Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.
This journal is © the Partner Organisations 2019

Supporting Information

Transition-metal-free synthesis of CMe_2CF_3-containing chroman-4-ones via decarboxylative trifluoroalkylation

Miao-Chang Liu,*[a,b] Wei Liu,[b] Hua-Yue Wu,[b] Yun-Bing Zhou,[b] Qiuping Ding,*[a] and Yiyuan Peng[a]

[a] *Key Laboratory of Functional Small Organic Molecules, Ministry of Education, Jiangxi Normal University, 99 Ziyang Road, Nanchang 330022, China. E-mail: dqpjxnu@gmail.com*

[b] *College of Chemistry and Materials Engineering, Wenzhou University, Wenzhou 325035, China. E-mail: mcl@wzu.edu.cn*

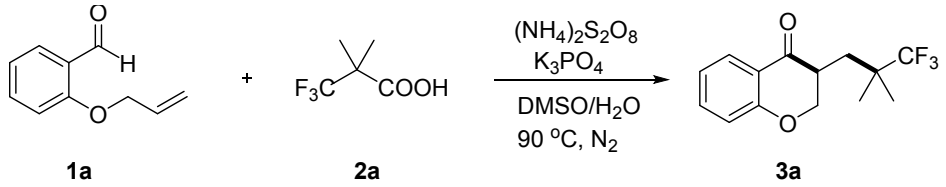
Table of Contents

1. General Information

Unless otherwise noted, materials were purchased from commercial suppliers and used without further purification. All the solvents were treated according to general methods. Melting points are uncorrected and recorded on Digital Melting Point Apparatus WRS-1B. ^{1}H NMR and ^{13}C NMR spectra were measured on a 500 MHz Bruker spectrometer (500 MHz for ^{1}H and 125 MHz for ^{13}C) using $CDCl_3$ as the solvent with tetramethylsilane (TMS) as the internal standard at room temperature. Chemical shifts are given in δ relative to TMS, the coupling constants J are given in Hz. High-resolution mass spectra were recorded on an ESI-Q-TOF mass spectrometer. Column chromatography was performed using EM silica gel 60 (300-400 mesh).

2. Experimental Procedure

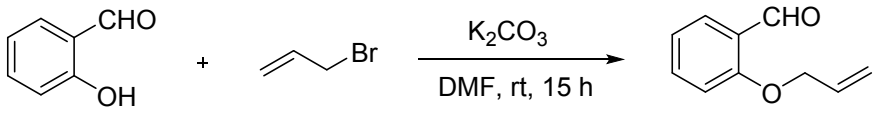
General Procedure for the preparation of 3a



1a **2a** **3a**

To the mixture of 3,3,3-trifluoro-2,2-dimethylpropanoic acid (0.6 mmol) and 2-(allyloxy)benzaldehyde (0.2 mmol) in a schlenk flask was added $(NH_4)_2S_2O_8$ (0.6 mmol) and K_3PO_4 (0.6 mmol) in DMSO/H_2O (v/v=2/1, 3 mL) under nitrogen atmosphere. The reaction was stirred at 90 °C for 24 h. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (40:1-8:1) to afford the corresponding products.

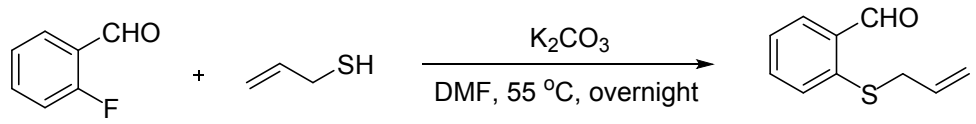
General procedure for the preparation of 1a[1]



1a

Salicylaldehyde (5 mmol) and potassium carbonate (7.5 mmol), in a 50 mL round bottomed flask was added 15 mL DMF and kept stirring at room temperature. To this stirring solution was added followed by the dropwise addition of allyl bromide (7.5 mmol). The reaction mixture was then stirred for 15 h at room temperature. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (20:1) to afford the o-(allyloxy)benzaldehyde **1a**.

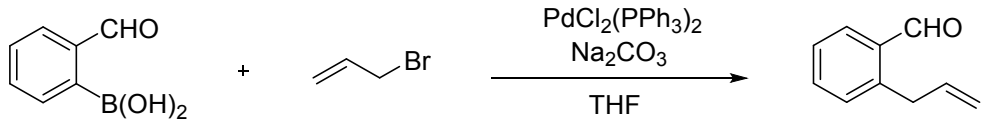
General procedure for the preparation of 1p[2]



1p

2-Fluorobenzaldehyde (5 mmol) and allyl mercaptan (10 mmol) in DMF (10 ml) were treated with potassium carbonate (10 mmol). The reaction mixture was heated to 55 °C overnight. On cooling to room temperature, the reaction was poured into water and extracted with ethyl acetate. The organic extract was washed once with water, then brine, dried ($MgSO_4$) and concentrated. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (20:1) to afford **1p**.

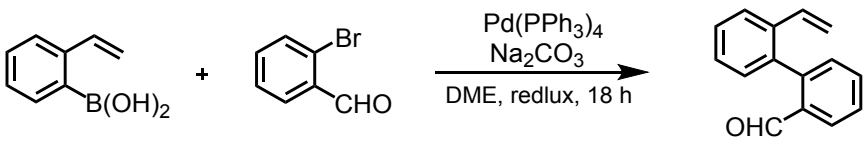
General Procedure for the preparation of 1q[3]



1q

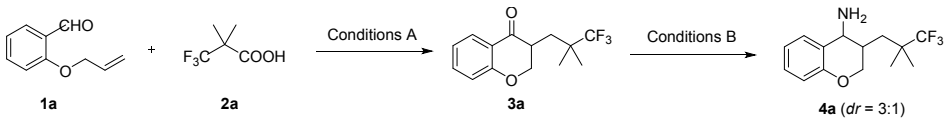
2-Formylphenylboronic acid (5 mmol) and allyl bromide (6 mmol) in THF (25 mL) in a 100 mL round-bottom flask. Then $PdCl_2(PPh_3)_2$ (0.125 mmol) and aq. Na_2CO_3 (1M, 10 mmol) solution was added. The reaction mixture was heated at reflux for 3-4 h. The reaction mixture was quenched with H_2O and extracted with CH_2Cl_2 three times. The combined organic layers were washed with H_2O, dried over $MgSO_4$, and concentrated in vacuo. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (30:1) to afford the desired **1q**.

General Procedure for the preparation of 1r[4]



A solution of tetrakis(triphenylphosphine)palladium (0.15 mmol) and 2-brombenzaldehyde (5 mmol) in dimethoxyethane (50 mL) was stirred 10 min at room temperature. A solution of (2-vinylphenyl)boronic acid (7.5 mmol) in ethanol (6 mL) and a solution of sodium carbonate (10 mmol) in water (6 mL) were added to the reaction mixture. After stirring 18 h under reflux and concentrated under reduced pressure. Purification with flash chromatography on silica gel using petroleum ether to afford the 2'-vinylbiphenyl-2-carbaldehyde **1r**.

General Procedure for the preparation of 4a



1a **2a** **3a** **4a** (*dr* = 3:1)

Conditions A: To the mixture of 3,3,3-trifluoro-2,2-dimethylpropanoic acid **2a** (0.6 mmol) and 2-(allyloxy)benzaldehyde **1a** (0.2 mmol) in a schlenk flask was added $(NH_4)_2S_2O_8$ (0.6 mmol) and K_3PO_4 (0.06 mmol) in DMSO/H_2O (v/v=2/1, 3 mL) under nitrogen atmosphere. The reaction was stirred at 90 ^oC for 24 h. Upon completion, the reaction mixture was concentrated under vacuum. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (40:1) to afford the ketone **3a**; **Conditions B**: The ketone **3a** (1.0 mmol), hydroxylamine hydrochloride (1.5 mmol), ammonium formate (9 mmol) and Zn powder (3 mmol) in methanol (5 mL) was stirred under reflux overnight. After completion of the reaction the mixture was filtered through Celite and the solvent was removed by vacuum rotary evaporation. The residue was treated with conc. HCl solution (2 mL) and water (15 mL), and then extracted with diethyl ether (2×10 mL) to remove organic residues. The aqueous phase was alkalized with ammonia solution to pH=10 and extracted with dichloromethane (4×25 mL). The organic phase was washed with brine, dried over Na_2SO_4 and the solvent removed under vacuum. The residue was purified by silica gel column chromatography using a petroleum ether/EtOAc (3:1) to afford **4a**.

Reference:

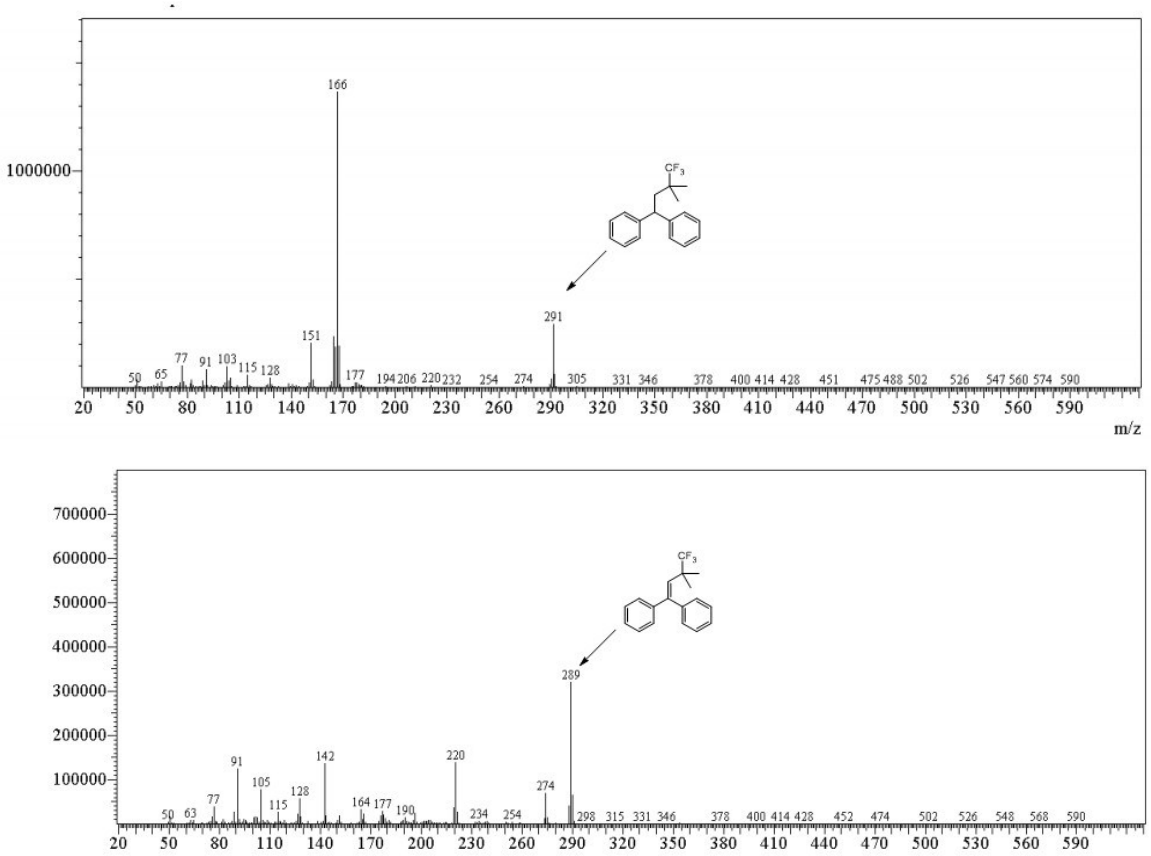
[1] 1. J. Zhao, P. Li, X. Li, C. Xia and F. Li, *Chem. Commun*., 2016, **52**, 3661. 2. A. Kuznetsov, A. Makarov, A. E. Rubtsov, A. V. Butin and V. Gevorgyan, *J. Org. Chem*., 2013, **78**, 12144.

[2] S. Saubern, J. M. Macdonald, J. H. Ryan, R. C. J. Woodgate, T. S. Louie, M. J. Fuchter, J. M. White and A. B. Holmes, *Tetrahedron*, 2010, **66**, 2761.

[3] D. Vasu and R. Liu, *Chem.–Eur. J*., 2012, **18**, 13638.

[4] G. A. Schmid and H.-J. Borschberg, *Helv. Chim. Acta*, 2001, **84**, 388.

3. The GC-MS data

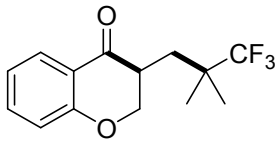


4. Analytical Data for All Products

Table S1. Crystal data and structure refinement for **3b**.

CCDC number	1965758	
Empirical formula	$C_{15}H_{17}F_3O_2$	
Formula weight	286.28	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P b c a	
Unit cell dimensions	a = 11.693(3) Å	α= 90°.
	b = 9.266(3) Å	β= 90°.
	c = 26.611(7) Å	γ = 90°.
Volume	2883.4(13) $Å^3$	
Z	8	
Density (calculated)	1.319 Mg/m^3	
Absorption coefficient	0.112 mm^{-1}	
F(000)	1200	
Crystal size	0.130 x 0.100 x 0.040 mm^3	
Theta range for data collection	2.907 to 24.993°.	
Index ranges	-13<=h<=13, -10<=k<=11, -31<=l<=30	
Reflections collected	12988	
Independent reflections	2520 [R(int) = 0.0789]	
Completeness to theta = 25.242°	96.7 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7453 and 0.5557	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2520 / 0 / 185	
Goodness-of-fit on F^2	1.047	
Final R indices [I>2sigma(I)]	R1 = 0.0602, wR2 = 0.1268	
R indices (all data)	R1 = 0.1277, wR2 = 0.1606	
Extinction coefficient	0.0025(6)	
Largest diff. peak and hole	0.184 and -0.173 $e.Å^{-3}$	

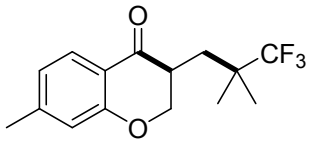
(S)-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3a

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (42.4 mg, 78% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.90-7.89 (m, 1H), 7.50-7.46 (m, 1H), 7.04-7.01 (m, 1H), 6.97-6.96 (m, 1H), 4.52 (dd, J = 11.5 Hz, J = 5.5 Hz, 1H), 4.20-4.15 (m, 1H), 2.88-2.83 (m, 1H), 2.36 (dd, J = 15.0 Hz, J = 4.0 Hz, 1H), 1.36-1.32 (dd, J = 14.5 Hz, J = 5.0 Hz, 1H), 1.18 (s, 3H), 1.17 (s, 3H); **^{13}C NMR** (125 MHz, DMSO-d_6) δ 194.1, 162.0, 136.4, 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 128.1, 122.0, 121.0, 118.2, 71.9, 42.2, 40.5 (q, $J_{C\text{-}F}$ = 25.0 Hz), 31.2, 22.1, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.1. **HRMS** (ESI) calcd for $C_{14}H_{16}F_3O_2$ $[M+H]^+$: 273.1102, found: 273.1106.

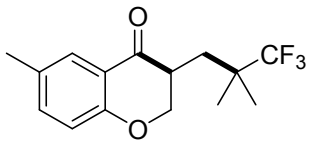
(S)-7-methyl-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3b

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford white solid (39.5 mg, 69% yield), mp: 73-74 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.78 (d, J = 8.0 Hz, 1H), 6.84 (d, J = 8.0 Hz, 1H), 6.76 (s, 1H), 4.49 (dd, J = 11.0 Hz, J = 5.0 Hz, 1H), 4.17-4.12 (m, 1H), 2.83-2.78 (m, 1H), 2.36 (s, 3H), 2.35-2.31 (m, 1H), 1.34 (dd, J = 14.5 Hz, J = 5.0 Hz, 1H), 1.18 (s, 3H), 1.17 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.8, 162.0, 147.9, 130.0, 129.9 (q, $J_{C\text{-}F}$ = 281.3 Hz), 123.4, 118.8, 118.2, 71.9, 42.2, 40.55 (q, $J_{C\text{-}F}$ = 23.8 Hz), 31.2, 22.4, 22.1, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{15}H_{17}F_3O_2Na$ $[M+Na]^+$: 309.1079, found: 309.1083.

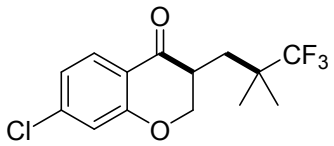
(S)-6-methyl-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3c

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (42.9 mg, 75% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.66 (s, 1H), 7.29-7.27 (m, 1H), 6.86-6.84 (m, 1H), 4.48 (dd, *J* = 11.0 Hz, *J* = 5.0 Hz, 1H), 4.16-4.11 (m, 1H), 2.83-2.78 (m, 1H), 2.35-2.33 (m, 1H), 2.30 (s, 3H), 1.33 (dd, *J* = 11.0 Hz, *J* = 5.5 Hz, 1H), 1.17 (s, 3H), 1.16 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.4, 160.0, 137.5, 131.4, 129.8 (q, J_{C-F} = 281.3 Hz), 127.6, 120.6, 118.0, 71.9, 42.3, 40.6 (q, J_{C-F} = 23.8 Hz), 31.2, 22.1, 20.9, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{15}H_{17}F_3O_2Na$ $[M+Na]^+$: 309.1079, found: 309.1083.

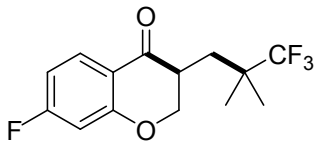
(S)-7-chloro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3d

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford white solid (40.7 mg, 66% yield), mp: 63-64 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.0 Hz, 1H), 7.01-7.00 (m, 2H), 4.53 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz,1H), 4.20-4.15 (m, 1H), 2.84 (m, 1H), 2.33 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 1.34 (dd, *J* = 15.0 Hz, *J* = 5.5 Hz, 1H), 1.18 (s, 3H), 1.17 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.1, 162.3, 142.3, 129.8 (q, J_{C-F} = 281.3 Hz), 129.3, 122.8, 119.6, 118.4, 72.1, 42.1, 40.8, 40.5 (q, J_{C-F} = 25.0 Hz), 31.2, 22.2 (q, J_{C-F} = 2.5 Hz), 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{14}H_{15}ClF_3O_2$ $[M+H]^+$: 307.0712, found: 307.0712.

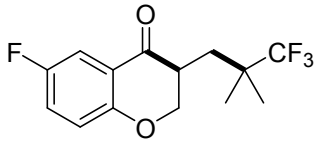
(S)-7-fluoro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3e

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford yellow oil (41.8 mg, 72% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.93-7.89 (m, 1H), 6.76-6.73 (m, 1H), 6.66-6.64 (m, 1H), 4.54 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.21-4.16 (m, 1H), 2.86-2.81 (m, 1H), 2.34 (dd, *J* = 15.0 Hz, *J* = 3.5 Hz, 1H), 1.33 (dd, *J* = 15.0 Hz, *J* = 11.5 Hz, 5.5H), 1.18 (s, 3H), 1.17 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 192.7, 167.9 (d, $J_{C\text{-}F}$ = 253.8 Hz), 163.6 (d, $J_{C\text{-}F}$ = 13.8 Hz), 130.6 (d, $J_{C\text{-}F}$ = 11.3 Hz), 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 118.0 (d, $J_{C\text{-}F}$ = 2.5 Hz), 110.4 (d, $J_{C\text{-}F}$ = 22.5 Hz), 105.0 (d, $J_{C\text{-}F}$ = 23.8 Hz), 72.3, 42.0, 40.52 (q, $J_{C\text{-}F}$ = 146.3 Hz), 31.2, 22.2, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0, -100.7. **HRMS** (ESI) calcd for $C_{14}H_{14}F_4O_2Na$ $[M+Na]^+$: 313.0828, found: 313.0818.

(S)-6-fluoro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one

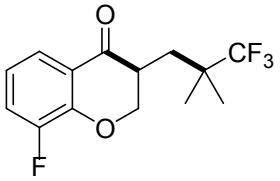


3f

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford yellow oil (42.3 mg, 73% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.55-7.53 (m, 1H), 7.22-7.18 (m, 1H), 6.96-6.94 (m, 1H), 4.52 (dd, *J* = 11.5 Hz, *J* = 5.5 Hz, 1H), 4.18-4.13 (m, 1H), 2.87-2.81 (m, 1H), 2.33 (dd, *J* = 14.5 Hz, *J* = 3.5 Hz, 1H), 1.35 (dd, *J* = 15.0 Hz, *J* = 5.5 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.4, 158.2, 157.8 (d, $J_{C\text{-}F}$ = 240.0 Hz), 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 124.0 (d, $J_{C\text{-}F}$ = 25.0 Hz), 121.4 (d, $J_{C\text{-}F}$ = 7.5 Hz), 119.9 (d, $J_{C\text{-}F}$ = 7.5 Hz), 113.0 (d, $J_{C\text{-}F}$ = 22.5 Hz), 72.03, 42.2, 40.54 (q, $J_{C\text{-}F}$ = 23.8 Hz), 22.2 (q, $J_{C\text{-}F}$ = 2.5 Hz), 20.73 (q, $J_{C\text{-}F}$ = 2.5 Hz) ; **^{19}F NMR** (470 MHz,

$CDCl_3$): δ [ppm] = -78.0, -121.4. **HRMS** (ESI) calcd for $C_{14}H_{14}F_4O_2Na$ $[M+Na]^+$: 313.0828, found: 313.0818.

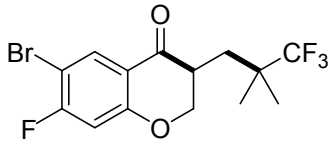
(S)-8-fluoro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3g

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford yellow oil (35.4 mg, 61% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.68-7.66 (m, 1H), 7.31-7.27 (m, 1H), 6.99-6.94 (m, 1H), 4.64 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.28-4.23 (m, 1H), 2.93-2.88 (m, 1H), 2.37 (dd, *J* = 15.0 Hz, *J* = 4.0 Hz, 1H), 1.36 (dd, *J* = 15.0 Hz, *J* = 5.0 Hz, 1H), 1.19 (s, 3H), 1.18 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.1, 152.0 (d, $J_{C\text{-}F}$ = 247.5 Hz), 150.4, 150.3, 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 123.2 (d, $J_{C\text{-}F}$ = 3.8 Hz), 122.2 (d, $J_{C\text{-}F}$ = 17.5 Hz), 121.4 (d, $J_{C\text{-}F}$ = 6.3 Hz), 72.4, 42.3, 40.5 (q, $J_{C\text{-}F}$ = 23.8 Hz), 31.1, 22.2, 20.8; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0, -135.6. **HRMS** (ESI) calcd for $C_{14}H_{14}F_4O_2Na$ $[M+Na]^+$: 313.0828, found: 313.0818.

(S)-6-bromo-7-fluoro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one

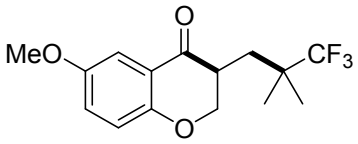


3h

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford yellow solid (42.7 mg, 58% yield), mp: 82-83 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.10-8.08 (m, 1H), 6.76-6.74 (m, 1H), 4.54 (dd, *J* = 11.5 Hz , *J* = 5.5 Hz, 1H), 4.21-4.16 (m, 1H), 2.86-2.81 (m, 1H), 2.32 (dd, *J* = 15.0 Hz, *J* = 3.5 Hz, 1H), 1.33 (dd, *J* = 14.5 Hz, *J* = 5.0 Hz, 1H), 1.17 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 191.7, 163.7 (d, $J_{C\text{-}F}$ = 255.0 Hz), 162.5 (d, $J_{C\text{-}F}$ = 12.5 Hz), 133.2 (d, $J_{C\text{-}F}$ = 3.8 Hz), 129.7 (q, $J_{C\text{-}F}$

= 281.3 Hz), 119.0 (d, $J_{C\text{-}F}$ = 2.5 Hz), 106.4 (d, $J_{C\text{-}F}$ = 25.0 Hz), 102.9 (d, $J_{C\text{-}F}$ = 22.5 Hz), 72.3, 41.9, 40.5 (q, $J_{C\text{-}F}$ = 25.0 Hz), 31.2, 22.2 (q, $J_{C\text{-}F}$ = 2.5 Hz), 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -77.8, -94.8. **HRMS** (ESI) calcd for $C_{14}H_{14}BrF_4O_2$ $[M+H]^+$: 369.0113, found: 369.0118.

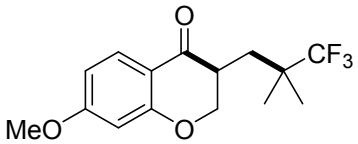
(S)-6-methoxy-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3i

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (38.7 mg, 64% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.32-7.31 (m, 1H), 7.10-7.08 (m, 1H), 6.91-6.89 (m, 1H), 4.48 (dd, *J* = 11.0 Hz, *J* = 5.0 Hz, 1H), 4.16-4.12 (m, 1H), 3.80 (s, 3H), 2.85-2.80 (m, 1H), 2.33 (dd, *J* = 11.0 Hz, *J* = 5.0 Hz, 1H), 1.37-1.18 (dd, *J* = 15.0 Hz, *J* = 5.5 Hz, 1H), 1.19 (s, 3H), 1.18 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.2, 156.7, 154.7, 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 125.6, 120.8, 119.5, 108.6, 72.0, 56.3, 42.3, 40.6 (q, $J_{C\text{-}F}$ = 25.0 Hz), 31.4, 22.1, 20.8; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{15}H_{18}F_3O_3$ $[M+H]^+$: 303.1208, found: 303.1212.

(S)-7-methoxy-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one

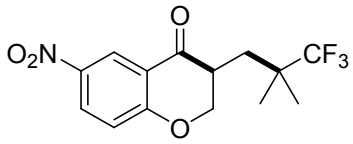


3j

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to

afford white solid (33.2 mg, 55% yield), mp: 90-91 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.83 (d, *J* = 8.5 Hz, 1H), 6.60-6.58 (m, 1H), 6.41-6.40 (m, 1H), 4.50 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.18-4.14 (m, 1H), 3.84 (s, 3H), 2.81-2.76 (m, 1H), 2.33 (dd, *J* = 15.0 Hz, *J* = 3.5 Hz, 1H), 1.34 (dd, *J* = 15.0 Hz, *J* = 5.5 Hz, 1H), 1.18 (s, 3H), 1.17 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 192.8, 166.5, 163.9, 129.9 (q, J_{C-F} = 281.3 Hz), 129.8, 114.9, 110.5, 101.1, 72.2, 56.1, 41.9, 40.55 (q, J_{C-F} = 25.0 Hz), 31.3, 22.2, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{15}H_{18}F_3O_3$ $[M+H]^+$: 303.1208, found: 303.1212.

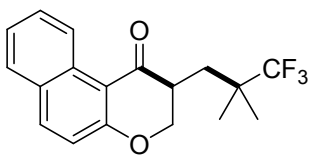
(S)-6-nitro-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-one



3k

Following the general procedure, using petroleum ether/AcOEt (8:1) as the eluant to afford yellow solid (38.7 mg, 61% yield), mp: 118-119 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.80-8.78 (m, 1H), 8.33 (m, *J* = 8.0 Hz, 1H), 7.12-7.10 (m, 1H), 4.66 (dd, *J* = 11.5 Hz, *J* = 5.5 Hz, 1H), 4.30-4.25 (m, 1H), 2.95-2.92 (m, 1H), 2.40-2.36 (m, 1H), 1.36 (dd, *J* = 15.0 Hz, *J* = 5.0 Hz, 1H), 1.19 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 192.0, 165.8, 142.8, 130.7, 129.7 (q, J_{C-F} = 281.3 Hz), 124.7, 120.6, 119.6, 72.2, 42.0, 40.5 (q, J_{C-F} = 23.8 Hz), 31.08, 22.4, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -77.8. **HRMS** (ESI) calcd for $C_{14}H_{14}F_3NO_4Na$ $[M+Na]^+$: 340.0773, found: 340.0771.

(S)-2-(3,3,3-trifluoro-2,2-dimethylpropyl)-2,3-dihydro-1H-benzo[f]chromen-1-one

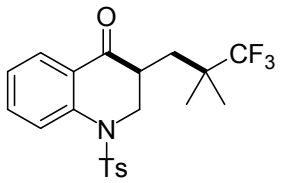


3l

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to

afford white solid (23.2 mg, 36% yield), mp: 104-105 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 9.40 (d, *J* = 9.0 Hz, 1H), 7.92 (d, *J* = 9.0 Hz, 1H), 7.75 (d *J* = 8.0 Hz, 1H), 7.64-7.61 (m, 1H), 7.44-7.41 (m, 1H), 7.08 (d, *J* = 9.0 Hz, 1H), 4.62 (dd, *J* = 11.0 Hz, *J* = 4.5 Hz, 1H), 4.33-4.29 (m, 1H), 2.93-2.88 (m, 1H), 2.39 (dd, *J* = 15.0 Hz, *J* = 4.5 Hz, 1H), 1.47 (dd, *J* = 15.0 Hz, *J* = 5.5 Hz, 1H), 1.21 (s, 3H), 1.18 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.3, 163.7, 137.9, 132.2, 130.1, 129.9 (q, J_{C-F} = 281.3 Hz),129.8, 129.0, 126.1, 125.4, 119.0, 112.5, 71.9, 42.8, 40.6 (q, J_{C-F} = 23.8 Hz), 31.8, 22.2, 20.7; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.0. **HRMS** (ESI) calcd for $C_{18}H_{18}F_3O_2$ $[M+H]^+$: 323.1259, found: 323.1259.

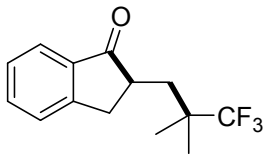
(S)-1-tosyl-3-(3,3,3-trifluoro-2,2-dimethylpropyl)-2,3-dihydroquinolin-4(1H)-one



3o

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford yellow solid (51.0 mg, 60% yield), mp: 101-102 °C. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.98-7.96 (m, 1H), 7.88-7.86 (m, 1H), 7.61-7.59 (m, 2H), 7.58-7.54 (m, 1H), 7.27-7.24 (m, 3H), 4.56 (dd, *J* = 14.0 Hz, *J* = 5.5 Hz, 1H), 3.67-3.61 (m, 1H), 2.47-2.42 (m, 1H), 2.39 (s, 3H), 2.33 (dd, *J* = 15.0 Hz, *J* = 3.0 Hz, 1H), 1.23 (dd, *J* = 14.5 Hz, *J* = 5.5 Hz, 1H), 1.11 (s, 3H), 1.09 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.0, 145.1, 142.8, 137.3, 135.1, 130.5, 129.7 (q, J_{C-F} = 281.3 Hz), 128.9, 127.4, 125.7, 125.1, 123.7, 52.5, 42.1, 40.5 (q, J_{C-F} = 25.0 Hz), 33.2, 22.0, 21.7, 21.0; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.1. **HRMS** (ESI) calcd for $C_{21}H_{22}F_3NO_3SNa$ $[M+Na]^+$: 448.1170, found: 448.1179.

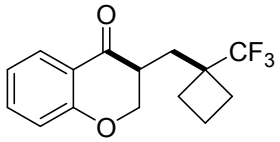
(R)-2-(3,3,3-trifluoro-2,2-dimethylpropyl)-2,3-dihydro-1H-inden-1-one



3q

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (36.9 mg, 72% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.77 (d, *J* = 7.5 Hz, 1H), 7.61-7.58 (m, 1H), 7.46 (d, *J* = 7.5 Hz, 1H), 7.39-7.36 (m, 1H), 3.49 (dd, *J* = 17.0 Hz, *J* = 8.0 Hz, 1H), 2.87 (dd, *J* = 17.0 Hz, *J* = 4.5 Hz, 1H), 2.68-2.64 (m, 1H), 2.37 (d, *J* = 14.5 Hz, 1H), 1.57 (dd, *J* = 14.5 Hz, *J* = 10.5 Hz, 1H), 1.23 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 208.2, 153.9, 136.5, 135.4, 129.9 (q, J_{C-F} = 281.3 Hz), 128.0, 126.9, 124.5, 44.5, 40.8 (q, J_{C-F} = 25.0 Hz), 38.5, 36.3, 22.3 (q, J_{C-F} = 2.5 Hz), 21.5 (q, J_{C-F} = 2.5 Hz); **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -77.6. **HRMS** (ESI) calcd for $C_{14}H_{15}F_3ONa$ $[M+Na]^+$: 279.0973, found: 279.0971.

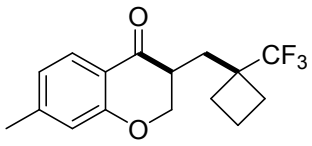
(S)-3-((1-(trifluoromethyl)cyclobutyl)methyl)chroman-4-one



3s

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (46.0 mg, 81% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.91-7.89 (m, 1H), 7.49-7.46 (m, 1H), 7.04-7.01 (m, 1H), 6.97-6.95 (m, 1H), 4.53 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.21-4.17 (m, 1H), 2.86-2.80 (m, 1H), 2.58-2.55 (m, 1H), 2.42-2.37 (m, 1H), 2.35-2.30 (m, 1H), 2.03-1.93 (m, 4H), 1.56-1.55 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.3, 162.1, 136.4, 129.4 (q, J_{C-F} = 277.5 Hz), 128.1, 122.0, 120.9, 118.2, 71.2, 44.67 (q, J_{C-F} = 26.3 Hz), 43.3, 30.4, 27.9 (q, J_{C-F} = 3.8 Hz), 26.3 (q, J_{C-F} = 2.5 Hz), 15.2; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -77.0. **HRMS** (ESI) calcd for $C_{15}H_{15}F_3O_2Na$ $[M+Na]^+$: 307.0922, found: 307.0938.

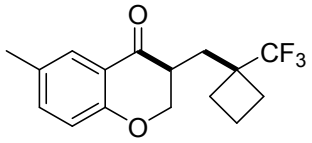
(S)-7-methyl-3-((1-(trifluoromethyl)cyclobutyl)methyl)chroman-4-one



3t

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (41.7 mg, 70% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 8.0 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 1H), 6.77 (s, 1H), 4.51 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.19-4.15 (m, 1H), 2.81-2.79 (m, 1H), 2.55 (dd, *J* = 15.0 Hz, *J* = 3.0 Hz, 1H), 2.41-2.30 (m, 1H), 2.36 (s, 3H), 2.03-1.95 (m, 4H), 1.61-1.55 (m, 2H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.0, 162.1, 147.9, 129.5 (q, J_{C-F} = 277.5 Hz), 128.0, 123.4, 118.7, 118.2, 71.2, 44.7 (q, J_{C-F} = 26.3 Hz), 43.3, 30.5, 27.9, 26.3, 22.4, 15.2; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -76.7. **HRMS** (ESI) calcd for $C_{16}H_{17}F_3O_2Na$ $[M+Na]^+$: 321.1079, found: 321.1079.

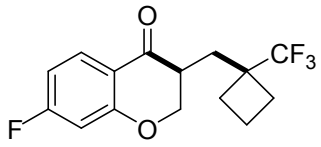
(S)-6-methyl-3-((1-(trifluoromethyl)cyclobutyl)methyl)chroman-4-one



3u

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (44.1 mg, 74% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.69 (s, 1H), 7.29 (d, *J* = 7.0 Hz, 1H), 6.87 (d, *J* = 7.0 Hz, 1H), 4.50 (dd, *J* = 11.5 Hz, *J* = 5.0 Hz, 1H), 4.19-4.15 (m, 1H), 2.83-2.78 (m, 1H), 2.56-2.52 (m, 1H), 2.41-2.37 (m, 1H), 2.31 (s, 3H), 2.04-1.94 (m, 4H), 1.60-1.56 (m, 2H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 194.5, 160.1, 137.5, 131.4, 129.4 (q, J_{C-F} = 277.5 Hz), 127.6, 120.5, 118.0, 71.2, 44.7 (q, J_{C-F} = 26.3 Hz), 43.4, 30.5, 27.9 (q, *J* = 3.8 Hz), 26.3 (q, *J* = 3.8 Hz), 20.9, 15.2; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -76.7. **HRMS** (ESI) calcd for $C_{16}H_{17}F_3O_2Na$ $[M+Na]^+$: 321.1079, found: 321.1079.

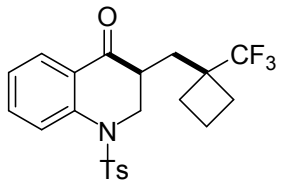
(S)-7-fluoro-3-((1-(trifluoromethyl)cyclobutyl)methyl)chroman-4-one



3v

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (44.1 mg, 73% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.94-7.91 (m, 1H), 6.77-6.73 (m, 1H), 6.67-6.64 (m, 1H), 4.56-4.53 (m, 1H), 4.23-4.19 (m, 1H), 2.84-2.79 (m, 1H), 2.57 (dd, *J* = 15.5 Hz, *J* = 4.0 Hz, 1H), 2.43-2.30 (m, 2H), 2.04-1.94 (m, 4H), 1.58-1.54 (m, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 192.9, 167.9 (d, J_{C-F} = 253.8 Hz), 163.7 (d, J_{C-F} = 13.8 Hz), 130.6 (d, J_{C-F} = 11.3 Hz), 129.4 (q, J_{C-F} = 277.5 Hz), 117.9 (d, J_{C-F} = 2.5 Hz), 110.4 (d, J_{C-F} = 22.5 Hz), 105.0 (d, J_{C-F} = 25.0 Hz), 71.6, 44.6 (q, J_{C-F} = 26.3 Hz), 43.1, 30.3, 27.9, 26.3, 15.2 ; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -76.7, -100.6. **HRMS** (ESI) calcd for $C_{15}H_{14}F_4O_2Na$ $[M+Na]^+$: 325.0828, found: 325.0860.

(S)-1-tosyl-3-((1-(trifluoromethyl)cyclobutyl)methyl)-2,3-dihydroquinolin-4(1H)-one

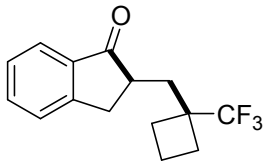


3w

Following the general procedure, using petroleum ether/AcOEt (10:1) as the eluant to afford yellow oil (59.4 mg, 68% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.97-7.89 (m, 2H), 7.56-7.54 (m, 3H), 7.26-7.20 (m, 3H), 4.61 (dd, *J* = 14.0 Hz, *J* = 5.5 Hz, 1H), 3.67-3.62 (m, 1H), 2.52 (dd, *J* = 15.5 Hz, *J* = 3.5 Hz, 1H), 2.45-2.39 (m, 2H), 2.37 (s, 3H), 2.27-2.21 (m, 1H), 2.00-1.80 (m, 4H), 1.44 (dd, *J* =15.0 Hz, *J* =6.0 Hz); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 195.3, 145.0, 142.9, 137.2, 135.2, 130.4, 129.3 (q, J_{C-F} =

277.5 Hz), 128.8, 127.4, 125.7, 125.2, 123.9, 52.0, 44.7 (q, $J_{C\text{-}F}$ =26.4 Hz), 43.0, 32.4, 27.7, 26.2, 22.0, 15.2; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -76.8. **HRMS** (ESI) calcd for $C_{22}H_{22}F_3NO_3SNa$ $[M+Na]^+$: 460.1170, found: 460.1184.

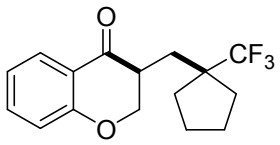
(R)-2-((1-(trifluoromethyl)cyclobutyl)methyl)-2,3-dihydro-1H-inden-1-one



3x

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (41.2 mg, 77% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.77 (d, *J* = 7.5 Hz, 1H), 7.61-7.58 (m, 1H), 7.46 (d, *J* = 7.5 Hz, 1H), 7.39-7.36 (m, 1H), 3.48 (dd, *J* = 17.5 Hz, *J* = 8.0 Hz, 1H), 2.89 (dd, *J* = 17.0 Hz, *J* = 4.0 Hz, 1H), 2.68-2.64 (m, 1H), 2.61-2.58 (m, 1H), 2.46-2.41 (m, 1H), 2.39-2.33 (m, 1H), 2.07-2.01 (m, 4H), 1.74 (dd, *J* = 15.0 Hz, *J* = 10.0 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 208.4, 154.2, 136.6, 135.4, 128.0, 126.9, 124.5, 45.0, 37.3, 35.5, 30.2, 27.9 (q, $J_{C\text{-}F}$ = 3.9 Hz), 26.1, 15.3; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -76.4. **HRMS** (ESI) calcd for $C_{15}H_{16}F_3O$ $[M+H]^+$: 269.1153, found: 269.1137.

(S)-3-((1-(trifluoromethyl)cyclopentyl)methyl)chroman-4-one

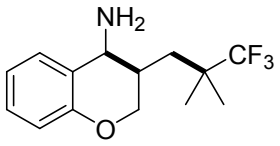


3y

Following the general procedure, using petroleum ether/AcOEt (40:1) as the eluant to afford colorless oil (44.7 mg, 75% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91-7.88 (m, 1H), 7.50-7.45 (m, 1H), 7.04-7.00 (m, 1H), 6.97-6.95 (m, 1H), 4.56 (dd, *J* = 11.2 Hz, *J* = 5.2 Hz, 1H), 4.20-4.14 (m, 1H), 2.91-2.85 (m, 1H), 2.43-2.38 (m, 1H), 2.05-1.98 (m, 1H), 1.96-1.89 (m, 1H), 1.75-1.73 (m, 4H), 1.62-1.54 (m, 2H), 1.44-1.39 (m, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 194.5, 162.1, 136.4, 130.5 (q, $J_{C\text{-}F}$ = 280.0 Hz), 128.1,

121.9, 120.9, 118.2, 71.5, 51.06 (q, $J_{C\text{-}F}$ = 23.0 Hz), 43.3, 34.9, 32.5, 30.9, 26.4 (d, $J_{C\text{-}F}$ = 9.0 Hz); **^{19}F NMR** (376 MHz, $CDCl_3$): δ [ppm] = -73.5. **HRMS** (ESI) calcd for $C_{16}H_{17}F_3O_2Na$ $[M+Na]^+$: 321.1078, found: 321.1086.

(3R,4S)-3-(3,3,3-trifluoro-2,2-dimethylpropyl)chroman-4-amine

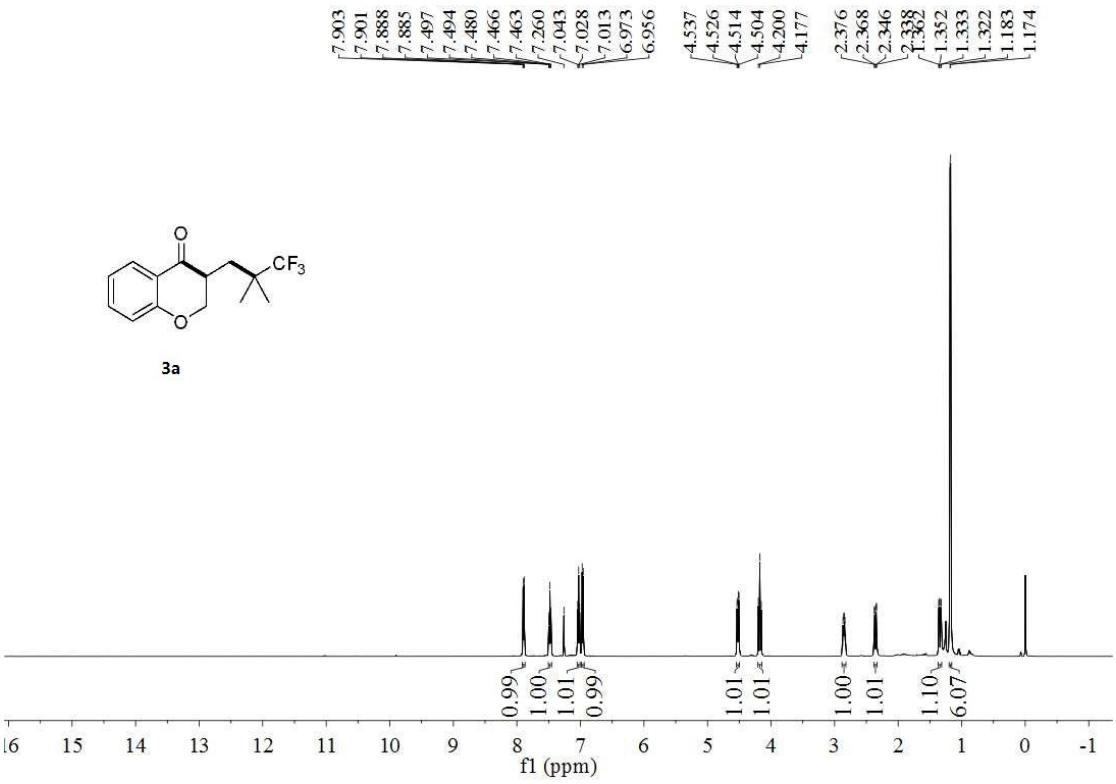


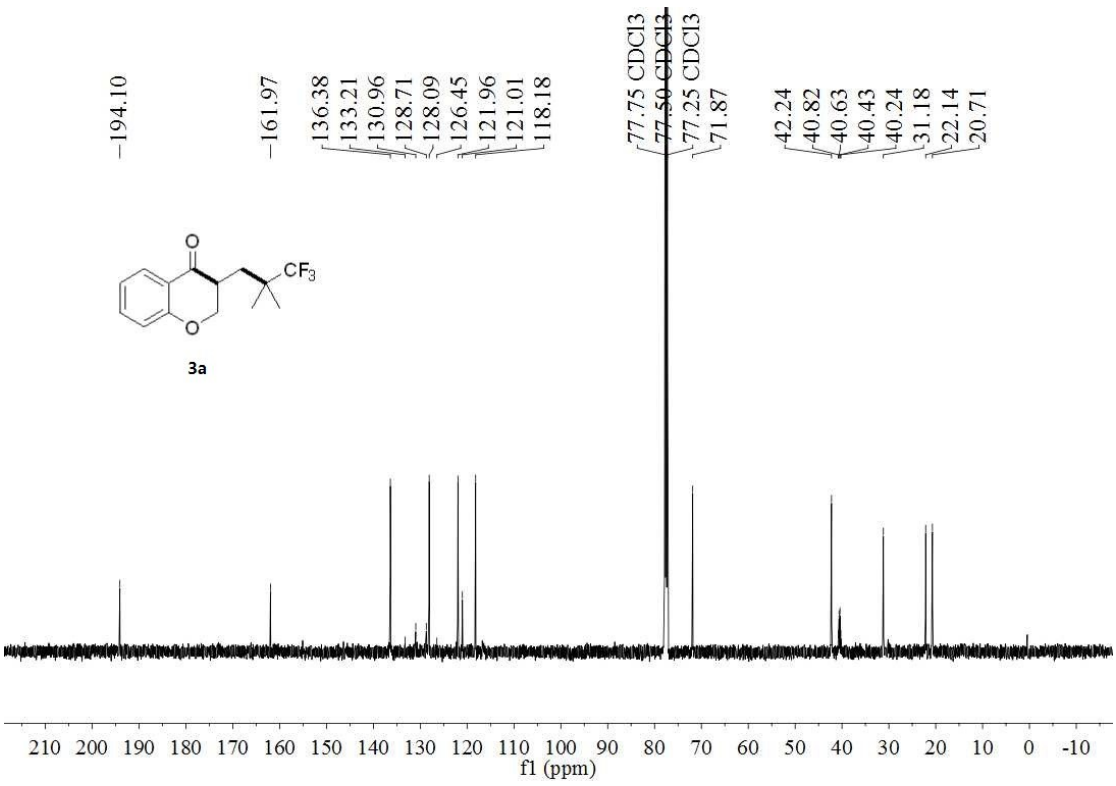
dr= 3:1

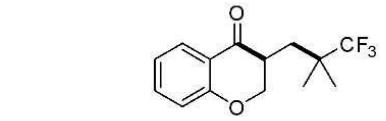
4a

Following the general procedure, using AcOEt as the eluant to afford yellow oil (150.1 mg, 55% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.74-7.73 (m, 1H), 7.60-7.55 (m, 2H), 7.35-7.32 (m, 1H), 3.94-3.91 (m, 2H), 3.56-3.55 (m, 1H), 2.35-2.31 (m, 1H), 2.14-2.11 (m, 1H), 1.17-1.14 (m, 1H), 1.11 (s, 3H), 0.98 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 163.8, 137.5, 130.6, 129.8 (q, $J_{C\text{-}F}$ = 281.3 Hz), 124.1, 121.9, 110.7, 66.5, 44.1, 41.1 (q, $J_{C\text{-}F}$ = 25.0 Hz), 36.4, 35.9, 21.9, 21.0; **^{19}F NMR** (470 MHz, $CDCl_3$): δ [ppm] = -78.2. **HRMS** (ESI) calcd for $C_{14}H_{19}F_3NO$ $[M+H]^+$: 274.1418, found: 274.1428.

5. NMR Spectra for All Products

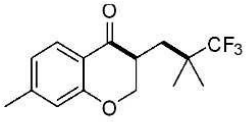






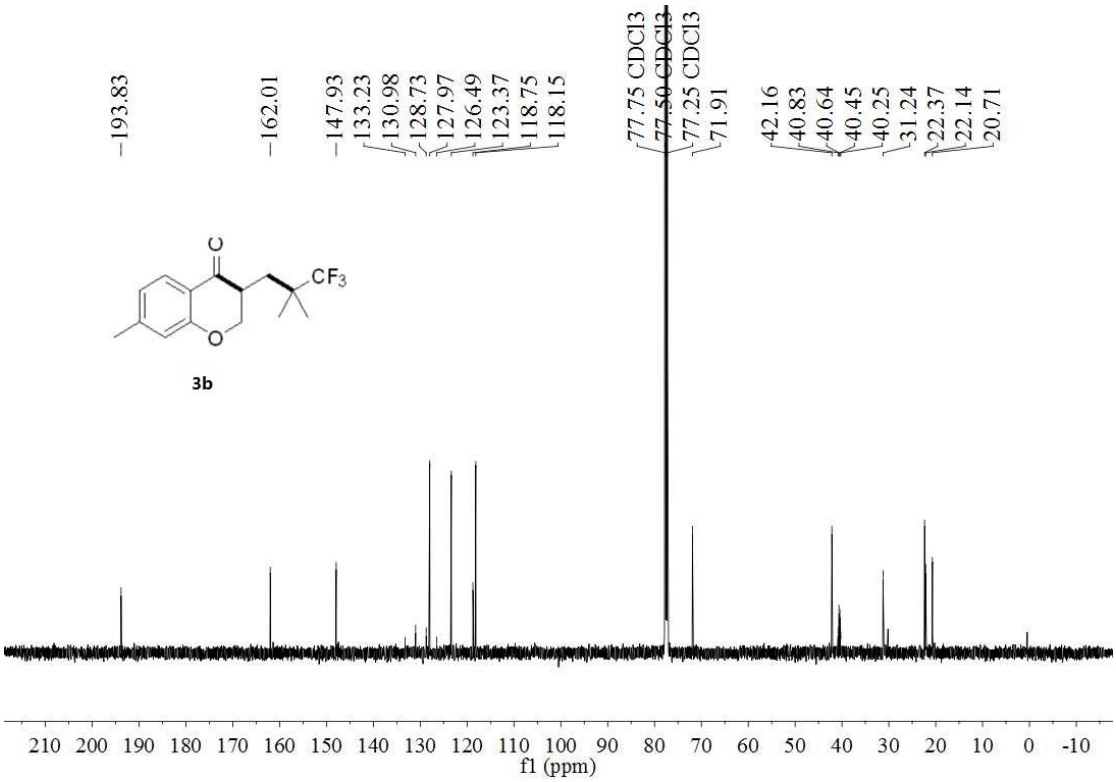
3a

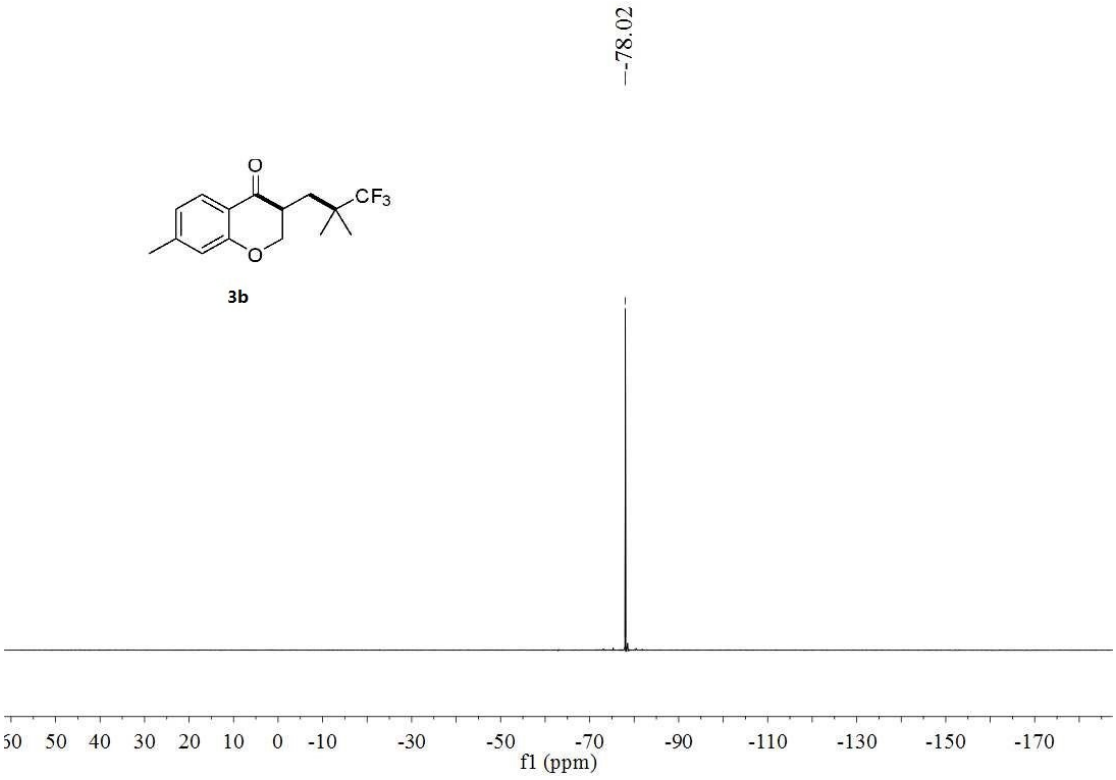
-78.06
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

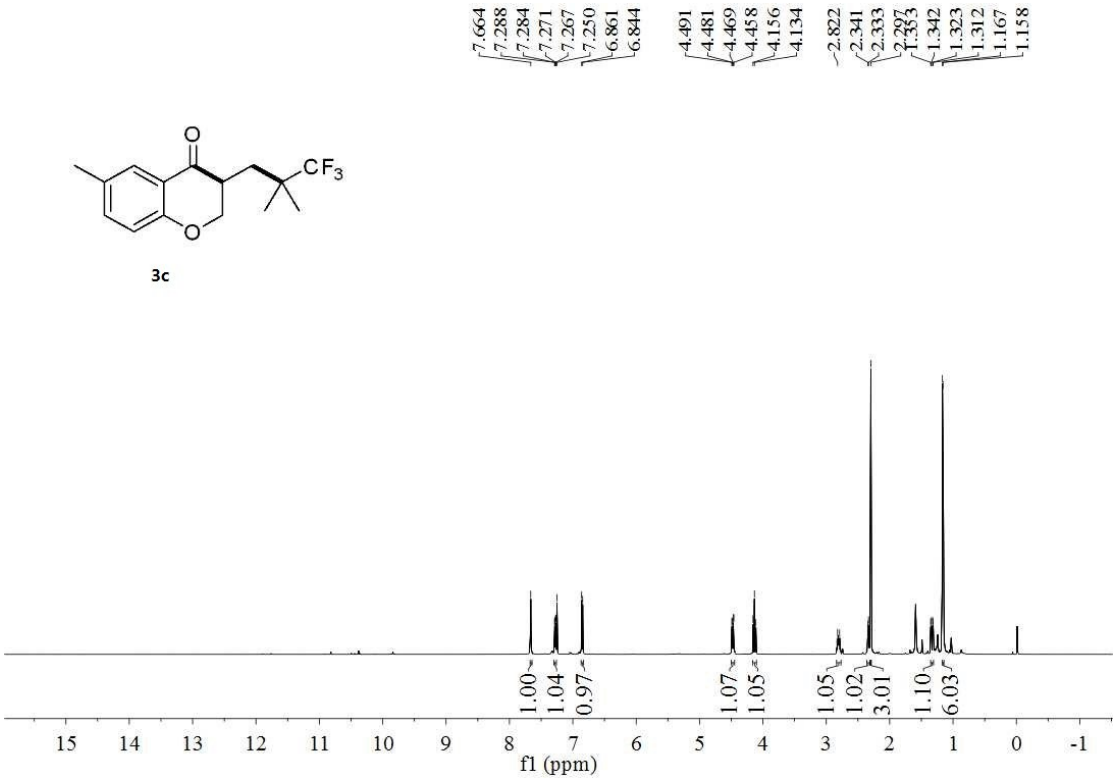


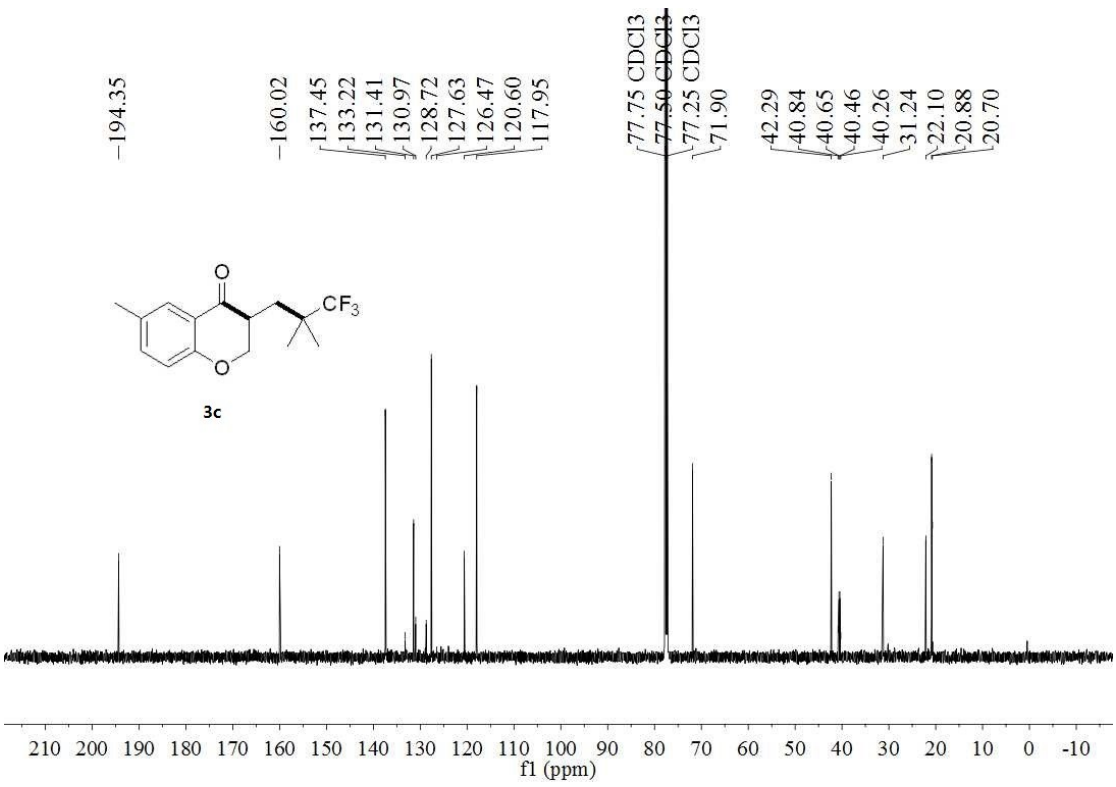
3b

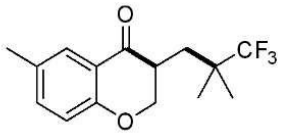
7.784
7.768
7.260
6.847
6.831
6.763
4.507
4.497
4.485
4.474
4.169
4.146
4.124
2.357
2.345
2.322
2.314
1.344
1.325
1.314
1.177
1.167
1.00
1.01
1.01
1.04
1.09
1.15
3.08
0.96
0.95
6.07
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


193.83
162.01
147.93
133.23
130.98
128.73
127.97
126.49
123.37
118.75
118.15
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.91
42.16
40.83
40.64
40.45
40.25
31.24
22.37
22.14
20.71
O
CF3
O
3b
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-78.02
O
CF3
O
3b
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

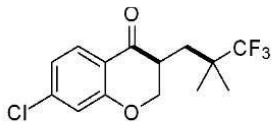

7.664
7.288
7.284
7.271
7.267
7.250
6.861
6.844
4.491
4.481
4.469
4.458
4.156
4.134
2.822
2.341
2.333
2.297
1.353
1.342
1.323
1.312
1.167
1.158
O
CF3
O
3c
1.00
1.04
0.97
1.07
1.05
1.05
1.02
3.01
1.10
6.03
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


194.35
160.02
137.45
133.22
131.41
130.97
128.72
127.63
126.47
120.60
117.95
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.90
42.29
40.84
40.65
40.46
40.26
31.24
22.10
20.88
20.70
O
CF3
O
3c
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



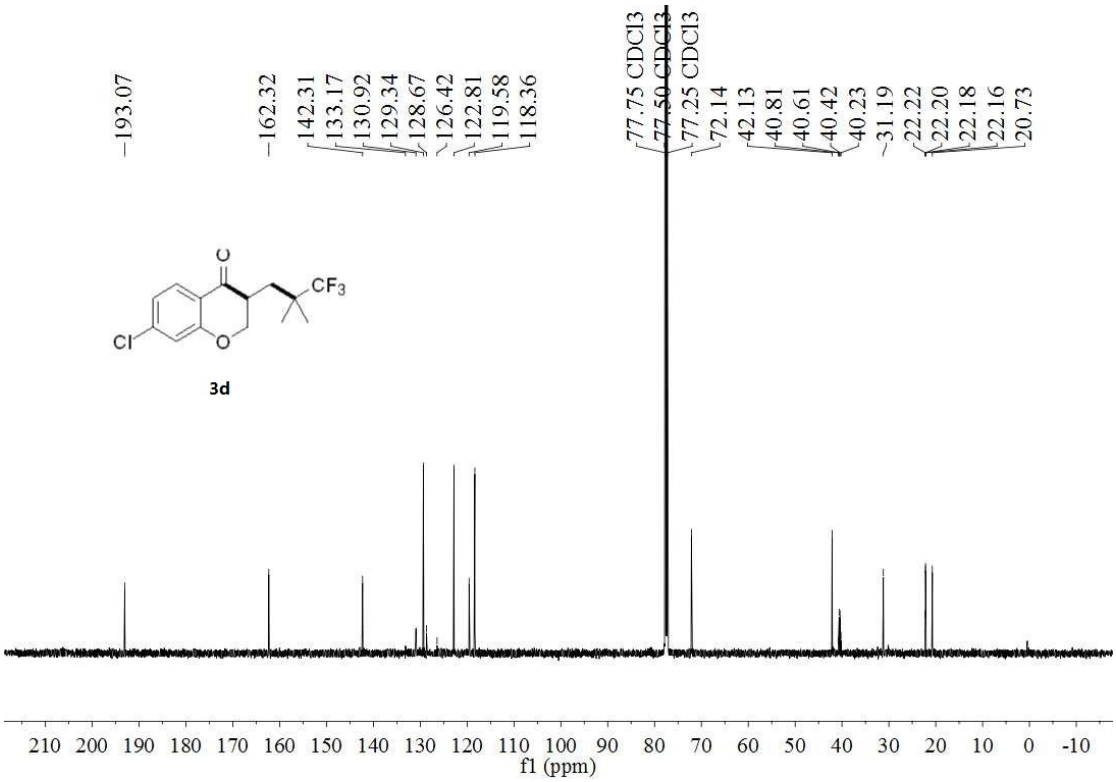
3c

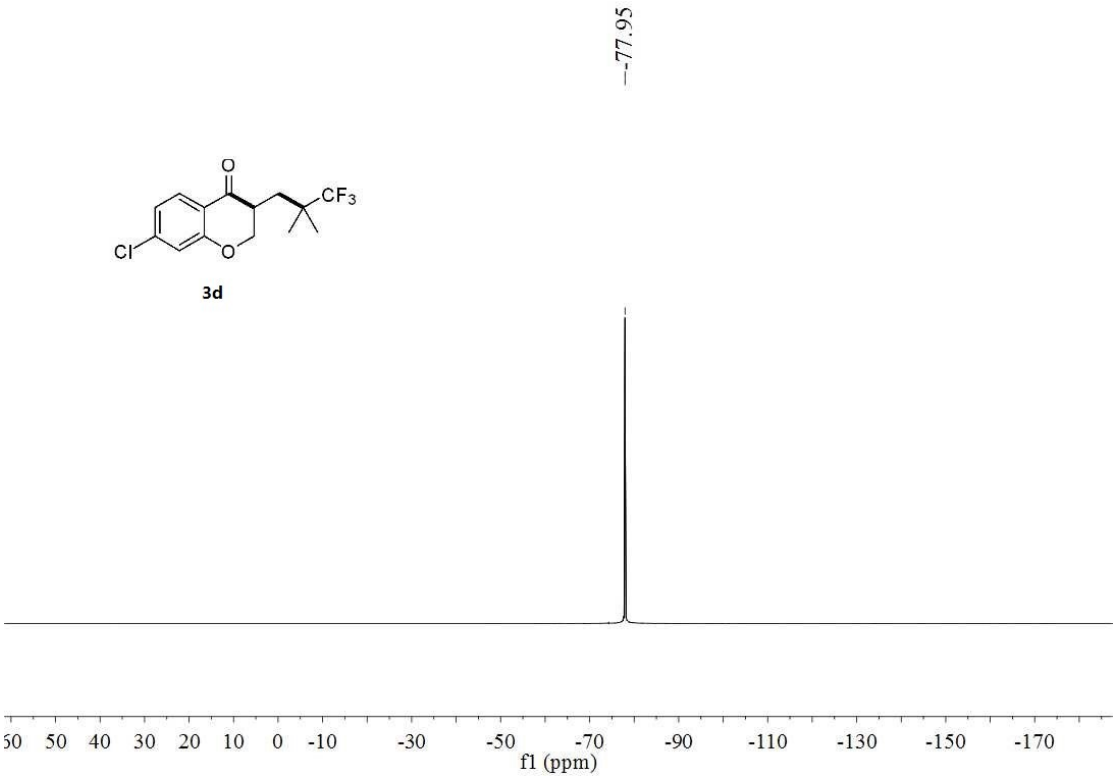
-78.02
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

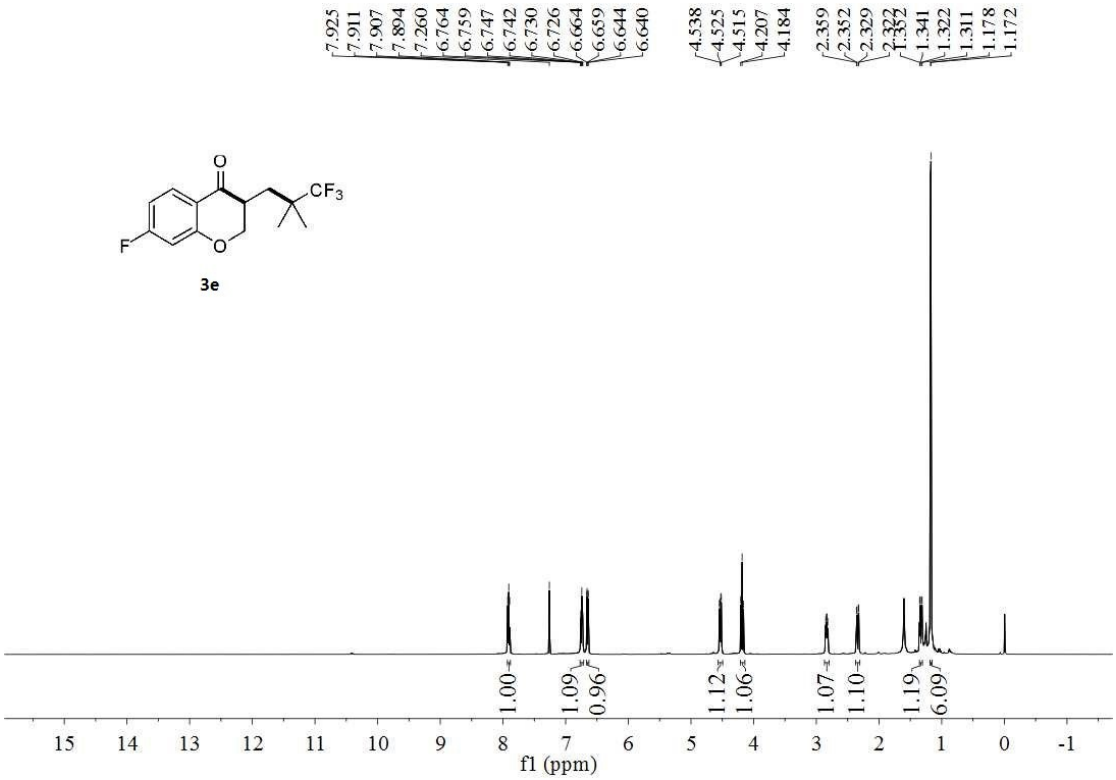


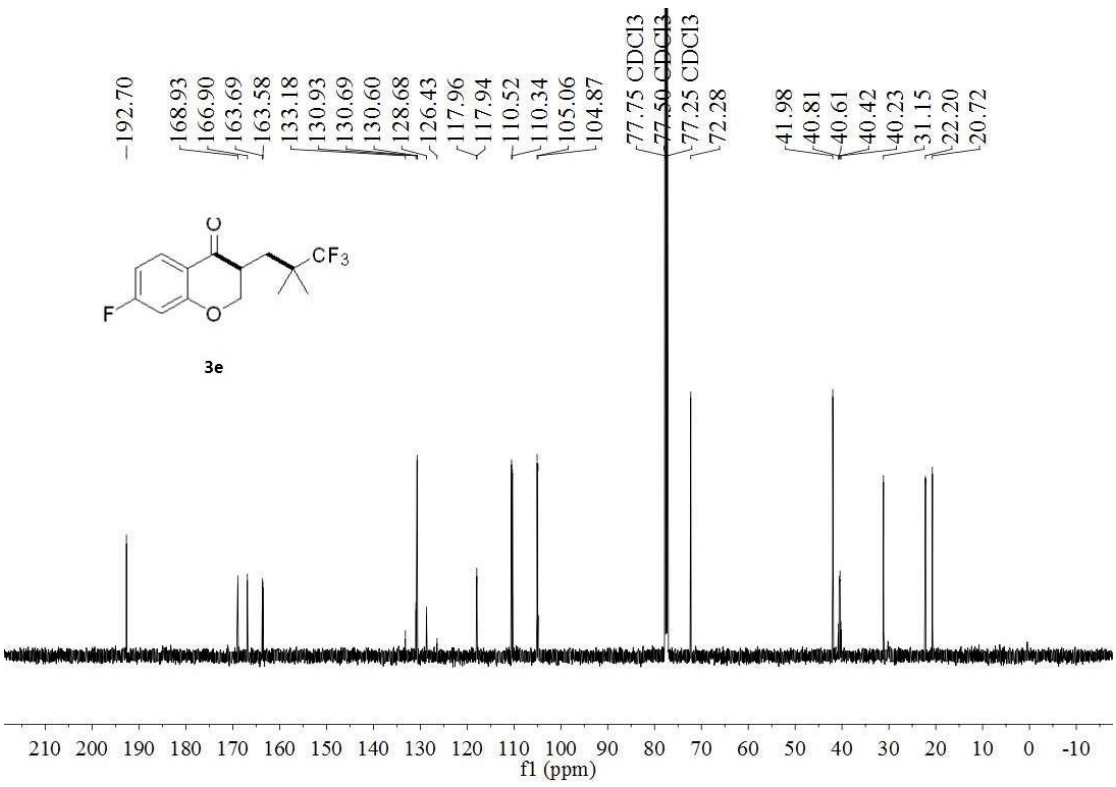
3d

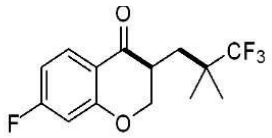
7.830
7.814
7.260
7.013
7.010
6.993
4.545
4.535
4.522
4.512
4.199
4.176
4.153
2.351
2.344
2.321
2.314
1.344
1.325
1.314
1.178
1.170
1.00
2.05
1.05
1.07
1.09
1.12
1.25
6.04
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


193.07
162.32
142.31
133.17
130.92
129.34
128.67
126.42
122.81
119.58
118.36
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.14
42.13
40.81
40.61
40.42
40.23
31.19
22.22
22.20
22.18
22.16
20.73
O
CF3
Cl
O
3d
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-77.95
O
CF3
Cl
O
3d
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

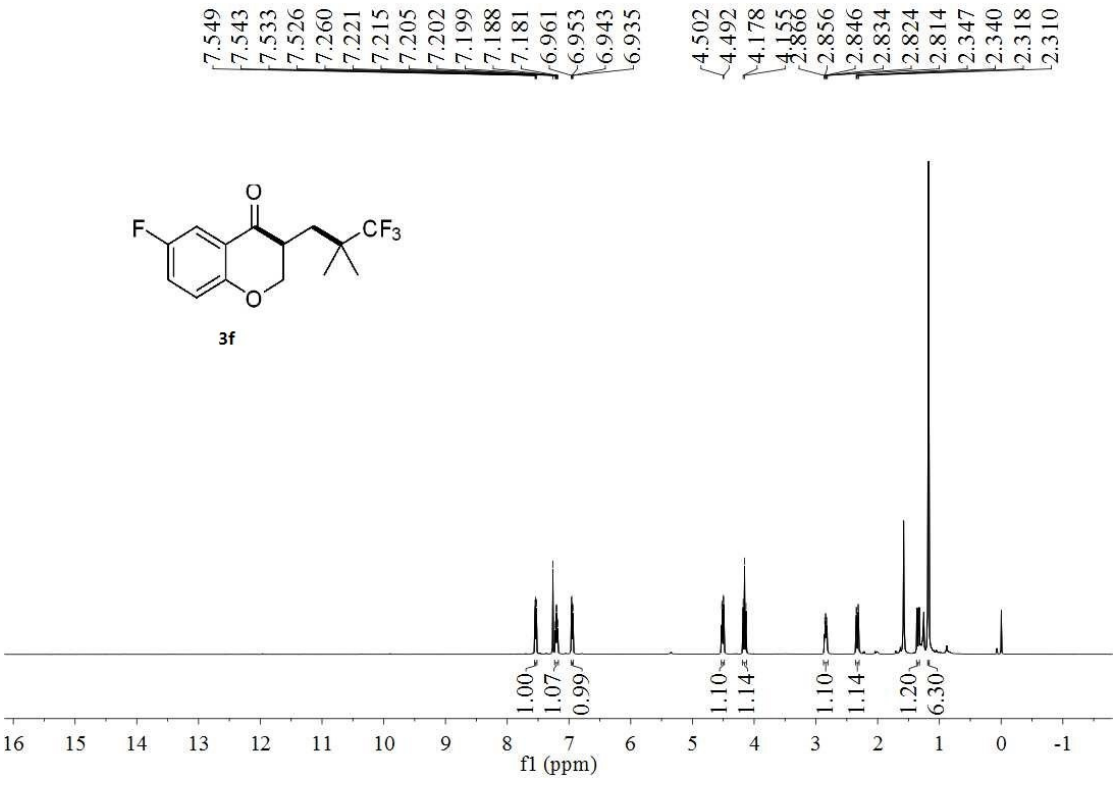

7.925
7.911
7.907
7.894
7.260
6.764
6.759
6.747
6.742
6.730
6.726
6.664
6.659
6.644
6.640
4.538
4.525
4.515
4.207
4.184
2.359
2.352
2.329
1.341
1.322
1.311
1.178
1.172
O
CF3
F
O
3e
1.00
1.09
0.96
1.12
1.06
1.07
1.10
1.19
6.09
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


192.70
168.93
166.90
163.69
163.58
133.18
130.93
130.69
130.60
128.68
126.43
117.96
117.94
110.52
110.34
105.06
104.87
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.28
41.98
40.81
40.61
40.42
40.23
31.15
22.20
20.72
O
CF3
F
O
3e
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
CF3
F
O

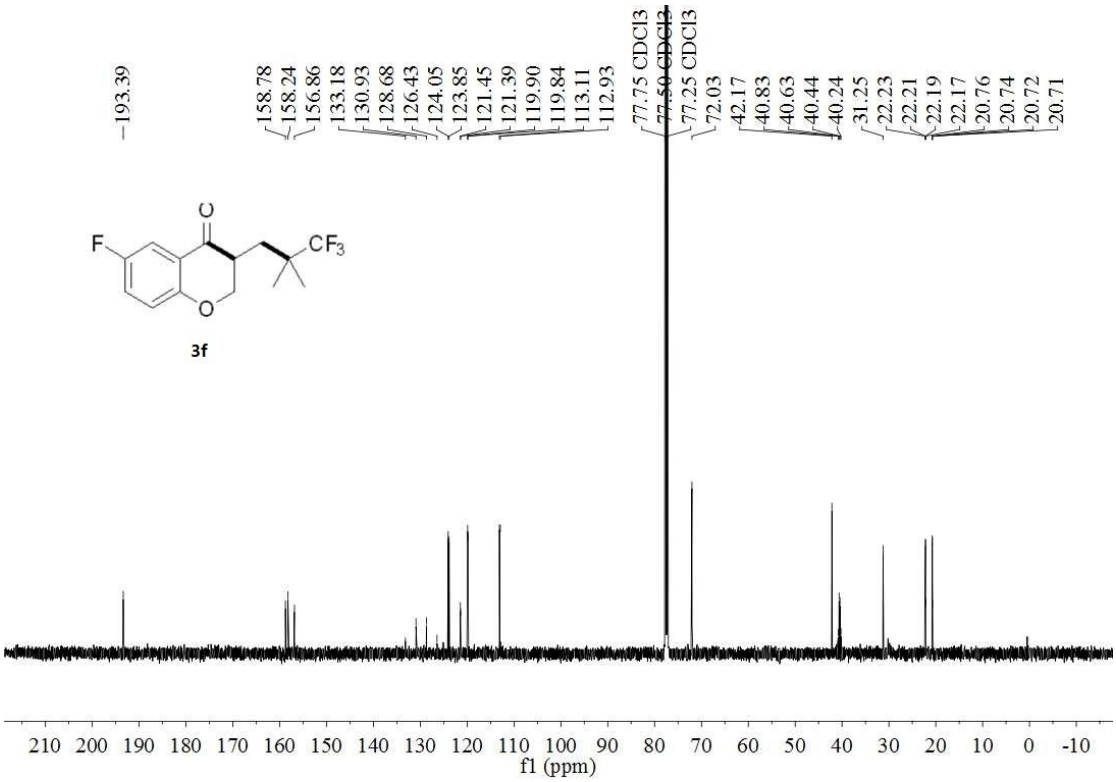
3e

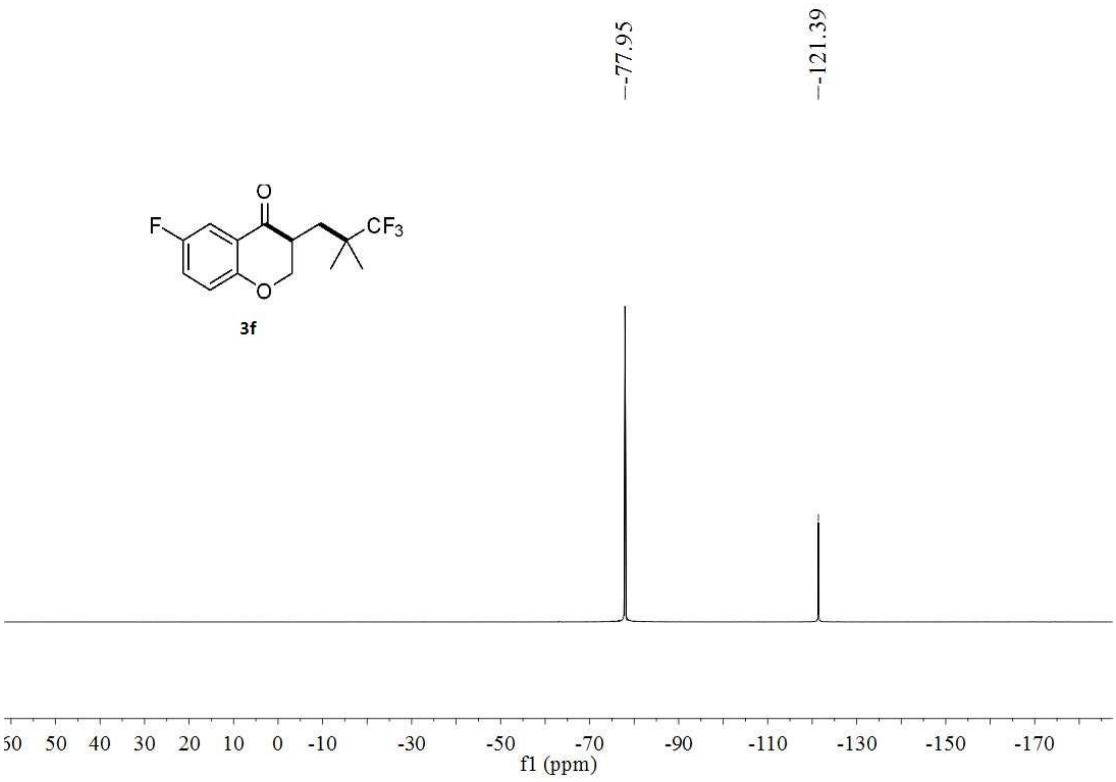
-77.95
-100.65
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)


7.549
7.543
7.533
7.526
7.260
7.221
7.215
7.205
7.202
7.199
7.188
7.181
6.961
6.953
6.943
6.935
4.502
4.492
4.178
4.155
2.866
2.856
2.846
2.834
2.824
2.814
2.347
2.340
2.318
2.310
1.00
1.07
0.99
1.10
1.14
1.10
1.14
1.20
6.30
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

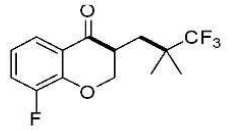
O
F
CF3
O

3f

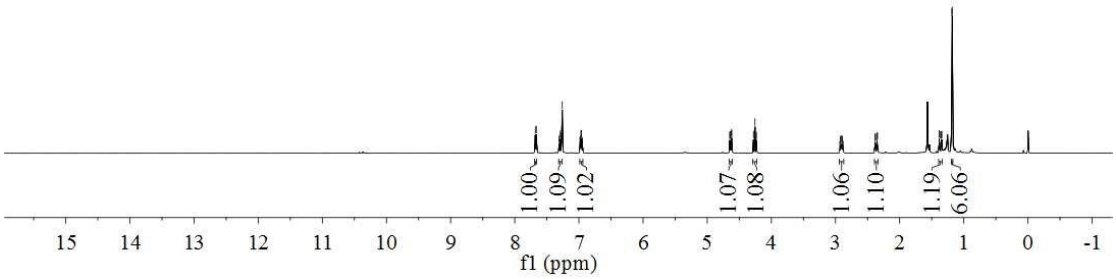

193.39
158.78
158.24
156.86
133.18
130.93
128.68
126.43
124.05
123.85
121.45
121.39
119.90
119.84
113.11
112.93
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.03
42.17
40.83
40.63
40.44
40.24
31.25
22.23
22.21
22.19
22.17
20.76
20.74
20.72
20.71
F
O
CF3
O
3f
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

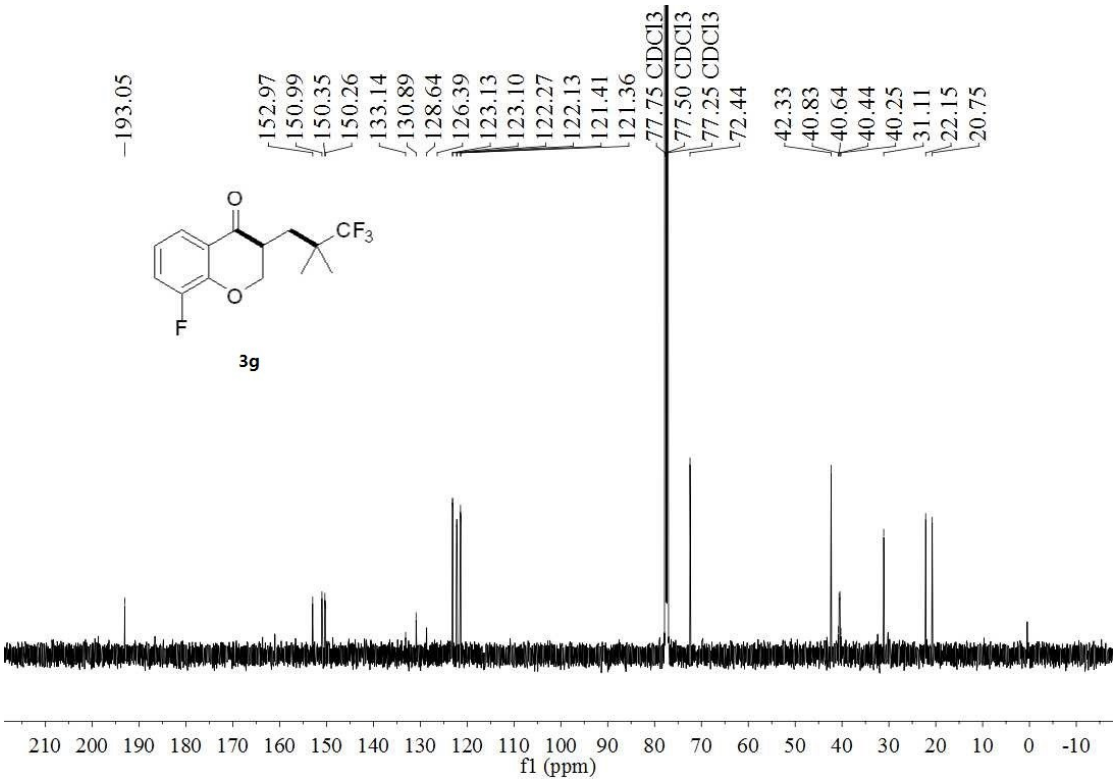

-77.95
-121.39
F
O
CF3
O
3f
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)


7.680
7.664
7.309
7.290
7.272
7.260
6.985
6.976
6.969
6.960
6.953
6.944
4.640
4.627
4.617
4.279
4.256
2.383
2.375
2.353
2.345
1.382
1.372
1.352
1.342
1.188
1.180

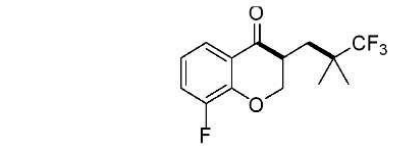

O
CF3
O
F

3g


1.00
1.09
1.02
1.07
1.08
1.06
1.10
1.19
6.06
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


193.05
152.97
150.99
150.35
150.26
133.14
130.89
128.64
126.39
123.13
123.10
122.27
122.13
121.41
121.36
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.44
42.33
40.83
40.64
40.44
40.25
31.11
22.15
20.75
O
CF3
O
F
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

3g

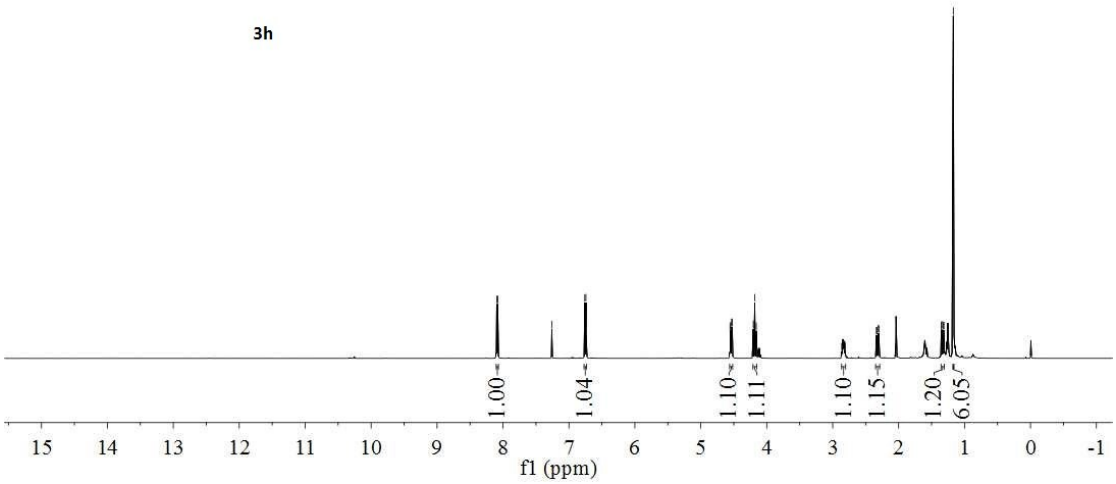


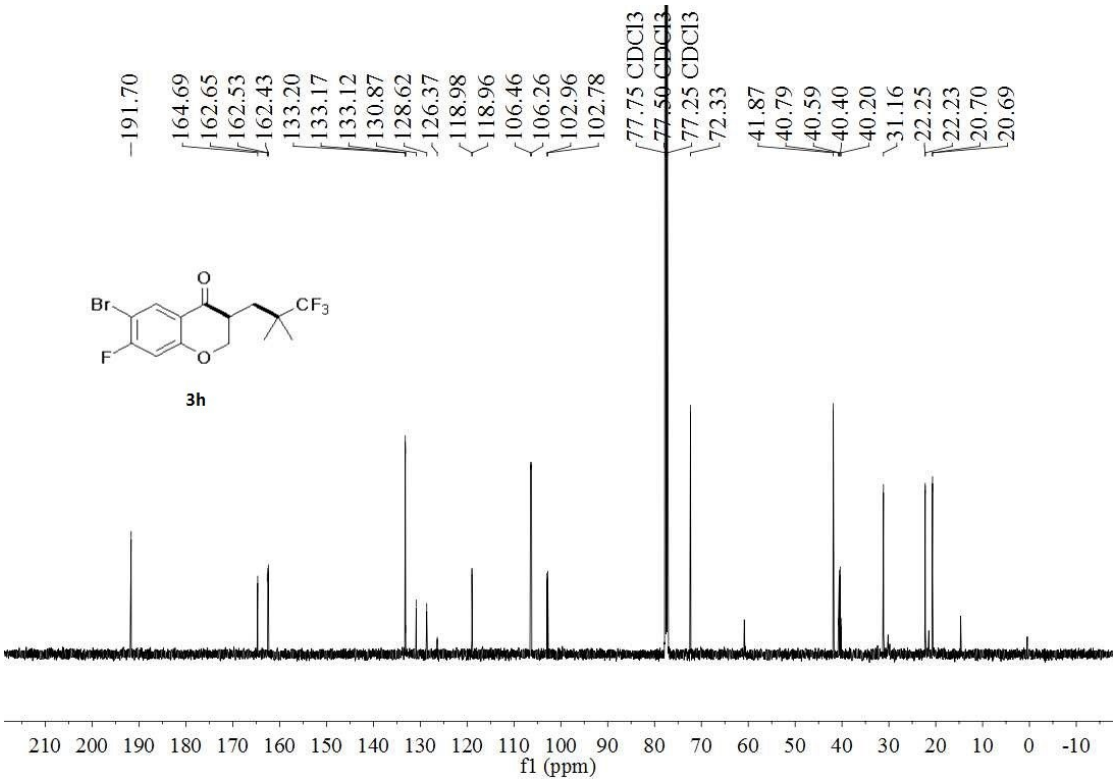
3g

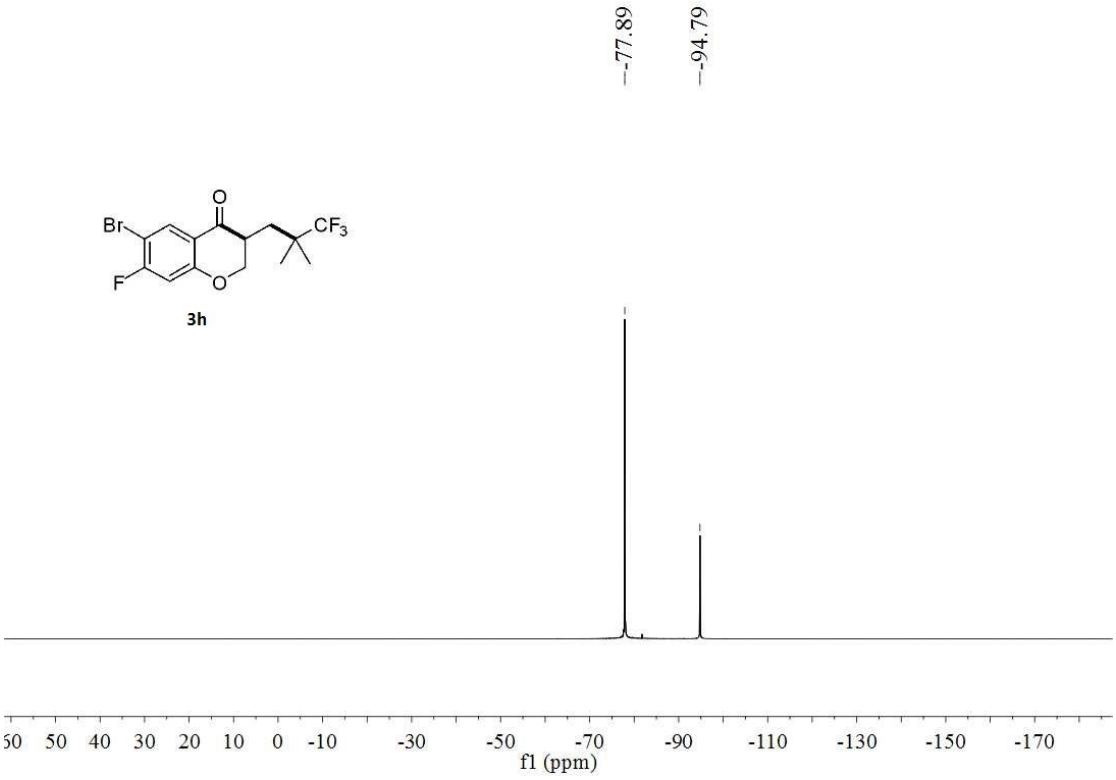
-77.97
-135.57
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

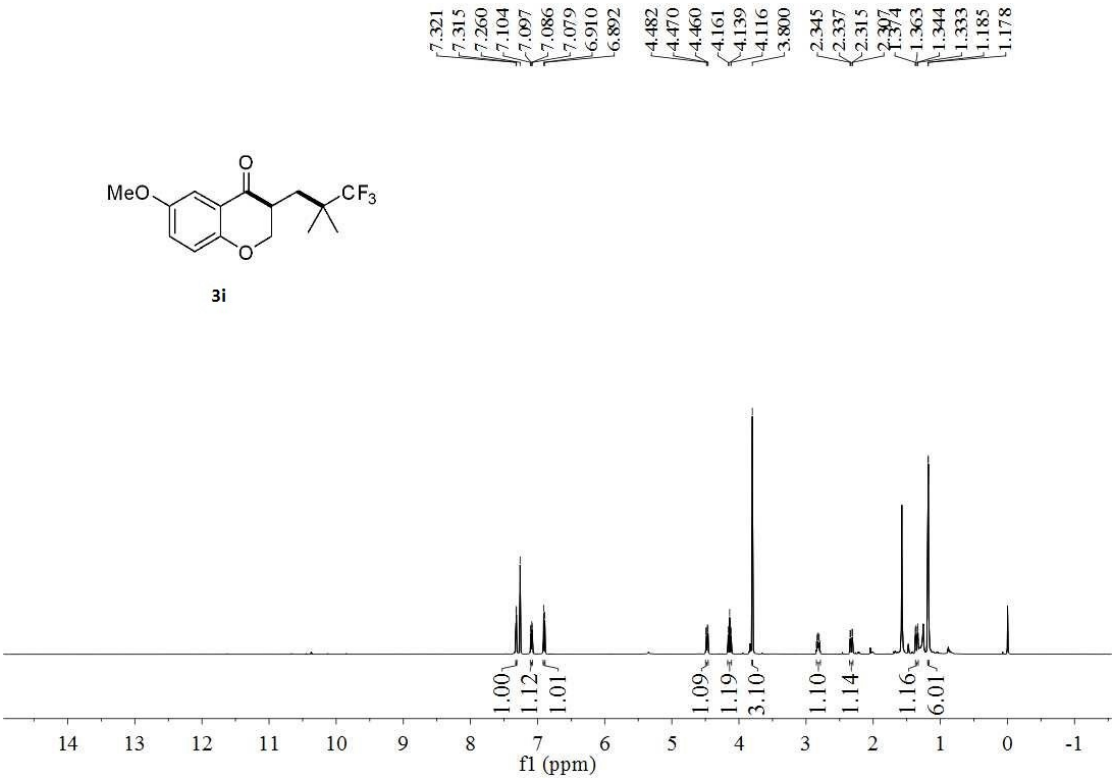

8.095
8.079
7.260
6.760
6.742
4.557
4.546
4.534
4.524
4.205
4.182
4.159
2.811
2.337
2.330
2.307
2.300
1.343
1.324
1.313
1.170

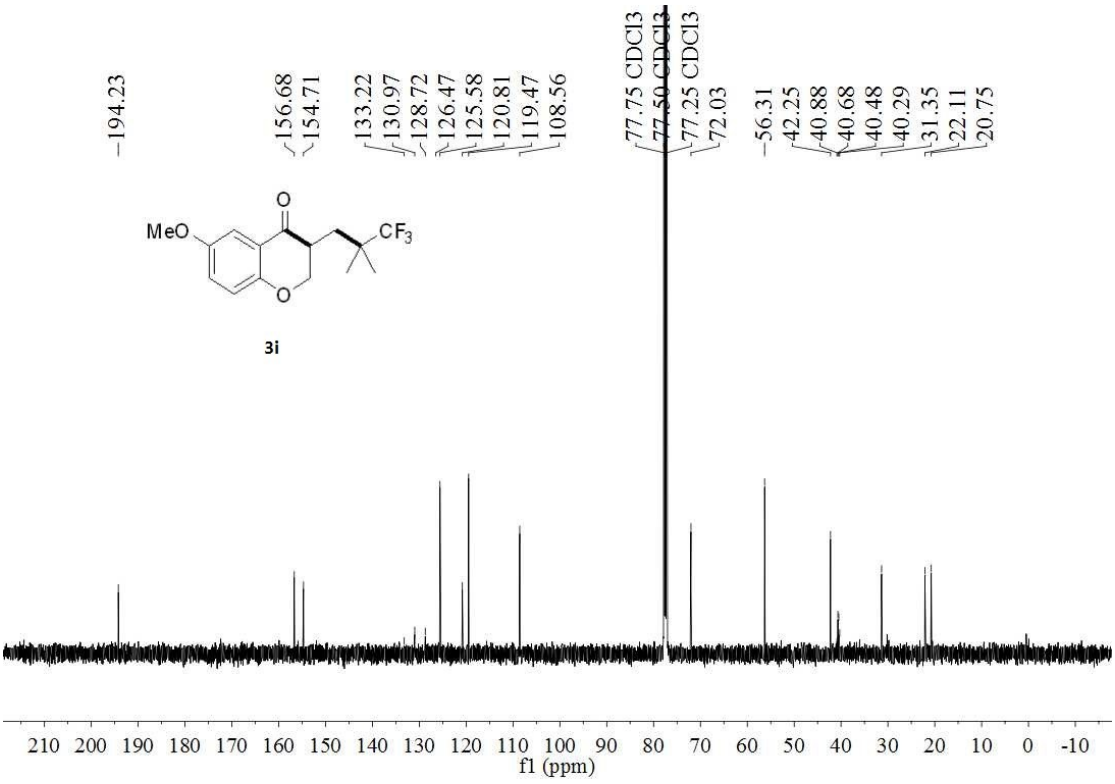
3h

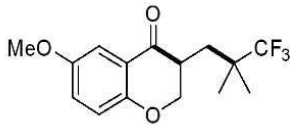

1.00
1.04
1.10
1.11
1.10
1.15
1.20
6.05
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


191.70
164.69
162.65
162.53
162.43
133.20
133.17
133.12
130.87
128.62
126.37
118.98
118.96
106.46
106.26
102.96
102.78
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.33
41.87
40.79
40.59
40.40
40.20
31.16
22.25
22.23
20.70
20.69
Br
F
O
CF3
3h
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-77.89
-94.79
Br
F
O
CF3
3h
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

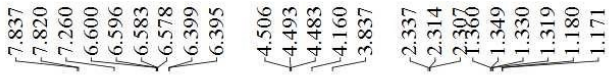

7.321
7.315
7.260
7.104
7.097
7.086
7.079
6.910
6.892
4.482
4.470
4.460
4.161
4.139
4.116
3.800
2.345
2.337
2.315
2.307
1.374
1.363
1.344
1.333
1.185
1.178
MeO
CF3
O
O
3i
1.00
1.12
1.01
1.09
1.19
3.10
1.10
1.14
1.16
6.01
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

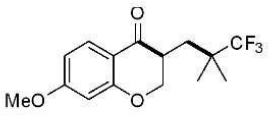

194.23
156.68
154.71
133.22
130.97
128.72
126.47
125.58
120.81
119.47
108.56
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.03
56.31
42.25
40.88
40.68
40.48
40.29
31.35
22.11
20.75
MeO
CF3
O
O
3i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


MeO
O
CF3
O

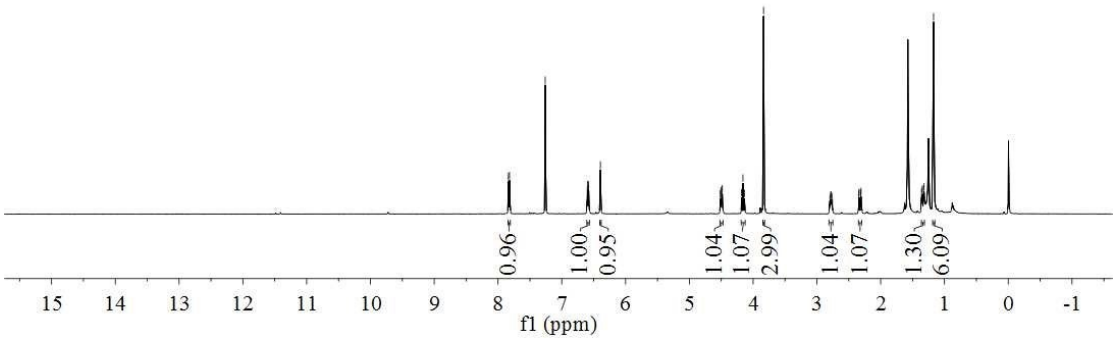
3i

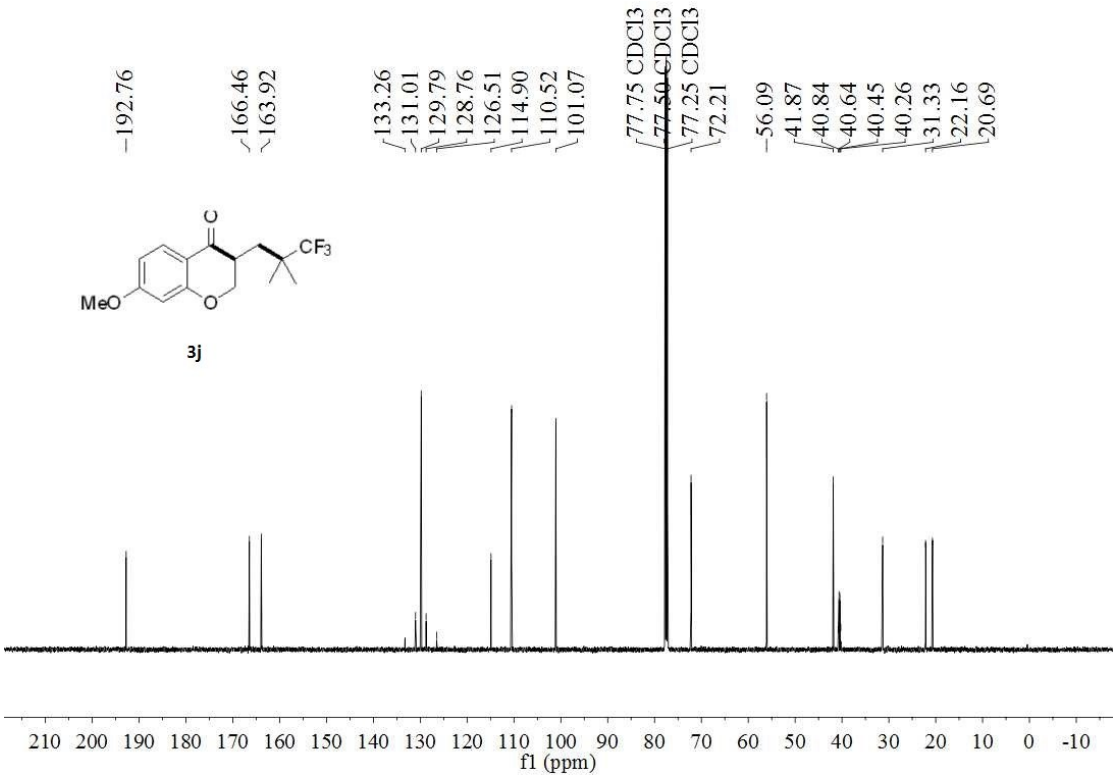
-78.01
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)


7.837
7.820
7.260
6.600
6.596
6.583
6.578
6.399
6.395
4.506
4.493
4.483
4.160
3.837
2.337
2.314
2.307
2.300
1.360
1.349
1.330
1.319
1.180
1.171

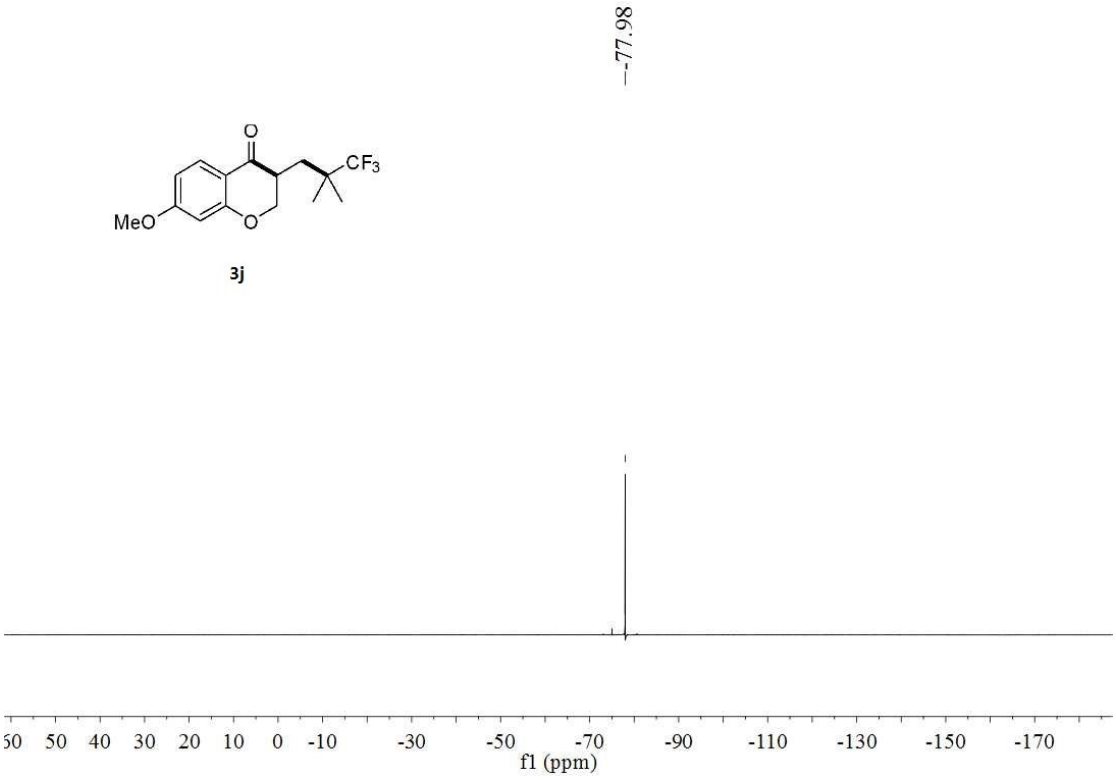

MeO
O
O
CF3

3j

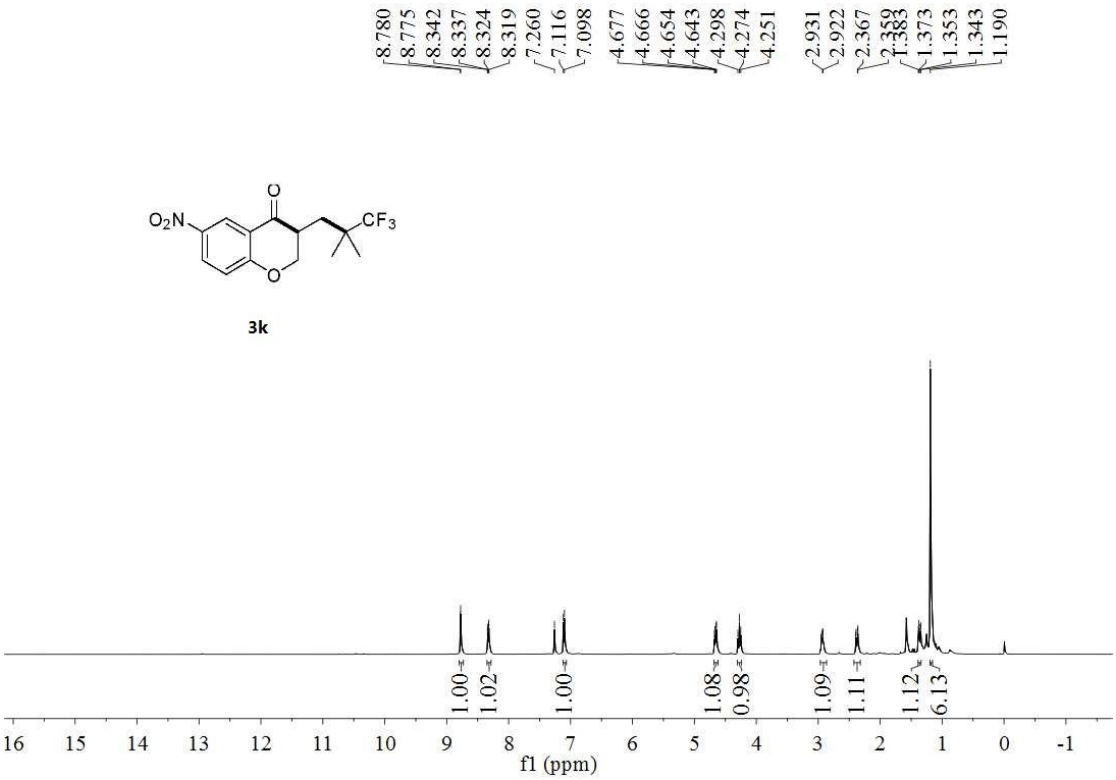

0.96
1.00
0.95
1.04
1.07
2.99
1.04
1.07
1.30
6.09
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

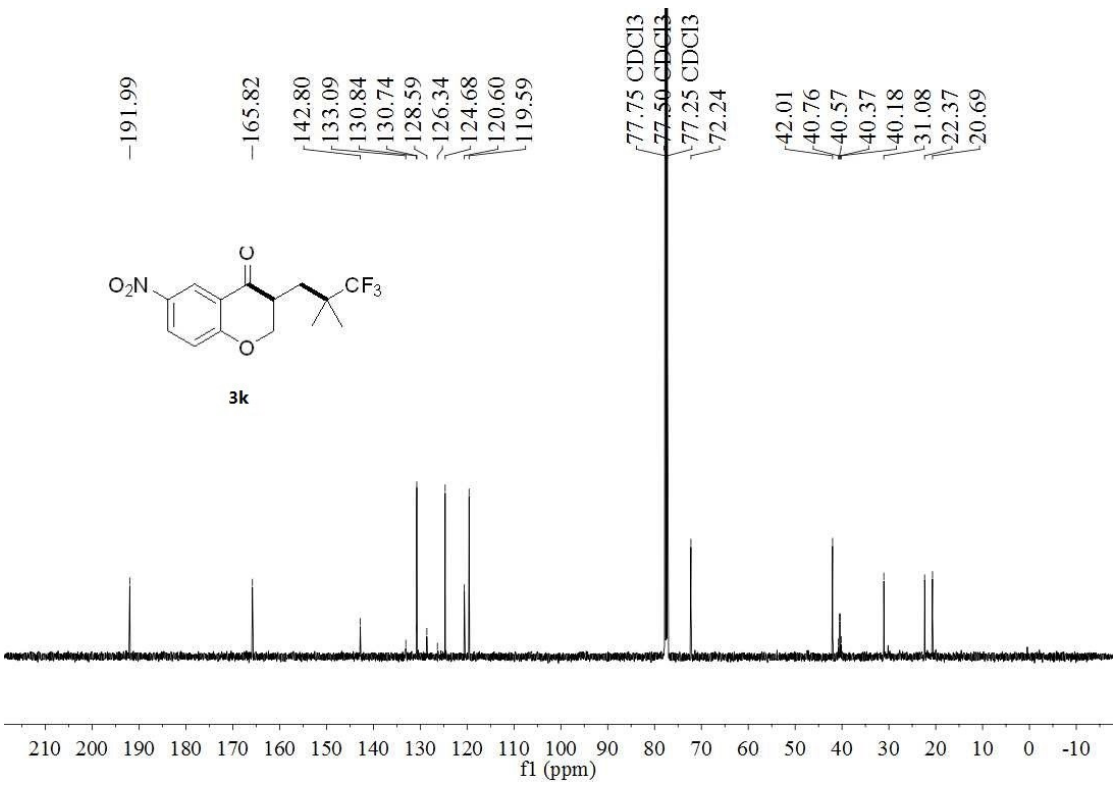

192.76
166.46
163.92
133.26
131.01
129.79
128.76
126.51
114.90
110.52
101.07
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.21
56.09
41.87
40.84
40.64
40.45
40.26
31.33
22.16
20.69
O
CF3
MeO
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

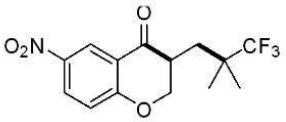
3j


-77.98
O
CF3
MeO
O
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

3j

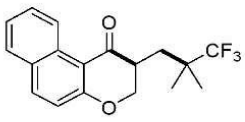

8.780
8.775
8.342
8.337
8.324
8.319
7.260
7.116
7.098
4.677
4.666
4.654
4.643
4.298
4.274
4.251
2.931
2.922
2.367
2.359
1.383
1.373
1.353
1.343
1.190
O2N
CF3
O
3k
1.00
1.02
1.00
1.08
0.98
1.09
1.11
1.12
6.13
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


191.99
165.82
142.80
133.09
130.84
130.74
128.59
126.34
124.68
120.60
119.59
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
72.24
42.01
40.76
40.57
40.37
40.18
31.08
22.37
20.69
O2N
CF3
O
3k
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



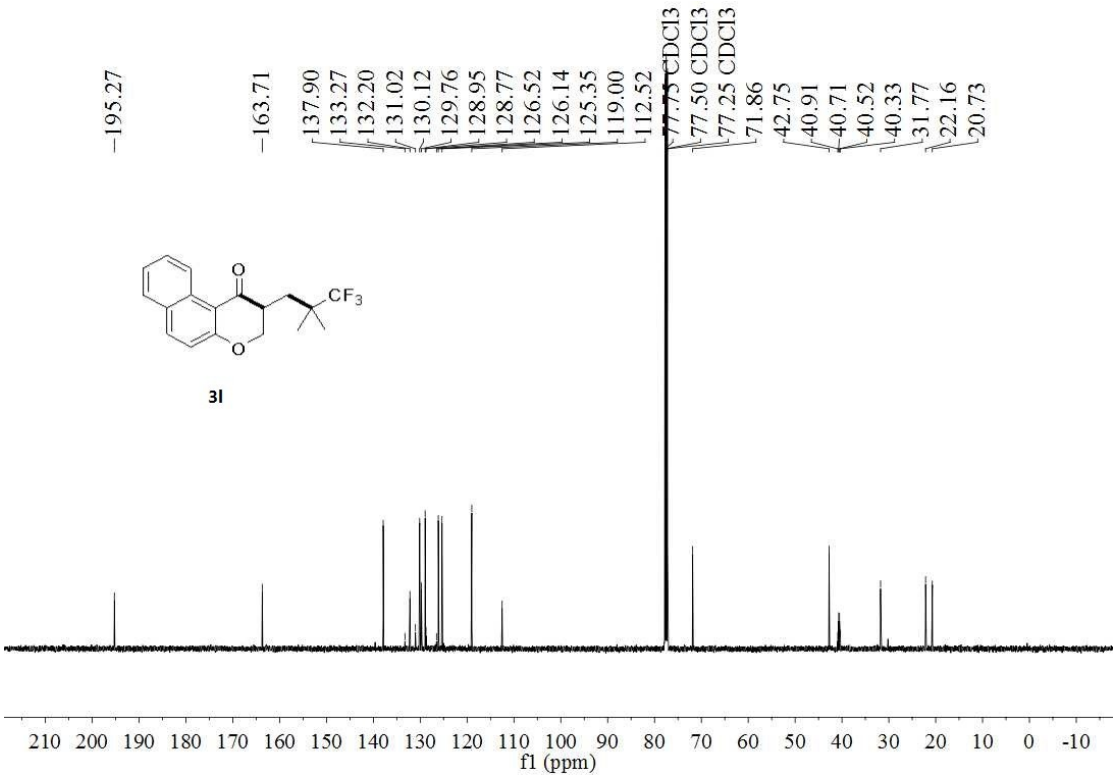
3k

-77.77
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

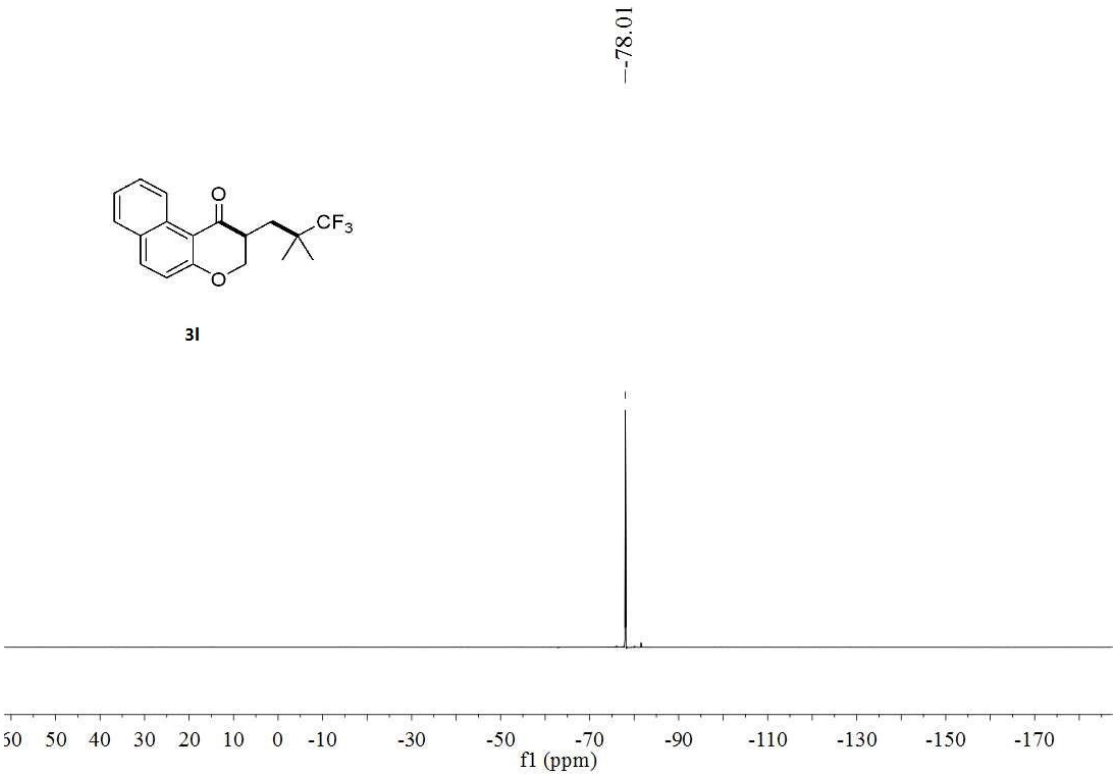


3l

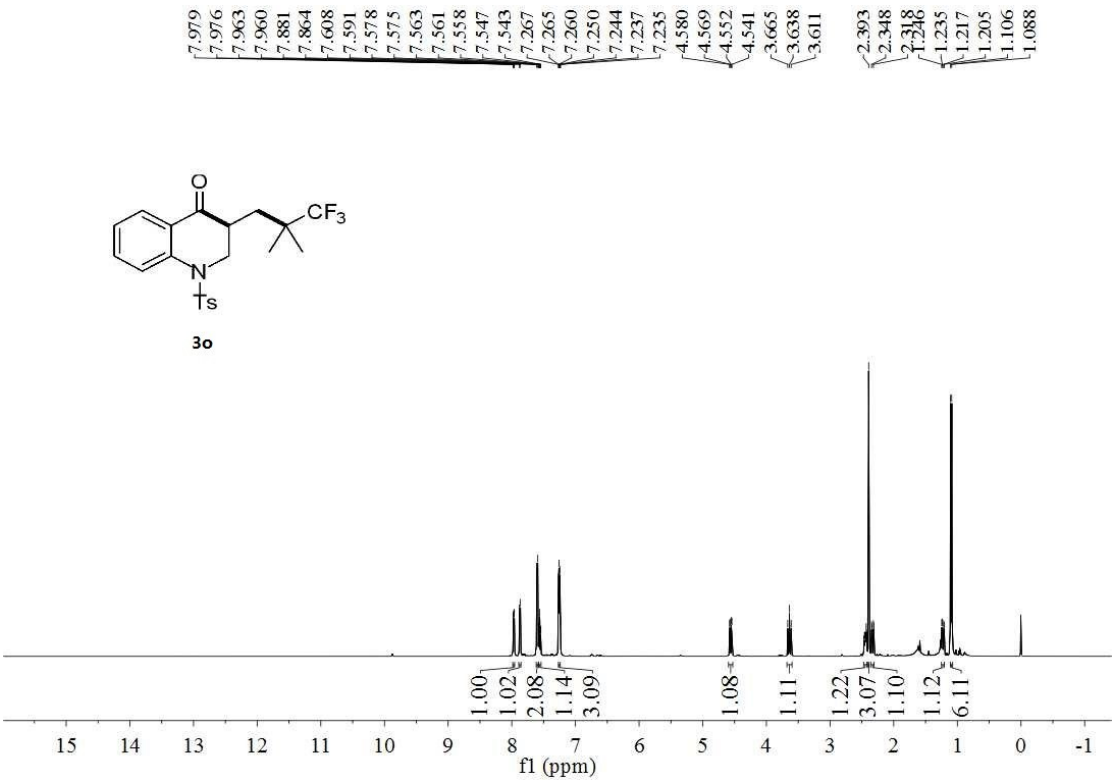
9.413
9.395
7.925
7.907
7.755
7.739
7.622
7.423
7.250
7.090
7.072
4.628
4.619
4.606
4.596
4.329
4.307
2.908
2.408
2.378
1.478
1.459
1.448
1.206
1.179
1.00
1.04
1.03
1.04
1.09
1.02
1.04
1.05
1.04
1.06
1.07
6.17
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

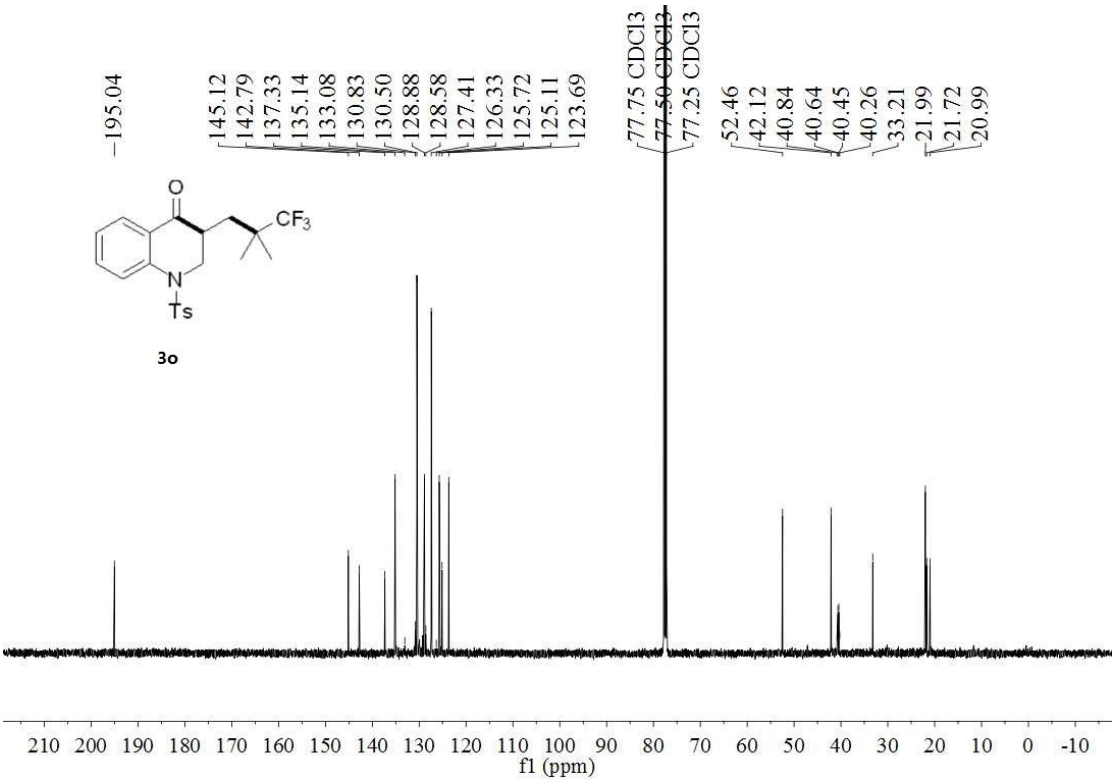

195.27
163.71
137.90
133.27
132.20
131.02
130.12
129.76
128.95
128.77
126.52
126.14
125.35
119.00
112.52
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.86
42.75
40.91
40.71
40.52
40.33
31.77
22.16
20.73
O
CF3
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

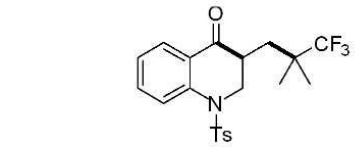
3l


-78.01
O
CF3
O
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

3l

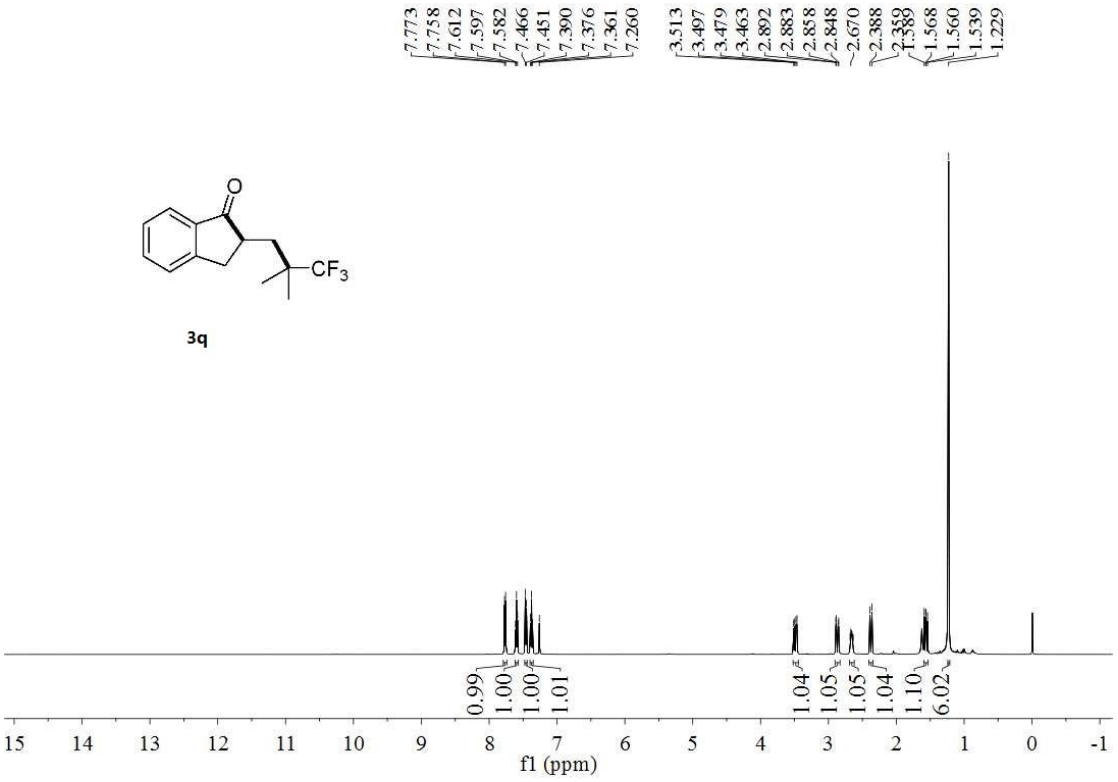

7.979
7.976
7.963
7.960
7.881
7.864
7.608
7.591
7.578
7.575
7.563
7.561
7.558
7.547
7.543
7.267
7.265
7.260
7.250
7.244
7.237
7.235
4.580
4.569
4.552
4.541
3.665
3.638
3.611
2.393
2.348
2.318
1.235
1.217
1.205
1.106
1.088
O
CF3
N
Ts
3o
1.00
1.02
2.08
1.14
3.09
1.08
1.11
1.22
3.07
1.10
1.12
6.11
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


195.04
145.12
142.79
137.33
135.14
133.08
130.83
130.50
128.88
128.58
127.41
126.33
125.72
125.11
123.69
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
52.46
42.12
40.84
40.64
40.45
40.26
33.21
21.99
21.72
20.99
O
CF3
N
Ts
3o
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

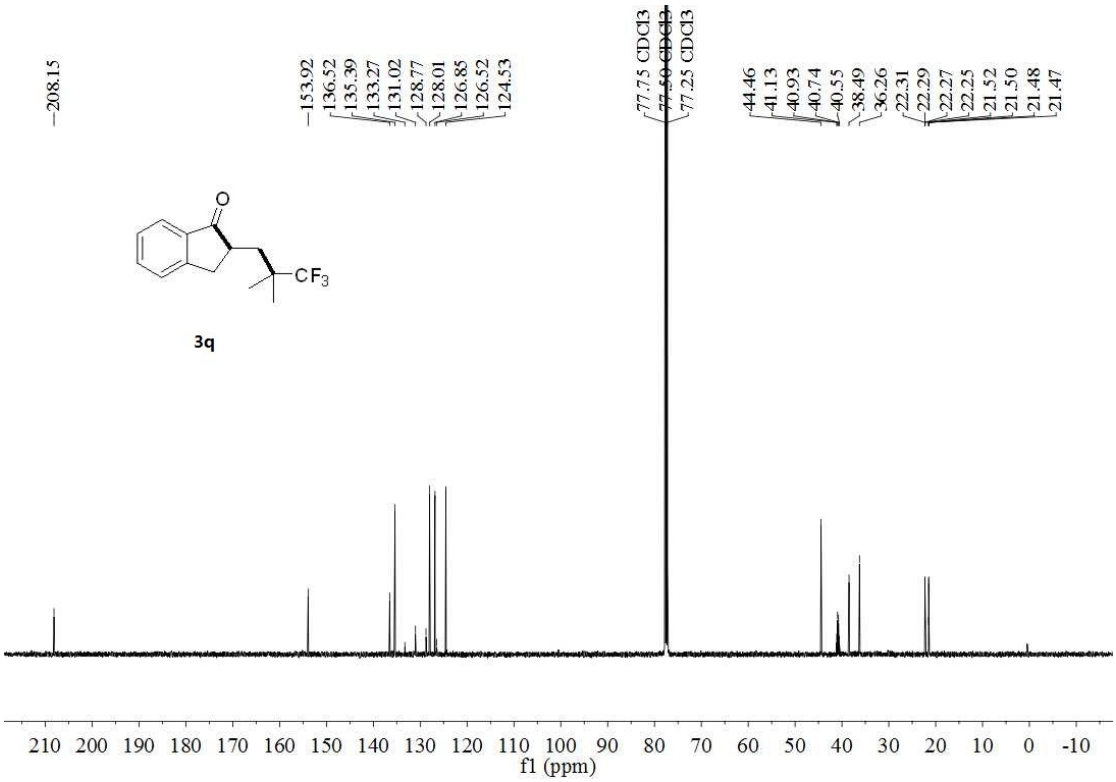

O
CF3
N
Ts

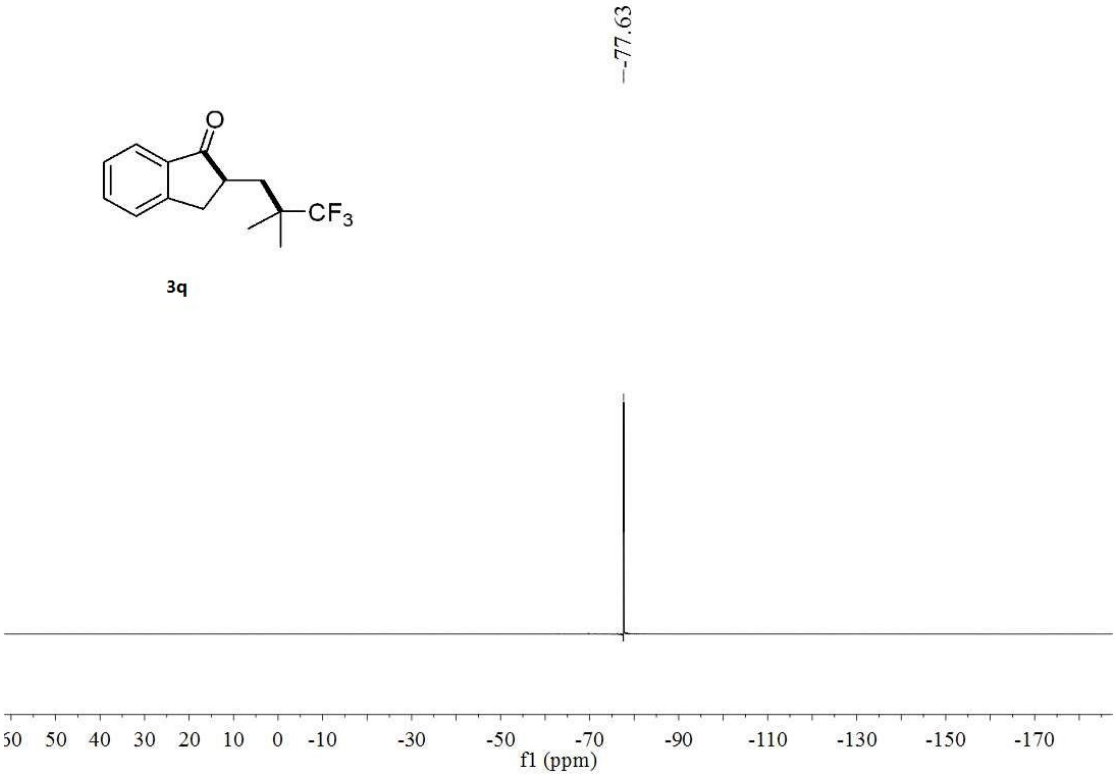
3o

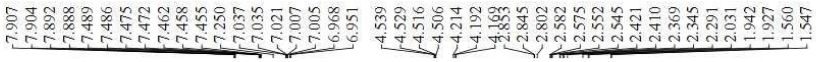
-78.06
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

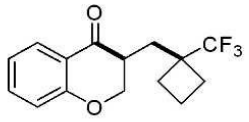

7.773
7.758
7.612
7.597
7.582
7.466
7.451
7.390
7.376
7.361
7.260
3.513
3.497
3.479
3.463
2.892
2.883
2.858
2.848
2.670
2.388
2.359
2.339
1.568
1.560
1.539
1.229
O
CF3
0.99
1.00
1.00
1.01
1.04
1.05
1.05
1.04
1.10
6.02
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

3q

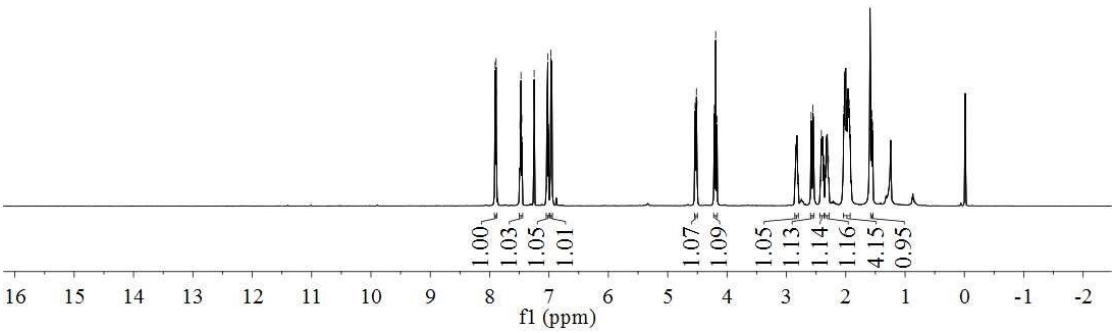

208.15
153.92
136.52
135.39
133.27
131.02
128.77
128.01
126.85
126.52
124.53
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
44.46
41.13
40.93
40.74
40.55
38.49
36.26
22.31
22.29
22.27
22.25
21.52
21.50
21.48
21.47
O
CF3
3q
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

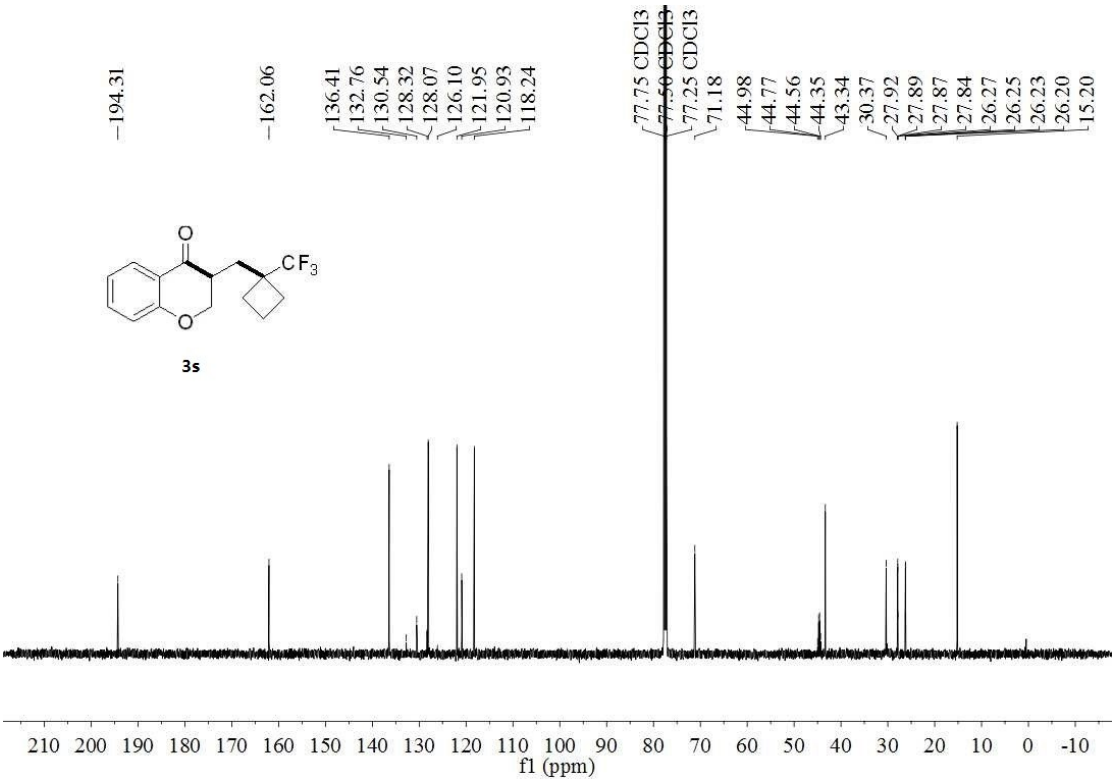

-77.63
O
CF3
3q
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

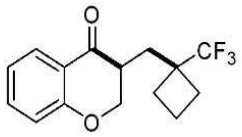

7.907
7.904
7.892
7.888
7.489
7.486
7.475
7.472
7.462
7.458
7.455
7.250
7.037
7.035
7.021
7.007
7.005
6.968
6.951
4.539
4.529
4.516
4.506
4.214
4.192
4.169
2.853
2.845
2.802
2.582
2.575
2.552
2.545
2.421
2.410
2.369
2.345
2.291
2.031
1.942
1.927
1.560
1.547


O
CF3
O

3s

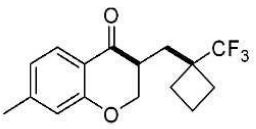

1.00
1.03
1.05
1.01
1.07
1.09
1.05
1.13
1.14
1.16
4.15
0.95
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2
f1 (ppm)


194.31
162.06
136.41
132.76
130.54
128.32
128.07
126.10
121.95
120.93
118.24
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.18
44.98
44.77
44.56
44.35
43.34
30.37
27.92
27.89
27.87
27.84
26.27
26.25
26.23
26.20
15.20
O
CF3
O
3s
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
CF3
O

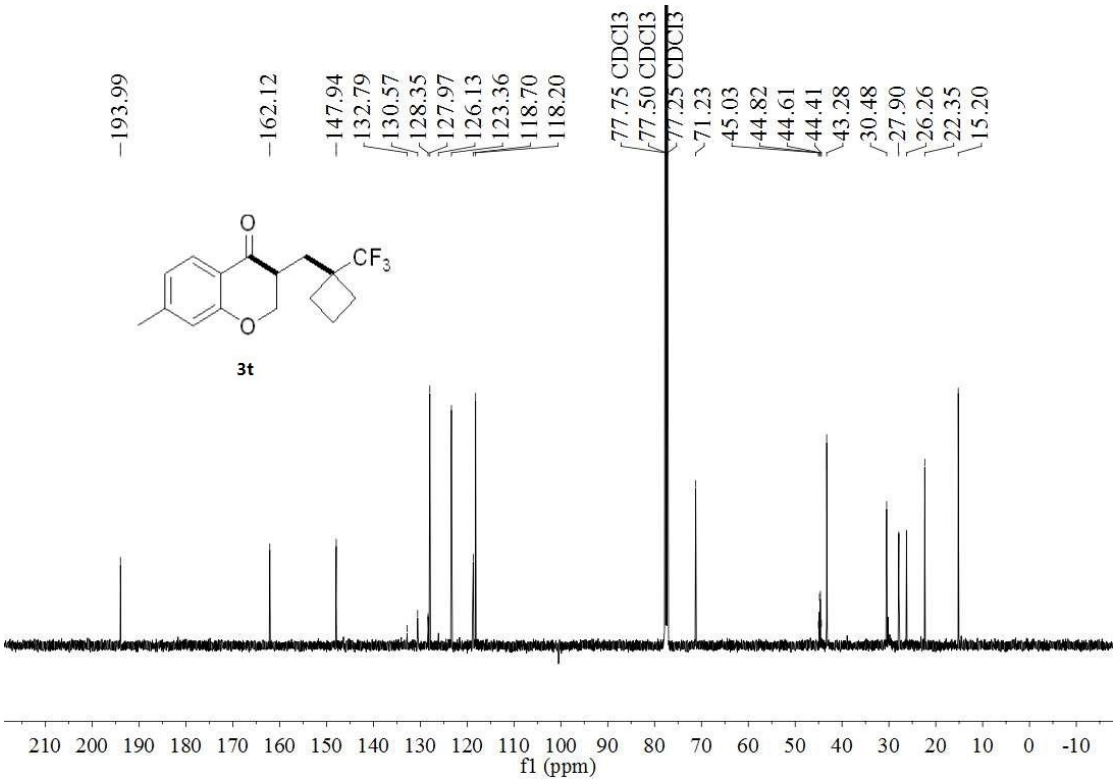
3s

-76.69
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

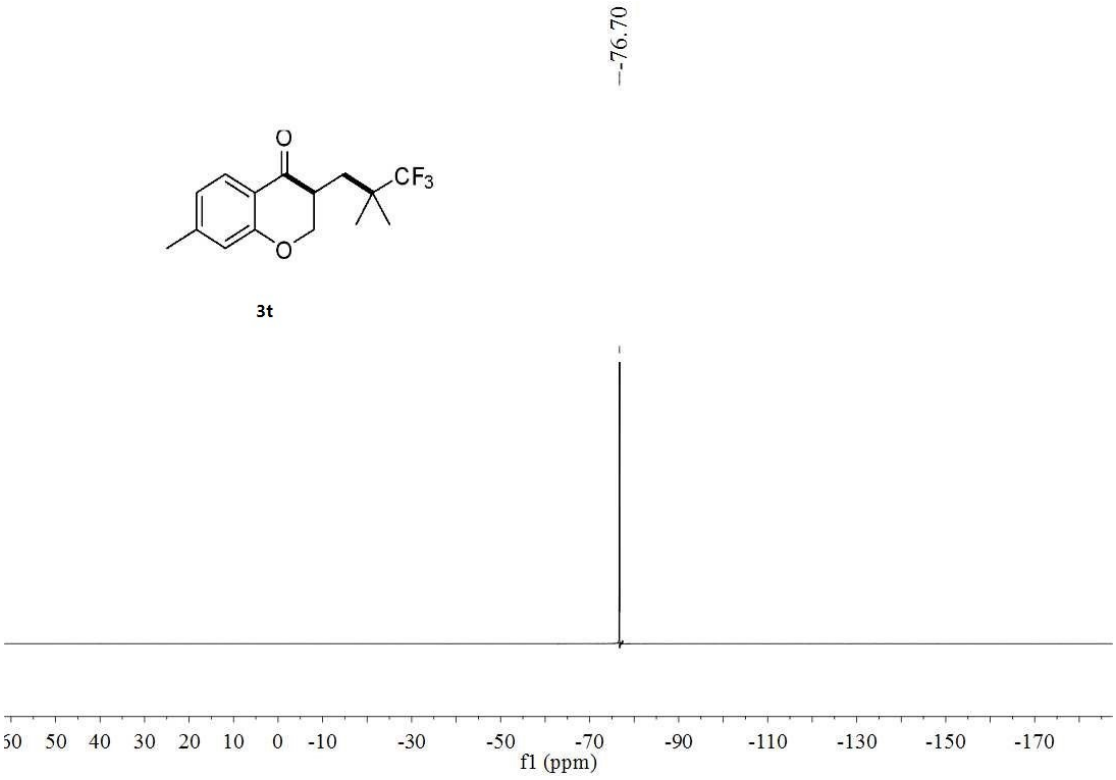

O
CF3
O

3t

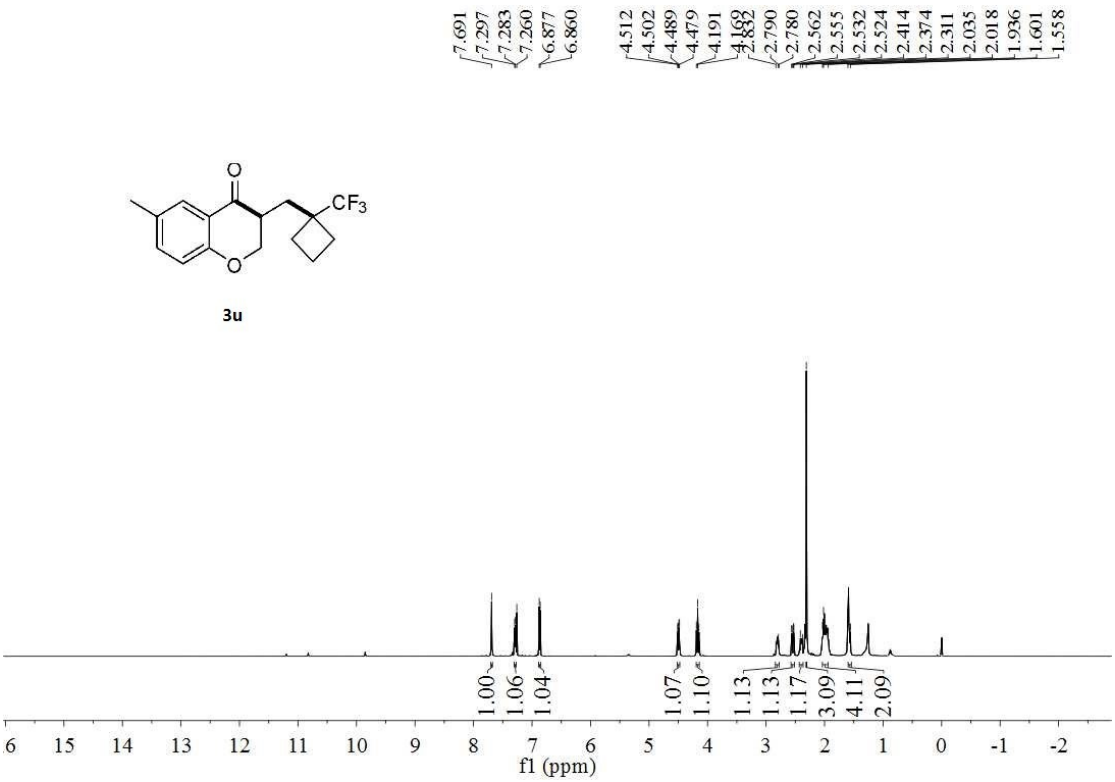
7.799
7.783
7.260
6.850
6.834
6.768
4.518
4.508
4.495
4.485
4.193
4.171
4.149
2.809
2.798
2.789
2.568
2.562
2.538
2.531
2.409
2.357
2.295
2.033
1.946
1.609
1.548
1.00
1.08
0.98
1.13
1.21
1.09
1.08
4.00
4.09
2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

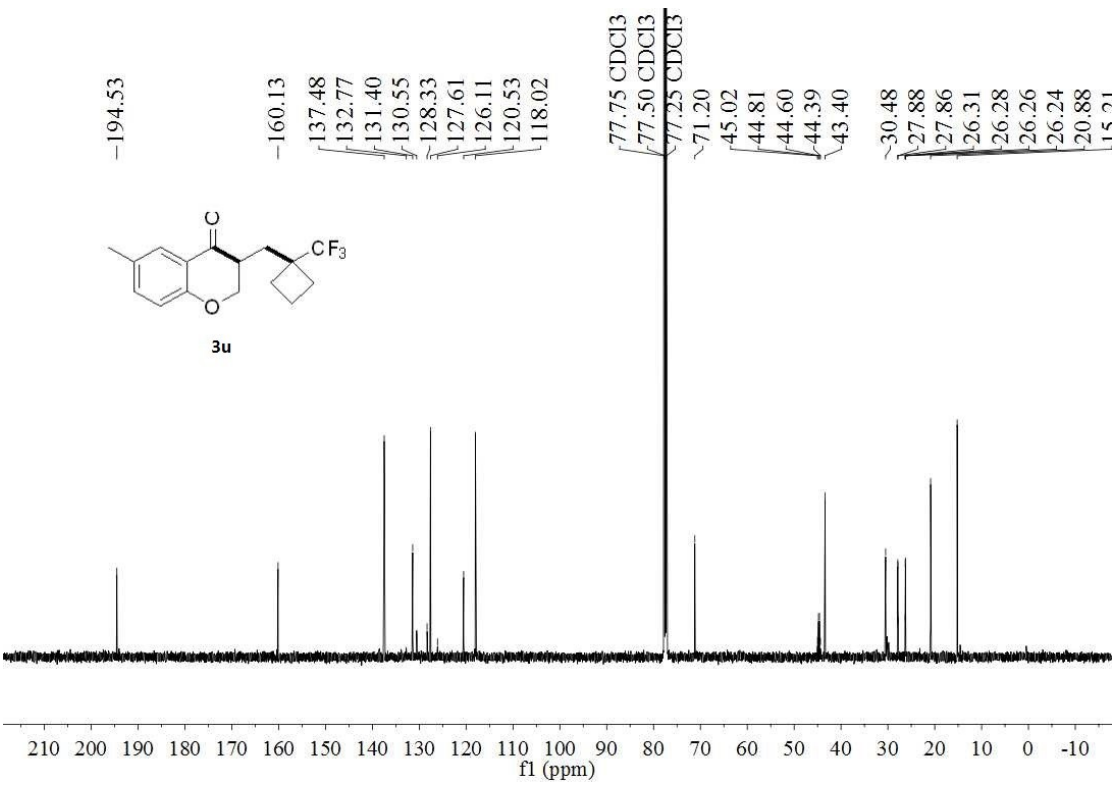

193.99
162.12
147.94
132.79
130.57
128.35
127.97
126.13
123.36
118.70
118.20
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.23
45.03
44.82
44.61
44.41
43.28
30.48
27.90
26.26
22.35
15.20
O
CF3
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

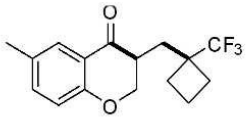
3t


-76.70
O
CF3
O
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

3t


7.691
7.297
7.283
7.260
6.877
6.860
4.512
4.502
4.489
4.479
4.191
2.790
2.780
2.562
2.555
2.532
2.524
2.414
2.374
2.311
2.035
2.018
1.936
1.601
1.558
O
CF3
O
3u
1.00
1.06
1.04
1.07
1.10
1.13
1.13
1.17
3.09
4.11
2.09
6 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2
f1 (ppm)

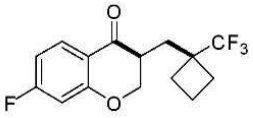

194.53
160.13
137.48
132.77
131.40
130.55
128.33
127.61
126.11
120.53
118.02
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.20
45.02
44.81
44.60
44.39
43.40
30.48
27.88
27.86
26.31
26.28
26.26
26.24
20.88
O
CF3
O
3u
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



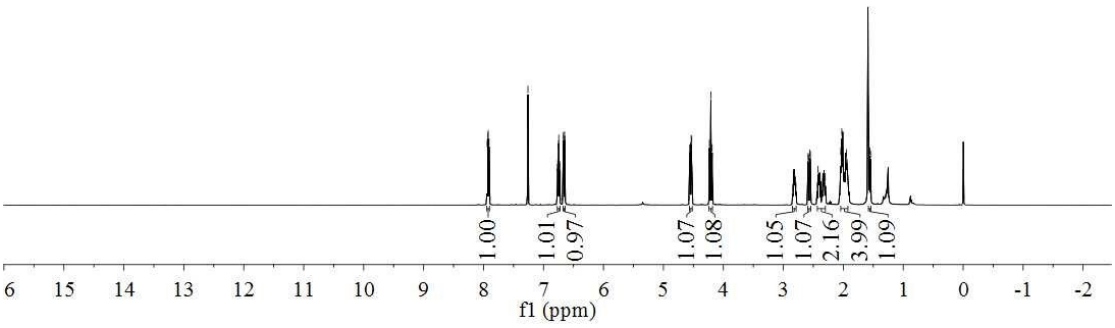
3u

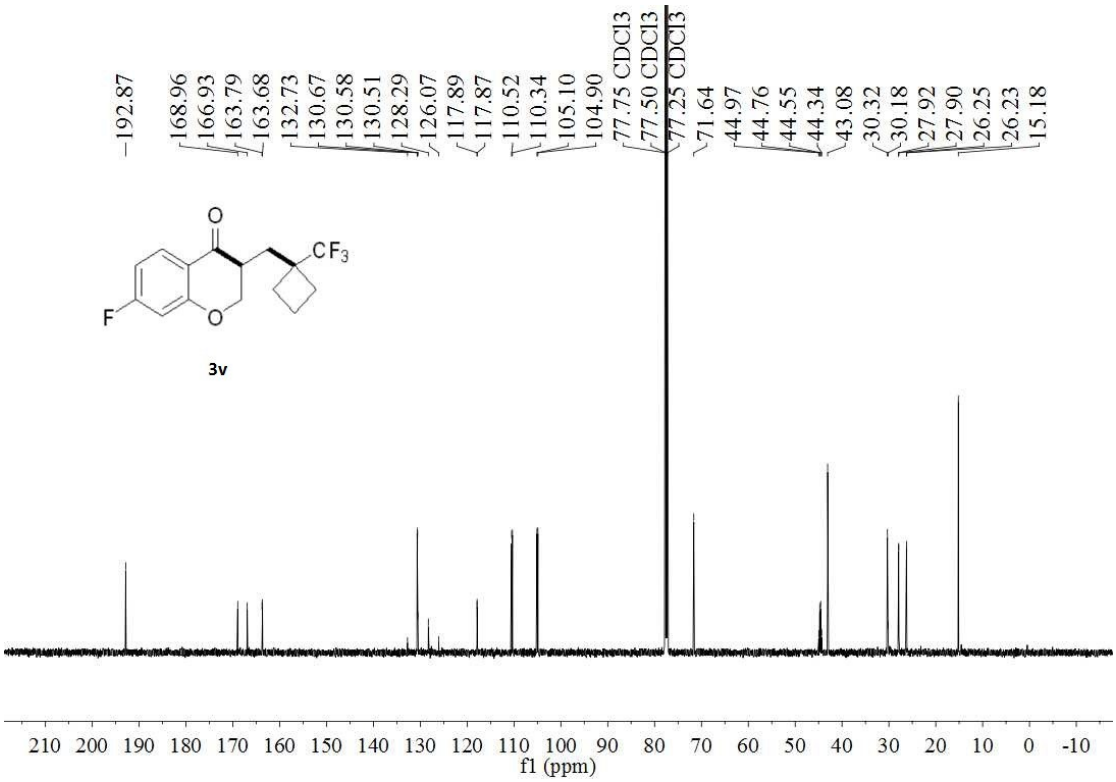
-76.70
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

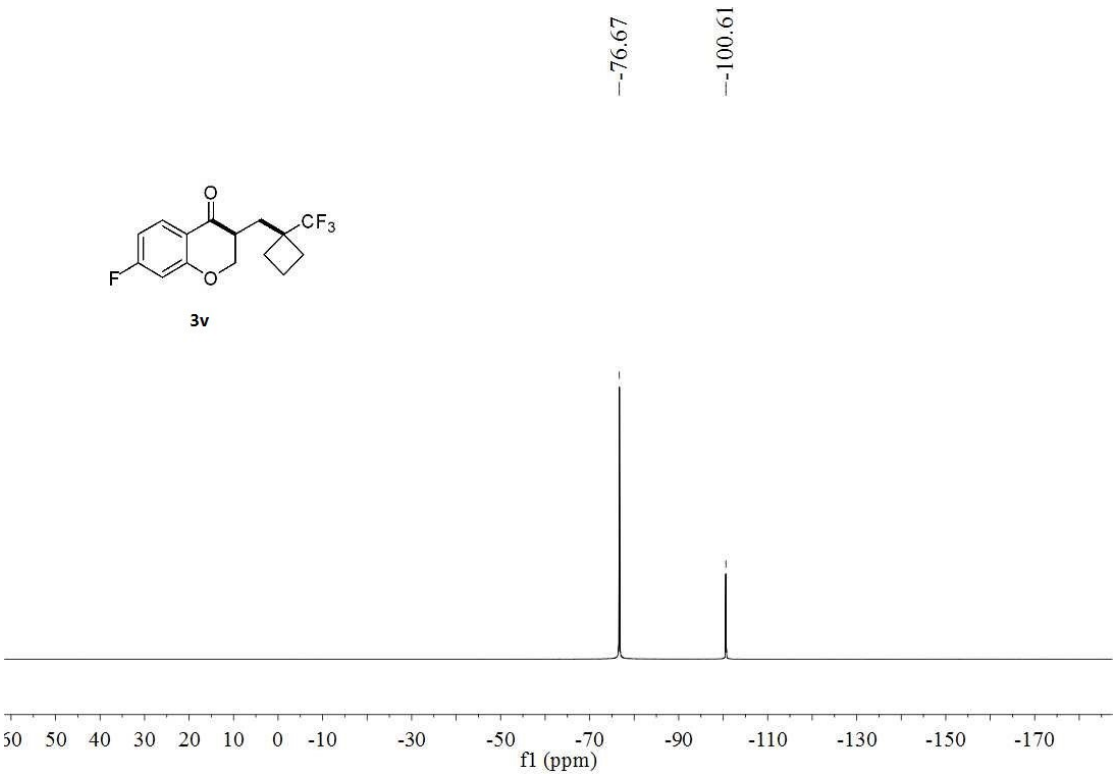
7.940
7.926
7.922
7.909
7.260
6.746
6.668
6.663
6.648
6.644
4.550
4.537
4.527
4.232
4.210
2.832
2.789
2.587
2.579
2.556
2.549
2.434
2.420
2.300
2.042
2.025
1.945
1.935
1.575
1.558
1.544

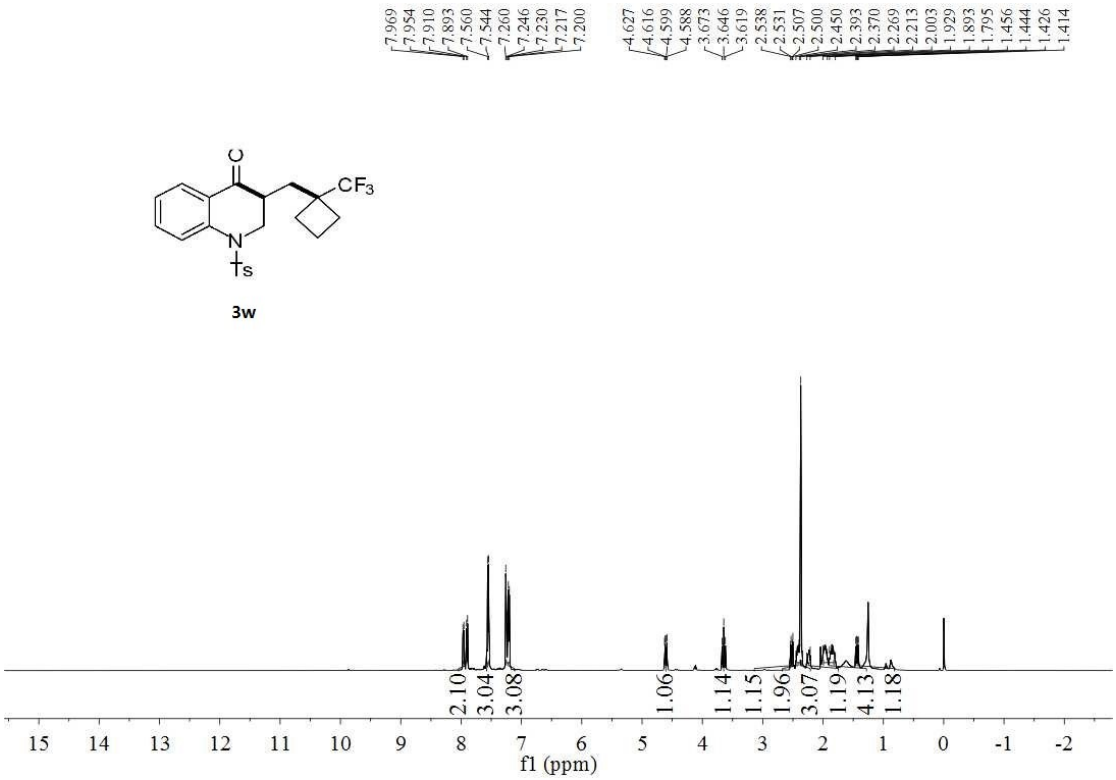


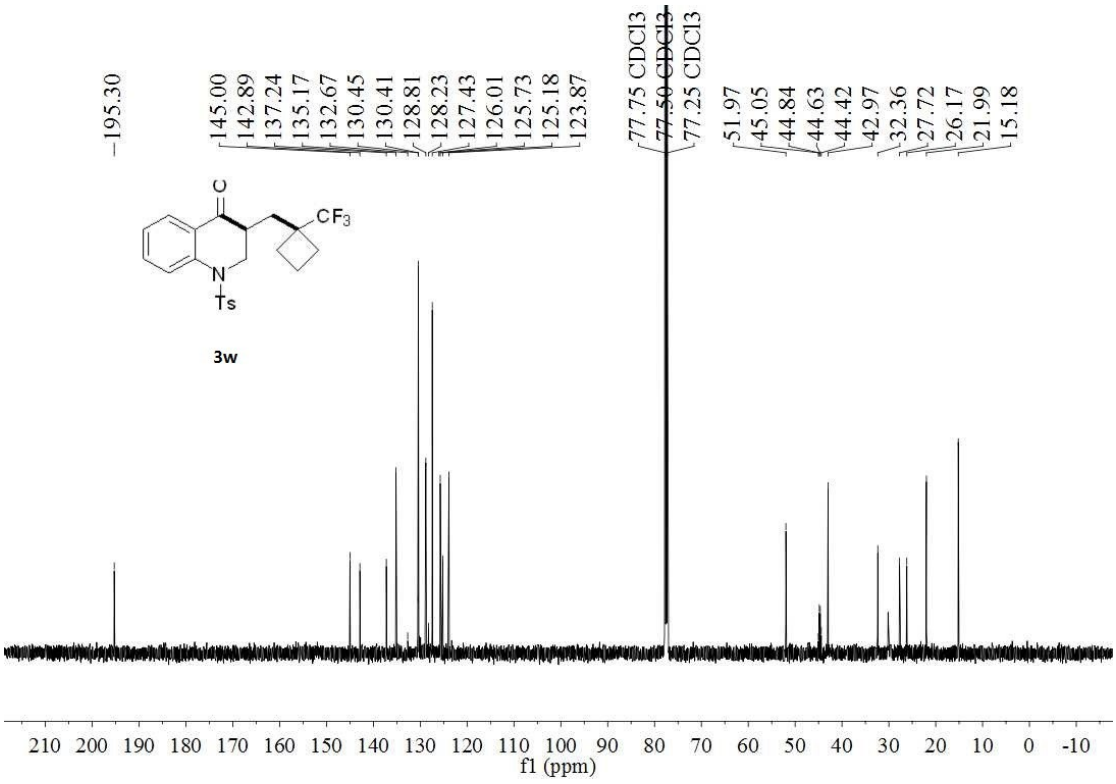
3v

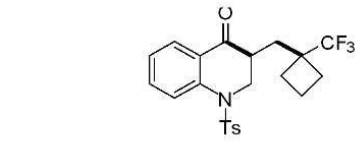

1.00
1.01
0.97
1.07
1.08
1.05
1.07
2.16
3.99
1.09
6 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2
f1 (ppm)


192.87
168.96
166.93
163.79
163.68
132.73
130.67
130.58
130.51
128.29
126.07
117.89
117.87
110.52
110.34
105.10
104.90
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
71.64
44.97
44.76
44.55
44.34
43.08
30.32
30.18
27.92
27.90
26.25
26.23
15.18
O
CF3
F
O
3v
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-76.67
-100.61
O
CF3
F
O
3v
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

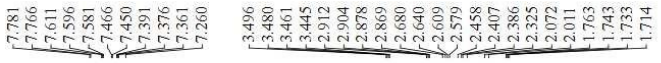

7.969
7.954
7.910
7.893
7.560
7.544
7.260
7.246
7.230
7.217
7.200
4.627
4.616
4.599
4.588
3.673
3.646
3.619
2.538
2.531
2.507
2.500
2.450
2.393
2.370
2.269
2.213
2.003
1.929
1.893
1.795
1.456
1.444
1.426
1.414
O
CF3
N
Ts
3w
2.10
3.04
3.08
1.06
1.14
1.15
1.96
3.07
1.19
4.13
1.18
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2
f1 (ppm)

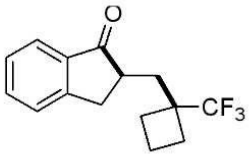

195.30
145.00
142.89
137.24
135.17
132.67
130.45
130.41
128.81
128.23
127.43
126.01
125.73
125.18
123.87
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
51.97
45.05
44.84
44.63
44.42
42.97
32.36
27.72
26.17
21.99
15.18
O
CF3
N
Ts
3w
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



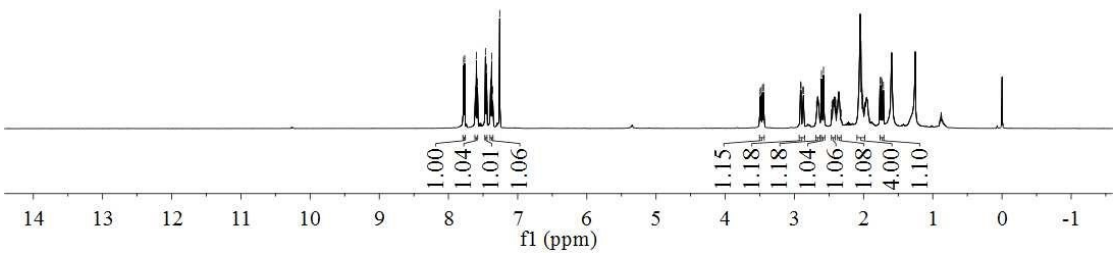
3w

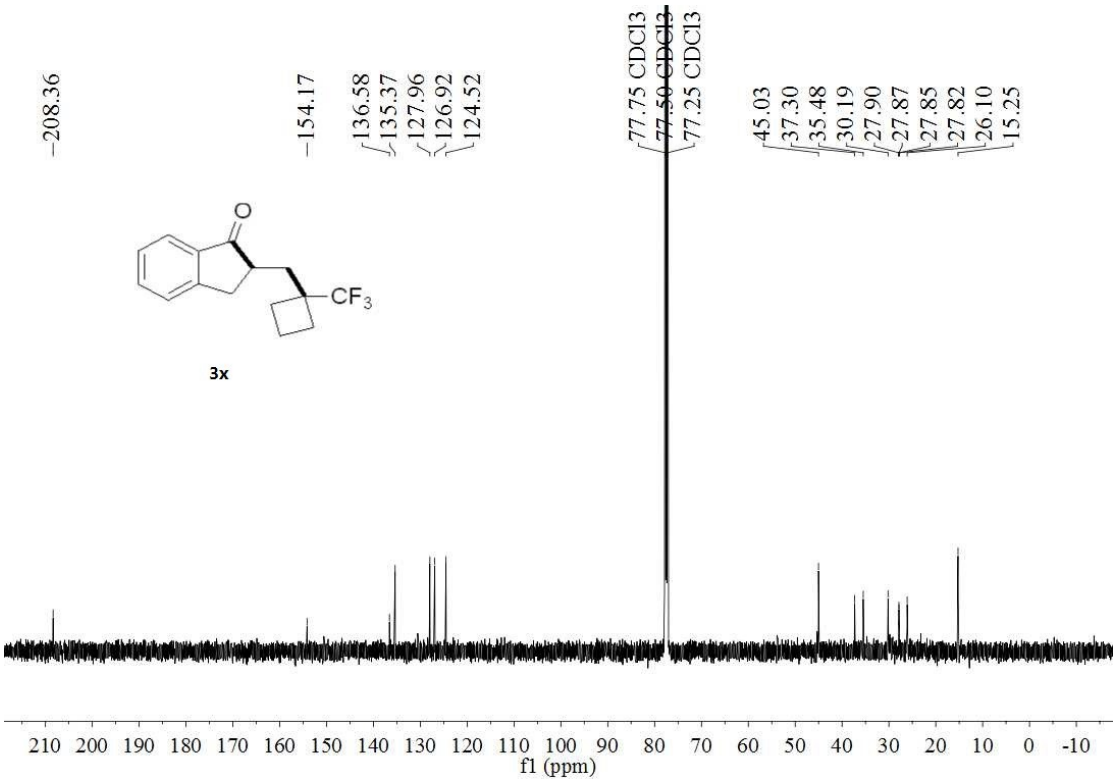
-76.78
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)


7.781
7.766
7.611
7.596
7.581
7.466
7.450
7.391
7.376
7.361
7.260
3.496
3.480
3.461
3.445
2.912
2.904
2.878
2.869
2.680
2.640
2.609
2.579
2.458
2.407
2.386
2.325
2.072
2.011
1.763
1.743
1.733
1.714

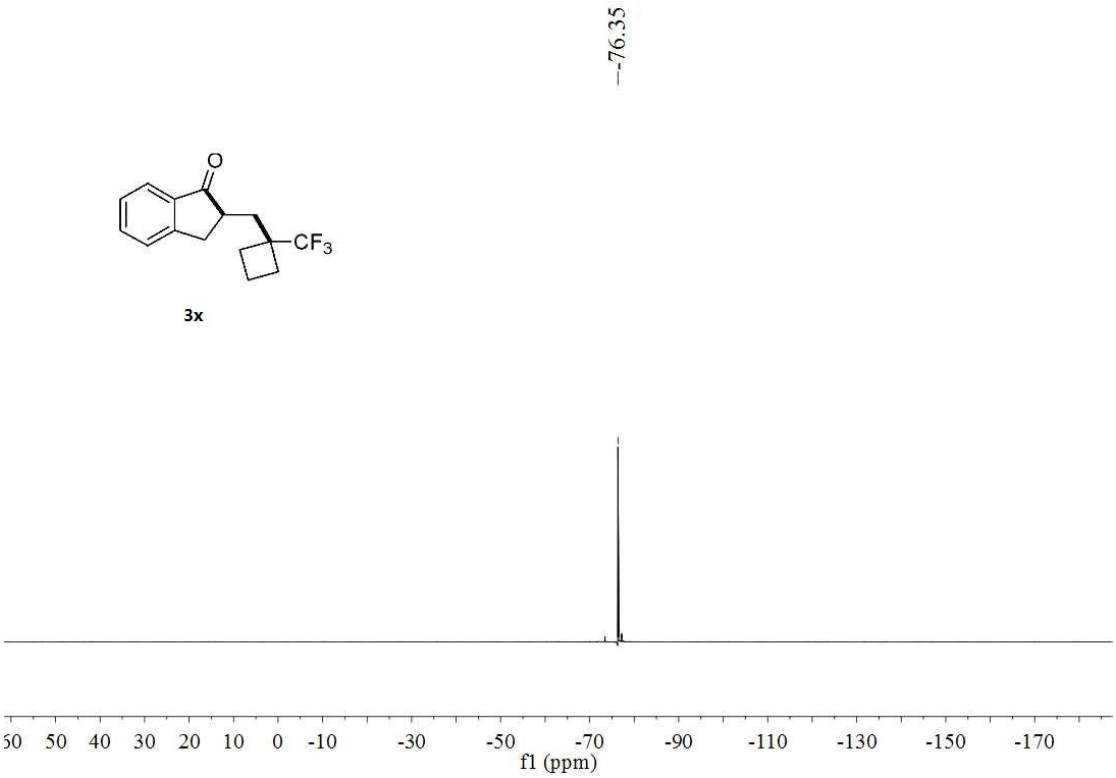


3x

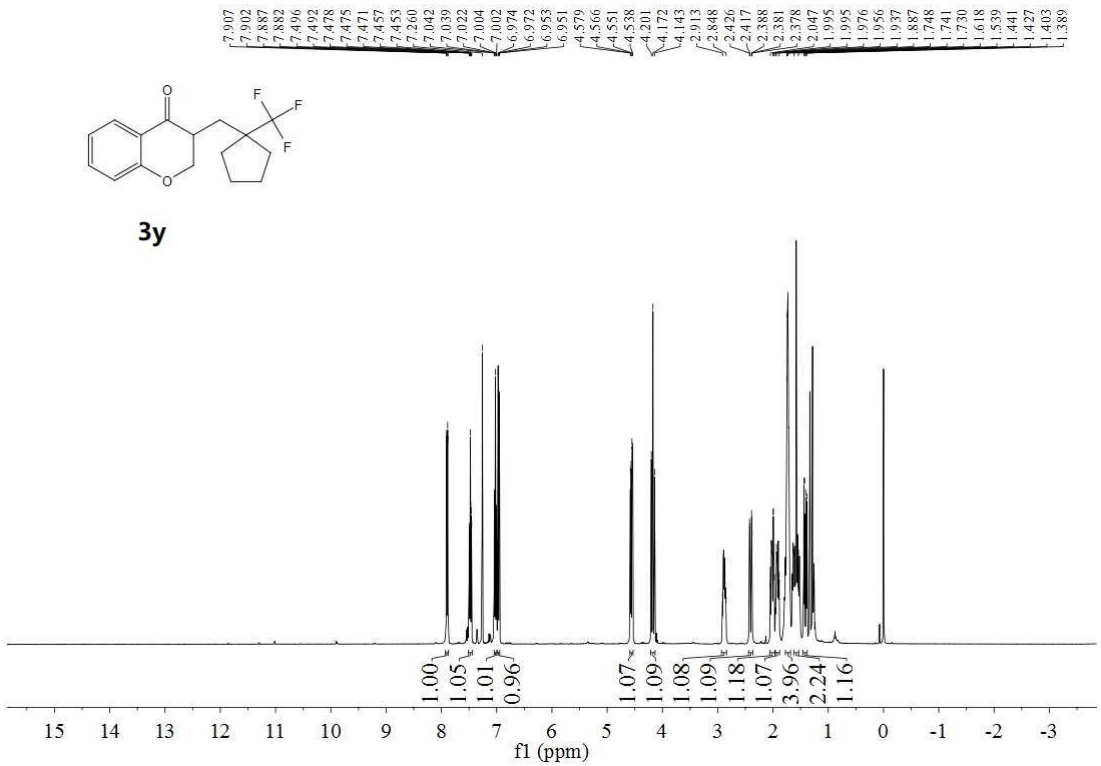

1.00
1.04
1.01
1.06
1.15
1.18
1.18
1.04
1.06
1.08
4.00
1.10
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

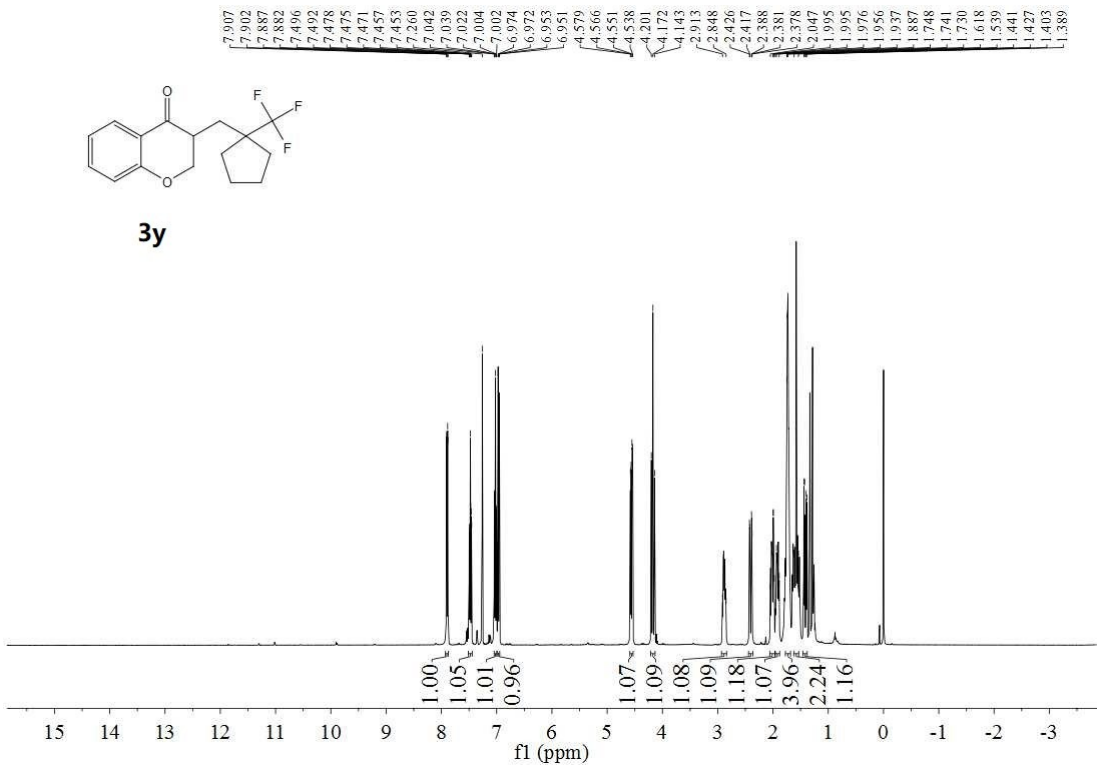

208.36
154.17
136.58
135.37
127.96
126.92
124.52
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
45.03
37.30
35.48
30.19
27.90
27.87
27.85
27.82
26.10
15.25
O
CF3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

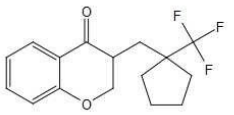
3x


-76.35
O
CF3
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)

3x

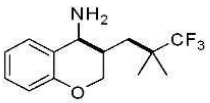

7.907
7.902
7.887
7.882
7.496
7.492
7.478
7.475
7.471
7.457
7.453
7.260
7.042
7.039
7.022
7.004
7.002
6.974
6.972
6.953
6.951
4.579
4.566
4.551
4.538
4.201
4.172
4.143
2.913
2.848
2.426
2.417
2.388
2.381
2.378
2.047
1.995
1.995
1.976
1.956
1.937
1.887
1.748
1.741
1.730
1.618
1.539
1.441
1.427
1.403
1.389
O
F
F
F
O
3y
1.00
1.05
1.01
0.96
1.07
1.09
1.08
1.09
1.18
1.07
3.96
2.24
1.16
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


7.907
7.902
7.887
7.882
7.496
7.492
7.478
7.475
7.471
7.457
7.453
7.260
7.042
7.039
7.022
7.004
7.002
6.974
6.972
6.953
6.951
4.579
4.566
4.551
4.538
4.201
4.172
4.143
2.913
2.848
2.426
2.417
2.388
2.381
2.378
2.047
1.995
1.995
1.976
1.956
1.937
1.887
1.748
1.741
1.730
1.618
1.539
1.441
1.427
1.403
1.389
O
F
F
F
O
3y
1.00
1.05
1.01
0.96
1.07
1.09
1.08
1.09
1.18
1.07
3.96
2.24
1.16
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



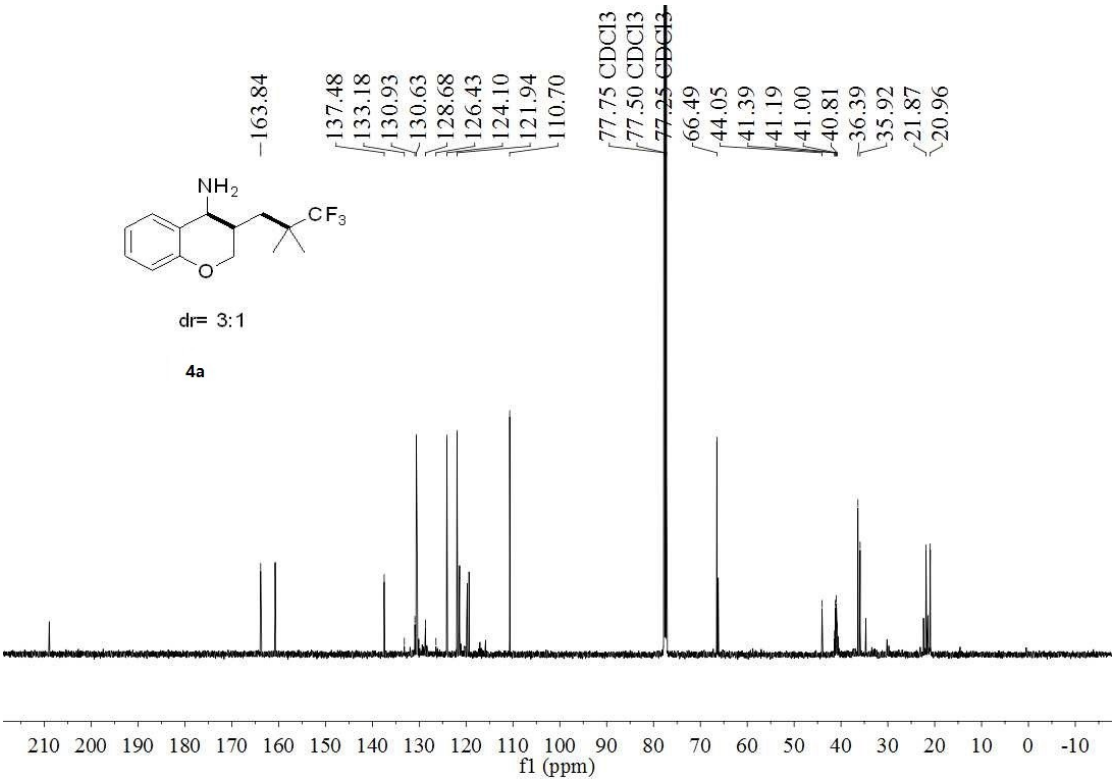
3y

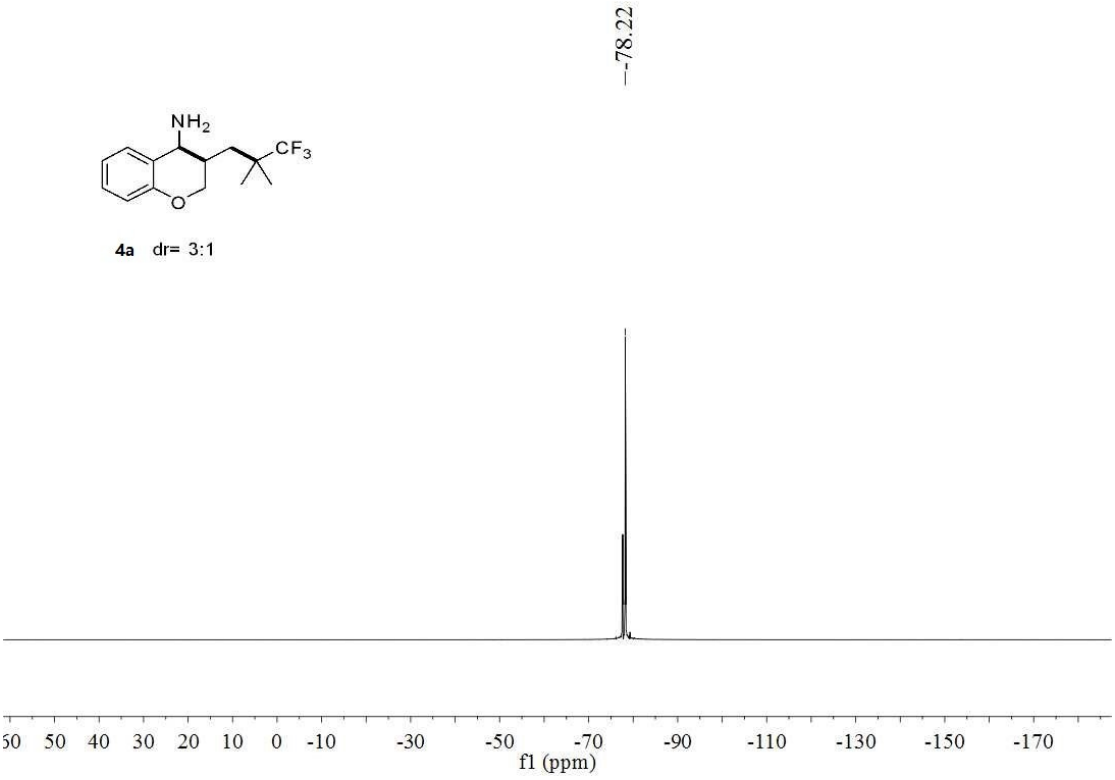
-73.46
1.00
-59 -60 -61 -62 -63 -64 -65 -66 -67 -68 -69 -70 -71 -72 -73 -74 -75 -76 -77 -78 -79 -80 -81 -82 -83 -84 -85 -86 -87 -88
f1 (ppm)



4a dr= 3:1

7.741
7.725
7.597
7.582
7.570
7.553
7.350
7.348
7.335
7.322
7.260
3.940
3.926
3.914
3.557
3.547
2.323
2.145
2.138
2.131
1.171
1.159
1.139
1.113
0.984
1.00
1.93
1.01
2.02
1.07
1.04
1.04
1.04
3.24
3.12
6 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


163.84
137.48
133.18
130.93
130.63
128.68
126.43
124.10
121.94
110.70
77.75 CDCl3
77.50 CDCl3
77.25 CDCl3
66.49
44.05
41.39
41.19
41.00
40.81
36.39
35.92
21.87
20.96
NH2
CF3
O
dr= 3:1
4a
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-78.22
NH2
CF3
O
4a dr= 3:1
50 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170
f1 (ppm)