2323.



ethyl 1-benzoyl-2-(diethylamino)indolizine-3-carboxylate (6):

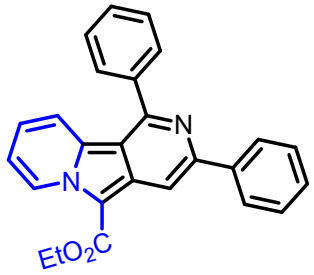
Yield 67%; 48 mg; black oil; TLC (PE:EtOAc, 6:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.47 (d, *J* = 7.2 Hz, 1H), 7.78 (d, *J* = 8.0 Hz, 2H), 7.52 (dd, *J* = 13.2, 7.6 Hz, 2H), 7.42 (t, *J* = 7.2 Hz, 2H), 7.10 (t, *J* = 8.0 Hz, 1H), 6.81 (t, *J* = 6.8 Hz, 1H), 4.41 (d, *J* = 7.2 Hz, 2H), 3.10 (q, *J* = 6.8 Hz, 4H), 1.41 (t, *J* = 6.8 Hz, 3H), 0.97 (t, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.1, 161.4, 149.8, 140.2, 138.6, 131.8, 129.3, 128.3, 128.2, 125.6, 117.2, 112.9, 108.3, 108.1, 59.9, 47.7, 14.5, 13.0. HRMS (ESI) m/z calcd for $C_{22}H_{25}N_2O_3^+$ $(M+H)^+$ 365.1806, found 365.1861.



ethyl 2-fluoro-1-(hydroxy(phenyl)methyl)indolizine-3-carboxylate (7):

Yield 81%; 50 mg; gray solid; mp 110-112 °C; TLC (PE:EtOAc, 5:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.26 (d, *J* = 7.2 Hz, 1H), 7.44 (dd, *J* = 13.6, 8.4 Hz, 3H), 7.31 (t, *J* = 7.6 Hz,

2H), 7.24 (d, J = 8.0 Hz, 1H), 7.02–6.90 (m, 1H), 6.73 (t, J = 7.2 Hz, 1H), 6.22 (s, 1H), 4.36 (q, J = 7.2 Hz, 2H), 1.38 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.7, 160.6, 156.6, 154.0, 142.6, 132.11, 132.05, 128.3, 127.2, 127.1, 126.2, 125.6, 123.2, 117.53, 117.48, 112.93, 112.91, 102.9, 102.8, 100.2, 100.0, 66.7, 60.0, 14.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -142.49. HRMS (ESI) m/z calcd for $C_{18}H_{17}NFO_3^+$ $(M+K)^+$ 352.0746, found 352.0734.



ethyl 1,3-diphenylpyrido[3,4-a]indolizine-5-carboxylate (8):

Yield 63%; 49 mg; brown solid; mp 156-158 ℃; TLC (PE:EtOAc, 8:1 v/v); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.12 (d, J = 17.6 Hz, 1H), 8.54 (d, J = 8.0 Hz, 1H), 8.22 (t, J = 8.0 Hz, 1H), 7.80 (d, J = 14.8 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 7.58 (s, 1H), 7.49 (d, J = 7.2 Hz, 1H), 7.41 (d, J = 6.8 Hz, 1H), 7.28 (d, J = 6.0 Hz, 1H), 7.22 (s, 1H), 4.57 (d, J = 6.8 Hz, 1H), 1.60 (dd, J = 13.6, 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.4, 156.1, 152.2, 140.6, 140.4, 135.8, 133.5, 129.1, 129.0, 128.7, 128.6, 128.3, 128.0, 127.4, 123.8, 119.6, 118.0, 112.4, 108.1, 104.5, 59.9, 14.8. HRMS (ESI) m/z calcd for $C_{26}H_{21}N_2O_2^+$ $(M+H)^+$ 393.1598, found 393.1600.

7. Crystallographic data and mole cular structure of 4b

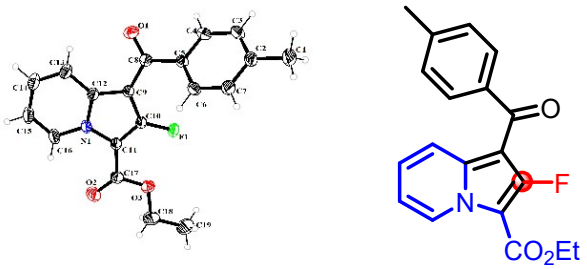


Figure S1. X-ray crysta structure of **4b** with 30% probability ellipsoids (ORTEP)

Crystal Data for Compound **4b**: CCDC 2307698 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic.

Sample preparation: In a 10 mL glass bottle, 15 mg of pure **4b** was completely dissolved in the mixed solvent of 3 mL $CHCl_2$, and then 2 mL of n-hexane was added slowly. After a week of solvent evaporation, some yellow transparent crystals were obtained. The crystals were mounted on a glass fiber for diffraction experiments. Intensity data were collected on a Bruker SMART APEX CCD diffractometer with Mo Kα radiation (0.71073 Å) at room temperature.

```
Bond precision:   C-C = 0.0023 A          Wavelength=0.71073

Cell:             a=20.904(3)     b=8.9557(13)          c=18.757(3)
                  alpha=90        beta=114.114(2)       gamma=90
Temperature:      296 K

                 Calculated                Reported
Volume           3205.1(8)                 3205.2(8)
Space group      C 2/c                     C 1 2/c 1
Hall group       -C 2yc                    -C 2yc
Moiety formula   C19 H16 F N O3            C19 H16 F N O3
Sum formula      C19 H16 F N O3            C19 H16 F N O3
Mr               325.33                    325.33
Dx,g cm-3        1.348                     1.348
Z                8                         8
Mu (mm-1)        0.099                     0.099
F000             1360.0                    1360.0
F000'            1360.75
h,k,lmax         31,13,27                  30,13,27
Nref             5533                      5150
Tmin,Tmax        0.977,0.985               0.671,0.746
Tmin'            0.971

Correction method= # Reported T Limits: Tmin=0.671 Tmax=0.746
AbsCorr = MULTI-SCAN

Data completeness= 0.931          Theta(max)= 31.942

R(reflections)= 0.0612( 4041)                wR2(reflections)=
                                             0.1901( 5150)
S = 1.087                 Npar= 220
```

Crystallographic data and mole cular structure of 5a

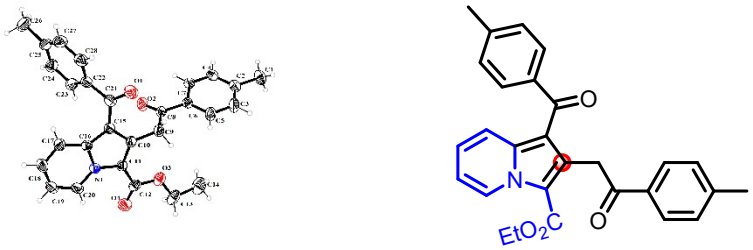


Figure S2. X-ray crysta structure of **5a** with 50% probability ellipsoids (ORTEP)

Crystal Data for Compound **5a**: CCDC 2307706 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic.

Sample preparation: In a 10 mL glass bottle, 15 mg of pure **5a** was completely dissolved in the mixed solvent of 3 mL $CHCl_2$, and then 2 mL of n-hexane was added slowly. After a week of solvent evaporation, some yellow transparent crystals were obtained. The crystals were mounted on a glass fiber for diffraction experiments. Intensity data were collected on a Bruker SMART APEX CCD diffractometer with Mo Kα radiation (0.71073 Å) at room temperature.

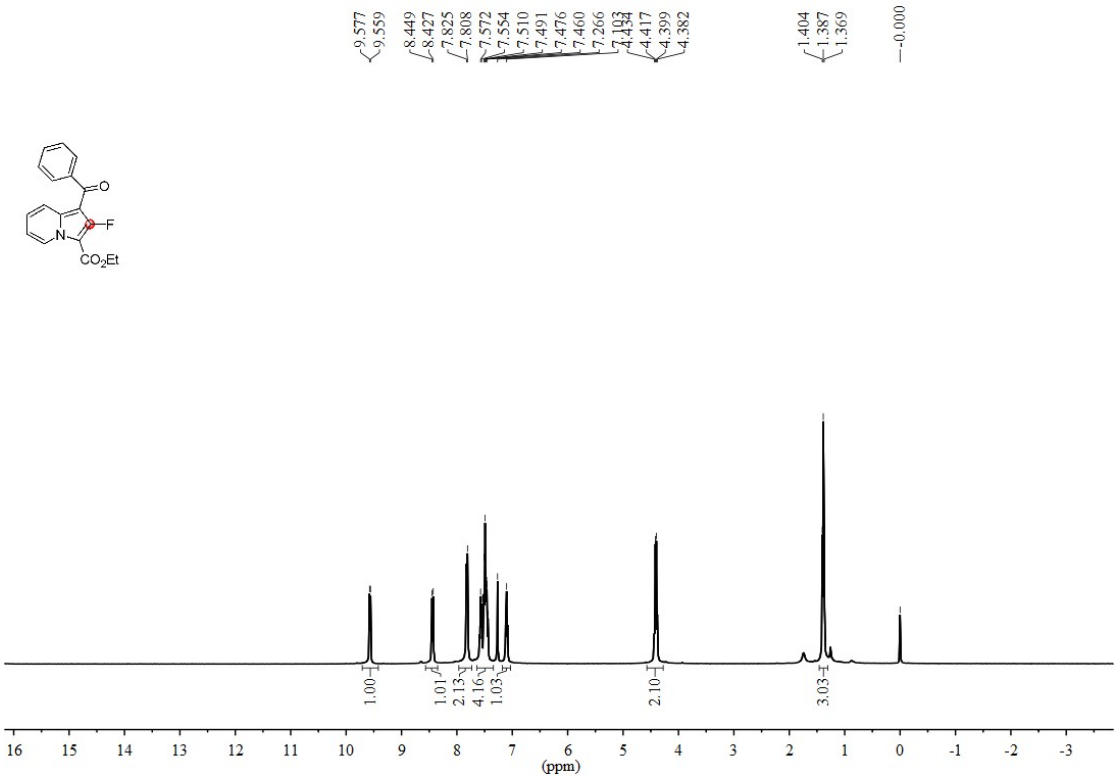
```
Bond precision:   C-C = 0.0029 A          Wavelength=0.71073

Cell:          a=9.4887(19)      b=11.208(2)      c=11.879(2)
               alpha=78.444(3)   beta=73.977(3)   gamma=82.966(3)
Temperature:   296 K

                Calculated                Reported
Volume          1186.6(4)                 1186.6(4)
Space group     P -1                      P -1
Hall group      -P 1                      -P 1
Moiety formula  C28 H25 N O4              C28 H25 N O4
Sum formula     C28 H25 N O4              C28 H25 N O4
Mr              439.49                    439.49
Dx,g cm-3       1.230                     1.230
Z               2                         2
Mu (mm-1)       0.082                     0.082
F000            464.0                     464.0
F000'           464.22
h,k,lmax        13,16,17                  13,16,17
Nref            7959                      7238
Tmin,Tmax       0.985,0.992               0.640,0.746
Tmin'           0.984

Correction method= # Reported T Limits: Tmin=0.640 Tmax=0.746
AbsCorr = MULTI-SCAN

Data completeness= 0.909          Theta(max)= 31.585

R(reflections)= 0.0650( 4283)                wR2(reflections)=
                                             0.2252( 7238)
S = 1.056                 Npar= 302
```

8. References

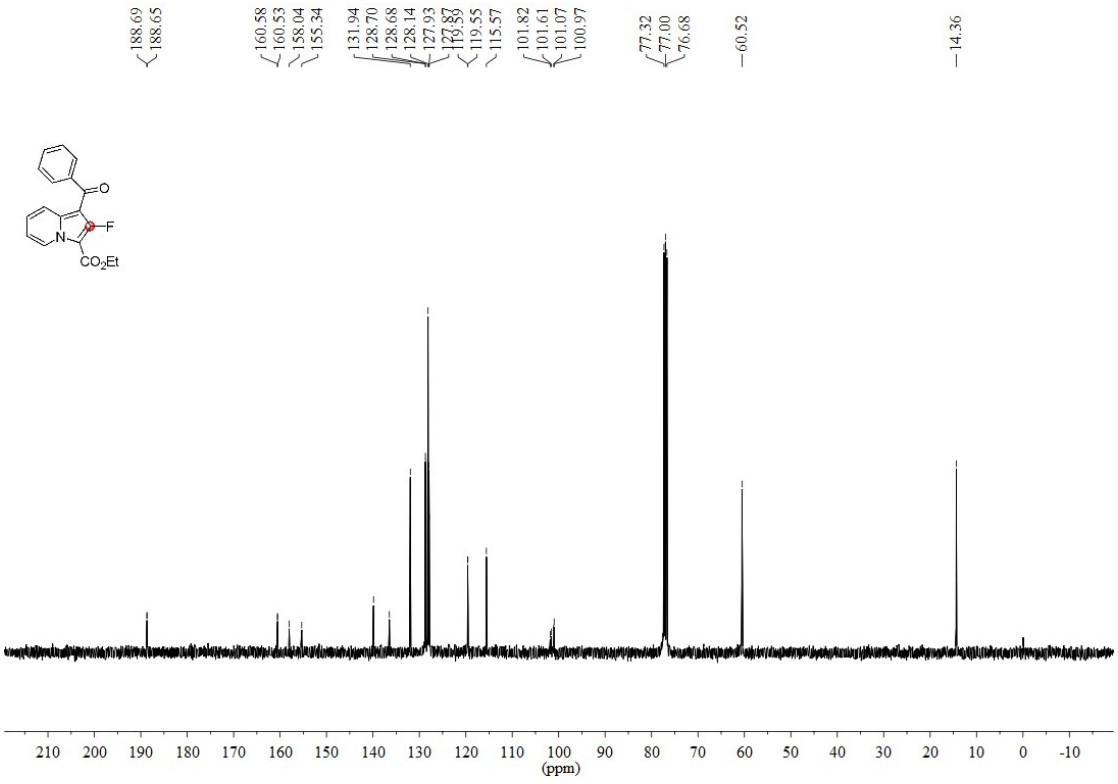
(1) (a) J. Vaitla, A. Bayer and K. H. Hopmann, *Angew. Chem. Int. Ed.*, **2017**, 56, 4277; (b) M. Barday, C. Janot, N. R. Halcovitch, J. Muir and C. Aïssa, *Angew. Chem. Int. Ed.,* **2017**, 56, 13117; (c) Y. Xu, X. Zhou, G. Zheng and X. Li, *Org. Lett.*, **2017**, 19, 5256; (d) C. Janot, P. Palamini, B. C. Dobson, J. Muir and C. Aïssa, *Org. Lett.*, **2018**, 21, 296. (e) J. Q. Zhang, D. D. Hu, J. Y. Song and H. J. Ren, *J. Org. Chem.*, **2021**, 86, 4646-4660.

9. NMR spectra of compounds

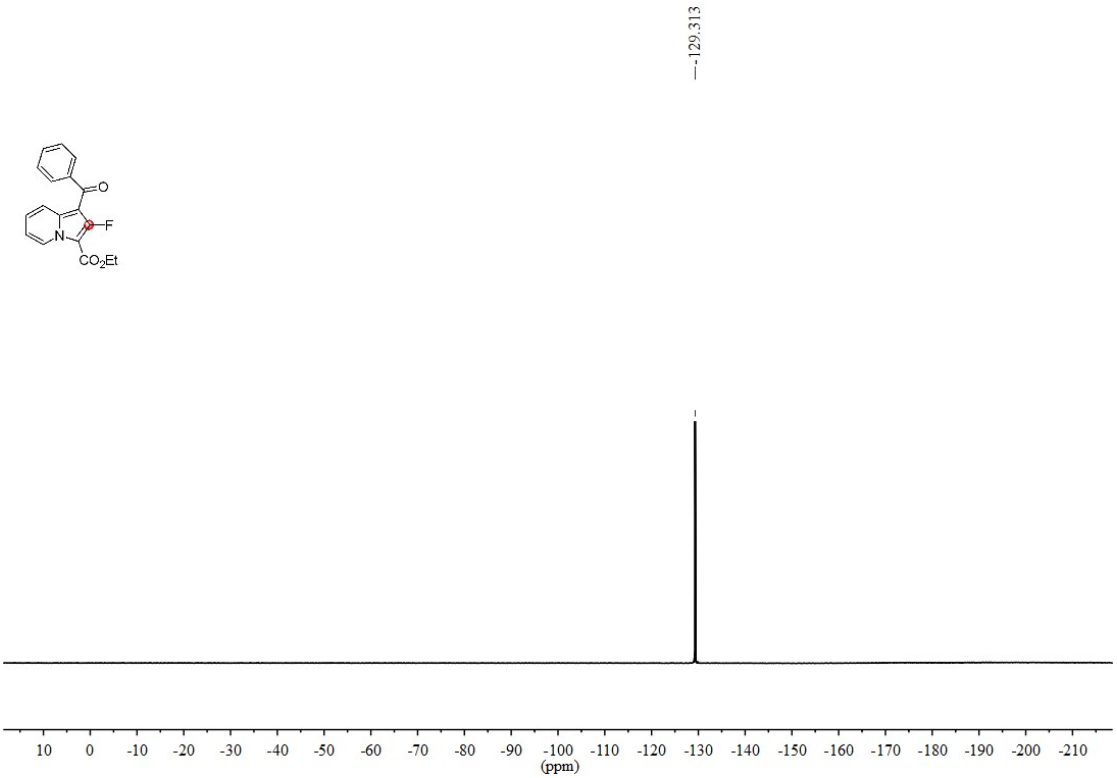
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4a**



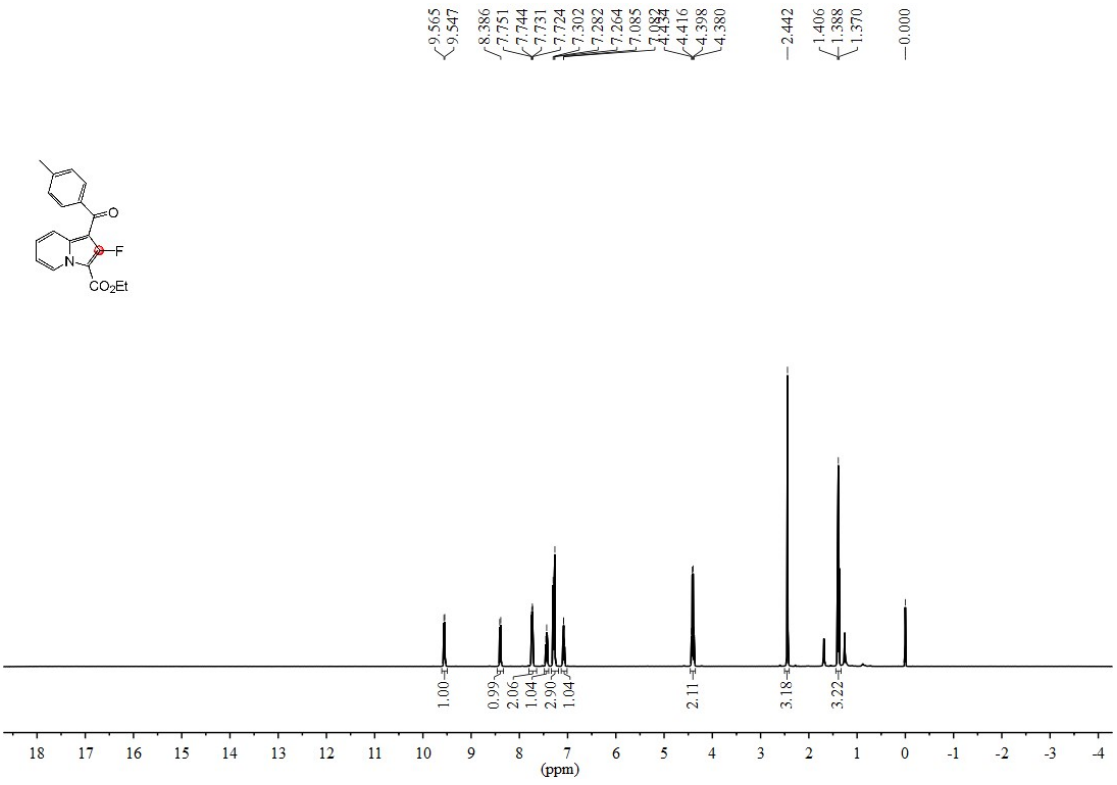
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4a**



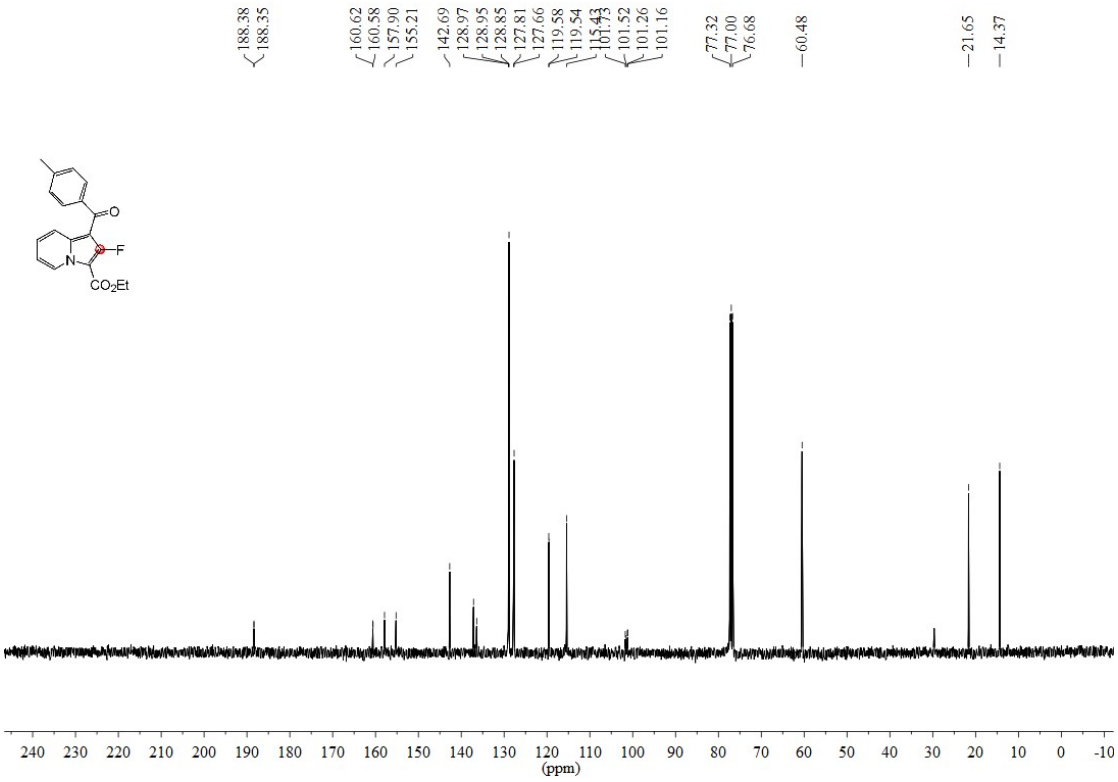
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4a**



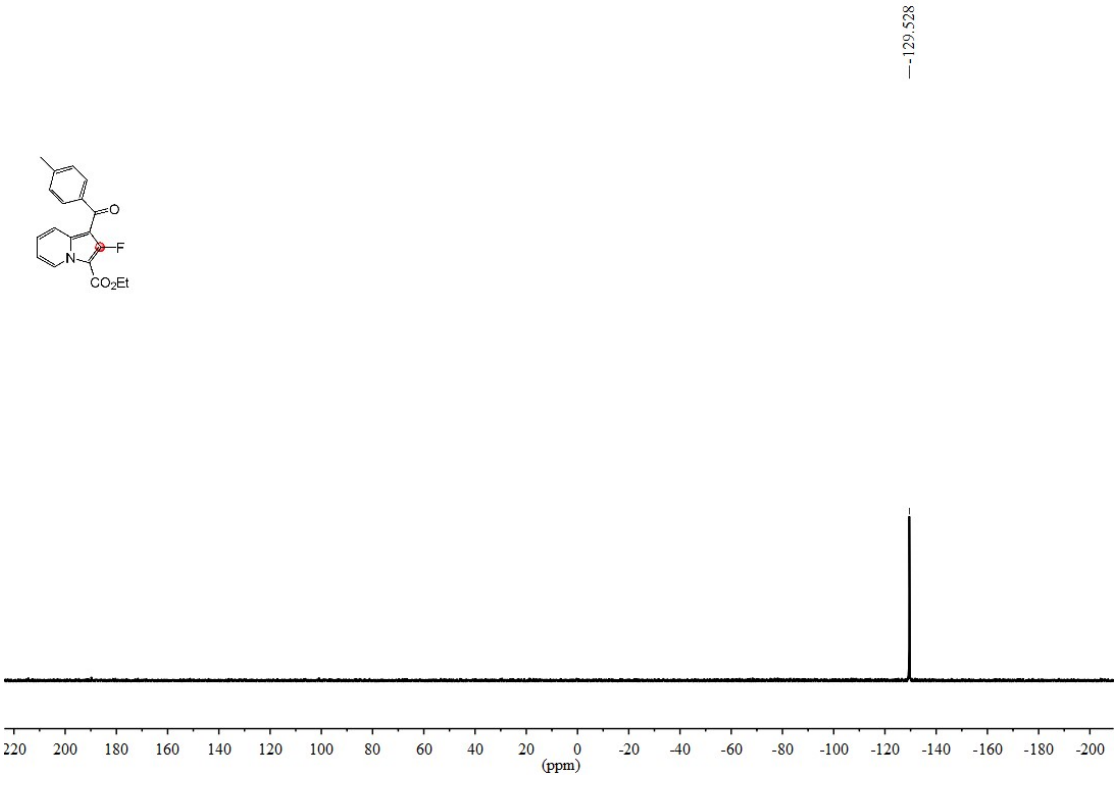
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4b**



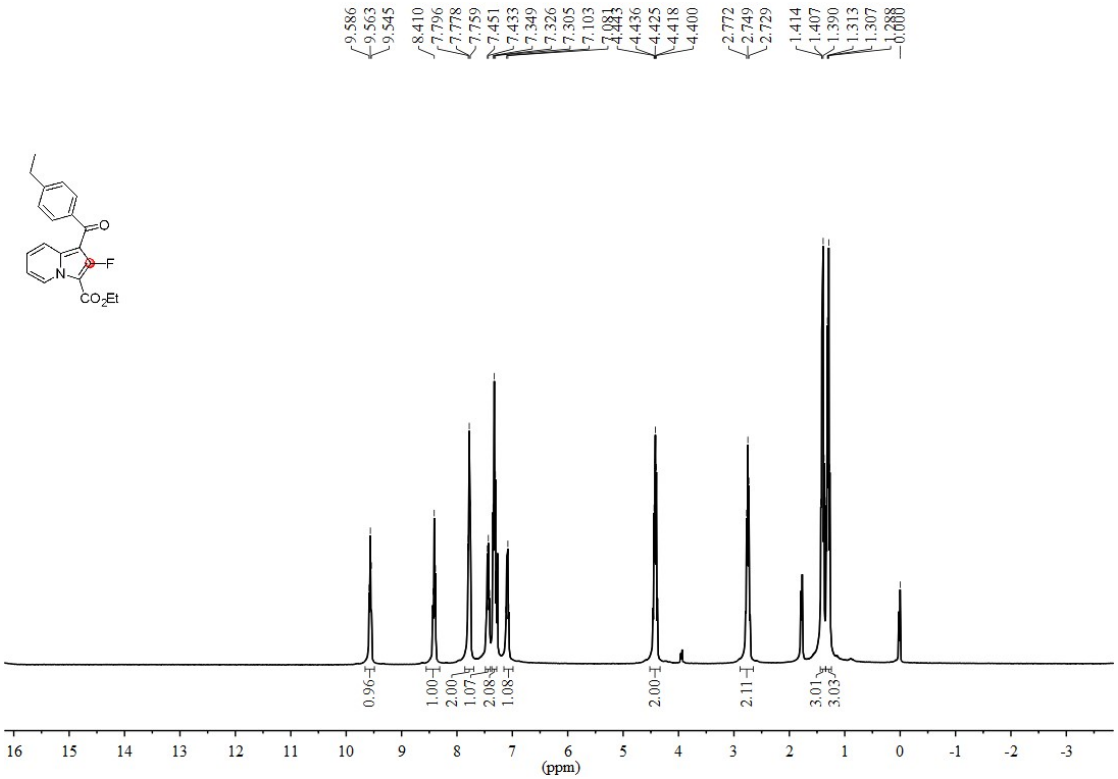
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4b**



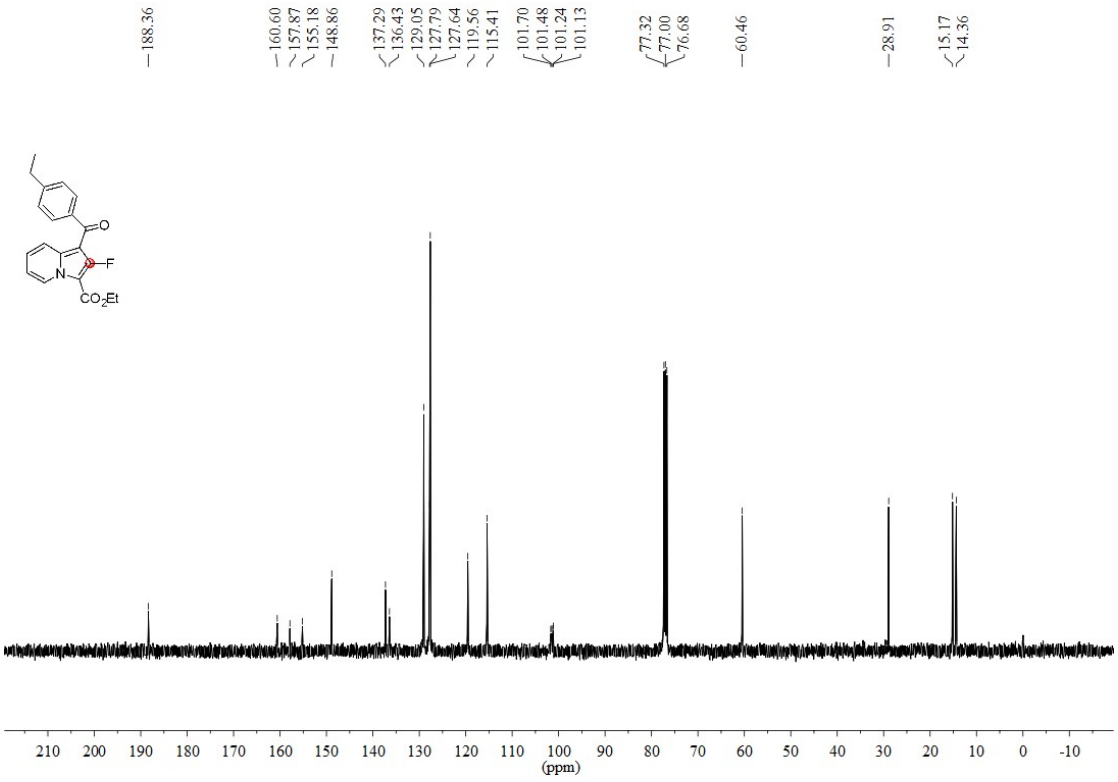
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4b**



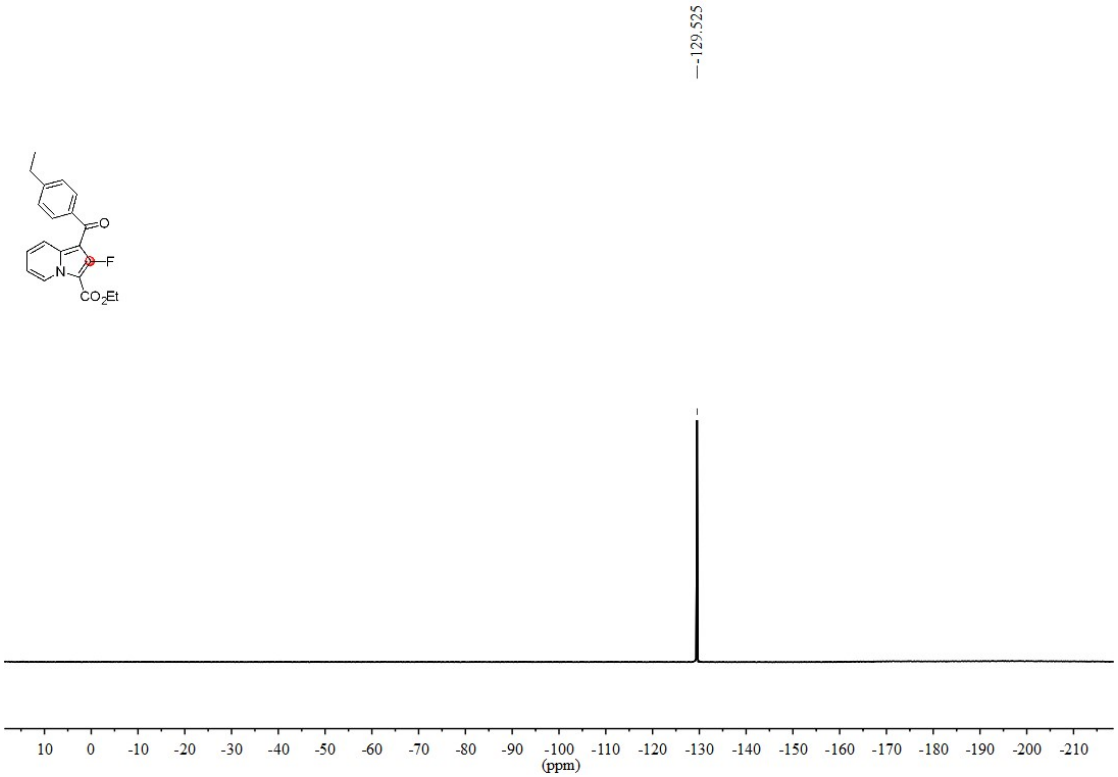
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4c**



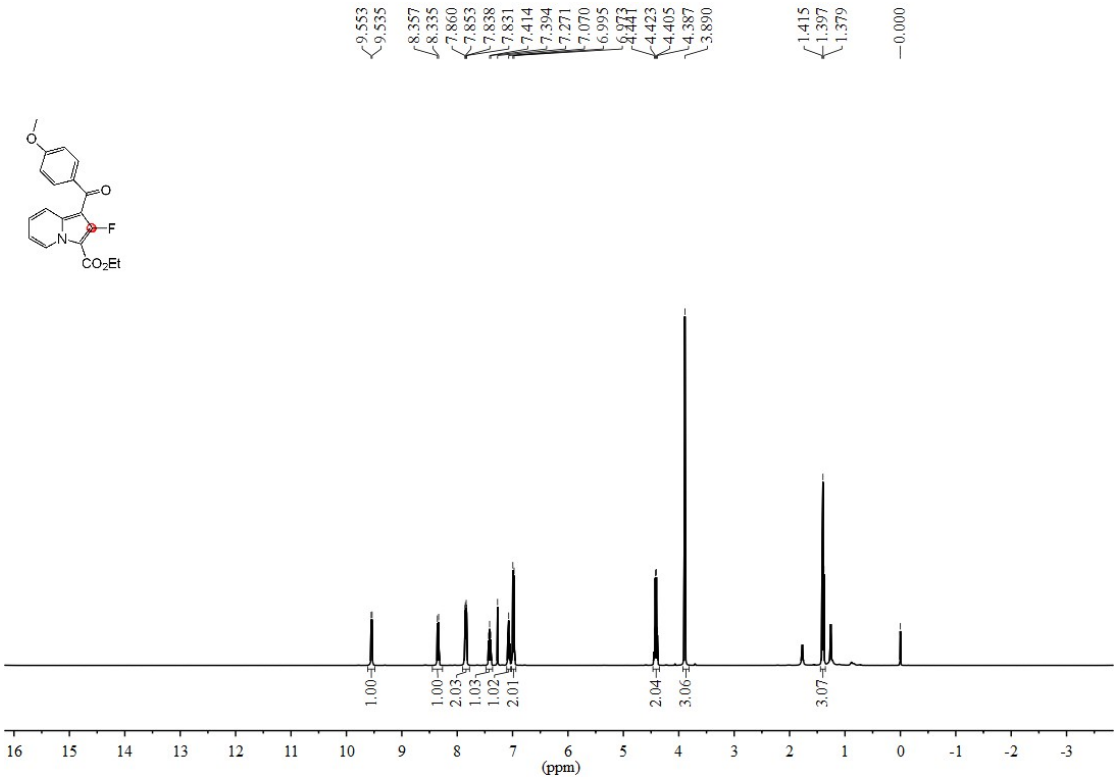
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4c**



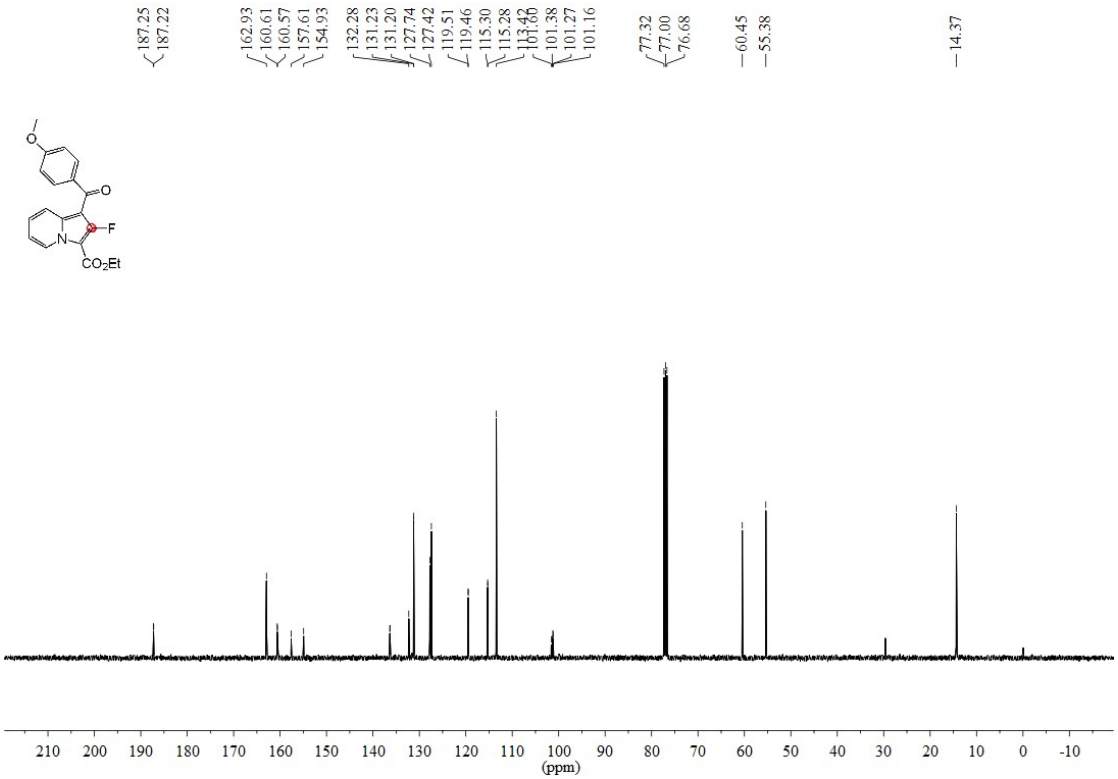
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4c**



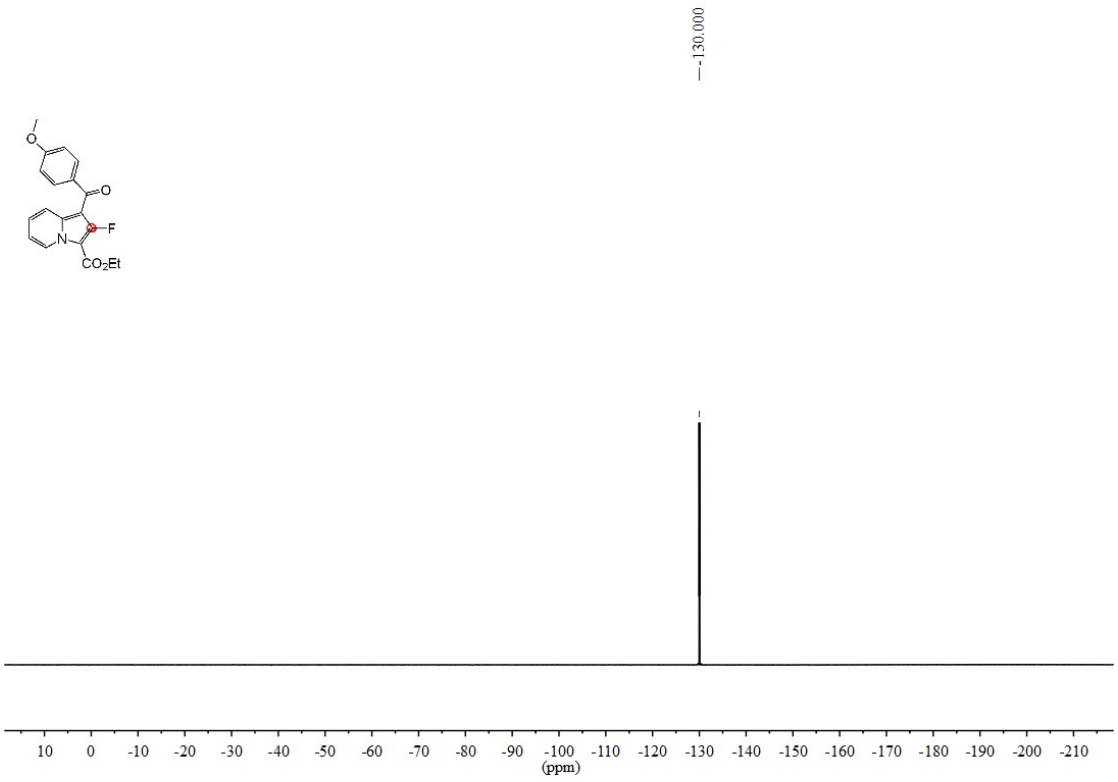
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4d**



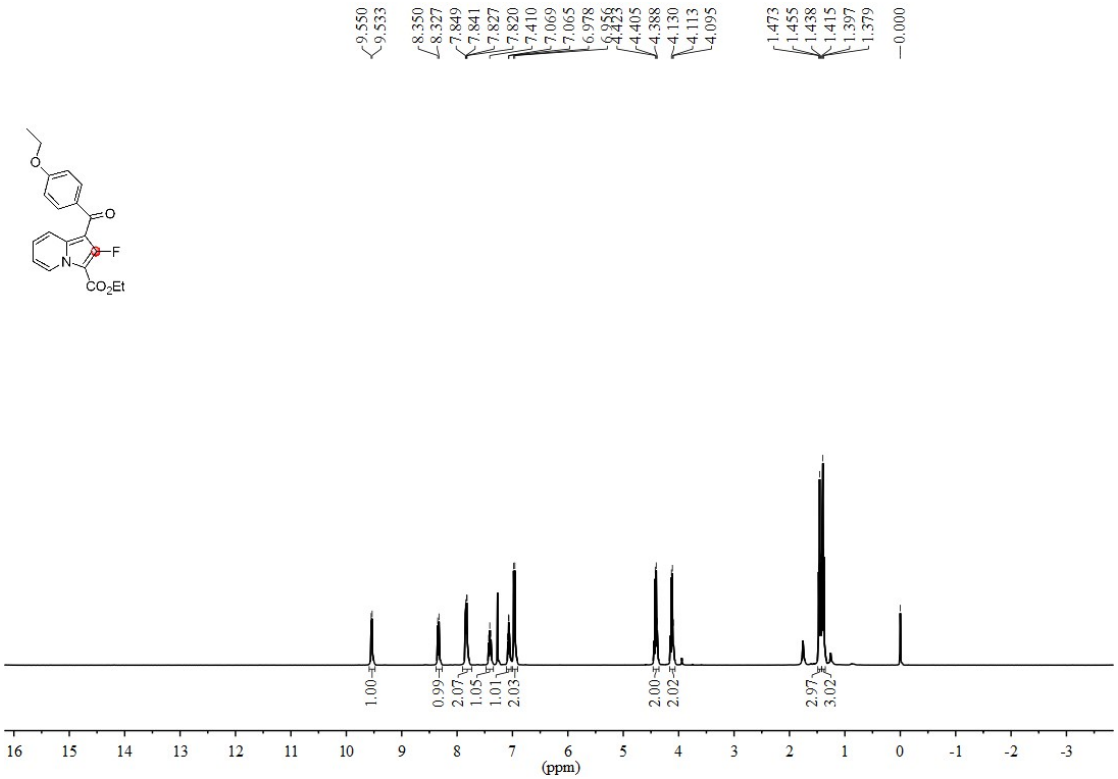
^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) of compound **4d**



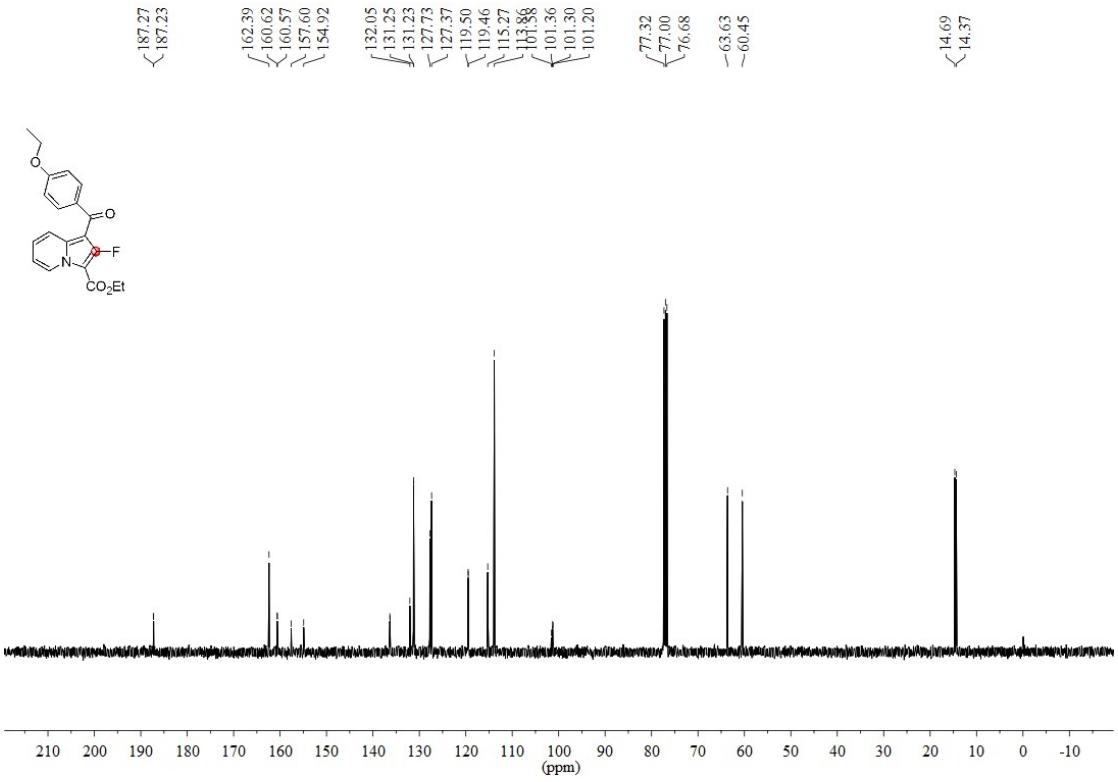
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4d**



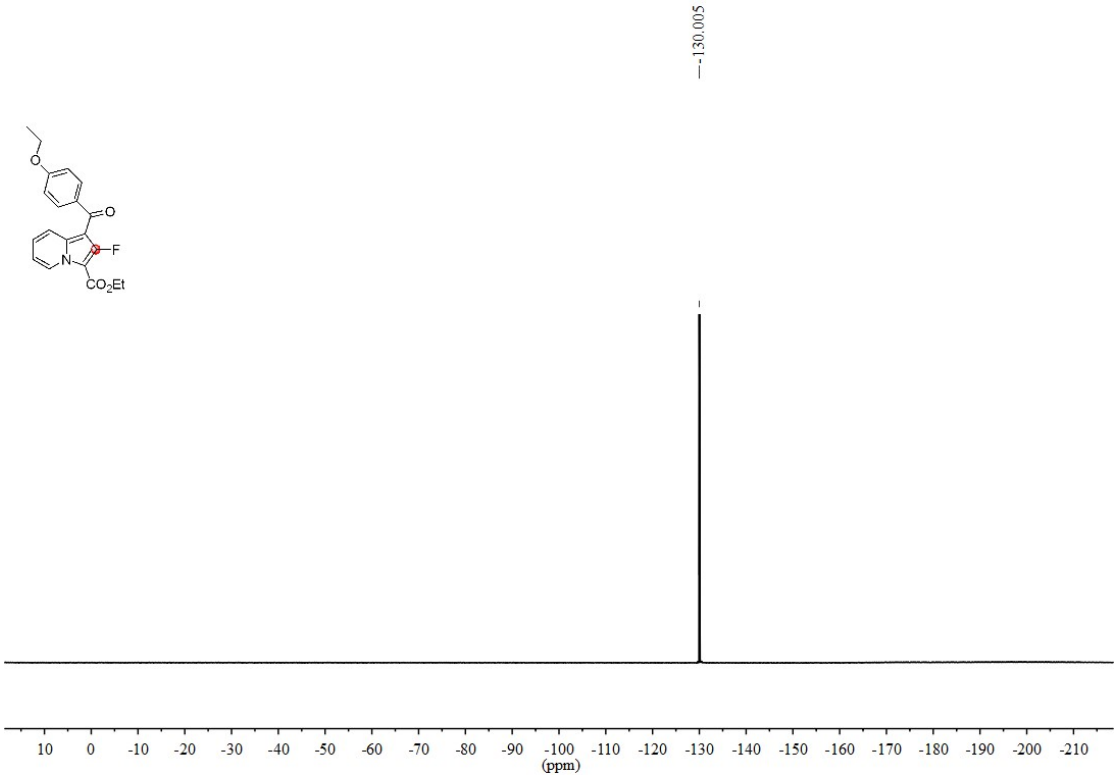
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4e**



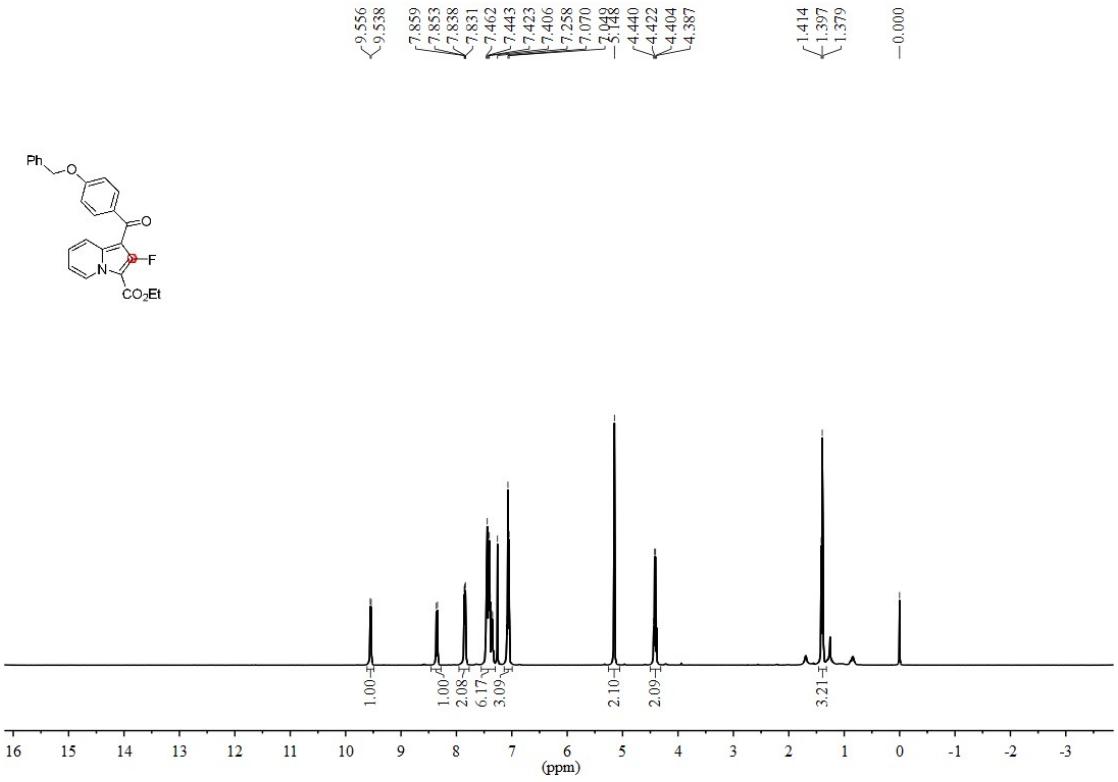
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4e**



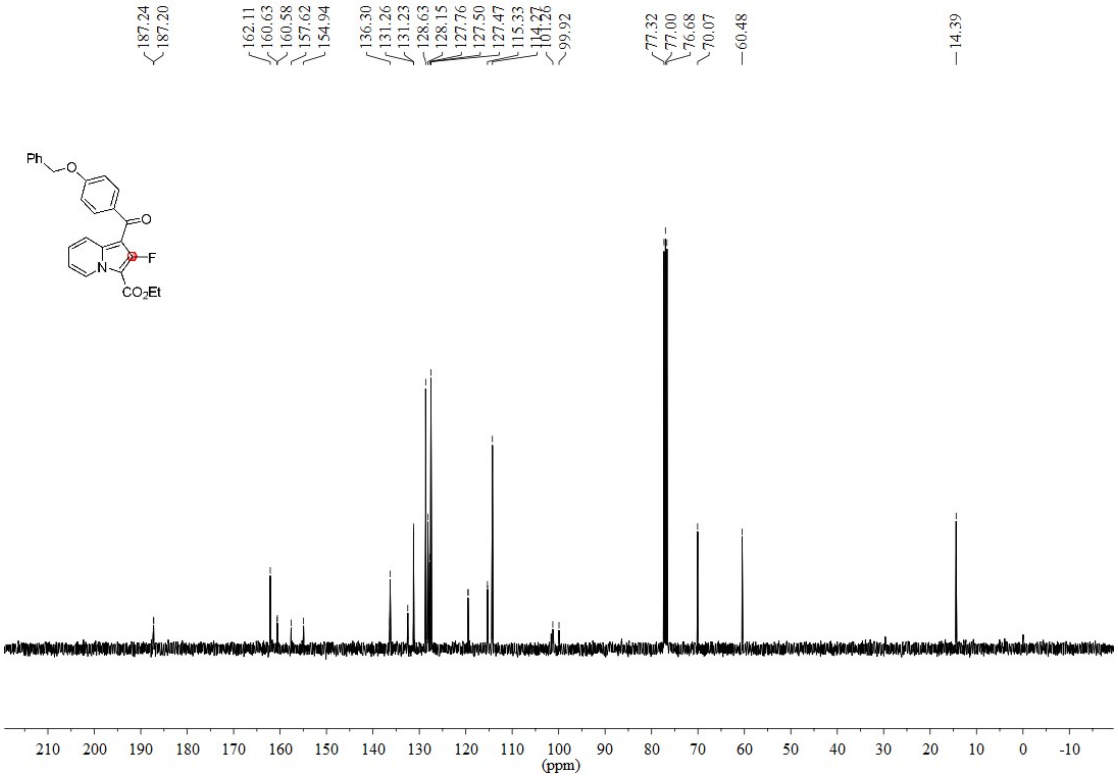
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4e**



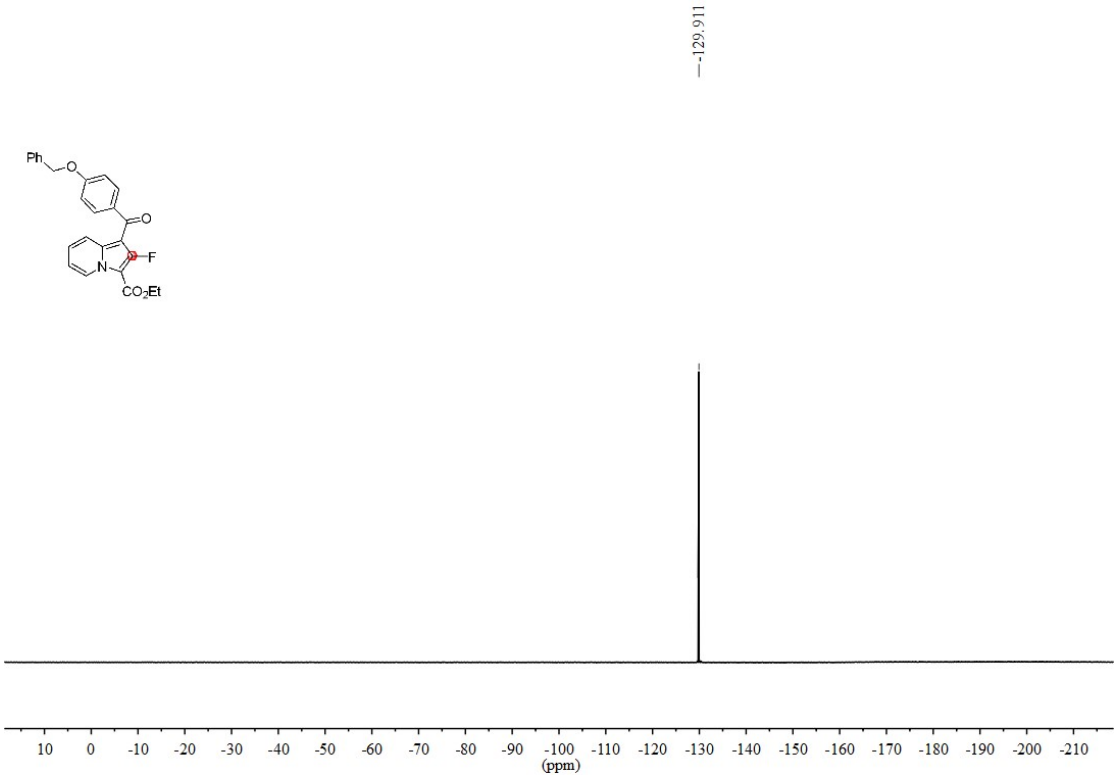
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4f**



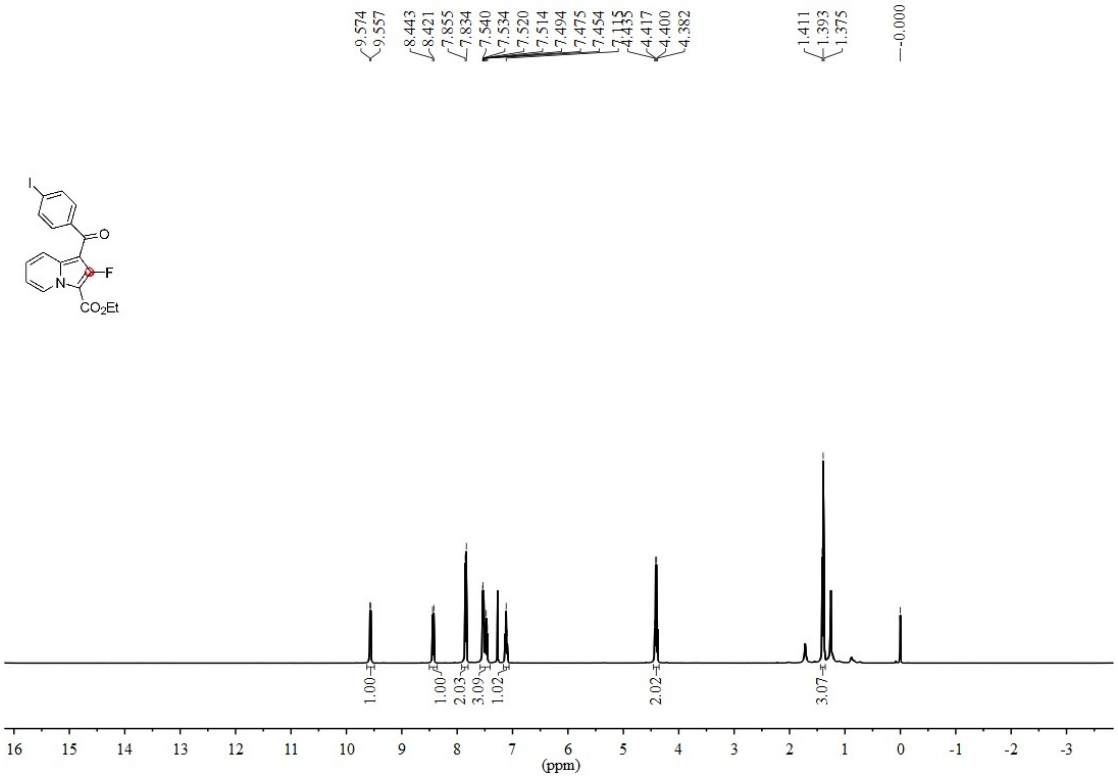
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4f**



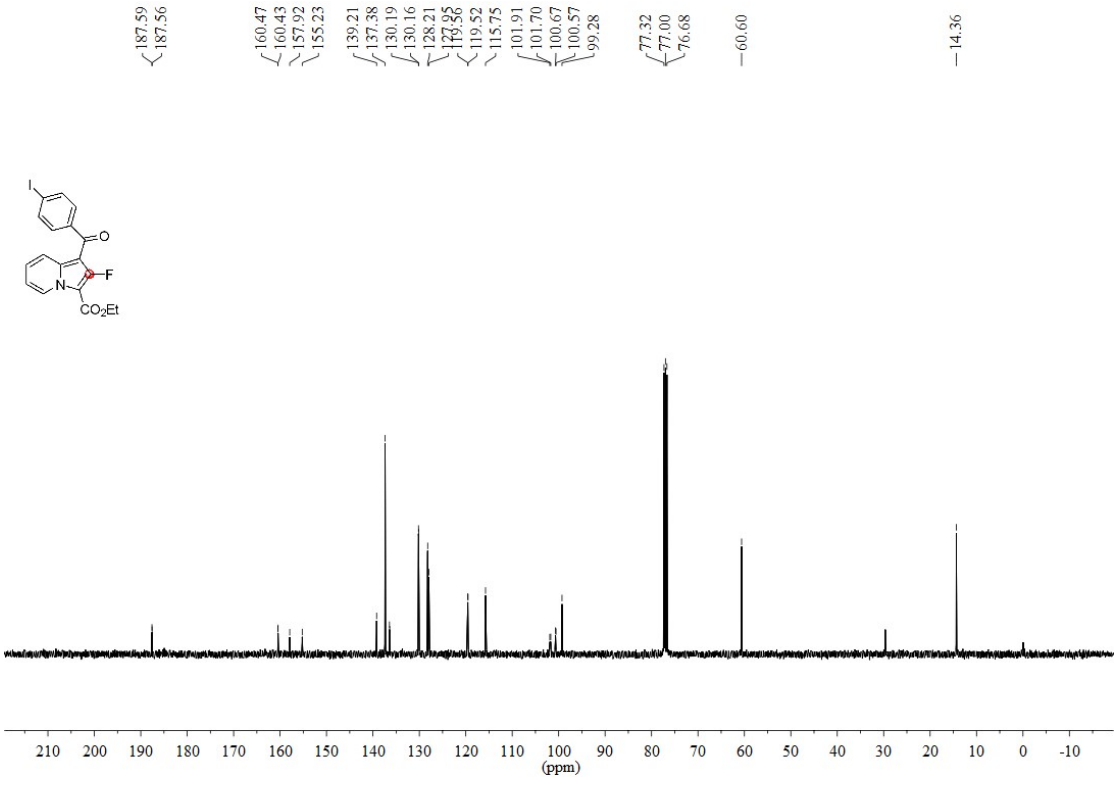
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4f**



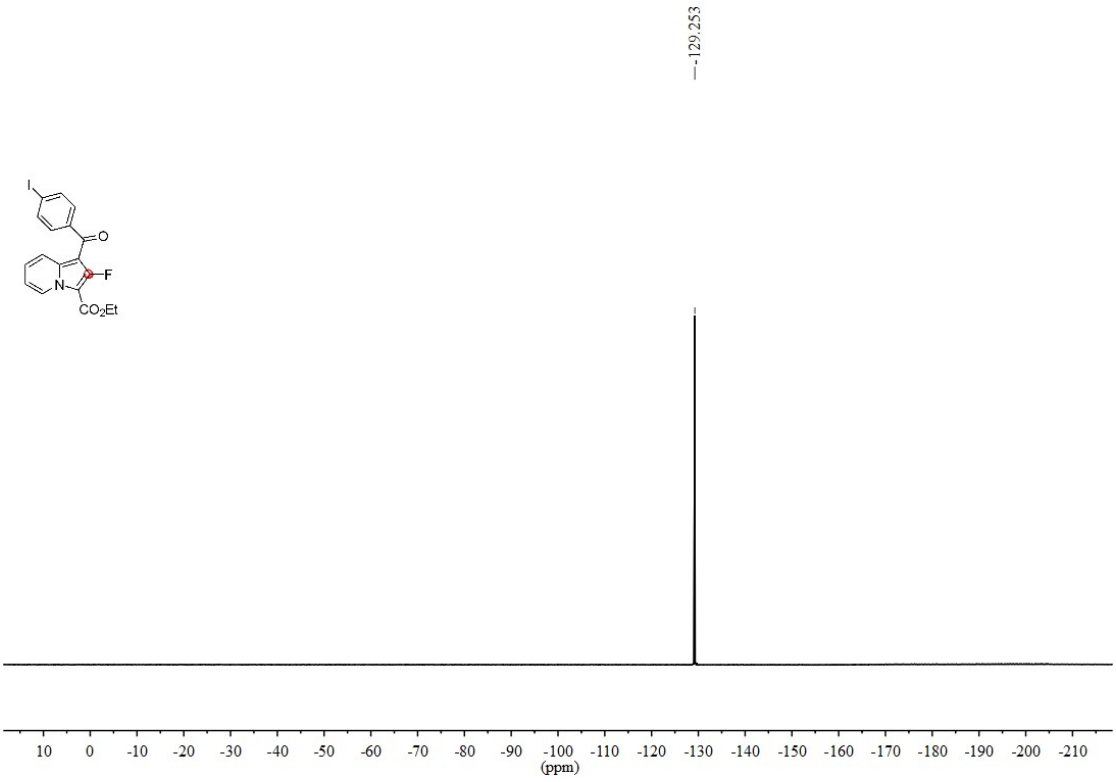
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4g**



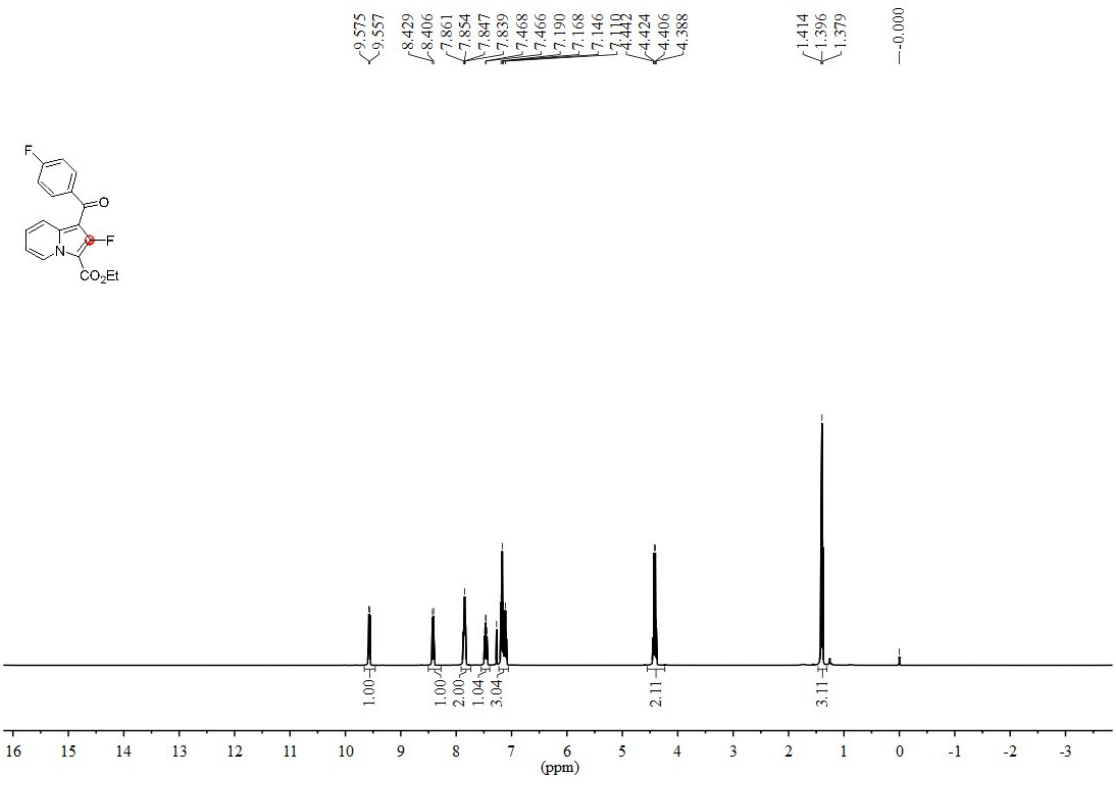
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4g**



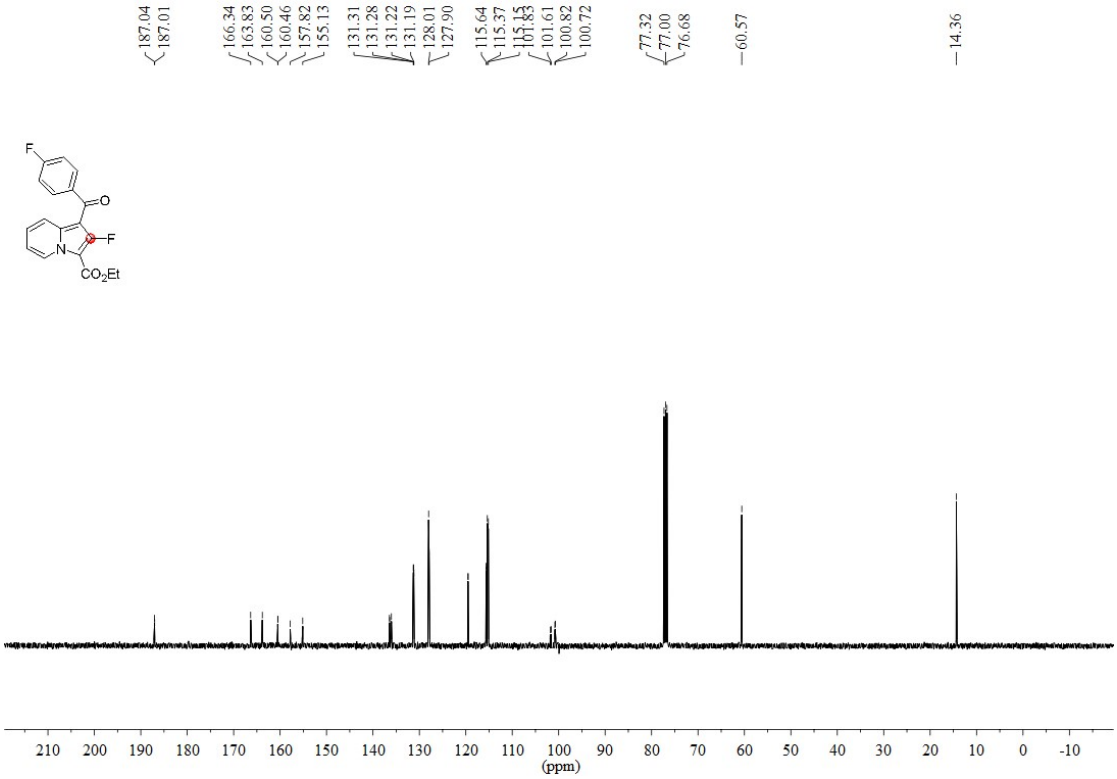
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4g**



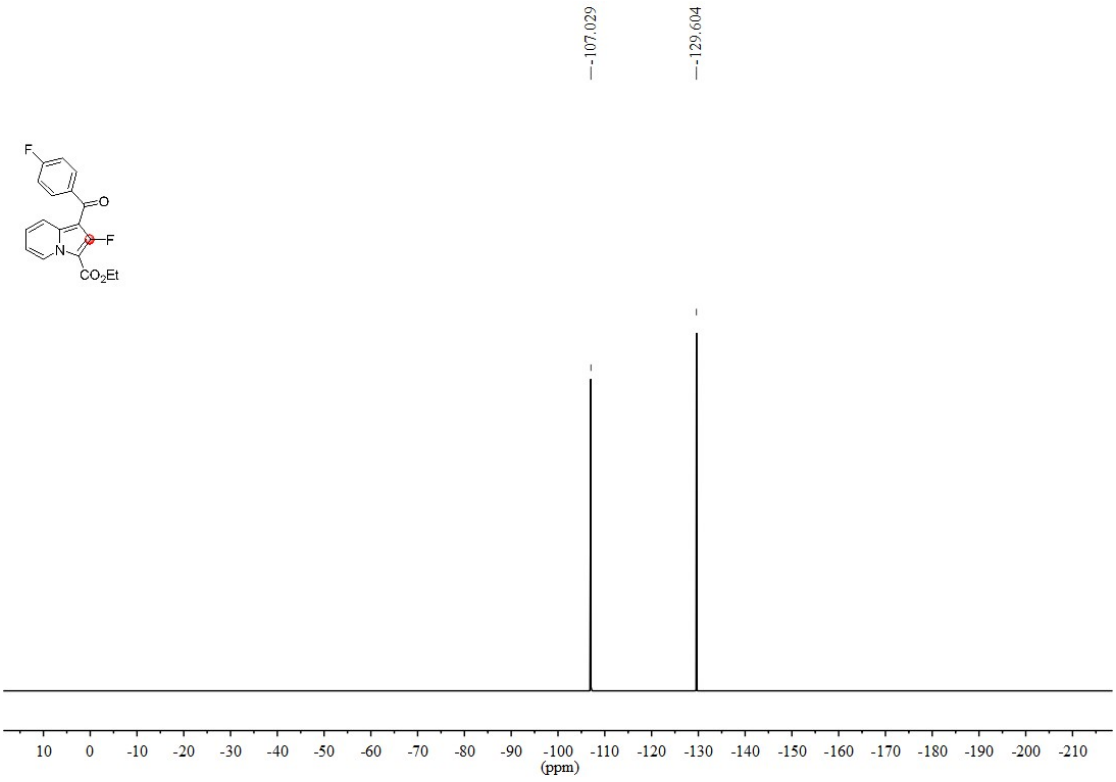
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4h**



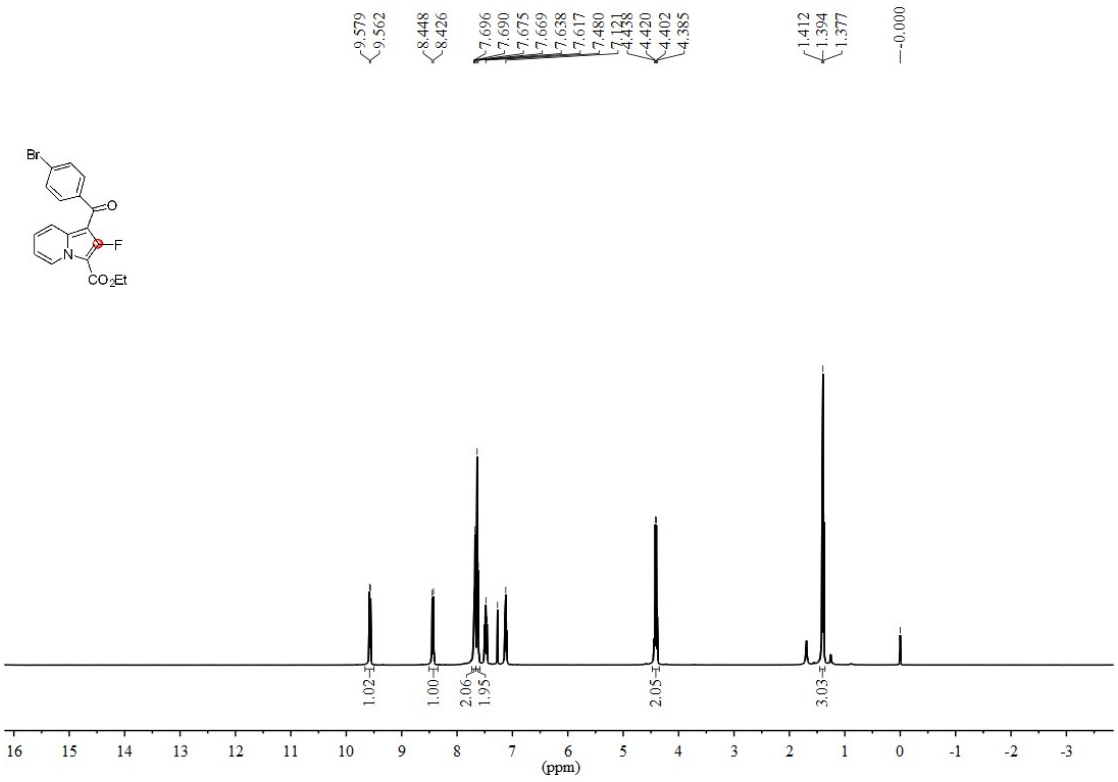
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4h**



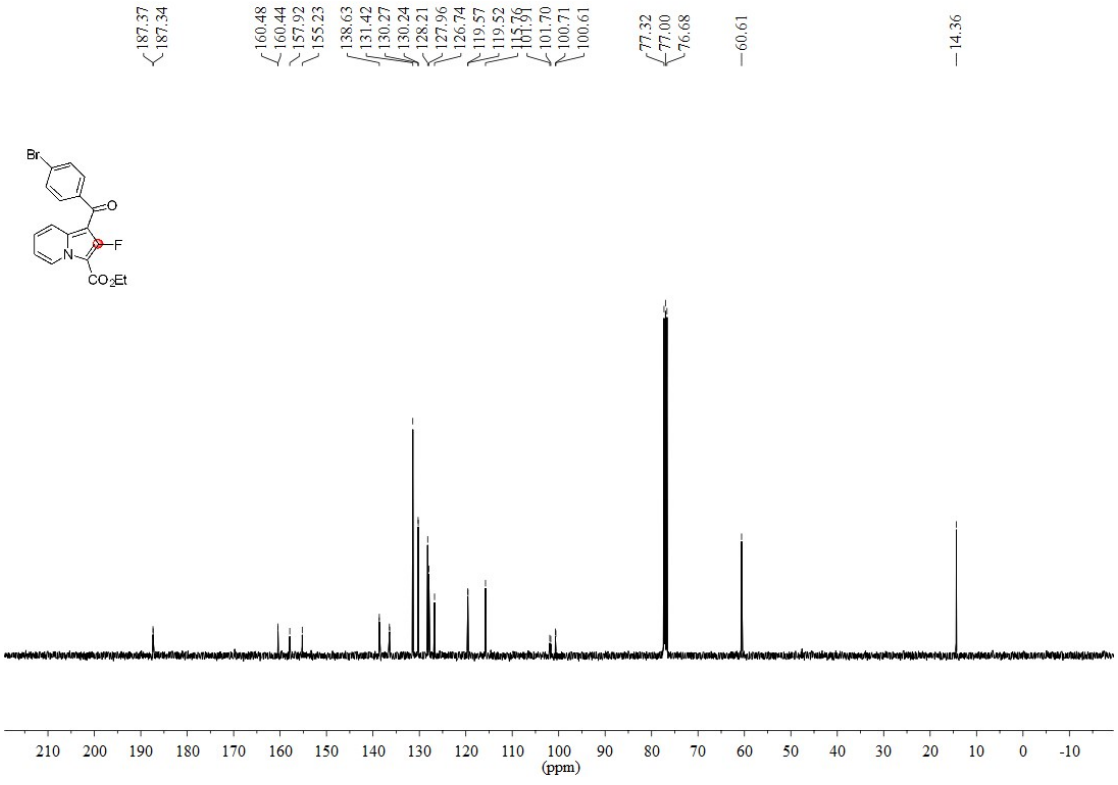
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4h**



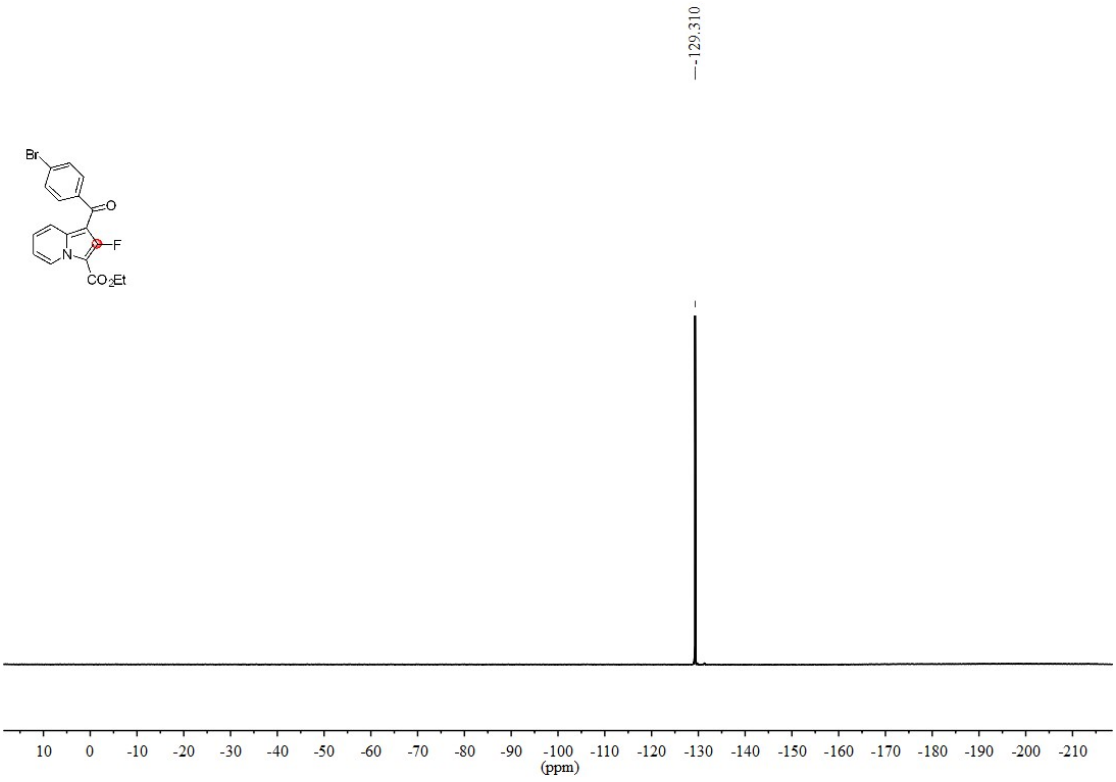
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4i**



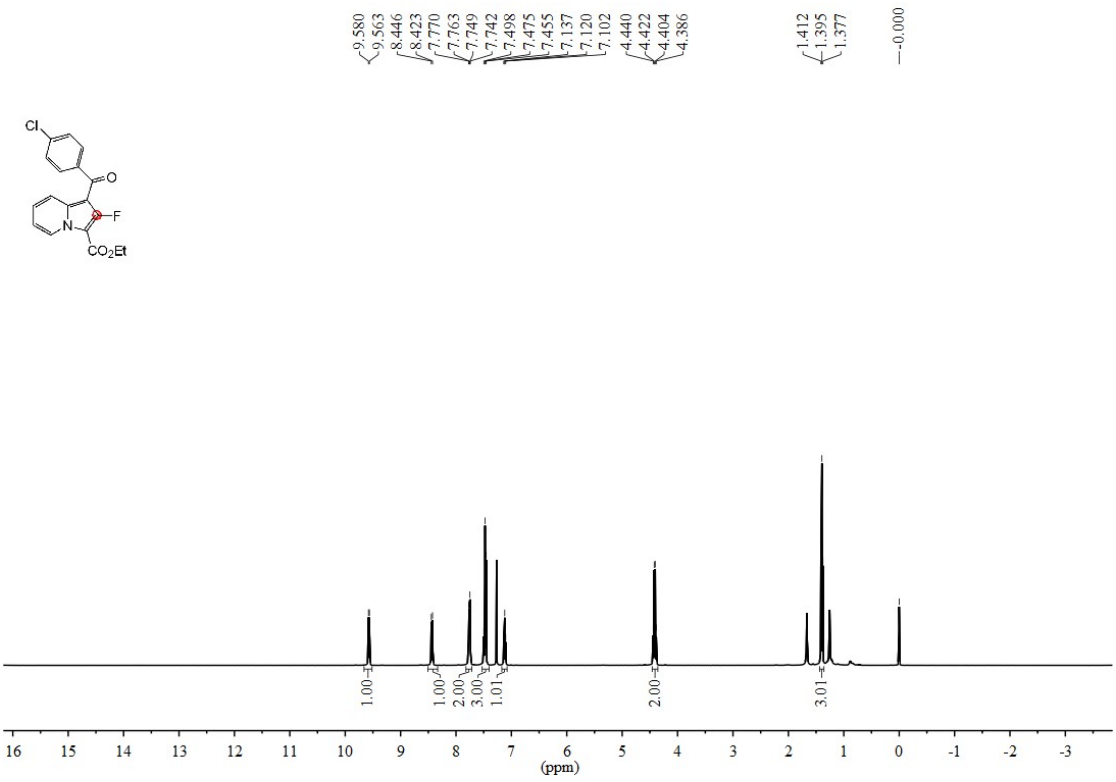
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4i**



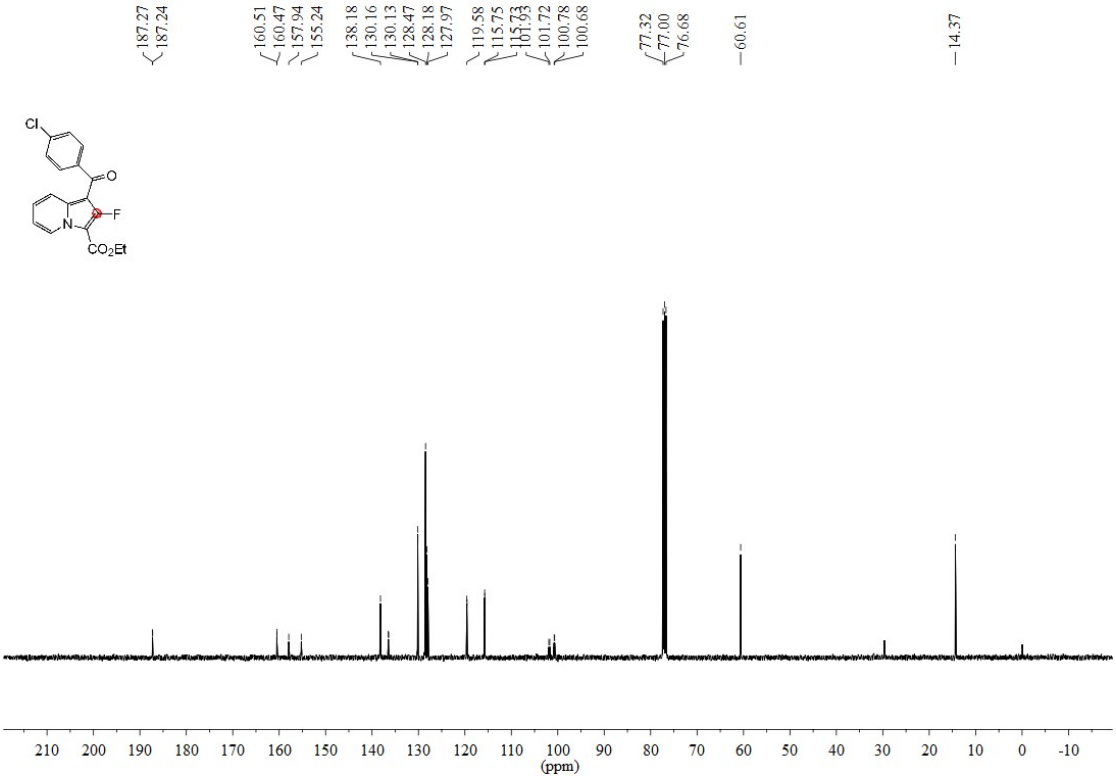
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4i**



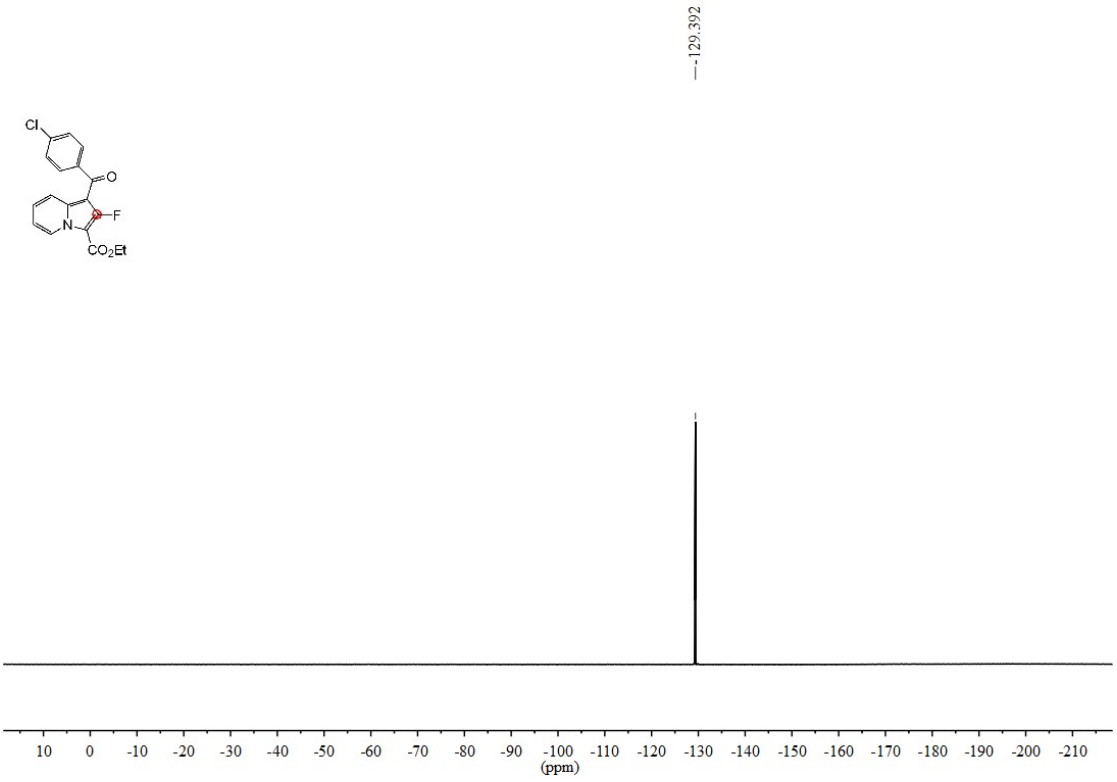
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4j**



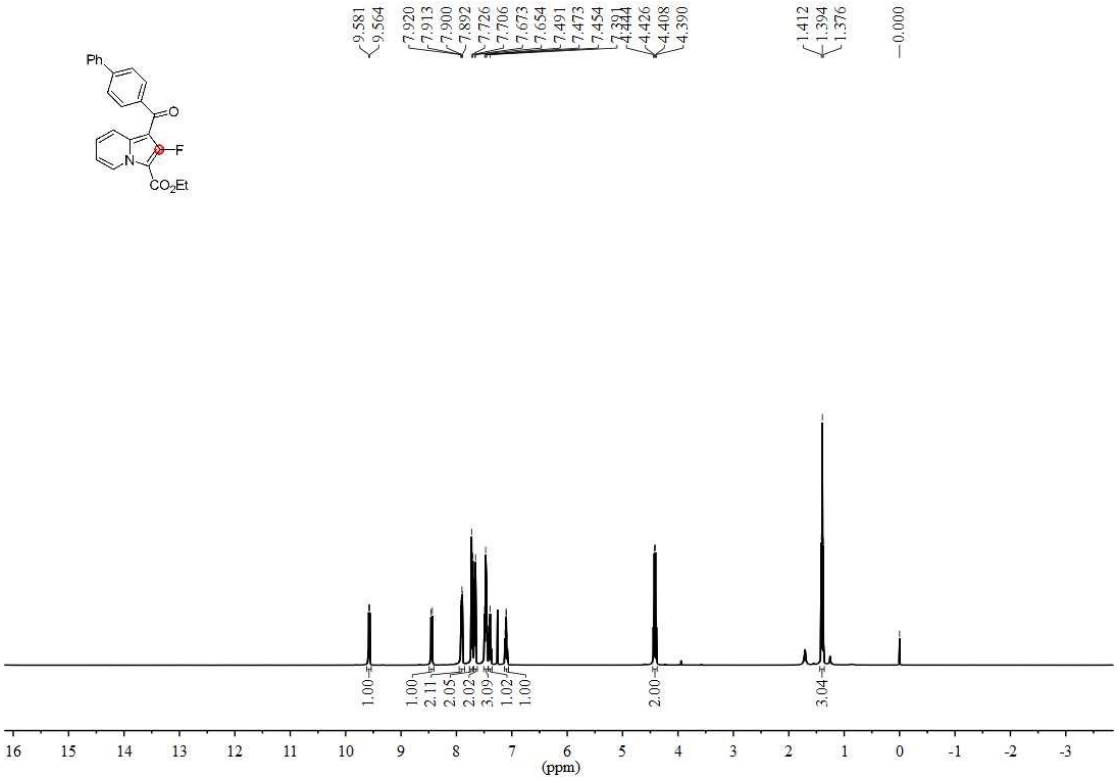
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4j**



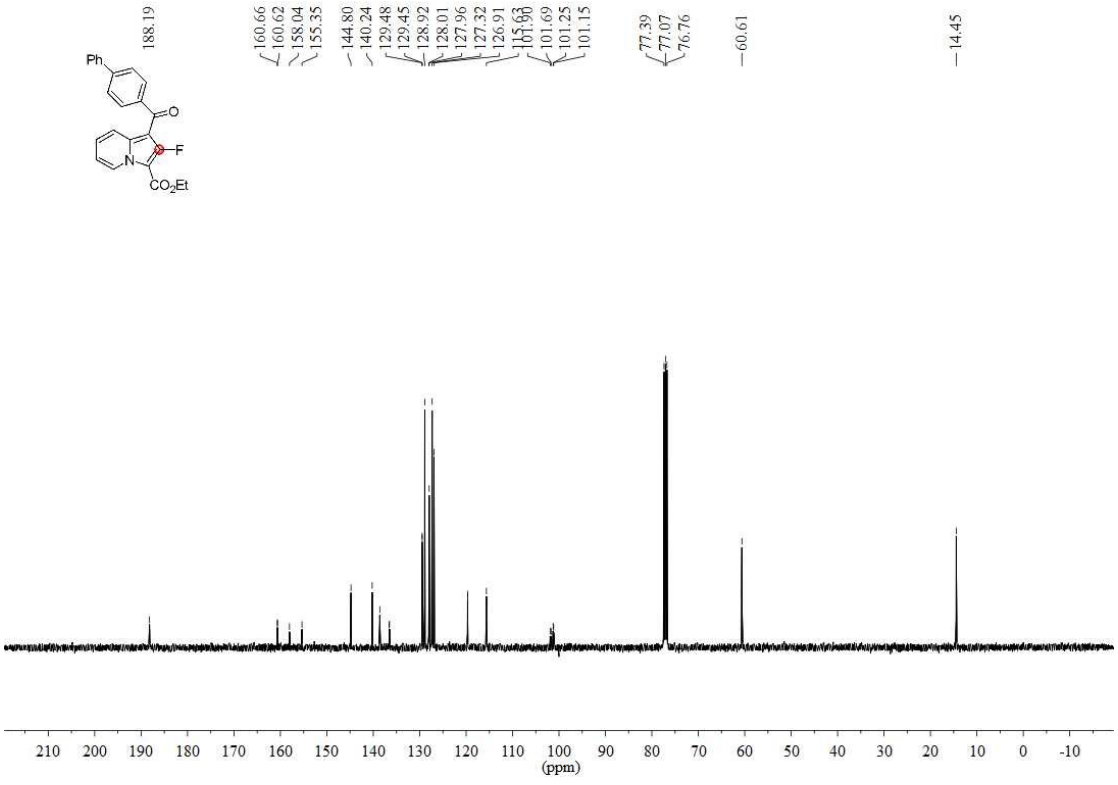
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4j**



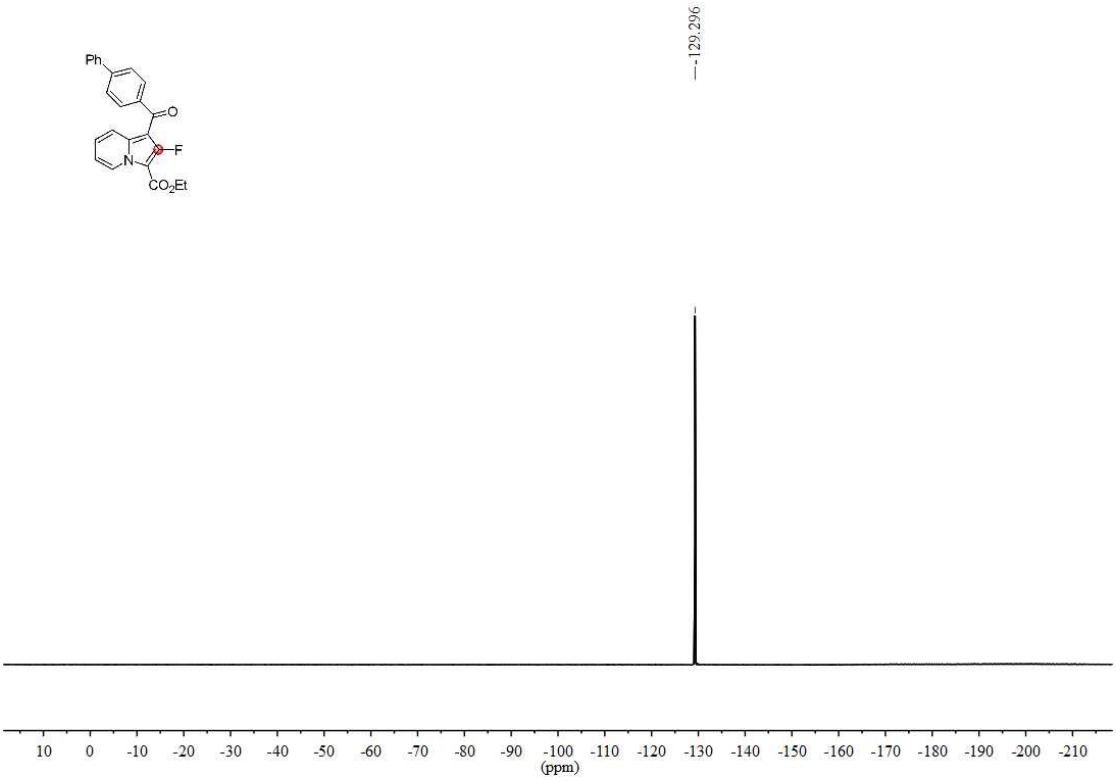
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4k**



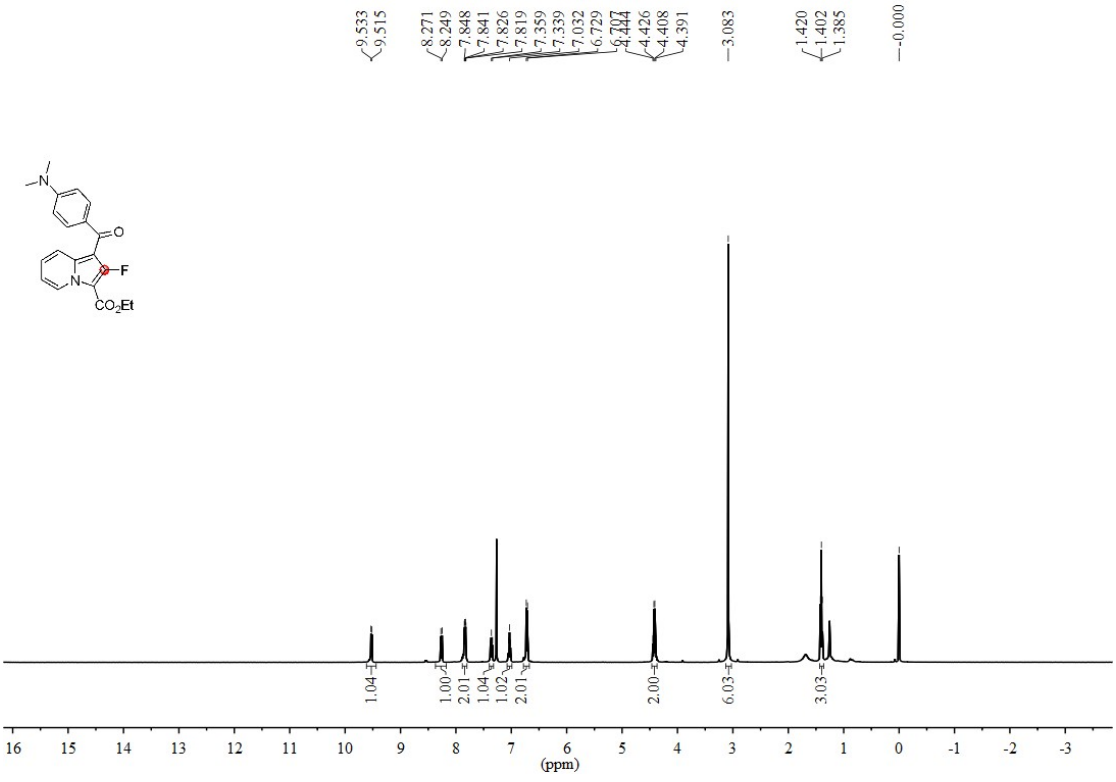
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4k**



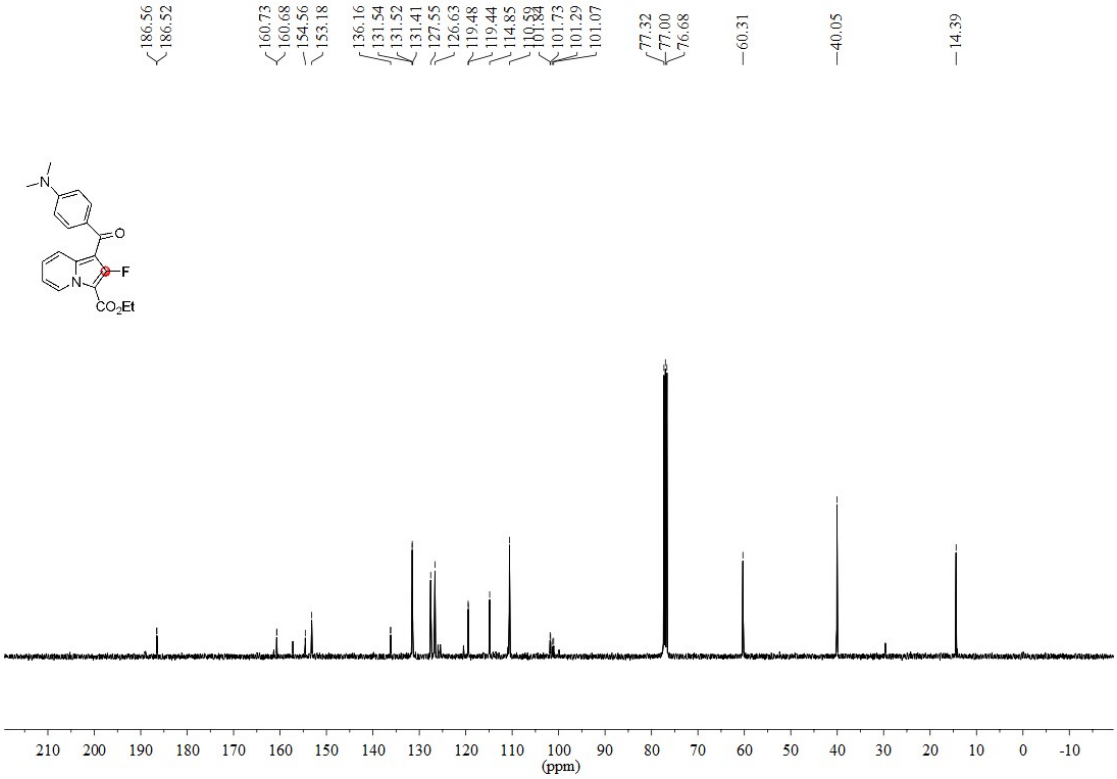
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4k**



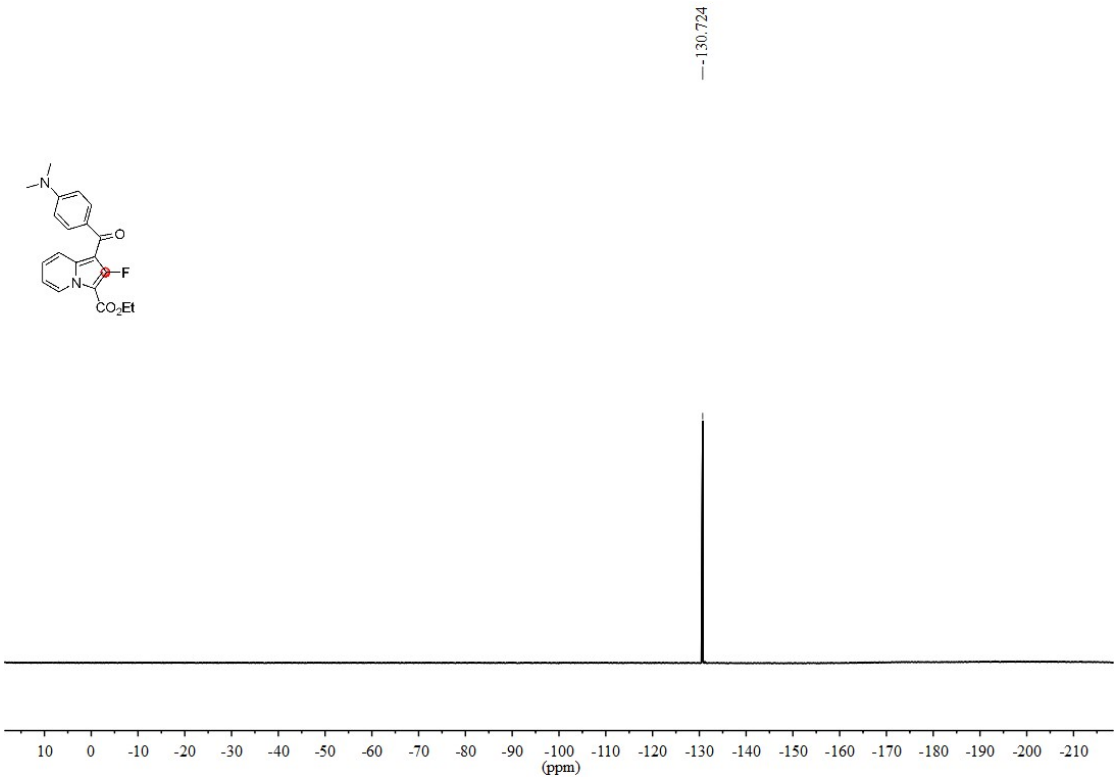
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4l**



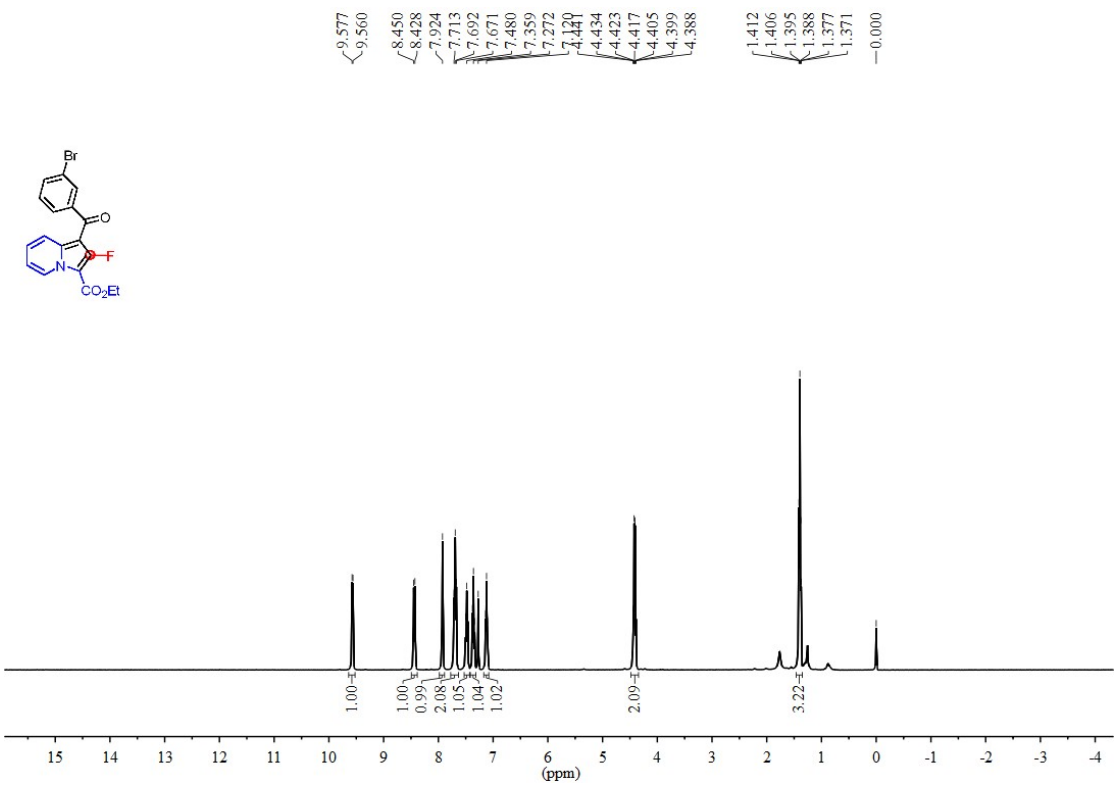
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4l**



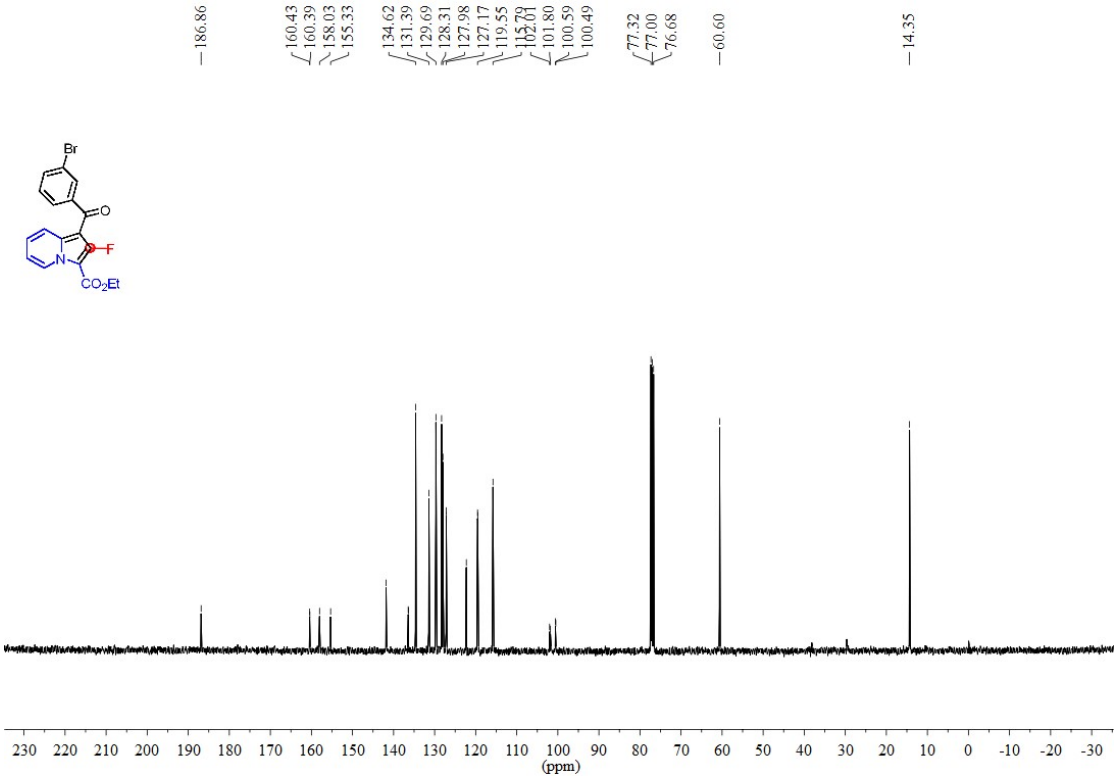
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4l**



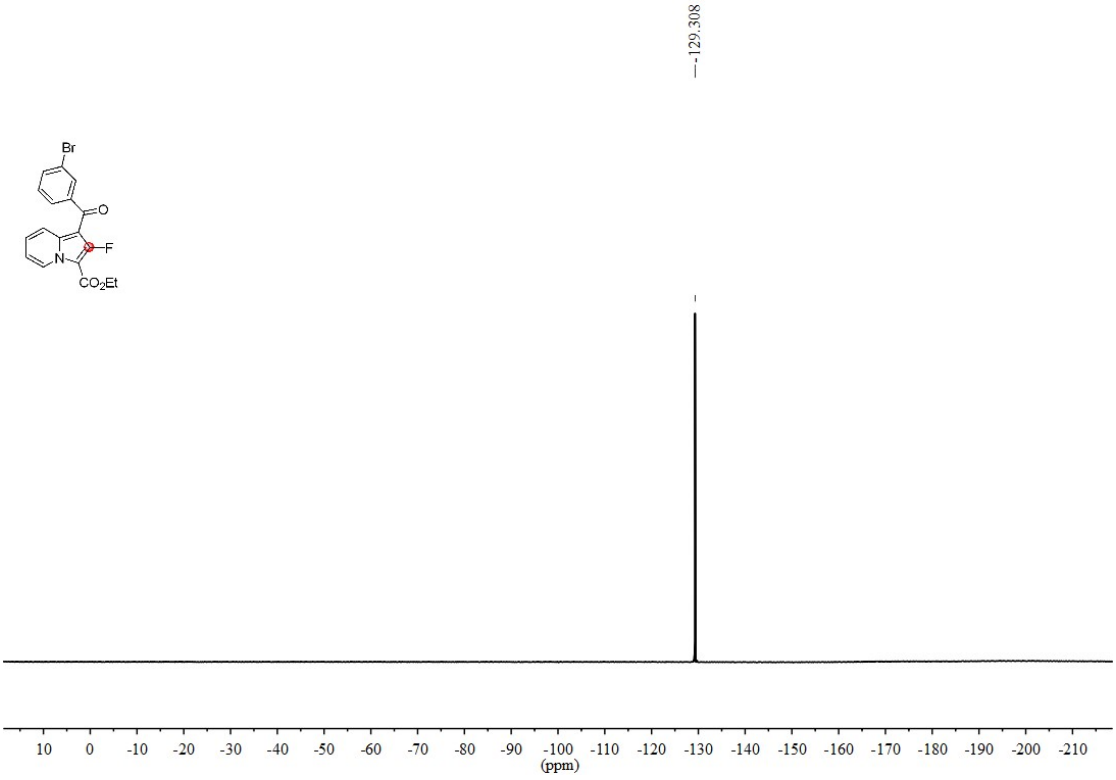
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4m**



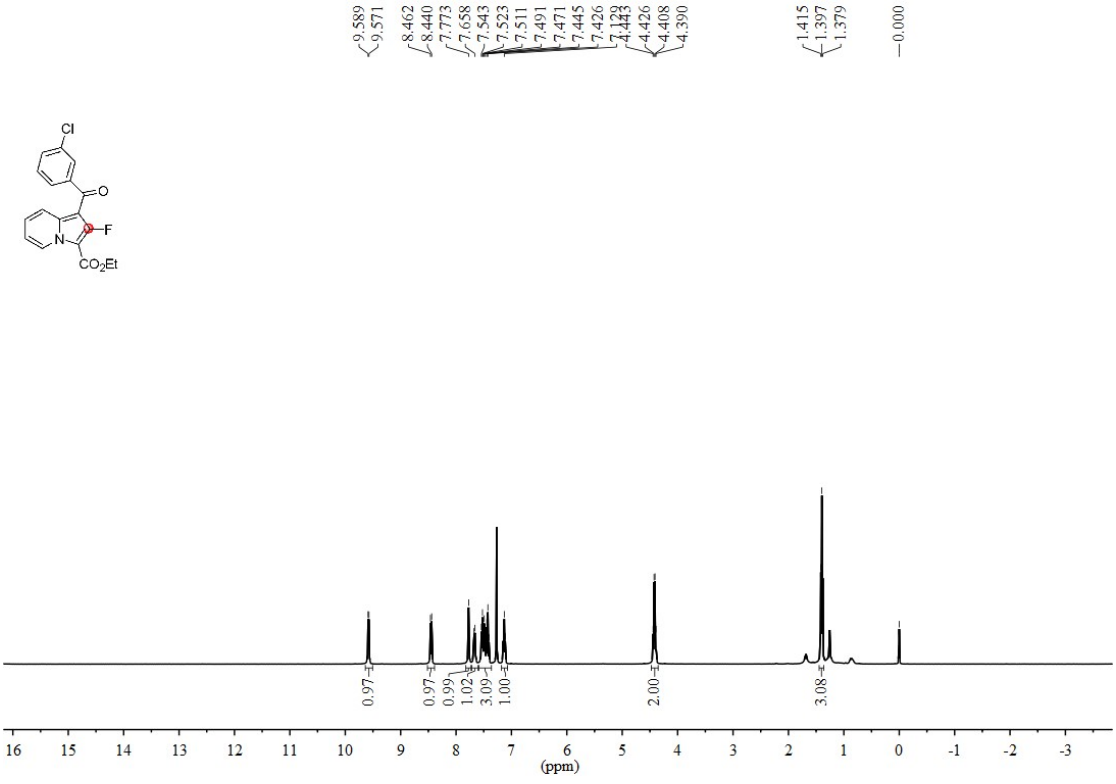
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4m**



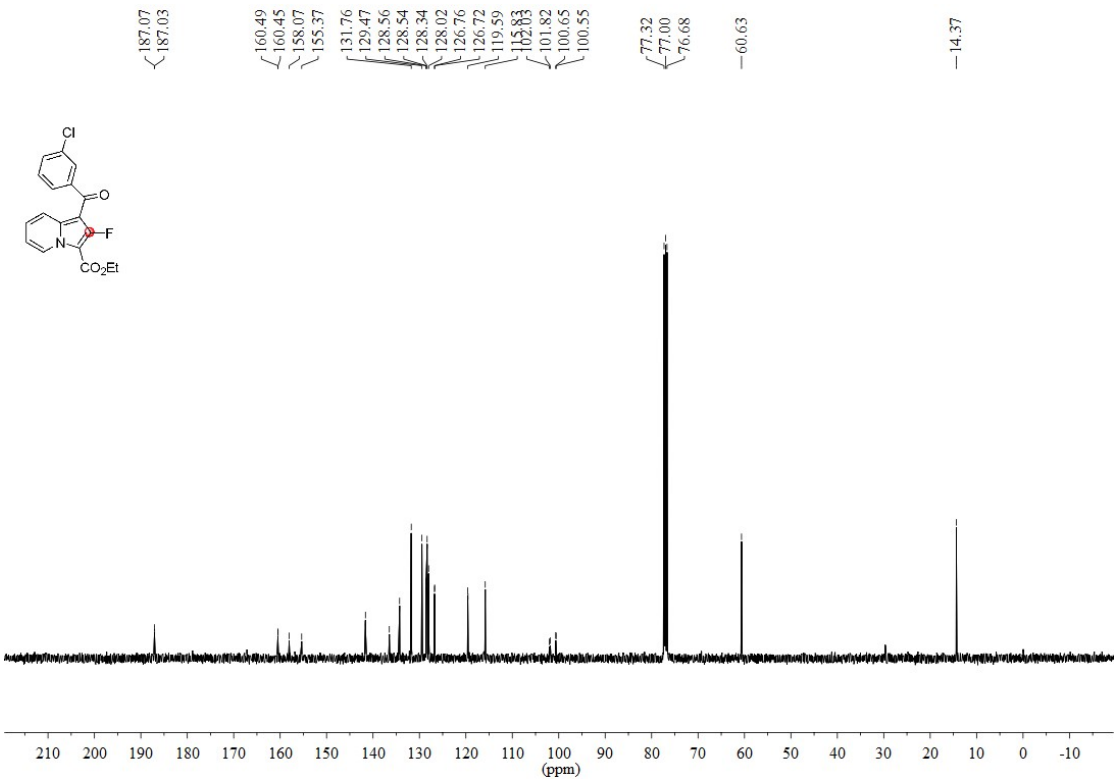
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4m**



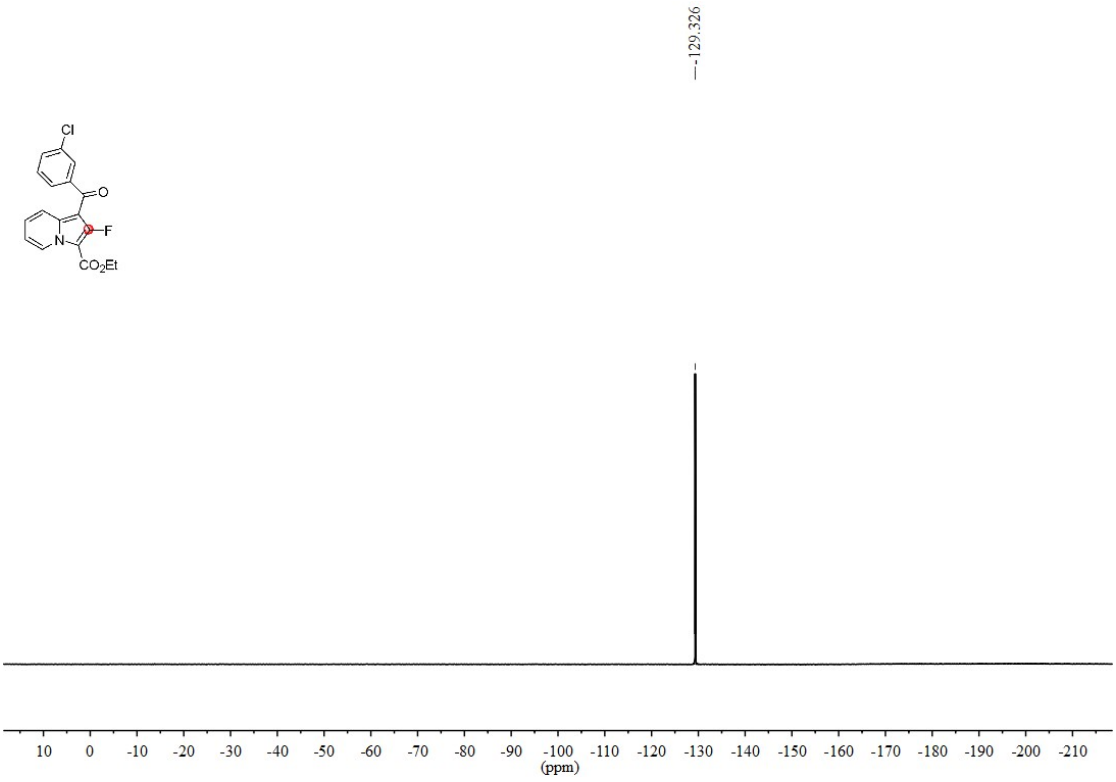
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4n**



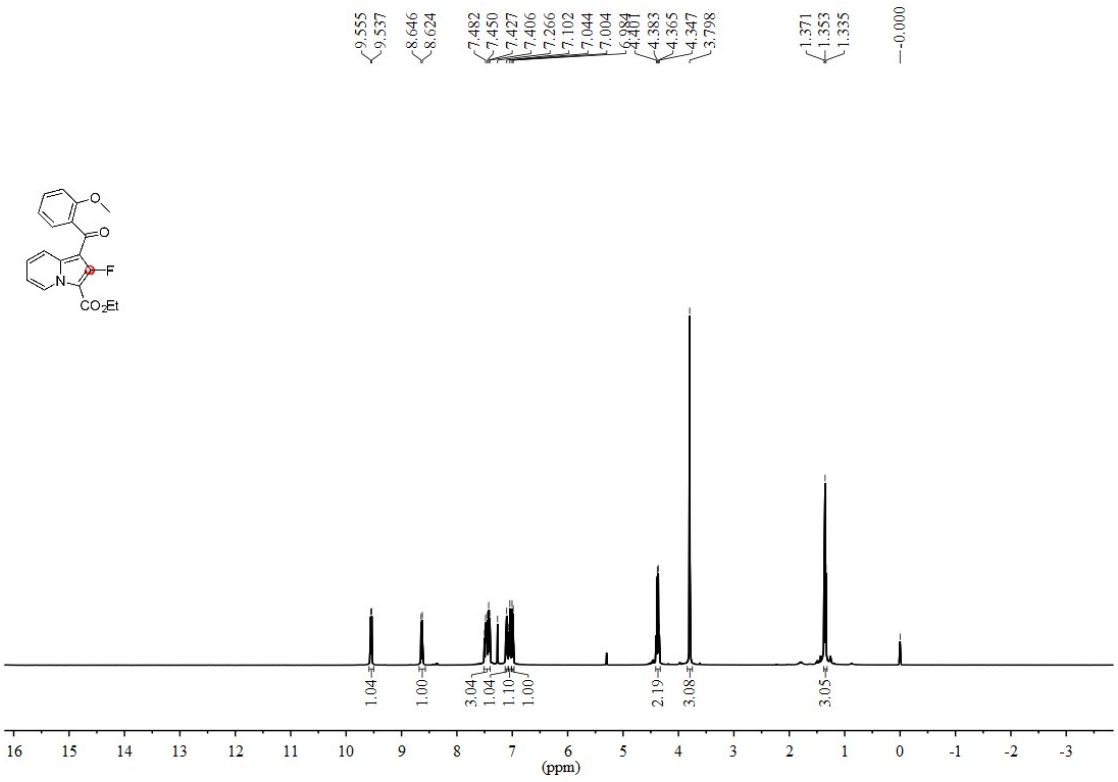
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4n**



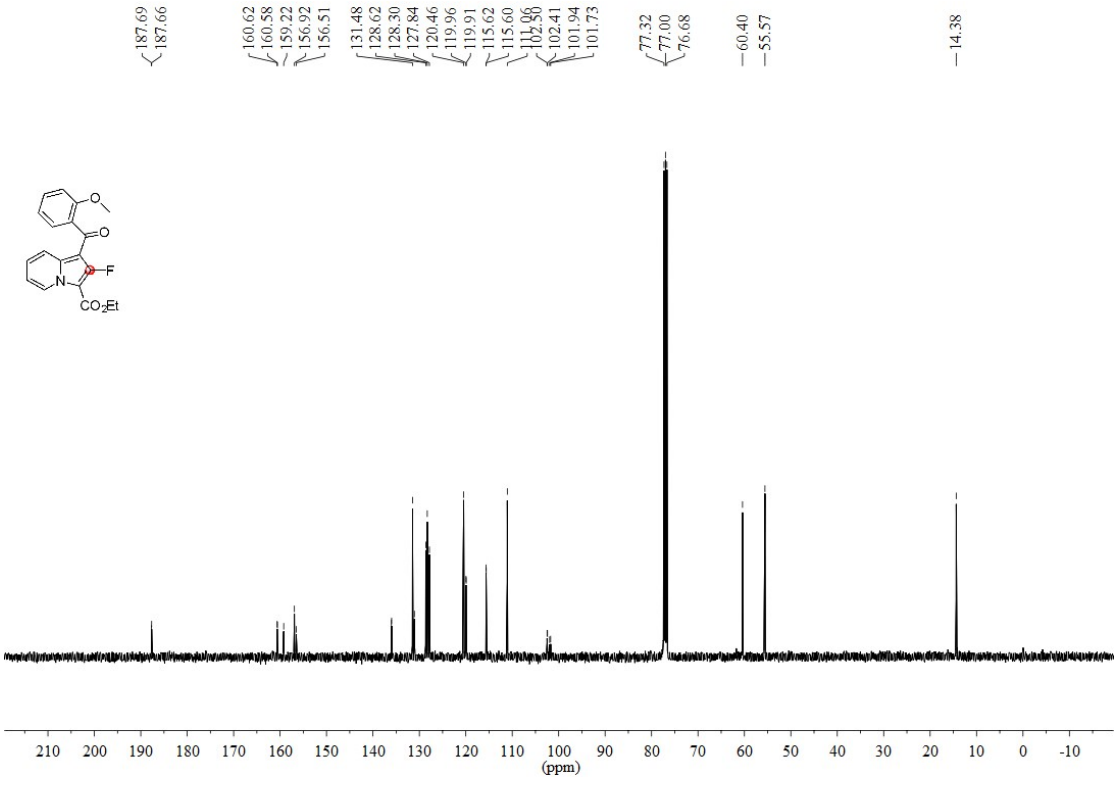
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4n**



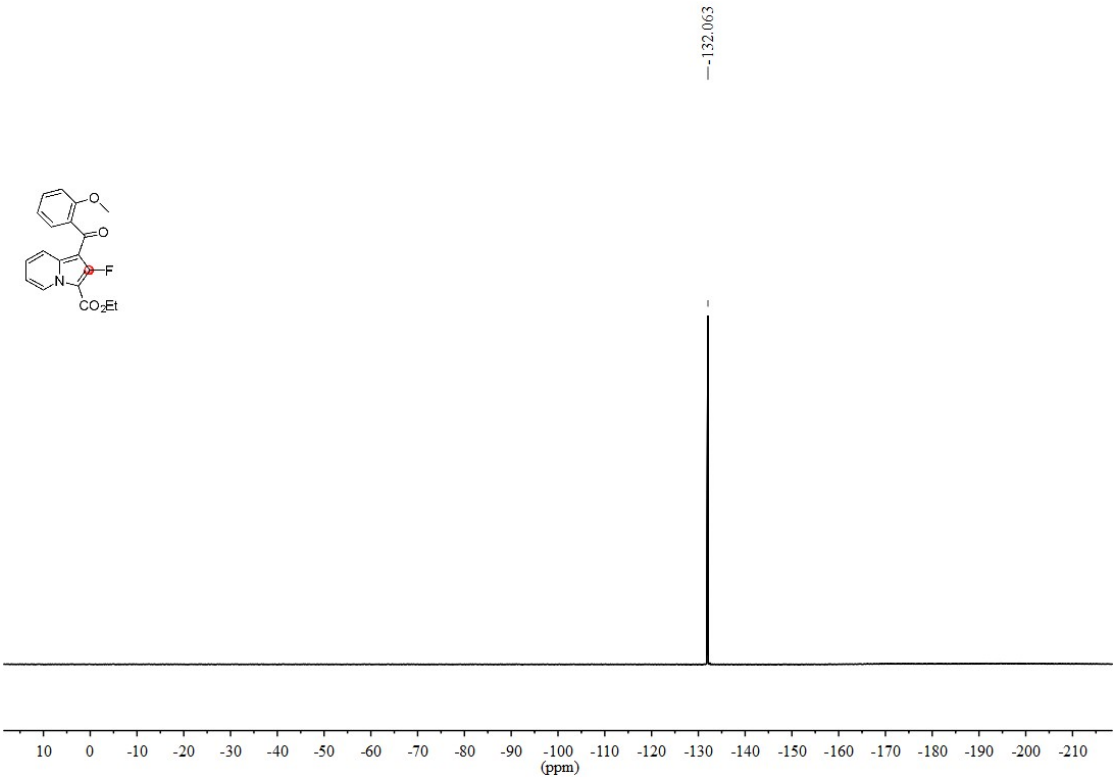
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4o**



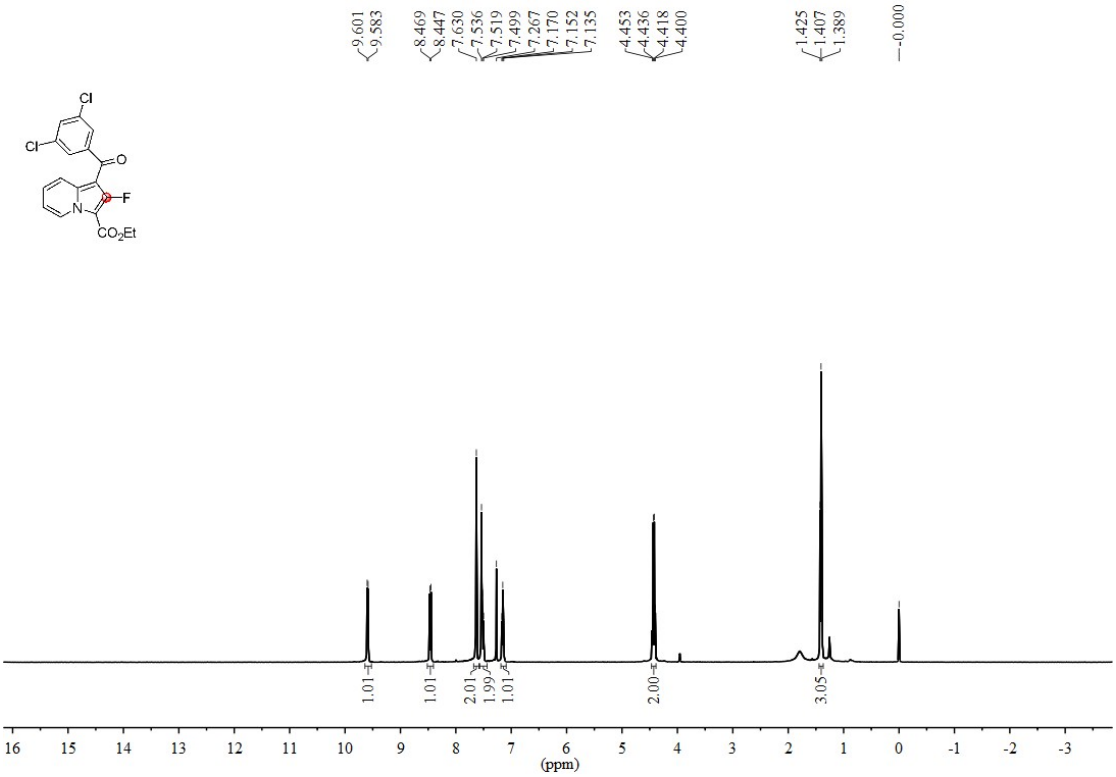
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4o**



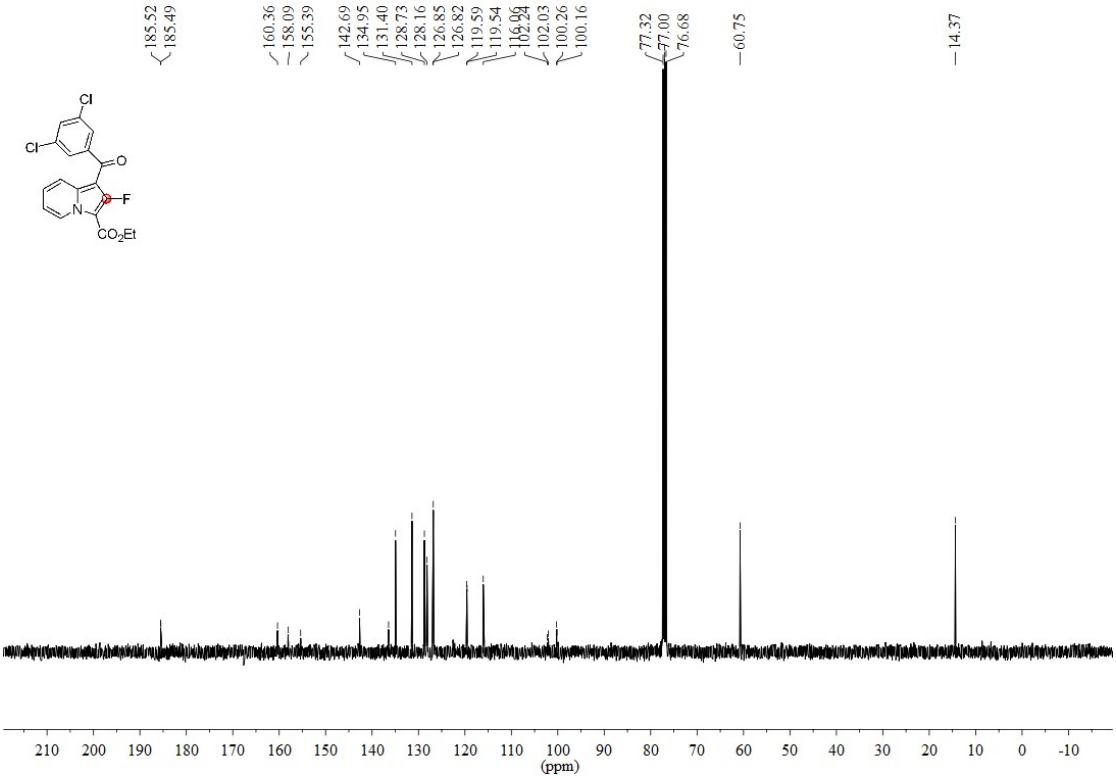
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4o**



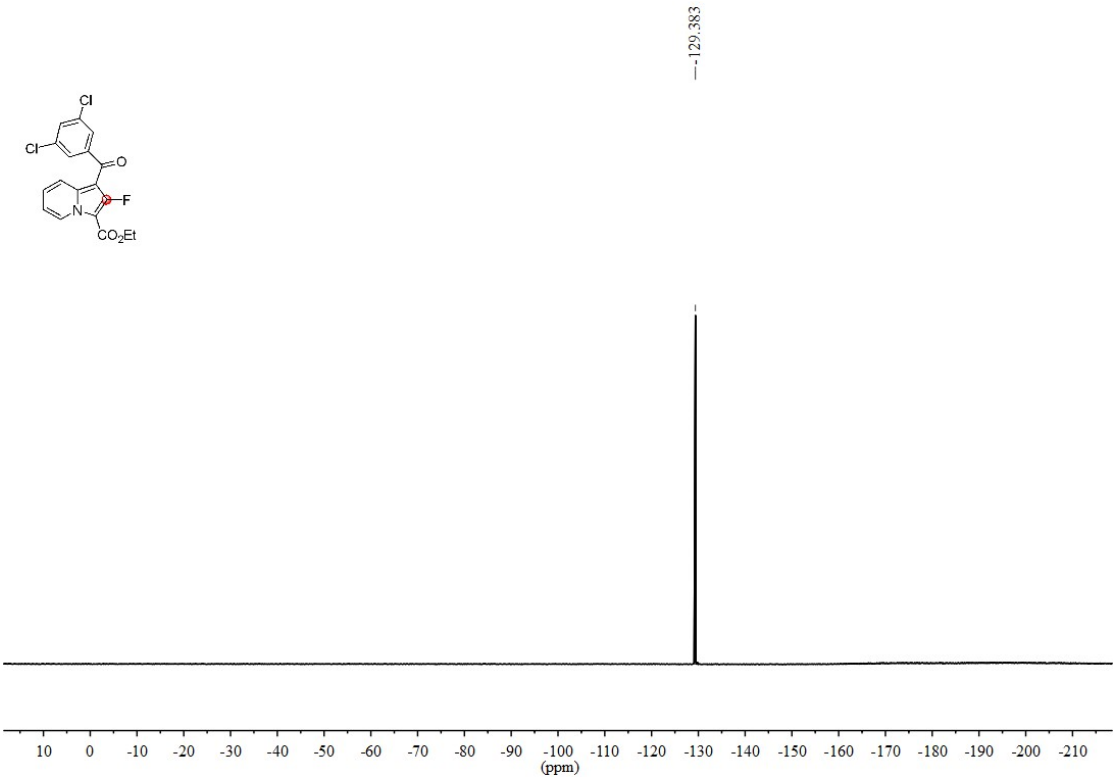
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4p**



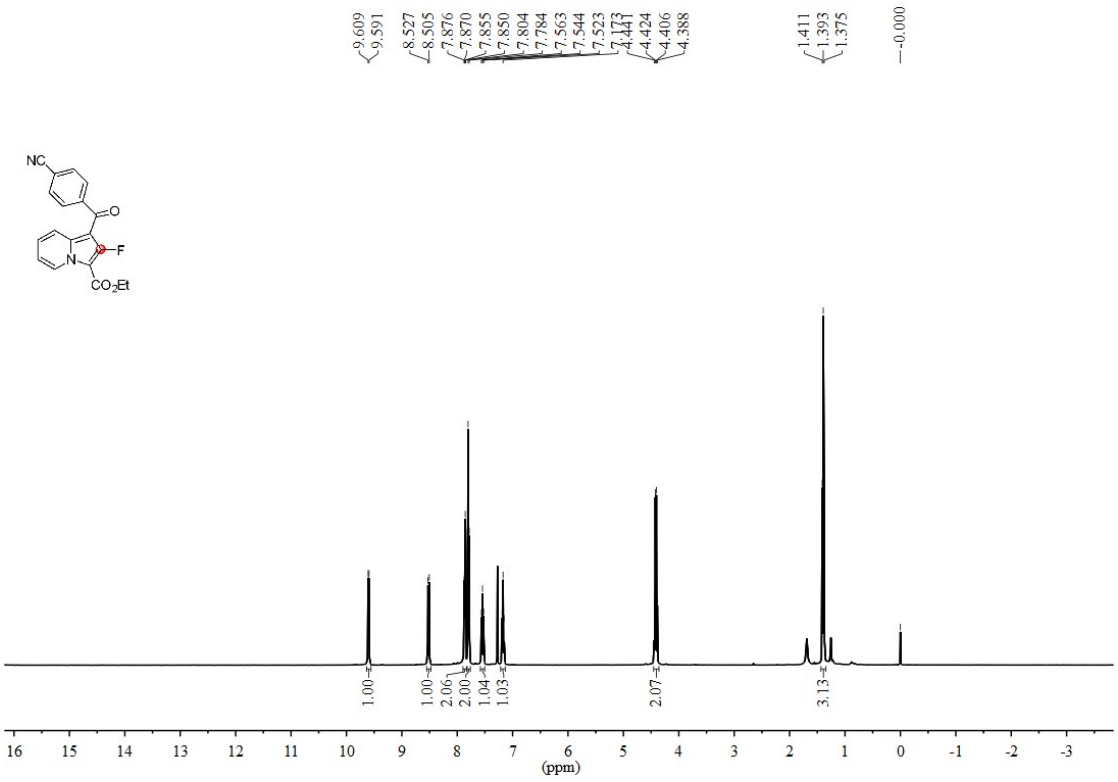
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4p**



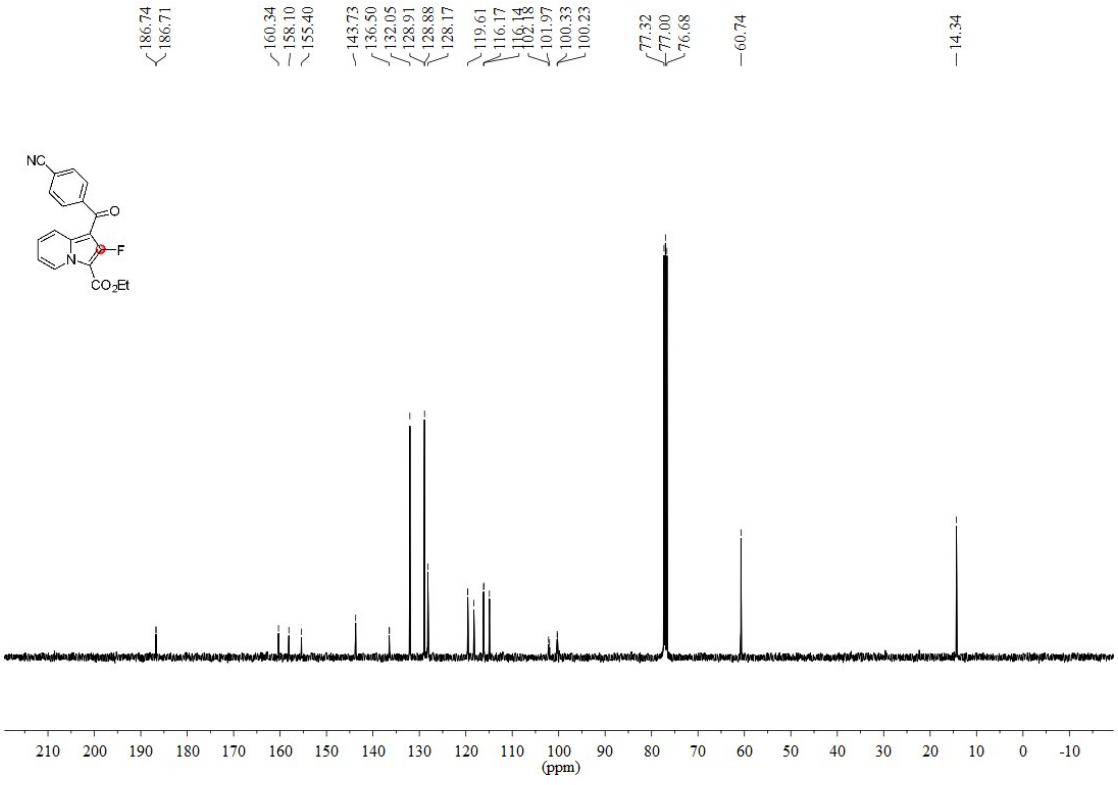
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4p**



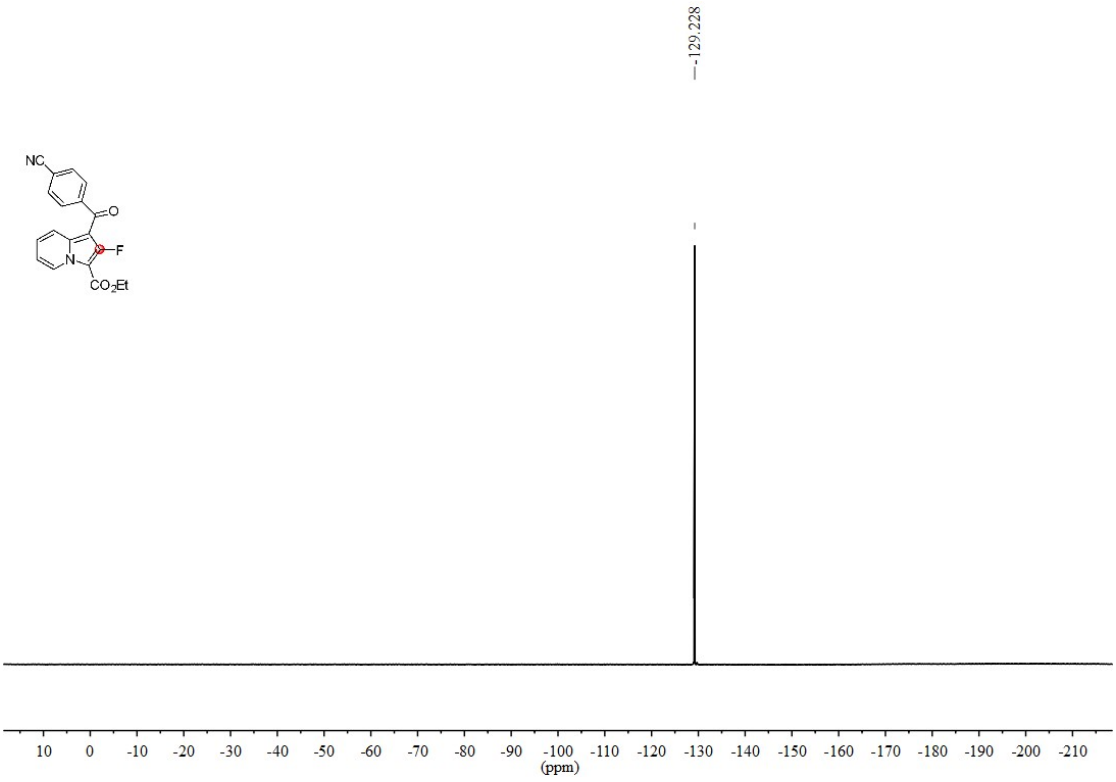
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4q**



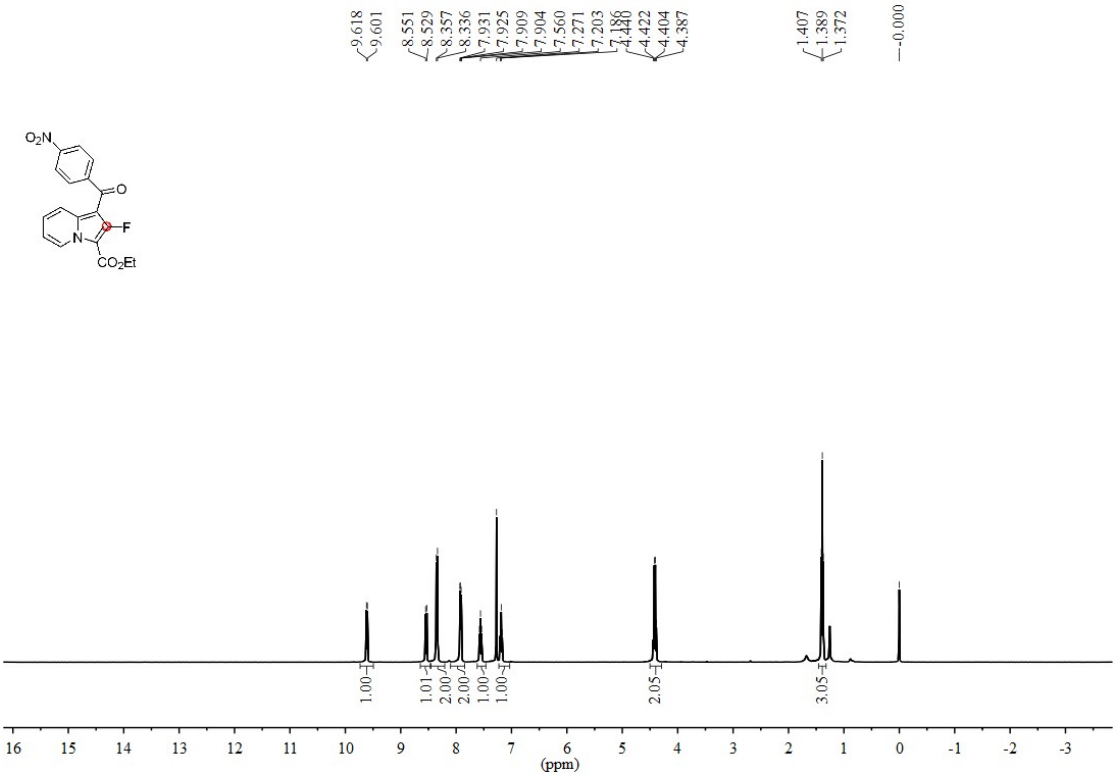
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4q**



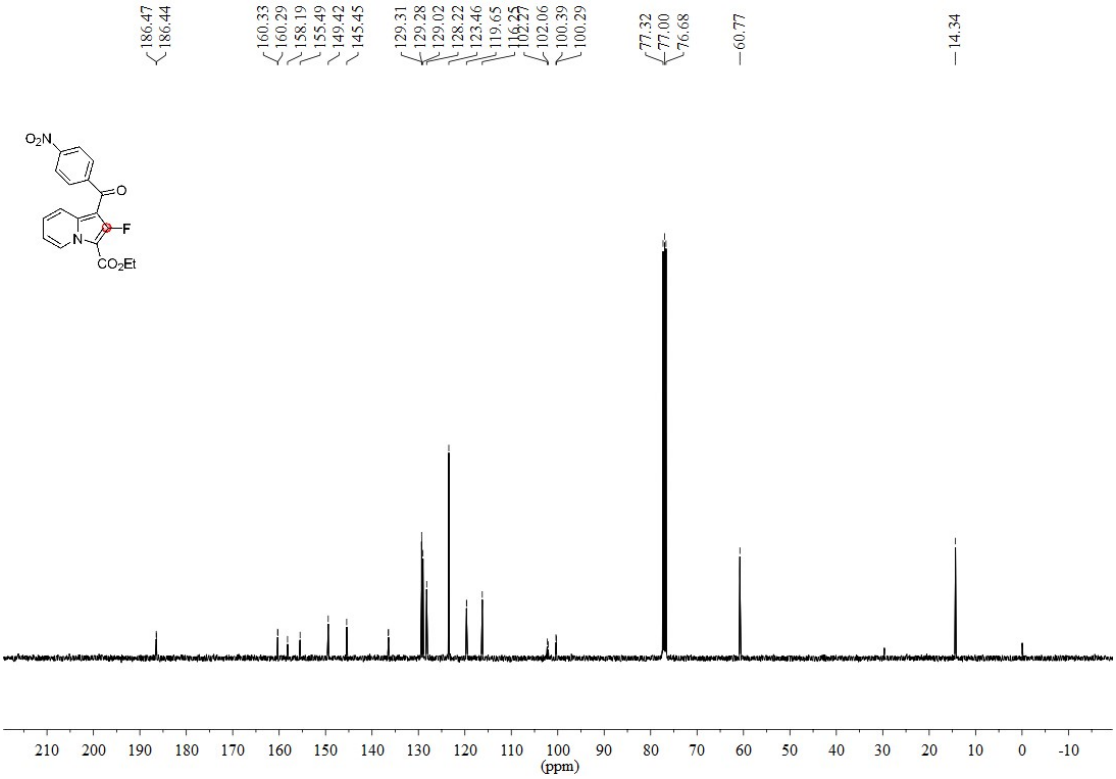
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4q**



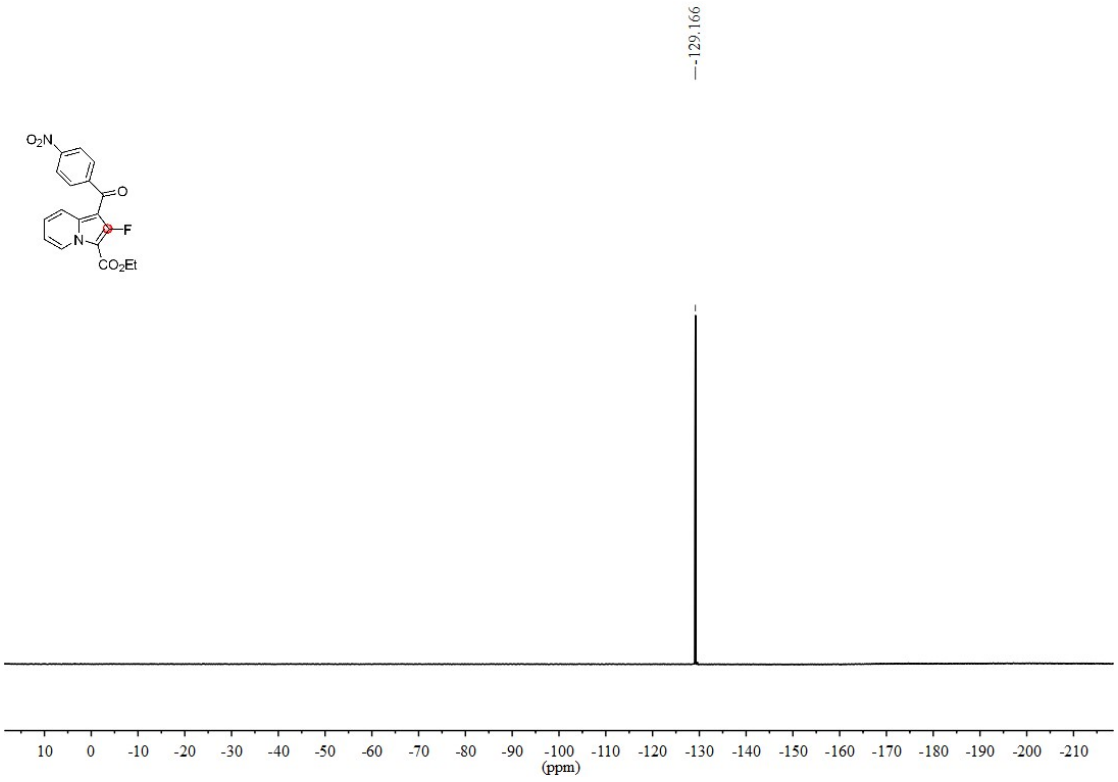
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4r**



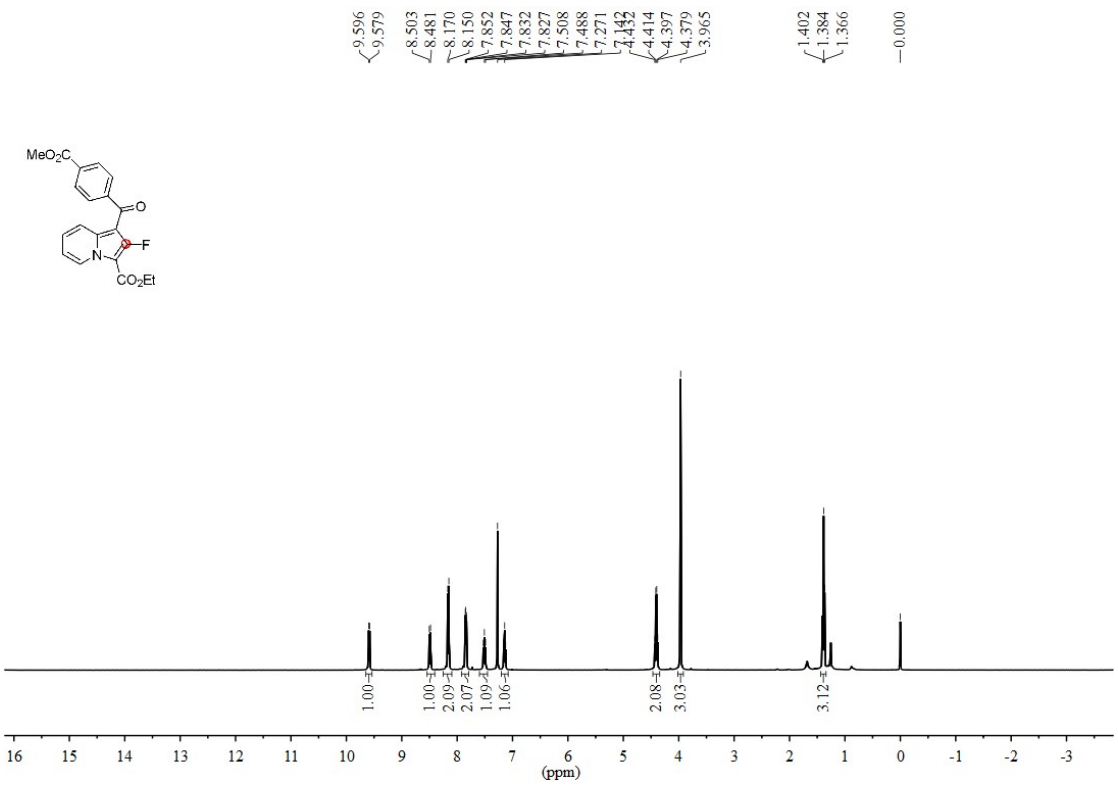
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4r**



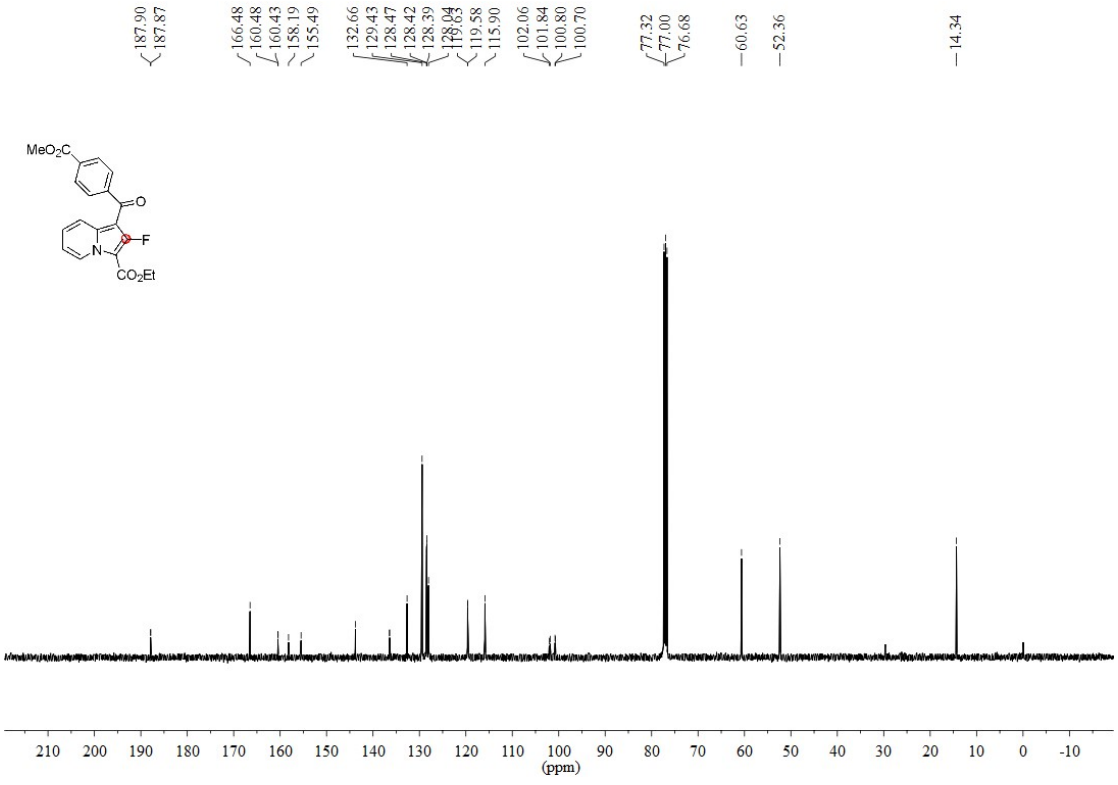
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4r**



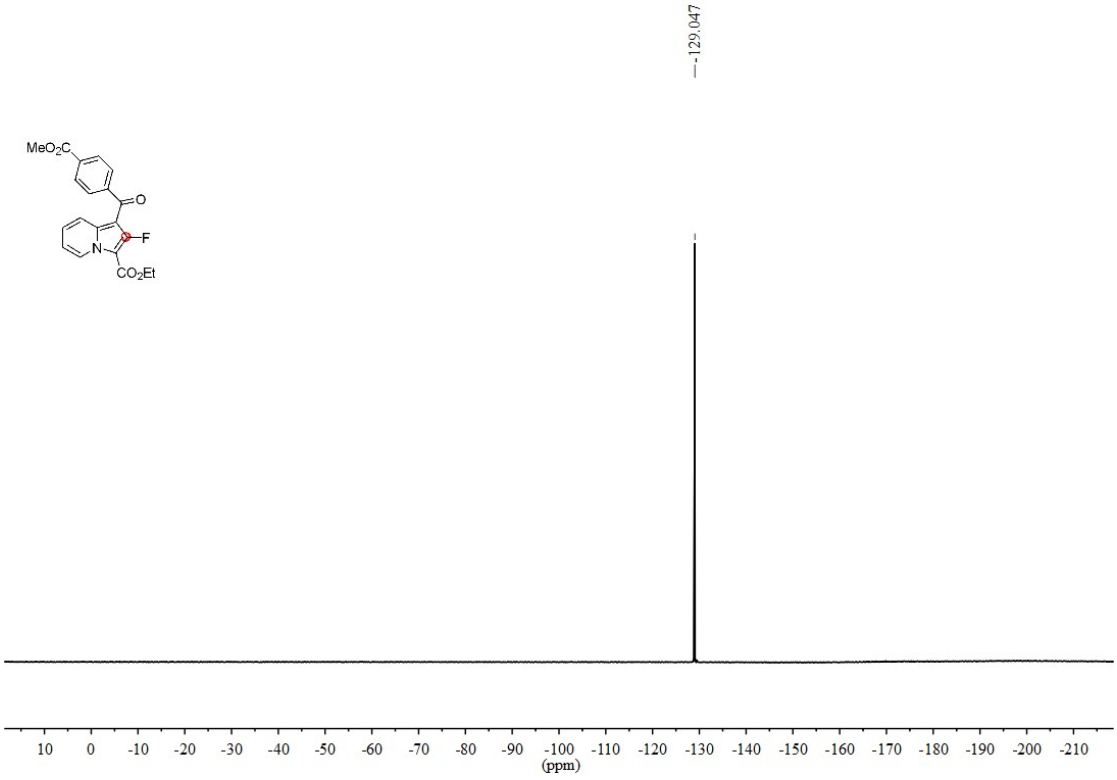
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4s**



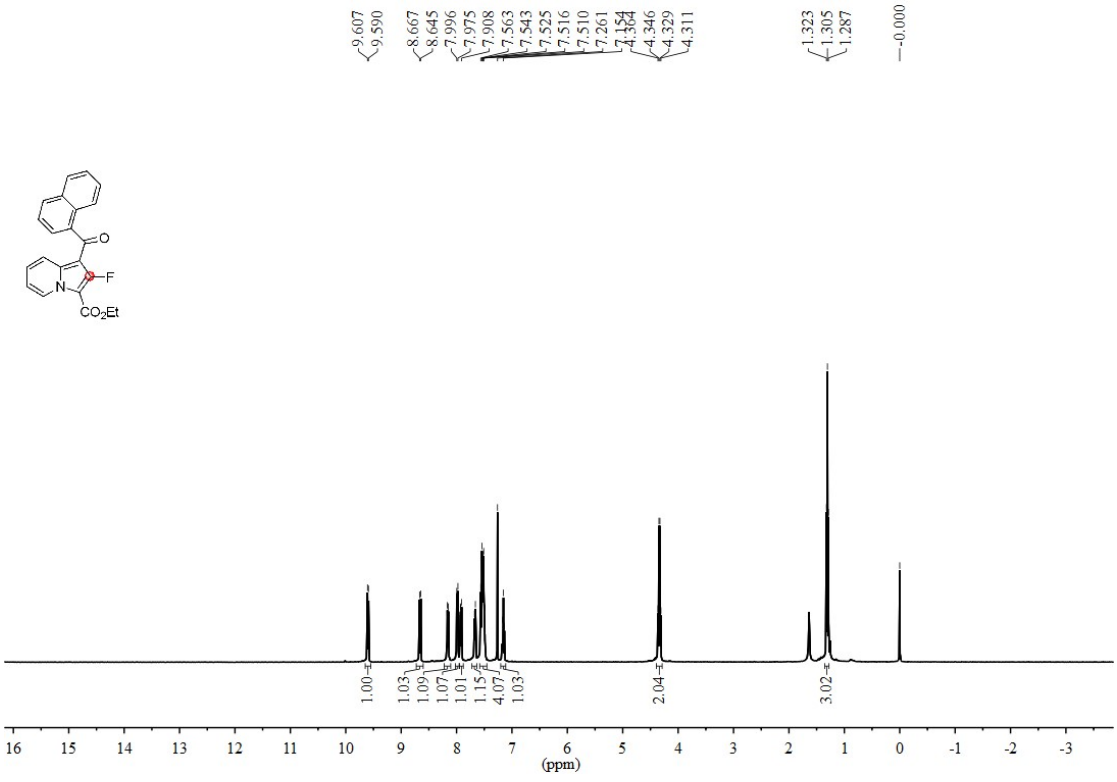
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4s**



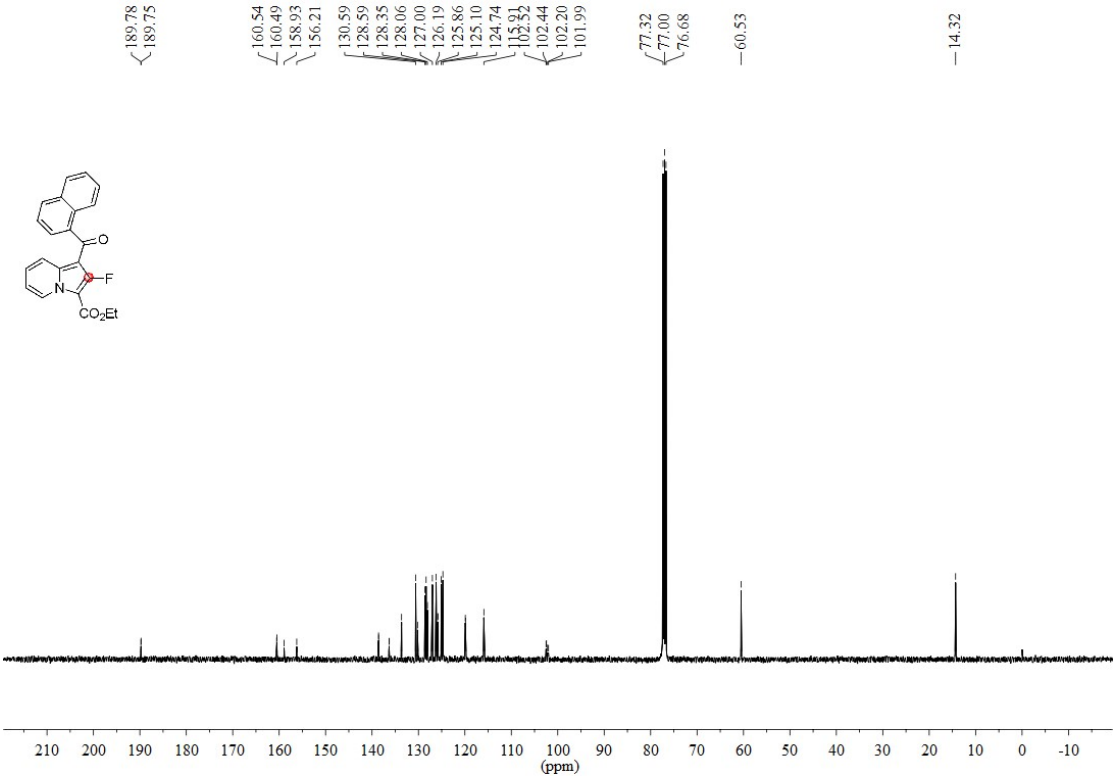
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4s**



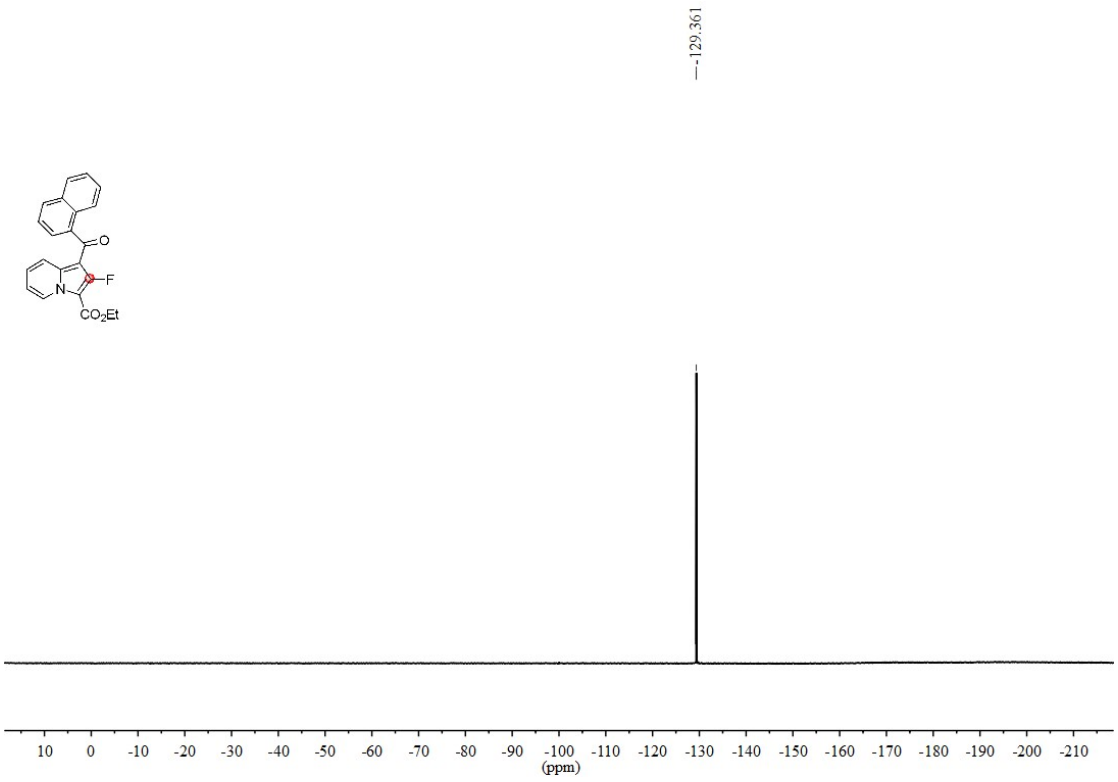
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4t**



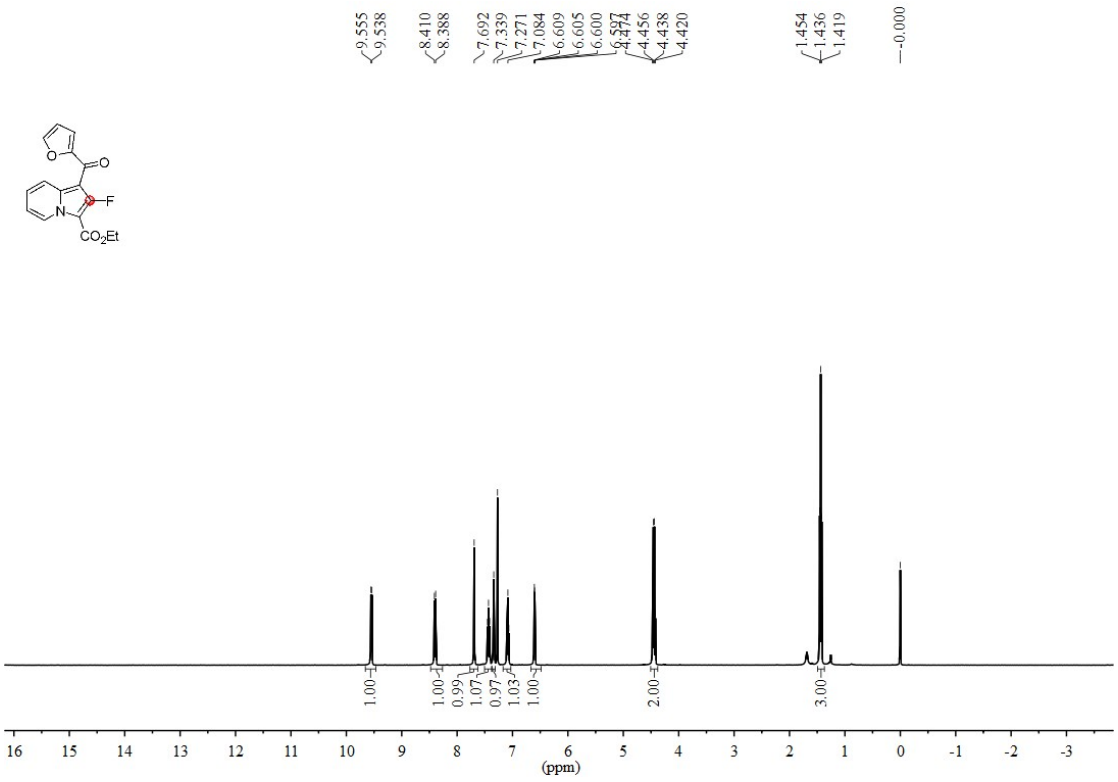
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4t**



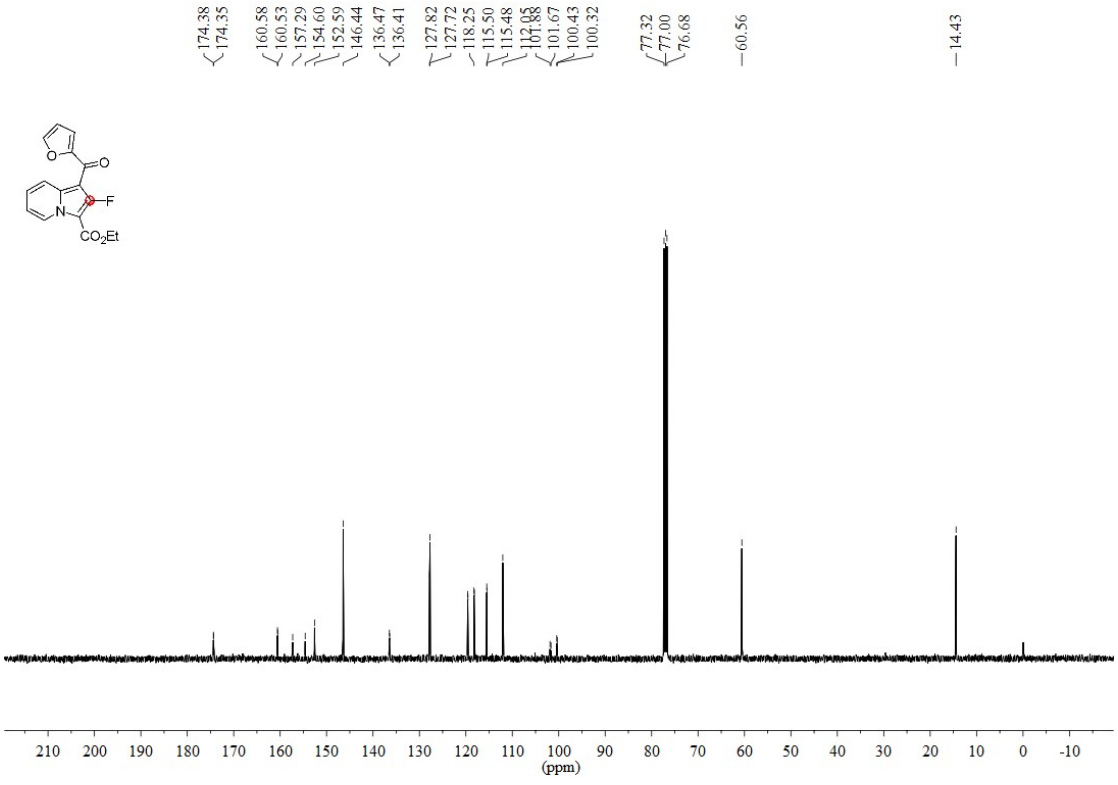
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4t**



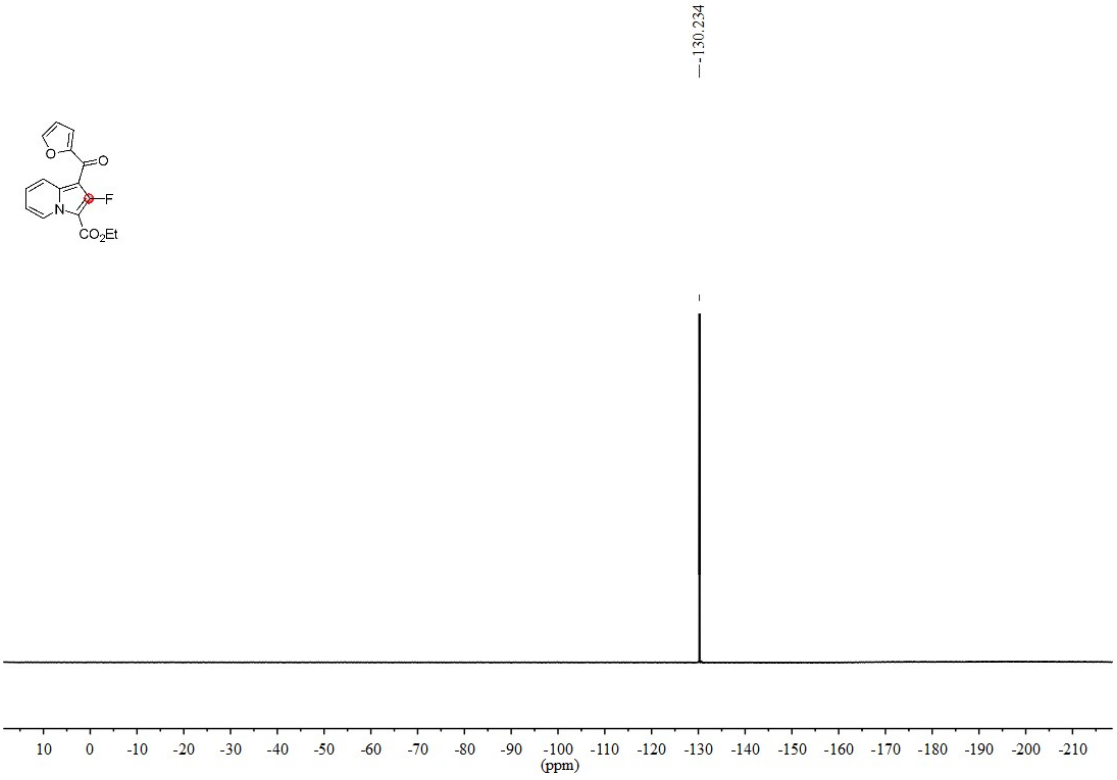
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4u**



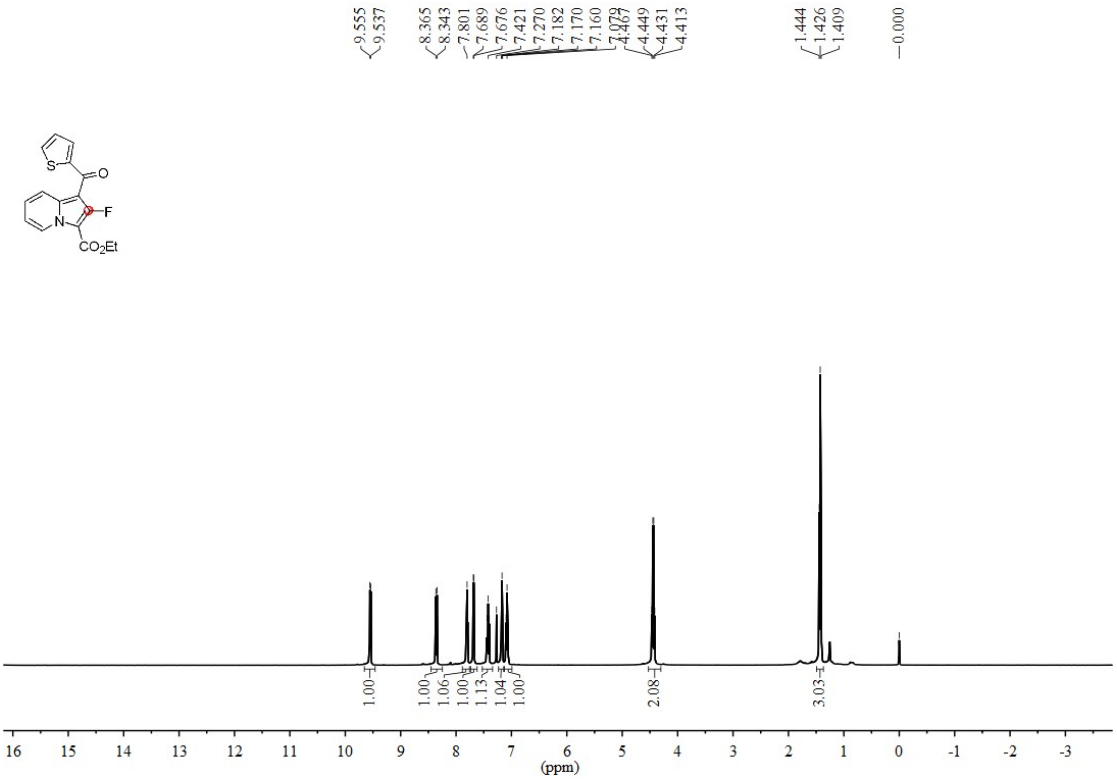
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4u**



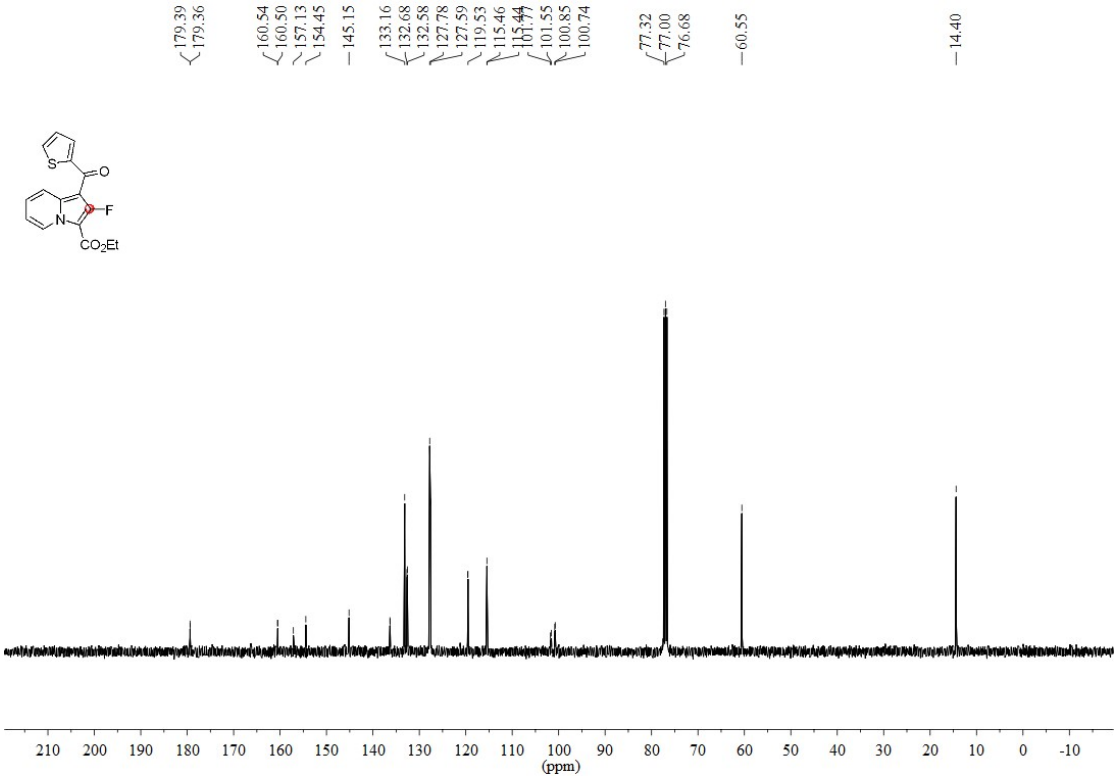
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4u**



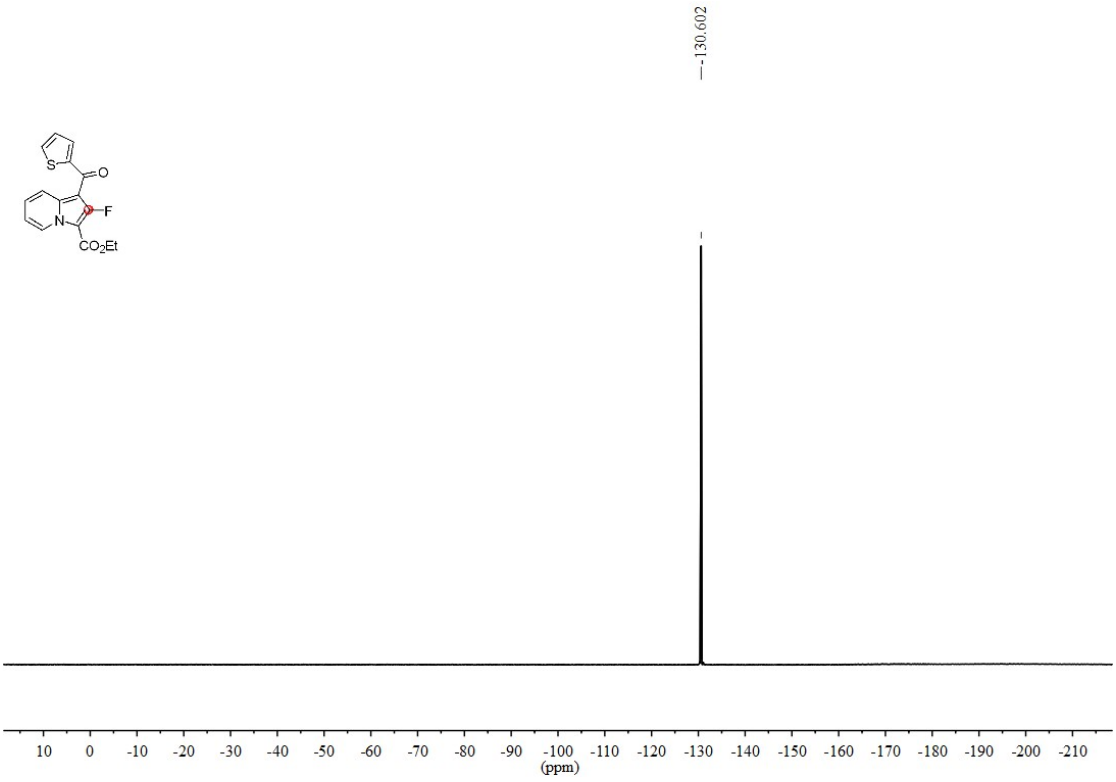
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4v**



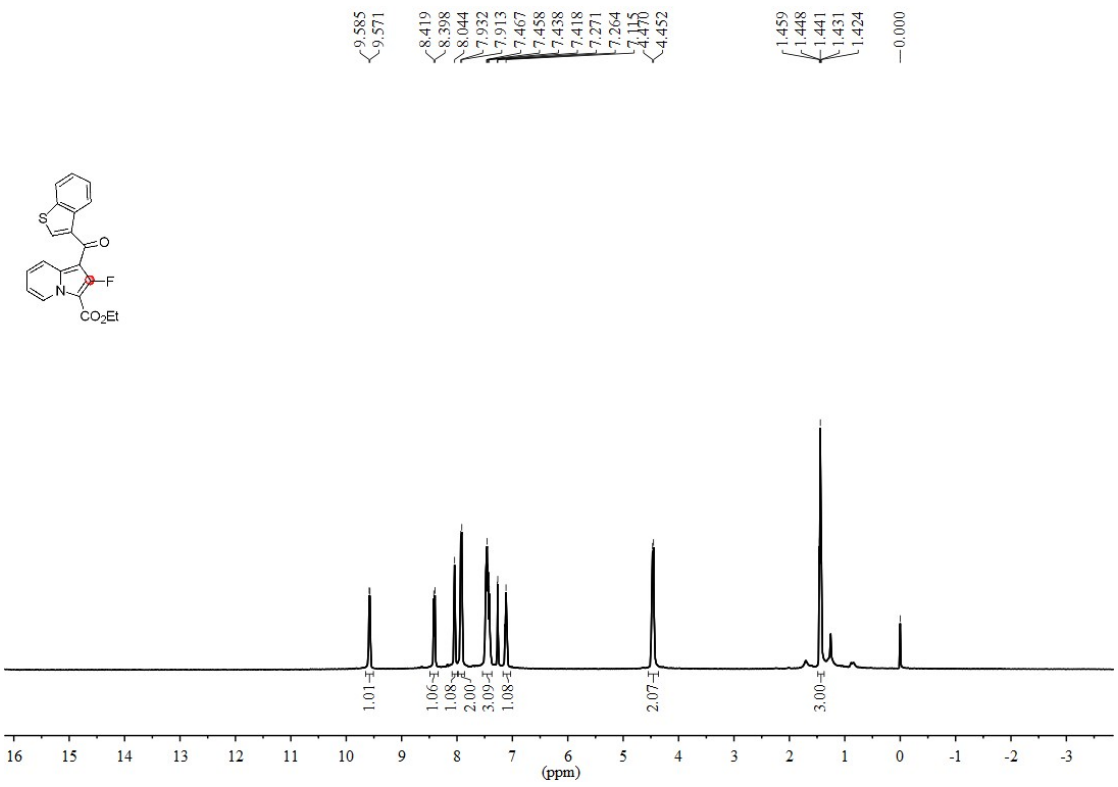
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4v**



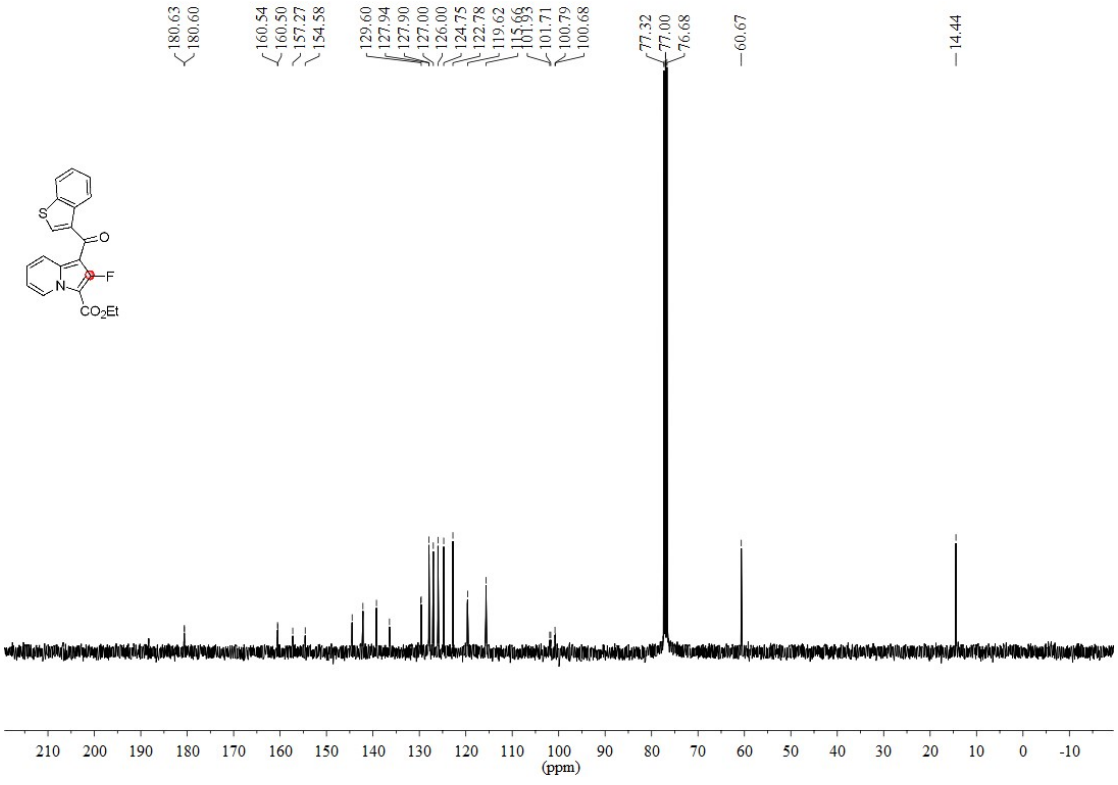
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4v**



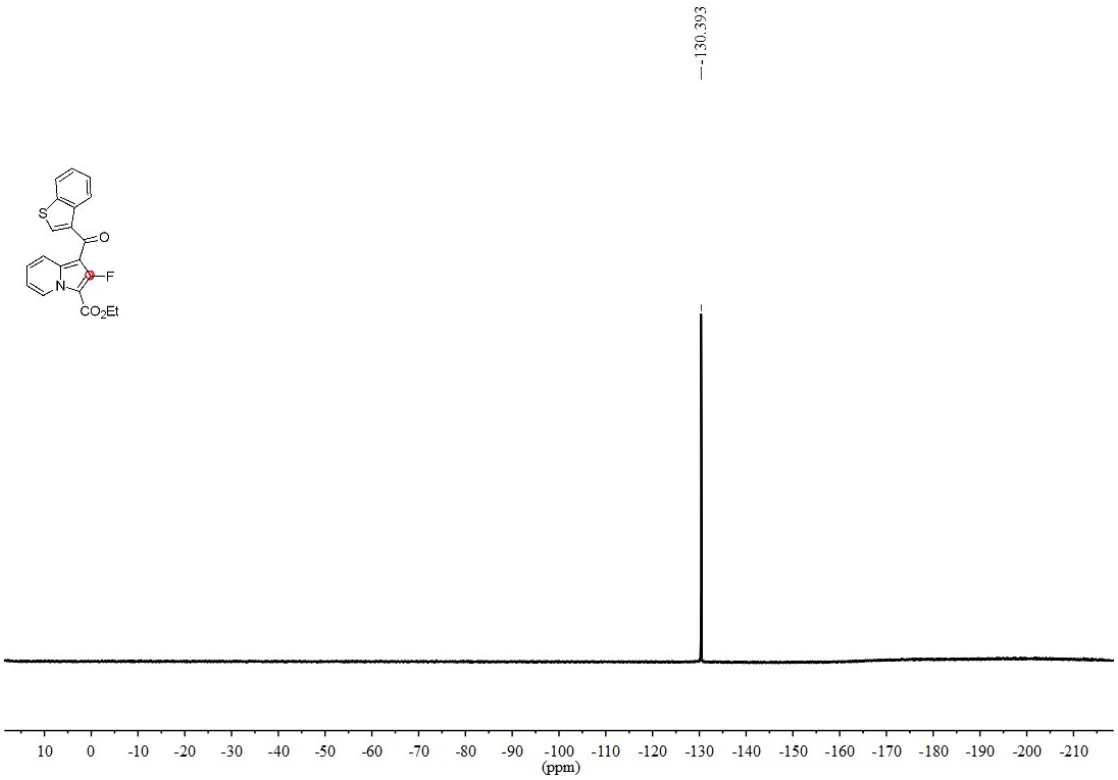
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4w**



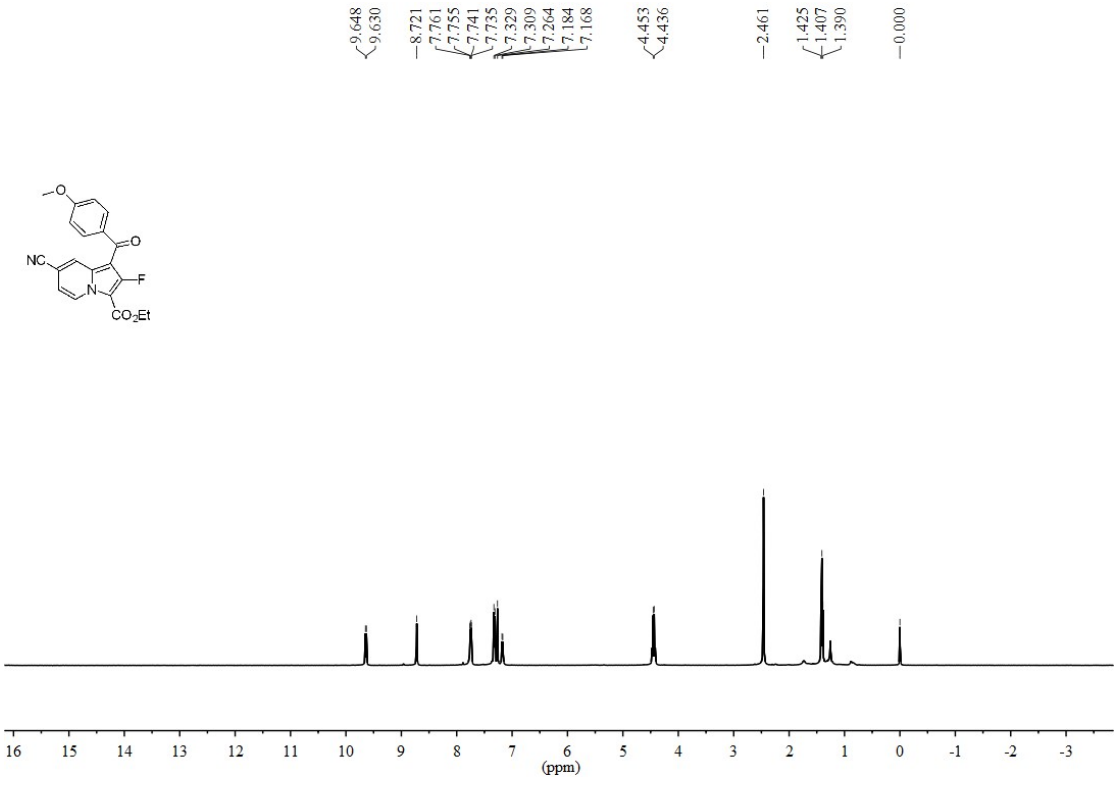
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4w**



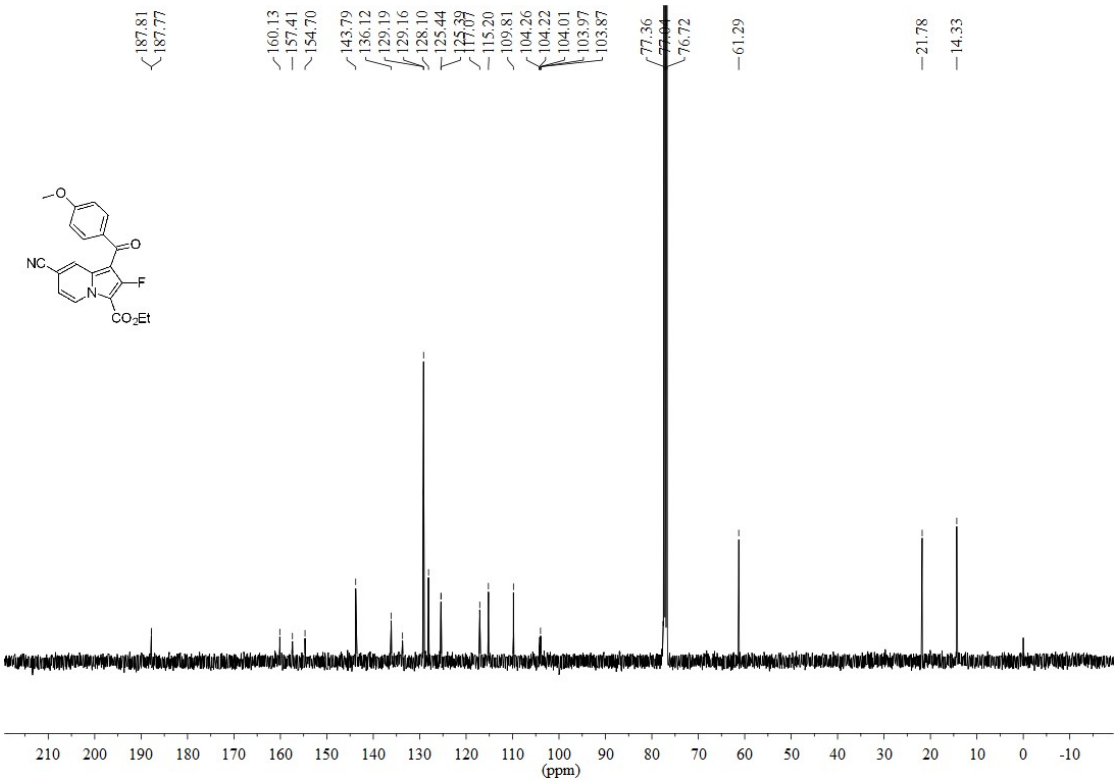
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4w**



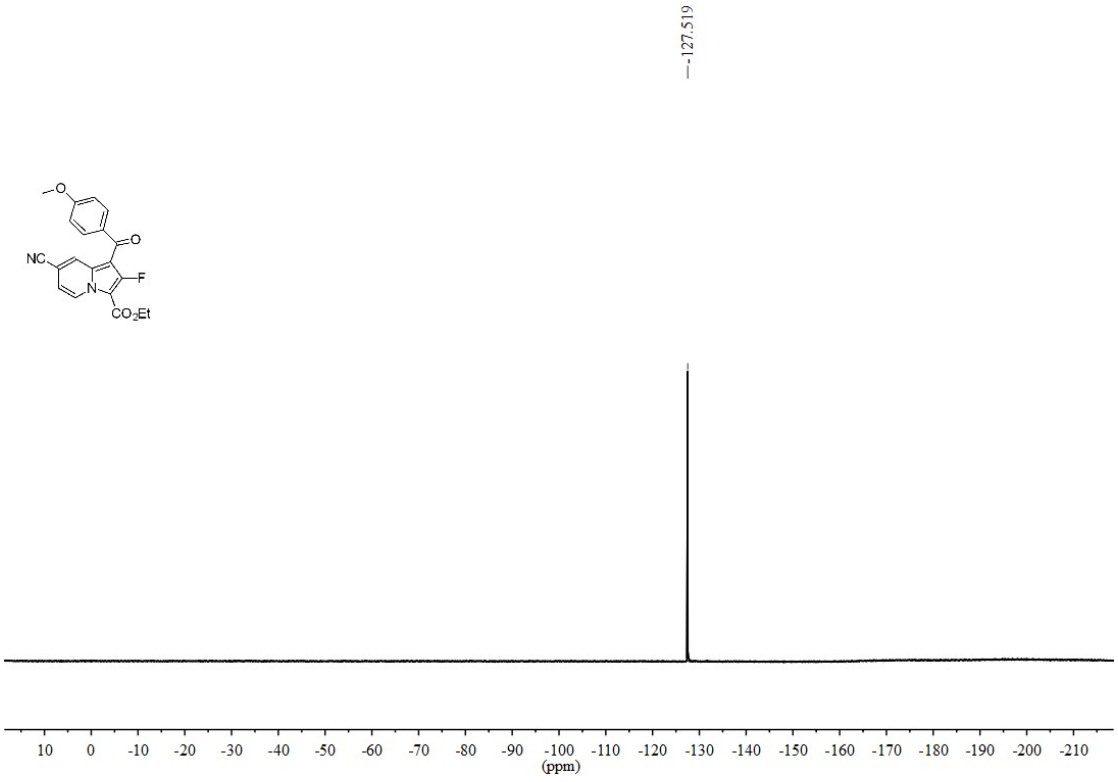
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4x**



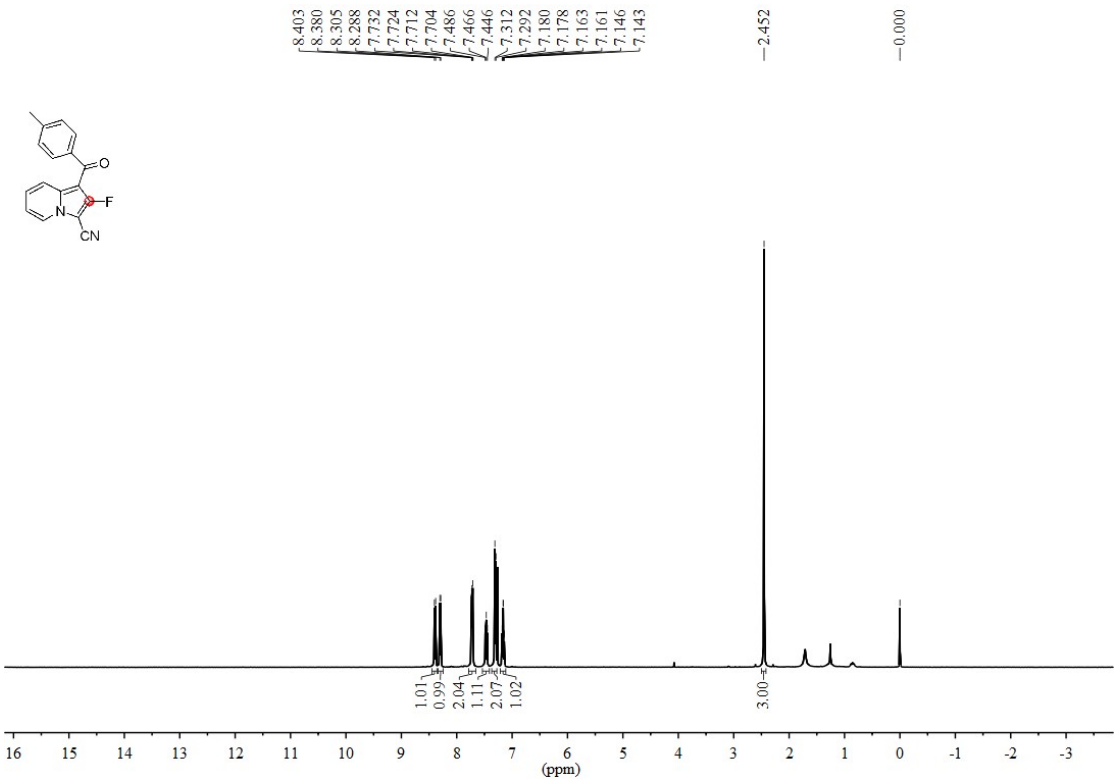
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4x**



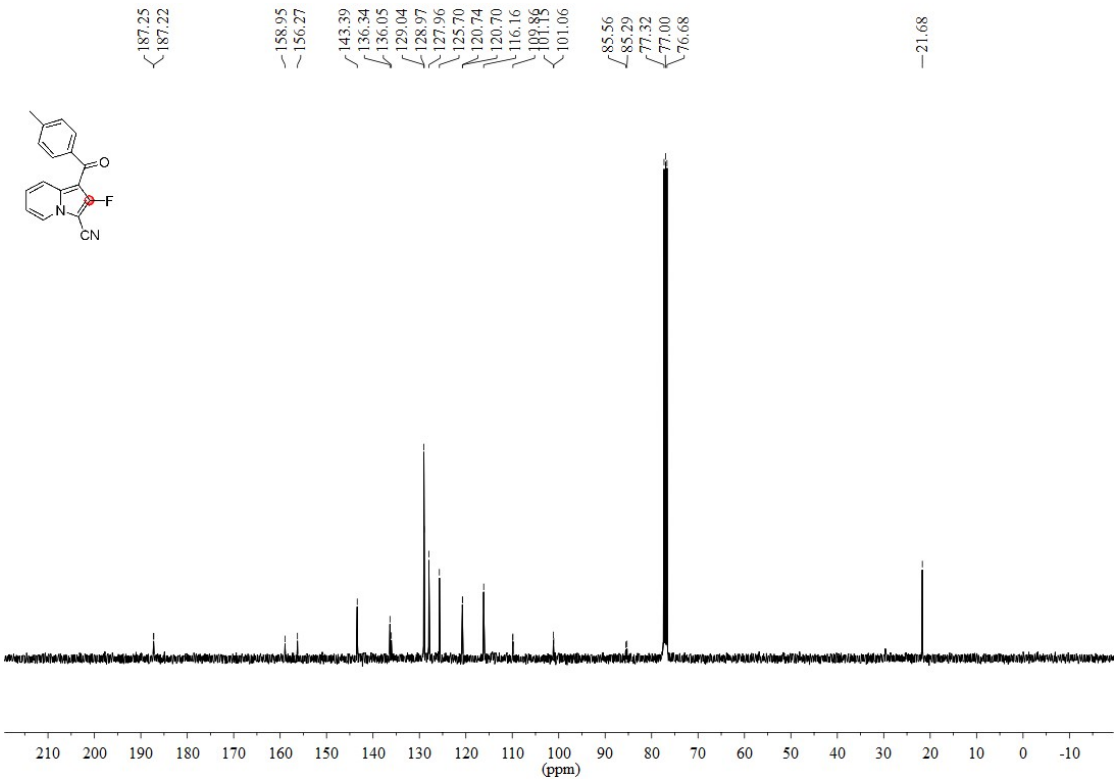
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4x**



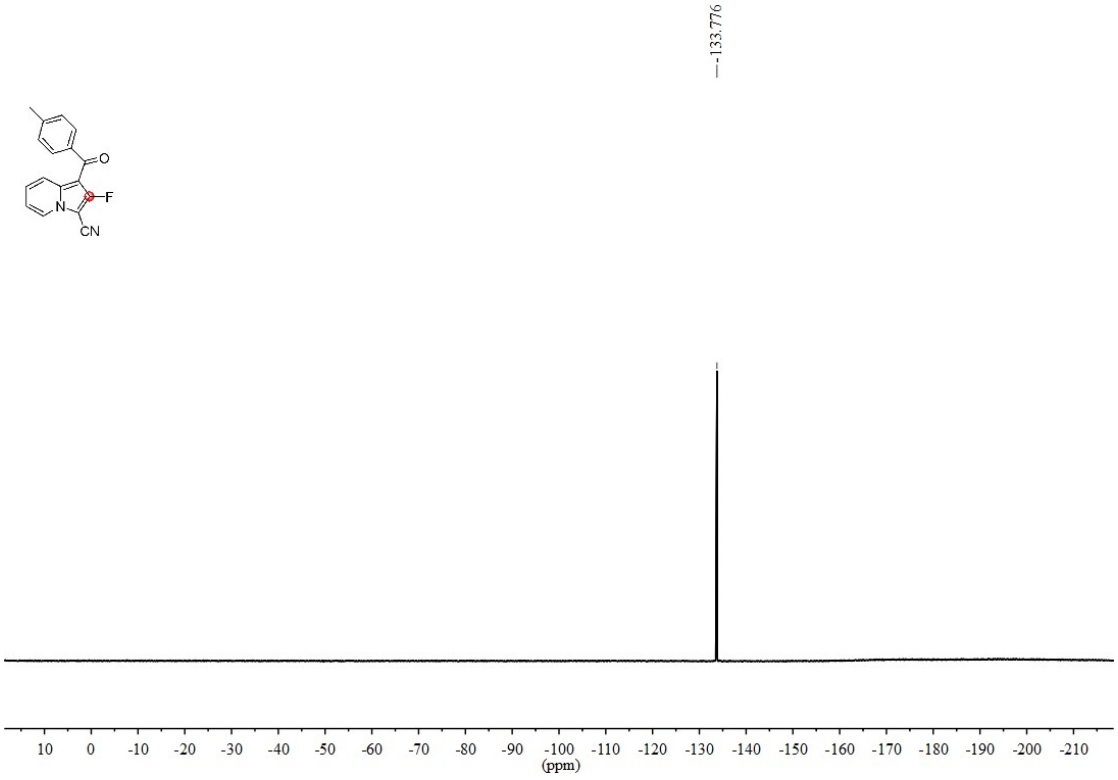
^{1}H NMR (400 MHz, $CDCl_3$) of compound **4y**



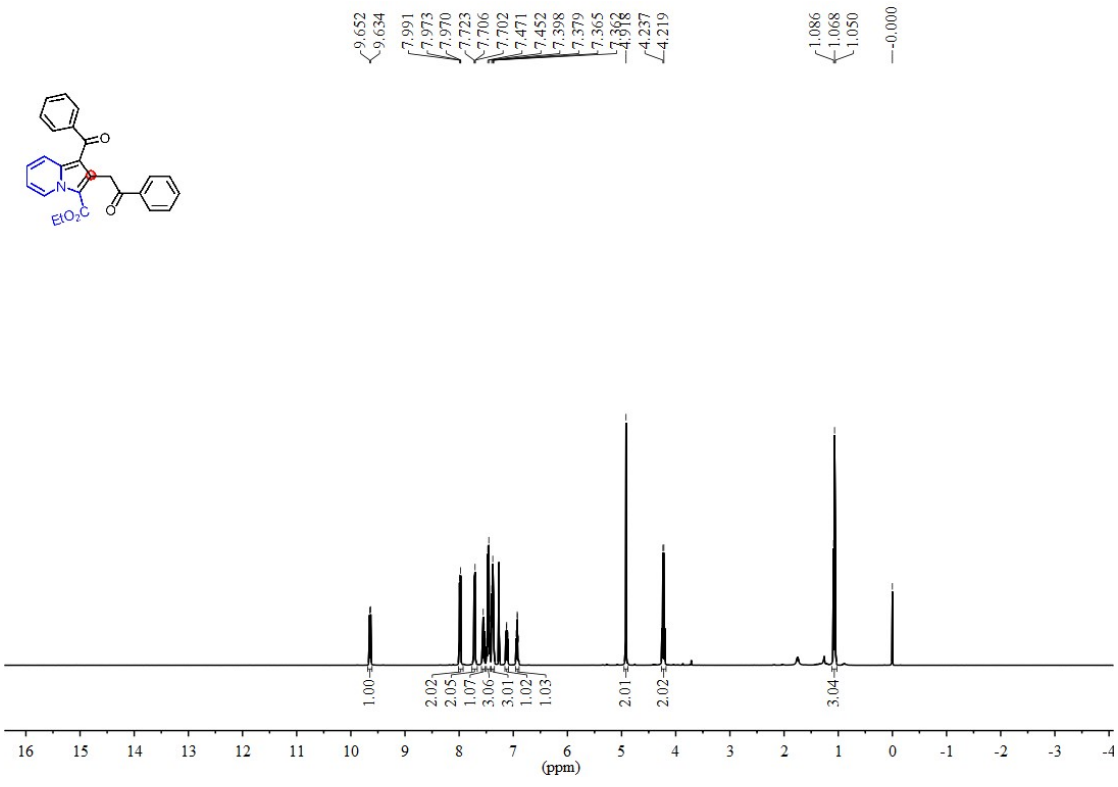
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **4y**



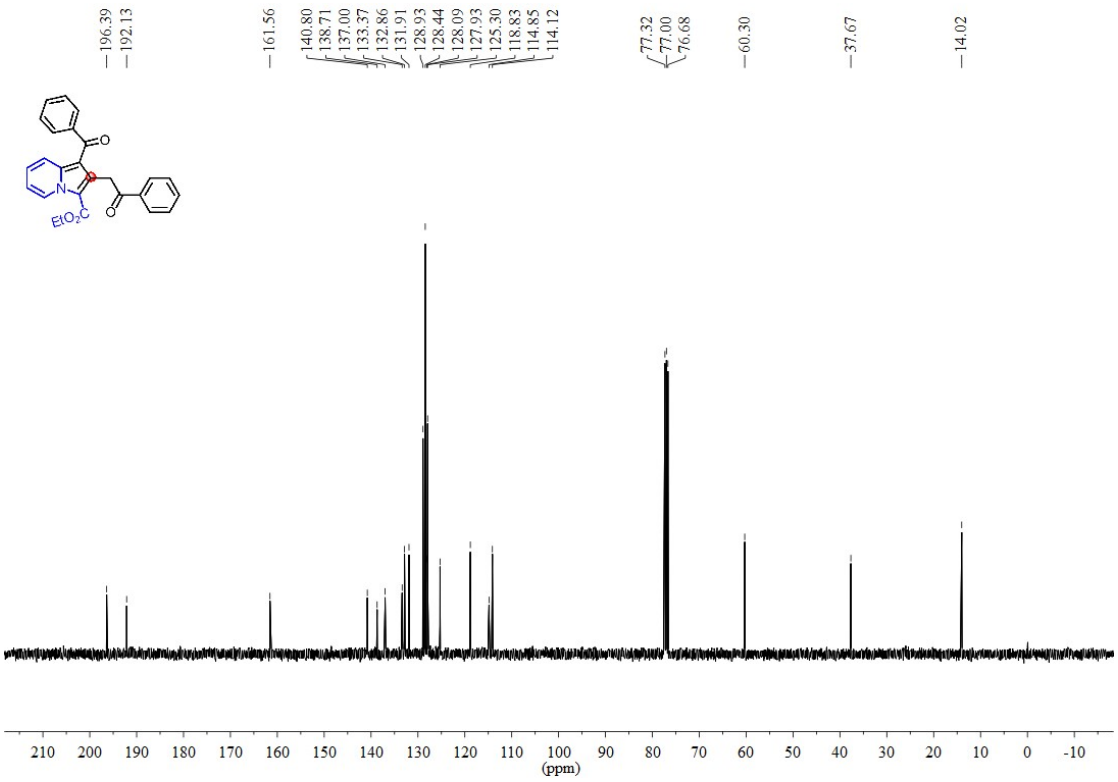
^{19}F NMR (376 MHz, $CDCl_3$) of compound **4y**



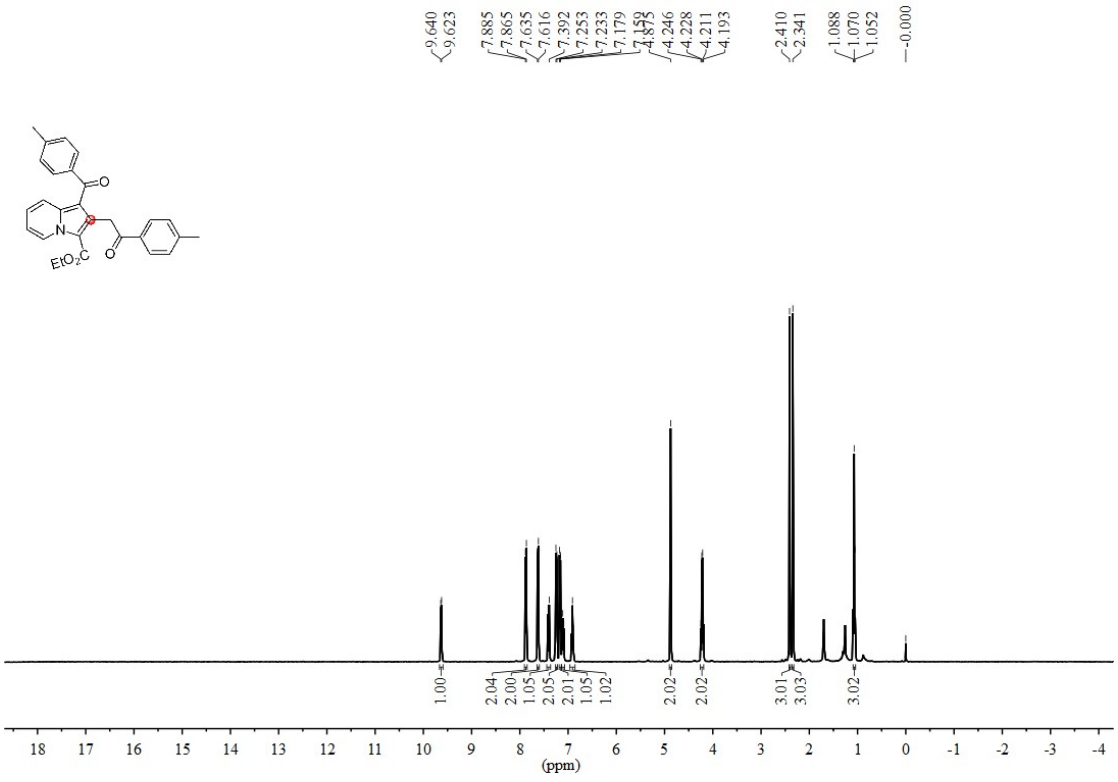
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5a**



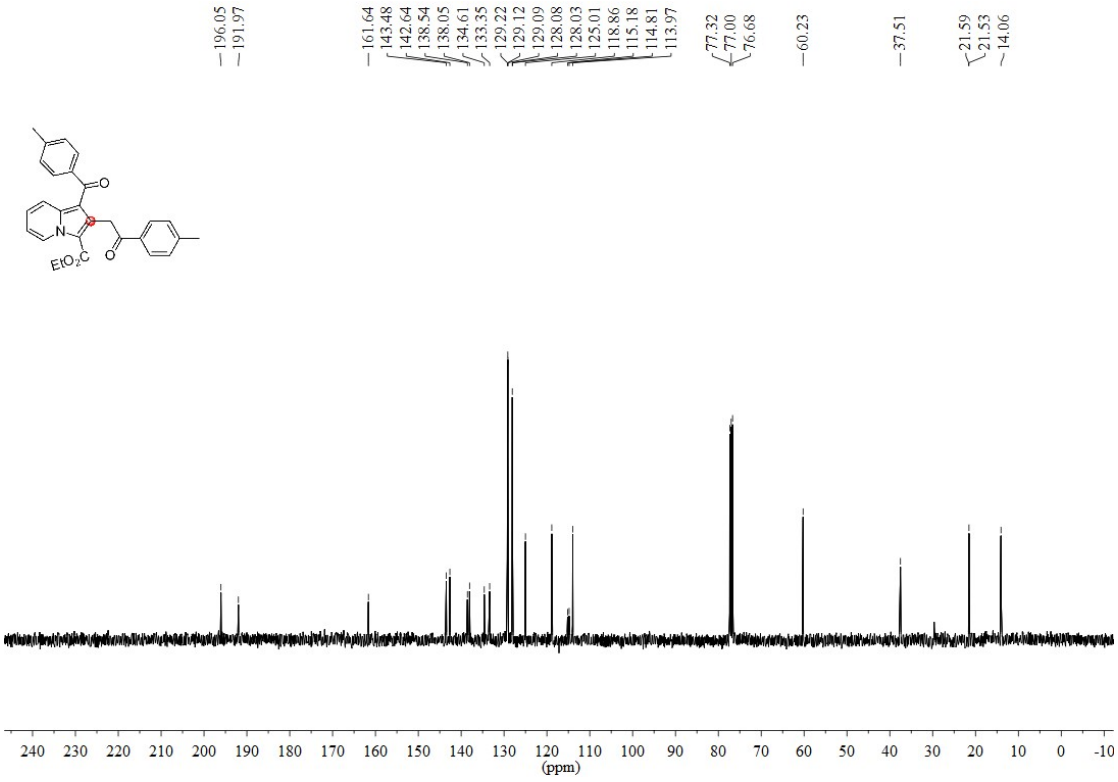
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5a**



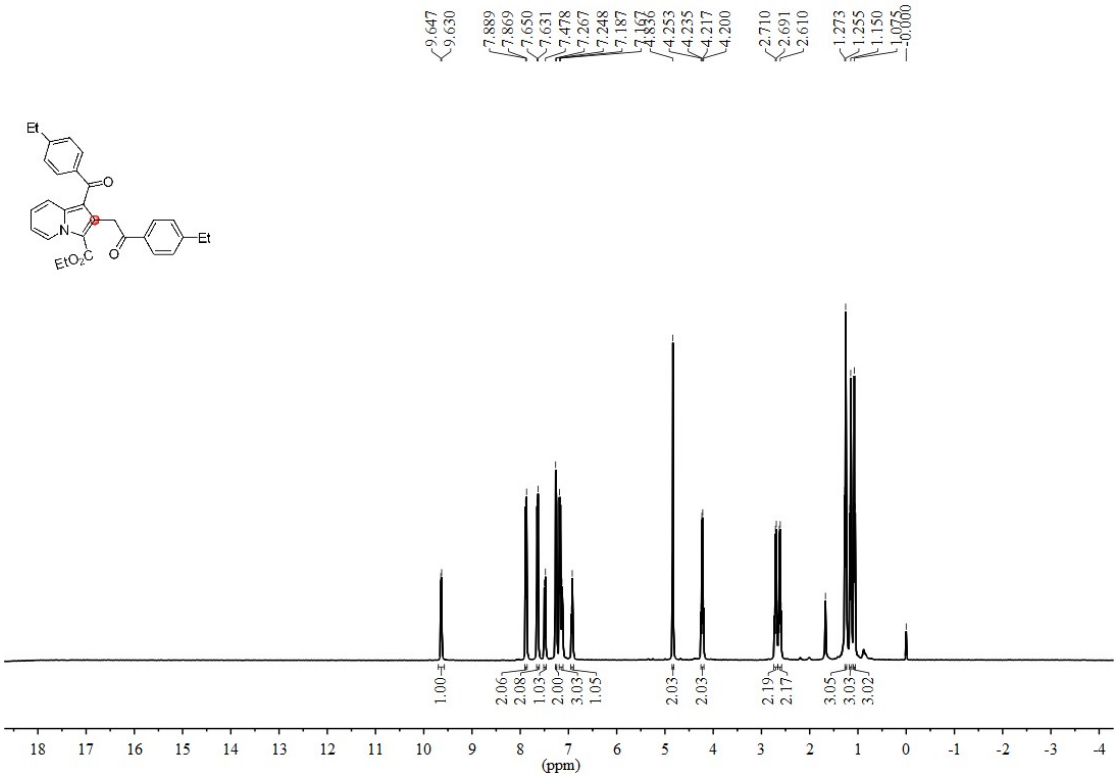
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5b**



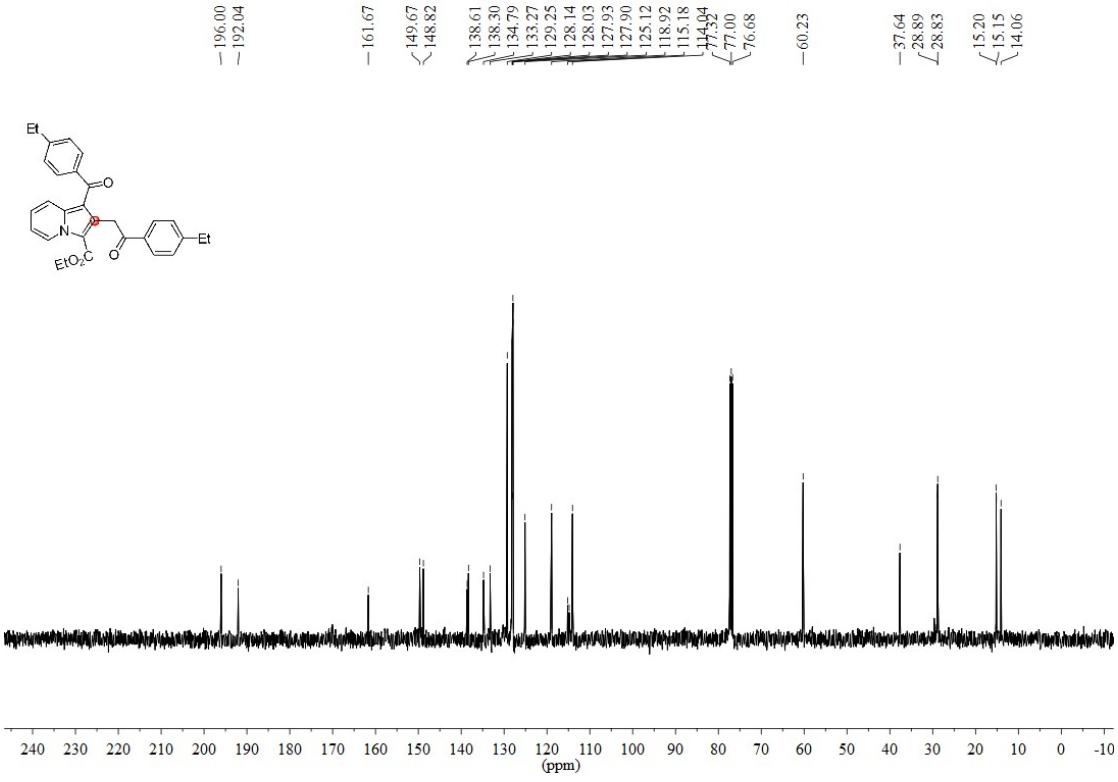
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5b**



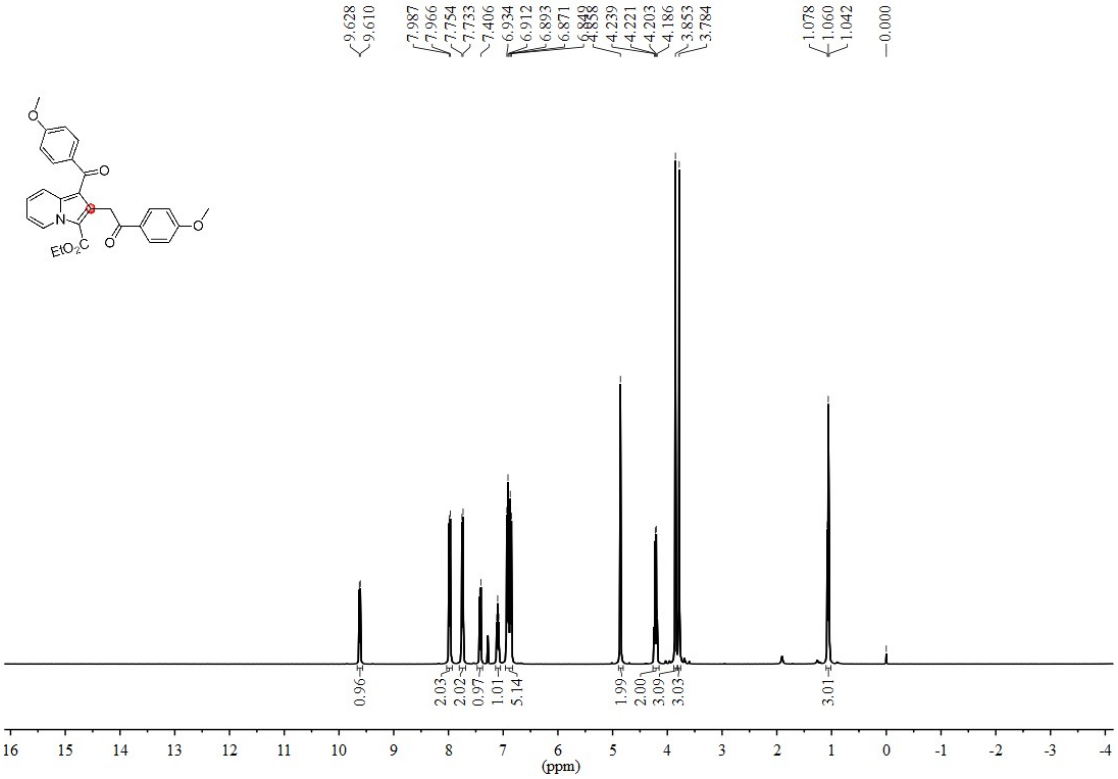
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5c**



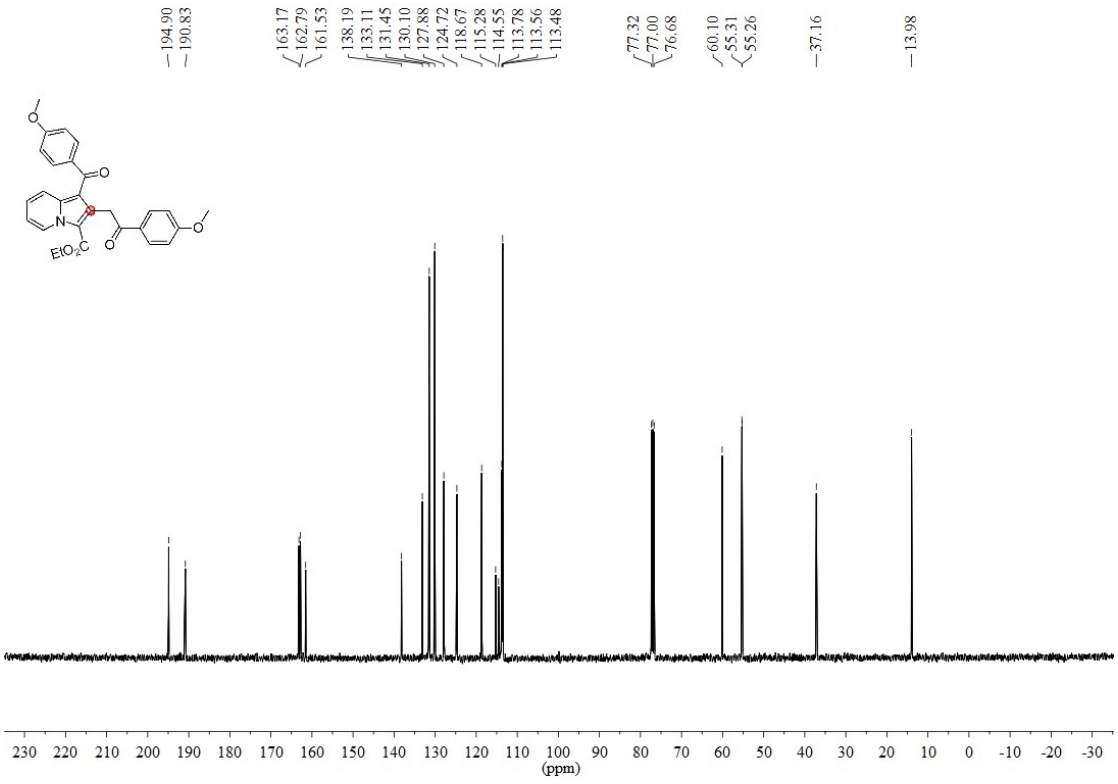
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5c**



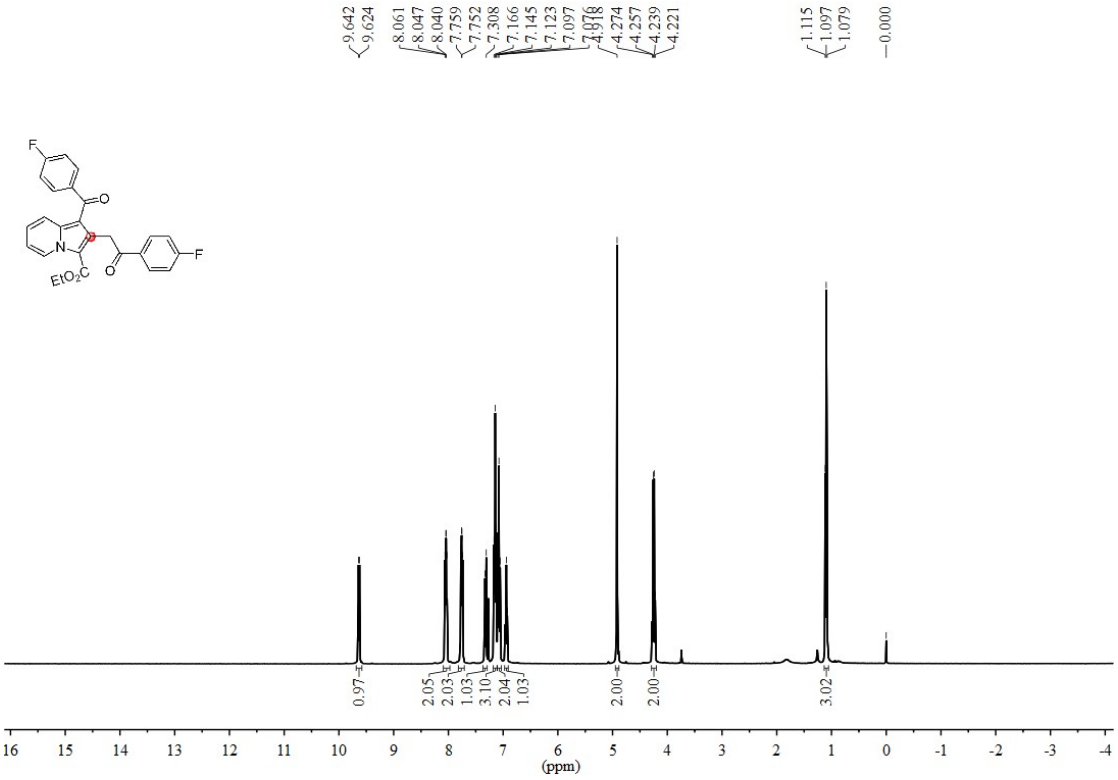
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5d**



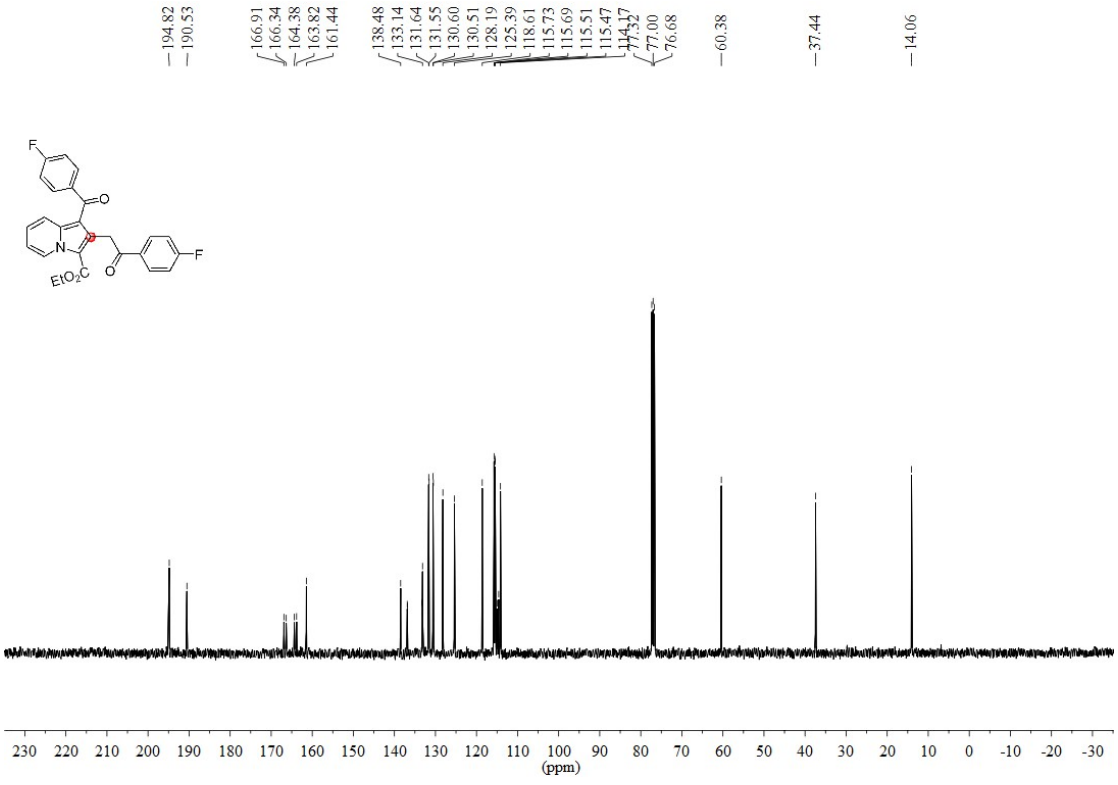
^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) of compound **5d**



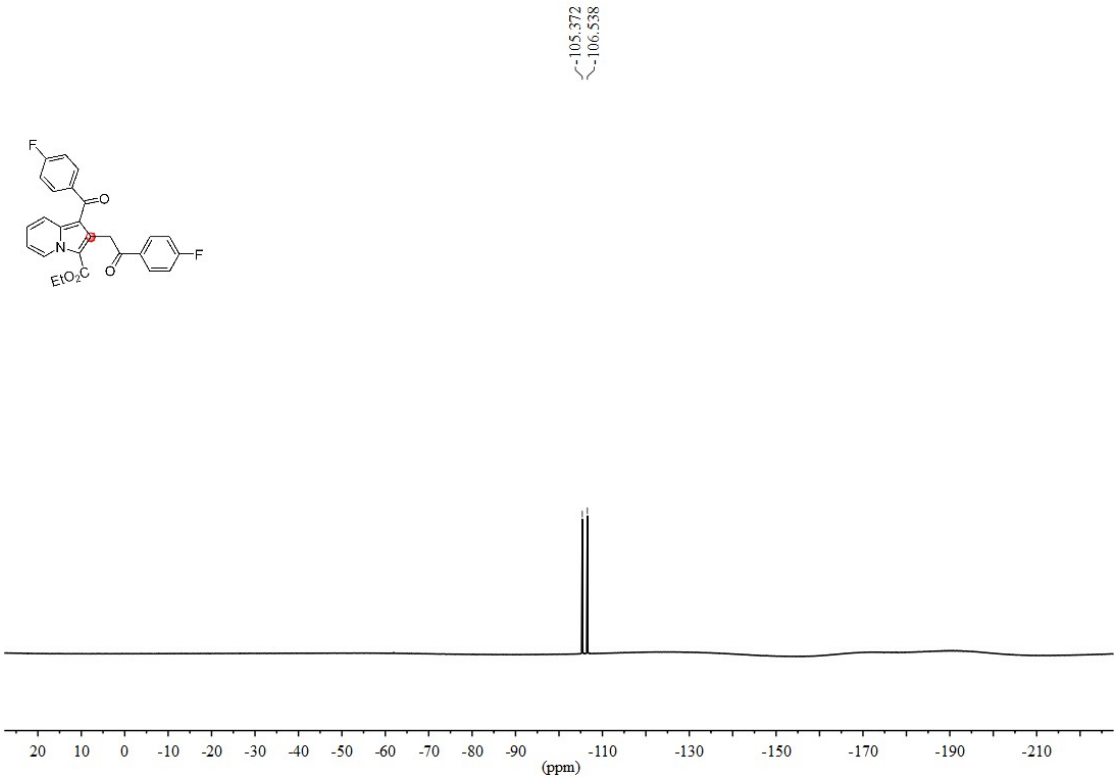
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5e**



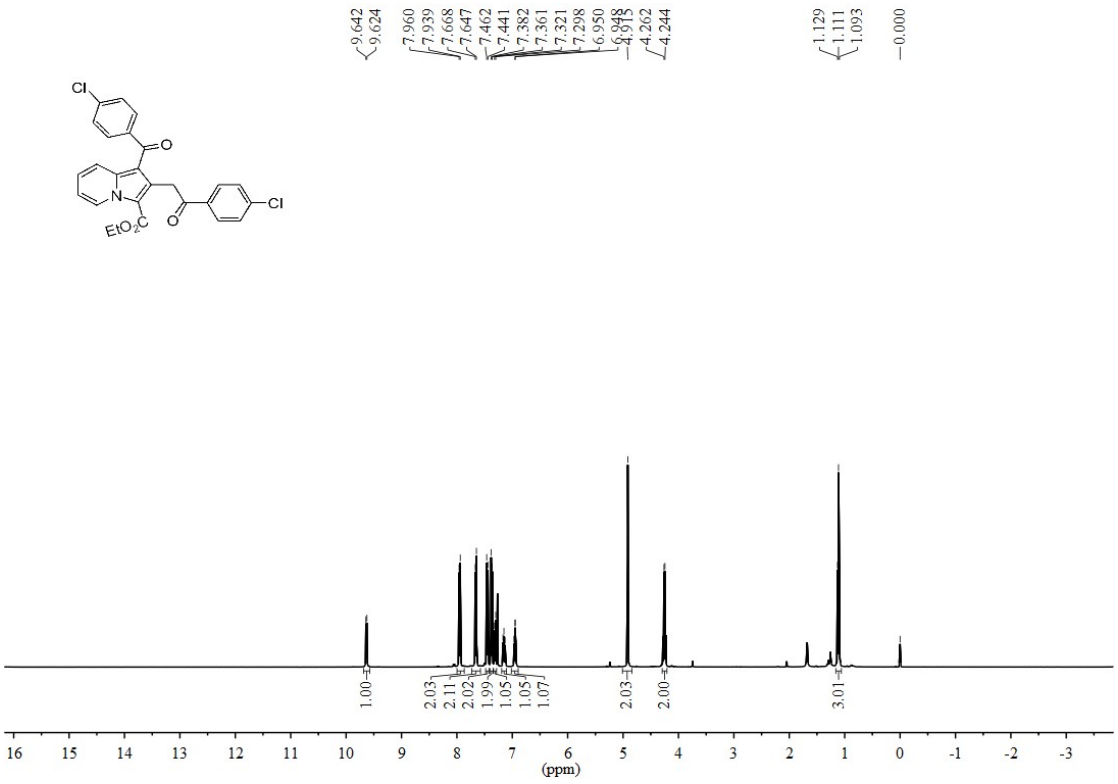
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5e**



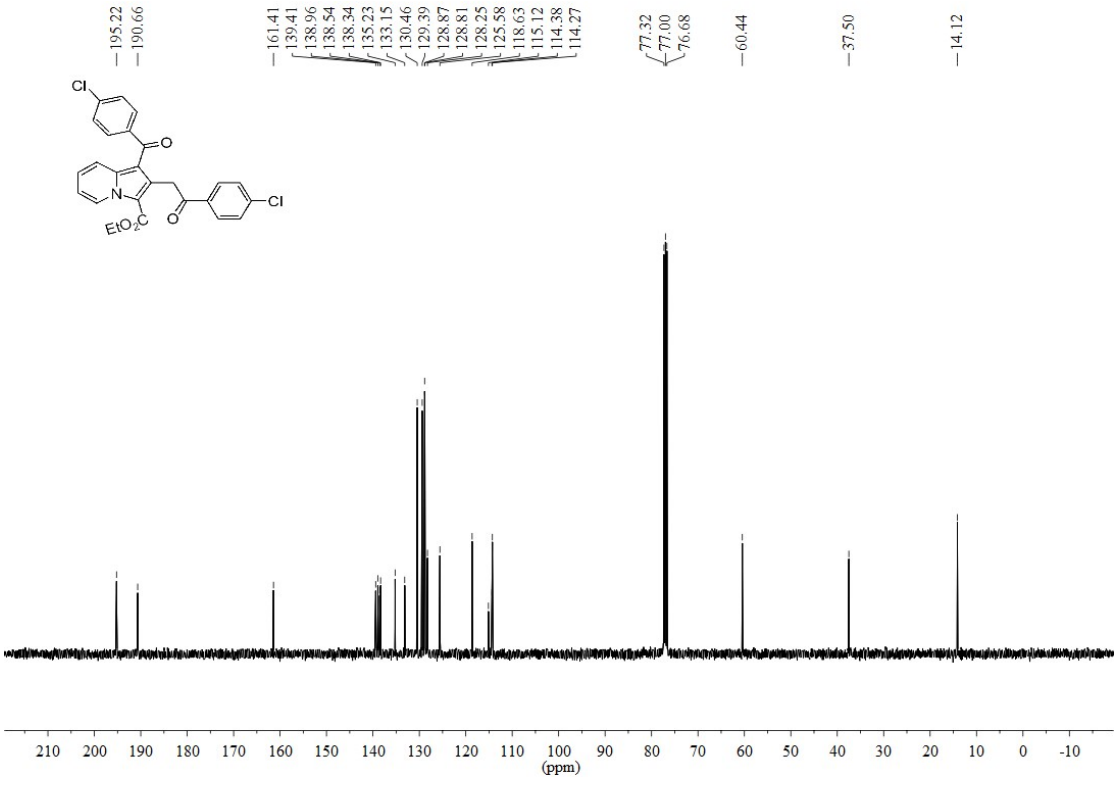
^{19}F NMR (376 MHz, $CDCl_3$) of compound **5e**



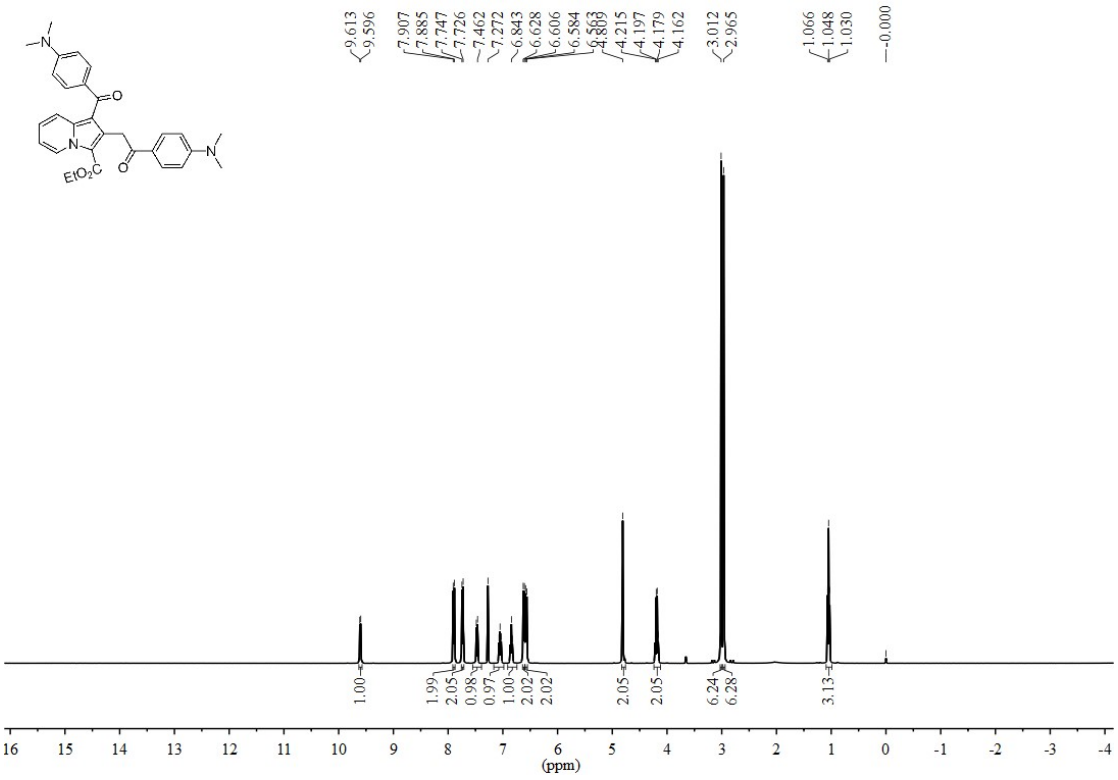
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5f**



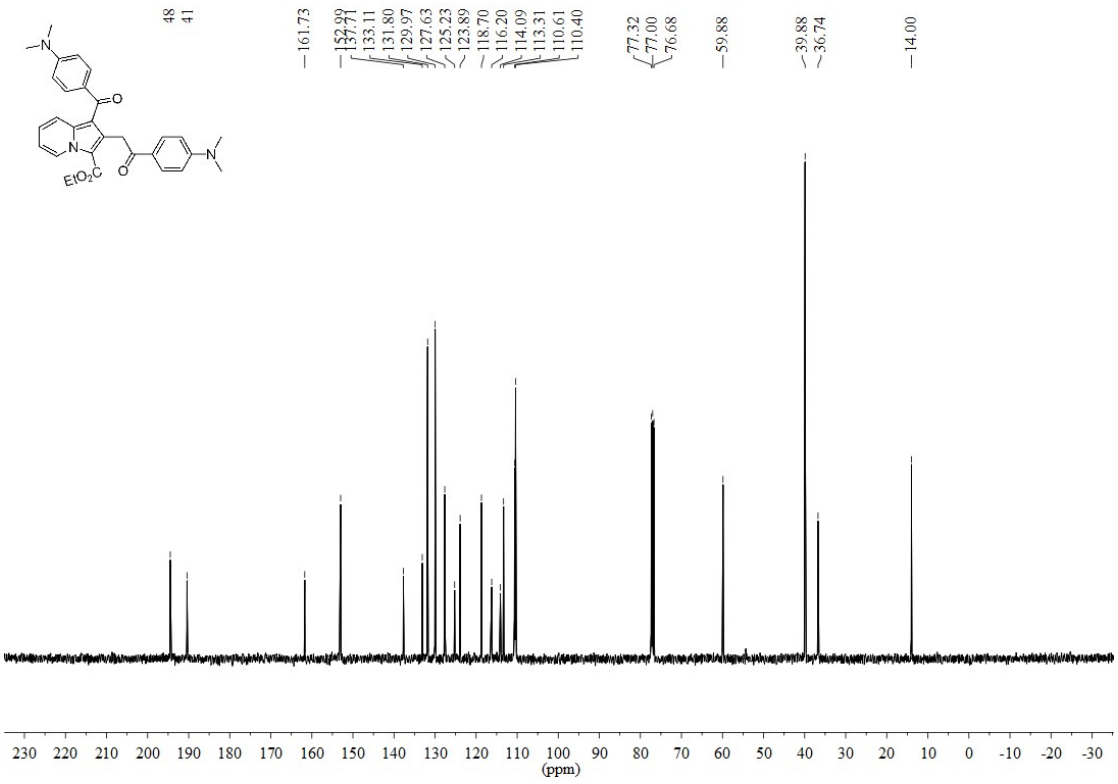
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5f**



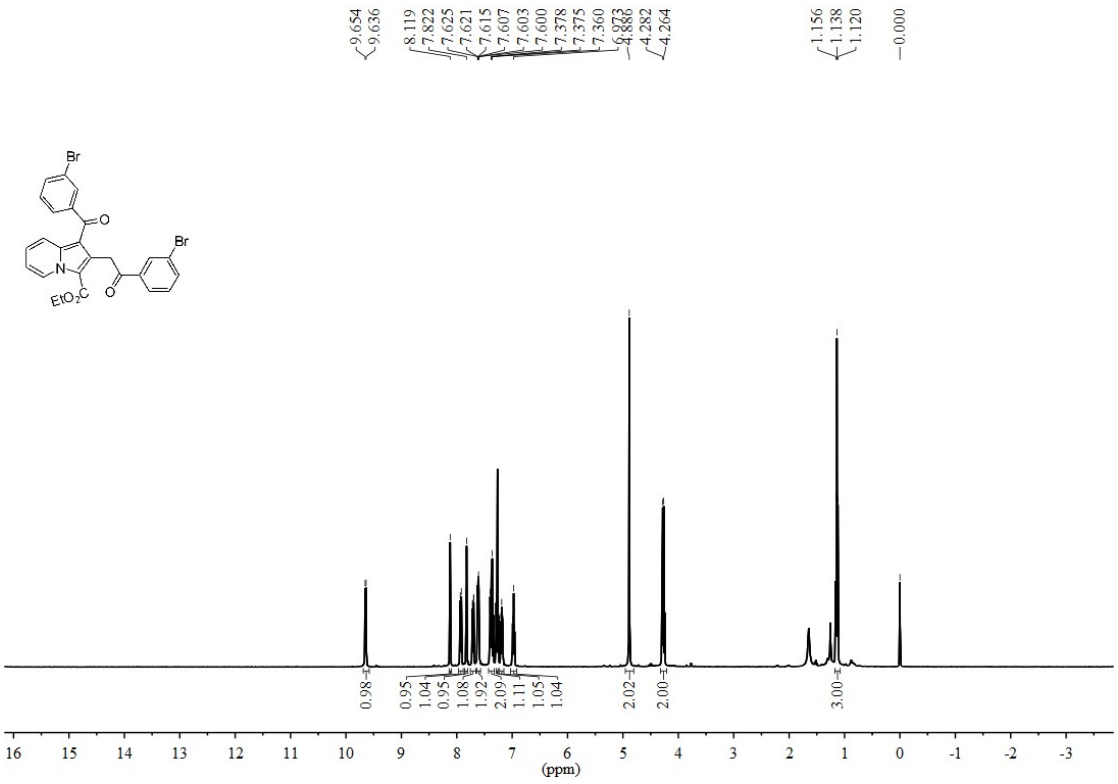
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5g**



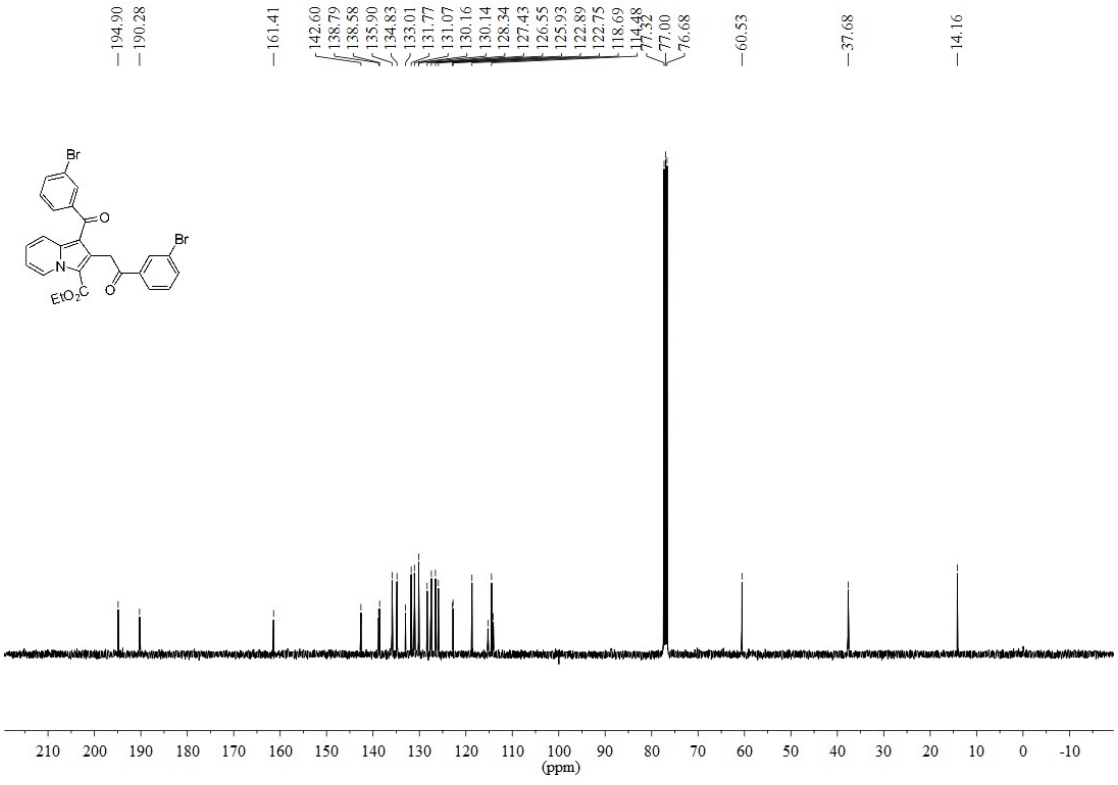
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5g**



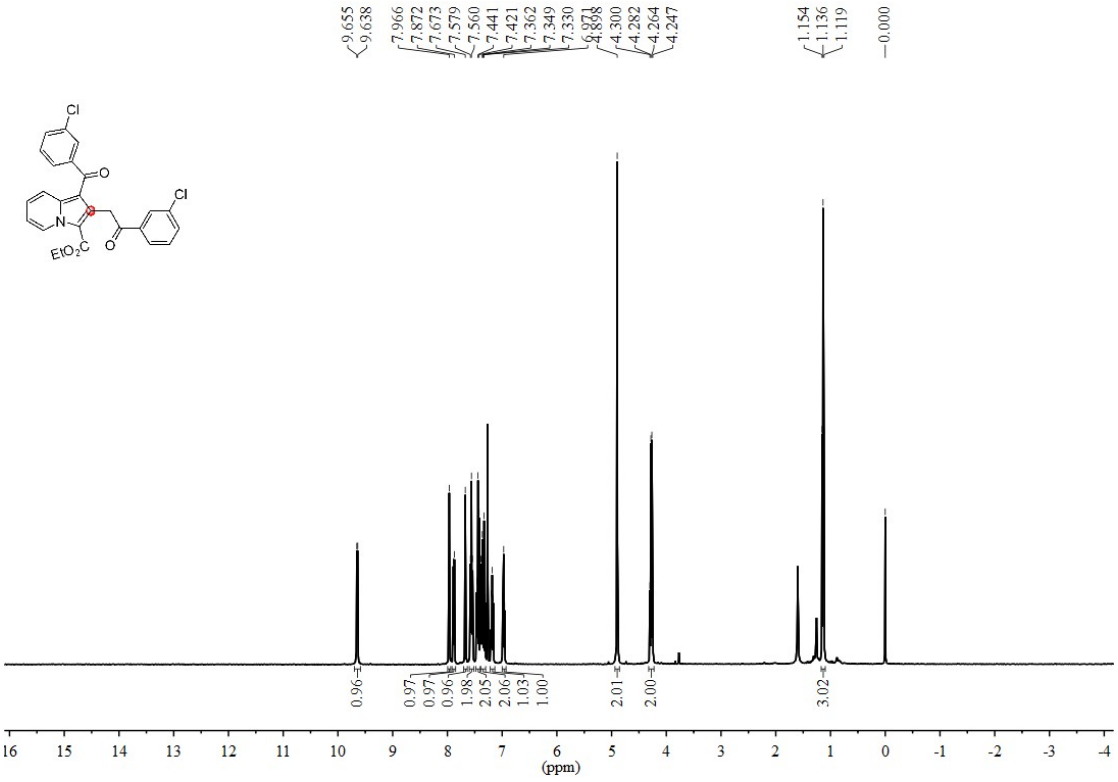
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5h**



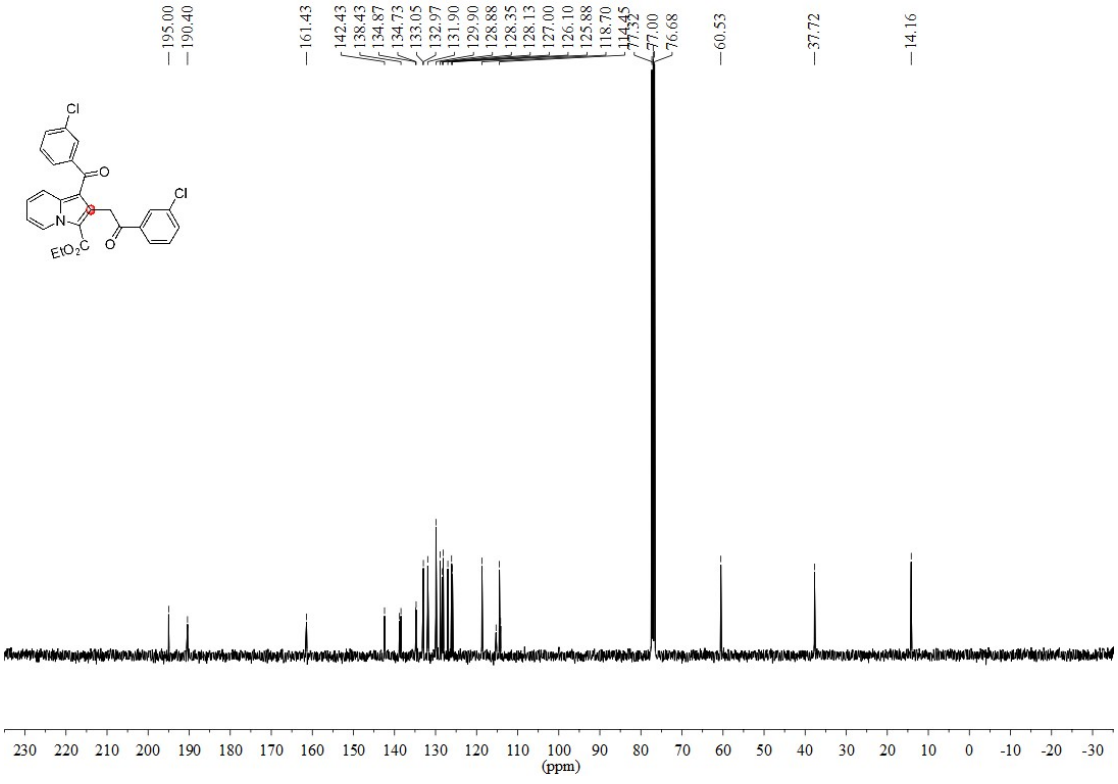
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5h**



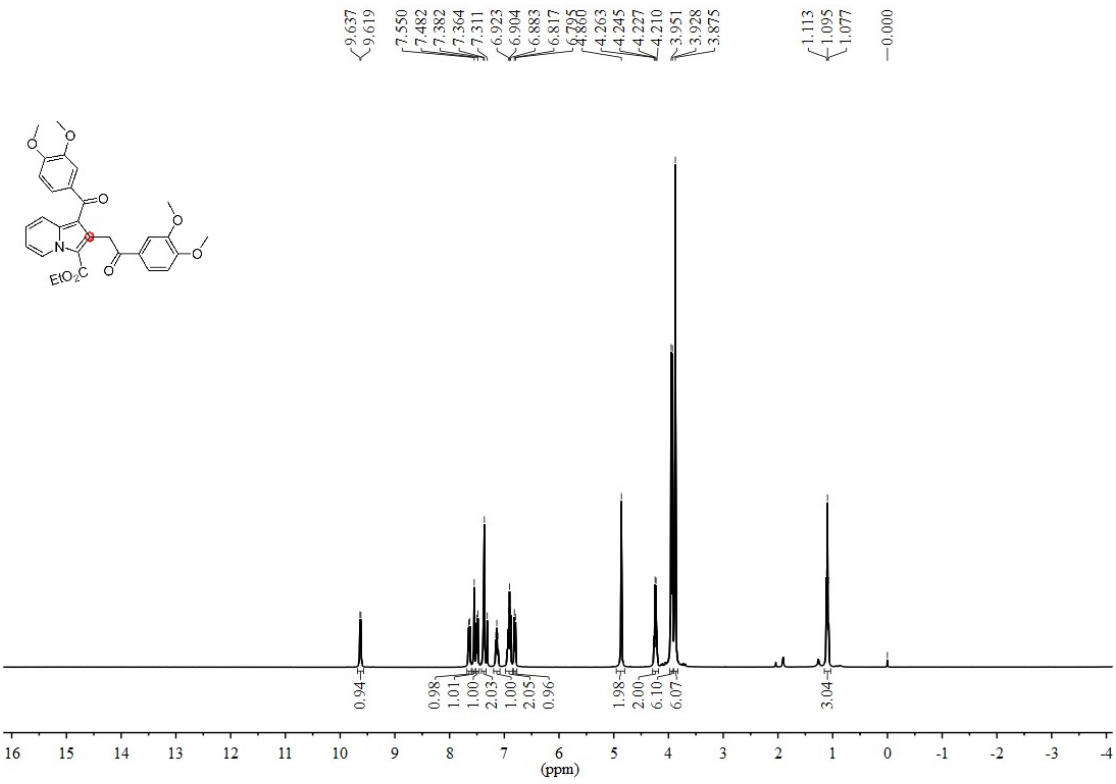
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5i**



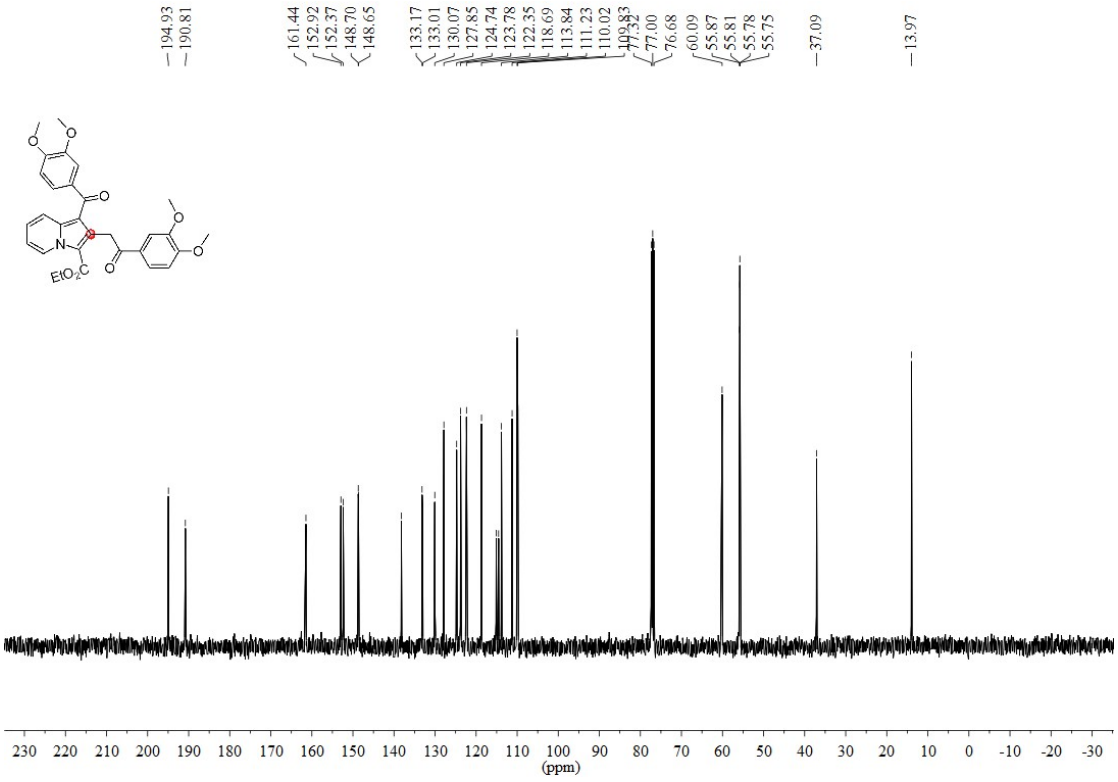
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5i**



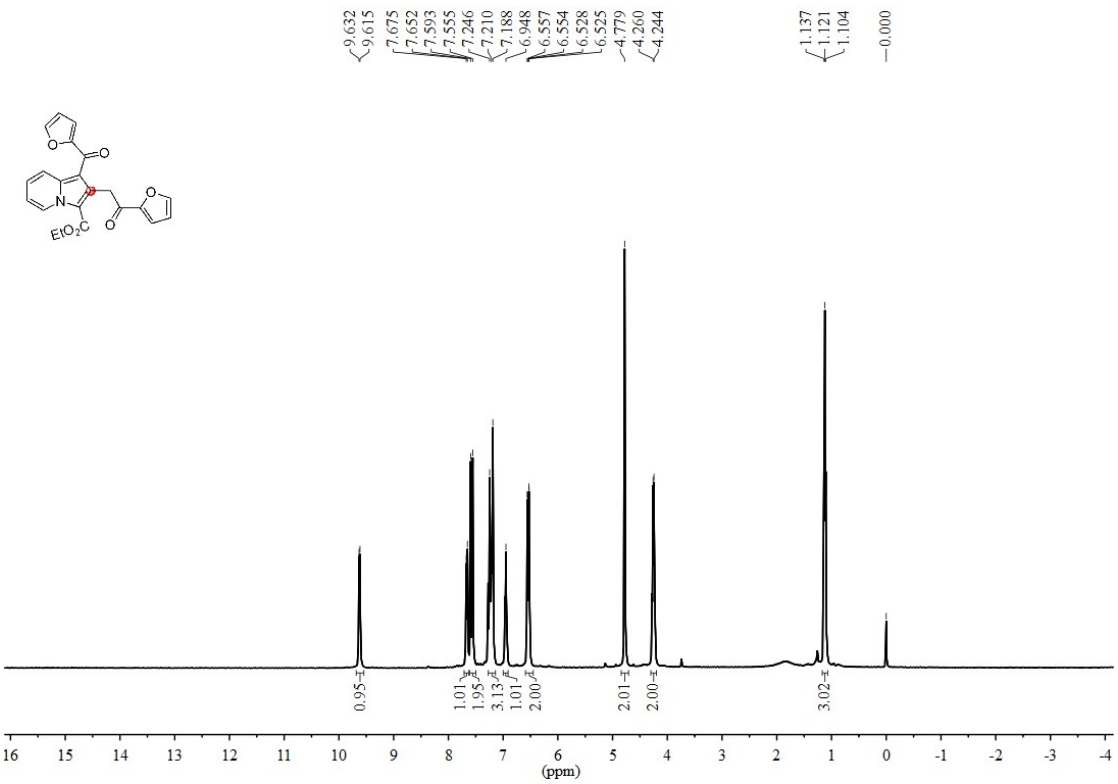
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5j**



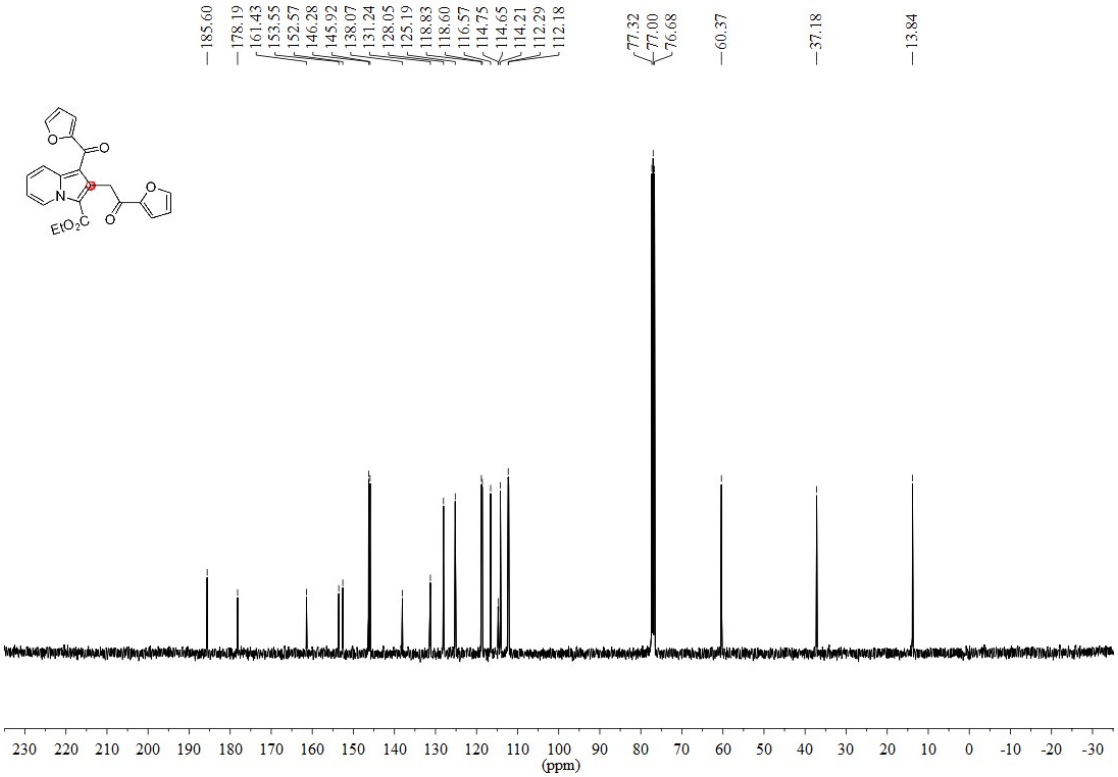
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5j**



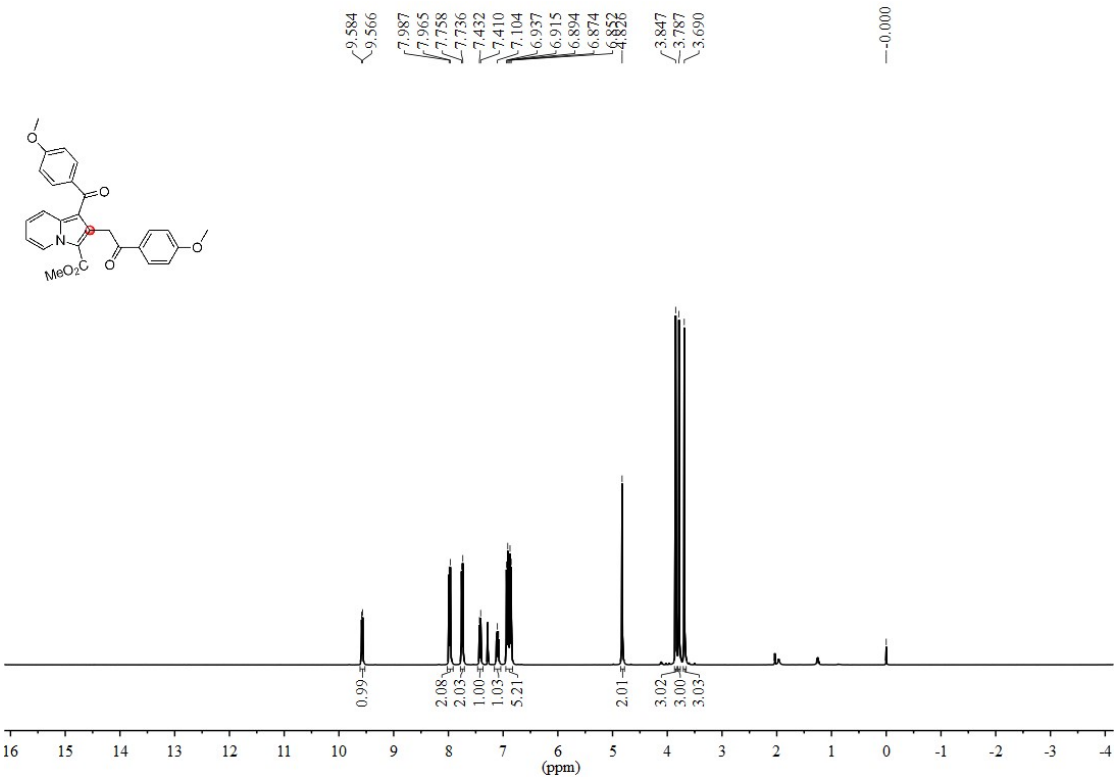
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5k**



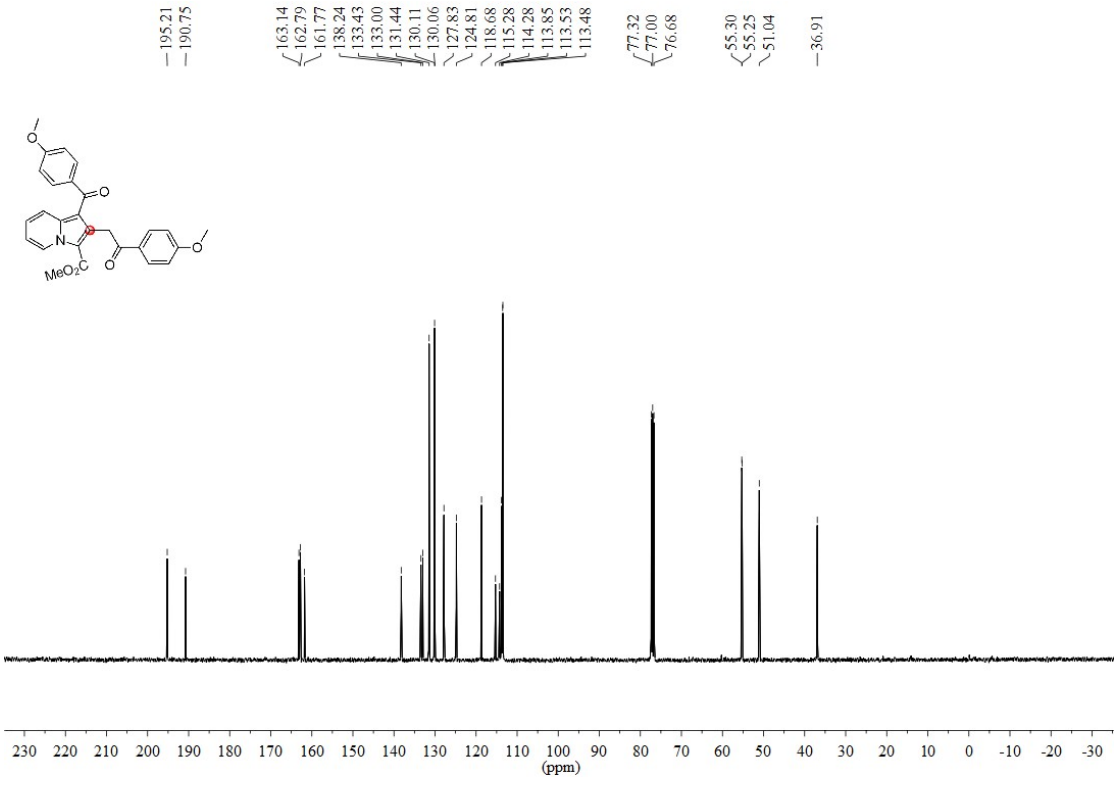
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5k**



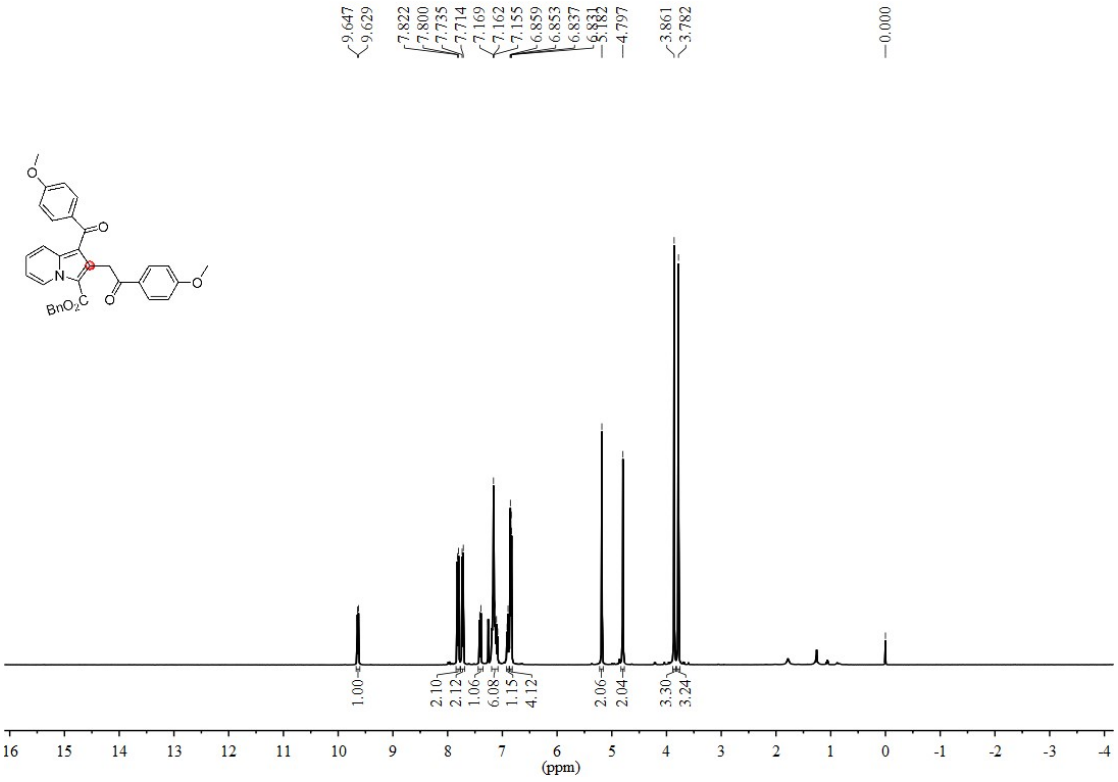
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5l**



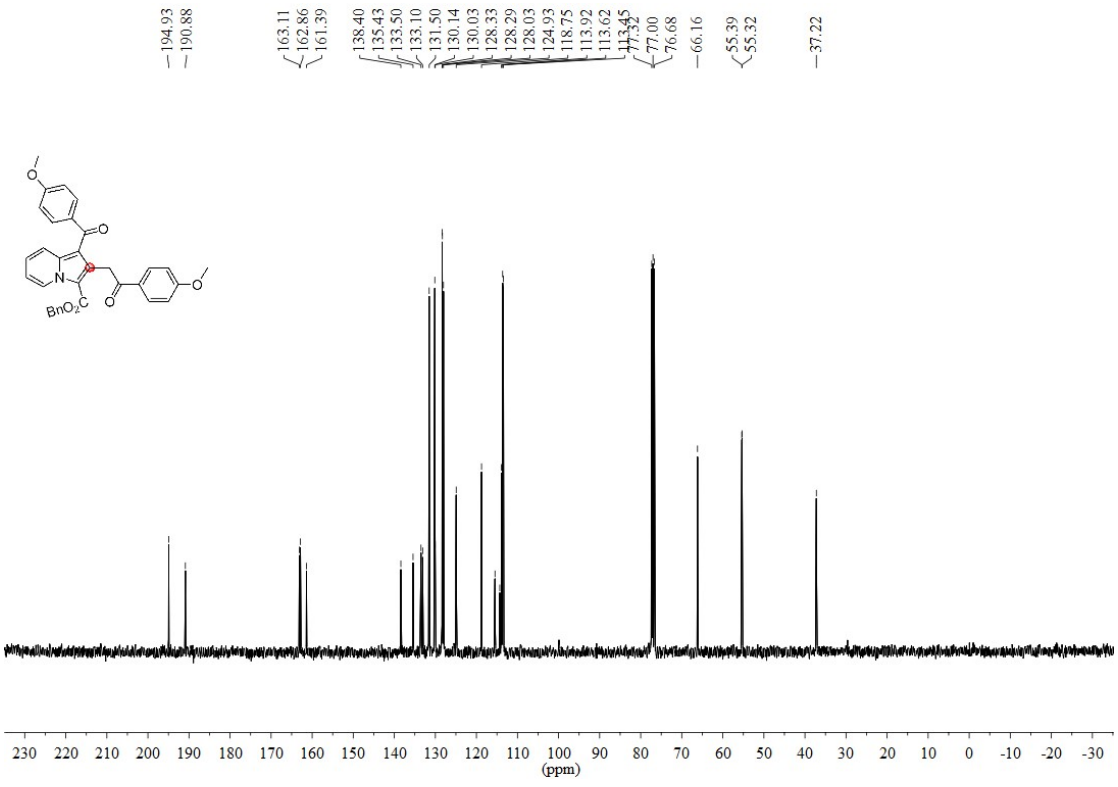
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5l**



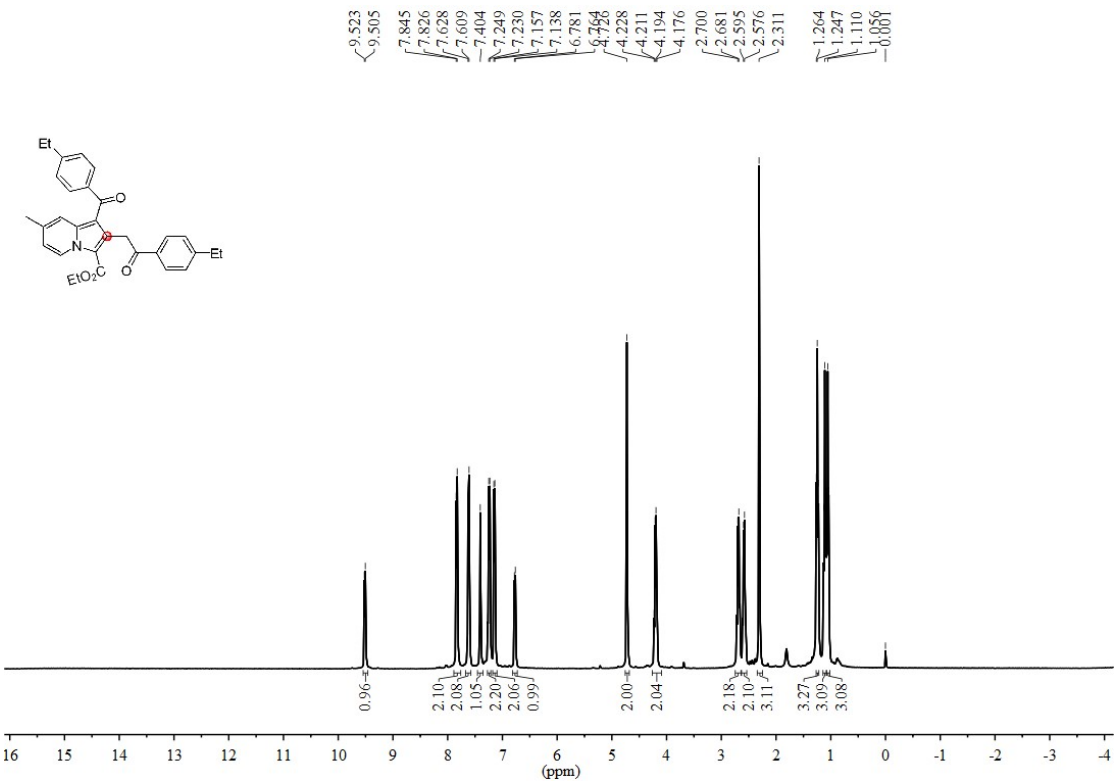
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5m**



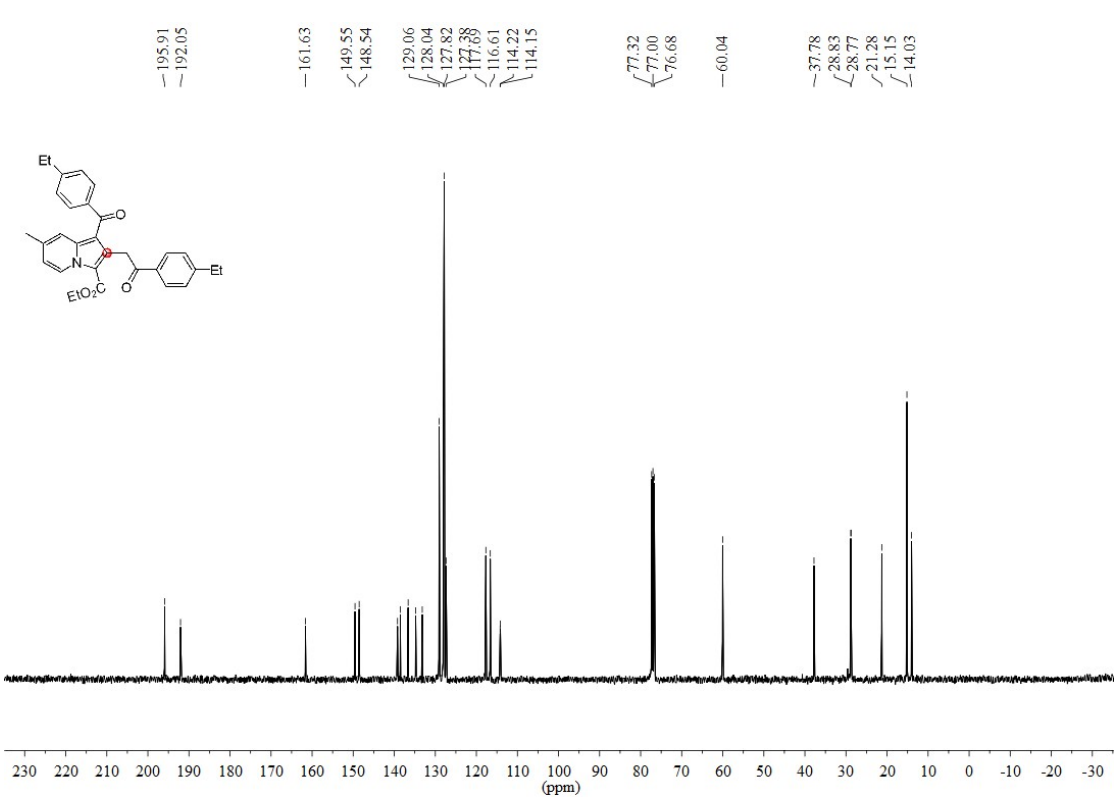
$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **5m**



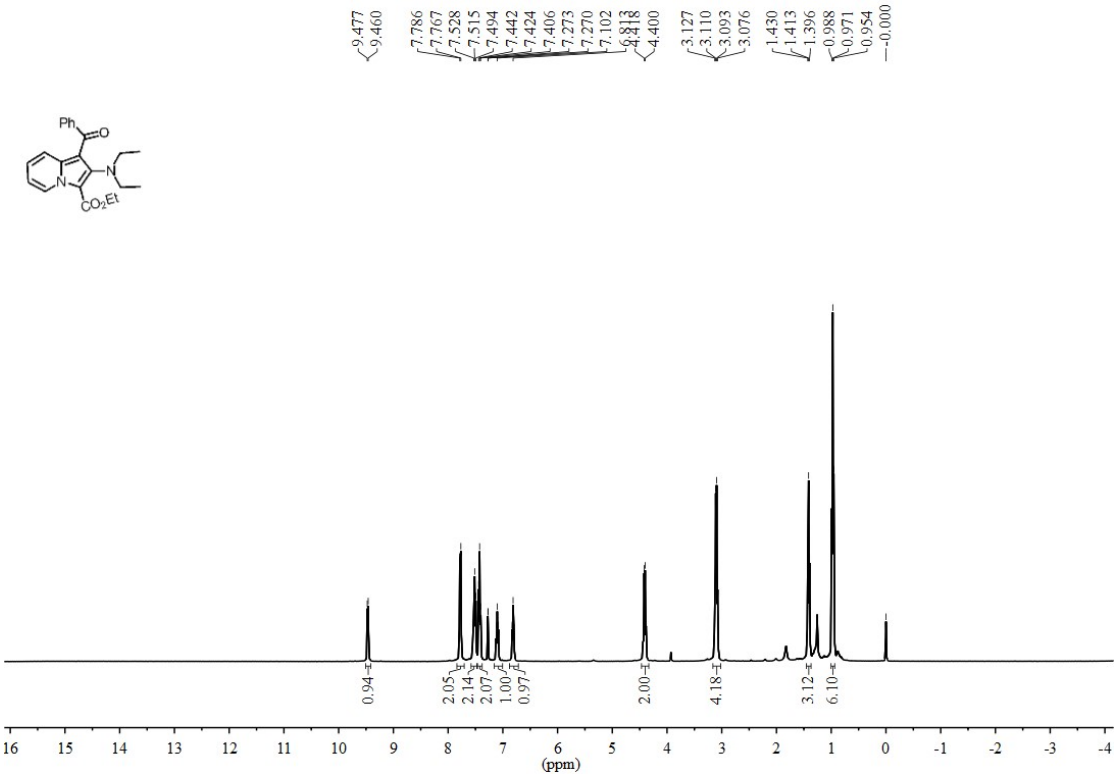
^{1}H NMR (400 MHz, $CDCl_3$) of compound **5n**



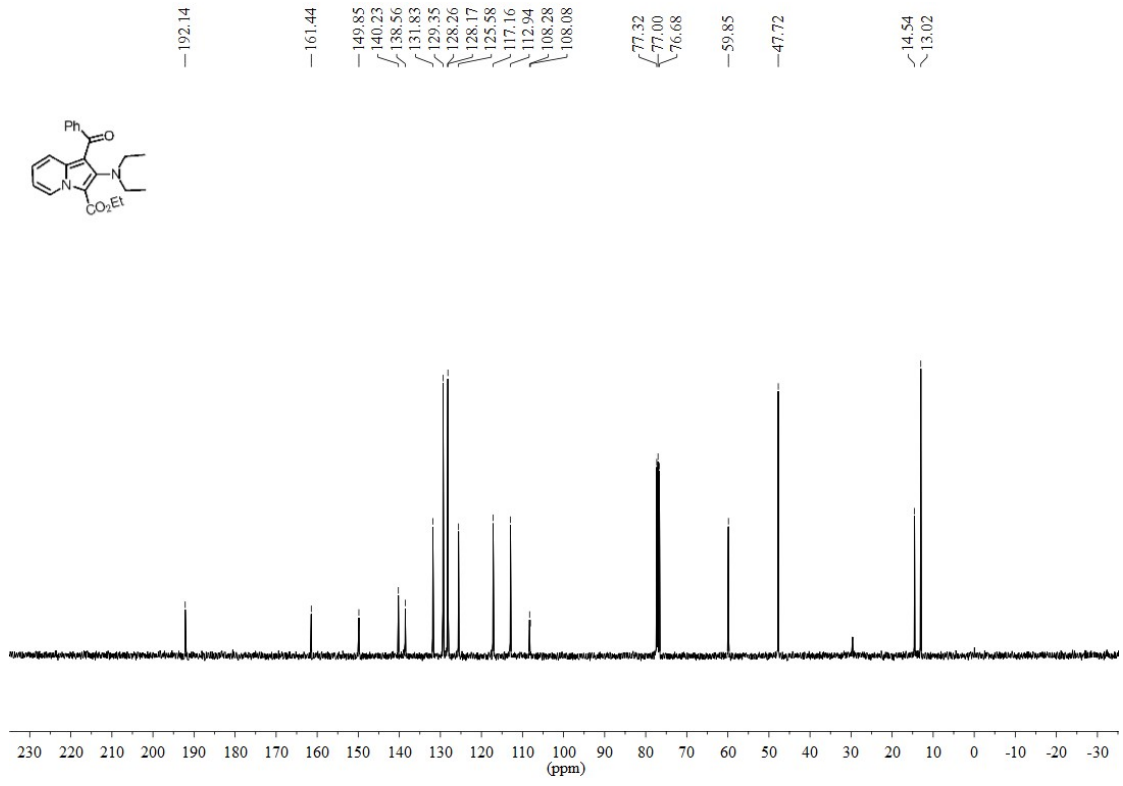
^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) of compound **5n**



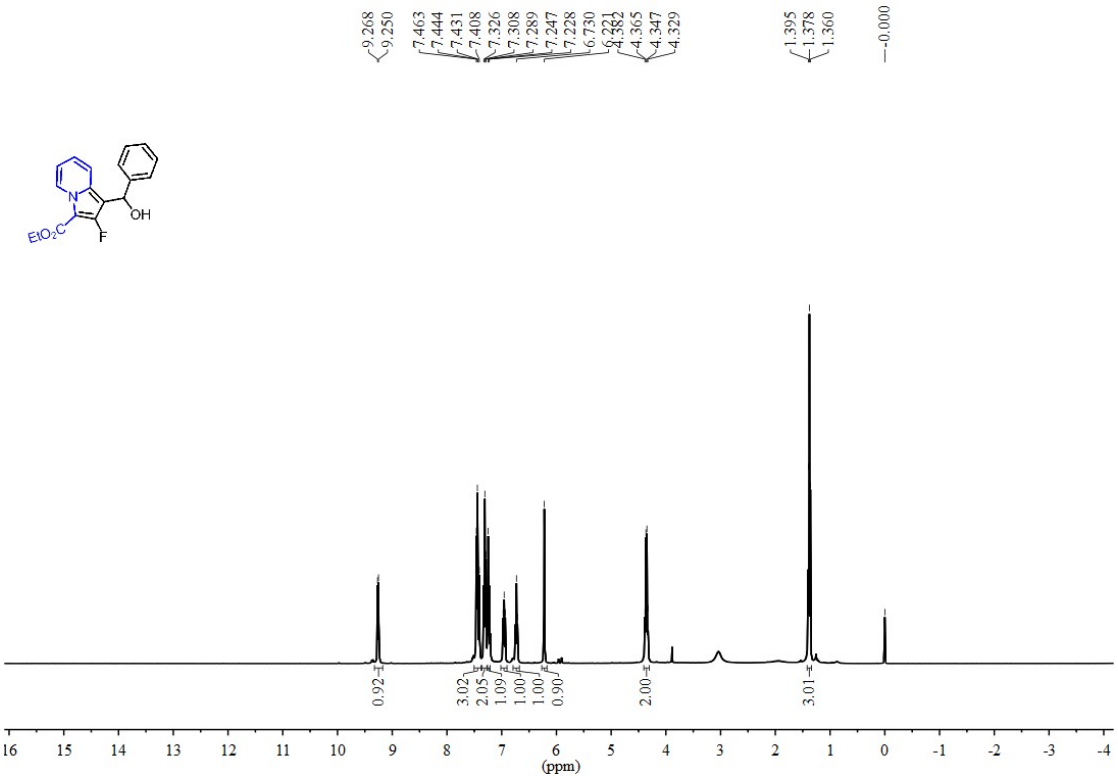
^{1}H NMR (400 MHz, $CDCl_3$) of compound **6**



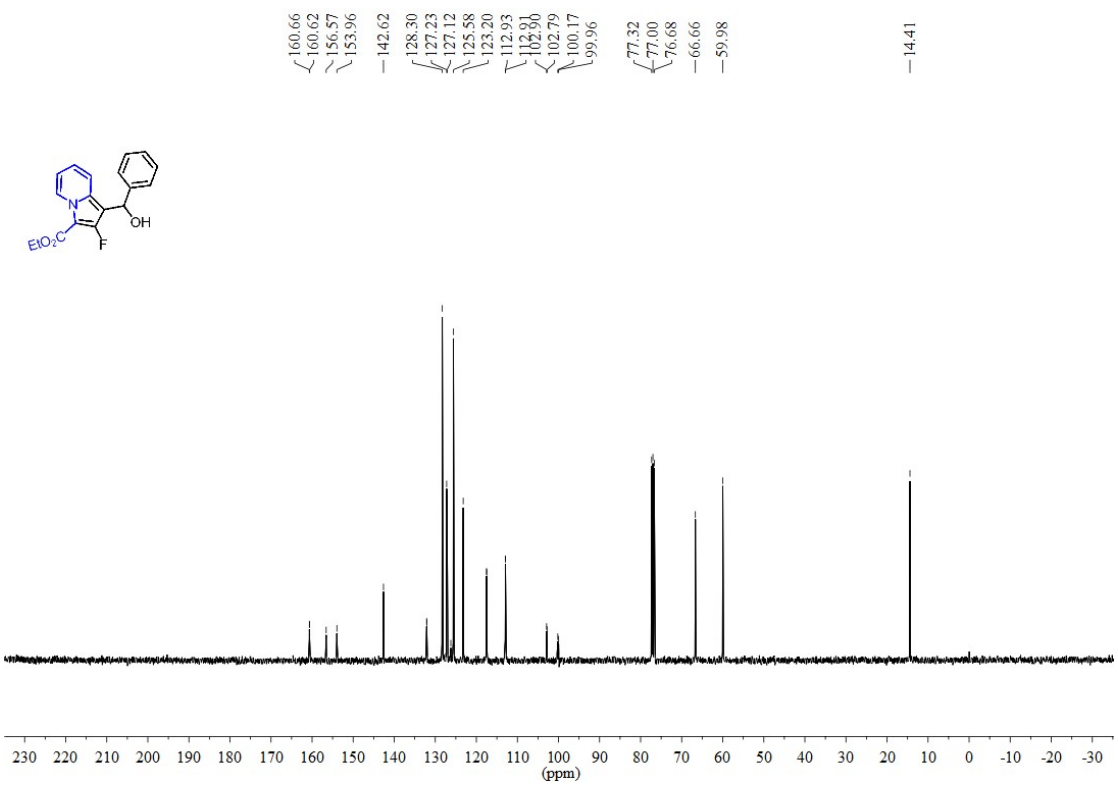
^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) of compound **6**



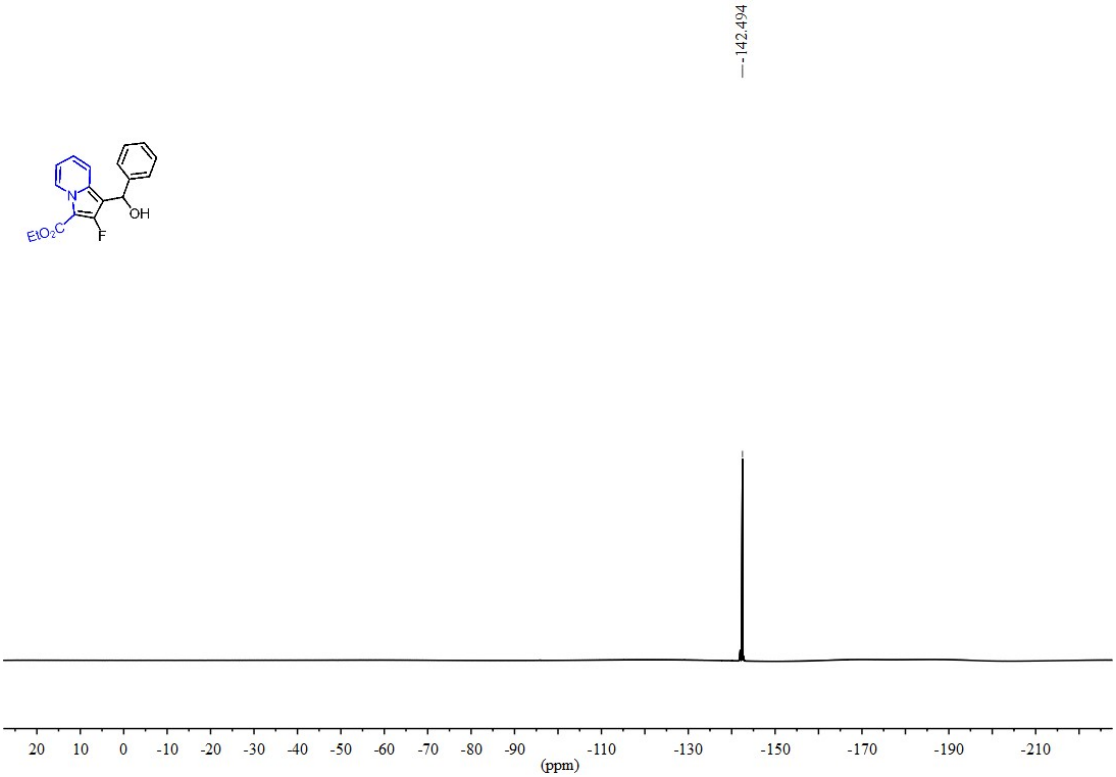
^{1}H NMR (400 MHz, $CDCl_3$) of compound **7**



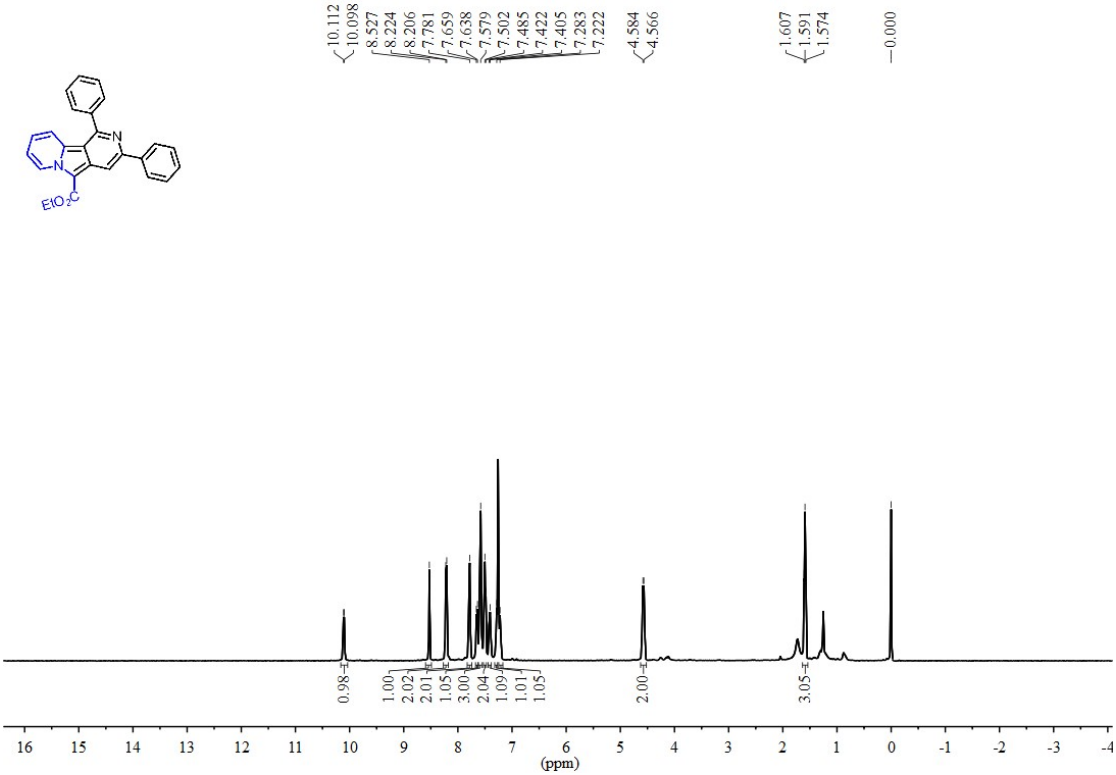
^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$) of compound **7**



^{19}F NMR (376 MHz, $CDCl_3$) of compound **7**



^{1}H NMR (400 MHz, $CDCl_3$) of compound **8**



$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$) of compound **8**