Supporting Information

Catalyst-Free Intramolecular Radical Cyclization Cascades initiated by direct homolysis of C_{sp}^3-Br under visible light

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General consideration

Unless otherwise specified, all reagents and solvents were obtained from commercial suppliers and used without further purification. The NMR spectra were recorded on a Bruker Avance 400 or 600 spectrometers at 400 MHz or 600MHz in $CDCl_3$ using tetramethylsilane as the internal standard. Chemical shifts (δ) are reported in ppm and coupling constants (J) in hertz (Hz). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, dd = doublet of doublet, t = triplet, dt = doublet of triplet, td = triplet of doublet, q = quartet, m = multiplet, ddd = doublet of doublet of doublet. Melting points were determined using a Büchi B-540 capillary melting point apparatus. High-resolution mass spectra were obtained with a Bruker Impact II UHR-QTOF. by ESI on a TOF mass analyzer. Steady-state and time-resolved emission spectroscopy were determined using an Edinburgh FLS1000. Column chromatography was performed on silica gel (200–300 mesh).

The Material of the Irradiation Vessel

Manufacturer: Xi 'an WATTCAS experimental equipment co. LTD

Model: WP-TEC-1020HSL

Broadband source: λ = 400–405 nm

Material of the irradiation vessel: borosilicate reaction tube

Distance from the light source to the irradiation vessel: 2.0 cm

photon flux density: 5.044×10^{-8} einstein s^{-1}

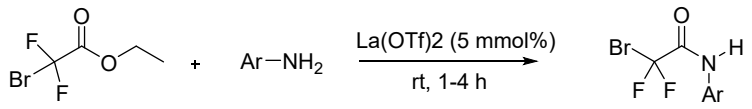
Not use any filters

Figure S1（Photographed by author Panyi Huang）

Experimental Procedures

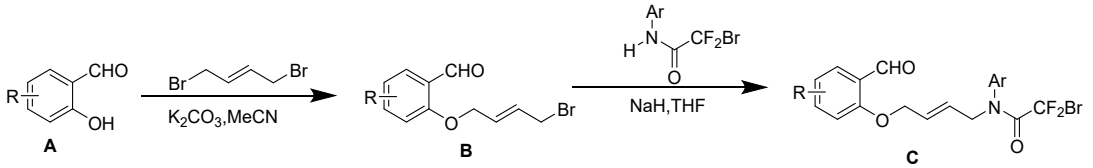
1. Synthesis of substrates

1.1 Synthesis of *α*-bromo-*α*,*α*-difluoroacetamides[1]



General procedure: A 20 mL tube equipped with a magnetic stir bar was charged with lanthanum trifluoromethane sulfonate (0.25 mmol, 5.0 mol %). The tube was backfilled with argon, and then ethyl bromodifluoroacetate (6.0 mmol) and amine (5.0 mmol) were added. The mixture was stirred at room temperature and monitored by TLC. After the amine was exhausted, the mixture was purified by silica gel column chromatography to give the target amide.

1.2 Synthesis of diverse 3-difluorolactam substituted chroman-4-ones[2,3]



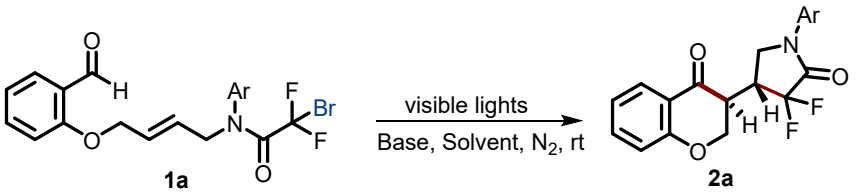
General procedure: To a solution of salicylaldehyde or its derivatives **A** (0.016 mol, 1 equiv.) in dry MeCN (25 mL) was added K_2CO_3 (0.018 mol. 1.1 equiv.) and (*E*)-1.4-dibromo-2-butene (0.018 mol, 1.1 equiv.). The mixture was stirred under reflux for 4 hours and then poured into water (100 mL). The resulting mixture was extracted with DCM (3 × 50 mL). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure to obtain crude product **B**. The crude product **B** was purified by silica gel column chromatography with Petroleum ether/EtOAc to give the target product **B**.

To a stirred solution of 2-bromo-2,2-difluoro-N-phenylacetamide (3.92 mmol, 1.00 equiv.) in THF (25 mL) was added sodium hydride (4.31 mmol, 1.1 equiv.) at 0 °C. The mixture was stirred for 30 min and **B** (4.31 mmol, 1.10 equiv.) was added. The resulting mixture was stirred at 85 °C until the reaction was completed (monitored by TLC), which was then diluted with water and extracted three times with CH_2Cl_2. The

combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure to obtain crude product **C**. The crude product **C** was purified by silica gel column chromatography with Petroleum ether/EtOAc to give the target product **C**.

2. Screening of Reaction Conditions

Table S1. Reaction optimization



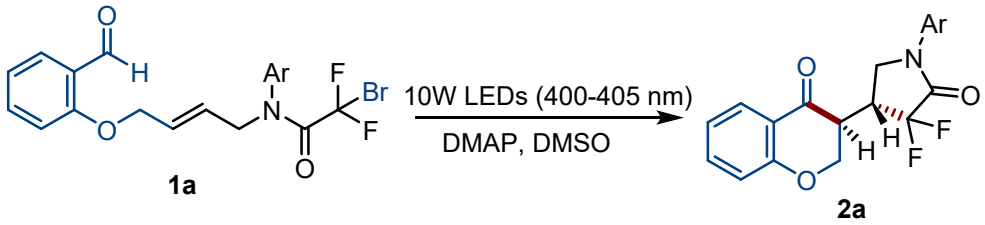
1a 2a

entry	Light source	solvent	additive	yield (%) [b]
1[c]	400-405 nm	DMSO	-	41
2	400-405 nm	DMSO	-	27
3	400-405 nm	DMSO	Na_2CO_3	53
4	400-405 nm	DMSO	$NaHCO_3$	57
5	400-405 nm	DMSO	NaOH	48
6	400-405nm	DMSO	TEA	73
7	400-405 nm	DMSO	DMAP	82
8	400-405nm	DMSO	DBU	80
9	400-405nm	DMF	DMAP	70
10	400-405nm	MeCN	DMAP	66
11	400-405nm	EtOAc	DMAP	trace
12	400-405nm	DCM	DMAP	trace
13	400-405nm	$CHCl_3$	DMAP	21%
14	365-370 nm	DMSO	DMAP	68
15	380-385 nm	DMSO	DMAP	71
16	420-425 nm	DMSO	DMAP	75
17	450-455 nm	DMSO	DMAP	trace
18	Dark	DMSO	DMAP	N.D.
19[d]	400-405nm	DMSO	DMAP	trace

[a] Reaction conditions: **1a** (0.2 mmol), additive (0.3 mmol), solvent (2 mL), rt, 400 nm, 10 h. [b] Isolated yield. [c] $Ir(ppy)_3$ (5 mol%). [d] under air.

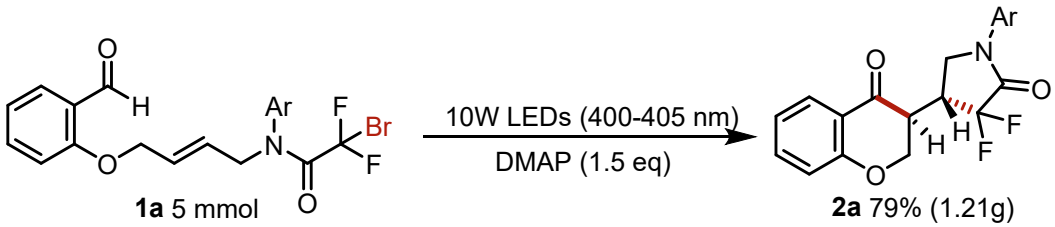
3. General procedure for the synthesis of products

3. 1 Synthesis of product 2a



General procedure: A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (0.2 mmol), DMAP (0.3 mmol), and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 10 h. After completion of the reaction, the resulting mixture was extracted with CH_2Cl_2 and the organic phase was then removed under vacuum. The residue was purified by column chromatography using a mixture of petroleum ether and ethyl acetate as eluent to give the desired product **2a**.

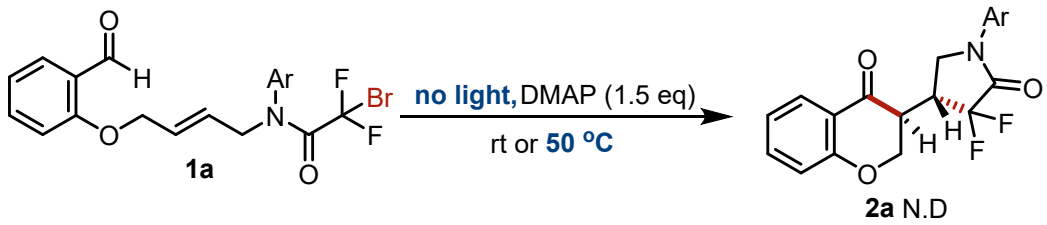
4. The Gram Scale Reaction



General procedure: A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (5 mmol), DMAP (7.5 mmol), and DMSO (8 mL) were added to a 50 mL reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 24 h. After completion of the reaction, the resulting mixture was extracted with CH_2Cl_2. The organic phase was evaporated under vacuum. The residue was purified by column chromatography using a mixture of petroleum ether and ethyl acetate as eluent to give the desired product **2a** with a 79% yield.

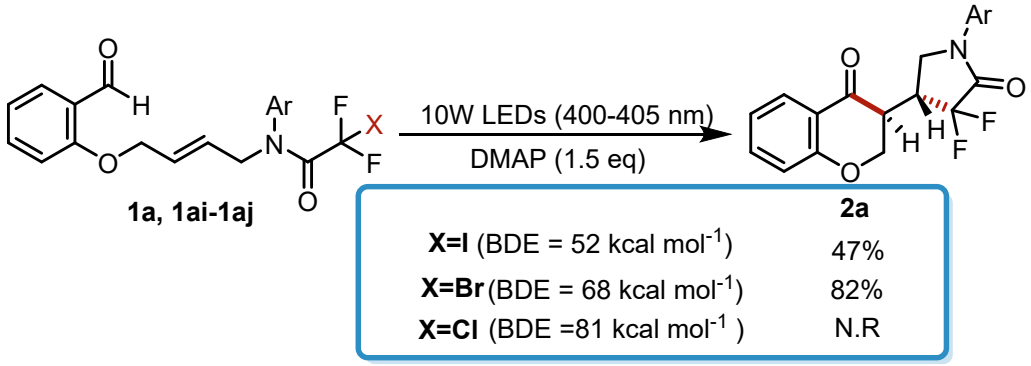
5. Mechanism investigation

5.1 Thermal sensitive reaction



A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (0.2 mmol), DMAP (0.3 mmol) and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The reaction was carried out in dark conditions, and the corresponding product **2a** was not obtained even after heating at 50 °C for 10 hours.

5.2. C-X control Experiment



General procedure: A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** or **1ai-1aj** (0.2 mmol), DMAP (0.3 mmol), and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 10 h. The resulting mixture was extracted with CH_2Cl_2 and the organic phase was then removed under vacuum. The residue was purified by column chromatography using a mixture of petroleum ether and ethyl acetate as eluent to give the desired product **2a**.

5.3 UV-visible absorption Spectra of 1a

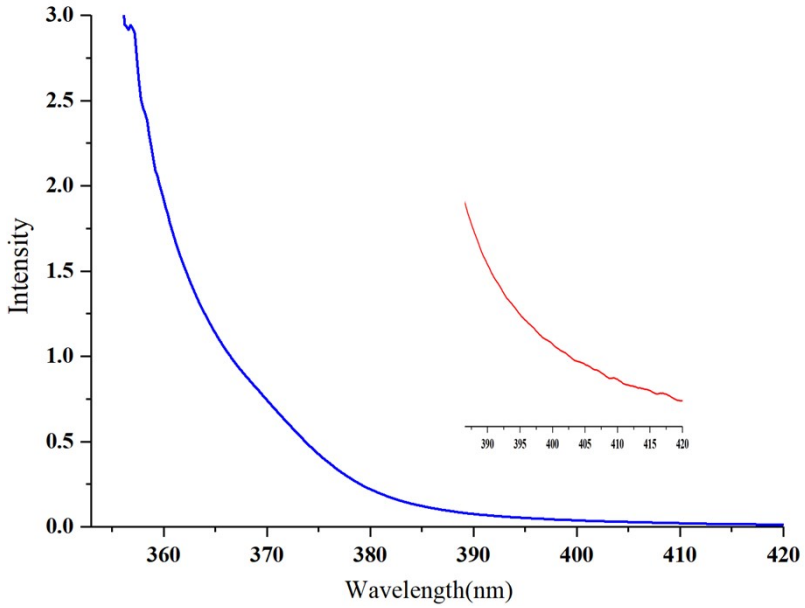


Figure S2. Absorption spectra of 1a (dissolved in DMSO)

5.4 The electron paramagnetic resonance (EPR) experiments

To determine the species of radical involved in the present reaction, 5,5-dimethyl-pyrroline-*N*-oxide (DMPO) were employed. There was no signal when DMPO was added into DMSO solution of 2-(allyloxy)aryl aldehyde derivatives (**1a**) and DMAP without light irradiation (Figure S6a). Irradiation of the above solution under N_2 with blue LEDs (400-405 nm) resulted in the formation of a strong characteristic signal of alkyl radical with DMPO (Figure S6b), indicating the formation of fluoroalkyl radical in the reaction.

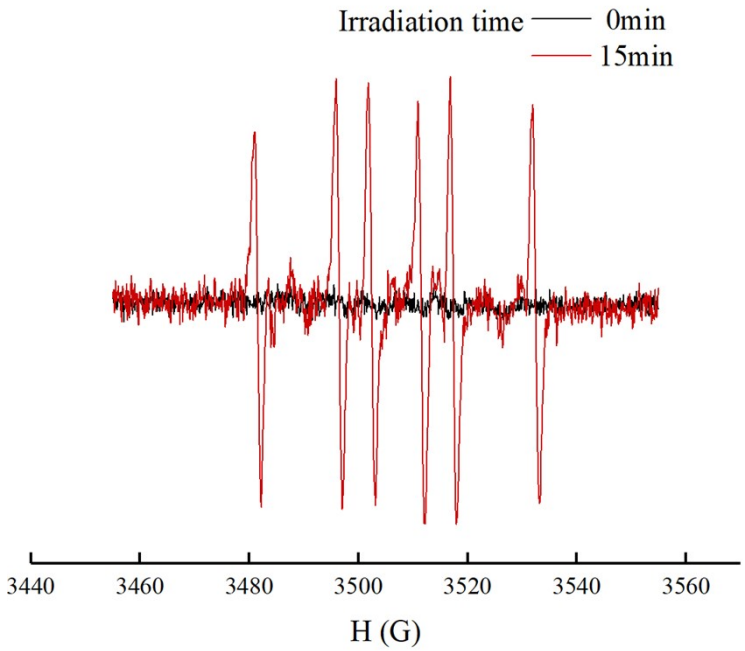
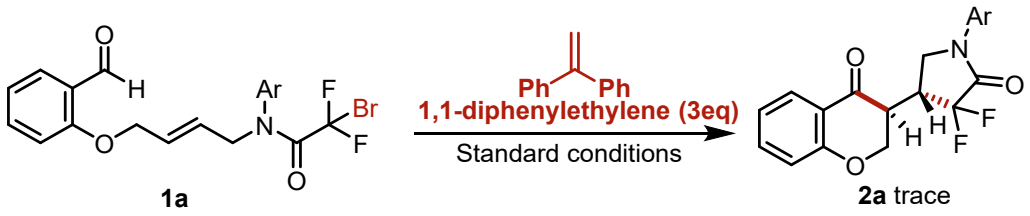


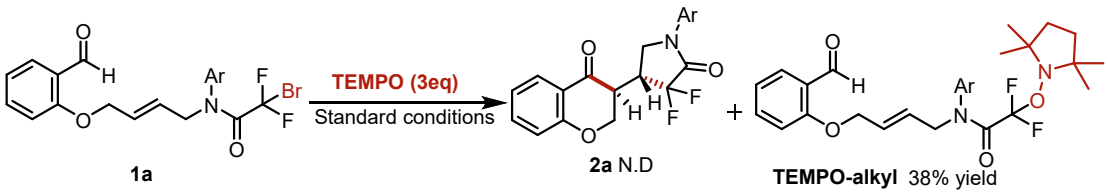
Figure S3. Electron spin resonance (ESR) spectra of DMPO with fluoroalkyl radical (a) A solution of DMPO (0.20 mol/L) with 2-(allyloxy)aryl aldehyde derivatives (**1a**) and DMAP in DMSO without light irradiation.
(b) A solution of DMPO (0.20 mol/L) with 2-(allyloxy)aryl aldehyde derivatives (**1a**) and DMAP in DMSO under blue LEDs (400-405 nm) irradiation for 15min.

5.5 Radical trapped experiment using 1,1-diphenylethylene as a radical scavenger

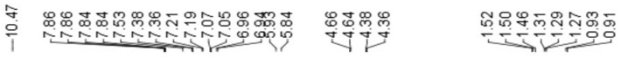


A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (0.2 mmol), DMAP (0.3 mmol) diphenylethylene (0.6 mmol) and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 10 h. Only trace amounts of product **2a** was detected monitored by TLC.

5.6 Radical trapped experiment using TEMPO as a radical scavenger



A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (0.2 mmol), DMAP (0.3 mmol) TEMPO (94 mg, 0.6 mmol) and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 10 h. Subsequently, the reaction mixture was diluted with ethyl acetate (20 mL), transferred to a 60 mL separatory funnel, and washed with water. After evaporation of the solvent, the crude reaction mixture was then purified by column chromatography. The adduct **TEMPO-alkyl** was detected by NMR analysis. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 10.49 (S, 1H), 7.90 – 7.80 (m, 1H), 7.59 – 7.50 (m, 1H), 7.43 – 7.31 (m, 3H), 7.24 – 7.17 (m, 2H), 7.09 – 7.01 (m, 1H), 6.99 – 6.91 (m, 1H), 6.06 – 5.90 (m, 1H), 5.86 – 5.74 (m, 1H), 4.65 (d, J = 4.7 Hz, 2H), 4.37 (d, J = 6.1 Hz, 2H), 1.55 – 1.42 (m, 4H), 1.35 – 1.21 (m, 2H), 0.92 (d, J = 11.7 Hz, 10H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 189.61, 160.72, 160.11 (C-F, $^2J_{C\text{-}F}$, J = 37.8 Hz), 140.25, 135.84, 129.27, 129.08, 129.03, 128.96, 128.45, 127.58, 125.08, 120.95, 116.66 (C-F, $^1J_{C\text{-}F}$, J = 274.7 Hz), 112.89, 68.01, 60.91, 53.27, 40.17, 33.35, 21.02, 16.85. **^{19}F NMR (376 MHz, $CDCl_3$)** δ -66.31.



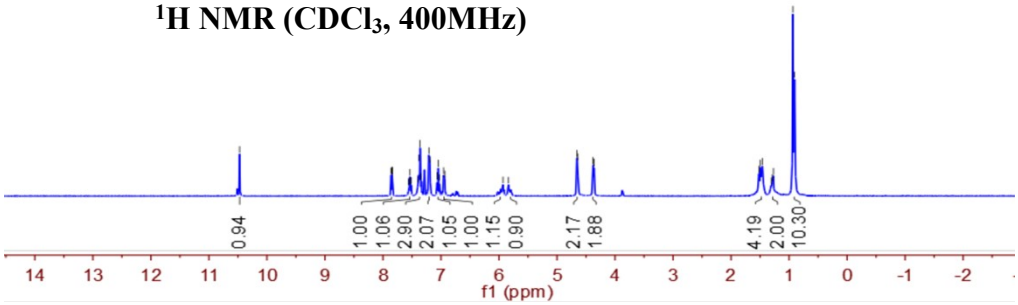


Figure S4. ^{1}H NMR spectra of **TEMPO-alkyl**.

^{13}C NMR ($CDCl_3$, 101MHz)

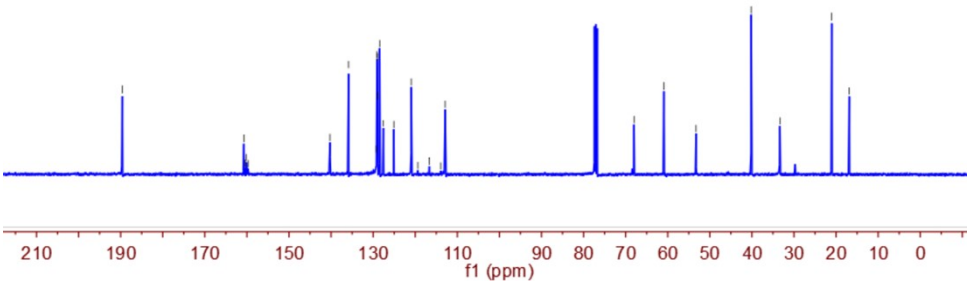


Figure S5. ^{13}C NMR spectra of **TEMPO-alkyl**.

^{19}F NMR ($CDCl_3$, 376 MHz)

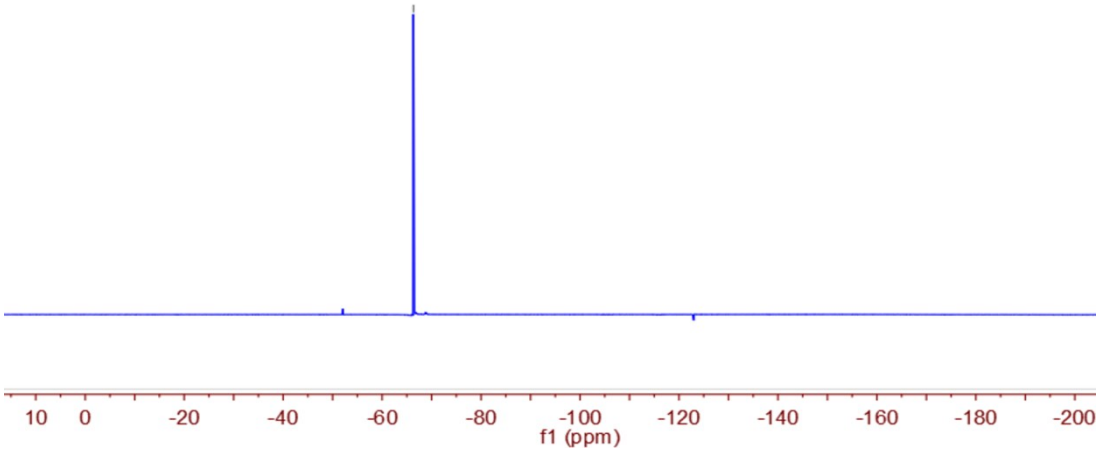
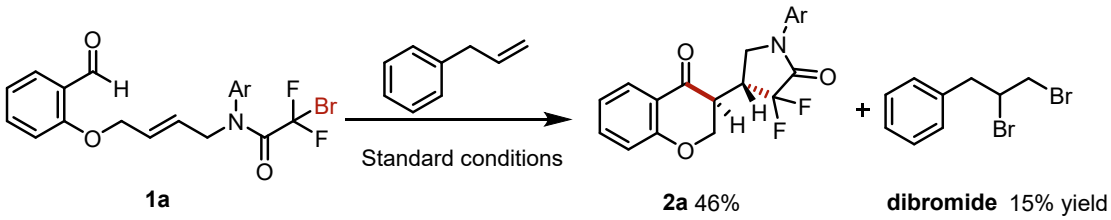
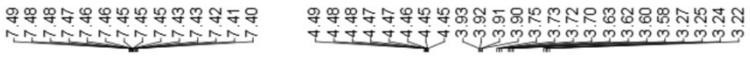


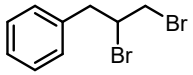
Figure S6. ^{19}F NMR spectra of **TEMPO-alkyl**.

5.7 Bromine radical trapping experiment



A mixture of 2-(allyloxy)aryl aldehyde derivatives **1a** (0.6 mmol), DMAP (0.9 mmol) allylbenzene (0.25 ml) and DMSO (2 mL) were added to a reaction tube. The tube was evacuated and backfilled with N_2 for three times. The mixture was then irradiated by 400–405 nm (10 w) for 24 h. Subsequently, the mixture was diluted with water (20.0 mL) and extracted with DCM (3 x 15.0 mL). After evaporation of the solvent, the crude reaction mixture was then purified by column chromatography. The adduct **dibromide** was detected by NMR analysis. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.49 – 7.39 (m, 5H), 4.51 – 4.42 (m, 1H), 3.91 (dd, *J* = 10.5, 4.2 Hz, 1H), 3.73 (dd, *J* = 10.5, 8.9 Hz, 1H), 3.61 (dd, *J* = 14.5, 4.8 Hz, 1H), 3.24 (dd, *J* = 14.5, 7.8 Hz, 1H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 136.99, 129.69, 128.70, 127.38, 52.70, 42.15, 36.39.





^{1}H NMR ($CDCl_3$, 400MHz)

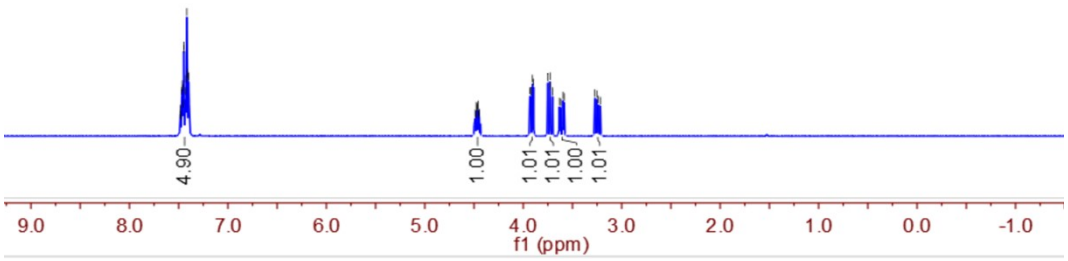
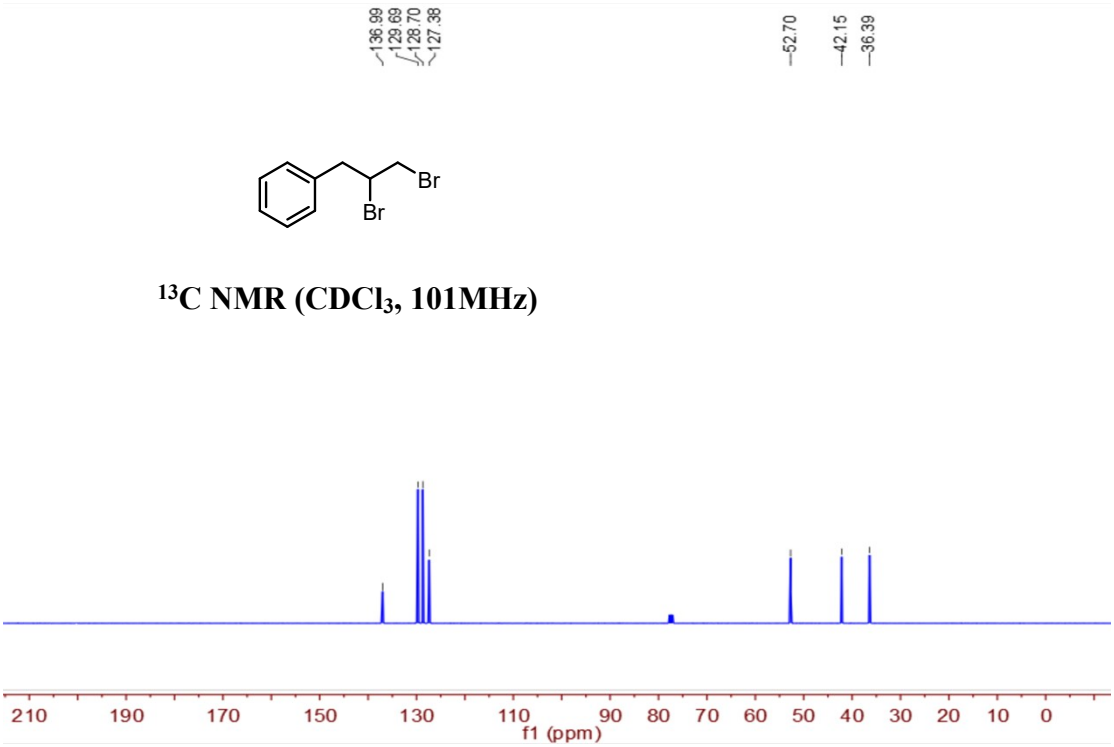


Figure S7. ^{1}H NMR spectra of **dibromide.**



^{13}C NMR ($CDCl_3$, 101MHz)

Figure S8. ^{13}C NMR spectra of **dibromide.**

5.8 On/off experiments of 2a

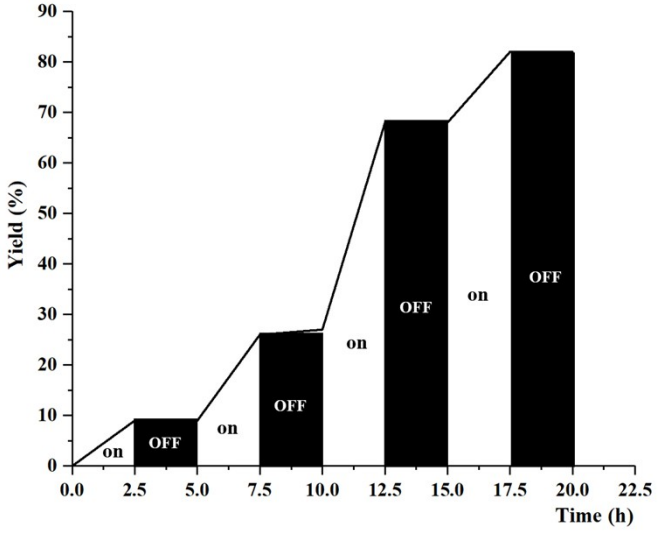


Figure S9. On/off experiments of 2a.

6. X-ray structure of 2y

CCDC: 2236364

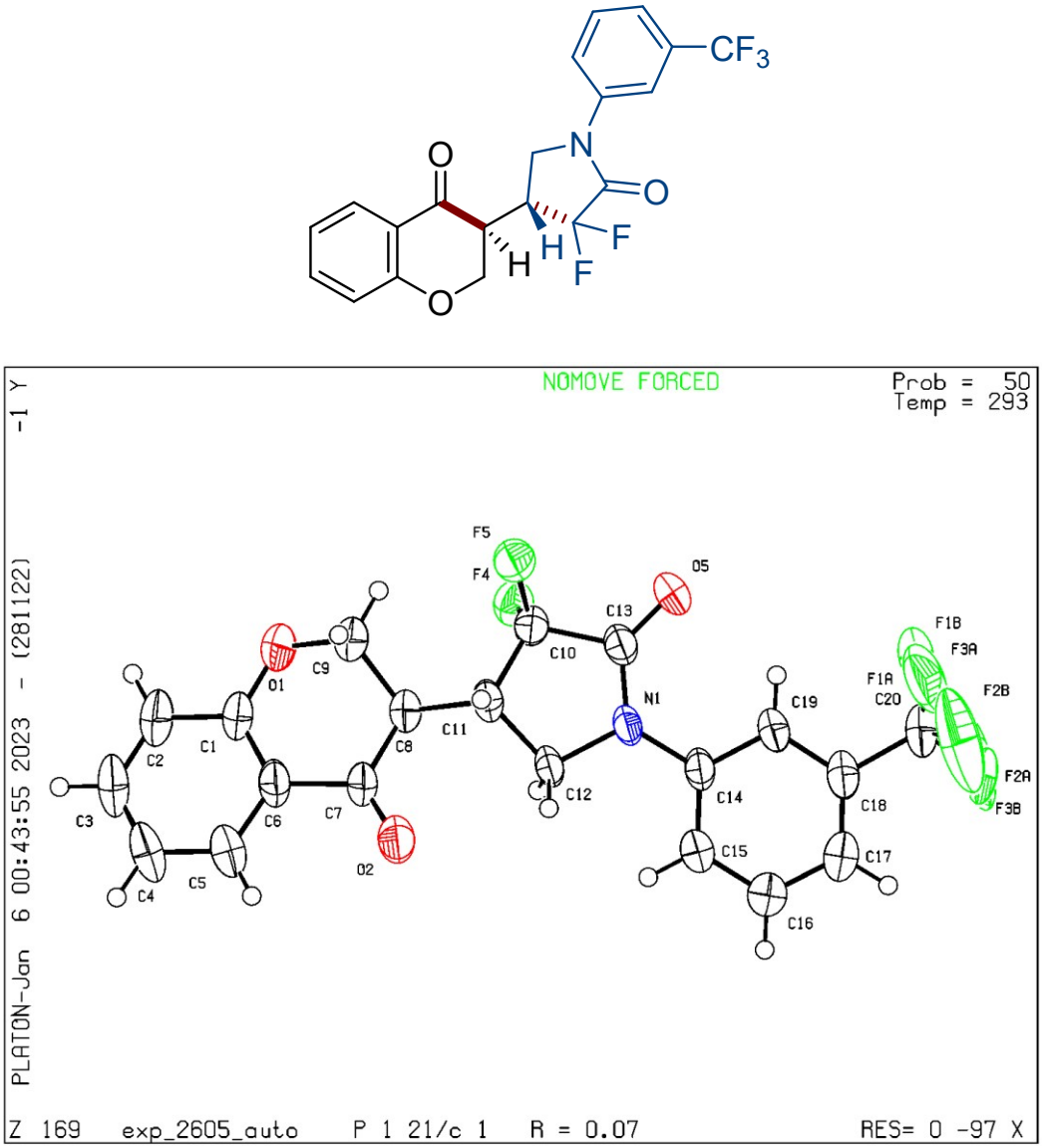


Figure S10. Crystal data and details of data collection and refinement for compound **2y.**

checkCIF/PLATON report

Structure factors have been supplied for datablock(s) exp_2605_auto

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No syntax errors found. CIF dictionary Interpreting this report

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                  alpha=90         beta=110.302(3)     gamma=90
Temperature:      293 K

                 Calculated                Reported
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Hall group       -P 2ybc                   -P 2ybc
Moiety formula   C20 H14 F5 N O3           C20 H14 F5 N O3
Sum formula      C20 H14 F5 N O3           C20 H14 F5 N O3
Mr               411.32                    411.32
Dx,g cm-3        1.508                     1.508
Z                4                         4
Mu (mm-1)        1.188                     1.188
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F000'            843.51
h,k,lmax         20,9,17                   20,9,17
Nref             3311                      3278
Tmin,Tmax        0.920,0.942               0.091,1.000
Tmin'            0.920

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Data completeness= 0.990          Theta(max)= 68.112

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                                             0.1987( 3278)
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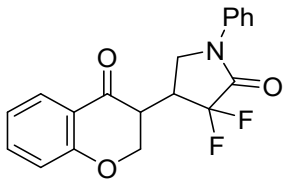
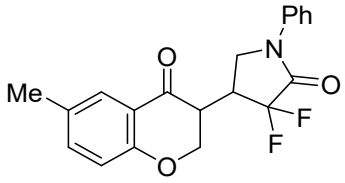
7. Characterization Data for the Products

3,3-difluoro-4-(4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2a)



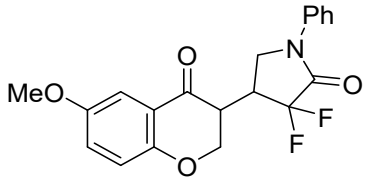
The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (56 mg, 82%), m.p. 129.4–130.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 – 7.86 (m, 1H), 7.71 – 7.64 (m, 2H), 7.59 – 7.52 (m, 1H), 7.43 (s, 2H), 7.27 (s, 1H), 7.11 – 7.03 (m, 2H), 4.87 – 4.79 (m, 1H), 4.60 – 4.51 (m, 1H), 4.29 (t, J = 8.8 Hz, 1H), 3.90 (s, 1H), 3.29 – 3.20 (m, 1H), 3.02 – 2.86 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.96, 161.52, 161.16 (C-F, $^{2}J_{C\text{-}F}$, J = 30.3 Hz), 137.65, 136.77, 129.19, 127.30, 126.31, 121.92, 120.03, 119.98, 118.04, 117.42 (C-F, $^{1}J_{C\text{-}F}$, J = 250.4 Hz), 68.48, 47.86, 43.88, 37.25 (C-F, $^{2}J_{C\text{-}F}$, J = 20.5 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -105.27, -105.98, -116.75, -117.46; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{15}F_2NNaO_3$ 366.0912; Found 366.0898.

3,3-difluoro-4-(6-methyl-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2b)



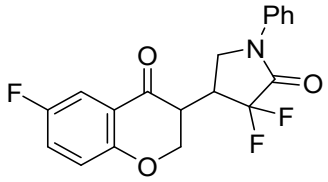
The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (56 mg, 78%), m.p. 167.7–168.8 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 (d, J = 7.8 Hz, 3H), 7.44 (t, J = 8.0 Hz, 2H), 7.37 (dd, J = 8.5, 2.1 Hz, 1H), 7.27 (t, J = 7.4 Hz, 1H), 6.96 (d, J = 8.5 Hz, 1H), 4.83 – 4.77 (m, 1H), 4.57 – 4.51 (m, 1H), 4.26 (t, J = 9.6 Hz, 1H), 3.91 (t, J = 9.6 Hz, 1H), 3.24 – 3.18 (m, 1H), 3.04 – 2.86 (m, 1H), 2.34 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.15, 161.22 (C-F, $^{2}J_{C\text{-}F}$, J = 30.0 Hz), 159.63, 137.91, 137.66, 131.46, 129.20, 126.80, 126.33, 120.02, 119.61, 117.83, 117.33 (C-F, $^{1}J_{C\text{-}F}$, J = 248.8 Hz), 68.49, 47.82, 43.90, 37.32 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz), 20.43.^{19}F NMR (565 MHz, $CDCl_3$) δ -105.49, -105.96, -116.93, -117.41; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1072.

3,3-difluoro-4-(6-methoxy-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2c)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (54 mg, 73%), m.p. 152.9–154.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 (d, J = 7.8 Hz, 2H), 7.44 (t, J = 8.0 Hz, 2H), 7.31 (d, J = 3.1 Hz, 1H), 7.28 (t, J = 6.1 Hz, 1H), 7.17 (dd, J = 9.0, 3.2 Hz, 1H), 7.00 (d, J = 9.0 Hz, 1H), 4.81 – 4.75 (m, 1H), 4.59 – 4.49 (m, 1H), 4.31 – 4.21 (m, 1H), 3.92 (t, J = 9.6 Hz, 1H), 3.83 (s, 3H), 3.25 – 3.18 (m, 1H), 3.03 – 2.88 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.01, 161.20 (C-F, $^{2}J_{C\text{-}F}$, J = 30.0 Hz), 156.31, 154.44, 137.65, 129.21, 126.34, 126.07, 120.00, 119.78, 119.38, 117.31 (C-F, $^{1}J_{C\text{-}F}$, J = 249.6 Hz), 107.51, 68.63, 55.81, 47.78, 43.82, 37.31 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.48, -105.95, -116.92, -117.40; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_4$ 396.1018; Found 396.1026.

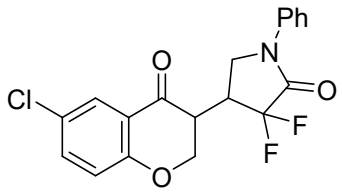
3,3-difluoro-4-(6-fluoro-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2d)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (62 mg, 87%), m.p. 162.4–163.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 (d, J = 7.8 Hz, 2H), 7.56 – 7.52 (m, 1H), 7.45 (t, J = 8.0 Hz, 2H), 7.30 – 7.27 (m, 2H), 7.09 – 7.03 (m, 1H), 4.86 – 4.79 (m, 1H), 4.58 – 4.51 (m, 1H), 4.30 (t, J = 9.6 Hz, 1H), 3.90 (t, J = 9.6 Hz, 1H), 3.30 – 3.20 (m, 1H), 3.00 – 2.88 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.27 (C-F, $^{4}J_{C\text{-}F}$, J = 1.6 Hz), 161.05 (C-F, $^{2}J_{C\text{-}F}$, J = 29.8 Hz), 157.84 (C-F, $^{4}J_{C\text{-}F}$, J = 1.4 Hz), 157.44 (C-F, $^{1}J_{C\text{-}F}$, J = 243.0 Hz), 137.59, 129.24, 126.41, 124.45 (C-F, $^{2}J_{C\text{-}F}$, J = 24.6 Hz), 120.40 (C-F, $^{3}J_{C\text{-}F}$, J = 6.6 Hz), 120.02, 119.83 (C-F, $^{3}J_{C\text{-}F}$, J = 7.4 Hz), 117.29 (C-F, $^{1}J_{C\text{-}F}$, J = 249.4 Hz), 112.21 (C-F, $^{2}J_{C\text{-}F}$, J = 23.4 Hz), 68.71, 47.80 (C-F, $^{3}J_{C\text{-}F}$, J = 7.1 Hz), 43.75 (C-F, $^{3}J_{C\text{-}F}$, J = 4.7 Hz), 37.29 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.43,

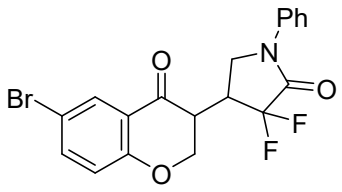
-105.91, -116.87, -117.34, -120.43; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}F_3NNaO_3$ 384.0818; Found 384.0801.

4-(6-chloro-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one (2e)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (68 mg, 85%), m.p. 187.2–188.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.85 (d, J = 2.5 Hz, 1H), 7.68 (d, J = 8.1 Hz, 2H), 7.50 (dd, J = 8.8, 2.5 Hz, 1H), 7.45 (t, J = 7.9 Hz, 2H), 7.28 (t, J = 8.4 Hz, 1H), 7.03 (d, J = 8.9 Hz, 1H), 4.88 – 4.82 (m, 1H), 4.59 – 4.53 (m, 1H), 4.30 (t, J = 9.4 Hz, 1H), 3.89 (t, J = 9.5 Hz, 1H), 3.30 – 3.21 (m, 1H), 2.99 – 2.86 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 190.91, 161.01 (C-F, $^2J_{C\text{-}F}$, J = 29.7 Hz), 159.97, 137.56, 136.64, 129.25, 127.54, 126.60, 126.43, 120.78, 120.03, 119.81, 117.27 (C-F, $^1J_{C\text{-}F}$, J = 249.3 Hz), 68.64, 47.78 (C-F, $^3J_{C\text{-}F}$, J = 7.0 Hz), 43.69 (C-F, $^3J_{C\text{-}F}$, J = 4.6 Hz), 37.29 (C-F, $^3J_{C\text{-}F}$, J = 20.5 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.41, -105.89, -116.82, -117.29; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}ClF_2NNaO_3$ 400.0522; Found 400.0509.

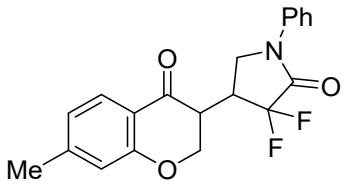
4-(6-bromo-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one (2f)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (64 mg, 80%), m.p. 199.2–200.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.03 – 7.99 (m, 1H), 7.68 (d, J = 8.5 Hz, 2H), 7.65 – 7.61 (m, 1H), 7.47 – 7.42 (m, 2H), 7.31 – 7.26 (m, 1H), 6.98 (d, J = 8.8 Hz, 1H), 4.86 (dd, J = 11.8, 4.3 Hz, 1H), 4.63 – 4.51 (m, 1H), 4.34 – 4.26 (m, 1H), 3.89 (t, J = 9.6 Hz, 1H), 3.32 – 3.15 (m, 1H), 3.00 – 2.86 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 190.76, 161.00 (C-F, $^2J_{C\text{-}F}$, J = 29.4 Hz), 160.41, 139.40, 137.56, 129.73, 129.25, 126.43, 121.26, 120.14, 120.03, 117.26 (C-F, $^1J_{C\text{-}F}$, J = 249.4 Hz), 114.63, 68.60, 47.77 (C-F, $^3J_{C\text{-}F}$, J = 7.1 Hz), 43.65 (C-F, $^3J_{C\text{-}F}$, J = 4.6 Hz), 37.29 (C-F, $^2J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565

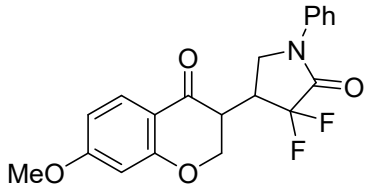
MHz, $CDCl_3$) δ -105.42, -105.89, -116.81, -117.29; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}BrF_2NO_3$ 422.0198; Found 422.0204.

3,3-difluoro-4-(7-methyl-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2g)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (53 mg, 74%), m.p. 168.8–170.3 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.78 (d, J = 8.0 Hz, 1H), 7.69 (d, J = 8.0 Hz, 2H), 7.44 (t, J = 8.0 Hz, 2H), 7.26 (t, J = 7.2 Hz, 1H), 6.90 (d, J = 8.1 Hz, 1H), 6.86 (s, 1H), 4.83 – 4.78 (m, 1H), 4.57 – 4.51 (m, 1H), 4.30 – 4.25 (m, 1H), 3.91 (t, J = 9.6 Hz, 1H), 3.24 – 3.18 (m, 1H), 2.99 – 2.88 (m, 1H), 2.40 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.59, 161.57, 161.22 (C-F, $^2J_{C\text{-}F}$, J = 29.9 Hz), 148.57, 137.66, 129.19, 127.18, 126.31, 123.36, 120.00, 117.97, 117.77, 117.41 (C-F, $^1J_{C\text{-}F}$, J = 249.5 Hz), 68.51, 47.85 (C-F, $^3J_{C\text{-}F}$, J = 7.1 Hz), 43.77 (C-F, $^3J_{C\text{-}F}$, J = 4.4 Hz), 37.36 (C-F, $^2J_{C\text{-}F}$, J = 20.4 Hz), 22.01. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.47, -105.94, -116.93, -117.40; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1055.

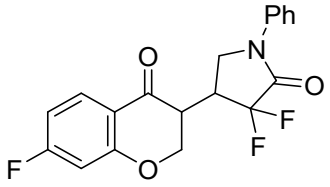
3,3-difluoro-4-(7-methoxy-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2h)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (52 mg, 70%), m.p. 155.3–156.5 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 8.9 Hz, 1H), 7.69 (d, J = 7.7 Hz, 2H), 7.44 (t, J = 8.0 Hz, 2H), 7.27 (t, J = 7.6 Hz, 1H), 6.67 – 6.62 (m, 1H), 6.48 (d, J = 2.4 Hz, 1H), 4.84 – 4.78 (m, 1H), 4.61 – 4.53 (m, 1H), 4.31 – 4.23 (m, 1H), 3.93 (t, J = 10.5 Hz, 1H), 3.88 (s, 3H), 3.22 – 3.13 (m, 1H), 3.01 – 2.86 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.41, 166.65, 163.61, 161.27 (C-F, $^2J_{C\text{-}F}$, J = 29.8 Hz), 137.68, 129.20, 129.06, 126.32, 120.01, 117.47 (C-F, $^1J_{C\text{-}F}$, J = 249.3 Hz), 113.83, 110.88, 100.65, 68.83, 55.79, 47.86 (C-F, $^3J_{C\text{-}F}$, J = 7.2 Hz), 43.45 (C-F, $^3J_{C\text{-}F}$, J = 4.4 Hz), 37.43 (C-F,

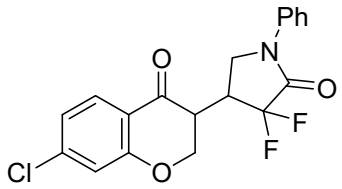
$^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.56, -106.03, -117.02, -117.49; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_4$ 396.1018; Found 396.1005.

3,3-difluoro-4-(7-fluoro-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2i)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a yellow solid (61 mg, 85%), m.p. 174.2–175.4 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (dd, J = 8.6, 6.7 Hz, 1H), 7.58 (d, J = 8.1 Hz, 2H), 7.33 (t, J = 7.9 Hz, 2H), 7.20 – 7.14 (m, 1H), 6.75 – 6.68 (m, 1H), 6.67 – 6.56 (m, 1H), 4.76 (dd, J = 11.7, 4.2 Hz, 1H), 4.47 (dd, J = 11.5, 9.5 Hz, 1H), 4.20 (t, J = 9.5 Hz, 1H), 3.79 (t, J = 9.6 Hz, 1H), 2.24 – 2.06 (m, 1H), 2.89 – 2.75 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 190.53, 167.85 (C–F, $^{1}J_{C\text{-}F}$, J = 257.9 Hz), 163.22 (C–F, $^{3}J_{C\text{-}F}$, J = 13.8 Hz), 161.04 (C–F, $^{2}J_{C\text{-}F}$, J = 29.7 Hz), 137.60, 129.97 (C–F, $^{3}J_{C\text{-}F}$, J = 11.5 Hz), 129.22, 126.37, 119.99, 117.28 (C–F, $^{1}J_{C\text{-}F}$, J = 249.5 Hz), 116.99, 110.56 (C–F, $^{2}J_{C\text{-}F}$, J = 22.9 Hz), 104.86 (C–F, $^{2}J_{C\text{-}F}$, J = 24.7 Hz), 68.97, 47.84 (C–F, $^{3}J_{C\text{-}F}$, J = 7.1 Hz), 43.60 (C–F, $^{3}J_{C\text{-}F}$, J = 4.5 Hz), 37.31 (C–F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -98.65, -105.40, -105.87, -116.84, -117.31; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}F_3NO_3$ 362.0999; Found 362.0995.

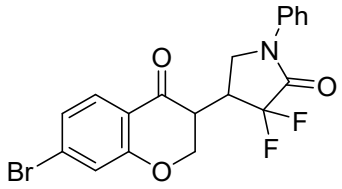
4-(7-chloro-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one（2j）



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (68 mg, 90%), m.p. 189.8–191.1 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, J = 8.3 Hz, 1H), 7.68 (d, J = 7.9 Hz, 2H), 7.44 (t, J = 7.7 Hz, 2H), 7.30 – 7.23 (m, 1H), 7.12 – 7.02 (m, 2H), 4.92 – 4.81 (m, 1H), 4.62 – 4.51 (m, 1H), 4.31 (t, J = 9.4 Hz, 1H), 3.89 (t, J = 9.4 Hz, 1H), 3.32 – 3.21 (m, 1H), 3.03 – 2.81 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 190.94, 161.81, 161.01 (C-F, $^{2}J_{C\text{-}F}$, J = 30.2 Hz), 142.78, 137.59, 129.23, 128.55, 126.39, 122.82, 119.99, 118.60, 118.19, 117.25 (C-F, $^{1}J_{C\text{-}F}$, J = 249.5 Hz), 68.83, 47.86, 43.75, 37.31 (t, J = 20.4 Hz). ^{19}F NMR

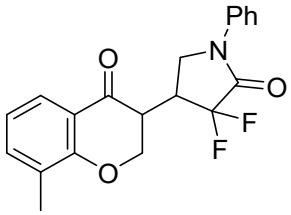
(565 MHz, $CDCl_3$) δ -105.37, -105.85, -116.79, -117.27; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}ClF_2NNaO_3$ 400.0522; Found 400.0518.

4-(7-bromo-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one (2k)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (70 mg, 83%), m.p. 202.7–204.1 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.75 (d, J = 8.4 Hz, 1H), 7.68 (d, J = 8.2 Hz, 2H), 7.44 (t, J = 7.8 Hz, 2H), 7.31 – 7.26 (m, 2H), 7.23 (d, J = 8.4 Hz, 1H), 4.89 – 4.83 (m, 1H), 4.62 – 4.52 (m, 1H), 4.31 (t, J = 9.4 Hz, 1H), 3.89 (t, J = 9.5 Hz, 1H), 3.31 – 3.20 (m, 1H), 3.01 – 2.83 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.12, 161.66, 161.01 (C-F, $^2J_{C-F}$, J = 29.4 Hz), 137.59, 131.37, 129.23, 128.51, 126.40, 125.68, 121.27, 120.01, 118.94, 117.23 (C-F, $^1J_{C-F}$, J = 249.5 Hz), 68.82, 47.86, 43.79, 37.33 (C-F, $^3J_{C-F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.37, -105.84, -116.79, -117.26; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}BrF_2NNaO_3$ 444.0017; Found 444.0014.

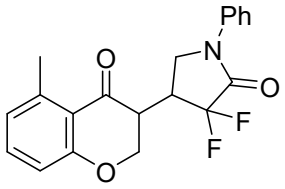
3,3-difluoro-4-(8-methyl-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2l)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (48 mg, 67%), m.p. 156.3–157.6 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.74 (d, J = 7.9 Hz, 1H), 7.72 – 7.67 (m, 2H), 7.47 – 7.39 (m, 3H), 7.31 – 7.24 (m, 1H), 7.04 – 6.92 (m, 1H), 4.94 – 4.83 (m, 1H), 4.62 – 4.51 (m, 1H), 4.35 – 4.27 (m, 1H), 3.92 – 3.84 (m, 1H), 3.30 – 3.20 (m, 1H), 3.07 – 2.88 (m, 1H), 2.29 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.38, 161.23 (C-F, $^2J_{C-F}$, J = 30.2 Hz), 159.79, 137.69, 137.58, 129.21, 127.46, 126.31, 124.85, 121.32, 119.99, 119.71, 117.46 (C-F, $^1J_{C-F}$, J = 249.2 Hz), 68.42, 47.89 (C-F, $^3J_{C-F}$, J = 7.1 Hz), 43.73 (C-F, $^3J_{C-F}$, J = 4.4 Hz), 37.29 (C-F, $^2J_{C-F}$, J = 20.4 Hz), 15.53. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.37, -105.84, -116.82, -117.30; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for

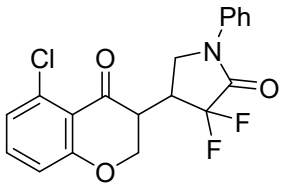
$C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1057.

3,3-difluoro-4-(5-methyl-4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2m)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (49 mg, 69%), m.p. 137.5–138.6 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, J = 7.7 Hz, 2H), 7.44 (t, J = 7.6 Hz, 2H), 7.38 (t, J = 7.6 Hz, 1H), 7.30 – 7.22 (dt, J = 8.4, 1.0 Hz, 1H), 6.91 (d, J = 8.1 Hz, 1H), 6.86 (d, J = 7.4 Hz, 1H), 4.84 – 4.75 (m, 1H), 4.54 – 4.46 (m, 1H), 4.31 (t, J = 9.5 Hz, 1H), 3.87 (t, 1H), 3.27 – 3.17 (m, 1H), 3.04 – 2.84 (m, 1H), 2.65 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.32, 162.51, 161.27 (C-F, $^2J_{C\text{-}F}$, J = 29.8 Hz), 142.37, 137.70, 135.37, 129.18, 126.31, 125.05, 120.07, 118.65, 117.52 (C-F, $^1J_{C\text{-}F}$, J = 249.3 Hz), 115.95, 67.85, 48.03 (C-F, $^3J_{C\text{-}F}$, J = 7.3 Hz), 45.00 (C-F, $^3J_{C\text{-}F}$, J = 4.2 Hz), 37.44 (C-F, $^2J_{C\text{-}F}$, J = 20.3 Hz), 22.81. ^{19}F NMR (376 MHz, $CDCl_3$) δ -105.29, -105.97, -116.82, -117.48; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1054.

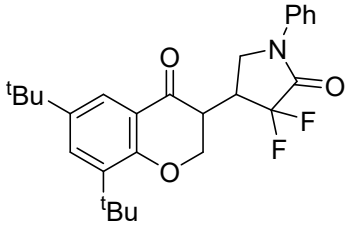
4-(5-chloro-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one (2n)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (59 mg, 78%), m.p. 154.7–115.6 ℃. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 (d, J = 7.8 Hz, 2H), 7.45 – 7.37 (m, 3H), 7.26 (t, J = 7.4 Hz, 1H), 7.10 (d, J = 7.9 Hz, 1H), 6.99 (d, J = 8.4 Hz, 1H), 4.90 – 4.83 (m, 1H), 4.53 – 4.46 (m, 1H), 4.41 (J = 9.0 Hz, 1H), 3.90 – 3.81 (m, 1H), 3.37 – 3.27 (m, 1H), 3.04 – 2.82 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 190.26, 162.85, 161.02 (C-F, $^2J_{C\text{-}F}$, J = 30.9 Hz), 137.61, 135.48, 134.44, 129.21, 126.36, 125.08, 119.99, 117.44 (C-F, $^1J_{C\text{-}F}$, J = 244.2 Hz), 117.39, 117.11, 68.08, 47.99 (C-F, $^3J_{C\text{-}F}$, J = 7.0 Hz), 44.72 (C-F, $^3J_{C\text{-}F}$, J = 4.4 Hz), 37.30 (C-F, $^2J_{C\text{-}F}$, J = 20.2 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -

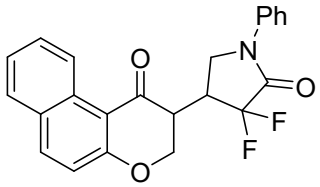
105.18, -105.65, -116.61, -117.08; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}ClF_2NO_3$ 378.0703; Found 378.0697.

4-(6,8-di-tert-butyl-4-oxochroman-3-yl)-3,3-difluoro-1-phenylpyrrolidin-2-one (2o)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (57 mg, 63%), m.p. 214.3–215.9 ℃. ^{1}H NMR (600 MHz, DMSO) δ 7.70 (d, *J* = 7.8 Hz, 2H), 7.66 (d, *J* = 2.4 Hz, 1H), 7.56 (d, *J* = 2.5 Hz, 1H), 7.48 (t, *J* = 8.0 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 1H), 4.79 – 4.72 (m, 1H), 4.58 (t, *J* = 10.7 Hz, 1H), 4.17 (t, *J* = 9.4 Hz, 1H), 4.01 (t, *J* = 8.3 Hz, 1H), 3.46 – 3.40 (m, 1H), 3.29 – 3.22 (m, 1H), 1.39 (s, 9H), 1.28 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.90, 161.30 (C-F, $^2J_{C\text{-}F}$, *J* = 29.7 Hz), 158.67, 143.98, 138.69, 137.72, 131.59, 129.18, 126.28, 121.20, 120.01, 119.98, 117.41 (C-F, $^2J_{C\text{-}F}$, *J* = 250.3 Hz), 68.00, 47.88, 43.74, 37.43 (C-F, $^2J_{C\text{-}F}$, *J* = 20.4 Hz), 35.17, 34.54, 31.26, 29.66. ^{19}F NMR (565 MHz, DMSO) δ -102.10, -102.56, -114.22, -114.69; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{27}H_{31}F_2NNaO_3$ 478.2164; Found 478.2154.

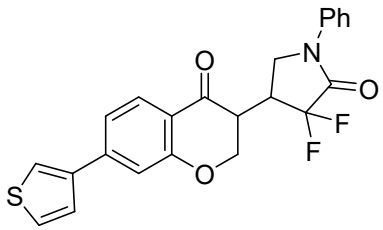
3,3-difluoro-4-(1-oxo-2,3-dihydro-1H-benzo[f]chromen-2-yl)-1-phenylpyrrolidin-2-one (2p)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (56mg, 71%), m.p. 176.7–177.9 ℃. ^{1}H NMR (600 MHz, $CDCl_3$) δ 9.39 (d, *J* = 8.6 Hz, 1H), 7.99 (d, *J* = 9.0 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.74 – 7.64 (m, 3H), 7.48 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 7.4 Hz, 1H), 7.17 (d, *J* = 9.0 Hz, 1H), 4.96 – 4.87 (m, 1H), 4.73 – 4.63 (m, 1H), 4.28 (t, *J* = 9.4 Hz, 1H), 3.94 (t, *J* = 9.5 Hz, 1H), 3.36 – 3.26 (m, 1H), 3.09 – 2.93 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.73, 163.73, 161.27 (C-F, $^2J_{C\text{-}F}$, *J* = 29.7

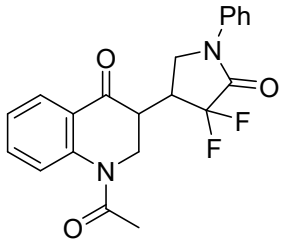
Hz), 138.34, 137.68, 131.37, 130.01, 129.33, 129.19, 128.72, 126.32, 125.43, 125.23, 120.05, 118.54, 117.48 (C-F, $^{1}J_{C\text{-}F}$, J = 249.8 Hz), 111.62, 68.39, 47.94 (C-F, $^{3}J_{C\text{-}F}$, J = 7.2 Hz), 44.51 (C-F, $^{3}J_{C\text{-}F}$, J = 4.4 Hz), 37.56 (C-F, $^{2}J_{C\text{-}F}$, J = 20.2 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.44, -105.91, -116.88, -117.35; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{18}F_2NO_3$ 394.1249; Found 394.1243.

3,3-difluoro-4-(4-oxo-7-(thiophen-3-yl)chroman-3-yl)-1-phenylpyrrolidin-2-one (2q)



The product was purified by column chromatography on silica gel (eluent: 20:1 petroleum ether: ethyl acetate) as a white solid (63 mg, 74%), m.p. 153.8–154.4 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, J = 2.2 Hz, 1H), 7.83 – 7.78 (m, 1H), 7.69 (d, J = 7.9 Hz, 2H), 7.48 – 7.41 (m, 4H), 7.40 – 7.37 (m, 1H), 7.28 (t, J = 7.4 Hz, 1H), 7.10 (d, J = 8.6 Hz, 1H), 4.91 – 4.81 (m, 1H), 4.65 – 4.55 (m, 1H), 4.30 (t, J = 9.4 Hz, 1H), 3.92 (t, J = 9.5 Hz, 1H), 3.33 – 3.24 (m, 1H), 3.07 – 2.89 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.99, 161.14 (C-F, $^{2}J_{C\text{-}F}$, J = 29.9 Hz), 160.59, 140.43, 137.63, 134.89, 130.07, 129.23, 126.74, 126.37, 125.93, 124.43, 120.28, 120.01, 118.59, 117.30 (C-F, $^{1}J_{C\text{-}F}$, J = 250.0 Hz), 68.56, 47.84, 43.93, 37.32 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -105.25, -105.96, -116.72, -117.43; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{17}F_2NNaO_3S$ 448.0789; Found 448.0793.

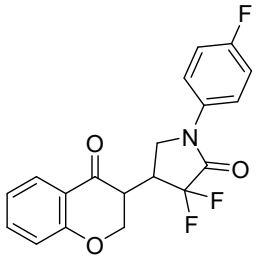
1-acetyl-3-(4,4-difluoro-5-oxo-1-phenylpyrrolidin-3-yl)-2,3-dihydroquinolin-4(1H)-one (2r)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (53 mg, 69%), m.p. 180.7–181.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, J = 7.7 Hz, 1H), 7.80 – 7.68 (m, 3H), 7.61 (t, J =

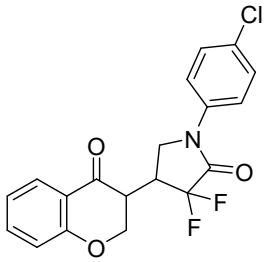
7.4 Hz, 1H), 7.45 (t, J = 7.8 Hz, 2H), 7.31 – 7.26 (m, 2H), 4.87 (d, J = 11.9 Hz, 1H), 4.47 (t, J = 9.4 Hz, 1H), 4.01 – 3.83 (m, 2H), 3.29 – 3.19 (m, 1H), 2.96 – 2.81 (m, 1H), 2.44 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.94, 169.48, 160.95 (C-F, $^2J_{C\text{-}F}$, J = 31.7 Hz), 143.71, 137.63, 134.91, 129.24, 127.83, 126.39, 125.36, 124.38, 124.12, 120.05, 117.52 (C-F, $^1J_{C\text{-}F}$, J = 250.6 Hz), 48.39, 47.69, 46.48, 38.60 (C-F, $^2J_{C\text{-}F}$, J = 20.0 Hz), 23.44. ^{19}F NMR (376 MHz, $CDCl_3$) δ -104.33, -105.04, -116.61, -117.32; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{21}H_{18}F_2N_2NaO_3$ 407.1177; Found 407.1174

3,3-difluoro-1-(4-fluorophenyl)-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2s)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (60 mg, 83%), m.p. 132.4–133.6 ℃. ^{1}H NMR (600 MHz, DMSO) δ 7.79 (d, J = 7.7 Hz, 1H), 7.74 (dd, J = 8.7, 4.8 Hz, 2H), 7.62 (t, J = 7.7 Hz, 1H), 7.32 (t, J = 8.1 Hz, 2H), 7.11 (t, J = 8.3 Hz, 2H), 4.78 – 4.69 (m, 1H), 4.59 (t, J = 11.0 Hz, 1H), 4.18 (t, J = 9.2 Hz, 1H), 4.03 – 3.93 (m, 1H), 3.53 – 3.44 (m, 1H), 3.32 – 3.22 (m, 1H). ^{13}C NMR (151 MHz, DMSO) δ 192.05, 161.45, 161.37 (C-F, $^2J_{C\text{-}F}$, J = 30.4 Hz), 160.14 (C-F, $^1J_{C\text{-}F}$, J = 243.6 Hz), 136.98, 134.59 (C-F, $^4J_{C\text{-}F}$, J = 2.6 Hz), 127.24, 123.06 (C-F, $^3J_{C\text{-}F}$, J = 8.3 Hz), 122.09, 120.60, 118.74 (C-F, $^1J_{C\text{-}F}$, J = 250.1 Hz), 118.23, 116.31 (C-F, $^2J_{C\text{-}F}$, J = 22.6 Hz), 68.58, 47.96 (C-F, $^3J_{C\text{-}F}$, J = 6.1 Hz), 44.04 (C-F, $^3J_{C\text{-}F}$, J = 4.0 Hz), 36.14 (C-F, $^2J_{C\text{-}F}$, J = 20.2 Hz). ^{19}F NMR (565 MHz, DMSO) δ -102.00, -102.47, -114.06, -114.53, -115.65; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}F_3NNaO_3$ 384.0818; Found 384.0803.

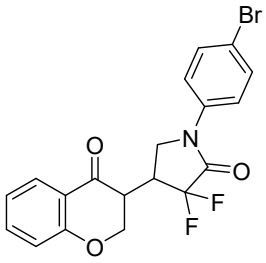
1-(4-chlorophenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2t)



The product was purified by column chromatography on silica gel (eluent: 10:1

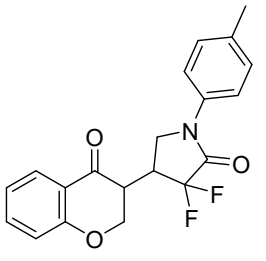
petroleum ether: ethyl acetate) as a white solid (65 mg, 86%), m.p. 136.2–137.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.69 – 7.63 (m, 2H), 7.59 – 7.54 (m, 1H), 7.43 – 7.38 (m, 2H), 7.12 – 7.03 (m, 2H), 4.88 – 4.81 (m, 1H), 4.61 – 4.51 (m, 1H), 4.29 (t, *J* = 9.6 Hz, 1H), 3.88 (t, *J* = 9.6 Hz, 1H), 3.29 – 3.22 (m, 1H), 3.02 – 2.89 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.94, 161.53, 161.16 (C-F, $^2J_{C\text{-}F}$, *J* = 30.0 Hz), 136.86, 136.19, 131.66, 129.29, 127.32, 121.98, 121.08, 119.98, 118.07, 117.14 (C-F, $^1J_{C\text{-}F}$, *J* = 249.3 Hz), 68.45, 47.79, 43.86, 37.24 (C-F, $^2J_{C\text{-}F}$, *J* = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.49, -105.96, -116.73, -117.21; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}ClF_2NO_3$ 378.0703; Found 378.0699.

1-(4-bromophenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2u)



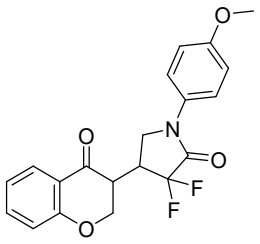
The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (50 mg, 77%), m.p. 154.1–155.4 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.63 – 7.58 (m, 2H), 7.57 – 7.52 (m, 3H), 7.13 – 7.07 (m, 1H), 7.05 (d, *J* = 8.3 Hz, 1H), 4.83 (dd, *J* = 11.6, 4.2 Hz, 1H), 4.55 (dd, *J* = 11.7, 9.2 Hz, 1H), 4.32 – 4.24 (m, 1H), 3.87 (t, *J* = 9.6 Hz, 1H), 3.31 – 3.20 (m, 1H), 3.03 – 2.88 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.93, 161.53, 161.16 (C-F, $^2J_{C\text{-}F}$, *J* = 30.0 Hz), 136.86, 136.70, 132.24, 127.31, 121.98, 121.33, 119.98, 119.43, 118.07, 117.19 (C-F, $^1J_{C\text{-}F}$, *J* = 249.4 Hz), 68.45, 47.72, 43.85, 37.21 (C-F, $^2J_{C\text{-}F}$, *J* = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.47, -105.94, -116.70, -117.18; HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}BrF_2NO_3$ 422.0198; Found 422.0196.

3,3-difluoro-4-(4-oxochroman-3-yl)-1-(p-tolyl)pyrrolidin-2-one (2v)



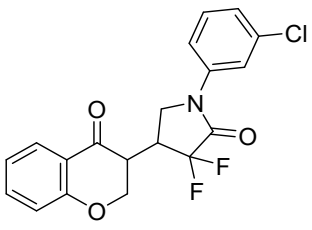
The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (56 mg, 79%), m.p. 136.6–137.9 ℃. ^{1}H NMR (600 MHz, DMSO) δ 7.79 (d, *J* = 7.3 Hz, 1H), 7.65 – 7.56 (m, 3H), 7.28 (d, *J* = 8.1 Hz, 2H), 7.15 – 7.09 (m, 2H), 4.73 (dd, *J* = 11.3, 4.4 Hz, 1H), 4.58 (t, *J* = 11.0 Hz, 1H), 4.18 (t, *J* = 9.3 Hz, 1H), 3.97 (t, *J* = 8.3 Hz, 1H), 3.56 – 3.44 (m, 1H), 3.31 – 3.21 (m, 1H), 2.32 (s, 3H). ^{13}C NMR (151 MHz, DMSO) δ 192.08, 161.43, 161.18 (C-F, $^{2}J_{C\text{-}F}$, *J* = 30.9 Hz), 136.96, 135.85, 135.76, 129.95, 127.22, 122.08, 120.62, 120.60, 118.82 (C-F, $^{1}J_{C\text{-}F}$, *J* = 249.7 Hz), 118.22, 68.58, 47.78 (C-F, $^{3}J_{C\text{-}F}$, *J* = 6.1 Hz), 44.03 (C-F, $^{3}J_{C\text{-}F}$, *J* = 4.0 Hz), 36.11 (C-F, $^{2}J_{C\text{-}F}$, *J* = 20.4 Hz), 20.97. ^{19}F NMR (565 MHz, DMSO) δ -102.03, -102.49, -114.04, -114.50; HRMS (ESI) m/z: $[M+Na]^{+}$ Calcd for $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1055.

3,3-difluoro-1-(4-methoxyphenyl)-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2w)



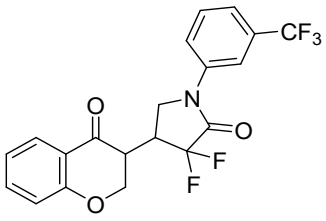
The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (61 mg, 82%), m.p. 134.5–135.6 ℃. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.61 – 7.53 (m, 3H), 7.11 – 7.03 (m, 2H), 6.97 – 6.92 (m, 2H), 4.84 (dd, *J* = 11.6, 4.3 Hz, 1H), 4.56 (dd, *J* = 11.7, 9.0 Hz, 1H), 4.24 (t, *J* = 9.5 Hz, 1H), 3.87 (t, *J* = 9.6 Hz, 1H), 3.83 (s, 3H), 3.29 – 3.19 (m, 1H), 3.01 – 2.86 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.02, 161.54, 160.86 (C-F, $^{2}J_{C\text{-}F}$, *J* = 29.8 Hz), 157.76, 136.77, 130.72, 127.31, 121.92, 121.72, 120.03, 118.05, 117.50 (C-F, $^{1}J_{C\text{-}F}$, *J* = 249.3 Hz), 114.34, 68.52, 55.51, 48.18 (C-F, $^{3}J_{C\text{-}F}$, *J* = 7.1 Hz), 43.91 (C-F, $^{3}J_{C\text{-}F}$, *J* = 4.5 Hz), 37.35 (C-F, $^{2}J_{C\text{-}F}$, *J* = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.28, -105.75, -116.66, -117.13; HRMS (ESI) m/z: $[M+Na]^{+}$ Calcd for $C_{20}H_{17}F_2NNaO_4$ 396.1018; Found 396.1006.

1-(3-chlorophenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2x)



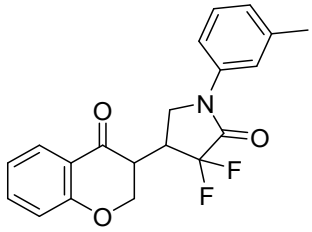
The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (65 mg, 86%), m.p. 136.7–137.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.89 (dd, J = 7.9, 1.5 Hz, 1H), 7.74 (t, J = 1.9 Hz, 1H), 7.62 (dd, J = 8.2, 1.4 Hz, 1H), 7.58 – 7.53 (m, 1H), 7.36 (t, J = 8.1 Hz, 1H), 7.24 (dd, J = 8.0, 1.1 Hz, 1H), 7.12 – 7.07 (m, 1H), 7.05 (d, J = 8.3 Hz, 1H), 4.84 (dd, J = 11.6, 4.2 Hz, 1H), 4.55 (dd, J = 11.7, 9.3 Hz, 1H), 4.33 – 4.27 (m, 1H), 3.87 (t, J = 9.6 Hz, 1H), 3.30 – 3.21 (m, 1H), 3.03 – 2.87 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.91, 161.53, 161.24 (C-F, $^{2}J_{C\text{-}F}$, J = 29.9 Hz), 138.72, 136.85, 135.02, 130.22, 127.32, 126.35, 121.98, 119.98, 118.05, 117.85, 117.14 (C-F, $^{1}J_{C\text{-}F}$, J = 249.5 Hz), 68.45, 47.77, 43.85, 37.25 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.53, -106.00, -116.77, -117.25; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{14}ClF_2NNaO_3$ 400.0522; Found 400.0508.

3,3-difluoro-4-(4-oxochroman-3-yl)-1-(3-(trifluoromethyl)phenyl)pyrrolidin-2-one (2y)



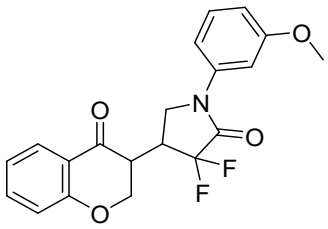
The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (53 mg, 65%), m.p. 156.5–157.6 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96 – 7.92 (m, 2H), 7.90 – 7.87 (m, 1H), 7.58 – 7.50 (m, 3H), 7.10 – 7.02 (m, 2H), 4.86 – 4.80 (m, 1H), 4.58 – 4.49 (m, 1H), 4.35 (t, J = 9.5 Hz, 1H), 3.92 (t, J = 9.5 Hz, 1H), 3.29 – 3.24 (m, 1H), 3.00 – 2.90 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.91, 161.52, 161.40 (C-F, $^{2}J_{C\text{-}F}$, J = 30.1 Hz), 138.19, 136.84, 131.66 (C-F, $^{2}J_{C\text{-}F}$, J = 32.8 Hz), 129.84, 127.27, 123.60 (C-F, $^{1}J_{C\text{-}F}$, J = 272.6 Hz), 122.99, 122.79 (C-F, $^{3}J_{C\text{-}F}$, J = 3.6 Hz), 121.96, 119.97, 118.03, 117.07 (C-F, $^{1}J_{C\text{-}F}$, J = 249.4 Hz), 116.51 (C-F, $^{3}J_{C\text{-}F}$, J = 3.8 Hz), 68.42, 47.74 (C-F, $^{3}J_{C\text{-}F}$, J = 7.1 Hz), 43.82 (C-F, $^{3}J_{C\text{-}F}$, J = 4.3 Hz), 37.26 (C-F, $^{3}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -62.70, -105.56, -106.04, -116.80, -117.27; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{14}F_5NNaO_3$ 434.0786; Found 434.0773.

3,3-difluoro-4-(4-oxochroman-3-yl)-1-(m-tolyl)pyrrolidin-2-one (2z)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (55 mg, 77%), m.p. 139.7–140.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90 (d, J = 7.3 Hz, 1H), 7.56 (t, J = 7.2 Hz, 1H), 7.48 (s, 2H), 7.31 (t, J = 8.1 Hz, 1H), 7.11 – 7.03 (m, 3H), 4.89 – 4.80 (m, 1H), 4.59 – 4.53 (m, 1H), 4.28 (t, J = 9.4 Hz, 1H), 3.89 (t, J = 9.4 Hz, 1H), 3.30 – 3.21 (m, 1H), 3.01 – 2.87 (m, 1H), 2.40 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.02, 161.55, 161.11 (C-F, $^{2}J_{C\text{-}F}$, J = 31.7 Hz), 139.22, 137.59, 136.77, 129.00, 127.30, 127.15, 121.92, 120.63, 120.03, 118.05, 117.38 (C-F, $^{1}J_{C\text{-}F}$, J = 250.2 Hz), 117.21, 68.51, 47.96, 43.91, 37.31 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz), 21.54. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.35, -105.82, -116.90, -117.37; HRMS (ESI) m/z: $[M+Na]^+$ $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1056.

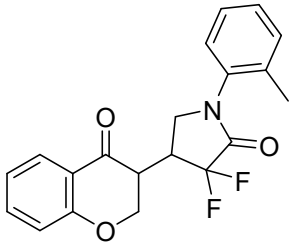
3,3-difluoro-1-(3-methoxyphenyl)-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2aa)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (54 mg, 72%), m.p. 152.3–153.7 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.88 (dd, J = 7.9, 1.6 Hz, 1H), 7.58 – 7.52 (m, 1H), 7.39 (t, J = 2.2 Hz, 1H), 7.31 (t, J = 8.2 Hz, 1H), 7.16 (dd, J = 8.1, 1.5 Hz, 1H), 7.09 – 7.06 (m, 1H), 7.04 (d, J = 8.3 Hz, 1H), 6.80 (dd, J = 8.2, 2.2 Hz, 1H), 4.82 (dd, J = 11.6, 4.3 Hz, 1H), 4.54 (dd, J = 11.7, 9.2 Hz, 1H), 4.31 – 4.24 (m, 1H), 3.91 – 3.84 (m, 1H), 3.83 (s, 3H), 3.28 – 3.20 (m, 1H), 3.01 – 2.83 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.93, 161.51, 161.20 (C-F, $^{2}J_{C\text{-}F}$, J = 29.8 Hz), 160.14, 138.80, 136.76, 129.89, 127.31, 121.92, 120.02, 118.03, 117.35 (C-F, $^{1}J_{C\text{-}F}$, J = 249.4 Hz), 112.08, 111.89, 106.08,

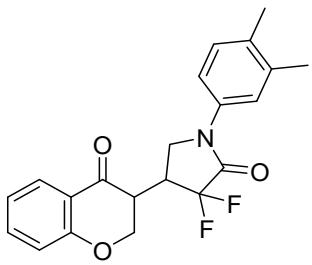
68.49, 55.44, 47.97, 43.88, 37.21 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.35, -105.82, -116.79, -117.27; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_4$ 396.1018; Found 396.1000.

3,3-difluoro-4-(4-oxochroman-3-yl)-1-(o-tolyl)pyrrolidin-2-one (2ab)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (41 mg, 58%), m.p. 143.2–144.6 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.75 (d, J = 7.8 Hz, 1H), 7.69 (d, J = 8.4 Hz, 2H), 7.49 – 7.38 (m, 3H), 7.26 (d, J = 7.3 Hz, 1H), 6.98 (t, J = 7.6 Hz, 1H), 4.88 (dd, J = 11.6, 4.3 Hz, 1H), 4.57 (dd, J = 11.6, 9.4 Hz, 1H), 4.37 – 4.28 (m, 1H), 3.90 (t, J = 9.6 Hz, 1H), 3.29 – 3.21 (m, 1H), 3.03 – 2.88 (m, 1H), 2.29 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.38, 161.23 (C-F, $^{2}J_{C\text{-}F}$, J = 29.8 Hz), 159.78, 137.66, 137.58, 129.21, 127.46, 126.33, 124.85, 121.32, 120.01, 119.69, 117.38 (C-F, $^{1}J_{C\text{-}F}$, J = 249.2 Hz), 68.42, 47.92, 43.75, 37.33 (C-F, $^{2}J_{C\text{-}F}$, J = 20.3 Hz), 15.53. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.42, -105.90, -116.87, -117.34; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{17}F_2NNaO_3$ 380.1069; Found 380.1054.

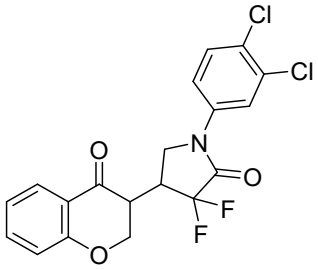
1-(3,4-dimethylphenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2ac)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (52 mg, 70%), m.p. 146.9–148.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90 (dd, J = 7.9, 1.7 Hz, 1H), 7.58 – 7.54 (m, 1H), 7.44 (d, J = 2.2 Hz, 1H), 7.39 (dd, J = 8.2, 2.4 Hz, 1H), 7.17 (d, J = 8.2 Hz, 1H), 7.11 – 7.07 (m, 1H), 7.06 (d, J = 8.4 Hz, 1H), 4.84 (dd, J = 11.5, 4.3 Hz, 1H), 4.56 (dd, J = 11.7, 9.1 Hz, 1H), 4.28 – 4.22 (m, 1H), 3.91 – 3.81 (m, 1H), 3.31 – 3.20 (m, 1H), 3.03 – 2.86

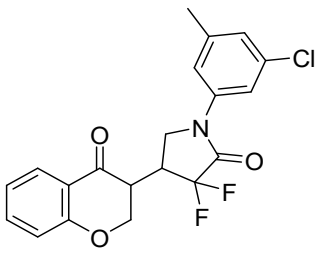
(m, 1H), 2.30 (s, 3H), 2.27 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.07, 161.55, 160.97 (C-F, $^{2}J_{C\text{-}F}$, J = 29.6 Hz), 137.61, 136.77, 135.37, 134.99, 130.15, 127.30, 121.92, 121.24, 120.04, 118.06, 117.60, 117.49 (C-F, $^{1}J_{C\text{-}F}$, J = 249.2 Hz), 68.53, 48.00 (C-F, $^{3}J_{C\text{-}F}$, J = 7.1 Hz), 43.93 (C-F, $^{3}J_{C\text{-}F}$, J = 4.5 Hz), 37.33 (C-F, $^{2}J_{C\text{-}F}$, J = 20.4 Hz), 19.98, 19.31. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.31, -105.78, -116.81, -117.29; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{21}H_{19}F_2NNaO_3$ 394.1225; Found 394.1214.

1-(3,4-dichlorophenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2ad)



The product was purified by column chromatography on silica gel (eluent: 10:1 petroleum ether: ethyl acetate) as a white solid (72 mg, 88%), m.p. 162.4–163.6 ℃. ^{1}H NMR (600 MHz, DMSO) δ 8.03 (d, J = 2.1 Hz, 1H), 7.80 – 7.77 (m, 1H), 7.75 – 7.70 (m, 2H), 7.64 – 7.59 (m, 1H), 7.13 – 7.09 (m, 2H), 4.73 (dd, J = 11.4, 4.7 Hz, 1H), 4.60 (t, J = 11.1 Hz, 1H), 4.21 (t, J = 9.4 Hz, 1H), 4.06 – 3.99 (m, 1H), 3.54 – 3.47 (m, 1H), 3.33 – 3.21 (m, 1H). ^{13}C NMR (151 MHz, DMSO) δ 191.97, 161.80 (C-F, $^{2}J_{C\text{-}F}$, J = 30.7 Hz), 161.43, 138.06, 137.00, 131.94, 131.41, 128.37, 127.21, 122.18, 122.07, 120.69, 120.55, 118.48 (C-F, $^{1}J_{C\text{-}F}$, J = 251.5 Hz), 118.21, 68.54, 47.52, 44.13, 35.91 (C-F, $^{2}J_{C\text{-}F}$, J = 20.2 Hz). ^{19}F NMR (565 MHz, DMSO) δ -101.53, -102.00, -113.92, -114.39; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{13}Cl_2F_2NNaO_3$ 434.0133; Found 434.0130.

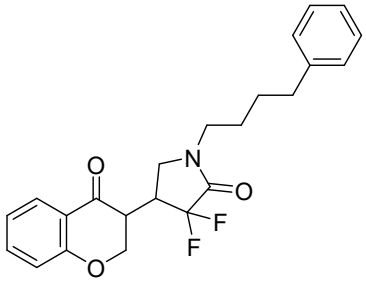
1-(3-chloro-5-methylphenyl)-3,3-difluoro-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2ae)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (62 mg, 79%), m.p. 154.1–155.4 ℃. ^{1}H

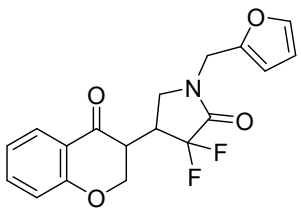
NMR (600 MHz, $CDCl_3$) δ 7.90 (dd, J = 7.8, 1.3 Hz, 1H), 7.61 – 7.51 (m, 2H), 7.41 (s, 1H), 7.15 – 7.00 (m, 3H), 4.84 (dd, J = 11.6, 4.1 Hz, 1H), 4.55 (dd, J = 11.6, 9.3 Hz, 1H), 4.28 (t, J = 9.4 Hz, 1H), 3.86 (t, J = 9.5 Hz, 1H), 3.34 – 3.18 (m, 1H), 3.00 – 2.84 (m, 1H), 2.38 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 191.97, 161.54, 161.19 (C-F, $^2J_{C\text{-}F}$, J = 29.9 Hz), 140.76, 138.48, 136.85, 134.64, 127.31, 127.05, 121.98, 119.99, 118.60, 118.06, 117.21, 117.12 (C-F, $^3J_{C\text{-}F}$, J = 249.4 Hz), 68.46, 47.84 (C-F, $^3J_{C\text{-}F}$, J = 7.1 Hz), 43.85 (C-F, $^3J_{C\text{-}F}$, J = 4.4 Hz), 37.25 (C-F, $^2J_{C\text{-}F}$, J = 20.4 Hz), 21.42. ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.48, -105.95, -116.81, -117.29; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{20}H_{16}ClF_2NNaO_3$ 414.0679; Found 414.0674.

3,3-difluoro-4-(4-oxochroman-3-yl)-1-(4-phenylbutyl)pyrrolidin-2-one (2af)



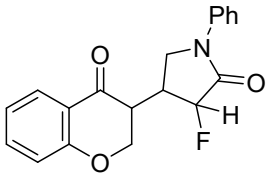
The product was purified by column chromatography on silica gel (eluent: 20:1 petroleum ether: ethyl acetate) as a white solid (66 mg, 83%), m.p. 140.5–141.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, J = 7.1 Hz, 1H), 7.56 (t, J = 7.2 Hz, 1H), 7.28 (d, J = 6.4 Hz, 2H), 7.18 (t, J = 6.9 Hz, 3H), 7.11 – 7.02 (m, 2H), 4.83 – 4.73 (m, 1H), 4.56 – 4.47 (m, 1H), 3.73 (t, J = 9.3 Hz, 1H), 3.49 – 3.30 (m, 3H), 3.19 – 3.09 (m, 1H), 2.86 – 2.71 (m, 1H), 2.66 (t, J = 6.0 Hz, 2H), 1.68 – 1.59 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.09, 162.43 (C-F, $^2J_{C\text{-}F}$, J = 29.8Hz), 161.54, 141.65, 136.72, 128.42, 128.41, 127.29, 125.95, 121.87, 120.05, 118.05, 117.74 (C-F, $^1J_{C\text{-}F}$, J = 251.1 Hz), 68.55, 46.72, 43.91, 43.27, 37.66 (C-F, $^2J_{C\text{-}F}$, J = 20.6 Hz), 35.23, 28.24, 26.13. ^{19}F NMR (376 MHz, $CDCl_3$) δ -106.61, -107.32, -116.59, -117.30. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{23}F_2NNaO_3$ 422.1538; Found 422.1534.

3,3-difluoro-1-(furan-2-ylmethyl)-4-(4-oxochroman-3-yl)pyrrolidin-2-one (2ag)



The product was purified by column chromatography on silica gel (eluent: 20:1 petroleum ether: ethyl acetate) as a white solid (55 mg, 79%), m.p. 121.7–122.8 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 7.9 Hz, 1H), 7.54 (t, *J* = 8.5 Hz, 1H), 7.40 (s, 1H), 7.11 – 7.00 (m, 2H), 6.40 – 6.29 (m, 2H), 4.82 – 4.74 (m, 1H), 4.55 (s, 2H), 4.52 – 4.45 (m, 1H), 3.82 (t, *J* = 9.5 Hz, 1H), 3.40 (t, *J* = 8.9 Hz, 1H), 3.18 – 3.07 (m, 1H), 2.87 – 2.71 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.99, 162.12 (C-F, $^{2}J_{C\text{-}F}$, *J* = 29.5Hz), 161.50, 147.77, 143.22, 136.69, 127.27, 121.86, 120.02, 118.02, 117.57 (C-F, $^{1}J_{C\text{-}F}$, *J* = 251.5 Hz), 110.61, 109.72, 68.53, 46.62, 43.91, 39.96, 37.62 (C-F, $^{2}J_{C\text{-}F}$, *J* = 20.7 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -106.54, -107.25, -116.58, -117.29. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{18}H_{15}F_2NNaO_4$ 370.0861; Found 370.0858.

3-fluoro-4-(4-oxochroman-3-yl)-1-phenylpyrrolidin-2-one (2ah)



The product was purified by column chromatography on silica gel (eluent: 15:1 petroleum ether: ethyl acetate) as a white solid (56 mg, 86%), m.p. 121.4–122.7 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.66 (dd, *J* = 8.6, 0.9 Hz, 2H), 7.58 – 7.53 (m, 1H), 7.44 – 7.37 (m, 2H), 7.25 – 7.20 (m, 1H), 7.11 – 7.07 (m, 1H), 7.05 (d, *J* = 8.4 Hz, 1H), 5.20 (dd, *J* = 52.9, 9.3 Hz, 1H), 4.79 – 4.72 (m, 1H), 4.57 – 4.48 (m, 1H), 4.25 (dd, *J* = 10.2, 8.7 Hz, 1H), 3.77 – 3.70 (m, 1H), 3.11 – 3.03 (m, 1H), 2.93 – 2.78 (m, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.26, 166.75 (C-F, $^{2}J_{C\text{-}F}$, *J* = 21.4 Hz), 161.55, 138.20, 136.66, 129.05, 127.32, 125.60, 121.92, 120.25, 119.82, 118.01, 91.88 (C-F, $^{1}J_{C\text{-}F}$, *J* = 191.3 Hz), 69.26, 47.94, 47.84 (C-F, $^{3}J_{C\text{-}F}$, *J* = 7.1 Hz), 37.54（C-F, $^{2}J_{C\text{-}F}$, *J* = 18.1 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -187.83; HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{16}FNNaO_3$ 348.1006; Found 348.0995.

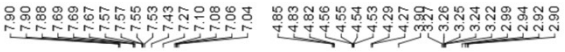
8. References

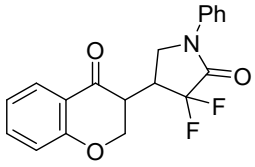
1. Wang, L.;Wei, X. J.; Jia, W. L.; Zhong, J. J.; Wu, L. Z.; Liu, Q. *Org. Lett*. **2014**, *16*, 5842-5845.

2. Gualandi, A.; Rodeghiero, G.; Faraone, A.; Patuzzo, F.; Marchini, M.; Calogero, F.; Perciaccante, R.; Jansen, P. T.; Ceroni, P.; Cozzi, P. G. *Chem. Commun.* **2019**, *55*, 6838-6841.

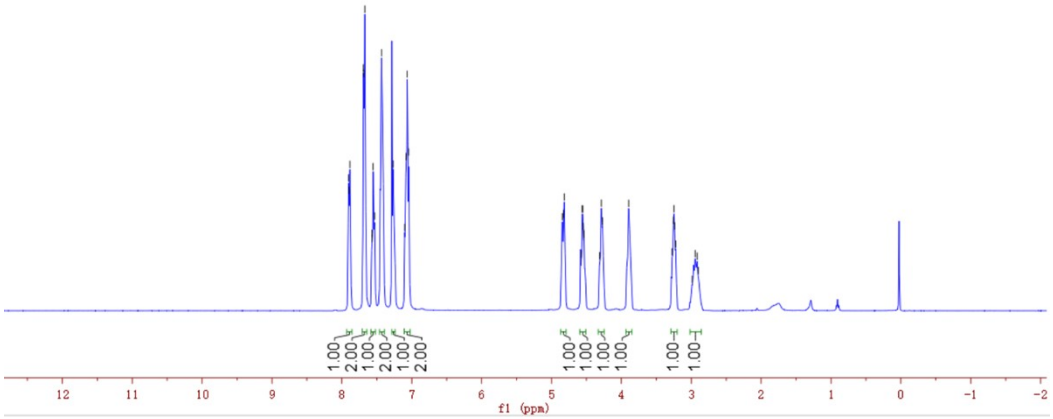
3. Johannes, K.; Lukasz, W.; Nicolai, C. *Angew. Chemie.* **2022**, doi: 10.1002/anie.202202306.

8 ^{1}H, ^{13}C and ^{19}F NMR spectra of products

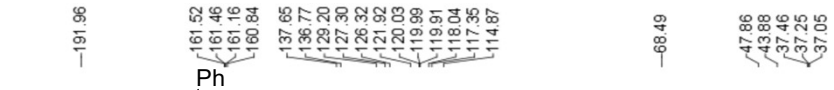


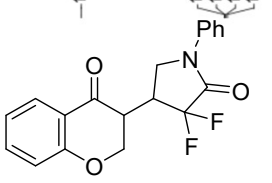


^{1}H NMR ($CDCl_3$, 400MHz)

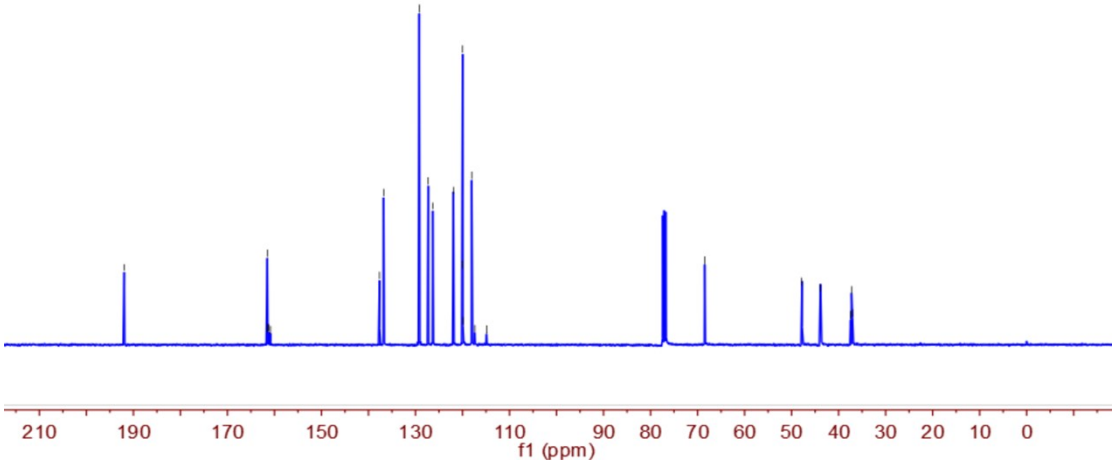


^{1}H NMR Spectrum of Compound 2a

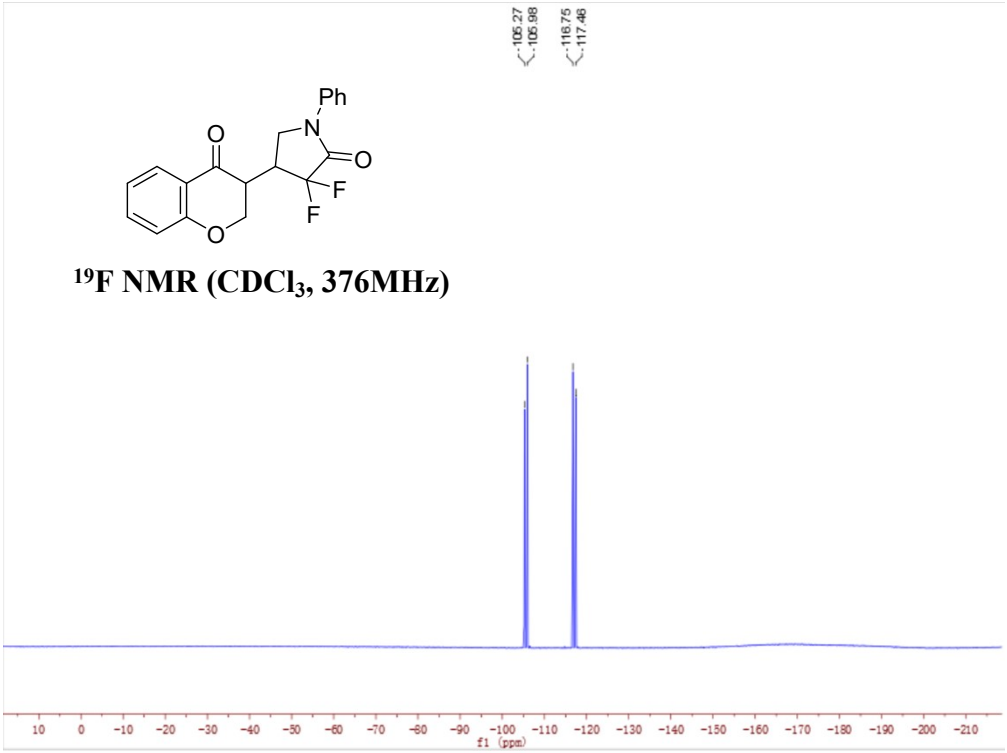




^{13}C NMR ($CDCl_3$, 101MHz)

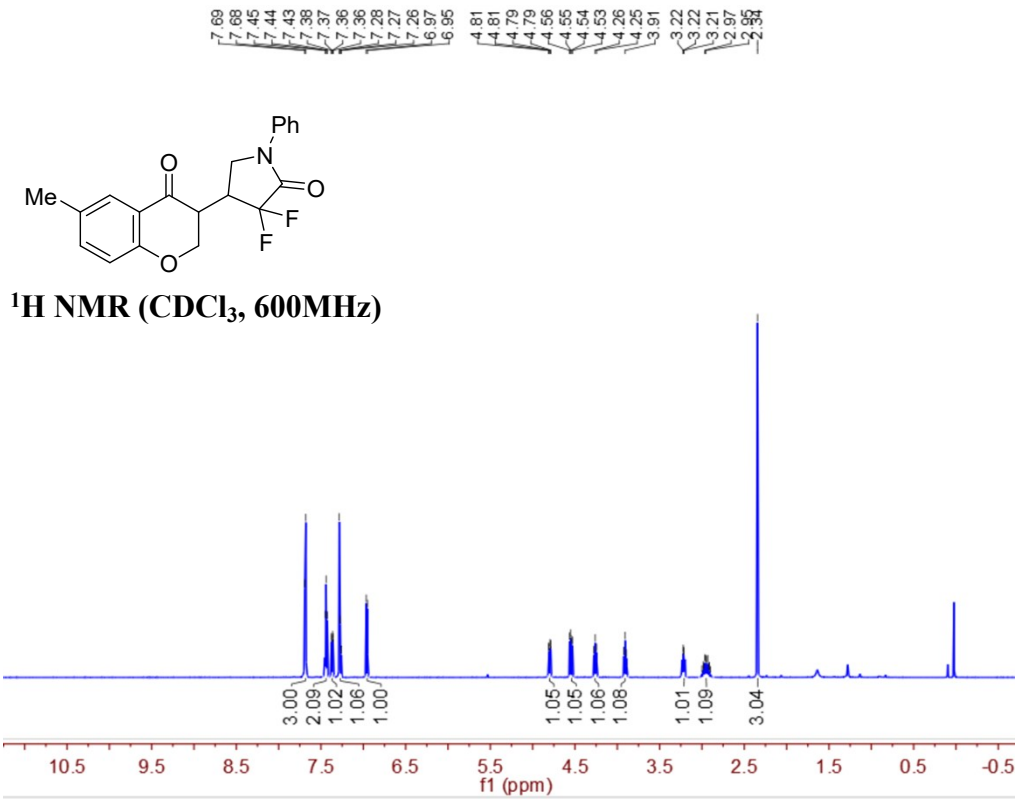


^{13}C NMR Spectrum of Compound 2a



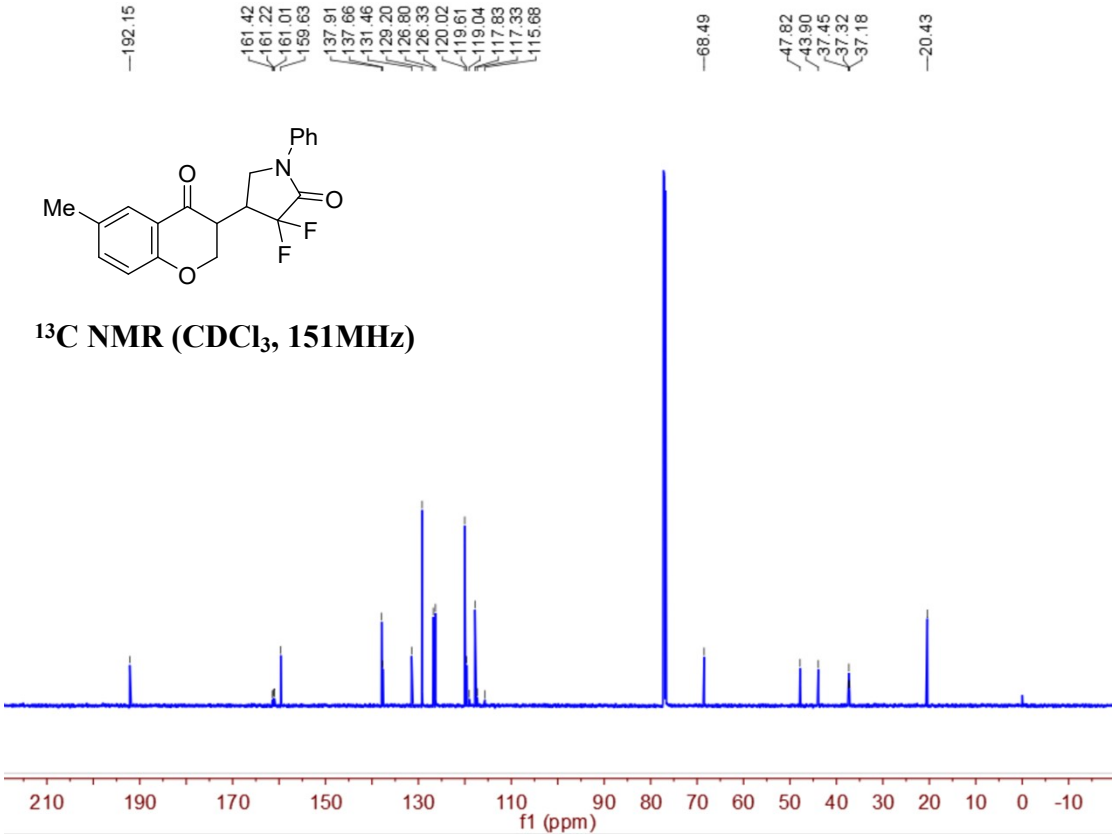
^{19}F NMR ($CDCl_3$, 376MHz)

^{19}F NMR Spectrum of Compound 2a



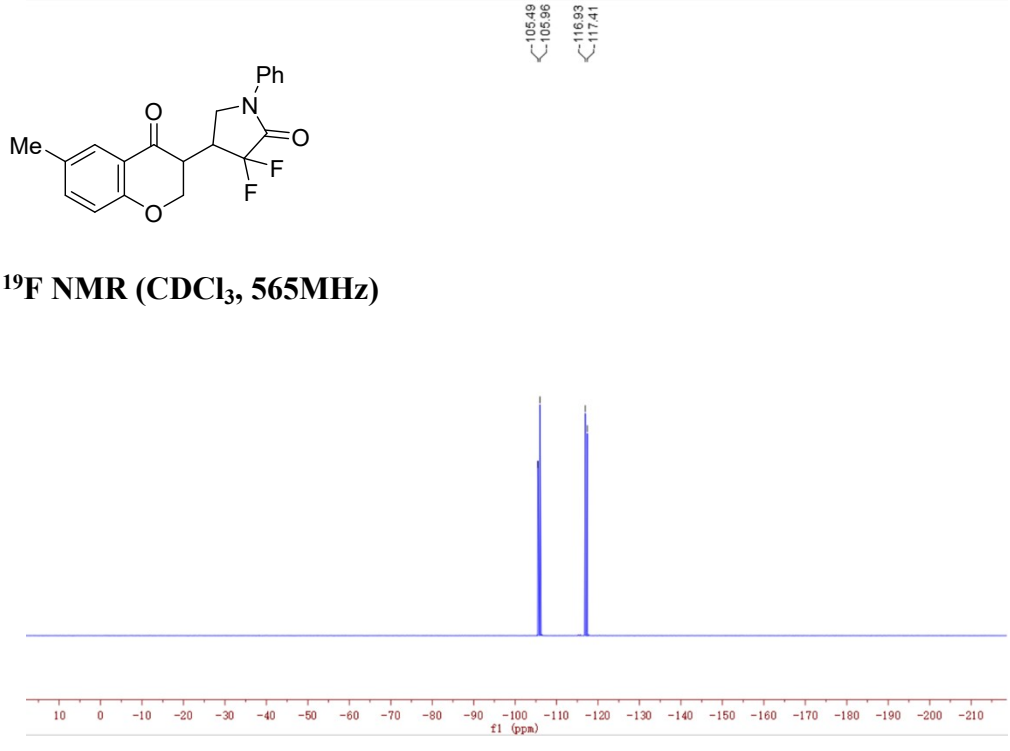
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2b



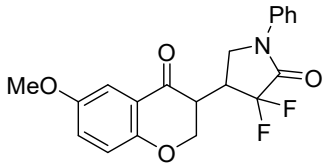
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2b



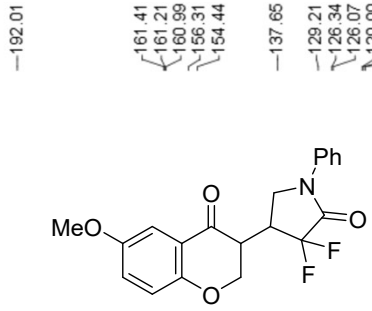
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2b



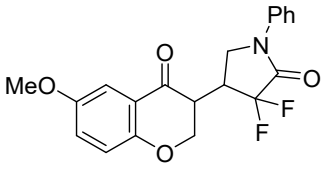
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2c



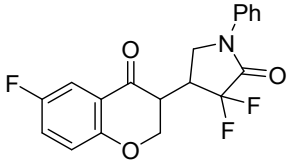
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2c

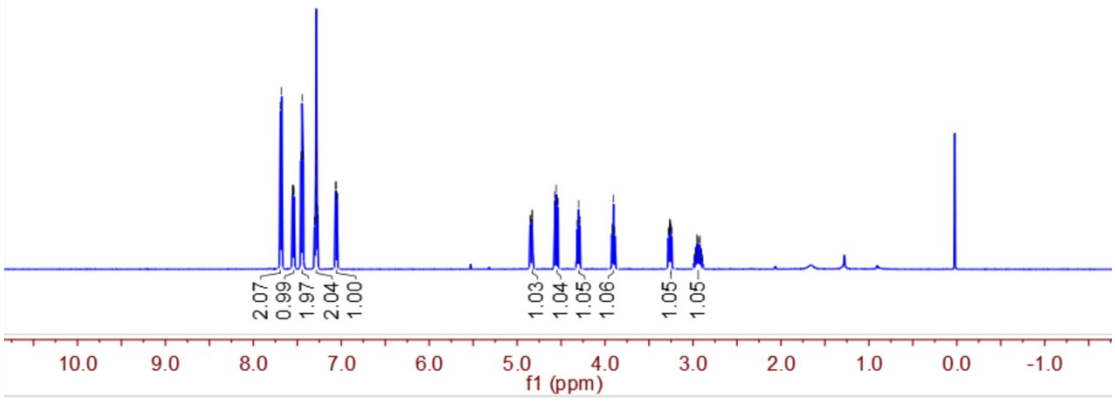


^{19}F NMR ($CDCl_3$, 565MHz)

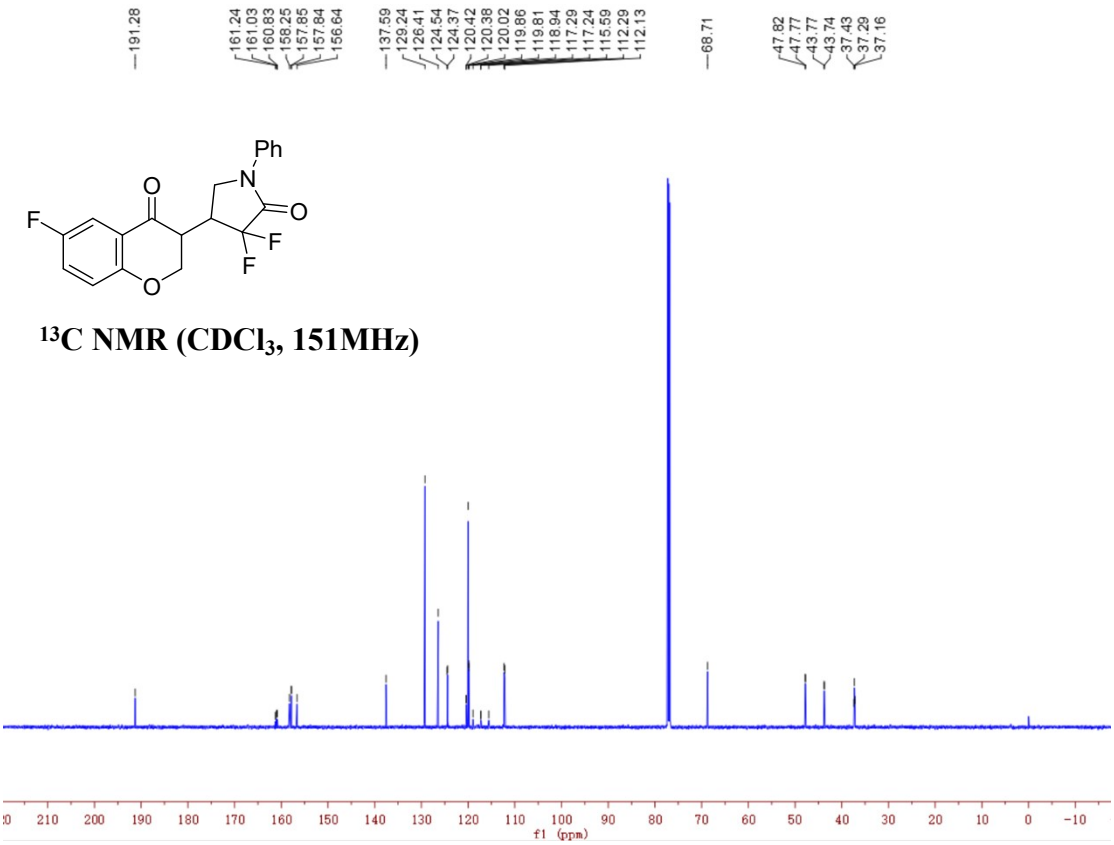
^{19}F NMR Spectrum of Compound 2c



^{1}H NMR ($CDCl_3$, 600MHz)

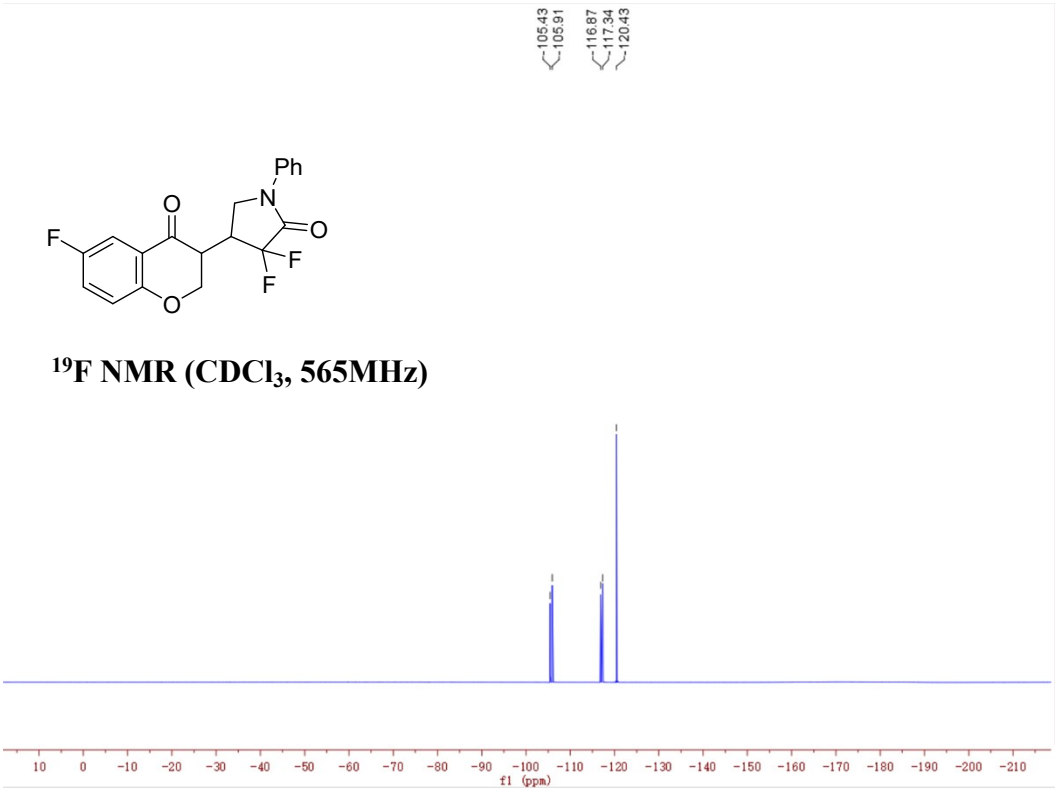


^{1}H NMR Spectrum of Compound 2d



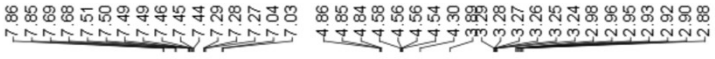
^{13}C NMR ($CDCl_3$, 151MHz)

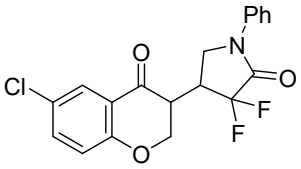
^{13}C NMR Spectrum of Compound 2d



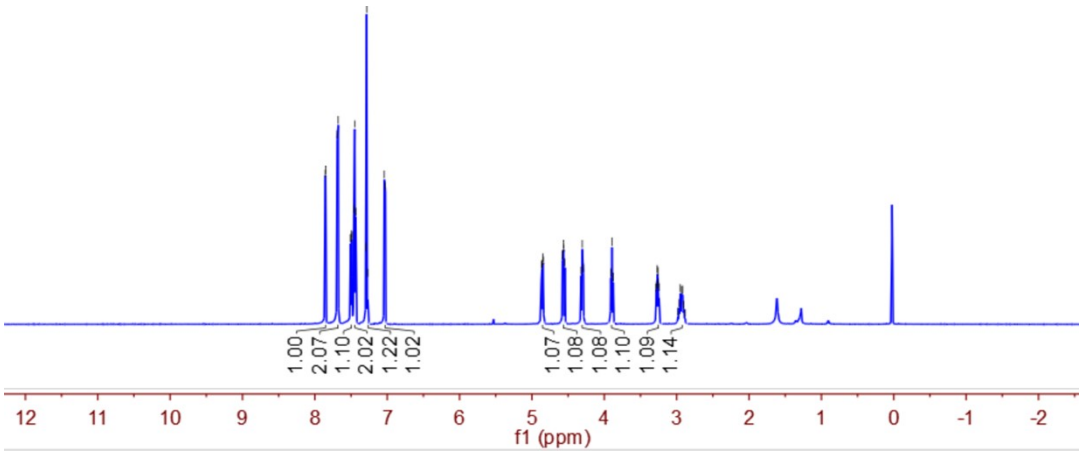
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2d

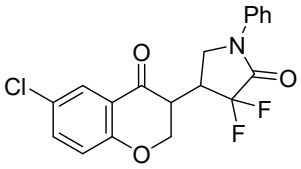




^{1}H NMR ($CDCl_3$, 600MHz)

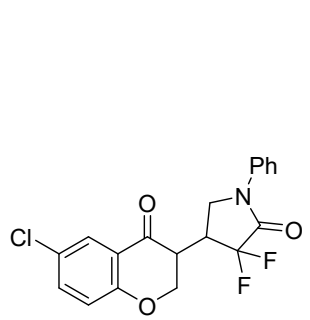


^{1}H NMR Spectrum of Compound 2e



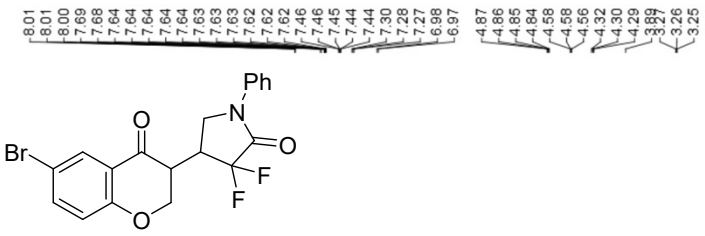
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2e

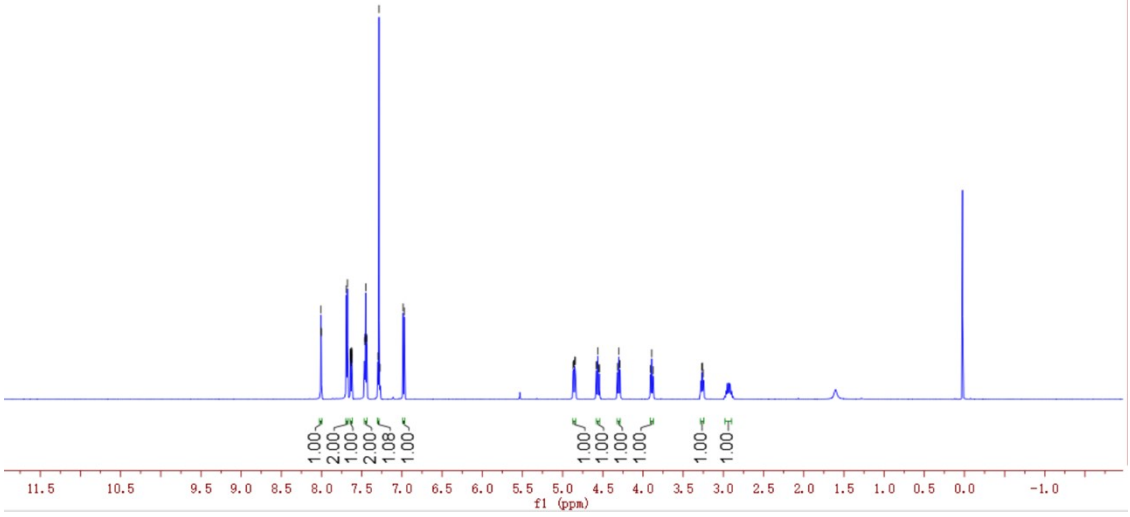


^{19}F NMR ($CDCl_3$, 565MHz)

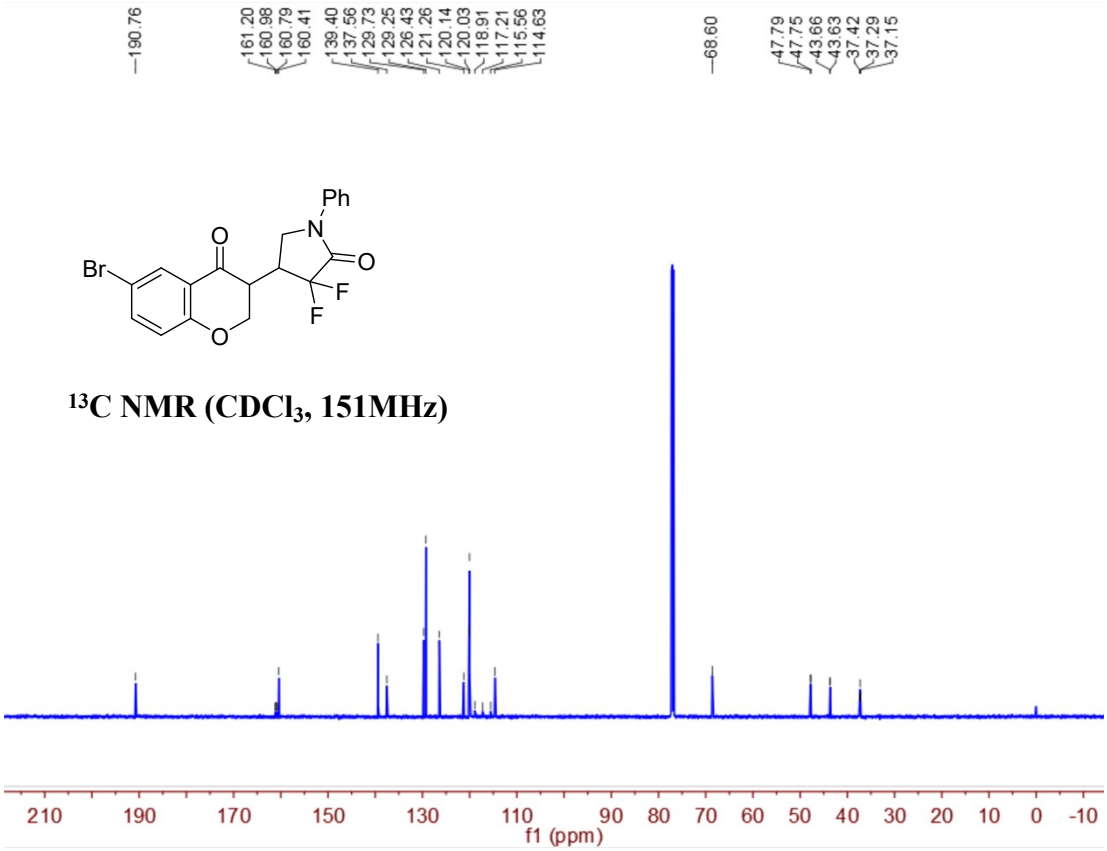
^{19}F NMR Spectrum of Compound 2e



^{1}H NMR ($CDCl_3$, 600MHz)

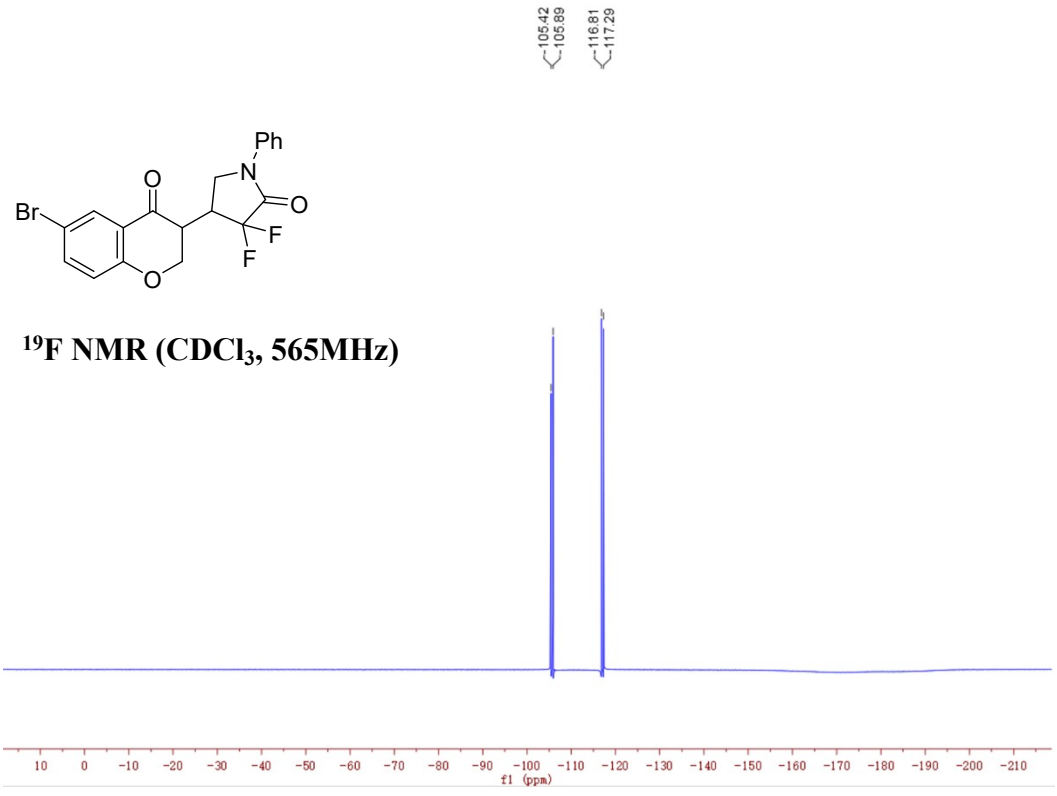


^{1}H NMR Spectrum of Compound 2f



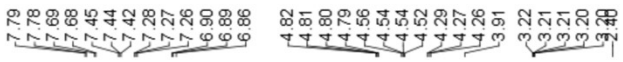
^{13}C NMR ($CDCl_3$, 151MHz)

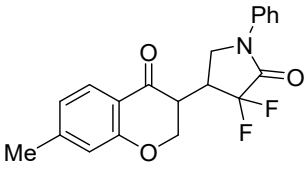
^{13}C NMR Spectrum of Compound 2f



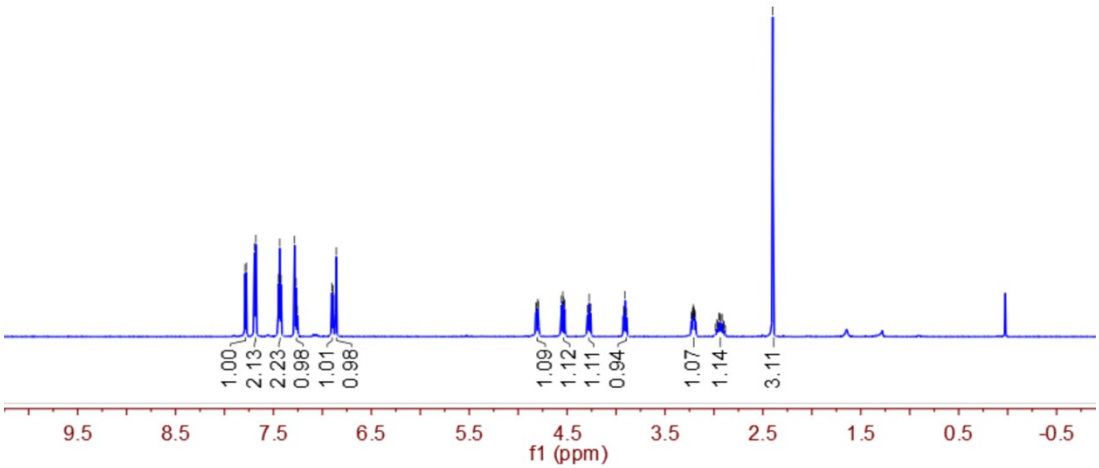
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2f

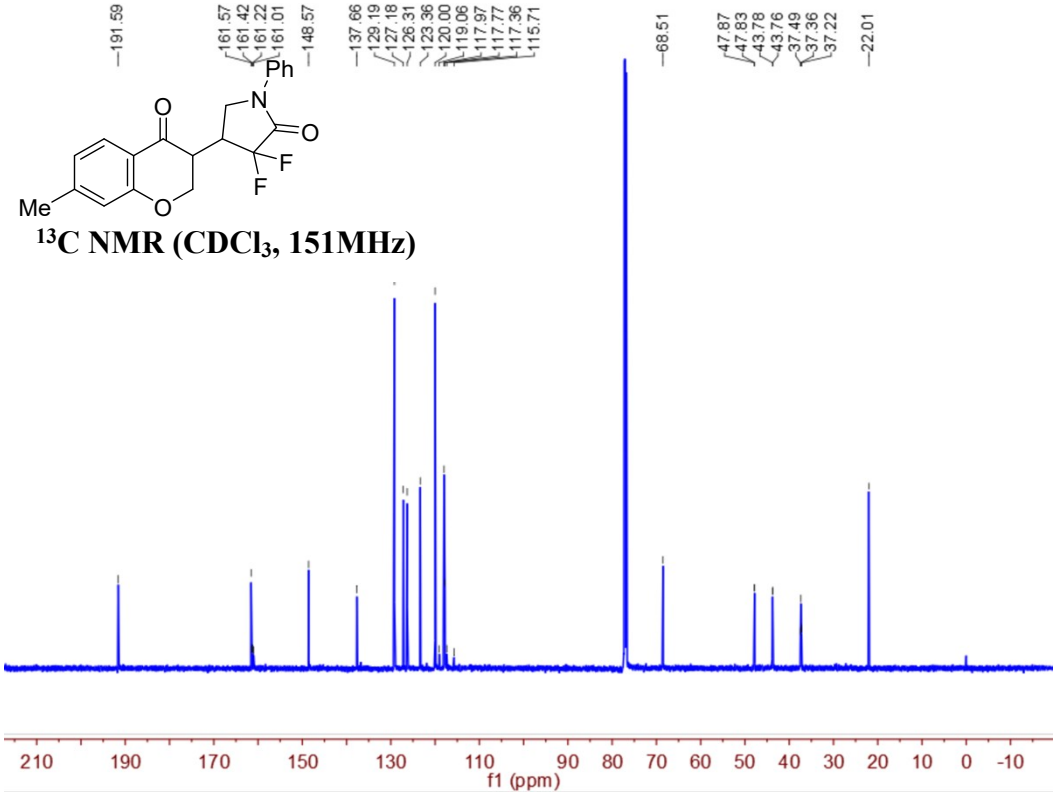




^{1}H NMR ($CDCl_3$, 600MHz)

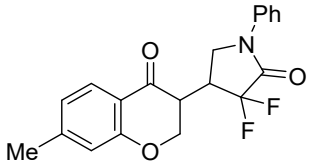


^{1}H NMR Spectrum of Compound 2g



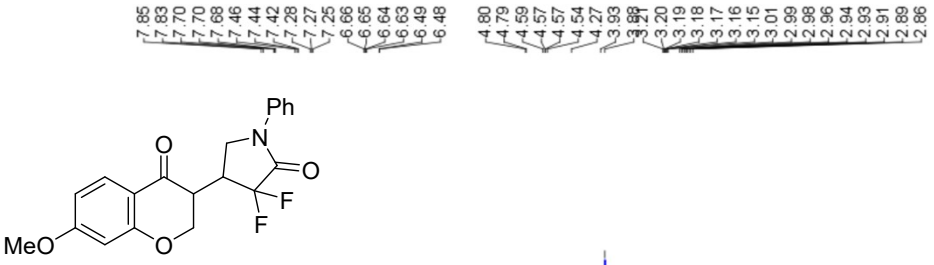
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2g

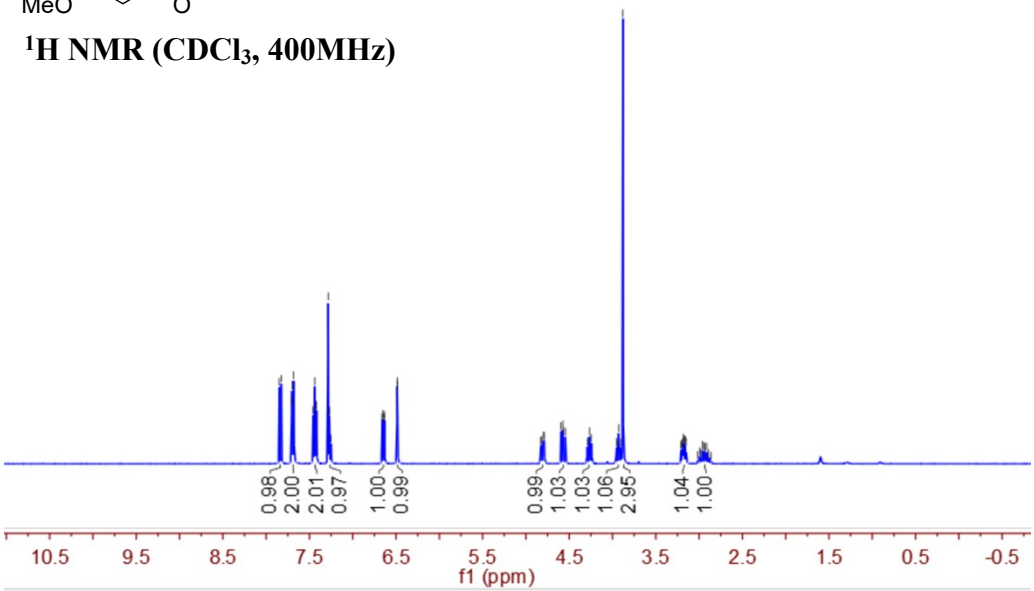


^{19}F NMR ($CDCl_3$, 565MHz)

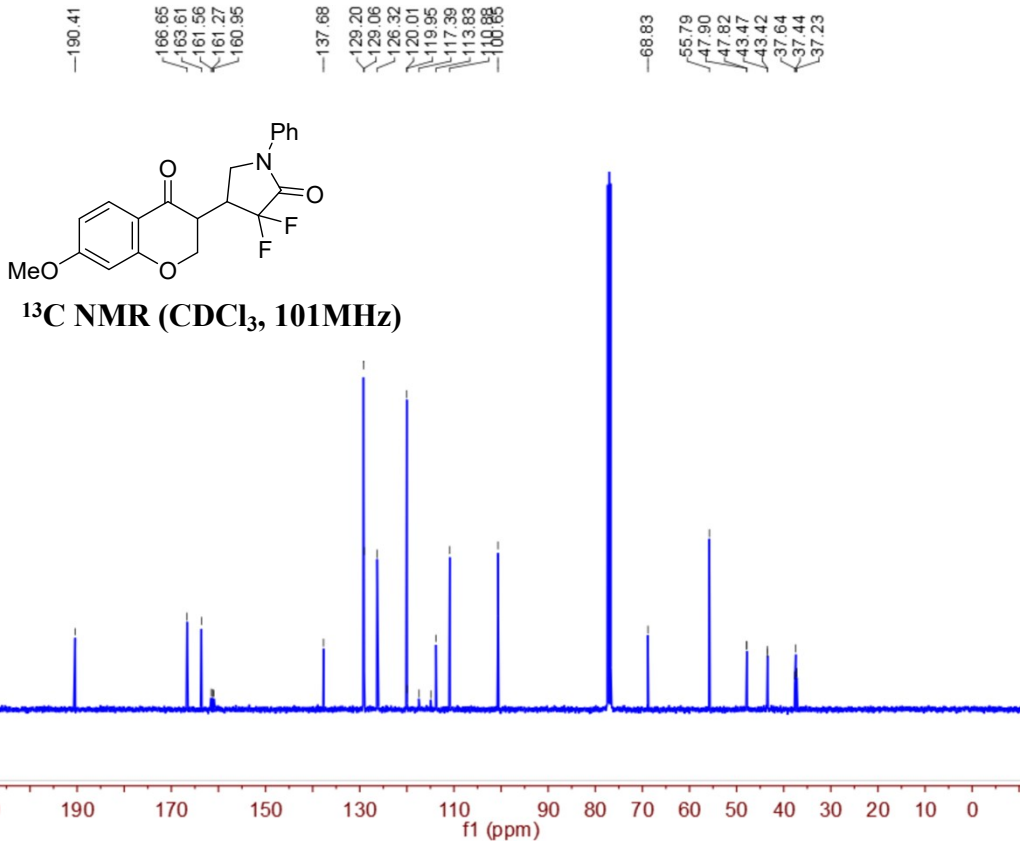
^{19}F NMR Spectrum of Compound 2g



^{1}H NMR ($CDCl_3$, 400MHz)

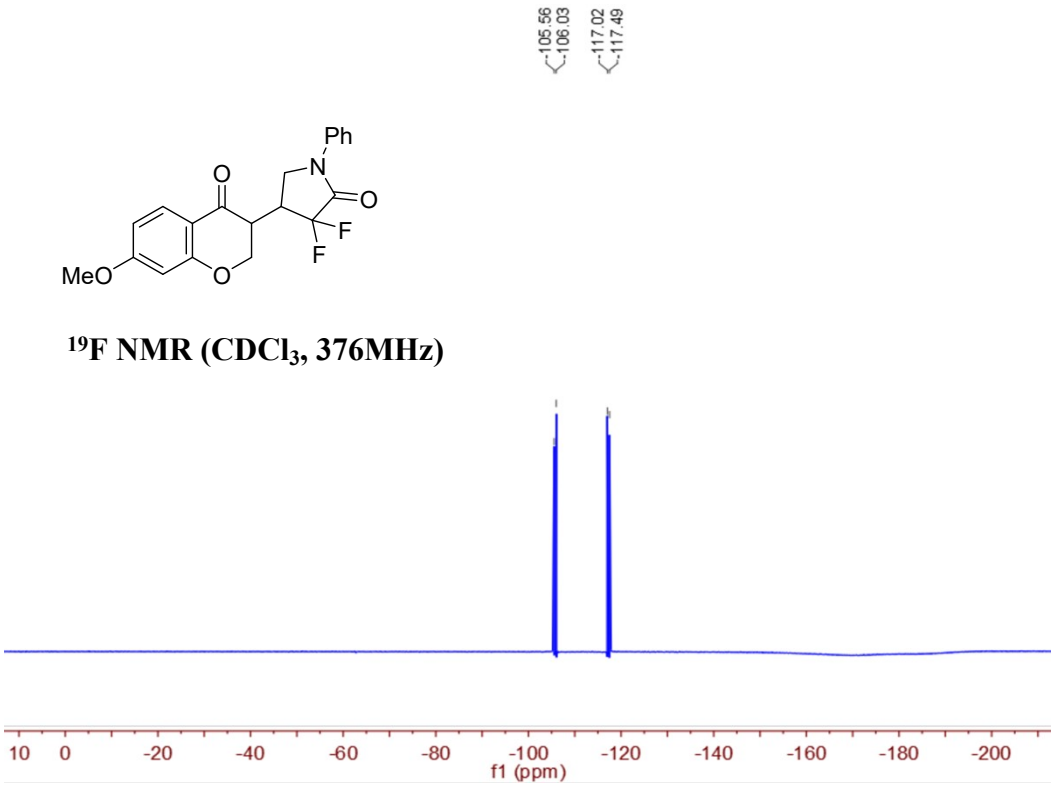


^{1}H NMR Spectrum of Compound 2h



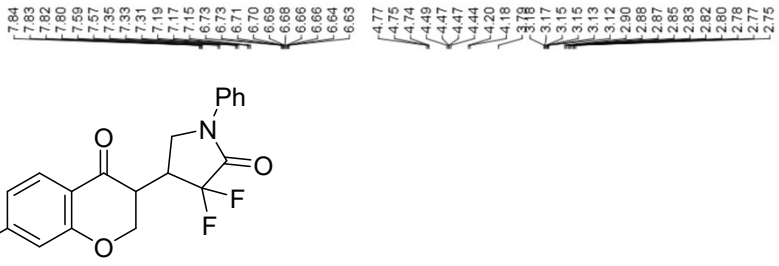
^{13}C NMR ($CDCl_3$, 101MHz)

^{13}C NMR Spectrum of Compound 2h

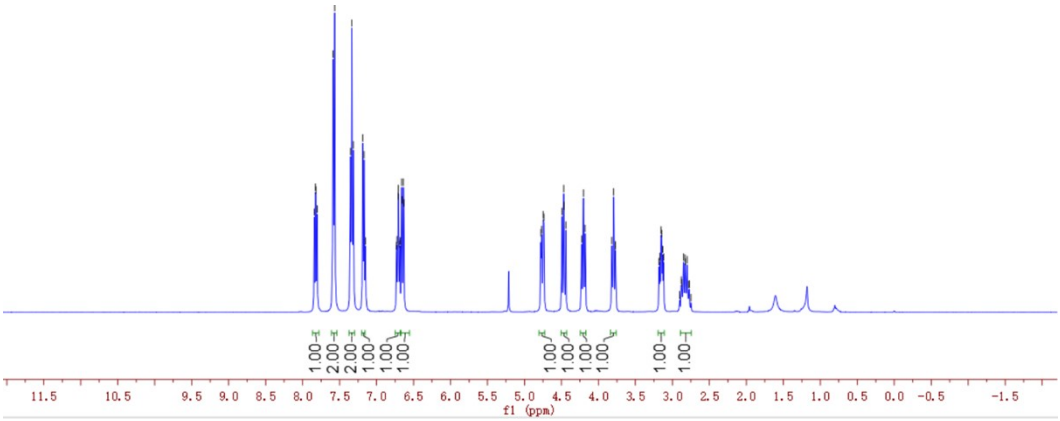


^{19}F NMR ($CDCl_3$, 376MHz)

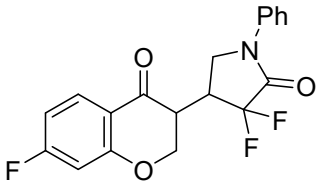
^{19}F NMR Spectrum of Compound 2h



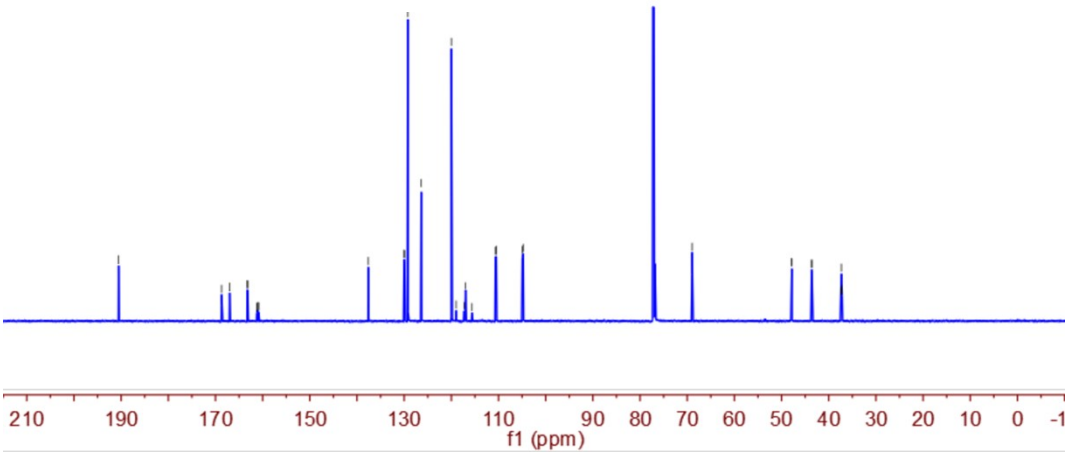
^{1}H NMR ($CDCl_3$, 400MHz)



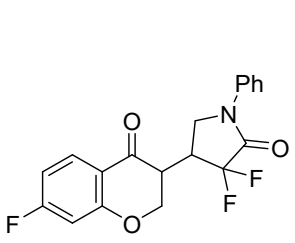
^{1}H NMR Spectrum of Compound 2i



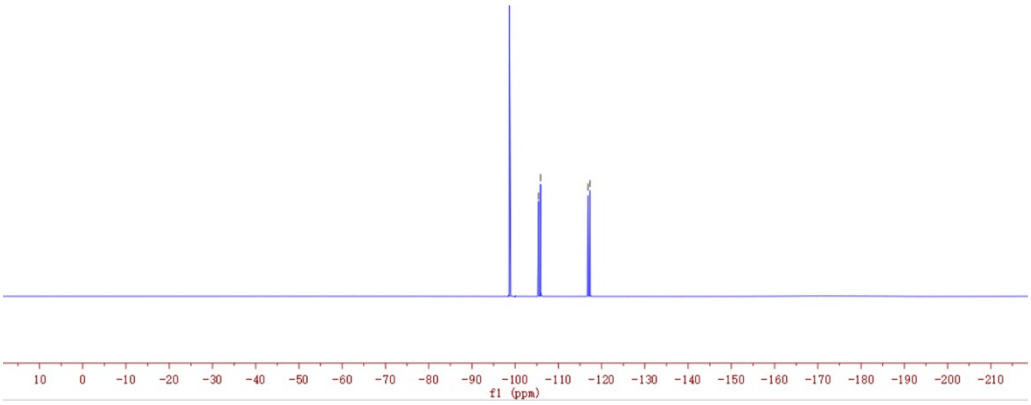
^{13}C NMR ($CDCl_3$, 101MHz)



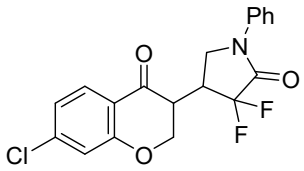
^{13}C NMR Spectrum of Compound 2i



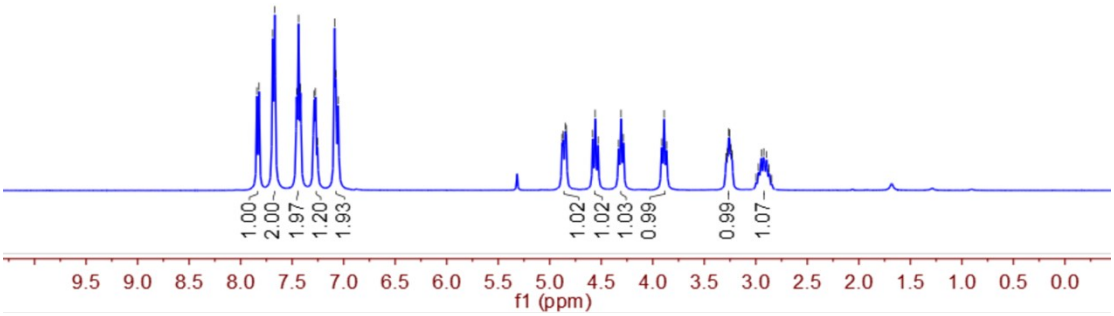
^{19}F NMR ($CDCl_3$, 376MHz)



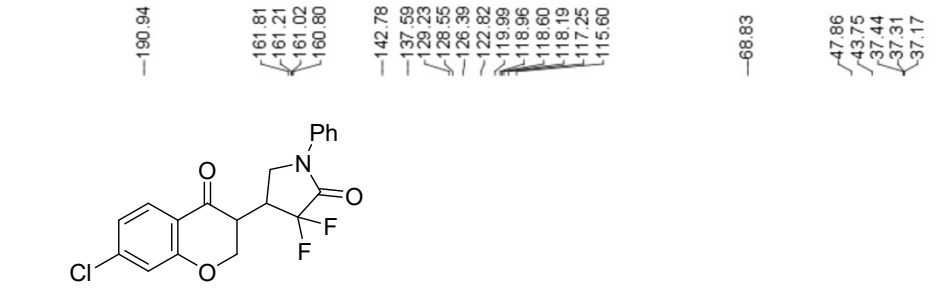
^{19}F NMR Spectrum of Compound 2i



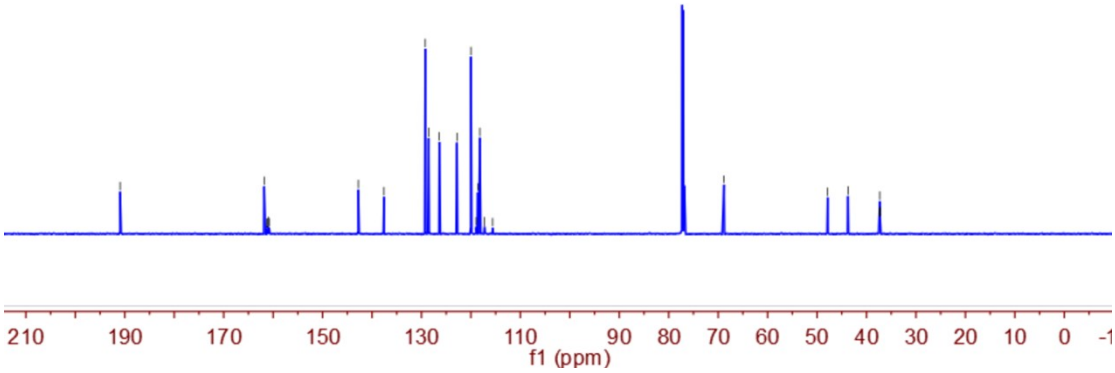
^{1}H NMR ($CDCl_3$, 400MHz)



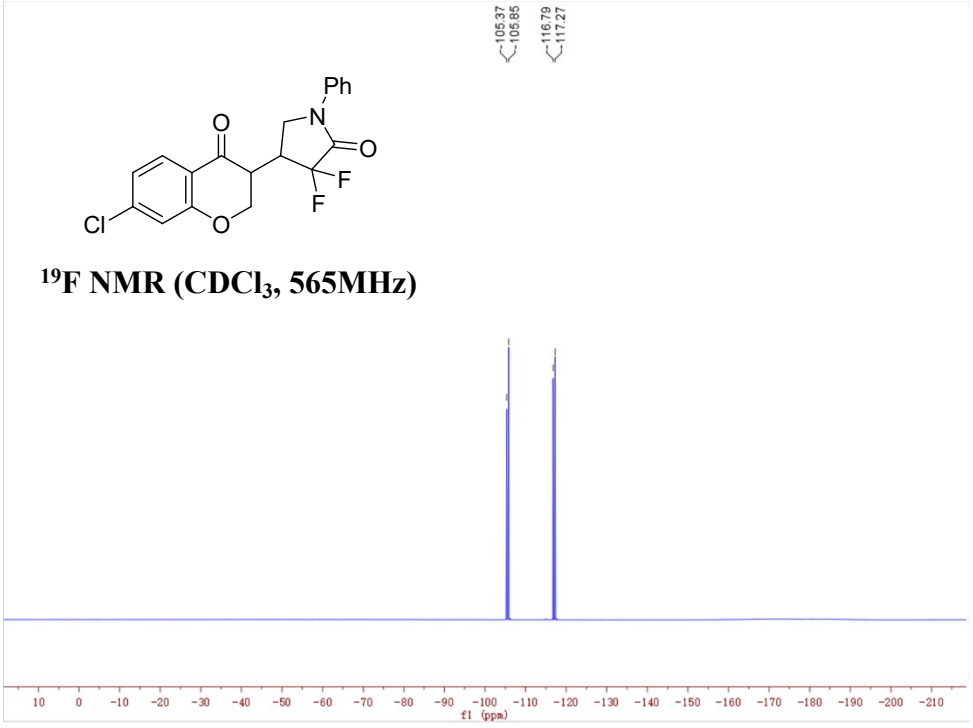
^{1}H NMR Spectrum of Compound 2j



^{13}C NMR ($CDCl_3$, 151MHz)

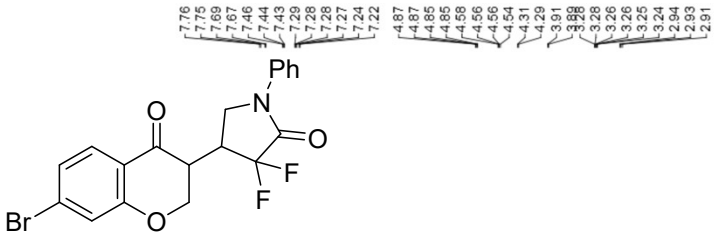


^{13}C NMR Spectrum of Compound 2j

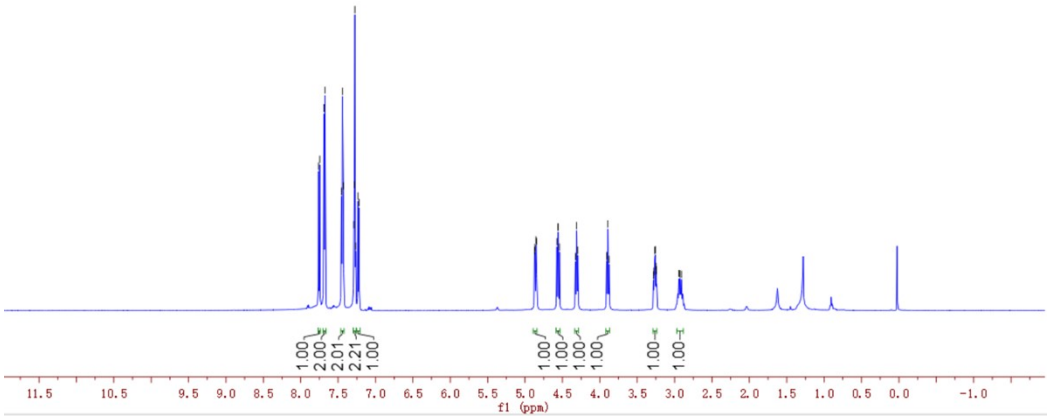


^{19}F NMR ($CDCl_3$, 565MHz)

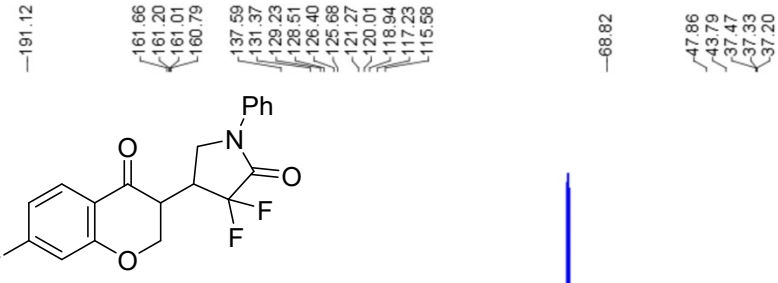
^{19}F NMR Spectrum of Compound 2j



^{1}H NMR ($CDCl_3$, 600MHz)

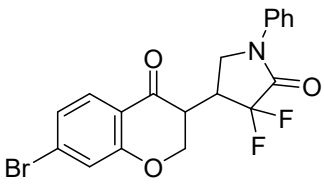


^{1}H NMR Spectrum of Compound 2k

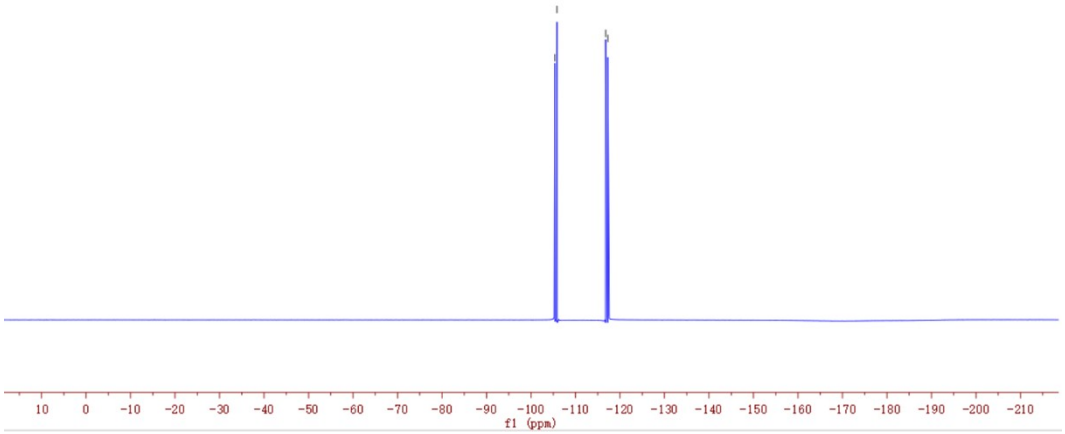


^{13}C NMR ($CDCl_3$, 151MHz)

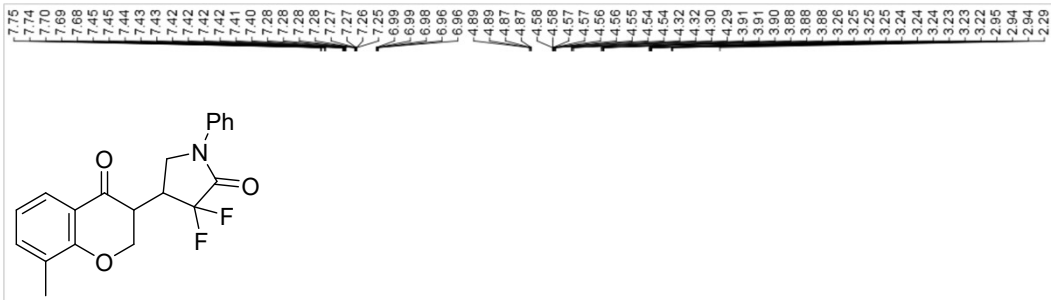
^{13}C NMR Spectrum of Compound 2k



^{19}F NMR ($CDCl_3$, 565MHz)

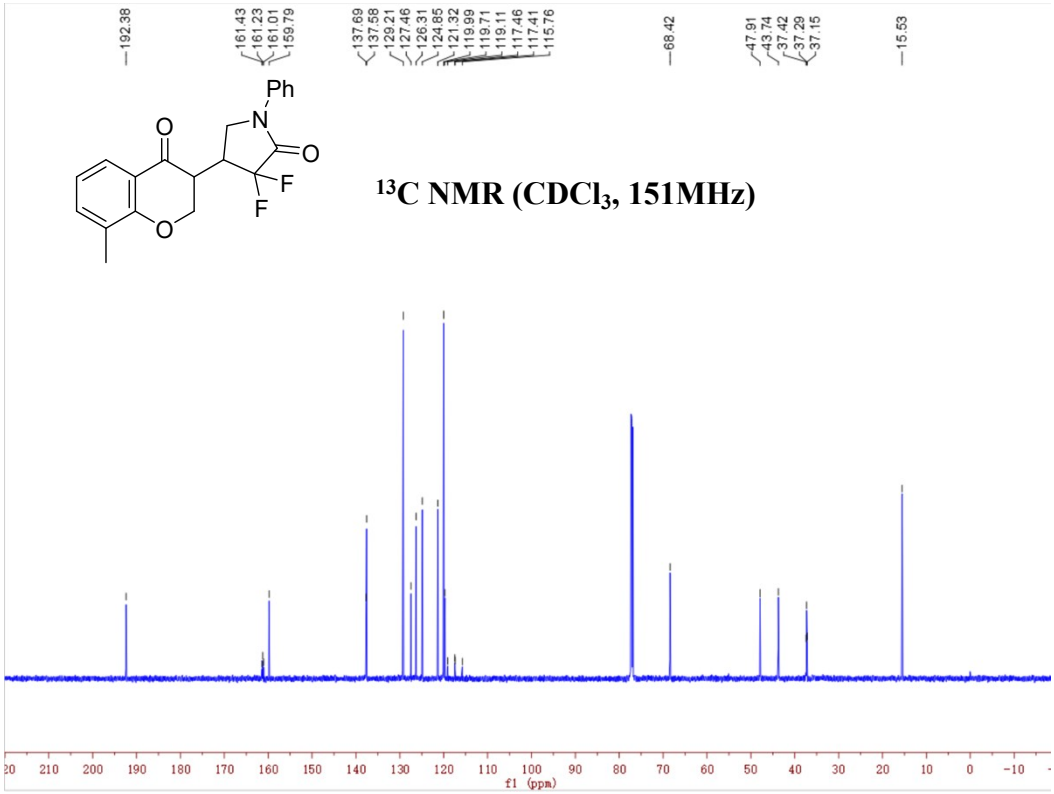


^{19}F NMR Spectrum of Compound 2k



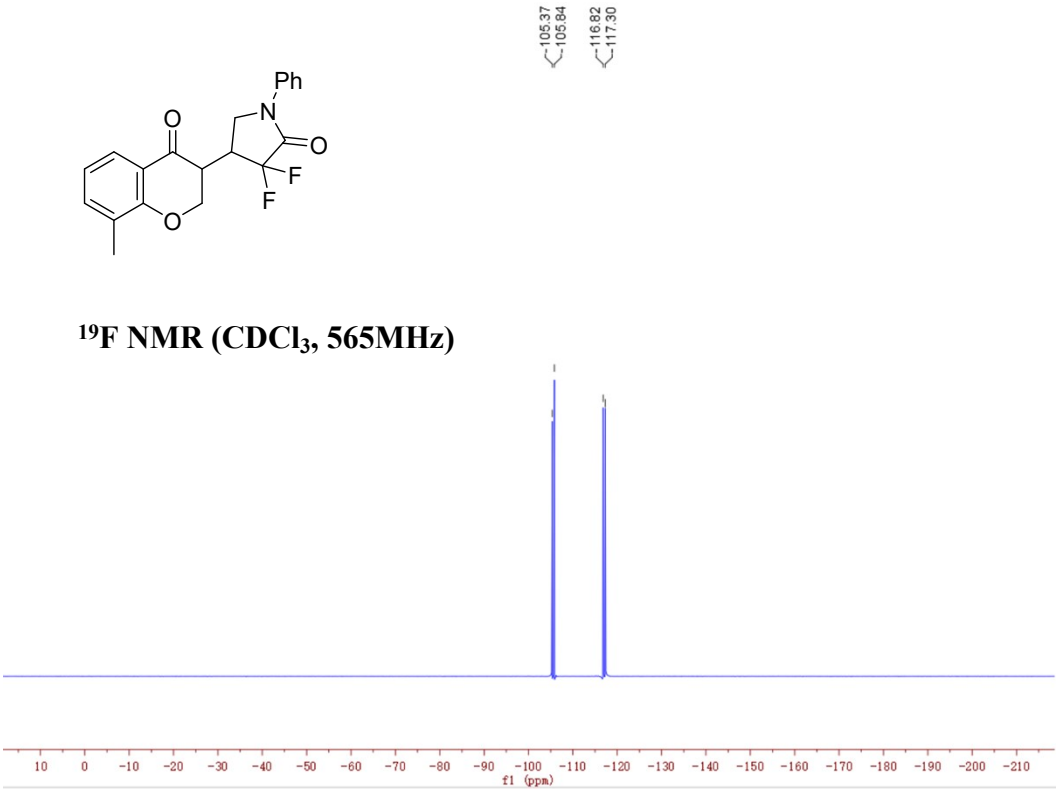
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2l



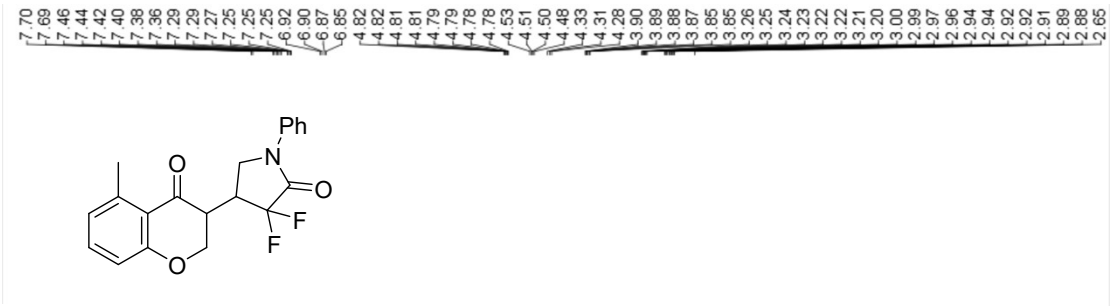
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2l

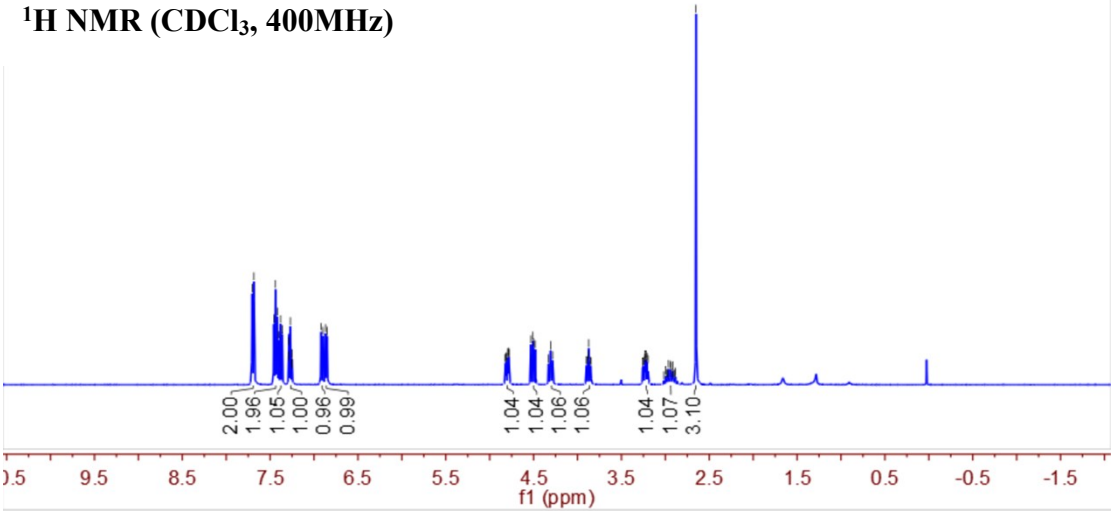


^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2l

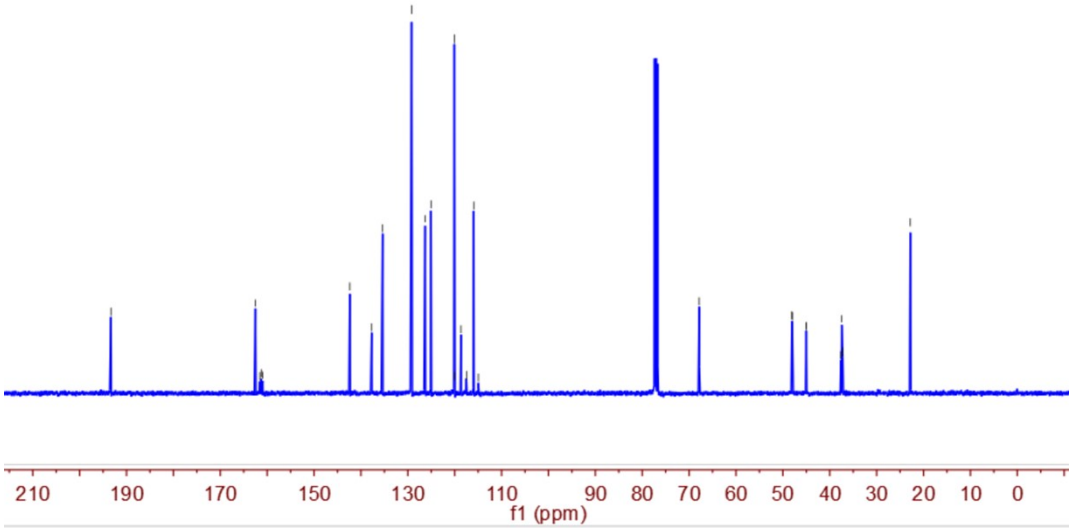


^{1}H NMR ($CDCl_3$, 400MHz)

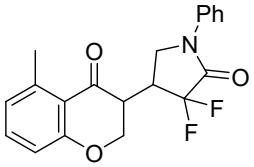


^{1}H NMR Spectrum of Compound 2m

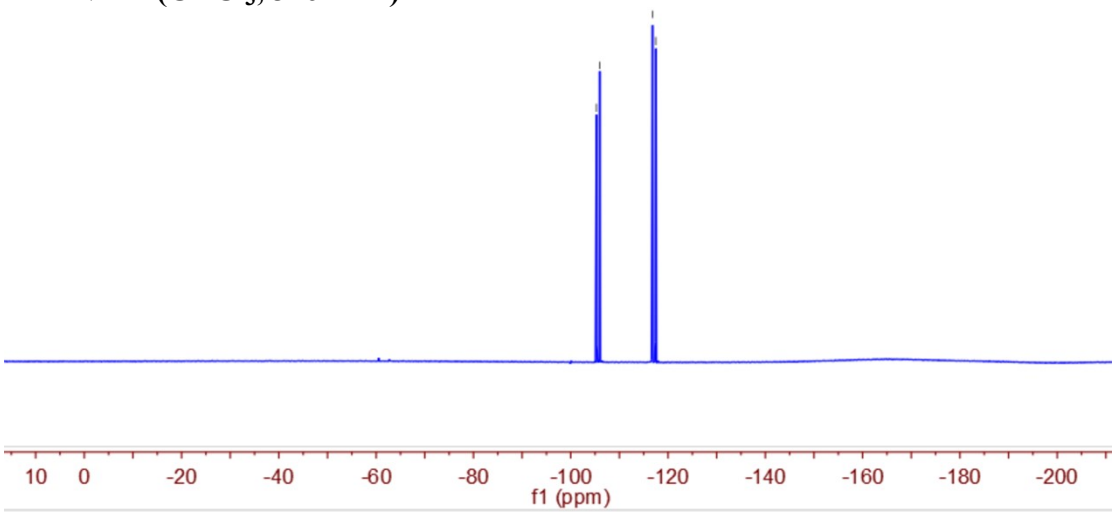
^{13}C NMR ($CDCl_3$, 101MHz)



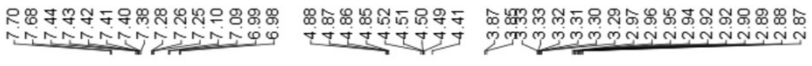
^{13}C NMR Spectrum of Compound 2m

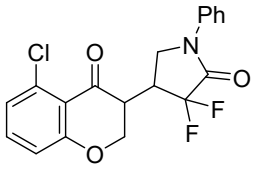


^{19}F NMR ($CDCl_3$, 376MHz)

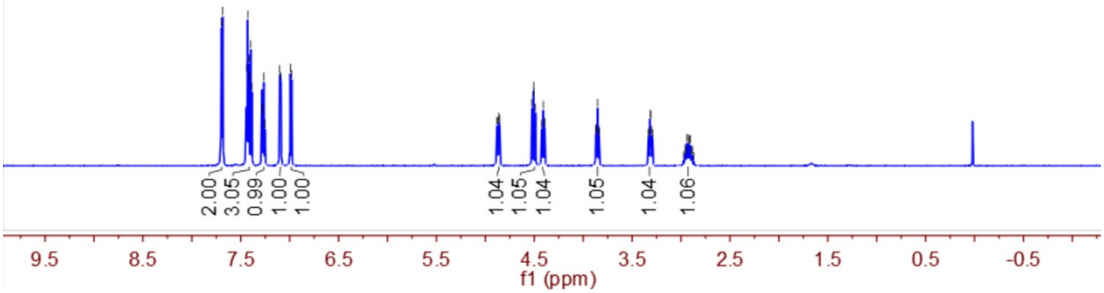


^{19}F NMR Spectrum of Compound 2m

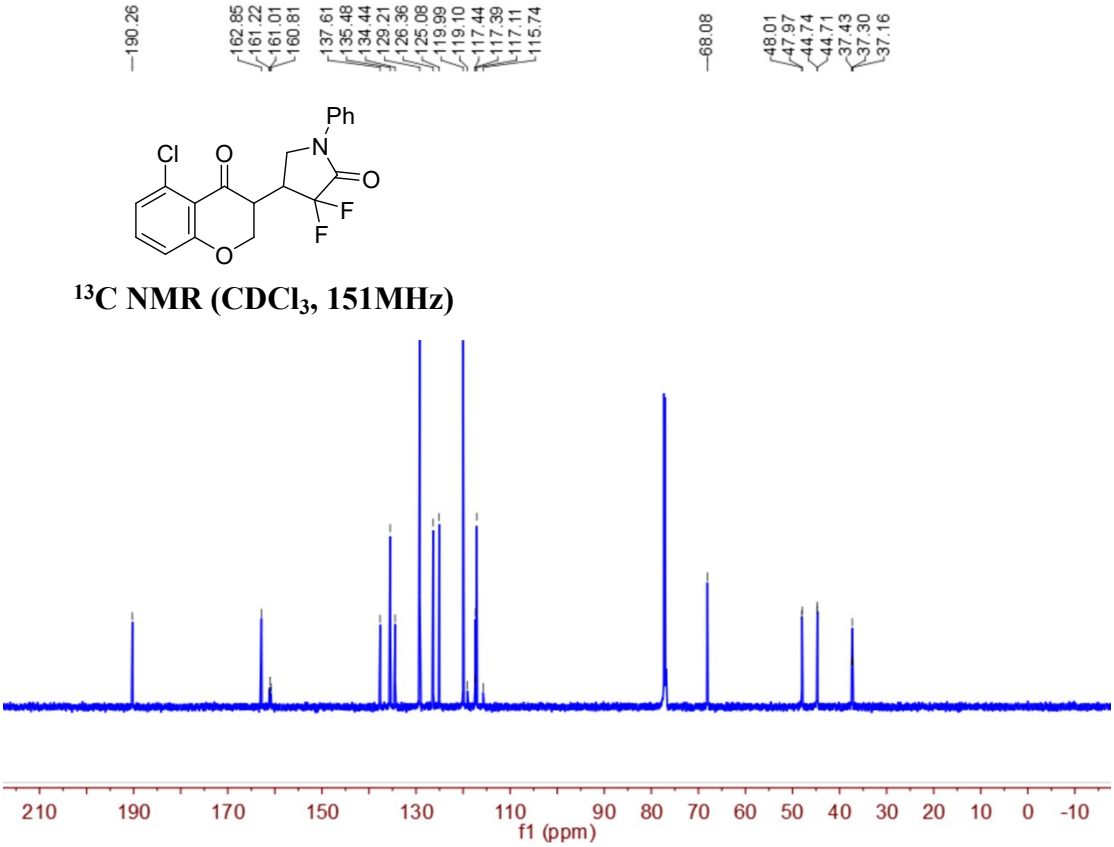




^{1}H NMR ($CDCl_3$, 600MHz)

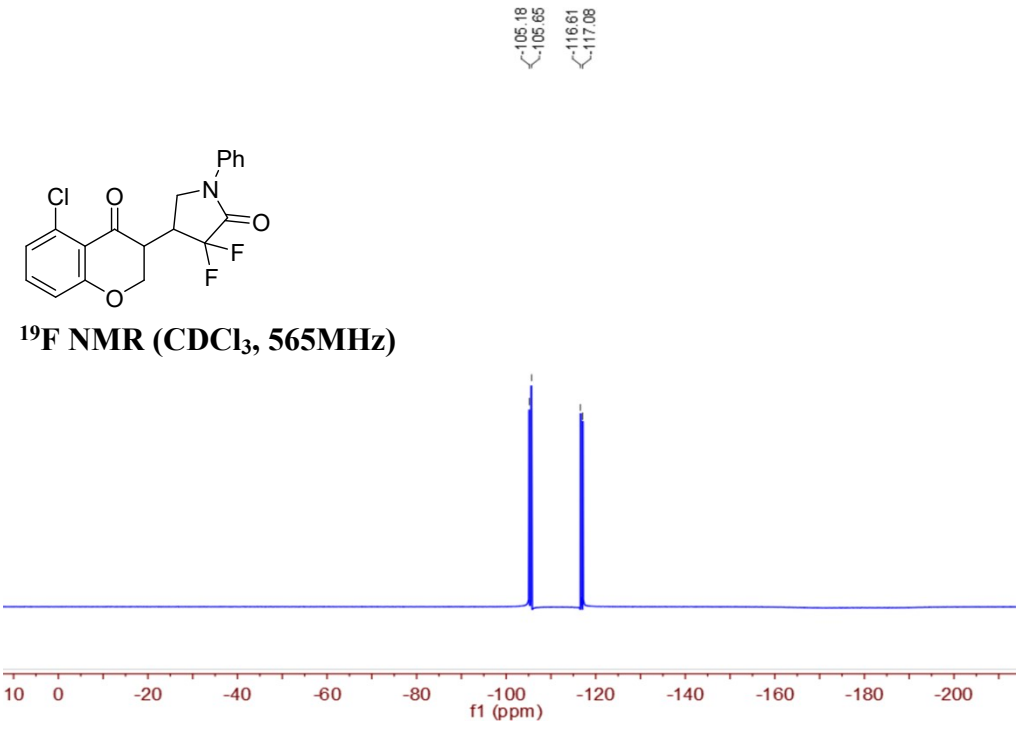


^{1}H NMR Spectrum of Compound 2n



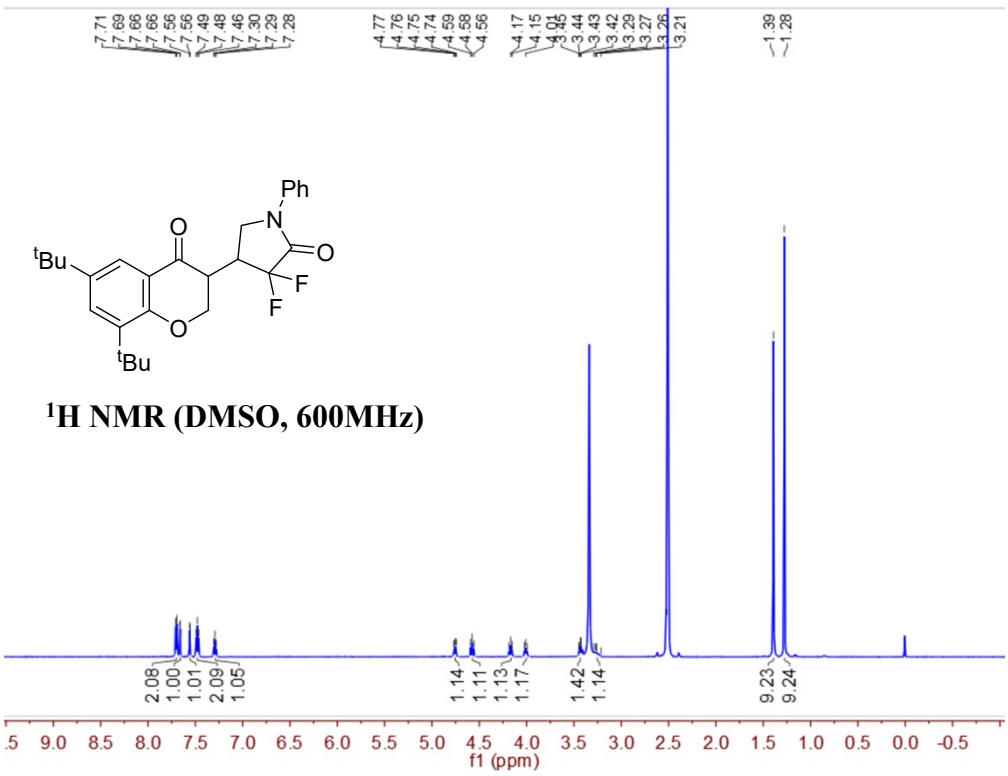
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2n



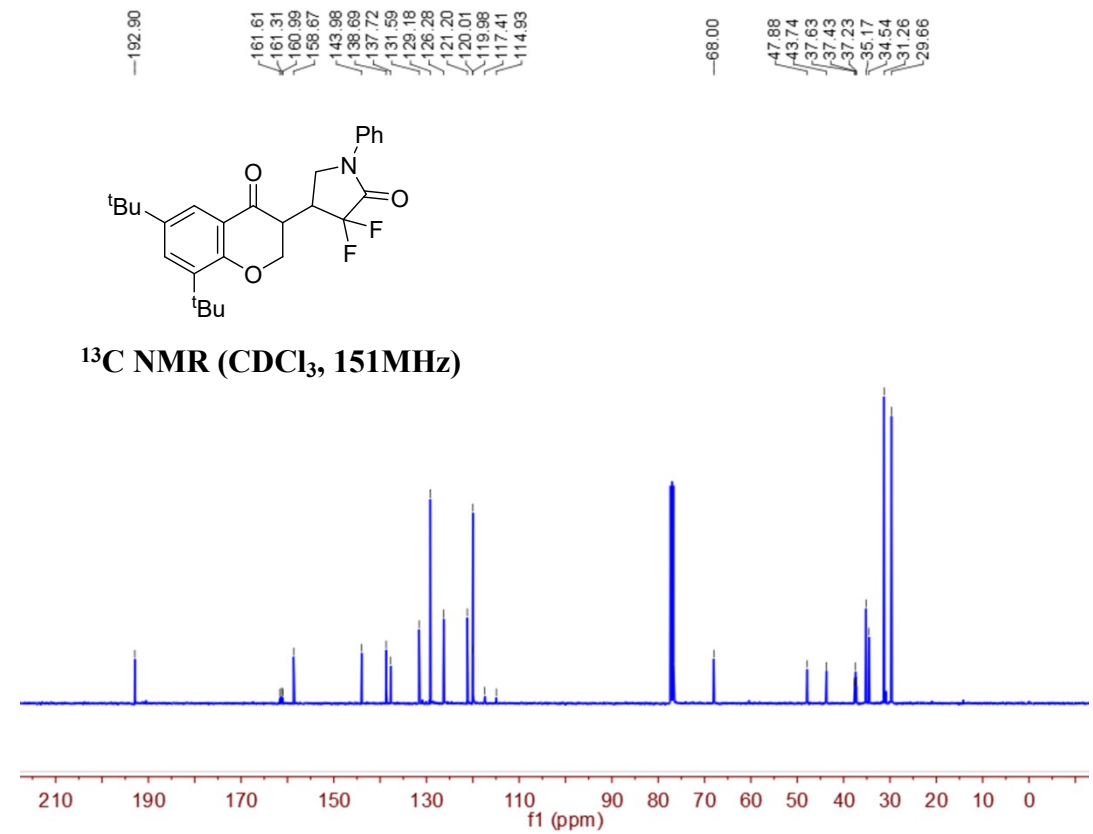
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2n



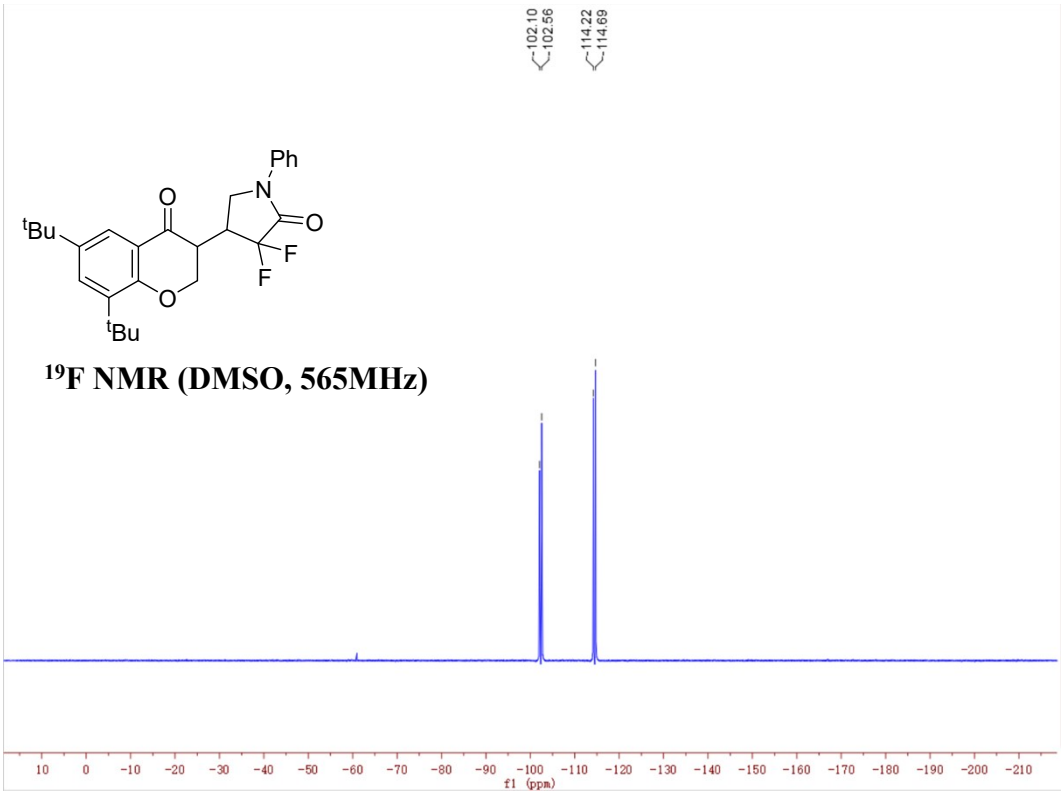
^{1}H NMR (DMSO, 600MHz)

^{1}H NMR Spectrum of Compound 2o

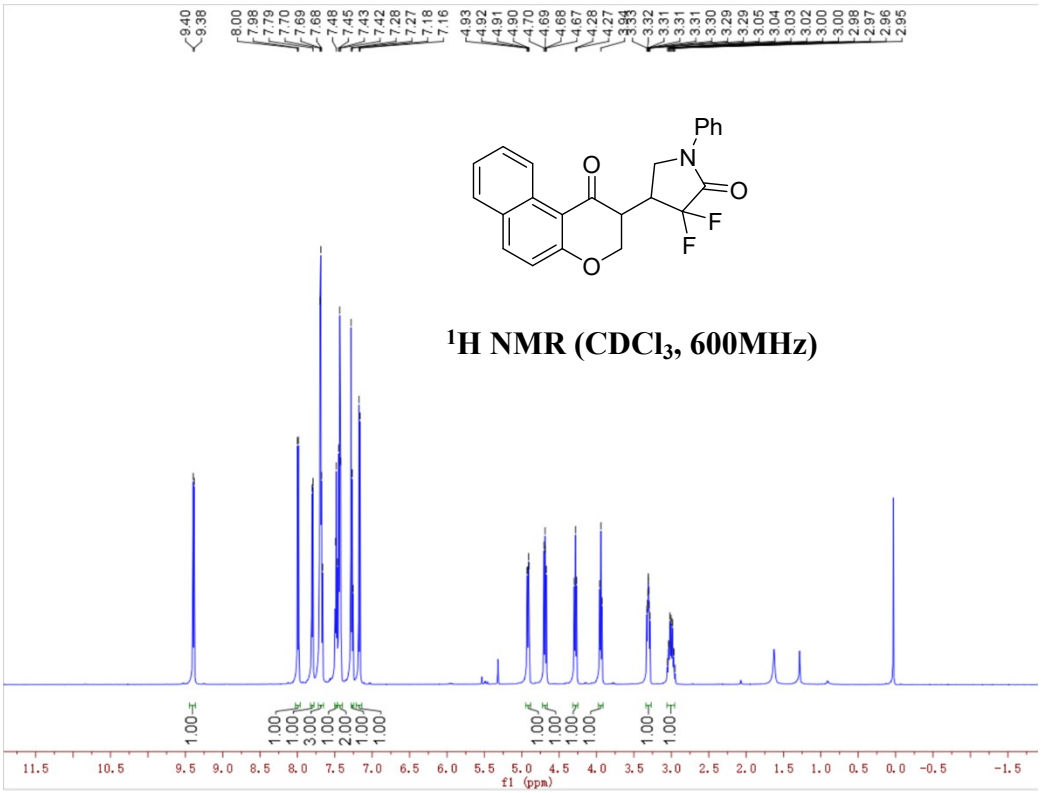


^{13}C NMR ($CDCl_3$, 151MHz)

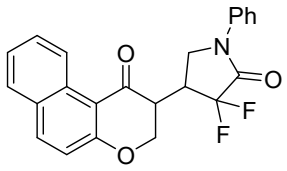
^{13}C NMR Spectrum of Compound 2o



^{19}F NMR Spectrum of Compound 2o

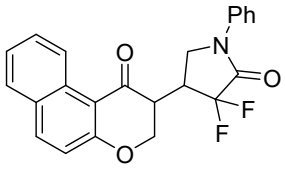


^{1}H NMR Spectrum of Compound 2p

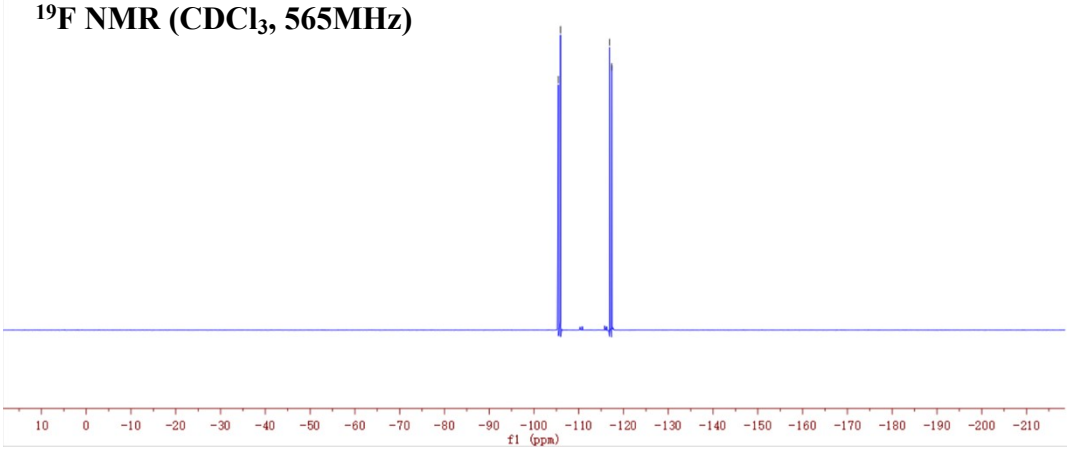


^{13}C NMR ($CDCl_3$, 151MHz)

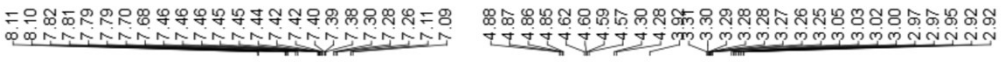
^{13}C NMR Spectrum of Compound 2p

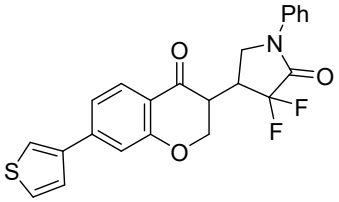


^{19}F NMR ($CDCl_3$, 565MHz)

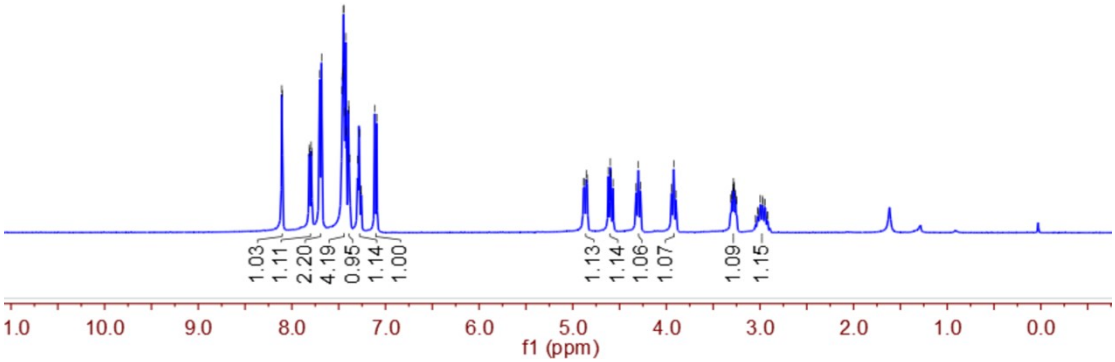


^{19}F NMR Spectrum of Compound 2p

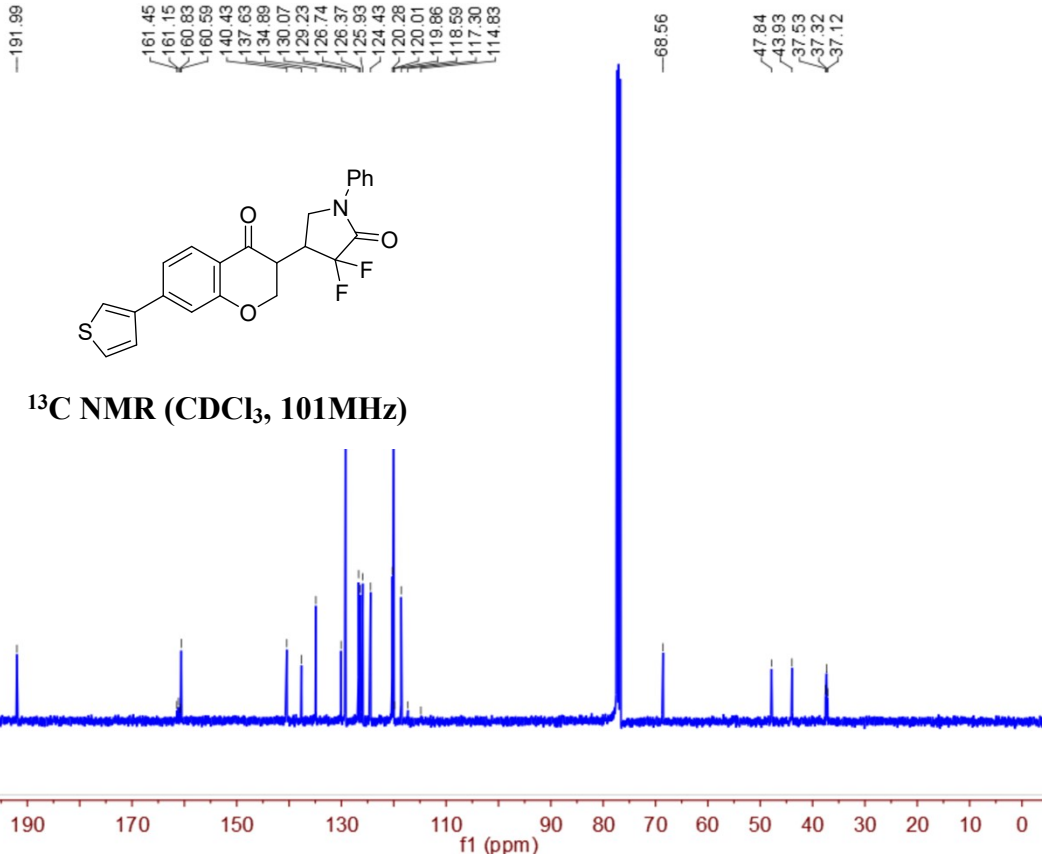




^{1}H NMR ($CDCl_3$, 400MHz)

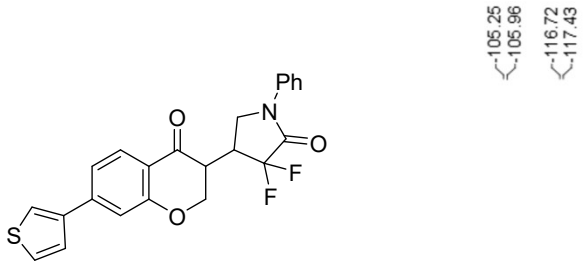


^{1}H NMR Spectrum of Compound 2q

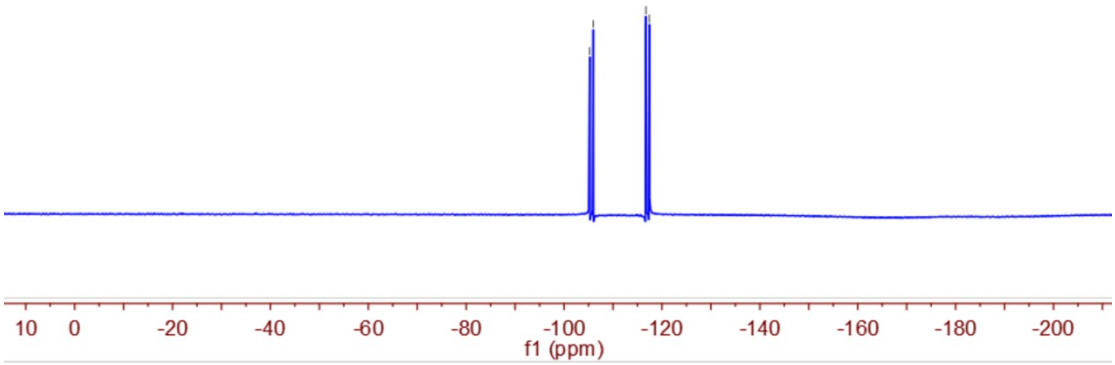


^{13}C NMR ($CDCl_3$, 101MHz)

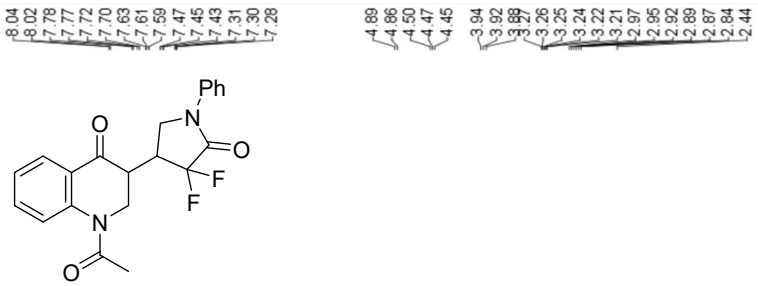
^{13}C NMR Spectrum of Compound 2q



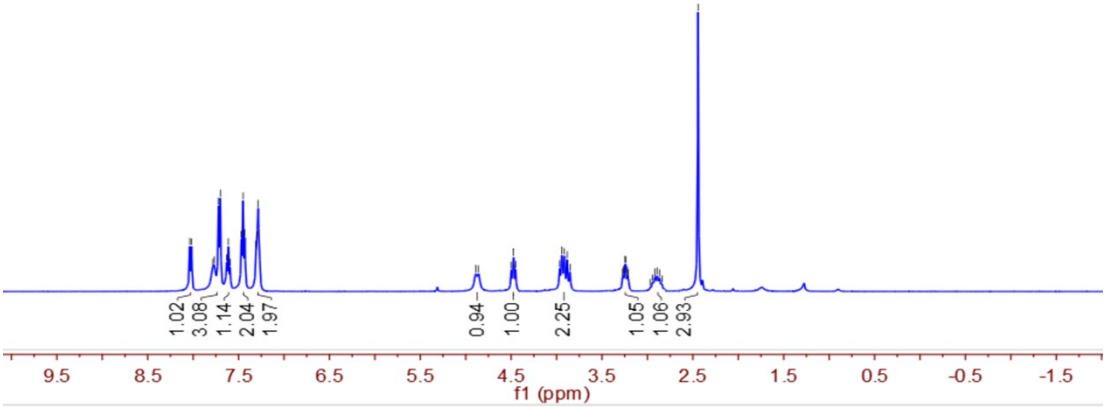
^{19}F NMR ($CDCl_3$, 376MHz)



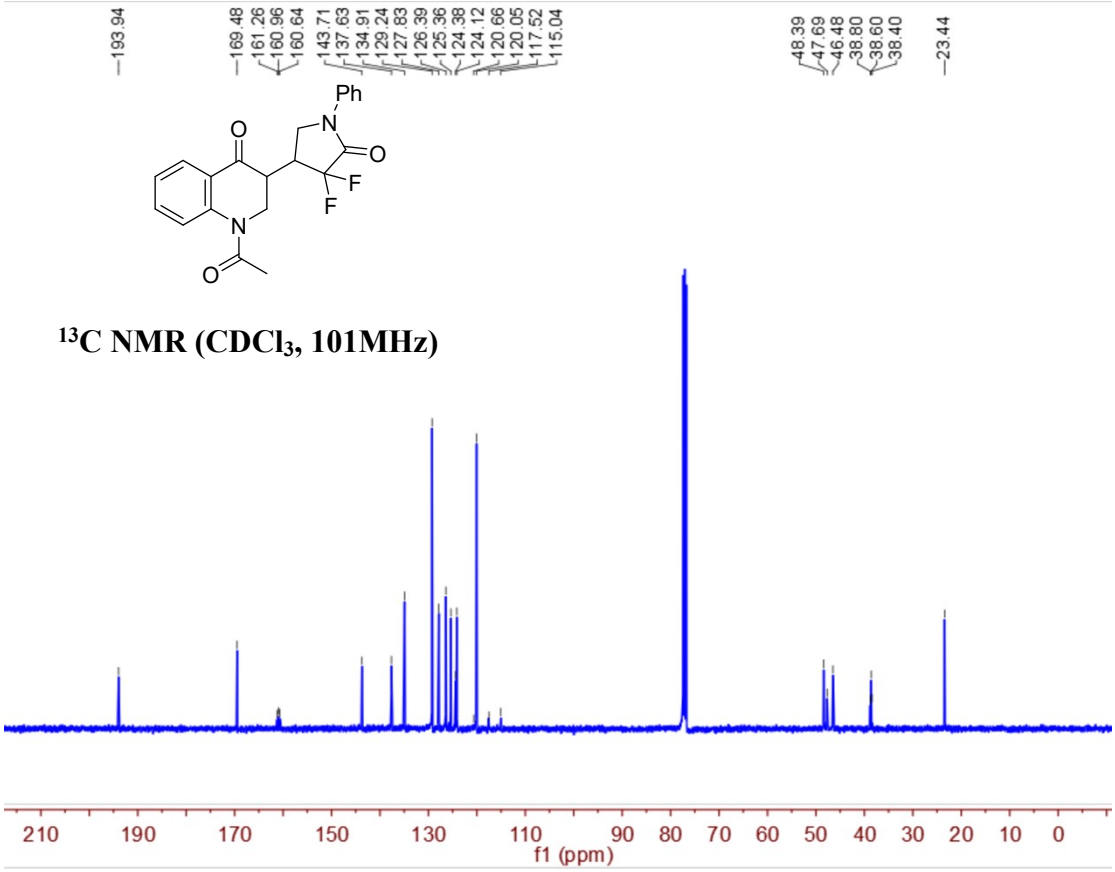
^{19}F NMR Spectrum of Compound 2q



^{1}H NMR ($CDCl_3$, 400MHz)

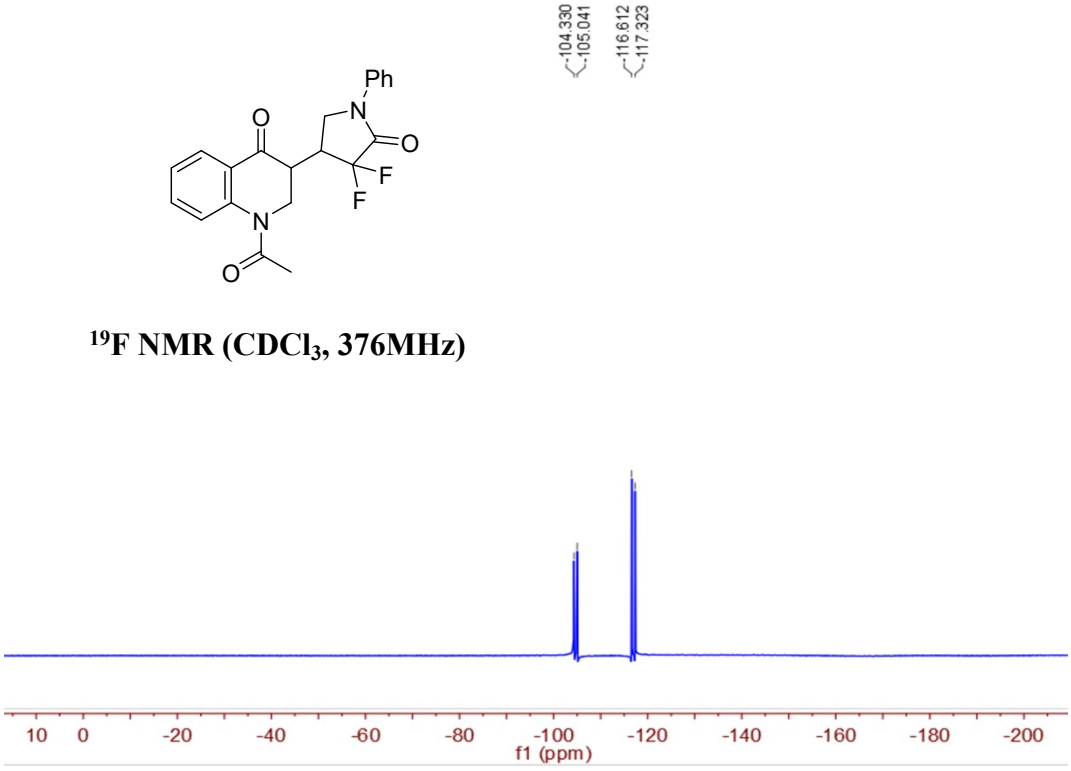


^{1}H NMR Spectrum of Compound 2r



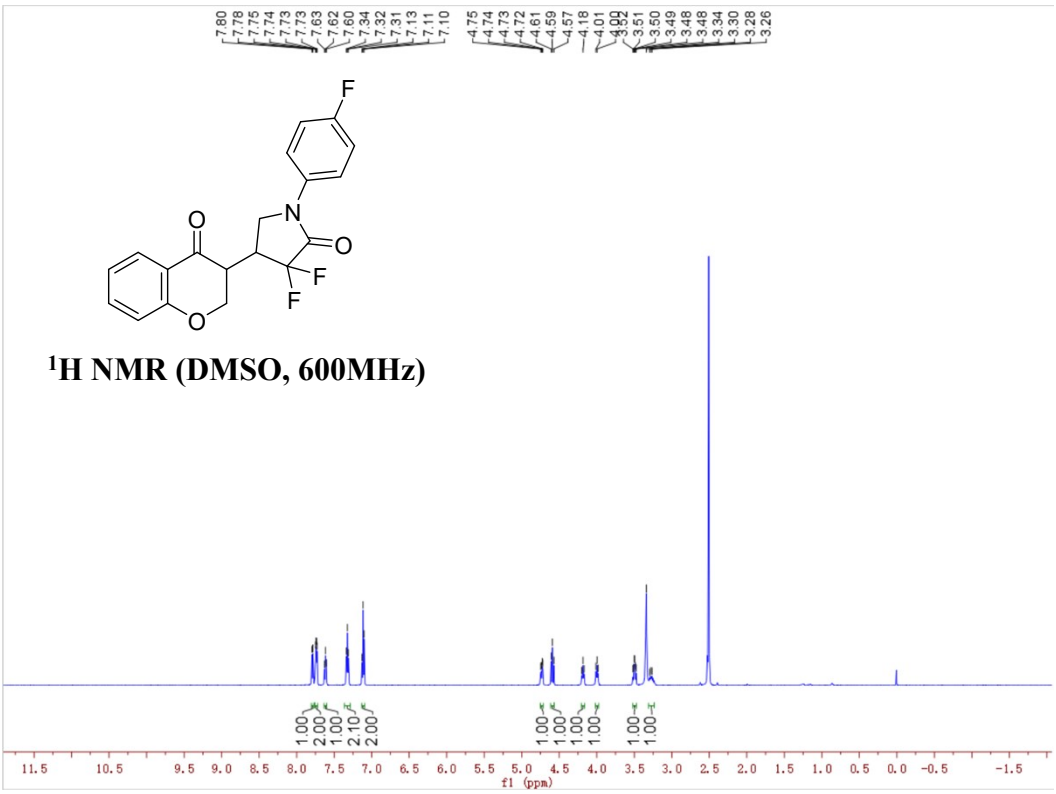
^{13}C NMR ($CDCl_3$, 101MHz)

^{13}C NMR Spectrum of Compound 2r



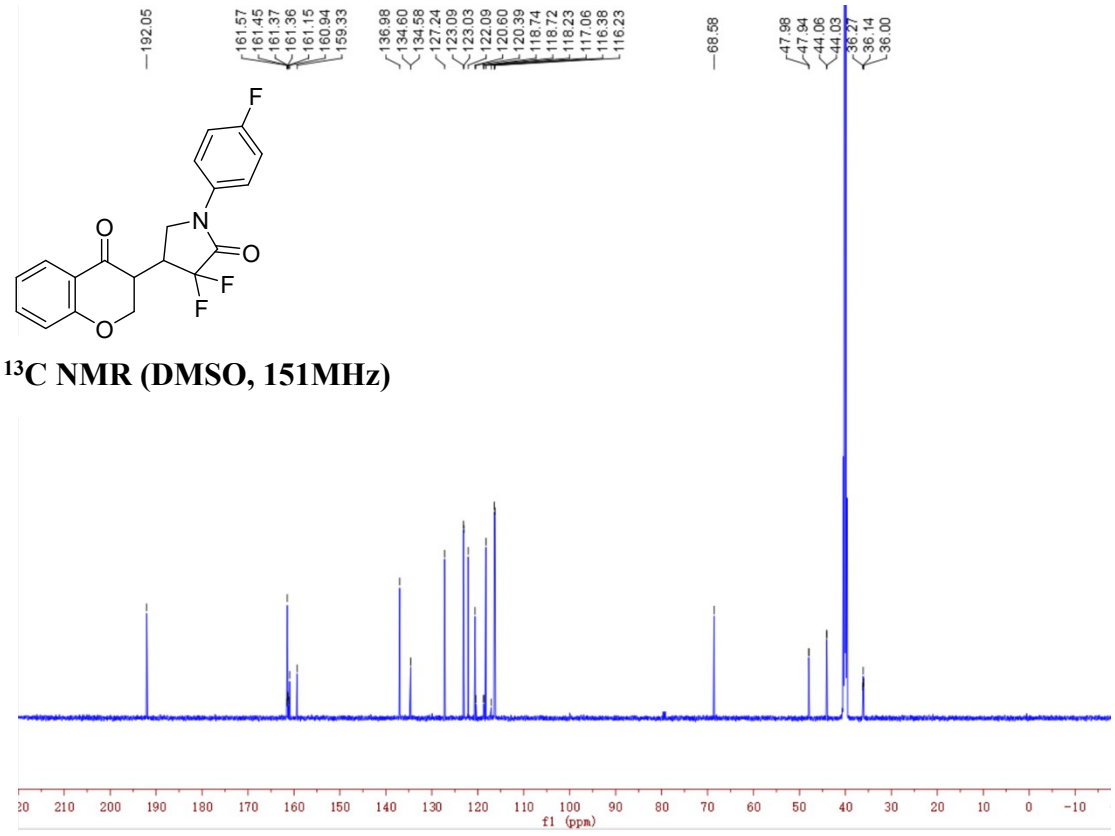
^{19}F NMR ($CDCl_3$, 376MHz)

^{19}F NMR Spectrum of Compound 2r



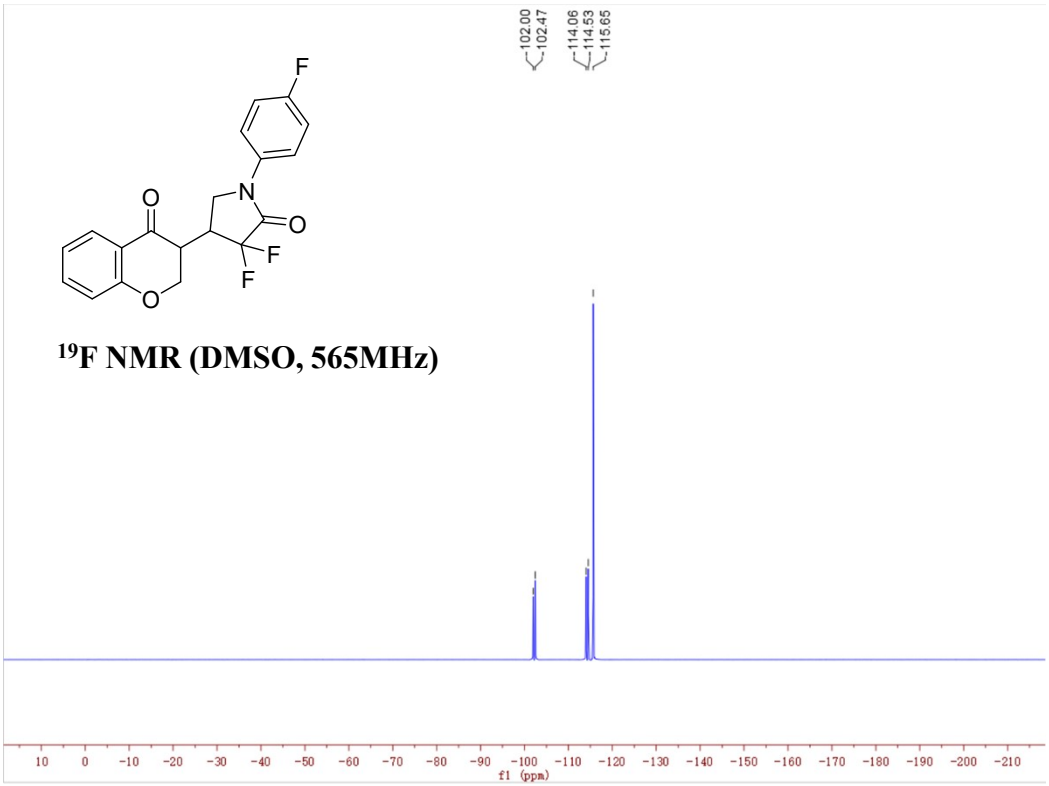
^{1}H NMR (DMSO, 600MHz)

^{1}H NMR Spectrum of Compound 2s



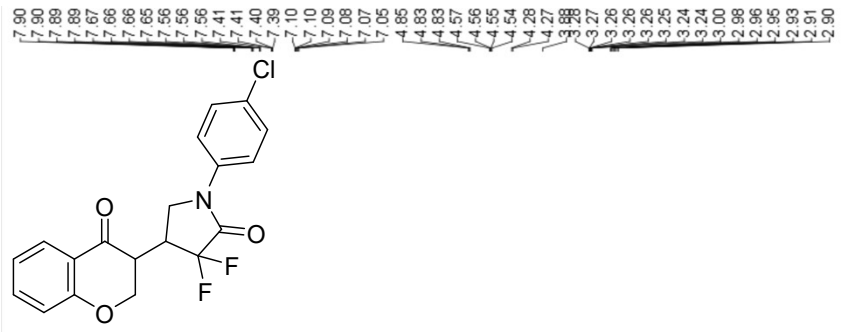
^{13}C NMR (DMSO, 151MHz)

^{13}C NMR Spectrum of Compound 2s

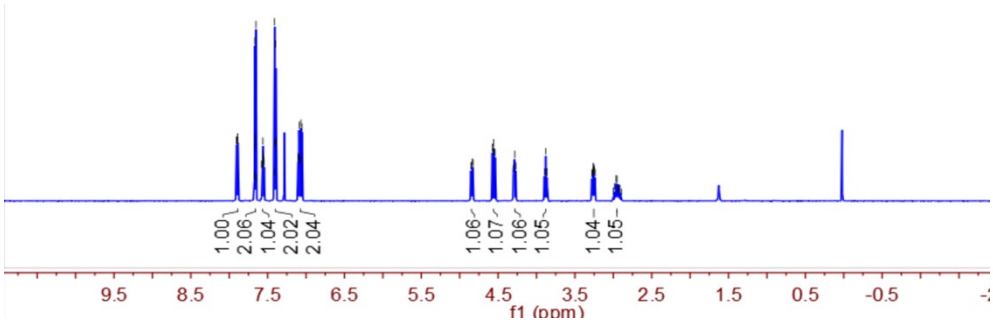


^{19}F NMR (DMSO, 565MHz)

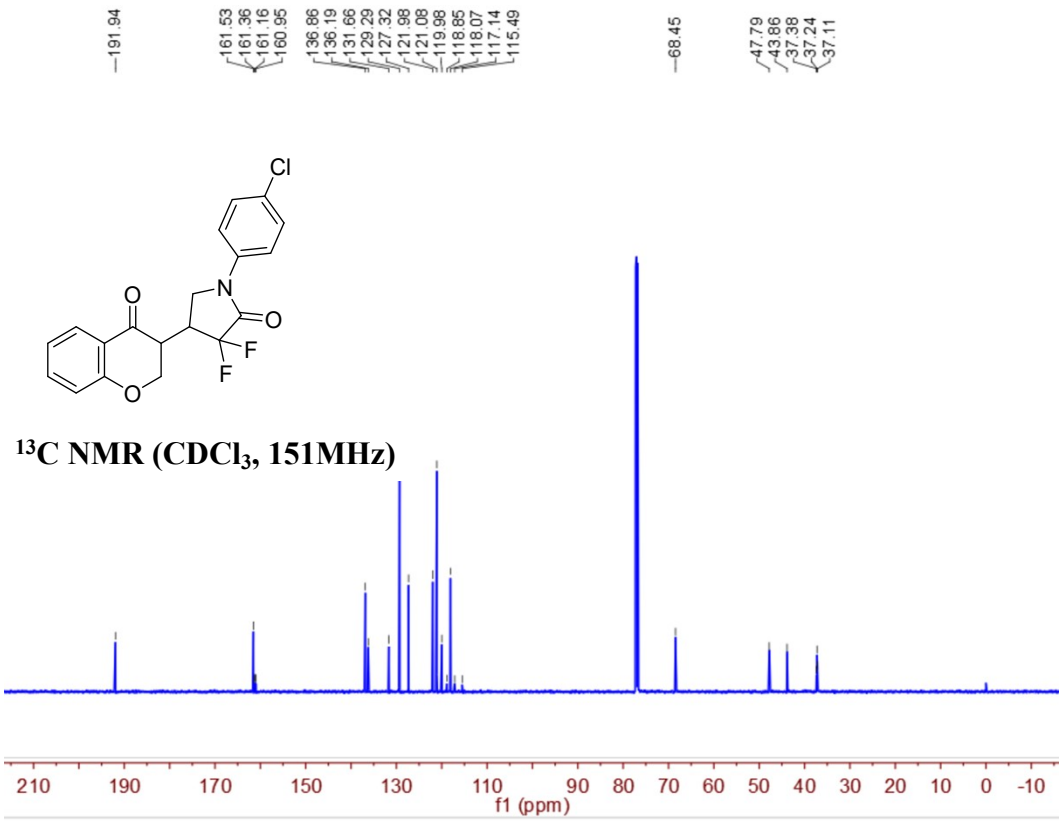
^{19}F NMR Spectrum of Compound 2s



^{1}H NMR ($CDCl_3$, 600MHz)

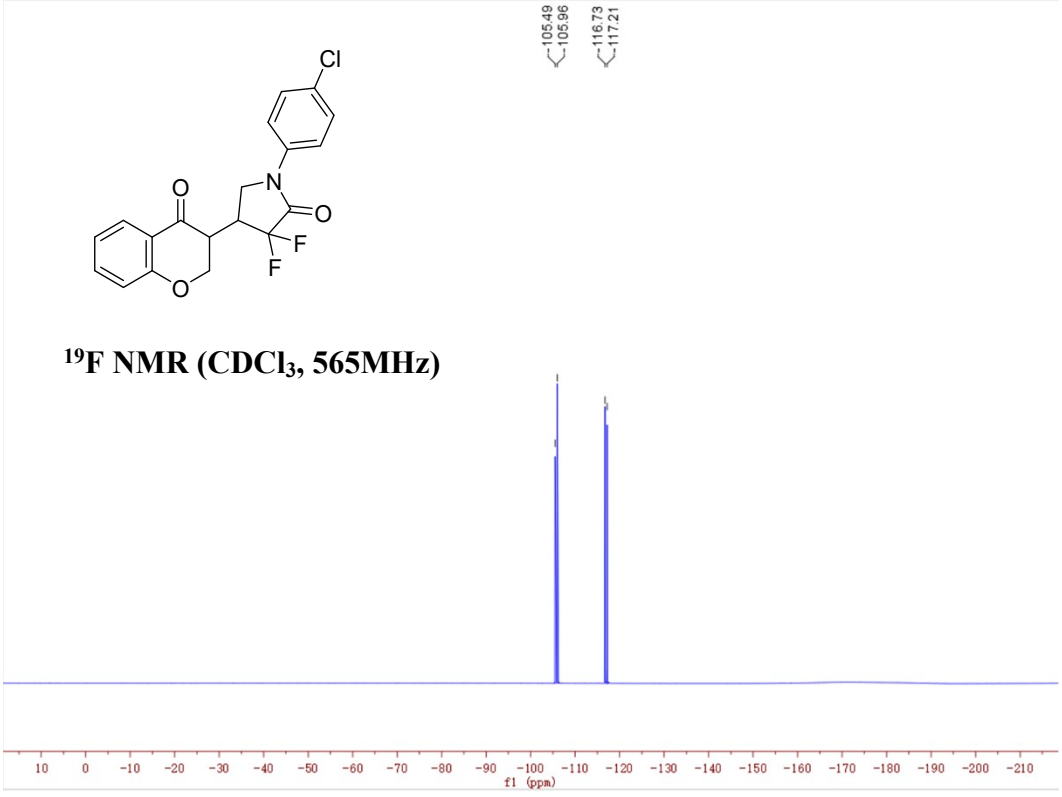


^{1}H NMR Spectrum of Compound 2t



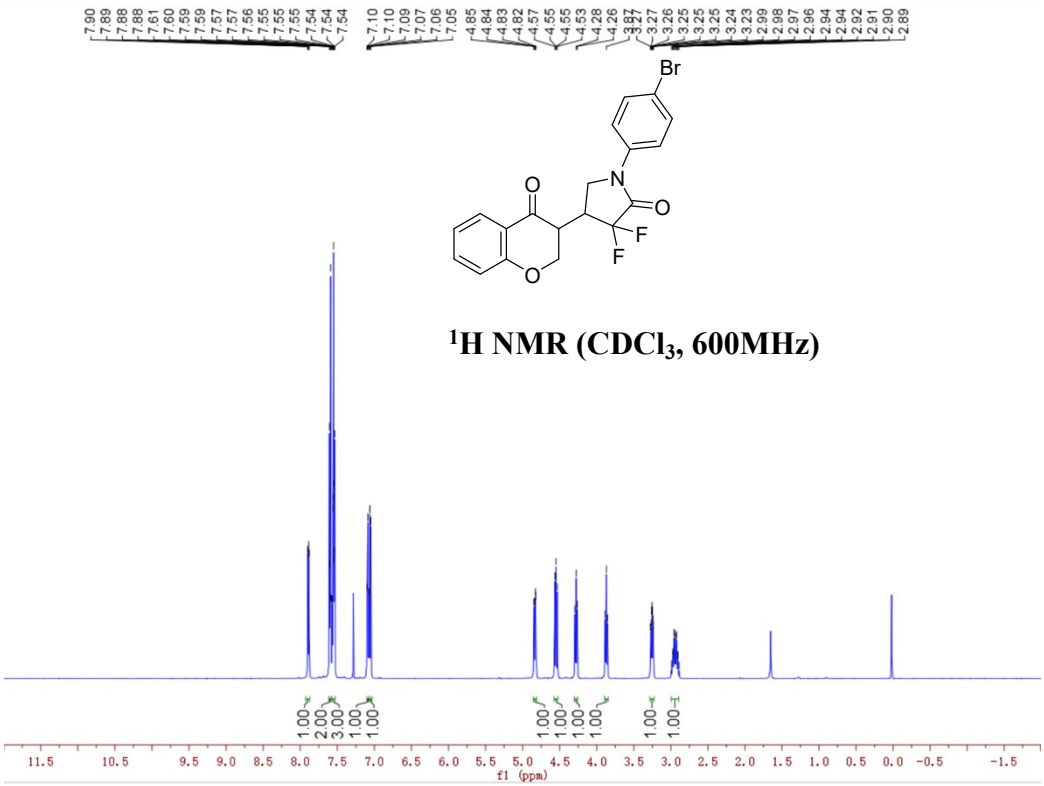
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2t



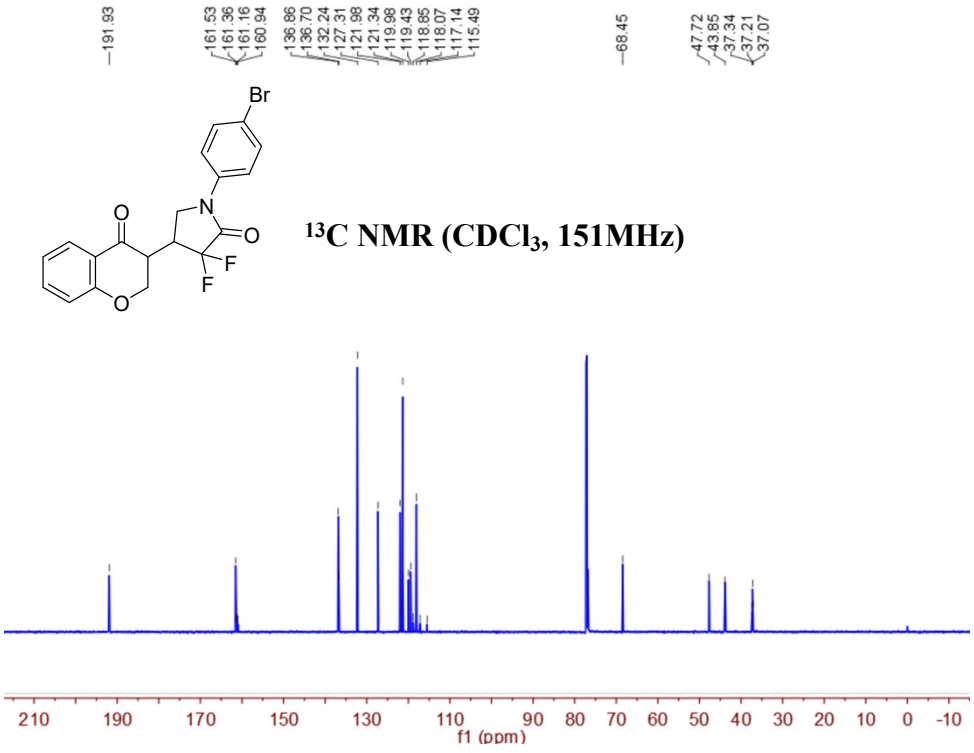
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2t



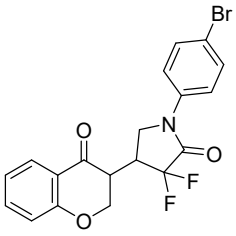
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2u

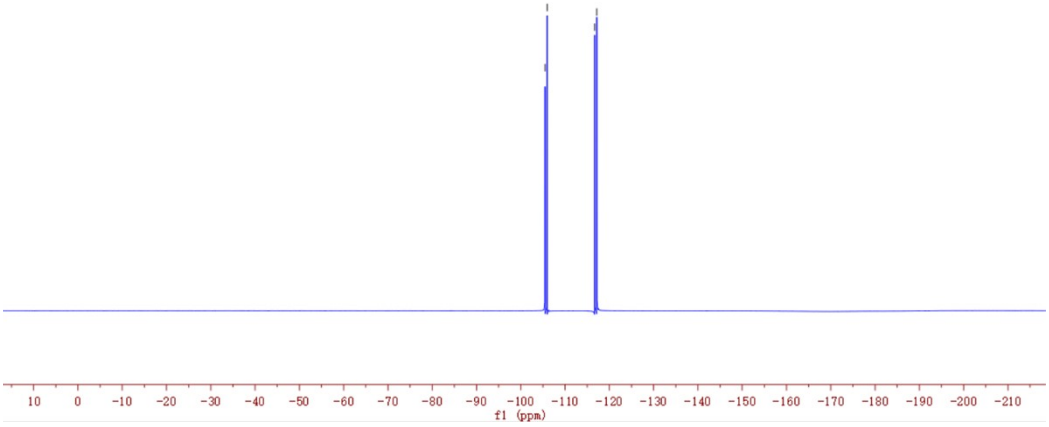


^{13}C NMR ($CDCl_3$, 151MHz)

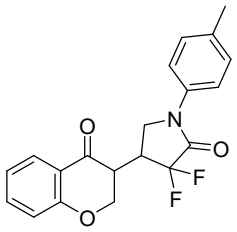
^{13}C NMR Spectrum of Compound 2u



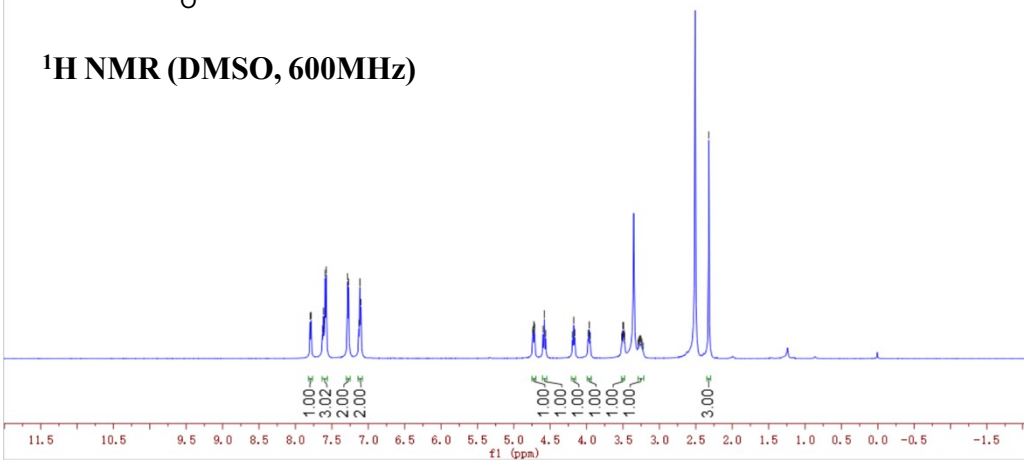
^{19}F NMR ($CDCl_3$, 565MHz)



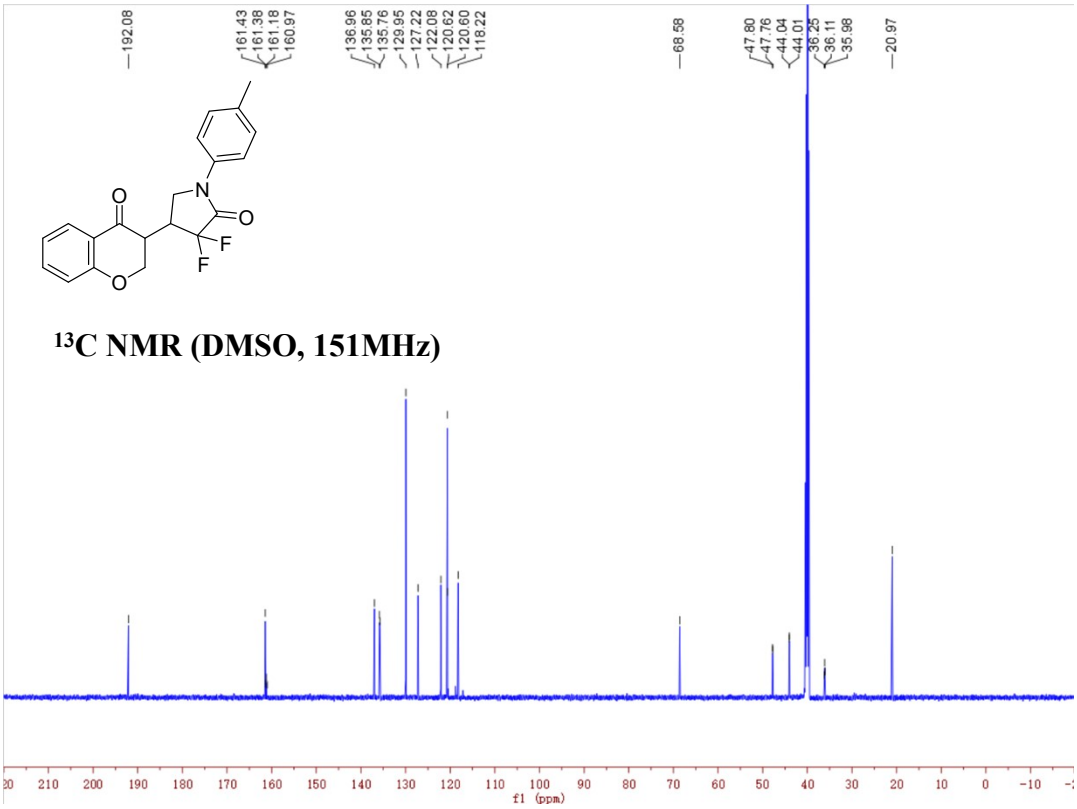
^{19}F NMR Spectrum of Compound 2u



^{1}H NMR (DMSO, 600MHz)

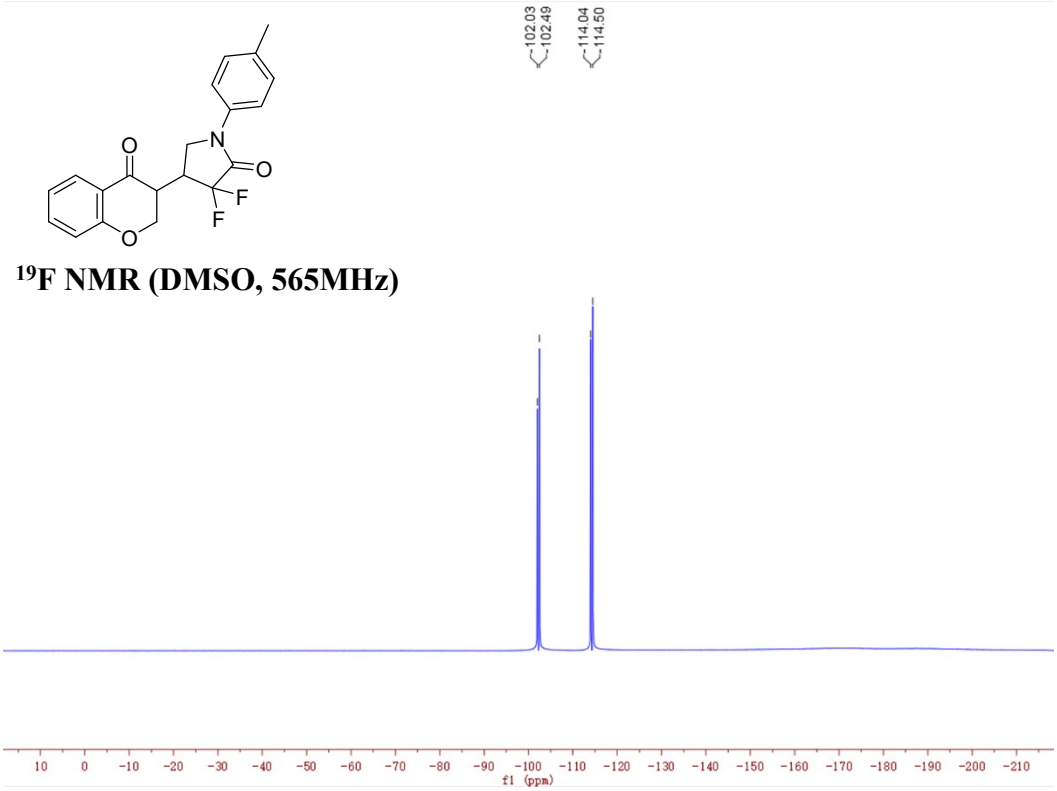


^{1}H NMR Spectrum of Compound 2v



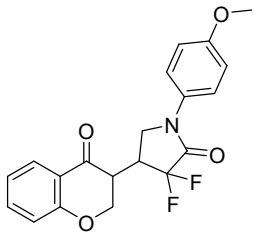
^{13}C NMR (DMSO, 151MHz)

^{13}C NMR Spectrum of Compound 2v



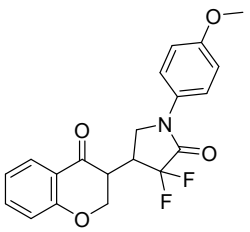
^{19}F NMR (DMSO, 565MHz)

^{19}F NMR Spectrum of Compound 2v

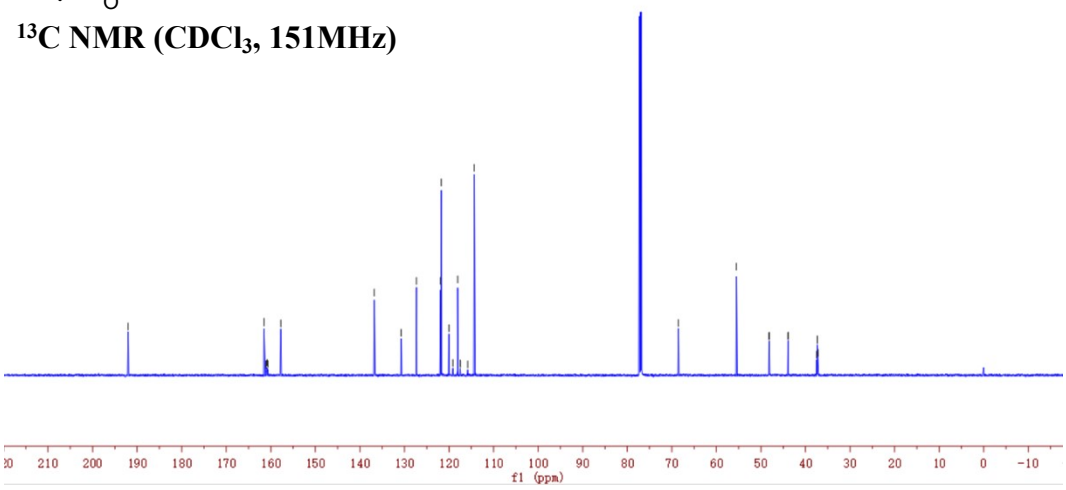


^{1}H NMR ($CDCl_3$, 600MHz)

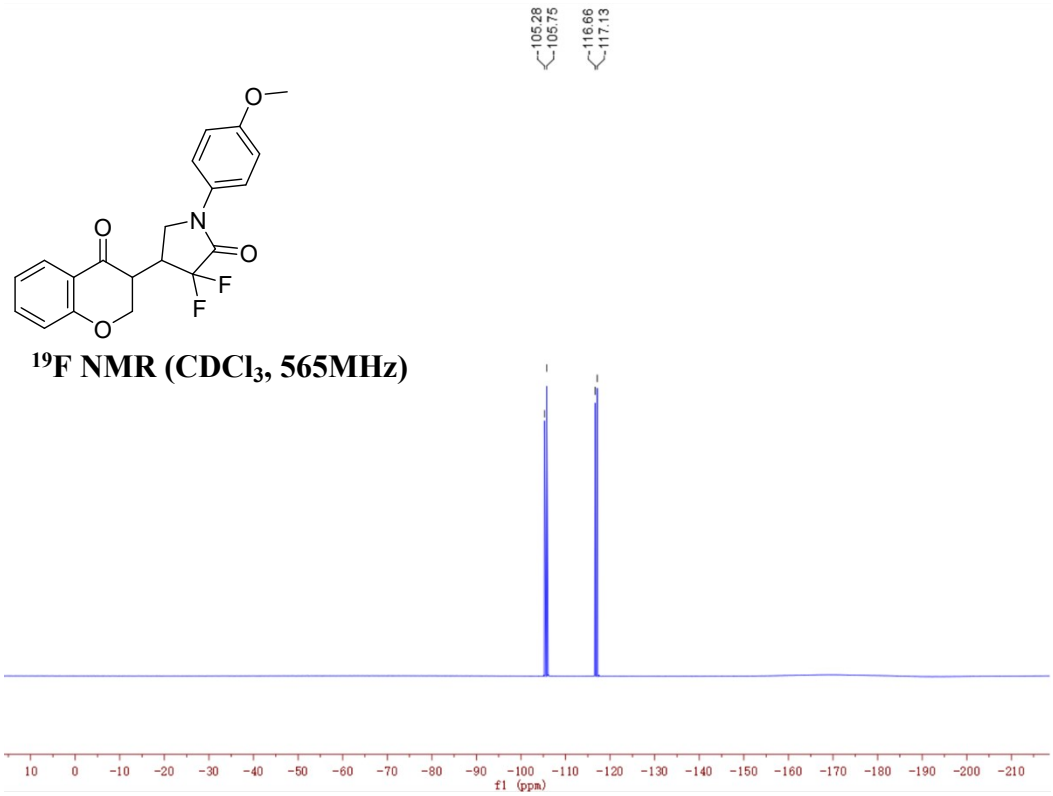
^{1}H NMR Spectrum of Compound 2w



^{13}C NMR ($CDCl_3$, 151MHz)

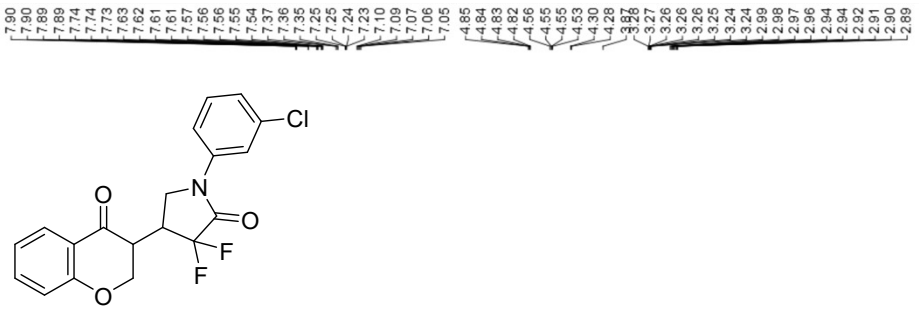


^{13}C NMR Spectrum of Compound 2w

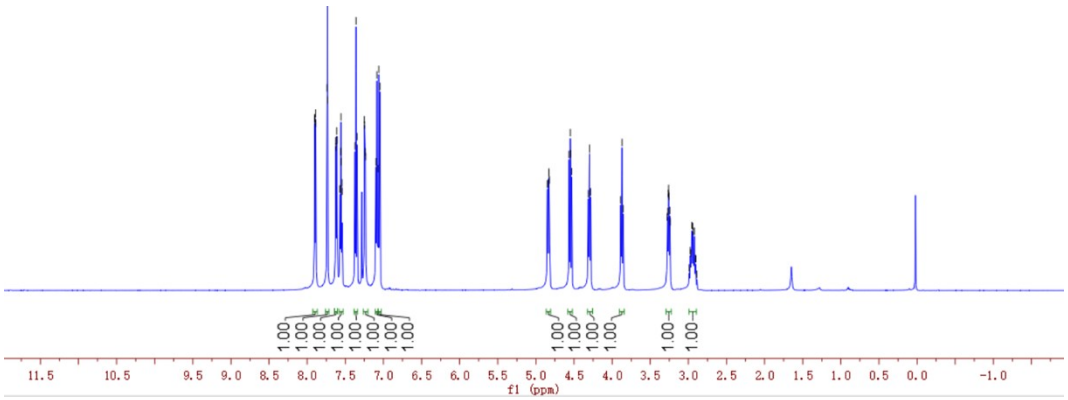


^{19}F NMR ($CDCl_3$, 565MHz)

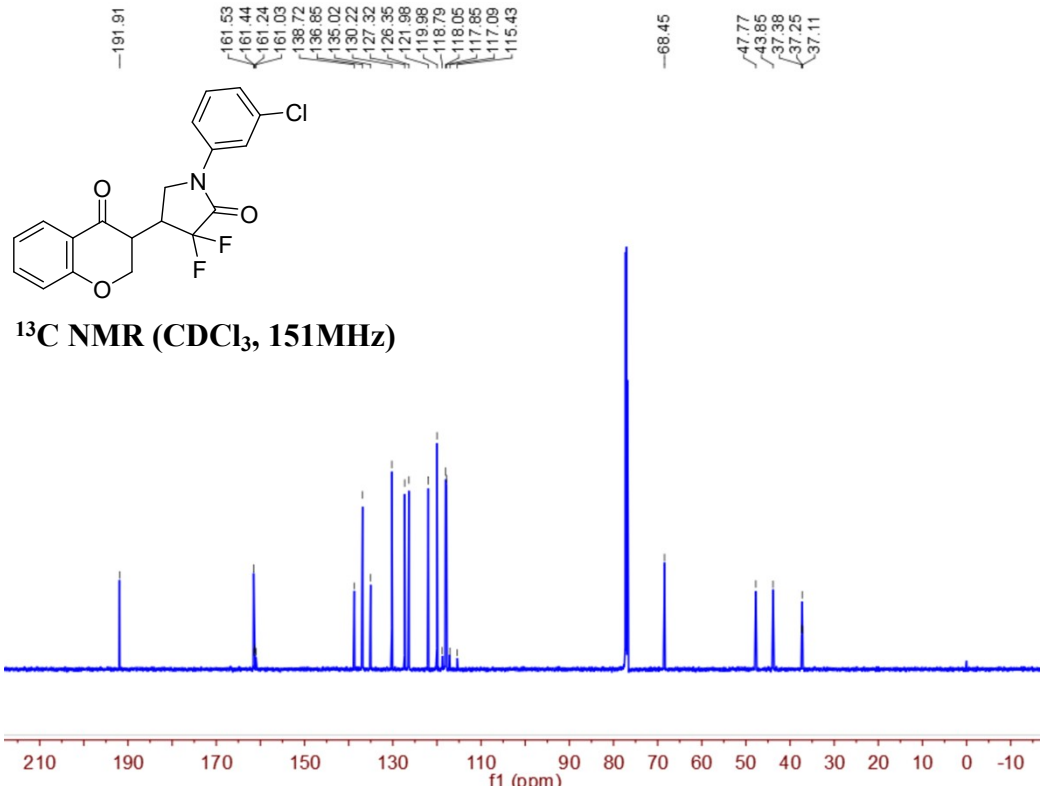
^{19}F NMR Spectrum of Compound 2w



^{1}H NMR ($CDCl_3$, 600MHz)



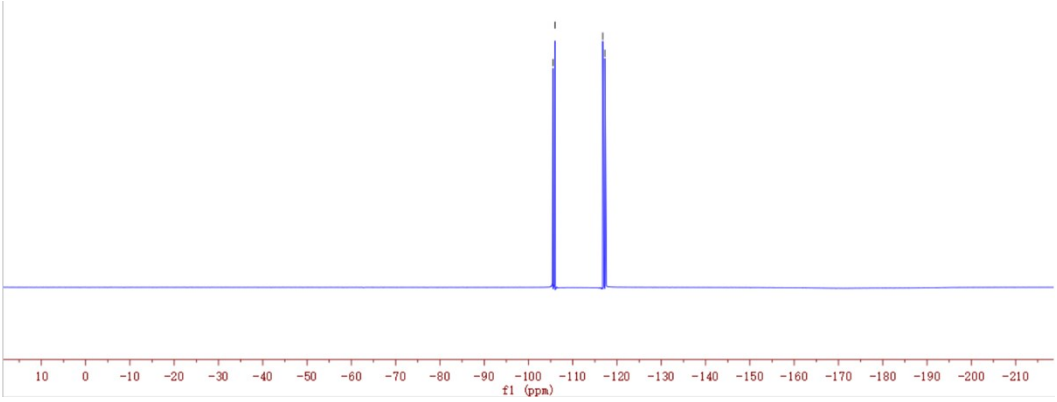
^{1}H NMR Spectrum of Compound 2x



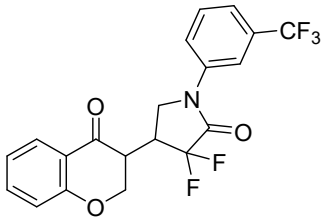
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2x

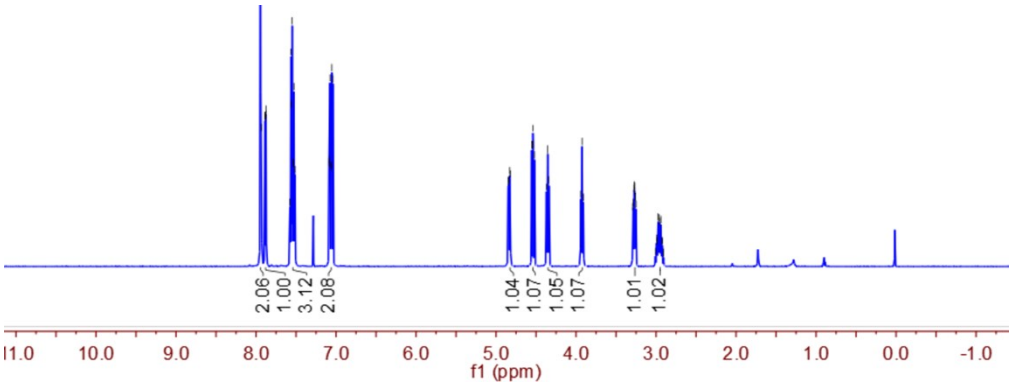
^{19}F NMR ($CDCl_3$, 565MHz)



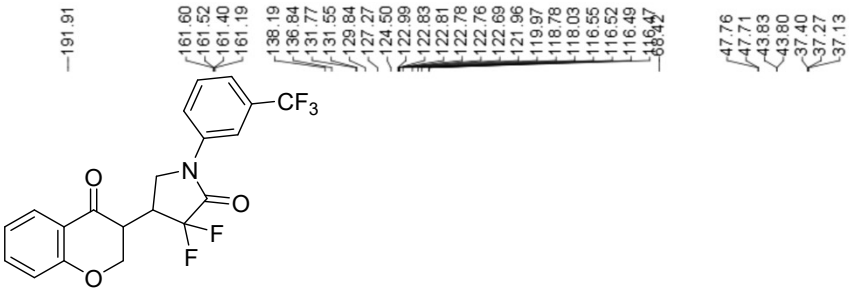
^{19}F NMR Spectrum of Compound 2x



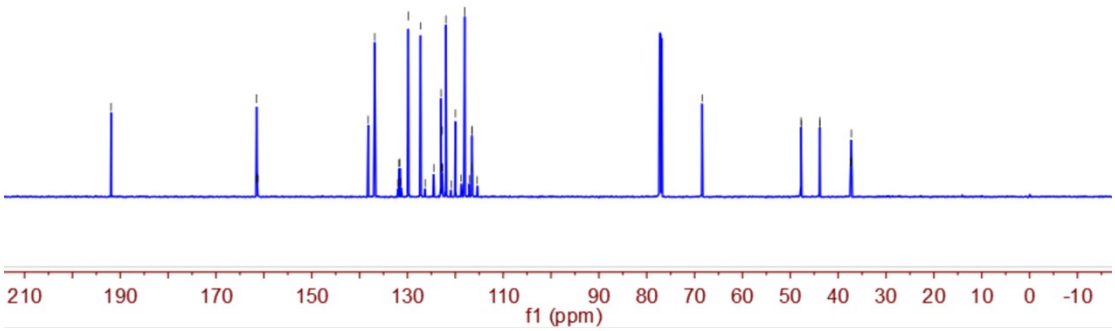
^{1}H NMR ($CDCl_3$, 600MHz)



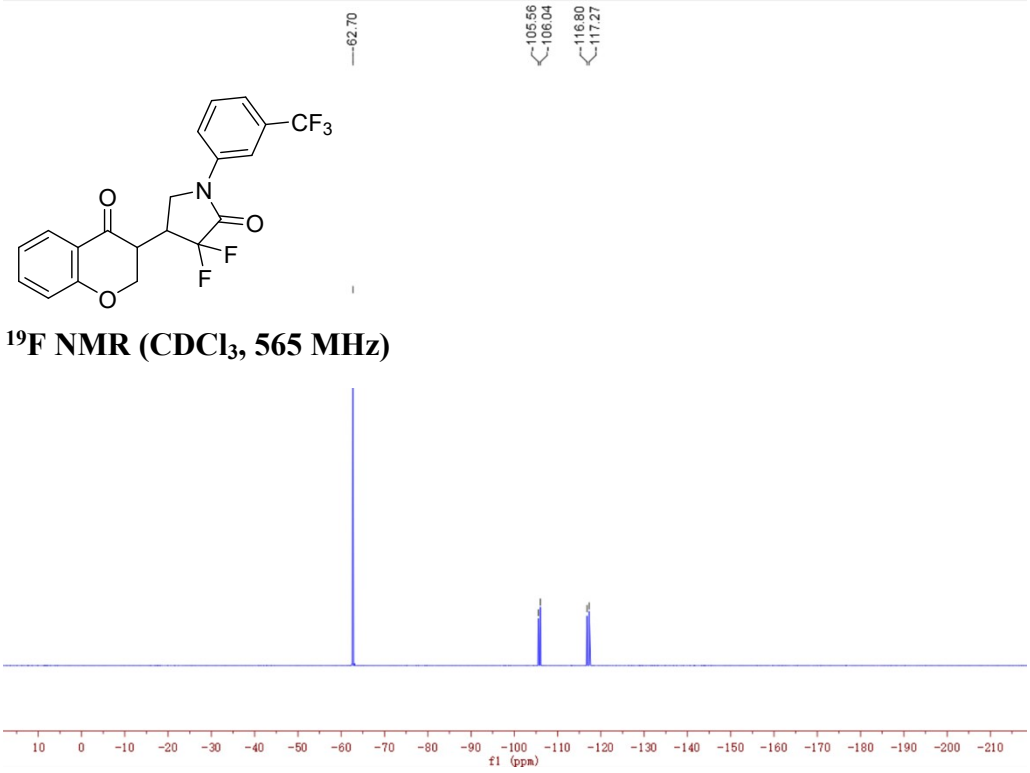
^{1}H NMR Spectrum of Compound 2y



^{13}C NMR ($CDCl_3$, 151MHz)

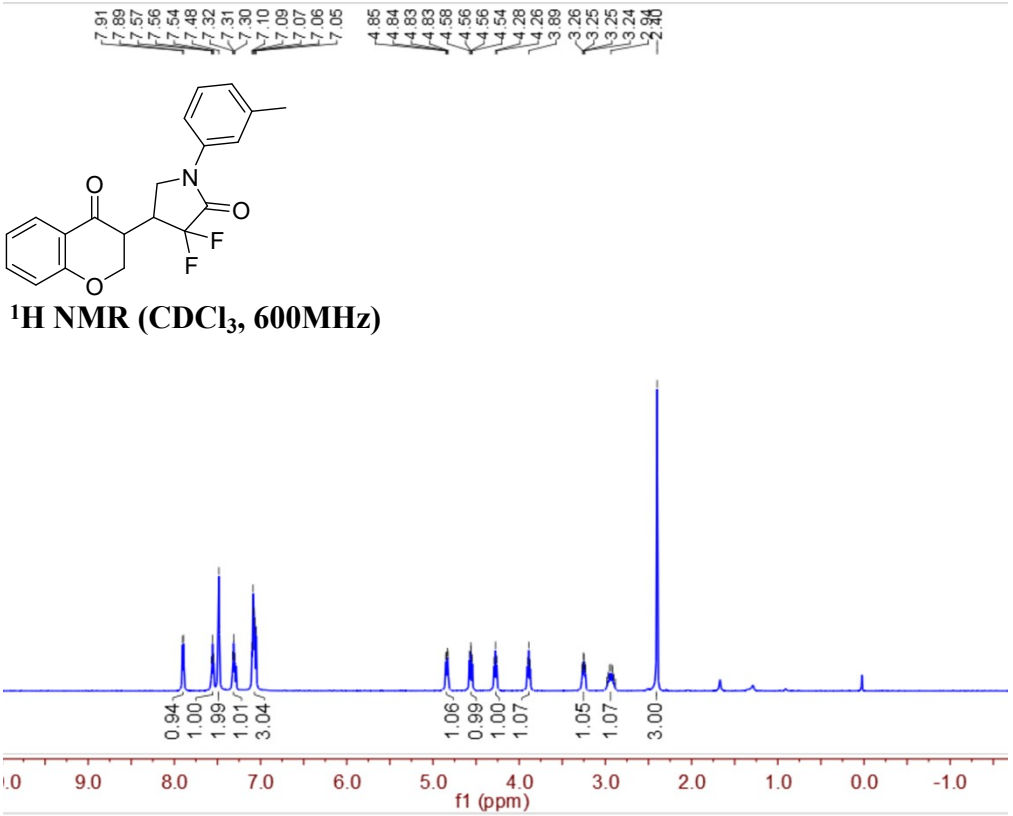


^{13}C NMR Spectrum of Compound 2y



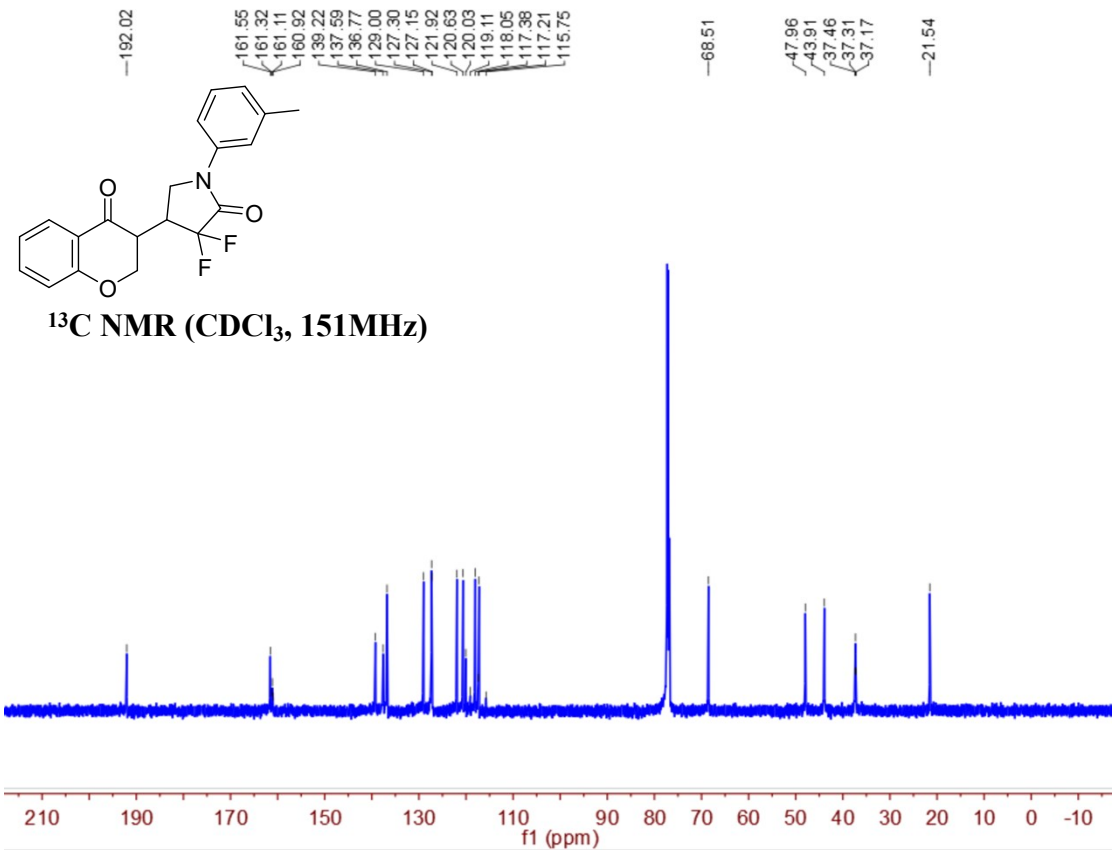
^{19}F NMR ($CDCl_3$, 565 MHz)

^{19}F NMR Spectrum of Compound 2y



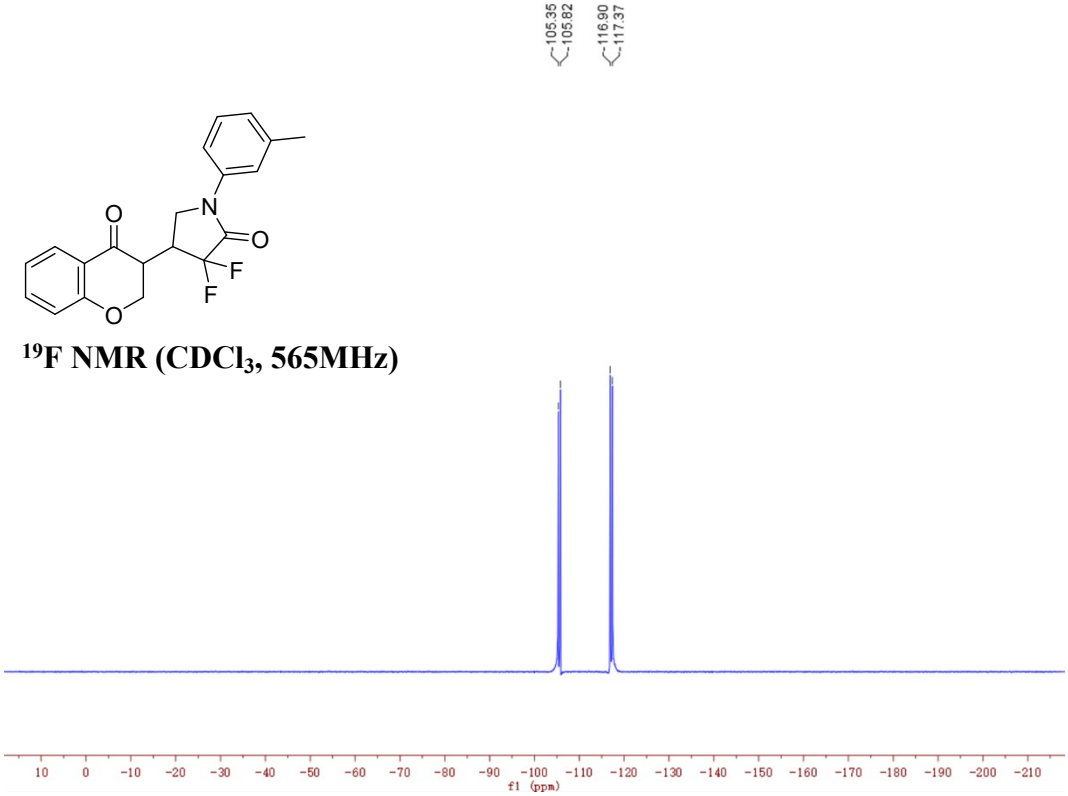
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2z



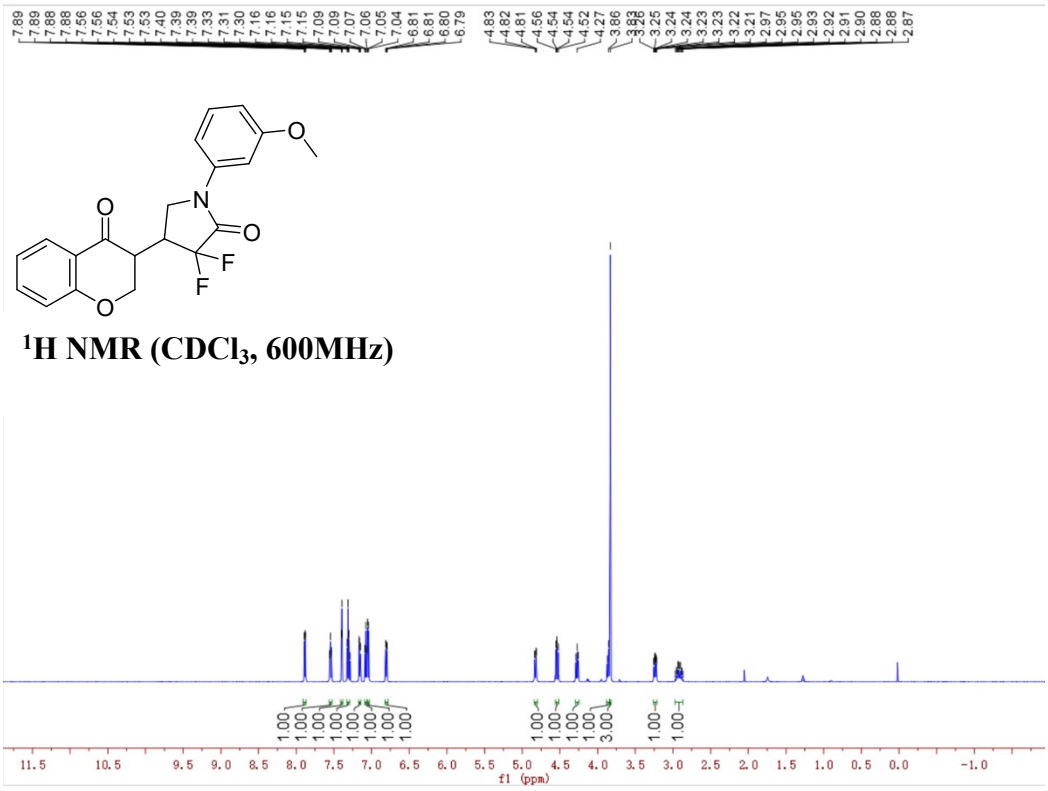
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2z



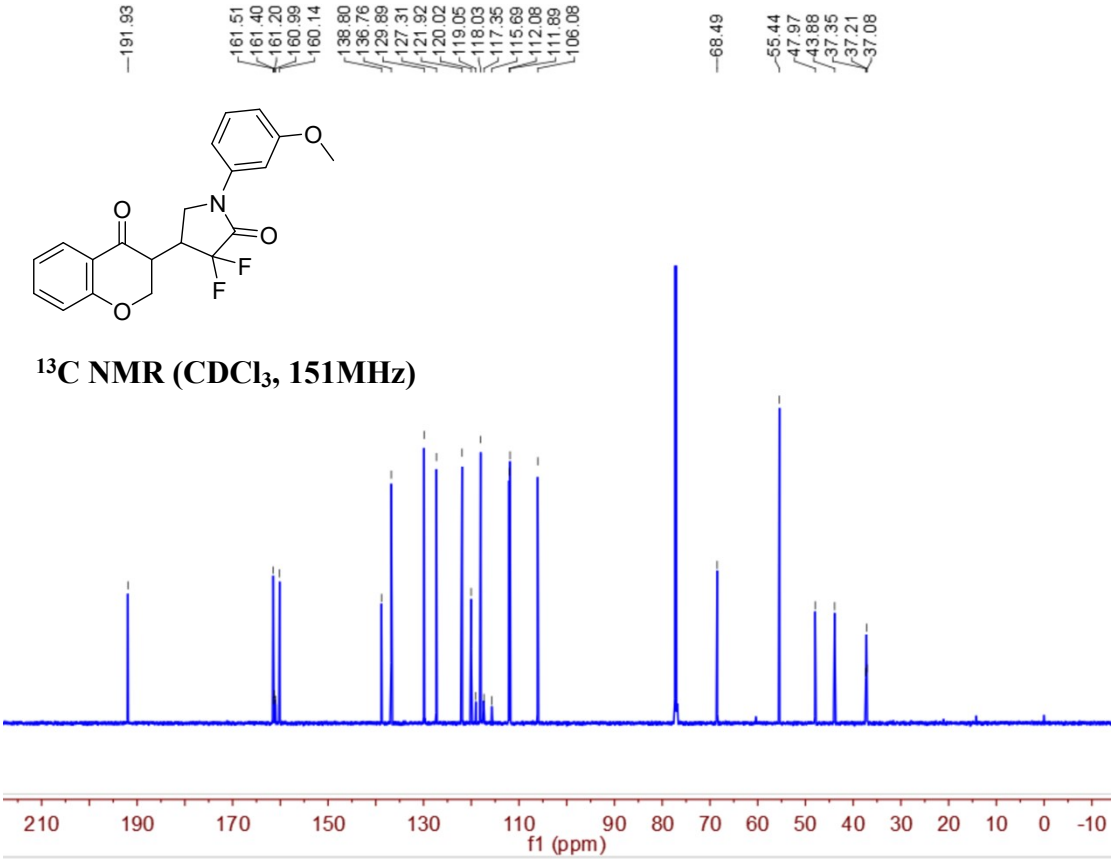
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2z



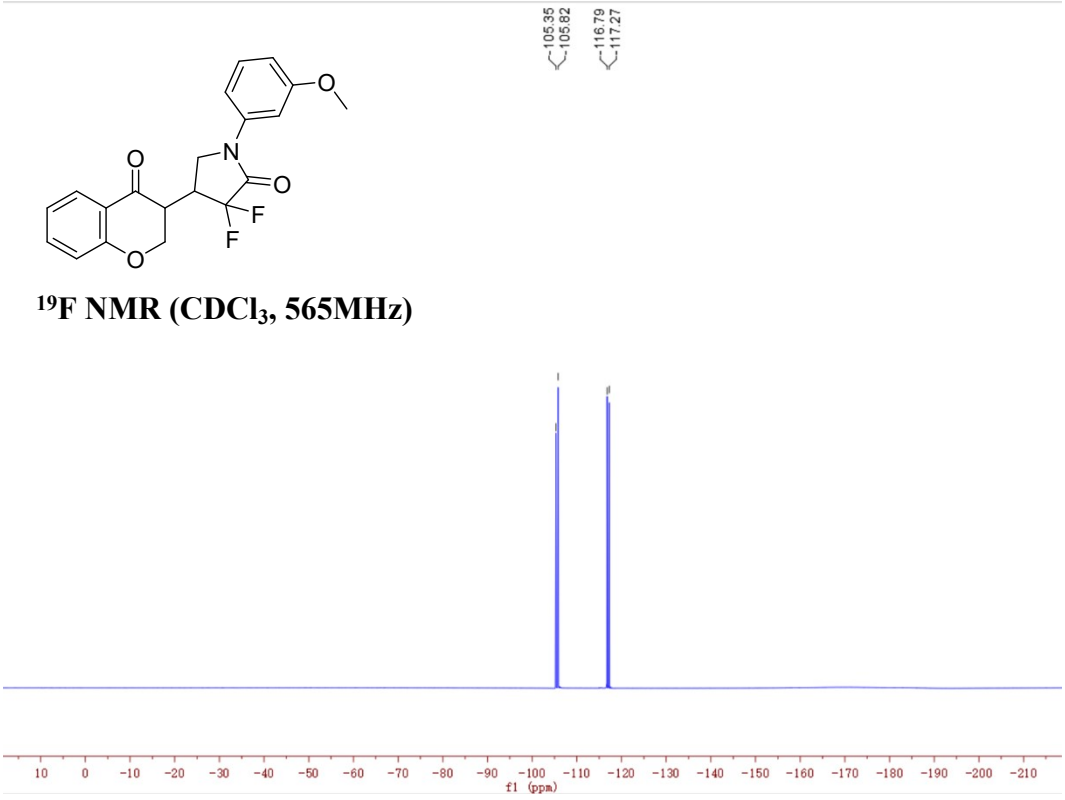
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2aa



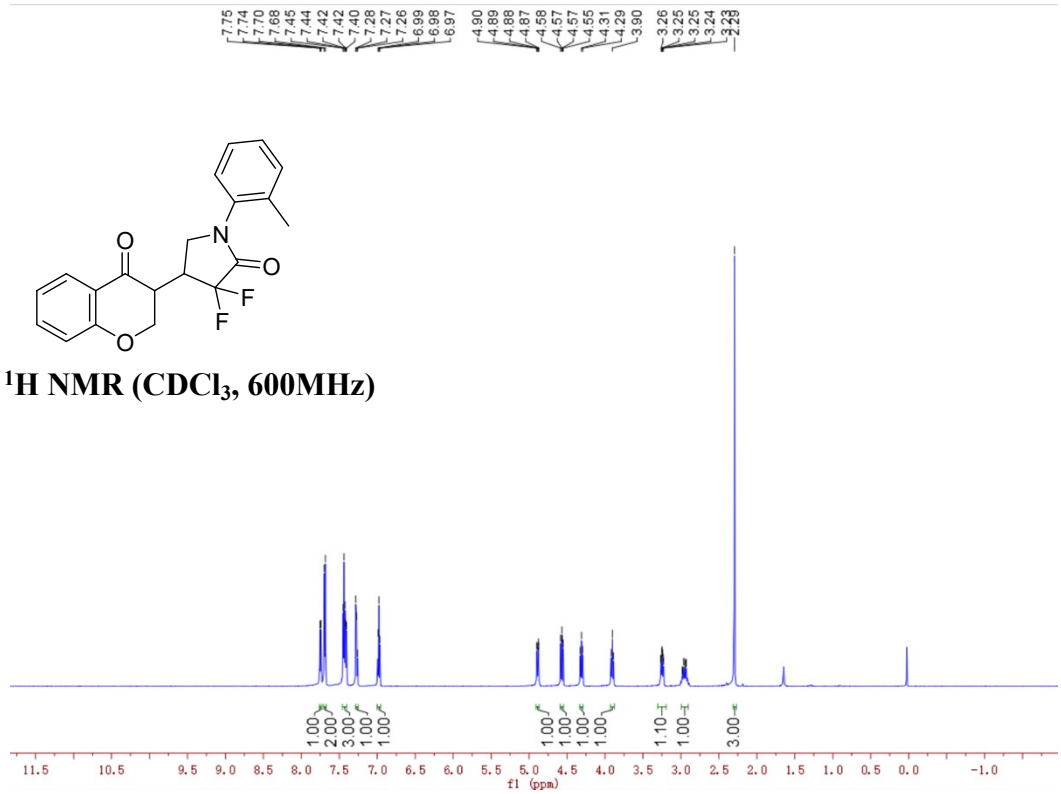
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2aa



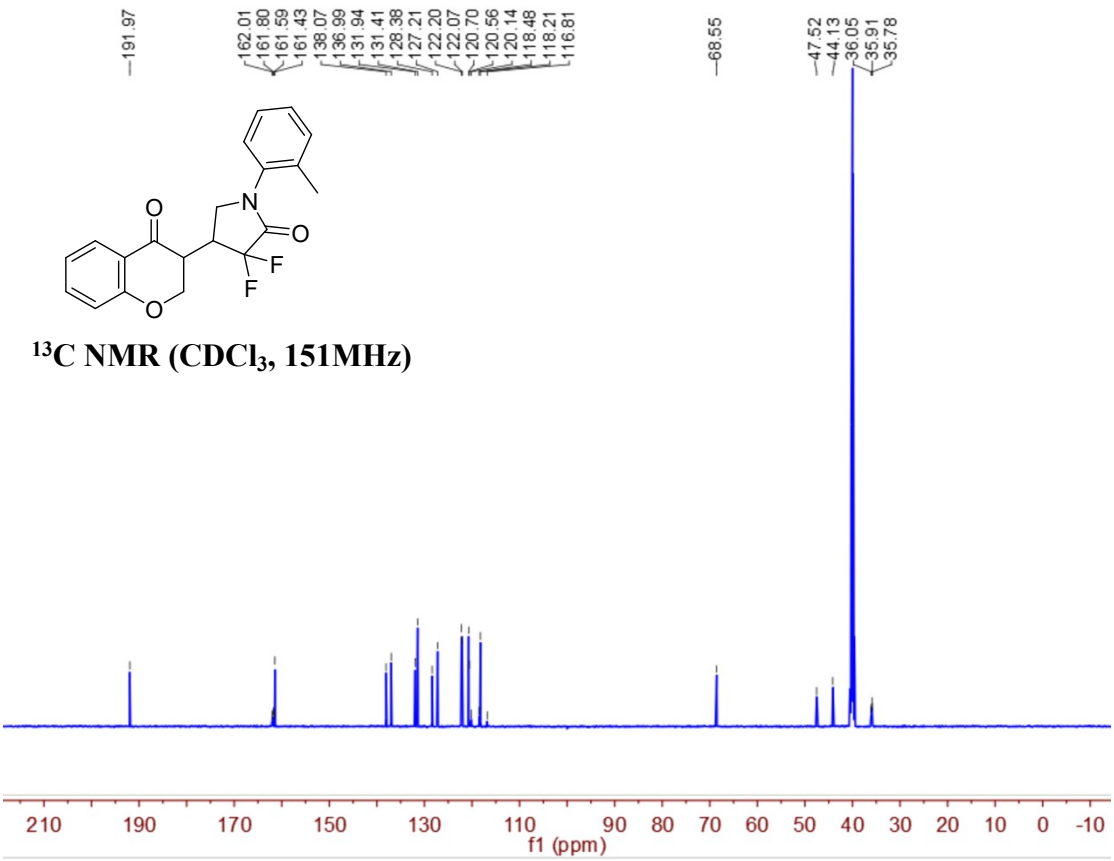
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2aa



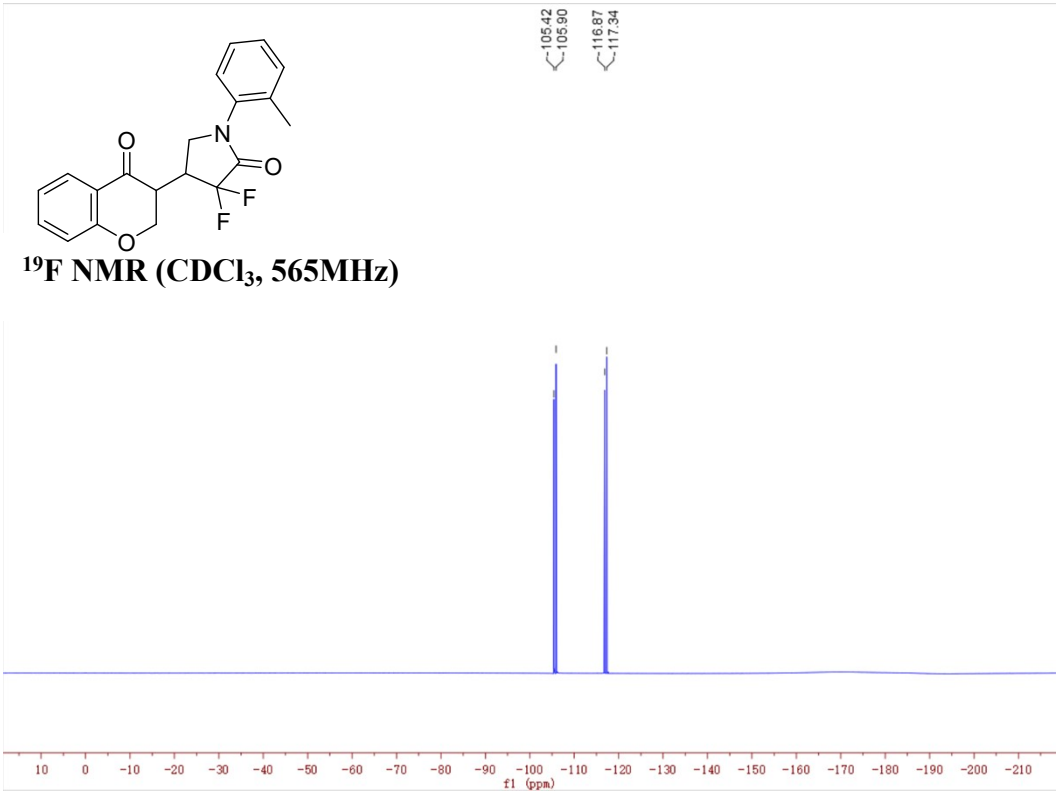
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2ab



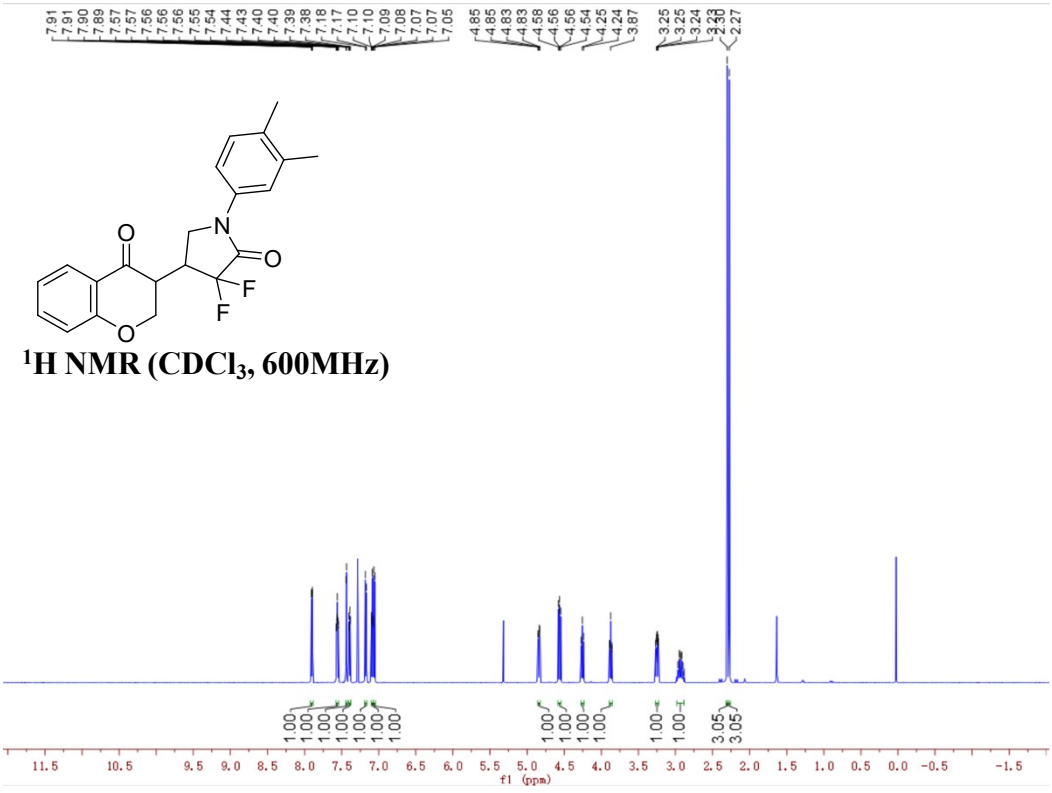
^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2ab



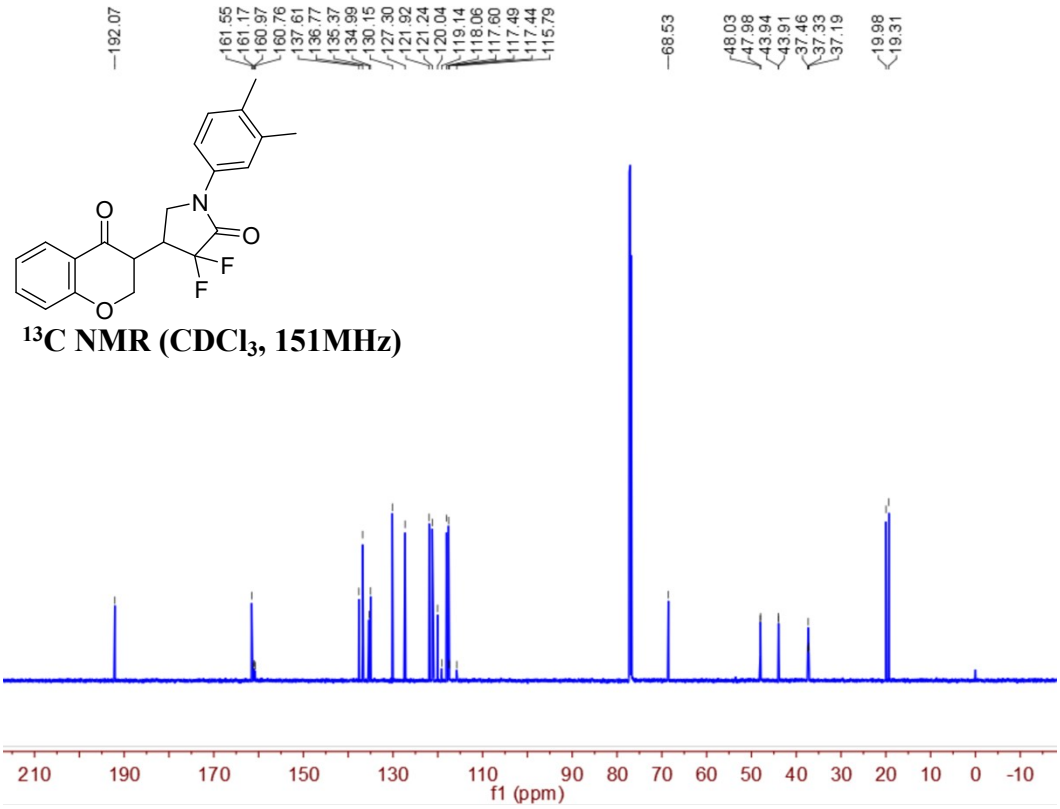
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2ab



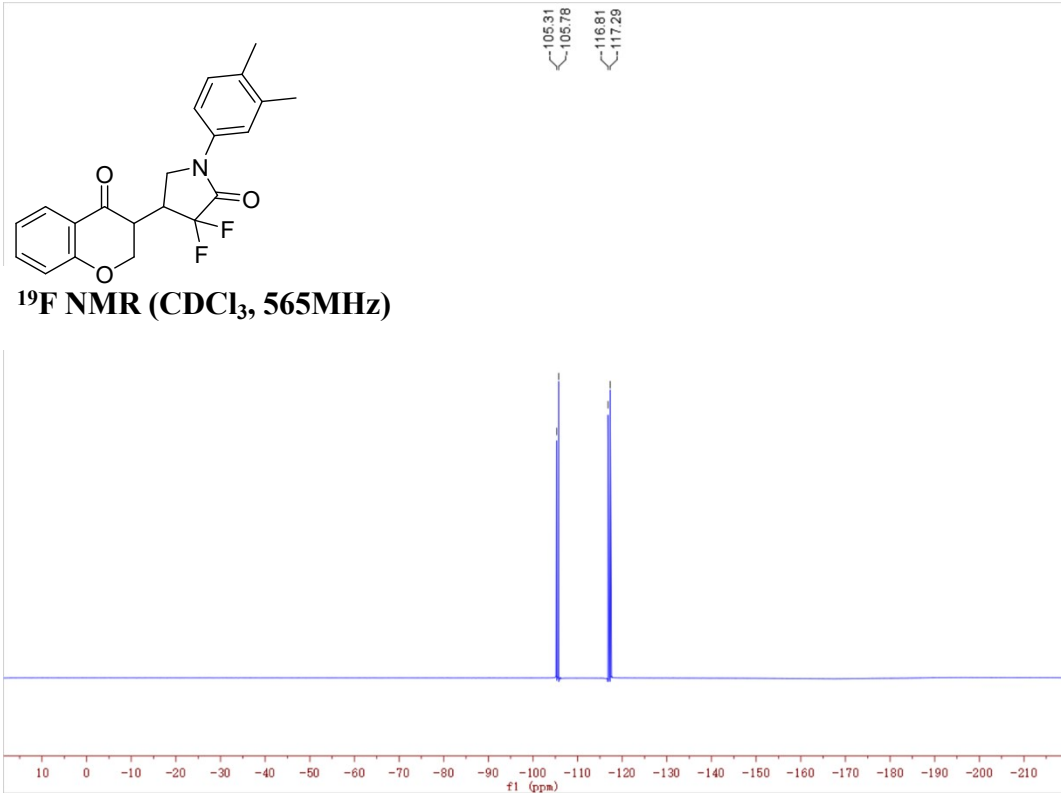
^{1}H NMR (CDCl$_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2ac



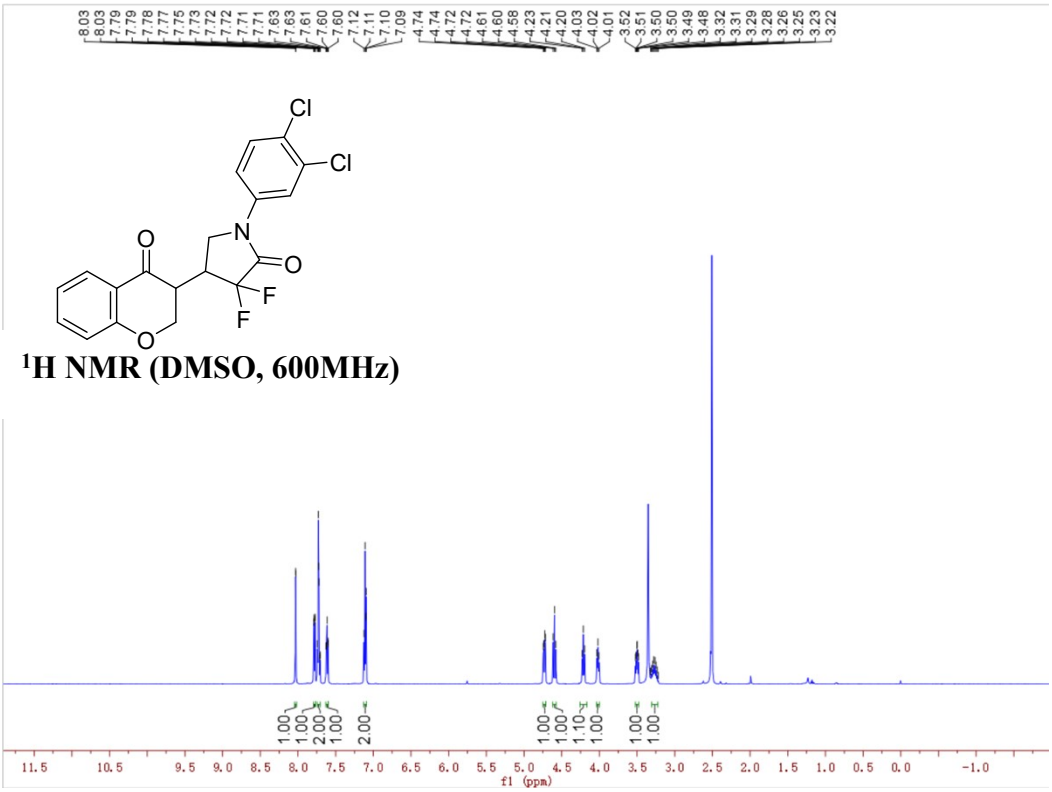
^{13}C NMR (CDCl$_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2ac



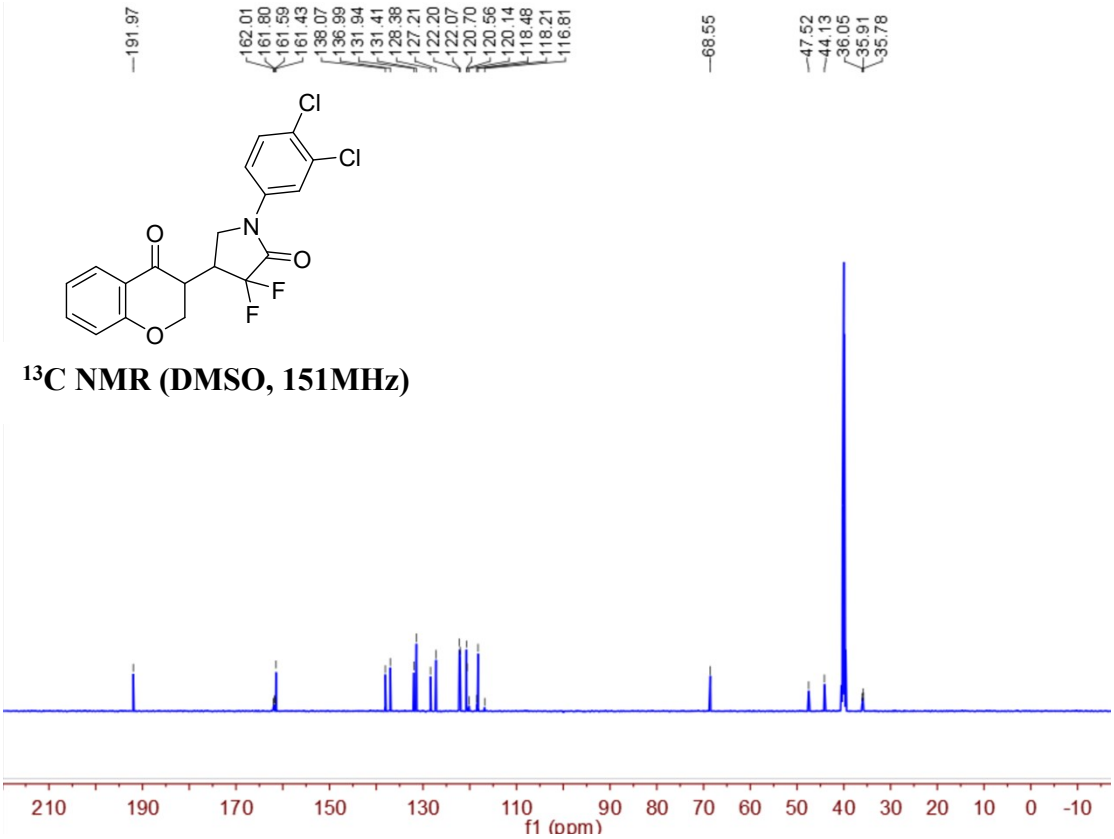
^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2ac



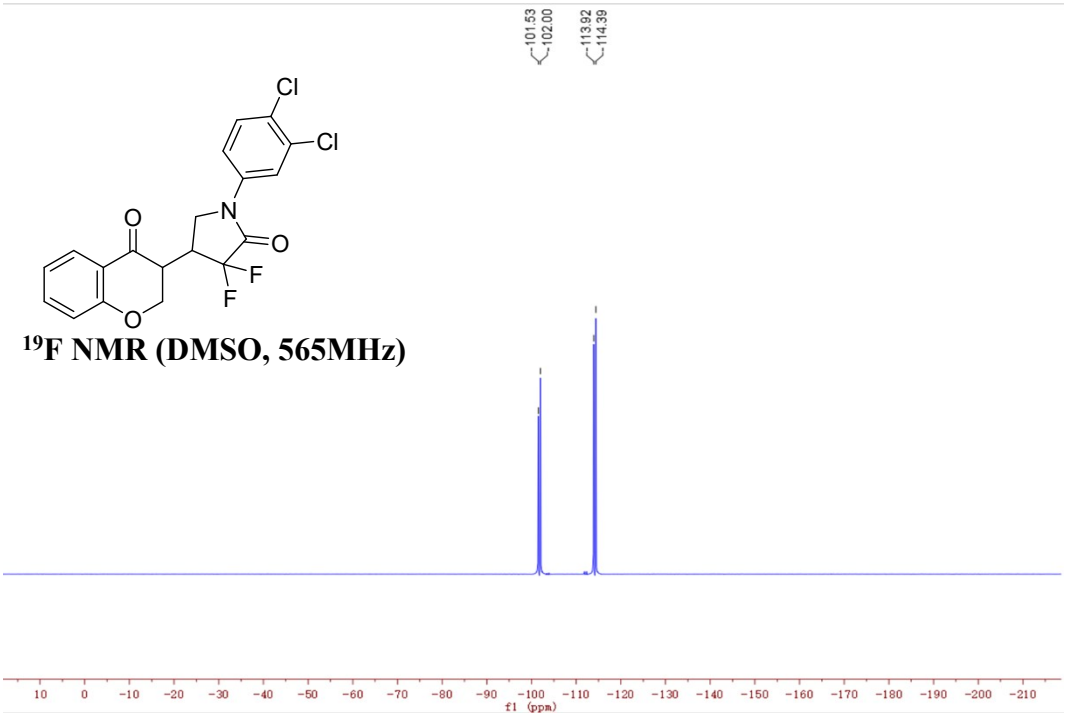
^{1}H NMR (DMSO, 600MHz)

^{1}H NMR Spectrum of Compound 2ad



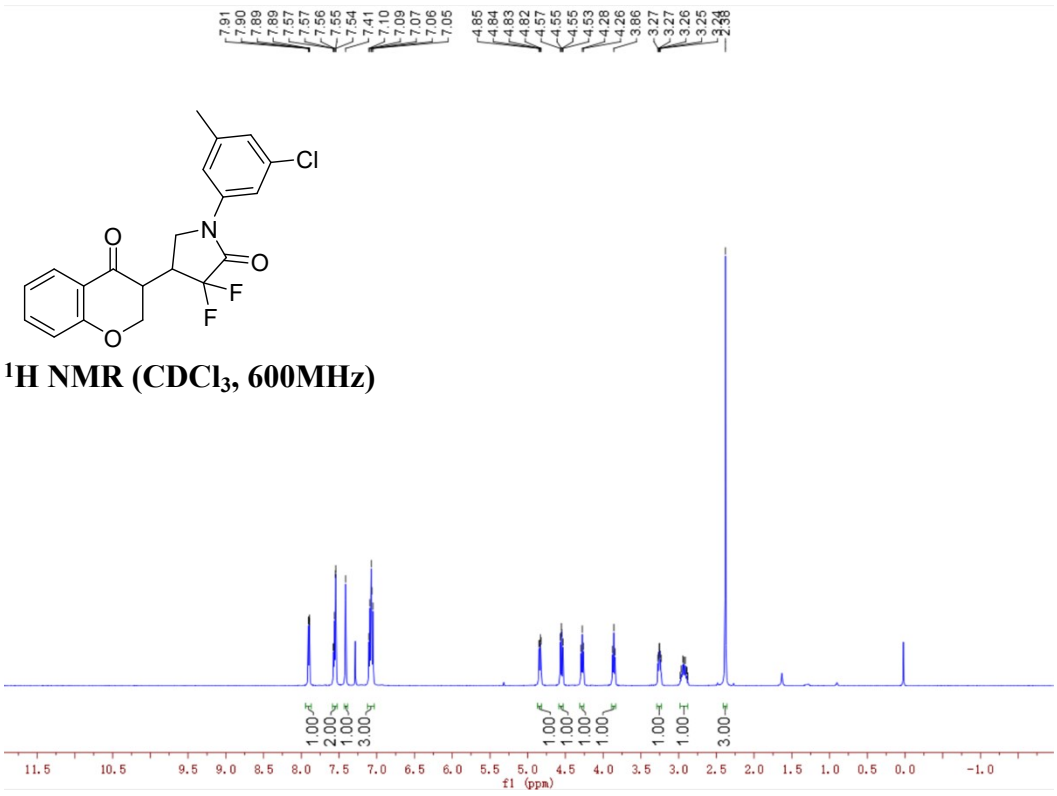
^{13}C NMR (DMSO, 151MHz)

^{13}C NMR Spectrum of Compound 2ad



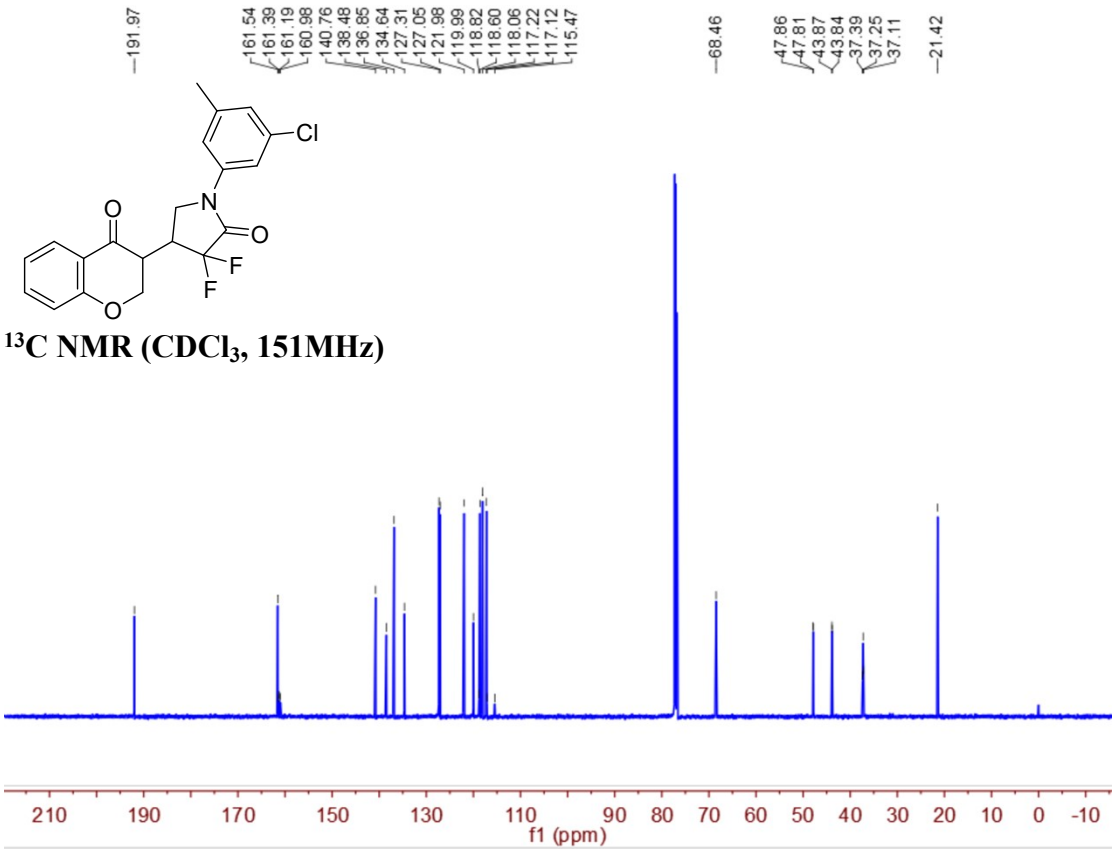
^{19}F NMR (DMSO, 565MHz)

^{19}F NMR Spectrum of Compound 2ad



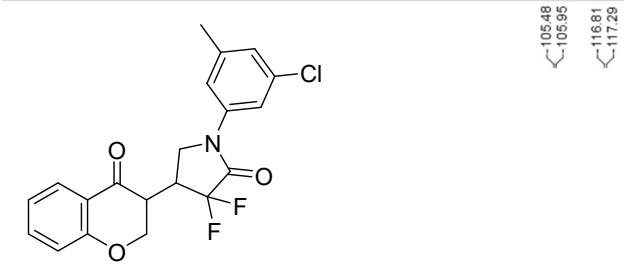
^{1}H NMR ($CDCl_3$, 600MHz)

^{1}H NMR Spectrum of Compound 2ae

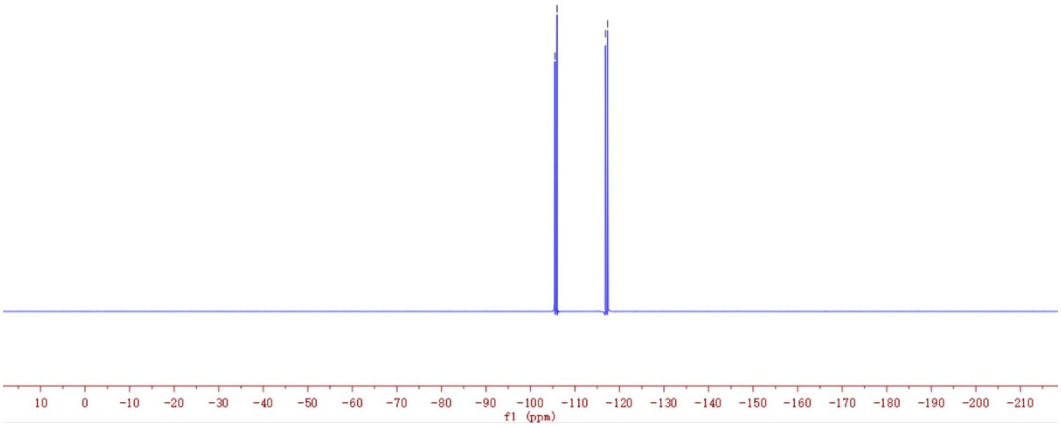


^{13}C NMR ($CDCl_3$, 151MHz)

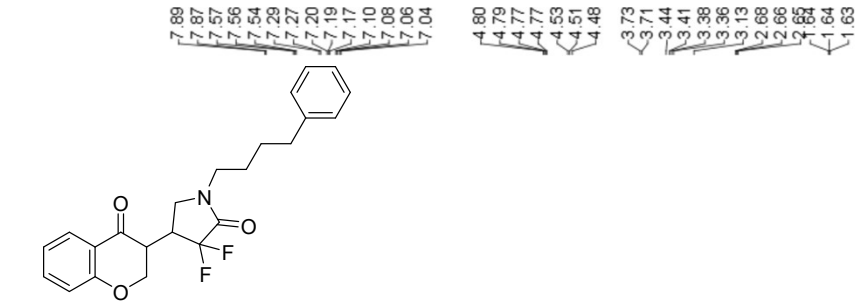
^{13}C NMR Spectrum of Compound 2ae



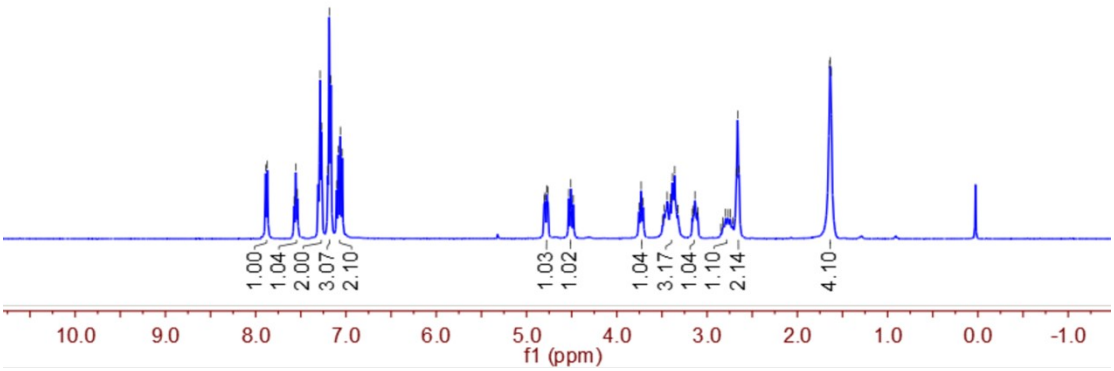
^{19}F NMR ($CDCl_3$, 565MHz)



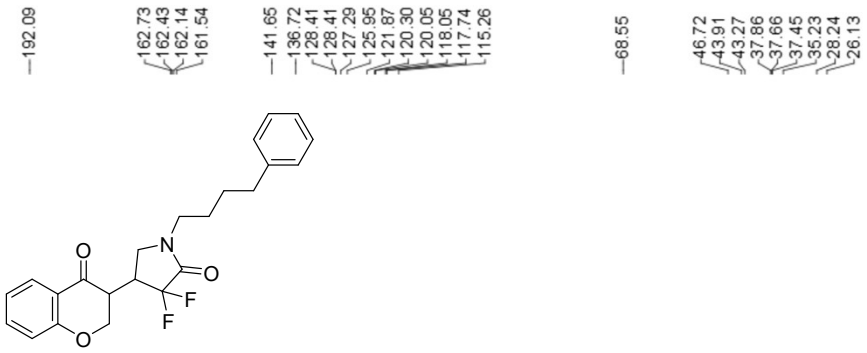
^{19}F NMR Spectrum of Compound 2ae



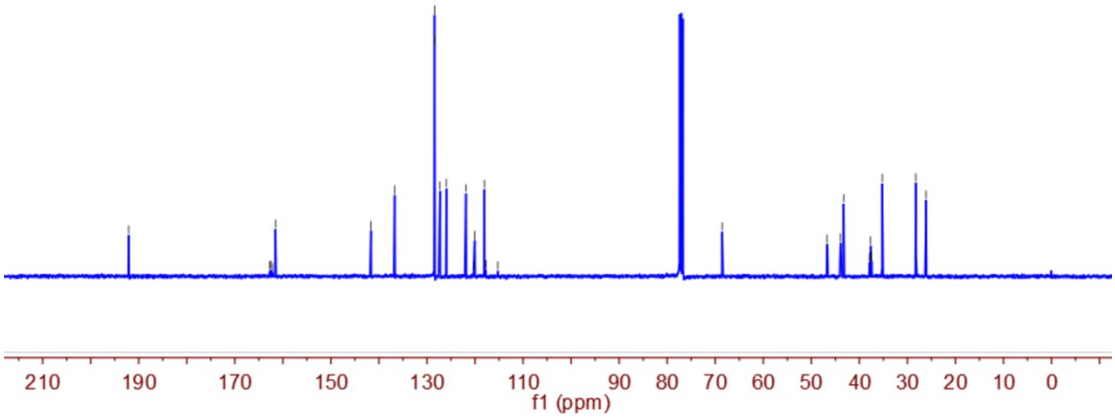
^{1}H NMR ($CDCl_3$, 400MHz)



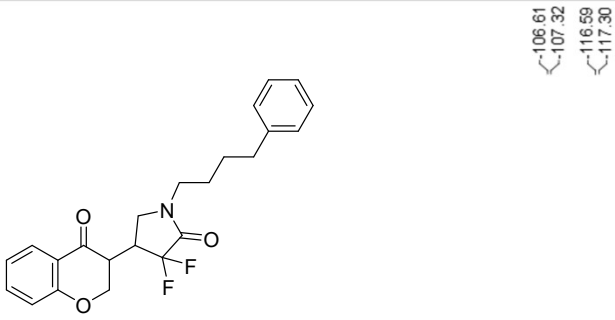
^{1}H NMR Spectrum of Compound 2af



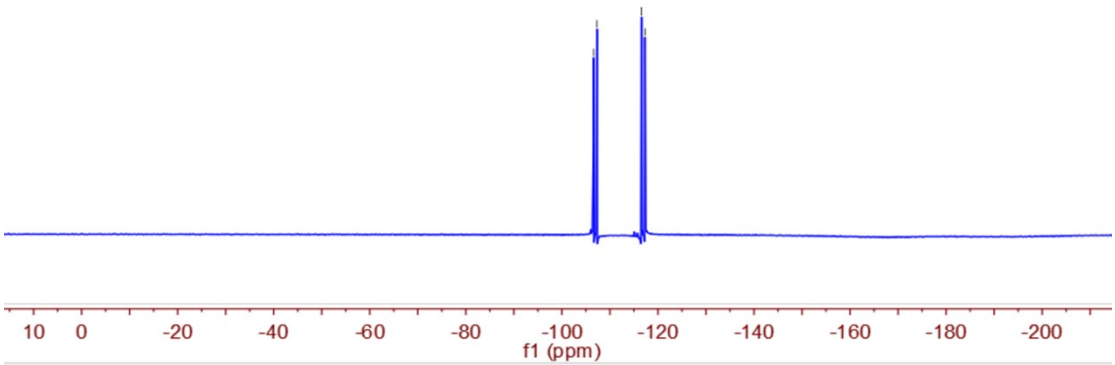
^{13}C NMR ($CDCl_3$, 101MHz)



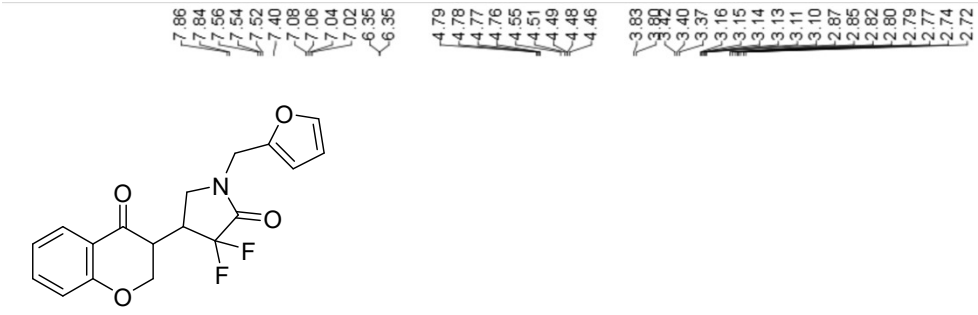
^{13}C NMR Spectrum of Compound 2af



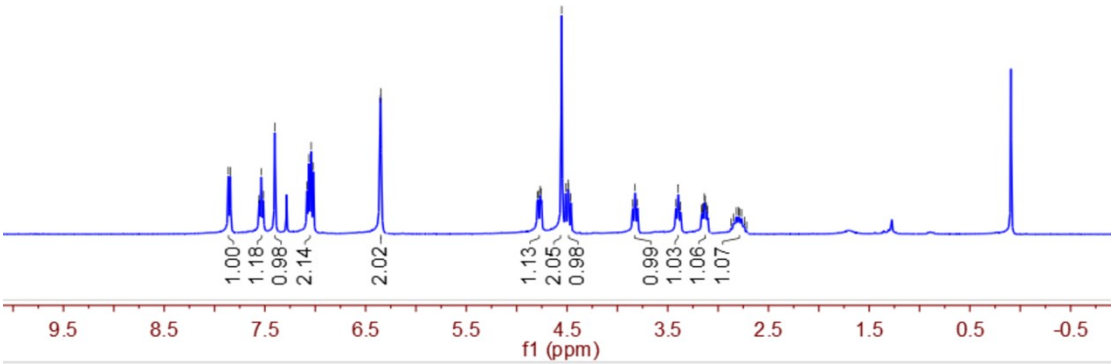
^{19}F NMR ($CDCl_3$, 376MHz)



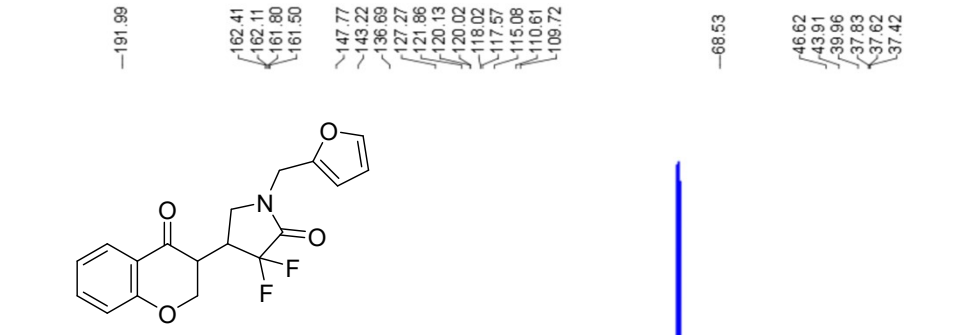
^{19}F NMR Spectrum of Compound 2af



^{1}H NMR ($CDCl_3$, 400MHz)

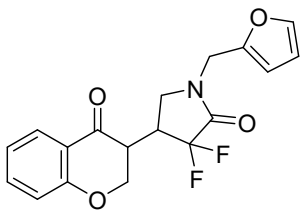


^{1}H NMR Spectrum of Compound 2ag

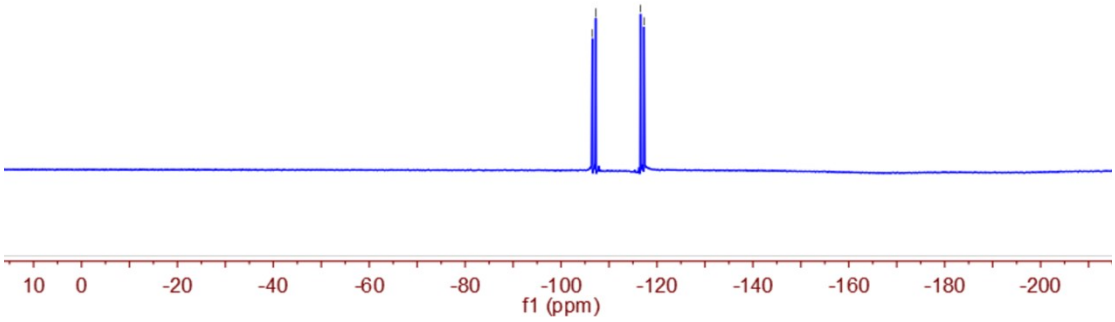


^{13}C NMR ($CDCl_3$, 101MHz)

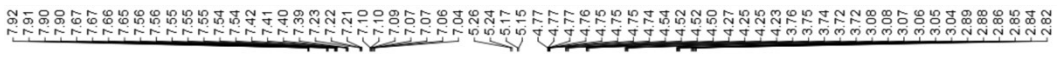
^{13}C NMR Spectrum of Compound 2ag

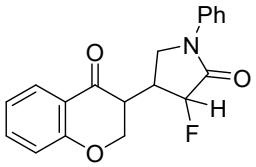


^{19}F NMR ($CDCl_3$, 376MHz)

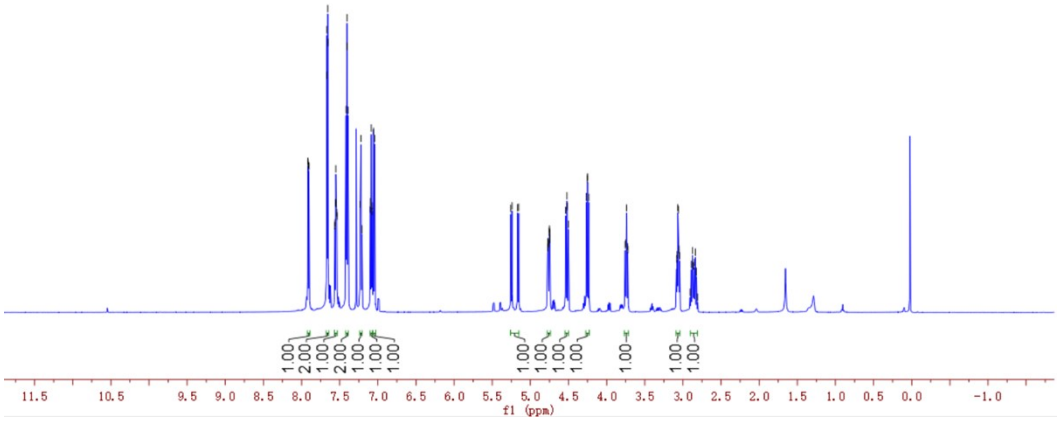


^{19}F NMR Spectrum of Compound 2ag

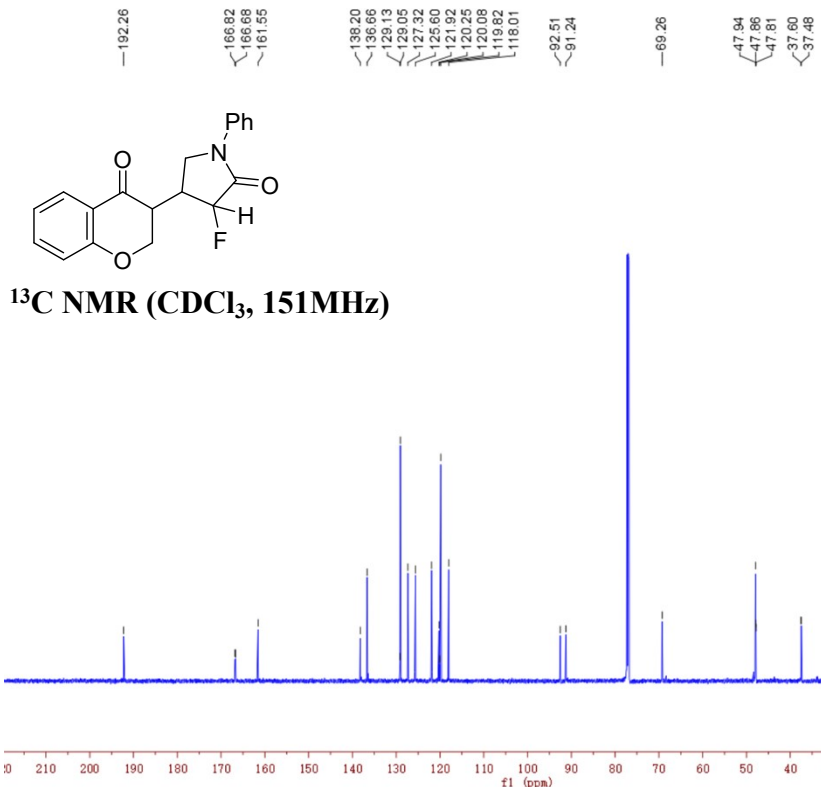




^{1}H NMR ($CDCl_3$, 600MHz)

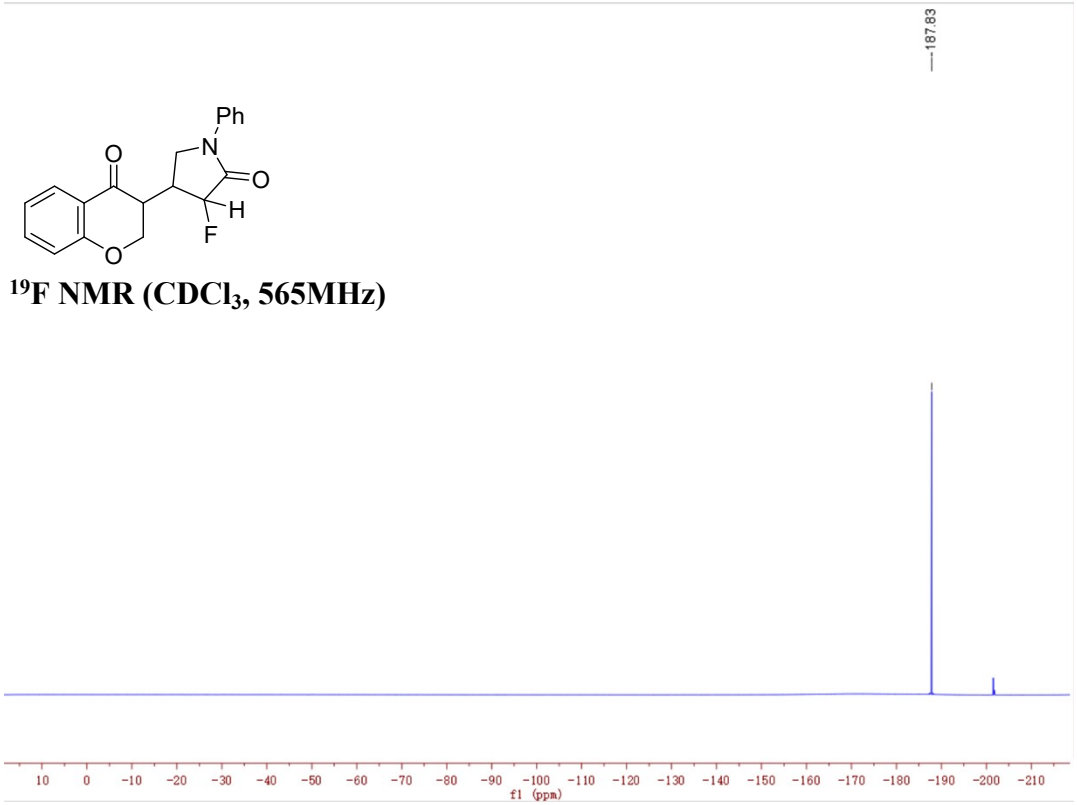


^{1}H NMR Spectrum of Compound 2ah



^{13}C NMR ($CDCl_3$, 151MHz)

^{13}C NMR Spectrum of Compound 2ah



^{19}F NMR ($CDCl_3$, 565MHz)

^{19}F NMR Spectrum of Compound 2ah