Supporting Materials to

Copper-catalyzed remote oxidation of alcohols initiated by radical difluoroalkylation of alkenes: a facile access to difluoroalkylated carbonyl compounds

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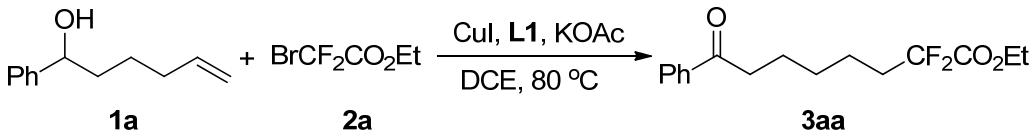
Experimental

General

Melting points reported here were measured by a melting point instrument and were uncorrected. ^{1}H, ^{13}C, and ^{19}F NMR spectra were measured on a 600 MHz NMR spectrometers with $CDCl_3$ as the solvent with tetramethylsilane (TMS) as the internal standard. High-resolution mass spectra (HRMS) analyses were run with a TOF MS instrument using an ESI source. The products were purified by column chromatography using silica gel (300−400 mesh) with a mixture of petroleum ether and EtOAc as the eluent.

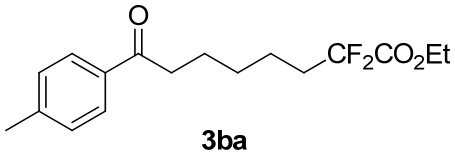
The starting materials **1**[1] and **2**[2] are prepared according to previously reported literature.

Genaral procedure for copper-catalyzed remote oxidation of alcohols initiated by radical difluoroalkylation of alkenes



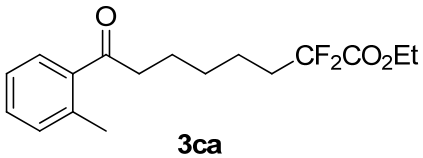
To a solution of **1a** (44.0 mg, 0.25 mmol) and **2a** (101.0 mg, 0.5 mmol) in 2 mL of 1,2-dichloroethane (DCE, super dry) was added **L1** (dtbpy, 13.4 mg, 0.05 mmol), CuI (4.7 mg, 0.025 mmol) and KOAc (49.0 mg, 0.5 mmol) under a nitrogen atmosphere. The sealed tube was then stirred at 80 °C for 12 hours. After completion (monitored by TLC), the reaction solution was concentrated in vacuo, and the residue was purified by silica gel column chromatography (petroleum ether/EtOAc) to gave 57 mg (yield: 77%) of **3aa** as a colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.95 (d, J = 7.9 Hz, 2H), 7.56 (t, J = 7.3 Hz, 1H), 7.46 (t, J = 7.7 Hz, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.98 (t, J = 7.3 Hz, 2H), 2.12–2.04 (m, 2H), 1.79–1.74 (m, 2H), 1.56–1.51 (m, 2H), 1.48–1.43 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.0, 164.3 (t, $J_{C\text{-}F}$ =

33.0 Hz), 136.9, 133.0, 128.6, 128.0, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.7, 38.1, 34.3 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.7, 23.8, 21.3 (t, $J_{C\text{-}F}$ = 4.4 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.9; HRMS (ESI) calcd for $C_{16}H_{20}F_2NaO_3$ $(M+Na)^+$ 321.1273, found 321.1269.



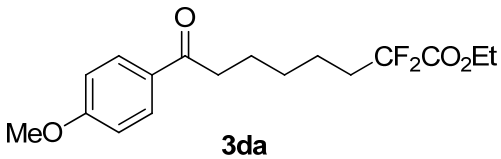
3ba

Compound ***3ba***: 61 mg, 78% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.85 (d, J = 8.2 Hz, 2H), 7.27–7.24 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.95 (t, J = 7.3 Hz, 2H), 2.41 (s, 3H), 2.12–2.03 (m, 2H), 1.78–1.73 (m, 2H), 1.54–1.50 (m, 2H), 1.47–1.42 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 199.7, 164.3 (t, $J_{C\text{-}F}$ = 32.9 Hz), 143.7, 134.5, 129.2, 128.1, 116.3 (t, $J_{C\text{-}F}$ = 250.0 Hz), 62.7, 38.0, 34.3 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.9, 21.6, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{17}H_{22}F_2NaO_3$ $(M+Na)^+$ 335.1429, found 335.1428.



3ca

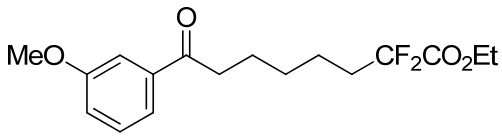
Compound ***3ca***: 43 mg, 55% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.63–7.57 (m, 1H), 7.38–7.35 (m, 1H), 7.28–7.23 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.90 (t, J = 7.3 Hz, 2H), 2.48 (s, 3H), 2.11–2.03 (m, 2H), 1.75–1.70 (m, 2H), 1.55–1.50 (m, 2H), 1.46–1.41 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 204.3, 164.3 (t, $J_{C\text{-}F}$ = 32.1 Hz), 138.1, 137.8, 131.9, 131.1, 128.2, 125.6, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.7, 41.2, 34.3 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.7, 23.9, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 21.2, 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{17}H_{22}F_2NaO_3$ $(M+Na)^+$ 335.1429, found 335.1428.



3da

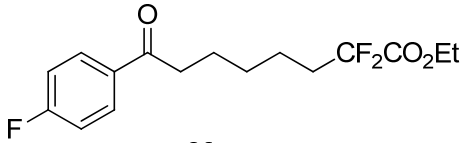
Compound ***3da***: 66 mg, 81% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.95–7.92 (m, 2H), 6.95–6.92 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 3.87 (s, 3H), 2.92 (t,

J = 7.3 Hz, 2H), 2.12–2.03 (m, 2H), 1.77–1.72 (m, 2H), 1.55–1.50 (m, 2H), 1.47–1.41 (m, 2H), 1.35 (t, J = 7.2 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 198.6, 164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 163.3, 130.2, 130.0, 116.2 (t, $J_{C\text{-}F}$ = 250.0 Hz), 113.6, 62.7, 55.4, 37.7, 34.2 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.9, 21.3 (t, $J_{C\text{-}F}$ = 4.2 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.9; HRMS (ESI) calcd for $C_{17}H_{22}F_2NaO_4$ $(M+Na)^+$ 351.1378, found 351.1366.



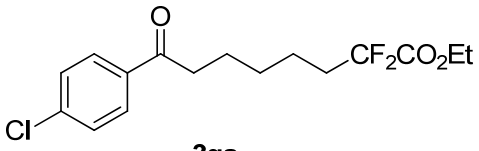
3ea

Compound ***3ea***: 59 mg, 72% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.53–7.52 (m, 1H), 7.48–7.47 (m, 1H), 7.37 (t, J = 7.9 Hz, 1H), 7.12–7.10 (m, 1H), 4.32 (q, J = 7.1 Hz, 2H), 3.86 (s, 3H), 2.96 (t, J = 7.3 Hz, 2H), 2.14–2.04 (m, 2H), 1.78–1.73 (m, 2H), 1.56–1.51 (m, 2H), 1.49–1.41 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 199.8, 164.3 (t, $J_{C\text{-}F}$ = 32.8 Hz), 159.8, 138.3, 129.5, 120.6, 119.4, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 112.3, 62.7, 55.4, 38.2, 34.3 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.7, 23.8, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{17}H_{22}F_2NaO_4$ $(M+Na)^+$ 351.1378, found 351.1366.



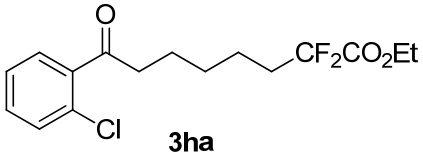
3fa

Compound ***3fa***: 57 mg, 72% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.99–7.97 (m, 2H), 7.13 (t, J = 8.5 Hz, 2H), 4.33 (q, J = 7.1 Hz, 2H), 2.95 (t, J = 7.3 Hz, 2H), 2.12–2.04 (m, 2H), 1.78–1.73 (m, 2H), 1.56–1.51 (m, 2H), 1.47–1.42 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 198.3, 165.7 (d, $J_{C\text{-}F}$ = 254.6 Hz), 164.3 (t, $J_{C\text{-}F}$ = 32.5 Hz), 133.4 (d, $J_{C\text{-}F}$ = 3.2 Hz), 130.6 (d, $J_{C\text{-}F}$ = 9.3 Hz), 116.2 (t, $J_{C\text{-}F}$ = 250.2 Hz), 115.6 (d, $J_{C\text{-}F}$ = 21.9 Hz), 62.8, 38.0, 34.3 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.7, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.48 (d, J = 3.2 Hz), -106.0; HRMS (ESI) calcd for $C_{16}H_{19}F_3NaO_3$ $(M+Na)^+$ 339.1179, found 339.1162.



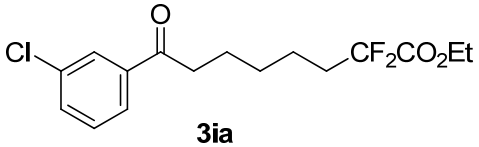
3ga

Compound ***3ga***: 66 mg, 79% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.90–7.88 (m, 2H), 7.45–7.42 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.95 (t, J = 7.3 Hz, 2H), 2.15–2.00 (m, 2H), 1.78–1.73 (m, 2H), 1.56–1.51 (m, 2H), 1.47–1.42 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 198.7, 164.3 (t, $J_{C\text{-}F}$ = 33.2 Hz), 139.4, 135.2, 129.4, 128.9, 116.2 (t, $J_{C\text{-}F}$ = 255.9 Hz), 62.7, 38.1, 34.2 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.6, 23.6, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{16}H_{19}ClF_2NaO_3$ $(M+Na)^+$ 355.0883, found 355.0879.



3ha

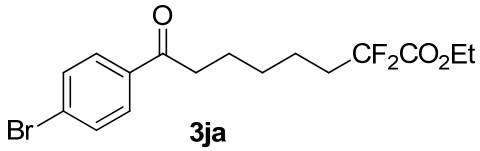
Compound ***3ha***: 42 mg, 51% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46–7.42 (m, 2H), 7.41–7.39 (m, 1H), 7.35–7.33 (m, 1H), 4.34 (q, J = 7.1 Hz, 2H), 2.96 (t, J = 7.3 Hz, 2H), 2.17–2.00 (m, 2H), 1.78–1.73 (m, 2H), 1.57–1.50 (m, 2H), 1.49–1.42 (m, 2H), 1.37 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 203.4, 164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 139.6, 131.5, 130.7, 130.5, 128.6, 126.9, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.7, 42.5, 34.2 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.5, 23.6, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{16}H_{19}ClF_2NaO_3$ $(M+Na)^+$ 355.0883, found 355.0879.



3ia

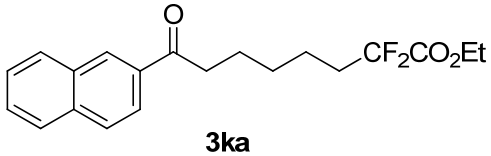
Compound ***3ia***: 56 mg, 67% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.92 (t, J = 1.8 Hz, 1H), 7.83–7.82 (m, 1H), 7.54–7.52 (m, 1H), 7.41 (t, J = 7.9 Hz, 1H), 4.33 (q, J = 7.1 Hz, 2H), 2.96 (t, J = 7.3 Hz, 2H), 2.15–2.02 (m, 2H), 1.78–1.73 (m, 2H), 1.56–1.51 (m, 2H), 1.47–1.42 (m, 2H), 1.36 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 198.6, 164.3 (t, $J_{C\text{-}F}$ = 32.2 Hz), 138.5, 134.93, 132.90, 129.9, 128.1, 126.1, 116.2 (t, $J_{C\text{-}F}$ = 250.2 Hz), 62.8, 38.2, 34.3 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.6, 23.6, 21.3 (t, $J_{C\text{-}F}$

= 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{16}H_{19}ClF_2NaO_3$ $(M+Na)^+$ 355.0883, found 355.0879.



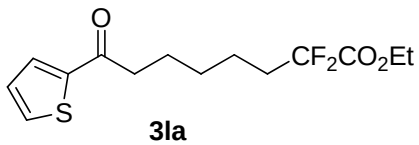
3ja

Compound ***3ja***: 71 mg, 76% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.83–7.80 (m, 2H), 7.61–7.59 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.94 (t, J = 7.3 Hz, 2H), 2.12–2.03 (m, 2H), 1.76–1.73 (m, 2H), 1.56–1.50 (m, 2H), 1.47–1.42 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 198.8, 164.3 (t, $J_{C\text{-}F}$ = 33.9 Hz), 135.6, 131.8, 129.5, 128.1, 116.2 (t, $J_{C\text{-}F}$ = 257.6 Hz), 62.7, 38.0, 34.2 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.6, 23.6, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{16}H_{19}BrF_2NaO_3$ $(M+Na)^+$ 399.0378, found 399.0373.



3ka

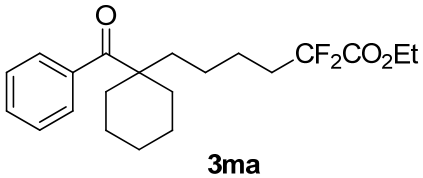
Compound ***3ka***: 48 mg, 55% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.47 (s, 1H), 8.04–8.02 (m, 1H), 7.97 (d, J = 8.1 Hz, 1H), 7.91–7.87 (m, 2H), 7.62–7.59 (m, 1H), 7.57–7.55 (m, 1H), 4.32 (q, J = 7.1 Hz, 2H), 3.12 (t, J = 7.3 Hz, 2H), 2.16–2.05 (m, 2H), 1.85–1.80 (m, 2H), 1.60–1.53 (m, 2H), 1.53–1.46 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.0, 164.4 (t, $J_{C\text{-}F}$ = 32.7 Hz), 135.5, 134.3, 132.5, 129.6, 129.5, 128.44, 128.40, 127.8, 126.8, 123.8, 116.3 (t, $J_{C\text{-}F}$ = 248.6 Hz), 62.8, 38.2, 34.3 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.9, 21.4 (t, $J_{C\text{-}F}$ = 4.3 Hz), 14.0; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.9; HRMS (ESI) calcd for $C_{20}H_{22}F_2NaO_3$ $(M+Na)^+$ 371.1429, found 371.1425.



3la

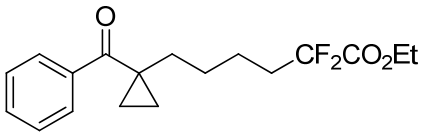
Compound ***3la***: 59 mg, 77% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.72–7.71 (m, 1H), 7.64–7.63 (m, 1H), 7.14–7.13 (m, 1H), 4.32 (q, J = 7.2 Hz, 2H), 2.91 (t, J = 7.3 Hz, 2H), 2.11–2.03 (m, 2H), 1.79–1.74 (m, 2H), 1.55–1.50 (m, 2H), 1.47–1.42 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 193.0,

164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 144.3, 133.5, 131.7, 128.1, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.7, 38.9, 34.2 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.6, 24.1, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0. HRMS (ESI) calcd for $C_{14}H_{18}F_2NaO_3S$ $(M+Na)^+$ 327.0837, found 327.0834.



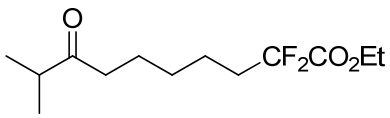
3ma

Compound ***3ma***: 70 mg, 76% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.61–7.58 (m, 2H), 7.47–7.45 (m, 1H), 7.41–7.38 (m, 2H), 4.30 (q, J = 7.1 Hz, 2H), 2.23–2.22 (m, 2H), 2.05–1.96 (m, 2H), 1.81–1.78 (m, 2H), 1.52–1.50 (m, 3H), 1.47–1.41 (m, 2H), 1.40–1.35 (m, 2H), 1.33 (t, J = 7.2 Hz, 3H), 1.30–1.26 (m, 5H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 208.9, 164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 139.8, 130.7, 128.1, 127.2, 116.1 (t, $J_{C\text{-}F}$ = 250.2 Hz), 62.7, 52.2, 39.0, 34.7, 34.2 (t, $J_{C\text{-}F}$ = 23.3 Hz), 26.0, 23.7, 22.9, 22.0 (t, $J_{C\text{-}F}$ = 4.2 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.1; HRMS (ESI) calcd for $C_{21}H_{28}F_2NaO_3$ $(M+Na)^+$ 389.1899, found 389.1897.



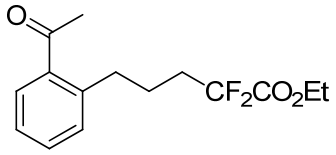
3na

Compound ***3b***: 58 mg, 71% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.77–7.76 (m, 2H), 7.46–7.44 (m, 1H), 7.39–7.3 (m, 2H), 4.21 (q, J = 7.1 Hz, 2H), 1.88–1.77 (m, 2H), 1.70–1.63 (m, 2H), 1.29–1.21 (m, 7H), 1.15 (q, J = 4.2 Hz, 2H), 0.71 (q, J = 4.3 Hz, 2H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 203.2, 164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 137.2, 132.0, 128.32, 128.30, 116.1 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.7, 36.0, 34.2 (t, $J_{C\text{-}F}$ = 23.2 Hz), 30.4, 27.4, 21.2 (t, $J_{C\text{-}F}$ = 4.2 Hz), 13.9, 12.8; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.1; HRMS (ESI) calcd for $C_{18}H_{22}F_2NaO_3$ $(M+Na)^+$ 347.1429, found 347.1418.



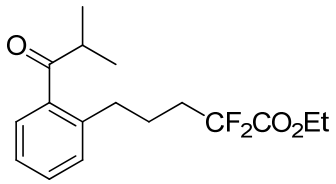
3oa

Compound ***3oa***: 46 mg, 70% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.33 (q, J = 7.1 Hz, 2H), 2.62–2.57 (m, 1H), 2.46 (t, J = 7.3 Hz, 2H), 2.10–2.01 (m, 2H), 1.61–1.56 (m, 2H), 1.51–1.44 (m, 2H), 1.39–1.31 (m, 5H), 1.09 (d, J = 6.9 Hz, 6H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 214.6, 164.3 (t, $J_{C\text{-}F}$ = 33.1 Hz), 116.2 (t, $J_{C\text{-}F}$ = 250.0 Hz), 62.7, 40.8, 39.8, 34.2 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.6, 23.2, 21.3 (t, $J_{C\text{-}F}$ = 4.2 Hz), 18.2, 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{13}H_{22}F_2NaO_3$ $(M+Na)^+$ 287.1429, found 287.1423.



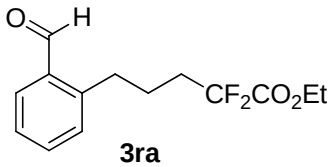
3pa

Compound ***3pa***: 50 mg, 71% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.70 (d, J = 7.7 Hz, 1H), 7.42–7.40 (m, 1H), 7.31–7.28 (m, 1H), 7.25 (d, J = 7.6 Hz, 1H), 4.33–4.29 (m, 2H), 2.92–2.90 (m, 2H), 2.58 (s, 3H), 2.18–2.09 (m, 2H), 1.80–1.75 (m, 2H), 1.36–1.30 (m, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 201.5, 164.2 (t, $J_{C\text{-}F}$ = 33.1 Hz), 141.4, 137.4, 131.6, 131.2, 129.5, 126.1, 116.2 (t, $J_{C\text{-}F}$ = 250.1 Hz), 62.6, 34.1 (t, $J_{C\text{-}F}$ = 23.1 Hz), 33.2, 29.6, 23.3 (t, $J_{C\text{-}F}$ = 4.2 Hz), 13.8; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.8; HRMS (ESI) calcd for $C_{15}H_{18}F_2NaO_3$ $(M+Na)^+$ 307.1116, found 307.1110.



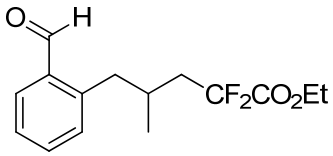
3qa

Compound ***3qa***: 51 mg, 65% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.55–7.54 (m, 1H), 7.40–7.38 (m, 1H), 7.29–7.25 (m, 2H), 4.31 (q, J = 7.1 Hz, 2H), 3.38–3.33 (m, 1H), 2.81–2.76 (m, 2H), 2.20–2.03 (m, 2H), 1.85–1.73 (m, 2H), 1.34 (t, J = 7.2 Hz, 3H), 1.16 (d, J = 6.9 Hz, 6H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 208.9, 164.3 (t, $J_{C\text{-}F}$ = 33.1 Hz), 140.9, 138.2, 130.80, 130.78, 127.8, 126.1, 116.2 (t, $J_{C\text{-}F}$ = 250.2 Hz), 62.7, 38.7, 34.2 (t, $J_{C\text{-}F}$ = 23.2 Hz), 32.9, 23.5 (t, $J_{C\text{-}F}$ = 4.1 Hz), 18.6, 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.9; HRMS (ESI) calcd for $C_{17}H_{22}F_2NaO_3$ $(M+Na)^+$ 335.1429, found 335.1426.



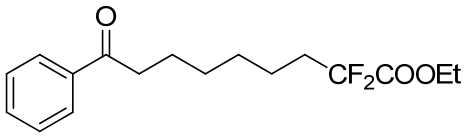
3ra

Compound ***3ra***: 51 mg, 75% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 10.22 (s, 1H), 7.85–7.83 (m, 1H), 7.56–7.54 (m, 1H), 7.46–7.43 (m, 1H), 7.30 (d, J = 7.6 Hz, 1H), 4.34 (q, J = 7.1 Hz, 2H), 3.14–3.11 (m, 2H), 2.24–2.11 (m, 2H), 1.88–1.77 (m, 2H), 1.36 (t, J = 7.2 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.6, 164.2 (t, $J_{C\text{-}F}$ = 33.0 Hz), 143.6, 133.8, 133.7, 133.6, 131.0, 126.9, 116.1 (t, $J_{C\text{-}F}$ = 250.4 Hz), 62.8, 34.1 (t, $J_{C\text{-}F}$ = 23.3 Hz), 32.0, 23.5 (t, $J_{C\text{-}F}$ = 4.2 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.8; HRMS (ESI) calcd for $C_{14}H_{16}F_2NaO_3$ $(M+Na)^+$ 293.0960, found 293.0955.



3sa

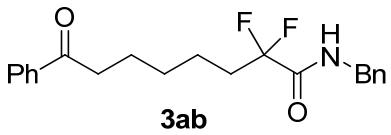
Compound ***3sa***: 52 mg, 73% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 10.22 (s, 1H), 7.84 (d, J = 7.6 Hz, 1H), 7.54–7.51 (m, 1H), 7.4–7.41 (m, 1H), 7.24 (d, J = 7.6 Hz, 1H), 4.34–4.22 (m, 2H), 3.15 (dd, J = 13.2, 6.0 Hz, 1H), 2.90 (dd, J = 13.2, 7.9 Hz, 1H), 2.22–2.14 (m, 1H), 2.09–1.98 (m, 2H), 1.33–1.31 (m, 3H), 0.99 (d, J = 6.4 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 192.4, 164.3 (t, $J_{C\text{-}F}$ = 33.0 Hz), 142.5, 134.1, 133.5, 132.9, 132.0, 127.0, 116.4 (t, $J_{C\text{-}F}$ = 251.0 Hz), 62.8, 40.4 (t, $J_{C\text{-}F}$ = 22.3 Hz), 39.9, 30.1 (t, $J_{C\text{-}F}$ = 3.2 Hz), 19.8, 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -102.3 (d, J = 259.7 Hz), -103.9 (d, J = 259,7 Hz); HRMS (ESI) calcd for $C_{15}H_{18}F_2NaO_3$ $(M+Na)^+$ 307.1116, found 307.1111.



3ta

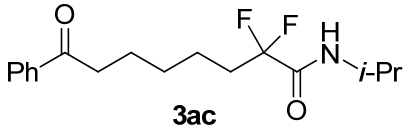
Compound ***3ta***: 52 mg, 67% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96–7.95 (m, 2H), 7.57–7.55 (m, 1H), 7.46 (t, J = 7.7 Hz, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.97 (t, J = 7.3 Hz, 2H), 2.12–1.97 (m, 2H), 1.77–1.72 (m, 2H), 1.53–1.45 (m,

2H), 1.42–1.39 (m, 4H), 1.35 (t, J = 7.2 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.2, 164.4 (t, $J_{C\text{-}F}$ = 33.1 Hz), 137.0, 132.9, 128.6, 128.0, 116.3 (t, $J_{C\text{-}F}$ = 250.0 Hz), 62.7, 38.4, 34.4 (t, $J_{C\text{-}F}$ = 23.1 Hz), 28.92, 28.90, 24.0, 21.3 (t, $J_{C\text{-}F}$ = 4.3 Hz), 13.9; ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.9; HRMS (ESI) calcd for $C_{17}H_{23}F_2O_3$ $(M+H)^+$ 313.1610, found 313.1608.



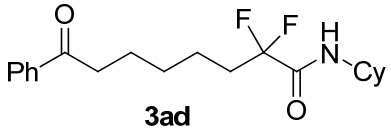
3ab

Compound ***3ab***: 71 mg, 79% yield, white solid, mp: 117–119 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.95–7.93 (m, 2H), 7.57–7.54 (m, 1H), 7.50–7.48 (m, 2H), 7.39–7.37 (m, 2H), 7.35–7.29 (m, 3H), 6.70 (s, 1H), 4.52 (d, J = 5.8 Hz, 2H), 2.99 (t, J = 7.3 Hz, 2H), 2.23–2.10 (m, 2H), 1.80–1.75 (m, 2H), 1.59–1.51 (m, 2H), 1.50–1.42 (m, 2H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.1, 164.3 (t, $J_{C\text{-}F}$ = 29.0 Hz), 136.9, 136.8, 133.0, 128.9, 128.6, 128.0, 127.9, 127.8, 118.3 (t, $J_{C\text{-}F}$ = 252.3 Hz), 43.5, 38.2, 33.7 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.8, 21.5 (t, $J_{C\text{-}F}$ = 4.2 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.1; HRMS (ESI) calcd for $C_{21}H_{23}F_2NNaO_2$ $(M+Na)^+$ 382.1589, found 382.1586.



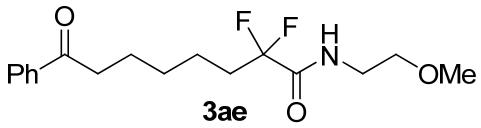
3ac

Compound ***3ac***: 64 mg, 82% yield, white solid, mp: 79–81 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96–7.94 (m, 2H), 7.57–7.54 (m, 1H), 7.51–7.40 (m, 2H), 6.18 (s, 1H), 4.13–4.07 (m, 1H), 2.97 (t, J = 7.3 Hz, 2H), 2.18–2.03 (m, 2H), 1.78–1.73 (m, 2H), 1.53–1.48 (m, 2H), 1.47–1.40 (m, 2H), 1.21 (d, J = 6.6 Hz, 6H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.1, 163.6 (t, $J_{C\text{-}F}$ = 30.1 Hz), 136.9, 133.0, 128.6, 128.0, 118.2 (t, $J_{C\text{-}F}$ = 252.2 Hz), 41.8, 38.2, 33.7 (t, $J_{C\text{-}F}$ = 23.4 Hz), 28.7, 23.8, 22.4, 21.5 (t, $J_{C\text{-}F}$ = 4.3 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.4; HRMS (ESI) calcd for $C_{17}H_{23}F_2NNaO_2$ $(M+Na)^+$ 334.1589, found 334.1583.



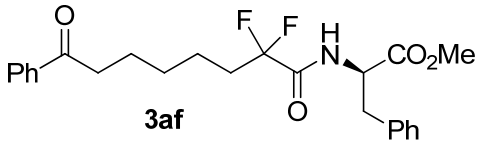
3ad

Compound ***3ad***: 57 mg, 65% yield, white solid, mp: 90–92 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96–7.95 (m, 2H), 7.56 (t, J = 7.4 Hz, 1H), 7.46 (t, J = 7.7 Hz, 2H), 6.22 (d, J = 5.8 Hz, 1H), 3.88–3.67 (m, 1H), 2.97 (t, J = 7.3 Hz, 2H), 2.20–2.02 (m, 2H), 1.99–1.87 (m, 2H), 1.77–1.71 (m, 4H), 1.67–1.60 (m, 1H), 1.53–1.41 (m, 4H), 1.41–1.33 (m, 2H), 1.23–1.17 (m, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.0, 163.3 (t, $J_{C\text{-}F}$ = 28.2 Hz), 136.9, 132.9, 128.6, 128.0, 118.3(t, $J_{C\text{-}F}$ = 252.2 Hz), 48.4, 38.2, 33.7 (t, $J_{C\text{-}F}$ = 33.5 Hz), 32.7, 28.7, 25.3, 24.7, 23.8, 21.5 (t, $J_{C\text{-}F}$ = 4.5 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.4; HRMS (ESI) calcd for $C_{20}H_{27}F_2NNaO_2$ $(M+Na)^+$ 374.1902, found 374.1904.



3ae

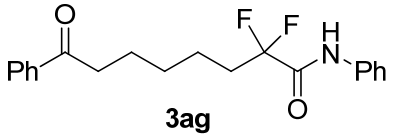
Compound ***3ae***: 66 mg, 81% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96–7.94 (m, 2H), 7.57–7.54 (m, 1H), 7.48–7.45 (m, 2H), 6.75 (s, 1H), 3.52–3.48 (m, 4H), 3.37 (s, 3H), 2.97 (t, J = 7.3 Hz, 2H), 2.18–2.04 (m, 2H), 1.78–1.73 (m, 2H), 1.56–1.48 (m, 2H), 1.48–1.41 (m, 2H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.1, 164.4 (t, $J_{C\text{-}F}$ = 29.0 Hz), 136.9, 132.9, 128.5, 128.0, 118.2 (t, $J_{C\text{-}F}$ = 252.1 Hz), 70.4, 58.8, 39.1, 38.2, 33.7 (t, $J_{C\text{-}F}$ = 23.4 Hz), 28.7, 23.8, 21.4 (t, $J_{C\text{-}F}$ = 4.3 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.4; HRMS (ESI) calcd for $C_{17}H_{23}F_2NNaO_3$ $(M+Na)^+$ 350.1538, found 350.1534.



3af

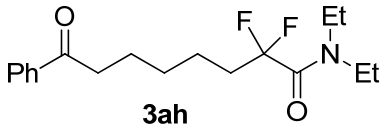
Compound ***3af***: 95 mg, 88% yield, white solid, mp: 101–103 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.96–7.95 (m, 2H), 7.57–7.55 (m, 1H), 7.48–7.45 (m, 2H), 7.32–7.28 (m, 2H), 7.25–7.24 (m, 1H), 7.15–7.06 (m, 2H), 6.80 (d, J = 7.7 Hz, 1H), 4.89 (q, J = 6.7 Hz, 1H), 3.76 (s, 3H), 3.22 (dd, J = 14.0, 5.6 Hz, 1H), 3.12 (dd, J = 14.0, 6.3 Hz, 1H), 2.96 (t, J = 7.3 Hz, 2H), 2.13–1.96 (m, 2H), 1.76–1.71 (m, 2H), 1.47–1.36 (m, 4H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.0, 164.0 (t, $J_{C\text{-}F}$ = 29.5 Hz), 163.6, 136.9, 135.1, 132.9, 129.1, 128.7, 128.5, 128.0, 127.4, 117.9 (t, $J_{C\text{-}F}$ = 252.2 Hz), 53.0, 52.5, 38.1,

37.6, 33.6 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.8, 21.3 (t, $J_{C\text{-}F}$ = 4.2 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.8 (d, J = 254.5 Hz), -106.9 (d, J = 254.4 Hz); HRMS (ESI) calcd for $C_{24}H_{27}F_2NNaO_4$ $(M+Na)^+$ 454.1800, found 454.1799.



3ag

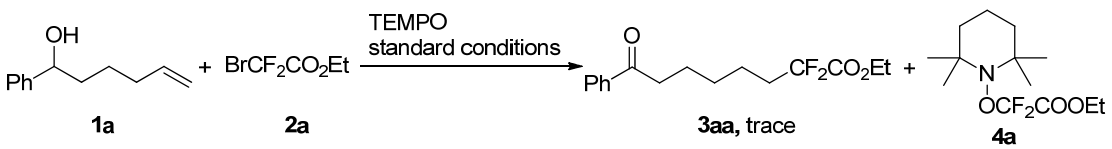
Compound ***3ag***: 44 mg, 51% yield, white solid, mp: 82–84 °C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.03 (s, 1H), 7.95–7.94 (m, 2H), 7.62–7.52 (m, 3H), 7.45 (t, J = 7.8 Hz, 2H), 7.38–7.36 (m, 2H), 7.19 (t, J = 7.4 Hz, 1H), 2.98 (t, J = 7.3 Hz, 2H), 2.26–2.10 (m, 2H), 1.79–1.74 (m, 2H), 1.60–1.55 (m, 2H), 1.51–1.41 (m, 2H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.1, 162.1 (t, $J_{C\text{-}F}$ = 28.8 Hz), 136.9, 136.0, 133.0, 129.2, 128.6, 128.0, 125.5, 120.2, 118.3 (t, $J_{C\text{-}F}$ = 253.6 Hz), 38.1, 33.6 (t, $J_{C\text{-}F}$ = 23.2 Hz), 28.7, 23.8, 21.5 (t, $J_{C\text{-}F}$ = 4.2 Hz); ^{19}F NMR (565 MHz, $CDCl_3$) δ -105.5; HRMS (ESI) calcd for $C_{20}H_{21}F_2NNaO_2$ $(M+Na)^+$ 368.1433, found 368.1431.



3ah

Compound ***3ah***: 37 mg, 45% yield, colorless oil; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.97–7.95 (m, 2H), 7.57–7.54 (m, 1H), 7.47–7.45 (m, 2H), 3.51 (q, J = 7.0 Hz, 2H), 3.38 (q, J = 7.1 Hz, 2H), 3.02–2.95 (m, 2H), 2.19–2.10 (m, 2H), 1.80–1.75 (m, 2H), 1.63–1.56 (m, 2H), 1.51–1.43 (m, 2H), 1.20 (t, J = 7.0 Hz, 3H), 1.15 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.2, 162.9 (t, $J_{C\text{-}F}$ = 29.3 Hz), 137.0, 132.9, 128.5, 128.0, 119.6 (t, $J_{C\text{-}F}$ = 254.0 Hz), 41.8 (t, $J_{C\text{-}F}$ = 6.3 Hz), 41.4, 38.3, 34.7 (t, J = 23.4 Hz), 29.0, 24.0, 21.4 (t, $J_{C\text{-}F}$ = 4.5 Hz), 14.3, 12.3; ^{19}F NMR (565 MHz, $CDCl_3$) δ -100.2; HRMS (ESI) calcd for $C_{18}H_{25}F_2NNaO_2$ $(M+Na)^+$ 348.1746, found 348.1740.

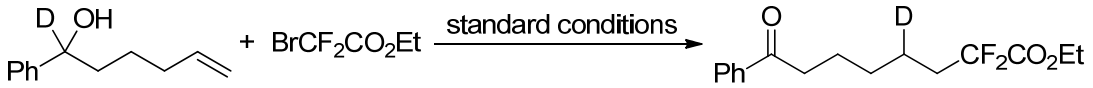
Mechanistic Studies:



1a **2a** **3aa,** trace **4a**

Under N_2, a mixture of **1a** (44.0 mg, 0.25 mmol), **2a** (101.0 mg, 0.5 mmol), **L1** (dtbpy,

13.4 mg, 0.05 mmol), CuI (4.7 mg, 0.025mmol), KOAc (98.0 mg, 0.5 mmol) and 1,2-dichloroethane (DCE, super dry, 2.0 mL). The sealed tube was then stirred at 80 °C. After 12 h, the reaction was stopped. The amount of **4a** were measured by crude ^{19}F NMR ($PhCF_3$ as internal standard). *Compound **3ah*** (known compound[3]): 53mg, 38% yield, colorless oil; ^1H NMR (400 MHz, $CDCl_3$) δ 4.37 (q, J = 7.1 Hz, 2H), 1.63–1.55 (m, 5H), 1.62–1.57 (m, 4H), 1.21 (s, 6H), 1.19 (s, 6H).



[D]-**1a** **2a** [D]-**3aa,** 50%

Under N_2, a 25 mL Schlenk tube equipped with a magnetic stir bar were charged with [D]-**1a** (44.0 mg, 0.25 mmol), **2a** (0.5 mmol, 2 equiv), CuI (4.7 mg, 0.025mmol), KOAc (98.0 mg, 0.5 mmol) and 1,2-dichloroethane (DCE, super dry, 2.0 mL). The sealed tube was then stirred at 80 °C for 12 hours. After completion (monitored by TLC), the reaction solution was concentrated in vacuo, and the residue was purified by silica gel column chromatography (petroleum ether/EtOAc) to gave 37 mg (yield: 50%) of [D]-**3aa** as a colorless oil; ^1H NMR (600 MHz, $CDCl_3$) δ 7.99–7.93 (m, 2H), 7.58–7.55 (m, 1H), 7.50–7.43 (m, 2H), 4.32 (q, J = 7.1 Hz, 2H), 2.98 (t, J = 7.3 Hz, 2H), 2.14–2.02 (m, 2H), 1.79–1.74 (m, 2H), 1.54–1.49 m, 1H), 1.46–1.43 (m, 2H), 1.35 (t, J = 7.1 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 200.0, 164.4 (t, $J_{C\text{-}F}$ = 33.0 Hz), 136.9, 133.0,128.6, 128.0, 116.3 (t, $J_{C\text{-}F}$ = 250.2 Hz), 62.8, 38.1, 34.2 (t, $J_{C\text{-}F}$ = 23.3 Hz), 28.6, 23.7, 21.0 (m), 14.0; ^{19}F NMR (565 MHz, $CDCl_3$) δ -106.0; HRMS (ESI) calcd for $C_{16}H_{19}DF_2NaO_3$ $(M+Na)^+$ 322.1335, found 322.1337.

References

[1] L. Li, L. Ye, S.-F. Ni, Z.-L. Li, S. Chen, Y.-M. Du, X.-H. Li, L. Dang and X.-Y. Liu, *Org. Chem. Front.,* 2017, **4**, 2139.

[2] (a) T. L. Andersen, M. W. Frederiksen, K. Domino and T. Skrydstrup. *Angew. Chem. Int. Ed.*, 2016, **55**, 10396; (b) L. An, Y.-L. Xiao, Q.-Q. Min and X. Zhang. *Angew. Chem. Int. Ed.*, 2015, **127**, 9207; (c) J.-W. Gu, Q.-Q. M, L.-C. Yu and X. Zhang. *Angew. Chem. Int. Ed.*, 2016, **55**, 12270.

[3] W. Fu, M. Zhu, G. Zou, C. Xu, Z. Wang and B. Ji, *J. Org. Chem.*, 2015, **80**, 4766.

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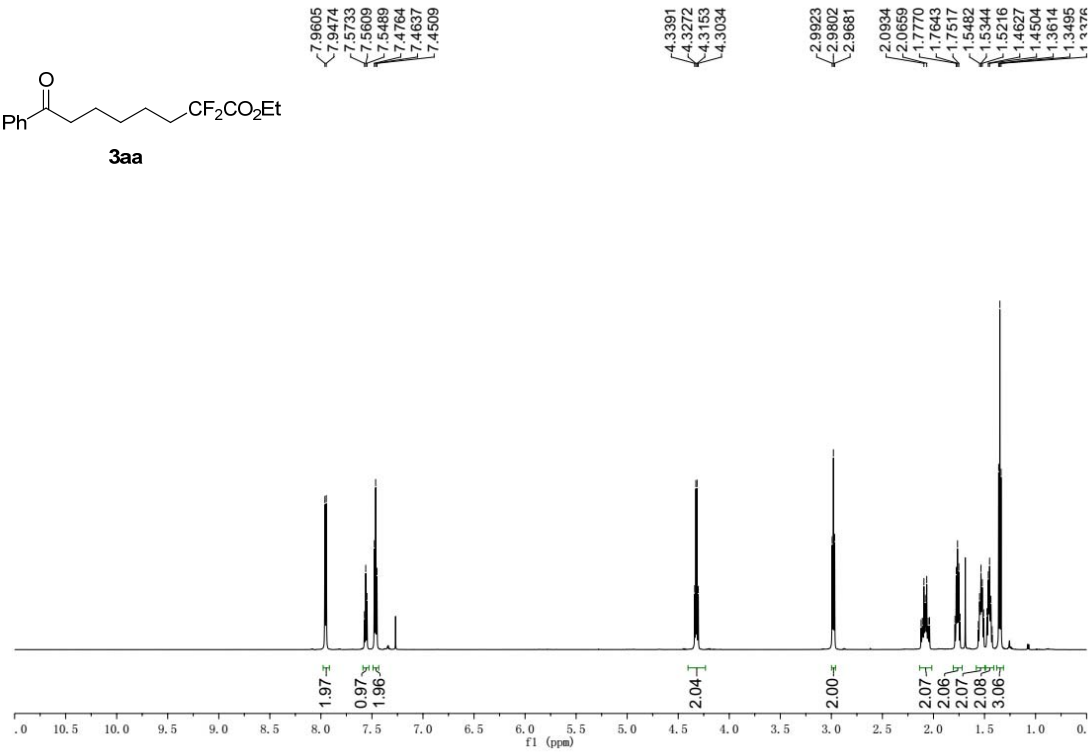
3aa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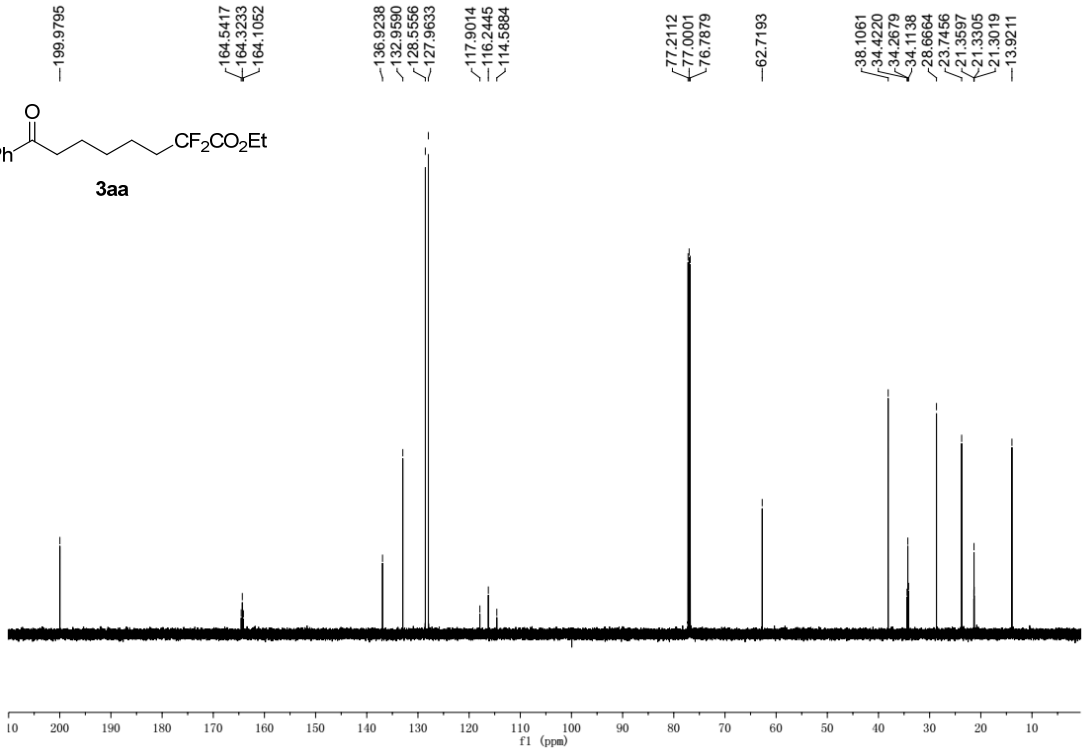
3aa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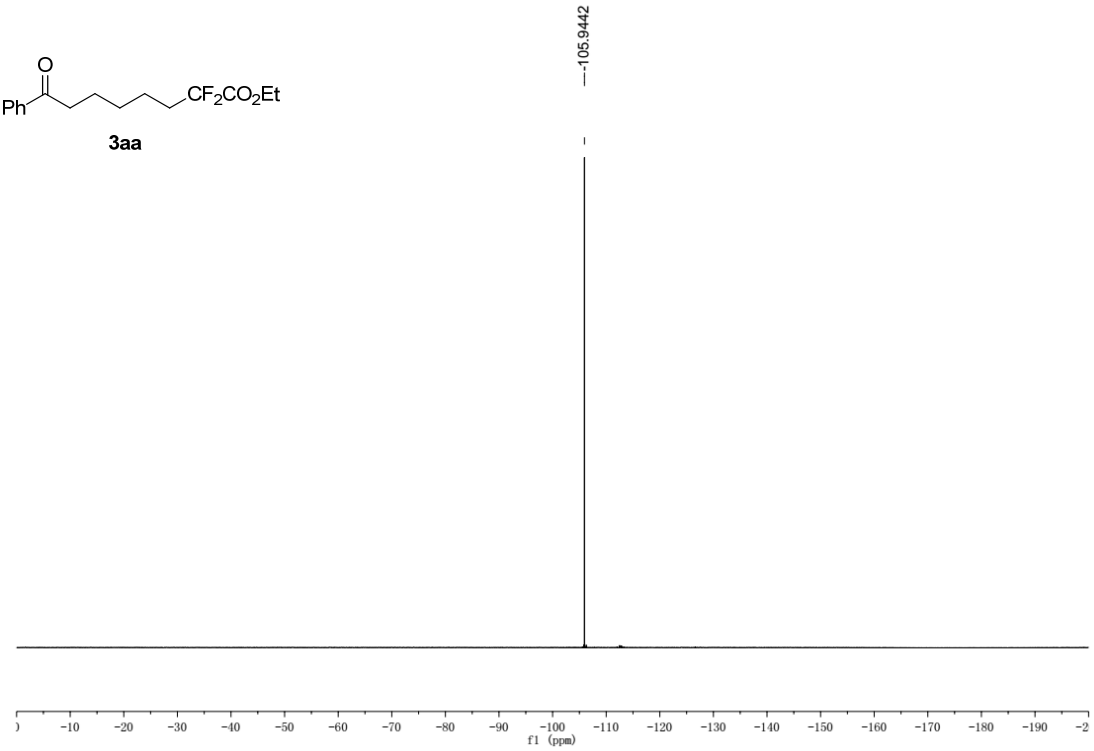
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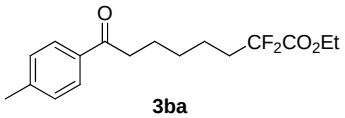
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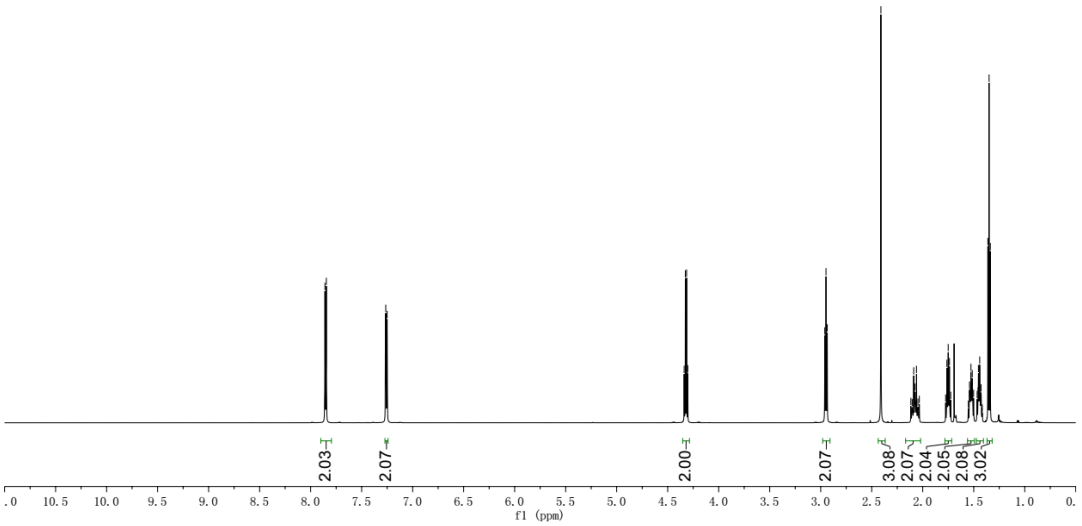
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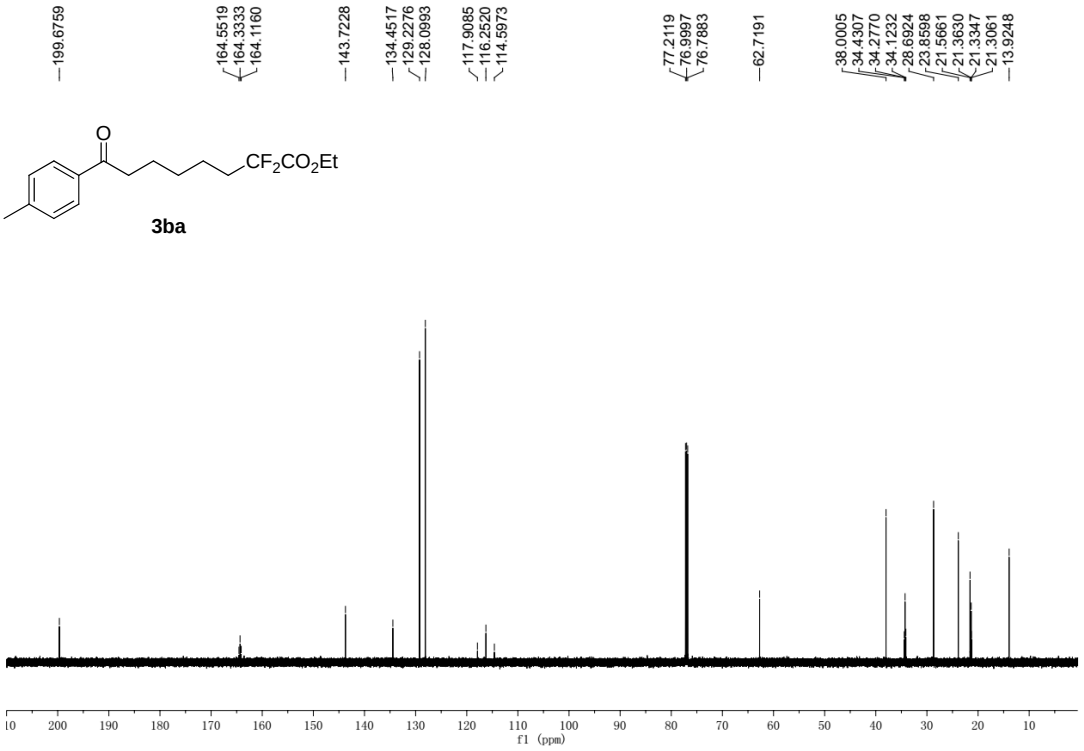
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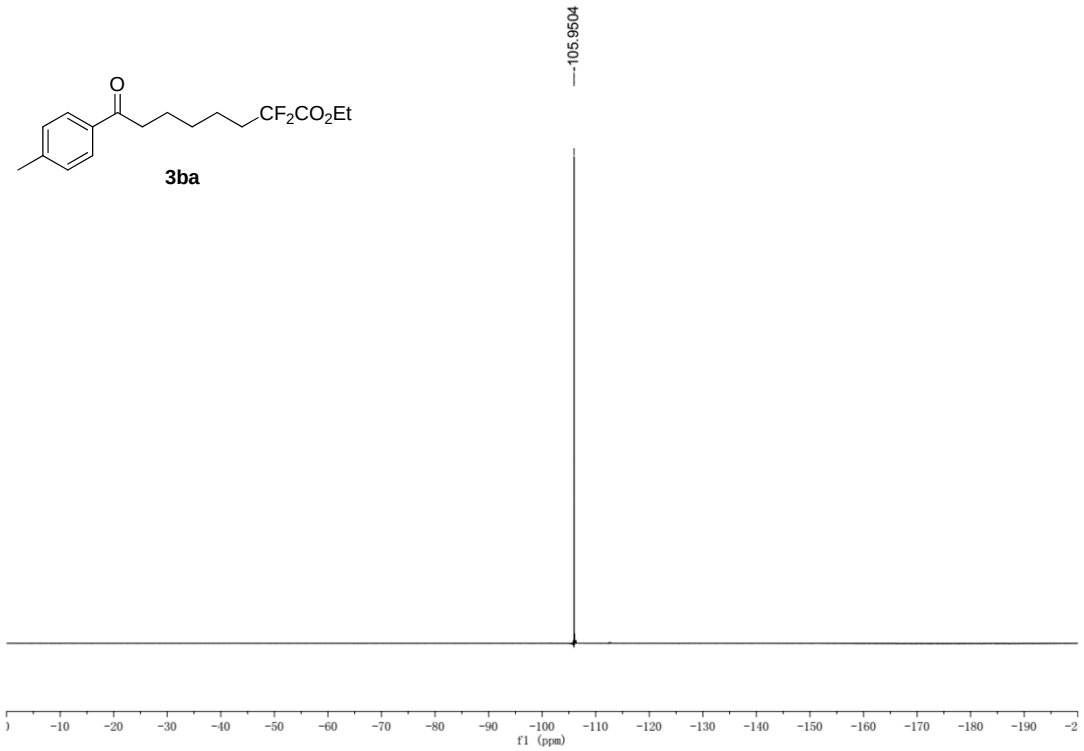
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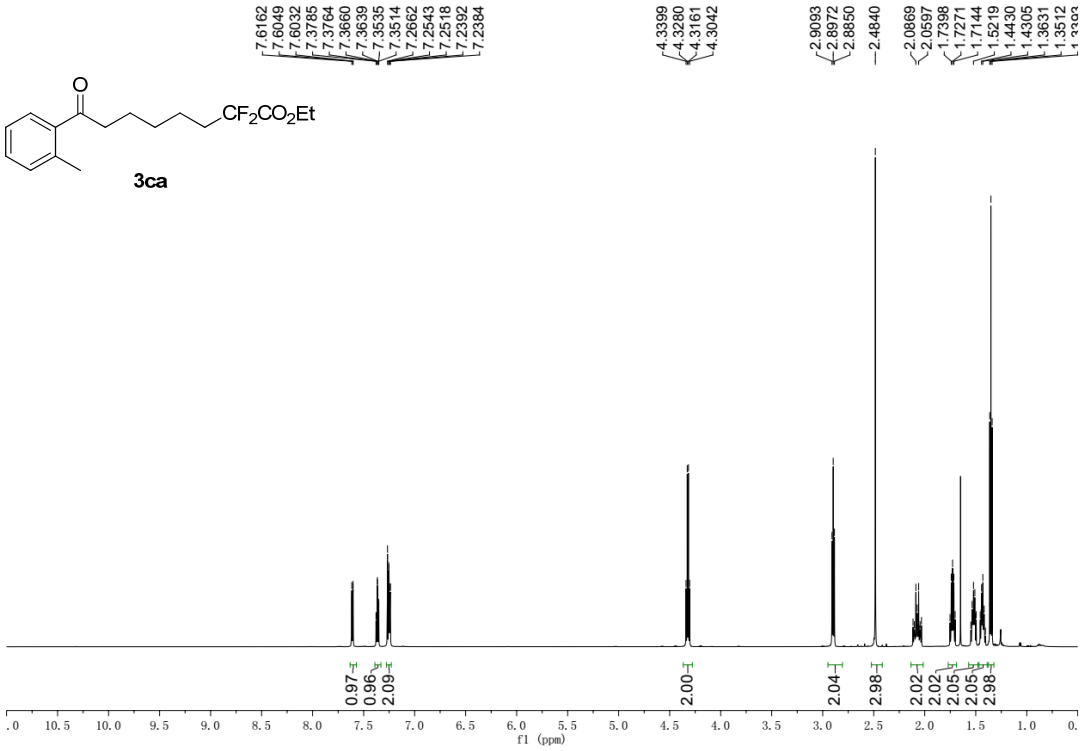
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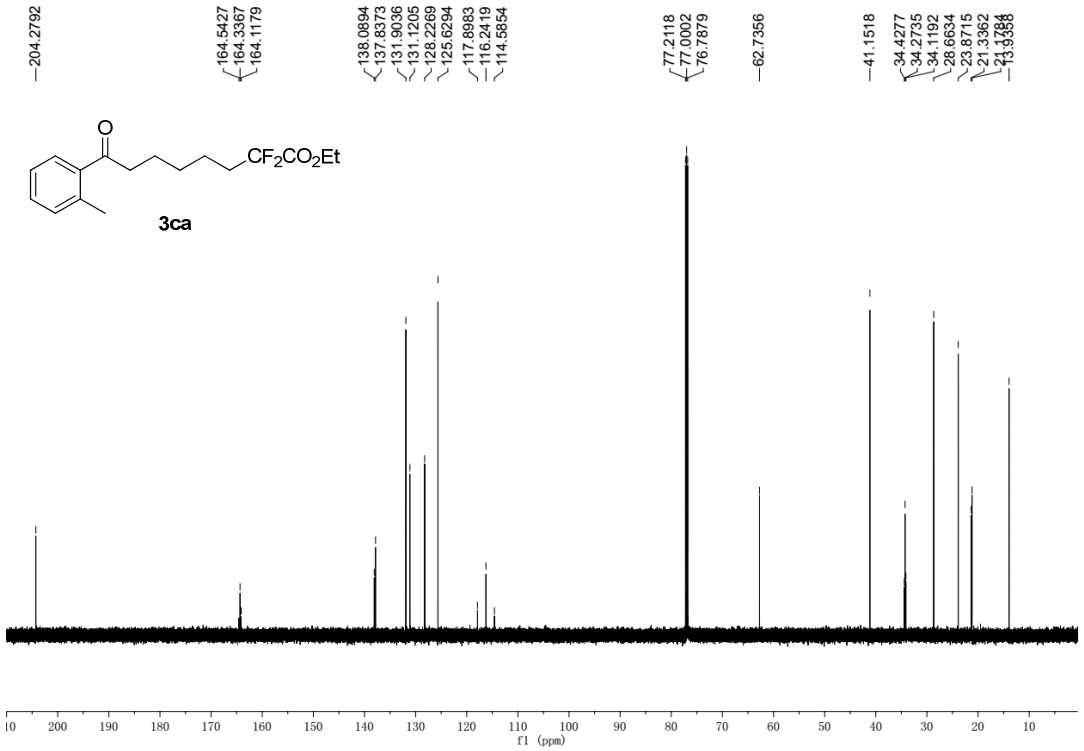
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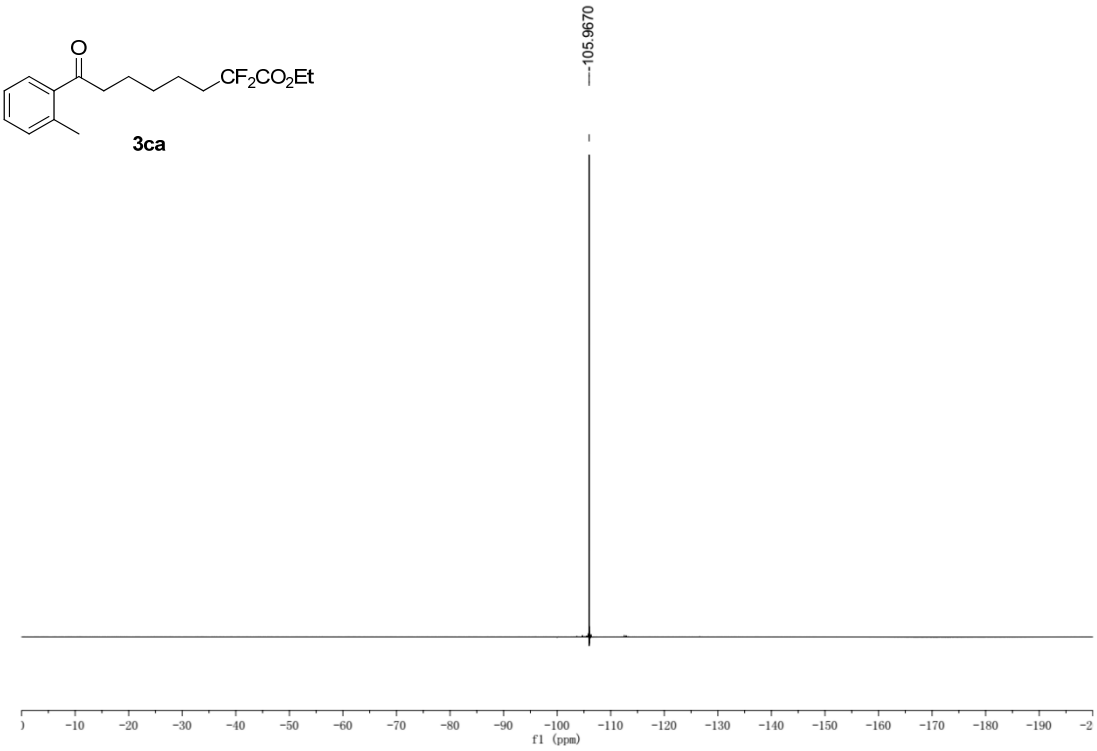
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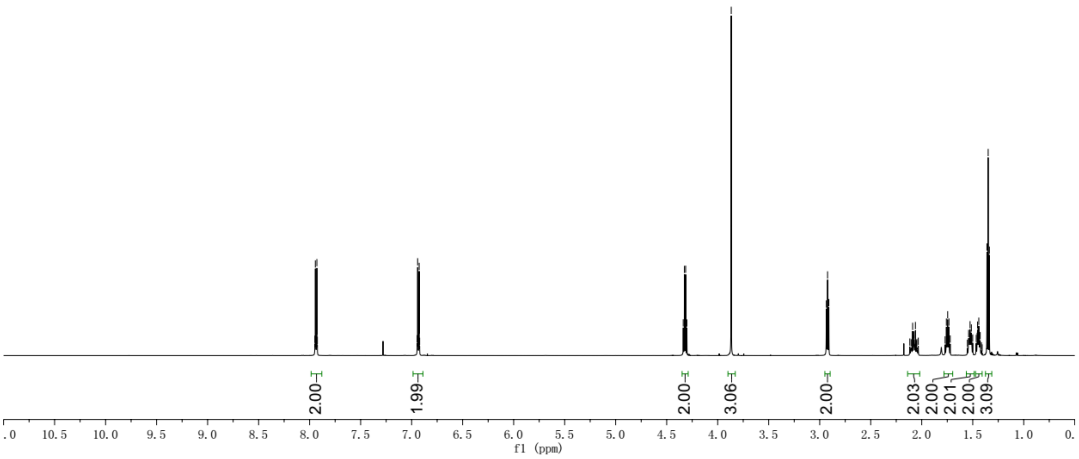
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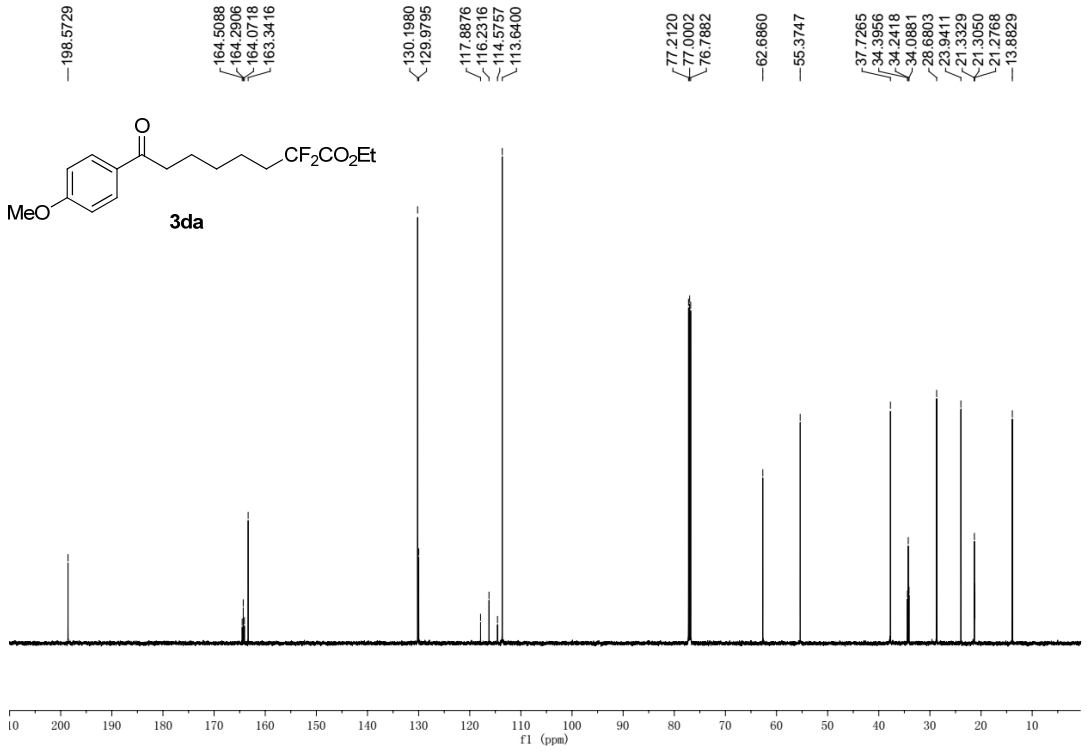
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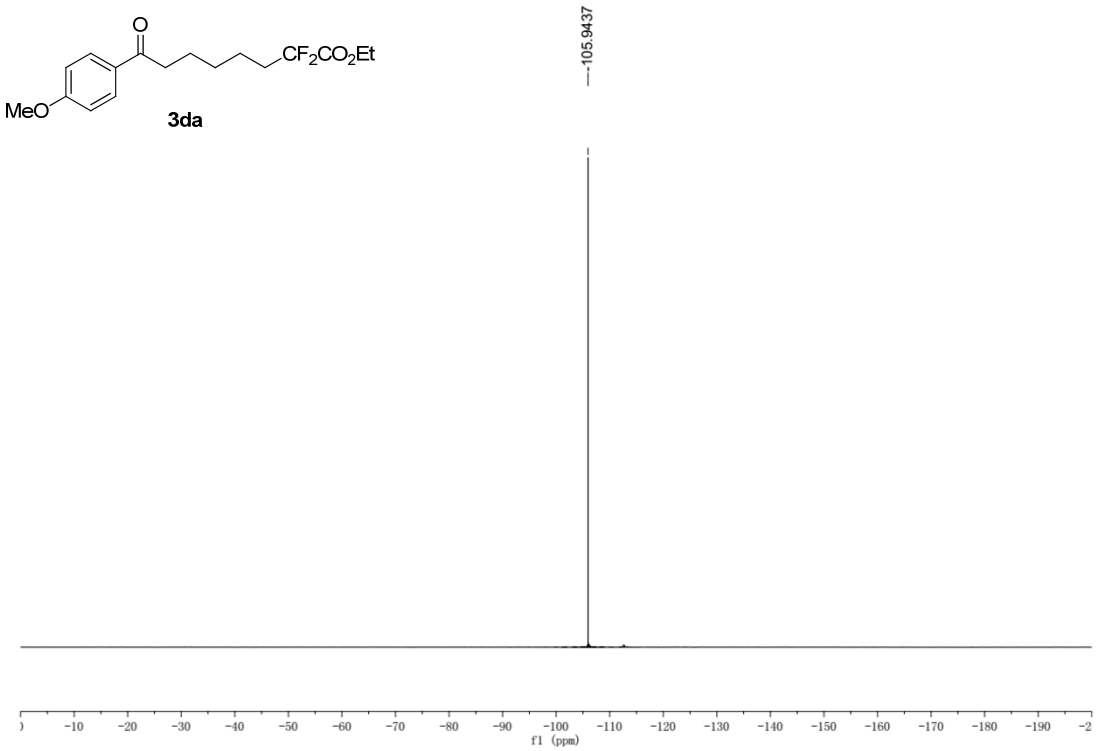
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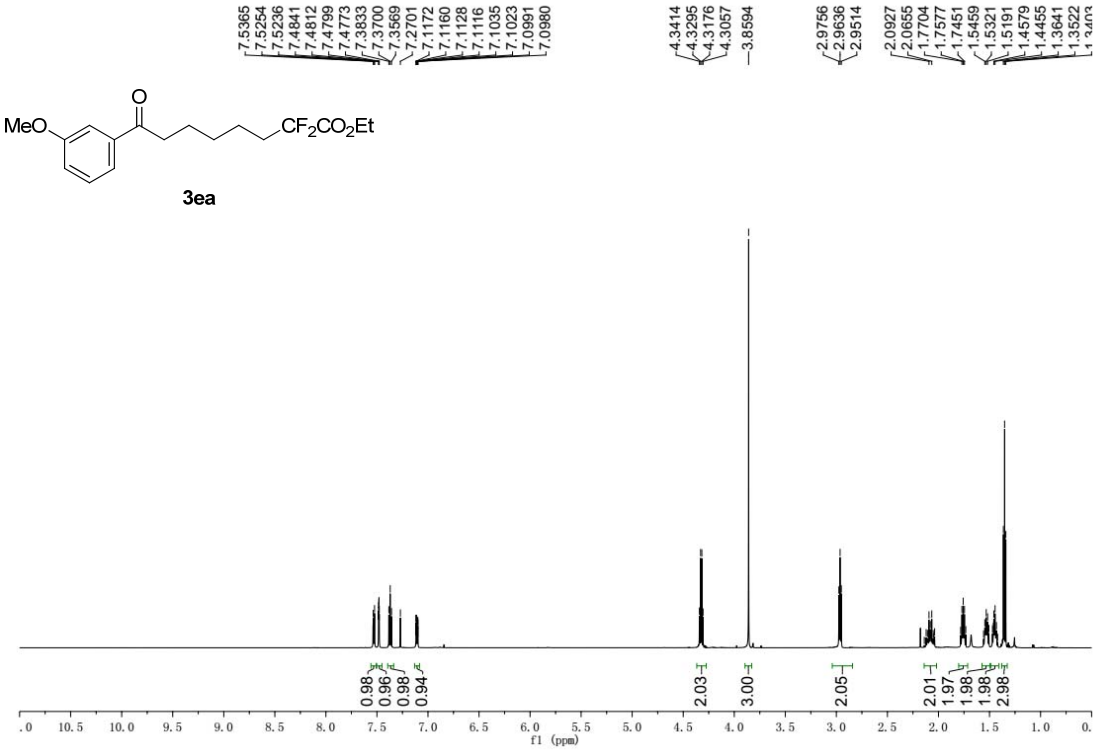
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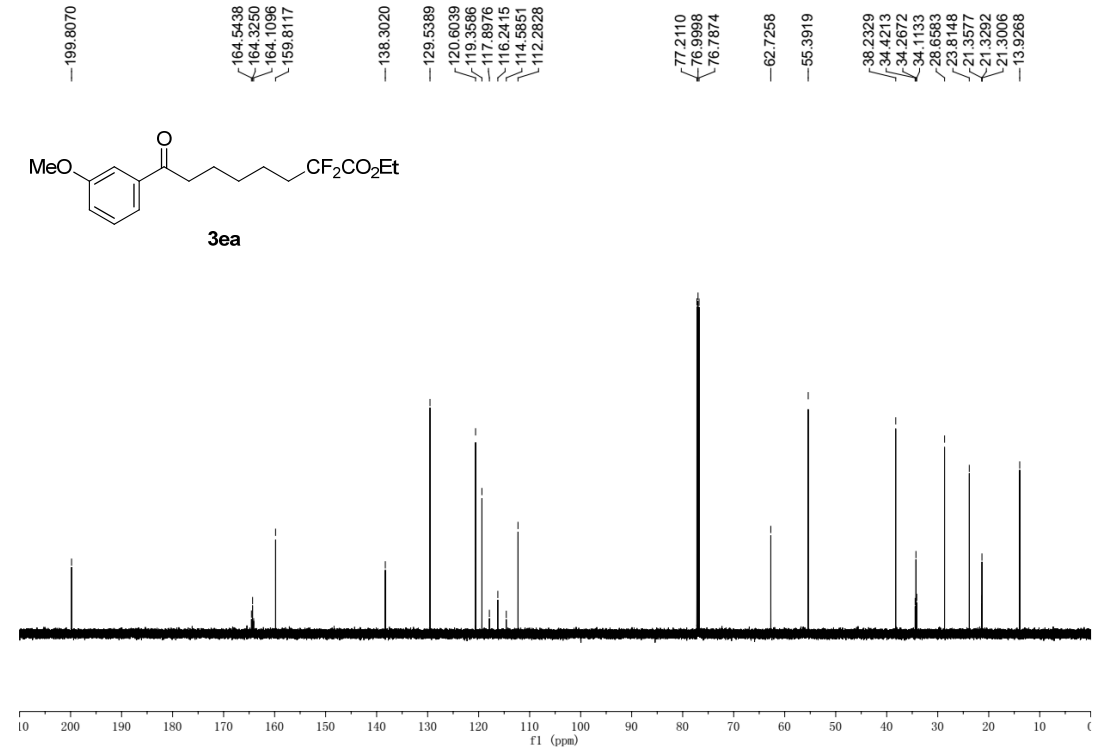
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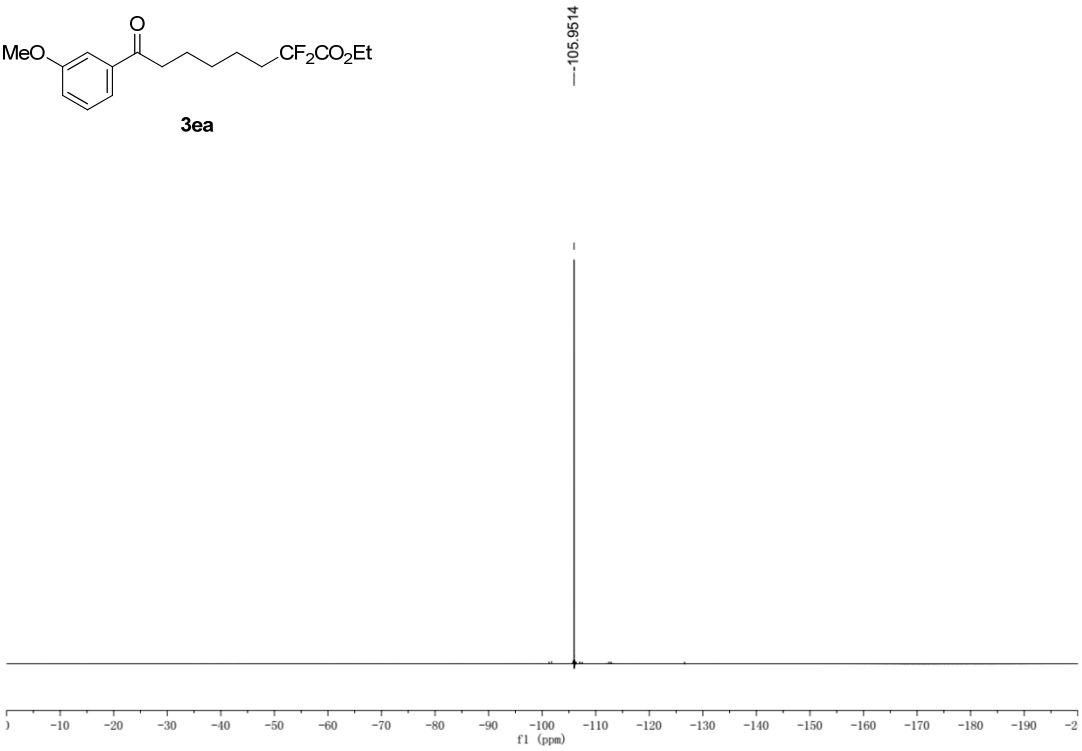
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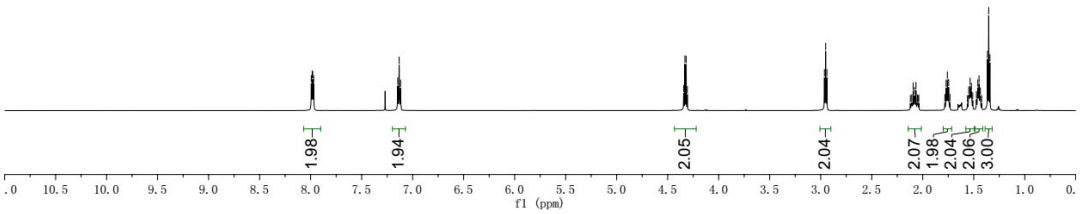
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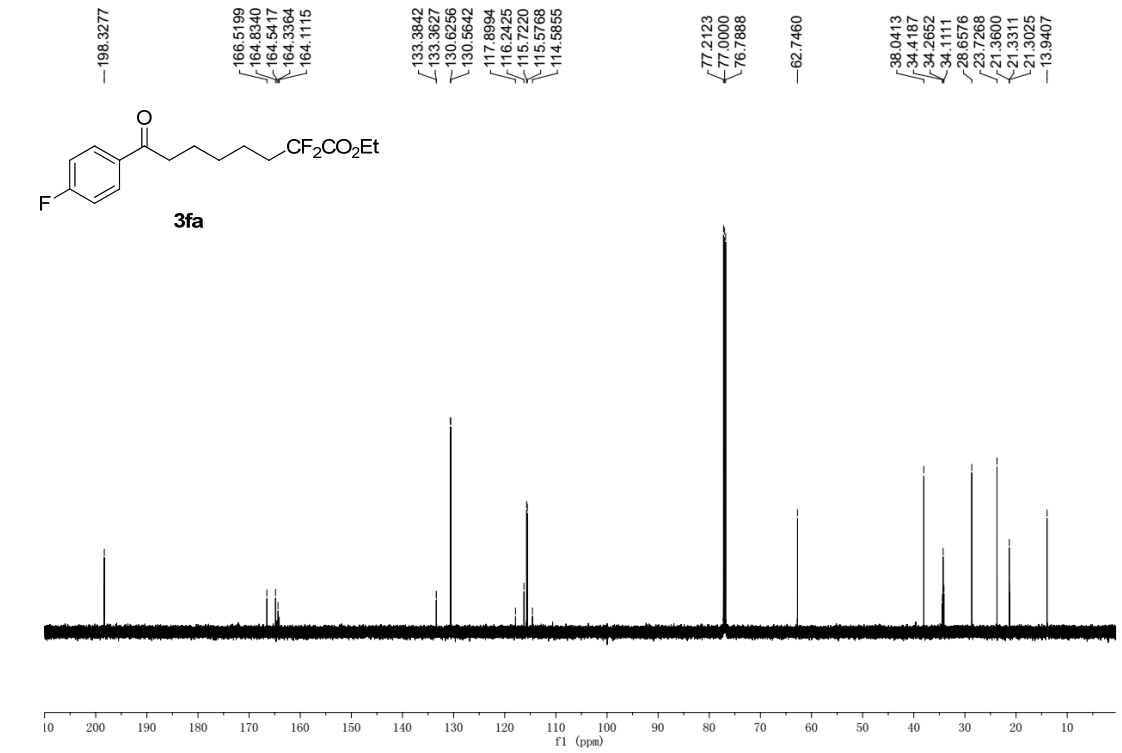
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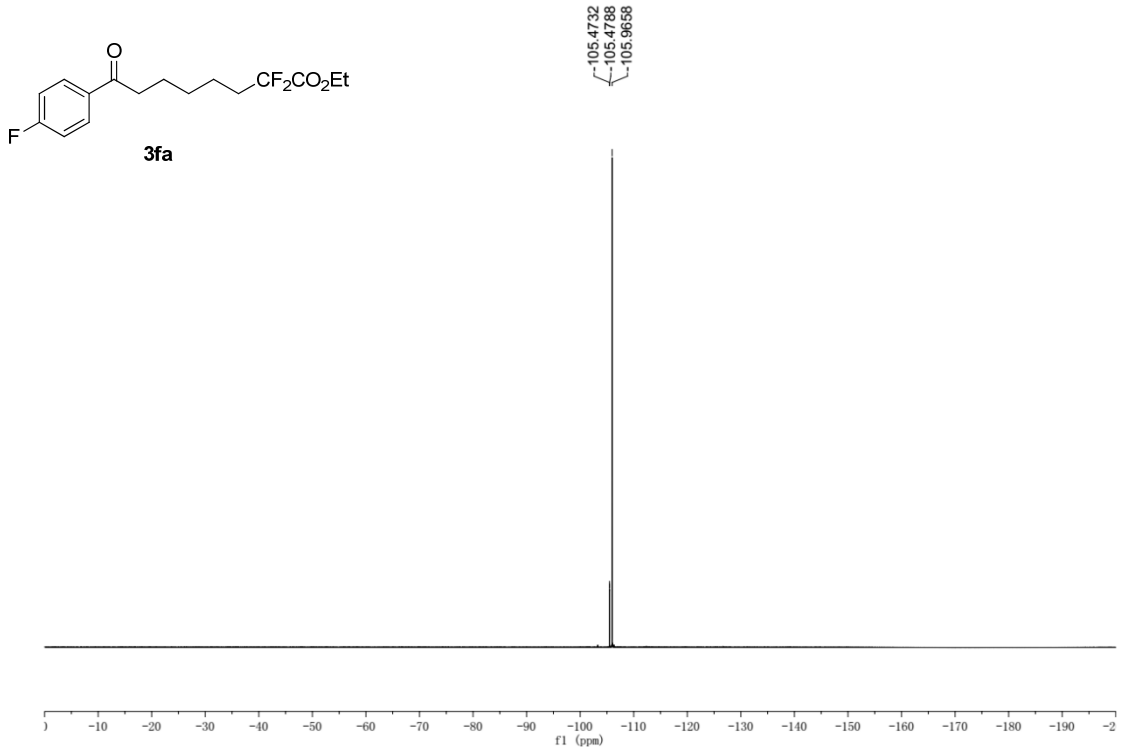
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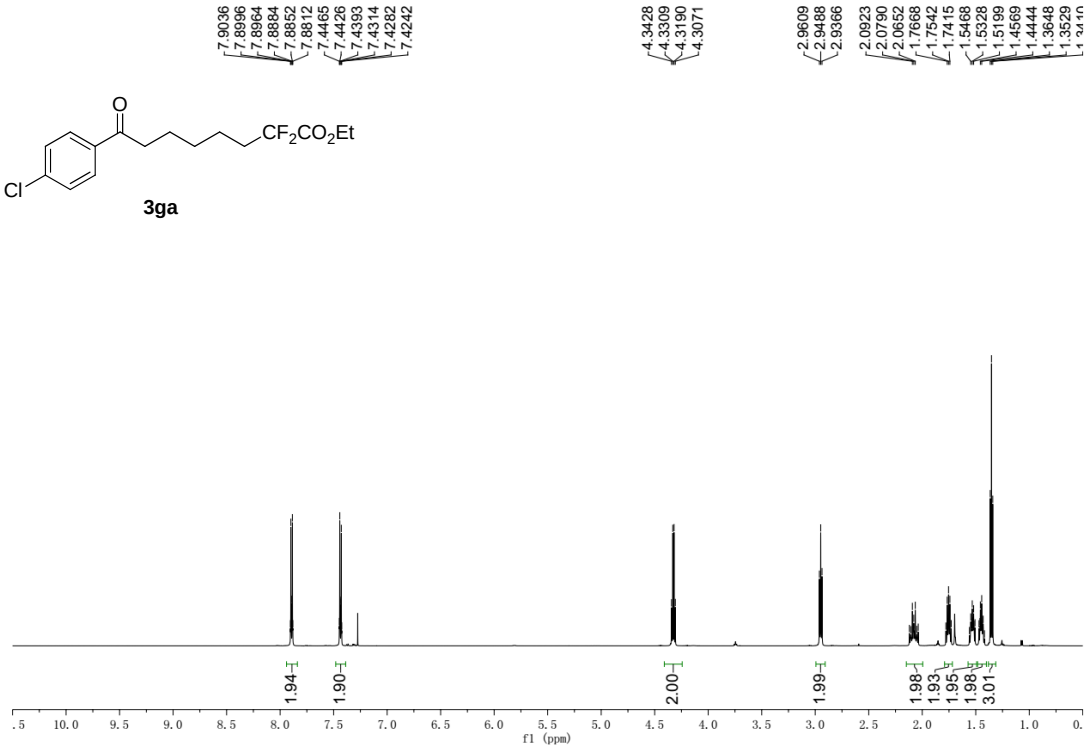
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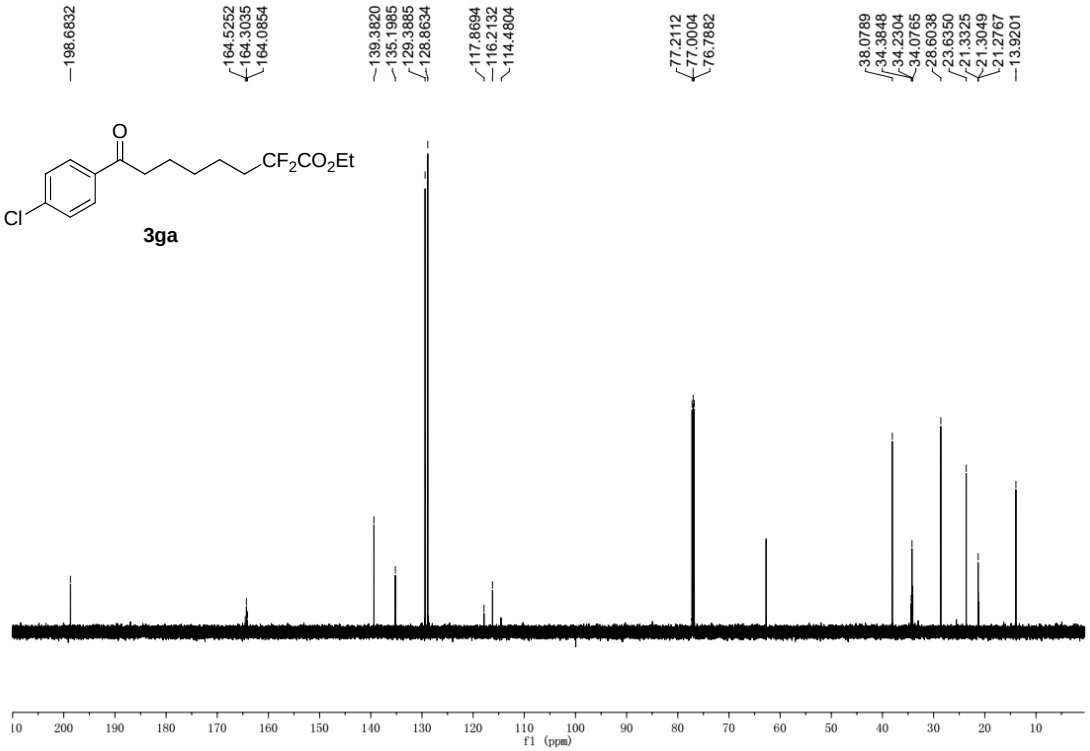
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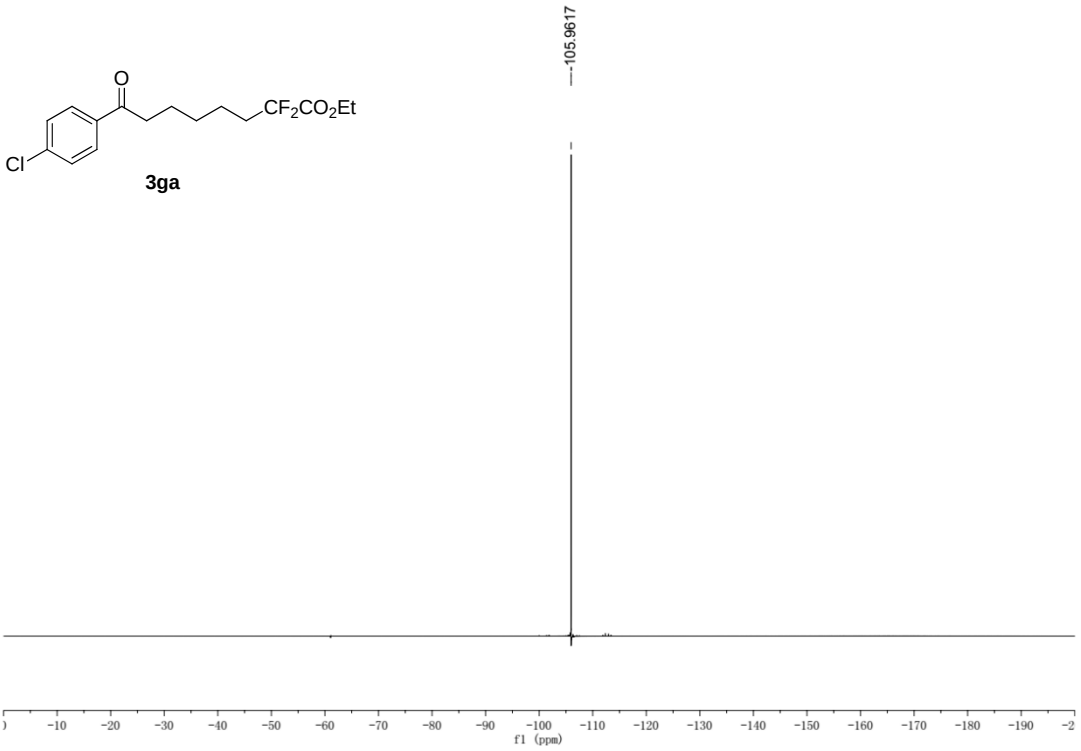
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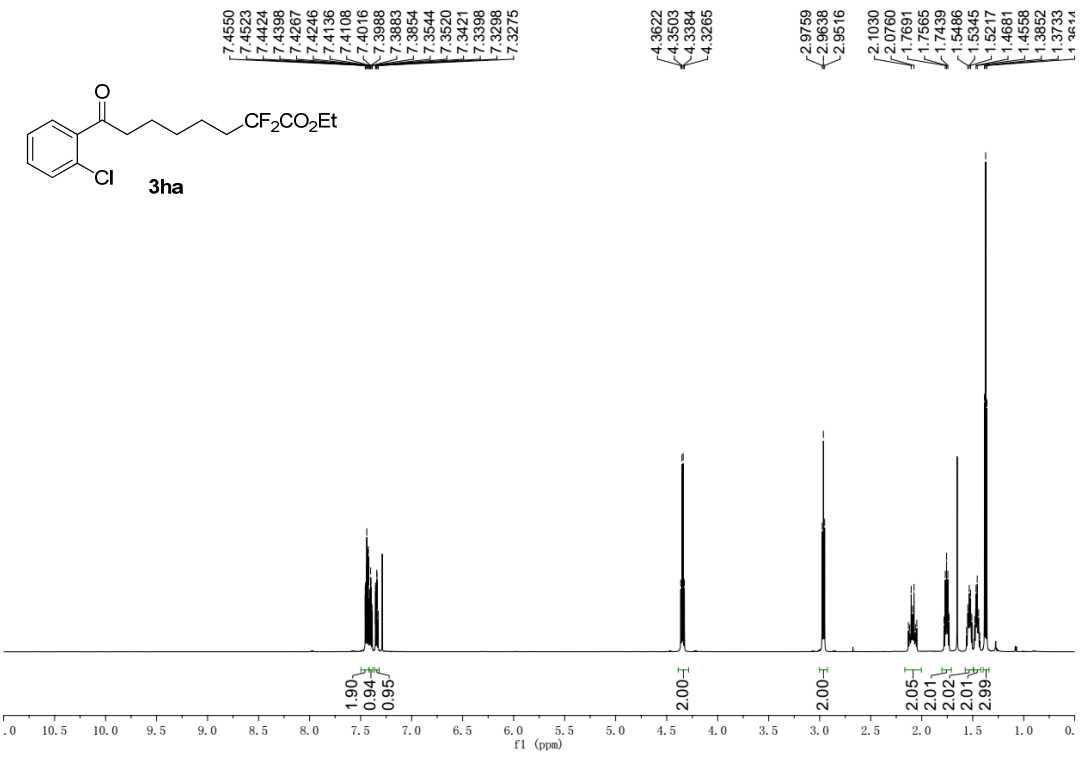
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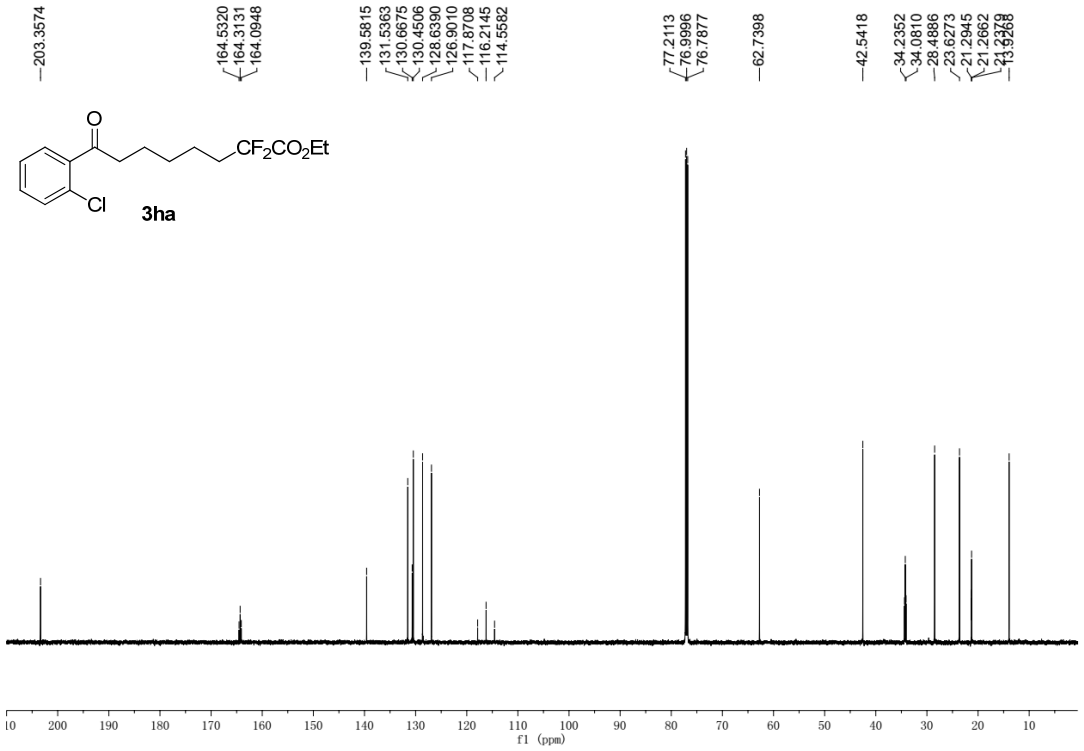
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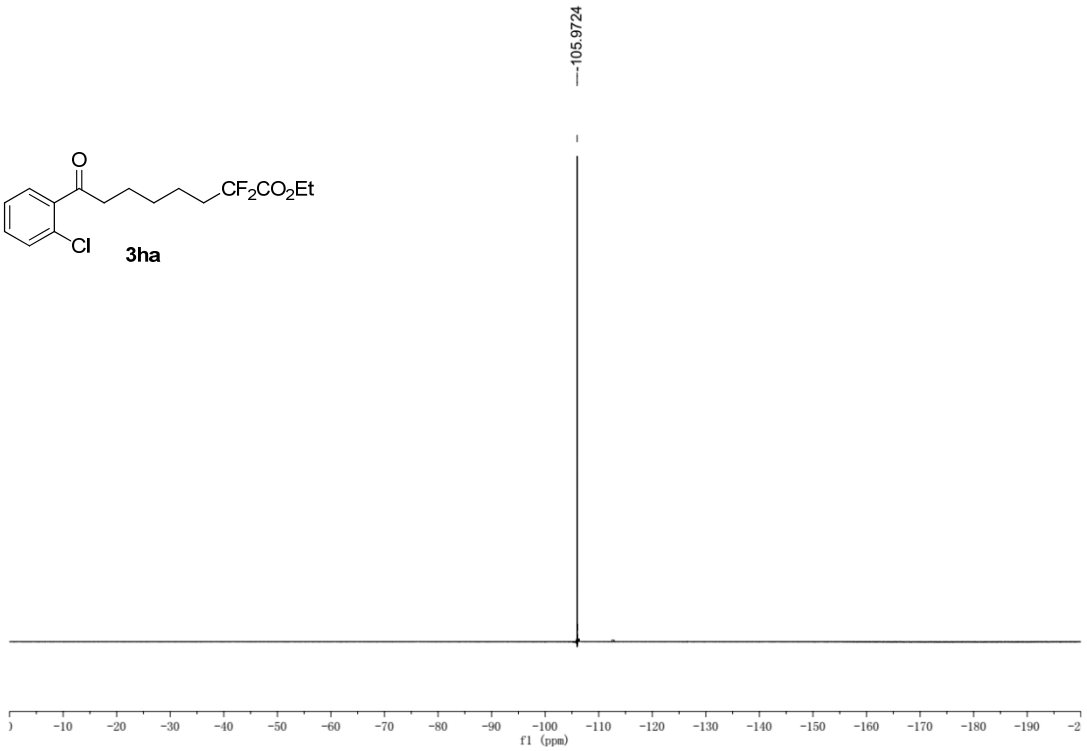
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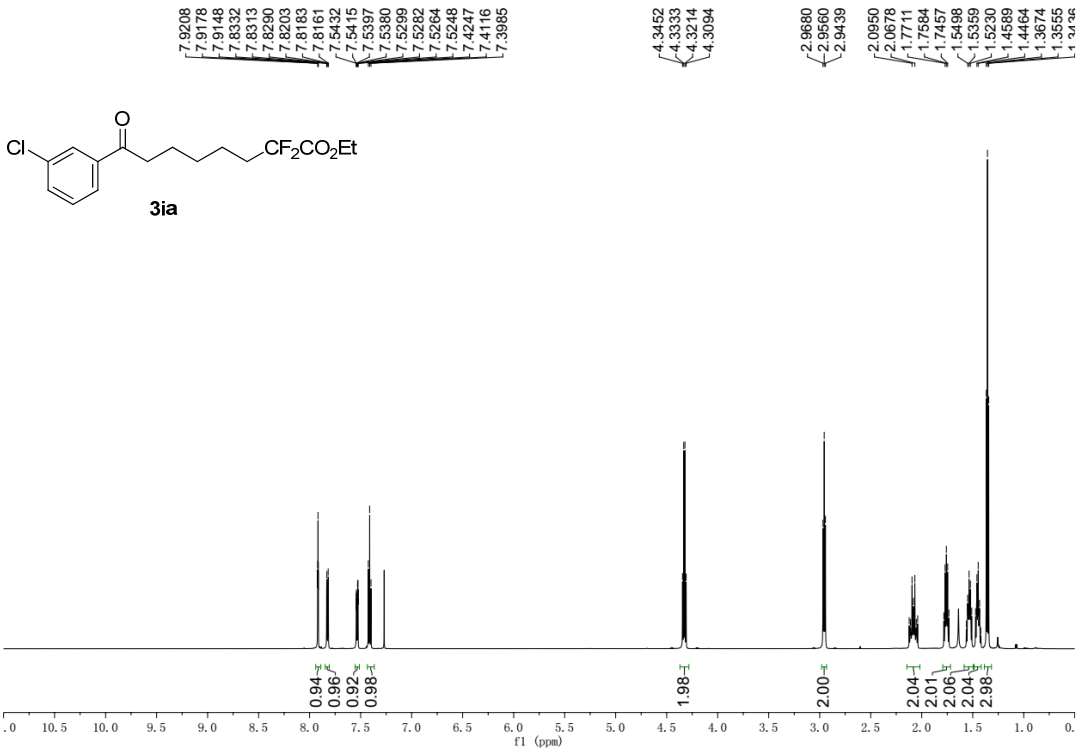
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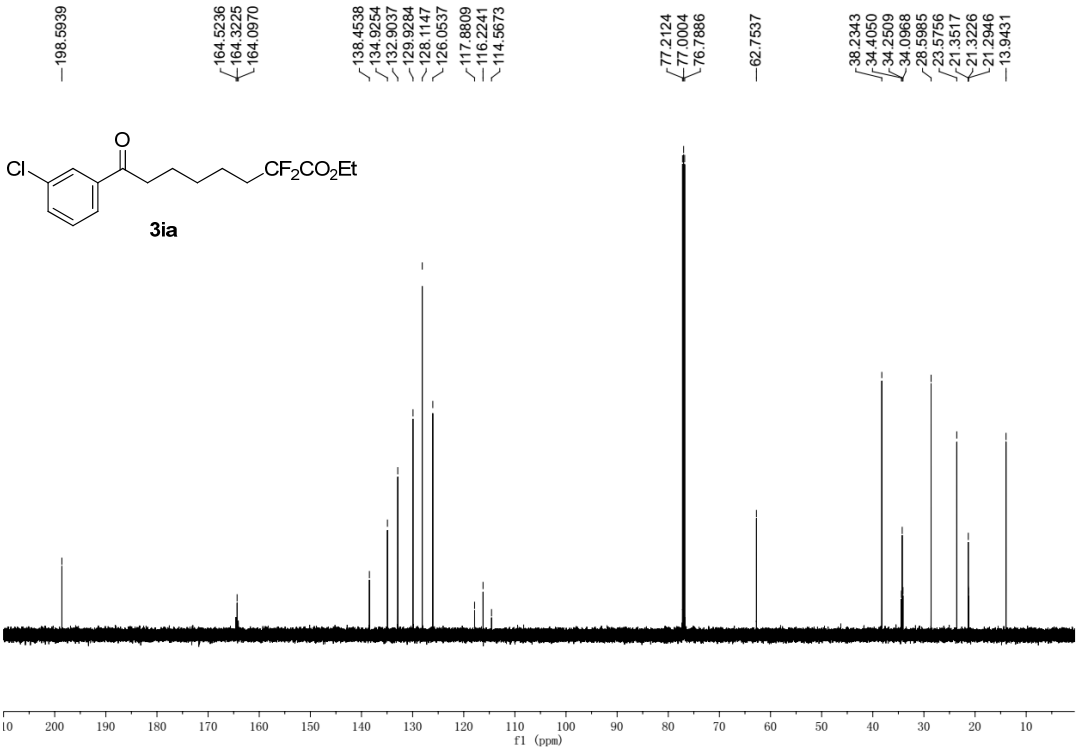
0.92
0.98
1.98
2.00
2.04
2.01
2.06
2.04
2.98
f1 (ppm)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126.0537
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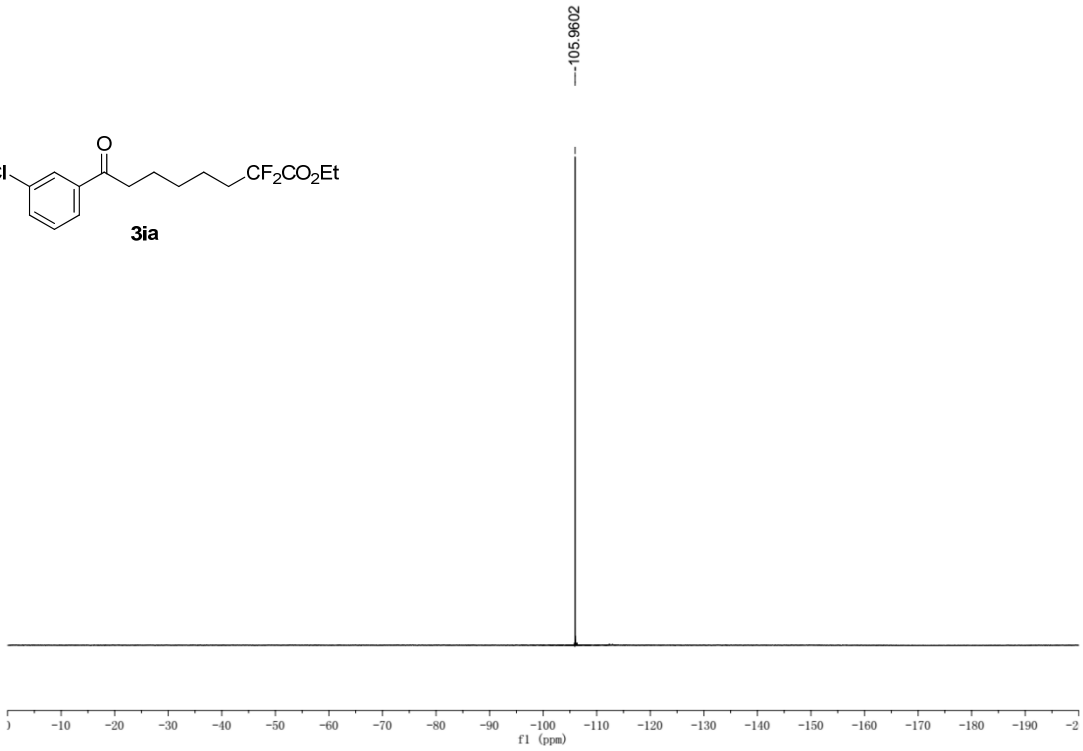
116.2241
114.5673
77.2124
77.0004
76.7886
62.7537
38.2343
34.4050
34.2509
34.0968
28.5985
23.5756
21.3517
21.3226
21.2946
13.9431
Cl
O
CF2CO2Et
3ia
f1 (ppm)

O
Cl
CF2CO2Et

3ia


-105.9602
f1 (ppm)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7.8180
7.8100
7.8068
7.8029
7.6115
7.6076
7.6043
7.5964
7.5932
7.5893
4.3415
4.3296
4.3177
4.3058
2.9539
2.9419
2.9297
2.0909
2.0638
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1.7301
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1.5174
1.4541
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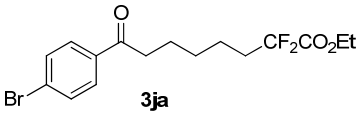
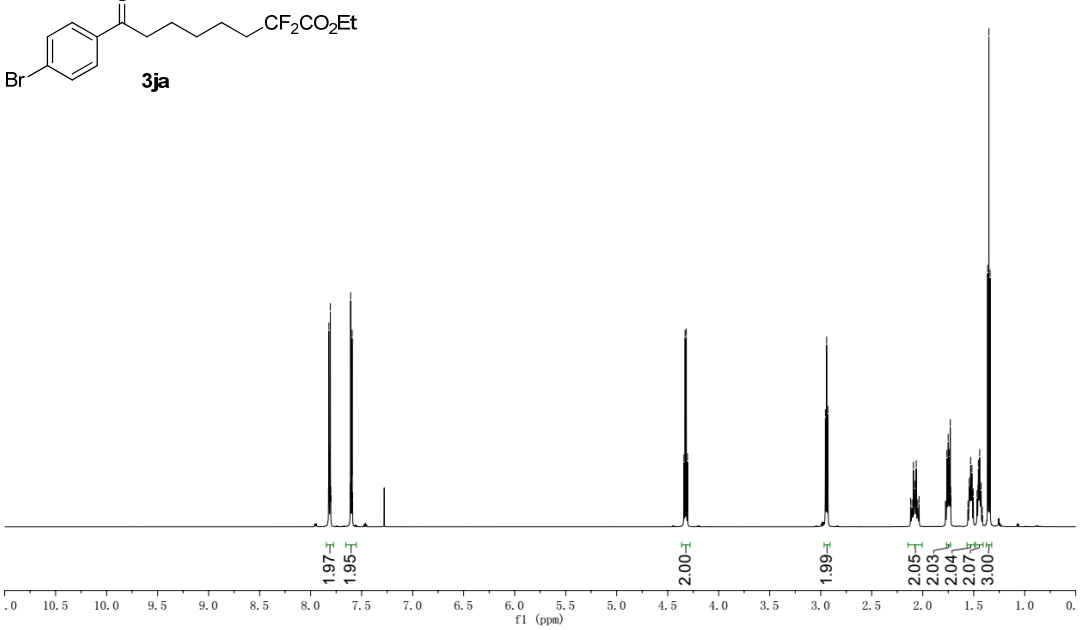
1.3636
1.3517


O
Br
CF2CO2Et

3ja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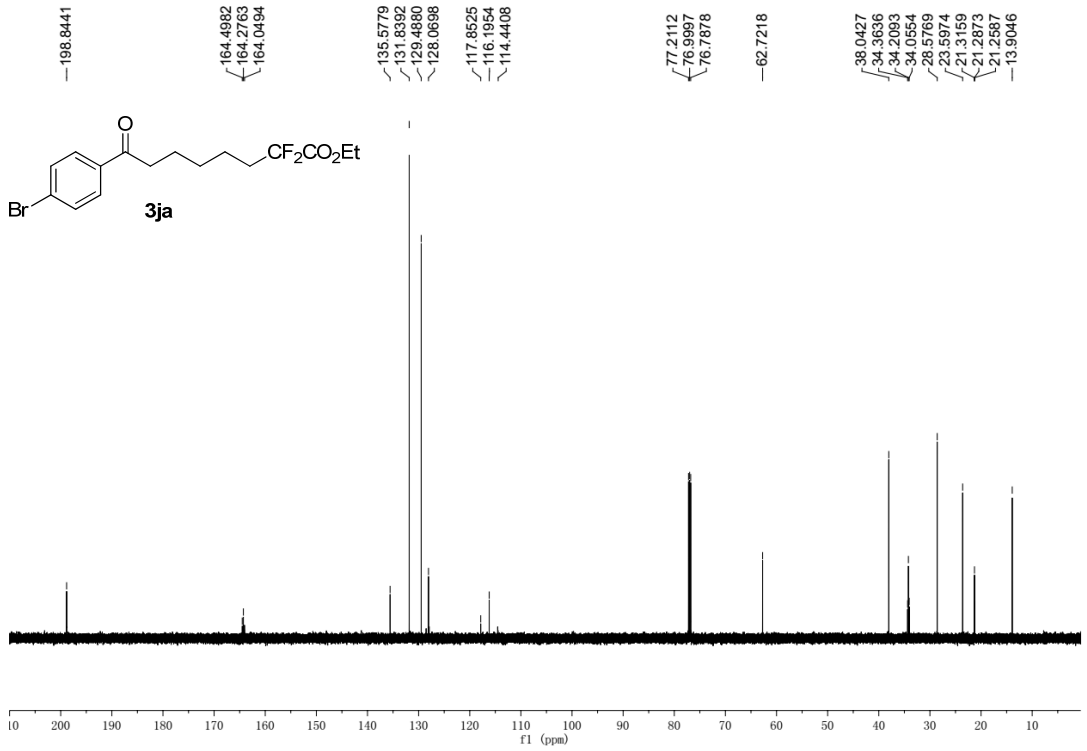
1.95
2.00
1.99
2.05
2.03
2.04
2.07
3.00
f1 (ppm)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164.2763
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117.8525
116.1954
114.4408
77.2112
76.9997
76.7878
62.7218
38.0427
34.3636
34.2093
34.0554
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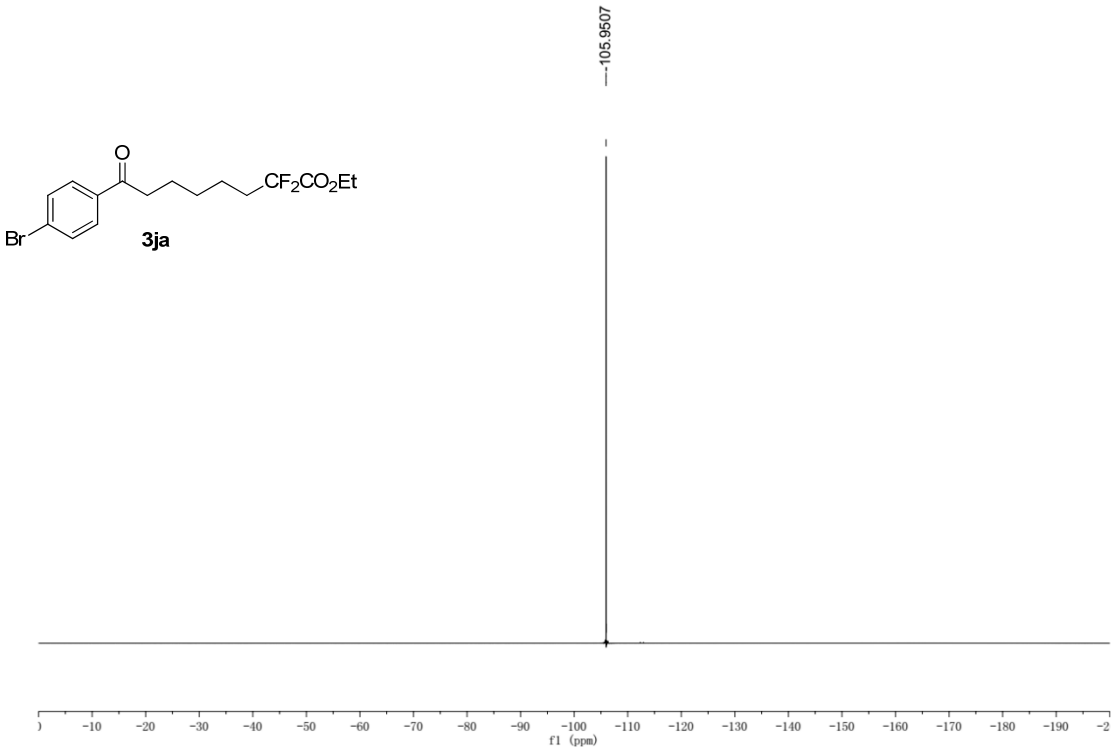
21.2873
21.2587
13.9046
O
CF2CO2Et
Br
3ja
f1 (ppm)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Br
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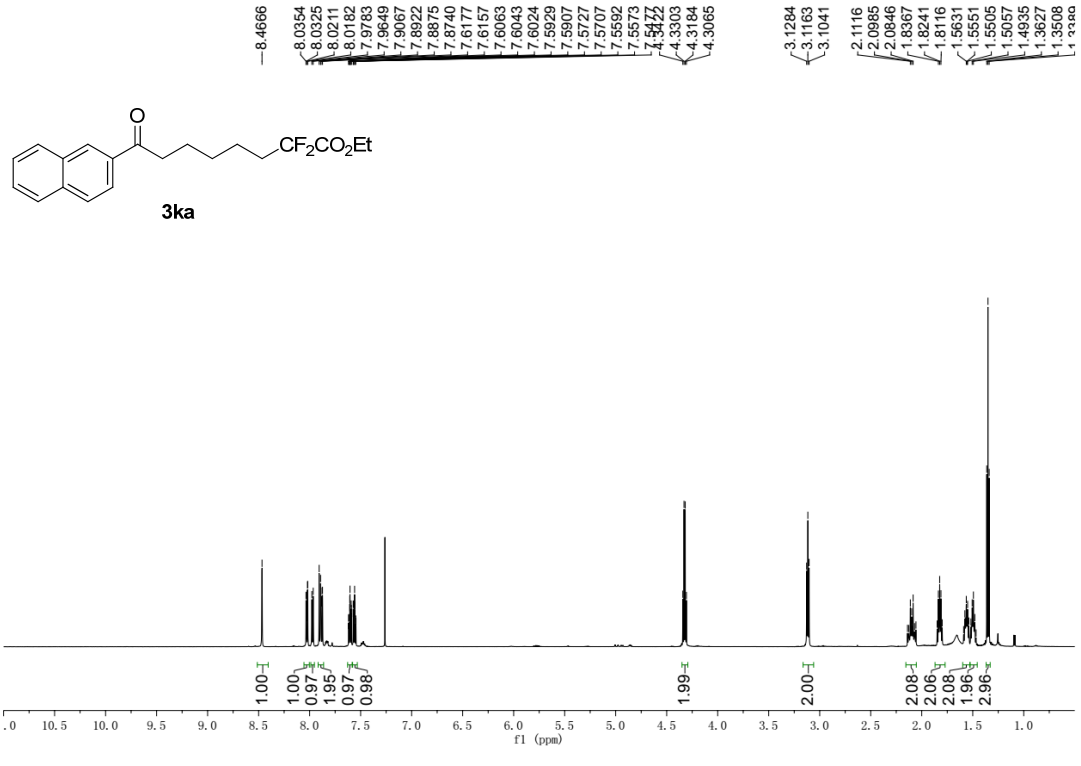
f1 (ppm)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8.0325
8.0211
8.0182
7.9783
7.9649
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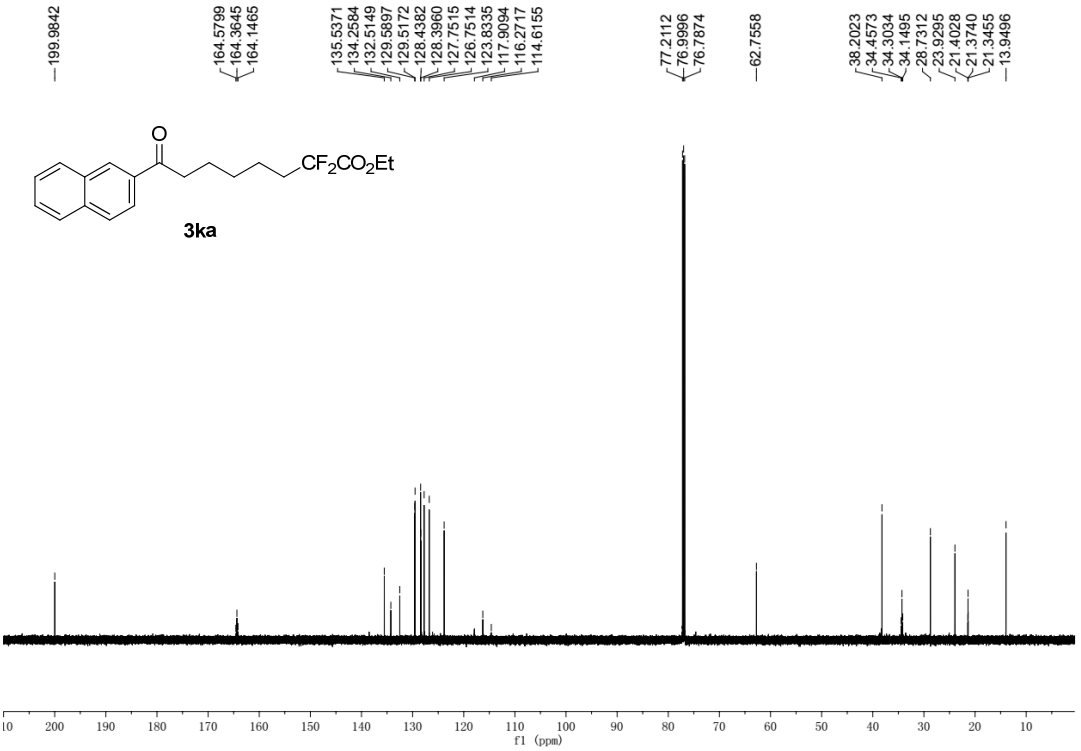
7.8922
7.8875
7.8740
7.6177
7.6157
7.6063
7.6043
7.6024
7.5929
7.5907
7.5727
7.5707
7.5592
7.5573
4.3303
4.3184
4.3065
3.1284
3.1163
3.1041
2.1116
2.0985
2.0846
1.8367
1.8241
1.8116
1.5631
1.5551
1.5505
1.5057
1.4935
1.3627
1.3508
O
CF2CO2Et
3ka
1.00
1.00
0.97
1.95
0.97
0.98
1.99
2.00
2.08
2.06
2.08
1.96
2.96
f1 (ppm)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129.5172
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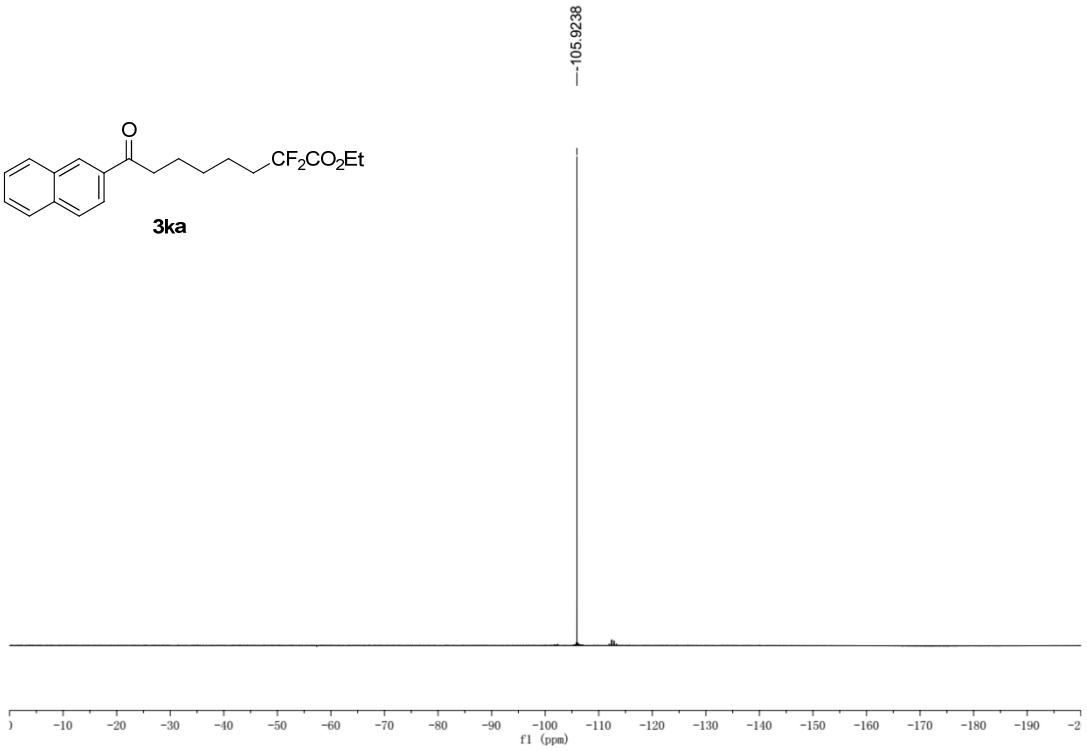
127.7515
126.7514
123.8335
117.9094
116.2717
114.6155
77.2112
76.9996
76.7874
62.7558
38.2023
34.4573
34.3034
34.1495
28.7312
23.9295
21.4028
21.3740
21.3455
13.9496
O
CF2CO2Et
3ka
f1 (ppm)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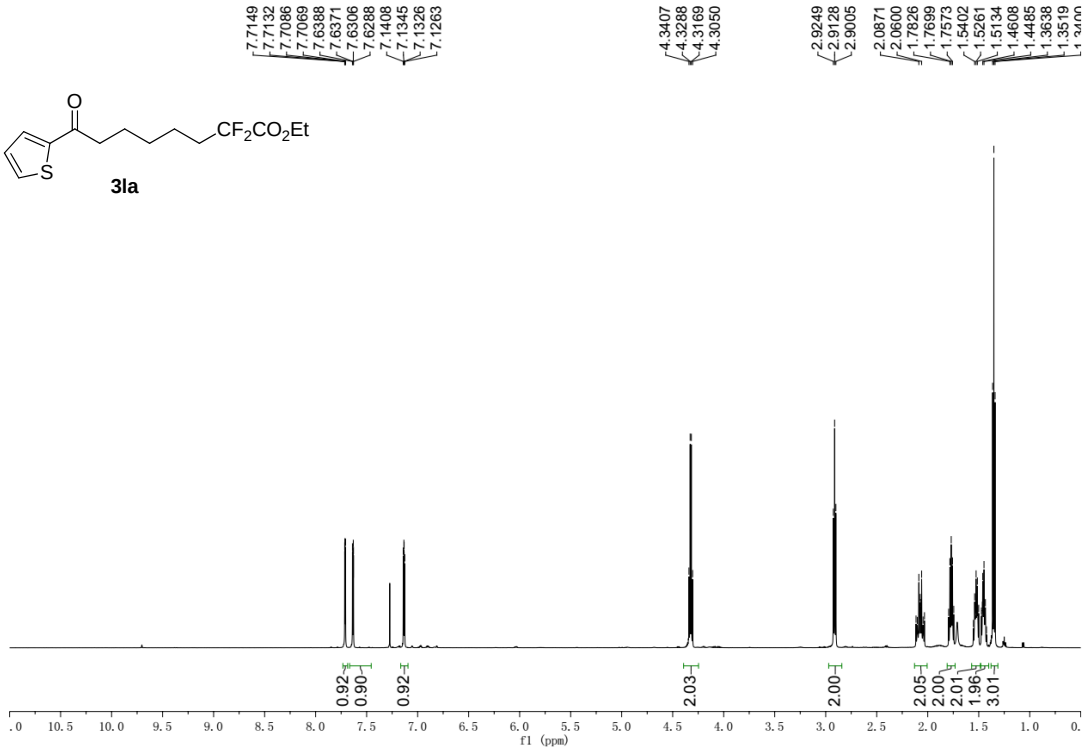
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7.7132
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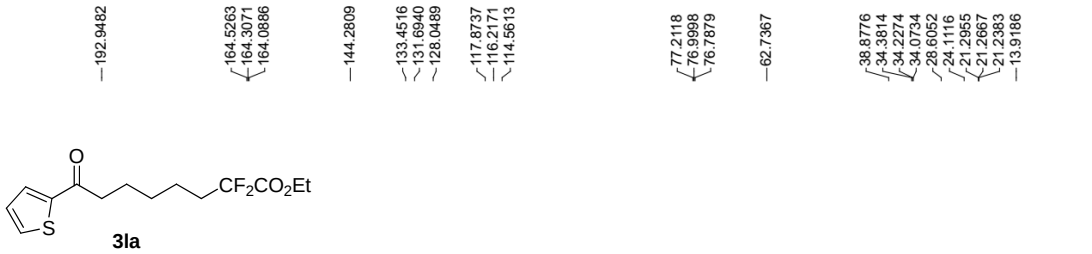
7.7069
7.6388
7.6371
7.6306
7.6288
7.1408
7.1345
7.1326
7.1263
4.3407
4.3288
4.3169
4.3050
2.9249
2.9128
2.9005
2.0871
2.0600
1.7826
1.7699
1.7573
1.5402
1.5261
1.5134
1.4608
1.4485
1.3638
1.3519
O
CF2CO2Et
S
3la
0.92
0.90
0.92
2.03
2.00
2.05
2.00
2.01
1.96
3.01
f1 (ppm)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144.2809
133.4516
131.6940
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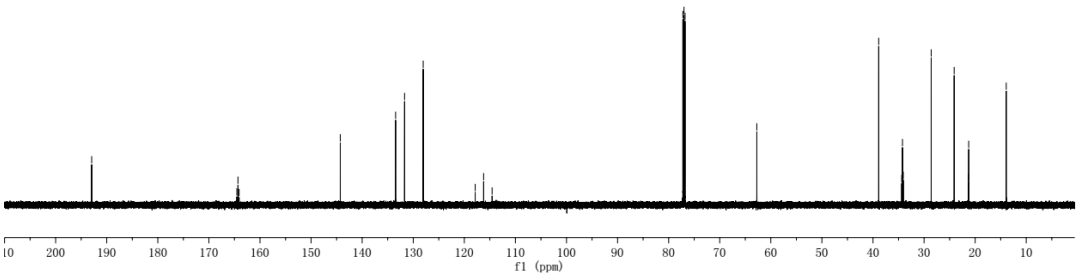
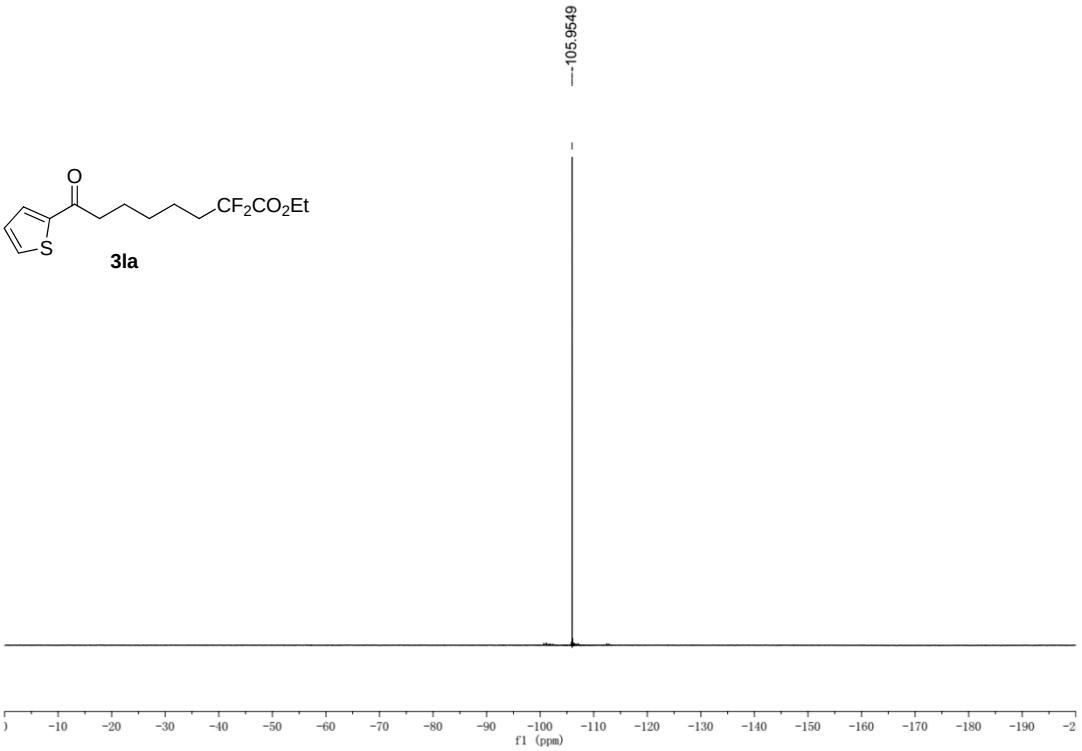
117.8737
116.2171
114.5613
77.2118
76.9998
76.7879
62.7367
38.8776
34.3814
34.2274
34.0734
28.6052
24.1116
21.2955
21.2667
21.2383
13.9186
O
CF2CO2Et
S

3la


f1 (ppm)


105.9549
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S
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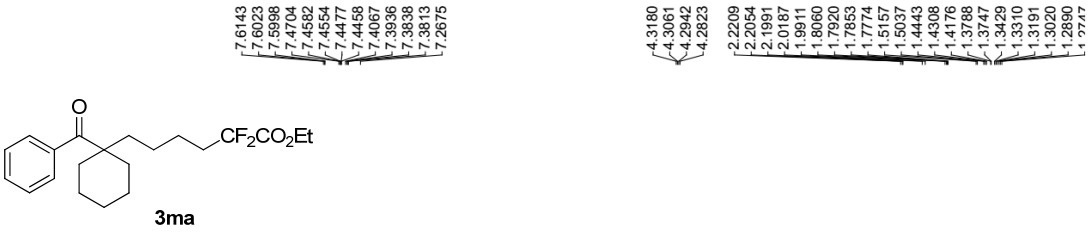
3la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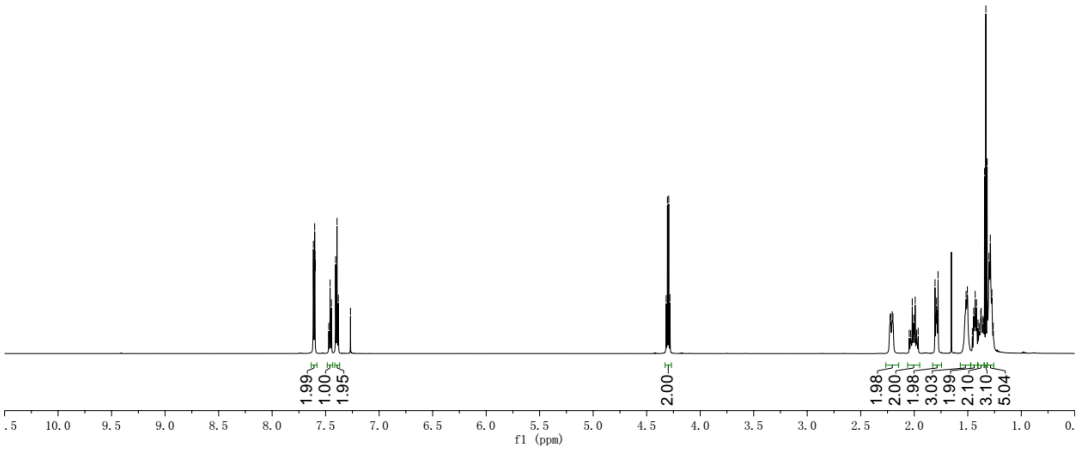
7.4477
7.4458
7.4067
7.3936
7.3838
7.3813
7.2675
4.3180
4.3061
4.2942
4.2823
2.2209
2.2054
2.1991
2.0187
1.9911
1.8060
1.7920
1.7853
1.7774
1.5157
1.5037
1.4443
1.4308
1.4176
1.3788
1.3747
1.3429
1.3310
1.3191
1.3020
1.2890
O
CF2CO2Et

3ma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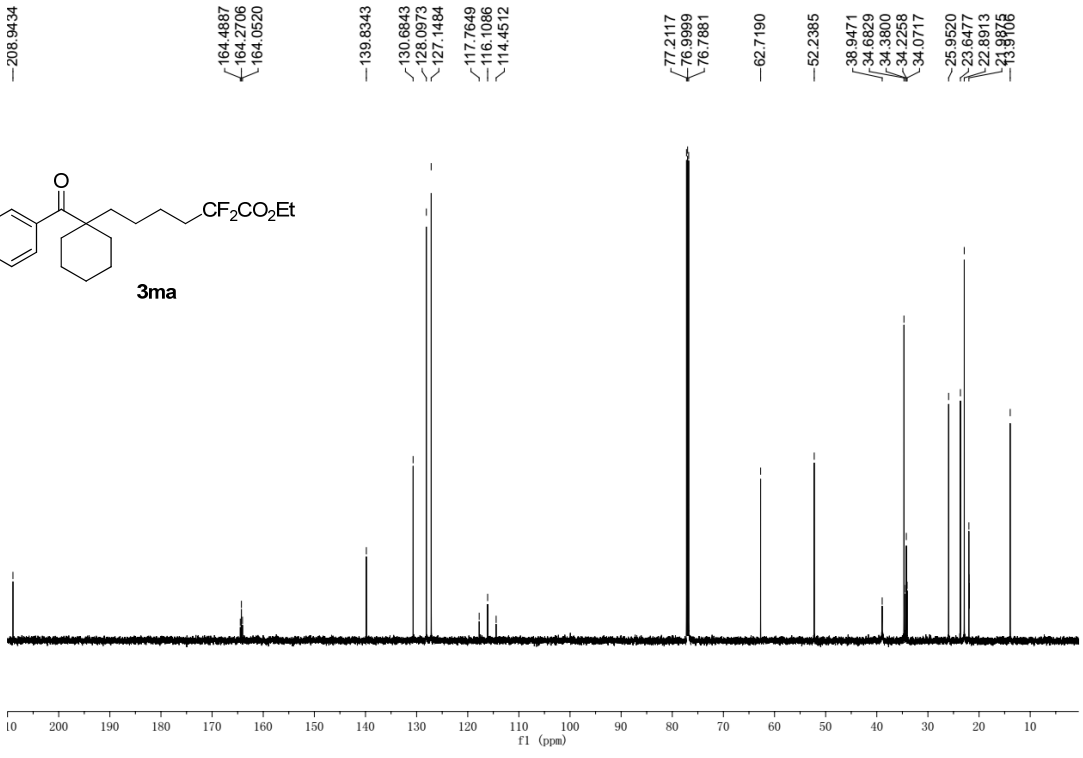
1.98
3.03
1.99
2.10
3.10
5.04
f1 (ppm)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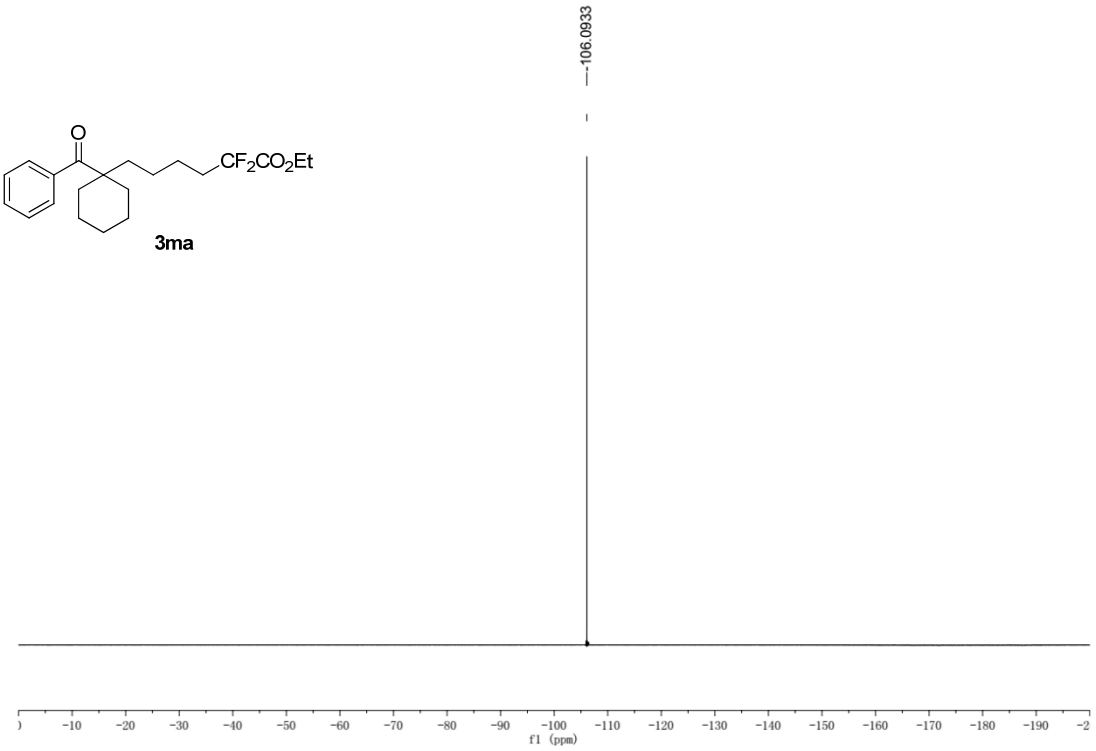
164.0520
139.8343
130.6843
128.0973
127.1484
117.7649
116.1086
114.4512
77.2117
76.9999
76.7881
62.7190
52.2385
38.9471
34.6829
34.3800
34.2258
34.0717
25.9520
23.6477
22.8913
21.9875
13.9106
O
CF2CO2Et
f1 (ppm)

3ma

O
CF2CO2Et

3ma


-106.0933
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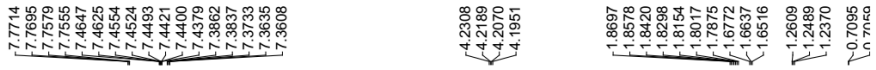
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7.7555
7.4647
7.4625
7.4554
7.4524
7.4493
7.4421
7.4400
7.4379
7.3862
7.3837
7.3733
7.3635
7.3608
4.2308
4.2189
4.2070
4.1951
1.8697
1.8578
1.8420
1.8298
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1.7875
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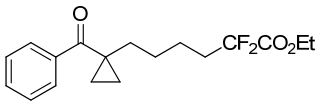
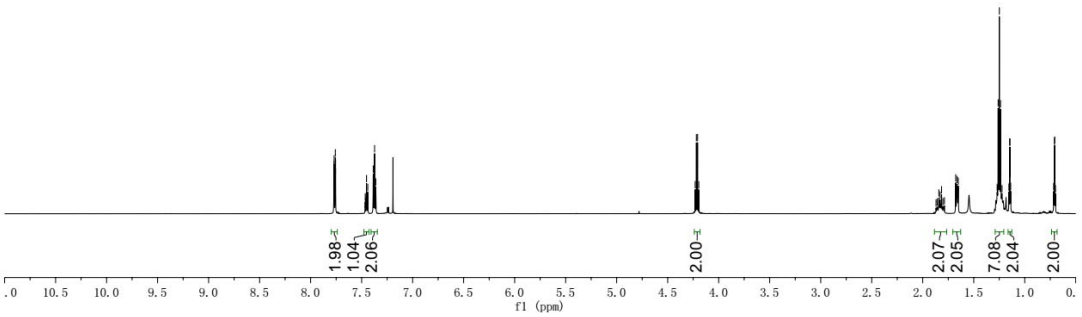
1.6637
1.6516
1.2609
1.2489
1.2370
0.7095


O
CF2CO2Et

3na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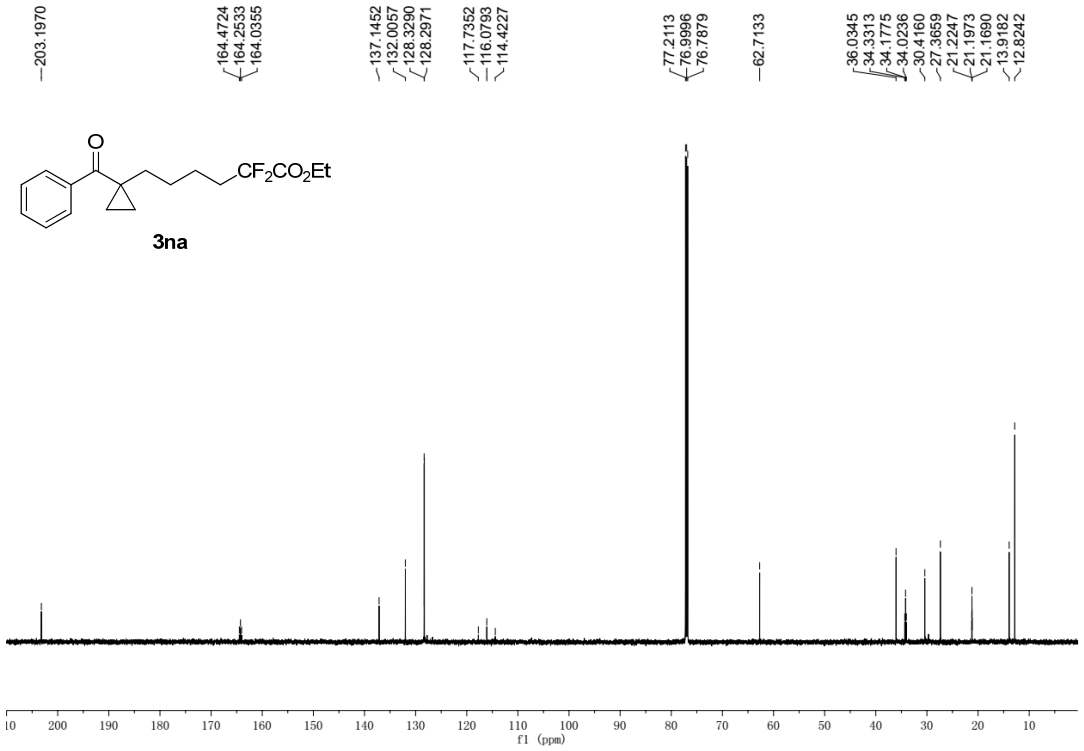
2.00
2.07
2.05
7.08
2.04
2.00
f1 (ppm)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128.3290
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116.0793
114.4227
77.2113
76.9996
76.7879
62.7133
36.0345
34.3313
34.1775
34.0236
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21.2247
21.1973
21.1690
13.9182
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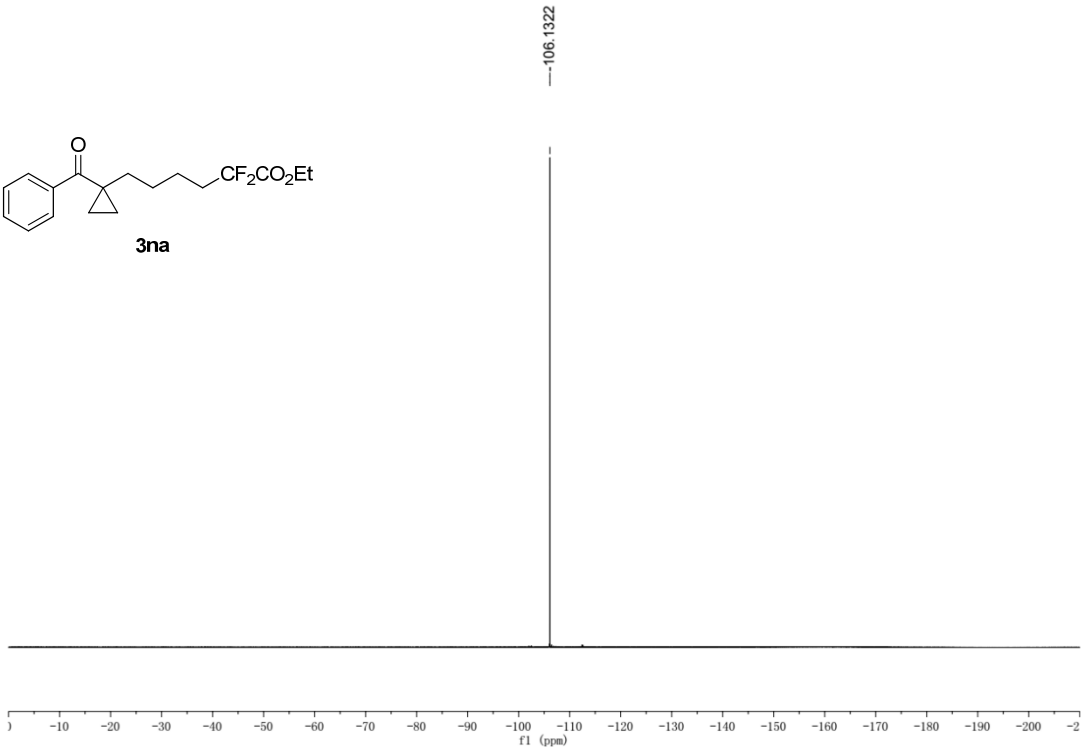
O
CF2CO2Et
3na
f1 (ppm)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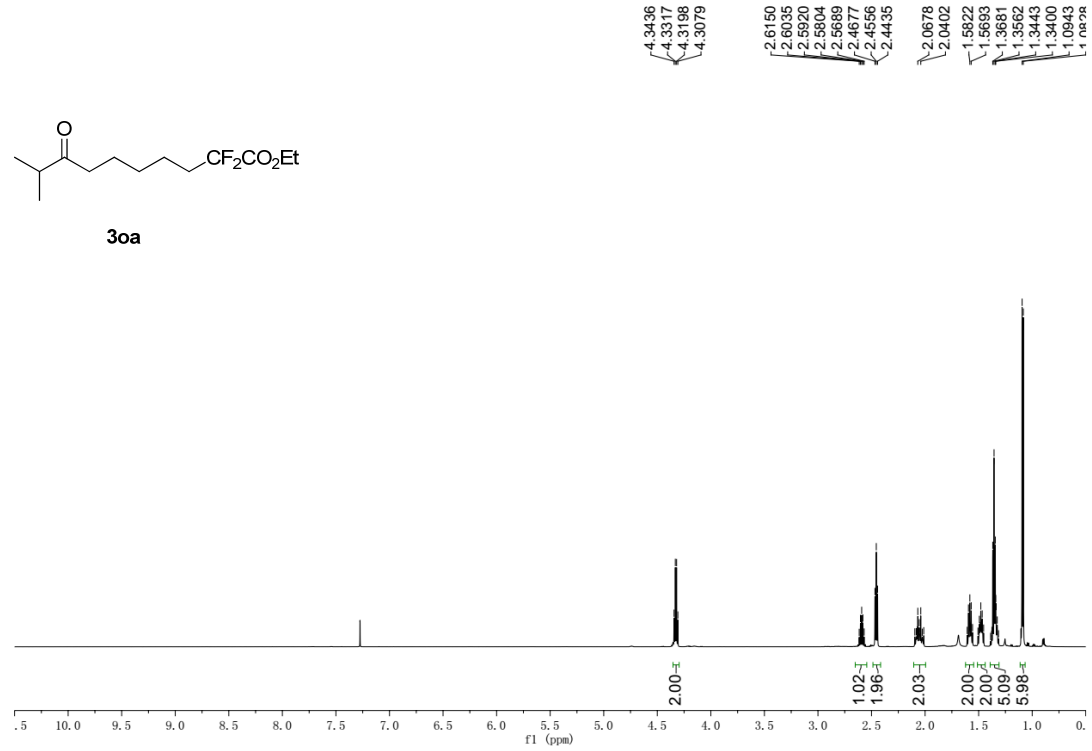
f1 (ppm)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4.3198
4.3079
2.6150
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2.5920
2.5804
2.5689
2.4677
2.4556
2.4435
2.0678
2.0402
1.5822
1.5693
1.3681
1.3562
1.3443
1.3400
1.0943
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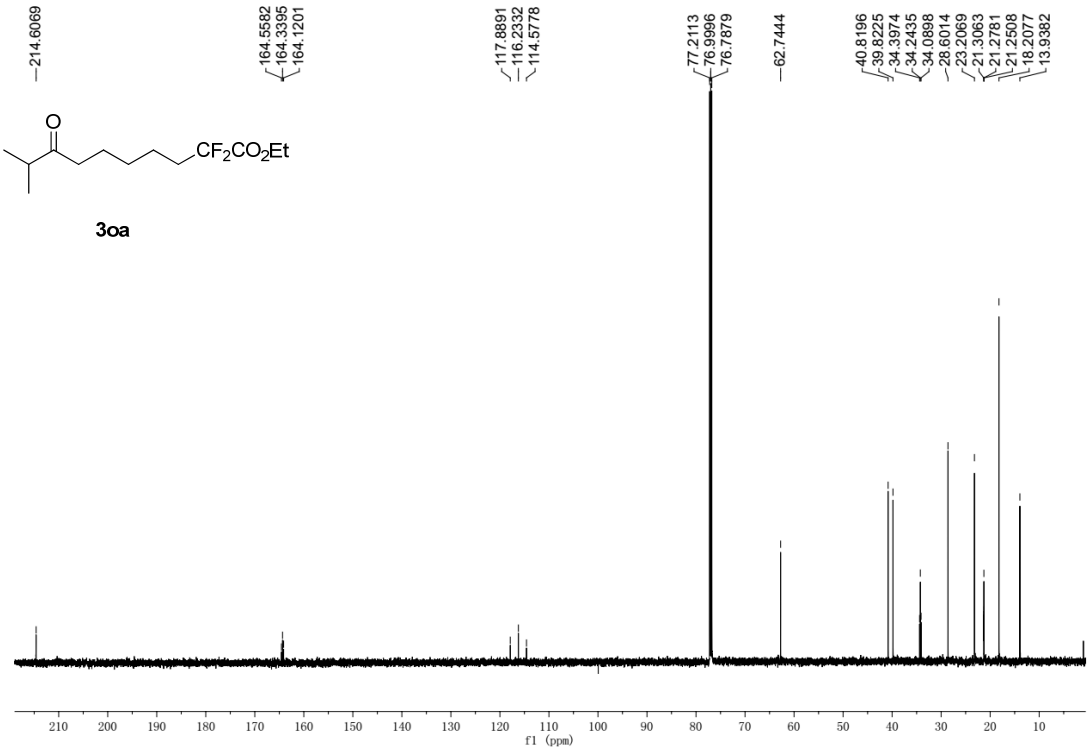
CF2CO2Et
3oa
2.00
1.02
1.96
2.03
2.00
2.00
5.09
5.98
f1 (ppm)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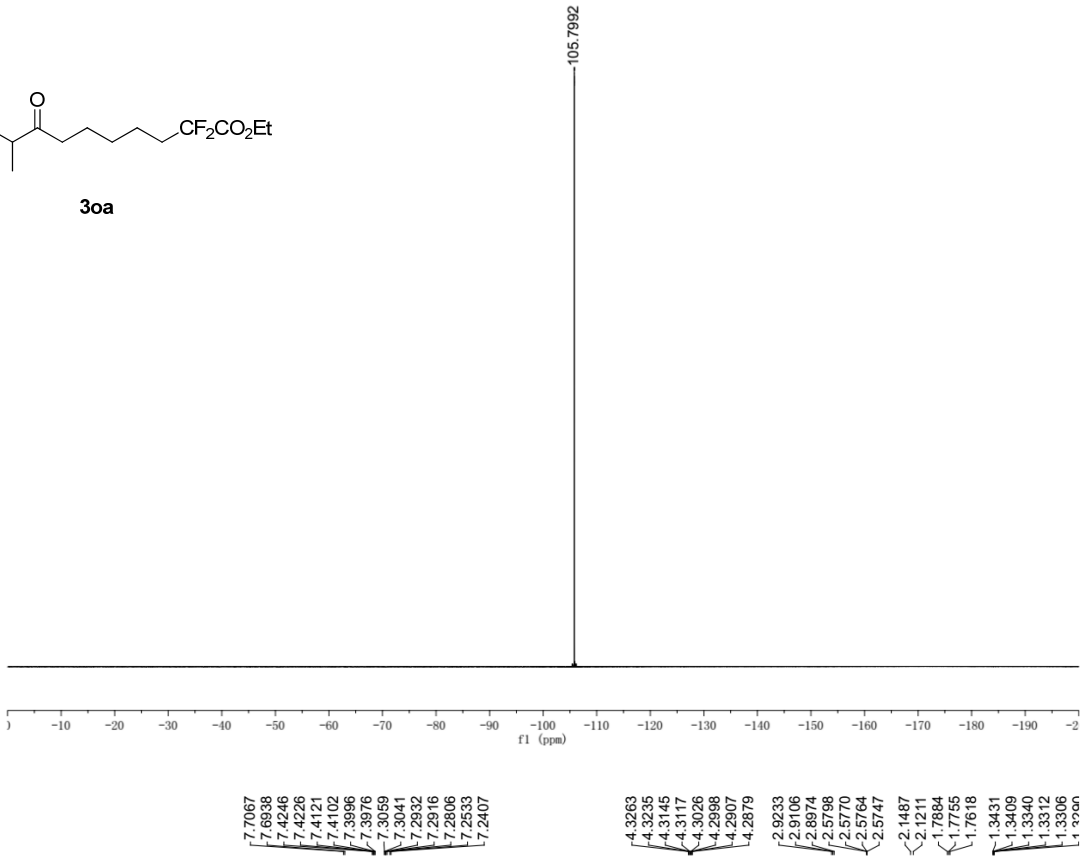
76.9996
76.7879
62.7444
40.8196
39.8225
34.3974
34.2435
34.0898
28.6014
23.2069
21.3063
21.2781
21.2508
18.2077
13.9382
O
CF2CO2Et
3oa
f1 (ppm)

O
CF2CO2Et

3oa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7.3059
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7.2806
7.2533
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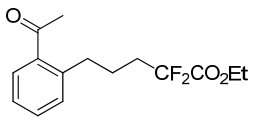
1.3306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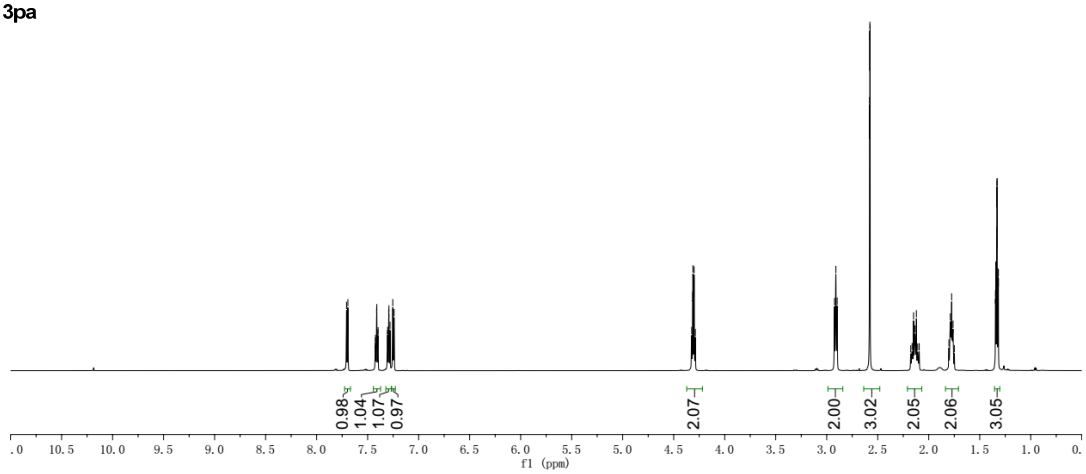
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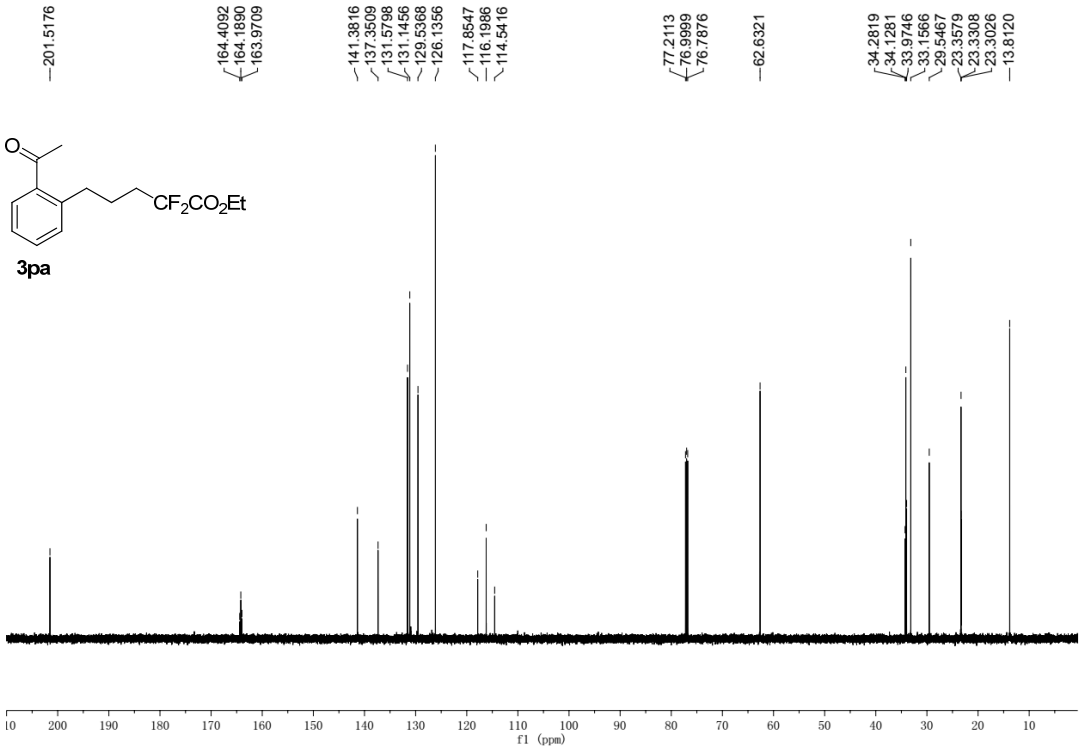
2.05
2.06
3.05
f1 (ppm)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34.1281
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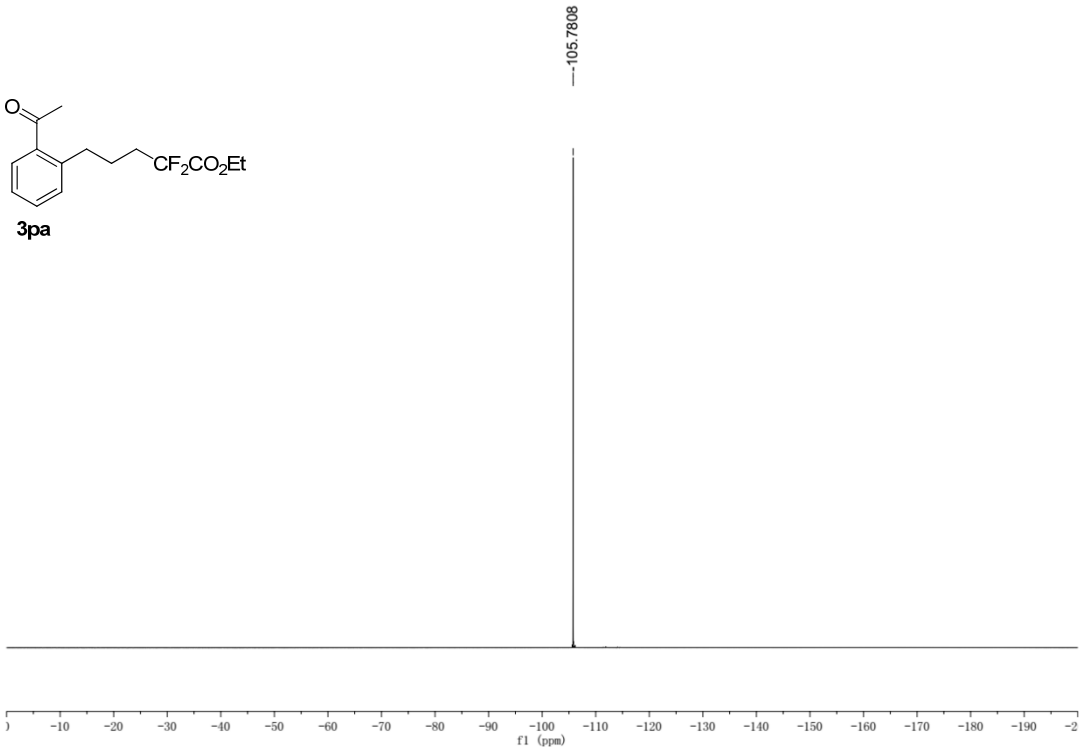
13.8120
O
CF2CO2Et
3pa
f1 (ppm)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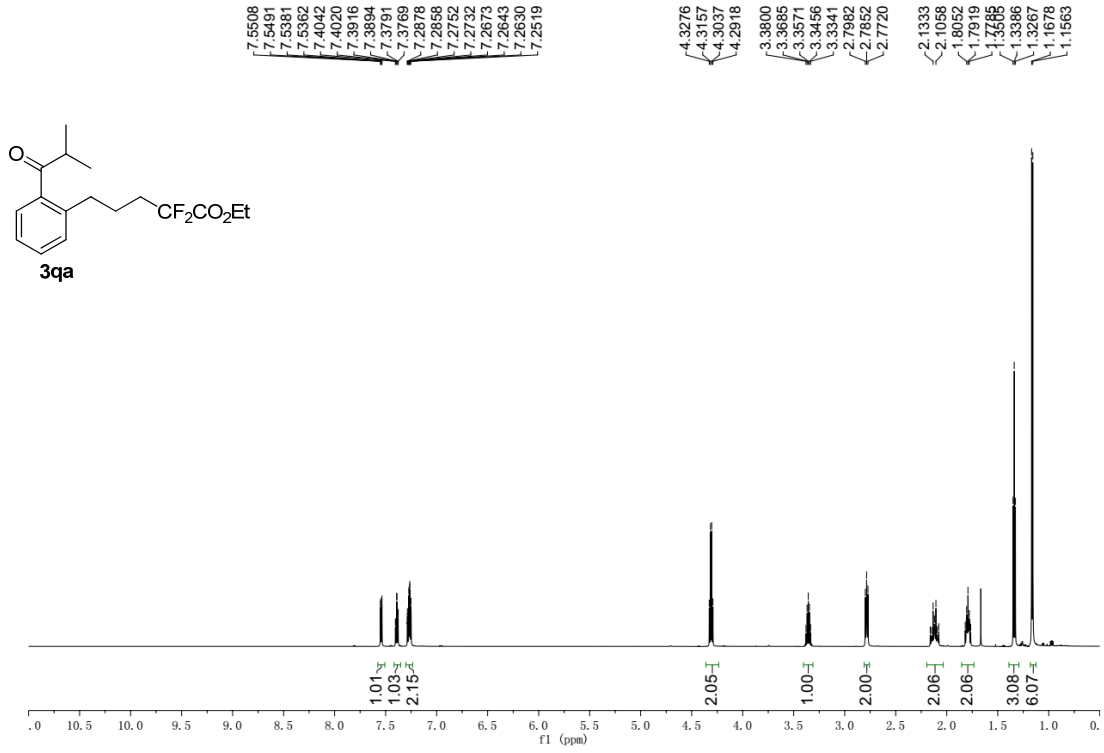
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7.3791
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7.2858
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7.2732
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7.2519
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4.3157
4.3037
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3.3341
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2.1058
2.1058
1.8052
1.7919
1.3386
1.3267
1.1678
1.1563
O
CF2CO2Et
3qa
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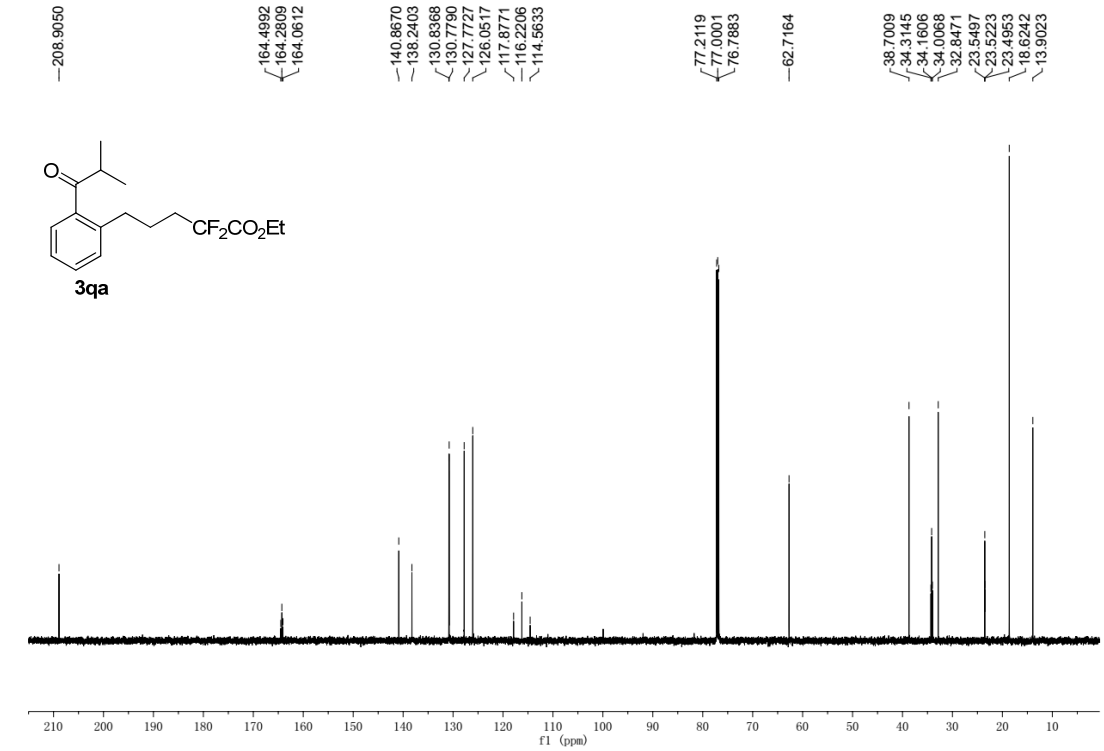
1.03
2.15
2.05
1.00
2.00
2.06
2.06
3.08
6.07
f1 (ppm)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130.8368
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126.0517
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114.5633
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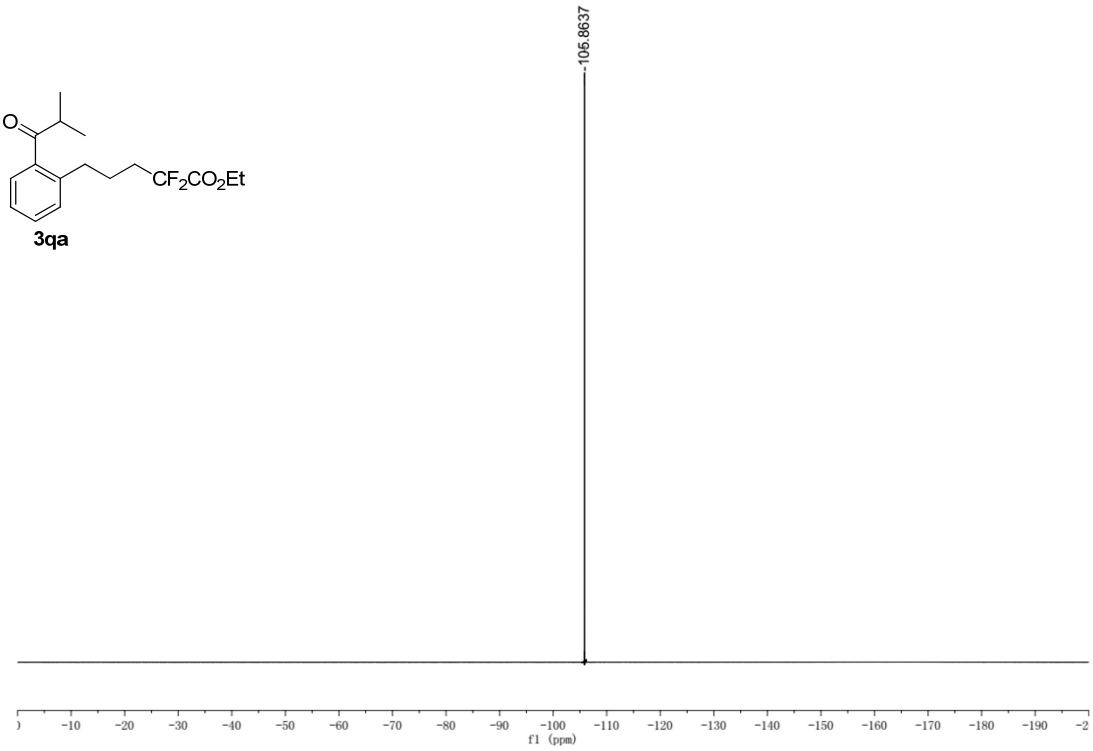
62.7164
38.7009
34.3145
34.1606
34.0068
32.8471
23.5497
23.5223
23.4953
18.6242
13.9023
O
CF2CO2Et
3qa
f1 (ppm)

O
CF2CO2Et

3qa


-105.8637
f1 (ppm)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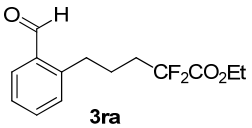
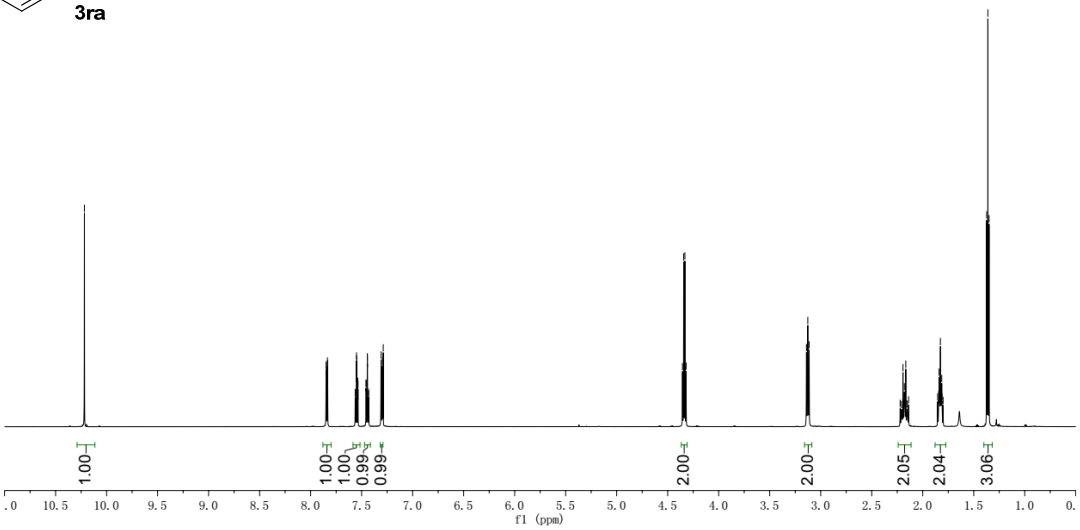
7.8461
7.8356
7.8334
7.5630
7.5606
7.5505
7.5481
7.5380
7.5355
7.4571
7.4554
7.4445
7.4429
7.4321
7.4304
7.3089
7.2963
7.2884
4.3552
4.3432
4.3313
4.3194
3.1397
3.1267
3.1136
2.1935
2.1801
2.1661
1.8401
1.8330
1.8269
1.3614
1.3495


O
H
CF2CO2Et

3ra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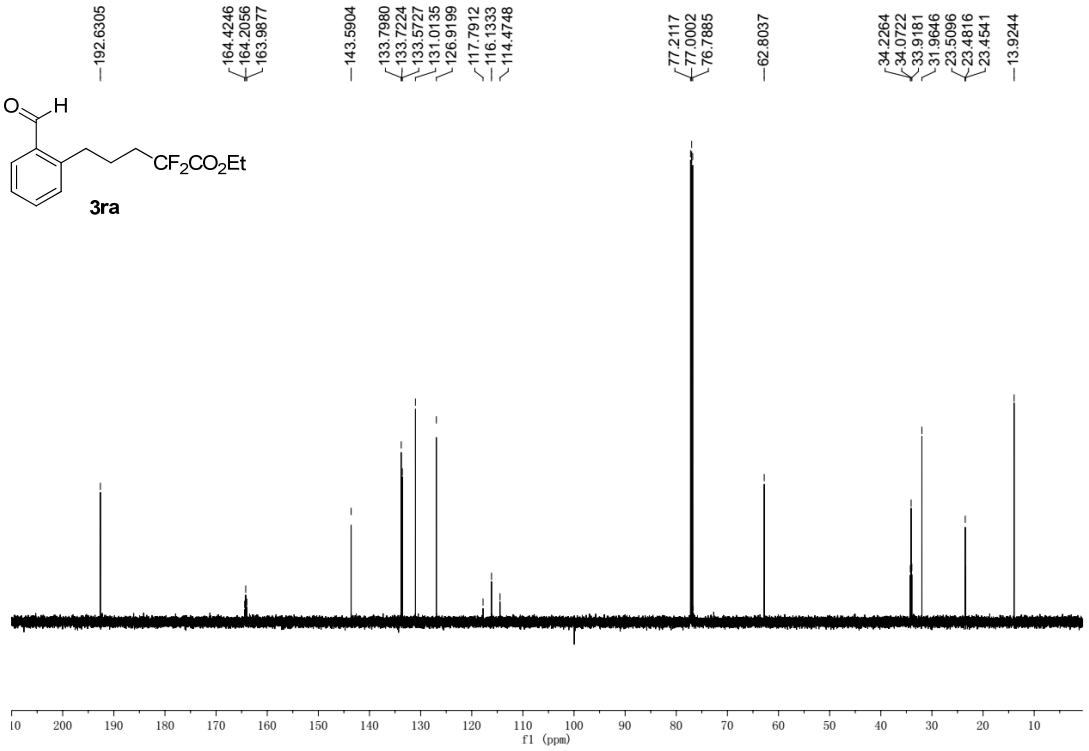
0.99
2.00
2.00
2.05
2.04
3.06
f1 (ppm)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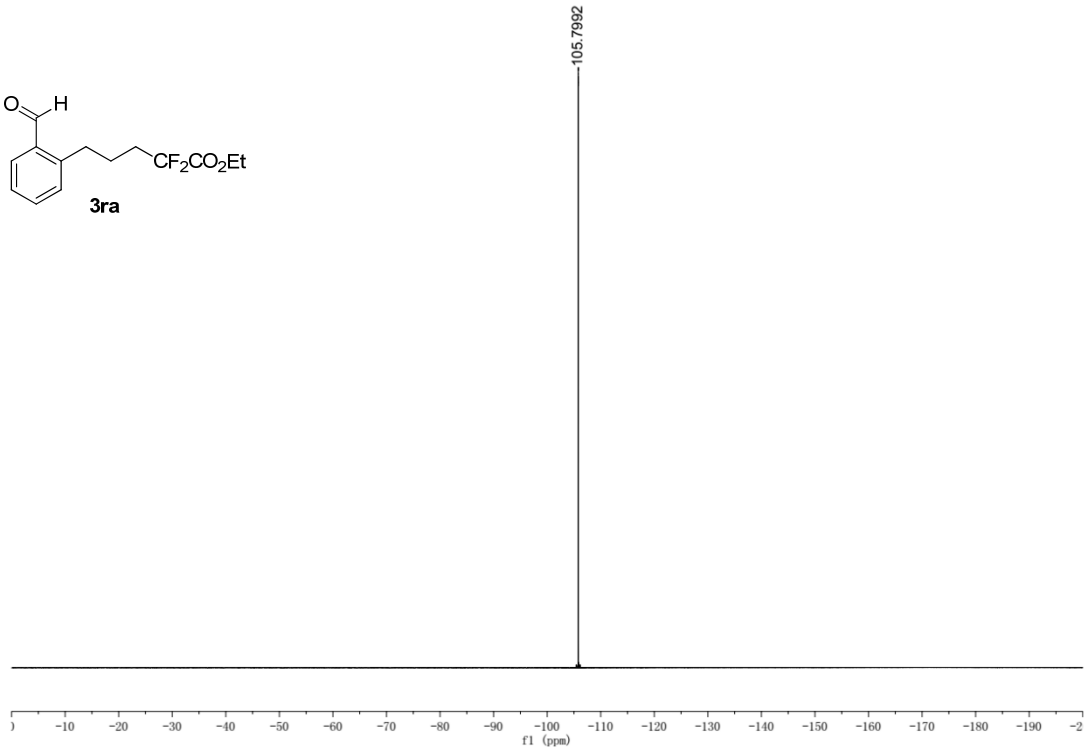
164.4246
164.2056
163.9877
143.5904
133.7980
133.7224
133.5727
131.0135
126.9199
117.7912
116.1333
114.4748
77.2117
77.0002
76.7885
62.8037
34.2264
34.0722
33.9181
31.9646
23.5096
23.4816
23.4541
13.9244
O
H
CF2CO2Et
3ra
f1 (ppm)


105.7992
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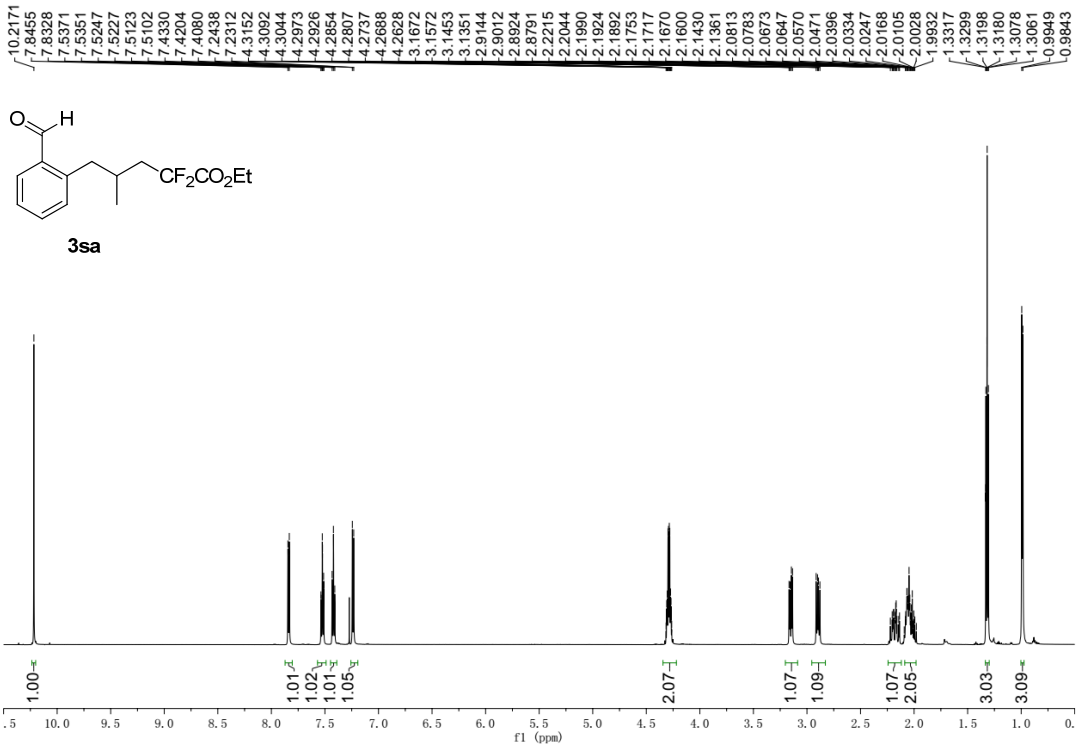
H
CF2CO2Et
3ra
f1 (ppm)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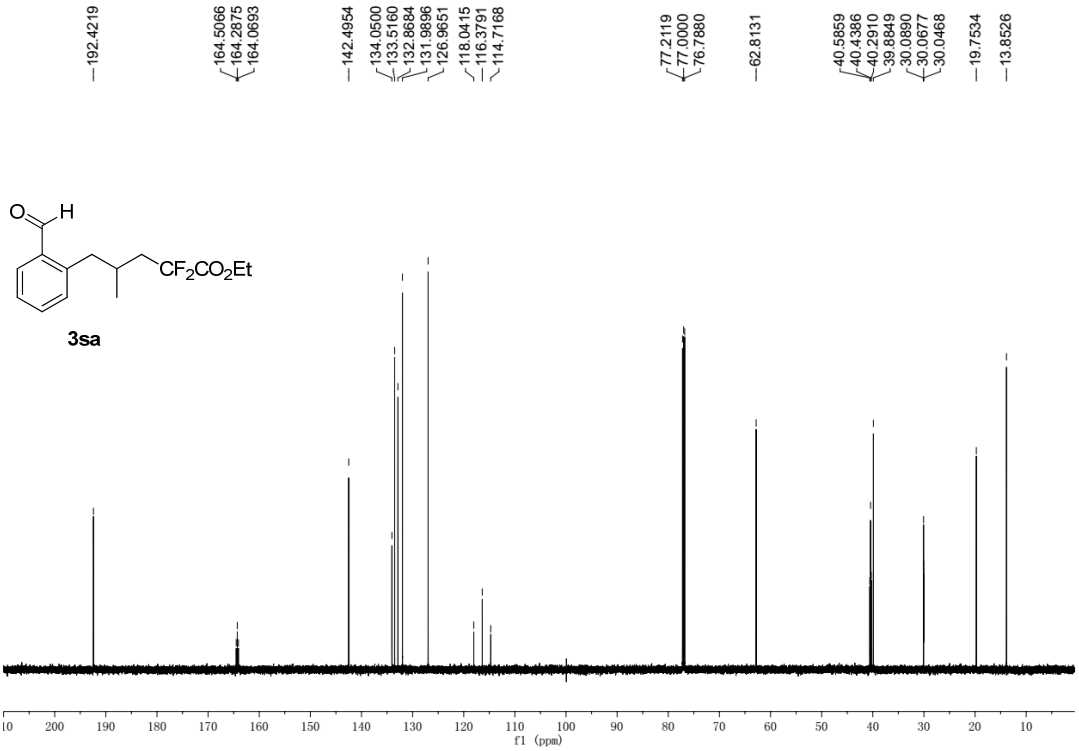
7.8455
7.8328
7.5371
7.5351
7.5247
7.5227
7.5123
7.5102
7.4330
7.4204
7.4080
7.2438
7.2312
4.3152
4.3092
4.3044
4.2973
4.2926
4.2854
4.2807
4.2737
4.2688
4.2628
3.1672
3.1572
3.1453
3.1351
2.9144
2.9012
2.8924
2.8791
2.2215
2.2044
2.1990
2.1924
2.1892
2.1753
2.1717
2.1670
2.1600
2.1430
2.1361
2.0813
2.0783
2.0673
2.0647
2.0570
2.0471
2.0396
2.0334
2.0247
2.0168
2.0105
2.0028
1.9932
1.3317
1.3299
1.3198
1.3180
1.3078
1.3061
0.9949
0.9843
O
H
CF2CO2Et
3sa
1.00
1.01
1.02
1.01
1.05
2.07
1.07
1.09
1.07
2.05
3.03
3.09
f1 (ppm)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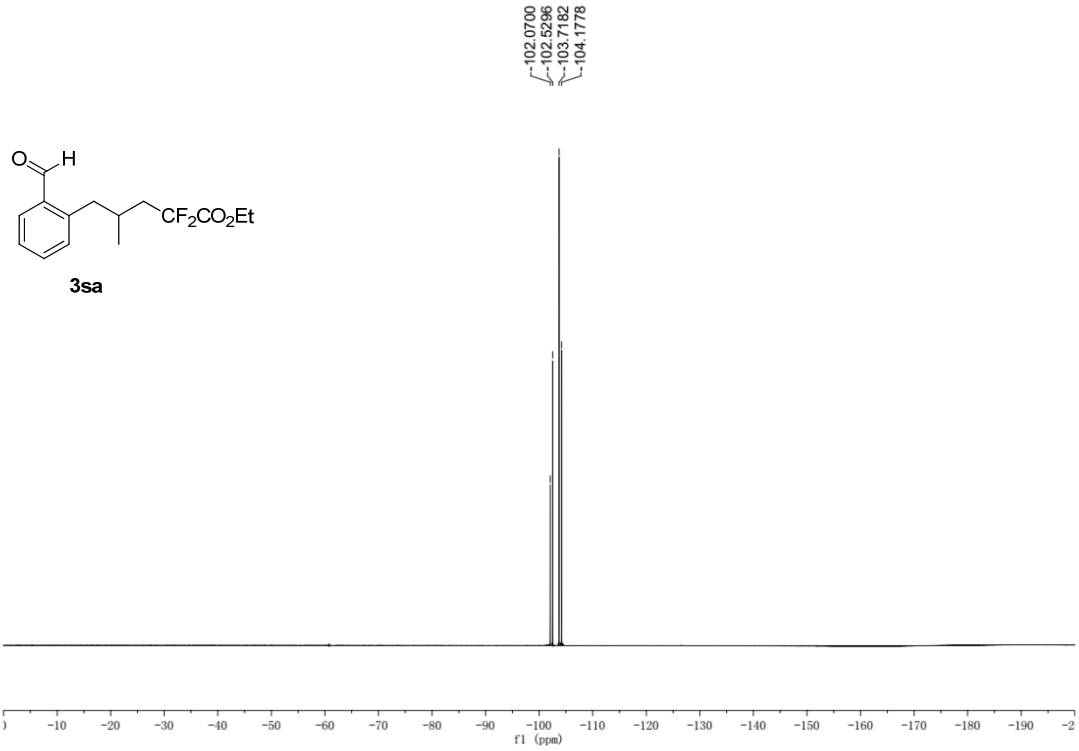
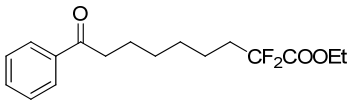
164.2875
164.0693
142.4954
134.0500
133.5160
132.8684
131.9896
126.9651
118.0415
116.3791
114.7168
77.2119
77.0000
76.7880
62.8131
40.5859
40.4386
40.2910
39.8849
30.0890
30.0677
30.0468
19.7534
13.8526
O
H
CF2CO2Et
3sa
f1 (ppm)

O
H
CF2CO2Et

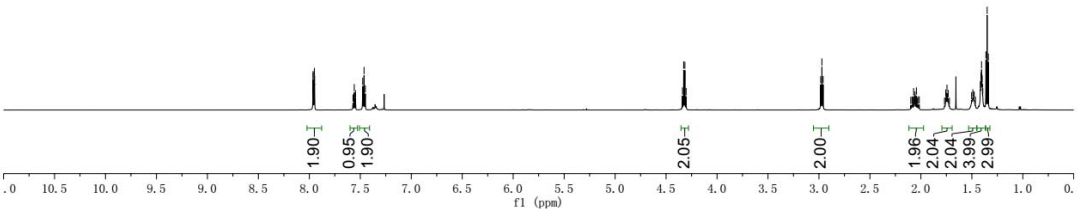
3sa


102.0700
102.5296
103.7182
104.1778
f1 (ppm)


7.9637
7.9626
7.9506
7.9484
7.5717
7.5594
7.5487
7.5471
7.4764
7.4633
7.4506
4.3392
4.3273
4.3153
4.3034
2.9832
2.9711
2.9588
2.0713
2.0440
1.7561
1.7440
1.4901
1.4167
1.4109
1.4047
1.3986
1.3927
1.3619
1.3500


O
CF2COOEt

3ta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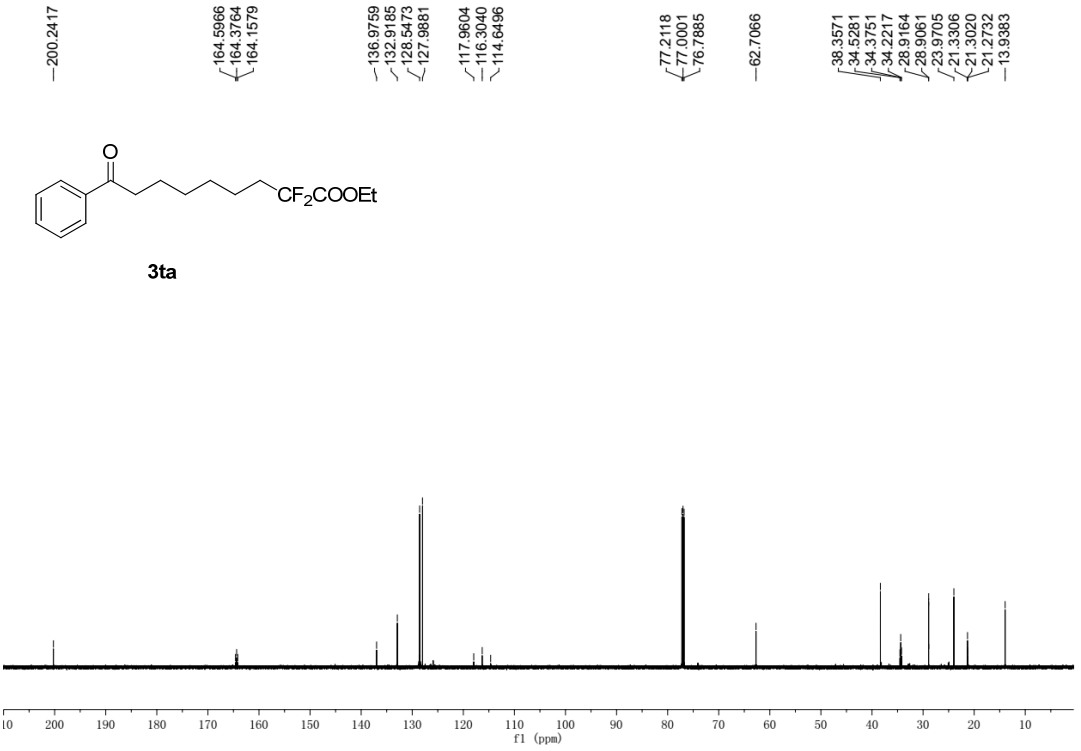
0.95
1.90
2.05
2.00
1.96
2.04
2.04
3.99
2.99
f1 (ppm)


200.2417
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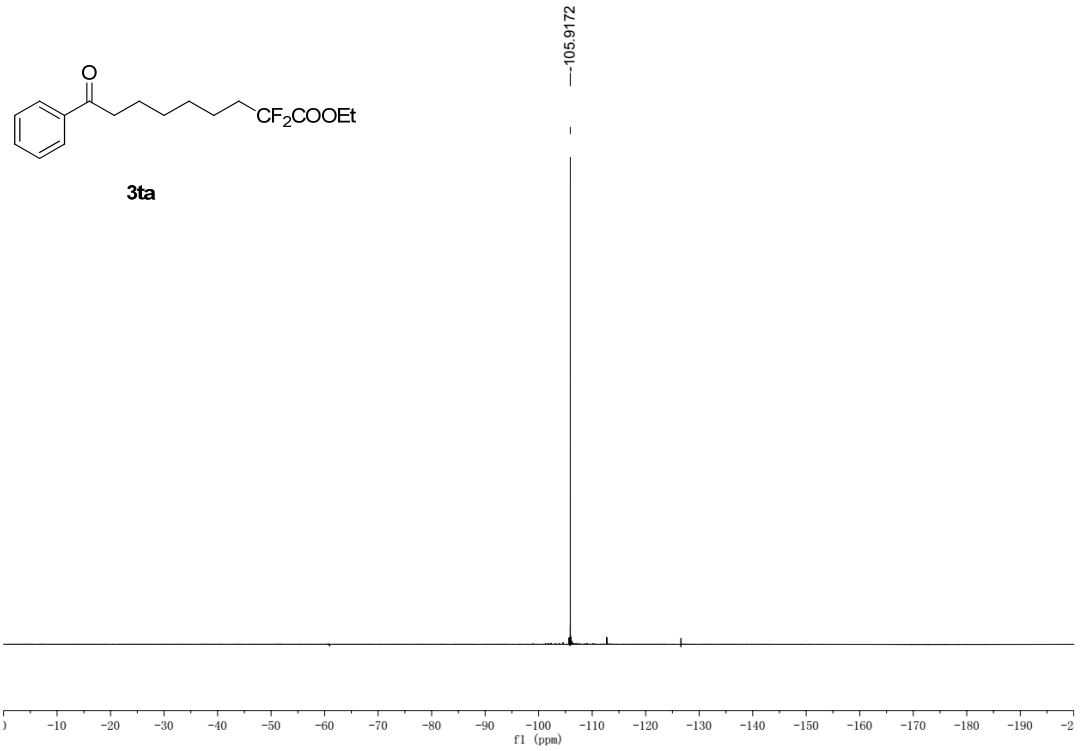
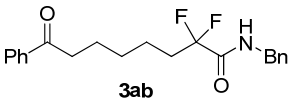
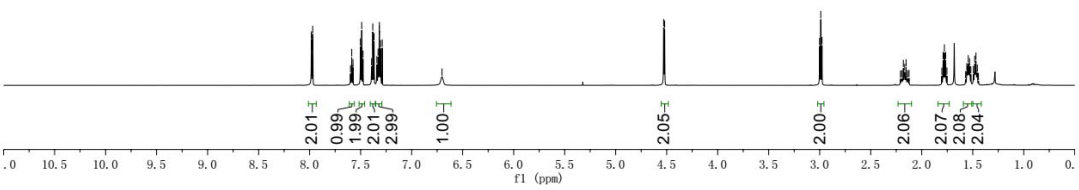
164.3764
164.1579
136.9759
132.9185
128.5473
127.9881
117.9604
116.3040
114.6496
77.2118
77.0001
76.7885
62.7066
38.3571
34.5281
34.3751
34.2217
28.9164
28.9061
23.9705
21.3306
21.3020
21.2732
13.9383
O
CF2COOEt
3ta
f1 (ppm)


105.9172
O
CF2COOEt
3ta
f1 (ppm)


O
F
F
H
N
Ph
Bn
O

3ab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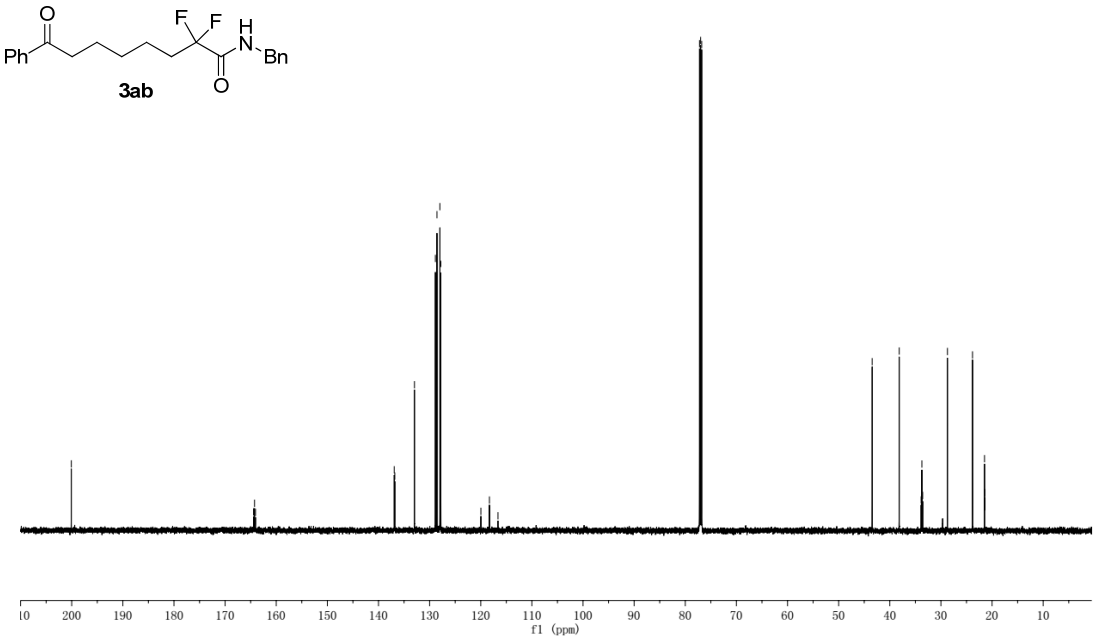
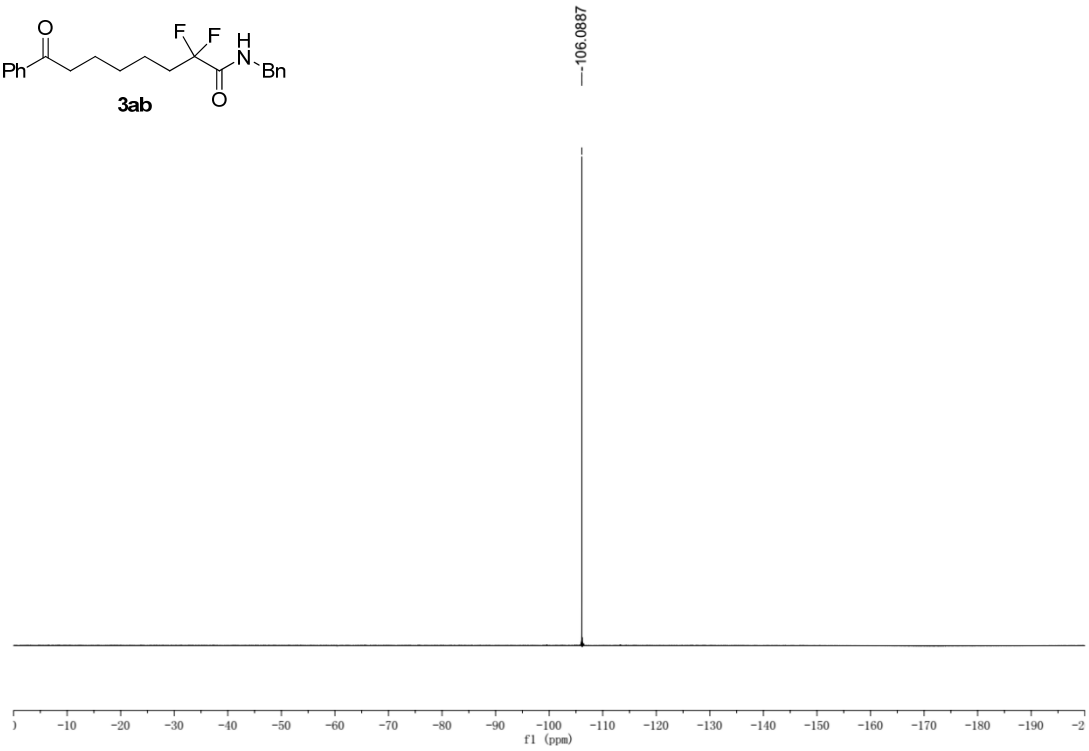
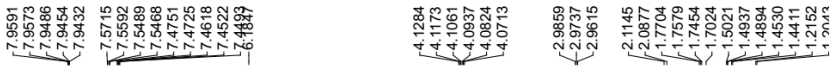
0.99
1.99
2.01
2.99
1.00
2.05
2.00
2.06
2.07
2.08
2.04
f1 (ppm)


O
F
F
H
N
Ph
Bn
O
3ab
f1 (ppm)

O
F
F
H
N
Ph
Bn
O

3ab


-106.0887
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190
f1 (ppm)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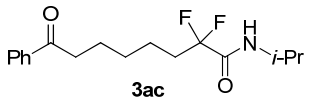
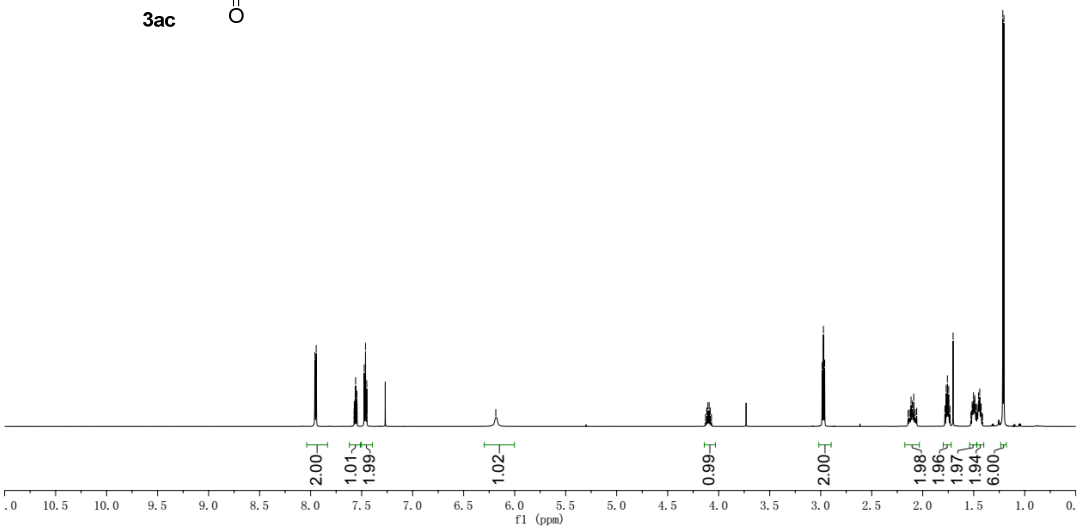
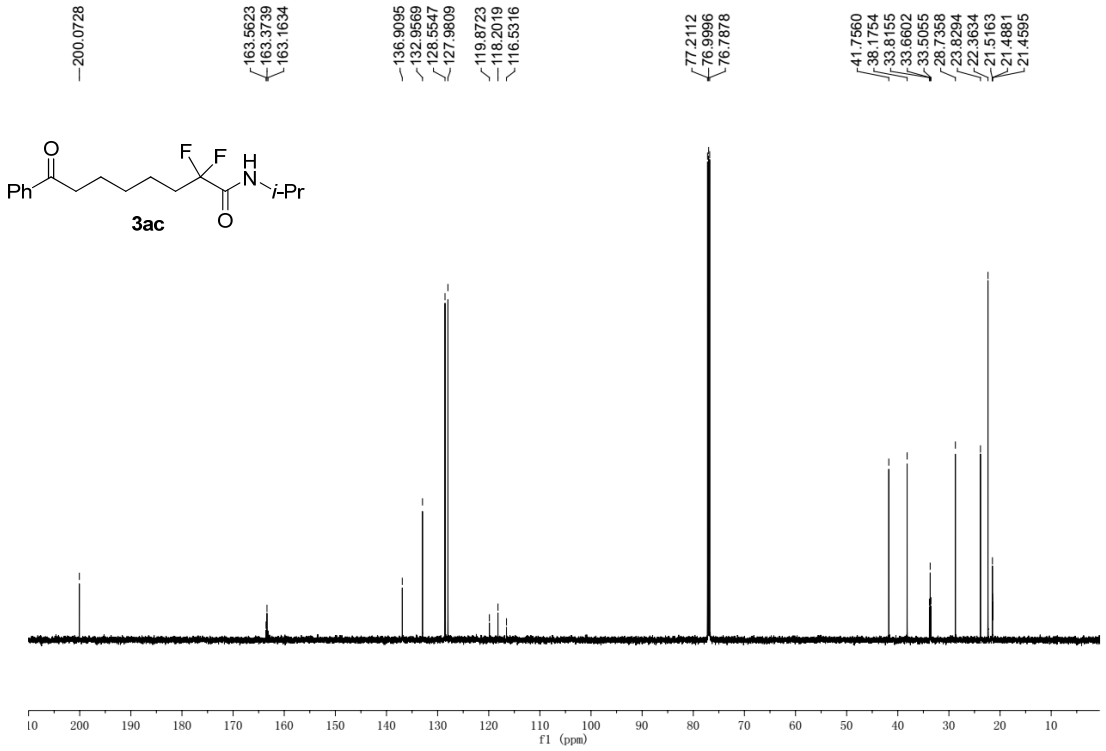
7.9573
7.9486
7.9454
7.9432
7.5715
7.5592
7.5489
7.5468
7.4751
7.4725
7.4618
7.4522
7.4483
6.1847
4.1284
4.1173
4.1061
4.0937
4.0824
4.0713
2.9859
2.9737
2.9615
2.1145
2.0877
1.7704
1.7579
1.7454
1.7024
1.5021
1.4937
1.4894
1.4530
1.4411
1.2152


O
F
F
H
N
Ph
i-Pr
O

3ac


2.00
1.01
1.99
1.02
0.99
2.00
1.98
1.96
1.97
1.94
6.00
f1 (ppm)


200.0728
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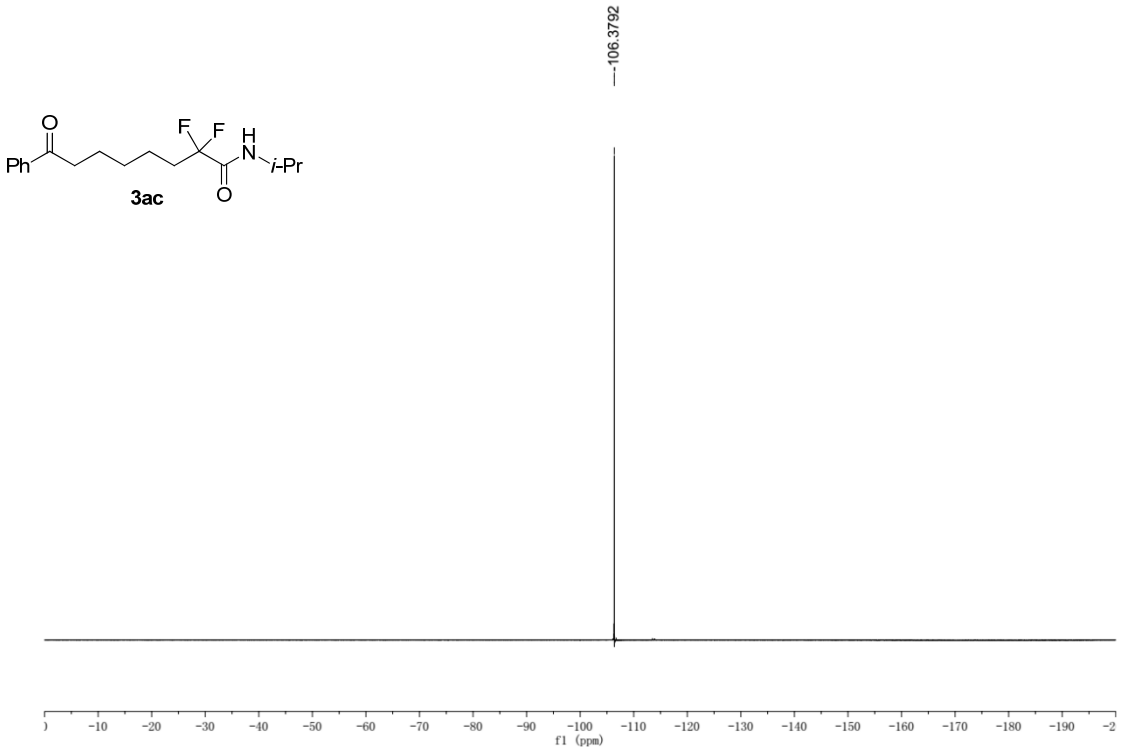
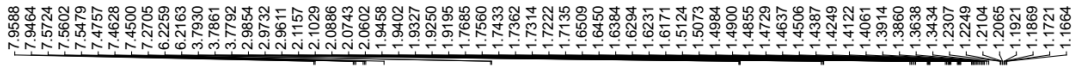
163.3739
163.1634
136.9095
132.9569
128.5547
127.9809
119.8723
118.2019
116.5316
77.2112
76.9996
76.7878
41.7560
38.1754
33.8155
33.6602
33.5055
28.7358
23.8294
22.3634
21.5163
21.4881
21.4595
Ph
F
F
H
N
i-Pr
O
O
3ac
f1 (ppm)


106.3792
Ph
F
F
H
N
i-Pr
O
O
3ac
f1 (ppm)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7.5724
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7.5479
7.4757
7.4628
7.4500
7.2705
6.2259
6.2163
3.7930
3.7861
3.7792
2.9854
2.9732
2.9611
2.1157
2.1029
2.0886
2.0743
2.0602
1.9458
1.9402
1.9327
1.9250
1.9195
1.7685
1.7560
1.7433
1.7362
1.7314
1.7222
1.7135
1.6509
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1.6384
1.6294
1.6231
1.6171
1.5124
1.5073
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1.4900
1.4855
1.4729
1.4637
1.4506
1.4387
1.4249
1.4122
1.4061
1.3914
1.3860
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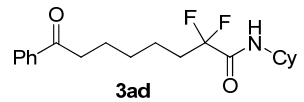
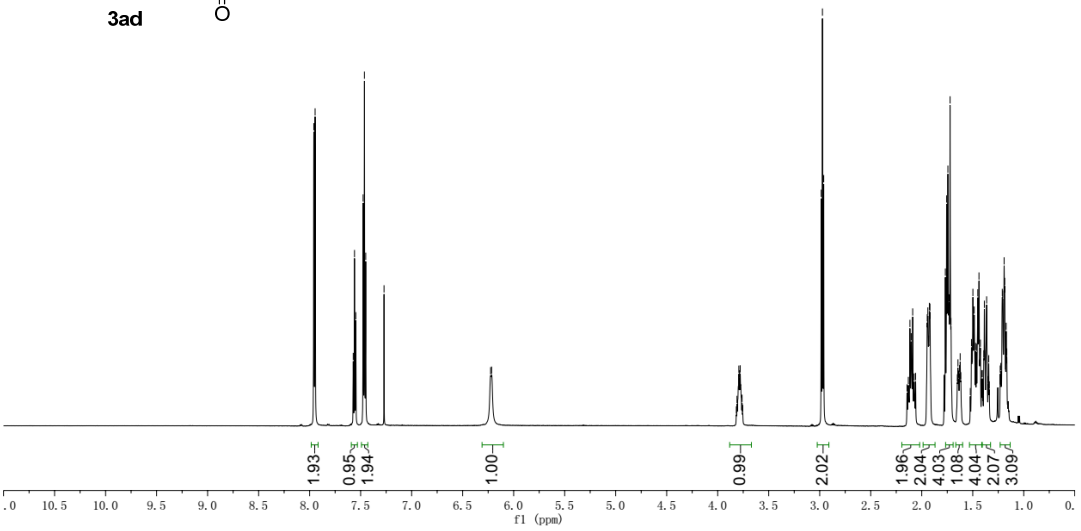
1.1721
1.1664


O
F
F
H
N
Cy
Ph
O

3ad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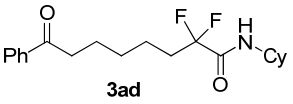
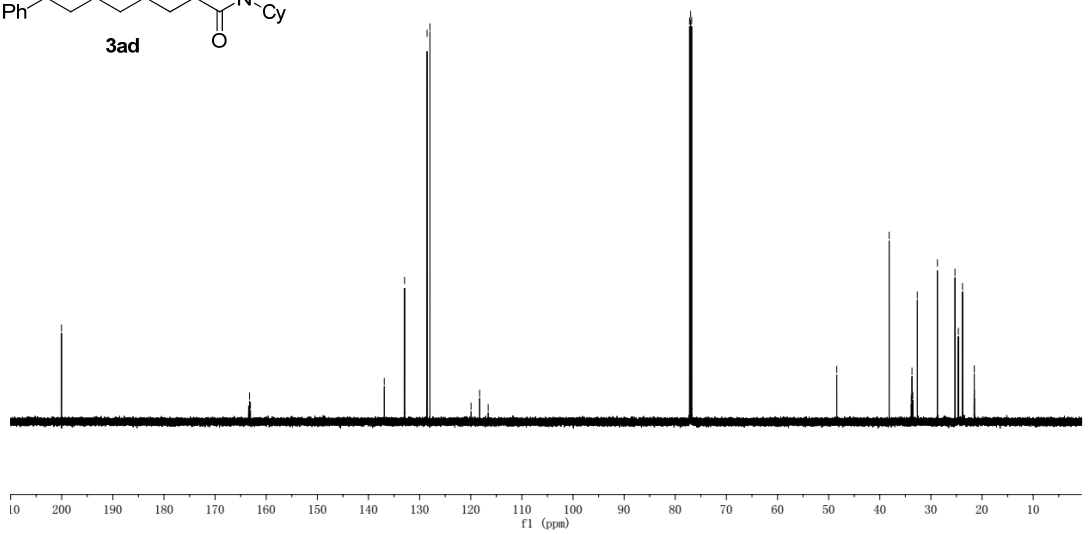
0.95
1.94
1.00
0.99
2.02
1.96
2.04
4.03
1.08
4.04
2.07
3.09
f1 (ppm)


200.0412
163.4627
163.2775
163.0894
136.9162
132.9428
128.5464
127.9754
119.9327
118.2614
116.5919
77.2121
77.0003
76.7883
48.4205
38.1626
33.8593
33.7052
33.5496
32.6654
28.7281
25.2923
24.6453
23.8222
21.5551
21.5260
21.4959


O
F
F
H
N
Cy
Ph
O

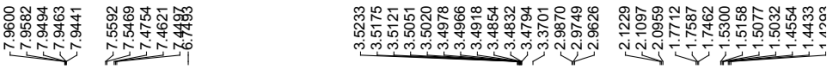
3ad


f1 (ppm)

O
F
F
H
N
Cy
Ph
O

3ad


-106.3508
f1 (ppm)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7.9494
7.9463
7.9441
7.5592
7.5469
7.4754
7.4621
7.4497
7.4483
3.5233
3.5175
3.5121
3.5051
3.5020
3.4978
3.4966
3.4918
3.4854
3.4832
3.4794
3.3701
2.9870
2.9749
2.9626
2.1229
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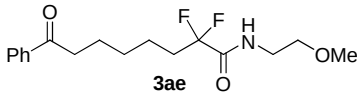
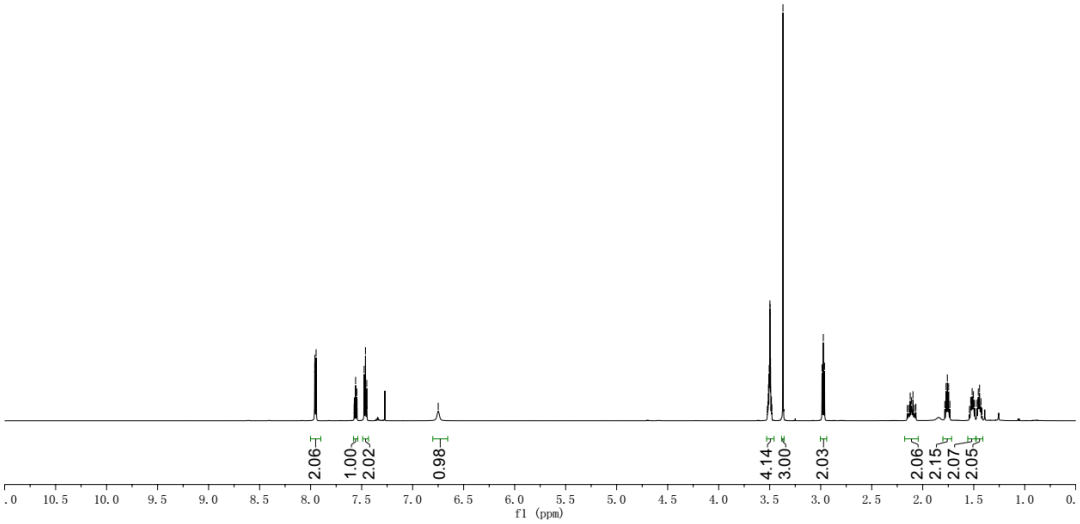
1.5158
1.5077
1.5032
1.4554
1.4433


O
F
F
H
N
OMe
Ph
O

3ae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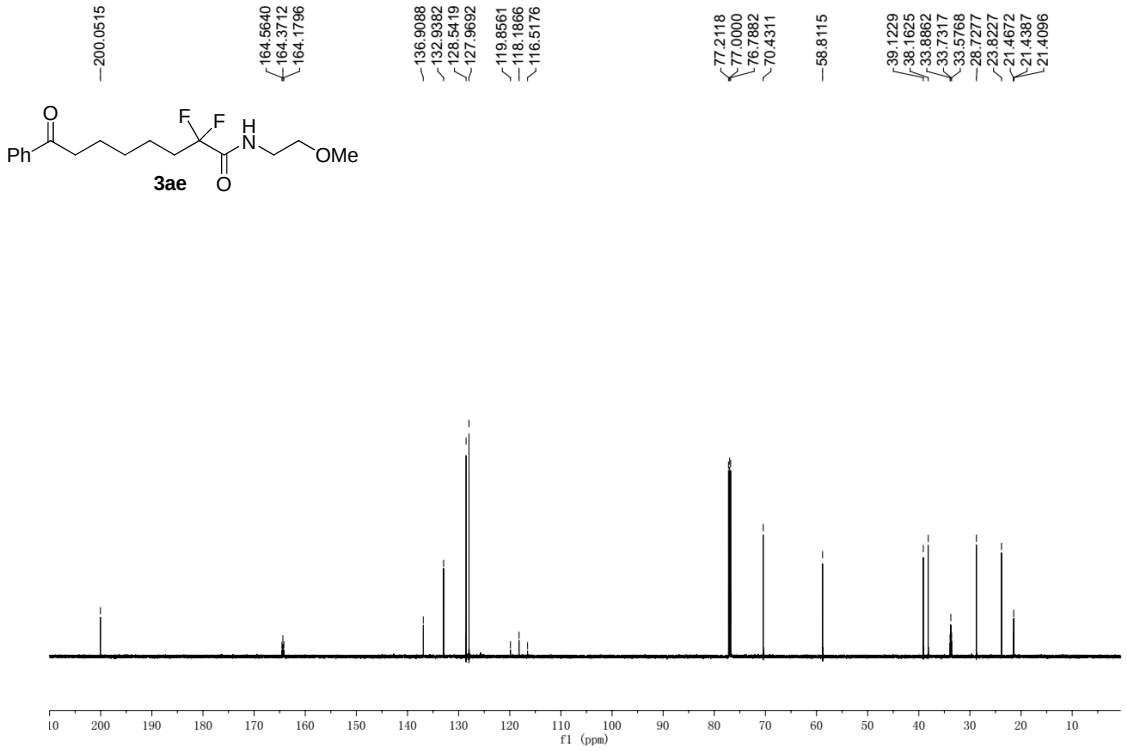
2.02
0.98
4.14
3.00
2.03
2.06
2.15
2.07
2.05
f1 (ppm)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164.1796
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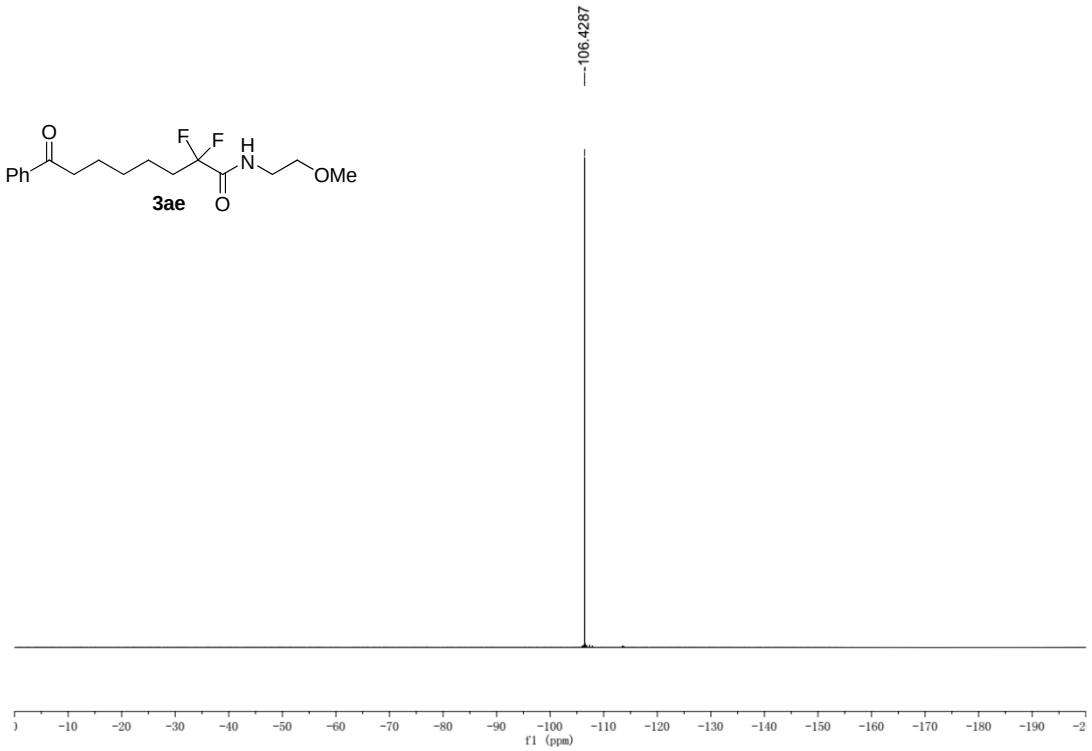
128.5419
127.9692
119.8561
118.1866
116.5176
77.2118
77.0000
76.7882
70.4311
58.8115
39.1229
38.1625
33.8862
33.7317
33.5768
28.7277
23.8227
21.4672
21.4387
21.4096
O
F
F
H
N
Ph
OMe
O
3ae
f1 (ppm)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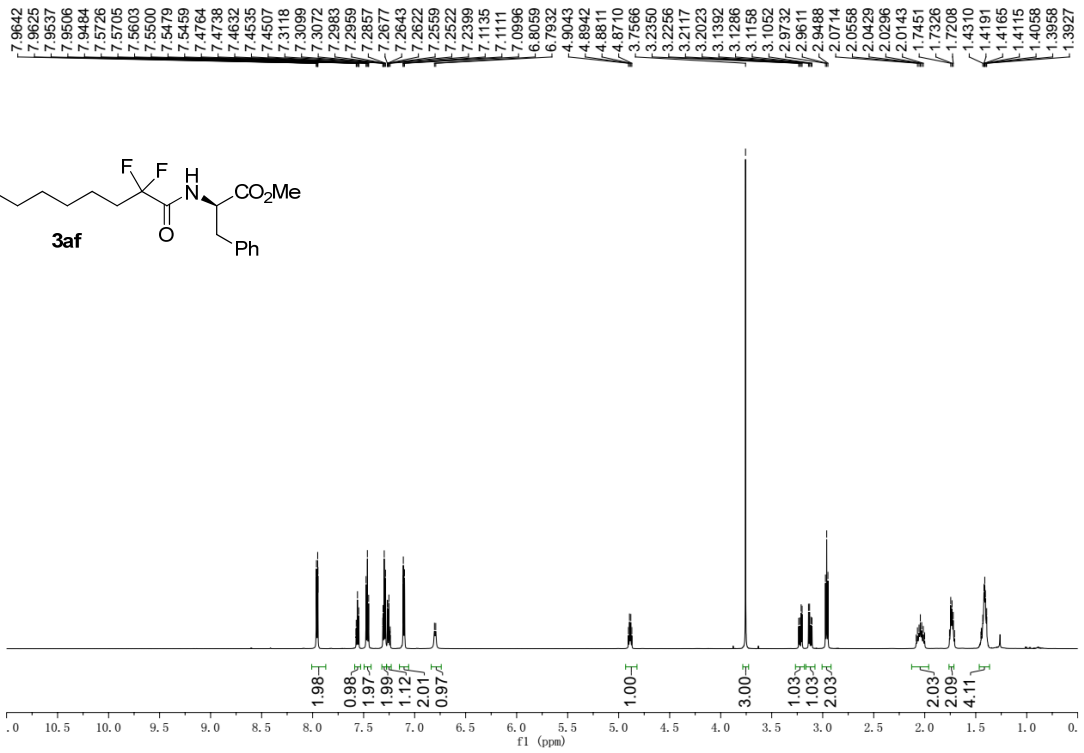
F
H
N
Ph
OMe
O
3ae
f1 (ppm)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7.9484
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7.5705
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7.5500
7.5479
7.5459
7.4764
7.4738
7.4632
7.4535
7.4507
7.3118
7.3099
7.3072
7.2983
7.2959
7.2857
7.2677
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7.2622
7.2559
7.2522
7.2399
7.1135
7.1111
7.0996
6.8059
6.7932
4.9043
4.8942
4.8811
4.8710
3.7566
3.2350
3.2256
3.2117
3.2023
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3.1286
3.1158
3.1052
2.9732
2.9611
2.9488
2.0714
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2.0429
2.0296
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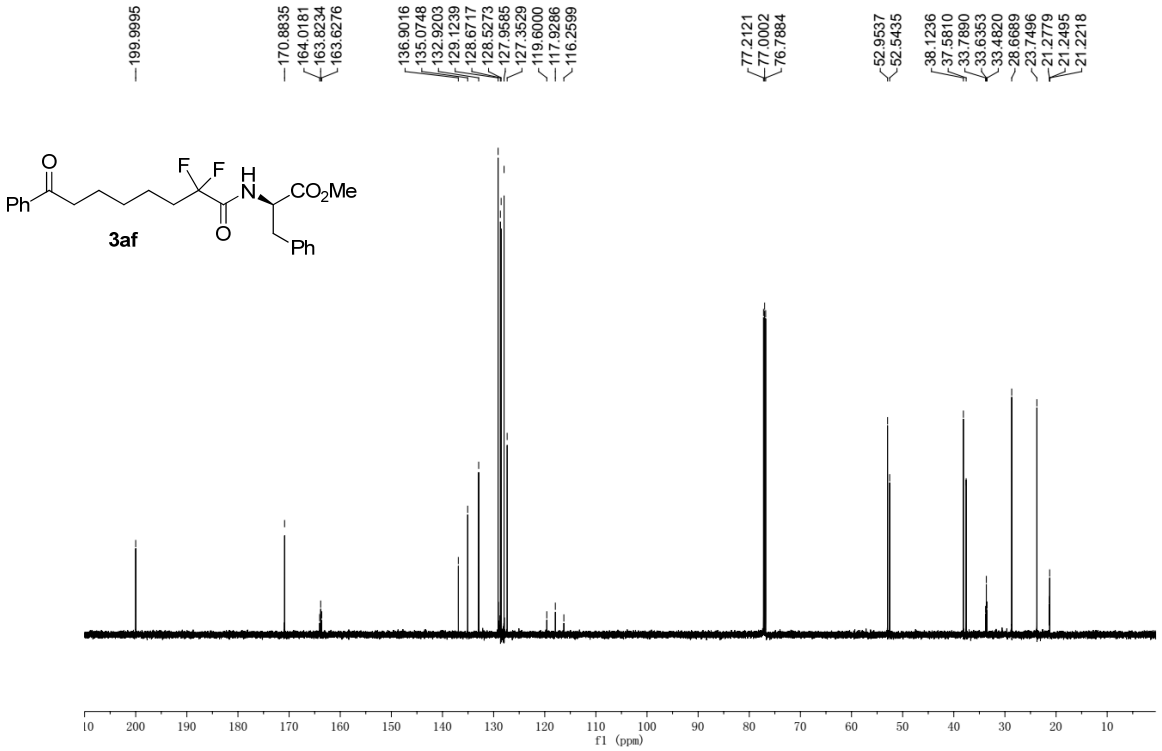
1.4115
1.4058
1.3958
1.3927
O
Ph
F
F
H
N
CO2Me
O
Ph
3af
1.98
0.98
1.97
1.99
1.12
2.01
0.97
1.00
3.00
1.03
1.03
2.03
2.03
2.09
4.11
f1 (ppm)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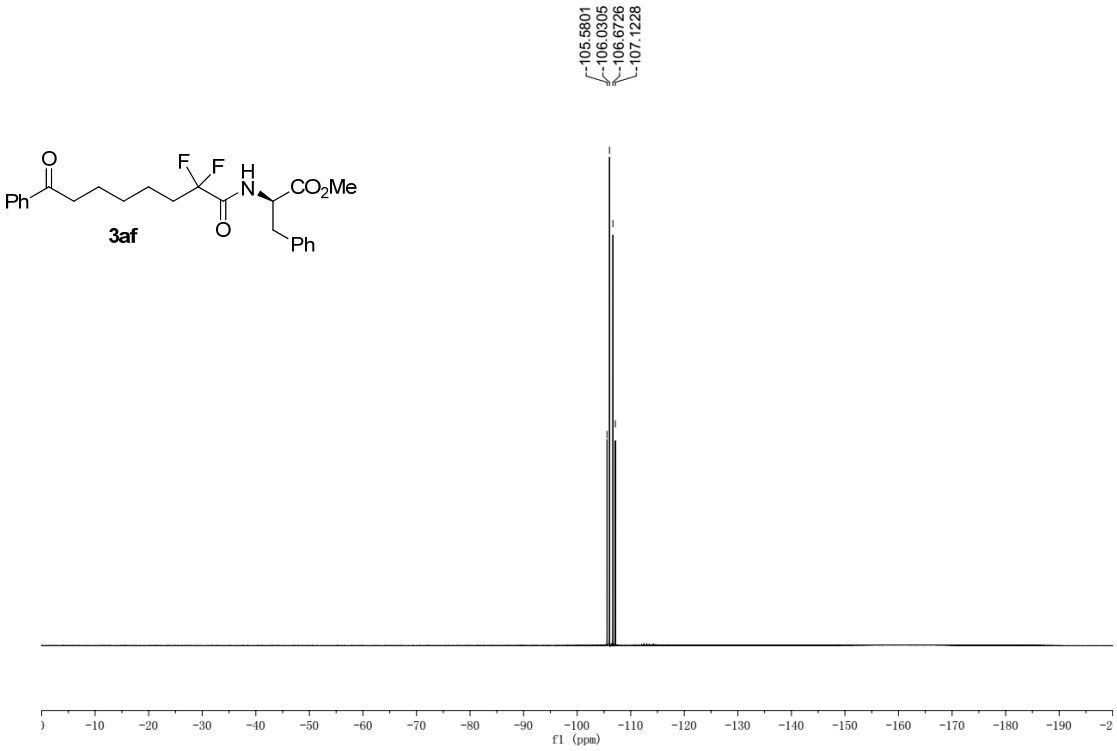
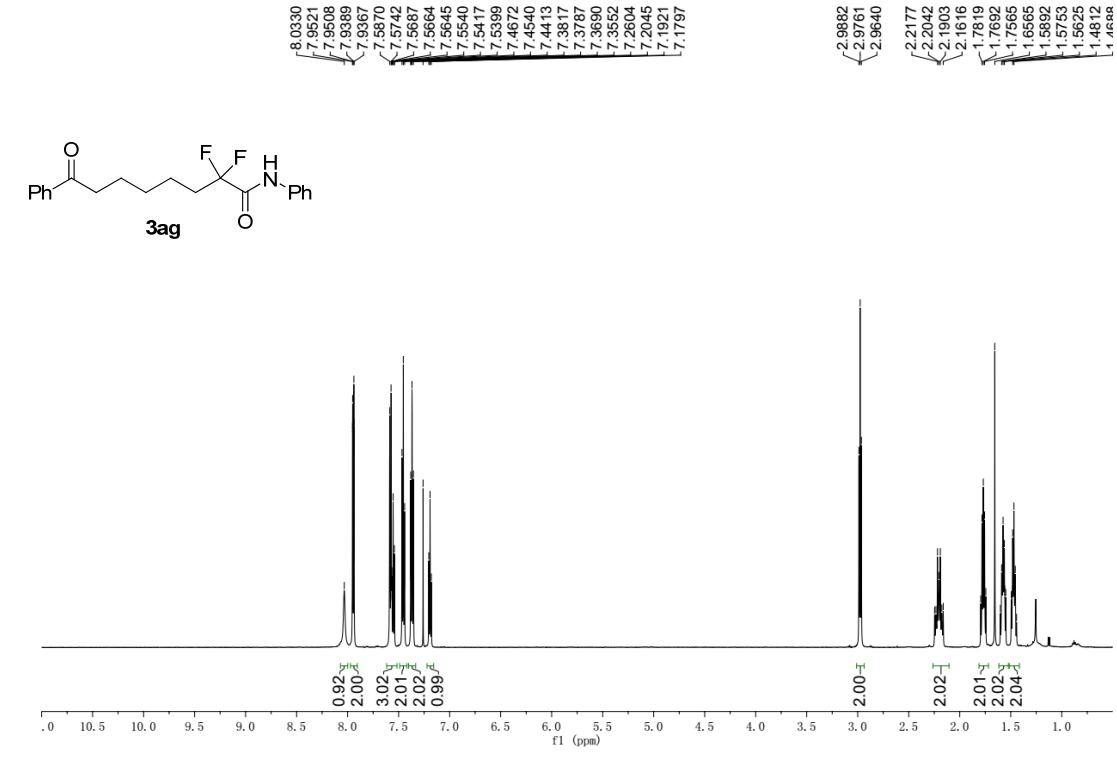
163.8234
163.6276
136.9016
135.0748
132.9203
129.1239
128.6717
128.5273
127.9585
127.3529
119.6000
117.9286
116.2599
77.2121
77.0002
76.7884
52.9537
52.5435
38.1236
37.5810
33.7890
33.6353
33.4820
28.6689
23.7496
21.2779
21.2495
21.2218
O
Ph
F
F
H
N
CO2Me
O
Ph
3af
f1 (ppm)


105.5801
106.0305
106.6726
107.1228
O
Ph
F
F
H
N
CO2Me
O
Ph
3af
f1 (ppm)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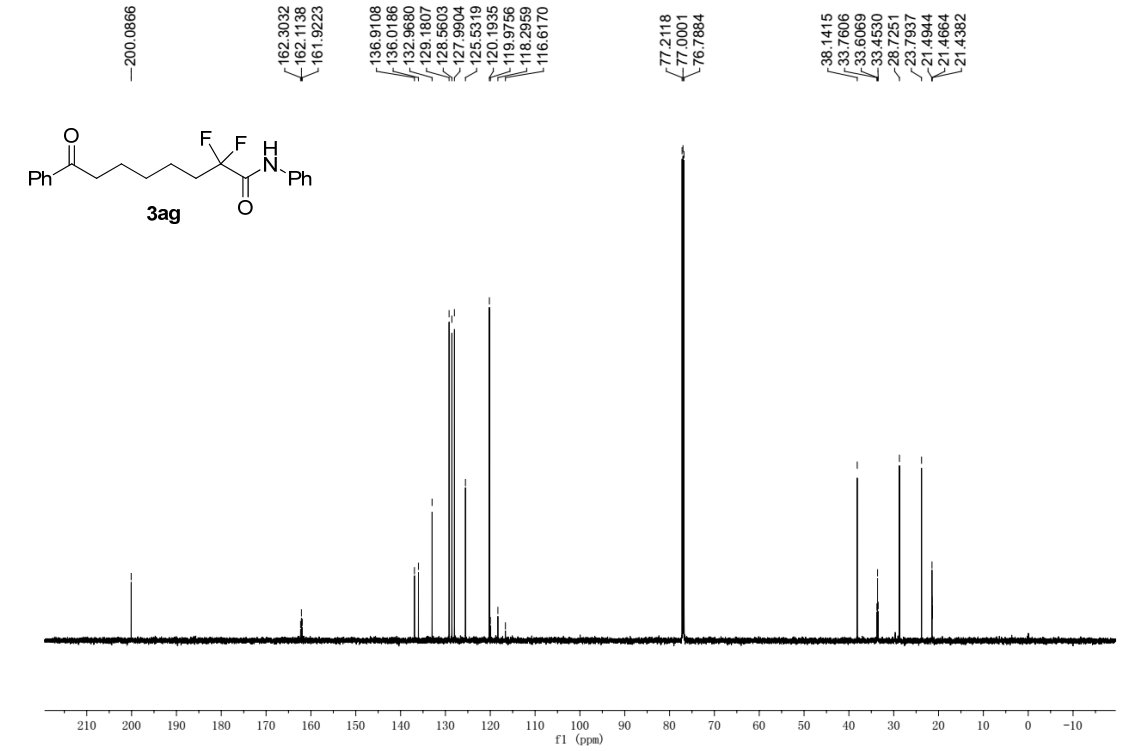
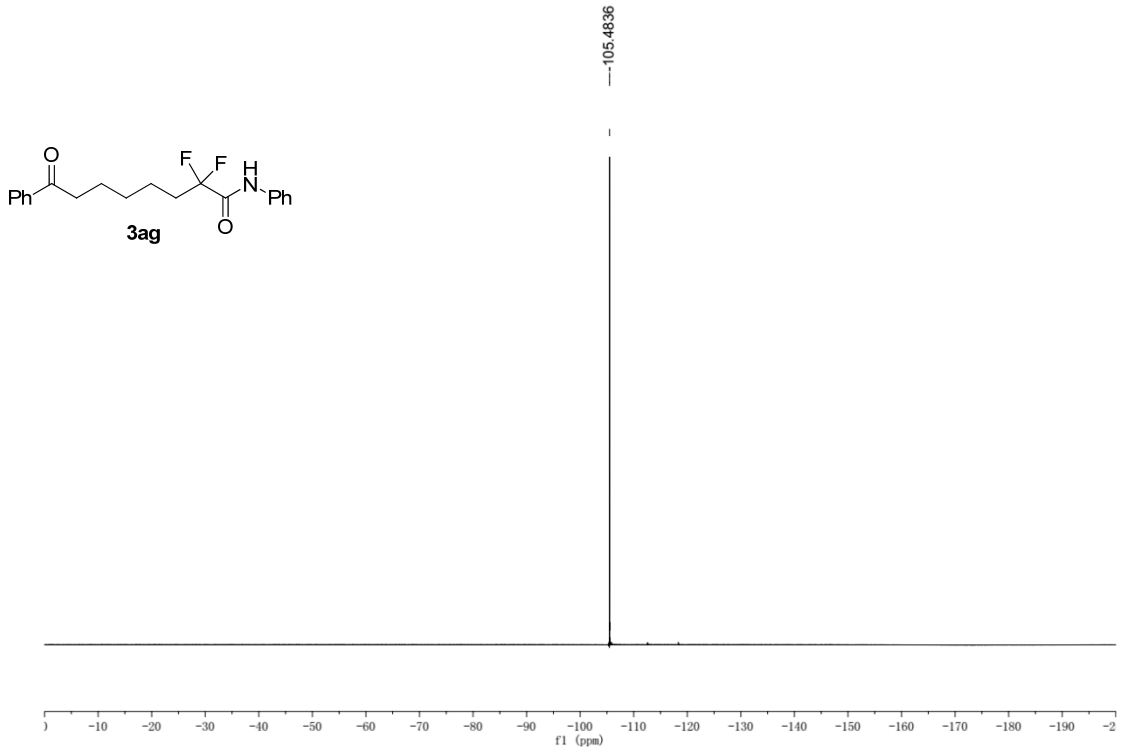
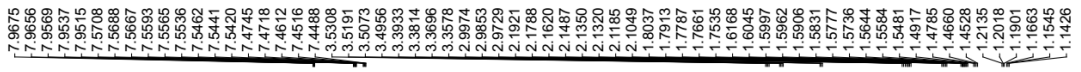
7.9521
7.9508
7.9389
7.9367
7.5870
7.5742
7.5687
7.5664
7.5645
7.5540
7.5417
7.5399
7.4672
7.4540
7.4413
7.3817
7.3787
7.3690
7.3552
7.2604
7.2045
7.1921
7.1797
2.9882
2.9761
2.9640
2.2177
2.2042
2.1903
2.1616
1.7819
1.7692
1.7565
1.6565
1.5892
1.5753
1.5625
1.4812
O
Ph
F
F
H
N
Ph
O
3ag
0.92
2.00
3.02
2.01
2.02
0.99
2.00
2.02
2.01
2.02
2.04
f1 (ppm)


200.0866
162.3032
162.1138
161.9223
136.9108
136.0186
132.9680
129.1807
128.5603
127.9904
125.5319
120.1935
119.9756
118.2959
116.6170
77.2118
77.0001
76.7884
38.1415
33.7606
33.6069
33.4530
28.7251
23.7937
21.4944
21.4664
21.4382
O
F
F
H
N
Ph
Ph
O
3ag
f1 (ppm)


105.4836
O
F
F
H
N
Ph
Ph
O
3ag
f1 (ppm)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7.9656
7.9569
7.9537
7.9515
7.5708
7.5688
7.5667
7.5593
7.5565
7.5536
7.5462
7.5441
7.5420
7.4745
7.4718
7.4612
7.4516
7.4488
3.5308
3.5191
3.5073
3.4956
3.3933
3.3814
3.3696
3.3578
2.9974
2.9853
2.9729
2.1921
2.1788
2.1620
2.1487
2.1350
2.1320
2.1185
2.1049
1.8037
1.7913
1.7787
1.7661
1.7535
1.6168
1.6045
1.5997
1.5962
1.5906
1.5831
1.5777
1.5736
1.5644
1.5584
1.5481
1.4917
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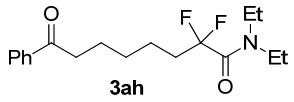
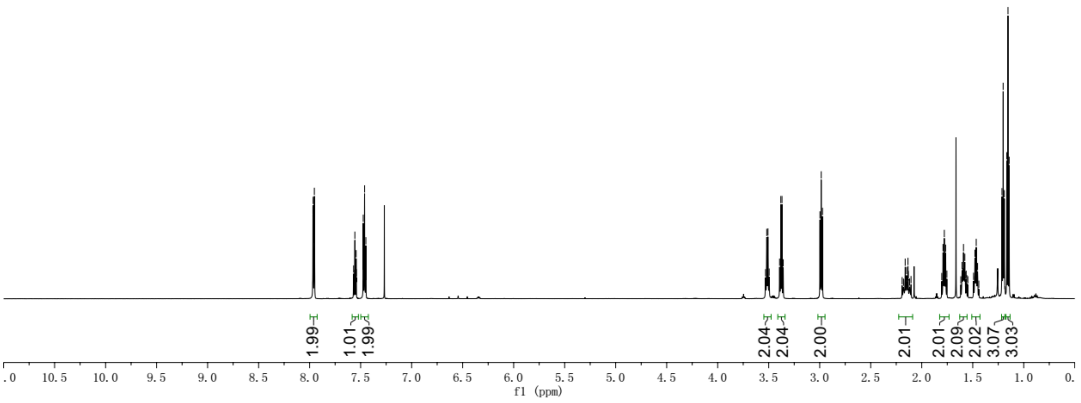
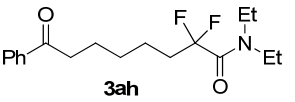
1.4528
1.2135
1.2018
1.1901
1.1663
1.1545
1.1426


O
F
F
Et
N
Et
Ph
O

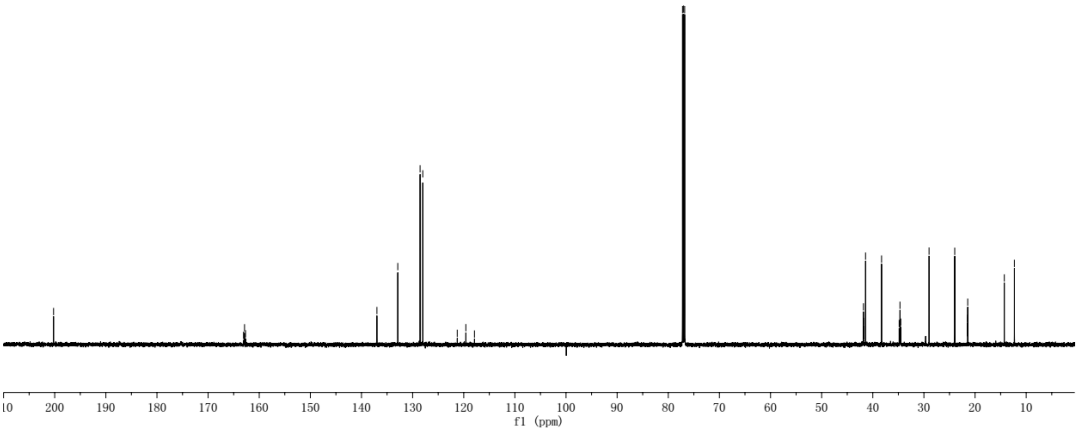
3ah


1.99
1.01
1.99
2.04
2.04
2.00
2.01
2.01
2.09
2.02
3.07
3.03
f1 (ppm)


200.2242
163.0703
162.8765
162.6817
136.9832
132.8994
128.5393
128.0135
121.2690
119.5858
117.9043
77.2122
77.0005
76.7887
41.8660
41.8243
41.7819
41.4156
38.2842
34.8361
34.6811
34.5266
28.9948
23.9724
21.4622
21.4327
21.4021
14.2812
12.3044

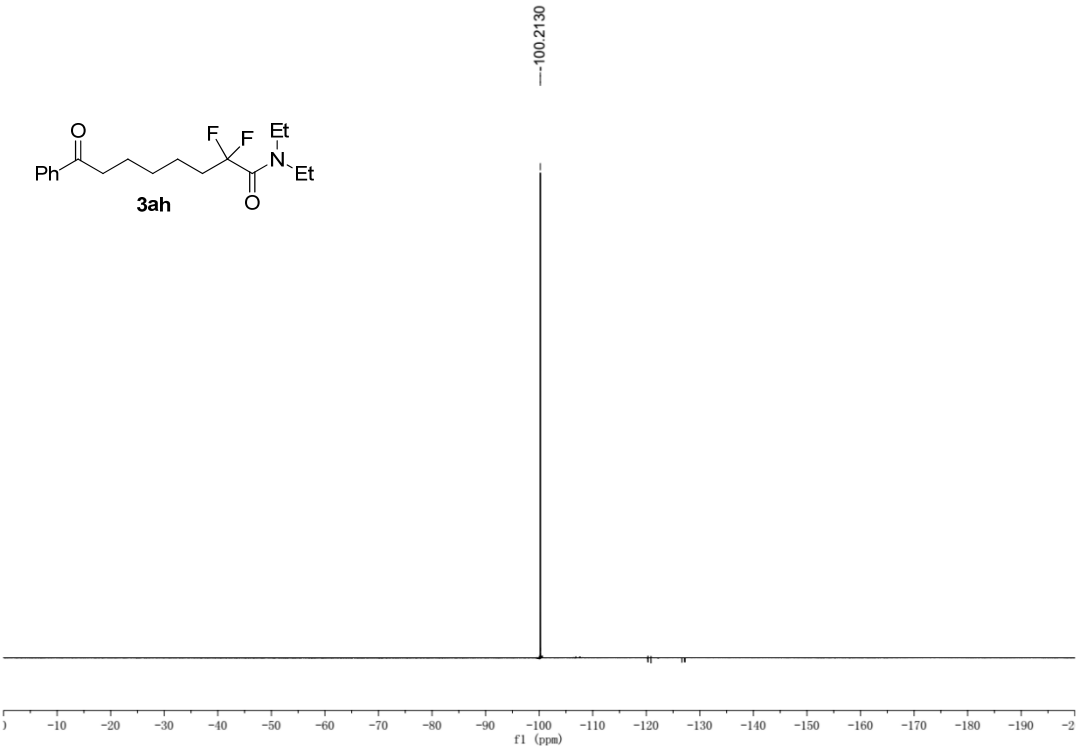

O
F
F
Et
N
Et
Ph
O

3ah


f1 (ppm)

O
F
F
Et
N
Et
Ph
O

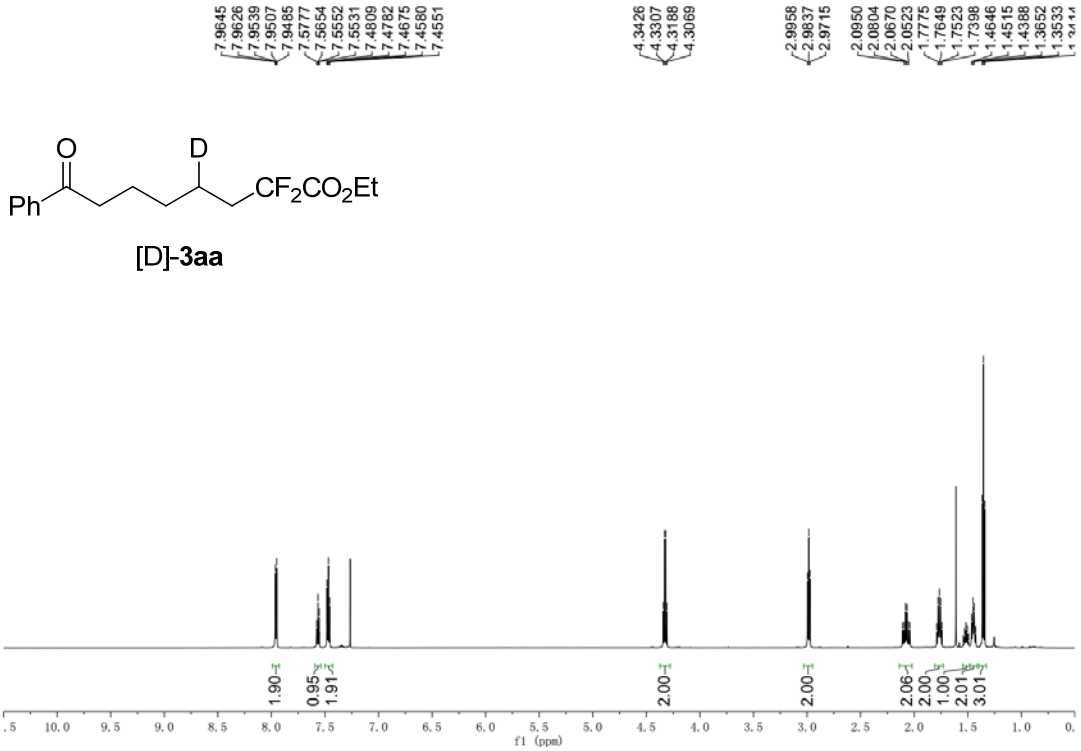
3ah

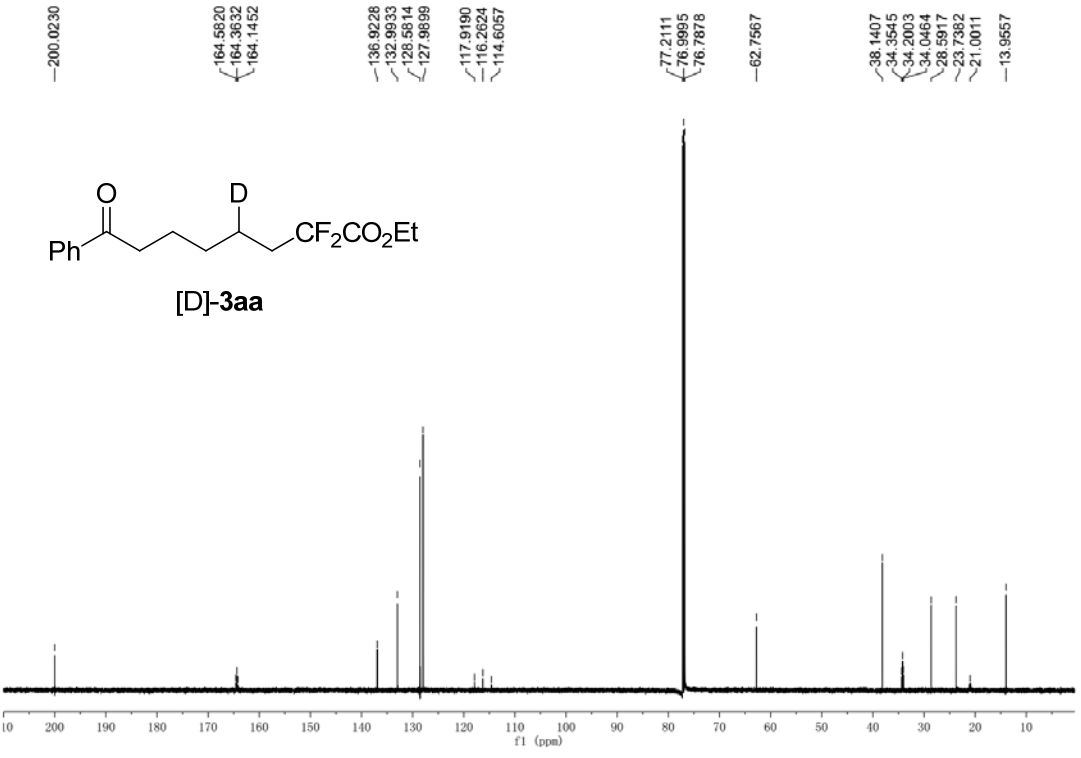

-100.2130
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)

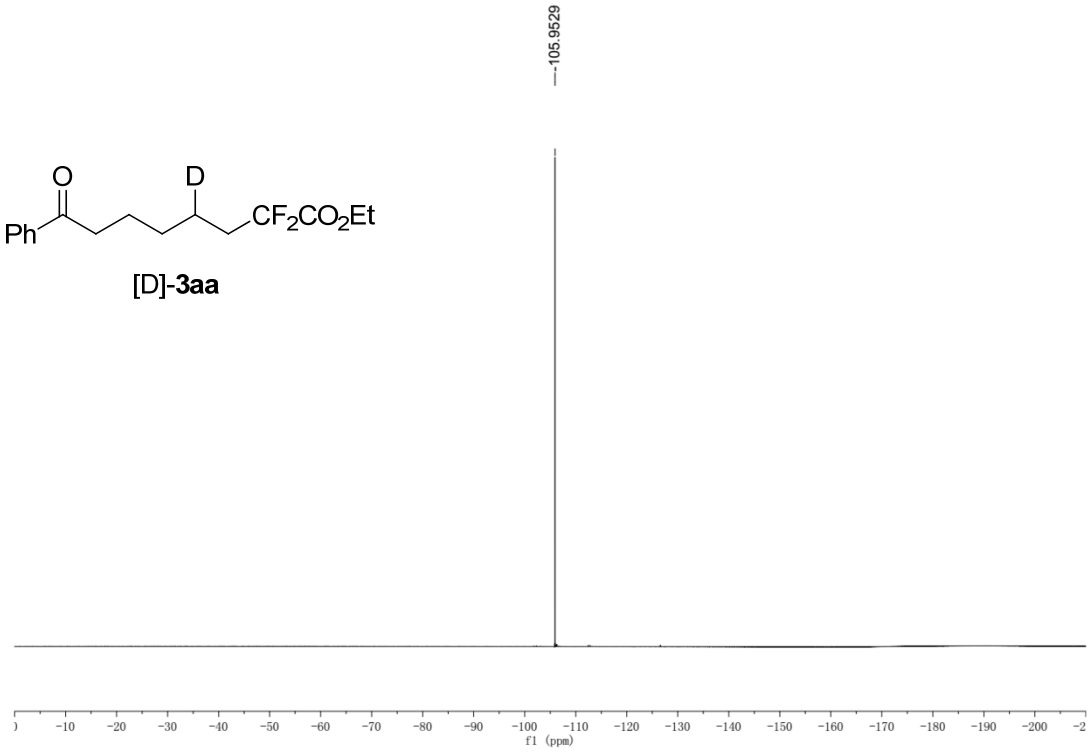

4.4011
4.3833
4.3654
4.3476
1.6178
1.6072
1.5906
1.5843
1.5676
1.4099
1.3920
1.3741
1.2148
1.1878
2.00
5.11
4.07
6.00
6.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f1 (ppm)

N
OCF2COOEt

4a


7.9645
7.9626
7.9539
7.9507
7.9485
7.5777
7.5654
7.5552
7.5531
7.4809
7.4782
7.4675
7.4580
7.4551
4.3426
4.3307
4.3188
4.3069
2.9958
2.9837
2.9715
2.0950
2.0804
2.0670
2.0523
1.7775
1.7649
1.7523
1.7398
1.4646
1.4515
1.4388
1.3652
1.3533
O
D
Ph
CF2CO2Et
[D]-3aa
1.90
0.95
1.91
2.00
2.00
2.06
2.00
1.00
2.01
3.01
f1 (ppm)


200.0230
164.5820
164.3632
164.1452
136.9228
132.9933
128.5814
127.9899
117.9190
116.2624
114.6057
77.2111
76.9995
76.7878
62.7567
38.1407
34.3545
34.2003
34.0464
28.5917
23.7382
21.0011
13.9557
O
D
Ph
CF2CO2Et
[D]-3aa
f1 (ppm)


-105.9529
O
D
Ph
CF2CO2Et
[D]-3aa
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
f1 (ppm)