Supporting Information for

Magnetic Nanoparticles Supported Ionic Liquid Catalysts for CO_2 Cycloaddition Reactions

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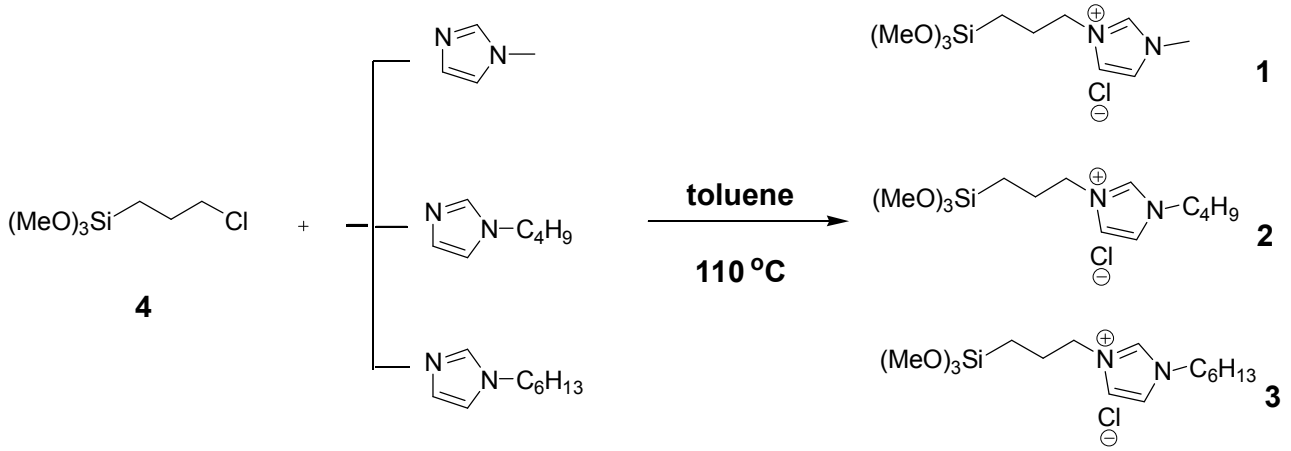
General procedure for the synthesis of catalysts:

Synthesis of precursor 1-3:

The precursor **1-3** were prepared based on the procedure of Shi et al.[1] The compound **4** (2 mmol) and imidazole (1 mmol) were mixed in 20 mL dry toluene and heated to 110 ^{o}C overnight. The mixture was cooled to room temperature, and washed by Et_2O at least 5 times, and dried in vacuum to give the pure product.



Scheme 1

1: ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.61-0.66 (2H, m), 1.99-2.03 (2H, m), 3.53 (9H, s), 4.14 (3H, s), 4.31-4.36 (2H, m), 7.51-7.79 (2H, m), 10.45 (1H, m); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 5.8, 24.0, 36.4, 50.5, 51.5, 121.9, 123.8, 137.5;

2: ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.31-0.36 (2H, m), 0.66 (3H, t), 1.04-1.12 (2H, m), 1.61-1.75 (4H, m), 3.20 (9H, s), 4.05-4.12 (4H, m), 7.31-7.50 (2H, m), 10.26 (1H, m); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 5.7, 13.2, 19.2, 23.9, 31.9, 49.4, 50.2, 51.3, 121.9, 122.3, 136.9;

3: ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.57-0.66 (2H, m), 0.79-0.86 (3H, m), 1.31 (6H, m), 1.93-2.02 (4H, m), 3.53 (9H, s), 4.36-4.38 (4H, m), 7.55-7.74 (2H, m), 10.63 (1H, m); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 5.7, 13.7, 22.1, 23.9, 25.7, 30.0, 30.9, 49.7, 50.2, 51.4, 122.0, 122.2, 137.1.

General procedure for the synthesis of PVP-stabilized magnetite nanoparticles:

Magnetite (Fe_3O_4) particles were prepared in a co-precipitation step based on the procedure of Massart et al[2] and T. J. Yoon, et al[3]. $FeCl_3 \cdot 6H_2O$ (22.0 g, 81.4 mmol) and $FeCl_2 \cdot 4H_2O$ (8.0 g, 40.7 mmol) were dissolved in 120mL deionized water under argon with vigorous stirring at 85 ^{o}C. the pH value of the solution was adjusted to 9 by concentrated $NH_3 \cdot H_2O$. After 4 hours, the magnetite precipitates were washed to pH=7 by deionized water. The black precipitate was collected with a permanent magnet under the reaction flask, and the supernatant was decanted. The sediment was redispersed in 100 mL of deionized water. The PVP aqueous solution (8.8 mL, 25.6 g/L) was added, and stirred for 1 day at room temperature. The PVP-stabilized magnetite nanoparticles were separated by addition of aqueous acetone (H_2O/acetone = 1/10, v/v) and centrifugation at 4000 rpm for 10 min. The supernatant solution was removed, and the precipitated particles were washed by ethanol twice. The particles were dried in vacuum.

General procedure for the synthesis of SiO_2-coated magnetite nanoparticles:

SiO_2-coated magnetite nanoparticles were prepared according to the procedure of Hyeon et al[4]. PVP stabilized magnetite nanoparticles (2.0 g) were dispersed in 400 mL ethanol. $NH_3.H_2O$ (12 mL) and TEOS (4.0 mL) was added successively. After stirring for 24 hours, the black precipitate was collected with a permanent magnet, and rinsed with ethanol three times. The product was dried and

stored in vacuum. The content of nitrogen is less than 0.3 % which is determined by elemental analysis.

Procedure for the synthesis of the MNP-1:

1.0 g SiO_2-coated magnetite nanoparticles were dispersed in 30 mL $CHCl_3$ by sonication for 1 hour. 0.28 g of **1** (1 mmol) was then added, and the reaction mixture was refluxed for 2 days under argon. After being cooled to room temperature, the products were sedimented on magnet and rinsed thrice with 100 mL $CHCl_3$. The obtained particles were dried in vacuum. The loading of the catalyst is determined to be 0.60 mmol/g by elemental analysis. IR spectrum (KBr, cm^{-1}): 3343, 2938, 1632, 1079 cm^{-1}.

Procedure for the synthesis of the MNP-2:

1.0 g SiO_2-coated magnetite nanoparticles were dispersed in 30 mL $CHCl_3$ by sonication for 1 hour. 0.32 g of **2** (1 mmol) was then added, and the reaction mixture was refluxed for 2 days under argon. After being cooled to room temperature, the products were sedimented on magnet and rinsed thrice with 100 mL $CHCl_3$. The obtained particles were dried in vacuum. The loading of the catalyst is determined to be 0.23 mmol/g by elemental analysis. IR spectrum (KBr, cm^{-1}): 3425, 2938, 2861, 1630, 1084 cm^{-1}.

Procedure for the synthesis of the MNP-3:

1.0 g SiO_2-coated magnetite nanoparticles were dispersed in 30 mL $CHCl_3$ by sonication for 1 hour. 0.35 g of **3** (1 mmol) was then added, and the reaction mixture was refluxed for 2 days under argon. After being cooled to room temperature, the products were sedimented on magnet and rinsed thrice with 100 mL $CHCl_3$. The obtained particles were dried in vacuum. The loading of the catalyst is determined to be 0.27 mmol/g by elemental analysis. IR spectrum (KBr, cm^{-1}): 3343, 2929, 2857, 1631, 1083 cm^{-1}.

Figure S1 **XRD pattern of magnetite nanoparticles**.

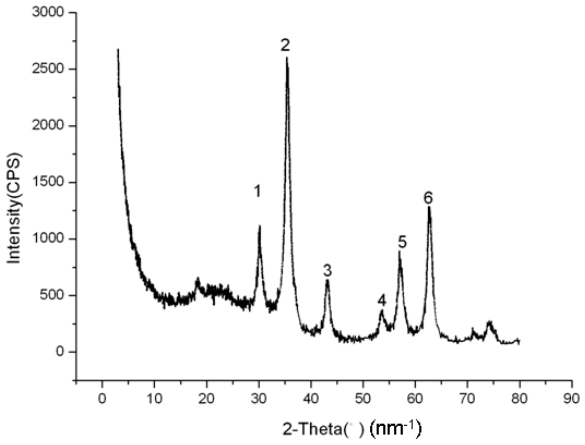
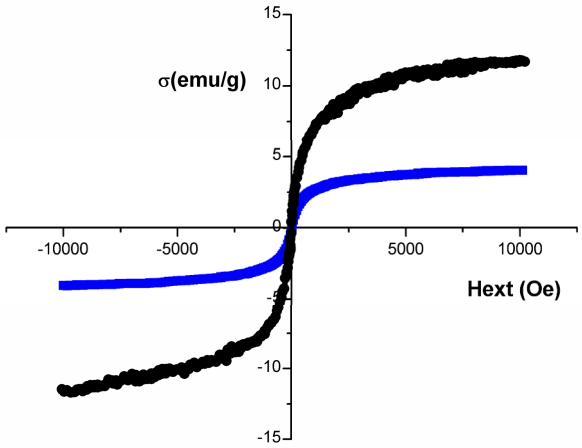


Table S1 **XRD of magnetite nanoparticles**

Sample	d (nm)					
Prepared Fe_3O_4	0.296	0.252	0.209	0.170	0.161	0.148
Standard Fe_3O_4	0.296	0.253	0.209	0.171	0.161	0.148

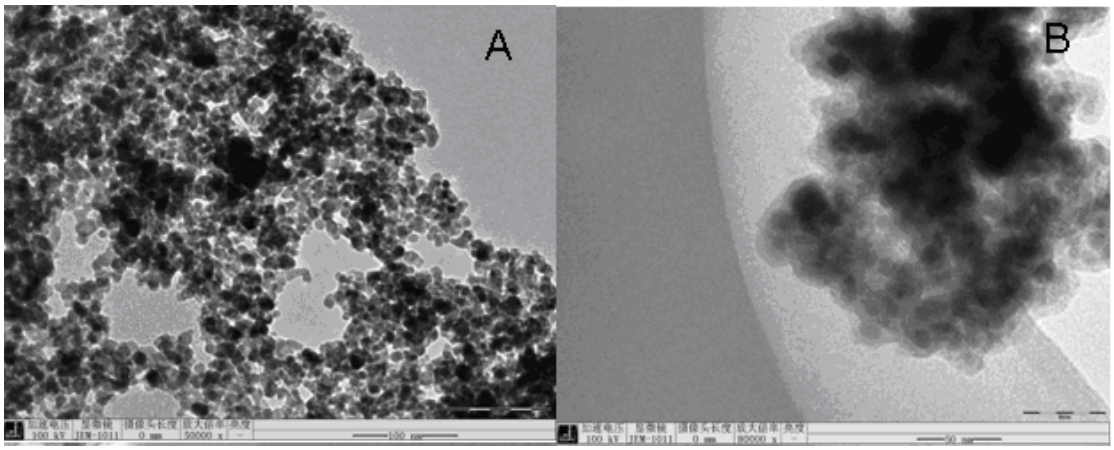
A dry powder sample of Fe_3O_4 was used to analyze the XRD pattern of the nanoparticles. The observed diffraction pattern coincides with the JCPDS database for magnetite. The interlayer spacings (d), calculated using the Bragg equation, agree well with the data for standard magnetite (Table S1).

Figure S2 **Magnetic curve of silica-coated magnetite (black) and Catalyst 1 (blue)**



The room-temperature magnetization curves of the magnetic nanoparticles before (black line) and after (blue line) functionalization prove that the magnetic nanoparticles are superparamagnetic. The saturation magnetization of samples changed from 11.7 emu/g to 4.2 emu/g because of the functionalization by precursor **1**.

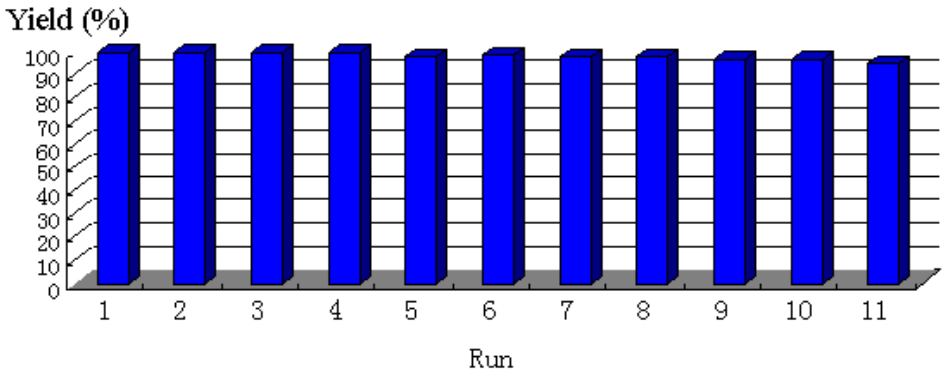
Figure S3 **TEM images (all the samples were prepared in MeOH).**



A: MNP; the size of the nanoparticles is about 8-10nm. The shape of the nanoparticles is spherical.

B: SiO_2-MNP; the thickness of the SiO_2 layer is about 1-2 nm.

Figure S4. **Catalyst recycling**[a]



[a]Epichlorohydrin (10 mmol), **MNP-1** (1 mol%), at 140 ^{o}C, 4 h, 1 MPa CO_2 pressure, and the results are determined by GC.

Reference:

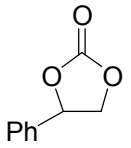
[1] **(**a) M. R. Grimmett, Imidazole and Benzimidazole Synthesis, Academic Press, London, 1997, p. 201; (b) K. Sukata, Bull. Chem. Soc. Jpn. 1983, **56**, 280 – 284; (c) T. Weskamp, V. P. W. Bohm, W. A. Herrmann, J. Organomet. Chem. 2000, **600**, 12–22. (d) L.Li, and J. Shi, *Adv. Synth. Catal.,* 2005, **347,** 1745 – 1749

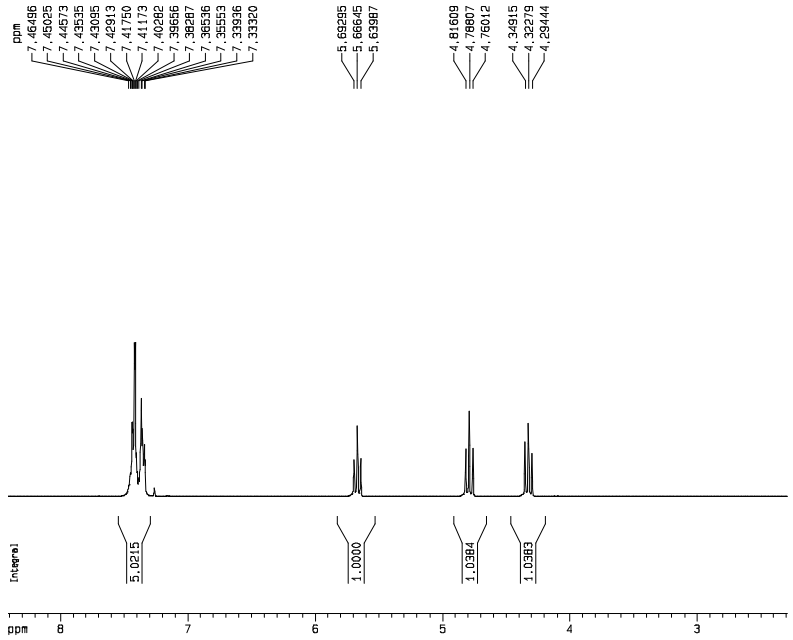
[2] A. Bee, R. Massart and S. Neveu, *J. Magn. Magn. Mater*., 1995, **149**, 6-9.

[3] T.-J. Yoon, J. S. K., B. G. Kim, K. N. Yu, M.-H. Cho and J.-K. Lee, *Angew. Chem. Int. Ed. ,* 2005, **44***,* 1068 –1071.

[4] M. Shokouhimehr, Y. Piao, J. Kim, Y. Jang, and T. Hyeon, *Angew. Chem. Int. Ed.,* 2007*,* **46***,* 7039-7043.

NMR spectra:



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RG                  90.5
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TE                 299.7 K
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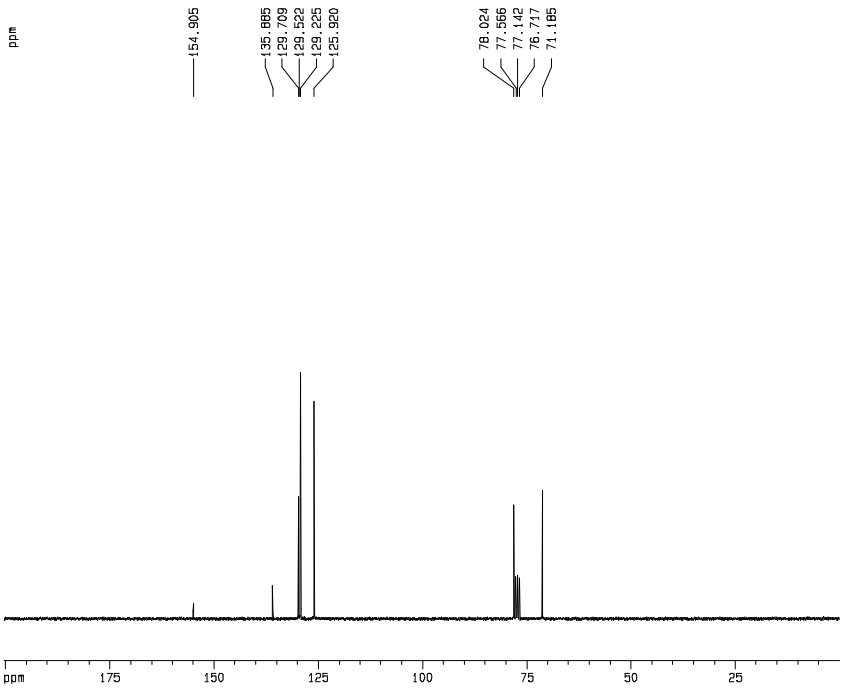


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NS                   101
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FIDRES           0.274439 Hz
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RG                 1290.2
DW                 27.800 usec
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TE                 298.0 K
D1              2.00000000 sec
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MCWRK           0.01500000 sec

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PL1                2.00 dB
SFO1          75.4752953 MHz

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NUC2                  1H
PCPD2             80.00 usec
PL2               -1.00 dB
PL12              20.16 dB
PL13              16.98 dB
SFO2          300.1312005 MHz

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WDW                   EM
SSB                    0
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GB                     0
PC                  1.40

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F2                 2.67 Hz
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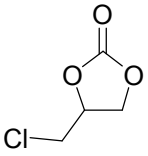

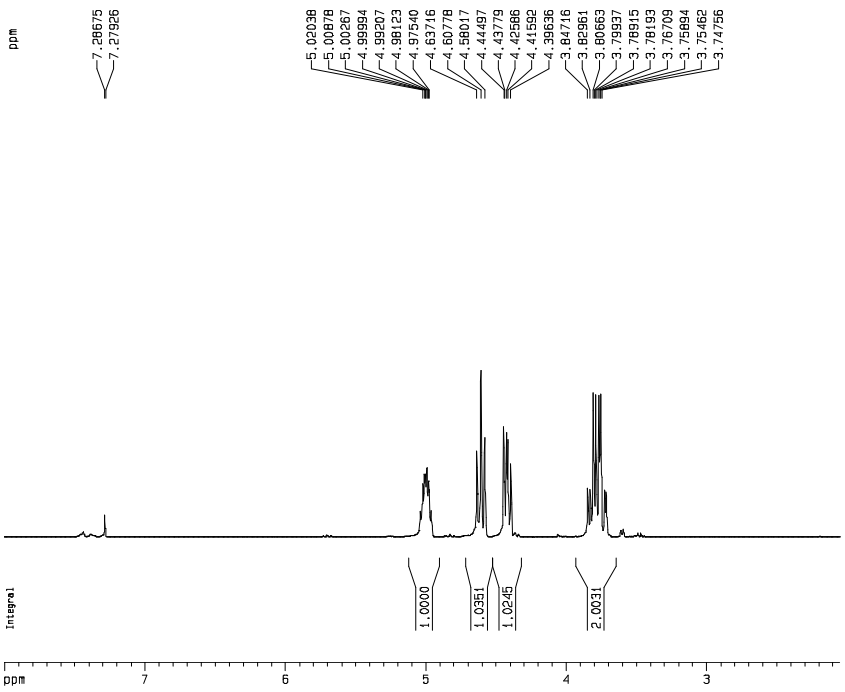


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PROCNO                 1

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PULPROG             zg30
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DS                     0
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FIDRES           0.137219 Hz
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RG                   128
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TE                 296.5 K
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MCREST        0.00000000 sec
MCWRK         0.01500000 sec

======== CHANNEL f1 ========
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P1                7.00 usec
PL1               -1.00 dB
SFO1         300.1324010 MHz

F2 - Processing parameters
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SF           300.1299983 MHz
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SSB                   0
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GB                    0
PC                 1.00

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CY                 4.00 cm
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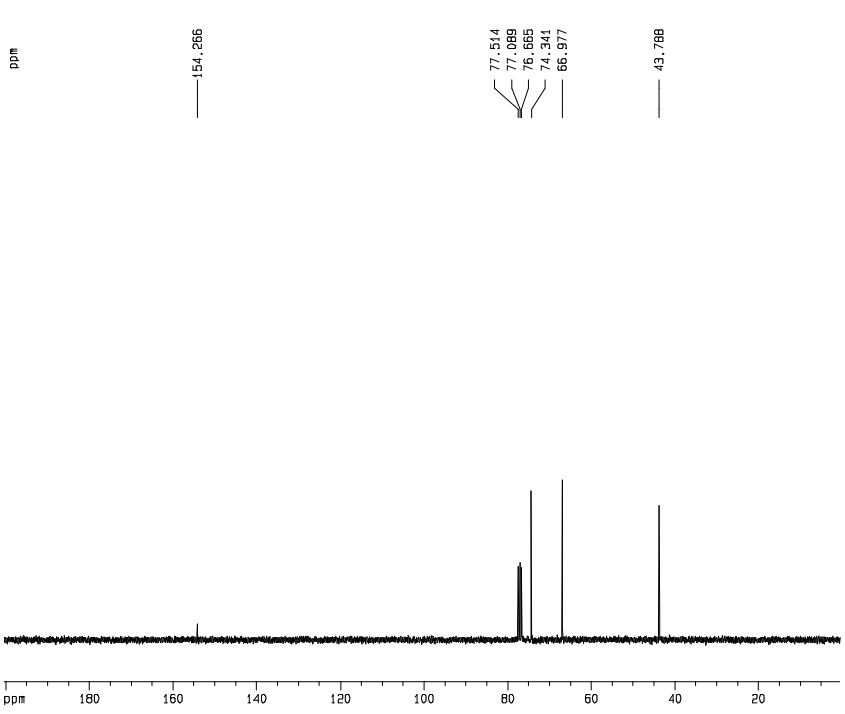


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FIDRES           0.274439 Hz
AQ               1.8219509 sec
RG                  574.7
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DE                 6.00 usec
TE                 297.2 K
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d11           0.03000000 sec
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MCREST        0.00000000 sec
MCWRK         0.01500000 sec

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PL1                2.00 dB
SFO1         75.4752953 MHz

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PCPD2            80.00 usec
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F2 - Processing parameters
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GB                    0
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1D NMR plot parameters
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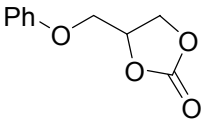

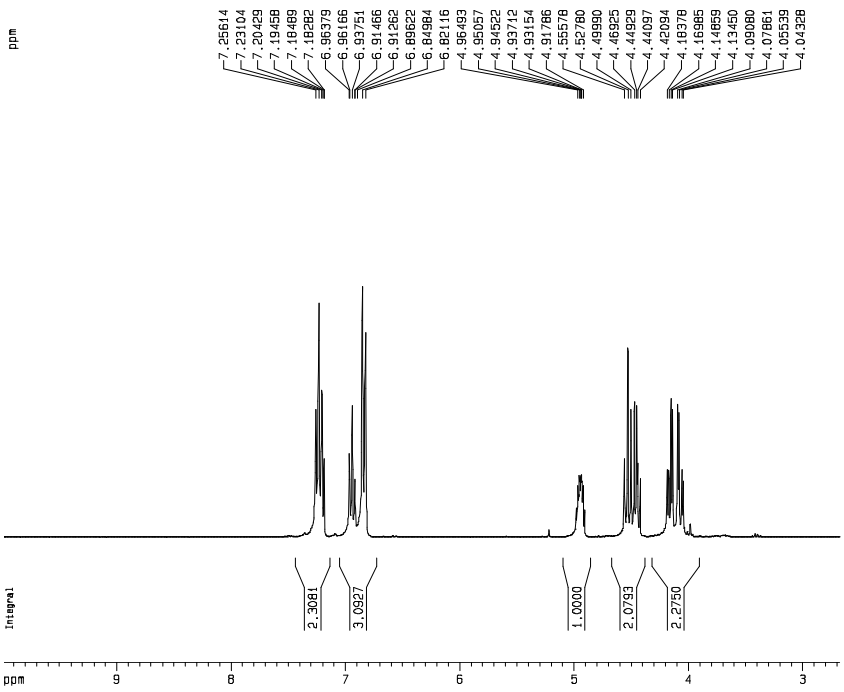


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DS                     0
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FIDRES          0.137219 Hz
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RG                   362
DW                55.600 usec
DE                 6.00 usec
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MCWRK          0.01500000 sec

======== CHANNEL f1 ========
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PL1               -1.00 dB
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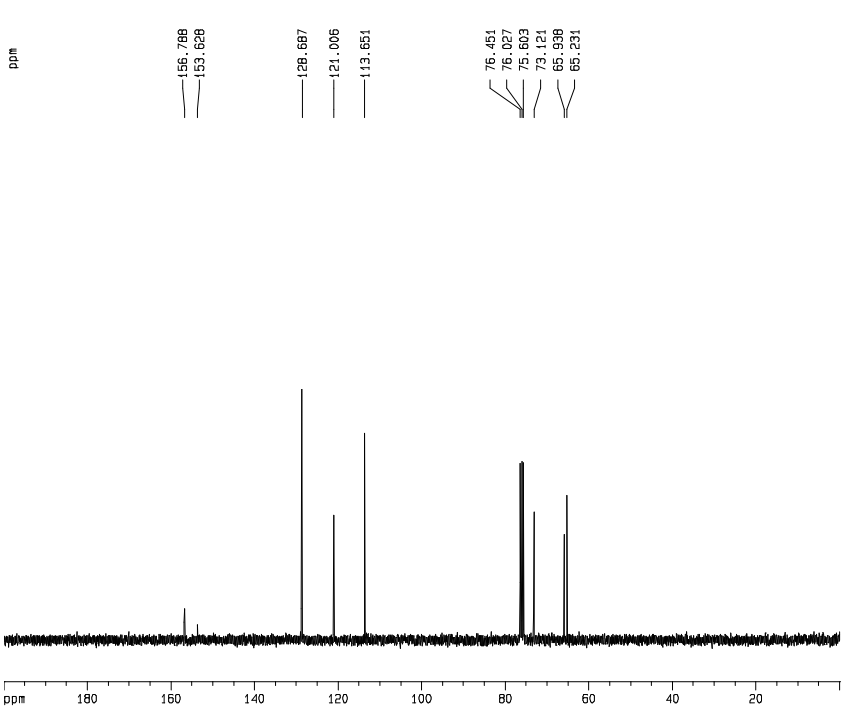


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d11            0.03000000 sec
DELTA          1.89999998 sec
MCREST         0.00000000 sec
MCWRK          0.01500000 sec

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P1                12.50 usec
PL1                2.00 dB
SFO1         75.4752953 MHz

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PCPD2             80.00 usec
PL2               -1.00 dB
PL12              20.16 dB
PL13              16.98 dB
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WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40

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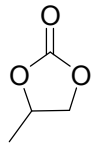

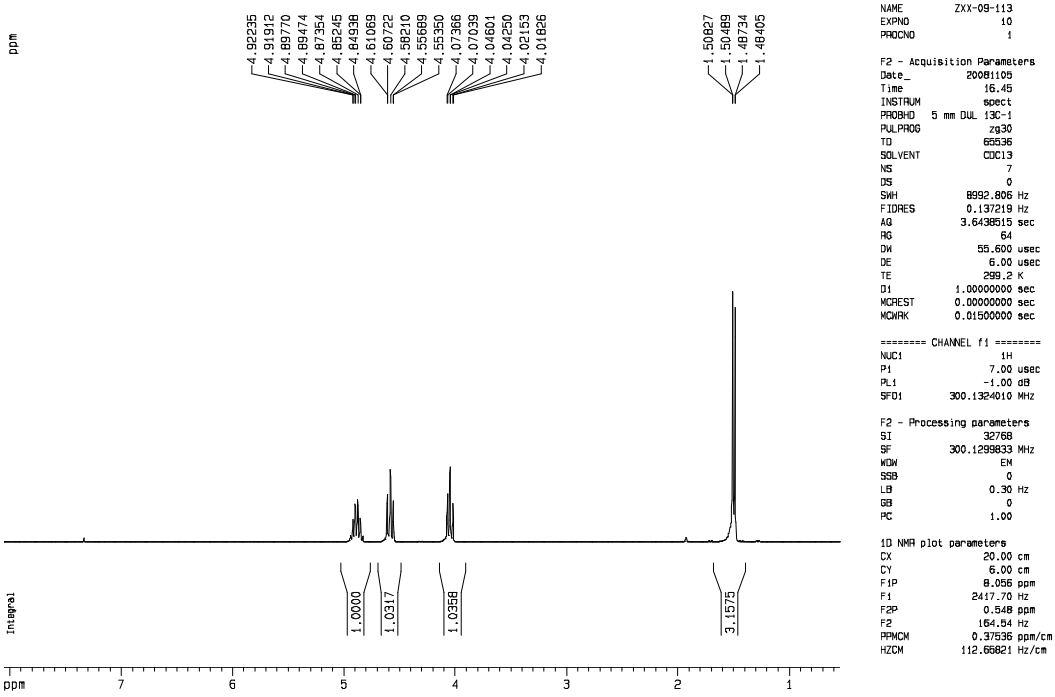


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RG                    64
DW                55.600 usec
DE                 6.00 usec
TE                299.2 K
D1           1.00000000 sec
MCREST       0.00000000 sec
MCWRK        0.01500000 sec

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P1                 7.00 usec
PL1               -1.00 dB
SFO1         300.1324010 MHz

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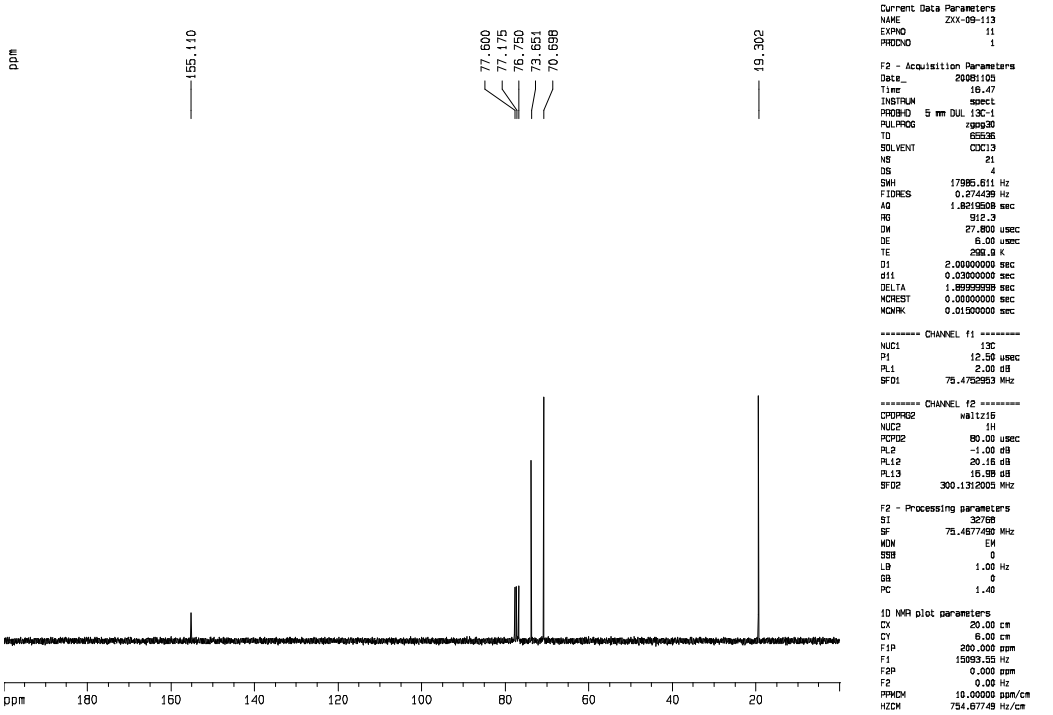


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D1           2.00000000 sec
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MCREST       0.00000000 sec
MCWRK        0.01500000 sec

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SFO1         75.4752953 MHz

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PL13              16.98 dB
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GB                     0
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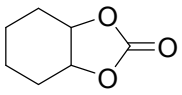
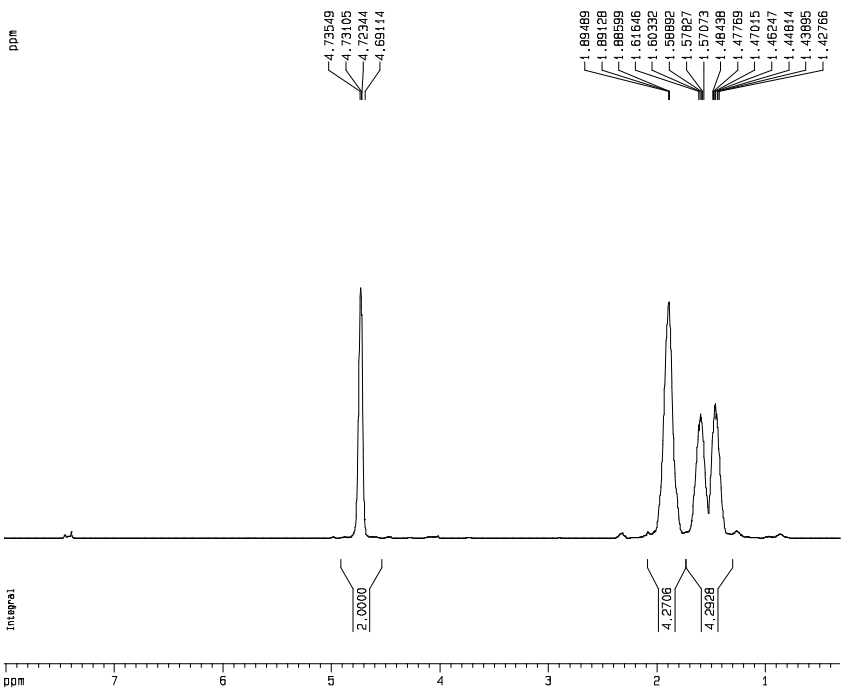
F2                 0.00 Hz
PPMCM          10.00000 ppm/cm
HZCM          754.67749 Hz/cm
```





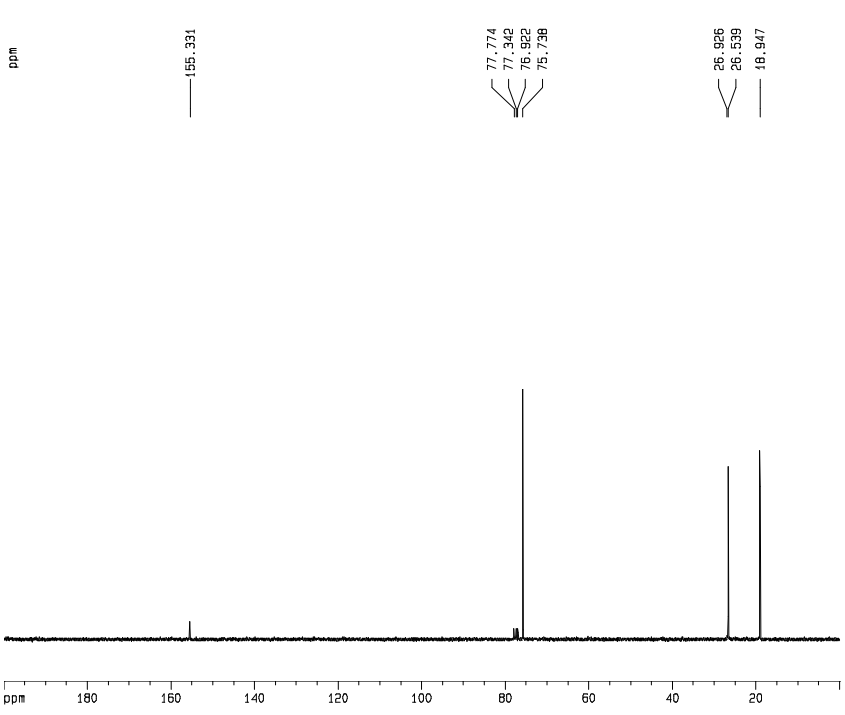

```
Current Data Parameters
NAME          ZXX-09-115
EXPNO                 10
PROCNO                 1

F2 - Acquisition Parameters
Date_           20081110
Time                15.41
INSTRUM             spect
PROBHD   5 mm DUL 13C-1
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    10
DS                     0
SWH              8992.806 Hz
FIDRES           0.137219 Hz
AQ               3.6438615 sec
RG                  28.5
DW                 55.600 usec
DE                  6.00 usec
TE                 300.4 K
D1              1.00000000 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                  1H
P1                  7.00 usec
PL1                -1.00 dB
SFO1          300.1324010 MHz

F2 - Processing parameters
SI                 32768
SF            300.1299634 MHz
WDW                   EM
SSB                    0
LB                  0.30 Hz
GB                     0
PC                  1.00

1D NMR plot parameters
CX                 20.00 cm
CY                  6.00 cm
F1P                8.023 ppm
F1                2407.89 Hz
F2P                0.317 ppm
F2                 95.17 Hz
PPMCM             0.38529 ppm/cm
HZCM            115.63598 Hz/cm
```




```
Current Data Parameters
NAME          ZXX-09-115
EXPNO                 11
PROCNO                 1

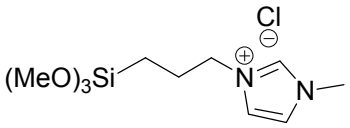
F2 - Acquisition Parameters
Date_           20081110
Time                15.43
INSTRUM             spect
PROBHD   5 mm DUL 13C-1
PULPROG          zgpg30
TD                 65536
SOLVENT            CDCl3
NS                    12
DS                     4
SWH             17985.611 Hz
FIDRES           0.274439 Hz
AQ               1.8219508 sec
RG                  8160.8
DW                 27.800 usec
DE                  6.00 usec
TE                 300.3 K
D1              2.00000000 sec
d11             0.03000000 sec
DELTA           1.89999998 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

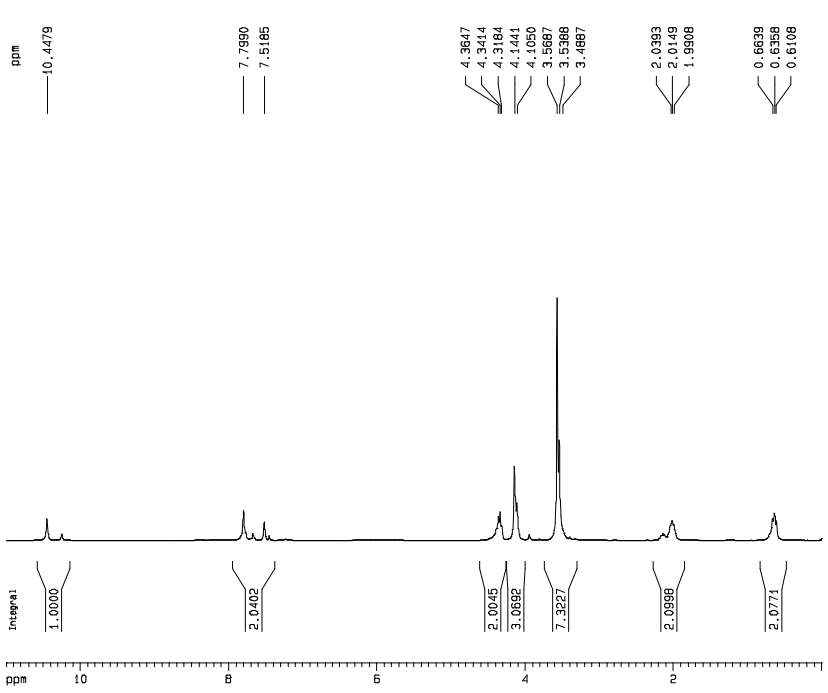
-------- CHANNEL f1 --------
NUC1                  13C
P1                 12.50 usec
PL1                 2.00 dB
SFO1          75.4752953 MHz

-------- CHANNEL f2 --------
CPDPRG2           waltz16
NUC2                  1H
PCPD2              80.00 usec
PL2                -1.00 dB
PL12               20.16 dB
PL13               15.98 dB
SFO2          300.1312005 MHz

F2 - Processing parameters
SI                 32768
SF            75.4677490 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40

1D NMR plot parameters
CX                 20.00 cm
CY                  6.00 cm
F1P               200.000 ppm
F1              15093.55 Hz
F2P                0.000 ppm
F2                 0.00 Hz
PPMCM          10.00000 ppm/cm
HZCM           754.67749 Hz/cm
```





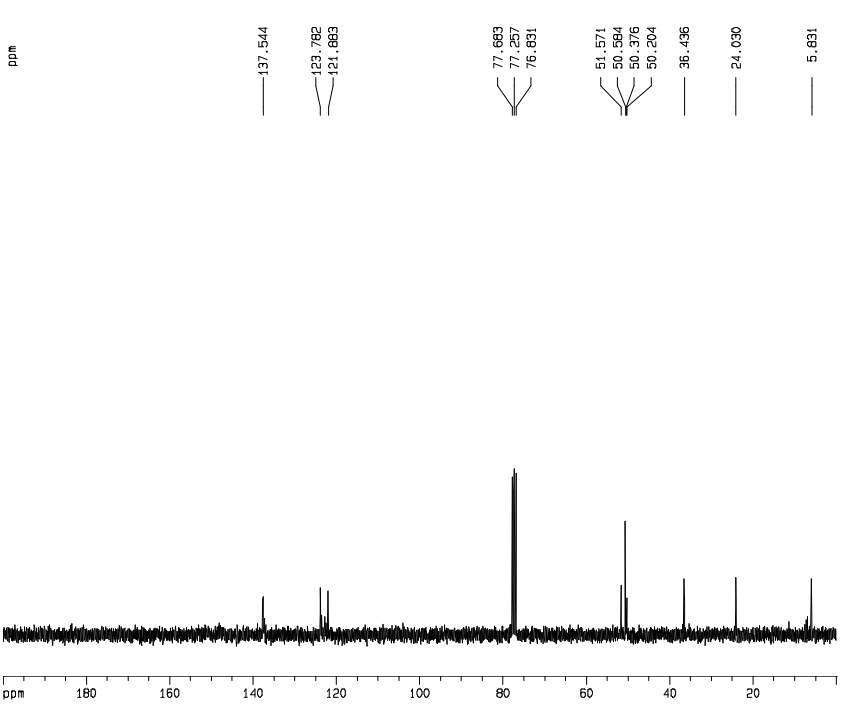

```
Current Data Parameters
NAME        ZXX-09-14B-1
EXPNO               20
PROCNO               1

F2 - Acquisition Parameters
Date_         20081205
Time             16.49
INSTRUM          spect
PROBHD  5 mm DUL 13C-1
PULPROG          zg30
TD              65536
SOLVENT          CDCl3
NS                  16
DS                   0
SWH          8992.806 Hz
FIDRES       0.137219 Hz
AQ           3.6438515 sec
RG                  64
DW             55.600 usec
DE              6.00 usec
TE             295.4 K
D1          1.00000000 sec
MCREST      0.00000000 sec
MCWRK       0.01500000 sec

======== CHANNEL f1 ========
NUC1                1H
P1              7.00 usec
PL1            -1.00 dB
SFO1       300.1324010 MHz

F2 - Processing parameters
SI              32768
SF         300.1299491 MHz
WDW                EM
SSB                 0
LB              0.30 Hz
GB                  0
PC              1.00

1D NMR plot parameters
CX             20.00 cm
CY              6.00 cm
F1P            11.000 ppm
F1           3301.43 Hz
F2P             0.000 ppm
F2              0.00 Hz
PPMCM        0.55000 ppm/cm
HZCM        165.07146 Hz/cm
```




```
Current Data Parameters
NAME        ZXX-09-14B-1
EXPNO               21
PROCNO               1

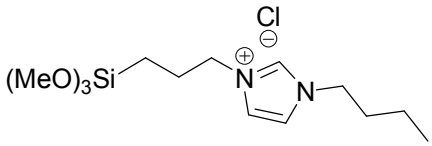
F2 - Acquisition Parameters
Date_         20081205
Time             16.52
INSTRUM          spect
PROBHD  5 mm DUL 13C-1
PULPROG          zgpg30
TD              65536
SOLVENT          CDCl3
NS                  18
DS                   4
SWH          17985.611 Hz
FIDRES       0.274439 Hz
AQ           1.8219508 sec
RG                9195.2
DW             27.800 usec
DE              6.00 usec
TE             295.9 K
D1          2.00000000 sec
D11         0.03000000 sec
DELTA       1.85599998 sec
MCREST      0.00000000 sec
MCWRK       0.01500000 sec

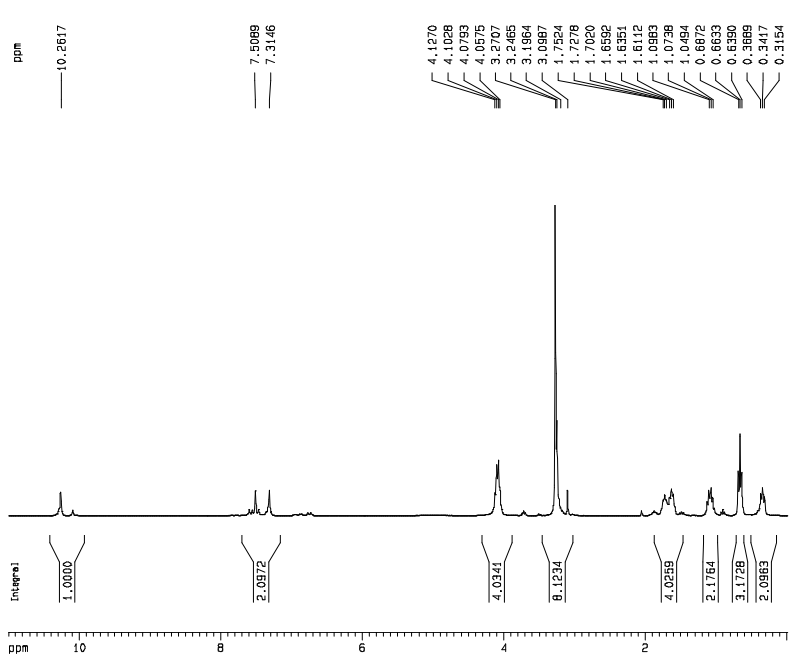
======== CHANNEL f1 ========
NUC1                13C
P1             12.50 usec
PL1             2.00 dB
SFO1       75.4752953 MHz

======== CHANNEL f2 ========
CPDPRG2         waltz16
NUC2                1H
PCPD2          80.00 usec
PL2            -1.00 dB
PL12           20.16 dB
PL13           16.98 dB
SFO2       300.1312005 MHz

F2 - Processing parameters
SI              32768
SF         75.4677490 MHz
WDW                EM
SSB                 0
LB              1.00 Hz
GB                  0
PC              1.40

1D NMR plot parameters
CX             20.00 cm
CY              4.00 cm
F1P           200.000 ppm
F1          15093.55 Hz
F2P             0.000 ppm
F2              0.00 Hz
PPMCM       10.00000 ppm/cm
HZCM        754.67749 Hz/cm
```





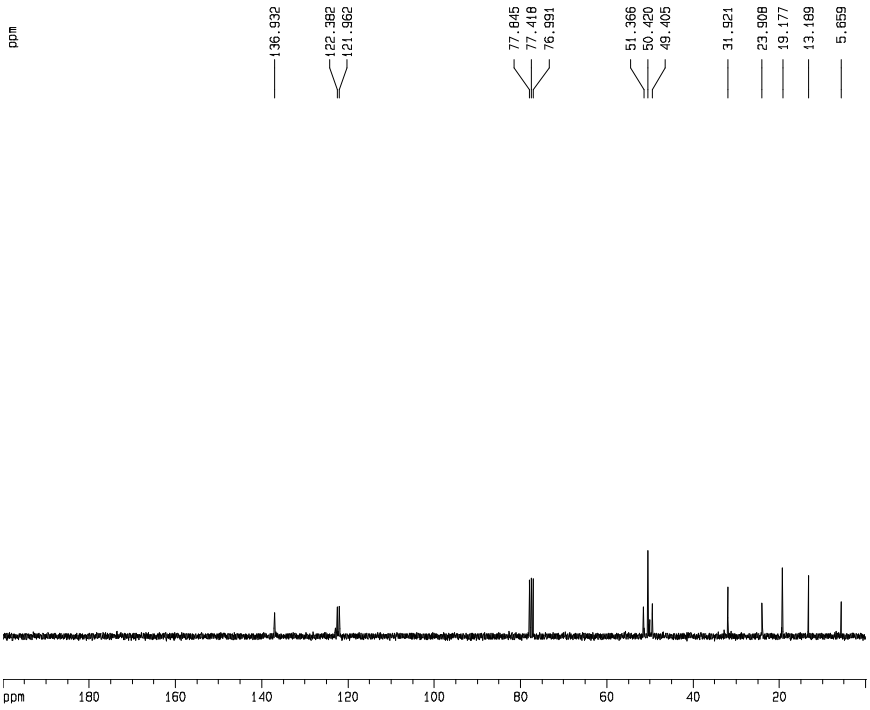

```
Current Data Parameters
NAME        ZXX-09-148-4
EXPNO                 10
PROCNO                 1

F2 - Acquisition Parameters
Date_          20081205
Time               8.38
INSTRUM           spect
PROBHD   5 mm DUL 13C-1
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                    7
DS                    0
SWH            8992.806 Hz
FIDRES        0.137219 Hz
AQ            3.6438615 sec
RG                 35.9
DW              55.600 usec
DE               6.00 usec
TE              294.7 K
D1            1.00000000 sec
MCREST        0.00000000 sec
MCWRK         0.01500000 sec

======== CHANNEL f1 ========
NUC1                  1H
P1                 7.00 usec
PL1                -1.00 dB
SFO1         300.1324010 MHz

F2 - Processing parameters
SI                32768
SF          300.1300000 MHz
WDW                  EM
SSB                   0
LB                 0.30 Hz
GB                    0
PC                 1.00

1D NMR plot parameters
CX                20.00 cm
CY                 8.00 cm
F1P               11.000 ppm
F1              3301.43 Hz
F2P                0.000 ppm
F2                 0.00 Hz
PPMCM          0.55000 ppm/cm
HZCM         165.07150 Hz/cm
```




```
Current Data Parameters
NAME        ZXX-09-148-4
EXPNO                 11
PROCNO                 1

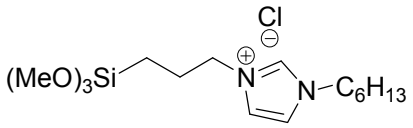
F2 - Acquisition Parameters
Date_          20081205
Time               8.41
INSTRUM           spect
PROBHD   5 mm DUL 13C-1
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                   12
DS                    4
SWH           17985.611 Hz
FIDRES        0.274439 Hz
AQ            1.8219508 sec
RG                18390.4
DW              27.800 usec
DE               6.00 usec
TE              295.0 K
D1            2.00000000 sec
d11           0.03000000 sec
DELTA         1.89999998 sec
MCREST        0.00000000 sec
MCWRK         0.01500000 sec

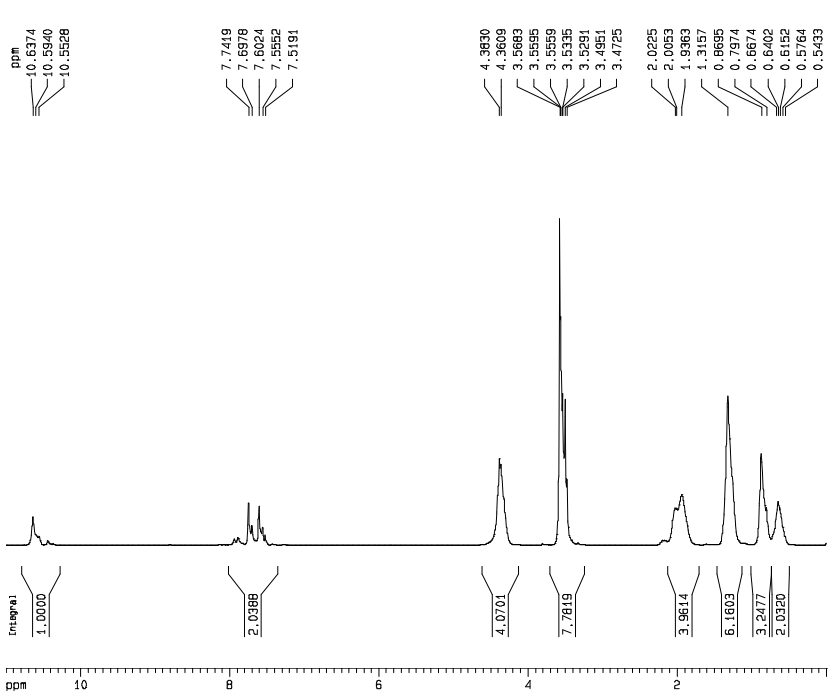
======== CHANNEL f1 ========
NUC1                 13C
P1                12.50 usec
PL1                2.00 dB
SFO1         75.4752953 MHz

======== CHANNEL f2 ========
CPDPRG2         waltz16
NUC2                 1H
PCPD2             80.00 usec
PL2               -1.00 dB
PL12              20.15 dB
PL13              16.98 dB
SFO2         300.1312005 MHz

F2 - Processing parameters
SI                32768
SF          75.4677490 MHz
WDW                  EM
SSB                   0
LB                 1.00 Hz
GB                    0
PC                 1.40

1D NMR plot parameters
CX                20.00 cm
CY                 2.00 cm
F1P              200.000 ppm
F1             15093.55 Hz
F2P                0.000 ppm
F2                 0.00 Hz
PPMCM         10.00000 ppm/cm
HZCM         754.67749 Hz/cm
```





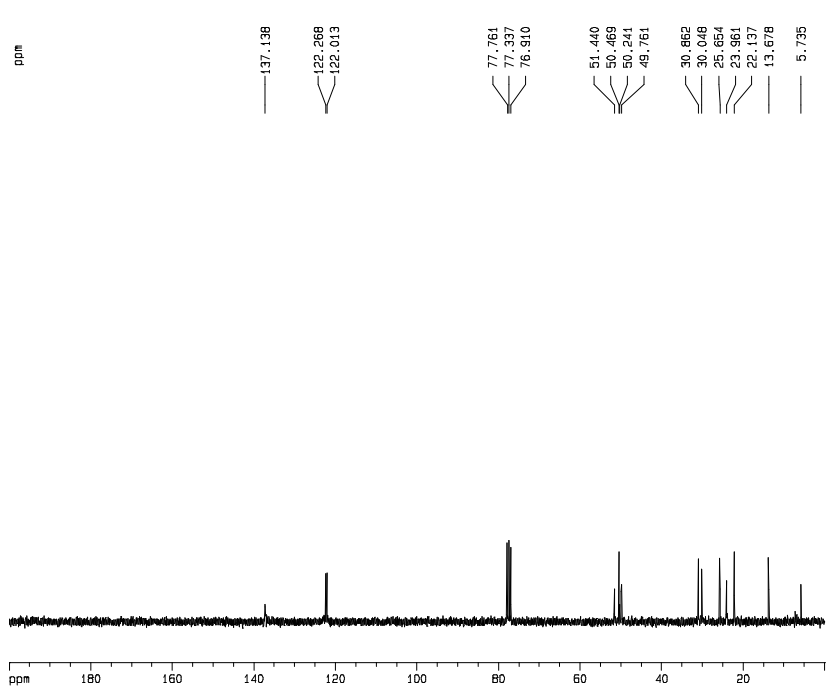

```
Current Data Parameters
NAME          ZXX-09-148-6
EXPNO                   10
PROCNO                   1

F2 - Acquisition Parameters
Date_              20081205
Time                  17.01
INSTRUM               spect
PROBHD   5 mm DUL 13C-1
PULPROG               zg30
TD                   65536
SOLVENT              CDCl3
NS                       7
DS                       0
SWH               8992.806 Hz
FIDRES            0.137219 Hz
AQ                3.6438515 sec
RG                    40.3
DW                   55.600 usec
DE                    6.00 usec
TE                   297.4 K
D1                1.00000000 sec
MCREST            0.00000000 sec
MCWRK             0.01500000 sec

======== CHANNEL f1 ========
NUC1                     1H
P1                    7.00 usec
PL1                  -1.00 dB
SFO1           300.1324010 MHz

F2 - Processing parameters
SI                       32768
SF                300.1299304 MHz
WDW                         EM
SSB                          0
LB                    0.30 Hz
GB                           0
PC                        1.00

1D NMR plot parameters
CX                      20.00 cm
CY                       8.00 cm
F1P                    11.000 ppm
F1                    3301.43 Hz
F2P                    0.000 ppm
F2                     0.00 Hz
PPMCM                 0.55000 ppm/cm
HZCM                165.07146 Hz/cm
```




```
Current Data Parameters
NAME          ZXX-09-148-6
EXPNO                   11
PROCNO                   1

F2 - Acquisition Parameters
Date_              20081205
Time                  17.03
INSTRUM               spect
PROBHD   5 mm DUL 13C-1
PULPROG            zgpg30
TD                   65536
SOLVENT              CDCl3
NS                      32
DS                       4
SWH              17985.611 Hz
FIDRES            0.274436 Hz
AQ                1.8219509 sec
RG                10321.3
DW                   27.800 usec
DE                    6.00 usec
TE                   297.2 K
D1                2.00000000 sec
d11               0.03000000 sec
DELTA             1.89999998 sec
MCREST            0.00000000 sec
MCWRK             0.01500000 sec

======== CHANNEL f1 ========
NUC1                    13C
P1                   12.50 usec
PL1                   2.00 dB
SFO1           75.4752953 MHz

======== CHANNEL f2 ========
CPDPRG2             waltz16
NUC2                     1H
PCPD2                80.00 usec
PL2                  -1.00 dB
PL12                 20.18 dB
PL13                 15.98 dB
SFO2           300.1312005 MHz

F2 - Processing parameters
SI                       32768
SF                75.4677490 MHz
WDW                         EM
SSB                          0
LB                    1.00 Hz
GB                           0
PC                        1.40

1D NMR plot parameters
CX                      20.00 cm
CY                       2.00 cm
F1P                   200.000 ppm
F1                   15093.55 Hz
F2P                    0.000 ppm
F2                     0.00 Hz
PPMCM                10.00000 ppm/cm
HZCM                754.67749 Hz/cm
```

IR spectra of the compound: