Supporting Information

For

Nickel-Catalyzed Monofluoroalkylation of Arylsilanes *via* Hiyama Cross-Coupling

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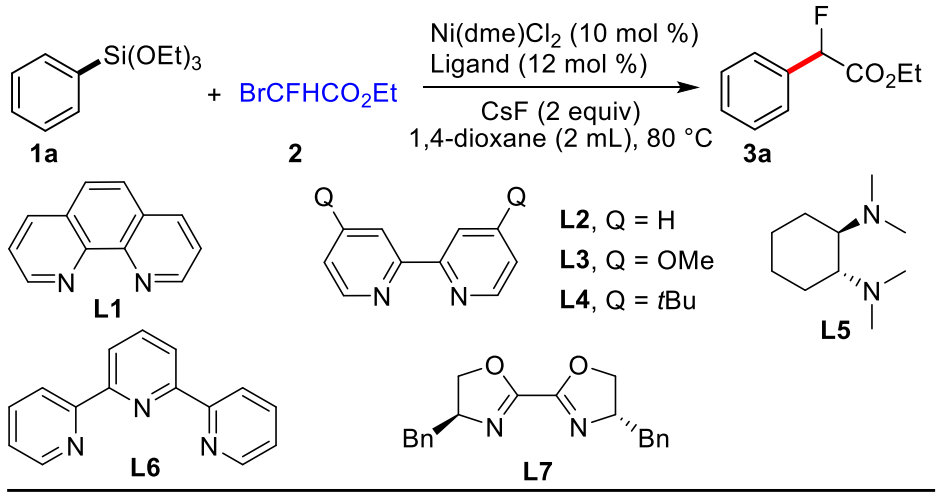
General information

NMR spectra were recorded on Bruker-400 MHz NMR spectrometer (400 MHz for ^{1}H; 101 MHz for ^{13}C and 376 MHz for ^{19}F). ^{1}H NMR chemical shifts were determined relative to internal $(CH_3)_4Si$ (TMS) at δ 0.0 or to the signal of a residual protonated solvent: $CDCl_3$ δ 7.26. ^{13}C NMR chemical shifts were determined relative to $CDCl_3$ δ 77.16. ^{19}F NMR chemical shifts were determined relative to external $CFCl_3$ at δ 0.0 or internal $PhCF_3$ at δ 63.0. High resolution mass spectra were recorded on P-SIMS-Gly of Bruker Daltonics Inc. using ESI-TOF (electrospray ionization-time of flight). 1,4-Dioxane was distilled from sodium immediately before use. $Ni(dme)Cl_2$ was obtained from Strem Chemicals. Inc (*J&K* purchased). 4,4'-Di*t*Bu-bpy was obtained from Macklin and used as received. CsF was obtained from *J&K*. $BrCHFCO_2Et$ was obtained from Fluorochem Ltd (UK) (*J&K* purchased) and used as received. dppp = 1,3-bis(diphenylphosphino)propane, TMEDA = *N*,*N*,*N'*,*N'*-tetramethylethylenediamine, DMF = *N*,*N*-dimethylformamide, DCM = dichloromethane, THF = tetrahydrofuran.

Optimization of reaction conditions

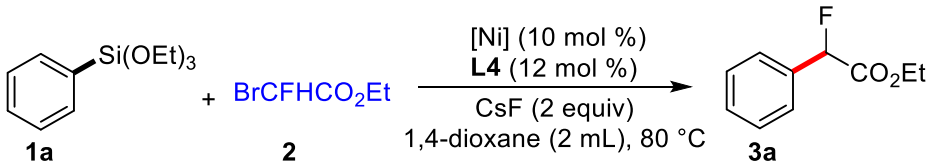
Table S1. Ligand screening[a]



Entry	ligand	Yield (%)[b]
1	-	0
2	**L1**	22
3	**L2**	26
4	**L3**	37
5	**L4**	**45**
6	**L5**	22
7	TMEDA	30
8	**L6**	0
9	**L7**	0
10	PPh_3	0
11	dppp	0

[a]The reaction conditions were as follows: **1a** (0.3 mmol, 1.5 equiv), **2** (0.2 mmol, 1.0 equiv), Ni(dme)Cl_2 (0.02 mmol, 10 mol %), ligand (0.024 mmol, 12 mol %), CsF (0.4 mmol, 2.0 equiv), 1,4-dioxane (2.0 mL), 80 °C, 24 h, N_2. [b]Yields determined by ^{19}F NMR using CF_3Ph as an internal standard.

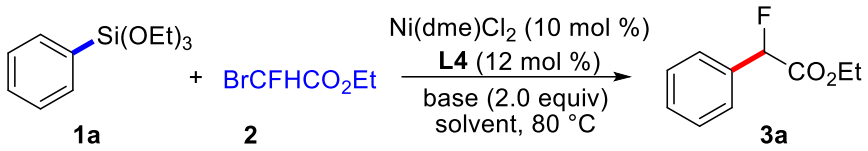
Table S2. Ni-source screening[a]



Entry	[Ni]	Yield (%)[b]	Entry	[Ni]	Yield (%)[b]
1	-	0	8	$NiCl_2$(dppe)	41
2	$NiBr_2$	41	9	$NiCl_2$(dppf)	41
3	NiI_2	37	10	$Ni(OTf)_2$	<5
4	$NiCl_2$	41	11	$Ni(NO_3)_2$•$6H_2O$	30
5	$Ni(acac)_2$	11	**12**	**$NiCl_2$(dme)**	**45**
6	$NiCl_2(PPh_3)_2$	37	13	$Ni(OAc)_2$	41
7	$NiCl_2$(dppp)	41			

[a]The reaction conditions were as follows: **1a** (0.3 mmol, 1.5 equiv), **2** (0.2 mmol, 1.0 equiv), [Ni] (0.02 mmol, 10 mol %), **L4** (0.024 mmol, 12 mol %), CsF (0.4 mmol, 2.0 equiv), 1,4-dioxane (2.0 mL), 80 °C, 24 h, N_2. [b]Yields determined by ^{19}F NMR using CF_3Ph as an internal standard.

Table S3. Base and solvent screening[a]

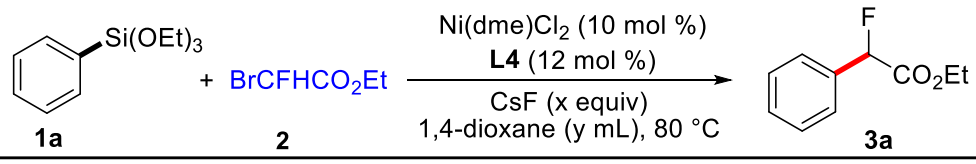


1a **2** **3a**

entry	base	solvent	yield (%)[b]	entry	base	solvent	yield (%)[b]
1	-	dioxane	0	**9**	**CsF**	dioxane	**45**
2	KOAc	dioxane	0	10	TBAF	dioxane	0
3	*t*BuOK	dioxane	0	11	CsF	THF	41
4	KF	dioxane	0	12	CsF	DMF	30
5	K_3PO_4	dioxane	0	13	CsF	DCM	37
6	Cs_2CO_3	dioxane	0	14	CsF	CH_3CN	22
7	K_2CO_3	dioxane	0	15	CsF	toluene	18
8	NaOH	dioxane	0				

[a]The reaction conditions were as follows: **1a** (0.3 mmol, 1.5 equiv), **2** (0.2 mmol, 1.0 equiv), $Ni(dme)Cl_2$ (0.02 mmol, 10 mol %), **L4** (0.024 mmol, 12 mol %), base (2 equiv), solvent (2 mL), 80 °C, 24 h, N_2. [b]Yields determined by ^{19}F NMR using CF_3Ph as an internal standard.

Table S4. Optimization of reaction conditions[a]



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

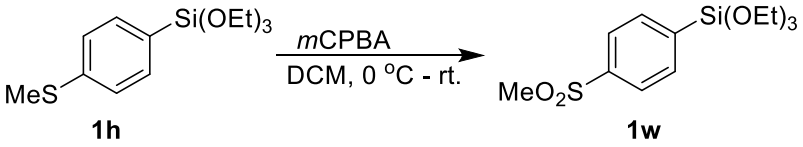
Entry	x	y	Yield (%)[b]	Entry	x	y	Yield (%)[b]
1	2.0	2.0	45	6	5.0	1.0	86
2	3.0	2.0	64	7	5.0	1.5	93
3	4.0	2.0	87	8	5.0	2.5	96(93)[c]
4	5.0	2.0	90	9	5.0	3.0	96
5	6.0	2.0	90	**10**[d]	**5.0**	**2.5**	**96(93)[c]**

[a]Unless otherwise noted, the reaction conditions were as follows: **1a** (0.3 mmol, 1.5 equiv), **2** (0.2 mmol, 1.0 equiv), $Ni(dme)Cl_2$ (0.02 mmol, 10 mol %), **L4** (0.024 mmol, 12 mol %), CsF (x equiv), 1,4-dioxane (y mL), 80 °C, 24 h, N_2. [b]Yields determined by ^{19}F NMR using CF_3Ph as an internal standard. [c]Isolated yield. [d]**1a** (1.2 equiv).

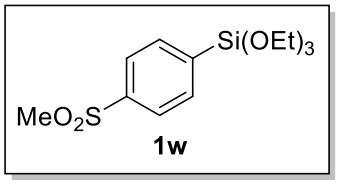
Preparation of arylsilanes 1.

The arylsilane **1a** was purchased and used directly from commercial sources, and substrates **1b-1m**[1], **1o-1r**[1], **1y-1z**[1], **1n**[2]**, 1s**[3], **1t**[4], **1u-1v**[5], **1x**[6]**, 1ab**[6] and **1ac**[7] were prepared in accordance with methods described in the literature.

Synthesis route toward 1w

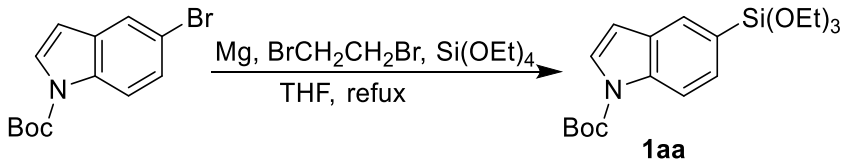


To a solution of **1h** (265 mg, 0.92 mmol) in DCM (5 mL) was added *m*CPBA (498 mg, 2.3 mmol) at 0 ℃. The reaction mixture was stirred for 2 h at room temperature. The solution was added saturated sodium hyposulfite (10 mL), and extracted with DCM (3 x 10 mL). The combined organic layers were washed with saturated sodium chloride (40 mL), dried over Na_2SO_4, filtered and concentrated in vacuo. The residue was then purified by flash column chromatography (PE/EA = 5:1) to give **1w** as a colorless oil (234 mg, 80%).



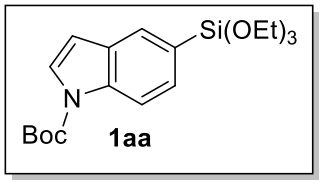
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.3 Hz, 2H), 7.86 (d, *J* = 8.3 Hz, 2H), 3.87 (q, *J* = 7.0 Hz, 6H), 3.03 (s, 6H), 1.24 (t, *J* = 7.0 Hz, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.1, 138.8, 135.7, 126.3, 59.1, 44.4, 18.2. HRMS (ESI) calcd. for $C_{13}H_{22}O_5SSiNa$ $[M+Na]^+$ 341.0855, found: 341.0851.

Synthesis route toward 1aa



A 250 mL three-neck flask was fitted with an addition funnel, a reflux condenser, a rubber septum, and a stir bar. The flask was charged with magnesium turnings (0.68 g, 28.3 mmol), flame-dried under vacuum, and back-filled with argon. Freshly dried THF (20 mL) and tetraethyl silicate (8.3 mL, 37.8 mmol) were added into the flask via syringe, and the addition funnel was charged with *N*-Boc-5-bromoindole (2.80 g, 9.45

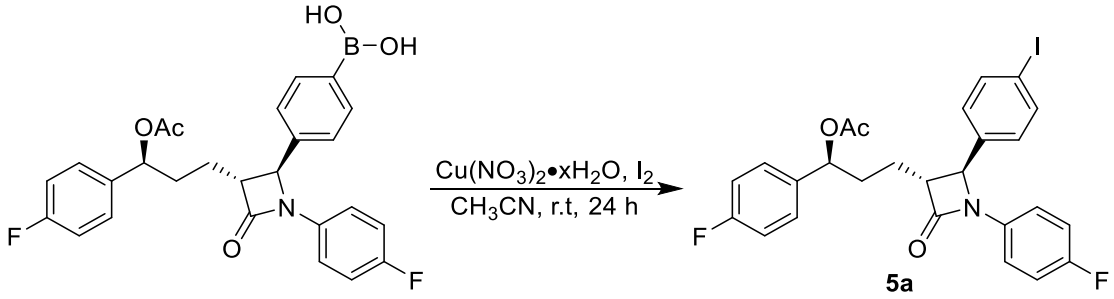
mmol) and 1, 2-dibromoethane (0.90 g, 4.73 mmol) dissolved in THF (15 mL). Then, the aryl bromide was added at such a rate that THF maintained a moderate reflux. After the reaction mixture was stirred at reflux overnight, it was cooled to room temperature. The saturated NH_4Cl solution was added carefully, and the solution was extracted with EtOAc (3 x 30 mL) for three times. The organic phase was dried over Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by silica gel column chromatograph (PE/EtOAc = 40/1) to give **1aa** as a colorless oil (1.62 g, 45%).



1aa

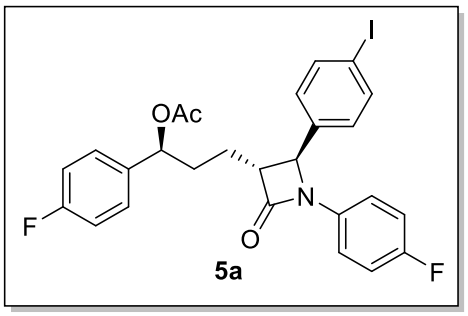
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 8.3 Hz, 1H), 7.92 (s, 1H), 7.62-7.60 (m, *2*H), 6.59 (d, *J* = 3.7 Hz, 1H), 3.88 (q, *J* = 7.0 Hz, 6H), 1.67 (s, 9H), 1.25 (t, *J* = 7.0 Hz, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 149.8, 136.7, 130.4, 128.4, 126.0, 124.2, 114.9, 107.5, 83.9, 77.4, 77.1, 76.8, 58.8, 28.2, 18.3. HRMS (ESI) calcd. for $C_{19}H_{29}NO_5SiNa$ $[M+Na]^+$ 402.1713, found: 402.1716.

Synthesis route towards ezetimibe derivative 5



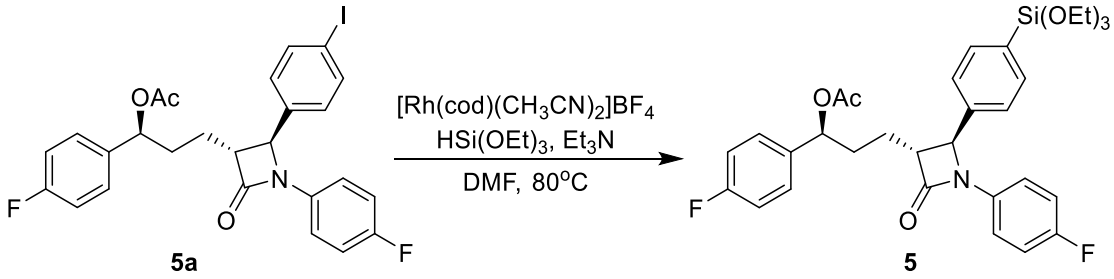
5a

To a 50 mL of round-bottom flask were added $Cu(NO_3)_2$•xH_2O (167 mg, 0.69 mmol), , iodine (588 mg, 2.31 mmol), acetylated ezetimibe boronic acid[8] (1.11 g, 2.31 mmol) and dry acetonitrile (15 mL). The reaction mixture was stirred for 24 h at room temperature under an argon atmosphere. After the addition of water (60 mL), the reaction was extracted with DCM (3 x 40 mL). The combined organic layers were washed with saturated sodium hyposulfite (40 mL), dried over Na_2SO_4, filtered and concentrated in vacuo. The residue was then purified by flash column chromatography (PE/EA = 3:1) to give **5a** as a colorless solid (900 mg, 69%).



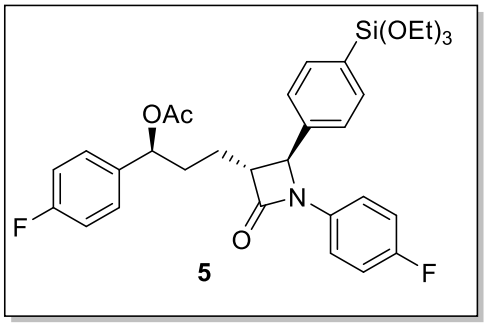
5a

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.4 Hz, 2H), 7.28-7.25 (m, 2H), 7.21-7.16 (m, 2H), 7.07-7.05 (d, *J* = 8.3 Hz, 2H), 7.02 (t, *J* = 8.7 Hz, 2H), 6.93 (t, *J* = 8.7 Hz, 2H), 5.69 (t, *J* = 6.7 Hz, 1H), 4.54 (d, *J* = 2.3 Hz, 1H), 3.04 (td, *J* = 7.7, 2.3 Hz, 1H), 2.05-1.99 (m, 5H), 1.93-1.81 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3, 166.6, 162.6 (d, *J* = 247 Hz), 159.2 (d, *J* = 244 Hz), 138.6, 137.3, 135.7 (d, *J* = 3.2 Hz), 133.7 (d, *J* = 2.7 Hz), 128.3 (d, *J* = 8.2 Hz), 127.8, 118.4 (d, *J* = 7.9 Hz), 116.0 (d, *J* = 22.7 Hz), 115.6 (d, *J* = 21.5 Hz), 94.3, 74.9, 60.8, 60.2, 33.7, 25.0, 21.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.6, -117.5. HRMS (ESI) calcd. for $C_{26}H_{22}F_2INO_3Na$ $[M+Na]^+$ 584.0510, found: 584.0509.



5a **5**

To a solution of $[Rh(cod)(MeCN)_2]BF_4$ (10 mg, 0.03 mmol) in dry DMF (3 ml) was added ezetimibe derivative **5a** (500 mg, 0.89 mmol), Et_3N (0.37 mL, 2.67 mmol), and triethoxysilane (0.32 mL, 1.78 mmol). After being stirred for 2.5 h at 80 ℃, then the solution was cooled to r.t. The mixture was diluted with EtOAc (100 mL) and washed three times with water, dried over Na_2SO_4, filtrated and concentrated under vacuum. The residue was purified by flash column chromatography (PE/EA = 3:1) to give **5** as a colorless oil (455 mg, 75%).



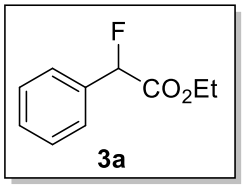
5

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.0 Hz, 2H), 7.32 (d, *J* = 8.0 Hz, 2H), 7.28-7.25 (m, 2H), 7.23-7.19 (m, 2H), 7.02 (t, *J* = 8.7 Hz, 2H), 6.92 (t, *J* = 8.7 Hz, 2H), 5.70 (t, *J* = 6.7 Hz, 1H), 4.59 (d, *J* = 2.2 Hz, 1H), 3.88 (q, *J* = 7.0 Hz, 6H), 3.07 (td, *J* = 7.7, 2.2 Hz, 1H), 2.09-2.00 (m, 5H), 1.92-1.83 (m, 2H), 1.25 (t, *J* = 7.0 Hz, 9H). ^{13}C NMR (101 MHz,

$CDCl_3$) δ 170.3, 166.9, 162.5 (d, *J* = 246.7 Hz), 159.1 (d, *J* = 243.5 Hz), 139.6, 135.8, 135.8, 133.9 (d, *J* = 2.7 Hz), 132.1, 128.3 (d, *J* = 8.3 Hz), 125.3, 118.4(d, *J* = 7.9 Hz), 116.0 (d, *J* = 22.7 Hz), 115.6 (d, *J* = 21.7 Hz), 74.9, 61.3, 60.1, 58.9, 33.7, 25.0, 21.3, 18.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.7, -117.9. HRMS (ESI) calcd. for $C_{32}H_{37}F_2NO_6SiNa$ $[M+Na]^+$ 620.2256, found: 620.2258.

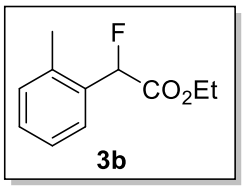
General Procedure for Nickel-Catalyzed Monofluoroalkylation of Arylsilanes *via* Hiyama Cross-Coupling

To a 25 mL of Schlenk tube were added Ni(dme)Cl_2 (10 mol %, 0.02 mmol, 4.4 mg), **L4** (12 mol %, 0.024 mmol, 6.5 mg) and CsF (5.0 equiv, 1 mmol, 152 mg) under air. The vessel was evacuated and backfilled with N_2 (3 times) and 1,4-dioxane (2.5 mL) was added via syringe. The mixture was stirred for 15 min, and then the arylsilane (1.2 or 2.0 equiv, 0.24 or 0.4 mmol) was added. After stirring for an additional 10 min, the $BrCFHCO_2Et$ (1.0 equiv, 0.2 mmol, 24 μL) was added, and the reaction mixture was heated in a preheated oil bath at 80 or 100 ˚C for 24 h. The reaction mixture was cooled to room temperature, diluted with EtOAc and filtered through a pad of celite. The filtrate was concentrated under vacuum and purified by flash column chromatography to give desired fluoroalkylated product **3**.



3a

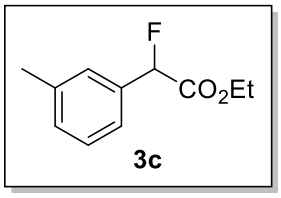
The product **3a**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (33.9 mg, 93% yield). ^1H NMR (400 MHz, $CDCl_3$) δ 7.48-7.46 (m, 2H), 7.42-7.40 (m, 3H), 5.77 (d, *J* = 47.8 Hz, 1H), 4.32-4.17 (m, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 27.6 Hz), 134.4 (d, *J* = 20.4 Hz), 129.7 (d, *J* = 2.22 Hz), 128.8, 126.7 (d, *J* = 6.16 Hz), 89.5 (d, *J* = 186.1 Hz), 61.9, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -179.8.



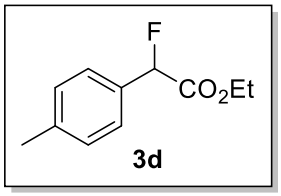
3b

The product **3b**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (31 mg, 79% yield). ^1H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.5 Hz, 1H), 7.32-7.20 (m, 3H), 5.97 (d, *J* = 47.3 Hz, 1H), 4.33-4.17 (m, 2H), 2.44 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0 (d, *J* = 27.9 Hz), 136.7 (d, *J* =

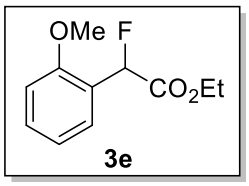
3.7 Hz), 132.9 (d, *J* = 19.2 Hz), 131.0, 129.7 (d, *J* = 2.6 Hz), 127.4 (d, *J* = 6.7 Hz), 126.4, 87.3 (d, *J* = 183.3 Hz), 61.9, 19.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -179.3.



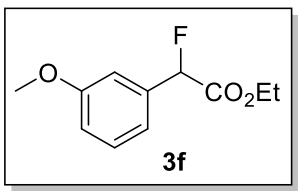
The product **3c**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (32.2 mg, 82% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31-7.24 (m, 3H), 7.22-7.20 (m, 1H), 5.73 (d, *J* = 47.9 Hz, 1H), 4.32-4.16 (m, 2H), 2.37 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8 (d, *J* = 27.6 Hz), 138.7, 134.3 (d, *J* = 20.2 Hz), 130.5 (d, *J* = 2.3 Hz), 128.7, 127.4 (d, *J* = 5.9 Hz), 123.9 (d, *J* = 6.0 Hz), 89.5 (d, *J* = 185.2 Hz), 61.9, 21.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -179.0



The product **3d**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (35.7 mg, 91% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 8.0 Hz, 2H), 7.21 (d, *J* = 8.0 Hz, 2H), 5.73 (d, *J* = 47.9 Hz, 1H), 4.31-4.16 (m, 2H), 2.37 (s, 3H), 1.26 (t, *J* = 7.1 Hz). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8 (d, *J* = 27.9 Hz), 139.8 (d, *J* = 2.5 Hz), 131.4 (d, *J* = 20.5 Hz), 129.5, 126.9 (d, *J* = 5.7 Hz), 89.4 (d, *J* = 184.7 Hz), 61.8, 21.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -177.6.

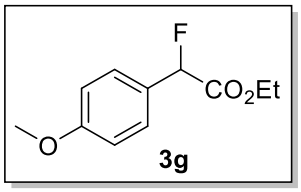


The product **3e**[9] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (31.4 mg, 74% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41-7.36 (m, 2H), 6.99 (tt, *J* = 7.5, 0.9 Hz, 1H), 6.93 (d, *J* = 8.6 Hz, 1H), 6.09 (d, *J* = 47.5 Hz, 1H), 4.32-4.20 (m, 2H), 3.86 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.2 (d, *J* = 27.7 Hz), 157.4 (d, *J* = 3.5 Hz), 131.4 (d, *J* = 3.1 Hz), 129.3 (d, *J* = 5.1 Hz), 123.0 (d, *J* = 19.3 Hz), 120.8 (d, *J* = 1.7 Hz), 111.2 (d, *J* = 1.4 Hz), 85.0 (d, *J* = 182.1 Hz), 61.6, 55.7, 14.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -177.9 (d, *J* = 47.4 Hz).

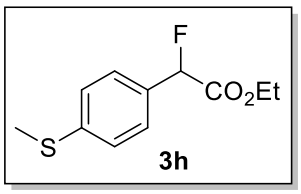


The product **3f**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (39.8 mg, 94% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (t, *J* = 7.9 Hz, 1H), 7.04 (d, *J* = 7.7 Hz, 1H), 7.01 (s, 1H), 6.93 (d, *J* = 8.3 Hz, 1H), 5.74 (d, *J* = 47.8 Hz, 1H), 4.31-4.17 (m, 2H), 3.81 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5 (d, *J* = 27.5 Hz), 159.9, 135.7 (d, *J* = 20.4 Hz), 129.9, 118.9

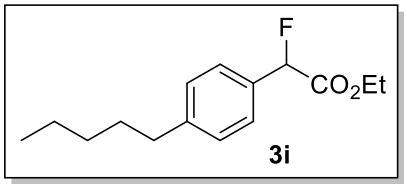
(d, *J* = 6.2 Hz), 115.4 (d, *J* = 2.0 Hz), 111.8 (d, *J* = 6.5 Hz), 89.3 (d, *J* = 185.8 Hz), 61.9, 55.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -180.2.



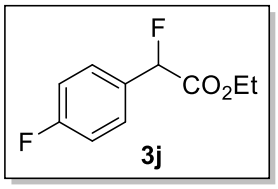
The product **3g**[8] was purified with silica gel chromatography (PE/EA = 20:1) as a colorless oil (38.6 mg, 91% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (dd, *J* = 8.5, 1.5 Hz, 1H), 6.92 (d, *J* = 8.3 Hz, 2H), 5.71 (d, *J* = 47.9 Hz, 1H), 4.32-4.17 (m, 2H), 3.82 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.9 (d, *J* = 28.5 Hz), 160.7 (d, *J* = 2.3 Hz), 128.6 (d, *J* = 5.3 Hz), 126.5 (d, *J* = 21.1 Hz), 114.3, 89.2 (d, *J* = 184.4 Hz), 61.8, 55.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -174.5.



The product **3h**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (42.9 mg, 94% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ7.37 (dd, *J* = 8.3, 1.3 Hz, 2H), 7.26 (d, *J* = 7.9 Hz, 2H), 5.72 (d, *J* = 47.7 Hz, 1H), 4.31-4.16 (m, 2H), 2.49 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 27.9 Hz), 140.9 (d, *J* = 2.6 Hz), 130.8 (d, *J* = 20.8 Hz), 127.3 (d, *J* = 5.8 Hz), 126.3, 89.1 (d, *J* = 185.3 Hz), 61.9, 15.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -178.3.

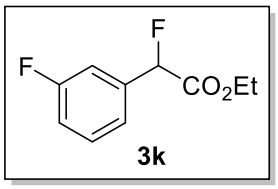


The product **3i** was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (46.9 mg, 93% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (dd, *J* = 8.0, 1.3 Hz, 2H), 7.21 (d, *J* = 7.9 Hz, 2H), 5.74 (d, *J* = 47.9 Hz, 1H), 4.32-4.17 (m, 2H), 2.61 (t, *J* = 7.6 Hz, 2H), 1.65-1.57 (m, 2H), 1.36-1.29 (m, 4H), 1.26 (t, *J* = 7.1 Hz, 3H), 0.89 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.9 (d, *J* = 27.8 Hz), 144.8 (d, *J* = 2.5 Hz), 131.6 (d, *J* = 20.6 Hz), 128.9, 126.9 (d, *J* = 5.7 Hz), 89.5 (d, *J* = 184.8 Hz), 61.8, 35.8, 31.6, 31.1, 22.6, 14.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -177.6. HRMS (ESI) calcd. for $C_{15}H_{21}FO_2Na$ $[M+Na]^+$ 275.1423, found: 275.1420.



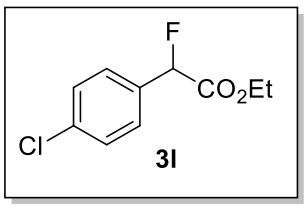
The product **3j**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (36.4 mg, 91% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48-7.44 (m, 2H), 7.12-7.08 (m, 2H), 5.75 (d, *J* = 47.5 Hz, 1H), 4.32-4.18 (m, 2H), 1.26 (t, *J* =

7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5 (d, *J* = 27.7 Hz), 163.5 (dd, *J* = 248.9, 2.4 Hz), 130.3 (dd, *J* = 21.0, 3.3 Hz), 128.8 (dd, *J* = 8.5, 6.0 Hz), 115.9 (d, *J* = 21.9 Hz), 88.8 (d, *J* = 185.8 Hz), 62.0, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -111.3 (d, *J* = 3.8 Hz), -178.4 (d, *J* = 3.8 Hz).



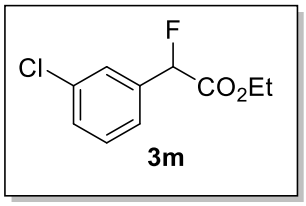
3k

The product **3k**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (36 mg, 90% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41-7.36 (m, 1H), 7.25 (d, *J* = 6.4 Hz, 1H), 7.20 (d, *J* = 9.2 Hz, 1H), 7.12-7.07 (m, 1H), 5.77 (d, *J* = 47.5 Hz, 1H), 4.33-4.19 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.1 (d, *J* = 27.1 Hz), 162.8 (d, *J* = 247.4 Hz), 136.6 (dd, *J* = 21.0, 7.5 Hz), 130.5 (d, *J* = 8.1 Hz), 122.2 (dd, *J* = 6.5, 3.1 Hz), 116.6 (dd, *J* = 21.1, 1.8 Hz), 113.6 (dd, *J* = 23.1, 6.9 Hz), 88.6 (dd, *J* = 187.0, 1.9 Hz), 62.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -111.8, -182.0.



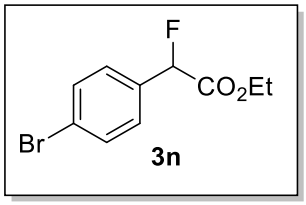
3l

The product **3l**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (38.5 mg, 91% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42-7.37 (m, 4H), 5.74 (d, *J* = 47.5 Hz, 1H), 4.31-4.17 (m, 2H), 1.25 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.2 (d, *J* = 27.4 Hz), 135.7 (d, *J* = 2.5 Hz), 132.8 (d, *J* = 20.9 Hz), 129.1, 128.0 (d, *J* = 6.2 Hz), 88.7 (d, *J* = 186.3 Hz), 62.1, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -180.8.

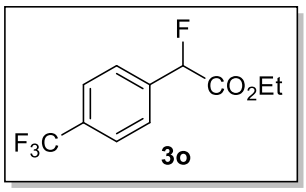


3m

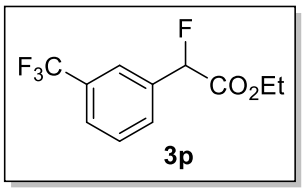
The product **3m** was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (39.8 mg, 92% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (s, 1H), 7.40-7.32 (m, 3H), 5.75 (d, *J* = 47.5 Hz, 1H), 4.33-4.19 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.0 (d, *J* = 27.1 Hz), 136.2 (d, *J* = 20.9 Hz), 134.8, 130.1, 129.8 (d, *J* = 1.8 Hz), 126.7 (d, *J* = 6.9 Hz), 124.7 (d, *J* = 6.4 Hz), 88.6 (d, *J* = 187.2 Hz), 62.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -182.1. HRMS (ESI) calcd. for $C_{10}H_{10}ClFO_2$ $[M+H]^+$ 239.0251, found: 239.0248.



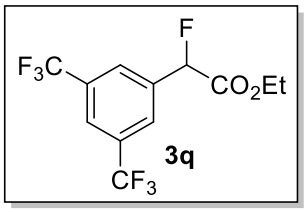
The product **3n**[8] was purified with silica gel chromatography (PE/EA = 20:1) as a colorless oil (43.8 mg, 84% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.3 Hz, 2H), 7.35 (d, *J* = 8.2 Hz, 2H), 5.73 (d, *J* = 47.5 Hz, 1H), 4.31-4.17 (m, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.1 (d, *J* = 27.3 Hz), 133.4 (d, *J* = 20.9 Hz), 132.0, 128.2 (d, *J* = 6.2 Hz), 123.9 (d, *J* = 2.6 Hz), 88.7 (d, *J* = 186.6 Hz), 62.1, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -181.3.



The product **3o**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (45 mg, 90% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.61 (d, *J* = 8.2 Hz, 2H), 5.85 (d, *J* = 47.5 Hz, 1H), 4.33-4.19 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.9 (d, *J* = 26.7 Hz), 138.2 (d, *J* = 20.9 Hz), 131.7 (q, *J* = 34.3 Hz), 126.8 (d, *J* = 6.8 Hz), 125.8 (q, *J* = 3.8 Hz), 123.9 (q, *J* = 270.7 Hz), 88.6 (d, *J* = 187.5 Hz), 62.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.8, -184.2.

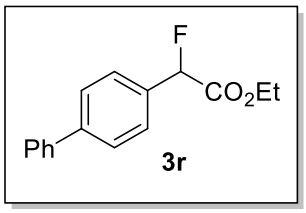


The product **3p**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (46.5 mg, 93% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 (s, 1H), 7.69-7.66 (m, 2H), 7.55 (t, *J* = 7.8 Hz, 1H), 5.84 (d, *J* = 47.4 Hz, 1H), 4.33-4.16 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.9 (d, *J* = 26.9 Hz), 135.4 (d, *J* = 21.1 Hz), 131.4 (q, *J* = 32.7 Hz), 129.8 (dd, *J* = 6.4, 1.0 Hz), 129.4, 126.5-126.4 (m, 1C), 123.8 (q, *J* = 270.9 Hz), 123.5-123.3 (m, 1C), 88.6 (d, *J* = 187.4 Hz), 62.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.8, -183.2.

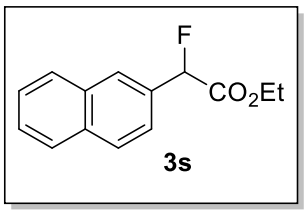


The product **3q**[9] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (55.4 mg, 87% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (s, 2H), 7.92 (s, 1H), 5.92 (d, *J* = 47.0 Hz, 1H), 4.35-4.23 (m, 2H), 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, C DCl_3) δ 167.1 (d, *J* = 26.3 Hz), 136.9 (d, *J* = 21.7 Hz), 132.4 (q, *J* = 33.9 Hz), 126.5-126.4 (m, 1C), 123.6-123.3 (m, 1C), 123.1 (q, *J* = 272.8 Hz), 87.92 (d, *J* = 189.8 Hz), 62.7, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.1,

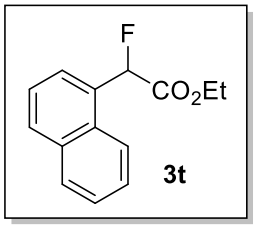
-186.3 (d, *J* = 47.0 Hz).



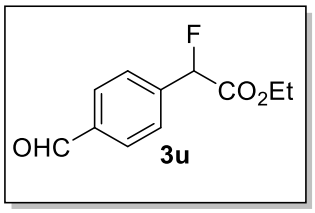
The product **3r**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (47 mg, 91% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65-7.54 (m, 6H), 7.47-7.44 (m, 2H), 7.37 (tt, *J* = 7.2, 2.0 Hz, 1H), 5.83 (d, *J* = 47.7 Hz, 1H), 4.35-4.20 (m, 2H), 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.7 (d, *J* = 27.6 Hz), 142.6 (d, *J* = 2.3 Hz), 140.3, 133.3 (d, *J* = 20.5 Hz), 128.9, 127.8, 127.6, 127.3, 127.2, 89.3 (d, *J* = 185.4 Hz), 62.0, 14.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -179.4.



The product **3s**[8] was purified with silica gel chromatography (PE/EA = 20:1) as a colorless solid (41.8 mg, 90% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (s, 1H), 7.91-7.85 (m, 3H), 7.58 (dd, *J* = 8.5, 1.5 Hz, 1H), 7.56-7.51 (m, 2H), 5.96 (d, *J* = 47.7 Hz, 1H), 4.34-4.19 (m, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 27.7 Hz), 133.7 (d, *J* = 1.4 Hz), 133.0, 131.7 (d, *J* = 20.3 Hz), 128.8, 128.4, 127.9, 127.0, 126.7, 126.7 (d, *J* = 5.8 Hz), 123.6 (d, *J* = 5.0 Hz), 89.6 (d, *J* = 185.5 Hz), 62.0, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -179.2.

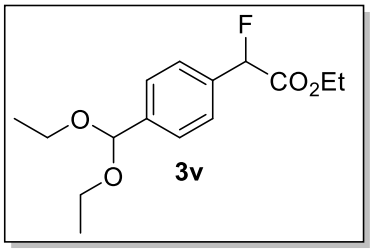


The product **3t** was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (34.8 mg, 75% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (d, *J* = 8.4 Hz, 1H), 7.91 (t, *J* = 7.5 Hz, 2H), 7.63-7.48 (m, 4H), 6.37 (d, *J* = 47.1 Hz, 1H), 4.34-4.15 (m, 2H), 1.21 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0 (d, *J* = 27.6 Hz), 133.9, 130.7 (d, *J* = 1.6 Hz), 130.6 (d, *J* = 2.4 Hz), 130.3 (d, *J* = 18.7 Hz), 128.9, 127.1, 126.9 (d, *J* = 8.0 Hz), 126.3, 125.2, 123.8 (d, *J* = 1.3 Hz), 88.7 (d, *J* = 185.2 Hz), 62.1, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -177.6. HRMS (ESI) calcd. for $C_{14}H_{13}FO_2Na$ $[M+Na]^+$ 255.0797, found: 255.0798.

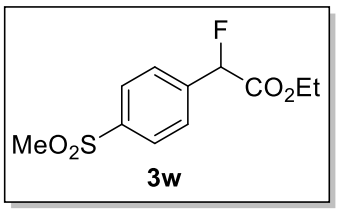


The product **3u**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless solid (33.6 mg, 80% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.0 (s, 1H), 7.92 (d, *J* = 7.9 Hz, 2H), 7.64 (d, *J* = 7.9 Hz, 2H), 5.86 (d, *J*

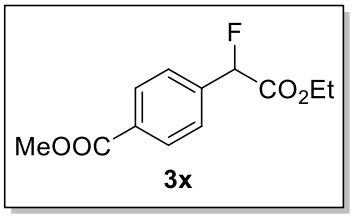
= 47.5 Hz, 1H), 4.31-4.17 (m, 2H), 1.25 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.7, 167.8 (d, *J* = 26.7 Hz), 140.5 (d, *J* = 20.4 Hz), 137.0, 130.1, 126.9 (d, *J* = 6.9 Hz), 88.8 (d, *J* = 187.7 Hz), 62.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -184.7.



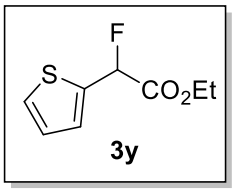
The product **3v** was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (48.3 mg, 85% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.2 Hz, 2H), 7.46 (d, *J* = 8.2 Hz, 2H), 5.77 (d, *J* = 47.8 Hz, 1H), 5.50 (s, 1H), 4.30-4.15 (m, 2H), 3.67-3.49 (m, 4H), 1.27-1.21 (m, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 27.6 Hz), 140.7 (d, *J* = 2.1 Hz), 134.3 (d, *J* = 20.5 Hz), 127.2, 126.6 (d, *J* = 6.1 Hz), 101.2, 89.2 (d, *J* = 185.4 Hz), 61.9, 61.3, 15.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -180.0. HRMS (ESI): calcd. for $C_{15}H_{21}FO_4Na$ $[M+Na]^+$ 307.1322, found: 307.1324.



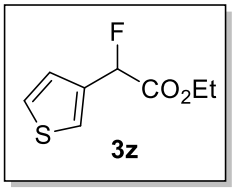
The product **3w** was purified with silica gel chromatography (PE/EA = 10:1) as a colorless solid (46.8 mg, 90% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.1 Hz, 2H), 7.69 (d, *J* = 8.1 Hz, 2H), 5.87 (d, *J* = 47.4 Hz, 1H), 4.32-4.18 (m, 2H), 3.06 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.5 (d, *J* = 26.5 Hz), 141.6 (d, *J* = 1.5 Hz), 140.1 (d, *J* = 20.8 Hz), 127.9, 127.2 (d, *J* = 7.0 Hz), 88.4 (d, *J* = 188.5 Hz), 62.5, 44.5, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -185.5. HRMS (ESI) calcd. for $C_{11}H_{14}FO_4S$ $[M+H]^+$ 261.0597, found: 261.0596.



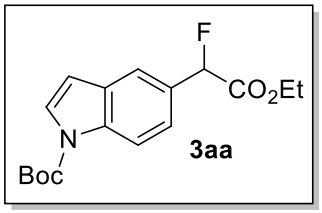
The product **3x** was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (41.3 mg, 86% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.1 Hz, 2H), 7.55 (d, *J* = 8.1 Hz, 2H), 5.83 (d, *J* = 47.6 Hz, 1H), 4.30-4.17 (m, 2H), 3.92 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.0 (d, *J* = 26.8 Hz), 166.5, 138.9 (d, *J* = 20.5 Hz), 131.2 (d, *J* = 1.7 Hz), 130.1, 126.4 (d, *J* = 6.7 Hz), 88.9 (d, *J* = 187.2 Hz), 62.2, 52.4, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -183.9. HRMS (ESI) calcd. for $C_{12}H_{14}FO_4$ $[M+H]^+$ 241.0876, found: 241.0877.



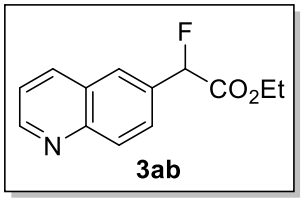
The product **3y** was purified with silica gel chromatography (PE/EA = 30:1) as a yellow oil (24.8 mg, 66% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (dt, *J* = 5.1, 1.4 Hz, 1H), 7.24-7.22 (m, 1H),7.05-7.03 (m, 1H), 5.99 (d, *J* = 48.5 Hz, 1H), 4.37-4.24 (m, 2H), 1.31 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.7 (d, *J* = 28.2 Hz), 135.6 (d, *J* = 23.0 Hz), 128.7 (d, *J* = 5.4 Hz), 128.3 (d, *J* = 3.2 Hz), 127.2 (d, *J* = 2.1 Hz), 84.9 (d, *J* = 185.8 Hz), 62.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -164.4. HRMS (ESI) calcd. for $C_8H_9FO_2SNa$ $[M+Na]^+$ 211.0205, found: 211.0203.



The product **3z** was purified with silica gel chromatography (PE/EA = 30:1) as a yellow oil (28.6 mg, 76% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47-7.46 (m, 1H), 7.37-7.34 (m, 1H), 7.17 (d, *J* = 5.0 Hz, 1H), 5.87 (d, *J* = 48.1 Hz, 1H), 4.34-4.21 (m, 2H), 1.29 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.3 (d, *J* = 27.0 Hz), 134.9 (d, *J* = 22.4 Hz), 126.9, 125.7 (d, *J* = 3.4 Hz), 124.9 (d, *J* = 7.4 Hz), 85.7 (d, *J* = 184.2 Hz), 62.0, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -176.2. HRMS (ESI) calcd. for $C_8H_9FO_2SNa$ $[M+Na]^+$ 211.0205, found: 211.0202.

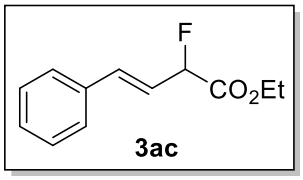


The product **3aa** was purified with silica gel chromatography (PE/EA = 5:1) as a colorless oil (50.8 mg, 79% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 8.6 Hz, 1H), 7.67 (s, 1H), 7.63 (d, *J* = 3.7 Hz, 1H), 7.41 (d, *J* = 8.6 Hz, 1H), 6.59 (d, *J* = 3.7 Hz, 1H), 5.85 (d, *J* = 47.8 Hz, 1H), 4.32-4.16 (m, 2H), 1.67 (s, 9H), 1.25 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0 (d, *J* = 28.5 Hz), 149.6, 135.8, 130.8, 128.7 (d, *J* = 20.7 Hz), 127.0, 123.0 (d, *J* = 5.1 Hz), 119.9 (d, *J* = 6.2 Hz), 115.6, 107.4, 89.8 (d, *J* = 185.0 Hz), 84.5, 61.8, 28.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -175.2. HRMS (ESI) calcd. for $C_{17}H_{20}FNO_4Na$ $[M+Na]^+$ 344.1274, found: 344.1272.

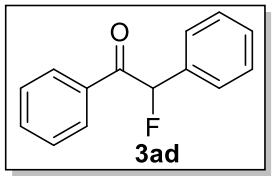


The product **3ab** was purified with silica gel chromatography (PE/EA = 3:1) as a colorless oil (40.1 mg, 86% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.94 (dd, *J* = 4.2, 1.6 Hz, 1H), 8.17 (d, *J* = 8.3 Hz, 1H), 8.13 (d, *J* = 8.8 Hz, 1H), 7.93 (s,

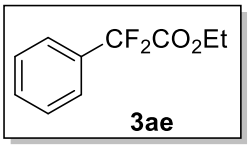
1H), 7.79 (dd, *J* = 8.8, 1.8 Hz, 1H), 7.43 (dd, *J* = 8.3, 4.2 Hz, 1H), 5.96 (d, *J* = 47.5 Hz, 1H), 4.32-4.17 (m, 2H), 1.24 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.3 (d, *J* = 27.2 Hz), 151.4, 148.5 (d, *J* = 1.4 Hz), 136.5, 132.6 (d, *J* = 20.5 Hz), 130.3, 127.9, 127.2 (d, *J* = 5.2 Hz), 126.2 (d, *J* = 7.6 Hz), 121.8, 89.1 (d, *J* = 186.7 Hz), 62.2, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -181.2. HRMS (ESI) calcd. for $C_{13}H_{13}FNO_2$ $[M+H]^+$ 234.0930, found: 234.0932.



The product **3ac**[8] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (24.1 mg, 58% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (m, 2H), 7.37-7.28 (m, 3H), 6.85 (dd, *J* = 16.0, 2.7 Hz, 1H), 6.29 (ddd, *J* = 16.0, 14.2, 6.5 Hz, 1H), 5.44 (ddd, *J* = 48.1, 6.5, 1.2 Hz, 1H), 4.33-4.25 (m, 2H), 1.36 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5 (d, *J* = 25.8 Hz), 135.5 (d, *J* = 11.4 Hz), 135.4 (d, *J* = 1.2 Hz), 128.9, 128.8, 127.0 (d, *J* = 1.1 Hz), 121.1 (d, *J* = 19.1 Hz), 88.7 (d, *J* = 183.6 Hz), 62.0, 14.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -183.7.



The product **3ad**[10] was purified with silica gel chromatography (PE/EA = 20:1) as a white solid (25.7 mg, 60% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.7 Hz, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.50-7.48 (m, 2H), 7.44-7.37 (m, 5H), 6.52 (d, *J* = 48.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.4 (d, *J* = 21.4 Hz), 134.3 (d, *J* = 19.9 Hz), 134.1, 133.9, 129.7 (d, *J* = 2.7 Hz), 129.2, 129.2, 128.8, 127.5 (d, *J* = 5.5 Hz), 94.0 (d, *J* = 185.7 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -175.8.

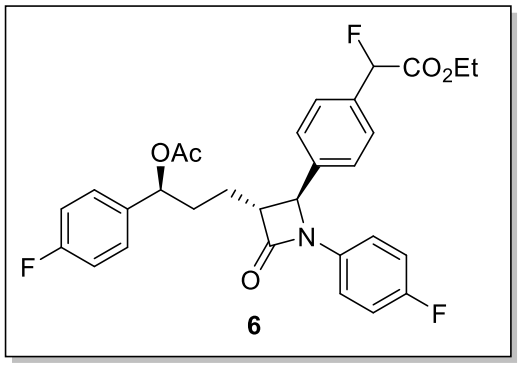


The product **3ae**[11] was purified with silica gel chromatography (PE/EA = 30:1) as a colorless oil (23.2 mg, 58% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62-7.60 (m, 2H), 7.52-7.43 (m, 3H), 4.30 (q, *J* = 7.1 Hz, 2H), 1.30 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.3 (t, *J* = 35.3 Hz), 132.9 (t, *J* = 25.5 Hz), 131.1 (t, *J* = 1.7 Hz), 128.7, 125.5 (t, *J* = 6.2 Hz), 113.5 (t, *J* = 252.0 Hz), 63.2, 14.0. ^{19}F NMR (376 MHz, $CDCl_3$) δ -103.9

Procedure of Monofluoroalkylation of Ezetimibe Derivative 5

To a 25 mL of Schlenk tube were added $Ni(dme)Cl_2$ (10 mol %, 0.01 mmol, 2.2 mg),

L4 (12 mol %, 0.012 mmol, 3.2 mg) and CsF (5.0 equiv, 0.5 mmol, 76 mg) under air. The vessel was evacuated and backfilled with N_2 (3 times) and 1,4-dioxane (1.3 mL) was added via syringe. The mixture was stirred for 15 min, and then the ezetimibe derivative (1.2 equiv, 0.12 mmol, 72 mg) was added. After stirring for an additional 10 min, the $BrCFHCO_2Et$ (1.0 equiv, 0.1 mmol, 12 μL) was added, and the reaction mixture was heated in a preheated oil bath at 80 ˚C for 24 h. The reaction mixture was cooled to room temperature, diluted with EtOAc and filtered through a pad of celite. The filtrate was concentrated under vacuum and purified by flash column chromatography (PE/EA = 3:1) to give **6** as a colorless oil (49 mg, 91%).

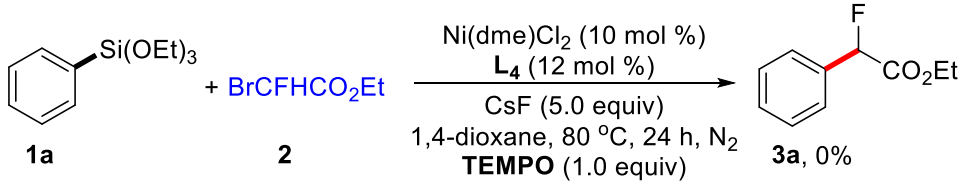


6

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.0 Hz, 2H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.28-7.25 (m, 2H), 7.22-7.18 (m, 2H), 7.01 (t, *J* = 8.6 Hz, 2H), 6.93 (t, *J* = 8.7 Hz, 2H), 5.78 (dd, *J* = 47.6, 2.6 Hz, 1H), 5.70 (t, *J* = 6.8 Hz, 1H), 4.62 (d, *J* = 2.1 Hz, 1H), 4.33-4.18 (m, 2H), 3.06 (td, *J* = 7.7, 1.6 Hz, 1H), 2.09-1.99 (m, 5H), 1.94-1.82 (m, 2H), 1.27 (td, *J* = 7.1, 1.7 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3, 168.3 (d, *J* = 27.1 Hz), 166.7, 162.5 (d, *J* = 246.8 Hz), 159.1 (d, *J* = 243.7 Hz), 139.1 (d, *J* = 2.0 Hz), 135.7 (d, *J* = 3.2 Hz), 134.9 (dd, *J* = 20.6, 1.0 Hz), 133.7 (d, *J* = 2.7 Hz), 128.3 (d, *J* = 8.2 Hz), 127.6 (dd, *J* = 6.2, 1.4 Hz), 126.3, 118.4 (d, *J* = 7.9 Hz), 116.0 (d, *J* = 22.7 Hz), 115.6 (d, *J* = 21.6 Hz), 88.9 (d, *J* = 186.4 Hz), 74.9, 62.1, 60.8 (d, *J* = 4.0 Hz), 60.2, 33.7, 25.0, 21.3, 14.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.7 (d, *J* = 2.8 Hz), -117.7 (d, *J* = 2.3 Hz), -180.8 (d, *J* = 23.2 Hz). HRMS (ESI) calcd. for $C_{30}H_{28}F_3NO_5Na$ $[M+Na]^+$ 562.1817, found: 562.1821.

Mechanistic studies

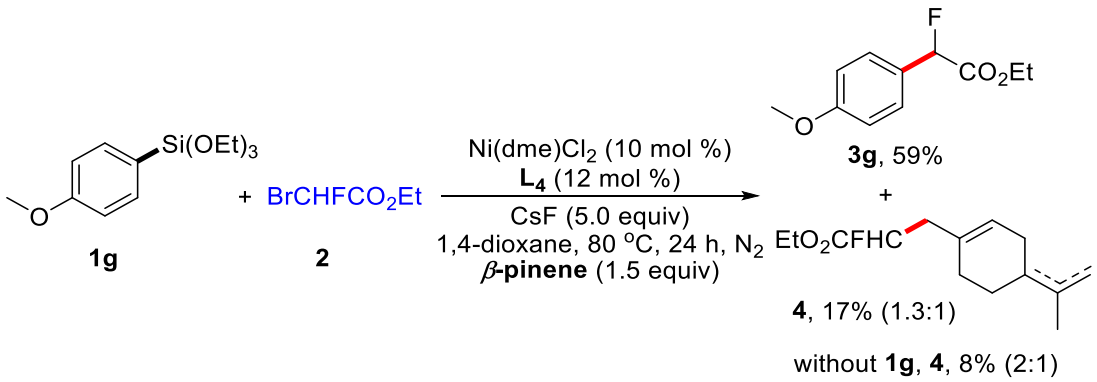
1. Radical Trapping Experiment with TEMPO



1a **2** **3a**, 0%

To a 25 mL of Schlenk tube were added Ni(dme)Cl_2 (10 mol %, 0.02 mmol, 4.4 mg), **L4** (12 mol %, 0.024 mmol, 6.5 mg) and CsF (5.0 equiv, 1 mmol, 152 mg) under air. The vessel was evacuated and backfilled with N_2 (3 times) and 1,4-dioxane (2.5 mL) was added via syringe. The mixture was stirred for 15 min, and then the **1a** (1.2 equiv, 0.3 mmol, 58 uL) was added. After stirring for an additional 10 min, the BrCFHCO2Et (1.0 equiv, 0.2 mmol, 24 uL) and TEMPO (1.0 equiv, 0.2 mmol, 31.3 mg) was added. The reaction mixture was heated in a preheated oil bath at 80 ˚C for 24 h. The reaction mixture was cooled to room temperature. No product **3a** was detected by crude ^{19}F NMR.

2. Procedure of Monofluoroalkylation of *β*-pinene



To a 25 mL of Schlenk tube were added Ni(dme)Cl_2 (10 mol %, 0.02 mmol, 4.4 mg), **L4** (12 mol %, 0.024 mmol, 6.5 mg) and CsF (5.0 equiv, 1 mmol, 152 mg) under air. The vessel was evacuated and backfilled with N_2 (3 times) and 1,4-dioxane (2.5 mL) was added via syringe. The mixture was stirred for 15 min, and then the arylsilane **1g** (1.2 equiv, 0.24 mmol) was added. After stirring for an additional 10 min, the BrCHFCO2Et (1.0 equiv, 0.2 mmol, 24 uL) and *β*-pinene (1.5 equiv, 0.3 mmol, 40.8 mg) was added. The reaction mixture was heated in a preheated oil bath at 80 ˚C for 24 h. The reaction mixture was cooled to room temperature, diluted with EtOAc and filtered through a pad of celite. The filtrate was concentrated under vacuum and purified by flash column chromatography (PE/EA = 40:1) to give product **3g** in 59% yield and ring-open diene product **4** in 17% yield (1.3:1 isomer ratio).

Without **1g**: **4** was obtained in 8% yield (2:1 isomer ratio).

4 (mixture): ^1H NMR (400 MHz, $CDCl_3$) δ 5.56 (d, *J* = 13.7 Hz, 1.08H), 5.07-5.01 (m,

0.55H), 4.94-4.89 (m, 0.55H), 4.71 (d, *J* = 6.4 Hz, 1H), 4.27-4.21 (m, 2.15H), 2.76 (s, 1.03H), 2.54 (dt, *J* = 26.6, 5.9 Hz, 2.21H), 2.32 (t, *J* = 6.3 Hz, 1H), 2.13-1.80 (m, 4.73H), 1.73 (s, 1.48H), 1.68 (s, 1.57H), 1.64 (s, 1.57H), 1.32-1.27 (m, 3.77H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.0 (d, *J* = 23.7 Hz), 149.9 (d, *J* = 5.0 Hz), 132.1 (d, *J* = 2.0 Hz), 131.6 (t, *J* = 1.8 Hz), 126.9, 125.5, 125.4 (d, *J* = 5.3 Hz), 122.4, 108.8 (d, *J* = 4.7 Hz), 88.4 (d, *J* = 186.1 Hz), 61.6, 40.8 (d, *J* = 4.3 Hz), 40.6 (d, *J* = 21.2 Hz), 30.9 (d, *J* = 3.5 Hz), 29.9, 29.7, 29.1, 29.0, 27.8 (d, *J* = 1.9 Hz), 26.6, 20.9, 20.3, 19.9, 14.3 (d, *J* = 5.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -189.3 (d, *J* = 180.8 Hz), -189.4. HRMS (ESI) calcd. for $C_{14}H_{22}FO_2$ $[M+H]^+$ 241.1604, found: 241.1602.

References

(1) (a) Yu, J.; Liu, J.; Shi, G.; Shao, C.; Zhang, Y. *Angew. Chem., Int. Ed*, **2015,** *54***,** 4079. (b) Manoso, A. S.; Ahn, C.; Soheili, A.; Handy, C. J.; Correia, R.; Seganish, W. M.; DeShong, P. *J. Org. Chem.* **2004**, *69*, 8305.

(2) Taylor, P. G.; Bassindale, A. R.; Aziz, Y.; Pourny, M.; Stevenson, R.; Hursthouse, M. B.; Coles, S. J. *Dalton Trans.* **2012**, *41*, 2048.

(3) Diachun, N. A.; Marcus, A. H.; Hussey, D. M.; Fayer, M. D. *J. Am. Chem. Soc.* **1994**, *116*, 1027.

(4) Jorapur, Y. R.; Shimada, T. *Synlett* **2012**, *23*, 1064.

(5) (a) Ishida, S.; Ito, M.; Horiuchi, H.; Hiratsuka, H.; Shiraishi, S.; Kyushin, S. *Dalton Trans.***2010**, *39*, 9421. (b) Swamy P, C. A.; Mukherjee, S.; Thilagar, P. *Chem. Commun*. **2013**, *49*, 993. (c) Swamy P, C. A.; Priyanka, R. N.; Thilagar, P. *Dalton Trans*. **2014**, *43*, 4067.

(6) (a) Murata, M.; Ishikura, M.; Nagata, M.; Watanabe, S.; Masuda, Y. *Org. Lett*. **2002**, *4*, 1843. (b) Tang, P.; Ritter, T. *Tetrahedron*. **2011**, *67*, 4449.

(7) Karabelas, K.; Hallberg, A. *J. Org. Chem.* **1986**, *51*, 5286.

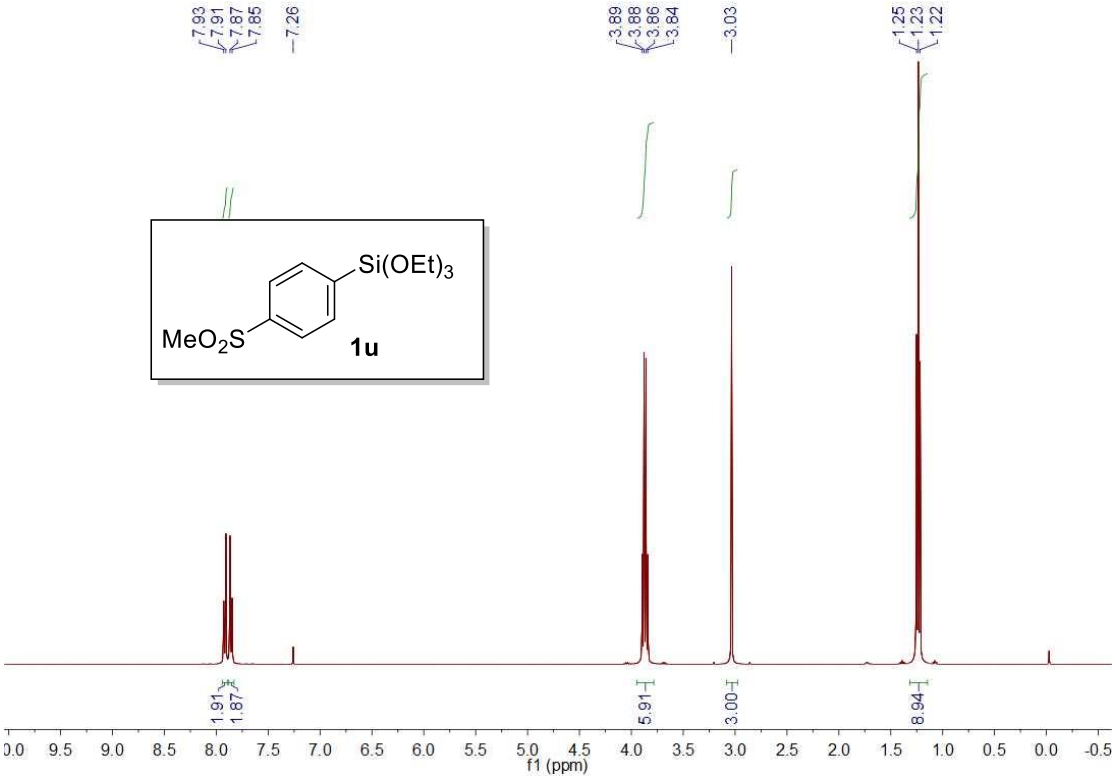
(8) Su, Y. -M.; Fen, G. -S.; Wang, Z. -Y.; Lan, Q.; Wang, X. -S. *Angew. Chem., Int. Ed*. **2015**, *54*, 6003.

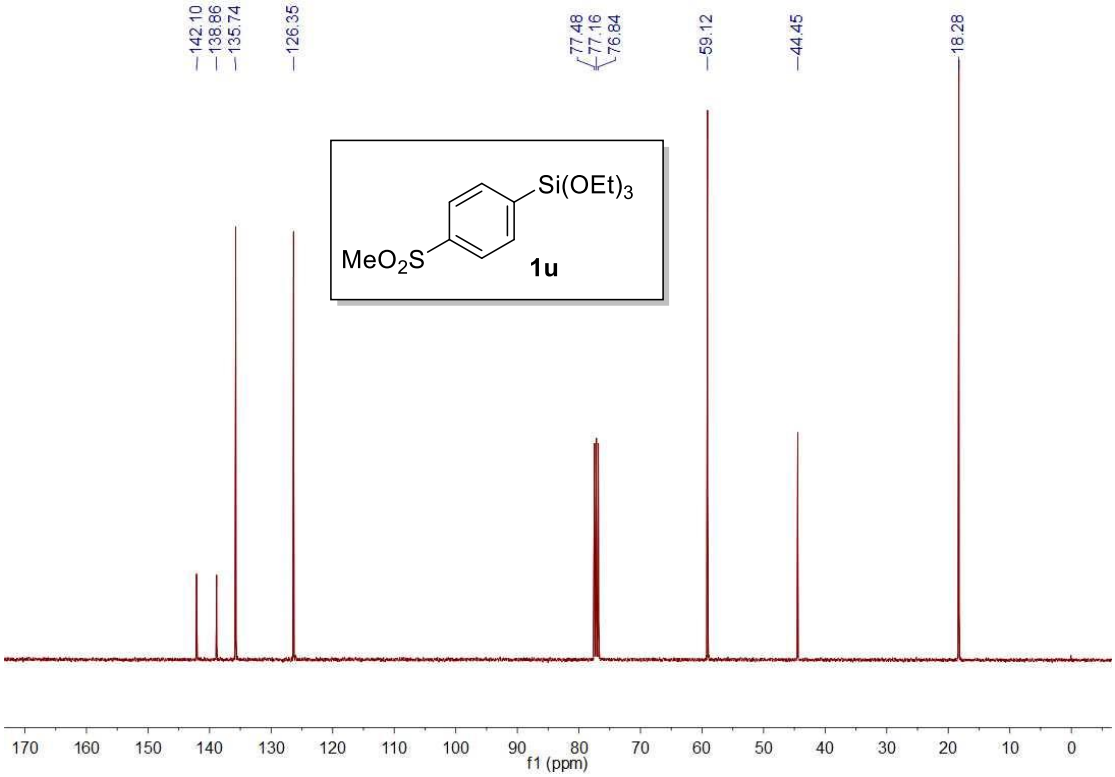
(9) Guo, C.; Yue, X.; Qing, F. -L. *Synthesis* **2010**, *11*, 1837.

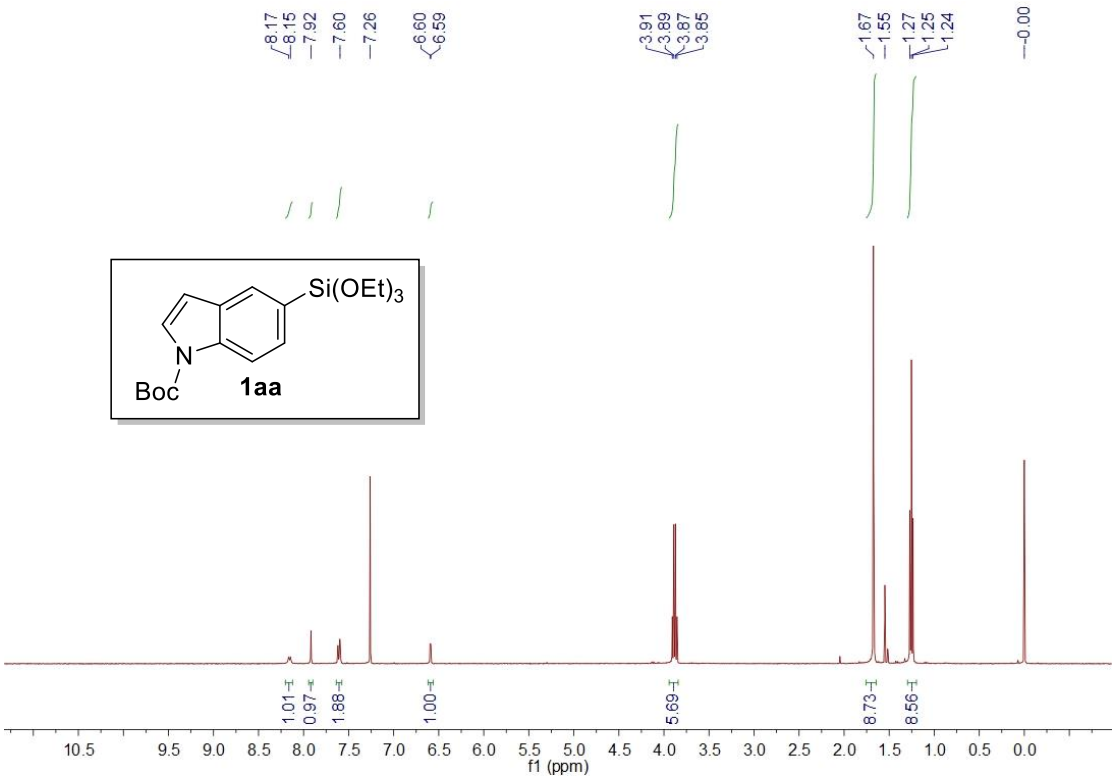
(10) Kitamura, T.; Muta, K.; Muta, K. *J. Org. Chem*. **2014**, *79*, 5842.

(11) Xiao, Y.-L.; Guo, W.-H.; He, G.-Z.; Pan, Q.; Zhang, X. *Angew. Chem., Int. Ed*. **2014**, *53*, 9909.

NMR spectra of new compounds (^{1}H NMR, ^{13}C NMR, ^{19}F NMR)



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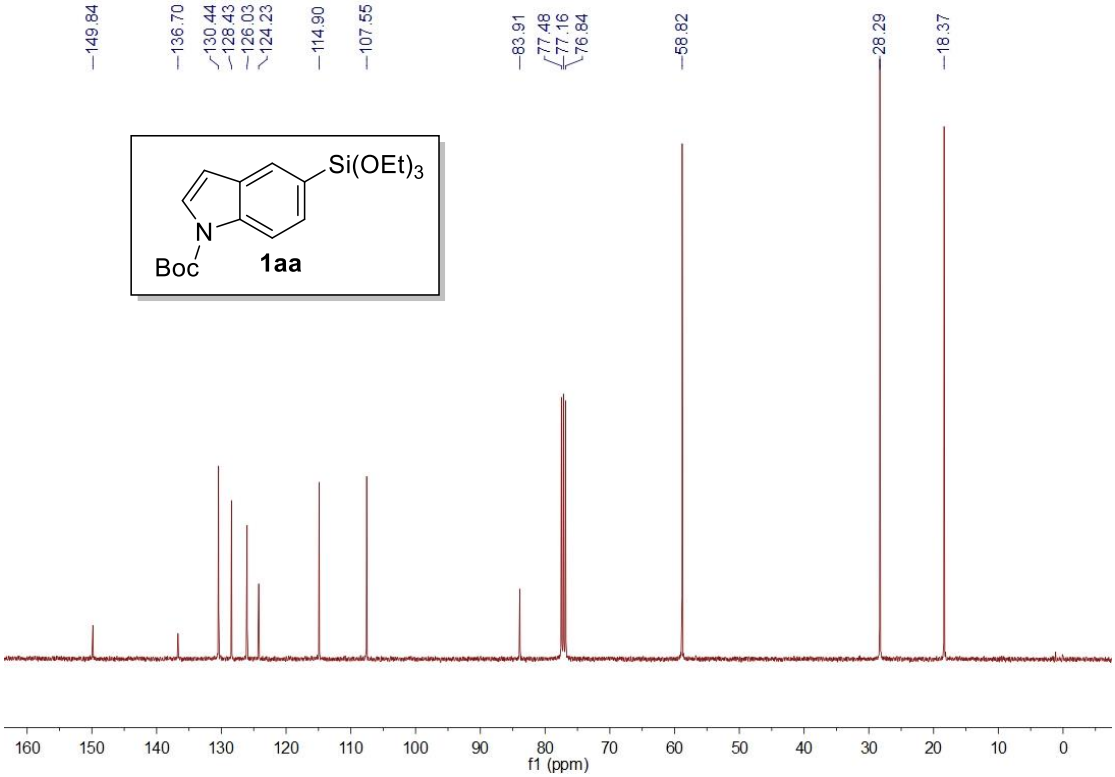
1.55
1.27
1.25
1.24
0.00
Si(OEt)3
N
Boc
1aa
1.01
0.97
1.88
1.00
5.69
8.73
8.56
f1 (ppm)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114.90
107.55
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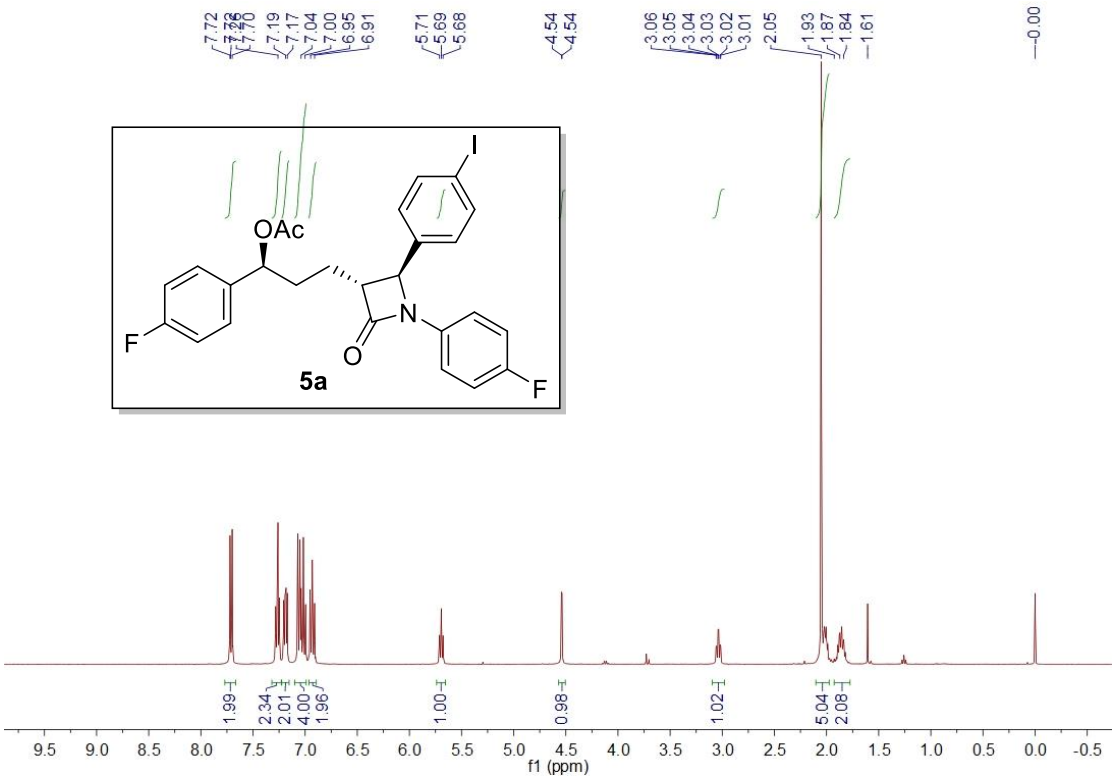
76.84
58.82
28.29
18.37
Si(OEt)3
N
Boc
1aa
f1 (ppm)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6.91
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5.69
5.68
4.54
4.54
3.06
3.05
3.04
3.03
3.02
3.01
2.05
1.93
1.87
1.84
1.61
0.00
OAc
I
F
N
O
F
5a
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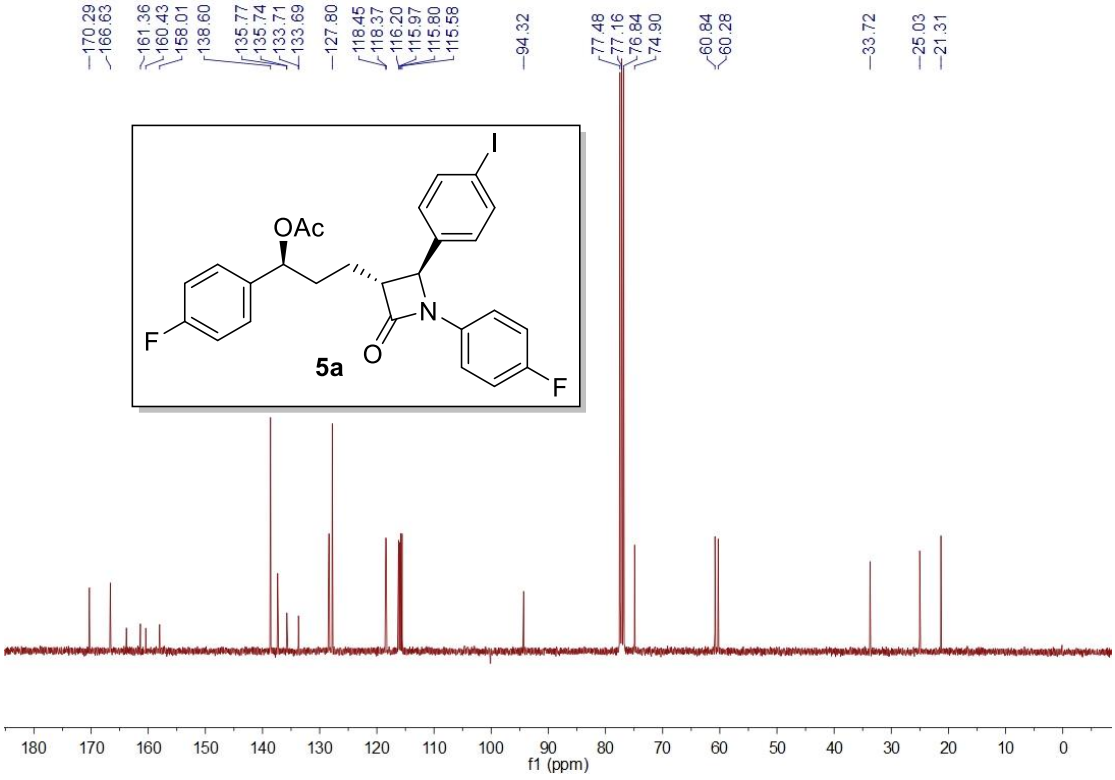
4.00
1.96
1.00
0.98
1.02
5.04
2.08
f1 (ppm)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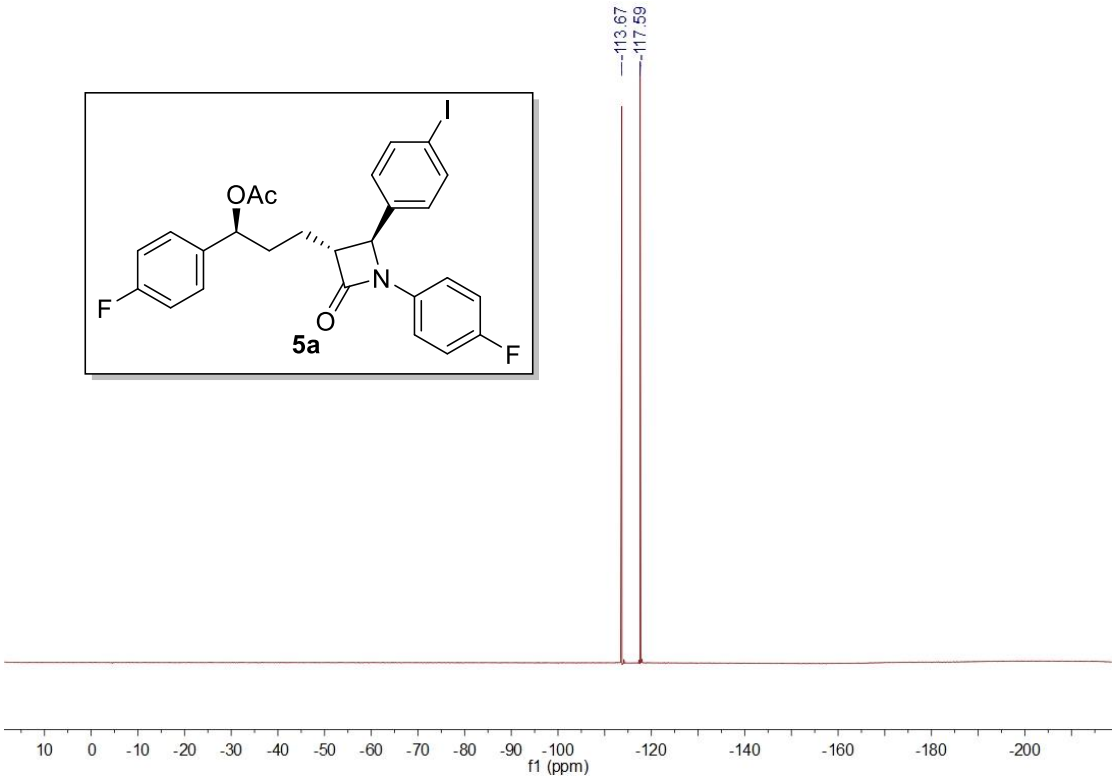
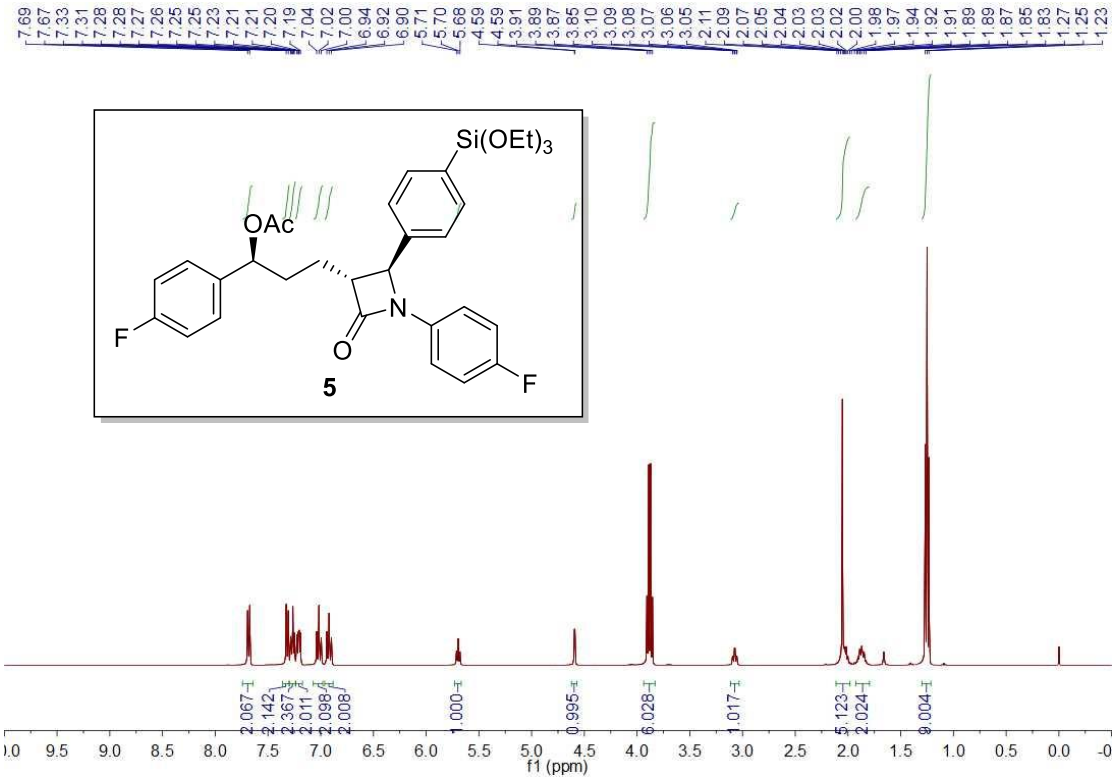
133.69
127.80
118.45
118.37
116.20
115.97
115.80
115.58
94.32
77.48
77.16
76.84
74.90
60.84
60.28
33.72
25.03
21.31
OAc
I
F
N
O
F
5a
f1 (ppm)


-113.67
-117.59
I
OAc
F
N
O
F
5a
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)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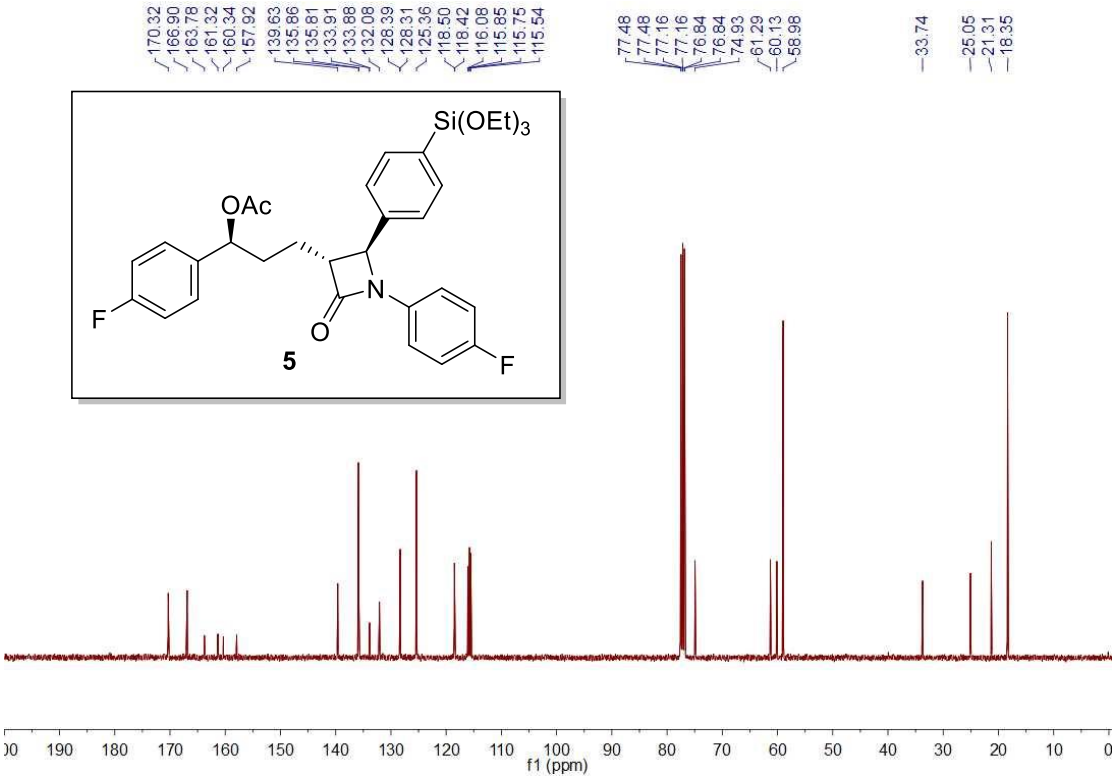
Si(OEt)3
OAc
F
N
O
F
5
2.067 2.142 2.367 2.011 2.098 2.008 1.000 0.995 6.028 1.017 5.123 2.024 9.004
f1 (ppm)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135.86
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133.91
133.88
132.08
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125.36
118.50
118.42
116.08
115.85
115.75
115.54
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77.48
77.16
77.16
76.84
76.84
74.93
61.29
60.13
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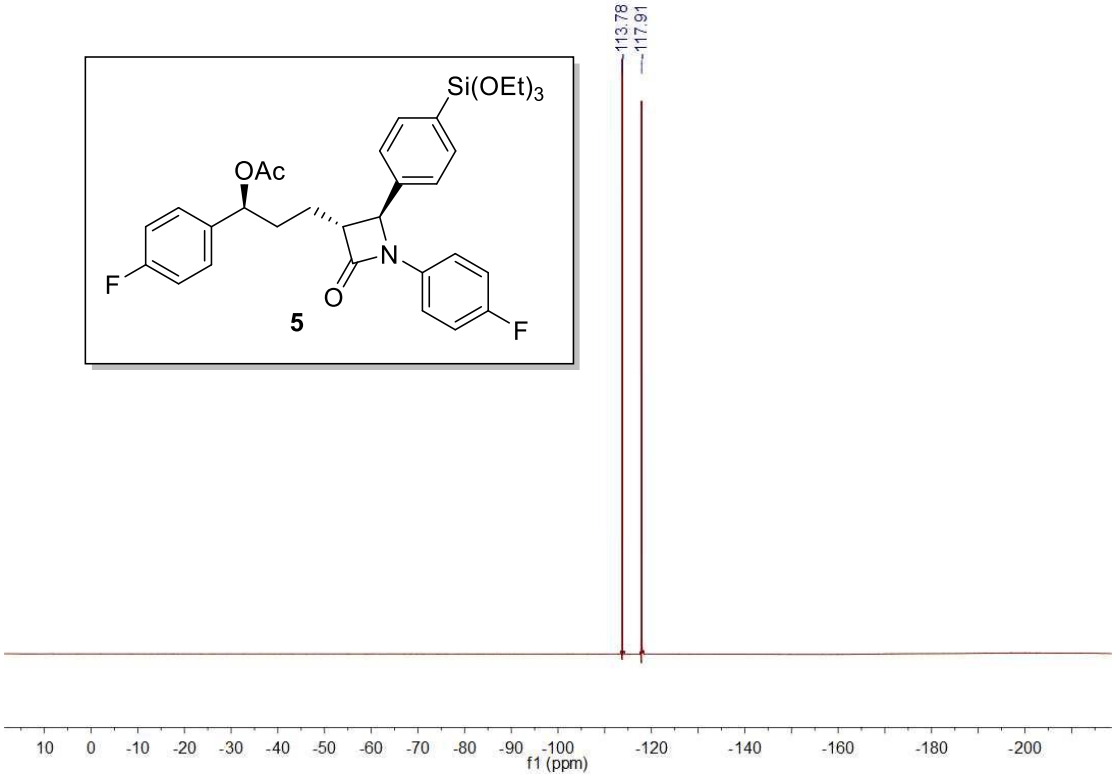
25.05
21.31
18.35
Si(OEt)3
OAc
F
N
O
F
5
f1 (ppm)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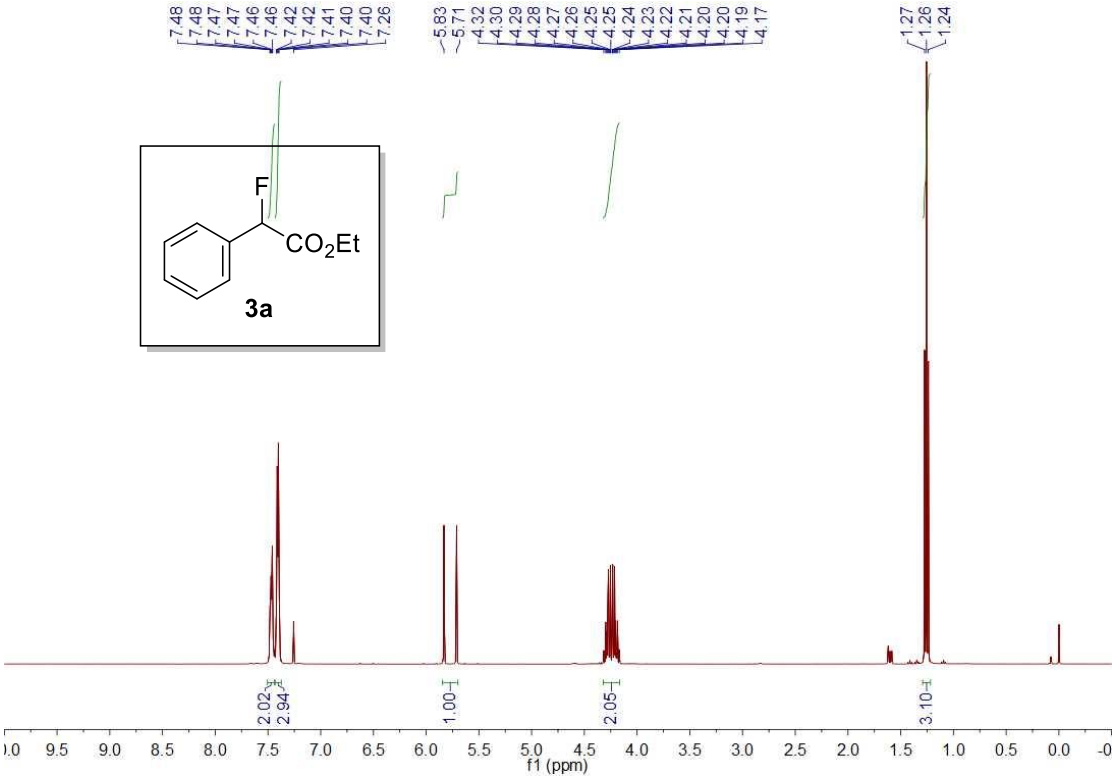
OAc
F
N
O
F
5
f1 (ppm)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7.42
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7.40
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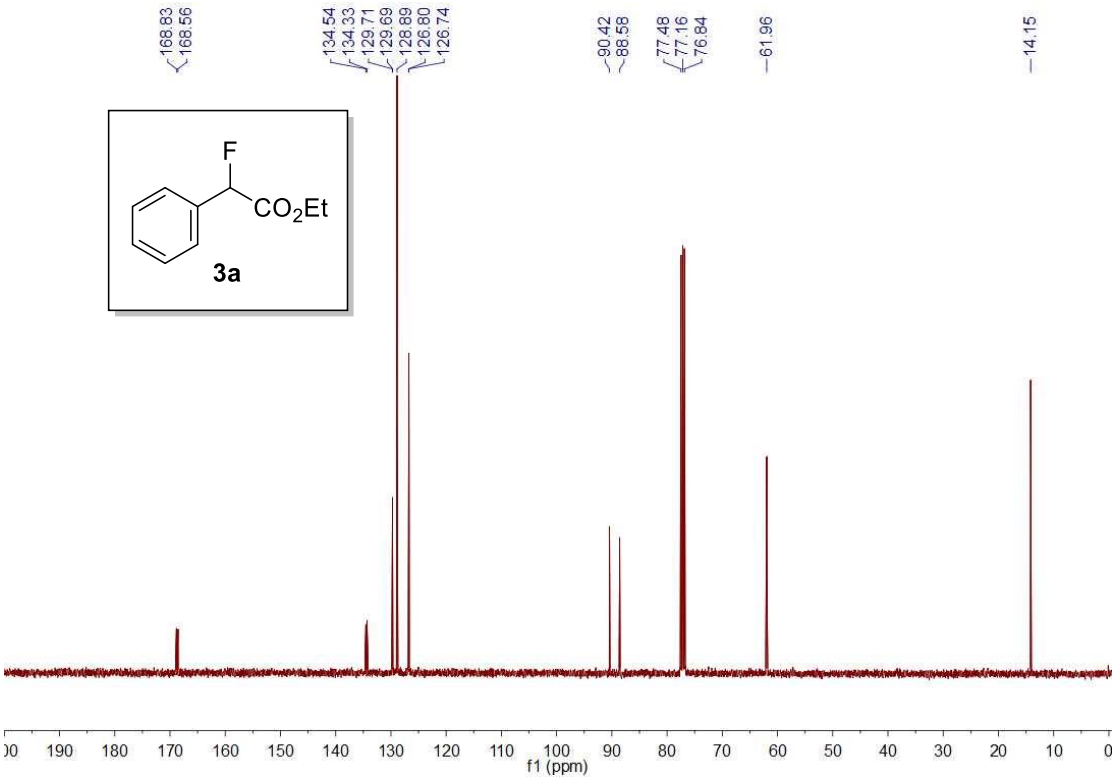
5.71
4.32
4.30
4.29
4.28
4.27
4.26
4.25
4.25
4.24
4.23
4.22
4.21
4.20
4.20
4.19
4.17
1.27
1.26
1.24
F
CO2Et
3a
2.02
2.94
1.00
2.05
3.10
f1 (ppm)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129.71
129.69
128.89
126.80
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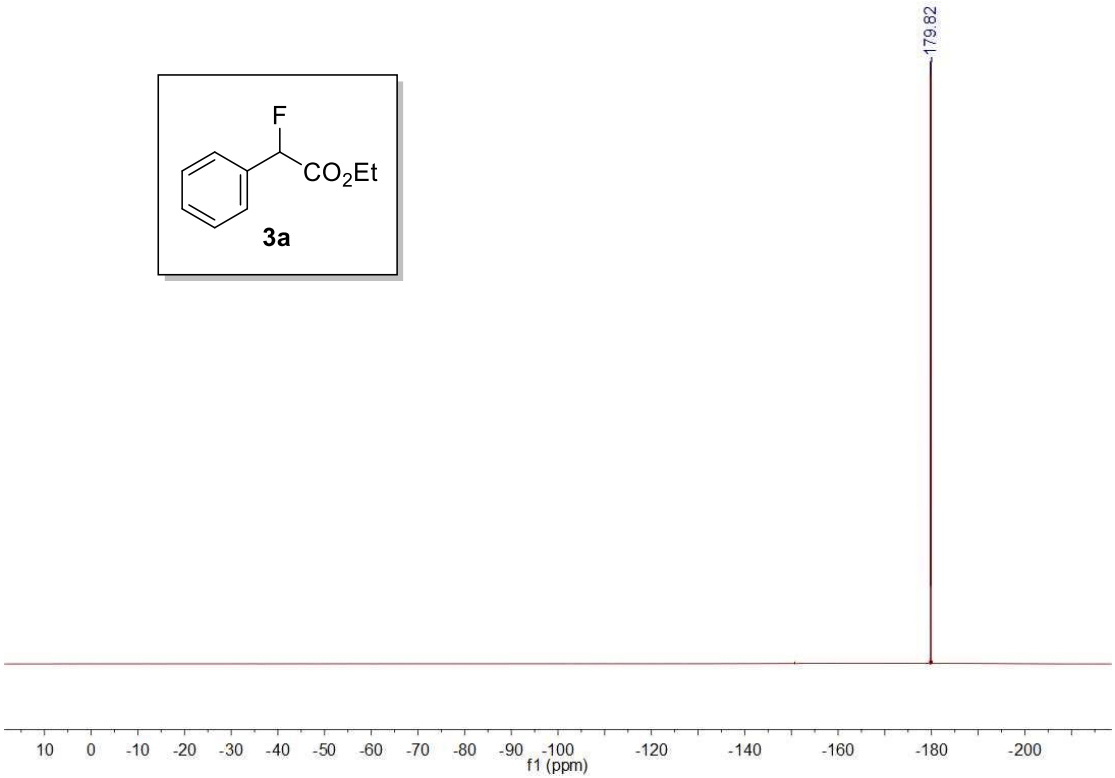
88.58
77.48
77.16
76.84
61.96
14.15
F
CO2Et
3a
f1 (ppm)


F
CO2Et
3a
179.82
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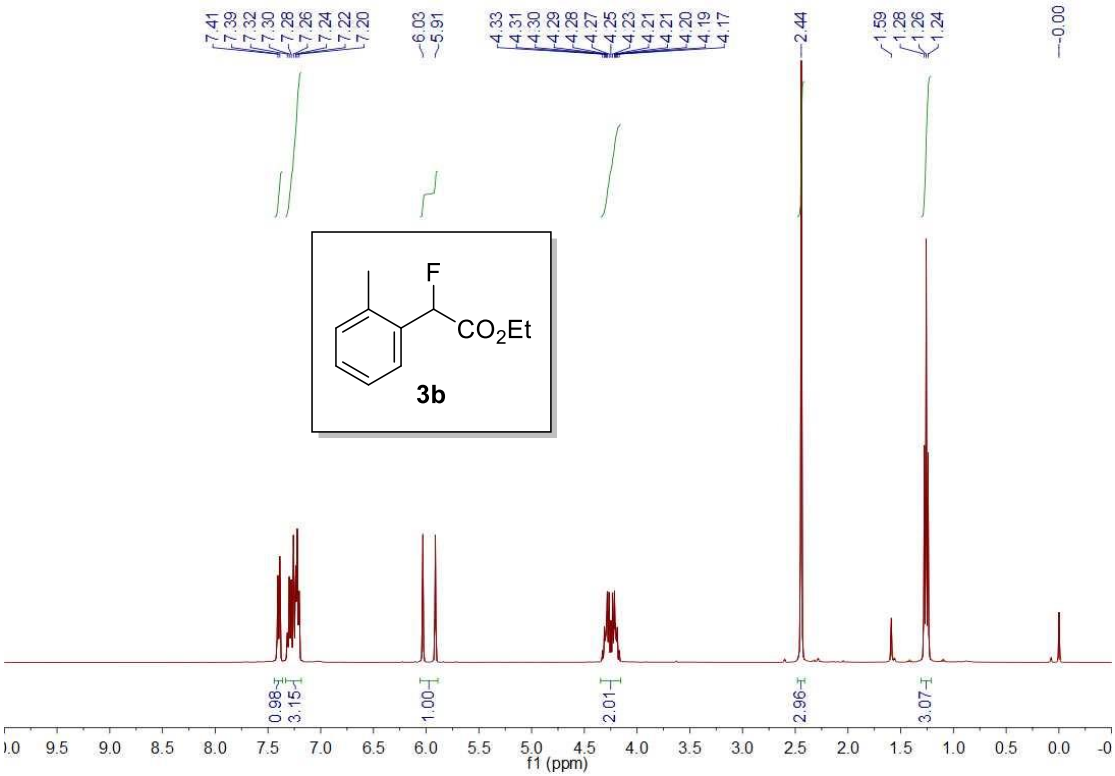
f1 (ppm)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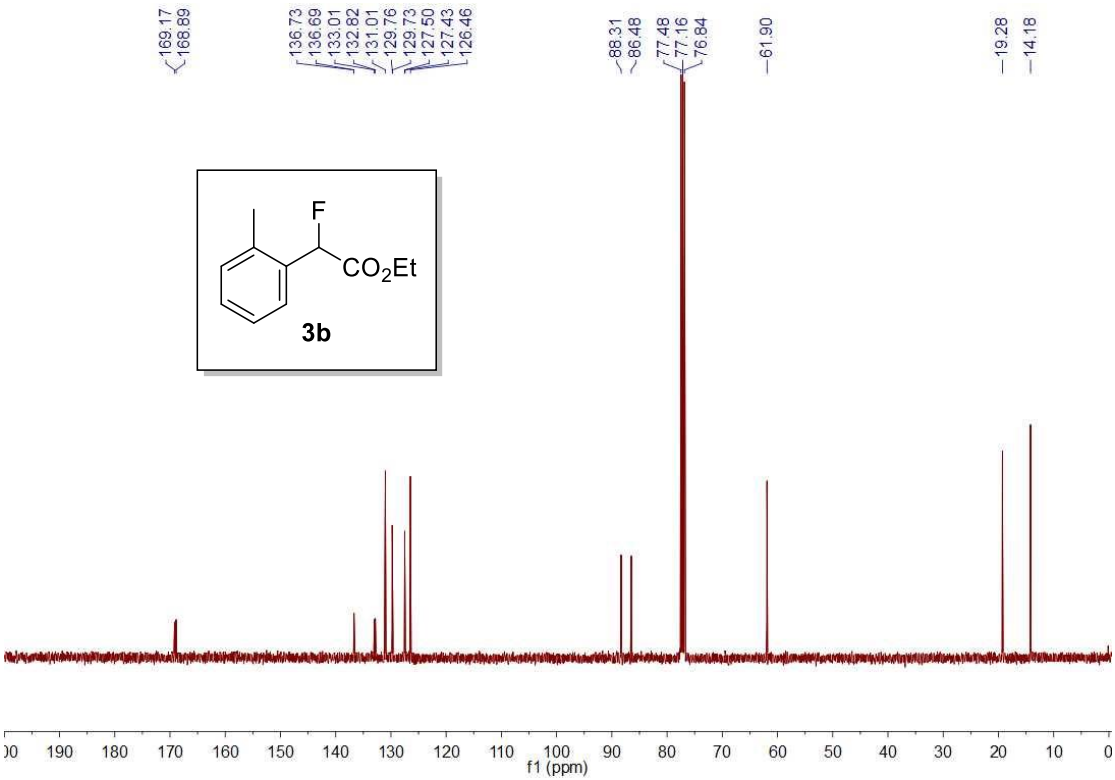
7.24
7.22
7.20
6.03
5.91
4.33
4.31
4.30
4.29
4.28
4.27
4.25
4.23
4.21
4.21
4.20
4.19
4.17
2.44
1.59
1.28
1.26
1.24
0.00
F
CO2Et
3b
0.98
3.15
1.00
2.01
2.96
3.07
f1 (ppm)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127.43
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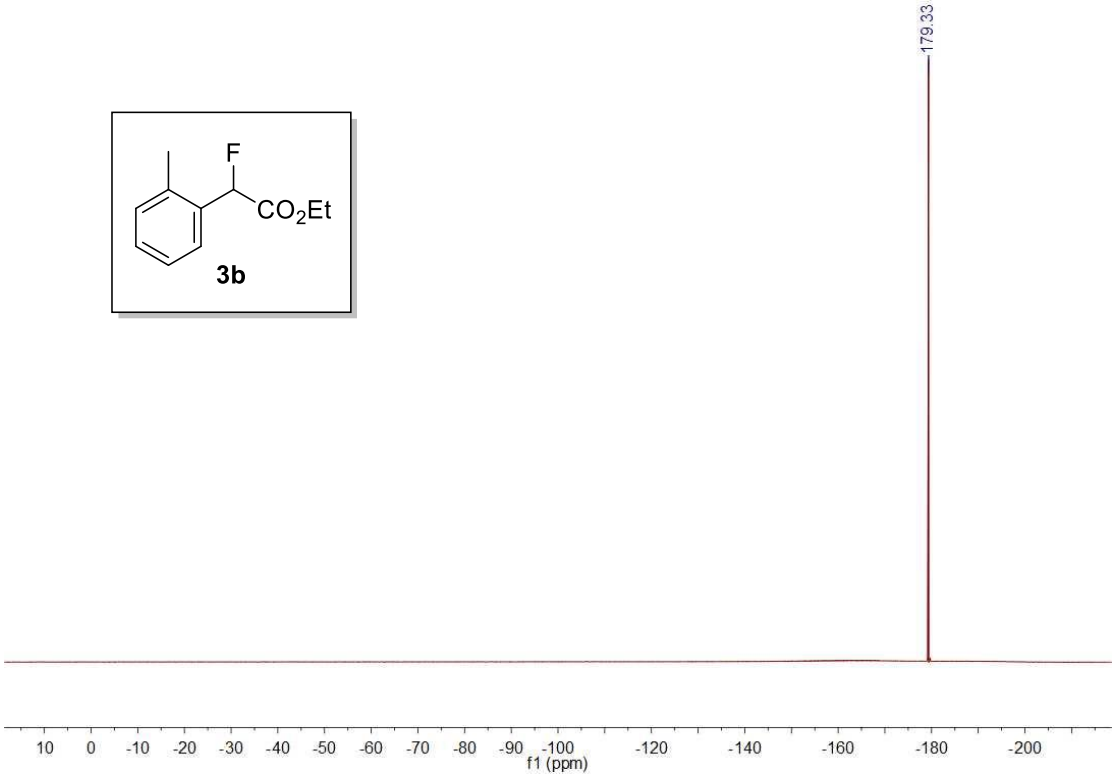
77.48
77.16
76.84
61.90
19.28
14.18
F
CO2Et
3b
f1 (ppm)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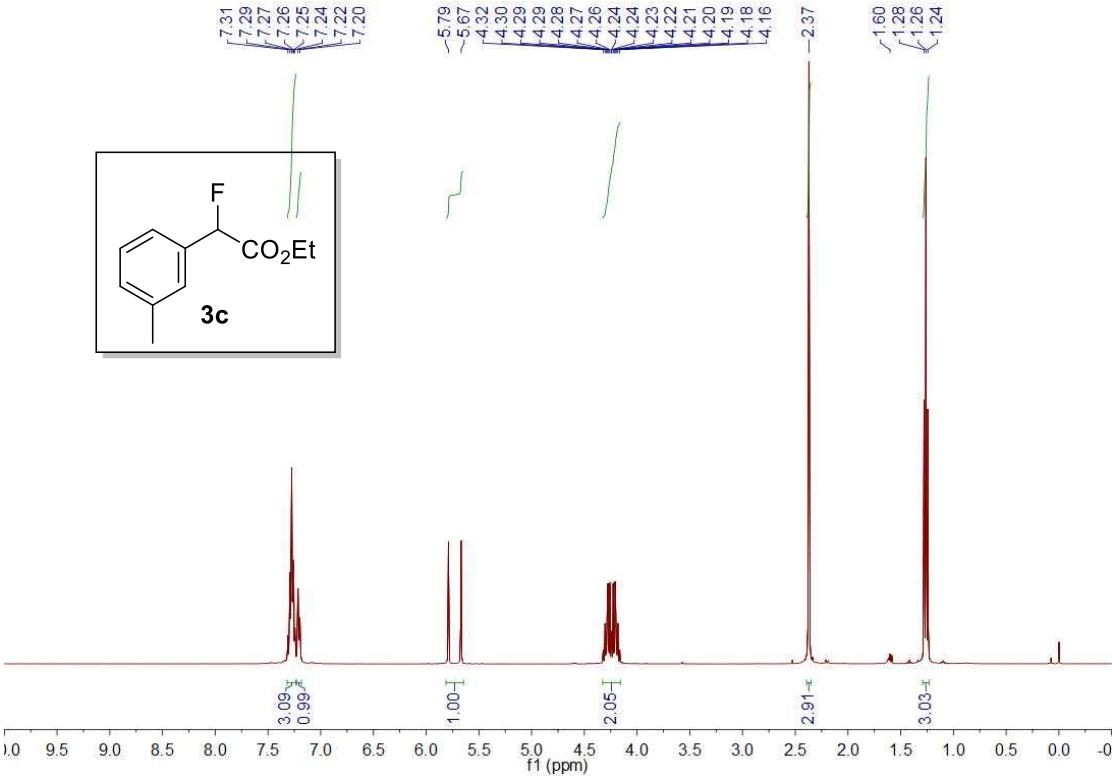
F
CO2Et
3b
f1 (ppm)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7.29
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4.29
4.29
4.28
4.27
4.26
4.24
4.24
4.23
4.22
4.21
4.20
4.19
4.18
4.16
2.37
1.60
1.28
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F
CO2Et
3c
3.09
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1.00
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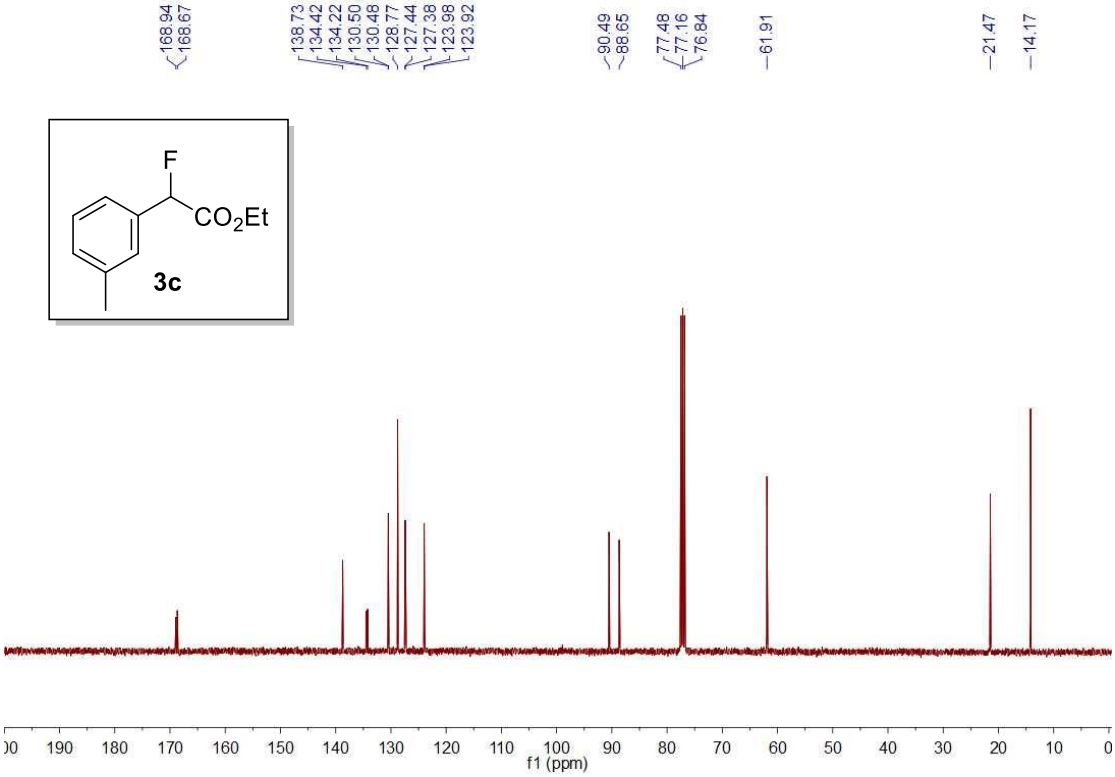
2.91
3.03
f1 (ppm)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123.92
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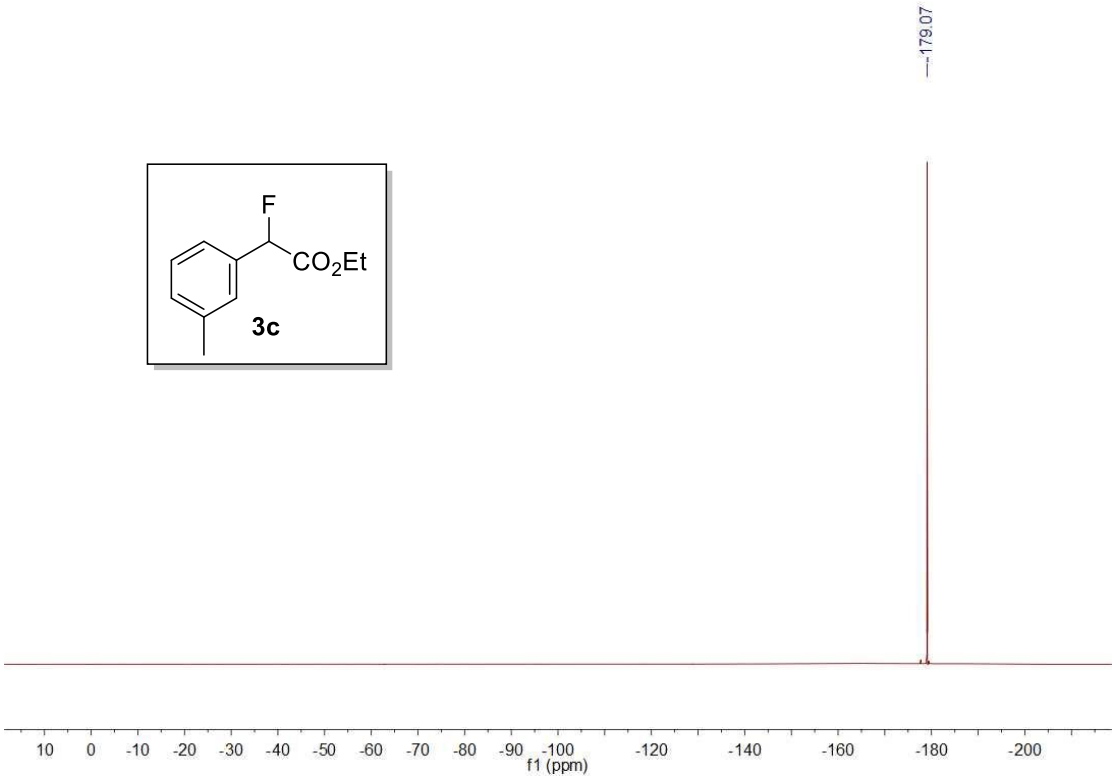
77.48
77.16
76.84
61.91
21.47
14.17
F
CO2Et
3c
f1 (ppm)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CO2Et
3c
-179.07
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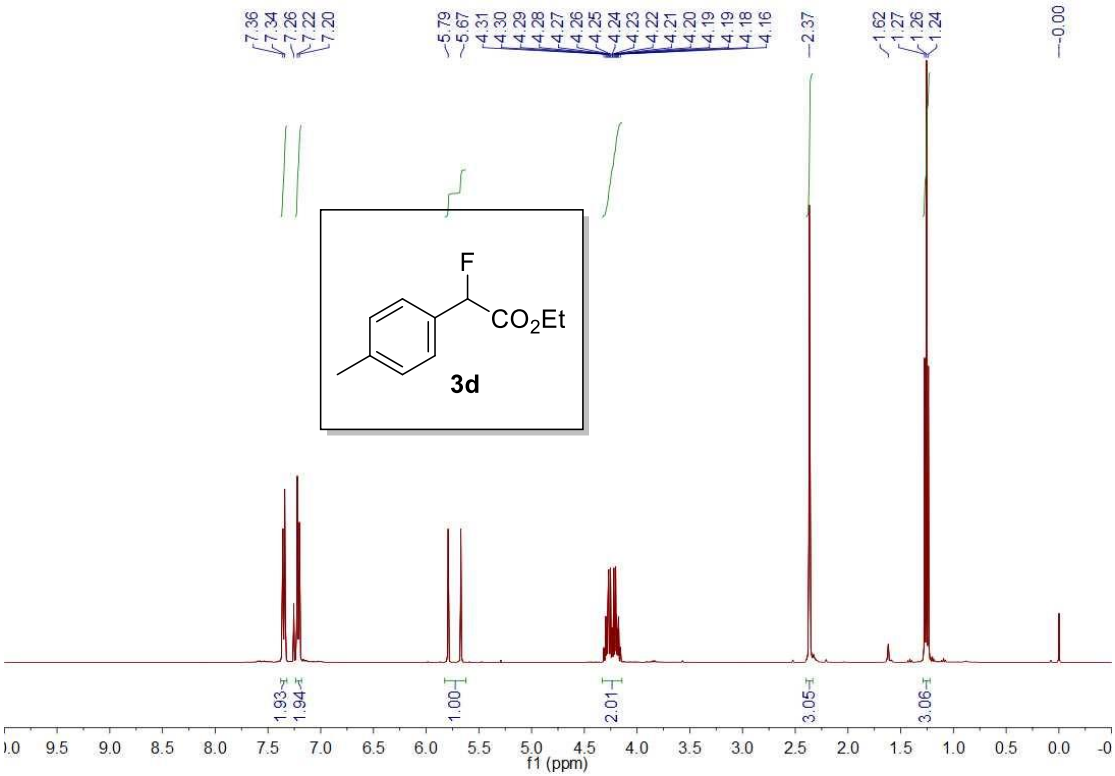
f1 (ppm)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4.26
4.25
4.24
4.23
4.22
4.21
4.20
4.19
4.18
4.16
2.37
1.62
1.27
1.26
1.24
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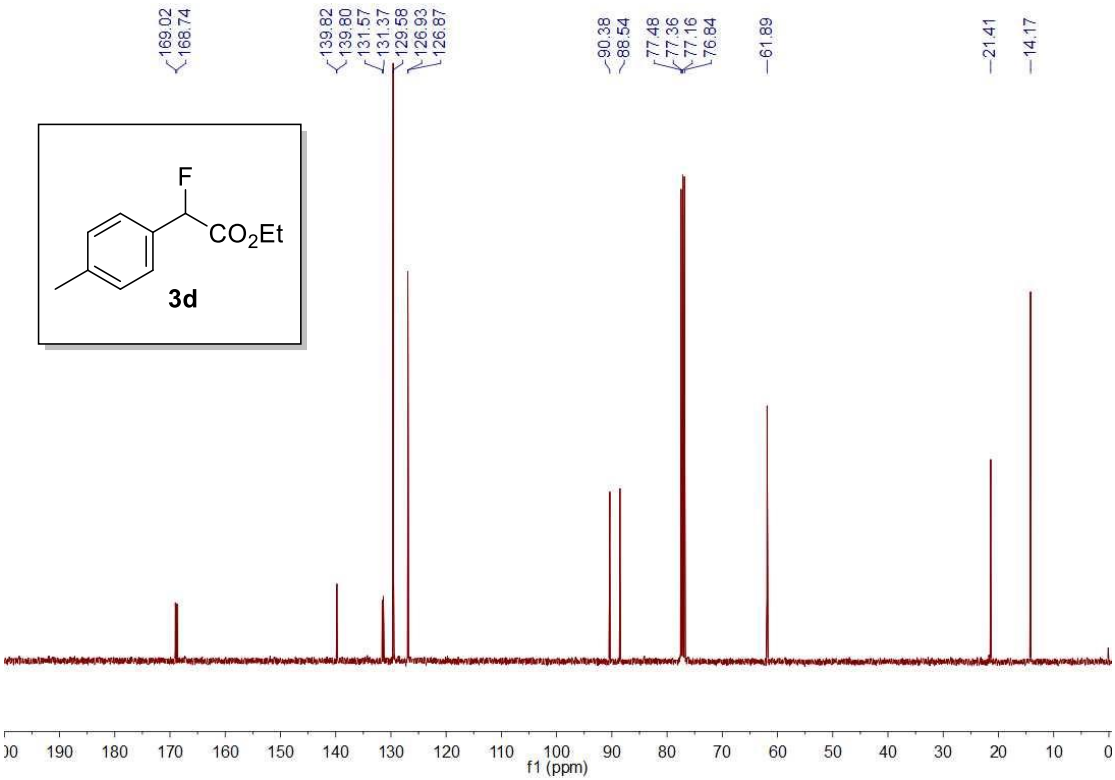
F
CO2Et
3d
1.93
1.94
1.00
2.01
3.05
3.06
f1 (ppm)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76.84
61.89
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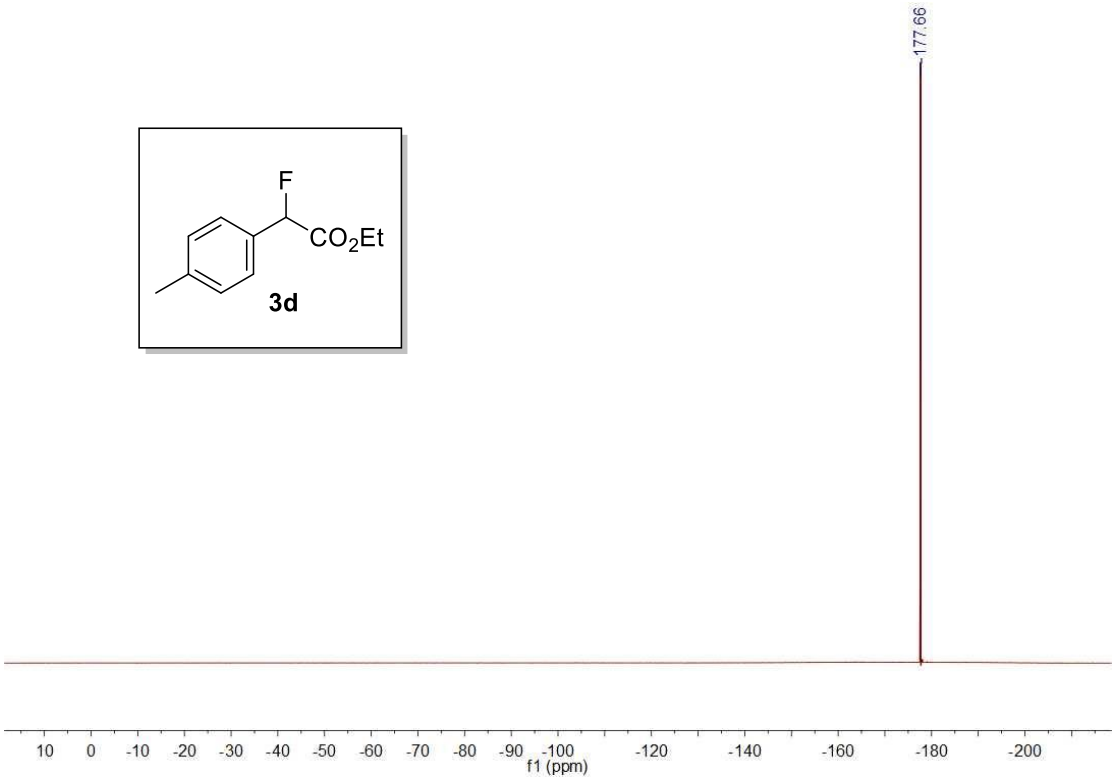
14.17
F
CO2Et
3d
f1 (ppm)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F
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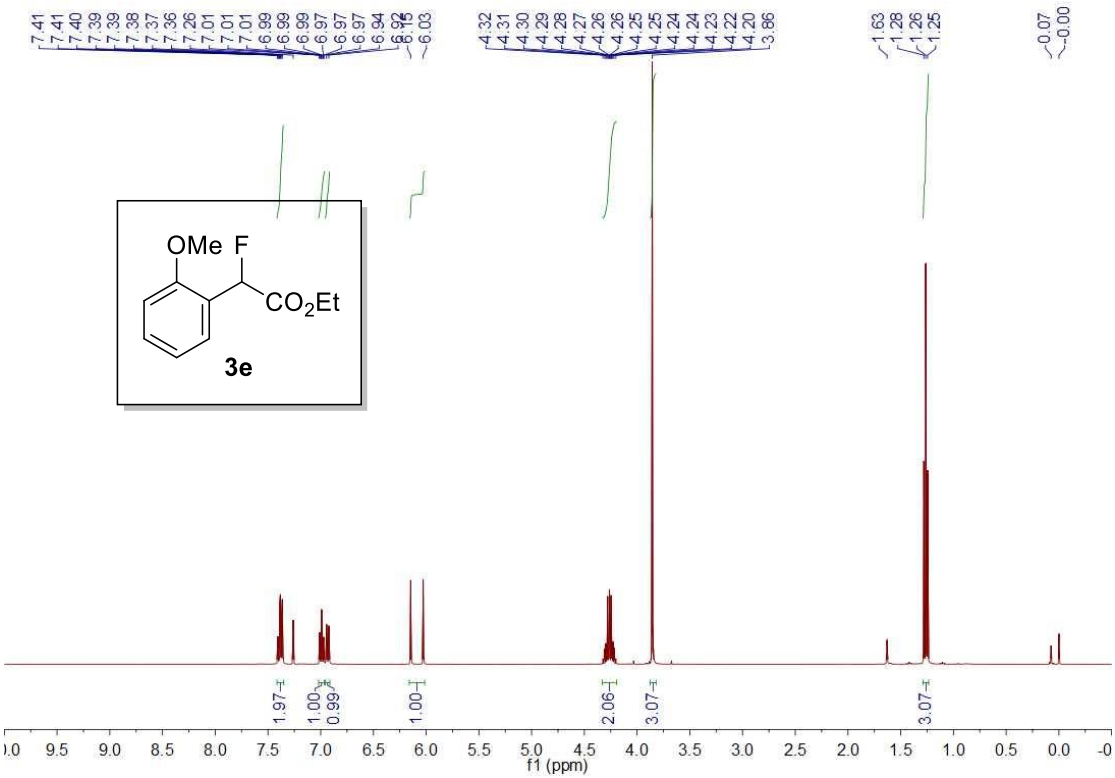
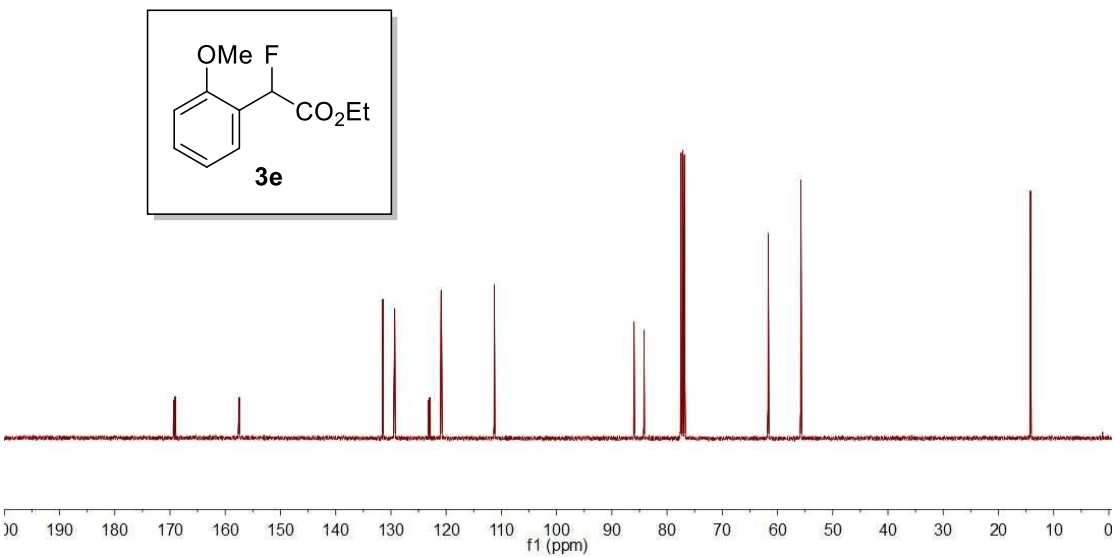
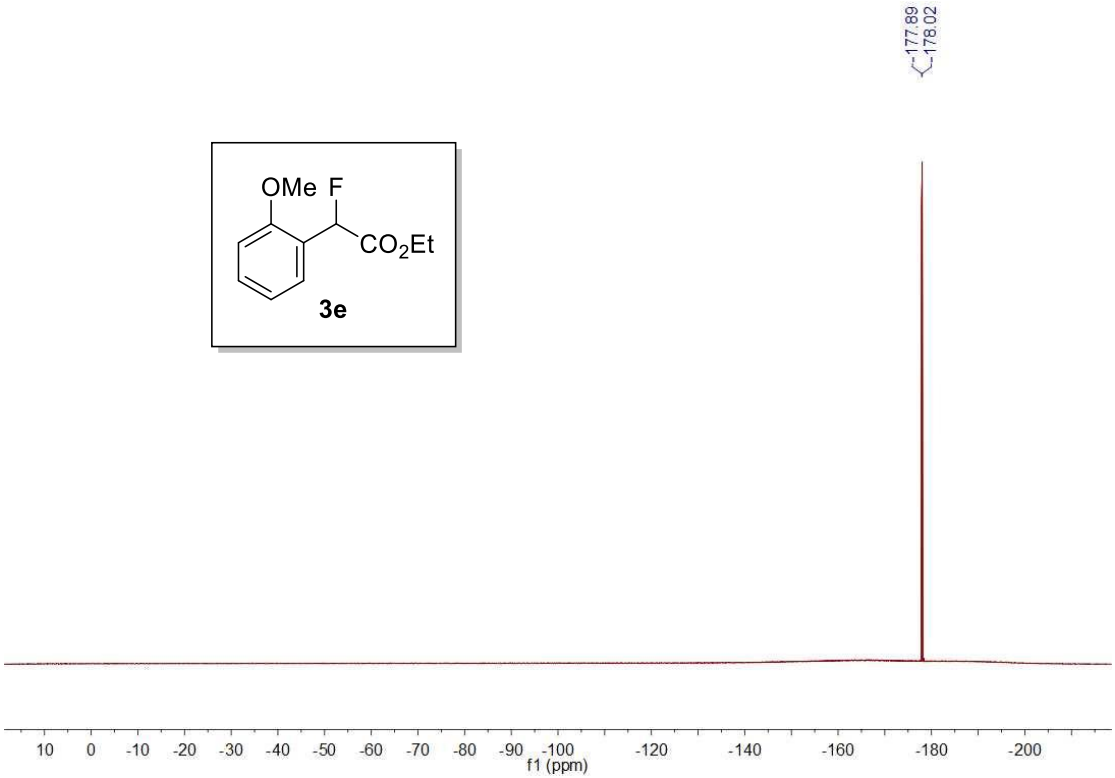
3d
f1 (ppm)


OMe F
CO2Et
3e
f1 (ppm)


OMe F
CO2Et
3e
f1 (ppm)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178.02
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CO2Et
3e
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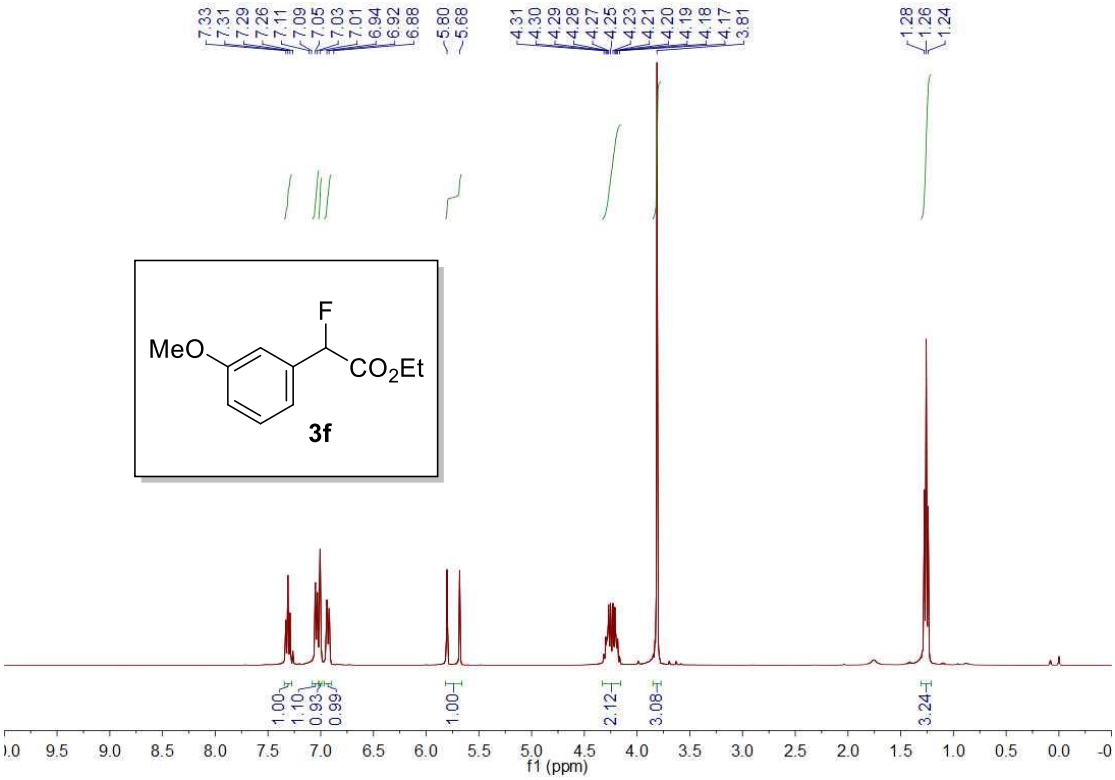
f1 (ppm)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7.03
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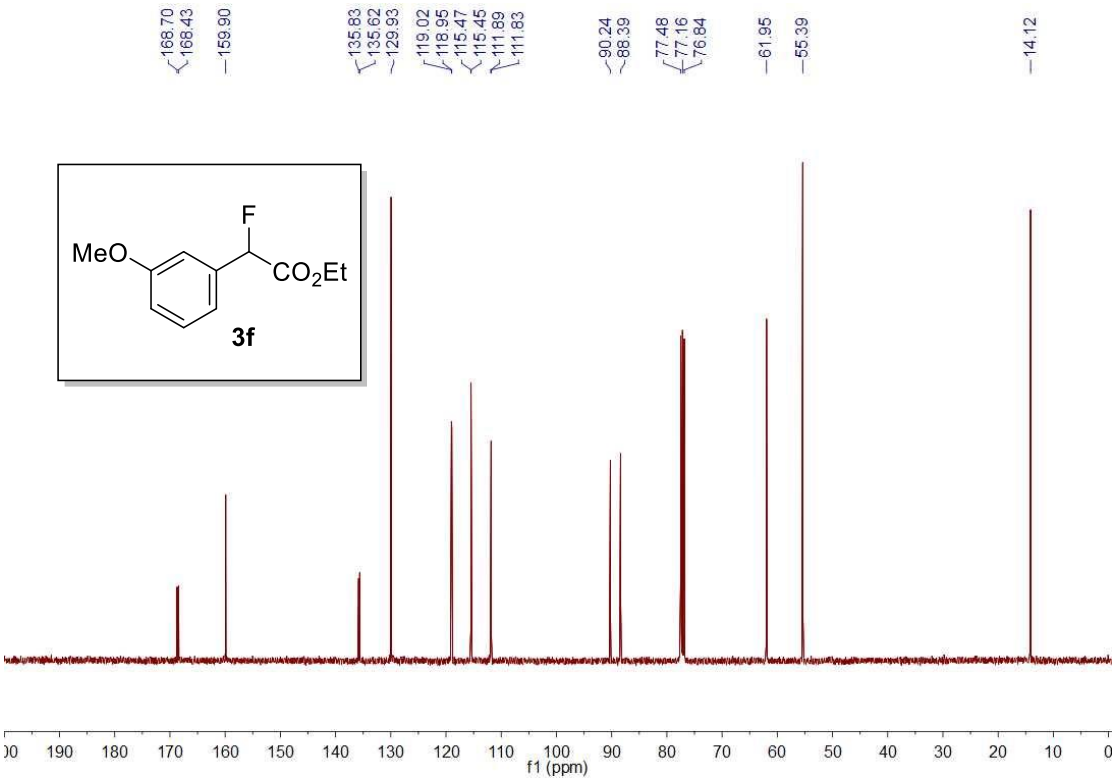
6.92
6.88
5.80
5.68
4.31
4.30
4.29
4.28
4.27
4.25
4.23
4.21
4.20
4.19
4.18
4.17
3.81
1.28
1.26
1.24
F
MeO
CO2Et
3f
1.00
1.10
0.93
0.99
1.00
2.12
3.08
3.24
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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111.83
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77.16
76.84
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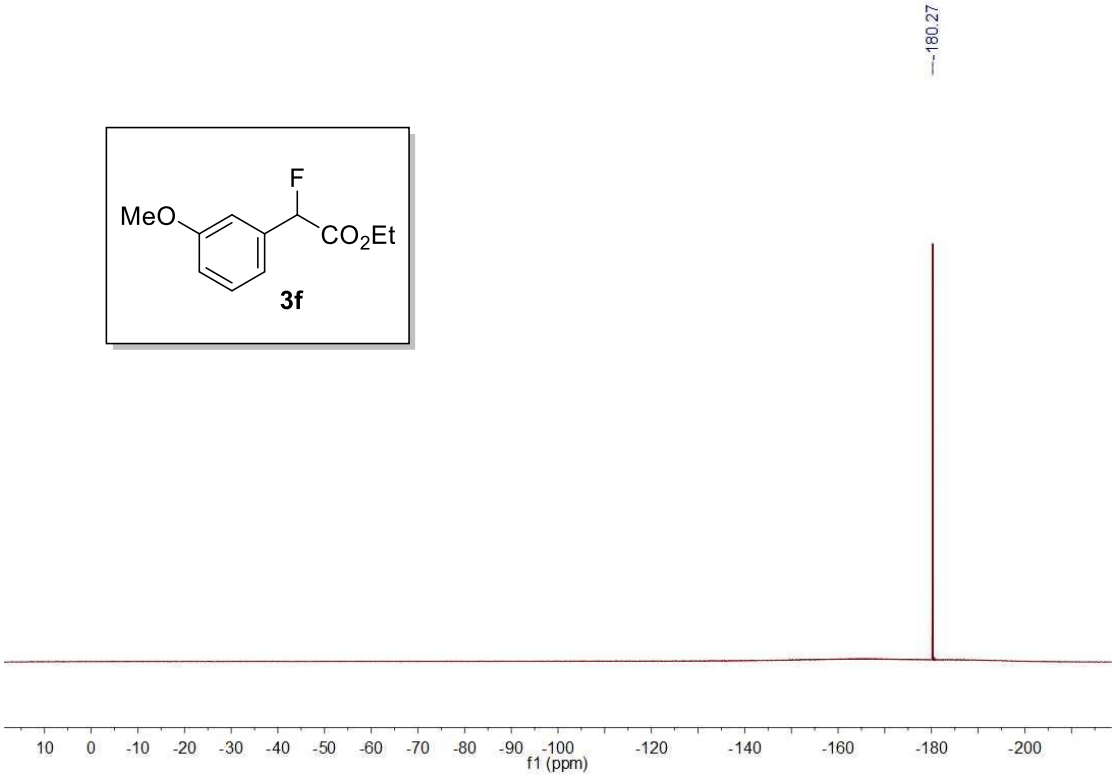
55.39
14.12
F
MeO
CO2Et
3f
f1 (ppm)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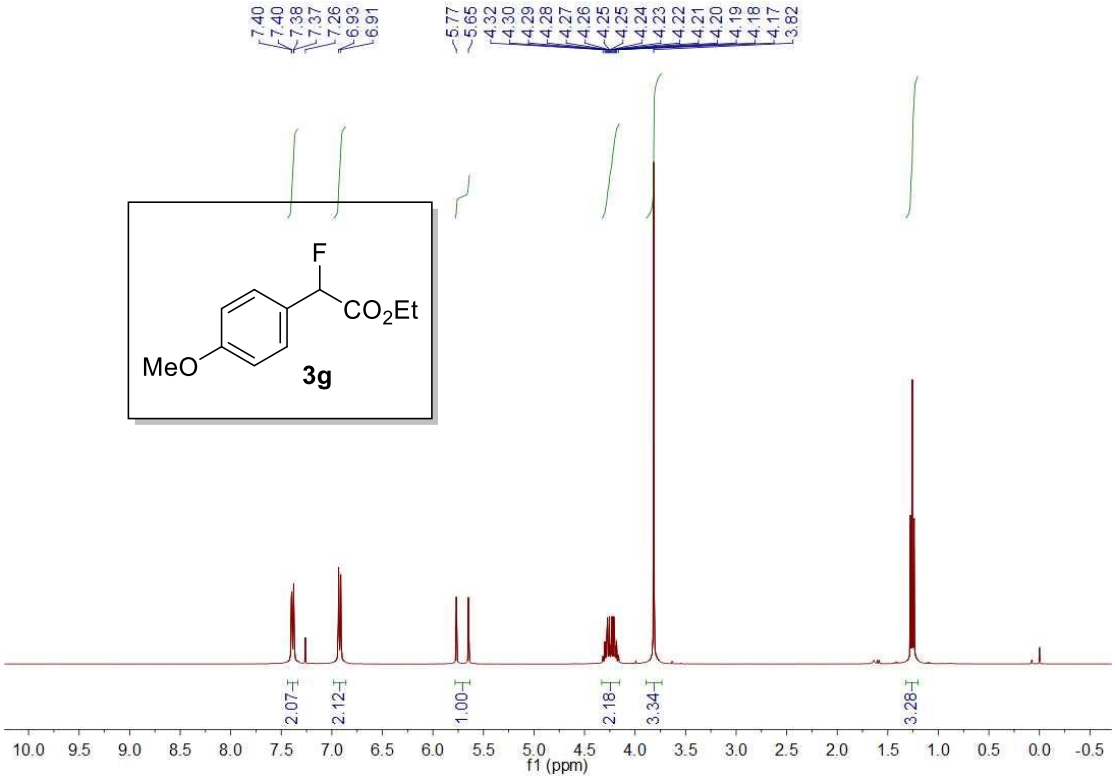
F
MeO
CO2Et
3f
f1 (ppm)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4.26
4.25
4.25
4.24
4.23
4.22
4.21
4.20
4.19
4.18
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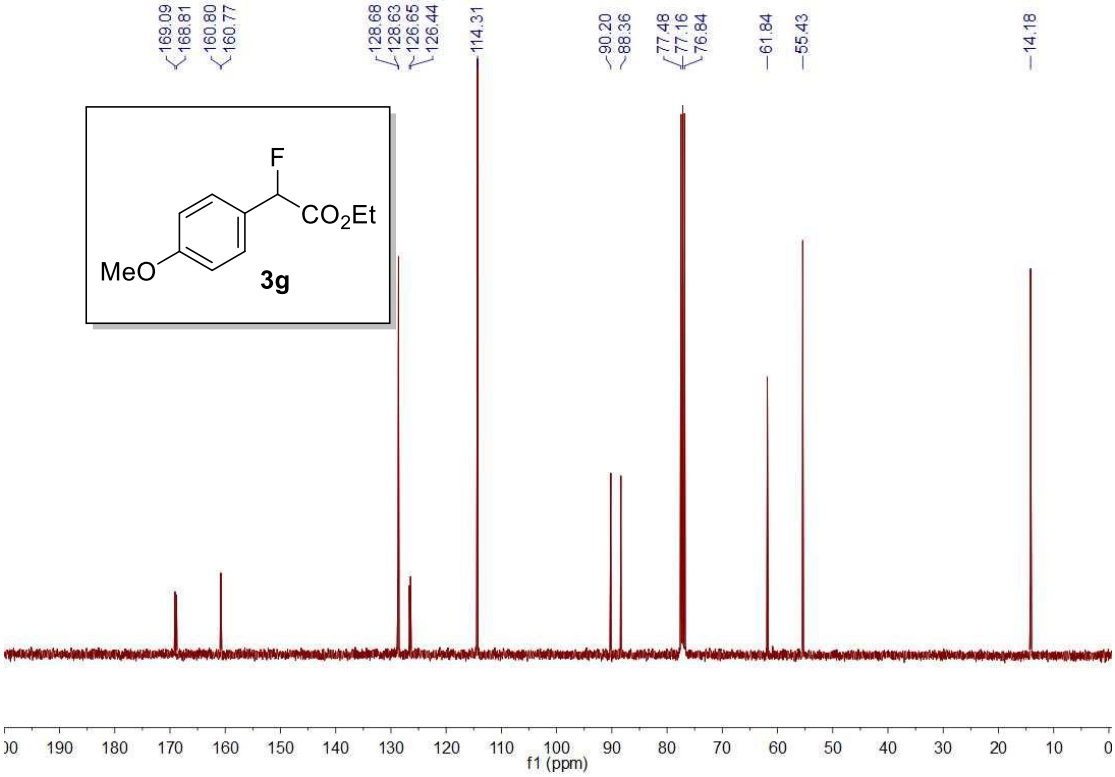
MeO
3g
2.07
2.12
1.00
2.18
3.34
3.28
f1 (ppm)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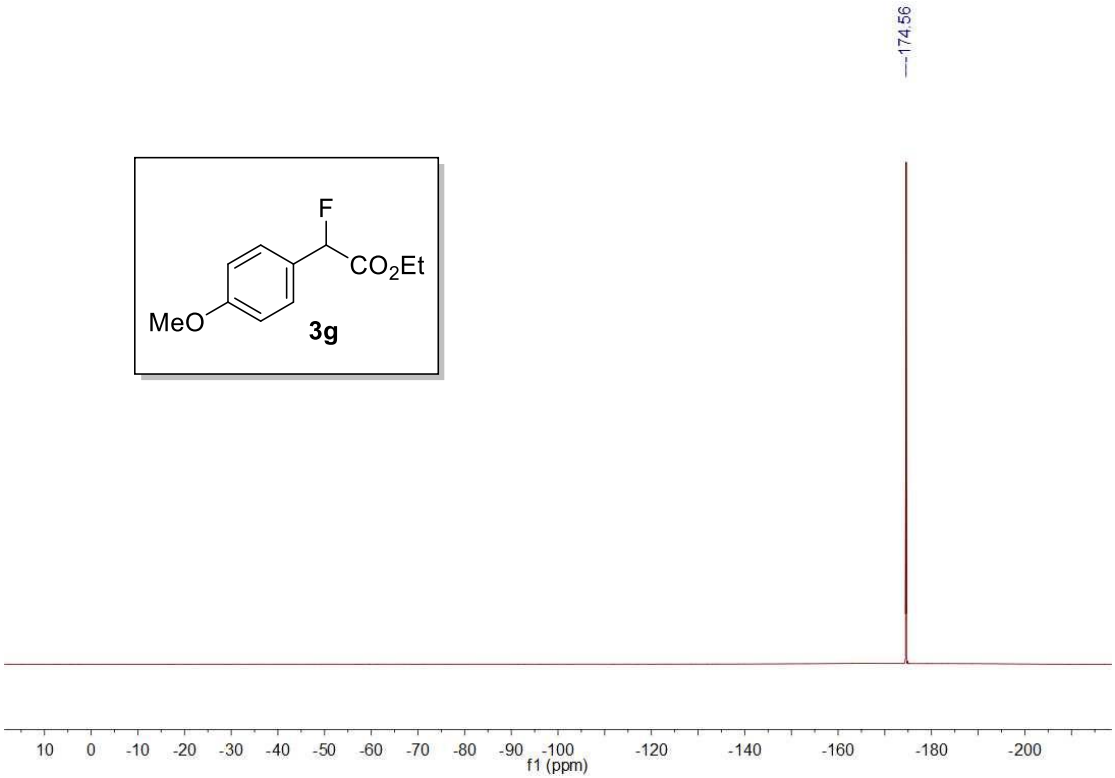
76.84
61.84
55.43
14.18
F
CO2Et
MeO
3g
f1 (ppm)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3g
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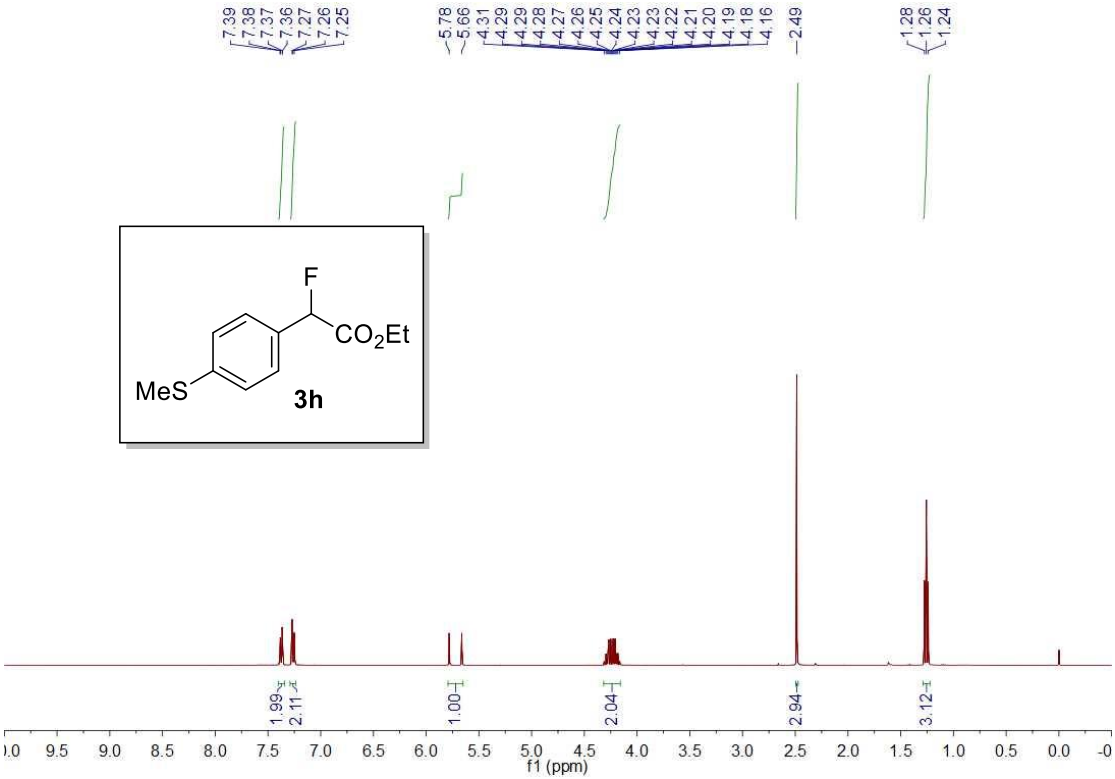
f1 (ppm)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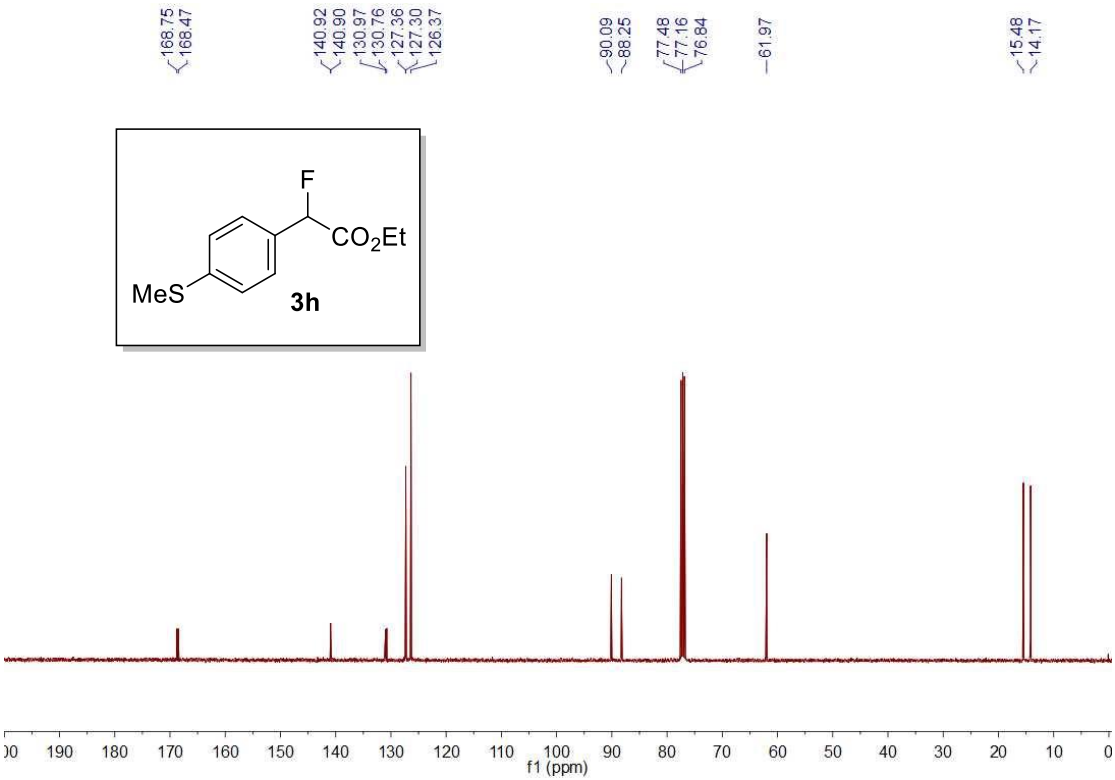
4.18
4.16
2.49
1.28
1.26
1.24
F
CO2Et
MeS
3h
1.99
2.11
1.00
2.04
2.94
3.12
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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127.30
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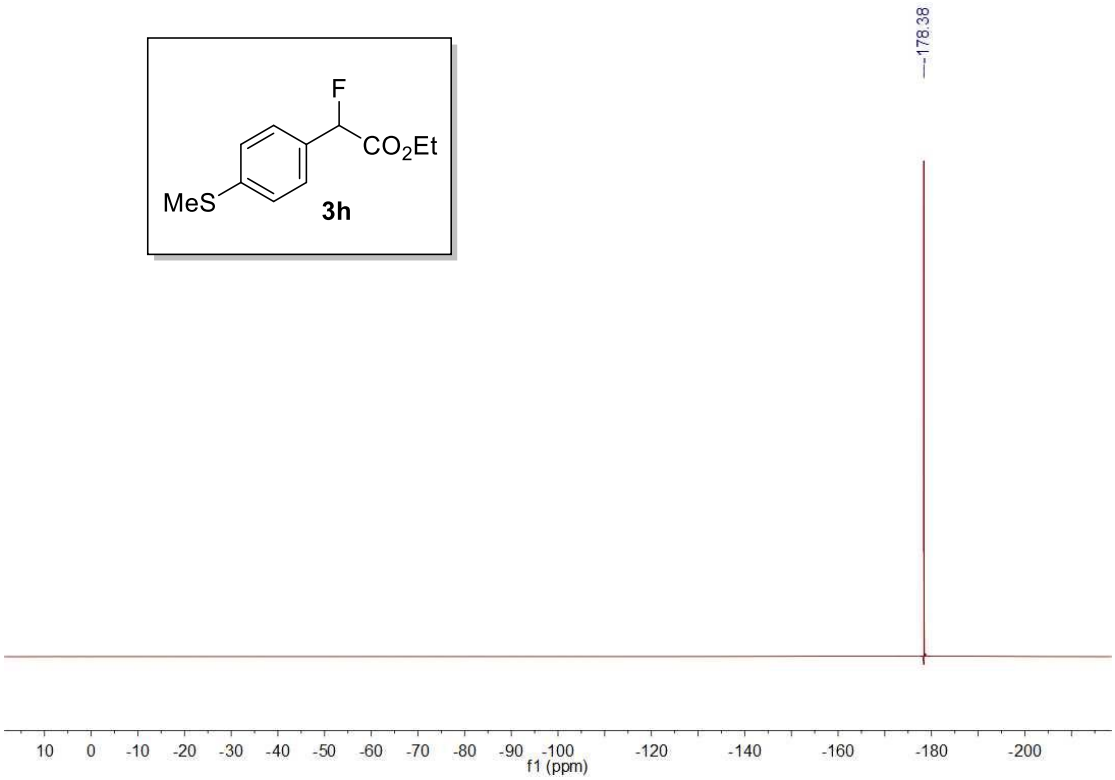
76.84
61.97
15.48
14.17
F
CO2Et
MeS
3h
f1 (ppm)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F
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MeS
3h
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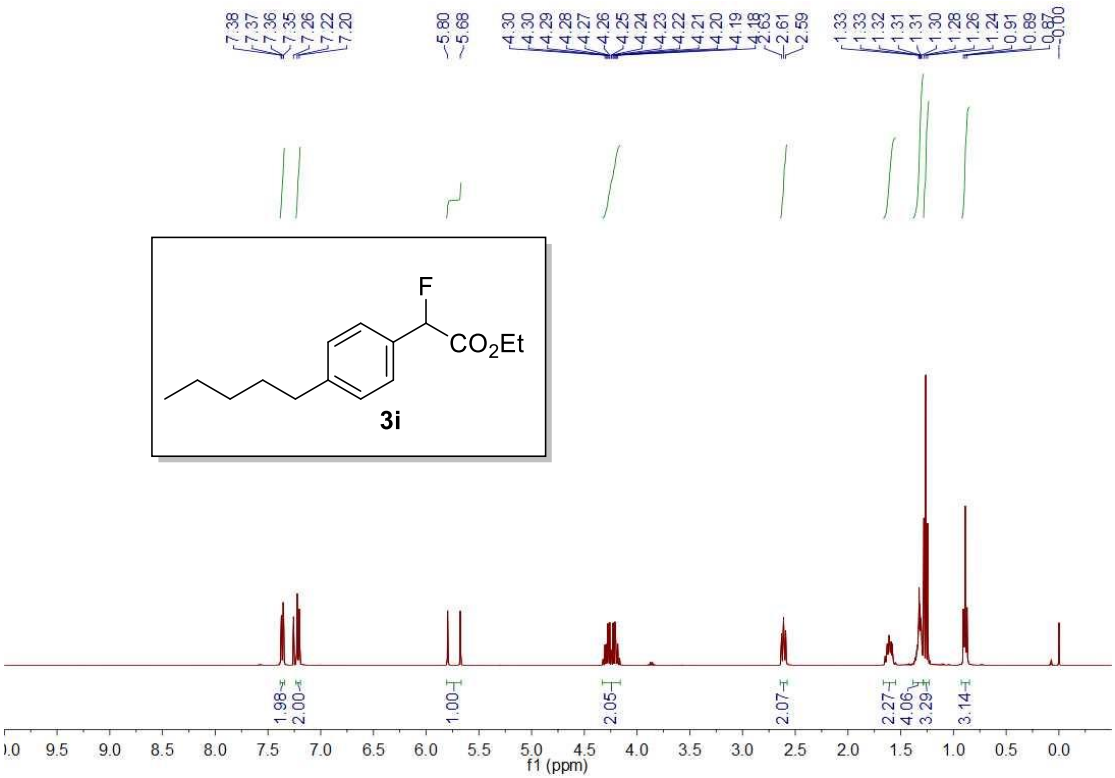
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1.31
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1.28
1.26
1.24
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0.89
0.87
0.00
F
CO2Et
3i
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1.00
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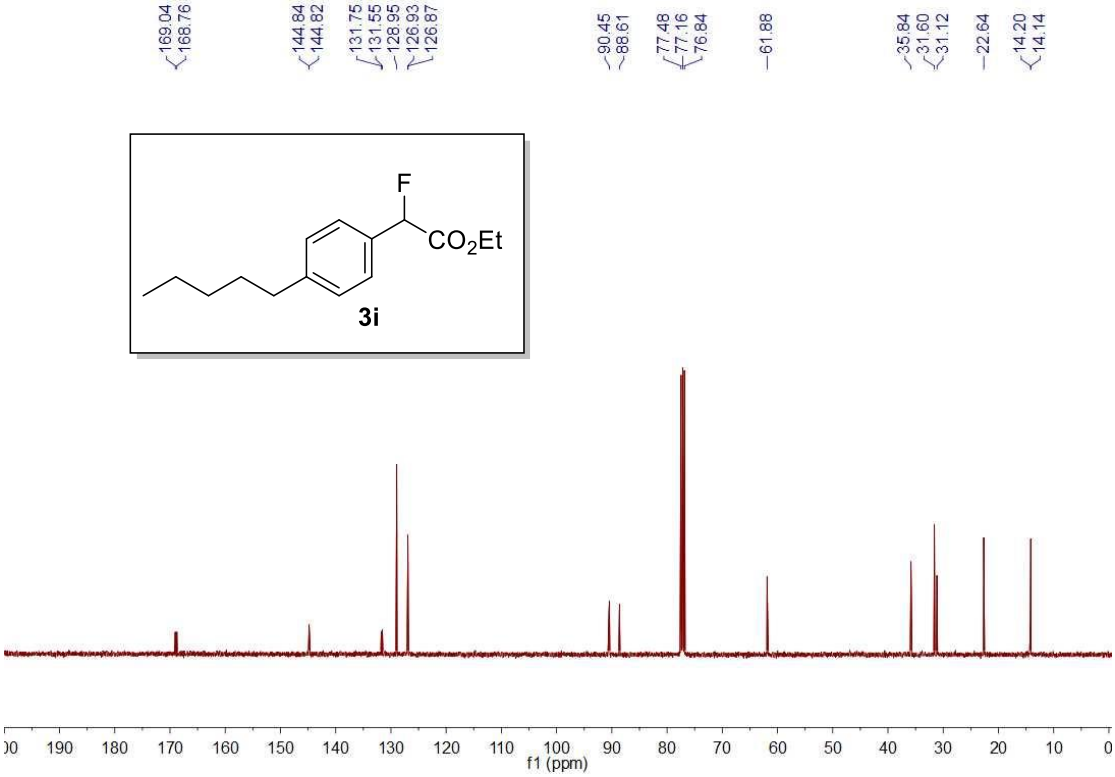
2.27
4.06
3.29
3.14
f1 (ppm)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88.61
77.48
77.16
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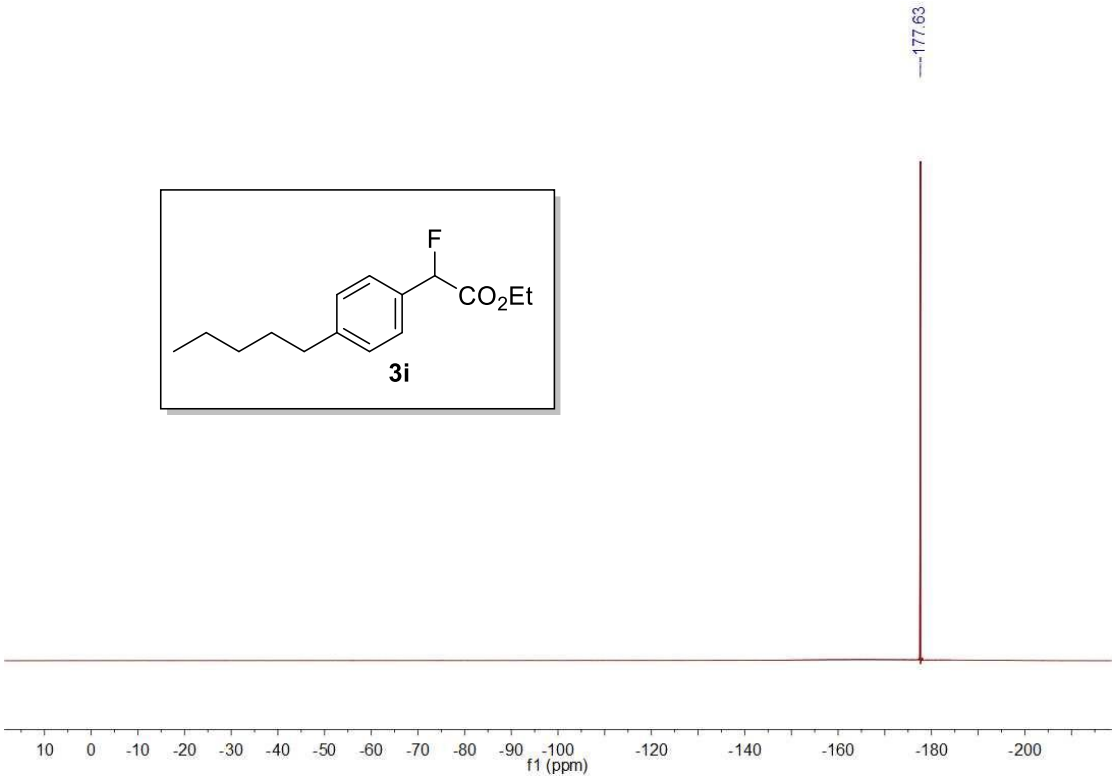
35.84
31.60
31.12
22.64
14.20
14.14
F
CO2Et
3i
f1 (ppm)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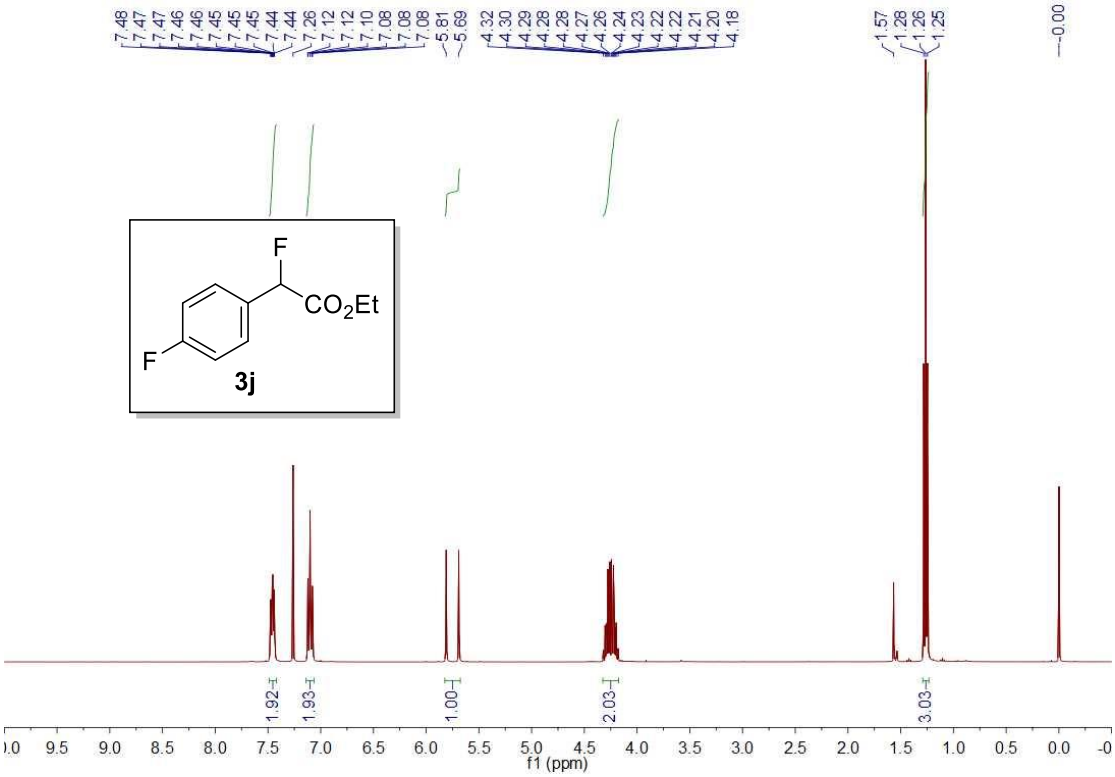
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7.10
7.08
7.08
7.08
5.81
5.69
4.32
4.30
4.29
4.28
4.28
4.27
4.26
4.24
4.23
4.22
4.22
4.21
4.20
4.18
1.57
1.28
1.26
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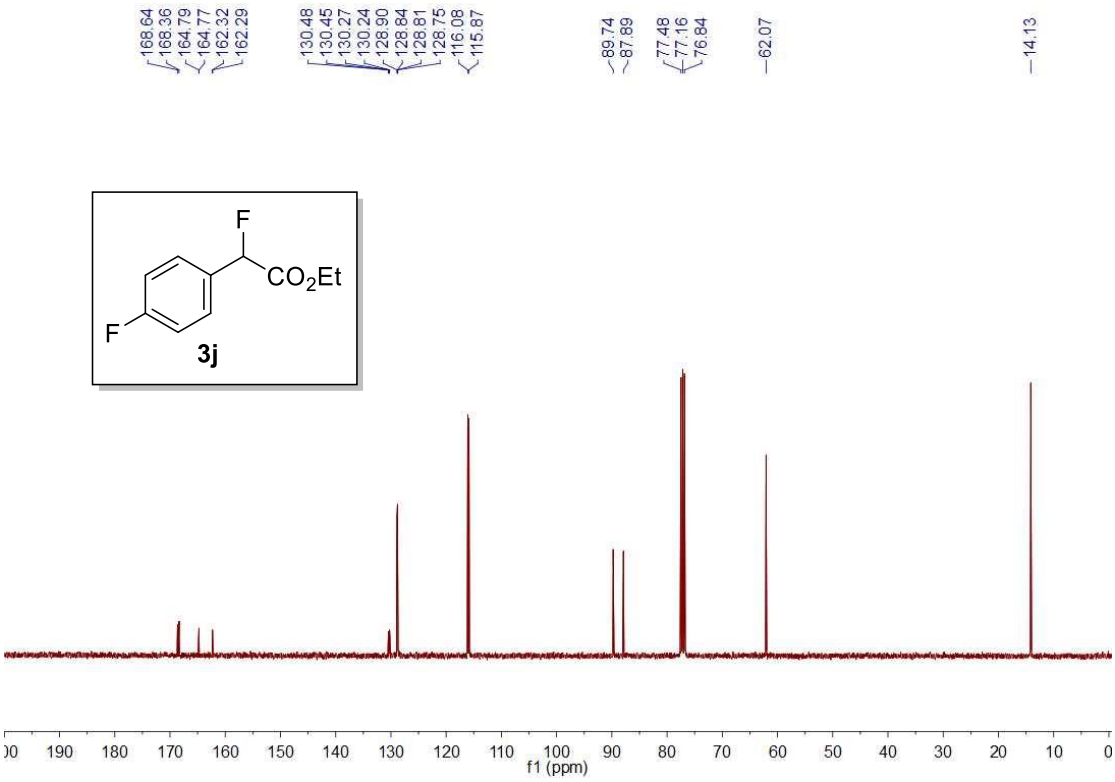
CO2Et
F
3j
1.92
1.93
1.00
2.03
3.03
f1 (ppm)

v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128.90
128.84
128.81
128.75
116.08
115.87
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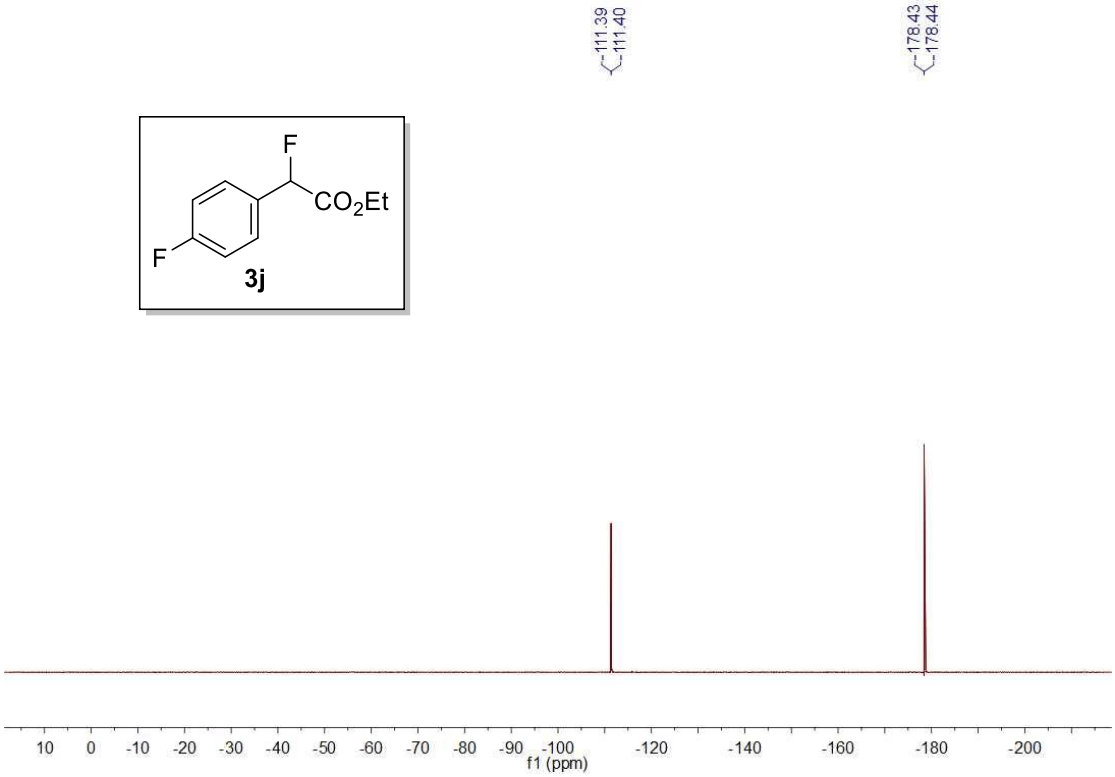
77.48
77.16
76.84
62.07
14.13
F
CO2Et
F
3j
f1 (ppm)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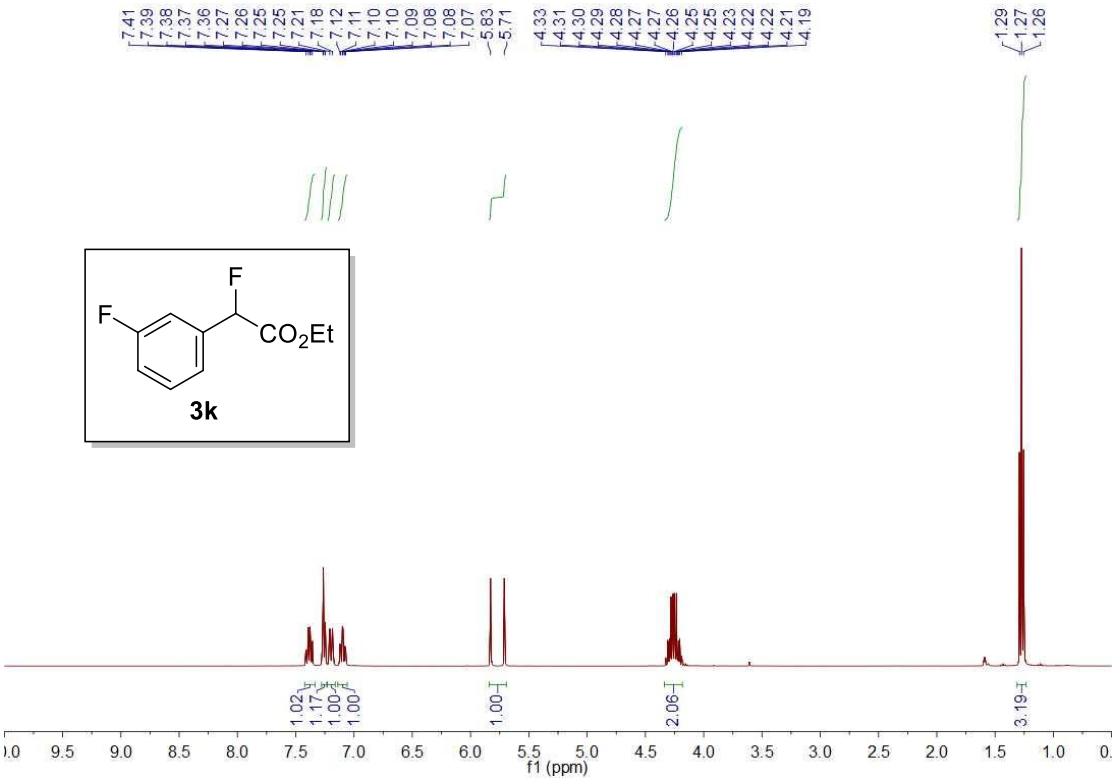
178.44
F
CO2Et
F
3j
f1 (ppm)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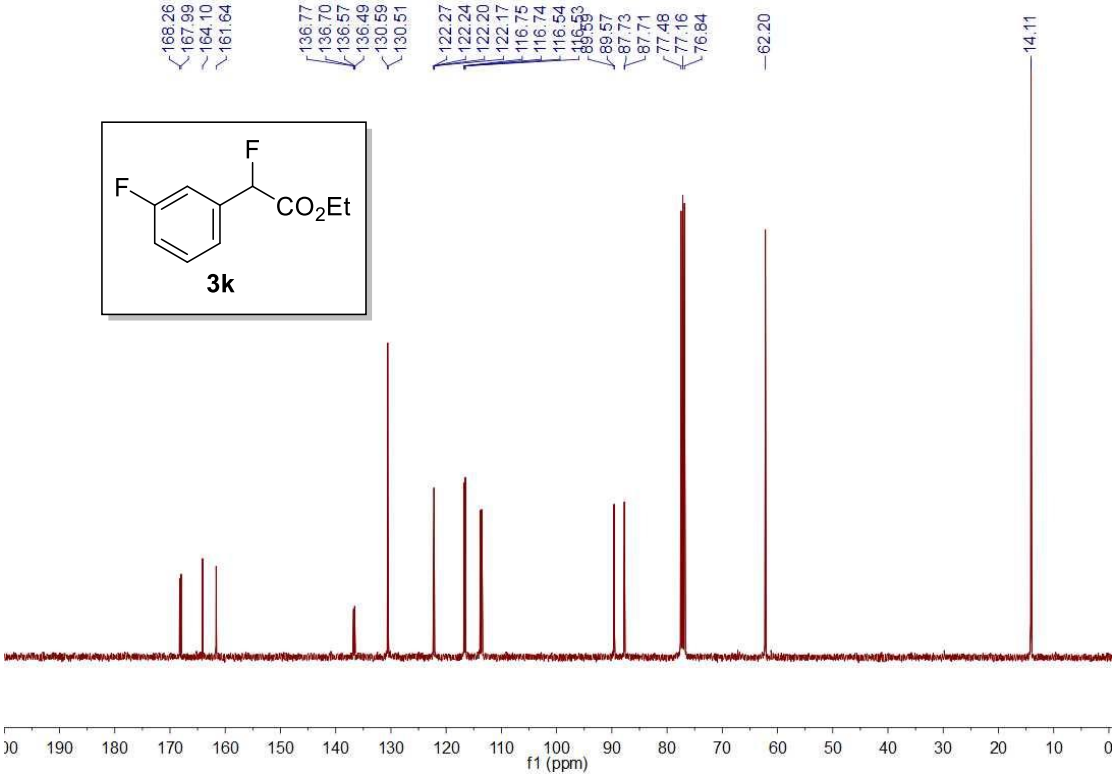
7.11
7.10
7.10
7.09
7.08
7.08
7.07
5.83
5.71
4.33
4.31
4.30
4.29
4.28
4.27
4.27
4.26
4.25
4.25
4.23
4.22
4.22
4.21
4.19
1.29
1.27
1.26
F
F
CO2Et
3k
1.02
1.17
1.00
1.00
1.00
2.06
3.19
f1 (ppm)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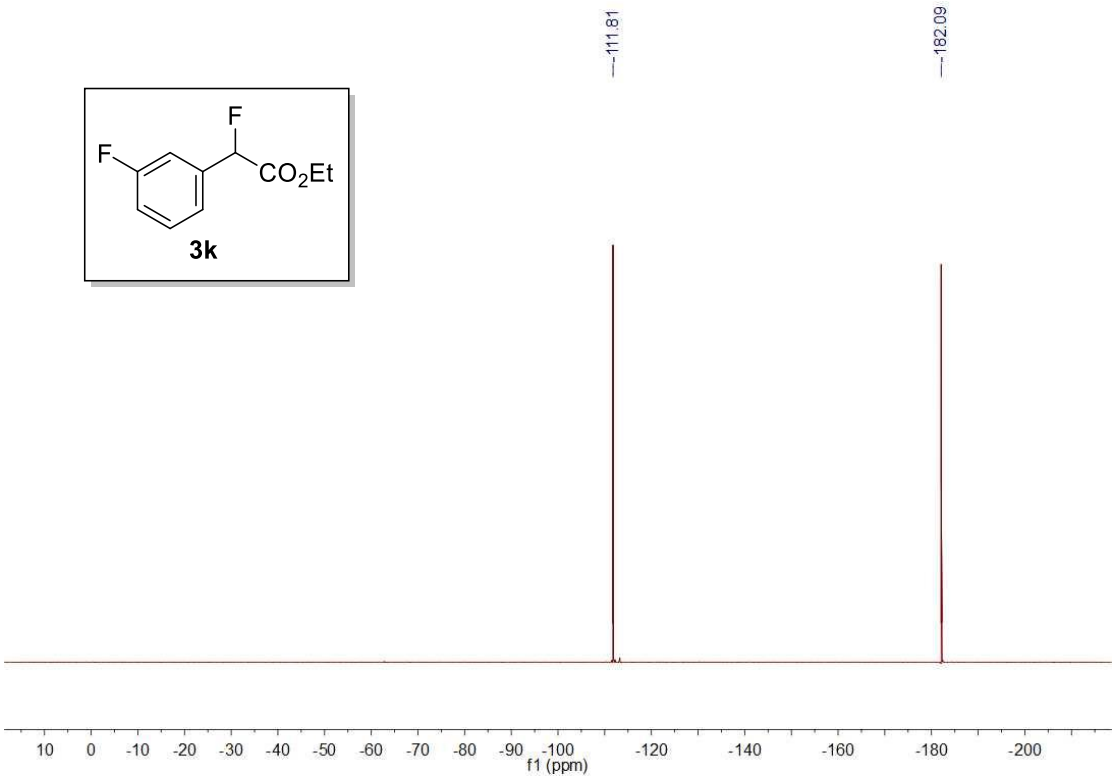
122.20
122.17
116.75
116.74
116.54
89.57
87.73
87.71
77.48
77.16
76.84
62.20
14.11
F
F
CO2Et
3k
f1 (ppm)


F
F
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3k
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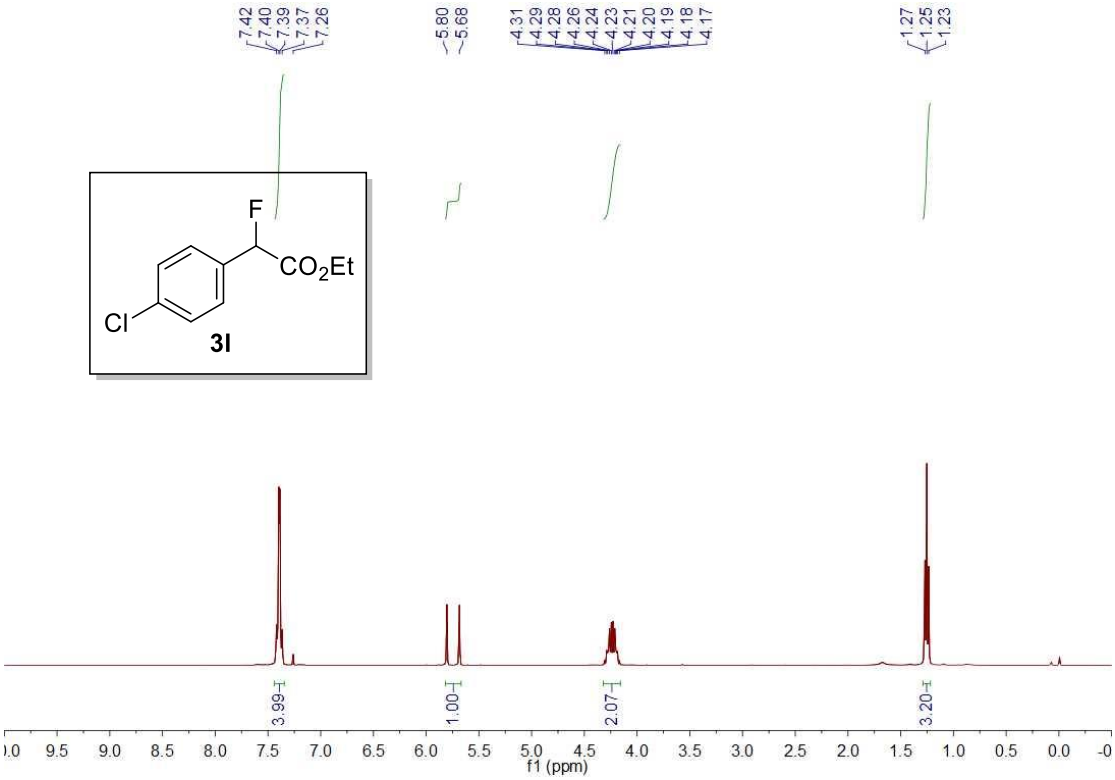
-182.09
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)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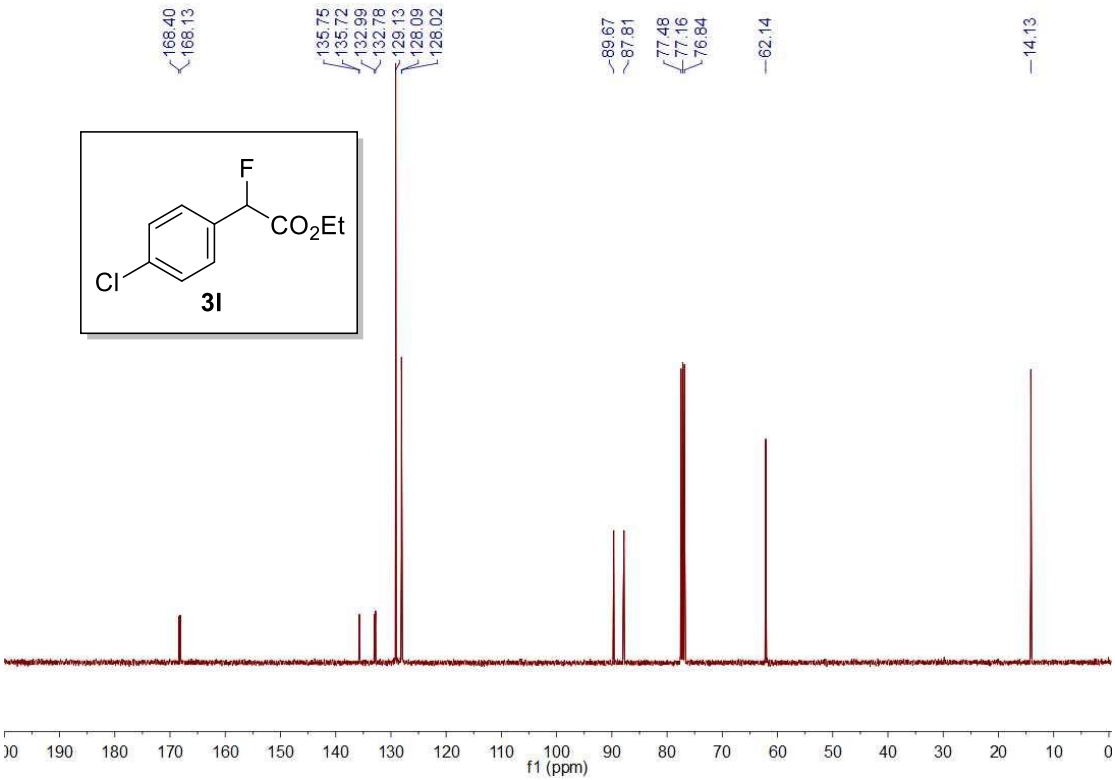
4.29
4.28
4.26
4.24
4.23
4.21
4.20
4.19
4.18
4.17
1.27
1.25
1.23
F
CO2Et
Cl
3l
3.99
1.00
2.07
3.20
f1 (ppm)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168.13
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135.72
132.99
132.78
129.13
128.09
128.02
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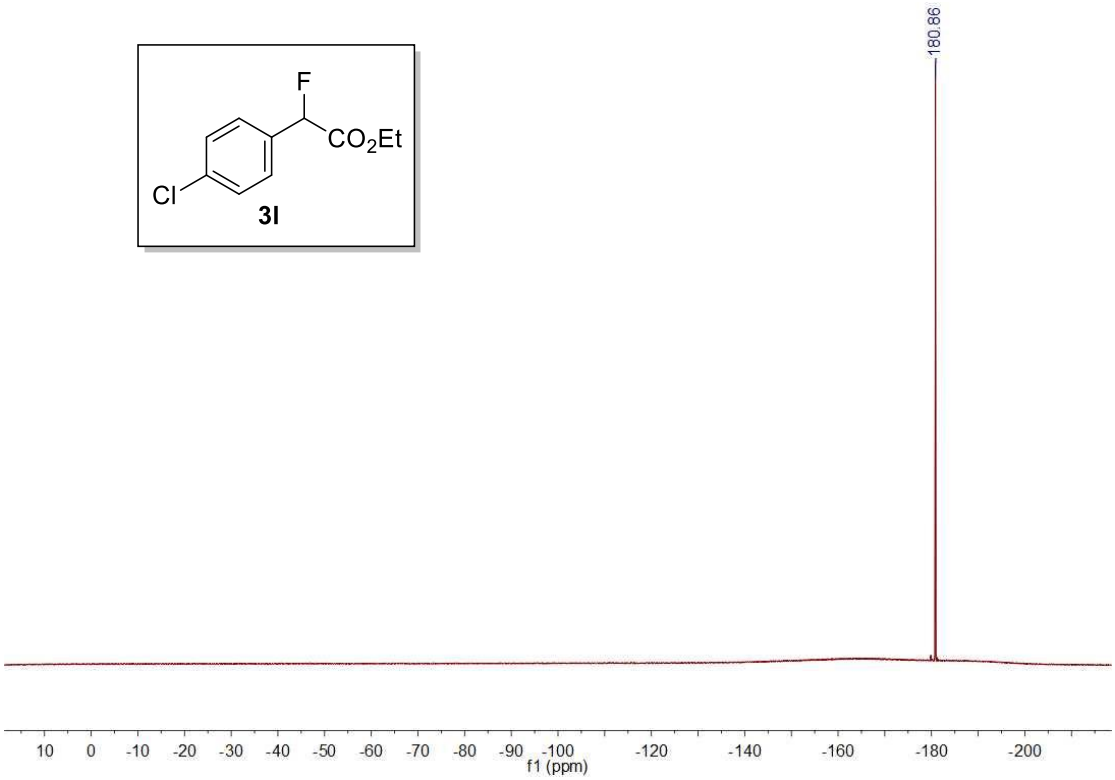
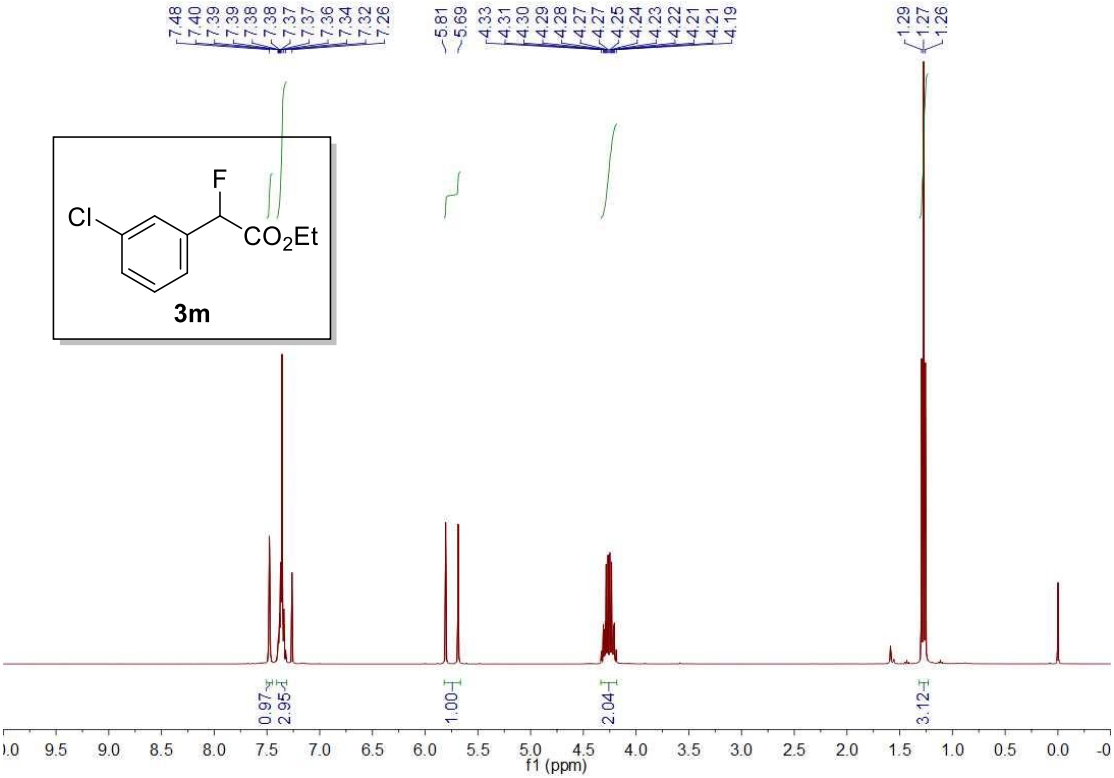
77.48
77.16
76.84
62.14
14.13
F
CO2Et
Cl
3l
f1 (ppm)


180.86
F
CO2Et
Cl
3l
f1 (ppm)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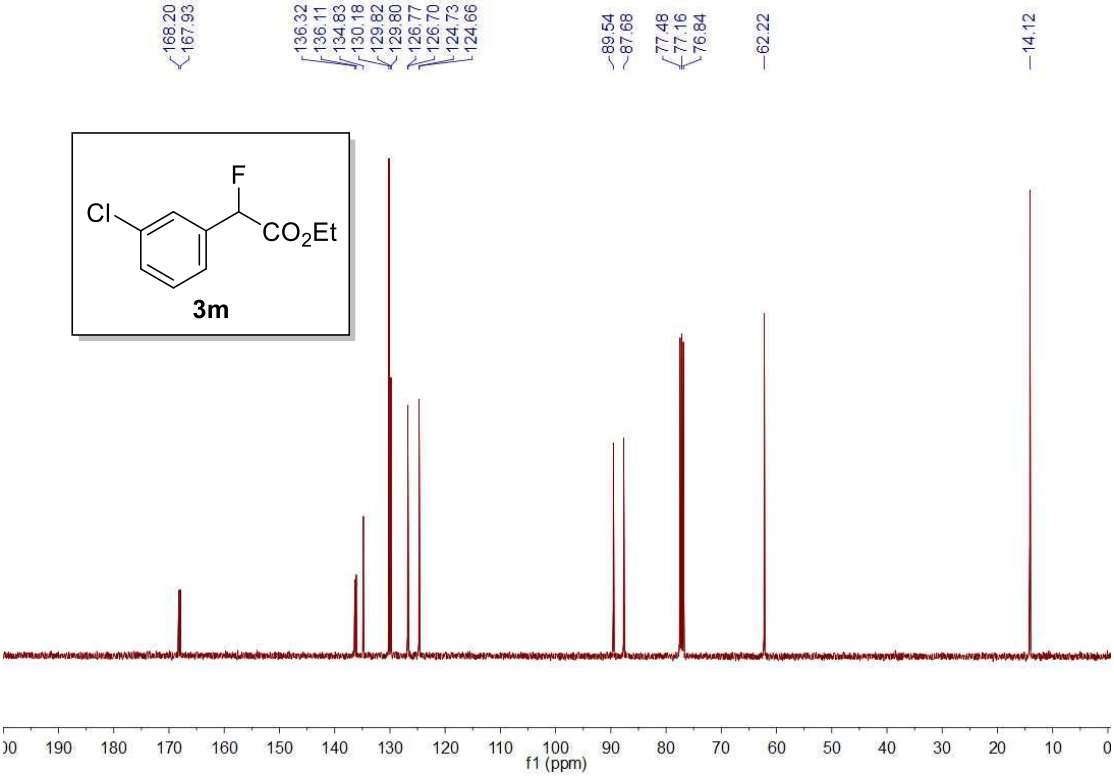
7.39
7.38
7.38
7.37
7.37
7.36
7.34
7.32
7.26
5.81
5.69
4.33
4.31
4.30
4.29
4.28
4.27
4.27
4.25
4.24
4.23
4.22
4.21
4.21
4.19
1.29
1.27
1.26
F
Cl
CO2Et
3m
0.97
2.95
1.00
2.04
3.12
f1 (ppm)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136.11
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130.18
129.82
129.80
126.77
126.70
124.73
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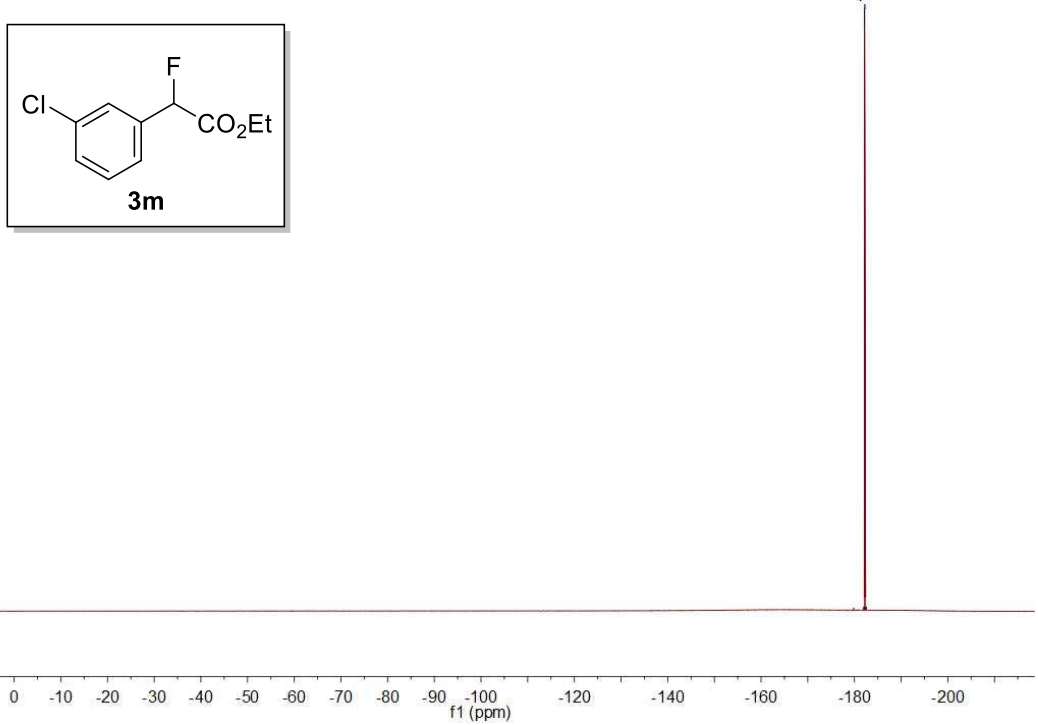
87.68
77.48
77.16
76.84
62.22
14.12
F
Cl
CO2Et
3m
f1 (ppm)


F
Cl
CO2Et
3m
182.16
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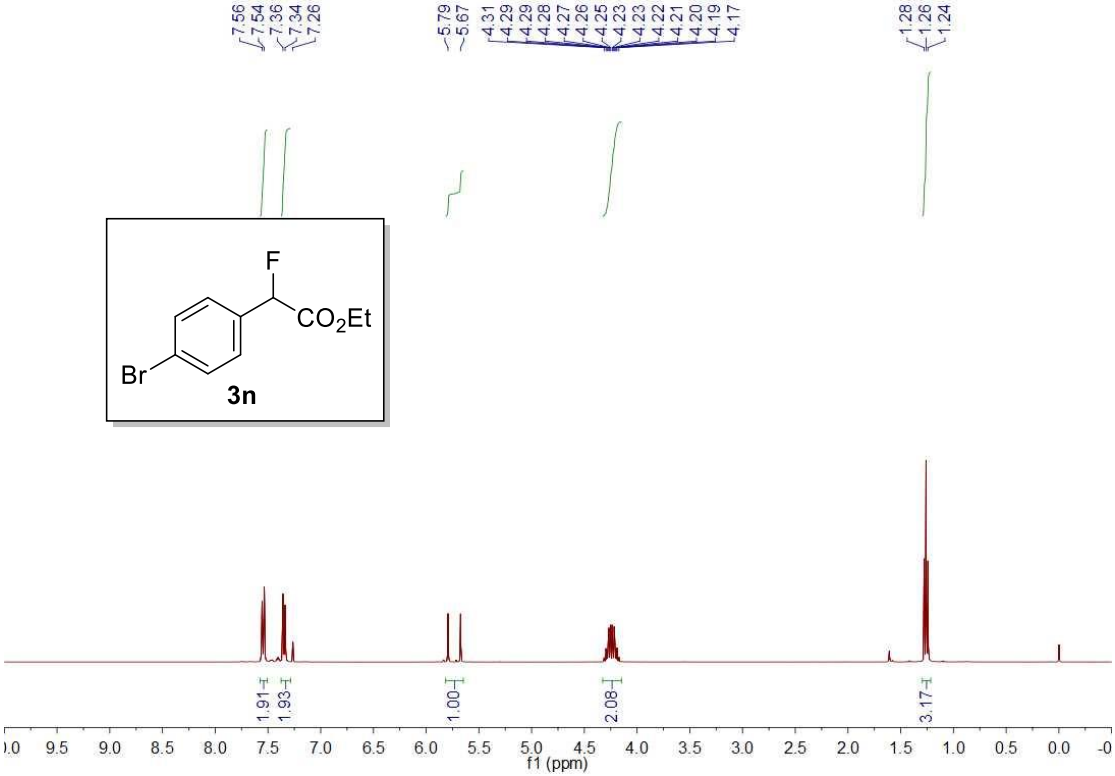
f1 (ppm)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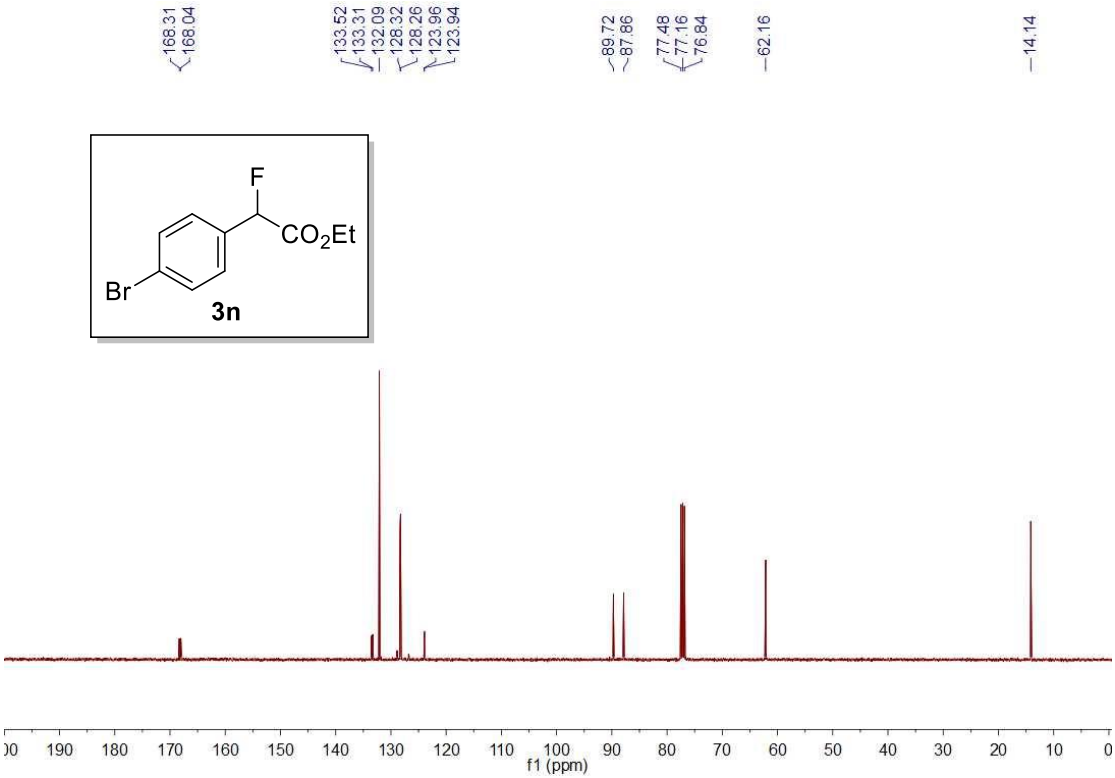
5.79
5.67
4.31
4.29
4.29
4.28
4.27
4.26
4.25
4.23
4.23
4.22
4.21
4.20
4.19
4.17
1.28
1.26
1.24
F
CO2Et
Br
3n
1.91
1.93
1.00
2.08
3.17
f1 (ppm)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132.09
128.32
128.26
123.96
123.94
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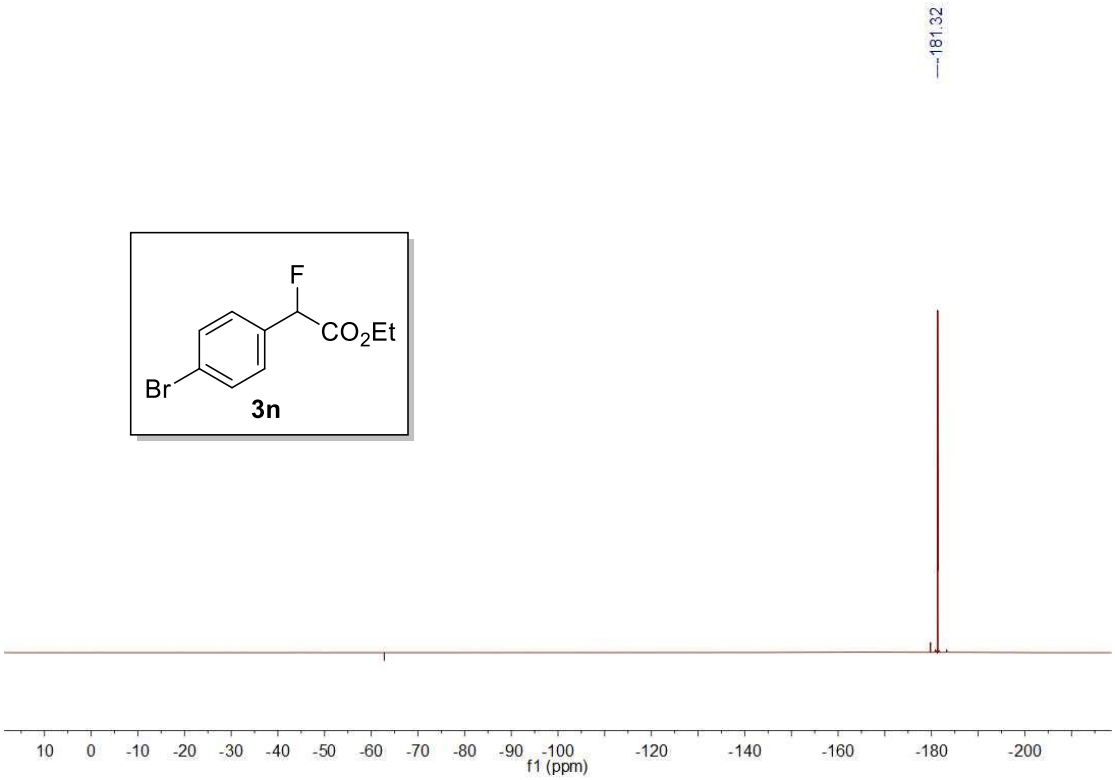
77.48
77.16
76.84
62.16
14.14
F
CO2Et
Br
3n
f1 (ppm)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F
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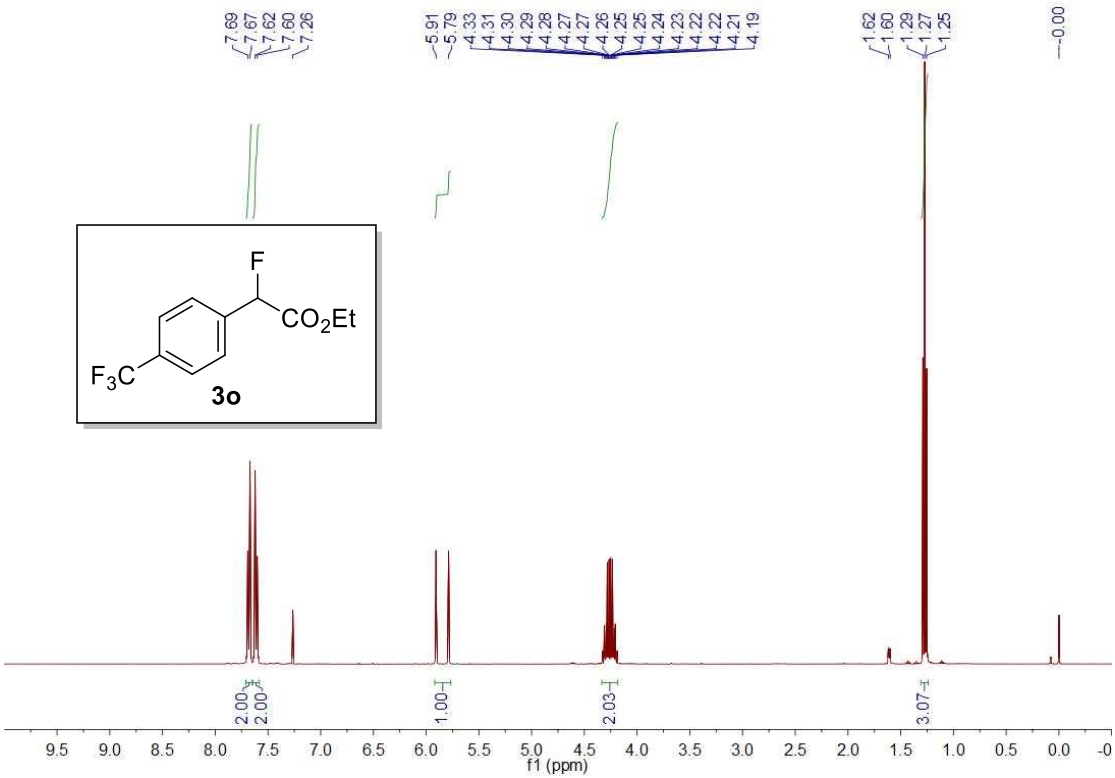
Br
3n
f1 (ppm)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7.62
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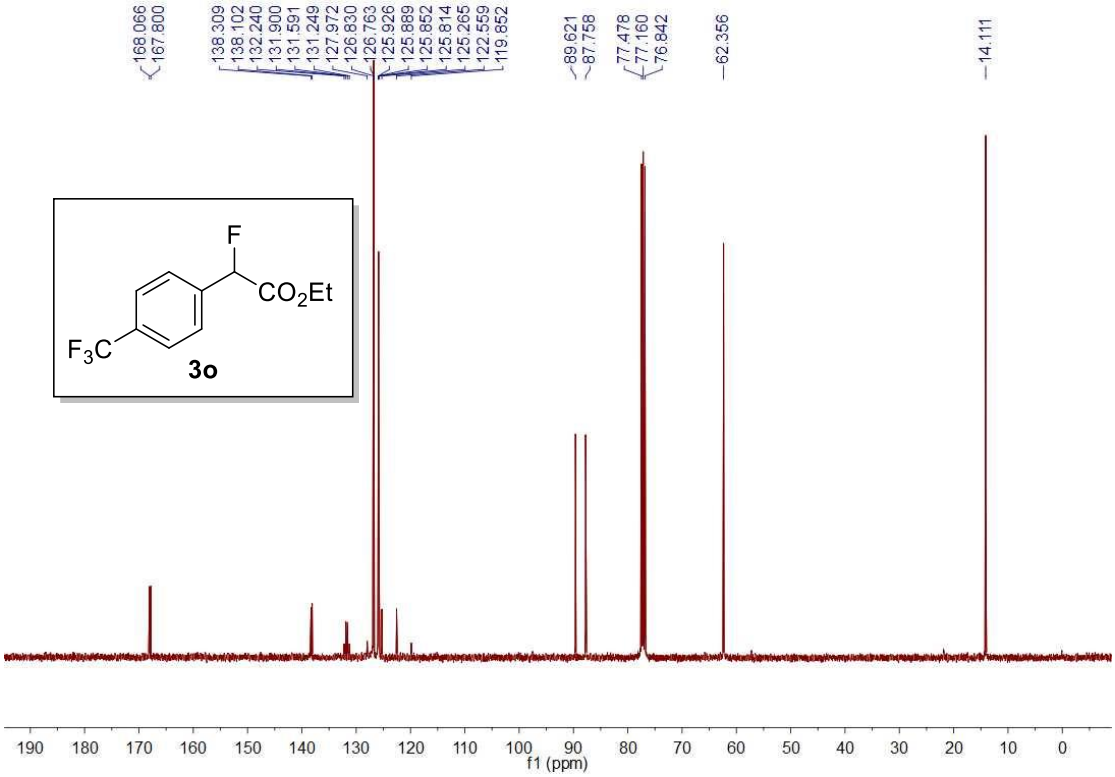
7.26
5.91
5.79
4.33
4.31
4.30
4.29
4.28
4.27
4.27
4.26
4.25
4.25
4.24
4.23
4.22
4.22
4.21
4.19
1.62
1.60
1.29
1.27
1.25
0.00
F
CO2Et
F3C
3o
2.00
2.00
1.00
2.03
3.07
f1 (ppm)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131.591
131.249
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126.830
126.763
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125.889
125.852
125.814
125.265
122.559
119.852
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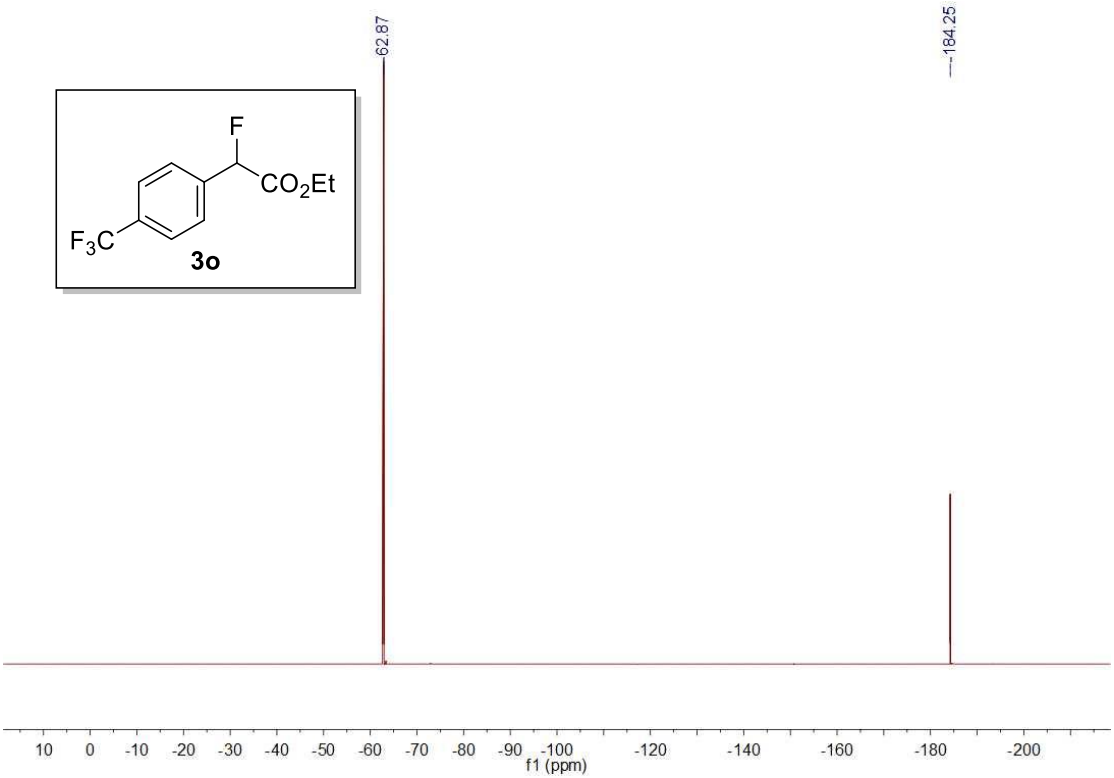
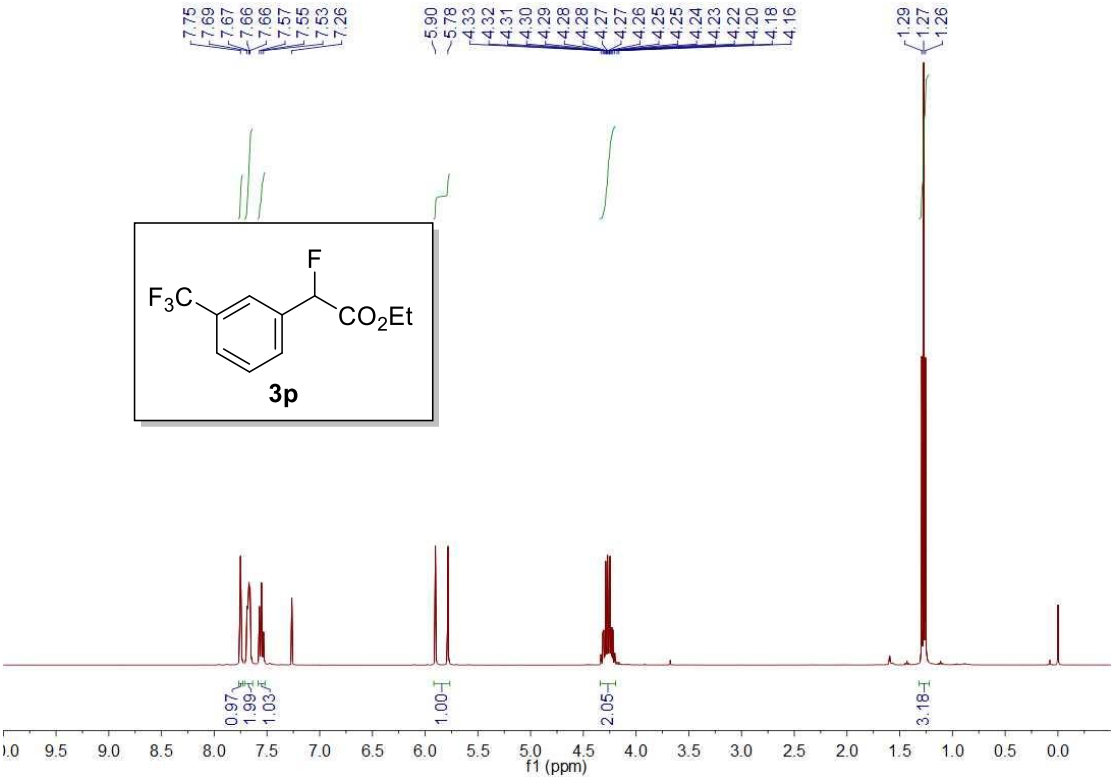
77.478
77.160
76.842
62.356
14.111
F
CO2Et
F3C
3o
f1 (ppm)


62.87
184.25
F
CO2Et
F3C
3o
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)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4.31
4.30
4.29
4.28
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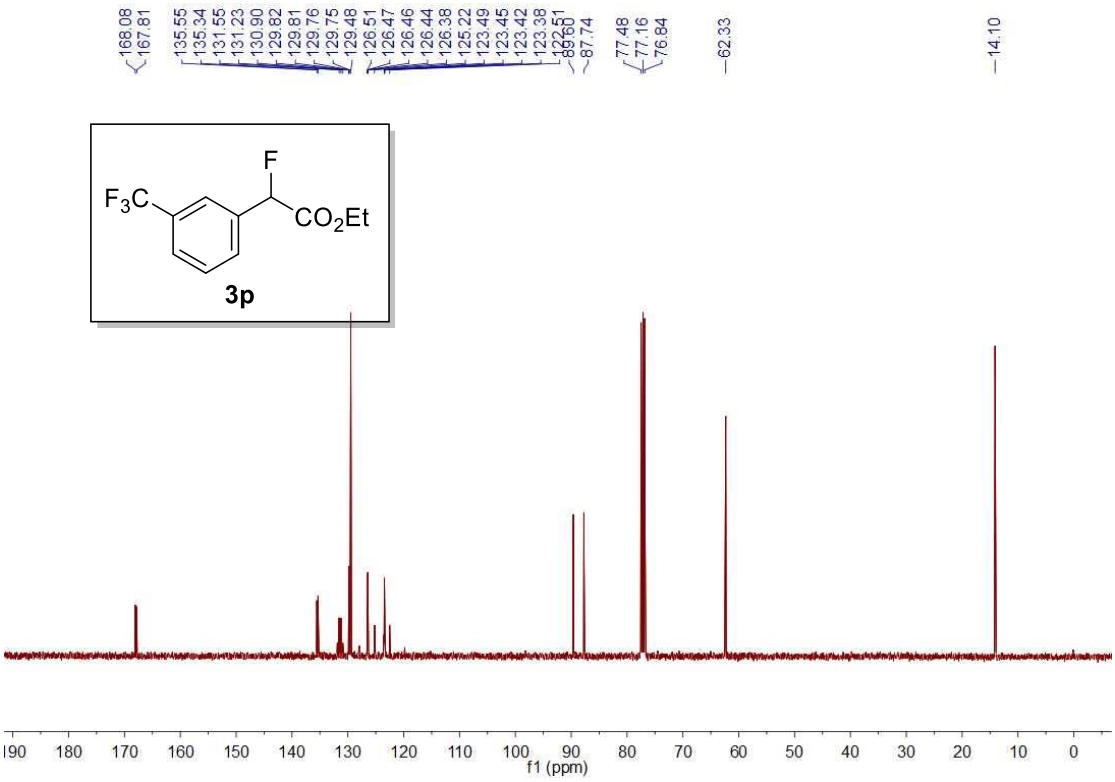
4.27
4.27
4.26
4.25
4.25
4.24
4.23
4.22
4.20
4.18
4.16
1.29
1.27
1.26
F
F3C
CO2Et
3p
0.97
1.99
1.03
1.00
2.05
3.18
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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126.47
126.46
126.44
126.38
125.22
123.49
123.45
123.42
123.38
122.51
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77.16
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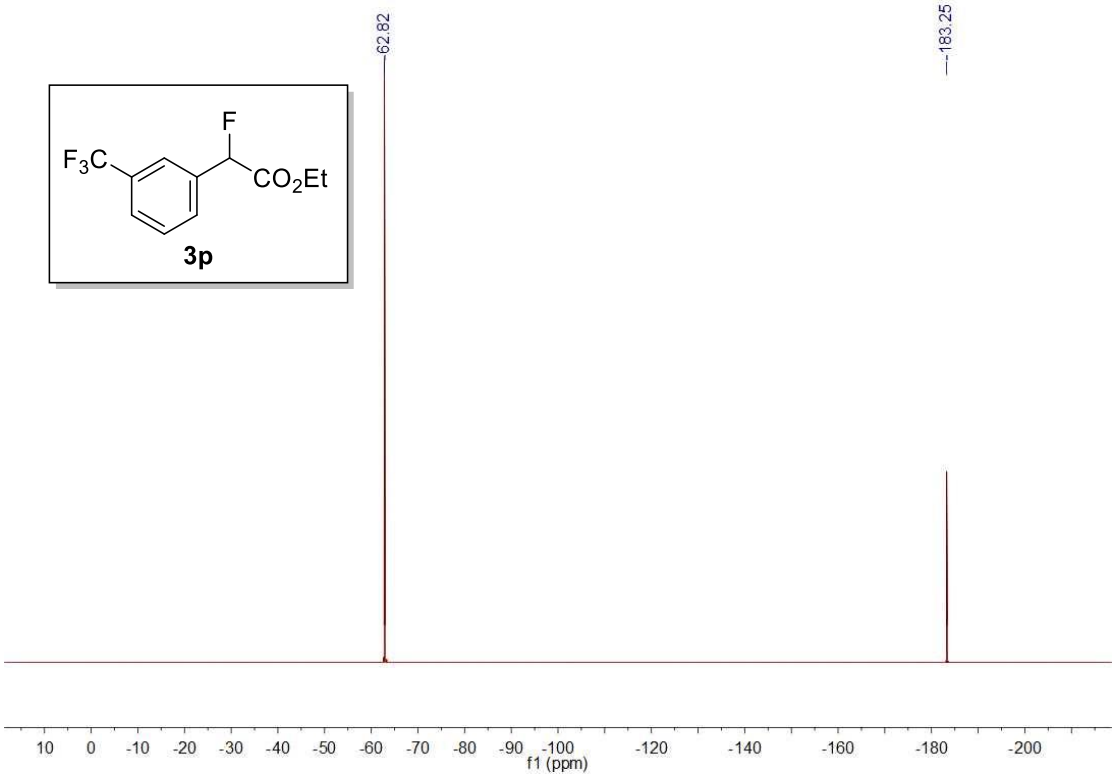
14.10
F
F3C
CO2Et
3p
f1 (ppm)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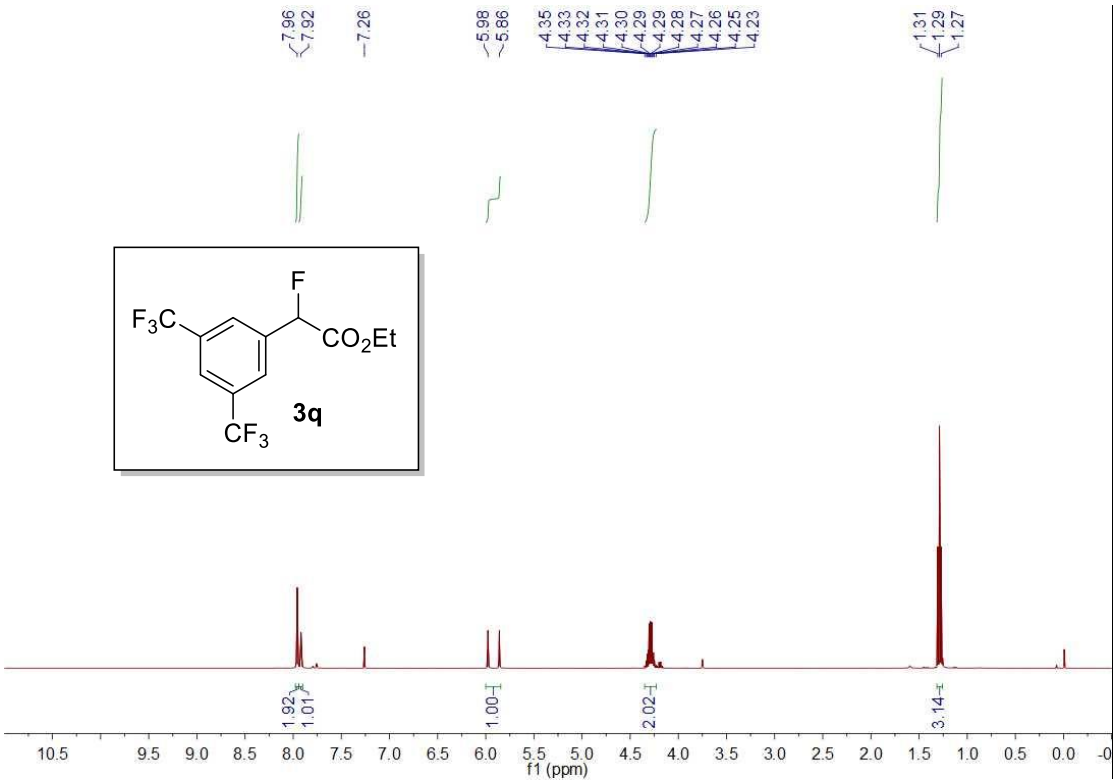
f1 (ppm)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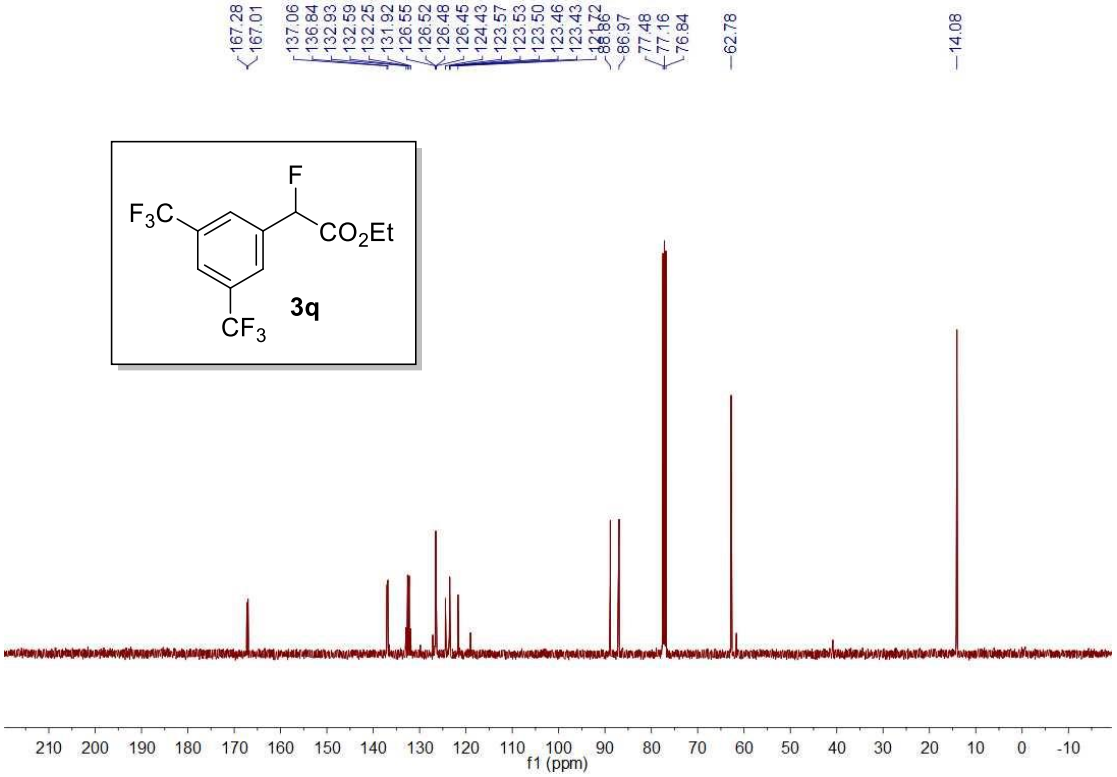
4.30
4.29
4.29
4.28
4.27
4.26
4.25
4.23
1.31
1.29
1.27
F
F3C
CO2Et
CF3
3q
1.92
1.01
1.00
2.02
3.14
f1 (ppm)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126.48
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124.43
123.57
123.53
123.50
123.46
123.43
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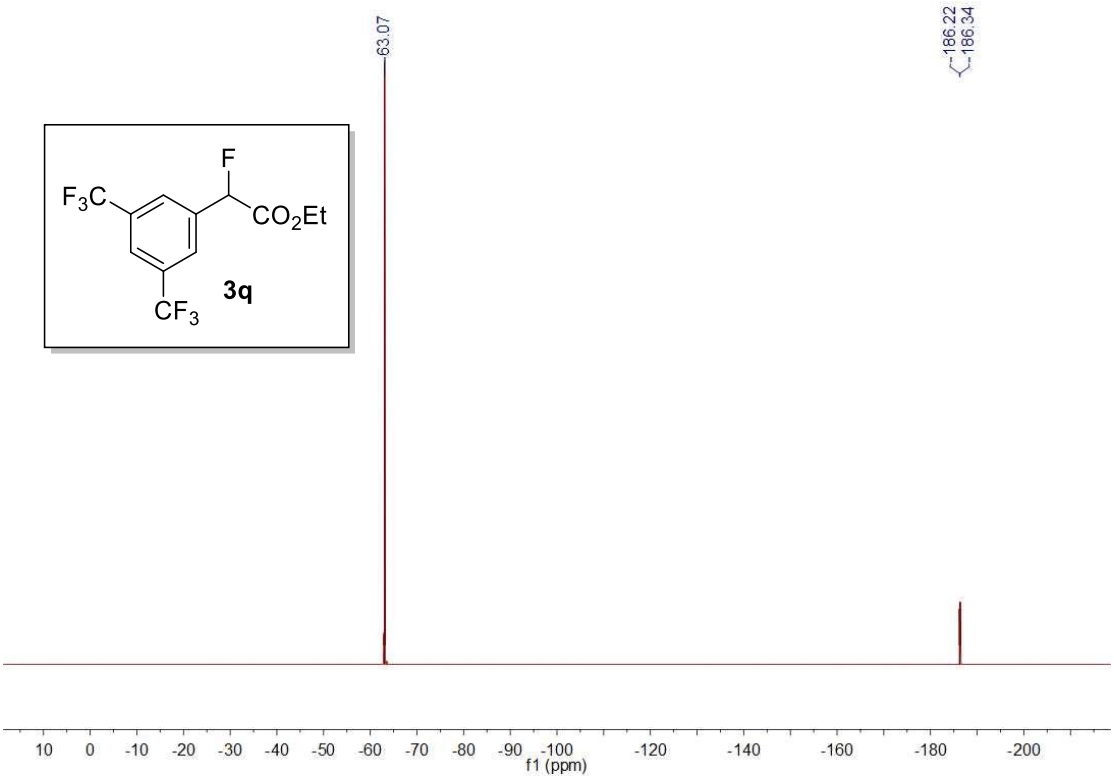
77.16
76.84
62.78
14.08
F
F3C
CO2Et
CF3
3q
f1 (ppm)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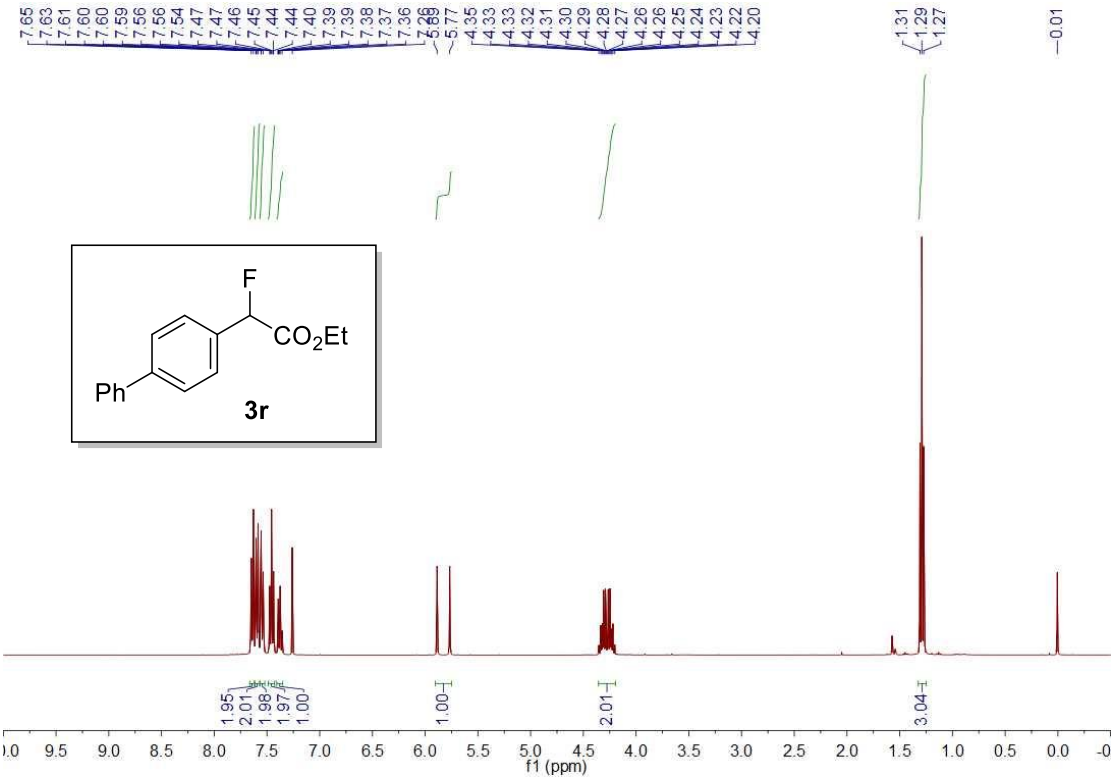
CO2Et
CF3
3q
f1 (ppm)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4.28
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4.26
4.26
4.25
4.24
4.23
4.22
4.20
1.31
1.29
1.27
0.01
F
CO2Et
Ph
3r
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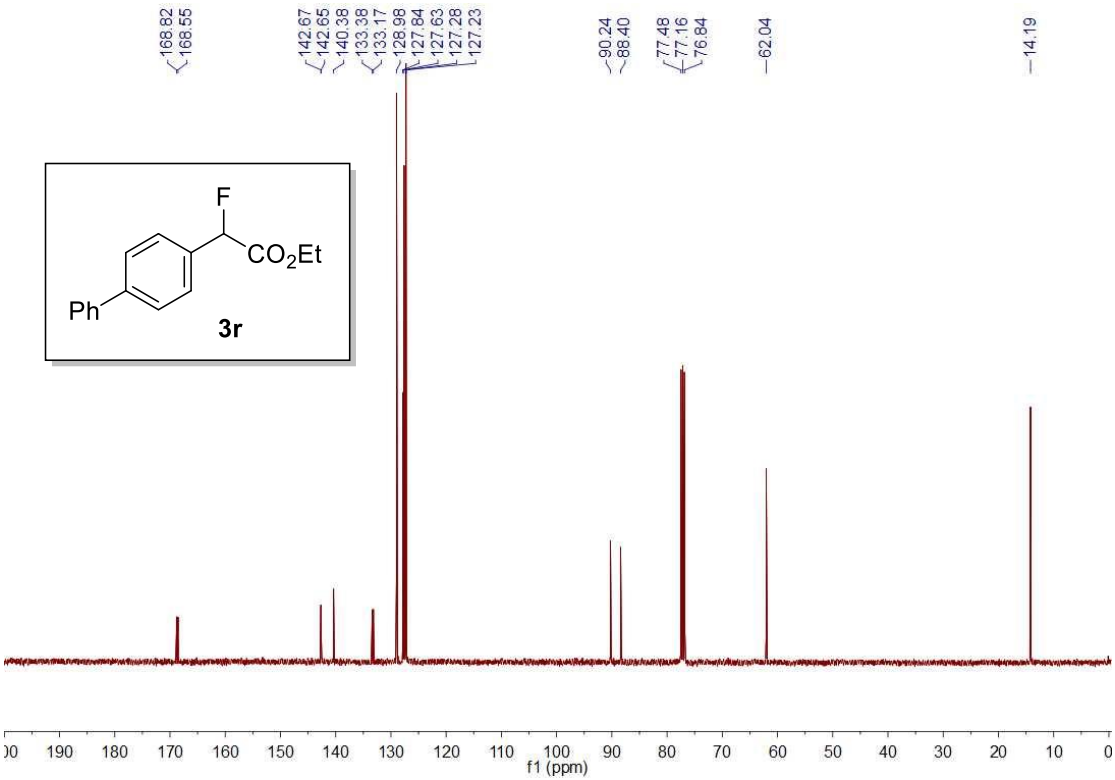
2.01
1.98
1.97
1.00
1.00
2.01
3.04
f1 (ppm)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127.28
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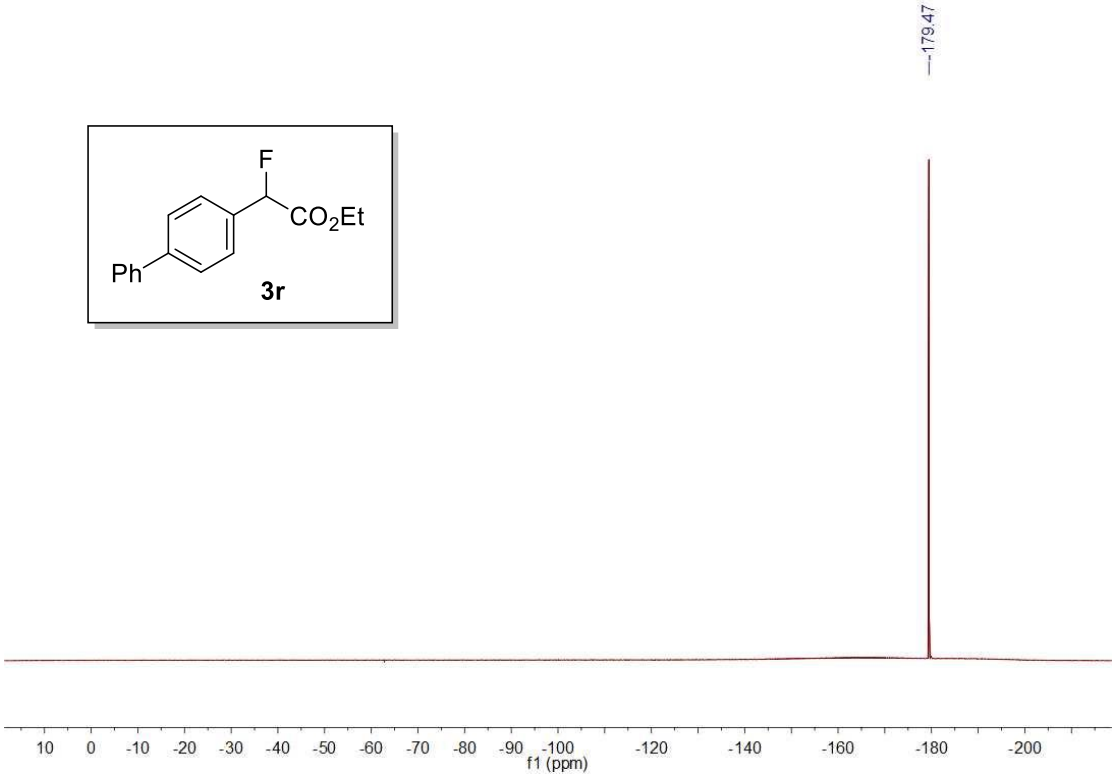
77.48
77.16
76.84
62.04
14.19
F
CO2Et
Ph
3r
f1 (ppm)


179.47
F
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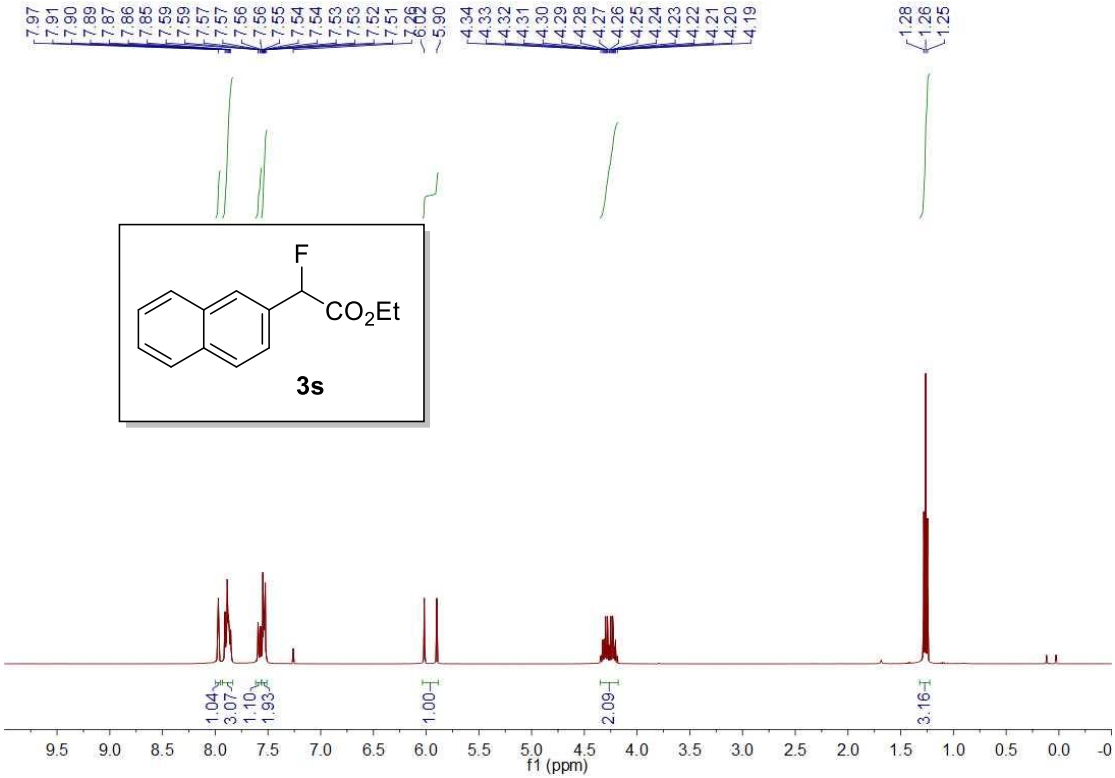
Ph
3r
f1 (ppm)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4.26
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4.24
4.23
4.22
4.21
4.20
4.19
1.28
1.26
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3s
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3.07
1.10
1.93
1.00
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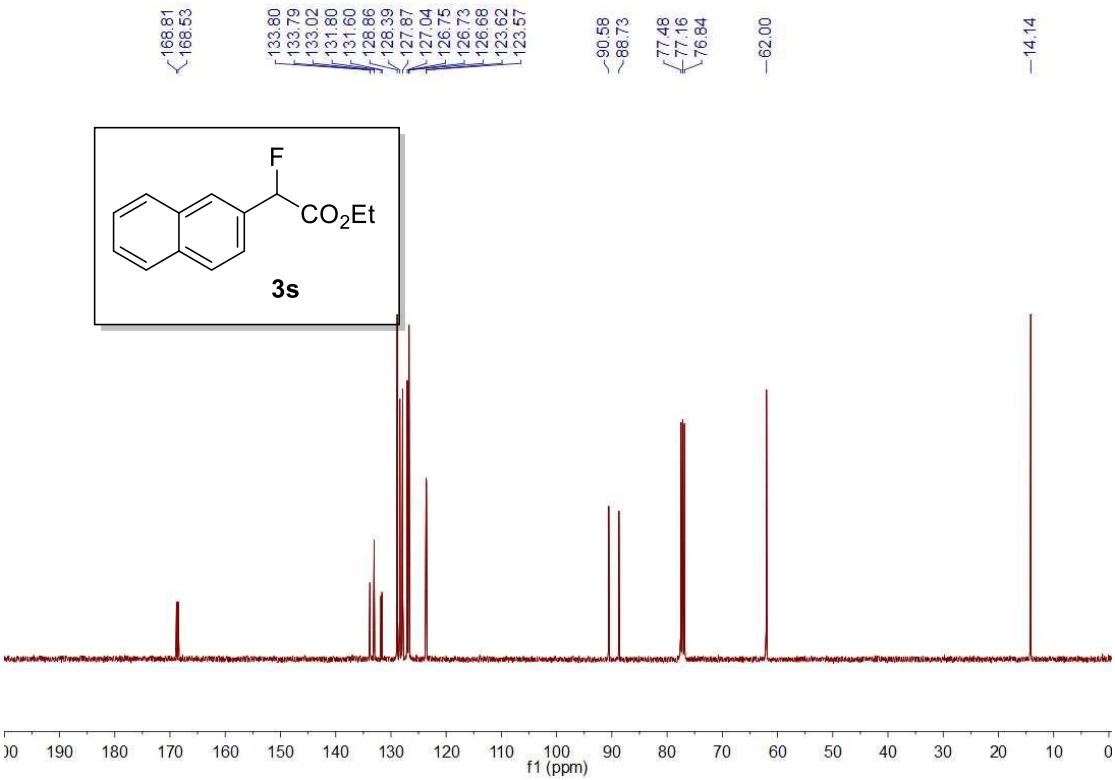
3.16
f1 (ppm)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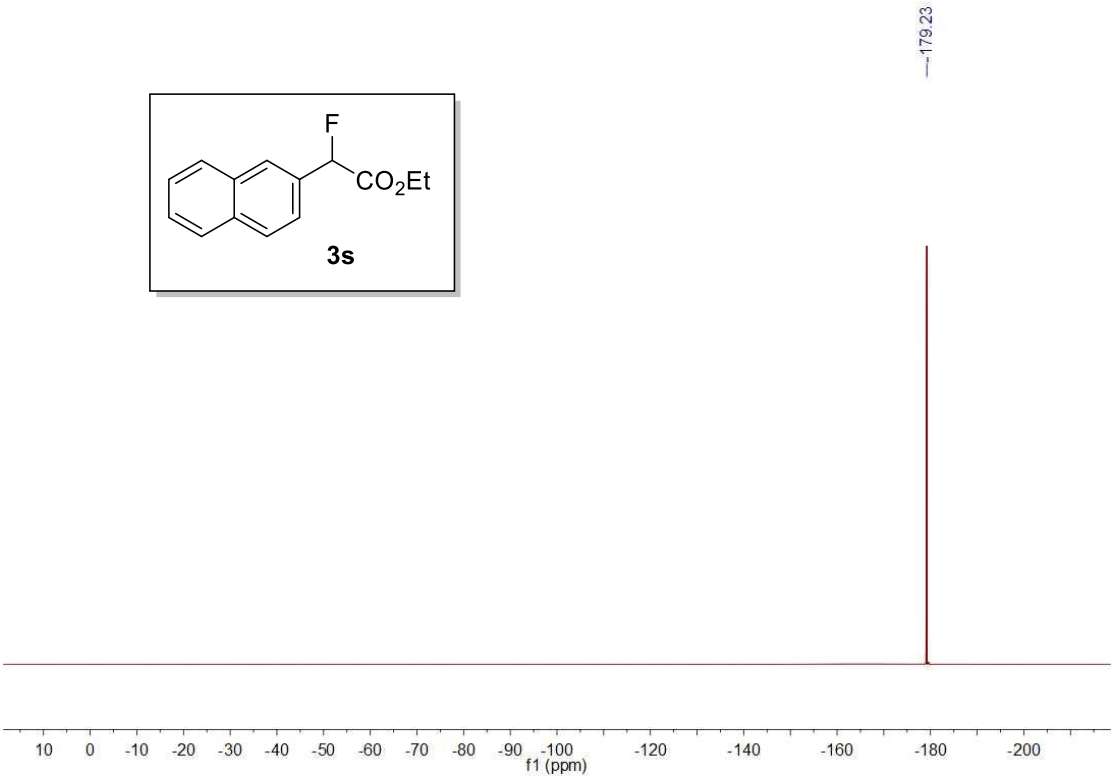
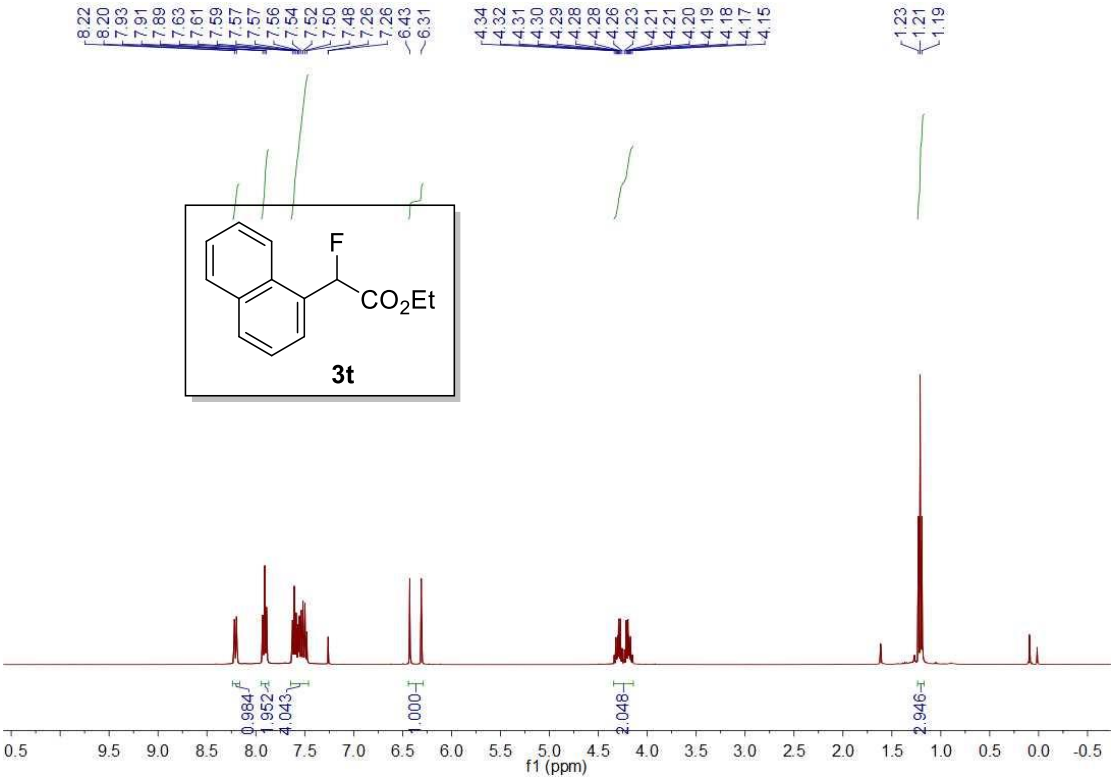
77.16
76.84
62.00
14.14
F
CO2Et
3s
f1 (ppm)


F
CO2Et
3s
179.23
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)


8.22
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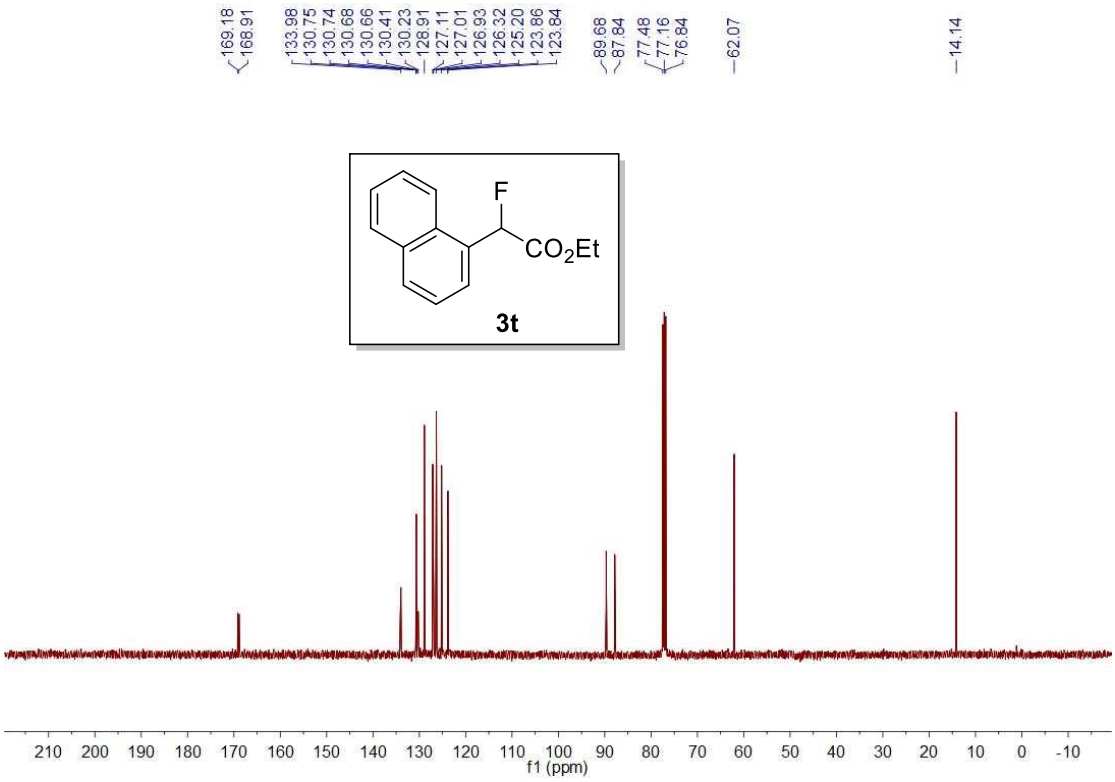
7.91
7.89
7.63
7.61
7.59
7.57
7.57
7.56
7.54
7.52
7.50
7.48
7.26
7.26
6.43
6.31
4.34
4.32
4.31
4.30
4.29
4.28
4.28
4.26
4.23
4.21
4.21
4.20
4.19
4.18
4.17
4.15
1.23
1.21
1.19
F
CO2Et
3t
0.984
1.952
4.043
1.000
2.048
2.946
0.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


169.18
168.91
133.98
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130.74
130.68
130.66
130.41
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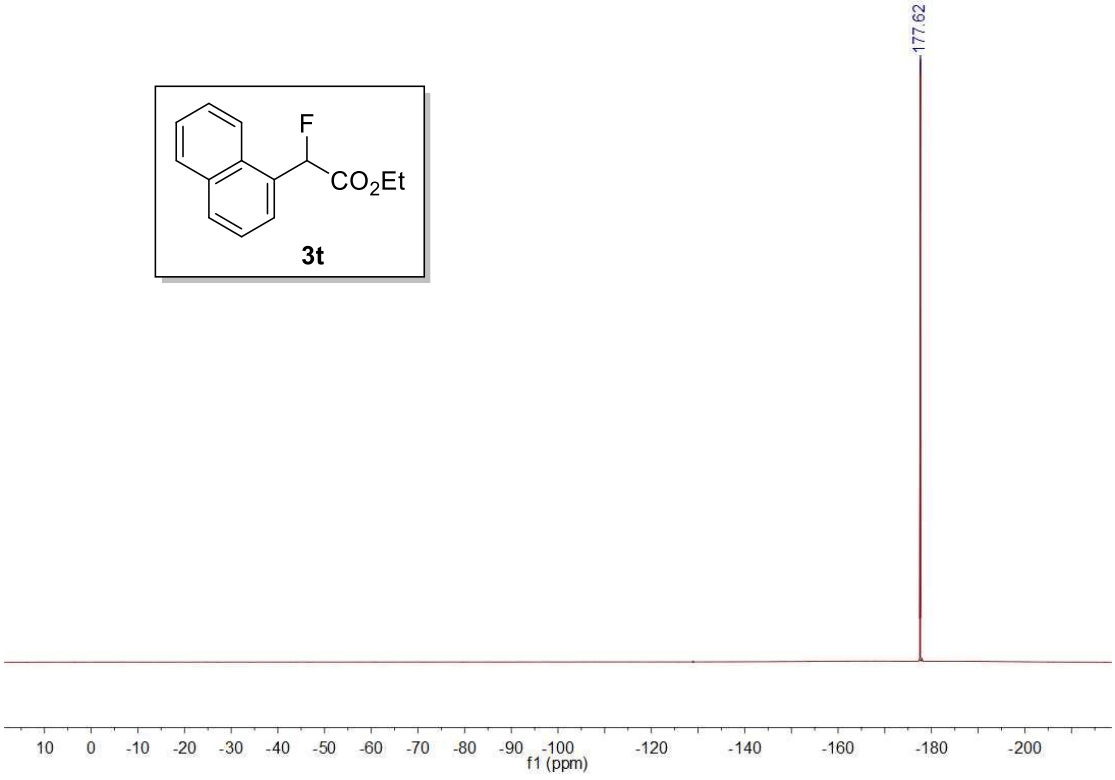
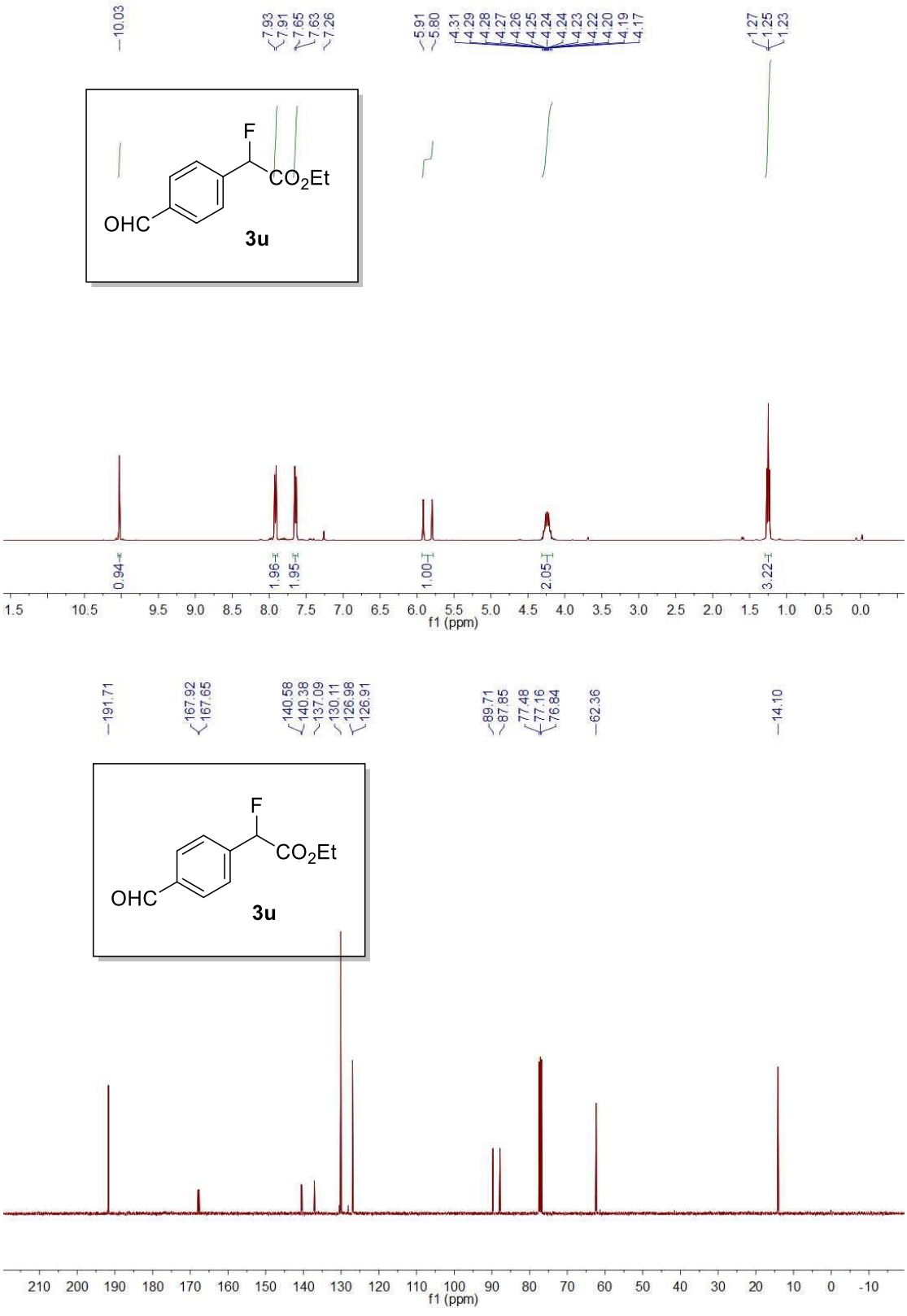
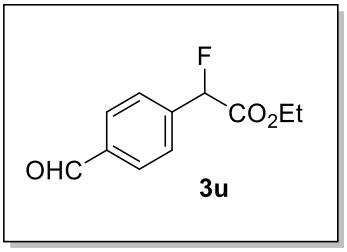
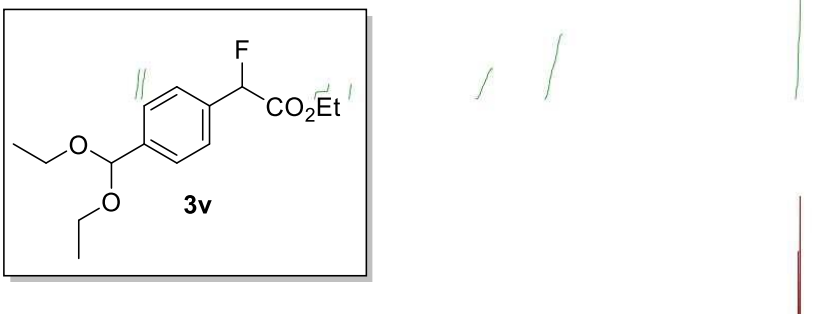
128.91
127.11
127.01
126.93
126.32
125.20
123.86
123.84
89.68
87.84
77.48
77.16
76.84
62.07
14.14
F
CO2Et
3t
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


177.62
F
CO2Et
3t
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)

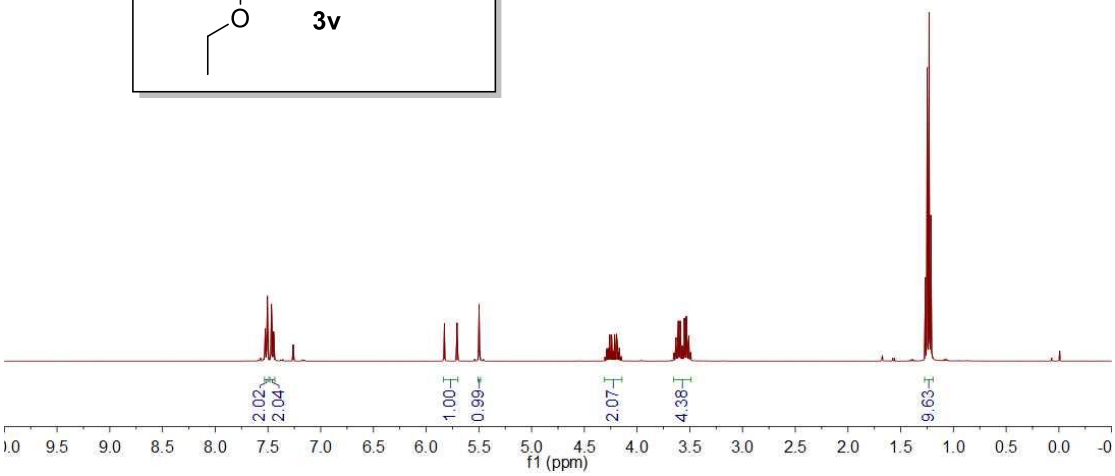

10.03
7.93
7.91
7.65
7.63
7.26
5.91
5.80
4.31
4.29
4.28
4.27
4.26
4.25
4.24
4.24
4.23
4.22
4.20
4.19
4.17
1.27
1.25
1.23
F
CO2Et
OHC
3u
0.94
1.96
1.95
1.00
2.05
3.22
f1 (ppm)
191.71
167.92
167.65
140.58
140.38
137.09
130.11
126.98
126.91
89.71
87.85
77.48
77.16
76.84
62.36
14.10
F
CO2Et
OHC
3u
f1 (ppm)

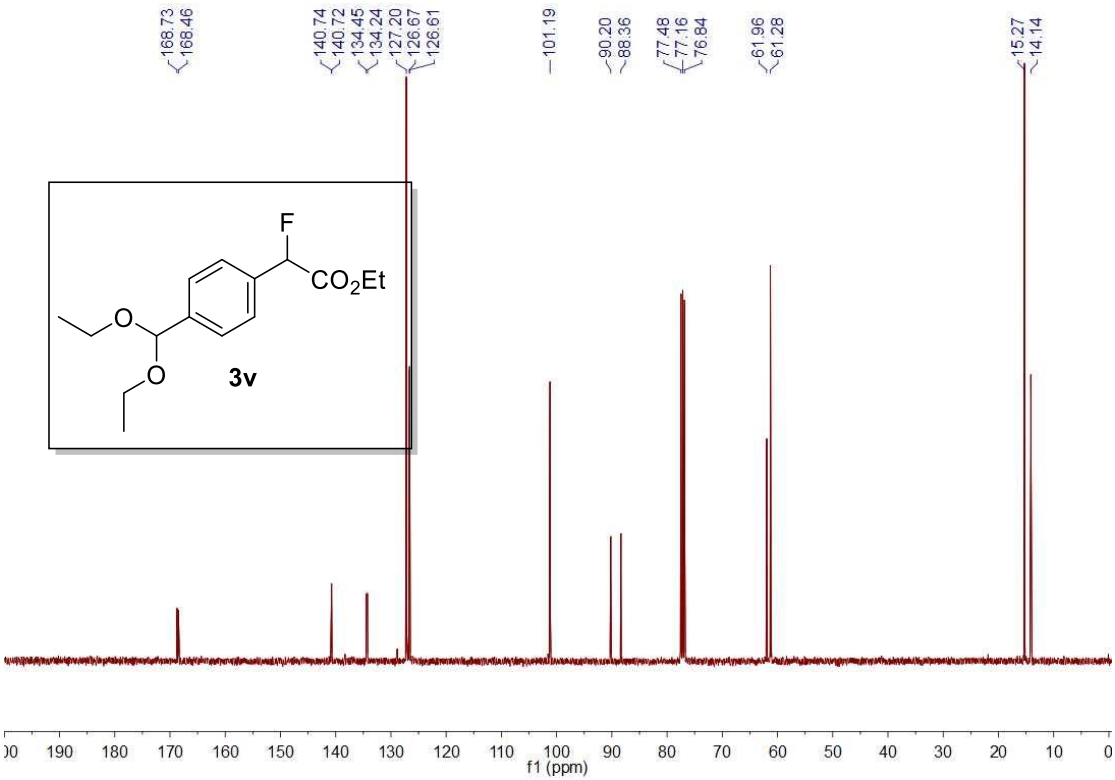

F
CO2Et
OHC
3u

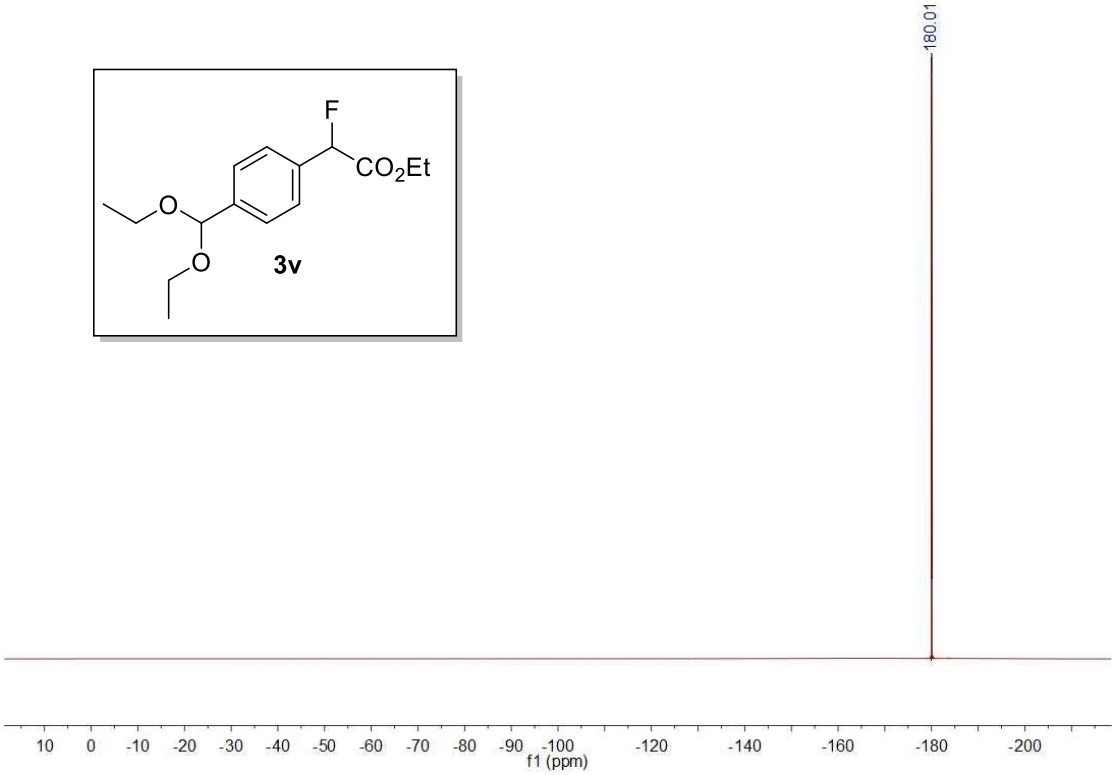
184.69
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)

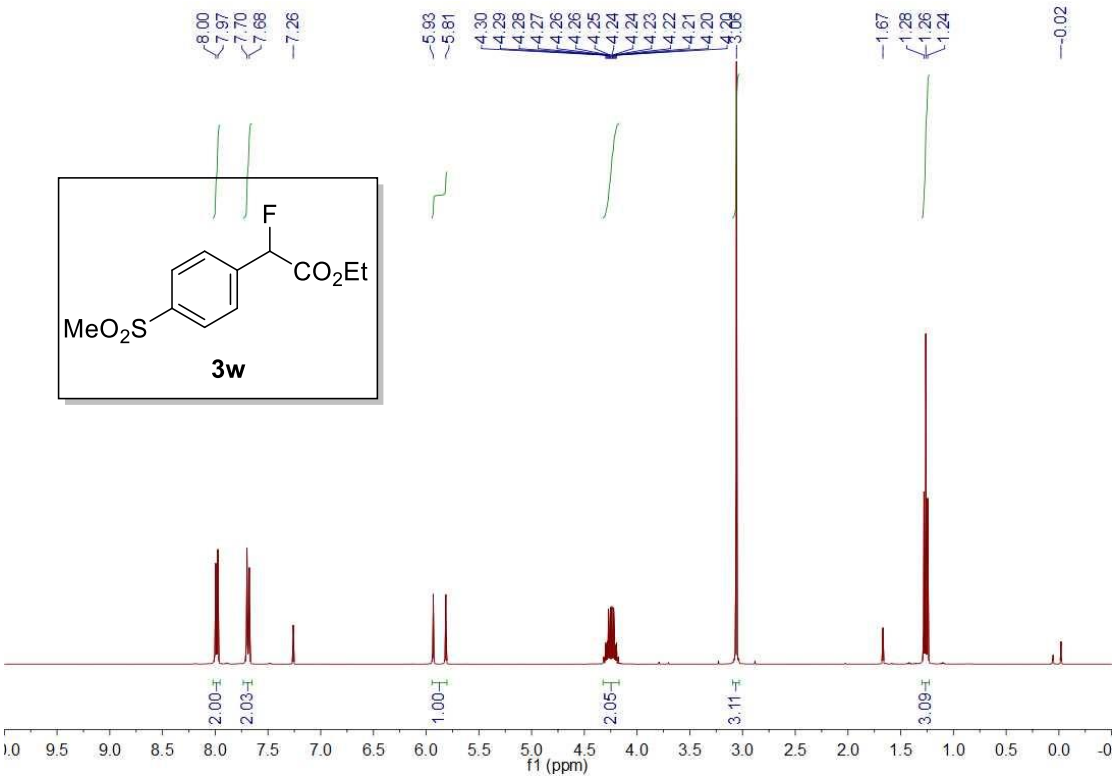

7.53
7.51
7.47
7.45
7.26
5.83
5.71
5.50
4.29
4.27
4.26
4.24
4.21
4.19
4.19
4.17
3.63
3.63
3.61
3.61
3.59
3.57
3.57
3.55
3.53
3.53
3.52
1.25
1.23
1.21

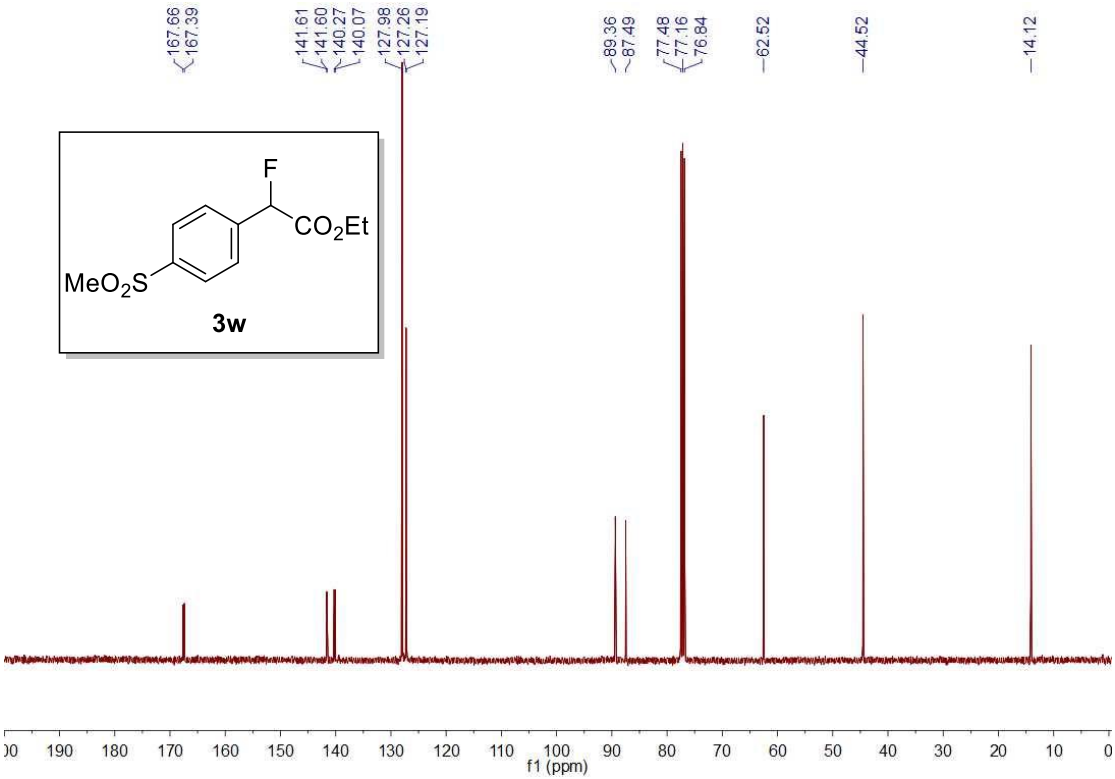
F
CO2Et
O
O
3v

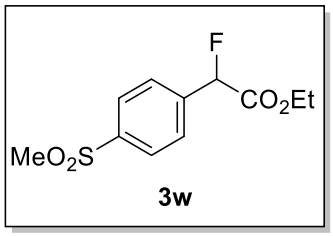

2.02
2.04
1.00
0.99
2.07
4.38
9.63
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


168.73
168.46
140.74
140.72
134.45
134.24
127.20
126.67
126.61
101.19
90.20
88.36
77.48
77.16
76.84
61.96
61.28
15.27
14.14
F
CO2Et
O
O
3v
f1 (ppm)


180.01
F
CO2Et
O
O
3v
f1 (ppm)

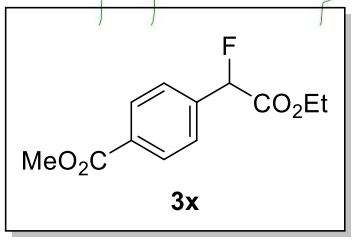

8.00
7.97
7.70
7.68
7.26
5.93
5.81
4.30
4.29
4.28
4.27
4.26
4.26
4.25
4.24
4.24
4.23
4.22
4.21
4.20
3.66
1.67
1.28
1.26
1.24
-0.02
F
CO2Et
MeO2S
3w
2.00
2.03
1.00
2.05
3.11
3.09
f1 (ppm)


167.66
167.39
141.61
141.60
140.27
140.07
127.98
127.26
127.19
89.36
87.49
77.48
77.16
76.84
62.52
44.52
14.12
F
CO2Et
MeO2S
3w
f1 (ppm)


F
CO2Et
MeO2S

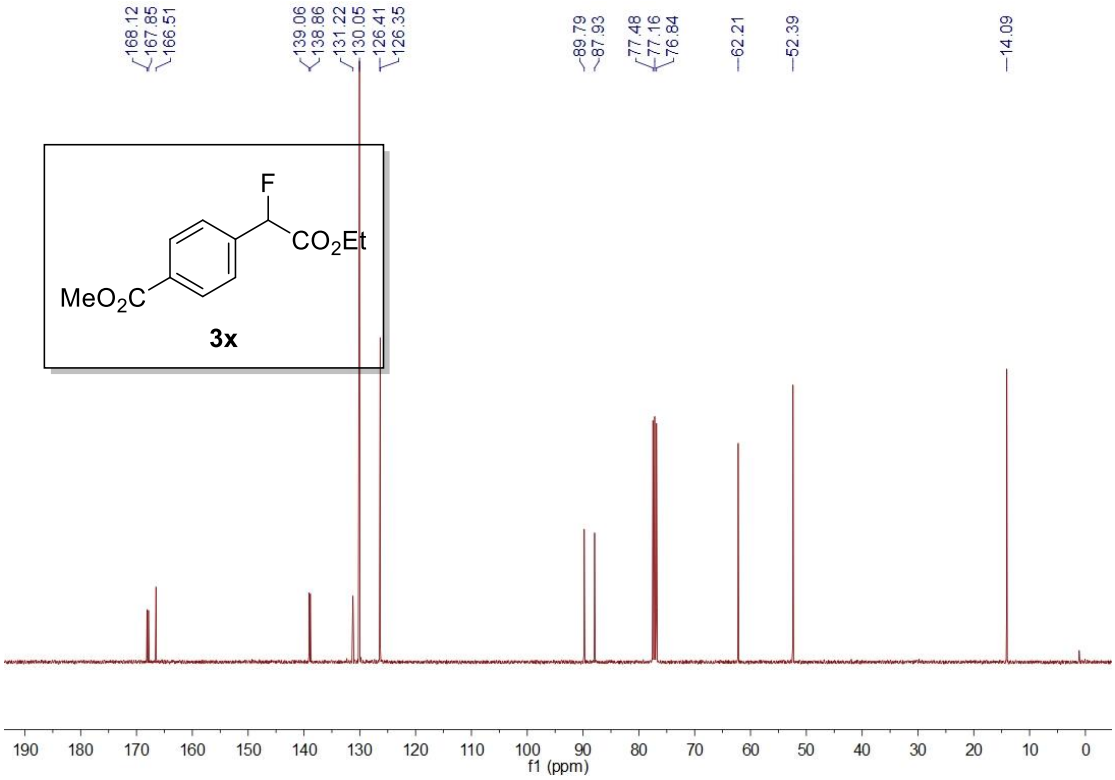
3w

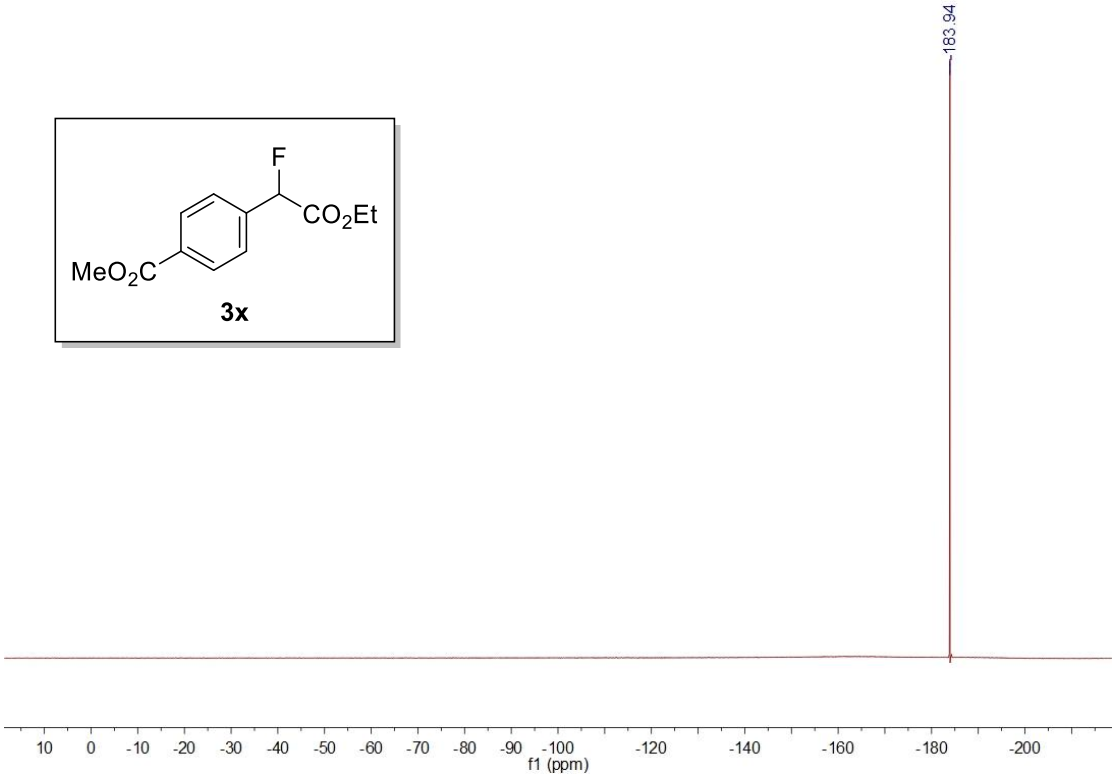
185.55
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)

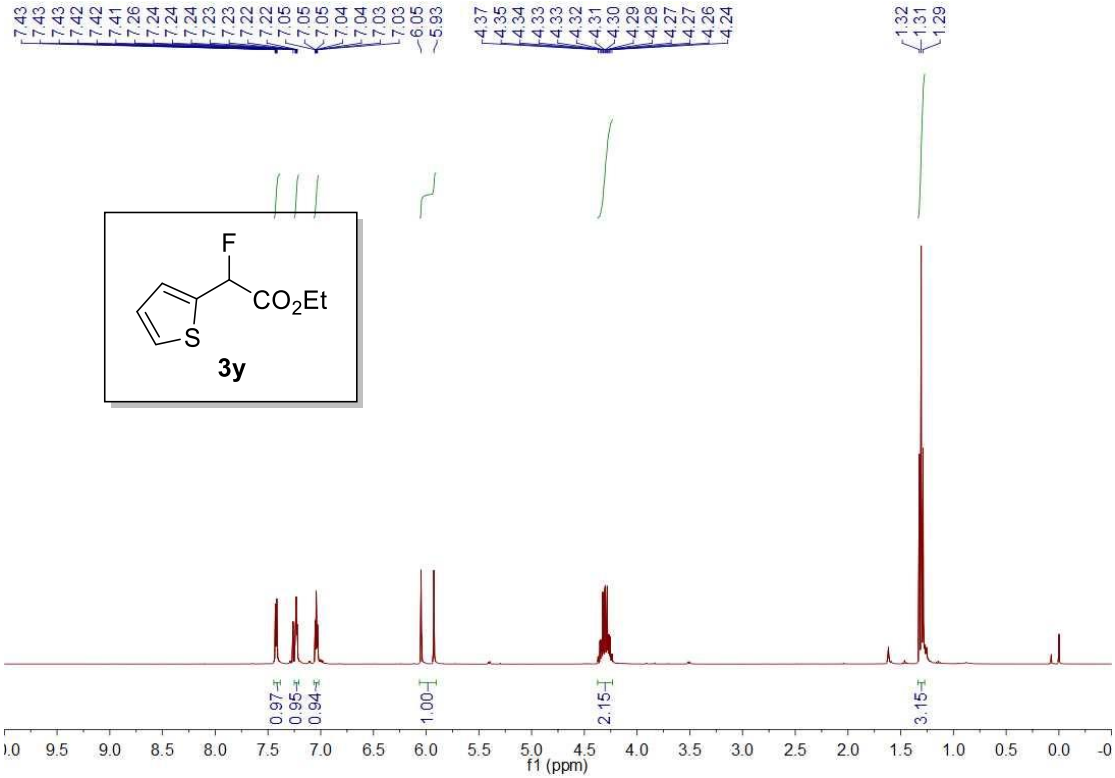

F
CO2Et
MeO2C

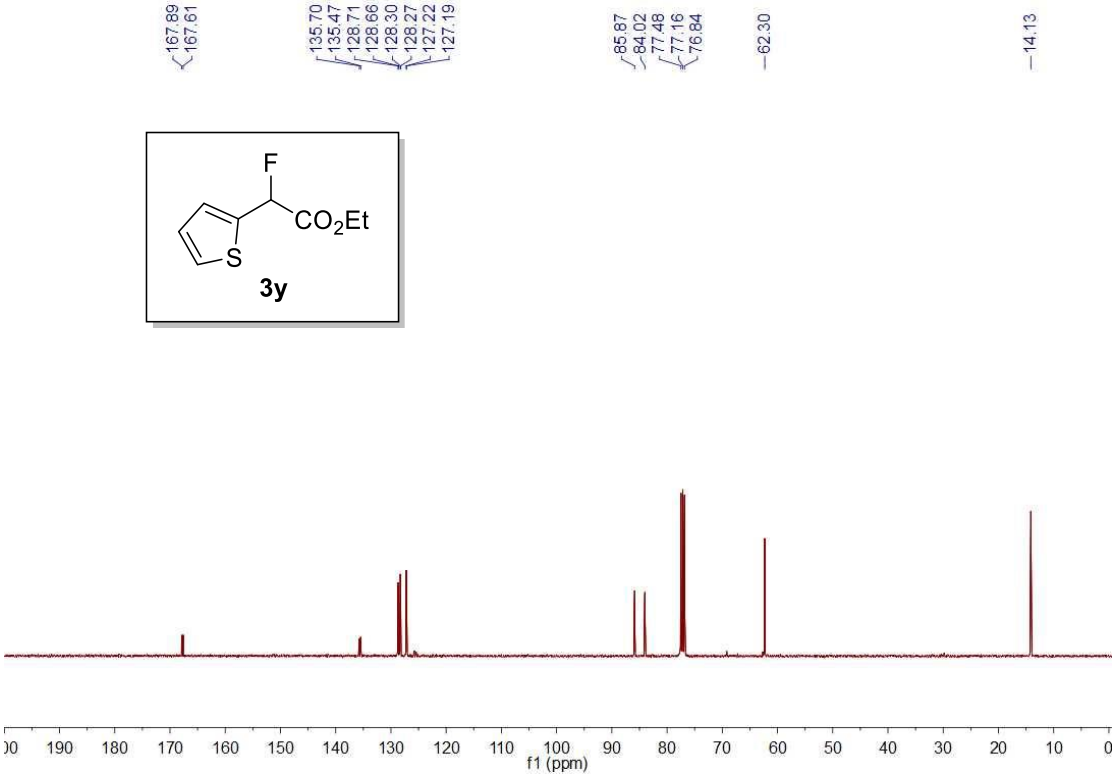
3x

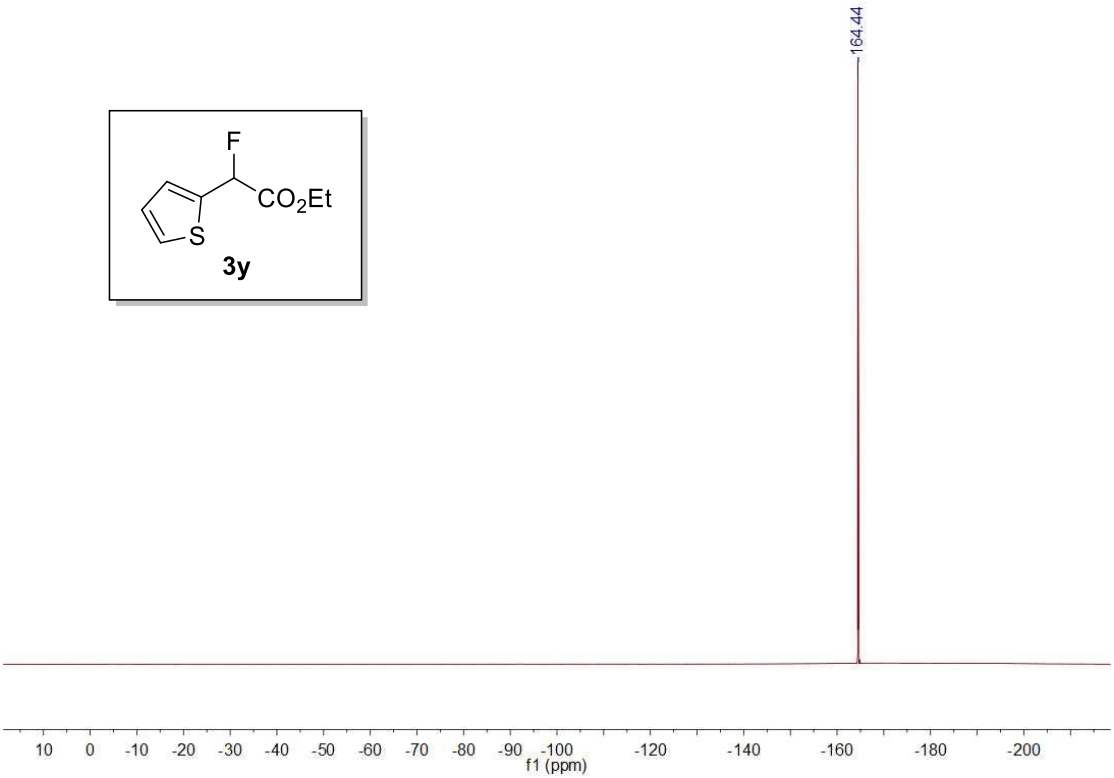
8.09
8.07
7.56
7.54
7.26
5.90
5.78
4.26
4.24
4.22
4.20
4.18
3.96
3.95
3.93
1.60
1.27
1.25
1.24
1.88
1.92
1.00
2.00
2.91
2.93
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

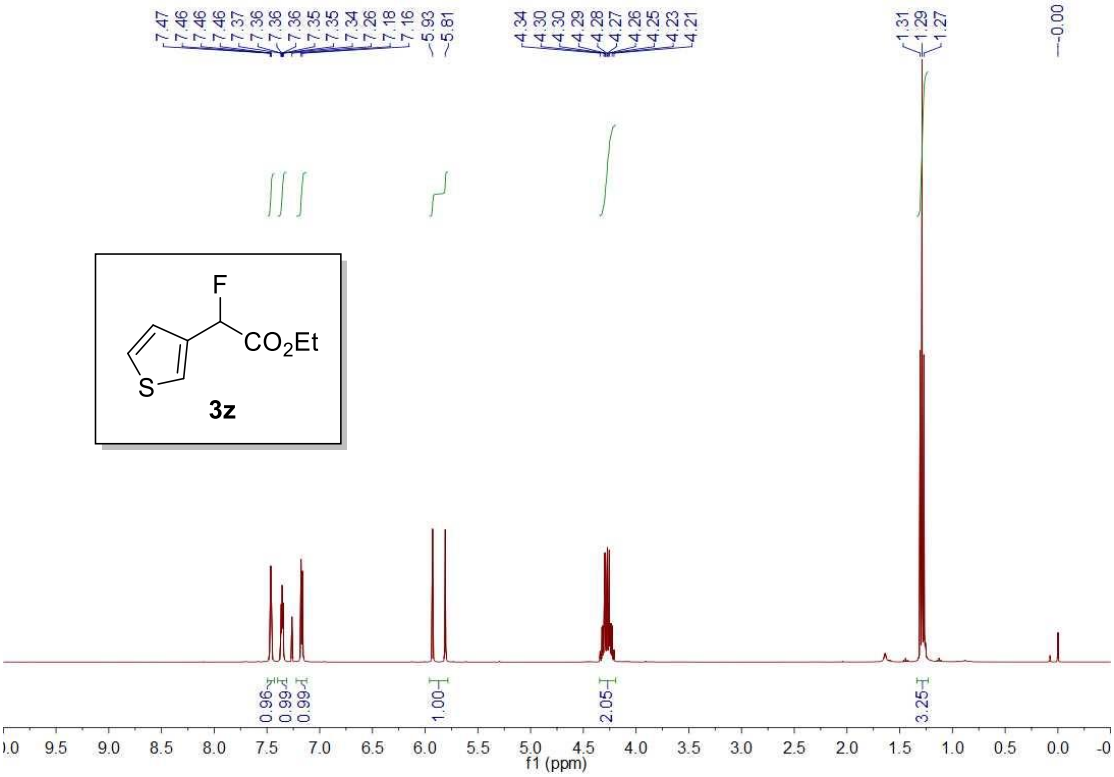

168.12
167.85
166.51
139.06
138.86
131.22
130.05
126.41
126.35
89.79
87.93
77.48
77.16
76.84
62.21
52.39
14.09
F
CO2Et
MeO2C
3x
f1 (ppm)


183.94
F
CO2Et
MeO2C
3x
f1 (ppm)


7.43
7.43
7.43
7.42
7.42
7.41
7.26
7.24
7.24
7.24
7.23
7.23
7.22
7.22
7.05
7.05
7.05
7.04
7.04
7.03
7.03
6.05
5.93
4.37
4.35
4.34
4.33
4.33
4.32
4.31
4.30
4.29
4.28
4.27
4.27
4.26
4.24
1.32
1.31
1.29
F
CO2Et
S
3y
0.97
0.95
0.94
1.00
2.15
3.15
f1 (ppm)


167.89
167.61
135.70
135.47
128.71
128.66
128.30
128.27
127.22
127.19
85.87
84.02
77.48
77.16
76.84
62.30
14.13
F
CO2Et
S
3y
f1 (ppm)


F
CO2Et
S
3y
164.44
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)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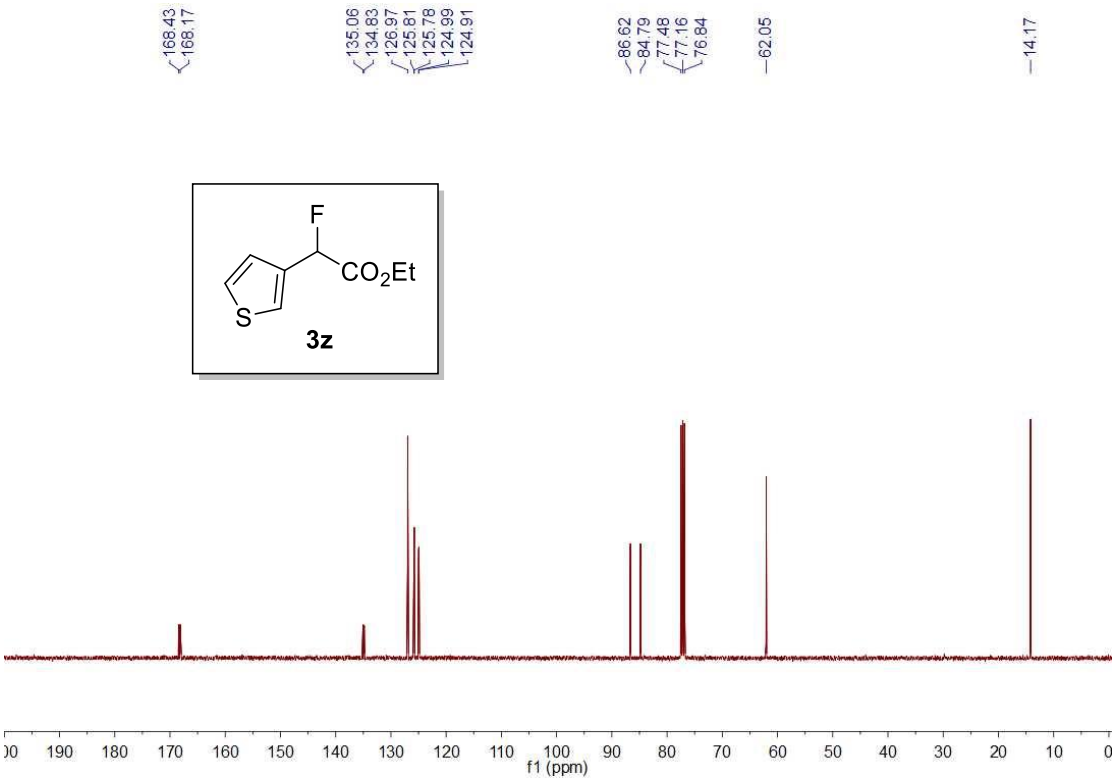
7.46
7.46
7.37
7.36
7.36
7.36
7.35
7.35
7.34
7.26
7.18
7.16
5.93
5.81
4.34
4.30
4.30
4.29
4.28
4.27
4.26
4.25
4.23
4.21
1.31
1.29
1.27
0.00
F
CO2Et
S
3z
0.96
0.99
0.99
1.00
2.05
3.25
f1 (ppm)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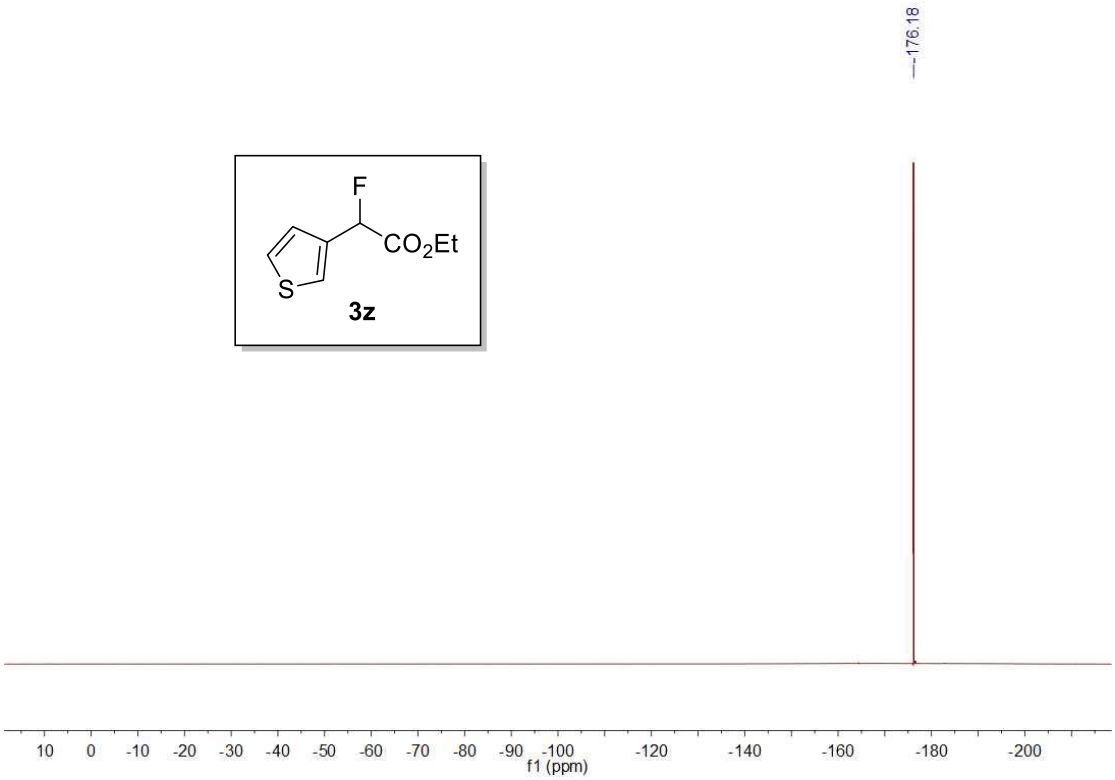
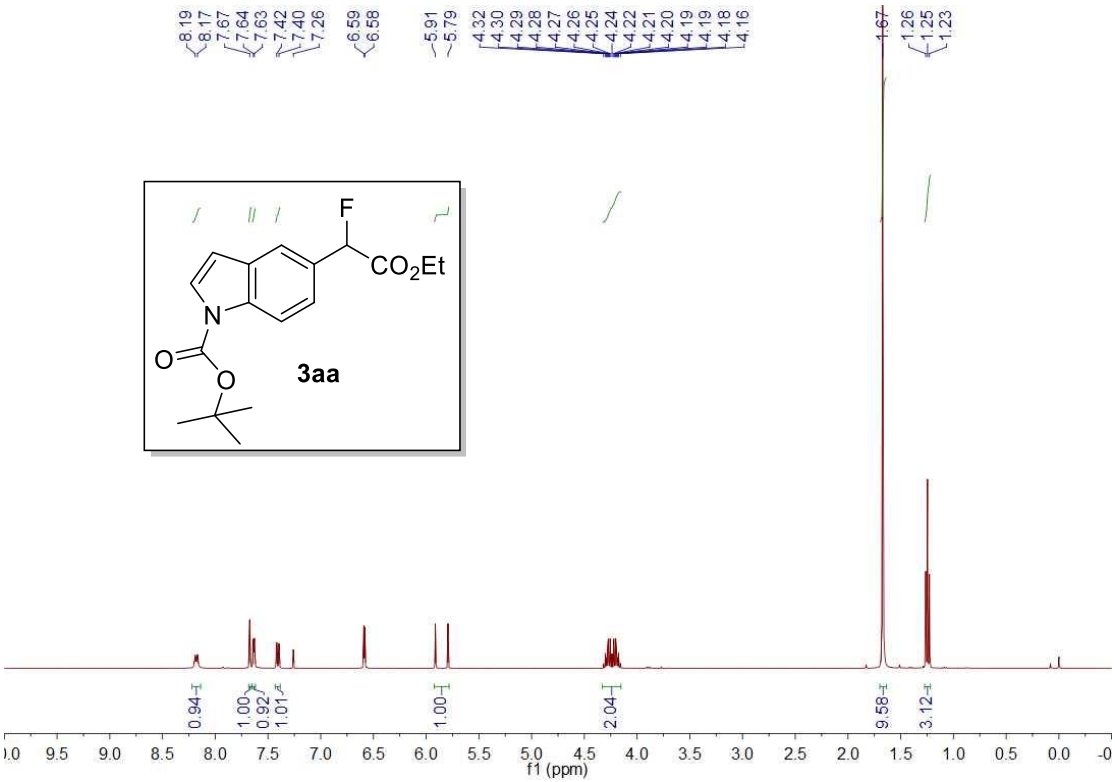
168.17
135.06
134.83
126.97
125.81
125.78
124.99
124.91
86.62
84.79
77.48
77.16
76.84
62.05
14.17
F
CO2Et
S
3z
f1 (ppm)


176.18
F
CO2Et
S
3z
f1 (ppm)


8.19
8.17
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7.63
7.42
7.40
7.26
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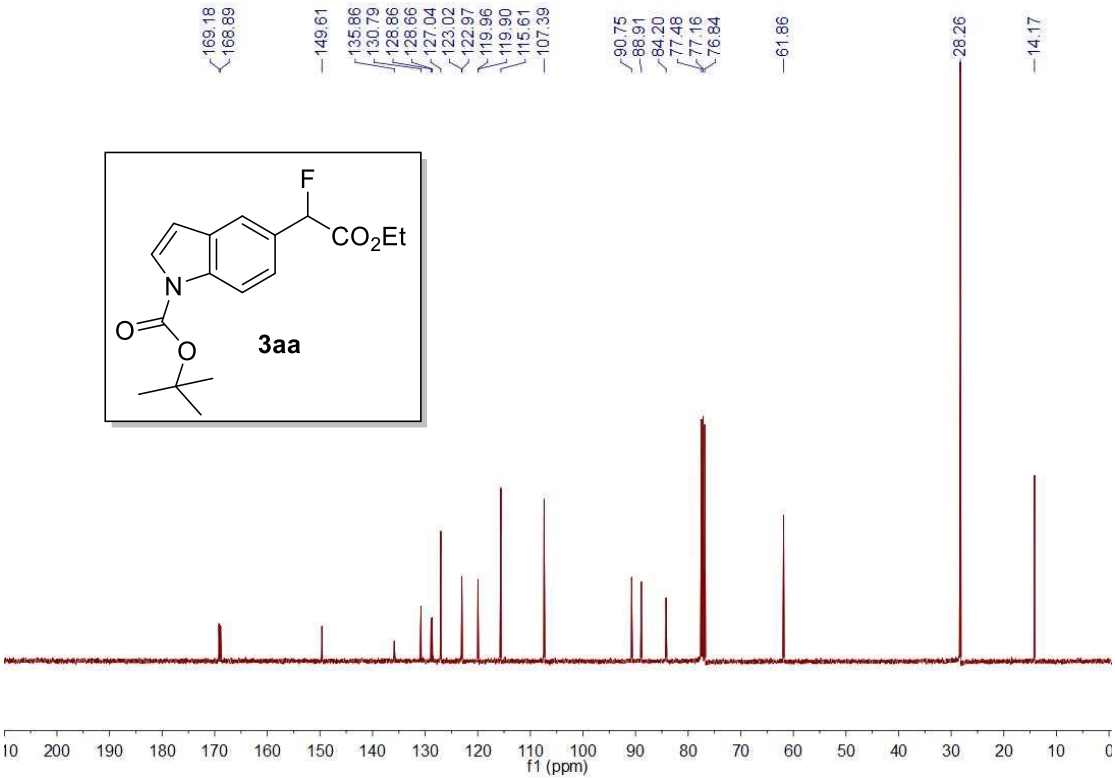
6.58
5.91
5.79
4.32
4.30
4.29
4.28
4.27
4.26
4.25
4.24
4.22
4.21
4.20
4.19
4.19
4.18
4.16
1.67
1.26
1.25
1.23
F
CO2Et
N
O
O
3aa
0.94
1.00
0.92
1.01
1.00
2.04
9.58
3.12
f1 (ppm)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128.86
128.66
127.04
123.02
122.97
119.96
119.90
115.61
107.39
90.75
88.91
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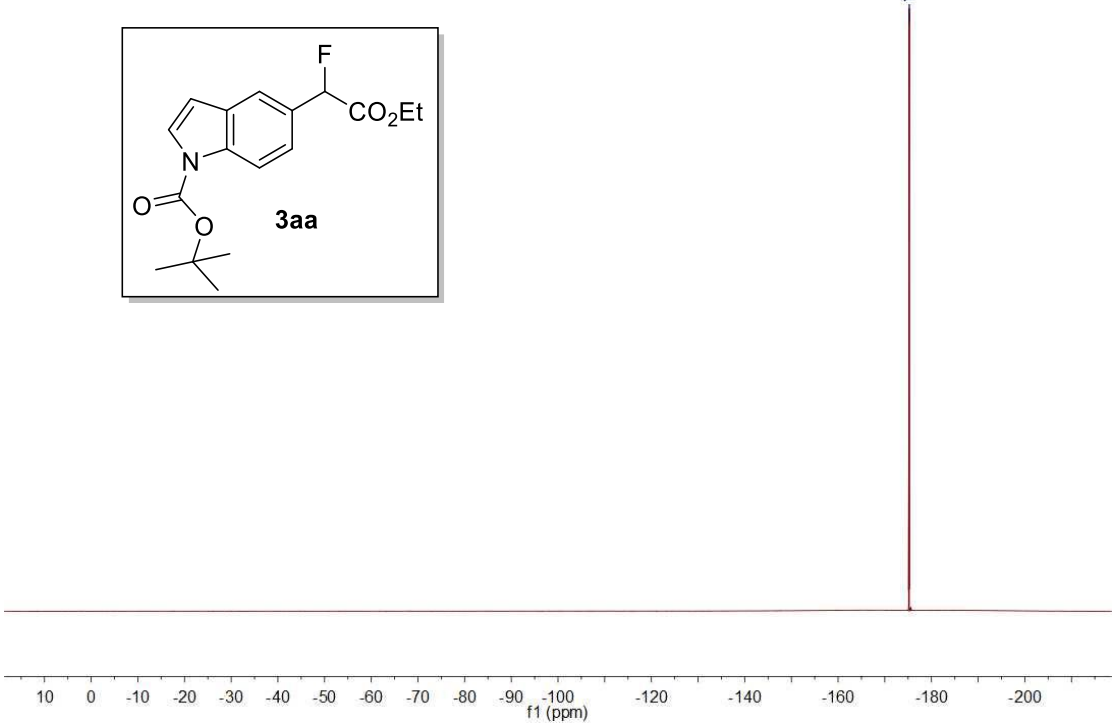
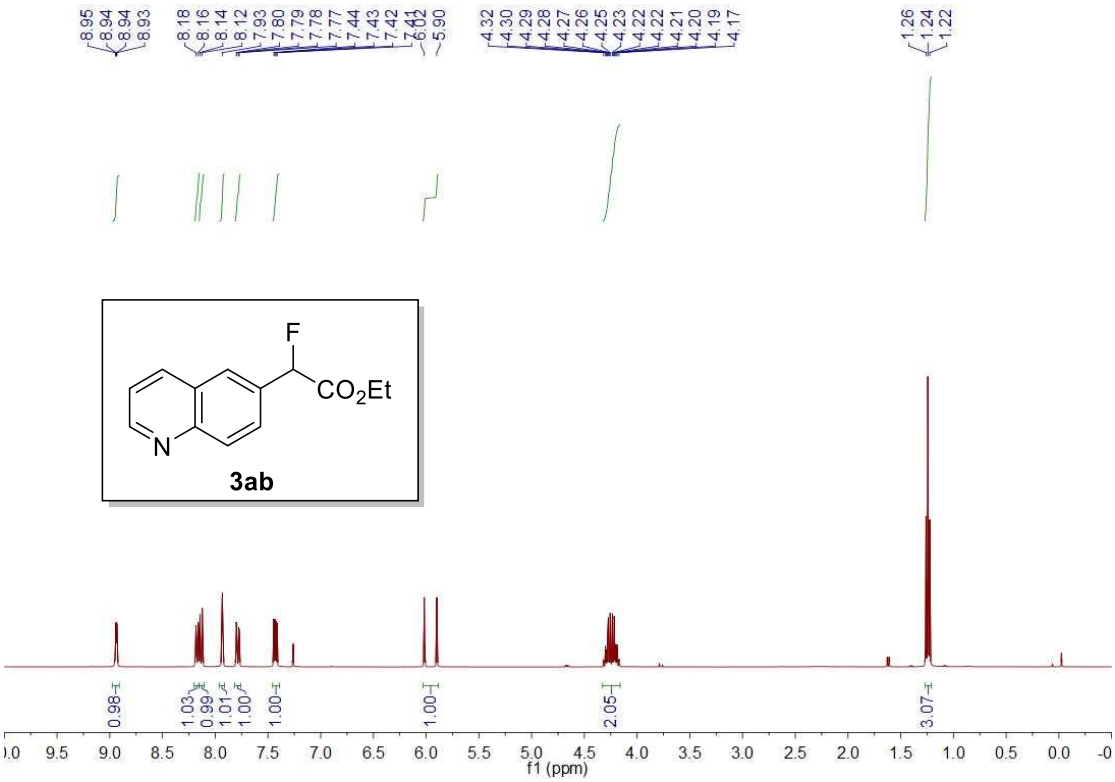
F
CO2Et
N
O
O
3aa
f1 (ppm)


F
CO2Et
N
O
O
3aa
175.23
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)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8.16
8.14
8.12
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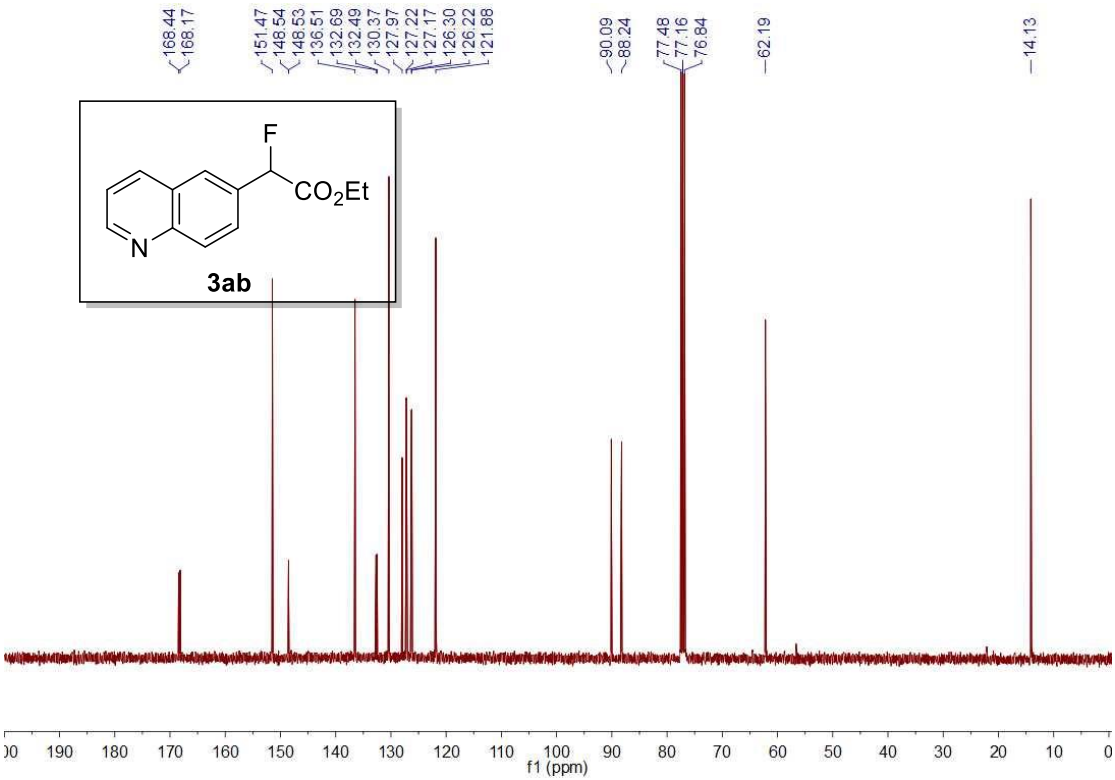
7.80
7.79
7.78
7.77
7.44
7.43
7.42
6.02
5.90
4.32
4.30
4.29
4.28
4.27
4.26
4.25
4.23
4.22
4.22
4.21
4.20
4.19
4.17
1.26
1.24
1.22
F
CO2Et
N
3ab
0.98
1.03
0.99
1.01
1.00
1.00
1.00
2.05
3.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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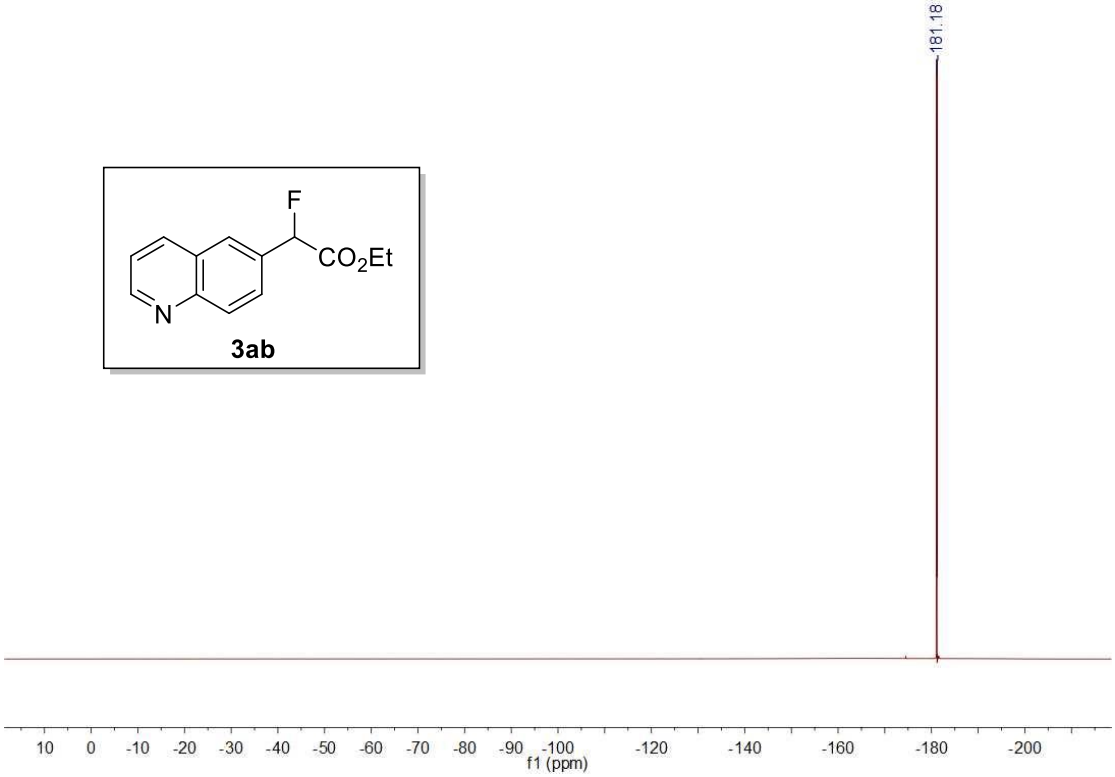
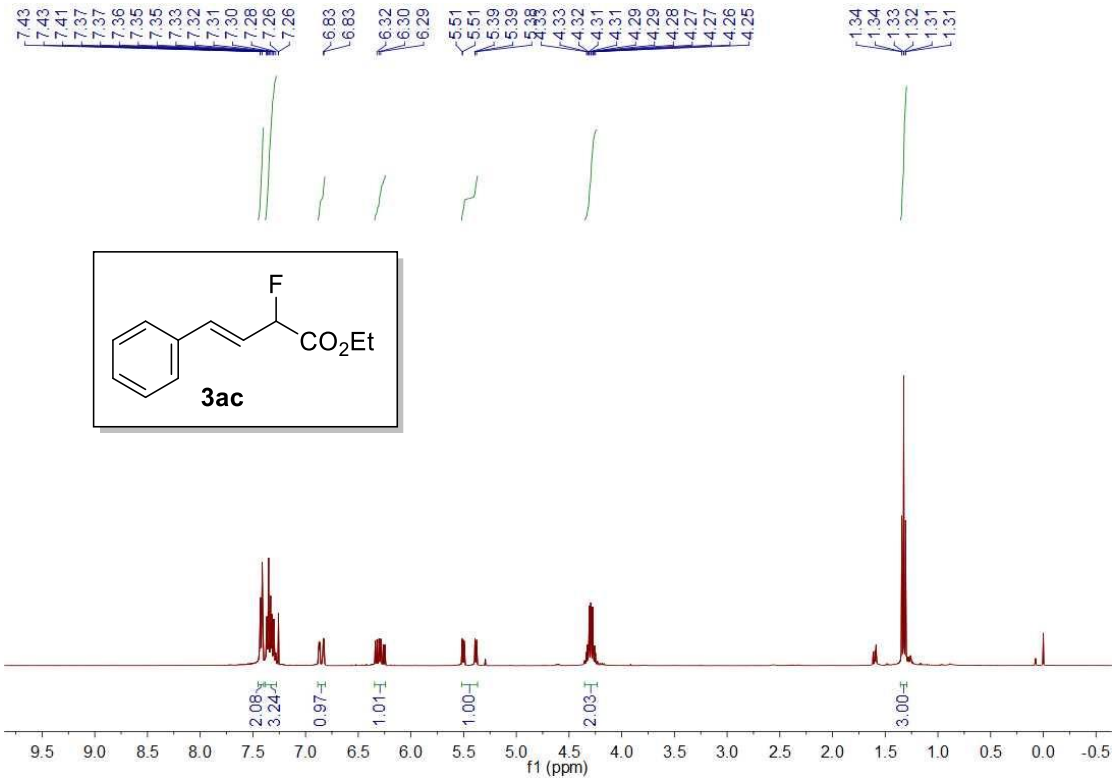
127.97
127.22
127.17
126.30
126.22
121.88
90.09
88.24
77.48
77.16
76.84
62.19
14.13
F
CO2Et
N
3ab
f1 (ppm)


181.18
F
CO2Et
N
3ab
f1 (ppm)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7.32
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7.26
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4.32
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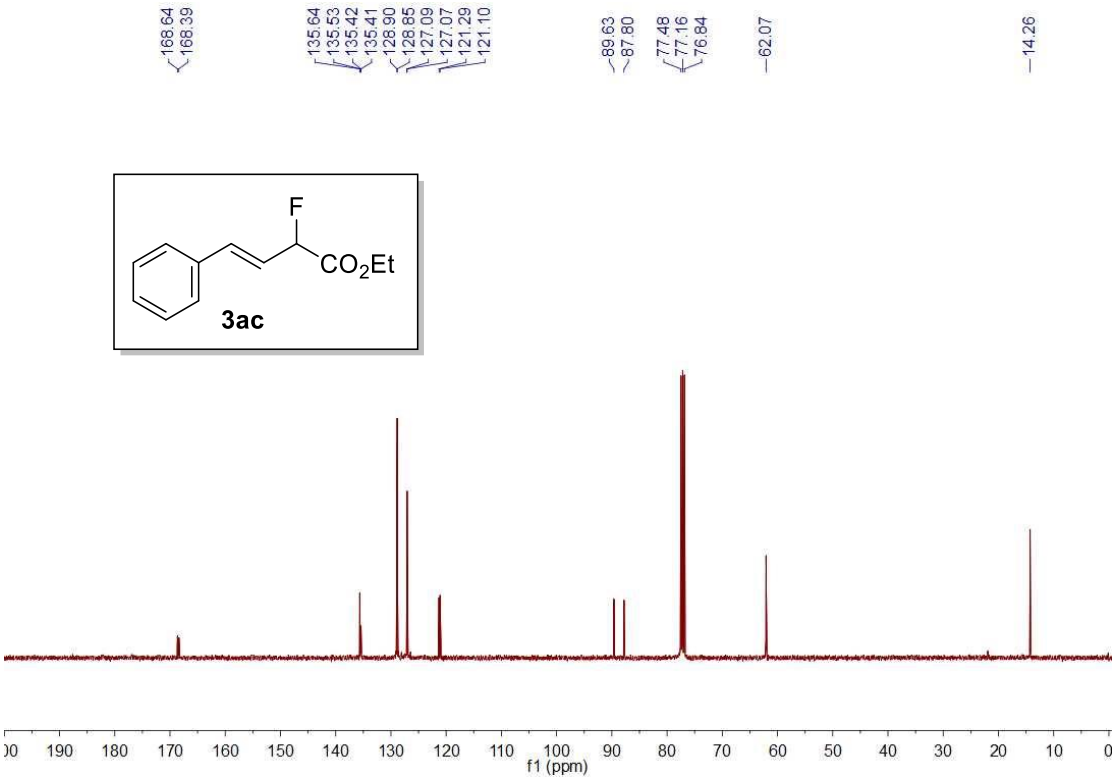
4.29
4.29
4.28
4.27
4.27
4.26
4.25
1.34
1.34
1.33
1.32
1.31
1.31
F
CO2Et
3ac
2.08
3.24
0.97
1.01
1.00
2.03
3.00
f1 (ppm)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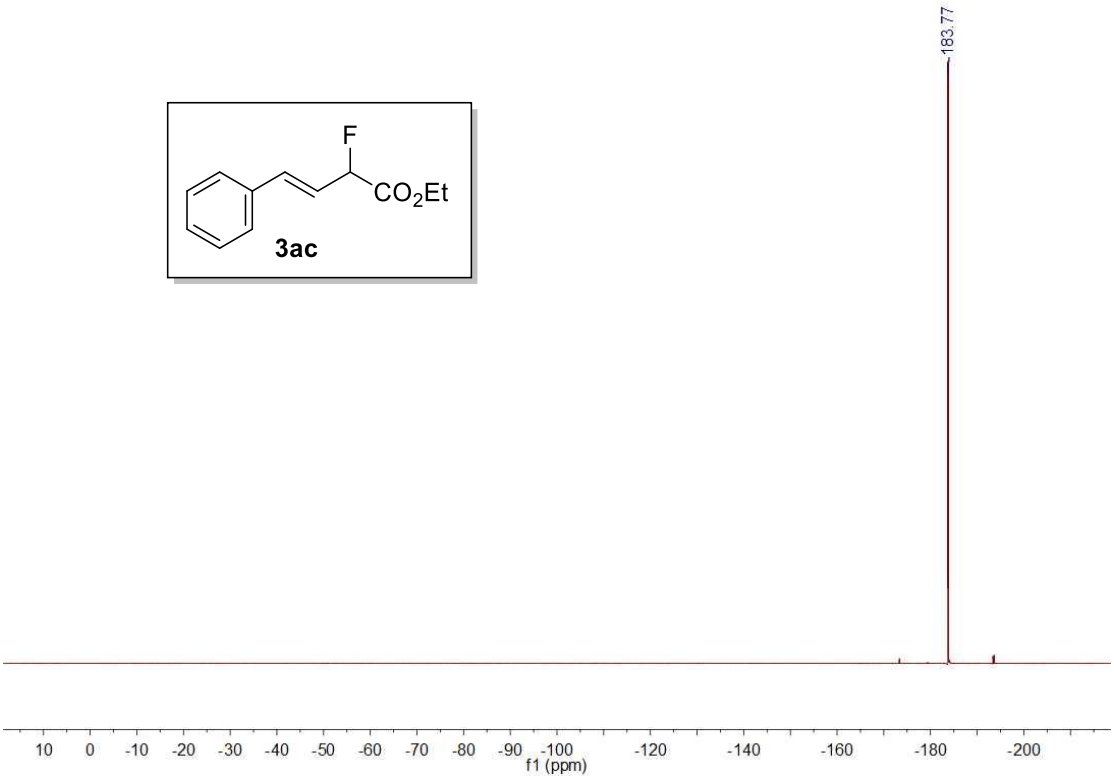
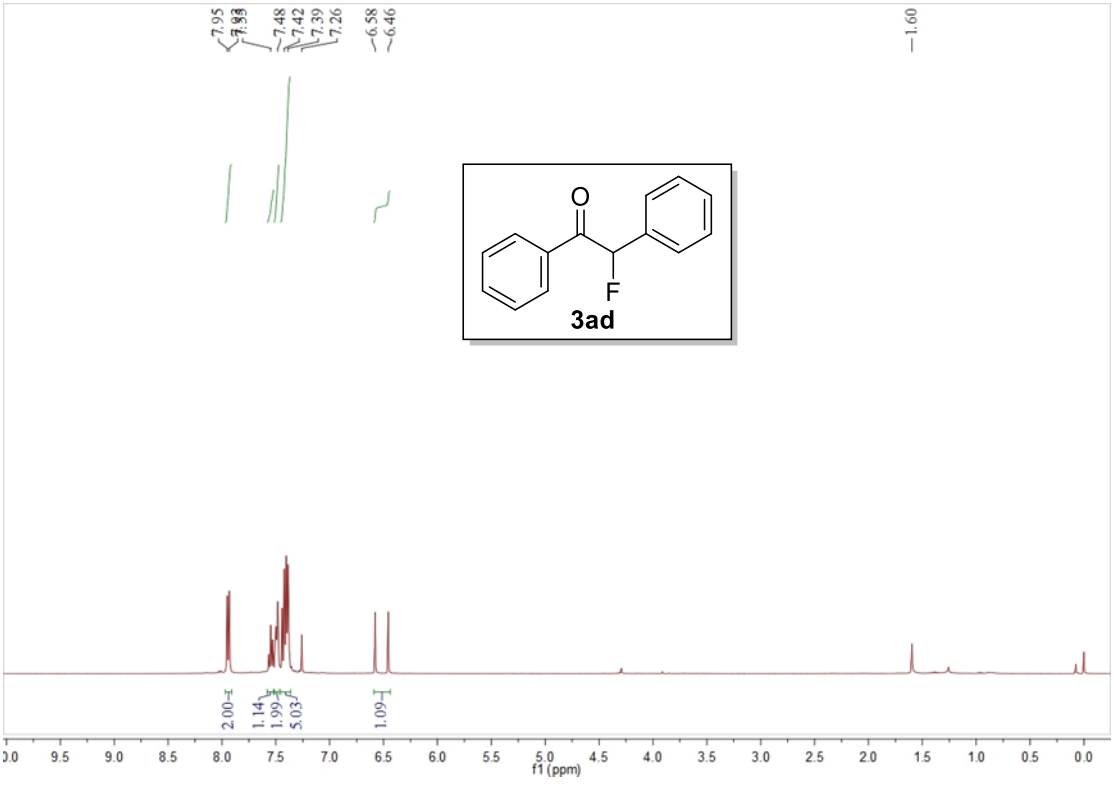
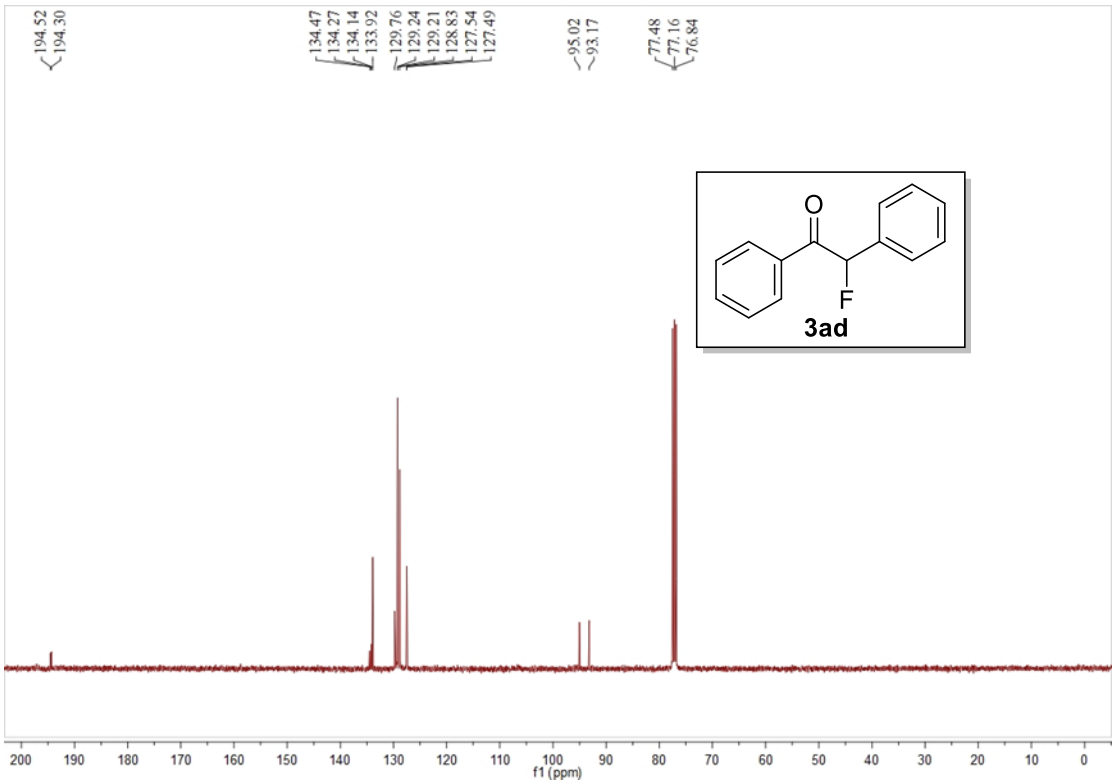
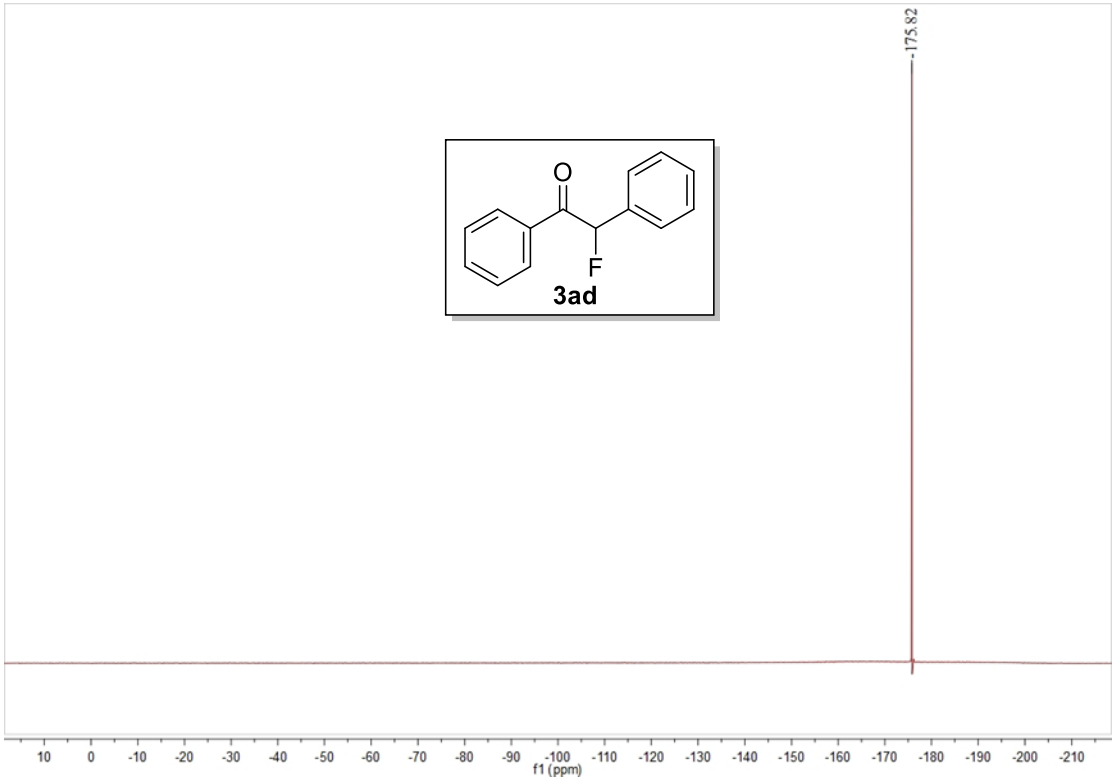
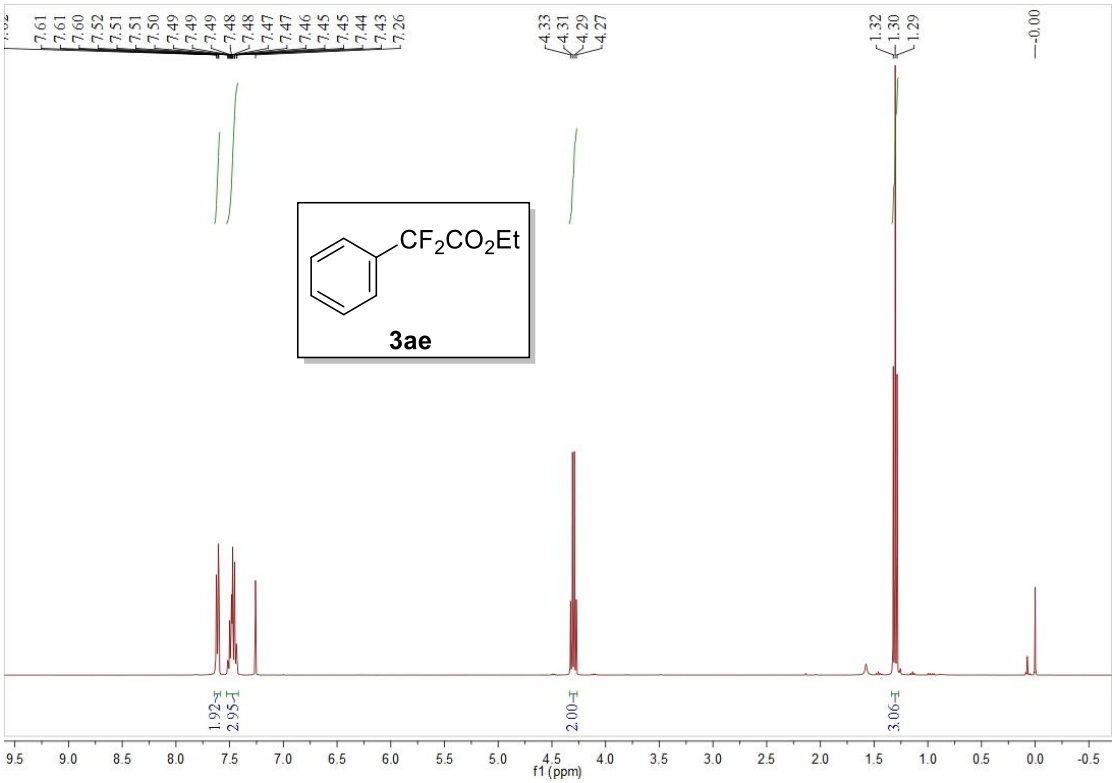
168.39
135.64
135.53
135.42
135.41
128.90
128.85
127.09
127.07
121.29
121.10
89.63
87.80
77.48
77.16
76.84
62.07
14.26
F
CO2Et
3ac
f1 (ppm)

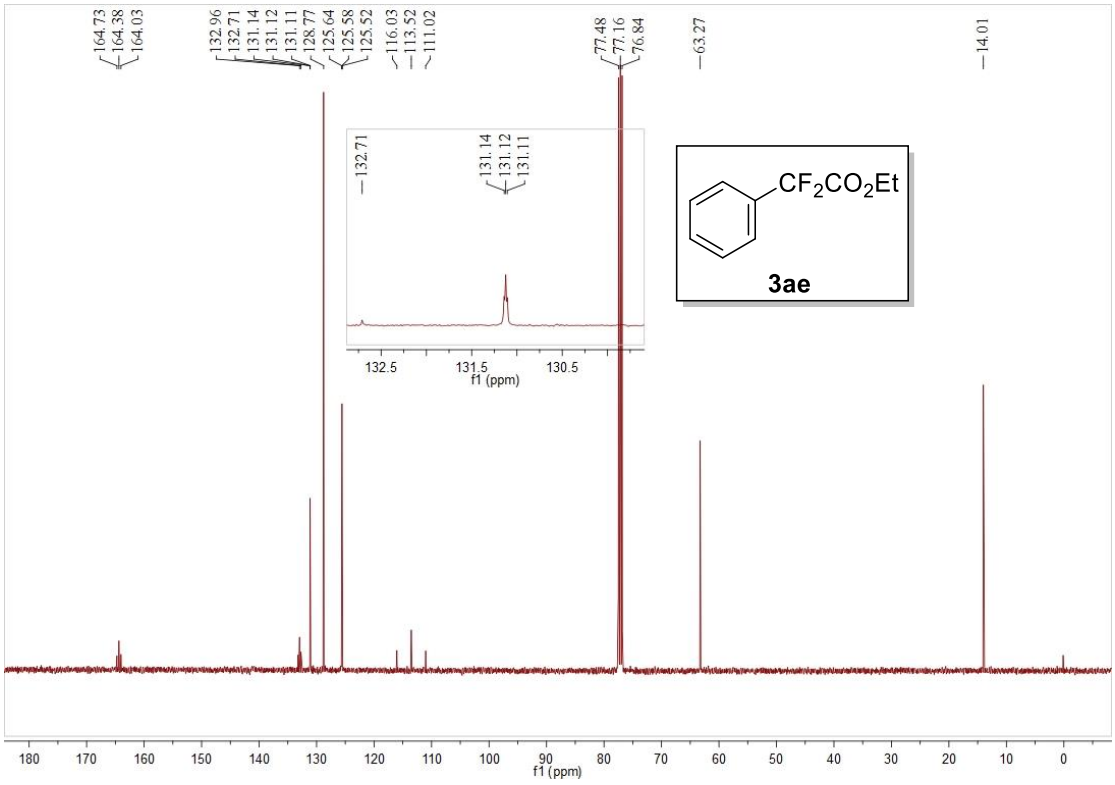

F
CO2Et
3ac
183.77
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -120 -140 -160 -180 -200
f1 (ppm)

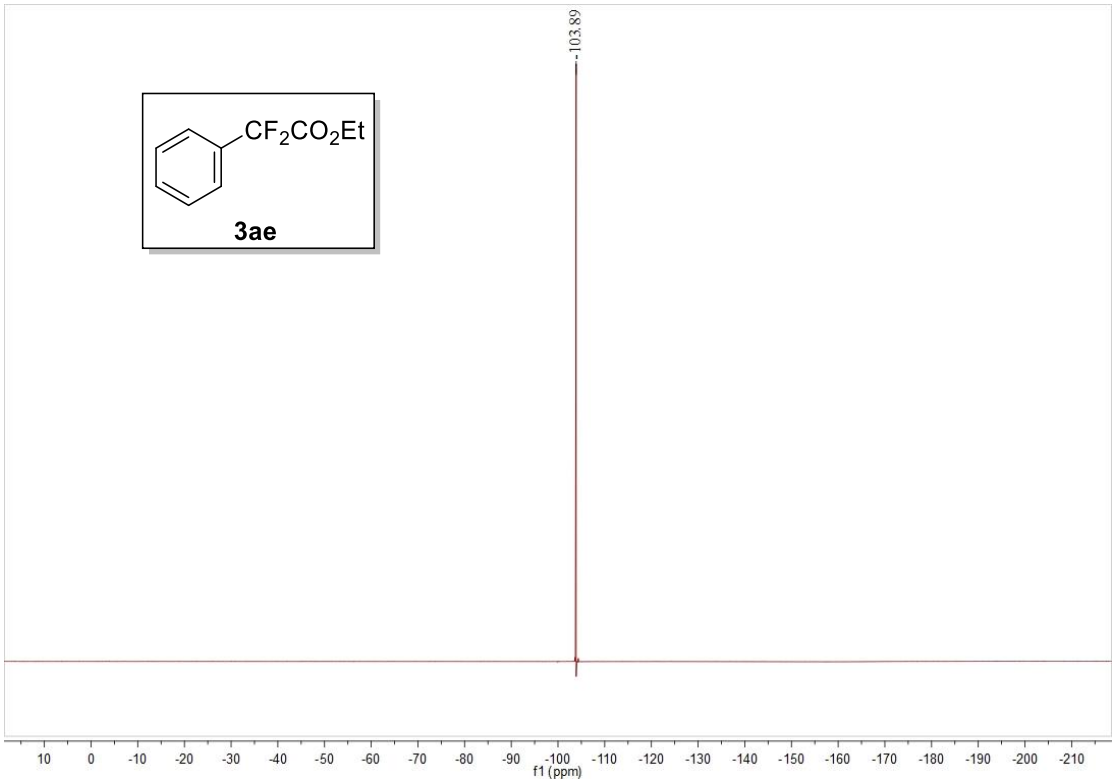

7.95
7.48
7.42
7.39
7.26
6.58
6.46
1.60
O
F
3ad
2.00
1.14
1.99
5.03
1.09
f1 (ppm)

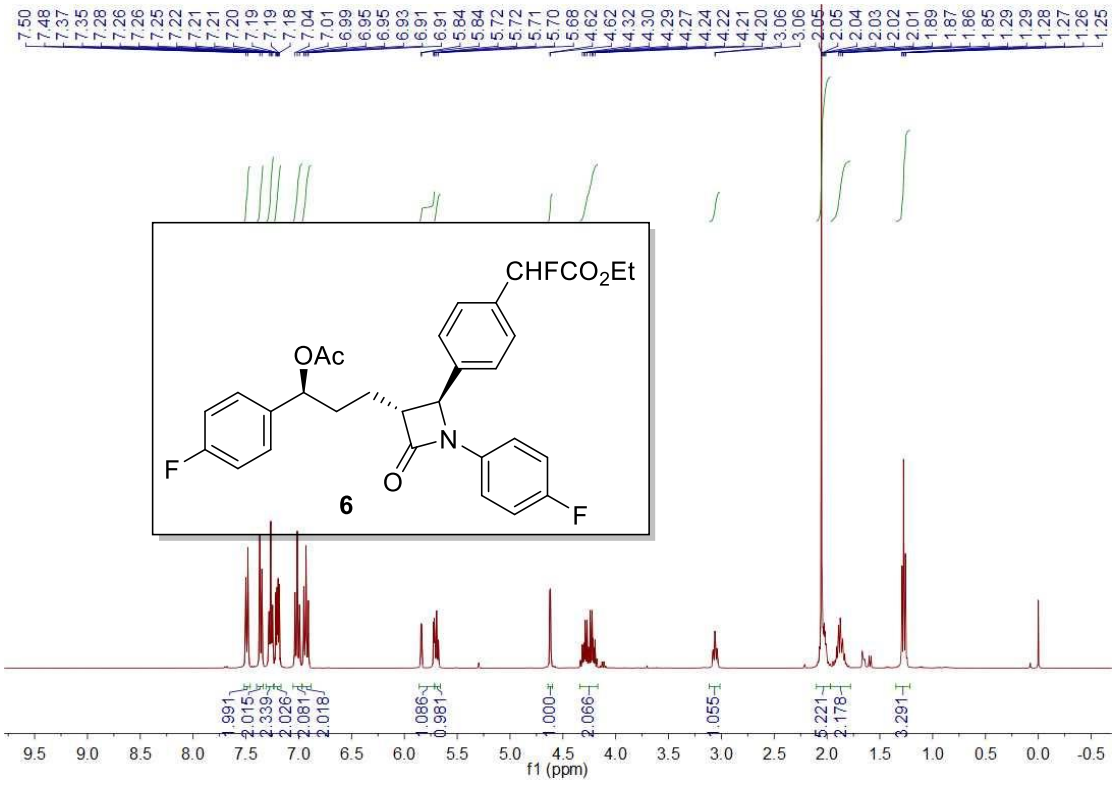

194.52
194.30
134.47
134.27
134.14
133.92
129.76
129.24
129.21
128.83
127.54
127.49
95.02
93.17
77.48
77.16
76.84
O
F
3ad
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

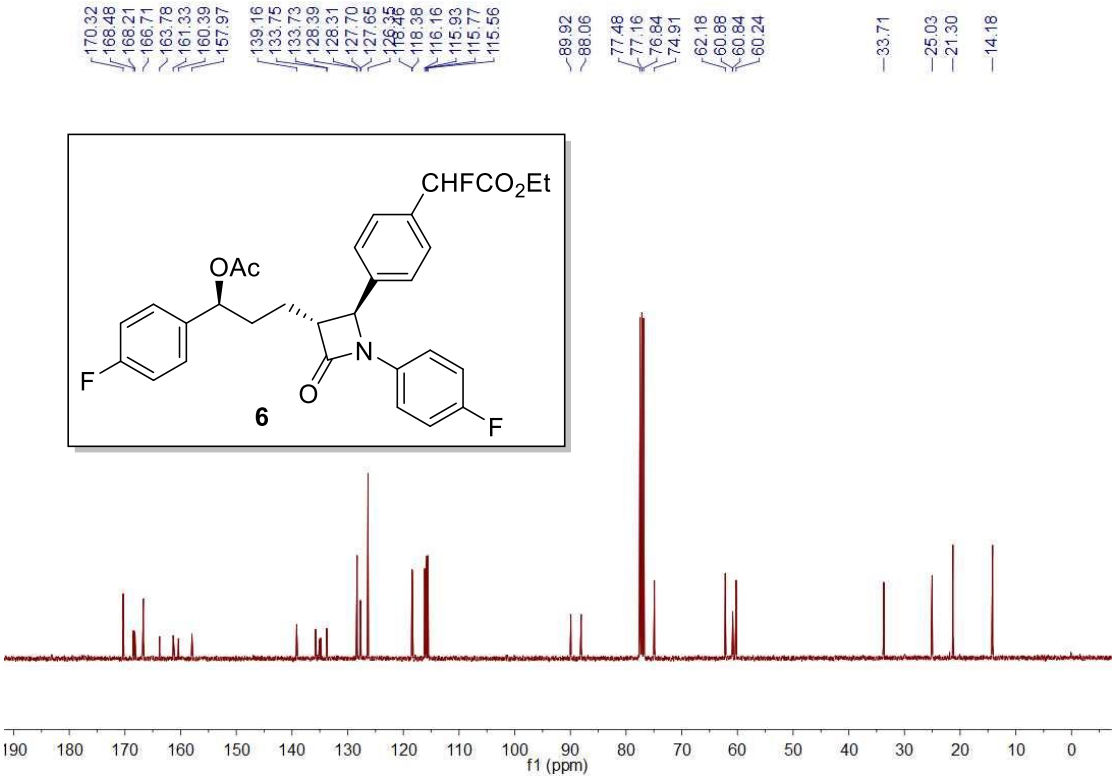

-175.82
O
F
3ad
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

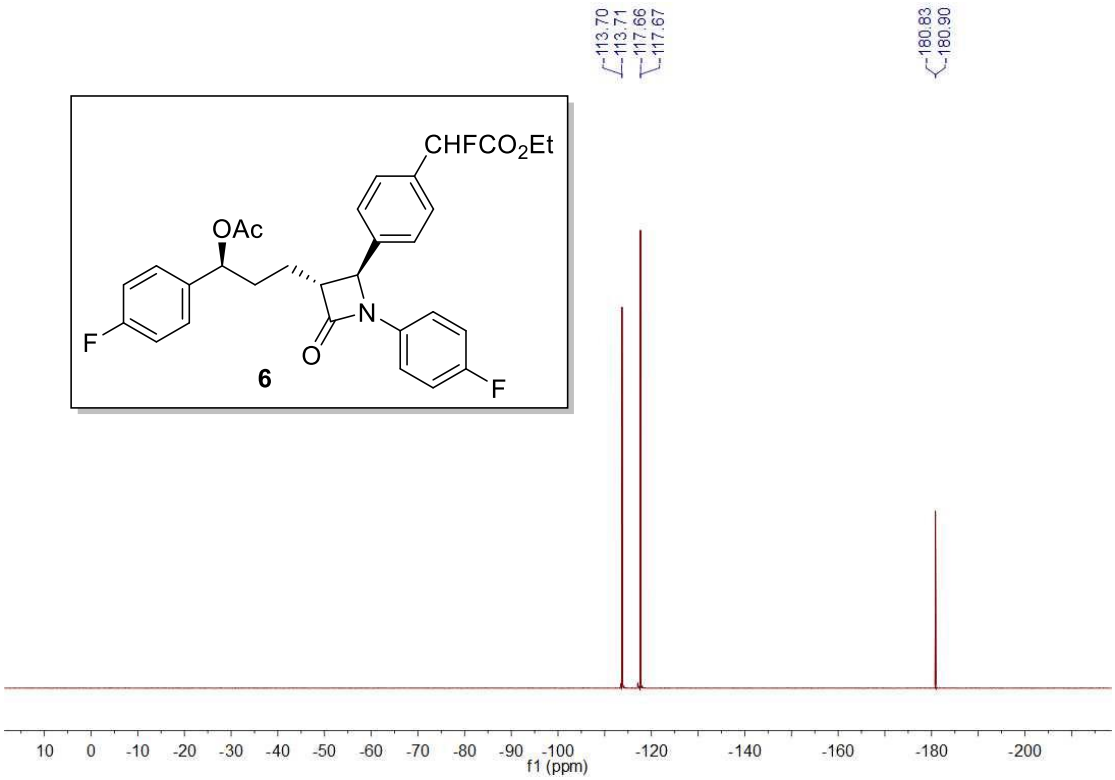

7.61
7.61
7.60
7.52
7.51
7.51
7.50
7.49
7.49
7.49
7.48
7.48
7.47
7.47
7.46
7.45
7.45
7.44
7.43
7.26
4.33
4.31
4.29
4.27
1.32
1.30
1.29
-0.00
CF2CO2Et
3ae
1.92
2.95
2.00
3.06
f1 (ppm)

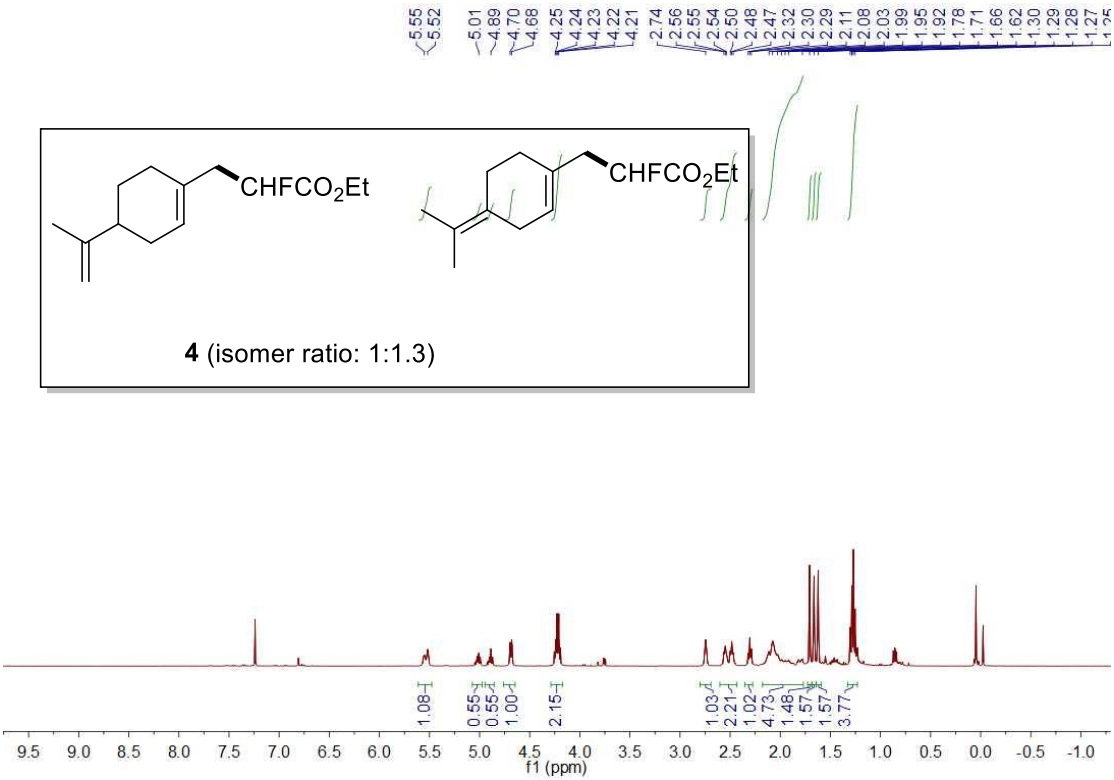

164.73
164.38
164.03
132.96
132.71
131.14
131.12
131.11
128.77
125.64
125.58
125.52
116.03
113.52
111.02
77.48
77.16
76.84
63.27
14.01
132.71
131.14
131.12
131.11
132.5
131.5
130.5
f1 (ppm)
CF2CO2Et
3ae
f1 (ppm)

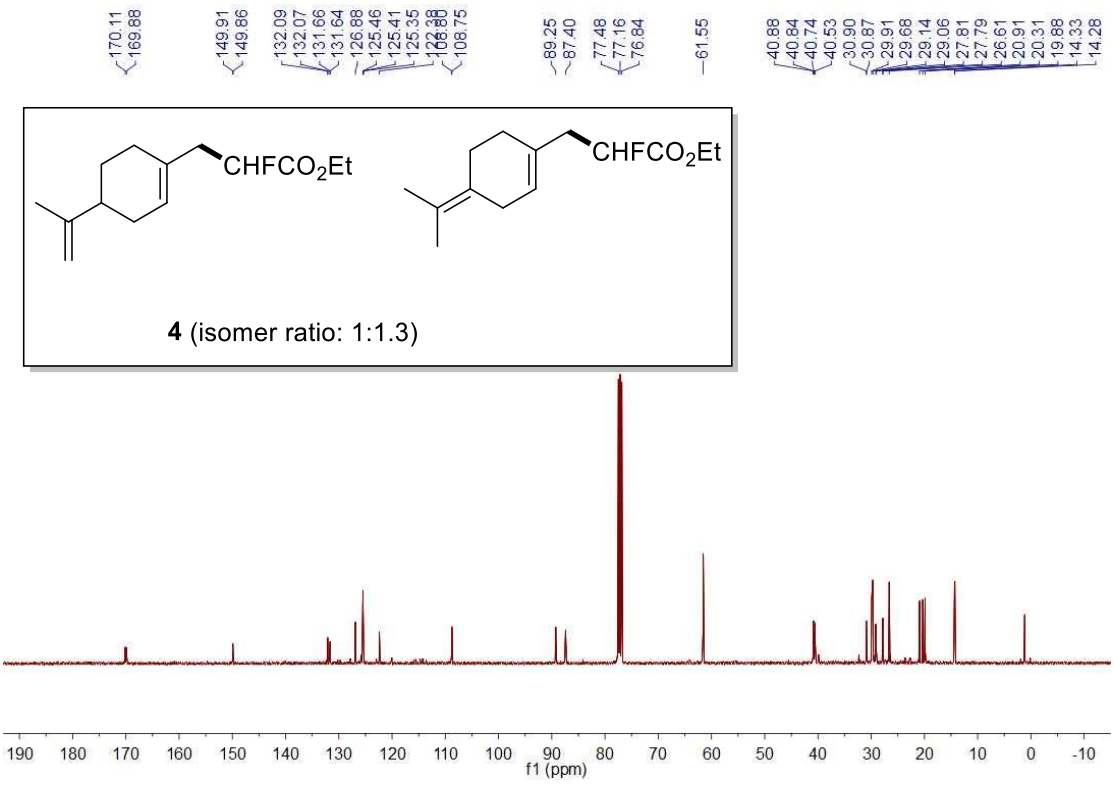

-103.89
CF2CO2Et
3ae
f1 (ppm)

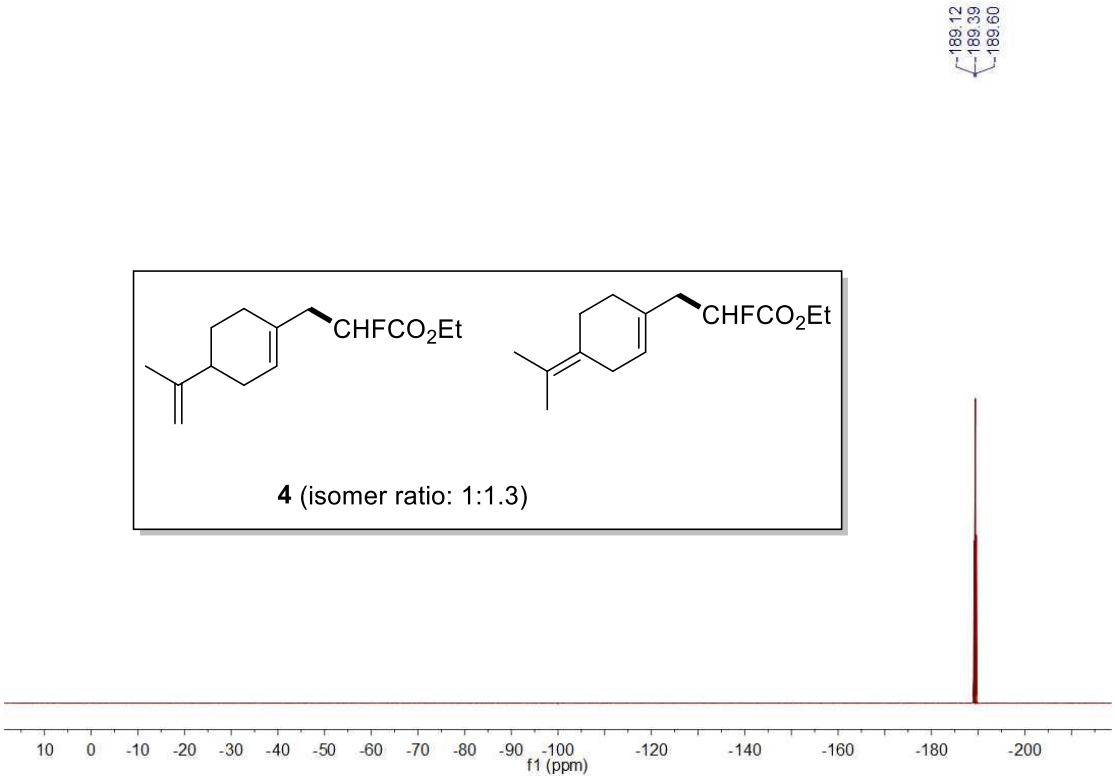

CHFCO2Et
OAc
F
N
O
F
6
f1 (ppm)


170.32
168.48
168.21
166.71
163.78
161.33
160.39
157.97
139.16
133.75
133.73
128.39
128.31
127.70
127.65
118.38
116.16
115.93
115.77
115.56
89.92
88.06
77.48
77.16
76.84
74.91
62.18
60.88
60.84
60.24
33.71
25.03
21.30
14.18
CHFCO2Et
OAc
F
N
O
F
6
f1 (ppm)


113.70
113.71
117.66
117.67
180.83
180.90
CHFCO2Et
OAc
F
N
O
F
6
f1 (ppm)


CHFCO2Et
CHFCO2Et
4 (isomer ratio: 1:1.3)
f1 (ppm)


CHFCO2Et
CHFCO2Et
4 (isomer ratio: 1:1.3)
f1 (ppm)


189.12
189.39
189.60
CHFCO2Et
CHFCO2Et
4 (isomer ratio: 1:1.3)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-120
-140
-160
-180
-200
f1 (ppm)