Copper(I)-catalyzed ring-opening cyanation of cyclopropanols

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Supporting Information

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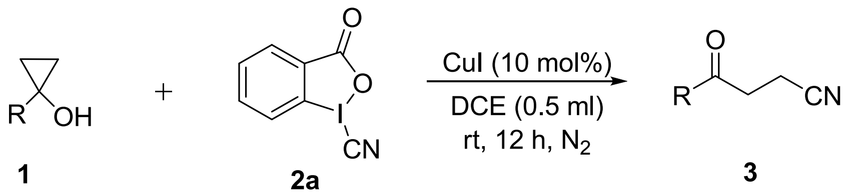
1. General Information and Starting Materials.

All reactions were carried out in Schlenk-tubes filled with nitrogen. The DCE and other solvents were obtained from commercial suppliers and used without further purification. The nitrogen used is 99.99% purity. Flash column chromatographic purification of products was accomplished using forced-flow chromatography on Silica Gel (200-300 mesh). ^{1}H NMR, ^{13}C NMR, ^{19}F NMR spectra were recorded on a Bruker Advance 400 or 600 spectrometer. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity, integration, and coupling constant (Hz). Data for ^{13}C NMR are reported in terms of chemical shift (δ ppm). ^{19}F NMR are reported in terms of chemical shift (δ ppm). Cyano hypervalent iodine reagents **2a** were synthesized according to the reported literatures.[1] All cyclopropanols were prepared by the addition of Grignard reagent according to the reported procedure.[2-4] The CuI was purified according to the literature before use.[5]

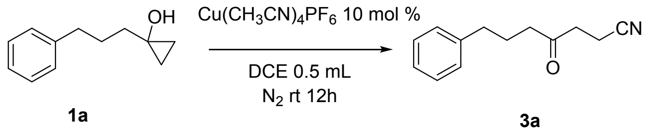
2. General Procedure for the Ring-Opening Cyanation.

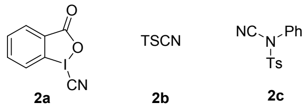


A 10 mL oven-dried Schlenk-tube was sequentially added cyclopropanols **1** (0.2 mmol), hypervalent iodine **2a** (81.9 mg, 0.3 mmol), CuI (3.8 mg, 10 mol%). The tube was evacuated and backfilled with N_2 (three times). Then DCE (0.5 mL) was added. The reaction mixture was stirred for 12 h at room temperature. The solution was then diluted with ethyl acetate (10 mL), washed with brine (3 mL), extracted with ethyl acetate (3*5 mL), dried over anhydrous Na_2SO_4, filtered, and evaporated under vacuum. The crude reaction mixture was purified by column chromatography (silica gel, ethyl acetate/petroleum ether) yielded the desired product **3**.

3. Studies of the "CN" source and Cu(II) catalyst

3.1 The studies of "CN" source

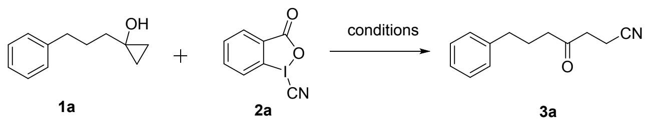




entry	Catalyst (0.1 equiv)	"CN" source	Oxidant	Yield (%)
1	$Cu(CH_3CN)_4PF_6$	**2a**	-	30
2	$Cu(CH_3CN)_4PF_6$	**2b**	BIOAc	trace
3	$Cu(CH_3CN)_4PF_6$	**2c**	BIOAc	0
4	$Cu(CH_3CN)_4PF_6$	**2b**	$K_2S_2O_8$	0
5	$Cu(CH_3CN)_4PF_6$	**2c**	$K_2S_2O_8$	0
6	$Cu(CH_3CN)_4PF_6$	**2b**	$PhI(OAc)_2$	0
7	$Cu(CH_3CN)_4PF_6$	**2c**	$PhI(OAc)_2$	0

We have tried other nonoxidative CN reagents with different oxidants compared to hypervalent iodine **2a** under the reaction conditions with $Cu(CH_3CN)_4PF_6$ as catalyst. However, no desired product was obtained.

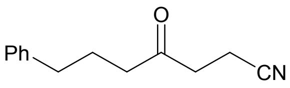
3.2 The studies of Cu(II) catalyst



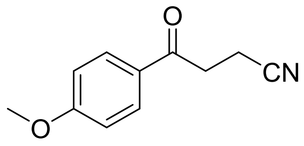
entry	Catalyst (0.1 equiv)	Solvents (0.5 ml)	Temp. (°C)	Time (h)	Yield (%)
1	$Cu(OAc)_2$	DCE	rt	12	55
2	$Cu(OTf)_2$	DCE	rt	12	14
3	$Cu(acac)_2$	DCE	rt	12	35

The reactions could also complete with Cu(II) catalyst, namely $Cu(OAc)_2$, $Cu(OTf)_2$, and $Cu(acac)_2$, under the standard conditions with a lower yield.

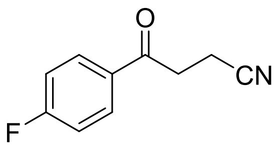
4. Characterization of products


4-oxo-7-phenylheptanenitrile (**3a**)

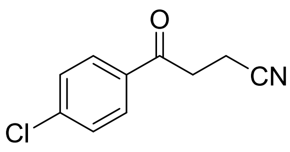
Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 78% yield as a yellow liquid (31.3 mg). ^{1}**H NMR** (600 MHz, $CDCl_3$) δ 7.29 (t, *J* = 7.5 Hz, 2H), 7.20 (t, *J* = 7.3 Hz, 1H), 7.16 (d, *J* = 7.5 Hz, 2H), 2.74 (t, *J* = 7.2 Hz, 2H), 2.63 (t, *J* = 7.5 Hz, 2H), 2.55 (t, *J* = 7.2 Hz, 2H), 2.45 (t, *J* = 7.4 Hz, 2H), 1.95 (p, *J* = 7.4 Hz, 2H). ^{13}**C NMR** (151 MHz, $CDCl_3$) δ 206.01, 141.23, 128.59, 128.58,126.24, 119.13, 41.63, 37.86, 35.01, 25.06, 11.47.


4-(4-methoxyphenyl)-4-oxobutanenitrile (**3b**)

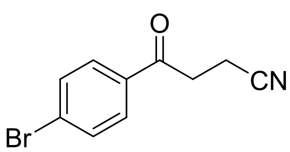
Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 65% yield as a yellow liquid (24.5 mg). ^{1}**H NMR** (600 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.9 Hz, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 3.88 (s, 3H), 3.32 (t, *J* = 7.3 Hz, 2H), 2.75 (t, *J* = 7.3 Hz, 2H). ^{13}**C NMR** (151 MHz,$CDCl_3$) δ 193.89, 164.19, 130.46, 128.81, 119.56, 114.13, 55.69, 33.99, 11.99.


4-(4-fluorophenyl)-4-oxobutanenitrile (**3c**)

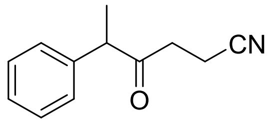
Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 79% yield as a yellow liquid (27.9 mg). ^{1}**H NMR** (600 MHz, CDCl3) δ 8.00 – 7.96 (m, 2H), 7.15 (t, *J* = 8.6 Hz, 2H), 3.35 (t, *J* = 7.2 Hz, 2H), 2.76 (t, *J* = 7.1 Hz, 2H). ^{13}**C NMR** (151 MHz, CDCl3) δ 193.85, 167.16, 165.46, 132.20, 130.89, 130.83, 119.21, 116.29, 116.14, 34.33, 11.94. ^{19}**F NMR** (376 MHz, $CDCl_3$) δ -103.50.


4-(4-chlorophenyl)-4-oxobutanenitrile (**3d**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 60% yield as a yellow liquid (23.1 mg). ^{1}**H NMR** (600 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.6 Hz, 2H), 7.48 (d, *J* = 8.6 Hz, 2H), 3.36 (t, *J* = 7.2 Hz, 2H), 2.78 (t, *J* = 7.2 Hz, 2H). ^{13}**C NMR** (151 MHz, $CDCl_3$) δ 194.26, 140.56, 133.99, 129.53, 129.34, 119.14, 34.39, 11.91.

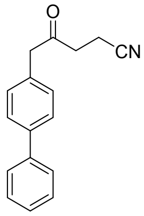

4-(4-bromophenyl)-4-oxobutanenitrile (**3e**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 55% yield as a yellow liquid (26.2 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.4 Hz, 2H), 7.65 (d, *J* = 8.4 Hz, 2H), 3.35 (t, *J* = 7.2 Hz, 2H), 2.78 (t, *J* = 7.1 Hz, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 194.47, 134.43, 132.37, 129.62, 129.37, 119.13, 34.38, 11.89.



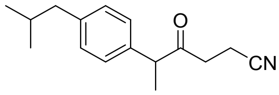
4-oxo-5-phenylhexanenitrile (**3f**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 51% yield as a yellow liquid (19 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.36 (t, *J* = 7.5 Hz, 2H), 7.30 (d, *J* = 7.4 Hz, 1H), 7.21 – 7.18 (m, 2H), 3.76 (d, *J* = 7.0 Hz, 1H), 2.71 (ddd, *J* = 19.6, 7.9, 6.6 Hz, 2H), 2.50 (ddd, *J* = 28.3, 7.9, 6.5 Hz, 2H), 1.43 (d, *J* = 7.0 Hz, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.38, 139.82, 129.37, 127.87, 127.76,119.00 , 52.96, 36.19, 17.23, 11.73.



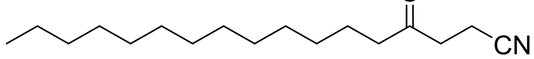
5-([1,1'-biphenyl]-4-yl)-4-oxopentanenitrile(**3g**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 69% yield as a yellow solid (34.3 mg). **^{1}H NMR** (600 MHz,$CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 4H), 7.44 (t, *J* = 7.7 Hz, 2H), 7.35 (t, *J* = 7.4 Hz, 1H), 7.27 (d, *J* = 8.1 Hz, 2H), 3.77 (s, 2H), 2.85 (t, *J* = 7.2 Hz, 2H), 2.55 (t, *J* = 7.2 Hz, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 203.77 , 140.65,140.61, 132.28, 129.87, 128.94, 127.84 , 127.58, 127.17, 118.92, 49.49, 37.19, 11.58.



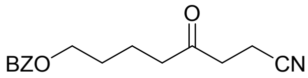
5-(4-isobutylphenyl)-4-oxohexanenitrile (**3h**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 48% yield as a yellow liquid (23.3 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.12 (d, *J* = 8.1 Hz, 2H), 7.09 (d, *J* = 8.1 Hz, 2H), 3.72 (q, *J* = 7.0 Hz, 1H), 2.71 (dddd, *J* = 46.7, 18.3, 8.1, 6.5 Hz, 2H), 2.56 – 2.41 (m, 4H), 1.85 (dt, *J* = 13.6, 6.8 Hz, 1H), 1.41 (d, *J* = 7.0 Hz, 3H), 0.90 (d, *J* = 6.6 Hz, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.63, 141.32, 137.02, 130.07, 127.58, 119.06, 52.62, 45.13, 36.10, 30.25, 22.49, 17.20, 11.76.



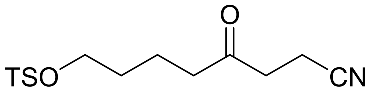
4-oxoheptadecanenitrile (**3i**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 69% yield as a yellow solid (36.5 mg). **^{1}H NMR** (600 MHz, CDl_3) δ 2.79 (t, *J* = 7.2 Hz, 2H), 2.58 (t, *J* = 7.2 Hz, 2H), 2.44 (t, *J* = 7.5 Hz, 2H), 1.63 – 1.56 (m, 2H), 1.28 – 1.25 (m, 20H), 0.88 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.33, 119.11, 42.68 , 37.82, 32.04, 29.78, 29.75,29.70,29.54,29.45, 29.27, 23.86, 22.80, 14.20, 11.50 .



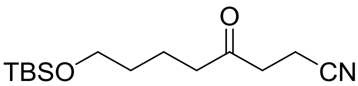
7-cyano-5-oxoheptyl benzoate (**3j**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 53% yield as a yellow liquid (27.5 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.05 – 8.02 (m, 2H), 7.58 – 7.54 (m, 1H), 7.45 (t, *J* = 7.8 Hz, 2H), 4.33 (t, *J* = 5.9 Hz, 2H), 2.81 (t, *J* = 7.2 Hz, 2H), 2.59 (t, *J* = 7.2 Hz, 2H), 2.55 (t, *J* = 6.8 Hz, 2H), 1.81 – 1.77 (m, 4H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 205.64, 166.71, 133.09, 130.36, 129.66, 128.51, 119.03, 64.45, 41.94, 37.89, 28.26, 20.23, 11.50 .



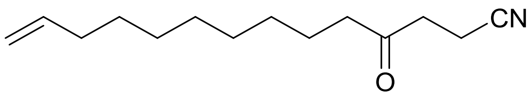
4-oxo-8-tosyloctanenitrile (**3k**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 2:1), obtained in 50% yield as a yellow liquid (30.9 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 4.02 (t, *J* = 5.7 Hz, 2H), 2.77 (t, *J* = 7.1 Hz, 2H), 2.57 (t, *J* = 7.1 Hz, 2H), 2.47 – 2.44 (m, 5H),1.67 (dd, *J* = 8.8, 5.8 Hz, 4H). **^{13}C NMR** (151 MHz,$CDCl_3$) δ 205.44, 144.99, 133.08, 130.00, 127.96, 119.03, 70.12, 41.43, 37.79, 29.79, 28.19, 21.73, 19.65, 11.45 .



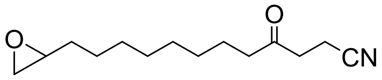
8-((tert-butyldimethylsilyl)oxy)-4-oxooctanenitrile(3l)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 48% yield as a yellow solid (25.8 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 3.60 (t, *J* = 6.2 Hz, 2H), 2.78 (t, *J* = 7.2 Hz, 2H), 2.57 (t, *J* = 7.2 Hz, 2H), 2.47 (t, *J* = 7.4 Hz, 2H), 1.65 (dt, *J* = 15.2, 7.5 Hz, 2H), 1.50 (dt, *J* = 13.2, 6.3 Hz, 2H), 0.87 (s, 9H), 0.03 (s, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.15, 119.09, 62.75, 42.35, 37.75, 32.17, 29.79, 26.05, 20.39, 11.47, -5.21.



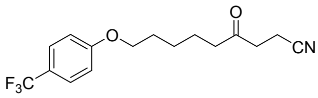
4-oxotetradec-13-enenitrile (**3m**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 50% yield as a yellow solid (22 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 5.81 (ddt, *J* = 16.9, 10.2, 6.7 Hz, 1H), 4.99 (ddd, *J* = 17.1, 3.5, 1.6 Hz, 1H), 4.94 – 4.91 (m, 1H), 2.79 (t, *J* = 7.2 Hz, 2H), 2.58 (t, *J* = 7.2 Hz, 2H), 2.44 (t, *J* = 7.5 Hz, 2H), 2.04 (td, *J* = 6.9, 1.1 Hz, 2H), 1.63 – 1.57 (m, 2H), 1.40 – 1.34 (m, 2H), 1.28 (s, 8H). **^{13}C NMR** (151 MHz, CDCl3) δ 206.38, 139.23, 119.14, 114.27, 42.63, 37.79, 33.86, 29.37, 29.35, 29.21, 29.13, 28.98, 23.80, 11.49.



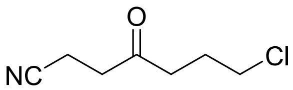
12-(oxiran-2-yl)-4-oxododecanenitrile (**3n**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 55% yield as a white solid (26 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 2.93 – 2.89 (m, 1H), 2.80 (t, J = 7.2 Hz, 2H), 2.75 (t, J = 4.5 Hz, 1H), 2.59 (t, J = 7.2 Hz, 2H), 2.48 – 2.43 (m, 3H), 1.60 (dd, J = 14.1, 7.0 Hz, 2H), 1.52 (dt, J = 8.5, 7.4 Hz, 2H), 1.45 (ddd, J = 19.6, 12.4, 5.6 Hz, 2H), 1.35 – 1.27 (m, 9H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.40, 119.16, 52.50, 47.22, 42.62, 37.80, 32.56, 29.44, 29.40, 29.32, 29.18, 26.05, 23.77, 11.50.



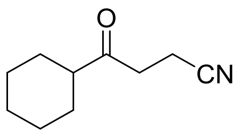
4-oxo-9-(4-(trifluoromethyl)phenoxy)nonanenitrile(**3o**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 65% yield as a yellow liquid (40.7 mg). **^{1}H NMR** (600 MHz, CDCl3) δ 7.52 (d, J = 8.6 Hz, 2H), 6.92 (d, J = 8.6 Hz, 2H), 3.98 (t, J = 6.3 Hz, 2H), 2.79 (t, J = 7.1 Hz, 2H), 2.57 (t, J = 7.1 Hz, 2H), 2.49 (t, J = 7.3 Hz, 2H), 1.83 – 1.77 (m, 2H), 1.68 (dt, J = 15.2, 7.5 Hz, 2H), 1.47 (dt, J = 18.6, 7.8 Hz, 2H). **^{13}C NMR** (151 MHz, CDCl3) δ 205.99, 161.56, 126.70,126.68, 125.49, 123.70, 119.08, 114.54, 67.90, 42.43, 37.89, 29.00, 25.73, 23.40,11.52. ^{19}F NMR (376 MHz, CDCl3) δ -61.41.



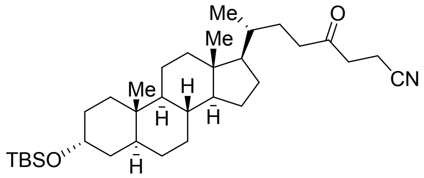
7-chloro-4-oxoheptanenitrile (**3p**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 42% yield as a yellow liquid (13.3 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 3.59 (t, J = 6.2 Hz, 2H), 2.84 (t, J = 7.1 Hz, 2H), 2.68 (t, J = 7.0 Hz, 2H), 2.60 (t, J = 7.1 Hz, 2H), 2.12 – 2.06 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$)δ 204.98, 118.91, 44.24, 39.21, 38.03, 26.21, 11.51 .



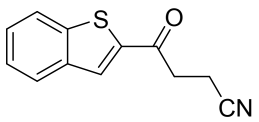
4-cyclohexyl-4-oxobutanenitrile (**3q**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 60% yield as a yellow liquid (19.7 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 2.83 (t, J = 7.2 Hz, 2H), 2.57 (t, J = 7.2 Hz, 2H), 2.37 (tt, J = 11.3, 3.4 Hz, 1H), 1.86 (d, J = 12.8 Hz, 2H), 1.82 – 1.77 (m, 2H), 1.71 – 1.65 (m, 1H), 1.38 – 1.19 (m, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 209.27, 119.26, 50.61, 35.87, 28.50, 25.83, 25.63, 11.59.



(R)-7-((3R,5S,8R,9S,10S,13R,14S,17R)-3-((tert-butyldimethylsilyl)oxy)-10,13-dimethylhexadecahydro-1H-cyclopenta[a]phenanthren-17-yl)-4-oxooctanenitrile(**3r**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 45% yield as a yellow solid (47.5 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 3.58 (ddd, *J* = 15.5, 10.6, 4.6 Hz, 1H), 2.86 – 2.76 (m, 2H), 2.59 (t, *J* = 7.2 Hz, 2H), 2.48 (ddd, *J* = 15.8, 10.3, 5.1 Hz, 1H), 2.37 (ddd, *J* = 16.3, 10.0, 6.0 Hz, 1H), 1.93 (dd, *J* = 9.3, 2.9 Hz, 1H), 1.87 – 1.71 (m, 6H), 1.56 (dd, *J* = 13.7, 10.4 Hz, 3H), 1.48 – 1.30 (m, 10H), 1.21 (tt, *J* = 12.8, 7.6 Hz, 5H), 1.15 – 1.02 (m, 6H), 0.96 – 0.93 (m, 1H), 0.92 – 0.86 (m, 16H), 0.65 – 0.61 (m, 3H), 0.06 (d, *J* = 6.2 Hz, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 206.76, 119.15, 72.98, 56.59, 56.11, 42.92, 42.47,40.42, 40.33, 39.59, 37.84, 37.12, 36.05, 35.76, 35.41, 34.76, 31.21, 29.87, 28.39, 27.46 , 26.56, 26.14, 24.35, 23.54, 20.98, 18.57,18.48, 12.19, 11.56, -4.42.

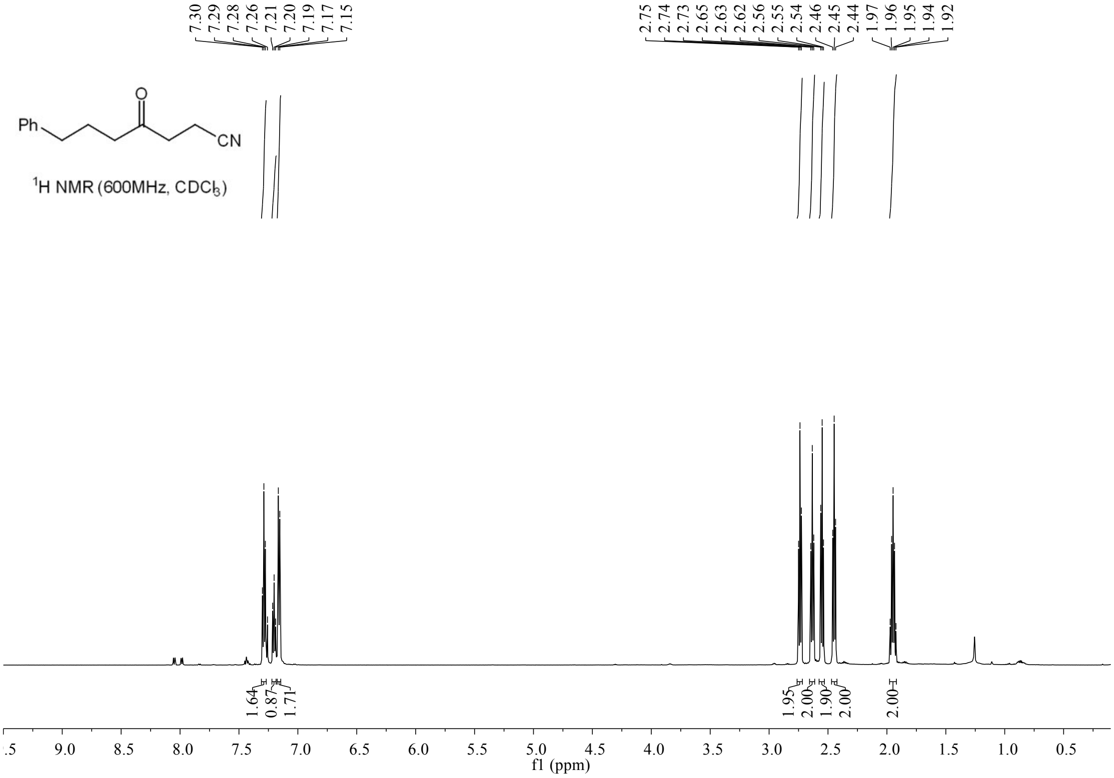


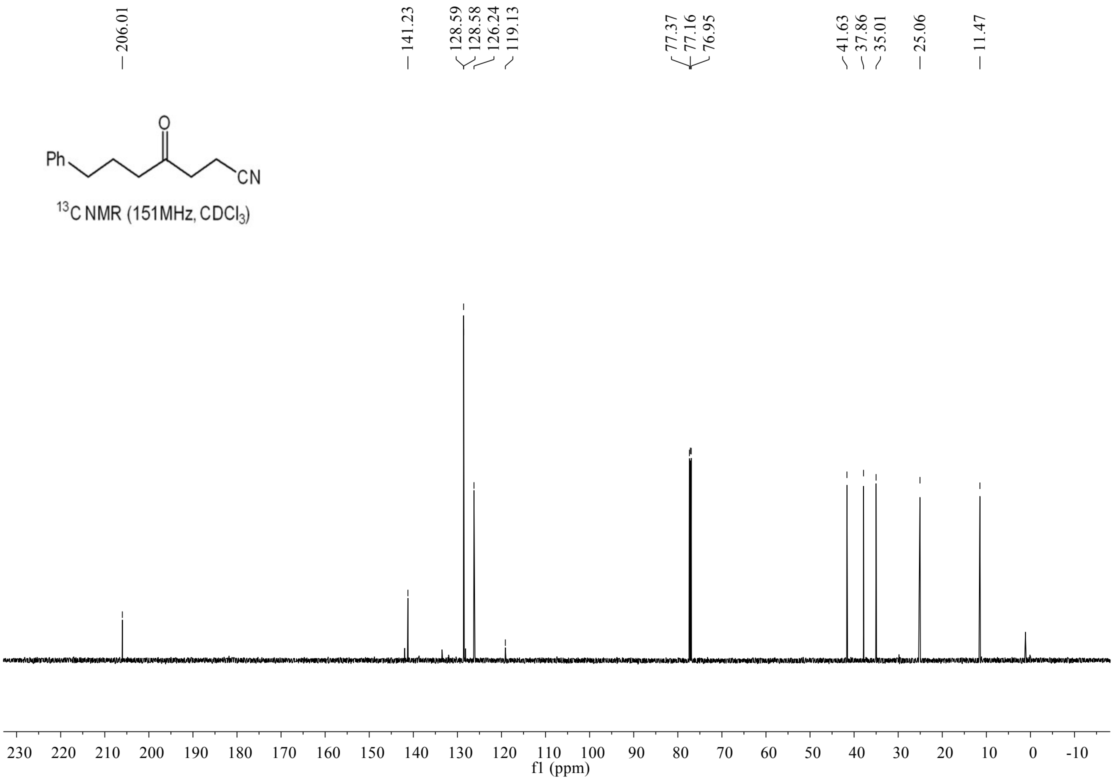
4-(benzo[b]thiophen-2-yl)-4-oxobutanenitrile (**3s**)

Following general procedure, the product was purified by flash column chromatography on silica gel (PE/EA = 5:1), obtained in 55% yield as a yellow solid (23.6 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.99 (s, 1H), 7.91 (d, *J* = 8.0 Hz, 1H), 7.88 (d, *J* = 8.2 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 7.46 – 7.41 (m, 1H), 3.42 (t, *J* = 6.8 Hz, 2H), 2.80 (t, *J* = 7.2 Hz, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 189.82, 142.71, 141.90, 138.97, 129.82, 128.04, 126.25, 125.41, 123.12, 119.05, 34.77, 11.91.

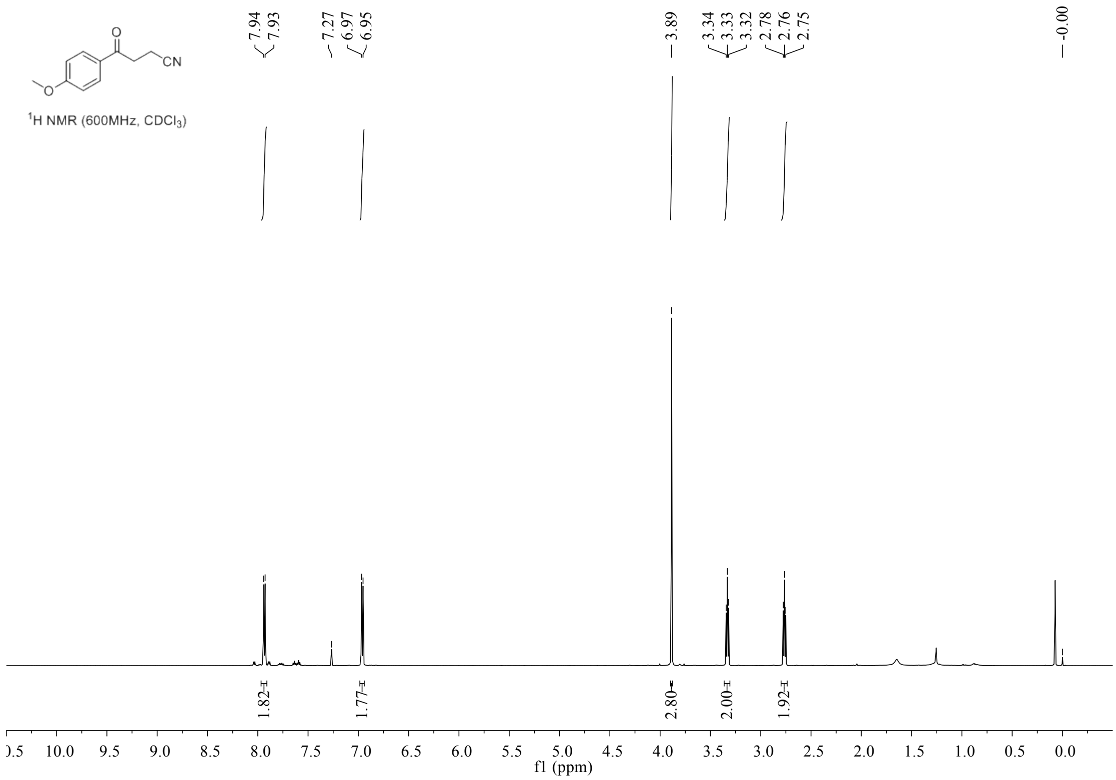
5. ^{1}H NMR and ^{13}C NMR spectra of products.

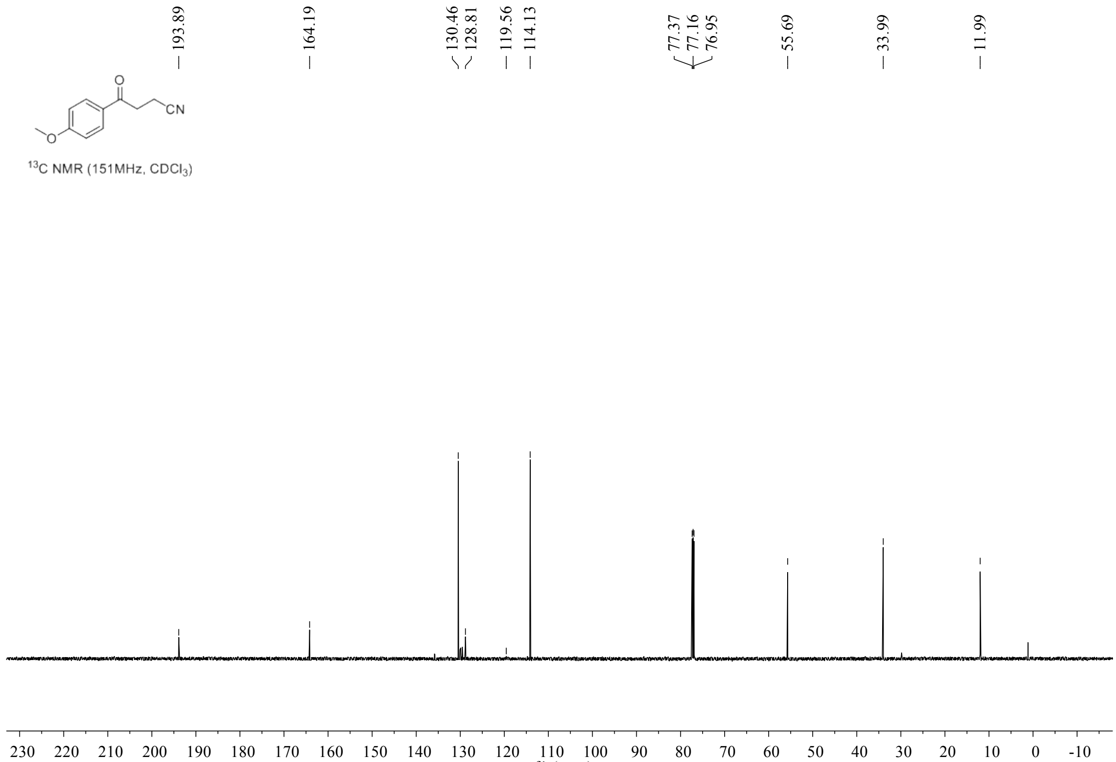
4-oxo-7-phenylheptanenitrile (**3a**)



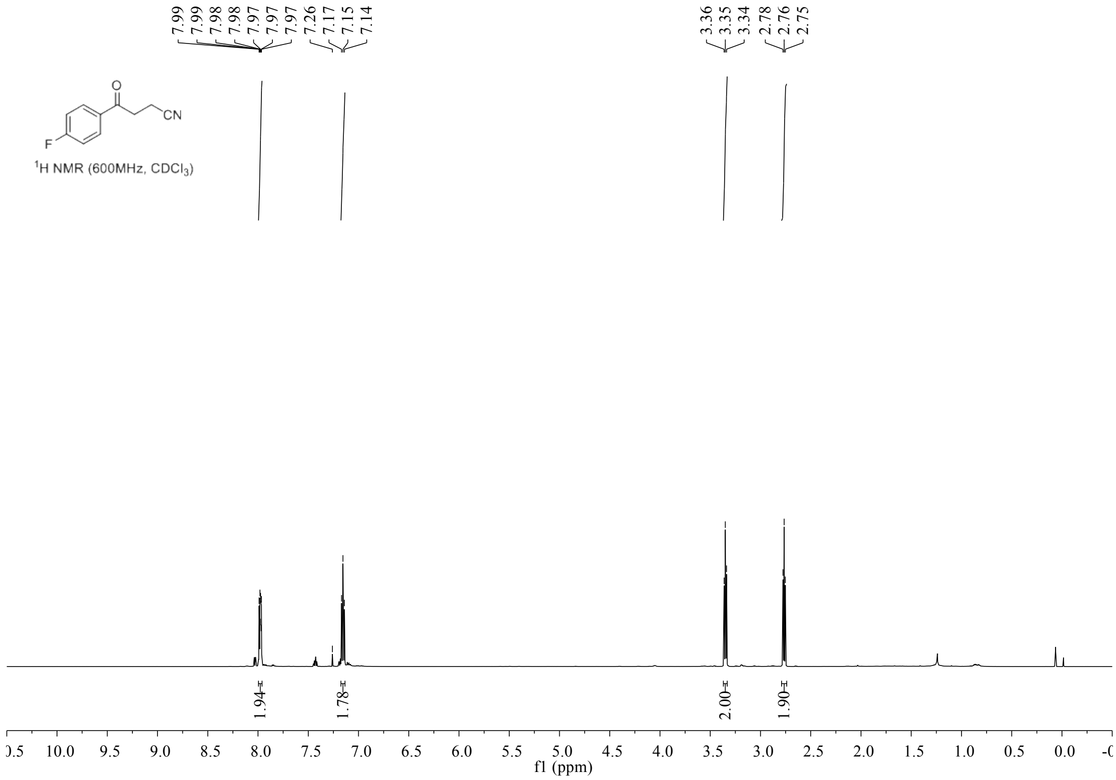


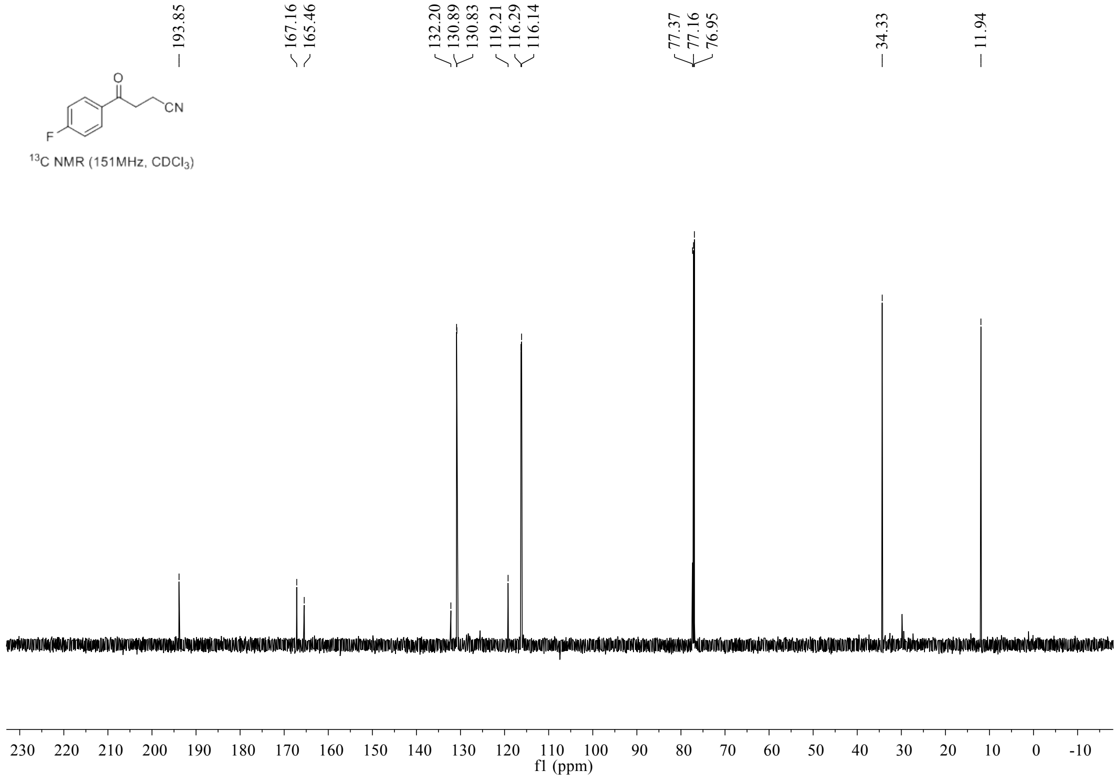
4-(4-methoxyphenyl)-4-oxobutanenitrile (**3b**)

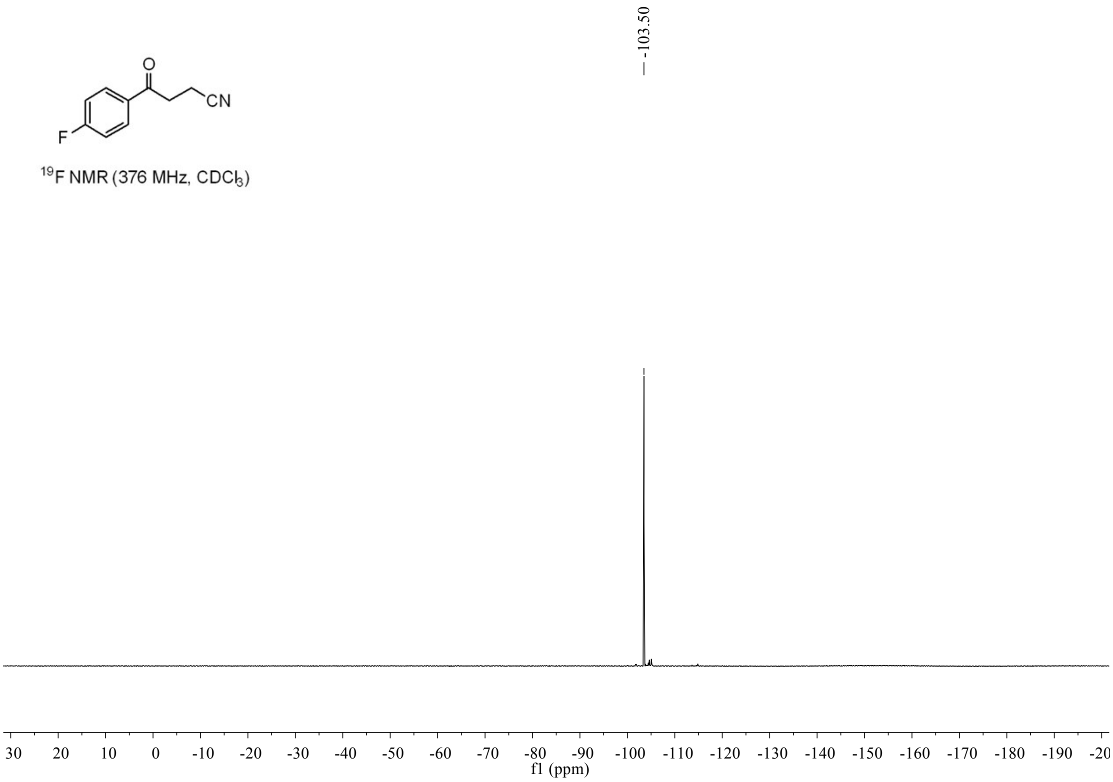




4-(4-fluorophenyl)-4-oxobutanenitrile(**3c**)

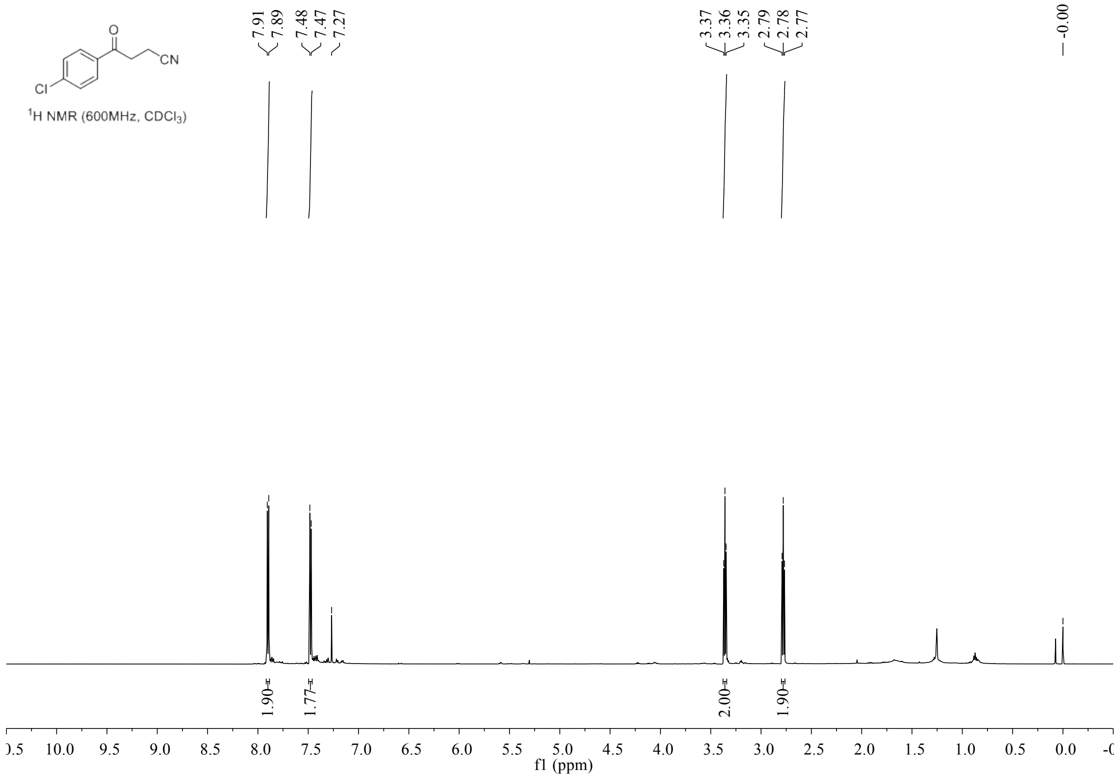


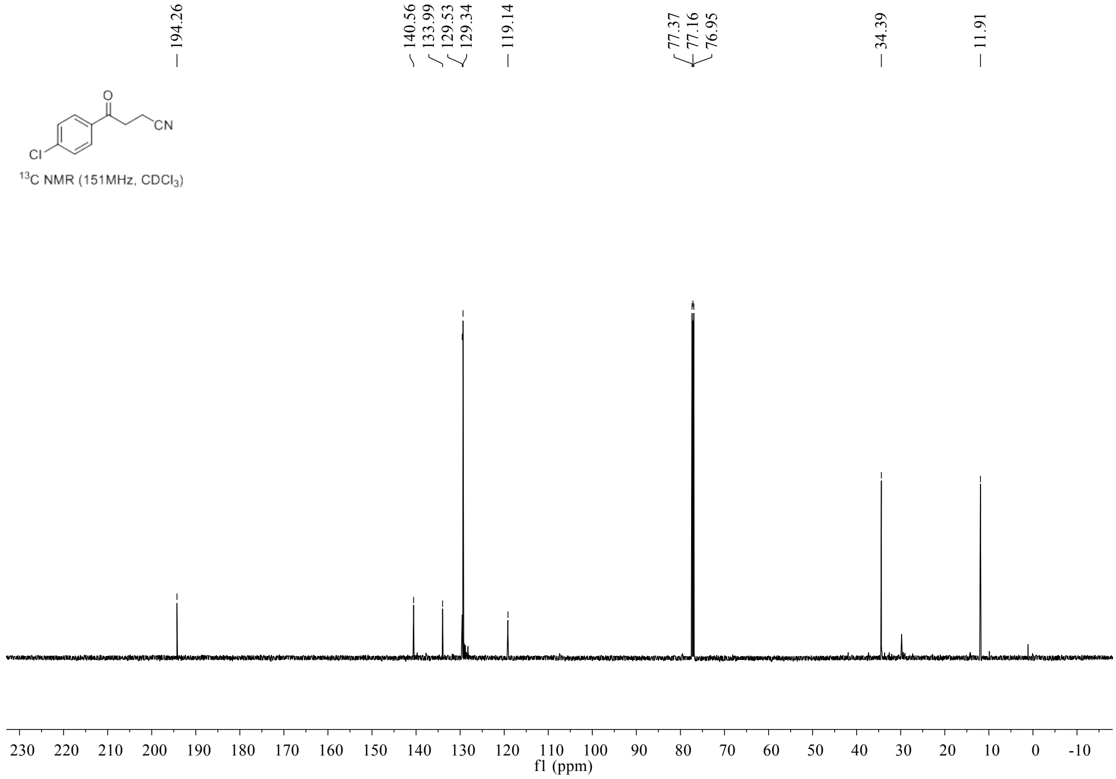




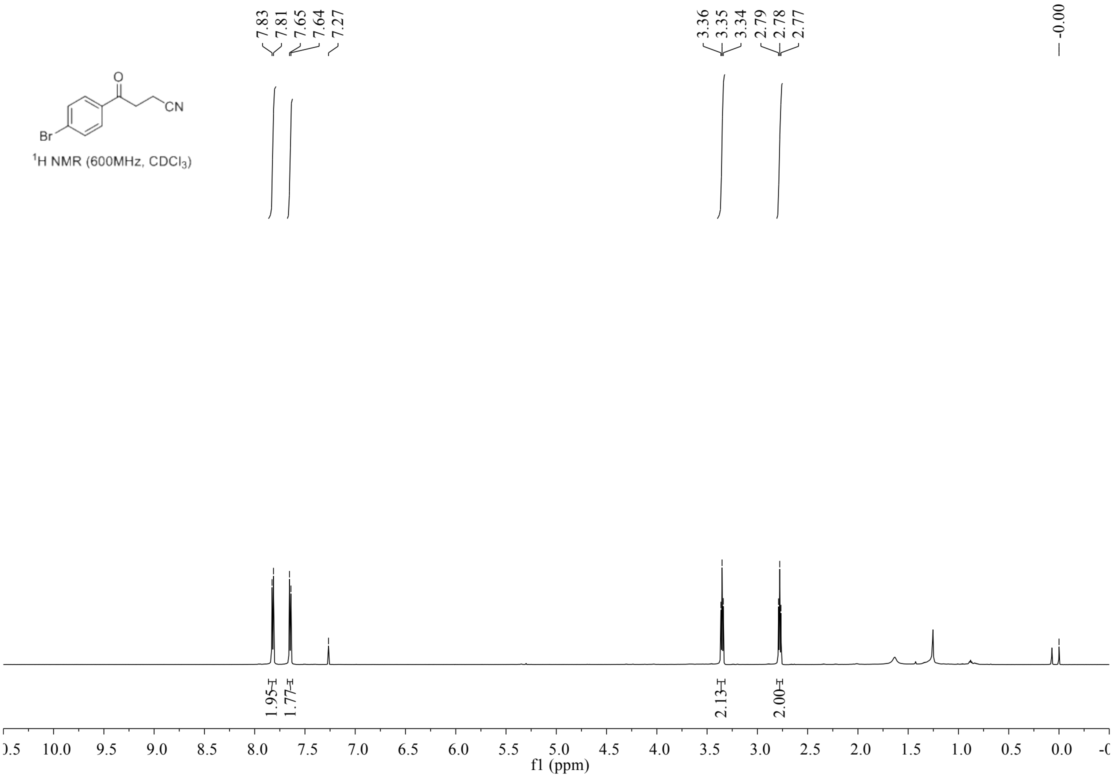
^{19}F NMR (376 MHz, $CDCl_3$)

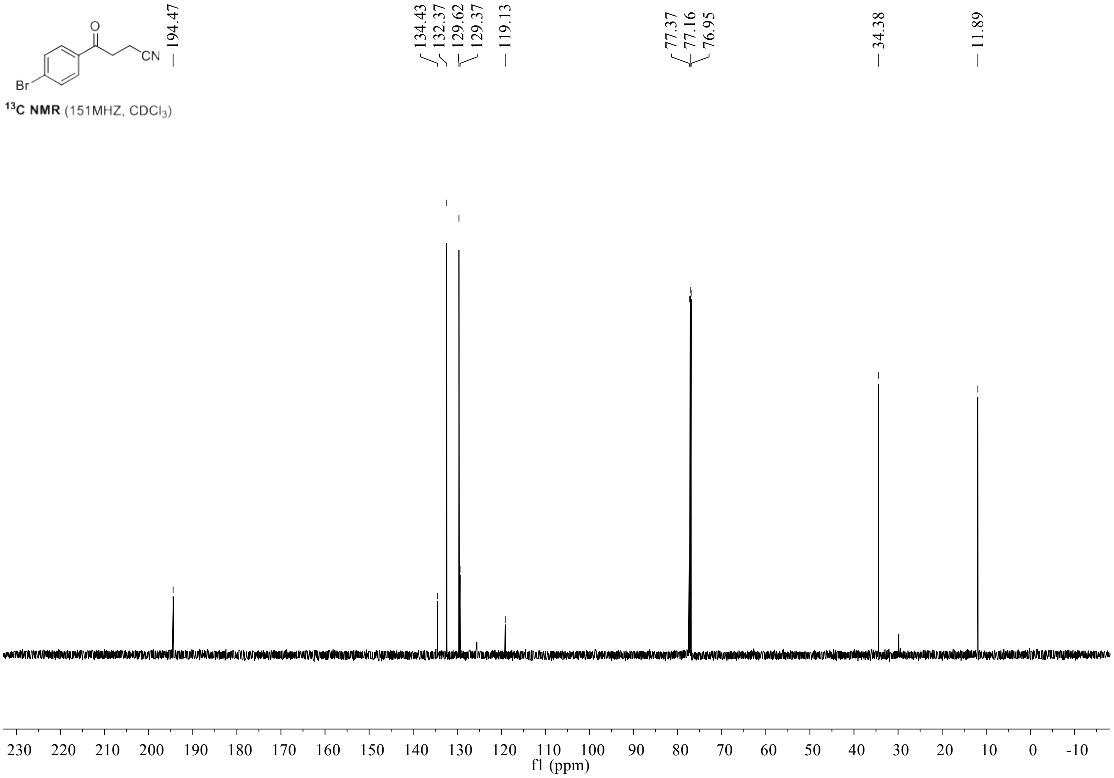
4-(4-chlorophenyl)-4-oxobutanenitrile (**3d**)



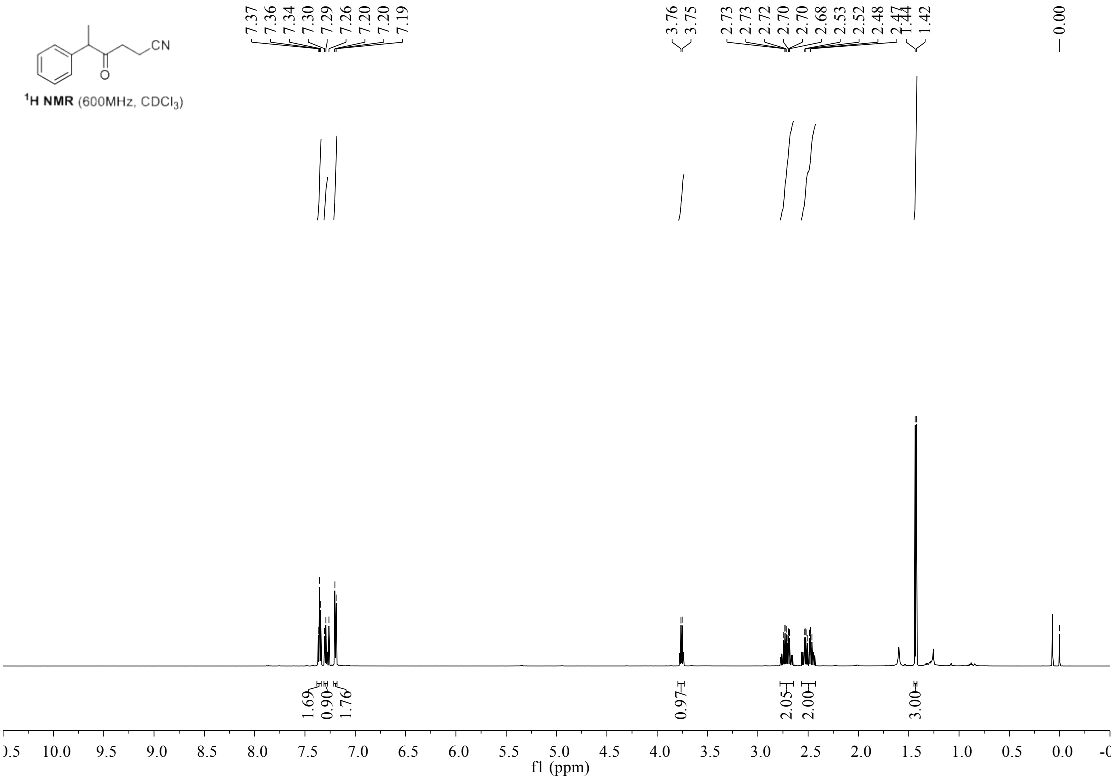


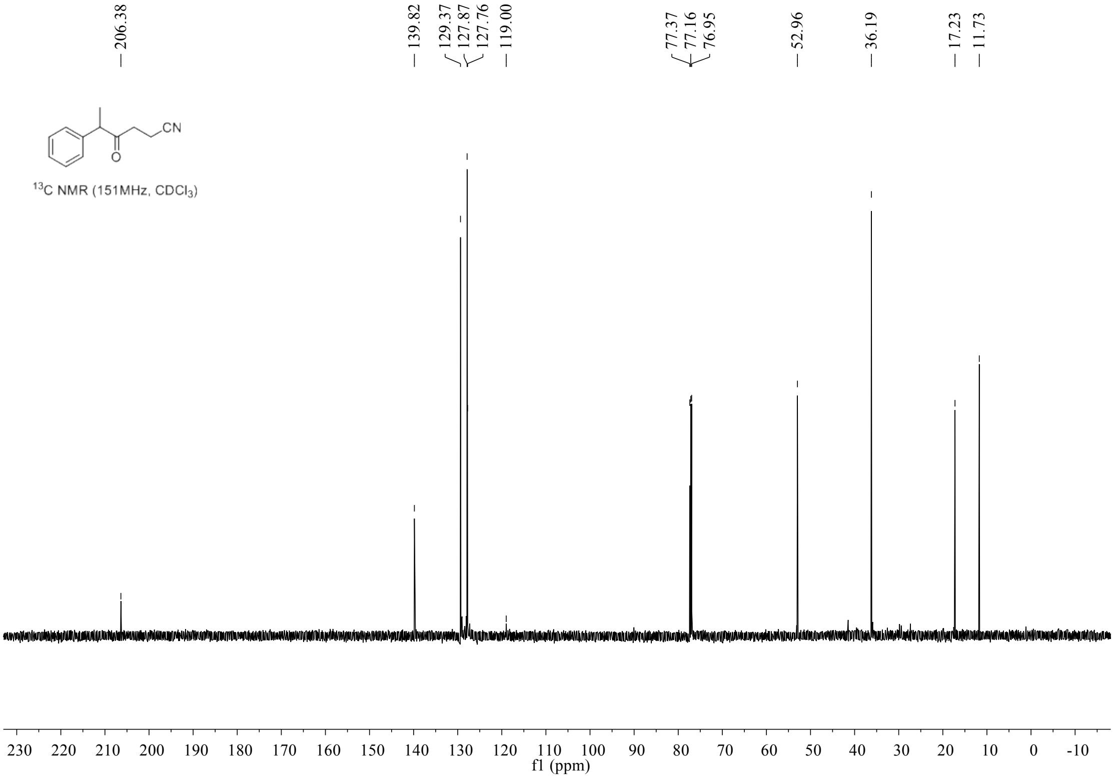
4-(4-bromophenyl)-4-oxobutanenitrile (**3e**)



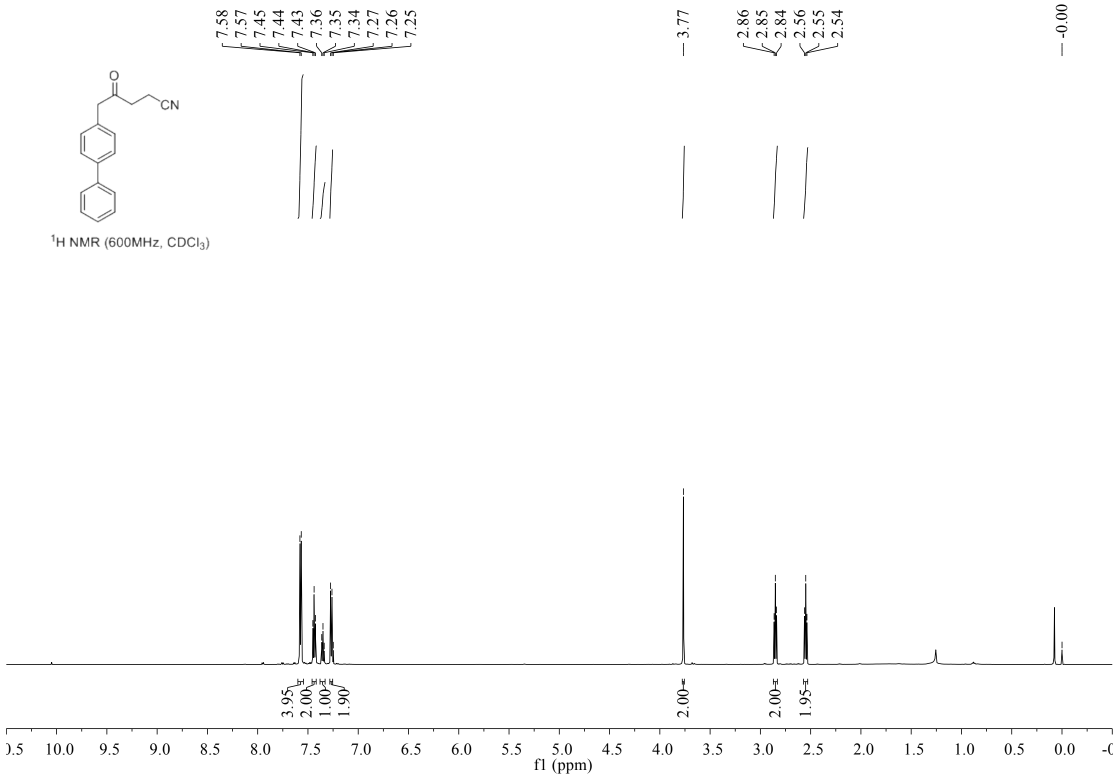


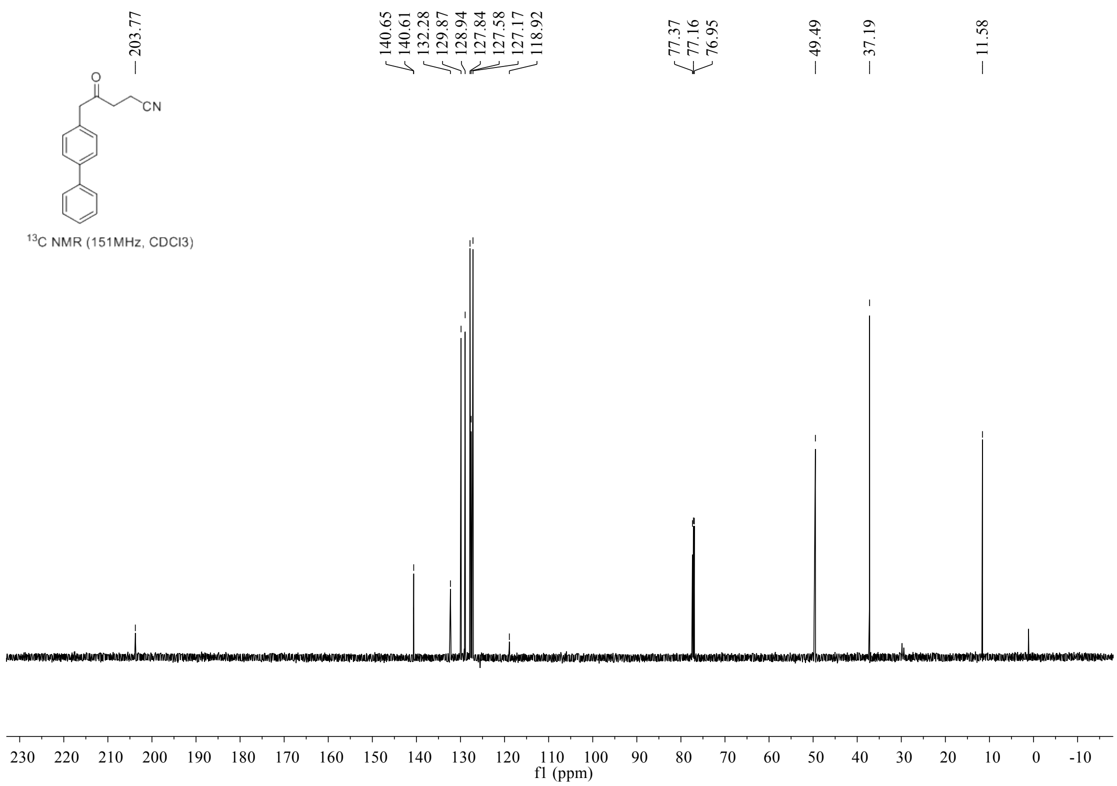
4-oxo-5-phenylhexanenitrile (**3f**)



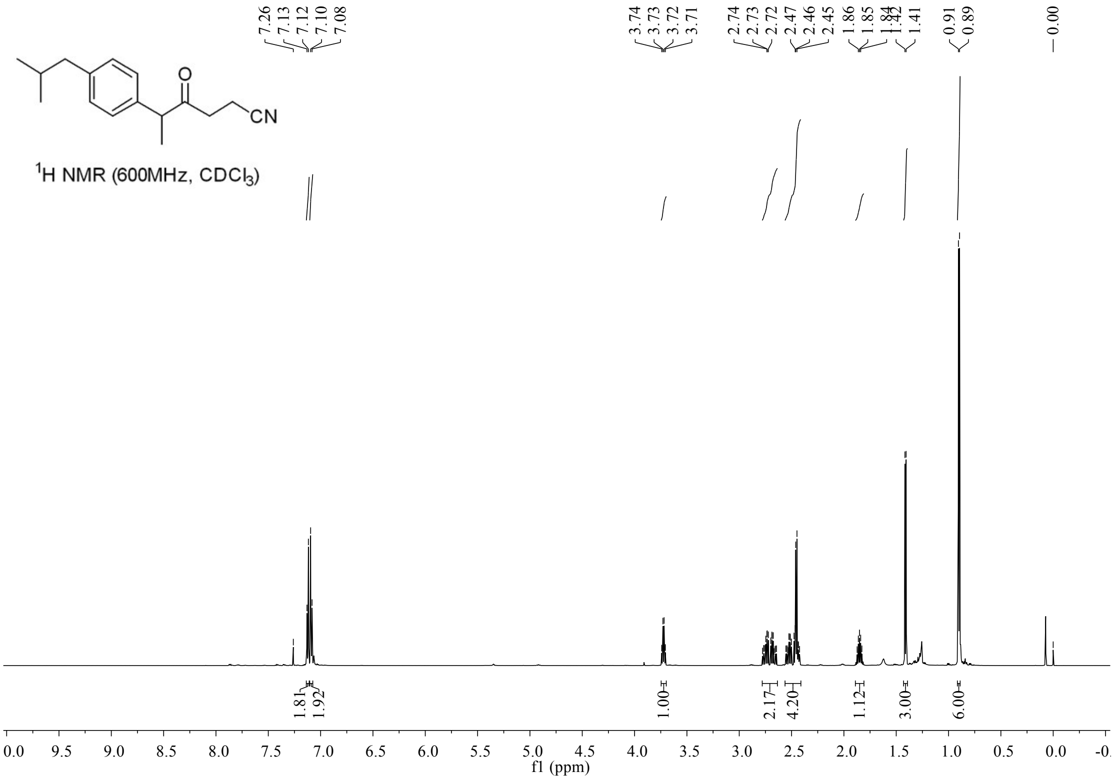


5-([1,1'-biphenyl]-4-yl)-4-oxopentanenitrile(**3g**)

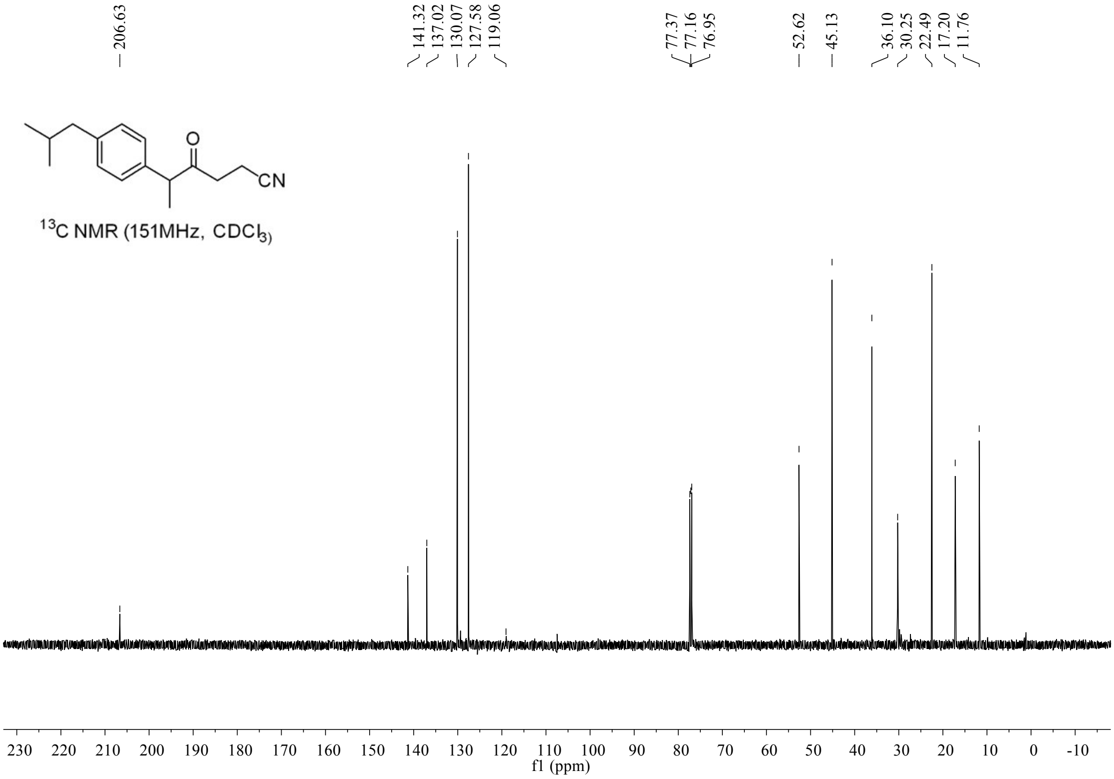




5-(4-isobutylphenyl)-4-oxohexanenitrile(**3h**)

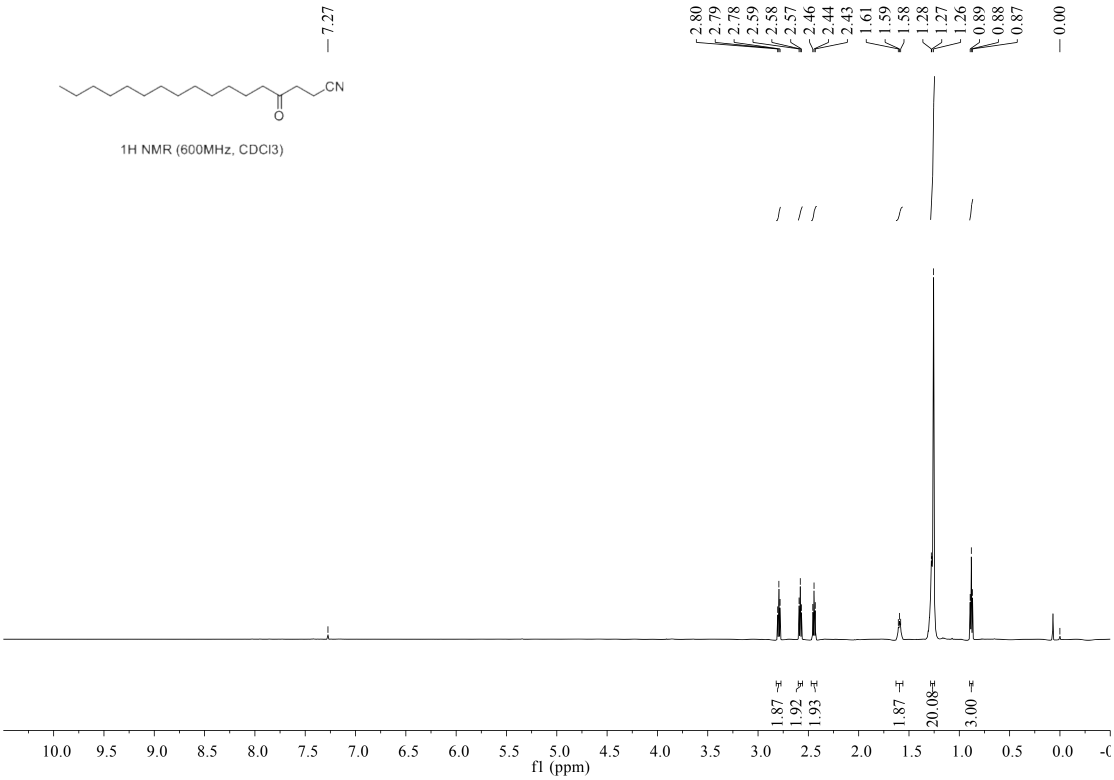


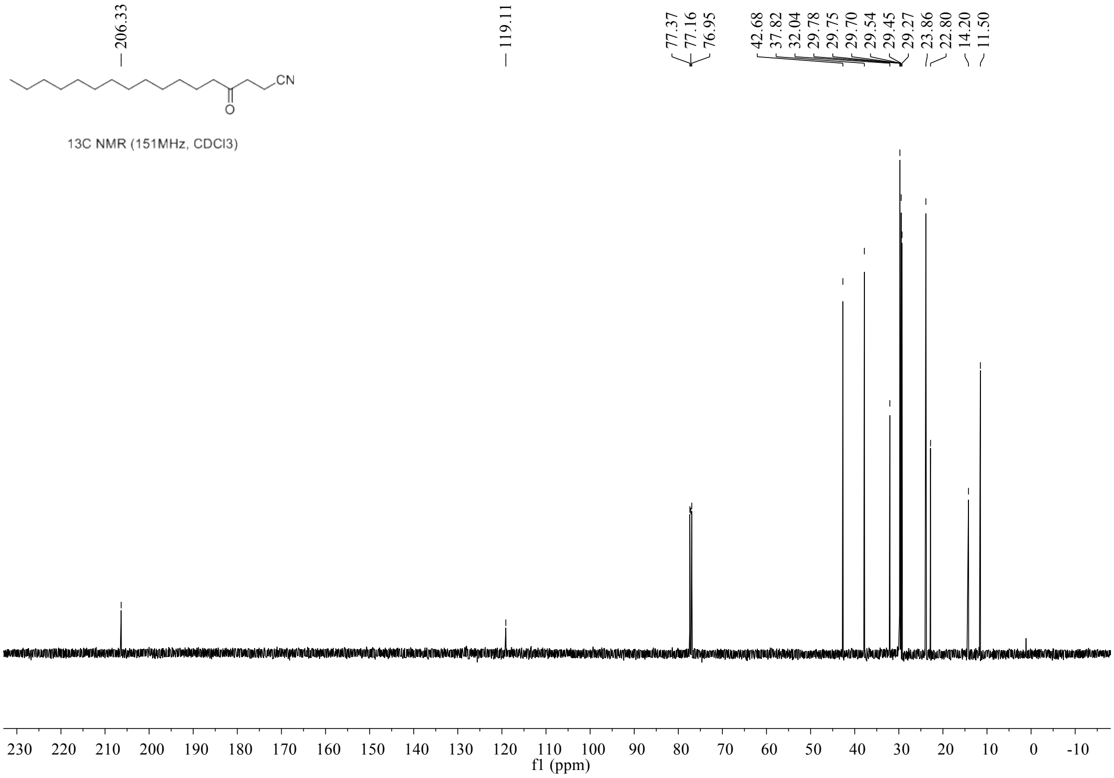
^{1}H NMR (600MHz, $CDCl_3$)



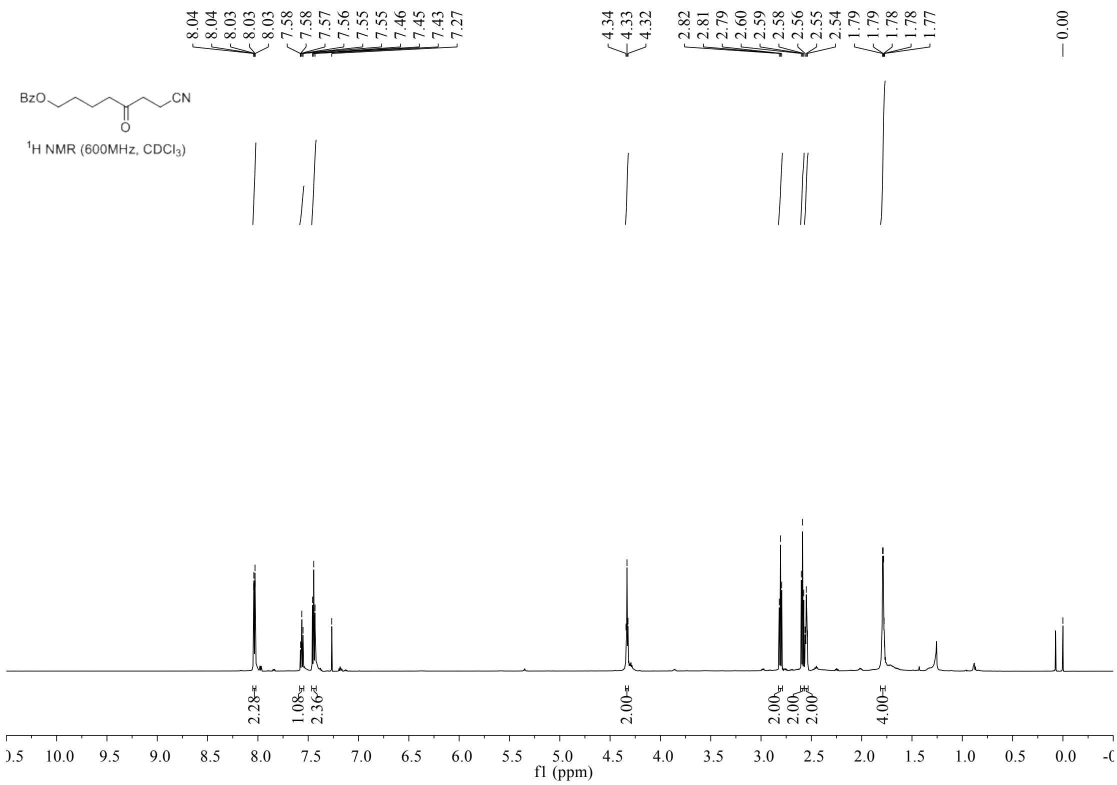
^{13}C NMR (151MHz, $CDCl_3$)

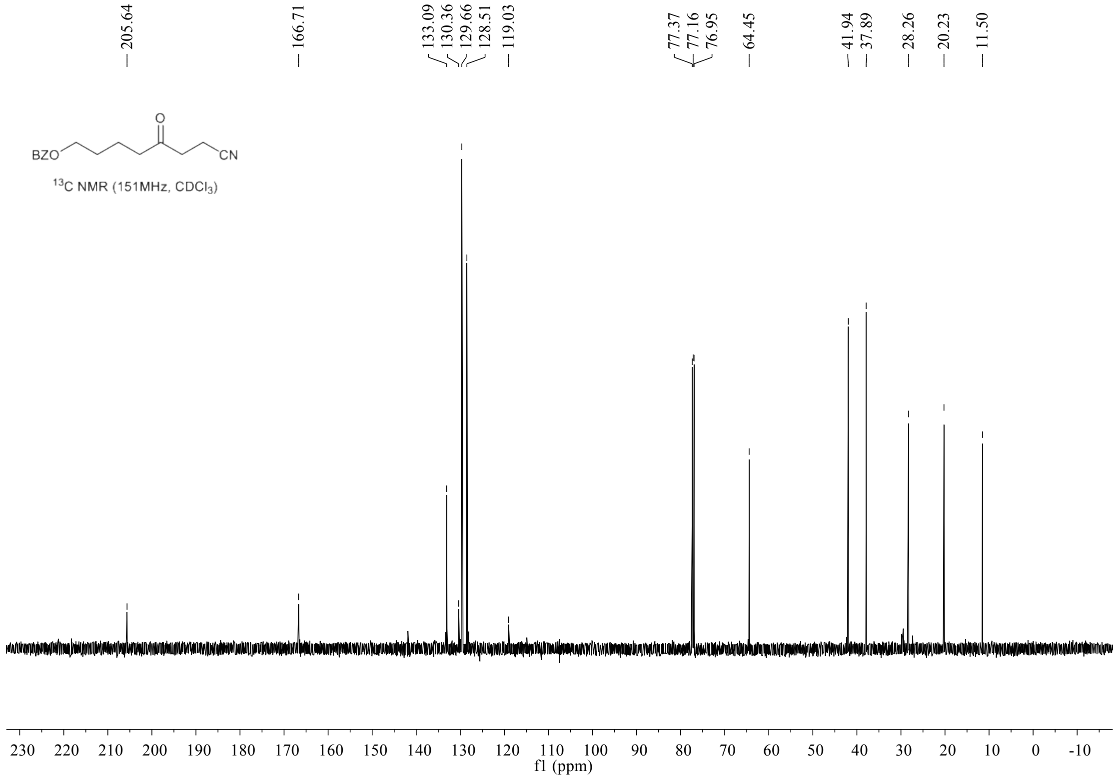
4-oxoheptadecanenitrile(**3i**)



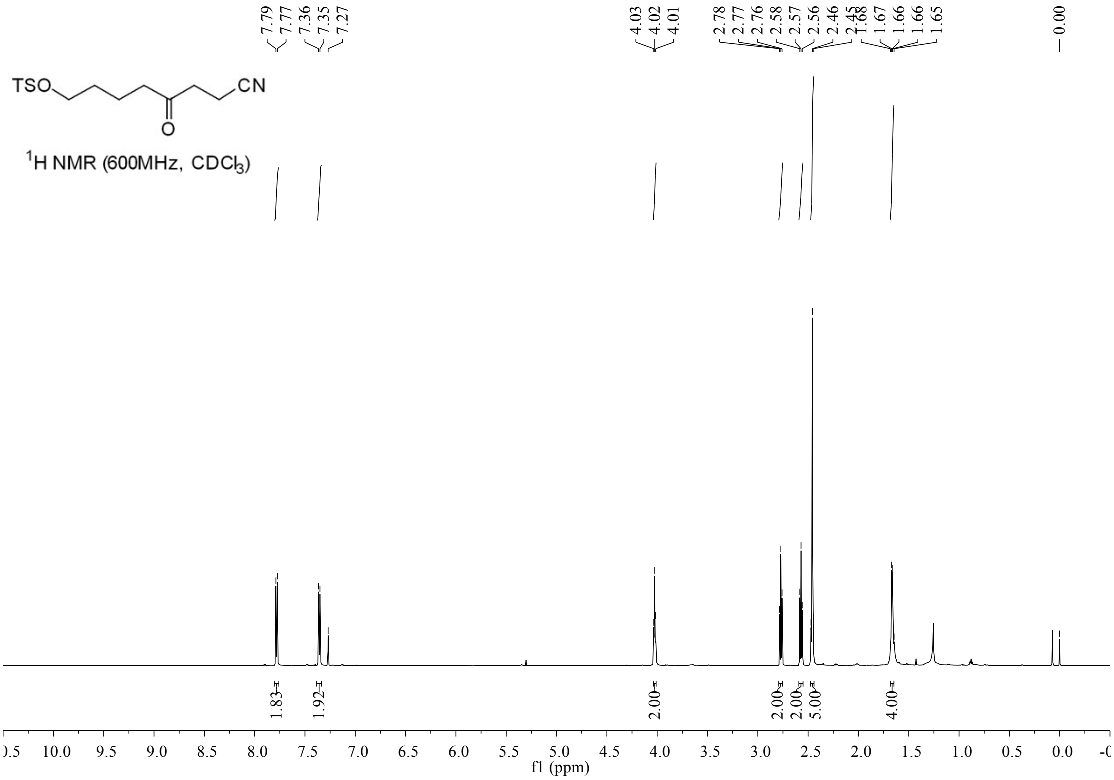


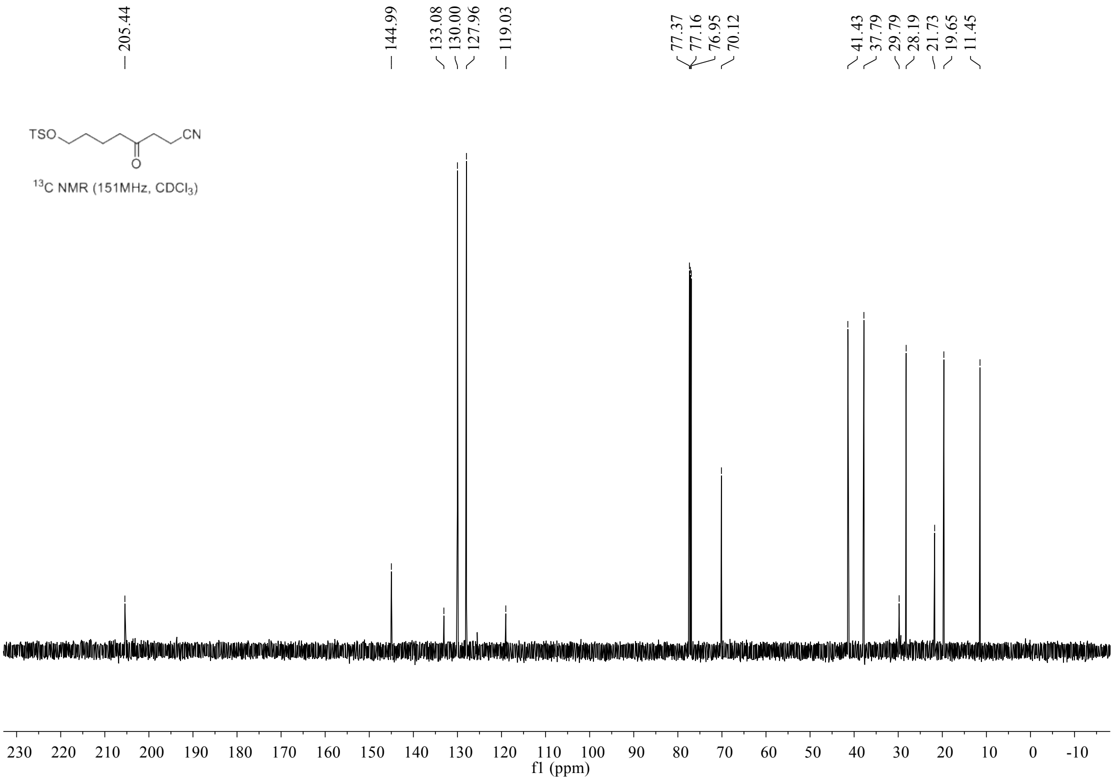
7-cyano-5-oxoheptyl benzoate(**3j**)



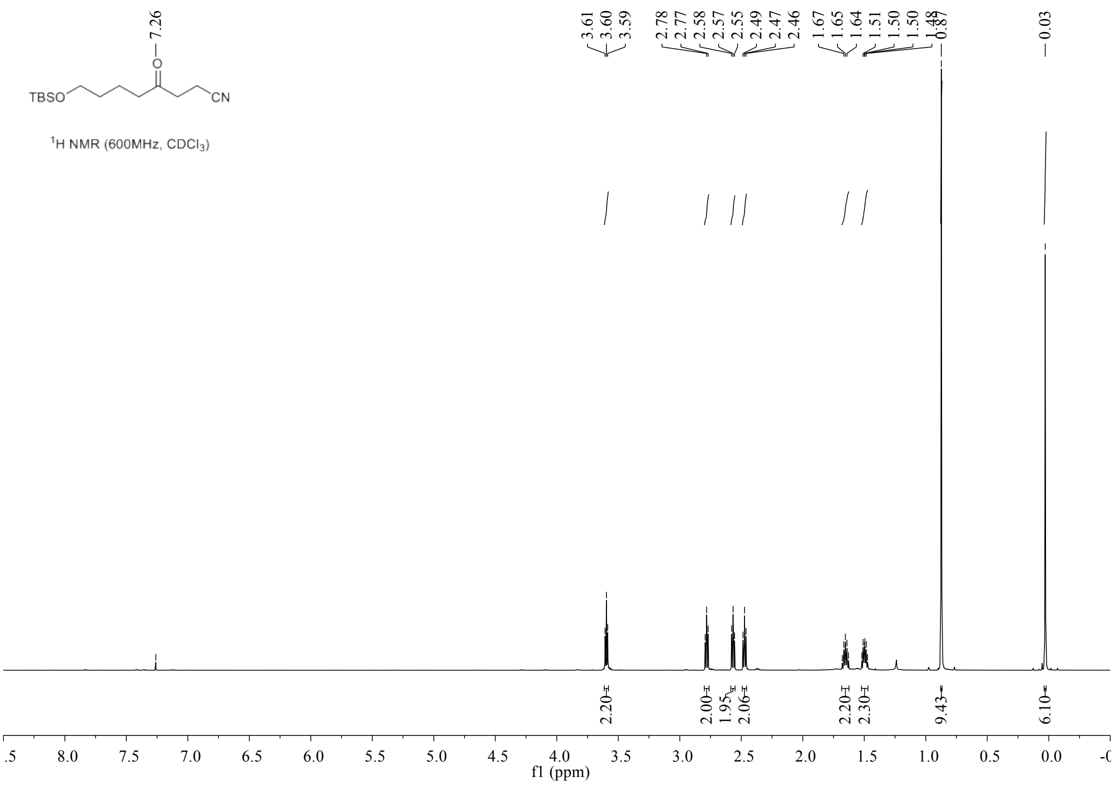


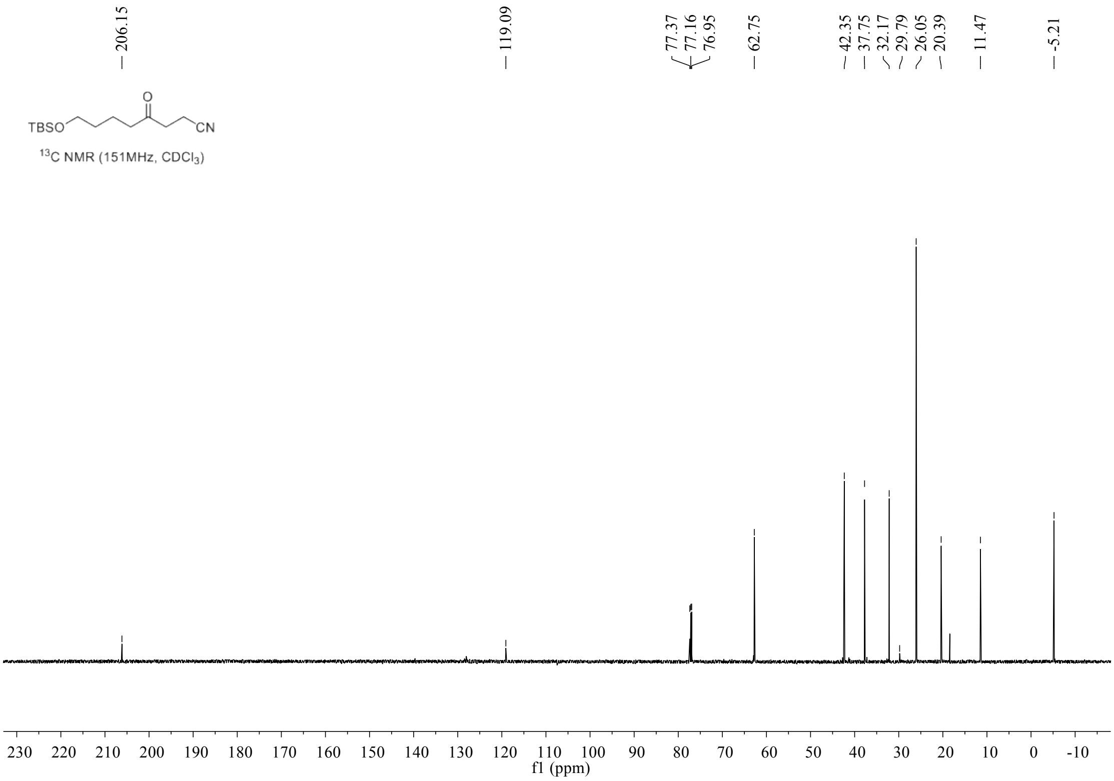
4-oxo-8-tosyloctanenitrile(**3k**)



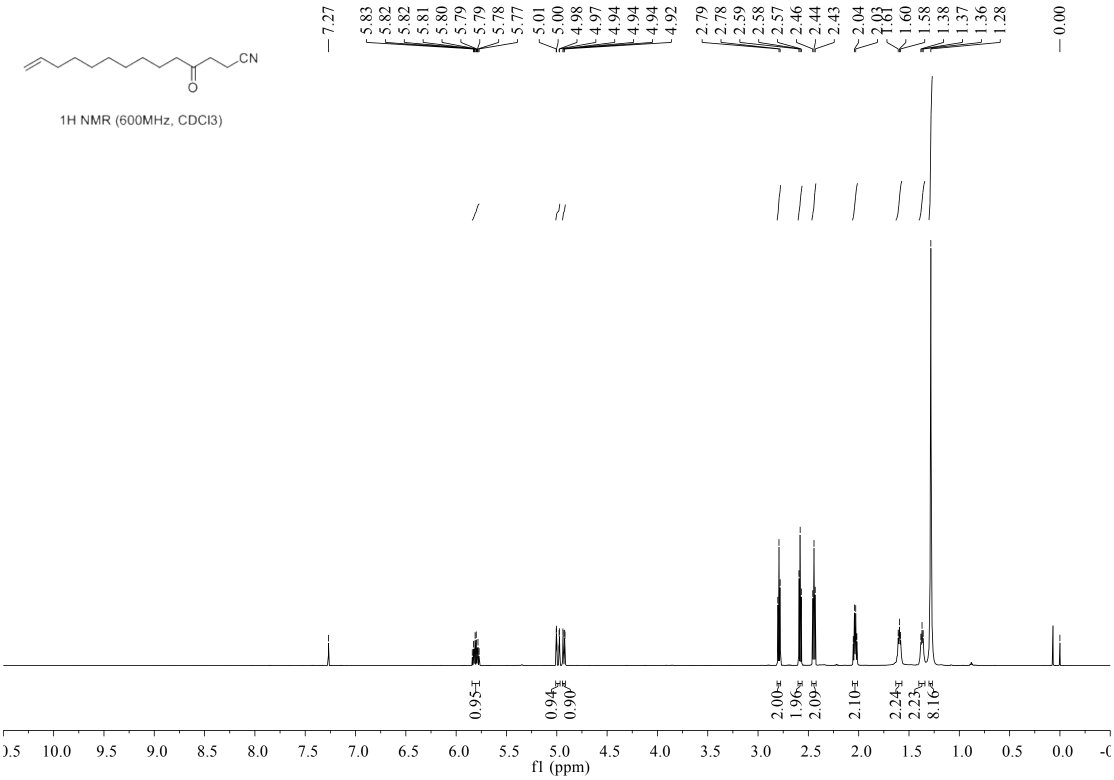


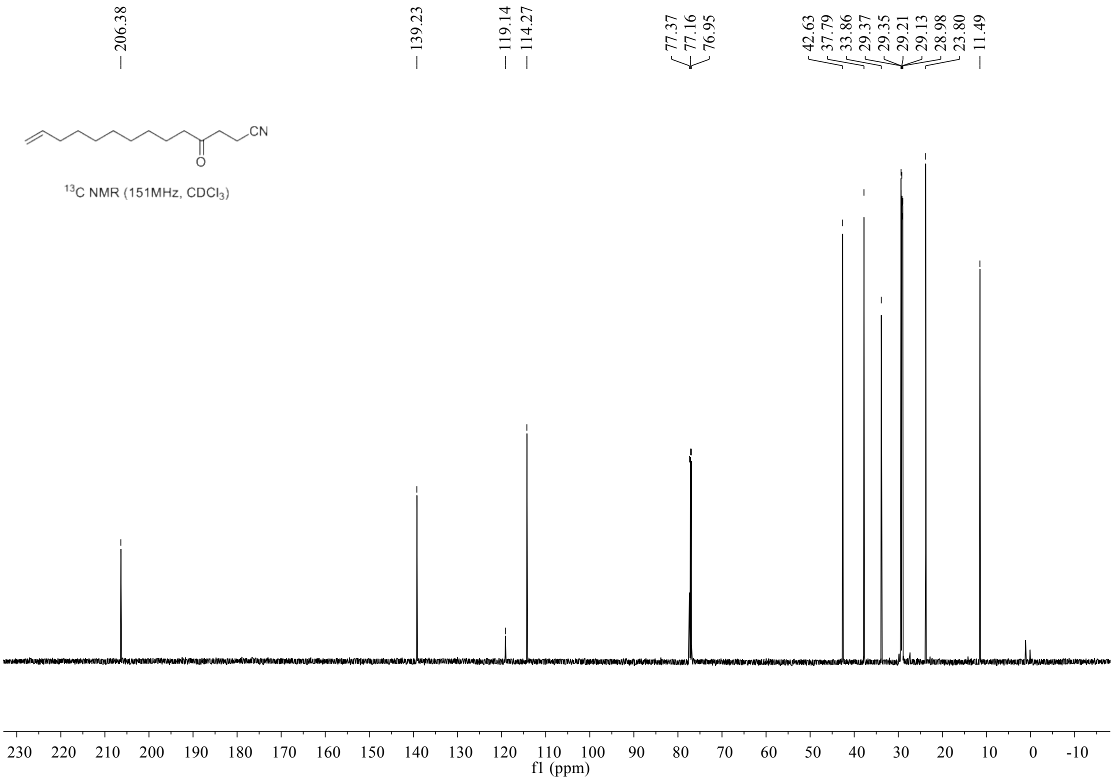
8-((tert-butyldimethylsilyl)oxy)-4-oxooctanenitrile(3l)



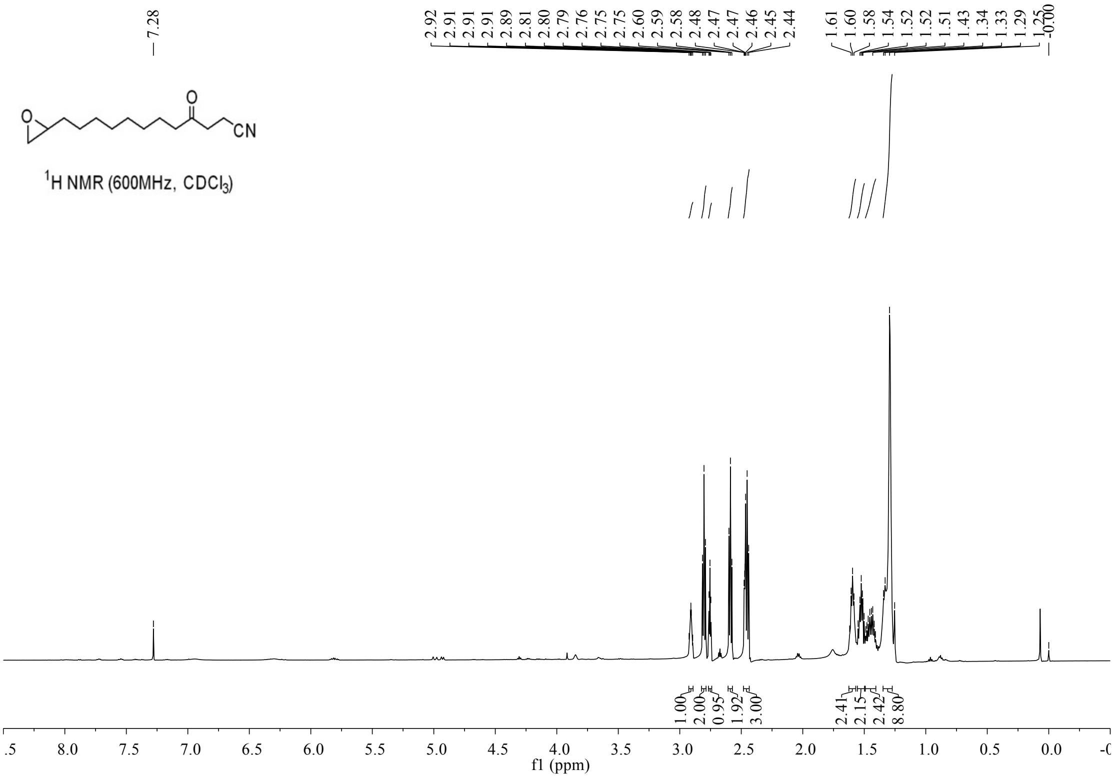


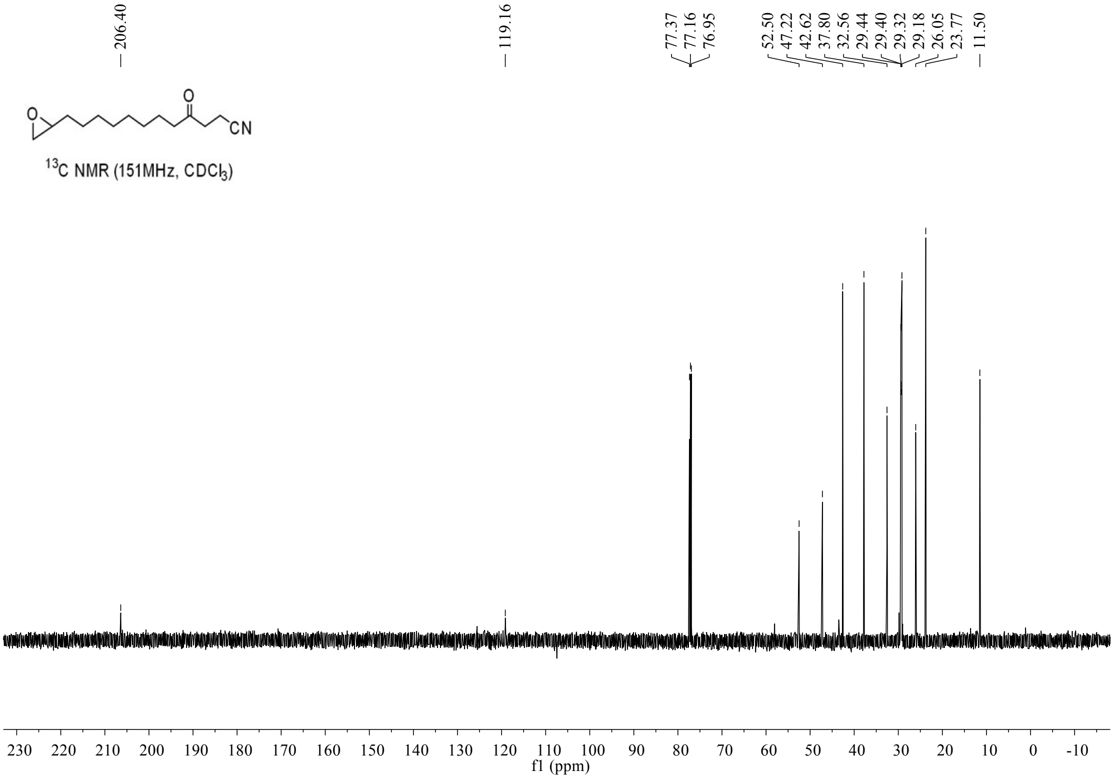
4-oxotetradec-13-enenitrile(**3m**)



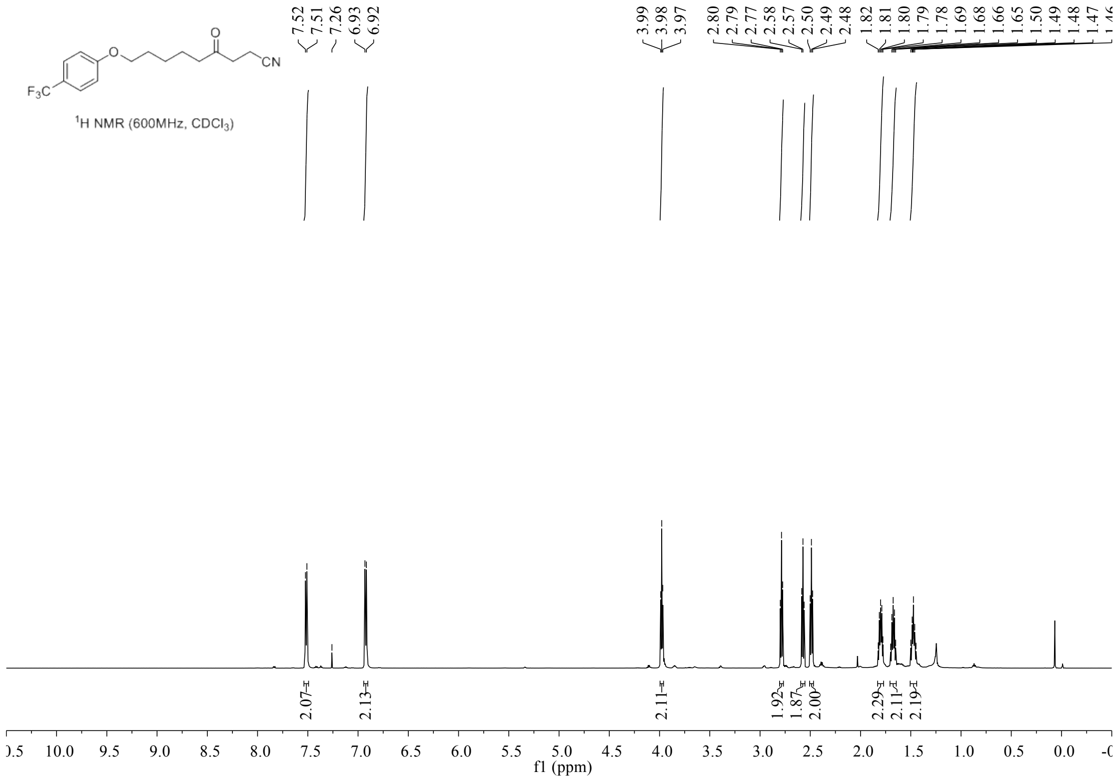


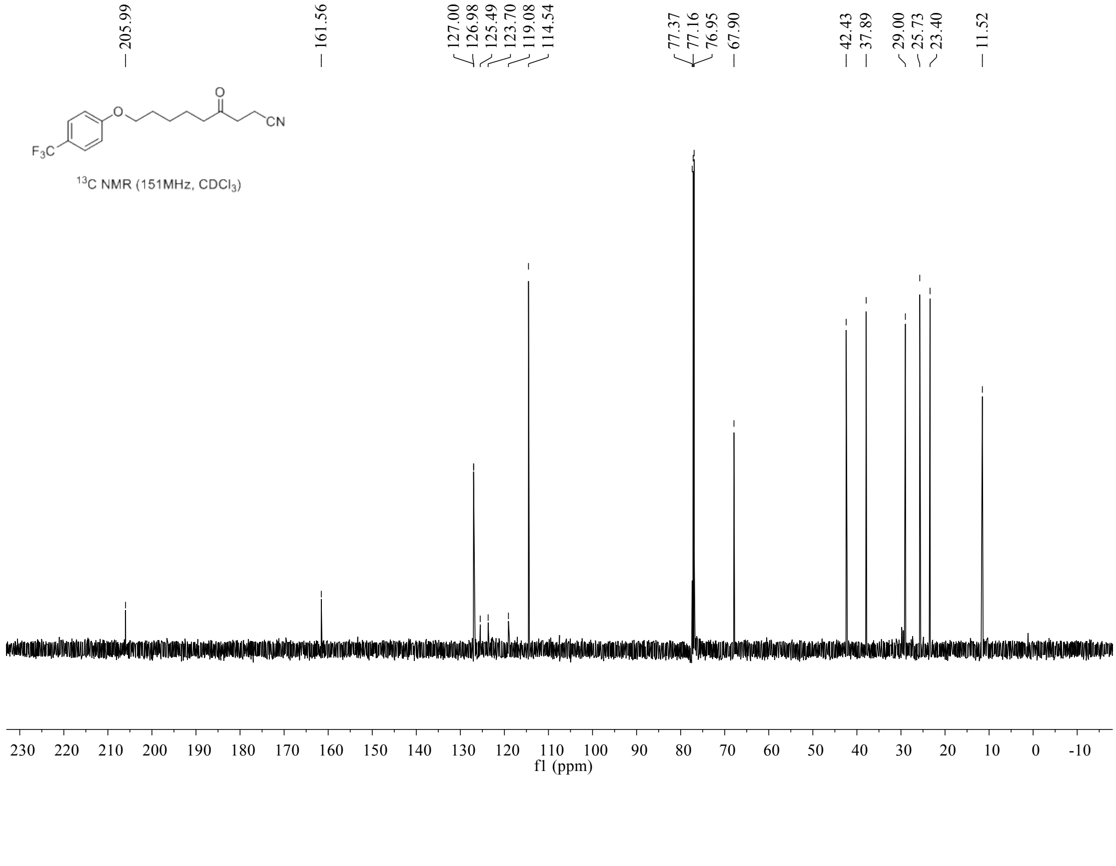
12-(oxiran-2-yl)-4-oxododecanenitrile(**3n**)

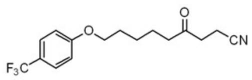




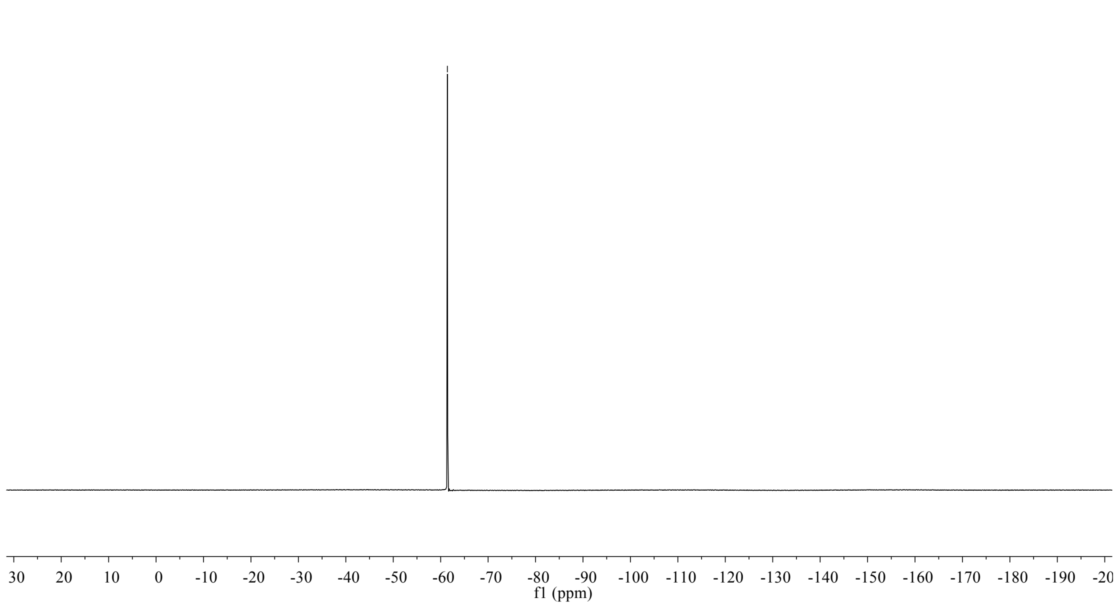
4-oxo-9-(4-(trifluoromethyl)phenoxy)nonanenitrile(**3o**)



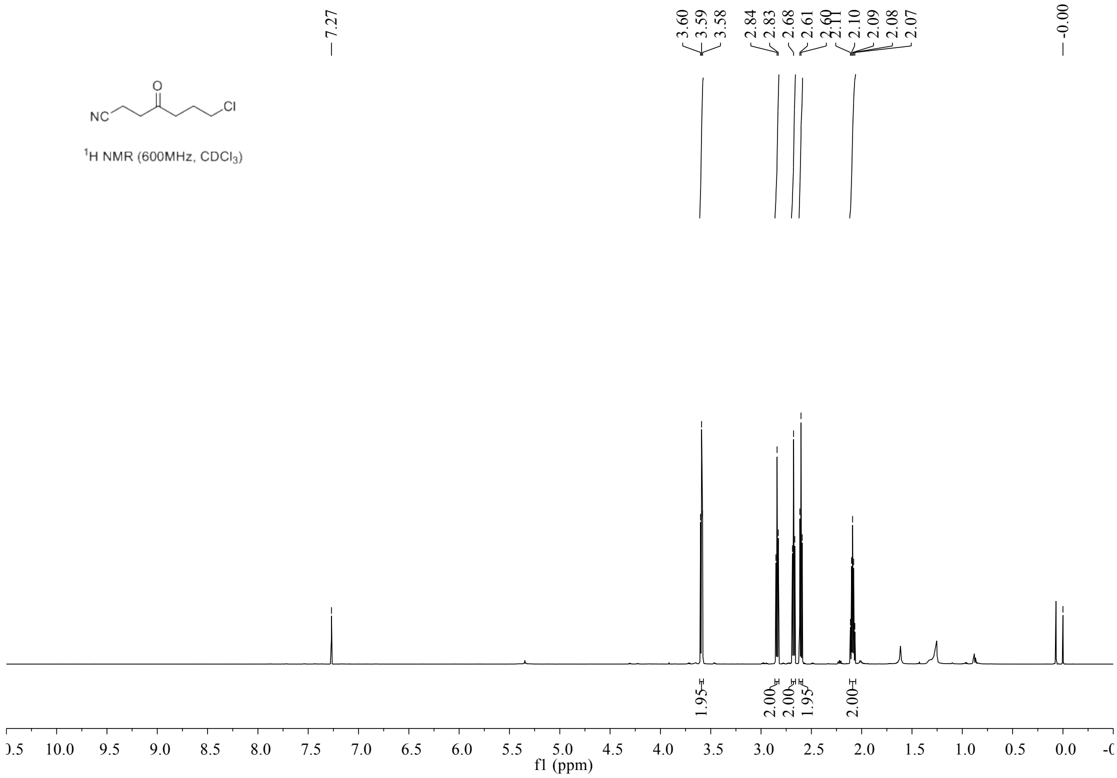


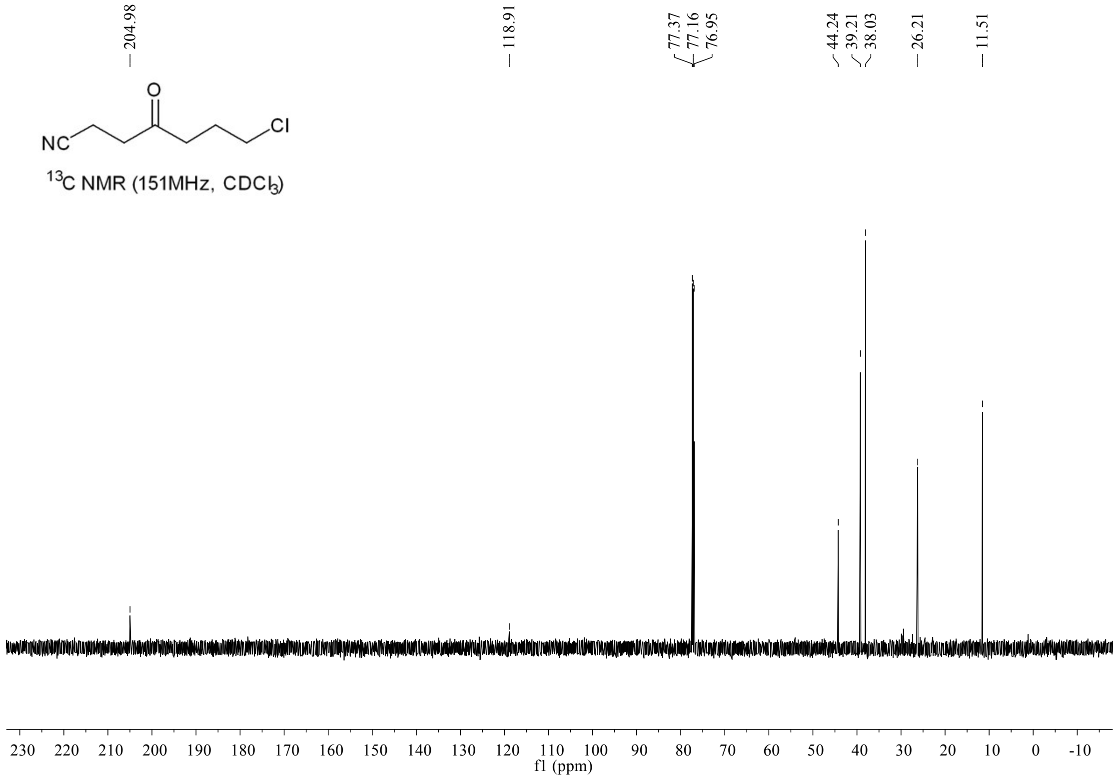


^{19}F NMR (376 MHz, $CDCl_3$)

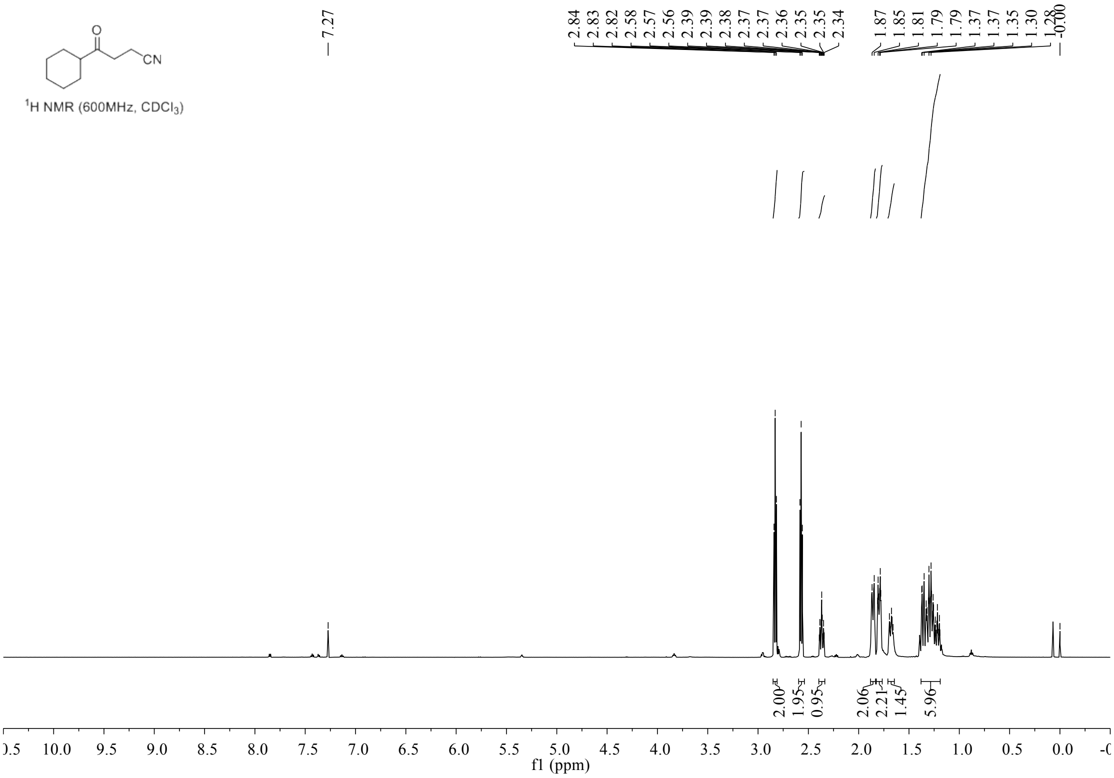


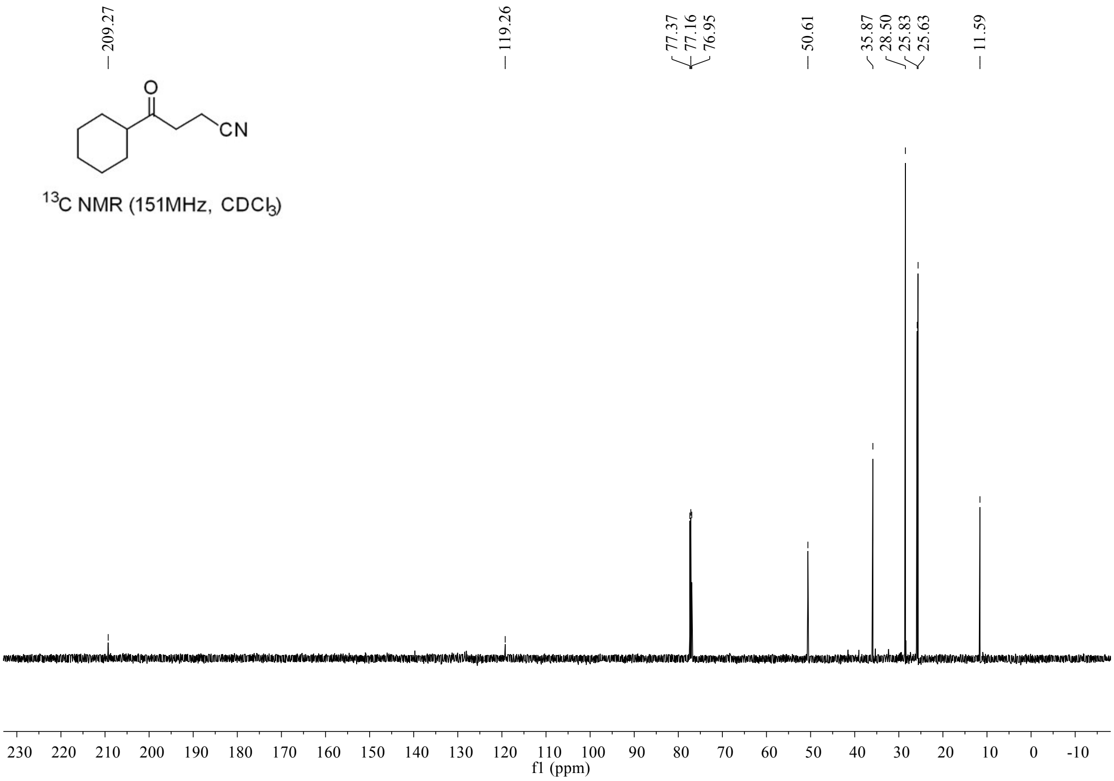
7-chloro-4-oxoheptanenitrile(**3p**)



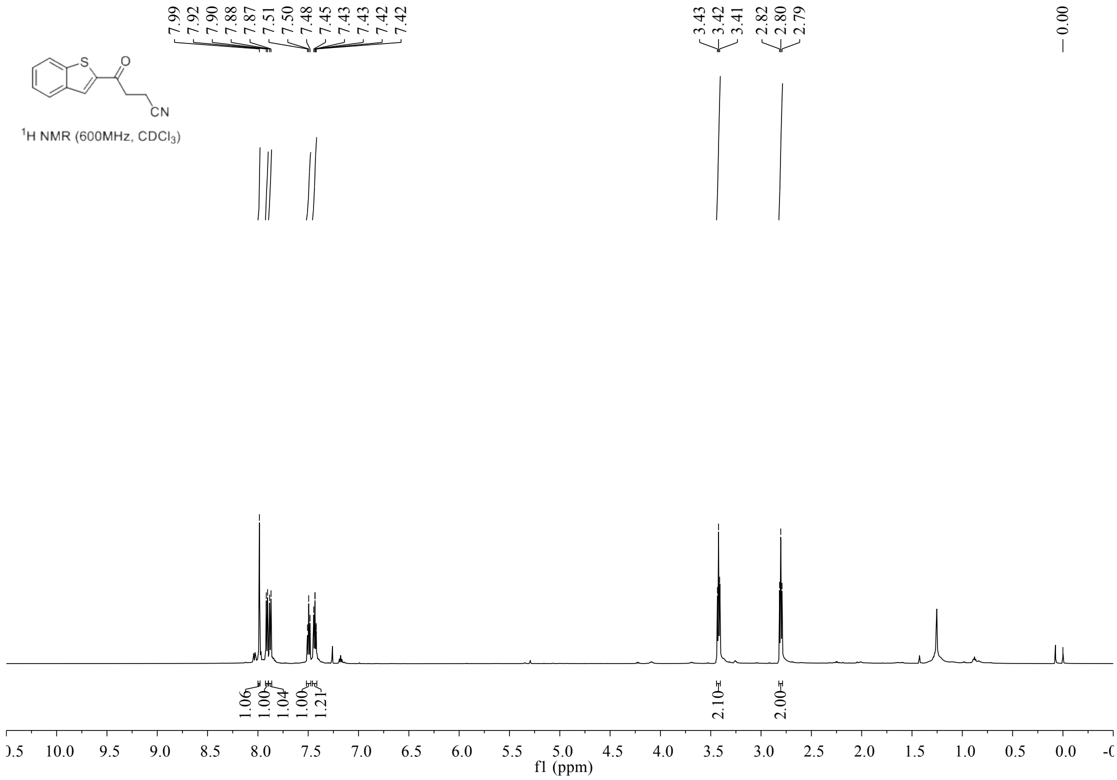


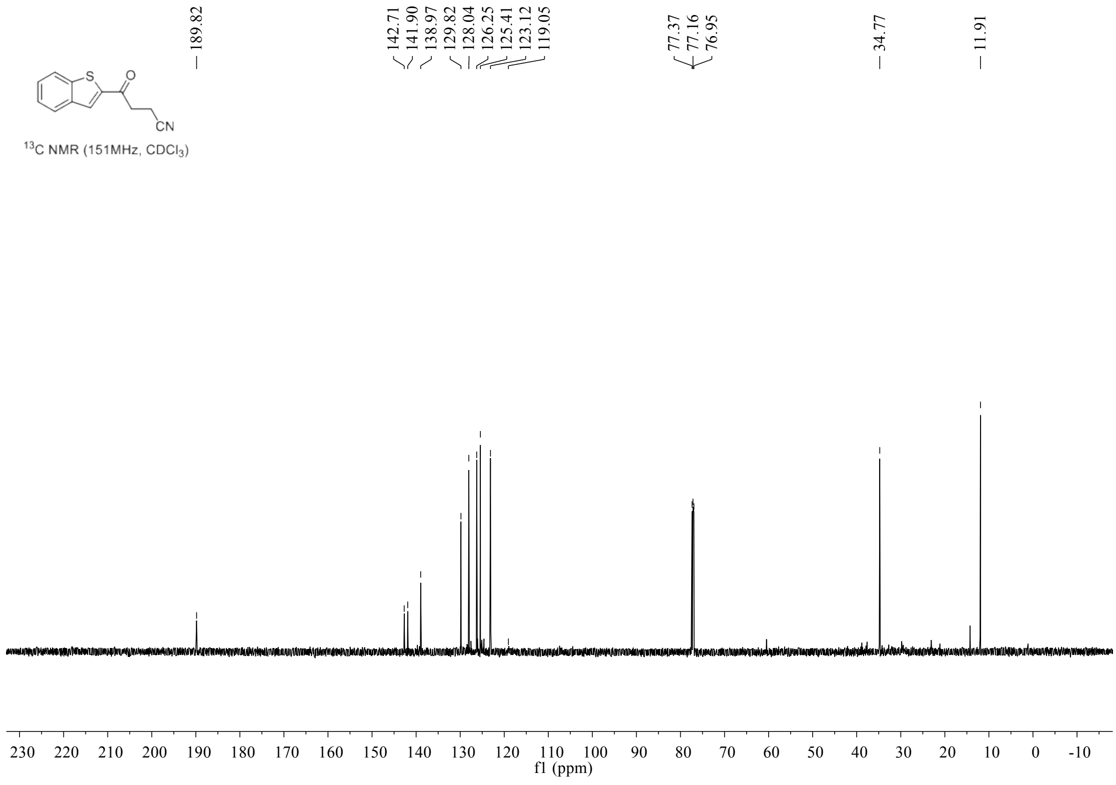
4-cyclohexyl-4-oxobutanenitrile(**3q**)



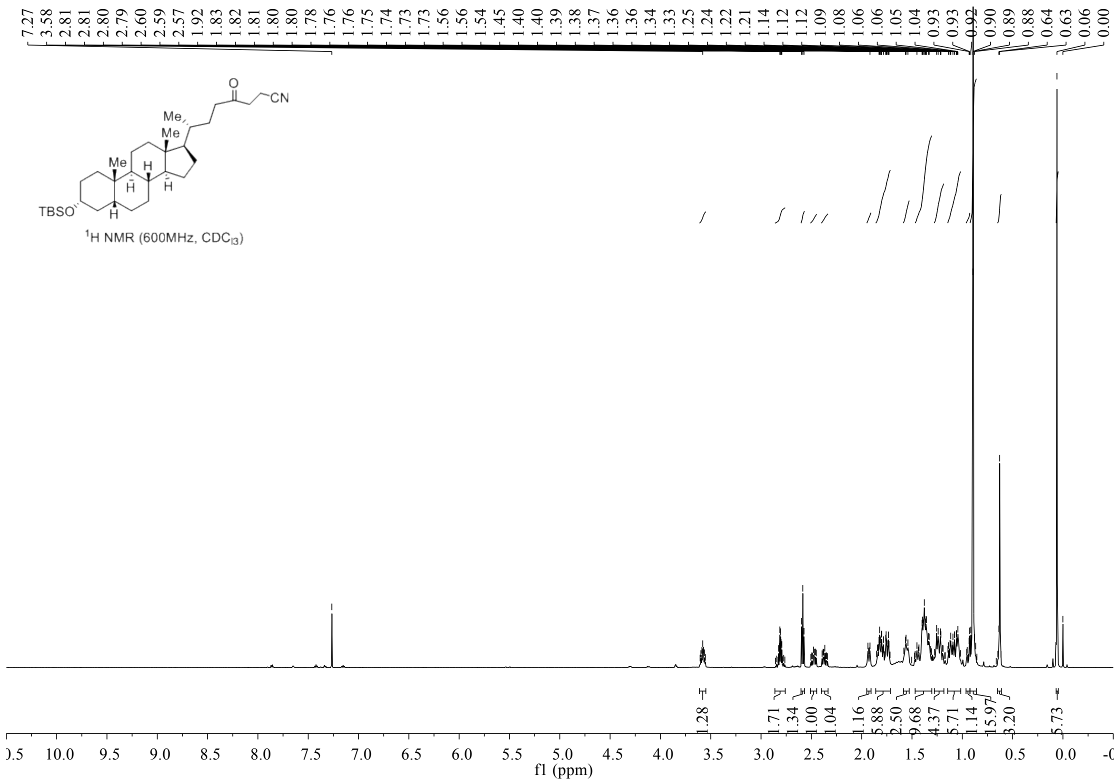


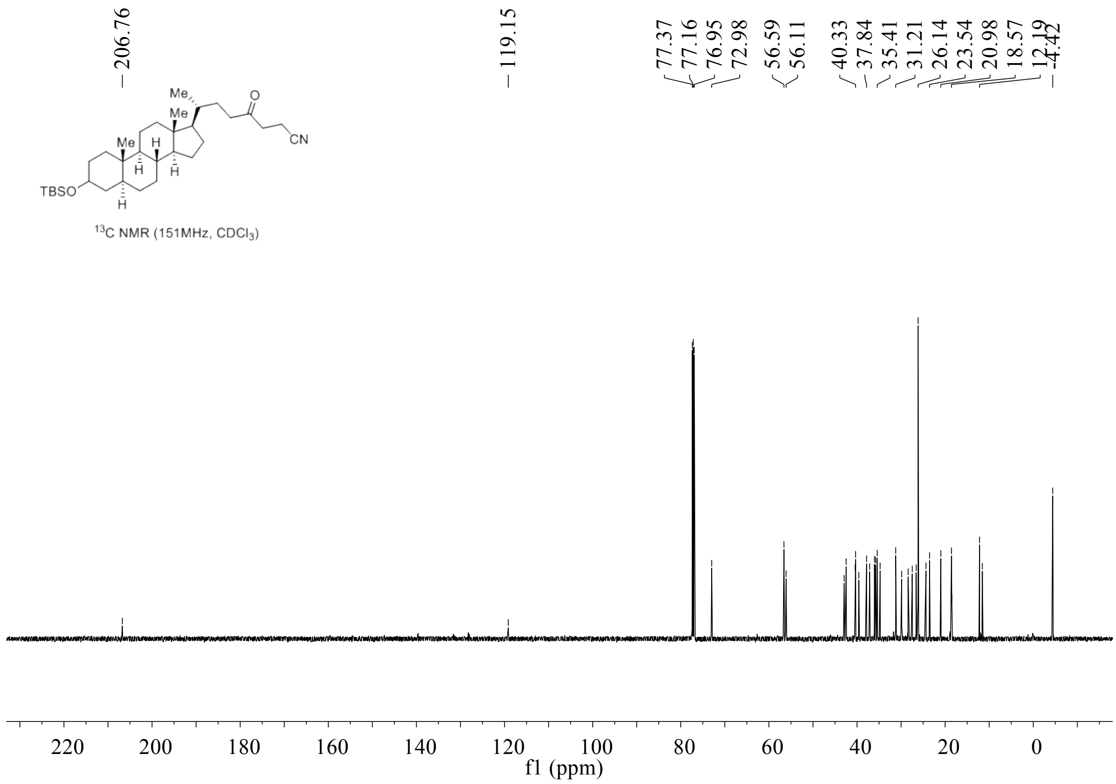
4-(benzo[b]thiophen-2-yl)-4-oxobutanenitrile(**3r**)





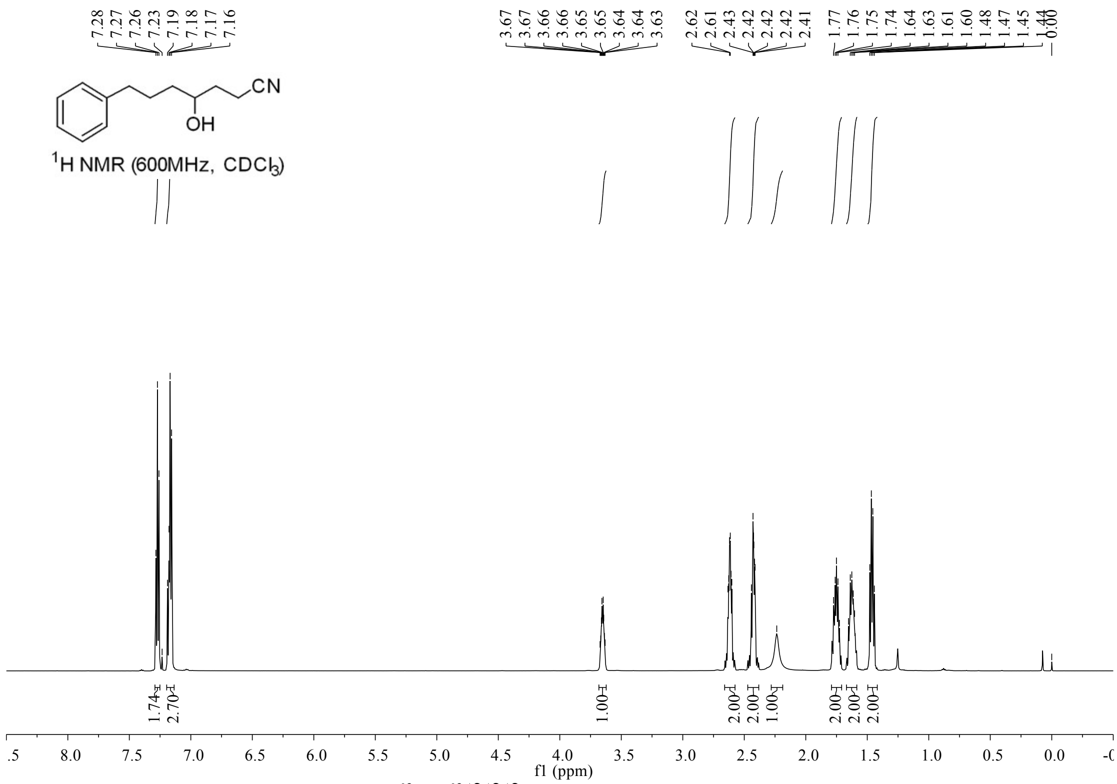
(R)-7-((3R,5S,8R,9S,10S,13R,14S,17R)-3-((tert-butyldimethylsilyl)oxy)-10,13-dimethylhexadecahydro-1H-cyclopenta[a]phenanthren-17-yl)-4-oxooctanenitrile(**3s**)

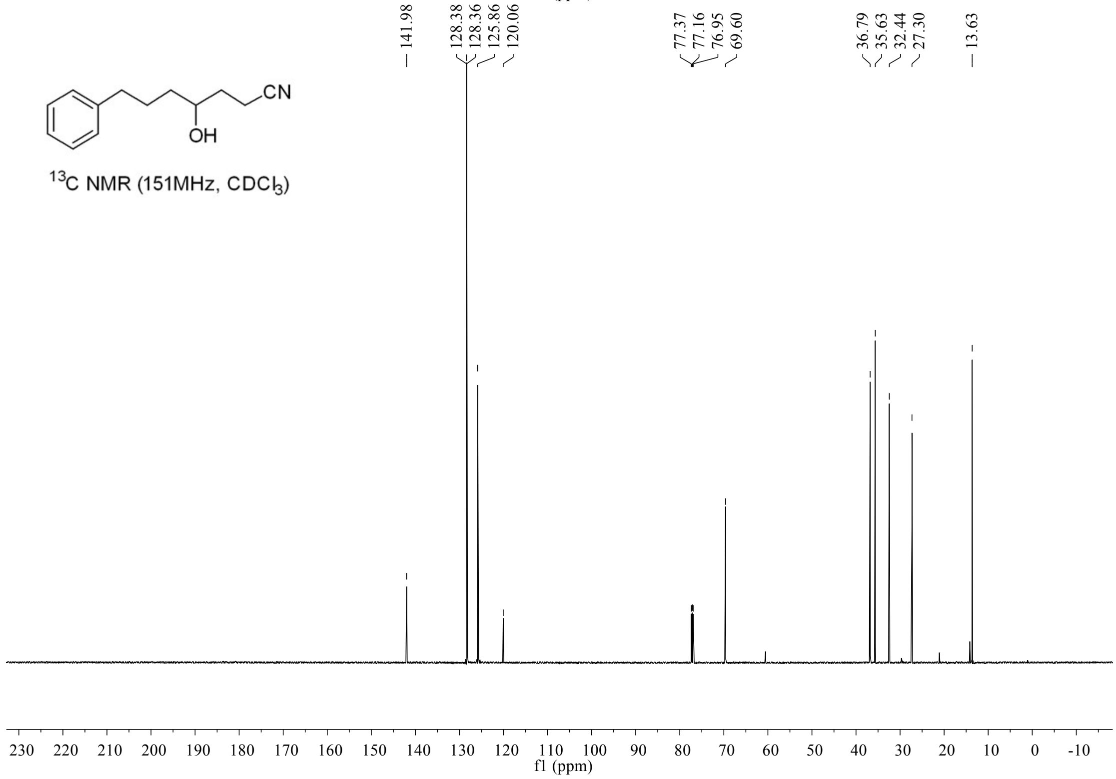




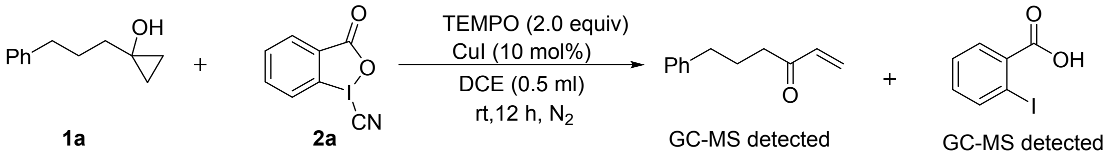
6. Functional group conversions of 3a

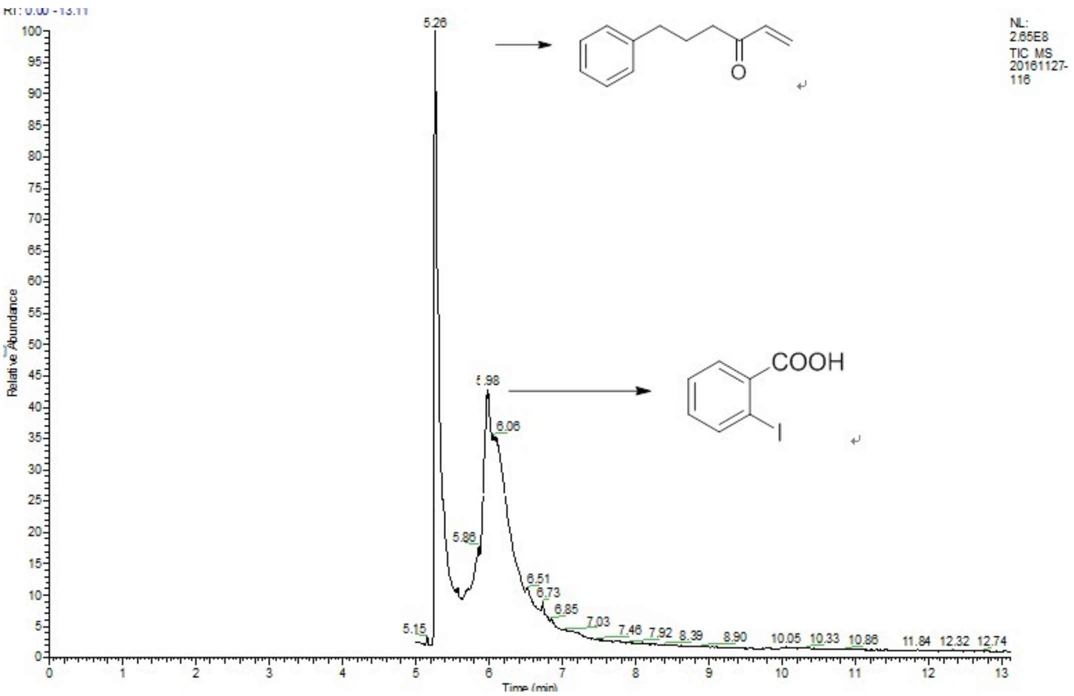
^{1}H NMR (600 MHz, CDCl3) δ 7.27 (t, J = 7.5 Hz, 2H), 7.17 (dd, J = 12.7, 7.3 Hz, 3H), 3.68 – 3.62 (m, 1H), 2.62 (td, J = 7.6, 4.0 Hz, 2H), 2.47 – 2.38 (m, 2H), 2.24 (s, 1H), 1.79 – 1.71 (m, 2H), 1.67 – 1.59 (m, 2H), 1.46 (dd, J = 14.7, 7.5 Hz, 2H). **^{13}C NMR** (151 MHz, CDCl3) δ 141.98, 128.38, 128.36, 125.86, 120.06, 69.60, 36.79, 35.63, 32.44, 27.30, 13.63.

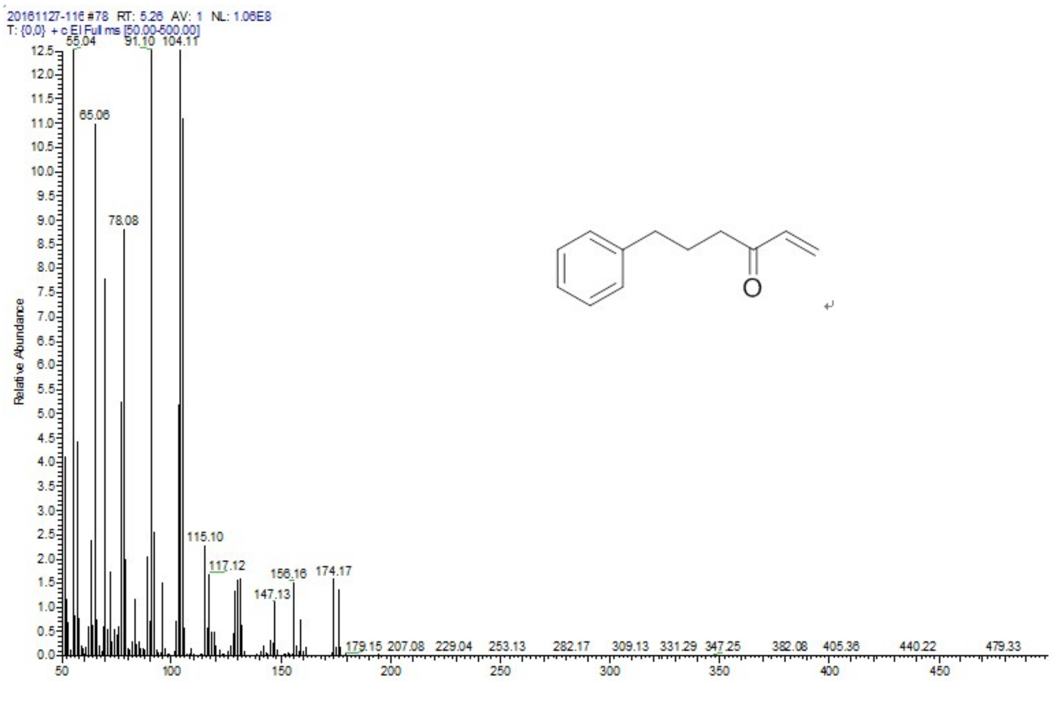


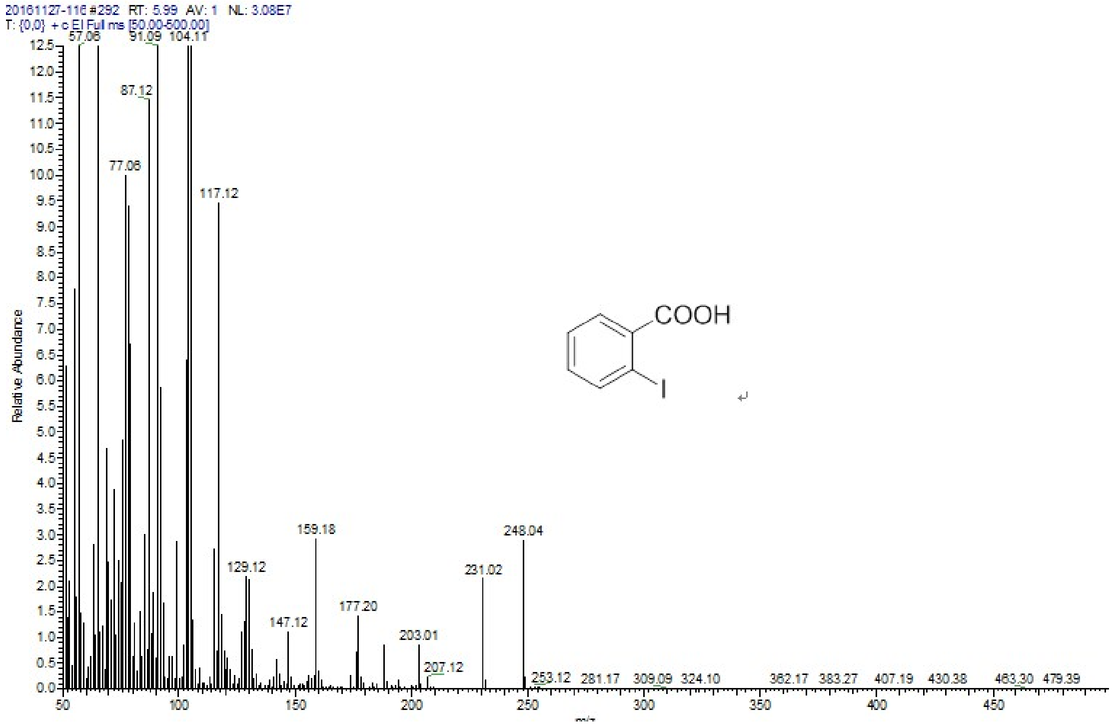


7. GC-MS Analysis of Radical-Inhibiting Experiment









8. References

1. M. Chen, Z. T. Huang and Q. Y. Zheng, *Org Biomol Chem.*, 2015, **13**, 8812.

2.(a) O. Kulinkovich and A. de Meijere, *Chem. Rev.,* 2000, **100**,2789; (b) O. Kulinkovich, Chem. Rev., 2003, **103**, 2597.

3. X. P. He, Y. J. Shu, J. J. Dai, W. M. Zhang, Y. S. Feng and H. J. Xu, *Org Biomol Chem*, 2015, **13**, 7159.

4. Y. Li, Z. Ye, T. M. Bellman, T. Chi and M. Dai, *Org Lett*, 2015, **17**, 2186.

5. R. K. Dieter, L. A. I. Silks, J. R. Fishpaugh and M. E. Kastner, *J. Am. Chem. Soc.,* 1985, **16**, 4679.