Supporting Information

One-Pot Synthesis of Ketones and Symmetrical Anhydrides from Carboxylic Acids

Sayanta Roy, Gobinda Dolai, SK Ariyan, Bhubaneswar Mandal*

Department of Chemistry, Laboratory of Peptide and Amyloid Research, Indian Institute of Technology Guwahati, Assam-781039, India. E-mail: bmandal@iitg.ac.in

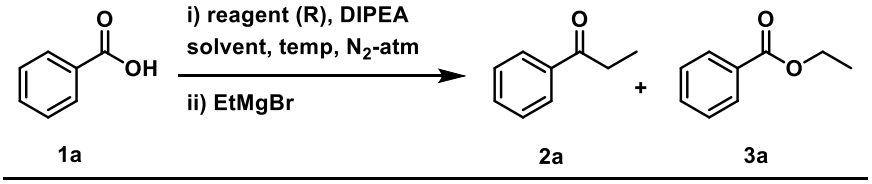
Table of contents

Experimental section:

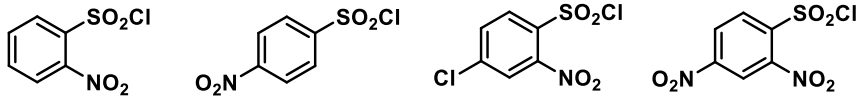
(A) General information

Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. All the reactions were performed in dry solvents. TLC (TLC Plates Aluminium Backed Silica Gel 60 F254 2.5 x 7.5 cm) was performed to monitor the reaction progress in solution. All the synthesized products were purified by either glass silica TLC or column chromatography using ethyl acetate and hexane as eluents. The isolated products were characterized by ^{1}H, $^{13}C\{^{1}H\}$ NMR, and HRMS analysis. All the NMR were recorded in $CDCl_3$ (Sigma Aldrich) solvent in 600 MHz Bruker instrument at 298 K. The chemical shifts are mentioned in ppm (parts per million) units. ^{1}H NMR is depicted as Chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, doublet of doublet (dd), m = multiplet), integration and coupling constant (*J* in Hz). All the High-resolution mass spectra (HRMS) were recorded using an electrospray ionization time-of-flight (ESI-TOF) Mass Spectrometer. Single-crystal X-ray experiments were performed using Bruker SC-XRD instrument. The data refinement was done using XShell 6.3.1 software.

Table S1. Optimization of reaction conditions for ketone synthesis



Reagents (R):

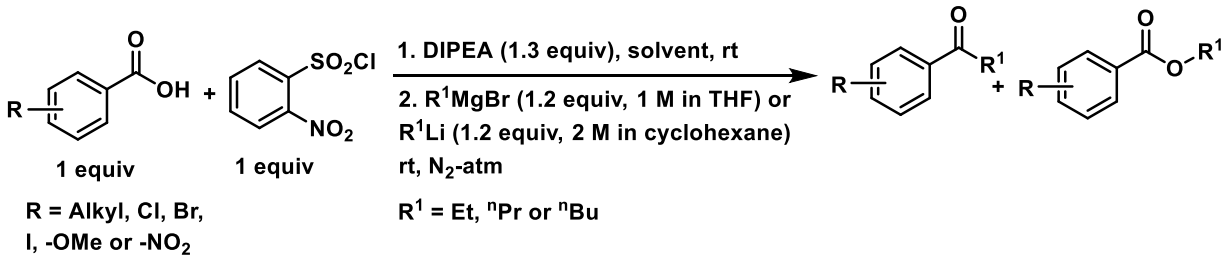


Entry	Reagents (R)	Solvent	Temp (°C)	Time	2a (%)	3a (%)
1[a]	1Xa	THF	-20	6 h	46	14
2[a]	1Xa	THF	0	2 h	49	15
3[a]	1Xa	THF	25	1.3 h	40	13
4[a]	1Xa	THF	40	1 h	13	8
5[b]	1Xa	THF	0	1.3 h	32	11
6[a]	1Xa	1,4-dioxane	0	2 h	10	8
7[a]	1Xa	diethyl ether	0	30 min	50	17
8[a]	1Xa	toluene	0	35 min	64	12
9[a]	1Xa	chlorobenzene	0	8 h	8	8
10[a]	1Xa	benzene	0	7 h	9	7
11[a]	1Xa	toluene	0	6 h	62	9
12[a]	1Xb	toluene	0	6 h	13	nd
13[a]	1Xc	toluene	0	6 h	24	6
14[a]	1Xd	toluene	0	6 h	nd	nd

Reaction conditions: [a]1a (1 mmol, 1 equiv), R (1 mmol, 1 equiv), DIPEA (1.3 mmol, 1.3 equiv), solvent, temp, N_2-atm, EtMgBr (1.2 mL, 1.2 mmol, 1.2 equiv, 1 M in THF); [b]EtMgBr (1.5 mL, 1.5 mmol, 1.5 equiv, 1 M in THF); nd = not determined; Isolated yield.

General procedure for the synthesis of ketones from carboxylic acids

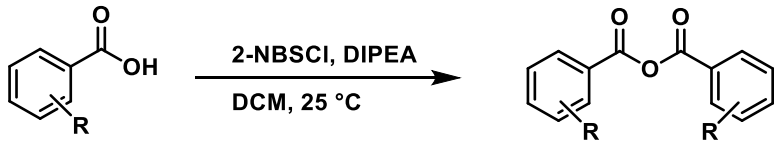
General procedure A:



To an oven-dried 25 mL two-neck round-bottom flask, carboxylic acid (1 mmol) and 2-nitrobenzenesulfonyl chloride (1 mmol) were added. After purging the flask with nitrogen, DIPEA (1.3 mmol) and dry solvent (2 mL toluene or THF (for aryl Grignard)) were introduced. The reaction mixture was stirred at room temperature for ~1 hour, and intermediate formation was monitored via TLC. Subsequently, the mixture was cooled in an ice bath, and R^1MgBr or ^nBuLi (1.2 mmol) was added dropwise. Upon complete consumption of the intermediate (confirmed by TLC), the reaction was quenched with saturated aq. NH_4Cl solution. The organic solvent was removed under reduced pressure using a rotary evaporator. The residue was extracted with ethyl acetate, dried over anhydrous Na_2SO_4, and concentrated. Purification was carried out using silica gel preparative TLC (ethyl acetate/hexane (1:99→2:98)) or column chromatography to obtain the final product.

Procedure for the synthesis of symmetrical anhydrides

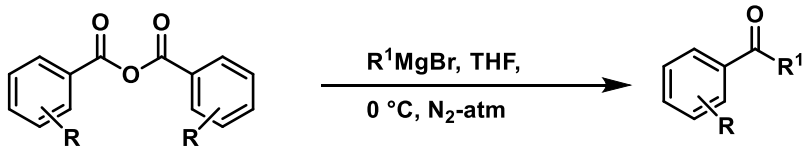
General procedure B:



To an oven-dried 25 mL round-bottom flask, carboxylic acid (1 mmol) and 2-nitrobenzenesulfonyl chloride (0.5 mmol) were added. After that, DIPEA (1 mmol) and DCM (2 mL) were introduced. The reaction mixture was stirred at room temperature for ~2 hours, and the consumption of the starting material was monitored via TLC. After completely consuming the starting material (confirmed by TLC), the reaction was concentrated under reduced pressure using a rotary evaporator. The crude was purified via silica gel column chromatography using ethyl acetate/hexane (2:98→5:95) to obtain the final product.

Procedure for the synthesis of ketones from the symmetrical anhydrides

General procedure C:



To an oven-dried 25 mL two-neck round-bottom flask, symmetrical anhydride (1 mmol) was added. After purging the flask with nitrogen, dry THF (2 mL) was introduced. It was then cooled in an ice bath, and R^1MgBr (1.2 mmol) was added dropwise. Upon complete

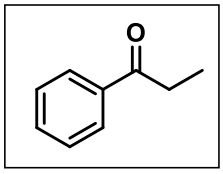
consumption of the anhydride (confirmed by TLC), the reaction was quenched with saturated NH_4Cl solution. The organic solvent was removed under reduced pressure using a rotary evaporator. The residue was extracted with ethyl acetate, dried over anhydrous Na_2SO_4, and concentrated. Purification was carried out via silica gel preparative TLC (ethyl acetate/hexane (1:99→2:98)) or column chromatography to obtain the final product.

Preparation of Grignard reagents:

Mg turnings (7.2 mmol, 1.2 equiv) were added to an oven-dried 50 mL two-neck round-bottom flask. The bottom of the flask was briefly heated using a heat gun, followed by nitrogen purging to maintain an inert atmosphere. After cooling to rt, anhydrous THF (6 mL) was added to the flask, and then the alkyl or aryl bromide (6 mmol, 1.0 equiv) was introduced. The reaction mixture was stirred for 1-2 hours to allow the formation of the Grignard reagent. Once the Grignard reagent was prepared, it was used directly in the next reaction step.

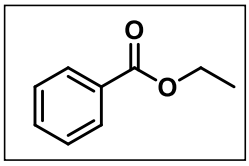
Characterization data of synthesized compounds:

Propiophenone (2a):



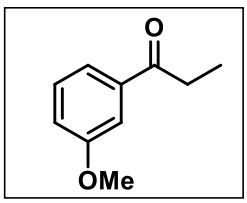
According to the general procedure A, product **2a** was isolated in 64% (86 mg) yield as a colourless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.97 – 7.93 (m, 2H), 7.53 (t, J = 7.4 Hz, 1H), 7.44 (t, J = 7.7 Hz, 2H), 2.99 (q, J = 7.3 Hz, 2H), 1.21 (t, J = 7.2 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 200.96, 137.05, 133.01, 128.68, 128.10, 31.90, 8.37; ESI-MS m/z: calculated for $C_9H_{11}O$, 135.0804 $[M+H]^+$; found 135.0456.

Ethyl benzoate (3a):



According to the general procedure A, product **3a** was isolated in 12% (18 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.05 (dd, J = 8.3, 1.7 Hz, 2H), 7.59 – 7.49 (m, 1H), 7.43 (t, J = 7.9 Hz, 2H), 4.37 (q, J = 7.1 Hz, 2H), 1.39 (t, J = 7.2 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 166.79, 132.97, 130.57, 129.66, 128.45, 61.11, 14.48; HRMS (ESI) m/z: calculated for $C_9H_{11}O_2$, 151.0754 $[M+H]^+$; found 151.0743.

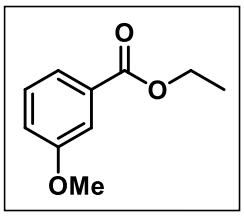
1-(3-Methoxyphenyl)propan-1-one[1] (2b):



According to the general procedure A, product **2b** was isolated in 65% (107 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.54 (d, J = 7.6 Hz, 1H), 7.49 (s, 1H), 7.36 (t, J = 7.9 Hz, 1H), 7.10 (dd, J = 8.2, 2.1 Hz, 1H), 3.85 (s, 3H), 2.99 (q, J = 7.2 Hz, 2H), 1.22 (t, J = 7.2 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 200.93, 159.93, 138.41, 129.73,

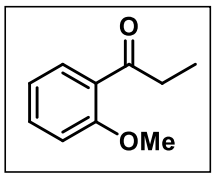
120.81, 119.49, 112.37, 55.61, 32.11, 8.48; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_2$, 165.0910 $[M+H]^+$; found 165.0910.

Ethyl 3-methoxybenzoate (3b):



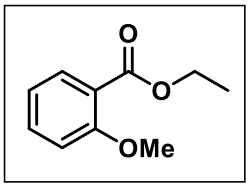
According to the general procedure A, product **3b** was isolated in 13% (23 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.64 (d, J = 7.7 Hz, 1H), 7.56 (s, 1H), 7.33 (t, J = 7.9 Hz, 1H), 7.11 – 7.07 (m, 1H), 4.37 (q, J = 7.1 Hz, 2H), 3.84 (s, 3H), 1.39 (t, J = 7.2 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 166.69, 159.63, 131.91, 129.51, 122.08, 119.49, 114.07, 61.25, 55.58, 14.49; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_3$, 181.0859 $[M+H]^+$; found 181.0857.

1-(2-Methoxyphenyl)propan-1-one (2c):



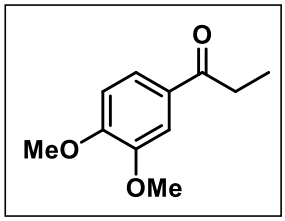
According to the general procedure A, product **2c** was isolated in 52% (85 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.68 (dd, J = 7.8, 1.8 Hz, 1H), 7.45 (td, J = 8.0, 1.9 Hz, 1H), 7.00 (t, J = 7.5 Hz, 1H), 6.96 (d, J = 8.5 Hz, 1H), 3.90 (s, 3H), 3.00 (q, J = 7.3 Hz, 2H), 1.16 (t, J = 7.3 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 203.81, 158.63, 133.38, 130.40, 128.59, 120.78, 111.64, 55.66, 37.22, 8.64; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_2$, 165.0910 $[M+H]^+$; found 165.0935.

Ethyl 2-methoxybenzoate (3c):



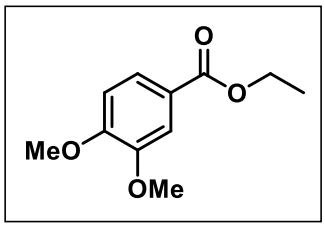
According to the general procedure A, product **3c** was isolated in 14% (25 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.78 (dd, J = 7.8, 1.9 Hz, 1H), 7.48 – 7.43 (m, 1H), 6.96 (dt, J = 7.4, 3.2 Hz, 2H), 4.35 (q, J = 7.2 Hz, 2H), 3.89 (s, 3H), 1.37 (t, J = 7.1 Hz, 3H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$): δ 166.36, 159.23, 133.55, 131.65, 120.43, 120.22, 112.09, 60.97, 56.11, 14.47; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_3$, 181.0859 $[M+H]^+$; found 181.0869.

1-(3,4-Dimethoxyphenyl)propan-1-one (2d):



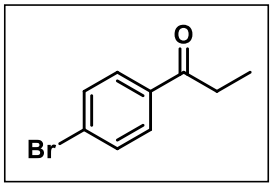
According to the general procedure A, product **2d** was isolated in 66% (128 mg) yield as off-white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.59 (d, J = 8.3 Hz, 1H), 7.53 (s, 1H), 6.88 (d, J = 8.4 Hz, 1H), 3.94 (d, J = 5.0 Hz, 6H), 2.97 (q, J = 7.2 Hz, 2H), 1.21 (t, J = 7.3 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 199.84, 153.18, 149.09, 130.28, 122.74, 110.14, 110.06, 56.24, 56.14, 31.50, 8.76; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_3$, 195.1016 $[M+H]^+$; found 195.1009.

Ethyl 3,4-dimethoxybenzoate (3d):



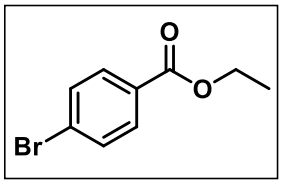
According to the general procedure A, product **3d** was isolated in 13% (27 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.68 (dd, J = 8.4, 2.0 Hz, 1H), 7.54 (d, J = 2.0 Hz, 1H), 6.88 (d, J = 8.5 Hz, 1H), 4.35 (q, J = 7.1 Hz, 2H), 3.93 (s, 6H), 1.38 (t, J = 7.1 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.63, 152.95, 148.66, 123.65, 123.13, 111.96, 110.28, 61.03, 56.19, 56.15, 14.59; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_4$, 211.0965 $[M+H]^+$; found 211.0986.

1-(4-Bromophenyl)propan-1-one[2] (2e):



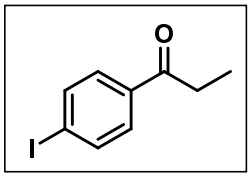
According to the general procedure A, product **2e** was isolated in 35% (75 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.83 (d, J = 8.2 Hz, 2H), 7.60 (d, J = 8.2 Hz, 2H), 2.98 (q, J = 7.4 Hz, 2H), 1.23 – 1.20 (m, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 199.96, 135.83, 132.09, 129.74, 128.21, 32.00, 8.35.

Ethyl 4-bromobenzoate[3] (3e):



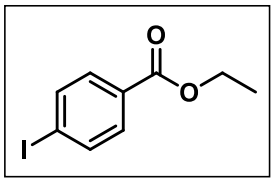
According to the general procedure A, product **3e** was isolated in 17% (39 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.90 (d, J = 8.1 Hz, 2H), 7.57 (d, J = 8.2 Hz, 2H), 4.37 (q, J = 7.2 Hz, 2H), 1.39 (t, J = 7.1 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.11, 131.86, 131.30, 129.60, 128.11, 61.46, 14.50.

1-(4-Iodophenyl)propan-1-one (2f):



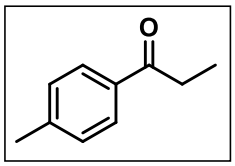
According to the general procedure A, product **2f** was isolated in 38% (99 mg) yield as off-white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.82 (d, J = 8.1 Hz, 2H), 7.67 (d, J = 8.3 Hz, 2H), 2.96 (q, J = 7.2 Hz, 2H), 1.21 (t, J = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.34, 138.06, 136.26, 129.63, 101.02, 31.94, 8.30; HRMS (ESI) m/z: calculated for $C_9H_{10}IO$, 260.9771 $[M+H]^+$; found 260.9787.

Ethyl 4-iodobenzoate (3f):



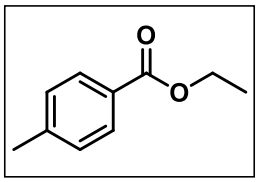
According to the general procedure A, product **3f** was isolated in 16% (44 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.79 (d, J = 8.5 Hz, 2H), 7.75 (d, J = 8.5 Hz, 2H), 4.36 (q, J = 7.2 Hz, 2H), 1.38 (t, J = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.35, 137.84, 131.21, 130.08, 100.83, 61.46, 14.49; HRMS (ESI) m/z: calculated for $C_9H_{10}IO_2$, 276.9720 $[M+H]^+$; found 276.9720.

1-(*p*-Tolyl)propan-1-one (2g):



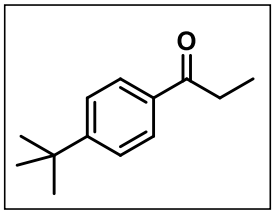
According to the general procedure A, product **2g** was isolated in 65% (96 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.87 (d, J = 6.4 Hz, 2H), 7.25 (d, J = 6.6 Hz, 2H), 2.98 (qd, J = 7.3, 1.8 Hz, 2H), 2.41 (s, 3H), 1.22 (td, J = 7.3, 1.7 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.76, 143.78, 134.65, 129.42, 128.30, 31.85, 21.81, 8.53; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O$, 149.0961 $[M+H]^+$; found 149.0961.

Ethyl 4-methylbenzoate (3g):



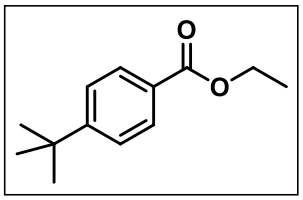
According to the general procedure A, product **3g** was isolated in 12% (20 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.93 (d, J = 7.7 Hz, 2H), 7.23 (d, J = 7.6 Hz, 2H), 4.36 (q, J = 7.1 Hz, 2H), 2.40 (s, 3H), 1.39 (t, J = 7.1 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.95, 143.63, 129.77, 129.23, 127.99, 60.97, 21.86, 14.57; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_2$, 165.0910 $[M+H]^+$; found 165.0905.

1-(4-(*tert*-Butyl)phenyl)propan-1-one (2h):



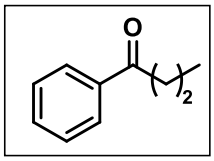
According to the general procedure A, product **2h** was isolated in 64% (122 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.91 (d, J = 8.4 Hz, 2H), 7.47 (d, J = 8.4 Hz, 2H), 2.99 (q, J = 7.3 Hz, 2H), 1.34 (s, 9H), 1.22 (t, J = 7.3 Hz, 3H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$): δ 200.83, 156.73, 134.46, 128.12, 125.67, 35.27, 31.88, 31.28, 8.53; HRMS (ESI) m/z: calculated for $C_{13}H_{19}O$, 191.1430 $[M+H]^+$; found 191.1414.

Ethyl 4-(*tert*-butyl)benzoate[4] (3h):



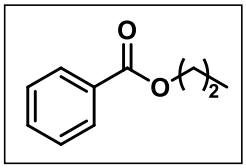
According to the general procedure A, product **3h** was isolated in 13% (27 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.98 (d, J = 8.3 Hz, 2H), 7.45 (d, J = 8.5 Hz, 2H), 4.36 (q, J = 7.1 Hz, 2H), 1.38 (t, J = 7.2 Hz, 3H), 1.33 (s, 9H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.86, 156.57, 129.56, 127.83, 125.46, 60.93, 35.23, 31.30, 14.55; HRMS (ESI) m/z: calculated for $C_{13}H_{19}O_2$, 207.1380 $[M+H]^+$; found 207.1392.

1-Phenylbutan-1-one (2i):



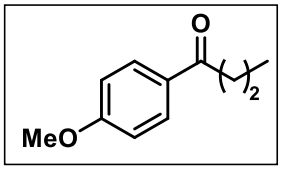
According to the general procedure A, product **2i** was isolated in 59% (87 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.96 (d, J = 7.3 Hz, 2H), 7.56 (t, J = 7.4 Hz, 1H), 7.46 (t, J = 7.7 Hz, 2H), 2.96 (t, J = 7.3 Hz, 2H), 1.77 (h, J = 7.3 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.77, 137.20, 133.12, 128.76, 128.24, 40.72, 17.94, 14.11; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O$, 149.0961 $[M+H]^+$; found 149.0959.

Propyl benzoate (3i):



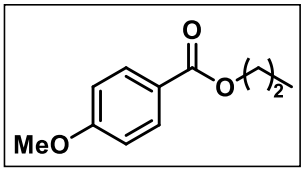
According to the general procedure A, product **3i** was isolated in 15% (25 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.05 (d, J = 7.2 Hz, 2H), 7.54 (t, J = 7.4 Hz, 1H), 7.43 (t, J = 7.7 Hz, 2H), 4.28 (t, J = 6.7 Hz, 2H), 1.79 (h, J = 7.3 Hz, 2H), 1.03 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.87, 132.97, 130.70, 129.70, 128.49, 66.70, 22.29, 10.69; HRMS (ESI) m/z: calculated for $C_{10}H_{13}O_2$, 165.0911 $[M+H]^+$; found 165.0909.

1-(4-Methoxyphenyl)butan-1-one (2j):



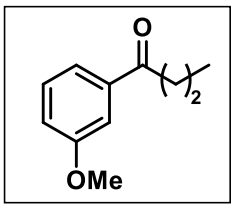
According to the general procedure A, product **2j** was isolated in 62% (111 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.94 (d, J = 8.9 Hz, 2H), 6.92 (d, J = 8.9 Hz, 2H), 3.86 (s, 3H), 2.89 (t, J = 7.4 Hz, 2H), 1.75 (p, J = 7.4 Hz, 2H), 0.99 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 199.38, 163.44, 130.49, 130.29, 113.81, 55.65, 40.40, 18.18, 14.16; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_2$, 179.1067 $[M+H]^+$; found 179.1065.

Propyl 4-methoxybenzoate (3j):



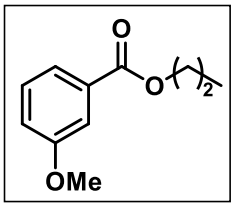
According to the general procedure A, product **3j** was isolated in 15% (29 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.00 (d, J = 9.0 Hz, 2H), 6.91 (d, J = 8.9 Hz, 2H), 4.24 (t, J = 6.7 Hz, 2H), 3.85 (s, 3H), 1.77 (h, J = 7.2 Hz, 2H), 1.01 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.68, 163.37, 131.71, 123.05, 113.70, 66.43, 55.59, 22.31, 10.74; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_3$, 195.1016 $[M+H]^+$; found 195.1009.

1-(3-Methoxyphenyl)butan-1-one (2k):



According to the general procedure A, product **2k** was isolated in 62% (111 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.54 (d, J = 7.6 Hz, 1H), 7.49 (t, J = 2.1 Hz, 1H), 7.36 (t, J = 7.9 Hz, 1H), 7.10 (dd, J = 8.2, 2.0 Hz, 1H), 3.85 (s, 3H), 2.93 (t, J = 7.3 Hz, 2H), 1.76 (h, J = 7.4 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.53, 159.93, 138.59, 129.72, 120.90, 119.53, 112.38, 55.62, 40.83, 18.01, 14.10; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_2$, 179.1067 $[M+H]^+$; found 179.1067.

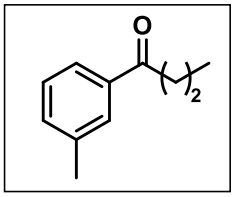
Propyl 3-methoxybenzoate (3k):



According to the general procedure A, product **3k** was isolated in 13% (25 mg) yield as pale-yellow liquid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.64 (d, J = 7.7 Hz, 1H), 7.57 (t, J = 2.1 Hz, 1H), 7.33 (td, J = 8.1, 3.4 Hz, 1H), 7.09 (dd, J = 8.3, 2.9 Hz, 1H), 4.27 (t, J = 6.7 Hz, 2H), 3.85 (s, 3H), 1.79 (h, J = 7.1 Hz, 2H), 1.03 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ

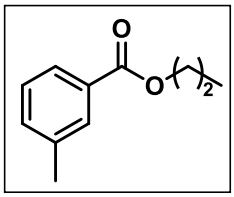
166.77, 159.73, 132.03, 129.54, 122.13, 119.43, 114.27, 66.83, 55.62, 22.30, 10.70; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_3$, 195.1016 $[M+H]^+$; found 195.1007.

1-(*m*-Tolyl)butan-1-one (2l):



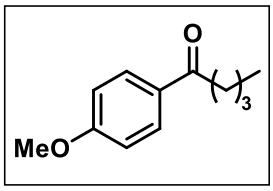
According to the general procedure A, product **2l** was isolated in 60% (97 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.79 – 7.74 (m, 2H), 7.38 – 7.32 (m, 2H), 2.94 (t, J = 7.3 Hz, 2H), 2.41 (s, 3H), 1.76 (h, J = 7.3 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 201.00, 138.52, 137.25, 133.85, 128.76, 128.61, 125.47, 40.79, 21.60, 18.01, 14.12; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O$, 163.1117 $[M+H]^+$; found 163.1116.

Propyl 3-methylbenzoate (3l):



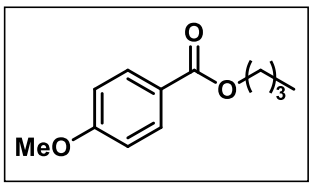
According to the general procedure A, product **3l** was isolated in 16% (28 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.88 – 7.83 (m, 2H), 7.35 (d, J = 7.7 Hz, 1H), 7.31 (t, J = 7.5 Hz, 1H), 4.27 (t, J = 6.7 Hz, 2H), 2.40 (s, 3H), 1.79 (h, J = 7.1 Hz, 2H), 1.03 (t, J = 7.5 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 167.03, 138.24, 133.71, 130.61, 130.22, 128.37, 126.83, 66.62, 22.29, 21.42, 10.68; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O_2$, 179.1067 $[M+H]^+$; found 179.1062.

1-(4-Methoxyphenyl)pentan-1-one (2m):



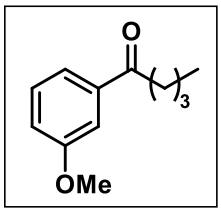
According to the general procedure A, product **2m** was isolated in 63% (121 mg) yield as colorless liquid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.94 (d, J = 8.8 Hz, 2H), 6.92 (d, J = 8.8 Hz, 2H), 3.86 (s, 3H), 2.91 (t, J = 7.5 Hz, 2H), 1.70 (dt, J = 15.1, 7.4 Hz, 2H), 1.39 (h, J = 7.4 Hz, 2H), 0.94 (t, J = 7.4 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 199.54, 163.44, 130.51, 130.29, 113.82, 55.65, 38.22, 26.91, 22.73, 14.19; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O_2$, 193.1223 $[M+H]^+$; found 193.1232.

Butyl 4-methoxybenzoate (3m):



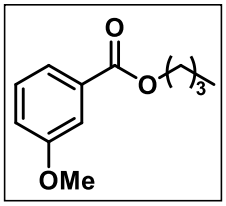
According to the general procedure A, product **3m** was isolated in 10% (21 mg) yield as colorless liquid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.99 (d, J = 9.0 Hz, 2H), 6.91 (d, J = 9.0 Hz, 2H), 4.28 (t, J = 6.6 Hz, 2H), 3.85 (s, 3H), 1.73 (p, J = 6.8 Hz, 2H), 1.50 – 1.43 (m, 2H), 0.97 (t, J = 7.4 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 166.67, 163.37, 131.71, 123.07, 113.70, 64.73, 55.59, 30.98, 19.47, 13.99; ESI-MS m/z: calculated for $C_{12}H_{17}O_3$, 209.1172 $[M+H]^+$; found 209.1169.

1-(3-Methoxyphenyl)pentan-1-one (2n):



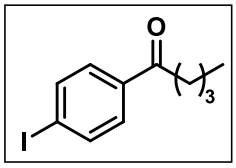
According to the general procedure A, product **2n** was isolated in 58% (112 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.54 (dt, J = 7.8, 1.2 Hz, 1H), 7.48 (dd, J = 2.7, 1.6 Hz, 1H), 7.36 (t, J = 7.9 Hz, 1H), 7.10 (dd, J = 8.3, 2.7 Hz, 1H), 3.85 (s, 3H), 2.95 (t, J = 7.5 Hz, 2H), 1.71 (p, J = 7.6 Hz, 2H), 1.40 (h, J = 7.4 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.70, 159.93, 138.56, 129.72, 120.91, 119.50, 112.41, 55.61, 38.65, 26.70, 22.66, 14.17; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O_2$, 193.1223 $[M+H]^+$; found 193.1233.

Butyl 3-methoxybenzoate (3n):



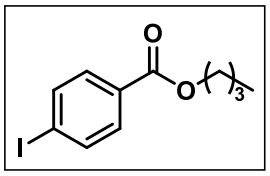
According to the general procedure A, product **3n** was isolated in 11% (23 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.64 (dt, J = 7.7, 1.3 Hz, 1H), 7.56 (dd, J = 2.7, 1.5 Hz, 1H), 7.34 (t, J = 8.0 Hz, 1H), 7.09 (ddd, J = 8.3, 2.7, 1.1 Hz, 1H), 4.32 (t, J = 6.7 Hz, 2H), 3.85 (s, 3H), 1.75 (p, J = 6.7 Hz, 2H), 1.47 (h, J = 7.4 Hz, 2H), 0.98 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.80, 159.65, 131.96, 129.56, 122.11, 119.43, 114.18, 65.16, 55.63, 30.92, 19.47, 14.00; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O_3$, 209.1172 $[M+H]^+$; found 209.1210.

1-(4-Iodophenyl)pentan-1-one[5] (2o):



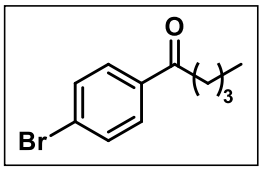
According to the general procedure A, product **2o** was isolated in 45% (130 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.82 (d, J = 8.5 Hz, 2H), 7.66 (d, J = 8.6 Hz, 2H), 2.91 (t, J = 7.4 Hz, 2H), 1.70 (p, J = 7.6 Hz, 2H), 1.40 (h, J = 7.4 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.03, 138.08, 136.52, 129.71, 100.95, 38.45, 26.57, 22.65, 14.14.

Butyl 4-iodobenzoate[6] (3o):



According to the general procedure A, product **3o** was isolated in 14% (43 mg) yield as yellowish oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.79 (d, J = 8.5 Hz, 2H), 7.74 (d, J = 8.5 Hz, 2H), 4.31 (t, J = 6.6 Hz, 2H), 1.74 (p, J = 6.8 Hz, 2H), 1.46 (h, J = 7.4 Hz, 2H), 0.97 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 166.37, 137.87, 131.20, 130.18, 100.74, 65.31, 30.91, 19.45, 13.96.

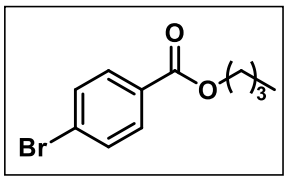
1-(4-Bromophenyl)pentan-1-one[7] (2p):



According to the general procedure A, product **2p** was isolated in 39% (94 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.82 (d, J = 8.6 Hz, 2H), 7.60 (d, J = 8.6 Hz, 2H), 2.93 (t, J = 7.4 Hz, 2H), 1.71 (p, J = 7.5 Hz, 2H), 1.40 (h, J = 7.4 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H);

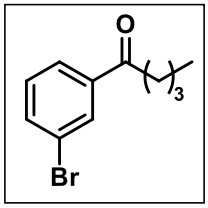
$^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 199.73, 135.99, 132.07, 129.82, 128.20, 38.50, 26.57, 22.64, 14.13.

Butyl 4-bromobenzoate[8] (3p):



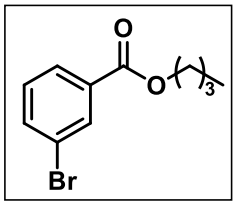
According to the general procedure A, product **3p** was isolated in 15% (39 mg) yield as pale yellowish oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.89 (d, J = 8.6 Hz, 2H), 7.57 (d, J = 8.6 Hz, 2H), 4.31 (t, J = 6.7 Hz, 2H), 1.74 (dt, J = 14.3, 6.7 Hz, 2H), 1.45 (dt, J = 14.8, 7.5 Hz, 2H), 0.97 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 166.16, 131.84, 131.26, 129.52, 128.09, 65.32, 30.86, 19.43, 13.97.

1-(3-Bromophenyl)pentan-1-one[9] (2q):



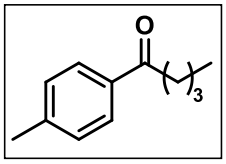
According to the general procedure A, product **2q** was isolated in 35% (84 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.07 (t, J = 1.9 Hz, 1H), 7.87 (dt, J = 7.8, 1.4 Hz, 1H), 7.69 – 7.66 (m, 1H), 7.34 (t, J = 7.8 Hz, 1H), 2.93 (t, J = 7.4 Hz, 2H), 1.71 (p, J = 7.5 Hz, 2H), 1.40 (h, J = 7.4 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 199.31, 139.03, 135.92, 131.34, 130.37, 126.77, 123.15, 38.61, 26.48, 22.61, 14.13.

Butyl 3-bromobenzoate[10] (3q):



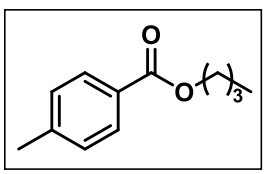
According to the general procedure A, product **3q** was isolated in 12% (31 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.16 (t, J = 1.8 Hz, 1H), 7.96 (dt, J = 7.7, 1.4 Hz, 1H), 7.67 (dt, J = 7.9, 1.5 Hz, 1H), 7.31 (t, J = 7.9 Hz, 1H), 4.32 (t, J = 6.7 Hz, 2H), 1.75 (p, J = 6.7 Hz, 2H), 1.47 (h, J = 7.4 Hz, 2H), 0.98 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 165.52, 135.94, 132.72, 132.64, 130.10, 128.32, 122.61, 65.48, 30.91, 19.44, 13.94.

1-(*p*-Tolyl)pentan-1-one (2r):



According to the general procedure A, product **2r** was isolated in 58% (102 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.88 (d, J = 7.9 Hz, 2H), 7.27 (d, J = 8.0 Hz, 2H), 2.96 (t, J = 7.5 Hz, 2H), 2.43 (s, 3H), 1.72 (q, J = 7.6 Hz, 2H), 1.42 (h, J = 7.4 Hz, 2H), 0.97 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 200.58, 143.81, 134.70, 129.41, 128.37, 38.43, 26.77, 22.70, 21.83, 14.18; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O$, 177.1274 $[M+H]^+$; found 177.1290.

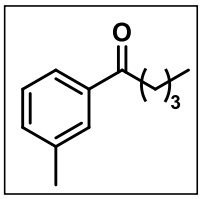
Butyl 4-methylbenzoate (3r):



According to the general procedure A, product **3r** was isolated in 13% (25 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.93 (d, J = 7.8 Hz, 2H), 7.23 (d, J = 7.9 Hz, 2H), 4.30 (t, J = 6.6 Hz, 2H), 2.40 (s, 3H), 1.74 (p, J = 6.9 Hz, 2H), 1.47 (h, J = 7.4 Hz, 2H), 0.97 (t, J = 7.4

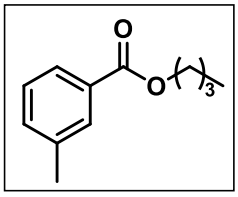
Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 167.03, 143.65, 129.75, 129.24, 127.91, 64.88, 30.97, 21.88, 19.49, 14.01; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O_2$, 193.1223 $[M+H]^+$; found 193.1237.

1-(*m*-Tolyl)pentan-1-one (2s):



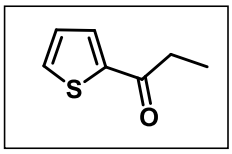
According to the general procedure A, product **2s** was isolated in 55% (97 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.80 – 7.72 (m, 2H), 7.38 – 7.31 (m, 2H), 2.95 (t, J = 7.5 Hz, 2H), 2.41 (s, 3H), 1.71 (p, J = 7.5 Hz, 2H), 1.44 – 1.37 (m, 2H), 0.95 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 201.11, 138.50, 137.23, 133.83, 128.75, 128.59, 125.47, 38.59, 26.69, 22.68, 21.58, 14.18; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O$, 177.1274 $[M+H]^+$; found 177.1270.

Butyl 3-methylbenzoate (3s):



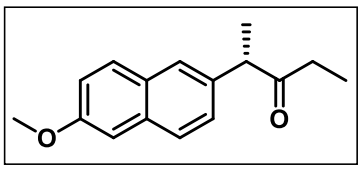
According to the general procedure A, product **3s** was isolated in 14% (27 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.87 – 7.83 (m, 2H), 7.36 (d, J = 7.6 Hz, 1H), 7.32 (t, J = 7.6 Hz, 1H), 4.31 (t, J = 6.6 Hz, 2H), 2.40 (s, 3H), 1.75 (p, J = 6.7 Hz, 2H), 1.48 (h, J = 7.4 Hz, 2H), 0.98 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 167.13, 138.30, 133.79, 130.57, 130.25, 128.42, 126.85, 65.00, 30.96, 21.51, 19.48, 14.01; HRMS (ESI) m/z: calculated for $C_{12}H_{17}O_2$, 193.1223 $[M+H]^+$; found 193.1234.

1-(Thiophen-2-yl)propan-1-one[11] (2t):



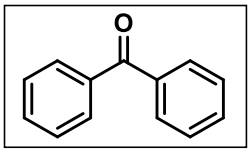
According to the general procedure A, product **2t** was isolated in 39% (55 mg) yield as colorless liquid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.71 (dd, J = 3.7, 1.2 Hz, 1H), 7.61 (dd, J = 5.0, 1.2 Hz, 1H), 7.12 (dd, J = 5.0, 3.7 Hz, 1H), 2.94 (q, J = 7.3 Hz, 2H), 1.23 (t, J = 7.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 194.10, 144.35, 133.41, 131.76, 128.22, 32.78, 8.73.

2-(6-Methoxynaphthalen-2-yl)pentan-3-one (2u):



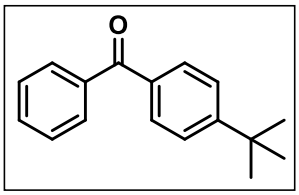
According to the general procedure A, product **2u** was isolated in 43% (104 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.71 (dd, J = 8.7, 2.5 Hz, 2H), 7.62 – 7.60 (m, 1H), 7.29 (dd, J = 8.5, 1.9 Hz, 1H), 7.16 (dd, J = 8.9, 2.6 Hz, 1H), 7.12 (d, J = 2.5 Hz, 1H), 3.92 – 3.87 (m, 4H), 2.41 (qq, J = 17.8, 7.3 Hz, 2H), 1.47 (d, J = 7.0 Hz, 3H), 0.97 (t, J = 7.3 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 211.96, 157.85, 136.23, 133.81, 129.35, 129.26, 127.64, 126.59, 126.56, 119.31, 105.78, 55.50, 52.80, 34.44, 17.71, 8.18; HRMS (ESI) m/z: calculated for $C_{16}H_{19}O_2$, 243.1380 $[M+H]^+$; found 243. 1385.

Benzophenone (2v):



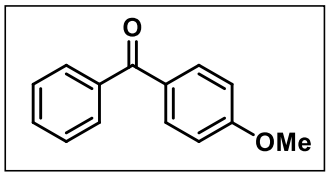
According to the general procedure A, product **2v** was isolated in 60% (109 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.81 (d, J = 7.3 Hz, 4H), 7.59 (t, J = 7.4 Hz, 2H), 7.49 (t, J = 7.7 Hz, 4H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 196.97, 137.80, 132.62, 130.27, 128.48; HRMS (ESI) m/z: calculated for $C_{13}H_{11}O$, 183.0805 $[M + H]^+$; found 183.0804.

4-(*tert*-Butyl)phenyl)(phenyl)methanone (2w):



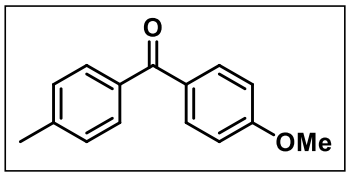
According to the general procedure A, product **2w** was isolated in 47% (112 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.83 – 7.79 (m, 2H), 7.77 (d, J = 8.4 Hz, 2H), 7.58 (t, J = 7.4 Hz, 1H), 7.52 – 7.46 (m, 4H), 1.37 (s, 9H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 196.69, 156.40, 138.15, 135.02, 132.38, 130.35, 130.19, 128.41, 125.46, 35.33, 31.36; HRMS (ESI) m/z: calculated for $C_{17}H_{19}O$, 239.1430 $[M + H]^+$; found 239.1438.

(4-Methoxyphenyl)(phenyl)methanone (2x):



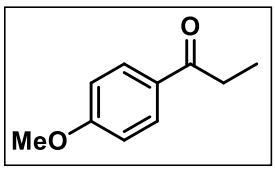
According to the general procedure A, product **2x** was isolated in 45% (96 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.83 (d, J = 8.8 Hz, 2H), 7.75 (d, J = 7.1 Hz, 2H), 7.56 (t, J = 7.4 Hz, 1H), 7.47 (t, J = 7.7 Hz, 2H), 7.00 – 6.92 (m, 2H), 3.88 (s, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 195.73, 163.39, 138.44, 132.73, 132.06, 130.30, 129.89, 128.35, 113.72, 55.66; HRMS (ESI) m/z: calculated for $C_{14}H_{13}O_2$, 213.0910 $[M + H]^+$; found 213.0917.

(4-Methoxyphenyl)(p-tolyl)methanone (2y):



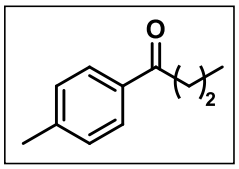
According to the general procedure A, product **2y** was isolated in 46% (104 mg) yield as white solid.^{1}H NMR (600 MHz, $CDCl_3$) 7.81 (d, J = 8.7 Hz, 2H), 7.68 (d, J = 8.1 Hz, 2H), 7.27 (d, J = 7.9 Hz, 2H), 6.96 (d, J = 8.7 Hz, 2H), 3.89 (s, 3H), 2.44 (s, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 195.59, 163.24, 142.83, 135.72, 132.64, 130.69, 130.22, 129.09, 113.69, 55.69, 21.83; HRMS (ESI) m/z: calculated for $C_{15}H_{15}O_2$, 227.1067 $[M + H]^+$; found 227.1069.

1-(4-Methoxyphenyl)propan-1-one (2z1):



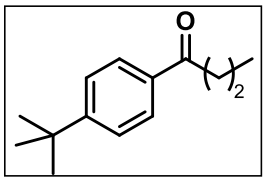
According to the general procedure C, product **2z1** was isolated in 81% (133 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.95 (d, J = 8.8 Hz, 2H), 6.92 (d, J = 8.8 Hz, 2H), 3.86 (s, 3H), 2.95 (q, J = 7.3 Hz, 2H), 1.20 (t, J = 7.3 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 199.80, 163.43, 130.40, 130.11, 113.81, 55.64, 31.60, 8.61; ESI-MS m/z: calculated for $C_{10}H_{13}O_2$, 165.1224 $[M+H]^+$; found 165.0915.

1-(*p*-Tolyl)butan-1-one (2z2):



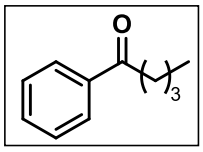
According to the general procedure C, product **2z2** was isolated in 82% (133 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.87 (d, J = 8.1 Hz, 2H), 7.25 (d, J = 7.9 Hz, 2H), 2.92 (t, J = 7.4 Hz, 2H), 2.41 (s, 3H), 1.76 (h, J = 7.4 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.41, 143.81, 134.70, 129.40, 128.35, 40.60, 21.83, 18.04, 14.12; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O$, 163.1117 $[M+H]^+$; found 163.1113.

1-(4-(*tert*-Butyl)phenyl)butan-1-one (2z3):



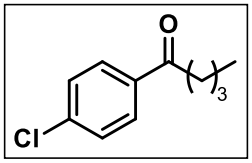
According to the general procedure C, product **2z3** was isolated in 79% (161 mg) yield as faint pink oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.91 (d, J = 8.5 Hz, 2H), 7.47 (d, J = 8.5 Hz, 2H), 2.93 (t, J = 7.3 Hz, 2H), 1.76 (q, J = 7.4 Hz, 2H), 1.34 (s, 9H), 1.00 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.40, 156.72, 134.64, 128.20, 125.66, 40.62, 35.26, 31.28, 18.05, 14.13; HRMS (ESI) m/z: calculated for $C_{14}H_{21}O$, 205.1587 $[M+H]^+$; found 205.1587.

1-Phenylpentan-1-one (2z4):



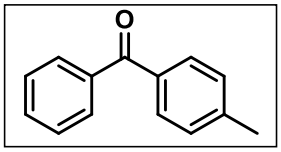
According to the general procedure C, product **2z4** was isolated in 82% (133 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.96 (d, J = 7.3 Hz, 2H), 7.55 (t, J = 7.4 Hz, 1H), 7.46 (t, J = 7.7 Hz, 2H), 2.97 (t, J = 7.4 Hz, 2H), 1.72 (p, J = 7.5 Hz, 2H), 1.41 (h, J = 7.4 Hz, 2H), 0.95 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.87, 137.18, 133.08, 128.73, 128.24, 38.52, 26.63, 22.67, 14.17; HRMS (ESI) m/z: calculated for $C_{11}H_{15}O$, 163.1117 $[M+H]^+$; found 163.1126.

1-(4-Chlorophenyl)pentan-1-one (2z5):



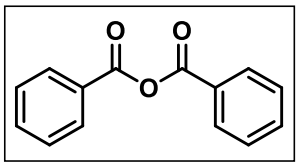
According to the general procedure C, product **2z5** was isolated in 75% (147 mg) yield as colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.88 (d, J = 8.5 Hz, 2H), 7.41 (d, J = 8.5 Hz, 2H), 2.92 (t, J = 7.4 Hz, 2H), 1.70 (p, J = 7.5 Hz, 2H), 1.39 (h, J = 7.4 Hz, 2H), 0.94 (t, J = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 199.48, 139.45, 135.56, 129.66, 129.03, 38.49, 26.57, 22.63, 14.11; HRMS (ESI) m/z: calculated for $C_{11}H_{14}ClO$, 197.0728 $[M+H]^+$; found 197.0737.

Phenyl(*p*-tolyl)methanone (2z6):



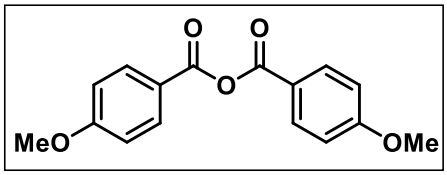
According to the general procedure C, product **2z6** was isolated in 91% (179 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.79 (d, J = 7.1 Hz, 2H), 7.73 (d, J = 8.1 Hz, 2H), 7.58 (t, J = 7.4 Hz, 1H), 7.48 (t, J = 7.7 Hz, 2H), 7.28 (d, J = 7.9 Hz, 2H), 2.44 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.72, 143.44, 138.15, 135.08, 132.36, 130.51, 130.13, 129.17, 128.41, 21.86; HRMS (ESI) m/z: calculated for $C_{14}H_{13}O$, 197.0961 $[M + H]^+$; found 197.0967.

Benzoic anhydride (4a):



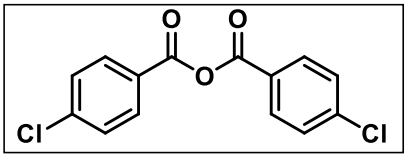
According to the general procedure B, product **4a** was isolated in 80% (90 mg) yield as crystalline solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.17 (d, J = 7.3 Hz, 4H), 7.68 (t, J = 7.5 Hz, 2H), 7.53 (t, J = 7.8 Hz, 4H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 162.56, 134.76, 130.77, 129.09, 129.03; HRMS (ESI) m/z: calculated for $C_{14}H_{10}NaO_3$, 249.0522 $[M+H]^+$; found 249.0525.

4-Methoxybenzoic anhydride (4b):



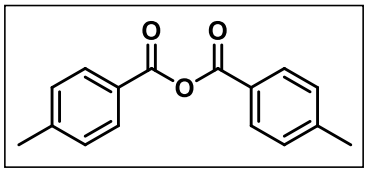
According to the general procedure B, product **4b** was isolated in 78% (112 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.10 (d, J = 9.0 Hz, 4H), 6.98 (d, J = 8.9 Hz, 4H), 3.89 (s, 6H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 164.77, 162.49, 133.03, 121.45, 114.33, 55.80; HRMS (ESI) m/z: calculated for $C_{16}H_{14}NaO_5$, 309.0733 $[M+H]^+$; found 309.0738.

4-Chlorobenzoic anhydride (4c):



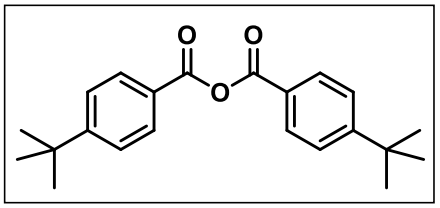
According to the general procedure B, product **4c** was isolated in 65% (95 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.08 (d, J = 8.6 Hz, 4H), 7.51 (d, J = 8.6 Hz, 4H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 161.50, 141.63, 132.09, 129.58, 127.26; ESI-MS m/z: calculated for $C_{14}H_9Cl_2O_3$, 294.9923 $[M+H]^+$; found 295.2882.

4-Methylbenzoic anhydride (4d):



According to the general procedure B, product **4d** was isolated in 80% (102 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.04 (d, J = 8.2 Hz, 4H), 7.32 (d, J = 8.0 Hz, 4H), 2.45 (s, 6H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 162.76, 145.78, 130.83, 129.78, 126.38, 22.06; HRMS (ESI) m/z: calculated for $C_{16}H_{14}NaO_3$, 277.0835 $[M+H]^+$; found 277.0840.

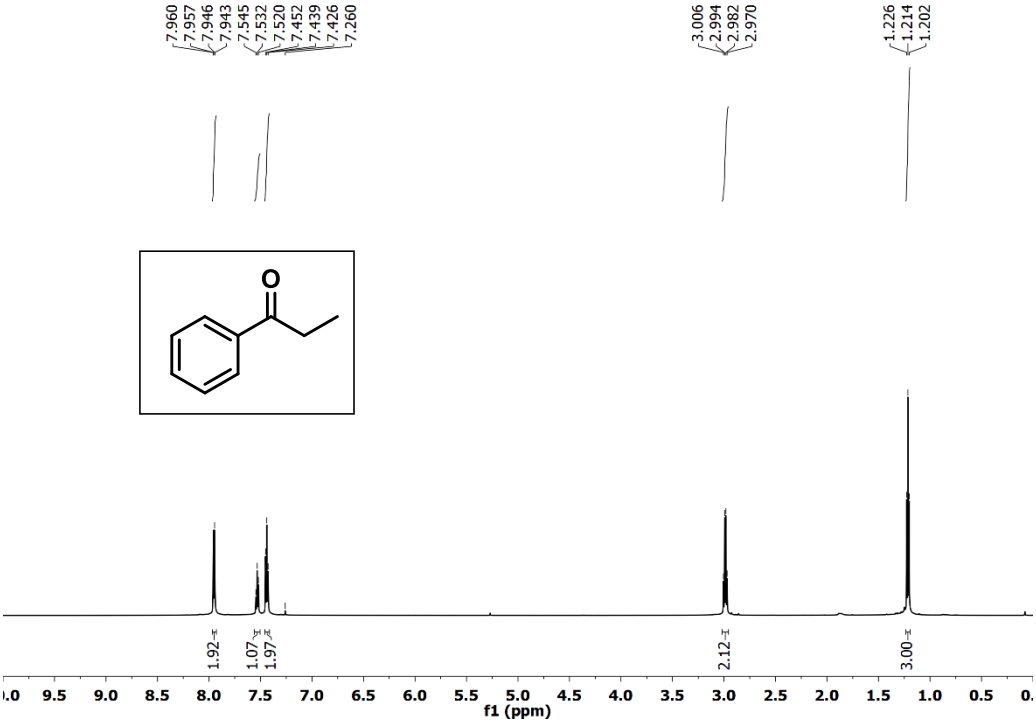
4-(*tert*-Butyl)benzoic anhydride (4e):



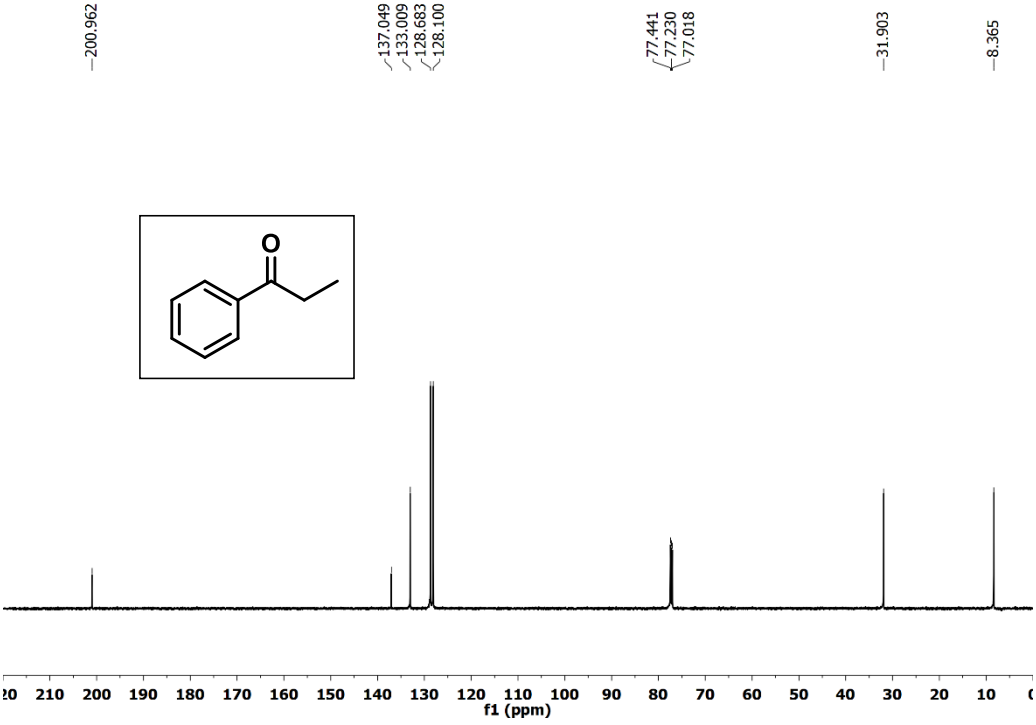
According to the general procedure B, product **4e** was isolated in 67% (113 mg) yield as white solid. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.09 (d, J = 8.6 Hz, 4H), 7.54 (d, J = 8.6 Hz, 4H), 1.37 (s, 18H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 162.70, 158.64, 130.70, 126.31, 126.06, 35.49, 31.23; HRMS (ESI) m/z: calculated for $C_{22}H_{26}NaO_3$, 361.1774 $[M+H]^+$; found 361.1778.

^{1}H and $^{13}C\{^{1}H\}$ NMR of all synthesized compounds

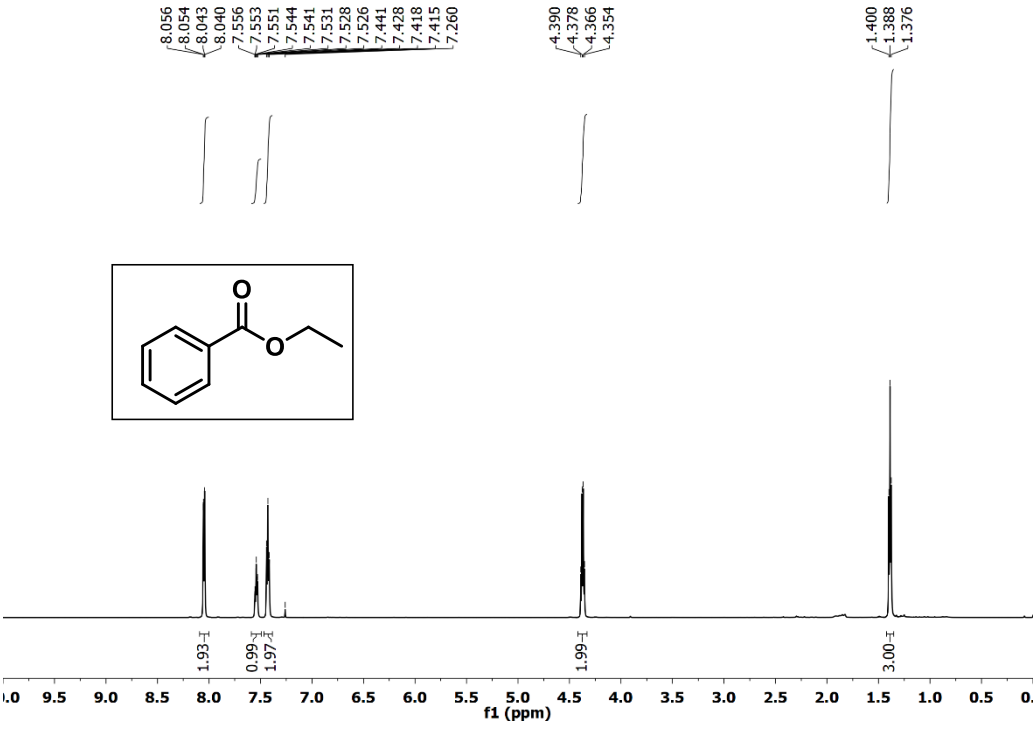
^{1}H NMR of ketone **2a** (600 MHz, $CDCl_3$)



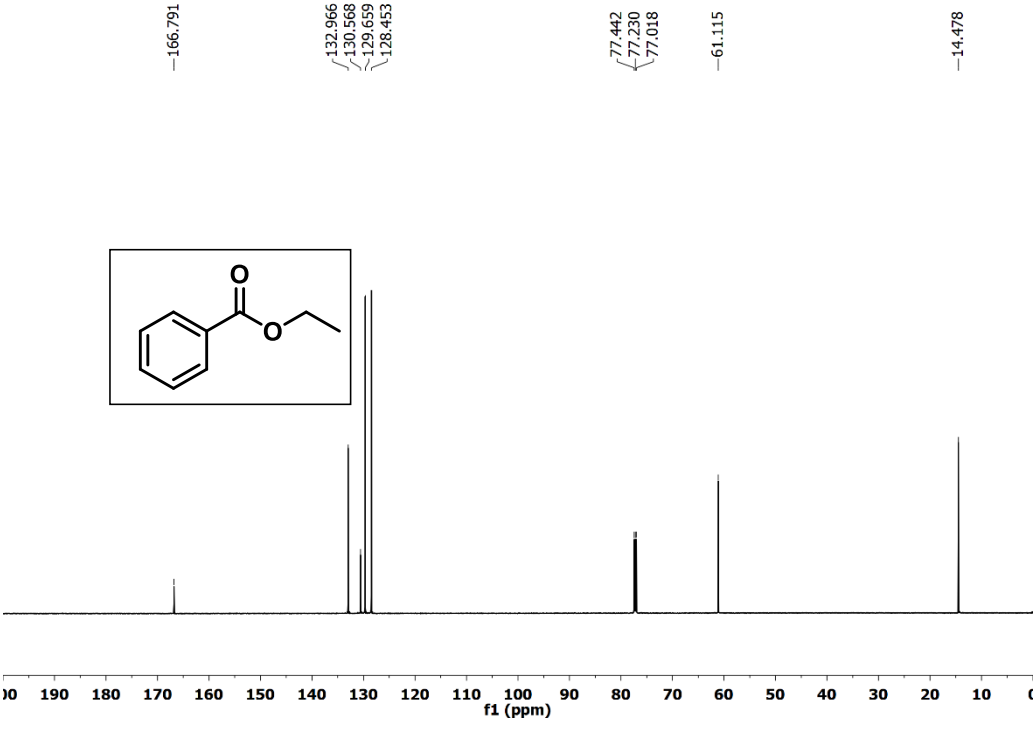
$^{13}C\{^{1}H\}$ NMR of ketone **2a** (151 MHz, $CDCl_3$)



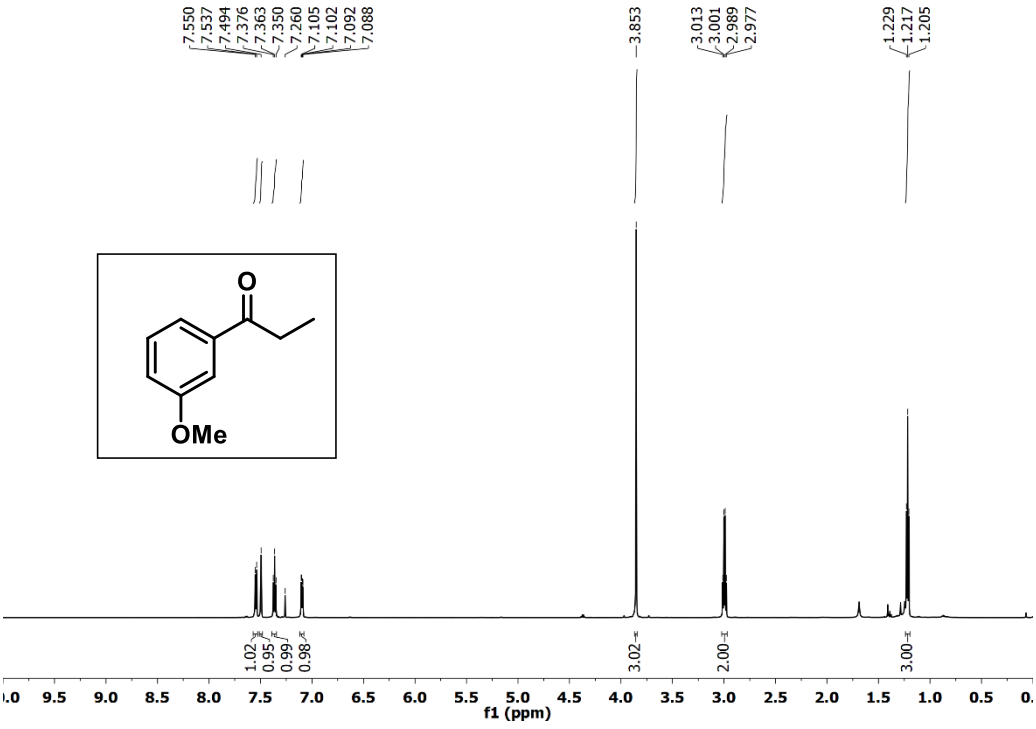
^{1}H NMR of ester **3a** (600 MHz, $CDCl_3$)



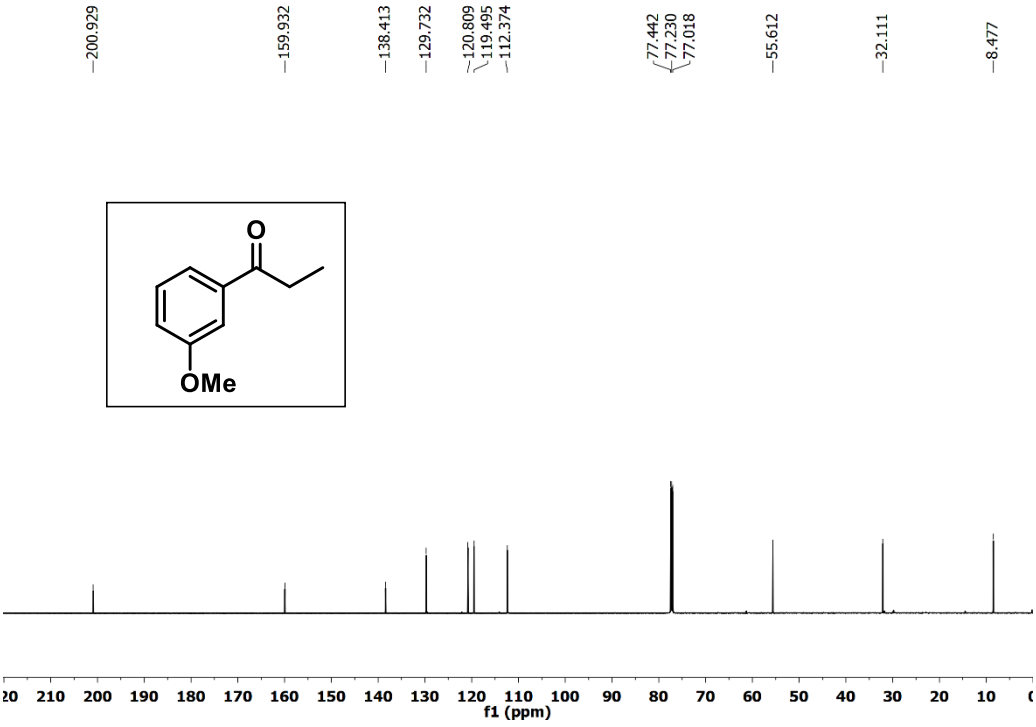
^{13}C{^{1}H} NMR of ester **3a** (151 MHz, $CDCl_3$)



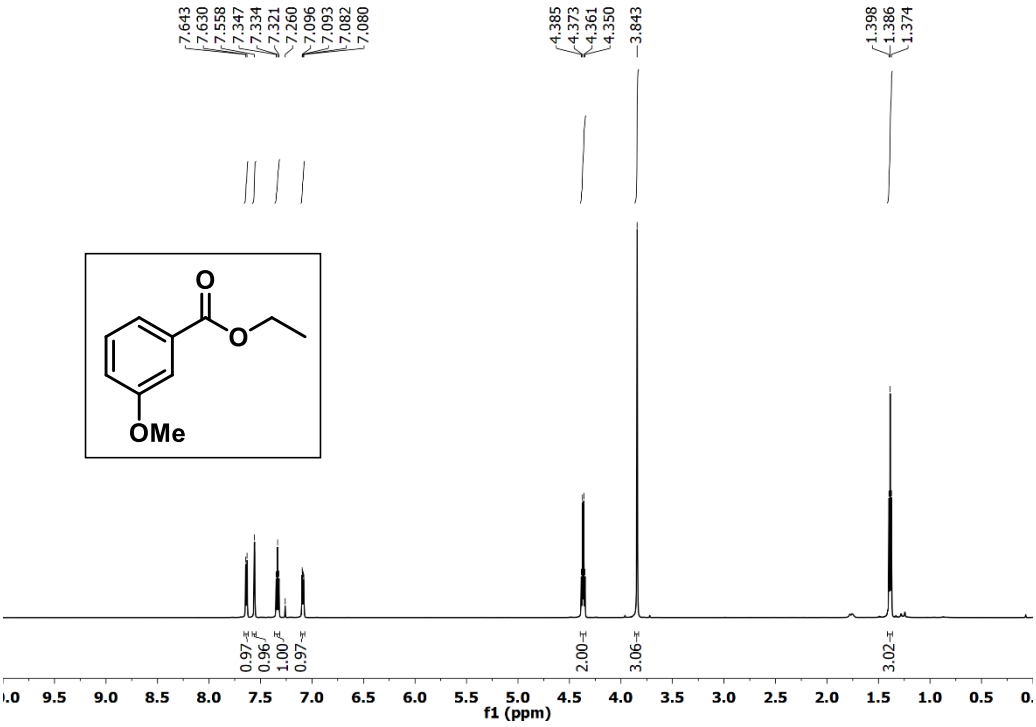
^{1}H NMR of ketone **2b** (600 MHz, $CDCl_3$)



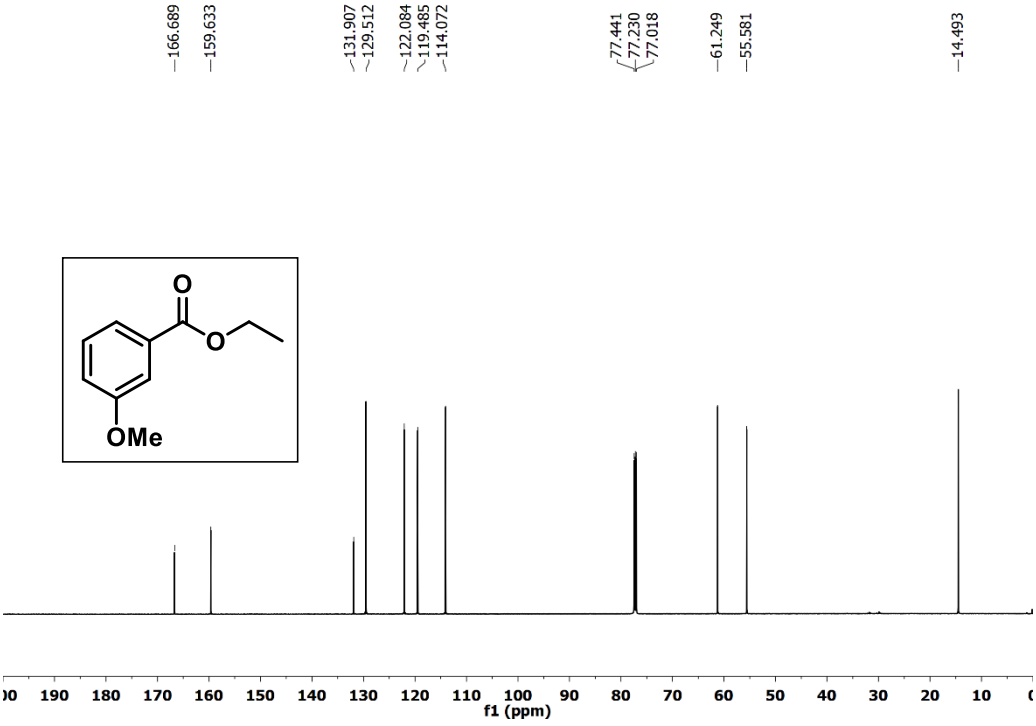
^{13}C{^{1}H} NMR of ketone **2b** (151 MHz, $CDCl_3$)



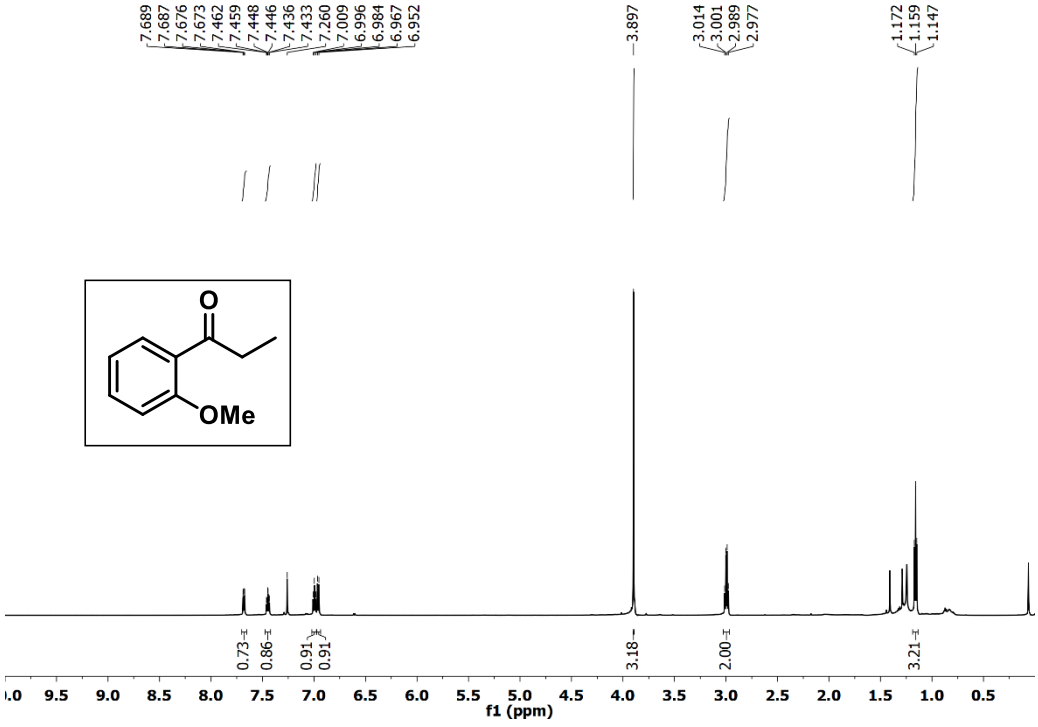
^{1}H NMR of ester **3b** (600 MHz, $CDCl_3$)



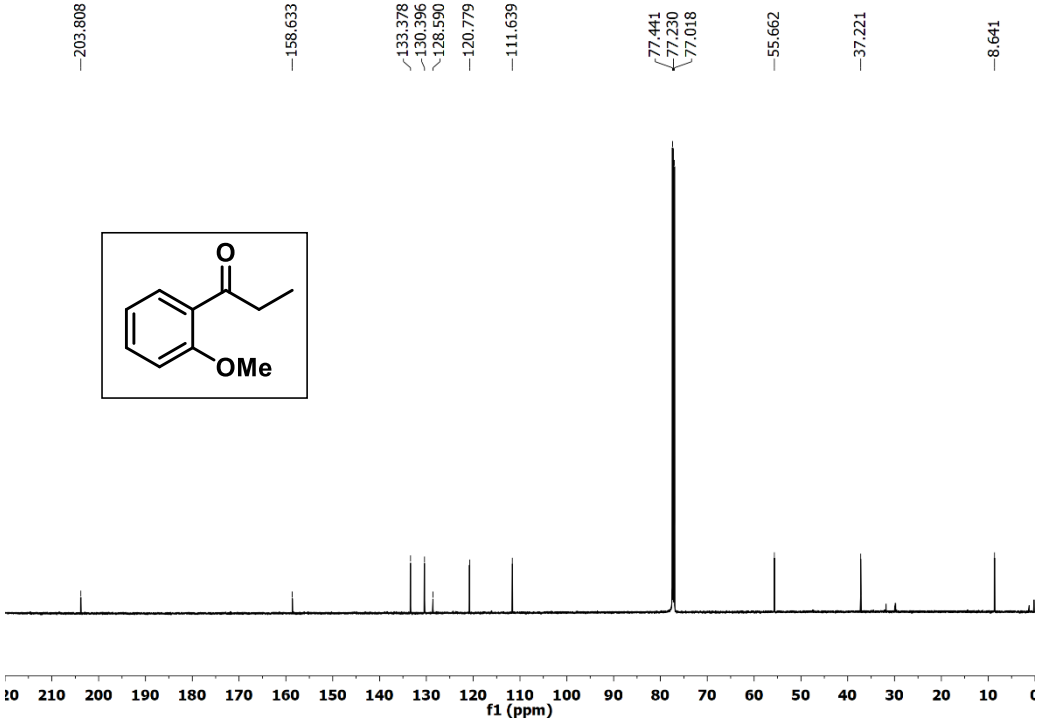
^{13}C{^{1}H} NMR of ester **3b** (151 MHz, $CDCl_3$)



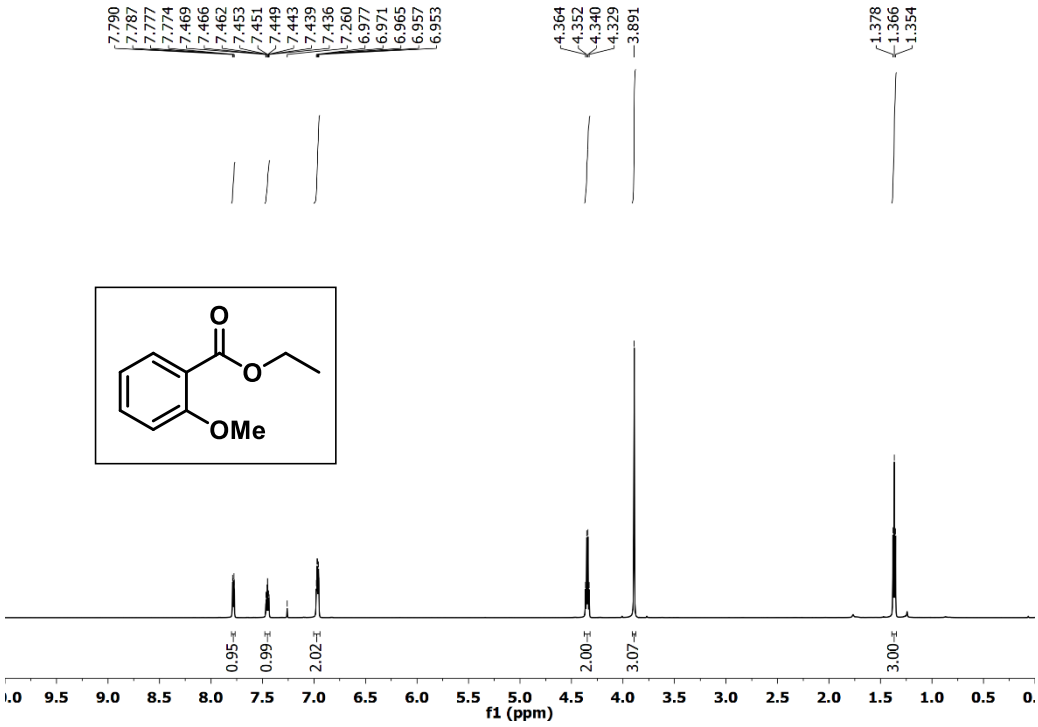
^{1}H NMR of ketone **2c** (600 MHz, $CDCl_3$)



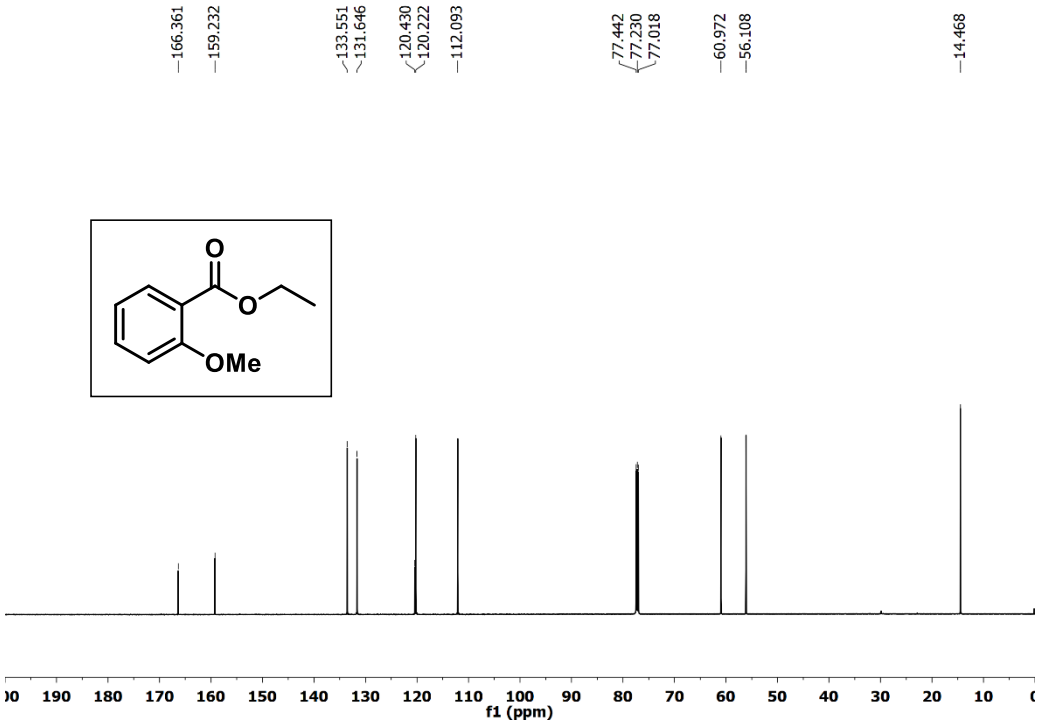
^{13}C{^{1}H} NMR of ketone **2c** (151 MHz, $CDCl_3$)



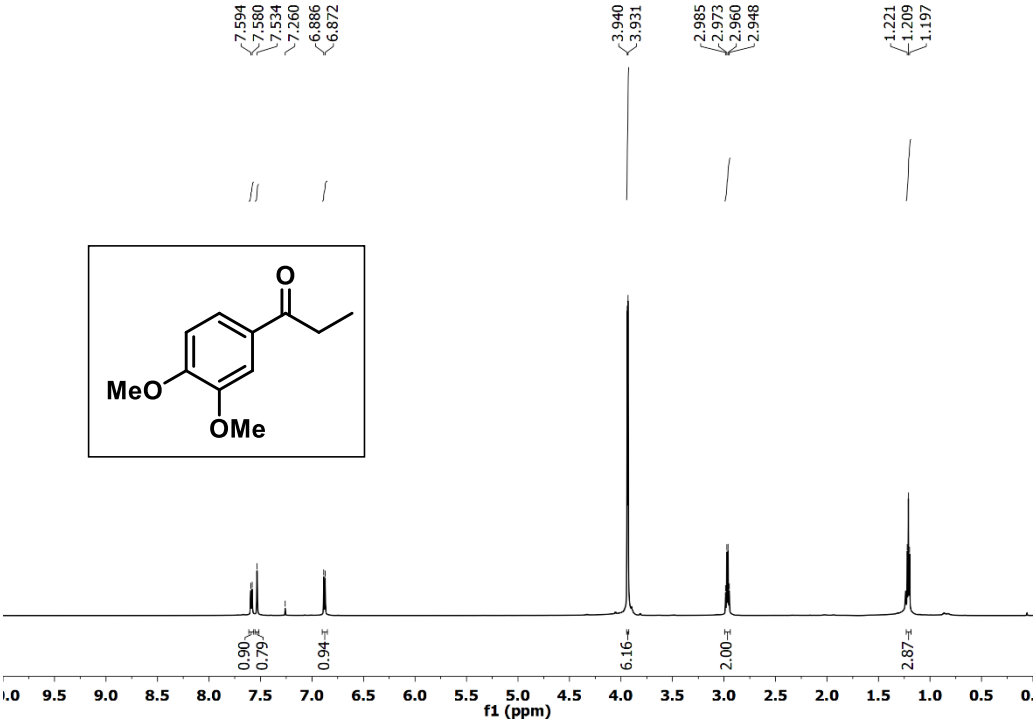
^{1}H NMR of ester **3c** (600 MHz, $CDCl_3$)



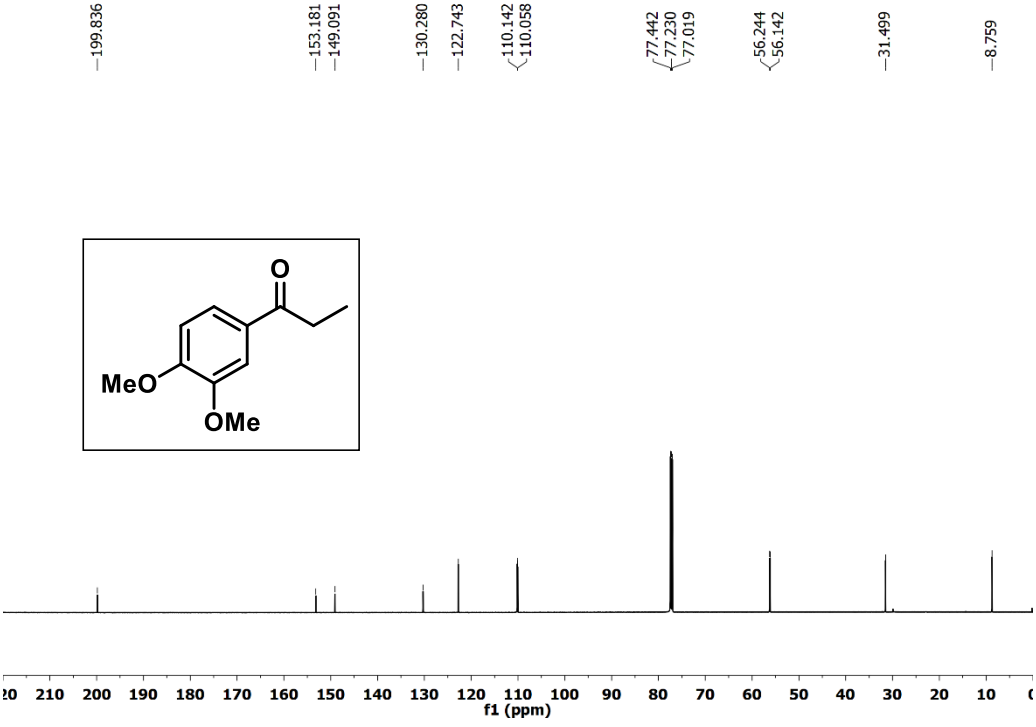
^{13}C{^{1}H} NMR of ester **3c** (151 MHz, $CDCl_3$)



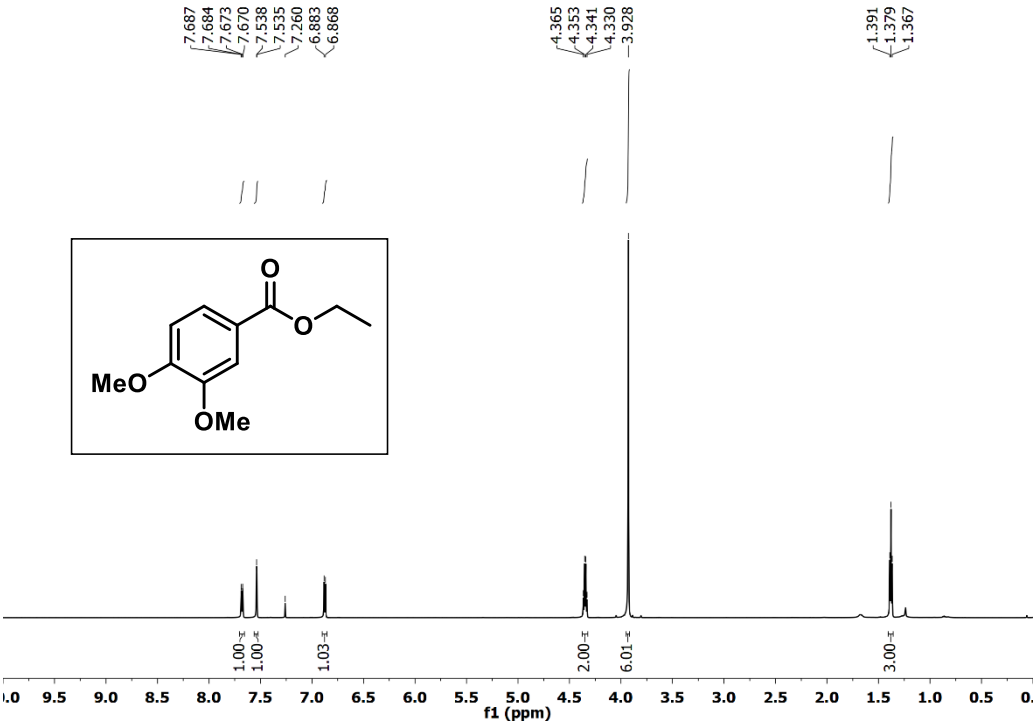
^{1}H NMR of ketone **2d** (600 MHz, $CDCl_3$)



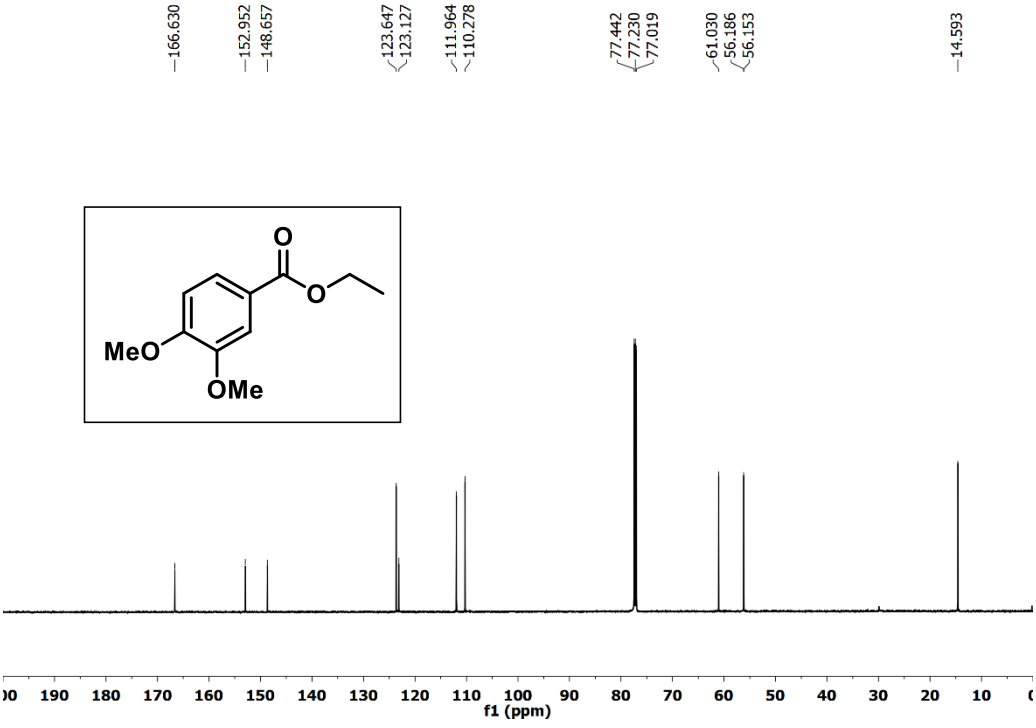
^{13}C{^{1}H} NMR of ketone **2d** (151 MHz, $CDCl_3$)



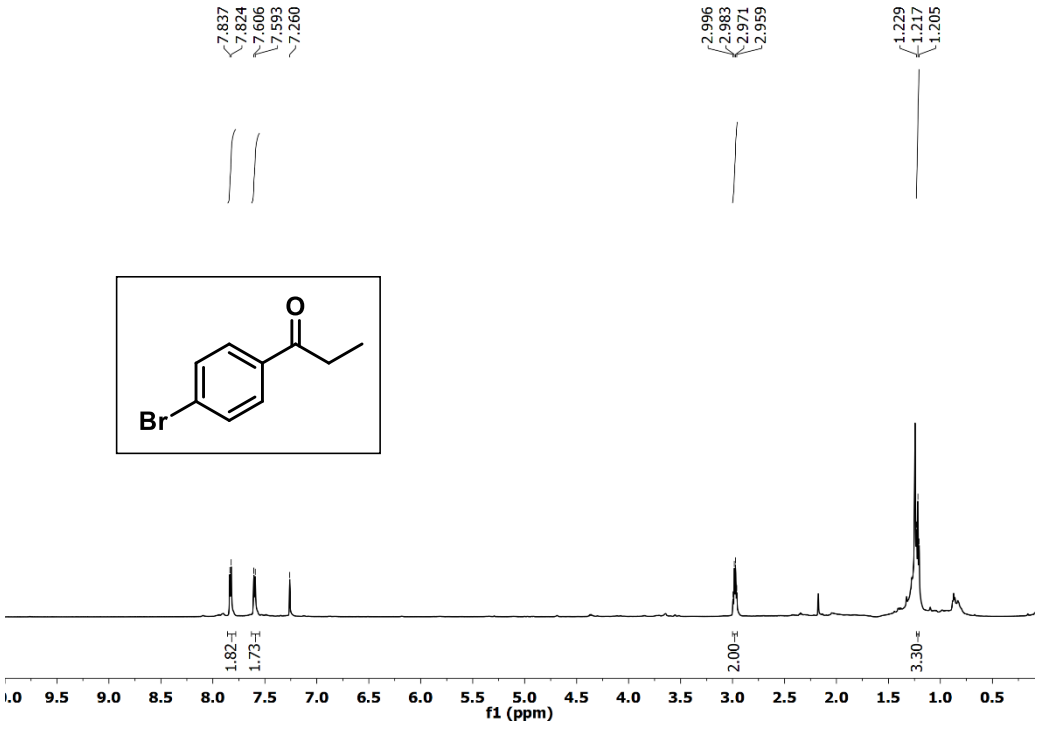
^{1}H NMR of ester **3d** (600 MHz, $CDCl_3$)



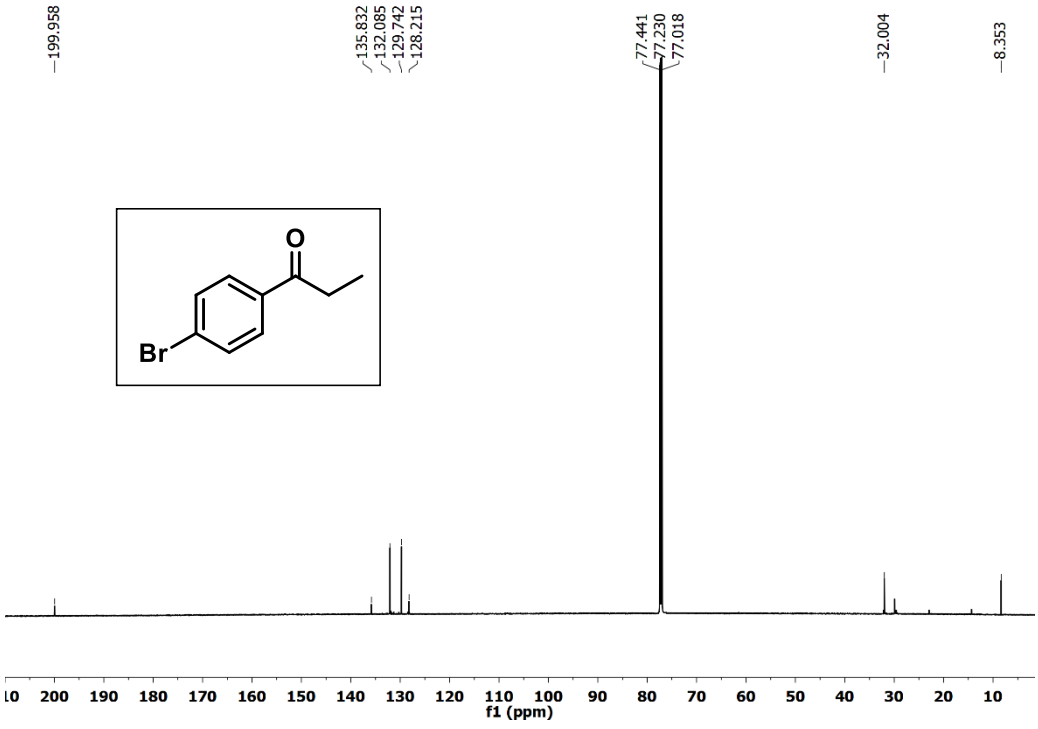
^{13}C{^{1}H} NMR of ester **3d** (151 MHz, $CDCl_3$)



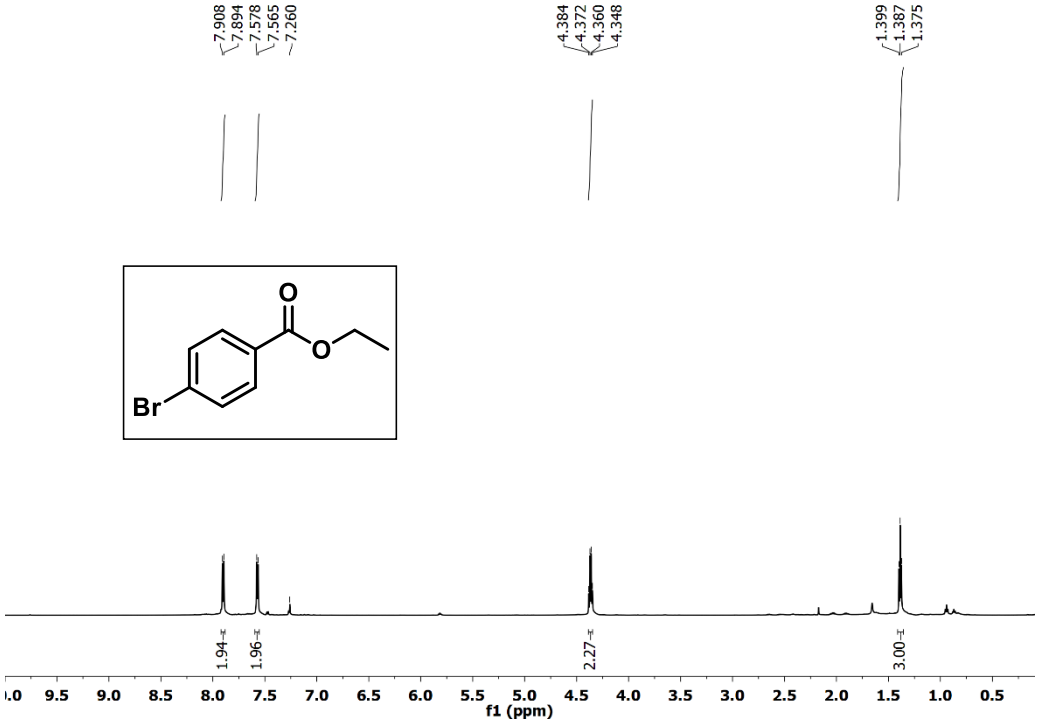
^{1}H NMR of ketone **2e** (600 MHz, $CDCl_3$)



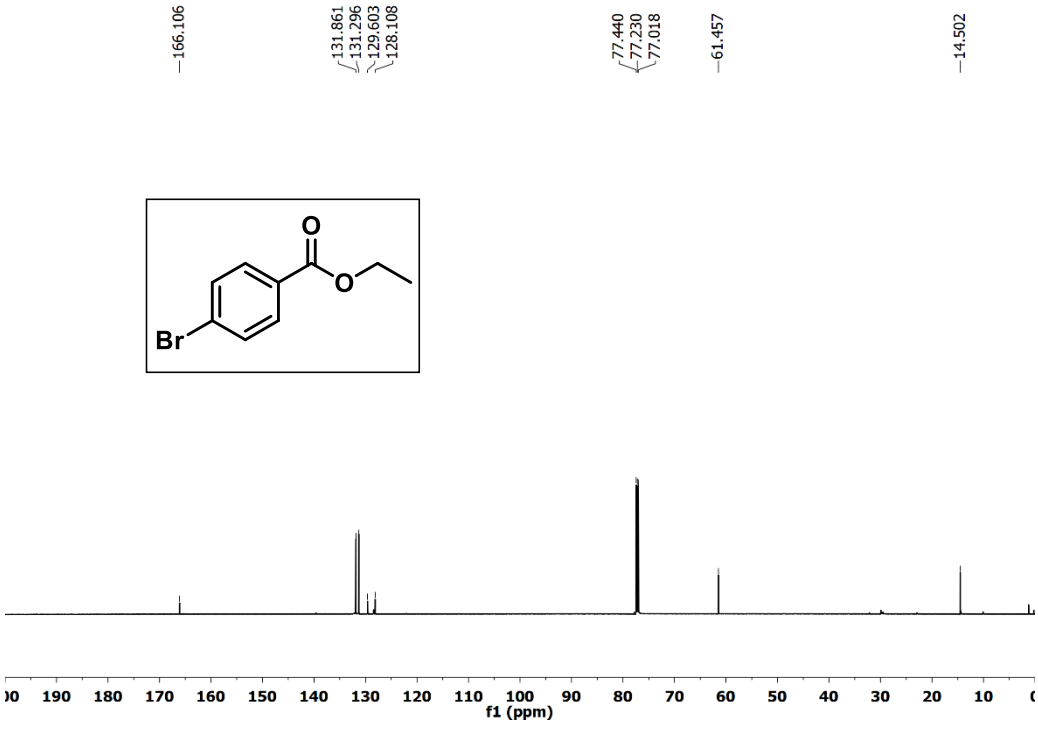
^{13}C{^{1}H} NMR of ketone **2e** (151 MHz, $CDCl_3$)



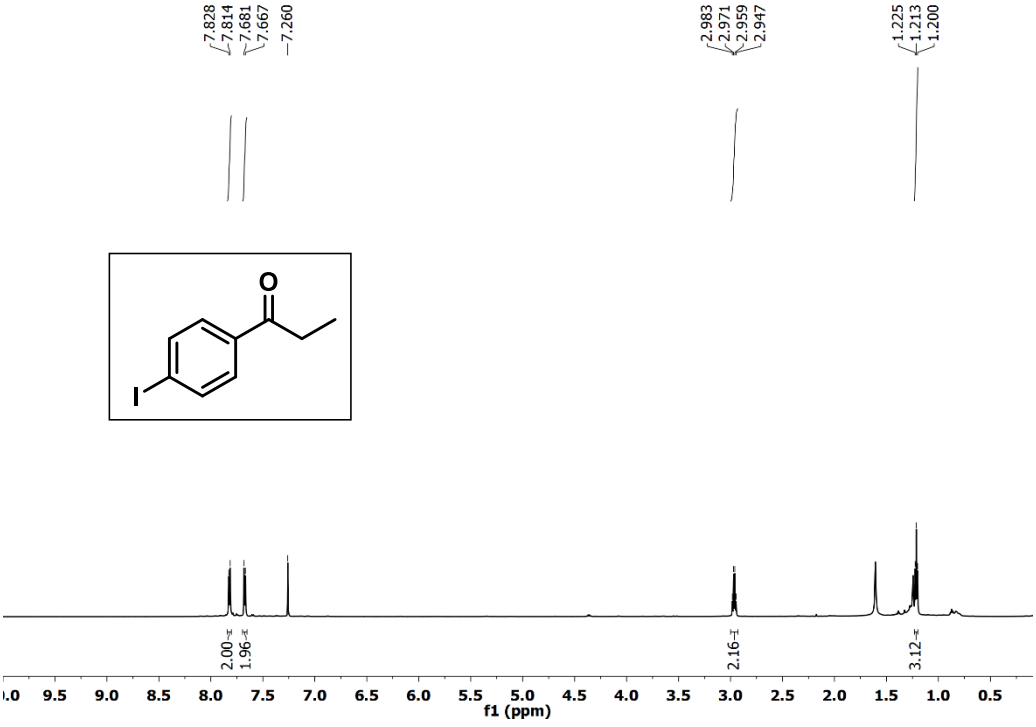
^{1}H NMR of ester **3e** (600 MHz, $CDCl_3$)



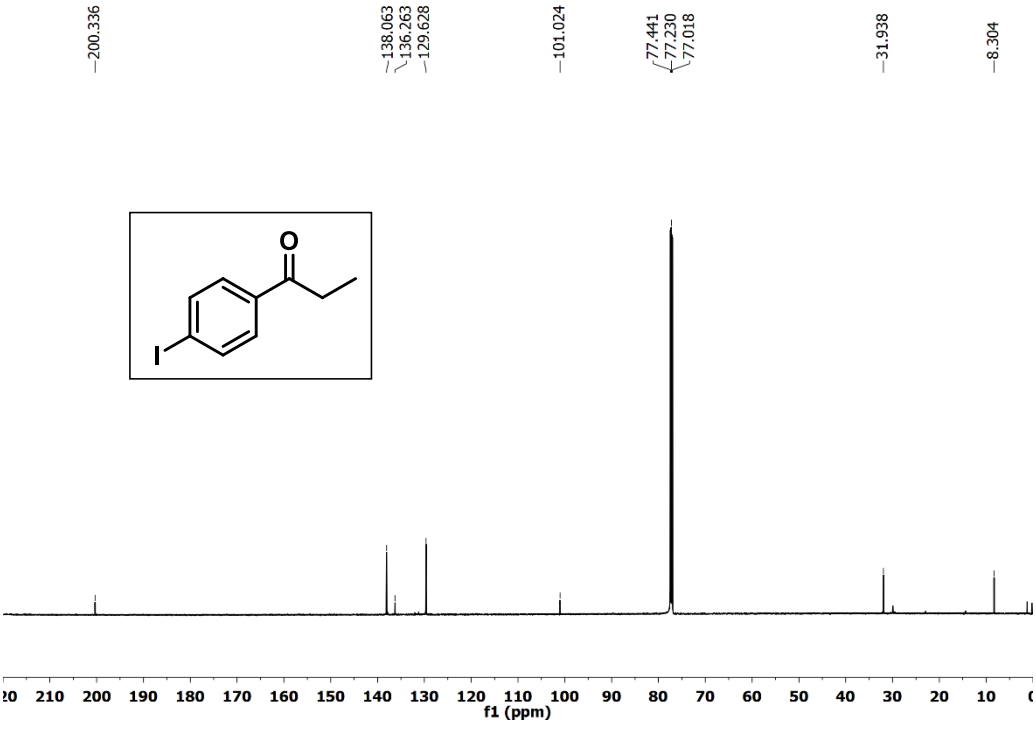
^{13}C{^{1}H} NMR of ester **3e** (151 MHz, $CDCl_3$)



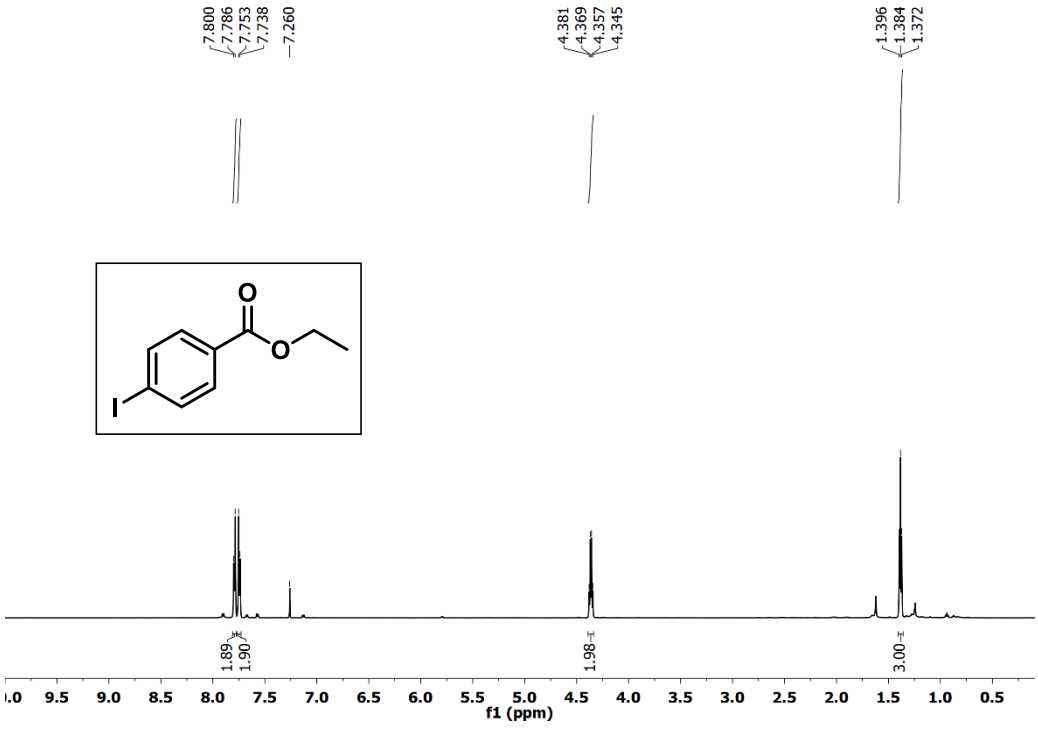
^{1}H NMR of ketone **2f** (600 MHz, $CDCl_3$)



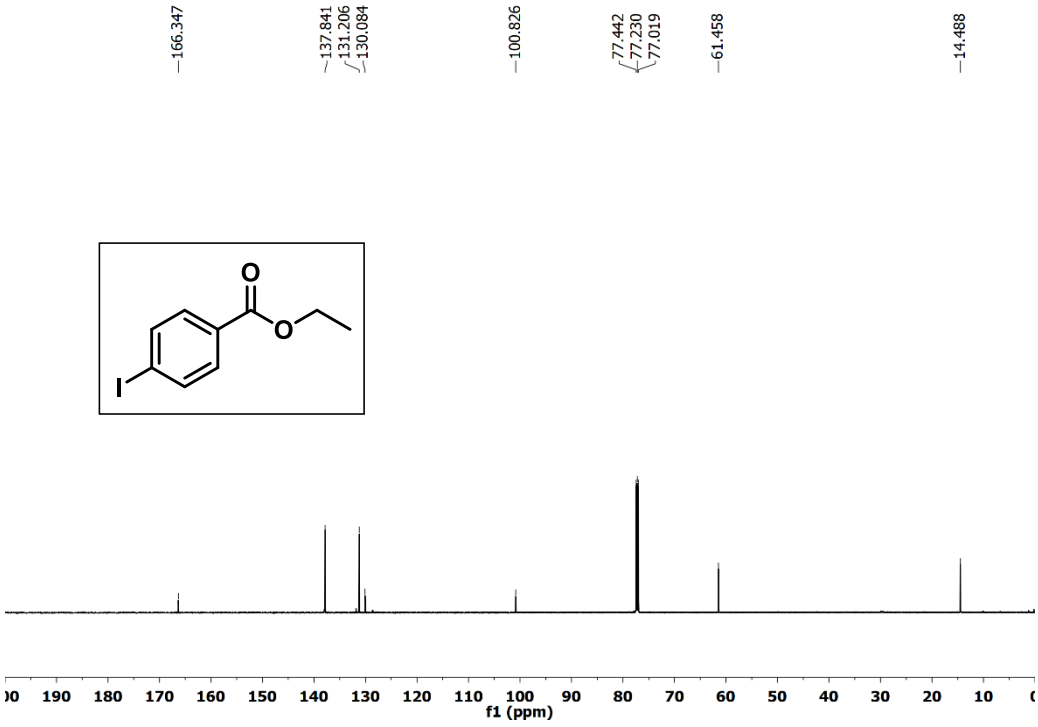
^{13}C{^{1}H} NMR of ketone **2f** (151 MHz, $CDCl_3$)



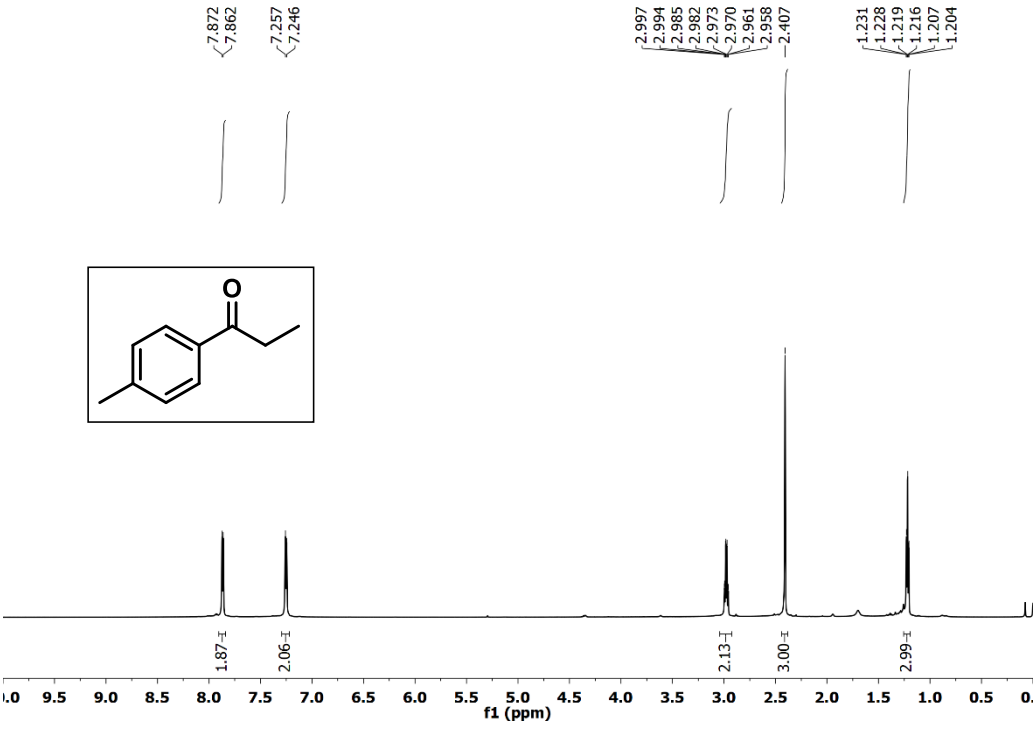
^{1}H NMR of ester **3f** (600 MHz, $CDCl_3$)



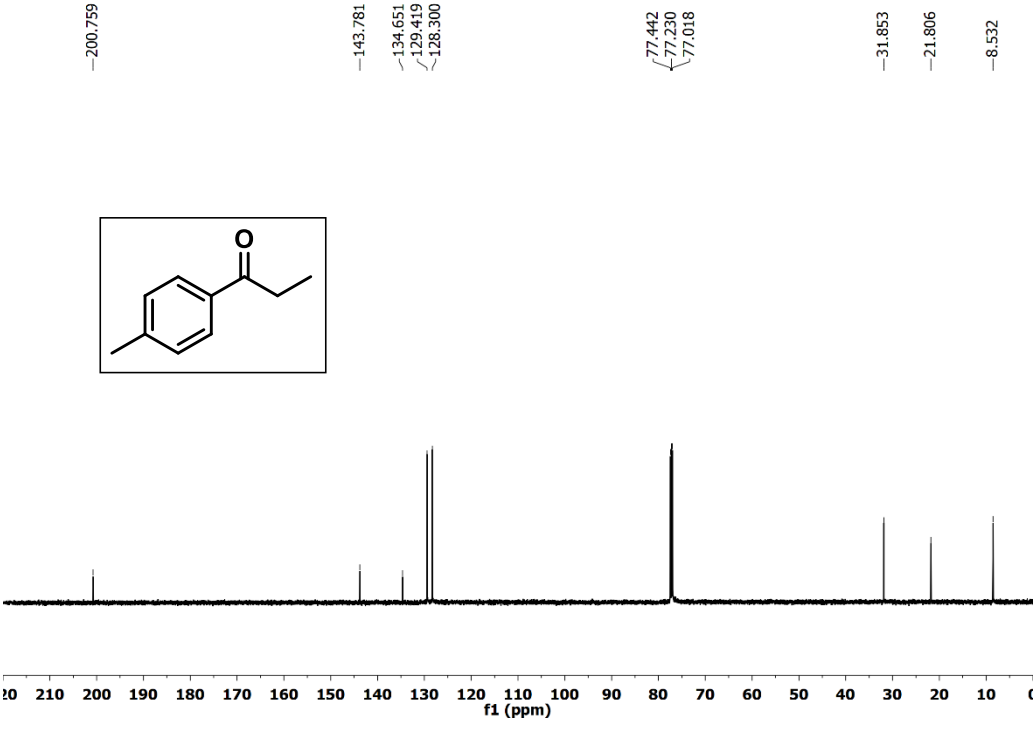
^{13}C{^{1}H} NMR of ester **3f** (151 MHz, $CDCl_3$)



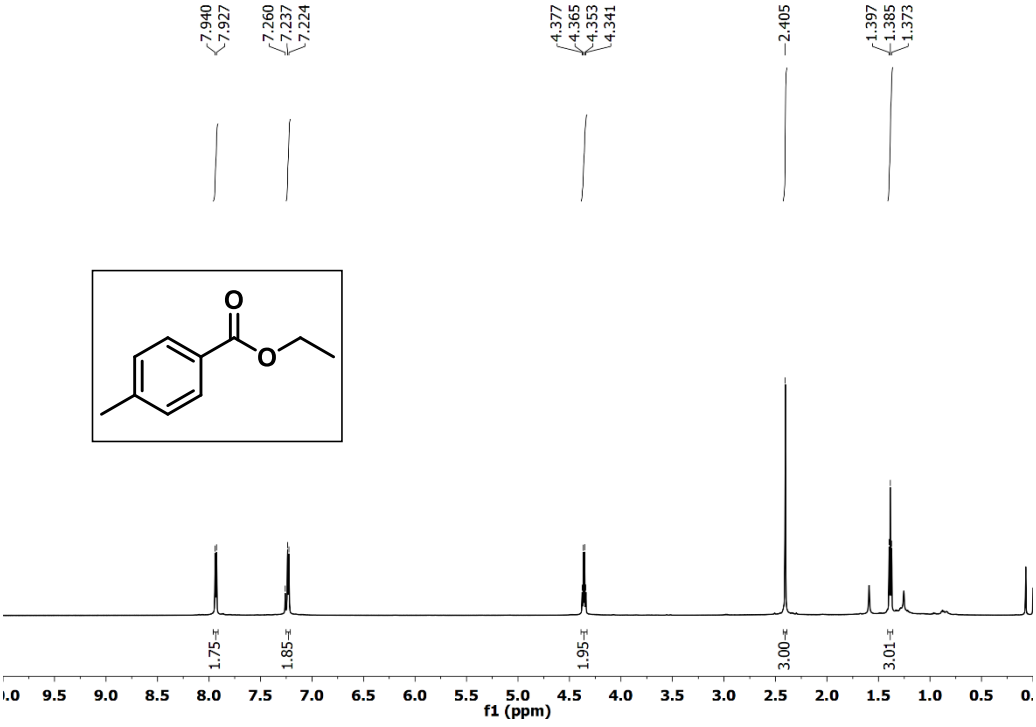
^{1}H NMR of ketone **2g** (600 MHz, $CDCl_3$)



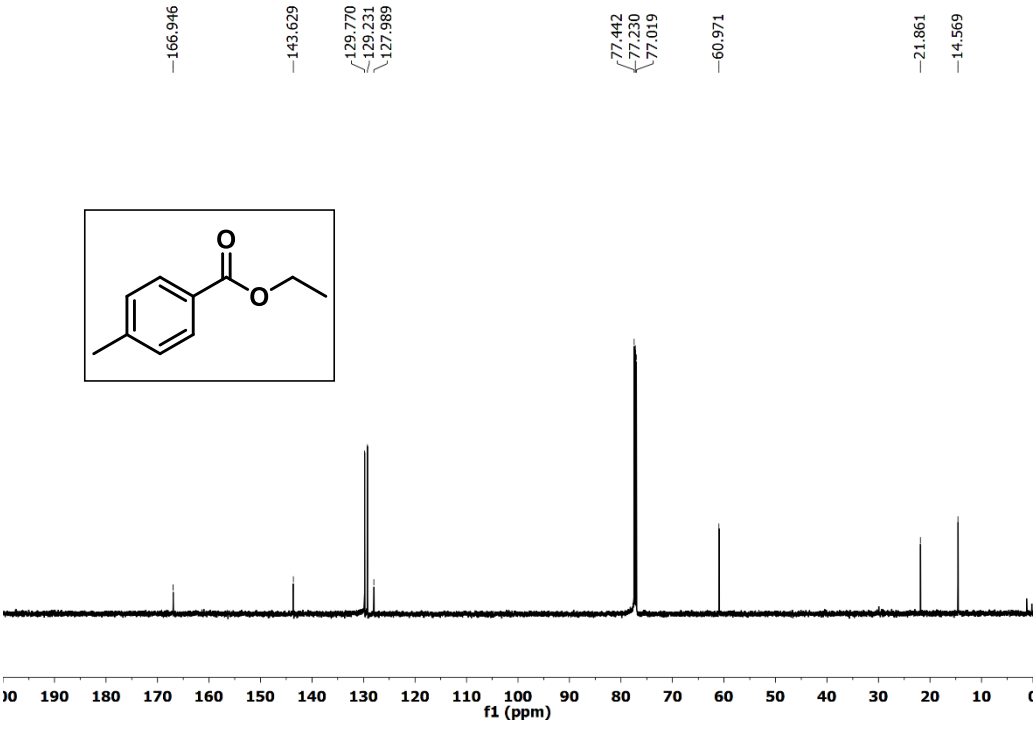
^{13}C{^{1}H} NMR of ketone **2g** (151 MHz, $CDCl_3$)



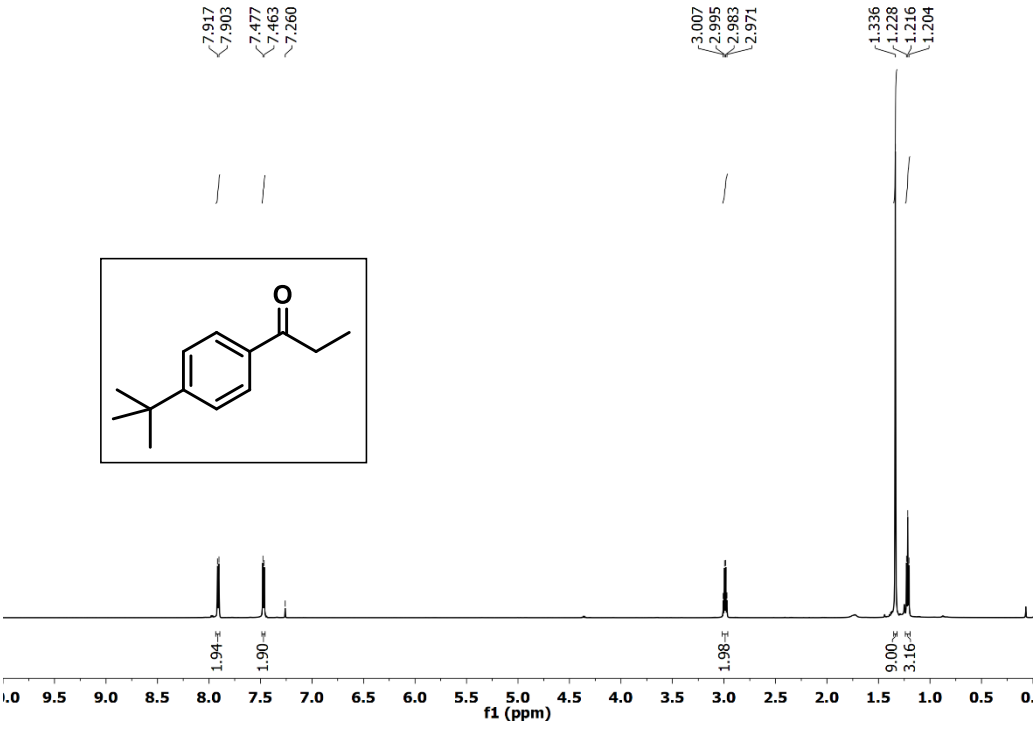
^{1}H NMR of ester **3g** (600 MHz, $CDCl_3$)



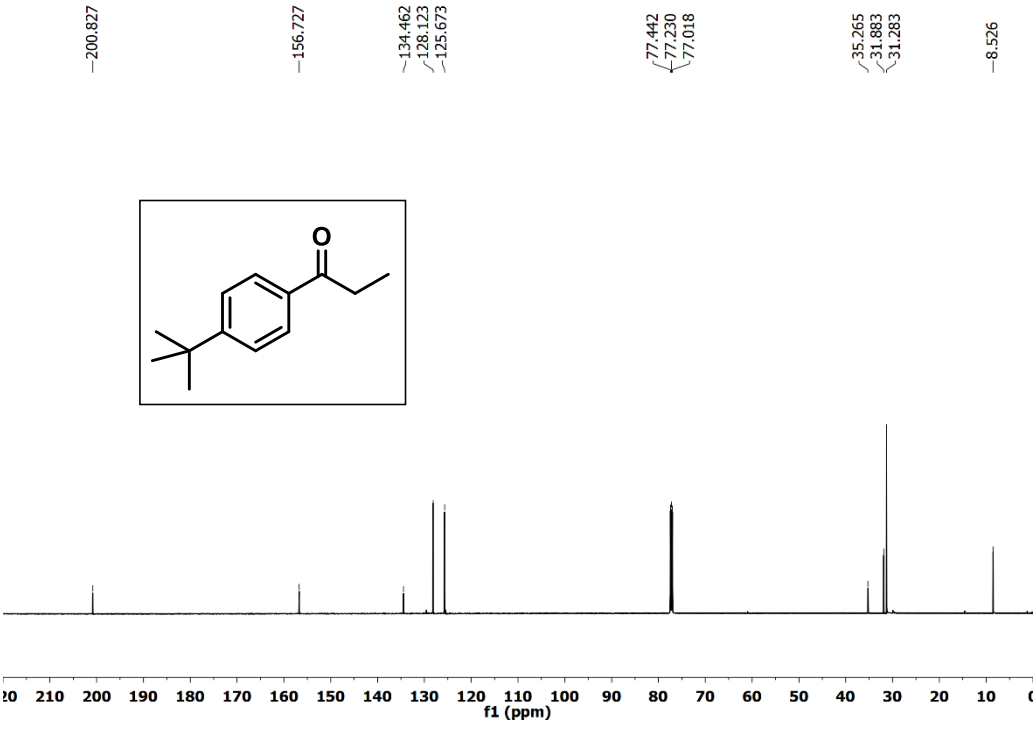
^{13}C{^{1}H} NMR of ester **3g** (151 MHz, $CDCl_3$)



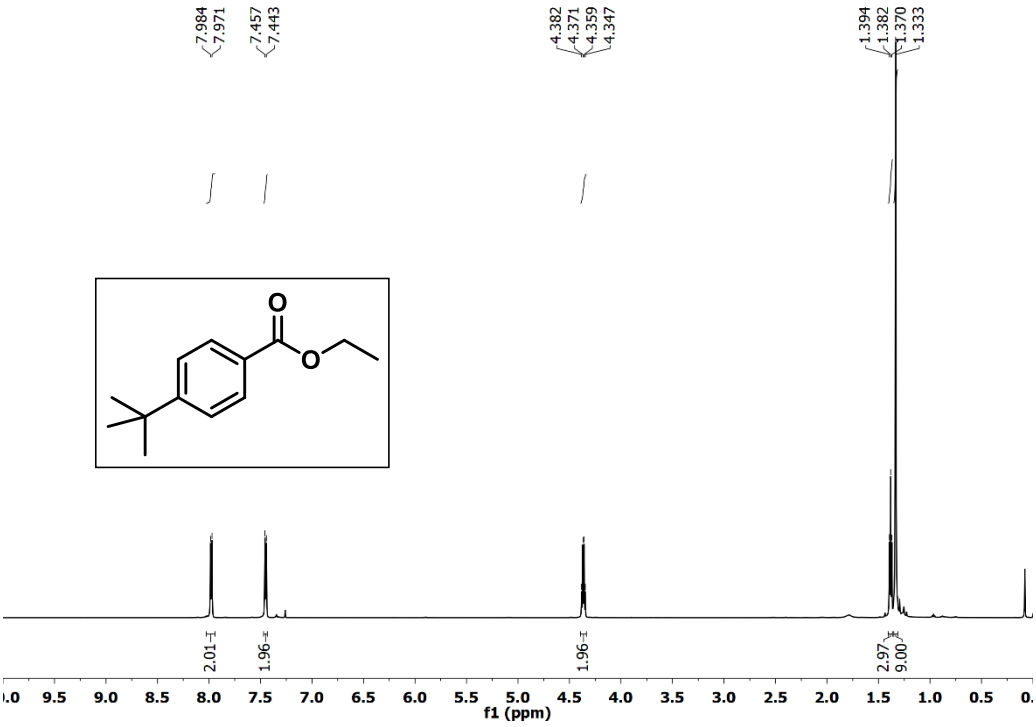
^{1}H NMR of ketone **2h** (600 MHz, $CDCl_3$)



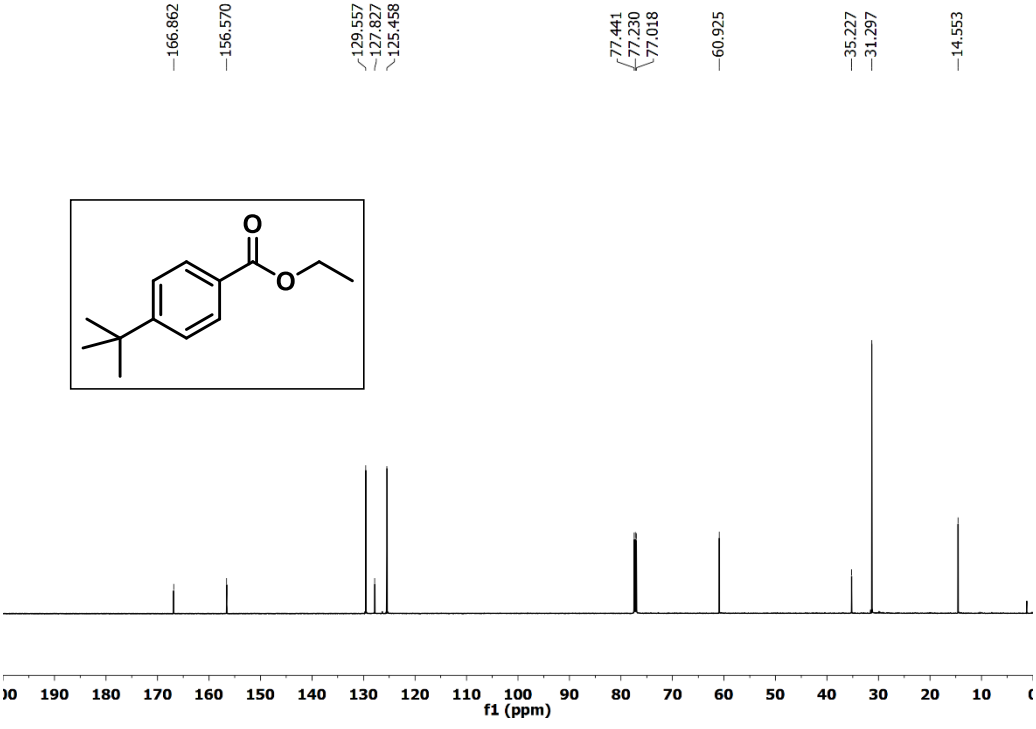
^{13}C{^{1}H} NMR of ketone **2h** (151 MHz, $CDCl_3$)



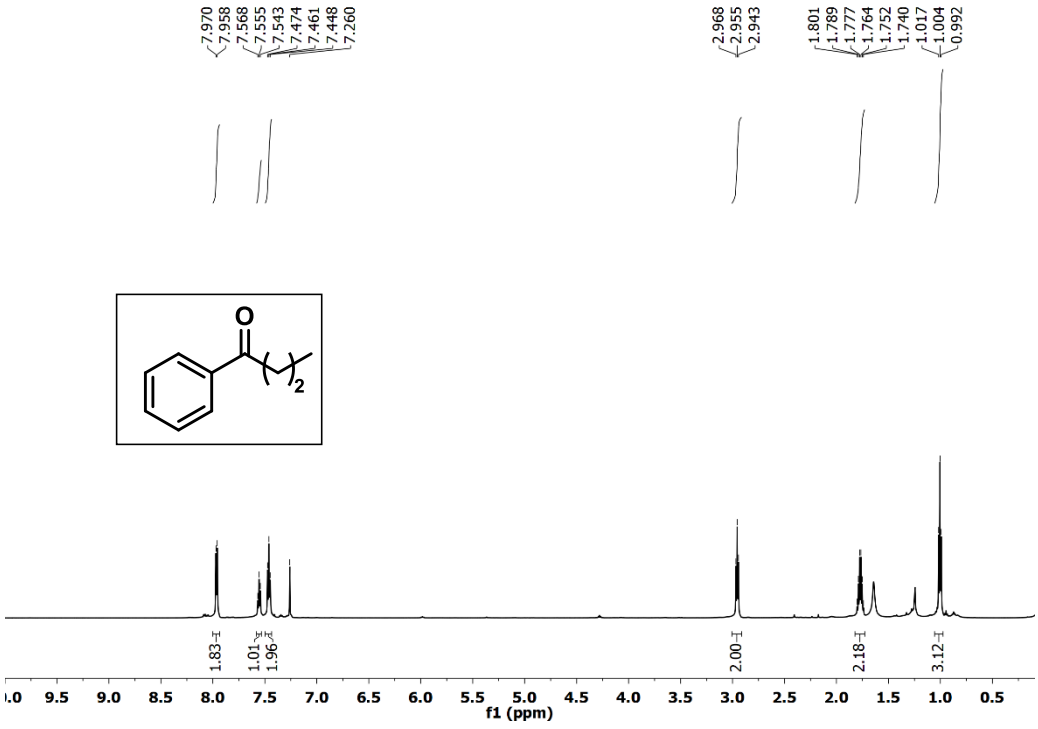
^{1}H NMR of ester **3h** (600 MHz, $CDCl_3$)



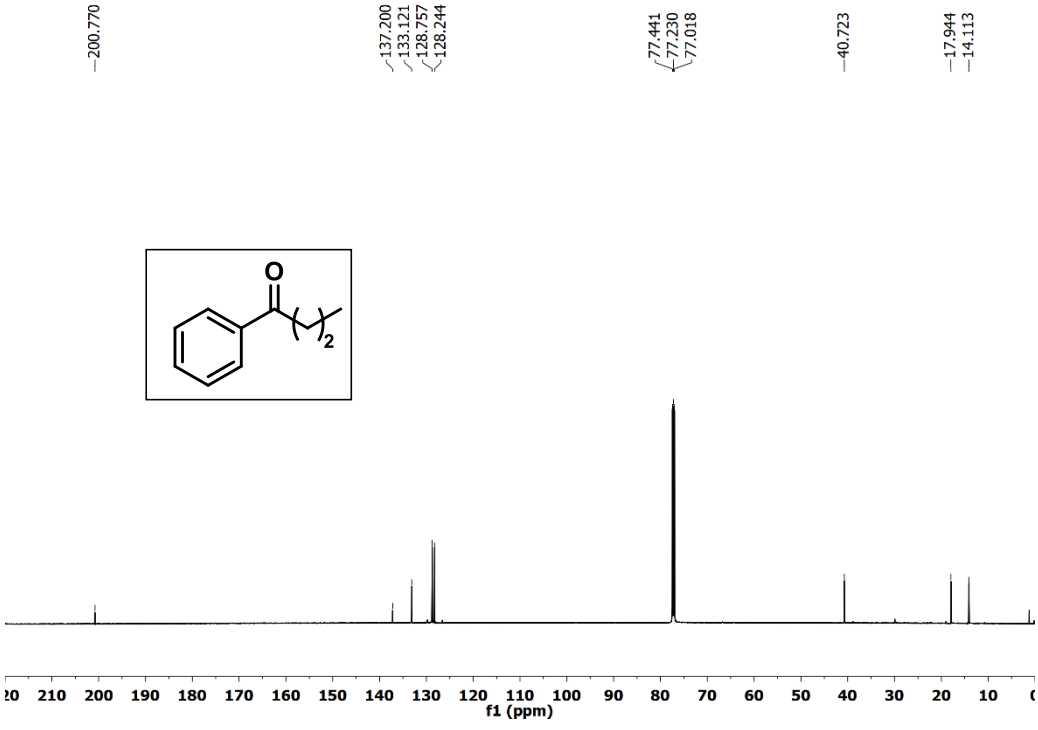
^{13}C{^{1}H} NMR of ester **3h** (151 MHz, $CDCl_3$)



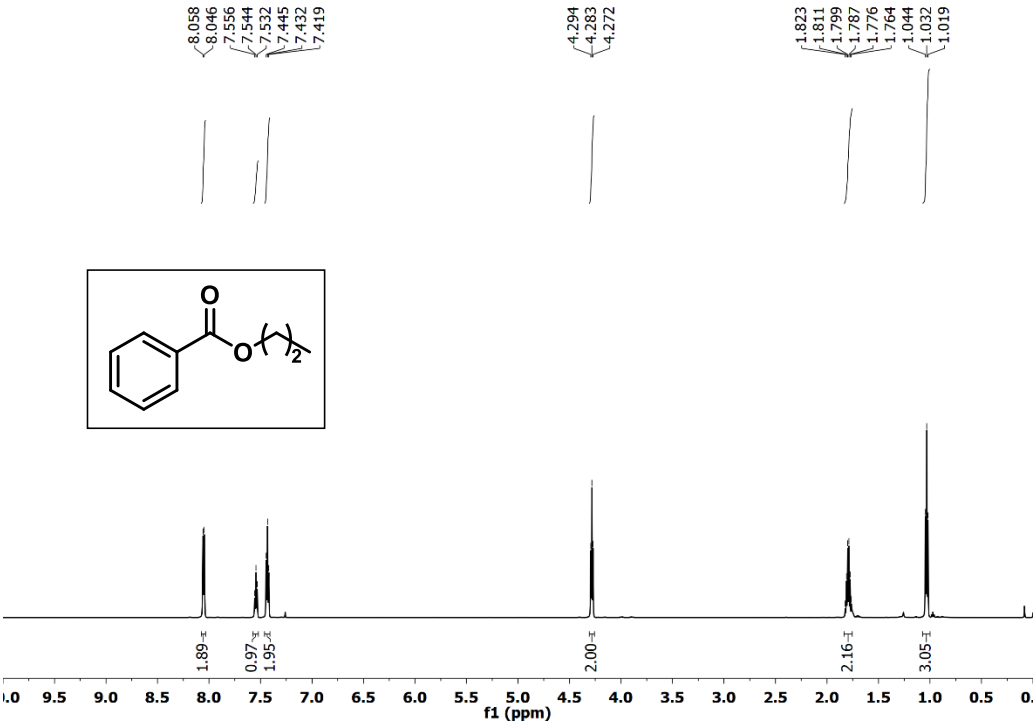
^{1}H NMR of ketone **2i** (600 MHz, $CDCl_3$)



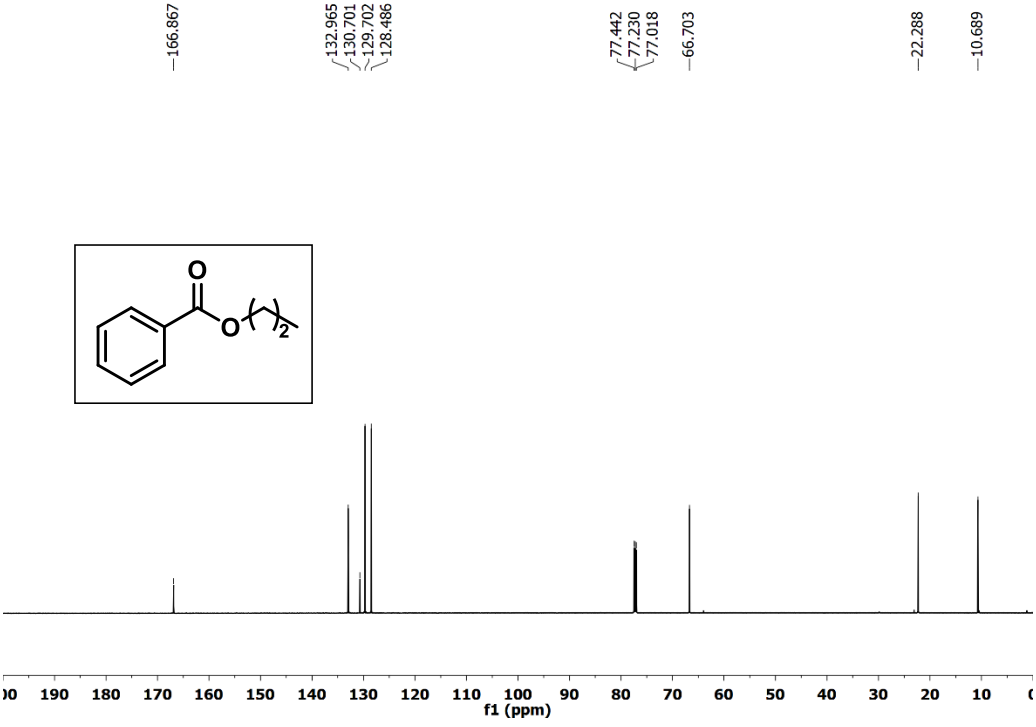
^{13}C{^{1}H} NMR of ketone **2i** (151 MHz, $CDCl_3$)



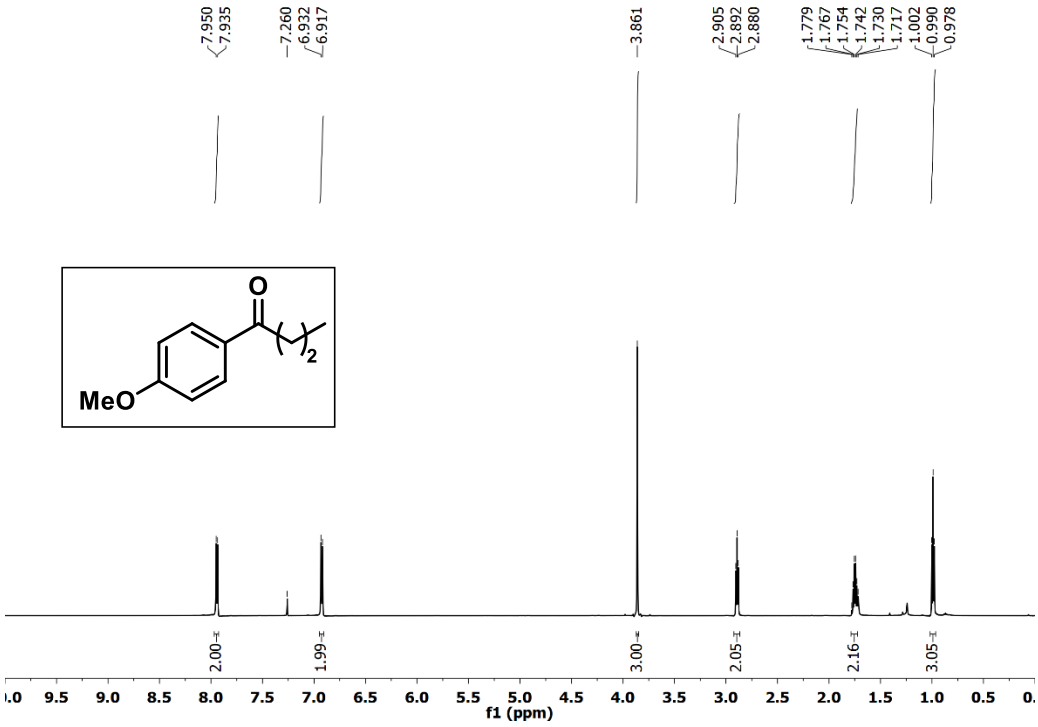
^{1}H NMR of ester **3i** (600 MHz, $CDCl_3$)



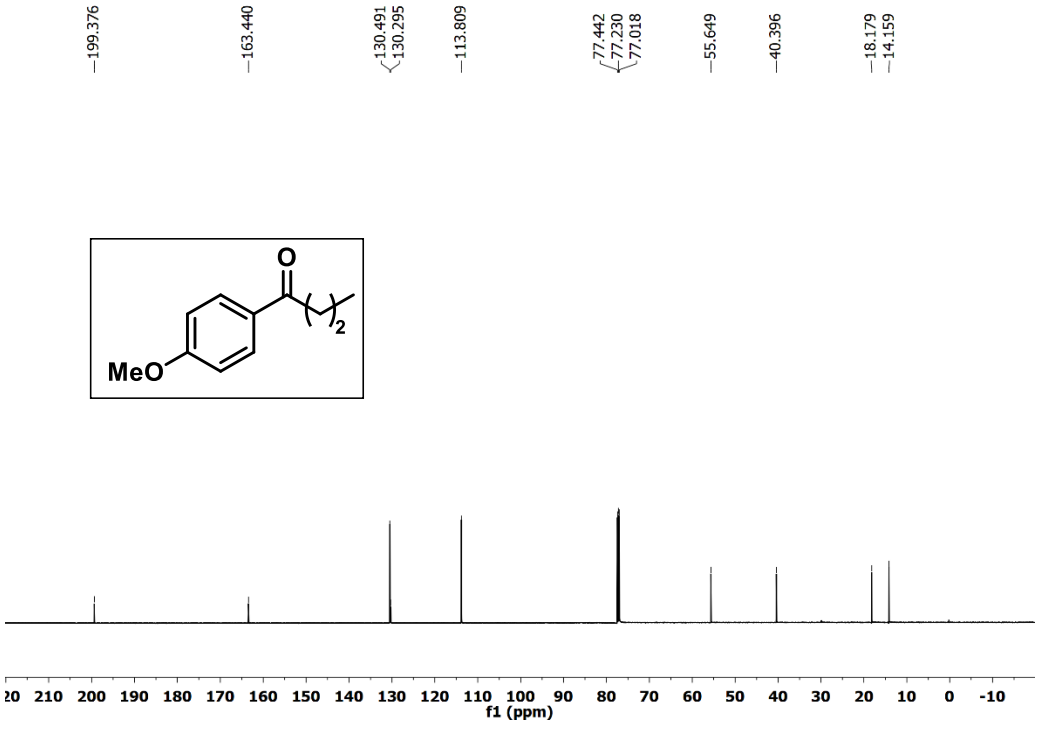
^{13}C{^{1}H} NMR of ester **3i** (151 MHz, $CDCl_3$)



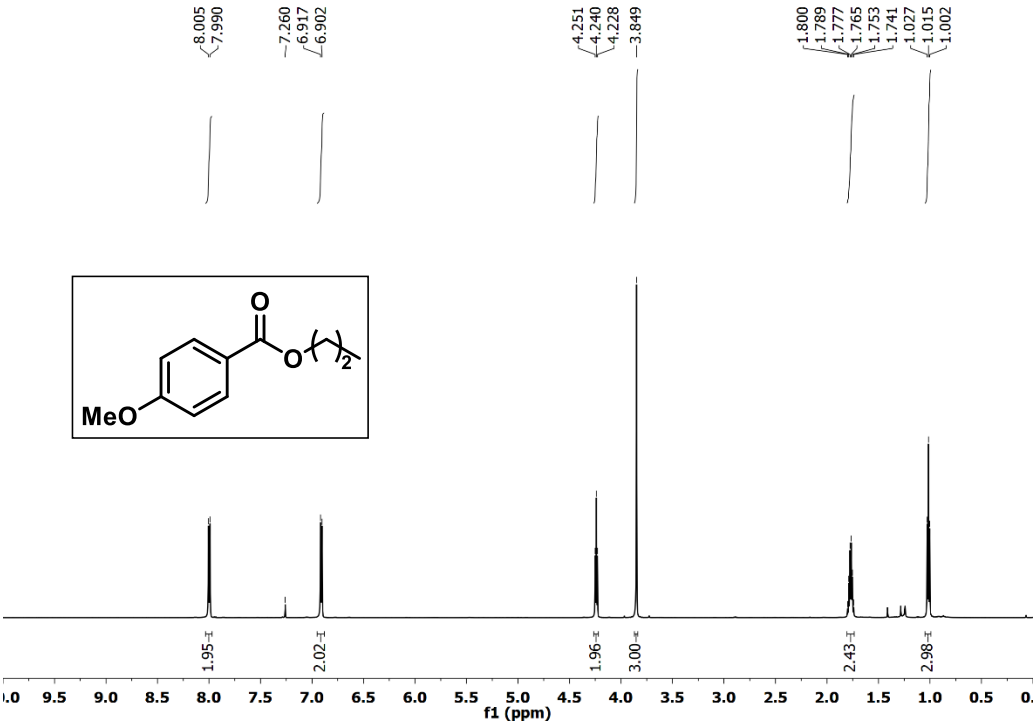
^{1}H NMR of ketone **2j** (600 MHz, $CDCl_3$)



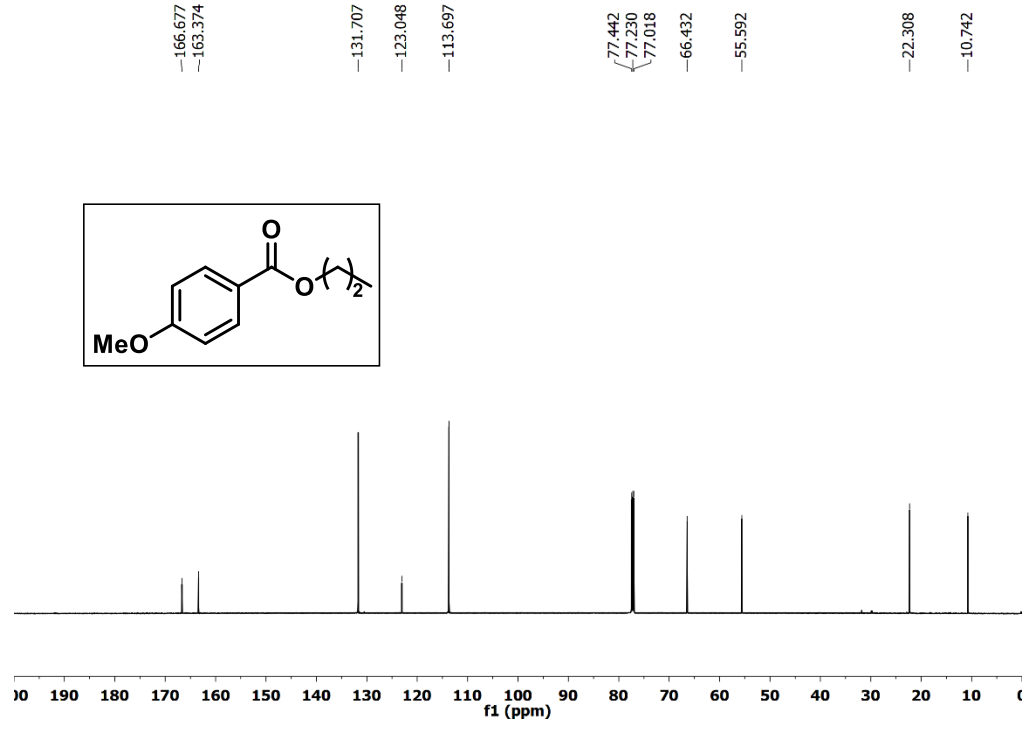
^{13}C{^{1}H} NMR of ketone **2j** (151 MHz, $CDCl_3$)



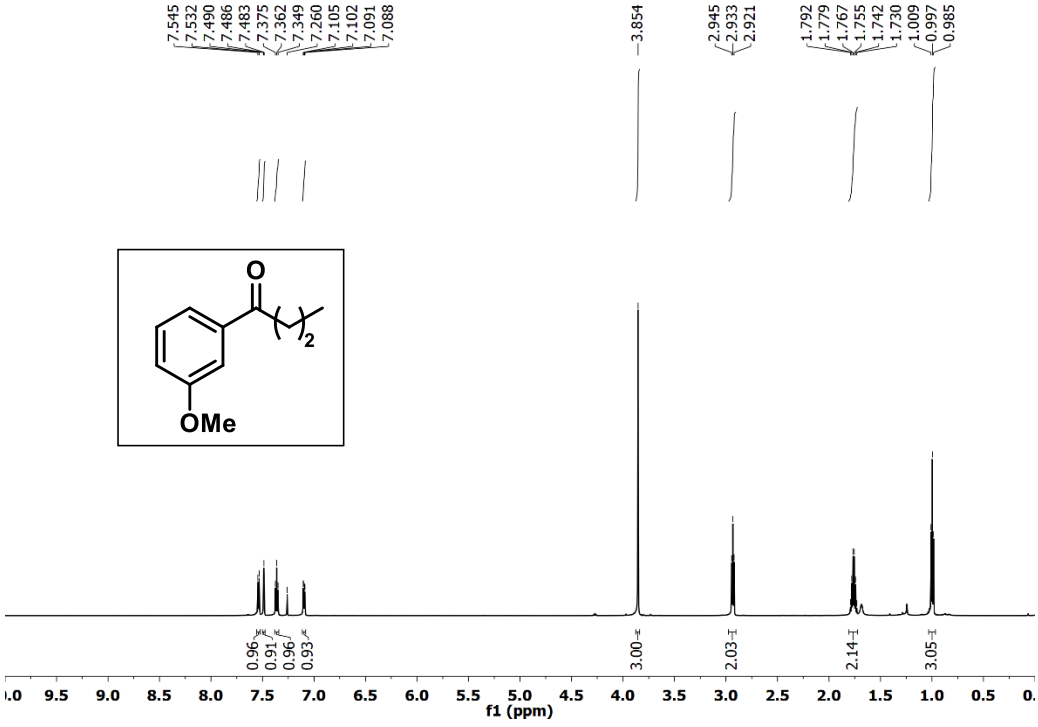
^{1}H NMR of ester **3j** (600 MHz, $CDCl_3$)



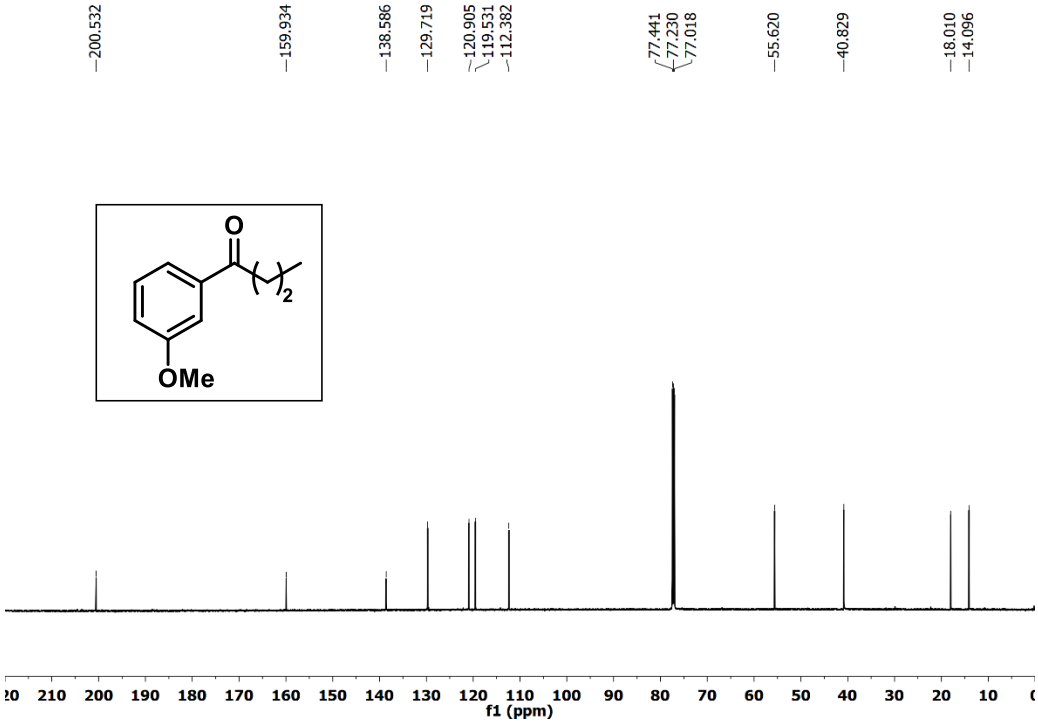
^{13}C{^{1}H} NMR of ester **3j** (151 MHz, $CDCl_3$)



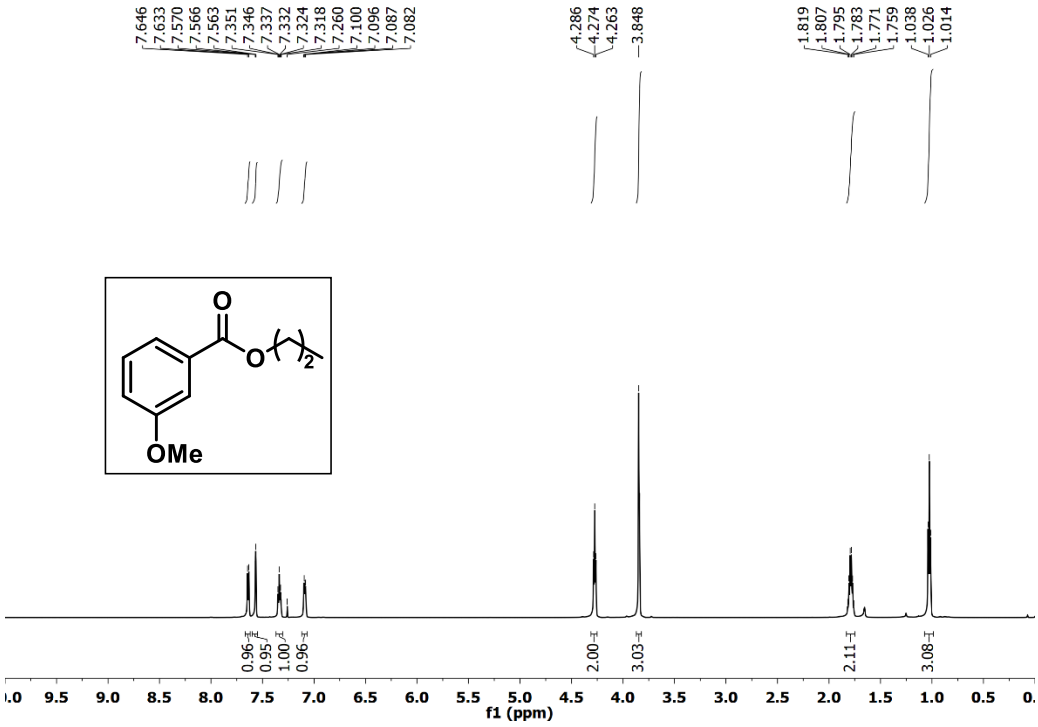
^{1}H NMR of ketone **2k** (600 MHz, $CDCl_3$)



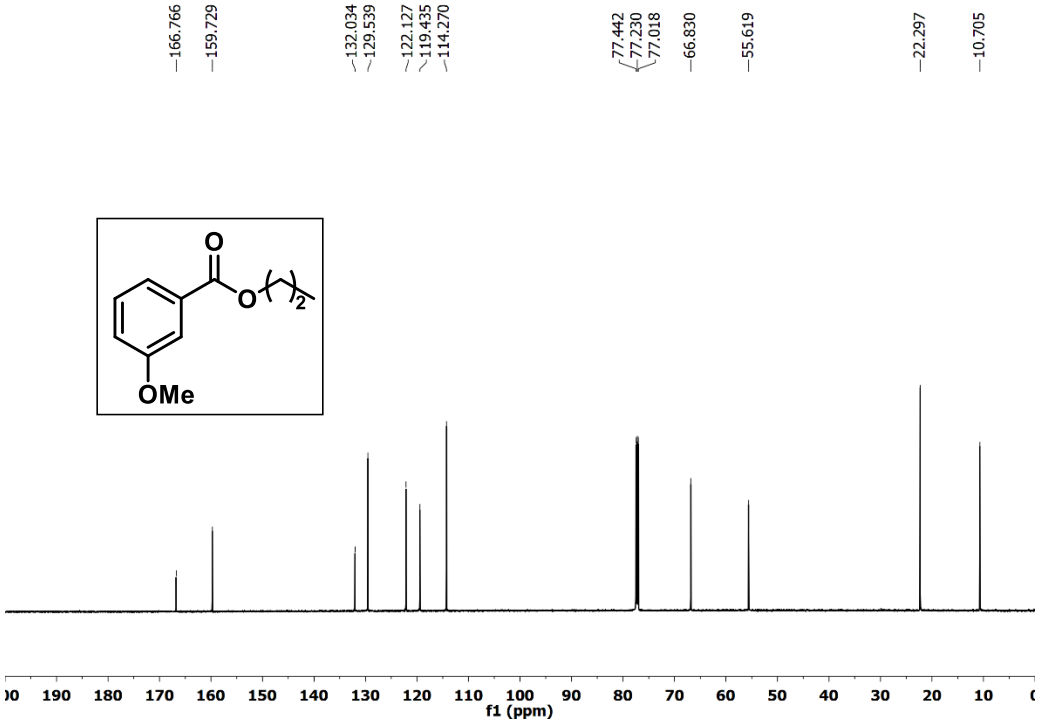
^{13}C{^{1}H} NMR of ketone **2k** (151 MHz, $CDCl_3$)



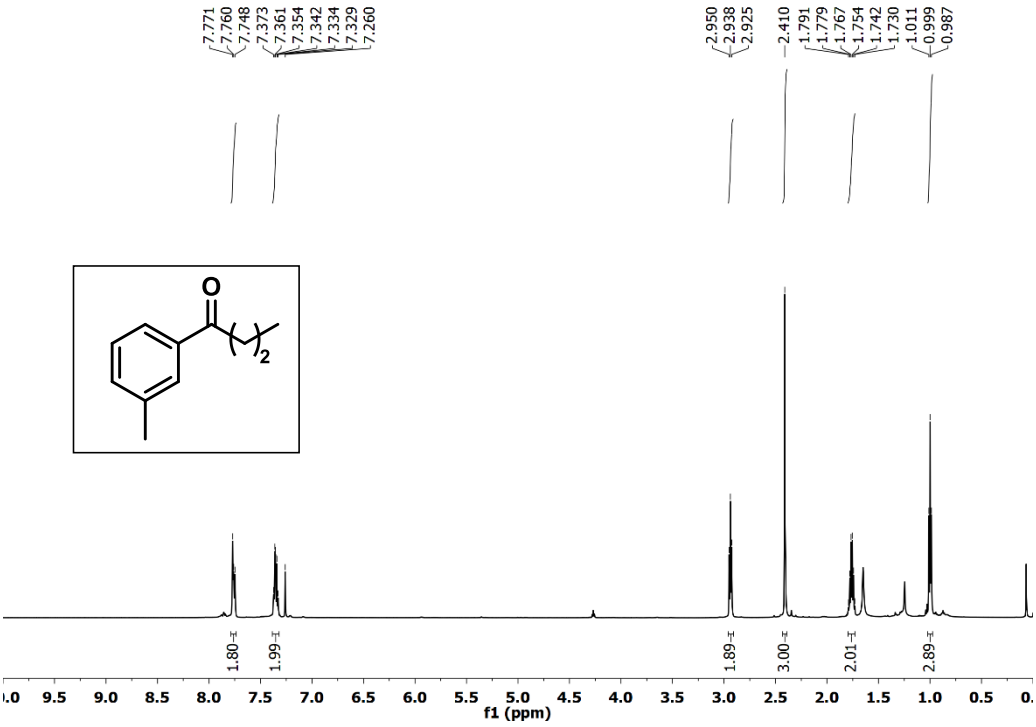
^{1}H NMR of ester **3k** (600 MHz, $CDCl_3$)



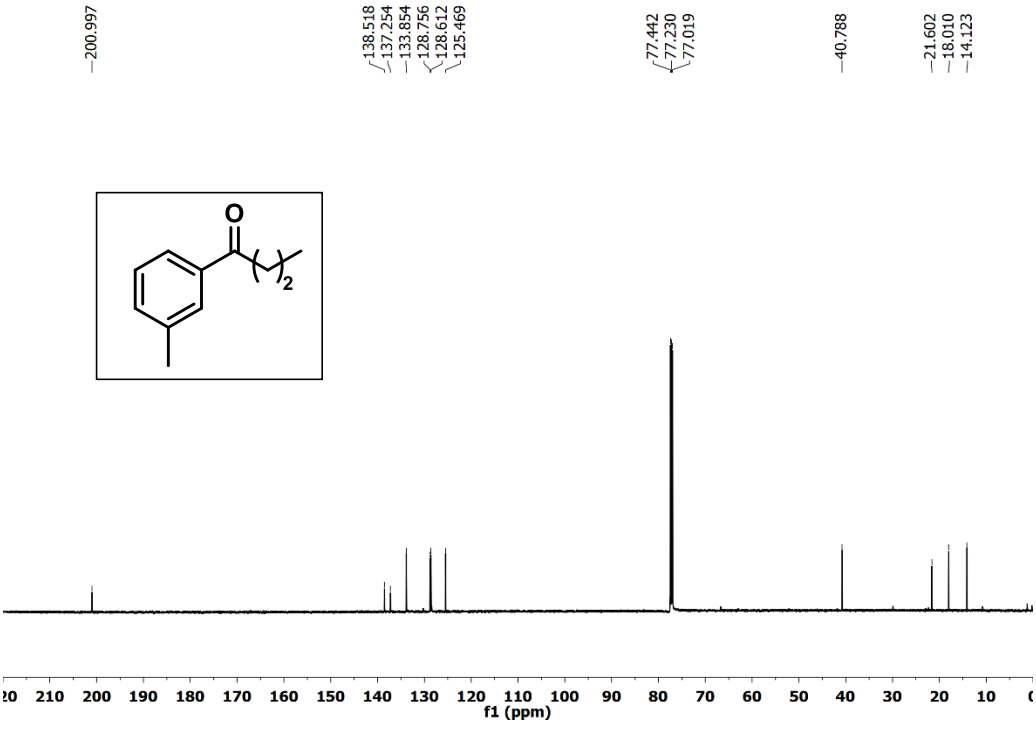
^{13}C{^{1}H} NMR of ester **3k** (151 MHz, $CDCl_3$)



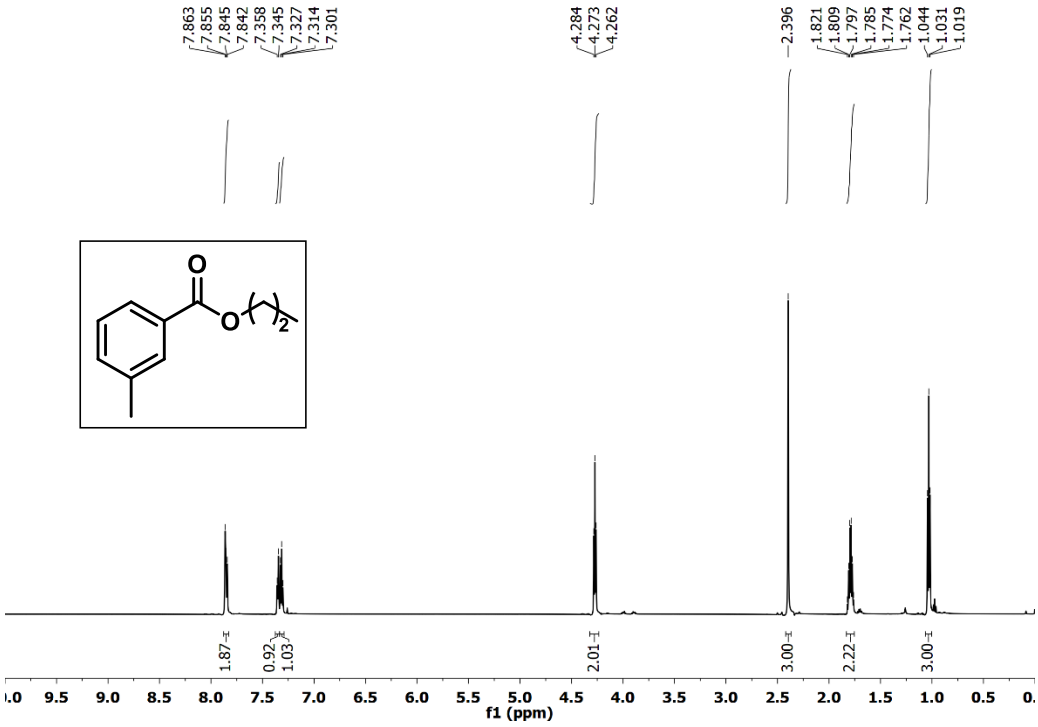
^{1}H NMR of ketone **2l** (600 MHz, $CDCl_3$)



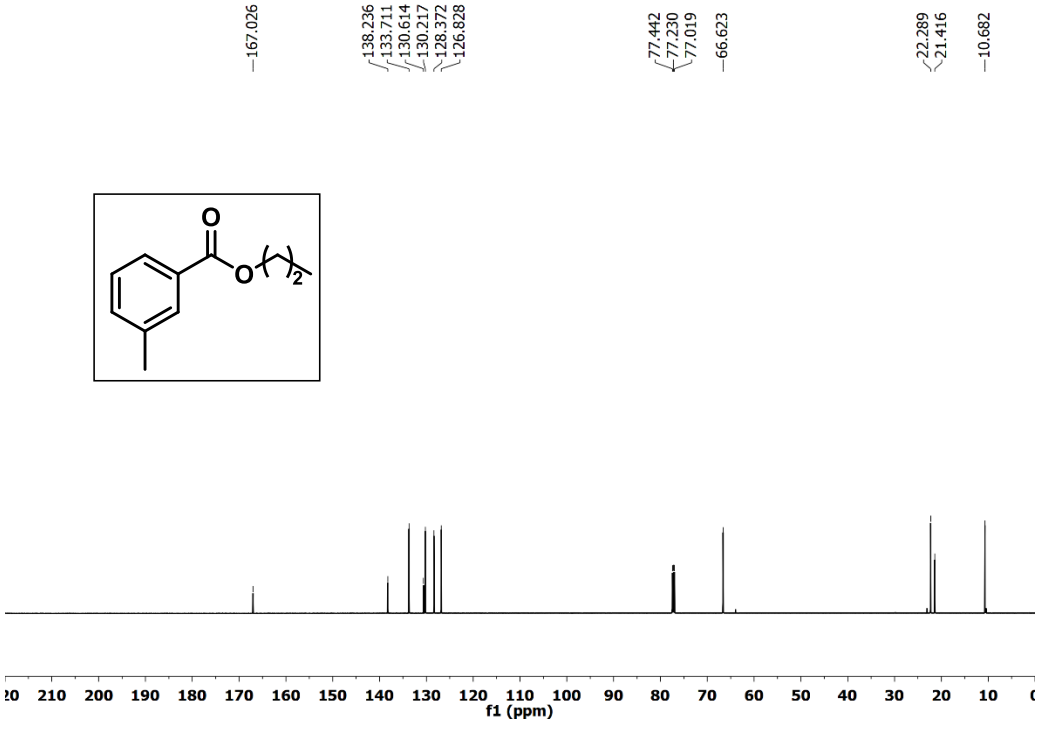
^{13}C{^{1}H} NMR of ketone **2l** (151 MHz, $CDCl_3$)



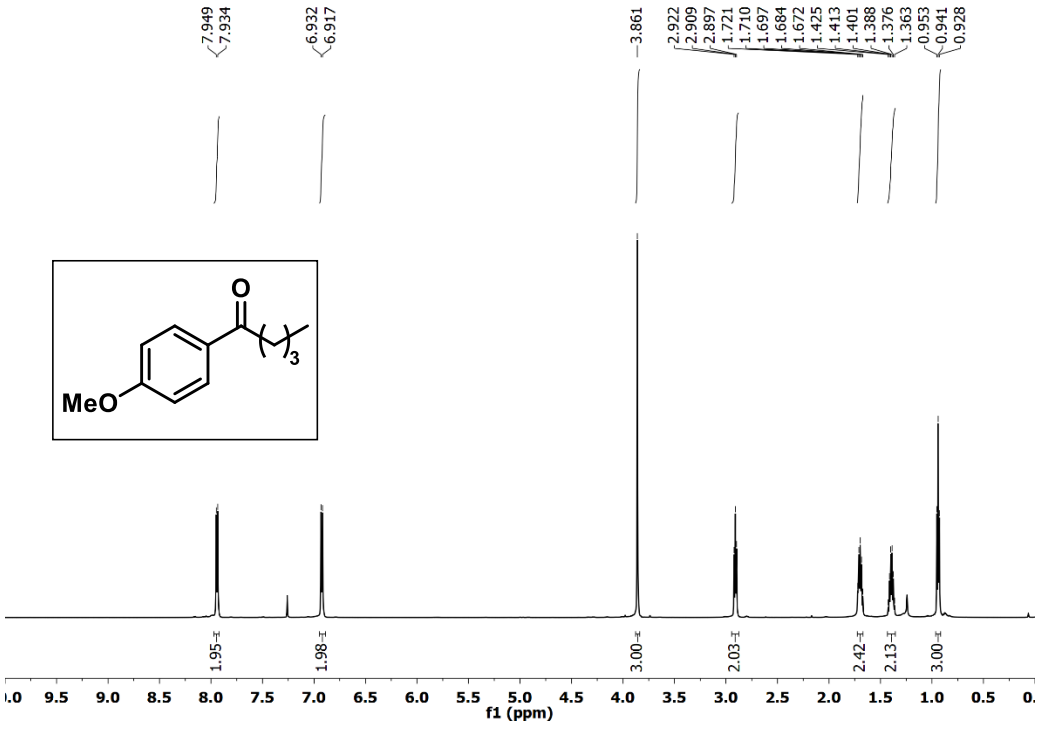
^{1}H NMR of ester **3l** (600 MHz, $CDCl_3$)



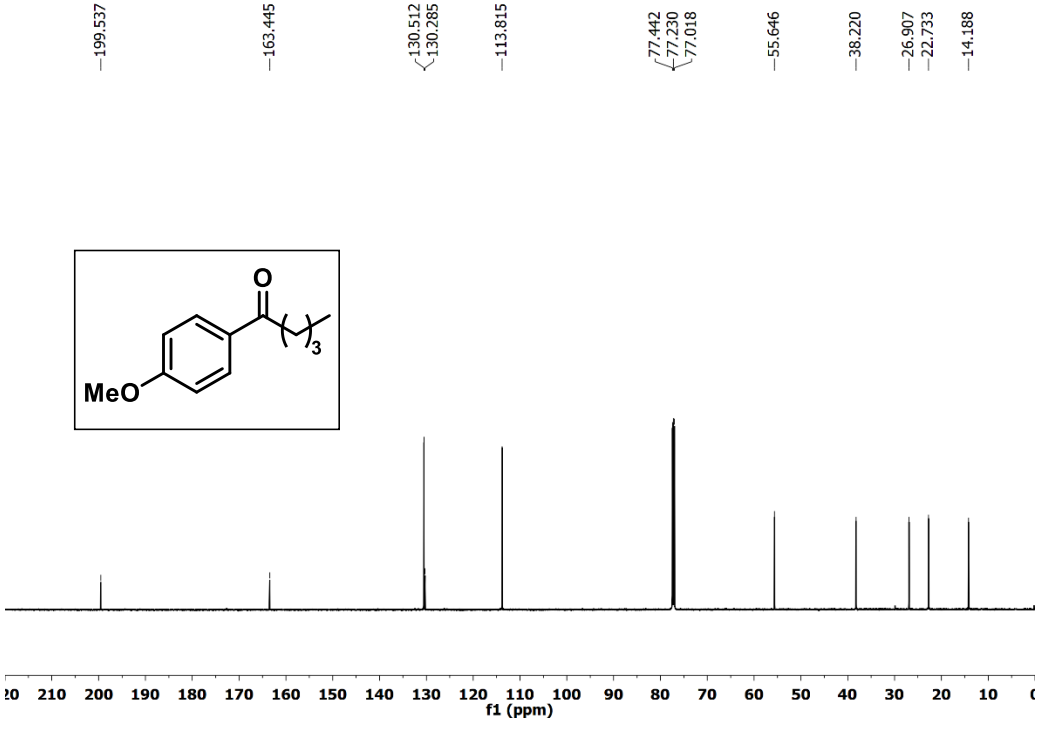
^{13}C{^{1}H} NMR of ester **3l** (151 MHz, $CDCl_3$)



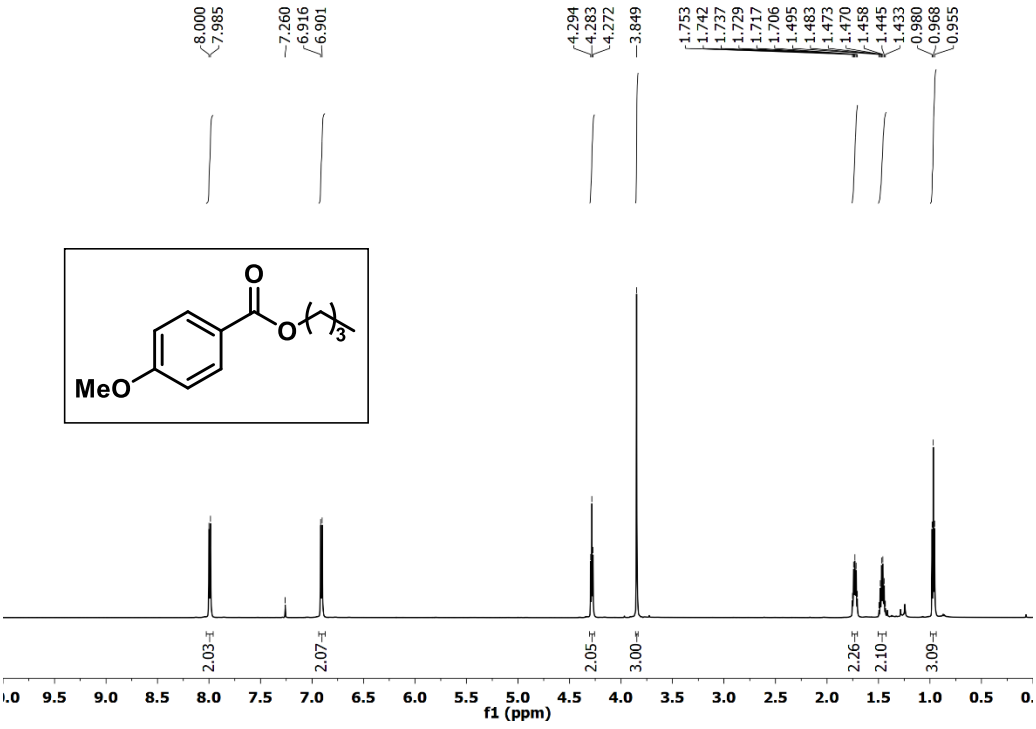
^{1}H NMR of ketone **2m** (600 MHz, $CDCl_3$)



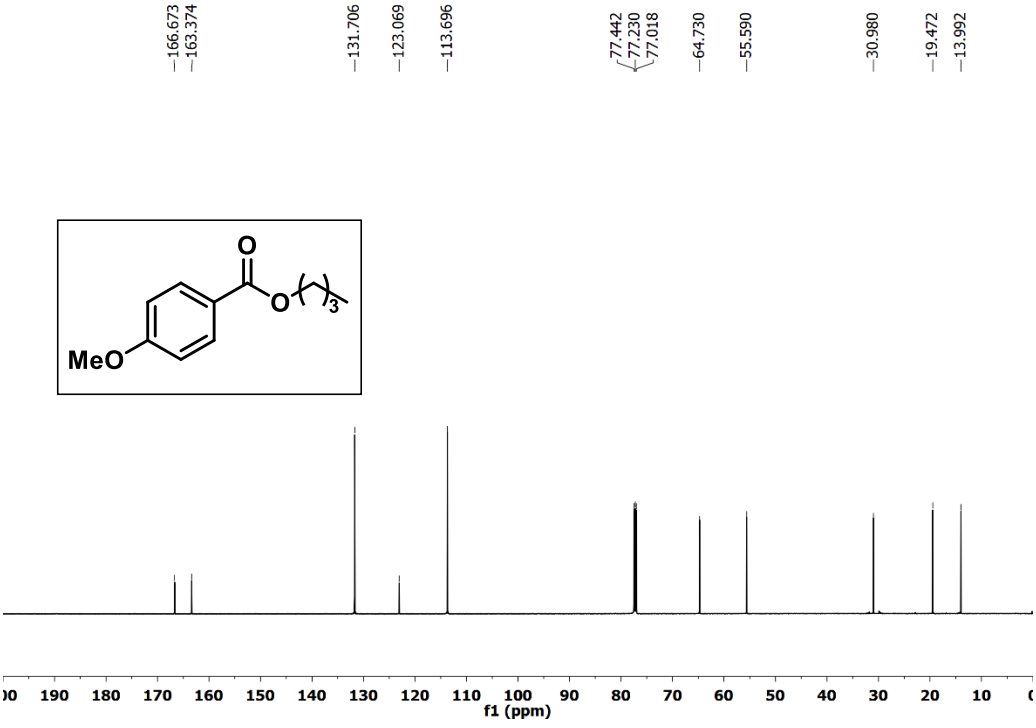
^{13}C{^{1}H} NMR of ketone **2m** (151 MHz, $CDCl_3$)



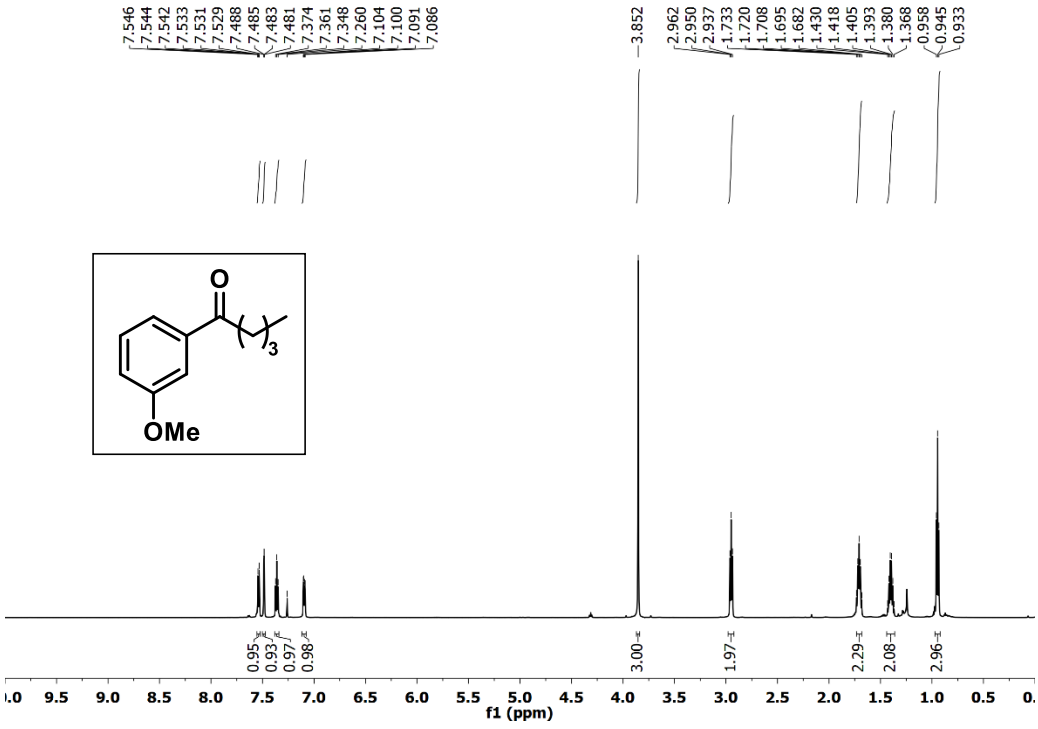
^{1}H NMR of ester **3m** (600 MHz, $CDCl_3$)



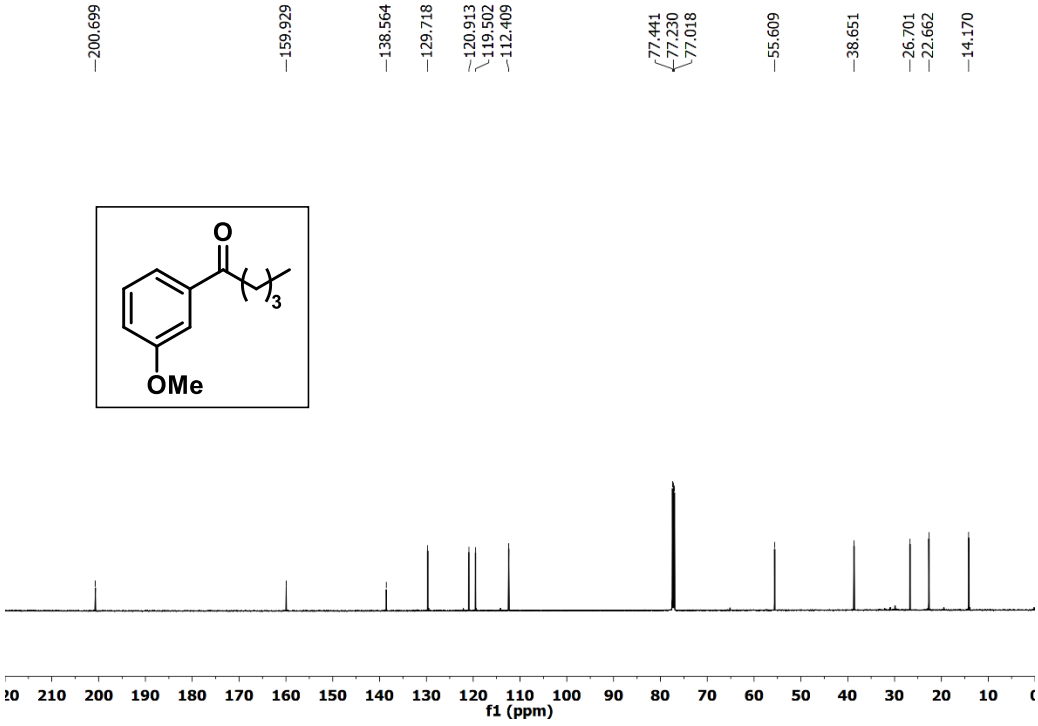
^{13}C{^{1}H} NMR of ester **3m** (151 MHz, $CDCl_3$)



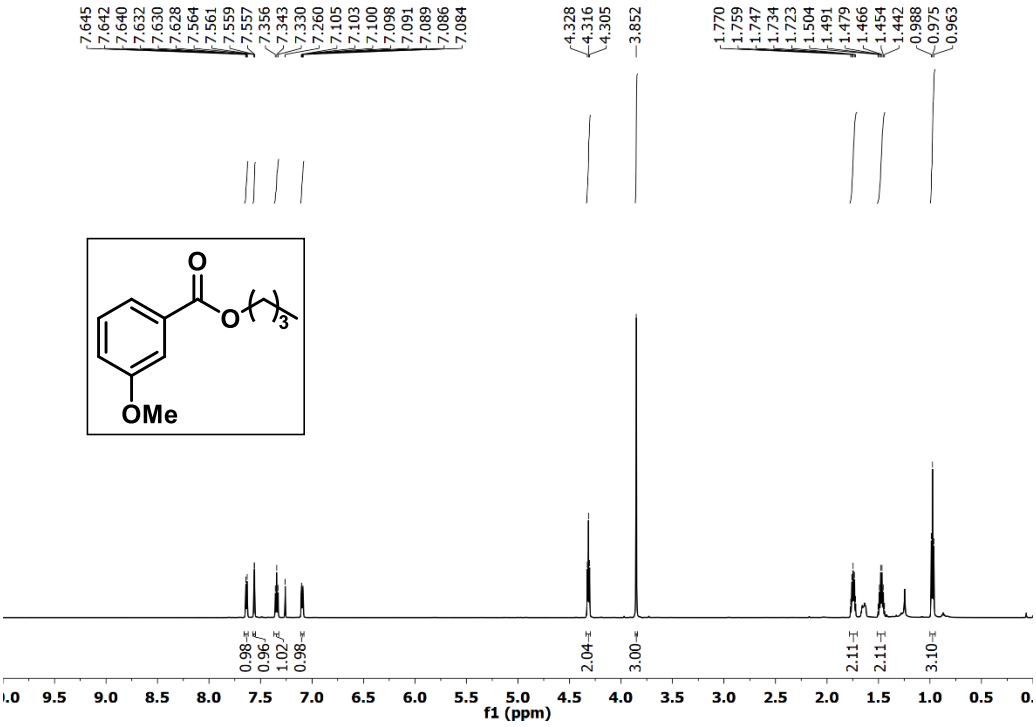
^{1}H NMR of ketone **2n** (600 MHz, $CDCl_3$)



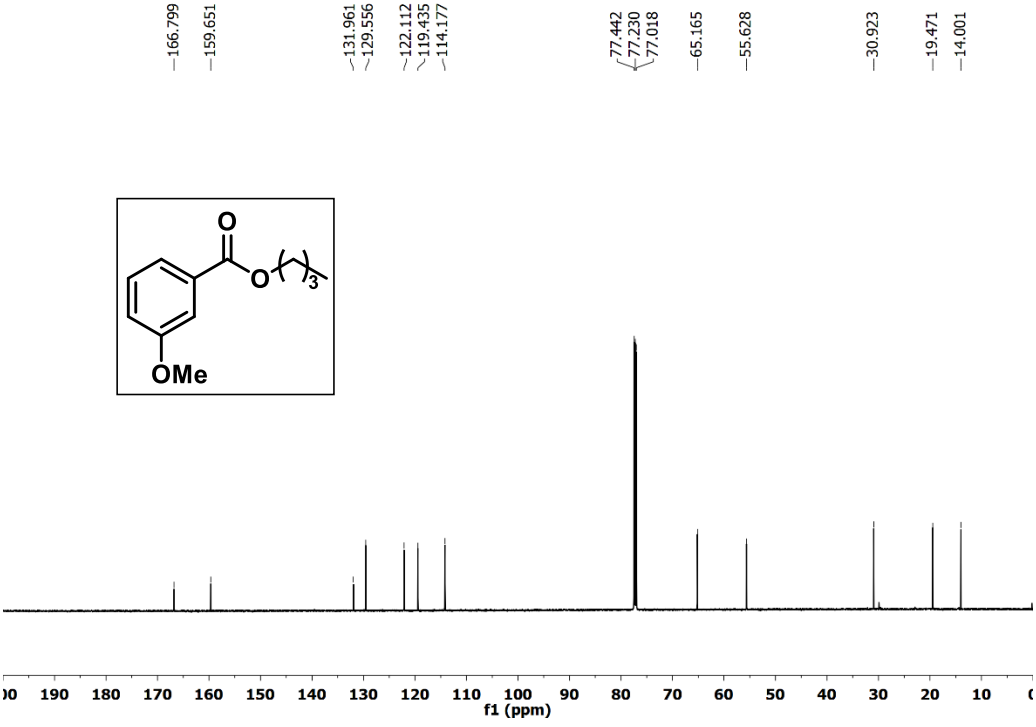
^{13}C{^{1}H} NMR of ketone **2n** (151 MHz, $CDCl_3$)



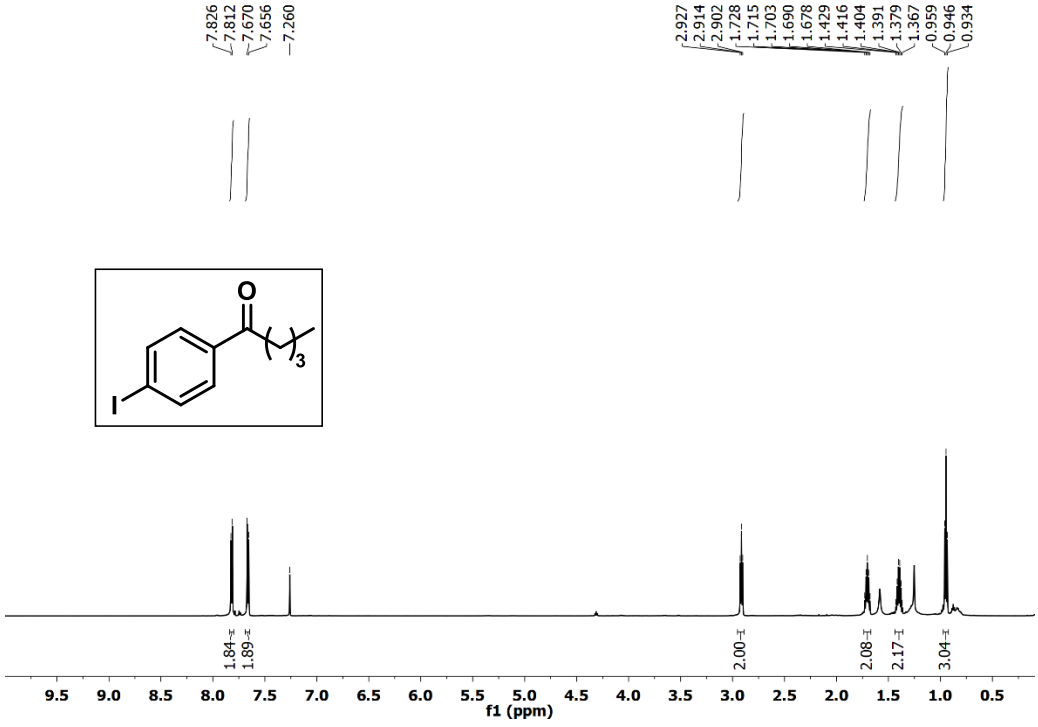
^{1}H NMR of ester **3n** (600 MHz, $CDCl_3$)



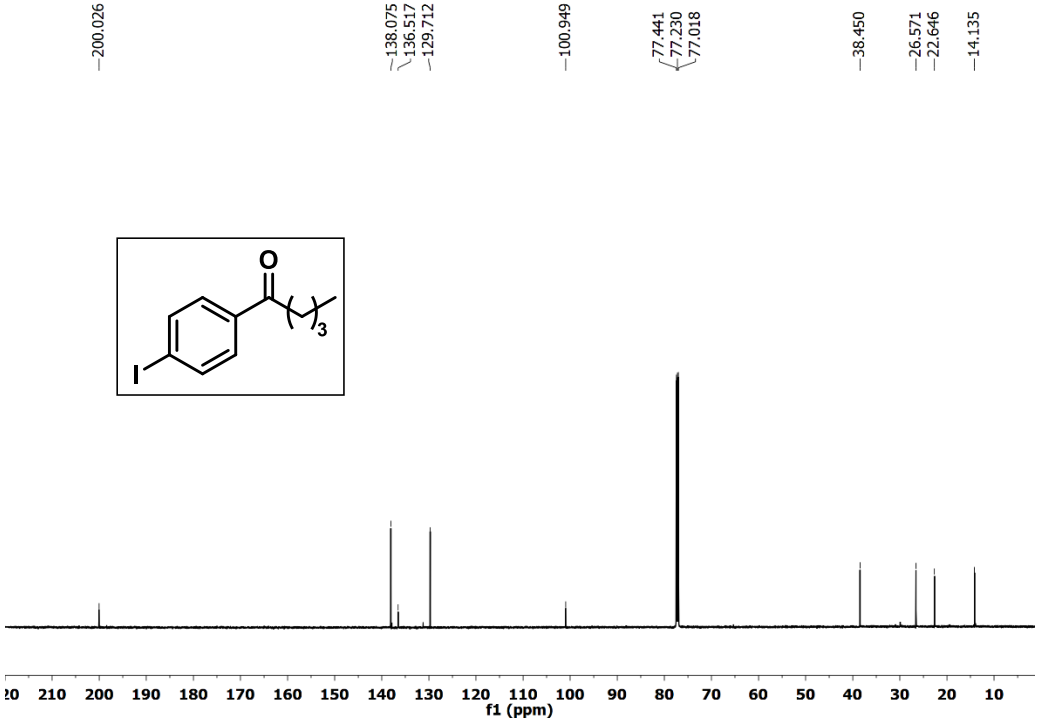
^{13}C{^{1}H} NMR of ester **3n** (151 MHz, $CDCl_3$)



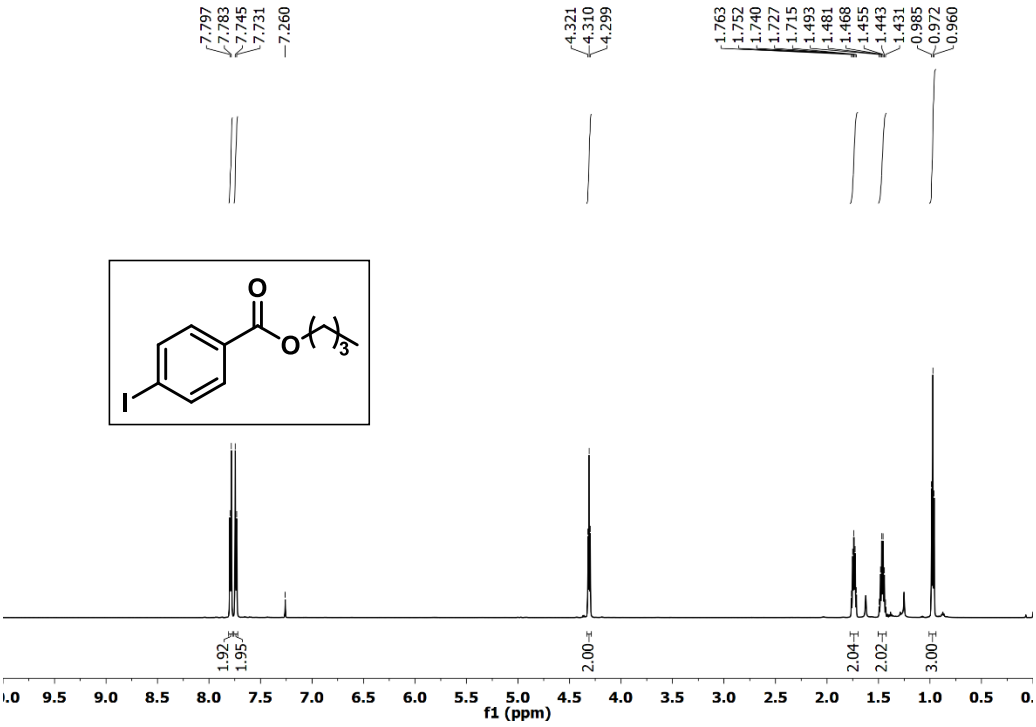
^{1}H NMR of ketone **2o** (600 MHz, $CDCl_3$)



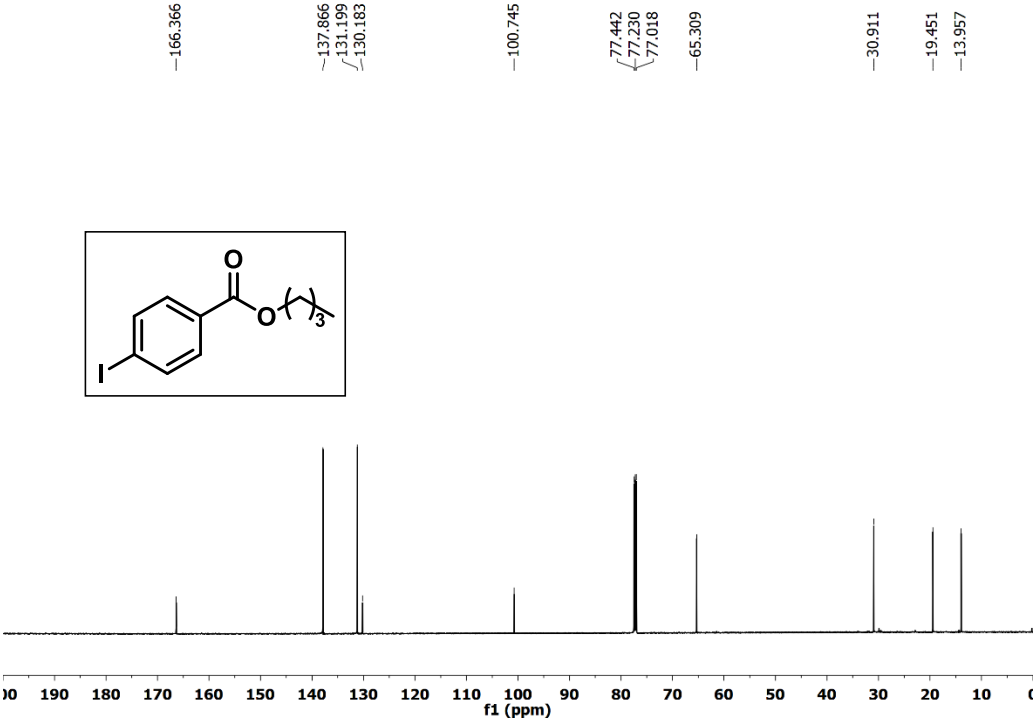
^{13}C{^{1}H} NMR of ketone **2o** (151 MHz, $CDCl_3$)



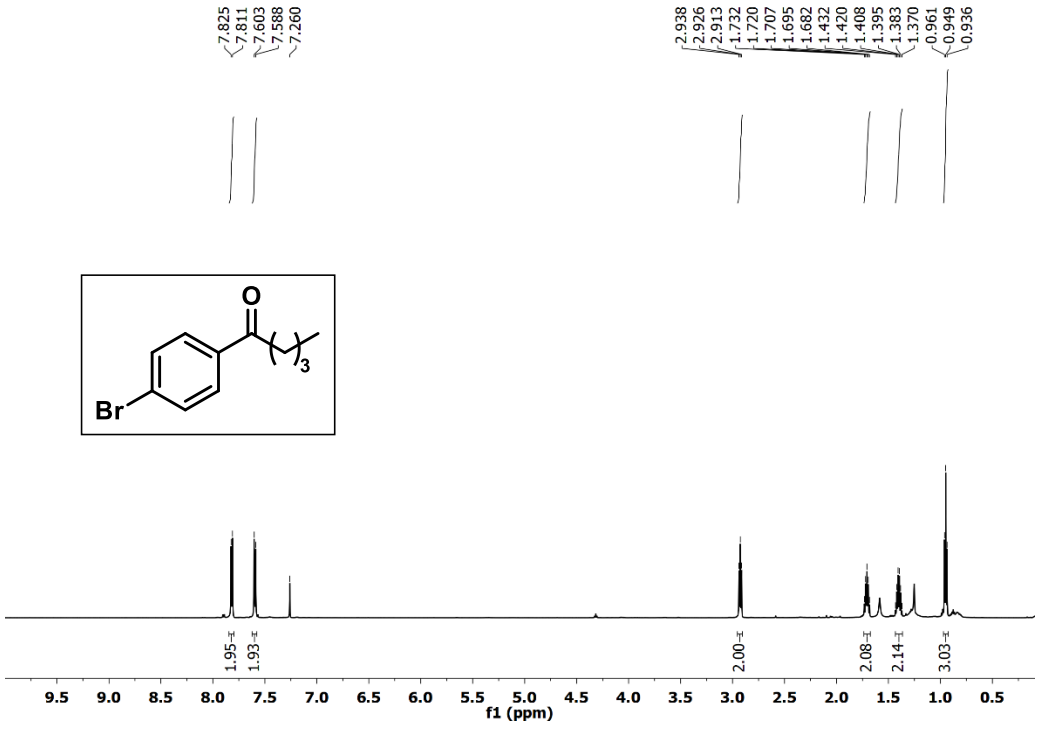
^{1}H NMR of ester **3o** (600 MHz, $CDCl_3$)



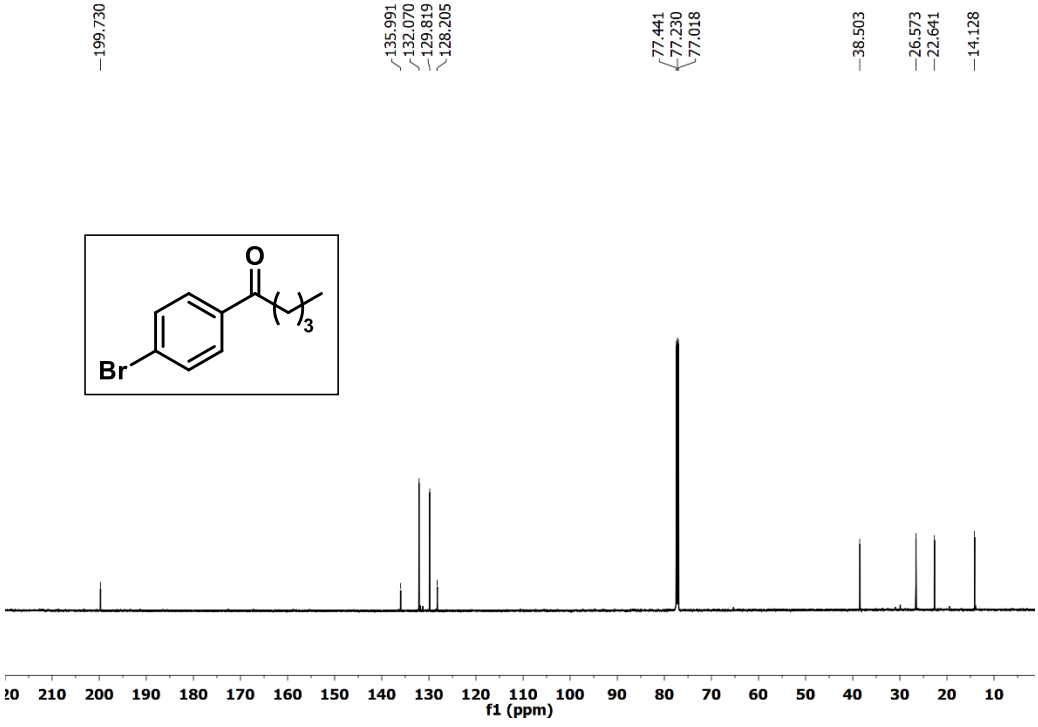
^{13}C{^{1}H} NMR of ester **3o** (151 MHz, $CDCl_3$)



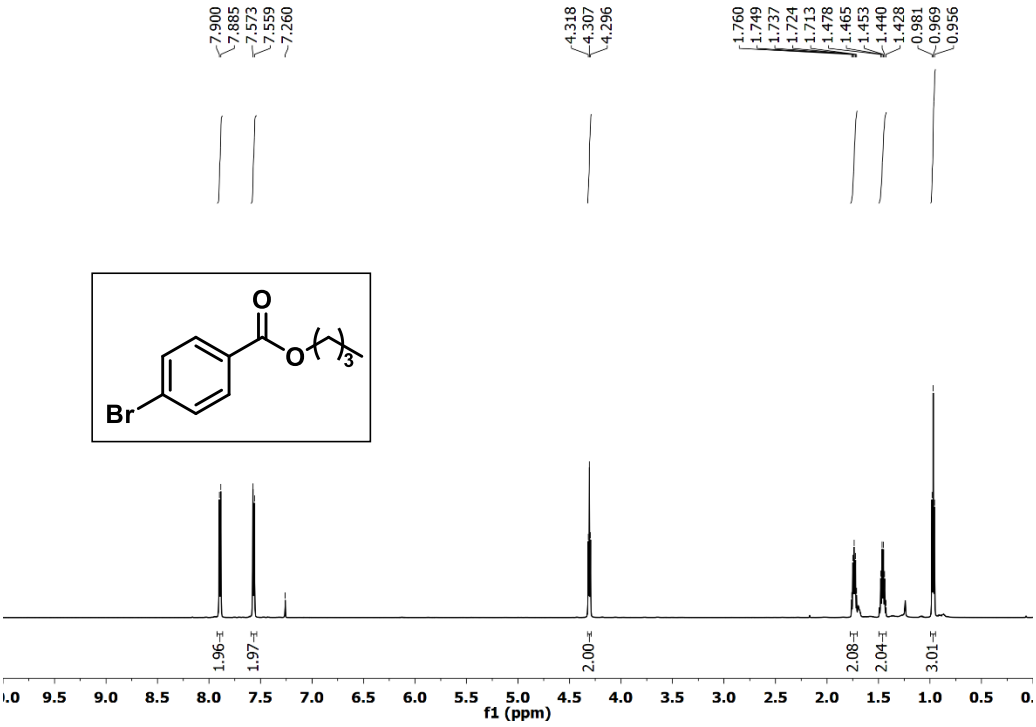
^{1}H NMR of ketone **2p** (600 MHz, $CDCl_3$)



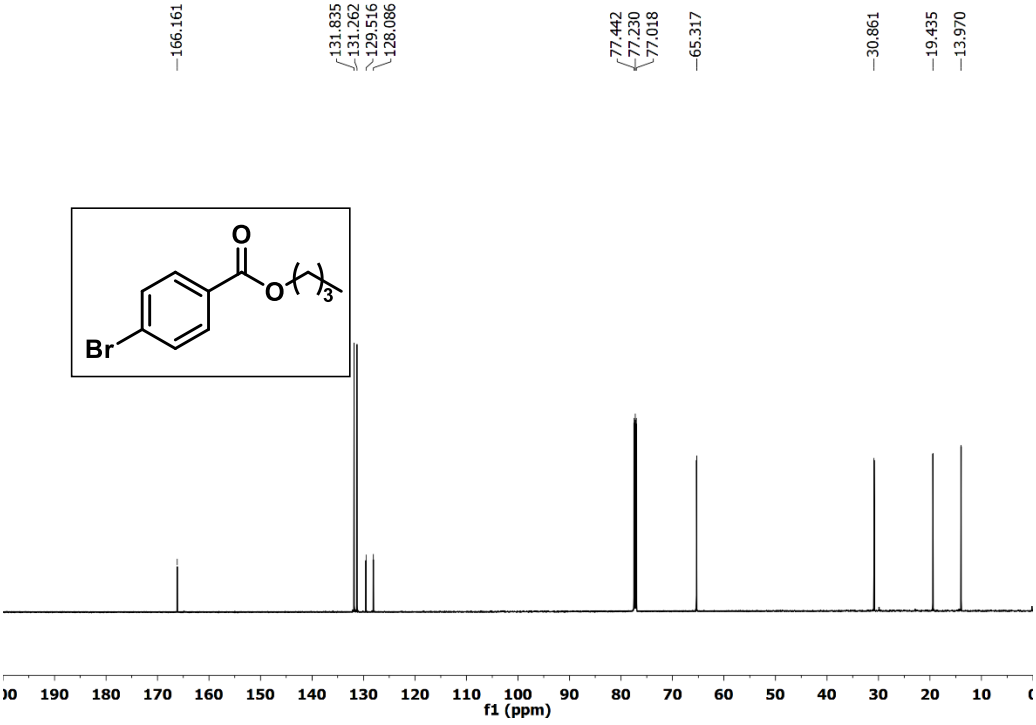
^{13}C{^{1}H} NMR of ketone **2p** (151 MHz, $CDCl_3$)



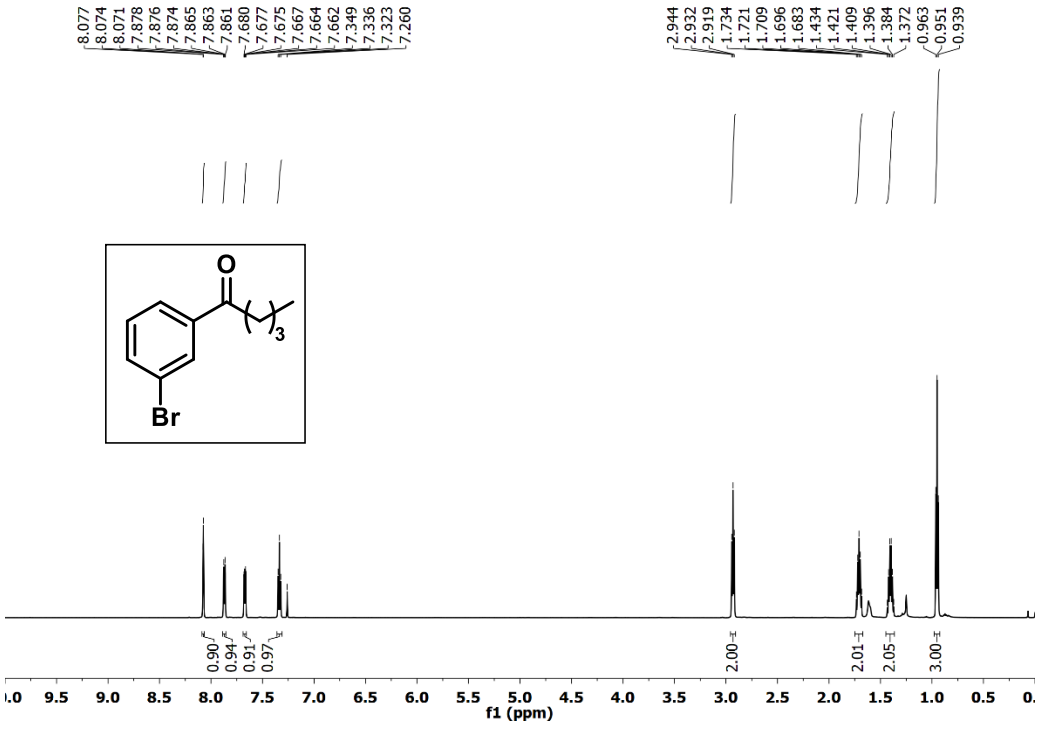
^{1}H NMR of ester **3p** (600 MHz, $CDCl_3$)



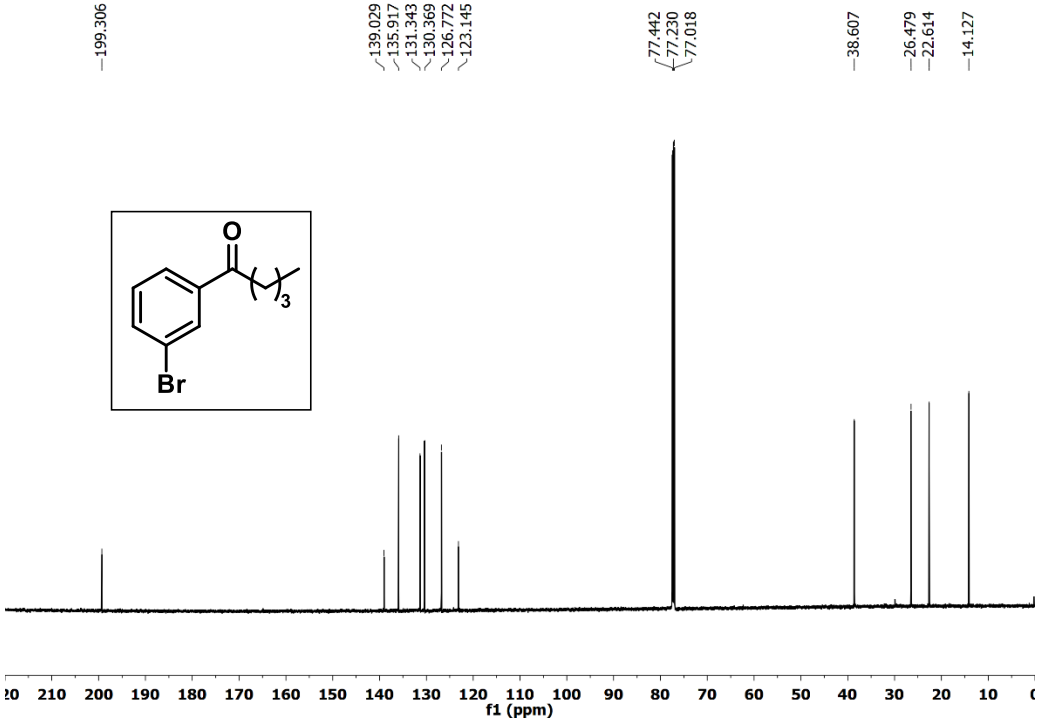
^{13}C{^{1}H} NMR of ester **3p** (151 MHz, $CDCl_3$)



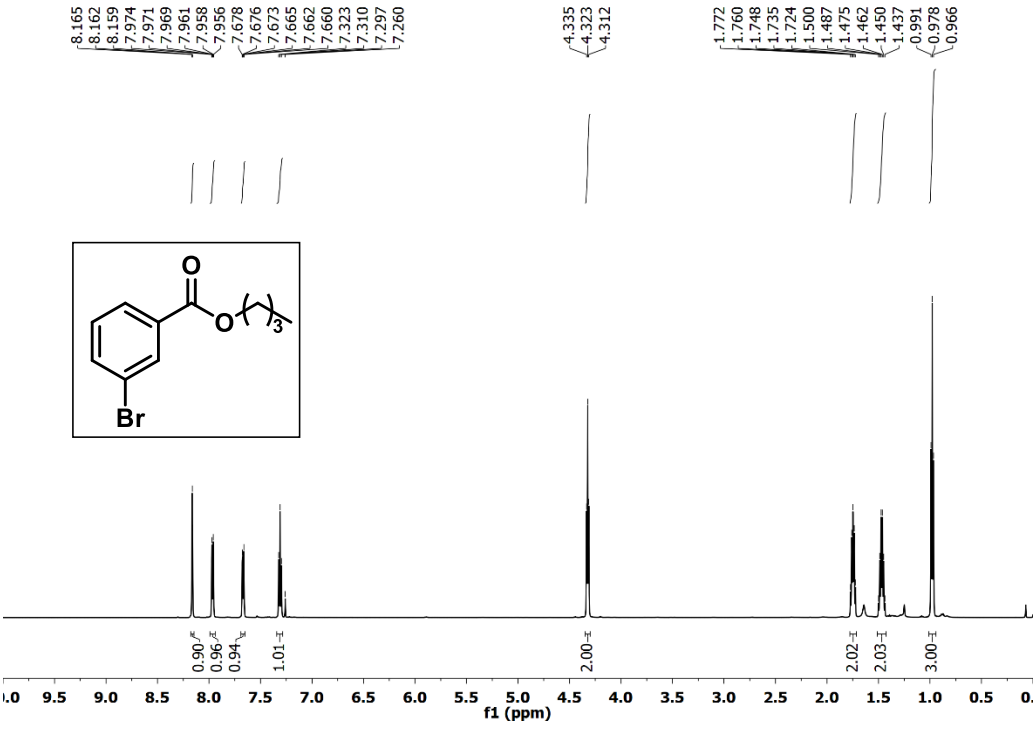
^{1}H NMR of ketone **2q** (600 MHz, $CDCl_3$)



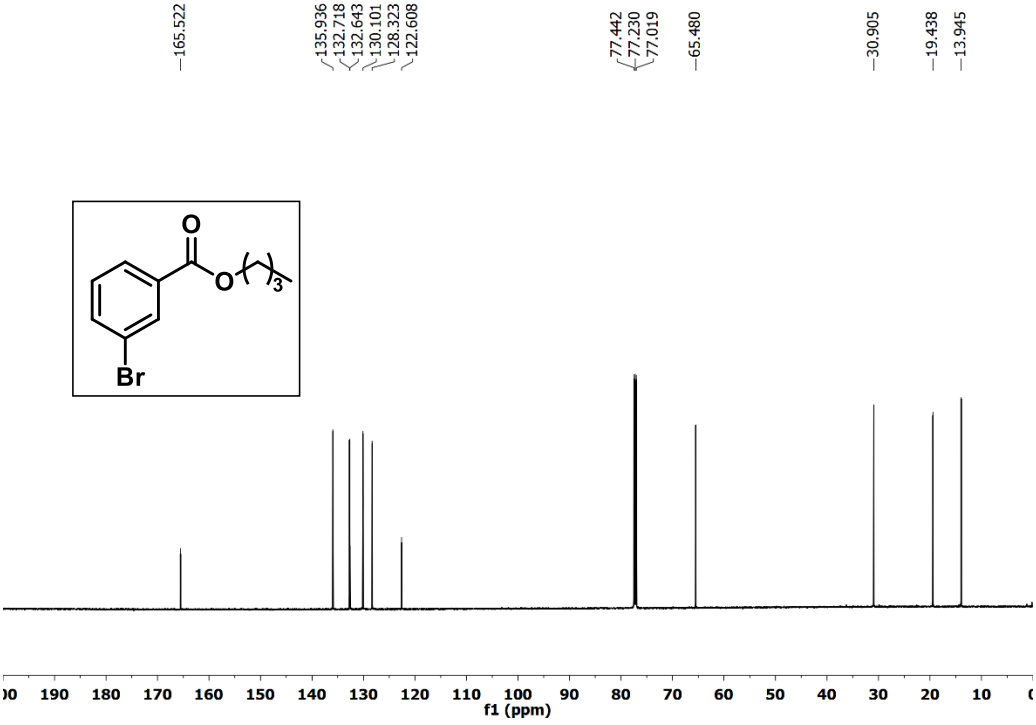
^{13}C{^{1}H} NMR of ketone **2q** (151 MHz, $CDCl_3$)



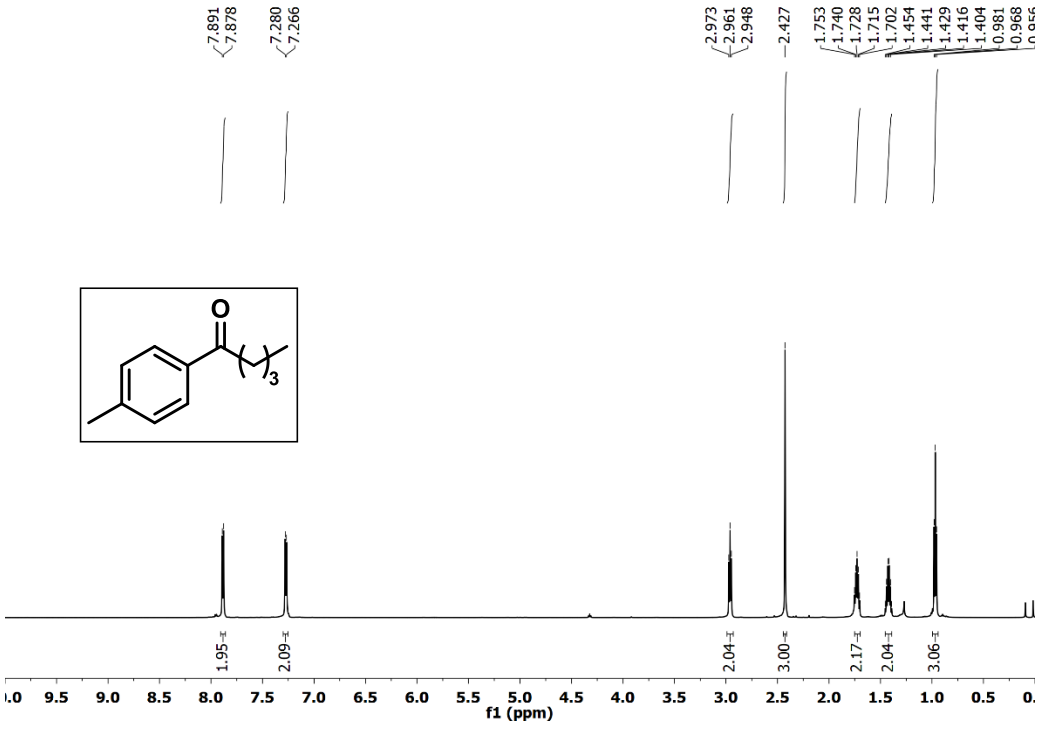
^{1}H NMR of ester **3q** (600 MHz, $CDCl_3$)



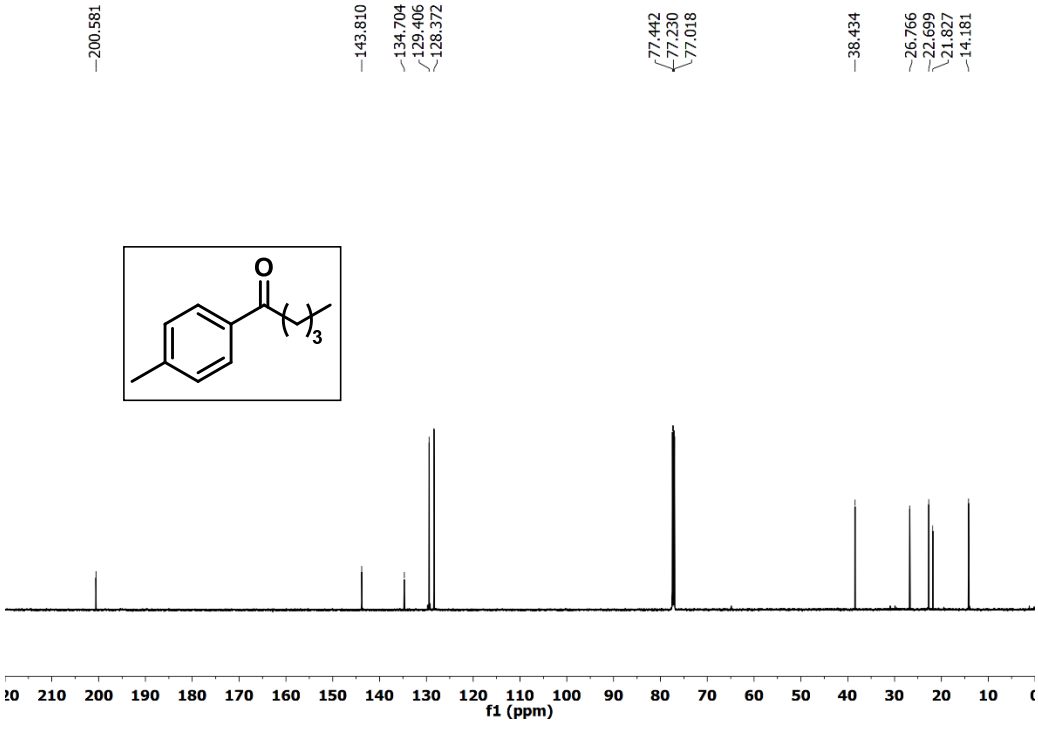
^{13}C{^{1}H} NMR of ester **3q** (151 MHz, $CDCl_3$)



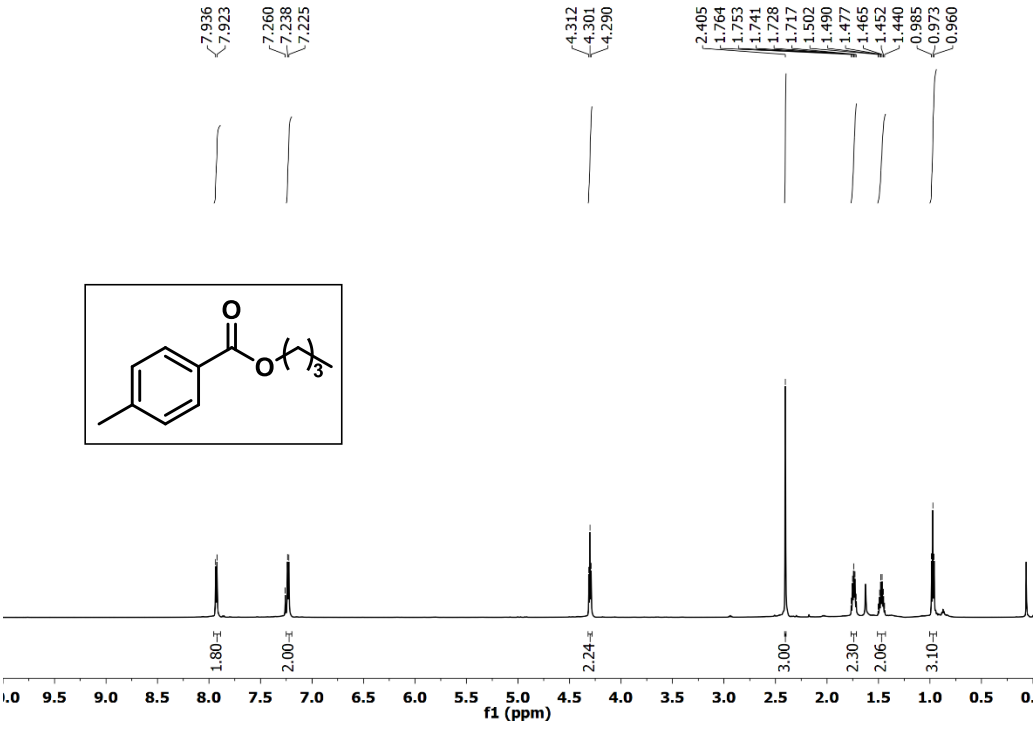
^{1}H NMR of ketone **2r** (600 MHz, $CDCl_3$)



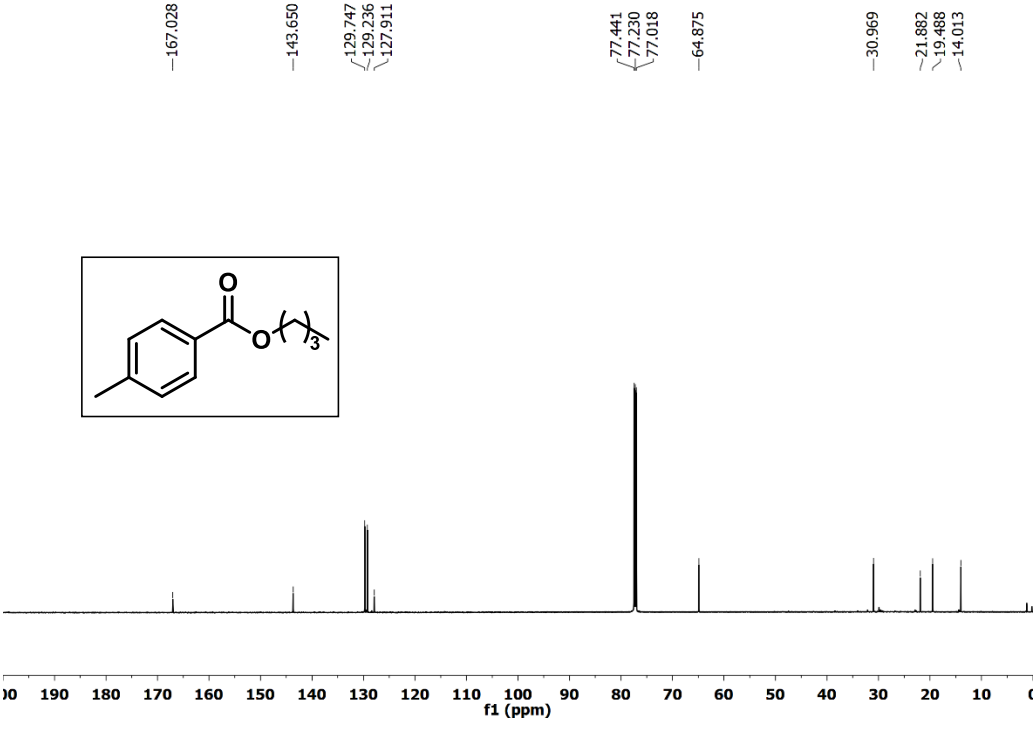
$^{13}C\{^{1}H\}$ NMR of ketone **2r** (151 MHz, $CDCl_3$)



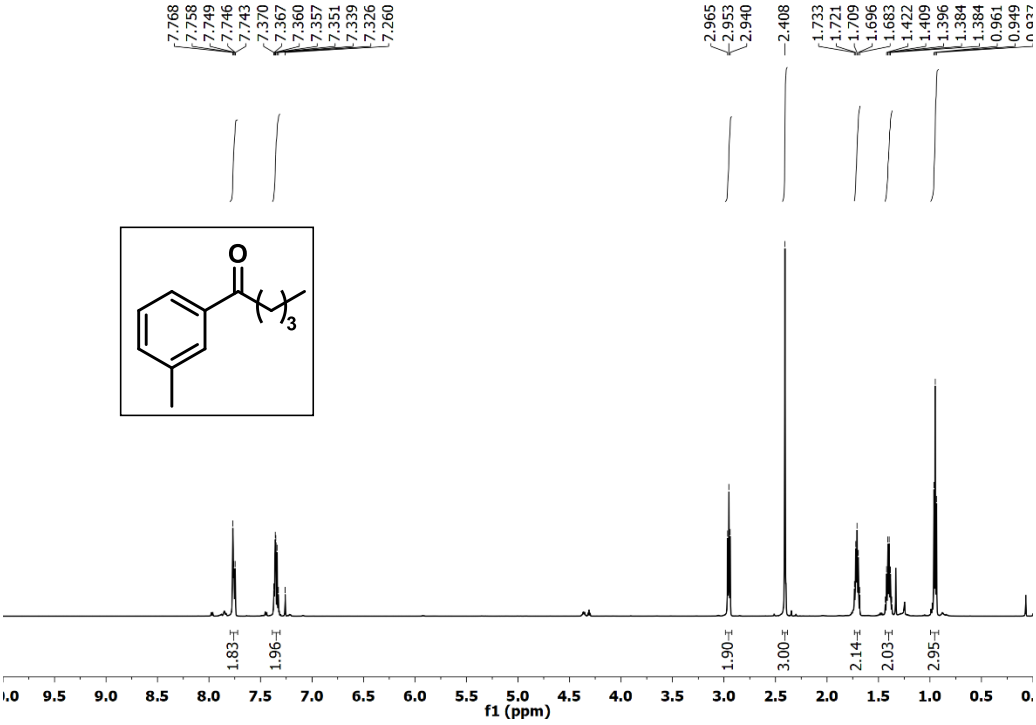
^{1}H NMR of ester **3r** (600 MHz, $CDCl_3$)



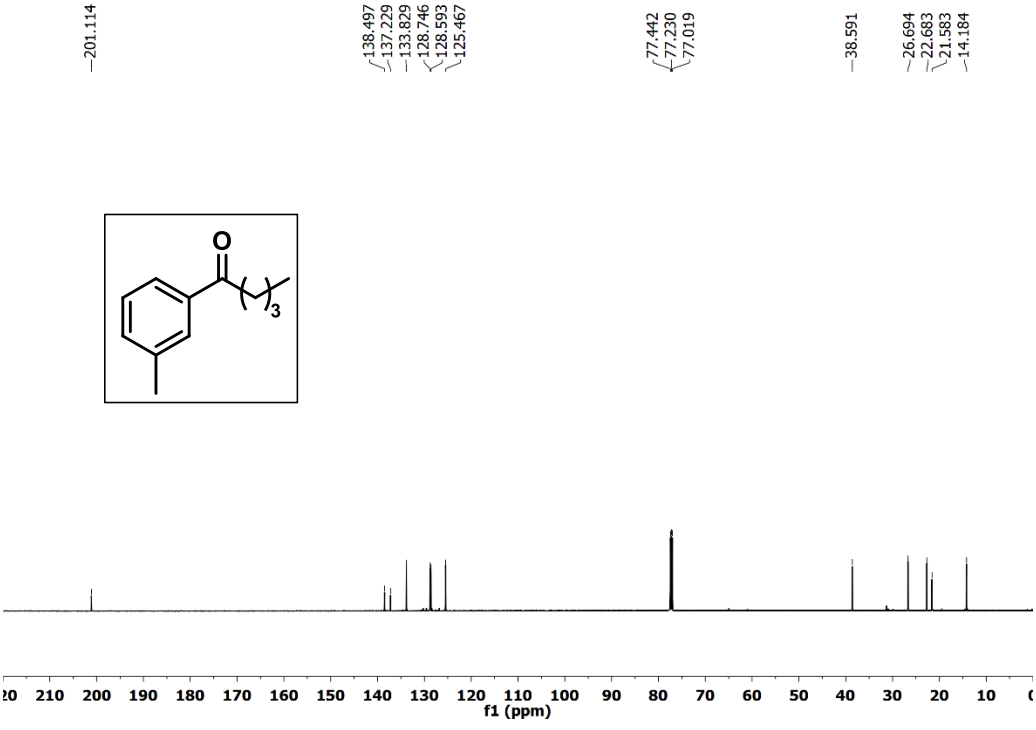
^{13}C{^{1}H} NMR of ester **3r** (151 MHz, $CDCl_3$)



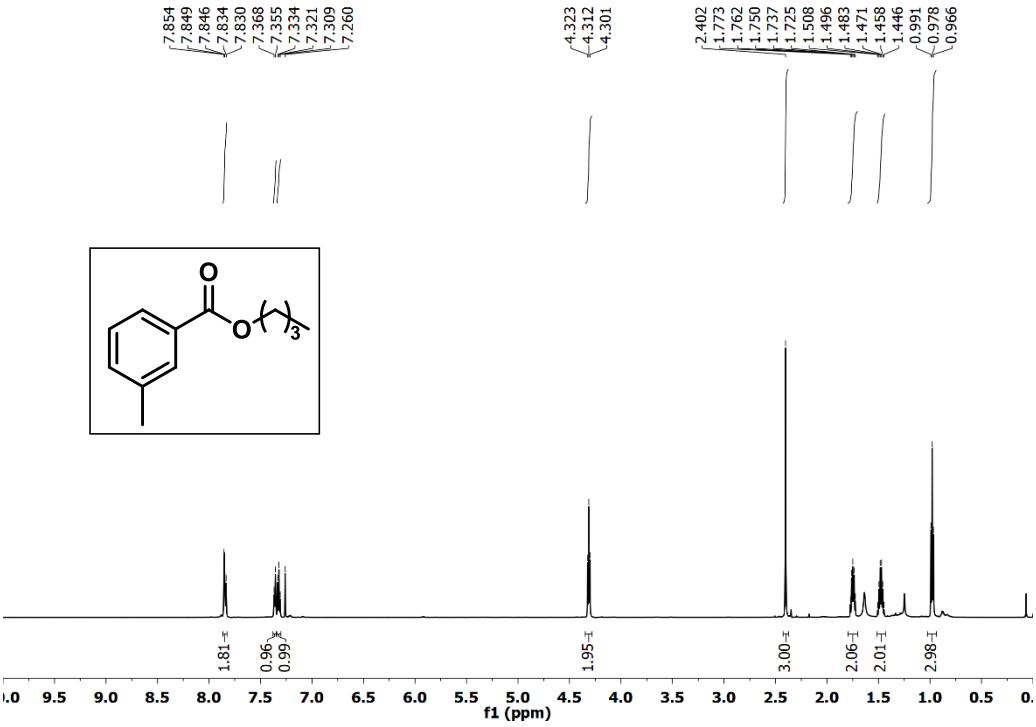
^{1}H NMR of ketone **2s** (600 MHz, $CDCl_3$)



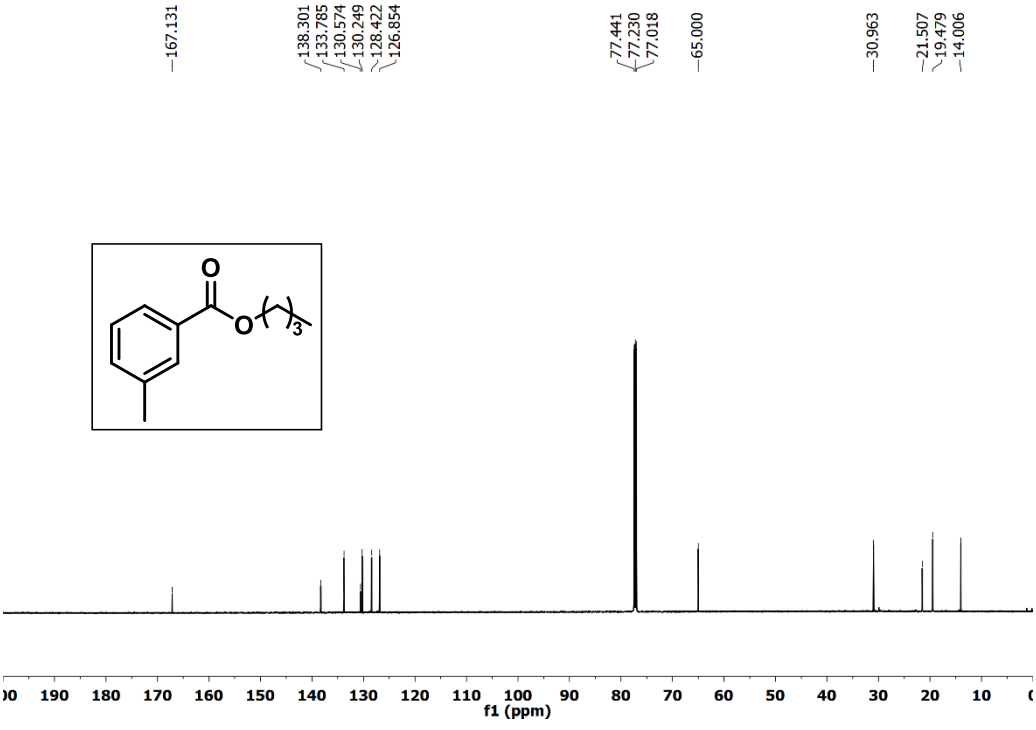
^{13}C{^{1}H} NMR of ketone **2s** (151 MHz, $CDCl_3$)



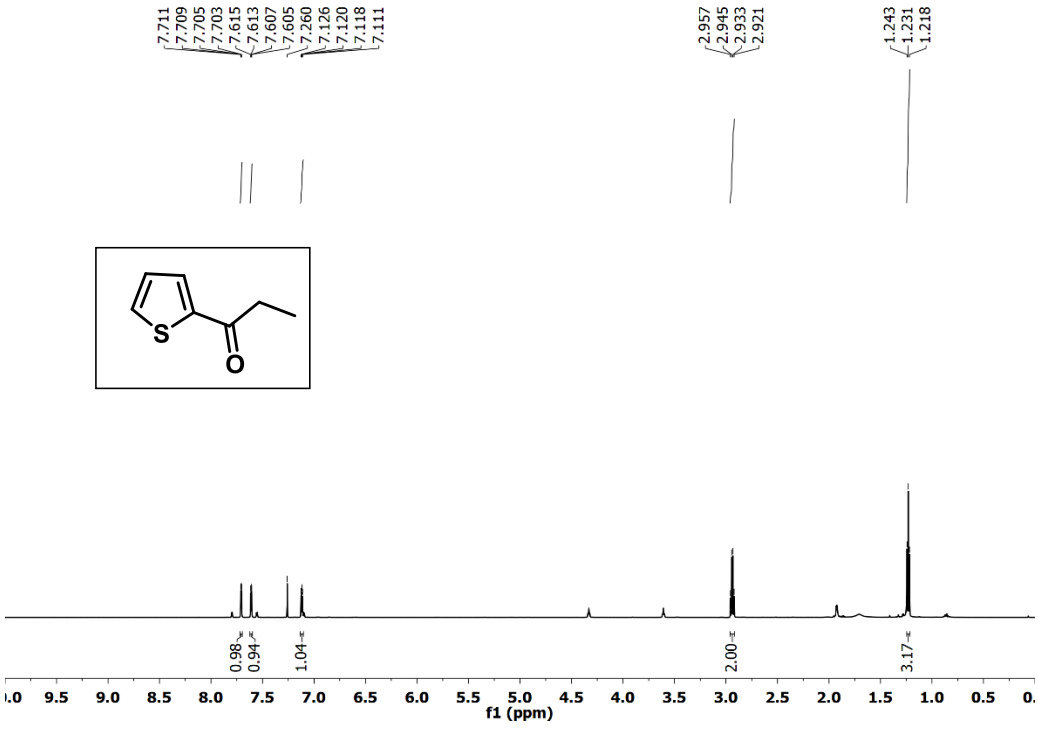
^{1}H NMR of ester **3s** (600 MHz, $CDCl_3$)



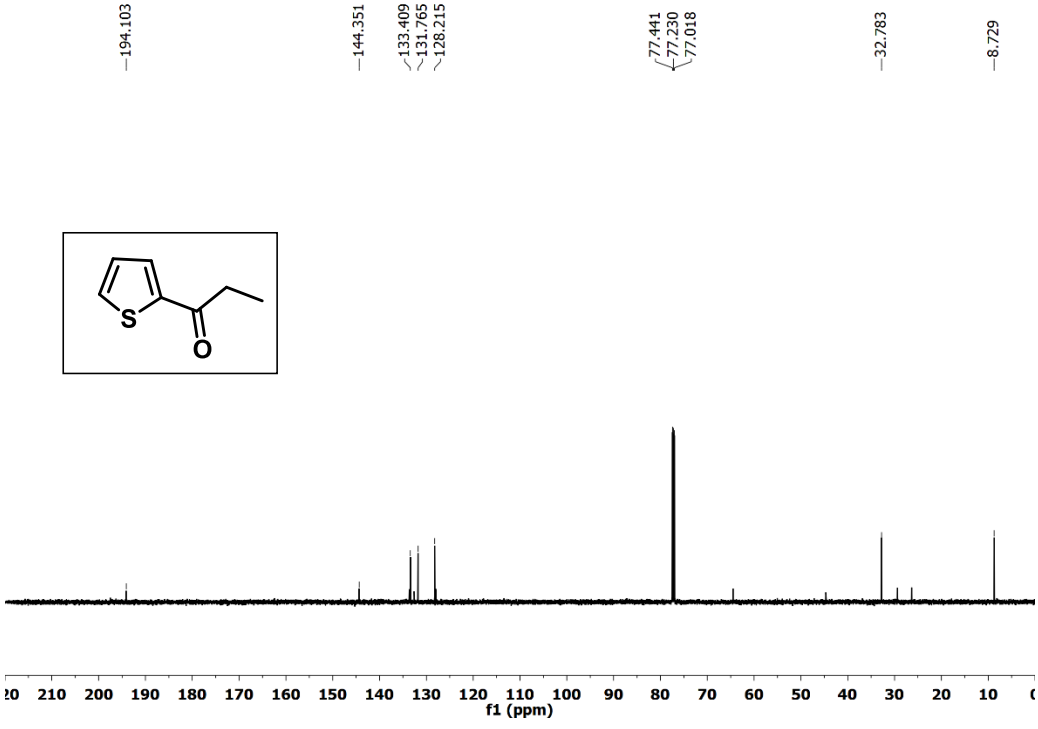
^{13}C{^{1}H} NMR of ester **3s** (151 MHz, $CDCl_3$)



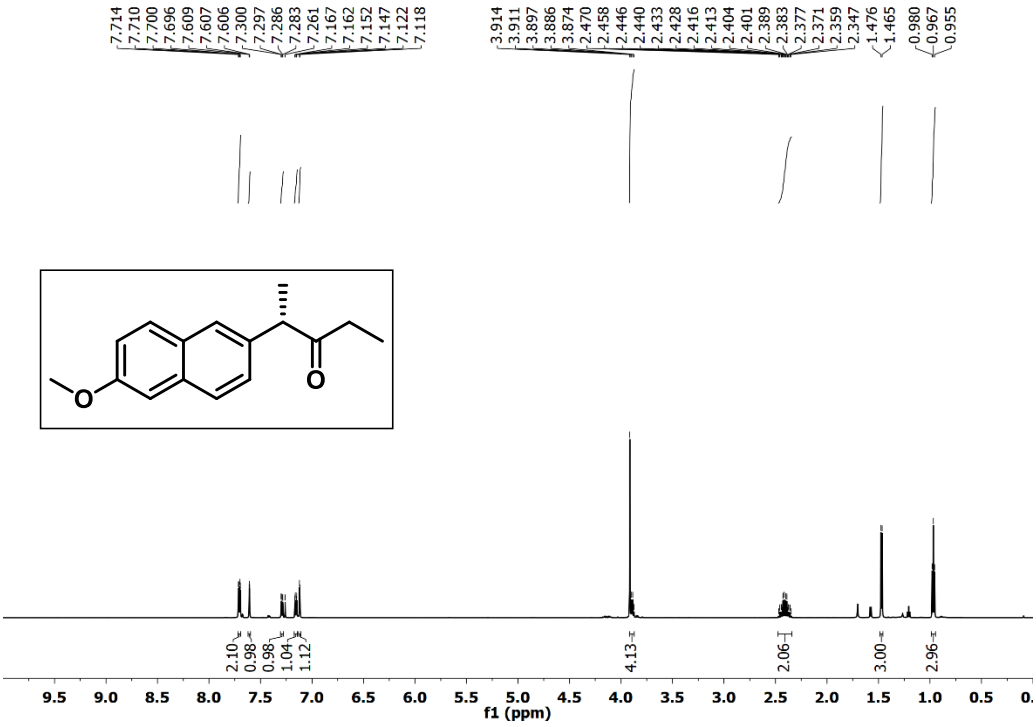
^{1}H NMR of ketone **2t** (600 MHz, $CDCl_3$)



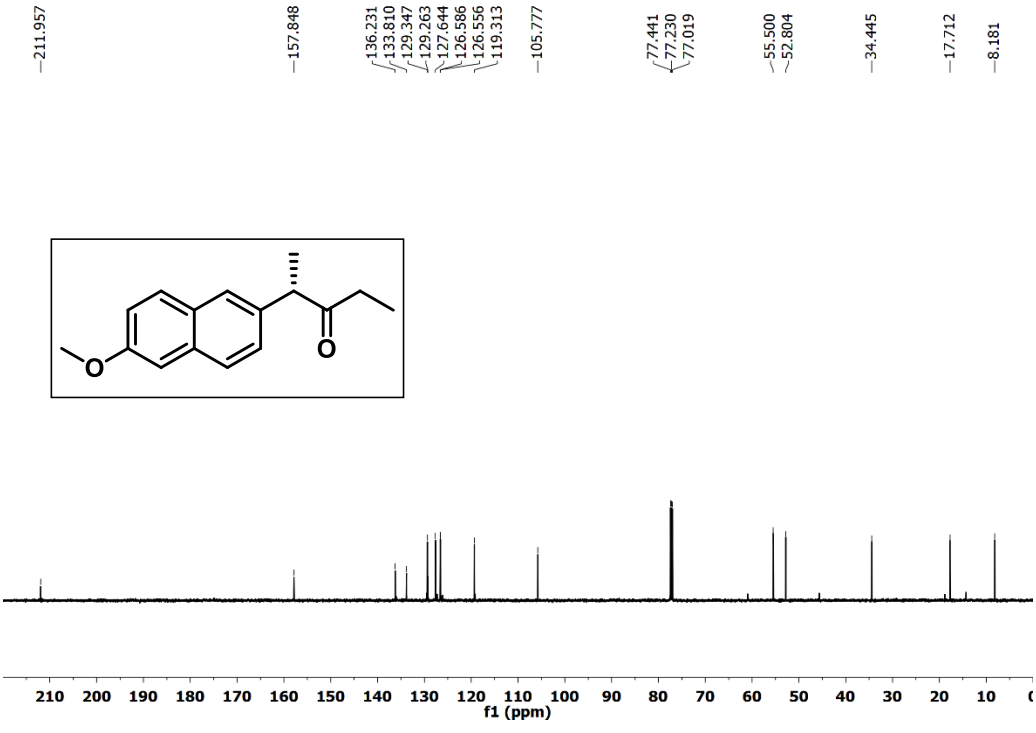
^{13}C{^{1}H} NMR of ketone **2t** (151 MHz, $CDCl_3$)



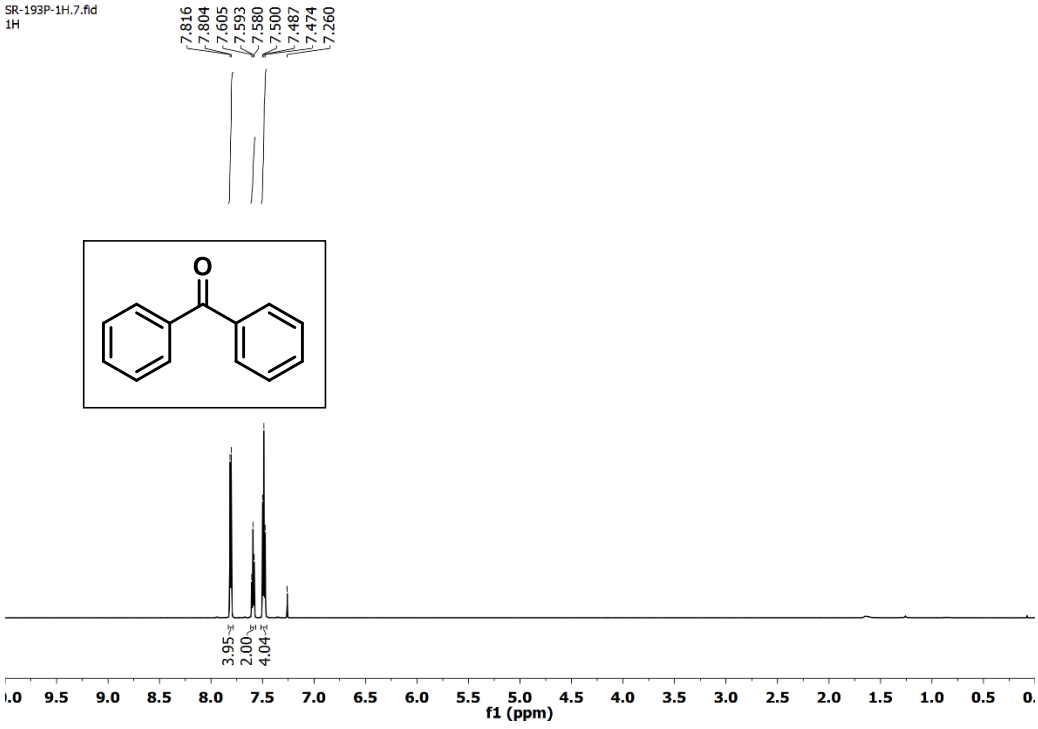
^{1}H NMR of ketone **2u** (600 MHz, $CDCl_3$)



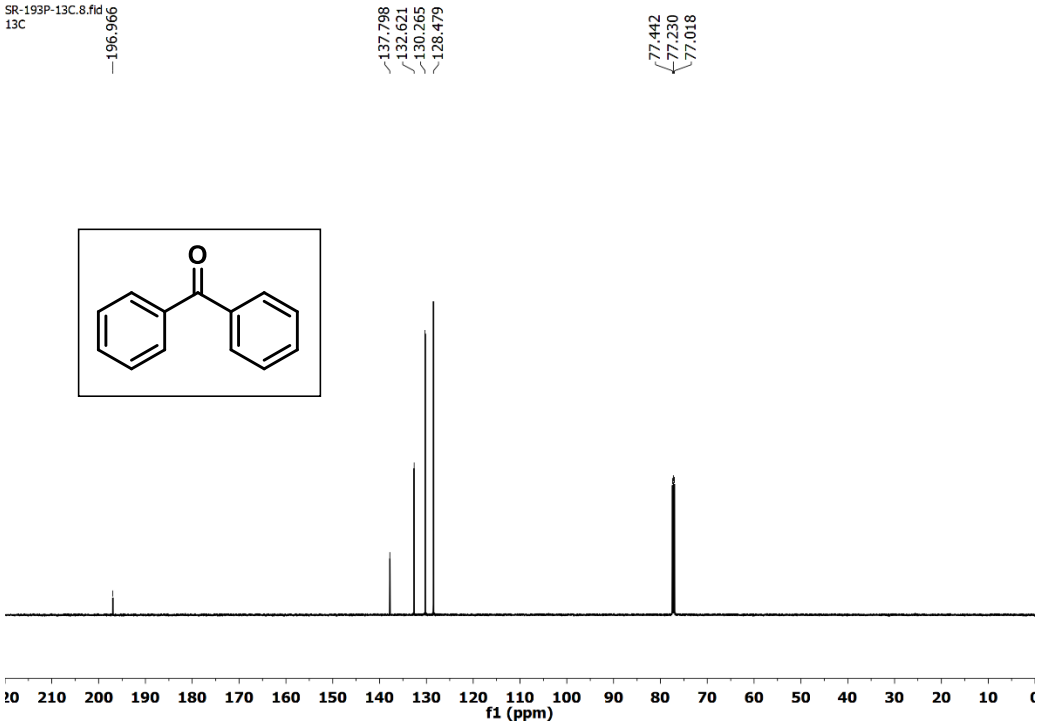
^{13}C{^{1}H} NMR of ketone **2u** (151 MHz, $CDCl_3$)



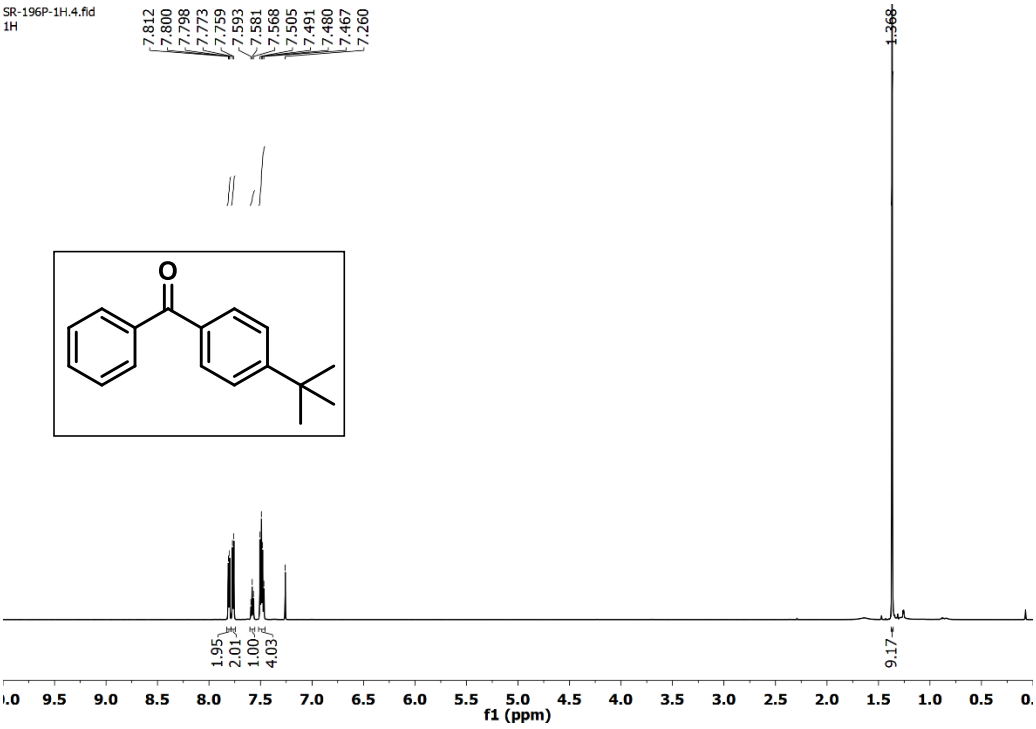
^{1}H NMR of ketone **2v** (600 MHz, $CDCl_3$)



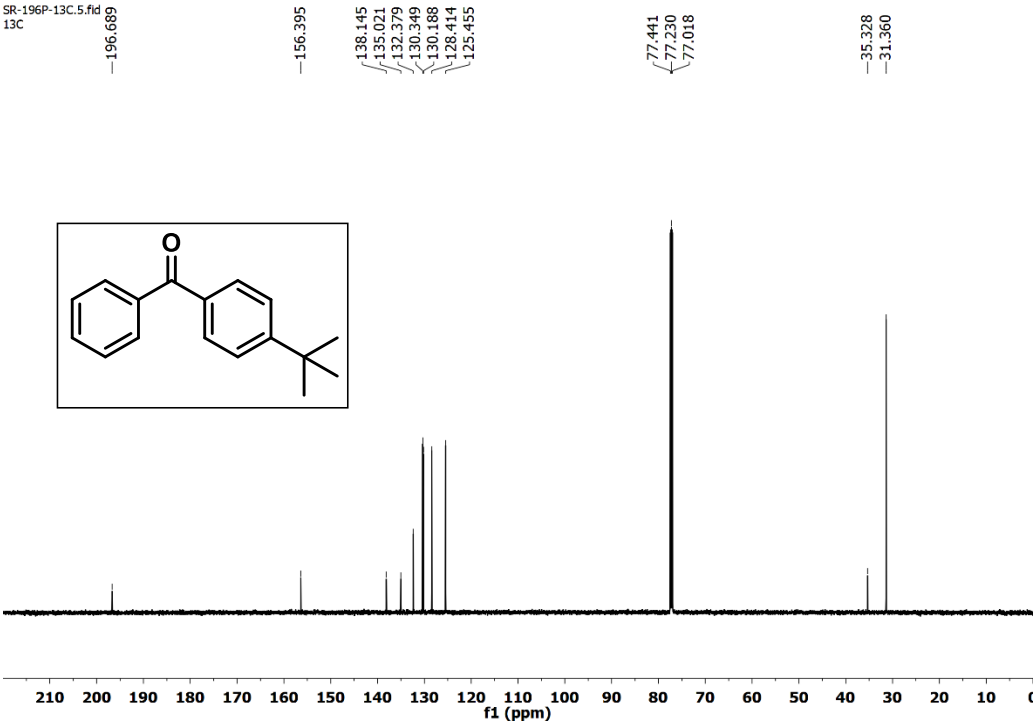
$^{13}C\{^{1}H\}$ NMR of ketone **2v** (151 MHz, $CDCl_3$)



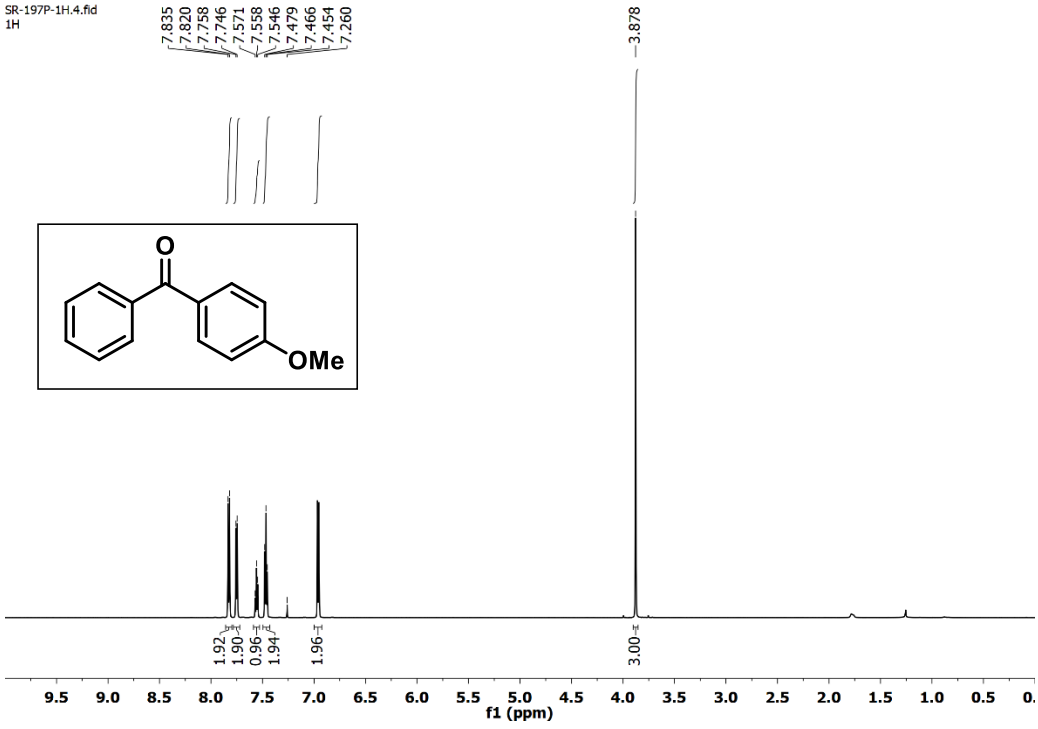
^{1}H NMR of ketone **2w** (600 MHz, $CDCl_3$)



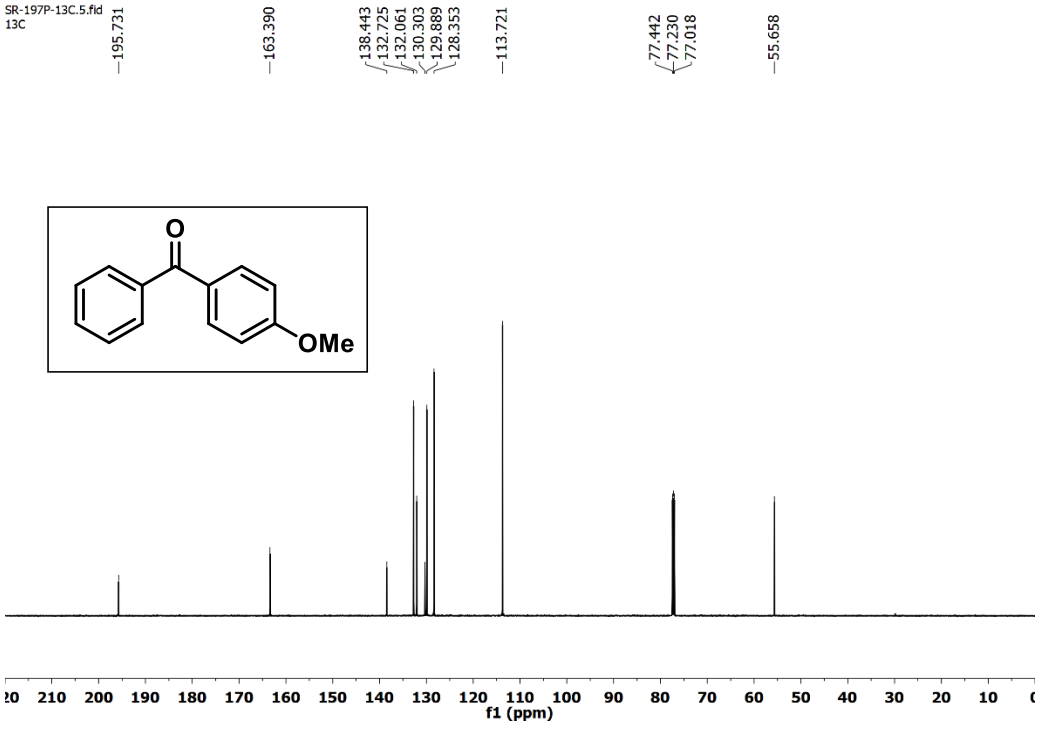
^{13}C{^{1}H} NMR of ketone **2w** (151 MHz, $CDCl_3$)



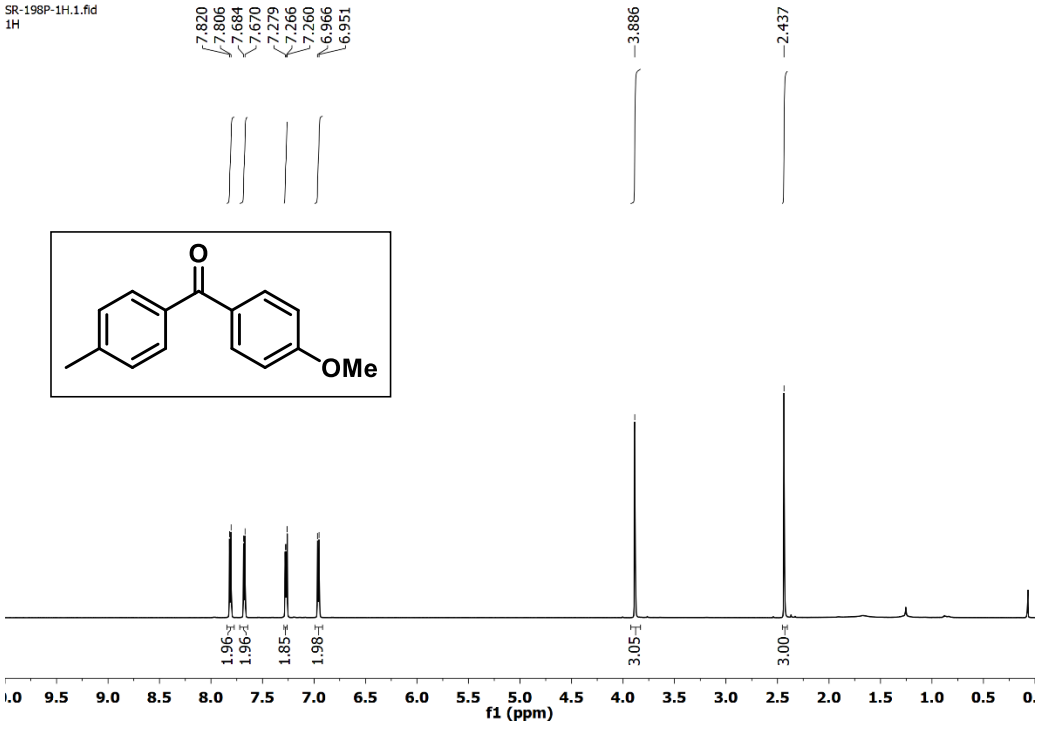
^{1}H NMR of ketone **2x** (600 MHz, $CDCl_3$)



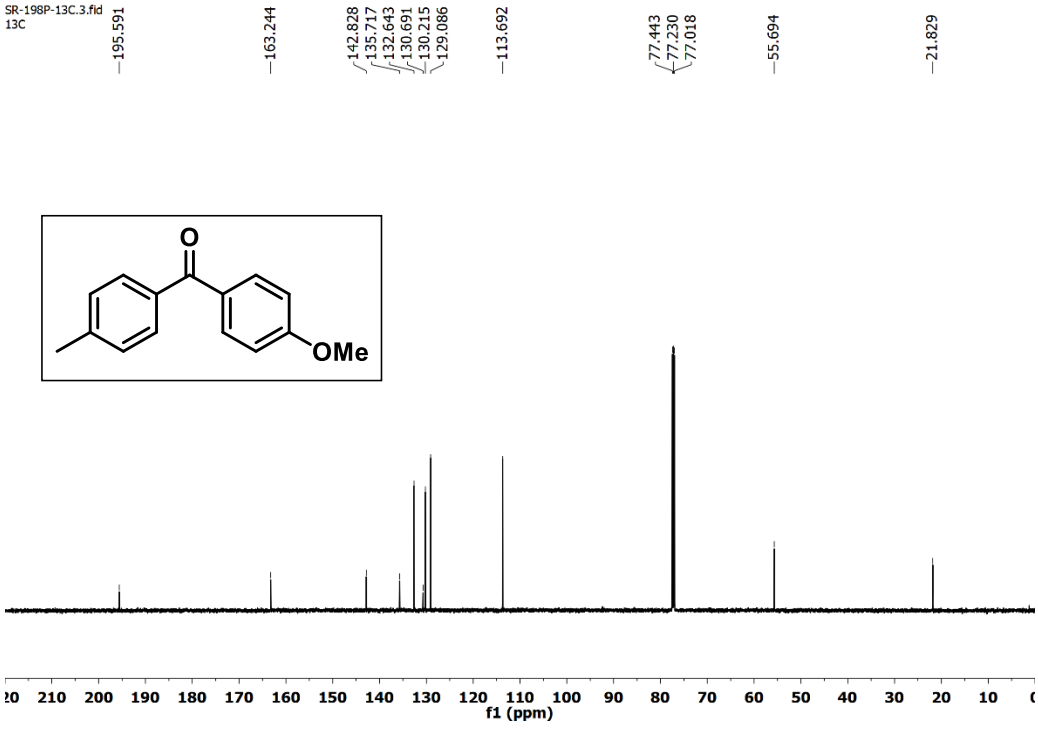
^{13}C{^{1}H} NMR of ketone **2x** (151 MHz, $CDCl_3$)



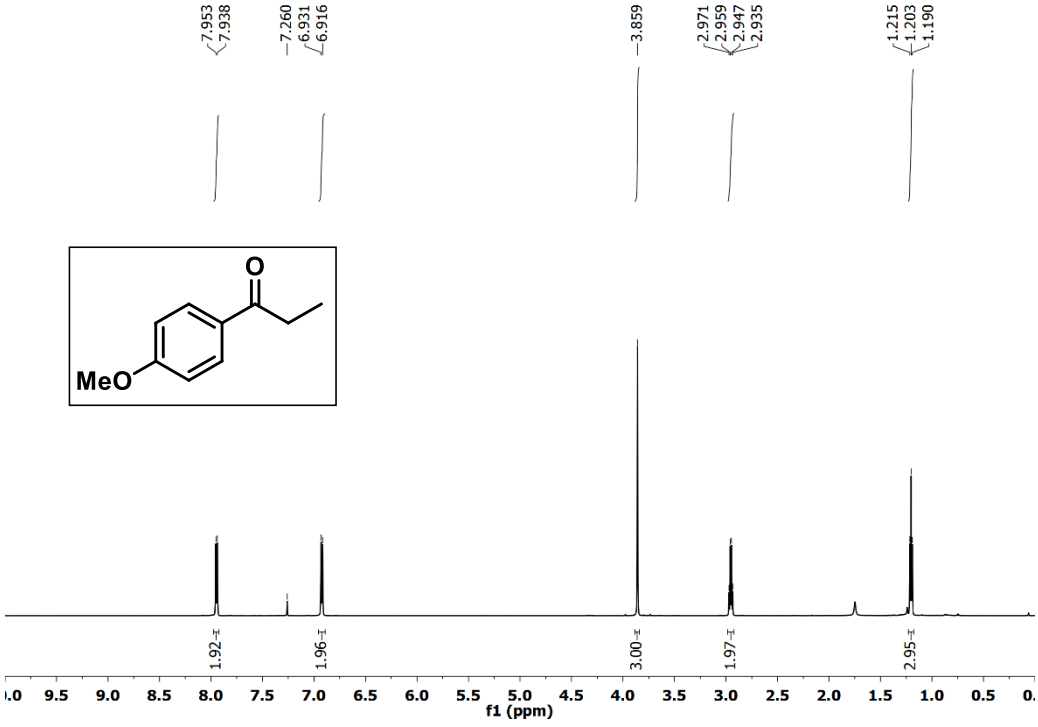
^{1}H NMR of ketone **2y** (600 MHz, $CDCl_3$)



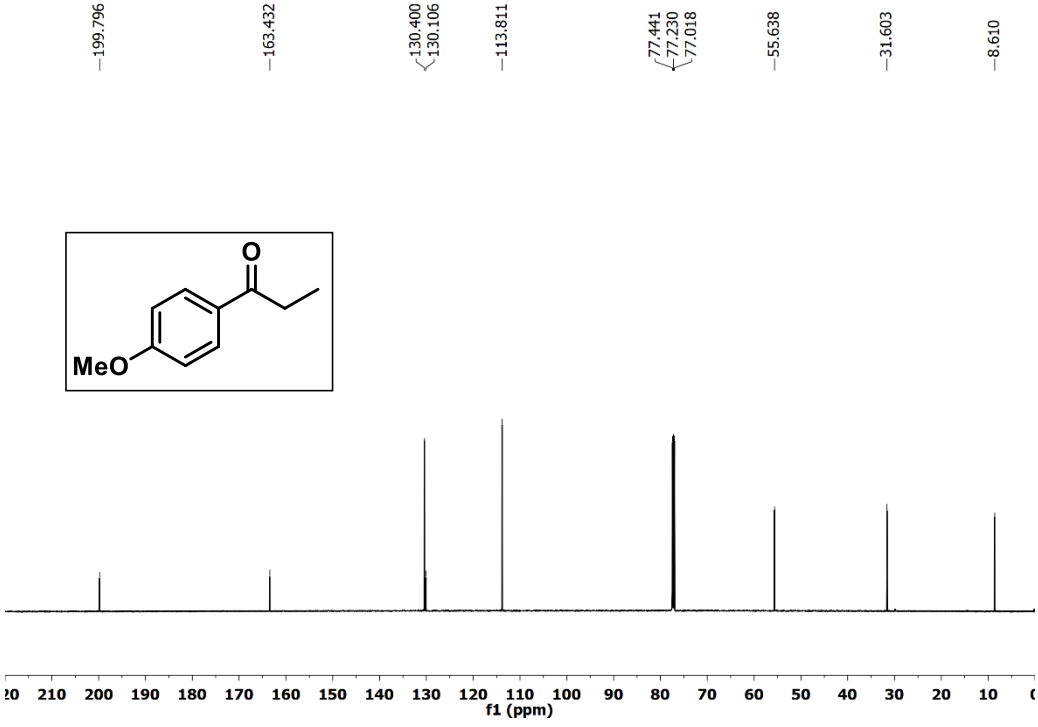
$^{13}C\{^{1}H\}$ NMR of ketone **2y** (151 MHz, $CDCl_3$)



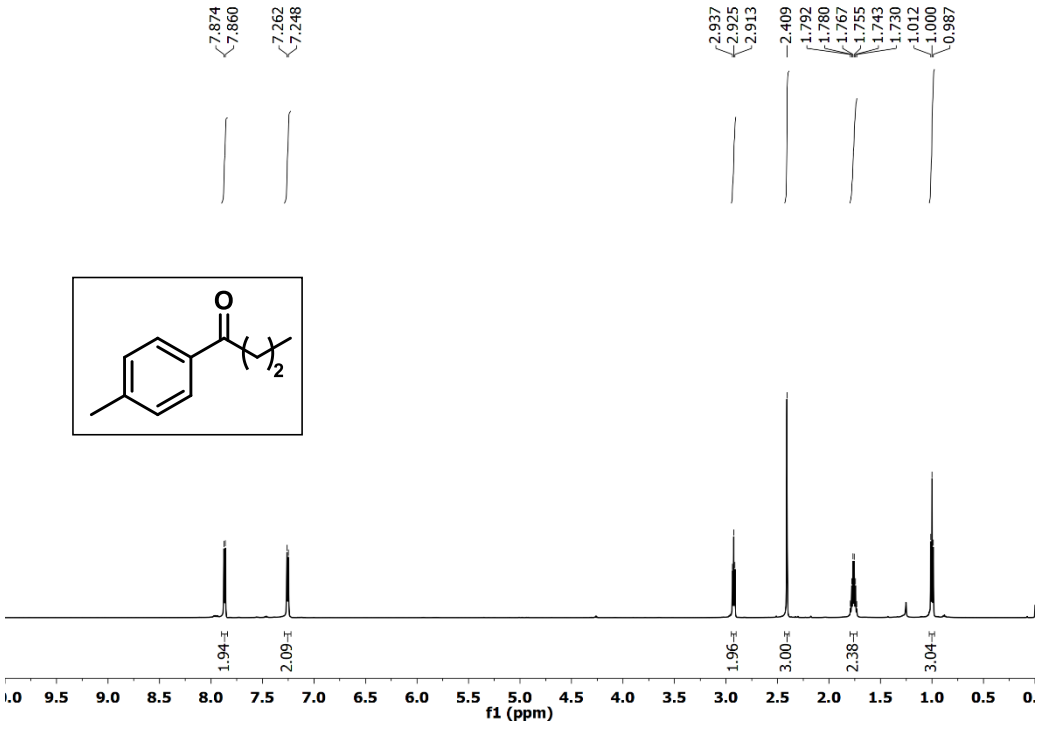
^{1}H NMR of ketone **2z1** (600 MHz, $CDCl_3$)



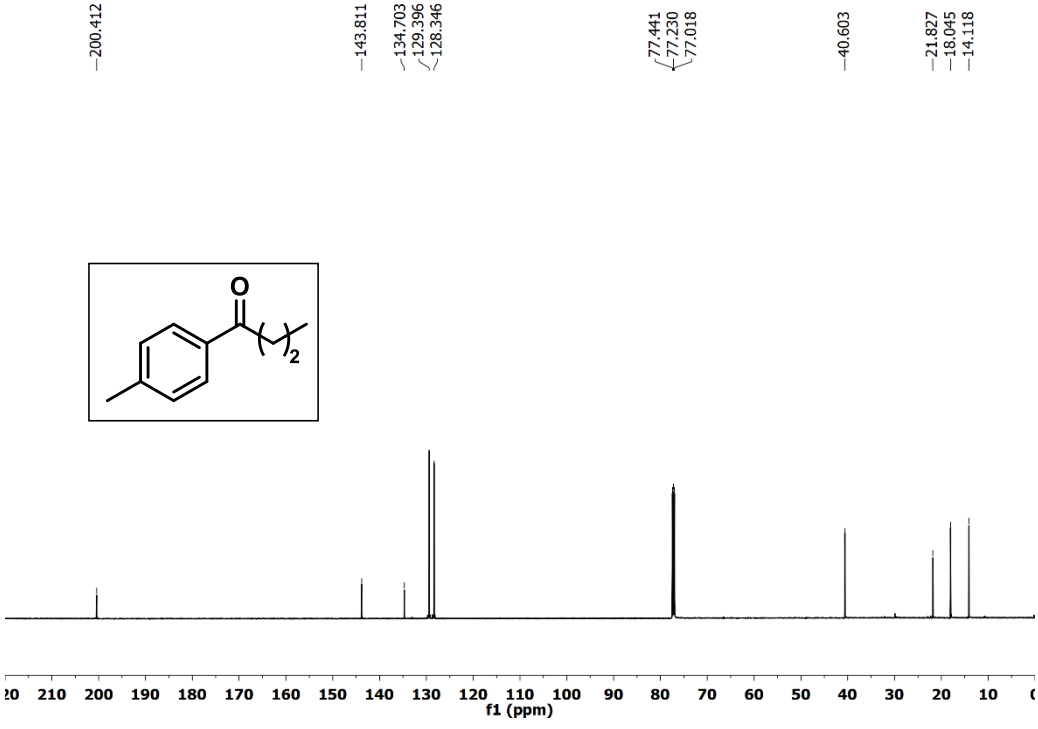
^{13}C{^{1}H} NMR of ketone **2z1** (151 MHz, $CDCl_3$)



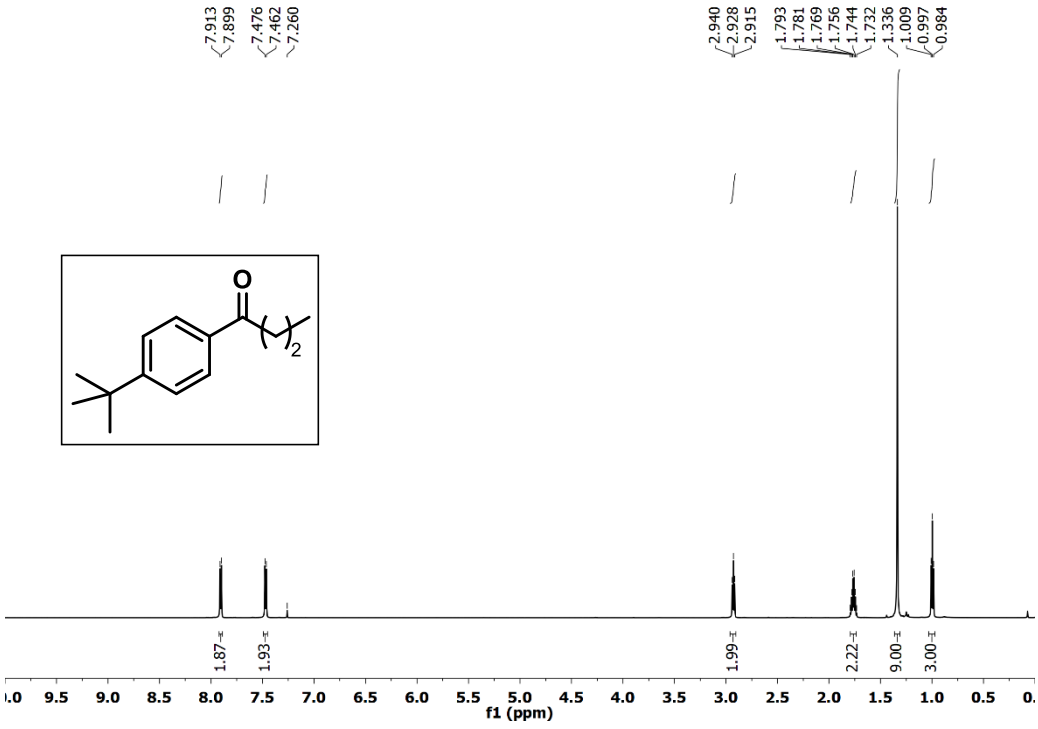
^{1}H NMR of ketone **2*z*2** (600 MHz, $CDCl_3$)



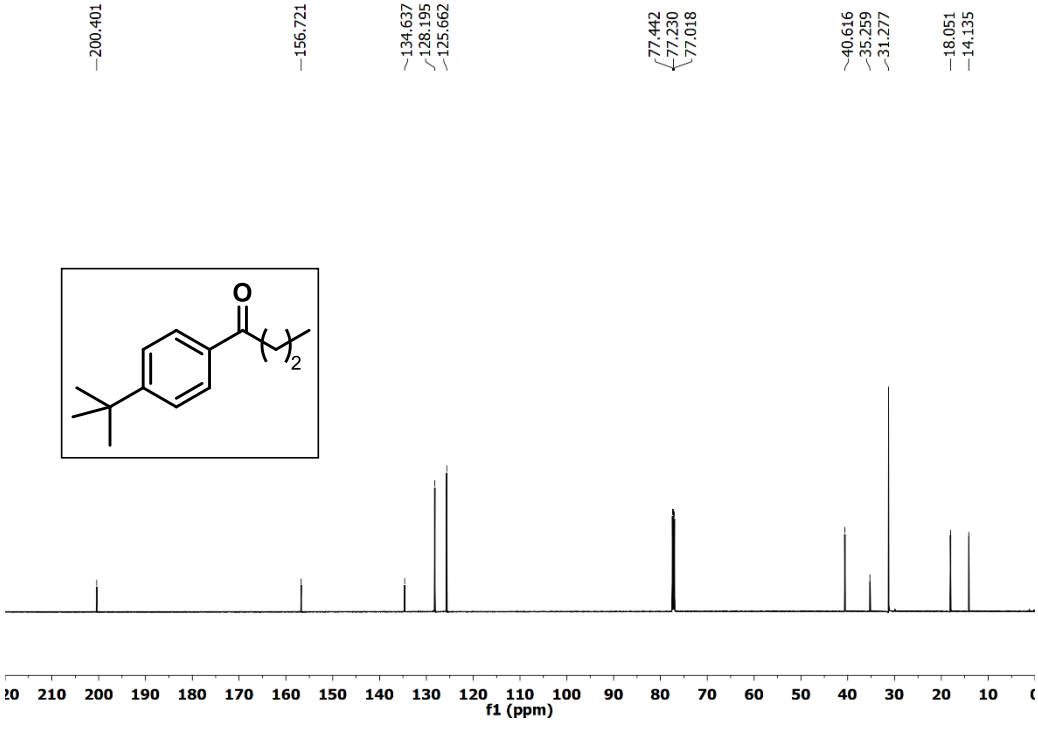
^{13}C{^{1}H} NMR of ketone **2*z*2** (151 MHz, $CDCl_3$)



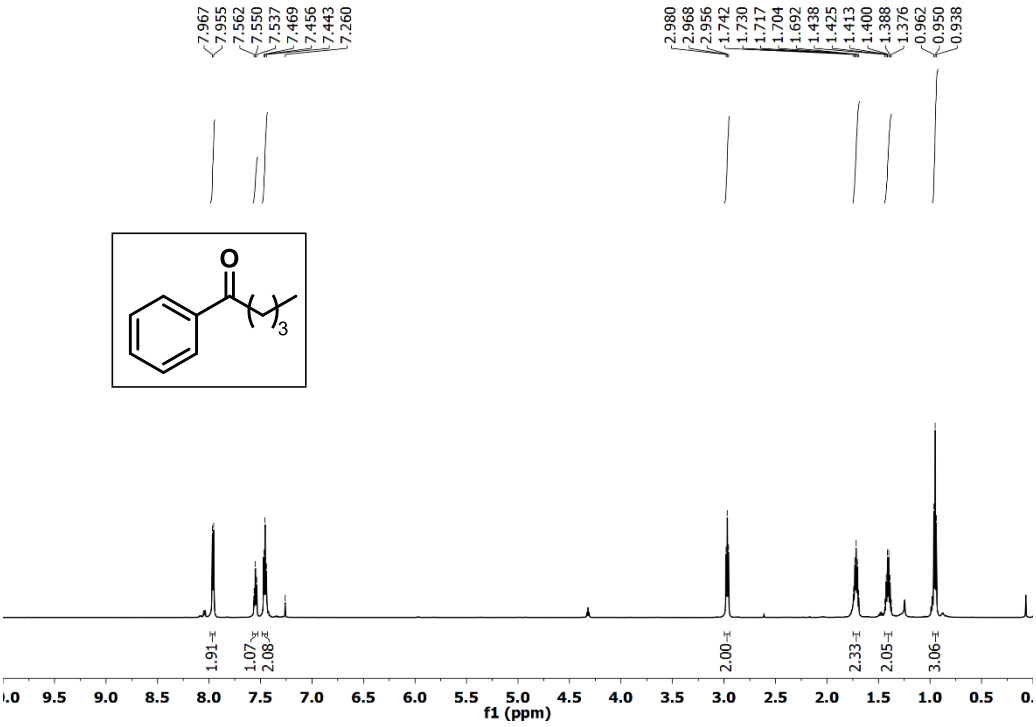
^{1}H NMR of ketone **2*z*3** (600 MHz, $CDCl_3$)



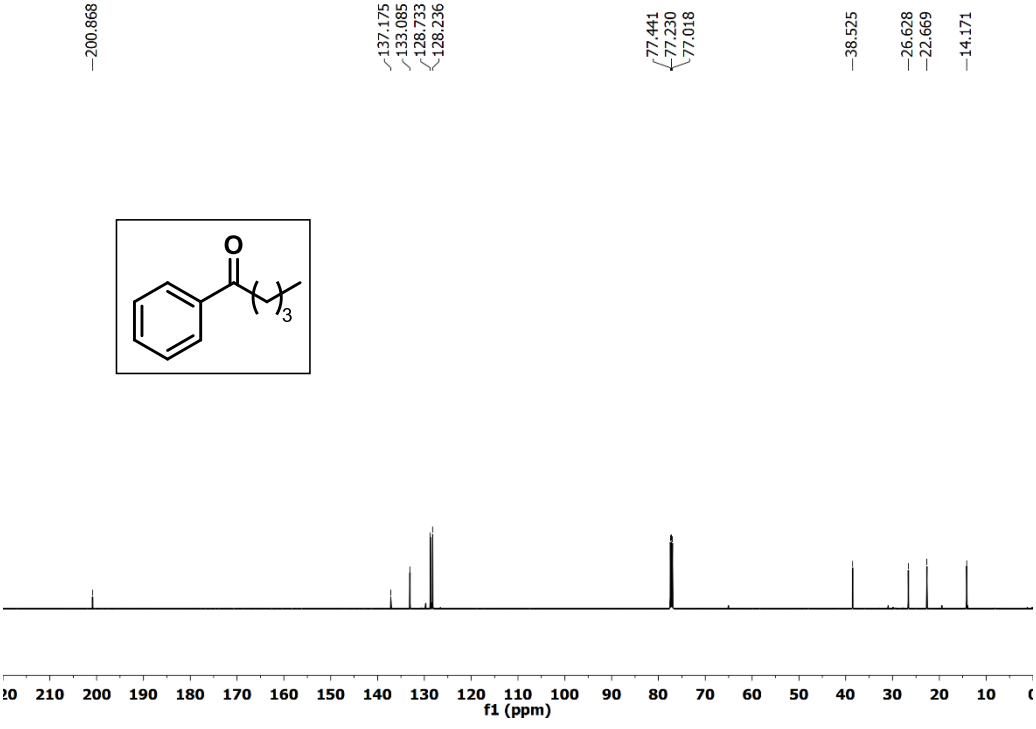
^{13}C{^{1}H} NMR of ketone **2*z*3** (151 MHz, $CDCl_3$)



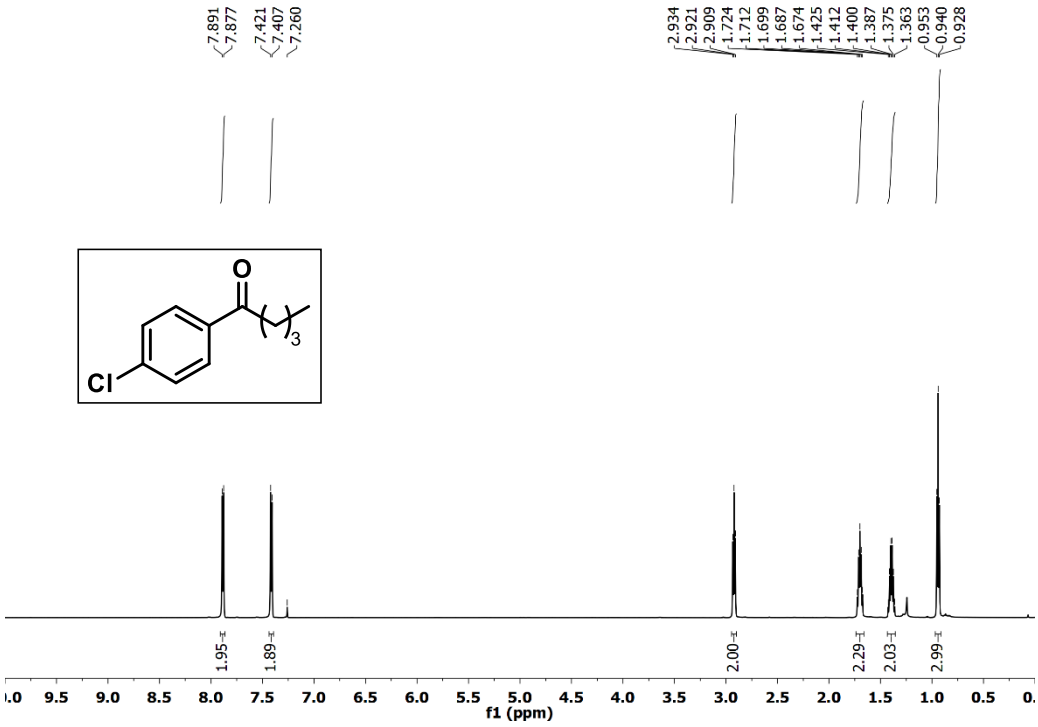
^{1}H NMR of ketone **2*z*4** (600 MHz, $CDCl_3$)



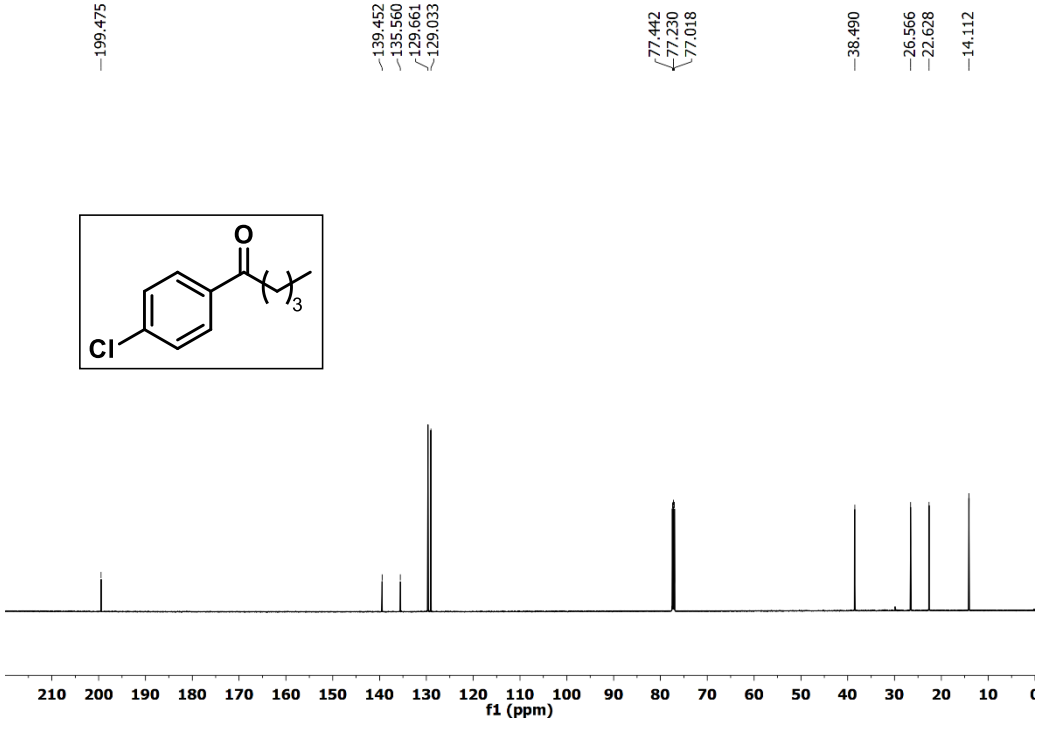
^{13}C{^{1}H} NMR of ketone **2*z*4** (151 MHz, $CDCl_3$)



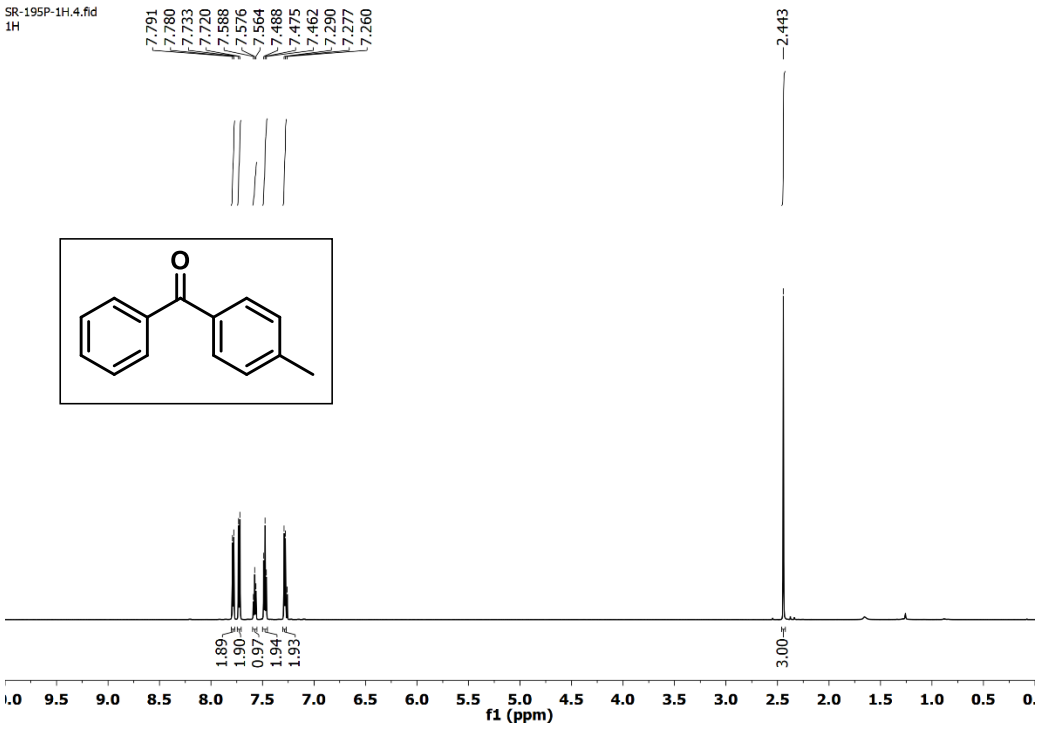
^{1}H NMR of ketone **2z5** (600 MHz, $CDCl_3$)



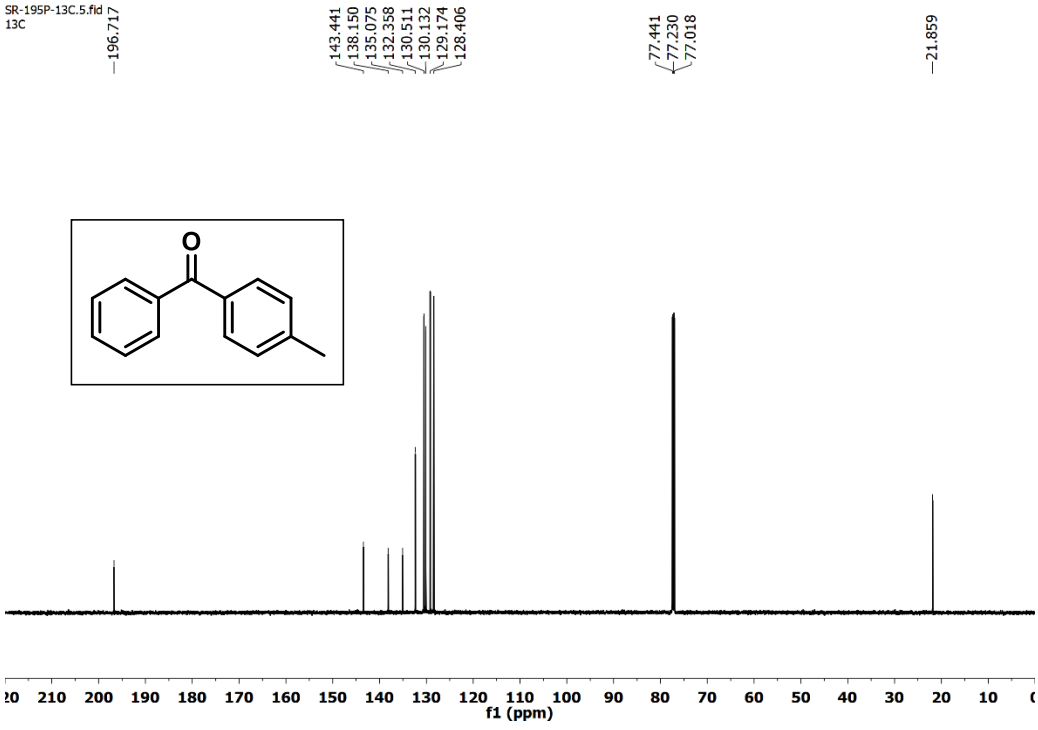
^{13}C{^{1}H} NMR of ketone **2z5** (151 MHz, $CDCl_3$)



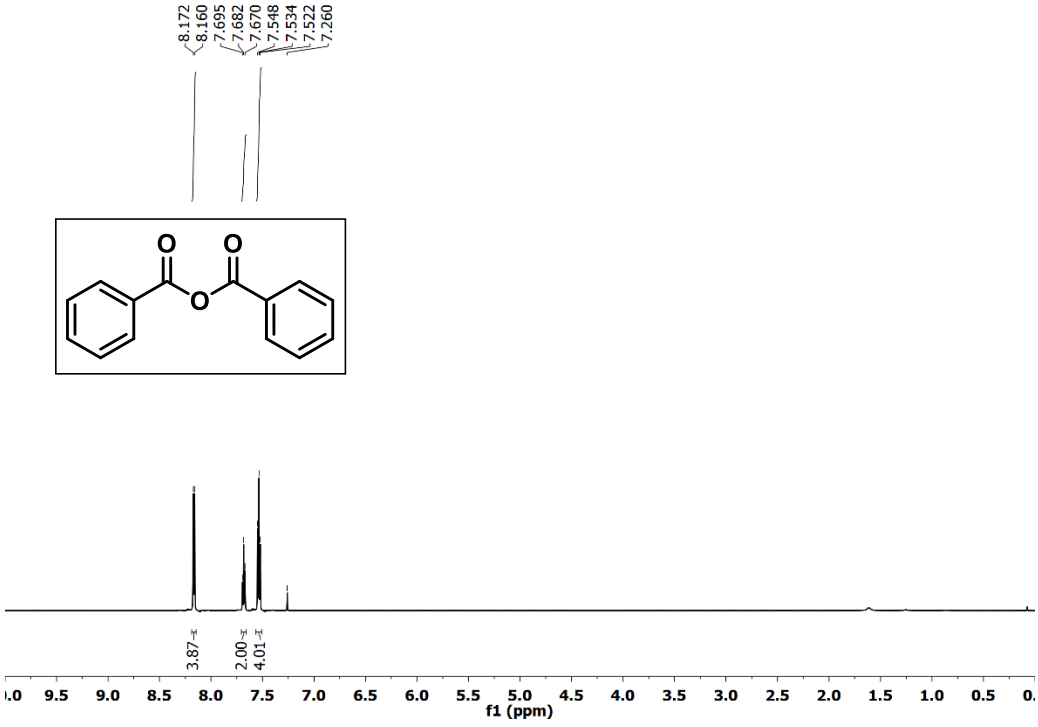
^{1}H NMR of ketone **2z6** (600 MHz, $CDCl_3$)



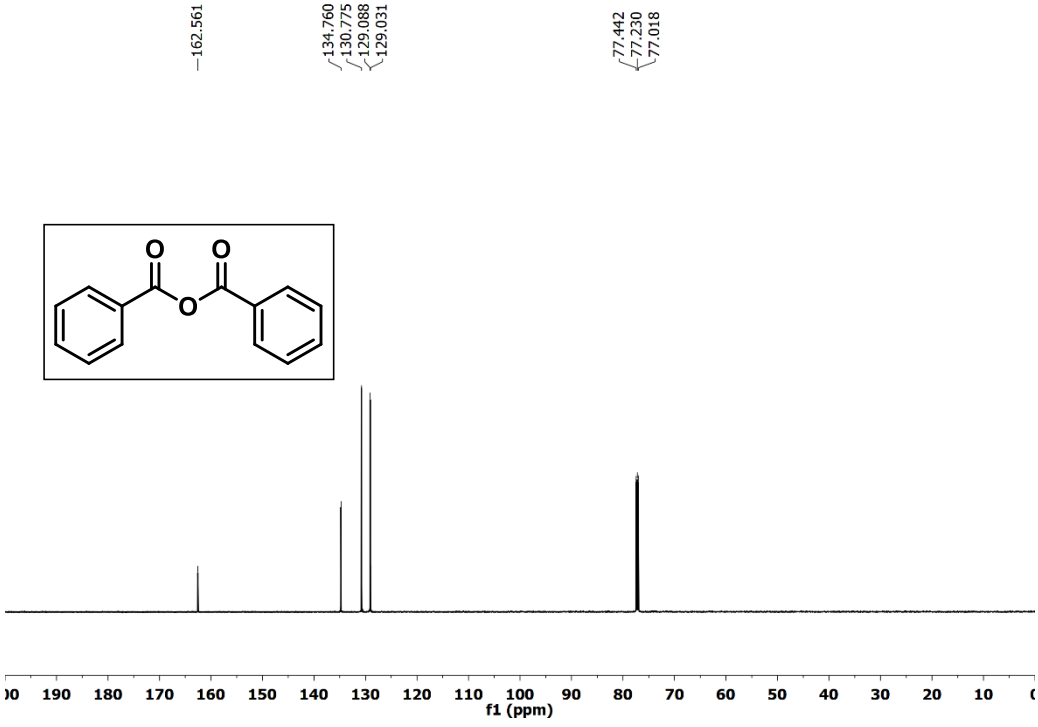
^{13}C{^{1}H} NMR of ketone **2z6** (151 MHz, $CDCl_3$)



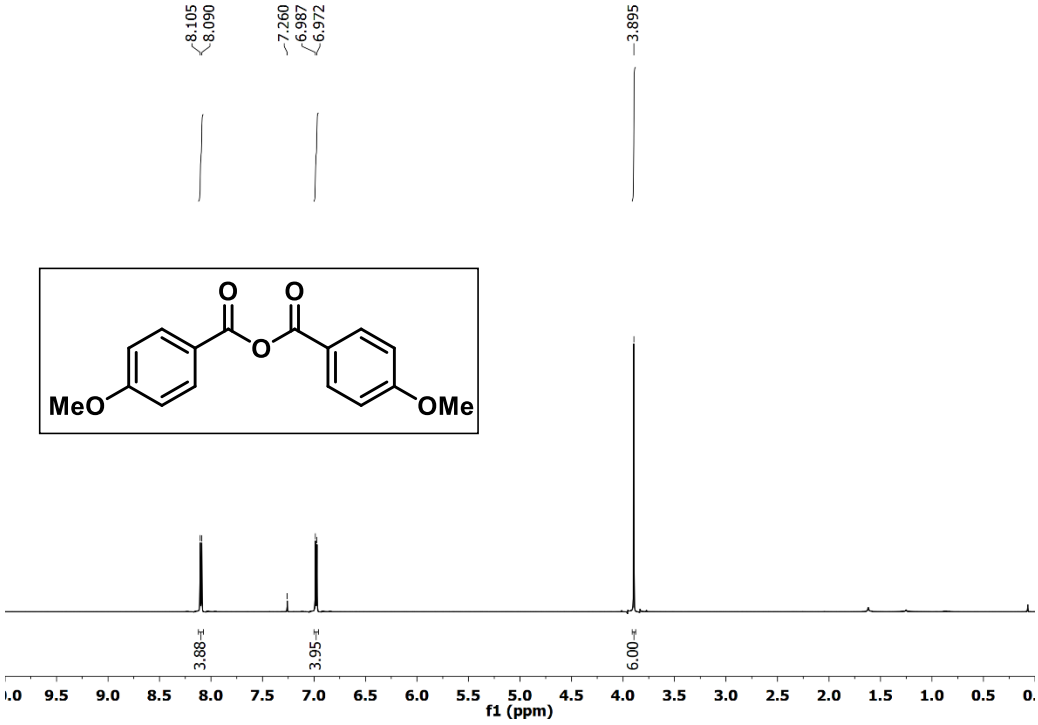
^{1}H NMR of anhydrides **4a** (600 MHz, $CDCl_3$)



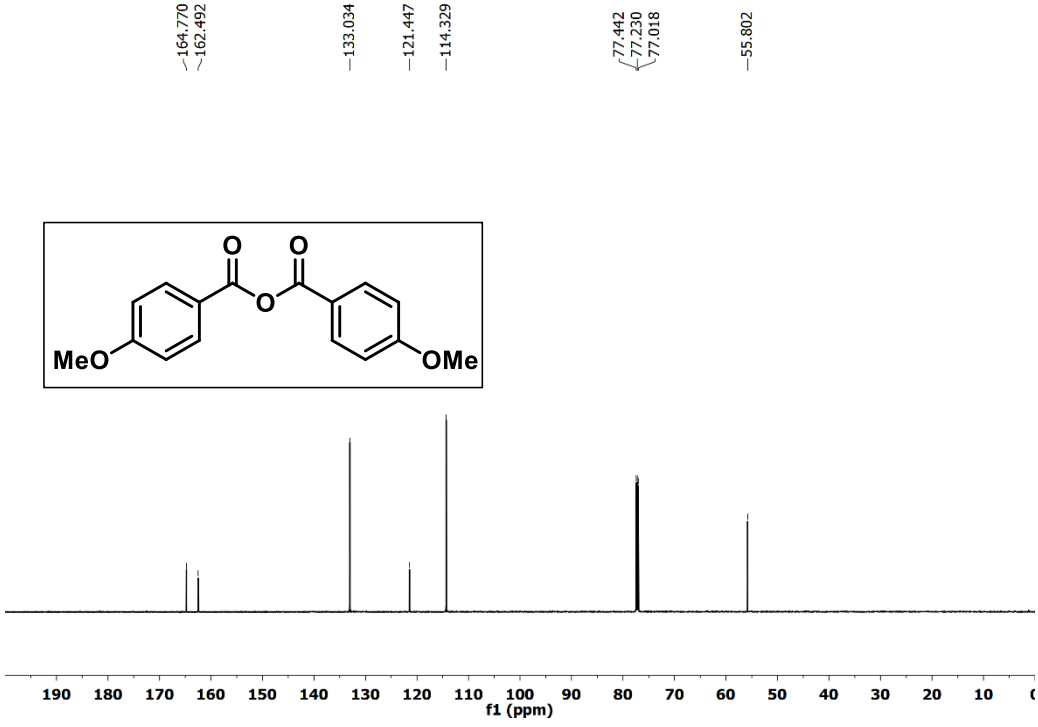
$^{13}C\{^{1}H\}$ NMR of anhydrides **4a** (151 MHz, $CDCl_3$)



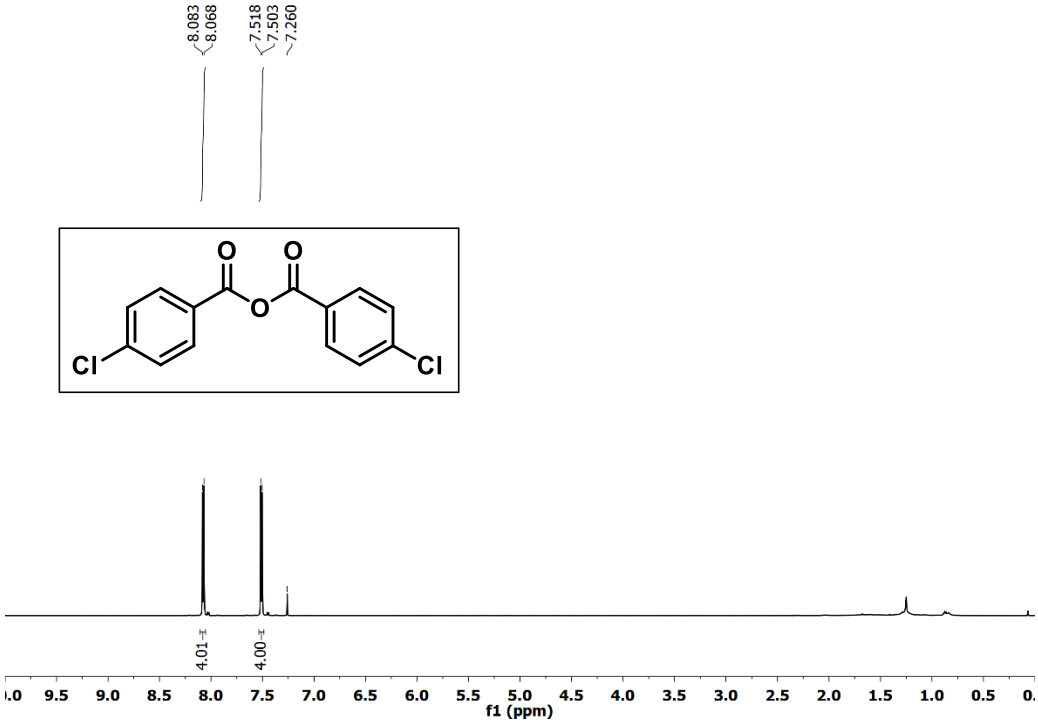
^{1}H NMR of anhydrides **4b** (600 MHz, $CDCl_3$)



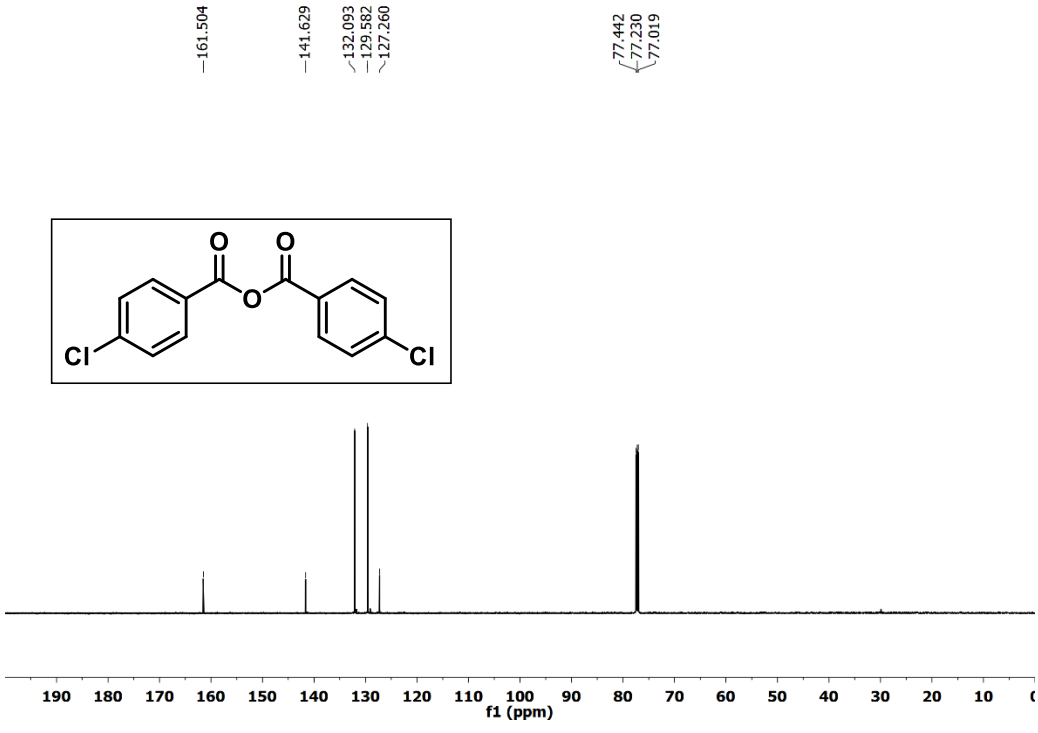
^{13}C{^{1}H} NMR of anhydrides **4b** (151 MHz, $CDCl_3$)



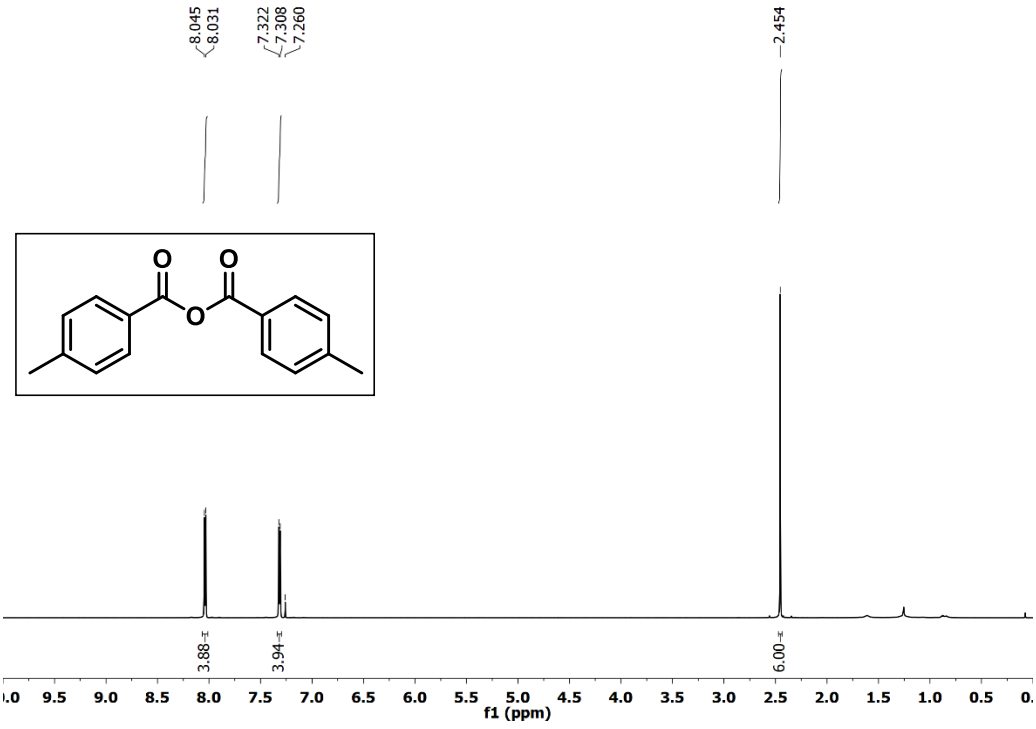
^{1}H NMR of anhydrides **4c** (600 MHz, $CDCl_3$)



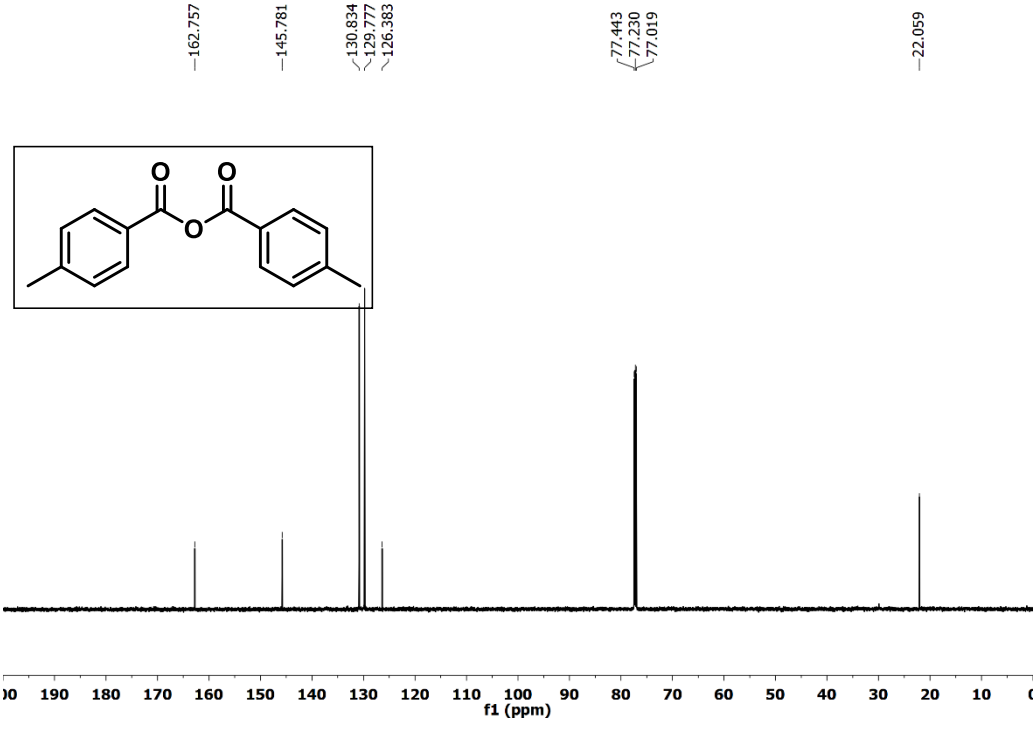
$^{13}C\{^{1}H\}$ NMR of anhydrides **4c** (151 MHz, $CDCl_3$)



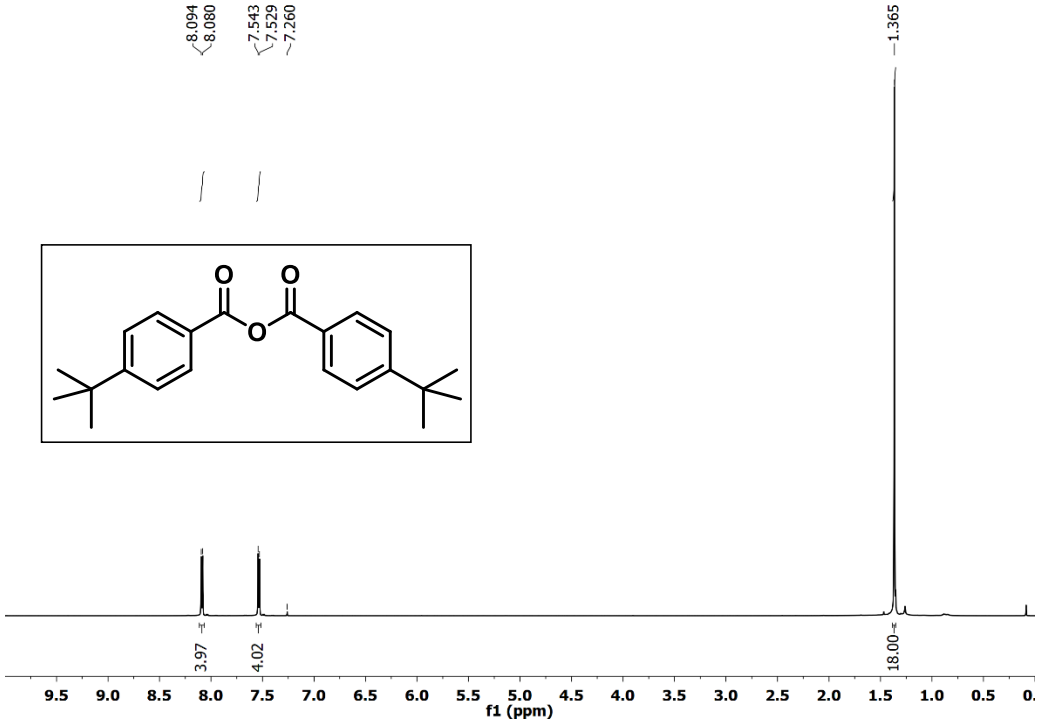
^{1}H NMR of anhydrides **4d** (600 MHz, $CDCl_3$)



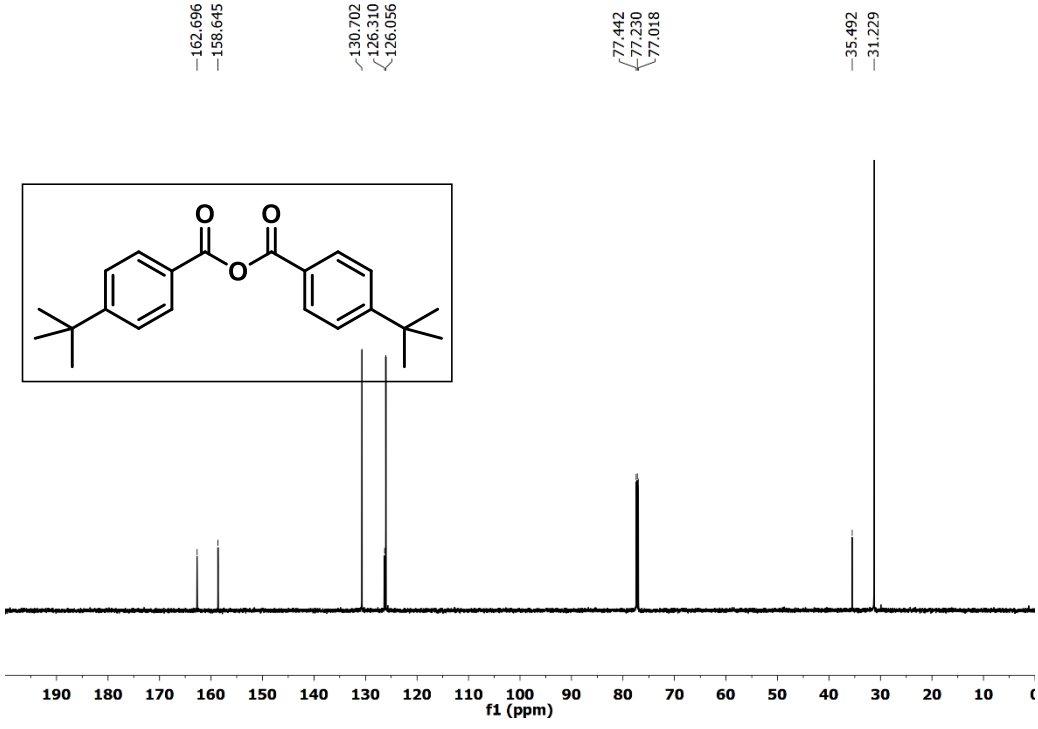
^{13}C{^{1}H} NMR of anhydrides **4d** (151 MHz, $CDCl_3$)



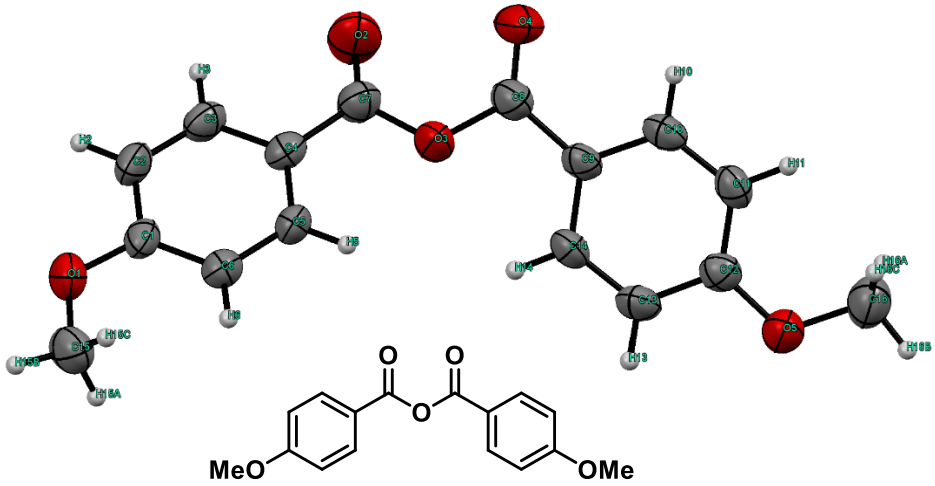
^{1}H NMR of anhydrides **4e** (600 MHz, $CDCl_3$)



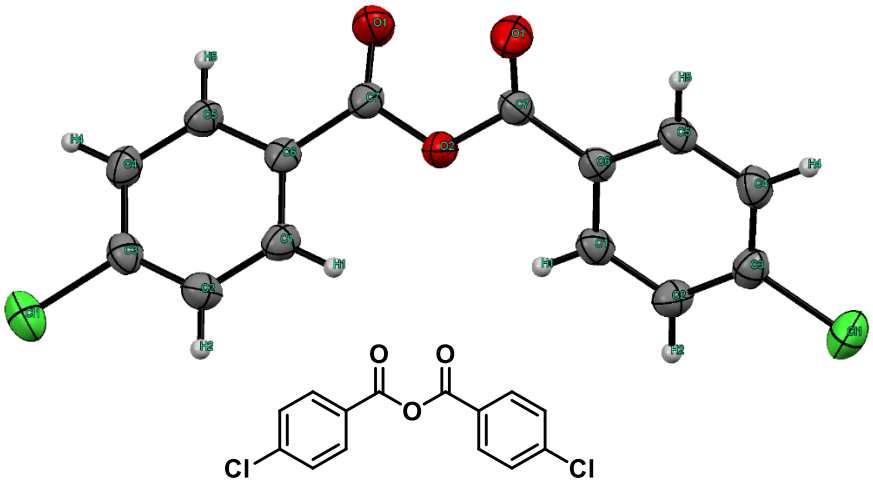
^{13}C{^{1}H} NMR of anhydrides **4e** (151 MHz, $CDCl_3$)



ORTEP diagrams and crystal parameters:



SC-XRD Data of **anhydride 4b**: The ORTEP diagram with an ellipsoid of 40% probability.



SC-XRD Data of **anhydride 4c**: The ORTEP diagram with an ellipsoid of 40% probability.

Figure S1. Crystal structure (ORTEP diagram) of **anhydride 4b** and **4c**.

Table S2. Crystal parameters and refinement data of anhydride 4b and 4c

Parameters	Anhydride 4b	Anhydride 4c
Formula	C16 H14 O5	C14 H8 Cl2 O3
Fw	286.27	295.10
Crystal system	Orthorhombic	Monoclinic
Space group	P 21 21 21	P 2/n
a/Å	3.984(2)	3.8927(14)
b/Å	11.356(6)	5.986(2)
c/Å	30.713(15)	27.223(10)
α/°	90.00	90.00
β/°	90.00	93.888(9)
γ/°	90.00	90.00
V/Å^3	1389.5(12)	632.9(4)
Z	4	2
D_c/g cm^{-3}	1.368	1.549
μ Mo $K_α$/mm^{-1}	0.102	0.512
F000	600	300
T/K	297(2)	297(2)
θ max.	26.24	25.62
Total no. of reflections	16435	13109
Independent reflections	2386	1113
Observed reflections	1862	996
Parameters refined	192	87
R_1, I > 2σ(I)	0.0946	0.0339
wR_2, I > 2σ(I)	0.2158	0.1269
GOF (F^2)	1.399	1.079
CCDC No.	2483964	2483963

References:

1. T. Xia, Z. Wei, B. Spiegelberg, H. Jiao, S. Hinze and J. G. de Vries, *Chem. Eur. J.*, 2018, **24**, 4043-4049.
2. A. Bouziane, B. Carboni, C. Bruneau, F. Carreaux and J.-L. Renaud, *Tetrahedron*, 2008, **64**, 11745-11750.
3. Y. Liu, X. Zhu, Y. Zhang, Z. Yi, X. Yang and H. Fu, *Org. Biomol. Chem.*, 2025, **23**, 183-187.
4. A. Conboy and M. F. Greaney, *Chem*, 2024, **10**, 1940-1949.
5. F. Bordi, S. Rivara, E. Dallaturca, C. Carmi, D. Pala, A. Lodola, F. Vacondio, L. Flammini, S. Bertoni, V. Ballabeni, E. Barocelli and M. Mor, *Eur. J. Med. Chem.*, 2012, **48**, 214-230.
6. D. Galicia-Badillo and B. Rodríguez-Molina, *Tetrahedron*, 2024, **167**, 134245.
7. S. Ghinato, D. Territo, A. Maranzana, V. Capriati, M. Blangetti and C. Prandi, *Chem. Eur. J.*, 2021, **27**, 2868-2874.
8. J. Li, Z. Yu, J. Zhao, C. Ma, L. Duan, Z. Liu, H. Sun, G. Zhao, Q. Liu and Q. Meng, *J. Org. Chem.*, 2025, **90**, 1245-1255.
9. M. Giannerini, C. Vila, V. Hornillos and B. L. Feringa, *Chem. Commun.*, 2016, **52**, 1206-1209.

10. A. Mastitski, E. Vellemäe, I. Ul Haq and J. Järv, *Org. Prep. Proced. Int.*, 2025, **57**, 228-238.
11. Y. Fu, X. L. Zhao, H. Hügel, D. Huang, Z. Du, K. Wang and Y. Hu, *Org. Biomol. Chem.*, 2016, **14**, 9720-9724.