Supporting Information

For

Reduction of Nitriles into Aldehydes Using Calcium Hypophosphite and Nickel Precursor

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1. General information

All reagents were obtained from commercial sources and used as received. $CuCl_2$ (ref: 10698) and $Ca(H_2PO_2)_2$ (ref: 56168), TDA (ref: L13544) were purchased from Alfa Aesar® and the second was placed always in desiccator. $Ni(OAc)_2.4H_2O$ Assay ≥ 99.0% (KT) (ref: 72225) was purchased from Fluka. 10% Pd/C (ref: 46-1900), 10% Pt/C (ref: 78-1610), 5% Pd/C (ref: 46-1950), $[RuCl_2(p\text{-cymene})]_2$ (ref: 44-0190), $NiCp_2$ (ref: 28-1301) were purchased from Strem Chemicals. $NiBr_2$ (ref: 217891), Ni $(acac)_2$ (ref: 283657), $Ni(Ph_3P)_2Br_2$ (ref: 331708), $Ni(Ph_3P)_4$ (ref : 244996), $Ni(cod)_2$ (ref: 244988), Ni~65 wt. % on SiO_2/Al_2O_3 (ref: 208779), 2,2'-bipyridine (ref: D216305) were purchased from Sigma Aldrich. Ni(dppe)Cl_2 (Catalog no. 363230050) was purchased from ACROS. $NiCl_2$ (ref: 45850) was purchased from Laurylab.

The complete references of the used sealed tubes are: ACE pressure tubes, Ace-Thred #7, order code (*Z*564564), length (10.2 cm), body O.D. (19 mm), capacity (9 mL), pressure rating (150

PSI or 10.3 bar). The pressure tube was closed by a front seal Ace O-rings, Silicone (wall 1.78 mm, I.D. 5.3 mm) provided by Sigma Aldrich (ref: 7855-207).

Silica gel (40–63 micron) was used for column chromatography. Thin layer chromatography was performed on precoated silica gel 60–F 254 plates. UV light, 2,4-dinitrophenylhydrzine was used for analysis of the TLC plates.

All compounds were characterized by spectroscopic data. The nuclear magnetic resonance (NMR) spectra were recorded either on a Bruker ALS 300 (^{1}H: 300 MHz, ^{13}C: 75 MHz), a DRX 300 (^{1}H: 300 MHz, ^{13}C: 75 MHz) or a Bruker DRX 400 (^{1}H: 400 MHz, ^{13}C: 100 MHz) spectrometer, in $CDCl_3$ or DMSO-d_6 at 293K. Chemical shifts are reported in parts per million (ppm) and are calibrated on residual solvent peaks: $CDCl_3$ 7.16 ppm in ^{1}H and 77.16 ppm in ^{13}C, or DMSO-d_6 2.50 ppm in ^{1}H and 39.52 ppm in ^{13}C. Spin-spin coupling constants (*J)* are given in Hz. The peak patterns are indicated as follows: (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet, and br. for broad).

GC-MS analyses were performed on a DSQ - Thermofinnigan spectrometer equipped with quadrupole analyzer and a DB-5MS capillary column (30.0 m × 0.25mm × 0.25µm). The carrier gas was helium, at a flow rate of 1 mL/min. Column temperature was initially 70 °C for 2 min, then gradually increased to 310 °C at 15 °C/min and finally kept at 310 °C for 10 min. The injector temperature was 220 °C and the transfer line temperature was 280 °C.

GC analyses were performed on a Shimadzu Gas Chromatograph GC-2025 equipped with a ZB-5-MS column (30.0 m × 0.25mm × 0.25µm). The carrier gas was N_2 at a flow rate of 1.27 mL/min. Column temperature was initially 70 °C for 2 min, then gradually increased to 280 °C at 15 °C/min and finally kept at 280 °C for 15 min. The injector temperature was 250 °C and for detection a FID was used at 280 °C.

2. General procedure

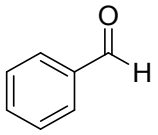
Procedure for the reduction of nitrile into aldehyde

In a sealed tube, Nickel(II)acetate tetrahydrate (49.7 mg, 0.2 mmol, 20 mol%) was introduced followed by water (1 mL, [$Ca(H_2PO_2)_2$]= 1M), the tube was stirred at room temperature. Calcium hypophosphite (170 mg, 1 mmol) was then added followed by calcium acetate monohydrate (70.4 mg, 0.4 mmol, 40 mol%). To this mixture was added the nitrile substrate (1 mmol) and ethanol absolute (1 mL, [nitrile] in ethanol= 1M), the tube was then sealed. The reaction mixture was stirred at 920 rpm and heated at 100°C. After the sufficient time for each substrate, the tube was cooled at room temperature, depressurized and an aliquot was taken and extracted with water and methylene chloride, diethyl ether or pentane for GC analysis to check the conversion of the starting material. The reaction mixture was then diluted by excess of water to remove ethanol and extracted with pentane, diethyleher or methylene chloride. The combined organic extracts were dried with Na_2SO_4, filtered and concentrated under reduced pressure (800 mbar). After concentration, aldehydes were obtained as oils or solids. If needed a flash chromatography column was done on silica gel by using gradient of different solvents according to the final product.

The conversion of the nitrile was determined by GC corresponding to 100-(the area of nitrile peak)

The products were characterized by NMR spectroscopy.

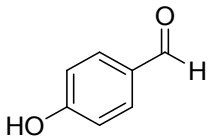
3. Characterization



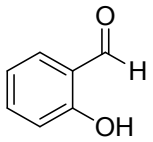
Chemical Formula: C_7H_6O
Molecular Weight: 106.12

Benzaldehyde [100-52-7]

Colorless oil. Eluent for isolation: 5:5 pentane/CH_2Cl_2. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.92 (s, 1H, C<u>H</u>O), 7.78 (d, *J*=5.4 Hz, 2H, CH_{Ar}), 7.53-7.50 (m, 1H, CH_{Ar}), 7.45-7.40 (m, 2H, CH_{Ar}) ppm **^{13}C NMR (75 MHz, $CDCl_3$):** δ 192.5 (C_q, C-HC=O), 136.5 (C_q, C_{Ar}), 134.6 (C_q, C_{Ar}), 129.8 (2 CH, C_{Ar}), 129.1 (CH, C_{Ar}) ppm. **GC:** retention time: 4.3 min.



Chemical Formula: $C_7H_6O_2$
Molecular Weight: 122.12



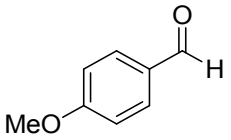
Chemical Formula: $C_7H_6O_2$
Molecular Weight: 122.12

4-Hydroxy benzaldehyde [123-08-0]

Offwhite powder. Eluent for isolation: 9:1 CH_2Cl_2/diethylether. **^{1}H NMR (300 MHz, DMSO-*d*$_6$):** δ 10.59 (s broad, 1 H, O*H*), 9.78 (s, 1H, C<u>H</u>O), 7.75 (d, *J*= 8.1 Hz, 2H, CH_{Ar}), 6.93 (d, *J*= 8.1Hz, 2H, CH_{Ar}), ppm. **^{13}C NMR (75 MHz, DMSO-*d*$_6$):** δ 191.0 (C_q, C-HC=O), 163.3 (C_q, C_{Ar}), 132.1 (CH, C_{Ar}), 128.5 (C_q, C_{Ar}), 115.9 (CH, C_{Ar}) ppm. **GC:** retention time: 8.7 min.

2-Hydroxy benzaldehyde [90-02-8]

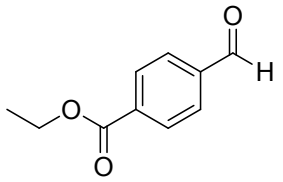
Colorless liquid. Eluent for isolation: 9:1 pentane/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 10.92 (s, 1 H, O*H*), 9.80 (s, 1H, C<u>H</u>O), 7.48-7.40 (m, 2H, CH_{Ar}), 6.95-6.88 (m, 2H, CH_{Ar}) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 196.8 (C_q, C-HC=O), 161.8 (C_q, C_{Ar}), 137.1 (CH, C_{Ar}), 133.8 (CH, C_{Ar}), 120.8 (C_q, C_{Ar}), 120.0 (CH, C_{Ar}), 117.8 (CH, C_{Ar}) ppm. **GC:** retention time: 5.3 min.



Chemical Formula: $C_8H_8O_2$
Molecular Weight: 136,15

4-methoxybenzaldehyde [123-11-5]

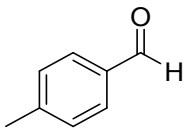
Colorless liquid. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.77 (s, 1 H, C<u>H</u>O), 7.73 (d, *J* = 8.1 Hz, 2 H, CH_{Ar}), 6.89 (d, *J* = 8.1 Hz, 2H, CH_{Ar}), 3.78 (s, 3H, OCH_3) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 190.9 (C_q, C-HC=O), 164.7 (C_q, C_{Ar}), 132.1(2 CH, C_{Ar}), 130.1 (C_q, C_{Ar}), 114.4 (2 CH, C_{Ar}), 55.7 (CH_3) ppm. **GC:** retention time: 7.8 min.



Chemical Formula: $C_{10}H_{10}O_3$
Molecular Weight: 178.18

Ethyl 4- formyl benzoate [6287-86-1]

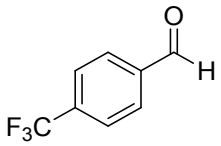
Colorless liquid. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.97 (s, 1 H, C<u>H</u>O), 8.08-7.99 (m, 2 H, CH_{Ar}), 7.82 (d, *J* = 8.1 Hz, 1 H, CH_{Ar}), 7.61 (d, *J* = 8.1 Hz, 1 H, CH_{Ar}), 4.28 (q, *J* = 7.9 Hz 2H, CH_2), 1.28 (t, *J* = 7.9 Hz, 3H, CH_3) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 191.68 (C_q, C-HC=O), 165.5 (C_q, C-HC=O), 139.04 (C_q, C_{Ar}), 135.4 (C_q, C_{Ar}), 130.1 (2 CH, C_{Ar}), 129.4 (2 CH, C_{Ar}), 61.5 (CH_2), 14.2 (CH_3) ppm. **GC:** retention time: 9.7 min.



Chemical Formula: C_8H_8O
Molecular Weight: 120.15

4-methyl benzaldehyde [104-87-0]

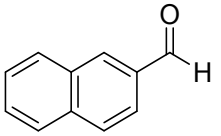
Colorless liquid. Eluent for isolation: 9:1 pentane/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.82 (s, 1 H, C<u>H</u>O), 7.65-7.62 (dd, 2 H, CH_{Ar}), 7.2-7.17(d, *J* = 8.1 Hz, 2H, CH_{Ar}), 2.29 (s, 3H, CH_3) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 191.0 (C_q, C-HC=O), 164.7 (C_q, C_{Ar}), 132.1 (2 CH, C_{Ar}), 130.1 (C_q, C_{Ar}), 114.4 (2 CH, C_{Ar}), 55.7 (CH_3) ppm. **GC:** retention time: 5.9 min.



Chemical Formula: $C_8H_5F_3O$
Molecular Weight: 174.12

4-(Trifluoromethyl) benzaldehyde [455-19-6]

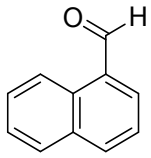
Light yellow liquid. Eluent for isolation: 9:1 pentane/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.99 (s, 1 H, C<u>H</u>O), 7.90 (d, *J* = 8.1 Hz, 2 H, C*H*$_{Ar}$), 7.79 (d, *J* = 8.1 Hz, 2H, C*H*$_{Ar}$) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 191.2 (C_q, C-HC=O), 138.8 (C_q, C_{Ar}), 130.0 (2 CH, C_{Ar}), 126.2 (2 CH, C_{Ar}), 125.4 (C_q, CF_3), 121.7 (C_q, C_{Ar}) ppm. **GC:** retention time: 4.2 min.



Chemical Formula: $C_{11}H_8O$
Molecular Weight: 156.18

2-Naphthalaldehyde [66-99-9]

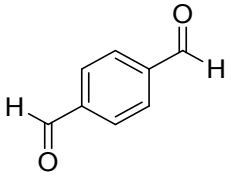
Slight yellow crystalline powder. Eluent for isolation: 9:1 CH_2Cl_2/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 10.05 (s, 1 H, C<u>H</u>O), 8.22 (s, 1H, CH_{Ar}), 7.91-7.78 (m, 4H, C*H*$_{Ar}$), 7.57-7.45 (m, 4H, CH_{Ar}) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 192.4 (C_q, C-HC=O), 136.5 (C_q, C_{Ar}), 134.6 (CH, C_{Ar}), 134.2 (2 C_q, C_{Ar}), 132.7 (C_q, C_{Ar}), 129.6 (CH, C_{Ar}), 129.2 (CH, C_{Ar}), 128.2 (CH, C_{Ar}), 127.2 (CH, C_{Ar}), 122.8 (CH, C_{Ar}) ppm. **GC:** retention time: 10.2 min.



Chemical Formula: $C_{11}H_8O$
Molecular Weight: 156.18

1-Naphthalaldehyde [66-77-3]

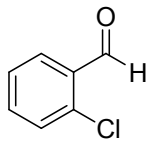
Colorless liquid. Eluent for isolation: 9:1 CH_2Cl_2/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 10.31 (s, 1 H, C<u>H</u>O), 9.16 (d, 1H, *J* = 8.1 Hz, CH_{Ar}), 8.00 (d, 1H, *J* = 8.1 Hz, CH_{Ar}), 7.90 (d, 1H, *J* = 5.4 Hz, CH_{Ar}), 7.83 (d, 1H, *J* = 5.4 Hz, CH_{Ar}), 7.63-7.47 (m, 3H, 3xC*H*$_{Ar}$) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 193.6 (C_q, CHO), 136.7 (CH, C_{Ar}), 135.3 (CH, C_{Ar}), 133.7 (C_q, C_{Ar}), 131.4 (C_q, C_{Ar}), 130.6 (CH, C_{Ar}), 129.1 (CH, C_{Ar}), 128.5 (CH, C_{Ar}), 127.0 (CH, C_{Ar}), 124.9 (CH, C_{Ar}) ppm. **GC:** retention time: 10.1 min.



Chemical Formula: $C_8H_6O_2$
Molecular Weight: 134,13

Terephthaldehyde [623-27-8]

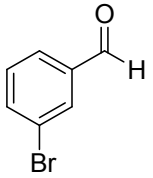
White crystals. Eluent for isolation: 9:1 pentane/diethylether. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 10.03 (s, 2 H, C<u>H</u>O), 7.95 (s, 4H, C*H*$_{Ar}$) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 191.6 (2 C_q, C-HC=O), 140.2 (2 C_q, C_{Ar}), 130.3 (4 CH, C_{Ar}) ppm. **GC:** retention time: 7.4 min.



Chemical Formula: C_7H_5ClO
Molecular Weight: 140,57

2-Chlorobenzaldehyde [89-98-5]

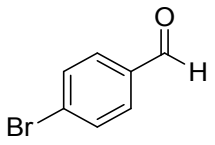
Colorless Liquid. Eluent for isolation: only pentane. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 10.38 (s, 1 H, C-CO-*H*), 7.83 (s, 1H, CH_{Ar}), 7.8-7.15 (m, 3H, CH_{Ar}) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 189.9 (C_q, C-HC=O), 138.1 (C_q, C_{Ar}), 135.3 (CH, C_{Ar}), 132.6 (C_q, C_{Ar}), 130.7 (CH, C_{Ar}), 129.5 (CH, C_{Ar}), 127.4 (CH, C_{Ar}) ppm. **GC:** retention time: 6.2 min.



Chemical Formula: C_7H_5BrO
Molecular Weight: 185,02

3-Bromobenzaldehyde [3132-99-8]

Yellow liquid. Eluent for isolation: 6:4 pentane/CH_2Cl_2. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.86 (s, 1 H, C<u>H</u>O), 7.92 (s, 1H, CH_{Ar}), 7.91-7.63 (m, 2H, CH_{Ar}), 7.35-7.29 (m, 1H, CH_{Ar}) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 190.9 (C_q, C-HC=O), 138.1 (C_q, C_{Ar}), 137.4 (CH, C_{Ar}), 132.5 (CH, C_{Ar}), 130.8 (CH, C_{Ar}), 128.5 (CH, C_{Ar}), 123.5 (C_q, C_{Ar}) ppm. **GC:** retention time: 7.3 min.



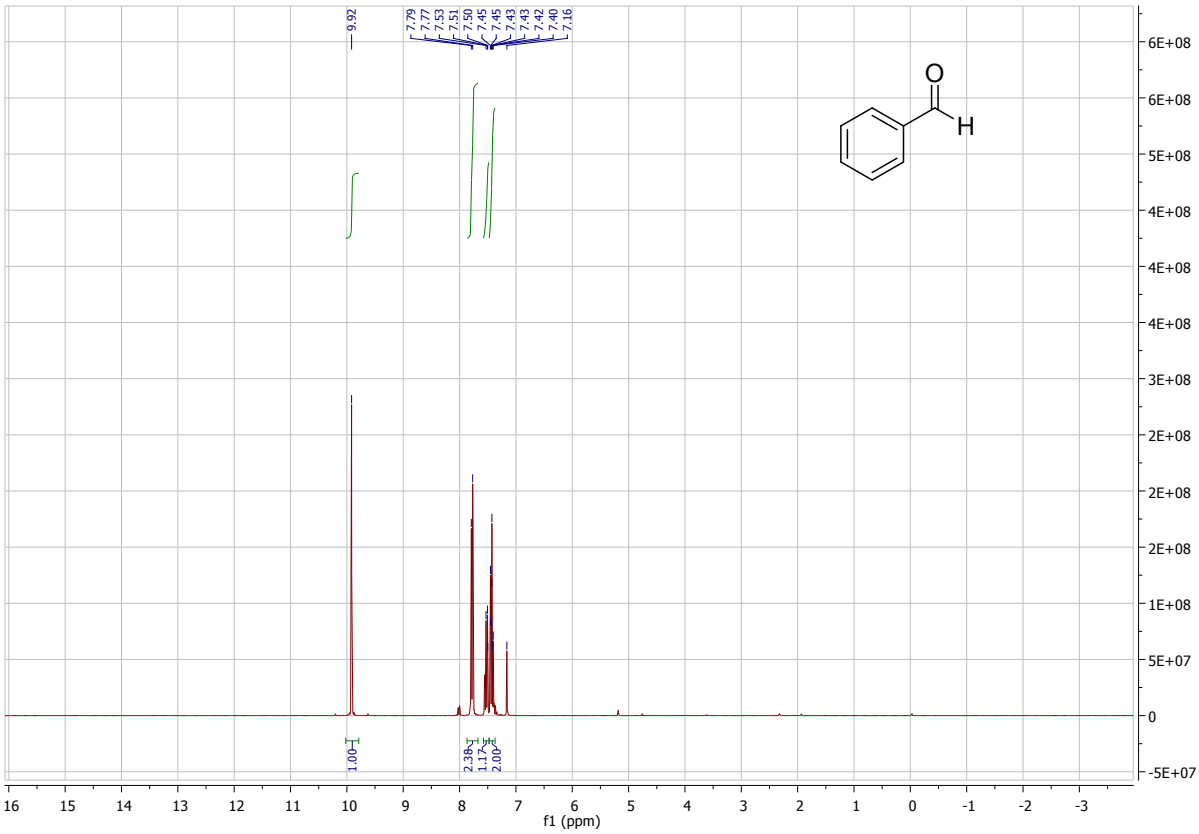
Chemical Formula: C_7H_5BrO
Molecular Weight: 185,02

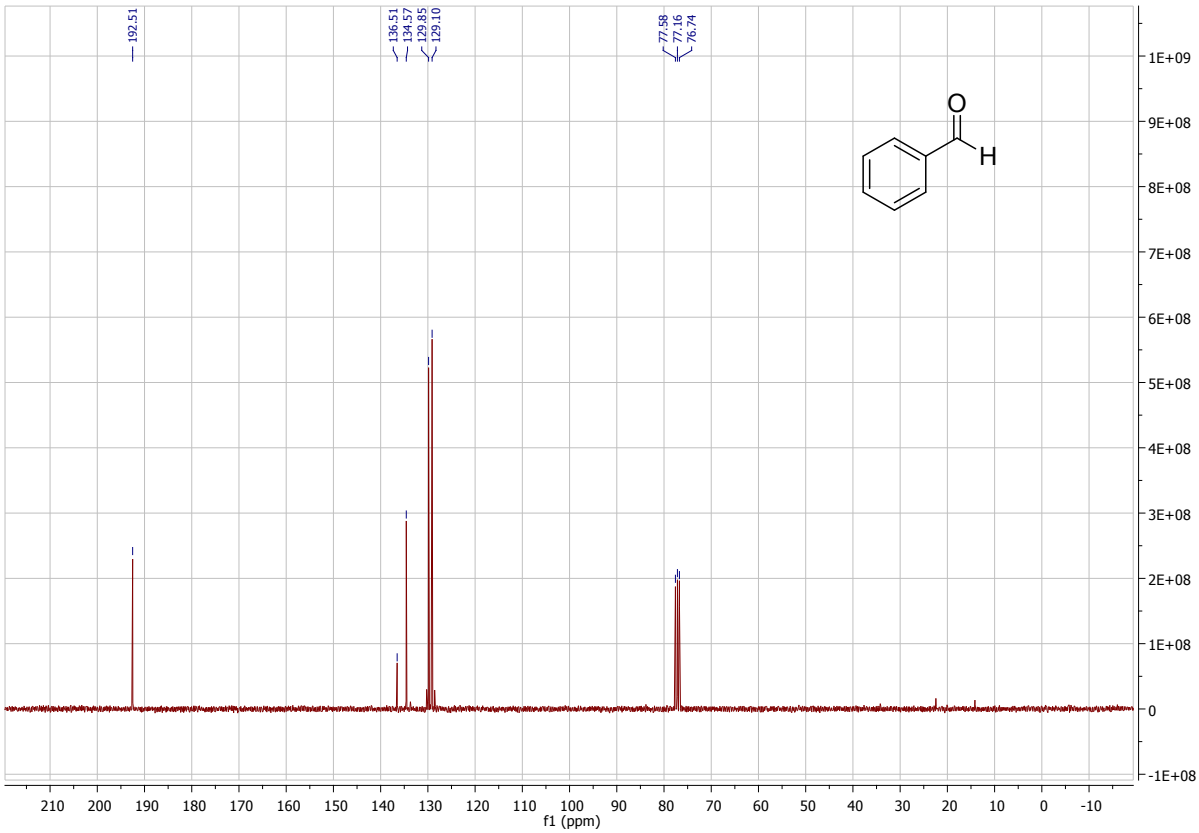
4-Bromobenzaldehyde [1122-91-4]

White crystals. Eluent for isolation: 6:4 pentane/CH_2Cl_2. **^{1}H NMR (300 MHz, $CDCl_3$):** δ 9.86 (s, 1 H, C<u>H</u>O), 7.64 (d, 2H, *J* = 8.1 Hz, CH_{Ar}), 7.54 (d, 2H, *J* = 8.1 Hz, CH_{Ar}) ppm. **^{13}C NMR (75 MHz, $CDCl_3$):** δ 191.2 (C_q, C-HC=O), 135.2 (C_q, C_{Ar}), 132.5 (2CH, C_{Ar}), 131.1 (2 CH, C_{Ar}), 129.9 (C_q, C_{Ar}) ppm. **GC:** retention time: 7.4 min.

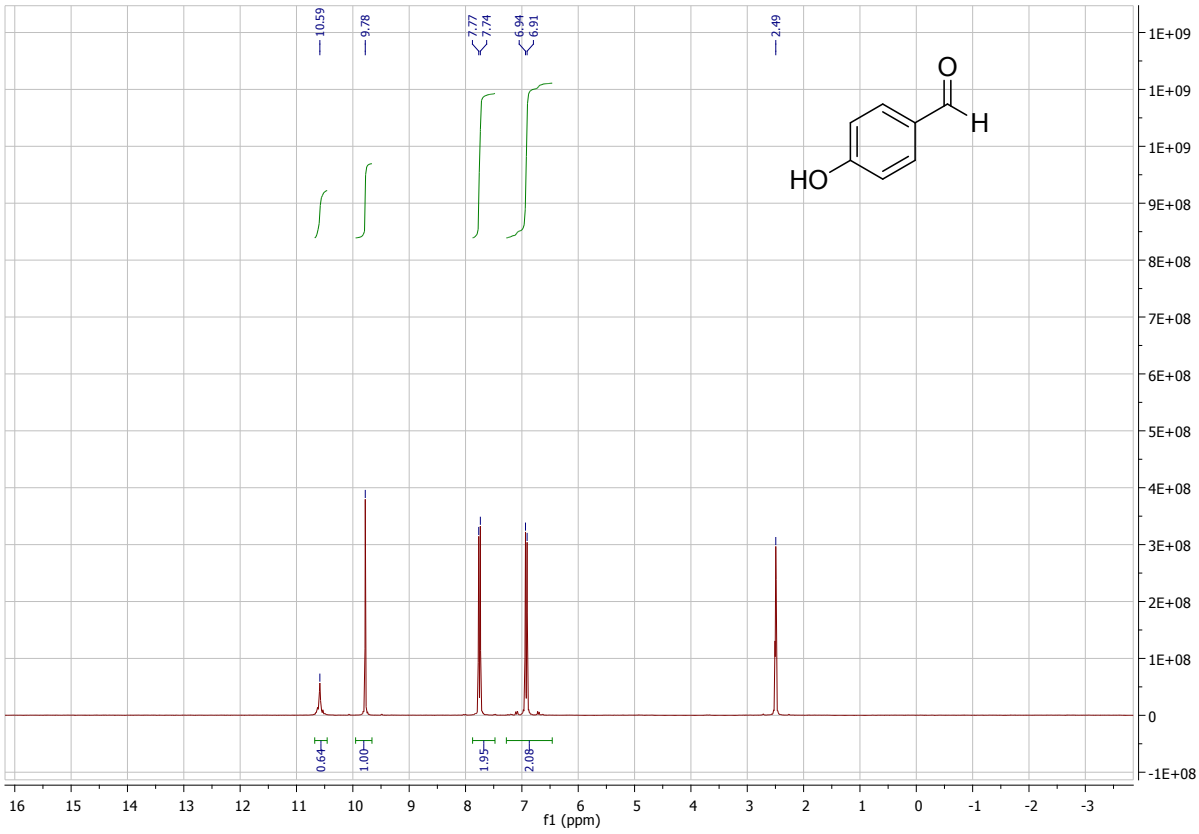
4. Spectra

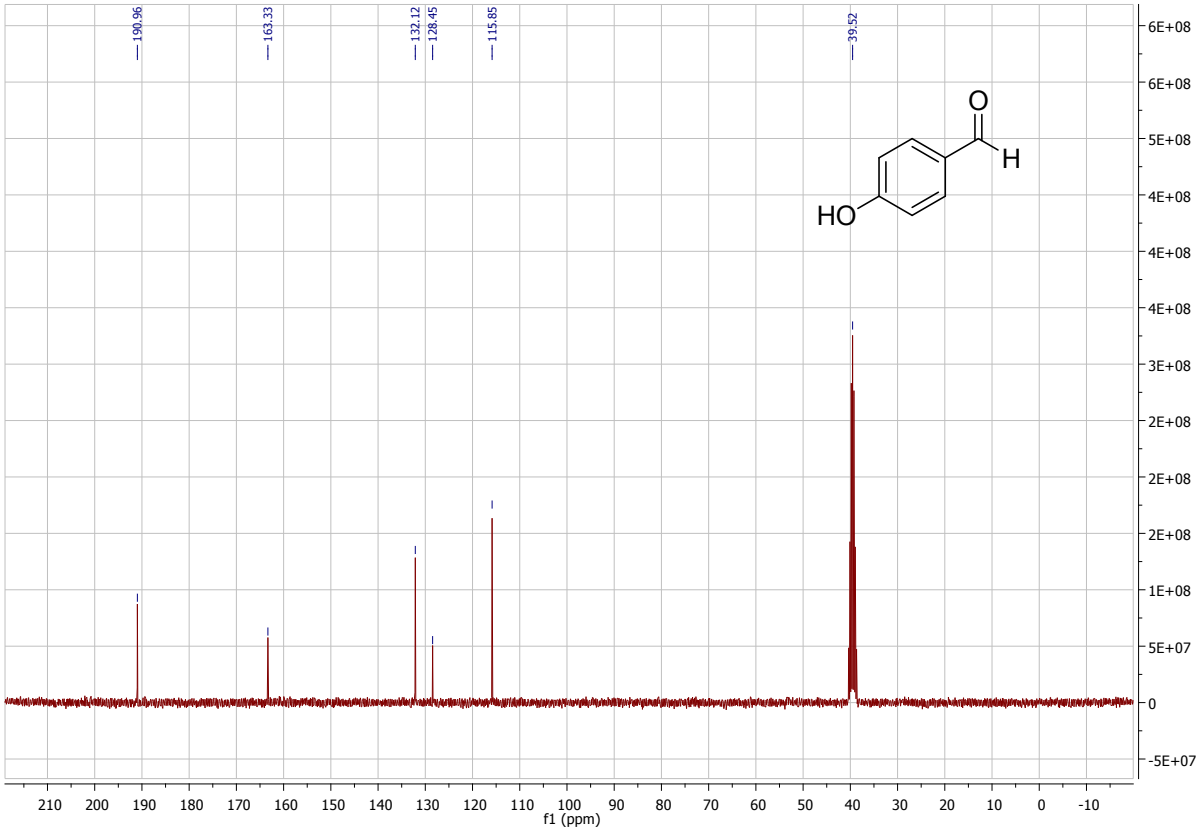
Benzaldehyde [100-52-7] (4b)



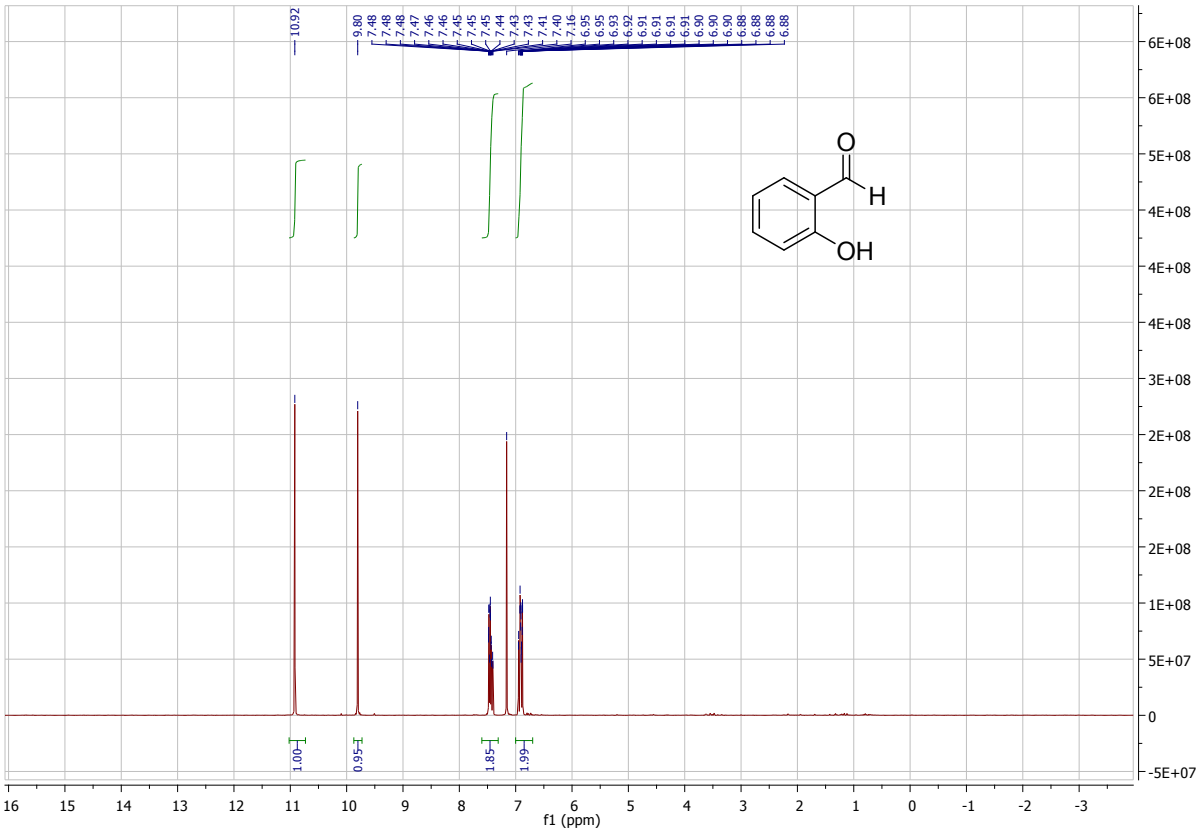


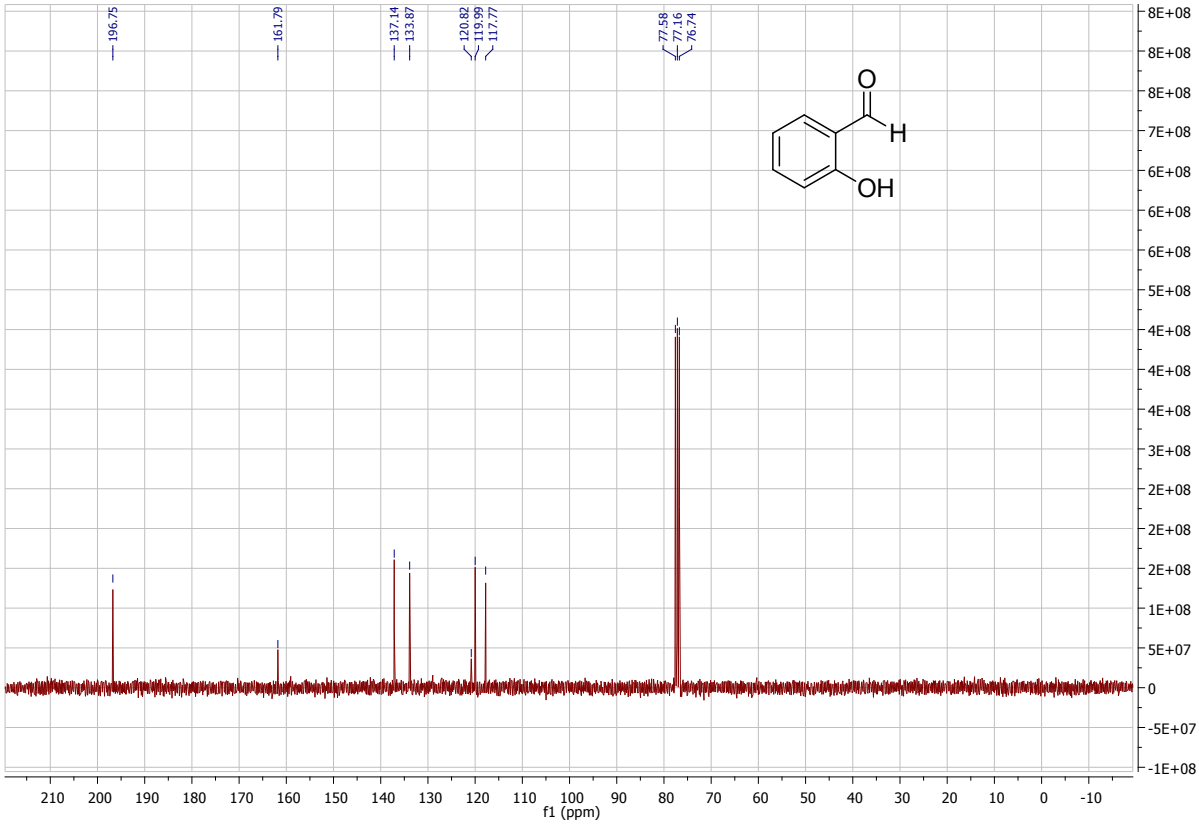
4-Hydroxy benzaldehyde [123-08-0]



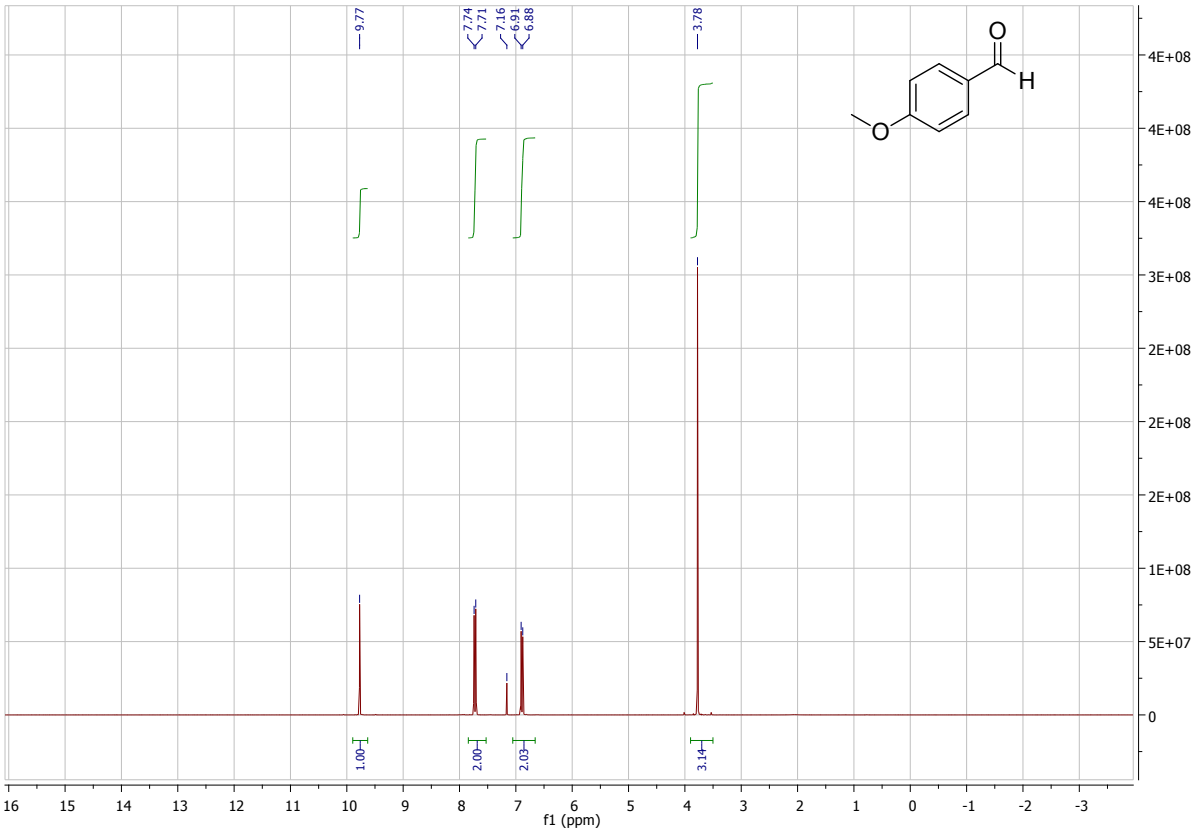


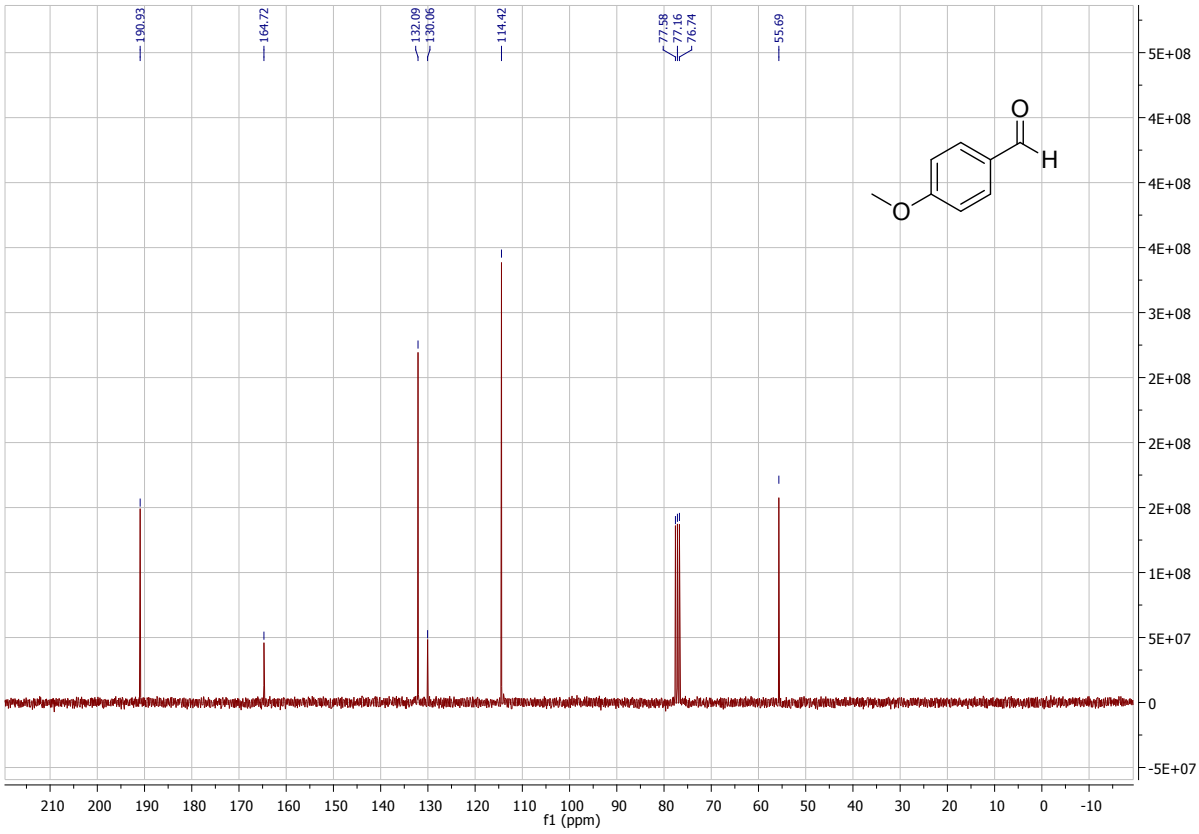
2-Hydroxy benzaldehyde [90-02-8] (6b)



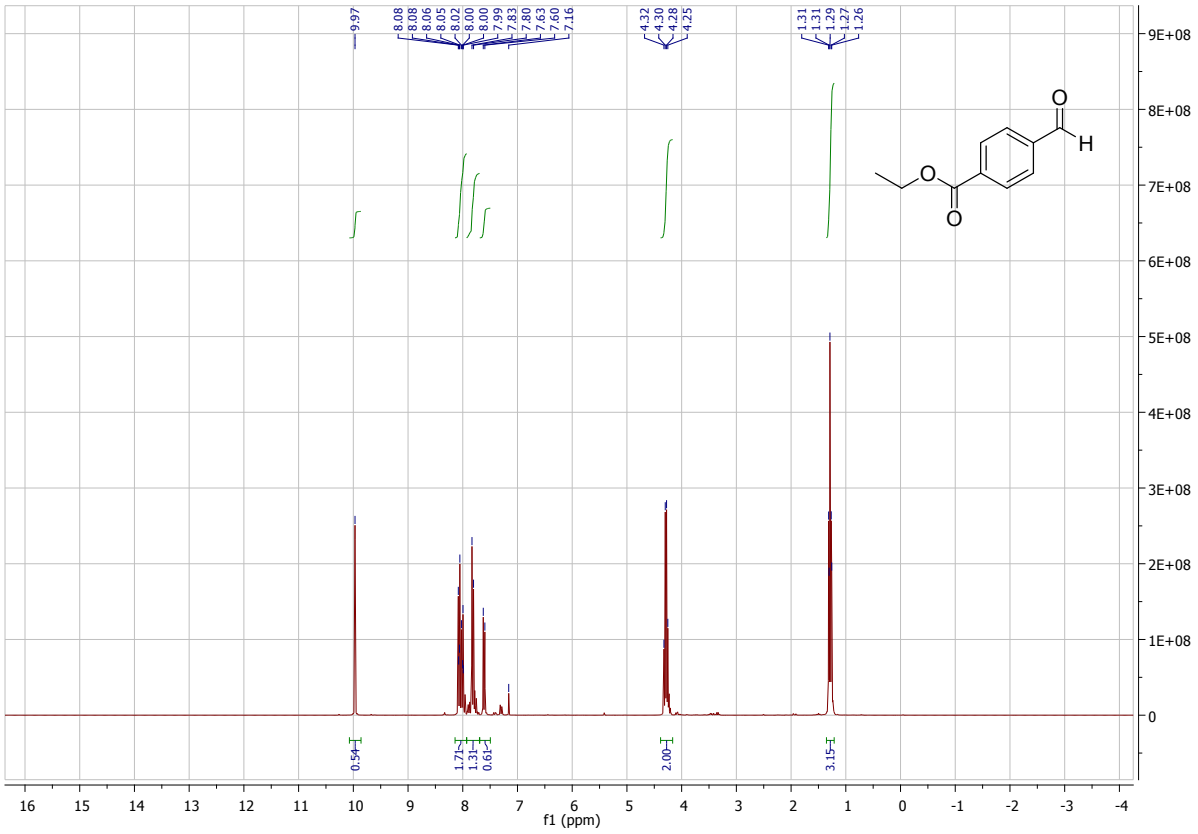


4-Methoxy benzaldehyde [123-11-5] (10b)

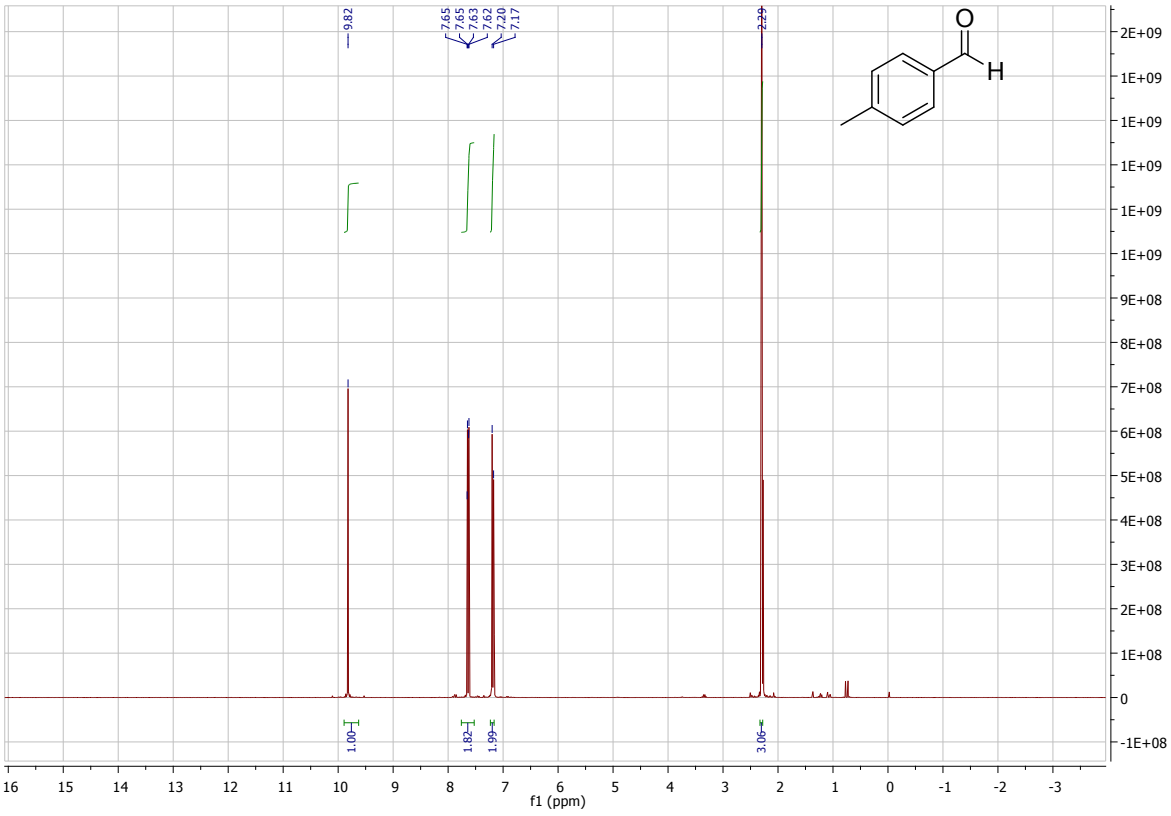


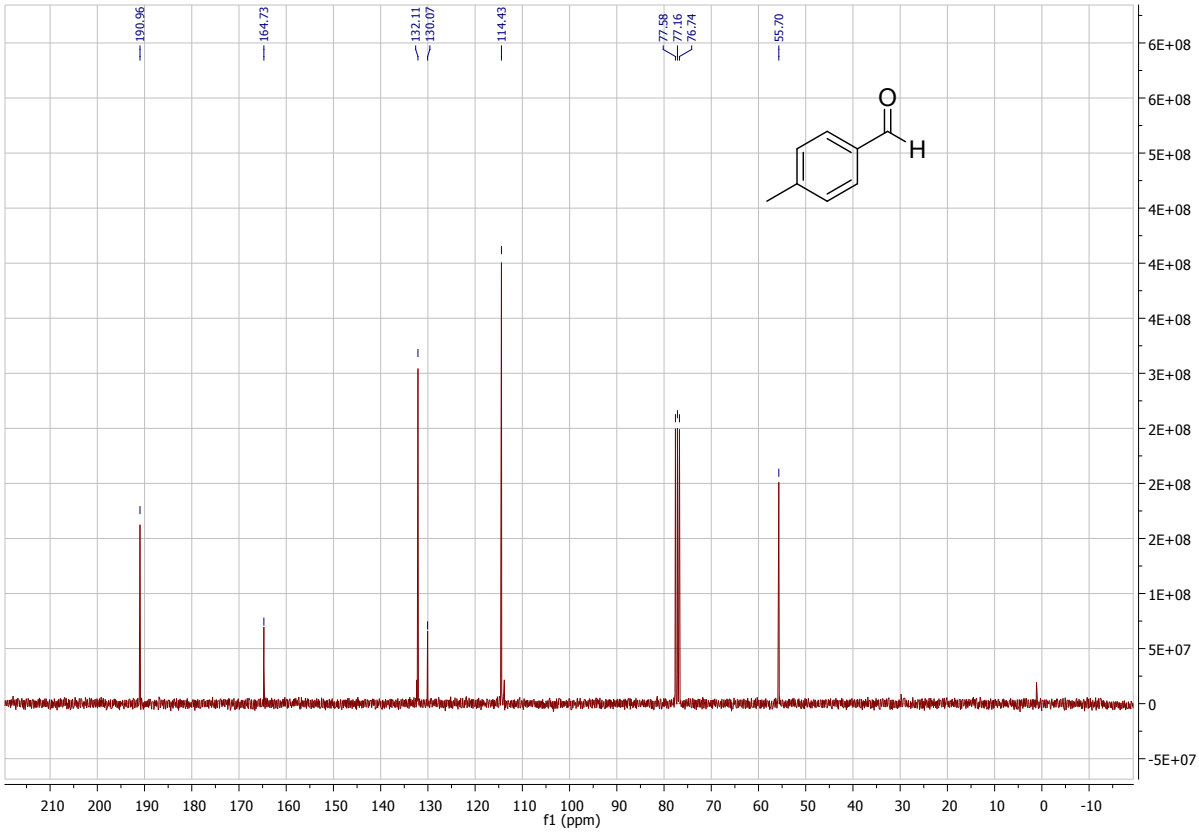


Ethyl 4-formylbenzoate [6287-86-1] (12b)

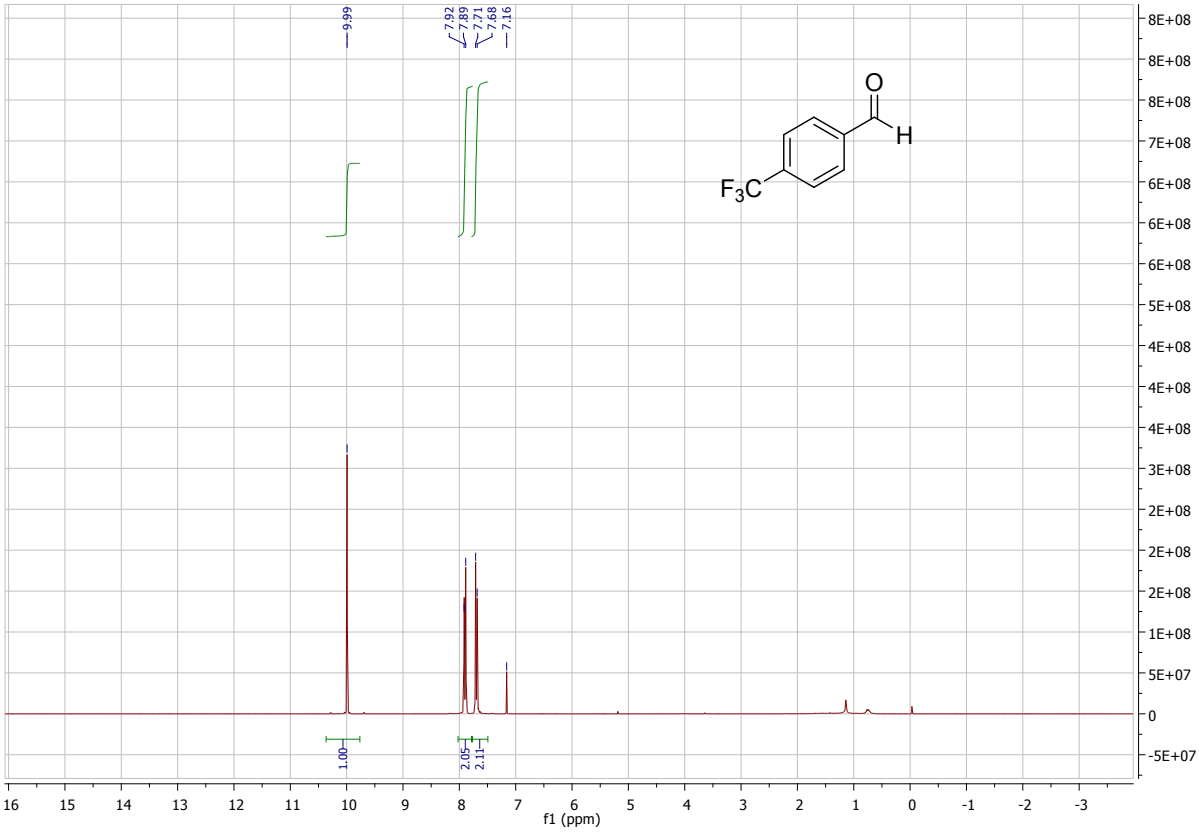


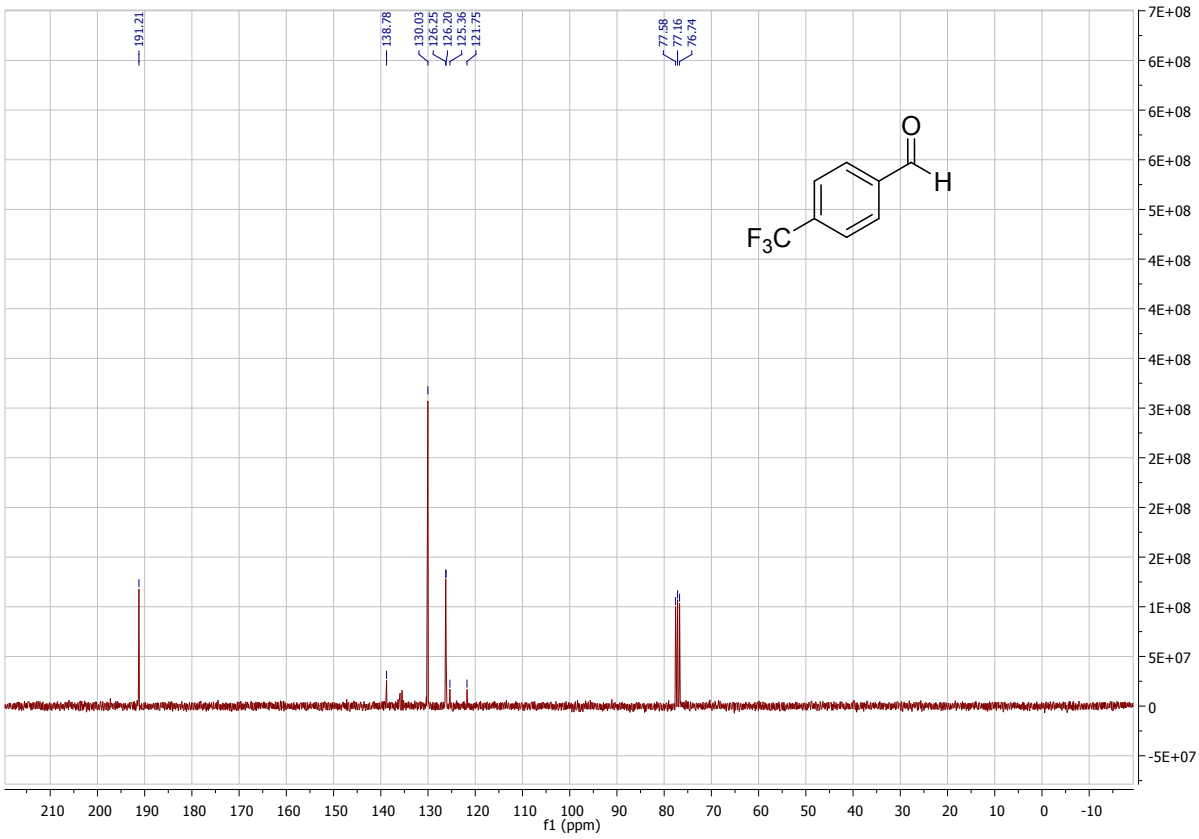
4-Methyl benzaldehyde [104-87-0] (14b)



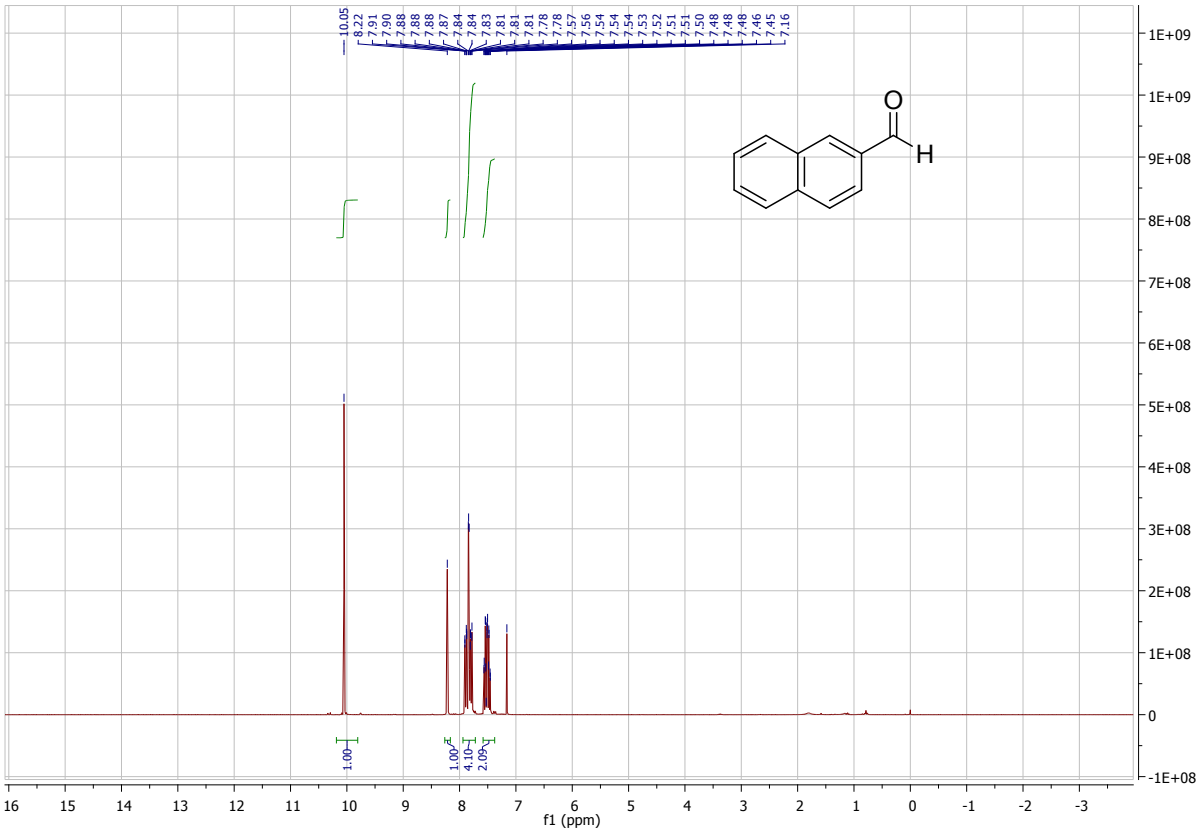


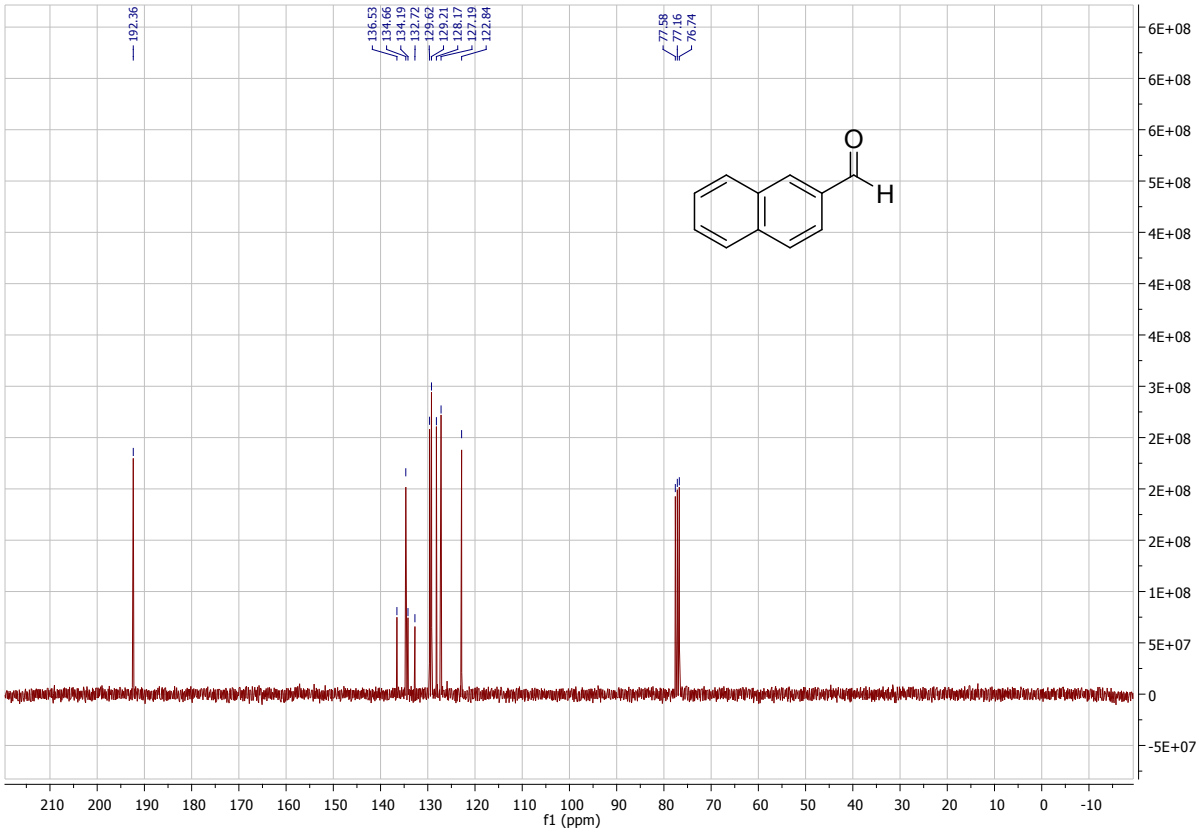
4-(Trifluoromethyl)benzaldehyde [455-19-6] (16b)



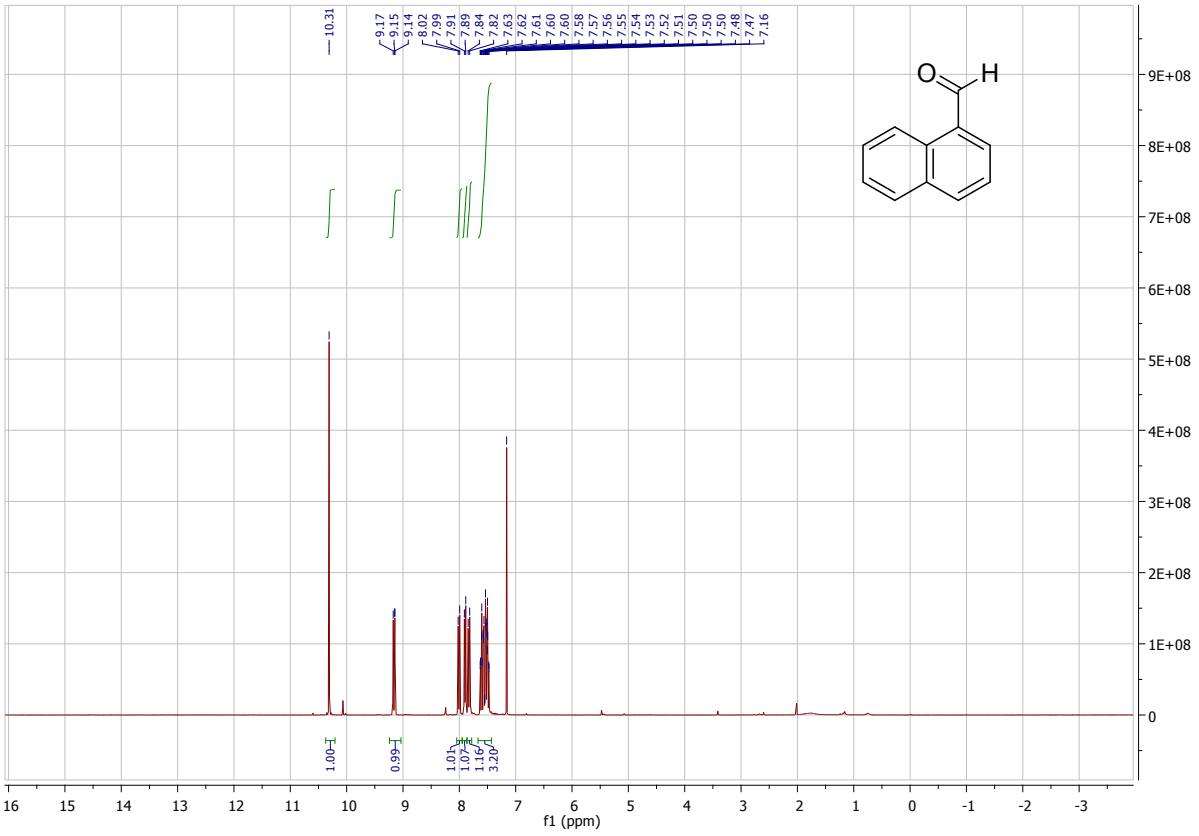


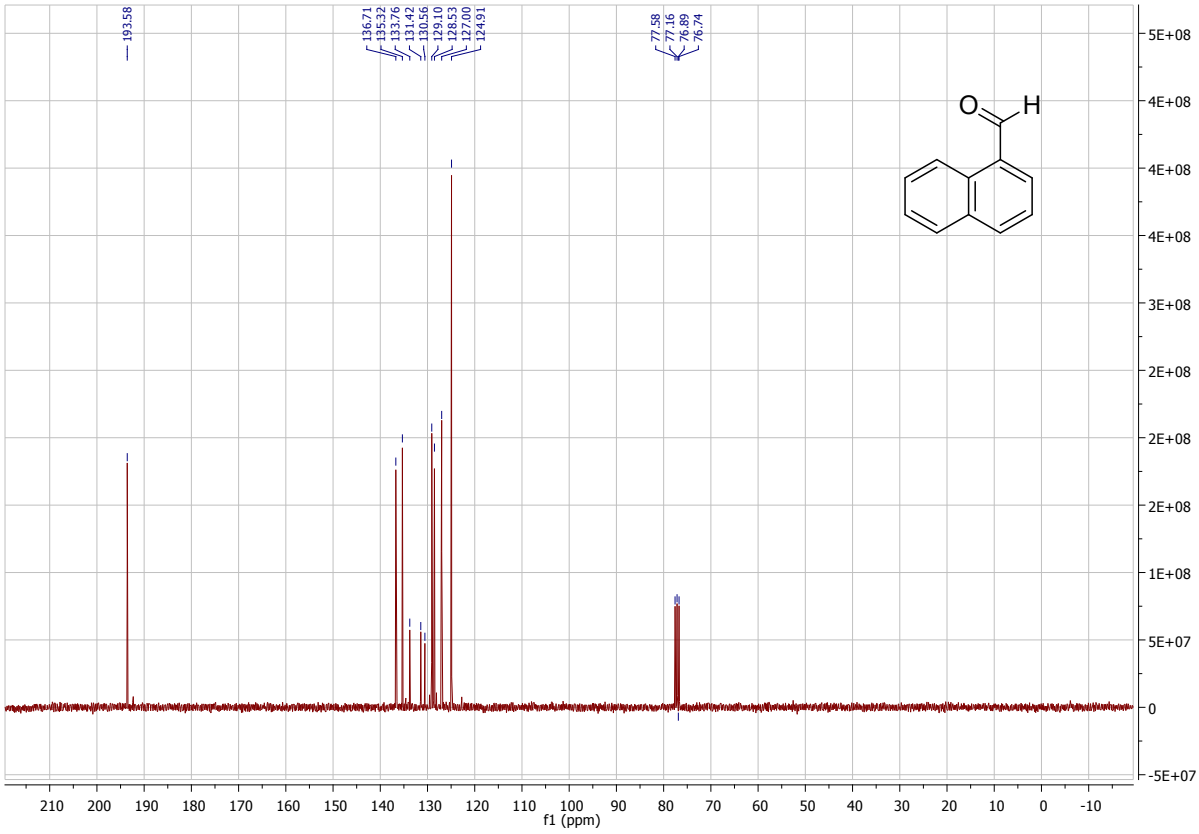
2-Naphthaldehyde [66-99-9] (18b)



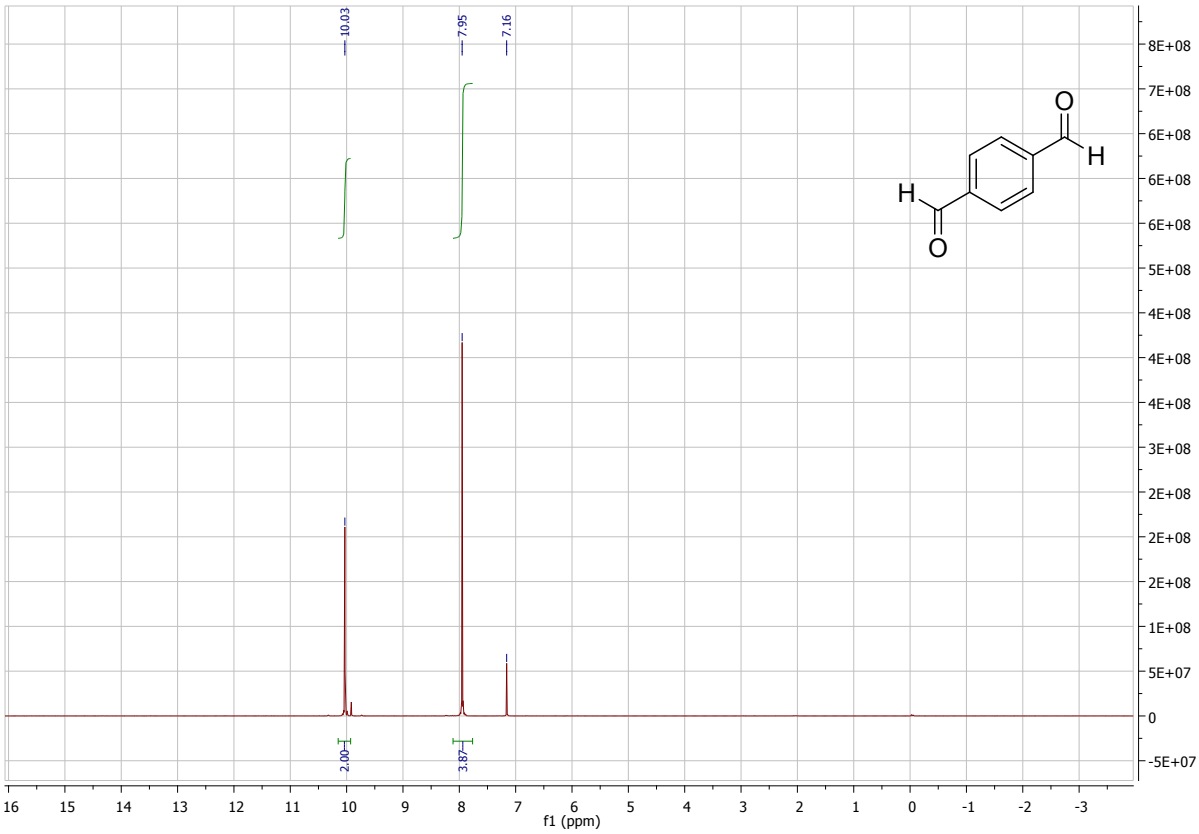


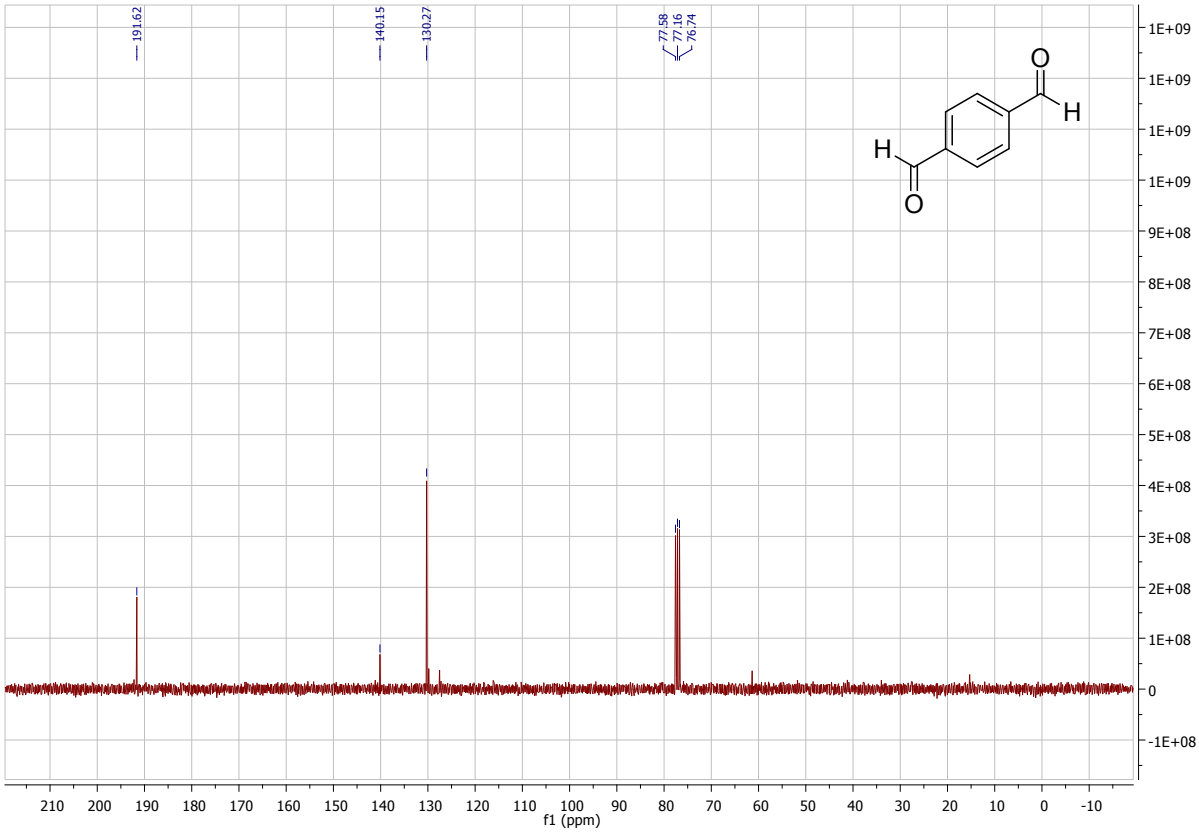
1-Naphthaldehyde [66-77-3] (18b)



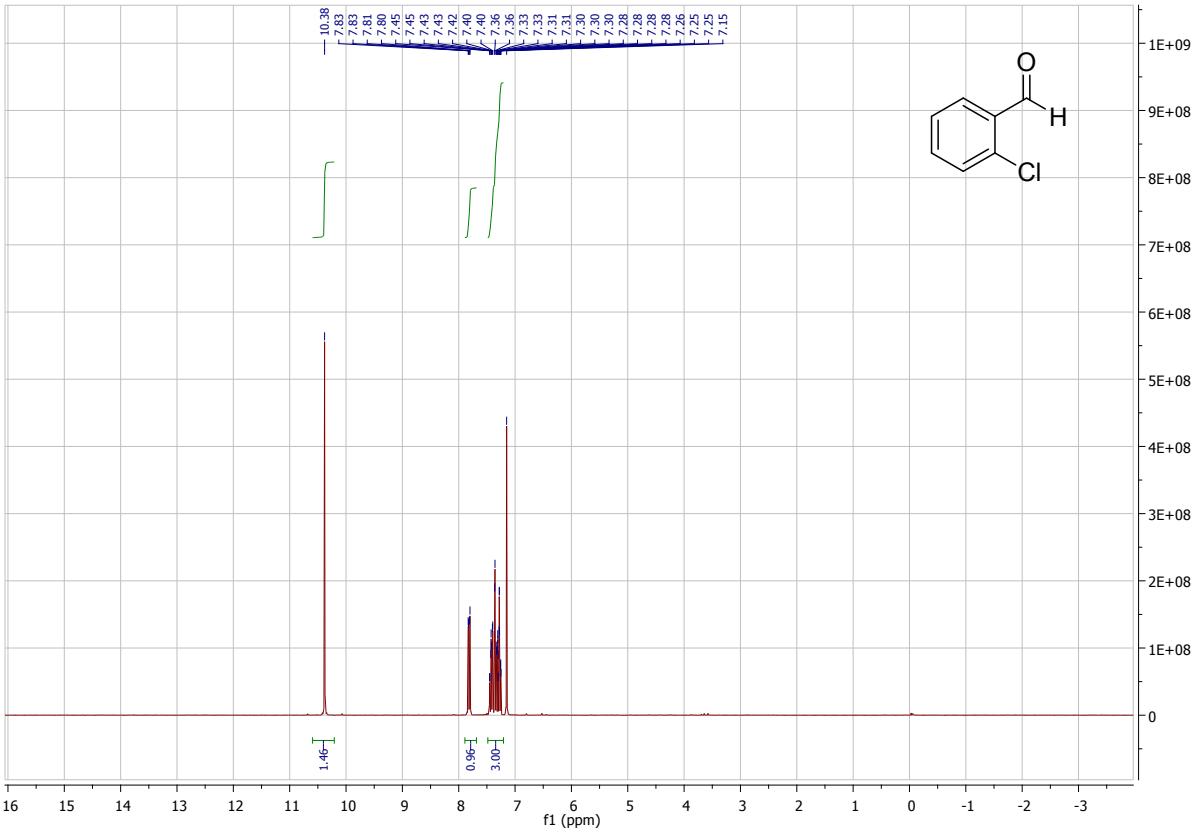


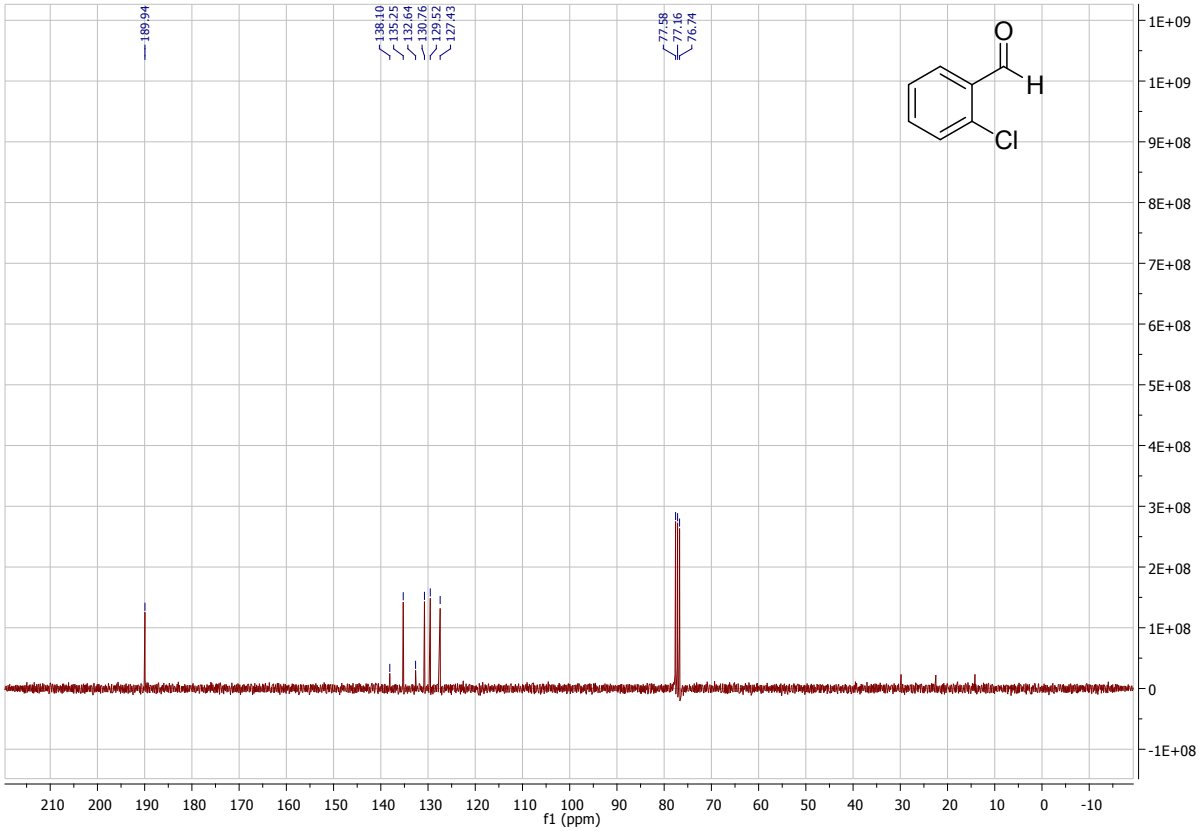
Terephthaldehyde [623-27-8]



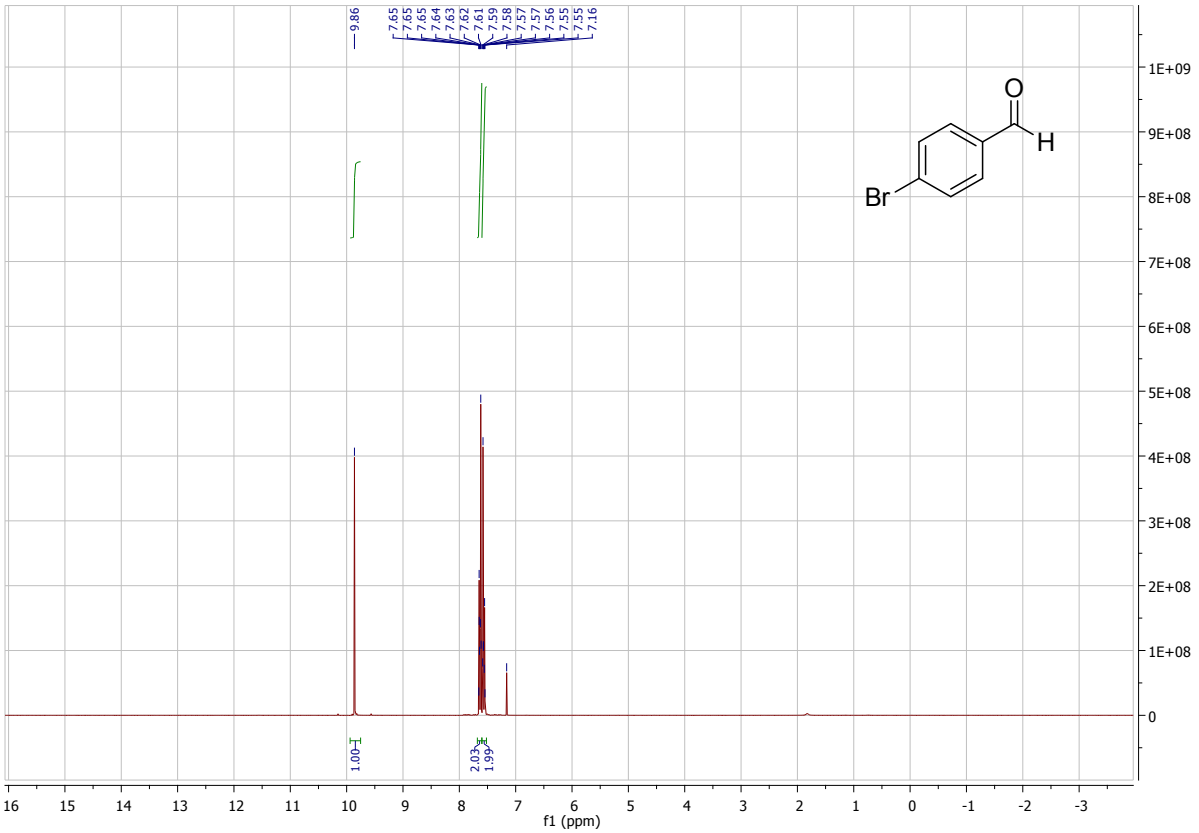


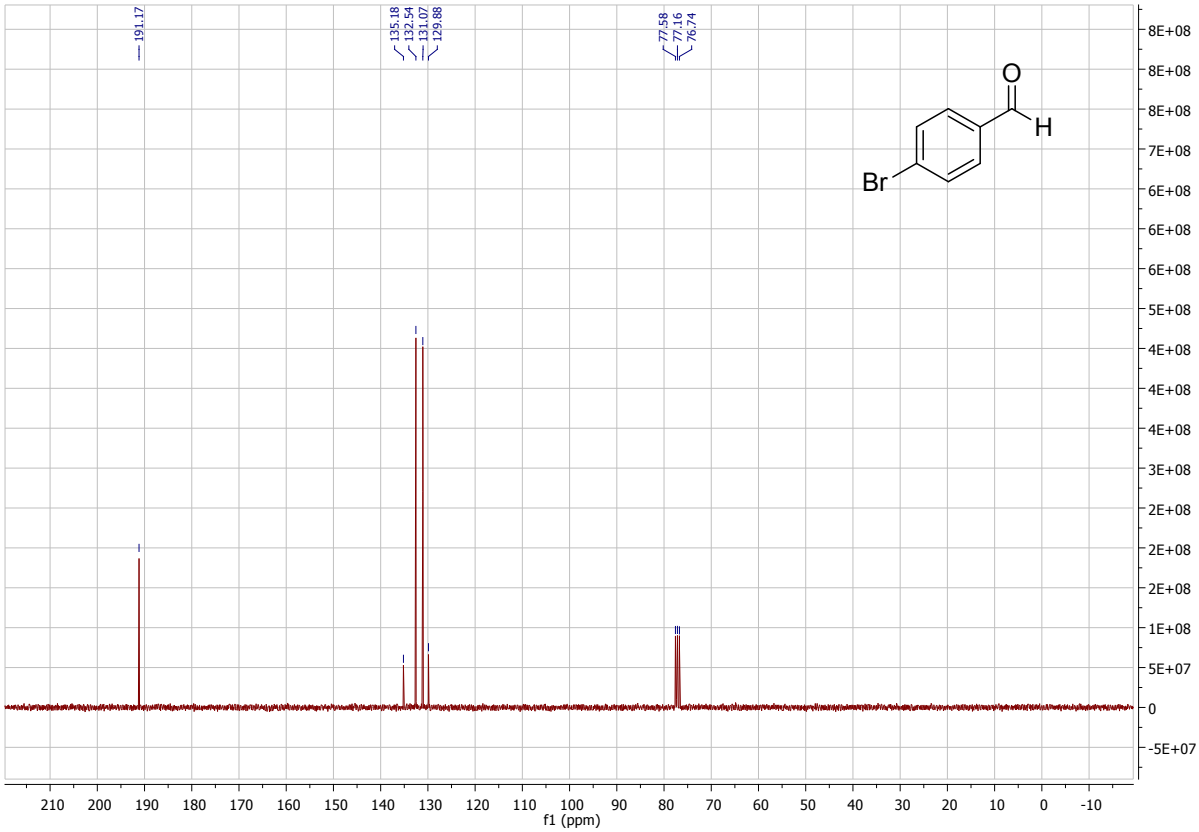
2-Chlorobenzaldehyde [89-98-5]



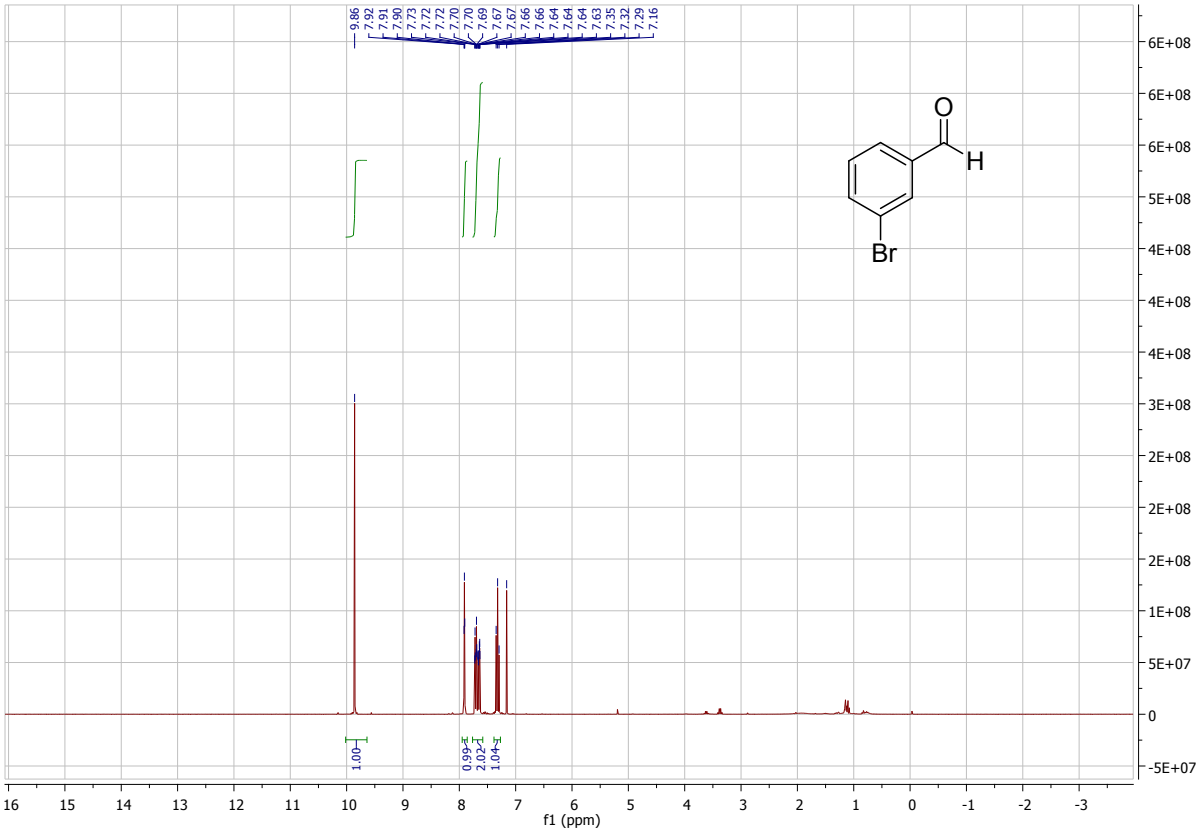


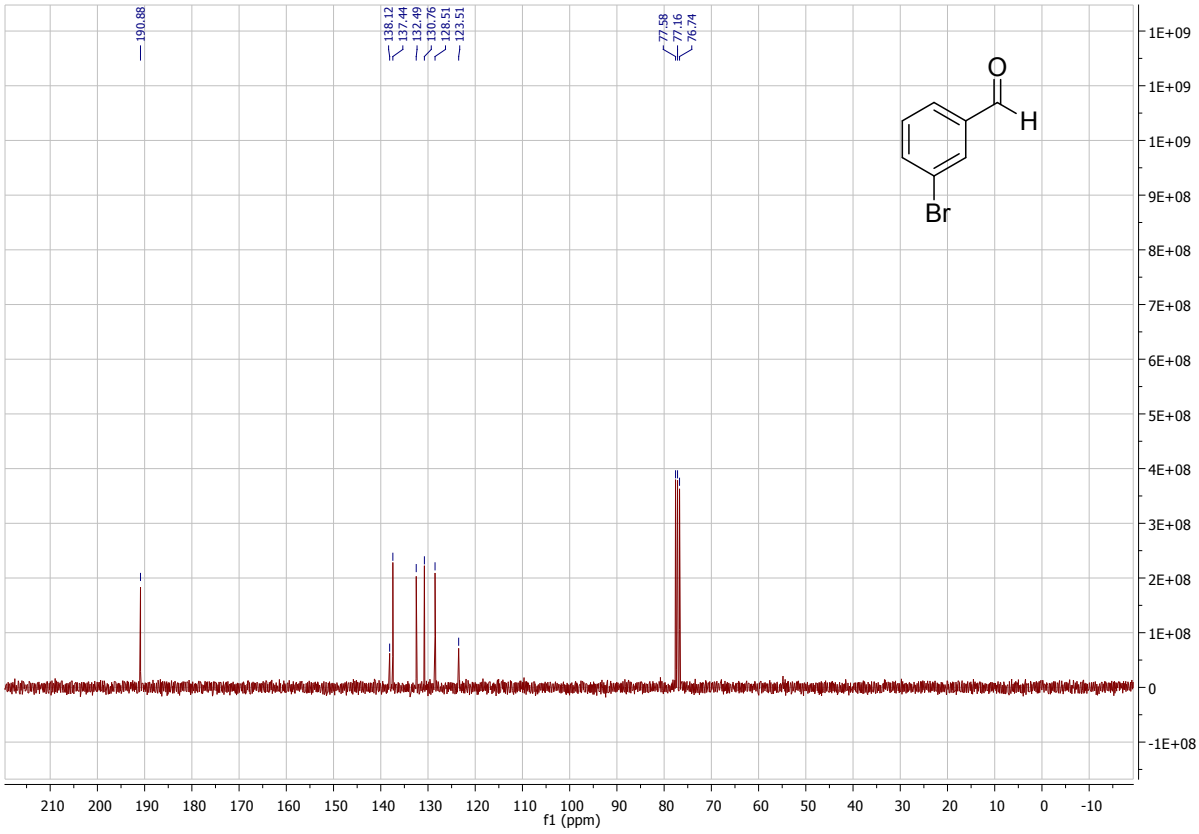
4-Bromobenzaldehyde [1122-91-4]





3-Bromobenzaldehyde [3132-99-8]




190.88
138.12
137.44
132.49
130.76
128.51
123.51
77.58
77.16
76.74
O
H
Br
1E+09
1E+09
1E+09
9E+08
8E+08
7E+08
6E+08
5E+08
4E+08
3E+08
2E+08
1E+08
0
-1E+08
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)