Photoinduced Catalyst-free Difluoromethylation-Cyclization of Indole Derivatives via Electron Donor-acceptor Complexes Under Visible Light

Hong-Xian Jin,[a] Yuping Zhu,[a] Jie Zhang,[a] Yun-Peng Zhang,[a] Ling Zhu,[a] Lipeng Long,[a] Zhengwang Chen[a], Haiqing Luo*[a] and Daohong Yu*[a]

[a] Jiangxi Province Key Laboratory of Synthetic Pharmaceutical Chemistry, Gannan Normal University, Ganzhou 341000, P. R. China

Supporting Information

Table of content

General information

All chemicals, unless otherwise noted, were purchased from commercial sources and used without further purification. All solvents for reactions and measurements were purified by standard methods. ^{1}H and proton-decoupled ^{13}C NMR spectra were recorded on Brucker 400 M or 500 M spectrometers. ^{19}F NMR spectra were recorded on Brucker 500 M spectrometers. ^{1}H NMR and ^{13}C NMR chemical shifts (δ) were determined relative to TMS at δ 0.0 ppm. Coupling constants (*J*) are in Hertz (Hz). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. All reactions were monitored by TLC or ^{1}H NMR analysis. Flash column chromatography was carried out using 300–400 mesh silica-gel at medium pressure.

High resolution mass spectra were recorded using a Q Exactive mass spectrometer (Thermo Fisher Scientific, USA. Gas chromatography-mass spectrometry (GC-MS) analyses were performed with an Agilent Technologies 7890A Network GC System equipped with an Agilent Technologies 5975C Network Mass Selective Detector (MSD).

All the *N*-alkene tethered indoles (**1a**-**1z**) were synthesized according to the previous literatures.[1] difluoromethyl (hetero)aryl sulfones (**2a**-**2f**) were synthesized according to the previous procedure.[2]

Unless stated otherwise, visible light irradiation was performed using 24 W 450 nm LEDs (3 W x 8) under argon atmosphere. All the reaction vessels used are the ordinary borosilicate glass test tubes. The illumination instruments were purchased from Hefei Hanhai Star Technology Co., Ltd. The photoreactor model is JH-3B14P45-T2A-M455, light 24 W (3 W x 8). In all the reactions, the filters were not used.

Figure S1. Reaction setup with cooling by running water.

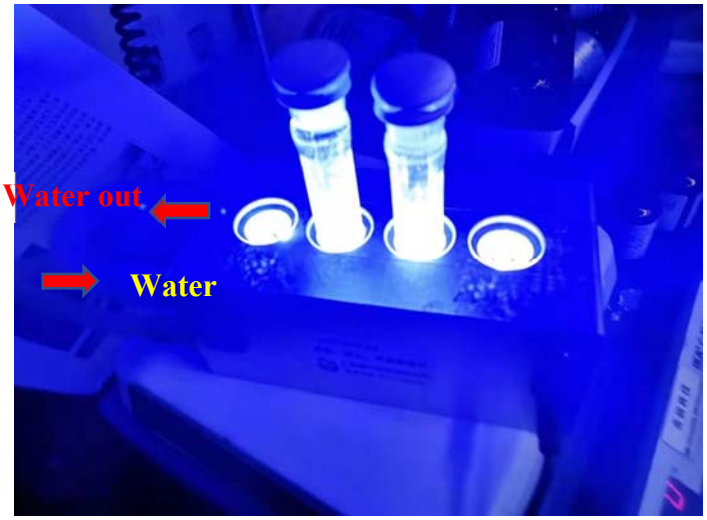
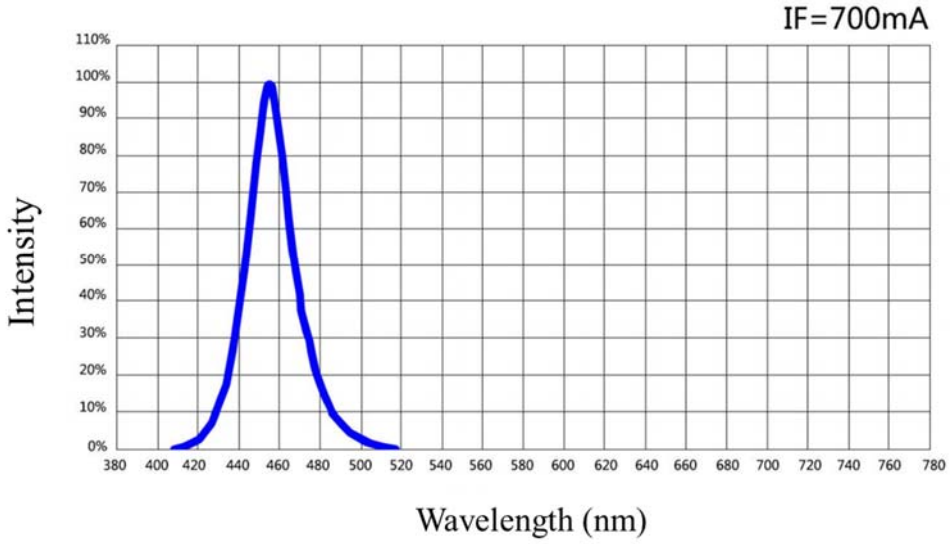


Figure S2. the distance from the light source to the irradiation vessel

The distance is about 3 mm from light source

Firgue S3. Wavelength of peak intensity and broadband source



Mechanistic experiment

Figure S4. The EDA complex detected by ^{19}F NMR Spetrum

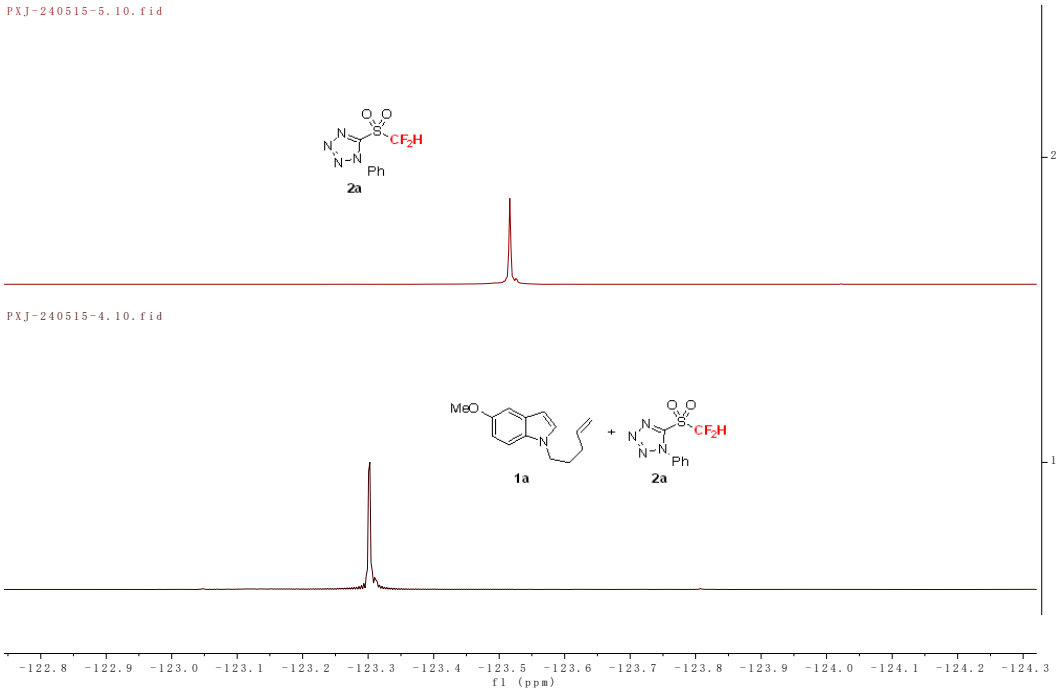


Figure S5. The UV-Vis Spetrum

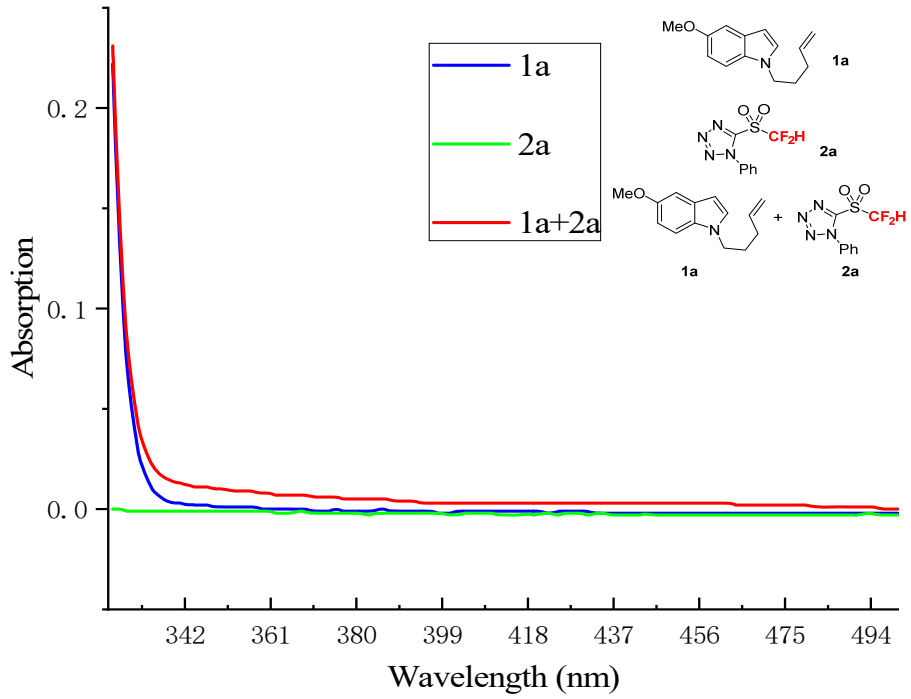
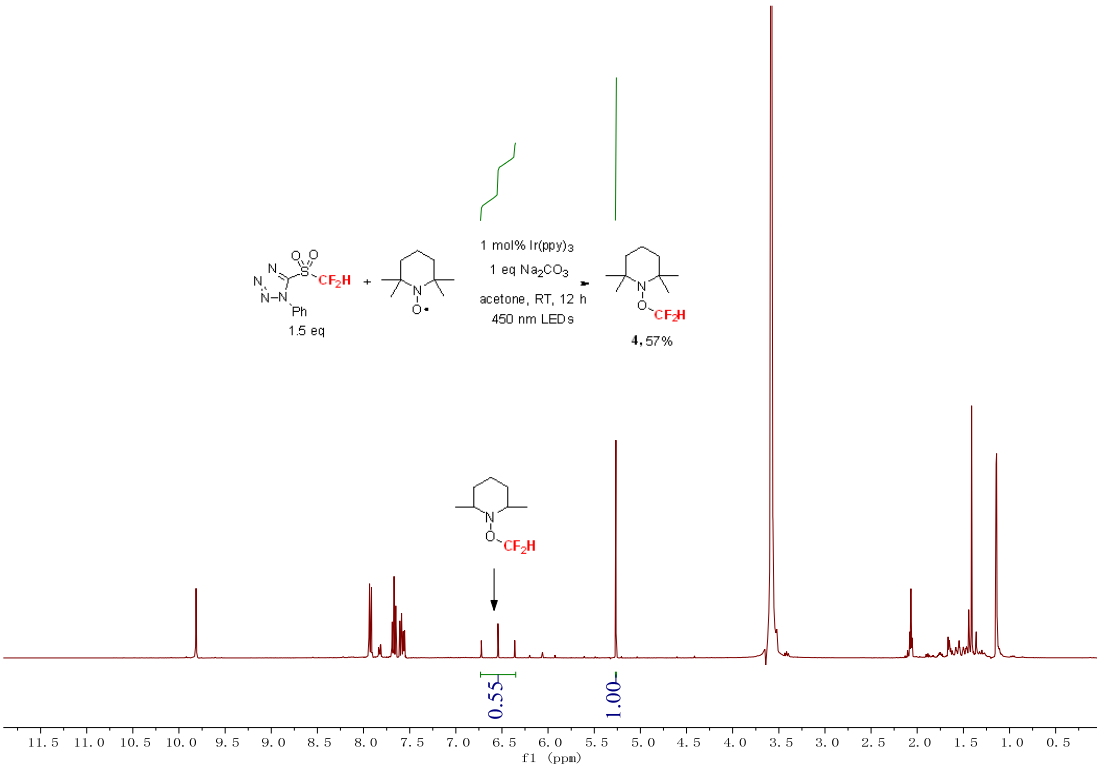
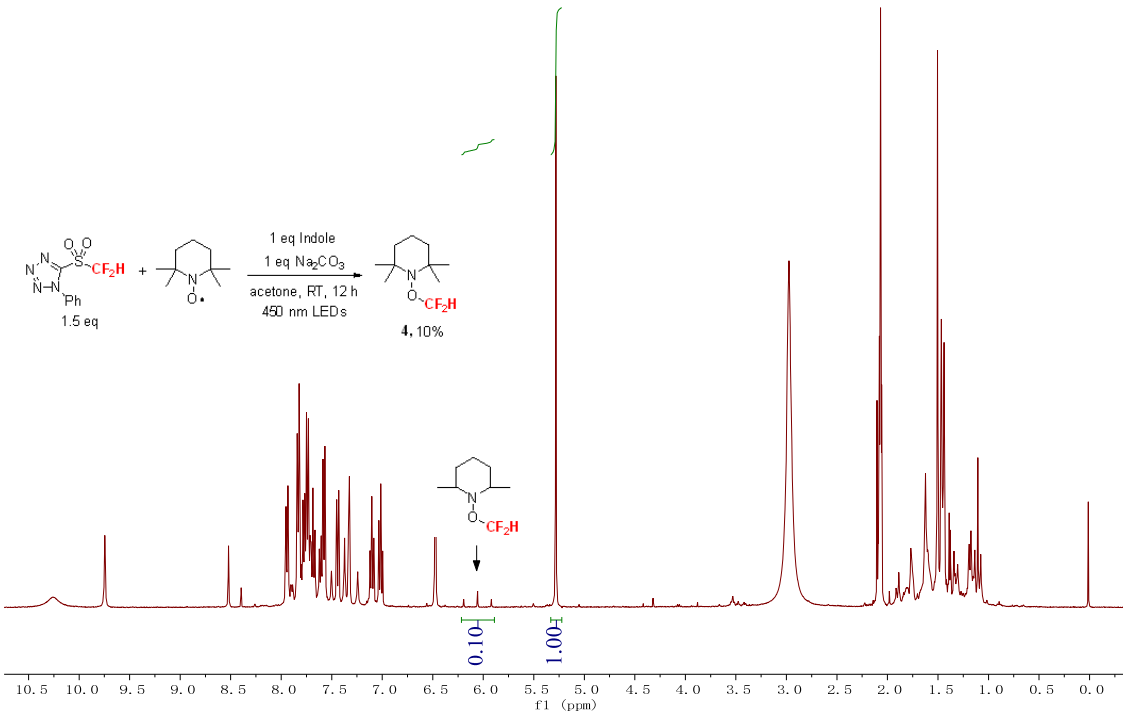
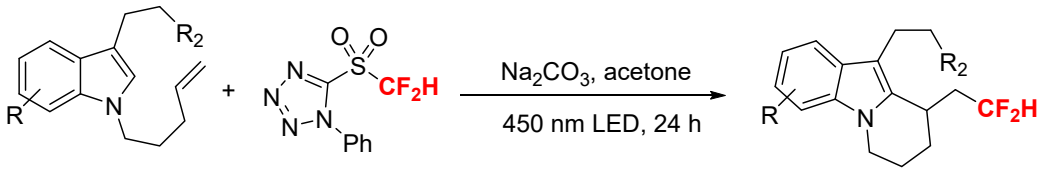


Figure S6. The radical trap experiments with TEMPO.





Scheme S1: unsuccessful examples



R = H, Me tryptamine derivatives	R = H, Me melatonin derivatives	tryptophan derivatives
NR[a]	NR[a]	NR[a]
NR[b]	NR[b]	NR[b]

a) **1a** (1.5 mmol, 3.0 equiv), **2** (0.5 mmol, 1.0 equiv) and Na_2CO_3 (0.5 mmol, 1.0 equiv) dissolved in acetone (5 mL) was irradiated under 450 nm LEDs for 24 h; b) 1 equiv 1-methyl-1H-indole was added.

Synthesis of 5-((difluoromethyl) sulfonyl)-1-Phenyl-1*H*-tetrazole (DFSPT):

To a mixture of KOH (144.6 g, 2.58 mol, 10 equiv) dissolved in H_2O (75mL), DME (75 mL), and MeCN (75 mL) in a 500-mL three neck round-bottom flask, which was cooled down to 0 °C, 1-Phenyl-*1H*-tetrazole-5-thiol (46 g, 0.258 mol) was added dropwise. CF_2HCl gas was bubbled into the stirred mixture from a balloon, CF_2HCl gas

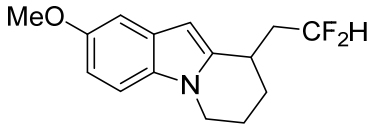
was bubbled until TLC indicated the 1-methyl-*1H*-tetrazole-5-thiol was consumed completely. The reaction was quenched by adding excess amount of H_2O, followed by extraction with ethyl acetate, washed with brine. The organic phase was dried over anhydrous $NaSO_4$. After the solution was filtered and the solvent was evaporated under vacuum, the residue was subjected to next step without further purification.

To a 500-mL beaker containing 5-(difluoromethylthio)-1-methyl-*1H*-tetrazole, were added CH_3CN (85 mL), CCl_4 (85 mL), H_2O (150 mL), $NaIO_4$ (111.5 g, 0.516 mol). The mixture was stirred with a mechanical stirrer. Ruthenium trichloride hydrate (0.256 g) dissolved in water (20 mL) was added dropwise for 10 minutes. The resulting mixture was stirred at room temperature for 1 h. TLC indicated the substrate was consumed. Thereafter, saturated $NaHCO_3$ was added until the PH = 8, and the resulting mixture was extracted with DCM (100 mL x 3). The combined organic phase was washed with brine, and then dried over anhydrous Na_2SO_4. The solvent was removed under reduced pressure and the residue was purified by flash column chromatography (PE:EA = 5:1) on silica gel to afford the product ***DFSPT*** as colorless solid (47.0 g, 75%).

General procedure for difluoromethylation-cyclization of *N*-alkene tethered indoles

To a 15 mL test tubes charged with a stirred bar, 5-((difluoromethyl)sulfonyl)-1-phenyl-1*H*-tetrazole (**DFSPT**) (0.2 mmol, 1.5 equiv), Na_2CO_3 (0.40 mmol, 1.0 eq), MeCN (2.0 mL) were added. Then *N*-alkene tethered indole (0.60 mmol, 3.0 equiv) was added into reaction mixture. The test tube was sealed with a rubber stopper, purged with the argon balloon for 10 minutes. The reaction mixture was stirred and irradiated by using 3 W blue LEDs at room temperature for 24 h. After completion of the reaction, the solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel to afford the product **3.**

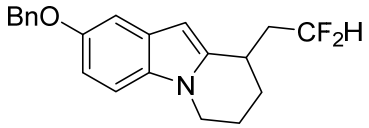
9-(2, 2-Difluoroethyl)-2-methoxy-6, 7, 8, 9-tetrahydropyrido [1, 2-*a*] indole (3a)



White solid (42.3 mg, 80%), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^1H NMR (400 MHz, $CDCl_3$) δ 7.20 (d, *J* = 8.7 Hz, 1H), 7.08 (d, *J* = 2.4 Hz, 1H), 6.88 (dd, *J* = 8.8, 2.5 Hz, 1H), 6.25 (s, 1H), 6.08 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.17 – 4.11 (m, 1H), 3.96 – 3.90 (m, 1H), 3.89 (s, 3H), 3.30 (tt, *J* = 9.1, 5.1

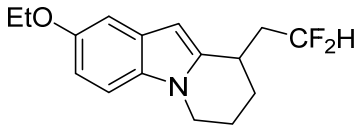
Hz, 1H), 2.51 (dtt, *J* = 20.0, 15.1, 5.2 Hz, 1H), 2.27 – 2.00 (m, 4H), 1.72 – 1.60 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.4, 139.6, 131.8, 128.3, 117.8 (t, *J* = 239.2 Hz), 110.8, 109.5, 102.1, 97.2, 55.97, 42.3, 39.1 (t, *J* = 20.7 Hz), 29.9 (t, *J* = 5.8 Hz), 27.2, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.20 (d, *J* = 283.7 Hz), -115.69 (d, *J* = 283.6 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{17}F_2NO - H]^+$: 266.1351, found: 266.1365.

2-(Benzyloxy)-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3b)



Orange-red liquid (54.4 mg, 80 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.54 (m, 2H), 7.47 – 7.43 (m, 2H), 7.40 – 7.36 (m, 1H), 7.22 (d, *J* = 8.8 Hz, 1H), 7.19 (d, *J* = 2.3 Hz, 1H), 6.99 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.26 (s, 1H), 6.09 (tt, *J* = 56.5, 4.7 Hz, 1H), 5.17 (s, 2H), 4.14 (dt, *J* = 11.1, 4.7 Hz, 1H), 3.93 (ddd, *J* = 11.6, 9.9, 4.8 Hz, 1H), 3.30 (tt, *J* = 9.0, 5.0 Hz, 1H), 2.53 (dtt, *J* = 20.0, 15.1, 5.1 Hz, 1H), 2.28 – 2.15 (m, 3H), 2.11 – 2.02 (m, 1H), 1.70 – 1.61 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.7, 139.7, 137.9, 132.0, 128.5, 128.3, 127.7, 127.5, 116.7 (t, *J* = 239.2 Hz), 111.7, 109.5, 103.9, 97.3, 71.0, 42.2, 39.1 (t, *J* = 20.8 Hz), 30.0 (t, *J* = 5.7 Hz), 27.2, 21.9; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.17 (d, *J* = 283.7 Hz), -115.69 (d, *J* = 283.7 Hz) ppm. HRMS (ESI) Calcd for $[C_{21}H_{21}F_2NO - H]^+$: 342.1664, found: 342.1671.

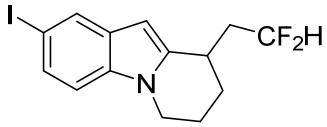
9-(2,2-difluoroethyl)-2-ethoxy-6,7,8,9-tetrahydropyrido[1,2-a]indole (3c)



White solid (46.0 mg, 82%), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 (d, *J* = 8.8 Hz, 1H), 7.09 (d, *J* = 2.4 Hz, 1H), 6.89 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.24 (s, 1H), 6.08 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.17 – 4.13 (m, 1H), 4.12 (q, *J* = 7.0 Hz, 2H), 3.96 – 3.89 (m, 1H), 3.29 (tt, *J* = 9.0, 5.1 Hz, 1H), 2.52 (dtt, *J* = 19.9, 15.0, 5.2 Hz, 1H), 2.26 – 2.00 (m, 4H), 1.70 – 1.64 (m, 1H), 1.49 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.65, 139.58, 131.81, 128.29, 116.70 (t, *J* = 239.2 Hz), 111.55, 109.51, 103.20, 97.19, 64.27, 42.23,

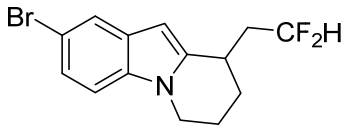
39.09 (t, J = 20.7 Hz), 29.94 (t, J = 5.8 Hz), 27.19, 21.85, 15.12; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.18 (d, J = 283.6 Hz), -115.69 (d, J = 283.6 Hz) ppm. HRMS (ESI) Calcd for $[C_{16}H_{19}F_2NO + H]^+$: 280.1508, found: 280.1517.

9-(2,2-difluoroethyl)-2-iodo-6,7,8,9-tetrahydropyrido[1,2-a]indole (3d)



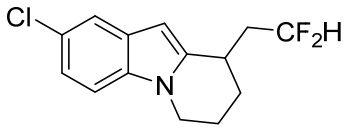
Purple solid (43.8 mg, 61 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, J = 1.5 Hz, 1H), 7.43 (dd, J = 8.5, 1.6 Hz, 1H), 7.06 (d, J = 8.5 Hz, 1H), 6.22 (s, 1H), 6.06 (tt, J = 56.4, 4.7 Hz, 1H), 4.17 – 4.11 (m, 1H), 3.91 (ddd, J = 11.7, 10.0, 4.8 Hz, 1H), 3.29 (tt, J = 8.9, 4.9 Hz, 1H), 2.50 (dtt, J = 19.8, 15.5, 5.1 Hz, 1H), 2.29 – 1.99 (m, 4H), 1.70 – 1.63 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.99, 135.50, 130.41, 129.13, 128.65, 116.47 (d, J = 239.4 Hz), 110.87, 96.85, 83.43, 42.22, 38.99 (t, J = 20.9 Hz), 29.84 (t, J = 5.7 Hz), 27.03, 21.73; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.25 (d, J = 284.1 Hz), -115.74 (d, J = 284.0 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}F_2NI + H]^+$: 362.0212, found: 362.0216.

2-Bromo-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3e)



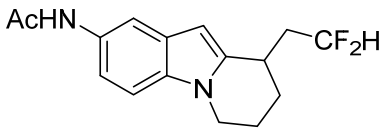
White solid (41.5 mg, 66 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, J = 1.8 Hz, 1H), 7.27 (dd, J = 8.6, 1.8 Hz, 1H), 7.15 (d, J = 8.6 Hz, 1H), 6.24 (s, 1H), 6.06 (tt, J = 56.4, 4.7 Hz, 1H), 4.16 (dt, J = 10.4, 4.8 Hz, 1H), 3.96 – 3.88 (m, 1H), 3.29 (tt, J = 9.0, 4.9 Hz, 1H), 2.51 (dtt, J = 20.0, 15.4, 5.1 Hz, 1H), 2.29 – 2.16 (m, 2H), 2.13 – 1.99 (m, 1H), 1.73 – 1.60 (m, 1H), 0.96 – 0.84 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.3, 135.0, 129.5, 123.6, 122.3, 116.4 (t, J = 239.5 Hz), 113.1, 110.3, 97.1, 42.2, 38.9 (t, J = 20.8 Hz), 30.5 – 29.5 (m), 27.0, 21.7; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.25 (d, J = 284.1 Hz), -115.73 (d, J = 284.0 Hz). HRMS (ESI) Calcd for $[C_{14}H_{14}BrF_2N + H]^+$: 314.0350, found:314.0351.

2-Chloro-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3f)



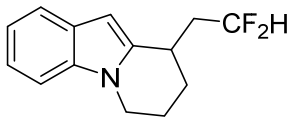
Yellow solid (41.6 mg, 77 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, *J* = 1.8 Hz, 1H), 7.19 (d, *J* = 8.6 Hz, 1H), 7.14 (dd, *J* = 8.6, 1.9 Hz, 1H), 6.25 (s, 1H), 6.07 (tt, *J* = 56.4, 4.7 Hz, 1H), 4.16 – 4.11 (m, 1H), 3.91 (ddd, *J* = 11.7, 10.0, 4.9 Hz, 1H), 3.29 (tt, *J* = 9.0, 4.9 Hz, 1H), 2.54 – 2.43 (m, 1H), 2.30 – 2.12 (m, 3H), 2.11 – 1.99 (m, 1H), 1.72 – 1.60 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.6, 134.9, 129.0, 125.5, 121.0, 119.3, 116.5 (t, *J* = 239.3 Hz), 109.8, 97.2, 42.3, 39.0 (t, *J* = 20.8 Hz), 29.9 (t, *J* = 5.7 Hz), 27.0, 21.7; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.23 (d, *J* = 284.2 Hz), -115.70 (d, *J* = 284.1 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}ClF_2N - H]^+$: 270.0855, found: 270.0869.

***N*-(9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indol-2-yl)acetamide (3g)**



Brown solid (41.3 mg, 70 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography.^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (s, 1H), 7.45 (s, 1H), 7.20 (dd, *J* = 8.3, 2.2 Hz, 2H), 6.16 (s, 1H), 6.04 (dt, *J* = 56.3, 4.5 Hz, 1H), 4.15 (ddd, *J* = 9.9, 8.5, 3.9 Hz, 1H), 4.01 (dt, *J* = 10.0, 7.5 Hz, 1H), 2.96 – 2.82 (m, 1H), 2.47 – 2.30 (m, 2H), 2.22 – 2.07 (m, 1H), 2.19 (s, 3H), 1.82 (br, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.49, 146.87, 132.80, 130.19, 130.16, 116.43 (t, *J* = 239.5 Hz), 115.29, 112.94, 109.51, 92.89, 43.13, 38.45 (t, *J* = 20.7 Hz), 35.07, 31.86 (t, *J* = 5.3 Hz), 31.85, 24.47; ^{19}F NMR (377 MHz, $CDCl_3$) δ -115.00 (d, *J* = 284.2 Hz), -116.77 (d, *J* = 284.3 Hz) ppm. HRMS (ESI) Calcd for $[C_{16}H_{18}F_2N_2O + H]^+$:293.1460, found:293.1465.

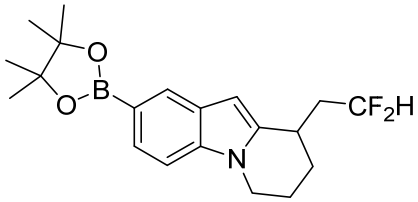
9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole(3h)



Yellow liquid (37.0 mg, 79%), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.7 Hz, 1H), 7.35

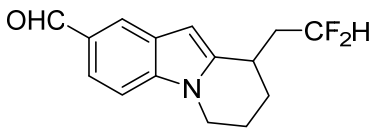
(d, *J* = 8.0 Hz, 1H), 7.26 (td, *J* = 7.0, 1.1 Hz, 1H), , 7.19 (td, *J* = 7.5, 1.1 Hz, 1H), 6.36 (s, 1H), 6.11 (tt, *J* = 56.4, 4.7 Hz, 1H), 4.24 – 4.19 (m, 1H), 3.98 (ddd, *J* = 11.7, 9.9, 4.9 Hz, 1H), 3.34 (tt, *J* = 9.0, 5.1 Hz, 1H), 2.56 (dtt, *J* = 20.1, 15.2, 5.1 Hz, 1H), 2.33 – 2.16 (m, 3H), 2.16 – 2.04 (m, 1H), 1.75 – 1.65 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.1, 136.5, 128.0, 120.9, 119.98, 119.95, 116.7 (t, *J* = 239.2 Hz), 108.9, 97.6, 42.2, 39.2 (t, *J* = 20.9 Hz), 30.0 (t, *J* = 5.7 Hz) , 27.3, 21.9; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.10 (d, *J* = 283.7 Hz), -115.61 (d, *J* = 283.7 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{15}F_2N - H]^+$: 236.1245, found:236.1257.

9-(2,2-difluoroethyl)-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-6,7,8,9-tetrahydropyrido[1,2-a]indole (3i)



Yellow solid (46.3 mg, 64 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (s, 1H), 7.66 (d, *J* = 8.2 Hz, 1H), 7.29 (d, *J* = 8.2 Hz, 1H), 6.31 (s, 1H), 6.06 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.21 – 4.16 (m, 1H), 3.97 – 3.90 (m, 1H), 3.29 (tt, *J* = 9.1, 4.9 Hz, 1H), 2.53 (dtt, *J* = 19.8, 15.1, 5.1 Hz, 1H), 2.24 – 2.00 (m, 4H), 1.70 – 1.61 (m, 1H), 1.41 (s, 12H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.19, 138.41, 127.76, 127.64, 127.15, 116.63 (t, *J* = 239.2 Hz), 108.33, 98.06, 83.44, 42.24, 39.03 (t, *J* = 20.7 Hz), 29.98 (t, *J* = 5.8 Hz), 27.20, 24.96, 24.91, 21.86; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.13 (d, *J* = 283.8 Hz), -115.64 (d, *J* = 283.7Hz) ppm.HRMS (ESI) Calcd for $[C_{20}H_{26}BF_2NO_2+H]^+$:362.2097, found:362.2111.

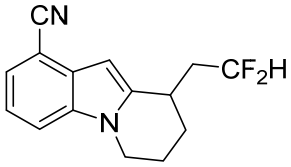
9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indole-2-carbaldehyde (3j)



Yellow solid (21.6 mg, 41 %), petroleum ether/ethyl acetate = 5:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.03 (s, 1H), 8.09 (d, *J* = 1.2 Hz, 1H), 7.76 (dd, *J* = 8.5, 1.5 Hz, 1H), 7.37 (d, *J* = 8.5 Hz, 1H), 6.46 (s, 1H), 6.08 (tt, *J* = 56.3, 4.6 Hz, 1H), 4.25 (ddd, *J* = 11.6, 7.2, 2.7 Hz, 1H), 4.00 (ddd, *J* = 11.9, 10.2,

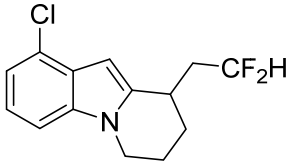
4.8 Hz, 1H), 3.33 (tt, *J* = 8.8, 4.8 Hz, 1H), 2.54 (dddt, *J* = 18.5, 16.0, 14.7, 5.0 Hz, 1H), 2.31 – 2.17 (m, 3H), 2.15 – 2.02 (m, 1H), 1.74 – 1.64 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.68, 141.26, 139.72, 129.74, 127.68, 125.09, 121.54, 116.34 (t, *J* = 239.4 Hz), 109.42, 99.51, 42.54, 38.98 (t, *J* = 20.8 Hz), 29.96 (t, *J* = 5.6 Hz), 26.96, 21.72; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.31 (d, *J* = 284.3 Hz), -115.74 (d, *J* = 284.3 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{15}F_2NO + H]^+$:293.1460, found:293.1465.

9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole-1-carbonitrile (3k)



Reddish-brown solid (37.9 mg, 73 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.2 Hz, 1H), 7.44 (dd, *J* = 7.4, 0.9 Hz, 1H), 7.19 (dd, *J* = 8.2, 7.4 Hz, 1H), 6.50 (s, 1H), 6.08 (tt, *J* = 56.3, 4.6 Hz, 1H), 4.25 – 4.20 (m, 1H), 4.02 – 3.95 (m, 1H), 3.33 (tt, *J* = 9.0, 4.8 Hz, 1H), 2.61 – 2.46 (m, 1H), 2.32 – 2.02 (m, 4H), 1.74 – 1.67 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.5, 136.1, 129.4, 125.0, 120.4, 118.9, 116.3 (t, *J* = 239.5 Hz), 113.55, 101.8, 96.7, 42.4, 38.9 (t, *J* = 20.9 Hz), 30.0 (t, *J* = 5.5 Hz), 26.9, 21.6; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.30 (d, *J* = 284.2 Hz), -115.83 (d, *J* = 284.4 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{14}F_2N - H]^+$: 261.1197, found: 261.1211.

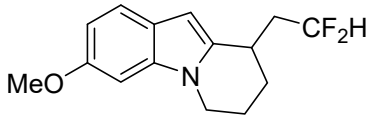
1-chloro-9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3l)



Yellow-brown solid (47.9 mg, 89 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 – 7.10 (m, 3H), 6.42 (s, 1H), 6.09 (tt, *J* = 56.4, 4.6 Hz, 1H), 4.19 – 4.14 (m, 1H), 3.96 – 3.90 (m, 1H), 3.30 (tt, *J* = 9.1, 4.8 Hz, 1H), 2.63 – 2.48 (m, 1H), 2.27 – 2.14 (m, 3H), 2.11– 2.00 (m, 1H), 1.71 – 1.62 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.0, 137.2, 126.7, 125.2, 121.5, 119.6, 116.5 (t, *J* = 239.5 Hz), 107.6, 96.2, 42.5, 39.0 (t, *J* = 21.0 Hz), 30.0 (t, *J* = 5.5

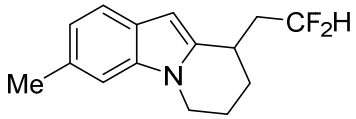
Hz), 27.1, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.16 (d, *J* = 284.2 Hz), -115.69 (d, *J* = 284.1 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}ClF_2N - H]^+$: 270.0855, found: 270.0867.

9-(2,2-difluoroethyl)-3-methoxy-6,7,8,9-tetrahydropyrido[1,2-a]indole (3m)



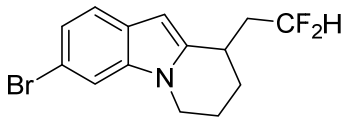
White solid (44.6 mg, 84 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.5 Hz, 1H), 6.83 (dd, *J* = 8.5, 2.2 Hz, 1H), 6.79 (d, *J* = 2.0 Hz, 1H), 6.24 (s, 1H), 6.08 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.12 (dq, *J* = 10.9, 6.2, 5.4 Hz, 1H), 3.91 (s, 3H), 3.93 – 3.86 (m, 1H) 3.28 (tt, *J* = 9.0, 5.1 Hz, 1H), 2.51 (dtt, *J* = 19.9, 14.9, 5.1 Hz, 1H), 2.29 – 2.01 (m, 4H), 1.70 – 1.60 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.79, 137.99, 137.10, 122.14, 120.52, 116.72 (t, *J* = 239.1 Hz), 109.47, 97.26, 92.95, 55.83, 42.25, 39.07 (t, *J* = 20.8 Hz), 30.01 (t, *J* = 5.8 Hz), 27.34, 21.93; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.11 (d, *J* = 283.6 Hz), -115.65 (d, *J* = 283.6 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{17}F_2NO+H]^+$: 266.1351, found:266.1351.

9-(2,2-Difluoroethyl)-3-methyl-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3n)



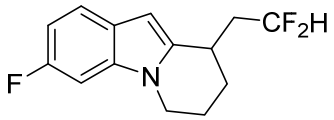
Yellow oily liquid (38.1 mg, 76 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.0 Hz, 1H), 7.15 (s, 1H), 7.04 (dd, *J* = 7.9, 1.4 Hz, 1H), 6.30 (s, 1H), 6.11 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.21 – 4.15 (m, 1H), 3.98 – 3.91 (m, 1H), 3.32 (tt, *J* = 9.1, 5.1 Hz, 1H), 2.58 (s, 1H), 2.61 – 2.47 (m, 1H), 2.31 – 2.15 (m, 3H), 2.13 – 2.03 (m, 1H), 1.73 – 1.63 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.4, 136.9, 130.7, 125.8, 121.6, 119.6, 116.8 (t, *J* = 239.1 Hz), 109.0, 97.3, 42.1, 39.2 (t, *J* = 20.5 Hz), 30.0 (t, *J* = 5.8 Hz), 27.4, 21.95, 21.89; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.08 (d, *J* = 283.6 Hz), -115.61 (d, *J* = 283.6 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{17}F_2N - H]^+$: 250.1401, found: 250.1414.

3-Bromo-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3o)



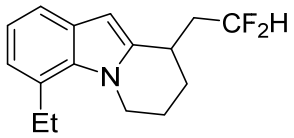
Brown solid (50.2 mg, 80 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.43 (m, 2H), 7.25 (dd, *J* = 8.4, 1.7 Hz, 1H), 6.29 (s, 1H), 6.08 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.12 – 4.07 (m, 1H), 3.91 – 3.84 (m, 1H), 3.27 (tt, *J* = 8.9, 4.8 Hz, 1H), 2.60 – 2.44 (m, 1H), 2.27– 2.19 (m, 2H), 2.16 – 1.95 (m, 2H), 1.70 – 1.60 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.0, 137.3, 126.8, 123.0, 121.2, 116.6 (t, *J* = 239.2 Hz), 114.3, 112.0, 97.8, 42.2, 39.0 (t, *J* = 21.1 Hz), 30.0 (t, *J* = 5.7 Hz), 27.1, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.22 (d, *J* = 284.0 Hz), -115.67 (d, *J* = 284.0 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}BrF_2N - H]^+$: 314.0350, found: 314.0353.

9-(2,2-Difluoroethyl)-3-fluoro-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3p)



Yellow-green solid (30.7 mg, 61 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (dd, *J* = 8.6, 5.3 Hz, 1H), 6.98 (dd, *J* = 9.8, 2.4 Hz, 1H), 6.92 (ddd, *J* = 9.7, 8.5, 2.3 Hz, 1H), 6.30 (s, 1H), 6.09 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.13 – 4.06 (m, 1H), 3.88 (ddd, *J* = 11.6, 10.0, 4.9 Hz, 1H), 3.29 (tt, *J* = 9.1, 5.0 Hz, 1H), 2.52 (dtt, *J* = 19.9, 15.4, 5.1 Hz, 1H), 2.30 – 2.10 (m, 3H), 2.12 – 2.02 (m, 1H), 1.72 – 1.62 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.3 (d, *J* = 236.7 Hz), 139.6 (d, *J* = 3.7 Hz), 136.4 (d, *J* = 11.8 Hz), 124.3, 120.5 (d, *J* = 10.0 Hz), 116.6 (t, *J* = 239.1 Hz), 108.3 (d, *J* = 24.3 Hz), 97.5, 95.4 (d, *J* = 26.1 Hz), 42.3, 39.1 (t, *J* = 21.0 Hz), 30.0 (t, *J* = 5.8 Hz), 27.2, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.22 (d, *J* = 284.0 Hz), -115.71 (d, *J* = 283.9 Hz), -121.74 (s) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}F_3N - H]^+$: 254.1151, found: 254.1164.

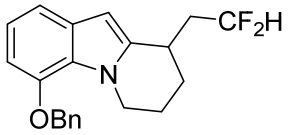
9-(2,2-Difluoroethyl)-4-ethyl-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3q)



Bright yellow solid (32.0 mg, 61 %), petroleum ether/ethyl acetate = 100:1 as an eluent

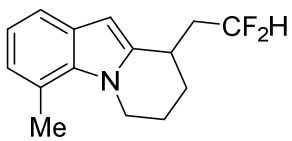
for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.7 Hz, 1H), 7.08 (t, *J* = 7.5 Hz, 1H), 7.01 (d, *J* = 7.1 Hz, 1H), 6.36 (s, 1H), 6.09 (tt, *J* = 56.6, 4.7 Hz, 1H), 4.57 (dt, *J* = 10.7, 4.9 Hz, 1H), 4.31 (ddd, *J* = 11.4, 9.7, 4.8 Hz, 1H), 3.34 (tt, *J* = 9.4, 5.4 Hz, 1H), 3.24 – 3.07 (m, 2H), 2.56 (dtt, *J* = 20.0, 14.9, 5.2 Hz, 1H), 2.33 – 2.16 (m, 3H), 2.16 – 2.02 (m, 1H), 1.66 (qd, *J* = 12.6, 11.0, 2.0 Hz,1H), 1.42 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.4, 135.1, 129.0, 127.7, 122.5, 120.0, 118.0, 116.7 (t, *J* = 239.1 Hz), 98.9, 45.5, 39.3 (t, *J* = 20.7 Hz), 30.4 (t, *J* = 5.8 Hz), 26.8, 26.2, 22.8, 16.7; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.20 (d, *J* = 283.7 Hz), -115.70 (d, *J* = 283.8 Hz).ppm. HRMS (ESI) Calcd for $[C_{16}H_{19}F_2N - H]^+$: 264.1558, found: 264.1572.

4-(Benzyloxy)-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indole(3r)



Orange solid (54.5 mg, 80 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 – 7.55 (m, 2H), 7.52 – 7.48 (m, 2H), 7.46 – 7.42 (m, 1H), 7.25 (d, *J* = 7.9 Hz, 1H), 7.06 (t, *J* = 7.8 Hz, 1H), 6.75 (d, *J* = 7.6 Hz, 1H), 6.33 (s, 1H), 6.10 (tt, *J* = 56.5, 4.7 Hz, 1H), 5.25 (s, 2H), 4.77 (dt, *J* = 12.7, 5.2 Hz, 1H), 4.39 (ddd, *J* = 12.9, 9.7, 4.6 Hz, 1H), 3.33 (tt, *J* = 9.6, 5.1 Hz, 1H), 2.55 (dtt, *J* = 19.9, 14.9, 5.2 Hz, 1H), 2.27 – 2.12 (m, 3H), 2.06 – 1.96 (m, 1H), 1.68 – 1.61 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.9, 139.4, 137.4, 130.3, 128.6, 127.9, 127.5, 120.2, 116.8 (t, *J* = 239.2 Hz), 113.3, 103.5, 98.4, 70.5, 46.0, 39.4 (t, *J* = 20.7 Hz), 30.2 (t, *J* = 5.8 Hz), 26.9, 22.5; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.26 (d, *J* = 283.6 Hz), -115.69 (d, *J* = 283.7 Hz) ppm. HRMS (ESI) Calcd for $[C_{21}H_{21}F_2NO - H]^+$: 342.1664, found: 342.1685.

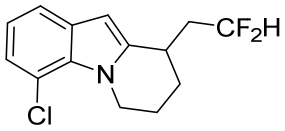
9-(2,2-Difluoroethyl)-4-methyl-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3s)



Yellow solid (40.7 mg, 82 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.06

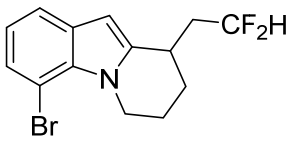
(t, *J* = 7.5 Hz, 1H), 6.95 (d, *J* = 7.1 Hz, 1H), 6.35 (d, *J* = 1.2 Hz, 1H), 6.11 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.71 – 4.65 (m, 1H), 4.38 (ddd, *J* = 11.6, 9.7, 4.9 Hz, 1H), 3.34 (tt, *J* = 9.2, 5.2 Hz, 1H), 2.84 (s, 3H), 2.57 (dtt, *J* = 20.0, 14.9, 5.2 Hz, 1H), 2.29 – 2.15 (m, 3H), 2.13 – 2.02 (m, 1H), 1.71 – 1.60 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.3, 135.8, 128.8, 124.2, 121.1, 120.0, 118.1, 116.8 (t, *J* = 239.0 Hz), 98.6, 45.8, 39.3 (t, *J* = 20.7 Hz), 30.4 (t, *J* = 5.8 Hz), 26.8, 22.7, 20.6; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.20 (d, *J* = 283.8 Hz), -115.68 (d, *J* = 283.6 Hz).ppm. HRMS (ESI) Calcd for $[C_{15}H_{17}F_2N - H]^+$: 250.1401, found: 250.1414.

4-chloro-9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3t)



Yellow-green solid (35.1 mg, 65 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.8 Hz, 1H), 7.14 (d, *J* = 7.7 Hz, 1H), 7.01 (t, *J* = 7.7 Hz, 1H), 6.34 (d, *J* = 1.3 Hz, 1H), 6.07 (tt, *J* = 56.4, 4.7 Hz, 1H), 4.90 (dt, *J* = 12.3, 5.0 Hz, 1H), 4.46 (ddd, *J* = 12.3, 9.8, 4.9 Hz, 1H), 3.30 (tt, *J* = 9.3, 5.1 Hz, 1H), 2.56 – 2.45 (m, 1H), 2.27 – 2.09 (m, 3H), 2.08 – 1.98 (m, 1H), 1.67 – 1.58 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.7, 132.2, 131.0, 122.9, 120.5, 118.7, 116.8, 116.5 (t, *J* = 239.3 Hz), 99.0, 45.6, 39.3 (t, *J* = 20.8 Hz), 30.3 (t, *J* = 5.6 Hz), 26.5, 22.3; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.31 (d, *J* = 283.7 Hz), -115.65 (d, *J* = 283.8 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}ClF_2N - H]^+$: 270.0855, found: 270.0869.

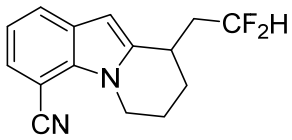
4-Bromo-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3u)



Bright yellow solid (43.3 mg, 69 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (dd, *J* = 7.8, 0.8 Hz, 1H), 7.34 (dd, *J* = 7.6, 0.8 Hz, 1H), 6.94 (t, *J* = 7.7 Hz, 1H), 6.32 (d, *J* = 1.3 Hz, 1H), 6.06 (tt, *J* = 56.5, 4.7 Hz, 1H), 4.96 (dt, *J* = 12.1, 4.9 Hz, 1H), 4.48 (ddd, *J* = 12.3, 9.8,

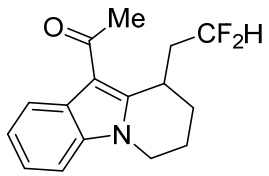
5.0 Hz, 1H), 3.30 (tt, *J* = 9.3, 5.3 Hz, 1H), 2.51 (dtt, *J* = 20.2, 15.2, 5.2 Hz, 1H), 2.27 – 2.11 (m, 3H), 2.07 – 1.96 (m, 1H), 1.67 – 1.58 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.8, 133.3, 131.2, 126.4, 120.9, 119.3, 116.5 (t, *J* = 239.3 Hz), 103.6, 99.0, 45.7, 39.3 (t, *J* = 20.8 Hz), 30.4 (t, *J* = 5.7 Hz), 26.5, 22.3; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.42 (d, *J* = 284.0 Hz), -115.78 (d, *J* = 284.1 Hz) ppm. HRMS (ESI) Calcd for $[C_{14}H_{14}BrF_2N - H]^+$: 314.0350, found: 314.0354.

9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole-4-carbonitrile (3v)



Bright yellow solid (27.1 mg, 52 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (dd, *J* = 7.9, 1.2 Hz, 1H), 7.49 (dd, *J* = 7.5, 1.1 Hz, 1H), 7.13 (t, *J* = 7.7 Hz, 1H), 6.40 (d, *J* = 1.3 Hz, 1H), 6.07 (tt, *J* = 56.3, 4.6 Hz, 1H), 4.77 (dt, *J* = 11.9, 4.9 Hz, 1H), 4.37 (ddd, *J* = 12.1, 9.9, 5.1 Hz, 1H), 3.32 (tt, *J* = 9.3, 4.9 Hz, 1H), 2.59 – 2.44 (m, 1H), 2.33 – 2.21 (m, 2H), 2.20 – 2.03 (m, 2H), 1.71 – 1.62 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.3, 134.8, 129.4, 127.8, 125.3, 119.6, 119.1, 116.3 (t, *J* = 239.5 Hz), 99.0, 93.5, 43.9, 39.1 (t, *J* = 21.0 Hz), 30.1 (t, *J* = 5.7 Hz), 26.5, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.47 (d, *J* = 284.4 Hz), -115.75 (d, *J* = 284.4 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{14}F_2N_2 - H]^+$: 261.1197, found: 261.1215.

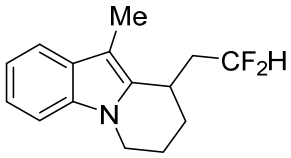
1-(9-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indol-10-yl)ethan-1-one (3w)



Light yellow solid (42.5 mg, 77 %), petroleum ether/ethyl acetate = 20:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 – 7.91 (m, 1H), 7.39 – 7.29 (m, 3H), 6.32 (dddd, *J* = 58.0, 56.1, 6.5, 3.0 Hz, 1H), 4.33 (dd, *J* = 12.2, 5.4 Hz, 1H), 4.05 – 4.02 (m, 1H), 3.93 – 3.86 (m, 1H), 2.73 (s, 3H), 2.39 – 2.08 (m, 5H), 1.95 – 1.85 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.8, 148.8, 136.1, 126.2, 122.6, 122.1,

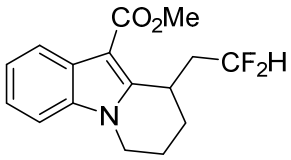
120.4, 118.2 (t, J = 239.7 Hz), 112.0, 109.8, 42.5, 37.9 (t, J = 19.9 Hz), 31.6, 28.5 (dd, J = 9.2, 2.1 Hz), 24.0 (d, J = 2.6 Hz), 17.5; ^{19}F NMR (377 MHz, $CDCl_3$) δ -110.31 (d, J = 282.5 Hz), -117.26 (d, J = 282.4 Hz) ppm. HRMS (ESI) Calcd for $[C_{16}H_{17}F_2NO - H]^+$: 278.1351, found: 278.1363.

9-(2,2-Difluoroethyl)-10-methyl-6,7,8,9-tetrahydropyrido[1,2-*a*]indole (3x)



Yellow solid (22.2 mg, 45 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, J = 7.7 Hz, 1H), 7.34 (d, J = 8.0 Hz, 1H), 7.27 (t, J = 7.4 Hz, 1H), 7.21 (t, J = 7.4 Hz, 1H), 5.98 (tt, J = 56.8, 3.8 Hz, 1H), 4.31 (dd, J = 12.0, 4.8 Hz, 1H), 3.82 (td, J = 11.4, 4.4 Hz, 1H), 3.57 – 3.56 (m, 1H), 2.36 (s, 3H), 2.31 – 2.20 (m, 3H), 2.11 – 2.02 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 136.4, 134.6, 128.8, 121.0. 119.4, 118.1, 116.8 (t, J = 239.2 Hz), 108.8, 105.7, 42.4, 38.9 (t, J = 20.3 Hz), 26.5 (t, J = 5.6 Hz), 26.0, 18.8, 8.5; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.99 (d, J = 282.8 Hz), -116.08 (d, J = 282.5 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{17}F_2N - H]^+$: 250.1401, found: 250.1412.

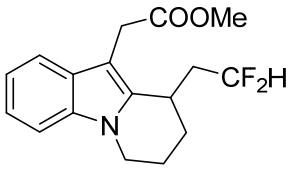
Methyl-9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-*a*]indole-10-carboxylate (3y)



Red-brown solid (18.5 mg, 63 %), petroleum ether/ethyl acetate = 50:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, J = 7.6, 1.0 Hz, 1H), 7.47 (dt, J = 8.2, 0.9 Hz, 1H), 7.22 (t, J = 7.8 Hz, 1H), 6.95 (t, J = 1.0 Hz, 1H), 6.09 (tt, J = 56.4, 4.7 Hz, 1H), 4.22 – 4.17 (m, 1H), 4.01 (s, 3H), 3.99 – 3.92 (m, 1H), 3.32 (tt, J = 9.3, 5.0 Hz, 1H), 2.62 – 2.52 (m, 1H), 2.27 – 2.13 (m, 3H), 2.11 – 2.03 (m, 1H), 1.70 – 1.62 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.1, 141.7, 137.3, 127. 7, 123.4, 120.5, 120.0, 116.5 (t, J = 239.3 Hz), 113.6, 99.0, 51.7, 42.3, 39.0 (t, J = 20.8 Hz), 30.0 (t, J = 5.7 Hz), 27.1, 21.8; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.15 (d, J = 283.8 Hz), -

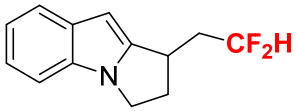
115.76 (d, J = 283.9 Hz) ppm. HRMS (ESI) Calcd for $[C_{16}H_{17}F_2NO_2 - H]^+$: 294.1300, found: 294.1317.

Methyl 2-(9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indol-10-yl)acetate (3z)



Yellow oily liquid (22.0 mg, 36 %), petroleum ether/ethyl acetate = 10:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (dm, J = 7.5 Hz, 1H), 7.31 (dt, J = 8.0, 1.0 Hz, 1H), 7.24 (td, J = 8.1, 1.3 Hz, 1H), 7.18 (td, J = 7.4, 1.2 Hz, 1H), 6.01 (tt, J = 56.4, 4.5 Hz, 1H), 4.31 (ddd, J = 12.0, 6.3, 1.8 Hz, 1H), 3.83 (td, J = 11.6, 5.0 Hz, 1H), 3.77 (s, 2H), 3.73 (s, 3H), 3.62 – 3.57 (m, 1H), 2.43 – 2.32 (m, 1H), 2.30 – 2.18(m, 2H), 2.13 – 2.08 (m, 2H), 2.02 – 1.95 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.40, 136.37, 136.25, 127.82, 121.28, 119.99, 118.39, 116.69 (t, J = 239.4 Hz), 109.03, 102.93, 52.04, 42.31, 38.64 (t, J = 20.4 Hz), 30.04, 26.09 (t, J = 5.5 Hz), 25.42, 18.30; ^{19}F NMR (377 MHz, $CDCl_3$) δ -115.13 (d, J = 283.2 Hz), -116.44 (d, J = 283.2 Hz) ppm. HRMS (ESI) Calcd for $[C_{17}H_{19}F_2NO_2 + H]^+$: 308.1457, found:308.1457.

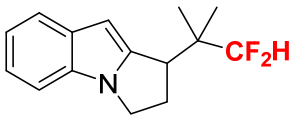
1-(2,2-difluoroethyl)-2,3-dihydro-1H-pyrrolo[1,2-a]indole (3aa)



White solid (38.1 mg, 76 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, J = 7.8 Hz, 1H), 7.29 – 7.27 (m, 1H), 7.18 (td, J = 8.1, 1.2 Hz, 1H), 7.11 (td, J = 7.5, 1.1 Hz, 1H), 6.23 (s, 1H), 6.07 (tdd, J = 56.4, 5.0, 4.0 Hz, 1H), 4.20 (ddd, J = 10.0, 8.4, 4.0 Hz, 1H), 4.06 (dt, J = 10.0, 7.5 Hz, 1H), 3.58 (p, J = 7.5 Hz, 1H), 2.90 (dtd, J = 11.9, 7.7, 4.0 Hz, 1H), 2.50 – 2.33 (m, 2H), 2.25 – 2.12 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.86, 132.74, 132.59, 120.83, 120.68, 119.44, 116.47 (t, J = 239.5 Hz), 109.50, 92.64, 43.00, 38.54 (t, J = 20.8 Hz), 35.12, 31.77 (t, J = 5.3 Hz); ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.97

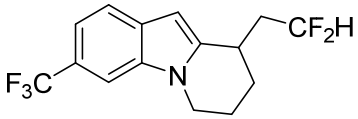
(dd, J = 284.3, 25.9 Hz), -116.77 (dd, J = 284.3, 25.9 Hz) ppm. HRMS (ESI) Calcd for $[C_{13}H_{13}F_2N + H]^+$: 222.1089, found: 222.1091.

1-(1,1-difluoro-2-methylpropan-2-yl)-2,3-dihydro-1H-pyrrolo[1,2-a]indole (3ab)



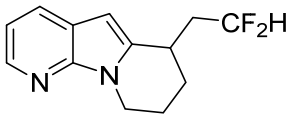
Colorless liquid (23.9 mg, 48%), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, J = 7.7 Hz, 1H), 7.32 (d, J = 8.0 Hz, 1H), 7.22 (ddd, J = 8.1, 7.0, 1.3 Hz, 1H), 7.15 (td, J = 7.5, 1.1 Hz, 1H), 6.39 (s, 1H), 6.05 (td, J = 55.5, 2.9 Hz, 1H), 4.35 (ddd, J = 11.9, 5.5, 4.0 Hz, 1H), 3.97 (ddd, J = 11.9, 9.8, 5.5 Hz, 1H), 2.40 – 2.16 (m, 3H), 1.62 (s, 3H), 1.46 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.86, 135.81, 128.23, 120.78, 120.02, 119.97, 116.90 (t, J = 240.8 Hz), 108.96, 96.29, 46.59 (t, J = 19.0 Hz), 41.04, 33.84 (dd, J = 5.6, 2.1 Hz), 30.34 (d, J = 1.5 Hz), 26.64 (d, J = 1.7 Hz), 18.57 (dd, J = 6.5, 4.9 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{18}F_2N + H]^+$: 250.1420, found: 250.1415.

9-(2,2-difluoroethyl)-3-(trifluoromethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indole (3ae)



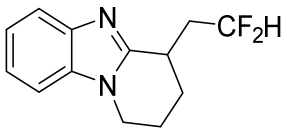
Yellow oily liquid (37.3 mg, 61 %), petroleum ether/ethyl acetate = 100:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.3 Hz, 1H), 7.59 (s, 1H), 7.38 (d, J = 8.2 Hz, 1H), 6.38 (s, 1H), 6.08 (tt, J = 56.4, 4.6 Hz, 1H), 4.24 (dt, J = 10.5, 4.7 Hz, 1H), 4.01 (td, J = 11.7, 10.8, 4.8 Hz, 1H), 3.34 (tt, J = 9.0, 5.0 Hz, 1H), 2.54 (dtt, J = 20.3, 15.6, 5.1 Hz, 1H), 2.33 – 2.03 (m, 4H), 1.75 – 1.65 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.06, 135.32, 130.27, 125.41 (q, J = 271.3 Hz), 122.84 (q, J = 31.7 Hz), 120.14, 116.60 (q, J = 3.6 Hz), 116.40 (t, J = 239.4 Hz), 106.42 (q, J = 4.4 Hz), 97.96, 42.32, 38.99 (t, J = 21.0 Hz), 30.01 (d, J = 5.4 Hz), 27.00, 21.67; ^{19}F NMR (377 MHz, $CDCl_3$) δ -60.25, -114.34 (d, J = 284.3 Hz), -115.76 (d, J = 284.0 Hz) ppm. HRMS (ESI) Calcd for $[C_{15}H_{15}F_5N + H]^+$: 304.1119, found: 304.1110.

6-(2,2-Difluoroethyl)-6,7,8,9-tetrahydropyrido[3,2-*b*]indolizine(3af)



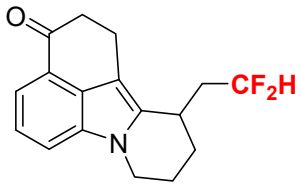
Yellow-green liquid (18.6 mg, 39 %), petroleum ether/ethyl acetate = 5:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (dd, *J* = 4.8, 1.6 Hz, 1H), 7.83 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.06 (dd, *J* = 7.8, 4.8 Hz, 1H), 6.25 (d, *J* = 1.4 Hz, 1H), 6.06 (tt, *J* = 56.4, 4.7 Hz, 1H), 4.45 – 4.41 (m, 1H), 4.05 (ddd, *J* = 12.5, 10.1, 4.7 Hz, 1H), 3.30 (tt, *J* = 9.1, 4.9 Hz, 1H), 2.57 – 2.44 (m, 1H), 2.28 – 2.11 (m, 3H), 2.09 – 1.98 (m, 1H), 1.71 – 1.61 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 147.7, 141.8, 139.9, 127.7, 120.7, 116.4 (t, *J* = 239.3 Hz), 116.1, 95.7, 41.1, 39.0 (t, *J* = 21.0 Hz), 30.0 (t, *J* = 5.7 Hz), 27.2, 21.6; ^{19}F NMR (377 MHz, $CDCl_3$) δ -114.40 (d, *J* = 284.2 Hz), -115.71 (d, *J* = 284.2 Hz) ppm. HRMS (ESI) Calcd for $[C_{13}H_{14}F_2N_2 - H]^+$: 237.1197, found: 237.1210.

4-(2,2-Difluoroethyl)-1,2,3,4-tetrahydrobenzo[4,5]imidazo[1,2-*a*]pyridine(3ag)



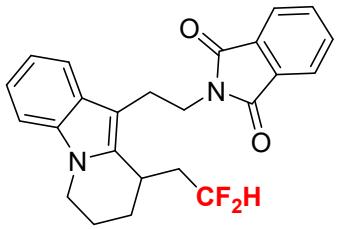
White solid (36.5 mg, 77 %), petroleum ether/ethyl acetate = 10:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 – 7.71 (m, 1H), 7.34 – 7.25 (m, 3H), 6.41 (tdd, *J* = 56.8, 5.4, 3.9 Hz, 1H), 4.21 (ddd, *J* = 12.0, 5.4, 3.4 Hz, 1H), 3.99 (td, *J* = 11.5, 4.8 Hz, 1H), 3.33 (dq, *J* = 12.3, 6.2 Hz, 1H), 2.78 (dtdd, *J* = 24.0, 14.2, 6.0, 3.8 Hz, 1H), 2.36 – 2.15 (m, 3H), 2.13 – 2.04 (m, 1H), 1.83 – 1.72 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.3, 142.5, 134.6, 122.4, 122.2, 119.1, 116.8 (t, *J* = 239.0 Hz), 109.0, 42.4, 38.0 (t, *J* = 21.3 Hz), 31.3 (dd, *J* = 6.4, 5.0 Hz), 27.5, 21.7; ^{19}F NMR (377 MHz, $CDCl_3$) δ -113.55 (d, *J* = 283.3 Hz), -117.60 (d, *J* = 283.2 Hz) ppm. HRMS (ESI) Calcd for $[C_{13}H_{14}F_2N_2 - H]^+$: 237.1197, found: 237.1210.

11-(2,2-difluoroethyl)-1,2,8,9,10,11-hexahydro-3H-benzo[cd]pyrido[1,2-a]indol-3-one (3ah)



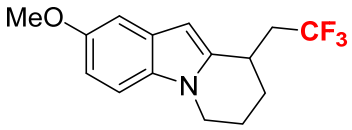
Brown solid (26.9 mg, 46%), petroleum ether/ethyl acetate = 10:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, *J* = 7.3 Hz, 1H), 7.44 (d, *J* = 7.9 Hz, 1H), 7.25 (t, *J* = 7.7 Hz, 1H), 5.98 (tt, *J* = 56.4, 4.6 Hz, 1H), 4.19 (dt, *J* = 11.4, 5.5 Hz, 1H), 4.04 (ddd, *J* = 11.5, 7.8, 5.0 Hz, 1H), 3.50 (dq, *J* = 10.7, 5.6 Hz, 1H), 3.26 – 3.16 (m, 2H), 2.94 – 2.90 (m, 2H), 2.45 (dddt, *J* = 19.2, 16.3, 14.7, 5.0 Hz, 1H), 2.24 – 2.10 (m, 4H), 1.96 – 1.89 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 198.51, 135.16, 134.53, 132.48, 125.08, 121.53, 116.36 (t, *J* = 239.5 Hz), 115.63, 113.67, 105.20, 42.92, 39.41, 38.49 (t, *J* = 20.6 Hz), 28.33 (t, *J* = 5.6 Hz), 26.47, 21.18, 20.09 ppm. HRMS (ESI) Calcd for $[C_{17}H_{17}F_2NO + H]^+$: 290.1351, found: 290.1328.

2-(2-(9-(2,2-difluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indol-10-yl)ethyl) isoindoline-1,3-dione (3ai)



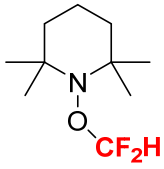
Yellow solid (35.1 mg, 43%), petroleum ether/ethyl acetate = 5:1 as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (dt, *J* = 4.7, 2.1 Hz, 1H), 7.83 – 7.68 (m, 2H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.23 – 7.02 (m, 1H), 6.07 (tt, *J* = 56.2, 4.5 Hz, 1H), 4.29 (dt, *J* = 11.9, 3.8 Hz, 1H), 4.09 – 3.89 (m, 1H), 3.83 (td, *J* = 11.2, 4.8 Hz, 1H), 3.63 (q, *J* = 4.2 Hz, 1H), 3.11 (tt, *J* = 7.5, 3.1 Hz, 1H), 2.31 (dddd, *J* = 36.2, 18.3, 9.8, 4.6 Hz, 1H), 2.17 – 2.03 (m, 1H), 1.97 (tt, *J* = 10.9, 4.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.30, 136.31, 135.86, 133.92, 132.25, 127.87, 123.23, 121.11, 119.80, 118.38, 116.76 (t, *J* = 239.7 Hz), 108.96, 106.25, 42.32, 39.08 (t, *J* = 20.2 Hz), 38.20, 26.40 (t, *J* = 5.4 Hz), 25.48, 23.47, 18.50 ppm. HRMS (ESI) Calcd for $[C_{24}H_{23}F_2N_2O_2 + H]^+$: 409.1722, found: 409.1709.

2-methoxy-9-(2,2,2-trifluoroethyl)-6,7,8,9-tetrahydropyrido[1,2-a]indole (3aj)[3]



White solid (23.2 mg, 41%), petroleum ether as an eluent for column chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (d, *J* = 8.8 Hz, 1H), 7.07 (d, *J* = 2.3 Hz, 1H), 6.87 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.25 (s, 1H), 4.19 (ddd, *J* = 11.5, 5.7, 3.6 Hz, 1H), 3.97 – 3.86 (m, 1H), 3.88 (s, 3H), 3.38 (tt, *J* = 9.8, 4.4 Hz, 1H), 2.86 (dqd, *J* = 15.4, 11.8, 3.7 Hz, 1H), 2.42 – 2.01 (m, 3H), 2.11 – 2.00 (m, 1H), 1.68 – 1.59 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.47, 139.01, 131.77, 128.18, 120.34 (q, *J* = 289.3 Hz), 111.07, 109.57, 102.03, 97.15, 55.94, 42.17, 39.02 (q, *J* = 28.3 Hz), 29.88 (q, *J* = 2.9 Hz), 27.08, 21.97 ppm.

1-(difluoromethoxy)-2,2,6,6-tetramethylpiperidine (4)



^{1}H NMR (400 MHz, $CDCl_3$) δ 6.37 (t, *J* = 72.8 Hz, 1H), 1.60 – 1.48 (m, 4H), 1.41 – 1.34 (m, 2H), 1.19 (s, 6H), 1.18 (s, 6H) ppm.

Reference:

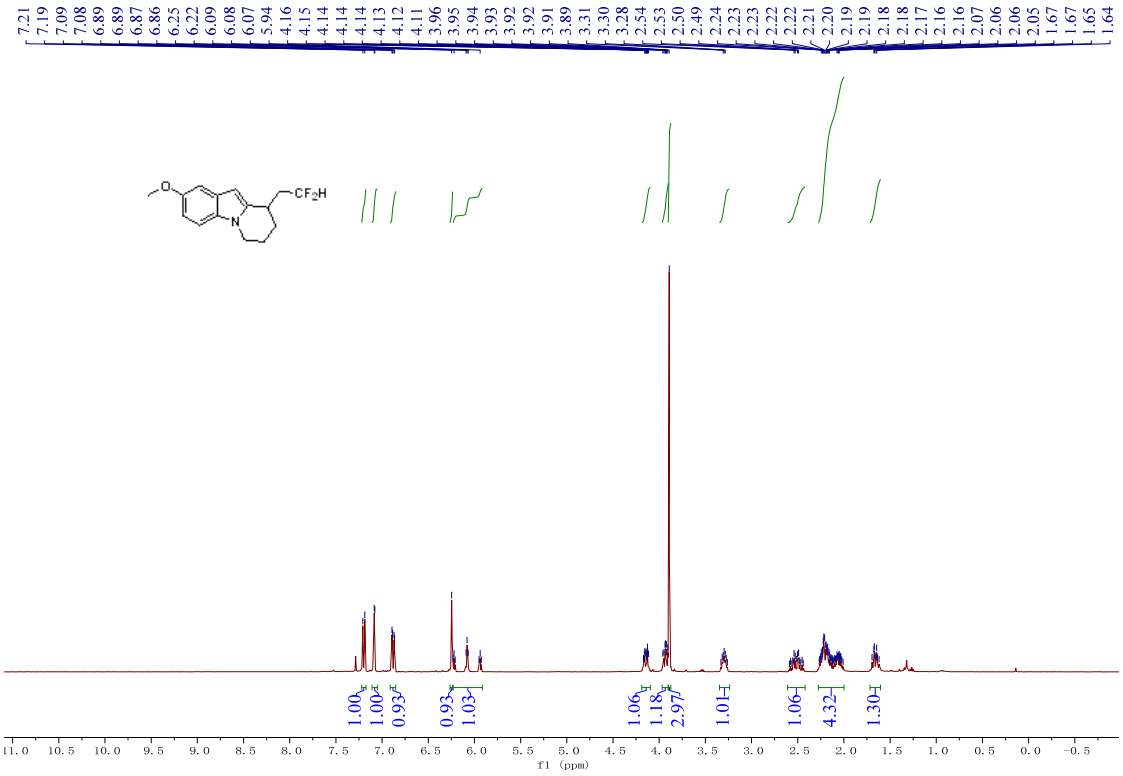
1 (a) S. Nishio, T. Somete, A. Sugie, T. Kobayashi, T. Yaita and A. Mori, *Axially Chiral Macrocyclic E-Alkene Bearing Bisazole Component Formed by Sequential C–H Homocoupling and Ring-Closing Metathesis*, *Org. Lett.*, 2012, **14**, 2476-2479; (b) P. N. Naik, A. Khan and R. S. Kusurkar, *Intramolecular Diels–Alder reaction for the synthesis of tetracyclic carbazoles and isocanthines*, *Tetrahedron*, 2013, **69**, 10733-10738; (c) E. L. Glaisyer, M. S. Watt and K. I. Booker-Milburn, *Pd(II)-Catalyzed [4 + 2] Heterocyclization Sequence for Polyheterocycle Generation*, *Org. Lett.*, 2018, **20**, 5877-5880; (d) S.-Z. Sun, L. Talavera, P. Spieß, C. S. Day and R. Martin, *sp3 Bis-Organometallic Reagents via Catalytic 1,1-Difunctionalization of Unactivated Olefins*, *Angew. Chem. Int. Ed.*, 2021, **60**, 11740-11744; (e) A. Banerjee, S. Sarkar, J. A. Shah, N. C. Frederiks, E. A. Bazan-Bergamino, C. J. Johnson and M.-Y. Ngai, *Excited-State Copper Catalysis for the Synthesis of Heterocycles*, *Angew. Chem. Int. Ed.*, 2022, **61**, e202113841.

2 (a) Y. Zhao, W. Huang, L. Zhu and J. Hu, *Difluoromethyl 2-Pyridyl Sulfone: A New gem-Difluoroolefination Reagent for Aldehydes and Ketones*, *Org. Lett.*, 2010, **12**, 1444-1447; (b) M. R. R., J. T. Edwards, T. Qin, M. M. Kruszyk, C. Bi, G. Che, D.-H. Bao, W. Qiao, L. Sun, M. R. Collins, O. O. Fadeyi , G. M. Gallego, J. J. Mousseau, P. Nuhant and S. Baran Phil, *Modular radical cross-coupling with sulfones enables access to sp3-rich (fluoro)alkylated scaffolds*, *Science*, 2018, **360**, 75-80; (c) Z. Wei, W. Miao, C. Ni and J. Hu, *Iron-Catalyzed Fluoroalkylation of Arylborates with Sulfone Reagents: Beyond the Limitation of Reduction Potential*, *Angew. Chem. Int. Ed.*, 2021, **60**, 13597-13602; (d) Z. Wei, Z. Lou, C. Ni, W. Zhang and J. Hu, *Visible-light-promoted S-trifluoromethylation of thiophenols with trifluoromethyl phenyl sulfone*, *Chem. Commun.*, 2022, **58**, 10024-10027; (e) H. Liang, Q. Wang, X. Zhou, R. Zhang, M. Zhou, J. Wei, C. Ni and J. Hu, *N-Heteroaromatic Fluoroalkylation through Ligand Coupling Reaction of Sulfones*, *Angew. Chem. Int. Ed.*, 2024, **63**, e202401091.

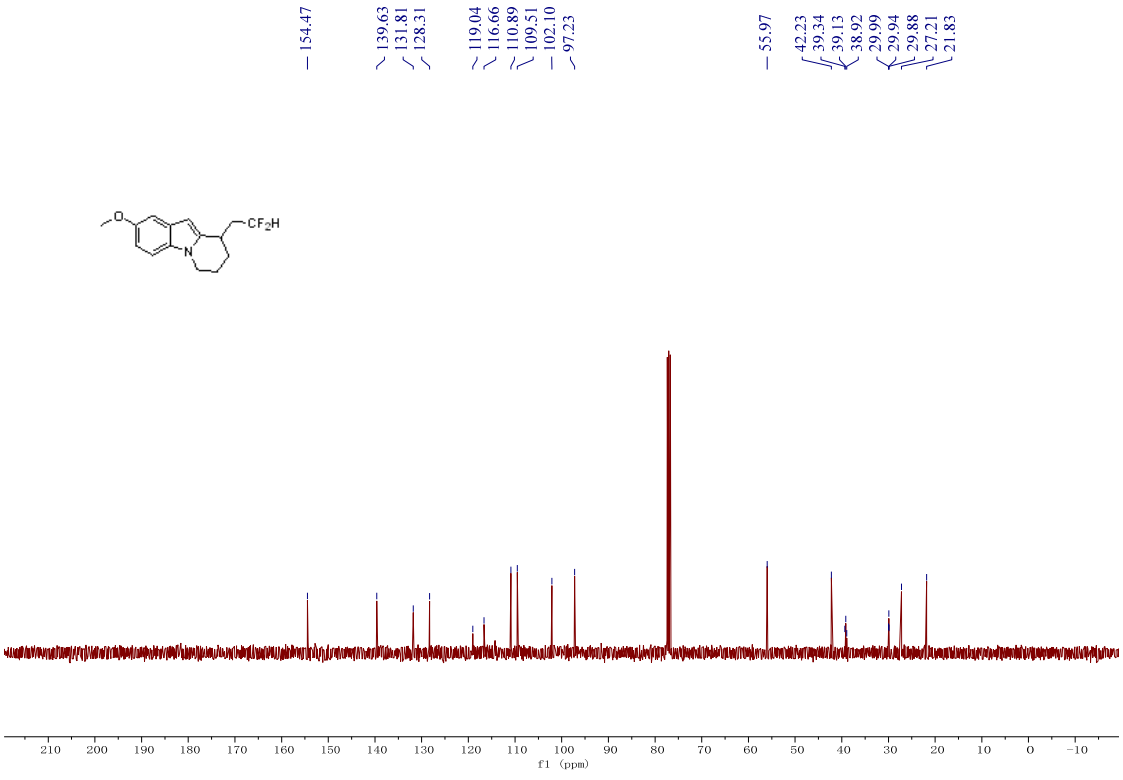
3 Q.-H. Zhou, J.-Y. Dai, W.-J. Zhao, X.-Y. Zhong, C.-Y. Liu, W.-W. Luo, Z.-W. Li, J.-S. Li and W.-D. Liu, *Photocatalytic synthesis of azaheterocycle-fused piperidines and pyrrolidines via tandem difunctionalization of unactivated alkenes*, *Org. Biomol. Chem.*, 2023, **21**, 3317-3322.

Spectra of products

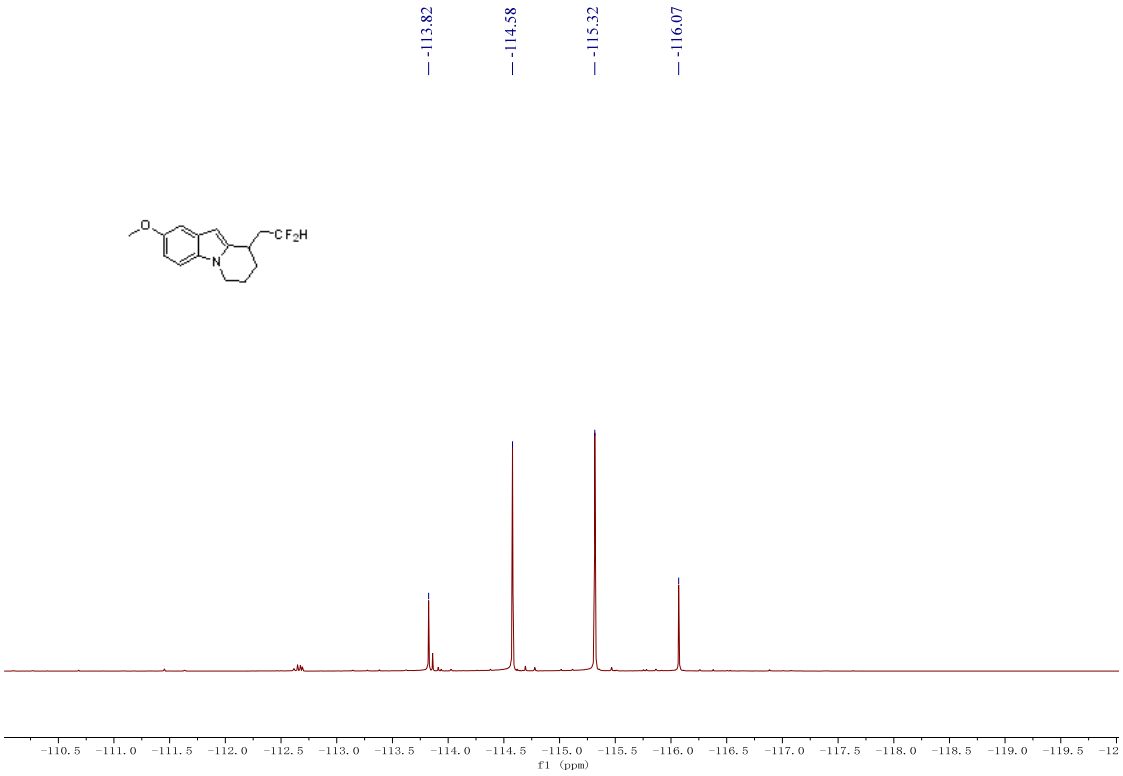
^{1}H NMR of 3a



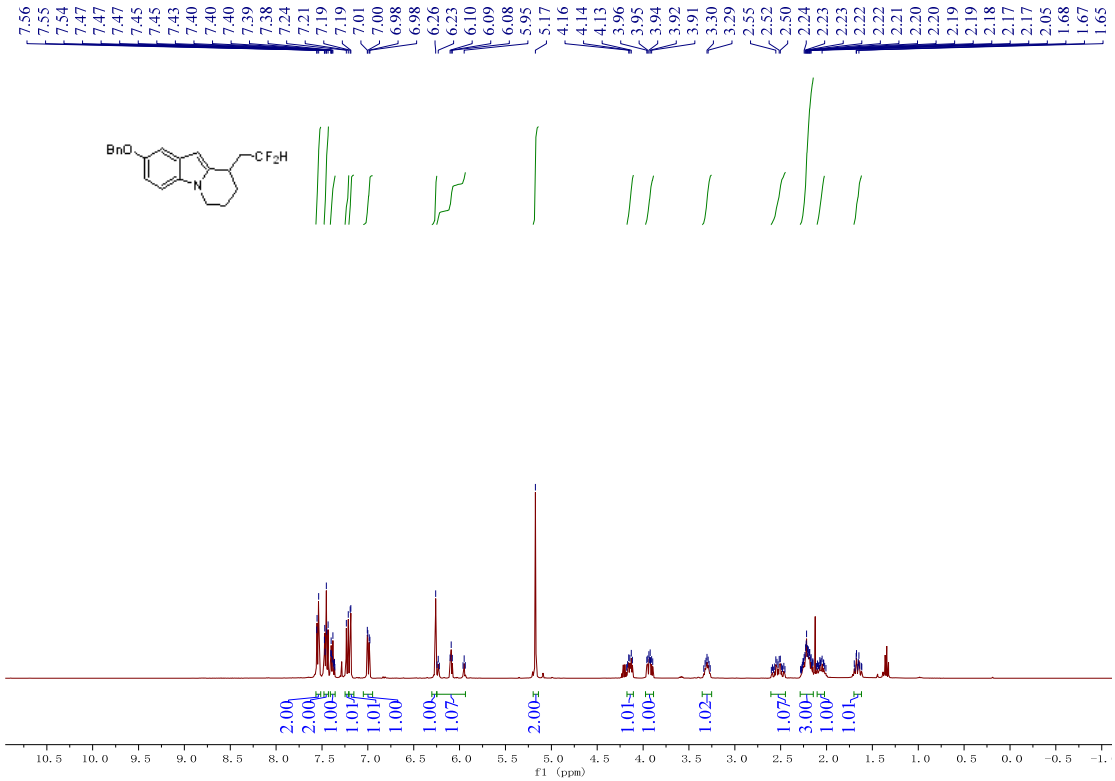
^{13}C NMR of 3a



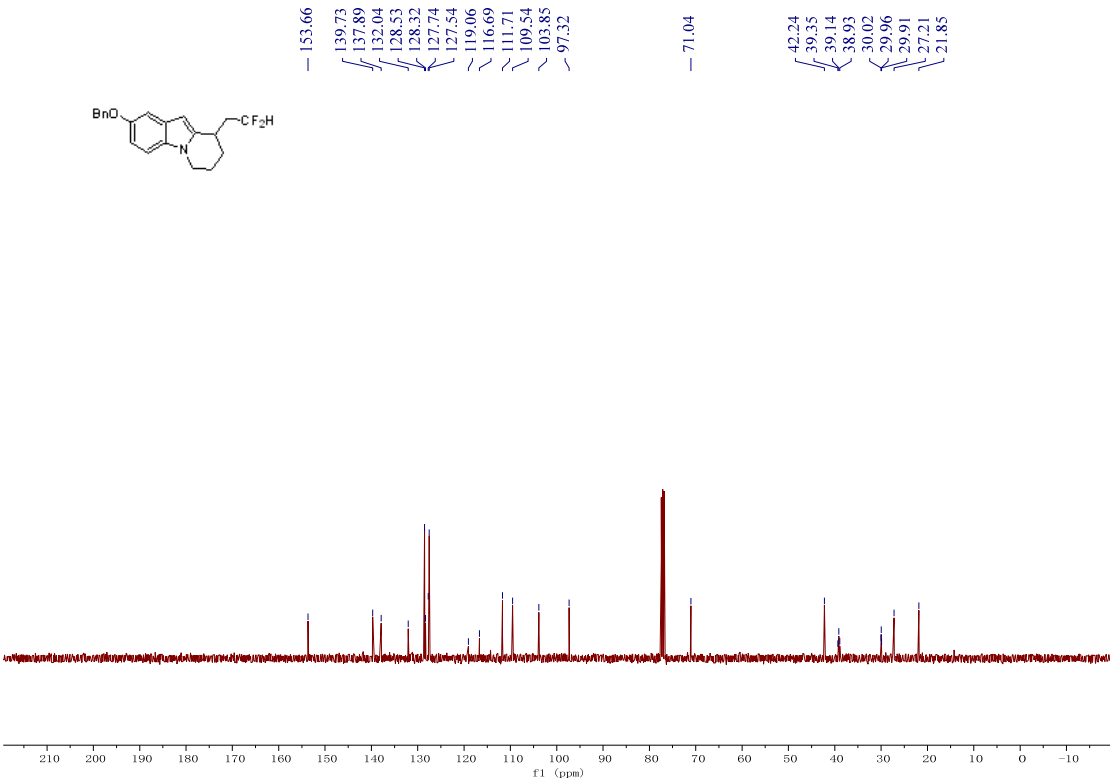
^{19}F NMR of 3a



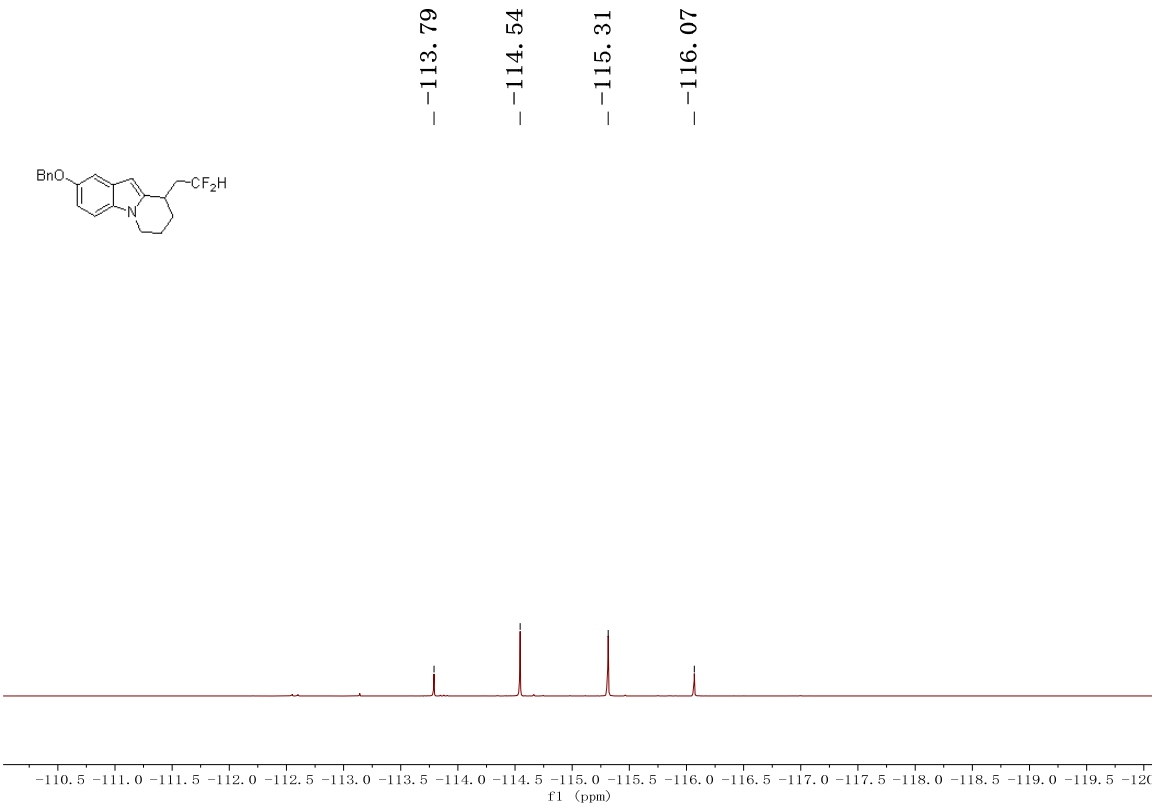
^{1}HNMR of 3b



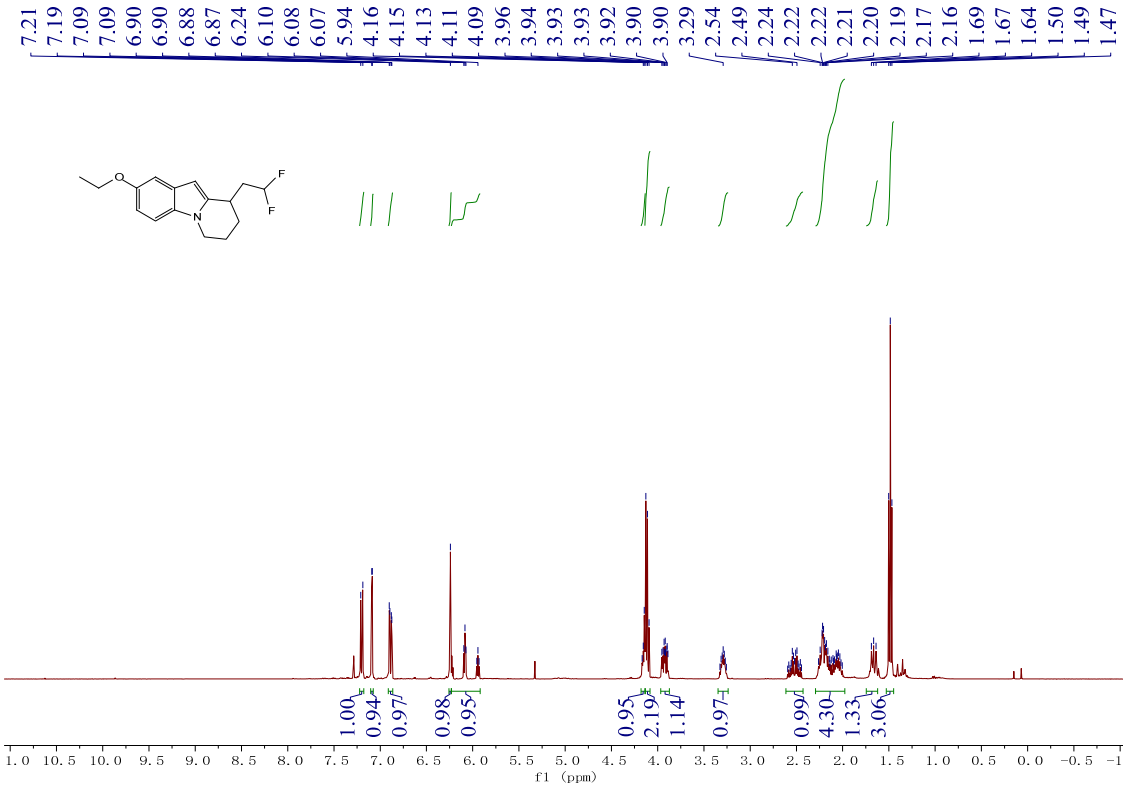
^{13}C NMR of 3b



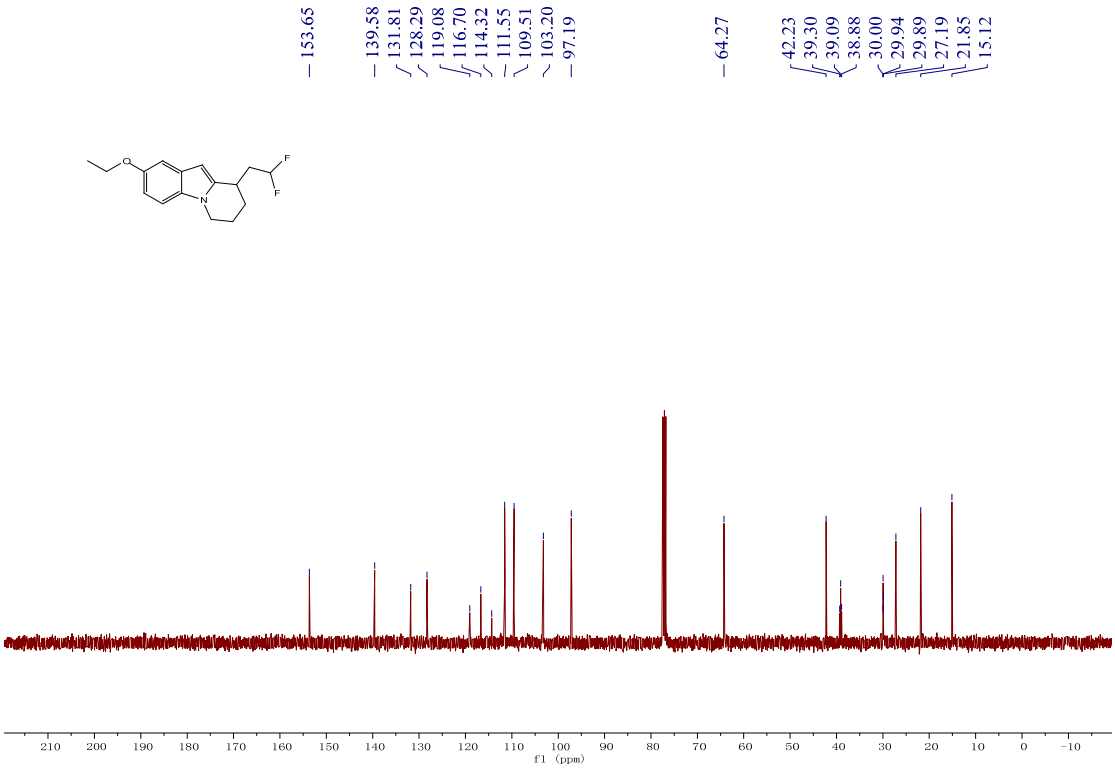
^{19}F NMR of 3b



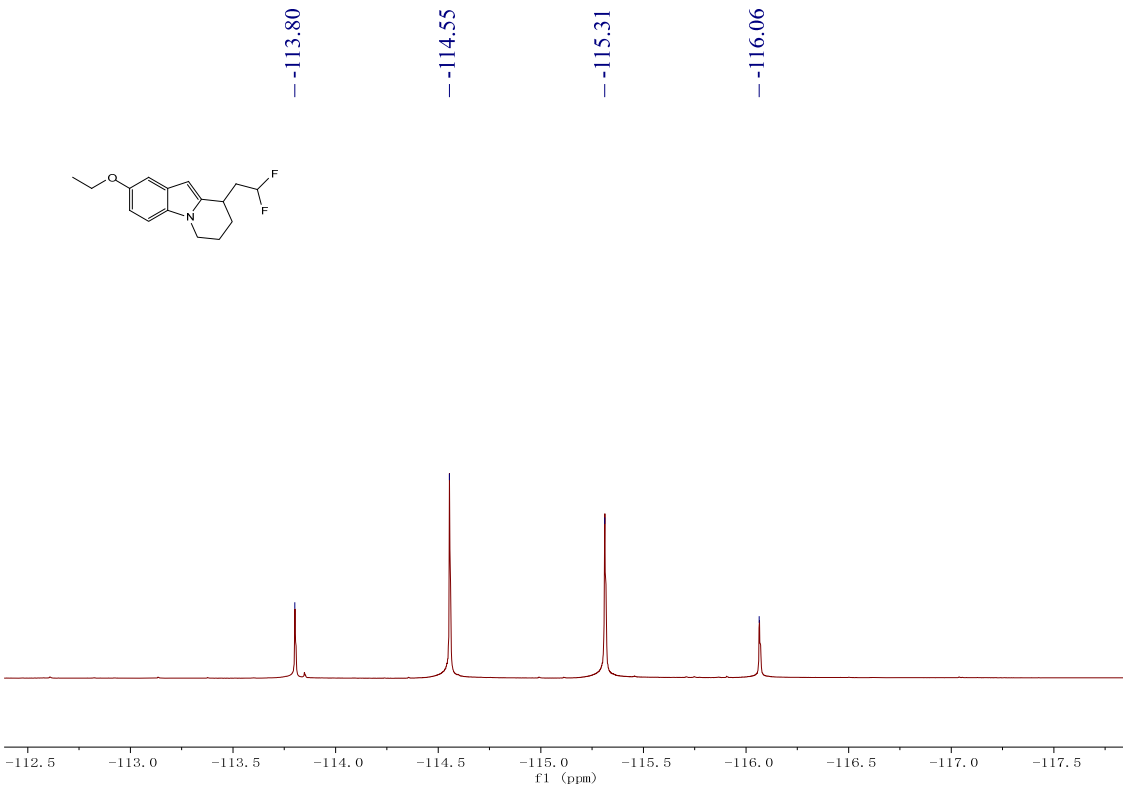
^{1}HNMR of 3c



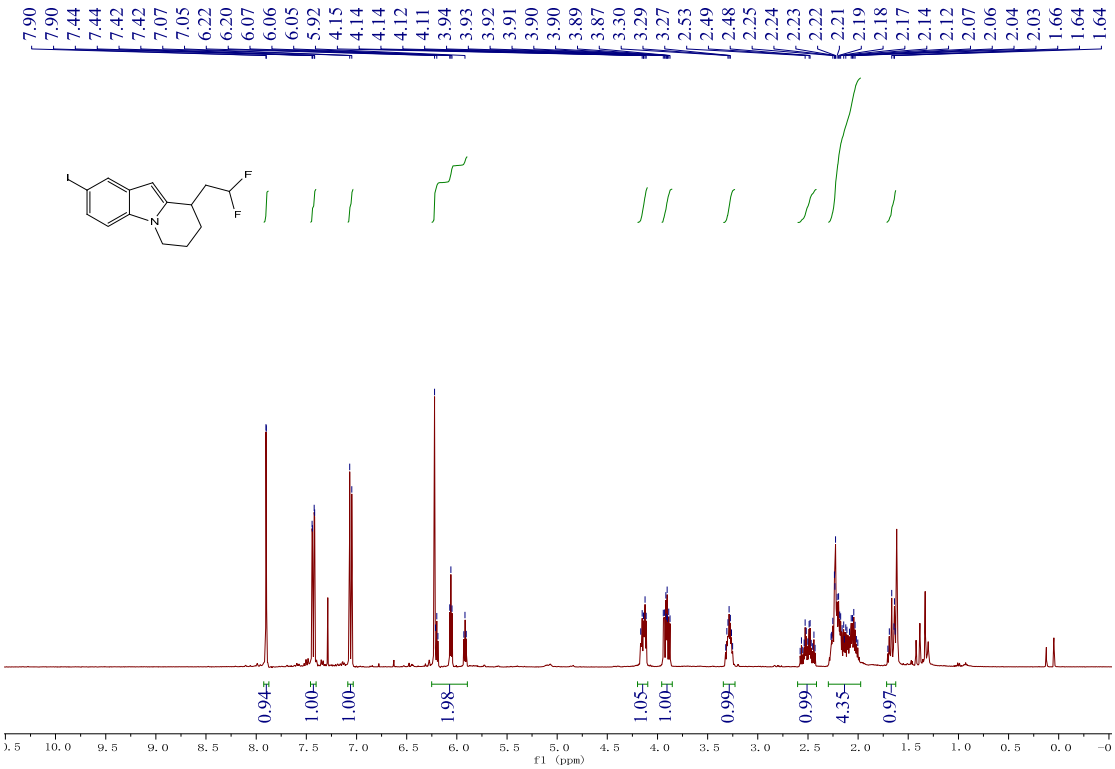
^{13}C NMR of 3c



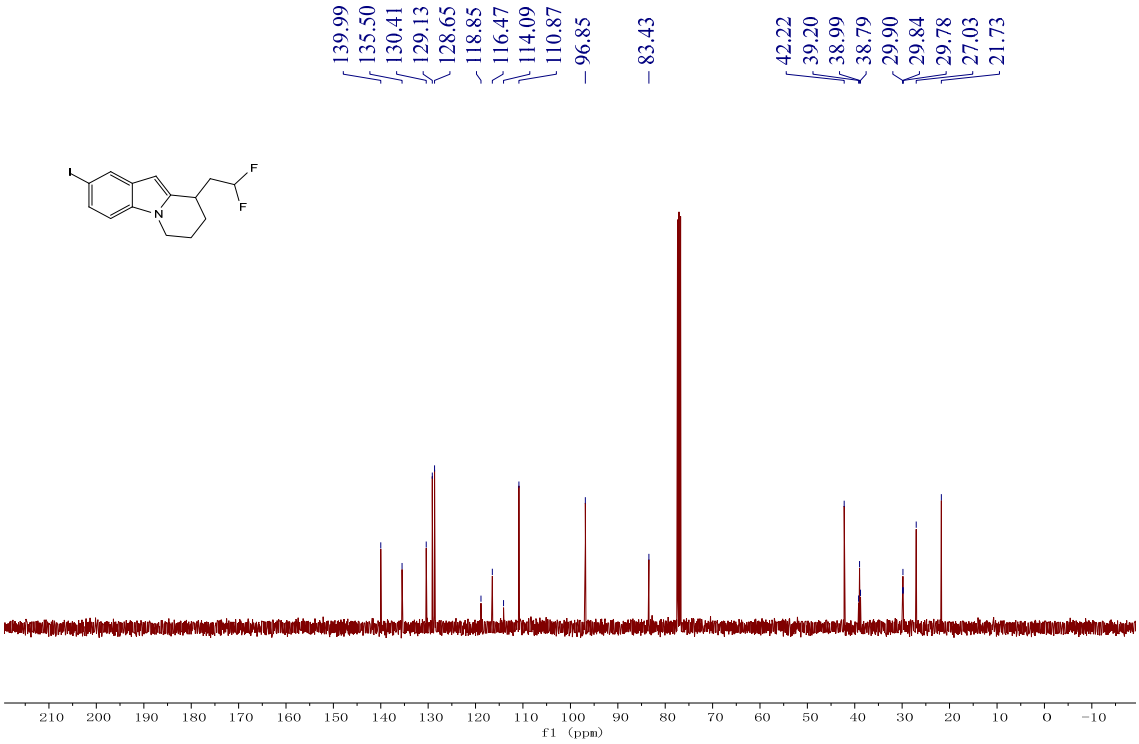
^{19}F NMR of 3c



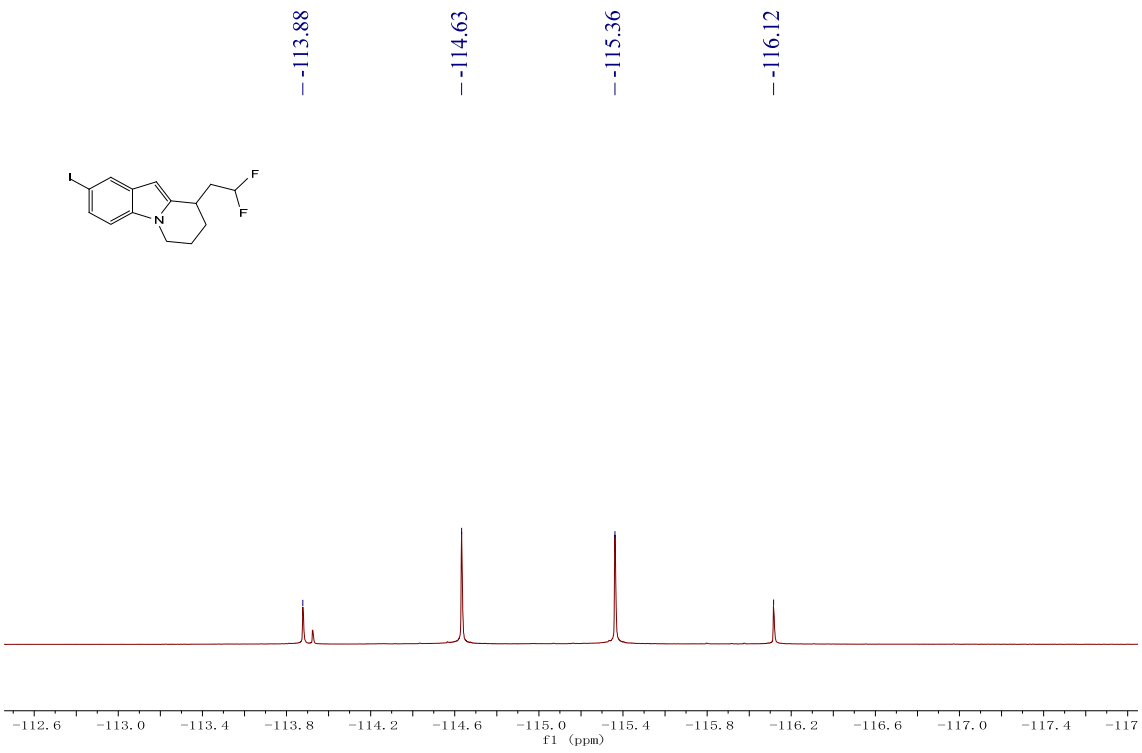
^{1}HNMR of 3d



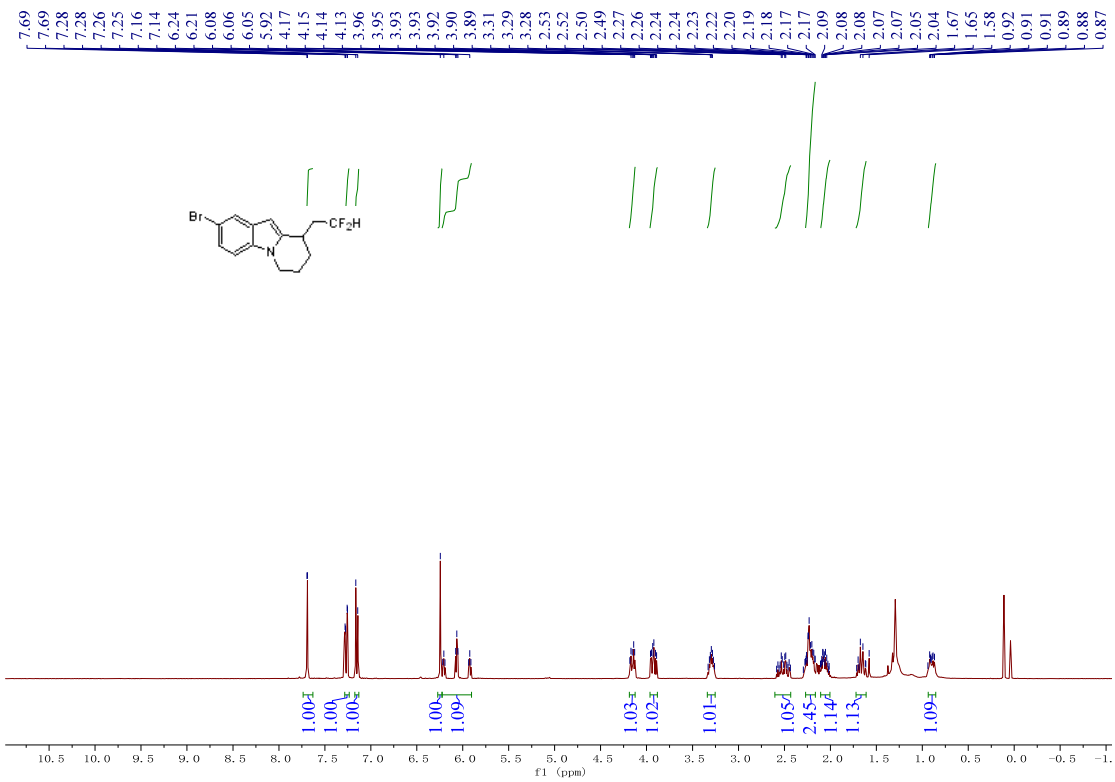
^{13}C NMR of 3d



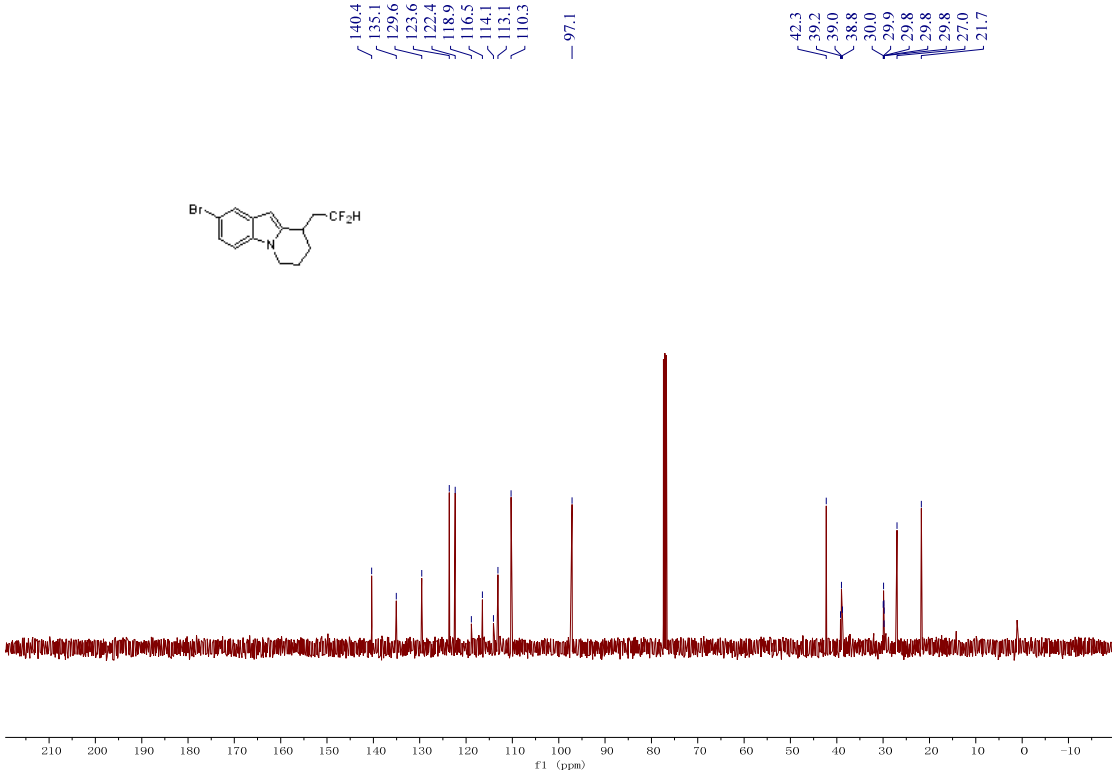
^{19}F NMR of 3d



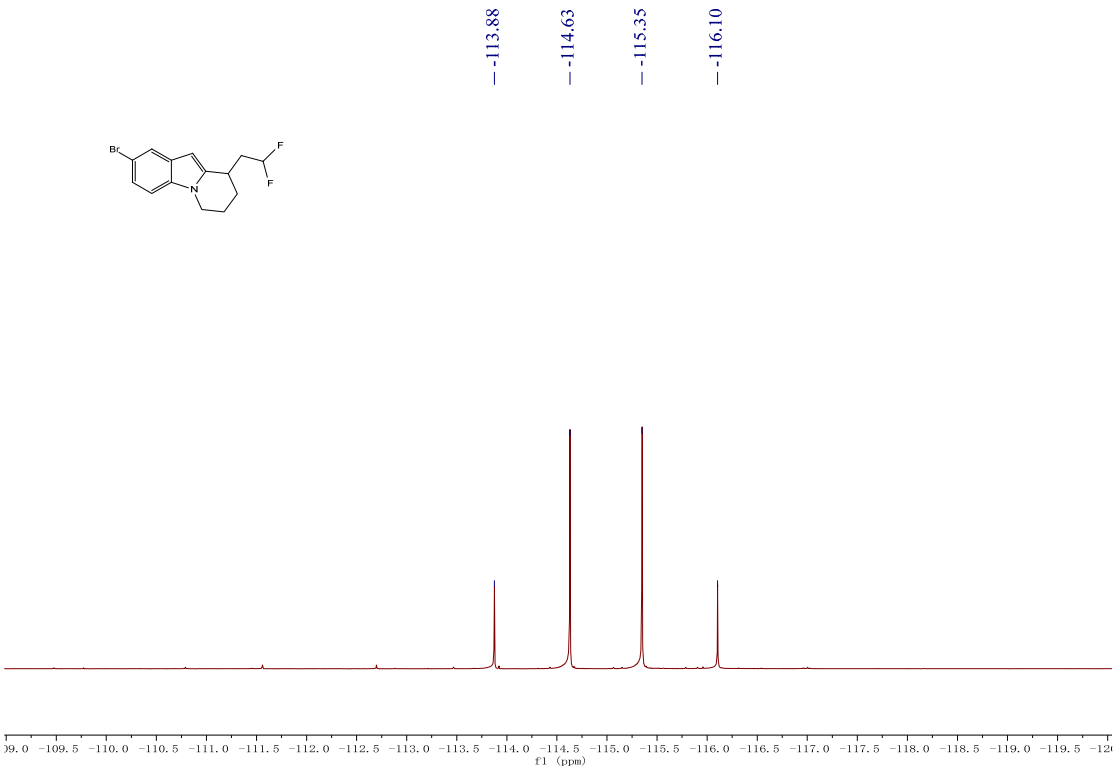
^{1}H NMR of 3e



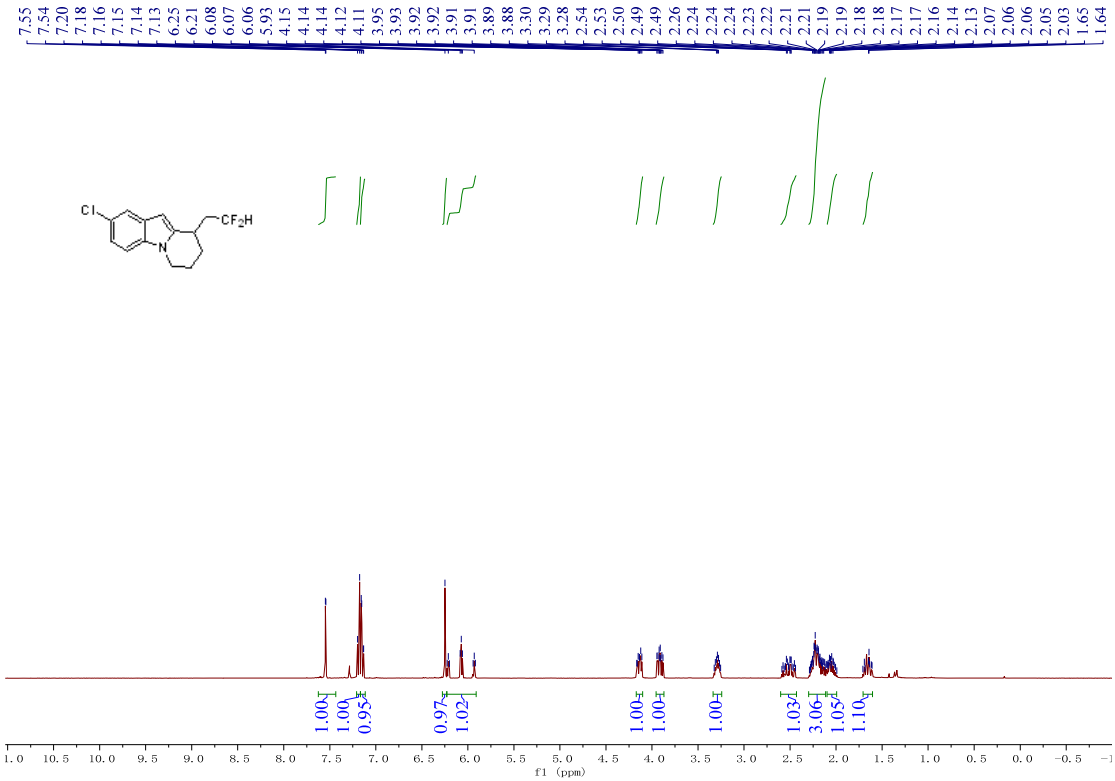
^{13}C NMR of 3e



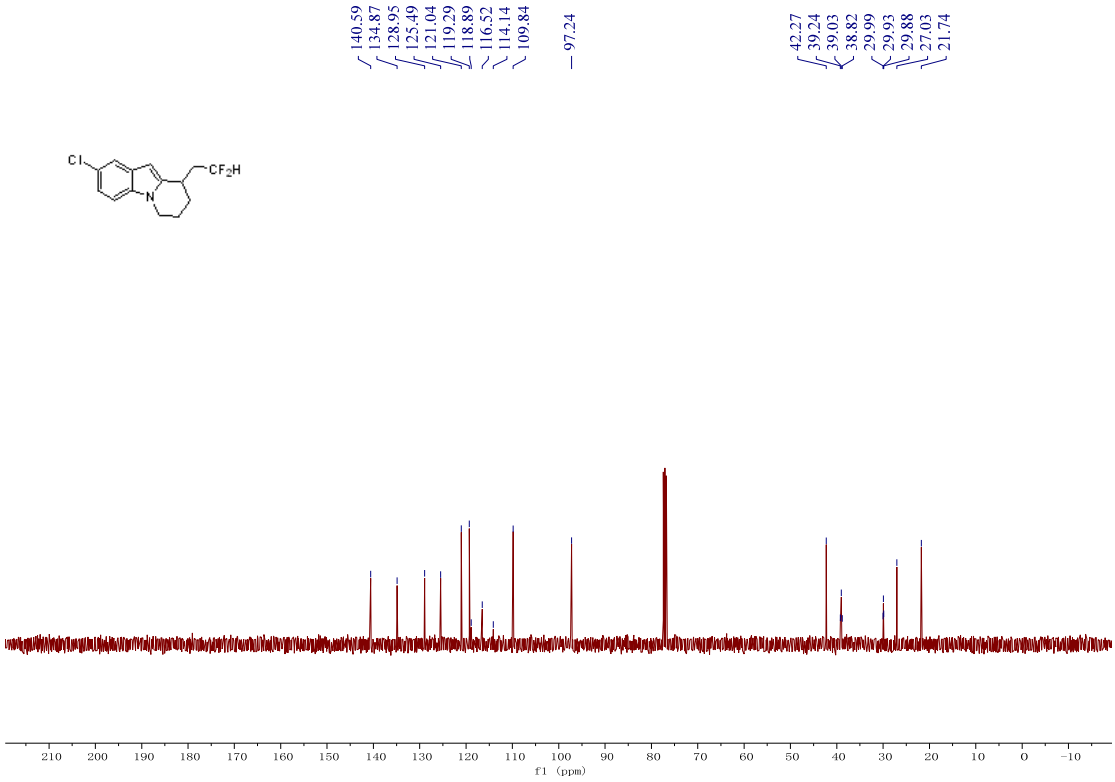
^{19}F NMR of 3e



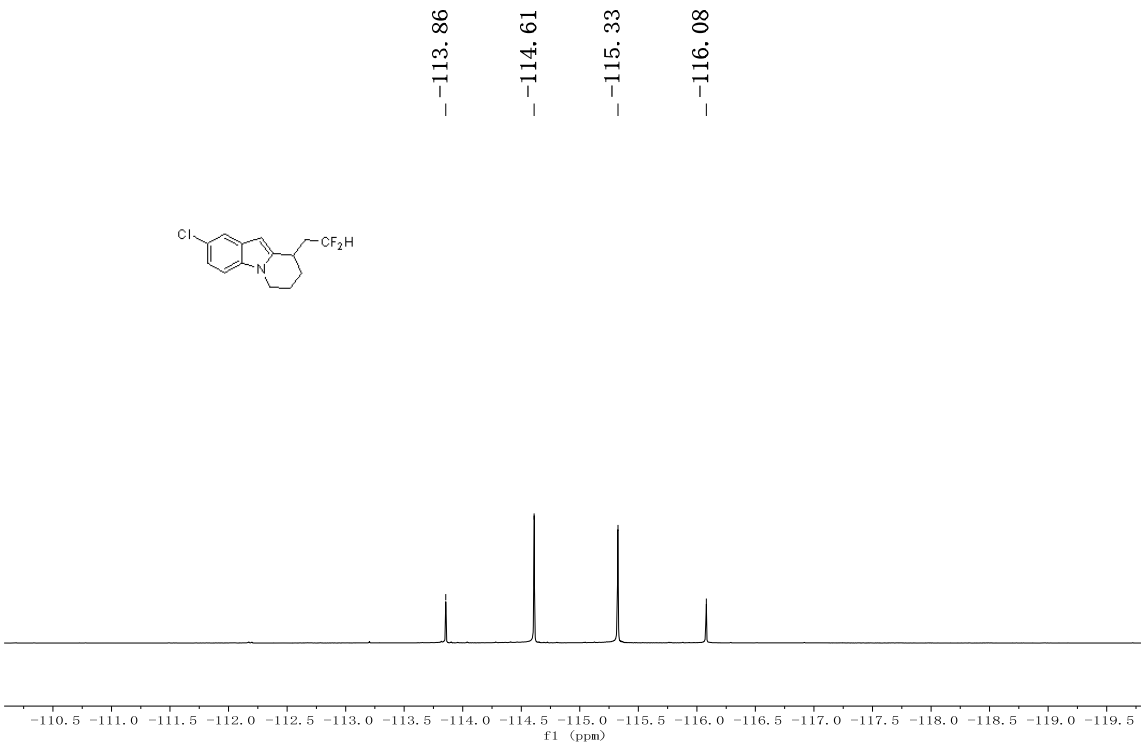
^{1}H NMR of 3f



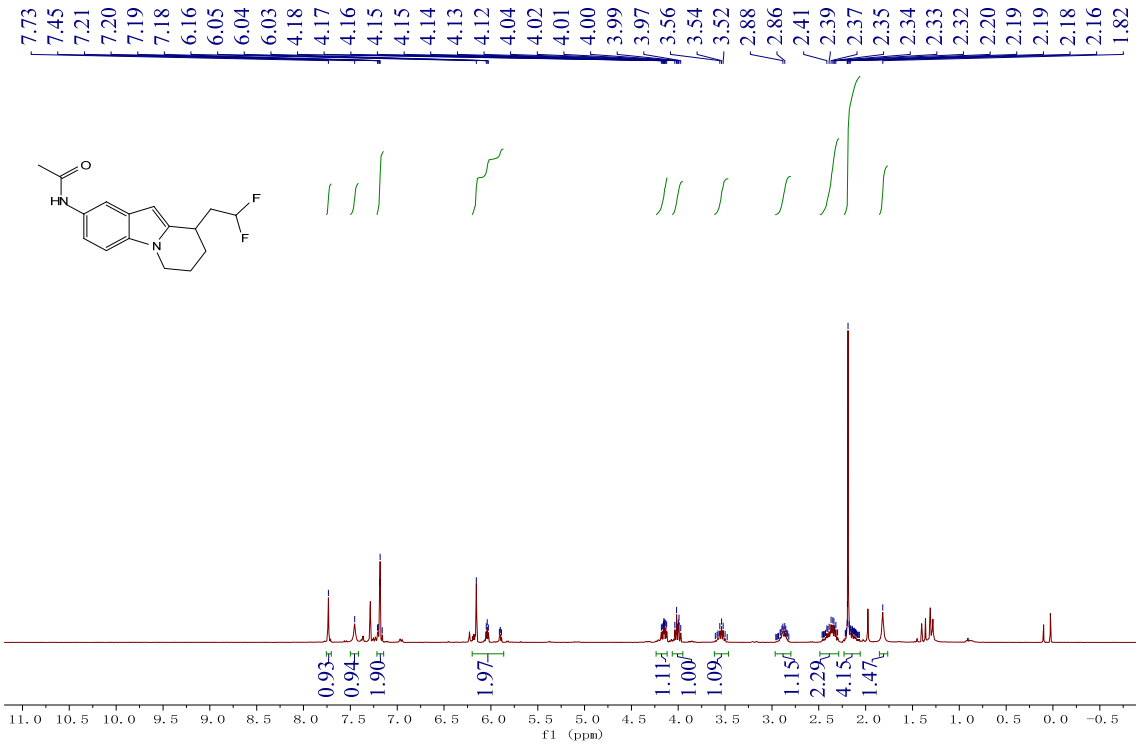
^{13}C NMR of 3f



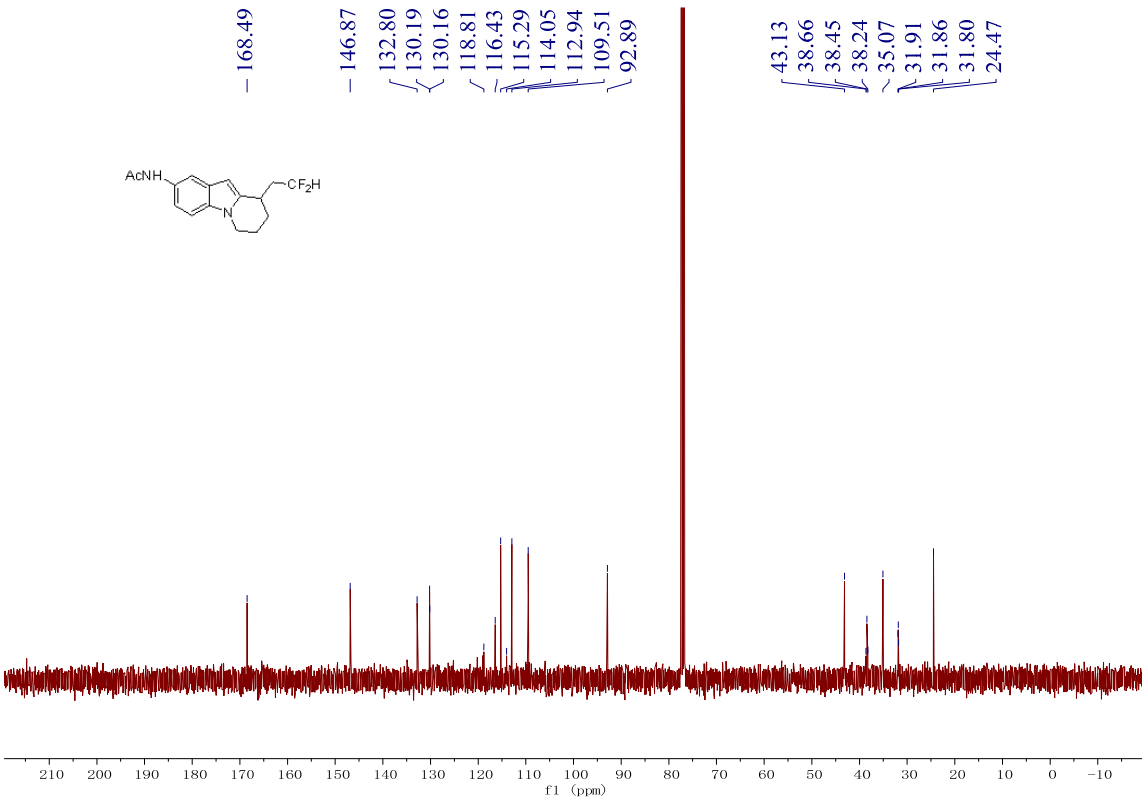
^{19}F NMR of 3f



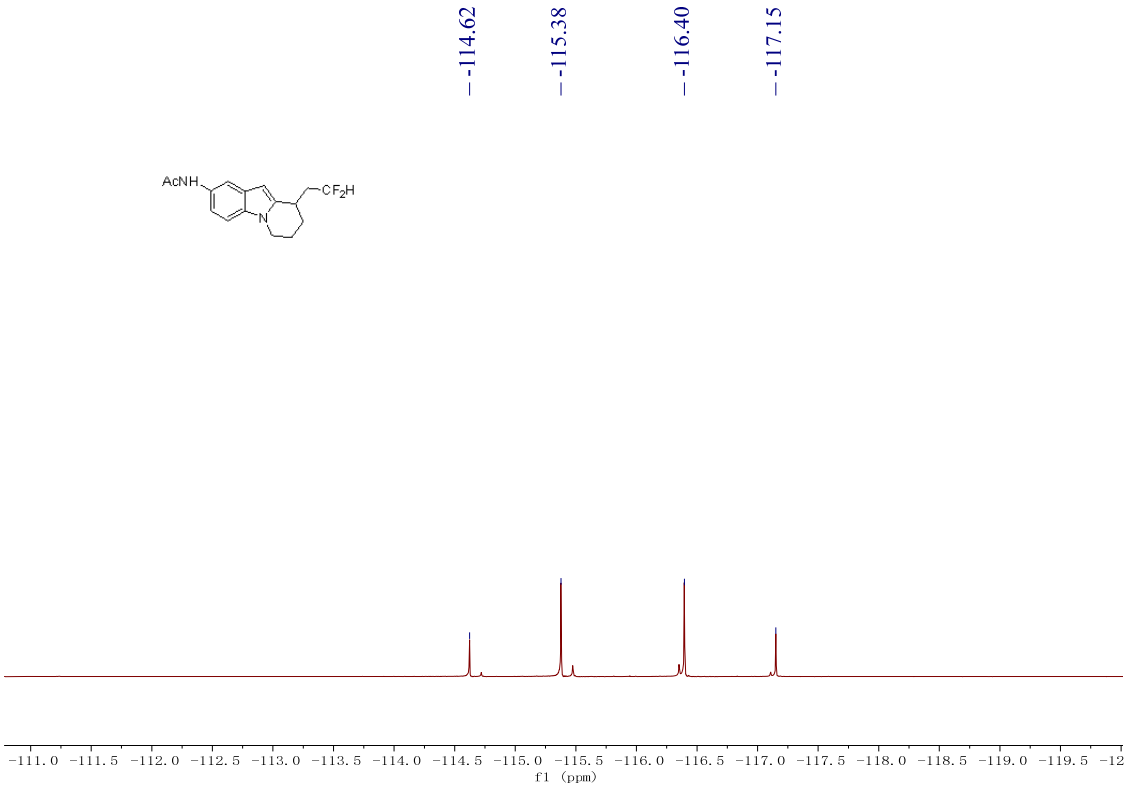
^{1}H NMR of 3g



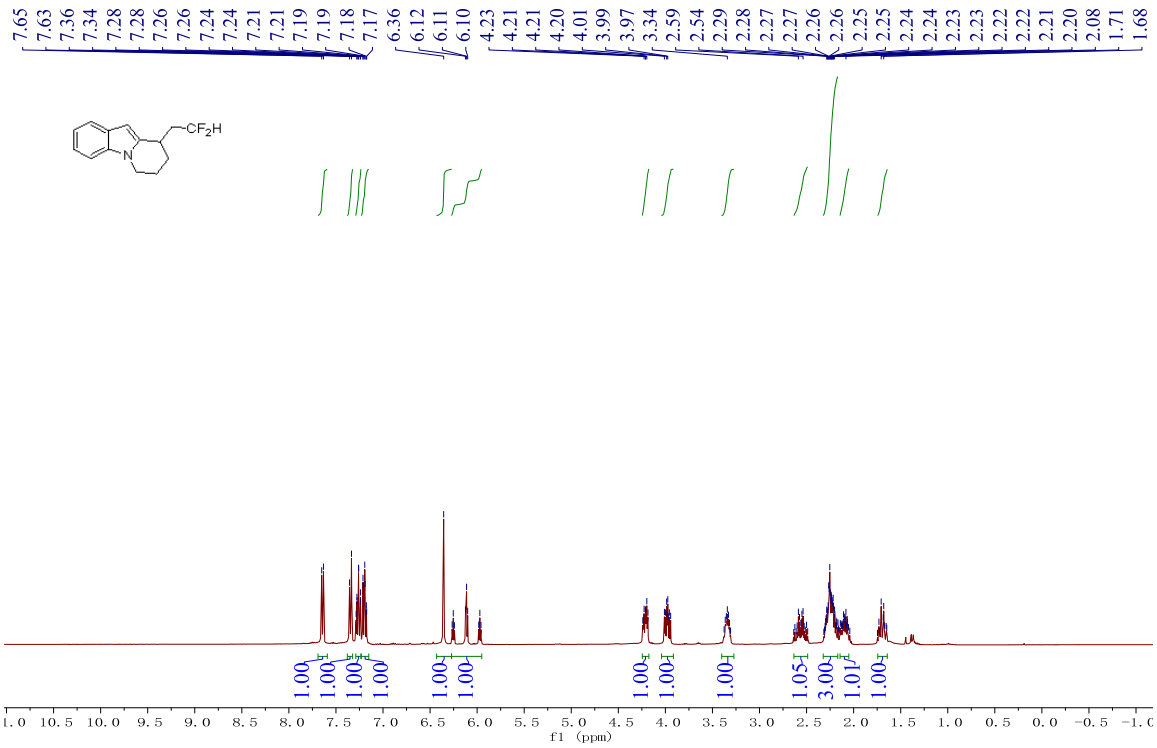
^{13}C NMR of 3g



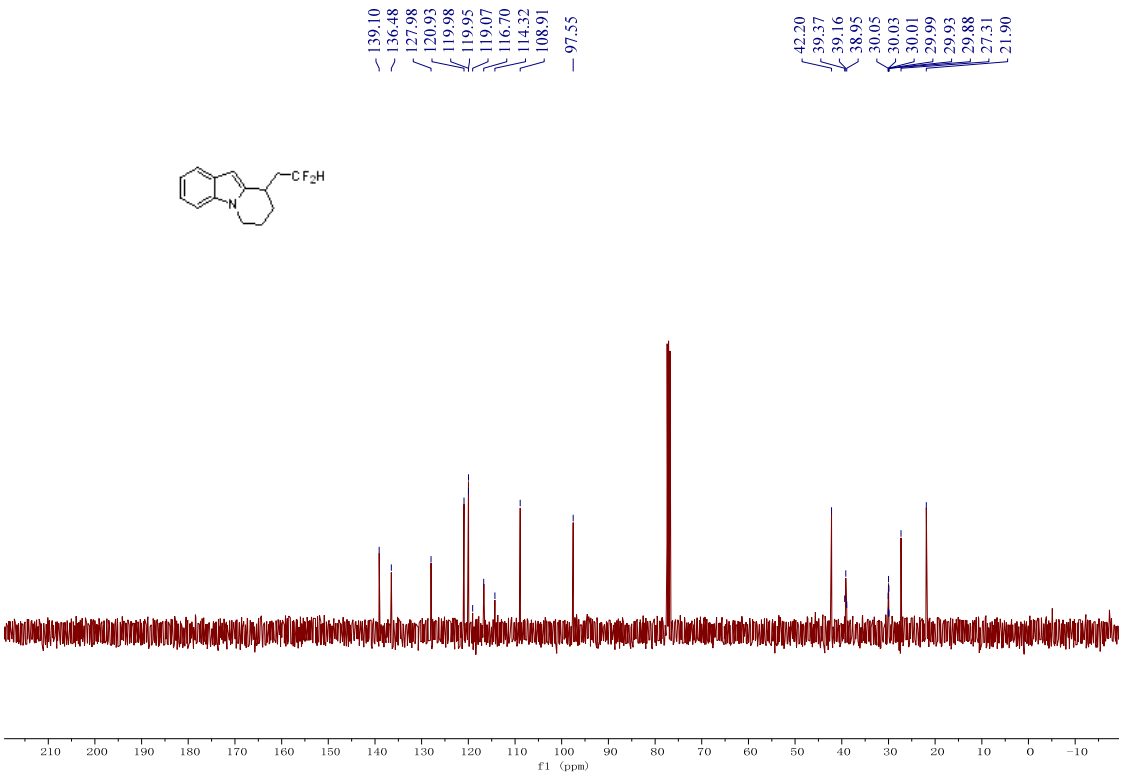
^{19}F NMR of 3g



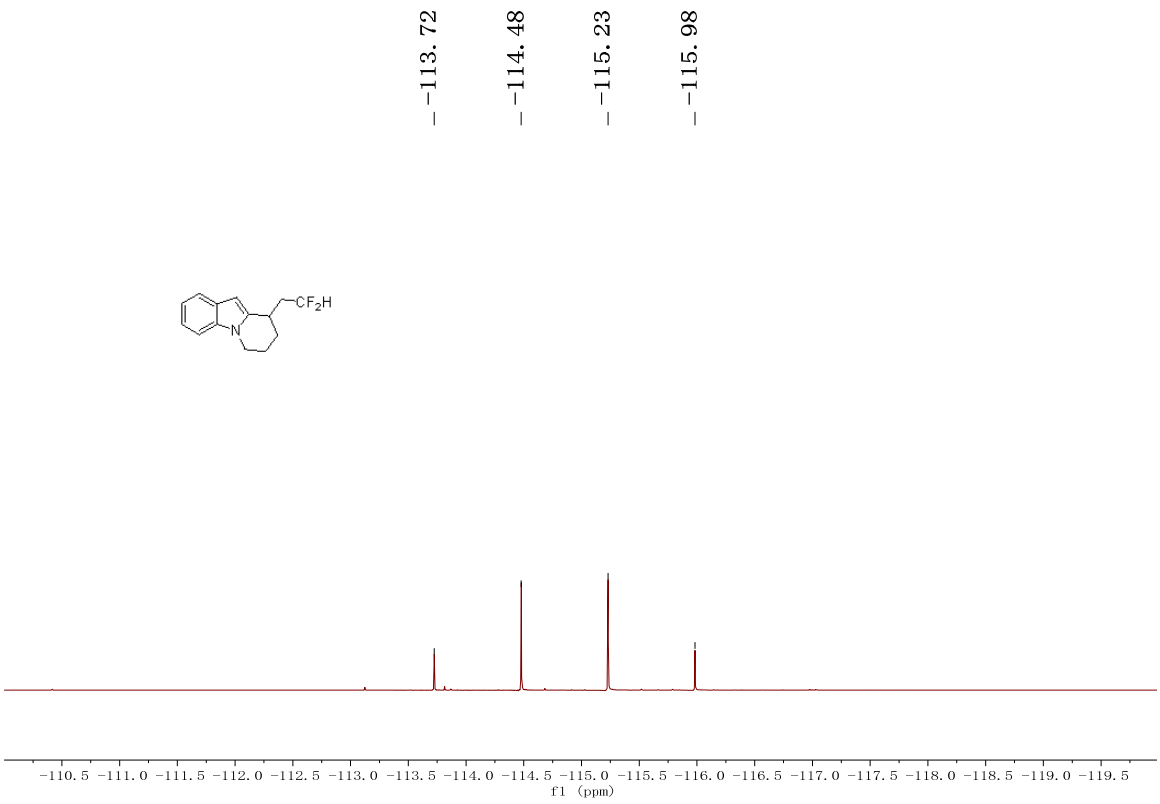
^{1}H NMR of 3h



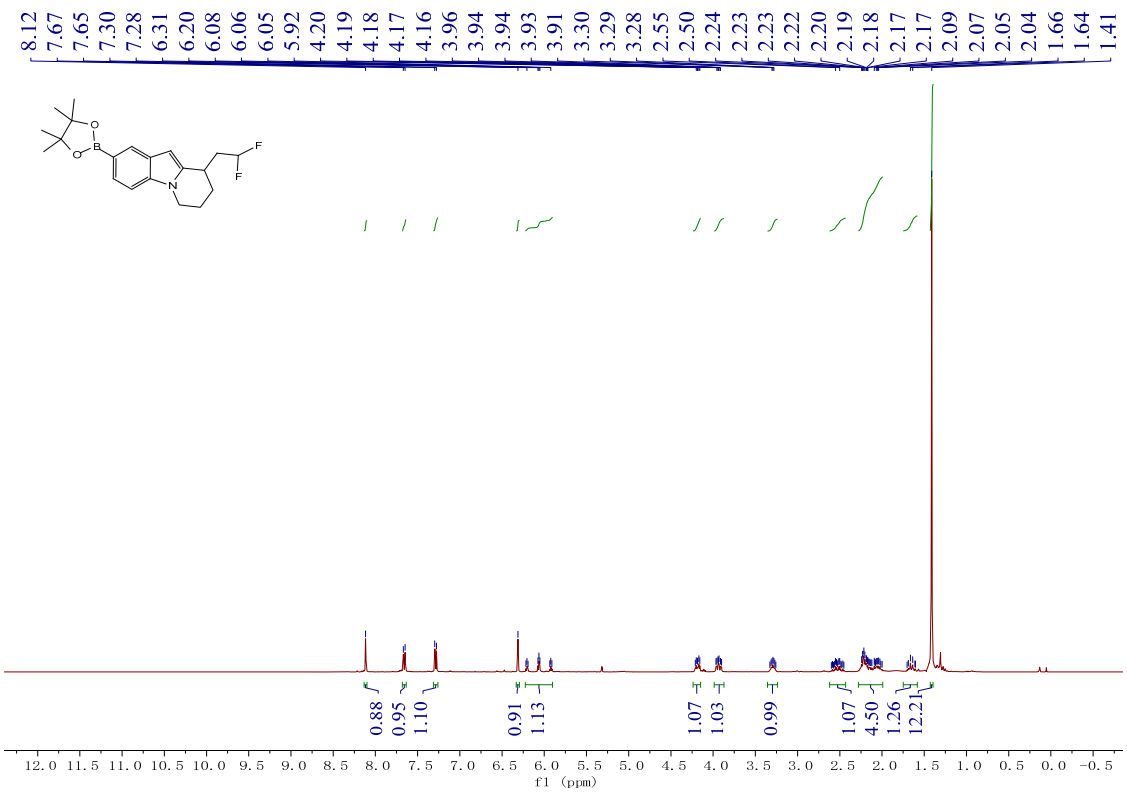
^{13}C NMR of 3h



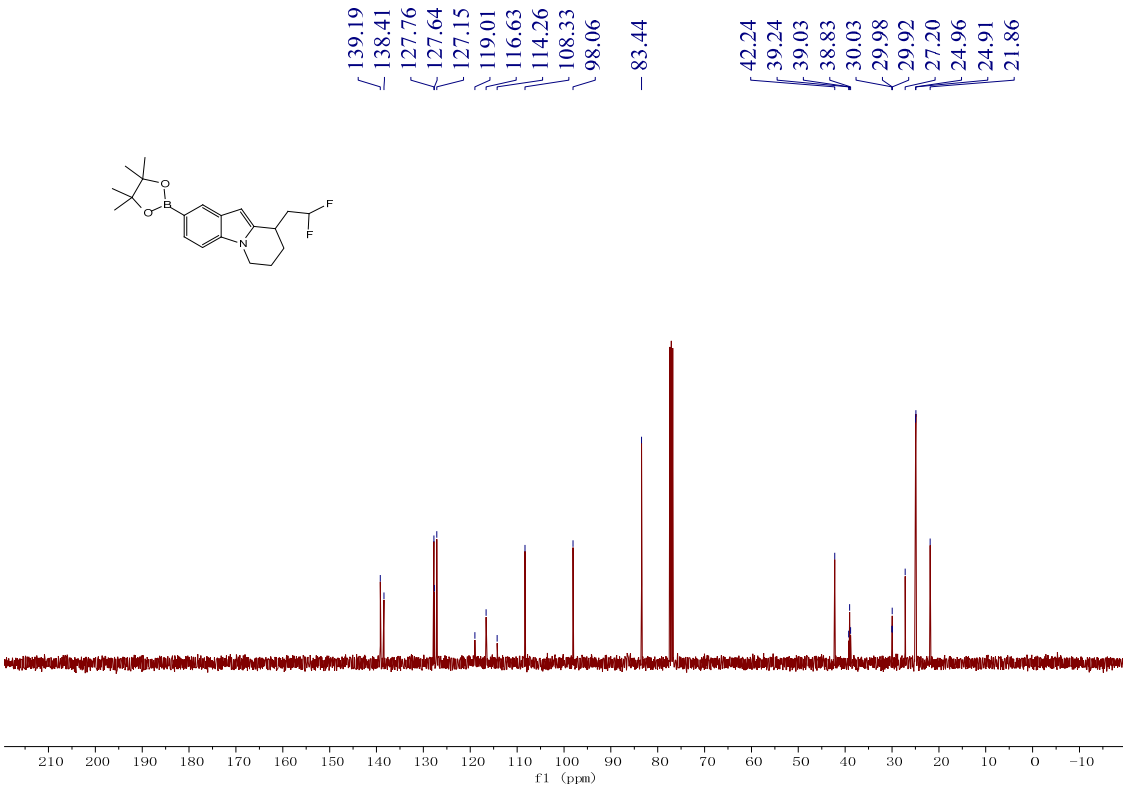
^{19}F NMR of 3h



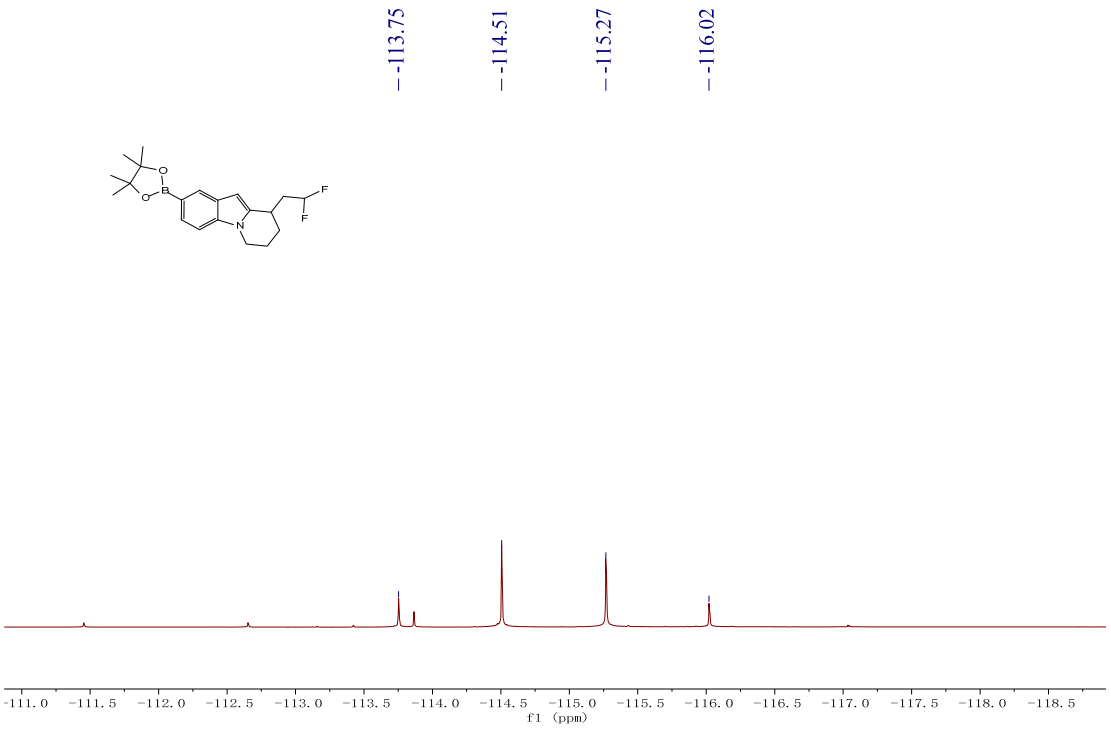
^{1}H NMR of 3i



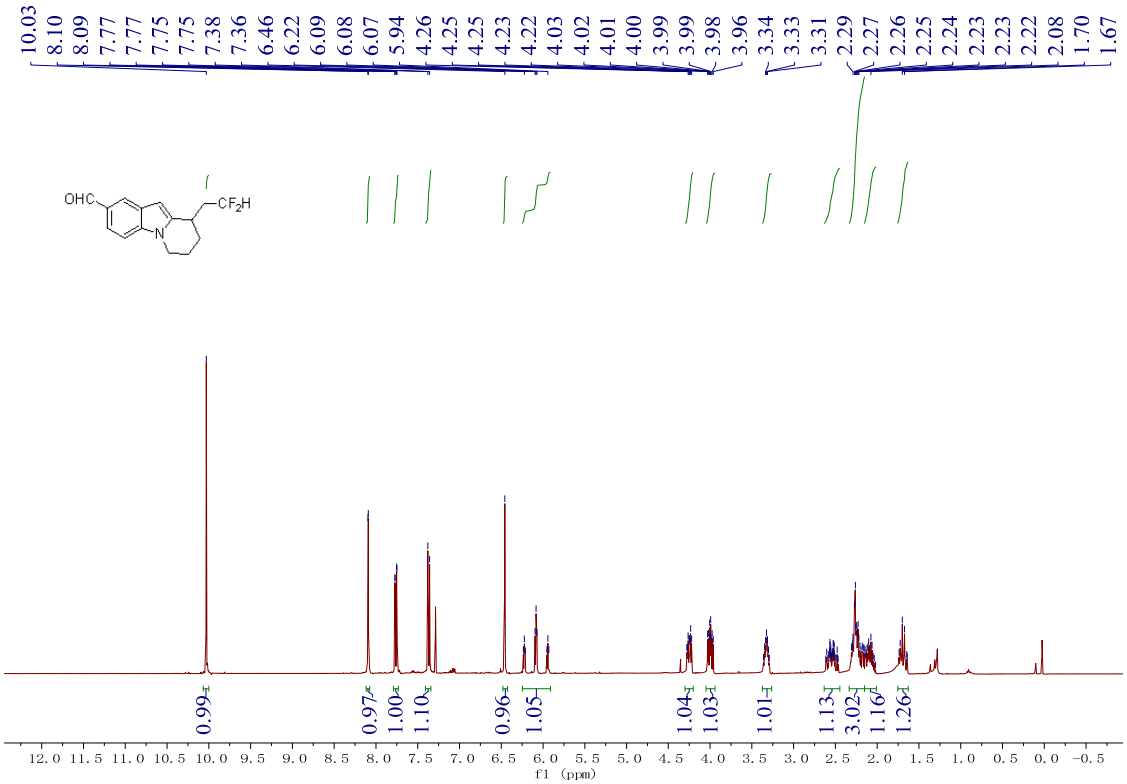
^{13}C NMR of 3i



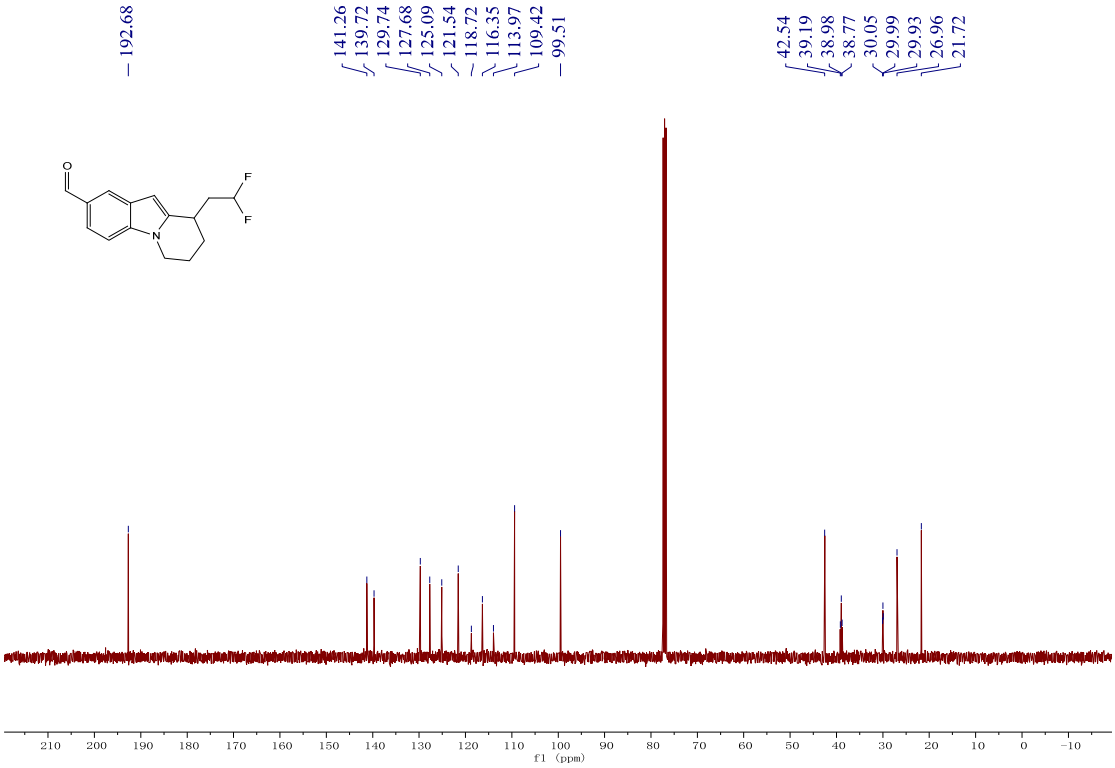
^{19}F NMR of 3i



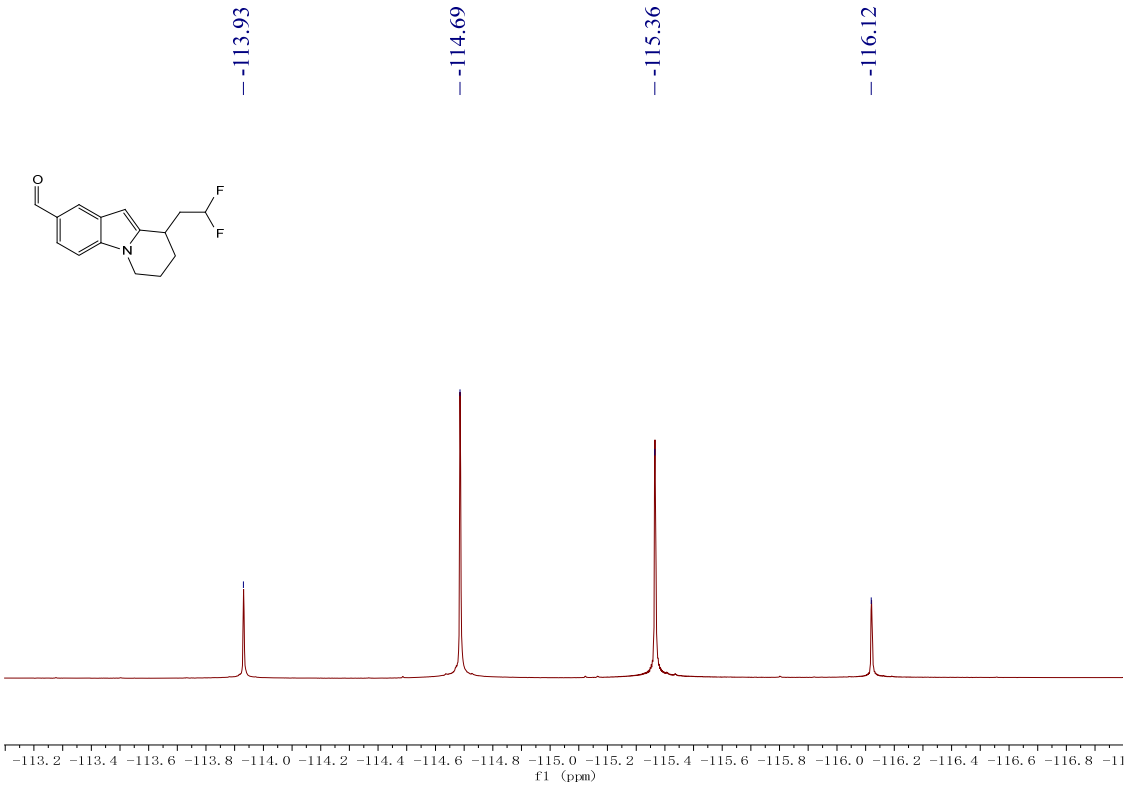
^{1}H NMR of 3j



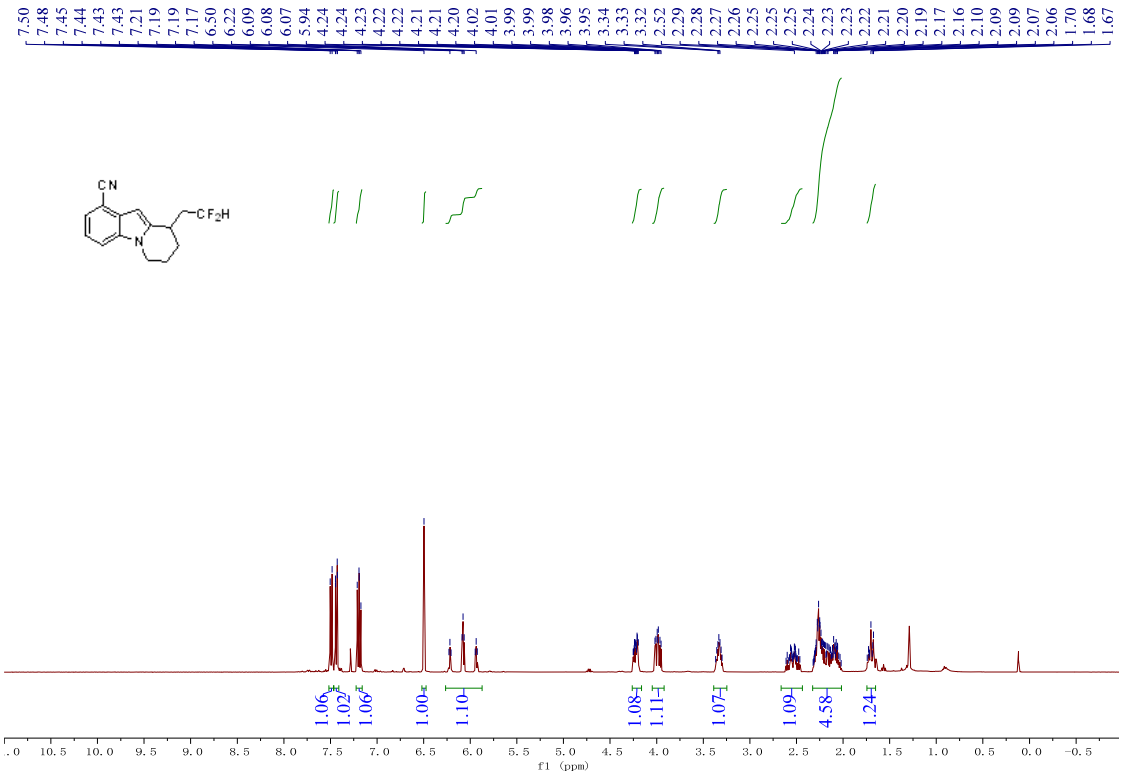
^{13}C NMR of 3j



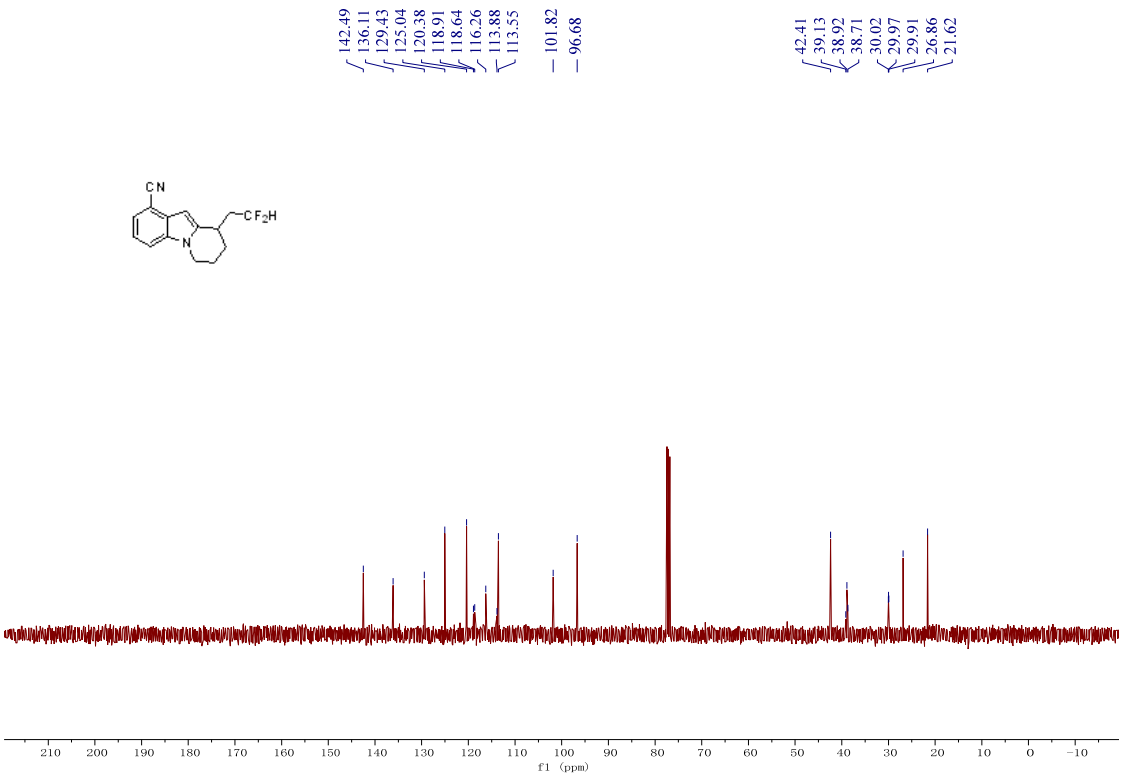
^{19}F NMR of 3j



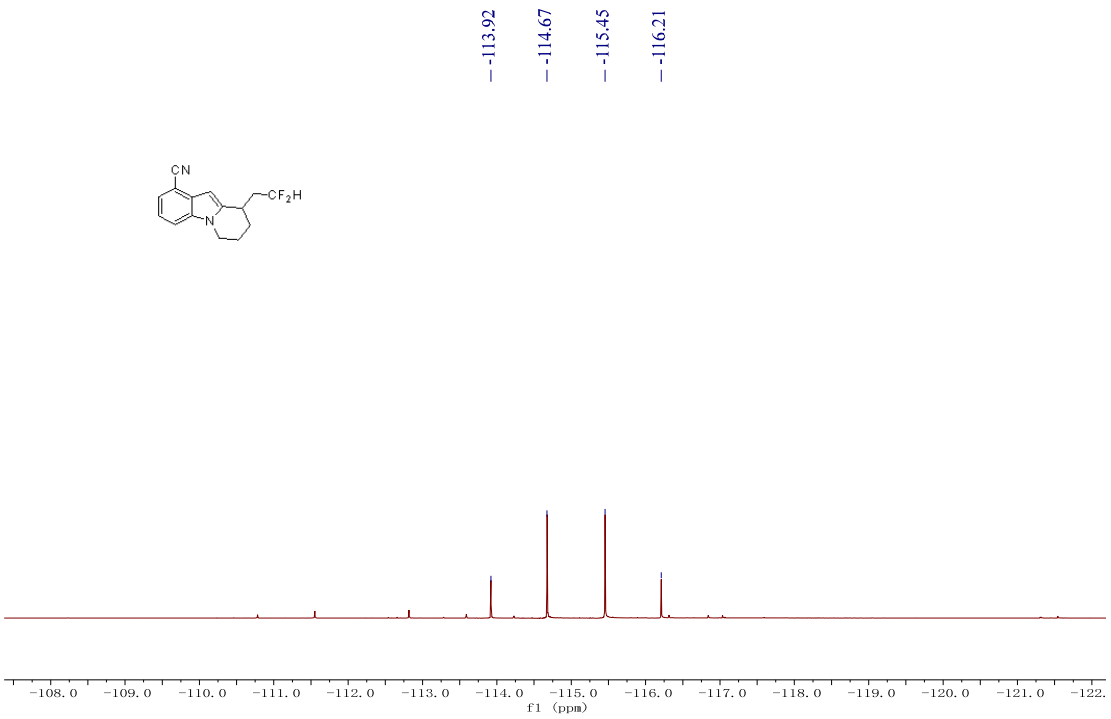
^{1}H NMR of 3k



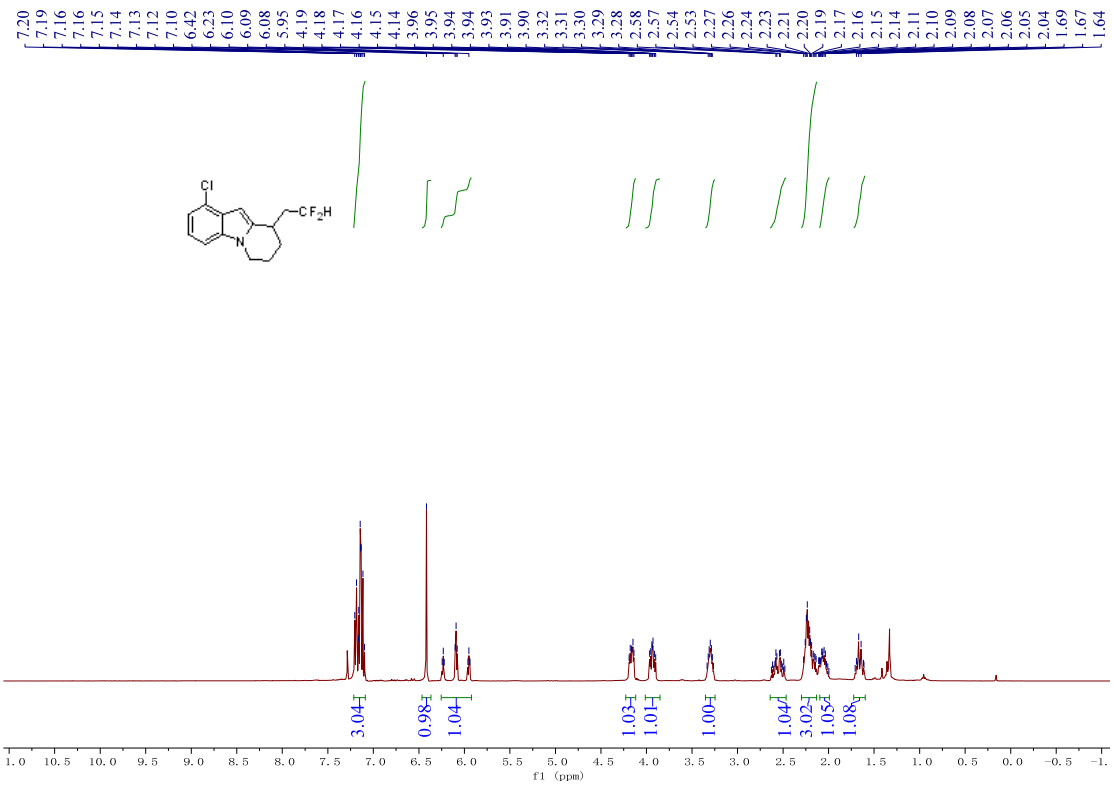
^{13}C NMR of 3k



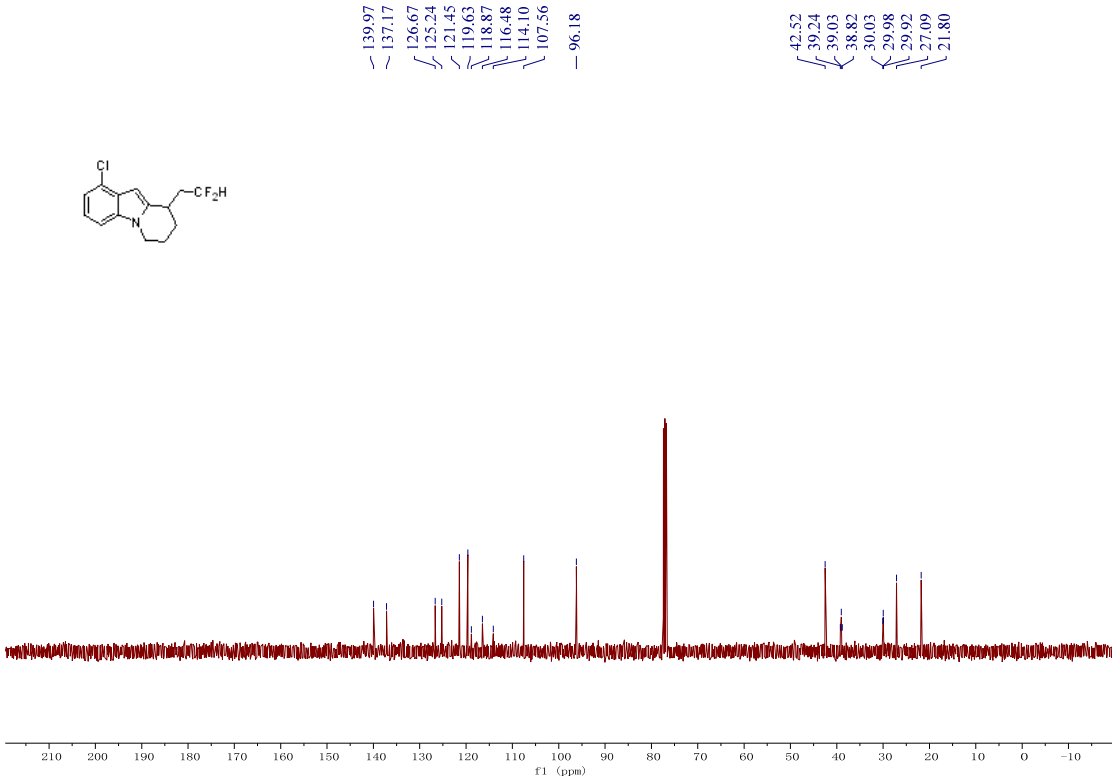
^{19}F NMR of 3k



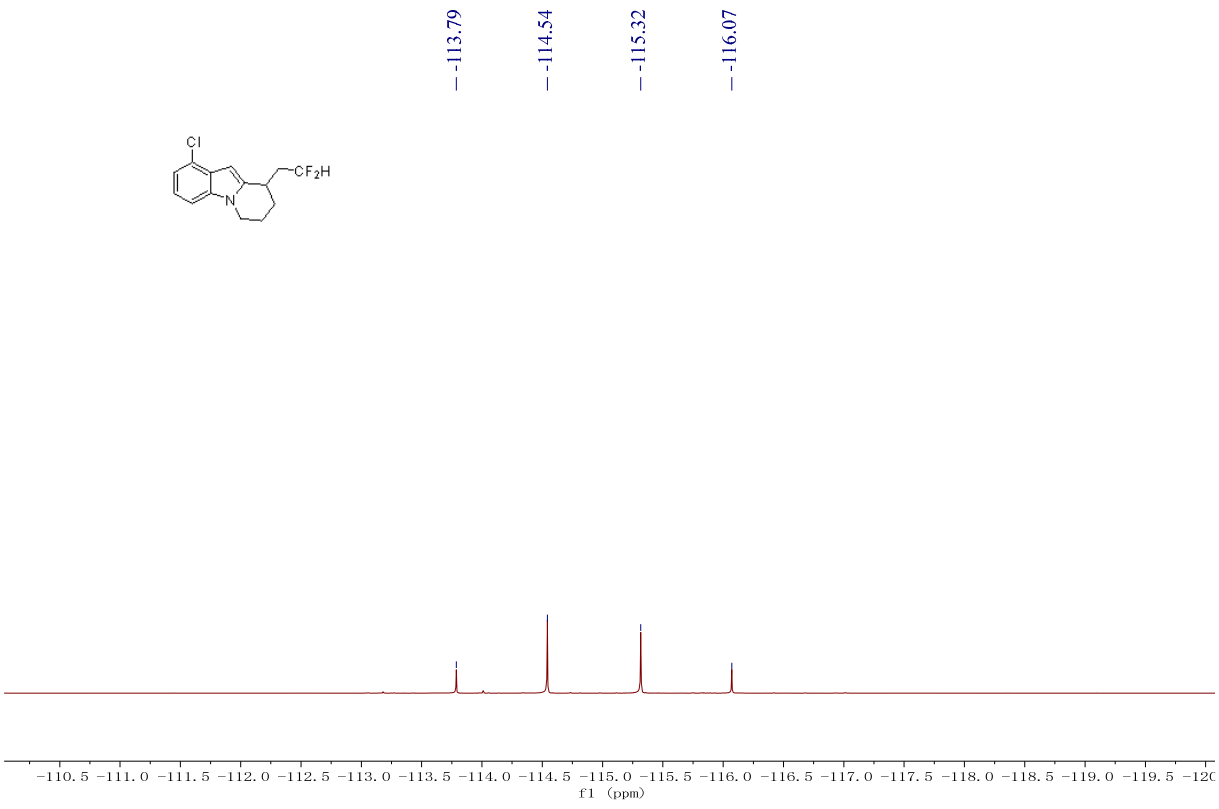
^{1}H NMR of 3l



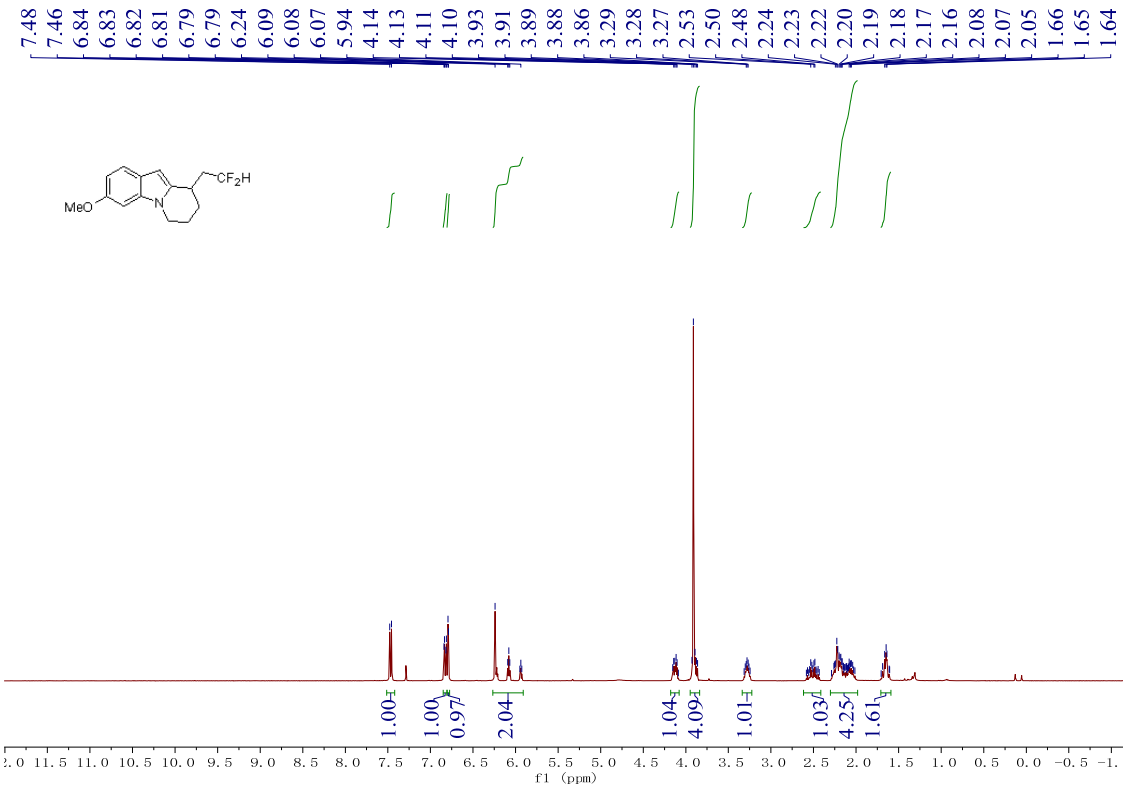
^{13}C NMR of 3l



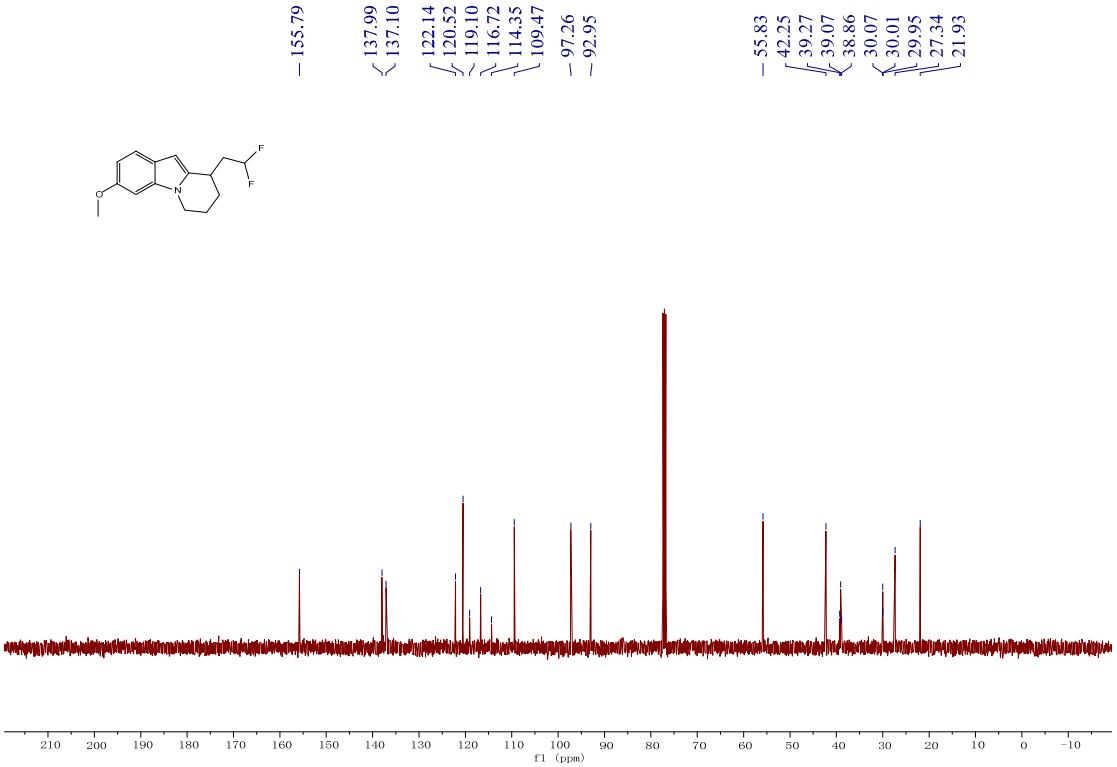
^{19}F NMR of 3l



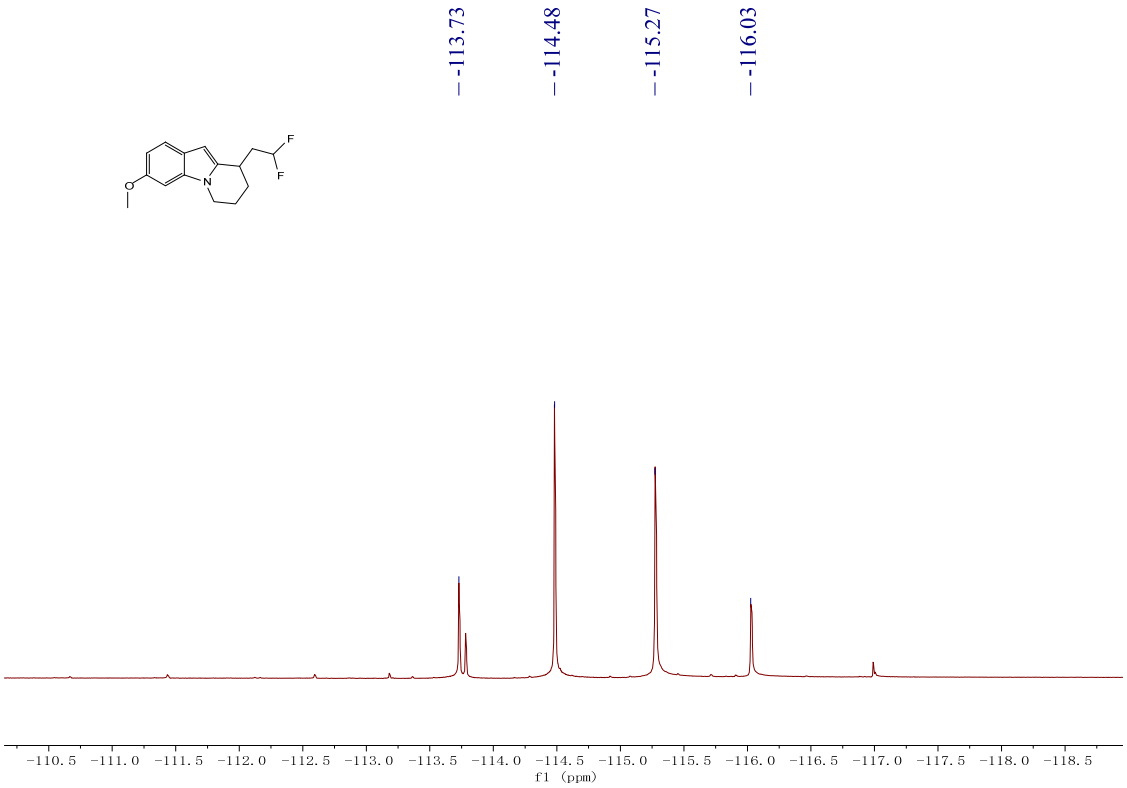
^{1}H NMR of 3m



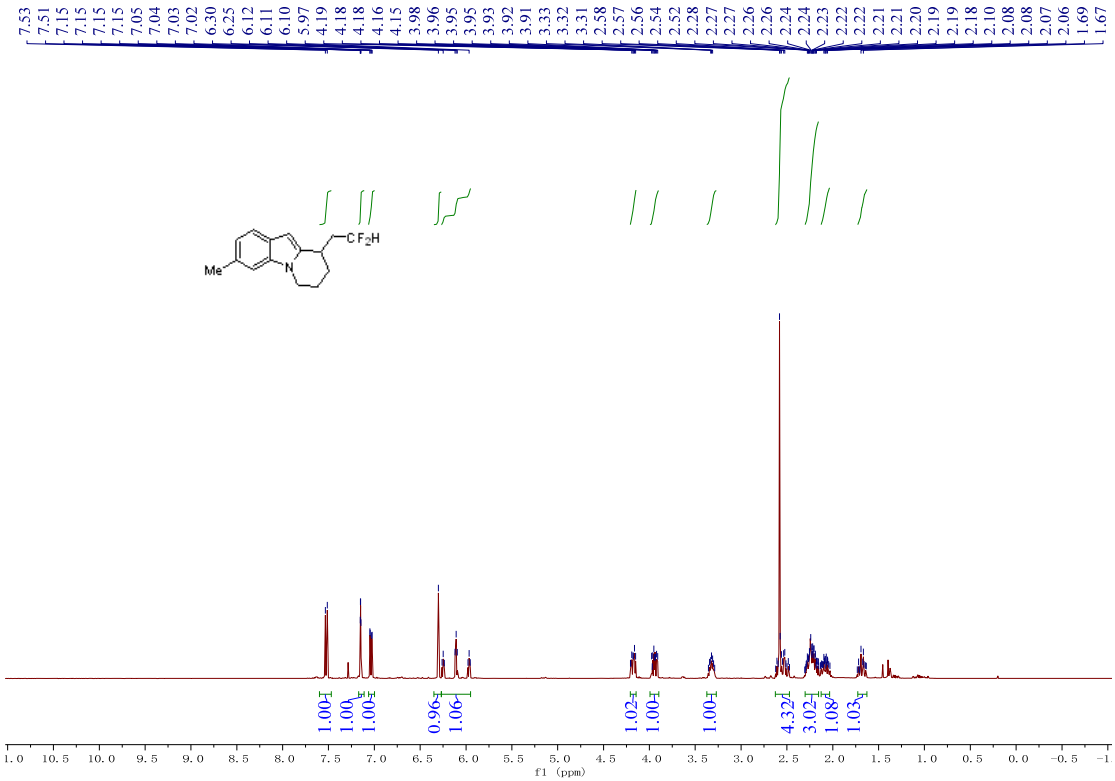
^{13}C NMR of 3m



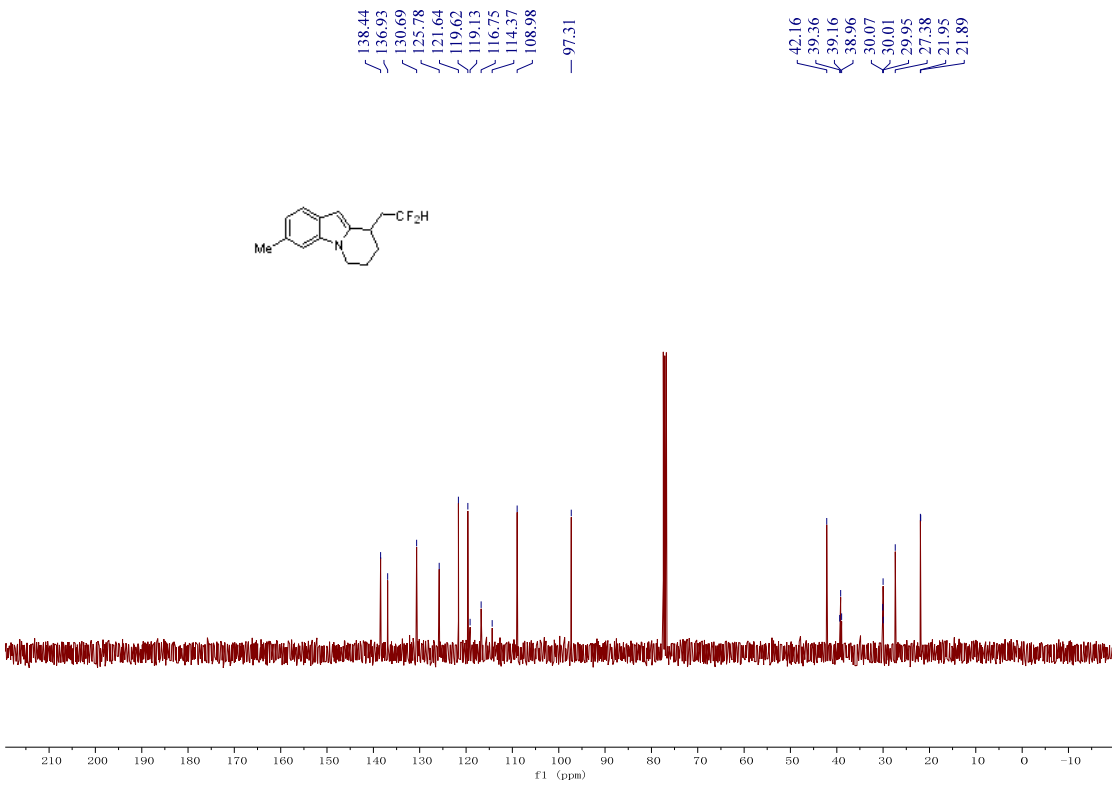
^{19}F NMR of 3m



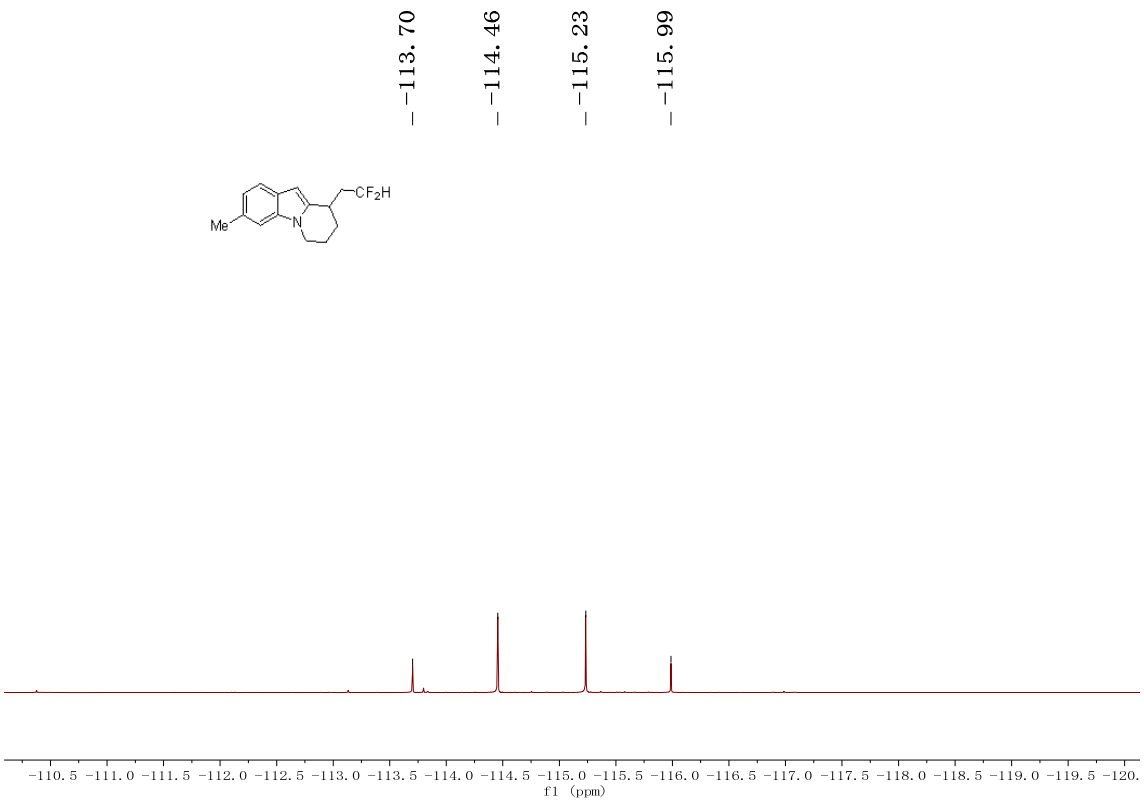
^{1}H NMR of 3n



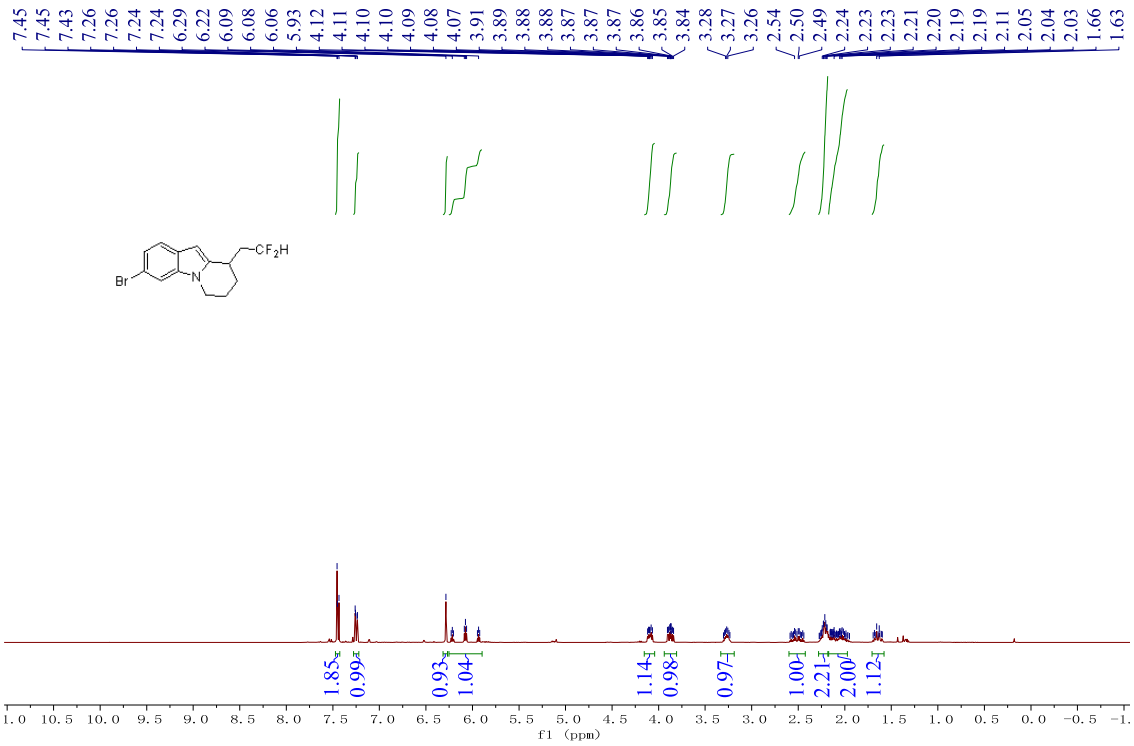
^{13}C NMR of 3n



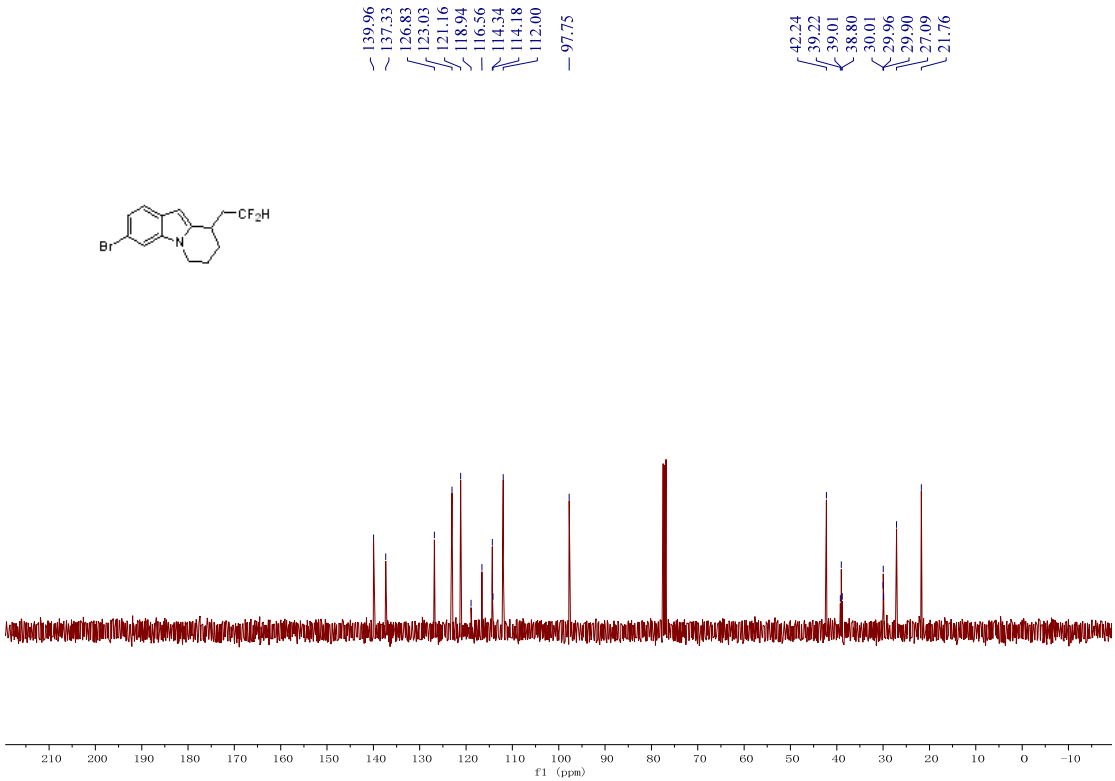
^{19}F NMR of 3n



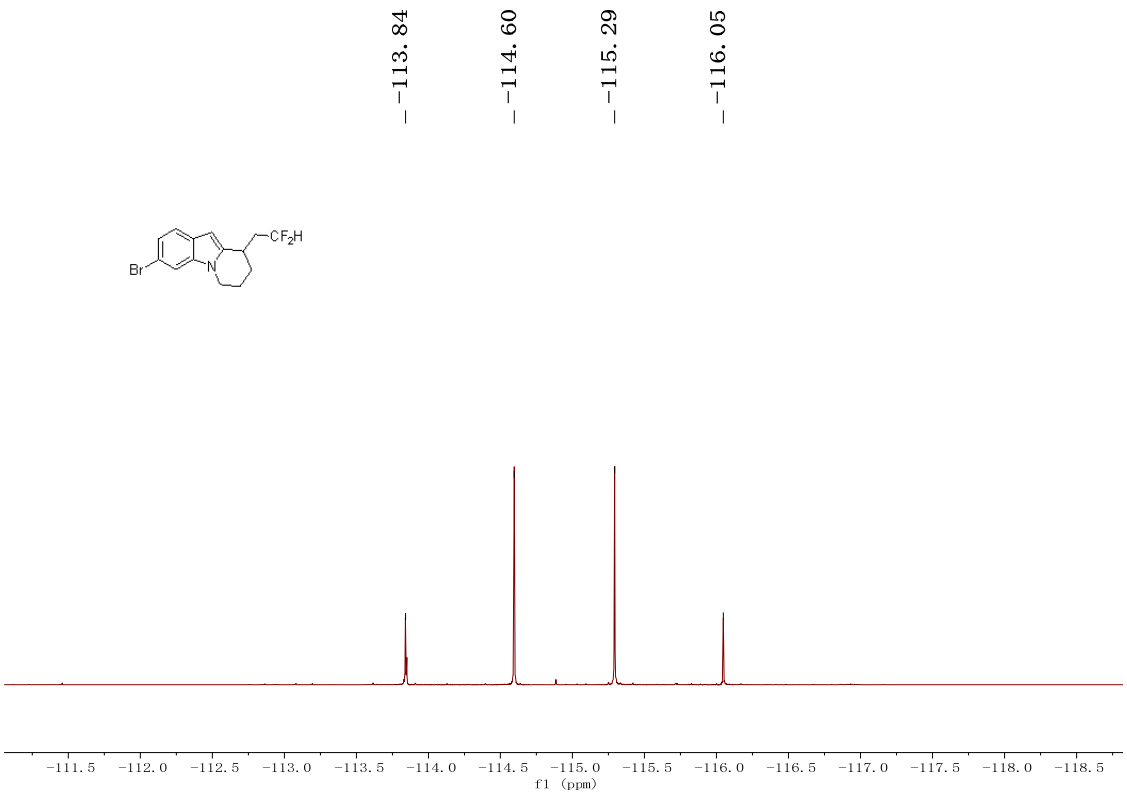
^{1}H NMR of 3o



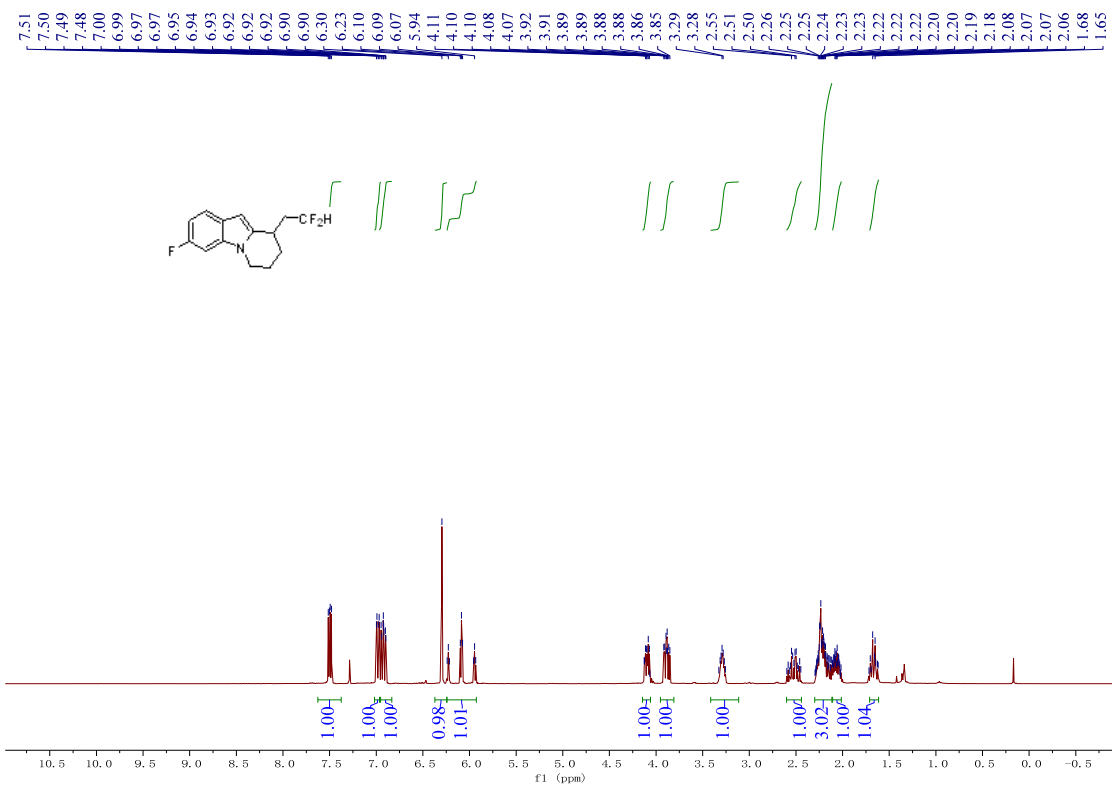
^{13}C NMR of 3o



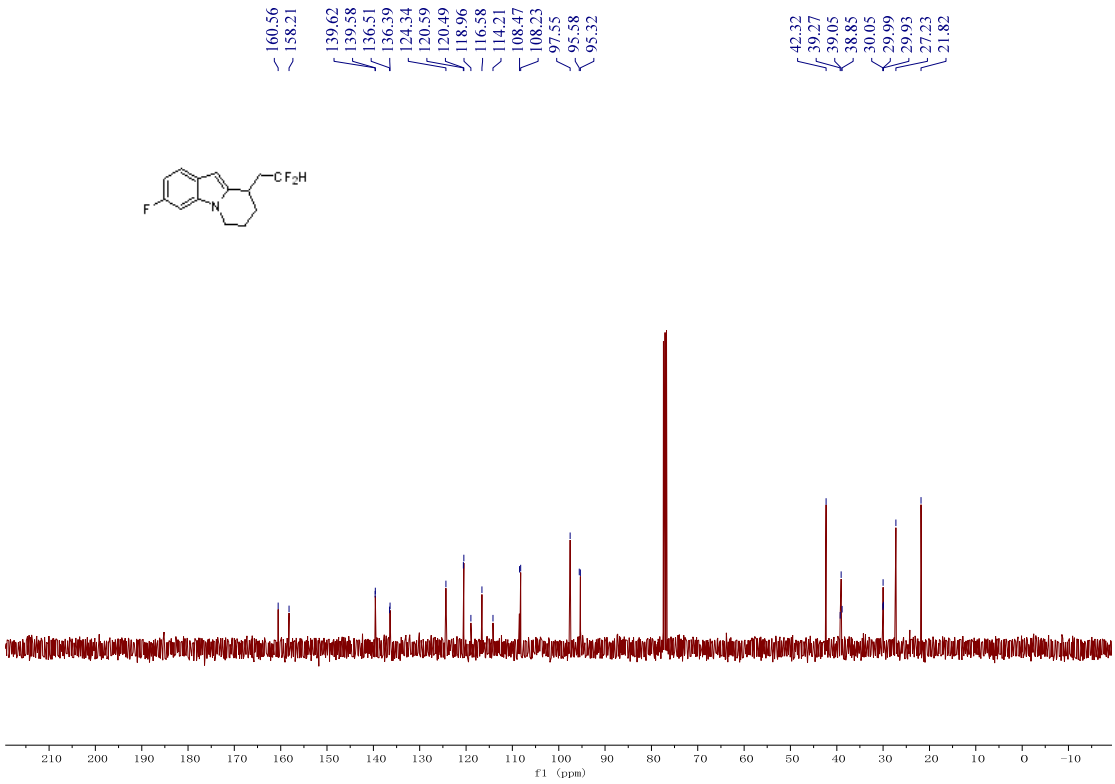
^{19}F NMR of 3o



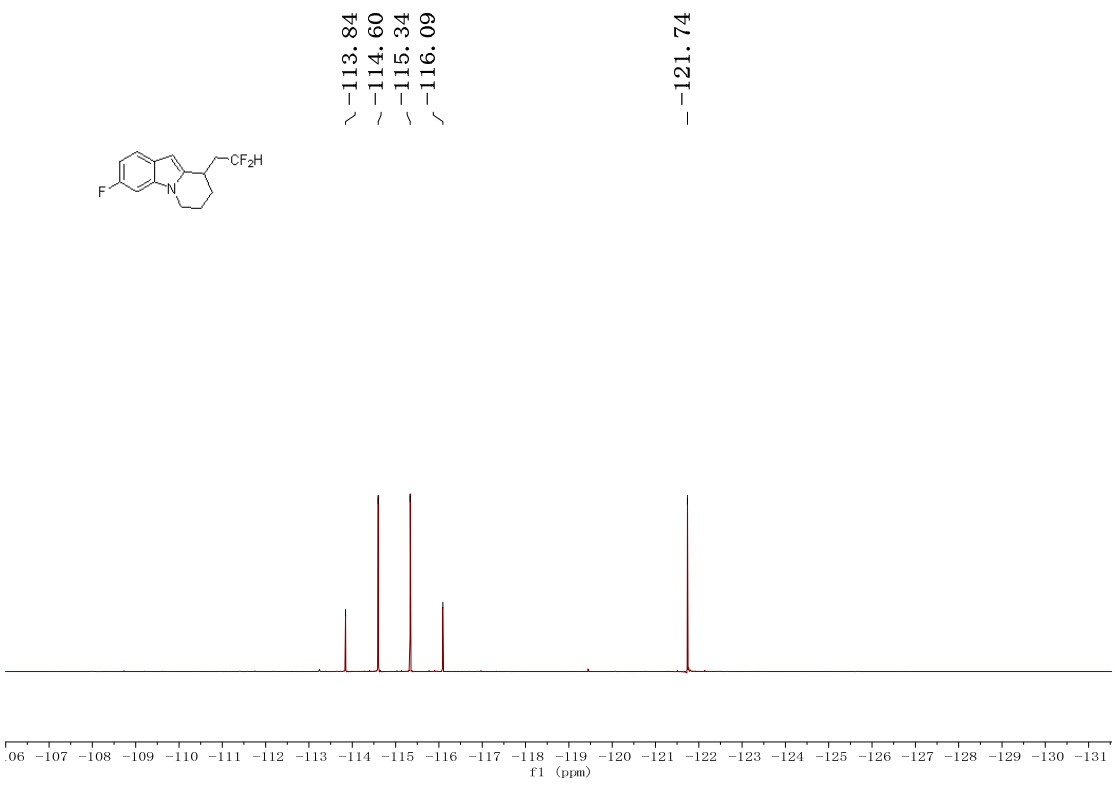
^{1}H NMR of 3p



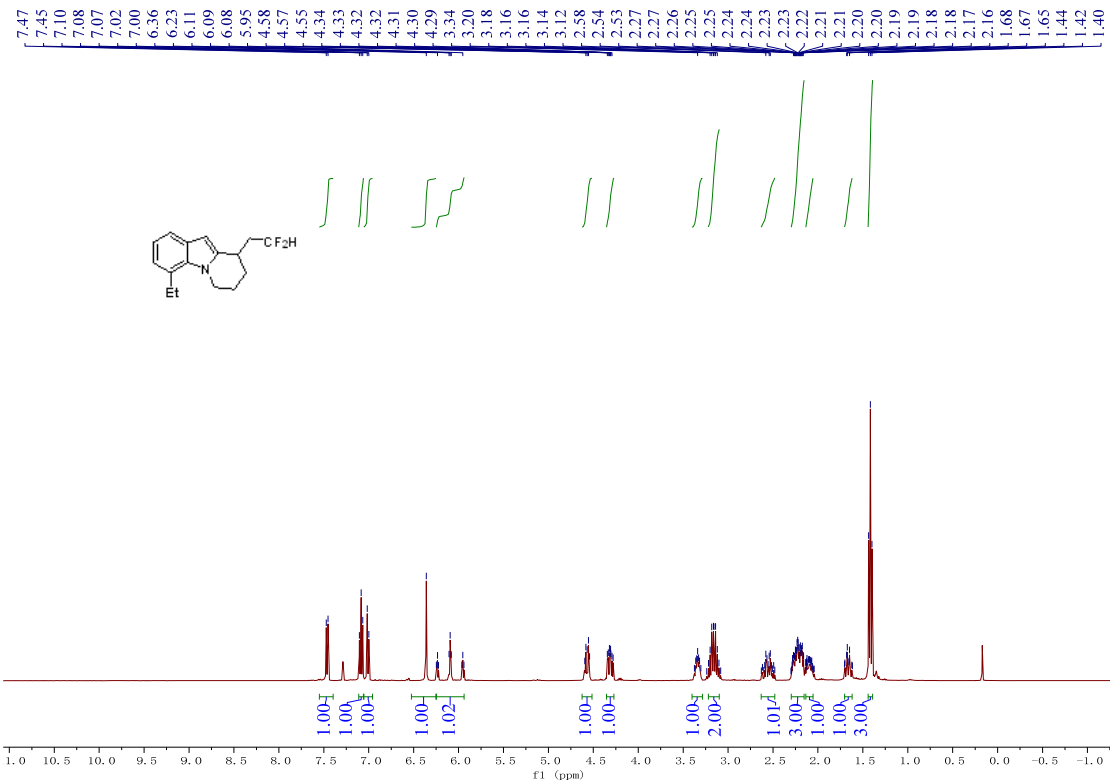
^{13}C NMR of 3p



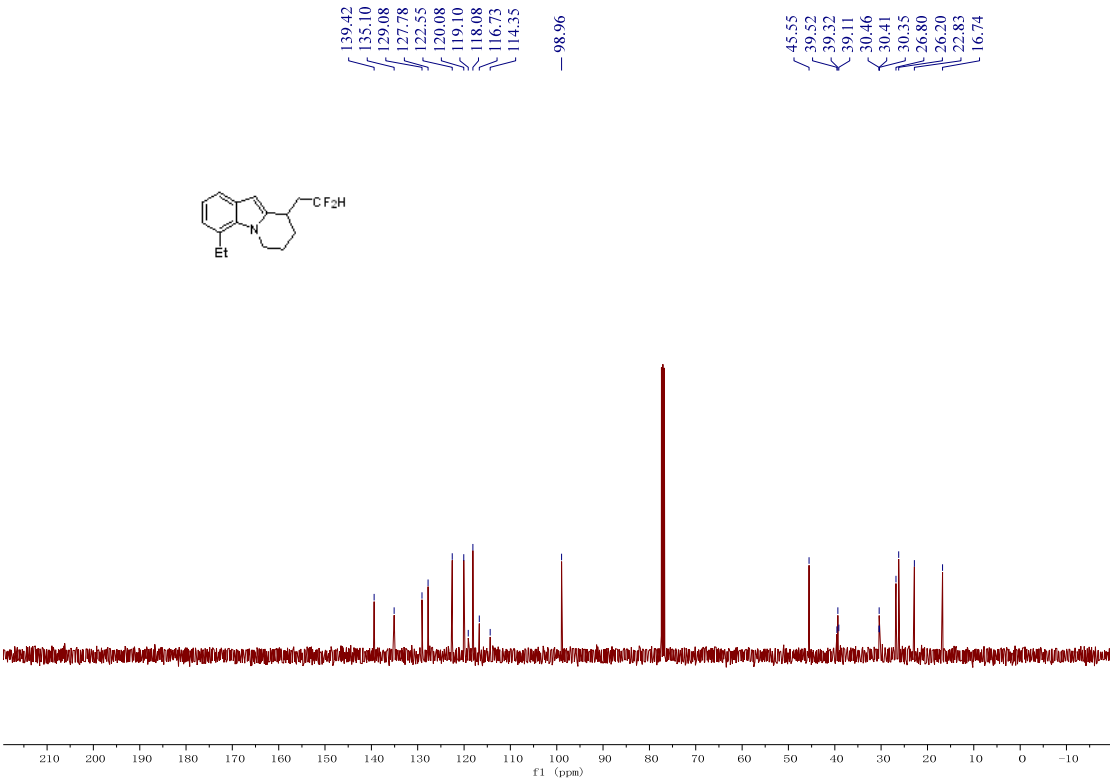
^{19}F NMR of 3p



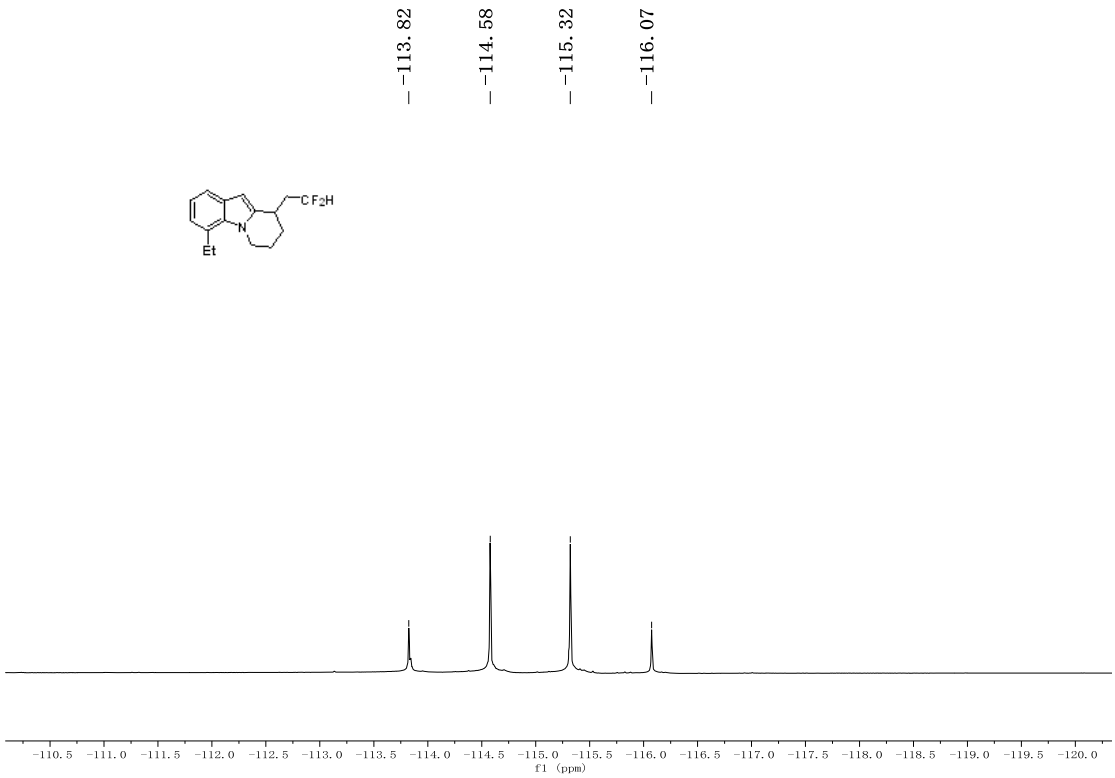
^{1}H NMR of 3q



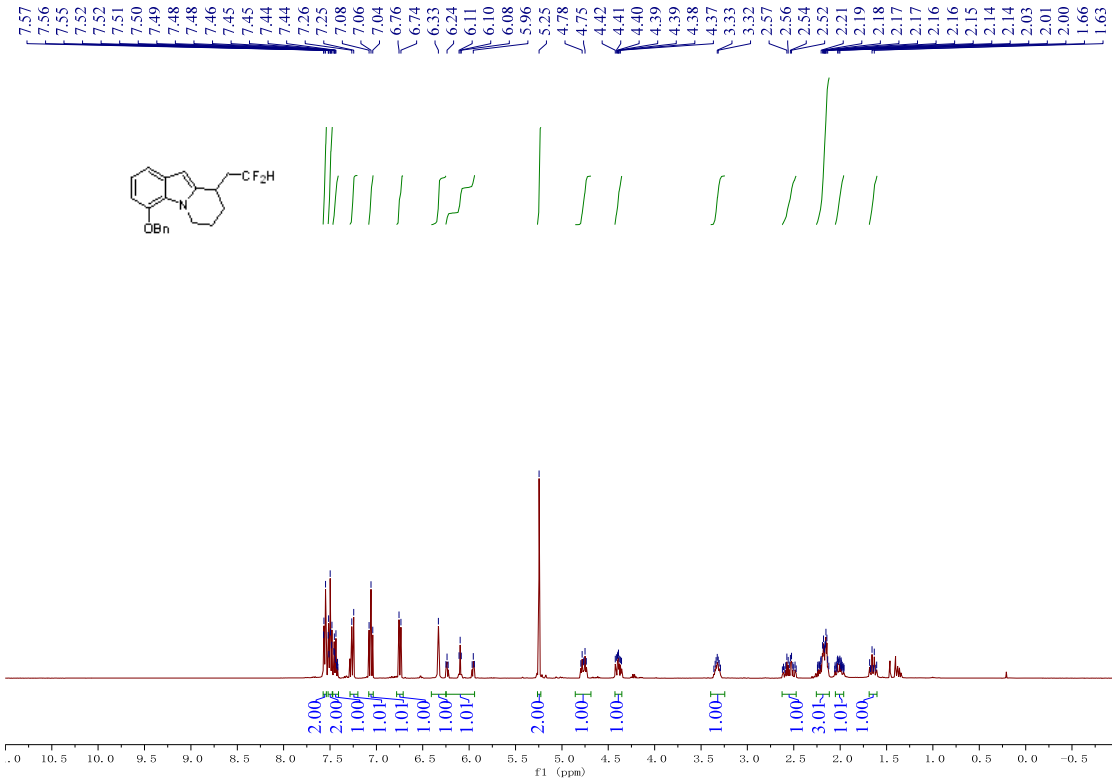
^{13}C NMR of 3q



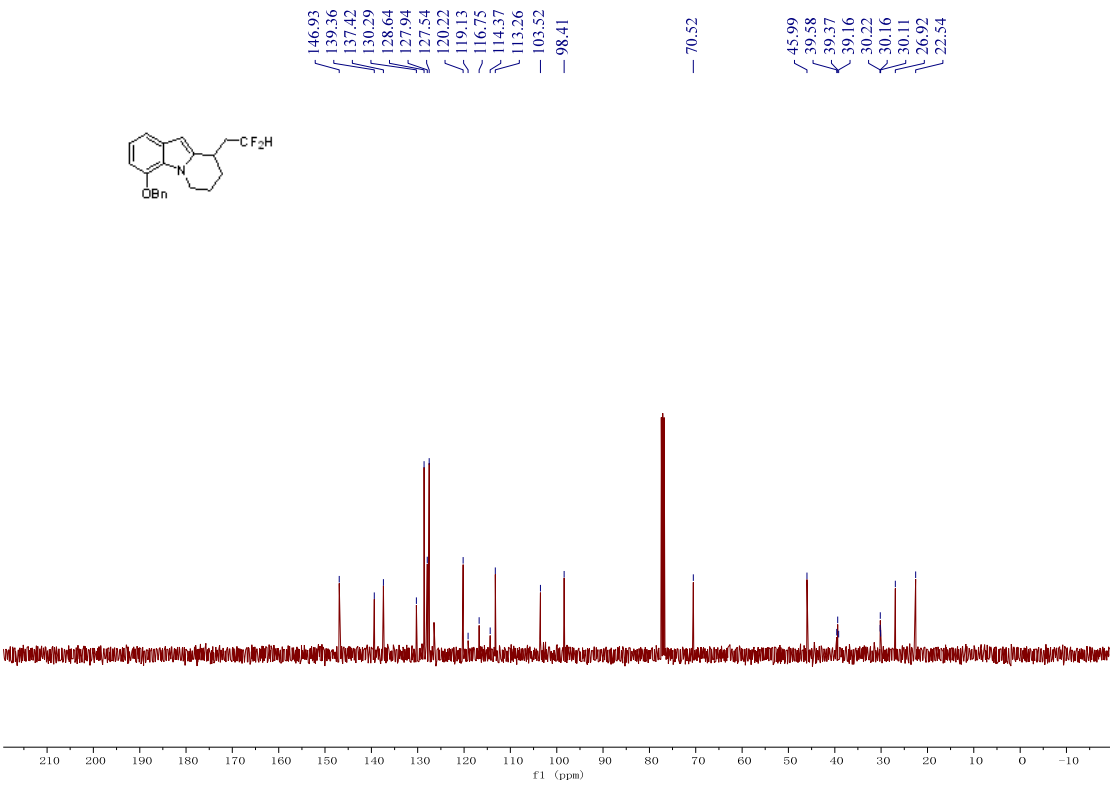
^{19}F NMR of 3q



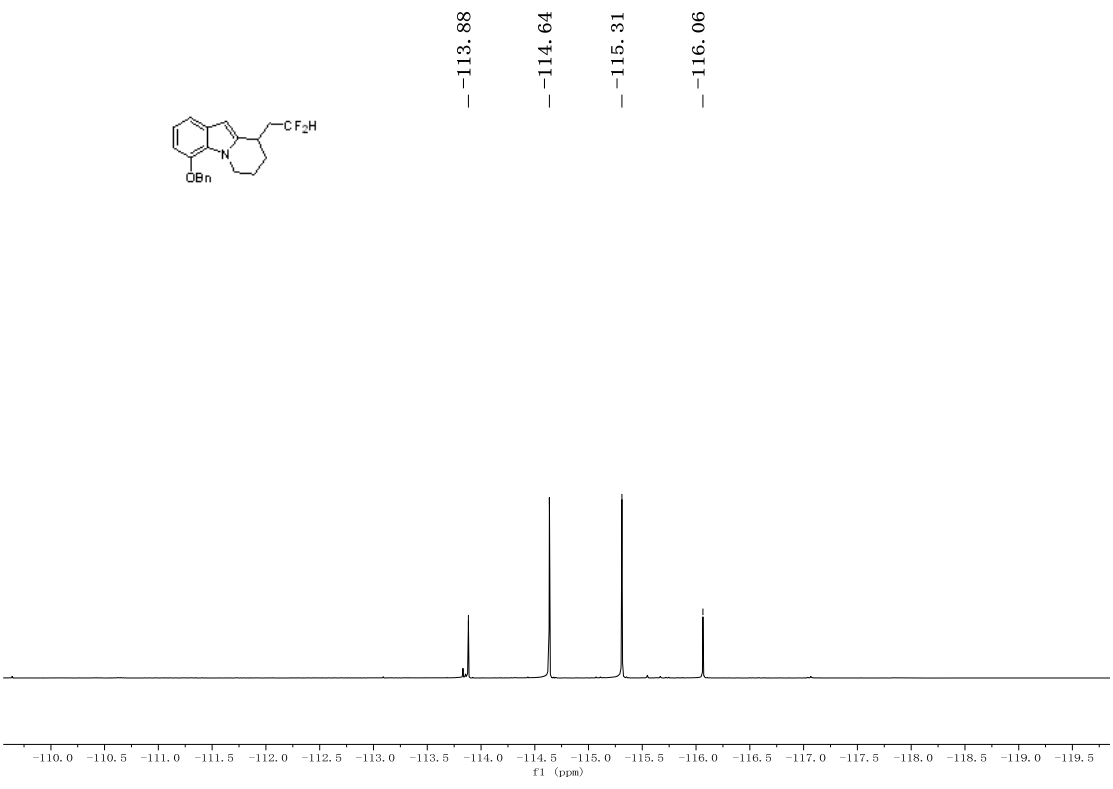
^{1}H NMR of 3r



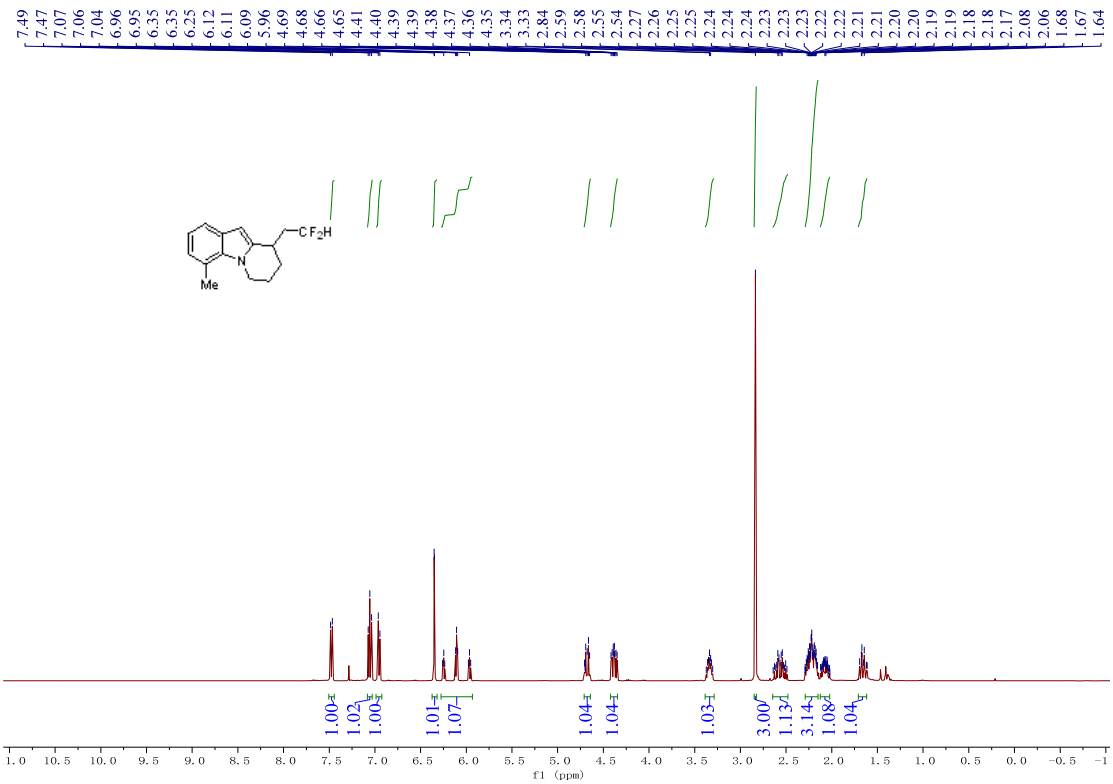
^{13}C NMR of 3r



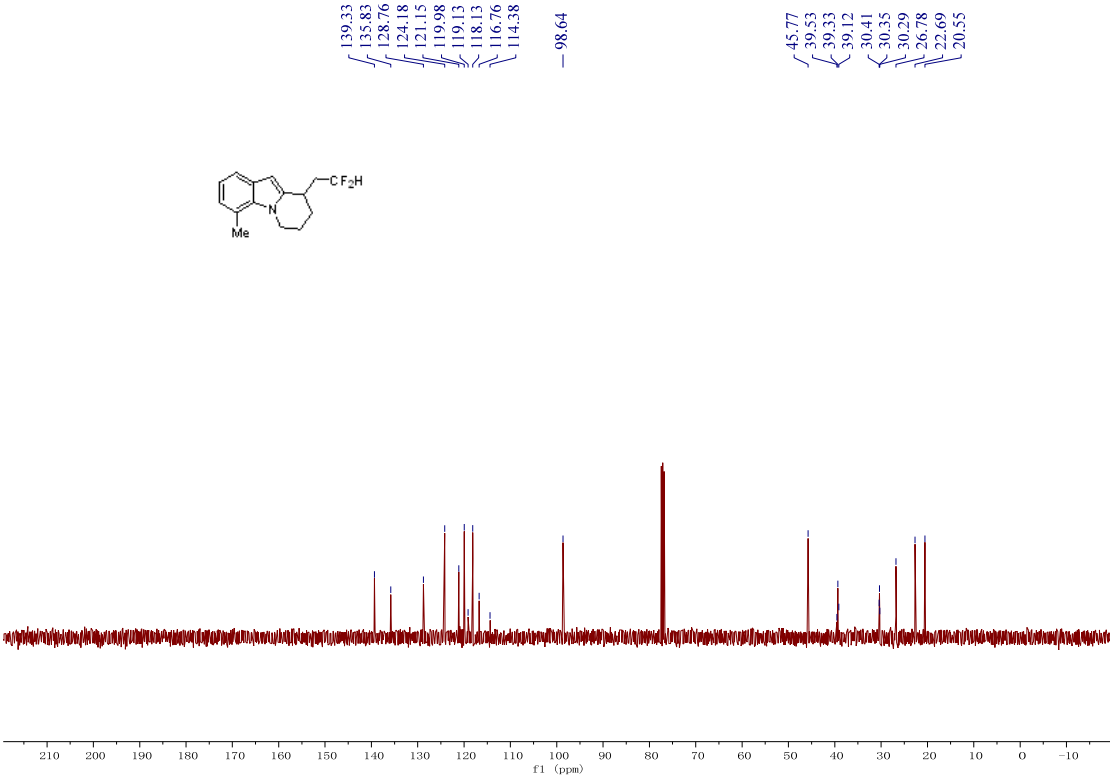
^{19}F NMR of 3r



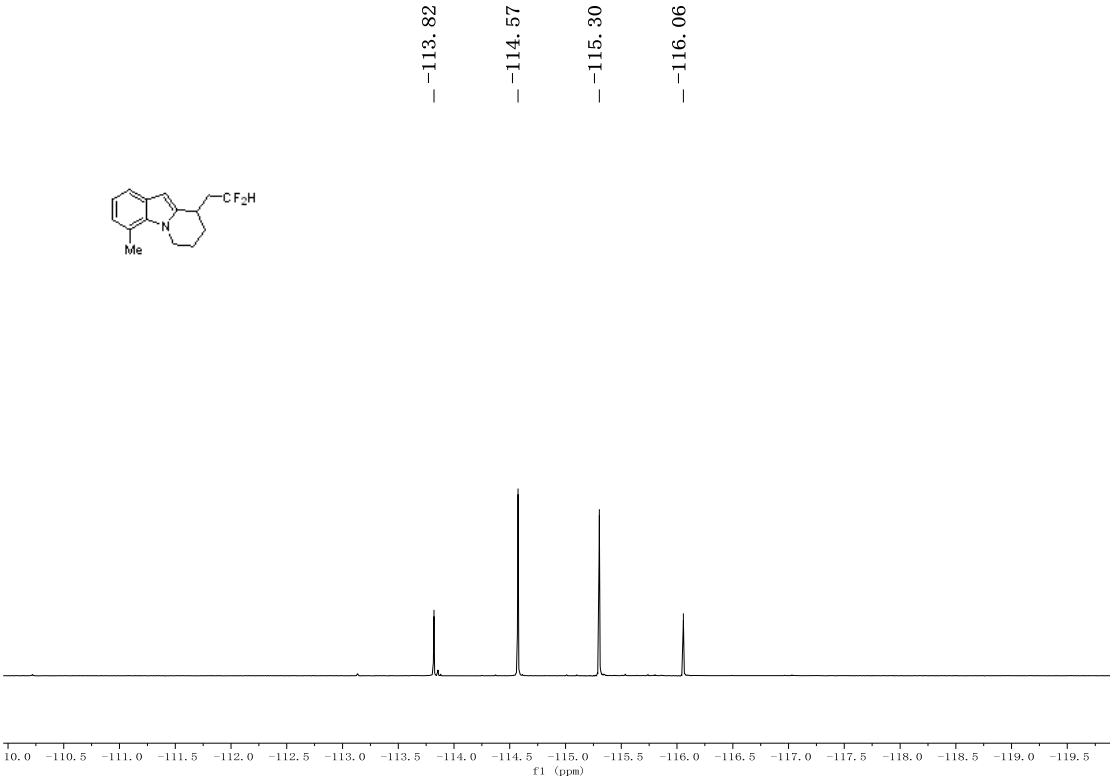
^{1}H NMR of 3s



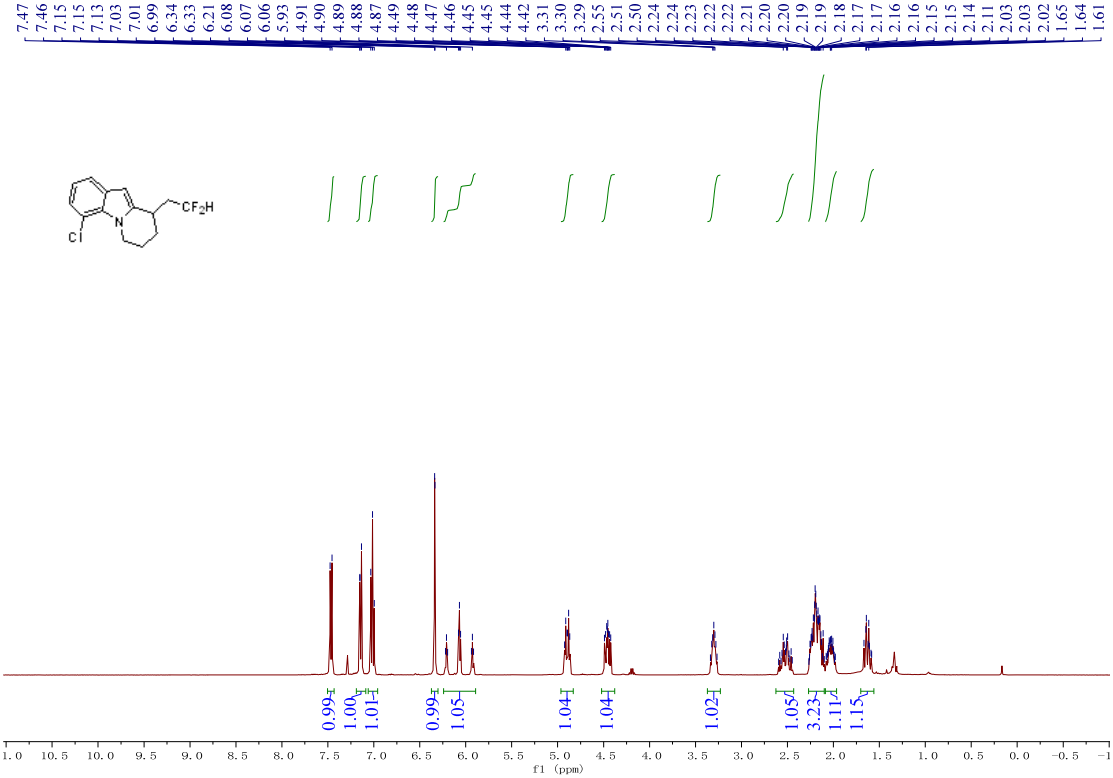
^{13}C NMR of 3s



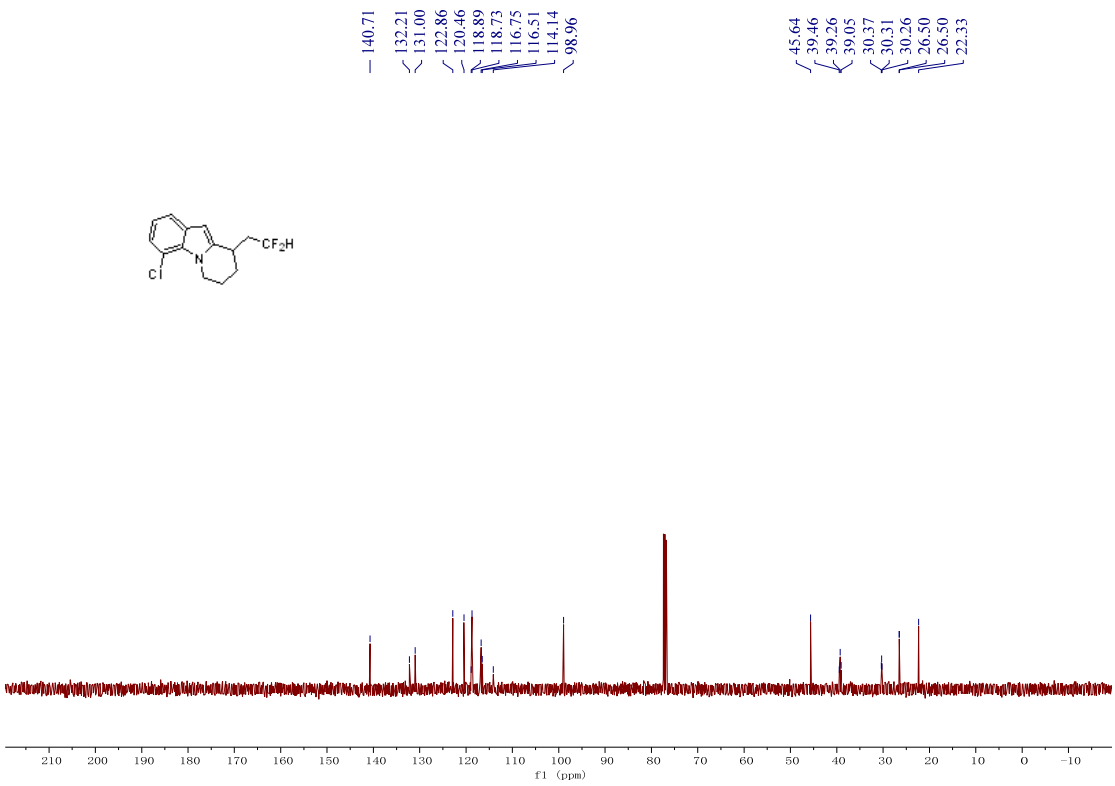
^{19}F NMR of 3s



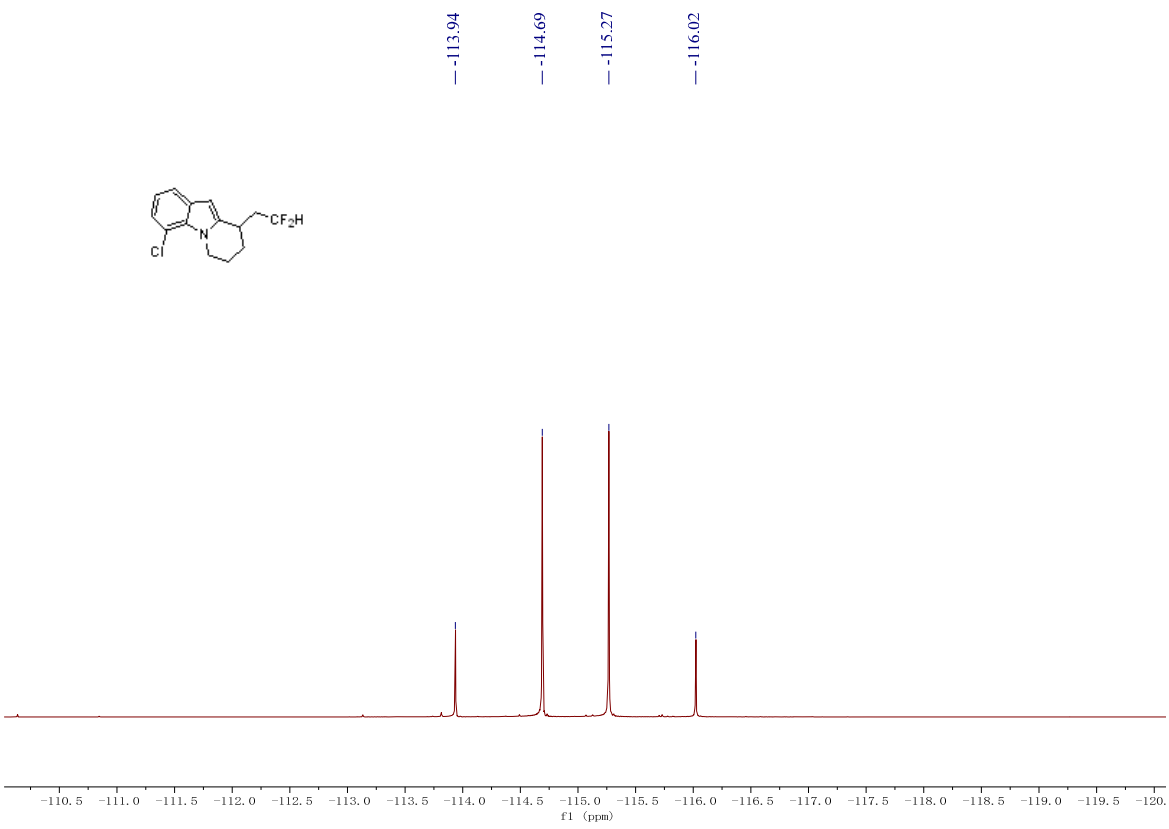
^{1}H NMR of 3t



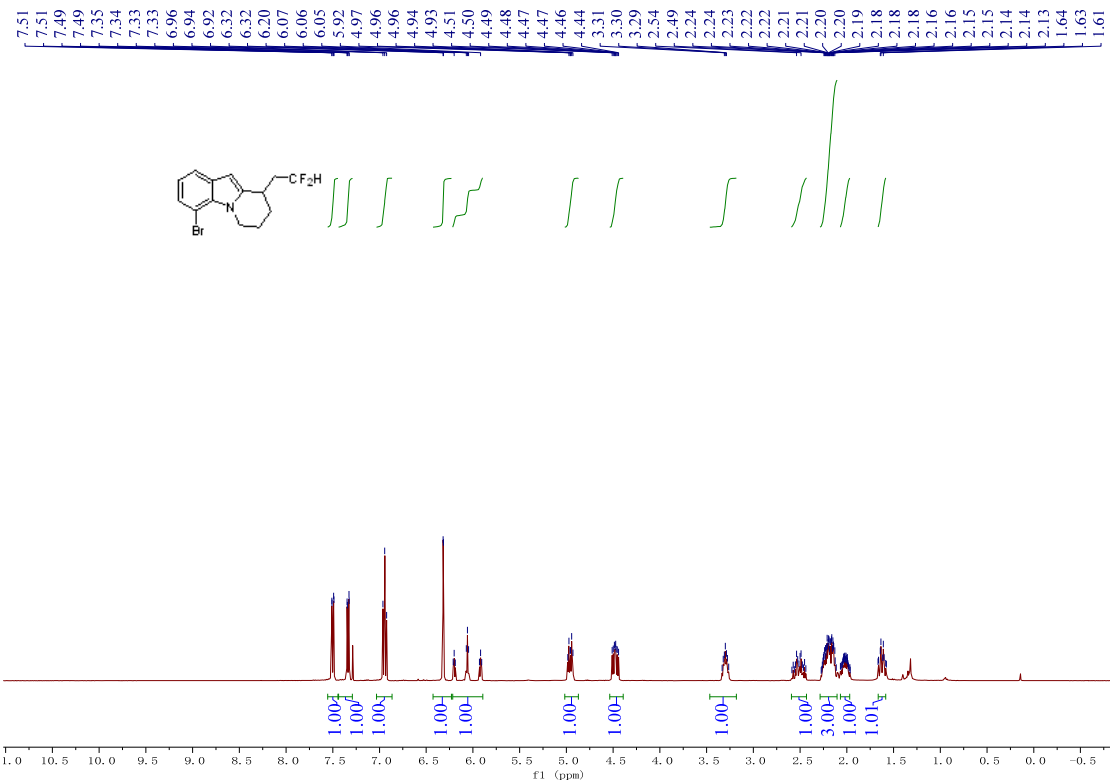
^{13}C NMR of 3t



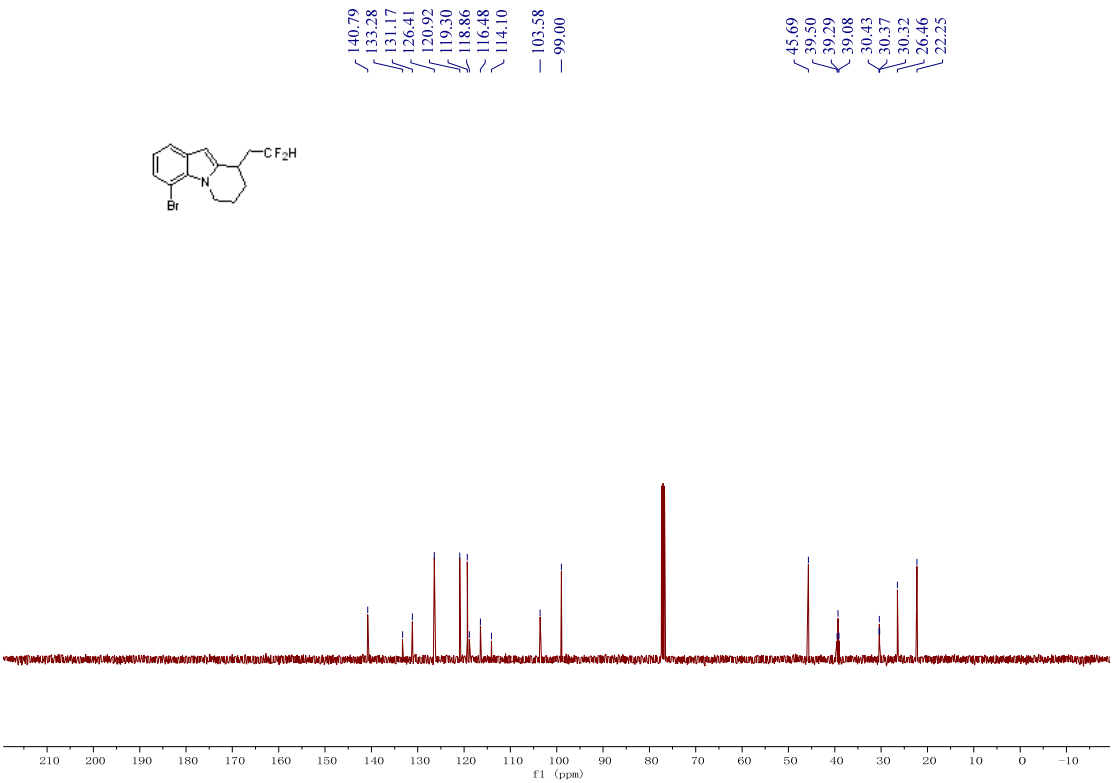
^{19}F NMR of 3t



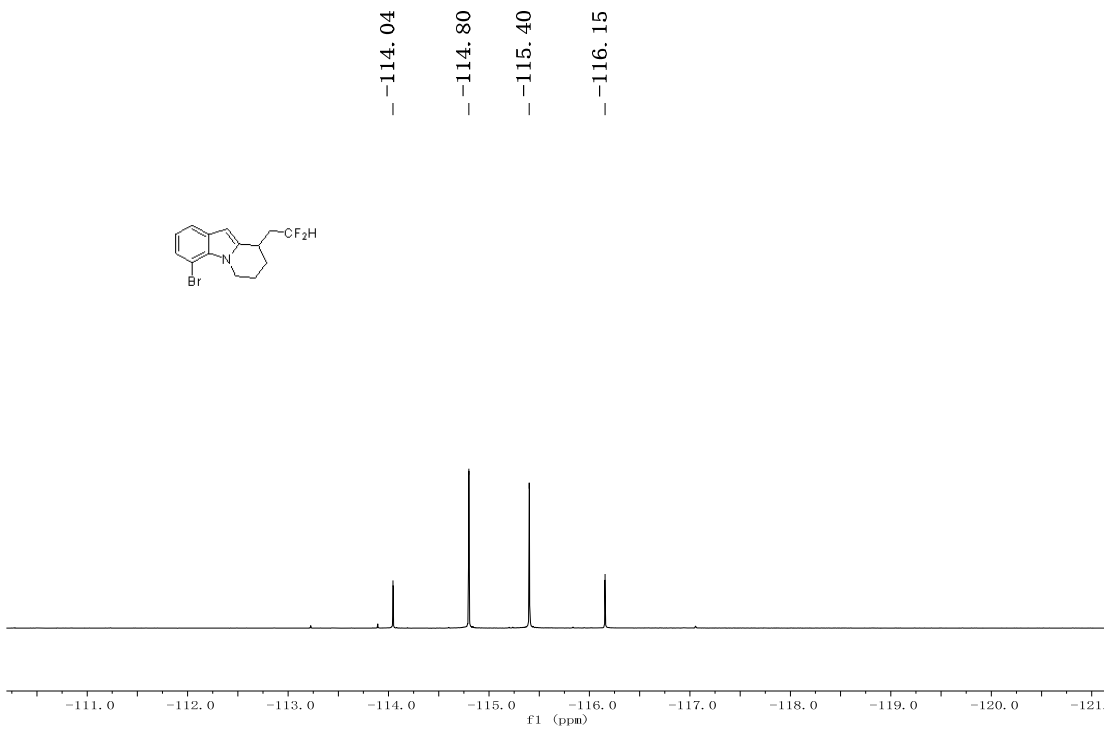
^{1}H NMR of 3u



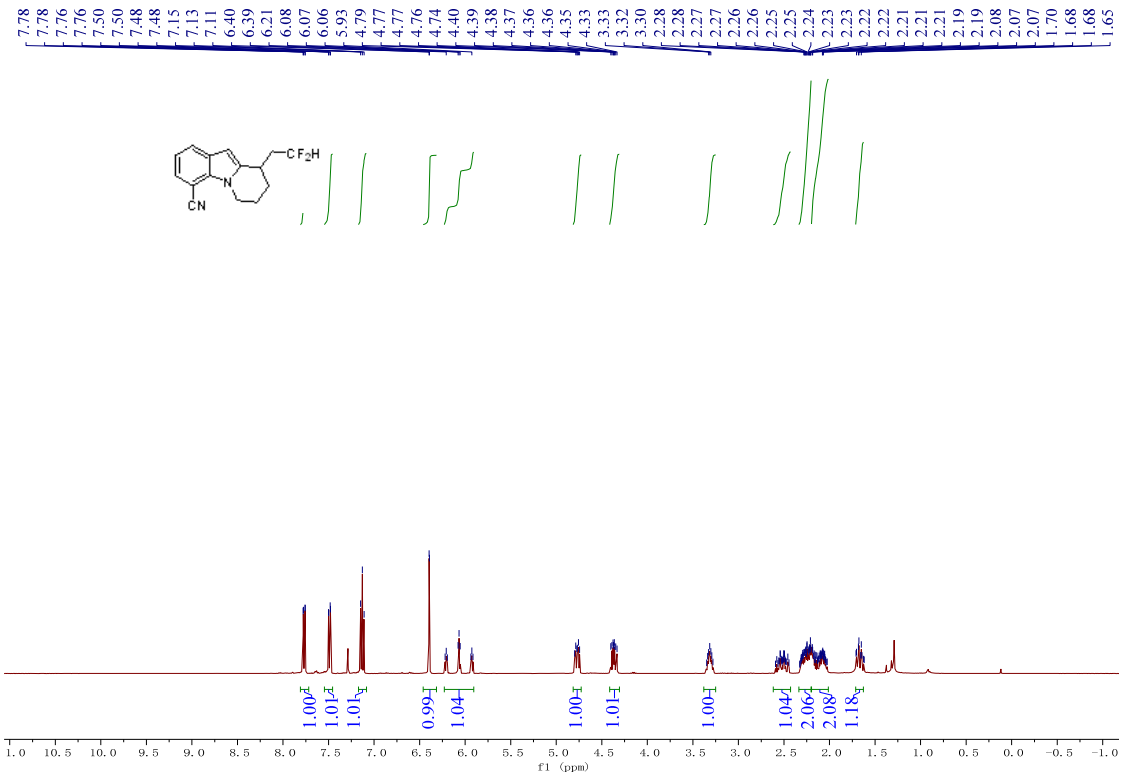
^{13}C NMR of 3u



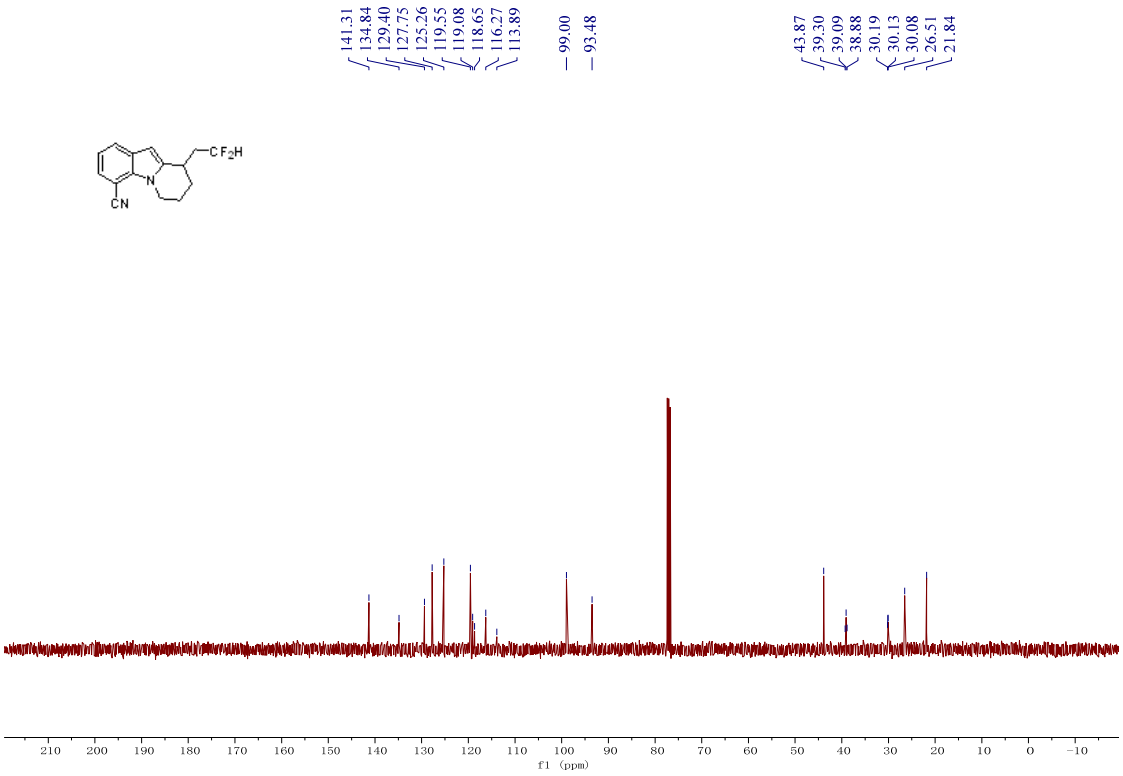
^{19}F NMR of 3u



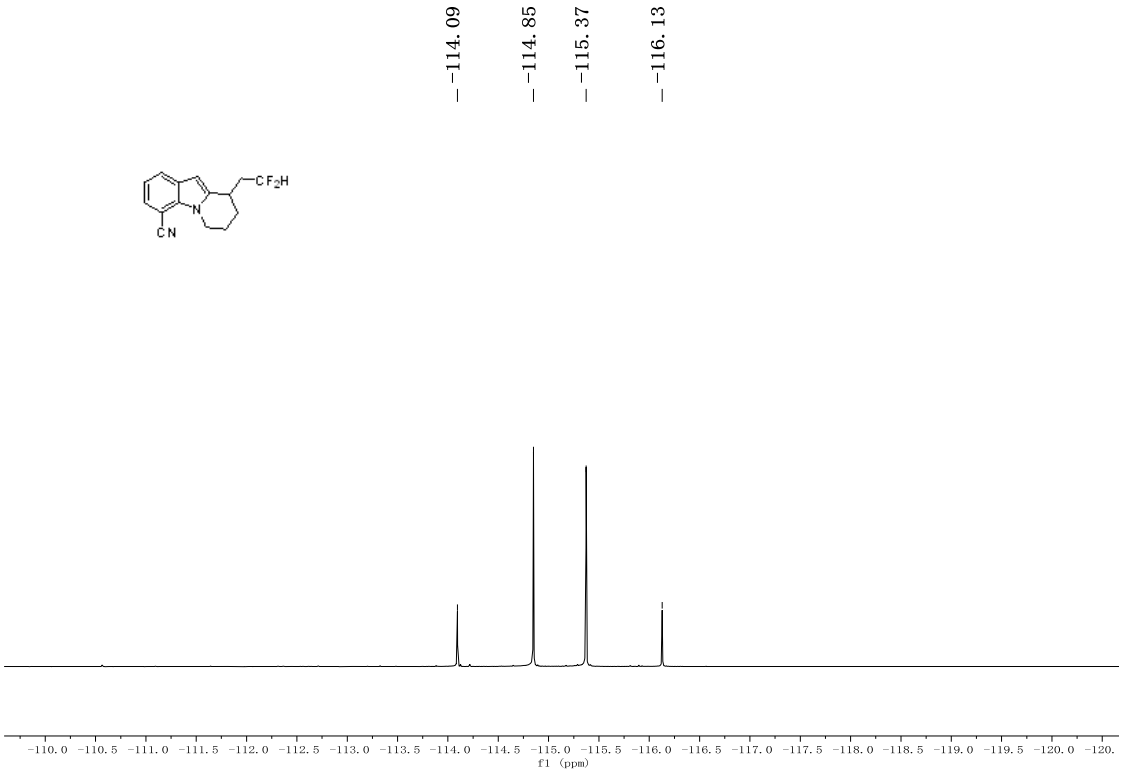
^{1}H NMR of 3v



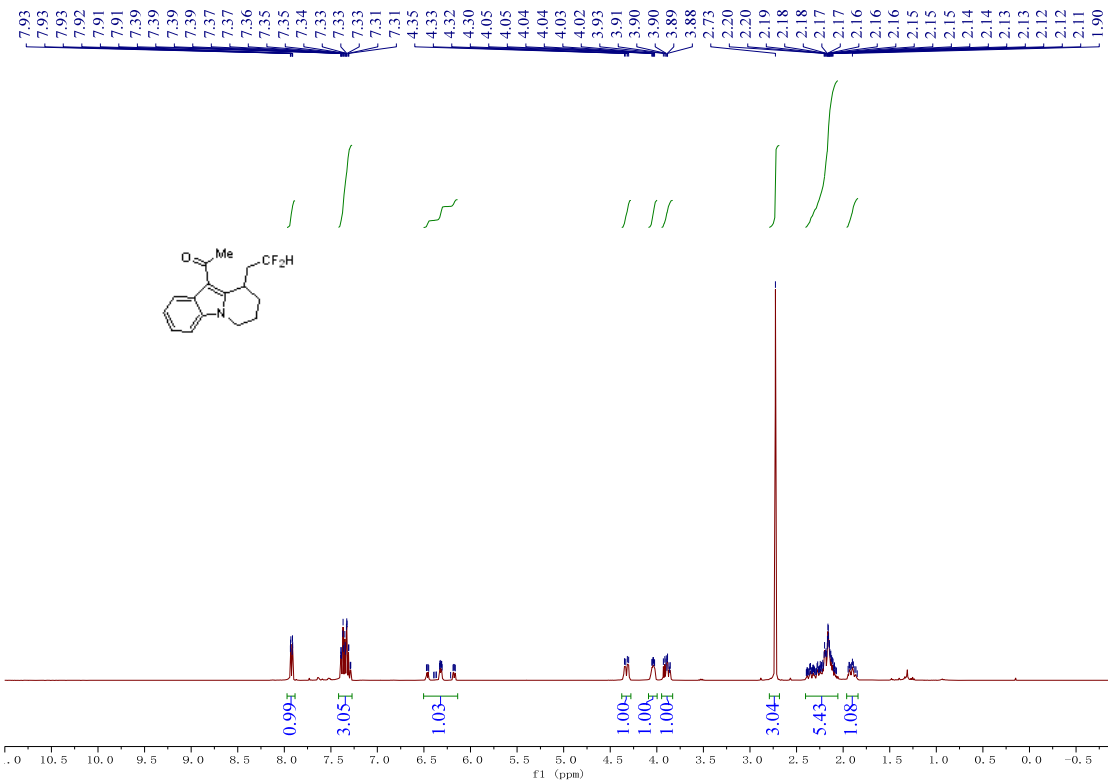
^{13}C NMR of 3v



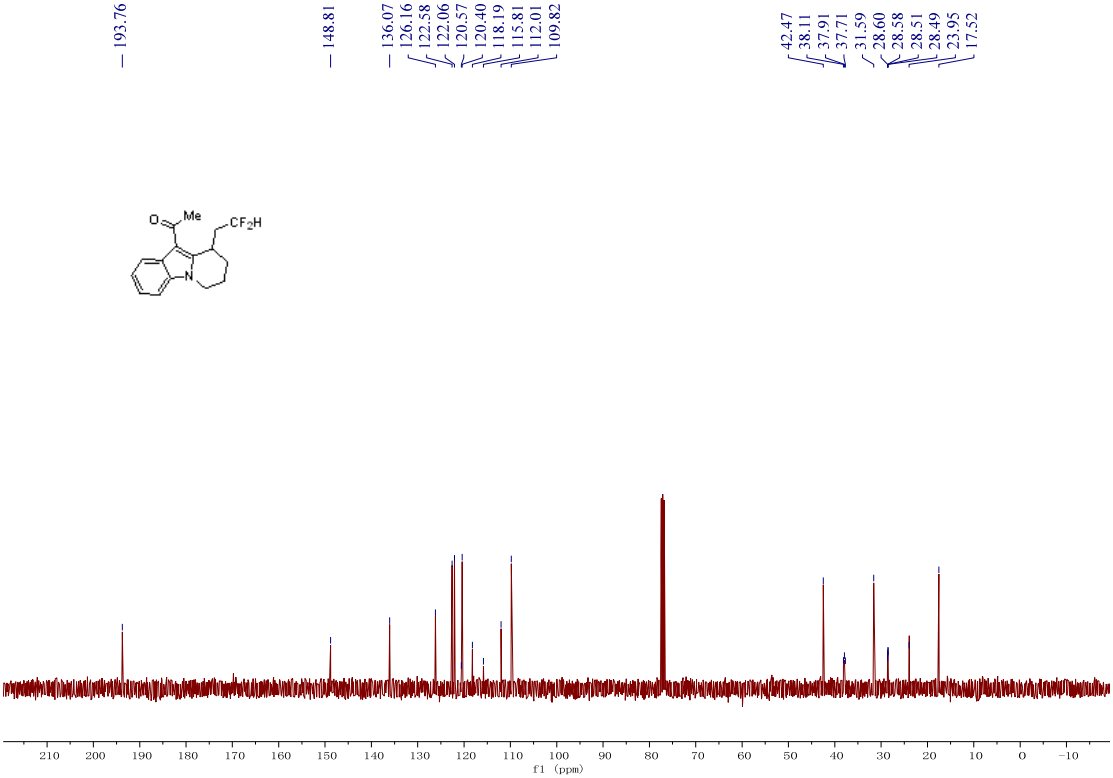
^{19}F NMR of 3v



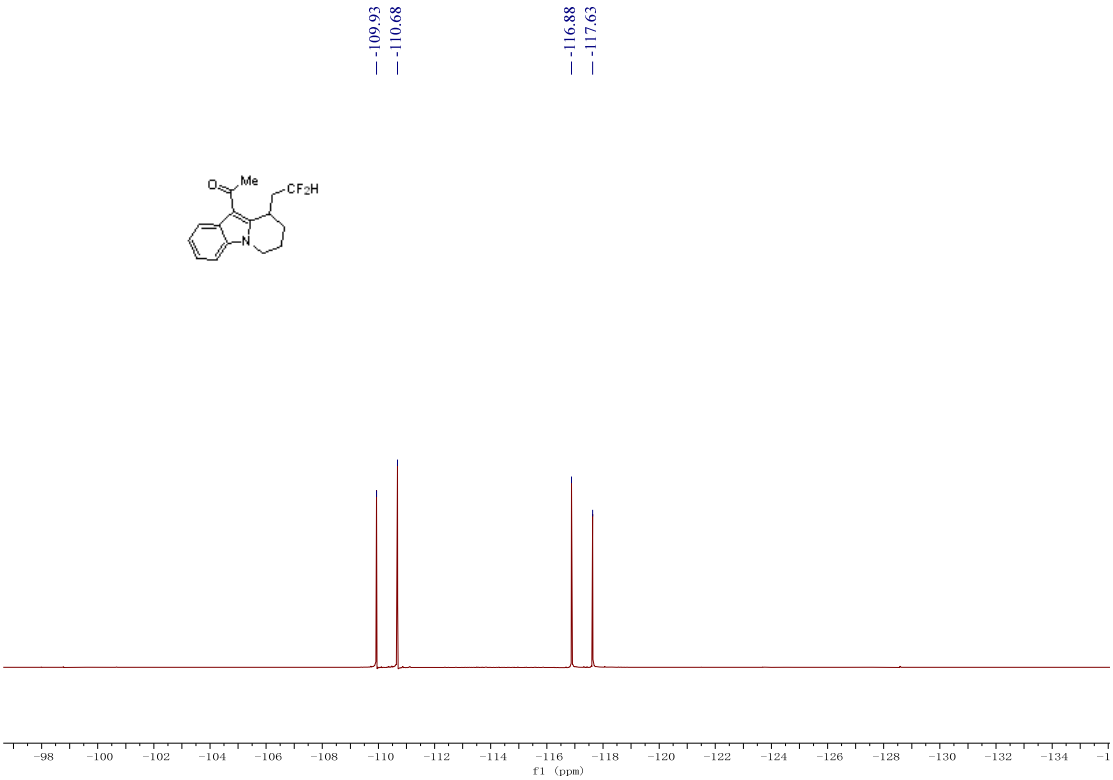
^{1}H NMR of 3w



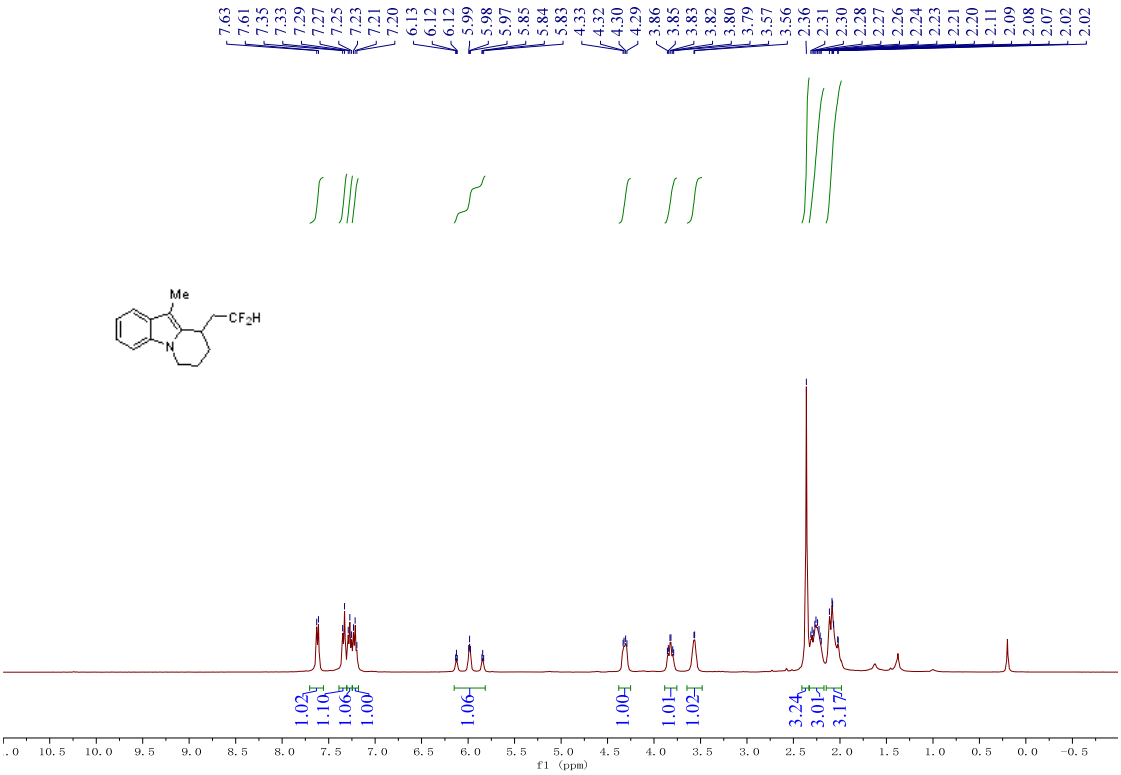
^{13}C NMR of 3w



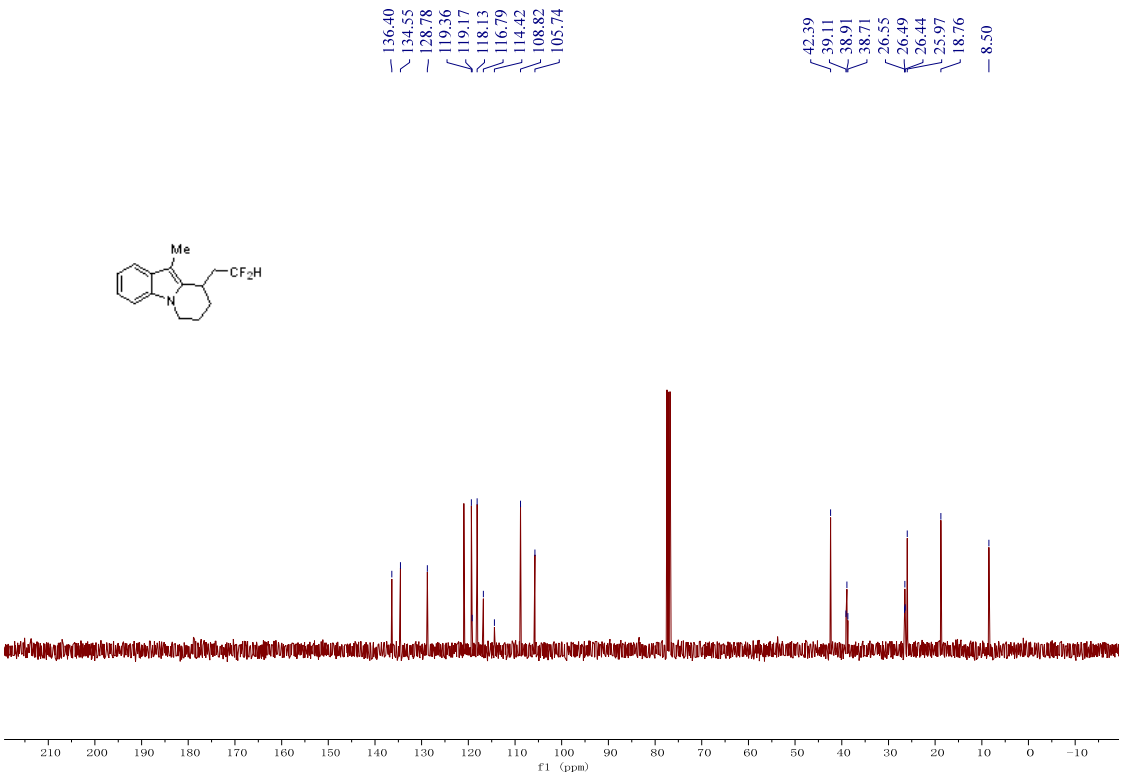
^{19}F NMR of 3w



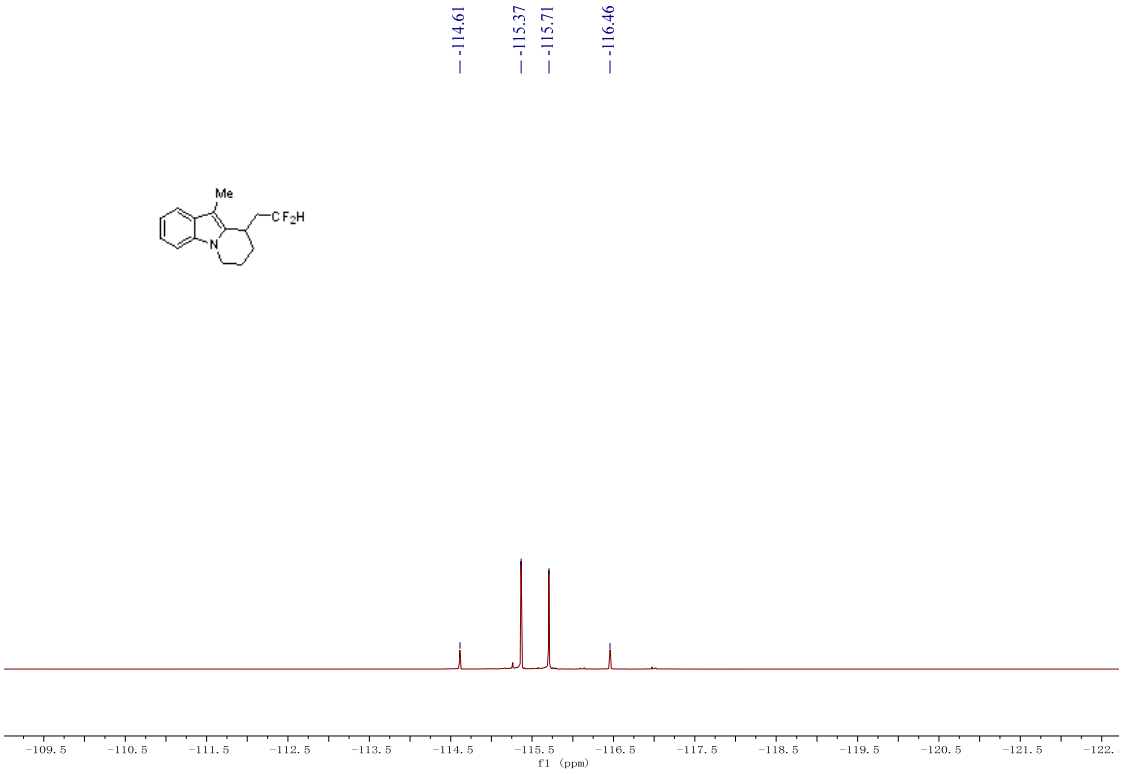
^{1}H NMR of 3x



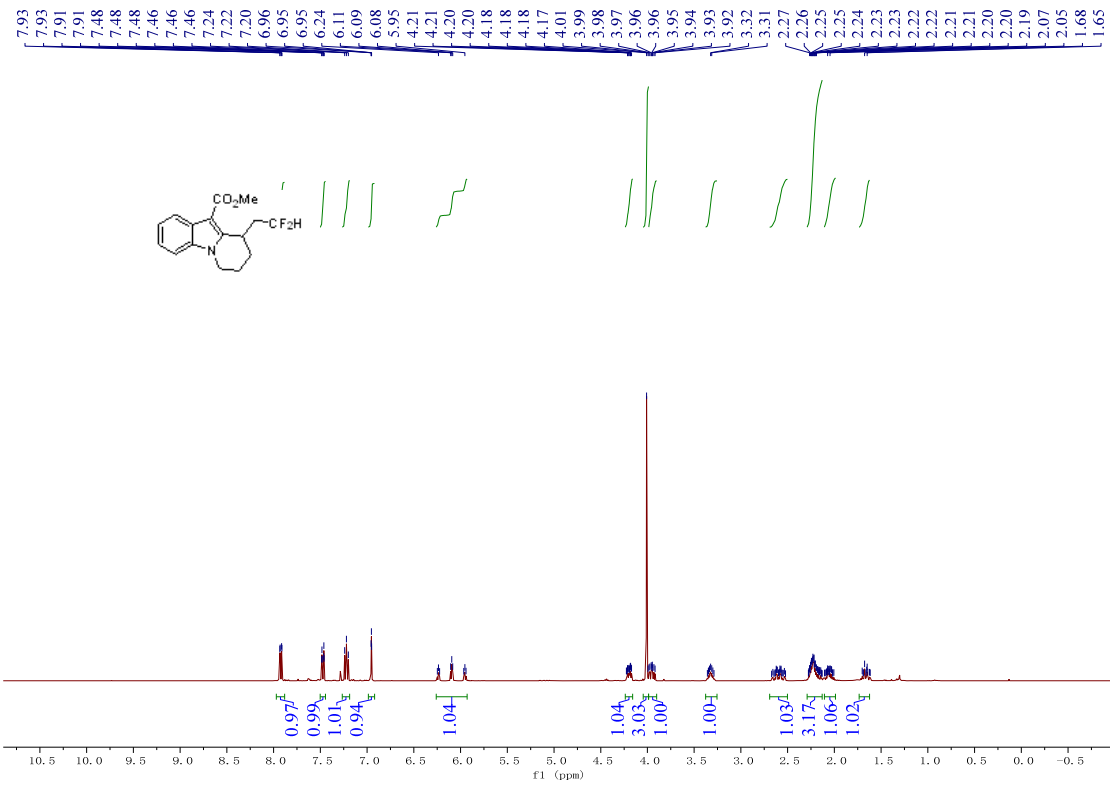
^{13}C NMR of 3x



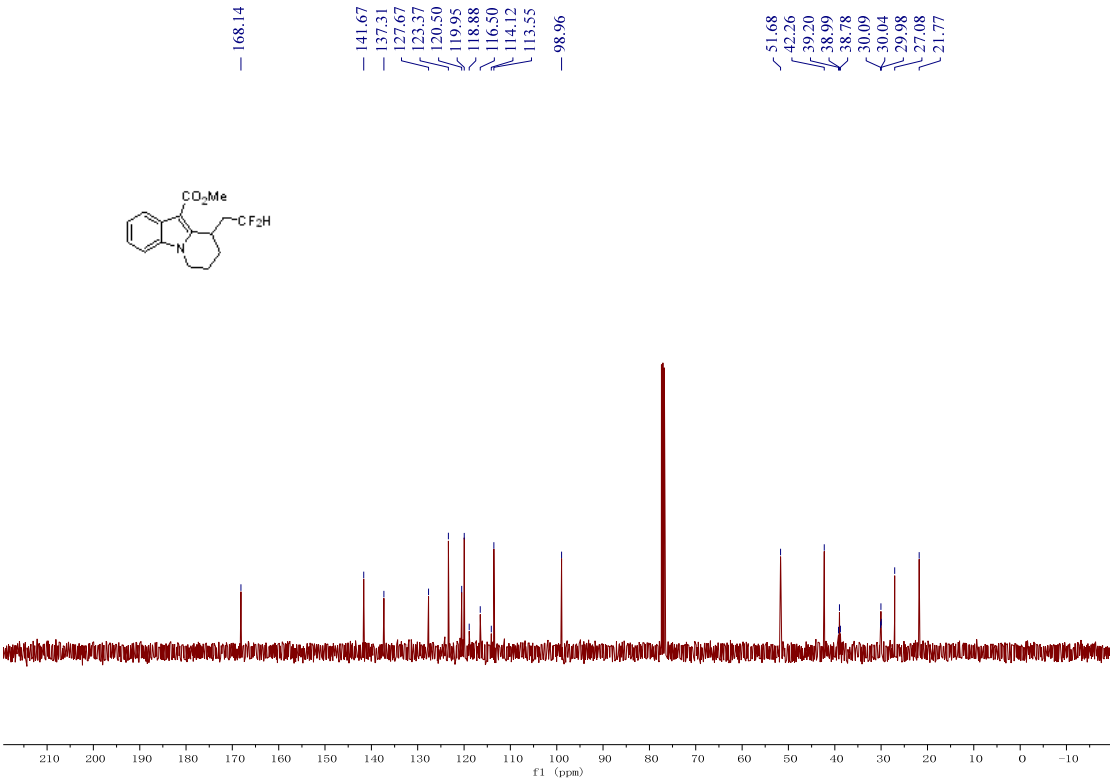
^{19}F NMR of 3x



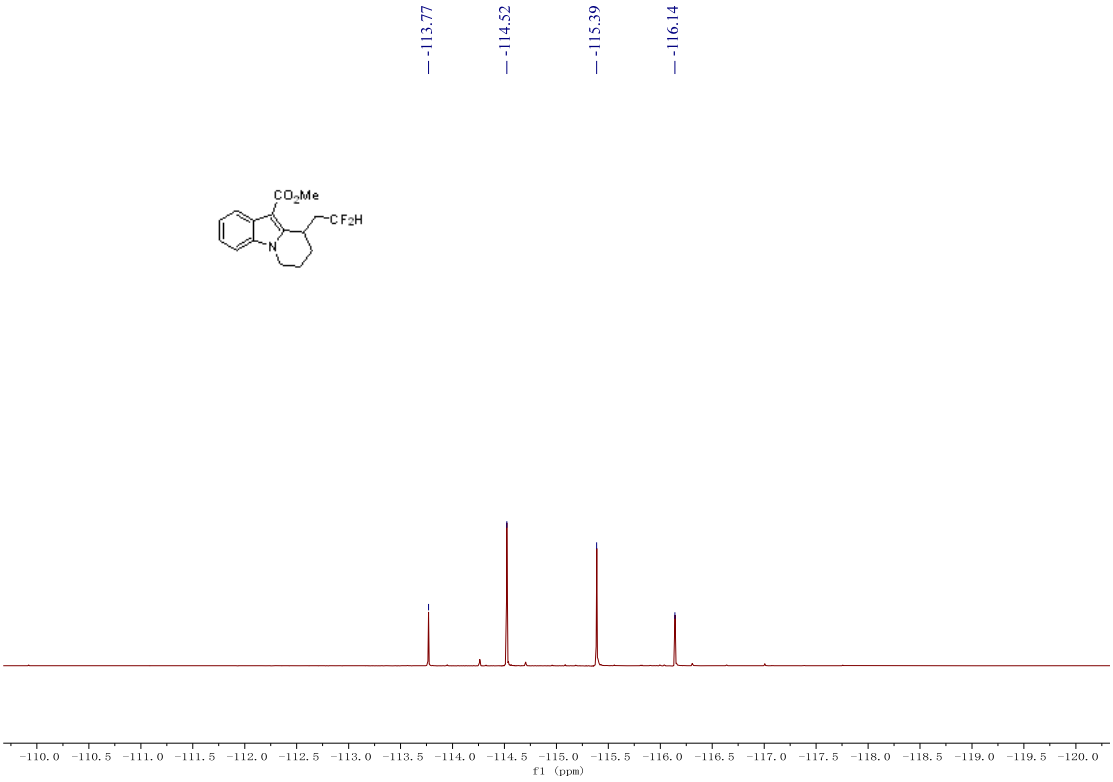
^{1}H NMR of 3y



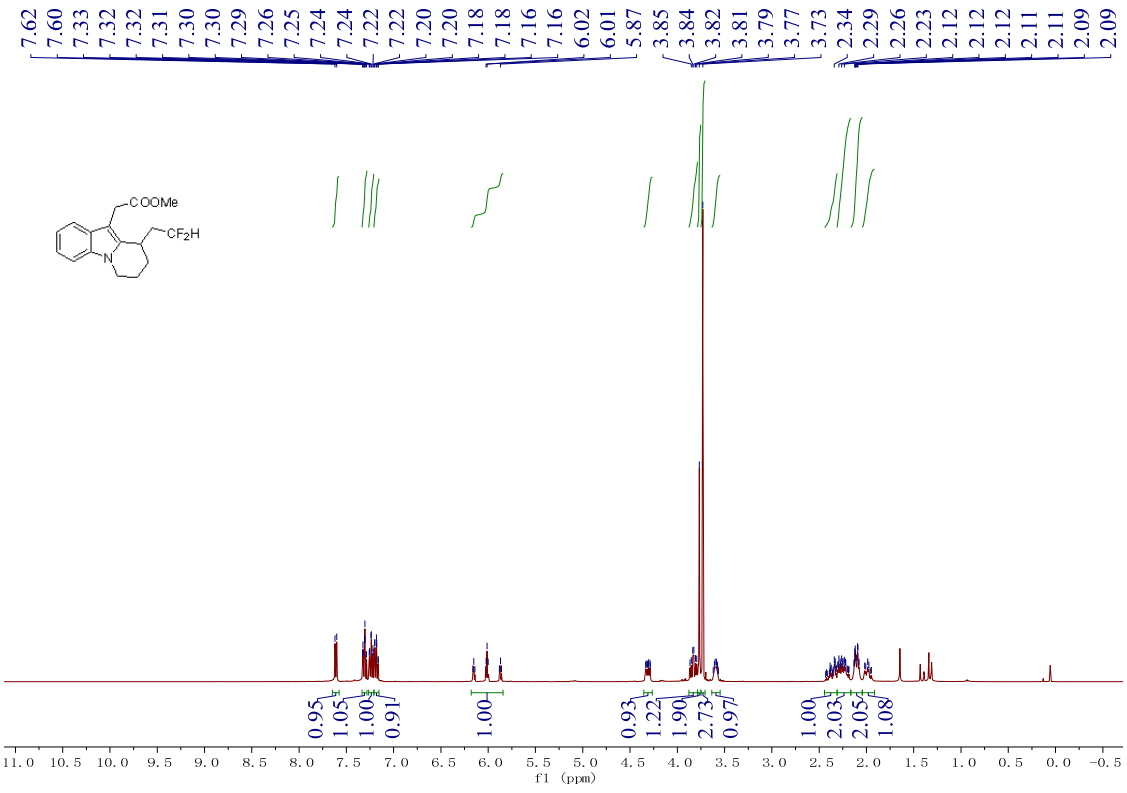
^{13}C NMR of 3y



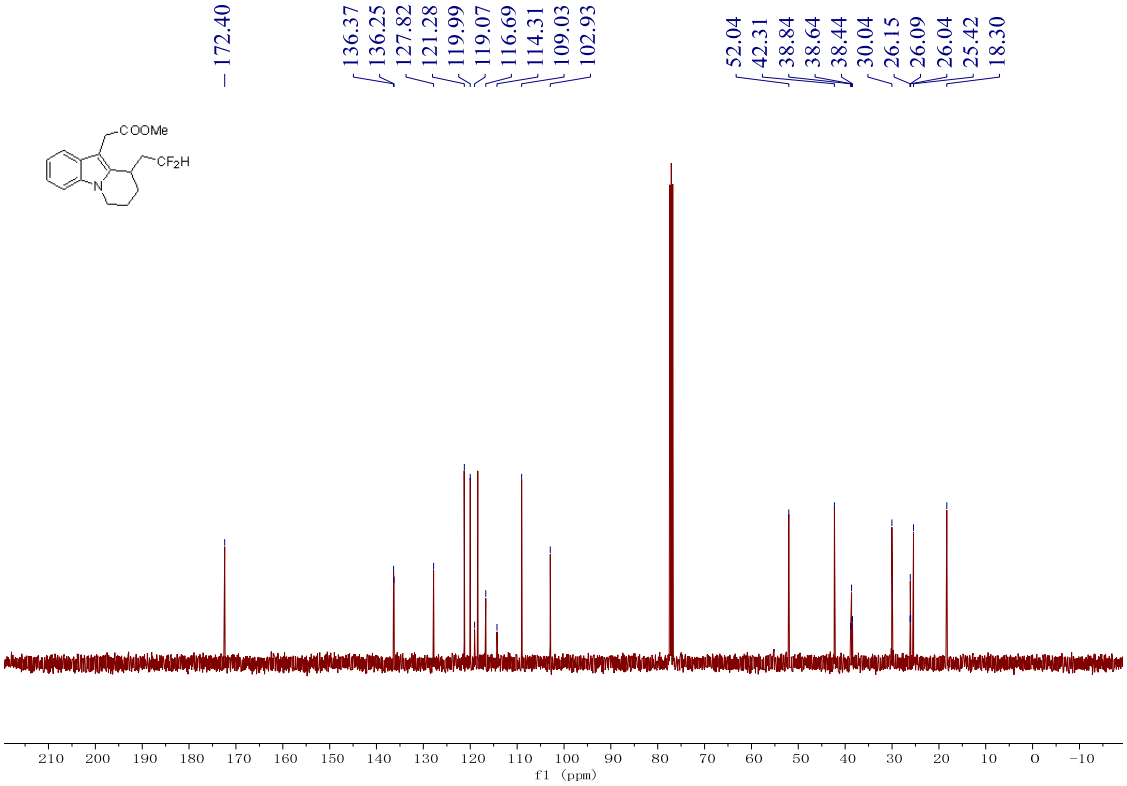
^{19}F NMR of 3y



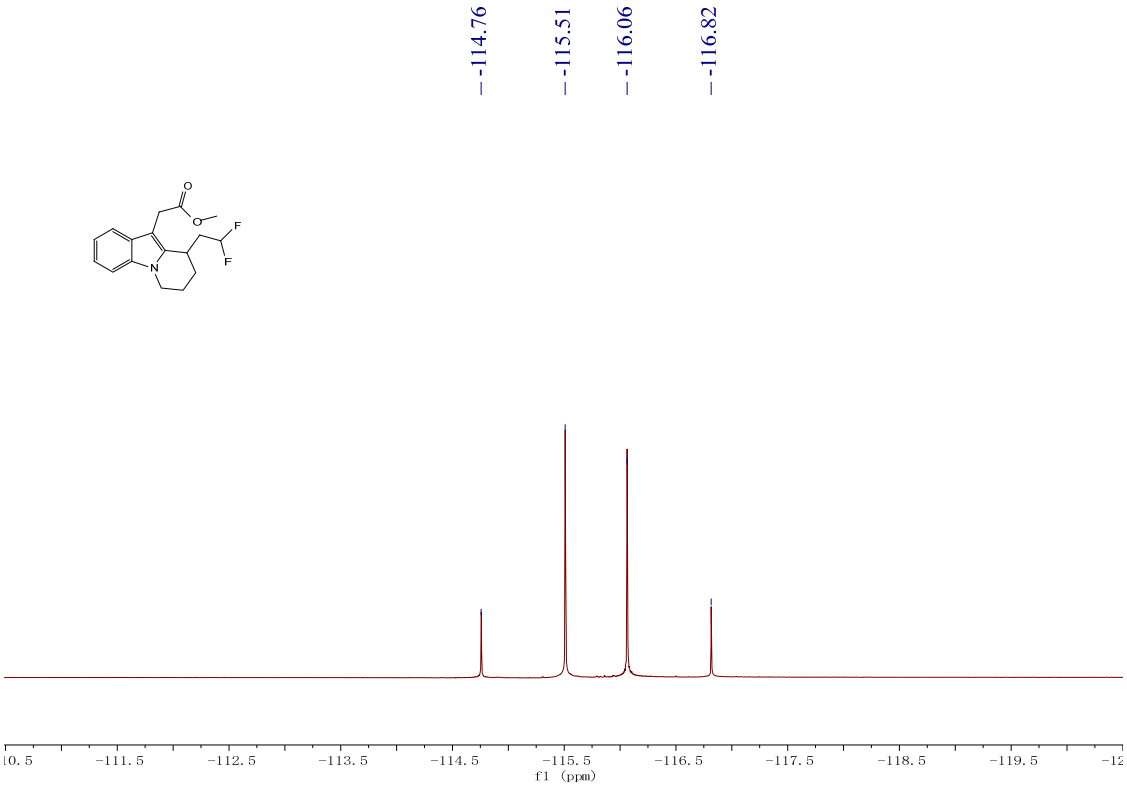
^{1}H NMR of 3z



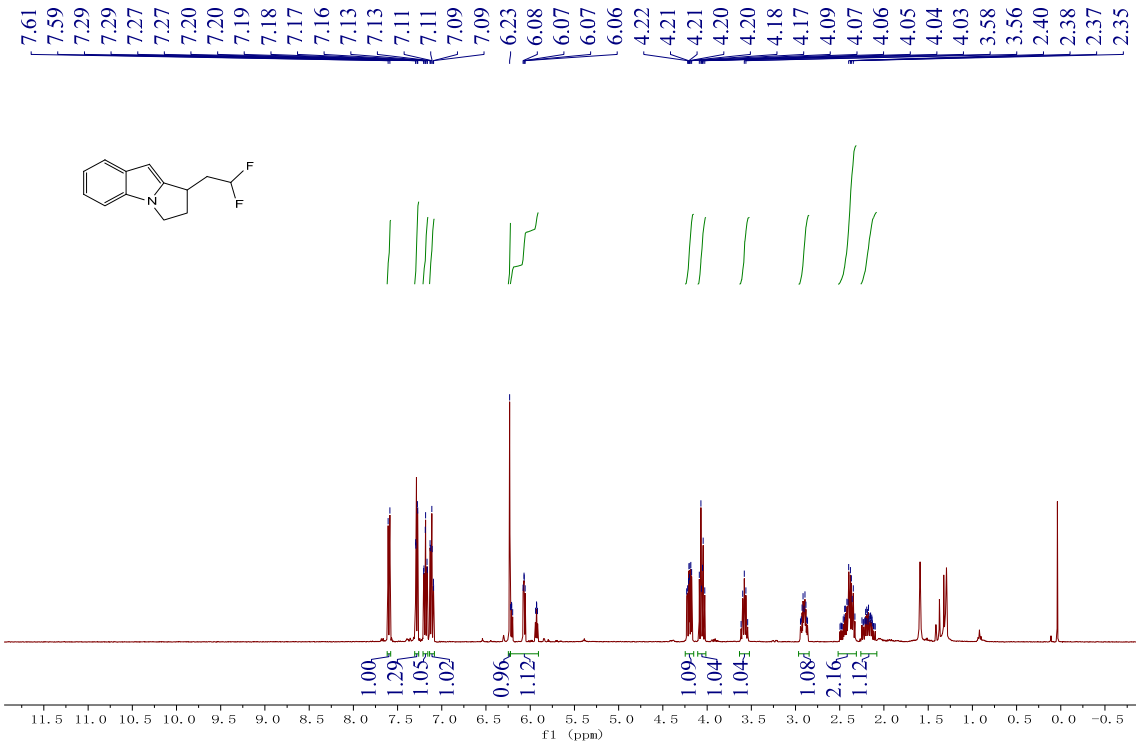
^{13}C NMR of 3z



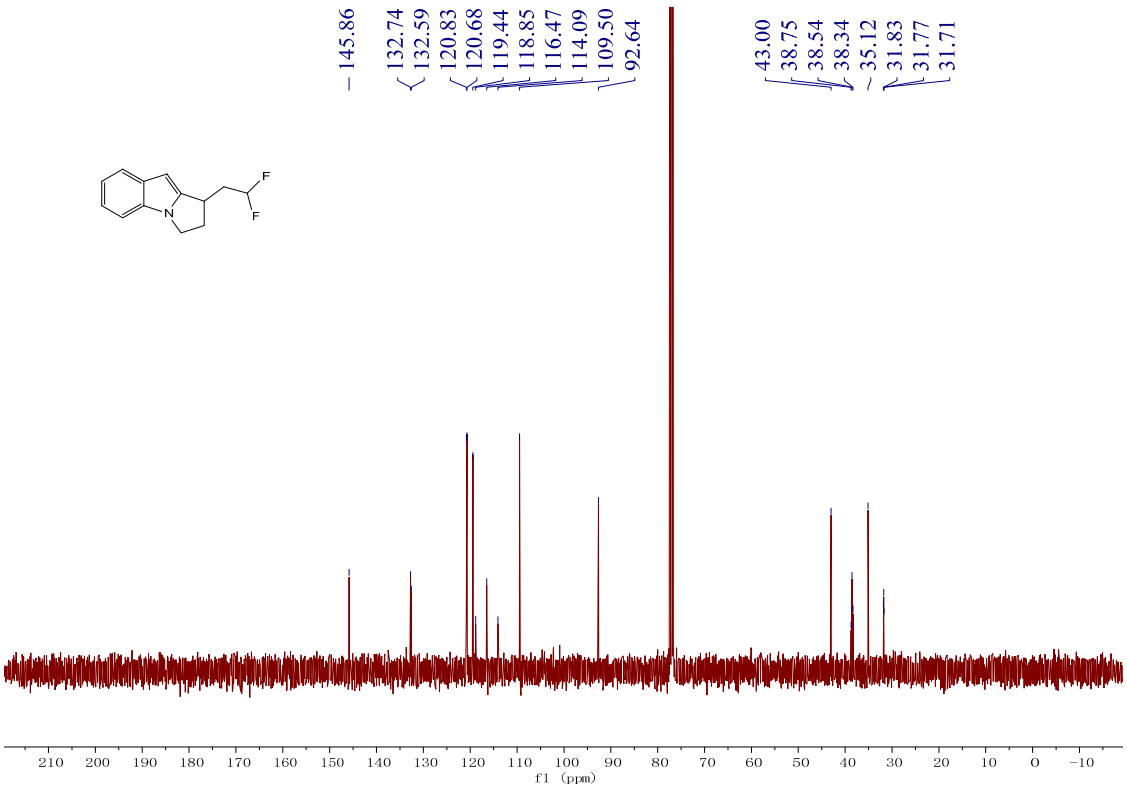
^{19}F NMR of 3z



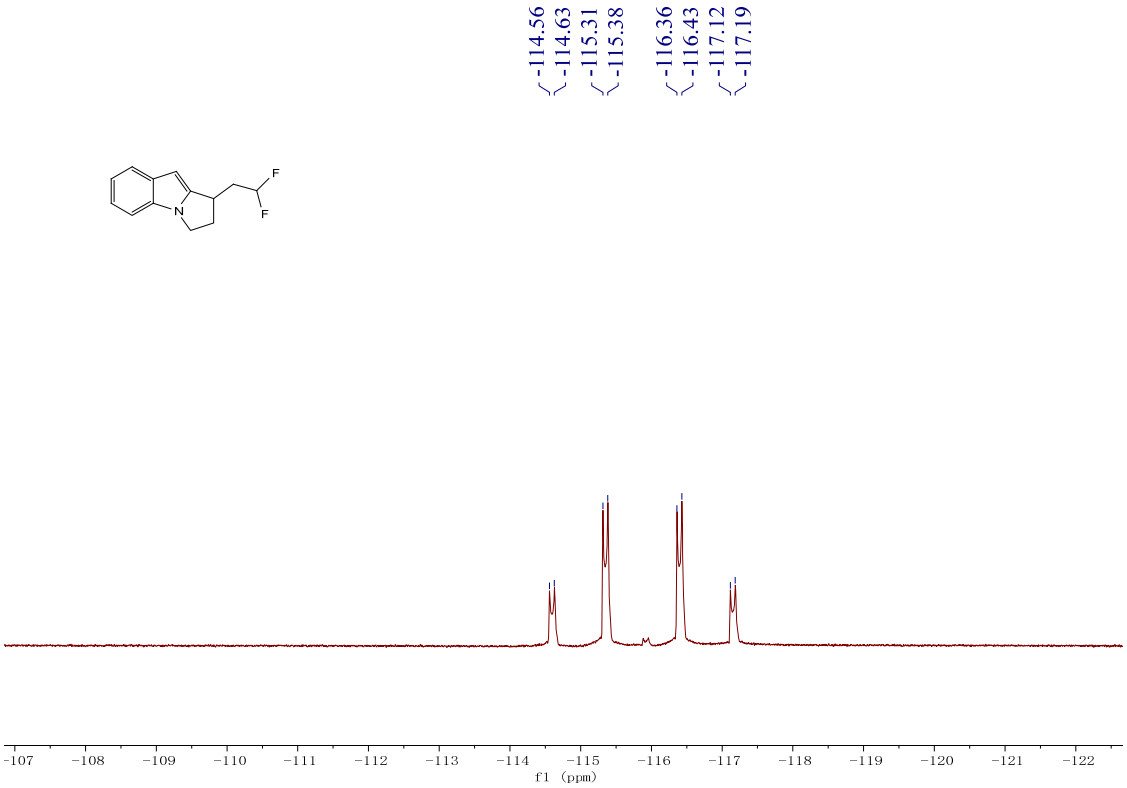
^{1}H NMR of 3aa



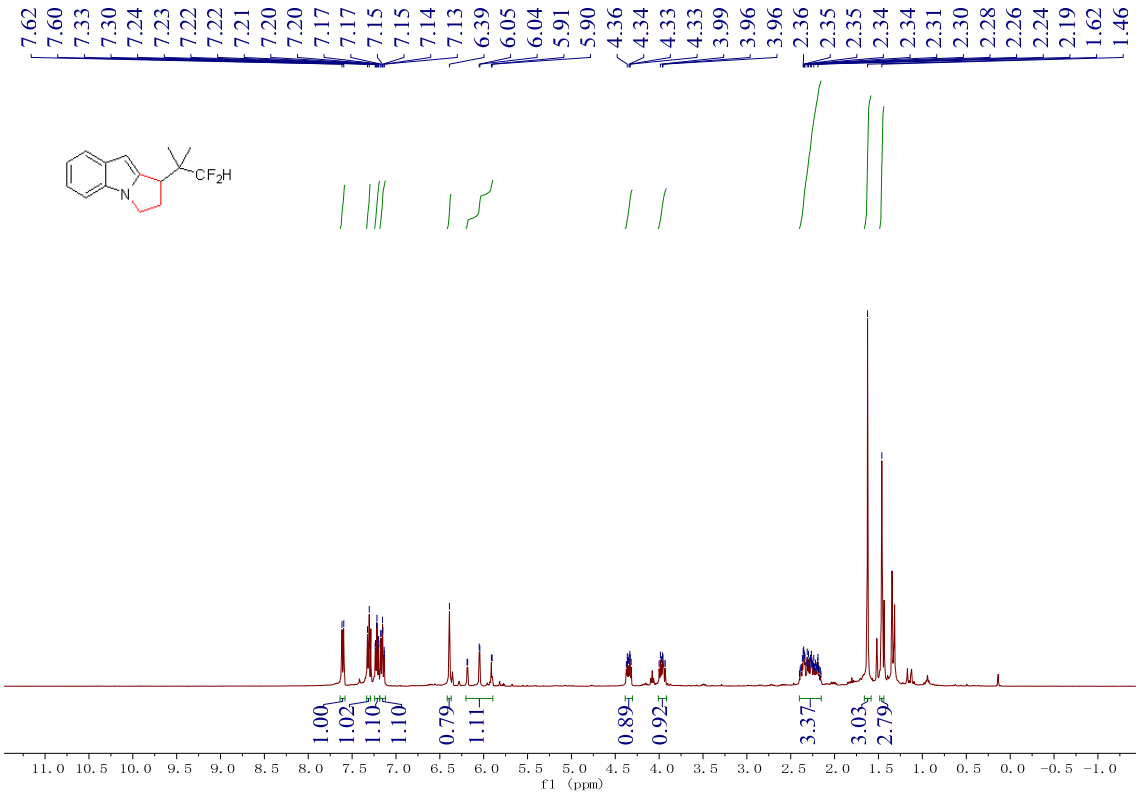
^{13}C NMR of 3aa



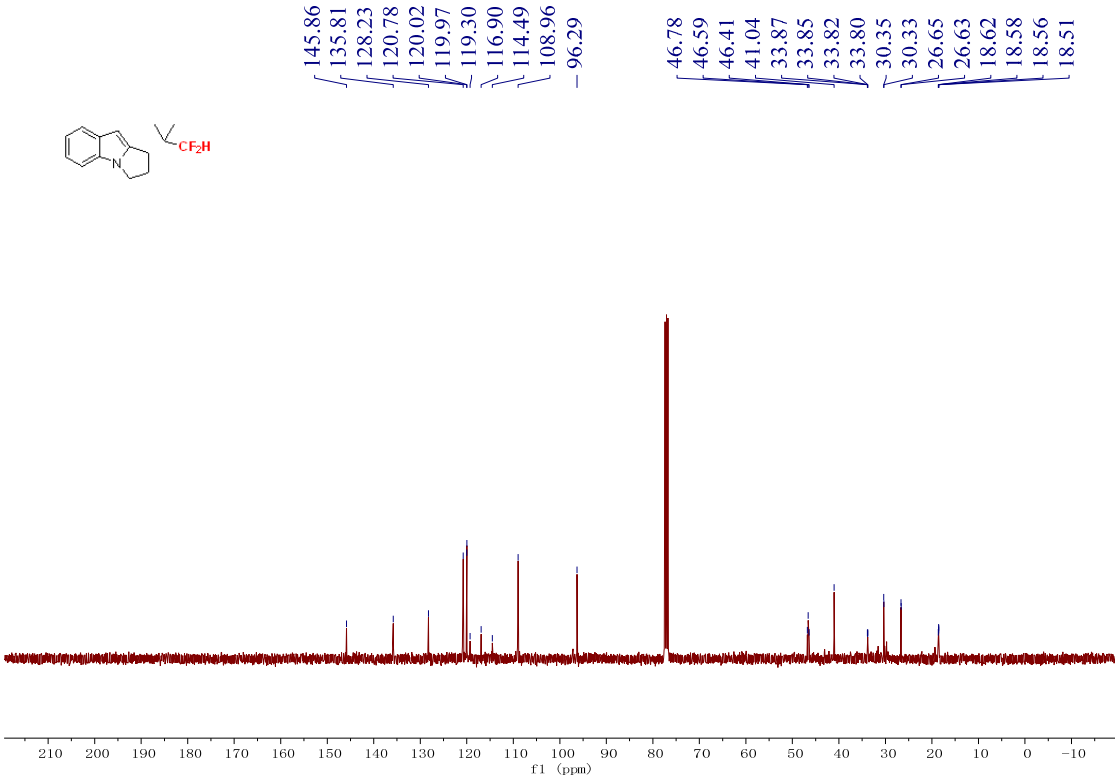
^{19}F NMR of 3aa



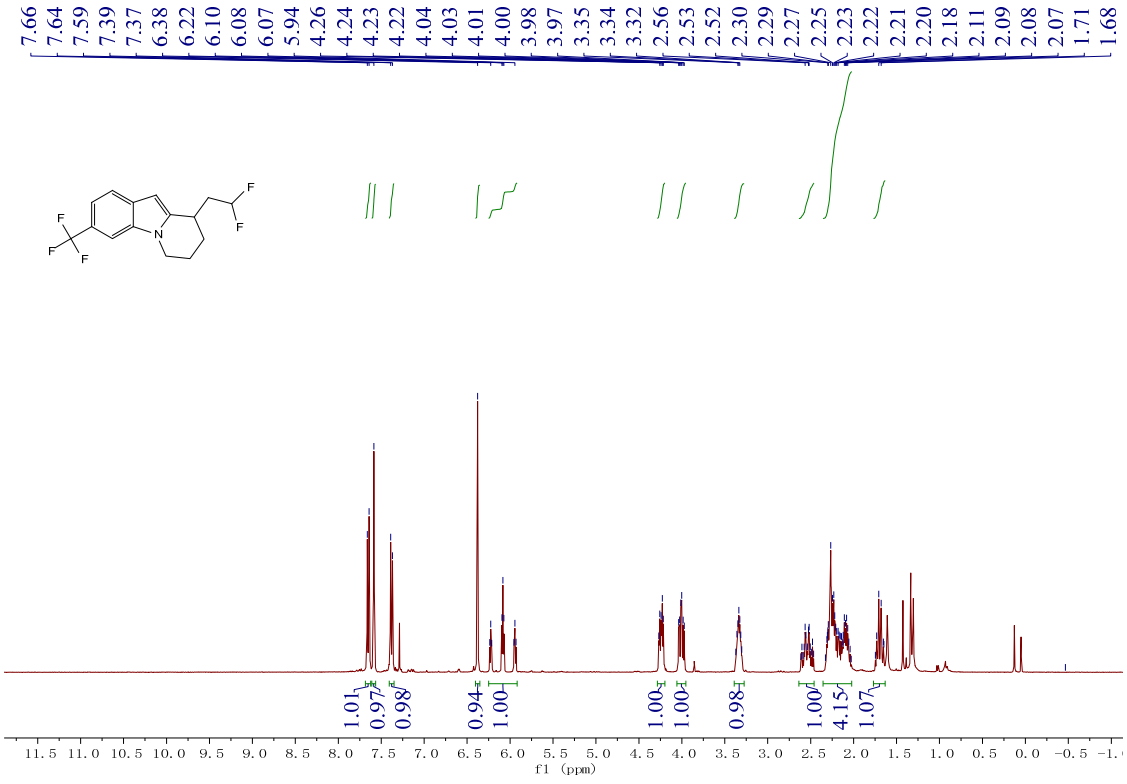
^{1}H NMR of 3ab



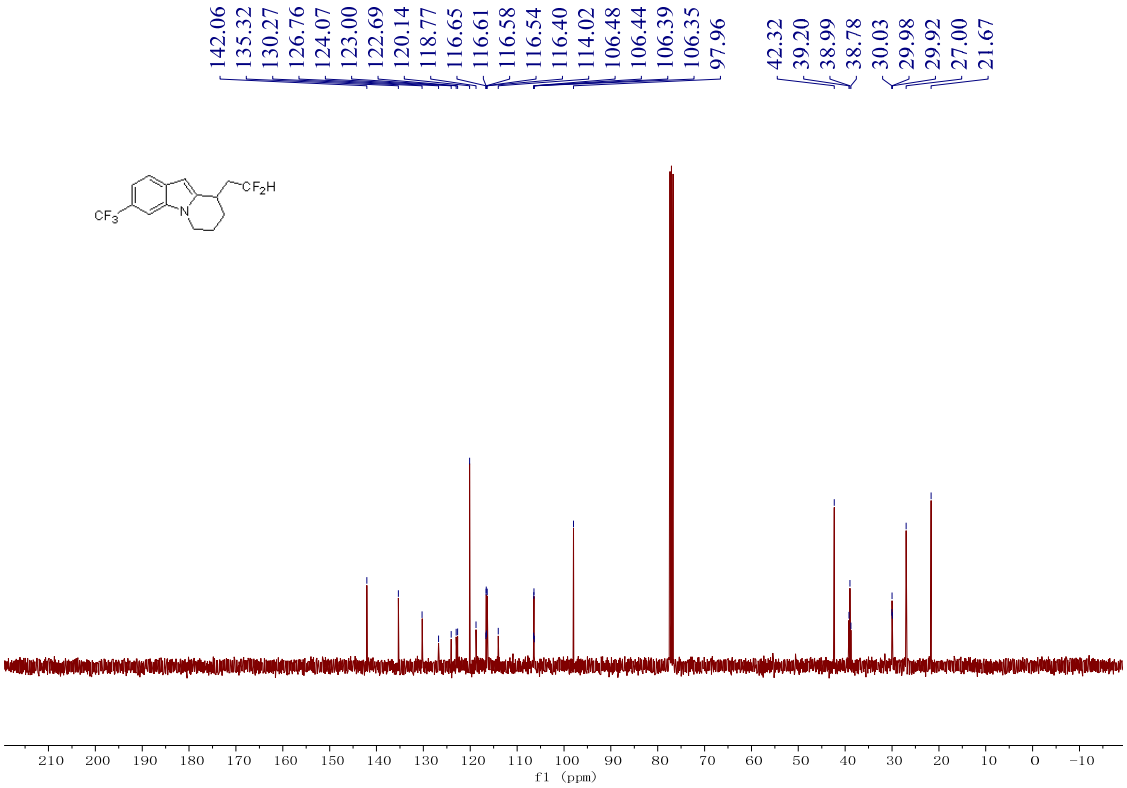
^{13}C NMR of 3ab



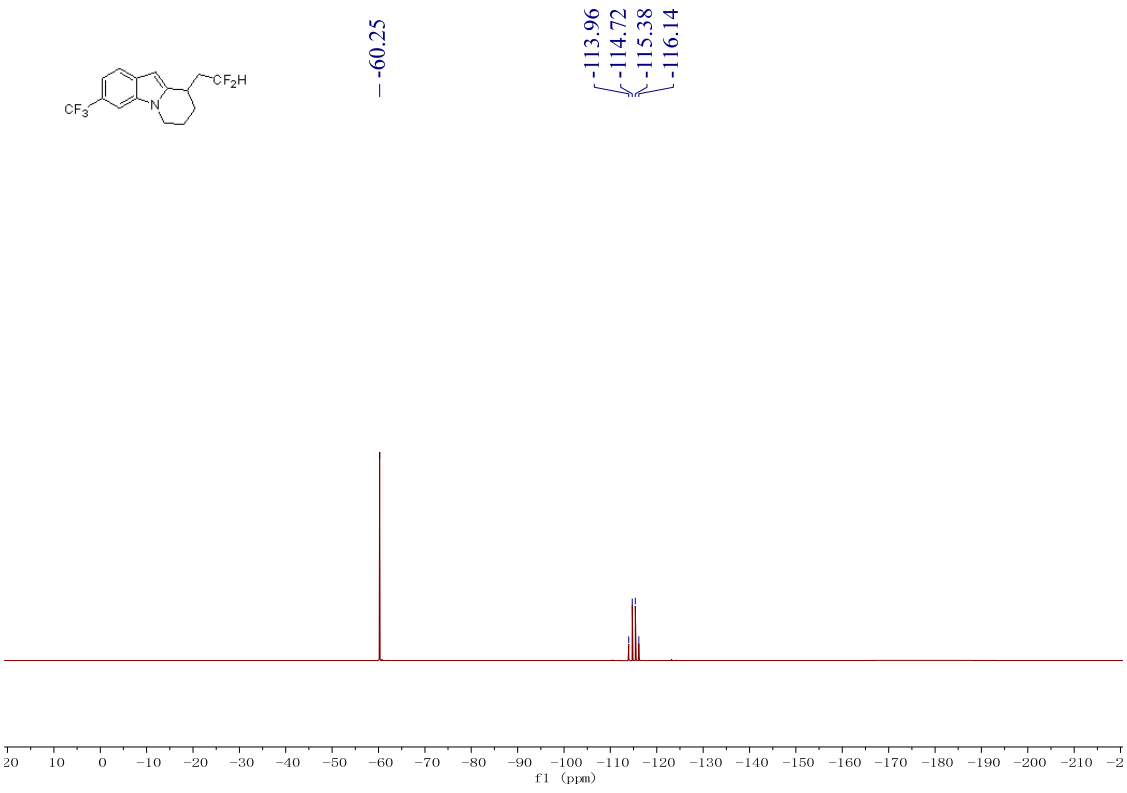
^{1}H NMR of 3ae



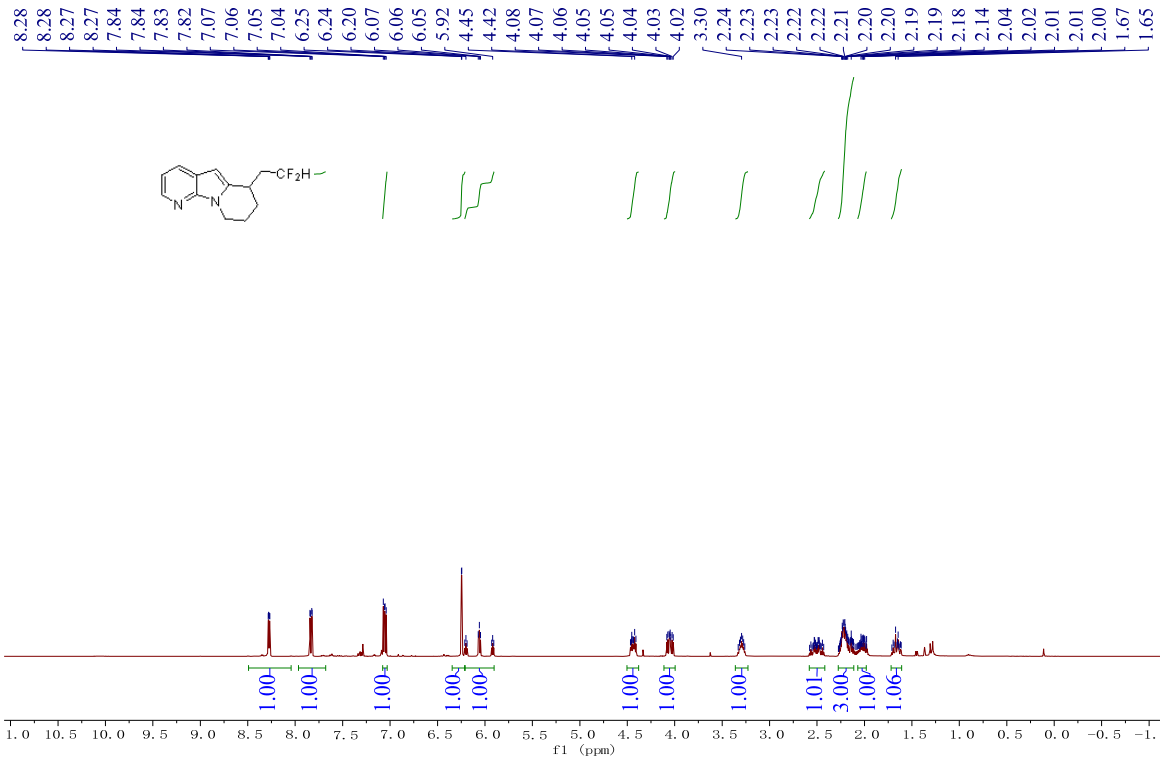
^{13}C NMR of 3ae



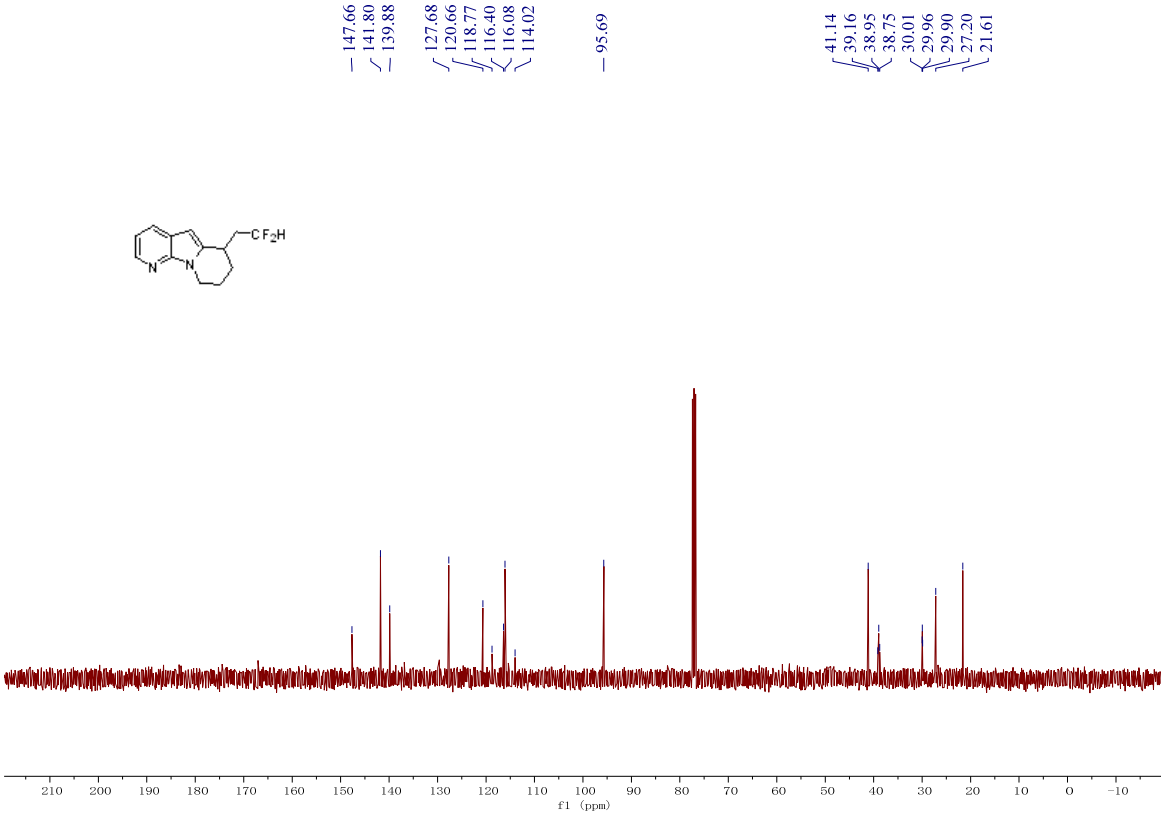
^{19}F NMR of 3ae



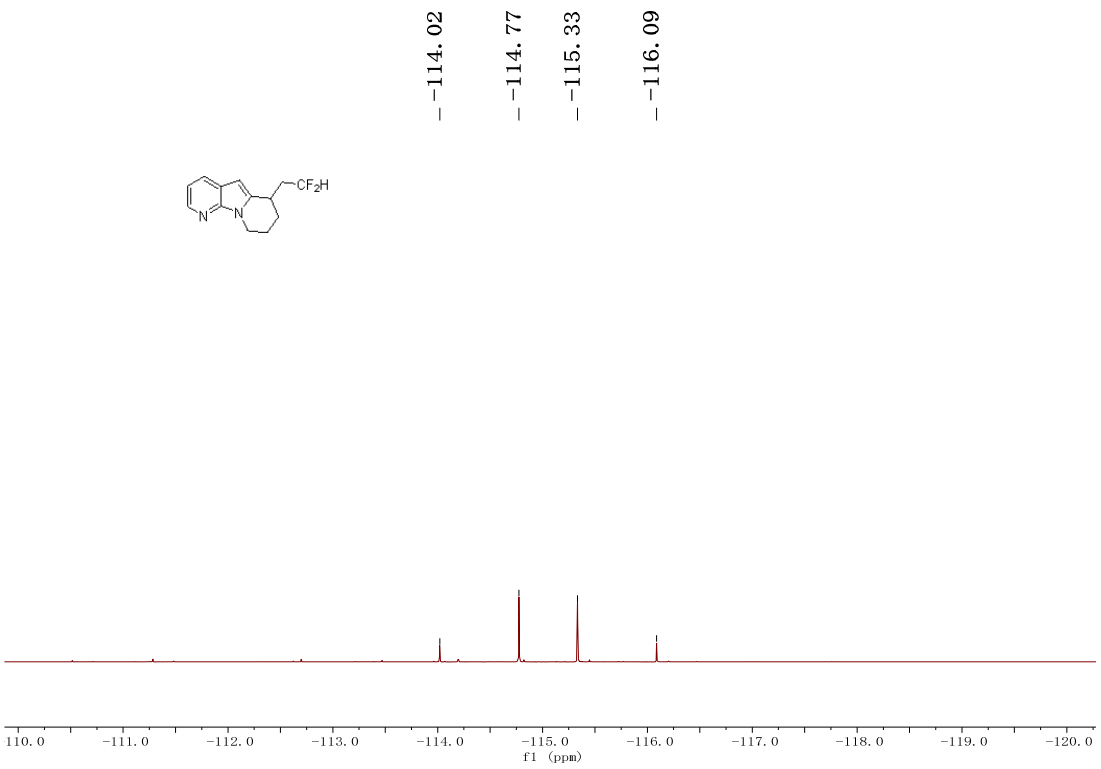
^{1}H NMR of 3af



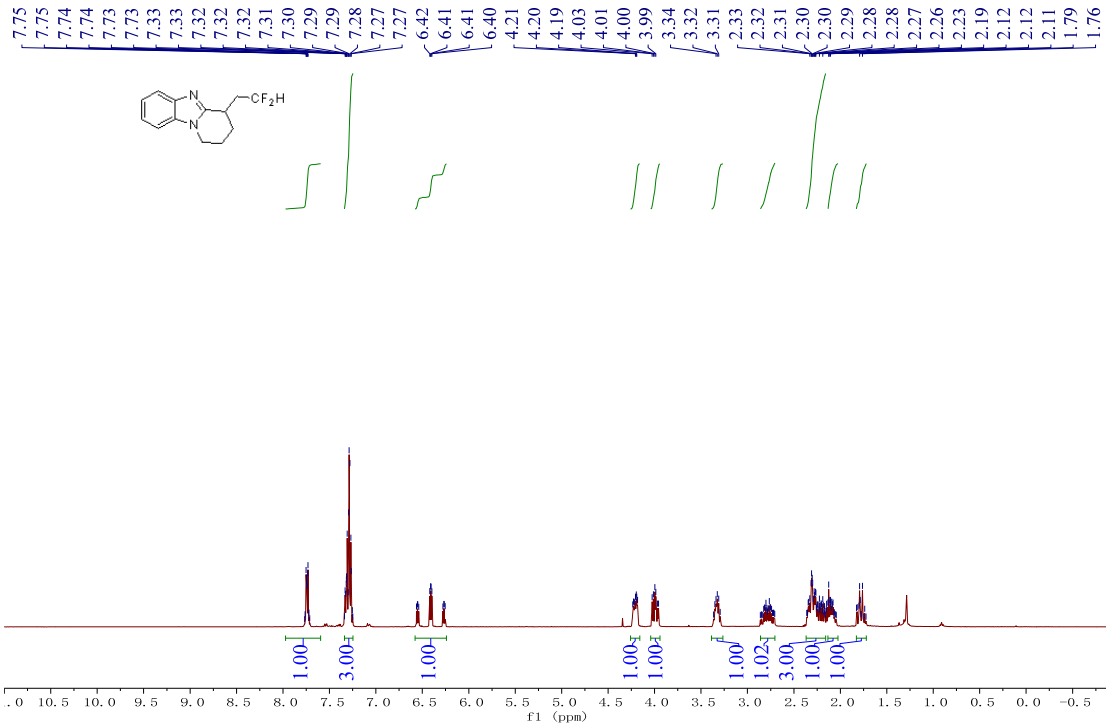
^{13}C NMR of 3af



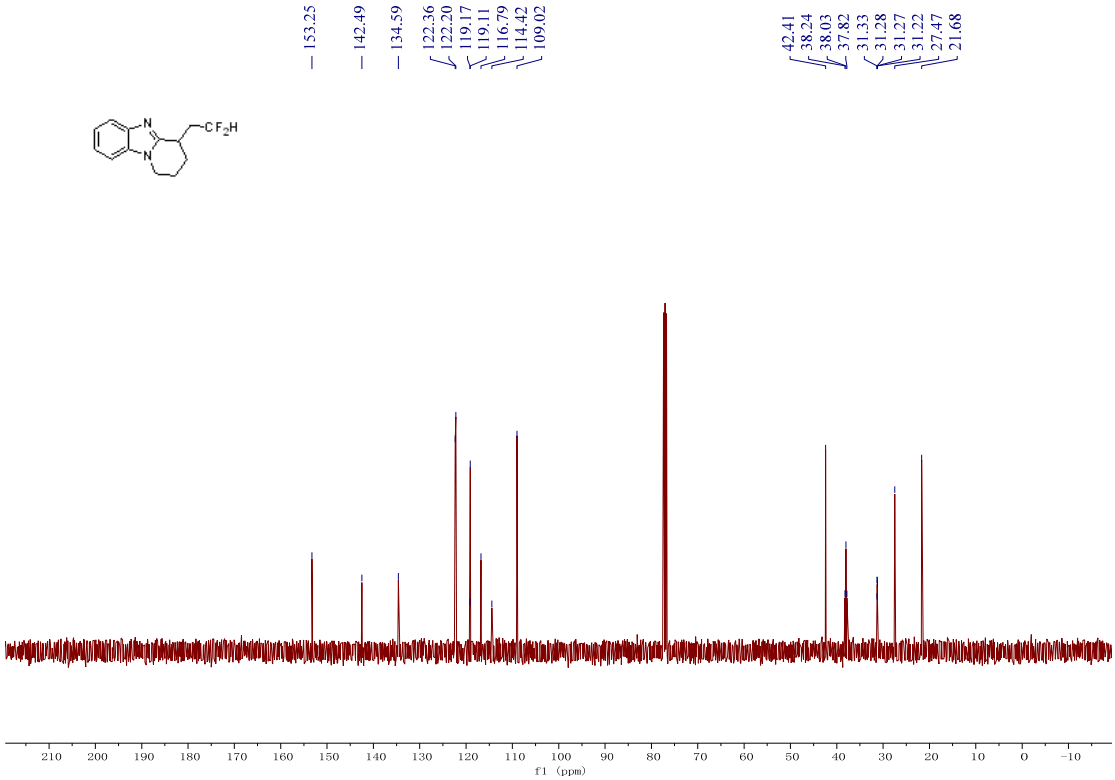
^{19}F NMR of 3af



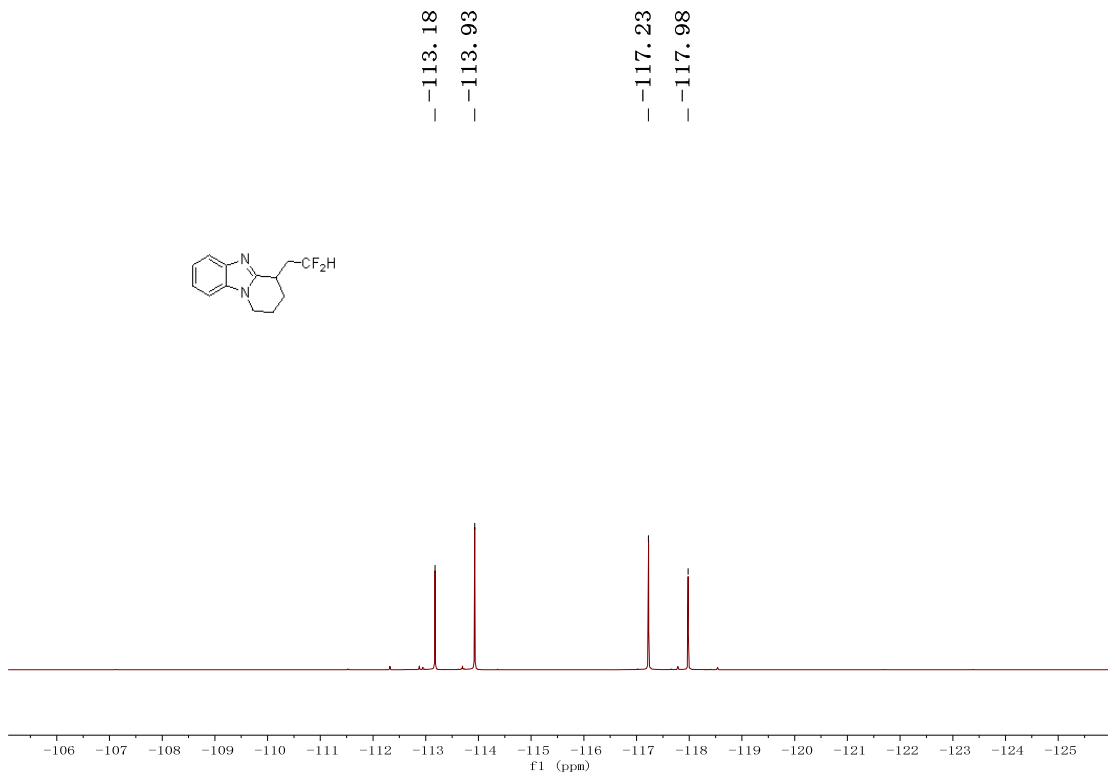
^{1}H NMR of 3ag



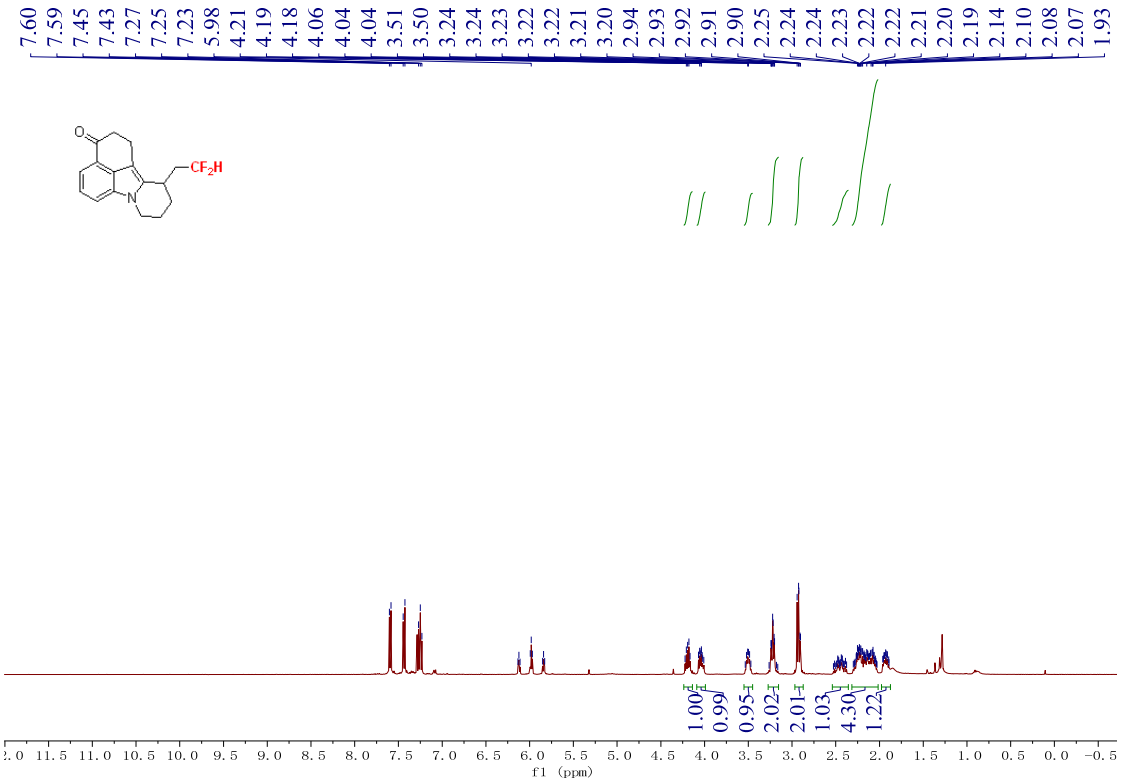
^{13}C NMR of 3ag



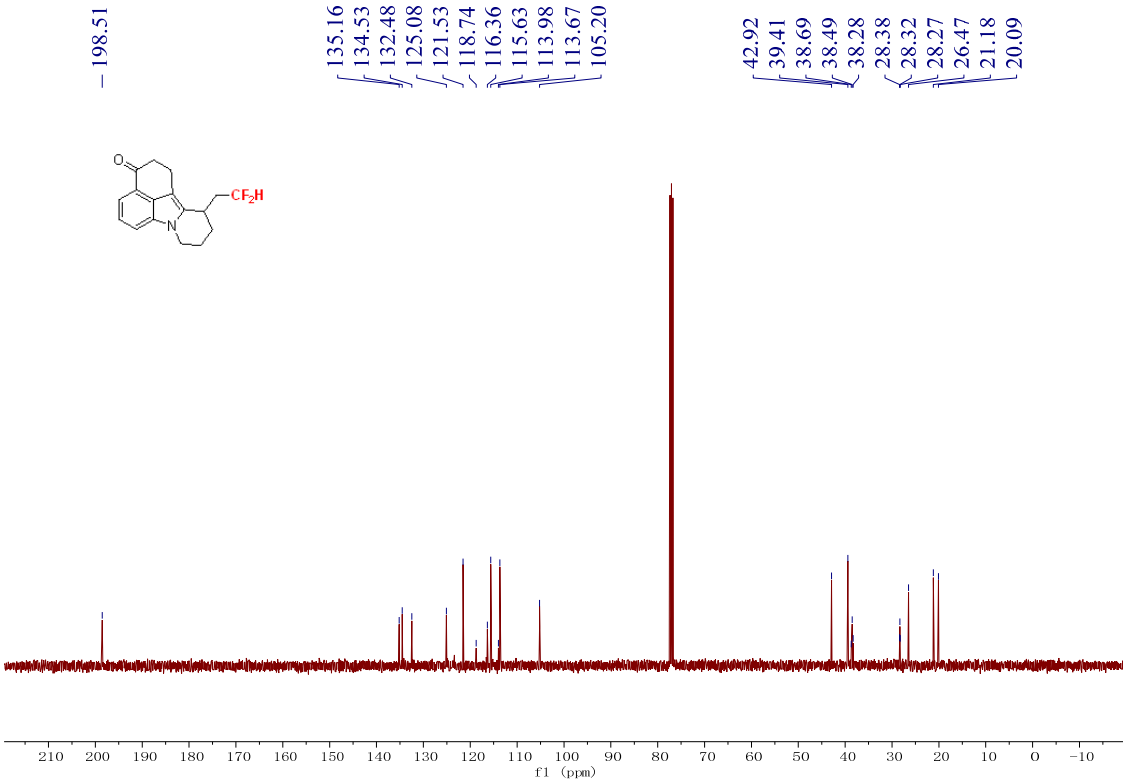
^{19}F NMR of 3ag



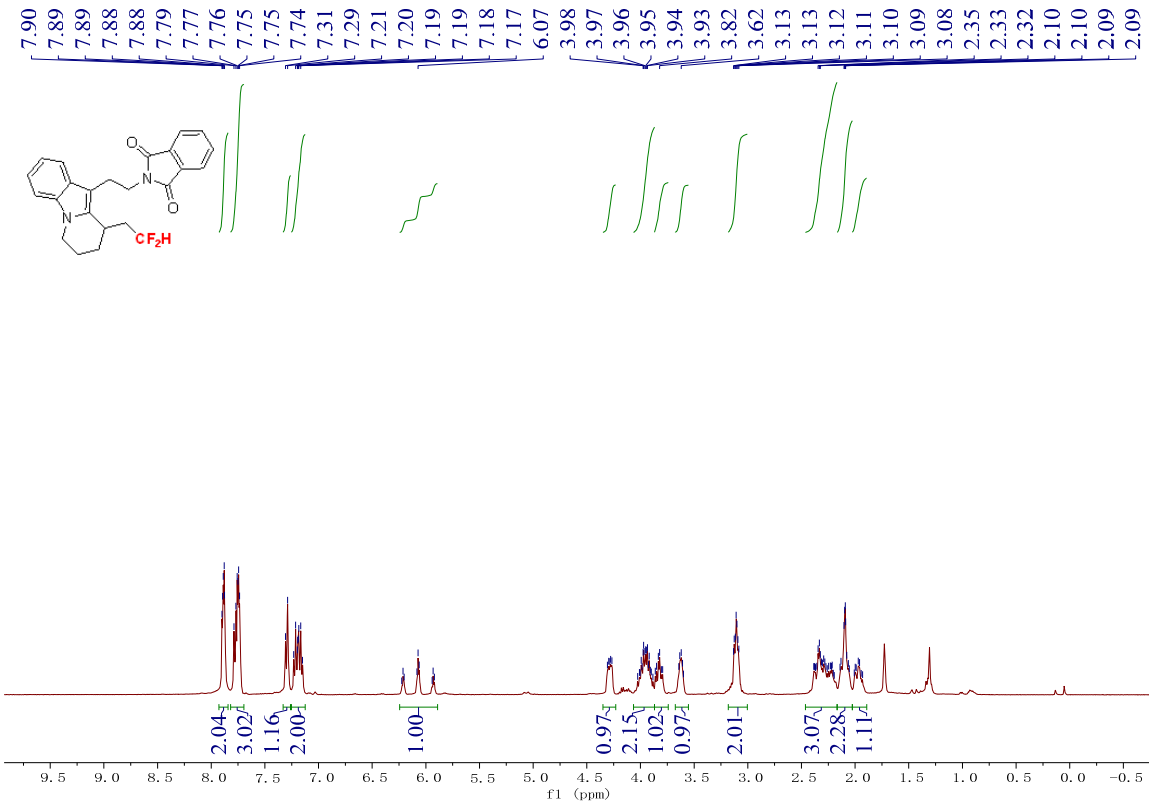
^{1}H NMR of 3ah



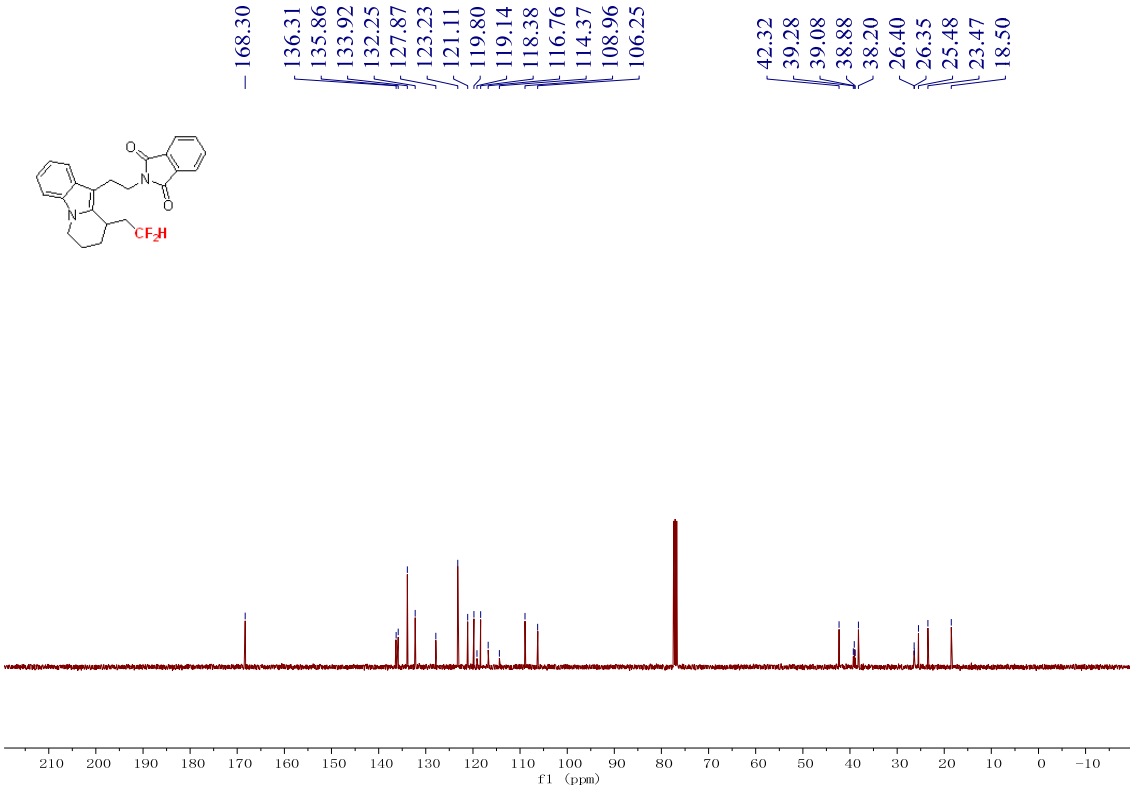
^{13}C NMR of 3ah



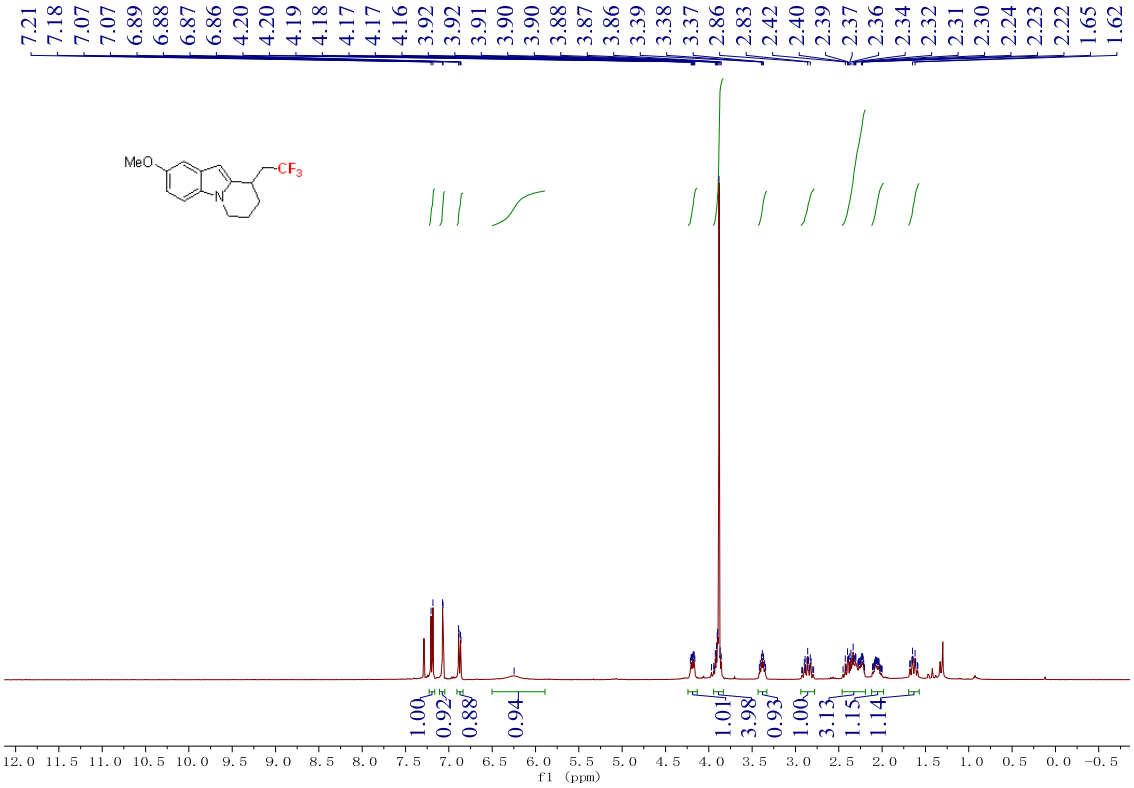
^{1}H NMR of 3ai



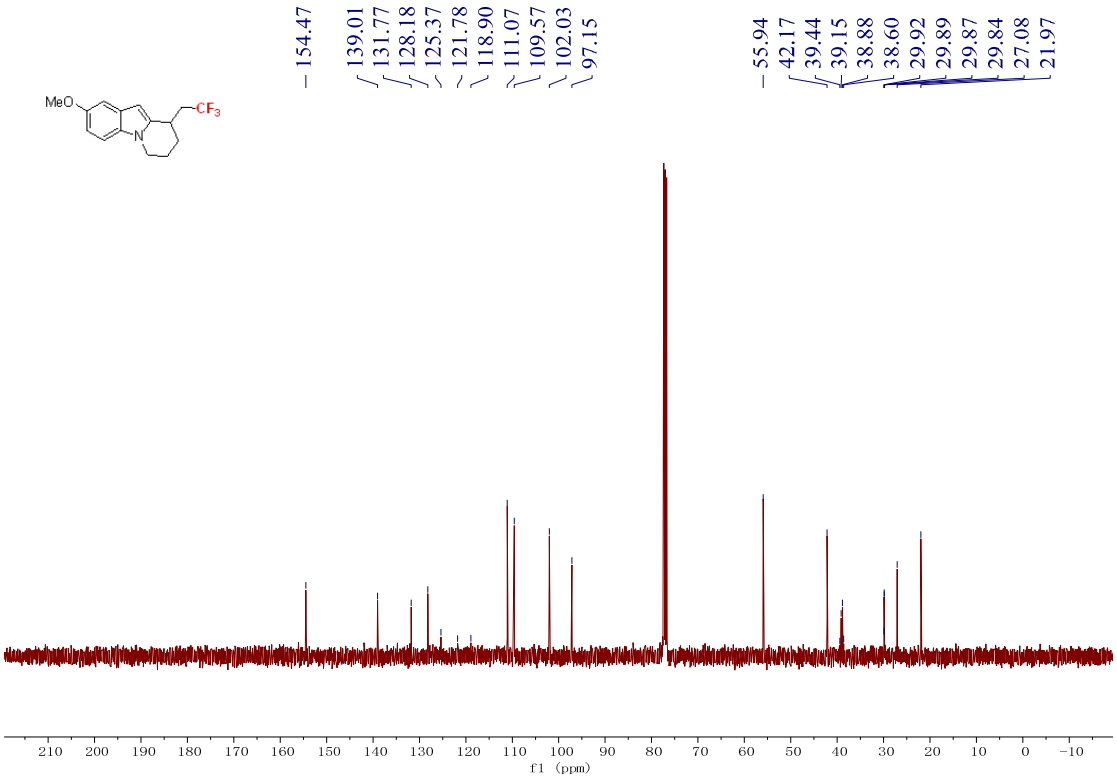
^{13}C NMR of 3ai



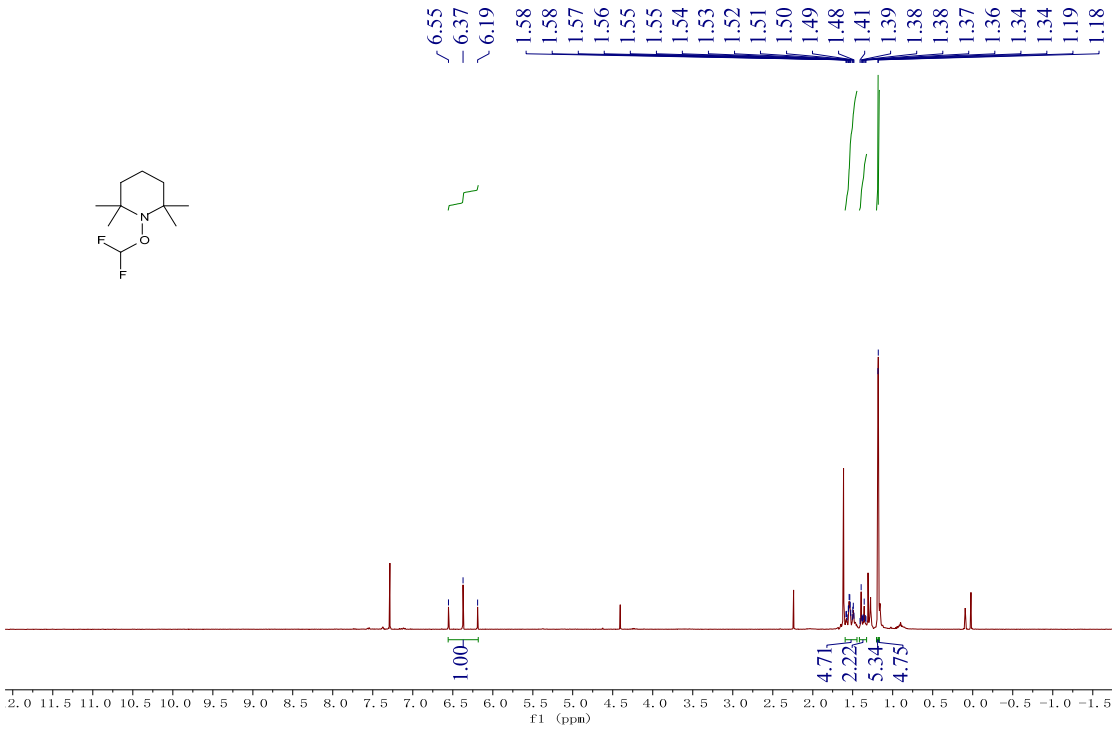
^{1}H NMR of 3aj



^{13}C NMR of 3aj



^{1}H NMR of 4


6.55
6.37
6.19
1.58
1.58
1.57
1.56
1.55
1.55
1.54
1.53
1.52
1.51
1.50
1.49
1.48
1.41
1.39
1.38
1.38
1.37
1.36
1.34
1.34
1.19
1.18
F
O
N
F
F
1.00
4.71
2.22
5.34
4.75
f1 (ppm)