Synthesis of Seven-Membered Heterocycles via Copper-Catalyzed Cross-Coupling of Terminal Alkynes with Diazo Compounds and Sequential Michael Addition

Shenghu Yan, Shengyu Cao and Jiangtao Sun

Jiangsu Key Laboratory of Advanced Catalytic Materials & Technology, School of Petrochemical Engineering, Changzhou University

Changzhou 213164, P. R. China.

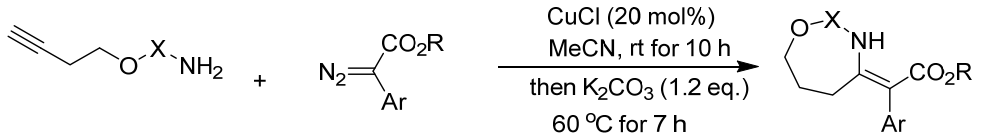
E-mail: jtsun@cczu.edu.cn or jtsun08@gmail.com;

Table of Contents

General information

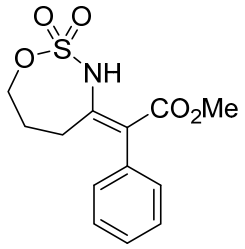
All of the reactions were carried out in flame-dried tube under argon atmosphere. Solvents were dried prior to use. For column chromatography, 200-300 mesh silica gel was used. ^{1}H NMR were recorded on Bruker 300 MHz or 400 MHz spectrometer and ^{13}C NMR were recorded on Bruker 100 MHz or 125MHz spectrometer in $CDCl_3$. HRMS were performed on Agilent 6540 Q-TOF mass spectrometer (ESI). Diazo compounds[1], but-3-yn-1-yl sulfamate[2] and but-3-yn-1-yl carbamate[3] were known compounds and prepared according to the literature procedures.

General procedure for table 2



1a (X= SO_2) **1b** (X= CO) **2** **3**

To a dry tube was added **1** (0.2 mmol), **2** (0.24 mmol), CuCl (0.04 mmol) and anhydrous MeCN (4 mL) under argon atmosphere, then the reaction mixture was stirred at room temperature under argon atmosphere for 10 h. Then K_2CO_3 (0.24 mmol) was added and the reaction mixture was stirred at 60 ^{o}C under argon atmosphere for 7 h. The reaction mixture was cooled and concentrated under vacuum, the residue was purified by column chromatography (silica gel, eluted with EtOAc:Petroleum ether = 1:20-1:10) to give the desired product.

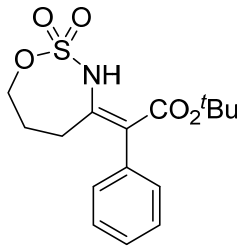


methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-phenylacetate(3a):

This compound was prepared via general procedure as a white solid (38 mg, yield: 65%), mp: 128-130 ^{o}C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.05 (s, 1H), 7.40-7.30 (m, 3H), 7.11 (d, *J* = 6.7 Hz,

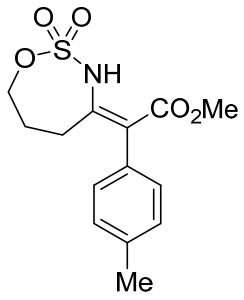
2H), 4.46-4.40 (m, 2H), 3.64 (s, 3H), 2.76-2.70 (m, 2H), 1.91 (dt, J = 10.4, 5.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.92, 150.85, 135.19, 130.88, 128.44, 127.66, 108.51, 72.48, 52.21, 28.83, 27.86. HRMS (ESI) calcd.for $C_{13}H_{16}NO_5S$ $[M+H]^+$: 298.0744, found: 298.0747.



tert-butyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-phenylacetate (3b):

This compound was prepared via general procedure as a white solid (42 mg, yield: 63%), mp: 131-133 °C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.19 (s, 1H), 7.29 (dd, J = 12.8, 9.9 Hz, 3H), 7.08 (d, J = 6.6 Hz, 2H), 4.44-4.40 (m, 2H), 2.73 (d, J = 10.7 Hz, 2H), 1.95-1.87 (m, 2H), 1.34 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.04, 149.33, 135.95, 130.78, 128.05, 127.13, 110.43, 81.90, 72.38, 28.94, 27.98, 27.95. HRMS (ESI) calcd.for $C_{16}H_{22}NO_5S$ $[M+H]^+$: 340.1213, found: 340.1210.

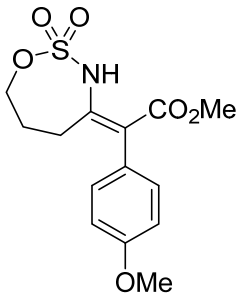


methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(p-tolyl)acetate (3c):

This compound was prepared via general procedure as a white solid (38 mg, yield: 61%), mp: 151-153 °C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.05 (s, 1H), 7.17 (d, J = 7.8 Hz, 2H), 7.00 (d, J = 7.8 Hz, 2H), 4.46-4.41 (m, 2H), 3.65 (s, 3H), 2.77-2.71 (m, 2H), 2.38 (s, 3H), 1.91 (dt, J = 10.5, 5.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.08, 150.76, 137.45, 132.11,

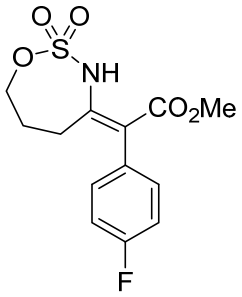
130.71, 129.19, 108.32, 72.47, 52.28, 28.80, 27.86, 21.27. HRMS (ESI) calcd.for $C_{14}H_{18}NO_5S$ $[M+H]^+$: 312.0900, found: 312.0904.



methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(4-methoxyphenyl)acetate (3d):

This compound was prepared via general procedure as a white solid (36 mg, yield: 55%), mp: 123-125 ^oC.

^1H NMR (400 MHz, $CDCl_3$) δ 12.05 (s, 1H), 7.03 (d, *J* = 8.6 Hz, 2H), 6.89 (d, *J* = 8.6 Hz, 2H), 4.46-4.42 (m, 2H), 3.83 (s, 3H), 3.65 (s, 3H), 2.78-2.73 (m, 2H), 1.94-1.88 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 174.64, 158.98, 150.88, 131.95, 113.84, 107.98, 72.45, 55.24, 52.28, 28.81, 27.85. HRMS (ESI) calcd.for $C_{14}H_{18}NO_6S$ $[M+H]^+$: 328.0849, found: 328.0846.

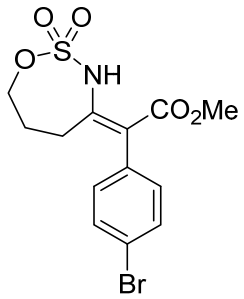


methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(4-fluorophenyl)acetate (3e):

This compound was prepared via general procedure as a white solid (46 mg, yield: 73%), mp: 126-128 ^oC.

^1H NMR (400 MHz, $CDCl_3$) δ 12.05 (s, 1H), 7.12-7.00 (m, 4H), 4.47-4.42 (m, 2H), 3.65 (s, 3H), 2.76-2.71 (m, 2H), 1.92 (dt, *J* = 10.2, 5.1 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.78, 163.46, 161.01, 151.24, 132.59, 132.51, 131.03, 131.00, 115.61,

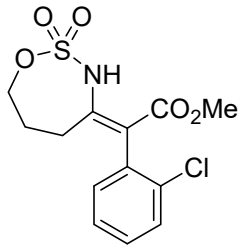
115.40, 107.35, 72.47, 52.31, 28.81, 27.74. HRMS (ESI) calcd.for $C_{13}H_{15}FNO_5S$ $[M+H]^+$: 316.0649, found: 316.0652.



methyl (Z)-2-(4-bromophenyl)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)acetate, hydrogen salt (3f):

This compound was prepared via general procedure as a white solid (52 mg, yield: 70%), mp: 134-136 ^oC.

^1H NMR (400 MHz, $CDCl_3$) δ 12.04 (s, 1H), 7.50 (d, *J* = 8.2 Hz, 2H), 6.99 (d, *J* = 8.2 Hz, 2H), 4.47-4.42 (m, 2H), 3.65 (s, 3H), 2.76-2.70 (m, 2H), 1.92 (dt, *J* = 10.3, 5.2 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.46, 151.19, 134.11, 132.60, 131.69, 121.94, 107.22, 72.44, 52.33, 28.82, 27.71. HRMS (ESI) calcd.for $C_{13}H_{15}BrNO_5S$ $[M+H]^+$: 375.9849, found: 375.9845.

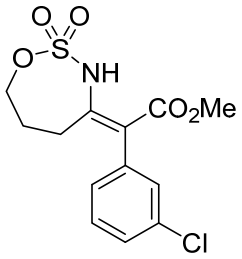


methyl (Z)-2-(2-chlorophenyl)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)acetate (3g):

This compound was prepared via general procedure as a colorless liquid (35 mg, yield: 53%).

^1H NMR (400 MHz, $CDCl_3$) δ 12.08 (s, 1H), 7.44 (d, *J* = 8.8 Hz, 1H), 7.30 (dd, *J* = 11.8, 6.4 Hz, 2H), 7.16 (d, *J* = 6.4 Hz, 1H), 4.44 (t, *J* = 4.8 Hz, 2H), 3.65 (s, 3H), 2.79-2.55 (m, 2H), 2.05-1.90 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.11, 151.35,

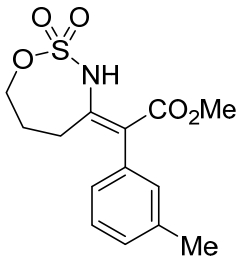
134.13, 132.67, 129.55, 129.43, 126.90, 106.18, 105.75, 72.59, 52.32, 28.91, 27.39. HRMS (ESI) calcd.for $C_{13}H_{15}ClNO_5S$ $[M+H]^+$: 332.0354, found: 332.0358.



methyl (Z)-2-(3-chlorophenyl)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)acetate (3h):

This compound was prepared via general procedure as a colorless liquid (43 mg, yield: 66%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.04 (s, 1H), 7.32 (dd, *J* = 10.2, 4.2 Hz, 2H), 7.13 (s, 1H), 7.03-6.98 (m, 1H), 4.48-4.41 (m, 2H), 3.66 (s, 3H), 2.78-2.69 (m, 2H), 1.93 (dt, *J* = 10.7, 5.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.43, 151.40, 136.95, 134.24, 130.98, 129.69, 129.16, 127.95, 107.18, 72.46, 52.37, 28.88, 27.72. HRMS (ESI) calcd.for $C_{13}H_{15}ClNO_5S$ $[M+H]^+$: 332.0354, found: 332.0351.

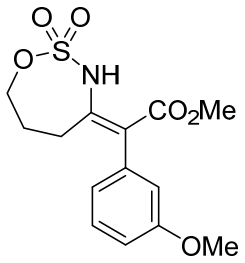


methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(m-tolyl)acetate (3i):

This compound was prepared via general procedure as a white solid (31 mg, yield: 50%), mp: 135-137 ^{o}C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.05 (s, 1H), 7.27-7.23 (m, 1H), 7.15 (d, *J* = 7.6 Hz, 1H), 6.91 (d, *J* = 9.5 Hz, 2H), 4.46-4.41 (m, 2H), 3.65 (s, 3H), 2.76-2.71 (t, 2H), 2.36 (s, 3H), 1.95-1.87 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.02, 150.72, 138.11,

135.02, 131.53, 128.46, 128.30, 127.87, 108.55, 72.50, 52.30, 28.86, 27.86, 21.45. HRMS (ESI) calcd.for $C_{14}H_{18}NO_5S$ $[M+H]^+$: 312.0900, found: 312.0903.

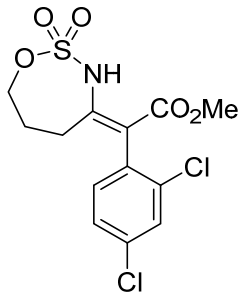


methyl

(Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(3-methoxyphenyl)acetate (3j):

This compound was prepared via general procedure as a colorless liquid (35 mg, yield: 53%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.04 (s, 1H), 7.29 (d, *J* = 7.9 Hz, 1H), 6.88 (d, *J* = 8.3 Hz, 1H), 6.73-6.63 (m, 2H), 4.46-4.42 (m, 2H), 3.81 (s, 3H), 3.65 (s, 3H), 2.77-2.72 (m, 2H), 1.92 (dt, *J* = 10.3, 5.1 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.85, 159.50, 150.85, 136.46, 129.44, 123.22, 116.71, 112.93, 108.24, 72.50, 55.26, 52.30, 28.82, 27.88. HRMS (ESI) calcd.for $C_{14}H_{18}NO_6S$ $[M+H]^+$: 328.0849, found: 328.0851.

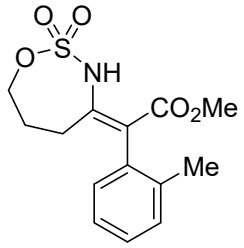


methyl

(Z)-2-(2,4-dichlorophenyl)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)acetate (3k):

This compound was prepared via general procedure as a white solid (44 mg, yield: 60%), mp: 124-126 ^{o}C.

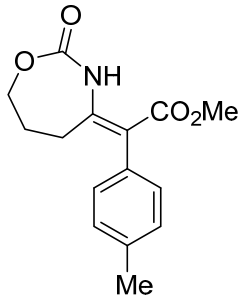
^{1}H NMR (400 MHz, $CDCl_3$) δ 12.06 (s, 1H), 7.46 (d, *J* = 2.0 Hz, 1H), 7.30-7.24 (m, 1H), 7.09 (d, *J* = 8.2 Hz, 1H), 4.49-4.42 (m, 2H), 3.65 (s, 3H), 2.76-2.58 (m, 2H), 2.08-1.82 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 168.79, 151.80, 136.28, 134.68, 133.42, 132.74, 129.51, 127.34, 104.60, 72.58, 52.37, 28.94, 27.33. HRMS (ESI) calcd.for $C_{13}H_{14}Cl_2NO_5S$ $[M+H]^+$: 365.9964, found: 365.9967.



methyl (Z)-2-(2,2-dioxido-1,2,3-oxathiazepan-4-ylidene)-2-(o-tolyl)acetate (3l):

This compound was prepared via general procedure as colorless liquid (28 mg, yield: 45%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.06 (s, 1H), 7.30-7.16 (m, 4H), 7.01 (d, *J* = 7.5 Hz, 1H), 4.47-4.40 (m, 2H), 3.64 (s, 3H), 2.73-2.57 (m, 2H), 2.14 (s, 3H), 1.95-1.85 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.77, 150.47, 137.87, 134.55, 130.98, 130.12, 128.15, 126.01, 107.17, 72.52, 52.29, 28.67, 27.64, 19.91. HRMS (ESI) calcd. for $C_{14}H_{18}NO_5S$ $[M+H]^+$: 312.0900, found: 312.0903.

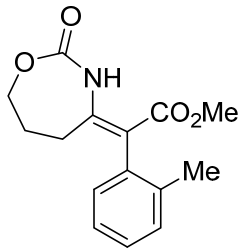


methyl (Z)-2-(2-oxo-1,3-oxazepan-4-ylidene)-2-(p-tolyl)acetate (3o):

This compound was prepared via general procedure as a colorless liquid (34 mg, yield: 61%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19-7.10 (m, 4H), 4.20 (t, *J* = 7.0 Hz, 2H), 3.66 (s, 3H), 3.27 (t, *J* = 7.8 Hz, 2H), 2.35 (s, 3H), 2.18-2.08 (m, 2H). ^{13}C NMR (100 MHz,

$CDCl_3$) δ 175.86, 172.32, 158.15, 136.33, 132.43, 130.34, 129.76, 128.68, 72.21, 51.31, 31.60, 24.15, 21.33. HRMS (ESI) calcd.for $C_{15}H_{18}NO_4$ $[M+H]^+$: 276.1230, found: 276.1233.



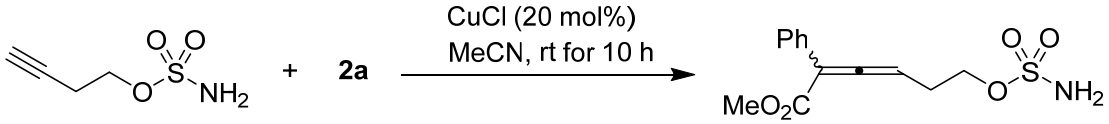
methyl (Z)-2-(2-oxo-1,3-oxazepan-4-ylidene)-2-(o-tolyl)acetate (3p):

This compound was prepared via general procedure as a colorless liquid (29 mg, yield: 52%).

^1H NMR (300 MHz, $CDCl_3$) δ 7.24-7.15 (m, 3H), 7.11 (d, *J* = 5.3 Hz, 1H), 4.19 (t, *J* = 7.0 Hz, 2H), 3.62 (s, 3H), 3.30 (t, *J* = 7.8 Hz, 2H), 2.19-2.09 (m, 5H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 181.33, 167.67, 133.17, 130.81, 129.70, 127.35, 125.45, 72.21, 51.29, 31.28, 24.13, 19.74. HRMS (ESI) calcd.for $C_{15}H_{18}NO_4$ $[M+H]^+$: 276.1230, found: 276.1234.

Control experiments for Scheme 2

1. Scheme 2-a

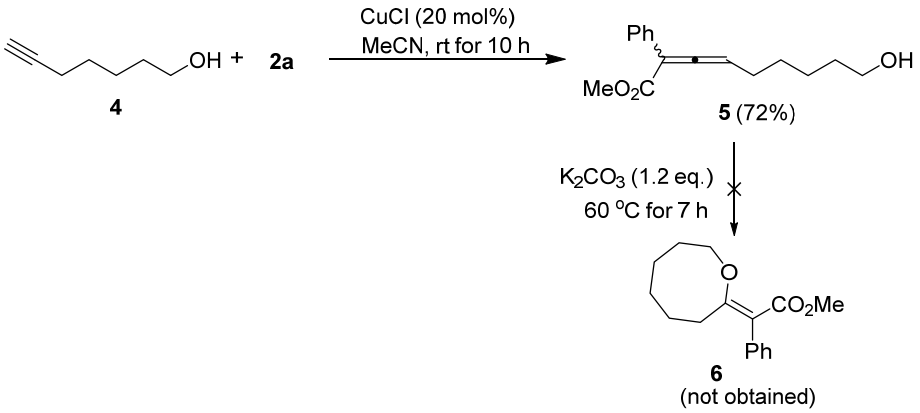


1a **3a'** (62%)

To a dry tube was added **1** (0.2 mmol), **2a** (0.24 mmol), CuCl (0.04 mmol) and anhydrous MeCN (4 mL) under argon atmosphere, then the reaction mixture was stirred at room temperature under argon atmosphere for 10 h. The reaction mixture was concentrated under vacuum, the residue was purified by column chromatography (silica gel, eluted with EtOAc:Petroleum ether = 1:10-1:5) to give **3a'** (29 mg, yield: 52%) as colorless liquid. ^1H NMR (300 MHz, $CDCl_3$) 7.49-7.46 (m, 2H), 7.40-7.31 (m, 3H), 5.86 (t, *J* = 6.7 Hz, 1H), 4.79 (s, 2H), 4.35 (t, *J* = 5.8 Hz, 2H), 3.84 (s, 3H),

2.70-2.61 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 211.93, 166.85, 132.17, 128.46, 128.43, 127.99, 104.60, 91.86, 68.92, 52.74, 27.73. HRMS (ESI) calcd. for $C_{13}H_{16}NO_5S$ $[M+H]^+$: 298.0744, found: 298.0741.

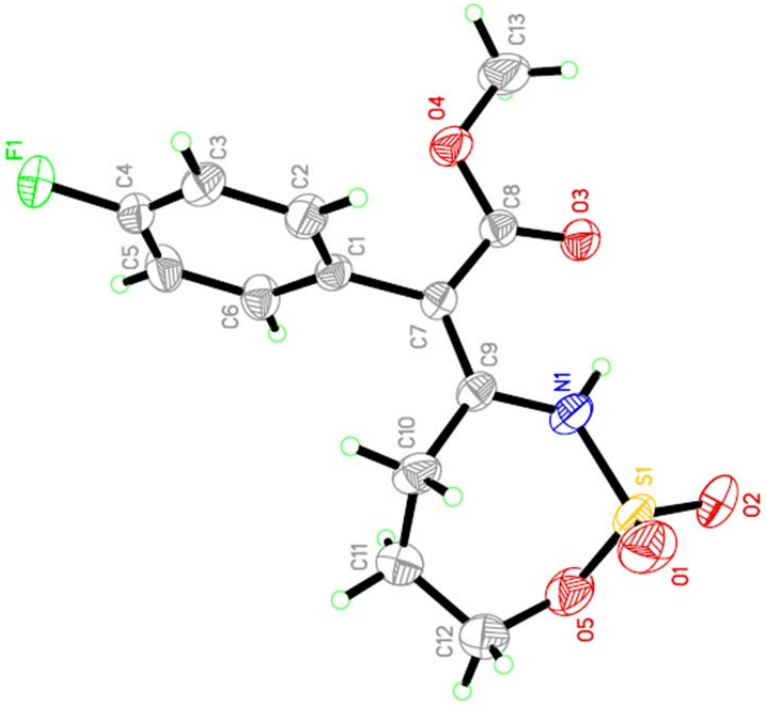
2. Scheme 2-b



To a dry tube was added **4** (0.2 mmol), **2a** (0.24 mmol), CuCl (0.04 mmol) and anhydrous MeCN (4 mL) under argon atmosphere, then the reaction mixture was stirred at room temperature under argon atmosphere for 10 h. The reaction mixture was concentrated under vacuum, the residue was purified by column chromatography (silica gel, eluted with EtOAc:Petroleum ether = 1:10-1:5) to give **5** (37 mg, yield: 72%) as colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52-7.46 (m, 2H), 7.37-7.31 (m, 2H), 7.30-7.26 (m, 1H), 5.81 (t, *J* = 6.9 Hz, 1H), 3.81 (s, 3H), 3.61 (t, *J* = 6.4 Hz, 2H), 2.25 (q, *J* = 7.1 Hz, 2H), 1.60-1.53 (m, 4H), 1.48-1.40 (m, 2H), 1.33 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 211.69, 166.98, 133.03, 128.39, 128.26, 127.52, 103.12, 96.03, 62.87, 52.34, 32.44, 28.49, 27.95, 25.12. HRMS (ESI) calcd. for $C_{16}H_{21}O_3$ $[M+H]^+$: 261.1485, found: 261.1483.

X-ray structure of 3e

The crystal structures have been deposited at the Cambridge Crystallographic Data Centre (CCDC 1547742, **3e**). The data can be obtained free of charge via the internet at www.ccdc.cam.ac.uk/data_request/cif.

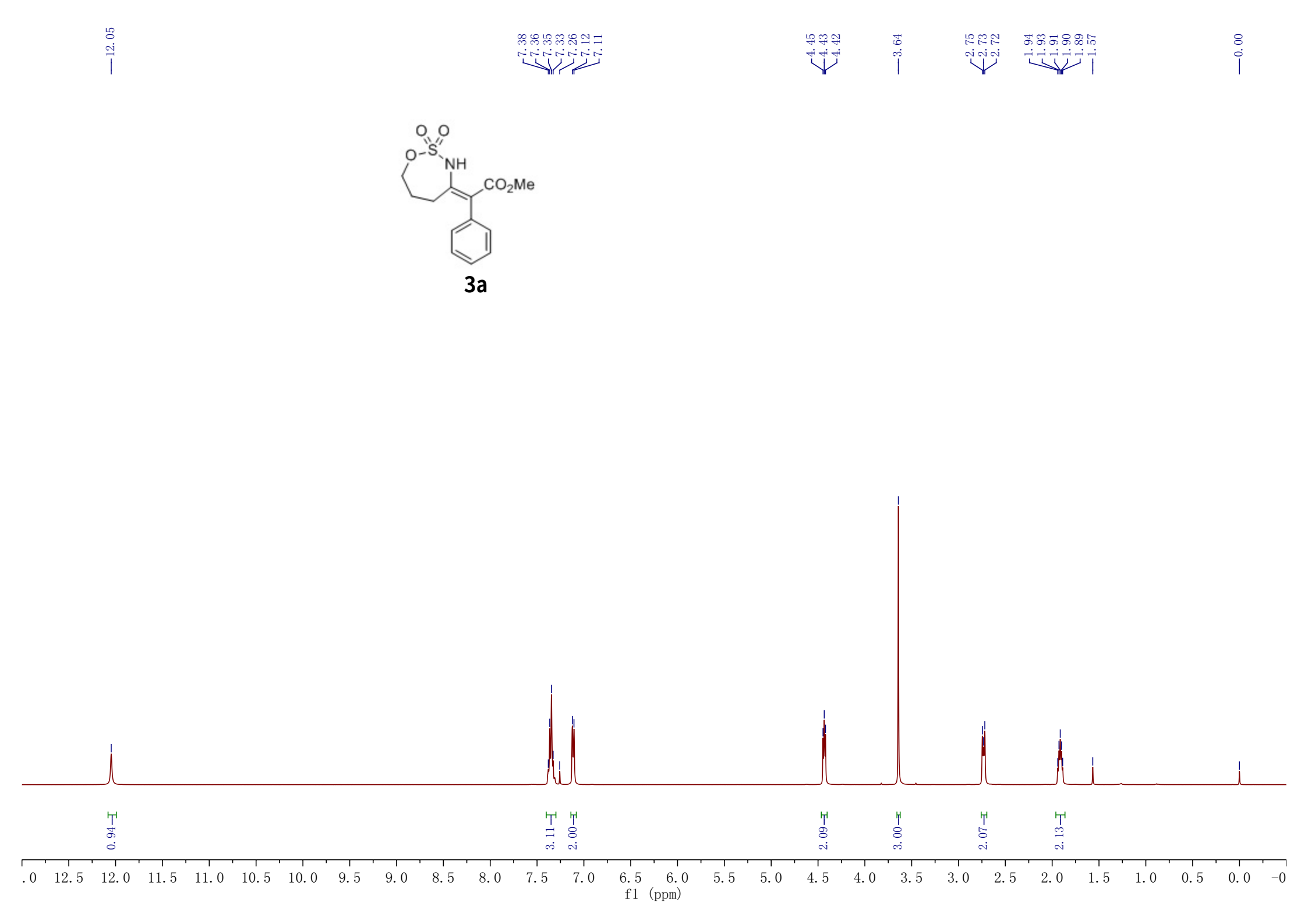


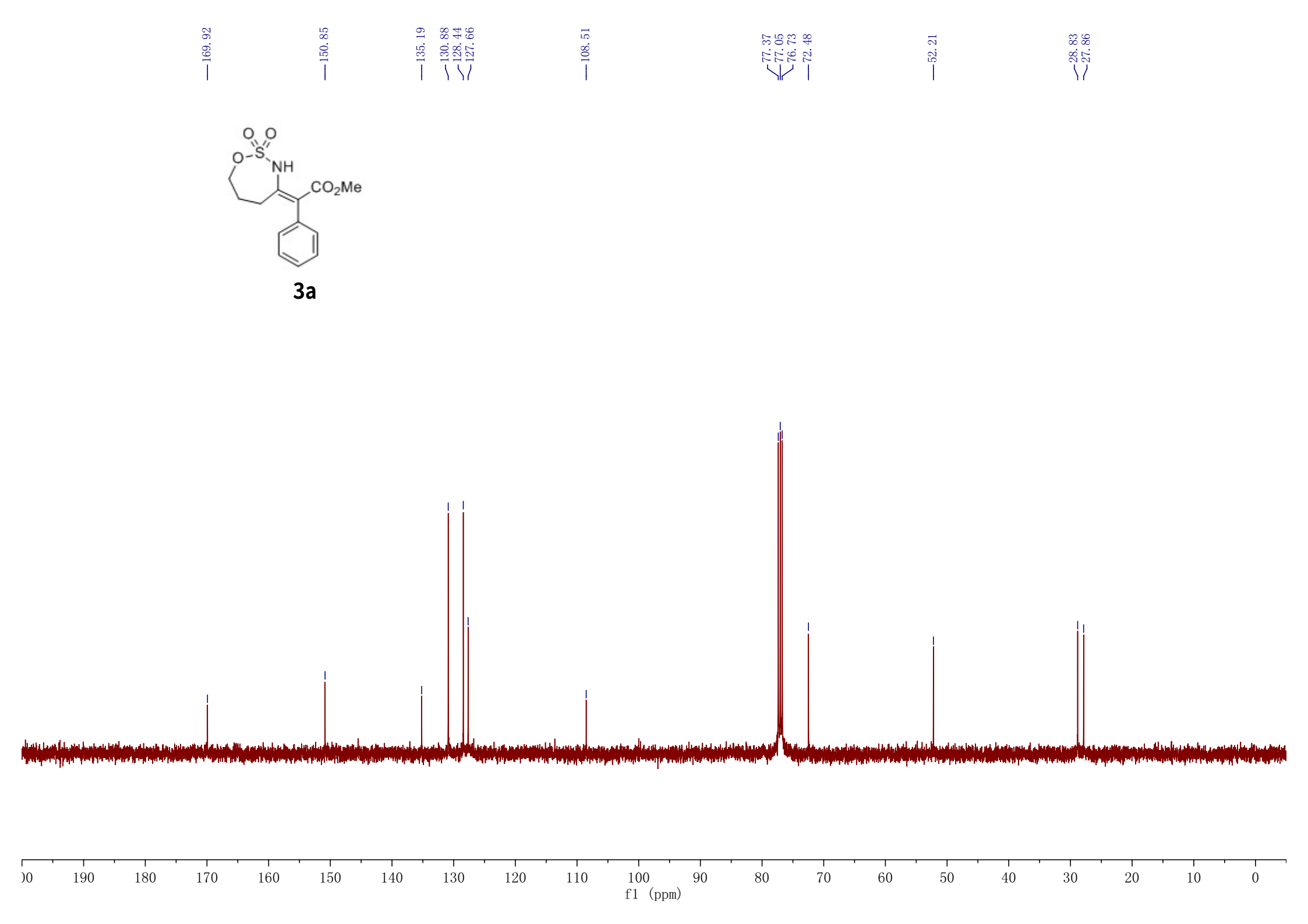
References:

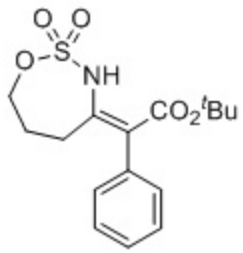
[1] H. Keipour, A. Jalba, L. Delage-Laurin, T. Ollevier, *J. Org. Chem.* **2017**, *82*, 3000.

[2] K. M. Erixon, C. L. Dabalos, F. J. Leeper, *Org. Biomol. Chem*. **2004**, 2, 1732.

[3] R. D. Grigg, J. W. Rigoli, S. Pearce, J. M. Schomaker, *Org. Lett.* **2012**, *14*, 280.

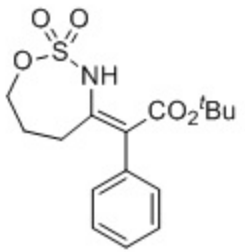

12.05
7.38
7.36
7.35
7.33
7.26
7.12
7.11
4.45
4.43
4.42
3.64
2.75
2.73
2.72
1.94
1.93
1.91
1.90
1.89
1.57
0.00
O
O
O
S
NH
CO2Me
3a
0.94
3.11
2.00
2.09
3.00
2.07
2.13
f1 (ppm)


169.92
150.85
135.19
130.88
128.44
127.66
108.51
77.37
77.05
76.73
72.48
52.21
28.83
27.86
O
O
O
S
NH
CO2Me
3a
f1 (ppm)


O
O
O
S
NH
CO2tBu

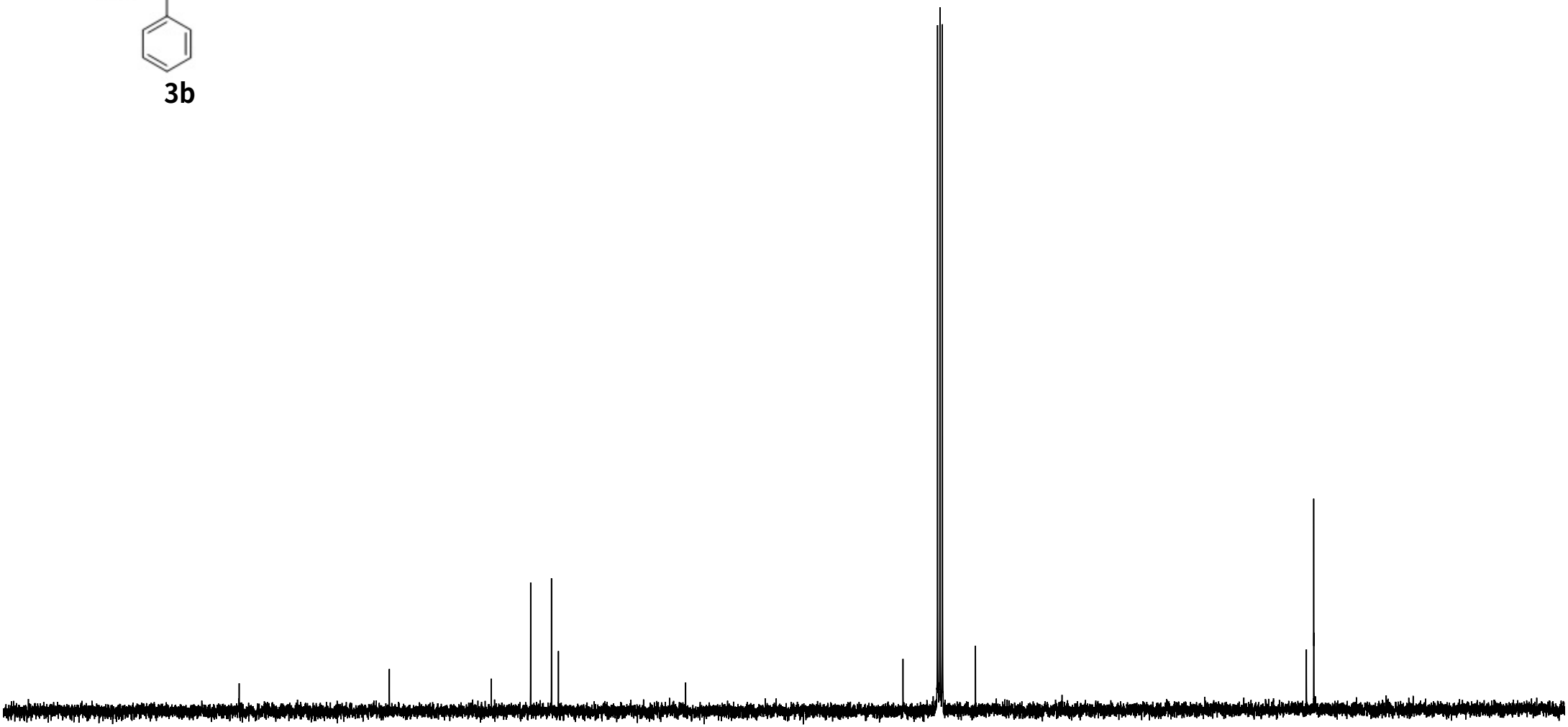
3b

12.19
7.32
7.30
7.29
7.26
7.08
7.07
4.44
4.42
4.41
2.75
2.72
1.91
1.57
1.34
0.00
1.01
2.93
1.96
2.06
2.08
2.06
9.00
f1 (ppm)



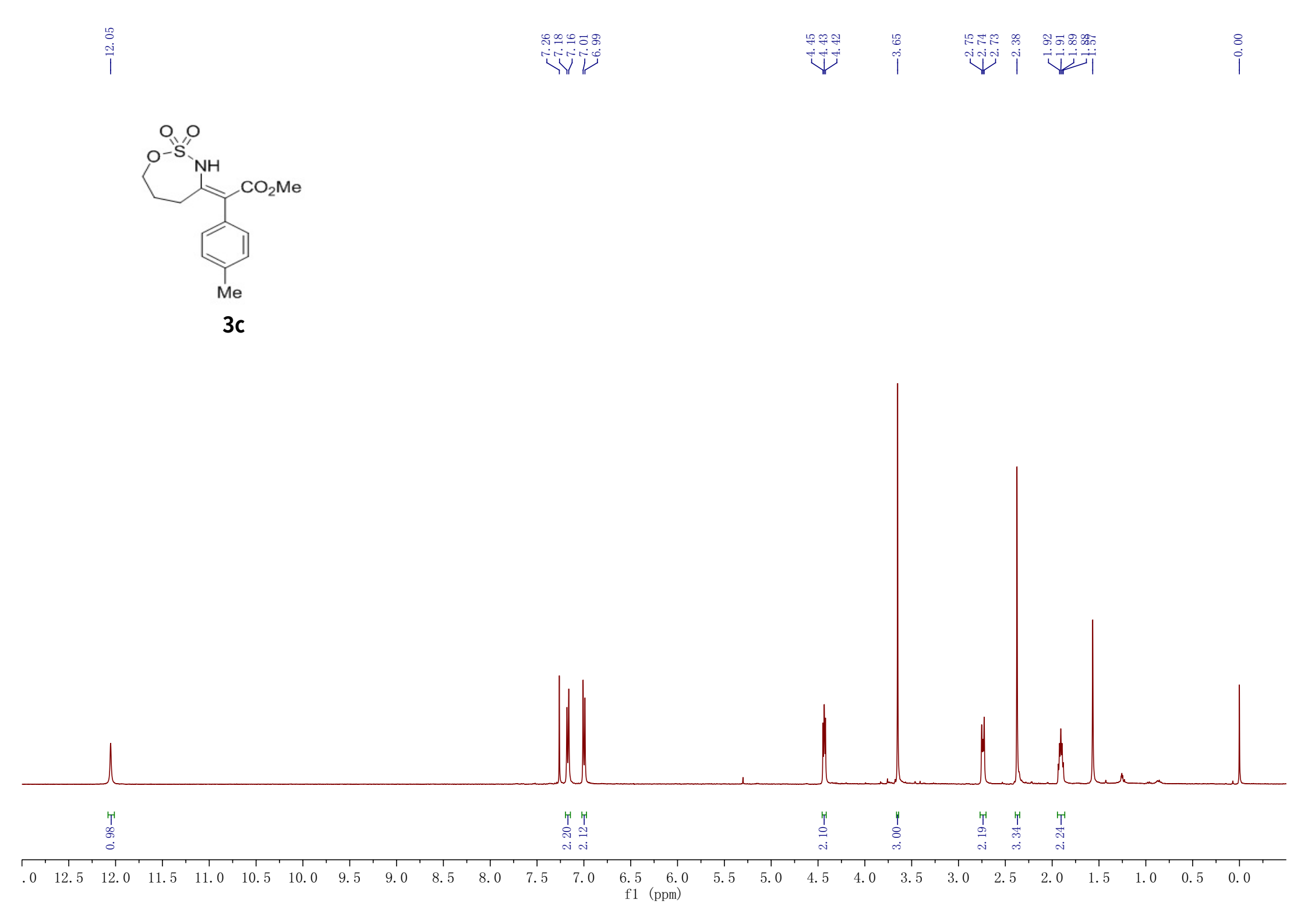
3b

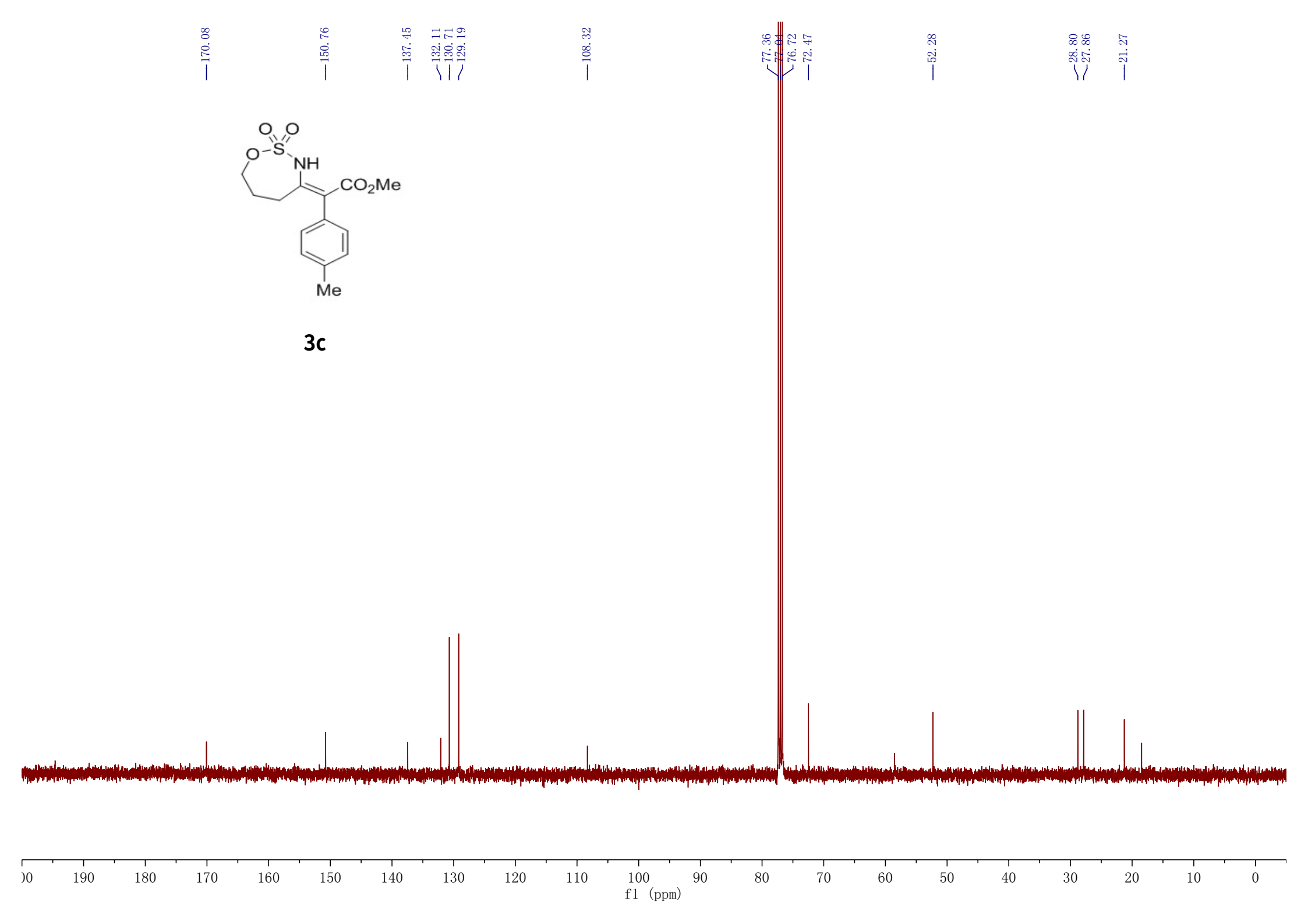
169.04
149.33
135.95
130.78
128.05
127.13
110.43
81.90
77.36
77.05
76.73
72.38
28.94
27.98
27.95

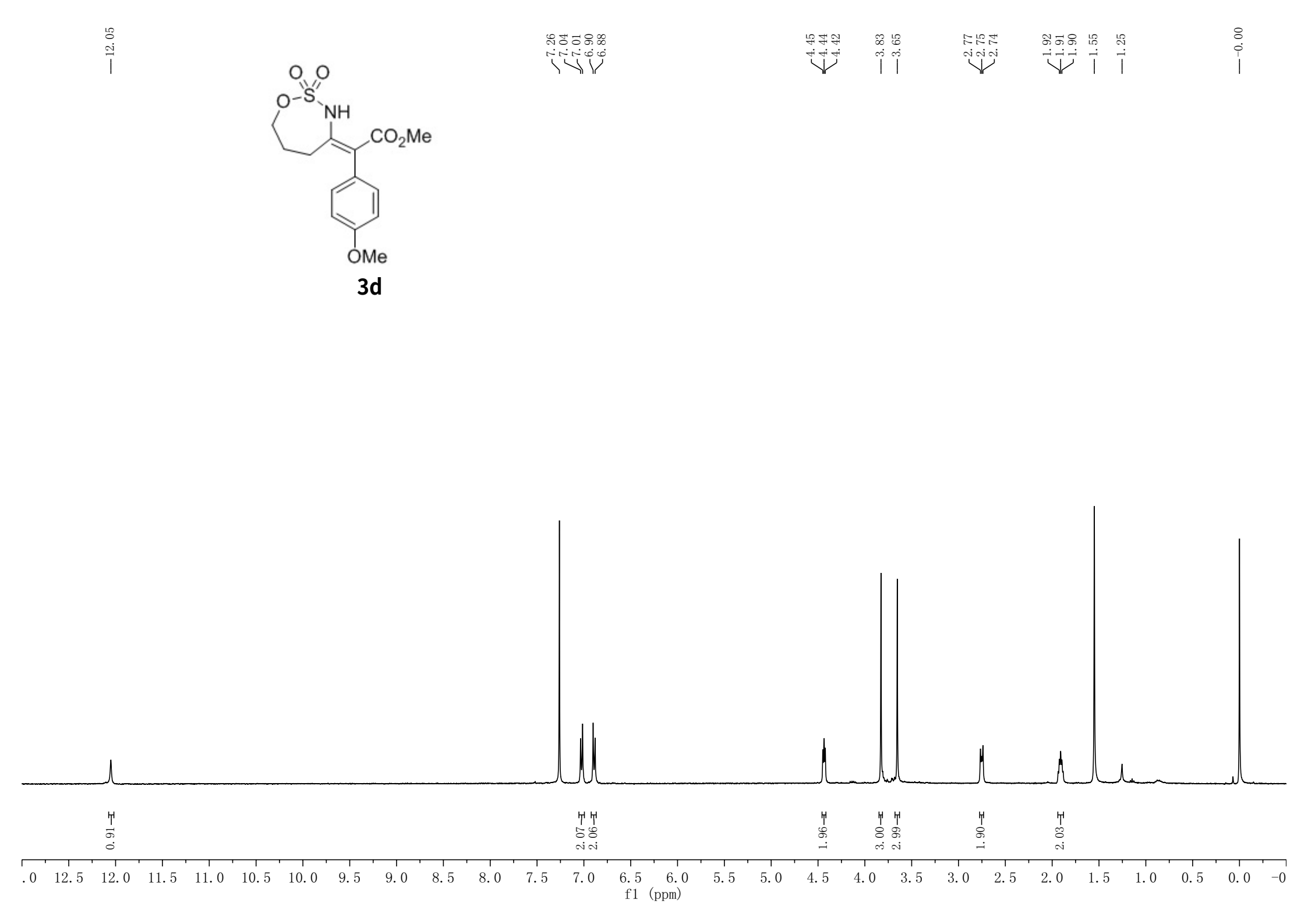


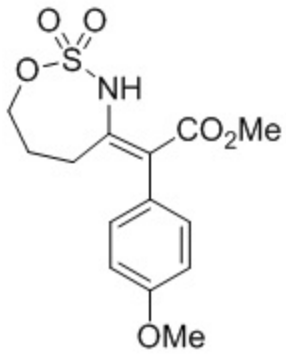
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

f1 (ppm)


12.05
7.26
7.18
7.16
7.01
6.99
4.45
4.43
4.42
3.65
2.75
2.74
2.73
2.38
1.92
1.91
1.89
1.57
0.00
O
O
O
S
NH
CO2Me
Me
3c
0.98
2.20
2.12
2.10
3.00
2.19
3.34
2.24
f1 (ppm)

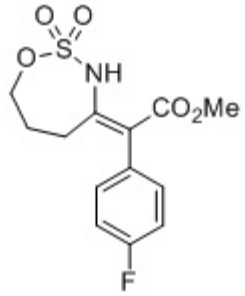

170.08
150.76
137.45
132.11
130.71
129.19
108.32
77.36
77.04
76.72
72.47
52.28
28.80
27.86
21.27
O
O
O
S
NH
CO2Me
Me
3c
f1 (ppm)


12.05
7.26
7.04
7.01
6.90
6.88
4.45
4.44
4.42
3.83
3.65
2.77
2.75
2.74
1.92
1.91
1.90
1.55
1.25
0.00
O
O
O
S
NH
CO2Me
OMe
3d
0.91
2.07
2.06
1.96
3.00
2.99
1.90
2.03
f1 (ppm)


O
O
O
S
NH
CO2Me
OMe

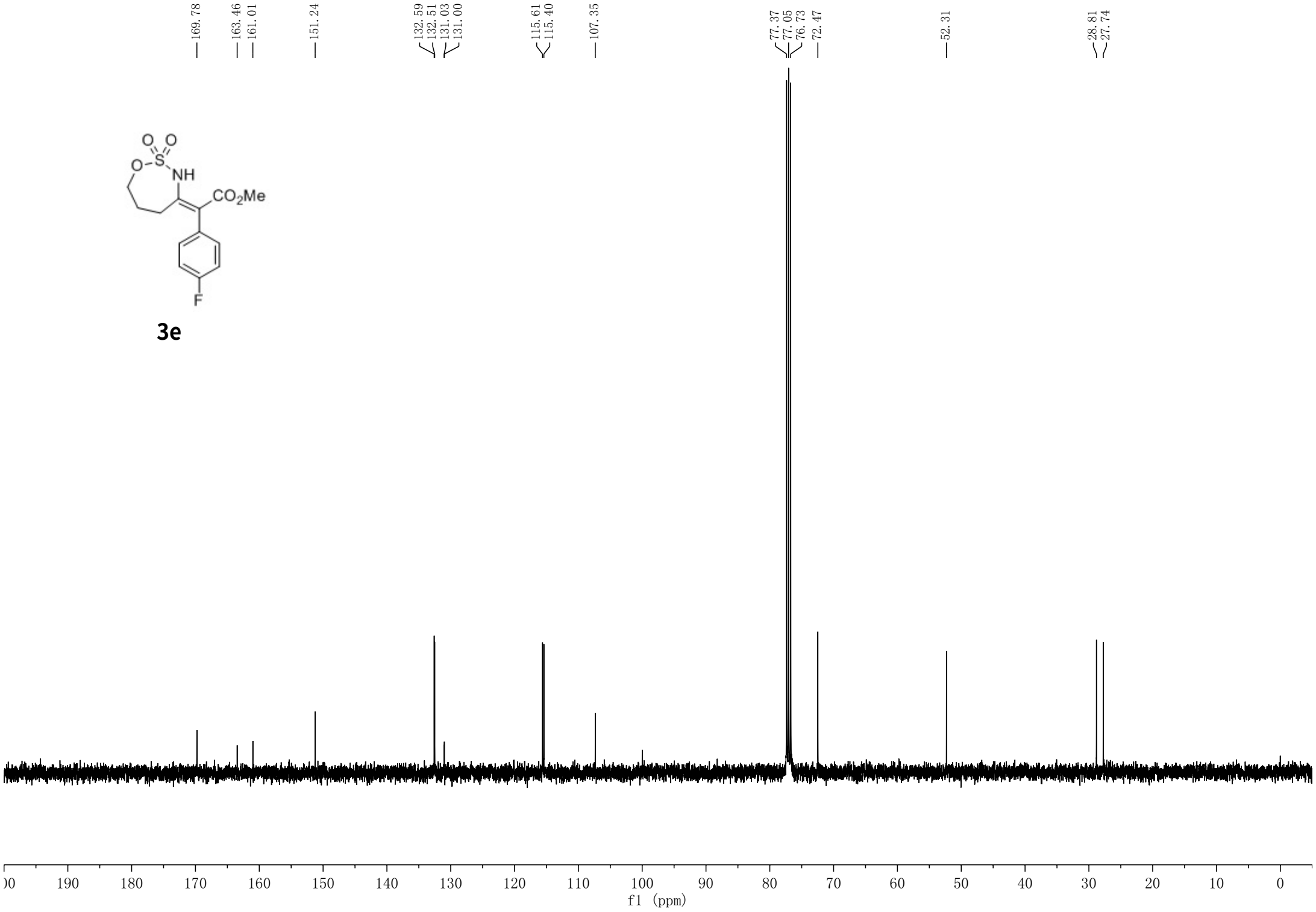
3d

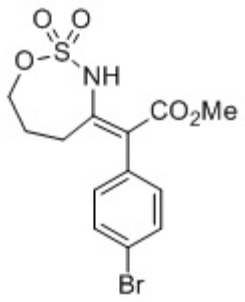
174.64
158.98
150.88
131.95
113.84
107.98
77.28
77.00
76.77
72.45
55.24
52.28
28.81
27.85
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
O
S
NH
CO2Me
F

3e

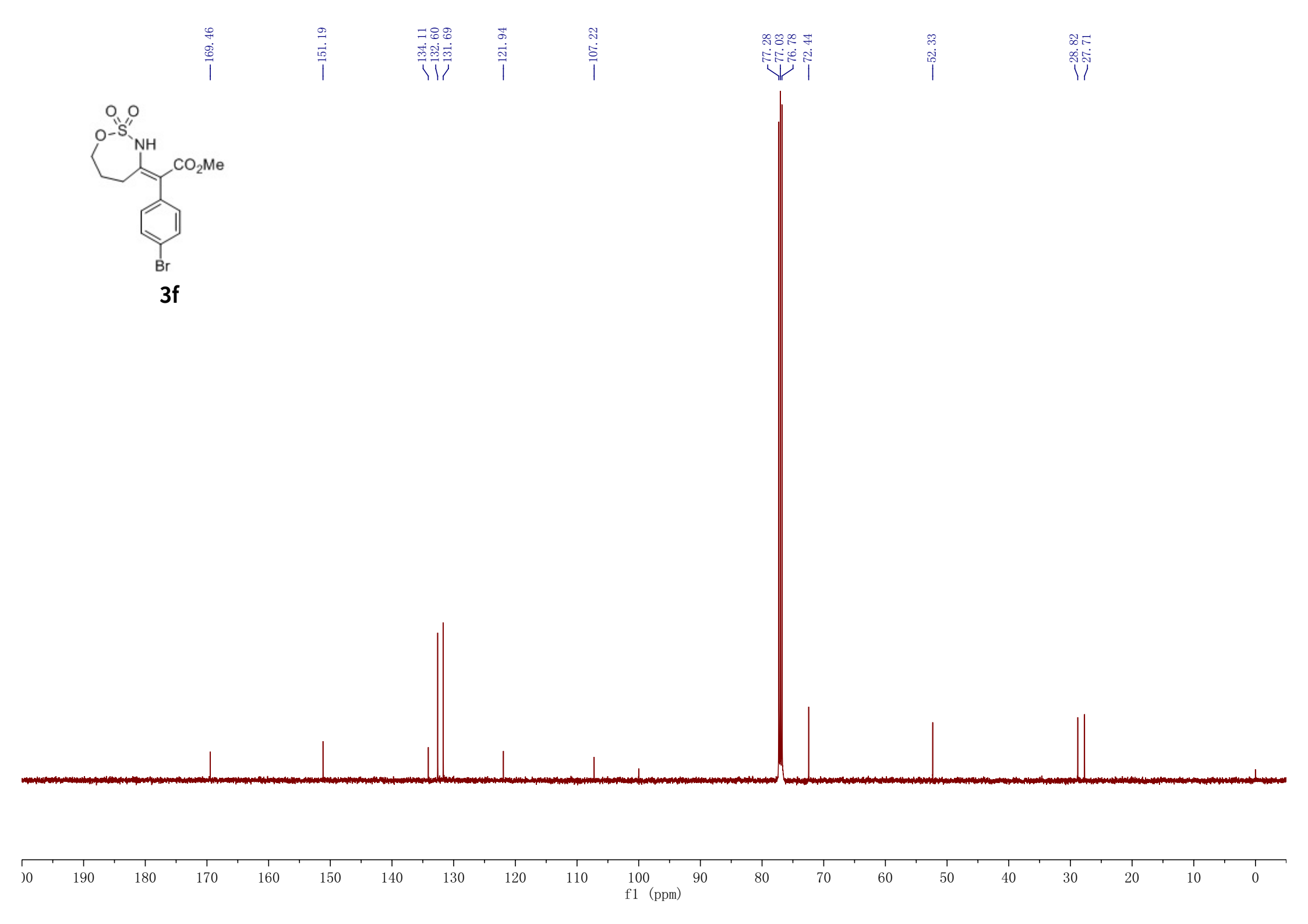
12.05
7.26
7.10
7.08
7.07
7.05
7.03
4.46
4.45
4.43
3.65
2.75
2.73
2.72
1.95
1.93
1.92
1.91
1.89
1.59
0.00
1.00
4.08
1.98
3.00
1.96
2.08
f1 (ppm)

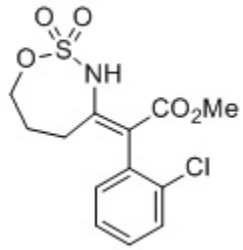

169.78
163.46
161.01
151.24
132.59
132.51
131.03
131.00
115.61
115.40
107.35
77.37
77.05
76.73
72.47
52.31
28.81
27.74
O
O
S
O
NH
CO2Me
F
3e
f1 (ppm)


O
O
O
S
NH
CO2Me
Br

3f

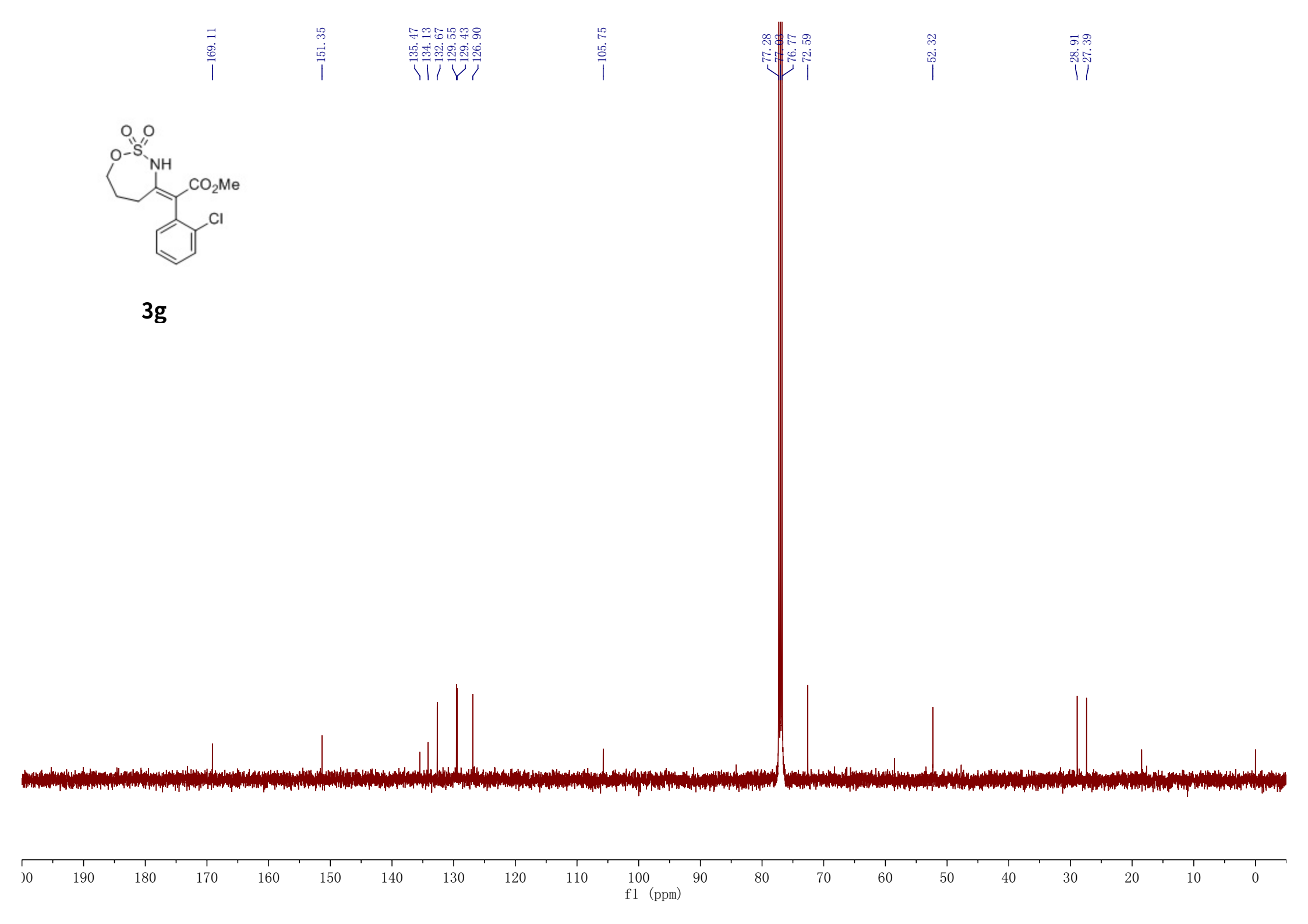
12.04
7.51
7.49
7.26
7.00
6.98
4.46
4.45
4.43
3.65
2.74
2.73
2.72
1.94
1.93
1.92
1.90
1.89
1.56
0.00
1.00
2.04
2.01
1.98
3.00
2.01
2.12
f1 (ppm)

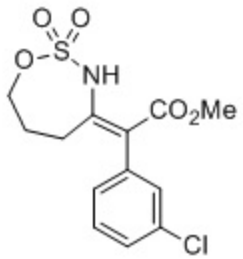

169.46
151.19
134.11
132.60
131.69
121.94
107.22
77.28
77.03
76.78
72.44
52.33
28.82
27.71
O
O
S
O
NH
CO2Me
Br
3f
f1 (ppm)


O
O
S
O
NH
CO2Me
Cl

3g

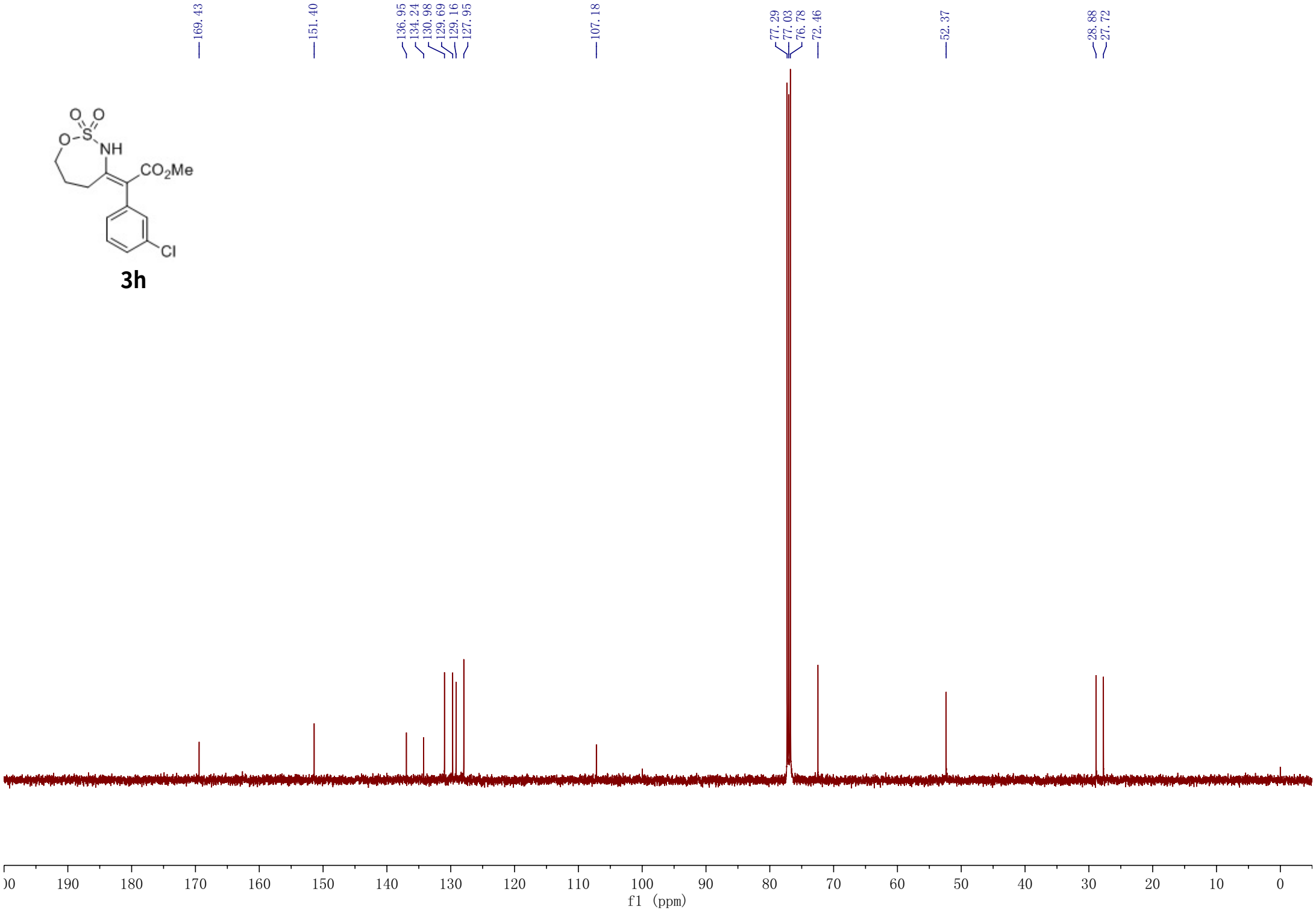
12.08
7.45
7.43
7.32
7.30
7.29
7.28
7.26
7.17
7.15
4.46
4.44
4.43
3.95
3.83
3.81
3.65
2.71
2.69
2.65
2.63
2.59
2.05
2.03
2.01
1.91
1.65
1.26
0.88
0.87
0.07
0.00
0.98
0.98
2.02
0.97
2.05
3.00
2.26
2.18
f1 (ppm)

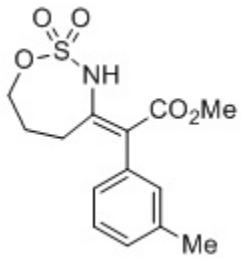

169.11
151.35
135.47
134.13
132.67
129.55
129.43
126.90
105.75
77.28
77.03
76.77
72.59
52.32
28.91
27.39
O
O
O
S
NH
CO2Me
Cl
3g
f1 (ppm)


O
O
S
O
NH
CO2Me
Cl

3h

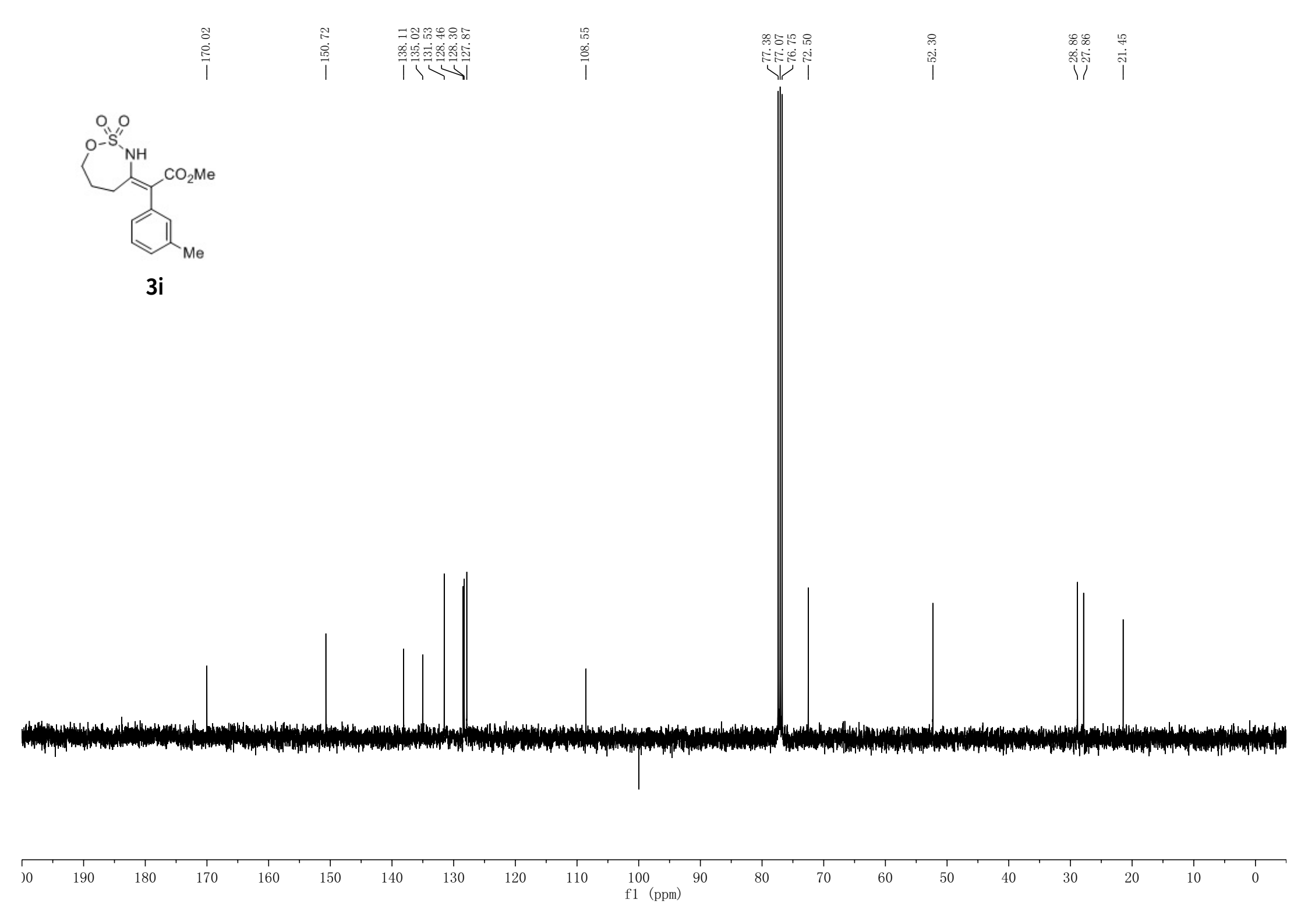
12.04
7.33
7.33
7.32
7.30
7.28
7.26
7.13
7.01
7.01
7.00
4.46
4.45
4.44
3.66
2.75
2.74
2.72
1.96
1.95
1.93
1.92
1.91
1.56
0.00
0.89
2.06
0.91
0.94
1.97
3.00
2.00
2.05
f1 (ppm)

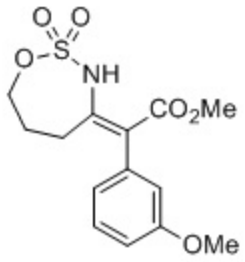

169.43
151.40
136.95
134.24
130.98
129.69
129.16
127.95
107.18
77.29
77.03
76.78
72.46
52.37
28.88
27.72
O
O
O
S
NH
CO2Me
Cl
3h
f1 (ppm)


O
O
O
S
NH
CO2Me
Me

3i

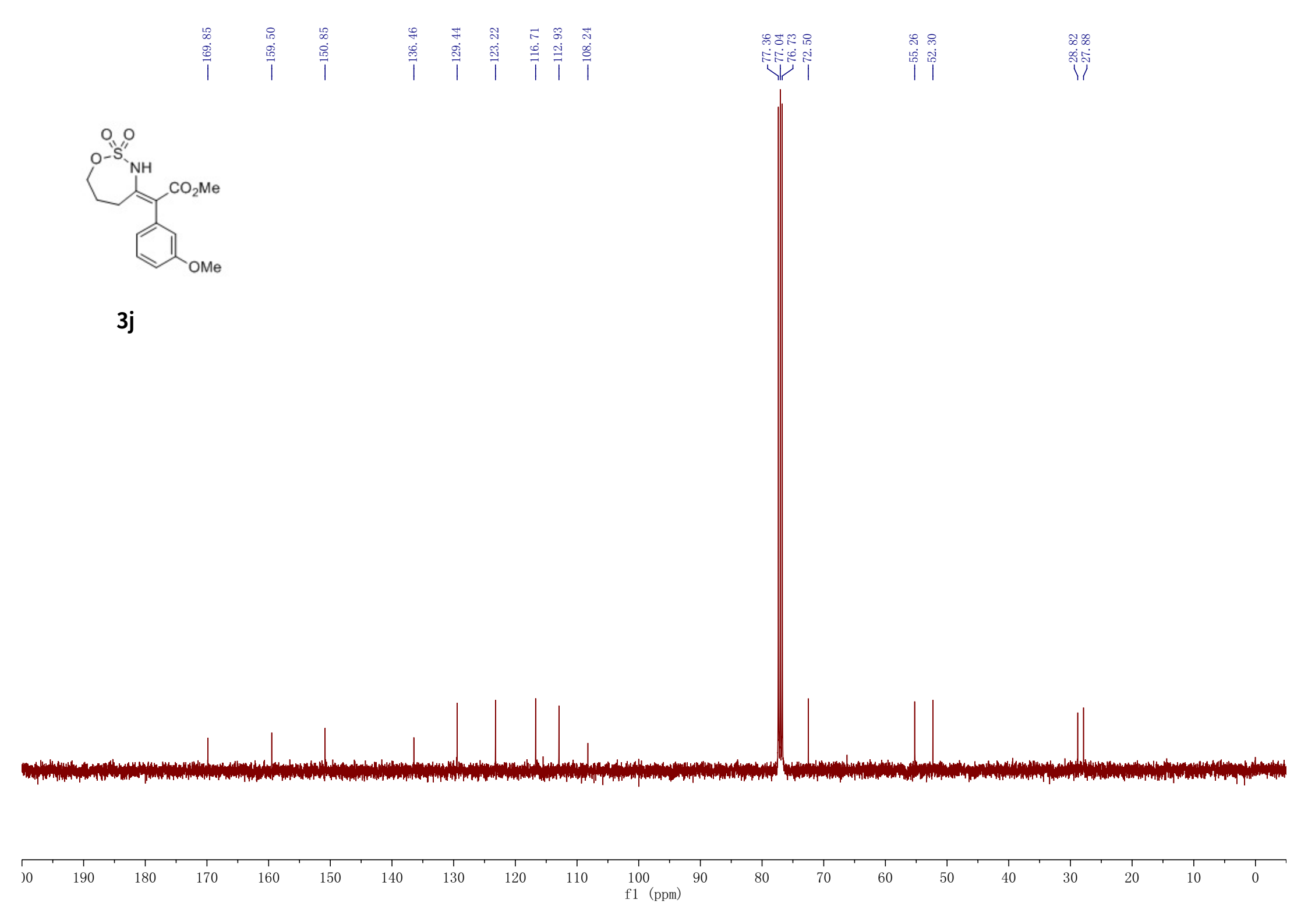
12.05
7.27
7.26
7.25
7.23
7.16
7.14
6.93
6.90
4.45
4.44
4.42
3.65
2.75
2.73
2.72
2.36
1.93
1.91
1.90
1.57
0.00
0.89
1.32
1.01
2.01
2.04
3.00
2.10
3.26
2.13
f1 (ppm)

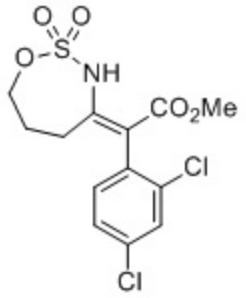

170.02
150.72
138.11
135.02
131.53
128.46
128.30
127.87
108.55
77.38
77.07
76.75
72.50
52.30
28.86
27.86
21.45
O
O
O
S
NH
CO2Me
Me
3i
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
O
S
NH
CO2Me
OMe

3j

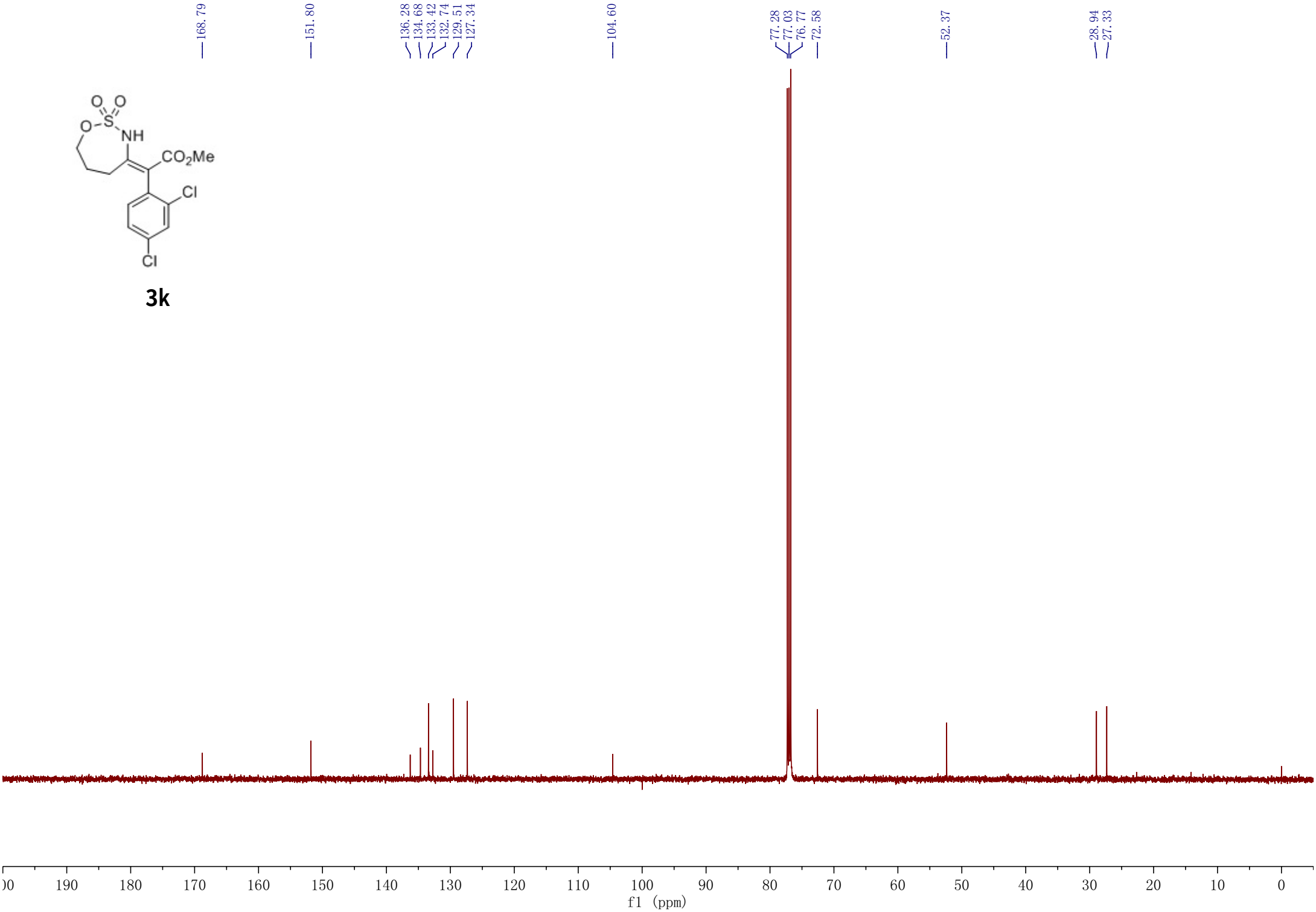
12.04
7.30
7.28
7.26
6.89
6.87
6.71
6.69
6.66
4.45
4.44
4.43
3.81
3.65
2.76
2.75
2.73
1.95
1.93
1.92
1.91
1.89
1.57
0.00
0.90
1.07
1.07
2.10
2.01
3.10
3.00
1.99
2.08
f1 (ppm)

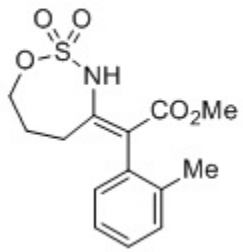

169.85
159.50
150.85
136.46
129.44
123.22
116.71
112.93
108.24
77.36
77.04
76.73
72.50
55.26
52.30
28.82
27.88
O
O
O
S
NH
CO2Me
OMe
3j
f1 (ppm)


O
O
S
O
NH
CO2Me
Cl
Cl

3k

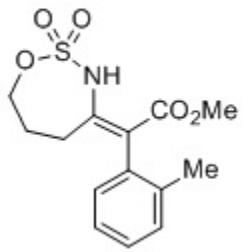
12.06
7.46
7.46
7.28
7.28
7.26
7.26
7.10
7.08
4.47
4.46
4.45
4.44
3.65
2.71
2.69
2.64
2.62
2.05
2.01
1.91
1.00
0.94
1.98
0.99
2.07
3.00
2.22
2.19
f1 (ppm)


168.79
151.80
136.28
134.68
133.42
132.74
129.51
127.34
104.60
77.28
77.03
76.77
72.58
52.37
28.94
27.33
O
O
O
S
NH
CO2Me
Cl
Cl
3k
f1 (ppm)


O
O
O
S
NH
CO2Me
Me

3l

12.06
7.26
7.24
7.24
7.22
7.21
7.20
7.19
7.18
7.02
7.00
4.45
4.44
4.43
4.42
4.42
3.64
2.68
2.67
2.66
2.65
2.64
2.63
2.62
2.14
1.90
1.89
1.89
1.88
1.88
0.00
0.84
0.99
1.25
1.26
0.95
2.02
3.00
2.16
2.97
2.08
f1 (ppm)

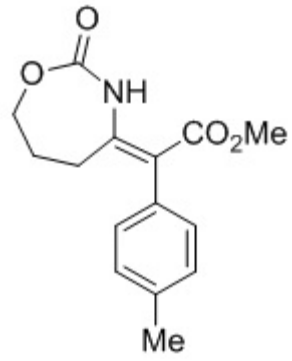


3l

169.77
150.47
137.87
134.55
130.98
130.12
128.15
126.01
107.17
77.37
77.05
76.73
72.52
52.29
28.67
27.64
19.91

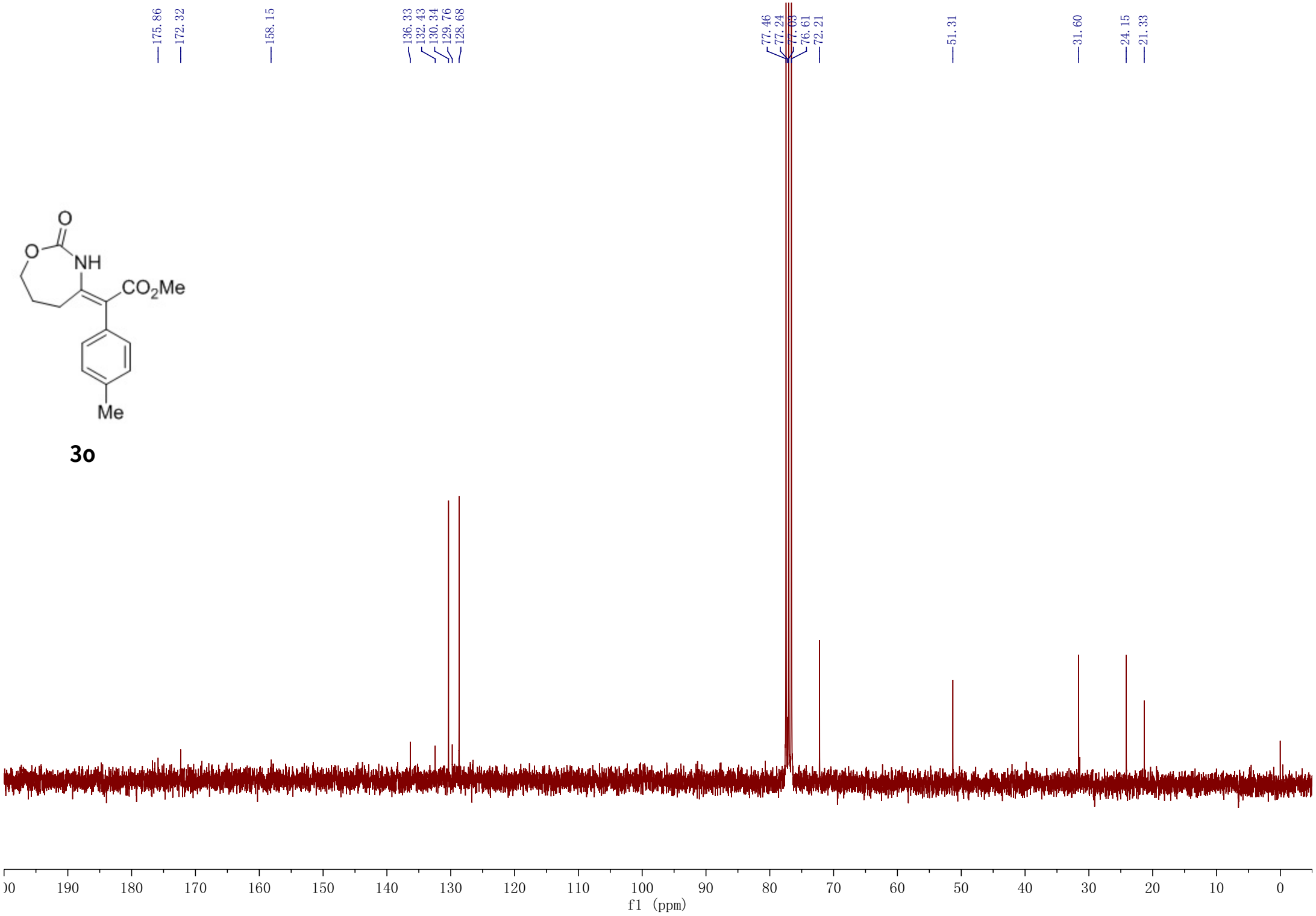
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

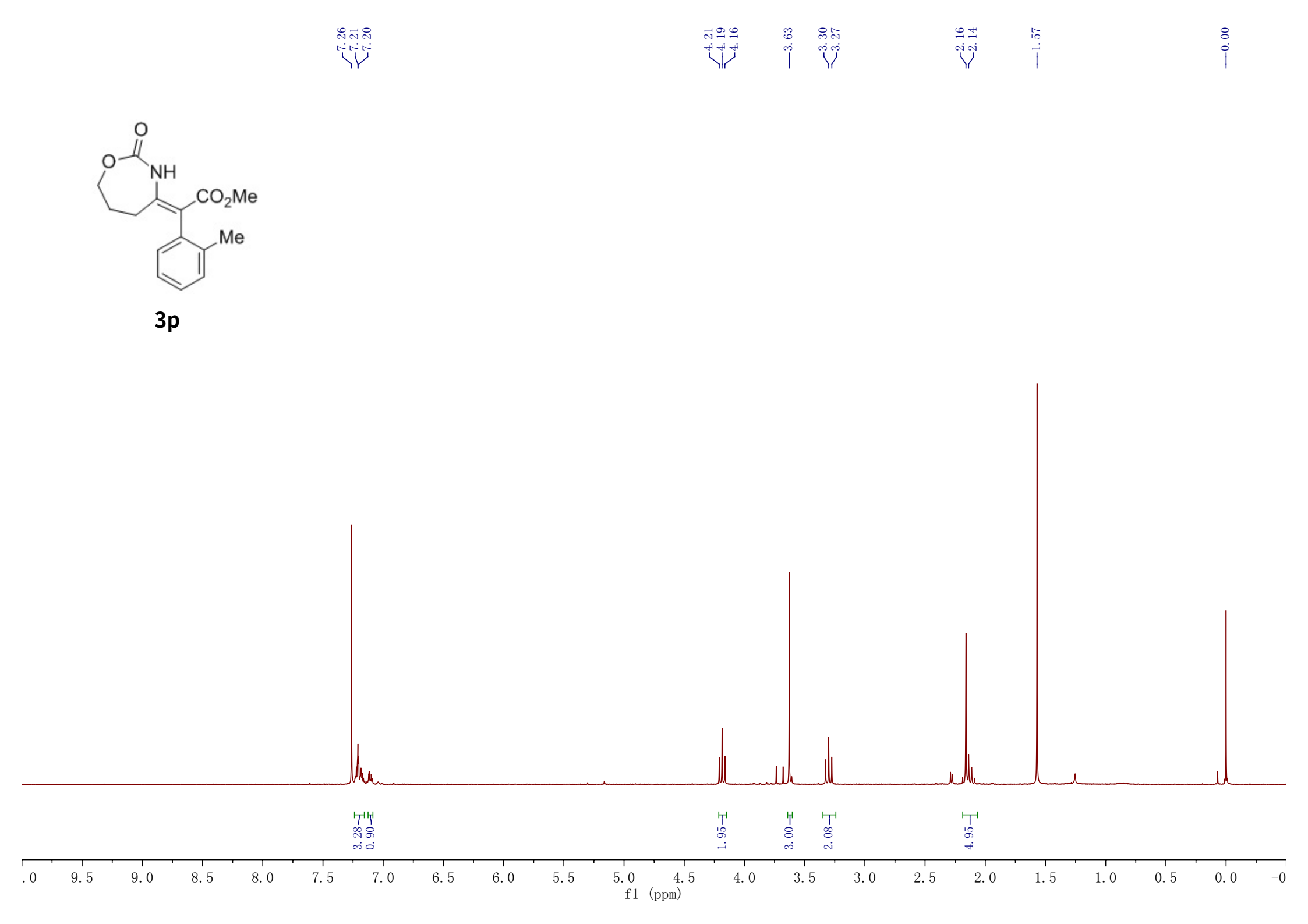
f1 (ppm)

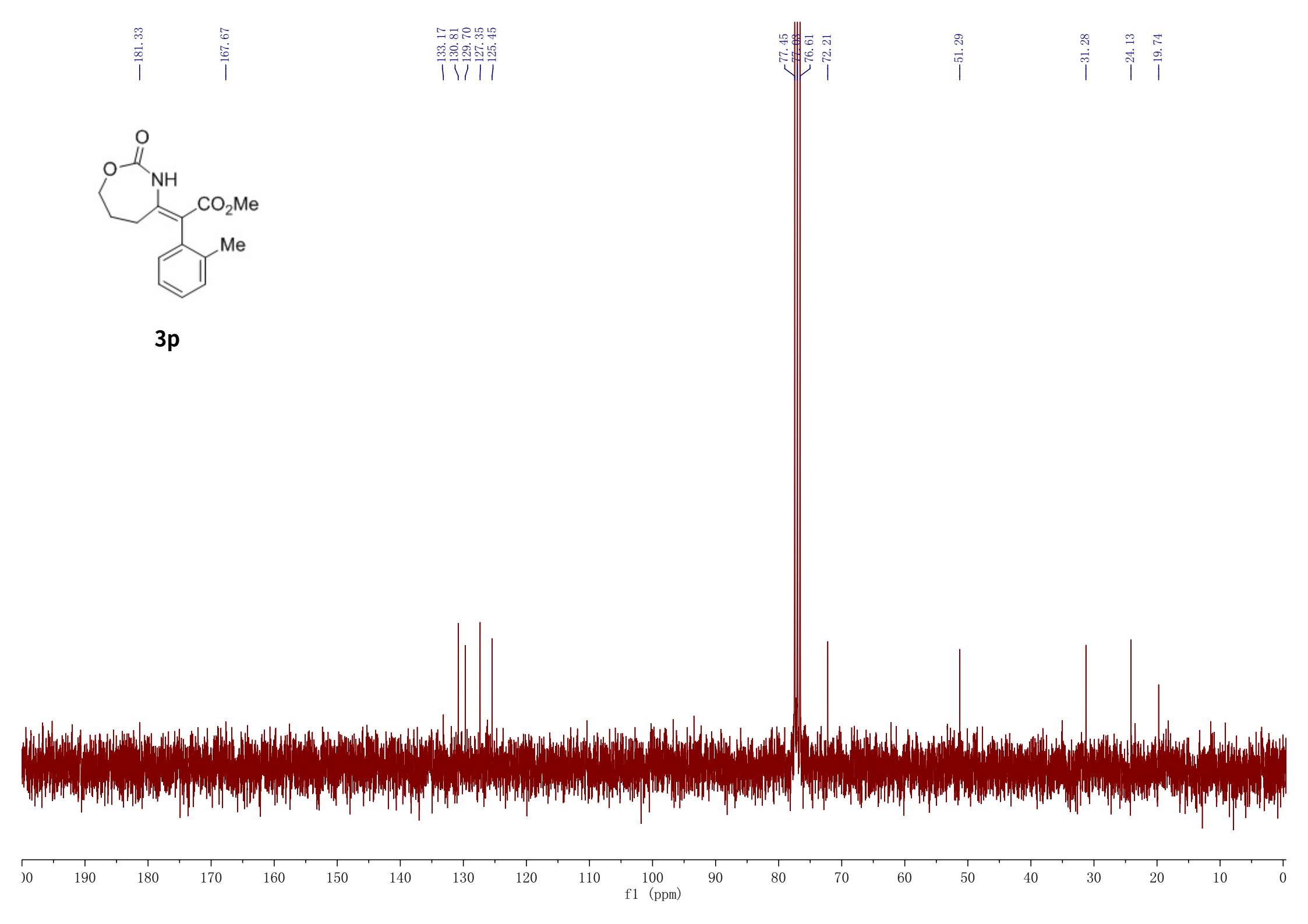

O
O
NH
CO2Me
Me

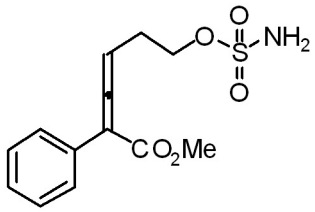
3o

7.26
7.15
4.22
4.20
4.18
3.66
3.29
3.27
3.25
2.44
2.35
2.15
2.13
2.11
1.56
0.07
0.00
4.01
2.02
3.00
1.99
3.04
2.13
f1 (ppm)


175.86
172.32
158.15
136.33
132.43
130.34
129.76
128.68
77.46
77.24
77.03
76.61
72.21
51.31
31.60
24.15
21.33
O
O
NH
CO2Me
Me
3o
f1 (ppm)

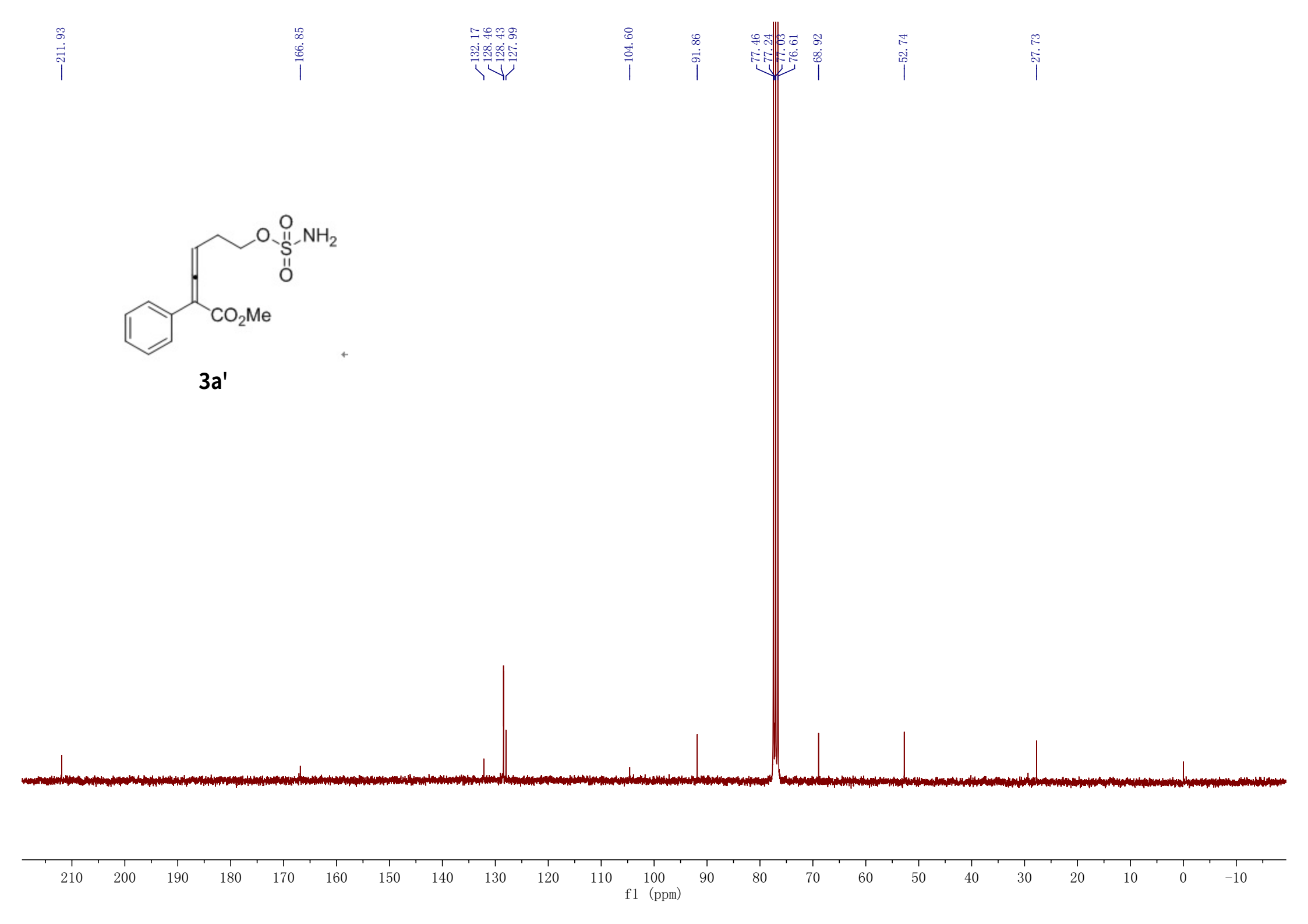

7.26
7.21
7.20
4.21
4.19
4.16
3.63
3.30
3.27
2.16
2.14
1.57
0.00
O
O
NH
CO2Me
Me
3p
3.28
0.90
1.95
3.00
2.08
4.95
f1 (ppm)

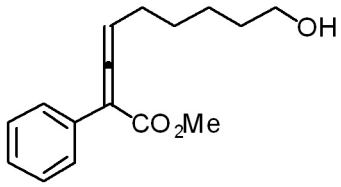

181.33
167.67
133.17
130.81
129.70
127.35
125.45
77.45
77.08
76.61
72.21
51.29
31.28
24.13
19.74
O
O
NH
CO2Me
Me
3p
f1 (ppm)


O
O
S
NH2
O
O
CO2Me

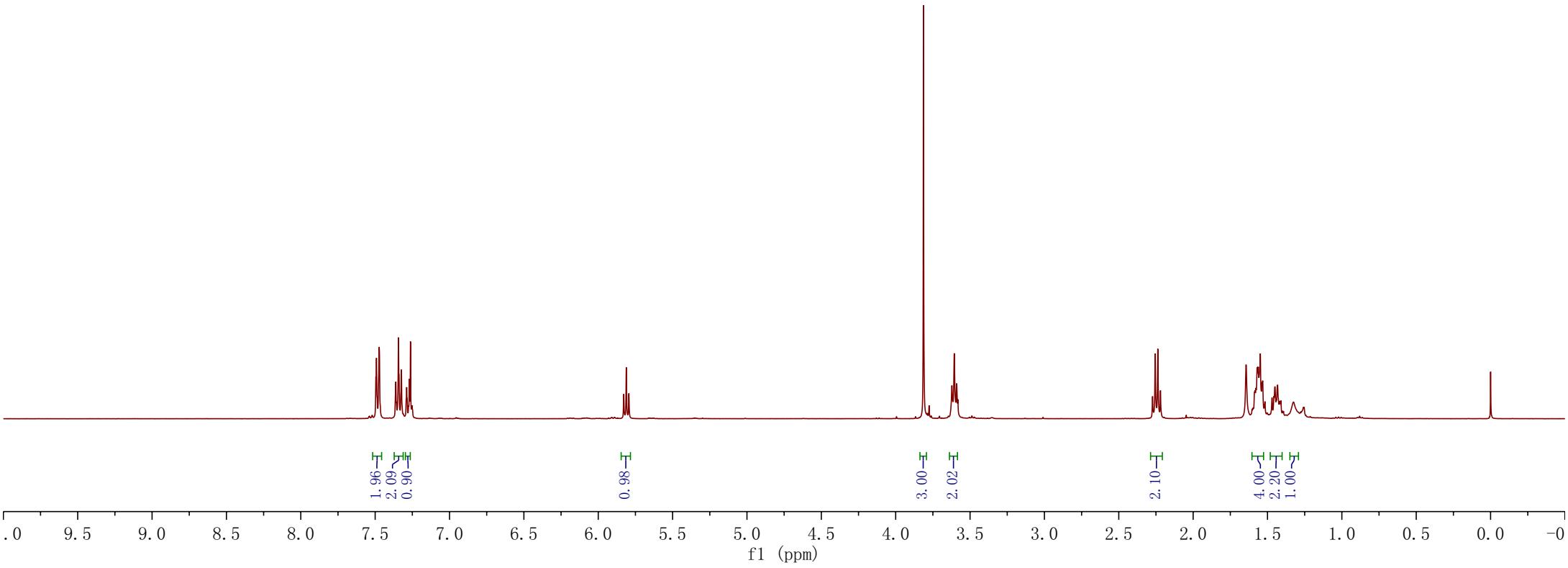
3a'

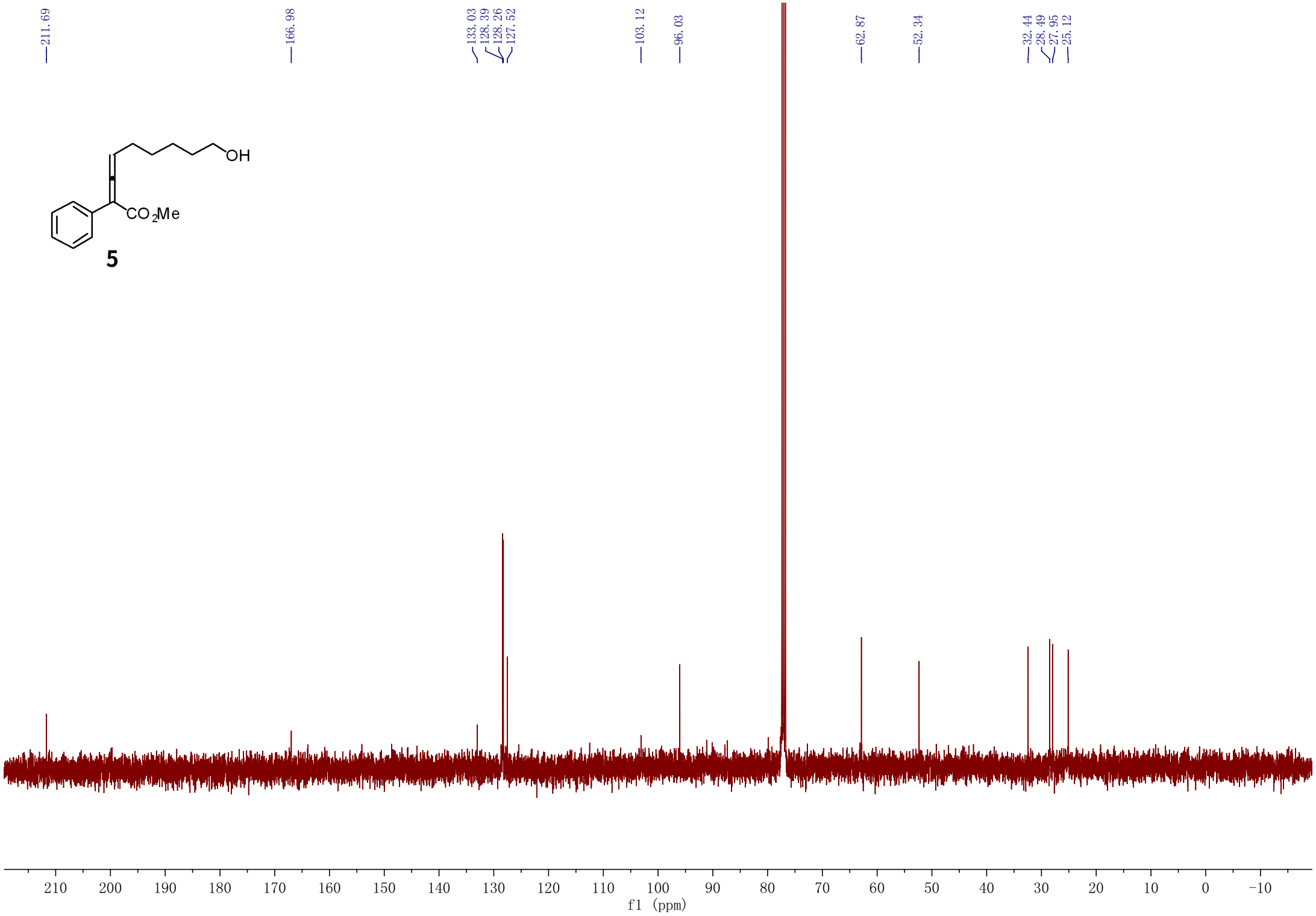
7.49
7.49
7.46
7.46
7.39
7.39
7.37
7.36
7.35
7.34
7.33
7.32
7.32
7.26
5.89
5.86
5.84
4.79
4.37
4.35
4.33
2.68
2.66
2.64
1.59
2.04
3.35
1.07
2.16
2.35
3.00
1.96
f1 (ppm)


211.93
166.85
132.17
128.46
128.43
127.99
104.60
91.86
77.46
77.24
77.03
76.61
68.92
52.74
27.73
O
O
S
O
NH2
O
CO2Me
3a'
f1 (ppm)


OH
CO2Me

5


7.49
7.49
7.47
7.36
7.36
7.34
7.34
7.32
7.29
7.29
7.28
7.27
7.26
5.83
5.81
5.79
3.81
3.62
3.61
3.59
2.27
2.26
2.24
2.22
1.64
1.58
1.58
1.57
1.56
1.55
1.55
1.53
1.52
1.47
1.46
1.45
1.44
1.43
1.42
1.41
1.33
1.25
0.00
1.96
2.09
0.90
0.98
3.00
2.02
2.10
4.00
2.20
1.00
f1 (ppm)


211.69
166.98
133.03
128.39
128.26
127.52
103.12
96.03
62.87
52.34
32.44
28.49
27.95
25.12
OH
CO2Me
5
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)