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A General and Efficient Mn-catalyzed Acceptorless Dehydrogenative Coupling of Alcohols with Hydroxide into Carboxylates

Zhihui Shao,[‡a] Yujie Wang,[‡a] Yaqian Liu,[a] Qian Wang,[a] Xiaoling Fu[b] and Qiang Liu*[a]

[a]Center of Basic Molecular Science (CBMS), Department of Chemistry, Tsinghua University, Beijing 100084, China.

[b]College of International Exchange, HanKou University, Wuhan 430212, China

qiang_liu@mail.tsinghua.edu.cn

Table of Contents

General Considerations S2

General procedures for acceptorless dehydrogenation of aromatic alcohols to carboxylic acids catalyzed by [Mn]-1 ..... S2

General procedures for acceptorless dehydrogenation of aliphatic alcohols to acids catalyzed by [Mn]-1 ..... S2

General procedure for transformation of amino alcohols to amino acids or Salts: S3

Table S1: Optimization for the Mn-Catalytzed dehydrogenation of benzyl alcohol to benzoic acid. S4

Gram-scale Dehydrogenative Coupling of Primary Alcohols: Activity Test S4

Control Experiments to Distinguish between Different Reaction Pathways S5

A Study of Reaction Progress of Dehydrogenation of 1a to 2a S6

Reactivity of Pincer Manganese Complexes S7

^{31}P NMR Study for the Resting State of the Catalytic Cycle S25

Characterization data of aromatic acids 2 ..... S26

Characterization data of aliphatic acids 4 ..... S30

Reference S35

NMR Spectra S37

General Considerations

The synthesis of ligands and preparation of manganese catalysts explored in this work were reported in our previous work.[1] The stoichiometric experiments of manganese complexes were carried out using non-deuterated THF as solvent. The chemical shifts of ^{31}P NMR spectra was standardized by absolute reference using ^{1}H NMR of THF, while the ^{1}H NMR of THF at different temperature was calibrated by adding 0.03 % volume fraction of TMS in the solution. Most solvents used were dried over solvent purification system (Innovative Technology PS-MD-5). Deuterated solvents were ordered from Cambridge Isotope Laboratories and distilled over sodium or calcium hydride. Benzyl alcohol was dried over magnesium activated by iodine and then collected by distillation under the protection of argon. Other regular chemicals were purchased from commercial sources with purity over 95% and used without further purification. NMR spectra were received using a Bruker 400 MHz spectrometer. Chemical shifts are reported in ppm relative to TMS. GC analyses were carried out on an SHIMADAZU GC 2010 PLUS system equipped with an SH-Rxi-5Sil MS (30 m x 250 μm x 25 μm). GC/MS analyses were carried out on an SHIMADAZU GC-MS-QP2010 SE W system equipped with aSH-Rxi-5Sil MS 30 meter, 0.25 mmID, 0.25 um df. X-Ray crystal structure analyses were performed with a MM007HF Saturn724+ system. Structure solution and refinement were accomplished with Sheldrick, 2014.

General procedures for acceptorless dehydrogenation of aromatic alcohols to carboxylic acids catalyzed by [Mn]-1

Under the protection of argon, alcohols **1** (5 mmol), **[Mn]-1** (4.9 mg, 0.01 mmol, 0.2 mol%), NaOH (220 mg, 5.5 mmol, 1.1 equiv), degassed water (180 ul, 2 eq) and anisole (1 mL) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) was added and the mixture was extracted with diethyl ether (3 × 5 mL). Then the aqueous phase was acidified with 6M HCl and extracted with ethyl acetate (3 × 10 mL). The combined ethyl acetate solution were washed with brine (15 mL), dried over anhydrous Na_2SO_4, and evaporated to dryness under reduced pressure, the pure acids was obtained and weighted for calculating the yield. Yield = n (acid) / n (alcohol).

General procedures for acceptorless dehydrogenation of aliphatic alcohols to acids catalyzed by [Mn]-1

Under the protection of argon, alcohols **3** (2.5 mmol), **[Mn]-1** (2.5 mg, 0.005 mmol, 0.1 mol%), KOH (562 mg, 10 mmol, 4 equiv), degassed water (90 μL, 2 eq) and anisole (2 mL) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) was added and the mixture was extracted with diethyl ether (3 × 5 mL). The aqueous phase was acidified with 6M HCl and extracted with ethyl acetate (3 × 10 mL). The combined ethyl acetate solution were

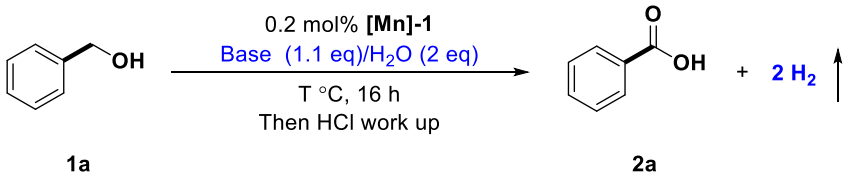
washed with brine (15 mL), dried over anhydrous Na_2SO_4, and evaporated to dryness under reduced pressure, the pure acids was obtained and weighted for calculating the yield. Yield = n (acid) / n (alcohol). For acids **4a-4d**, after cooling to room temperature, water (5 mL) and 6M HCl was added and extracted with ethyl acetate (3 × 10 mL). CH_2Br_2 as NMR internal standard was added to the extract. The yields of acid products were determined by NMR.

General procedure for transformation of amino alcohols to amino acids or Salts:

For 3-(Dimethylamino)propanoicacid **4q** and 6-Aminocaproic acid **4s**, after cooling to room temperature, 2 mL water was added, leading to a homogeneous solution, and the aqueous phase was extracted with ethyl acetate (3 × 10 mL). Then 2 mmol of pyridine was added to the crude reaction mixture as an internal standard. Then 0.05 mL of the solution was dissolved in D_2O for determination of the conversion of amino alcohols and the yield of amino acids salt by ^1H NMR spectroscopy.

Isolation of *N*-isopropylamino acetic acid **4r**: After reaction, the reaction mixture was transferred to a 100 mL flask. 6M HCl was added dropwise until the pH value reached ca. 5. Then the solvent was evaporated, resulting in a brown residue. Ethanol (50 mL) was added to the brown residue and the mixture was refluxed for 0.5 h, and the resulting solution was filtered. The procedure was repeated for two more times and the filtrates were combined. The solution was concentrated under vacuum and a light pink solid was obtained. The solid was washed with diethyl ether (3 × 15 mL) and dried, offering *N*-isopropylamino acetic acid **4r** in 85% yield.

Table S1: Optimization for the Mn-Catalytzed dehydrogenation of benzyl alcohol to benzoic acid.[a]

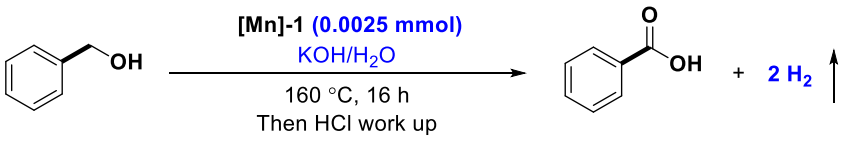


1a **2a**

entry	Base	T (℃)	Conv. **1a** (%)[b]	Yield **2a** (%)[b]
1	NaOH	160	97	94
2	KOH	160	95	92
3	*t*BuOK	160	74	74
4	NaOAc	160	14	1
5	NaOEt	160	89	42
6	NaOH	140	55	50
7[c]	NaOH	160	65	44
8[d]	NaOH	160	85	78
9[e]	NaOH	160	96	96

[a] Reaction conditions: benzyl alcohol (5 mmol), base (1.1 eq), **[Mn]-1** (0.01 mmol), H_2O (2 eq), 160 °C, under argon, 16 h. [b] Determined by GC with diphenyl as an internal standard. [c] NaOH (0.5 eq). [d] without H_2O. [e] Anisole (1 ml)

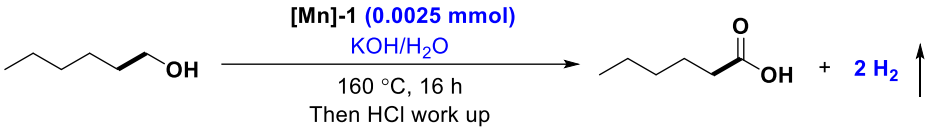
Gram-scale Dehydrogenative Coupling of Primary Alcohols: Activity Test



1a **2a**

50 mmol **TON=14630, Y=73 %**

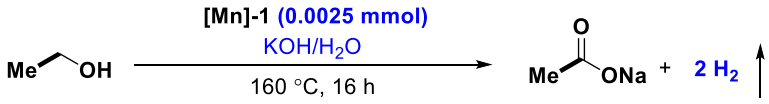
Under the protection of argon, benzyl alcohol **1a** (50 mmol), **[Mn]-1** (1.25 mg, 0.0025 mmol, 0.005 mol%), KOH (3.09 g, 55 mmol, 1.1 equiv) and degassed water (990 μL, 55 mmol, 1.1 eq) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) and 6M HCl was added and extracted with ethyl acetate (3 × 10 mL). Biphenyl as an internal standard for GC analysis was added to the extract. The yield of **2a** was determined by GC analysis. TON = n_{2a} / $n_{[Mn]-1}$



3c **4c**

20 mmol **TON=7400, Y=93 %**

Under the protection of argon, 1-hexanol **3c** (20 mmol), **[Mn]-1** (1.25 mg, 0.0025 mmol, 0.0125 mol%), KOH (4.49 g, 80 mmol, 4 equiv), degassed water (396 μL, 22 mmol, 1.1 eq) and anisole (12 mL) were added sequentially to a 50 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) and 6M HCl was added and extracted with ethyl acetate (3 × 10 mL). CH_2Br_2 as an internal standard was added to the extract. The yield of **4c** was determined by NMR. TON = n_{4c} / $n_{[Mn]-1}$

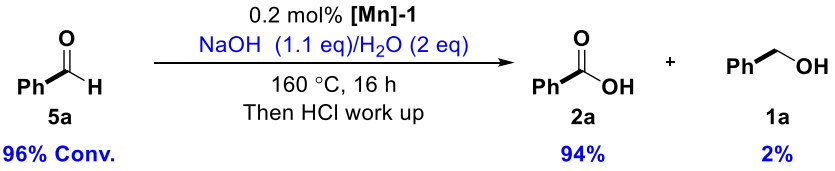


3a **4a**

80 mmol **TON=13680, Y=43 %**

Under the protection of argon, ethanol **3a** (80 mmol), **[Mn]-1** (1.25 mg, 0.0025 mmol, 0.003215 mol%), KOH (8.99 g, 160 mmol, 2 equiv), degassed water (1.58 mL, 88 mmol, 1.1 eq) and anisole (12 mL) were added sequentially to a 100 mL autoclave equipped with a mechanistic stir. The reaction was stirred for 48 hours at 160 °C. After cooling to room temperature, water (5 mL) was added and extracted with ethyl acetate (3 × 10 mL). DMSO as an internal standard for NMR analysis was added to the aqueous phase. The yield of AcONa was determined by NMR. TON = n_{4a} / $n_{[Mn]-1}$

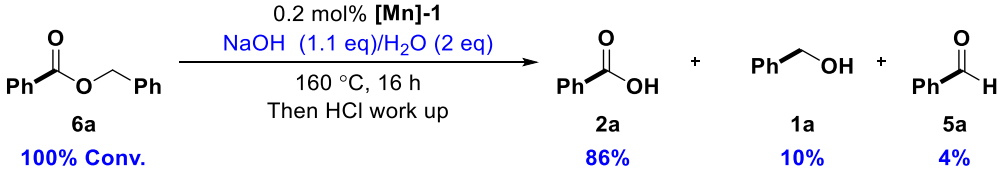
Control Experiments to Distinguish between Different Reaction Pathways



5a **2a** **1a**

96% Conv. **94%** **2%**

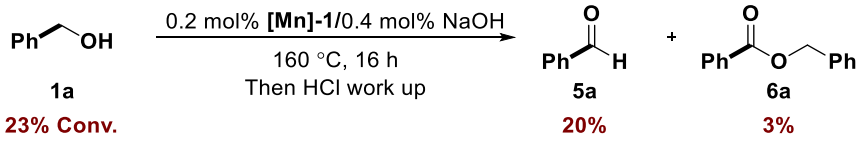
Under the protection of argon, benzaldehyde **5a** (5 mmol), **[Mn]-1** (4.9 mg, 0.01 mmol, 0.2 mol%), NaOH (220 mg, 5.5 mmol, 1.1 equiv) and degassed water (180 μL, 10 mmol, 2 eq) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) and 6M HCl was added and extracted with ethyl acetate (3 × 10 mL). Diphenyl as an internal standard for GC analysis was added to the combined extract for determination of the conversion of benzaldehyde **5a** and the yields of benzoic acid **2a** and benzyl alcohol **1a**.



6a **2a** **1a** **5a**

100% Conv. **86%** **10%** **4%**

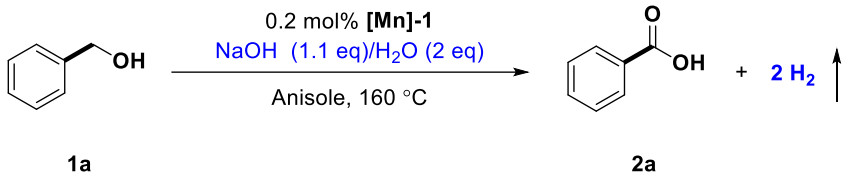
Under the protection of argon, benzyl benzoate **6a** (2.5 mmol), **[Mn]-1** (2.5 mg, 0.005 mmol, 0.2 mol%), NaOH (110 mg, 2.75 mmol, 1.1 equiv) and degassed water (90 μL, 5 mmol, 2 eq) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, water (5 mL) and 6M HCl was added and extracted with ethyl acetate (3 × 10 mL). Diphenyl as an internal standard for GC analysis was added to the combined extract for determination of the conversion of benzyl benzoate **6a** and the yields of benzoic acid **2a**, benzyl alcohol **1a** and benzaldehyde **5a**.



Under the protection of argon, benzyl alcohol **1a** (5 mmol), **[Mn]-1** (4.9 mg, 0.01 mmol, 0.2 mol%) and NaOH (0.8 mg, 0.02 mmol, 0.4 mol%) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, diphenyl as an internal standard for GC analysis was added directly to the reaction mixtures for determination of the conversion of benzyl alcohol **1a** and the yields of benzaldehyde **5a** and benzyl benzoate **6a**.

Under the protection of argon, benzyl alcohol **1a** (5 mmol) and **[Mn]-D** (4.3 mg, 0.01 mmol, 0.2 mol%) were added sequentially to a 25 mL schlenck tube equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. After cooling to room temperature, diphenyl as internal standard for GC analysis was added directly to the reaction mixtures for determination of the conversion of benzyl alcohol **1a** and the yields of benzaldehyde **5a** and benzyl benzoate **6a**.

A Study of Reaction Progress of Dehydrogenation of 1a to 2a



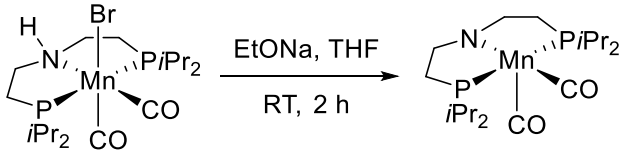
Under the protection of argon, benzyl alcohol **1a** (5 mmol), **[Mn]-1** (4.9 mg, 0.01 mmol, 0.2 mol%), NaOH (220 mg, 5.5 mmol, 1.1 equiv), degassed water (180 μL, 10 mmol, 2 eq), anisole (2 mL) and diphenyl (50 mg) were added sequentially to a 25 mL three-necked round-bottomed flask equipped with a magnetic stir bar. The reaction was stirred at 160 °C for 16 hours under an argon atmosphere open to a bubbler. Samples were taken from reaction mixtures under argon atmosphere for GC analysis to determine the conversion of benzyl alcohol **1a** and the amount of benzaldehyde **5a** over reaction time.

Table S2: Results of GC analysis of components in reaction mixtures over reaction time

	n_{1a} (mmol) / Conv.(%)	n_{5a} (mmol) / Yield (%)
10 min	3.9 / 22	0.07 / 1.4
30 min	1.96 / 61	0.05 / 1
1 h	1.42 / 72	0.03 / 0.6
2 h	0.5 / 90	0.02 / 0.4
3 h	0.42 / 92	0.03 / 0.6
4h	0.3 / 94	0.01 / 0.2

Reactivity of Pincer Manganese Complexes

Preparation of amido manganese complex [Mn]-D



[Mn]-1 **[Mn]-D**

100 % Conversion

A dried 10 mL Schlenk flask was charged with **[Mn]-1** (0.15 g, 0.3 mmol), sodium ethoxide (61 mg, 0.9 mmol) and THF (4 mL) in sequence. The solution soon turned into dark red. The reaction was stirred for 1 hour at room temperature. After the volatiles were removed under reduced pressure, the residue was dissolved in hexane (4 mL) and filtered through celite, The hexane solution was concentrated to 2 mL and the solution was kept at -20 °C overnight. Red solid precipitate were collected and dried to give **[Mn]-D** (87 mg, 69%).

^{1}H NMR (400 MHz, C_6D_6) δ 2.96 (s, 4H), 1.99 (d, J = 4.7 Hz, 4H), 1.38 (s, 1H), 0.98 (d, J = 5.7 Hz, 12H), 0.84 (d, J = 4.2 Hz, 12H). ^{13}C NMR (101 MHz, C_6D_6) δ 64.89 (J = 10.1 Hz,), 26.29 (J = 10.1 Hz), 22.85(J = 5.6 Hz), 18.08, 17.48. ^{31}P NMR (162 MHz, C_6D_6) δ 112.99 (s).[1]

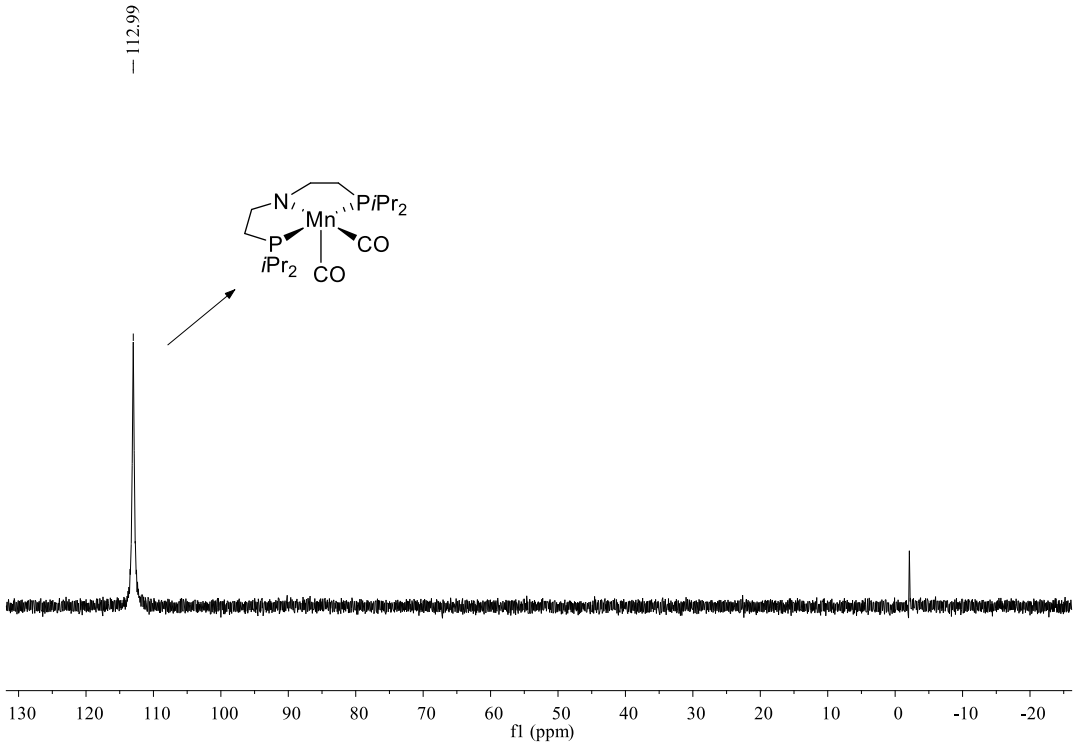
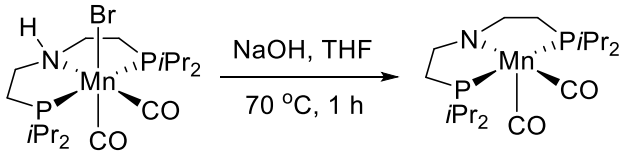


Figure S1. ^{31}P NMR (162 MHz, C_6D_6) of **[Mn]-D**

Conversion of [Mn]-1 to [Mn]-D with NaOH



[Mn]-1 **[Mn]-D**

100 % Conversion

A 10 mL dried Schlenk bottle was charged with complex **[Mn]-1** (0.02 mmol, 10 mg), 100 equiv. of NaOH (2 mmol, 80 mg) and dry THF (2 mL) in sequence. The solution was stirred at 70 °C for 1 h and then the resulting solution was submitted to ^{31}P NMR investigation. ^{31}P NMR (162 MHz, THF). δ 113.23 (s) for **[Mn]-D**.

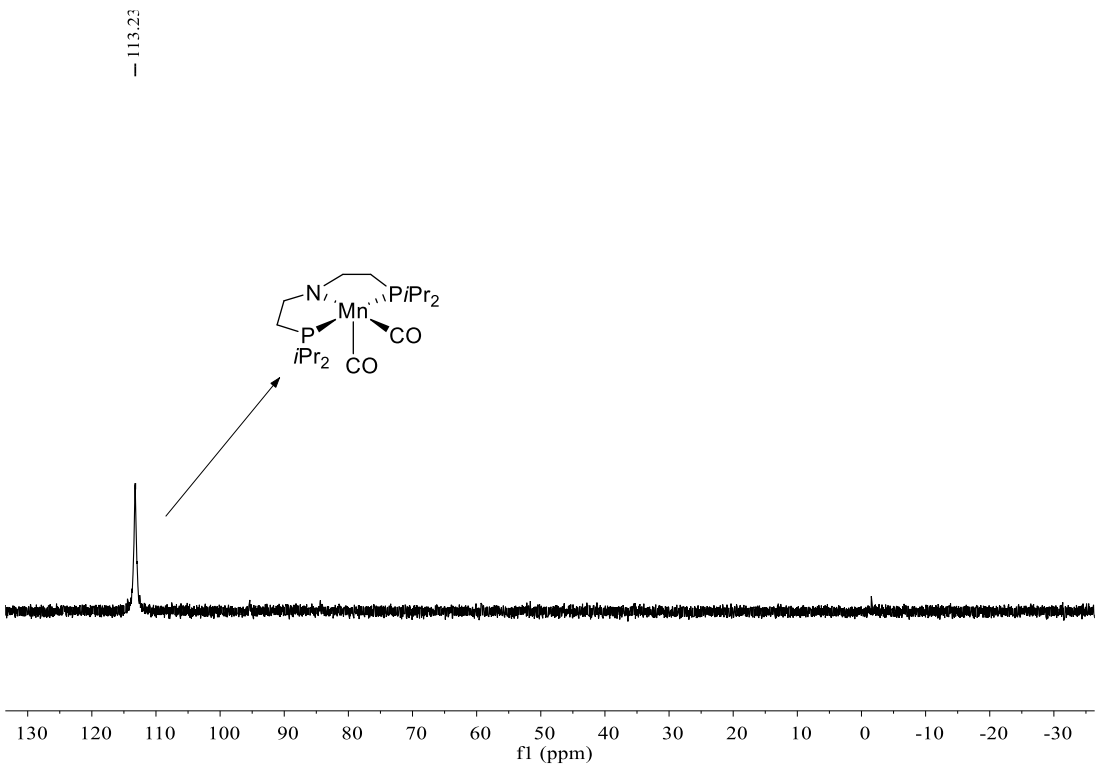
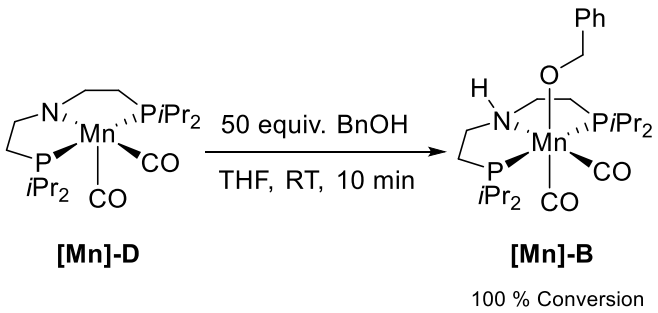


Figure S2. ^{31}P NMR (162 MHz, THF). **[Mn]-1** (0.02 mmol) and NaOH (2 mmol) was dispersed in THF (2 mL), The mixture was stirred at 70 °C for 1 h.

Benzyloxy manganese Complex [Mn]-B



[Mn]-D **[Mn]-B**

100 % Conversion

A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 50 equiv. of BnOH (0.5 mmol, 50 μL) in sequence. The solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. ^{31}P NMR (162 MHz, THF) δ 84.67 (br) for **[Mn]-B**.

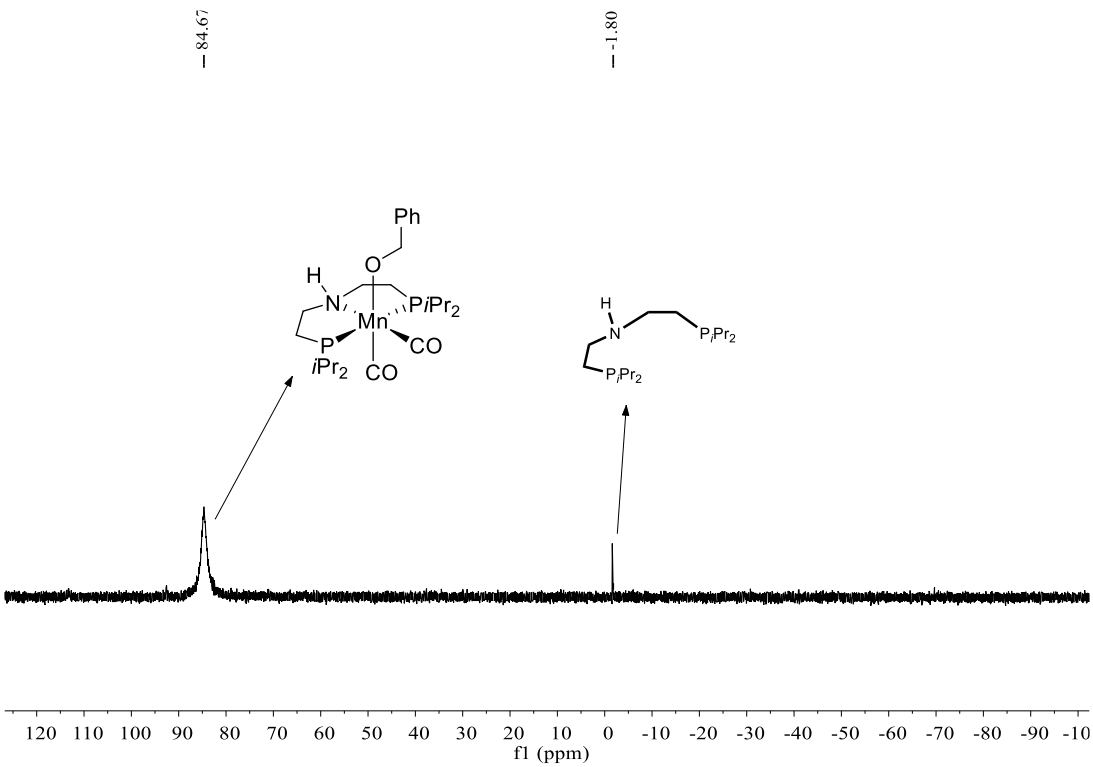
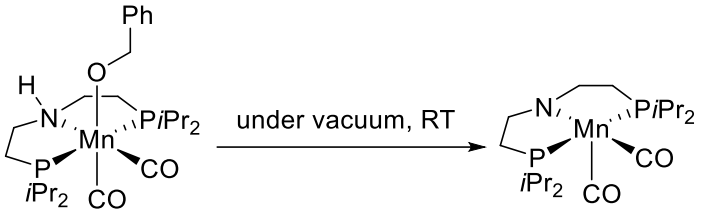


Figure S3. ^{31}P NMR (162 MHz, THF). Addition of 50 equiv. of BnOH to amido species **[Mn]-D**.

Reactivity of [Mn]-B in vacuum



[Mn]-B **[Mn]-D**

15 % Conversion

A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 50 equiv. of BnOH (0.5 mmol, 50 μL) in sequence. **[Mn]-B** was formed rapidly. And then the mixture was concentrated in vacumm (10 Pa) at room temperature. The residue was submitted to ^{31}P NMR investigation after 20 min.^{31}P NMR (162 MHz, THF). δ 112.95 (s) for **[Mn]-D**, 84.85 (br) for **[Mn]-B**.

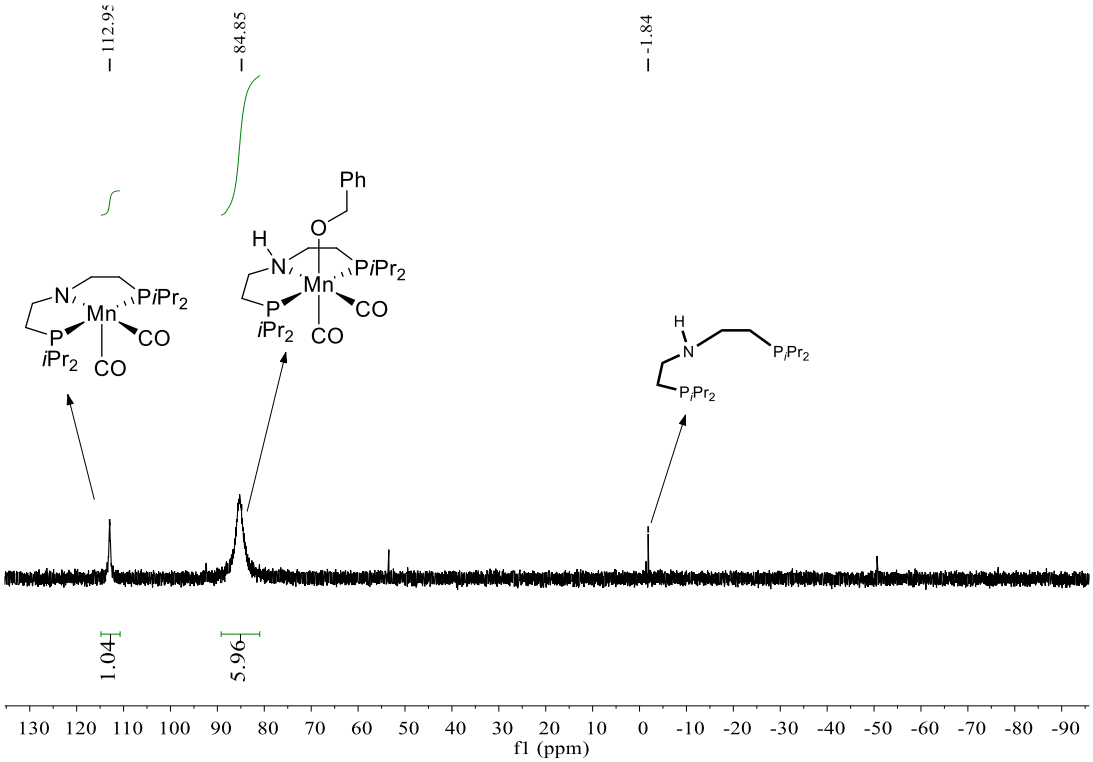
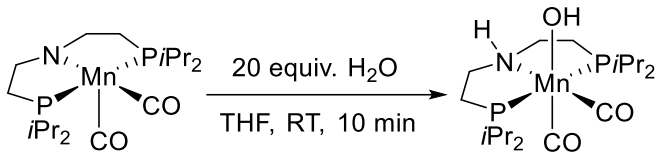


Figure S4. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and BnOH (0.5 mmol) was dissolved in THF (0.5 mL) at RT, **[Mn]-B** was rapidly formed. The volatiles were removed under vacuum.

Reactivity of [Mn]-1 with H_2O



[Mn]-D **[Mn]-A**

100 % Conversion

A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 20 equiv. of H_2O (0.2 mmol, 3.6 mg) in sequence. The solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. ^{31}P NMR (162 MHz, THF) δ 86.89 (br) for **[Mn]-A**.

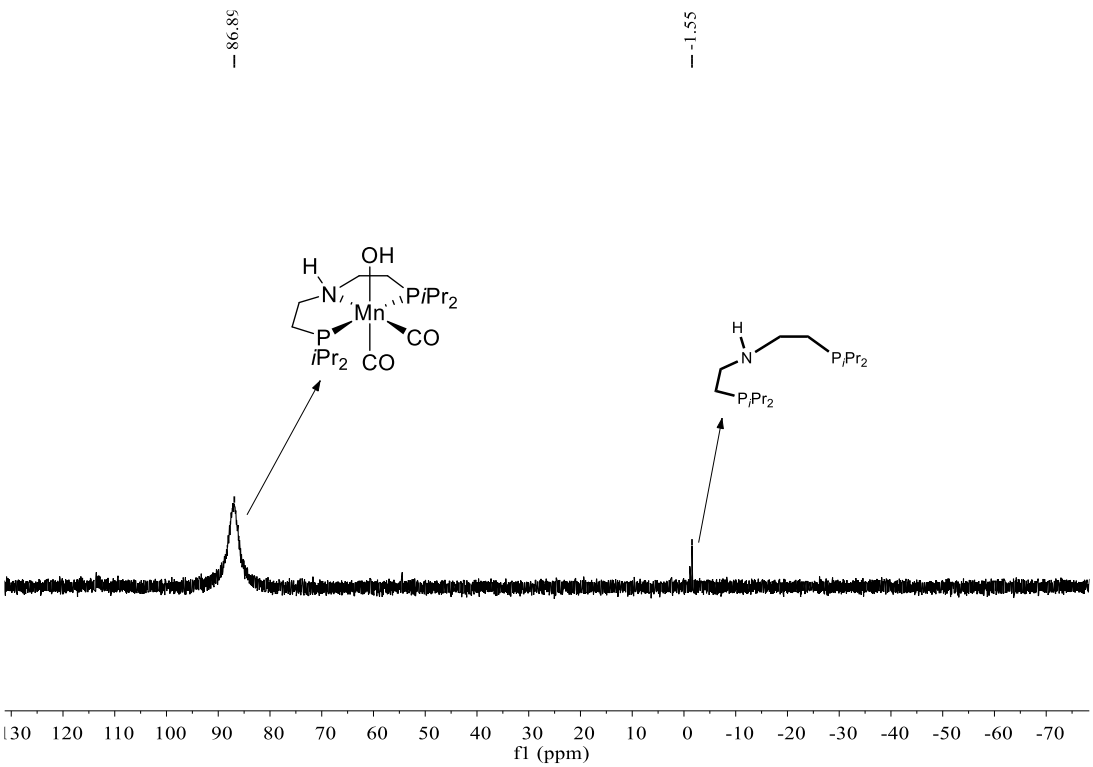
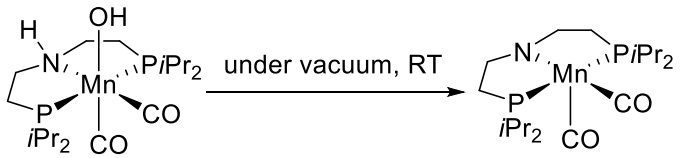


Figure S5. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (0.2 mmol) was dissolved in THF (0.5 mL) at RT.

Reactivity of [Mn]-A in vacumm



[Mn]-A **[Mn]-D**

100 % Conversion

A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), H_2O (0.2 mmol, 3.6 mg) and THF (0.5 mL) in sequence. The solution was stirred at room temperature for 10 min then concentrated in vacumm. The residue was submitted to ^{31}P NMR investigation.^{31}P NMR (162 MHz, THF). δ 113.23(s) for **[Mn]-D**.

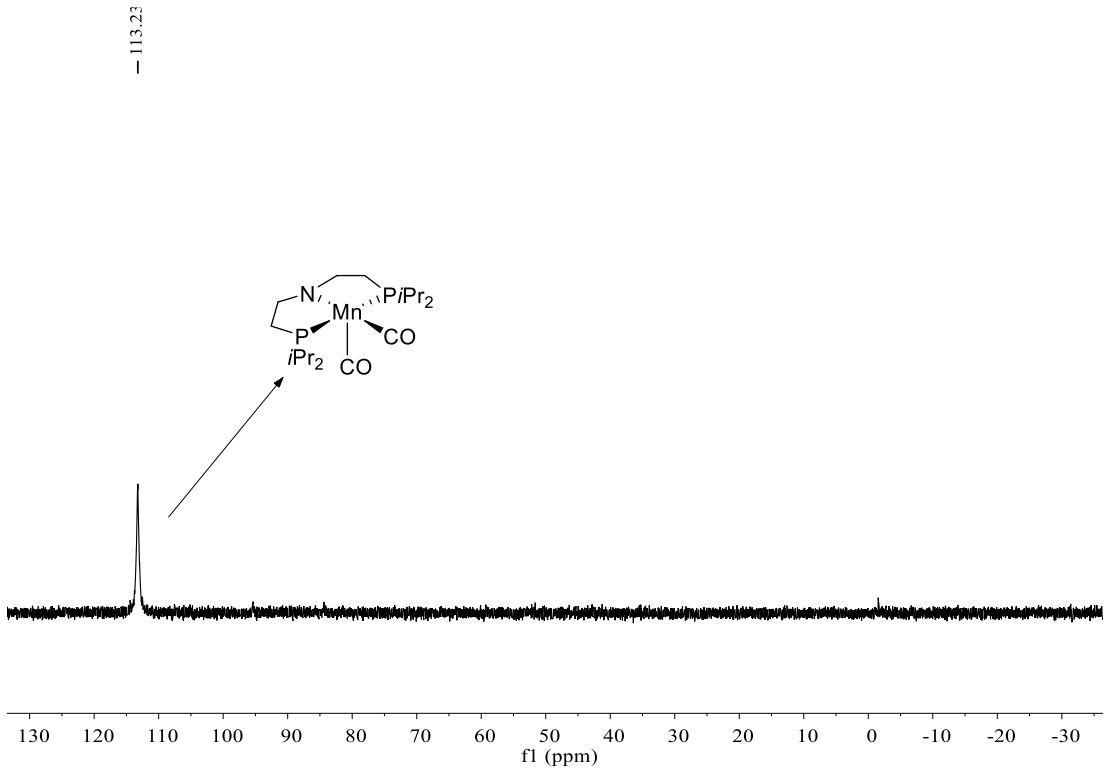
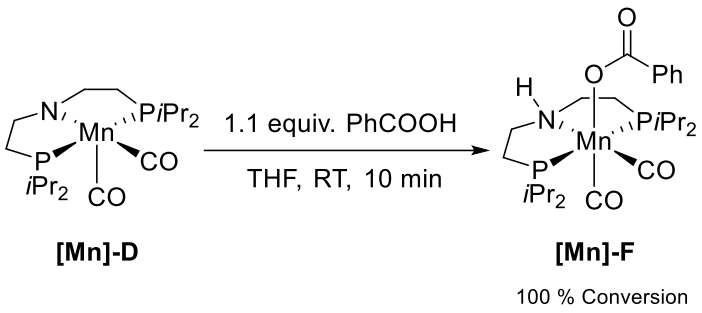


Figure S6. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (0.2 mmol) was dissolved in THF (0.5 mL) at RT, **[Mn]-A** was rapidly formed in 100% conversion. The volatiles were removed under vacuum.

Reactivity of [Mn]-D with PhCOOH



[Mn]-D **[Mn]-F**

100 % Conversion

A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 1.1 equiv. of PhCOOH (0.011 mmol, 1.3 mg) in sequence. The solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. ^{31}P NMR (162 MHz, THF) δ 88.17 (s) for **[Mn]-F**.

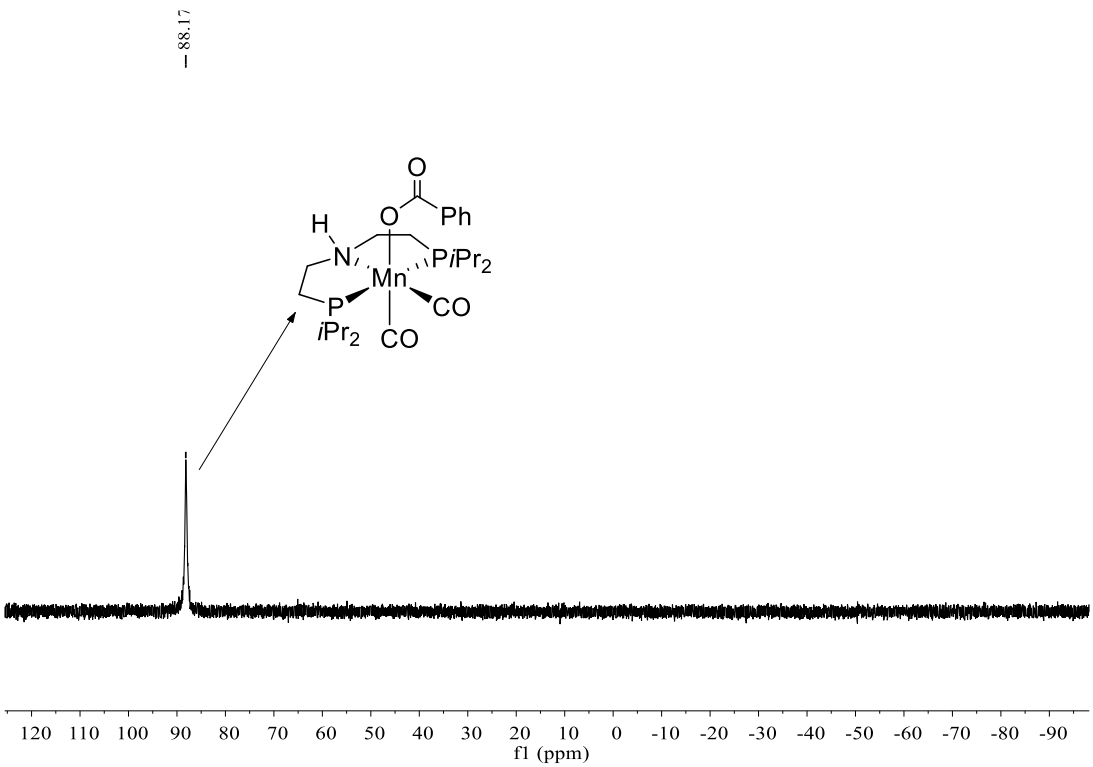


Figure S7. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and PhCOOH (0.011 mmol) was dissolved in THF (0.5 mL) at RT.

The solid structure of **[Mn]-F** was obtained by the slow diffusion of hexane to the **[Mn]-F** solution in dichloromethane.

^{1}H NMR (400 MHz, C_6D_6) δ 8.95 (s, 1H), 8.37 (d, *J* = 7.2 Hz, 2H), 7.20-7.15 (m, 3H), 2.97 (br, 2H), 2.18 (s, 4H), 1.93 (s, 2H), 1.73 (s, 4H), 1.34 (m, 18H), 0.83 (s, 6H). ^{13}C NMR (101 MHz, C_6D_6) δ 130.2, 52.50（*J* = 5.5 Hz,）, 27.57（*J* = 5.5 Hz）, 26.24 (*J* = 7.7 Hz), 24.14 (*J* = 10.1 Hz), 20.12, 20.01, 18.46, 17.40. ^{31}P NMR (162 MHz, C_6D_6) δ 87.87 (s).[2]

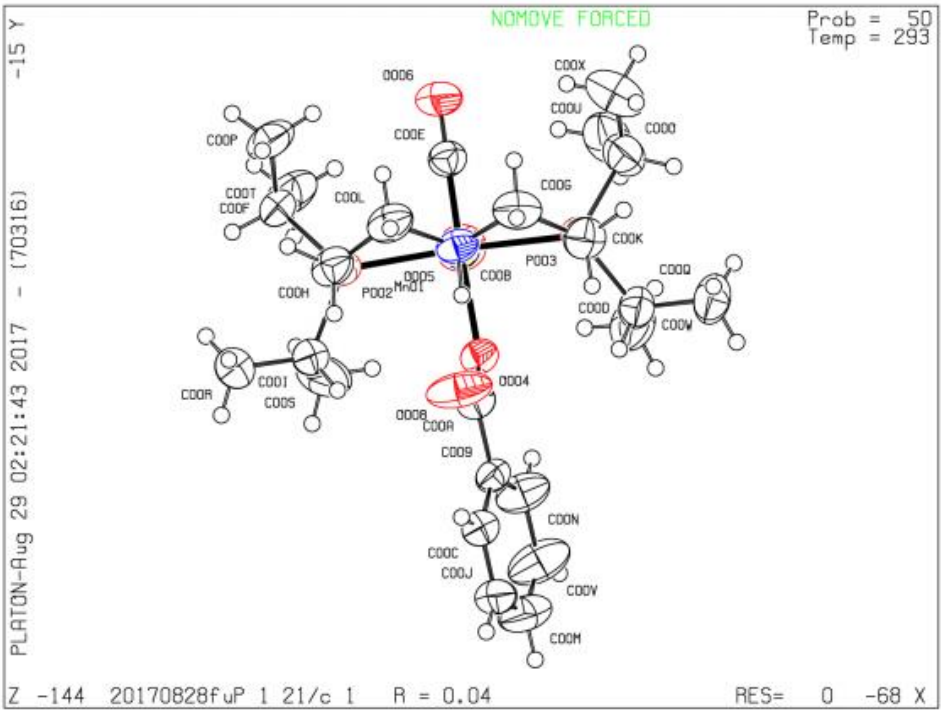
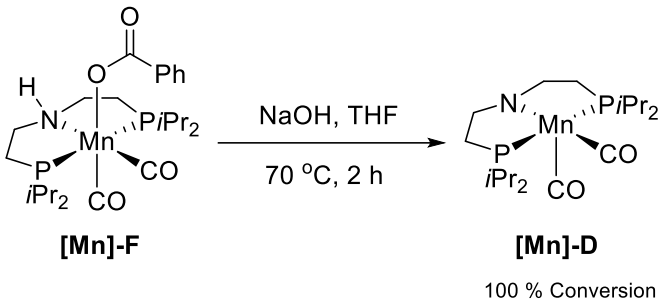


Figure S8. Crystal structure of complex **[Mn]-F** .

Crystallographic data of **[Mn]-F**

CCDC number	Formula	Crystal system	Space group	a[Å]	b[Å]	c[Å]
1571240	$C_{25}H_{42}MnNO_4P_2$	Monoclinic	P 1 21/c 1	10.3240(2)	15.3363(3)	17.7097(4)
α[°]	β[°]	γ[°]	Cell volume[Å^3]	Z	Crystal size[mm^3]	Density [mg/cm^3]
90	92.367(2)	90	2801.62(10)	4	0.1*0.2*0.2	1.274
T[K]	Theta range[°]	Reflections collected	Independent reflections	Data/ restraints/ parameters	Goodness-of-fit on F^2	
293(2)	4.2660 to 65.6780	10165	9849[R(int)= 0.0245]	4691/0/306	1.050	

Conversion of [Mn]-F to [Mn]-D with NaOH



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 10 mg) and dry THF (0.5 mL) in sequence, then 1.1 equiv. of PhCOOH (0.011 mmol, 1.3 mg) was added. The colour of the solution

was soon changed into luminous yellow from dark red. After that 100 equiv. of NaOH (1 mmol, 40 mg) was added. The solution was stirred at 70 °C for 2 h and then the resulting solution was cooled down to RT and submitted to ^{31}P NMR investigation. ^{31}P NMR (162 MHz, THF). δ 113.18 (s) for **[Mn]-D**.

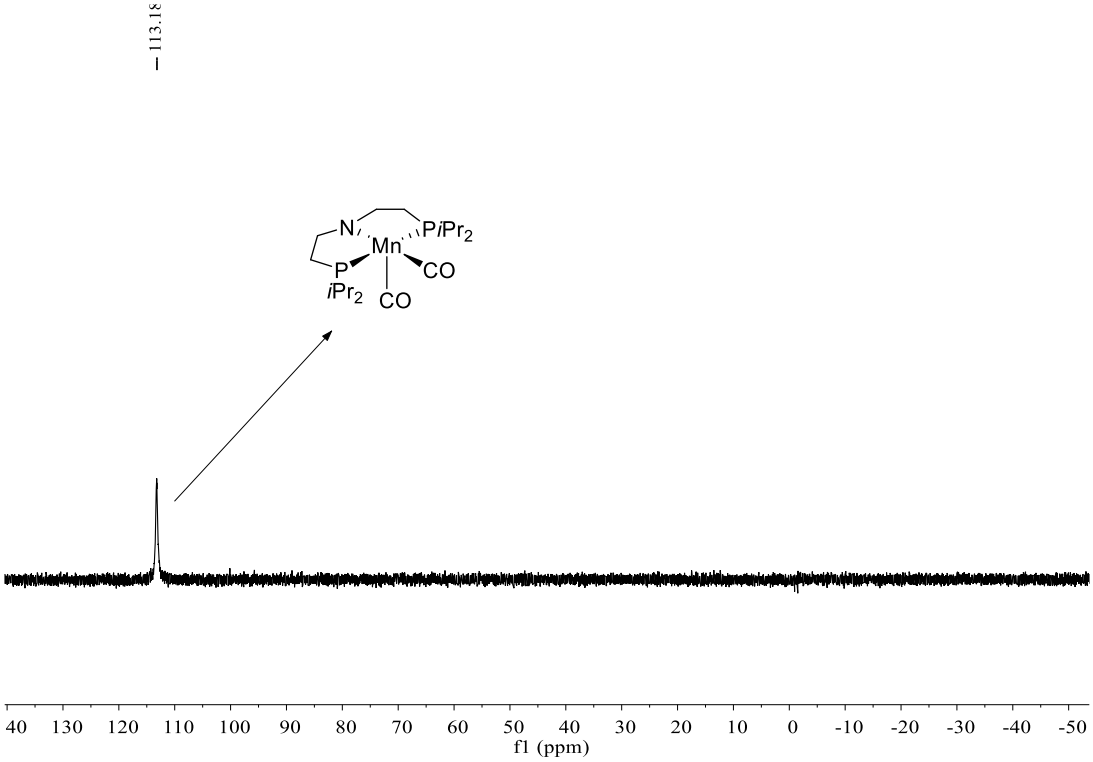
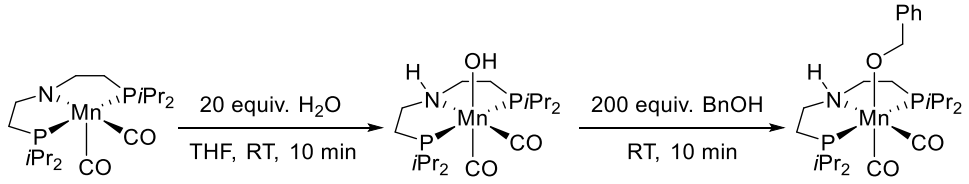


Figure S9. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and PhCOOH (0.011 mmol) was dissolved in THF (0.5 mL), **[Mn]-F** was rapidly formed in 100% conversion. The mixture was heated to 70 °C for 2 h.

Conversion of [Mn]-A to [Mn]-B with BnOH



A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 20 equiv. of H_2O (0.2 mmol, 3.6 mg) in sequence. The solution was stirred at room temperature for 10 min and then 200 equiv. of BnOH (2 mmol, 200 μL) was added. The resulted solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. Low temperature NMR was investigated in order to completely separate the ^{31}P NMR signals of **[Mn]-A** and **[Mn]-B**. ^{31}P NMR (162 MHz, THF) δ 84.15 (s) for **[Mn]-B**, 86.89 (s) for **[Mn]-A** at RT.

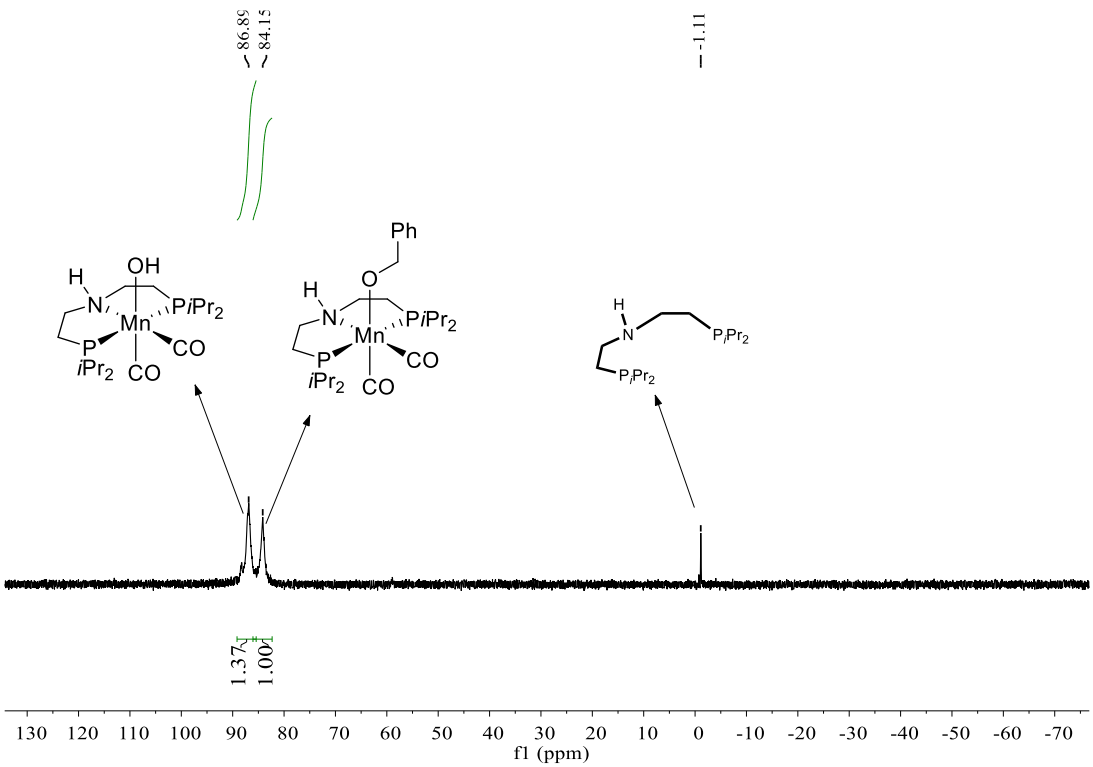


Figure S10. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (0.2 mmol) was dissolved in THF (0.5 mL), **[Mn]-A** was formed rapidly at RT. And then BnOH (2 mmol, 200 μL) was added.

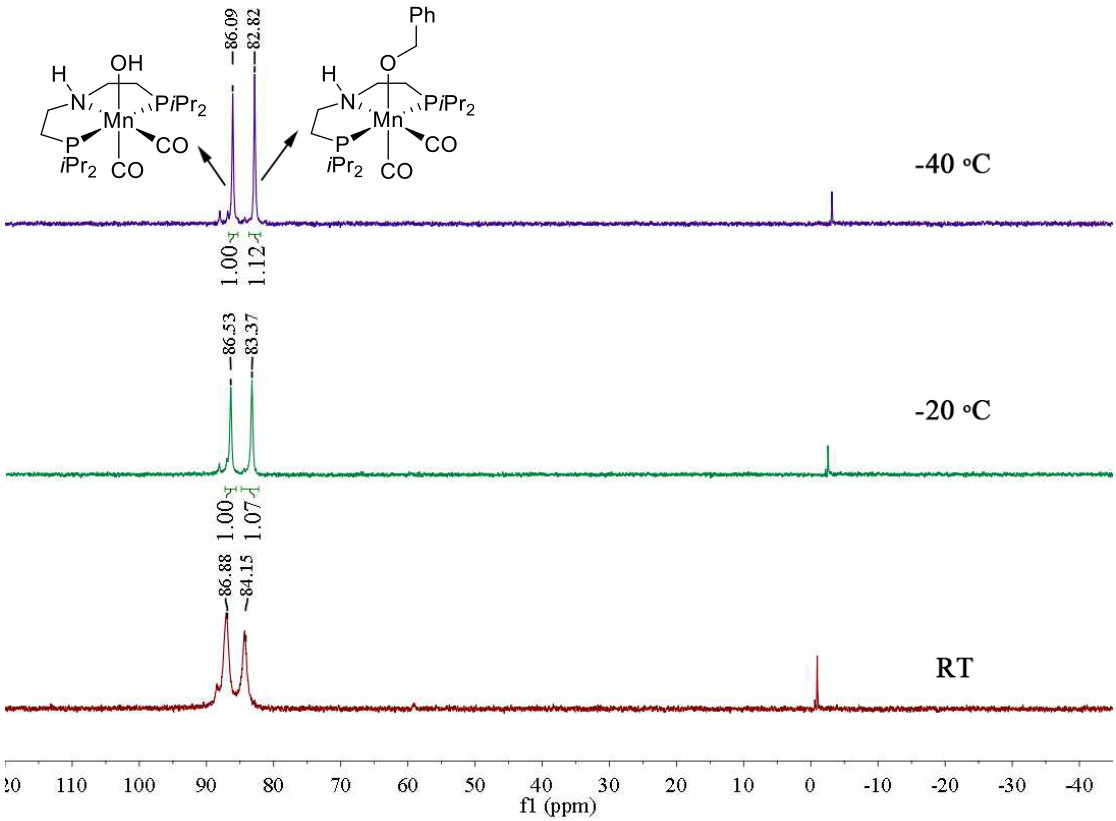
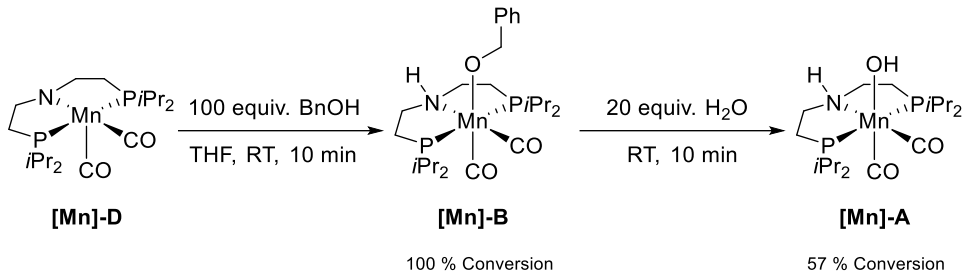


Figure S11. ^{31}P NMR (162 MHz, THF) investigated at different temperature.

Conversion of [Mn]-B to [Mn]-A with H_2O



A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 100 equiv. of BnOH (1 mmol, 100 μL) in sequence. The solution was stirred at room temperature for 10 min and then 20 equiv. of H_2O (0.2 mmol, 3.6 mg) was added. The resulted solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. Low temperature NMR was investigated in order to completely separate the ^{31}P NMR signals of **[Mn]-A** and **[Mn]-B**. ^{31}P NMR (162 MHz, THF) δ 84.45 (s) for **[Mn]-B**, 86.37 (s) for **[Mn]-A** at RT.

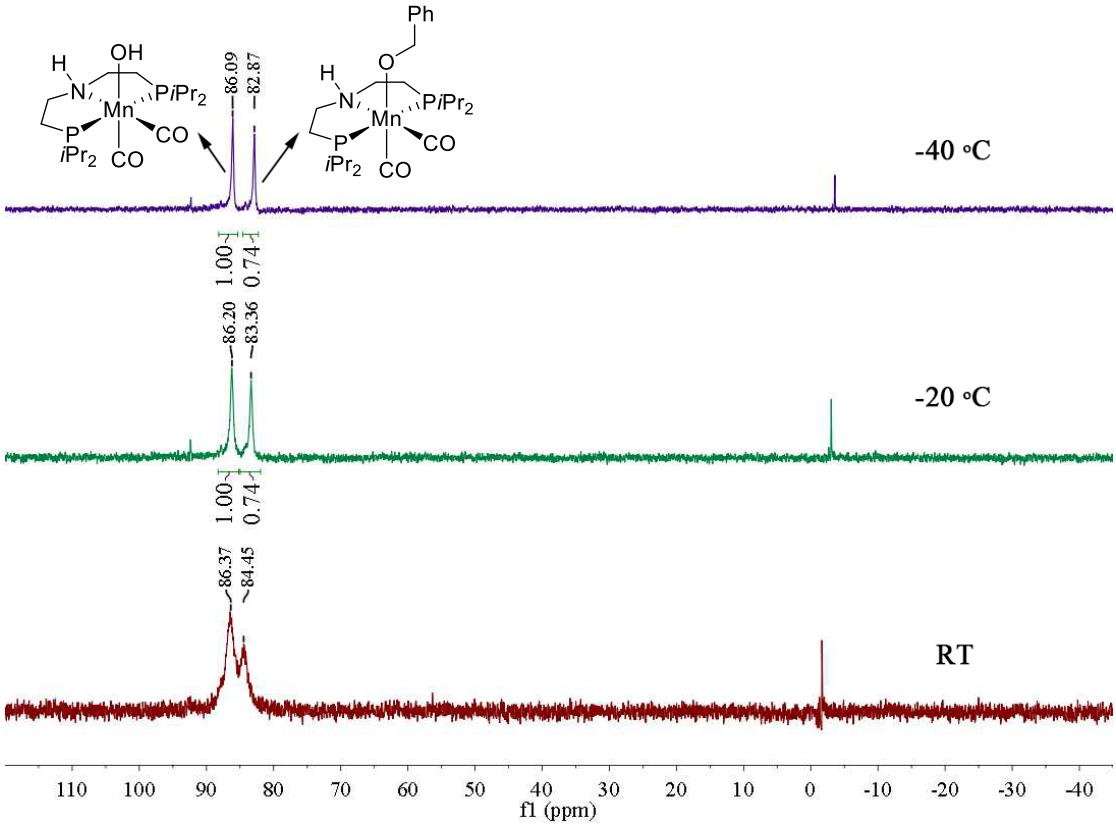
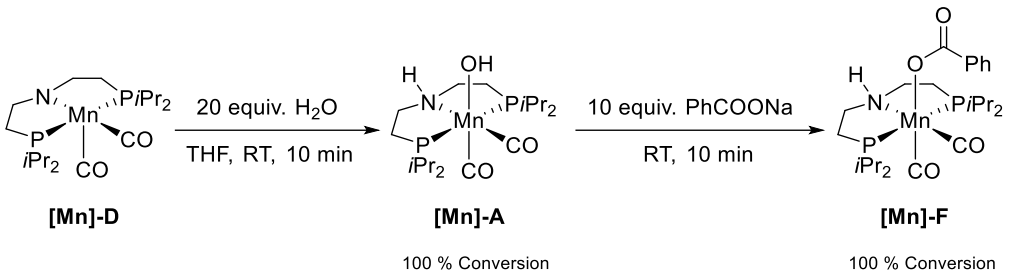


Figure S12. ^{31}P NMR (162 MHz, THF) investigated at different temperature. **[Mn]-D** (0.01 mmol) and BnOH (1 mmol, 100 μL) was dissolved in THF (0.5 mL), **[Mn]-B** was formed rapidly at RT. And then H_2O (0.2 mmol) was added.

Conversion of [Mn]-A to [Mn]-F with PhCOONa



A dried NMR tube was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 20 equiv. of H_2O (0.2 mmol, 3.6 mg) in sequence. **[Mn]-A** was formed rapidly and then 10 equiv. of PhCOONa (0.1 mmol, 14.5 mg) was added. The resulted solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 10 min. ^{31}P NMR (162 MHz, THF) δ 88.14 (s) for **[Mn]-F**.

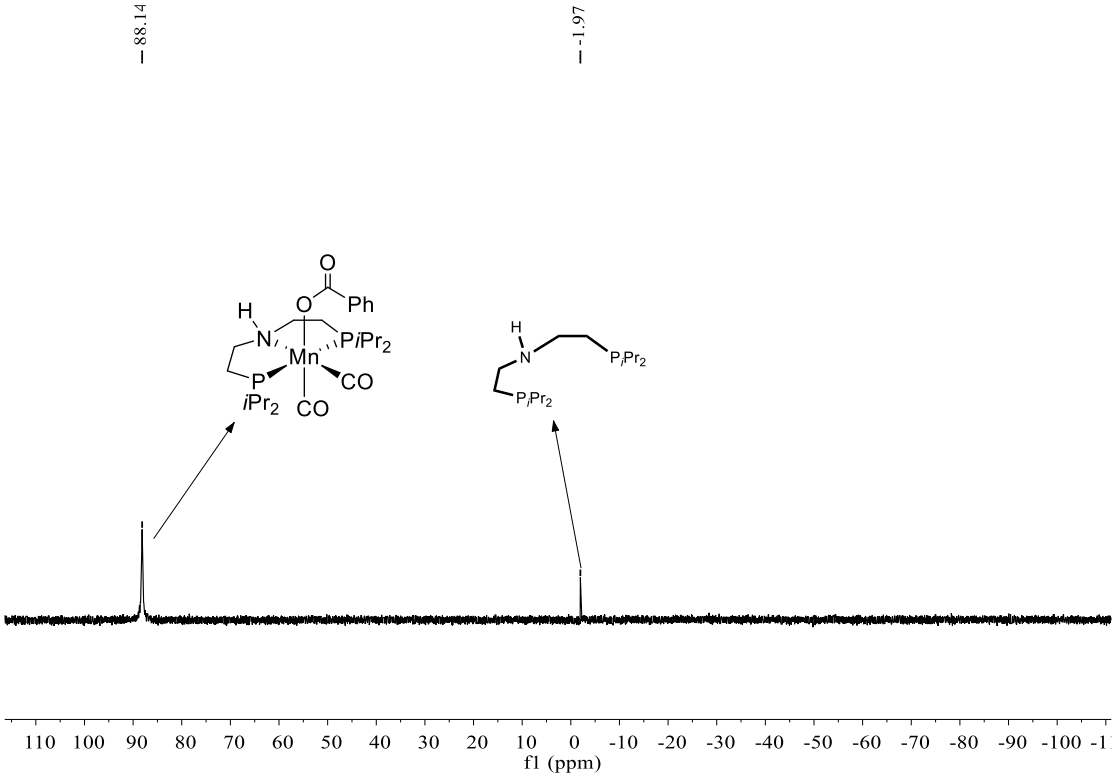
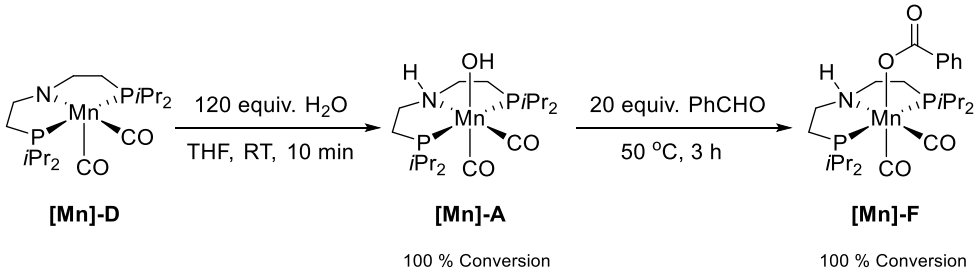


Figure S13. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (0.2 mmol) was dissolved in THF (0.5 mL), **[Mn]-A** was formed rapidly at RT. And then PhCOONa (0.1 mmol, 14.5 mg) was added.

Conversion of [Mn]-A to [Mn]-F with PhCHO



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 120 equiv. of H_2O (1.2 mmol, 21.6 mg) in sequence. **[Mn]-A** was formed rapidly. And then 20

equiv. of PhCHO (0.2 mmol, 20 μL) was added. The resulted solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 6 h. **[Mn]-A** was not fully converted into **[Mn]-F** at room temperature.[3] Nevertheless, we found that this reaction could reached almost 100 % conversion after heating at 50 ºC for 3 hourss. ^{31}P NMR (162 MHz, THF) δ 88.01 (s) for **[Mn]-F**.

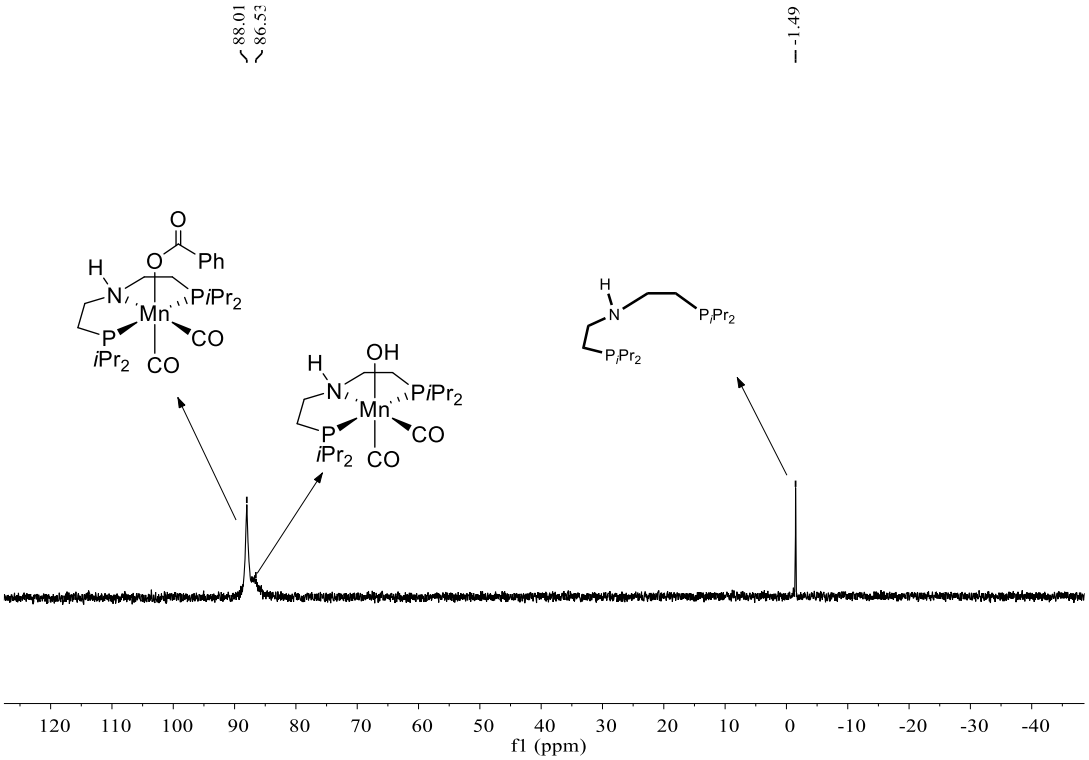


Figure S14. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (1.2 mmol) was dissolved in THF (0.5 mL), **[Mn]-A** was formed rapidly at RT. And then PhCHO (0.2 mmol, 20 μL) was added. The mixture was stirred at RT for 6 h.

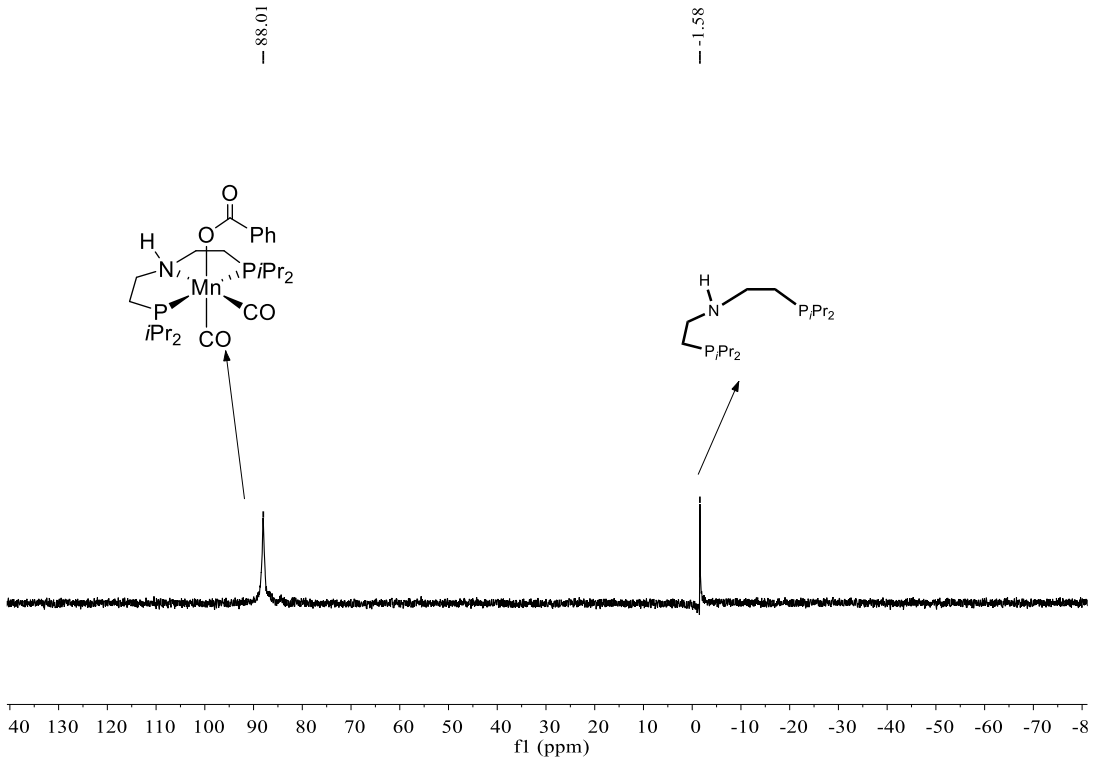
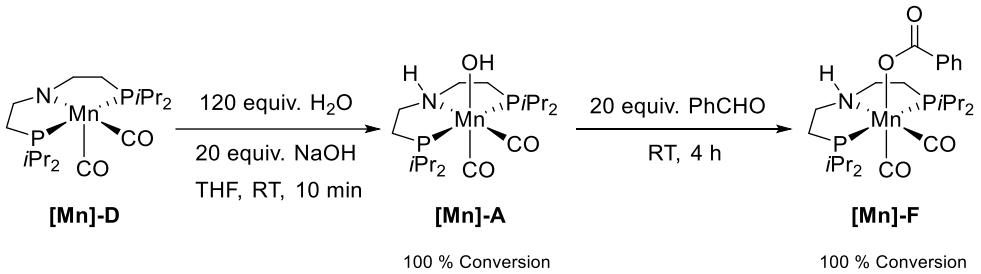


Figure S15. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol) and H_2O (1.2 mmol) was dissolved in THF (0.5 mL), Then PhCHO (0.2 mmol, 20 μL) was added after stirring at RT for 6 h and then heated at 50 ºC for 3 h.

Conversion of [Mn]-A to [Mn]-F with NaOH and PhCHO



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL), 120 equiv. of H_2O (1.2 mmol, 21.6 mg) and 20 equiv. of NaOH (0.2 mmol, 8 mg) in sequence. **[Mn]-A** was formed rapidly. And then 20 equiv. of PhCHO (0.2 mmol, 20 μL) was added. The resulted solution was submitted to ^{31}P NMR investigation after stirring at room temperature for 4 h. ^{31}P NMR (162 MHz, THF) δ 88.01 (s) for **[Mn]-F**.

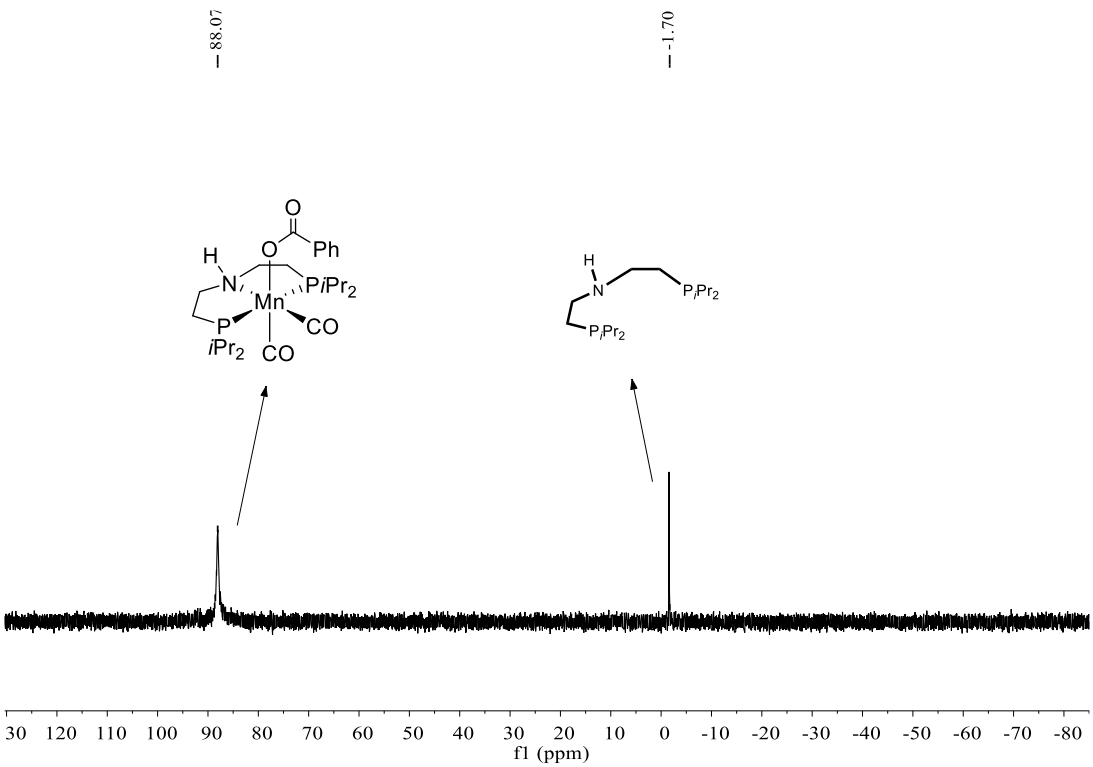
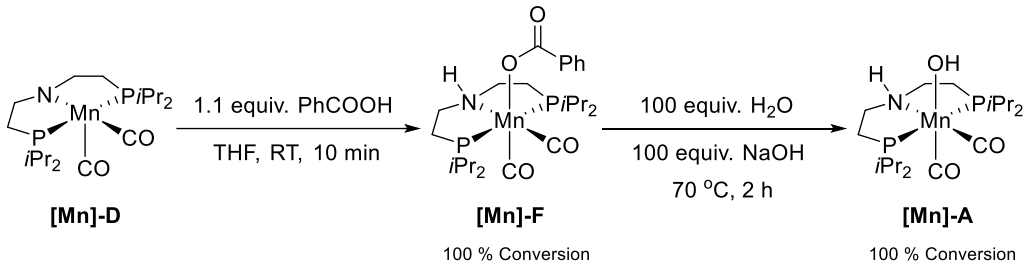


Figure S16. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol), NaOH (0.2 mmol, 8 mg) and H_2O (1.2 mmol) was dissolved in THF (0.5 mL), **[Mn]-A** was formed rapidly at RT. And then PhCHO (0.2 mmol, 20 μL) was added.

Conversion of [Mn]-F to [Mn]-A with NaOH and H_2O



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 1.1 equiv. of PhCOOH (0.011 mmol, 1.3 mg) in sequence. The colour of the solution was soon changed 100 equiv. of NaOH (1 mmol，40 mg) and H_2O (1 mmol, 18 mg) was added. The mixture wa into luminous yellow from dark red. After that s stirred at 70 ºC for 2 h and then the resulting solution was cooled down to RT and submitted to ^{31}P NMR investigation. **[Mn]-A** and **[Mn]-D** was both existing at RT. **[Mn]-A** was predominant at lower temperature for NMR measurement. ^{31}P NMR (162 MHz, THF). δ 113.01 (s) for **[Mn]-D**, 86.72 (s) for **[Mn]-A** at RT.

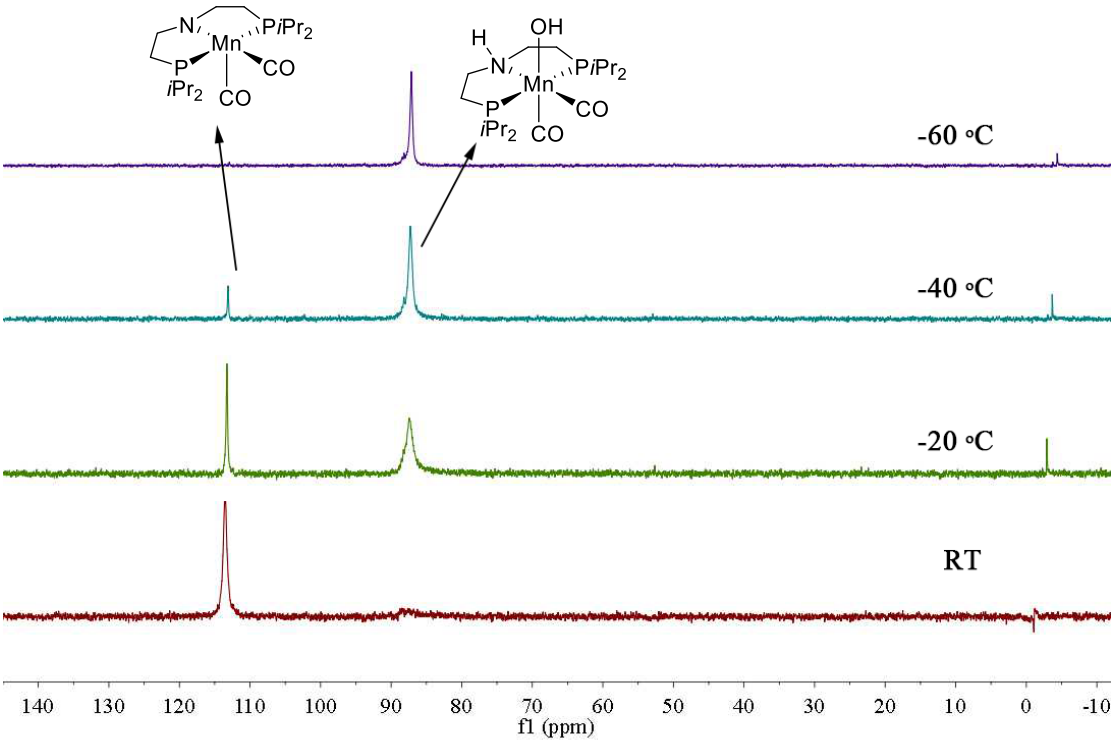
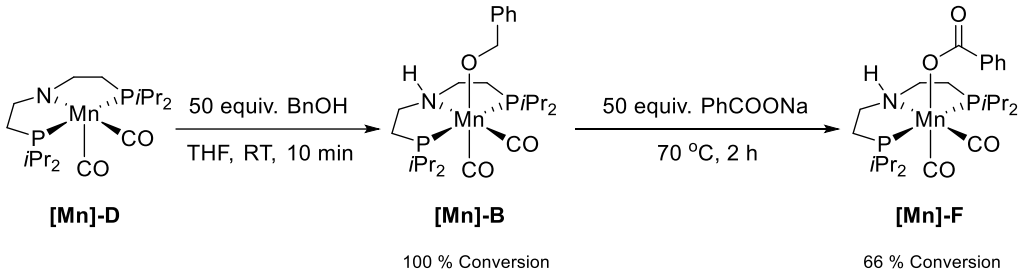


Figure S17. ^{31}P NMR (162 MHz, THF) investigated at different temperature. **[Mn]-D** (0.01 mmol, 4.2 mg) and PhCOOH (0.011 mmol, 1.3 mg) was dissolved in THF (0.5 mL). And then NaOH (1 mmol, 40 mg) and H_2O (1 mmol, 18 mg) was added, the mixture was heated to 70 °C for 2 h.

Conversion of [Mn]-B to [Mn]-F with PhCOONa



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (1 mL) and 50 equiv. of BnOH (0.5 mmol, 50 μL) in sequence. **[Mn]-B** was formed rapidly. And then 50 equiv. of PhCOONa (0.5 mmol, 74 mg) was added. The mixture was stirred at 70 °C for 2 h and then the resulting solution was cooled down to RT and submitted to ^{31}P NMR investigation. ^{31}P NMR (162 MHz, THF) δ 88.01 (s) for **[Mn]-F**.

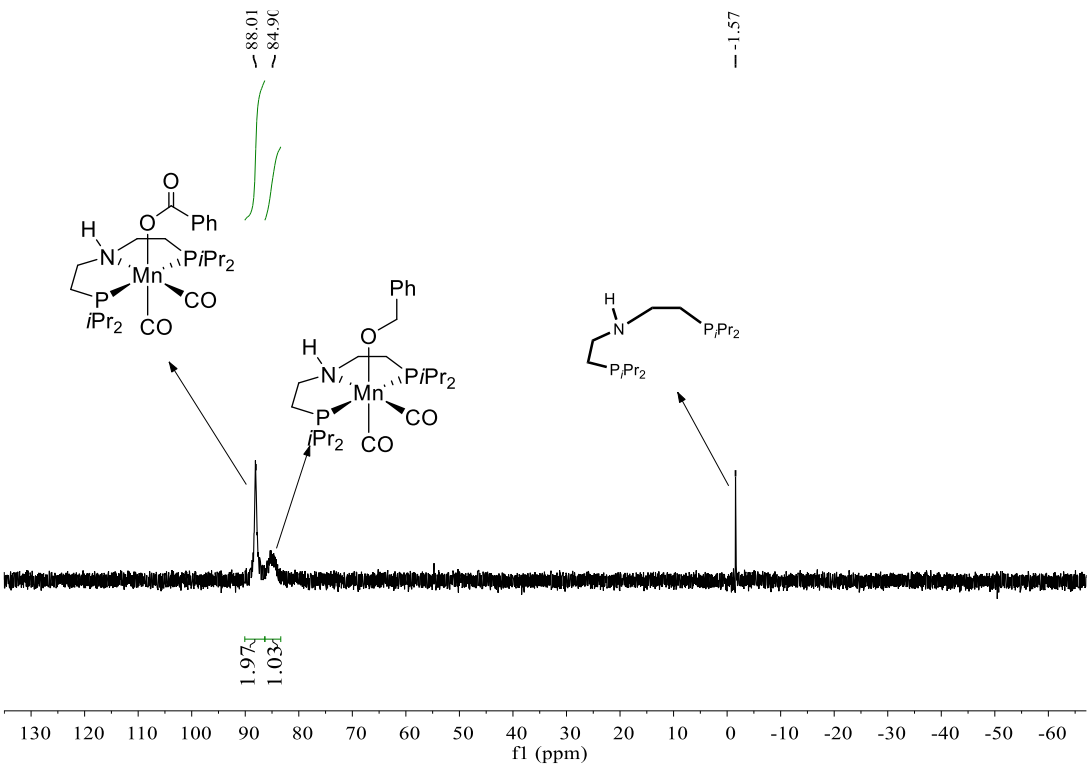
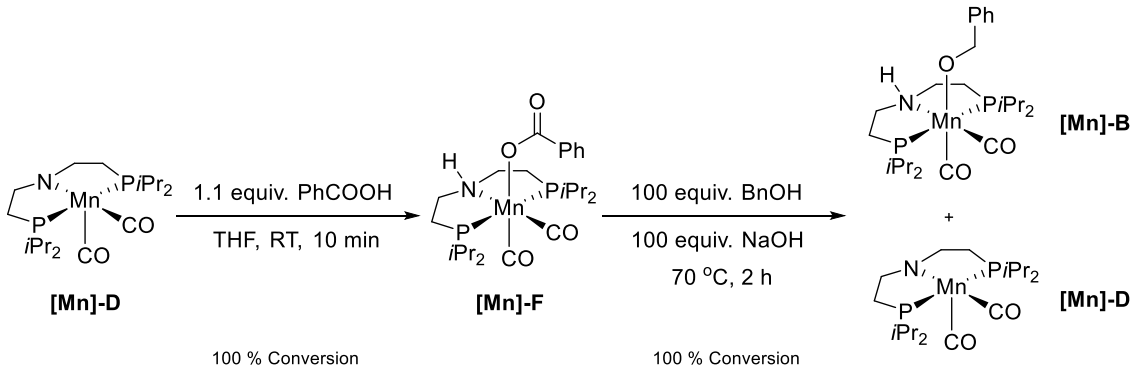


Figure S18. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol, 4.2 mg) and BnOH (0.5 mmol, 50 μL) was dissolved in THF (0.5 mL). And then PhCOONa (0.5 mmol, 74 mg) was added, the mixture was heated to 70 ºC for 2 h.

Conversion of [Mn]-F to [Mn]-B with NaOH and BnOH



A 10 mL dried Schlenk bottle was charged with complex **[Mn]-D** (0.01 mmol, 4.2 mg), dry THF (0.5 mL) and 1.1 equiv. of PhCOOH (0.011 mmol, 1.3 mg) in sequence. The colour of the solution was soon changed into luminous yellow from dark red. After that 100 equiv. of NaOH (1 mmol，40 mg) and BnOH (1 mmol, 100 μL) was added. The mixture was stirred at 70 ºC for 2 h and then the resulting solution was cooled down to RT and submitted to ^{31}P NMR investigation. ^{31}P NMR (162 MHz, THF). δ 113.15 (s) for **[Mn]-D**, 94.31 (s) for **[Mn]-B´**, 84.90 (s) for **[Mn]-B**.

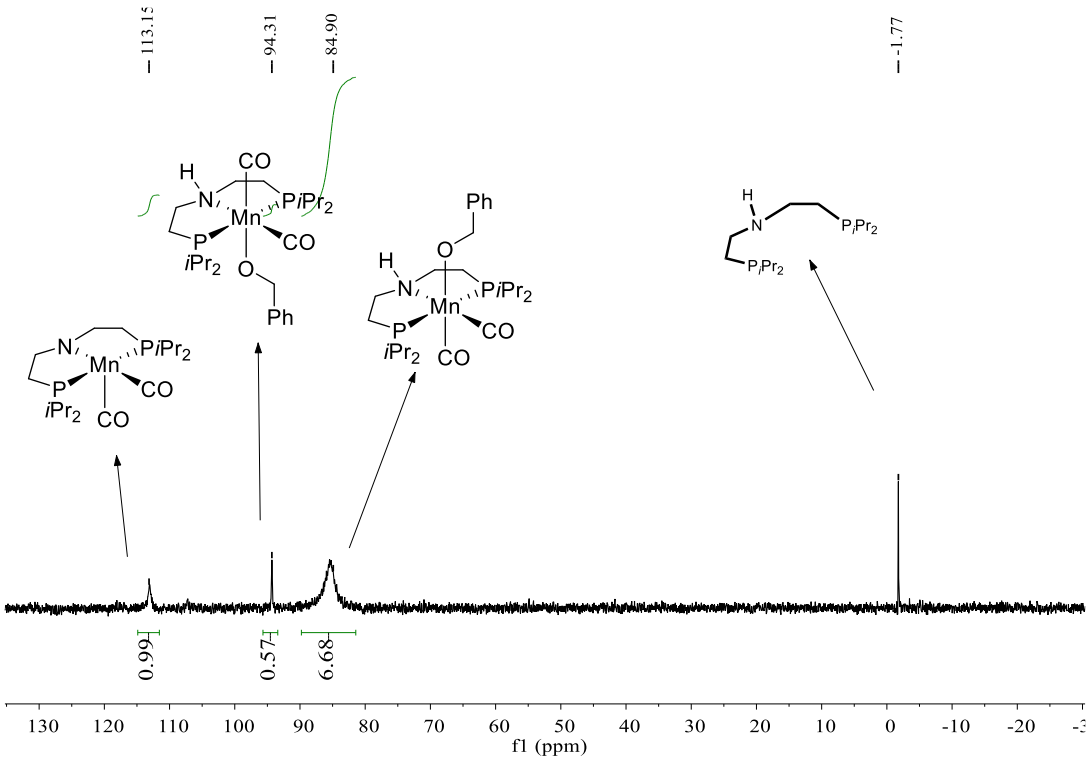
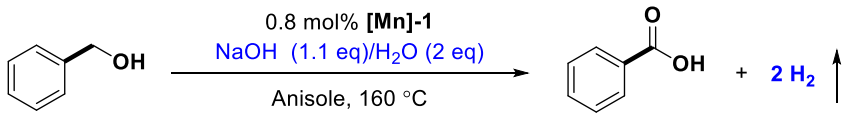


Figure S19. ^{31}P NMR (162 MHz, THF). **[Mn]-D** (0.01 mmol, 4.2 mg) and PhCOOH (0.011 mmol, 1.3 mg) was dissolved in THF (0.5 mL). And then NaOH (1 mmol, 40 mg) and BnOH (1 mmol, 100 μL) was added, the mixture was heated to 70 ºC for 2 h.

^{31}P NMR Study for the Resting State of the Catalytic Cycle



1a **2a**

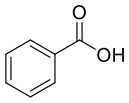
Under the protection of argon, benzyl alcohol **1a** (5 mmol), **[Mn]-1** (19.6 mg, 0.04 mmol, 0.8 mol%), NaOH (220 mg, 5.5 mmol, 1.1 equiv), degassed water (180 μL, 10 mmol, 2 eq), anisole (2 mL) and diphenyl (50 mg) were added sequentially to a 25 mL three-necked round-bottomed flask equipped with a magnetic stir bar. The reaction was stirred at 160 ºC for 16 hours under an argon atmosphere open to a bubbler. 0.2 mL solution was taken from the reaction mixtures under argon protection and diluted by THF to 0.5 mL. And then the above solution was submitted to ^{31}P NMR and GC analysis. The manganese species observed in the catalytic reaction were detected by ^{31}P NMR which was carried out at -20 ºC in order to completely separate the ^{31}P NMR signals of all species. The conversion of benzyl alcohol **1a** was determined by GC results.

Table S3: ^{31}P NMR Study for the Resting State of the Catalytic Cycle

	n_{1a} (mmol) / Conv.(%)	Mn Complexs
15 min	4.56 / 9	**[Mn]-A, [Mn]-B, [Mn]-F** 4.2 : 8.4 : 1
30 min	4.46 / 11	**[Mn]-A, [Mn]-B, [Mn]-F** 9.3 : 33.3 : 1
50 min	2.82 / 44	**[Mn]-A, [Mn]-B** 1 : 5
90 min	2.12 / 58	**[Mn]-A, [Mn]-B** 1 : 6.25

Characterization data of aromatic acids 2

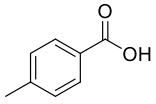
Benzoic acid 2a[4]



2a

Product was isolated as white solid (96 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.98 (s, 1H), 8.28 – 7.85 (m, 2H), 7.74 – 7.54 (m, 1H), 7.52 – 7.39 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.81, 133.23, 131.24, 129.73, 128.94.

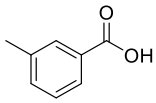
4-Methylbenzoic acid 2b[4]



2b

Product was isolated as white solid (95 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.76 (s, 1H), 7.84 (d, J = 8.2 Hz, 2H), 7.30 (d, J = 7.9 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 161.75, 143.46, 129.78, 129.57, 128.52, 21.58.

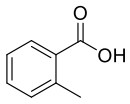
3-Methylbenzoic acid 2c[5]



2c

Product was isolated as white solid (93 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.85 (s, 1H), 8.07 – 7.62 (m, 2H), 7.49 – 7.20 (m, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.86, 138.33, 133.88, 131.20, 130.18, 128.88, 126.90, 21.25.

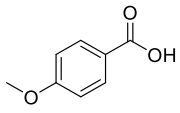
2-Methylbenzoic acid 2d[5]



2d

Product was isolated as white solid (93 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.78 (s, 1H), 8.15 – 7.65 (m, 1H), 7.62 – 7.35 (m, 1H), 7.29 (d, J = 7.7 Hz, 2H), 2.53 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 169.13, 139.42, 132.11, 131.93, 130.95, 130.61, 126.65, 21.65.

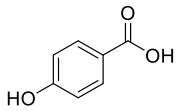
4-Methoxybenzoic Acid 2e[6]



2e

Product was isolated as white solid (88 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.60 (s, 1H), 7.90 (d, J = 8.7 Hz, 2H), 7.02 (d, J = 8.8 Hz, 2H), 3.83 (s, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.45, 163.30, 1331.79, 123.46, 114.25, 55.8.

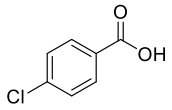
4-Hydroxybenzoic acid 2f[7]



2f

Product was isolated as white solid (61 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.39 (s, 1H), 10.27 (s, 1H), 7.80 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.63, 162.05, 131.99, 121.81, 115.57.

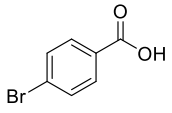
4-Chlorobenzoic acid 2g[4]



2g

Product was isolated as white solid (92 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.16 (s, 1H), 7.95 (d, J = 8.7 Hz, 2H), 7.57 (dq, J = 6.6, 2.8, 2.3 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 166.91, 138.25, 131.59, 130.11, 129.20.

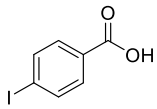
4-Bromobenzoic acid 2h[4]



2h

Product was isolated as white solid (91 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.16 (s, 1H), 7.87 (d, J = 8.4 Hz, 2H), 7.70 (ddd, J = 7.0, 4.5, 2.3 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.05, 132.13, 131.73, 130.48, 127.32.

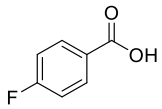
4-Iodobenzoic acid 2i[4]



2i

Product was isolated as white solid (88 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.96 – 7.79 (m, 2H), 7.78 – 7.57 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.36, 138.03, 131.52, 130.76, 101.55.

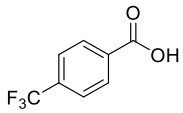
4-Fluorobenzoic acid 2j[4]



2j

Product was isolated as white solid (70 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.01 (s, 1H), 8.00 (ddd, J = 8.8, 5.7, 2.6 Hz, 2H), 7.27 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ166.82, 165.35 (d, J = 250.7 Hz), 132.50 (d, J = 9.4 Hz), 127.80 (d, J = 2.7 Hz), 115.95 (d, J = 22.0 Hz).

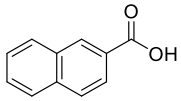
4-(Trifluoromethyl)benzoic acid 2k[4]



2k

Product was isolated as white solid (66 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.46 (s, 1H), 8.13 (d, J = 8.0 Hz, 2H), 7.85 (dd, J = 7.7, 5.0 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 135.05, 132.95 (q, J = 31.9 Hz), 130.53, 126.00 (q, J = 3.7 Hz), 124.25 (q, J = 272.7 Hz).

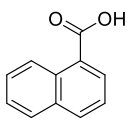
2-Naphthoic acid 2l[5]



2l

Product was isolated as white solid (89 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.09 (s, 1H), 8.63 (s, 1H), 8.11 (dd, J = 7.9, 1.5 Hz, 1H), 8.06 – 7.88 (m, 3H), 7.62 (dddd, J = 19.6, 8.1, 6.9, 1.4 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.92, 135.40, 132.62, 130.98, 129.72, 128.74, 128.60, 128.58, 128.10, 127.23, 125.64.

1-Naphthoic acid 2m[4]

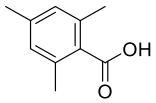


2m

Product was isolated as white solid (89 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.15 (s, 1H), 8.88 (d, J

= 8.4 Hz, 1H), 8.16 (dd, J = 7.9, 4.6 Hz, 2H), 8.02 (dd, J = 8.3, 4.2 Hz, 1H), 7.74 – 7.50 (m, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 169.12, 133.94, 133.38, 131.16, 130.31, 129.06, 128.21, 128.01, 126.64, 125.97, 125.34.

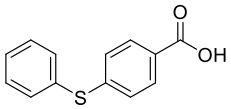
2,4,6-Trimethylbenzoic acid 2n[5]



2n

Product was isolated as white solid (57 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.97 (s, 1H), 6.88 (s, 2H), 2.24 (d, J = 3.4 Hz, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 171.29, 138.43, 134.10, 132.98, 128.43, 21.08, 19.78.

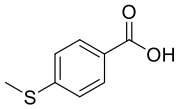
4-(Phenylthio)benzoic Acid 2o[8]



2o

Product was isolated as white solid (89 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.96 (s, 1H), 8.68 – 7.71 (m, 2H), 7.68 – 7.37 (m, 4H), 7.34 – 7.09 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.28, 143.24, 133.69, 132.13, 130.64,130.42, 129.34, 128.94, 128.08.

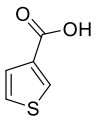
4-(Methylthio)benzoic acid 2p[9]



2p

Product was isolated as white solid (87 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.82 (s, 1H), 8.26 – 7.62 (m, 2H), 7.34 (dd, J = 8.5, 1.9 Hz, 2H), 2.53 (s, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.48, 145.23, 130.16, 127.20, 125.35, 14.44.

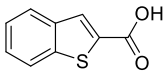
3-Thiophenezoic acid 2q[10]



2q

Product was isolated as white solid (76 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.69 (s, 1H), 8.93 – 8.13 (m, 1H), 7.60 (dt, J = 5.1, 3.2 Hz, 1H), 7.43 (dt, J = 5.0, 1.1 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 164.02, 134.78, 133.69, 128.20, 127.69, 127.67.

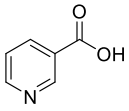
Thianaphthene-2-carboxylic acid 2r[11]



2r

Product was isolated as yellowish solid (59 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.42 (s, 1H), 8.12 (s, 1H), 8.09 – 7.89 (m, 2H), 7.65 – 7.14 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 163.98, 141.78, 139.18, 135.19, 130.71, 127.48, 126.20, 125.52, 123.43.

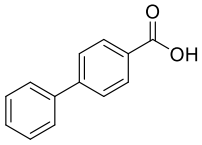
Nicotinic acid 2s[6]



2s

Product was isolated as white solid (85 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.18 (d, J = 2.0 Hz, 1H), 9.02 (dd, J = 5.4, 1.5 Hz, 1H), 8.73 (dt, J = 8.1, 1.7 Hz, 1H), 7.98 (dd, J = 8.0, 5.3 Hz, 1H). 13C NMR (101 MHz, DMSO-d_6) δ 164.78, 148.11, 145.62, 143.25, 129.47, 126.75.

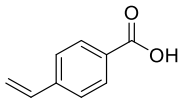
4-Biphenylcarboxylic acid 2t[5]



2t

Product was isolated as white solid (89 %). ^{1}H NMR (400 MHz, DMSO-d6) δ 8.03 (d, J = 8.3 Hz, 2H), 7.81 (d, J = 7.8 Hz, 2H), 7.74 (d, J = 7.6 Hz, 2H), 7.56 – 7.48 (m, 2H), 7.44 (d, J = 7.2 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d6) δ 167.60, 144.79, 139.49, 130.42, 130.08, 129.55, 128.75, 127.42, 127.27.

4-Vinylbenzoic acid 2u[4]

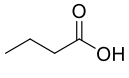


2u

Product was isolated as white solid (68 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.91 (s, 1H), 8.10 – 7.79 (m, 2H), 7.59 (d, J = 8.2 Hz, 2H), 6.81 (dd, J = 17.7, 10.9 Hz, 1H), 5.98 (d, J = 17.7 Hz, 1H), 5.41 (d, J = 11.0 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.51, 141.75, 136.30, 130.39, 130.13, 126.68, 117.44.

Characterization data of aliphatic acids 4

Butyric acid 4b[12]

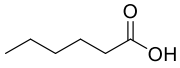


4b

Product was determined by NMR yield (54 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.93 (s, 1H), 2.16 (t,

J = 7.3 Hz, 2H), 1.51 (h, J = 7.3 Hz, 2H), 0.87 (t, J = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.75, 35.96, 18.35, 13.84.

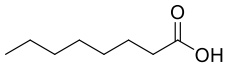
Hexanoic acid 4c[12]



4c

Product was determined by NMR yield (94 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.93 (s, 1H), 2.17 (t, J = 7.4 Hz, 2H), 1.49 (p, J = 7.3 Hz, 2H), 1.26 (m, 4H), 0.85 (s, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.86, 34.04, 31.25, 24.63, 22.30, 14.14.

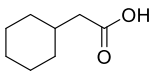
Octanoic acid 4d[13]



4d

Product was determined by NMR yield (88 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.93 (s, 1H), 2.17 (t, J = 7.4 Hz, 2H), 1.49 (t, J = 7.2 Hz, 2H), 1.24 (d, J = 4.0 Hz, 8H), 0.85 (t, J = 6.7 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.82, 34.09, 31.66, 29.03, 28.93, 24.97, 22.53, 14.26.

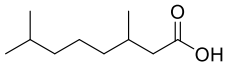
Cyclohexylacetic acid 4e[14]



4e

Product was isolated as colorless oil (83 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.98 (s, 1H), 2.06 (dd, J = 7.0, 2.9 Hz, 2H), 1.80 – 1.51 (m, 6H), 1.39 – 1.04 (m, 3H), 0.92 (qd, J = 12.4, 11.9, 3.3 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.06, 42.00, 34.67, 32.89, 26.22, 26.05.

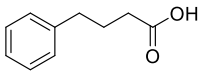
3,7-Dimethyl octanoicacid 4f[15]



4f

Product was isolated as colourless oil (70 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.96 (s, 1H), 2.18 (dd, J = 14.9, 6.0 Hz, 1H), 1.98 (dd, J = 14.9, 8.0 Hz, 1H), 1.88 – 1.75 (m, 1H), 1.51 (dp, J = 13.2, 6.6 Hz, 1H), 1.35 – 1.19 (m, 3H), 1.12 (m, 3H), 0.86 (dd, J = 11.6, 6.7 Hz, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.34, 41.81, 39.05, 36.77, 30.10, 27.81, 24.57, 22.94, 22.84, 19.95.

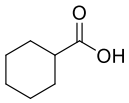
4-Phenylbutyric acid 4g[16]



4g

Product was isolated as white solid (80 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.06 (s, 1H), 7.43 – 7.25 (m, 2H), 7.23 – 7.13 (m, 3H), 2.59 (dd, J = 8.5, 6.8 Hz, 2H), 2.22 (t, J = 7.4 Hz, 2H), 2.22 (t, J = 7.4 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.70, 142.01, 128.76, 126.27, 34.87, 33.52, 26.77.

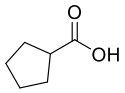
Cyclohexanecarboxylic acid 4h[12]



4h

Product was isolated as colourless oil (88 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.95 (s, 1H), 2.18 (tt, J = 10.8, 3.7 Hz, 1H), 1.87 – 1.74 (m, 2H), 1.66 (dt, J = 12.0, 3.6 Hz, 2H), 1.57 (dt, J = 10.8, 3.6 Hz, 1H), 1.47 – 1.04 (m, 5H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.11, 42.66, 29.12, 25.89, 25.38.

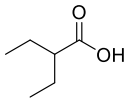
Cyclopentanecarboxylic acid 4i[14]



4i

Product was isolated as colourless oil (80 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.92 (s, 1H), 2.63 (m, 1H), 1.88 – 1.73 (m, 2H), 1.73 – 1.44 (m, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.69, 43.61, 29.88, 25.80.

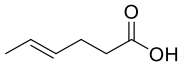
2-Ethylbutyric acid 4j[17]



4j

Product was isolated as colourless oil (95 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.03 (s, 1H), 2.07 (tt, J = 8.3, 5.6 Hz, 1H), 1.67 – 1.30 (m, 4H), 0.84 (t, J = 7.4 Hz, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.20, 48.54, 24.90, 12.12.

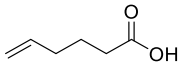
4-hexenoic acid 4k[18]



4k

Product was isolated as colourless oil (82 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.06 (s, 1H), 5.87 – 5.00 (m, 2H), 2.34 – 2.21 (m, 2H), 2.17 (m, 2H), 1.67 – 1.51 (m, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.41, 130.28, 125.60, 34.14, 27.90, 18.11.

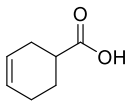
5-hexenoic acid 4l[19]



4l

Product was isolated as colourless oil (47 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.02 (s, 1H), 6.04 – 5.51 (m, 1H), 5.28 – 4.64 (m, 2H), 2.20 (td, J = 7.5, 2.2 Hz, 2H), 2.09 – 1.87 (m, 2H), 1.58 (p, J = 7.5 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.77, 138.53, 115.67, 33.39, 32.98, 24.07.

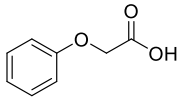
3-Cyclohexenecarboxylic acid 4m[12]



4m

Product was isolated as colourless oil (83 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.10 (s, 1H), 5.65 (d, J = 2.0 Hz, 2H), 2.43 (m, 1H), 2.26 – 1.96 (m, 4H), 1.90 (m, 1H), 1.53 (m, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 176.92, 126.94, 125.83, 38.89, 27.53, 25.19, 24.41.

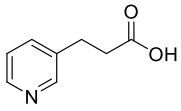
Phenoxyacetic acid 4n[20]



4n

Product was isolated as white solid (77%). 1H NMR (400 MHz, DMSO-d_6) δ 13.00 (s, 1H), 7.73 – 7.12 (m, 2H), 7.07 – 6.70 (m, 3H), 4.67 (s, 2H). 13C NMR (101 MHz, DMSO-d_6) δ 170.68, 158.18, 129.91, 121.42, 114.85, 64.82.

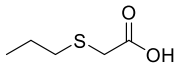
3-Pyridinepropionic acid 4o[21]



4o

Product was isolated as yellowish solid (64 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.26 (s, 1H), 8.43 (dd, J = 23.5, 3.5 Hz, 2H), 7.66 (dd, J = 7.7, 2.1 Hz, 1H), 7.30 (dd, J = 7.8, 4.8 Hz, 1H), 2.82 (d, J = 7.5 Hz, 2H), 2.59 (d, J = 7.5 Hz, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.02, 150.06, 147.73, 136.77, 136.28, 123.84, 35.19, 27.91.

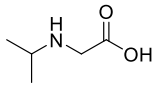
(Propylthio)acetic acid 4p[22]



4p

Product was isolated as colourless oil (67 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ12.36 (s, 1H), 3.18 (s, 2H), 2.55 (t, J = 7.2 Hz, 2H), 1.54 (h, J = 7.3 Hz, 2H), 0.92 (t, J = 7.3 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 172.06, 34.19, 33.58, 22.31, 13.57.

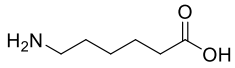
(Isopropylamino)acetic acid 4q[23]



4q

Product was isolated as yellowish solid (85 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.23 (s, 2H), 3.62 (s, 2H), 3.27 (p, J = 6.5 Hz, 1H), 1.22 (d, J = 6.5 Hz, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 168.78, 49.71, 45.31, 18.81.

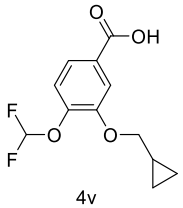
6-Aminocaproic acid 4s[24]



4s

Product was determinded by NMR yield (75 %). ^{1}H NMR (400 MHz, D_2O) δ 2.76 (t, J = 7.5 Hz, 2H), 1.96 (t, J = 7.4 Hz, 2H), 1.44 (p, J = 7.6 Hz, 2H), 1.35 (p, J = 7.4 Hz, 2H), 1.22 – 1.04 (m, 2). 13C NMR (101 MHz, D_2O) δ 183.33, 39.17, 37.11, 26.33, 25.30, 25.08.

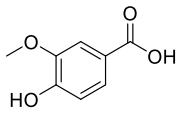
3-Cyclopropylmethoxy-4-difluoromethoxy-benzoic acid 4v[25]



4v

Product was isolated via column chromatography (CH_2Cl_2/MeOH = 10:1) as white solid (46 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 13.09 (s, 1H), 7.65 – 7.50 (m, 2H), 7.27 (d, J = 8.2 Hz, 1H), 7.21 (t, J = 74.1 Hz, 1H), 3.94 (d, J = 6.9 Hz, 2H), 0.82 – 0.46 (m, 2H), 0.51 – -0.05 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 166.99, 149.87, 143.85, 143.82, 129.14, 122.75, 120.57, 116.87 (t, J = 258.4 Hz), 115.18, 73.58, 10.36, 3.47.

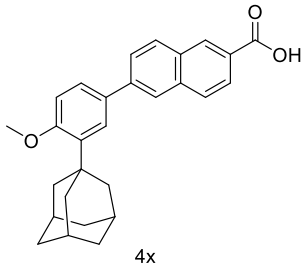
Vanillic acid 4w[26]



4w

Product was isolated as brown oil (64 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ12.51 (s, 1H), 9.84 (s, 1H), 7.46 (d, J = 7.5 Hz, 2H), 6.85 (d, J = 8.4 Hz, 1H), 3.81 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.69, 151.53, 147.66, 123.95, 122.06, 115.48, 113.13, 55.96.

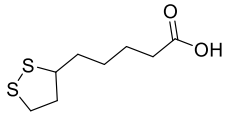
Adapalene 4x[27]



4x

Product was isolated as white solid (60 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ13.06 (s, 1H), 8.61 (d, J = 1.6 Hz, 1H), 8.22 (d, J = 1.7 Hz, 1H), 8.16 (d, J = 8.7 Hz, 1H), 8.08 (d, J = 8.7 Hz, 1H), 7.99 (dd, J = 8.5, 1.7 Hz, 1H), 7.89 (dd, J = 8.6, 1.9 Hz, 1H), 7.66 (dd, J = 8.5, 2.3 Hz, 1H), 7.58 (d, J = 2.4 Hz, 1H), 7.12 (d, J = 8.5 Hz, 1H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 167.93, 159.06, 140.68, 138.51, 135.93, 131.98, 131.38, 130.71, 130.30, 128.81, 128.11, 126.41, 126.22, 125.96, 125.56, 124.55, 113.19, 55.82, 40.54, 37.09, 37.02, 28.87.

Lipoic acid 4y[28]



4y

Product was isolated as yellowish solid (42 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ12.01 (s, 1H), 3.61 (dq, J = 8.7, 6.2 Hz, 1H), 3.30 – 3.01 (m, 2H), 2.42 (m, 1H), 2.21 (t, J = 7.3 Hz, 2H), 1.87 (dq, J = 13.5, 6.8 Hz, 1H), 1.67 (m, 1H), 1.61 – 1.44 (m, 3H), 1.43 – 1.30 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 174.81, 56.57, 40.39, 38.58, 34.59, 33.97, 28.71, 24.75.

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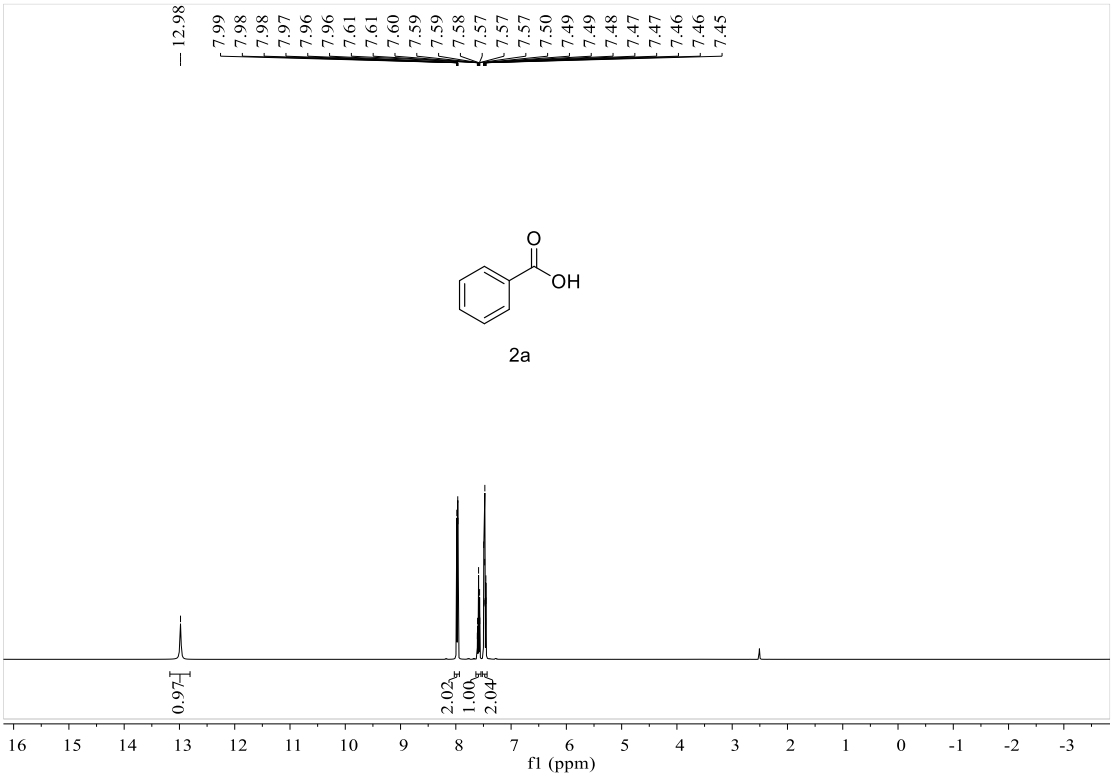
NMR Spectra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7.96
7.96
7.61
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7.60
7.59
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7.57
7.57
7.57
7.50
7.49
7.49
7.48
7.47
7.47
7.46
7.46
7.45
O
OH
2a
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2.02
1.00
2.04
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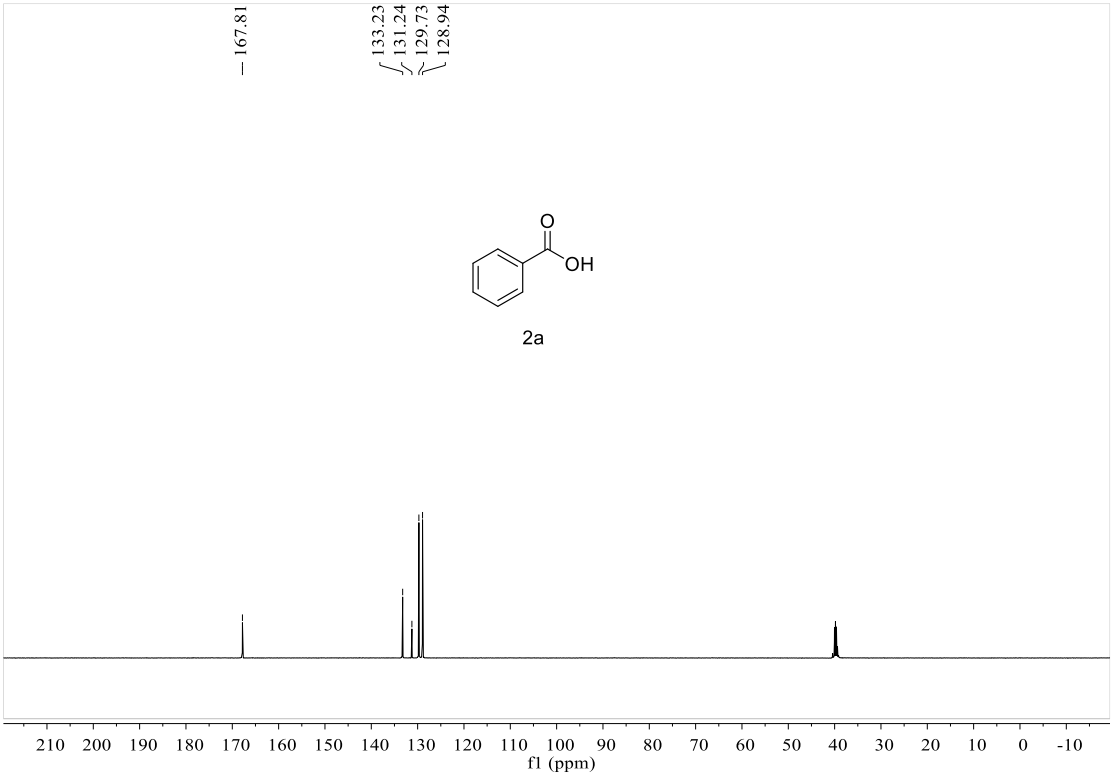
f1 (ppm)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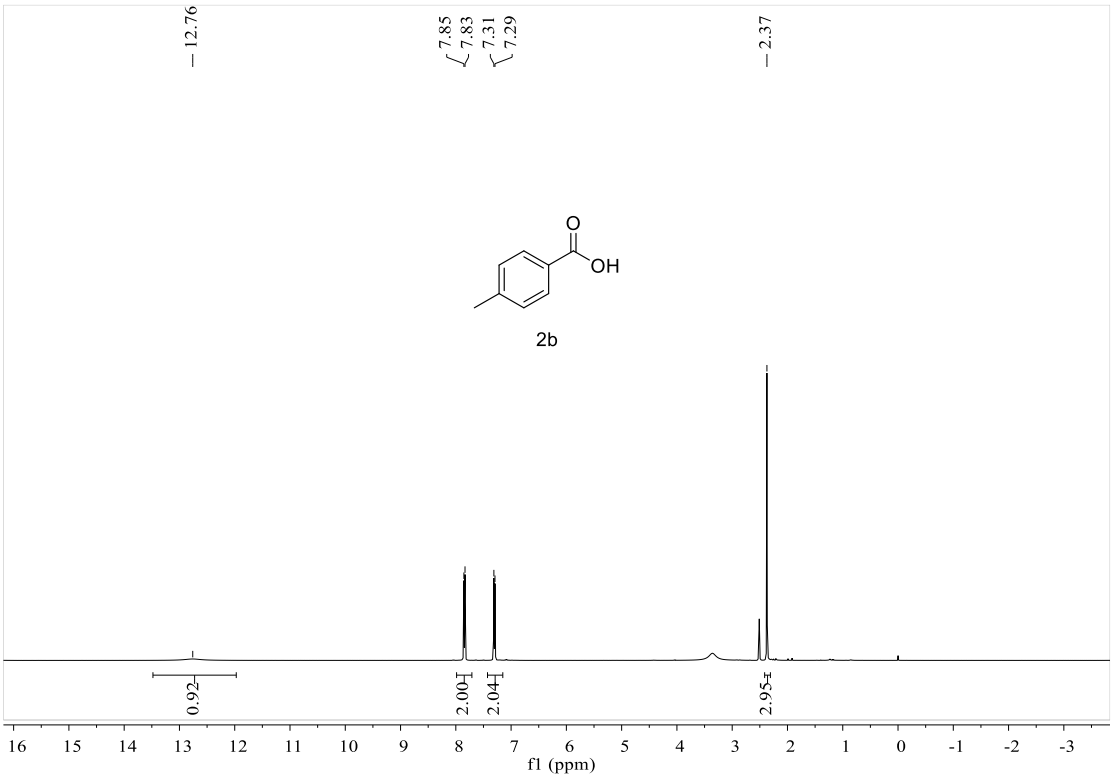
f1 (ppm)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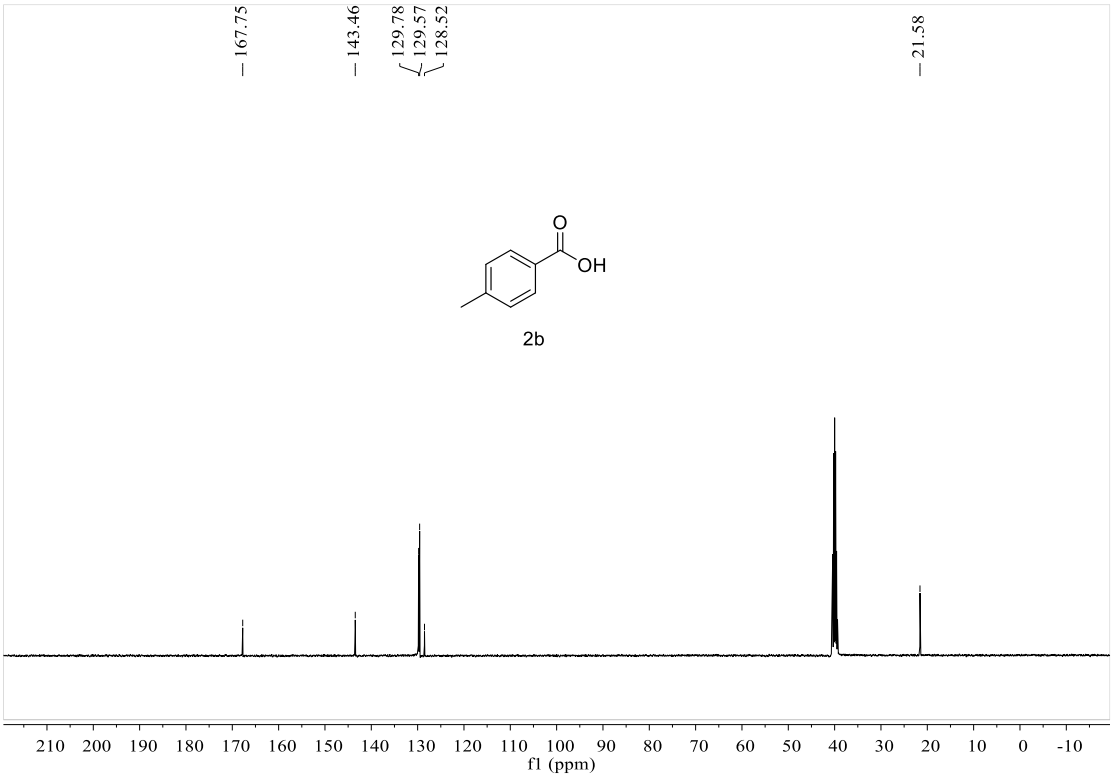
f1 (ppm)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OH
2b
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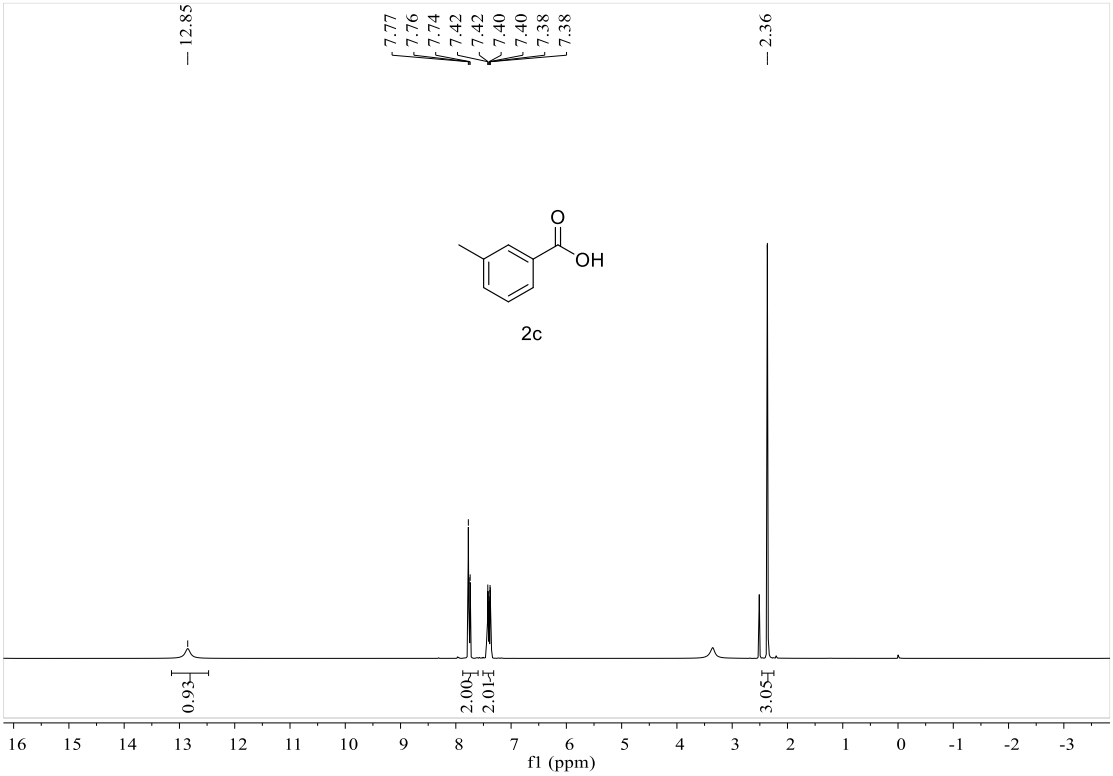
f1 (ppm)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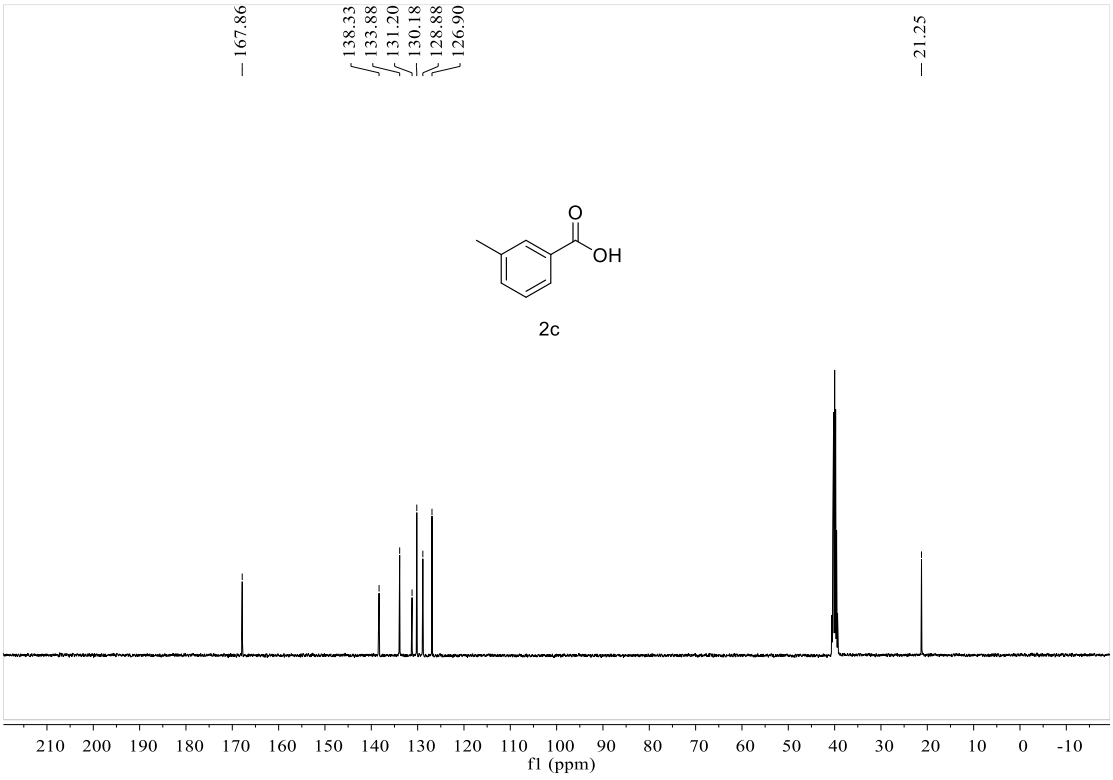
f1 (ppm)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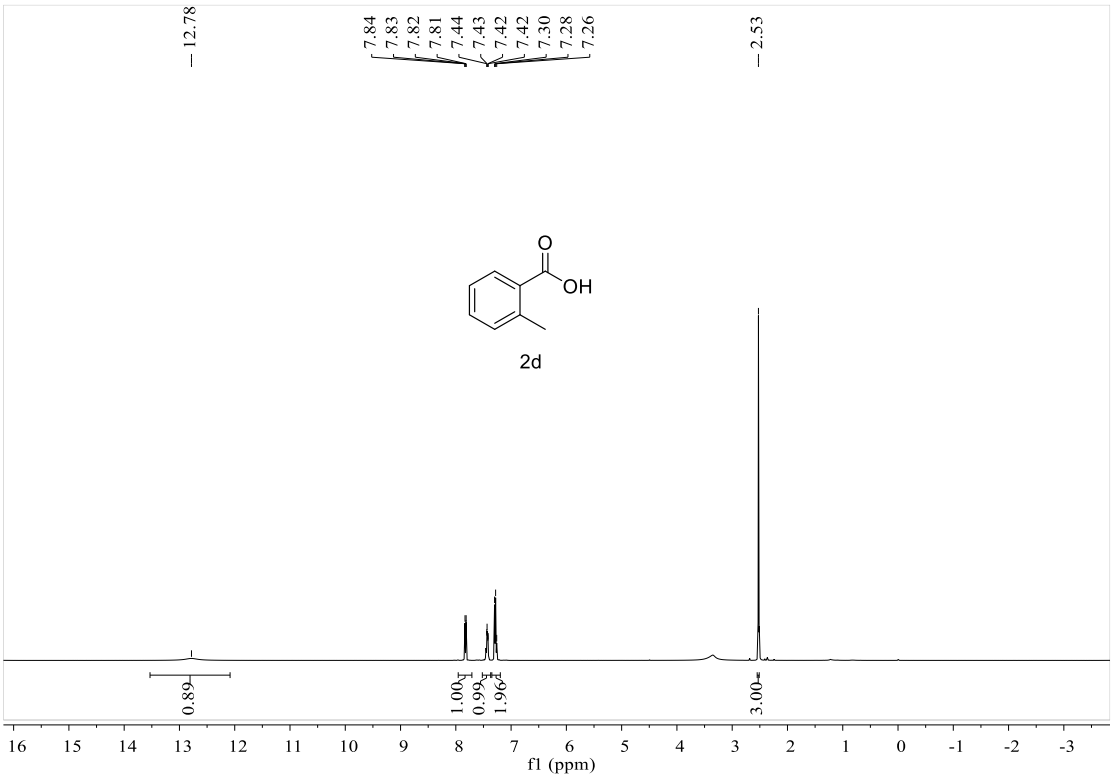
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7.42
7.30
7.28
7.26
2.53
O
OH
2d
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0.99
1.96
3.00
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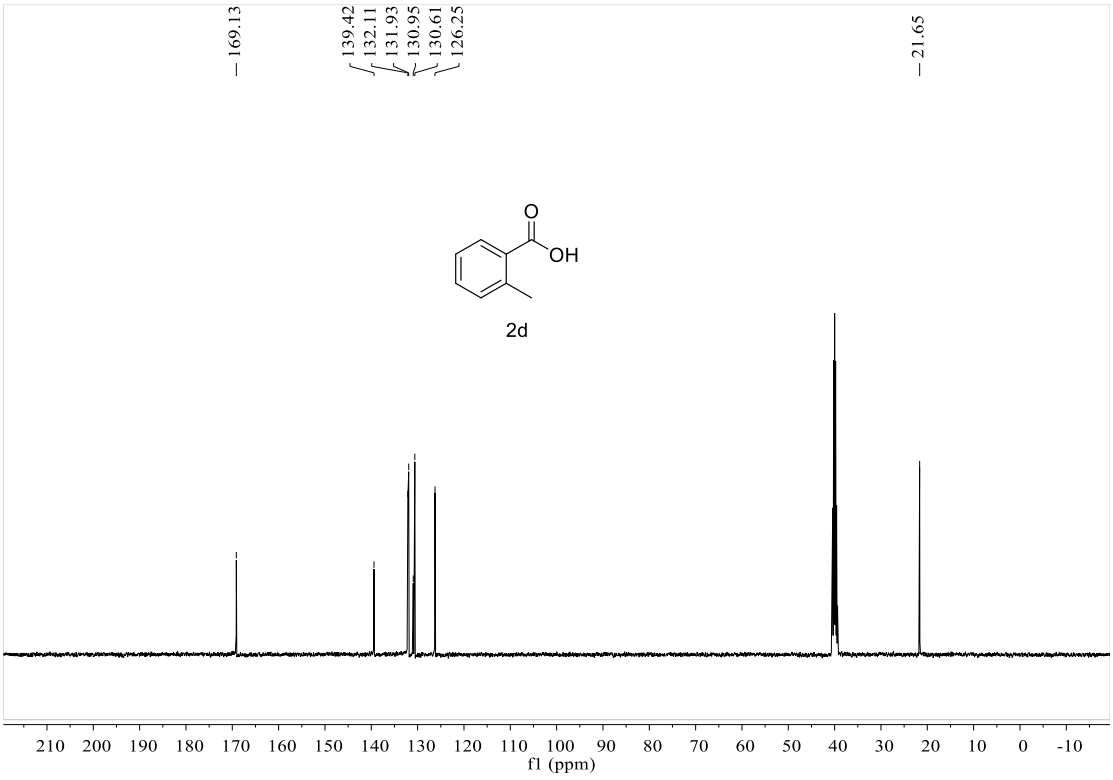
f1 (ppm)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OH
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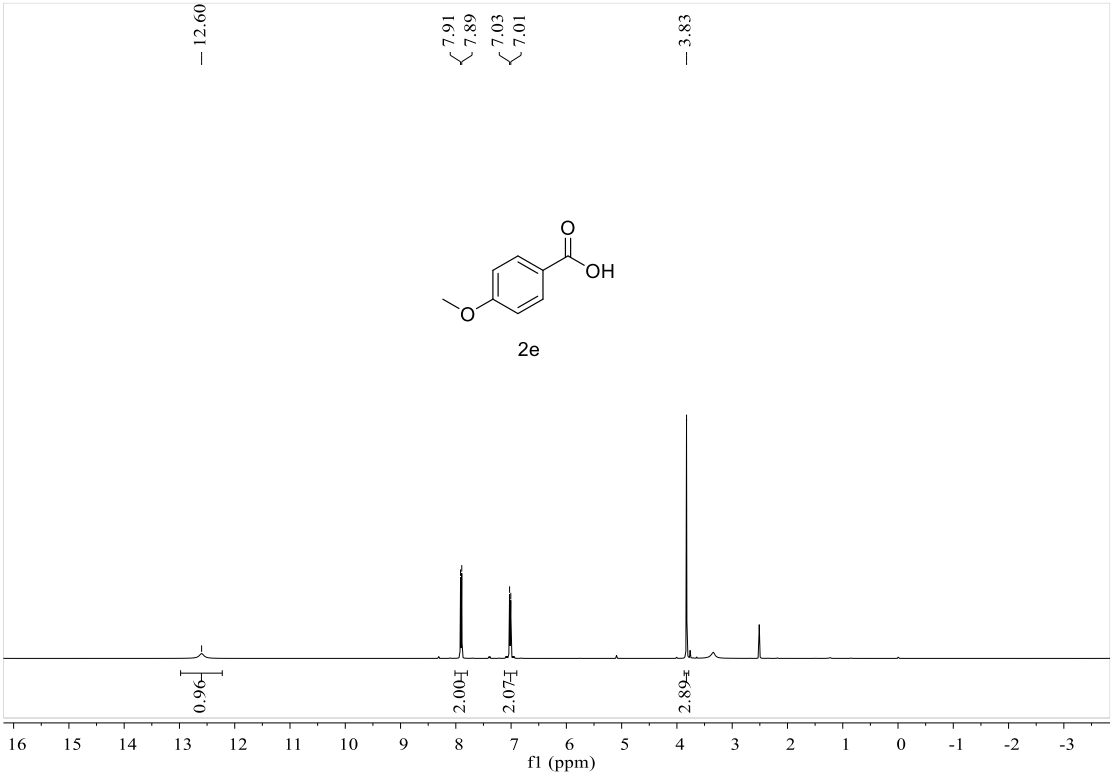
f1 (ppm)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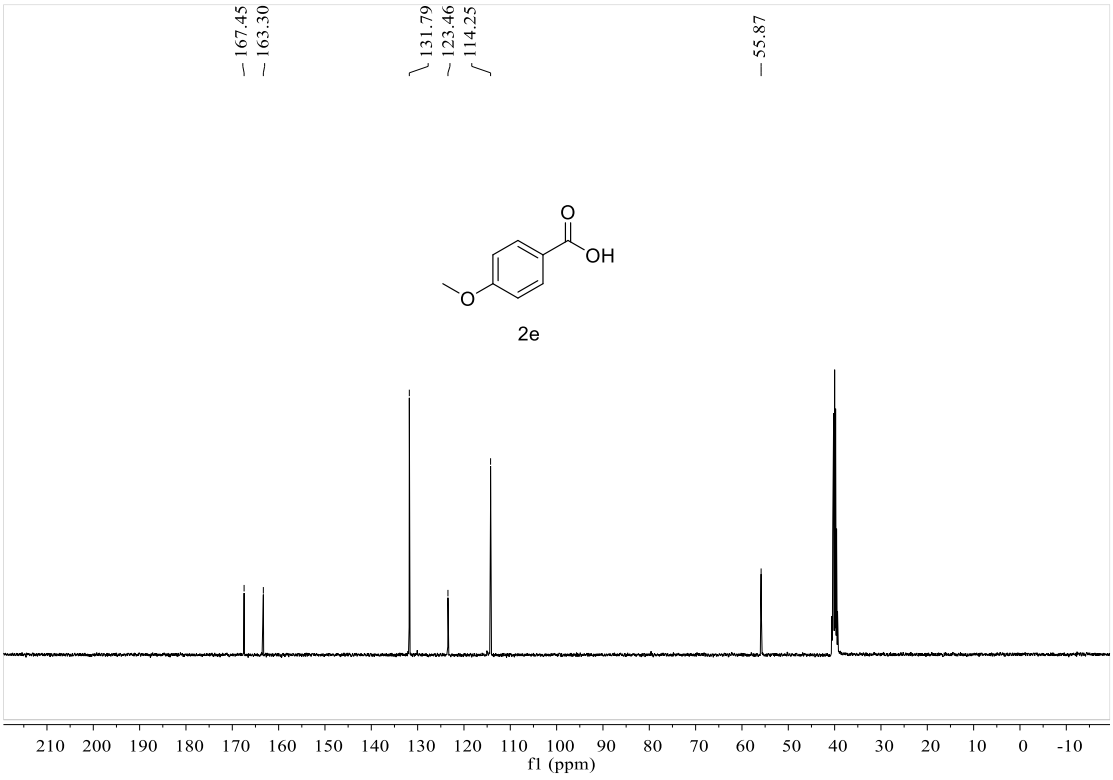
f1 (ppm)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O
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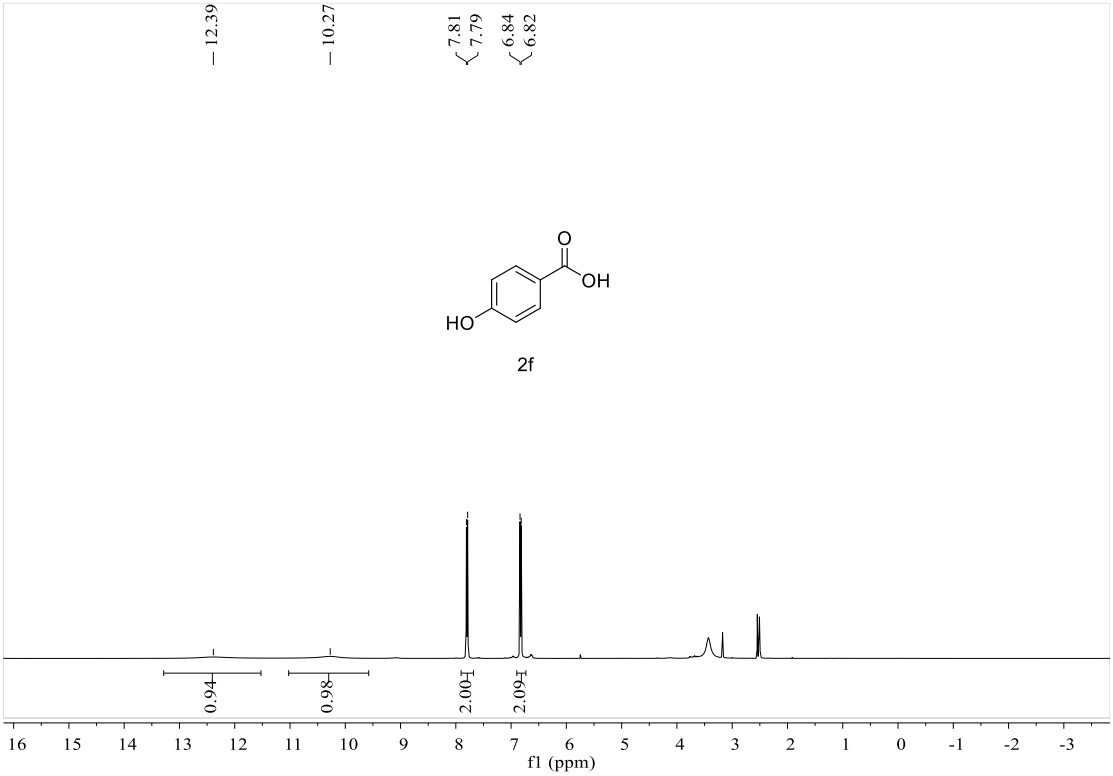
f1 (ppm)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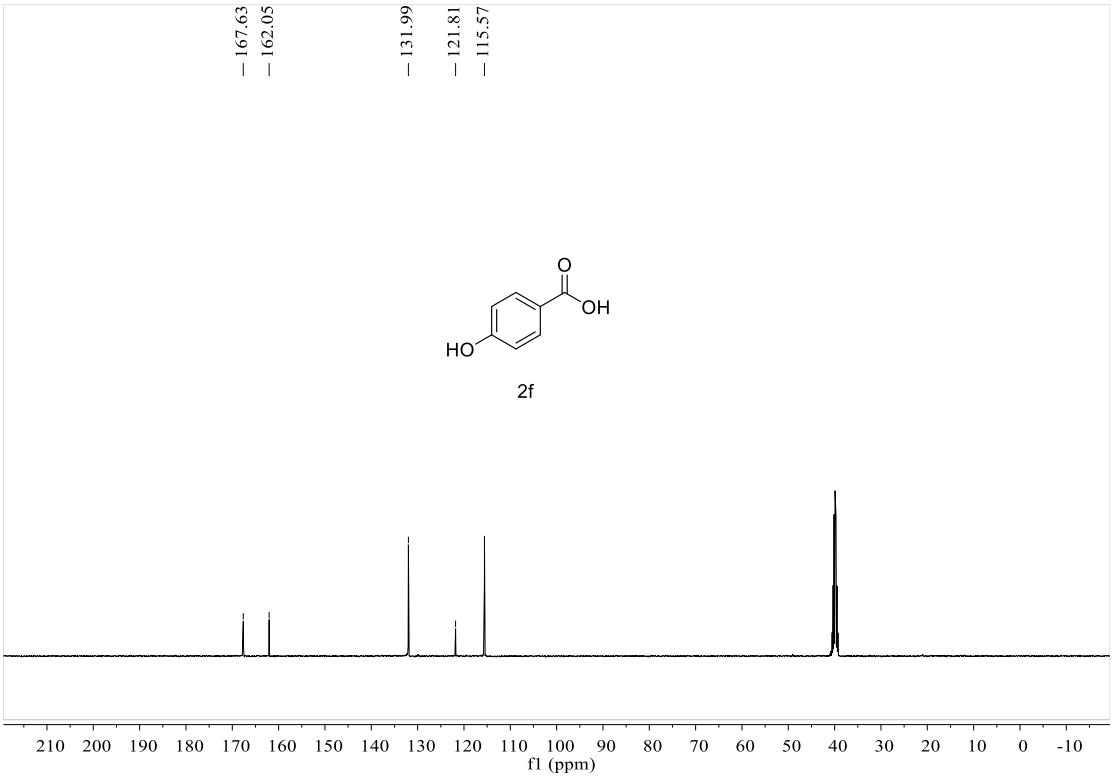
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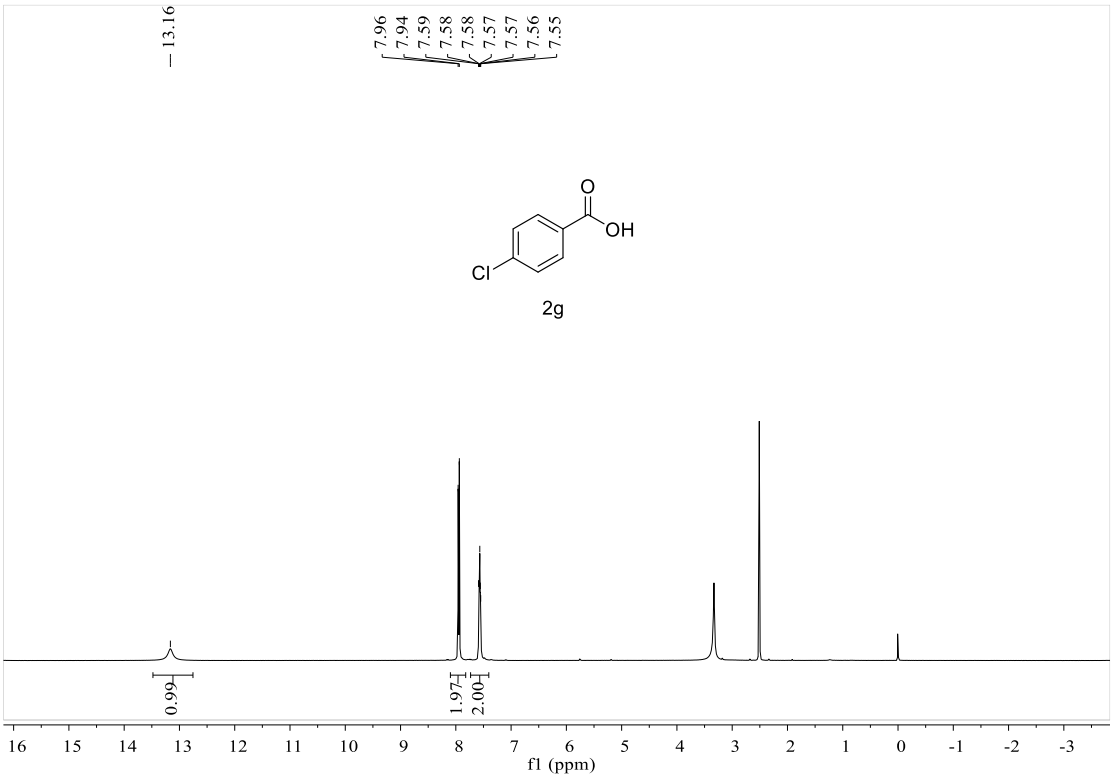
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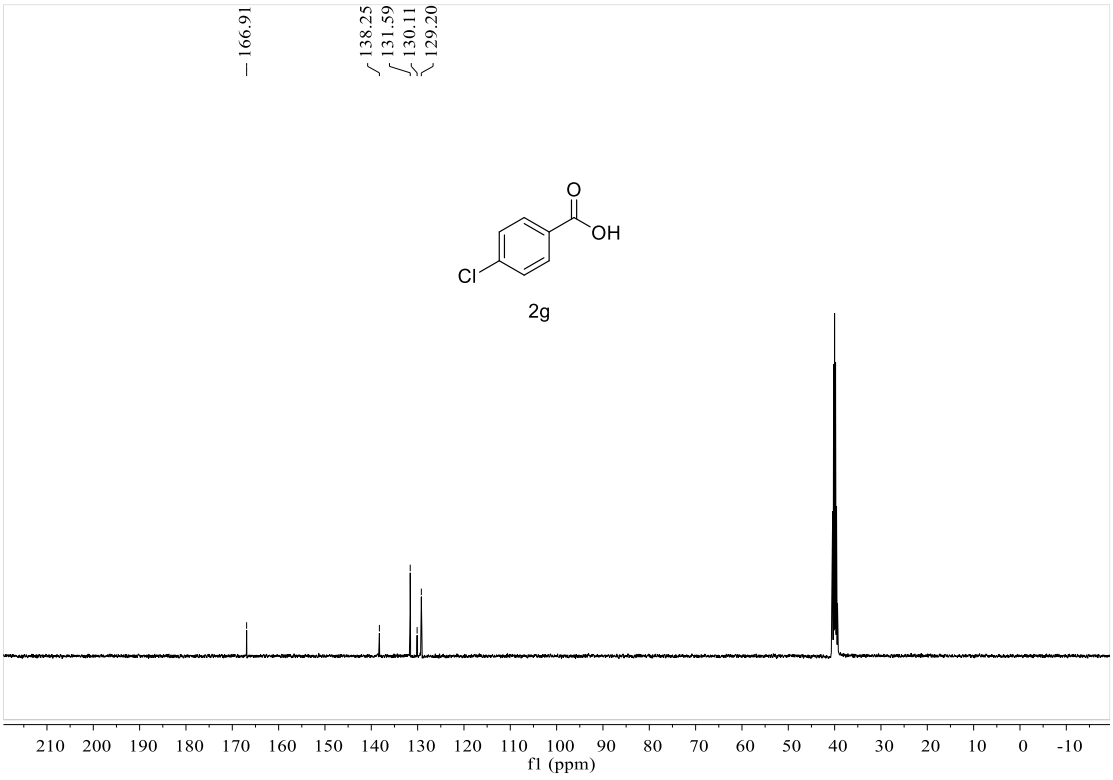
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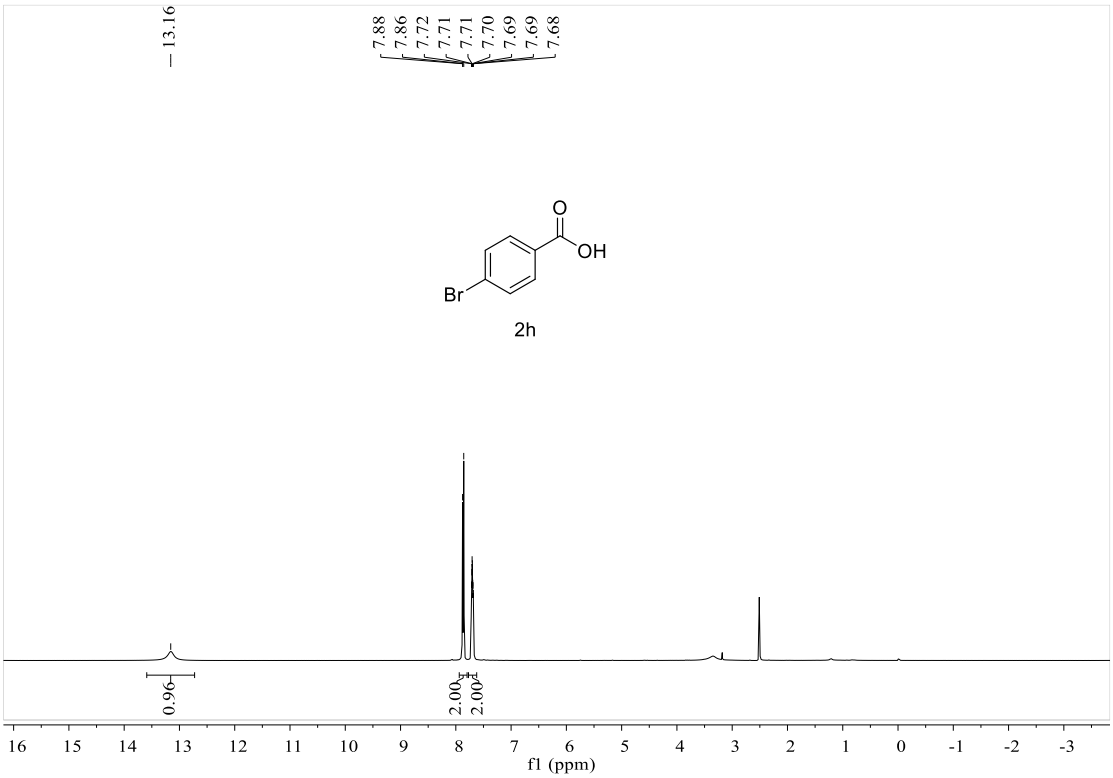
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0.96
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2.00
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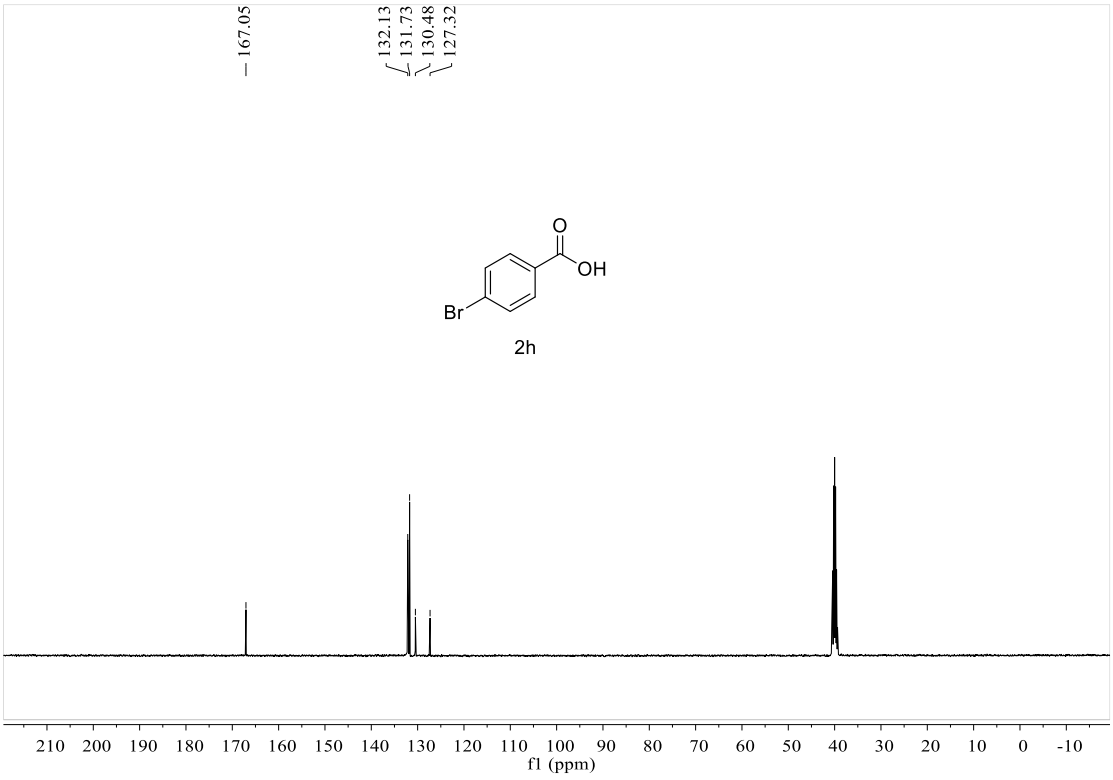
f1 (ppm)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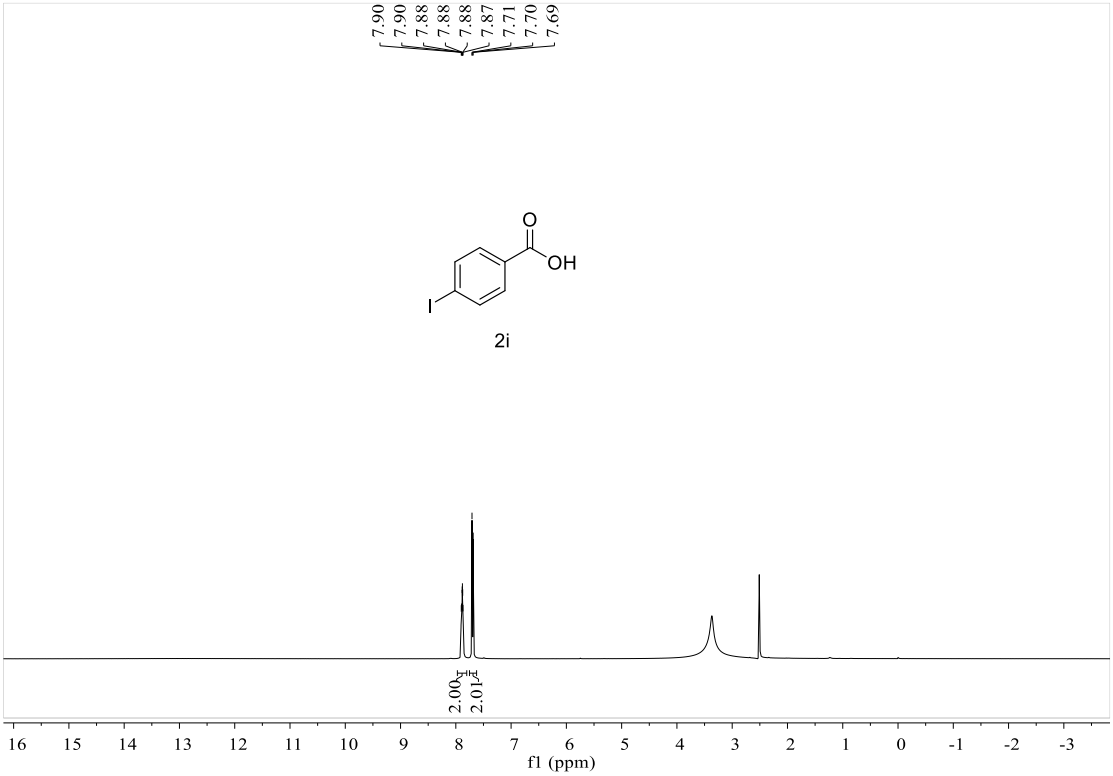
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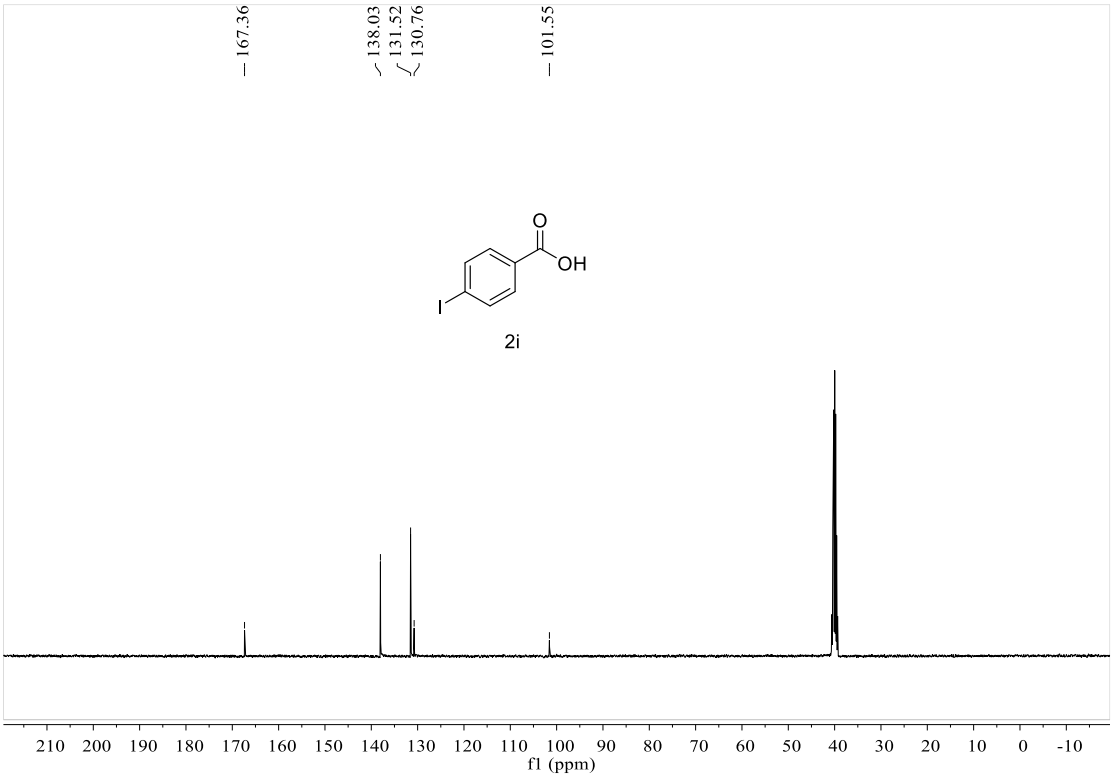
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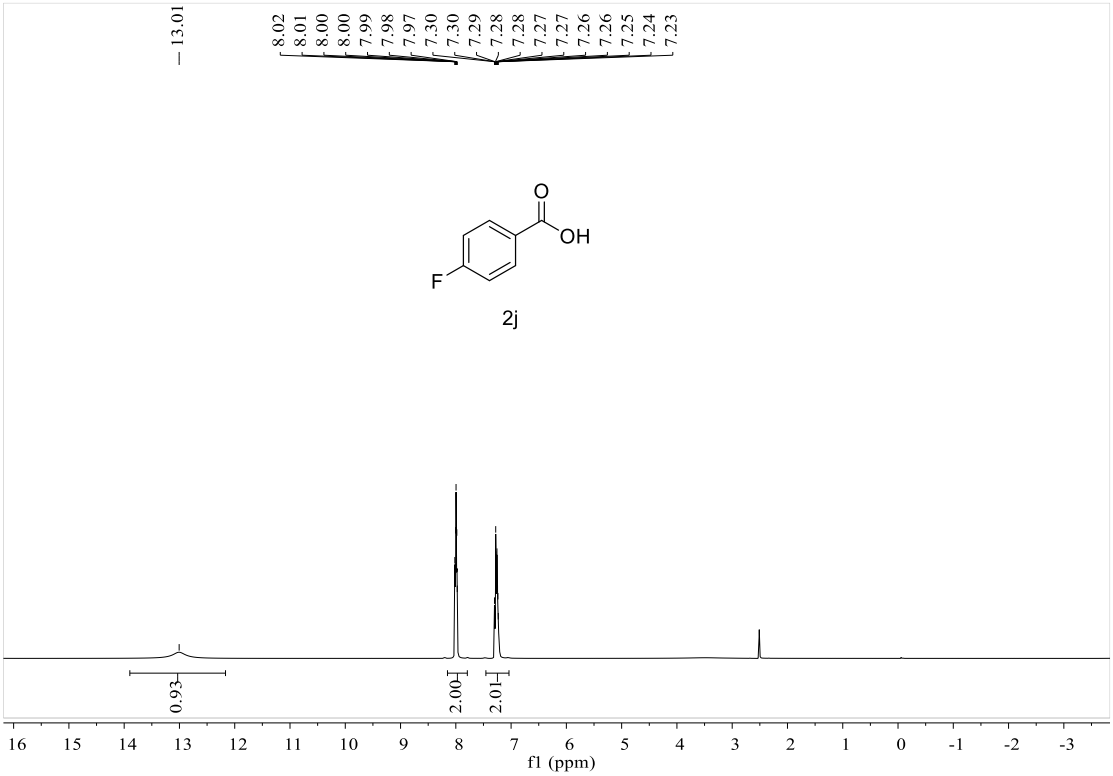
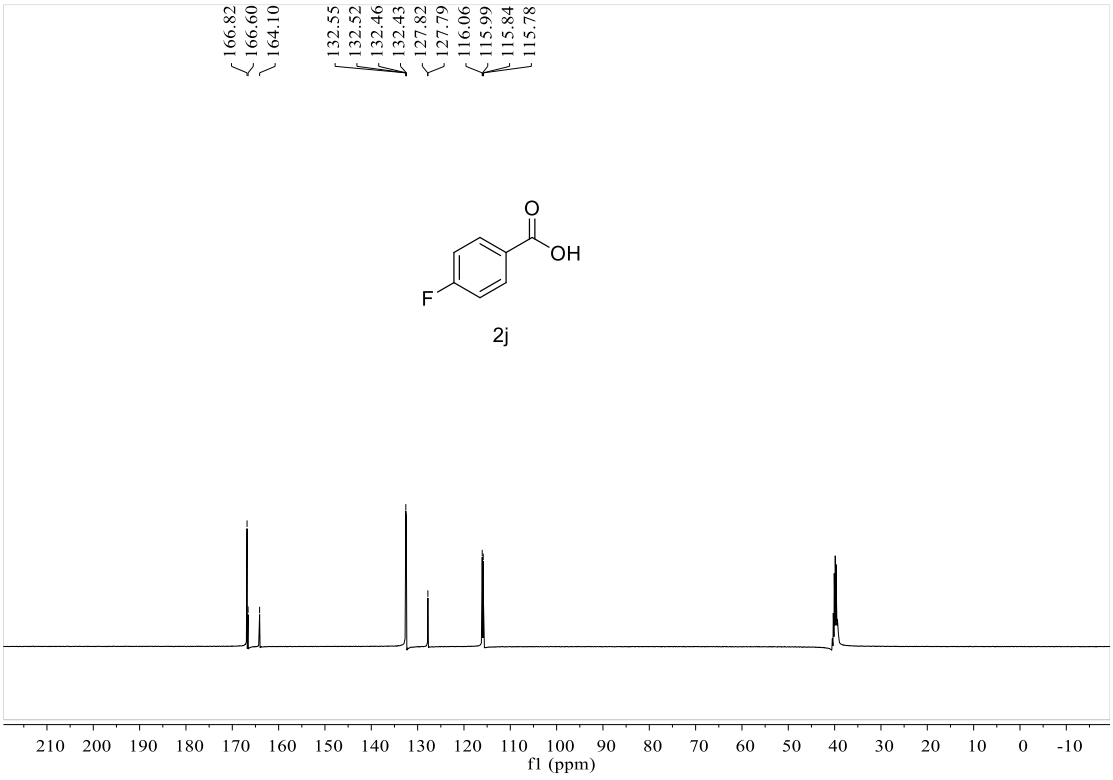
f1 (ppm)


13.01
8.02
8.01
8.00
8.00
7.99
7.98
7.97
7.30
7.30
7.29
7.28
7.28
7.27
7.27
7.26
7.26
7.25
7.24
7.23
O
OH
F
2j
0.93
2.00
2.01
f1 (ppm)


166.82
166.60
164.10
132.55
132.52
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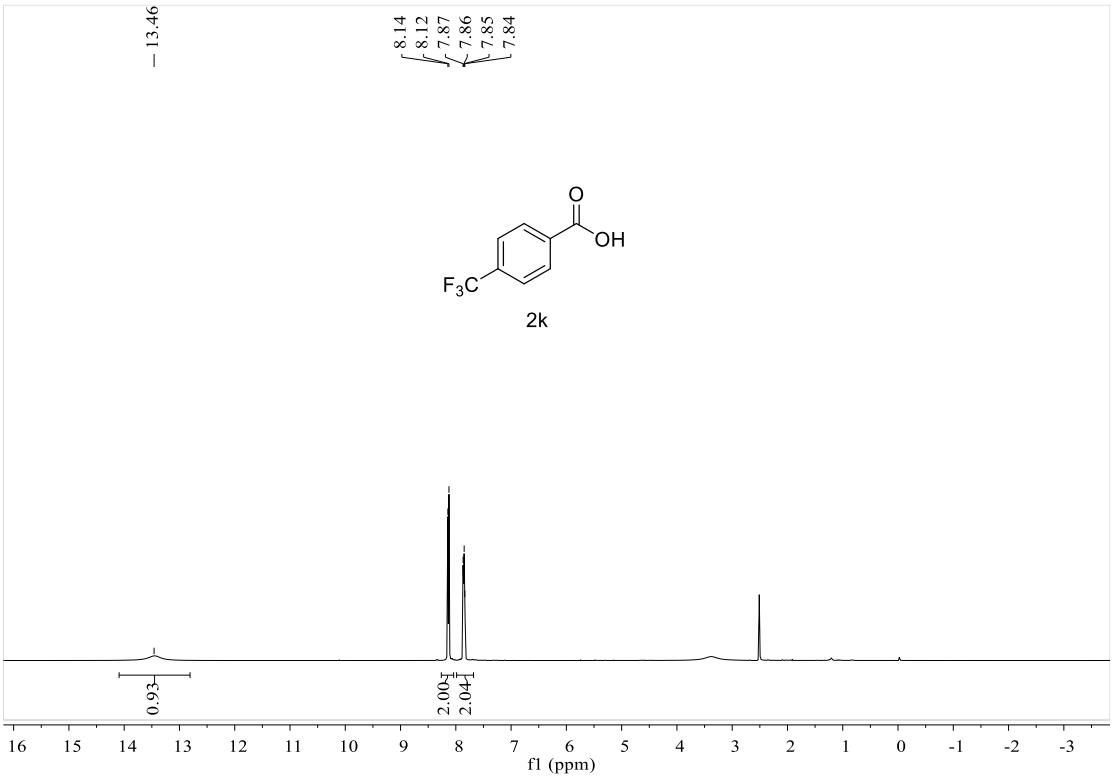
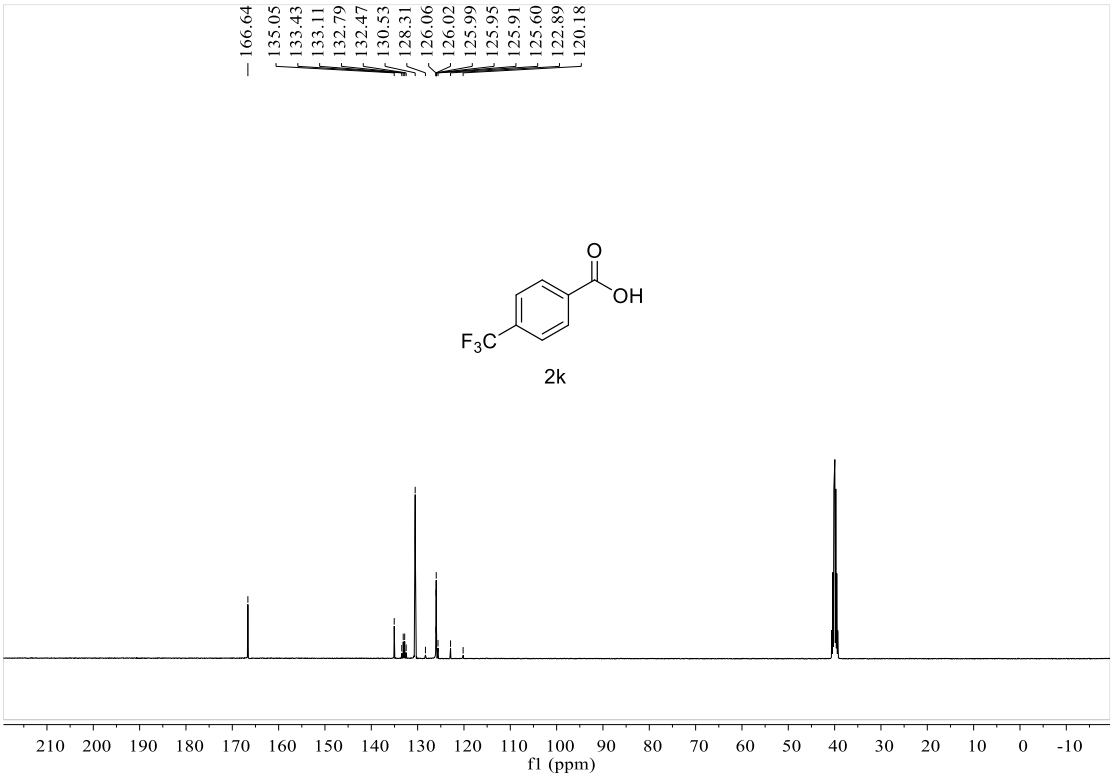
132.43
127.82
127.79
116.06
115.99
115.84
115.78
O
OH
F
2j
f1 (ppm)


13.46
8.14
8.12
7.87
7.86
7.85
7.84
O
OH
F3C
2k
0.93
2.00
2.04
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


166.64
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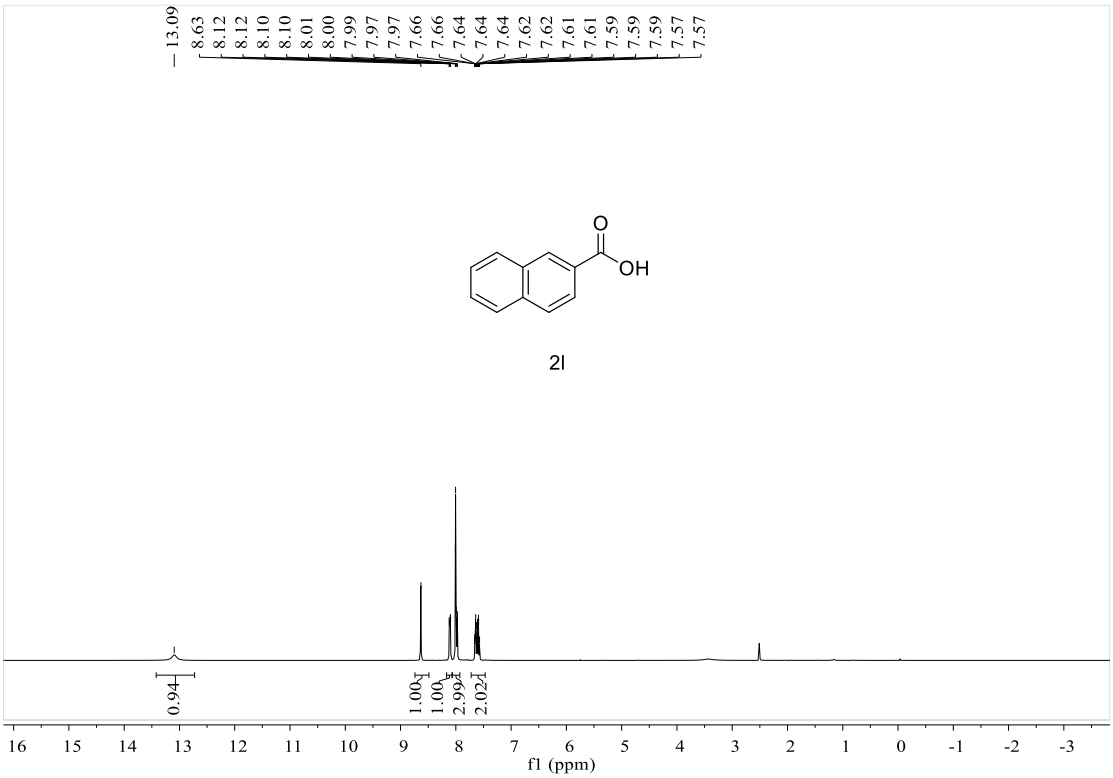
133.11
132.79
132.47
130.53
128.31
126.06
126.02
125.99
125.95
125.91
125.60
122.89
120.18
O
OH
F3C
2k
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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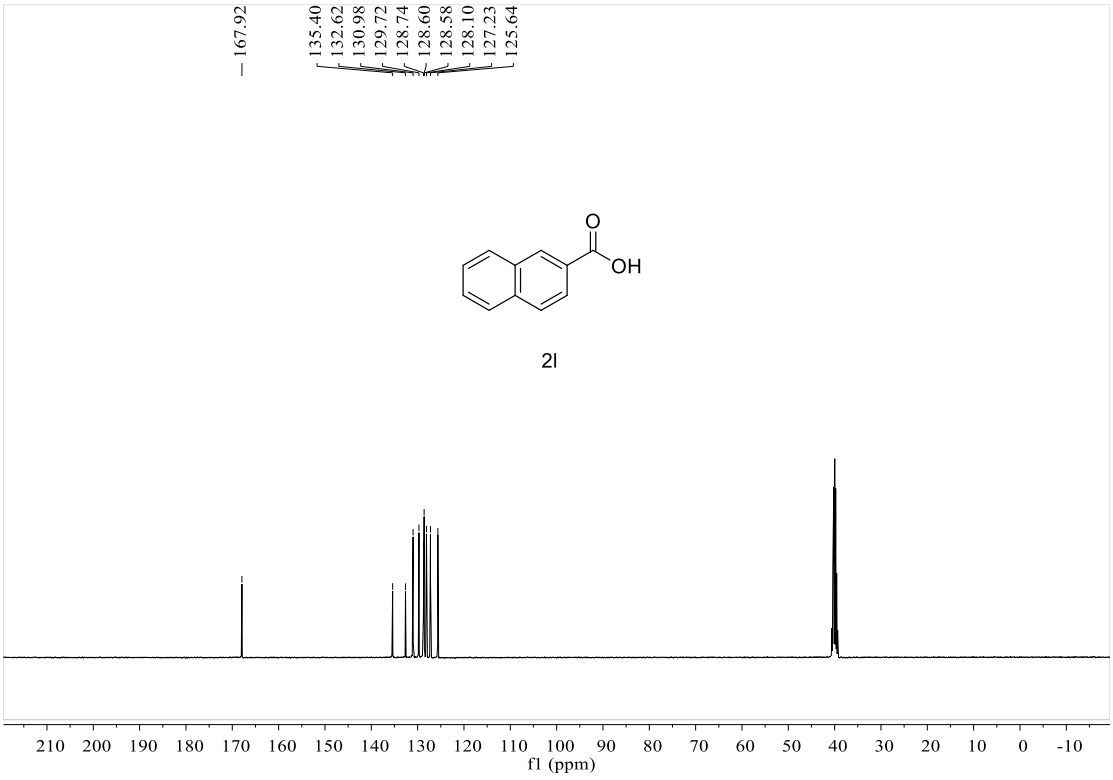
8.12
8.12
8.10
8.10
8.01
8.00
7.99
7.97
7.97
7.66
7.66
7.64
7.64
7.64
7.62
7.62
7.61
7.61
7.59
7.59
7.59
7.57
7.57
O
OH
0.94
1.00
1.00
2.99
2.02
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

2l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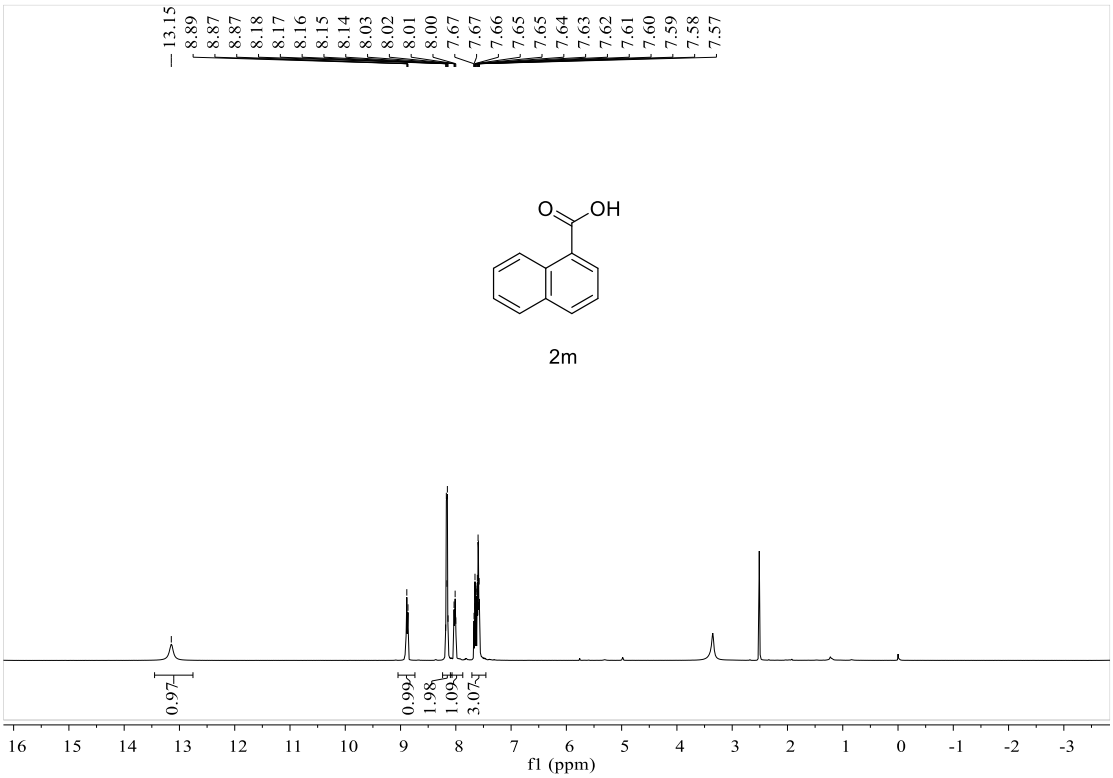
135.40
132.62
130.98
129.72
128.74
128.60
128.58
128.10
127.23
125.64
O
OH
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

2l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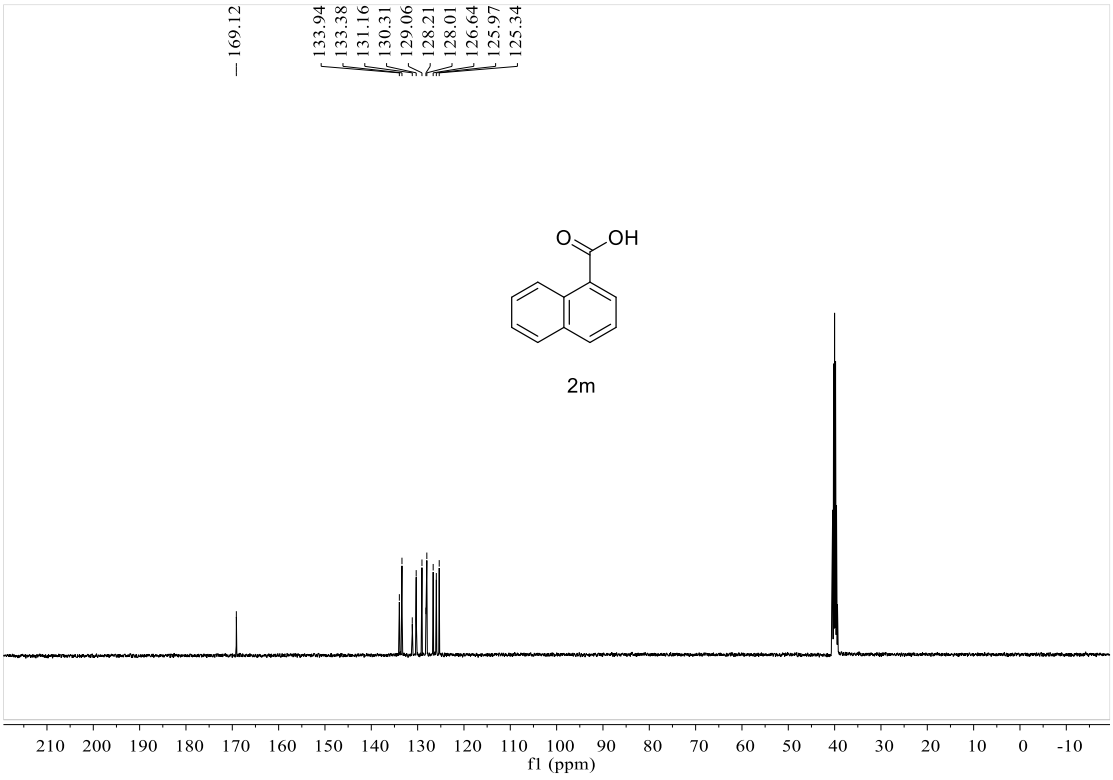
8.89
8.87
8.87
8.18
8.17
8.16
8.15
8.14
8.03
8.02
8.01
8.00
7.67
7.67
7.66
7.65
7.65
7.64
7.63
7.62
7.61
7.60
7.59
7.58
7.57
O
OH
2m
0.97
0.99
1.98
1.09
3.07
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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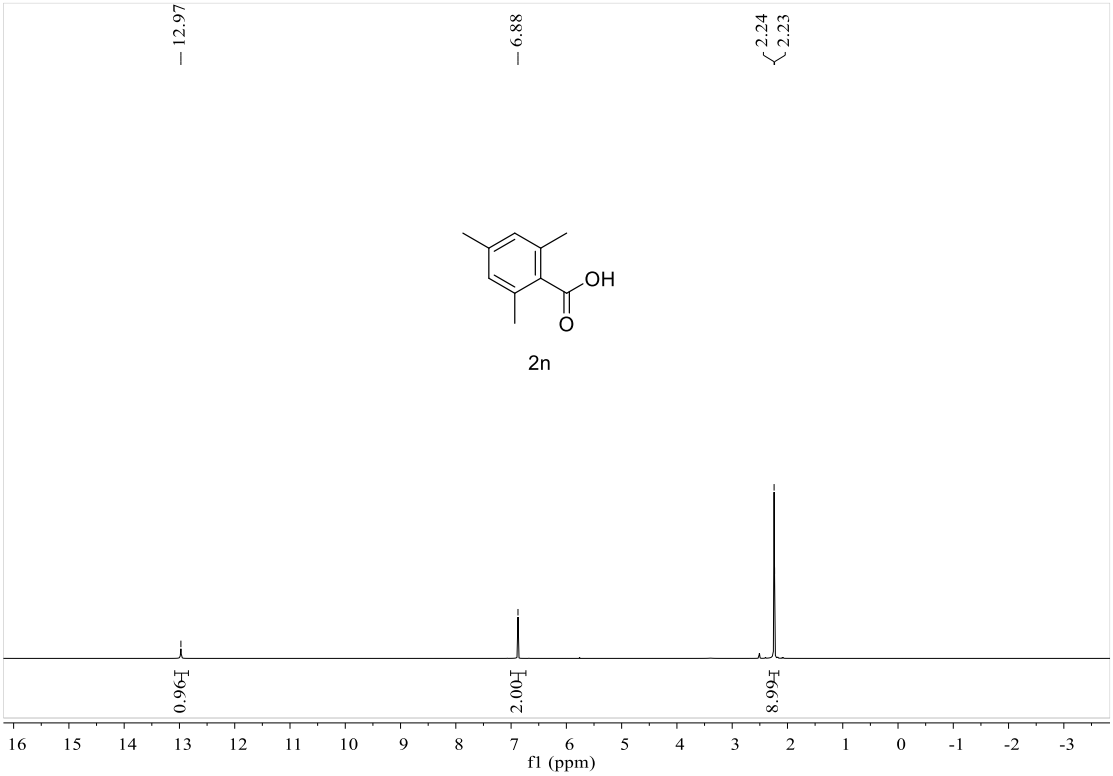
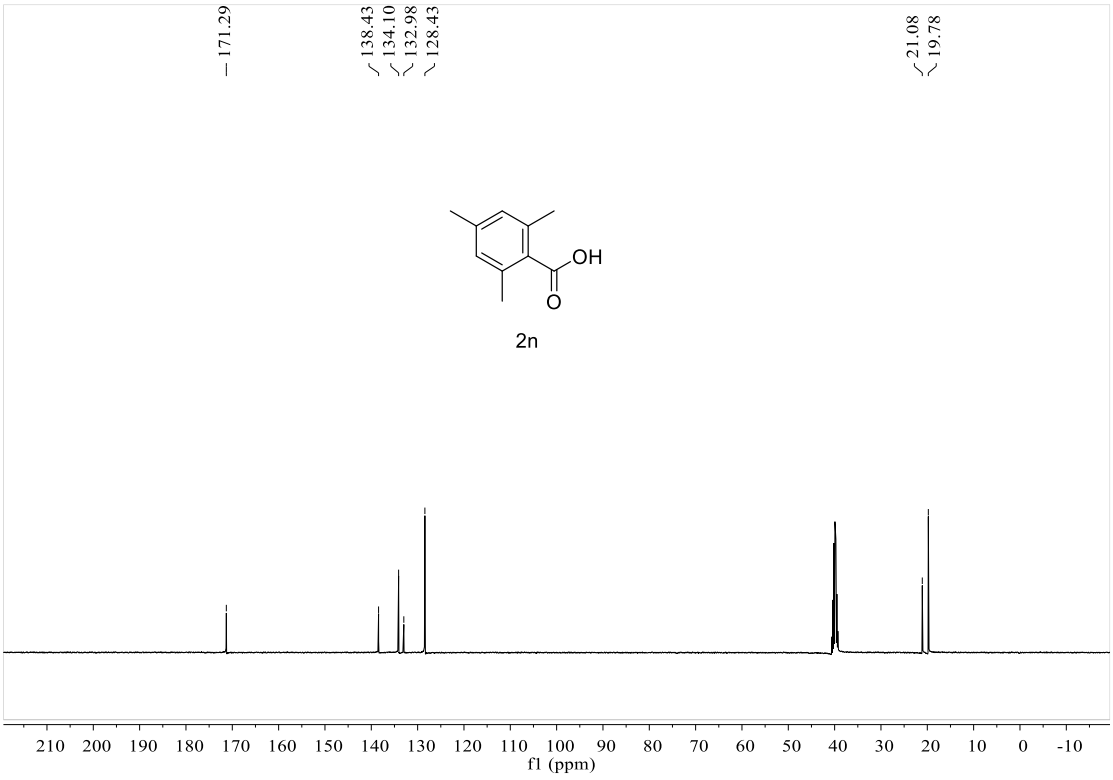
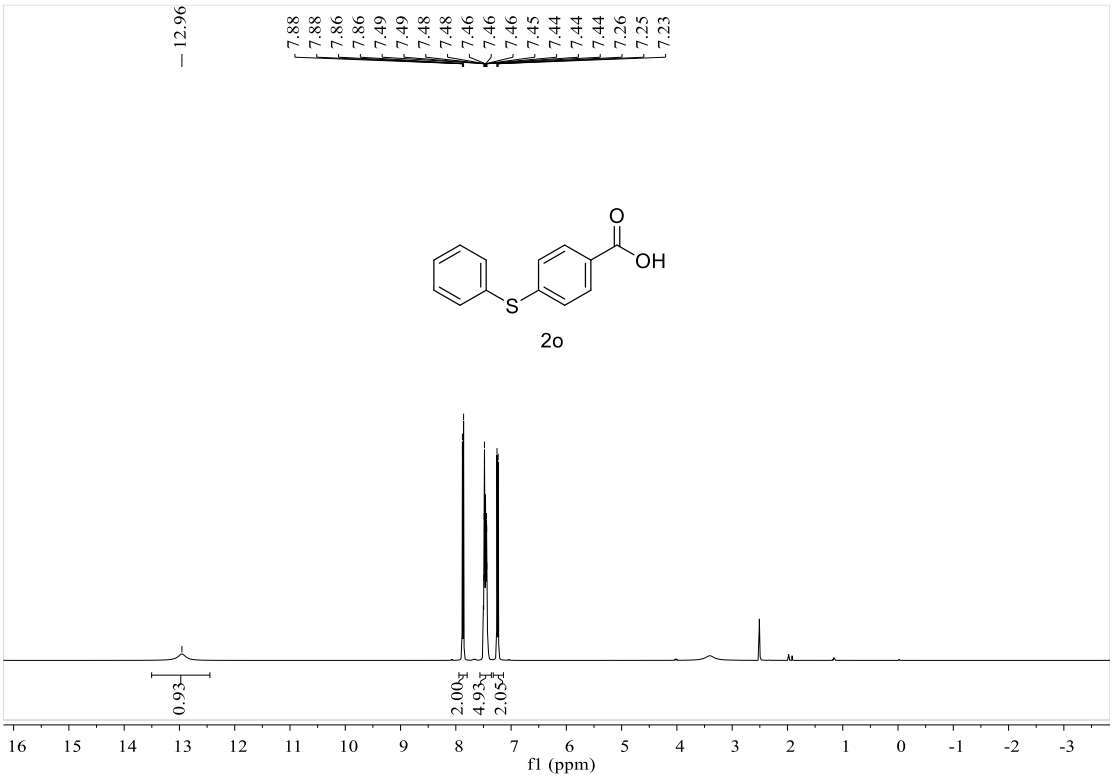
133.94
133.38
131.16
130.31
129.06
128.21
128.01
126.64
125.97
125.34
O
OH
2m
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


12.97
6.88
2.24
2.23
OH
O
2n
0.96
2.00
8.99
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


171.29
138.43
134.10
132.98
128.43
21.08
19.78
OH
O
2n
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)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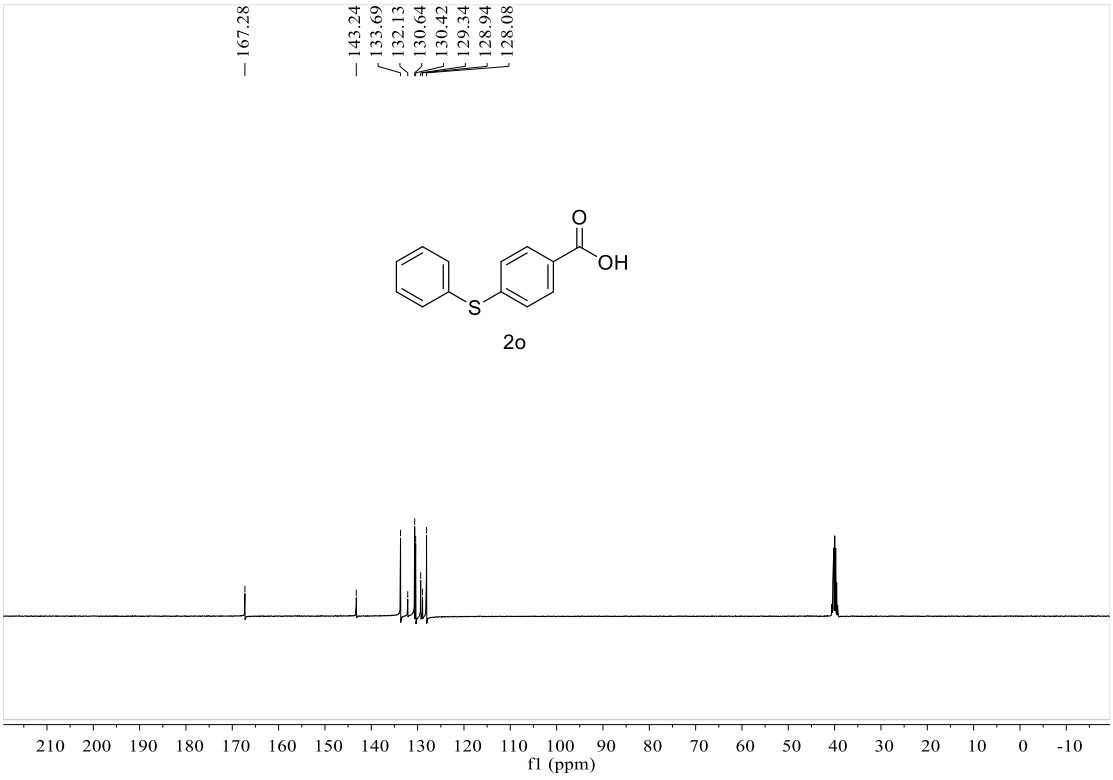
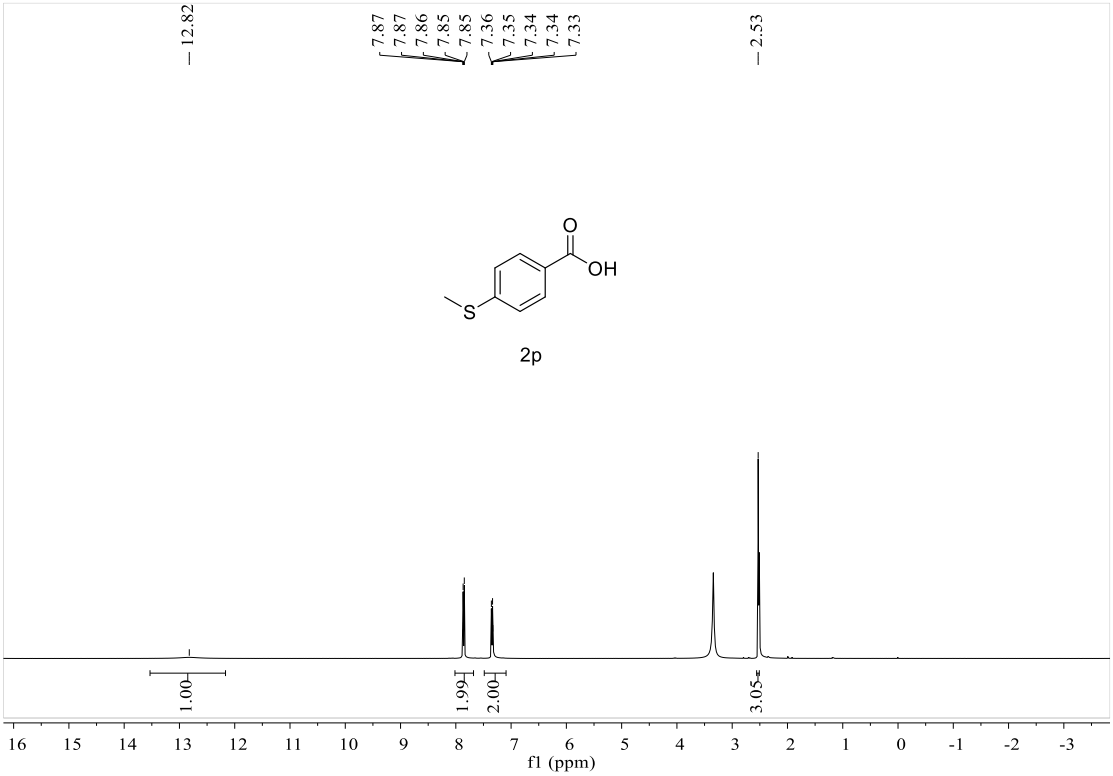
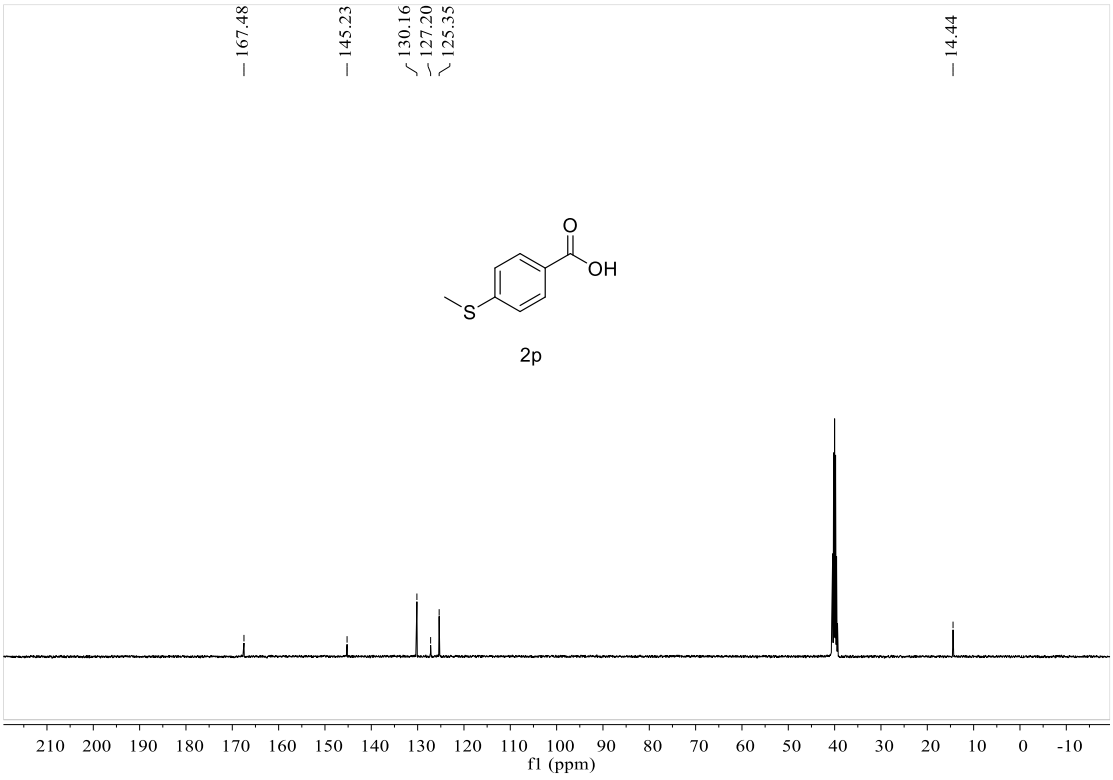
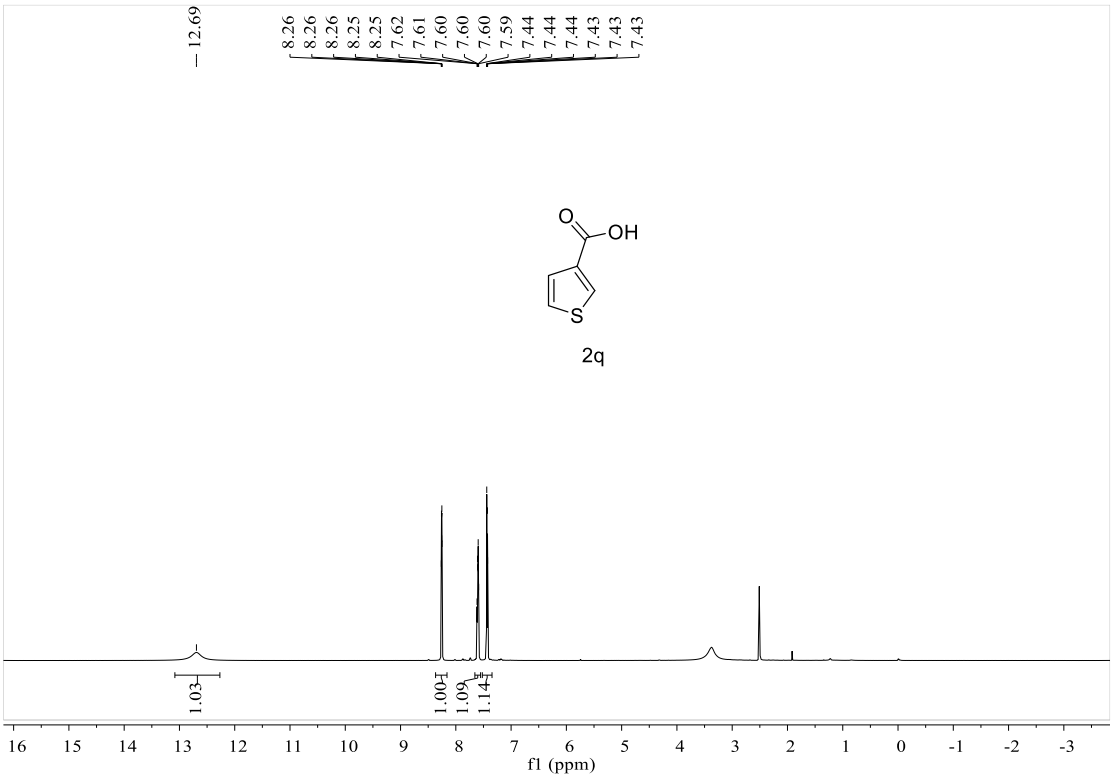
7.88
7.88
7.86
7.86
7.49
7.49
7.48
7.48
7.46
7.46
7.46
7.45
7.44
7.44
7.44
7.26
7.25
7.23
O
OH
S
2o
0.93
2.00
4.93
2.05
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


167.28
143.24
133.69
132.13
130.64
130.42
129.34
128.94
128.08
O
OH
S
2o
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)


12.82
7.87
7.87
7.86
7.85
7.85
7.36
7.35
7.34
7.34
7.33
2.53
O
OH
S
2p
1.00
1.99
2.00
3.05
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


167.48
145.23
130.16
127.20
125.35
14.44
O
OH
S
2p
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)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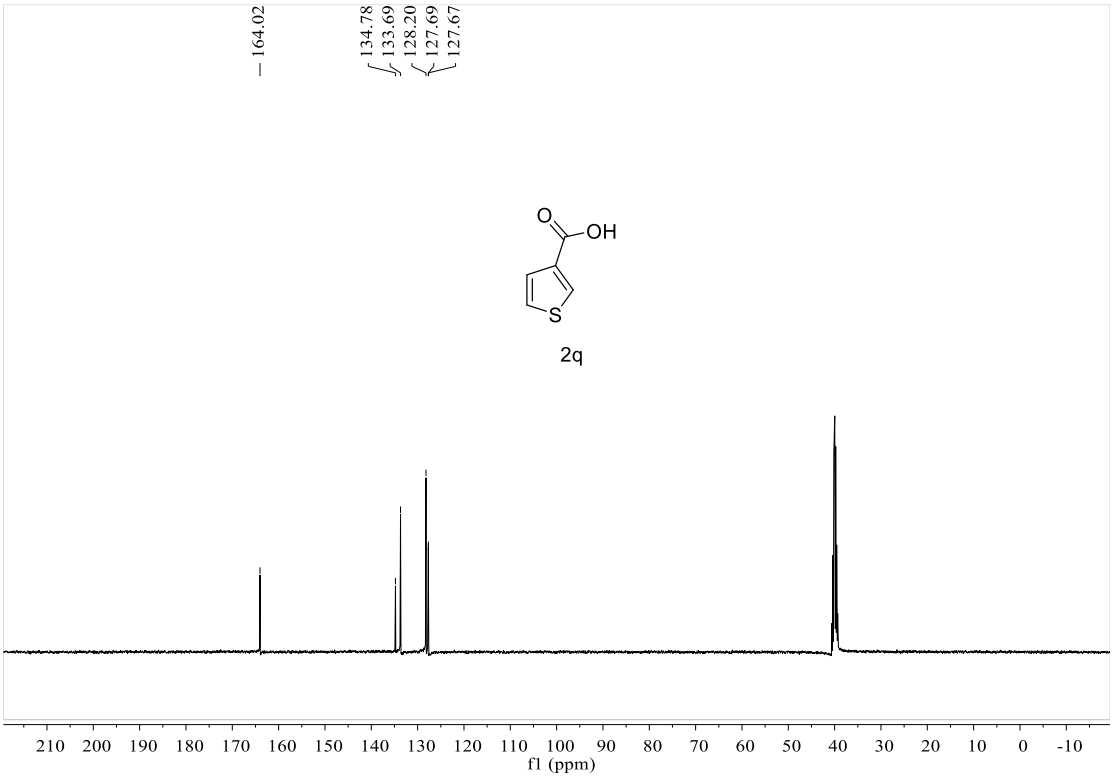
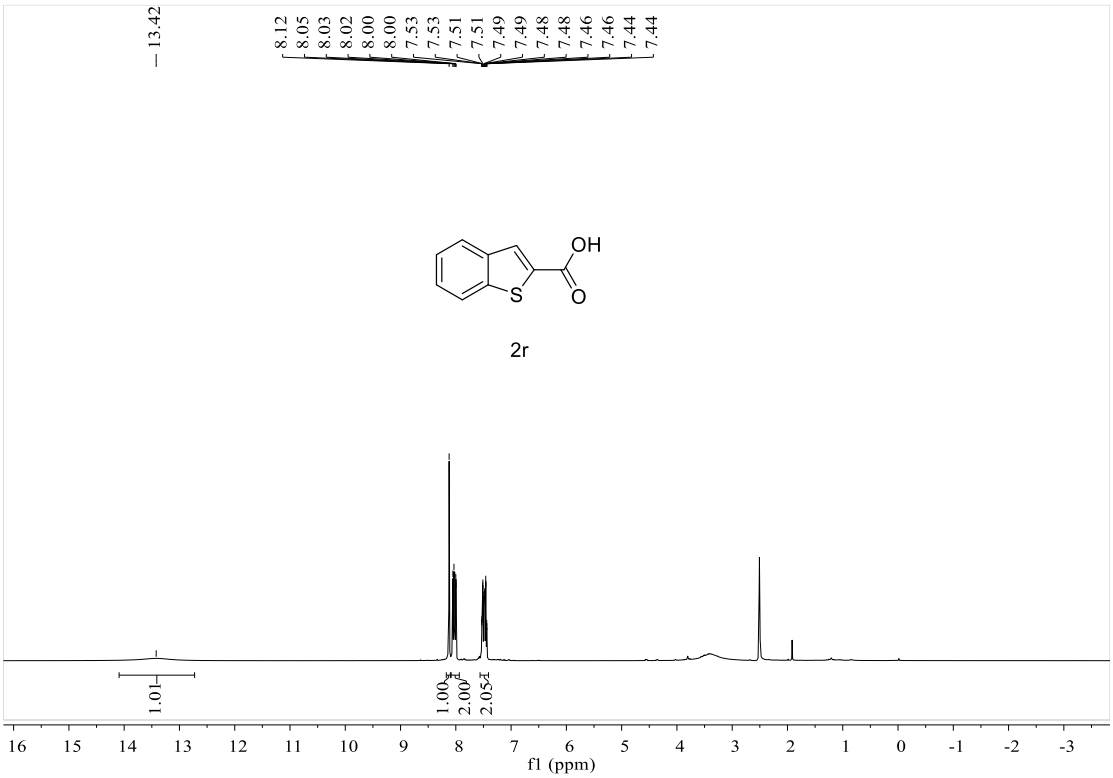
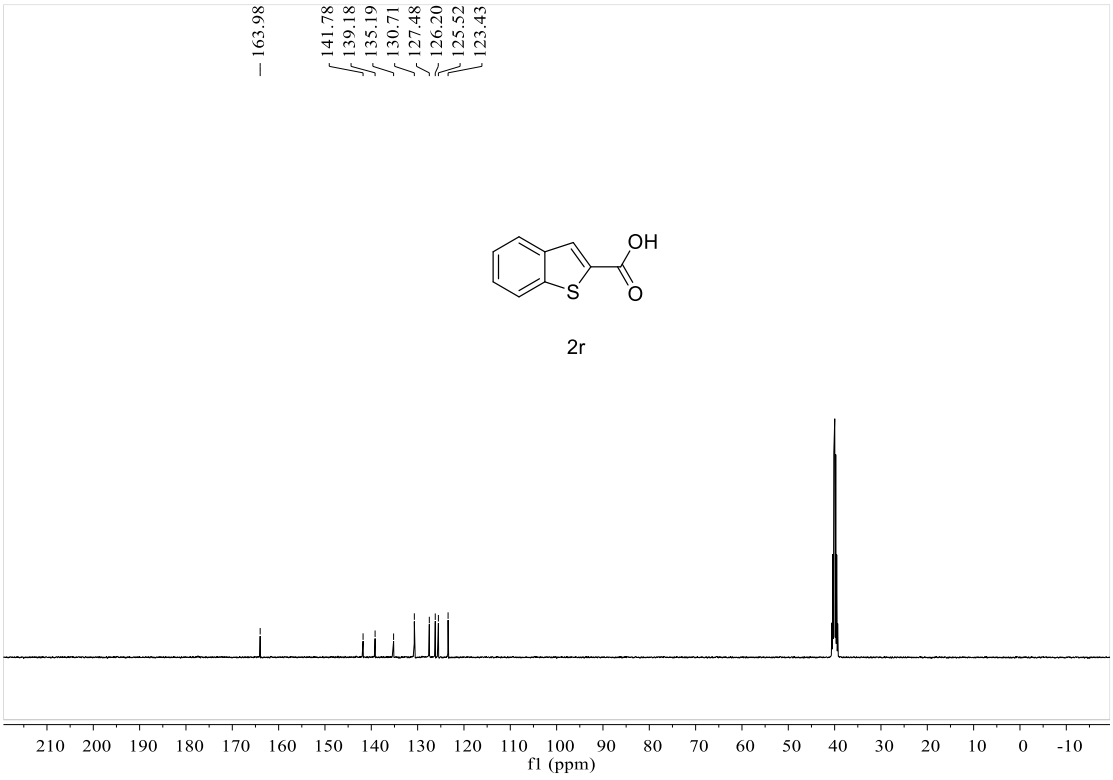
8.26
8.26
8.26
8.25
8.25
7.62
7.61
7.60
7.60
7.60
7.59
7.44
7.44
7.44
7.43
7.43
7.43
O
OH
S
2q
1.03
1.00
1.09
1.14
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

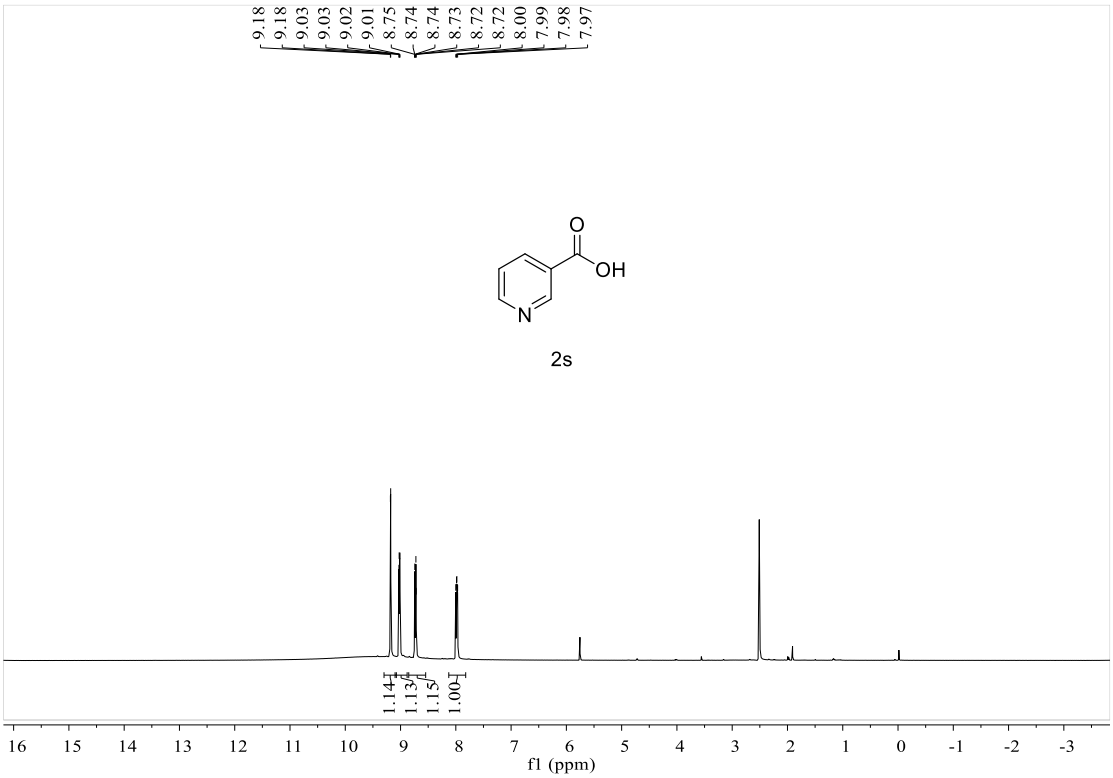

164.02
134.78
133.69
128.20
127.69
127.67
O
OH
S
2q
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

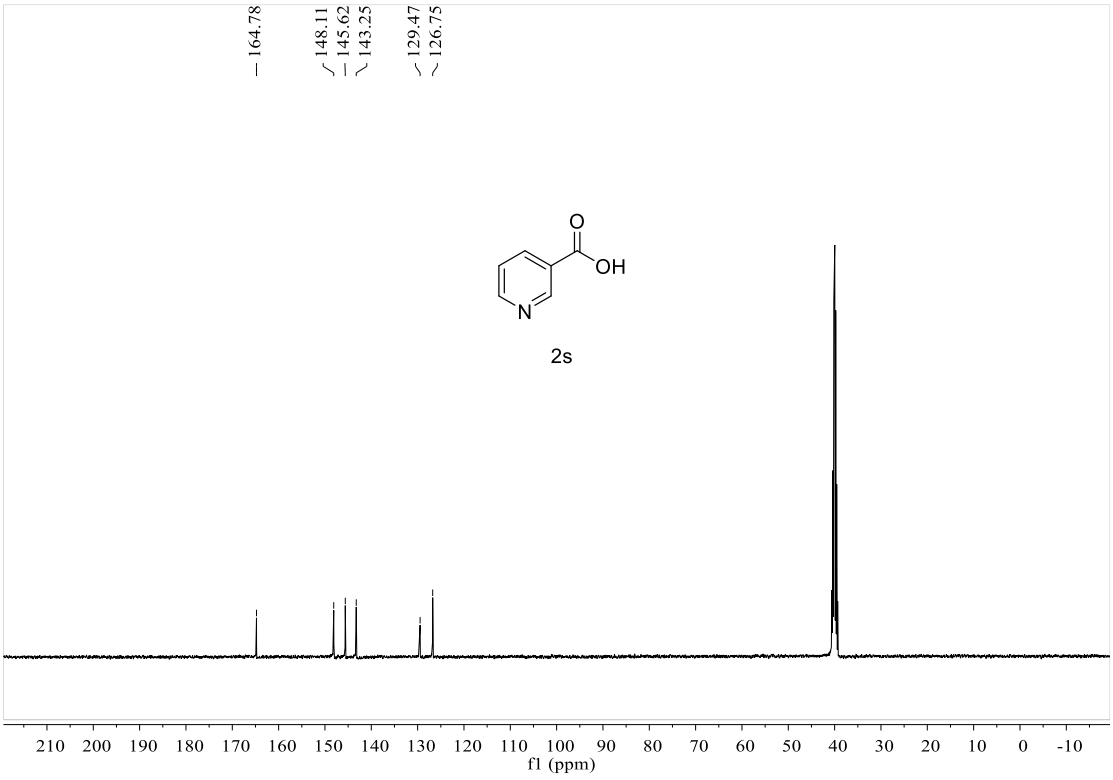

13.42
8.12
8.05
8.03
8.02
8.00
8.00
7.53
7.53
7.51
7.51
7.49
7.49
7.48
7.48
7.46
7.46
7.44
7.44
OH
S
O
1.01
1.00
2.00
2.05
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

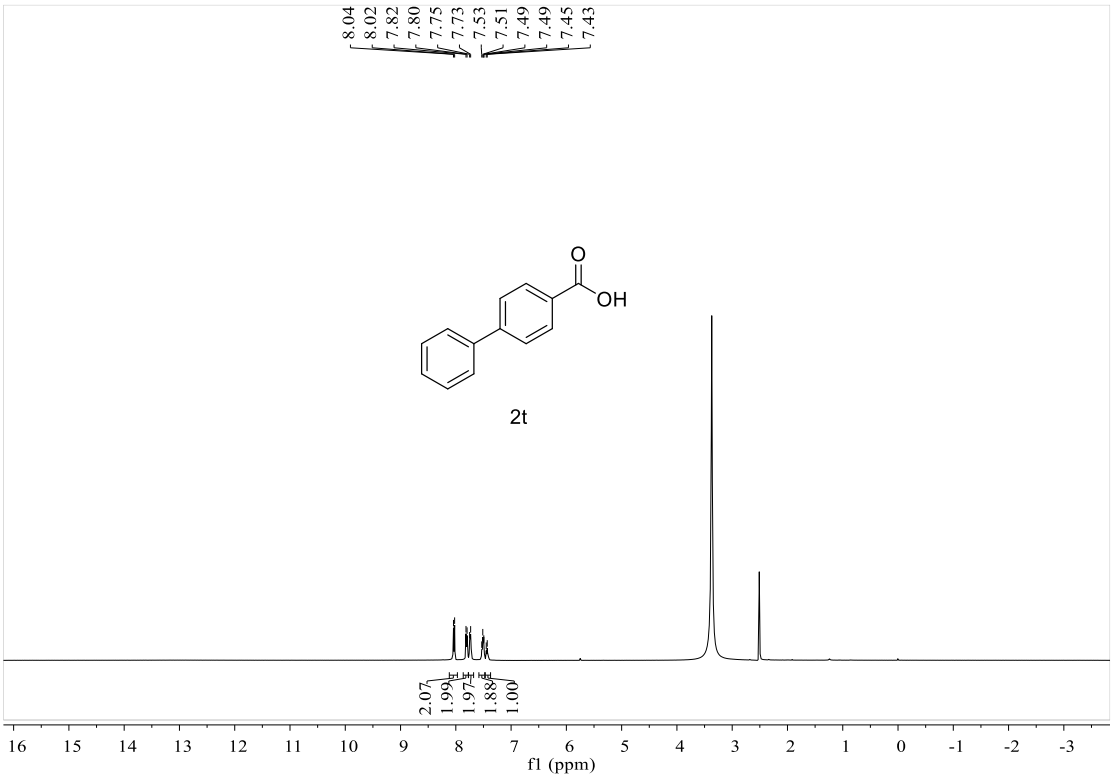
2r

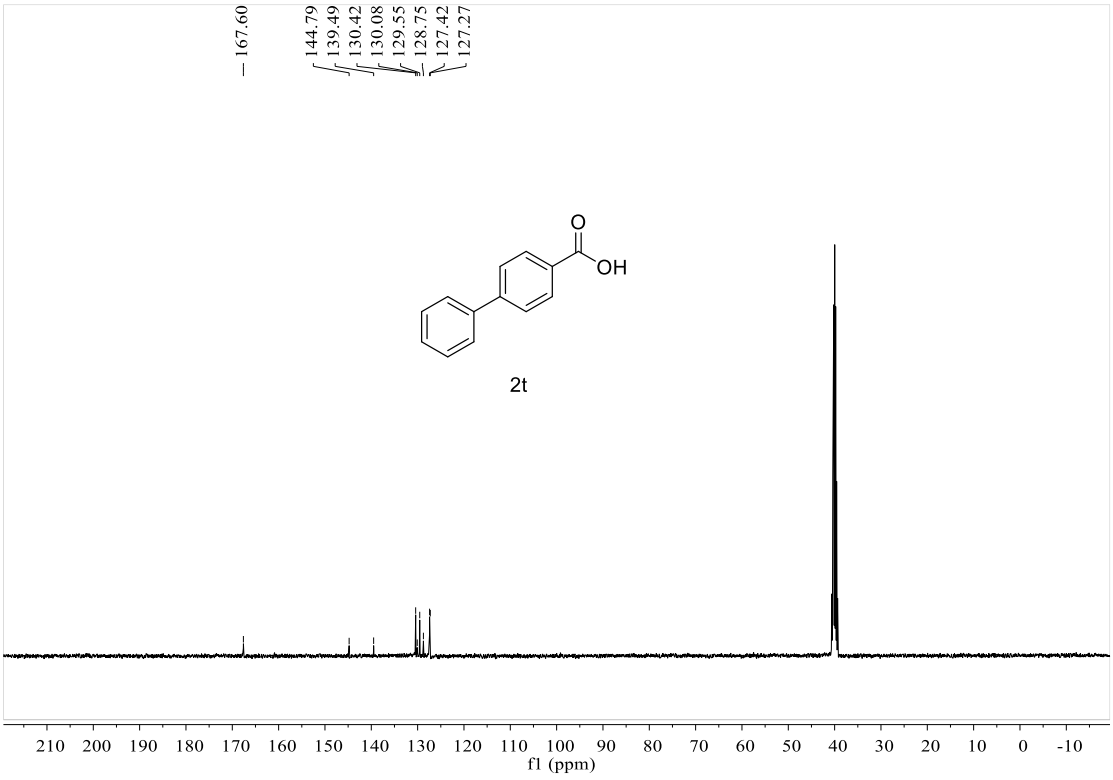

163.98
141.78
139.18
135.19
130.71
127.48
126.20
125.52
123.43
OH
S
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

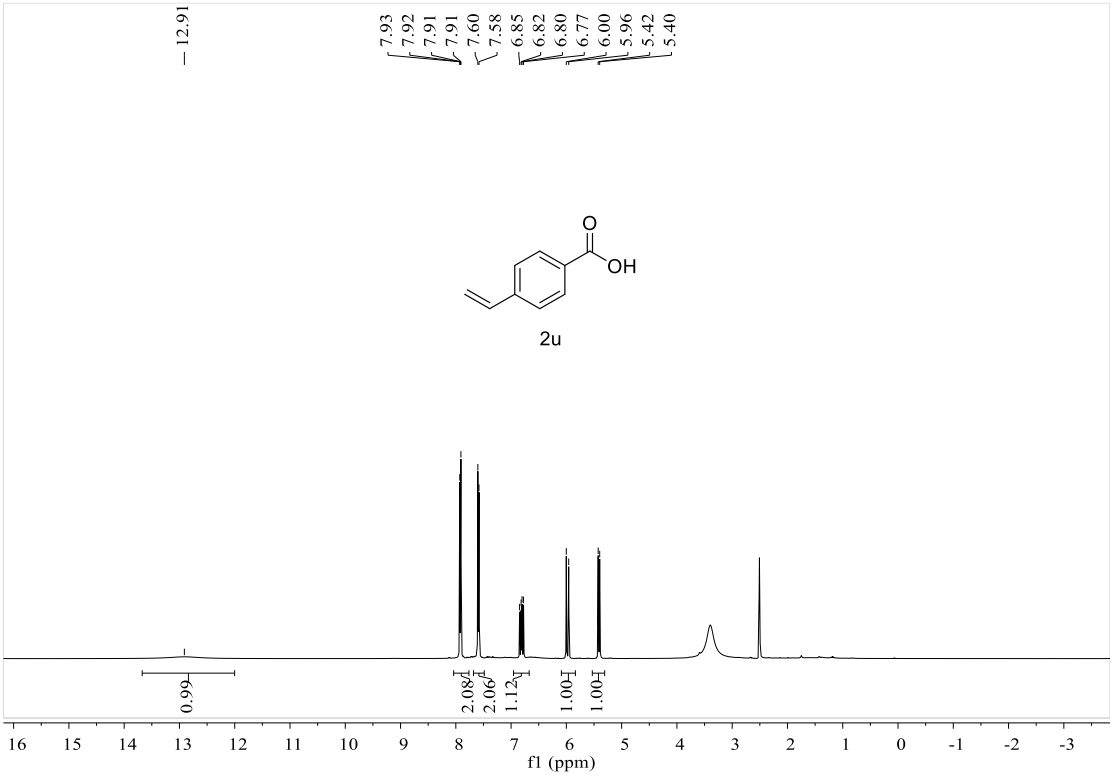
2r


9.18
9.18
9.03
9.03
9.02
9.01
8.75
8.74
8.74
8.73
8.72
8.72
8.00
7.99
7.98
7.97
O
OH
N
2s
1.14
1.13
1.15
1.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


164.78
148.11
145.62
143.25
129.47
126.75
O
OH
N
2s
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)


8.04
8.02
7.82
7.80
7.75
7.73
7.53
7.51
7.49
7.49
7.45
7.43
O
OH
2t
2.07
1.99
1.97
1.88
1.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


167.60
144.79
139.49
130.42
130.08
129.55
128.75
127.42
127.27
O
OH
2t
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)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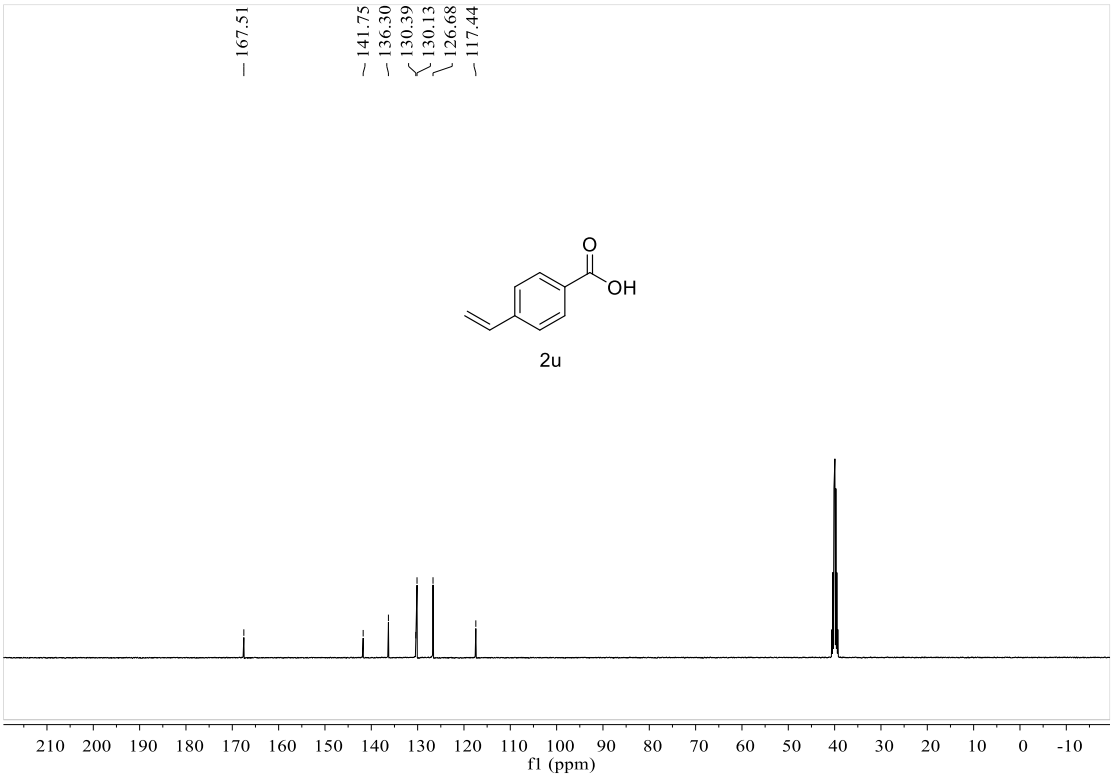
7.91
7.91
7.60
7.58
6.85
6.82
6.80
6.77
6.00
5.96
5.42
5.40
O
OH
2u
0.99
2.08
2.06
1.12
1.00
1.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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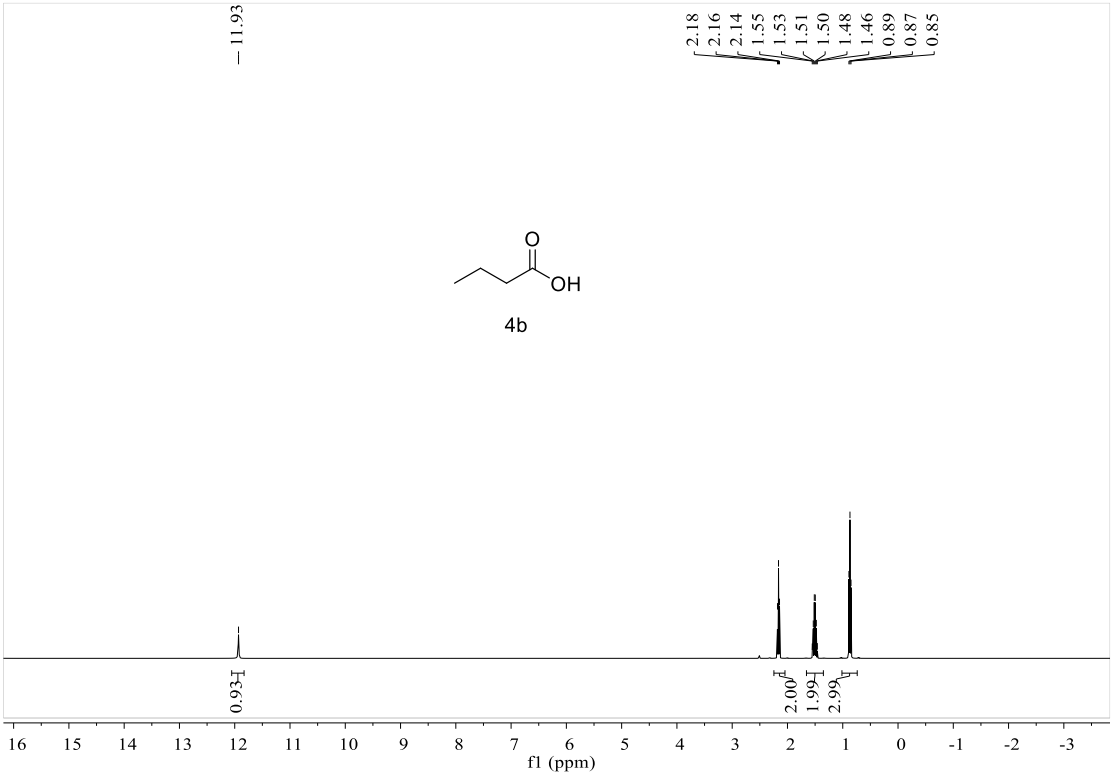
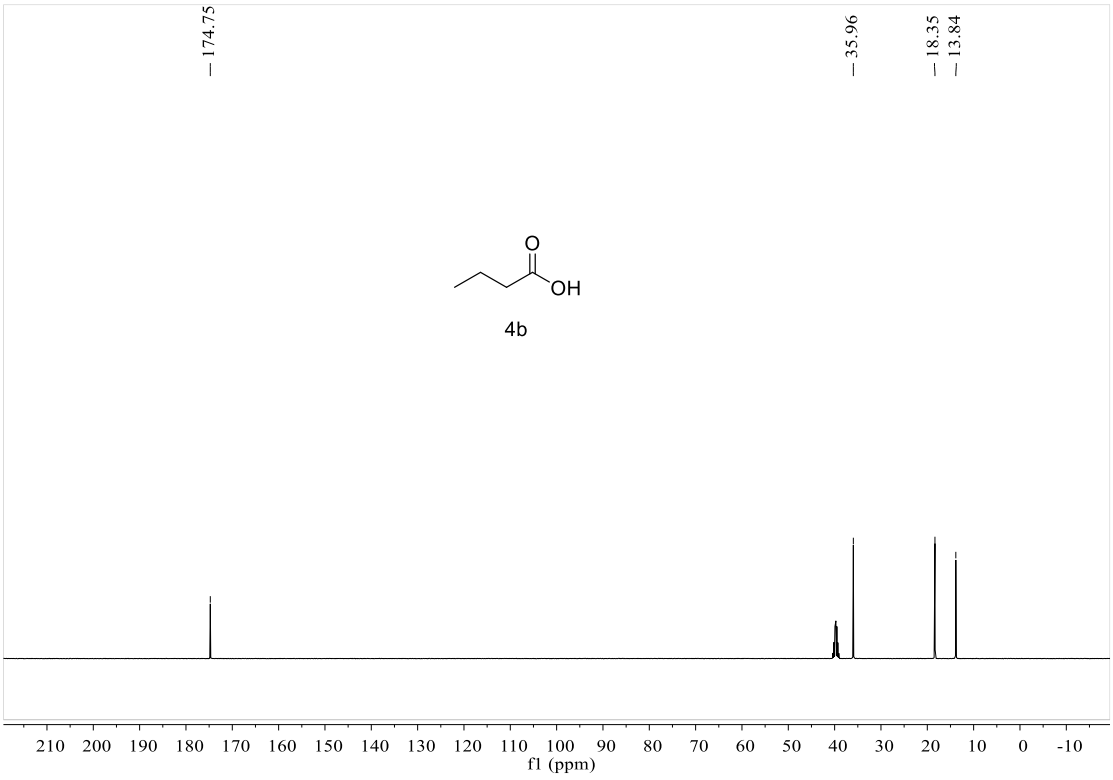
141.75
136.30
130.39
130.13
126.68
117.44
O
OH
2u
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


11.93
2.18
2.16
2.14
1.55
1.53
1.51
1.50
1.48
1.46
0.89
0.87
0.85
O
OH
4b
0.93
2.00
1.99
2.99
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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35.96
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13.84
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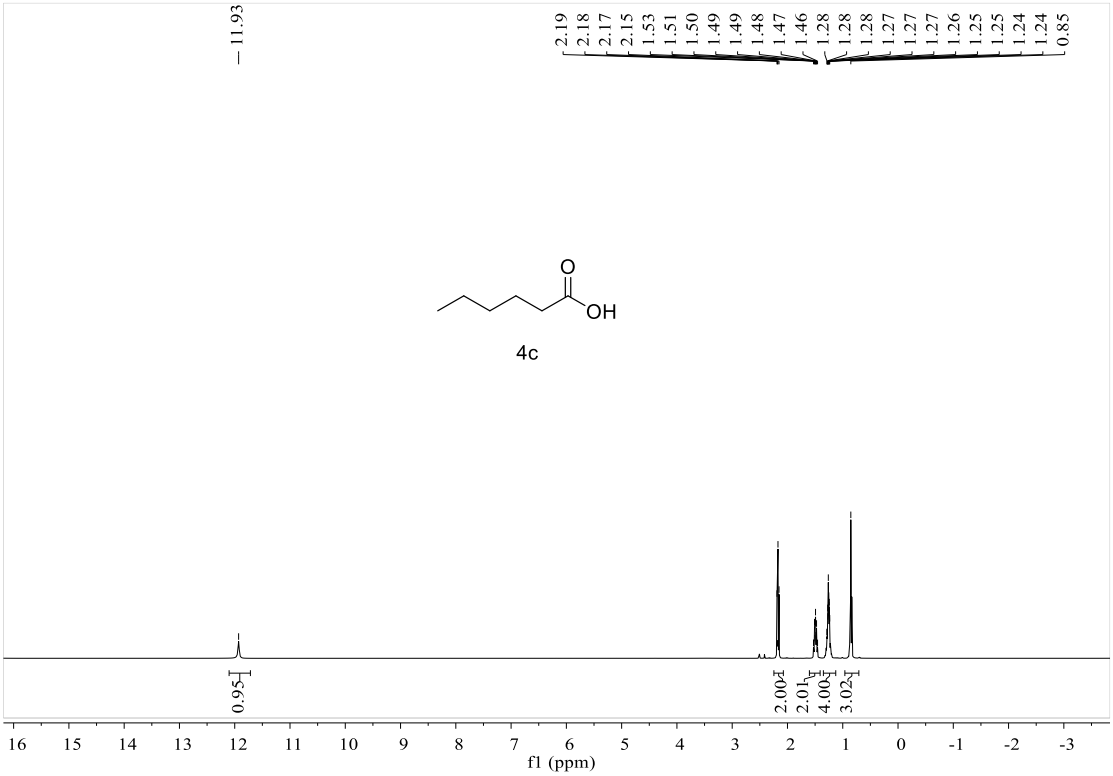
OH
4b
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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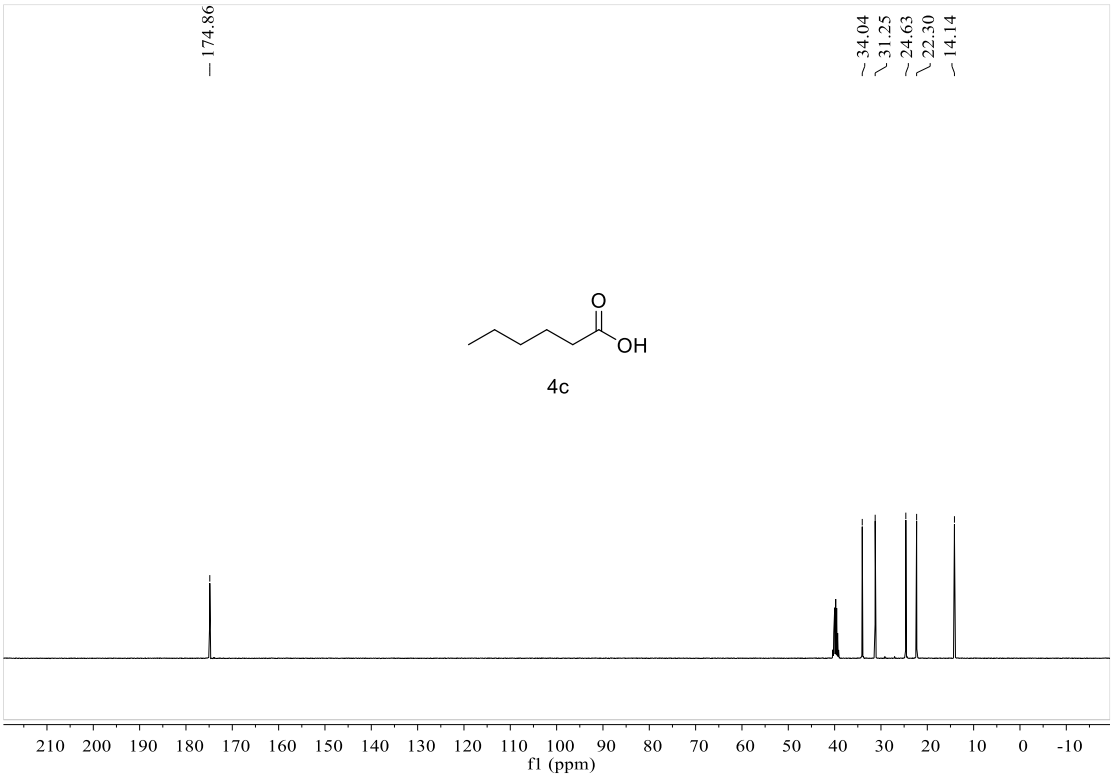
2.19
2.18
2.17
2.15
1.53
1.51
1.50
1.49
1.49
1.48
1.47
1.46
1.28
1.28
1.28
1.27
1.27
1.27
1.26
1.25
1.25
1.24
1.24
0.85
O
OH
4c
0.95
2.00
2.01
4.00
3.02
f1 (ppm)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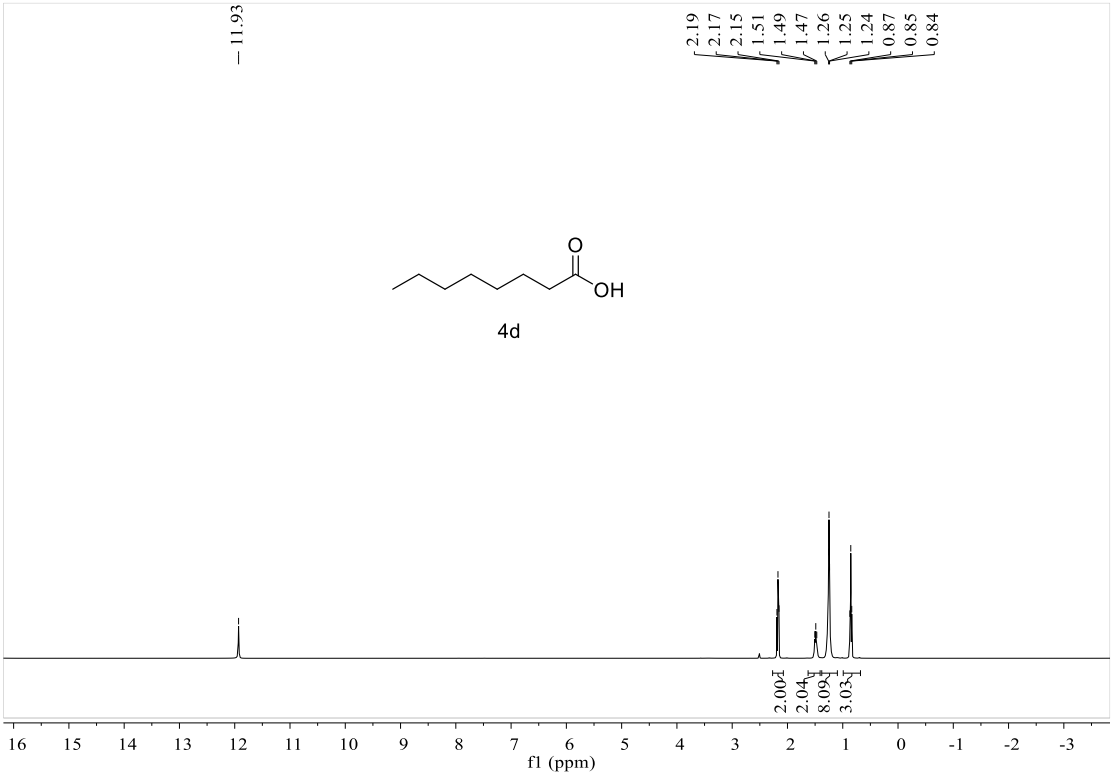
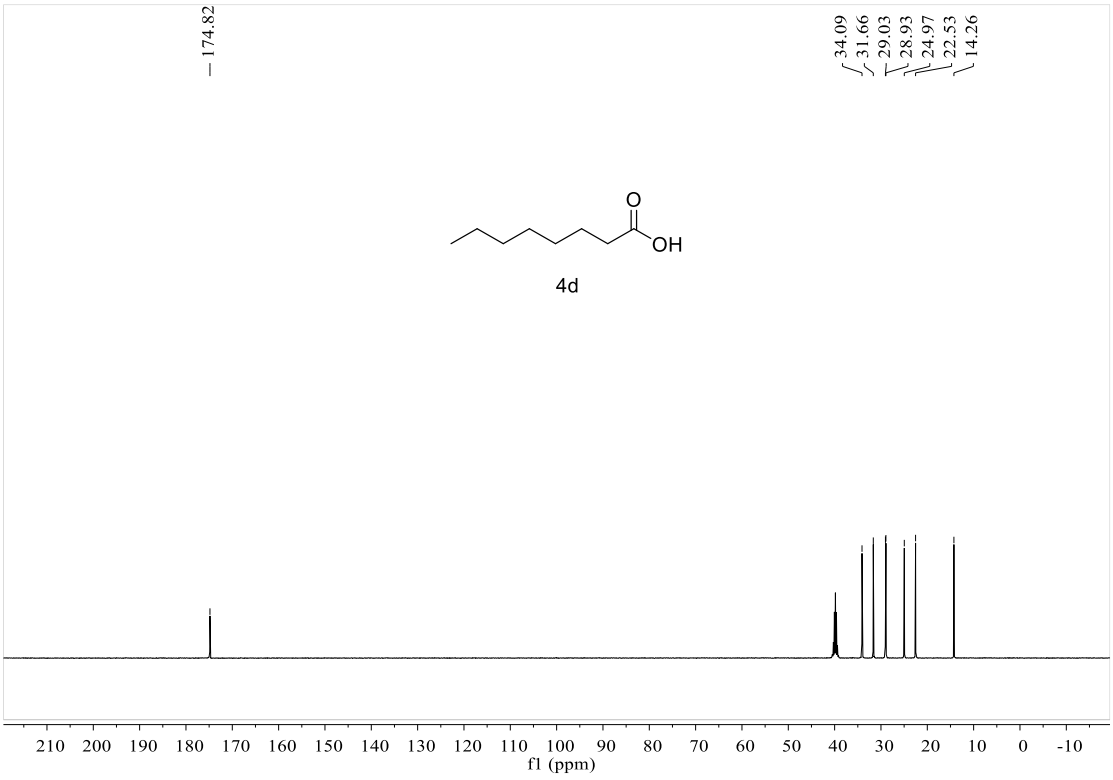
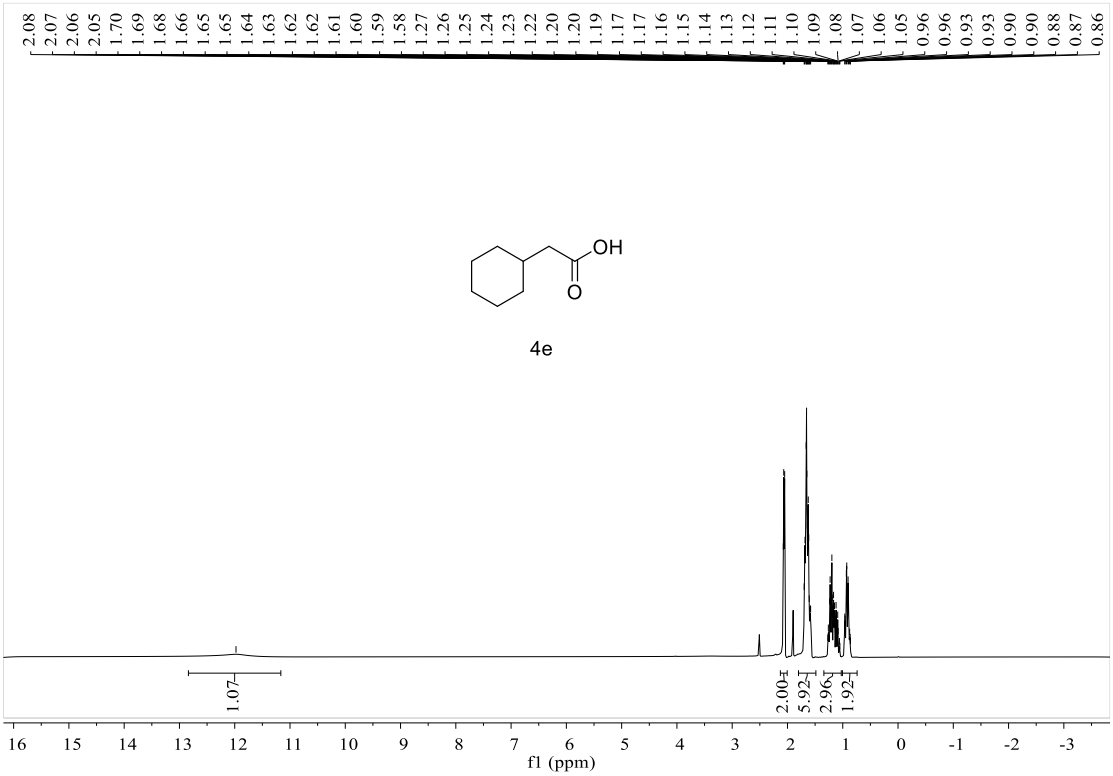
24.63
22.30
14.14
O
OH
4c
f1 (ppm)


11.93
2.19
2.17
2.15
1.51
1.49
1.47
1.26
1.25
1.24
0.87
0.85
0.84
O
OH
4d
2.00
2.04
8.09
3.03
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


174.82
34.09
31.66
29.03
28.93
24.97
22.53
14.26
O
OH
4d
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)


2.08 2.07 2.06 2.05 1.70 1.69 1.68 1.66 1.65 1.65 1.64 1.63 1.62 1.62 1.61 1.60 1.59 1.58 1.27 1.26 1.25 1.24 1.23 1.22 1.20 1.20 1.19 1.17 1.17 1.16 1.15 1.14 1.13 1.12 1.11 1.10 1.09 1.08 1.07 1.06 1.05 0.96 0.96 0.93 0.93 0.90 0.90 0.88 0.87 0.86
OH
O
4e
1.07
2.00
5.92
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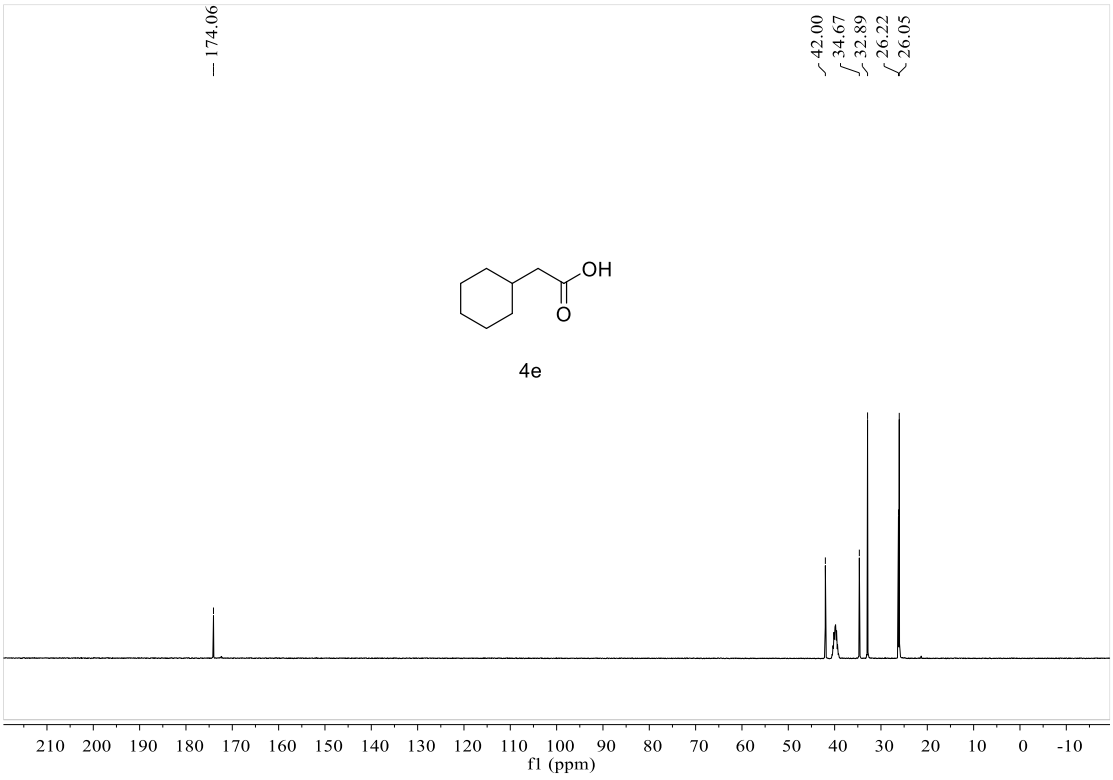
1.92
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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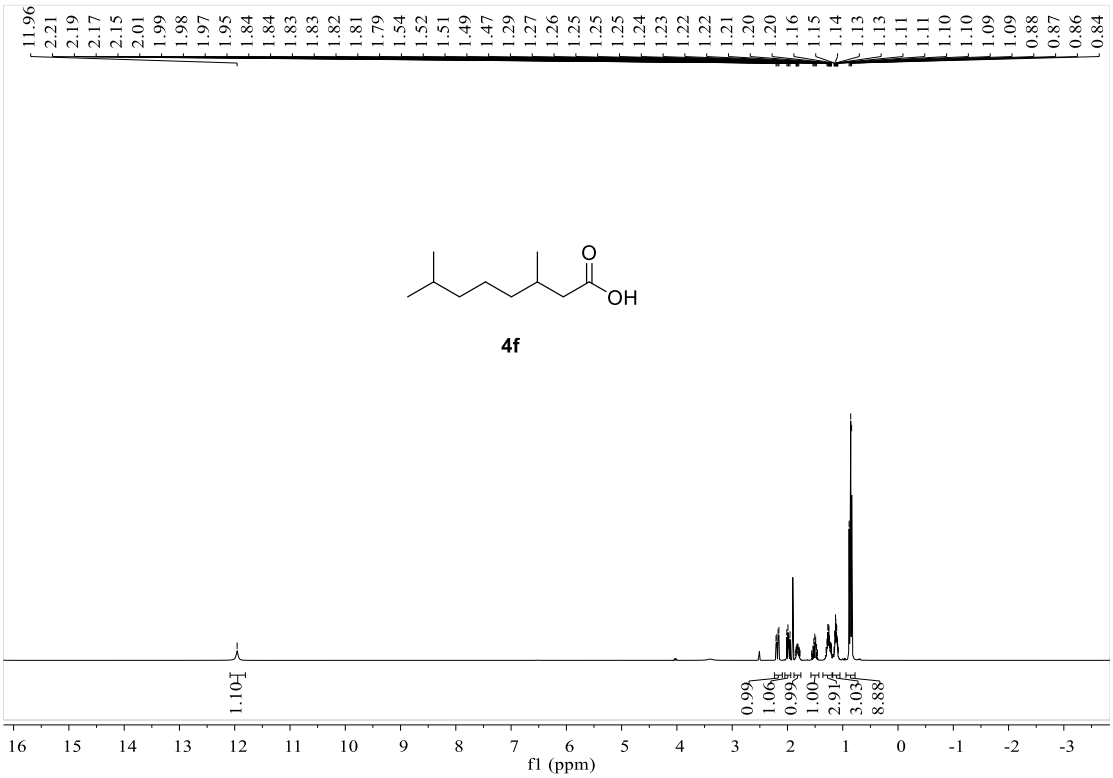
34.67
32.89
26.22
26.05
OH
O
4e
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


11.96
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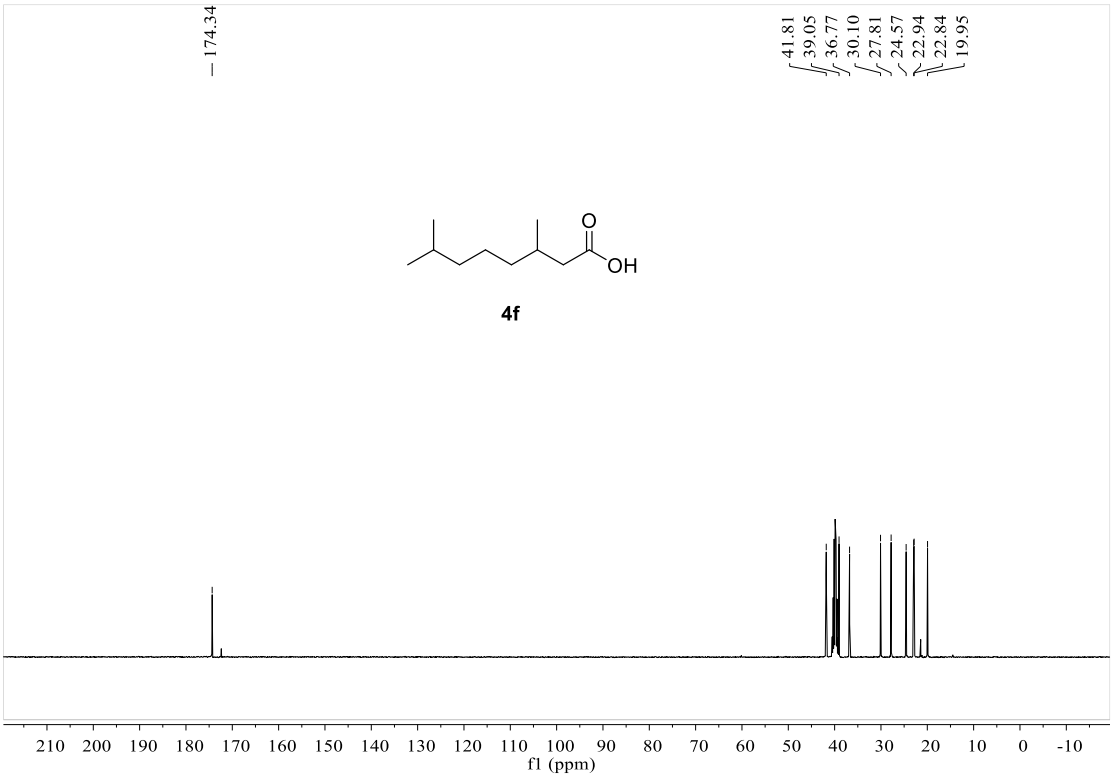
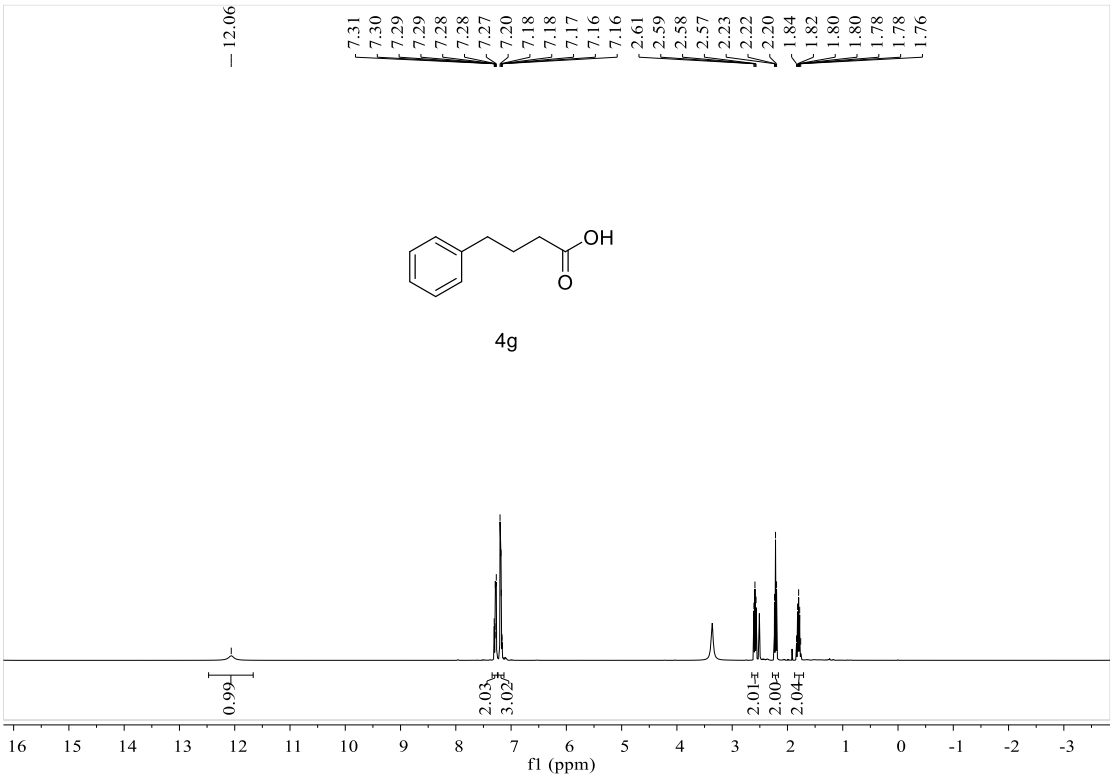
1.98
1.97
1.95
1.84
1.84
1.83
1.83
1.82
1.81
1.79
1.54
1.52
1.51
1.49
1.47
1.29
1.27
1.26
1.25
1.25
1.25
1.24
1.23
1.22
1.22
1.21
1.20
1.20
1.16
1.15
1.14
1.13
1.13
1.11
1.11
1.10
1.10
1.09
1.09
0.88
0.87
0.86
0.84
O
OH
4f
1.10
0.99
1.06
0.99
1.00
2.91
3.03
8.88
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


174.34
41.81
39.05
36.77
30.10
27.81
24.57
22.94
22.84
19.95
O
OH
4f
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)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7.31
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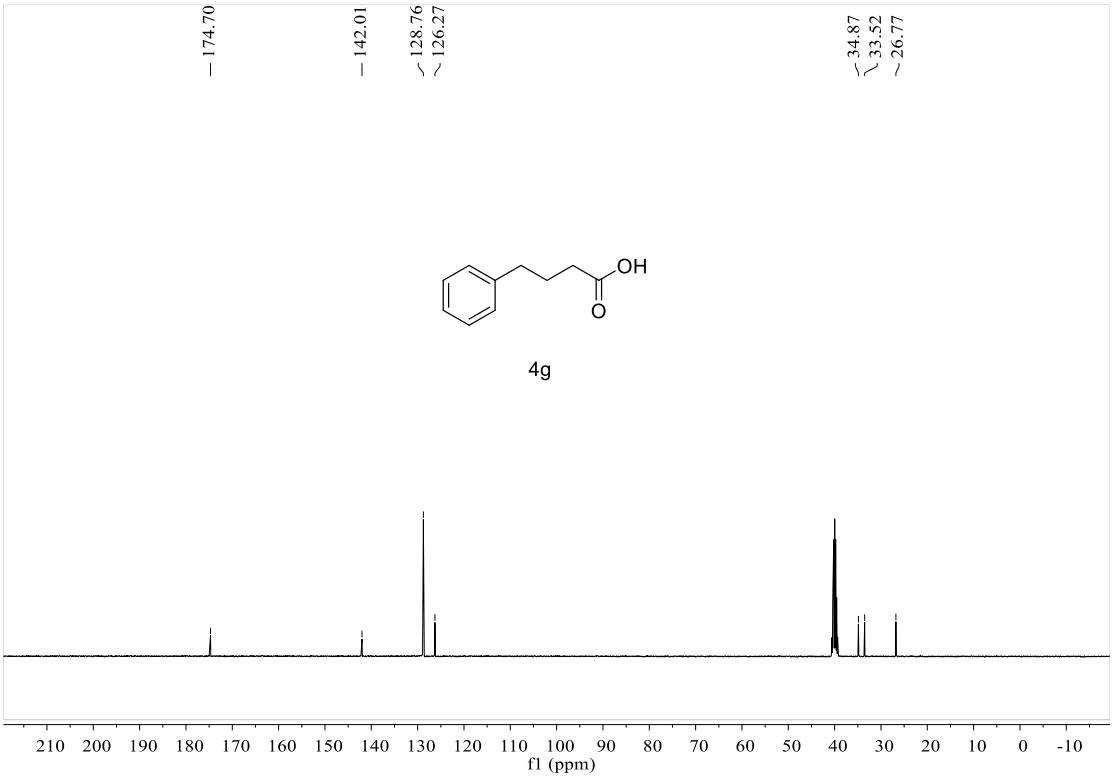
7.29
7.28
7.28
7.27
7.20
7.18
7.18
7.17
7.16
7.16
2.61
2.59
2.58
2.57
2.23
2.22
2.20
1.84
1.82
1.80
1.80
1.78
1.78
1.76
OH
O
4g
0.99
2.03
3.02
2.01
2.00
2.04
f1 (ppm)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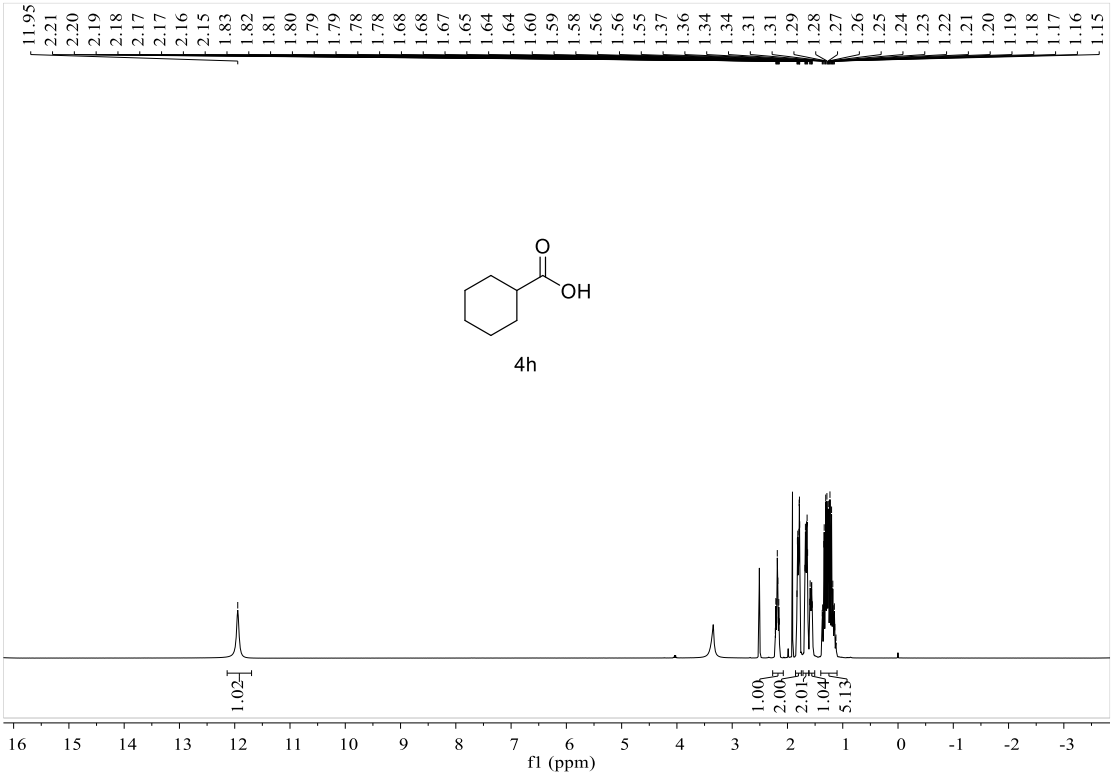
142.01
128.76
126.27
34.87
33.52
26.77
OH
O
4g
f1 (ppm)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2.18
2.17
2.17
2.16
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1.83
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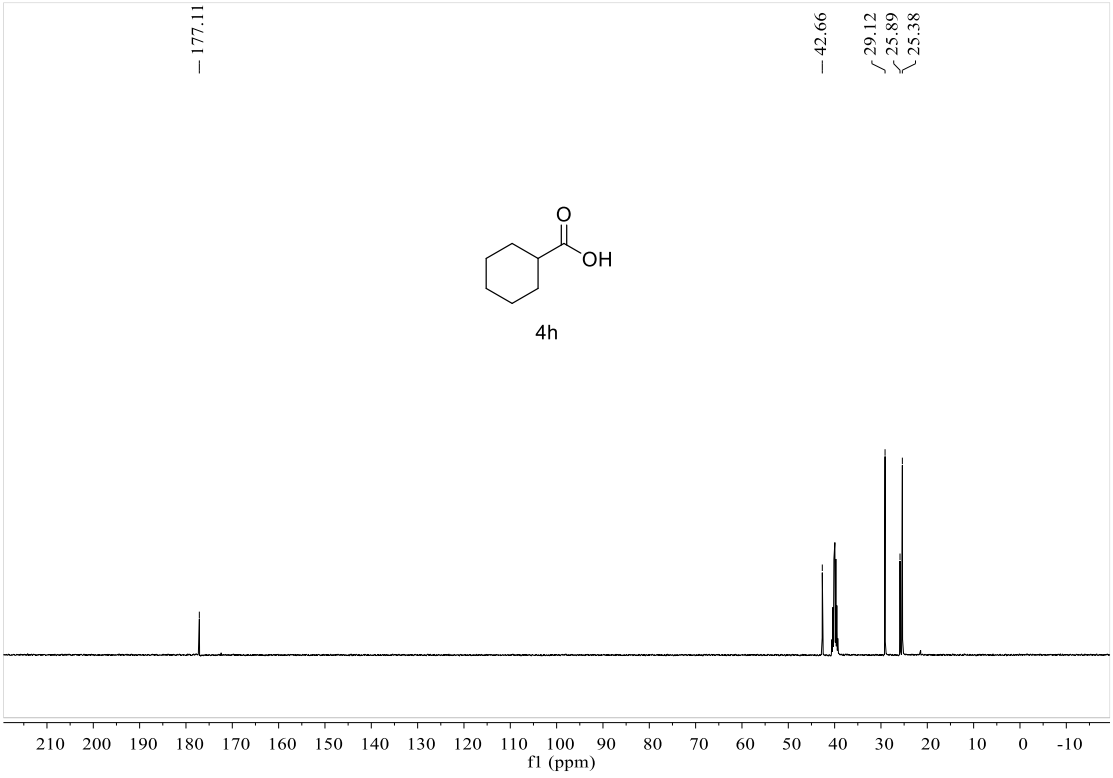
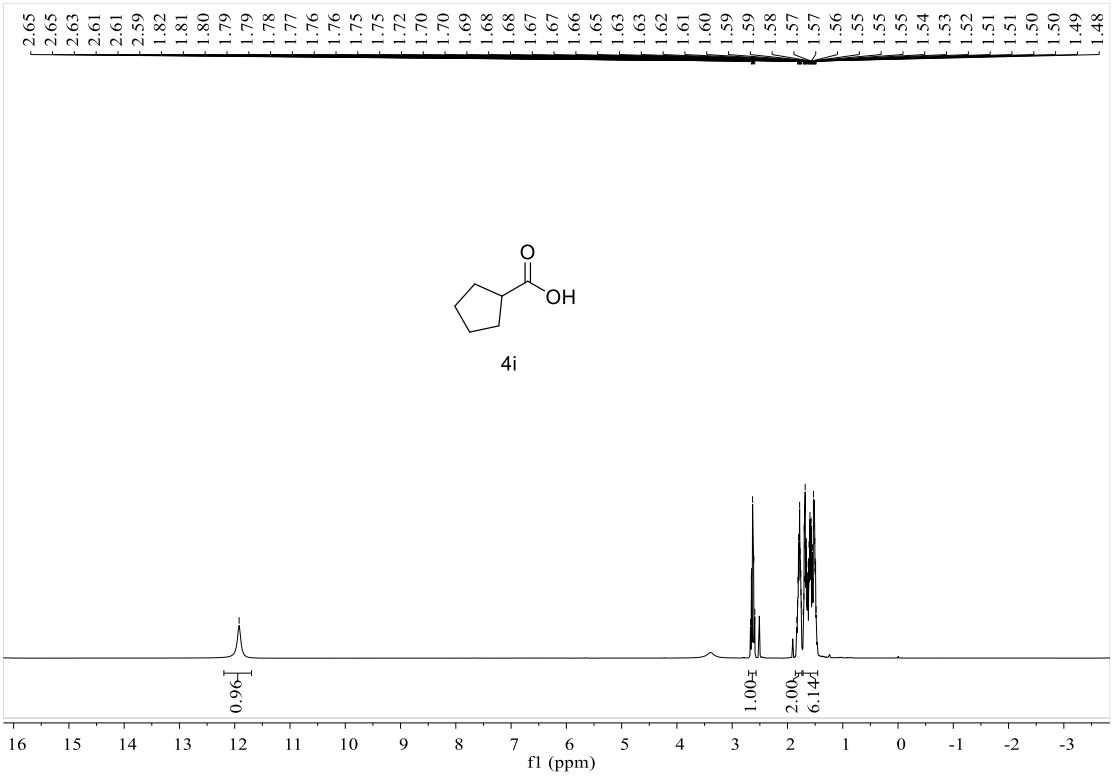
1.81
1.80
1.79
1.79
1.78
1.78
1.68
1.68
1.67
1.65
1.64
1.64
1.60
1.59
1.58
1.56
1.56
1.55
1.37
1.36
1.34
1.34
1.31
1.31
1.29
1.28
1.27
1.26
1.25
1.24
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
O
OH
4h
1.02
1.00
2.00
2.01
1.04
5.13
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


177.11
42.66
29.12
25.89
25.38
O
OH
4h
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)


2.65 2.65 2.63 2.61 2.61 2.59 1.82 1.81 1.80 1.79 1.79 1.78 1.77 1.76 1.76 1.75 1.75 1.72 1.70 1.70 1.69 1.68 1.68 1.67 1.67 1.66 1.65 1.63 1.63 1.62 1.61 1.60 1.59 1.59 1.58 1.57 1.57 1.56 1.55 1.55 1.55 1.54 1.53 1.52 1.51 1.51 1.50 1.50 1.49 1.48
O
OH
4i
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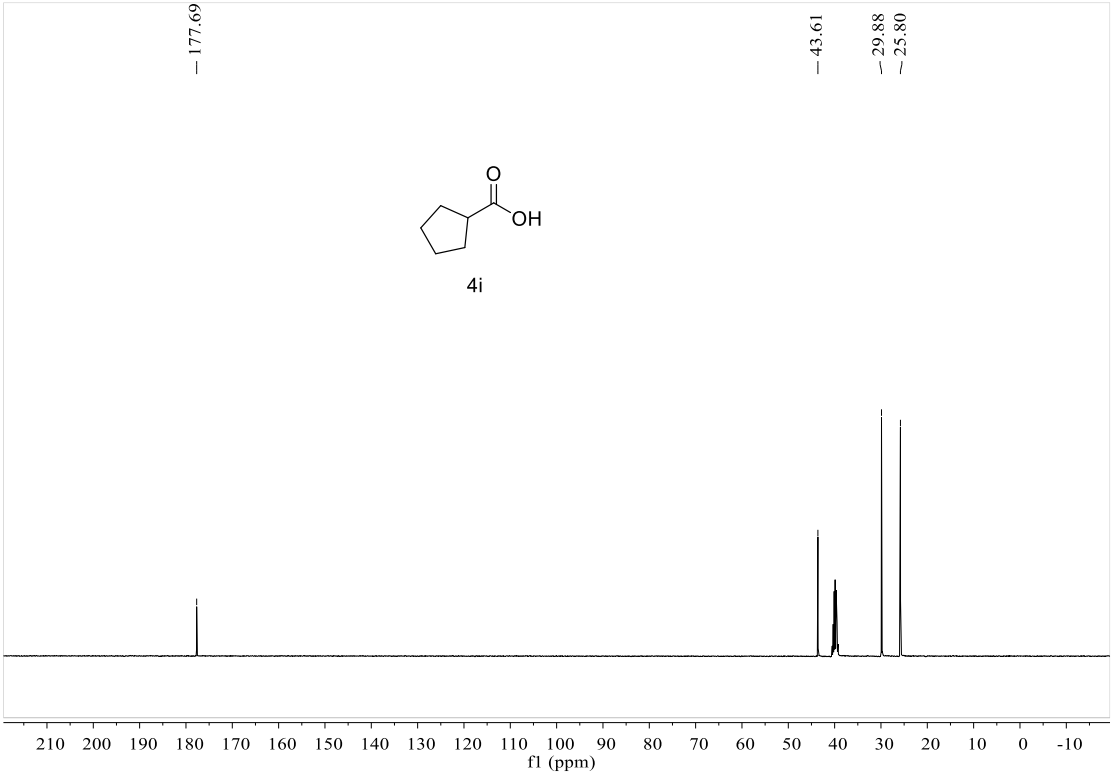
1.00
2.00
6.14
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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OH
4i
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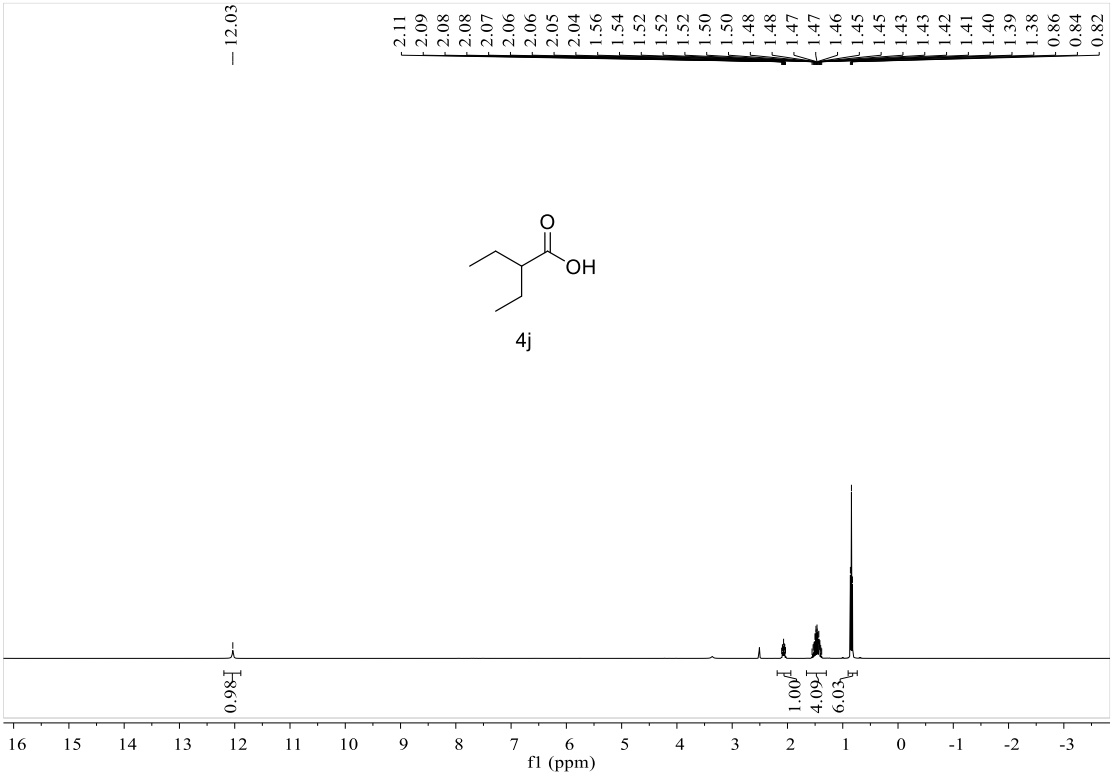
f1 (ppm)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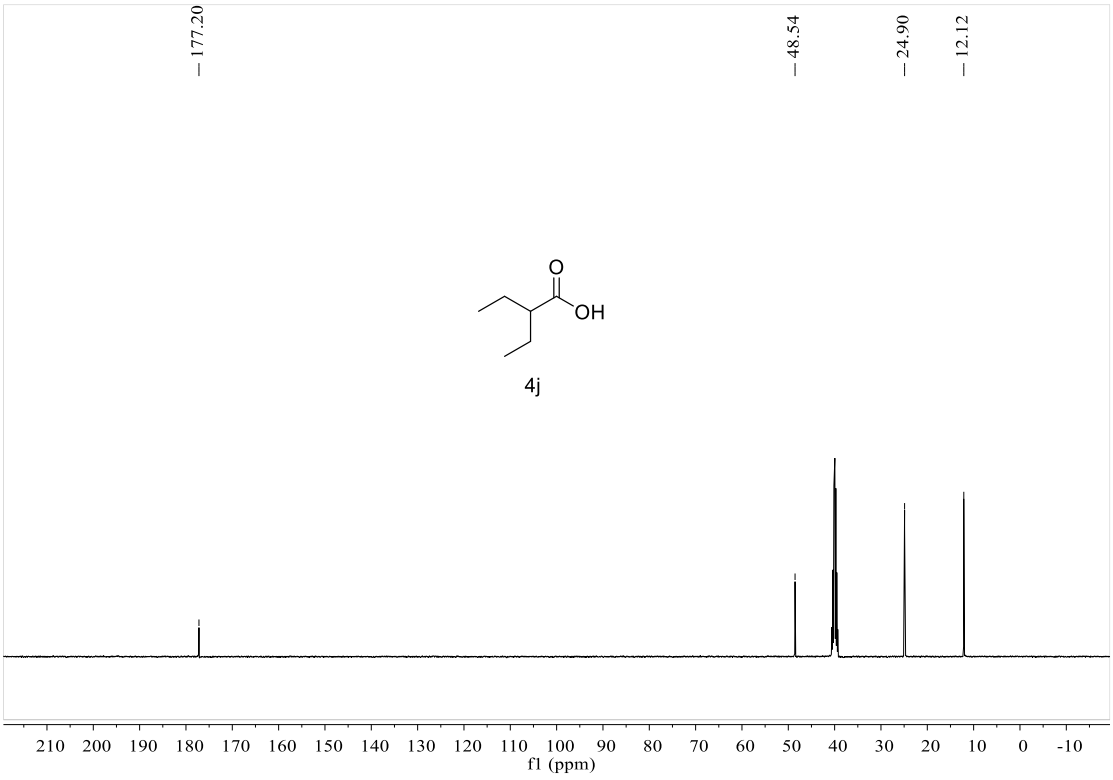
2.08
2.07
2.06
2.06
2.05
2.04
1.56
1.54
1.52
1.52
1.52
1.50
1.50
1.48
1.48
1.47
1.47
1.46
1.45
1.45
1.43
1.43
1.42
1.41
1.40
1.39
1.38
0.86
0.84
0.82
O
OH
4j
0.98
1.00
4.09
6.03
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


177.20
48.54
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OH
4j
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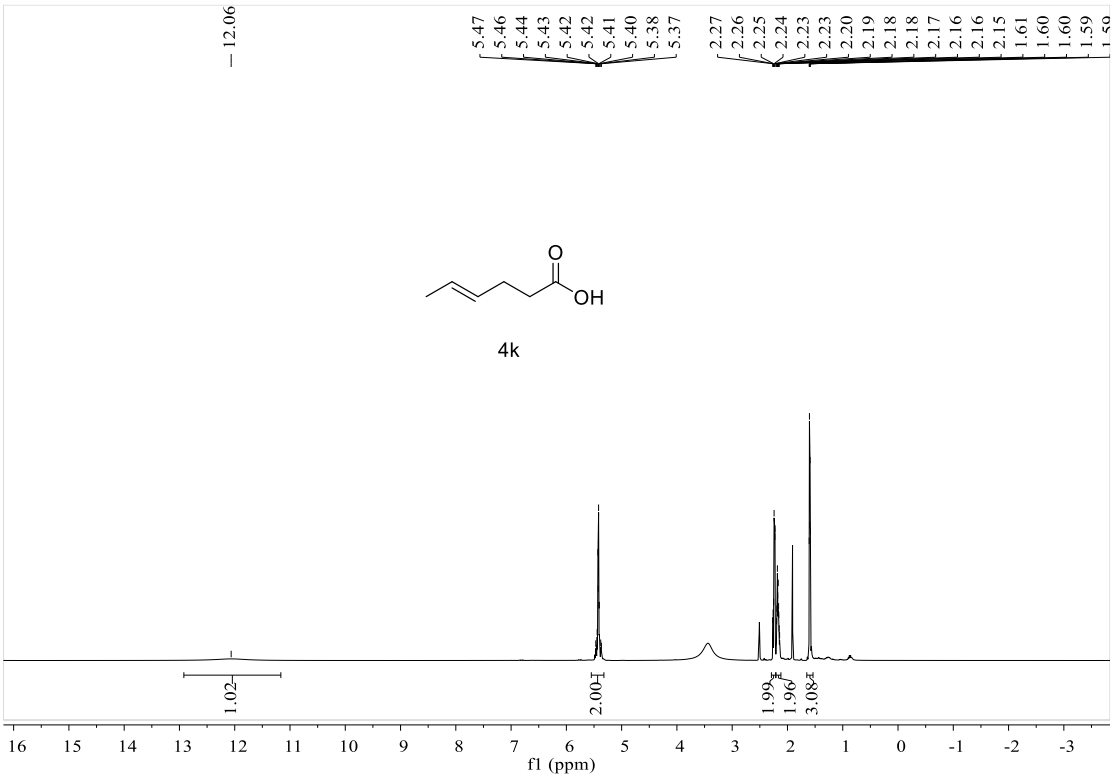
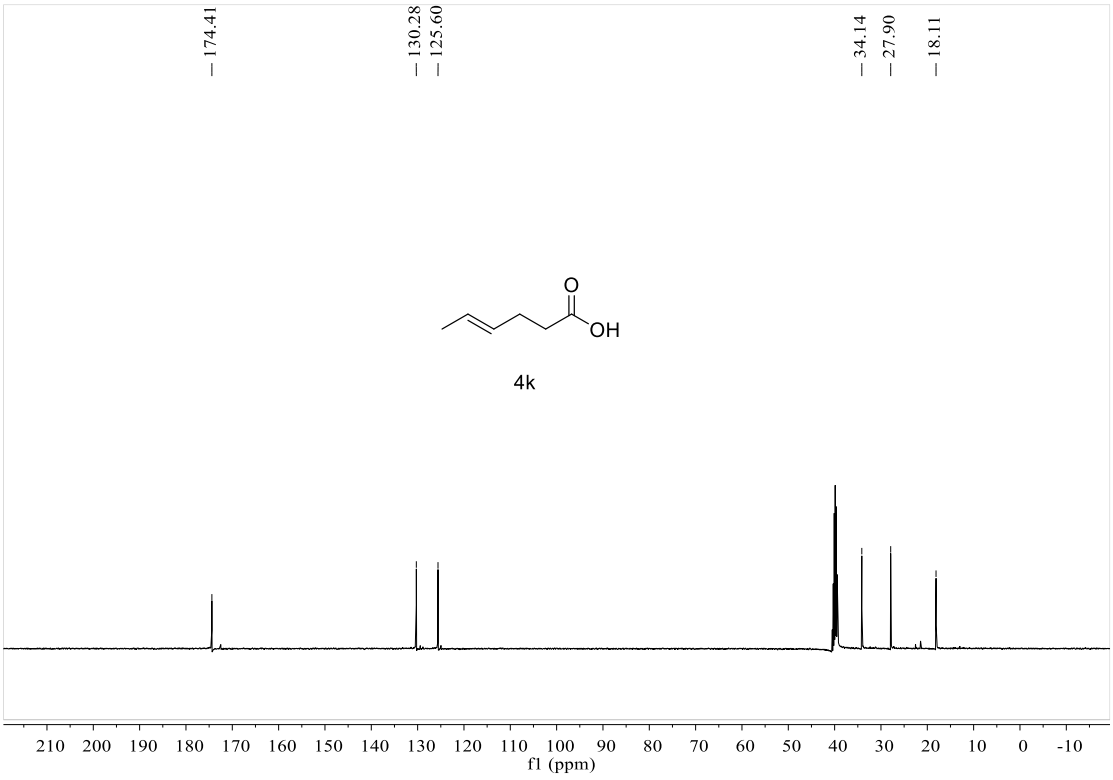
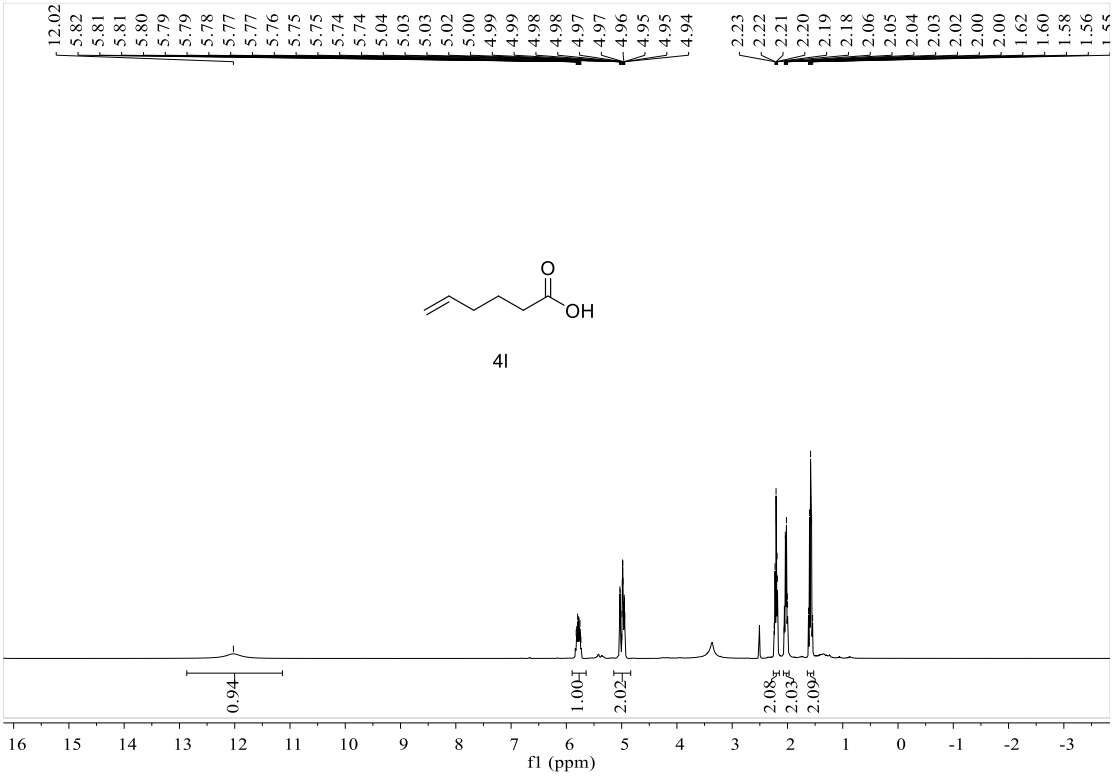
f1 (ppm)


12.06
5.47
5.46
5.44
5.43
5.42
5.42
5.41
5.40
5.38
5.37
2.27
2.26
2.25
2.24
2.23
2.23
2.20
2.19
2.18
2.18
2.17
2.16
2.16
2.15
1.61
1.60
1.60
1.59
O
OH
4k
1.02
2.00
1.99
1.96
3.08
f1 (ppm)


174.41
130.28
125.60
34.14
27.90
18.11
O
OH
4k
f1 (ppm)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5.82
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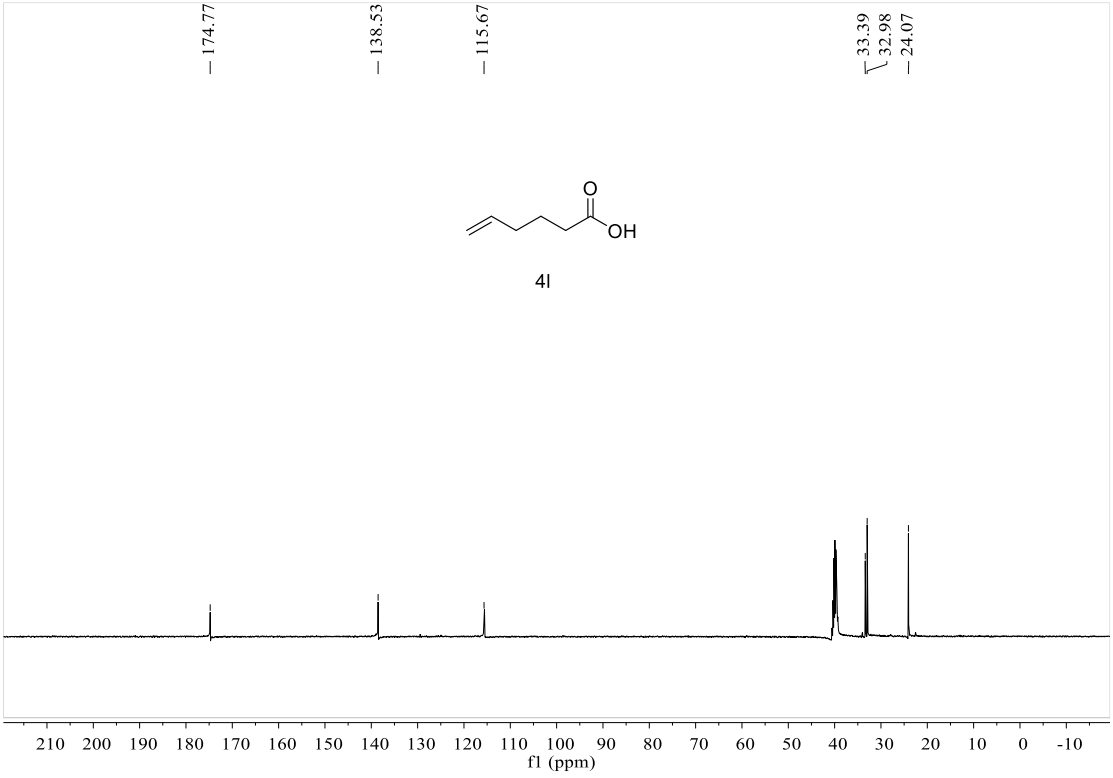
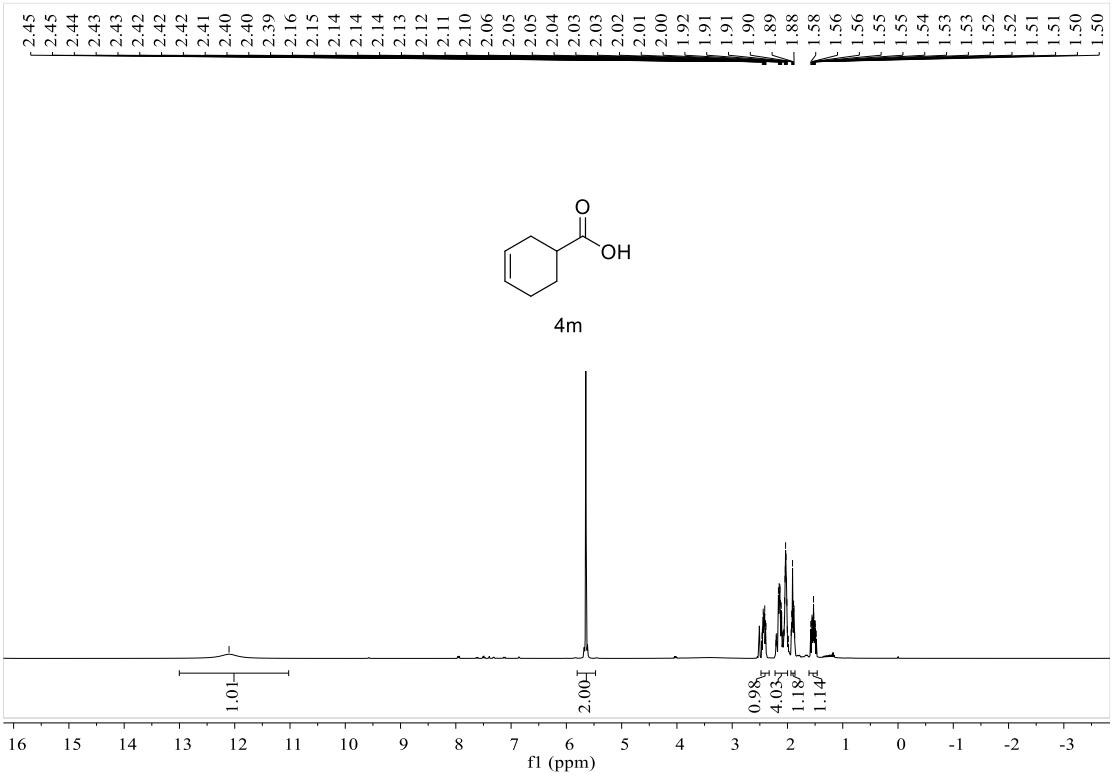
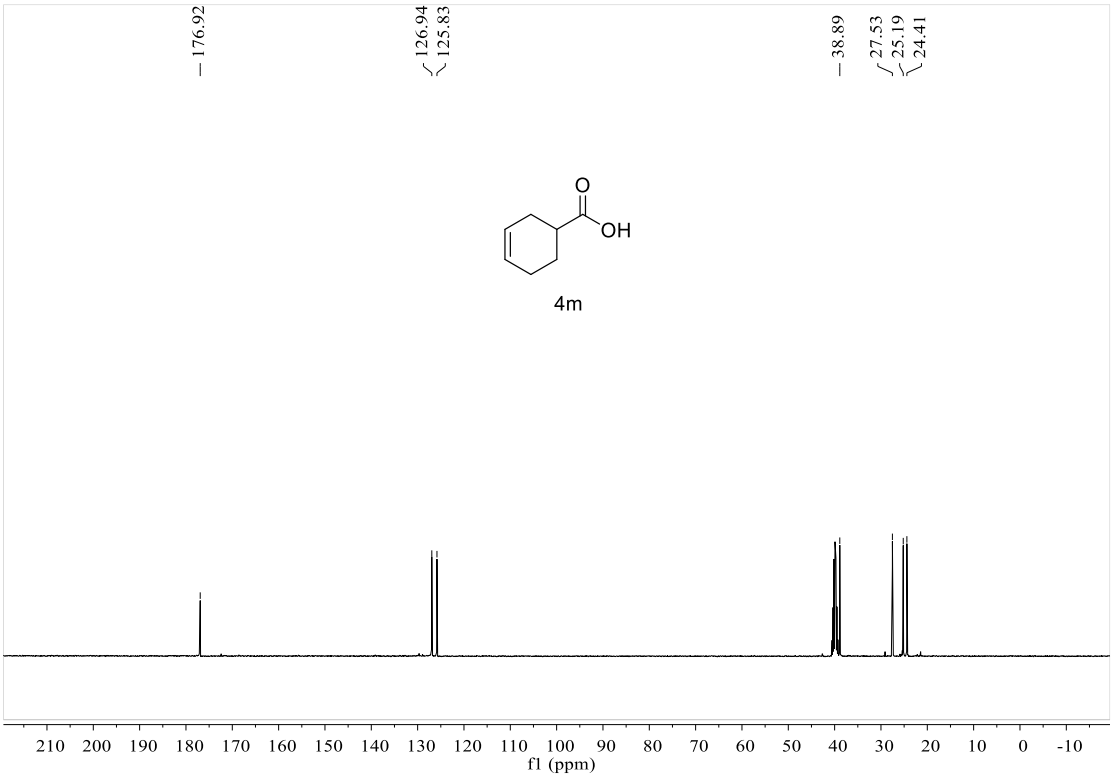
5.81
5.80
5.79
5.79
5.78
5.77
5.77
5.76
5.75
5.75
5.74
5.74
5.04
5.03
5.03
5.02
5.00
4.99
4.99
4.98
4.98
4.97
4.97
4.96
4.95
4.95
4.94
2.23
2.22
2.21
2.20
2.19
2.18
2.06
2.05
2.04
2.03
2.02
2.00
2.00
1.62
1.60
1.58
1.56
O
OH
0.94
1.00
2.02
2.08
2.03
2.09
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

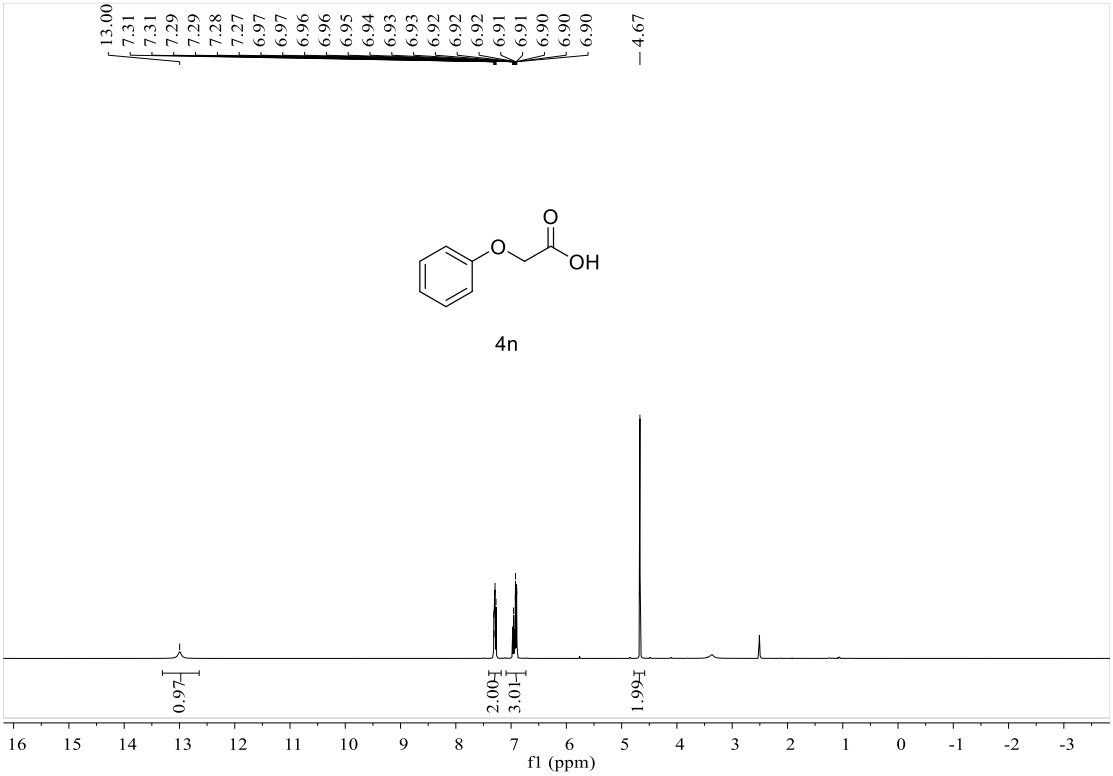
4l


174.77
138.53
115.67
33.39
32.98
24.07
O
OH
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)

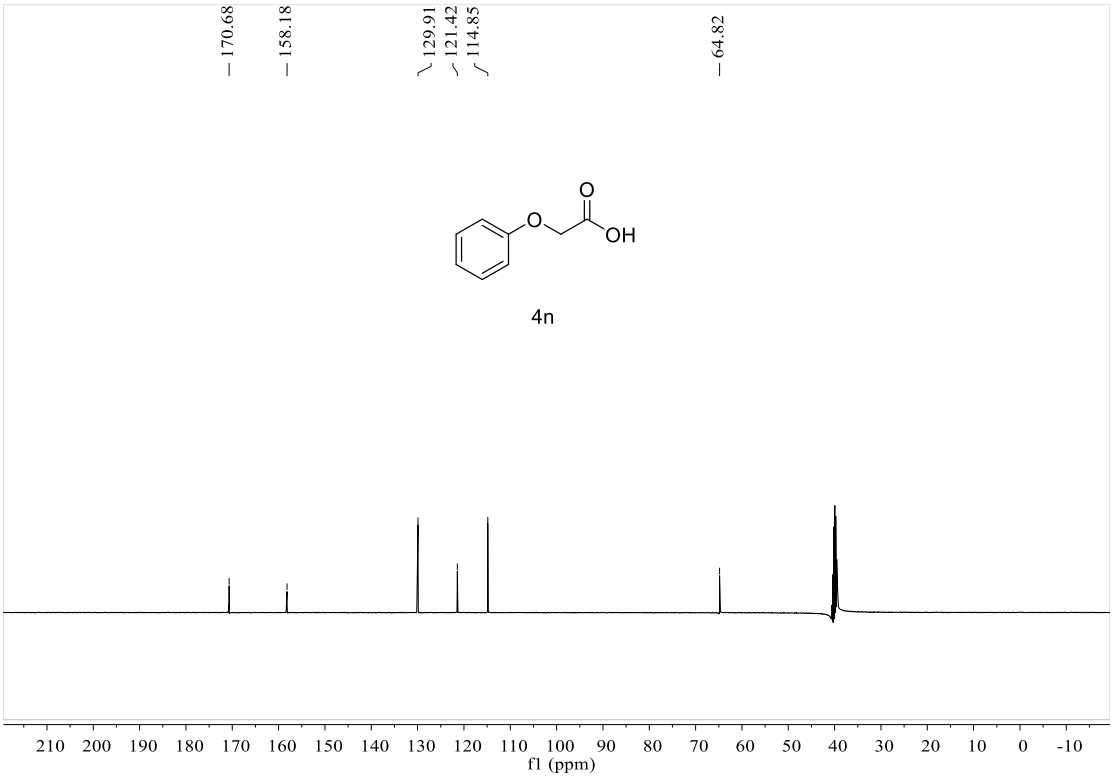
4l


2.45 2.45 2.44 2.43 2.43 2.42 2.42 2.42 2.41 2.40 2.40 2.39 2.16 2.15 2.14 2.14 2.13 2.12 2.11 2.10 2.06 2.05 2.05 2.04 2.03 2.03 2.02 2.01 2.00 1.92 1.91 1.91 1.90 1.89 1.88 1.58 1.56 1.56 1.55 1.55 1.54 1.53 1.53 1.52 1.52 1.51 1.51 1.50 1.50
O
OH
4m
1.01
2.00
0.98
4.03
1.18
1.14
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

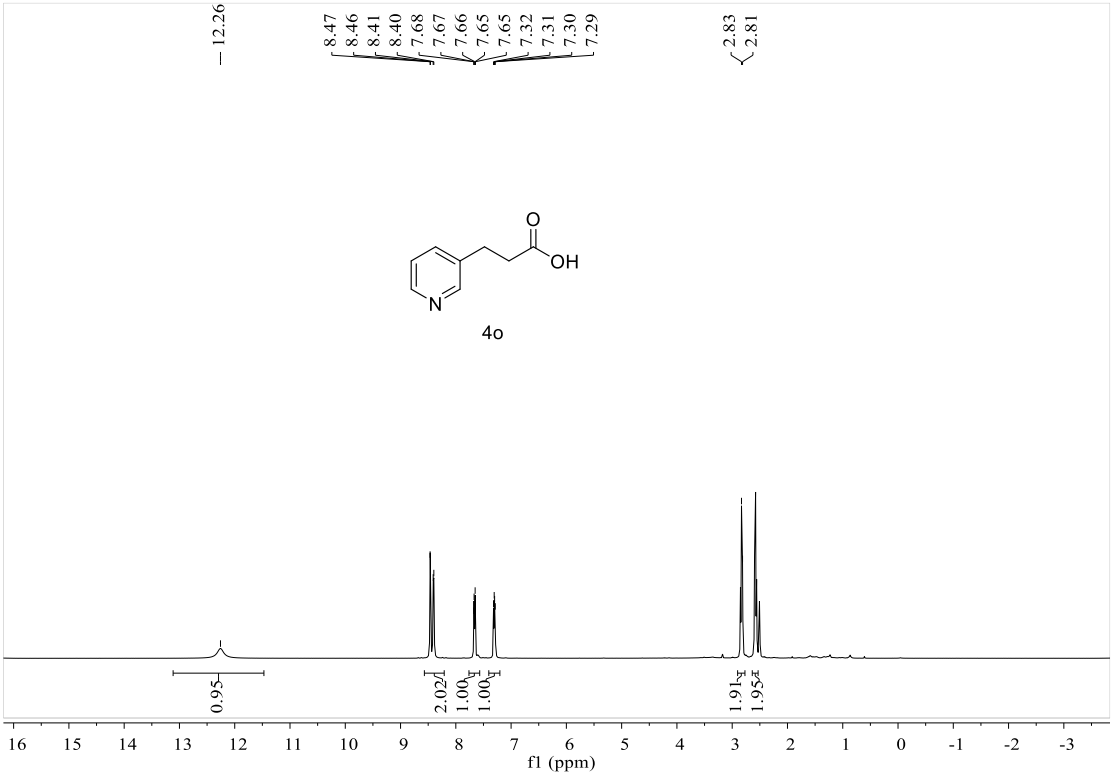

176.92
126.94
125.83
38.89
27.53
25.19
24.41
O
OH
4m
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


13.00
7.31
7.31
7.29
7.29
7.28
7.27
6.97
6.97
6.96
6.96
6.95
6.94
6.93
6.93
6.92
6.92
6.92
6.91
6.91
6.90
6.90
6.90
4.67
O
O
OH
0.97
2.00
3.01
1.99
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

4n


170.68
158.18
129.91
121.42
114.85
64.82
O
O
OH
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)

4n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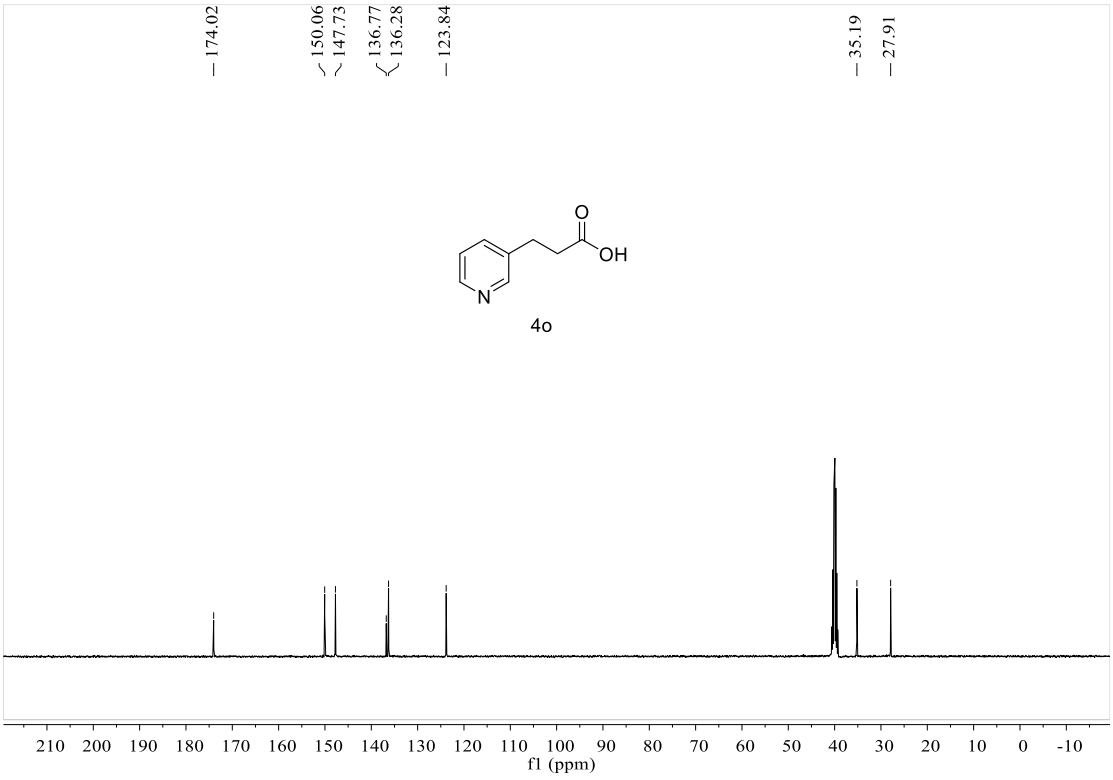
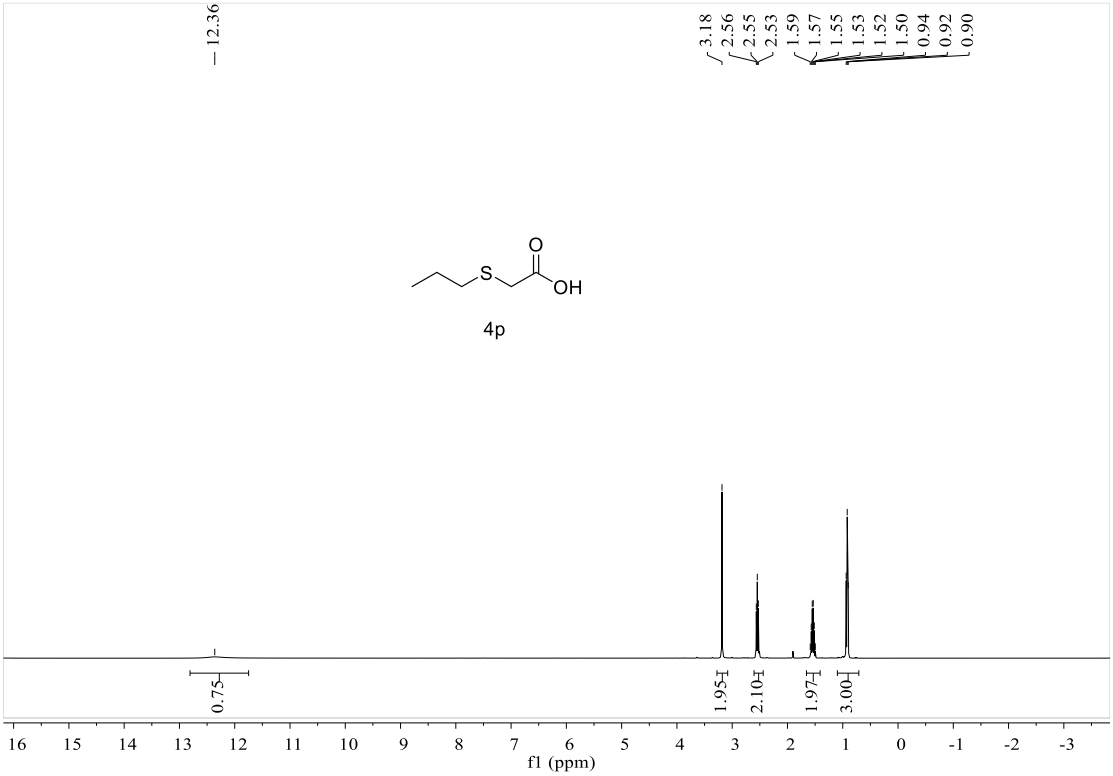
8.47
8.46
8.41
8.40
7.68
7.67
7.66
7.65
7.65
7.32
7.31
7.30
7.29
2.83
2.81
O
OH
N
4o
0.95
2.02
1.00
1.00
1.91
1.95
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


174.02
150.06
147.73
136.77
136.28
123.84
35.19
27.91
O
OH
N
4o
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)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2.55
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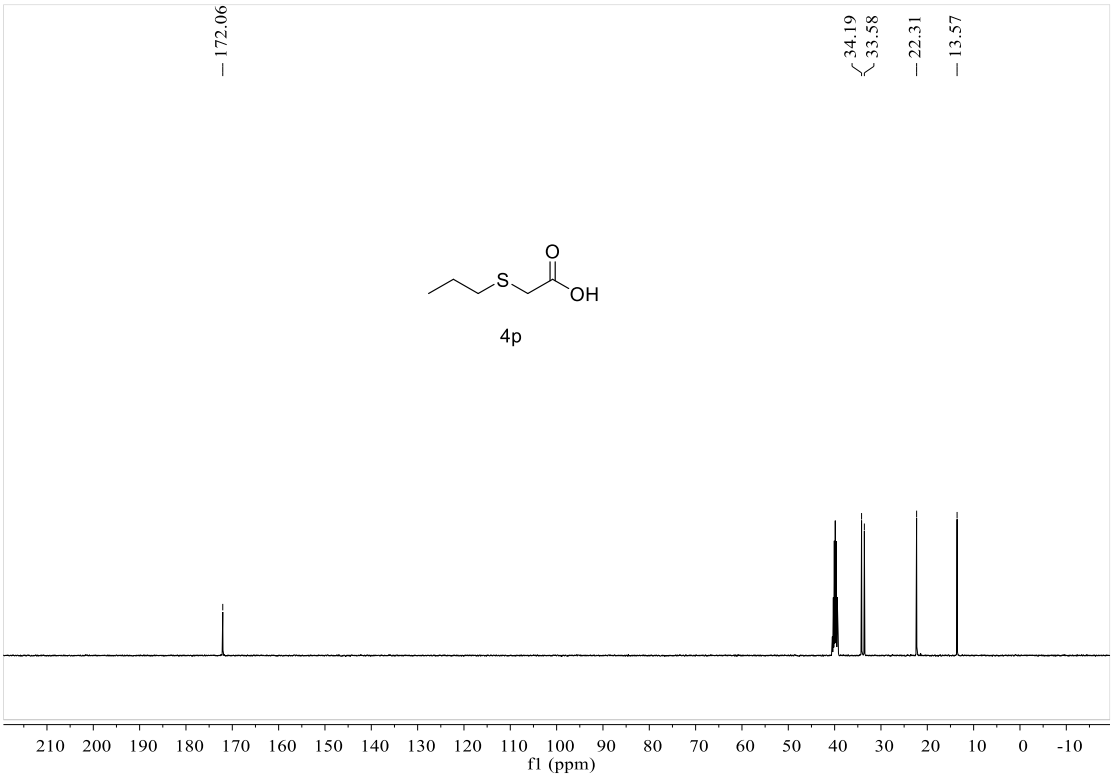
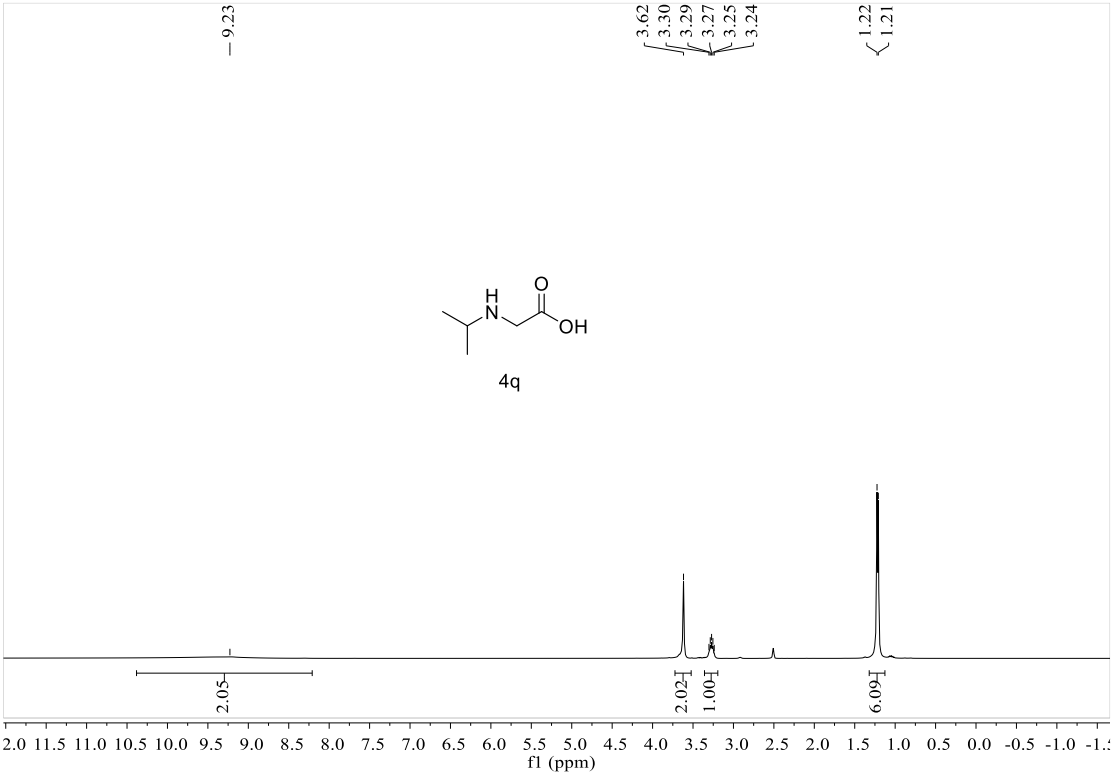
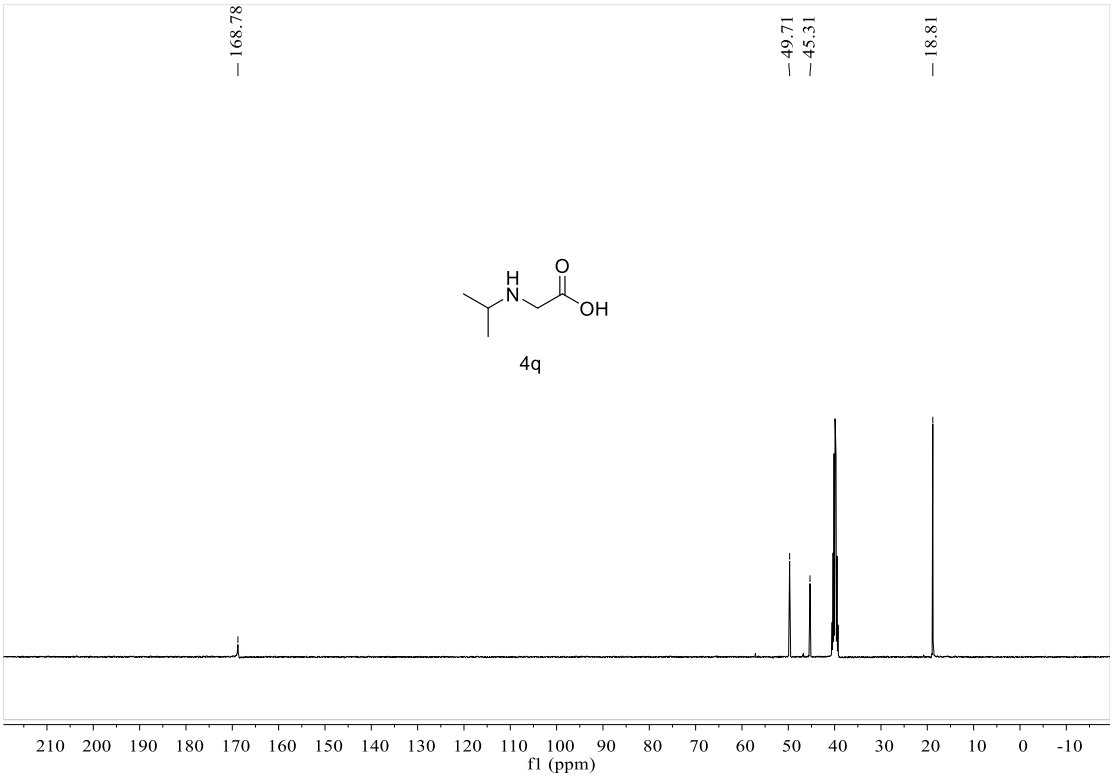
1.59
1.57
1.55
1.53
1.52
1.50
0.94
0.92
0.90
O
S
OH
4p
0.75
1.95
2.10
1.97
3.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


172.06
34.19
33.58
22.31
13.57
O
S
OH
4p
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)


9.23
3.62
3.30
3.29
3.27
3.25
3.24
1.22
1.21
4q
2.05
2.02
1.00
6.09
f1 (ppm)


168.78
49.71
45.31
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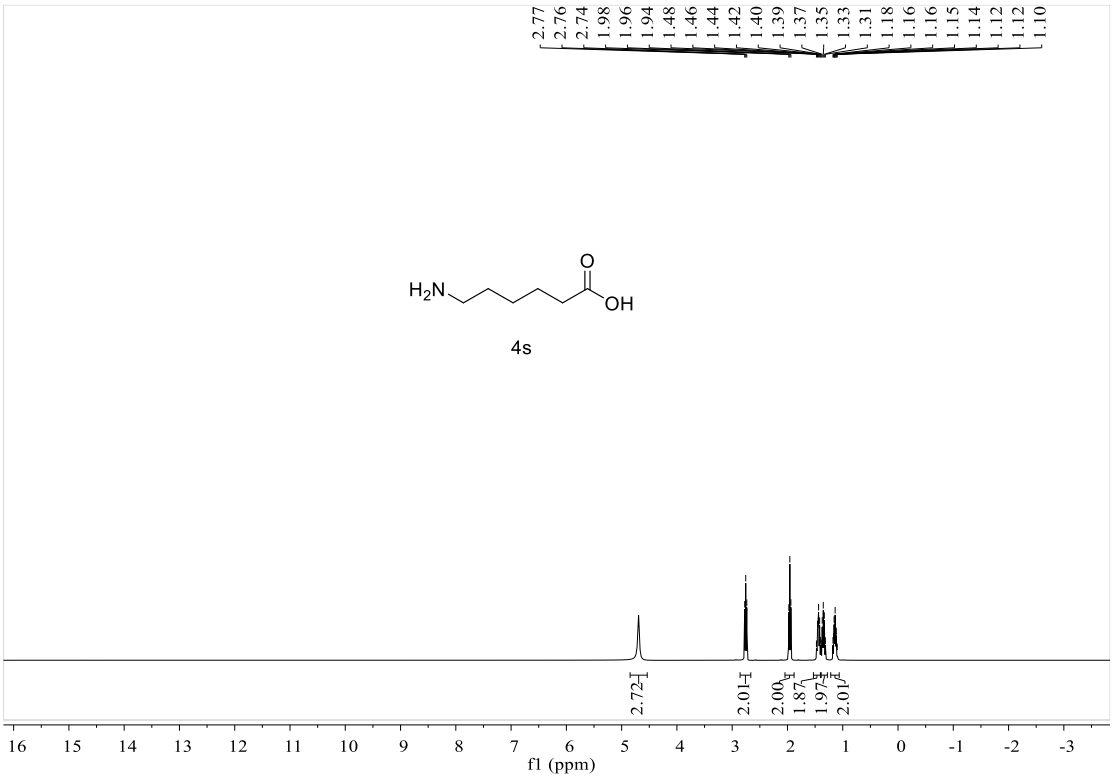
f1 (ppm)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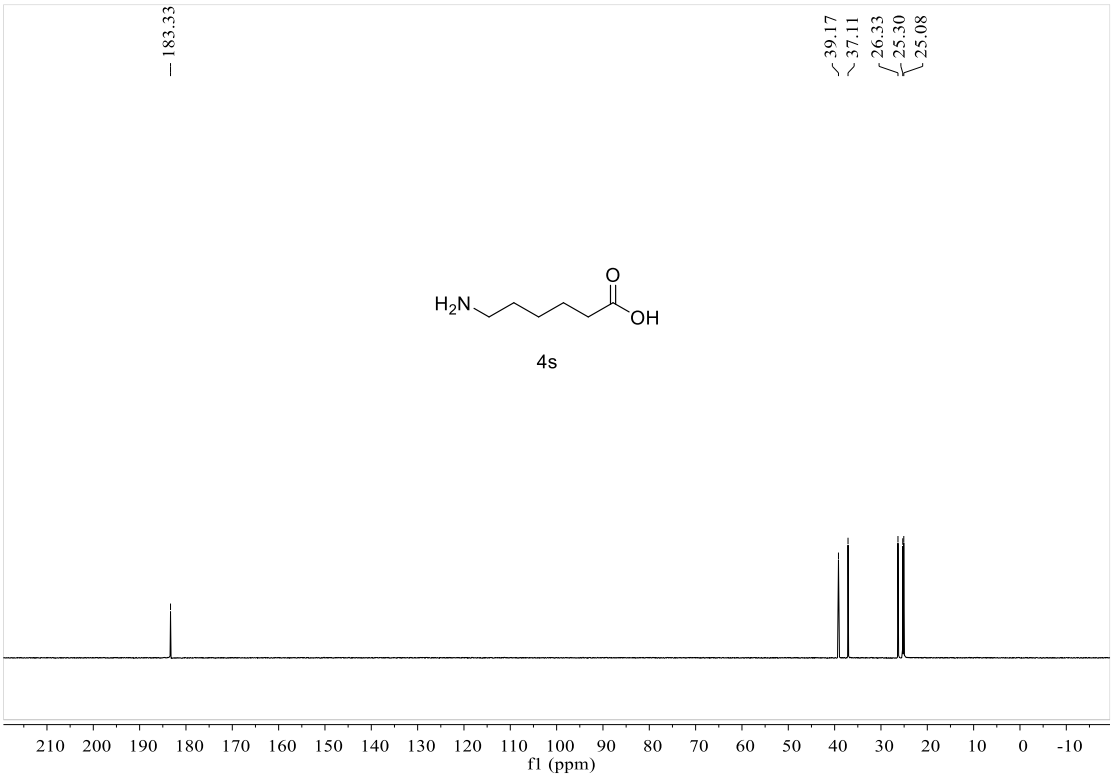
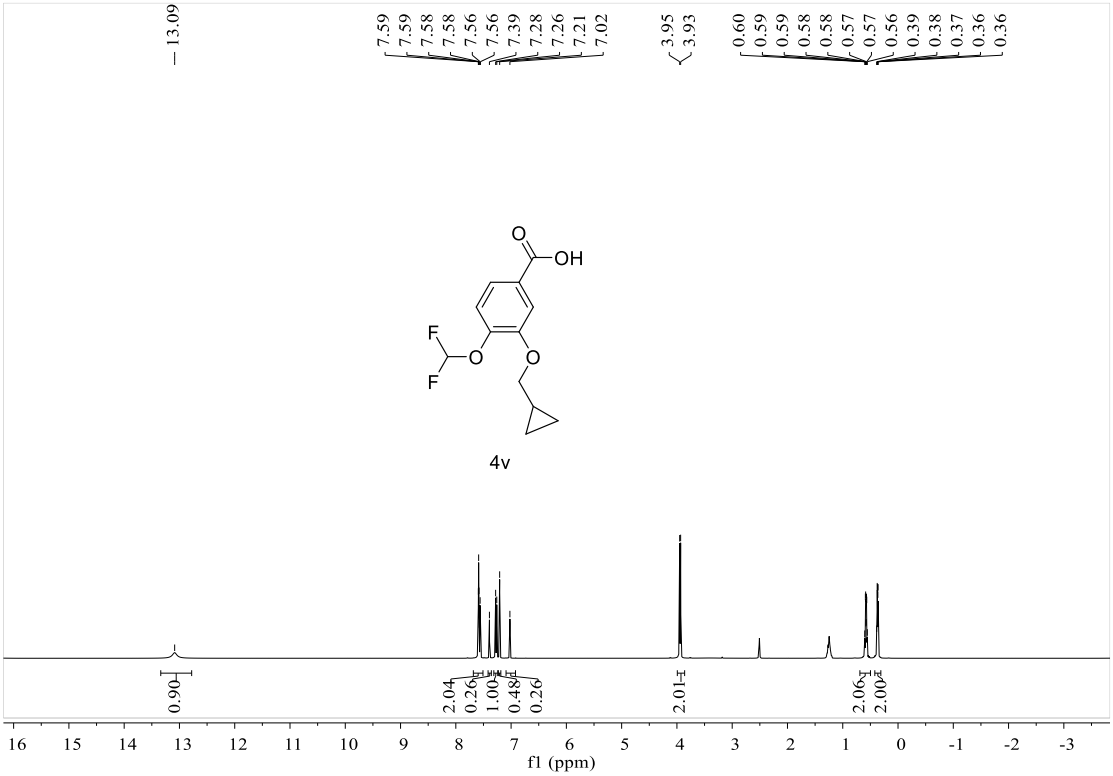
2.76
2.74
1.98
1.96
1.94
1.48
1.46
1.44
1.42
1.40
1.39
1.37
1.35
1.33
1.31
1.18
1.16
1.16
1.15
1.14
1.12
1.12
1.10
H2N
O
OH
4s
2.72
2.01
2.00
1.87
1.97
2.01
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


183.33
39.17
37.11
26.33
25.30
25.08
H2N
O
OH
4s
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)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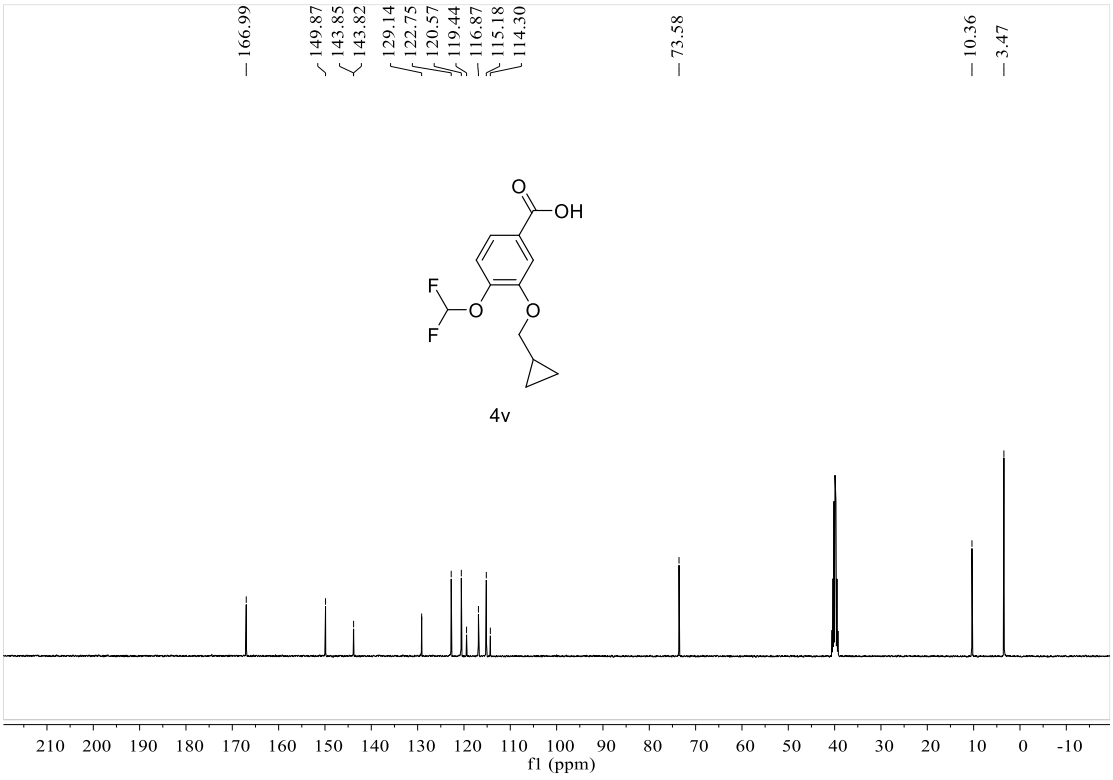
7.58
7.56
7.56
7.39
7.28
7.26
7.21
7.02
3.95
3.93
0.60
0.59
0.59
0.58
0.58
0.57
0.57
0.56
0.39
0.38
0.37
0.36
0.36
O
OH
F
F
O
O
4v
0.90
2.04
0.26
1.00
0.48
0.26
2.01
2.06
2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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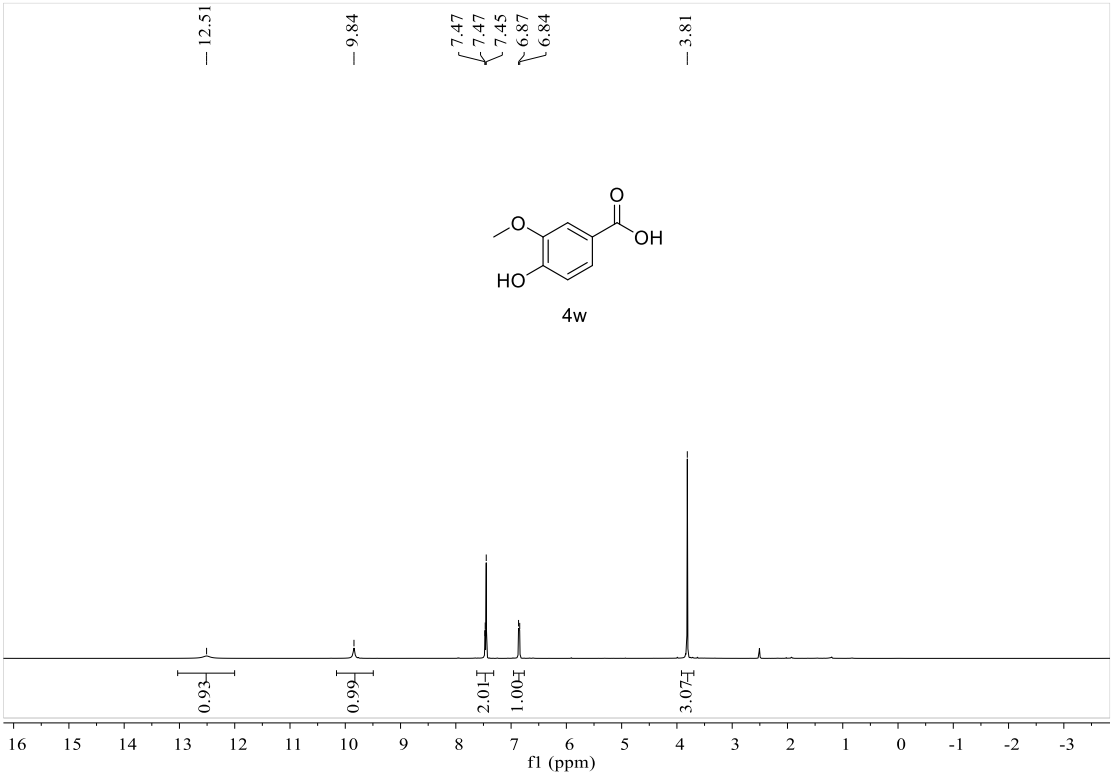
114.30
73.58
10.36
3.47
O
OH
F
F
O
O
4v
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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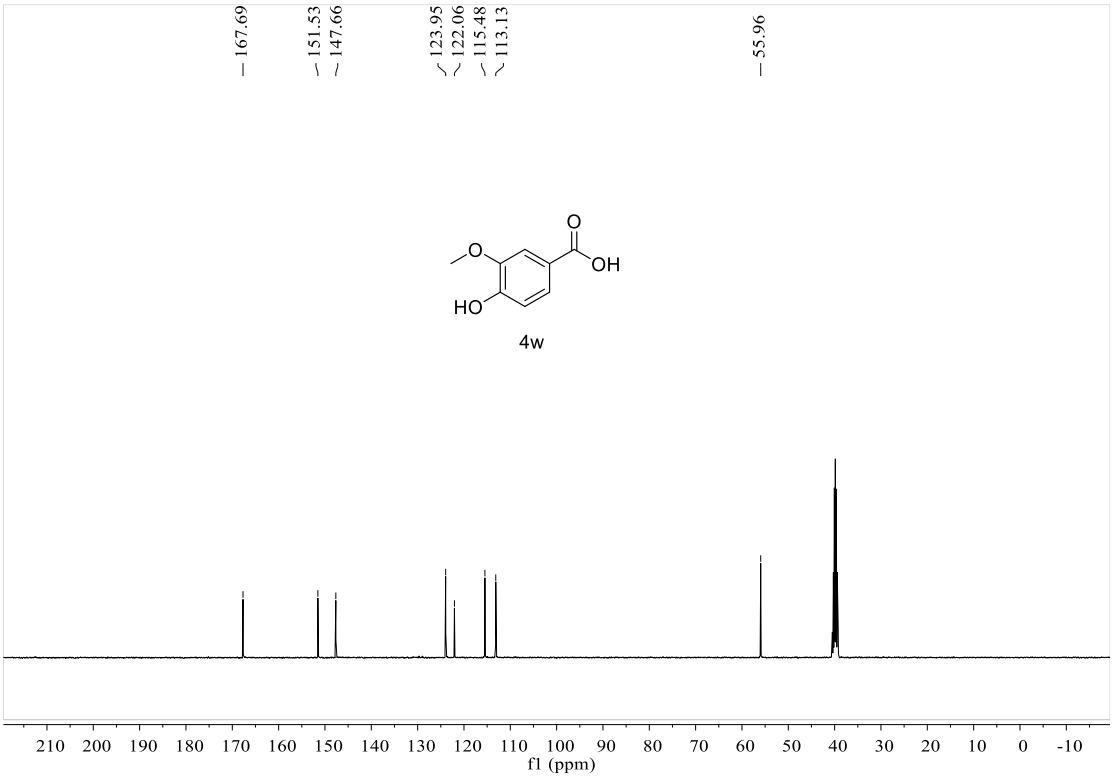
7.47
7.45
6.87
6.84
3.81
O
OH
O
HO
4w
0.93
0.99
2.01
1.00
3.07
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)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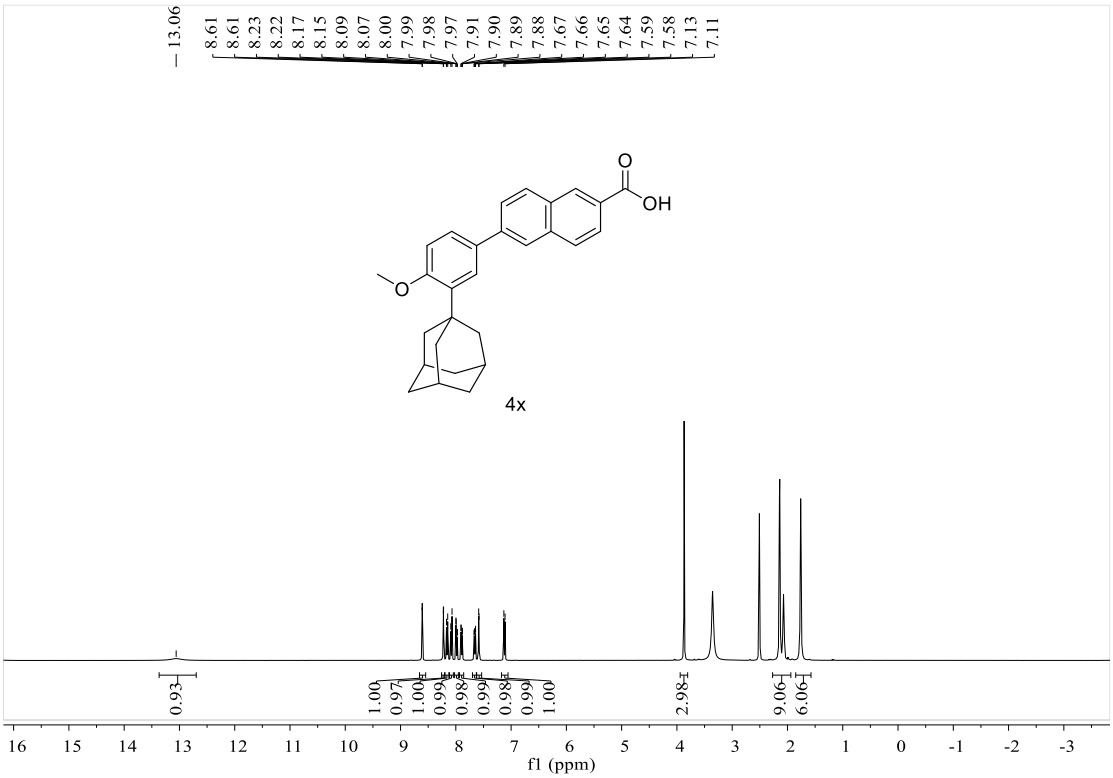
151.53
147.66
123.95
122.06
115.48
113.13
55.96
O
OH
O
HO
4w
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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8.61
8.23
8.22
8.17
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8.09
8.07
8.00
7.99
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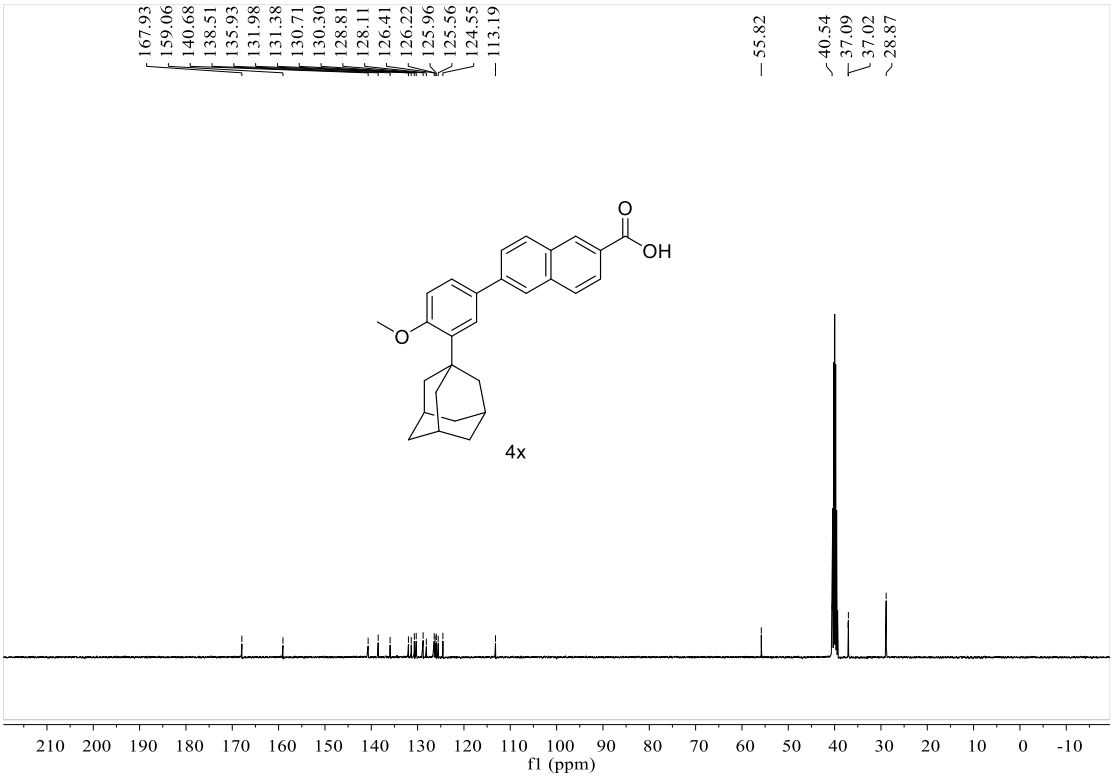
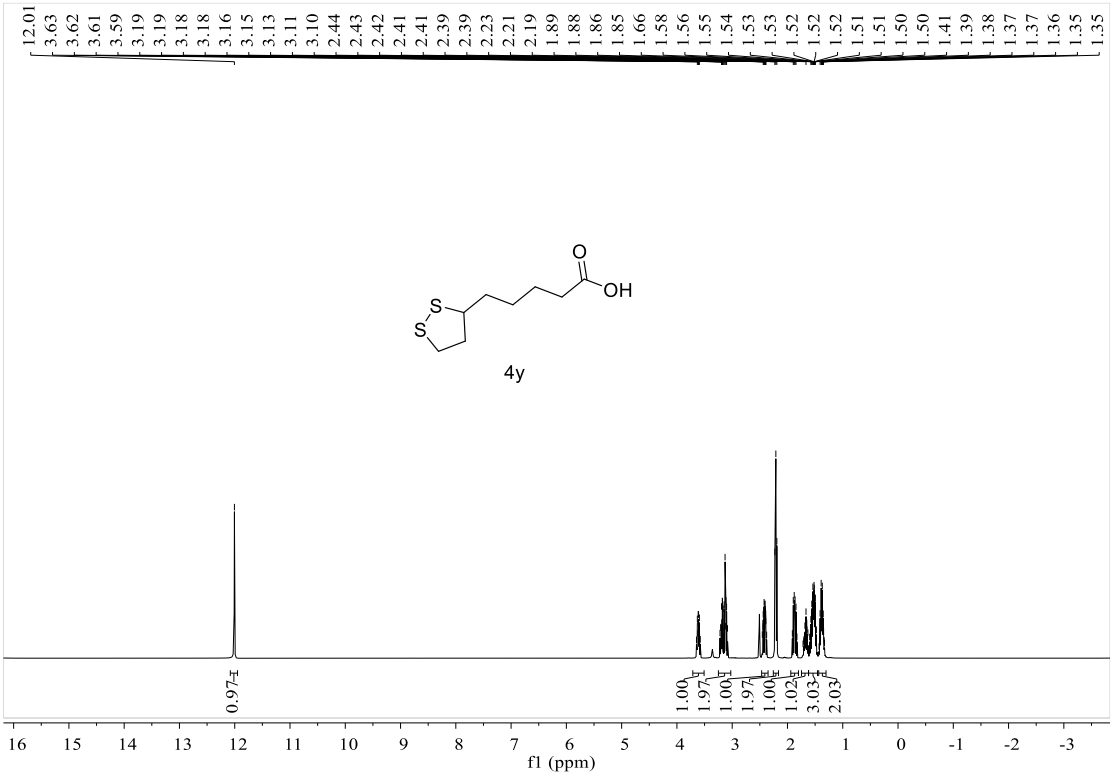
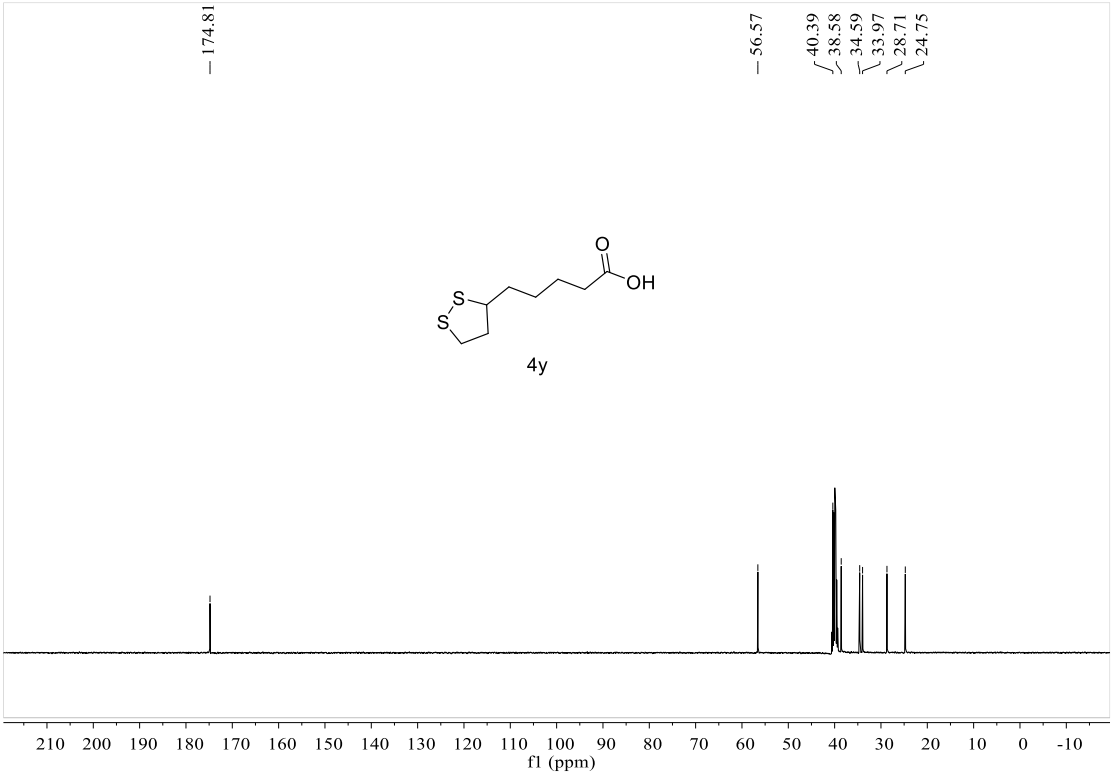
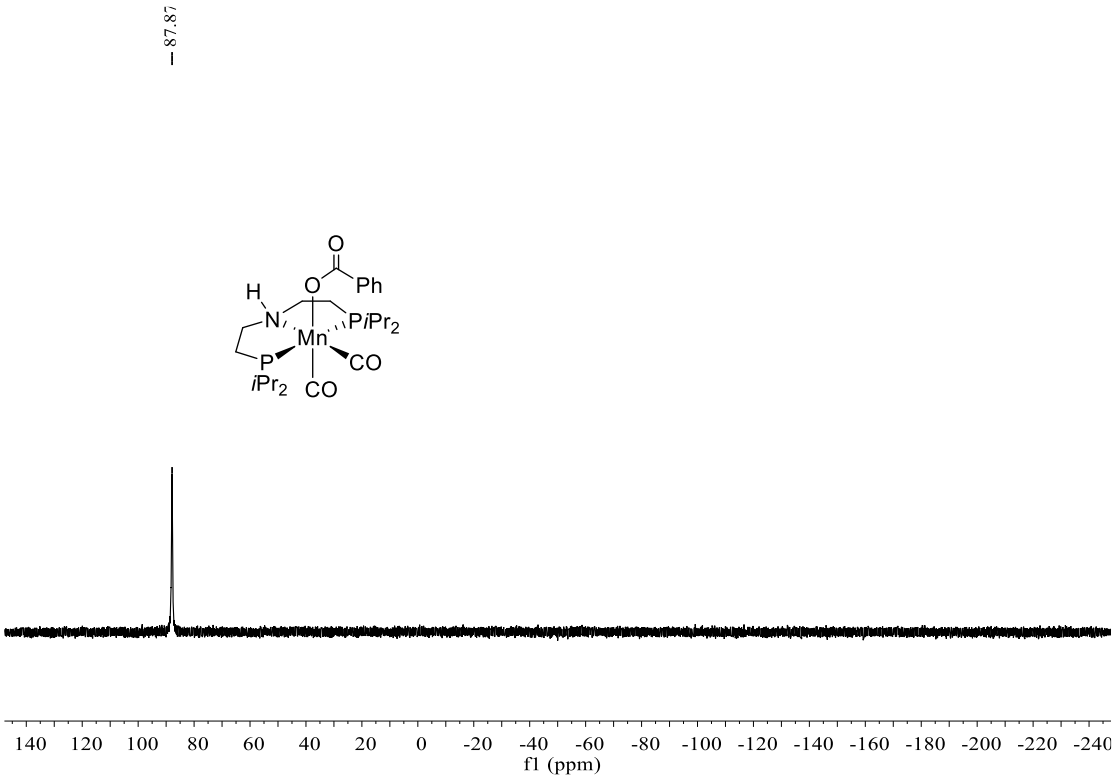
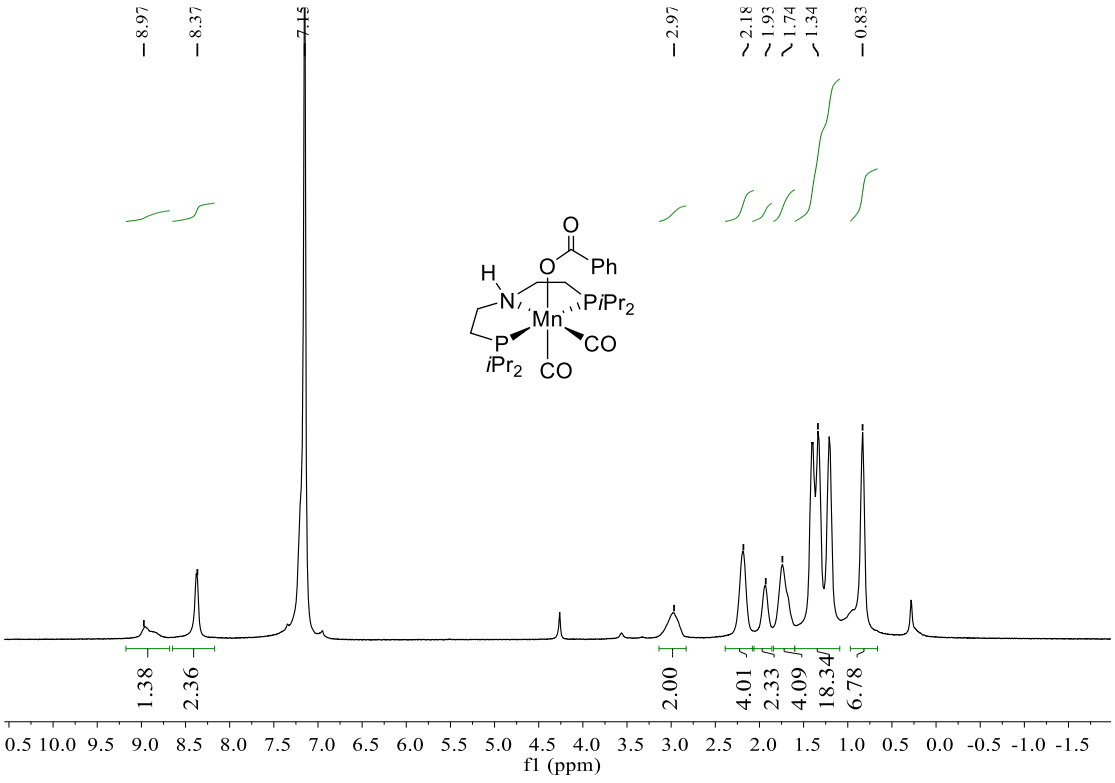
7.91
7.90
7.89
7.88
7.67
7.66
7.65
7.64
7.59
7.58
7.13
7.11
O
OH
O
4x
0.93
1.00
0.97
1.00
0.99
0.98
0.99
0.98
0.99
1.00
2.98
9.06
6.06
f1 (ppm)

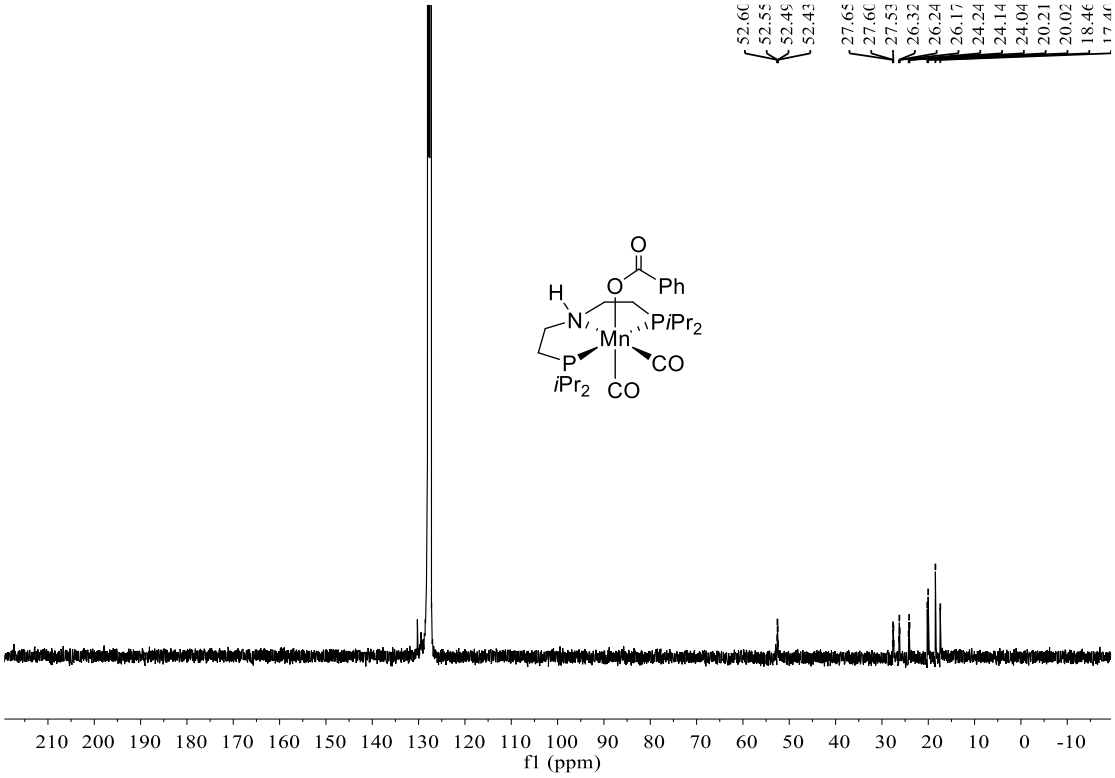

167.93
159.06
140.68
138.51
135.93
131.98
131.38
130.71
130.30
128.81
128.11
126.41
126.22
125.96
125.56
124.55
113.19
55.82
40.54
37.09
37.02
28.87
O
OH
O
4x
f1 (ppm)


12.01
3.63
3.62
3.61
3.59
3.19
3.19
3.18
3.18
3.16
3.15
3.13
3.11
3.10
2.44
2.43
2.42
2.41
2.41
2.39
2.39
2.23
2.21
2.19
1.89
1.88
1.86
1.85
1.66
1.58
1.56
1.55
1.54
1.53
1.53
1.52
1.52
1.52
1.51
1.51
1.50
1.50
1.41
1.39
1.38
1.37
1.37
1.36
1.35
1.35
O
OH
S
S
4y
0.97
1.00
1.97
1.00
1.97
1.00
1.02
3.03
2.03
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)


174.81
56.57
40.39
38.58
34.59
33.97
28.71
24.75
O
OH
S
S
4y
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)


87.87
O
O
Ph
H
N
Mn
PiPr2
P
iPr2
CO
CO
140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240
f1 (ppm)


8.97
8.37
7.15
2.97
2.18
1.93
1.74
1.34
0.83
O
O
Ph
H
N
Mn
PiPr2
P
iPr2
CO
CO
1.38
2.36
2.00
4.01
2.33
4.09
18.34
6.78
0.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)


52.60
52.55
52.49
52.43
27.65
27.60
27.53
26.32
26.24
26.17
24.24
24.14
24.04
20.21
20.02
18.46
17.46
O
O
Ph
H
N
Mn
PiPr2
P
iPr2
CO
CO
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)