Supporting Information

Electrochemically Driven Cross-Electrophile Esterification of Alkyl Halides

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General Analytical Information

Nuclear Magnetic Resonance spectra were recorded on a Bruker Avance 400 MHz instruments at ambient temperature. All ^{1}H NMR spectra were measured in part per million (ppm) relative to the signals of tetramethylsilane (TMS, 0.00 ppm) added into the deuterated chloroform ($CDCl_3$, 7.30 ppm) unless otherwise stated. Data for ^{1}H NMR were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, m = multiplet, dd = doublet of doublets, dt = doublet of triplets, td = triplet of doublets), coupling constants, and integration. All ^{13}C NMR spectra were reported in ppm relative to tetramethylsilane (0.00 ppm) unless otherwise stated, and were obtained with complete ^{1}H decoupling. All GC analyses were performed on a Perkin-Elmer Clarus 400 GC system with an FID detector. High-resolution mass spectra were obtained with an AB Triple 5600 mass spectrometer by ESI on a TOF mass analyzer.

General Reagent Information

Unless otherwise noted, all chemicals used in the preparations of starting materials and in the electrochemically driven cross-electrophile esterification of alkyl halides were commercially available and were used as received without further purifications or prepared according to previous work. Solvents transferred to the glove box without exposure to air. Anhydrous dimethylacetamide (DMA) (99.8% purity) were purchased from China National Pharmaceutical Group Corporation.

General Procedure for Electrochemically Driven Cross-Electrophile Esterification of Alkyl Halides

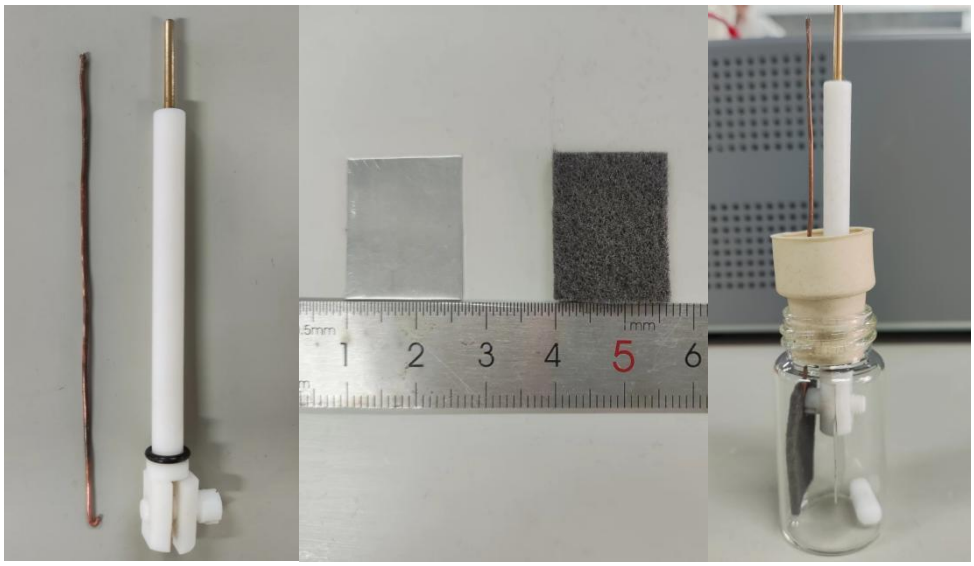


Figure S1 Hand-made electrochemical cell

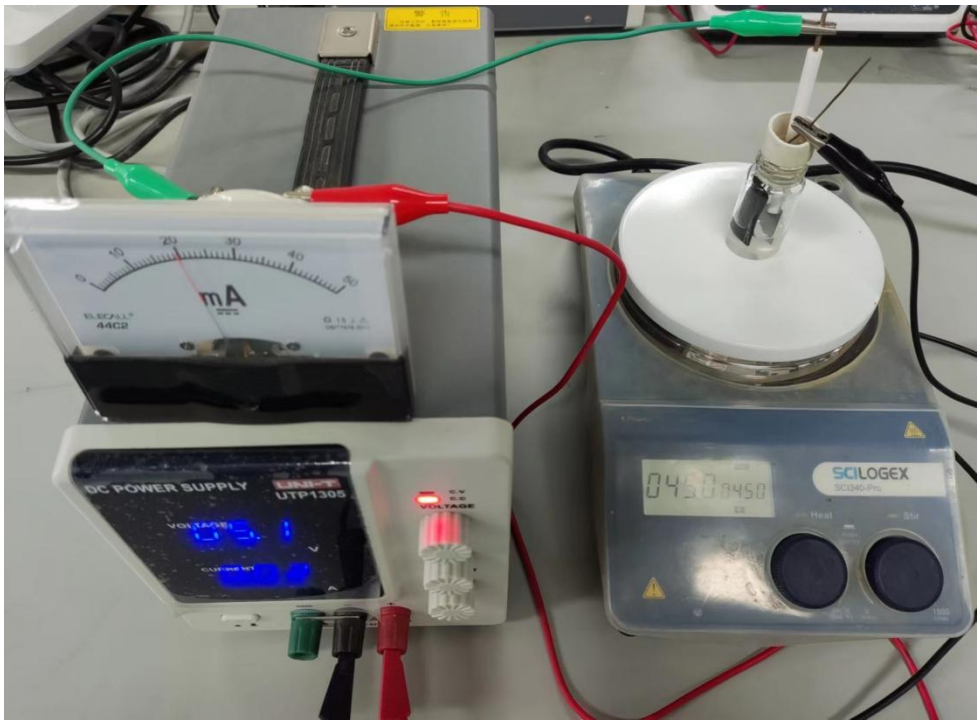
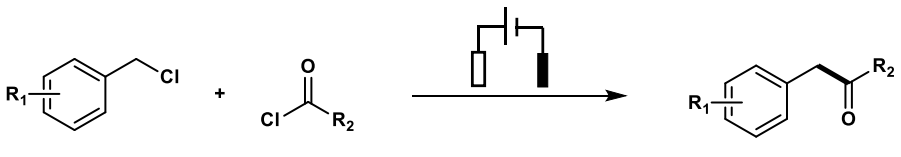


Figure S2 Electrochemical reactor



1 2 3

An oven-dried 20 mL re-sealable screw-cap test tube equipped with a Teflon-coated magnetic stir bar was charged with $^{n}Bu_4NOAc$ (0.2 M) in the glove. Then DMA (4 mL), THF (2 mL), alkyl halides (0.5 mmol), alkyl halides (4.5eq), were added into the tube in turn. All these procedures were conducted in the glovebox. Screw the vial cap with electrode (Zn anode (16 mm X 20 mm), graphite felt cathode (16 mm X 20 mm)) onto the vial to finger tight and adapt the electrochemical cell. Then removed from the glove box. The reaction mixture was stirred and electrolyzed at a constant current (20 mA) at room temperature for 5h. After electrolysis, the product was extracted from the crude reaction mixture with ethyl acetate (4 X 30 mL). The organic layers were combined, and washed with brine (60 mL). Dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

Large Scale Reaction Procedure

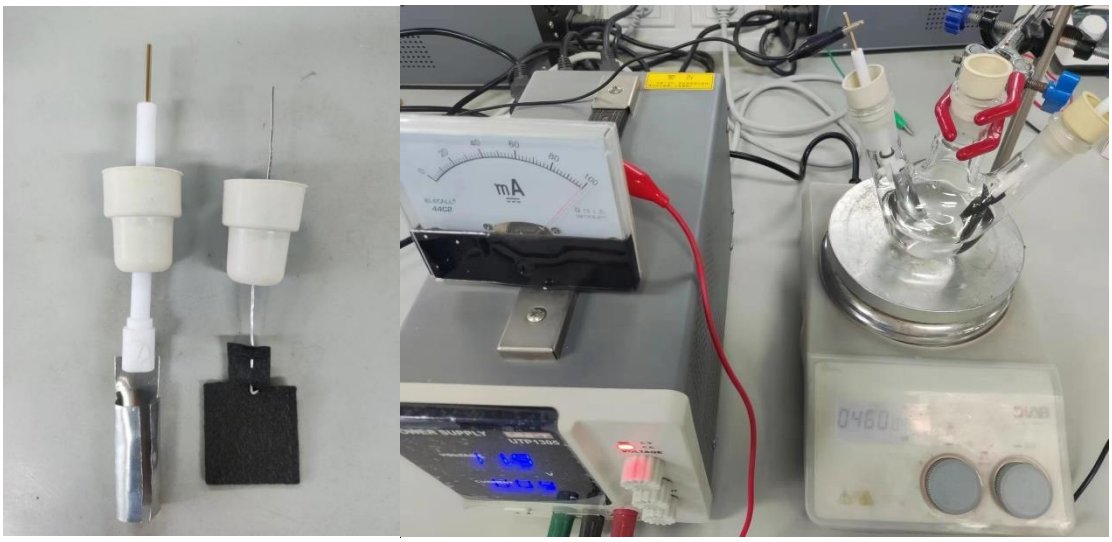
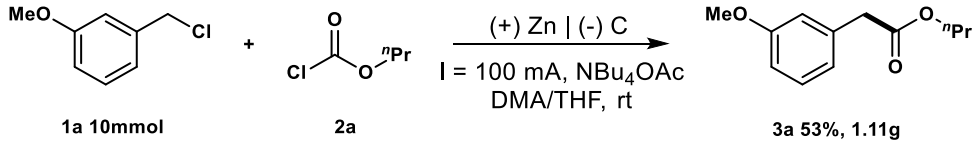
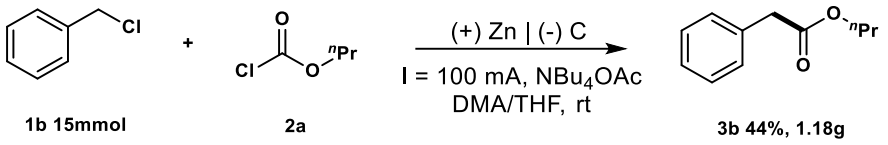


Figure S3 Scale reaction set-up



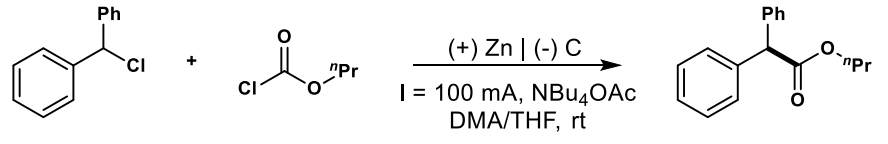
An oven-dried 100 mL three-necked flask equipped with a Teflon-coated magnetic stir bar was charged with $^{n}Bu_4NOAc$ (0.2 M) in the glove. Then 40 mL DMA and 20 mL THF, 3-methoxybenzyl chloride **1a** (10 mmol), ClCOOPr **2a** (45 mmol) were added into the three-necked flask in turn. All these procedures were conducted in the glovebox. Screw the vial cap with electrode onto the vial to finger tight and adapt the electrochemical cell. Then removed from the glove box. The reaction mixture was stirred and electrolyzed at a constant current (100 mA) at room temperature for 12 h.

After electrolysis, the product was extracted from the crude reaction mixture with ethyl acetate (3 X 80 mL). The organic layers were combined, and washed with brine (160 mL). Dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.



1b 15mmol 2a 3b 44%, 1.18g

An oven-dried 100 mL three-necked flask equipped with a Teflon-coated magnetic stir bar was charged with $^{n}Bu_4NOAc$ (0.2 M) in the glove. Then 40 mL DMA and 20 mL THF, benzyl chloride **1b** (15 mmol), ClCOOPr **2a** (45 mmol) were added into the three-necked flask in turn. All these procedures were conducted in the glovebox. Screw the vial cap with electrode onto the vial to finger tight and adapt the electrochemical cell. Then removed from the glove box. The reaction mixture was stirred and electrolyzed at a constant current (100 mA) at room temperature for 12 h. After electrolysis, the product was extracted from the crude reaction mixture with ethyl acetate (3 X 80 mL). The organic layers were combined, and washed with brine (160 mL). Dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

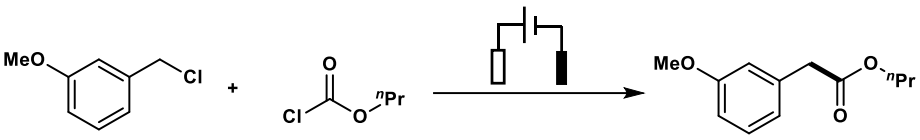


1ak 10mmol 2a 3ak 66%, 1.68g

An oven-dried 100 mL three-necked flask equipped with a Teflon-coated magnetic stir bar was charged with $^{n}Bu_4NOAc$ (0.2 M) in the glove. Then 40 mL DMA and 20 mL THF, chlorodiphenylmethane **1ak** (10 mmol), ClCOOPr **2a** (45 mmol) were added into the three-necked flask in turn. All these procedures were conducted in the glovebox. Screw the vial cap with electrode onto the vial to finger tight and adapt the electrochemical cell. Then removed from the glove box. The reaction mixture was stirred and electrolyzed at a constant current (100 mA) at room temperature for 12h. After electrolysis, the product was extracted from the crude reaction mixture with ethyl acetate (3 X 80 mL). The organic layers were combined, and washed with brine (160 mL). Dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

Optimizations of Electrochemically Driven Cross-Electrophile Esterification of Benzyl halides

Table 1. Screening of the Reaction Conditions



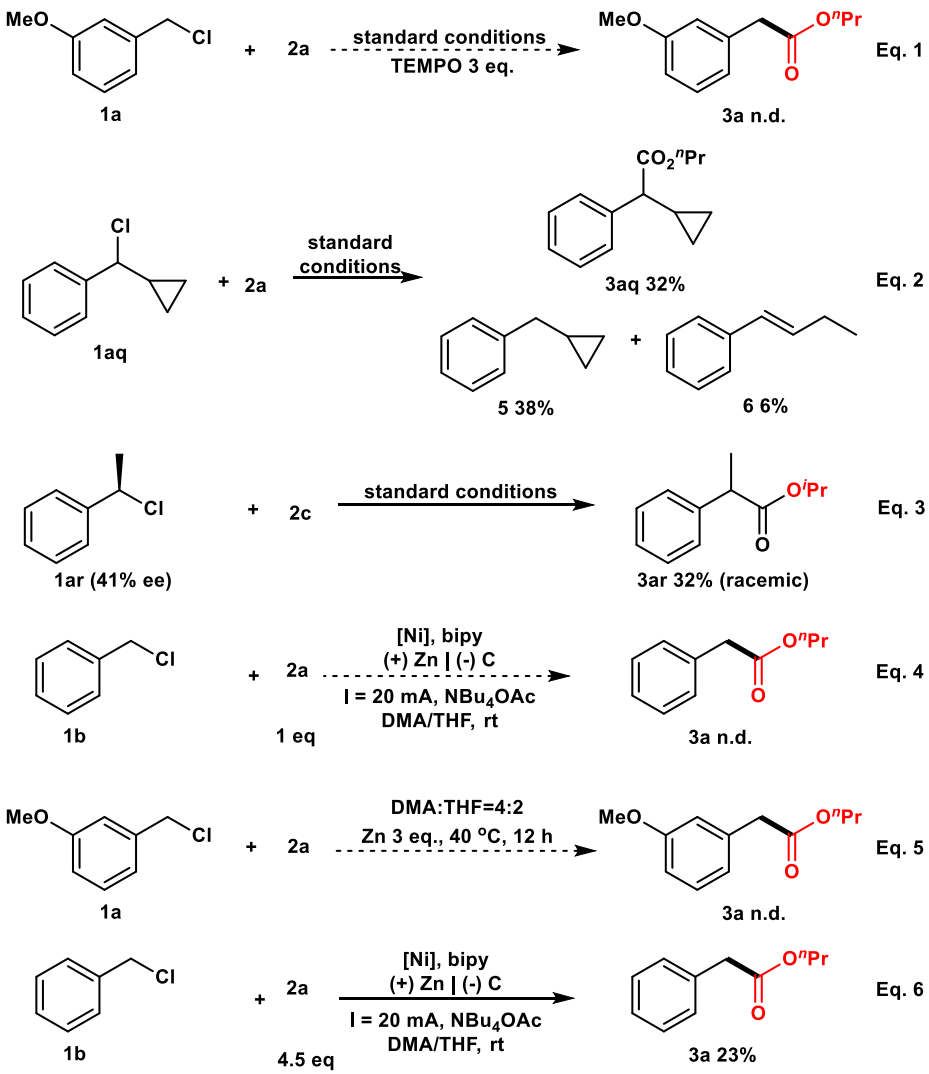
1a 2a 3a

entry	deviation from standard conditions	yield **3a** [%]
1	**none**	**68 (78)**[c]
2[b]	Zn powder	0
3	I = 10 mA	59
4	I = 15 mA	56
5	I = 25 mA	53
6	I = 30 mA	50
7	t= 4 h	53
8	t= 6h	58
9	Fe instead of Zn	61
10	Mg instead of Zn	30
11	Cu instead of Zn	25
12	Pt instead of graphite felt	31
13	Fe instead of graphite felt	42
14	Cu instead of graphite felt	36
15	Zn instead of graphite felt	58
16	^{n}Bu$_4$NBr instead of ^{n}Bu$_4$NOAc	43
17	^{n}Bu$_4$NI instead of ^{n}Bu$_4$NOAc	24
18	^{n}Bu$_4$NCl instead of ^{n}Bu$_4$NOAc	0
19	^{n}Bu$_4$NPF$_6$ instead of ^{n}Bu$_4$NOAc	0
20	Et$_4$NCl instead of ^{n}Bu$_4$NOAc	0
21	DMA instead of DMA/THF	45
22	NMP instead of DMA/THF	28
23	DMA/1,4-Dioxane of DMA/THF	57
24	DMA/THF 3:3 instead of DMA/THF 4:2	53
25	DMA/THF 5:1 of DMA/THF 4:2	43
26	0.1 M ^{n}Bu$_4$NOAc	35
27	0.3 M ^{n}Bu$_4$NOAc	65
28	2 eq **2a**	22
29	3 eq **2a**	51
30	5 eq **2a**	63
31	Without ^{n}Bu$_4$NOAc	0
32	Without current	0

[a] Reaction condition : 0.5 mmol **1a**, 4.5 eq **2a**, 0.2 M $^{n}Bu_4NOAc$, DMA/THF = 4 ml:2 ml, Zn anode, graphite felt cathode, undivided cell, constant current of 20 mA, rt, 5h. Conversion was measured by GC using naphthalene as an internal standard. [b] No electrode and electrolyte, 3 equiv. Zn powder. [c] Isolated yield.

Control Experiments

In order to gain a better understanding of the reaction's mechanism, we conducted several control experiments.



Eq. 1 followed the General Procedure, with adding free radical inhibitor, TEMPO. After reaction, no product was detected.

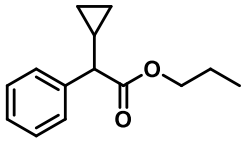
Eq. 2 followed the General Procedure using (chloro(cyclopropyl)methyl)benzene (0.5 mmol) and propyl chlorocarbonate (4.5 eq) as the substrate. After purification, the yield of **3aq** is 32%, **5** is 38%, **6** is 6%

Eq. 3 followed the General Procedure using (R)-(1-chloroethyl)benzene (41% ee) (0.5 mmol) and isopropyl chlorocarbonate (4.5 eq) as the substrate. After purification, the yield of **3ar** is 32%.

Eq. 4 followed the General Procedure using (chloromethyl)benzene (0.5 mmol) and propyl chlorocarbonate (1 eq) as the substrate. Add catalyst $NiCl_2$·dme (10% mmol) and ligand bpy (15% mmol), After purification, the yield of **3a** is nd.

Eq. 5 Standard reaction without current, adding 3eq zinc powder reaction at 40℃ for 12h reaction will not occur.

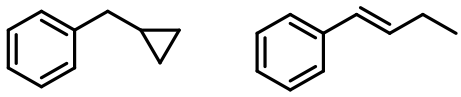
Eq. 6 followed the General Procedure using (chloromethyl)benzene (0.5 mmol) and propyl chlorocarbonate (4.5 eq) as the substrate. Add catalyst $NiCl_2$·dme (10% mmol) and ligand bpy (15% mmol), After purification, the yield of **3a** is 23%.



Propyl 2-cyclopropyl-2-phenylacetate The product was purified by silica gel column chromatography, using PE/EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 – 7.19 (m, 4H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.63 (s, 2H), 2.68 (q, *J* = 7.6 Hz, 2H), 1.69 (h, *J* = 7.2 Hz, 2H), 1.27 (t, *J* = 7.6 Hz, 3H), 0.96 (t, *J* = 7.4 Hz, 3H).

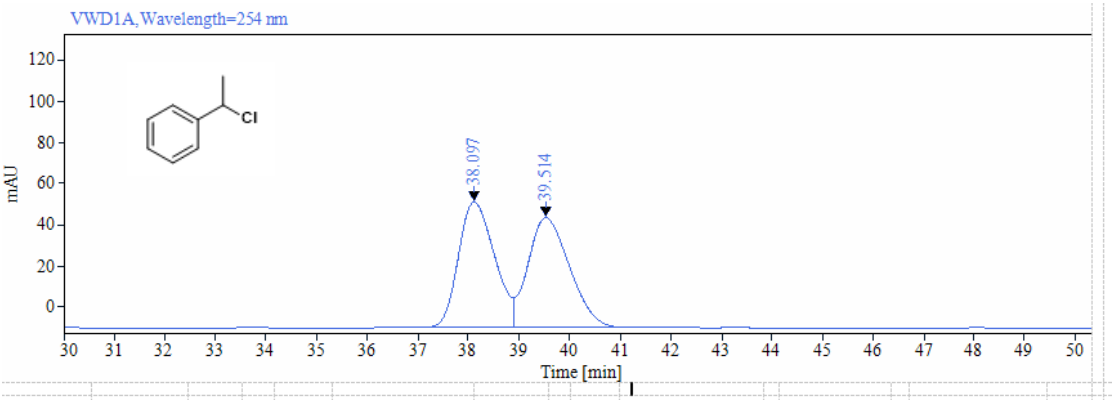
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.97, 143.01, 131.38, 129.19, 128.07, 66.44, 41.06, 28.52, 21.98, 15.62, 10.39.



(cyclopropylmethyl)benzene and (E)-but-1-en-1-ylbenzene The product was purified by silica gel column chromatography, using PE/EA = 120/1 (v/v) as an eluent. According to the spectrum, **(cyclopropylmethyl)benzene : (E)-but-1-en-1-ylbenzene=7:1.**

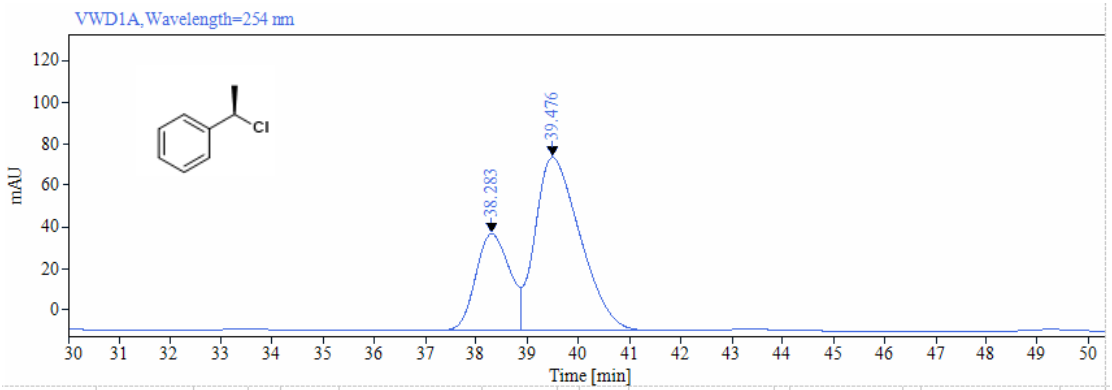
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.23 (m, 41H), 6.38 (d, *J* = 16.0 Hz, 1H), 6.27 (dt, *J* = 15.8, 6.3 Hz, 1H), 2.55 (d, *J* = 6.9 Hz, 14H), 2.23 (p, *J* = 7.4, 6.9 Hz, 2H), 1.09 (t, *J* = 7.5 Hz, 3H), 1.09 – 0.99 (m, 7H), 0.59– 0.55 (m, 14H), 0.20 (q, *J* = 5.0 Hz, 14H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 142.15(major), 137.92(minor), 132.63(minor), 128.76(major), 128.45(major), 128.33(minor), 128.21(minor), 126.73(minor), 125.88(major), 125.80(minor), 40.33(majo r), 26.05(minor), 13.64(minor), 11.83(major), 4.64(major).



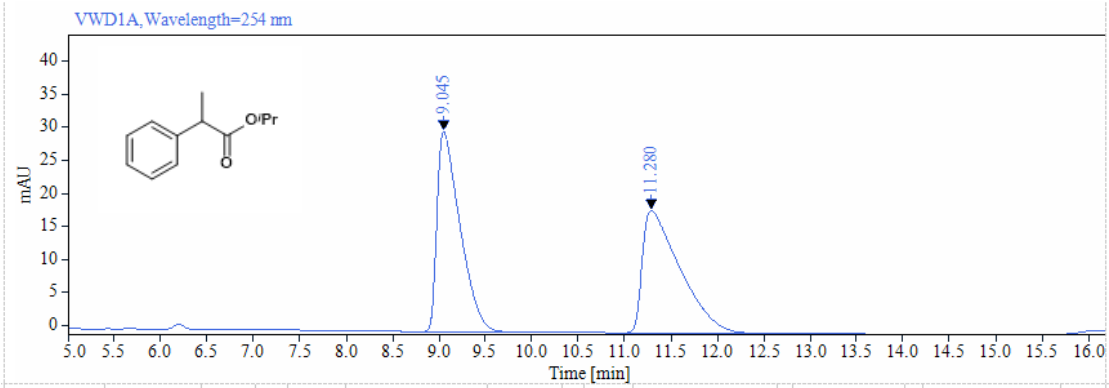
Signal: VWD1A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	38.097	BV	1.92	3037.62	61.01	49.85
2	39.514	VB	2.34	3056.45	53.38	50.15



Signal: VWD1A, Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	38.283	BV	1.75	2161.38	46.54	29.68
2	39.476	VB	2.70	5122.08	83.42	70.32



Signal: VWD1A,Wavelength=254 nm

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.045	BB	1.77	521.71	30.31	50.00
2	11.280	BB	1.72	521.65	18.53	50.00

Cyclic Voltammetry

Cyclic voltammograms in solvent (10 mL) by using glassy carbon as the working electrode, Pt wire as the counter electrode and Ag/AgCl as the reference electrode under N_2 at room temperature. NMP (10mL) containing 0.1 M $^{n}Bu_4NBr$ was poured into the electro chemical cell in all experiments. The scan rate was 100 mV s^{-1}.

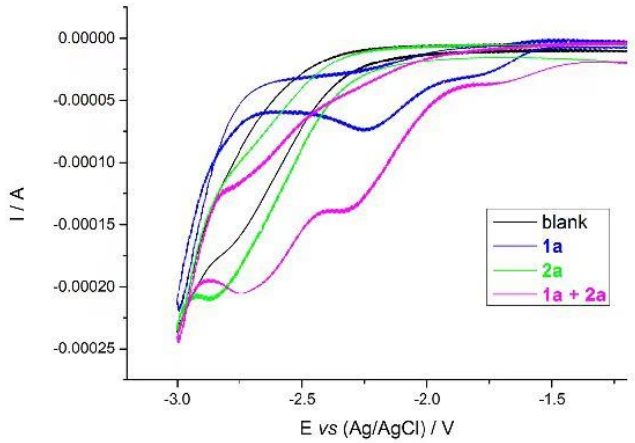
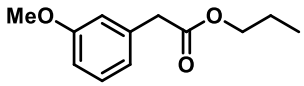


Figure S4: Cyclic voltammograms recorded on a glassy carbon electrode at 100 mVs^{-1} in: black: NMP (10 mL), $^{n}Bu_4NBr$ (1 mol); **1a**: NMP (10 mL), $^{n}Bu_4NBr$ (1 mol), 3-methoxybenzyl chloride (0.1 mmol); **2a**: NMP (10 mL), $^{n}Bu_4NBr$ (1 mol), propyl chlorocarbonate (0.1 mmol); **1a**+**2a**: NMP

(10 mL), $^{n}Bu_4NBr$ (1 mol); **1a**: NMP (10 mL), $^{n}Bu_4NBr$ (1 mol), 3-methoxybenzyl chloride (0.1 mmol), propyl chlorocarbonate (0.1 mmol).

Analytical Data of Substrates and Products

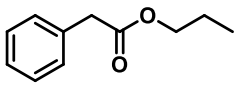


1-(4-(tert-butyl)phenyl)-2-(4-fluorophenyl)ethan-1-one Light yellow liquid (81.1 mg, 78% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.29 – 7.25 (m, 1H), 6.92 – 6.83 (m, 3H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.83 (s, 3H), 3.63 (s, 2H), 1.72 – 1.63 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.61, 159.66, 135.61, 129.52, 121.62, 114.82, 112.63, 66.51, 55.20, 41.52, 21.96, 10.38.

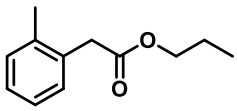
HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{12}H_{16}LiO_3^+$ 215.1254; Found 215.1239.



propyl 2-phenylacetate[1] Light yellow liquid (47.2 mg, 53% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.29 (m, 5H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.66 (s, 2H), 1.68 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

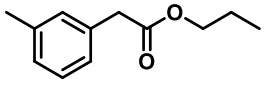
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.75, 134.21, 129.27, 128.56, 127.05, 66.49, 41.49, 21.97, 10.38.



propyl 2-(o-tolyl)acetate Light yellow liquid (63.4 mg, 66% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 – 7.18 (m, 4H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.68 (s, 2H), 2.37 (s, 3H), 1.69 (h, *J* = 6.9 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

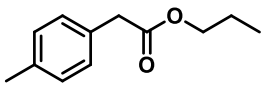
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.66, 136.84, 132.96, 130.33, 130.17, 127.36, 126.13, 66.44, 39.31, 21.99, 19.64, 10.38.



propyl 2-(m-tolyl)acetate Light yellow liquid (50.9 mg, 53% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 30/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.11 (m, 4H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.63 (s, 2H), 2.39 (s, 3H), 1.74 – 1.64 (m, 2H), 0.96 (t, *J* = 7.4 Hz, 3H).

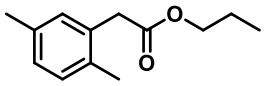
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.86, 138.18, 134.09, 130.03, 128.45, 127.80, 126.28, 66.46, 41.41, 21.98, 21.40, 10.39.



propyl 2-(p-tolyl)acetate Light yellow liquid (56.6 mg, 59% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 – 7.16 (m, 4H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.62 (s, 2H), 2.37 (s, 3H), 1.68 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.96, 136.64, 131.14, 129.25, 129.12, 66.44, 41.06, 21.97, 21.12, 10.39.

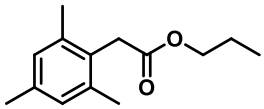


propyl 2-(2,5-dimethylphenyl)acetate Light yellow liquid (63.9 mg, 62% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 – 7.02 (m, 3H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.64 (s, 2H), 2.34 (d, *J* = 10.4 Hz, 6H), 1.69 (h, *J* = 7.2 Hz, 2H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.81, 135.53, 133.63, 132.69, 130.91, 130.22, 128.04, 66.42, 39.26, 22.00, 20.93, 19.15, 10.39.

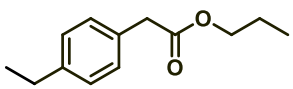
HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{13}H_{18}LiO_2^+$ 213.1461; Found 213.1466.



propyl 2-mesitylacetate Light yellow liquid (59.4 mg, 54% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.93 (s, 2H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.71 (s, 2H), 2.34 (d, *J* = 16.7 Hz, 9H), 1.69 (h, *J* = 7.1 Hz, 2H), 0.97 (t, *J* = 7.4 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.68, 137.02, 136.44, 128.91, 128.75, 66.34, 35.14, 22.03, 20.96, 20.28, 10.43.

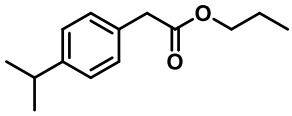
HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{14}H_{20}NaO_2^+$ 243.1356; Found 243.1368.



propyl 2-(4-ethylphenyl)acetate Light yellow liquid (55.6 mg, 54% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 – 7.19 (m, 4H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.63 (s, 2H), 2.68 (q, *J* = 7.6 Hz, 2H), 1.69 (h, *J* = 7.2 Hz, 2H), 1.27 (t, *J* = 7.6 Hz, 3H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.97, 143.01, 131.38, 129.19, 128.07, 66.44, 41.06, 28.52, 21.98, 15.62, 10.39.

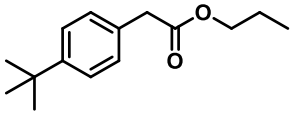


propyl 2-(4-isopropylphenyl)acetate Light yellow liquid (63.8 mg, 58% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.22 (m, 4H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.64 (s, 2H), 2.93 (h, *J* = 6.9 Hz, 1H), 1.70 (h, *J* = 7.2 Hz, 2H), 1.29 (d, *J* = 7.0 Hz, 6H), 0.97 (t, *J* = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.98, 147.61, 131.51, 129.19, 126.64, 66.44, 41.03, 33.80, 24.04, 21.99, 10.40.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{14}H_{20}NaO_2^+$ 243.1356; Found 243.1351.

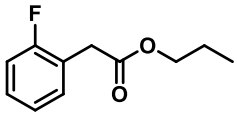


propyl 2-(4-(tert-butyl)phenyl)acetate Light yellow liquid (73.7 mg, 63% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.27 (m, 4H), 4.11 (t, *J* = 6.7 Hz, 2H), 3.65 (s, 2H), 1.70 (h, *J* = 7.1 Hz, 2H), 1.37 (s, 9H), 0.97 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.96, 149.86, 131.16, 128.93, 125.51, 66.44, 40.92, 34.49, 31.39, 21.99, 10.41.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{15}H_{22}LiO_2^+$ 241.1774; Found 241.1792.



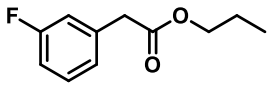
propyl 2-(2-fluorophenyl)acetate Light yellow liquid (51.0 mg, 52% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.26 (m, 2H), 7.16 – 7.07 (m, 2H), 4.11 (t, *J* = 6.7 Hz, 2H), 3.71 (d, *J* = 1.2 Hz, 2H), 1.68 (hept, *J* = 6.9 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.85, 161.08 (d, *J* = 246.4 Hz), 131.45 (d, *J* = 4.0 Hz), 129.02 (d, *J* = 8.1 Hz), 124.10 (d, *J* = 3.7 Hz), 121.56 (d, *J* = 15.8 Hz), 115.36 (d, *J* = 21.7 Hz), 66.65, 34.59 (d, *J* = 3.2 Hz), 21.93, 10.31.

^{19}F NMR (377 MHz, $CDCl_3$) δ -117.27.

HRMS (ESI) m/z: $[M + NH_4]^+$ Calcd for $C_{11}H_{17}FNO_2^+$ 214.1238; Found 214.1246.



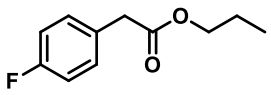
propyl 2-(3-fluorophenyl)acetate Light yellow liquid (49.0 mg, 50% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 – 7.29 (m, 1H), 7.10 – 6.97 (m, 3H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.65 (s, 2H), 1.68 (h, *J* = 7.2 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.13, 162.79 (d, *J* = 245.8 Hz), 136.44 (d, *J* = 7.9 Hz), 129.96 (d, *J* = 8.4 Hz), 124.99 (d, *J* = 2.9 Hz), 116.31 (d, *J* = 21.8 Hz), 114.04 (d, *J* = 21.0 Hz), 66.67, 41.09 (d, *J* = 1.8 Hz), 21.93, 10.34.

^{19}F NMR (377 MHz, $CDCl_3$) δ -113.25.

HRMS (ESI) m/z: $[M + K]^+$ Calcd for $C_{11}H_{13}FKO_2^+$ 235.0531; Found 235.0529.



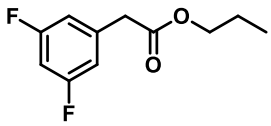
propyl 2-(4-fluorophenyl)acetate Light yellow liquid (43.1 mg, 44% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 1200/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 – 7.28 (m, 2H), 7.06 – 7.02 (m, 2H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.62 (s, 2H), 1.67 (dtd, *J* = 14.1, 7.4, 6.7 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.60, 161.98 (d, *J* = 245.2 Hz), 130.83 (d, *J* = 8.0 Hz), 129.89 (d, *J* = 3.3 Hz), 115.39 (d, *J* = 21.3 Hz), 66.57, 40.56, 21.94, 10.36.

^{19}F NMR (377 MHz, $CDCl_3$) δ -115.85.

HRMS (ESI) m/z: $[M + K]^+$ Calcd for $C_{11}H_{13}FKO_2^+$ 235.0531; Found 235.0545.



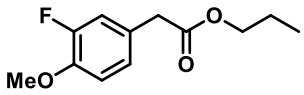
propyl 2-(3,5-difluorophenyl)acetate Light yellow liquid (73.8 mg, 69% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.88 – 6.83 (m, 2H), 6.75 (tt, *J* = 9.0, 2.4 Hz, 1H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.63 (s, 2H), 1.68 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.47, 162.92 (dd, *J* = 248.3, 12.9 Hz), 137.60 (t, *J* = 9.7 Hz), 112.54 – 112.02 (m), 102.66 (t, *J* = 25.2 Hz), 66.84, 40.95 (t, *J* = 2.0 Hz), 21.90, 10.32.

^{19}F NMR (377 MHz, $CDCl_3$) δ -110.02.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{11}H_{13}F_2O_2^+$ 215.0878; Found 215.0881.



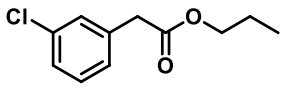
propyl 2-(3-fluoro-4-methoxyphenyl)acetate Light yellow liquid (58.8 mg, 52% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 – 6.90 (m, 3H), 4.07 (t, *J* = 6.7 Hz, 2H), 3.89 (s, 3H), 3.56 (s, 2H), 1.67 (h, *J* = 7.2 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.49, 152.13 (d, *J* = 245.5 Hz), 146.68 (d, *J* = 10.6 Hz), 127.00 (d, *J* = 6.7 Hz), 125.00 (d, *J* = 3.6 Hz), 117.05 (d, *J* = 18.7 Hz), 113.29 (d, *J* = 2.2 Hz), 66.57, 56.23, 40.36 (d, *J* = 1.4 Hz), 21.93, 10.35.

^{19}F NMR (377 MHz, $CDCl_3$) δ -135.26.

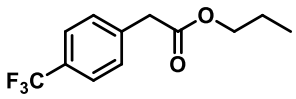
HRMS (ESI) m/z: $[M + NH_4]^+$ Calcd for $C_{12}H_{19}FNO_3^+$ 244.1344; Found 244.1354.



propyl 2-(3-chlorophenyl)acetate Light yellow liquid (78.4 mg, 74% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 – 7.26 (m, 3H), 7.20 (ddd, *J* = 5.5, 3.5, 1.6 Hz, 1H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.62 (s, 2H), 1.68 (dtd, *J* = 14.1, 7.4, 6.6 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.05, 136.03, 134.27, 129.76, 129.46, 127.51, 127.29, 66.69, 40.99, 21.93, 10.35.



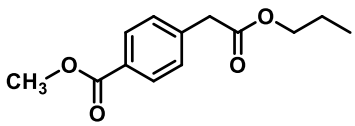
propyl 2-(4-(trifluoromethyl)phenyl)acetate Light yellow liquid (45.5 mg, 37% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.0 Hz, 2H), 7.44 (d, *J* = 7.9 Hz, 2H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.72 (s, 2H), 1.68 (h, *J* = 7.1 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.89, 138.13, 129.69, 129.41 (q, *J* = 32.5 Hz), 125.47 (q, *J* = 3.8 Hz), 121.45 (d, *J* = 271.9 Hz), 66.78, 41.16, 21.91, 10.33.

^{19}F NMR (377 MHz, $CDCl_3$) δ -62.53.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{12}H_{13}F_3LiO_2^+$ 253.1022; Found 253.1047.

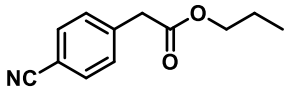


methyl 4-(2-oxo-2-propoxyethyl)benzoate Light yellow liquid (56.4 mg, 48% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.3 Hz, 2H), 7.39 (d, *J* = 8.3 Hz, 2H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.93 (s, 3H), 3.70 (s, 2H), 1.71 – 1.60 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.94, 166.89, 139.34, 129.83, 129.36, 128.96, 66.70, 52.12, 41.41, 21.91, 10.34.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{13}H_{17}O_4^+$ 237.1121; Found 237.1121.

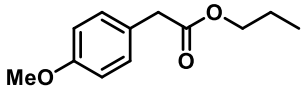


propyl 2-(4-cyanophenyl)acetate Light yellow liquid (42.6 mg, 42% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.1 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.69 (s, 2H), 1.64 (h, *J* = 7.1 Hz, 2H), 0.90 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.41, 139.54, 132.28, 130.20, 118.74, 111.03, 66.85, 41.30, 21.88, 10.33.

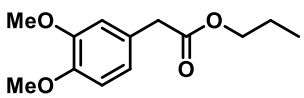
HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{12}H_{14}NO_2^+$ 240.1019; Found 240.1023.



propyl 2-(4-methoxyphenyl)acetate[2] Light yellow liquid (55.1 mg, 53% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.4 Hz, 2H), 6.90 (d, *J* = 8.6 Hz, 2H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.82 (s, 3H), 3.59 (s, 2H), 1.67 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.08, 158.63, 130.29, 126.28, 113.95, 66.41, 55.25, 40.55, 21.97, 10.40.

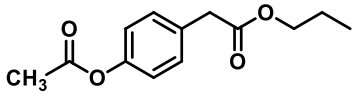


propyl 2-(3,4-dimethoxyphenyl)acetate Light yellow liquid (70.2 mg, 59% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.83 (d, *J* = 5.3 Hz, 3H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.87 (d, *J* = 6.4 Hz, 6H), 3.56 (s, 2H), 1.65 (h, *J* = 7.2 Hz, 2H), 0.92 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.93, 148.82, 148.04, 126.64, 121.37, 112.29, 111.09, 66.42, 55.85, 55.80, 40.97, 21.95, 10.38.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{13}H_{18}LiO_4^+$ 245.1360; Found 245.1356.

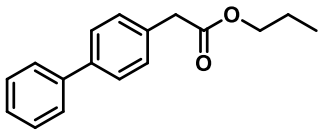


propyl 2-(4-acetoxyphenyl)acetate Light yellow liquid (61.4 mg, 52% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, *J* = 8.2 Hz, 2H), 7.07 (d, *J* = 8.3 Hz, 2H), 4.08 (dd, *J* = 7.2, 6.2 Hz, 2H), 3.64 (s, 2H), 2.32 (d, *J* = 1.0 Hz, 3H), 1.67 (h, *J* = 7.1 Hz, 2H), 0.96 – 0.92 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.46, 169.54, 149.69, 131.76, 130.32, 121.65, 66.57, 40.80, 21.93, 21.16, 10.37.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{13}H_{17}O_4^+$ 237.1121; Found 237.1131.

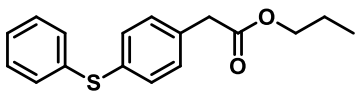


propyl 2-([1,1'-biphenyl]-4-yl)acetate Light yellow liquid (90.2 mg, 71% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.61 (m, 4H), 7.50 (dd, *J* = 8.4, 6.9 Hz, 2H), 7.42 (dd, *J* = 8.5, 6.8 Hz, 3H), 4.14 (t, *J* = 6.7 Hz, 2H), 3.73 (s, 2H), 1.72 (h, *J* = 7.1 Hz, 2H), 0.99 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.77, 140.84, 140.03, 133.26, 129.74, 128.82, 127.35, 127.31, 127.12, 66.60, 41.11, 22.02, 10.45.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}NaO_2^+$ 277.1199; Found 277.1182.

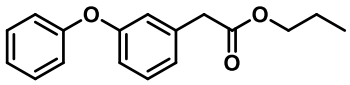


propyl 2-(3-(phenylthio)phenyl)acetate Light yellow liquid (85.8 mg, 60% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.26(m, 9H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.64 (s, 2H), 1.73 – 1.64 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.45, 135.83, 134.37, 133.24, 131.33, 130.91, 130.18, 129.22, 127.04, 66.61, 40.99, 21.96, 10.40.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{17}H_{18}LiO_2S^+$ 293.1182; Found 293.1186.

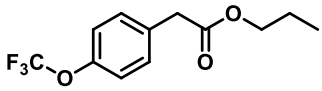


propyl 2-(3-phenoxyphenyl)acetate Light yellow liquid (82.4 mg, 61% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.13 (m, 4H), 7.09 – 6.95 (m, 5H), 4.10 (t, *J* = 6.7 Hz, 2H), 3.64 (s, 2H), 1.68 (h, *J* = 7.1 Hz, 2H), 0.96 (t, *J* = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.36, 157.43, 157.07, 136.08, 129.82, 129.80, 124.15, 123.37, 119.74, 119.04, 117.45, 66.56, 41.31, 21.98, 10.42.

HRMS (ESI) m/z: $[M + K]^+$ Calcd for $C_{17}H_{18}KO_3^+$ 309.0888; Found 309.0890.



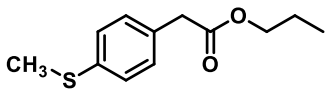
propyl 2-(4-(trifluoromethoxy)phenyl)acetate Light yellow liquid (65.5 mg, 50% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.33 (m, 2H), 7.22 – 7.19 (m, 2H), 4.09 (td, *J* = 6.7, 3.8 Hz, 2H), 3.66 (s, 2H), 1.72 – 1.63 (m, 2H), 0.94 (td, *J* = 7.4, 2.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.25, 132.89, 130.68, 129.26, 128.54, 121.07, 66.67, 40.63, 21.92, 10.31.

^{19}F NMR (377 MHz, $CDCl_3$) δ -57.92.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{12}H_{13}F_3LiO_3^+$ 269.0971; Found 269.0990.

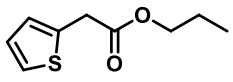


propyl 2-(4-(methylthio)phenyl)acetate Light yellow solid (67.2 mg, 60% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (s, 4H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.61 (s, 2H), 2.50 (s, 3H), 1.67 (dtd, *J* = 14.1, 7.4, 6.6 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 136.77, 130.69, 129.41, 126.51, 126.50, 66.19, 40.55, 21.62, 15.63, 10.44.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{12}H_{17}O_2S^+$ 225.0944; Found 225.0934.

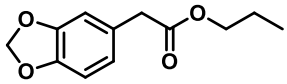


propyl 2-(thiophen-2-yl)acetate Light yellow liquid (50.6 mg, 55% yield). The product was puripropyl 2-(thiophen-2-yl)acetatefied by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.29 (m, 1H), 7.19 – 7.18 (m, 1H), 7.08 (dd, *J* = 4.9, 1.3 Hz, 1H), 4.10 (td, *J* = 6.7, 1.1 Hz, 2H), 3.69 (s, 2H), 1.69 (h, *J* = 7.1, 6.7 Hz, 2H), 0.96 (td, *J* = 7.5, 1.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.27, 133.77, 128.52, 125.69, 122.80, 66.54, 35.95, 21.97, 10.39.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_9H_{12}NaO_2S^+$ 207.0450; Found 207.0455.

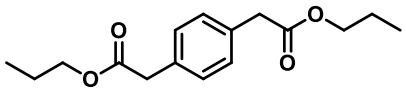


propyl 2-(benzo[d][1,3]dioxol-5-yl)acetate Light yellow liquid (48.8 mg, 44% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.82 – 6.74 (m, 3H), 5.97 (s, 2H), 4.07 (t, *J* = 6.7 Hz, 2H), 3.55 (s, 2H), 1.67 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.83, 147.72, 146.64, 127.76, 122.39, 109.73, 108.27, 101.02, 66.50, 41.04, 21.95, 10.38.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{12}H_{15}O_4^+$ 223.0965; Found 223.0950.

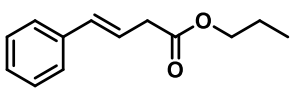


dipropyl 2,2'-(1,4-phenylene)diacetate White solid (44.48 mg, 32% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 (s, 4H), 4.08 (t, *J* = 6.7 Hz, 4H), 3.63 (s, 4H), 1.67 (dtd, *J* = 14.1, 7.4, 6.7 Hz, 4H), 0.94 (t, *J* = 7.4 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.61, 132.97, 129.42, 66.47, 41.08, 21.95, 10.34.

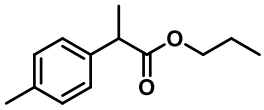
HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{16}H_{23}O_4^+$ 279.1591; Found 279.1589.



propyl (E)-4-phenylbut-3-enoate Light yellow liquid (71.4 mg, 70% yield, E/Z=13:1). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.42 – 7.18 (m, 5H), 6.54 (dt, *J* = 15.9, 1.5 Hz, 1H), 6.35 (dt, *J* = 15.8, 7.1 Hz, 1H), 4.13 (dt, *J* = 10.1, 6.7 Hz, 2H), 3.29 (dd, *J* = 7.1, 1.4 Hz, 1.5H), 1.79 (d, *J* = 7.2 Hz, 0.5H), 1.76 – 1.66 (m, 2H), 0.97 (dt, *J* = 19.6, 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.68 (major), 167.24 (minor), 139.64 (major), 136.92 (major), 135.21 (minor), 135.05 (minor), 133.35 (major), 129.80 (minor), 128.54 (major), 127.92 (minor), 127.53 (major), 127.30 (minor), 126.29 (major), 121.92 (minor), 66.41 (major), 66.34 (minor), 38.48, 22.03 (minor), 21.99 (major), 10.46 (minor), 10.39 (major).

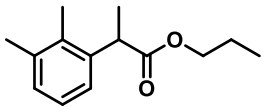


propyl 2-(p-tolyl)propanoate Light yellow liquid (62.8 mg, 61% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.17 (m, 4H), 4.07 (td, *J* = 6.7, 2.2 Hz, 2H), 3.74 (q, *J* = 7.2 Hz, 1H), 2.37 (s, 3H), 1.65 (dtd, *J* = 14.1, 7.4, 6.6 Hz, 2H), 1.53 (d, *J* = 7.2 Hz, 3H), 0.91 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.83, 137.75, 136.66, 129.27, 127.36, 66.29, 45.21, 21.96, 21.08, 18.61, 10.34.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{13}H_{18}LiO_2^+$ 213.1461; Found 213.1466.

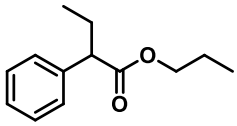


propyl 2-(2,3-dimethylphenyl)propanoate Light yellow liquid (69.3 mg, 63% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.17 – 7.08 (m, 3H), 4.07 (pd, *J* = 7.1, 6.5, 3.9 Hz, 3H), 2.32 (d, *J* = 15.8 Hz, 6H), 1.64 (h, *J* = 7.0 Hz, 2H), 1.51 (d, *J* = 7.1 Hz, 3H), 0.90 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 175.19, 139.23, 137.00, 134.26, 128.64, 125.75, 124.39, 66.30, 41.89, 21.95, 21.09, 18.10, 15.14, 10.33.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{14}H_{20}NaO_2^+$ 243.1356; Found 243.1338.

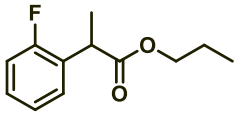


propyl 2-phenylbutanoate Light yellow liquid (46.4 mg, 45% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 5H), 4.16 – 3.99 (m, 2H), 3.49 (t, *J* = 7.7 Hz, 1H), 2.20 – 2.08 (m, 1H), 1.84 (dt, *J* = 13.6, 7.4 Hz, 1H), 1.64 (h, *J* = 7.1 Hz, 2H), 0.95-0.88 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.19, 139.29, 128.51, 127.97, 127.11, 66.23, 53.63, 26.71, 21.96, 12.23, 10.33.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{13}H_{19}O_2^+$ 207.1380; Found 207.1385.

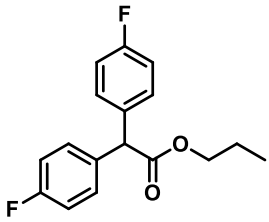


propyl 2-(2-fluorophenyl)propanoate Light yellow liquid (51.5 mg, 49% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.24 (m, 2H), 7.16 – 7.05 (m, 2H), 4.11 – 4.03 (m, 3H), 1.63 (h, *J* = 7.2 Hz, 2H), 1.54 (d, *J* = 7.2 Hz, 3H), 0.88 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.02, 160.37 (d, *J* = 245.9 Hz), 128.67 (d, *J* = 4.1 Hz), 128.58 (d, *J* = 8.4 Hz), 128.00 (d, *J* = 14.9 Hz), 124.24 (d, *J* = 3.6 Hz), 115.40 (d, *J* = 22.2 Hz), 66.51, 38.49 (d, *J* = 2.8 Hz), 21.91, 17.50, 10.26.

^{19}F NMR (377 MHz, $CDCl_3$) δ -118.25.



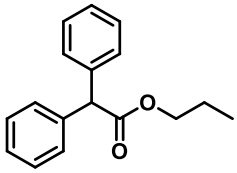
propyl 2,2-bis(4-fluorophenyl)acetate Light yellow liquid (130.5 mg, 90% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.34 – 7.29 (m, 4H), 7.09 – 7.03 (m, 4H), 5.03 (s, 1H), 4.16 (t, *J* = 6.7 Hz, 2H), 1.69 (dtd, *J* = 14.1, 7.4, 6.7 Hz, 2H), 0.92 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.38, 162.05 (d, *J* = 246.2 Hz), 134.44 (d, *J* = 3.3 Hz), 130.13 (d, *J* = 8.0 Hz), 115.54 (d, *J* = 21.5 Hz), 67.00, 55.56, 21.91, 10.33.

^{19}F NMR (377 MHz, $CDCl_3$) δ -115.16.

HRMS (ESI) m/z: $[M + NH_4]^+$ Calcd for $C_{17}H_{20}F_2NO_2^+$ 308.1457; Found 308.1440.

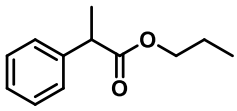


propyl 2,2-diphenylacetate Light yellow solid (95.3 mg, 75% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.29 (m, 10H), 5.13 (s, 1H), 4.20 (t, *J* = 6.7 Hz, 2H), 1.73 (h, *J* = 7.2 Hz, 2H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.63, 138.87, 128.68, 128.63, 127.28, 66.85, 57.27, 22.00, 10.42.

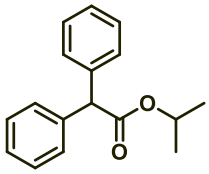
HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}NaO_2^+$ 277.1199; Found 277.1200.



propyl 2-phenylpropanoate[3] Light yellow liquid (48.0 mg, 50% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.27 (m, 5H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.76 (q, *J* = 7.2 Hz, 1H), 1.68 – 1.59 (m, 2H), 1.54 (d, *J* = 7.2 Hz, 3H), 0.89 (t, *J* = 7.4 Hz, 3H).

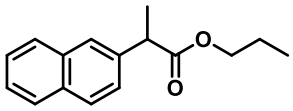
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.66, 140.71, 128.58, 127.50, 127.07, 66.34, 45.61, 21.94, 18.54, 10.31.



isopropyl 2,2-diphenylacetate[4] Light yellow solid (90.2 mg, 71% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.29 (m, 10H), 5.15 (hept, *J* = 6.3 Hz, 1H), 5.05 (s, 1H), 1.29 (d, *J* = 6.3 Hz, 6H).

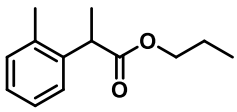
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.04, 138.93, 128.64, 128.58, 127.19, 68.66, 57.32, 21.73.



propyl 2-(naphthalen-2-yl)propanoate Light yellow liquid (75.0 mg, 62% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 – 7.81 (m, 4H), 7.55 – 7.48 (m, 3H), 4.10 (td, *J* = 6.7, 2.0 Hz, 2H), 3.95 (q, *J* = 7.1 Hz, 1H), 1.69-1.61 (m, 5H), 0.90 (t, *J* = 7.4 Hz, 3H).

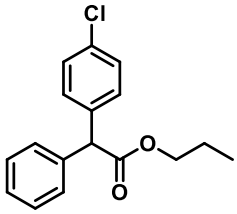
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.65, 138.19, 133.48, 132.58, 128.28, 127.83, 127.65, 126.15, 126.14, 125.83, 125.79, 66.45, 45.77, 21.97, 18.60, 10.36.



propyl 2-(o-tolyl)propanoate Light yellow liquid (57.7 mg, 56% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.16 (m, 4H), 4.09 – 3.95 (m, 3H), 2.42 (s, 3H), 1.62 (ddd, *J* = 14.2, 7.5, 6.8 Hz, 2H), 1.52 (d, *J* = 7.2 Hz, 3H), 0.89 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.95, 139.26, 135.71, 130.43, 126.87, 126.48, 126.38, 66.30, 41.36, 21.94, 19.67, 17.87, 10.31.

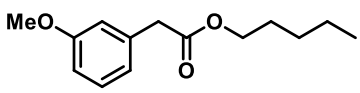


propyl 2-(4-chlorophenyl)-2-phenylacetate Light yellow liquid (111.7 mg, 98% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.32 (m, 9H), 5.07 (s, 1H), 4.19 (t, *J* = 6.7 Hz, 2H), 1.71 (h, *J* = 7.2 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.26, 138.42, 137.38, 133.21, 130.10, 128.76, 128.75, 128.52, 127.48, 66.99, 56.55, 21.97, 10.40.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{17}ClNaO_2^+$ 311.0809; Found 311.0828.

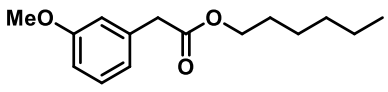


pentyl 2-(3-methoxyphenyl)acetate Light yellow liquid (74.3 mg, 63% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.25 (m, 1H), 6.92 – 6.83 (m, 3H), 4.12 (t, *J* = 6.7 Hz, 2H), 3.83 (s, 3H), 3.62 (s, 2H), 1.79 – 1.62 (m, 2H), 1.33 (tt, *J* = 4.8, 3.5 Hz, 4H), 0.94 – 0.90 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.61, 159.67, 135.62, 129.51, 121.62, 114.82, 112.63, 65.08, 55.19, 41.54, 28.27, 28.03, 22.32, 13.99.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{14}H_{20}NaO_3^+$ 259.1305; Found 259.1291.

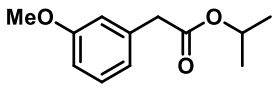


hexyl 2-(3-methoxyphenyl)acetate Light yellow liquid (76.3 mg, 61% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.25 (m, 1H), 6.92 – 6.83 (m, 3H), 4.12 (t, *J* = 6.7 Hz, 2H), 3.83 (s, 3H), 3.62 (s, 2H), 1.68 – 1.61 (m, 2H), 1.38 – 1.27 (m, 6H), 0.93 – 0.90 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.61, 159.67, 135.62, 129.51, 121.61, 114.83, 112.62, 65.09, 55.17, 41.54, 31.41, 28.54, 25.54, 22.56, 14.02.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{15}H_{22}NaO_3^+$ 273.1461; Found 273.1446.

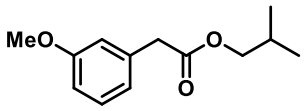


isopropyl 2-(3-methoxyphenyl)acetate Light yellow liquid (63.4 mg, 61% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 (t, *J* = 7.8 Hz, 1H), 6.91 – 6.83 (m, 3H), 5.05 (hept, *J* = 6.3 Hz, 1H), 3.83 (s, 3H), 3.59 (s, 2H), 1.27 (d, *J* = 6.3 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.06, 159.65, 135.75, 129.49, 121.57, 114.75, 112.58, 68.24, 55.18, 41.77, 21.80.

HRMS (ESI) m/z: $[M + K]^+$ Calcd for $C_{12}H_{16}KO_3^+$ 247.0731; Found 247.0738.

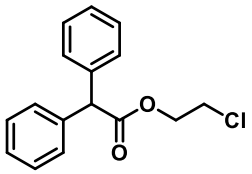


isobutyl 2-(3-methoxyphenyl)acetate Light yellow liquid (71.0 mg, 64% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.25 (m, 1H), 6.92 – 6.83 (m, 3H), 3.91 (d, *J* = 6.7 Hz, 2H), 3.83 (s, 3H), 3.64 (s, 2H), 1.95 (dp, *J* = 13.4, 6.7 Hz, 1H), 0.93 (d, *J* = 6.8 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.57, 159.67, 135.63, 129.51, 121.65, 114.81, 112.66, 70.98, 55.19, 41.56, 27.72, 19.06.

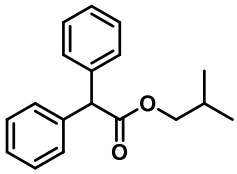
HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{13}H_{18}LiO_3^+$ 229.1411; Found 229.1419.



2-chloroethyl 2,2-diphenylacetate Light yellow liquid (69.9 mg, 51% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.31 (m, 10H), 5.15 (s, 1H), 4.45 (dd, *J* = 6.3, 5.3 Hz, 2H), 3.71 (dd, *J* = 6.3, 5.2 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.19, 138.35, 128.70, 128.65, 127.44, 64.68, 56.95, 41.40.

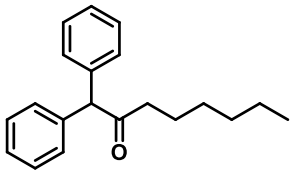


isobutyl 2,2-diphenylacetate Light yellow liquid(109.9 mg, 82% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.29 (m, 10H), 5.11 (s, 1H), 4.00 (d, *J* = 6.6 Hz, 2H), 1.98 (dp, *J* = 13.4, 6.7 Hz, 1H), 0.92 (d, *J* = 6.7 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.58, 138.83, 128.68, 128.59, 127.25, 71.29, 57.32, 27.75, 19.07.

HRMS (ESI) m/z: $[M + K]^+$ Calcd for $C_{18}H_{20}KO_2^+$ 307.1095; Found 307.1090.

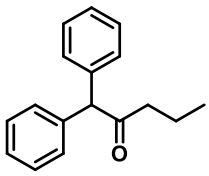


1,1-diphenyloctan-2-one Light yellow liquid (61.6 mg, 44% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.35 (m, 4H), 7.32 – 7.27 (m, 6H), 5.18 (s, 1H), 2.59 (t, *J* = 7.4 Hz, 2H), 1.67 – 1.60 (m, 2H), 1.34 – 1.25 (m, 6H), 0.90 (t, *J* = 6.8 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 208.82, 138.53, 128.99, 128.69, 127.19, 64.14, 42.98, 31.58, 28.77, 23.98, 22.51, 14.08.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{20}H_{25}O^+$ 281.1900; Found 281.1905.

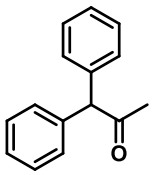


1,1-diphenylpentan-2-one Light yellow liquid (79.7 mg, 67% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.29 (m, 10H), 5.19 (s, 1H), 2.61 – 2.57 (m, 2H), 1.73 – 1.64 (m, 2H), 0.93 (td, *J* = 7.4, 1.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 208.68, 138.54, 129.00, 128.71, 127.21, 64.15, 44.88, 17.47, 13.69.

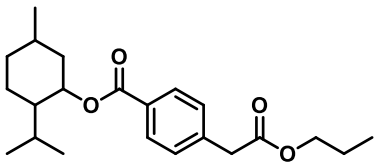
HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{17}H_{19}O^+$ 239.1430; Found 239.1419.



1,1-diphenylpropan-2-one[5] Light yellow liquid (66.2 mg, 63% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.26 (m, 10H), 5.18 (s, 1H), 2.30 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 206.62, 138.32, 129.03, 128.78, 127.32, 65.08, 30.14.

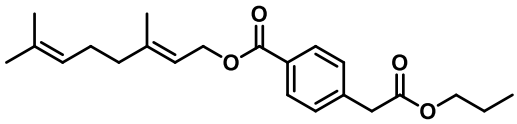


2-isopropyl-5-methylphenyl 4-(2-oxo-2-propoxyethyl)benzoate White solid (139.8 mg, 79% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.3 Hz, 2H), 7.39 – 7.37 (m, 2H), 4.95 (td, *J* = 10.9, 4.4 Hz, 1H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.70 (s, 2H), 2.14 (dtd, *J* = 12.0, 3.9, 1.7 Hz, 1H), 1.98 (pd, *J* = 7.0, 2.8 Hz, 1H), 1.78 – 1.54 (m, 6H), 1.14 (dtd, *J* = 15.4, 12.4, 9.7 Hz, 2H), 0.96 – 0.92 (m, 10H), 0.81 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.92, 165.83, 139.09, 129.81, 129.71, 129.27, 74.81, 66.66, 47.29, 41.40, 40.98, 34.34, 31.45, 26.52, 23.66, 22.05, 21.93, 20.77, 16.54, 10.33.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{22}H_{32}LiO_4^+$ 367.2455; Found 367.2468.

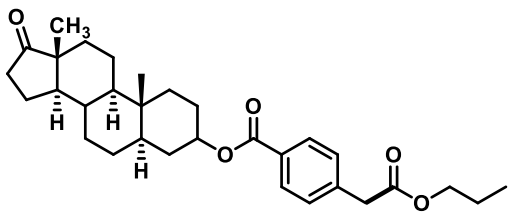


(E)-3,7-dimethylocta-2,6-dien-1-yl 4-(2-oxo-2-propoxyethyl)benzoate White solid (75.2 mg, 42% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 8.02 (m, 2H), 7.40 – 7.37 (m, 2H), 5.51 – 5.47 (m, 1H), 5.15 – 5.11 (m, 1H), 4.86 (d, *J* = 7.0 Hz, 2H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.70 (s, 2H), 2.17 – 2.10 (m, 4H), 1.79 (d, *J* = 1.3 Hz, 3H), 1.71 (d, *J* = 1.4 Hz, 3H), 1.69 – 1.66 (m, 2H), 1.64 (d, *J* = 1.2 Hz, 3H), 0.93 (t, *J* = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.93, 166.44, 142.38, 139.18, 131.85, 129.85, 129.38, 129.27, 123.75, 118.39, 66.68, 61.89, 41.46, 39.56, 26.32, 25.68, 21.92, 17.71, 16.57, 10.32, 1.04.

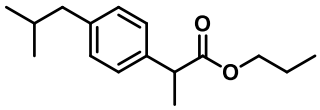
HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{30}NaO_4^+$ 381.2036; Found 381.2052.



(5R,9R,10R,13R,14R)-10,13-dimethyl-17-oxohexadecahydro-1H-cyclopenta[a]phenanthren-3-yl 4-(2-oxo-2-propoxyethyl)benzoate White solid (158 mg, 64% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.2 Hz, 2H), 4.86 (tt, *J* = 11.4, 4.9 Hz, 1H), 3.98 (t, *J* = 6.7 Hz, 2H), 3.60 (s, 2H), 2.40 – 2.33 (m, 1H), 2.05 – 1.95 (m, 1H), 1.87 (ddd, *J* = 12.1, 8.7, 6.0 Hz, 2H), 1.77 – 1.66 (m, 4H), 1.65 – 1.50 (m, 5H), 1.49 – 1.37 (m, 3H), 1.31 – 1.18 (m, 7H), 0.81 – 0.78 (m, 10H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 221.41, 171.03, 165.96, 139.19, 129.86, 129.75, 129.33, 74.17, 66.75, 54.39, 51.43, 47.88, 44.78, 41.50, 36.82, 35.95, 35.79, 35.12, 34.12, 31.60, 30.90, 28.38, 27.60, 21.99, 21.87, 20.57, 13.91, 12.38, 10.43.



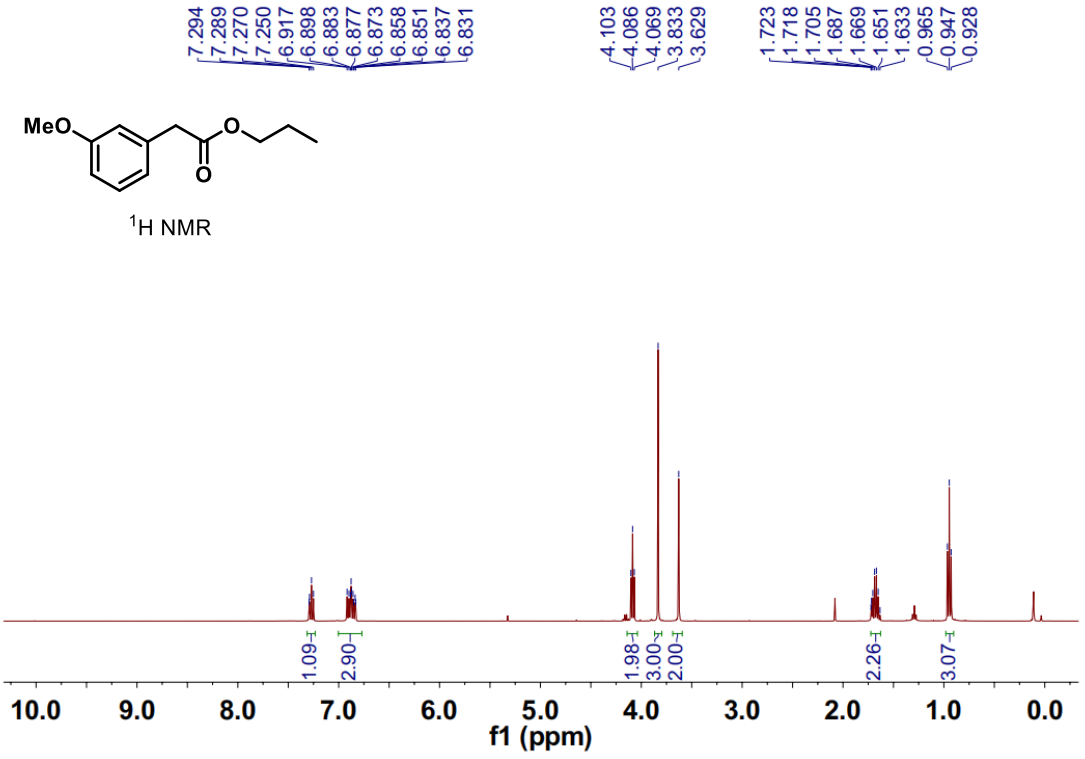
propyl 2-(4-isobutylphenyl)propanoate White solid (71.9 mg, 58% yield). The product was purified by silica gel column chromatography, using petroleum ether /EA = 120/1 (v/v) as an eluent.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 – 7.19 (m, 2H), 7.10 – 7.08 (m, 2H), 4.02 (t, *J* = 6.7 Hz, 2H), 3.69 (d, *J* = 7.2 Hz, 1H), 2.45 – 2.43 (m, 2H), 1.83 (dq, *J* = 13.6, 6.8 Hz, 1H), 1.59 (h, *J* = 7.4 Hz, 2H), 1.49 (d, *J* = 7.2 Hz, 3H), 0.90 – 0.82 (m, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.92, 140.52, 138.01, 129.35, 127.24, 66.30, 45.30, 45.13, 30.29, 22.46, 22.02, 18.57, 10.35.

HRMS (ESI) m/z: $[M + Li]^+$ Calcd for $C_{16}H_{24}LiO_2^+$ 255.1931; Found 255.1943.

NMR Spectra of Substrates and Products



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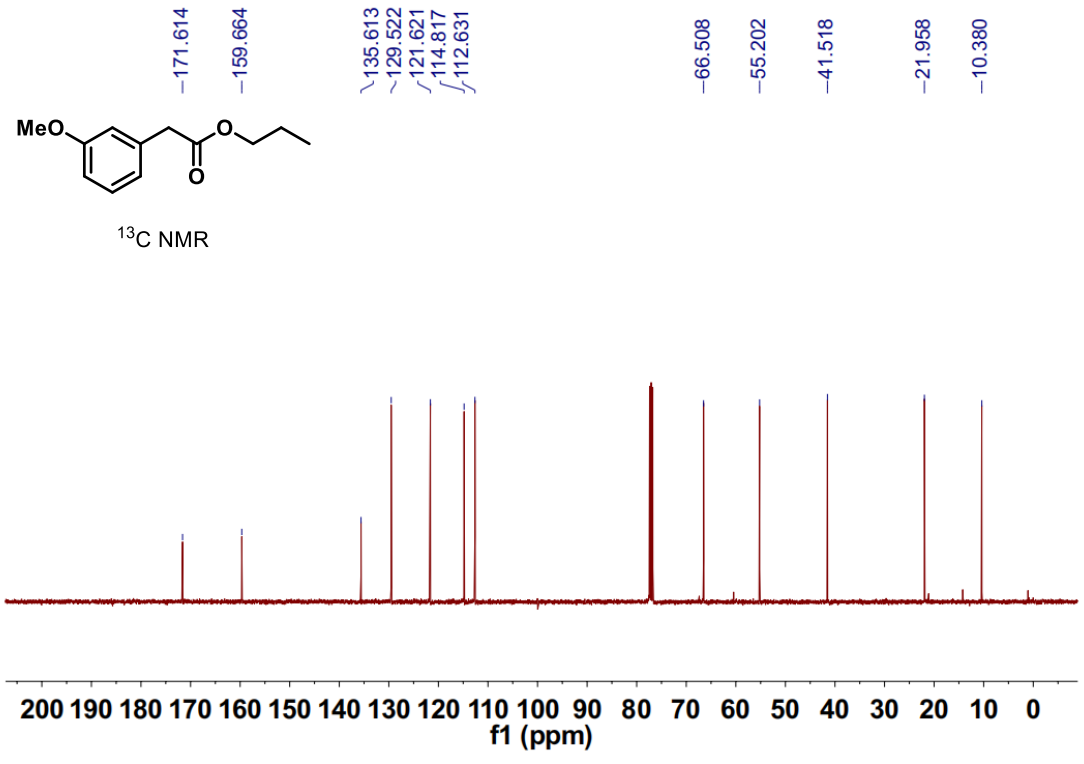

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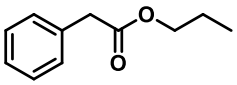

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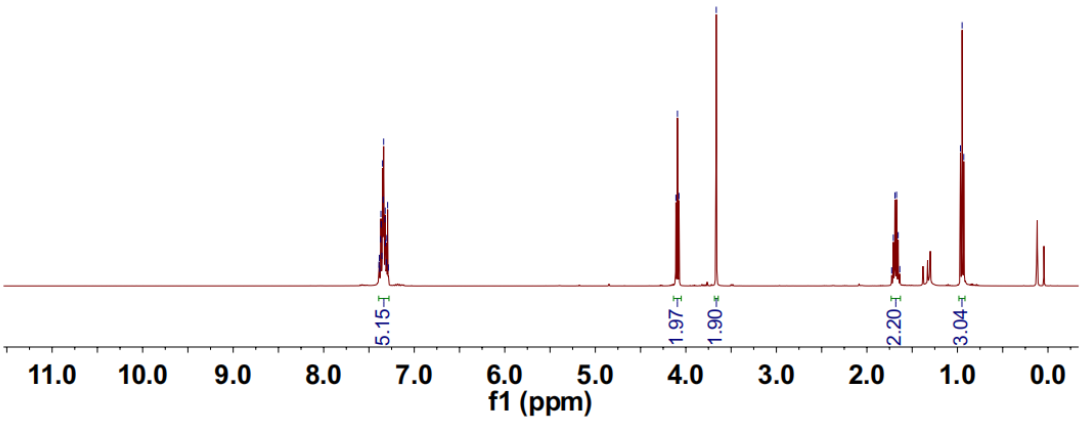

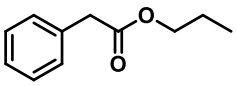

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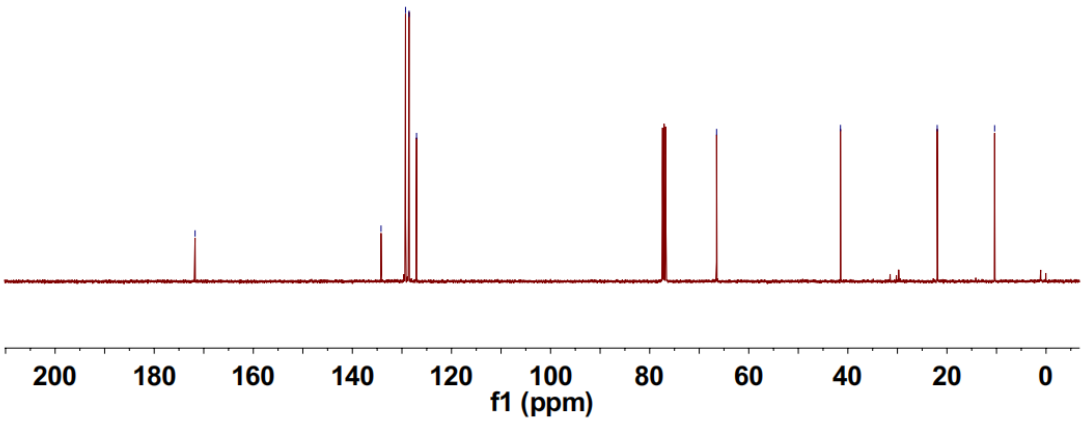

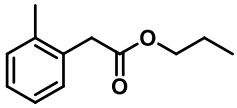

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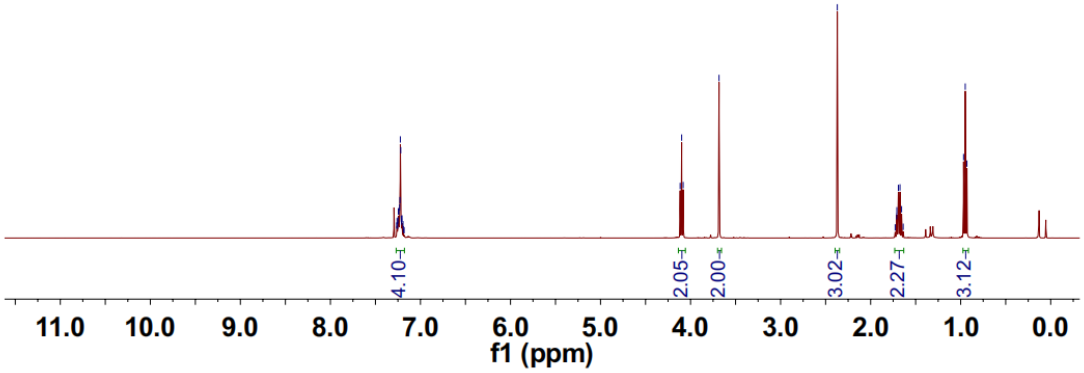

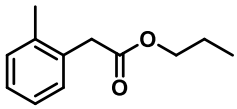

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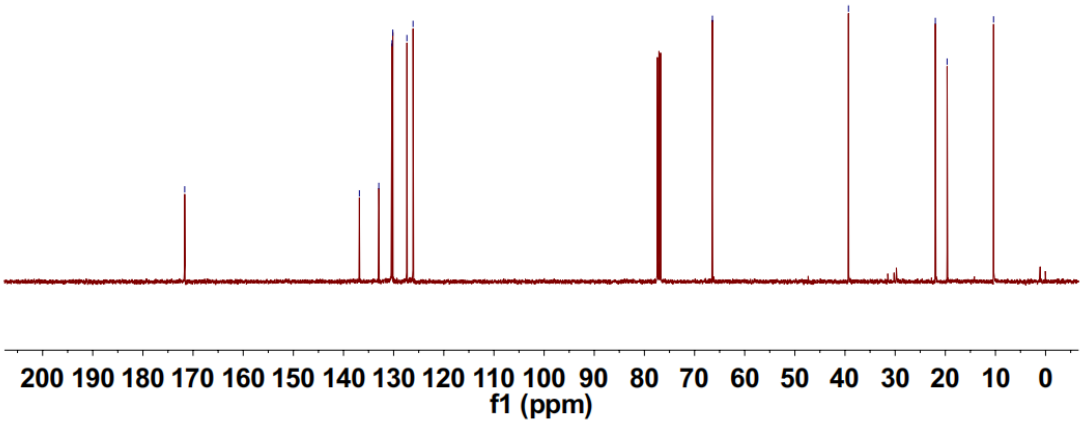

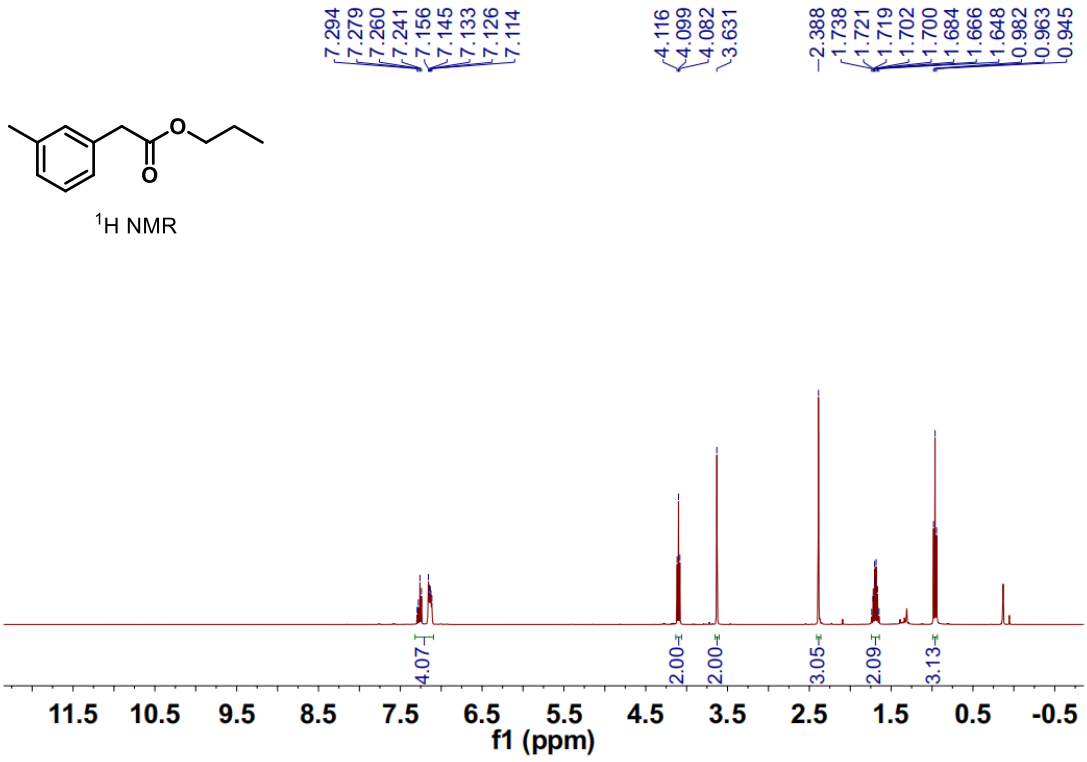
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1.719
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1.666
1.648
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0.945
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O
1H NMR
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2.00
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3.05
2.09
3.13
11.5
10.5
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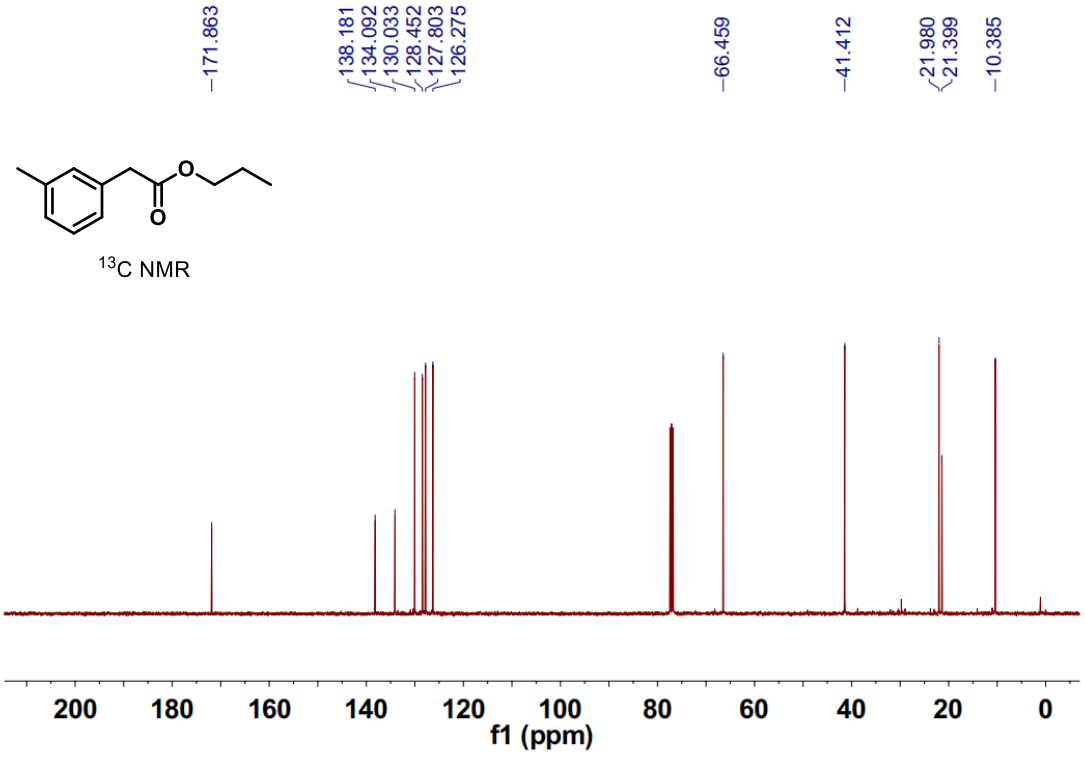
f1 (ppm)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21.980
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O
13C NMR
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180
160
140
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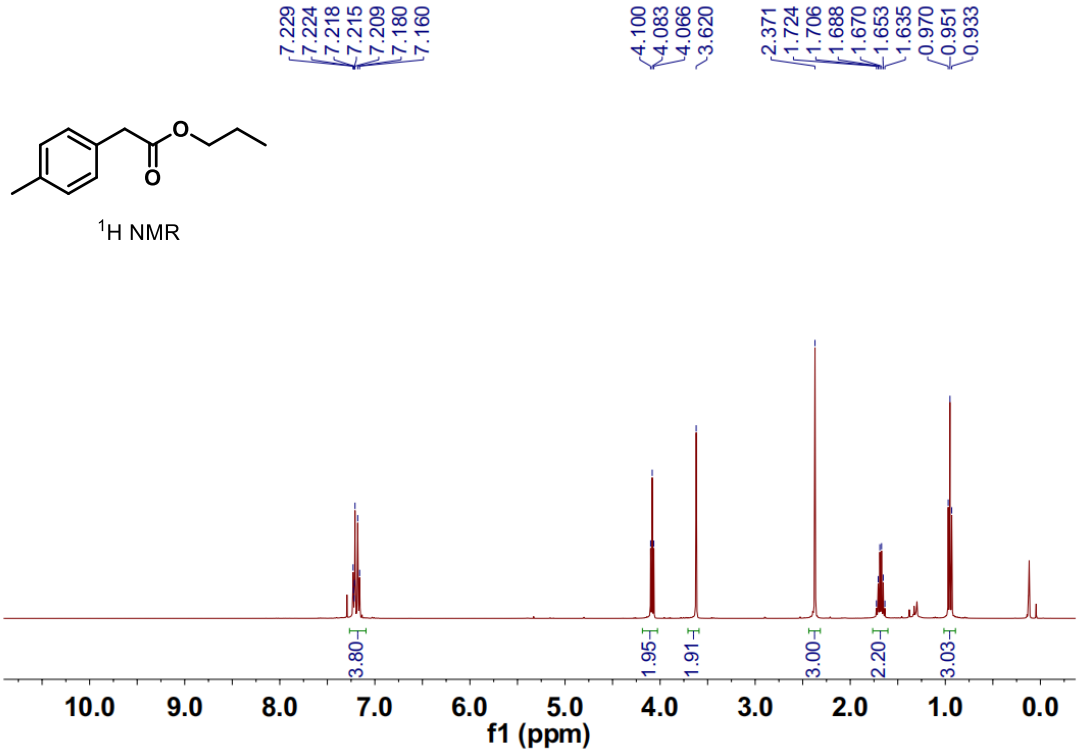
100
80
60
40
20
0
f1 (ppm)



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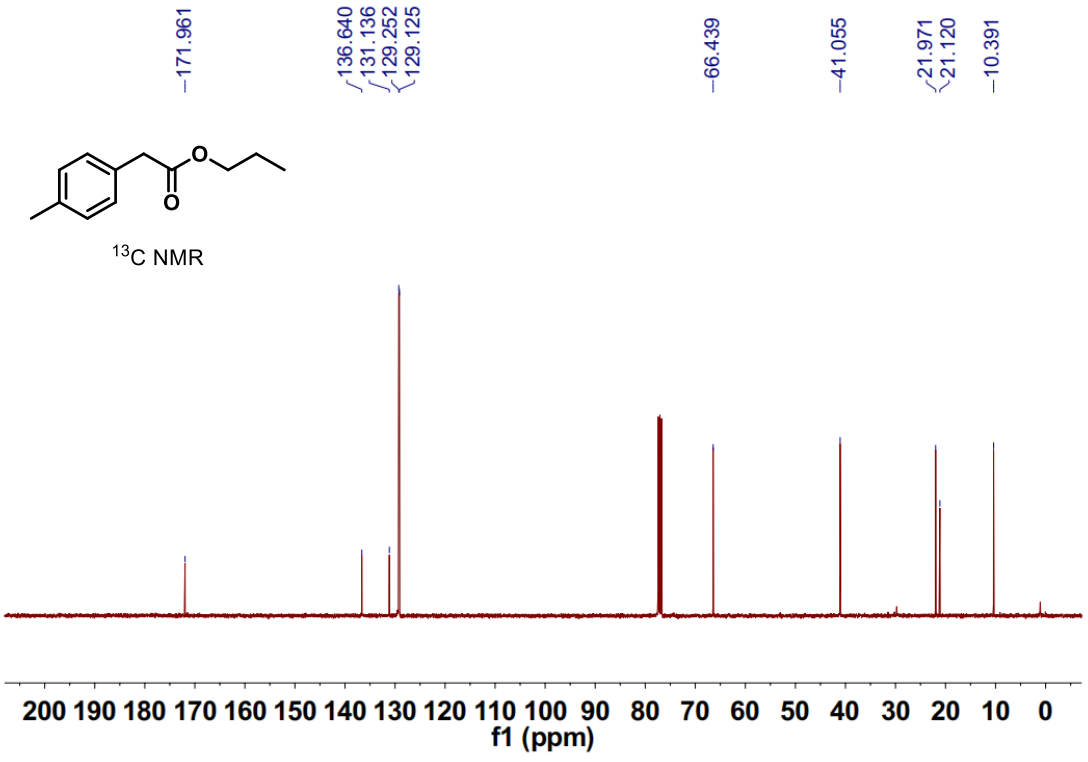
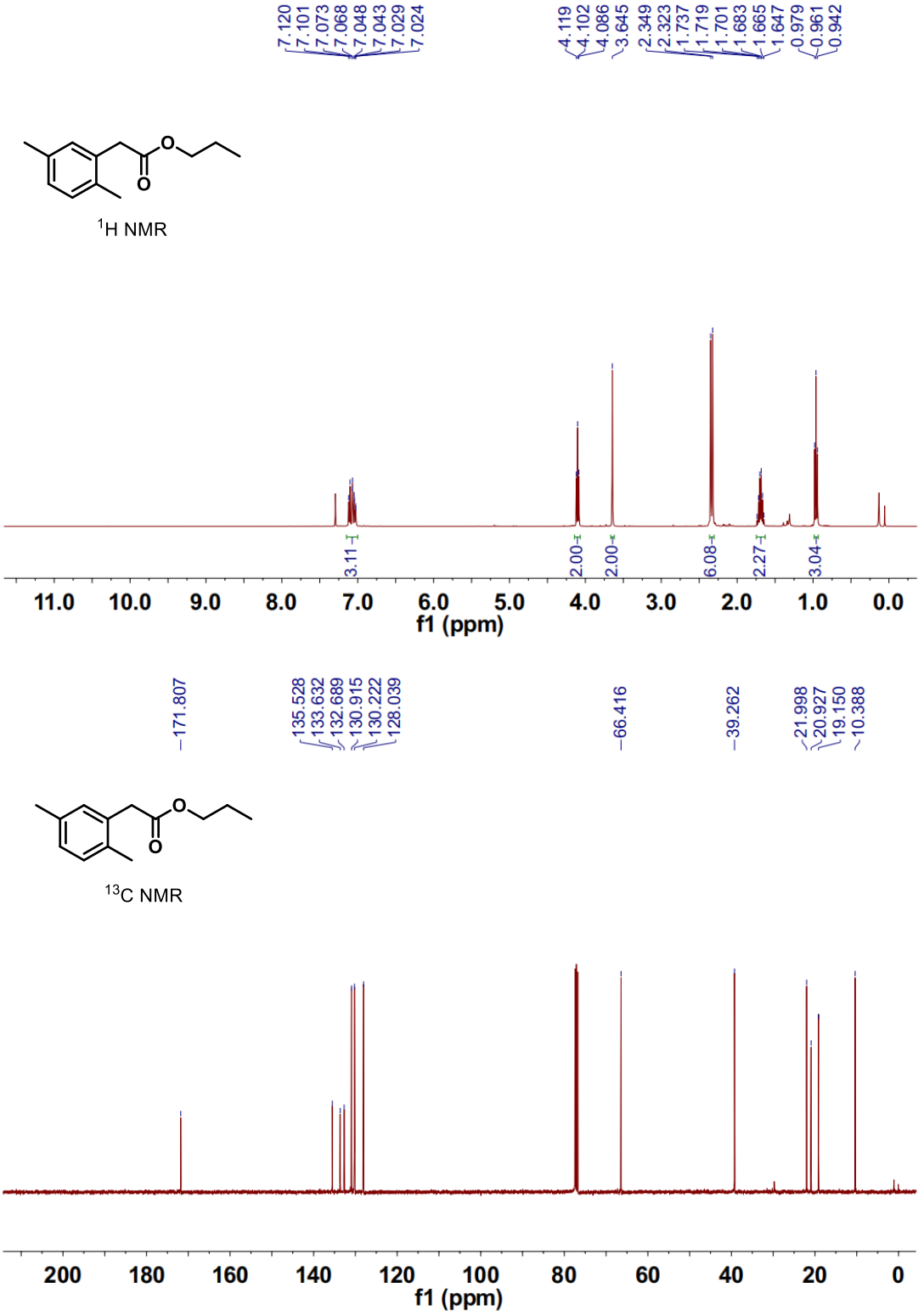


^{13}C NMR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3.04
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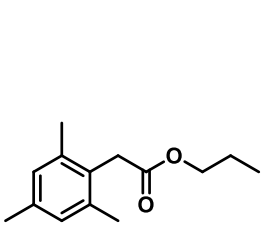
f1 (ppm)



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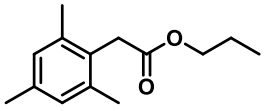

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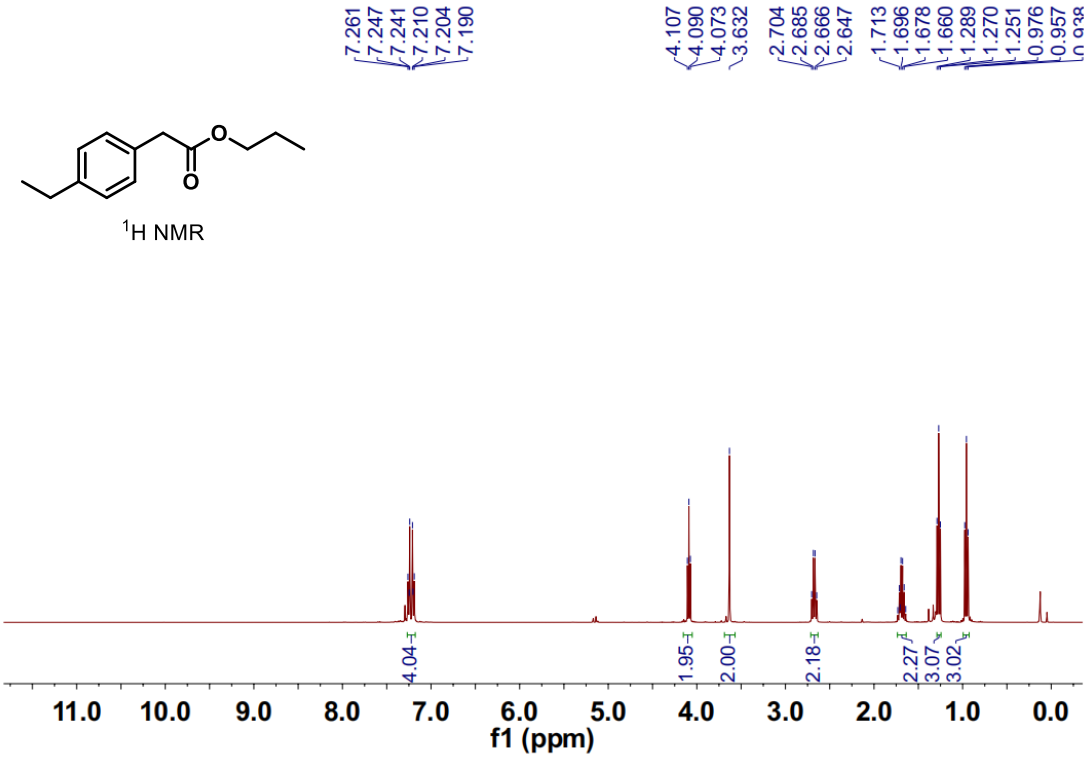
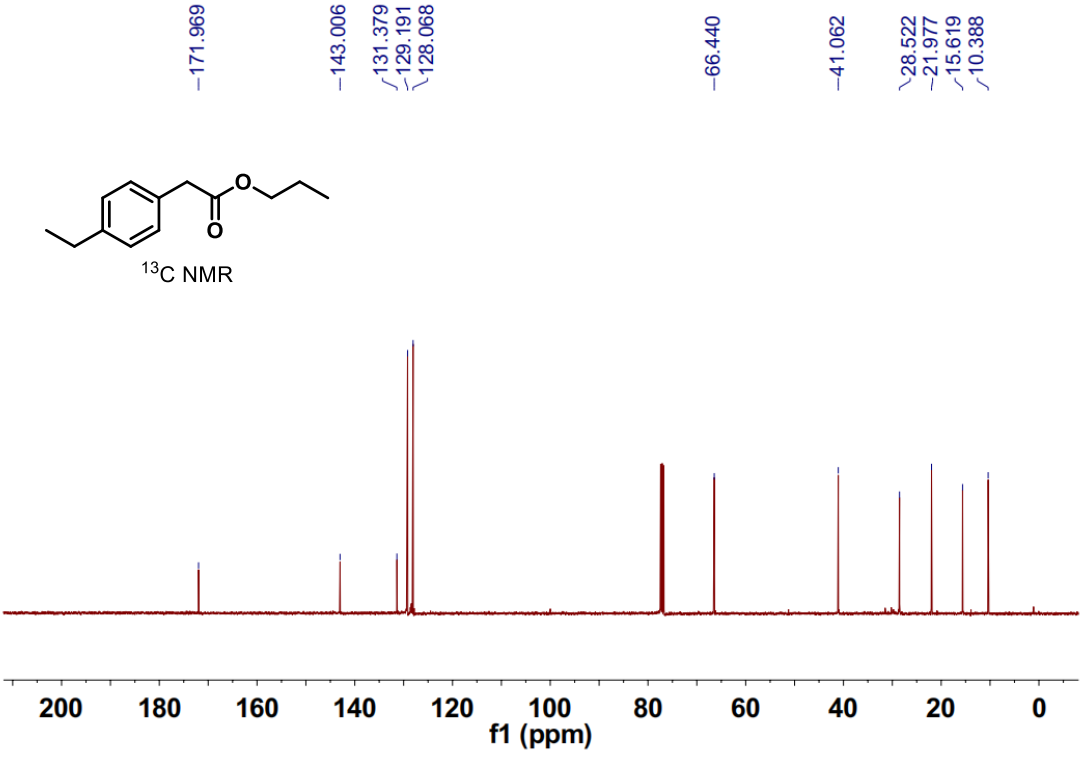
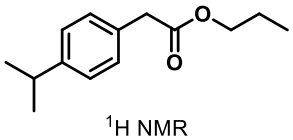


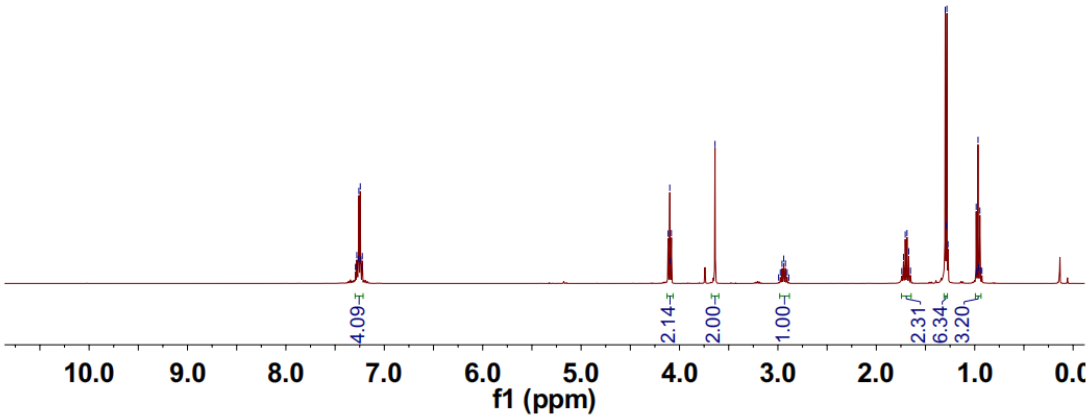
^{1}H NMR

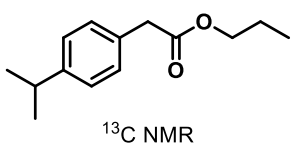


^{13}C NMR

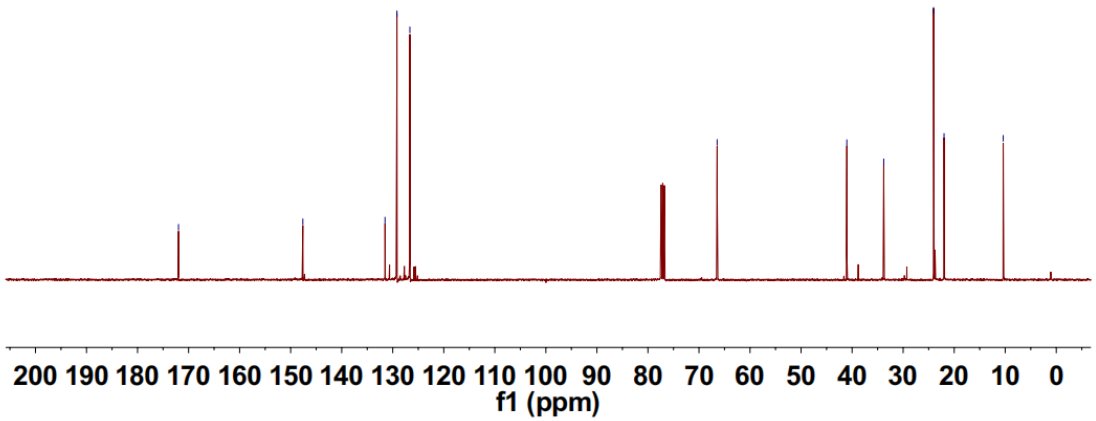


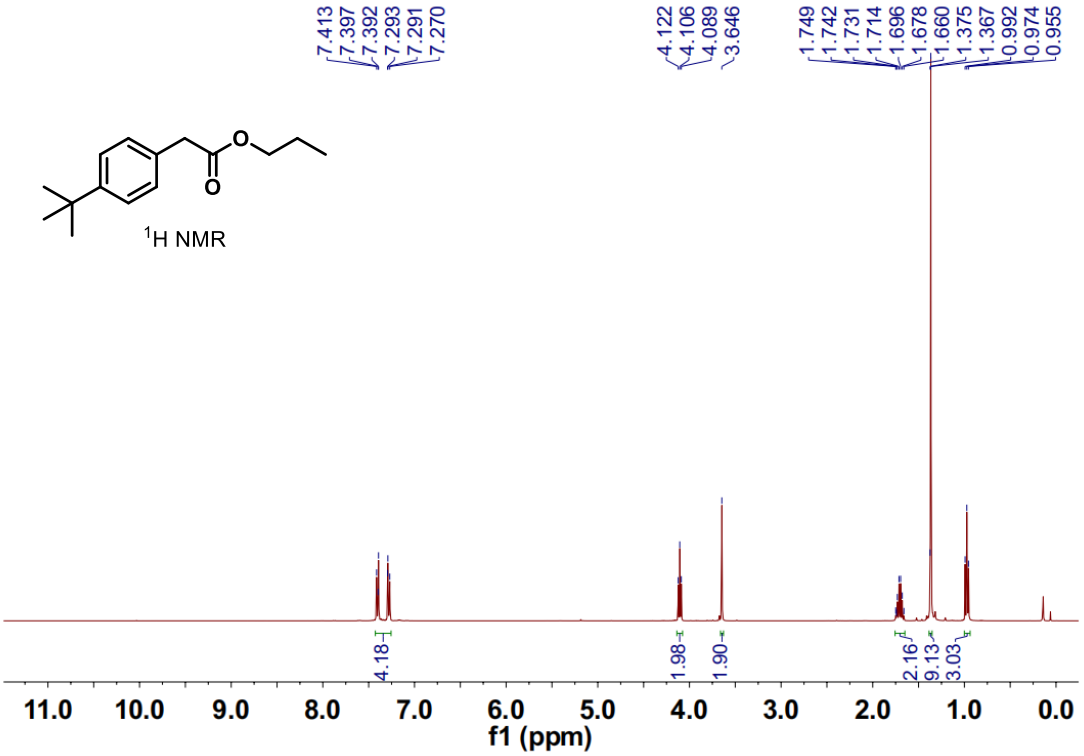
^{1}H NMR



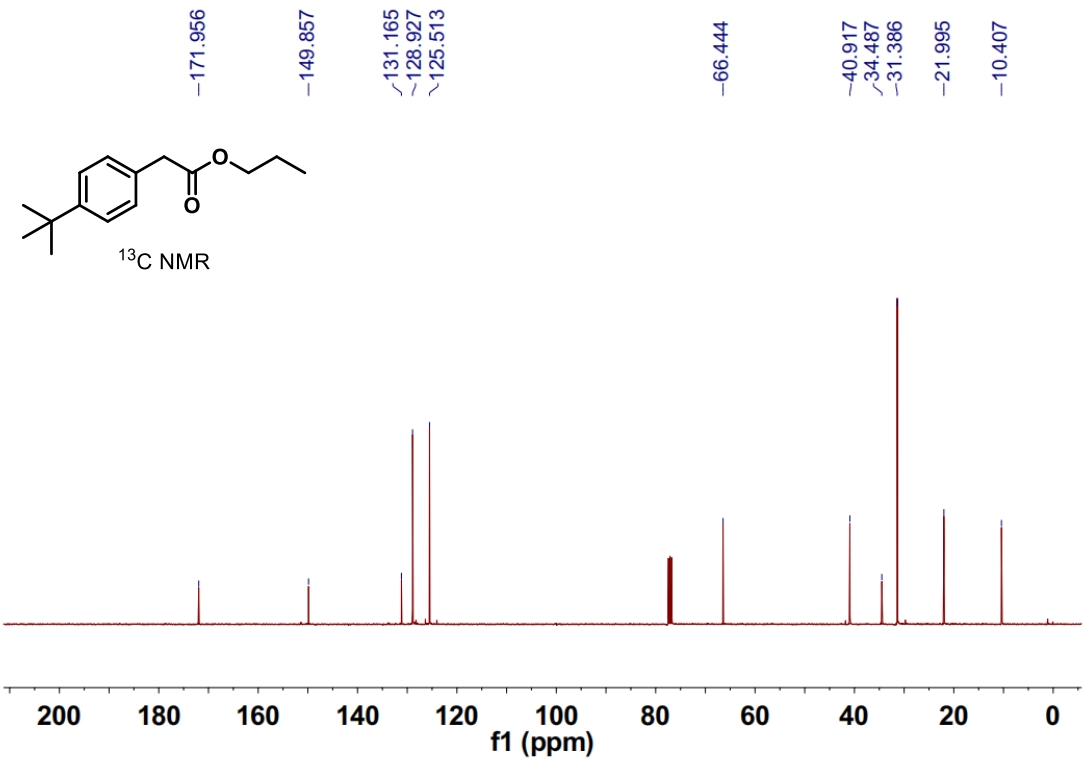


^{13}C NMR

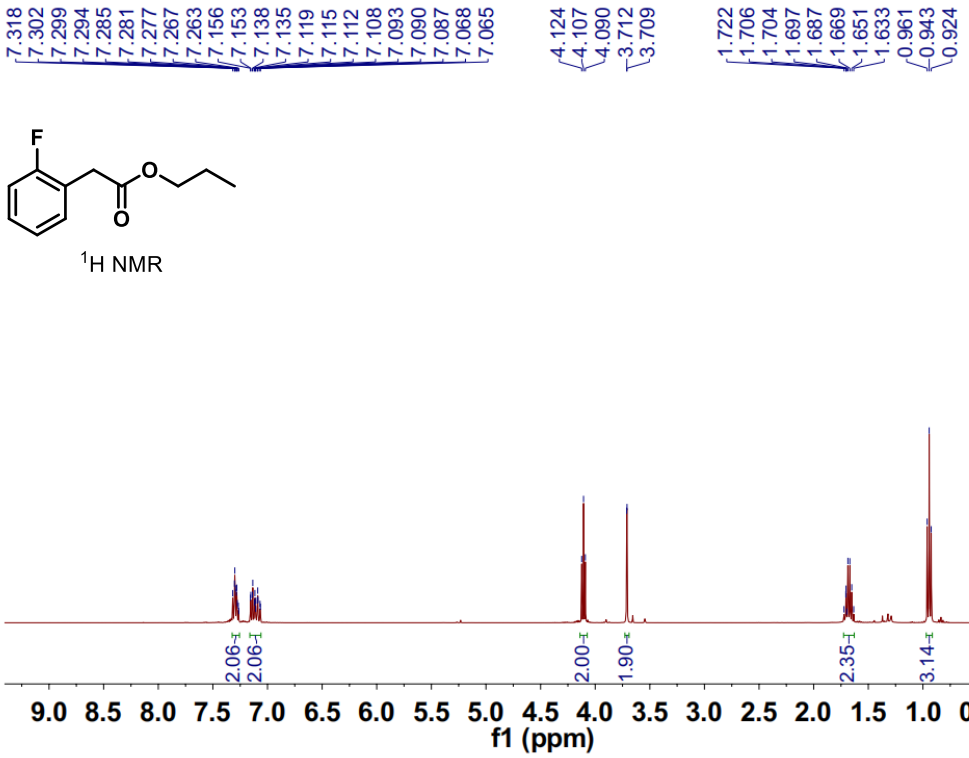




^{1}H NMR



^{13}C NMR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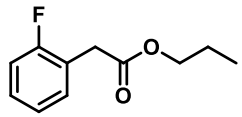
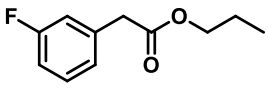
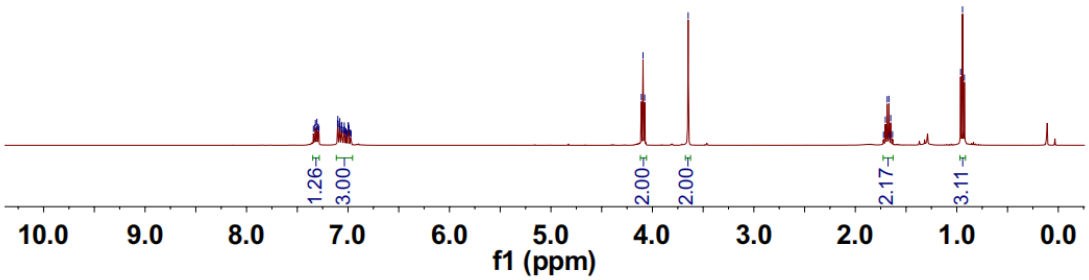
7.302
7.299
7.294
7.285
7.281
7.277
7.267
7.263
7.156
7.153
7.138
7.135
7.119
7.115
7.112
7.108
7.093
7.090
7.087
7.068
7.065
4.124
4.107
4.090
3.712
3.709
1.722
1.706
1.704
1.697
1.687
1.669
1.651
1.633
0.961
0.943
0.924
F
O
O
1H NMR
2.06
2.06
2.00
1.90
2.35
3.14
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
170.853
162.303
159.854
131.471
131.431
129.060
128.980
124.114
124.078
121.636
121.478
115.467
115.251
66.645
34.601
34.569
21.934
10.315
F
O
O
13C NMR
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

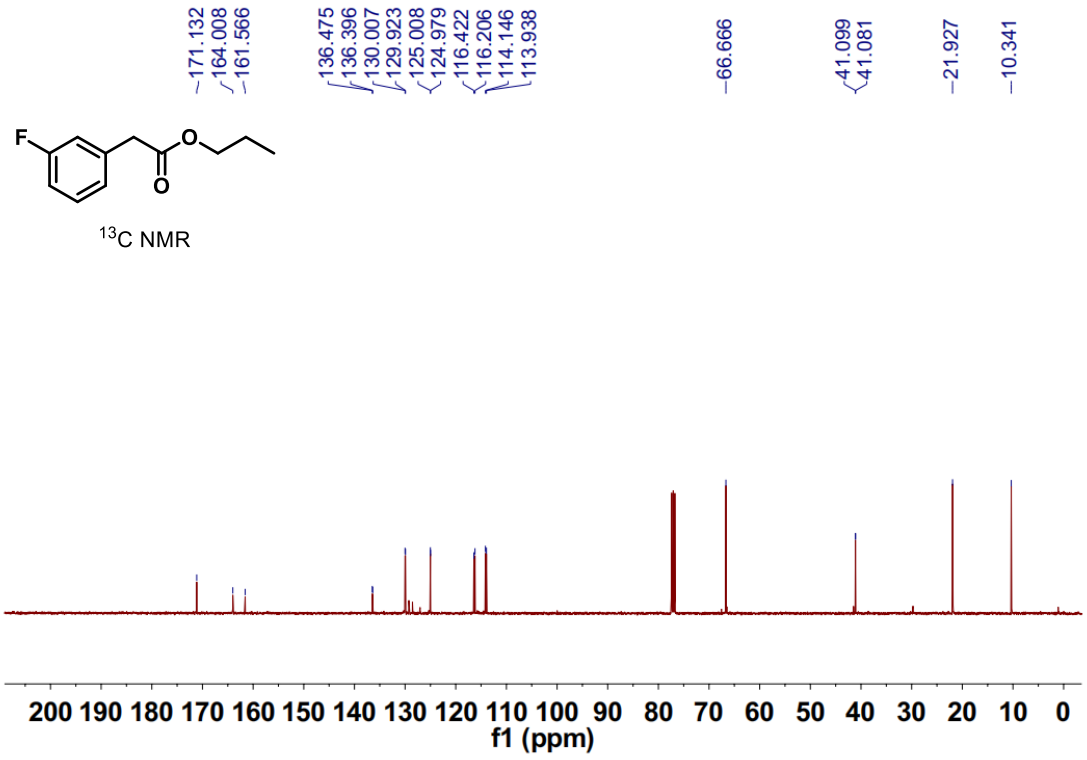


^{19}F NMR

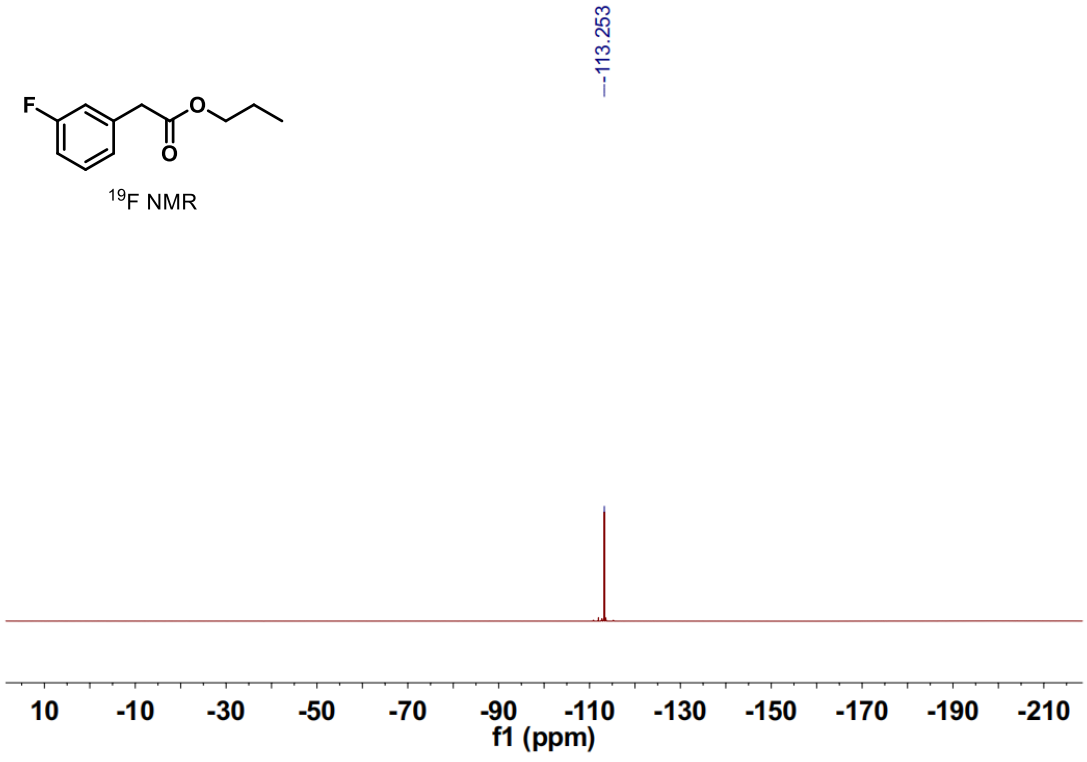


^{1}H NMR

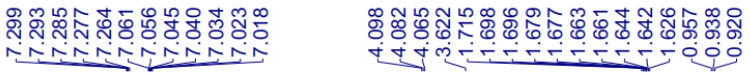


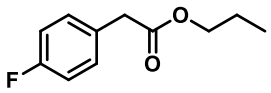


^{13}C NMR

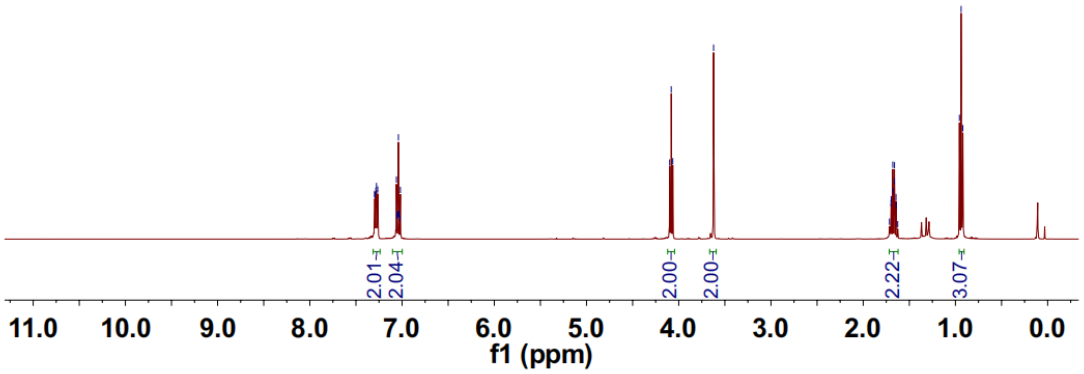


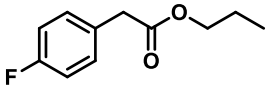
^{19}F NMR



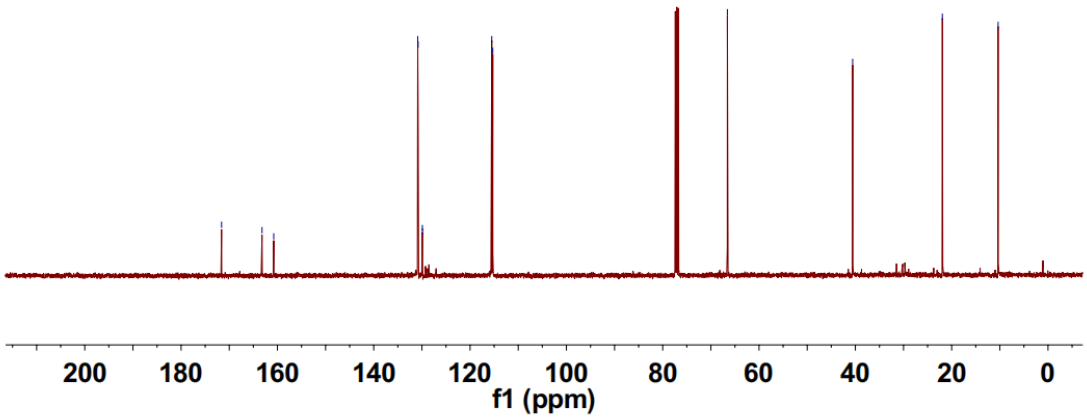


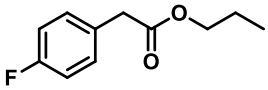
^{1}H NMR



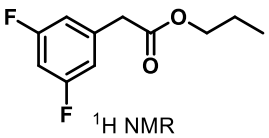


^{13}C NMR

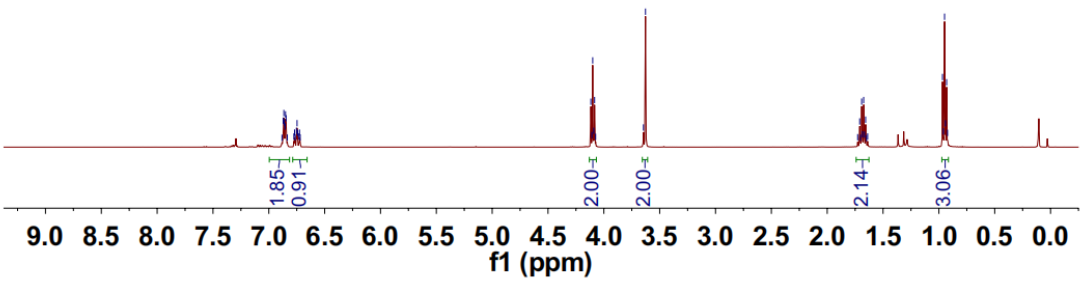


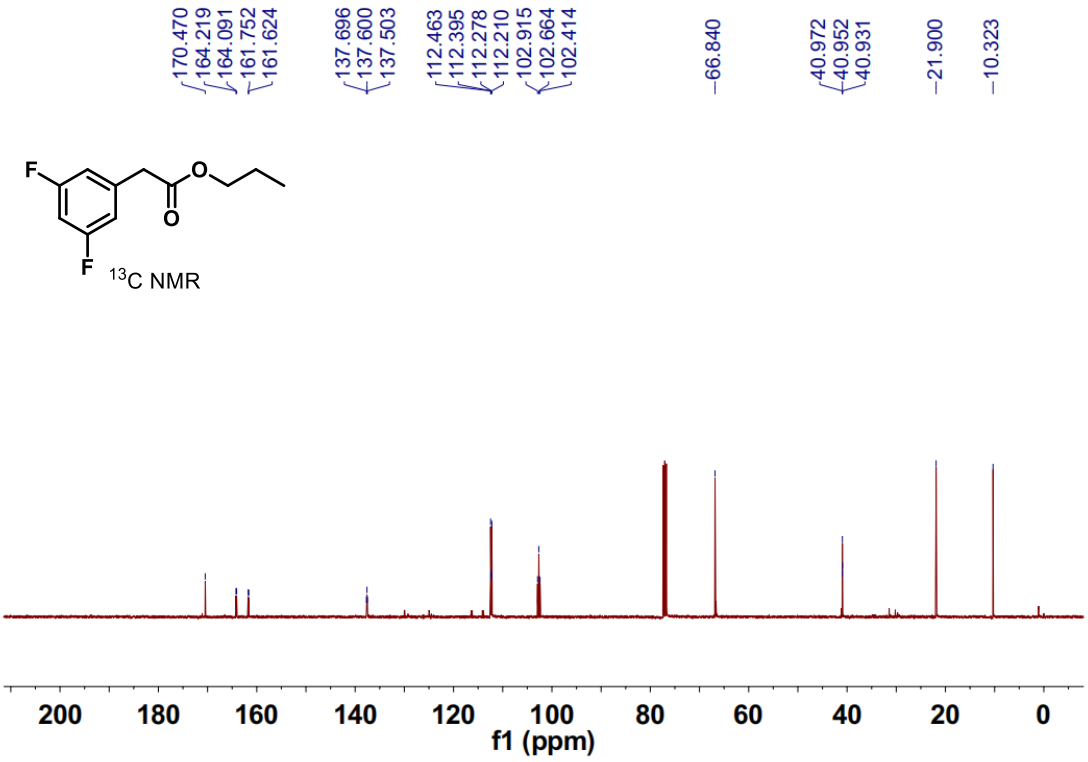


^{19}F NMR



^{1}H NMR

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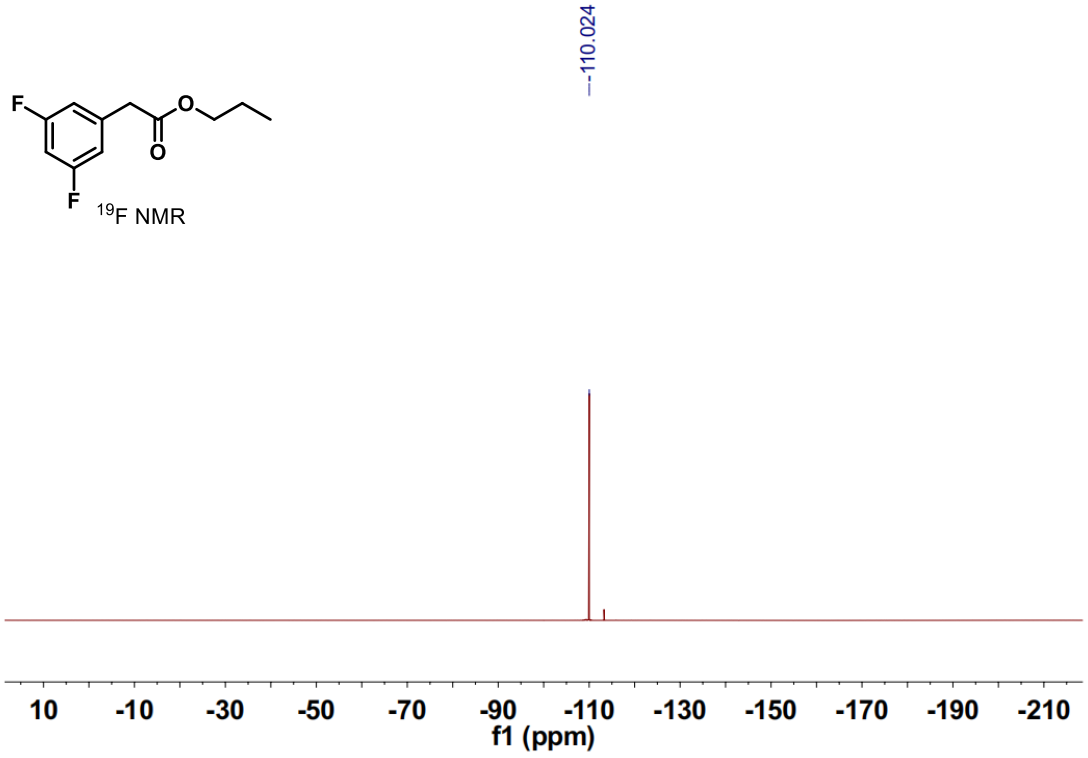
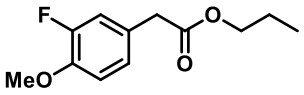
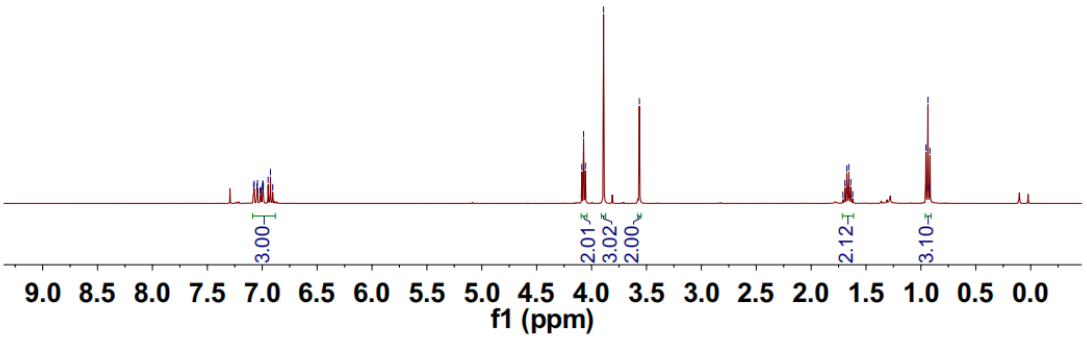
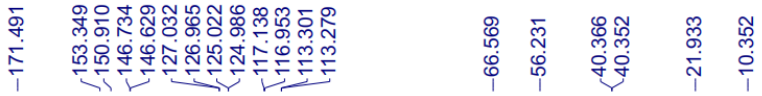
164.219
164.091
161.752
161.624
137.696
137.600
137.503
112.463
112.395
112.278
112.210
102.915
102.664
102.414
66.840
40.972
40.952
40.931
21.900
10.323
F
O
O
F
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

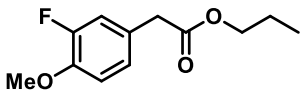

110.024
F
O
O
F
19F NMR
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)



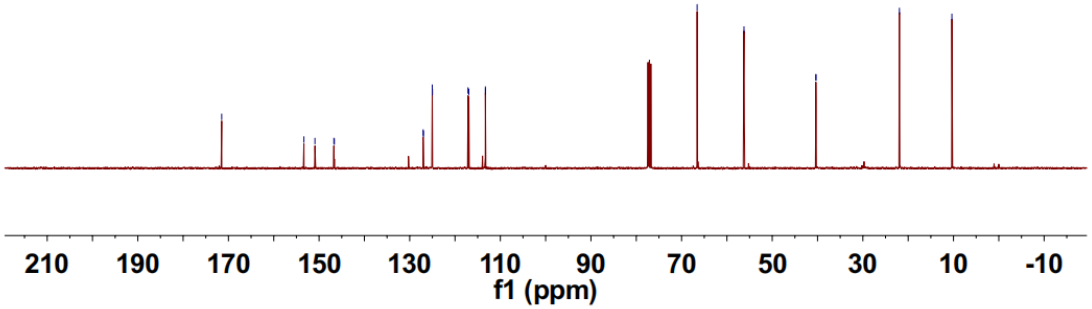
^{1}H NMR

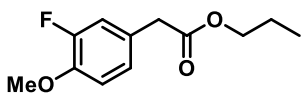




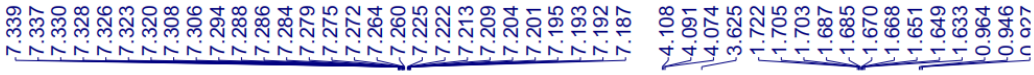


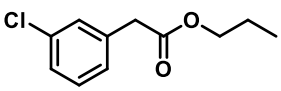
^{13}C NMR



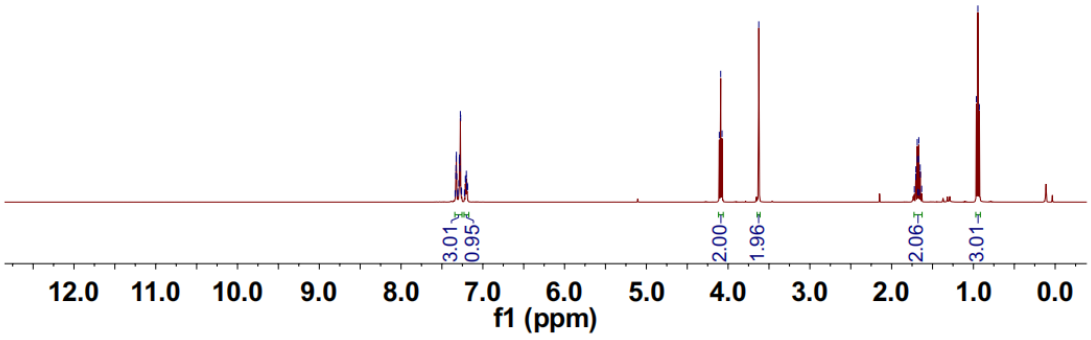


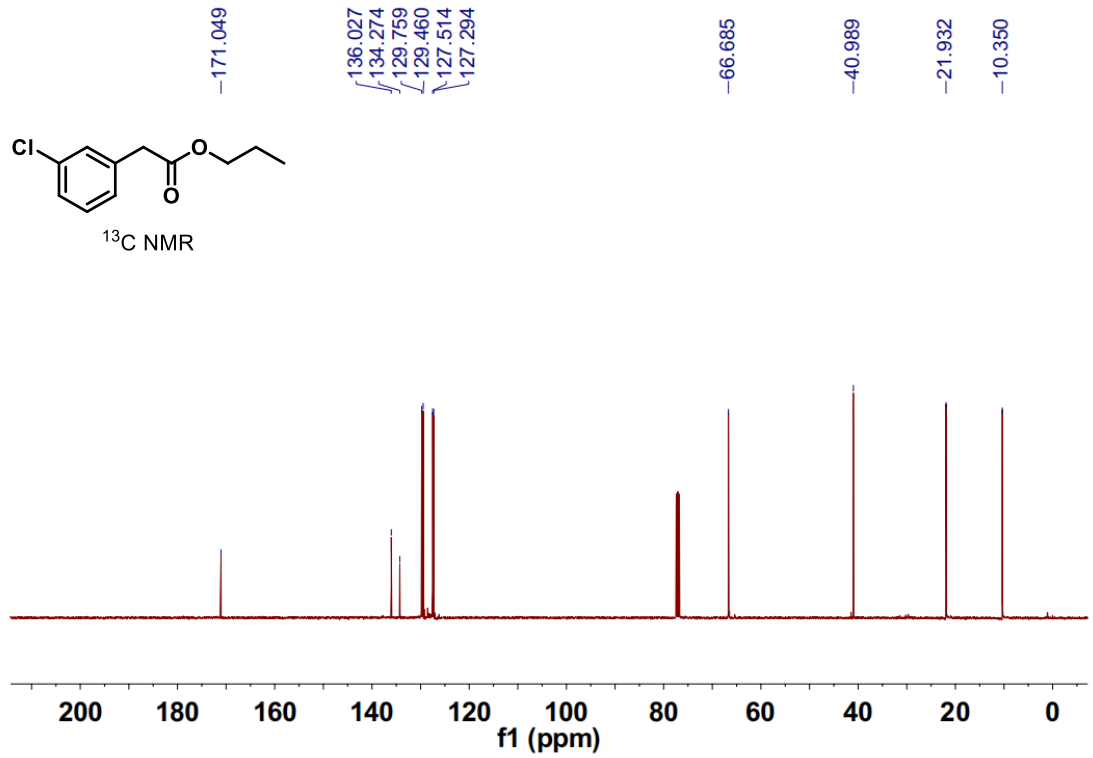
^{19}F NMR

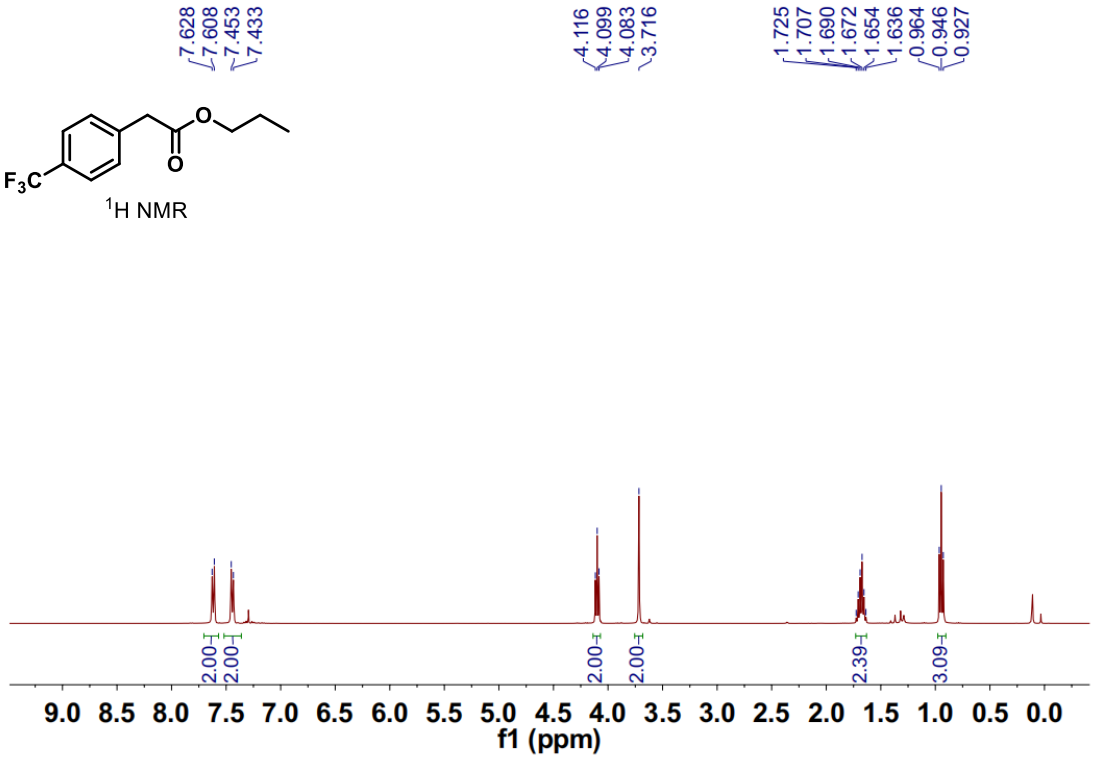




^{1}H NMR




171.049
136.027
134.274
129.759
129.460
127.514
127.294
66.685
40.989
21.932
10.350
Cl
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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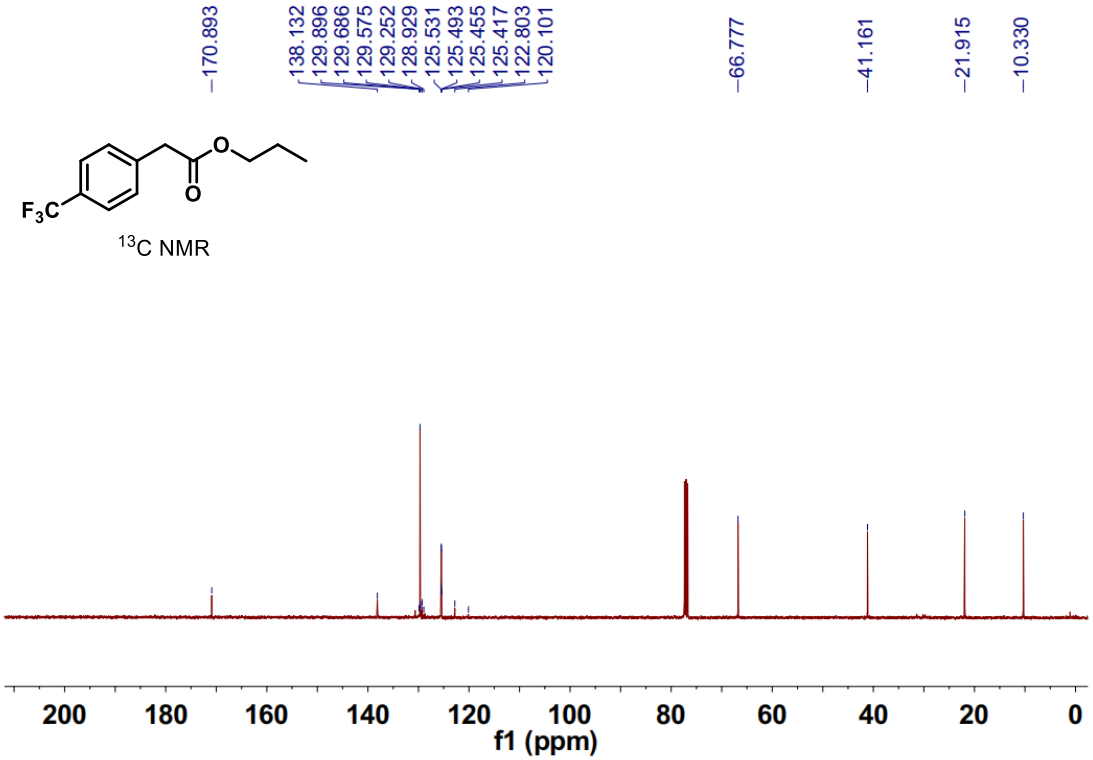
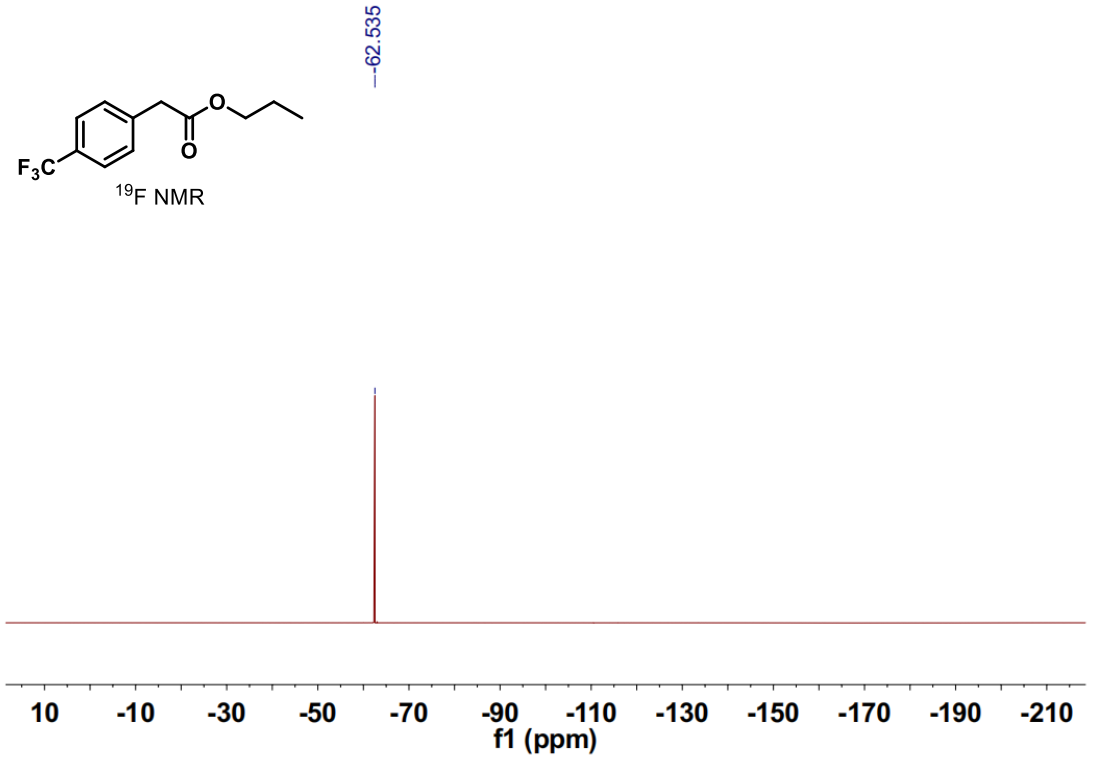
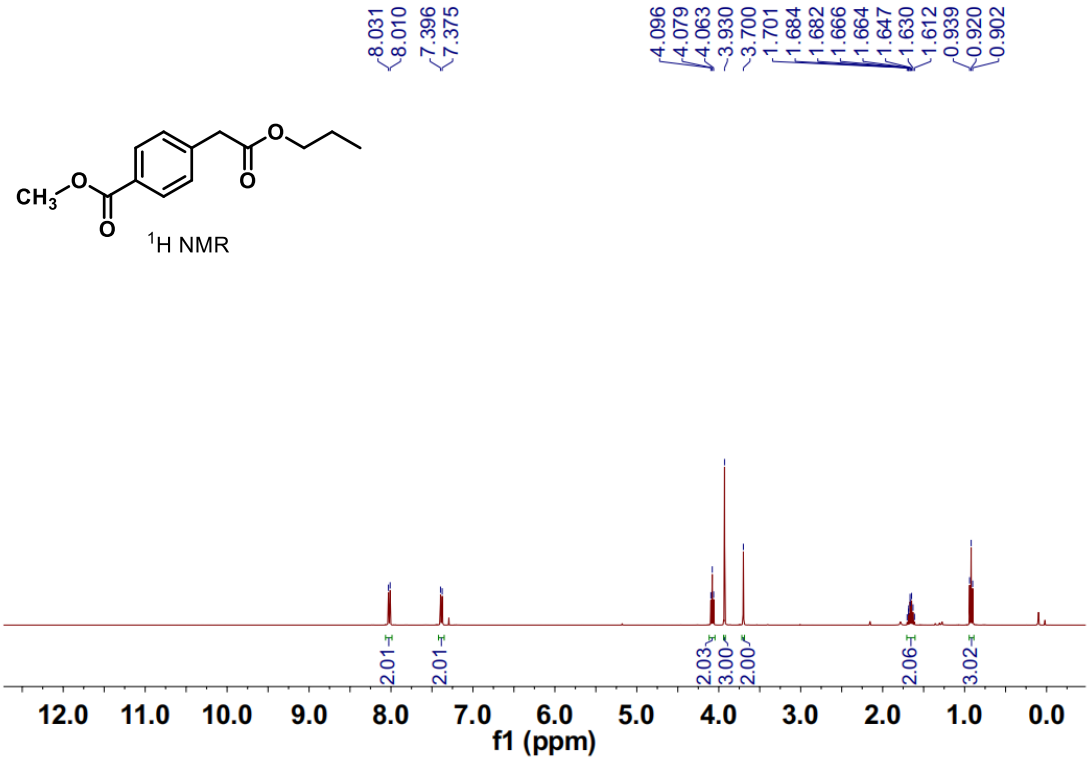
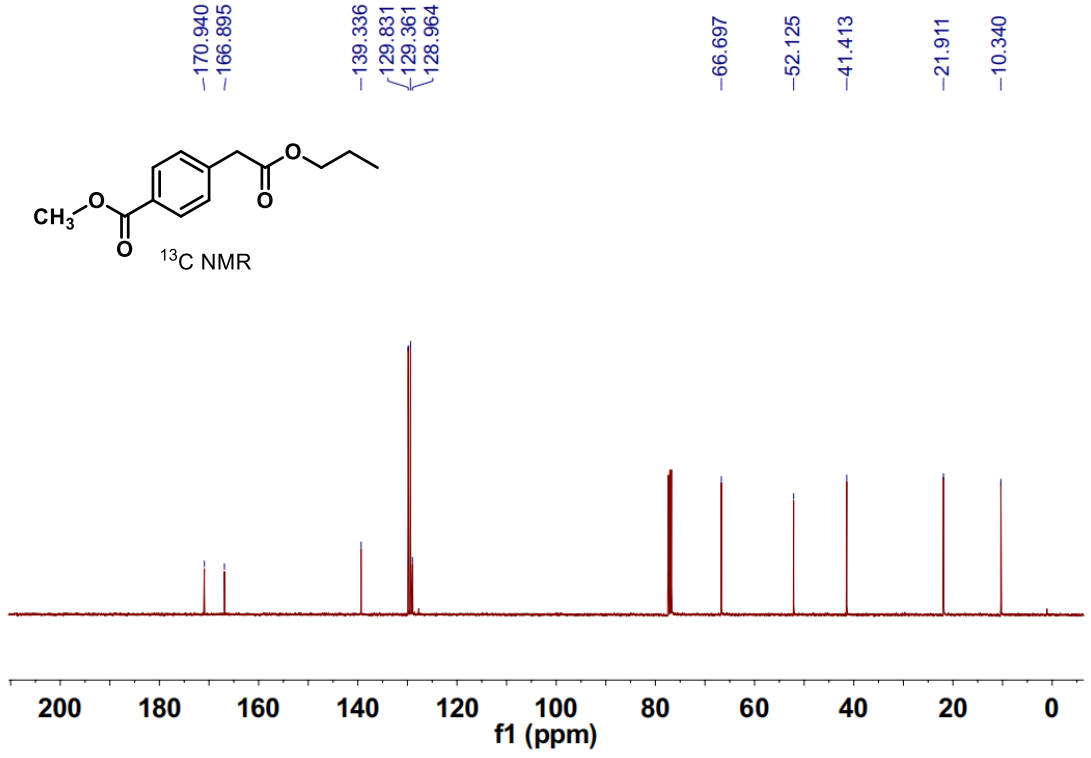
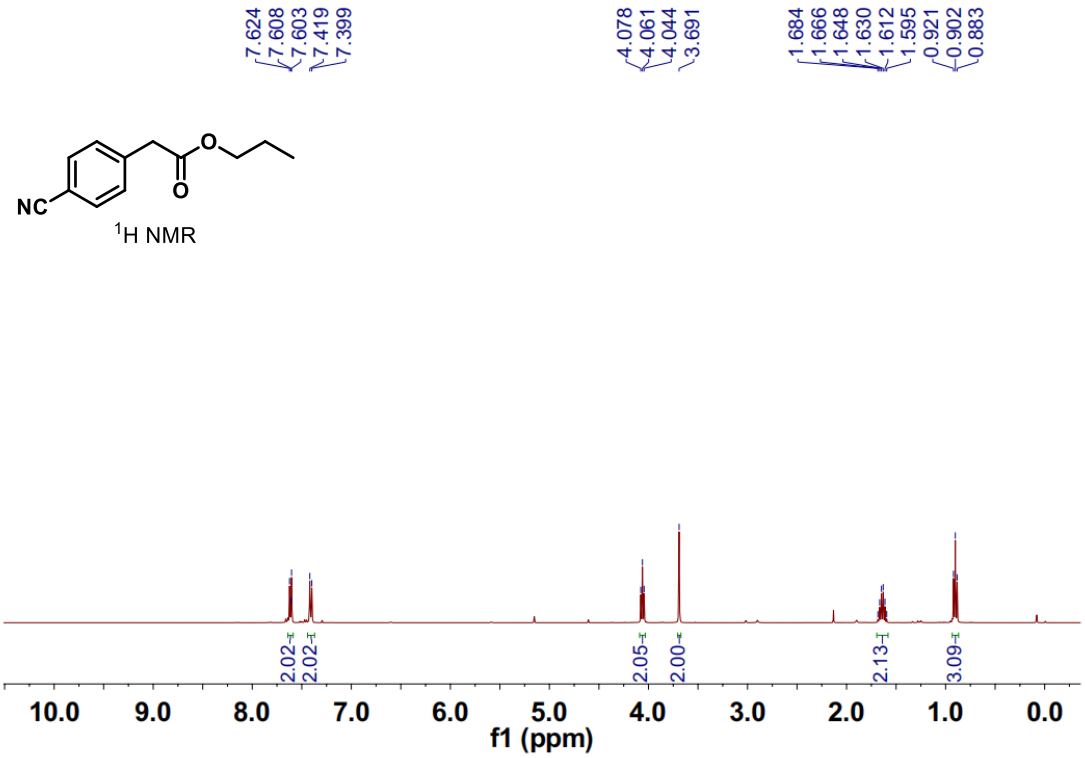
7.608
7.453
7.433
4.116
4.099
4.083
3.716
1.725
1.707
1.690
1.672
1.654
1.636
0.964
0.946
0.927
O
O
F3C
1H NMR
2.00
2.00
2.00
2.00
2.39
3.09
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

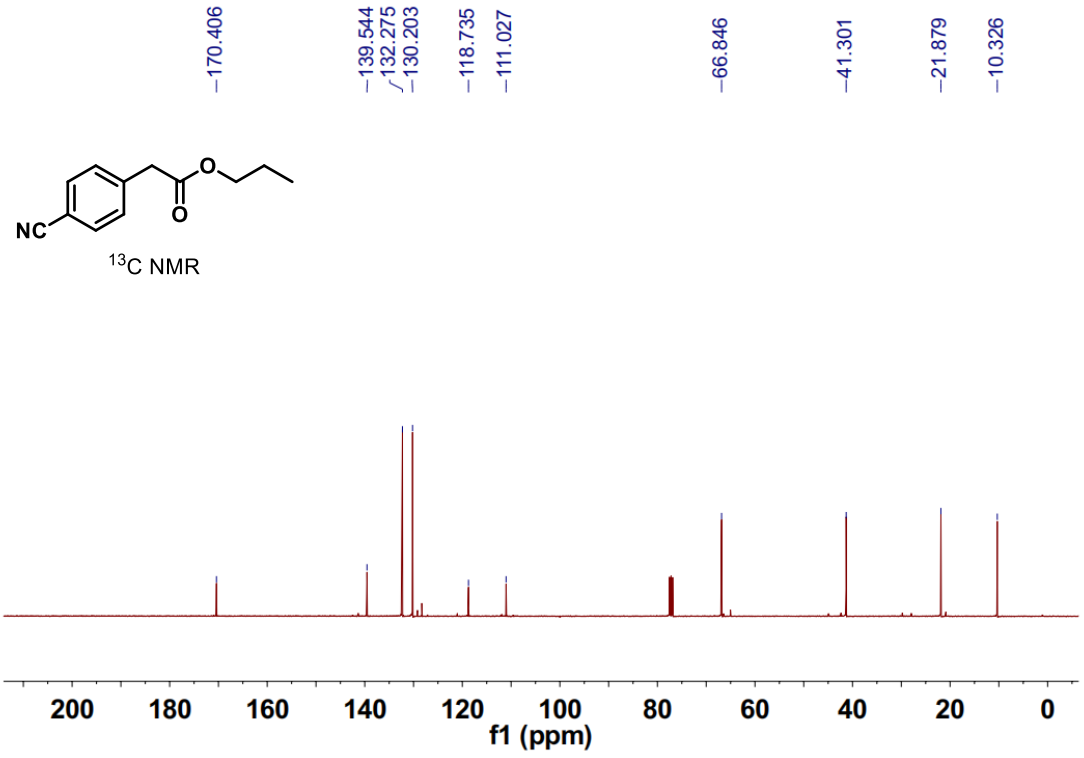

170.893
138.132
129.896
129.686
129.575
129.252
128.929
125.531
125.493
125.455
125.417
122.803
120.101
66.777
41.161
21.915
10.330
O
O
F3C
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

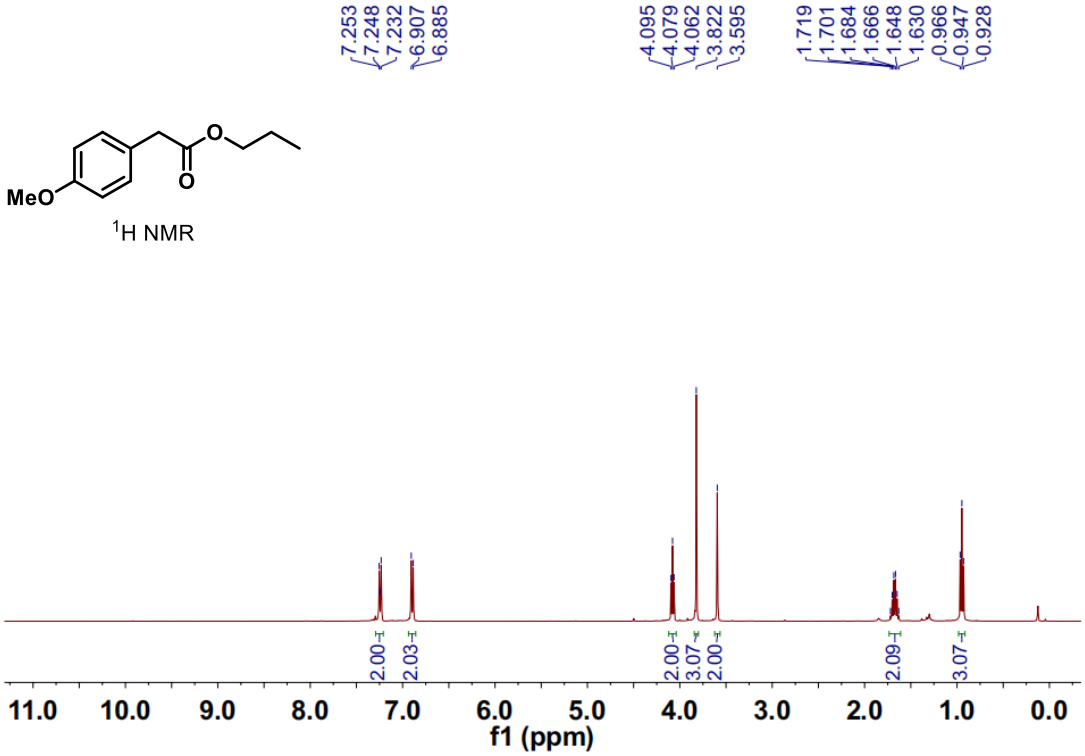

62.535
O
O
F3C
19F NMR
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)


8.031
8.010
7.396
7.375
4.096
4.079
4.063
3.930
3.700
1.701
1.684
1.682
1.666
1.664
1.647
1.630
1.612
0.939
0.920
0.902
CH3
O
O
O
O
1H NMR
2.01
2.01
2.03
3.00
2.00
2.06
3.02
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

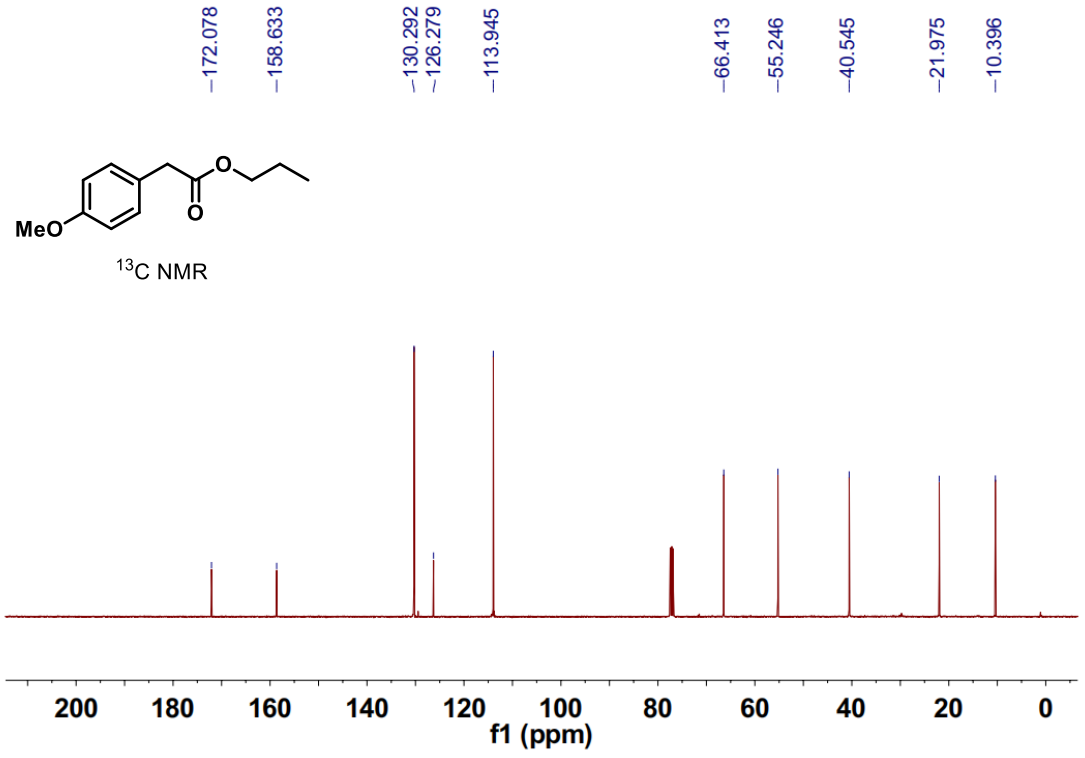

170.940
166.895
139.336
129.831
129.361
128.964
66.697
52.125
41.413
21.911
10.340
CH3
O
O
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)


7.624
7.608
7.603
7.419
7.399
4.078
4.061
4.044
3.691
1.684
1.666
1.648
1.630
1.612
1.595
0.921
0.902
0.883
NC
O
O
1H NMR
2.02
2.02
2.05
2.00
2.13
3.09
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

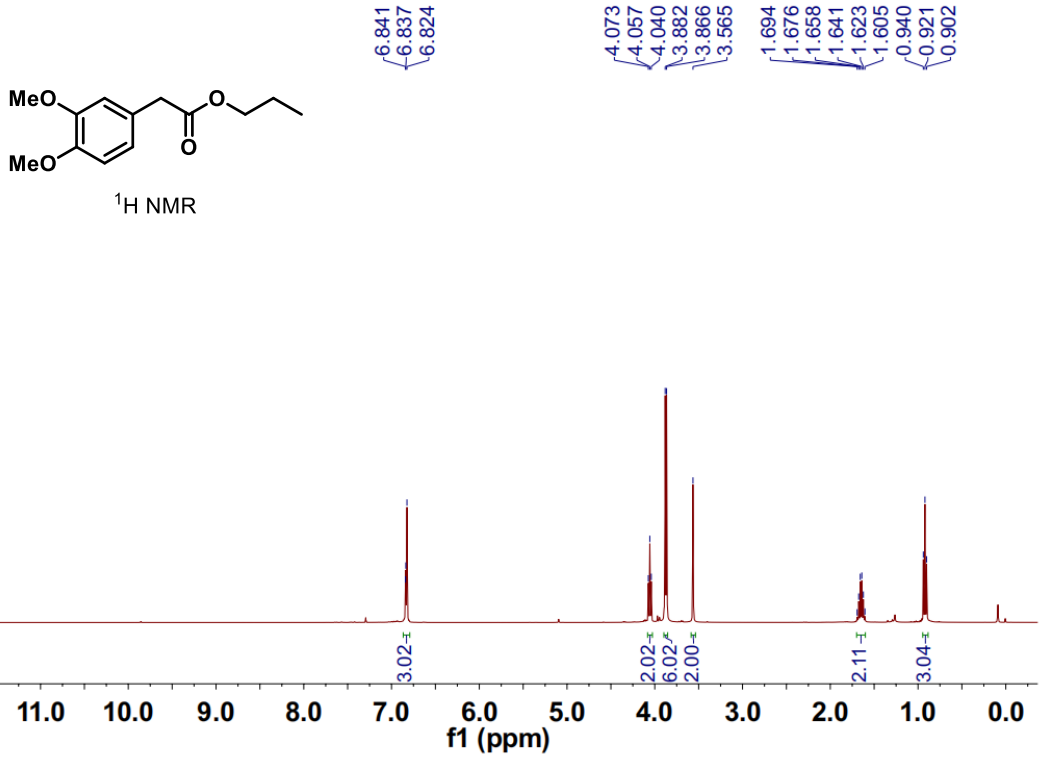

170.406
139.544
132.275
130.203
118.735
111.027
66.846
41.301
21.879
10.326
NC
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)



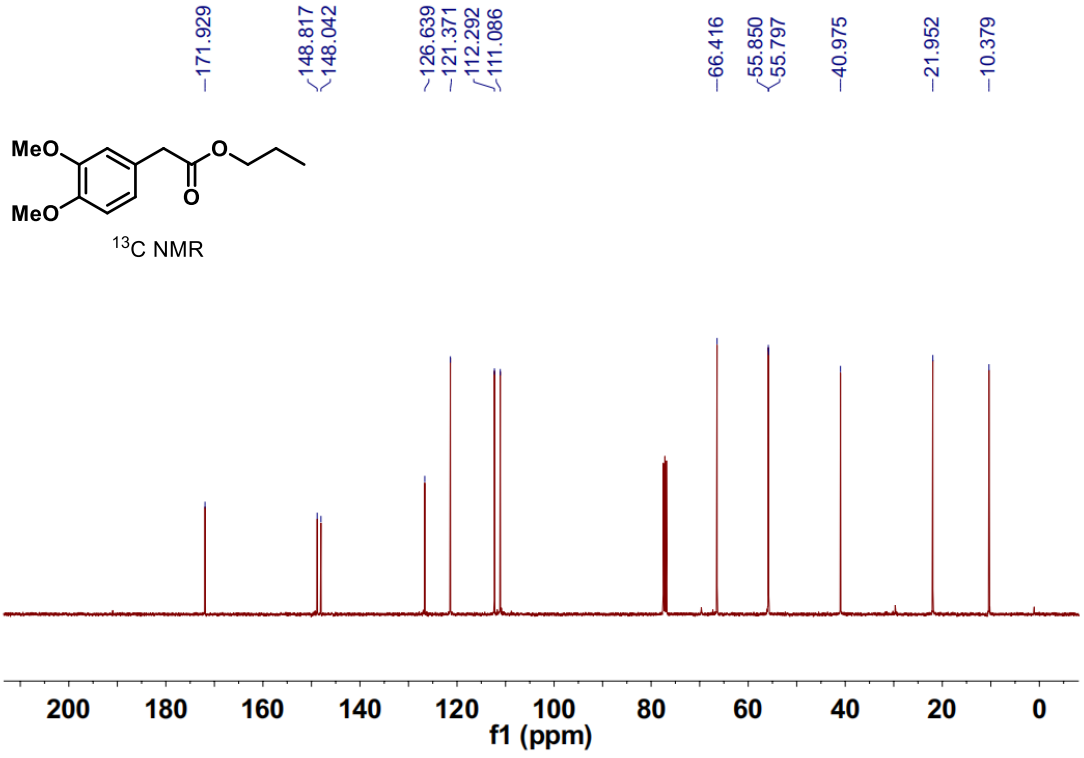
^{1}H NMR



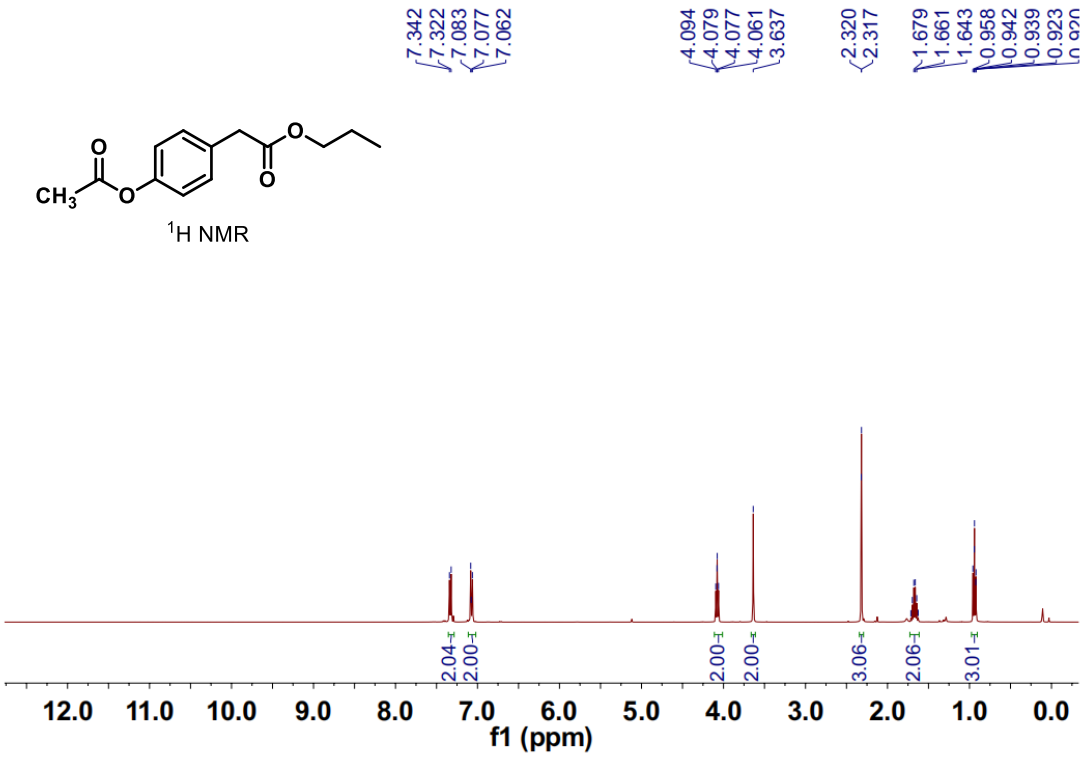
^{13}C NMR



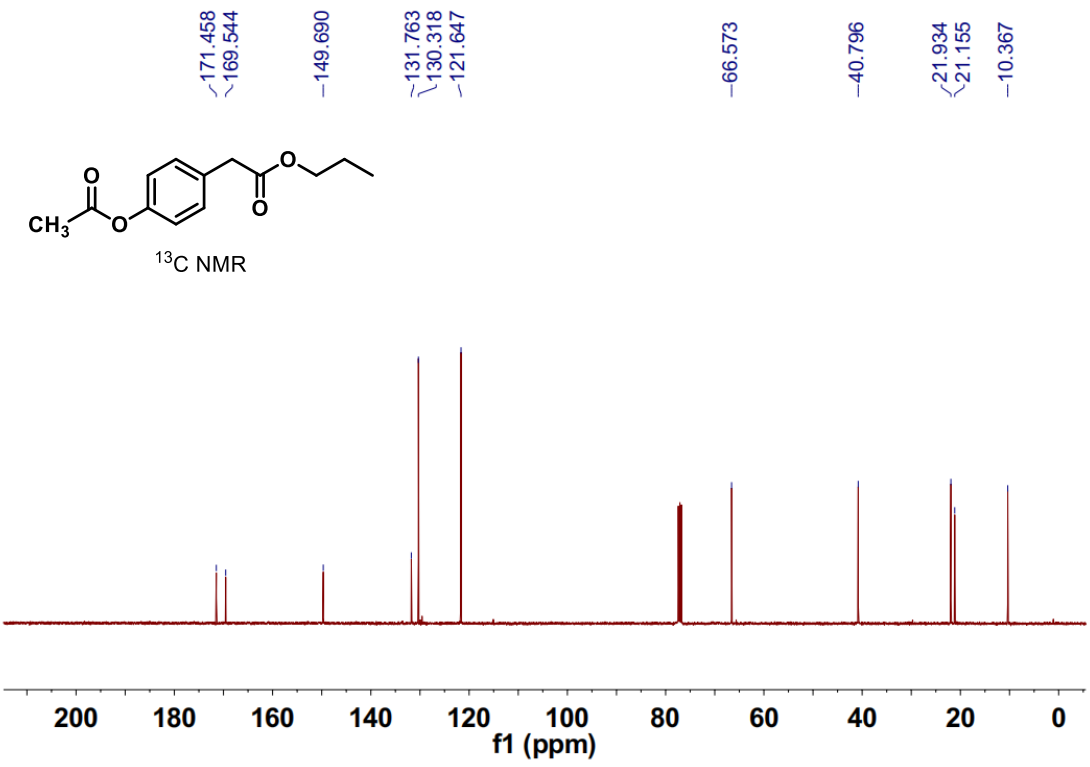
^{1}H NMR



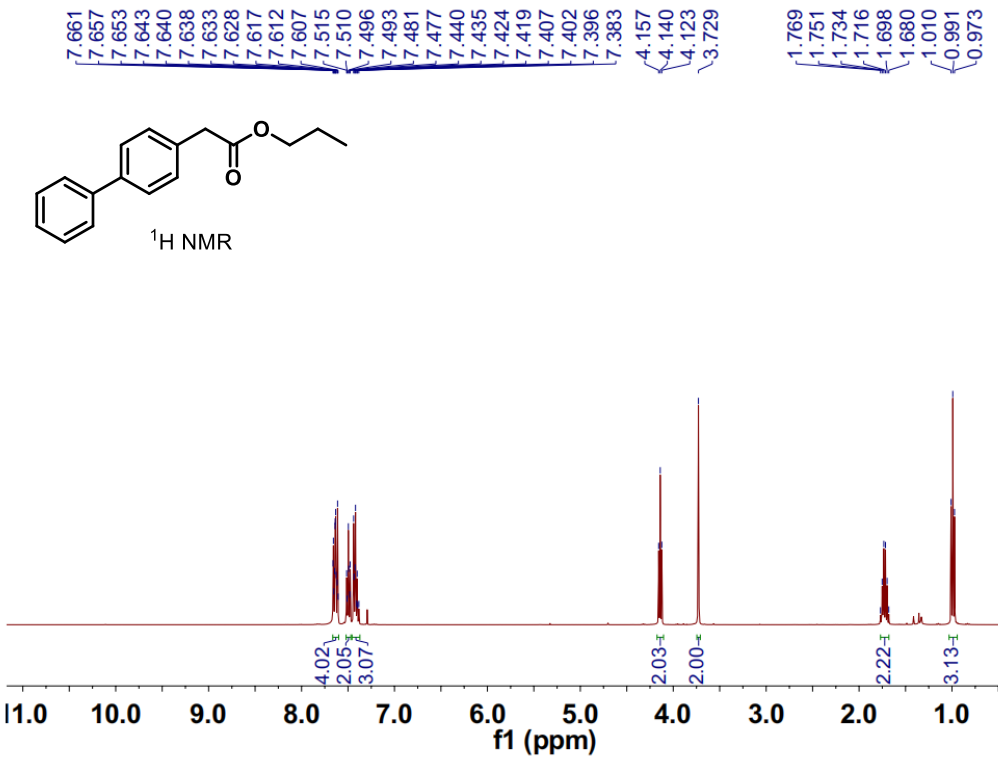
^{13}C NMR



^{1}H NMR



^{13}C NMR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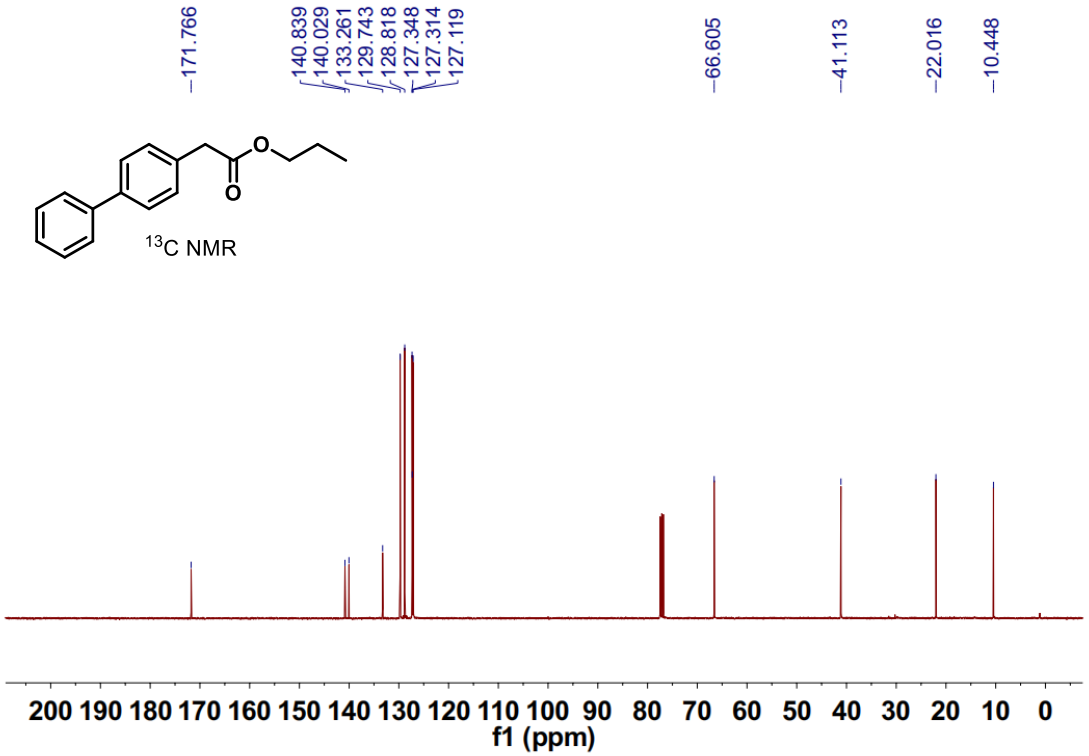
7.657
7.653
7.643
7.640
7.638
7.633
7.628
7.617
7.612
7.607
7.515
7.510
7.496
7.493
7.481
7.477
7.440
7.435
7.424
7.419
7.407
7.402
7.396
7.383
4.157
4.140
4.123
3.729
1.769
1.751
1.734
1.716
1.698
1.680
1.010
0.991
0.973
O
O
1H NMR
4.02
2.05
3.07
2.03
2.00
2.22
3.13
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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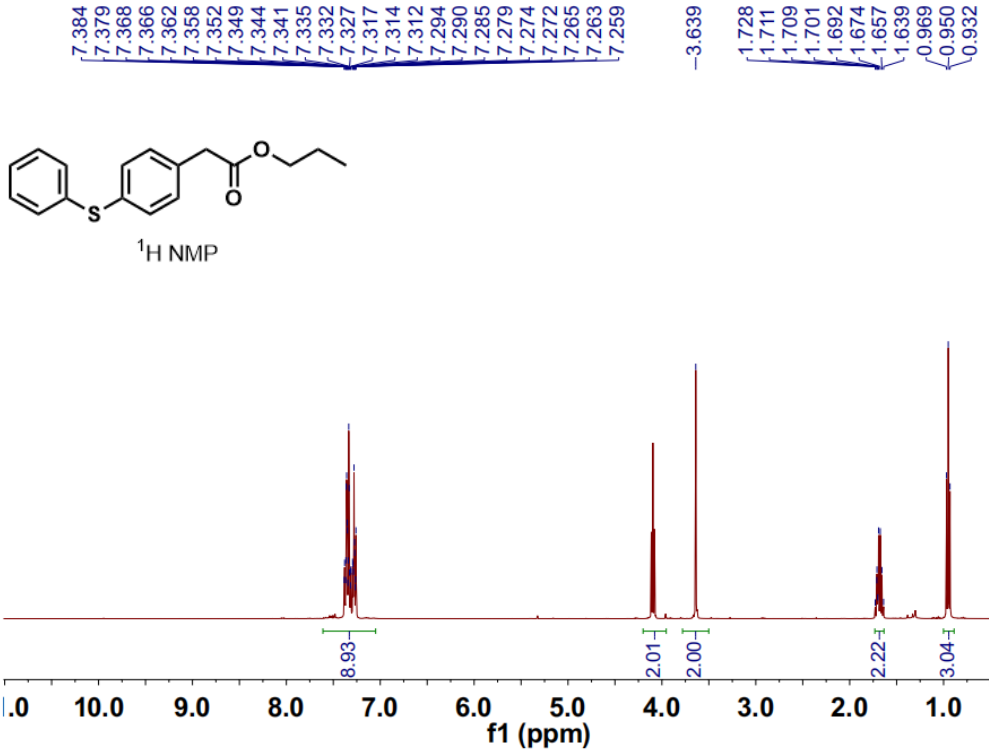
140.839
140.029
133.261
129.743
128.818
127.348
127.314
127.119
66.605
41.113
22.016
10.448
O
O
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.379
7.368
7.366
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7.358
7.352
7.349
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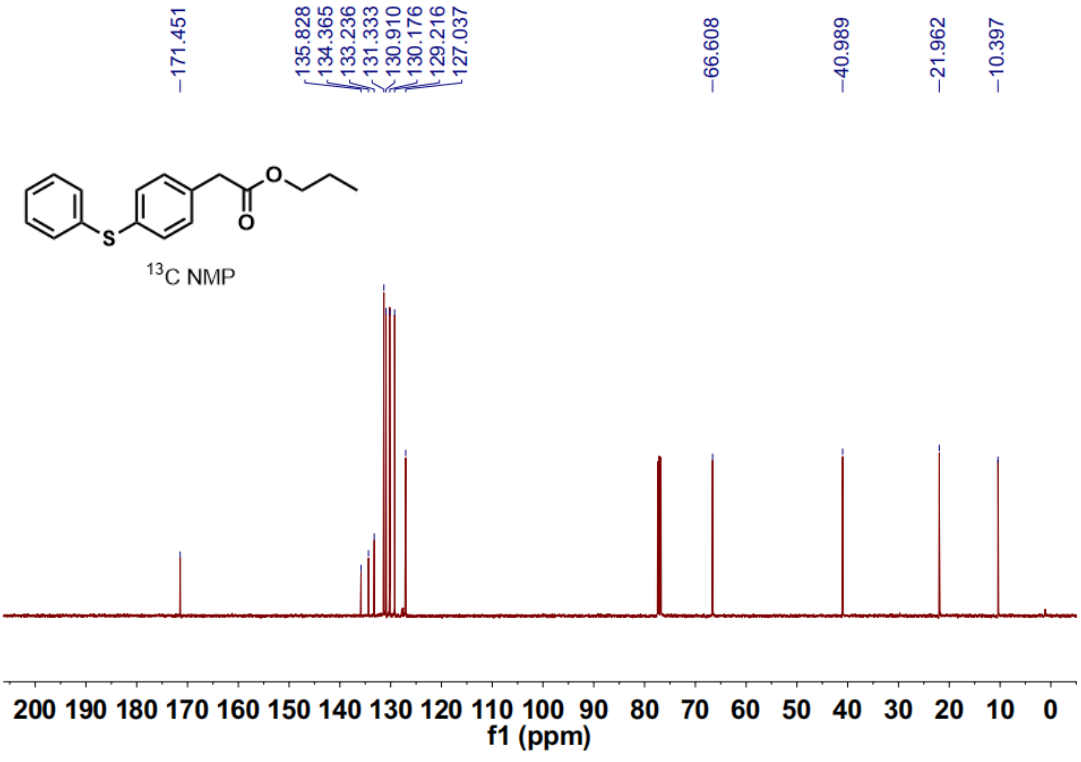
7.341
7.335
7.332
7.327
7.317
7.314
7.312
7.294
7.290
7.285
7.279
7.274
7.272
7.265
7.263
7.259
3.639
1.728
1.711
1.709
1.701
1.692
1.674
1.657
1.639
0.969
0.950
0.932
O
O
S
1H NMP
8.93
2.01
2.00
2.22
3.04
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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135.828
134.365
133.236
131.333
130.910
130.176
129.216
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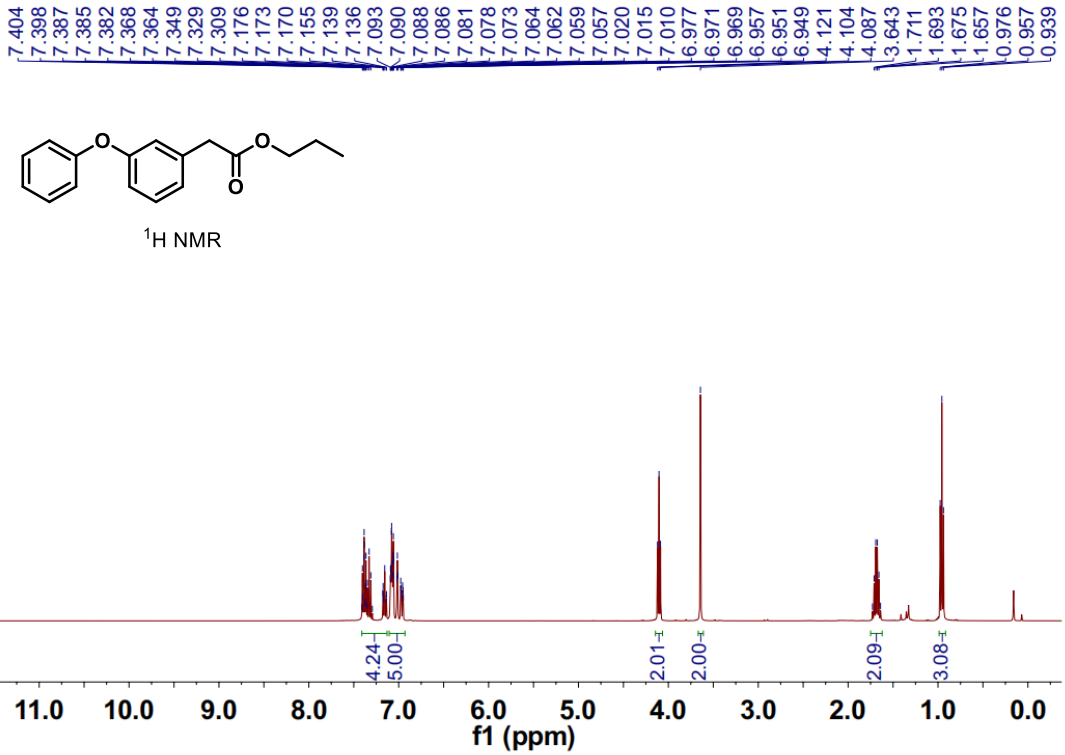
66.608
40.989
21.962
10.397
O
O
S
13C NMP
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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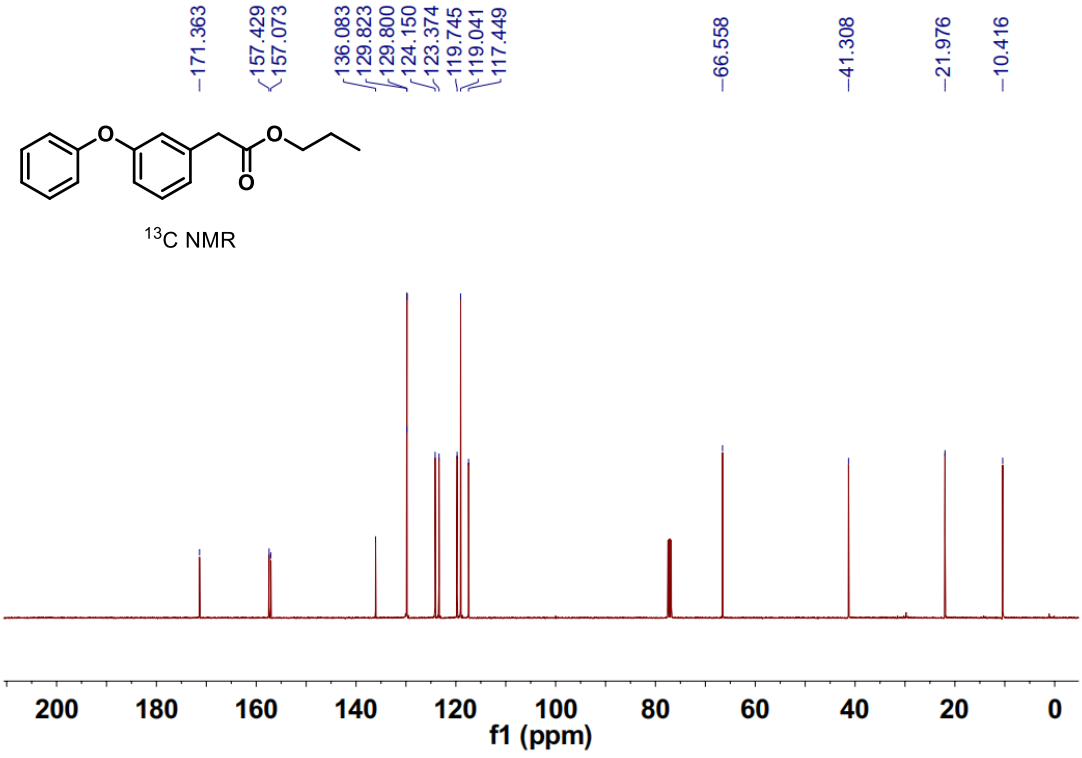
7.387
7.385
7.382
7.368
7.364
7.349
7.329
7.309
7.176
7.173
7.170
7.155
7.139
7.136
7.093
7.090
7.088
7.086
7.081
7.078
7.073
7.064
7.062
7.059
7.057
7.020
7.015
7.010
6.977
6.971
6.969
6.957
6.951
6.949
4.121
4.104
4.087
3.643
1.711
1.693
1.675
1.657
0.976
0.957
0.939
O
O
O
1H NMR
4.24
5.00
2.01
2.00
2.09
3.08
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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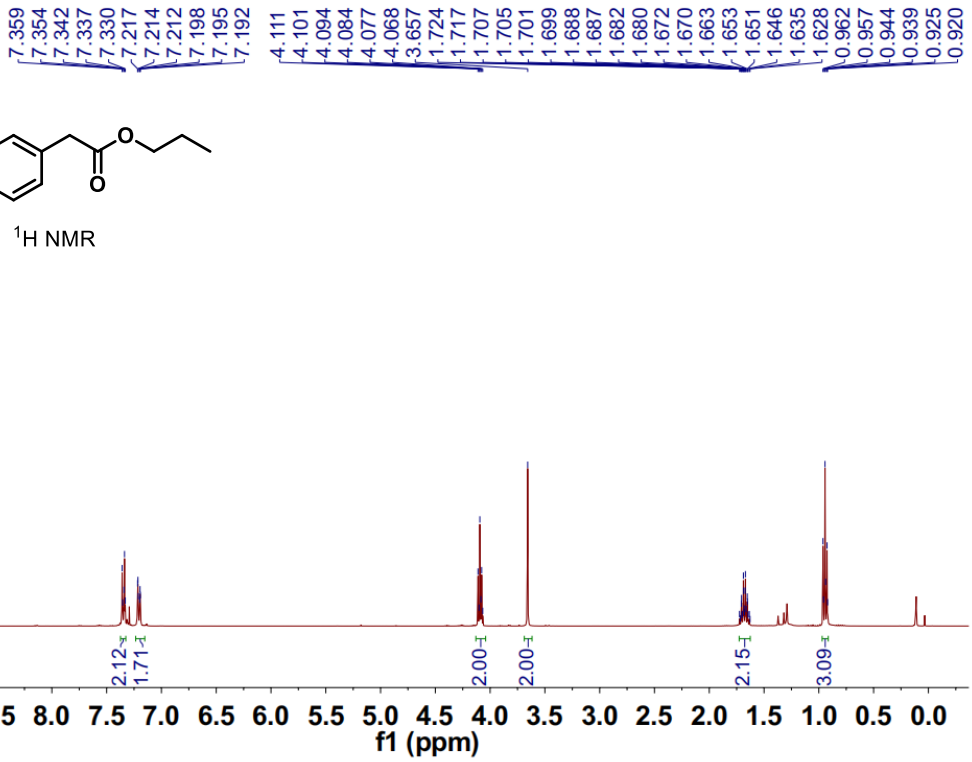
157.073
136.083
129.823
129.800
124.150
123.374
119.745
119.041
117.449
66.558
41.308
21.976
10.416
O
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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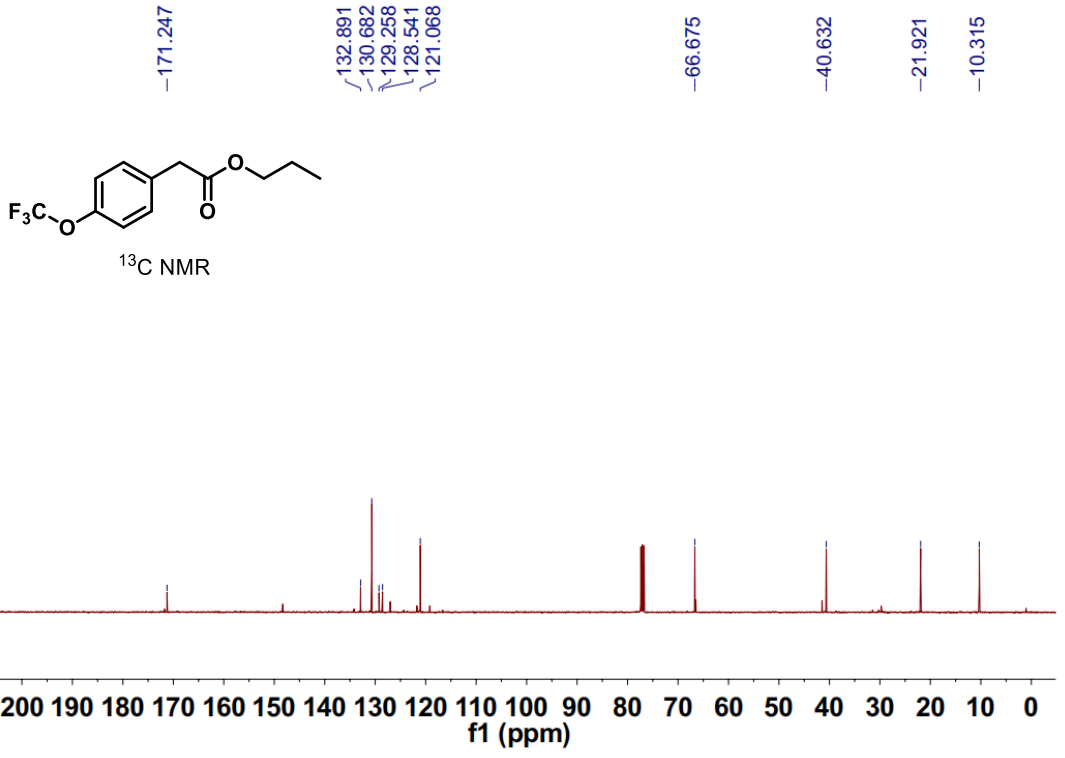
7.354
7.342
7.337
7.330
7.217
7.214
7.212
7.198
7.195
7.192
4.111
4.101
4.094
4.084
4.077
4.068
3.657
1.724
1.717
1.707
1.705
1.701
1.699
1.688
1.687
1.682
1.680
1.672
1.670
1.663
1.653
1.651
1.646
1.635
1.628
0.962
0.957
0.944
0.939
0.925
0.920
F3C
O
O
O
1H NMR
2.12
1.71
2.00
2.00
2.15
3.09
.5 9.0 8.5 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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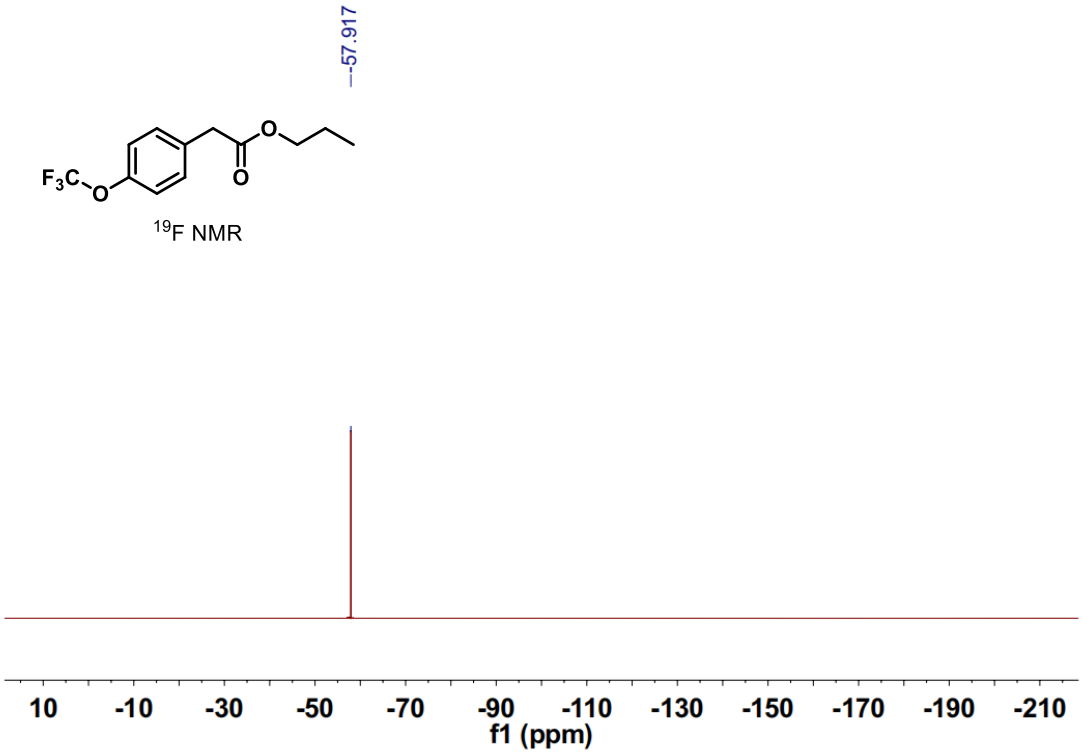
132.891
130.682
129.258
128.541
121.068
66.675
40.632
21.921
10.315
F3C
O
O
O
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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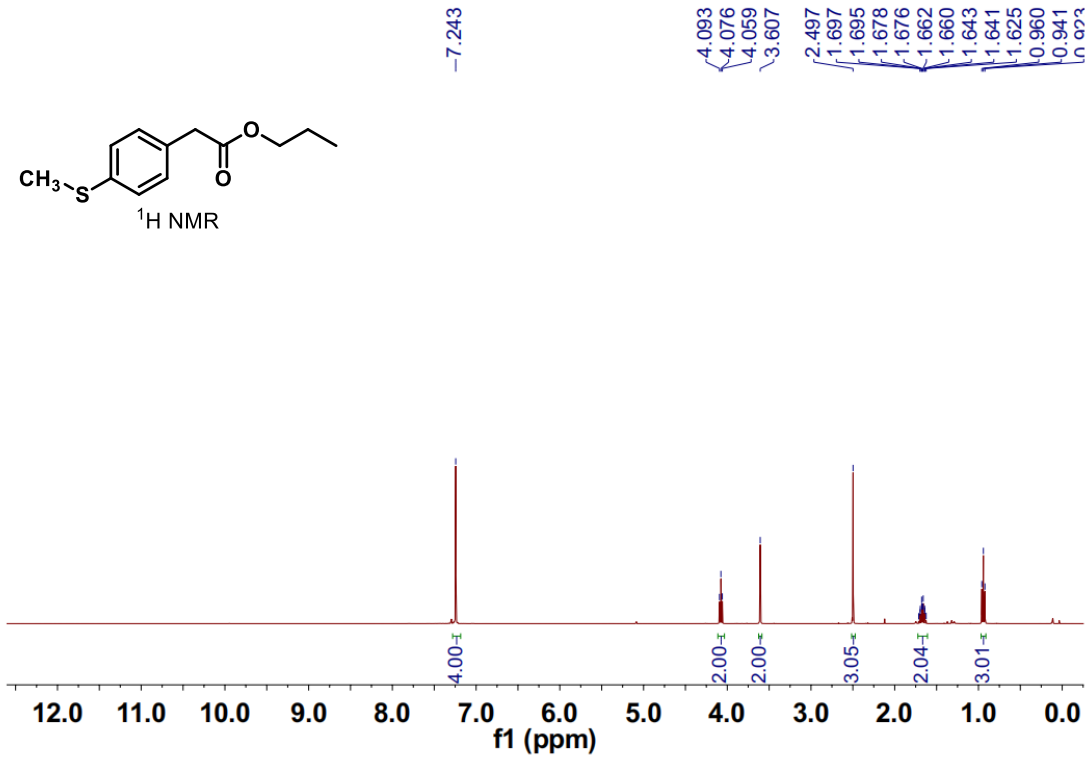
F3C
O
O
O
19F NMR
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)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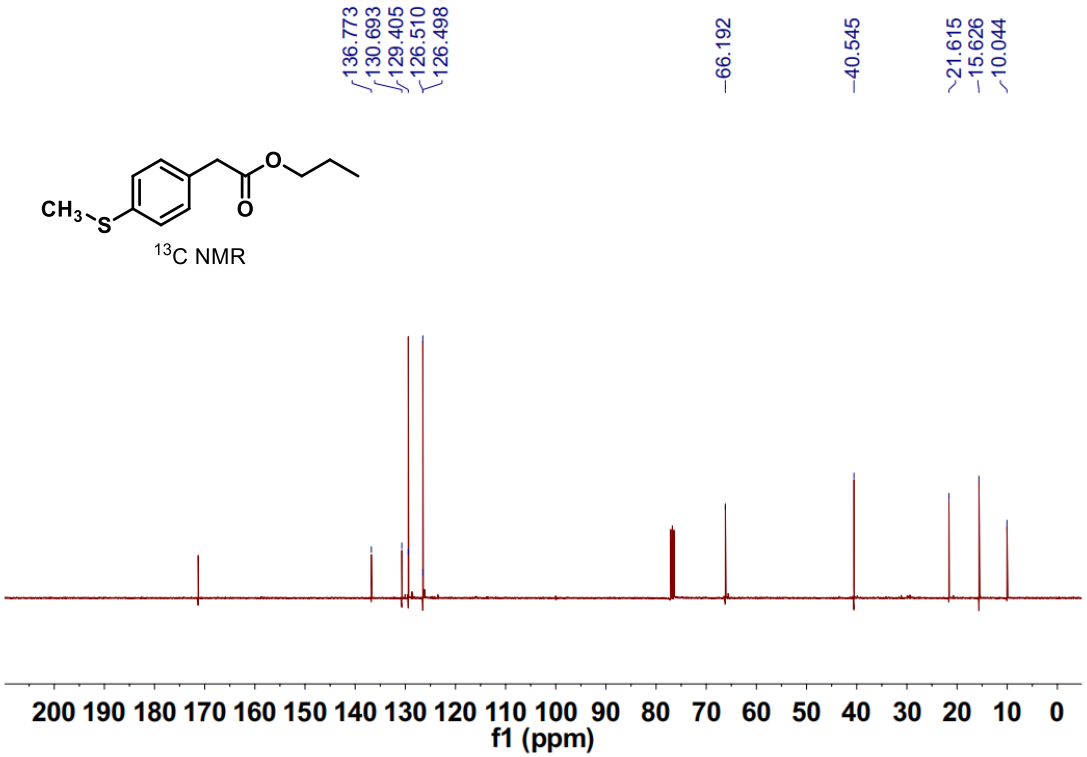
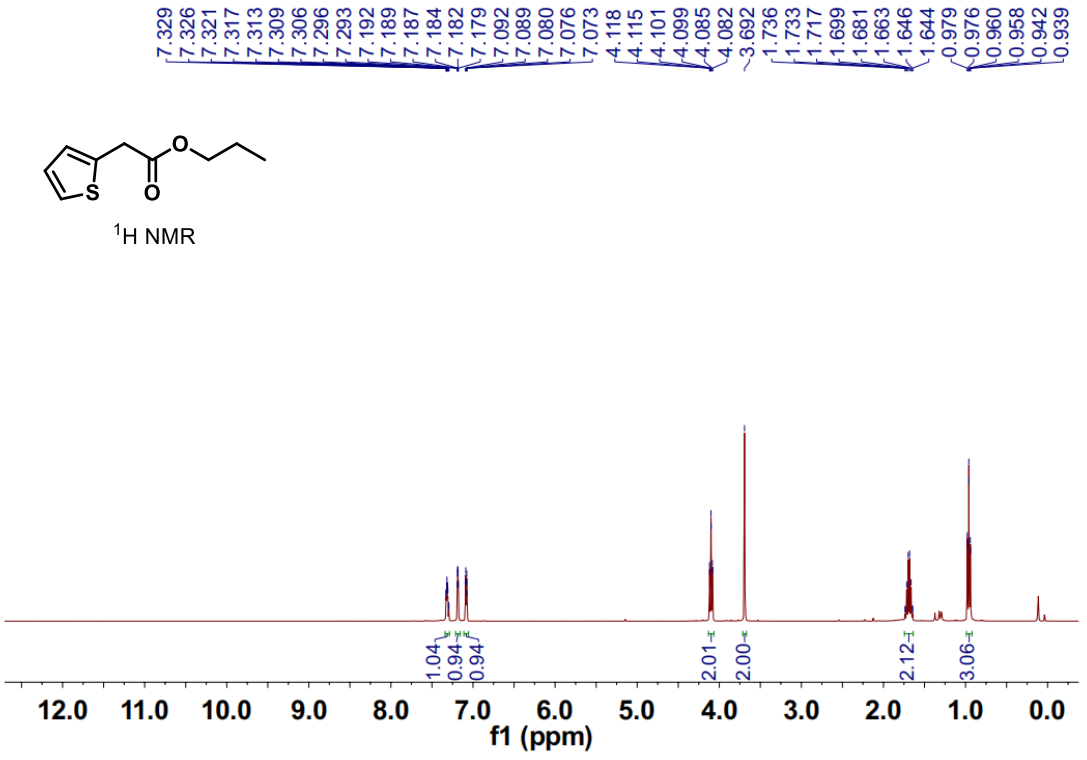
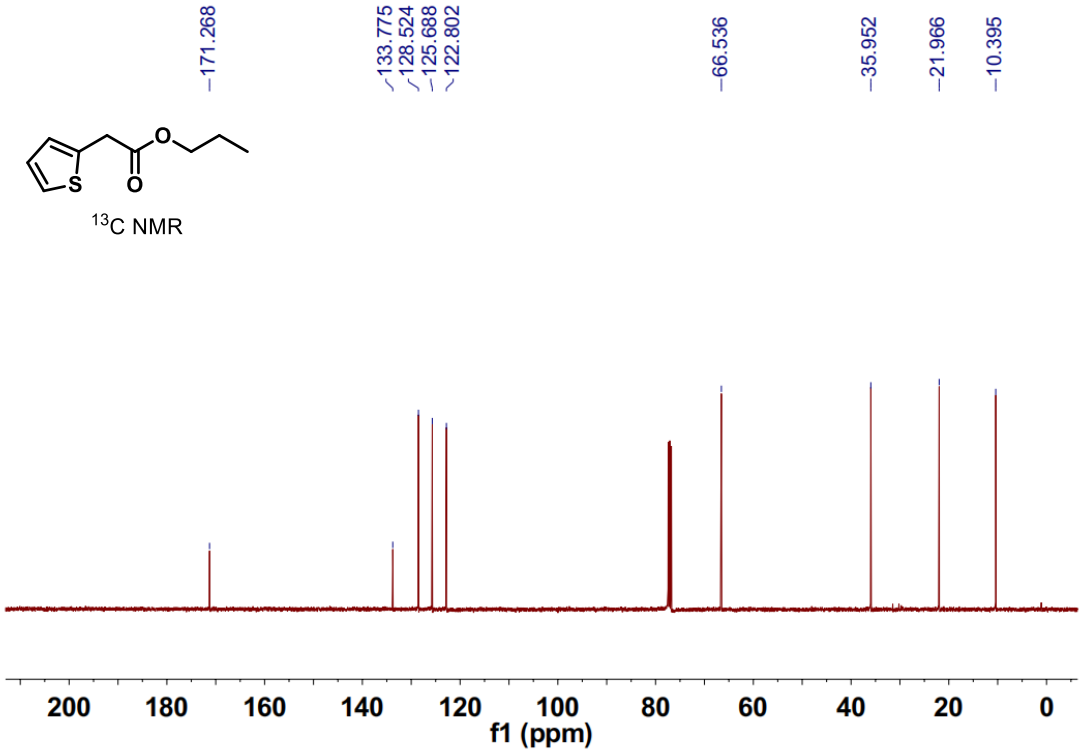
4.093
4.076
4.059
3.607
2.497
1.697
1.695
1.678
1.676
1.662
1.660
1.643
1.641
1.625
0.960
0.941
CH3
S
O
O
1H NMR
4.00
2.00
2.00
3.05
2.04
3.01
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)



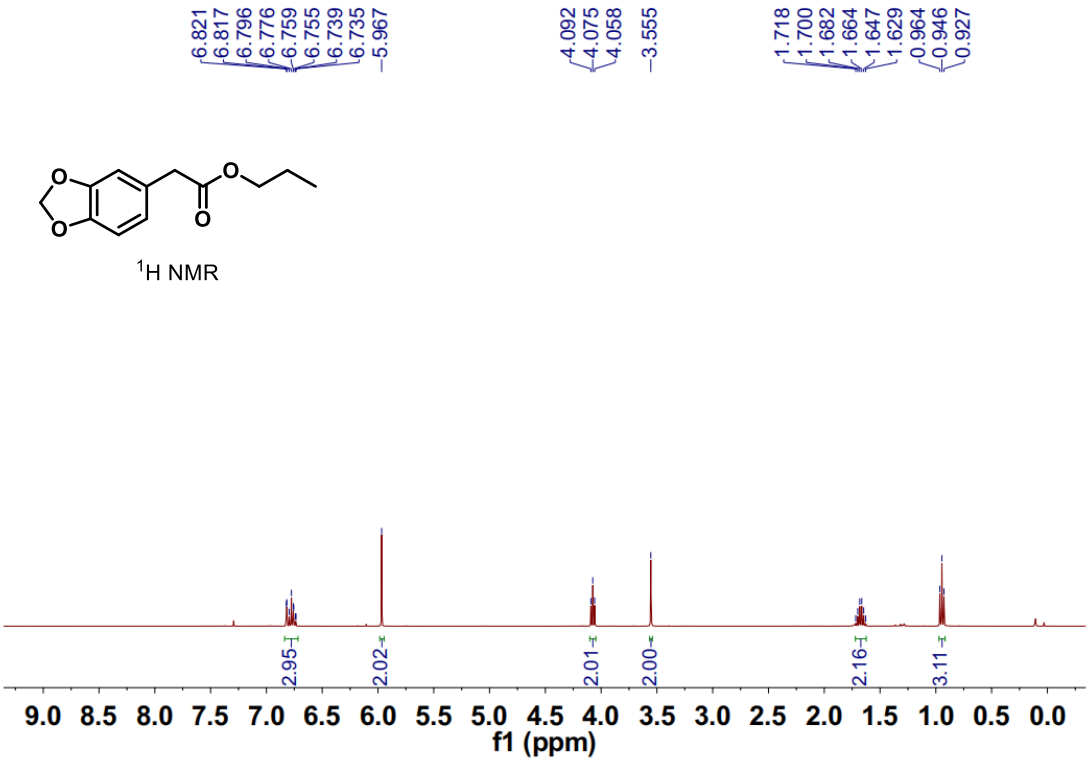
^{13}C NMR



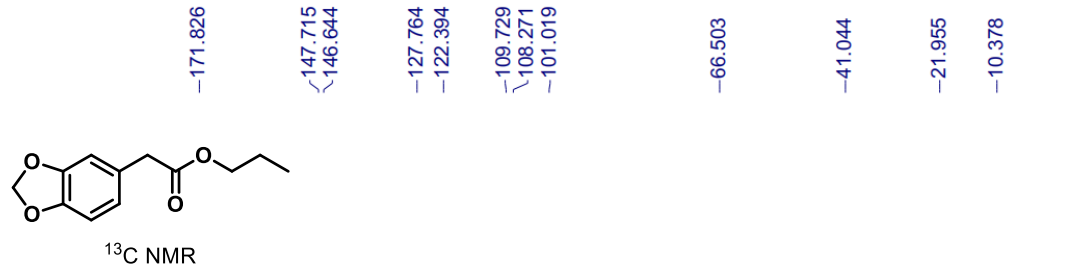
^{1}H NMR



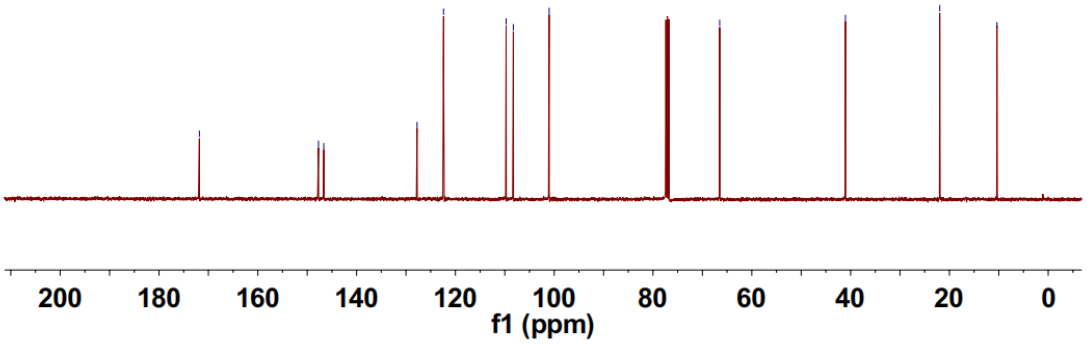
^{13}C NMR

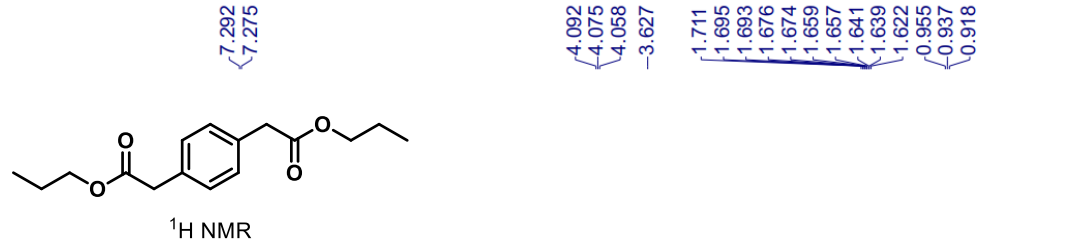


^{1}H NMR

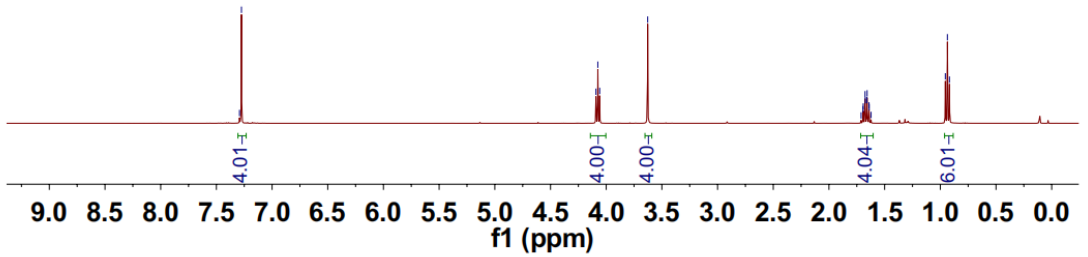


^{13}C NMR

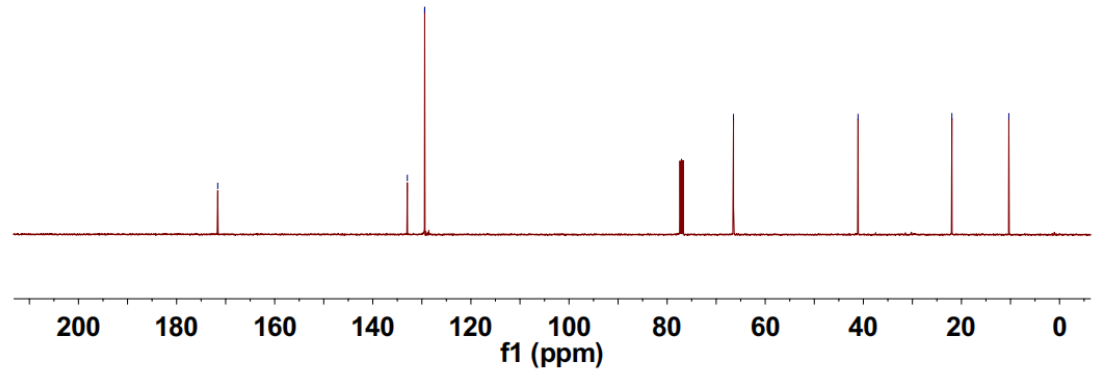


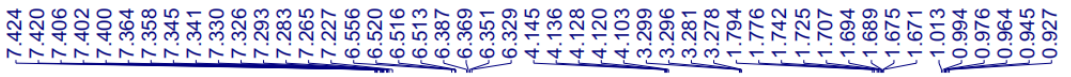


^{1}H NMR

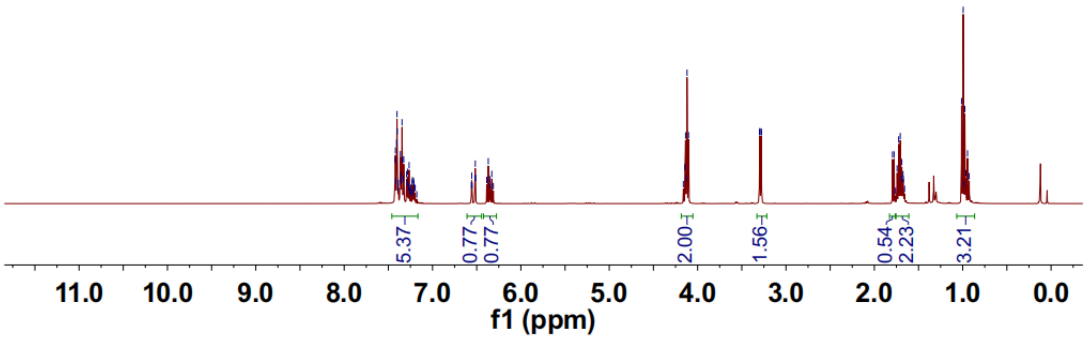


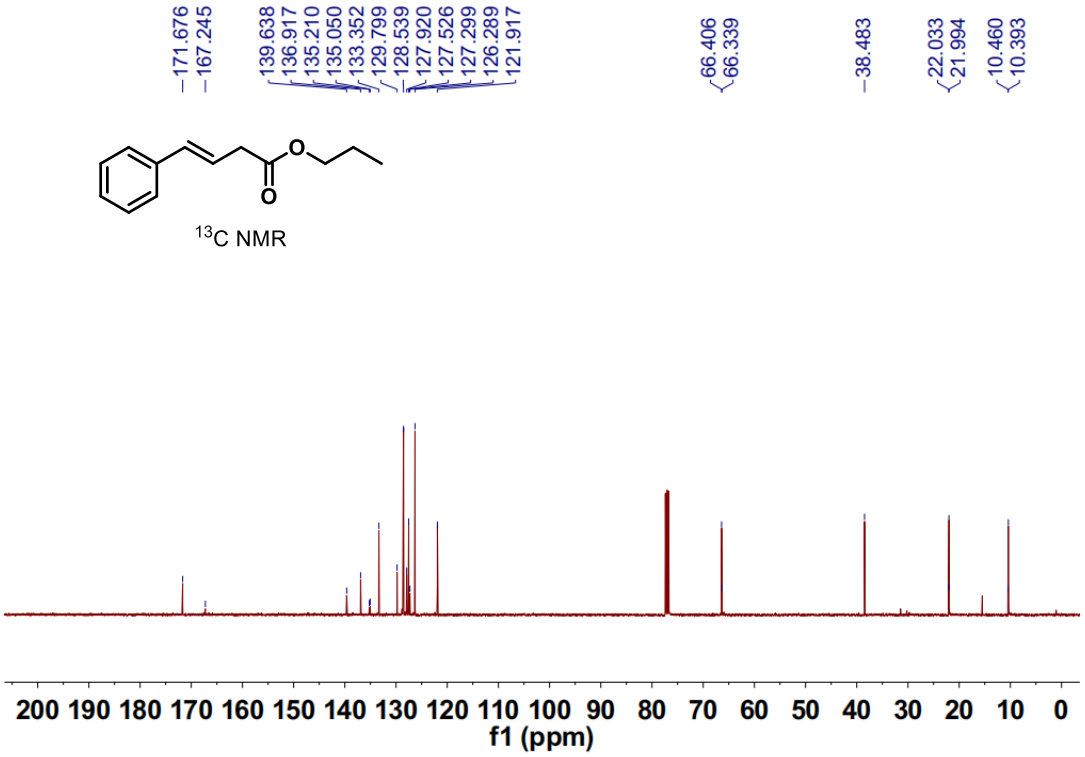
^{13}C NMR



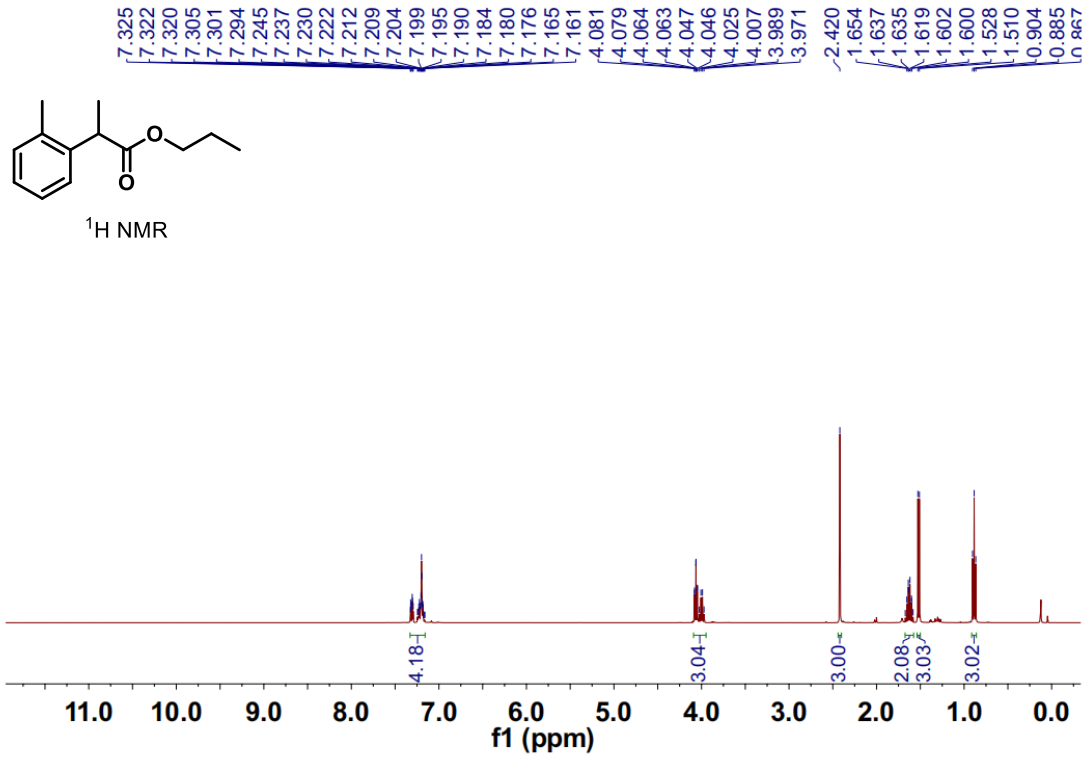


^{1}H NMR

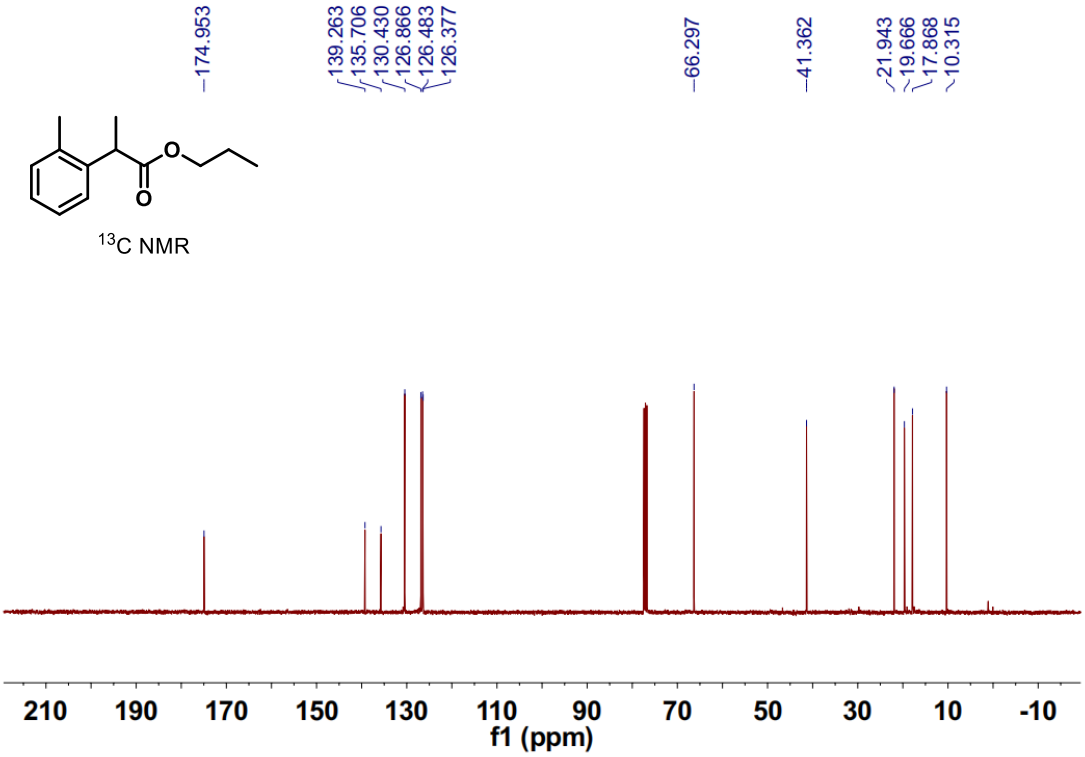




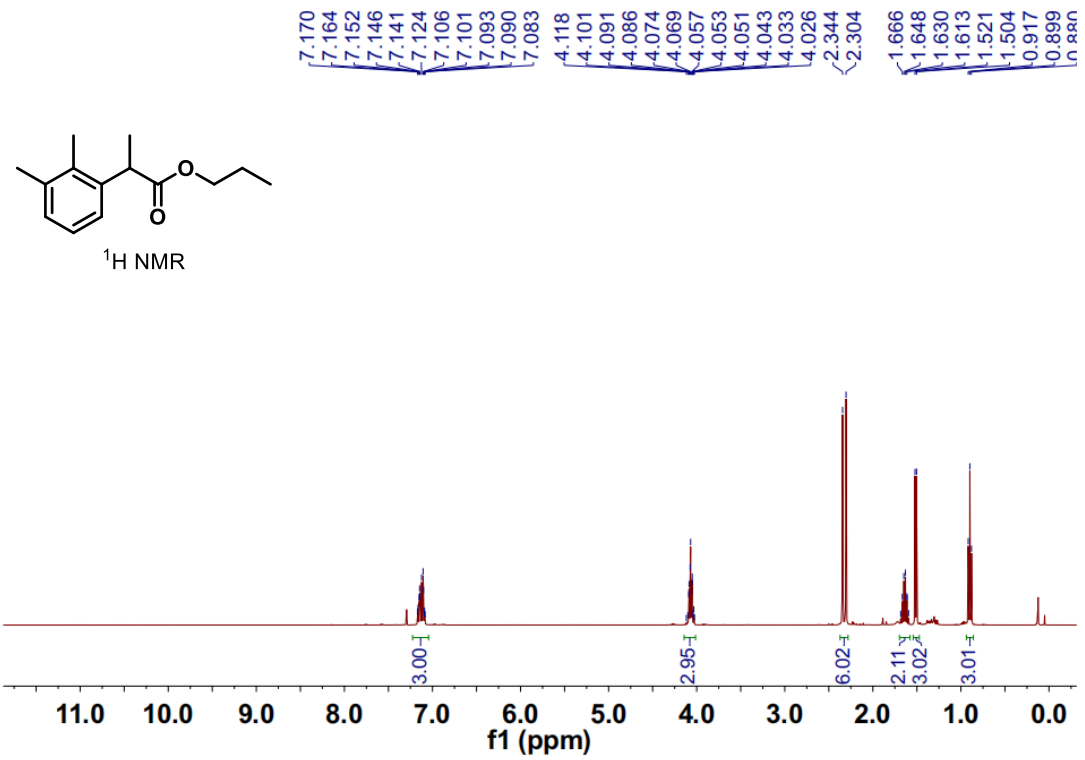
^{13}C NMR



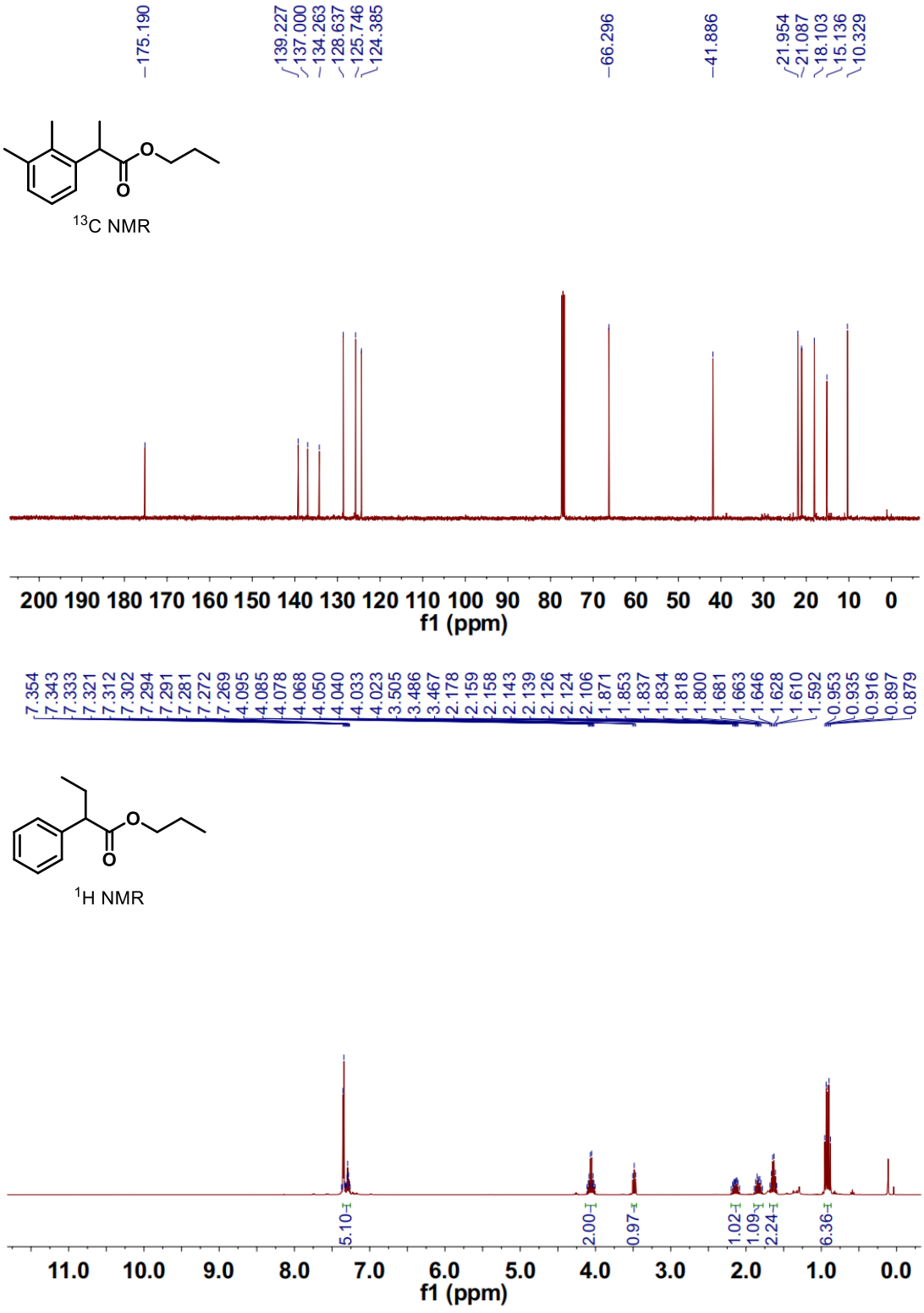
^{1}H NMR



^{13}C NMR



^{1}H NMR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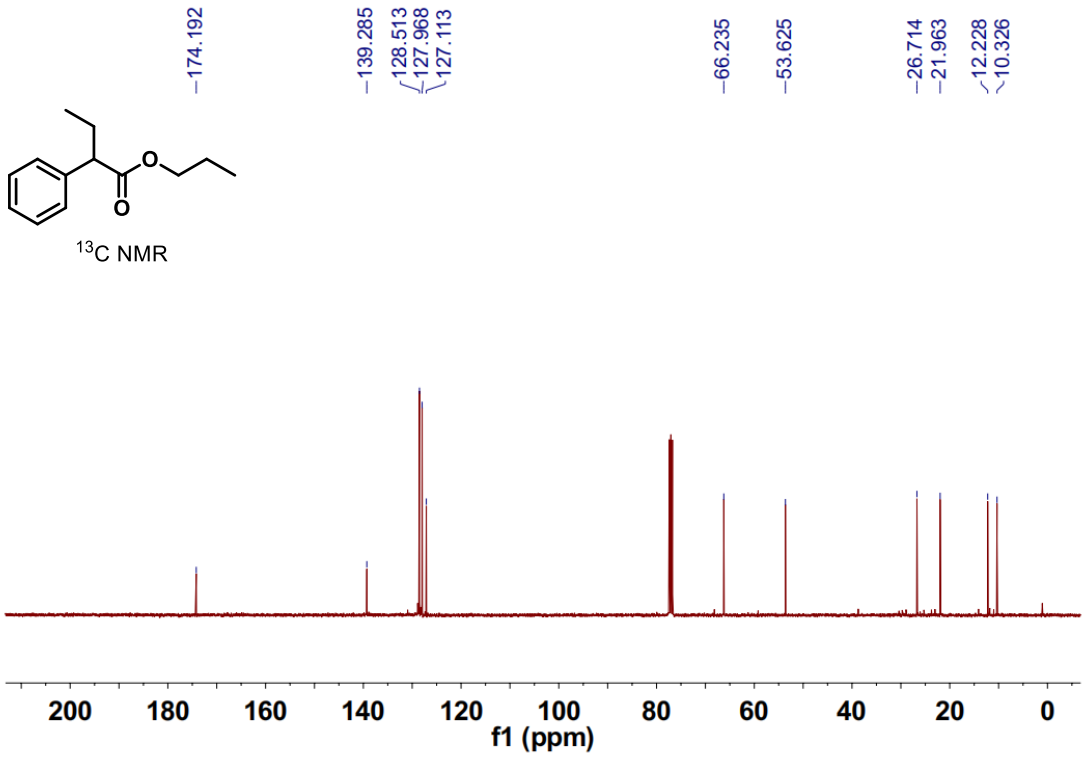
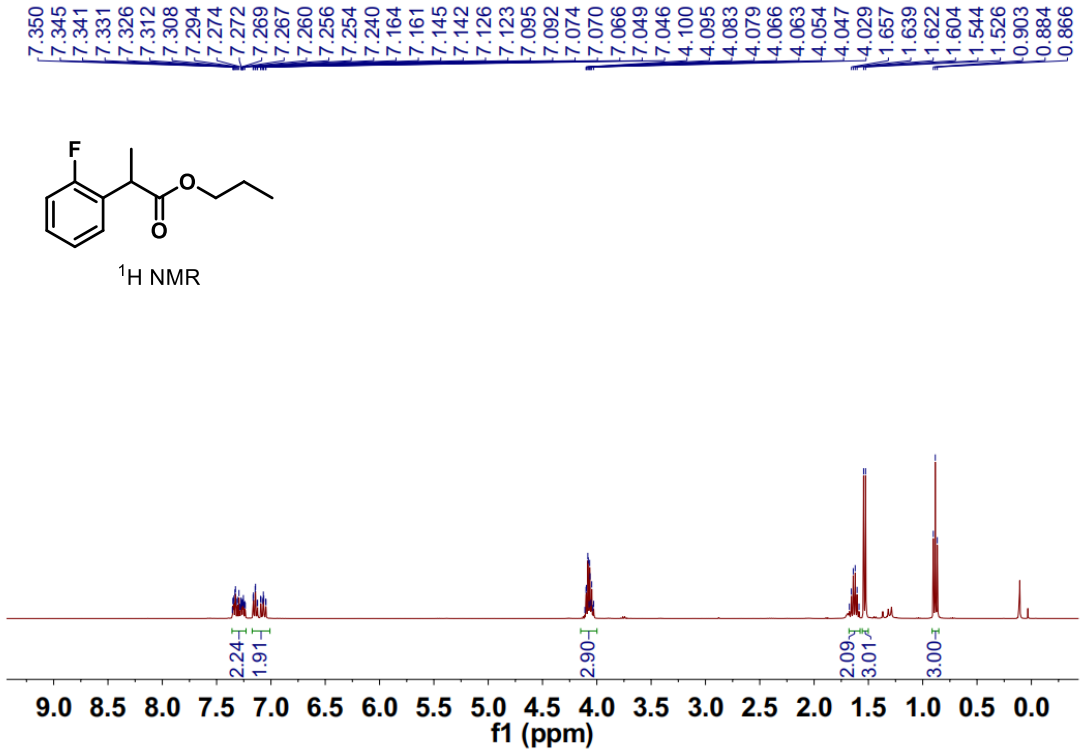
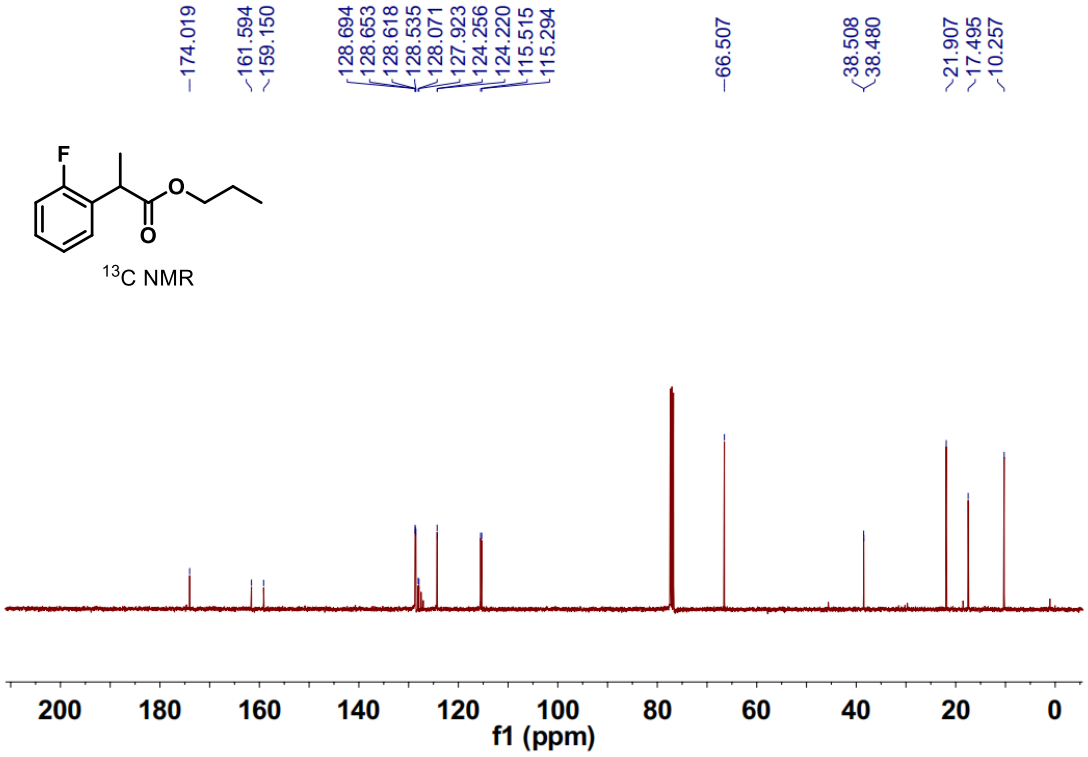
139.227
137.000
134.263
128.637
125.746
124.385
66.296
41.886
21.954
21.087
18.103
15.136
10.329
O
O
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)
7.354
7.343
7.333
7.321
7.312
7.302
7.294
7.291
7.281
7.272
7.269
4.095
4.085
4.078
4.068
4.050
4.040
4.033
4.023
3.505
3.486
3.467
2.178
2.159
2.158
2.143
2.139
2.126
2.124
2.106
1.871
1.853
1.837
1.834
1.818
1.800
1.681
1.663
1.646
1.628
1.610
1.592
0.953
0.935
0.916
0.897
0.879
O
O
1H NMR
5.10
2.00
0.97
1.02
1.09
2.24
6.36
11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)



^{13}C NMR



^{1}H NMR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161.594
159.150
128.694
128.653
128.618
128.535
128.071
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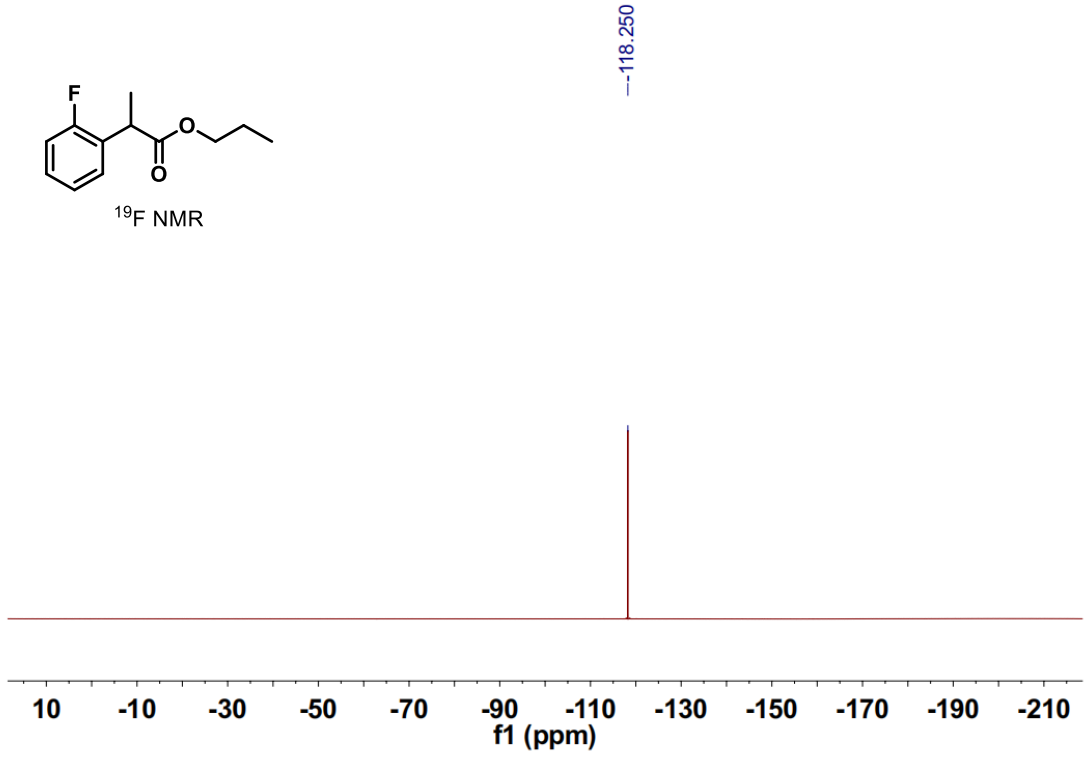
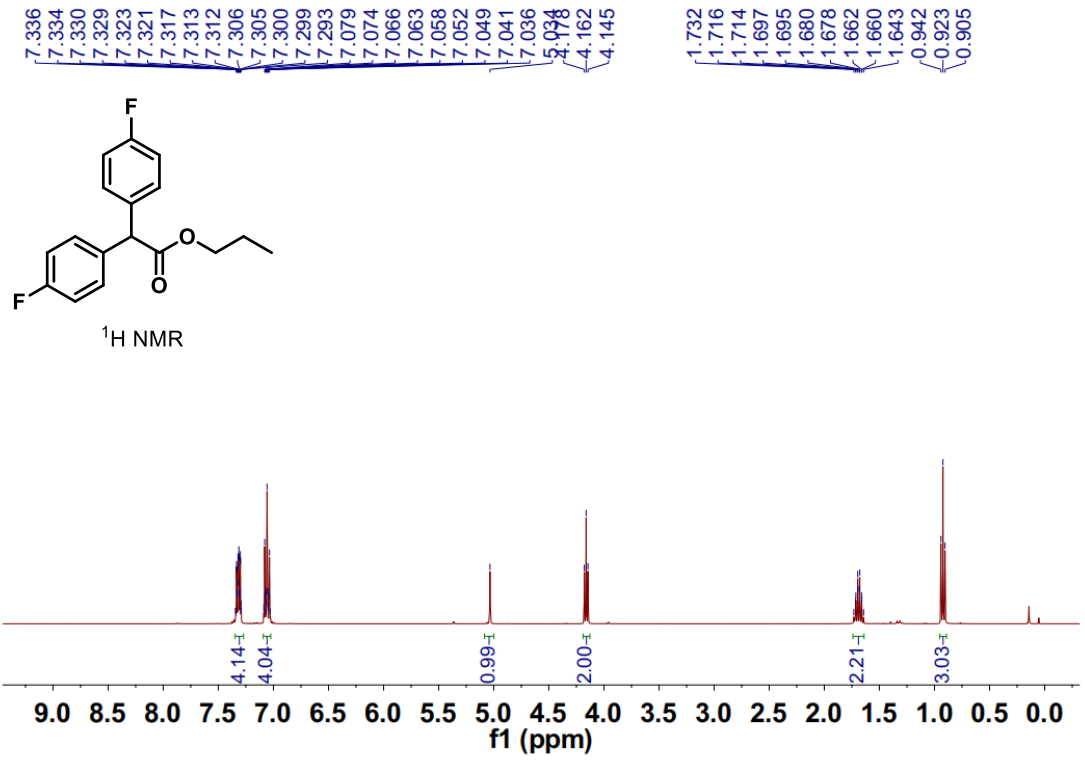
124.256
124.220
115.515
115.294
66.507
38.508
38.480
21.907
17.495
10.257
F
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)


118.250
F
O
O
19F NMR
10
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
f1 (ppm)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7.293
7.079
7.074
7.066
7.063
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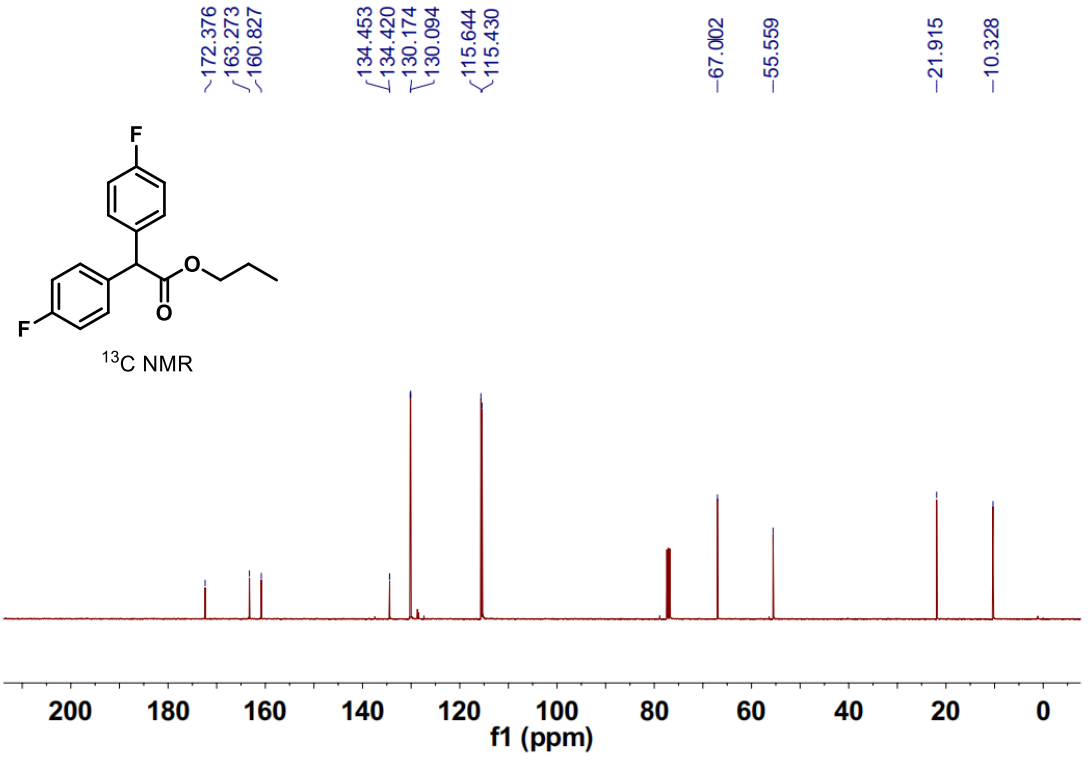
7.052
7.049
7.041
7.036
5.034
5.018
4.162
4.145
1.732
1.716
1.714
1.697
1.695
1.680
1.678
1.662
1.660
1.643
0.942
0.923
0.905
F
O
O
F
1H NMR
4.14
4.04
0.99
2.00
2.21
3.03
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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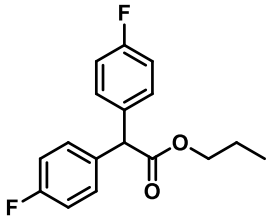
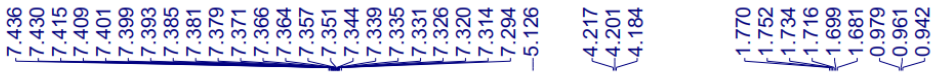
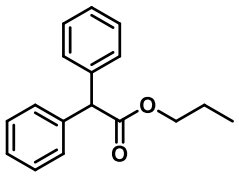
163.273
160.827
134.453
134.420
130.174
130.094
115.644
115.430
67.002
55.559
21.915
10.328
F
O
O
F
13C NMR
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

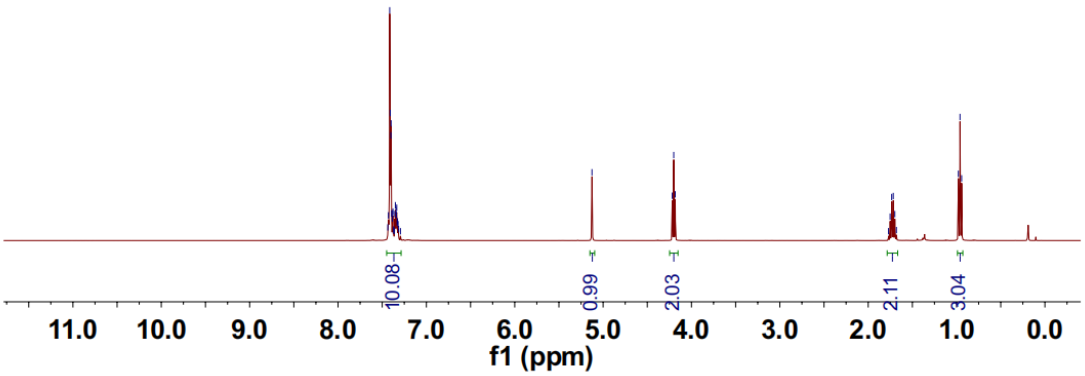


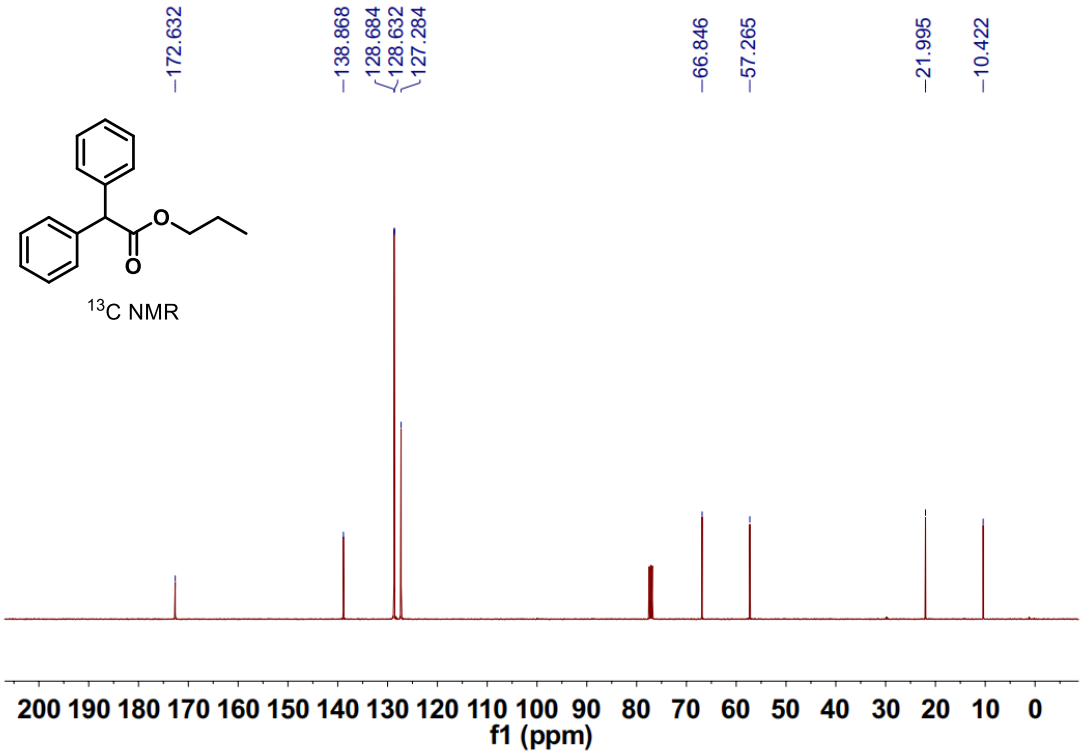
^{19}F NMR





^{1}H NMR

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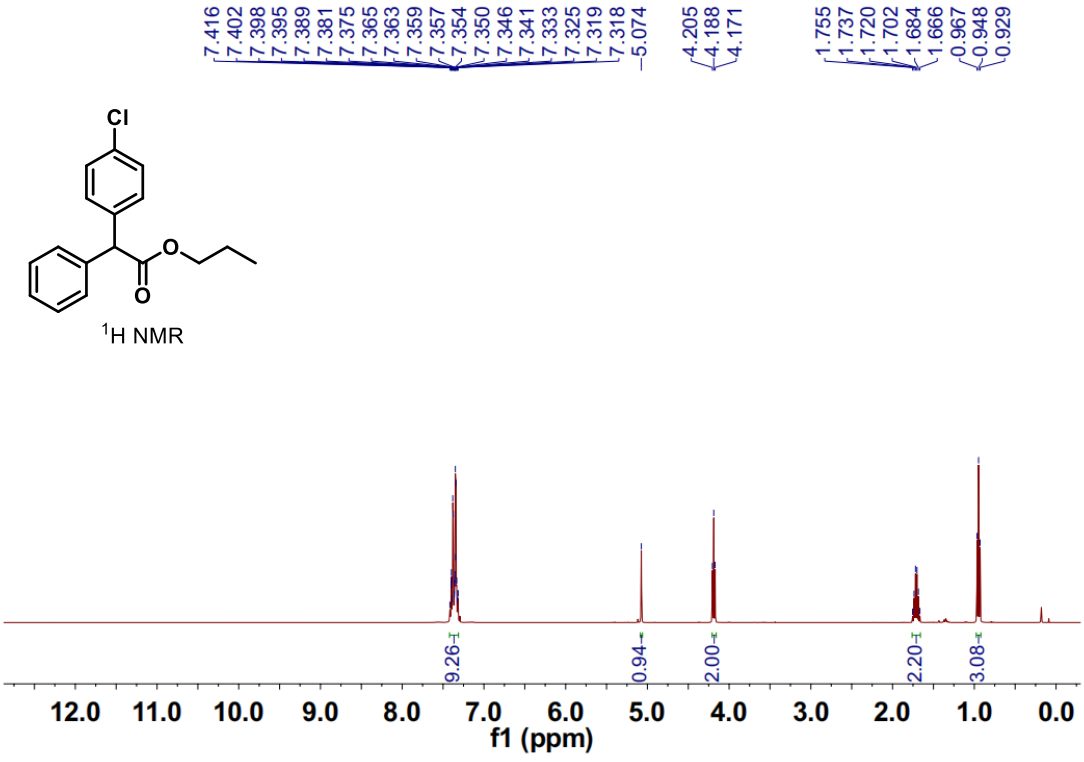
138.868
128.684
128.632
127.284
66.846
57.265
21.995
10.422
O
O
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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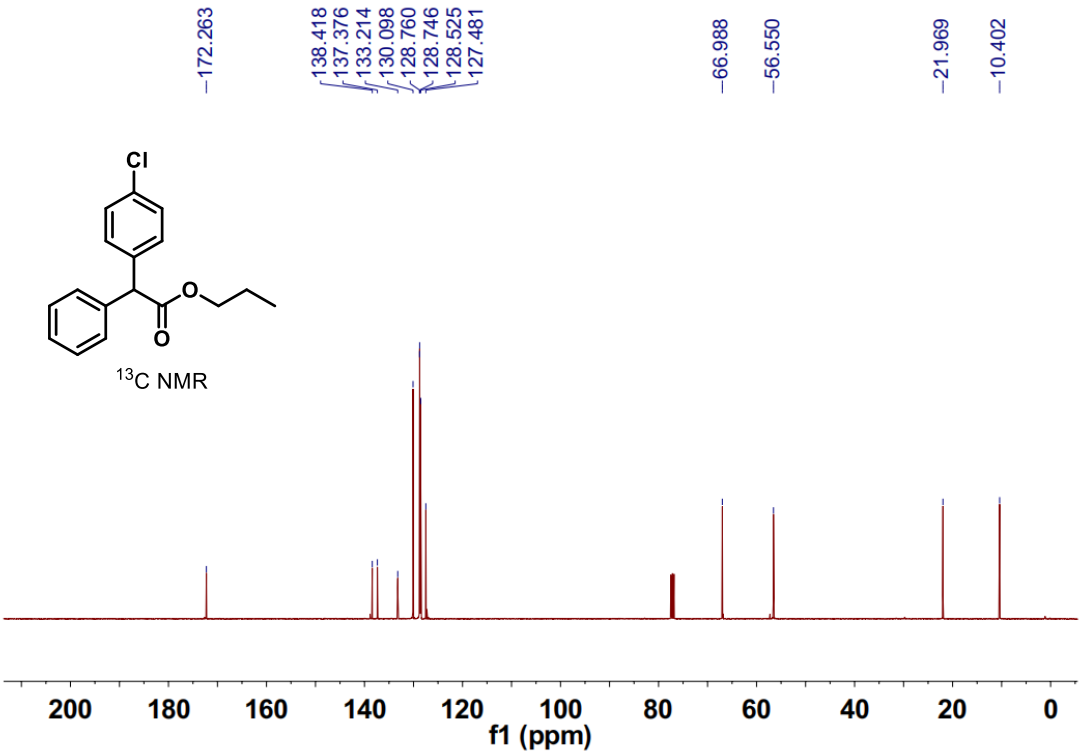
7.402
7.398
7.395
7.389
7.381
7.375
7.365
7.363
7.359
7.357
7.354
7.350
7.346
7.341
7.333
7.325
7.319
7.318
5.074
4.205
4.188
4.171
1.755
1.737
1.720
1.702
1.684
1.666
0.967
0.948
0.929
Cl
O
O
1H NMR
9.26
0.94
2.00
2.20
3.08
12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)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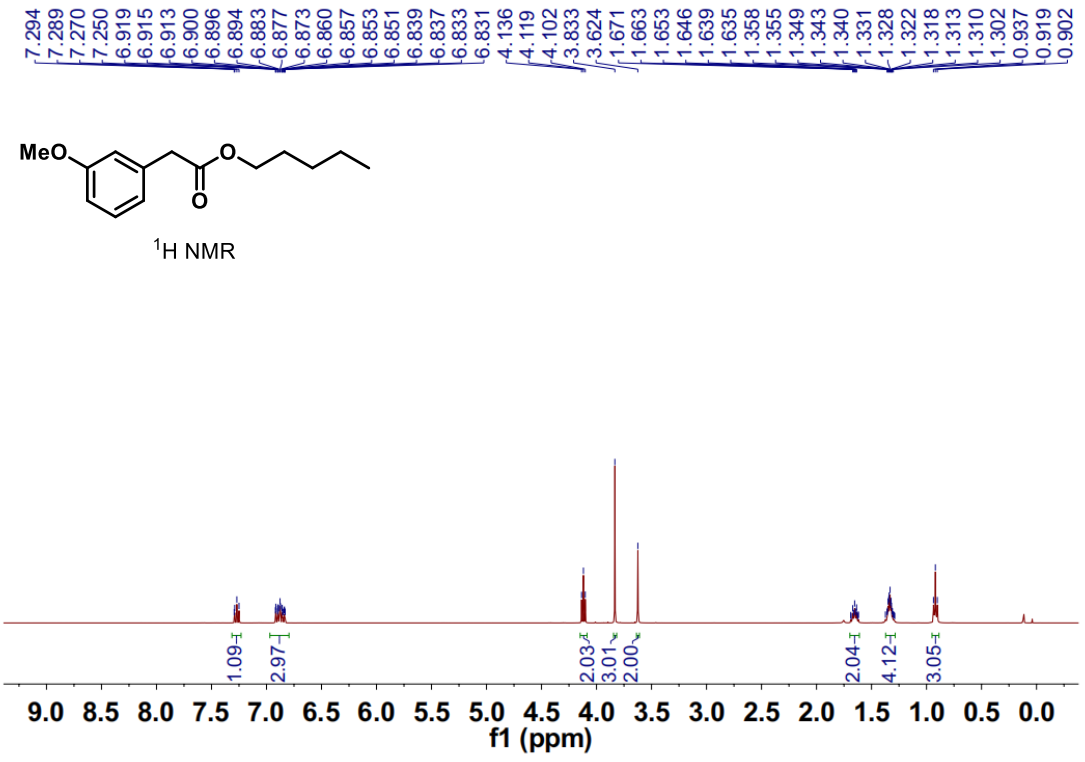
138.418
137.376
133.214
130.098
128.760
128.746
128.525
127.481
66.988
56.550
21.969
10.402
Cl
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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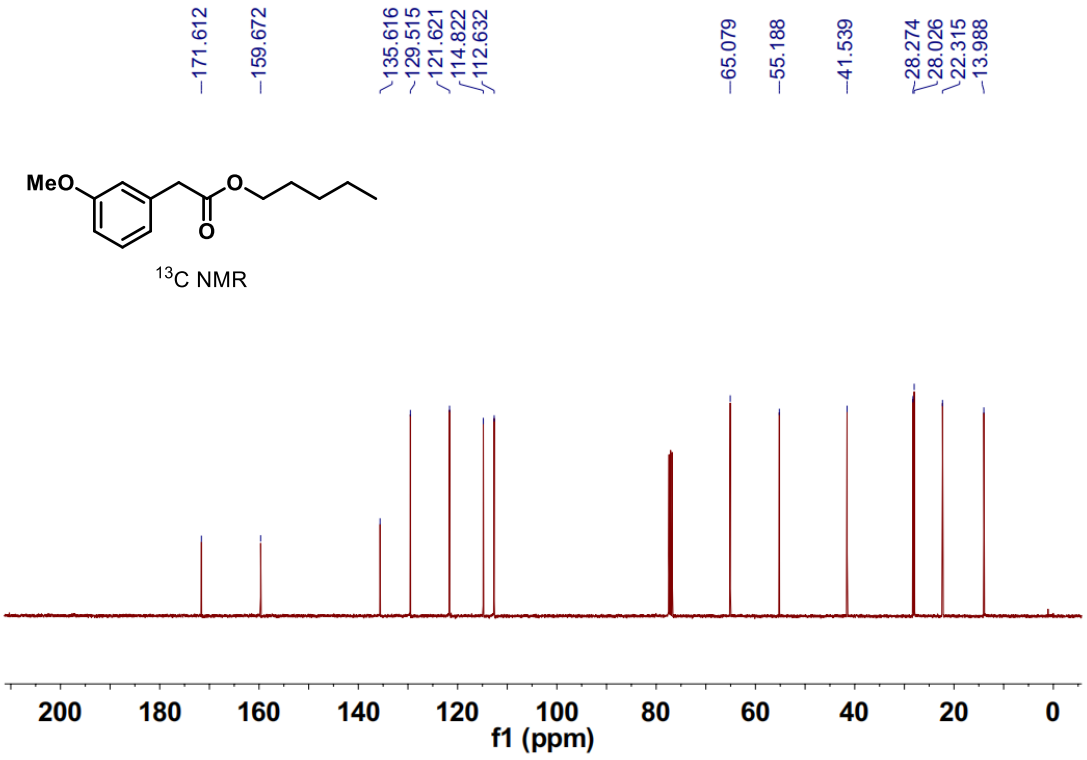
7.289
7.270
7.250
6.919
6.915
6.913
6.900
6.896
6.894
6.883
6.877
6.873
6.860
6.857
6.853
6.851
6.839
6.837
6.833
6.831
4.136
4.119
4.102
3.833
3.624
1.671
1.663
1.653
1.646
1.639
1.635
1.358
1.355
1.349
1.343
1.340
1.331
1.328
1.322
1.318
1.313
1.310
1.302
0.937
0.919
0.902
MeO
O
O
1H NMR
1.09
2.97
2.03
3.01
2.00
2.04
4.12
3.05
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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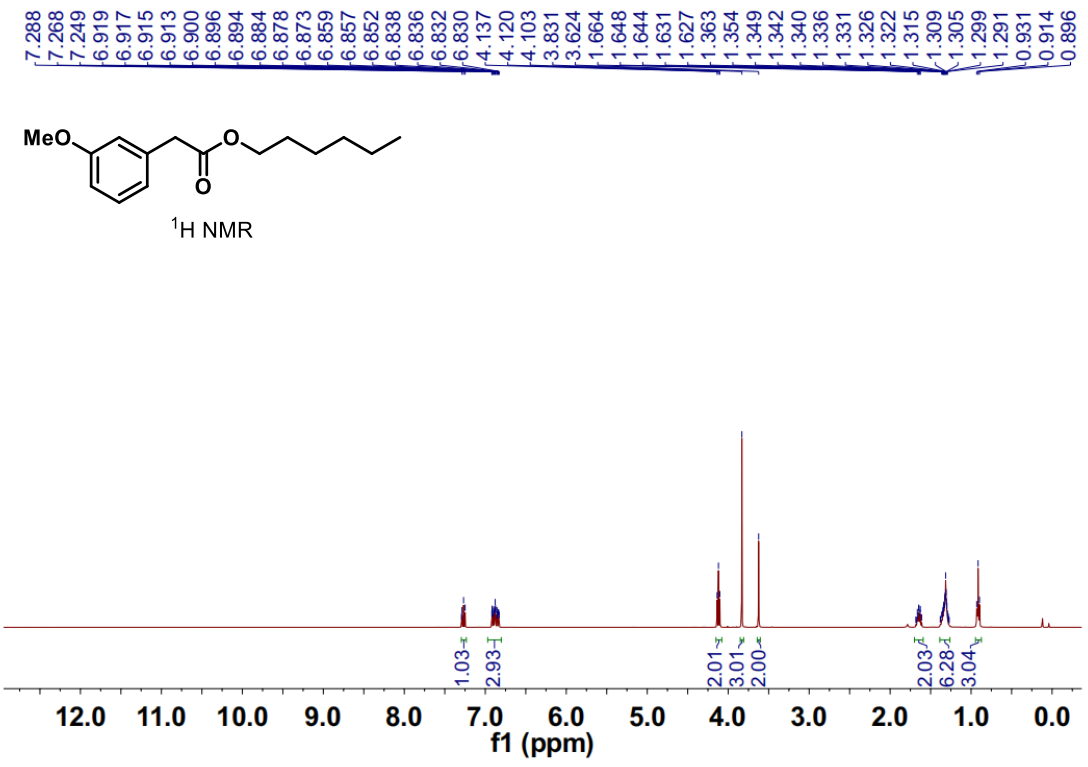
159.672
135.616
129.515
121.621
114.822
112.632
65.079
55.188
41.539
28.274
28.026
22.315
13.988
MeO
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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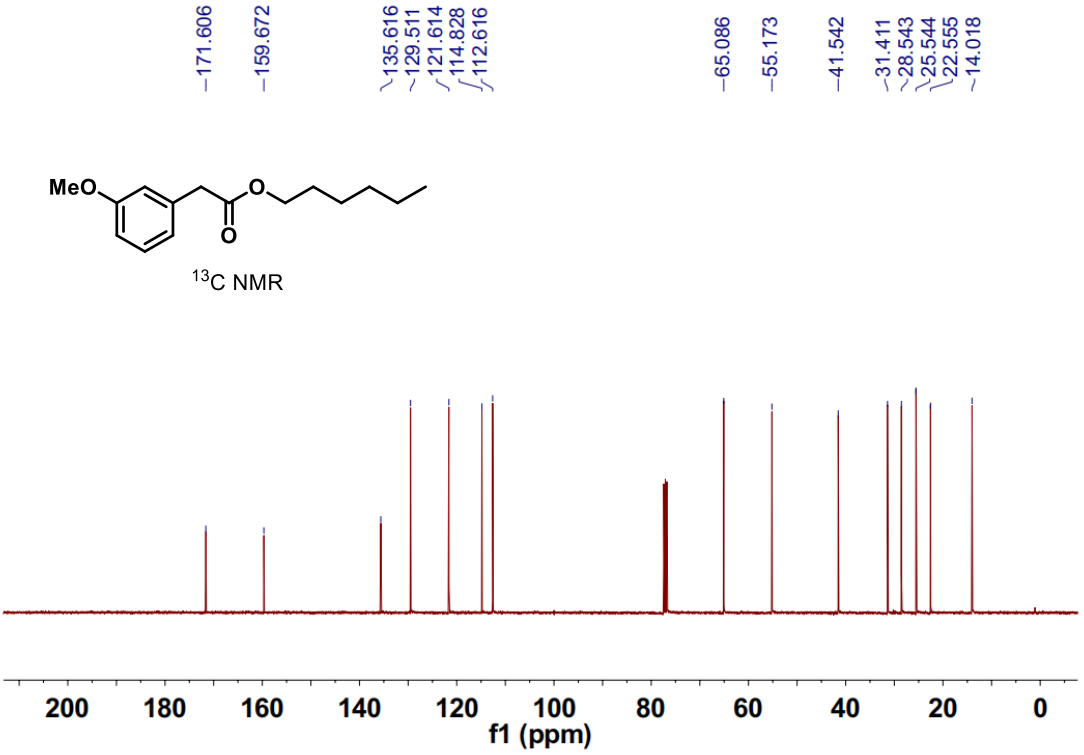
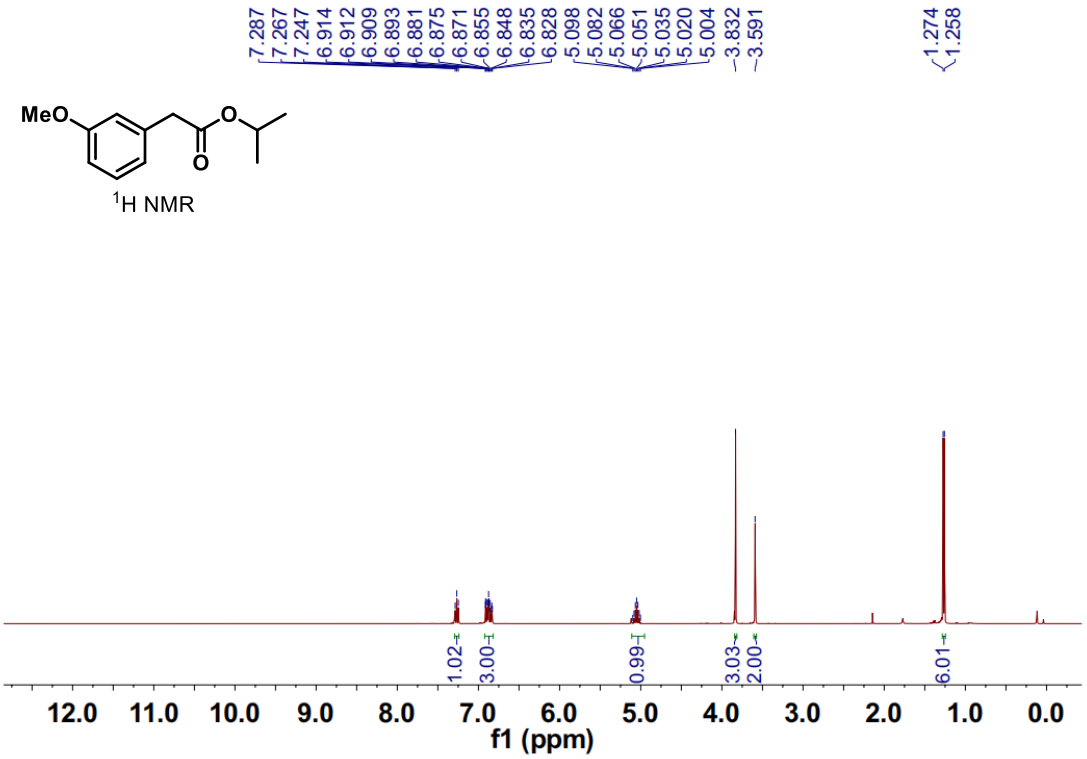
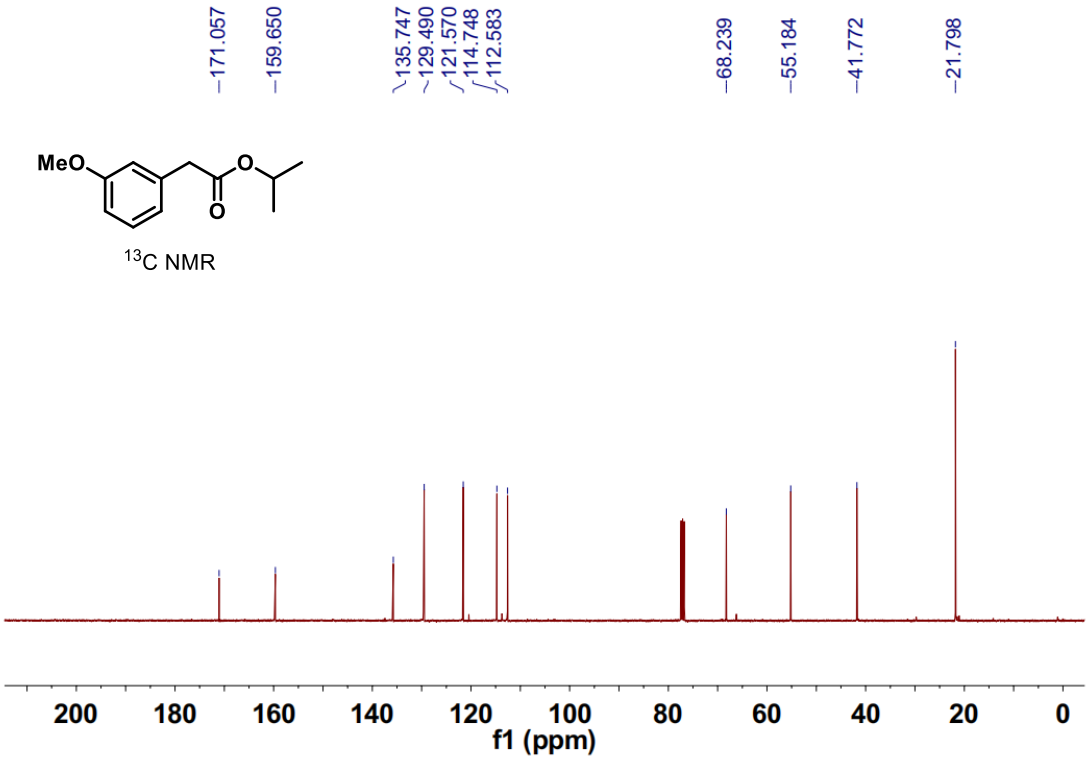
7.268
7.249
6.919
6.917
6.915
6.913
6.900
6.896
6.894
6.884
6.878
6.873
6.859
6.857
6.852
6.838
6.836
6.832
6.830
4.137
4.120
4.103
3.831
3.624
1.664
1.648
1.644
1.631
1.627
1.363
1.354
1.349
1.342
1.340
1.336
1.331
1.326
1.322
1.315
1.309
1.305
1.299
1.291
0.931
0.914
0.896
MeO
O
O
1H NMR
1.03
2.93
2.01
3.01
2.00
2.03
6.28
3.04
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)



^{13}C NMR



^{1}H NMR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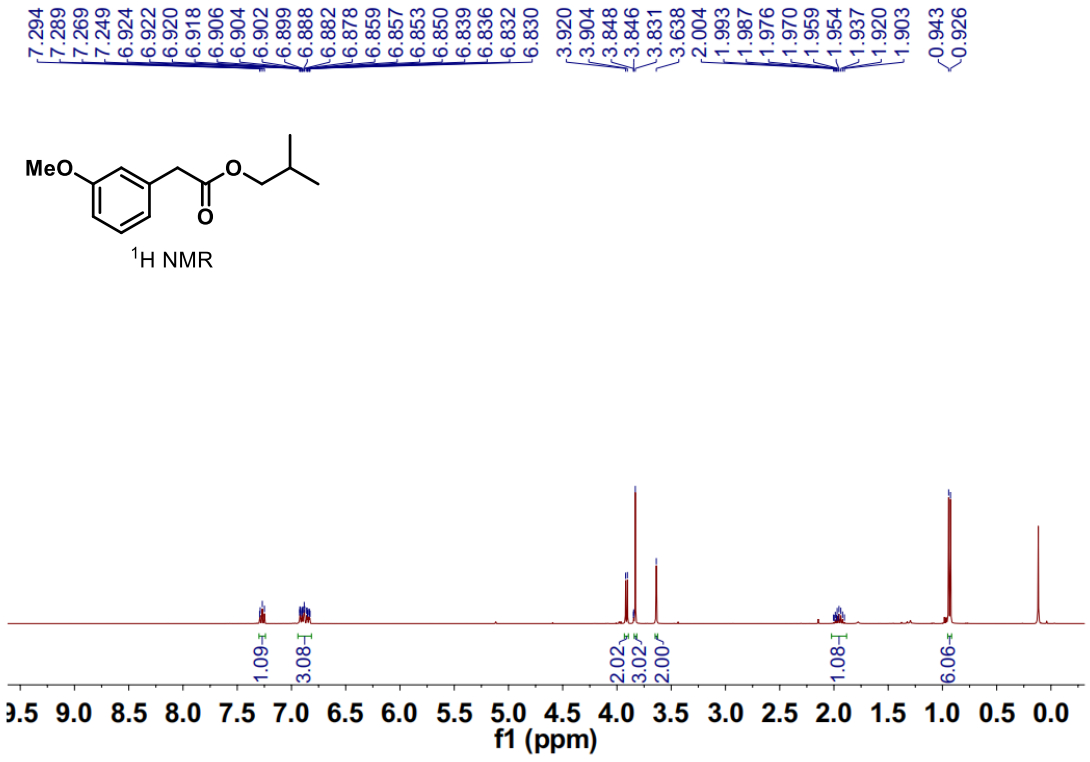
135.747
129.490
121.570
114.748
112.583
68.239
55.184
41.772
21.798
MeO
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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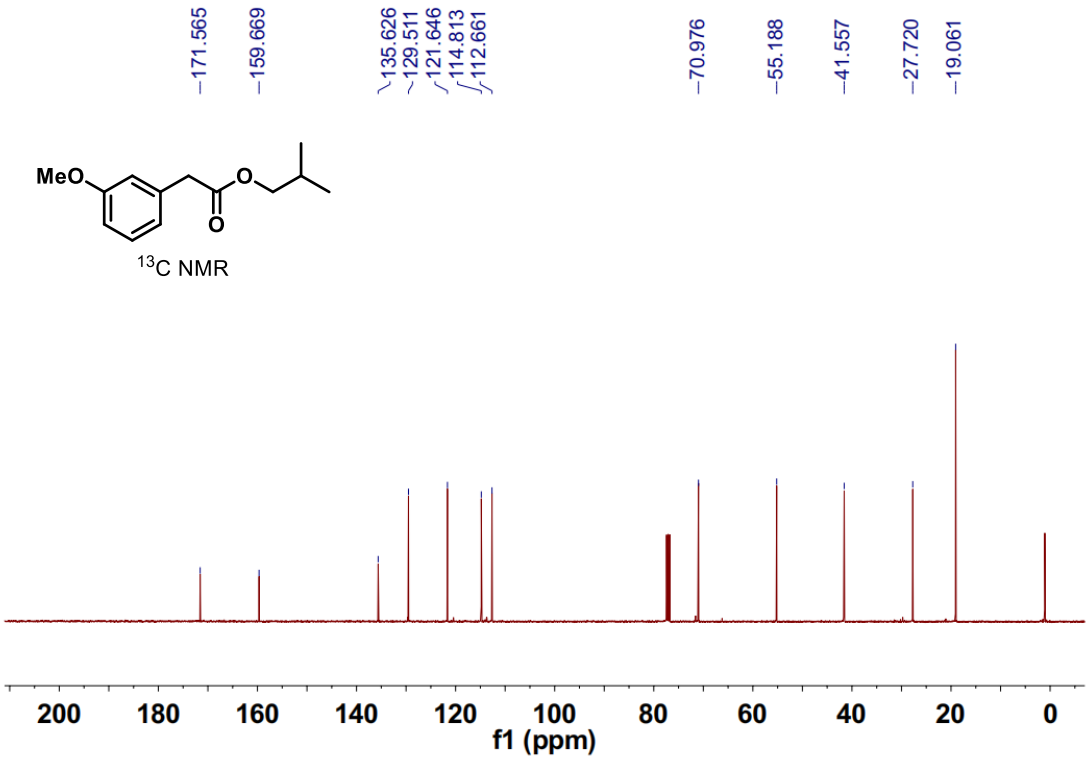
7.289
7.269
7.249
6.924
6.922
6.920
6.918
6.906
6.904
6.902
6.899
6.888
6.882
6.878
6.859
6.857
6.853
6.850
6.839
6.836
6.832
6.830
3.920
3.904
3.848
3.846
3.831
3.638
2.004
1.993
1.987
1.976
1.970
1.959
1.954
1.937
1.920
1.903
0.943
0.926
MeO
O
O
1H NMR
1.09
3.08
2.02
3.02
2.00
1.08
6.06
9.5
9.0
8.5
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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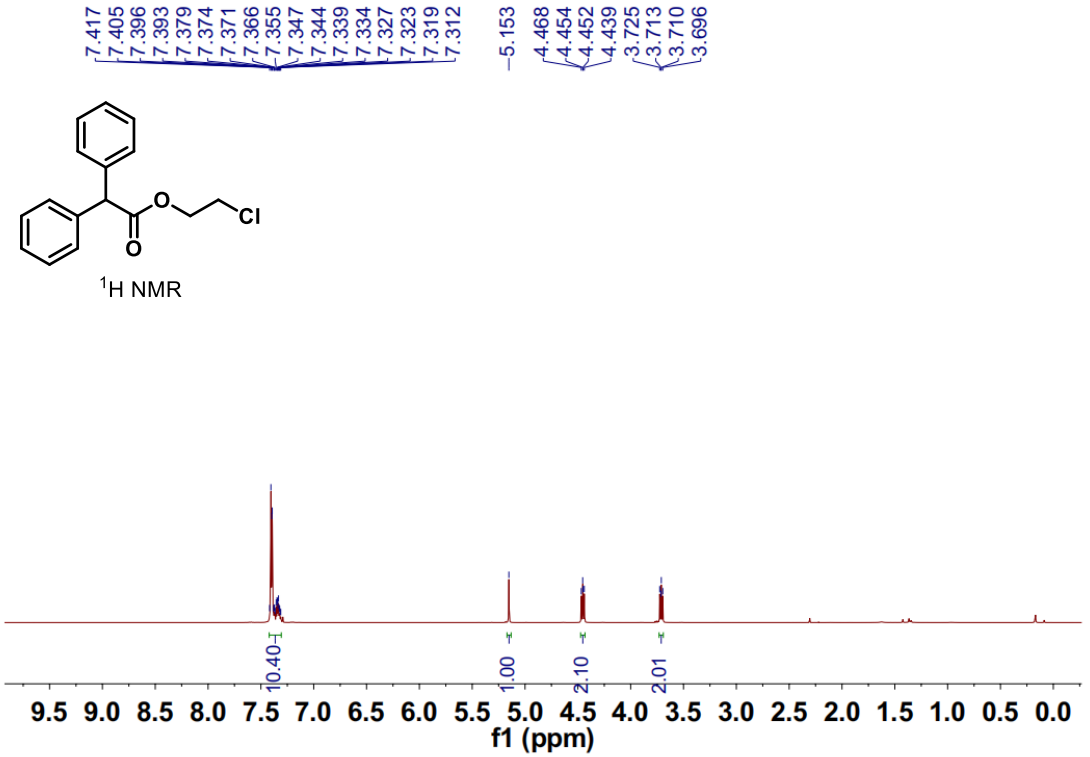
135.626
129.511
121.646
114.813
112.661
70.976
55.188
41.557
27.720
19.061
MeO
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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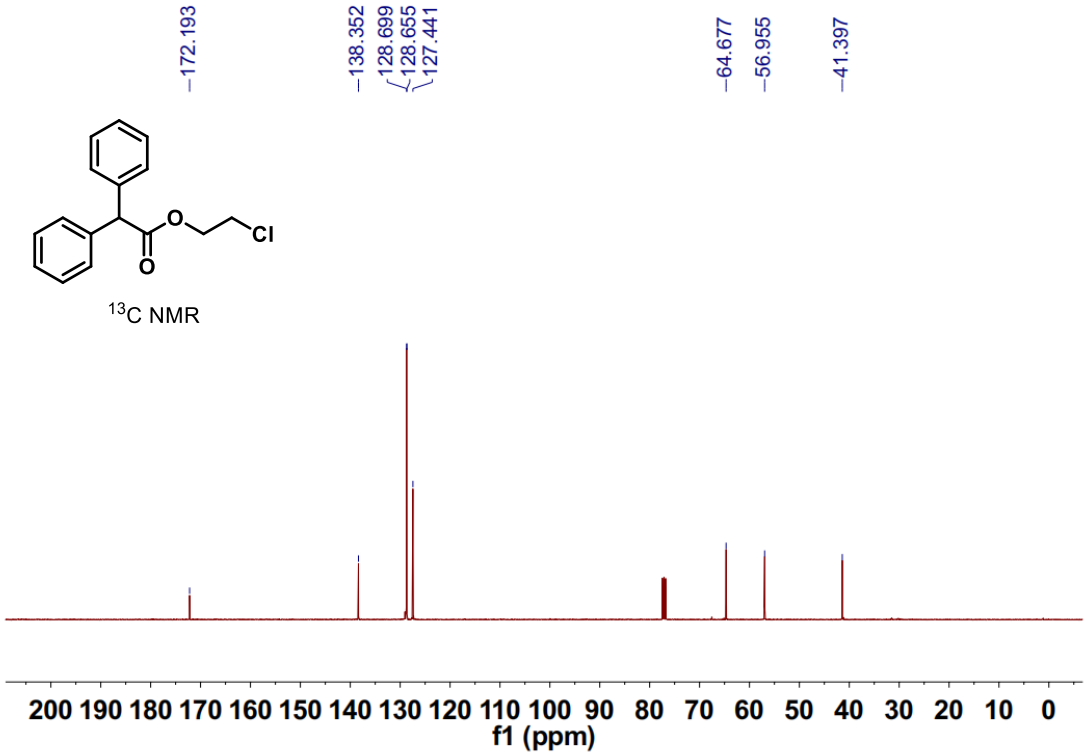
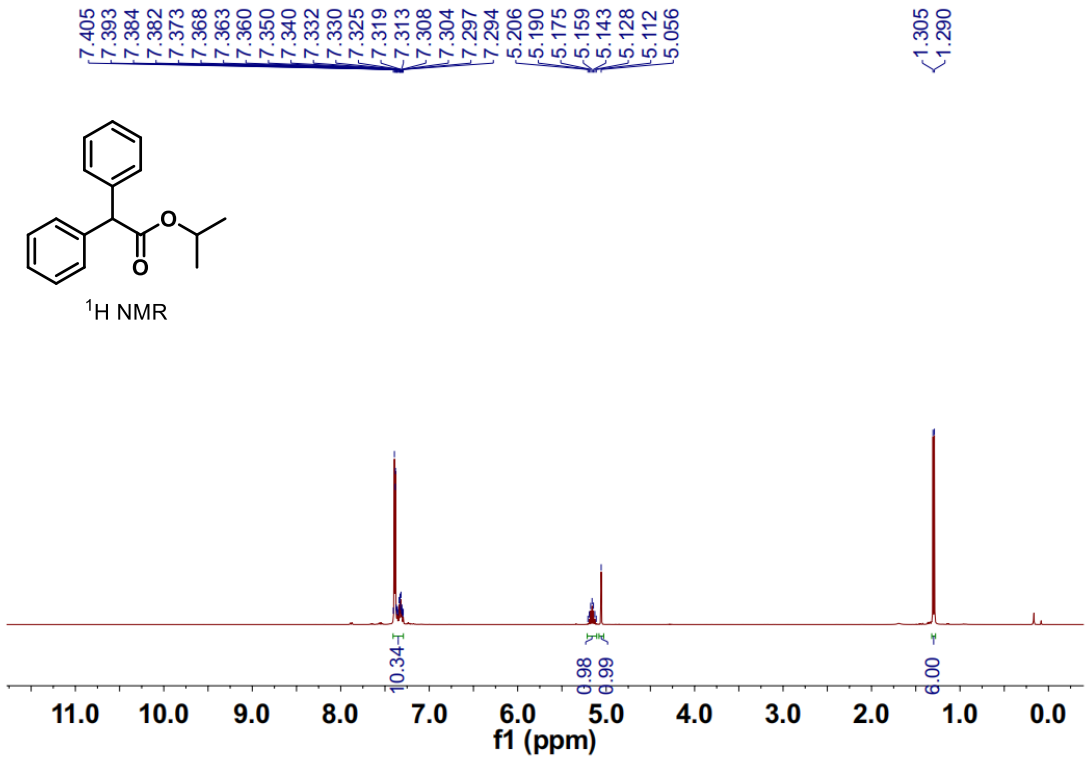
7.396
7.393
7.379
7.374
7.371
7.366
7.355
7.347
7.344
7.339
7.334
7.327
7.323
7.319
7.312
5.153
4.468
4.454
4.452
4.439
3.725
3.713
3.710
3.696
O
O
Cl
1H NMR
10.40
1.00
2.10
2.01
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


172.193
138.352
128.699
128.655
127.441
64.677
56.955
41.397
O
O
Cl
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.382
7.373
7.368
7.363
7.360
7.350
7.340
7.332
7.330
7.325
7.319
7.313
7.308
7.304
7.297
7.294
5.206
5.190
5.175
5.159
5.143
5.128
5.112
5.056
1.305
1.290
O
O
1H NMR
10.34
0.98
0.99
6.00
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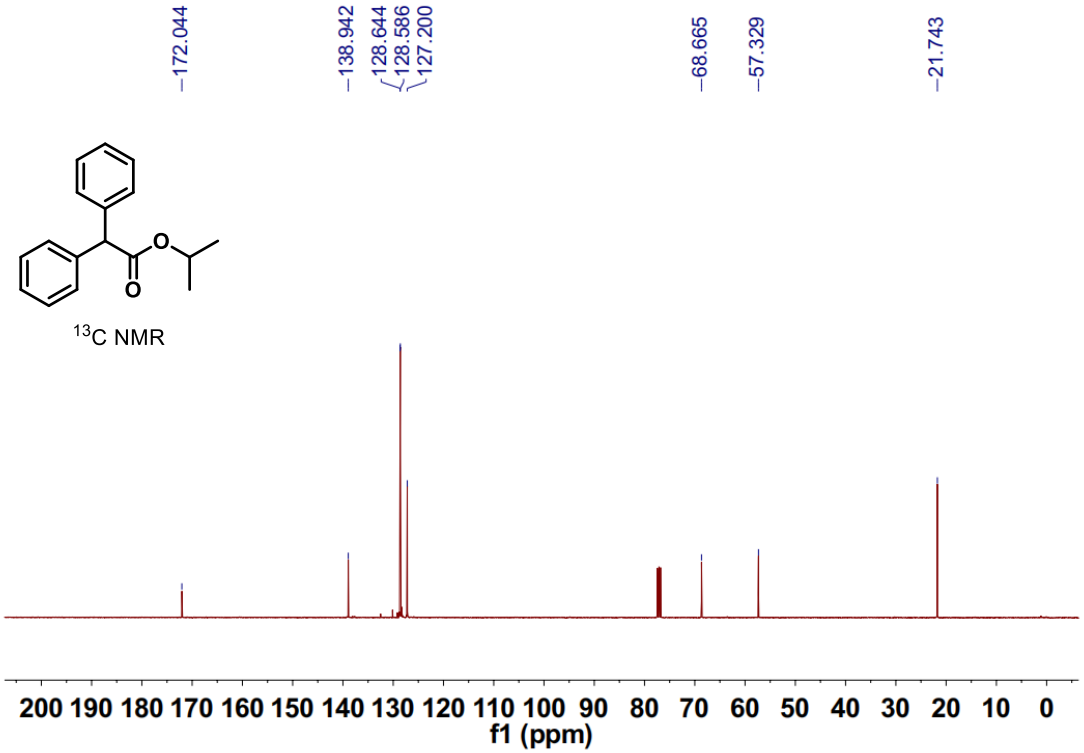
f1 (ppm)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128.586
127.200
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21.743
O
O
13C NMR
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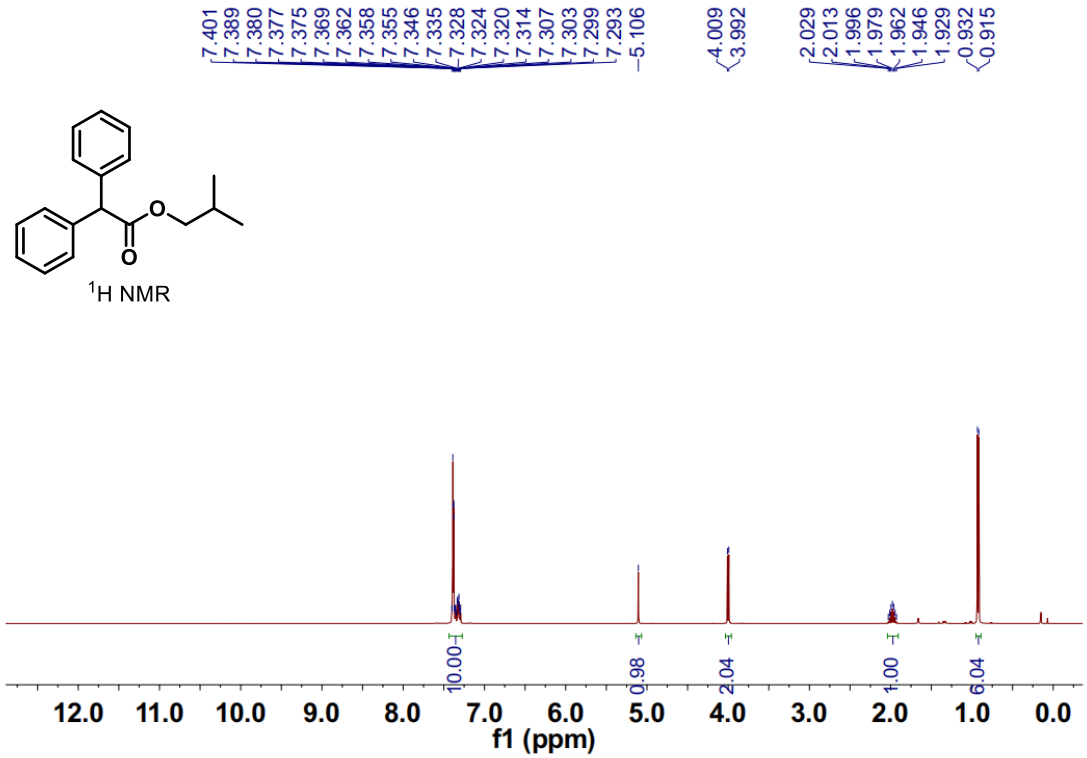
f1 (ppm)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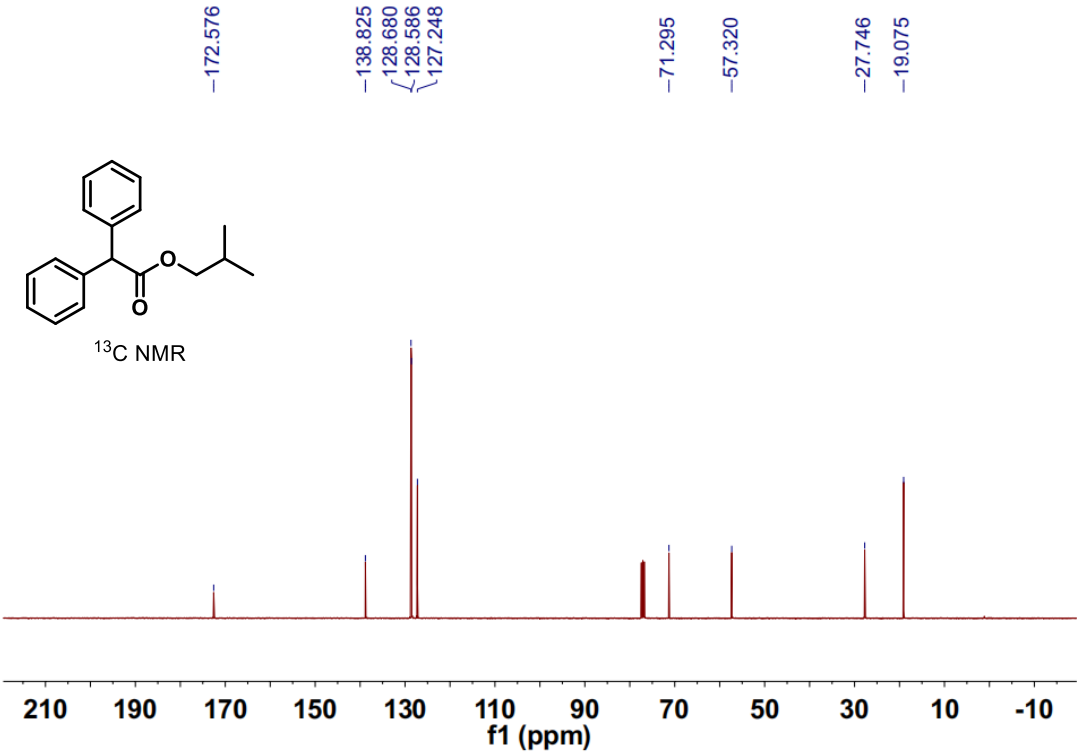
7.377
7.375
7.369
7.362
7.358
7.355
7.346
7.335
7.328
7.324
7.320
7.314
7.307
7.303
7.299
7.293
5.106
4.009
3.992
2.029
2.013
1.996
1.979
1.962
1.946
1.929
0.932
0.915
O
O
1H NMR
10.00
0.98
2.04
1.00
6.04
12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)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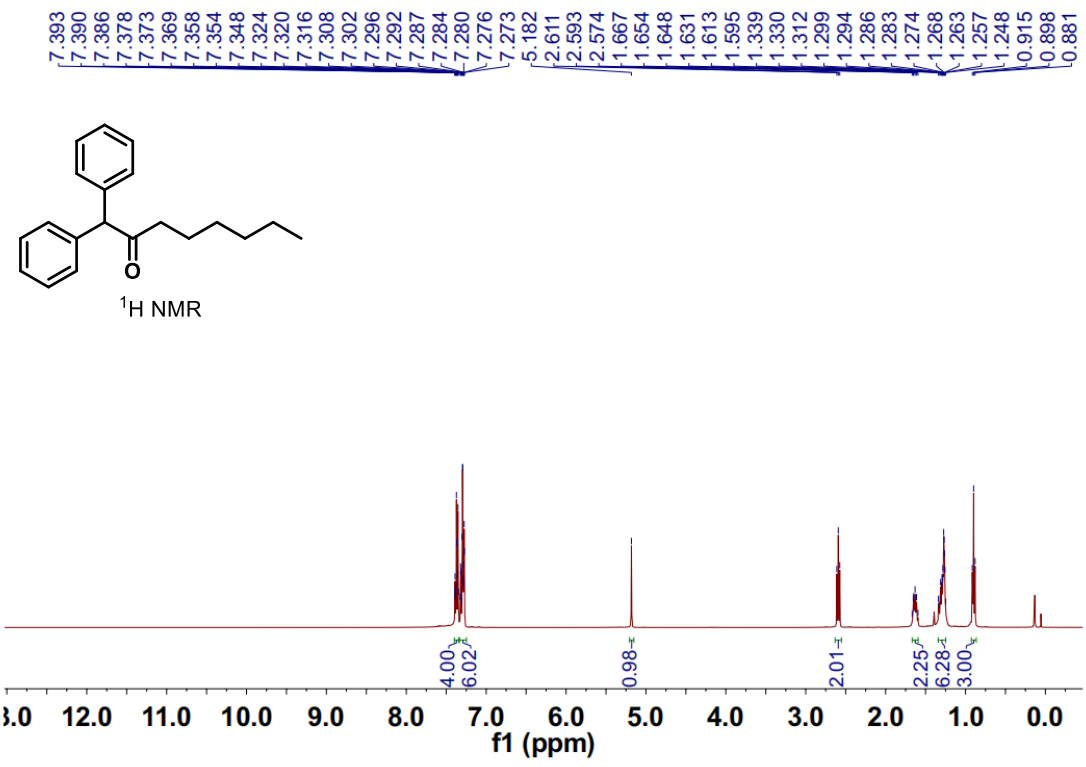
O
O
13C NMR
210 190 170 150 130 110 90 70 50 30 10 -10
f1 (ppm)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7.386
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7.373
7.369
7.358
7.354
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7.324
7.320
7.316
7.308
7.302
7.296
7.292
7.287
7.284
7.280
7.276
7.273
5.182
2.611
2.593
2.574
1.667
1.654
1.648
1.631
1.613
1.595
1.339
1.330
1.312
1.299
1.294
1.286
1.283
1.274
1.268
1.263
1.257
1.248
0.915
0.898
0.881
O
1H NMR
4.00
6.02
0.98
2.01
2.25
6.28
3.00
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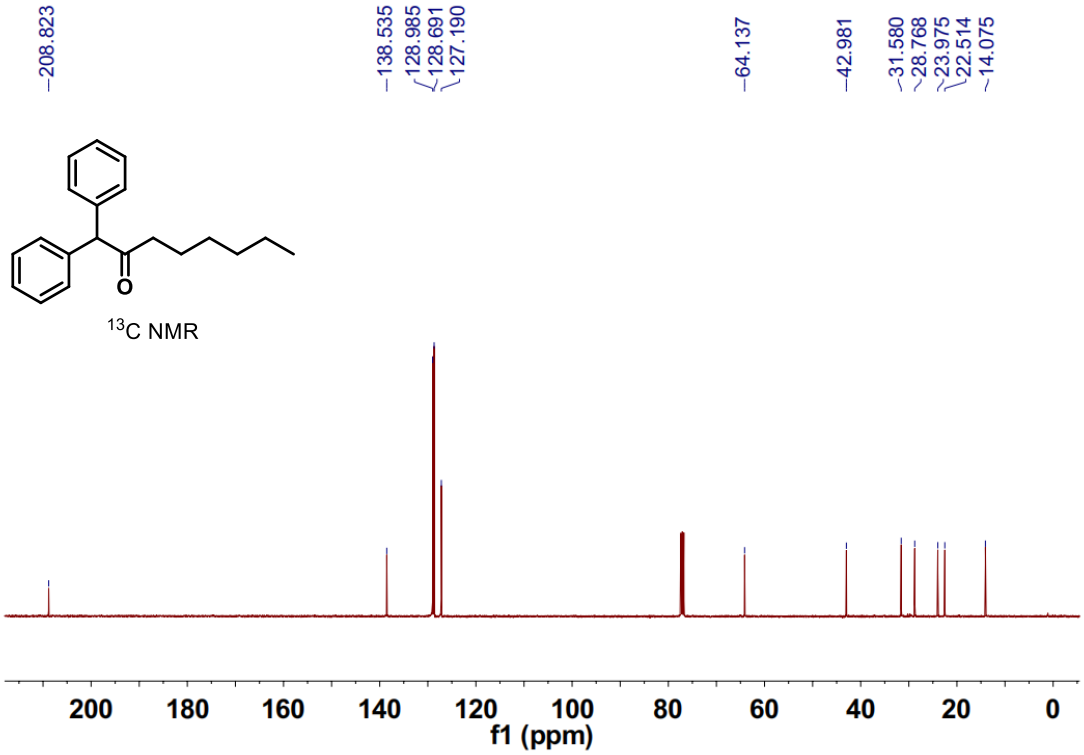
f1 (ppm)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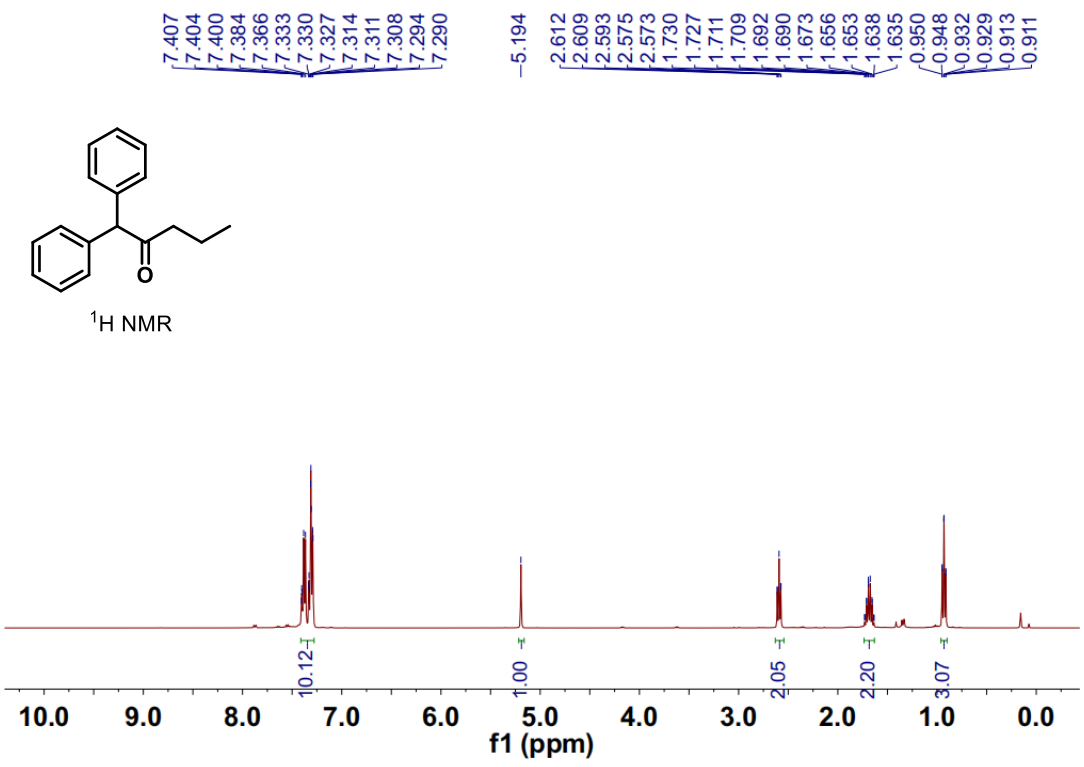
128.691
127.190
64.137
42.981
31.580
28.768
23.975
22.514
14.075
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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7.400
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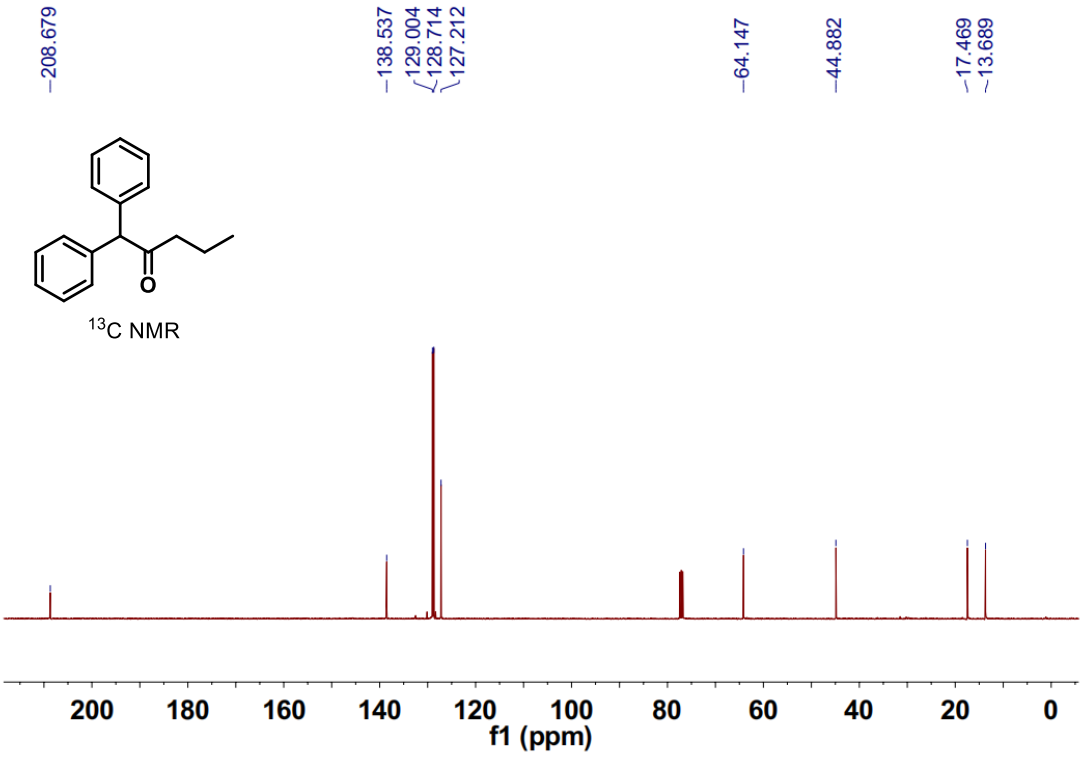
7.366
7.333
7.330
7.327
7.314
7.311
7.308
7.294
7.290
5.194
2.612
2.609
2.593
2.575
2.573
1.730
1.727
1.711
1.709
1.692
1.690
1.673
1.656
1.653
1.638
1.635
0.950
0.948
0.932
0.929
0.913
0.911
O
1H NMR
10.12
1.00
2.05
2.20
3.07
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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O
13C NMR
200
180
160
140
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100
80
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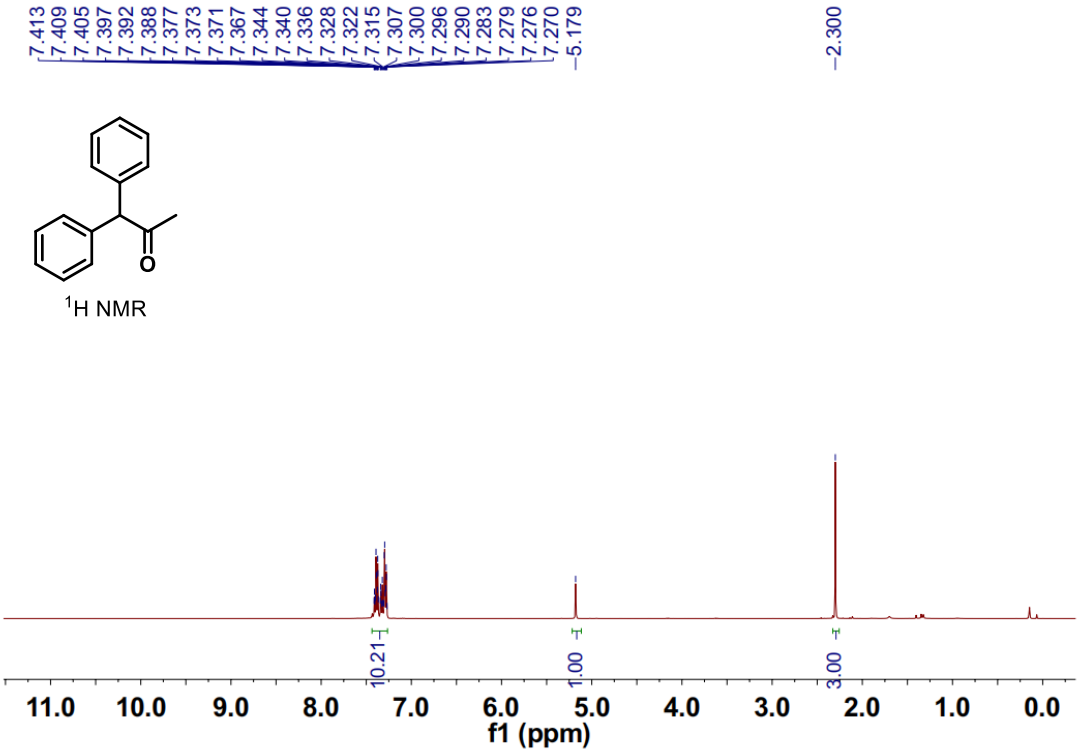
40
20
0
f1 (ppm)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7.397
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7.388
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7.373
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7.367
7.344
7.340
7.336
7.328
7.322
7.315
7.307
7.300
7.296
7.290
7.283
7.279
7.276
7.270
5.179
2.300
O
1H NMR
10.21
1.00
3.00
11.0
10.0
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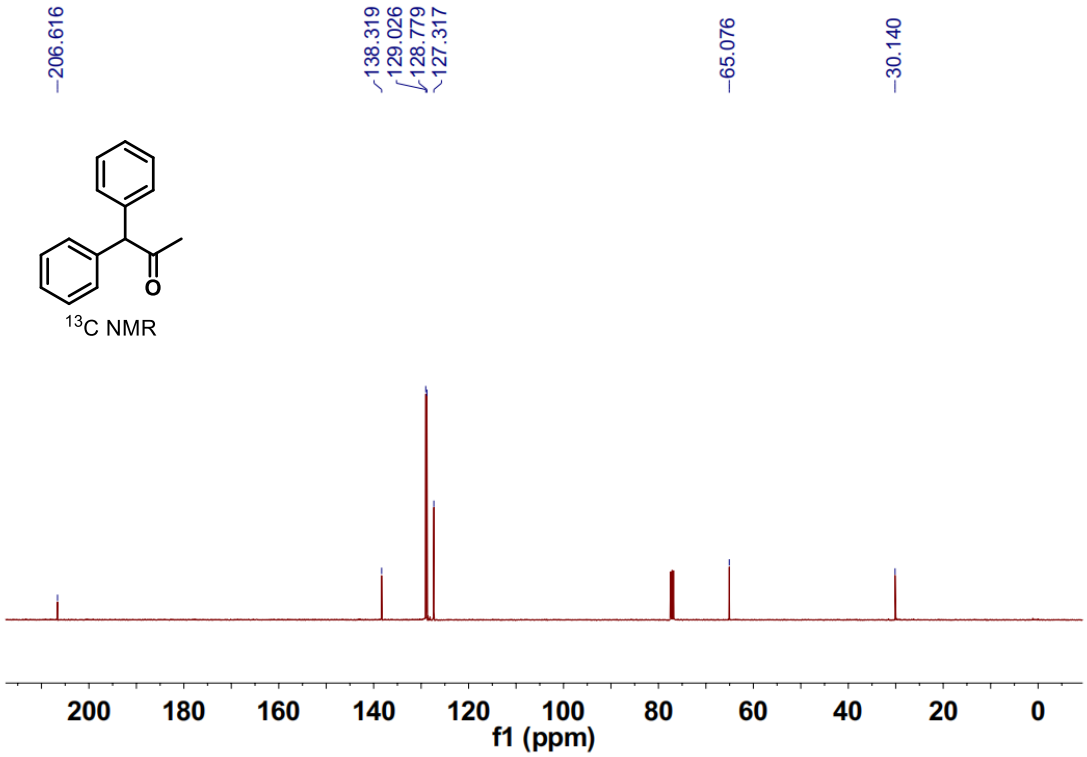
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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127.317
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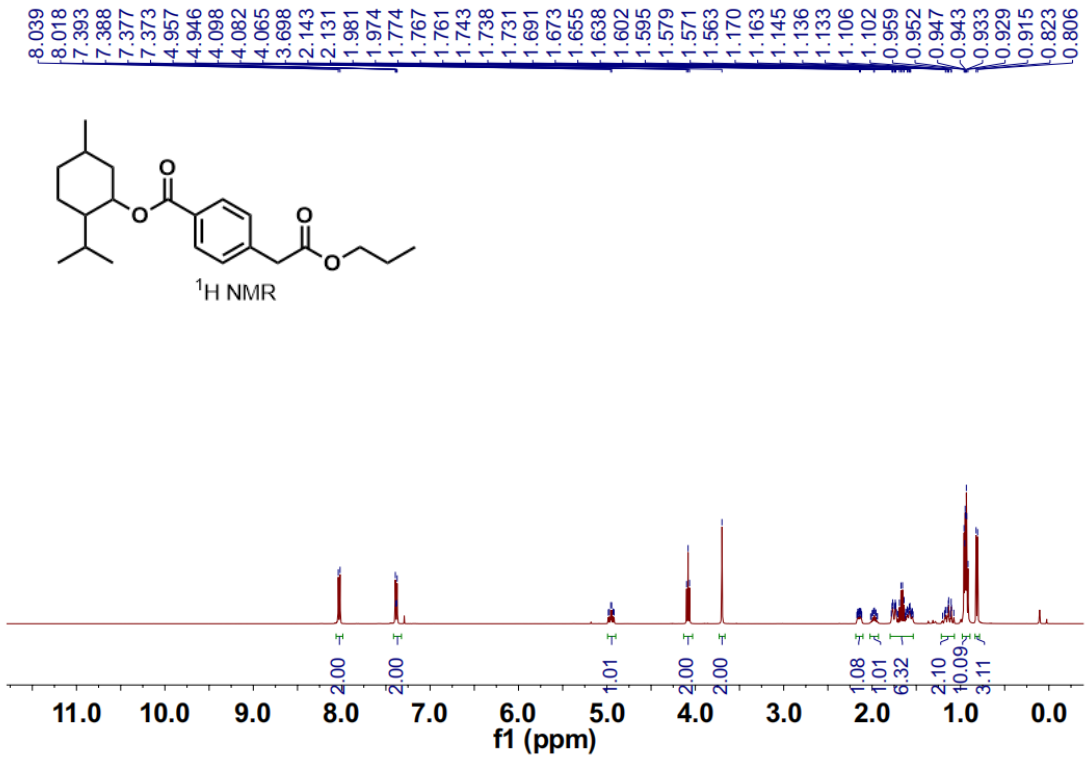
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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8.018
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7.388
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7.373
4.957
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2.131
1.981
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1.767
1.761
1.743
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1.731
1.691
1.673
1.655
1.638
1.602
1.595
1.579
1.571
1.563
1.170
1.163
1.145
1.136
1.133
1.106
1.102
0.959
0.952
0.947
0.943
0.933
0.929
0.915
0.823
0.806
O
O
O
O
1H NMR
2.00
2.00
1.01
2.00
2.00
1.08
1.01
6.32
2.10
10.09
3.11
11.0
10.0
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5.0
4.0
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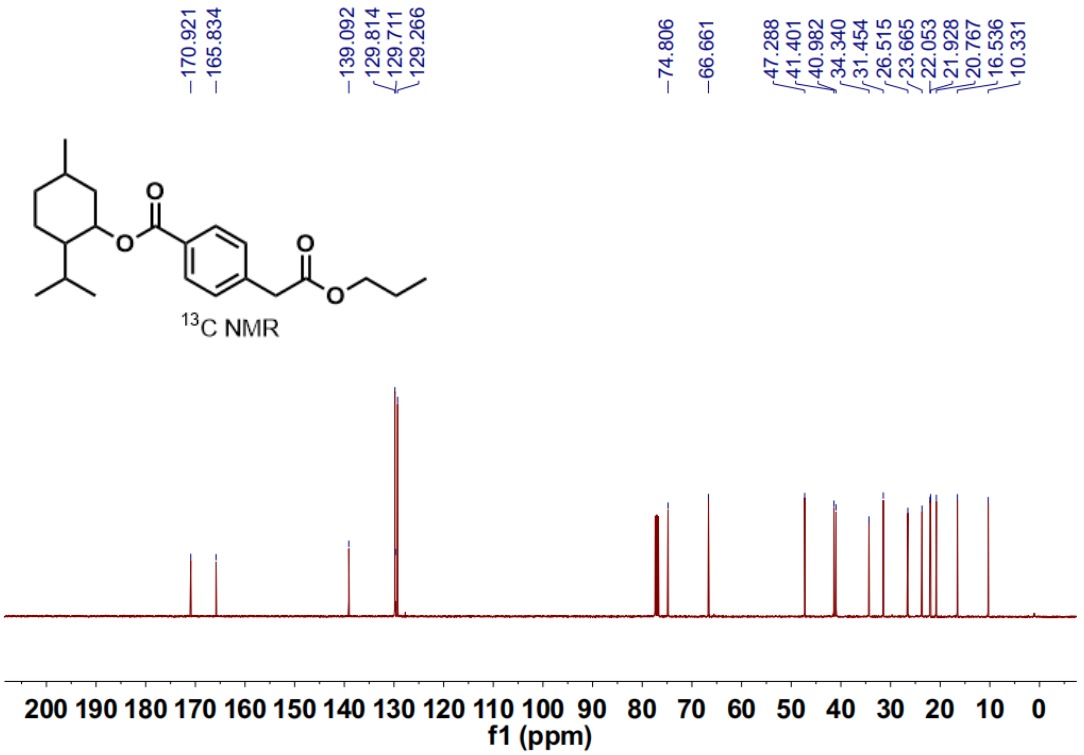
2.0
1.0
0.0
f1 (ppm)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129.266
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66.661
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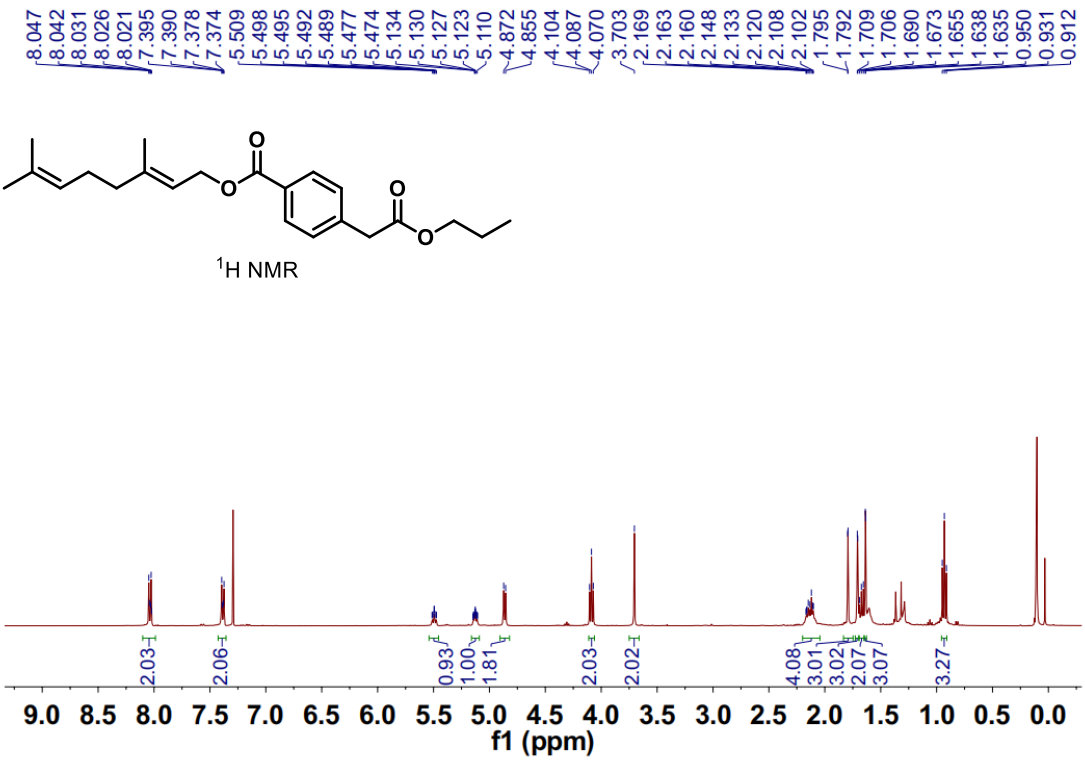
41.401
40.982
34.340
31.454
26.515
23.665
22.053
21.928
20.767
16.536
10.331
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.378
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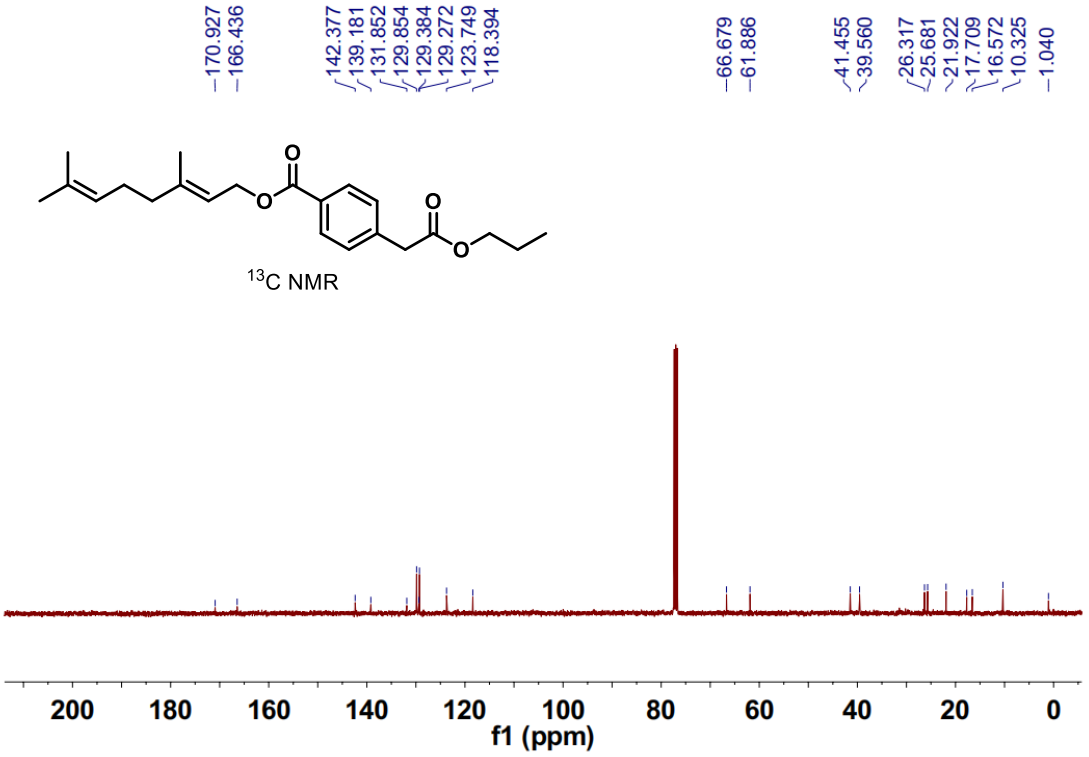
5.495
5.492
5.489
5.477
5.474
5.134
5.130
5.127
5.123
5.110
4.872
4.855
4.104
4.087
4.070
3.703
2.169
2.163
2.160
2.148
2.133
2.120
2.108
2.102
1.795
1.792
1.709
1.706
1.690
1.673
1.655
1.638
1.635
0.950
0.931
0.912
1H NMR
2.03
2.06
0.93
1.00
1.81
2.03
2.02
4.08
3.01
3.02
2.07
3.07
3.27
9.0 8.5 8.0 7.5 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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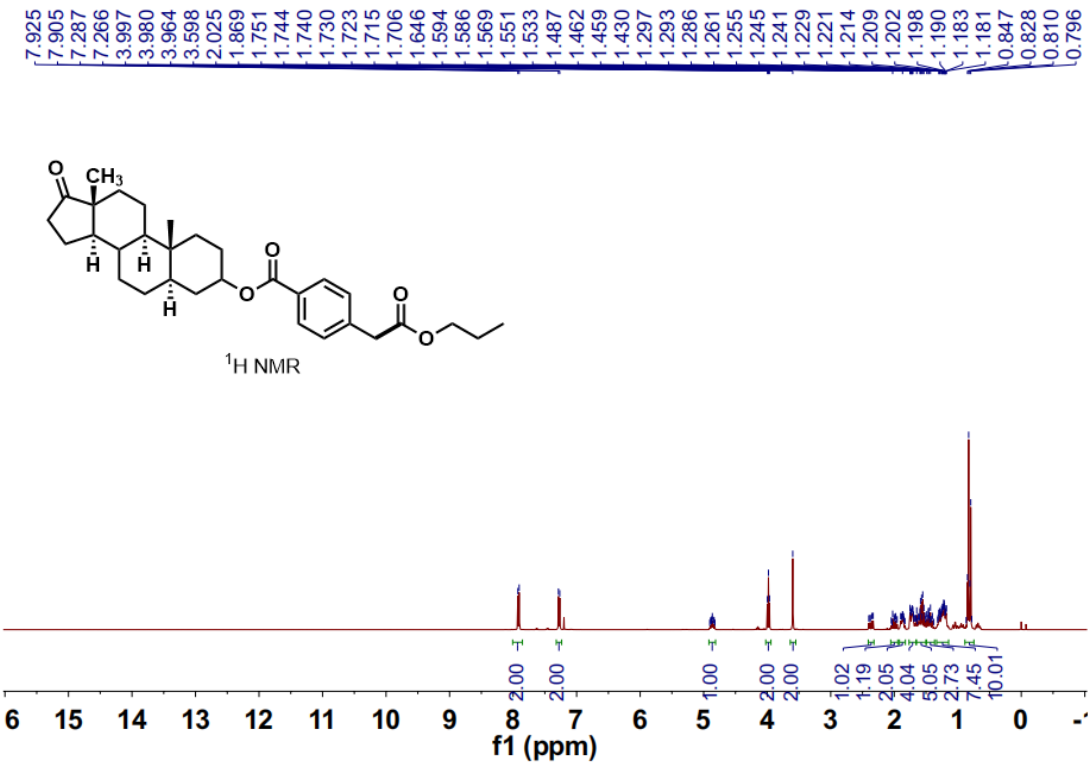
166.436
142.377
139.181
131.852
129.854
129.384
129.272
123.749
118.394
66.679
61.886
41.455
39.560
26.317
25.681
21.922
17.709
16.572
10.325
1.040
O
O
O
O
13C NMR
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)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7.287
7.266
3.997
3.980
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3.598
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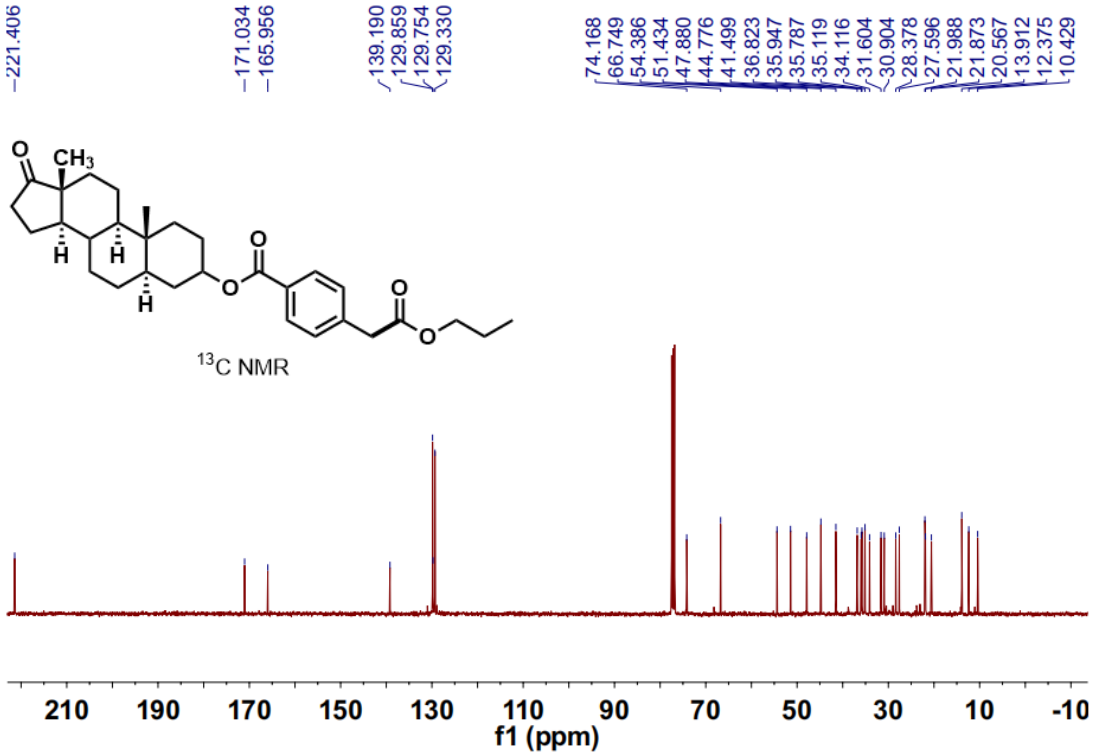
1.744
1.740
1.730
1.723
1.715
1.706
1.646
1.594
1.586
1.569
1.551
1.533
1.487
1.462
1.459
1.430
1.297
1.293
1.286
1.261
1.255
1.245
1.241
1.229
1.221
1.214
1.209
1.202
1.198
1.190
1.183
1.181
0.847
0.828
0.810
0.796
O
CH3
H
H
H
O
O
O
O
1H NMR
2.00
2.00
1.00
2.00
2.00
1.02
1.19
2.05
4.04
5.05
2.73
7.45
10.01
6
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)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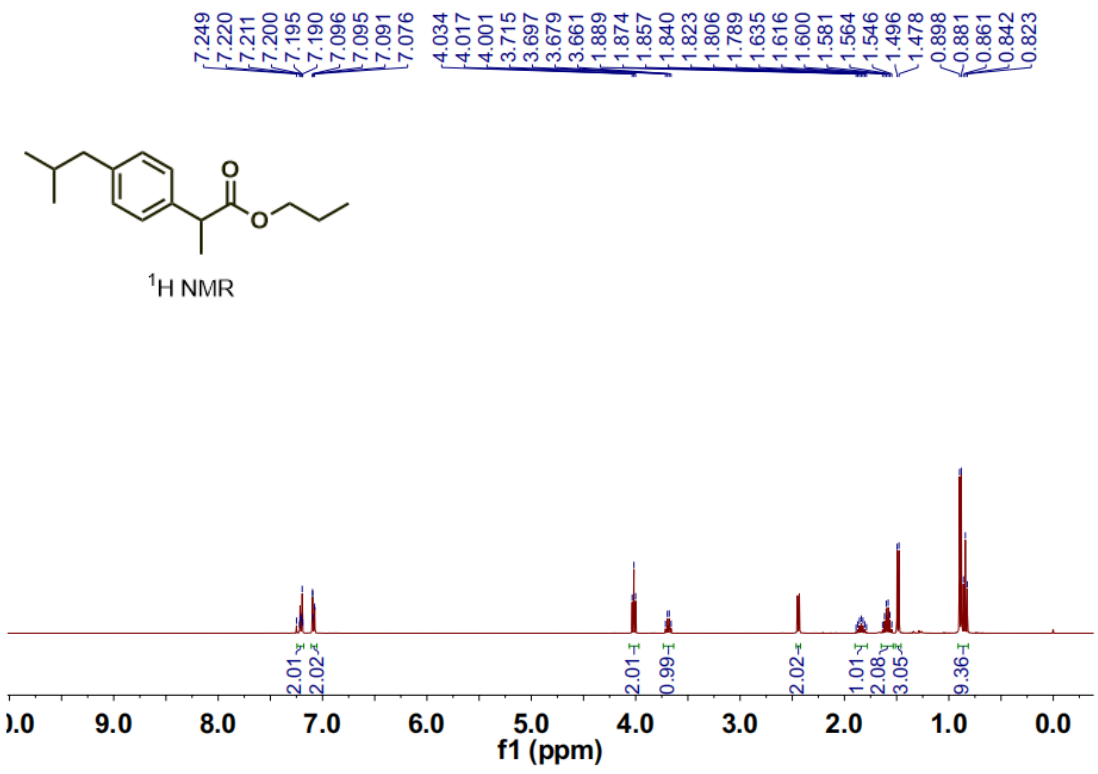
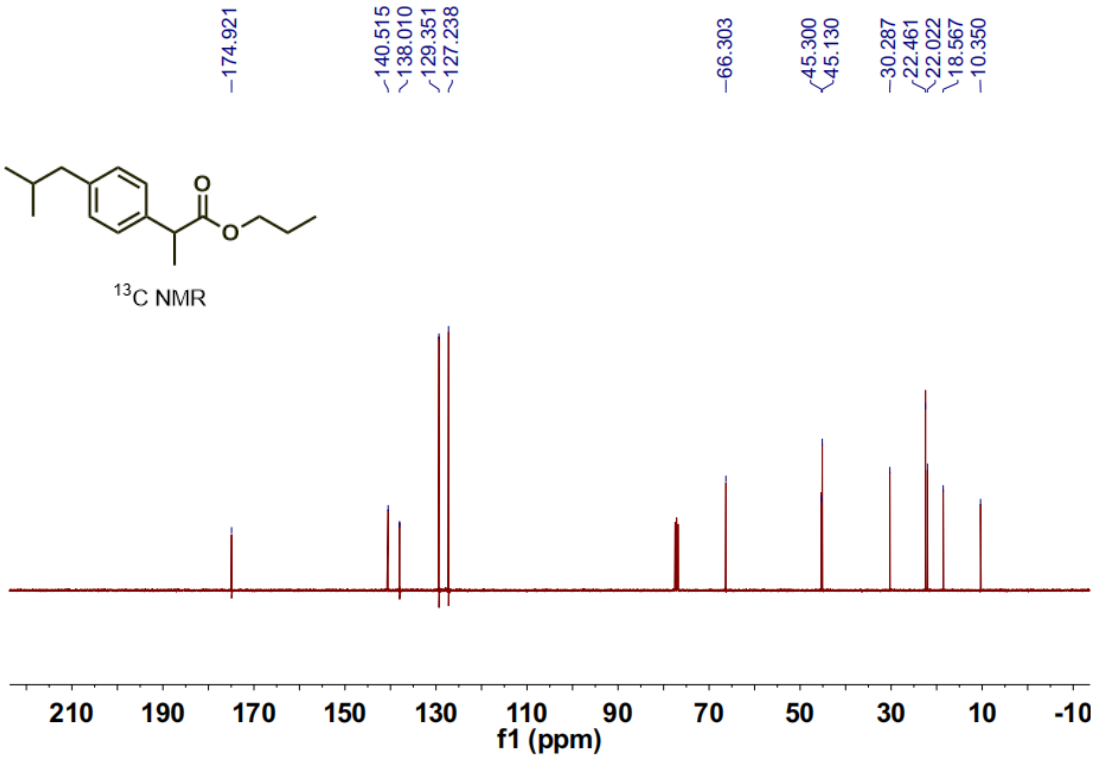
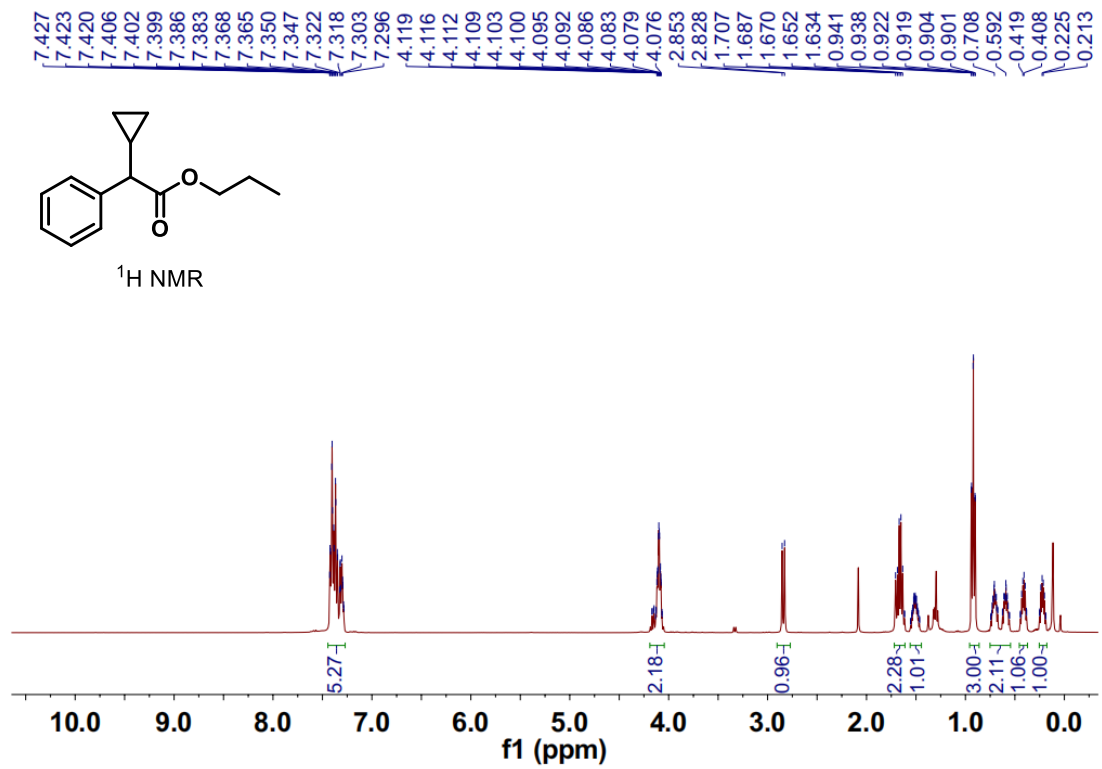
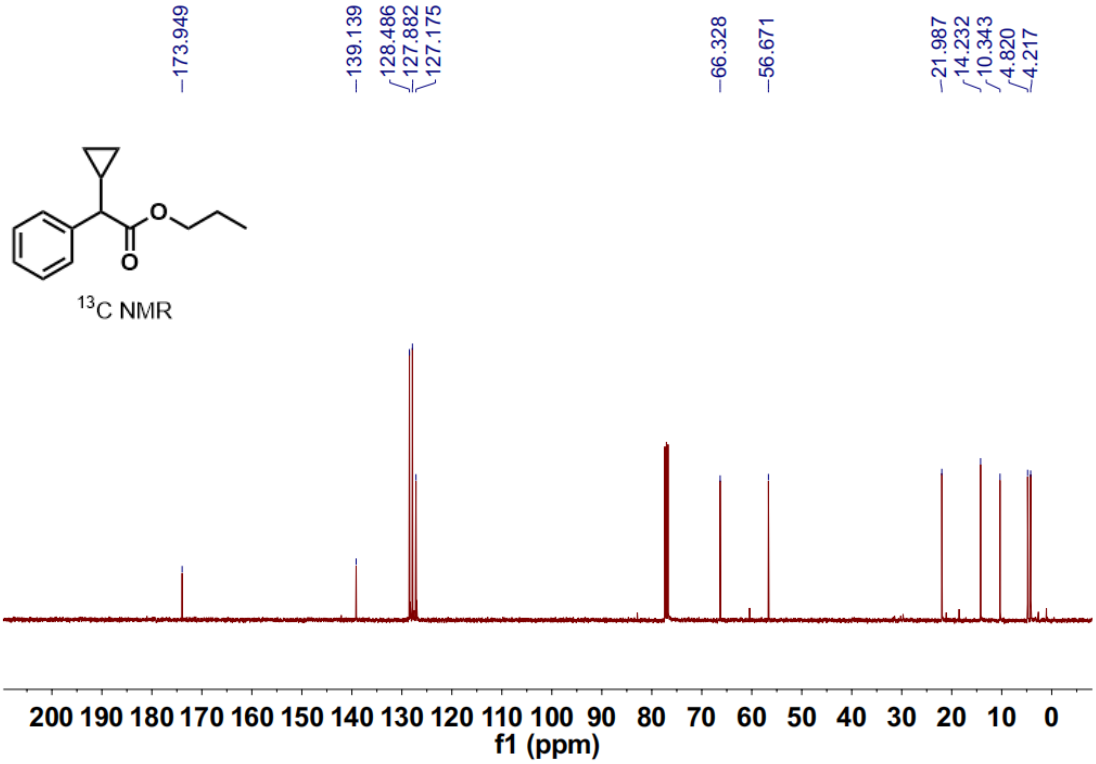
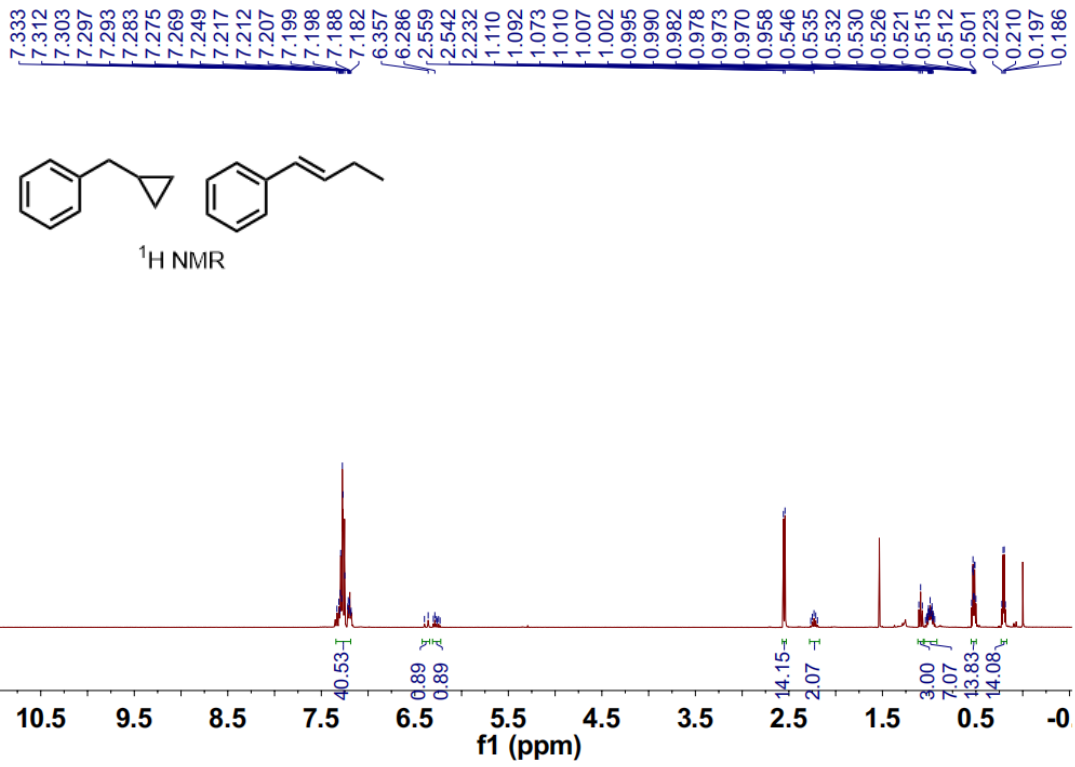
171.034
165.956
139.190
129.859
129.754
129.330
74.168
66.749
54.386
51.434
47.880
44.776
41.499
36.823
35.947
35.787
35.119
34.116
31.604
30.904
28.378
27.596
21.988
21.873
20.567
13.912
12.375
10.429
O
CH3
H
H
H
O
O
O
O
13C NMR
210
190
170
150
130
110
90
70
50
30
10
-10
f1 (ppm)

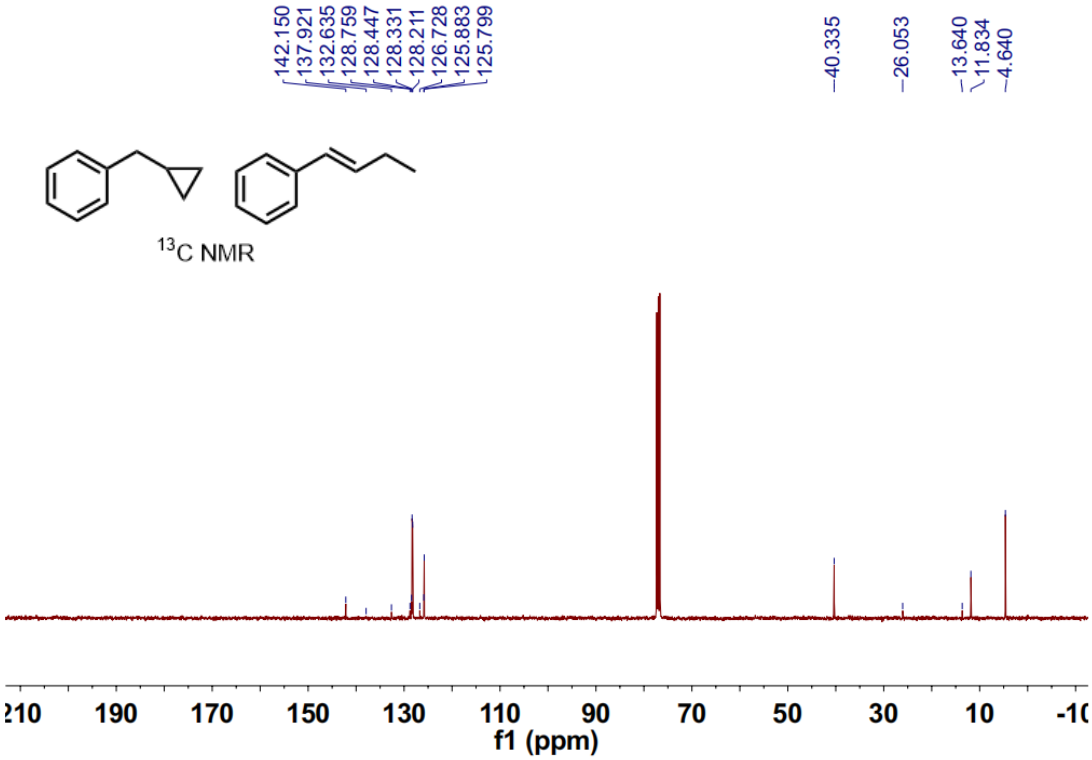

7.249
7.220
7.211
7.200
7.195
7.190
7.096
7.095
7.091
7.076
4.034
4.017
4.001
3.715
3.697
3.679
3.661
1.889
1.874
1.857
1.840
1.823
1.806
1.789
1.635
1.616
1.600
1.581
1.564
1.546
1.496
1.478
0.898
0.881
0.861
0.842
0.823
O
O
1H NMR
2.01
2.02
2.01
0.99
2.02
1.01
2.08
3.05
9.36
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


174.921
140.515
138.010
129.351
127.238
66.303
45.300
45.130
30.287
22.461
22.022
18.567
10.350
O
O
13C NMR
210
190
170
150
130
110
90
70
50
30
10
-10
f1 (ppm)


7.427
7.423
7.420
7.406
7.402
7.399
7.386
7.383
7.368
7.365
7.350
7.347
7.322
7.318
7.303
7.296
4.119
4.116
4.112
4.109
4.103
4.100
4.095
4.092
4.086
4.083
4.079
4.076
2.853
2.828
1.707
1.687
1.670
1.652
1.634
0.941
0.938
0.922
0.919
0.904
0.901
0.708
0.592
0.419
0.408
0.225
0.213
O
O
1H NMR
5.27
2.18
0.96
2.28
1.01
3.00
2.11
1.06
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


173.949
139.139
128.486
127.882
127.175
66.328
56.671
21.987
14.232
10.343
4.820
4.217
O
O
13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.333
7.312
7.303
7.297
7.293
7.283
7.275
7.269
7.249
7.217
7.212
7.207
7.199
7.198
7.188
7.182
6.357
6.286
2.559
2.542
2.232
1.110
1.092
1.073
1.010
1.007
1.002
0.995
0.990
0.982
0.978
0.973
0.970
0.958
0.546
0.535
0.532
0.530
0.526
0.521
0.515
0.512
0.501
0.223
0.210
0.197
0.186
1H NMR
40.53
0.89
0.89
14.15
2.07
3.00
7.07
13.83
14.08
10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)


142.150
137.921
132.635
128.759
128.447
128.331
128.211
126.728
125.883
125.799
40.335
26.053
13.640
11.834
4.640
13C NMR
210
190
170
150
130
110
90
70
50
30
10
-10
f1 (ppm)

References

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[3] Grabulosa A, Frew J J R, Fuentes J A, et al. Palladium complexes of bulky ortho-trifluoromethylphenyl-substituted phosphines: Unusually regioselective catalysts for the hydroxycarbonylation and alkoxycarbonylation of alkenes [J]. Journal of Molecular Catalysis A: Chemical, 2010, 330(1-2): 18-25.

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