Supporting Information

Function-oriented ionic polymers featuring high-density active sites for sustainable carbon dioxide conversion

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Section 1 Characterization

Fourier transform infrared spectroscopy (FTIR) spectra of the samples were obtained under ambient conditions at a resolution of 4 cm^{-1} in the wave number range of 4000-400 cm^{-1} by using an EQUINOX 55 spectrometer. Elemental analyses for C, H, N and O were detected on a Vario EL cube instrument. Thermogravimetry and differential thermogravimetric (TG-DTG) was carried out in a NETZSCH TG 209 F3 Tarsus instrument by heating samples from 40 °C to 850 ^{o}C at a heating rate of 10 °C·min^{-1} under air atmosphere. Liquid ^{1}H and ^{13}C NMR data were collected on a Bruker Varian INOVA500NB or Bruker AVANCE 400 spectrometer using TMS as an internal standard. The Solid-state ^{13}C NMR spectrum was recorded on Bruker AVANCE 400 spectrometer. The bromine content was measured by oxygen flask combustion and mercury nitrate titration technique. X-ray photoelectron spectroscopy (XPS) analysis was carried out on an ESCALAB 250 spectrometer. Field emission scanning electron microscopy (SEM) images were obtained by a FEI Quanta 400 FEG. Transmission electron microscopy (TEM) and EDS-mapping experiments were performed on JEM-2100F field emission electron microscope (JEOL, Japan) with an acceleration voltage of 200 kV, which incorporated a probe corrector and a super-X EDS system. The N_2 adsorption and desorption measurements were performed on a Micromeritic ASAP2020M analyzer at 77 K. Specific surface areas (S_{BET}) were calculated using Brunauer-Emmett-Teller (BET) methods and the pore size distributions were analyzed by using nonlocal density functional theory (NLDFT). All samples were degassed at 130 °C for 10 h under vacuum before analysis. X-Ray diffraction patterns of the powder samples were obtained with a Bruker AXS D8 Advanced SWAX diffractometer by depositing powder on glass substrate, from 2θ = 4.0° to 60° with 0.1° increment at 25 °C. Isotherms of carbon dioxide were collected from Micromeritic ASAP2020M at 273 K and 298 K. Fluorescence property of sample was recorded by a FLS980 steady-state fluorescence spectrometer with a Xe lamp as the excitation light source. Gas chromatographic (GC) analysis was performed on a GC2010 gas chromatograph (Shimadzu) equipped with a flame ionization detection and a capillary column (Rtx-5, 30 m × 0.32 mm × 0.25 μm).

Sction 2 Catalyst testing

Typical procedures for the cycloaddition reaction of epoxides with CO_2

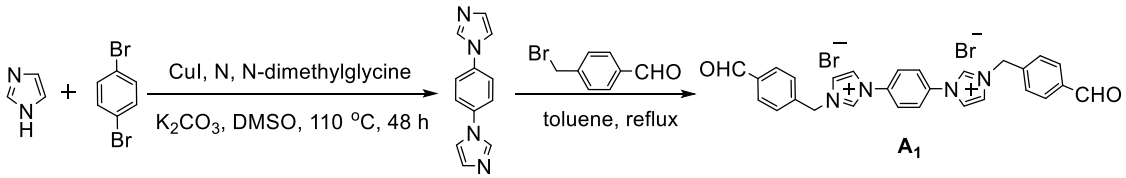
The reaction was performed in a stainless steel autoclave with a Teflon tube. Firstly, the epoxide and catalyst were quickly added into the autoclave. After sealing and purging with CO_2 for 3 times, the autoclave was pressurized with CO_2 to the requested pressure, followed by stirring at the needed temperature. After reaction, the autoclave was cooled to 0 °C and the excess of CO_2 was released slowly. Subsequently, the reaction mixture was extracted with ethyl acetate (3 × 2 mL), and the product yield and selectivity were determined by GC analysis through the internal standard method. The purity and structure of products were also confirmed by ^{1}H NMR, ^{13}C NMR spectra, and GC-MS analysis. For catalytic evaluation under low CO_2 concentration, simulated flue gas, a gas mixture of 15% CO_2 and 85% N_2 in volume, was used under defined conditions. The recycled catalyst was obtained through filtering, washing and drying, and then used for the next run without further purification. For each recyclability test, three parallel experiments were done, and the yield was taken as the average.

Typical procedures for the *N*-formylation reaction of amine with CO_2 and $PhSiH_3$

The reaction was performed in a stainless steel autoclave with a Teflon tube. Firstly, the amine, $PhSiH_3$ and catalyst were quickly added into the autoclave. After sealing and purging with CO_2 for 3 times, the autoclave was pressurized with CO_2 to the requested pressure, followed by stirring at the needed temperature. After reaction, the excess of CO_2 was vented at 0 ^{o}C. Subsequently, the reaction mixture was extracted with ethyl ether (3 × 2 mL), and the product yield and selectivity were determined by GC analysis through the internal standard method. The purity and structure of products were also confirmed by ^{1}H NMR, ^{13}C NMR spectra, and GC-MS analysis. For catalytic evaluation under low CO_2 concentration, simulated flue gas, a gas mixture of 15% CO_2 and 85% N_2 in volume, was used under defined conditions. The recycled catalyst was obtained through filtering, washing and drying, and then used for the next run without further purification. For each recyclability test, three parallel experiments were done, and the yield was taken as the average.

Section 3 Synthesis

Synthesis of A_1

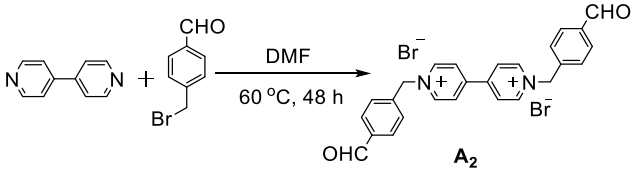


Scheme S1. Synthesis of A_1

Following a modified procedure from reference *1:* 1,4-Dibromobenzene (4.72 g, 20 mmol), 1H-imidazole (3.40 g, 50 mmol), copper iodide (0.76 g, 4 mmol), N, N-dimethylglycine (0.83 g, 8 mmol), potassium carbonate (11.06 g, 80 mmol) and Methyl sulfoxide (50 mL) was added to a 100 mL Schlenk flash, then the system was degassed by stirring under vacuum and backfilling with nitrogen three times. After the reaction mixture was heated at 110 ^{o}C for 48 h, water and ethyl acetate were added. The organic phase was separated, and the aqueous phase was extracted with ethyl acetate for three times. Then the combined organic phase was washed with brine, dried over anhydrous magnesium sulfate, and concentrated in vacuo. The residue was purified by silica gel column chromatography with CH_2Cl_2/MeOH (10/1, v/v) as eluent to afford 1, 4-bis(1-imidazolyl)benzene as pale yellow solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (t, *J* = 1.1 Hz, 2H), 7.51 (s, 4H), 7. 30 (t, *J* = 1.4 Hz, 2H), 7.23 (t, *J* = 1.1 Hz, 2H).

A solution of 1, 4-bis(1-imidazolyl)benzene (0.53 g, 2.5 mmol) and 4-(bromomethyl) benzaldehyde (1.0 g, 5.0 mmol) in acetonitrile (20 mL) was stirred at 80 ^{o}C for 24 h under N_2 atmosphere. The resulting precipitate was filtered, washed with acetonitrile and diethyl ether, and dried in vacuo to afford the target product (**A_1**) as a white solid (1.45 g, 95 %). ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.30 (s, 2H), 10.07 (s, 2H), 8.52 (s, 2H), 8.17 (m, 6H), 8.00 (d, *J* = 8.0 Hz, 2H), 7.78 (d, *J* = 7.8 Hz, 4H), 5.72 (s, 4H).

Synthesis of A2

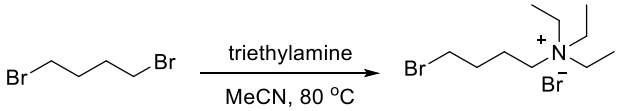


Scheme S2. Synthesis of A_2

A solution of 4,4'-bipyridine (0.39 g, 2.5 mmol) and 4-(bromomethyl)benzaldehyde (1.0 g, 5.0

mmol) in N,N-Dimethylformamide (20 mL) was stirred at 60 ℃ for 48 h under N_2 atmosphere. The resulting precipitate was filtered, washed with N,N-dimethylformamide and diethyl ether, , and dried in vacuo to yield the target product (**A_2**) as a white solid (1.28 g, 92 %). ^{1}H NMR (500 MHz, DMSO-d_6): δ 10.03 (s, 2H), 9.56 (d, *J* = 6.5 Hz, 4H), (d, *J* = 6.4 Hz, 4H), 7.99 (d, *J* = 7.9 Hz, 4H), 7.80 (d, *J*=8.0 Hz, 4H), 6.09 (s, 4H).^{13}C NMR (126 MHz, DMSO-d_6): δ 193.2, 149.8, 146.5, 140.6, 137.1, 130.6, 130.0, 127.8, 63.3.

Synthesis of (2-bromobutyl)triethylammonium bromide ([BrBuNEt$_3$]Br)



Scheme S3. Synthesis of [BrBuNEt$_3$]Br

Following a modified procedure from reference *2*: Triethylamine (0.33 g, 3.3 mmol), 1,4-dibromobutane (1.4 g, 6.6 mmol) and CH_3CN (35 mL) were refluxed at 80 °C under N_2 for 4 h. Upon cooling, the solvent was evaporated under reduced pressure, and then the residue was dissolved into hot CH_3CN. Cooling of this solution gave precipitate which was mostly the dicationic product. After removing the precipitate by filtration, ethyl acetate was added to the filtrate. Simultaneously, the white solid was appeared, which was obtained by filtration and dried under vacuum to give **BrBuNEt$_3$]Br** (0.52 g, 50% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.30 (t, *J* = 7.4 Hz, 9 H), 1.80-1.86 (m, 2 H), 1.91-2.97 (m, 2 H), 3.42-3.37 (m, 8 H), 3.47-3.45 (t, *J* = 6.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 56.56, 53.57, 32.9,0 28.98, 20.49, 8.15.

Section 4 XPS Spectra

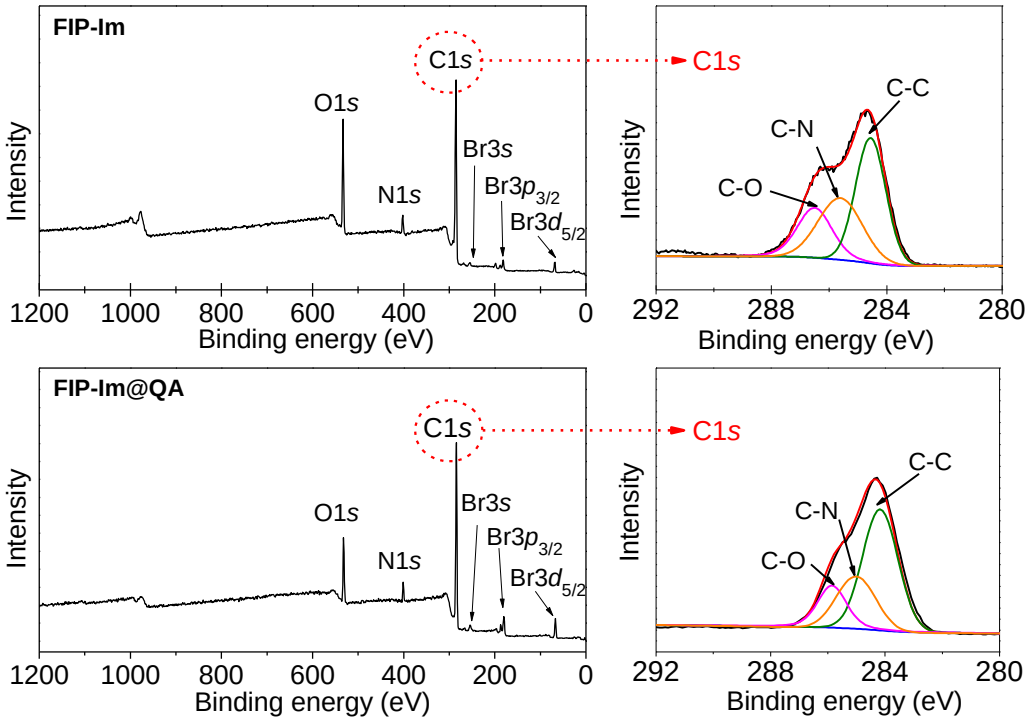


Figure S1. Full XPS survey spectrum for **FIP-Im** and **FIP-Im@QA** recorded from 0 to 1200 eV

Section 5 Elemental Analysis

Table S1 Elemental analysis for catalysts.

Sample	CHN Elemental Analysis (wt%)				Br content (mmol g^{-1})
	C	H	N	O	
IL-free	77.18	4.12	0	0	0
FIP-Im@M	60.35	3.94	7.52	8.18	2.44
FIP-Im	58.37	3.86	7.56	8.26	2.51
FIP-Im after 6 cycles	58.42	3.82	7.59	8.32	2.48
FIP-Py	59.50	3.82	4.08	9.78	2.64
FIP-Im@QA	55.73	5.76	7.78	5.13	4.40
FIP-Im@QA after 6 cycles	55.62	5.83	6.81	5.16	4.34

Section 6 Thermogravimetric Analysis

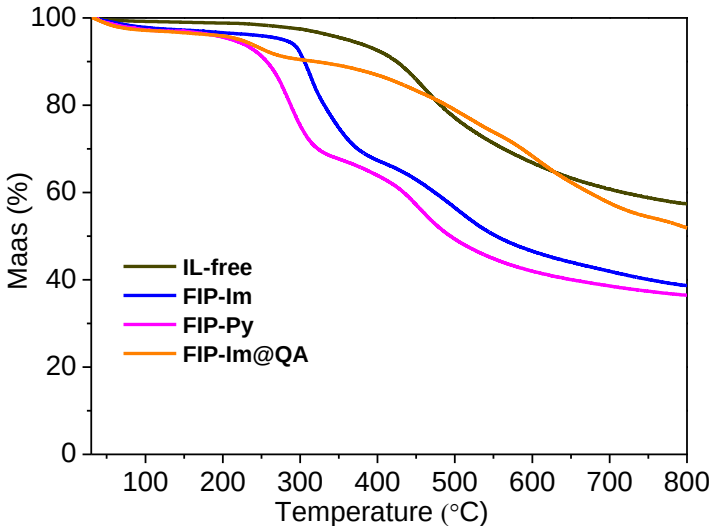


Figure S2. TGA curves of the obtained catalysts

Section 7 SEM and TEM Analysis

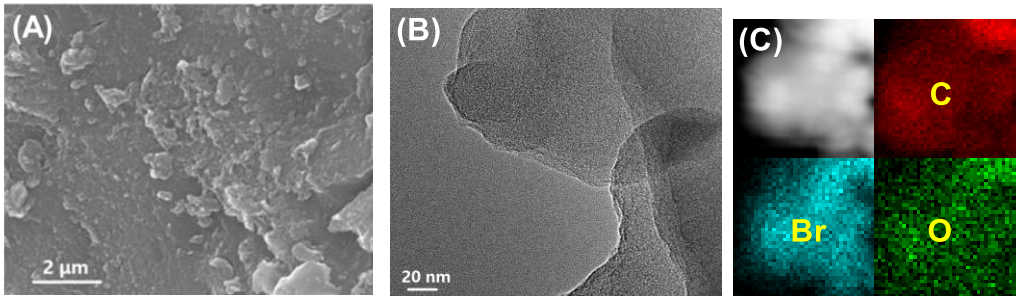


Figure S3. (A) SEM, (B) TEM, and (C) EDS elemental mapping images of **FIP-Im**

Section 8 N_2 Sorption Isotherms

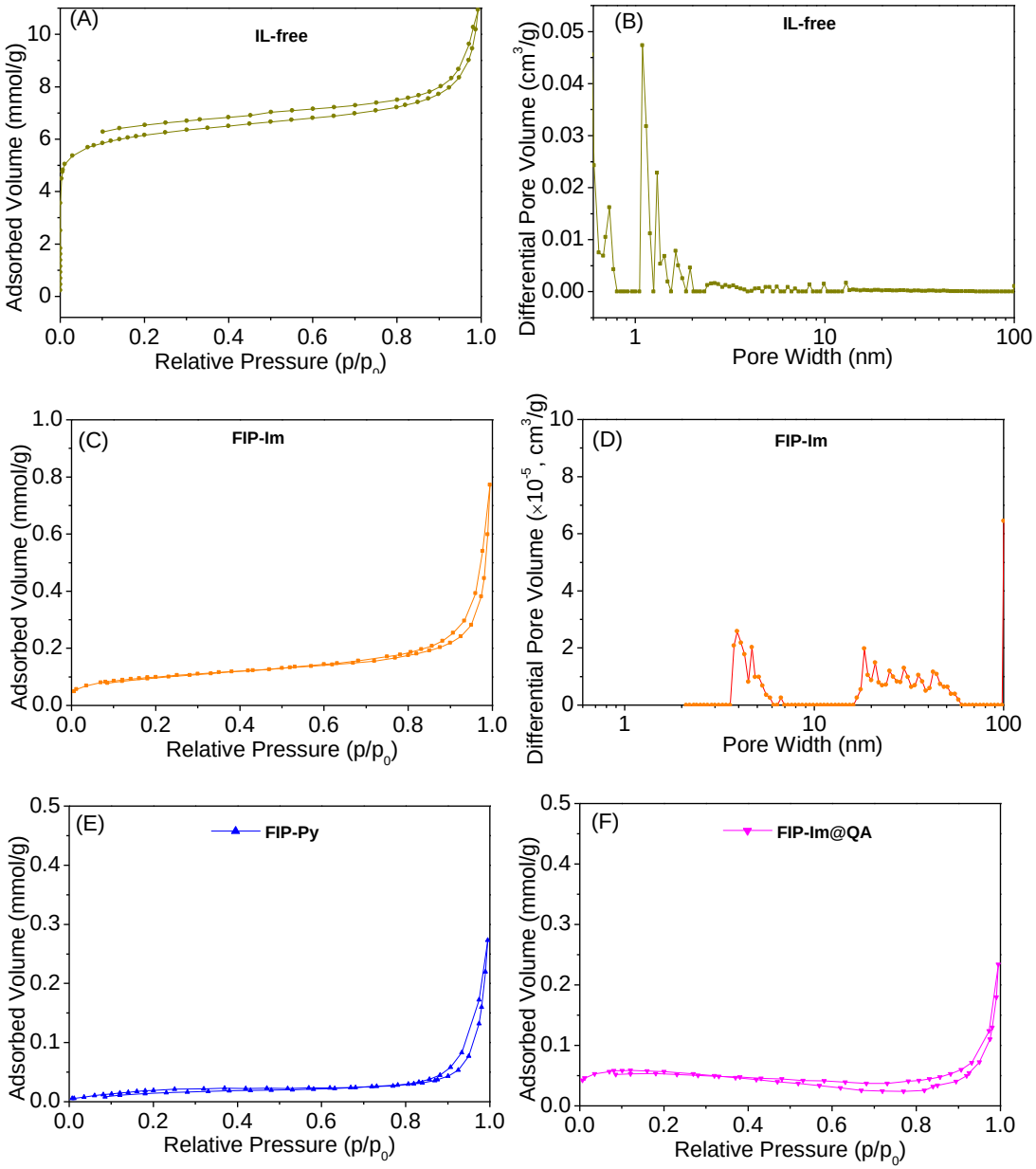


Figure S4. (A) N_2 sorption isotherms of samples at 77 K and (B) corresponding pore size distribution curve based on the DFT calculation model.

Section 9 PXRD Patterns

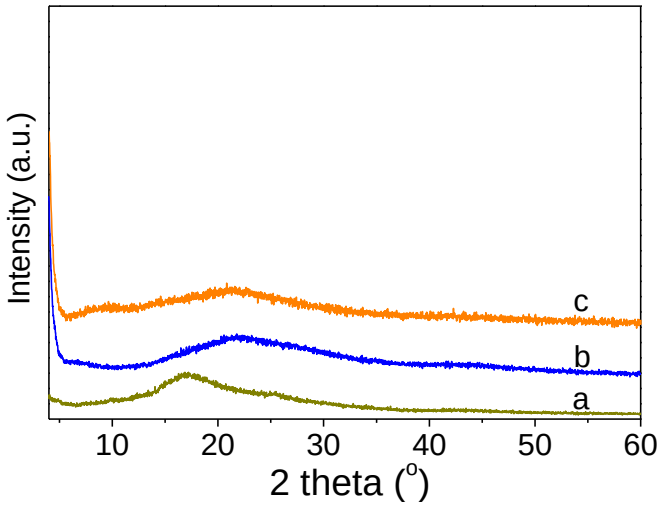


Figure S5. PXRD curves of **IL-free**(a), **FIP-Im**(b) and **FIP-Im@QA**(c). (The PXRD pattern shows a very broad peak at 2θ = 10 ~ 30° for each sample)

Section 10 CO_2 Sorption Isotherms and Selectivity of CO_2 over N_2

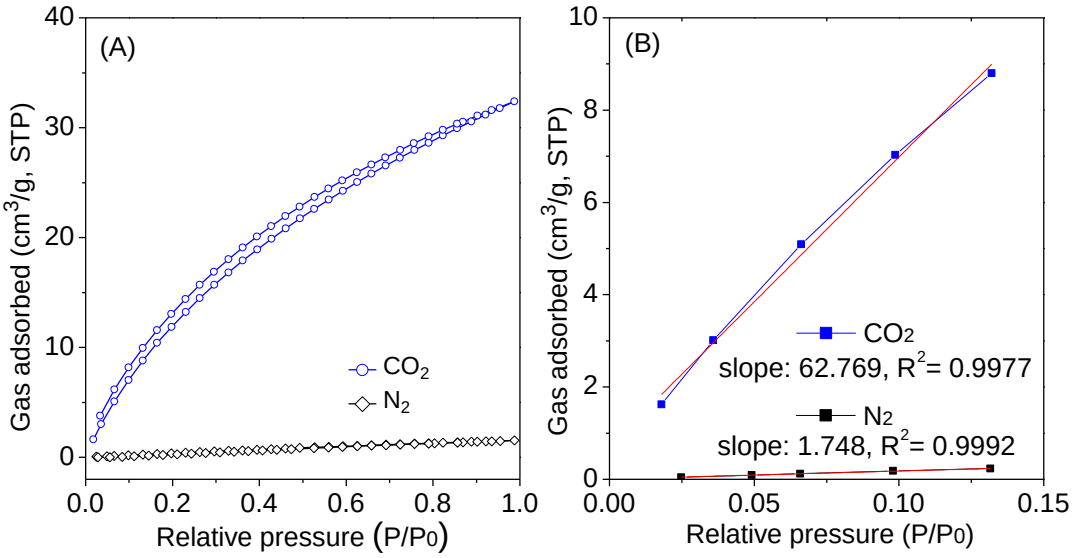


Figure S6. (A) Gas sorption isotherms and (B) adsorption selectivity of CO_2 over N_2 for **FIP-Im** from initial slope calculations of CO_2 and N_2 isotherms at 273 K

Section 11 Fluorescence Property

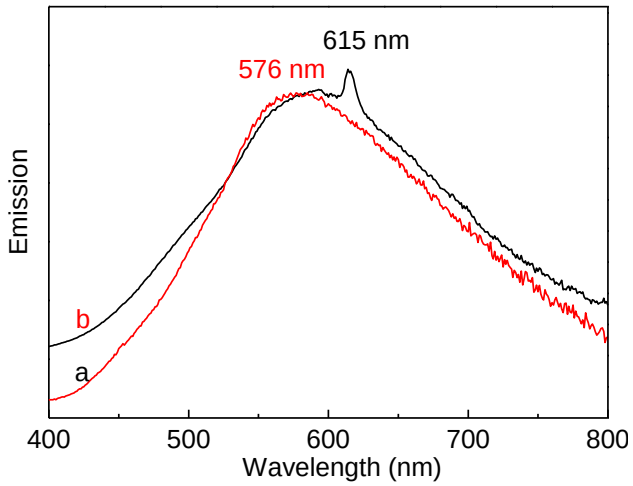


Figure S7. Fluorescence emission spectra of **FIP-Im** (a) and **FIP-Im@QA** (b) with excitation at 303 nm.

Section 12 Activity Comparison

Table S2. **Activity comparison in the propylene oxide to propylene carbonate conversion reaction**

Catalyst (mol%)	Additive (mol%)	Solvent	T (^{o}C)	CO_2 (MPa)	t (h)	Yield (%)	Ref.
FIP-Im (5)	-[a]	-	80	1.0	10	99	This work
PDBA-Cl-SCD (2.4)	-	-	90	0.1	6	99.6	[3]
NP-NHC (5 wt%)	-	-	120	0.1	24	98	[4]
NPILs-BPA (0.5)	-		150	2.0	4	98	[5]
SBA-[V0.15OH0.60]$R_2$37 (0.65)	-		140	2.0	6	99	[6]
TBB-Bpy-a (80 mg)	-	-	120	1.0	4	99	[7]
PDMBr (1.3)	-	-	110	1.0	4	98.7	[8]
TBB-Bpy-a (4 wt%)	-	-	90	1.0	12	99	[9]
mesoPILC (50 mg)	-		150	1.0	6	92	[10]
DVB-HTA (0.22)	-		120	1.2	6	93	[11]
SYSU-Zn@IL2 (0.16)	-	-	80	1.0	12	99	[12]
DVB@ISA (0.25)	-	-	60	1.0	24	17	[13]
Al-CPOP (1)	-	-	120	0.1	24	67	[14]
TBB-Bpy@Salen-Co (0.2)	-	-	60	1.0	6	99.2	[15]
Mg-por/pho@POP (0.5)	-	-	140	3.0	1	78	[16]
PPh_3-ILBr-$ZnBr_2$@POPs (0.0125)	-	-	120	3.0	1	44	[17]
$1P^{+}$Br-&$ZnBr_2$-1PPh_3@POPs (0.0125)	-	-	120	3.0	1	49.8	[18]
Py-Zn@MA (0.28)	-	-	150	2.0	6	96	[19]
POM3-IM (5)	-	EtOH	120	1.0	8	96	[20]
HIP-Br-2 (4)	$ZnBr_2$ (4)	DMF	25	0.1	96	99	[21]
Zn@SBMMP (1.2)	TBAB (1.8)	DCE	80	2.0	4	95	[22]
g-C_3N_4-475-NaOH (0.4 g)	ZnI_2 (38 mg)		140	2.0	6	89.5	[23]
Bp-Zn@MA (0.086)	TBAB (0.55)		100	1.0	1.5	99	[24]
PPS⊂COF-TpBpy-Cu (0.1)	-		25	0.1	72	94	[25]
IL-ZIF-90 (0.5)	-		120	1.0	3	697	[26]
HF-MOP (5)	TBAI (5)		80	2.0	18	89	[27]
Co-CMP	TBAB (7.2)		100	3.0	1	98.1	[28]
Al-MON (0.05)	TBAC (0.15)		60	1.0	12	71	[29]
In-MOF (0.23)	TBAB (2.5)		80	2.0	4	93.9	[30]
Cu-MOF (0.2)	TBAB (10)		25	0.1	48	96	[31]
Co/POP-TPP (0.22)	TBAB (0.7)	-	29	0.1	24	94.8	[32]
Cu/POP-Bpy (0.5)	TBAB (7)	-	29	0.1	48	99	[33]

[a] Not added additive or solvent.

Table S3. Activity Comparison in the *N*-formylation reaction of *N*-methylaniline with CO_2 and hydrosilanes

Catalyst (mol%)	Hydrosilane (mmol)	Solvent	T (^oC)	CO_2 (MPa)	t (h)	Yield (h^{-1})	Ref.
FIP-Im@QA (6)	$PhSiH_3$ (1.0 eq.)	-[a]	35	1.0	14	99	This work
F-PNHC-Zn (5.0)	PhSiH3 (3 eq.)	THF	80	1.0	24	71	[34]
ILSZ1 (1)	$PhSiH_3$ (1.0 eq.)	-	40	1.5	3	100	[35]
DVB@ISZ (0.25)	$PhSiH_3$ (1.0 eq.)	-	40	1.0	20	96	[13]
$[Et_4NBr]$50%-Py-COF (5)	$PhSiH_3$ (2.0 eq.)	DMF	30	0.1	24	94	[36]
Cs_2CO_3 (5)	$PhSiH_3$ (1.0 eq.)	CH_3CN	25	0.1	12	94	[37]
[BMIm]Cl (100)	$PhSiH_3$ (2.0 eq.)	-	30	1.0	5	95	[38]
Glycine Betaine (3)	$PhSiH_3$ (2.0 eq.)	CH_3CN	25	0.5	4	95	[39]
Glycine Betaine (10)	Ph_2SiH_2(4.0 eq.)	CH_3CN	50	1.0	12	96	[40]
$Fe(acac)_2$ (5)+PP_3 (5)	$PhSiH_3$ (1.0 eq.)	THF	25	0.1	18	95	[41]
$Cu(OAc)_2$ (0.07)+dppb (0.21)	PMHS (2.3 eq.)	Dioxane	80	0.1	30	87	[42]
TBAF (5)	$(EtO)_3SiH$	CH_3CN	30	0.1	4	90	[43]
TBAF·$3H_2O$ (10)	$PhSiH_3$ (1.2 eq.)	-	25	0.1	6	99	[44]
IPr (5)	$PhSiH_3$ (1 eq.)	THF	25	0.1	24	99	[45]
ZnPc (0.5) + DMF (200)	$PhSiH_3$ (1 eq.)	-	25	0.1	6	99	[46]
$Ph_3P^+CHRCOO^-$ (5.0)	$PhSiH_3$ (2 eq.)	CH_3CN	100	2.0	24	91	[47]
NHP-H (5.0)	$PhSi_2H_2$ (3.0 eq.)	CD_3CN	25	0.1	4	97	[48]
CsF (10.0)	$PhSi(Me)_2H$	DMSO	80	0.1	39	60	[49]
TBD (5.0)	$PhSiH_3$ (1 eq.)	-	100	0.1	24	100	[50]
Poly-NHC	$PhSiH_3$ (2.5 eq.)	DMF	25	0.1	20	66	[51]

[a] Not added solvent.

Section 13 Characterization for the Reused Catalyst

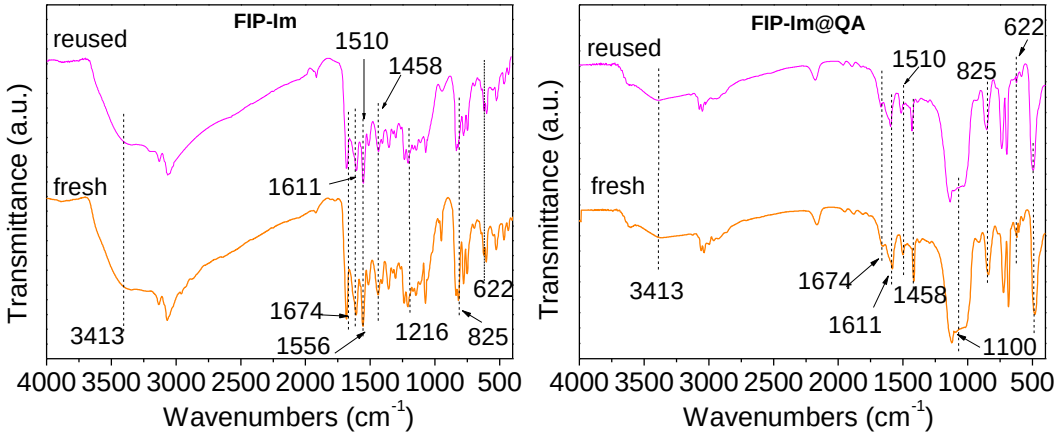


Figure S8. FTIR spectra of the fresh and reused **FIP-Im** and **FIP-Im@QA**

Section 14 ^{1}H NMR spectra of $PhSiH_3$ or *N*-methylaniline and its mixture with catalyst

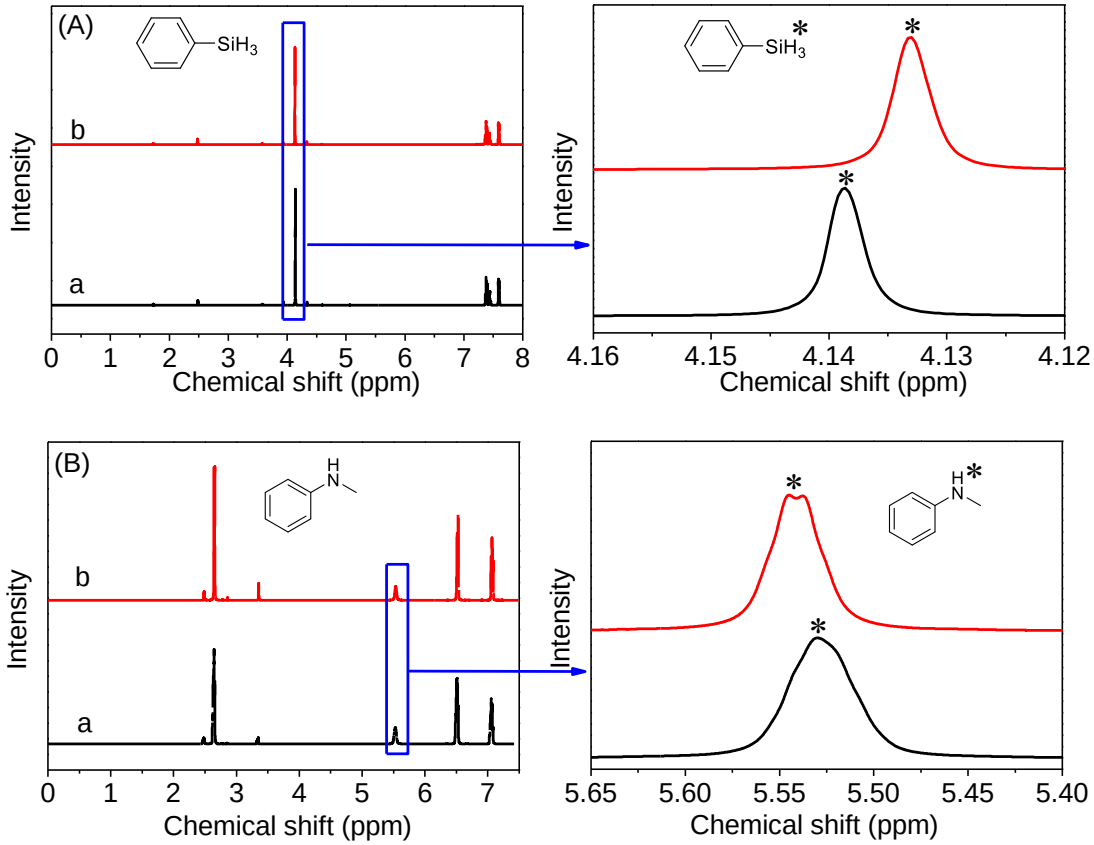
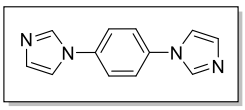
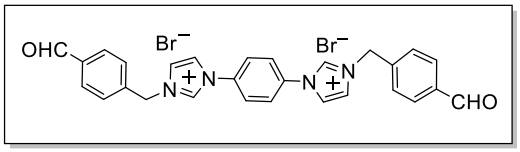


Figure S9. ^{1}H NMR spectra of (A) $PhSiH_3$ (a) and its mixture with **FIP-Im@QA** (b) and (B) *N*-methylaniline and its mixture with **FIP-Im@QA** (b) (DMSO-*d6*, 298 K)

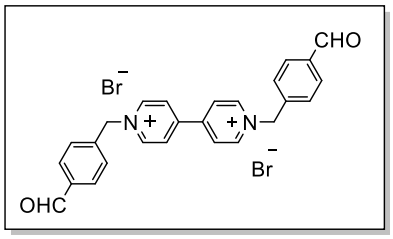
Section 14 NMR Spectra



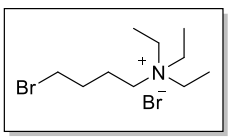
^{1}H NMR (500 MHz, $CDCl_3$, 25 ^{o}C, TMS): δ (ppm) = 7.87 (t, *J* = 1.1 Hz, 2H), 7.51 (s, 4H), 7. 30 (t, *J* = 1.4 Hz, 2H), 7.23 (t, *J* = 1.1 Hz, 2H).



^{1}H NMR (400 MHz, DMSO-d_6, 25 ^{o}C, TMS): δ (ppm) = 10.30 (s, 2H), 10.07 (s, 2H), 8.52 (s, 2H), 8.17 (m, 6H), 8.00 (d, *J* = 8.0 Hz, 2H), 7.78 (d, *J* = 7.8 Hz, 4H), 5.72 (s, 4H).

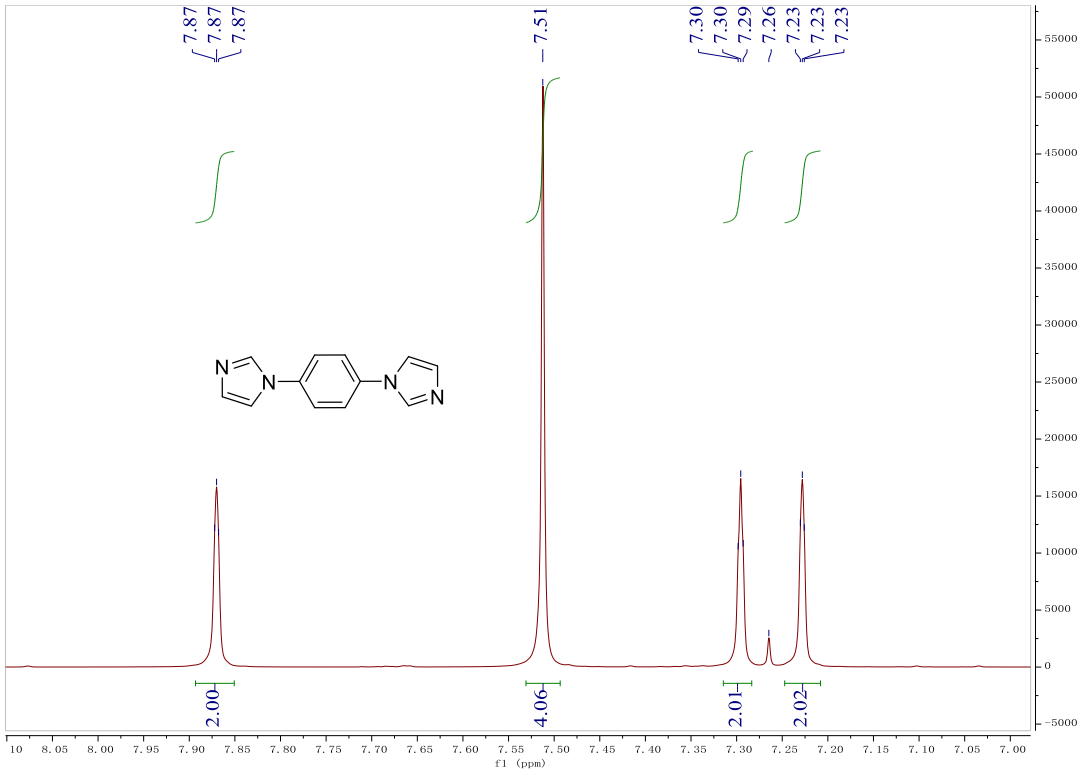


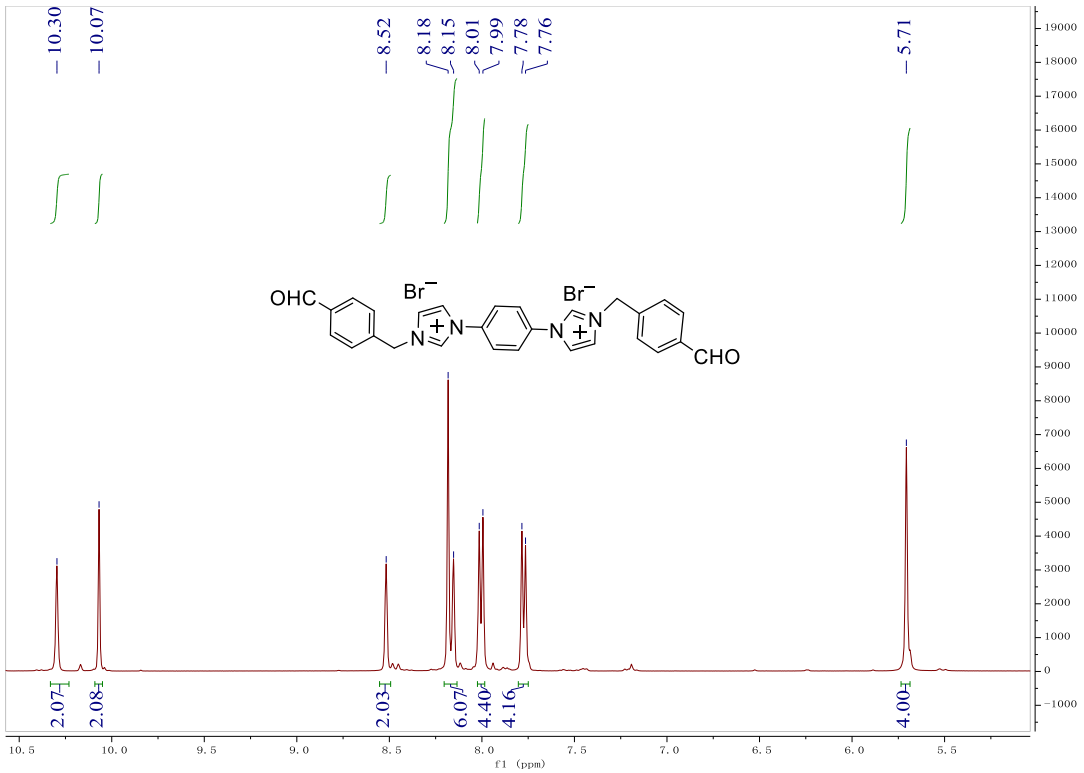
^{1}H NMR (500 MHz, DMSO-d_6, 25 ^{o}C, TMS): δ (ppm) = 10.03 (s, 2H), 9.56 (d, *J* = 6.5 Hz, 4H), (d, *J* = 6.4 Hz, 4H), 7.99 (d, *J* = 7.9 Hz, 4H), 7.80 (d, *J*=8.0 Hz, 4H), 6.09 (s, 4H).^{13}C NMR (126 MHz, DMSO-d_6) , 25 ^{o}C, TMS): δ (ppm) = 193.2, 149.8, 146.5, 140.6, 137.1, 130.6, 130.0, 127.8, 63.3.

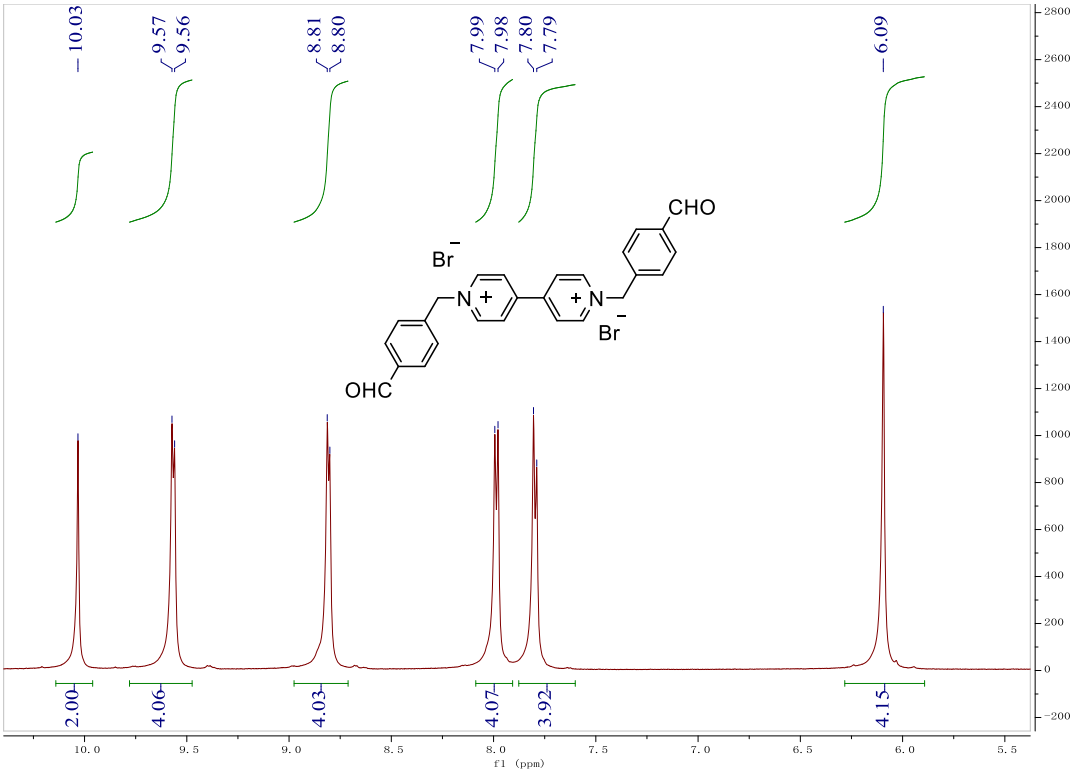


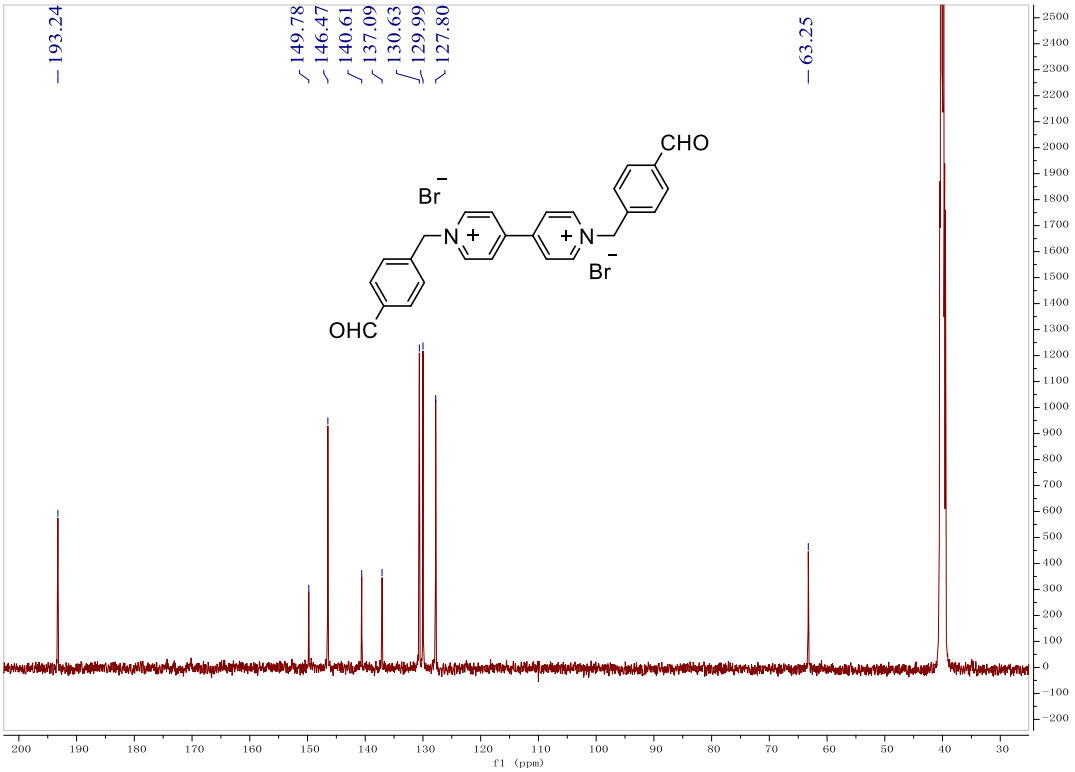
^{1}H NMR (500 MHz, $CDCl_3$) , 25 ^{o}C, TMS) δ (ppm) = 1.30 (t, *J* = 7.4 Hz, 9 H), 1.80-1.86 (m, 2 H), 1.91-2.97 (m, 2 H), 3.42-3.37 (m, 8 H), 3.47-3.45 (t, *J* = 6.3 Hz, 2H). ^{13}C NMR

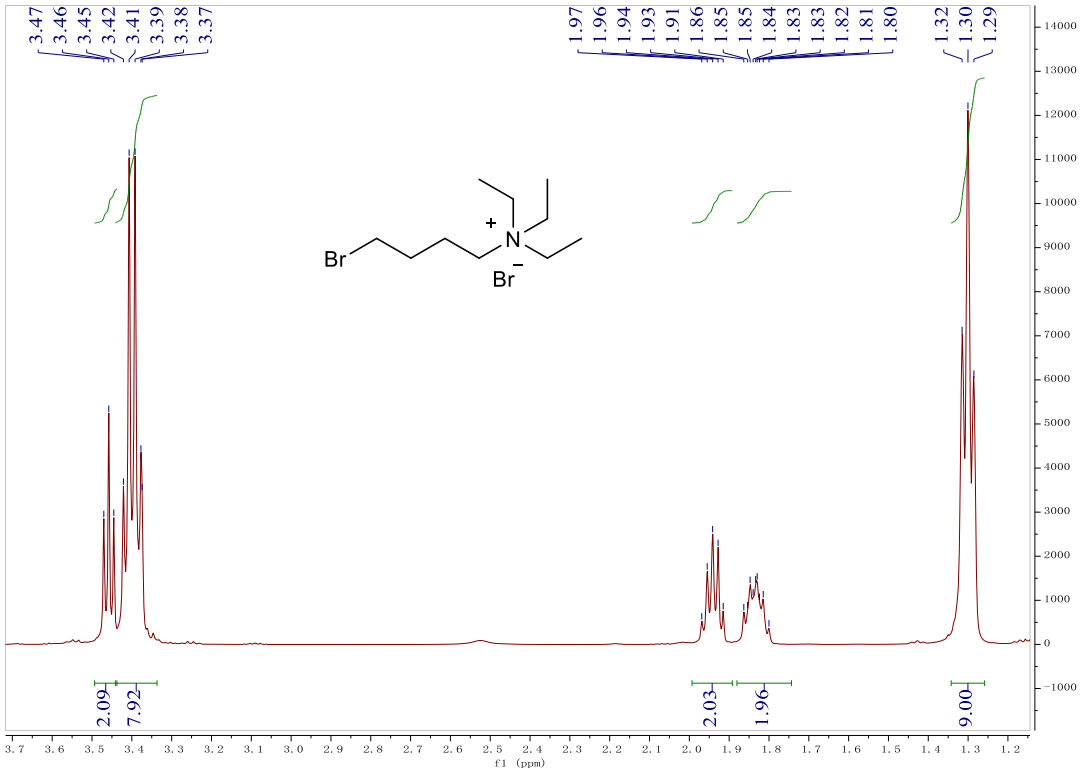
(126 MHz, $CDCl_3$, 25 ^{o}C, TMS): δ (ppm) = 56.56, 53.57, 32.9,0 28.98, 20.49, 8.15.

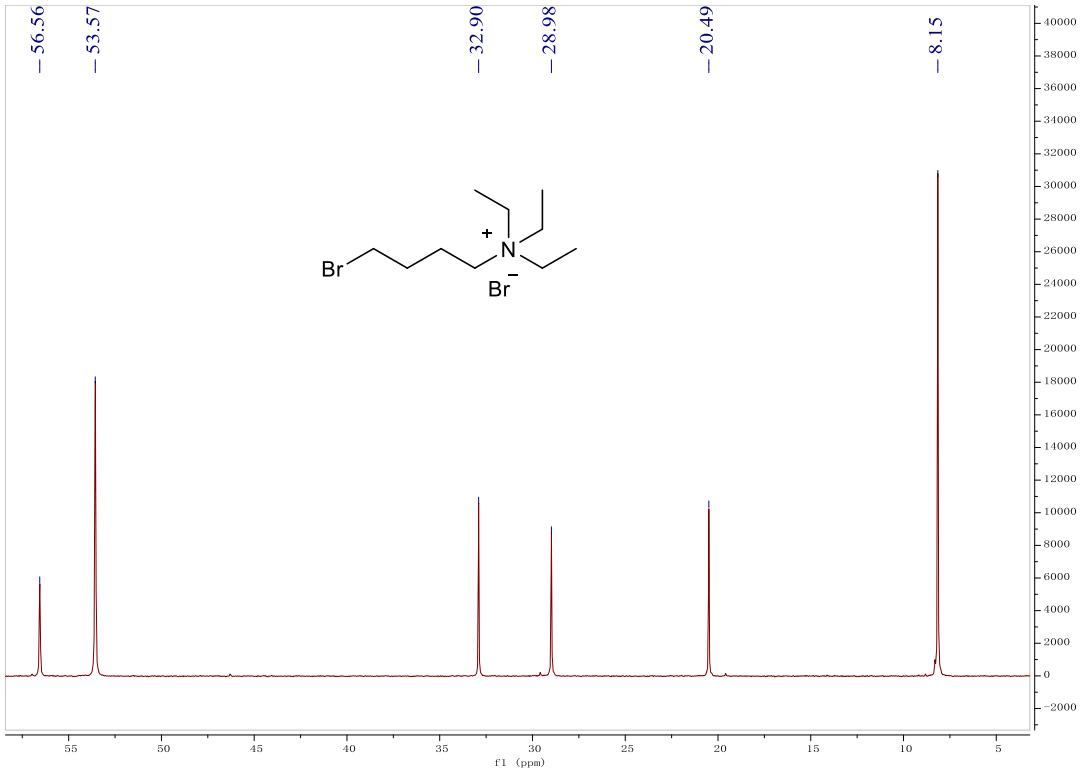





10.03
9.57
9.56
8.81
8.80
7.99
7.98
7.80
7.79
6.09
CHO
Br
N
N
Br
OHC
2.00
4.06
4.03
4.07
3.92
4.15
f1 (ppm)

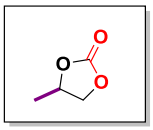

193.24
149.78
146.47
140.61
137.09
130.63
129.99
127.80
63.25
CHO
Br
N
N
Br
OHC
f1 (ppm)


3.47
3.46
3.45
3.42
3.41
3.39
3.38
3.37
1.97
1.96
1.94
1.93
1.91
1.86
1.85
1.85
1.84
1.83
1.83
1.82
1.81
1.80
1.32
1.30
1.29
Br
N
Br
2.09
7.92
2.03
1.96
9.00
f1 (ppm)


56.56
53.57
32.90
28.98
20.49
8.15
Br
N
Br
f1 (ppm)

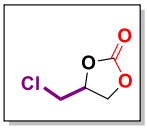
The ^{1}H NMR and ^{13}C NMR spectral copies of various synthesized cyclic carbonates:

4-methyl-1,3-dioxolan-2-one:



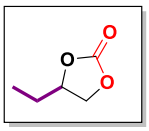
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 4.77-4.86 (m, 1H, ring C*H*-CH_3), 4.49-4.53 (t, 1H, *J* = 8 Hz, ring CH_2), 1.41-1.43 (d, 3H, *J* = 8 Hz, CH_3); ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 155.15, 73.70, 70.72, 19.31.

4-(chloromethyl)-1,3-dioxolan-2-one:



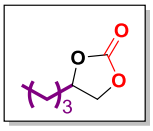
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 4.98-5.04 (m, 1H, C*H*-CH_2), 4.59-4.63 (t, *J* = 8 Hz, 1H, ring CH_2), 4.40-4.44 (dd, *J* = 8 Hz, 4 Hz, 1H, ring CH_2), 3.72-3.84 (m, 2 H, CH_2-Cl); ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 154.35, 74.38, 67.00, 43.86.

4-ethyl-1,3-dioxolan-2-one:



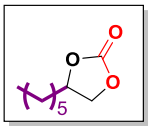
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 4.58-4.63 (m, 1H), 4.45-4.48 (t, *J* = 10 Hz, 1H), 4.00-4.03 (t, *J* = 10 Hz, 1H), 1.64-1.75 (m, 2H), 0.92-0.95 (t, *J* = 10 Hz, 3H); ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 155.21, 78.11, 69.06, 26.79, 8.38.

4-butyl-1,3-dioxolan-2-one:



^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 4.59-4.64 (m, 1H), 4.42-4.45 (t, *J* = 10 Hz, 1H), 3.95-3.98 (t, *J* = 10 Hz, 1H), 1.63-1.71 (m, 1H), 1.55-1.62 (m, 1H), 1.19-1.36 (m, 4H), 0.79-0.82 (t, *J* = 10 Hz, 3H); ^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 155.16, 77.15, 69.41, 33.35, 26.33,22.13, 13.66.

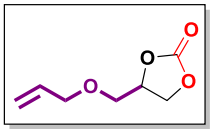
4-hexyl-1,3-dioxolan-2-one:



^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 4.62-4.68 (m, 1H), 4.46-4.49 (t, *J* = 10 Hz, 1H), 3.99-4.02 (t, *J* = 10 Hz, 1H), 1.69-1.76 (m, 1H), 1.59-1.65 (m, 1H), 1.34-1.44 (m, 1H),

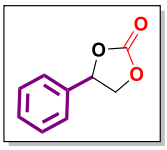
1.20-1.33 (m, 7H), 0.80-0.83 (t, *J* = 10 Hz, 3H); ^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 155.16, 77.14, 69.42, 33.77, 31.46, 28.73, 24.26, 22.39, 13.92.

4-((allyloxy)methyl)-1,3-dioxolan-2-one:

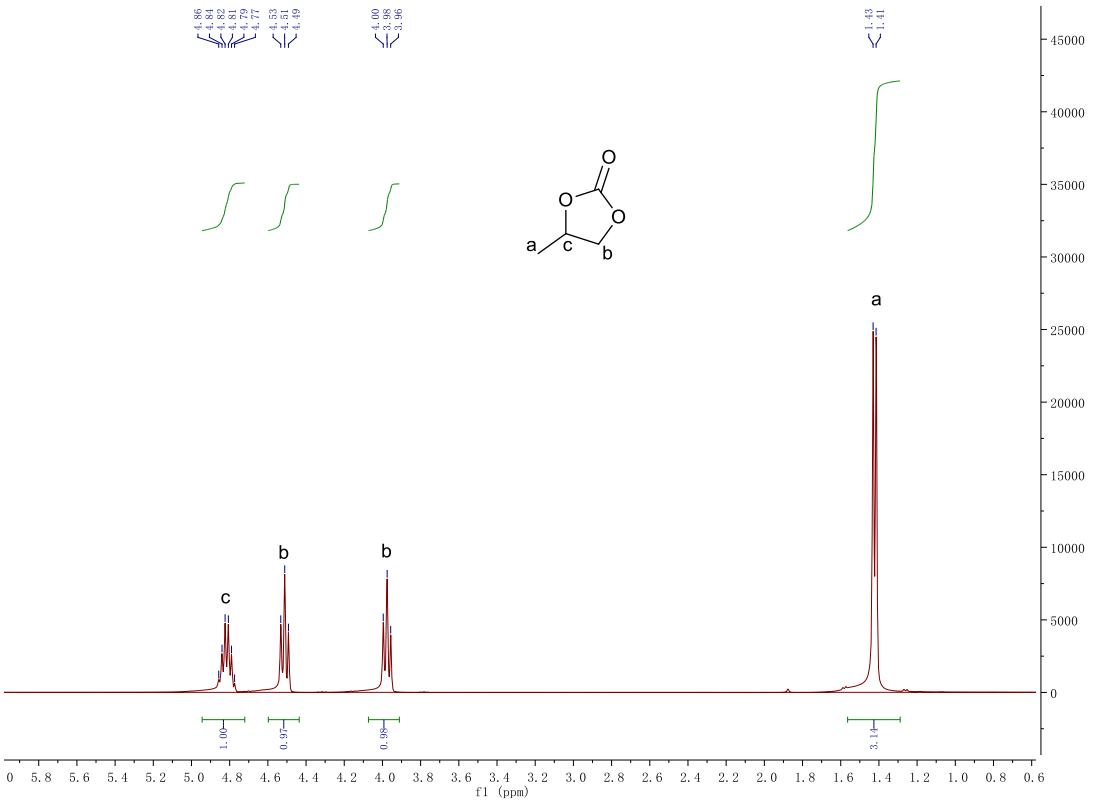


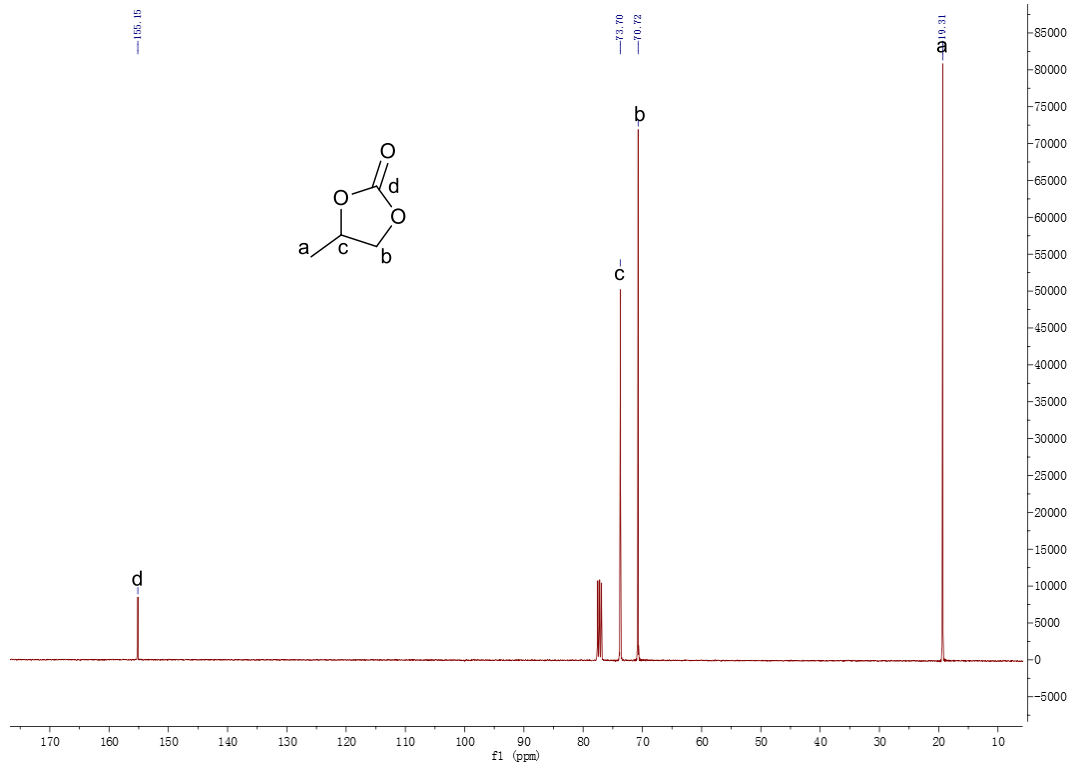
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 5.83-5.92 (m, 1H), 5.19-5.31 (dd, *J* = 10 Hz, 2H), 4.84-4.87 (m, 1H), 4.50-4.54 (t, *J* = 8 Hz, 1H), 4.38-4.42 (d, *J* = 8 Hz, 1H), 4.01-4.10 (m, 2H), 3.60-3.73 (m, 2H). ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 155.06, 133.17, 117.79, 75.17, 72.51, 68.86, 66.27.

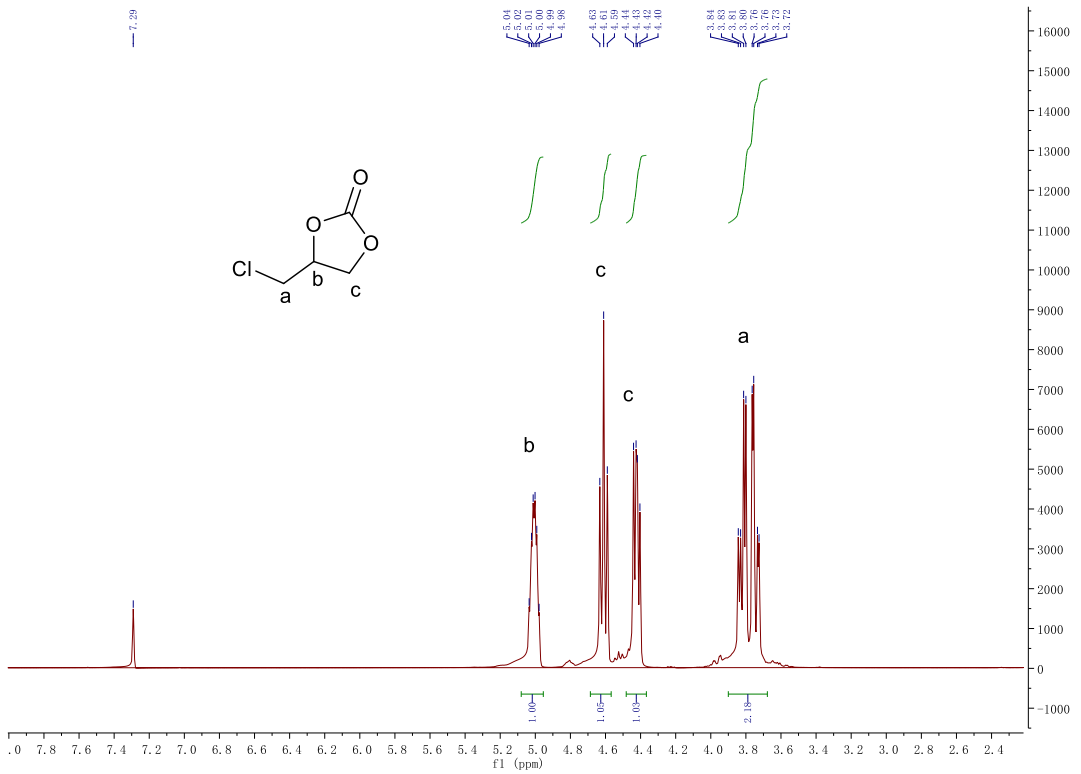
4-phenyl-1,3-dioxolan-2-one:

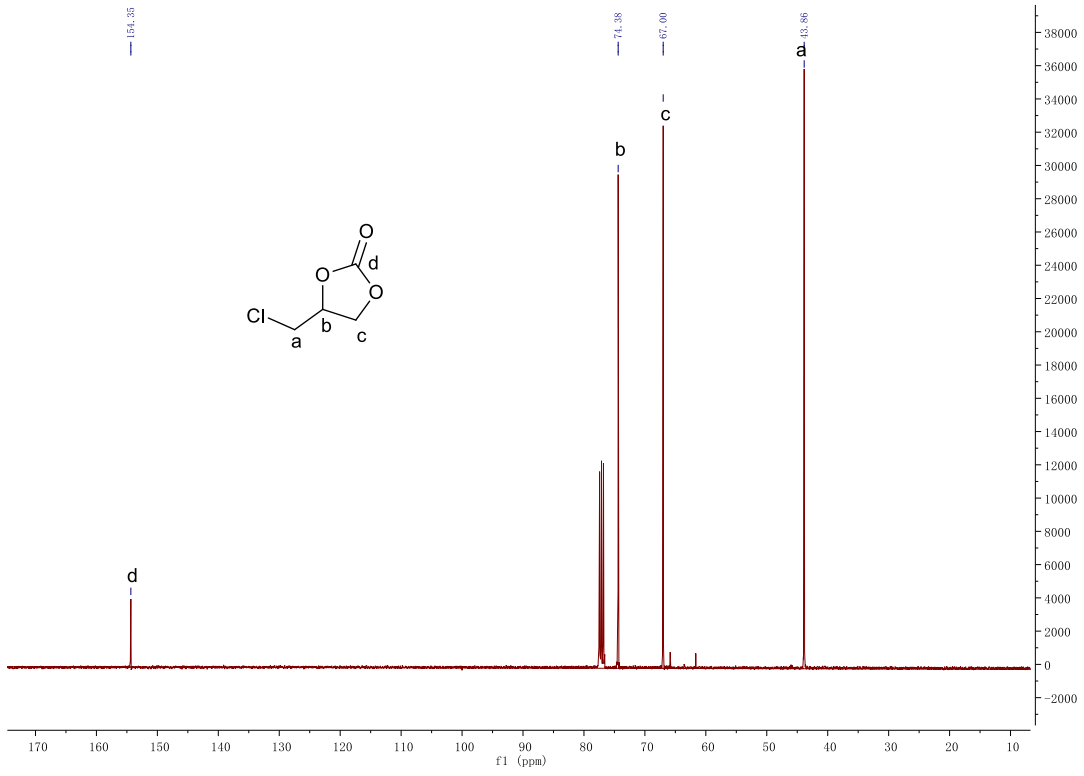


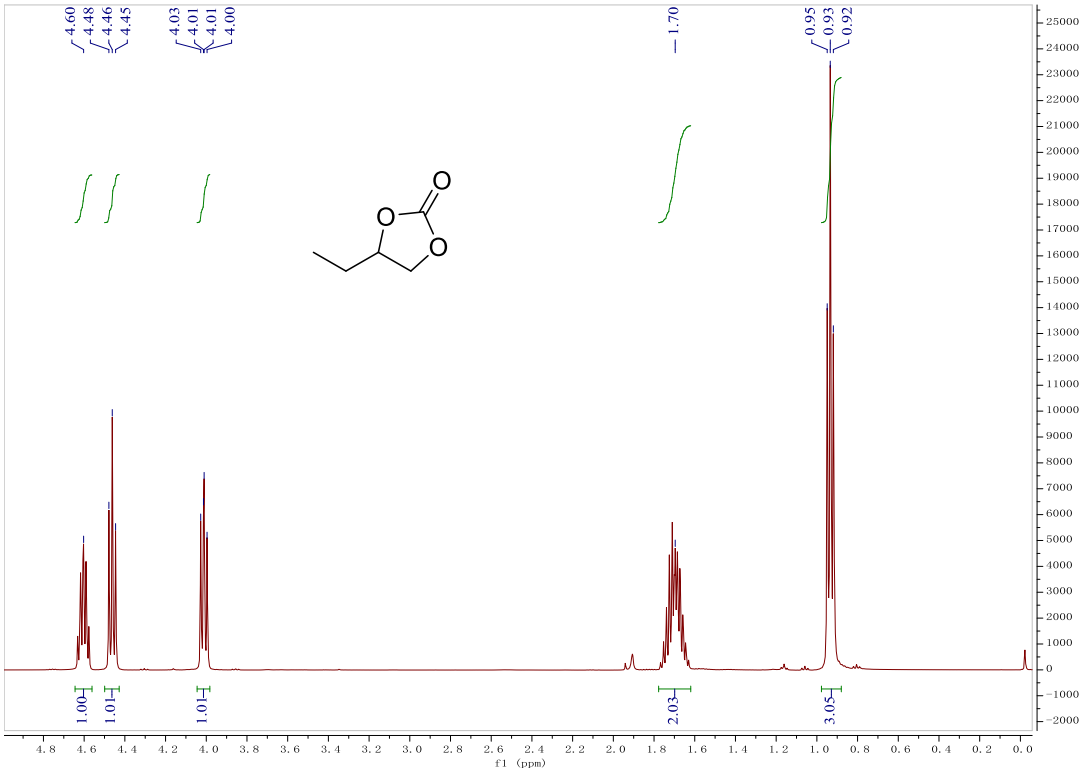
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 7.28-7.38 (m, 4H, ring ArH), 5.58-5.62 (t, 1H, *J* = 8 Hz, PhCHO), 4.71-4.75 (t, 1H, *J* = 8 Hz, OCH_2), 4.26-4.30 (t, 1H, *J* = 8 Hz, OCH_2); ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 153.75, 134.78, 128.72, 128.23, 124.83, 76.95, 70.13.

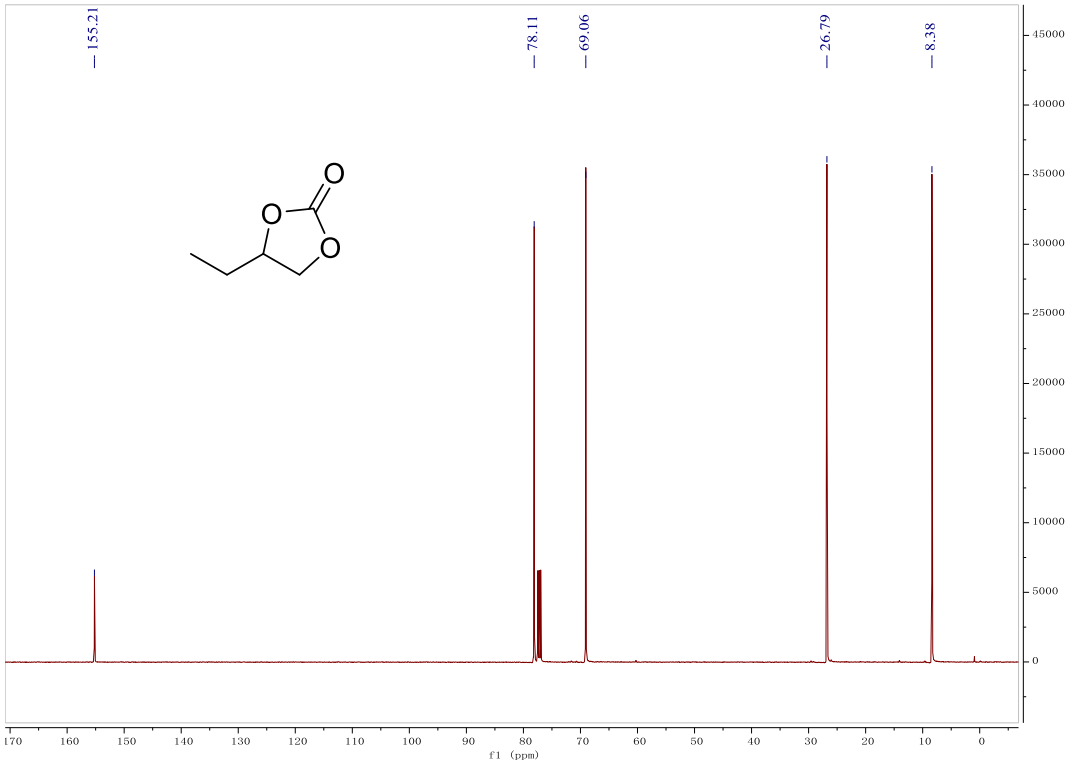

4.86
4.84
4.82
4.81
4.79
4.77
4.53
4.51
4.49
4.00
3.98
3.96
1.43
1.41
O
O
O
a
c
b
a
b
b
c
1.00
0.97
0.98
3.14
f1 (ppm)

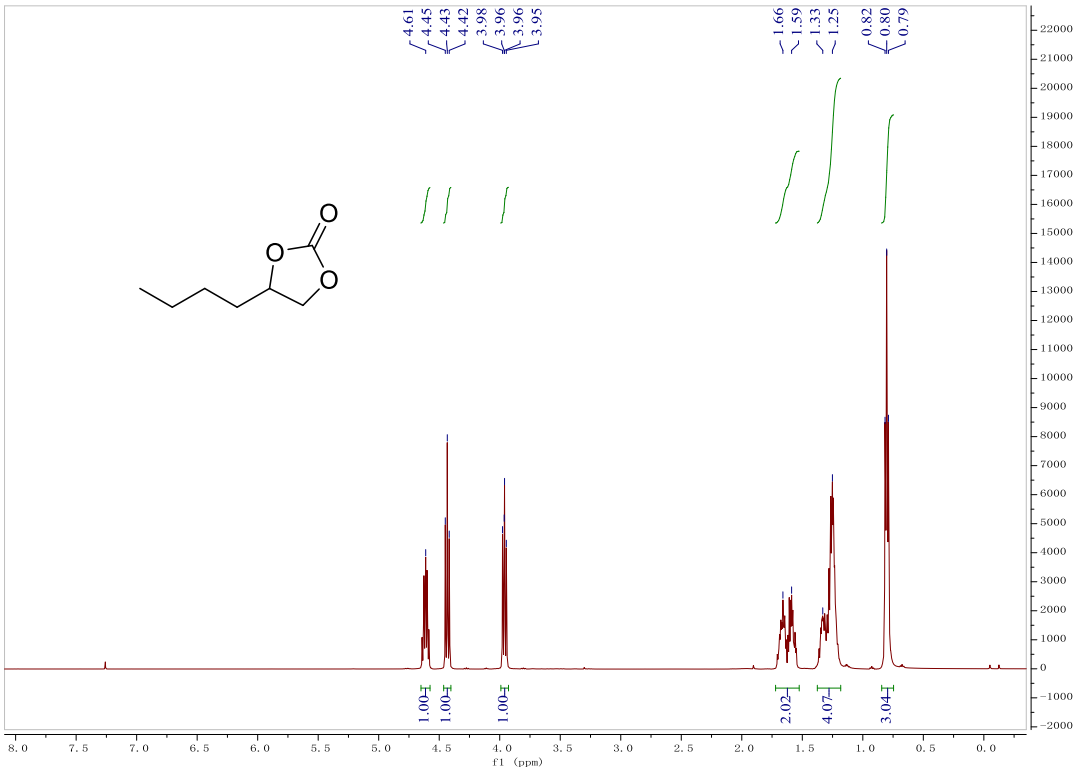

155.15
73.70
70.72
19.81
O
O
O
d
a
c
b
d
c
b
a
f1 (ppm)

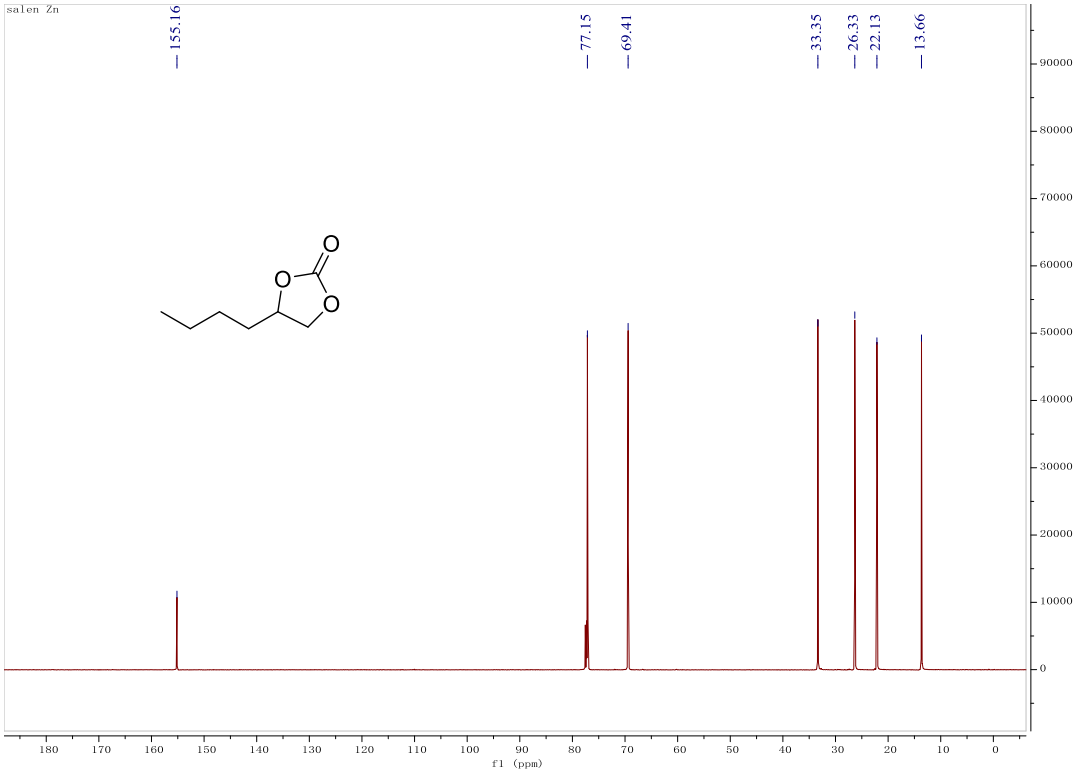

7.29
5.04
5.02
5.01
5.00
4.99
4.98
4.63
4.61
4.59
4.44
4.43
4.42
4.40
3.84
3.83
3.81
3.80
3.76
3.75
3.73
3.72
Cl
O
O
O
a
b
c
a
b
c
c
1.00
1.05
1.03
2.18
f1 (ppm)

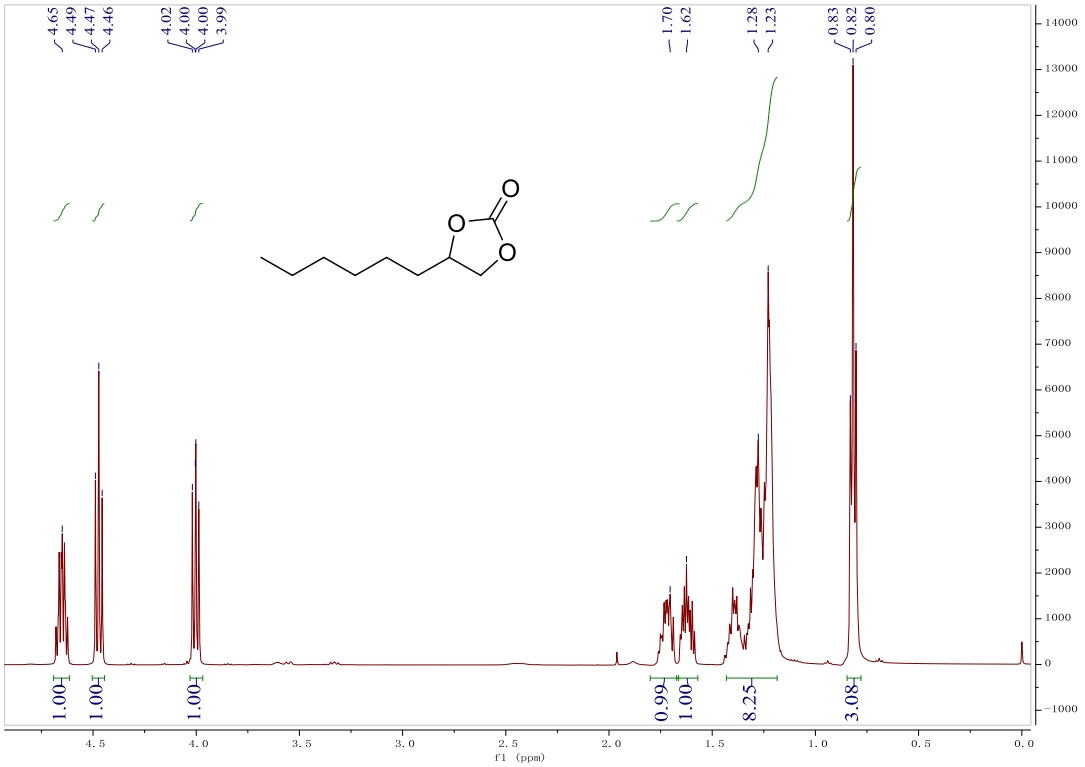

154.35
74.38
67.00
43.86
Cl
O
O
O
d
a
b
c
d
a
b
c
f1 (ppm)

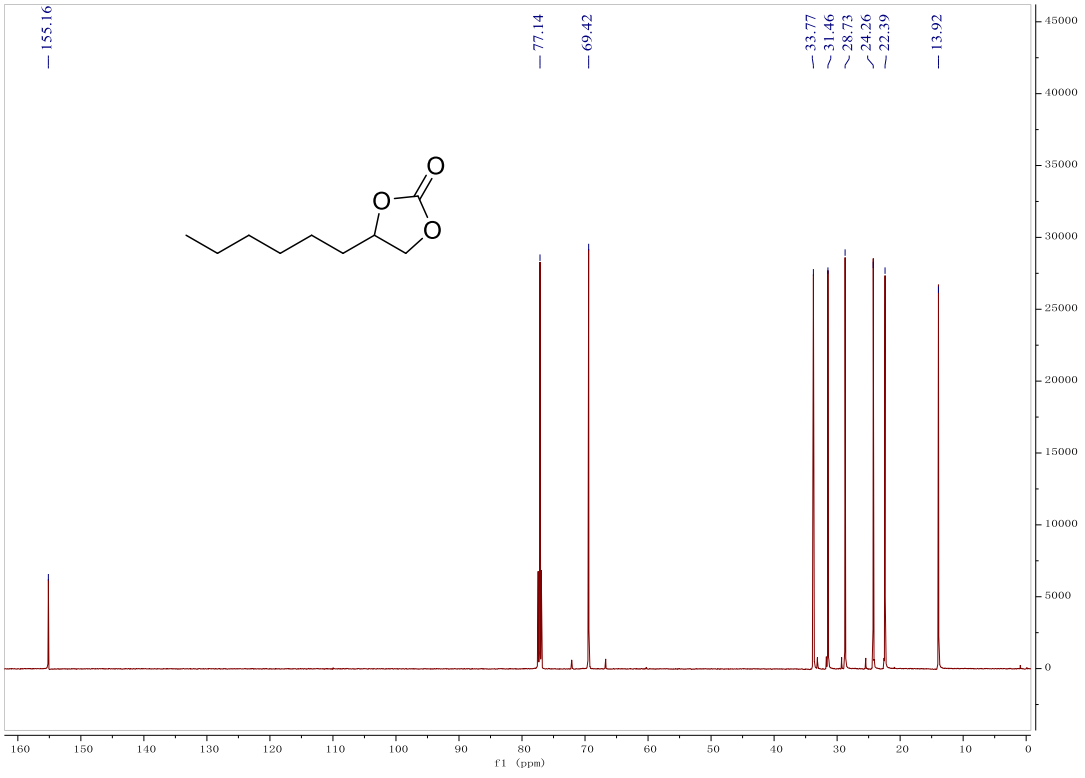

4.60
4.48
4.46
4.45
4.03
4.01
4.01
4.00
1.70
0.95
0.93
0.92
1.00
1.01
1.01
2.03
3.05
f1 (ppm)

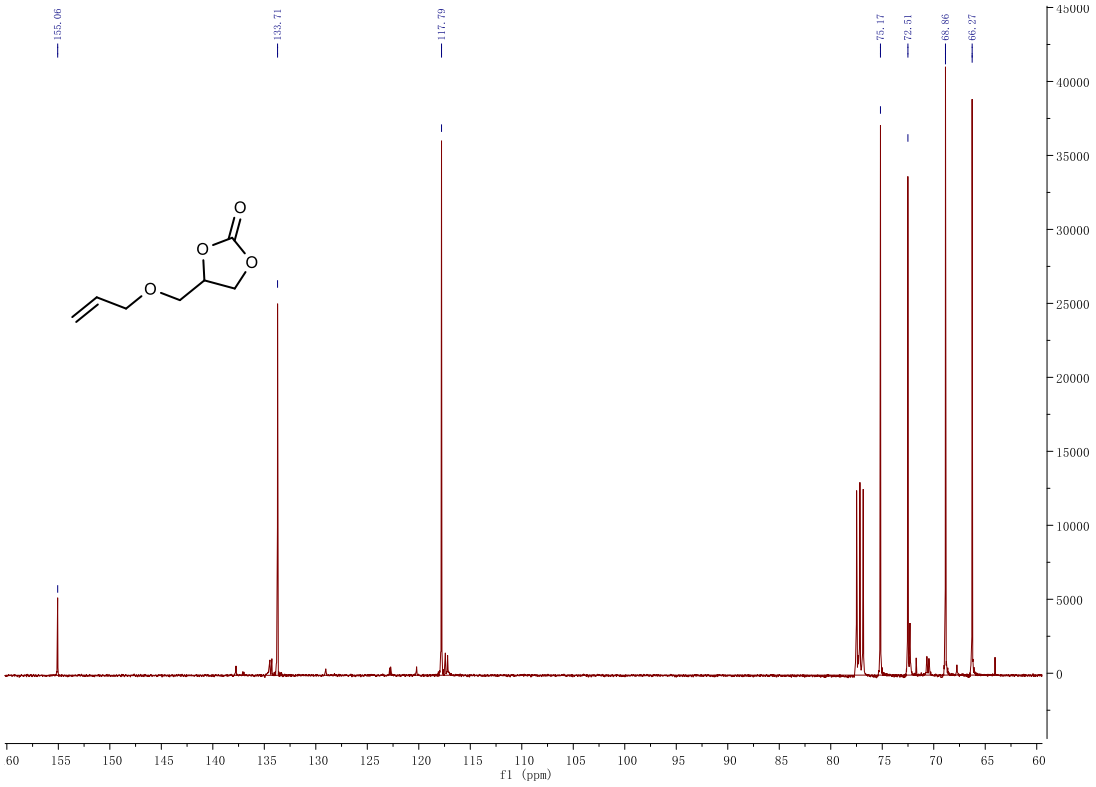

155.21
78.11
69.06
26.79
8.38
f1 (ppm)

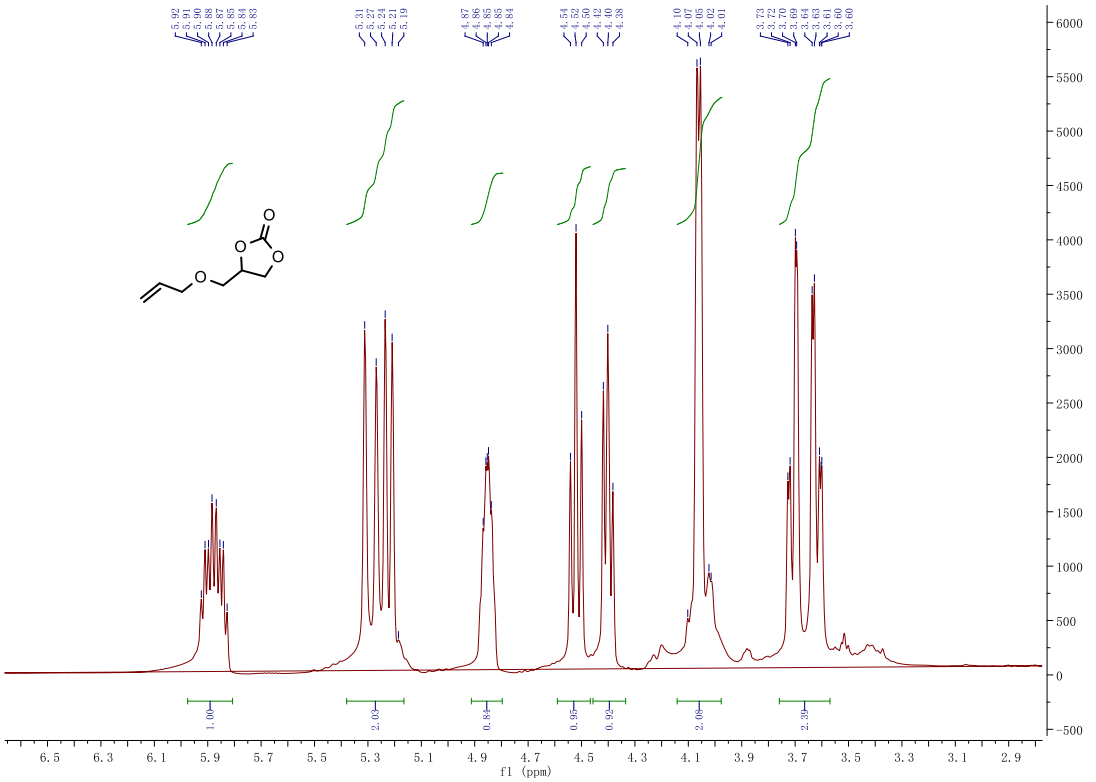

4.61
4.45
4.43
4.42
3.98
3.96
3.96
3.95
1.66
1.59
1.33
1.25
0.82
0.80
0.79
1.00
1.00
1.00
2.02
4.07
3.04
f1 (ppm)

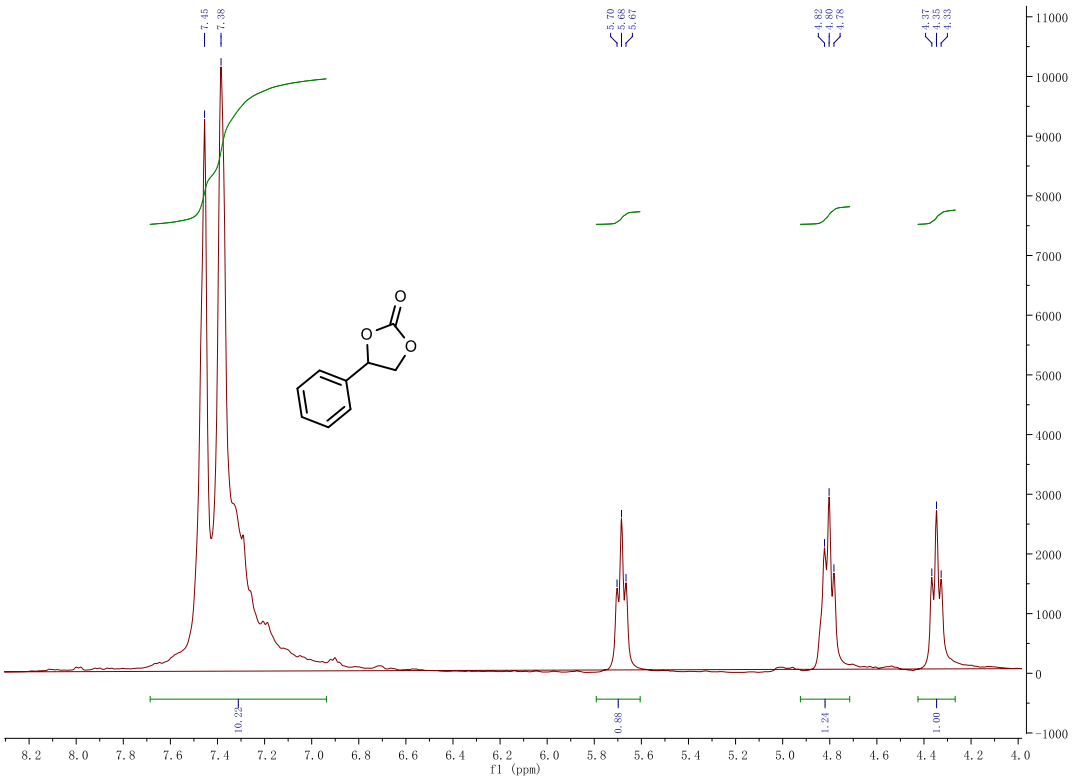

salen Zn
155.16
77.15
69.41
33.35
26.33
22.13
13.66
f1 (ppm)

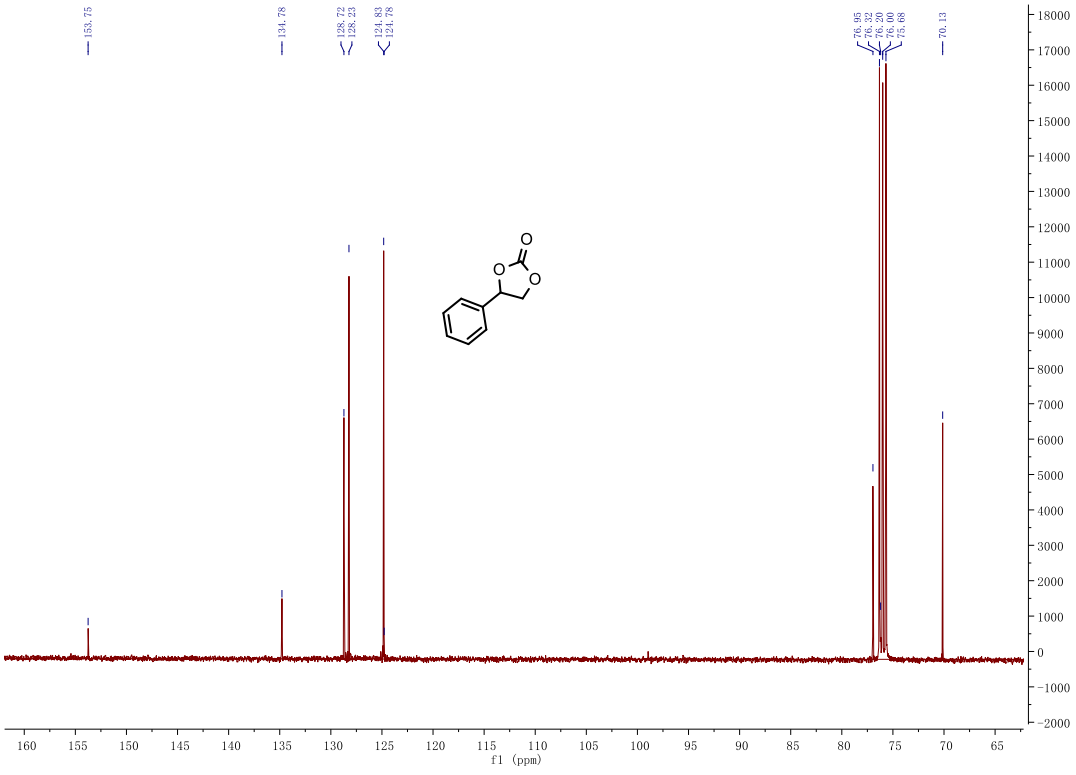

4.65
4.49
4.47
4.46
4.02
4.00
4.00
3.99
1.70
1.62
1.28
1.23
0.83
0.82
0.80
1.00
1.00
1.00
0.99
1.00
8.25
3.08
f1 (ppm)


155.16
77.14
69.42
33.77
31.46
28.73
24.26
22.39
13.92
f1 (ppm)


155.06
133.71
117.79
75.17
72.51
68.86
66.27
f1 (ppm)

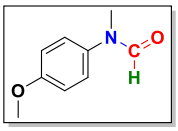

5.92
5.91
5.90
5.88
5.87
5.86
5.84
5.83
5.31
5.27
5.24
5.21
5.19
4.87
4.86
4.85
4.85
4.84
4.54
4.52
4.50
4.42
4.40
4.38
4.10
4.07
4.05
4.02
4.01
3.73
3.72
3.70
3.69
3.64
3.63
3.61
3.60
3.60
1.00
2.03
0.84
0.95
0.92
2.09
2.39
f1 (ppm)


7.45
7.38
5.70
5.68
5.67
4.82
4.80
4.78
4.37
4.35
4.33
10.22
0.88
1.24
1.00
f1 (ppm)


153.75
134.78
128.72
128.23
124.83
124.78
76.95
76.32
76.20
76.00
75.68
70.13
f1 (ppm)

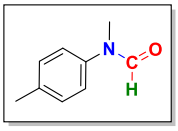
The ^{1}H NMR and ^{13}C NMR spectral copies of various synthesized formamides:

N-(4-methoxyphenyl)-N-methylformamide:



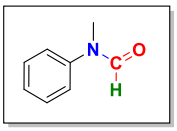
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.30(s, 1H), 7.05-7.07(d, 2H), *δ* 6.89-6.91(d, 2H), 3.78(s, 3H), 3.23(s, 3H). ^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 162.42, 158.24, 135.12, 124.52, 114.70, 55.44, 32.57.

N-methyl-N-(p-tolyl)formamide:



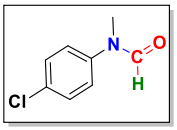
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.25(s, 1H), 7.04-7.06(d, 2H), 6.88-6.90(d, 2H), 3.13(s, 3H), 2.20(s, 3H)；^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 162.65, 139.50, 136.46, 130.15, 122. 51, 32.27, 0.81.

N-methyl-N-phenylformamide:



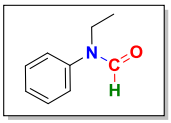
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.45(s, 1H), 7.37-7.40(t, 2H), 7.23-7.26(t, 1H), 7.13-7.15(d, 2H), 3.29(s, 3H)； ^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 162.71, 141.99, 129.65, 126.57, 122. 40, 32.23.

N-(4-chlorophenyl)-N-methylformamide:



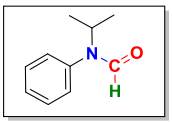
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.38(s, 1H), 7.34-7.37(d, 2H), 7.04-7.06(d, 2H), 3.25(s, 3H)； ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 163.44, 142.05, 135.48, 131.09, 124.89, 33.42.

N-(1-Phenylethyl)formamide:



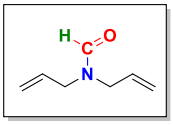
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.14(s, 1H), 7.22-7.25(t, 2H), 7.11-7.14(t, 1H), 6.96-6.98(d, 2H), 3.66-3.70(m, 2H), 0.96-0.99(t, 3H)； ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 162.56 , 140.49, 129.66, 127.09, 124.28, 40.32, 12.93.

N-isopropyl-N-phenylformamide:



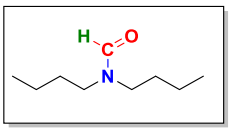
^{1}H NMR ($CDCl_3$, 500 MHz, 25 ^{o}C, TMS): δ (ppm) = 7.99-8.03(s, 1H), 6.99-7.27(m , 5H), 4.61-4.66(m, 1H), 1.04-1.05(d, 6H), 3.66-3.70(m, 2H), 0.96-0.99(t, 3H)； ^{13}C NMR ($CDCl_3$, 126 MHz, 25 ^{o}C, TMS): δ (ppm) = 163.13, 137.96, 129.29, 128.80, 128.37, 46.16, 20.77.

N,N-diallylformamide:



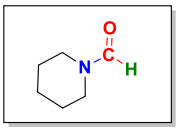
^{1}H NMR (DMSO-*d6*, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.09(s, 1H), 5.63-5.83(m, 2H), 5.09-5.19(m, 4H), 3.79-3.84(m, 4H)； ^{13}C NMR (DMSO-*d6*, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 164.40, 136.19, 134.60, 119.59, 119.07, 50.51, 45.44.

N,N-dibutylformamide:



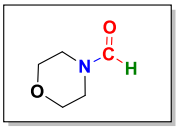
^{1}H NMR (DMSO-*d6*, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 8.00(s, 1H), 3.16-3.21(m, 4H), 1.38-1.49(m, 4H), 1.19-1.27(m ,4H) ; 0.86-0.90(m, 6H)；^{13}C NMR (DMSO-*d6*, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 164.33, 47.87, 42.61, 32.08, 30.77, 21.39, 20.91, 15.47, 15.34.

N-Cyclohexylformamide:



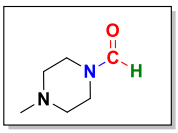
^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 7.96(s, 1H), 6.10(s, 1H), 3.75-3.83(m, 1H), 1.56-1.87(m, 4H), 1.11-1.38(m, 6H)；^{13}C NMR (DMSO-*d6*, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 165.31, 162.10, 52.56, 48.51, 35.83, 34.21, 26.81, 26.37, 26.13.

Morpholine-4-carbaldehyde:

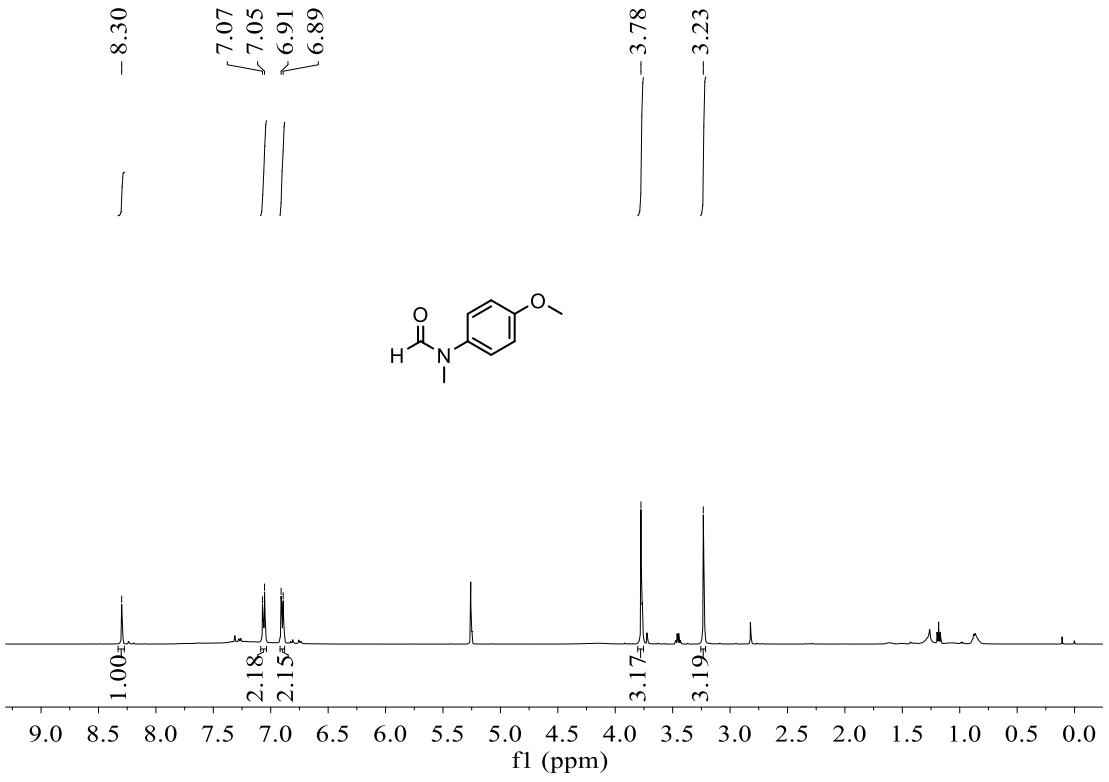


^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 7.87(s, 1H), 3.48-3.52(m, 4H), 3.39-3.42(t, 2H), 3.19-3.21(t, 2H)；^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 159.94, 66.12, 65.30, 44.72, 39.54 .

4-methylpiperazine-1-carbaldehyde:



^{1}H NMR ($CDCl_3$, 400 MHz, 25 ^{o}C, TMS): δ (ppm) = 7.94(s, 1H), 3.48-3.50(t, 2H), 3.30-3.33(t, 2H), 2.24-2.36(m, 4H)； ^{13}C NMR ($CDCl_3$, 101 MHz, 25 ^{o}C, TMS): δ (ppm) = 162.03, 56.48, 55.32, 47.17, 46.56, 40.90.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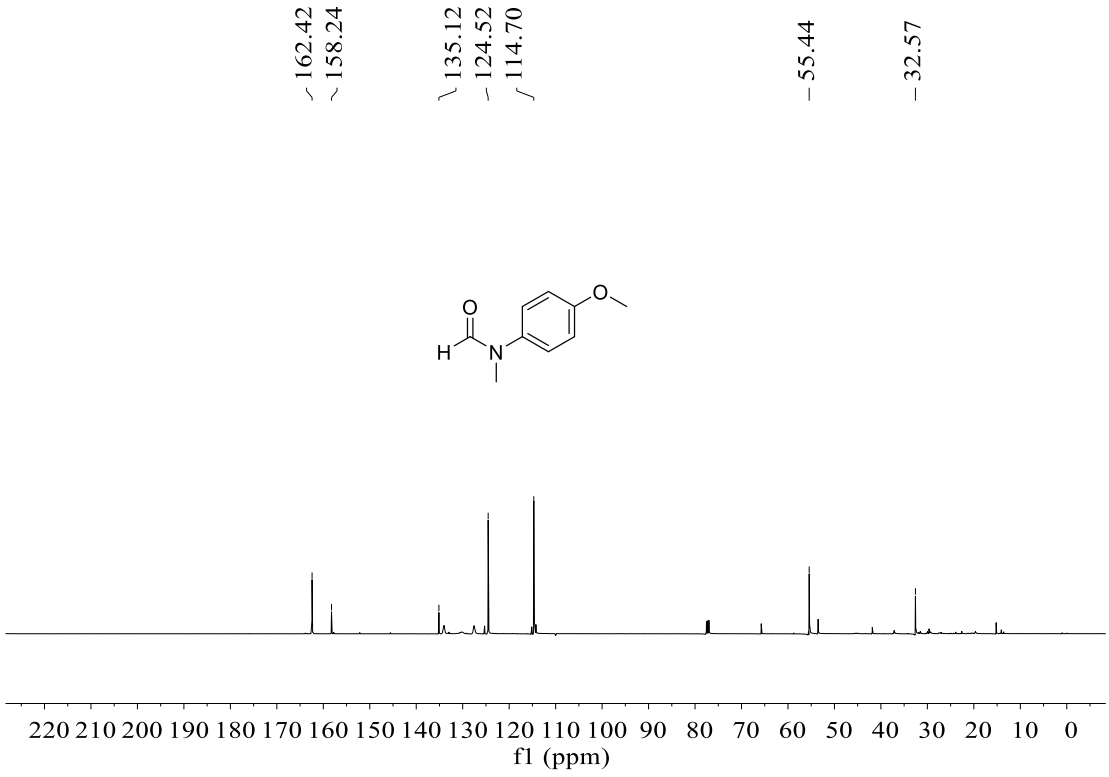
7.05
6.91
6.89
3.78
3.23
O
H
N
O
1.00
2.18
2.15
3.17
3.19
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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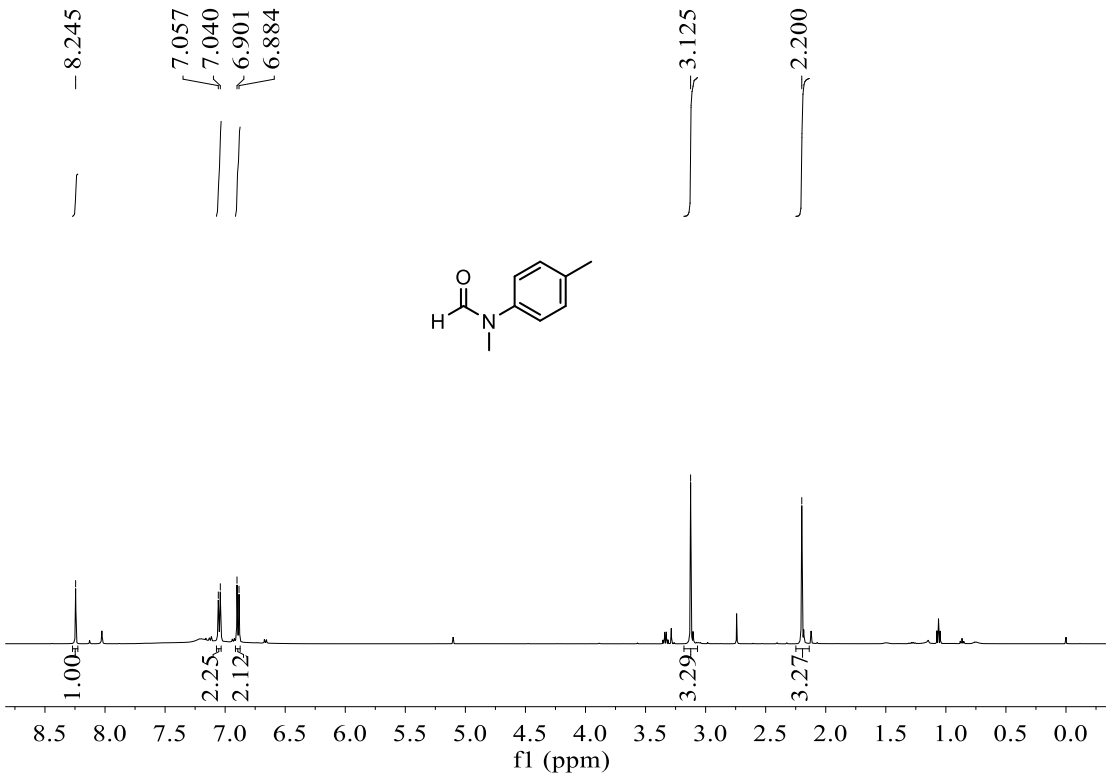
158.24
135.12
124.52
114.70
55.44
32.57
O
H
N
O
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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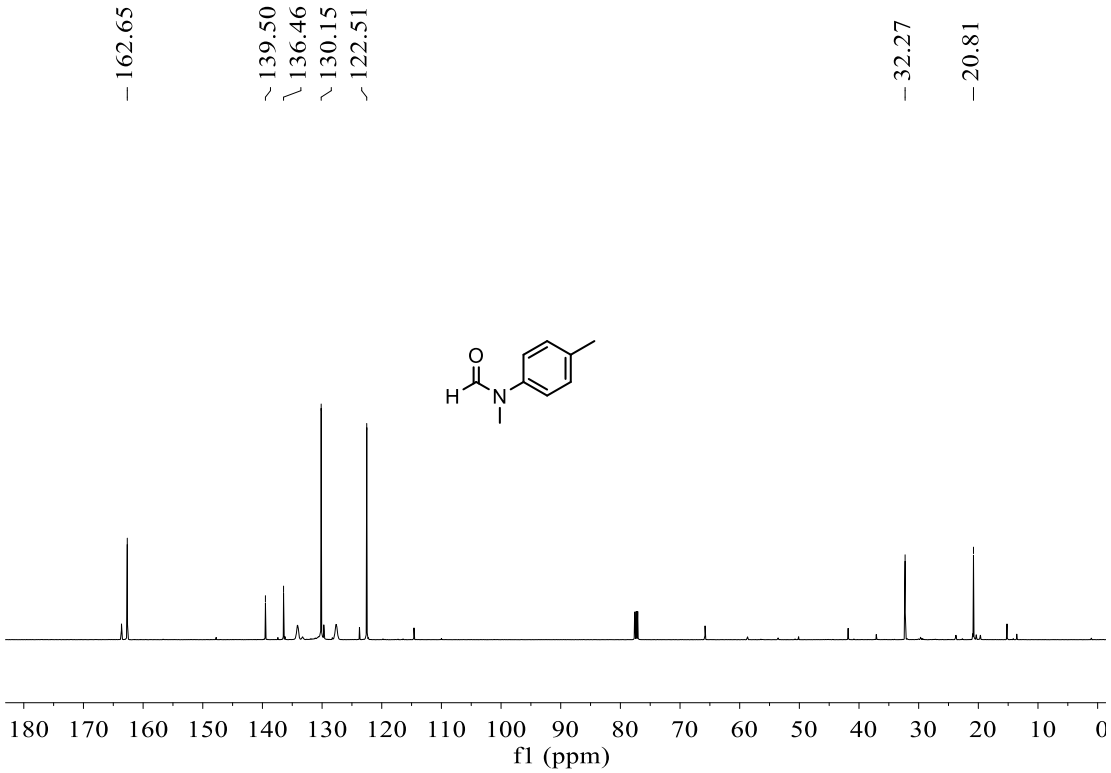
7.057
7.040
6.901
6.884
3.125
2.200
1.00
2.25
2.12
3.29
3.27
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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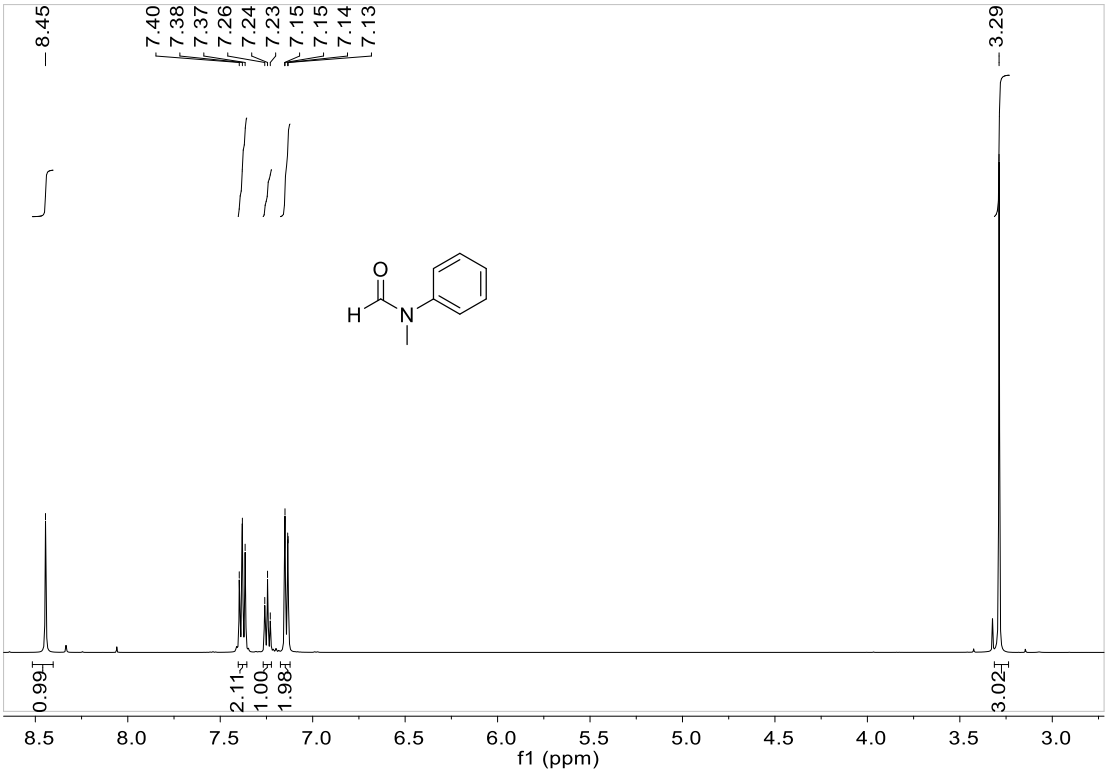
139.50
136.46
130.15
122.51
32.27
20.81
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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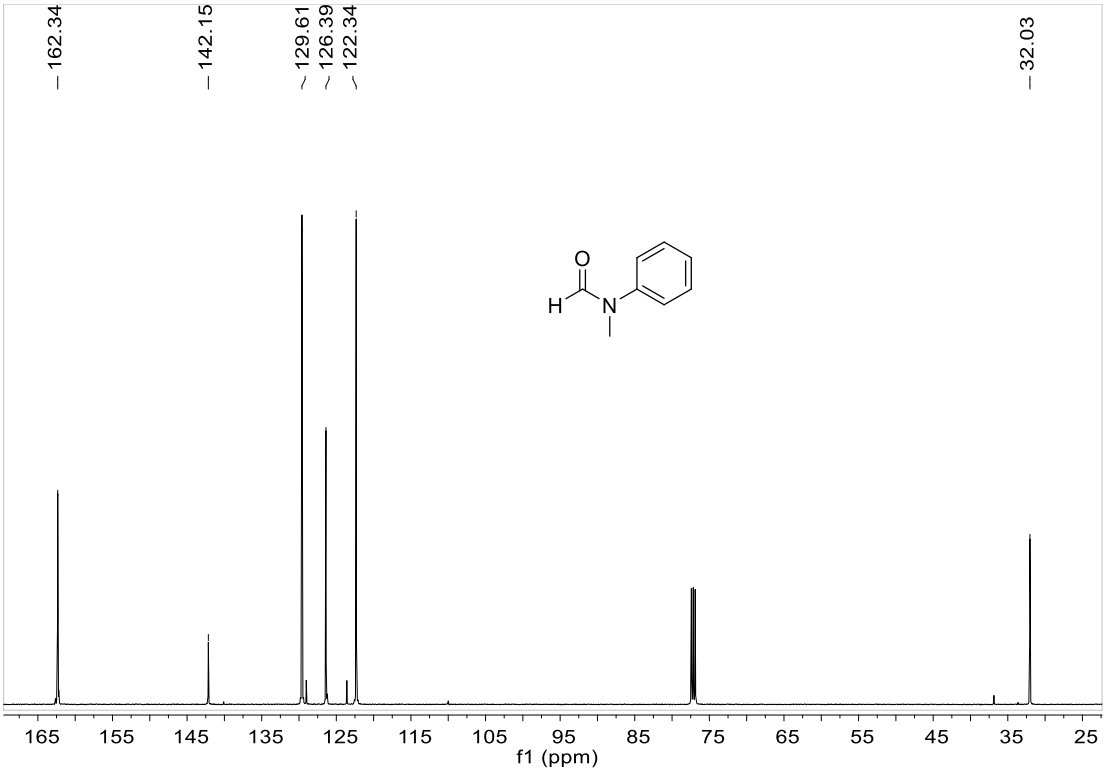
7.40
7.38
7.37
7.26
7.24
7.23
7.15
7.15
7.14
7.13
3.29
O
H
N
0.99
2.11
1.00
1.98
3.02
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
f1 (ppm)


162.34
142.15
129.61
126.39
122.34
32.03
O
H
N
165
155
145
135
125
115
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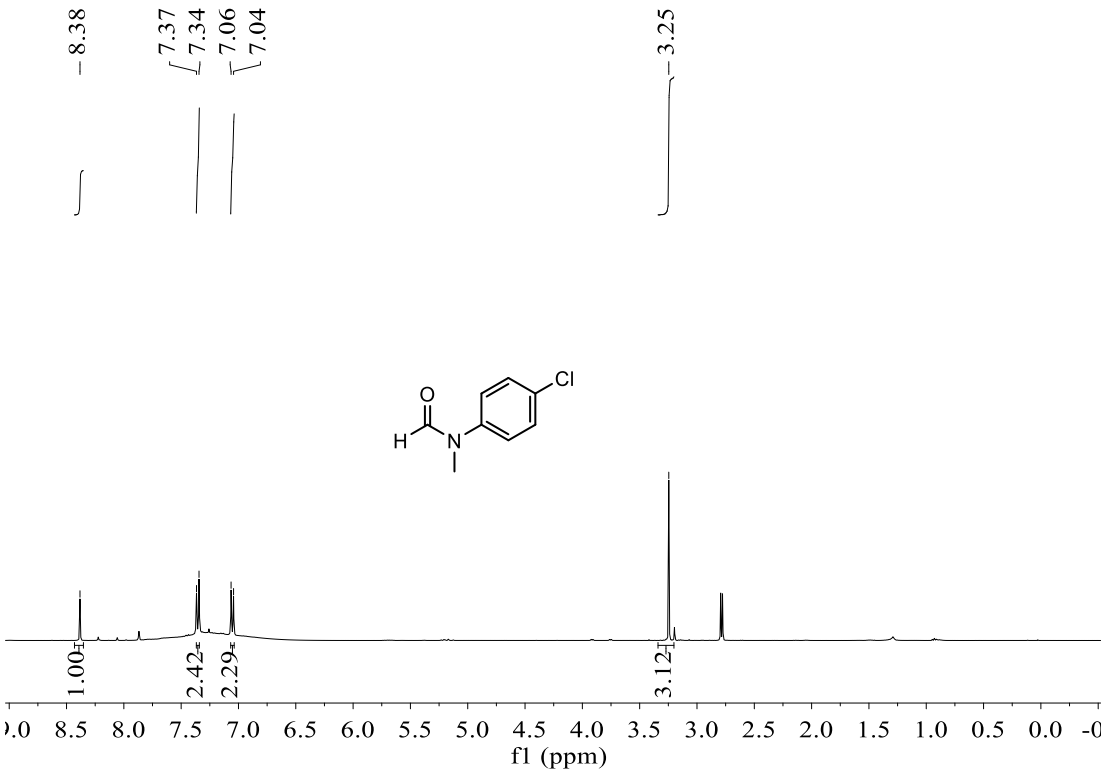
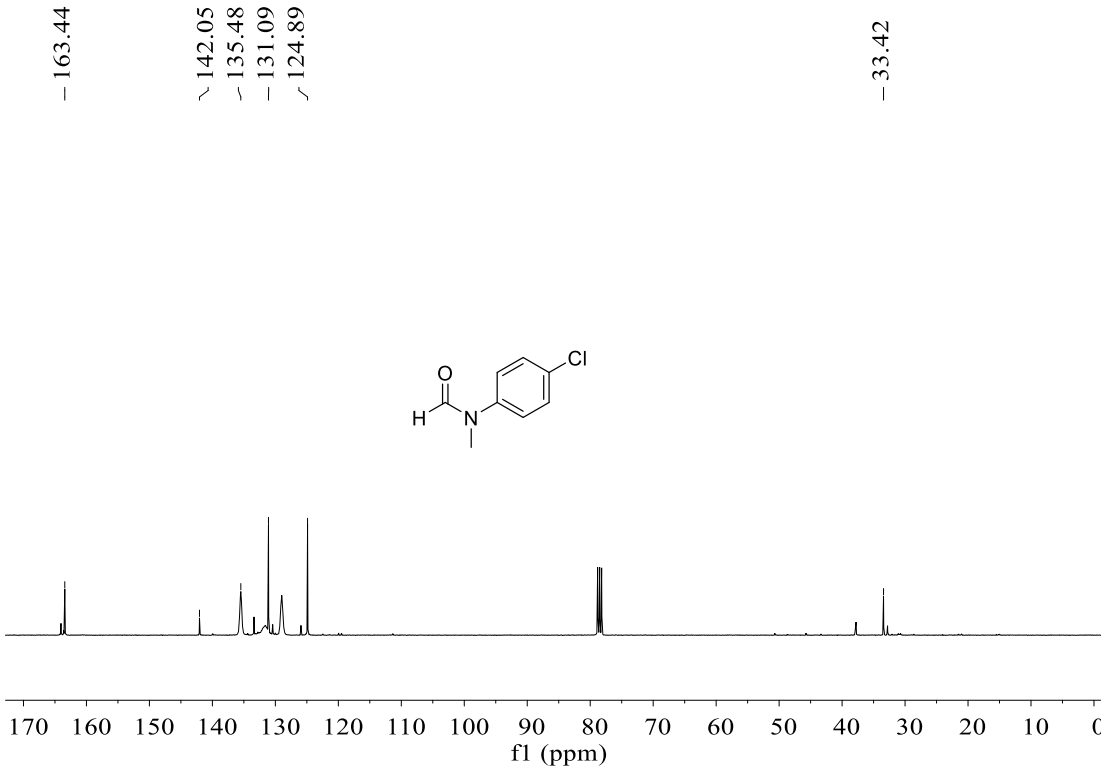
85
75
65
55
45
35
25
f1 (ppm)


8.38
7.37
7.34
7.06
7.04
3.25
Cl
O
H
N
1.00
2.42
2.29
3.12
f1 (ppm)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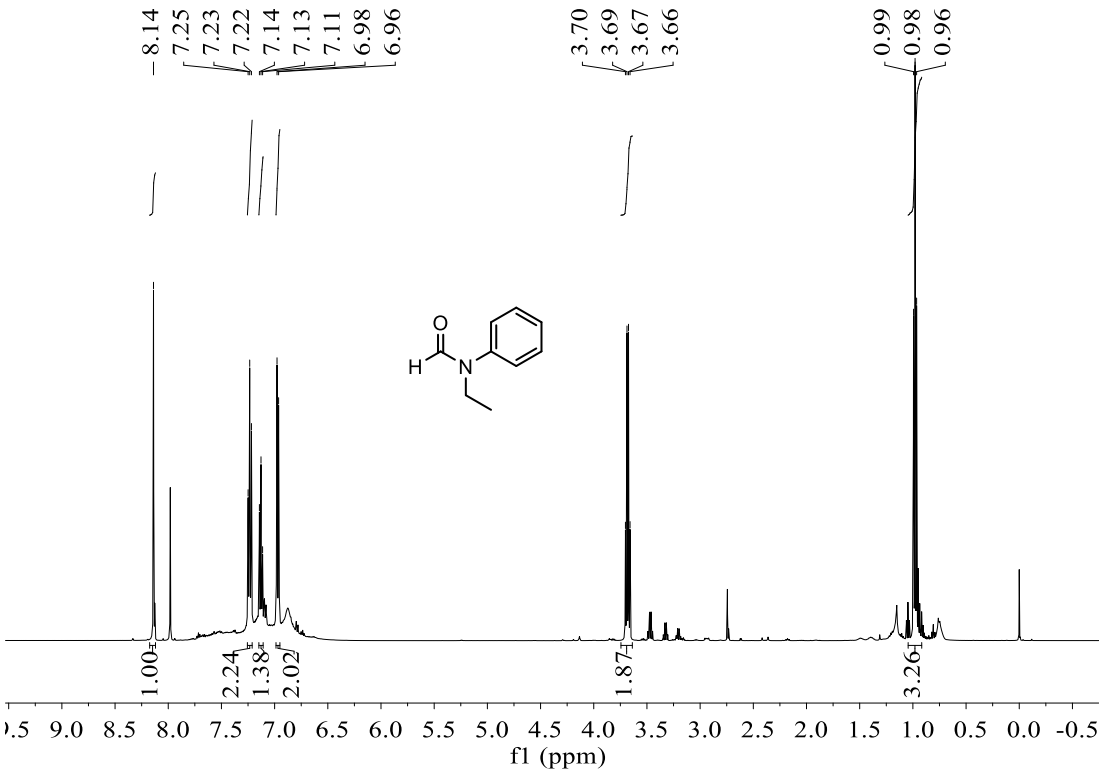
142.05
135.48
131.09
124.89
33.42
Cl
O
H
N
f1 (ppm)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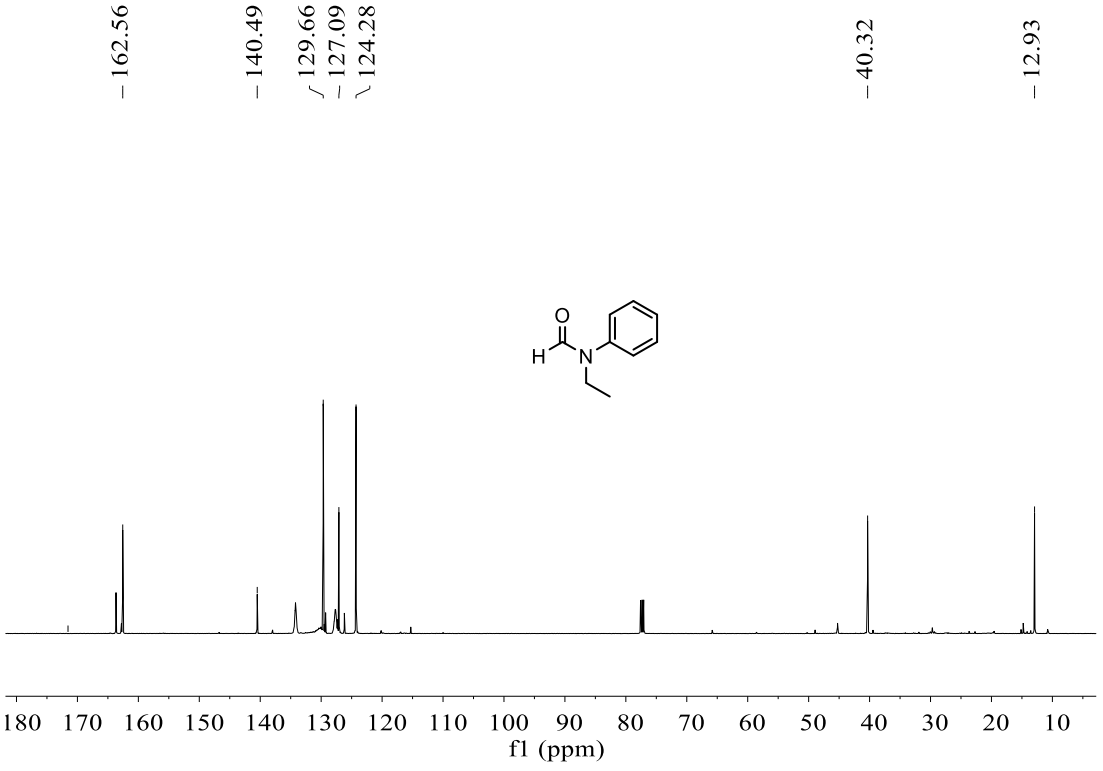
7.25
7.23
7.22
7.14
7.13
7.11
6.98
6.96
3.70
3.69
3.67
3.66
0.99
0.98
0.96
1.00
2.24
1.38
2.02
1.87
3.26
f1 (ppm)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140.49
129.66
127.09
124.28
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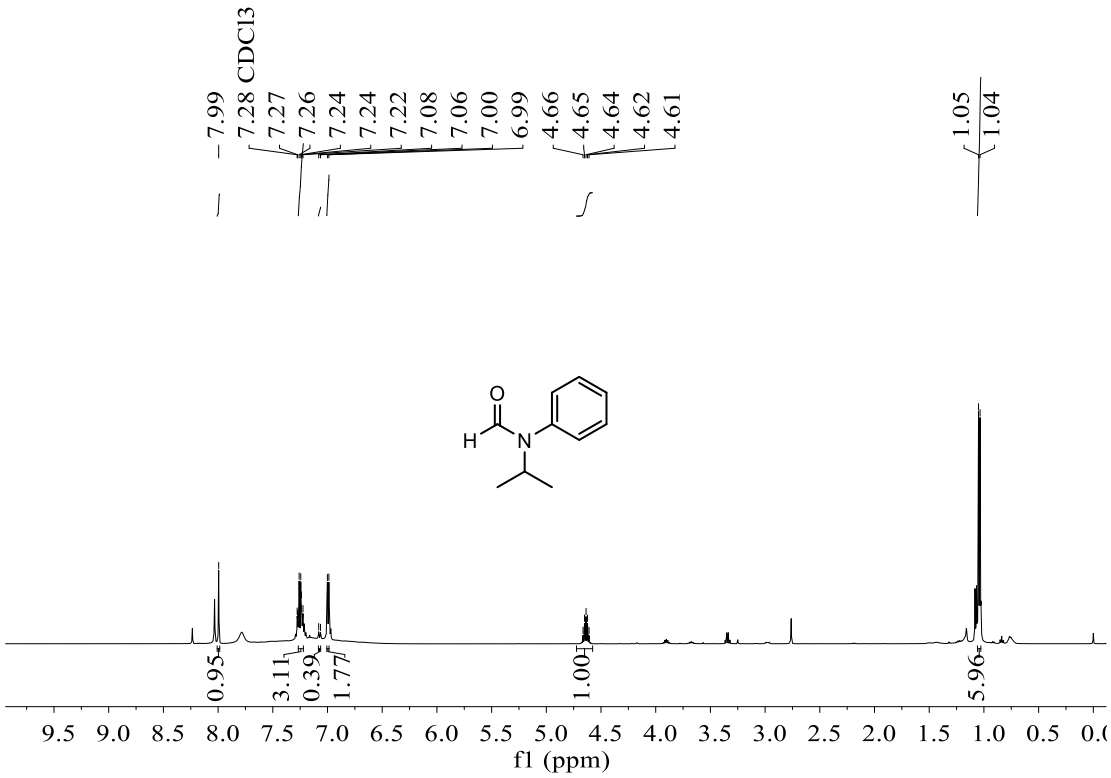
12.93
f1 (ppm)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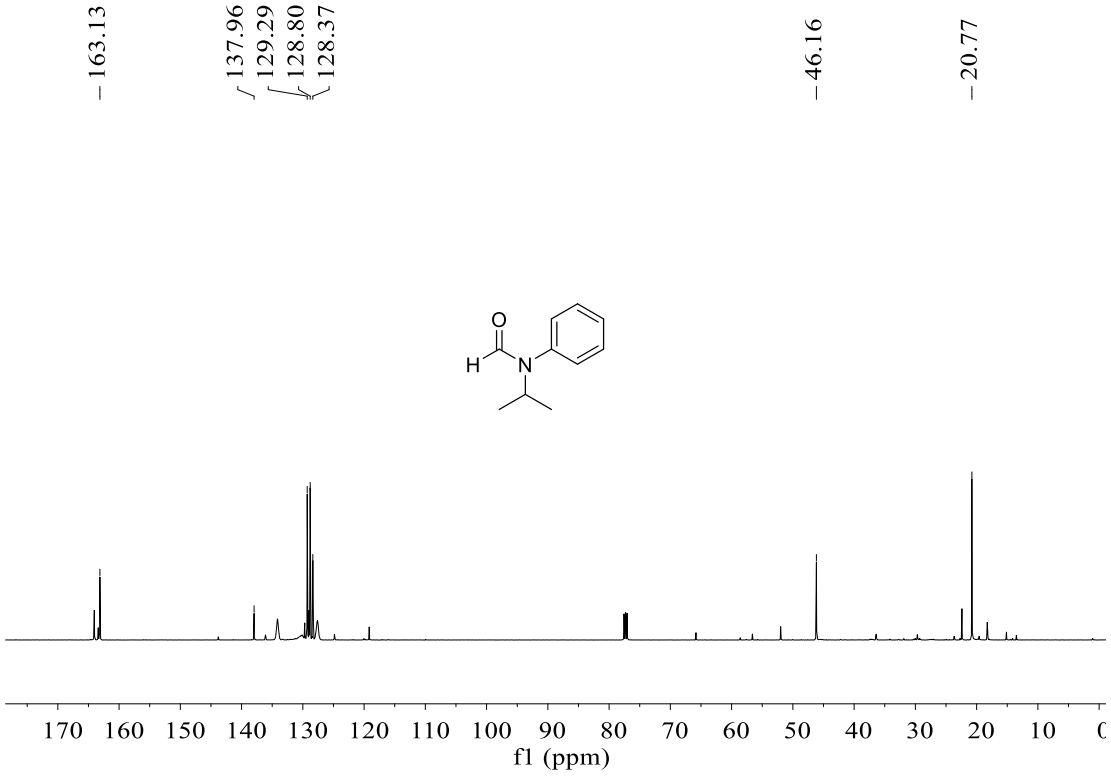
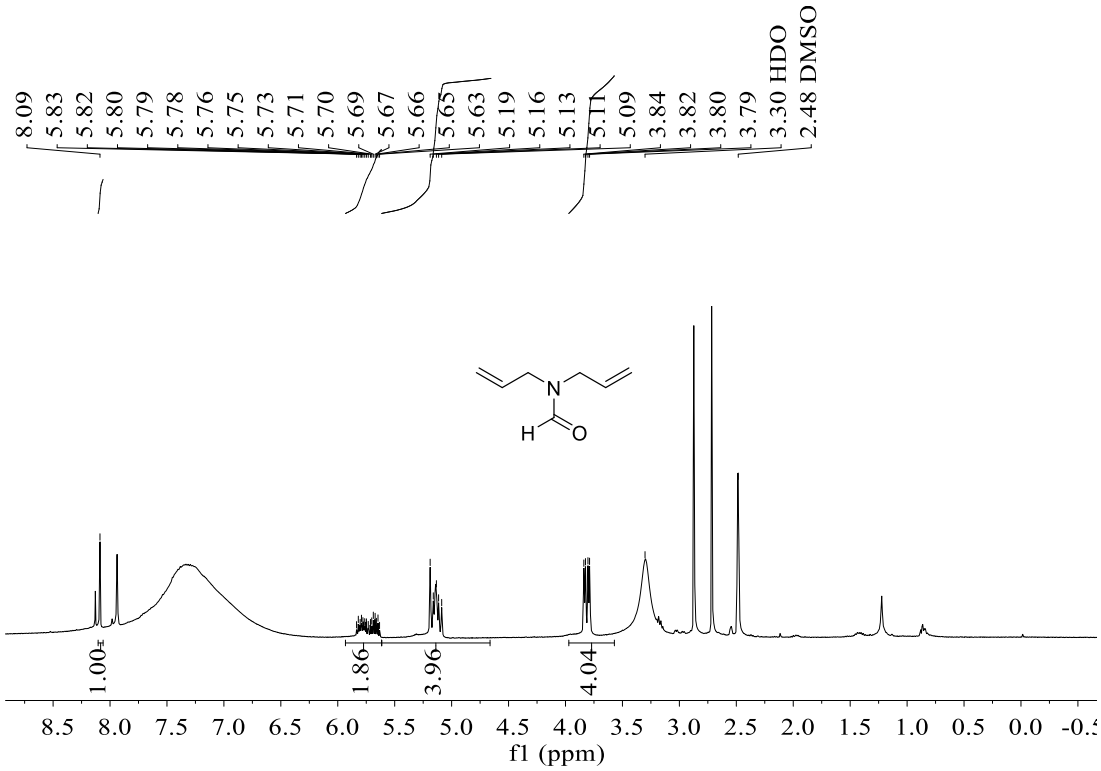
7.28 CDCl3
7.27
7.26
7.24
7.24
7.22
7.08
7.06
7.00
6.99
4.66
4.65
4.64
4.62
4.61
1.05
1.04
O
H
N
0.95
3.11
0.39
1.77
1.00
5.96
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


163.13
137.96
129.29
128.80
128.37
46.16
20.77
O
H
N
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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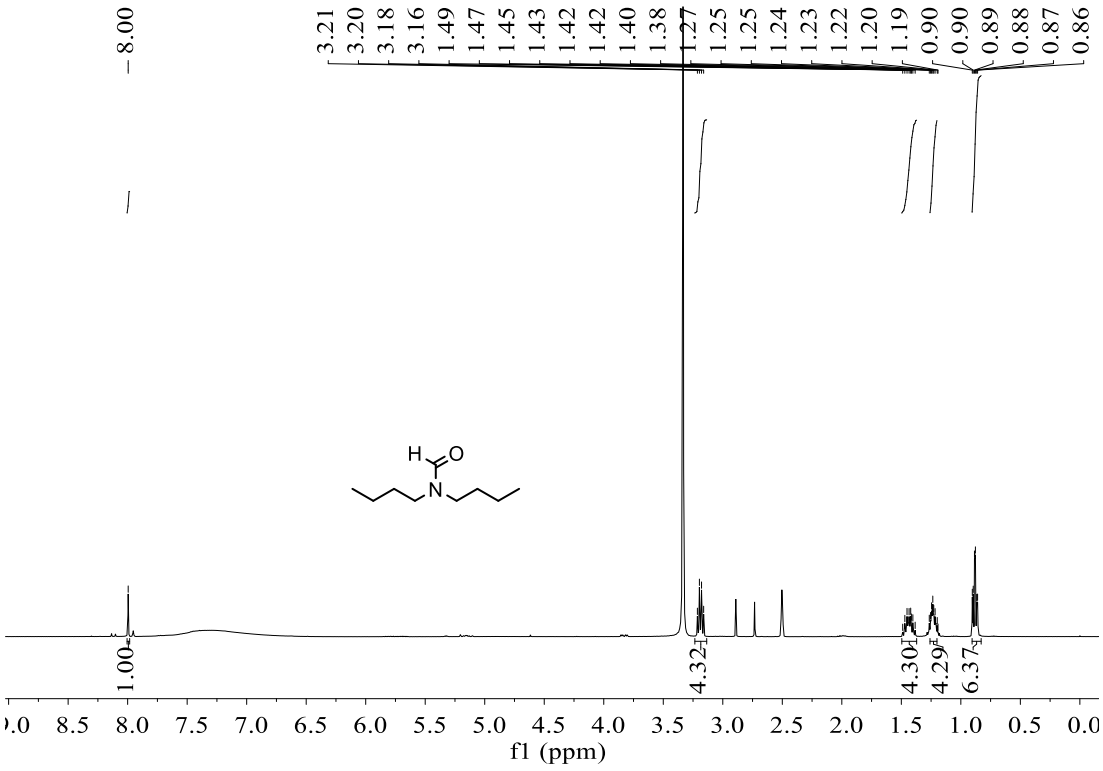
5.83
5.82
5.80
5.79
5.78
5.76
5.75
5.73
5.71
5.70
5.69
5.67
5.66
5.65
5.63
5.19
5.16
5.13
5.11
5.09
3.84
3.82
3.80
3.79
3.30 HDO
2.48 DMSO
N
H
O
1.00
1.86
3.96
4.04
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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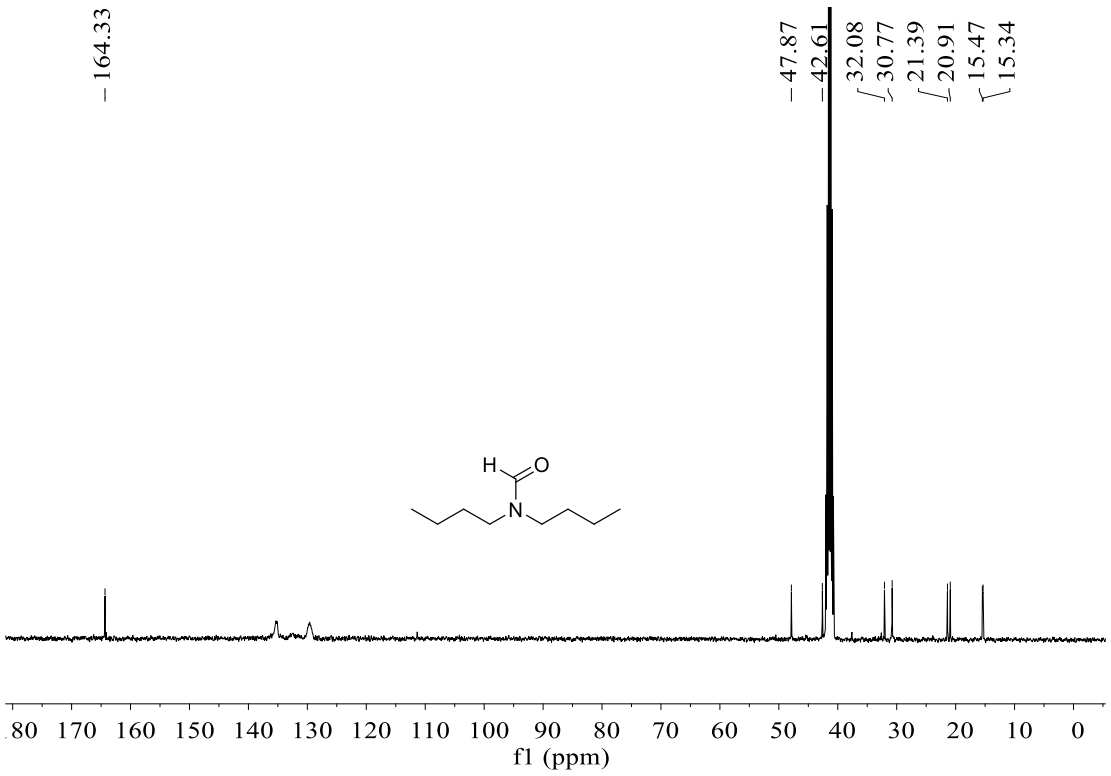
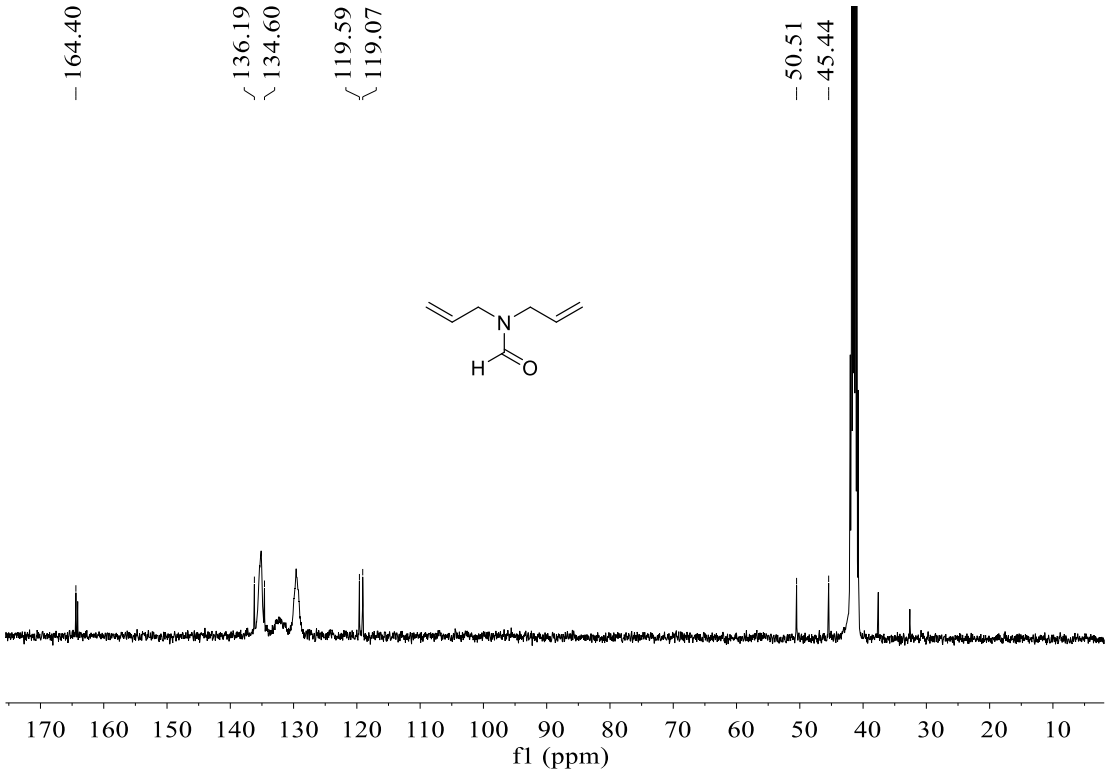
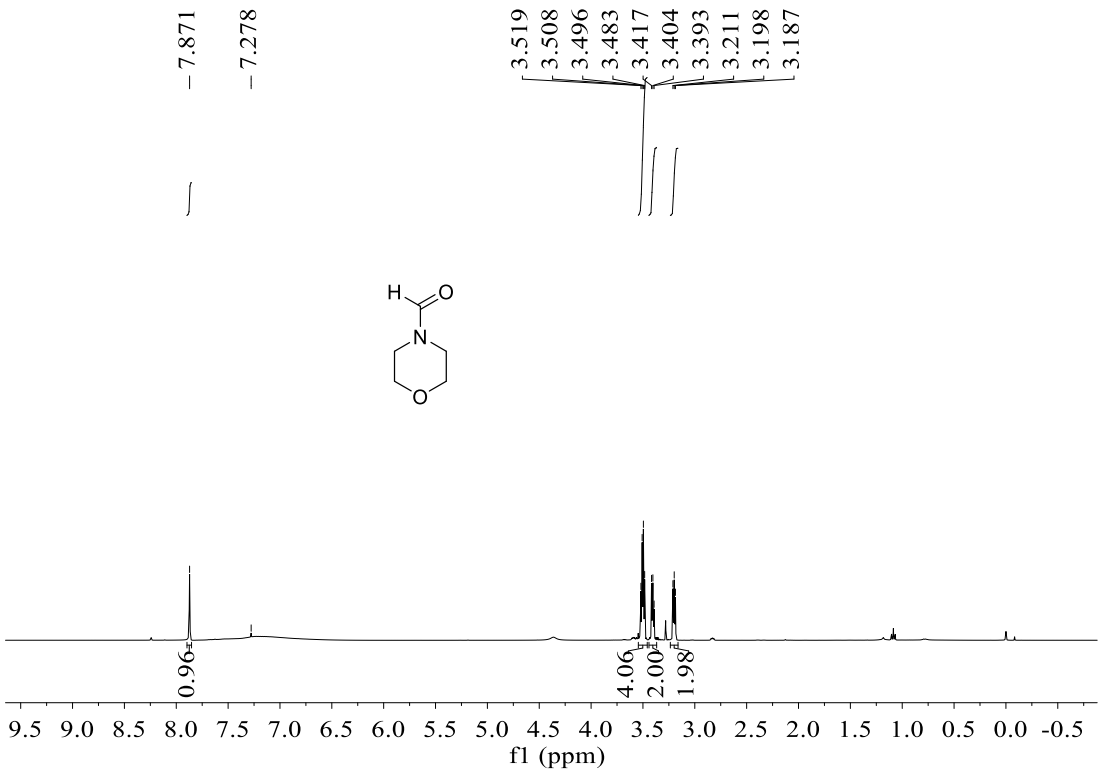
3.21
3.20
3.18
3.16
1.49
1.47
1.45
1.43
1.42
1.42
1.40
1.38
1.27
1.25
1.25
1.24
1.23
1.22
1.20
1.19
0.90
0.90
0.89
0.88
0.87
0.86
H
O
N
1.00
4.32
4.30
4.29
6.37
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


164.33
47.87
42.61
32.08
30.77
21.39
20.91
15.47
15.34
H
O
N
80 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


164.40
136.19
134.60
119.59
119.07
50.51
45.44
N
H
O
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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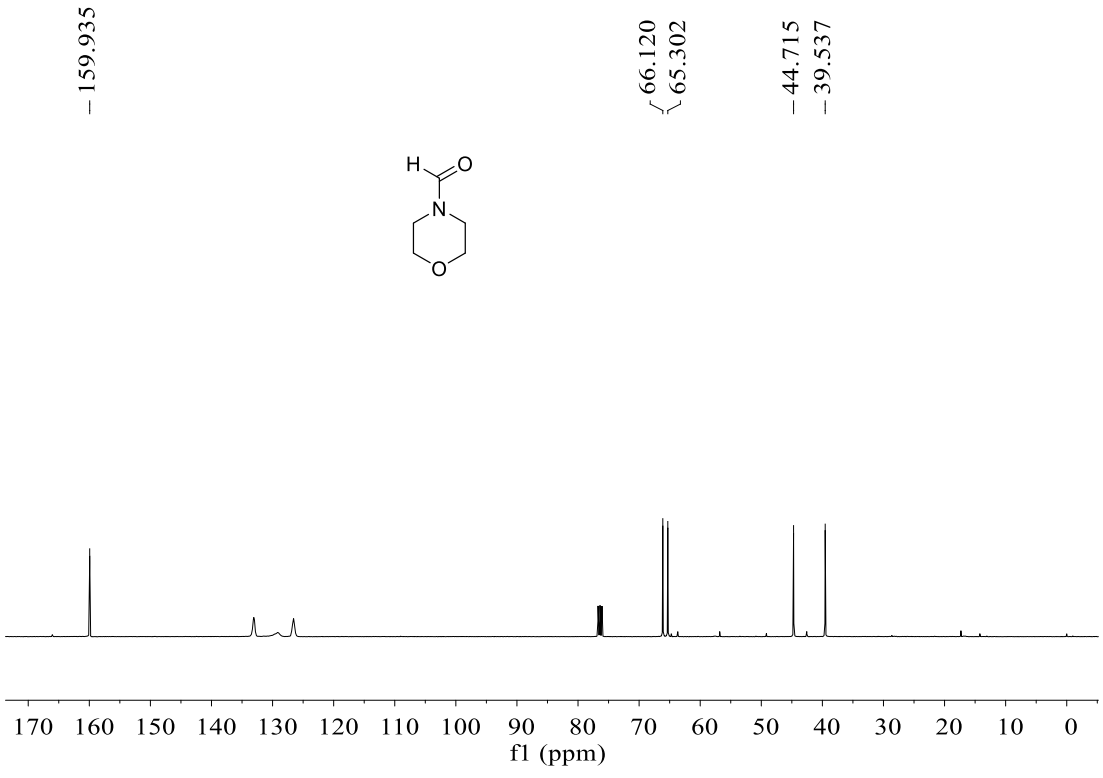
7.278
3.519
3.508
3.496
3.483
3.417
3.404
3.393
3.211
3.198
3.187
0.96
4.06
2.00
1.98
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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44.715
39.537
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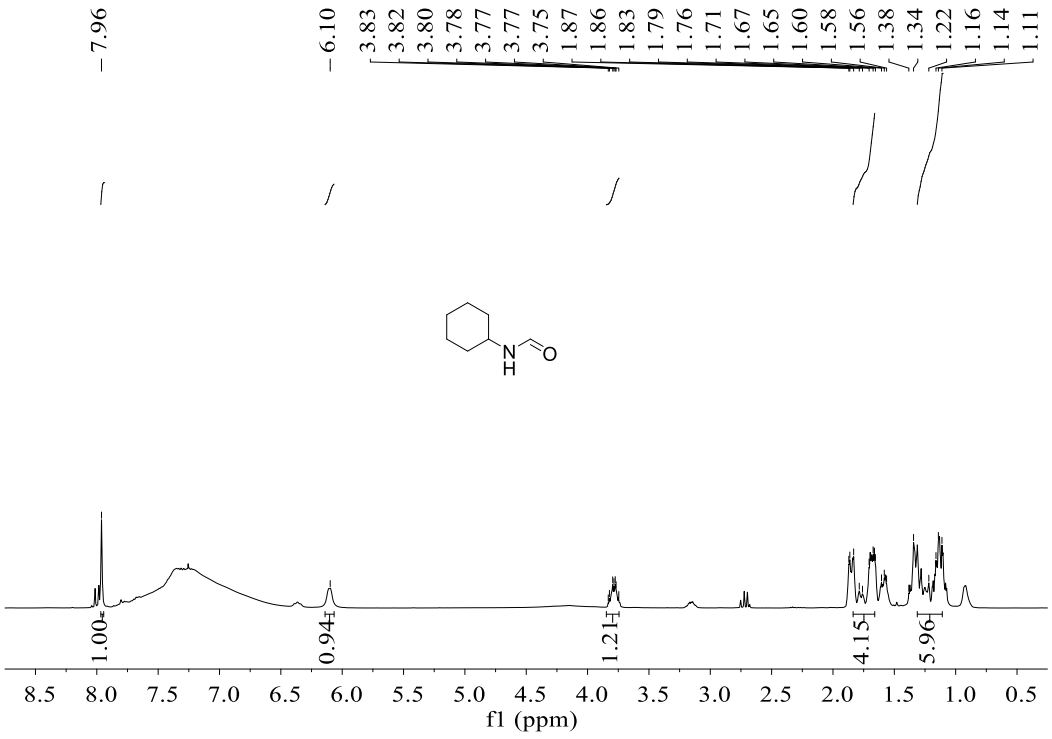
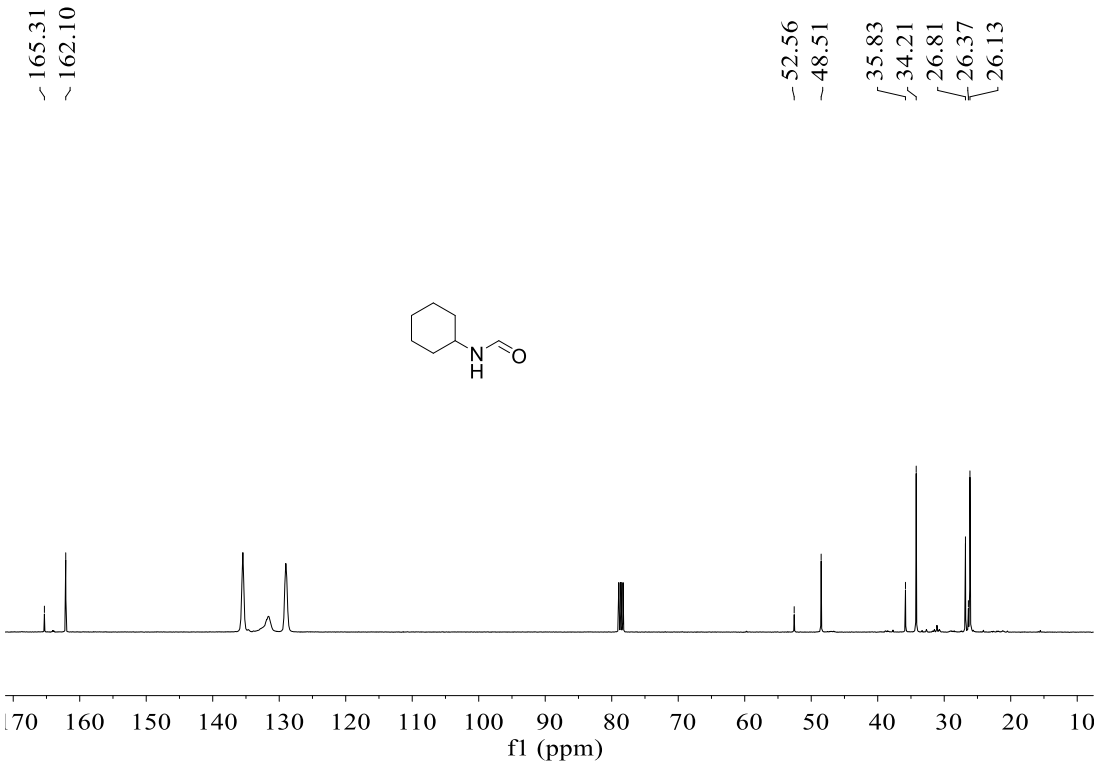
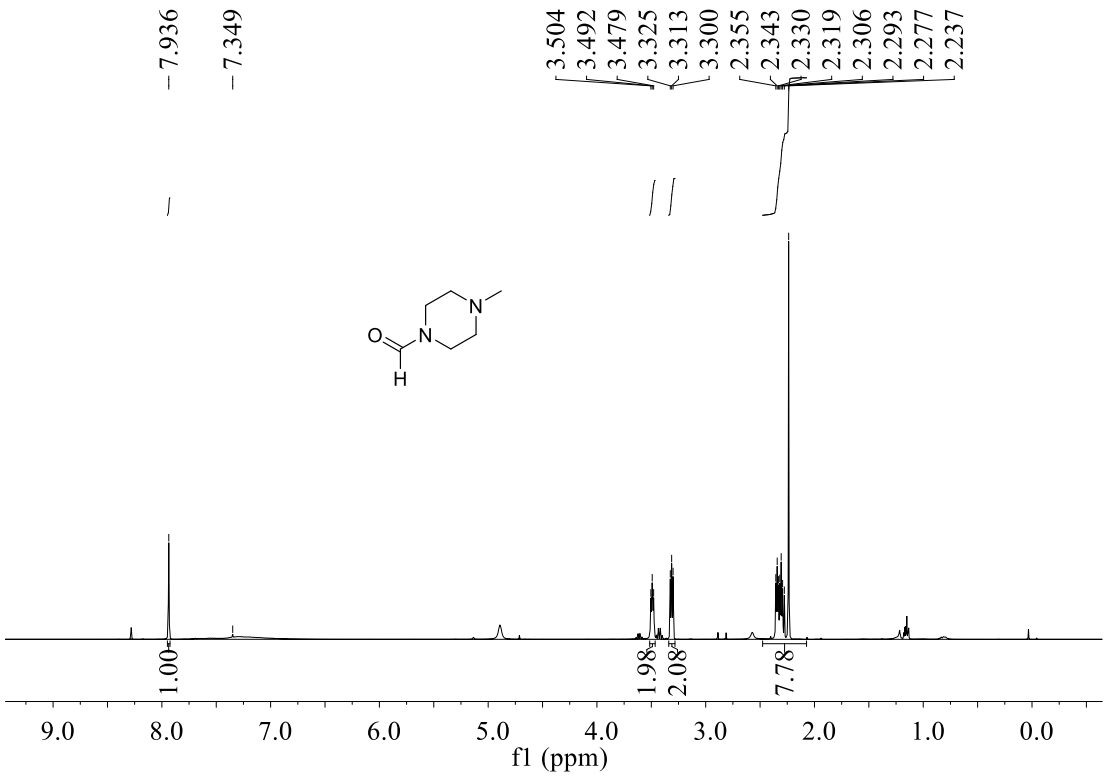
f1 (ppm)


7.96
6.10
3.83
3.82
3.80
3.78
3.77
3.77
3.75
1.87
1.86
1.83
1.79
1.76
1.71
1.67
1.65
1.60
1.58
1.56
1.38
1.34
1.22
1.16
1.14
1.11
1.00
0.94
1.21
4.15
5.96
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
f1 (ppm)


165.31
162.10
52.56
48.51
35.83
34.21
26.81
26.37
26.13
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.936
7.349
3.504
3.492
3.479
3.325
3.313
3.300
2.355
2.343
2.330
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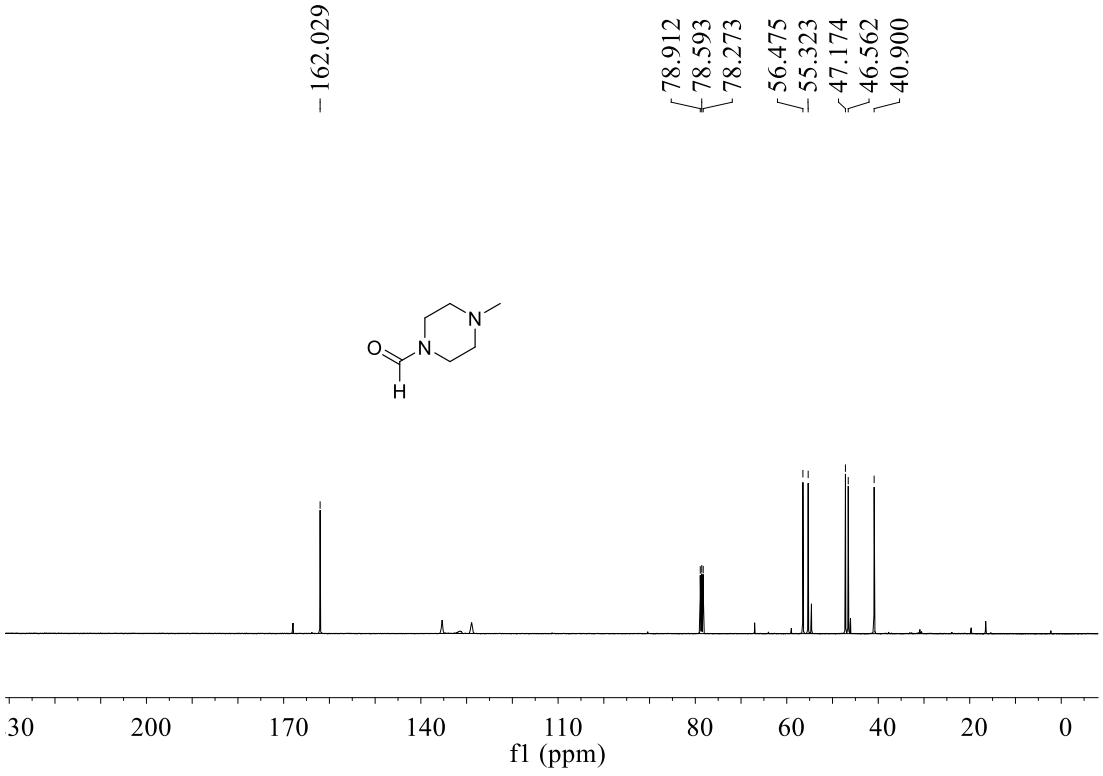
2.306
2.293
2.277
2.237
1.00
1.98
2.08
7.78
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


162.029
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78.273
56.475
55.323
47.174
46.562
40.900
30
200
170
140
110
80
60
40
20
0
f1 (ppm)

Section 15 References

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