Electronic Supplementary Material (ESI) for RSC Advances
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Supporting information

Palladium-catalyzed annulation reactions of methyl *o*-halobenzoates with azabicyclic alkenes: a general protocol for the construction of benzo[*c*]phenanthridine derivatives

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State Key Laboratory of Elemento-Organic Chemistry, Nankai University, Tianjin 300071, China.

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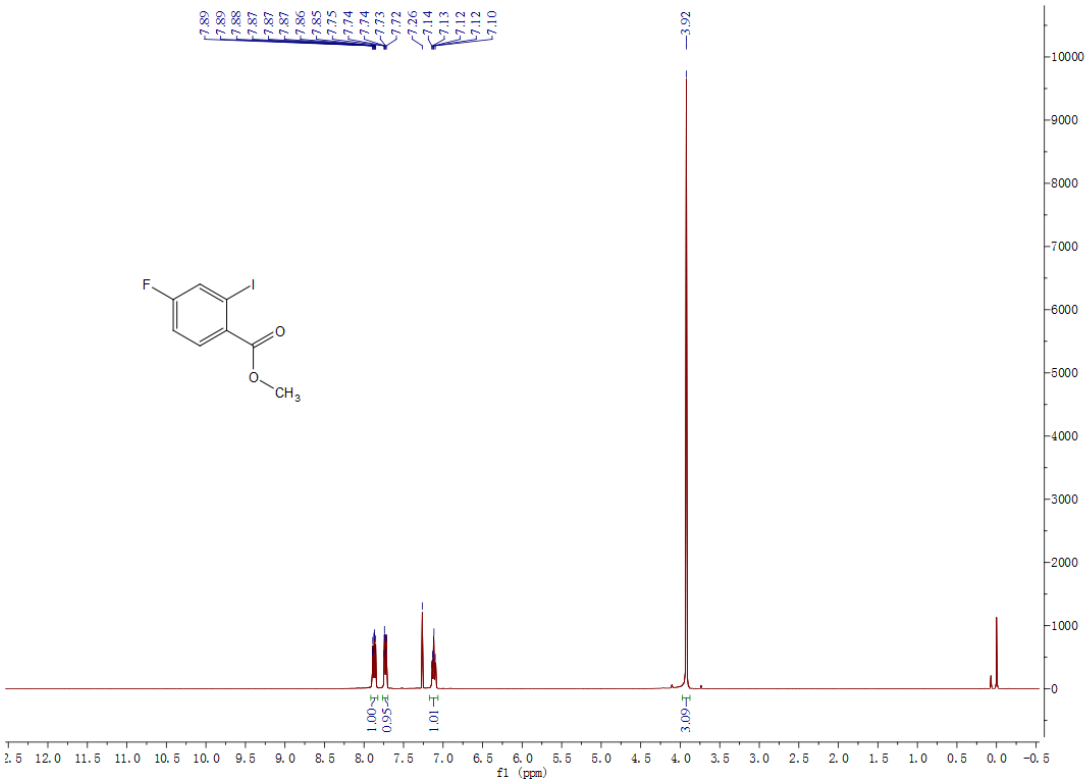
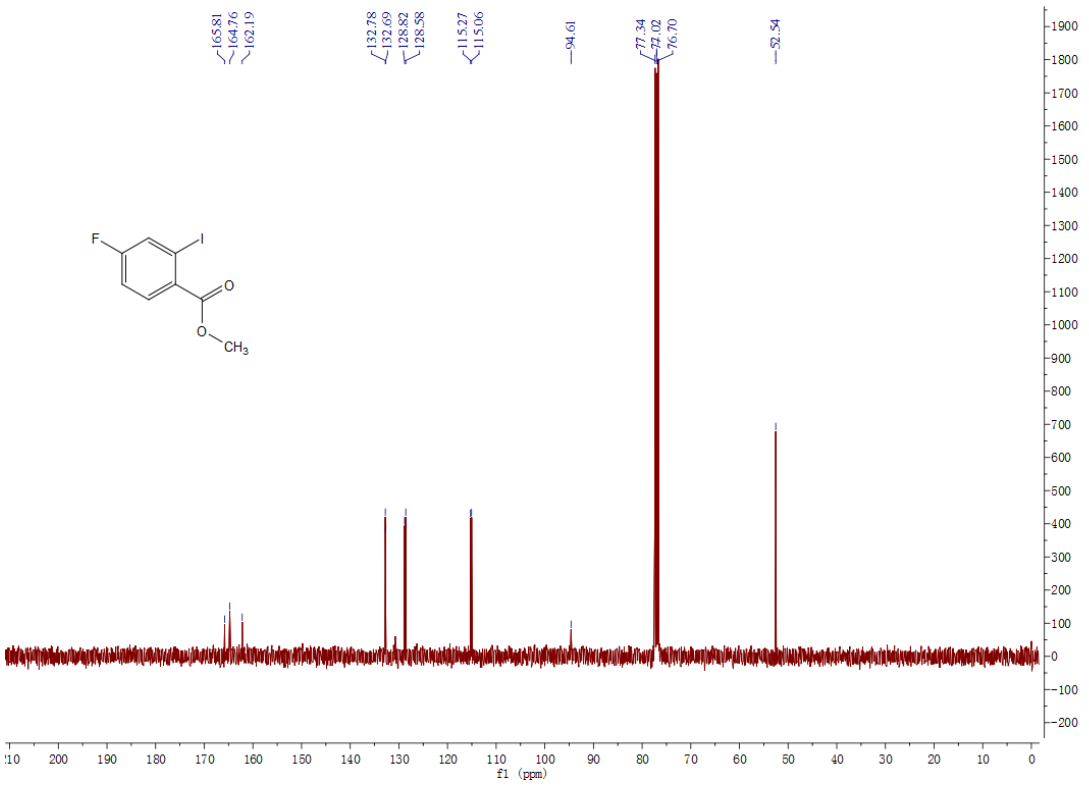
1a





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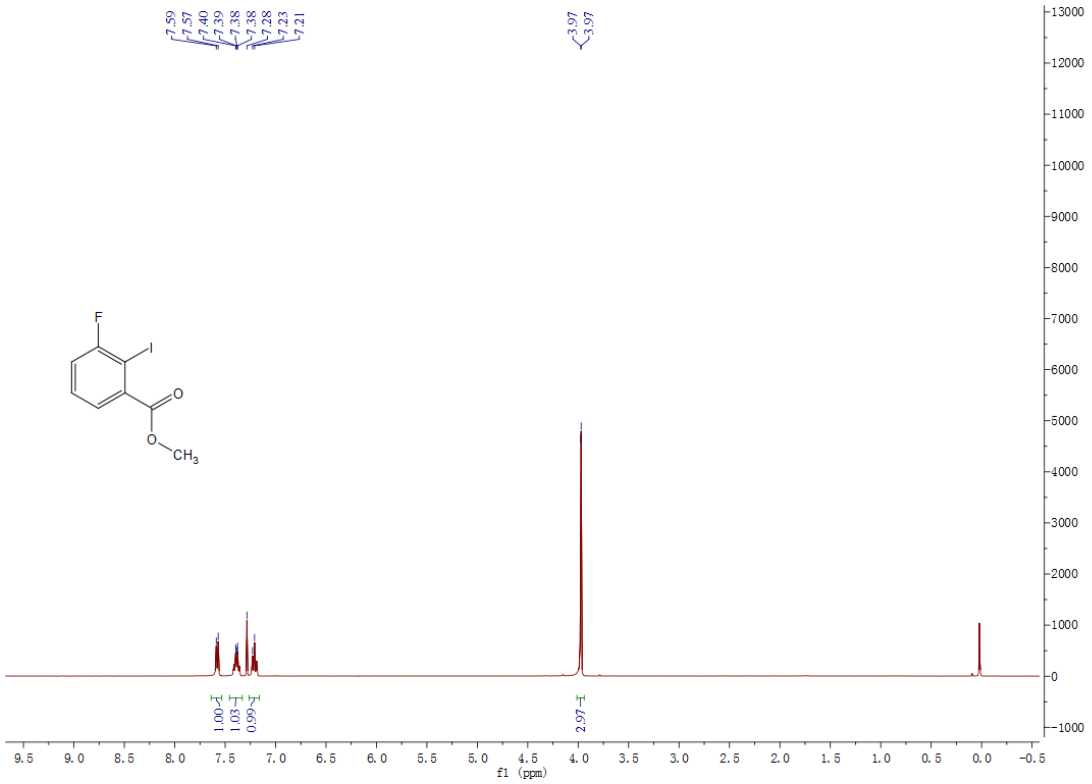
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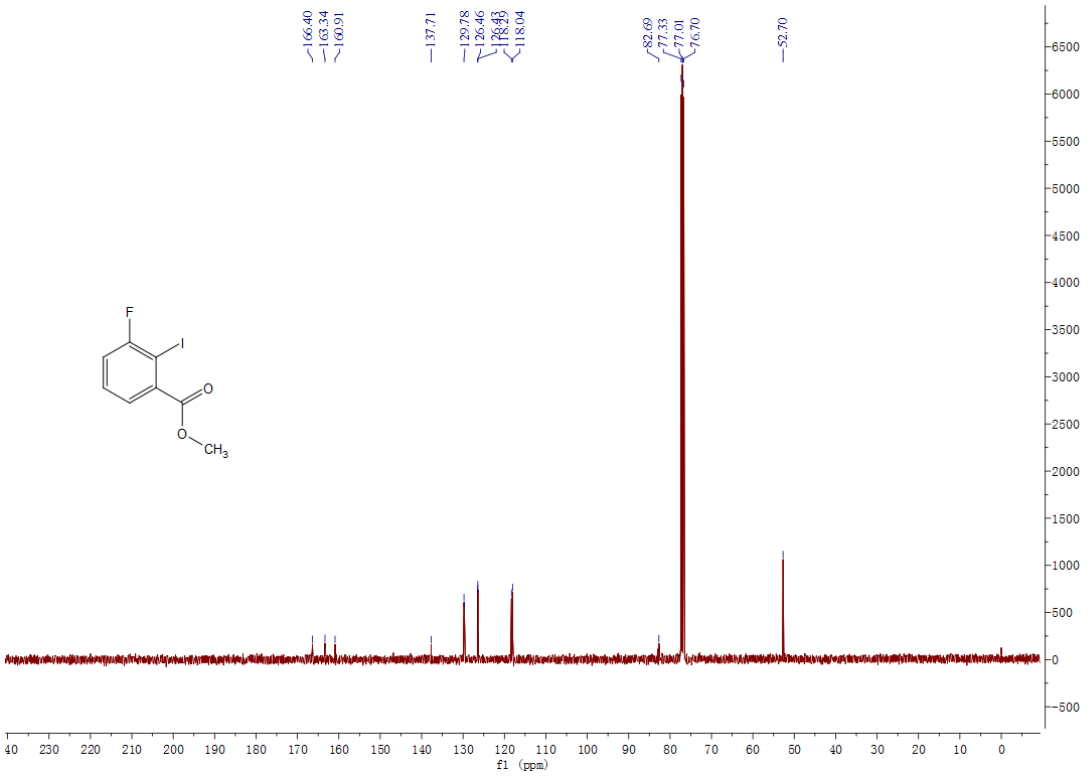
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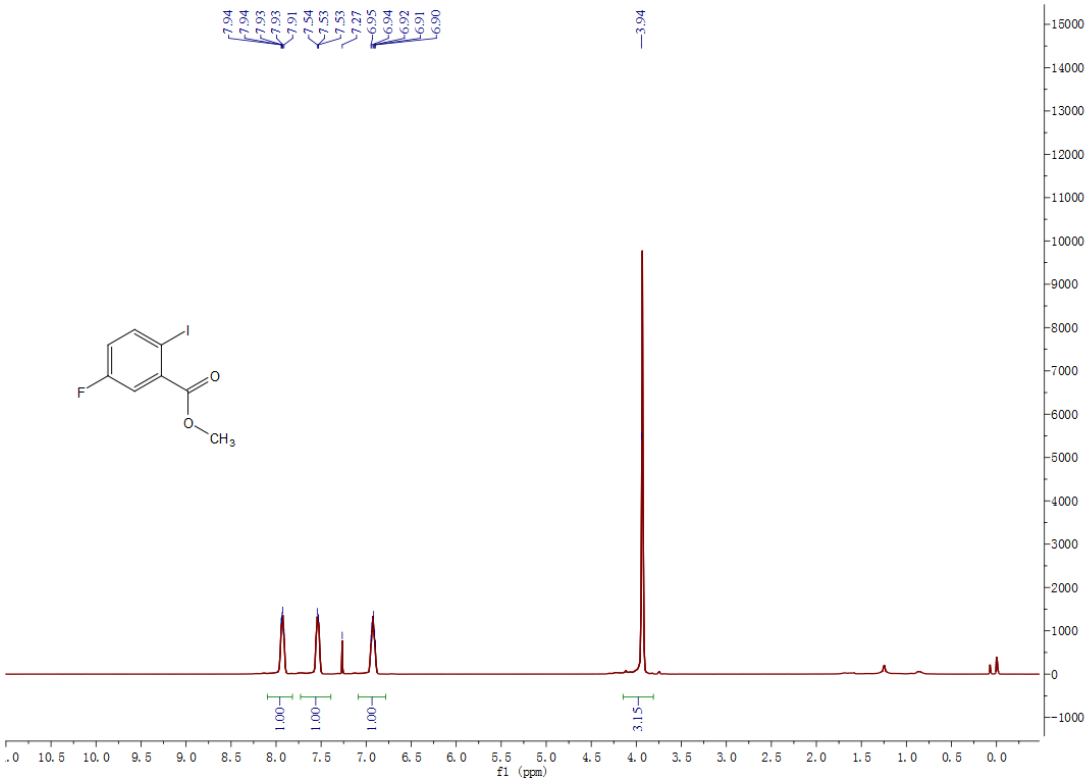
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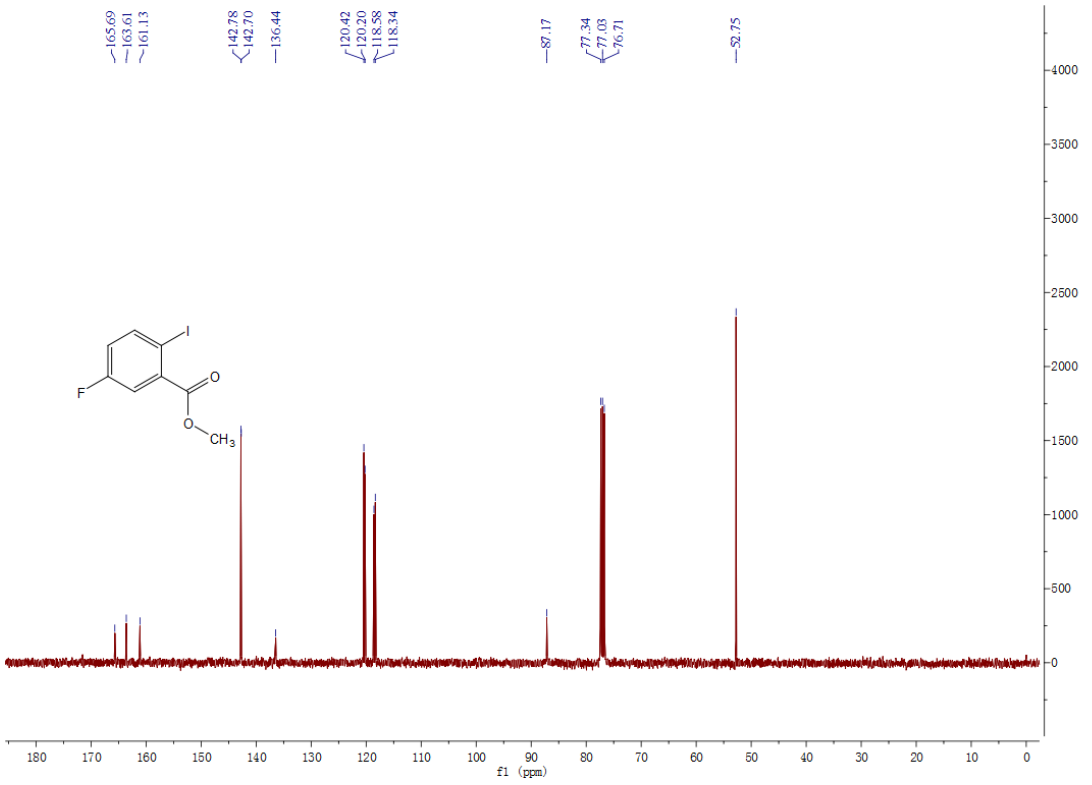
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O
CH3
f1 (ppm)

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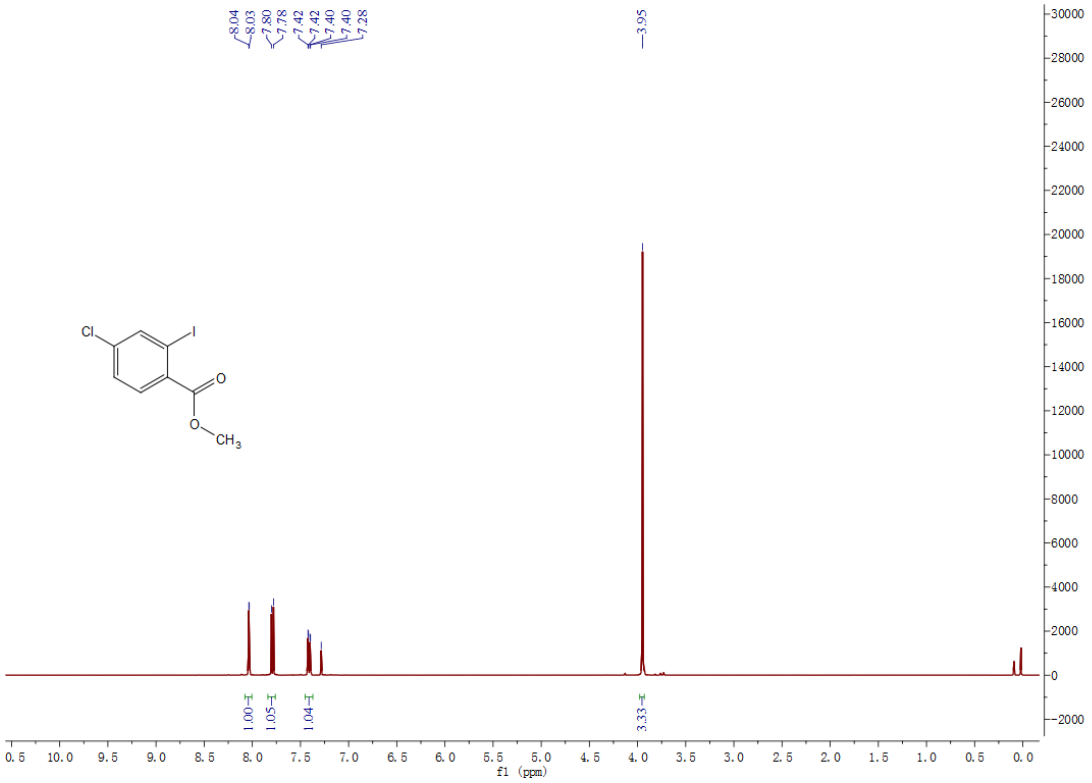

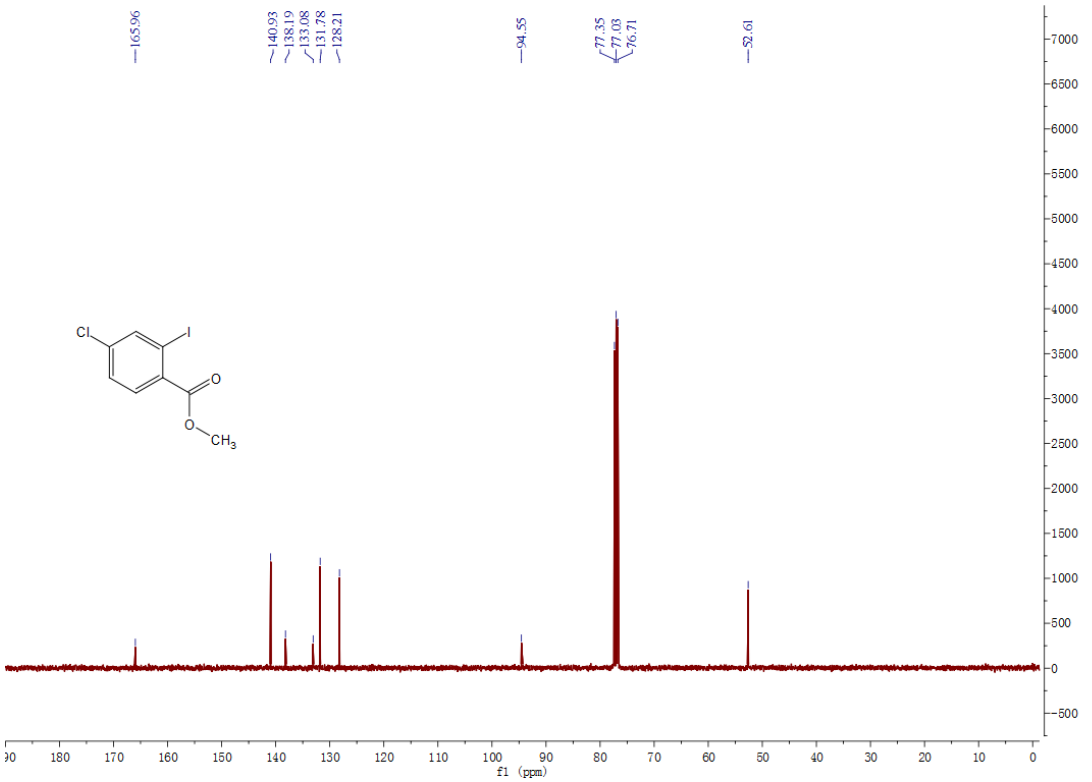

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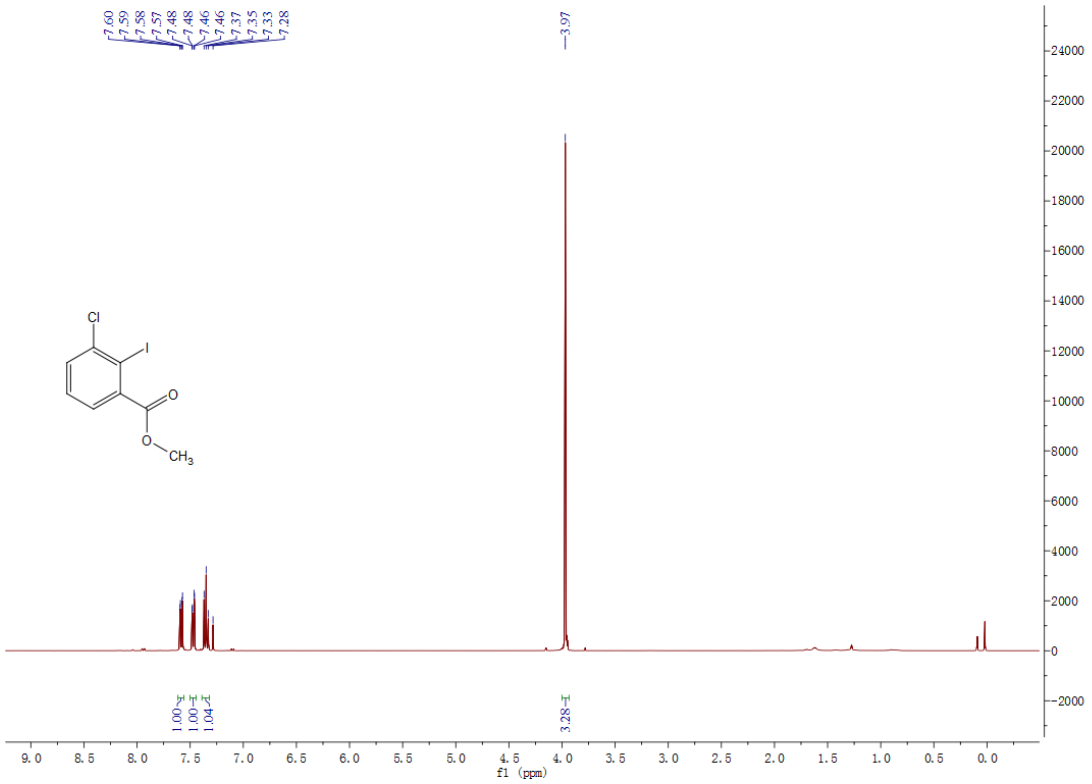
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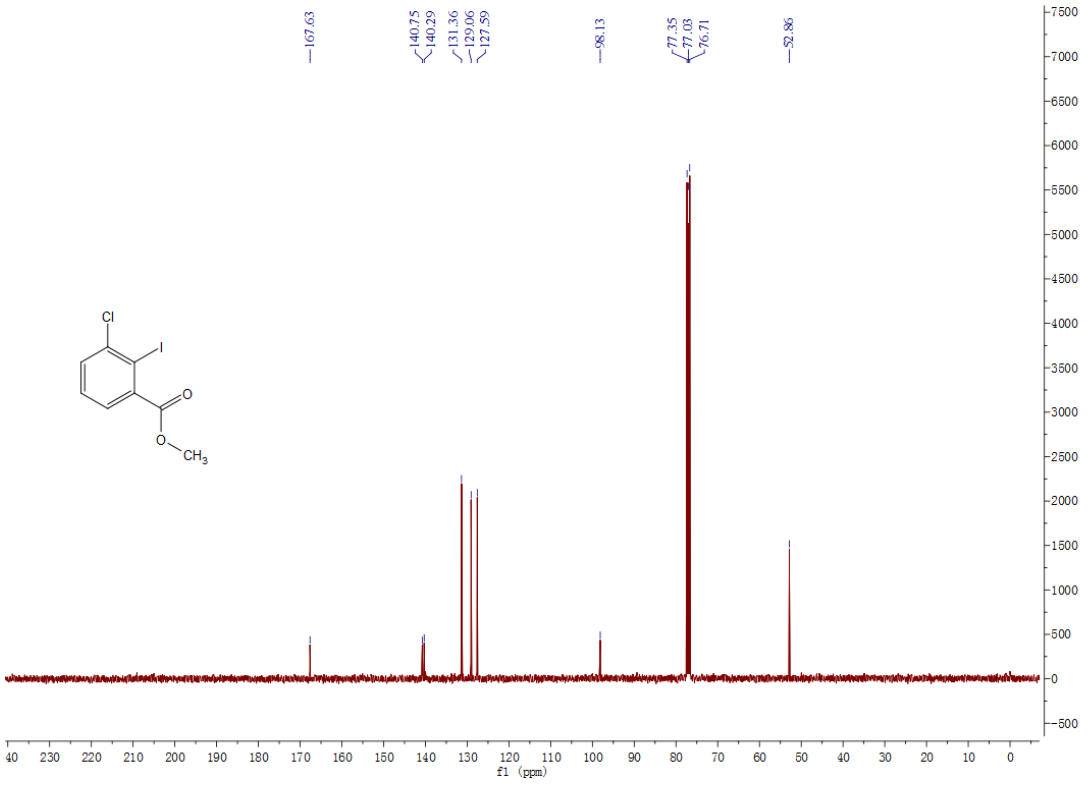
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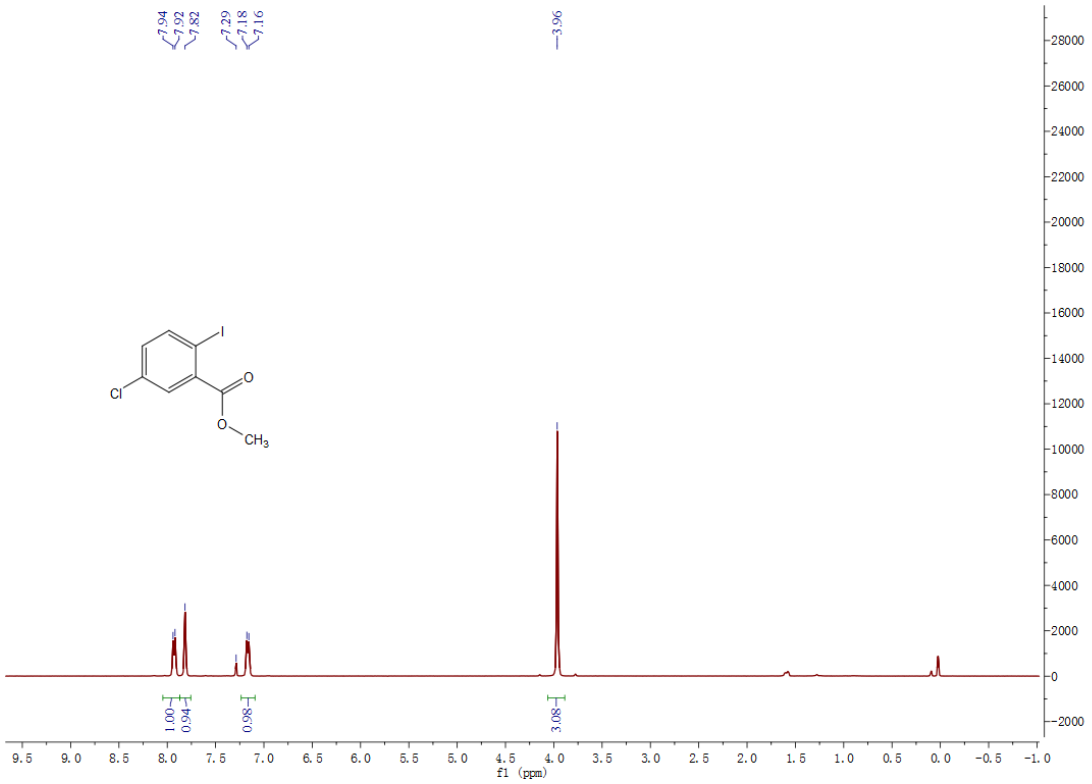
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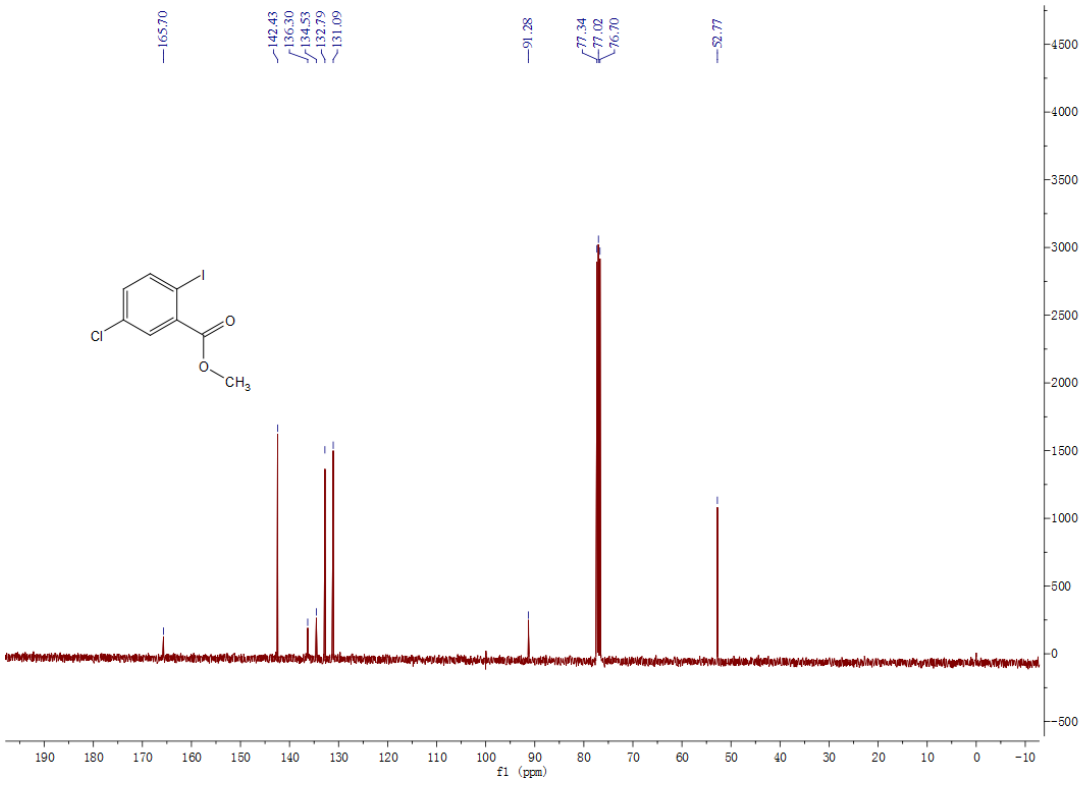
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f1 (ppm)

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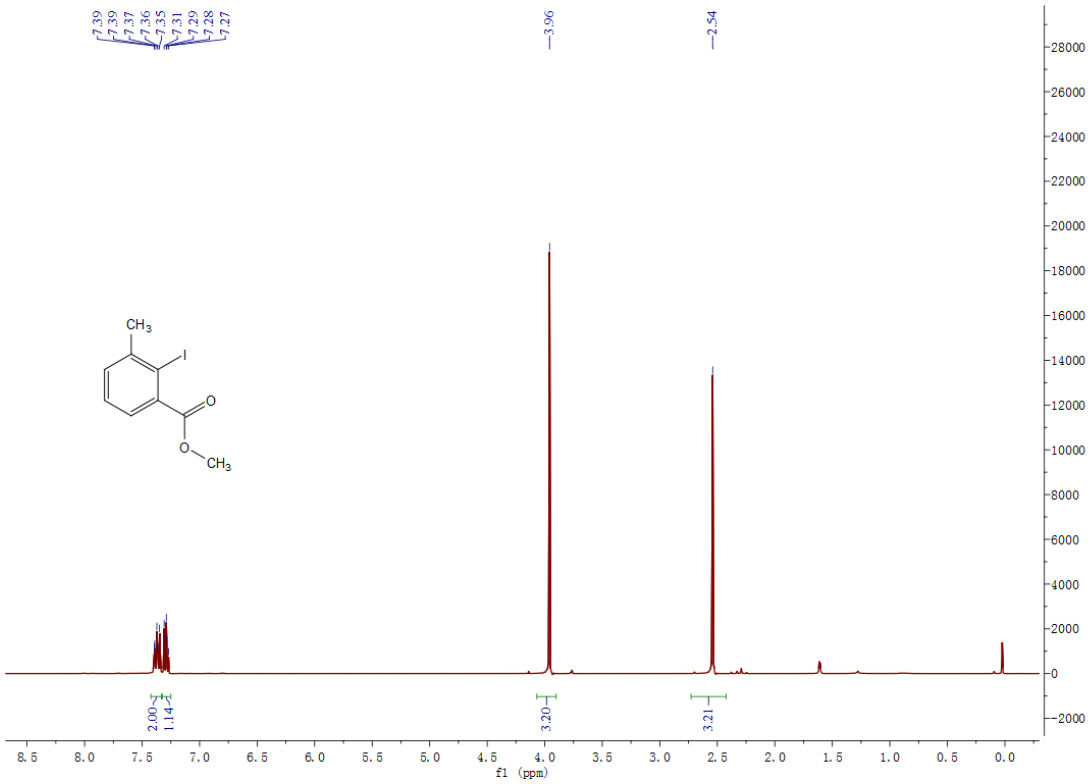
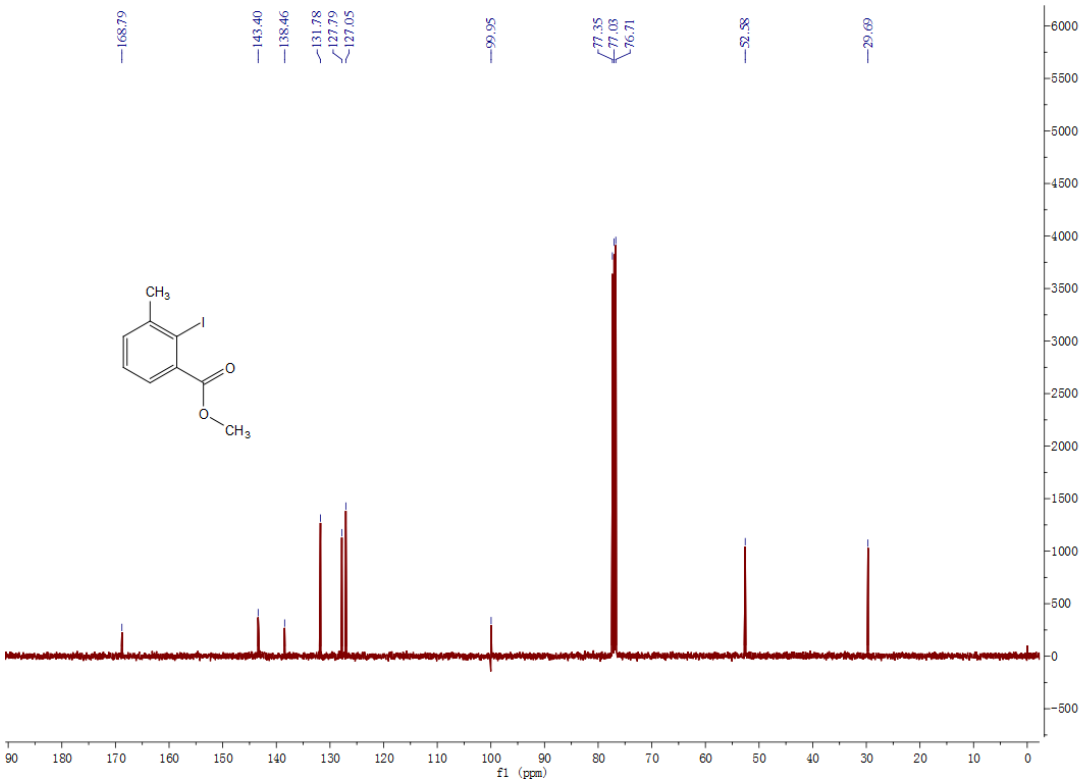
1g





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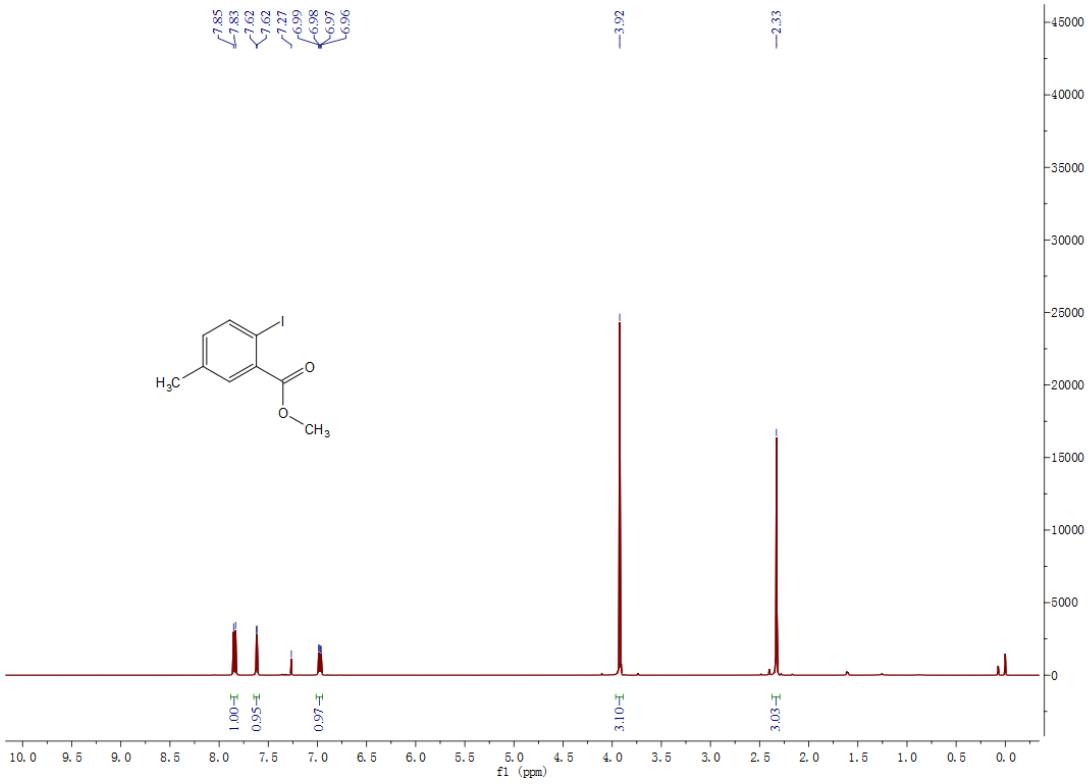
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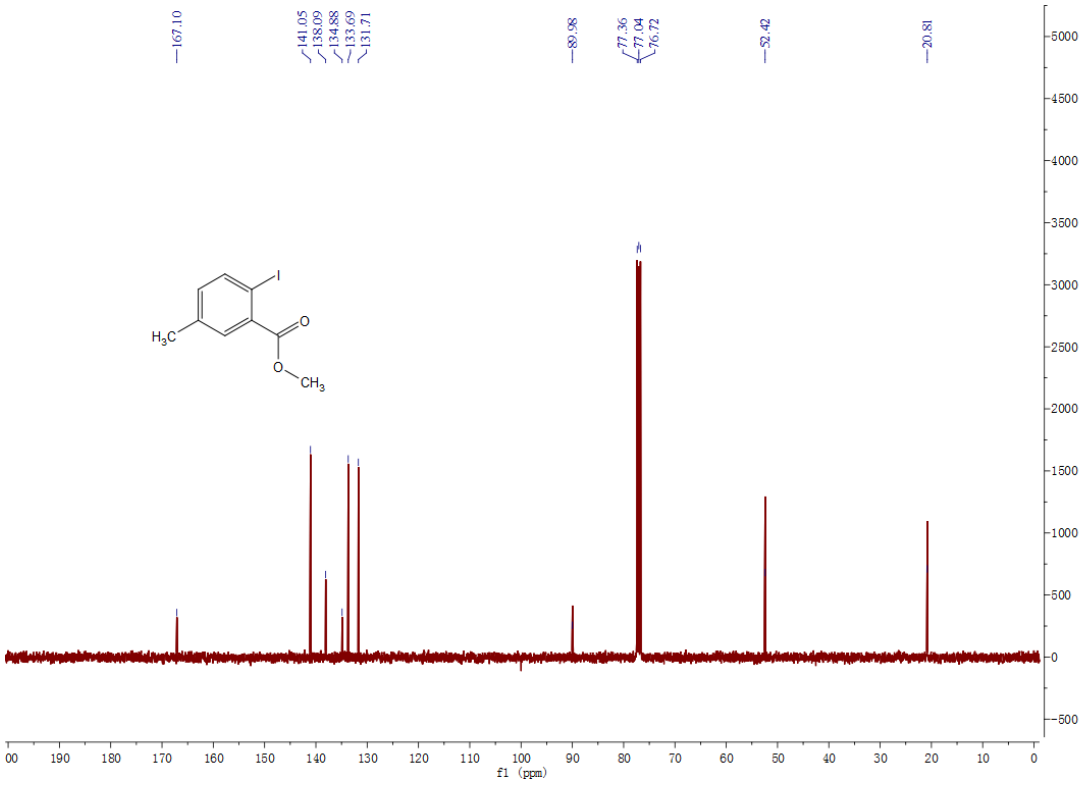
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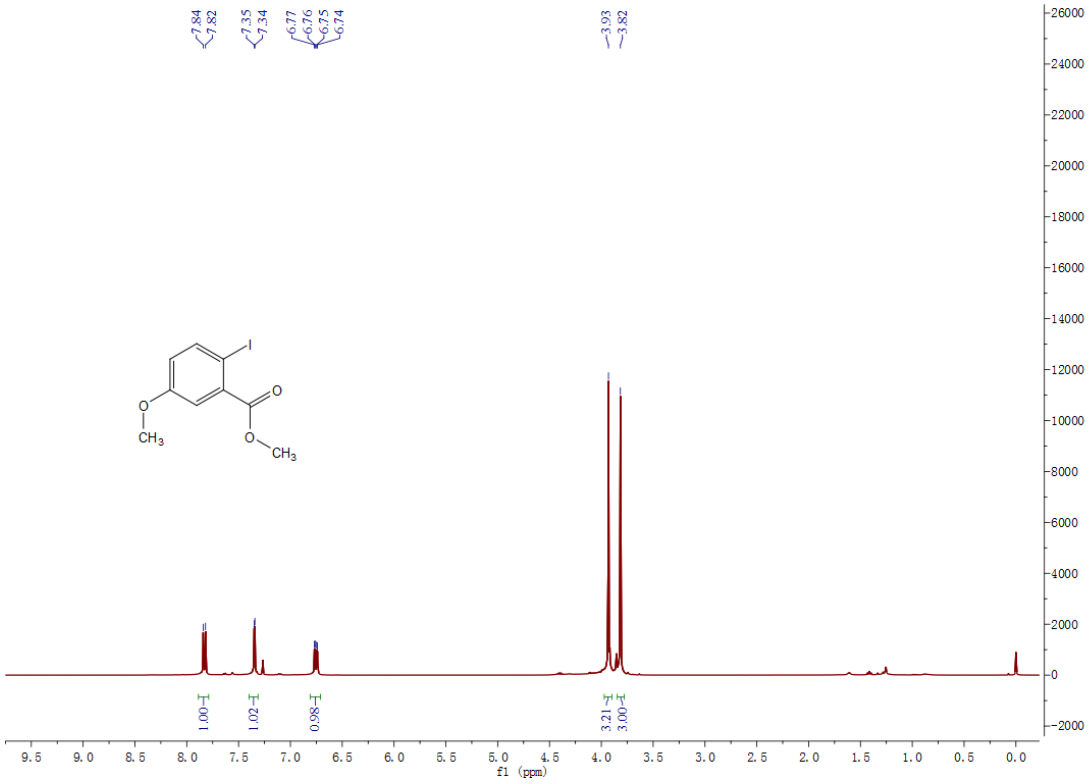
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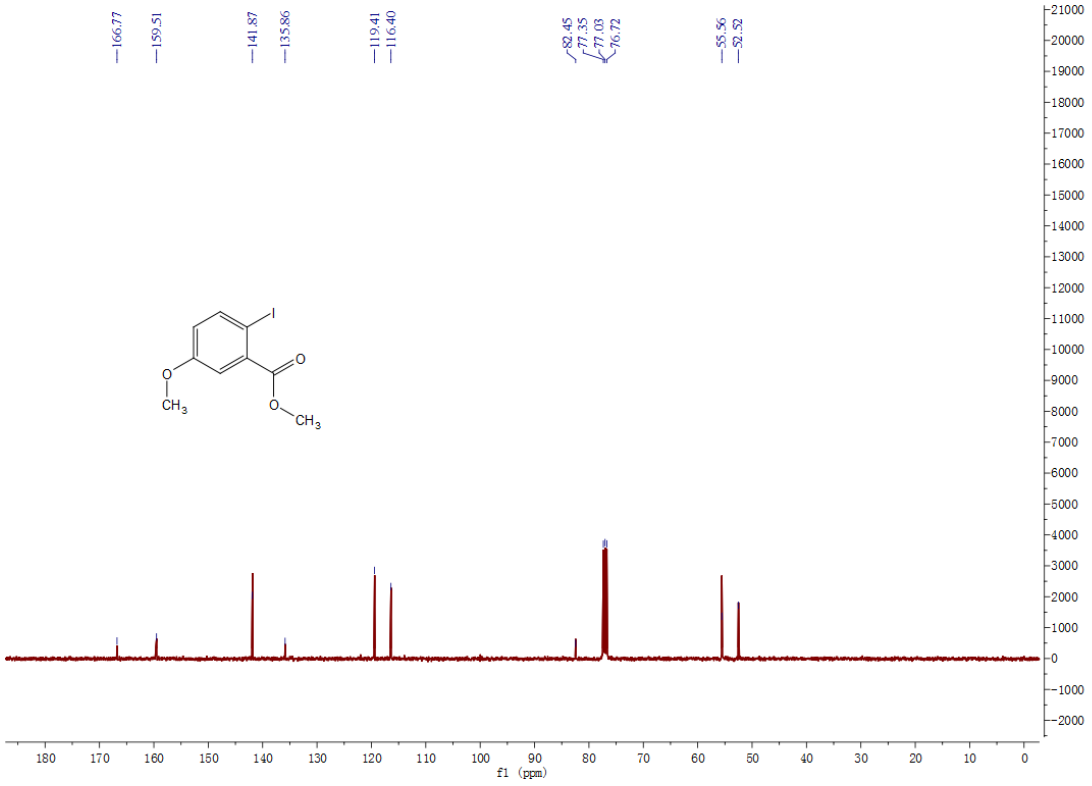
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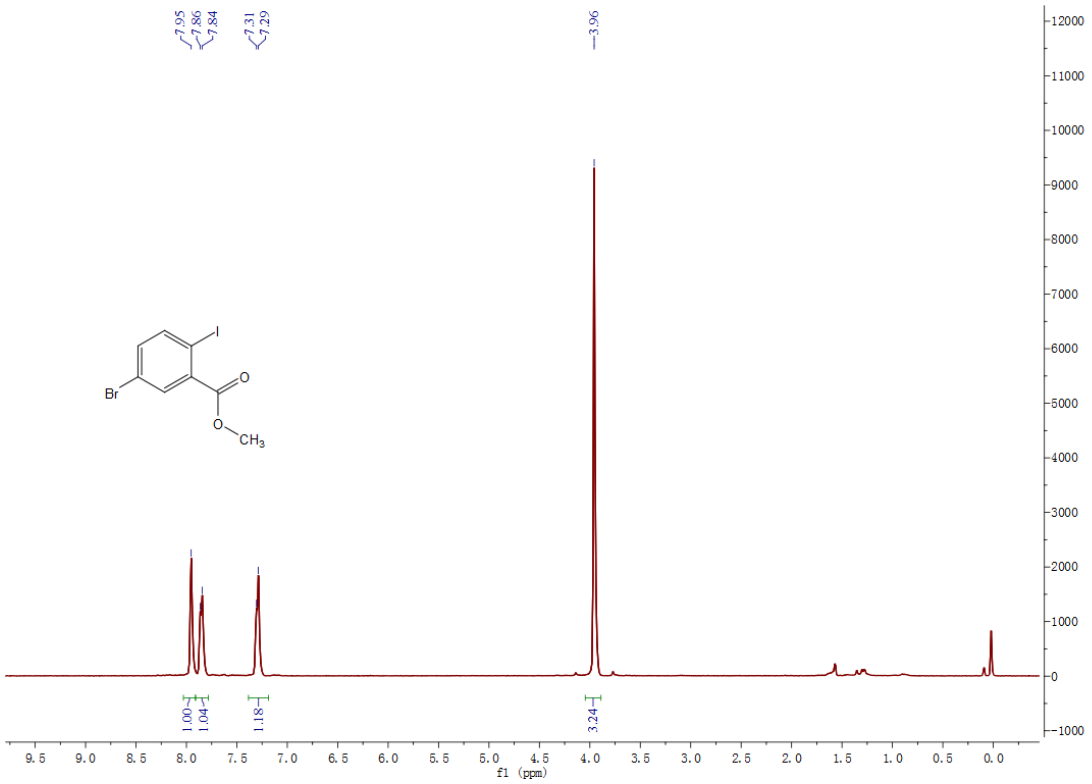
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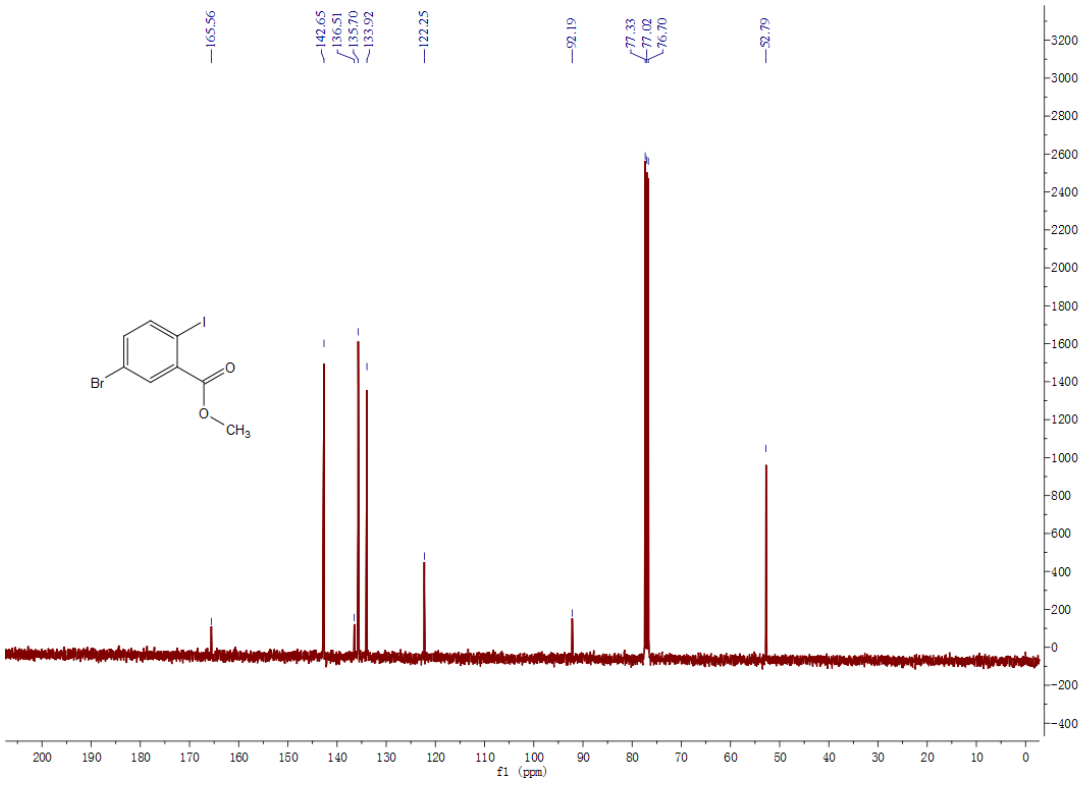
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f1 (ppm)

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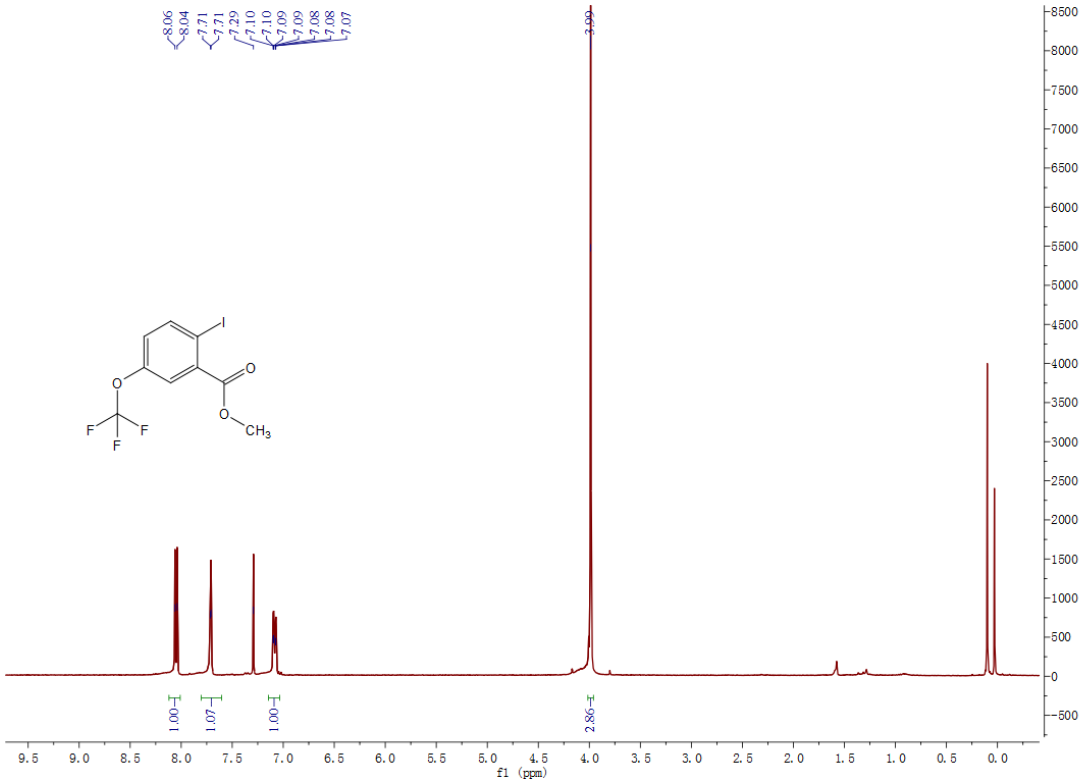

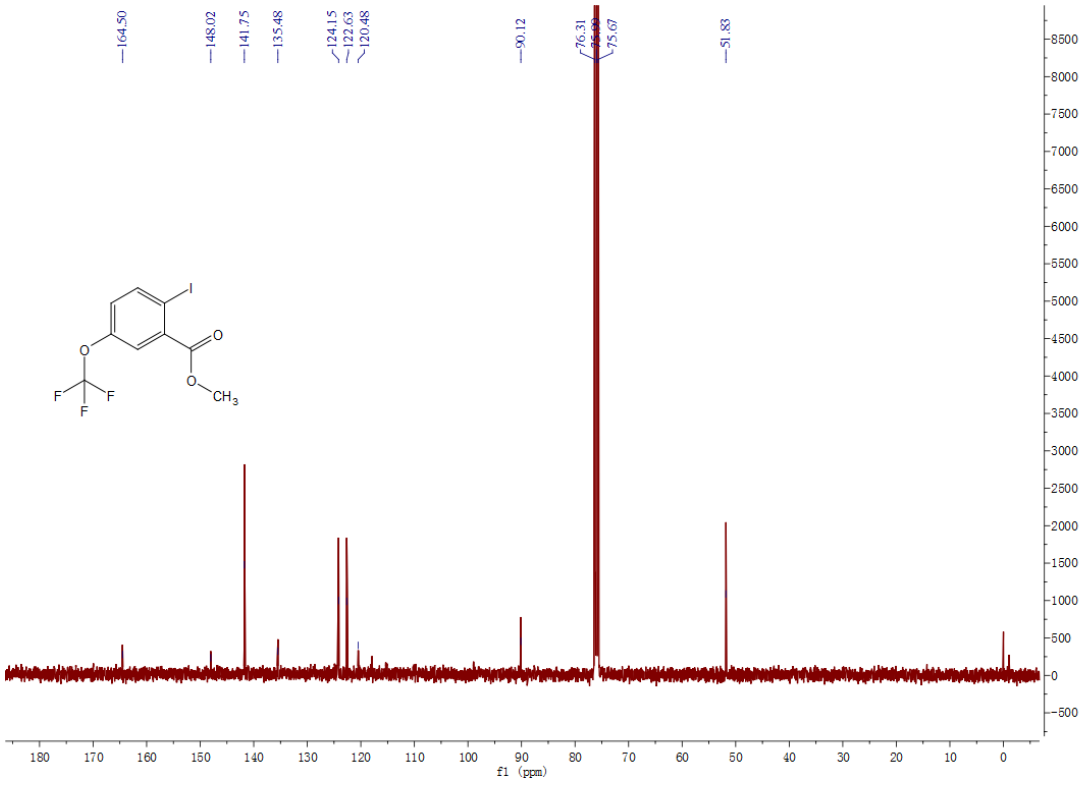

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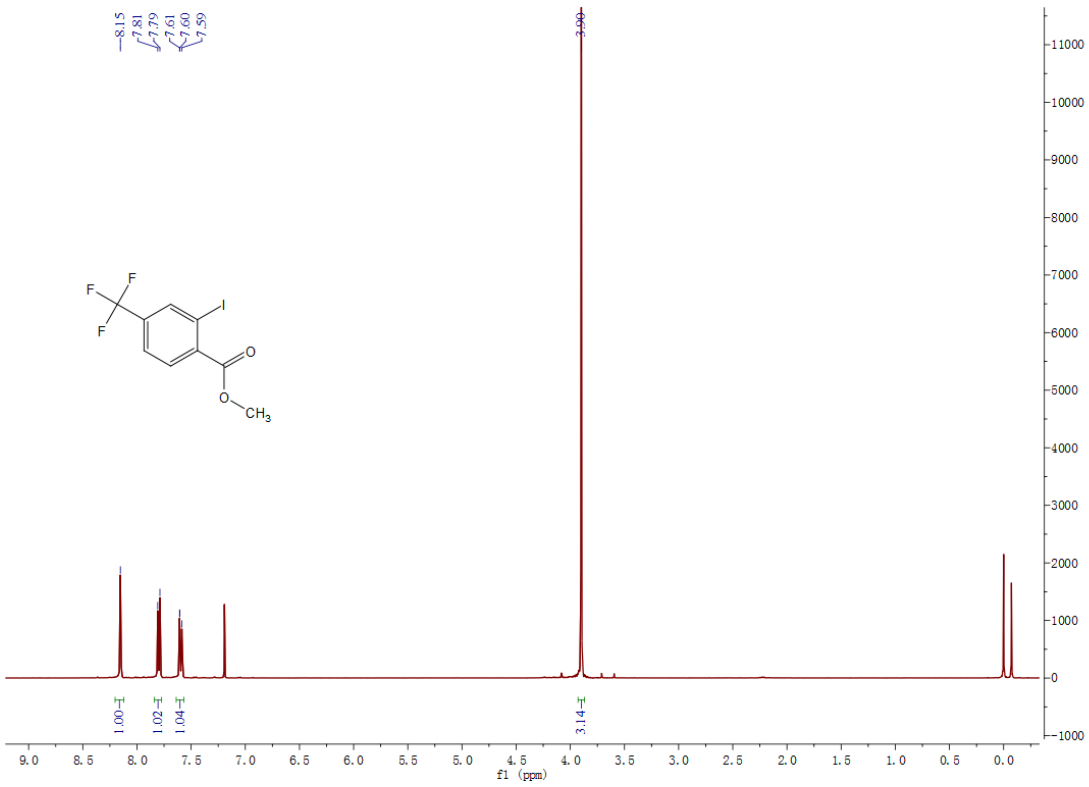
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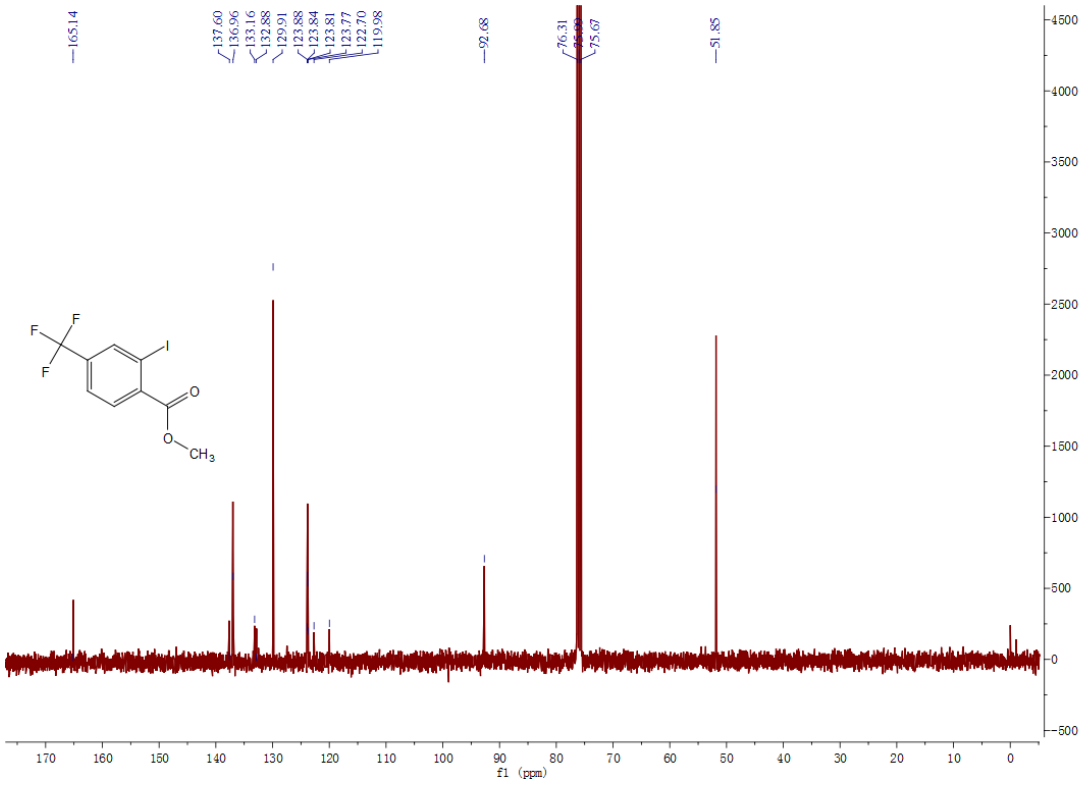
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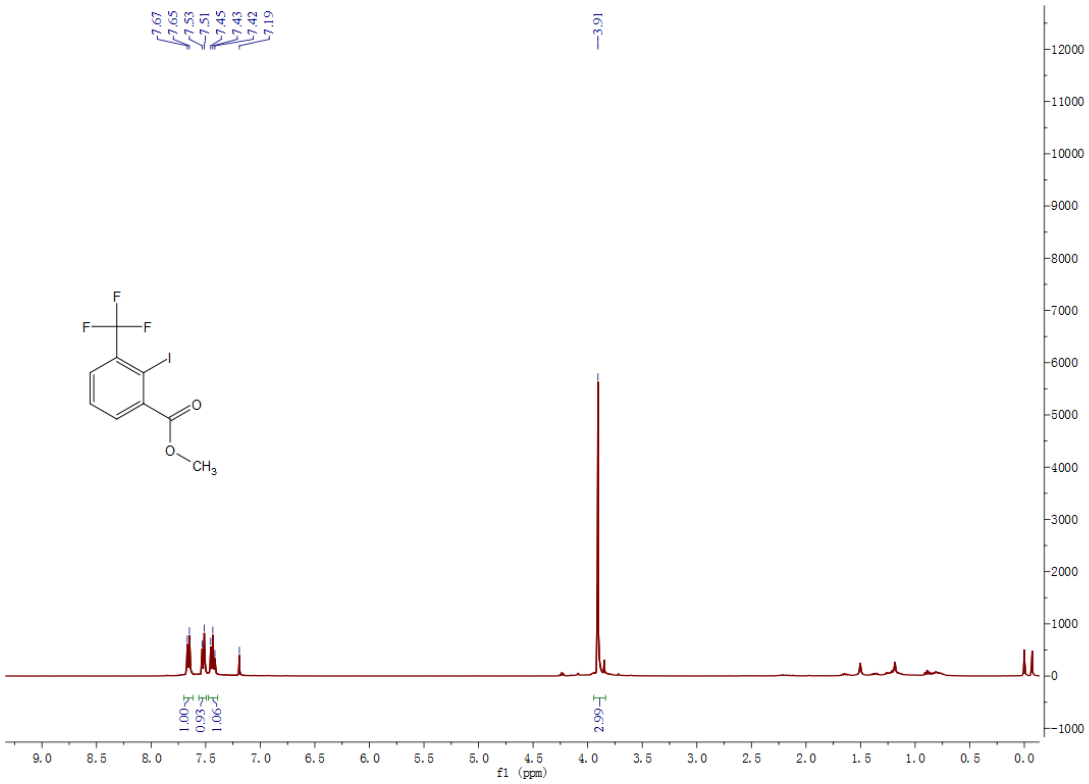
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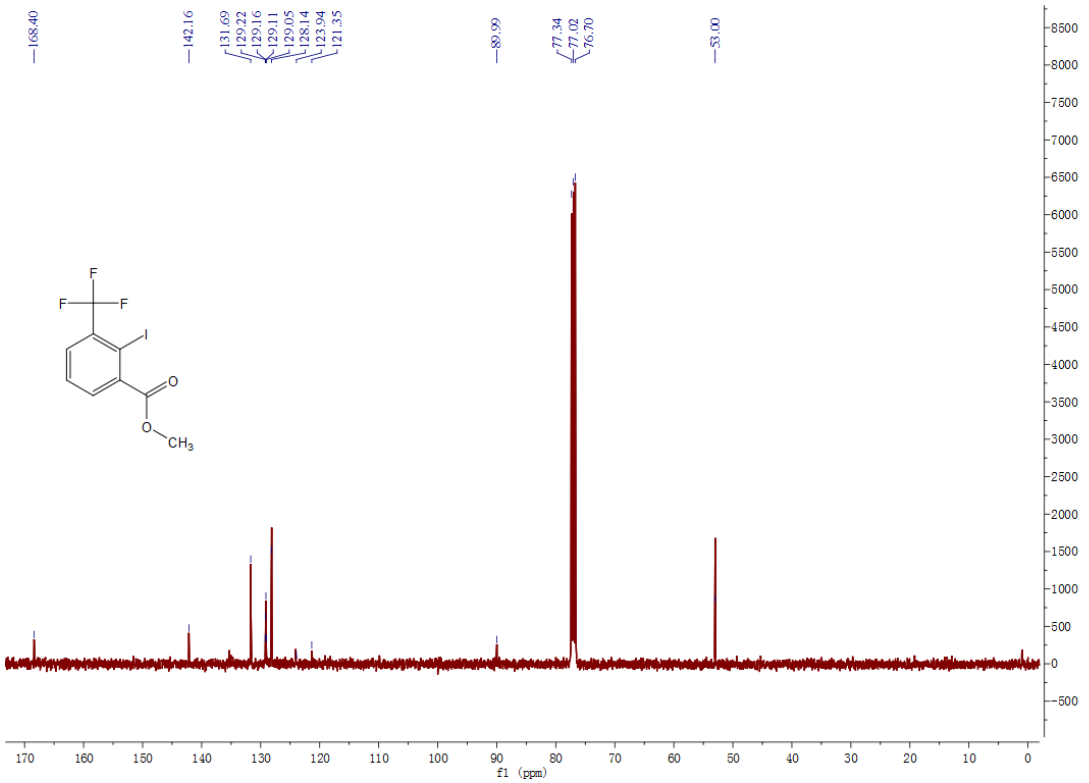
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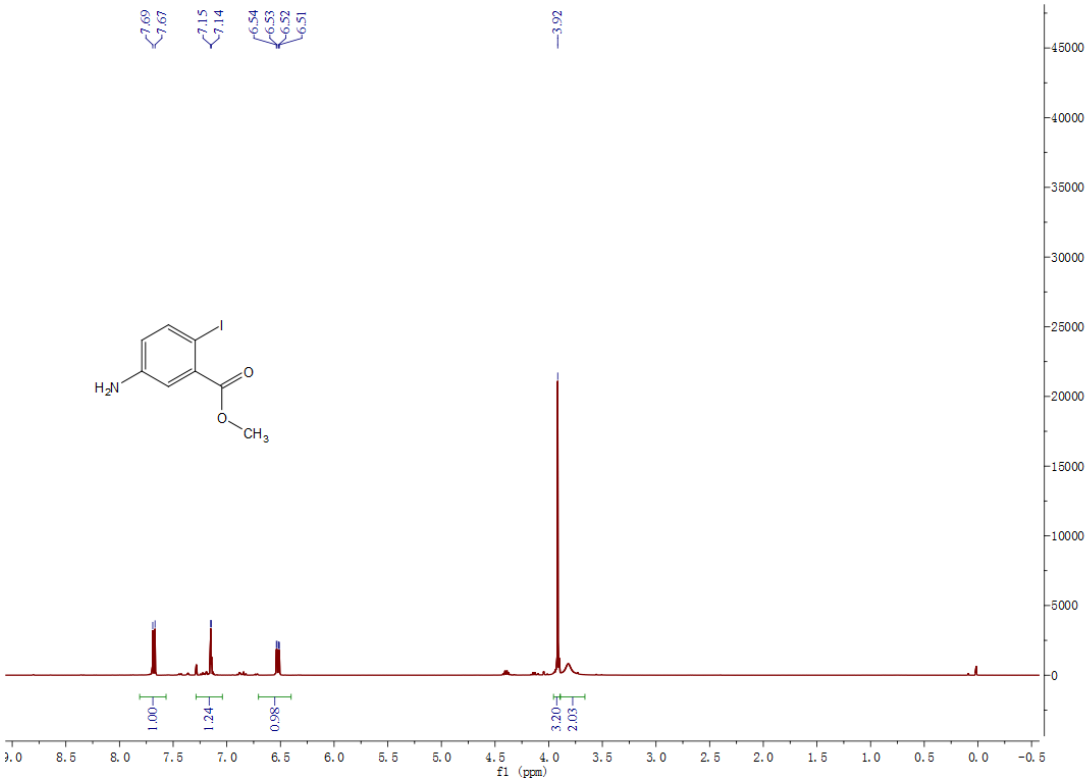
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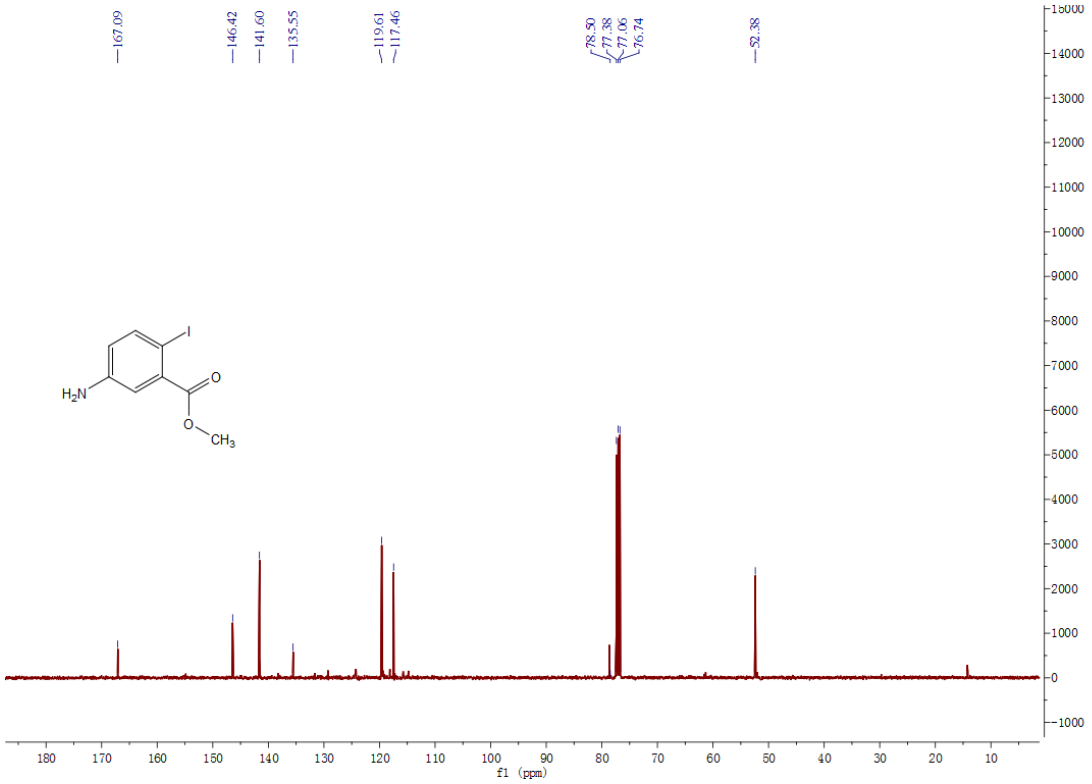
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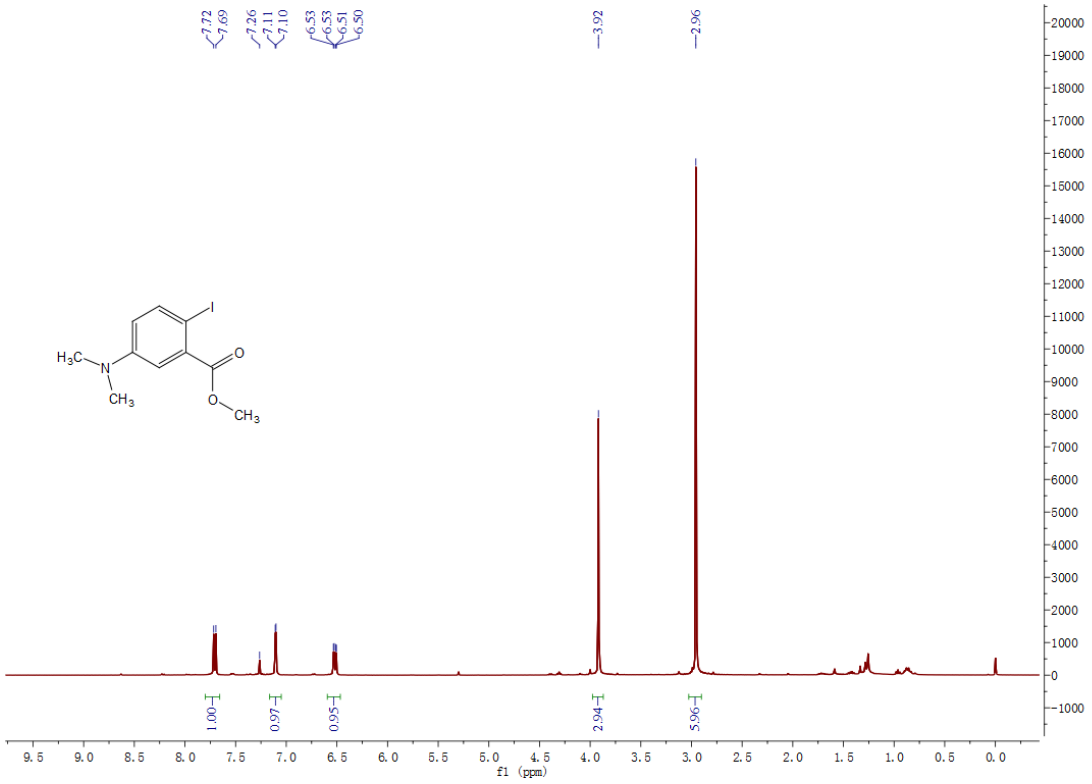
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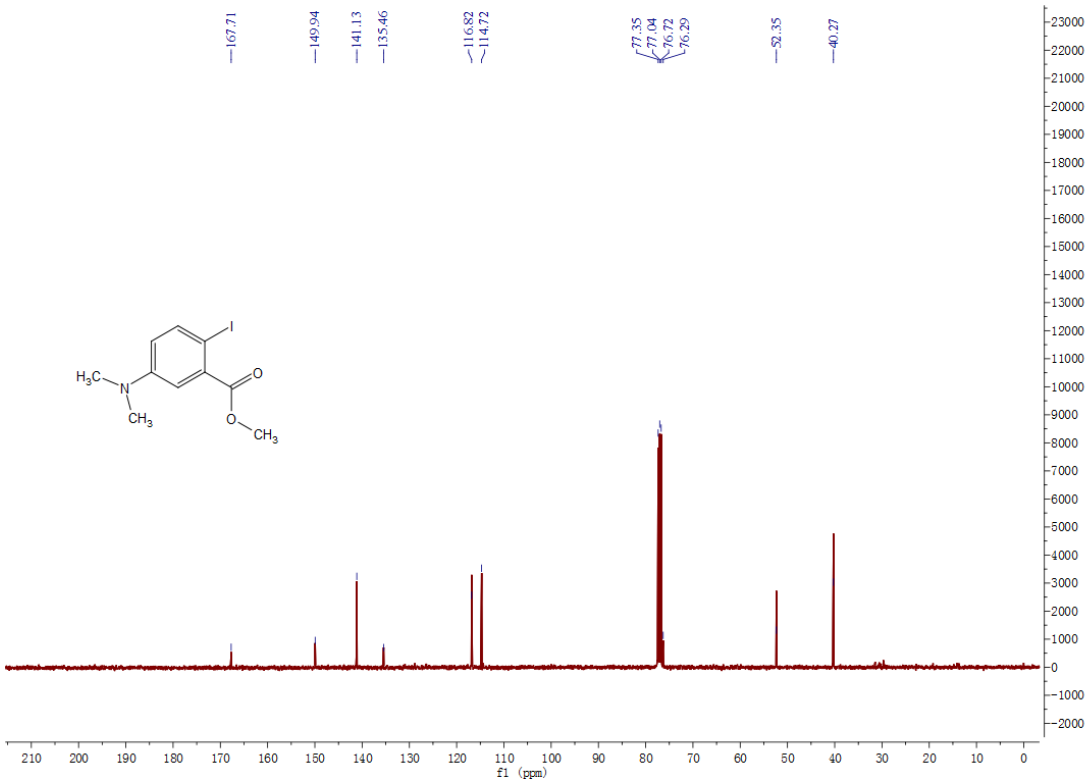
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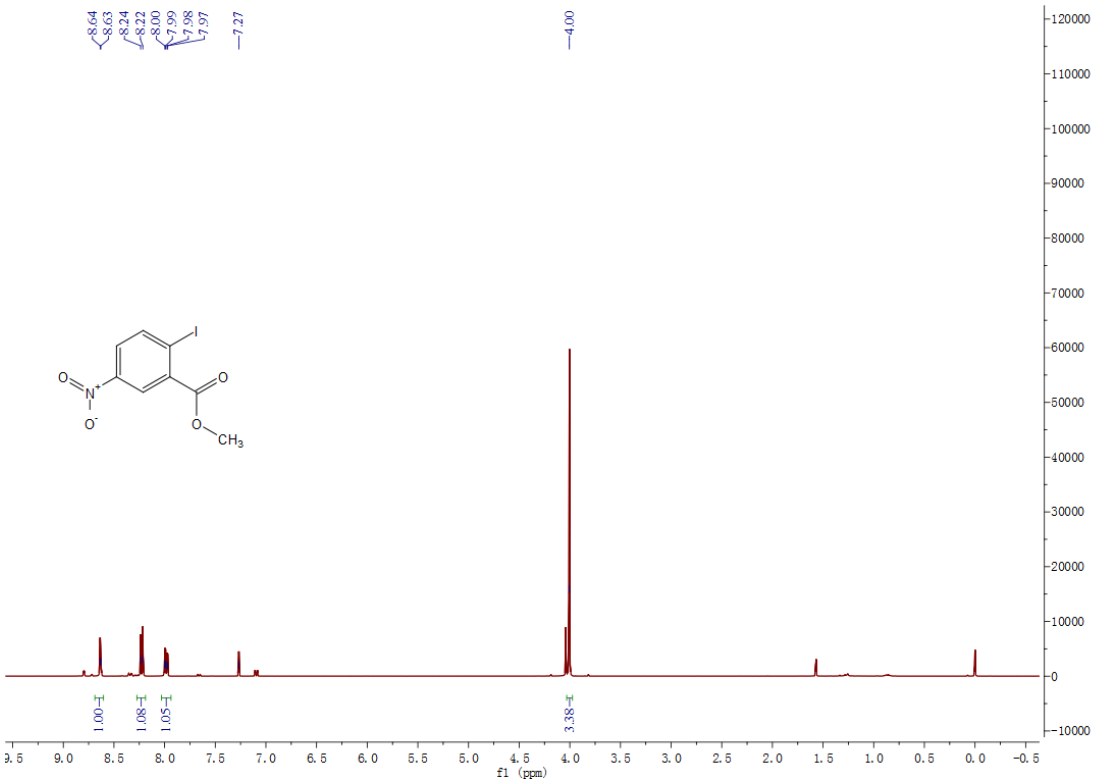
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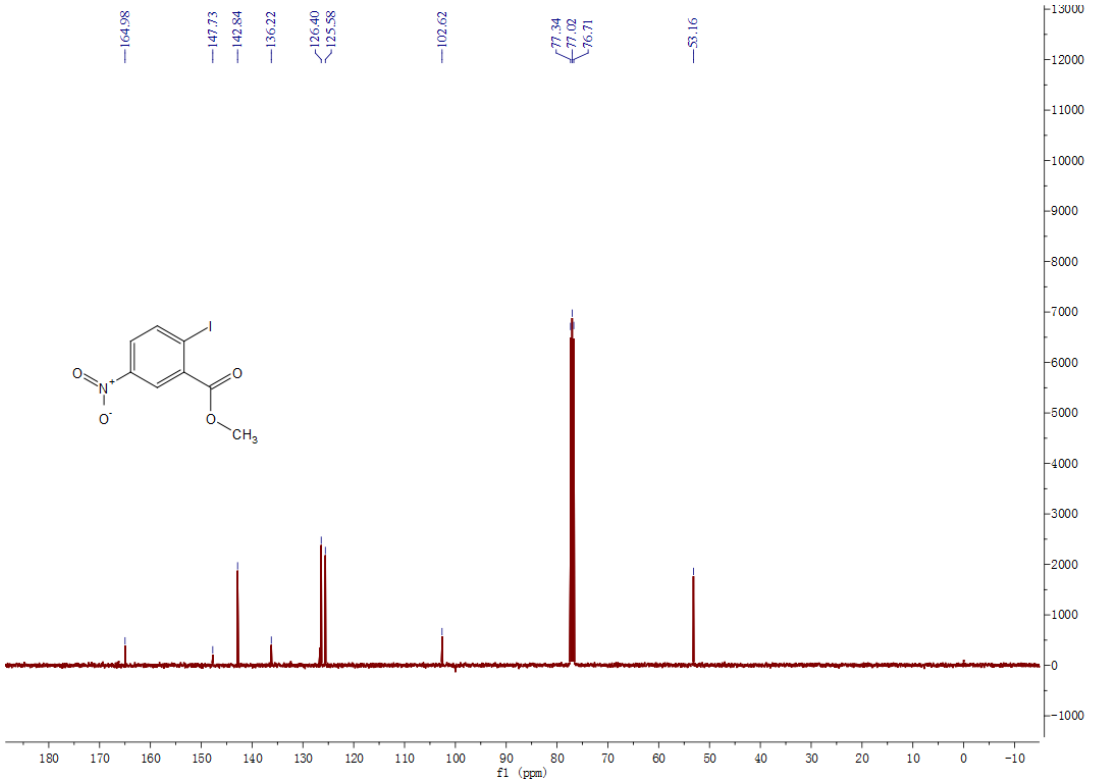
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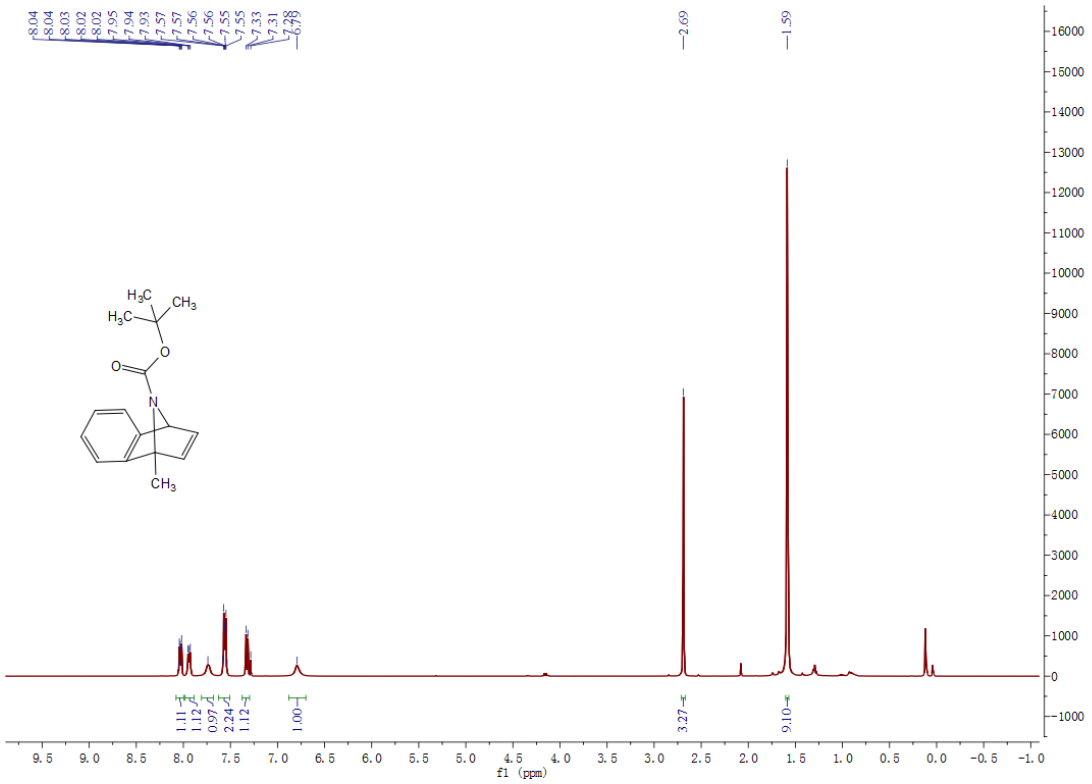
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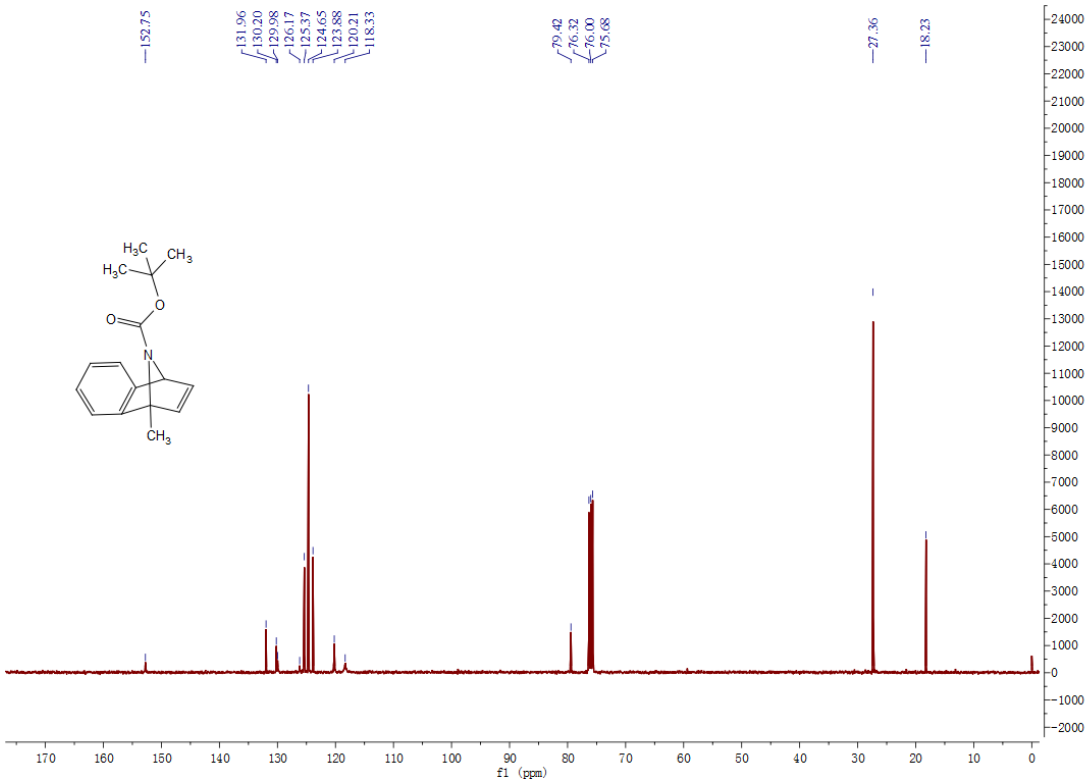
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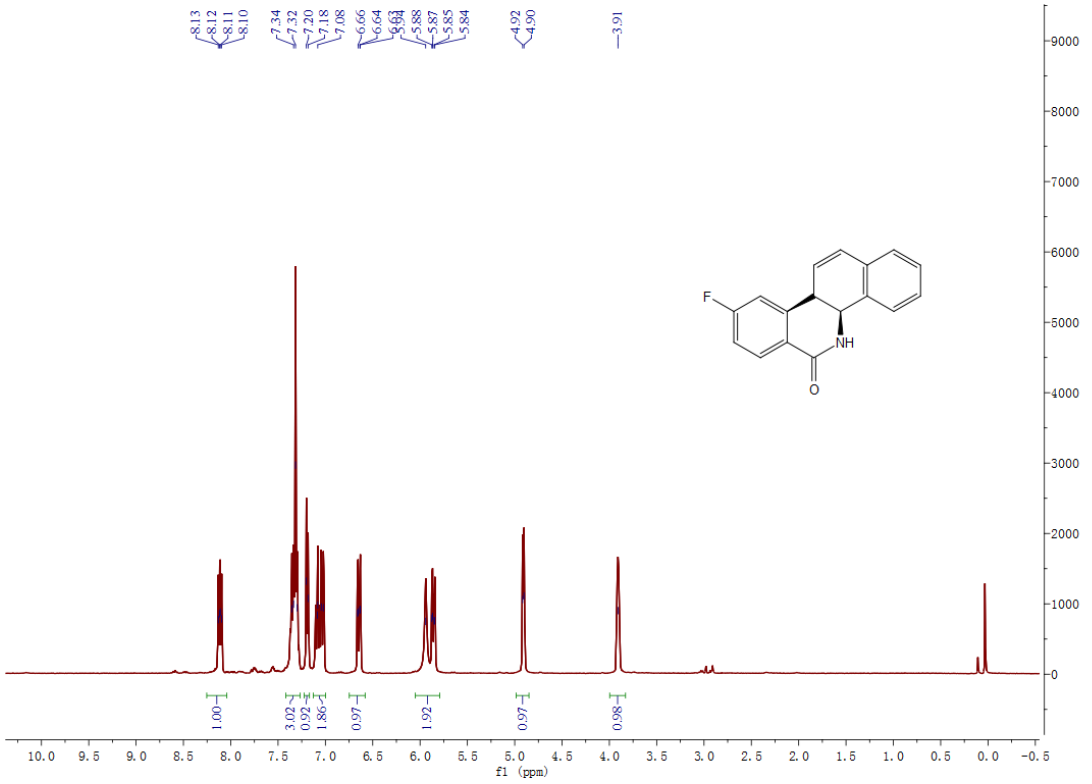
3aa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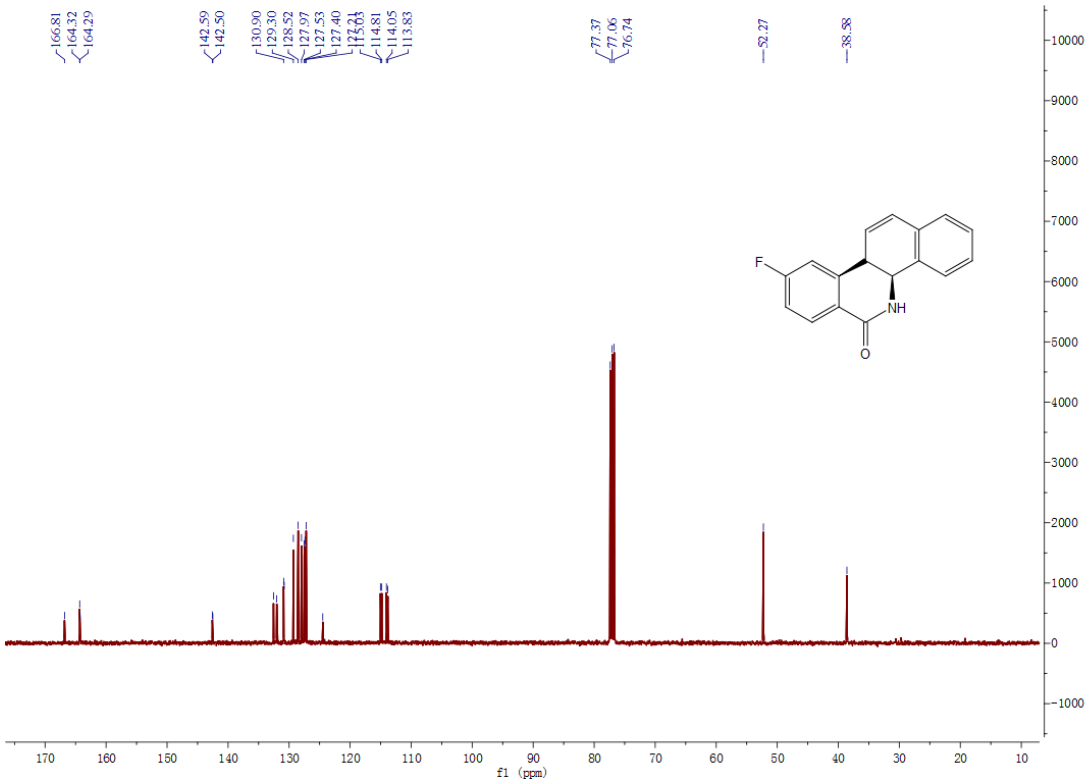
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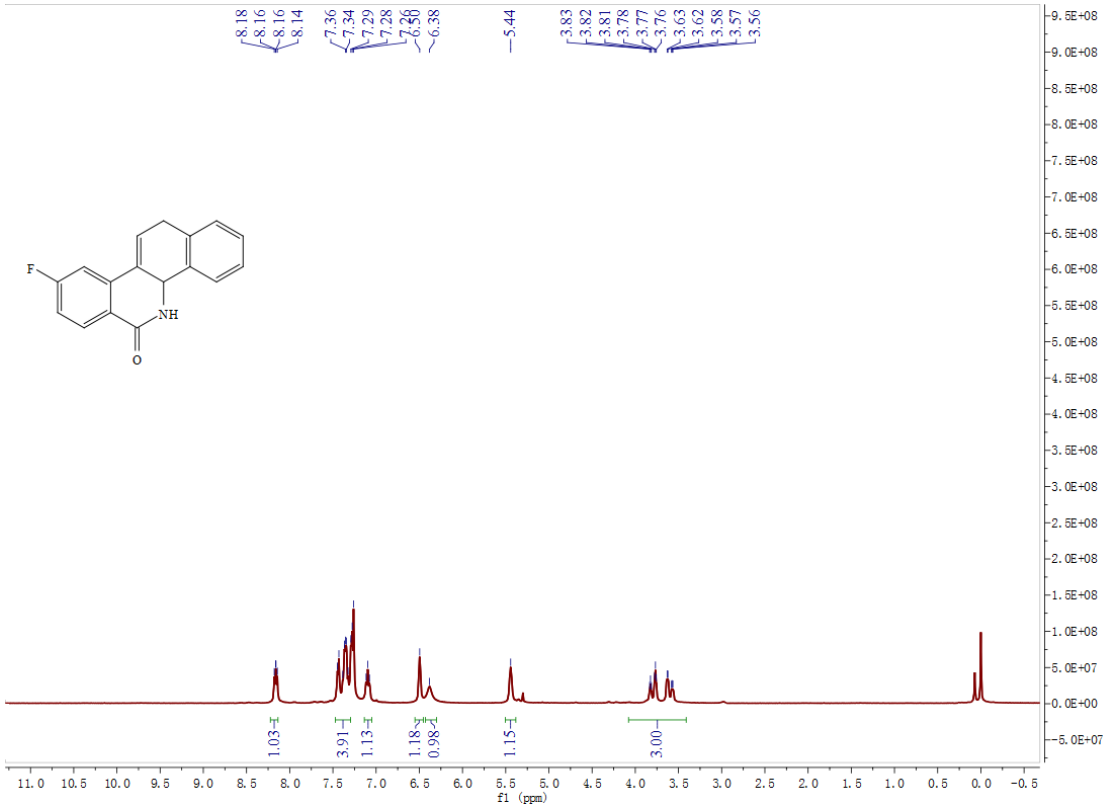
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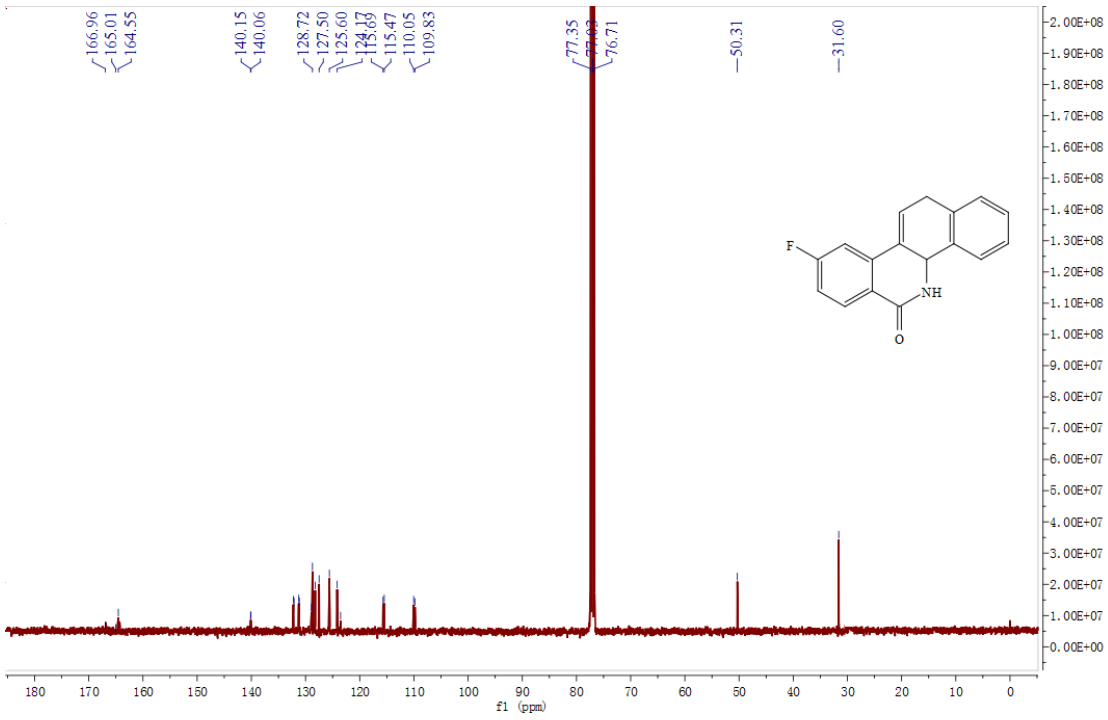
3.82
3.81
3.78
3.77
3.76
3.63
3.62
3.58
3.57
3.56
F
NH
O
1.03
3.91
1.13
1.18
0.98
1.15
3.00
f1 (ppm)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164.55
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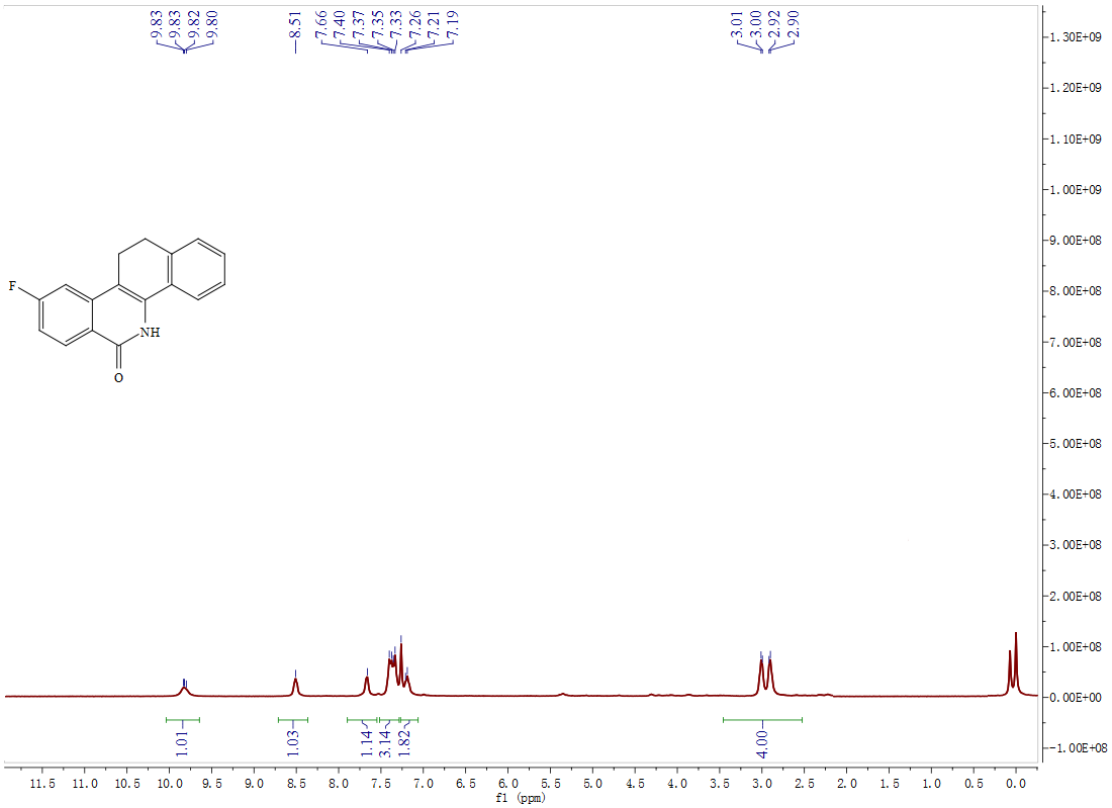
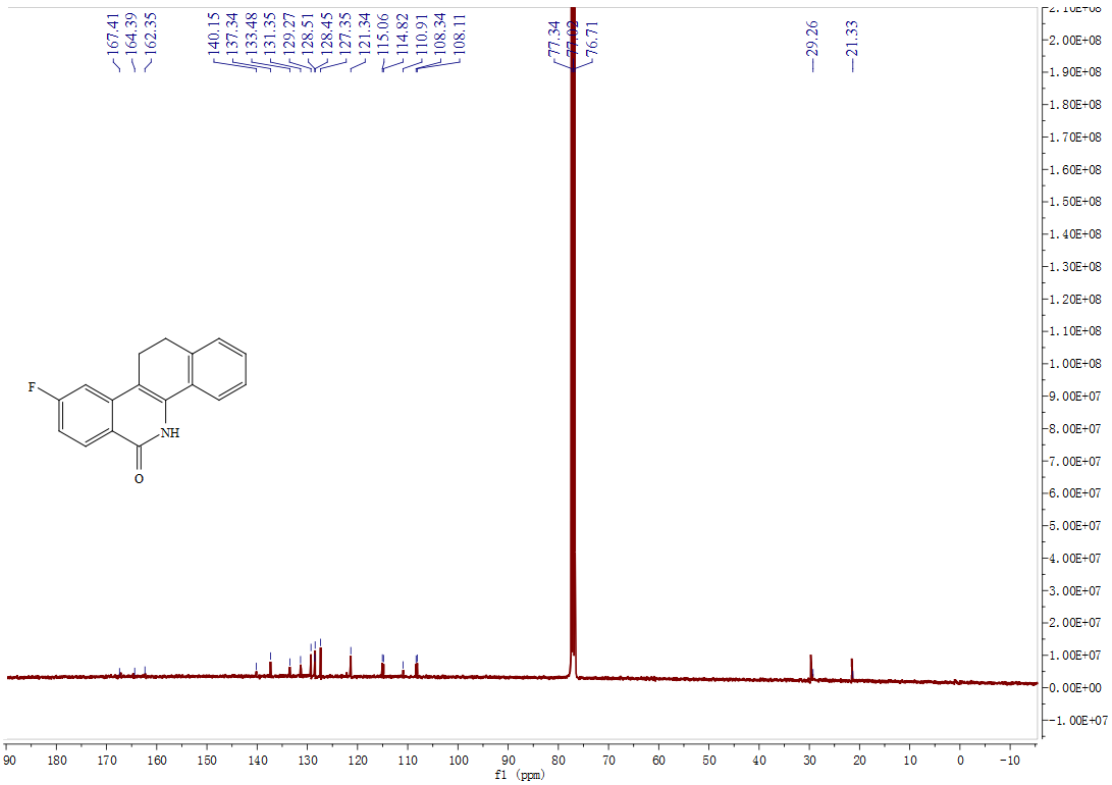
128.72
127.50
125.60
124.17
115.69
115.47
110.05
109.83
77.35
77.03
76.71
50.31
31.60
F
NH
O
f1 (ppm)

5aa


9.83
9.83
9.82
9.80
8.51
7.66
7.40
7.37
7.35
7.33
7.26
7.21
7.19
3.01
3.00
2.92
2.90
F
NH
O
1.01
1.03
1.14
3.14
1.82
4.00
f1 (ppm)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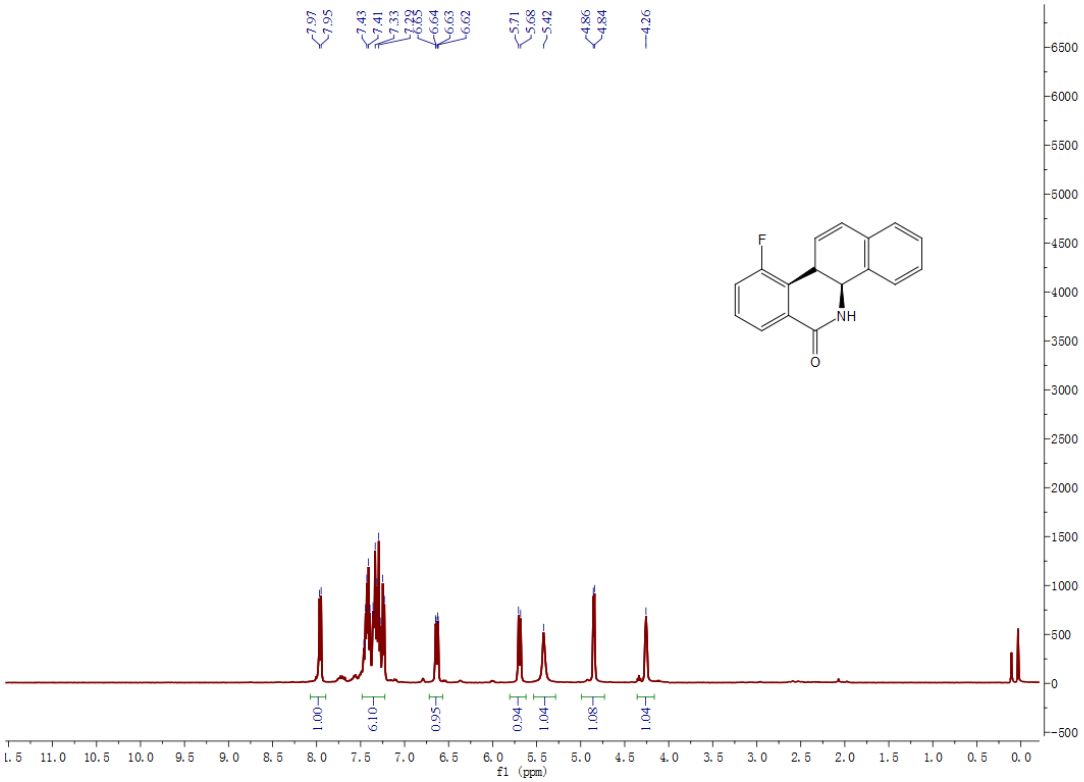
164.39
162.35
140.15
137.34
133.48
131.35
129.27
128.51
128.45
127.35
121.34
115.06
114.82
110.91
108.34
108.11
77.34
76.71
29.26
21.33
F
NH
O
f1 (ppm)

3ab


7.97
7.95
7.43
7.41
7.33
7.32
6.65
6.64
6.63
6.62
5.71
5.68
5.42
4.86
4.84
4.26
F
NH
O
1.00
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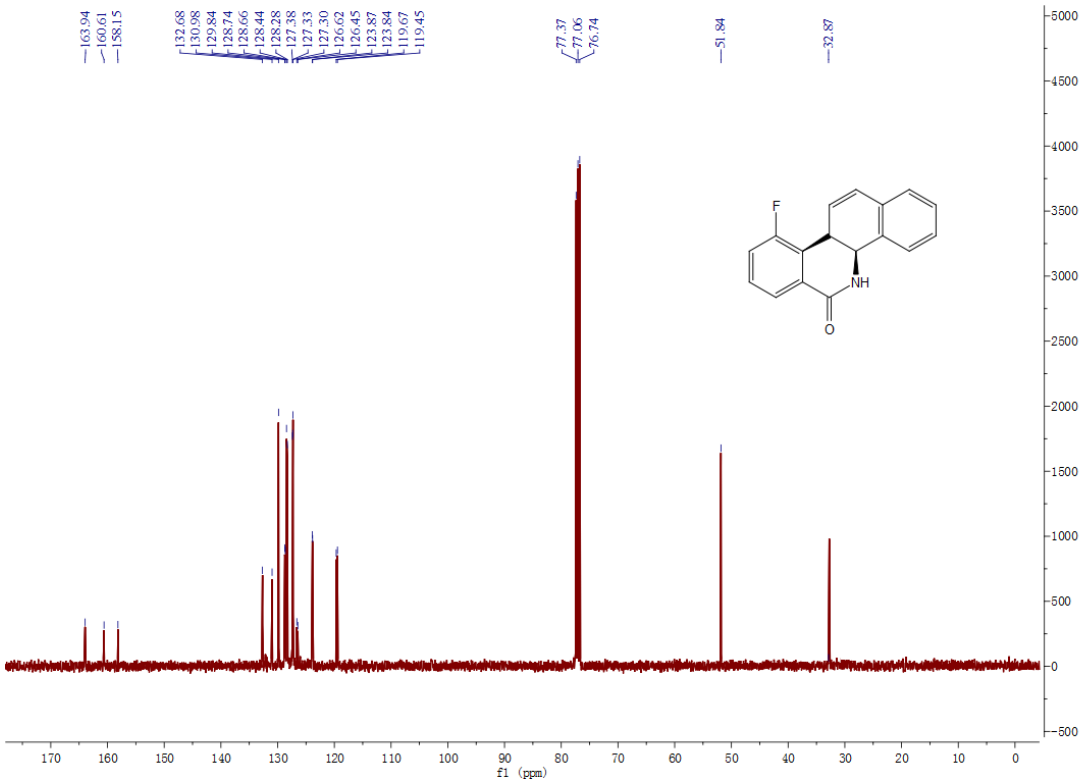
0.94
1.04
1.08
1.04
f1 (ppm)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132.68
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129.84
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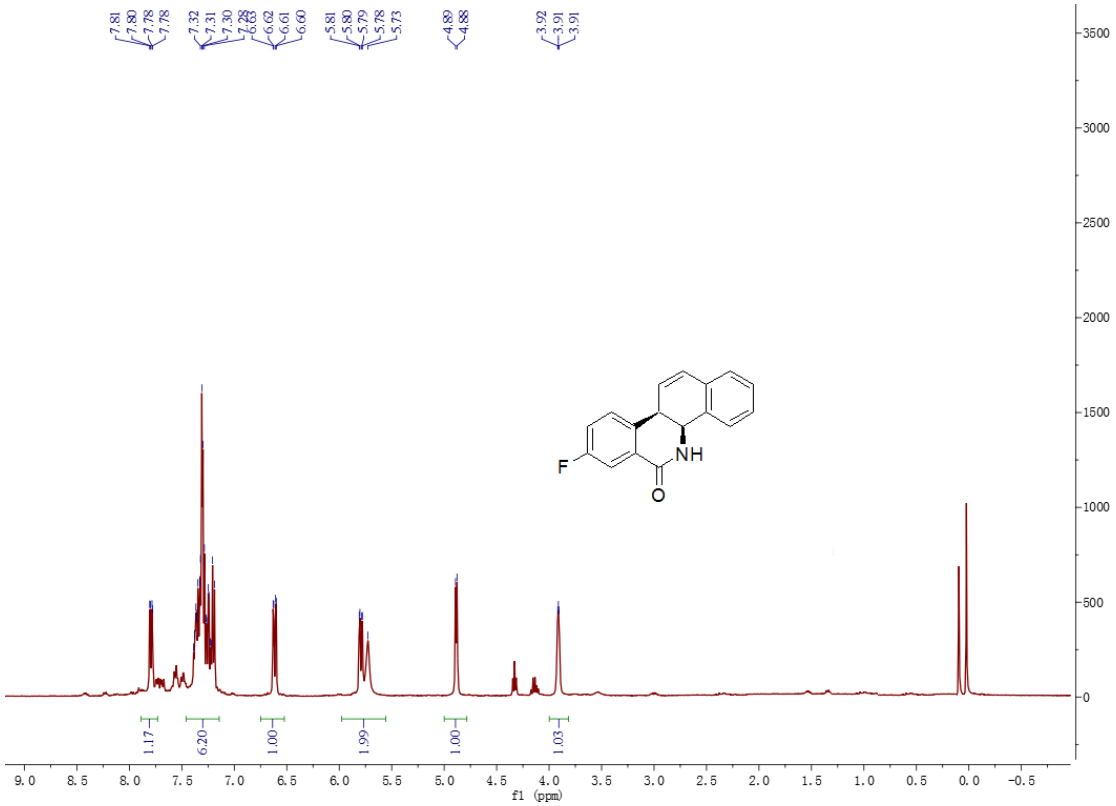
128.66
128.44
128.28
127.38
127.33
127.30
126.62
126.45
123.87
123.84
119.67
119.45
77.37
77.06
76.74
51.84
32.87
F
NH
O
f1 (ppm)

3ac


7.81
7.80
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7.32
7.31
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6.61
6.60
5.81
5.80
5.79
5.78
5.73
4.89
4.88
3.92
3.91
3.91
F
NH
O
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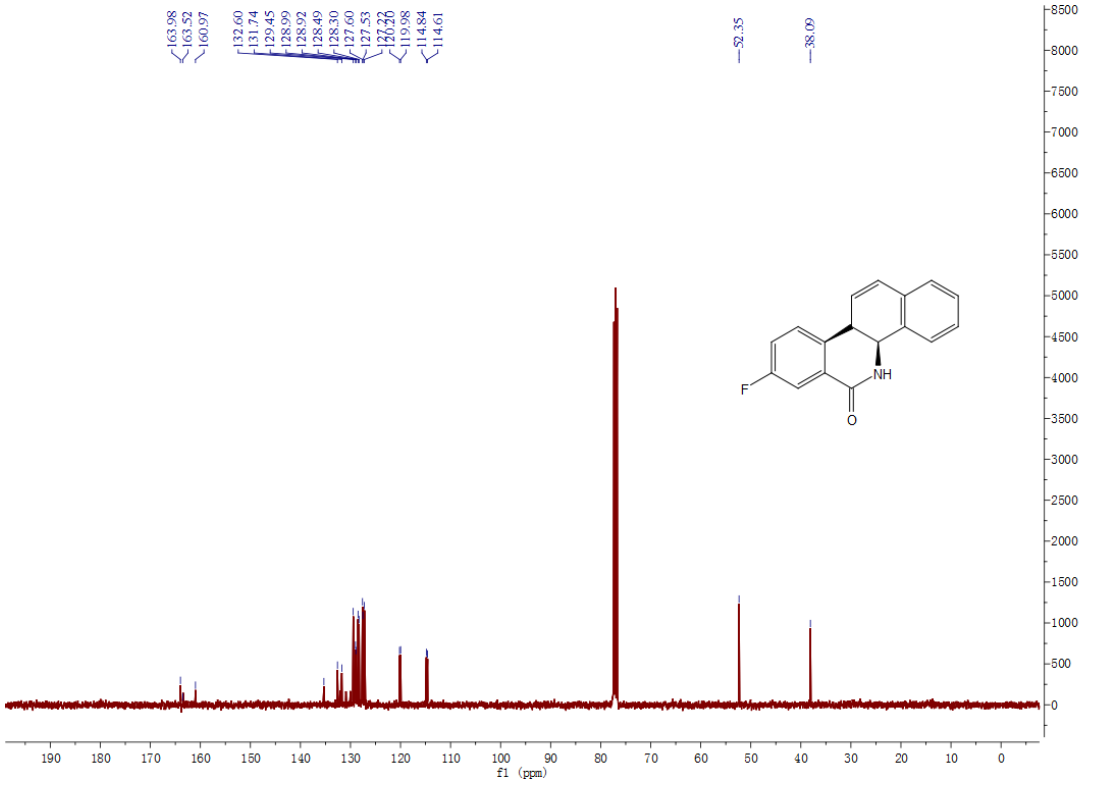
6.20
1.00
1.99
1.00
1.03
f1 (ppm)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163.52
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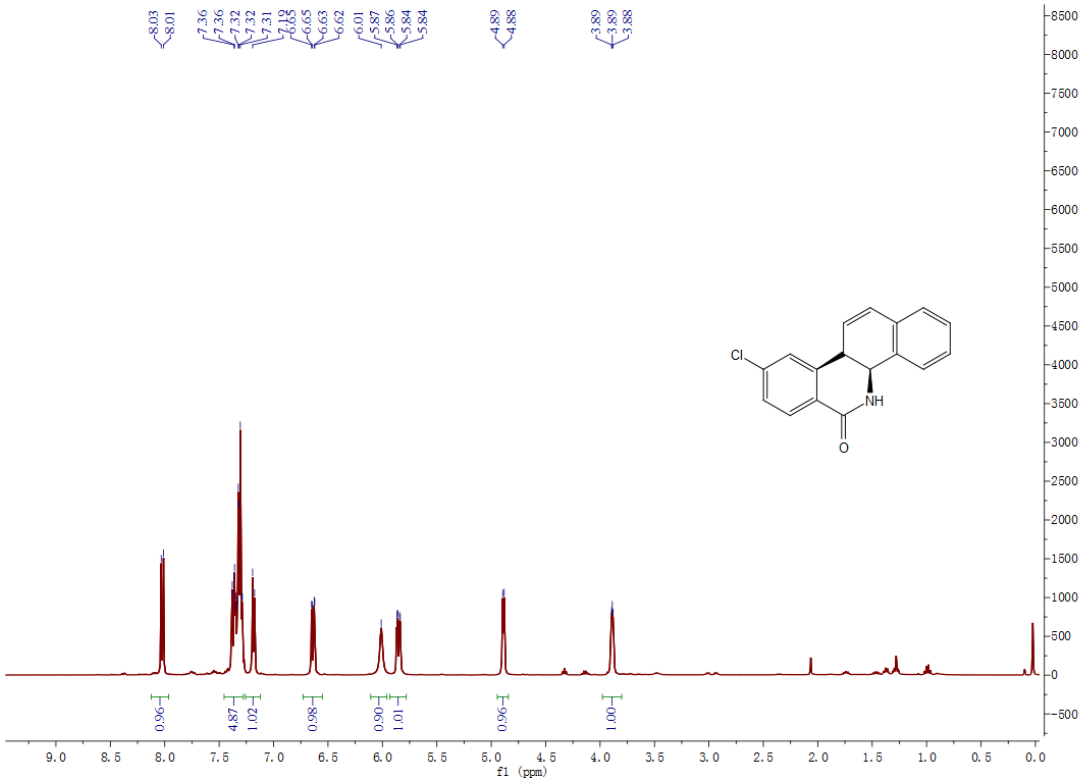
131.74
129.45
128.99
128.92
128.49
128.30
127.60
127.53
119.98
114.84
114.61
52.35
38.09
F
NH
O
f1 (ppm)

3ad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8.01
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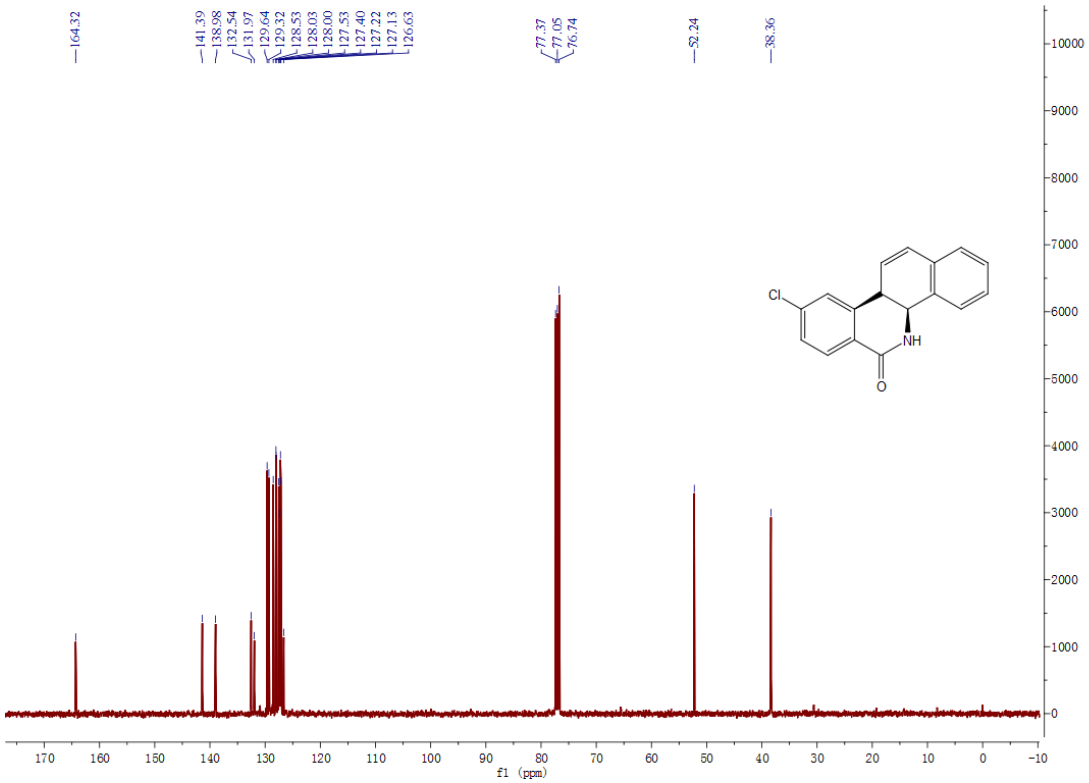
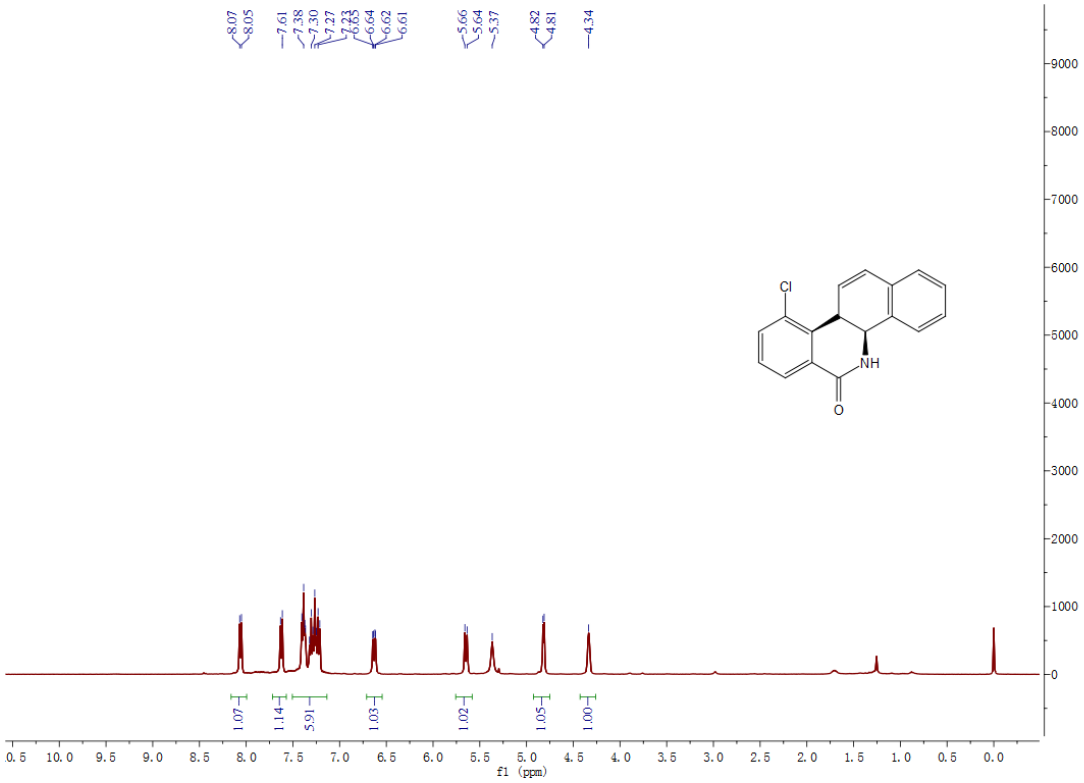
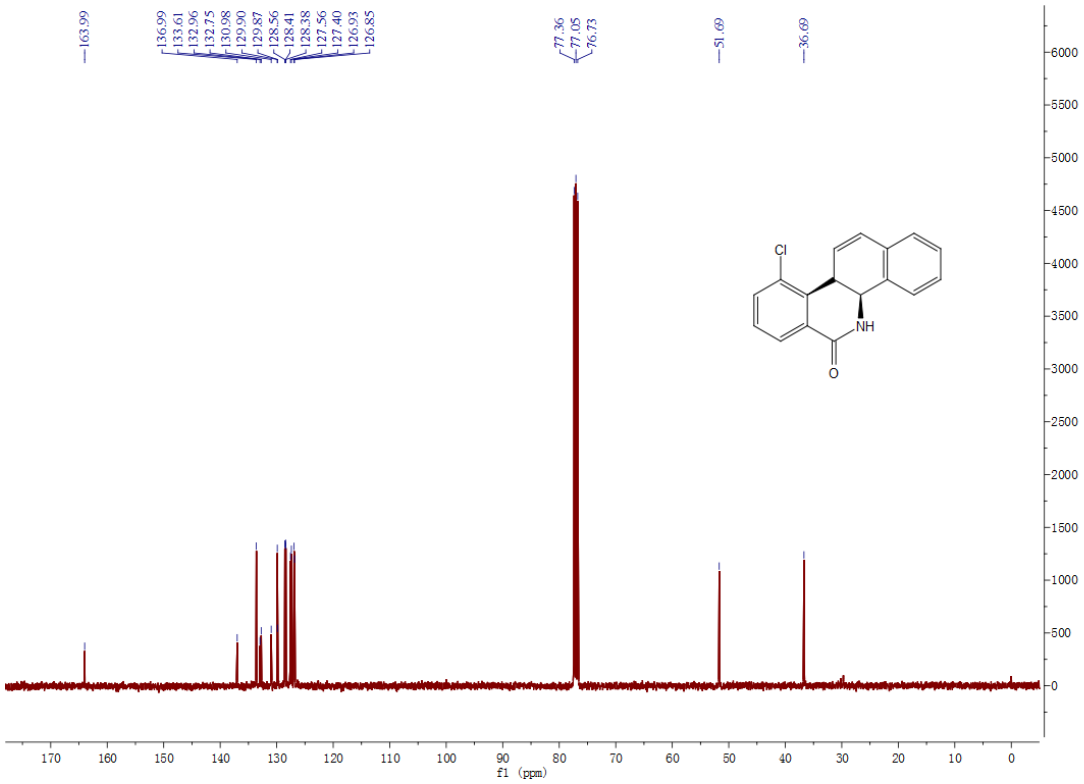
7.36
7.32
7.32
7.31
7.19
6.65
6.63
6.62
6.01
5.87
5.86
5.84
5.84
4.89
4.88
3.89
3.89
3.88
Cl
NH
O
0.96
4.87
1.02
0.98
0.90
1.01
0.96
1.00
f1 (ppm)


164.32
141.39
138.98
132.54
131.97
129.64
129.32
128.53
128.03
128.00
127.53
127.40
127.22
127.13
126.63
77.37
77.05
76.74
52.24
38.36
Cl
NH
O
f1 (ppm)

3ae


8.07
8.05
7.61
7.38
7.30
7.27
7.23
6.65
6.64
6.62
6.61
5.66
5.64
5.37
4.82
4.81
4.34
Cl
NH
O
1.07
1.14
5.91
1.03
1.02
1.05
1.00
f1 (ppm)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132.96
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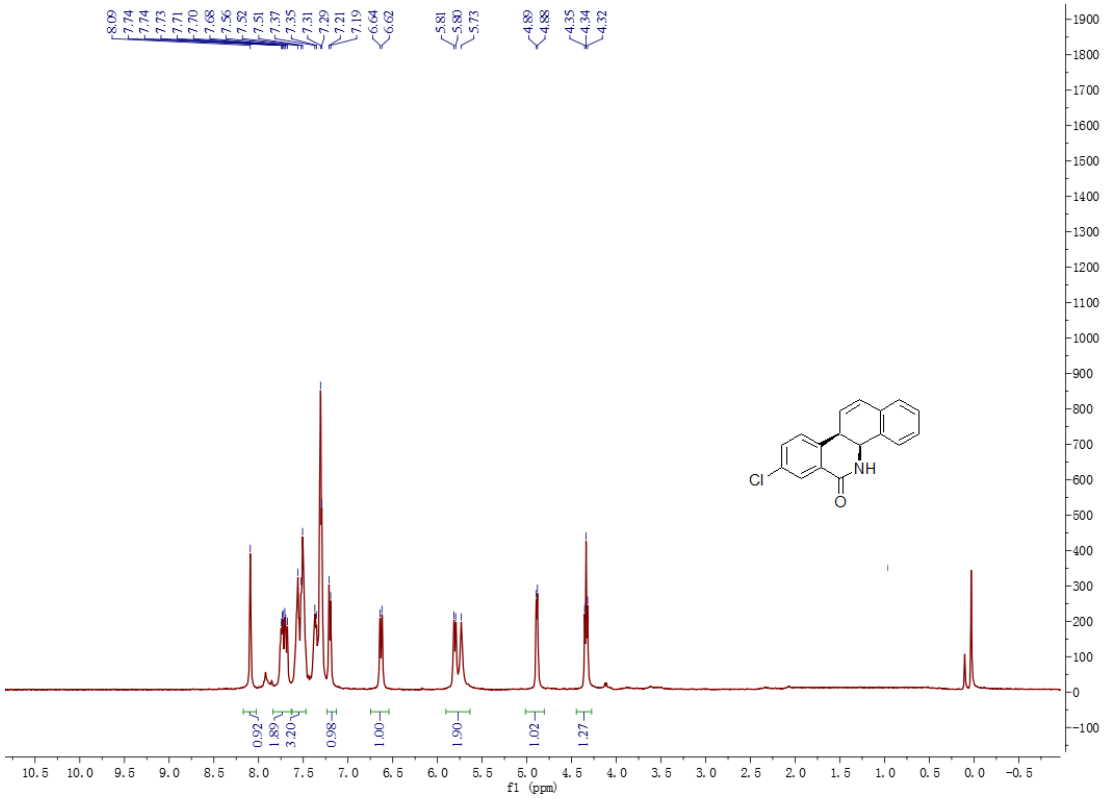
130.98
129.90
129.87
128.56
128.41
128.38
127.56
127.40
126.93
126.85
77.36
77.05
76.73
51.69
36.69
Cl
NH
O
f1 (ppm)

3af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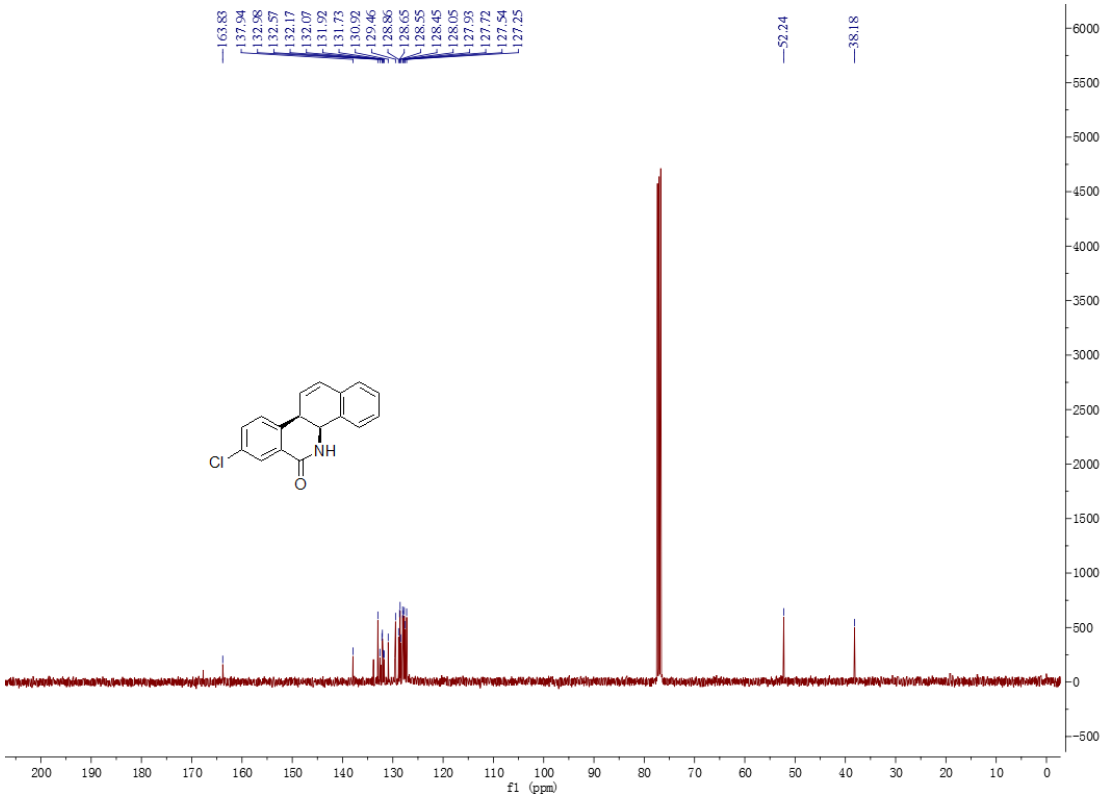
7.74
7.74
7.73
7.71
7.70
7.68
7.56
7.52
7.51
7.37
7.35
7.31
7.29
7.21
7.19
6.64
6.62
5.81
5.80
5.73
4.89
4.88
4.35
4.34
4.32
Cl
NH
O
0.92
1.89
3.20
0.98
1.00
1.90
1.02
1.27
f1 (ppm)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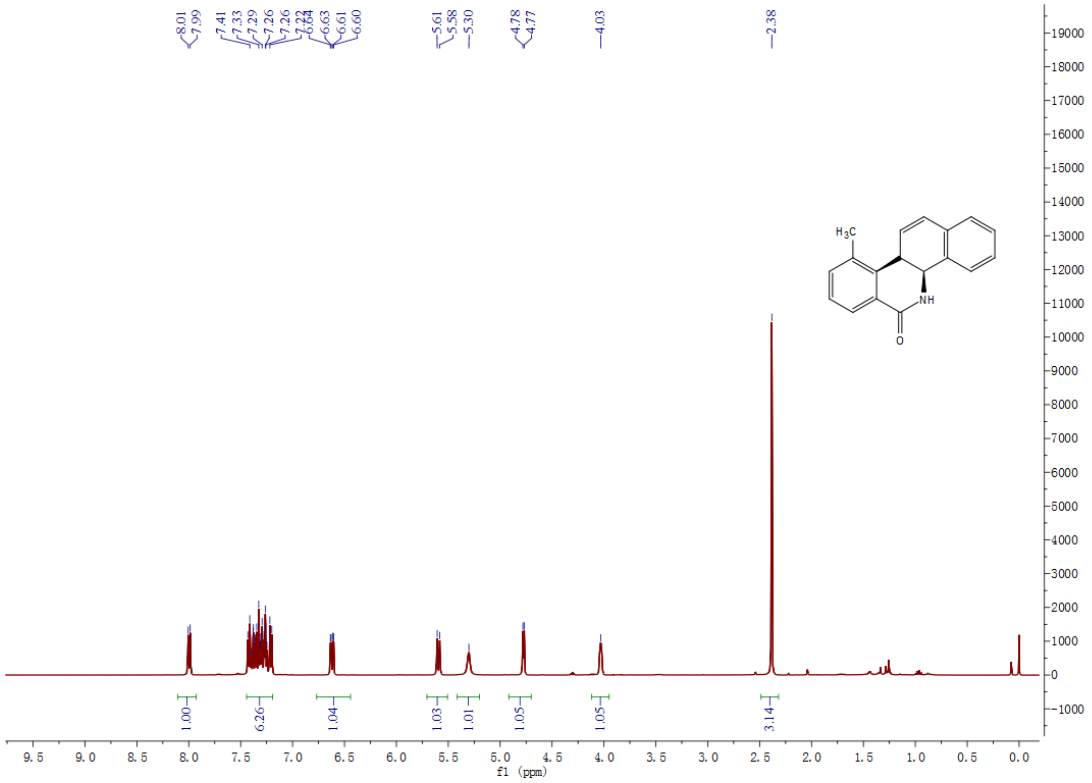
132.07
131.92
131.73
130.92
129.46
128.86
128.65
128.55
128.45
128.05
127.93
127.72
127.54
127.25
52.24
38.18
Cl
NH
O
f1 (ppm)

3ag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7.26
7.26
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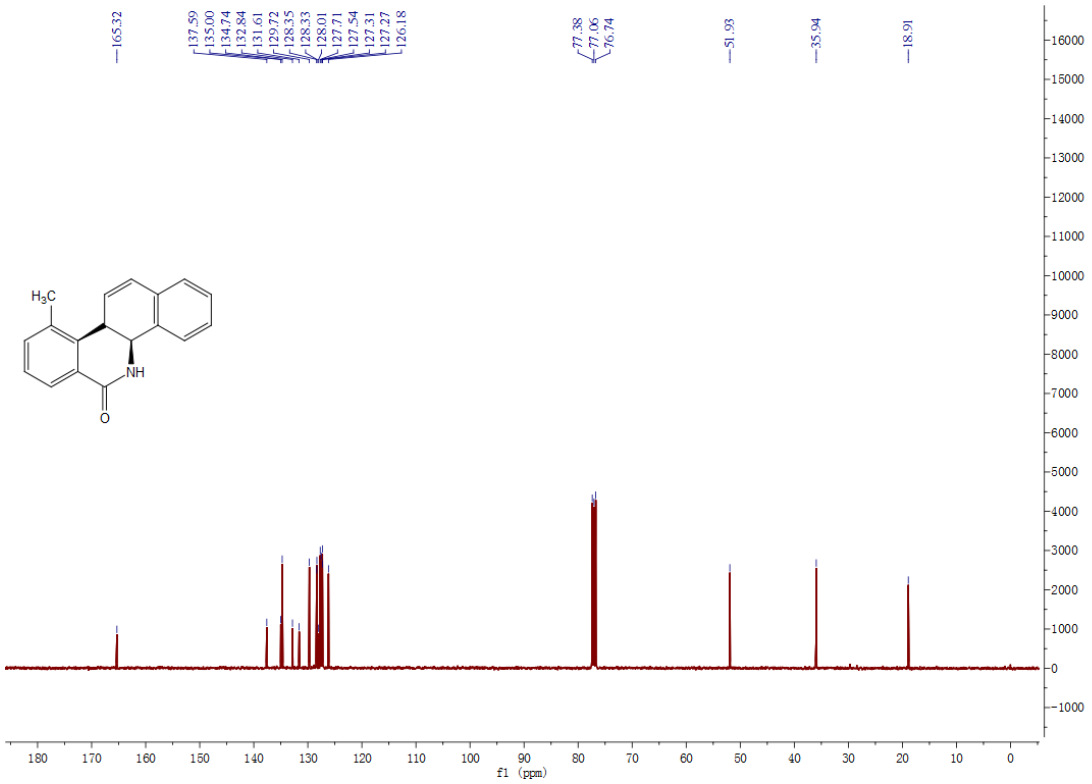
6.63
6.61
6.60
5.61
5.58
5.30
4.78
4.77
4.03
2.38
H3C
NH
O
1.00
6.26
1.04
1.03
1.01
1.05
1.05
3.14
f1 (ppm)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132.84
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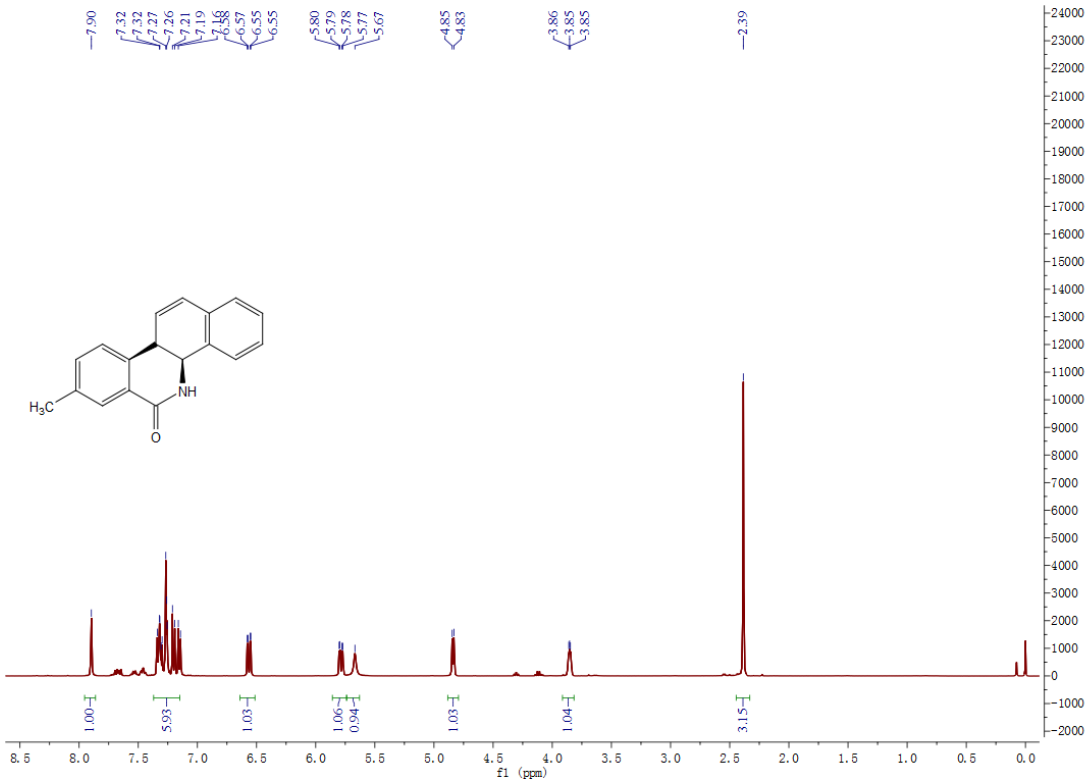
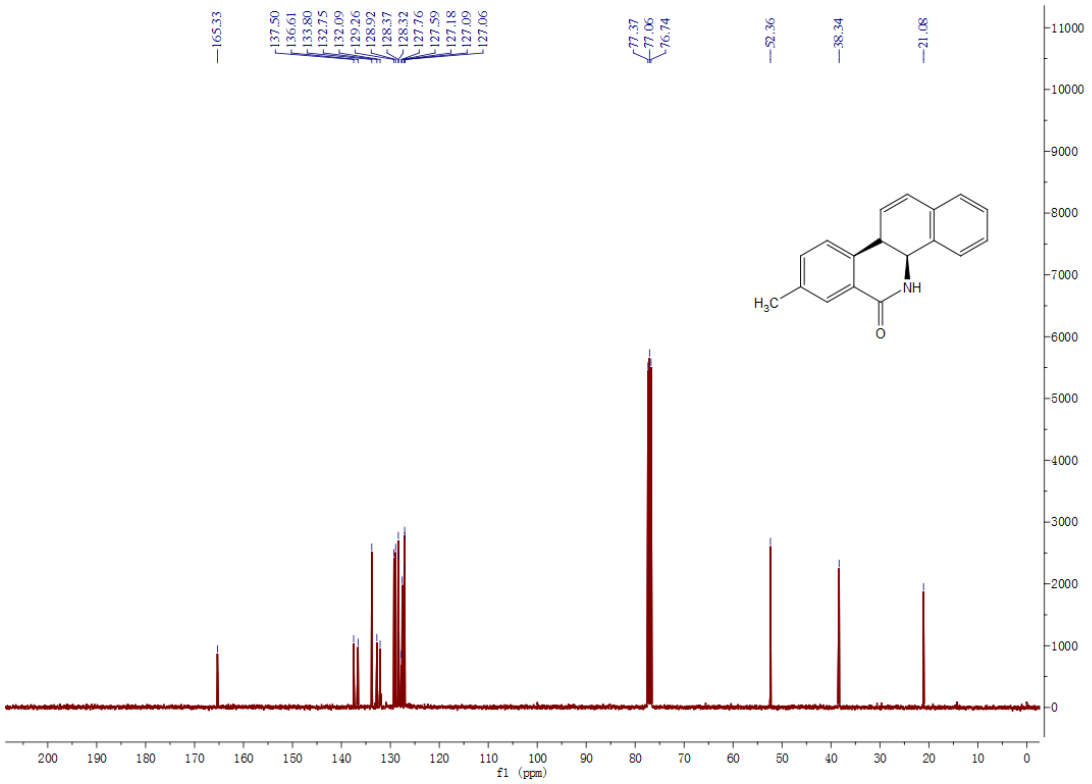
129.72
128.35
128.33
128.01
127.71
127.54
127.31
127.27
126.18
77.38
77.06
76.74
51.93
35.94
18.91
H3C
NH
O
f1 (ppm)

3ah


7.90
7.32
7.32
7.27
7.26
7.21
7.19
6.58
6.57
6.55
6.55
5.80
5.79
5.78
5.77
5.67
4.85
4.83
3.86
3.85
3.85
2.39
NH
O
H3C
1.00
5.93
1.03
1.06
0.94
1.03
1.04
3.15
f1 (ppm)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133.80
132.75
132.09
129.26
128.92
128.37
128.32
127.76
127.59
127.18
127.09
127.06
77.37
77.06
76.74
52.36
38.34
21.08
NH
O
H3C
f1 (ppm)

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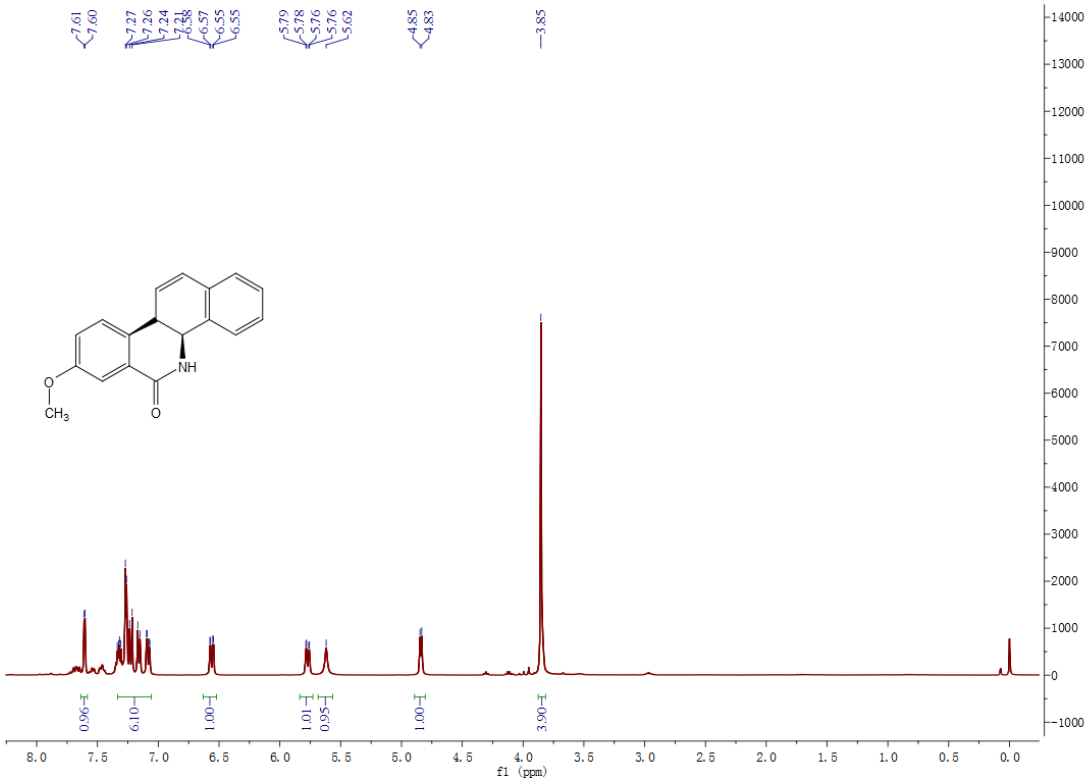
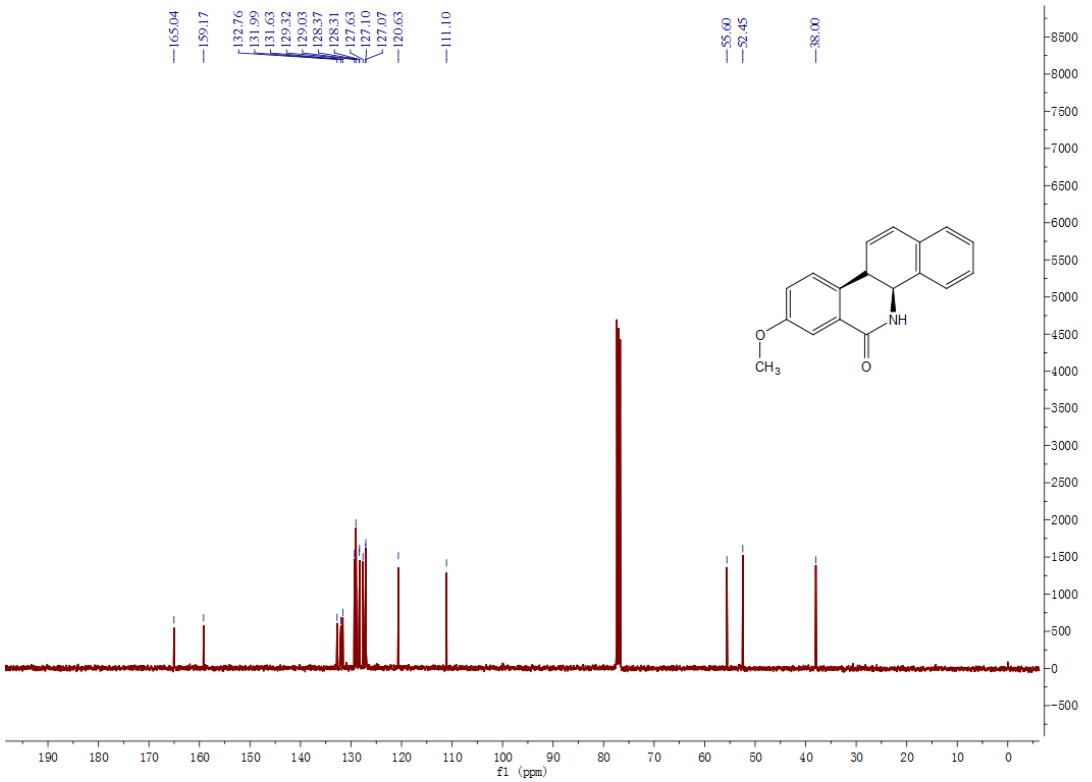
3ai





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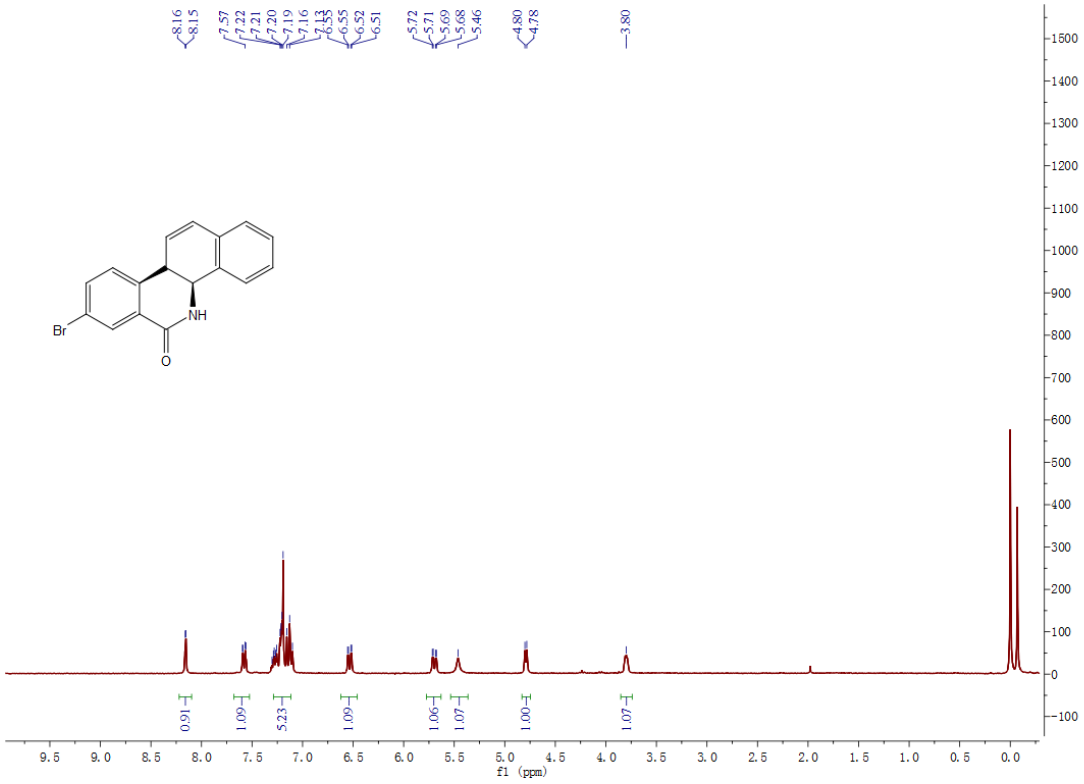
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6.55
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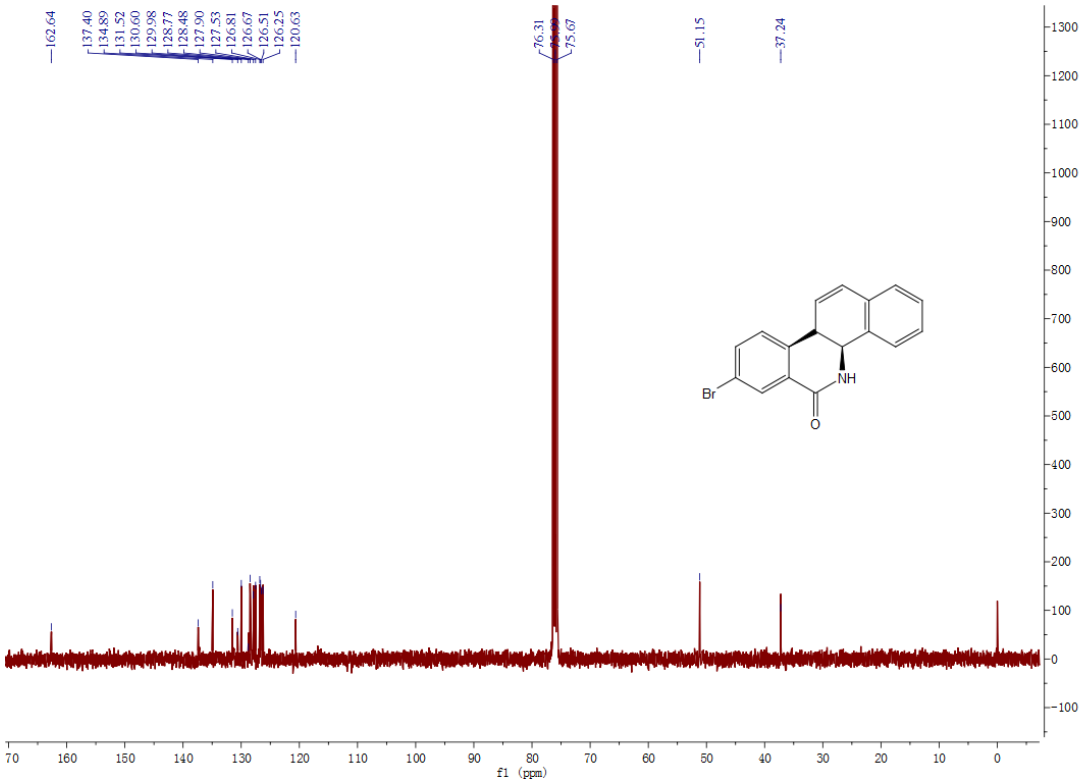
6.52
6.51
5.72
5.71
5.69
5.68
5.46
4.80
4.78
3.80
Br
NH
O
0.91
1.09
5.23
1.09
1.06
1.07
1.00
1.07
f1 (ppm)


162.64
137.40
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131.52
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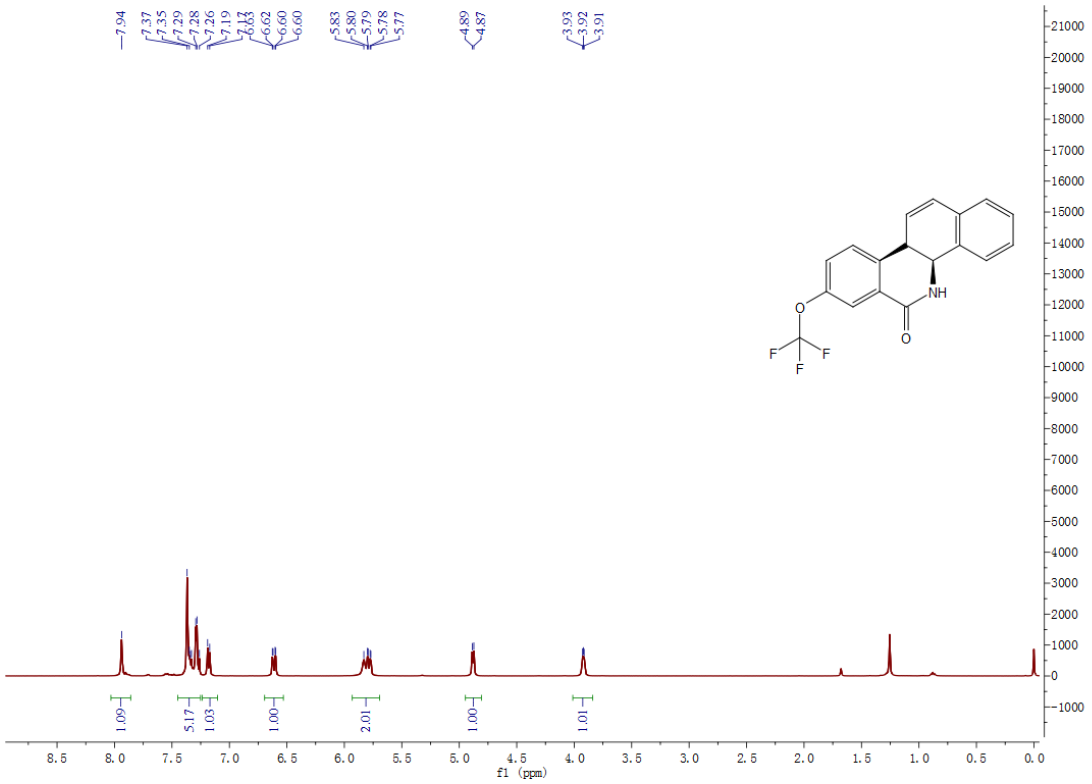
129.98
128.77
128.48
127.90
127.53
126.81
126.67
126.51
126.25
120.63
76.31
75.67
51.15
37.24
Br
NH
O
f1 (ppm)

3ak


7.94
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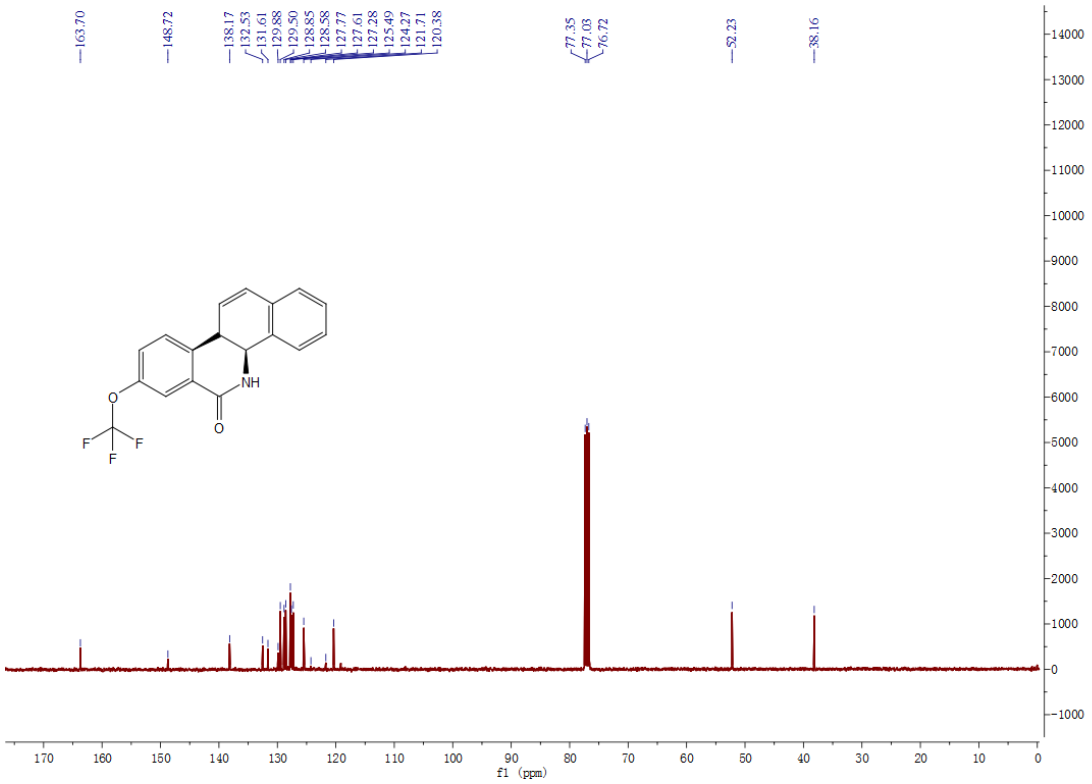
7.28
7.26
7.19
6.63
6.62
6.60
6.60
5.83
5.80
5.79
5.78
5.77
4.89
4.87
3.93
3.92
3.91
NH
O
O
F
F
F
1.09
5.17
1.03
1.00
2.01
1.00
1.01
f1 (ppm)


163.70
148.72
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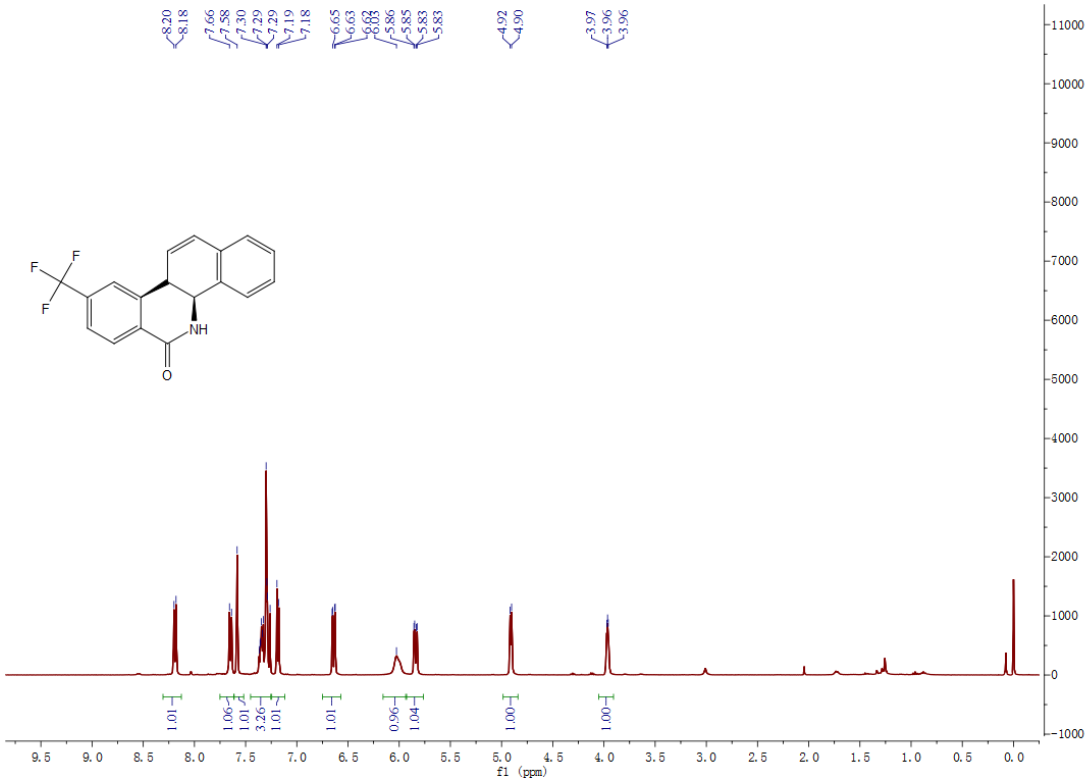
129.88
129.50
128.85
128.58
127.77
127.61
127.28
125.49
124.27
121.71
120.38
77.35
77.03
76.72
52.23
38.16
NH
O
O
F
F
F
f1 (ppm)

3al


8.20
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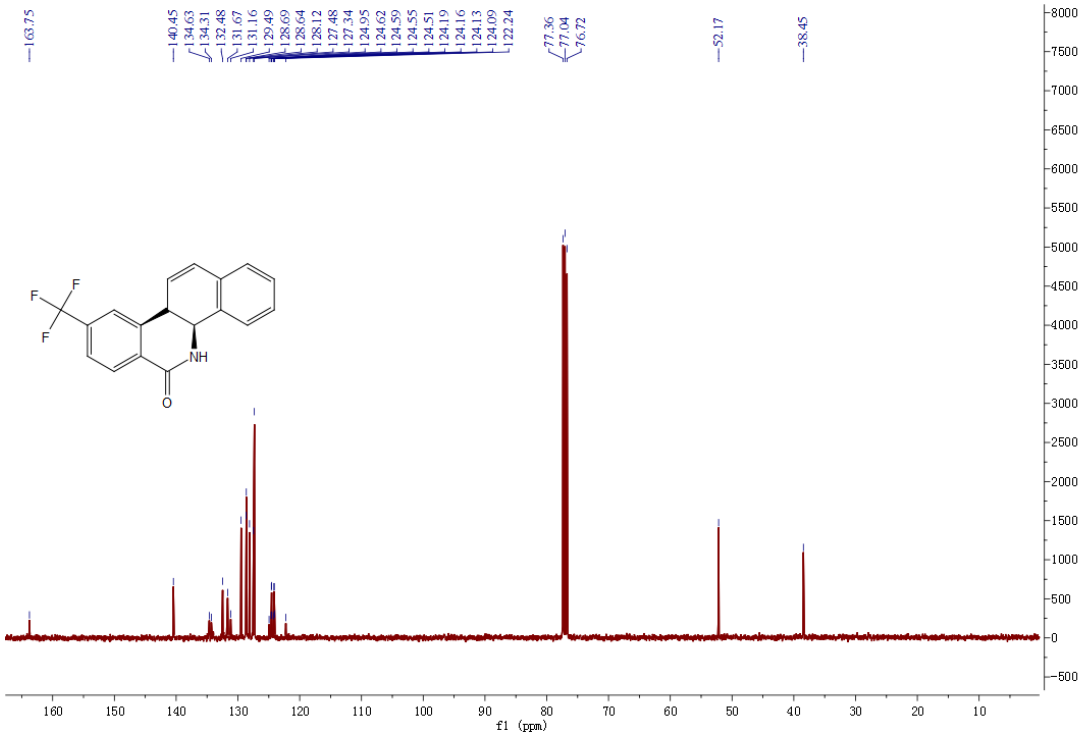
7.19
7.18
6.65
6.63
6.62
5.86
5.85
5.83
5.83
4.92
4.90
3.97
3.96
3.96
F
F
F
NH
O
1.01
1.06
1.01
3.26
1.01
1.01
0.96
1.04
1.00
1.00
f1 (ppm)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128.12
127.48
127.34
124.95
124.62
124.59
124.55
124.51
124.19
124.16
124.13
124.09
122.24
77.36
77.04
76.72
52.17
38.45
F
F
F
NH
O
f1 (ppm)

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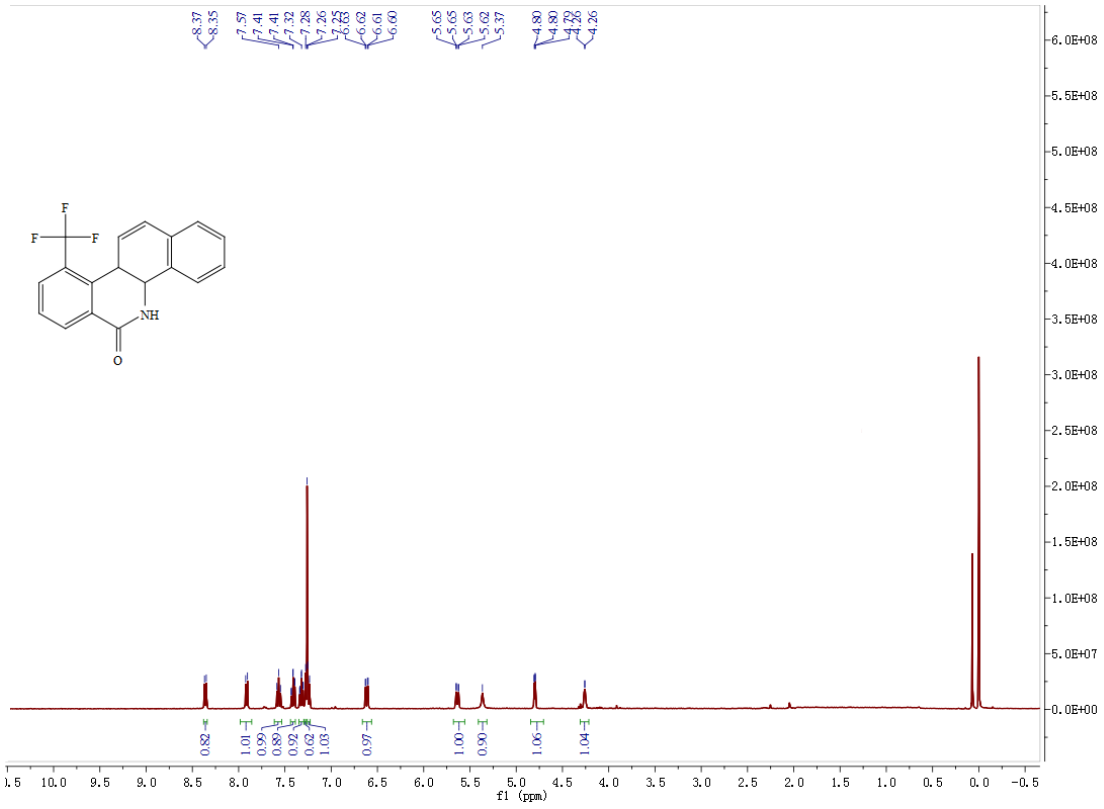
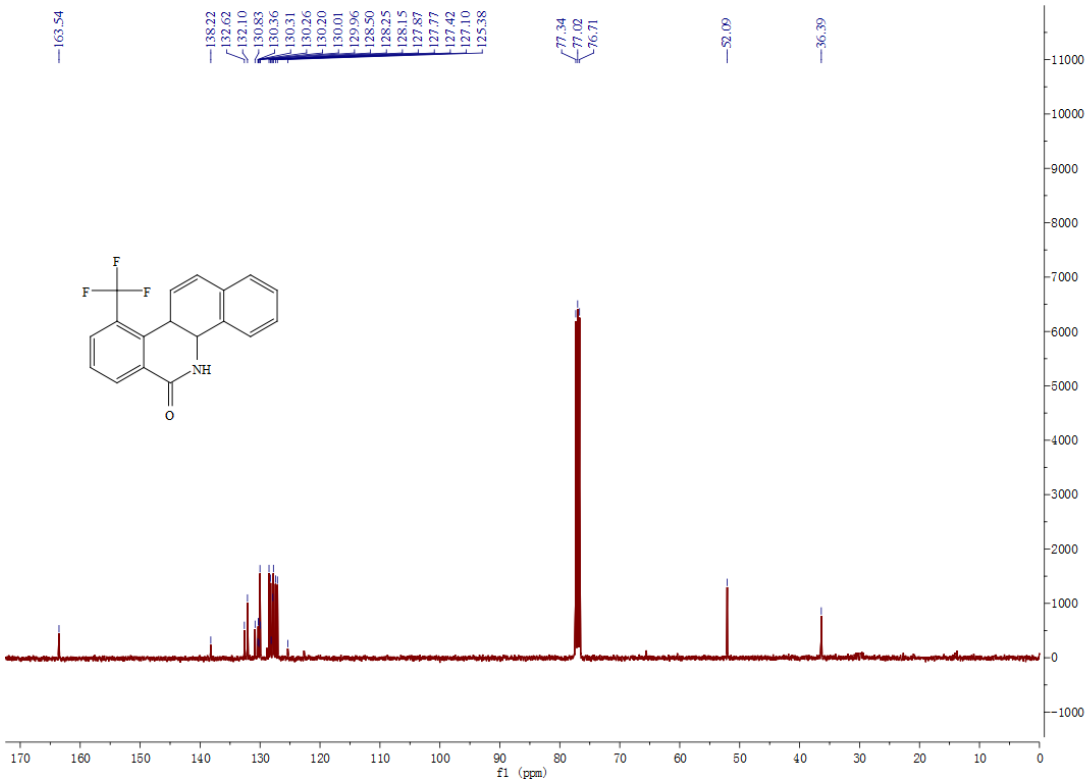
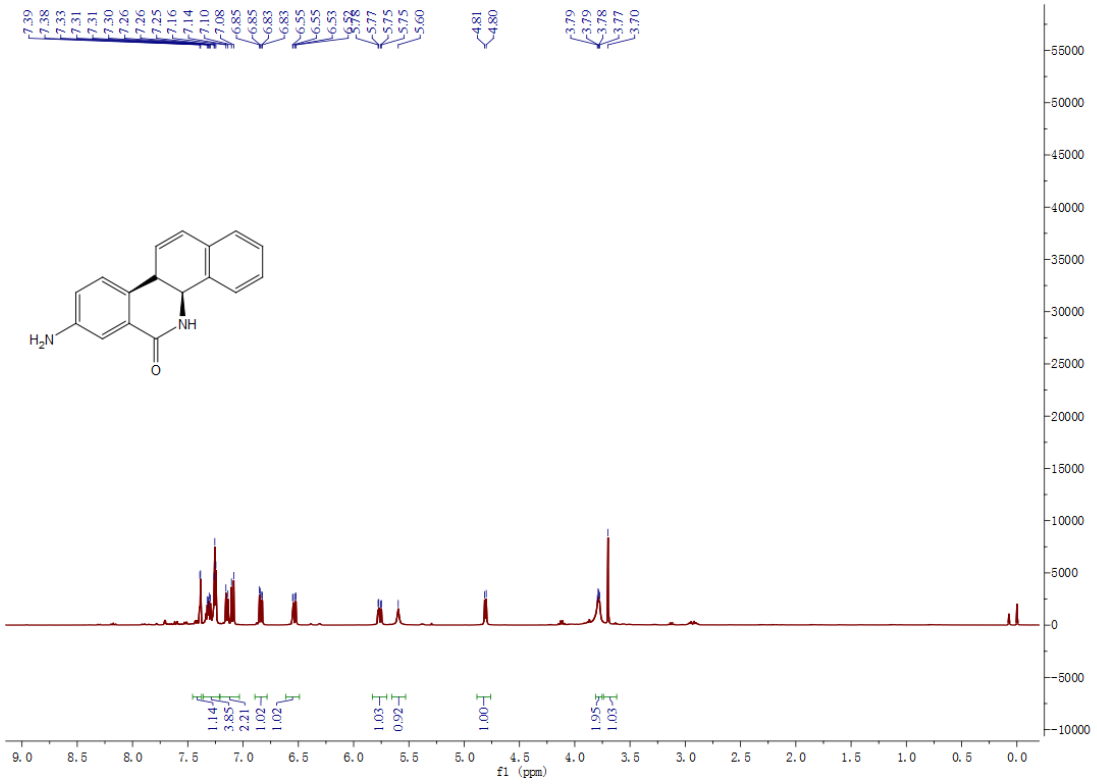
3am





3an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7.31
7.31
7.30
7.26
7.26
7.25
7.16
7.14
7.10
7.08
6.85
6.85
6.83
6.83
6.55
6.55
6.53
6.52
5.77
5.75
5.75
5.60
4.81
4.80
3.79
3.79
3.78
3.77
3.70
H2N
NH
O
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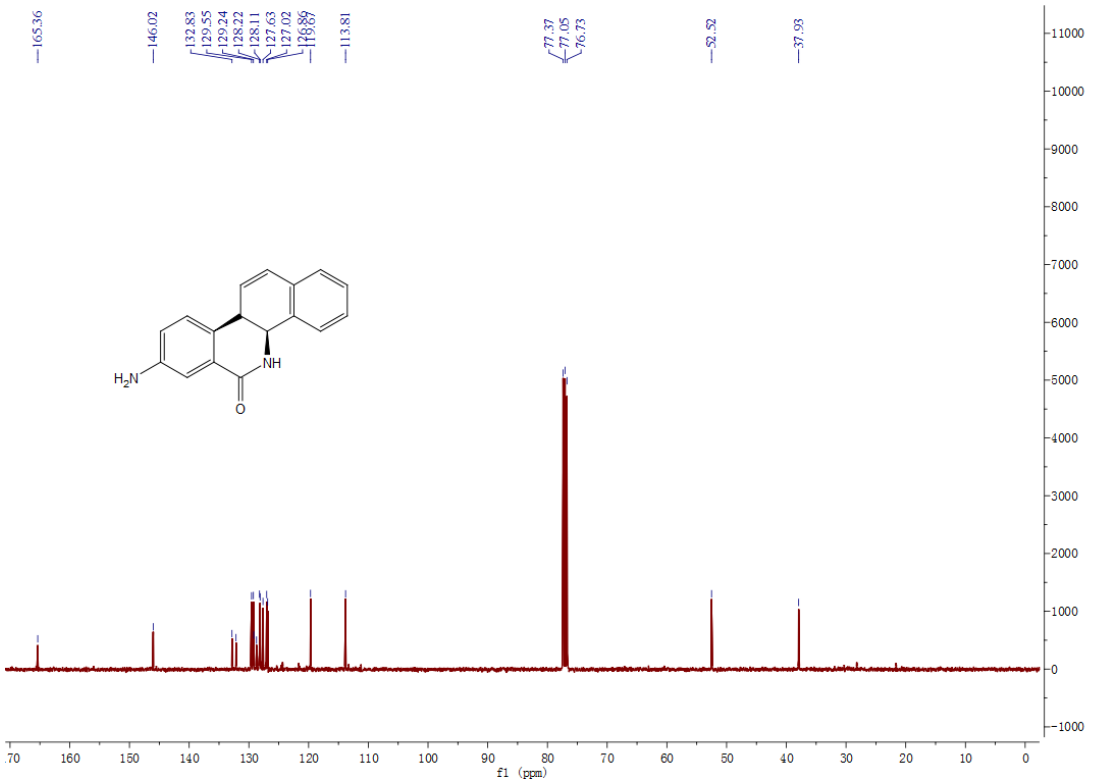
3.85
2.21
1.02
1.02
1.03
0.92
1.00
1.95
1.03
f1 (ppm)


165.36
146.02
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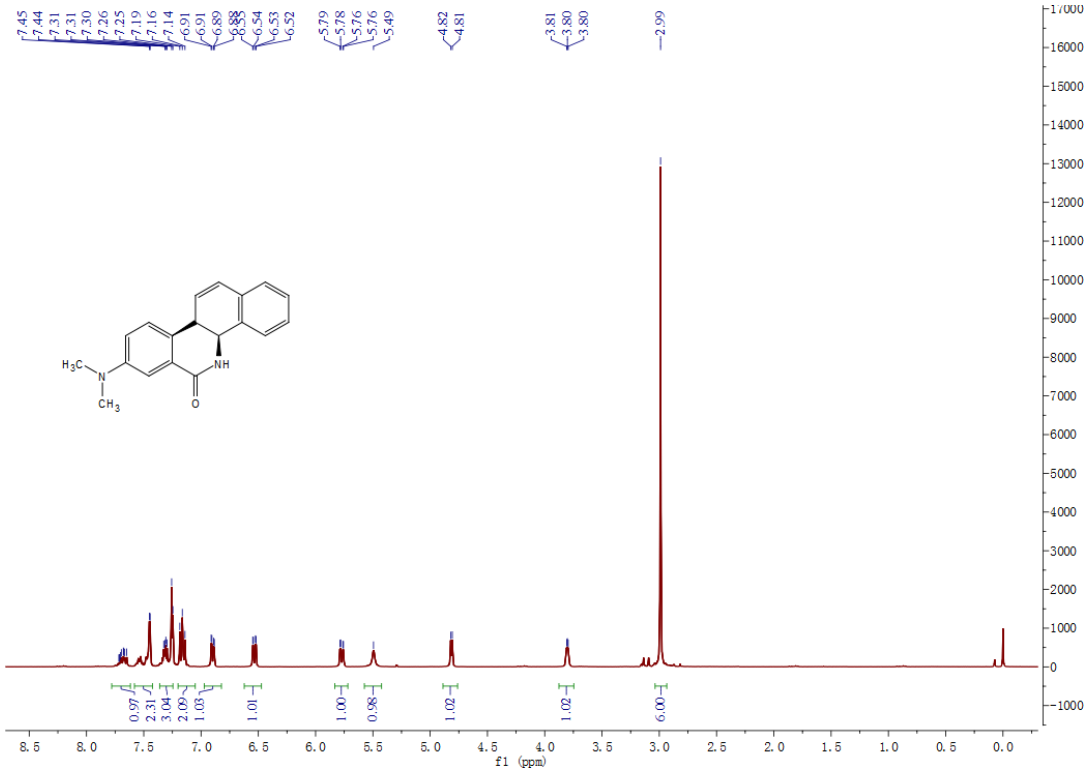
129.55
129.24
128.22
128.11
127.63
127.02
113.81
77.37
77.05
76.73
52.52
37.93
H2N
NH
O
f1 (ppm)

3ao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7.16
7.14
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6.91
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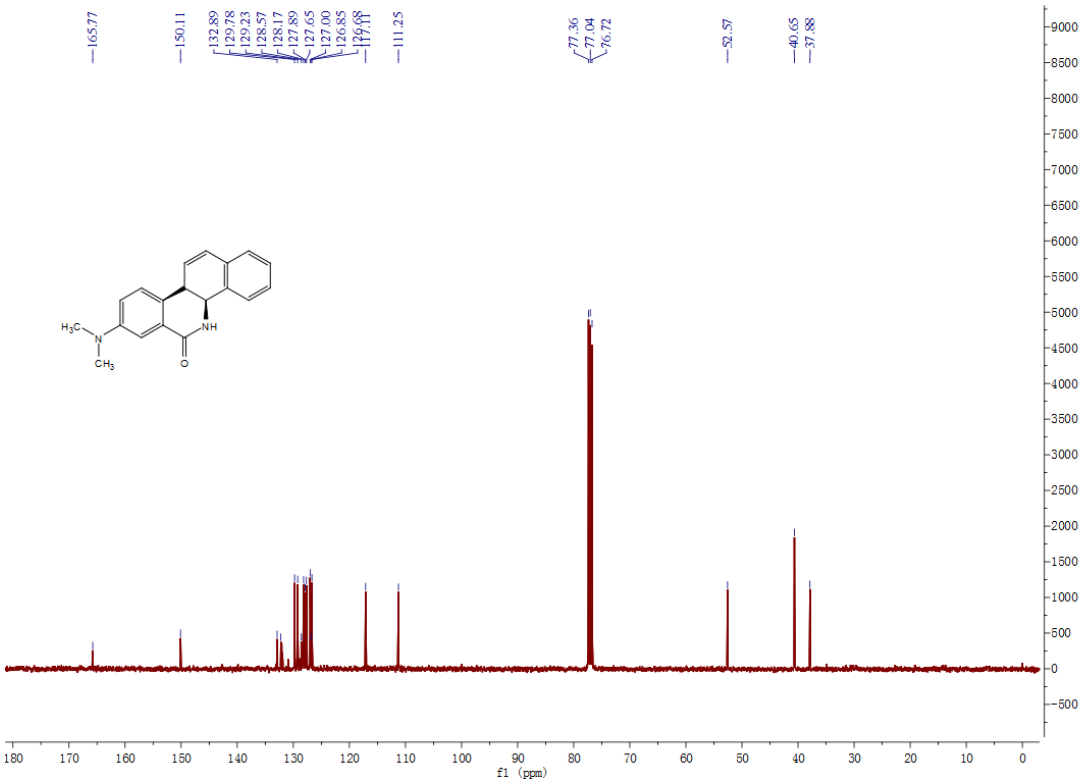
6.88
6.55
6.54
6.53
6.52
5.79
5.78
5.76
5.76
5.49
4.82
4.81
3.81
3.80
3.80
2.99
0.97
2.31
3.04
2.09
1.03
1.01
1.00
0.98
1.02
1.02
6.00
f1 (ppm)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150.11
132.89
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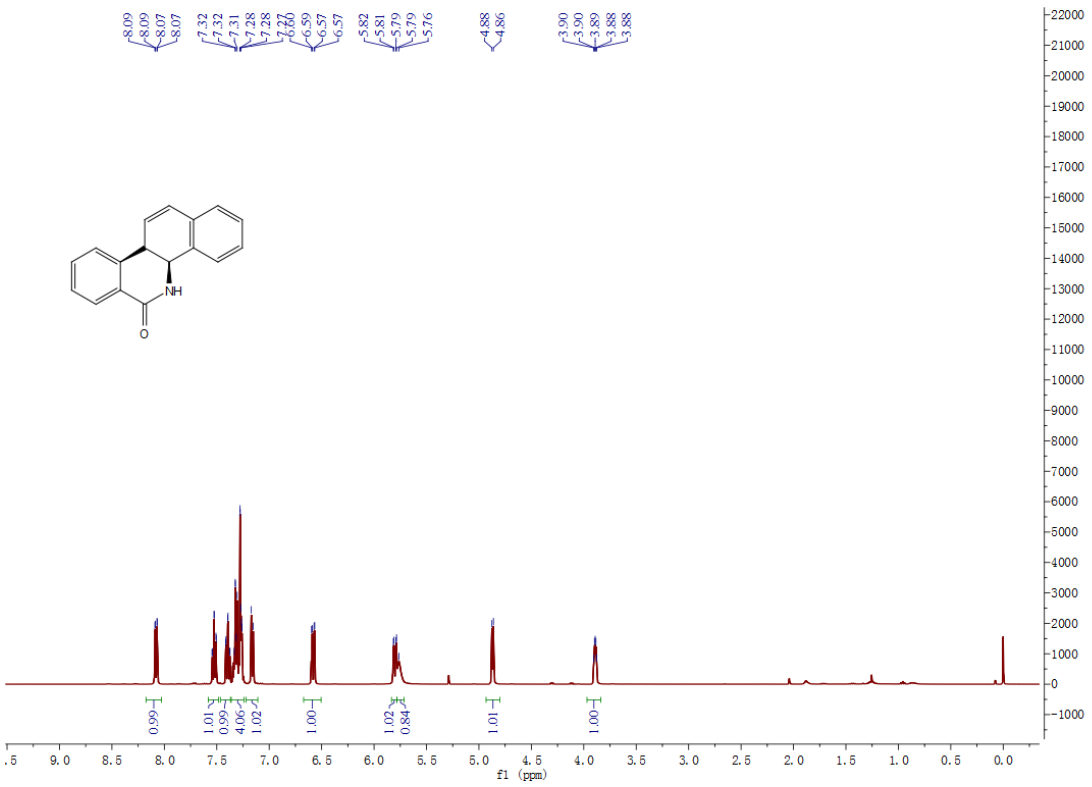
129.23
128.57
128.17
127.89
127.65
127.00
126.85
126.68
117.11
111.25
77.36
77.04
76.72
52.57
40.65
37.88
f1 (ppm)

3ap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8.09
8.07
8.07
7.32
7.32
7.31
7.28
7.28
6.59
6.57
6.57
5.82
5.81
5.79
5.79
5.76
4.88
4.86
3.90
3.90
3.89
3.88
3.88
NH
O
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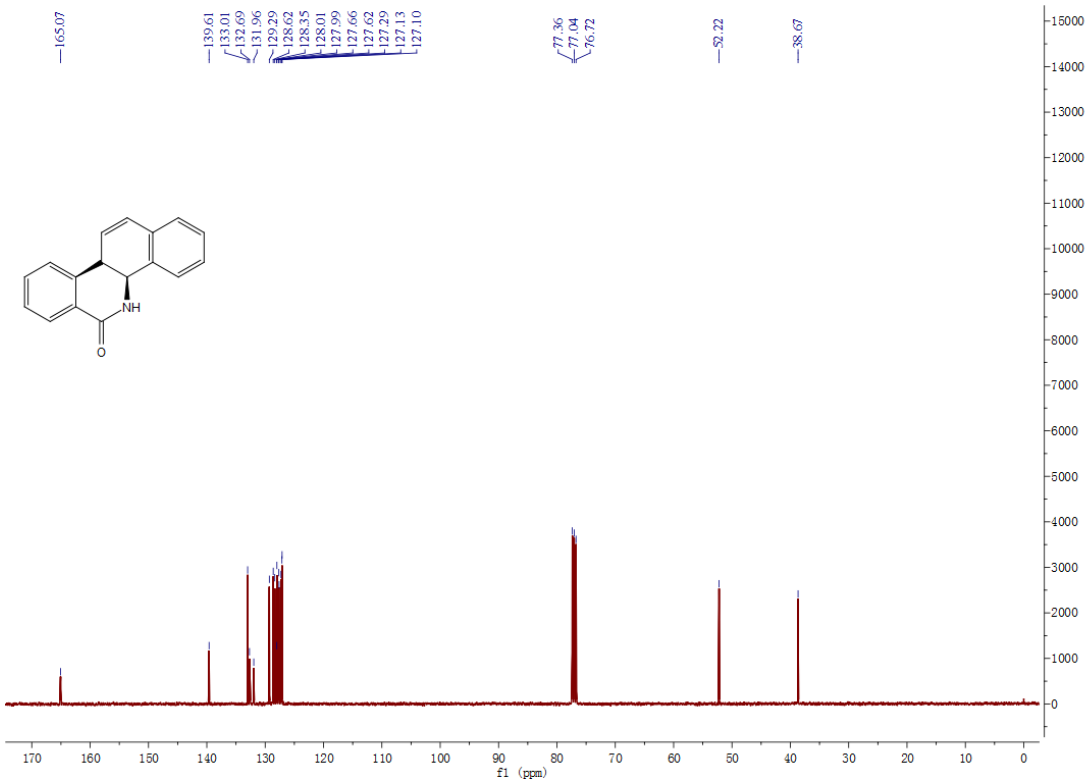
1.01
0.99
4.06
1.02
1.00
1.02
0.84
1.01
1.00
f1 (ppm)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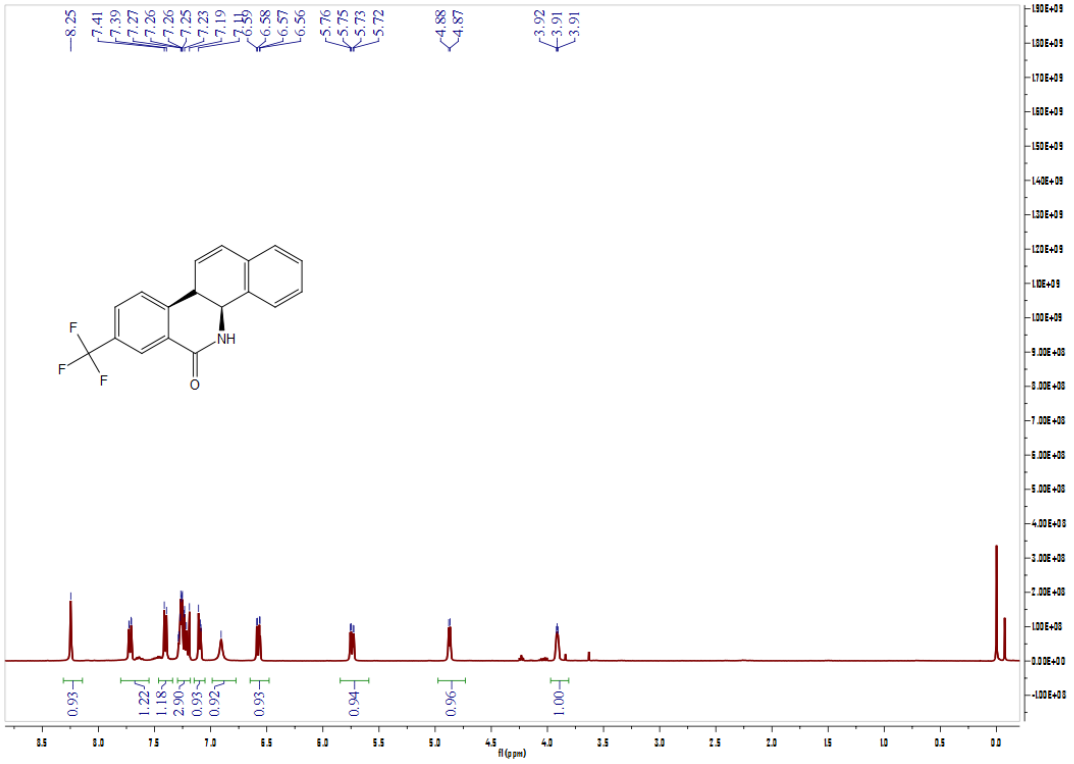
129.29
128.62
128.35
128.01
127.99
127.66
127.62
127.29
127.13
127.10
77.36
77.04
76.72
52.22
38.67
NH
O
f1 (ppm)

3ax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7.41
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7.27
7.26
7.26
7.25
7.23
7.19
7.11
6.59
6.58
6.57
6.56
5.76
5.75
5.73
5.72
4.88
4.87
3.92
3.91
3.91
NH
O
F
F
F
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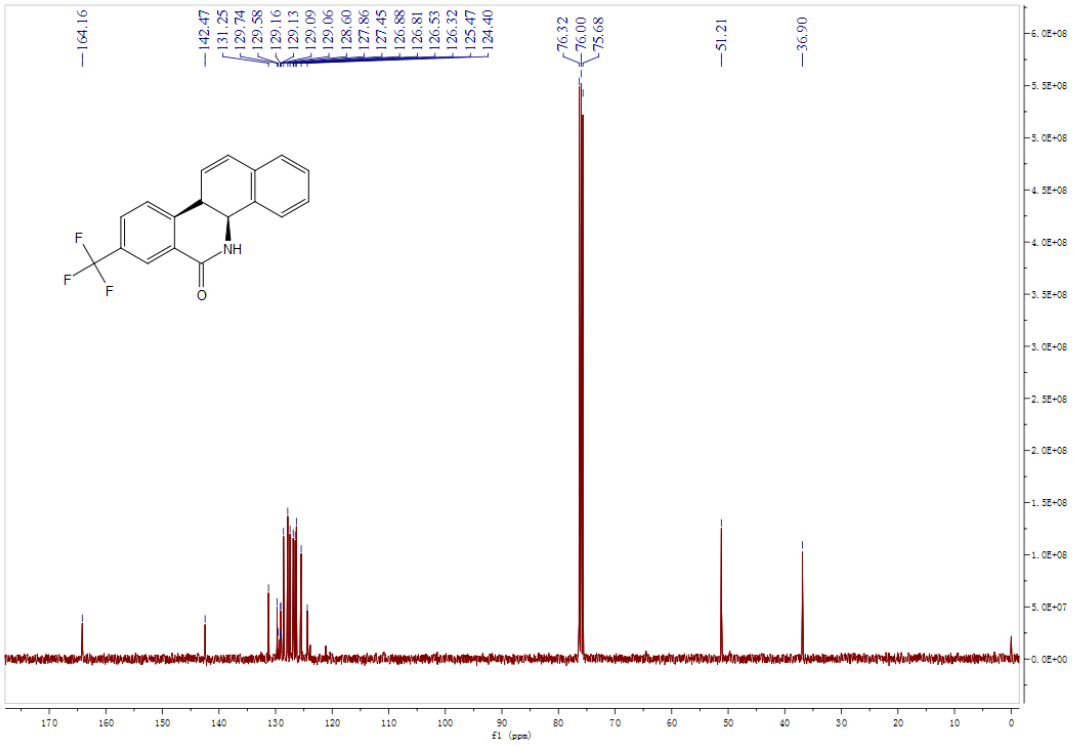
1.22
1.18
2.90
0.93
0.92
0.93
0.94
0.96
1.00
f1 (ppm)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142.47
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129.74
129.58
129.16
129.13
129.09
129.06
128.60
127.86
127.45
126.88
126.81
126.53
126.32
125.47
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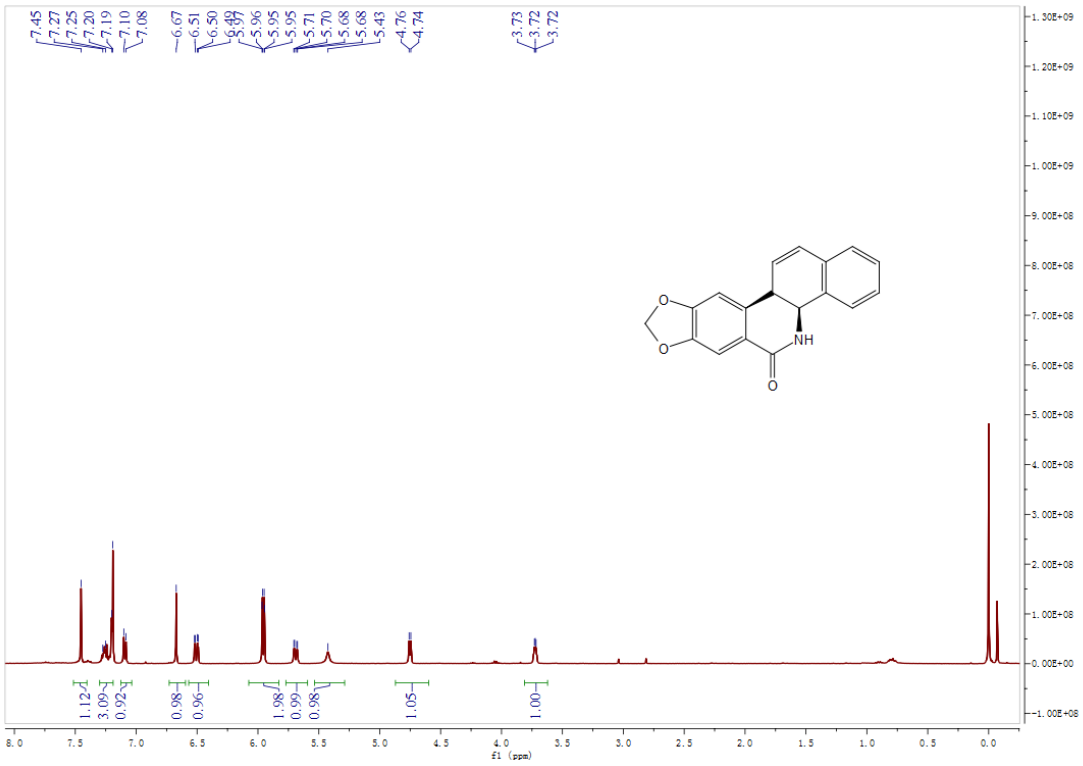
76.32
76.00
75.68
51.21
36.90
NH
O
F
F
F
f1 (ppm)

3ay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7.27
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7.19
7.10
7.08
6.67
6.51
6.50
5.96
5.95
5.95
5.71
5.70
5.68
5.68
5.43
4.76
4.74
3.73
3.72
3.72
O
O
NH
O
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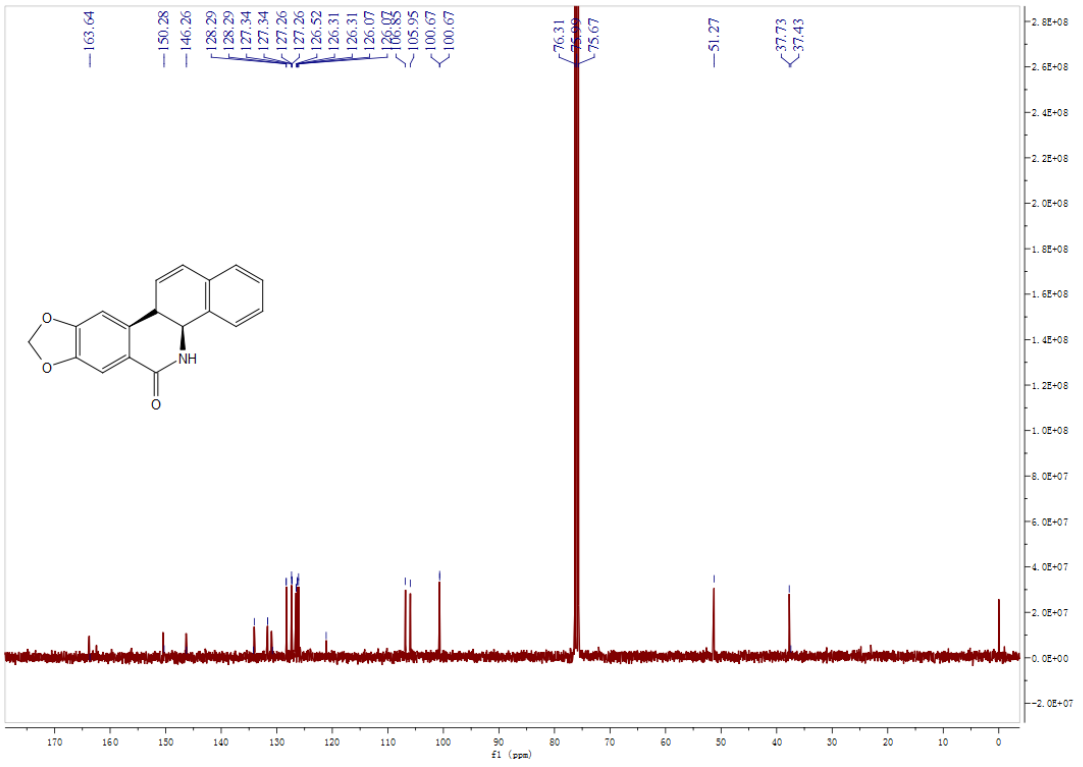
3.09
0.92
0.98
0.96
1.98
0.99
0.98
1.05
1.00
f1 (ppm)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128.29
127.34
127.34
127.26
127.26
126.52
126.31
126.31
126.07
108.85
105.95
100.67
100.67
76.31
75.67
51.27
37.73
37.43
O
O
NH
O
f1 (ppm)

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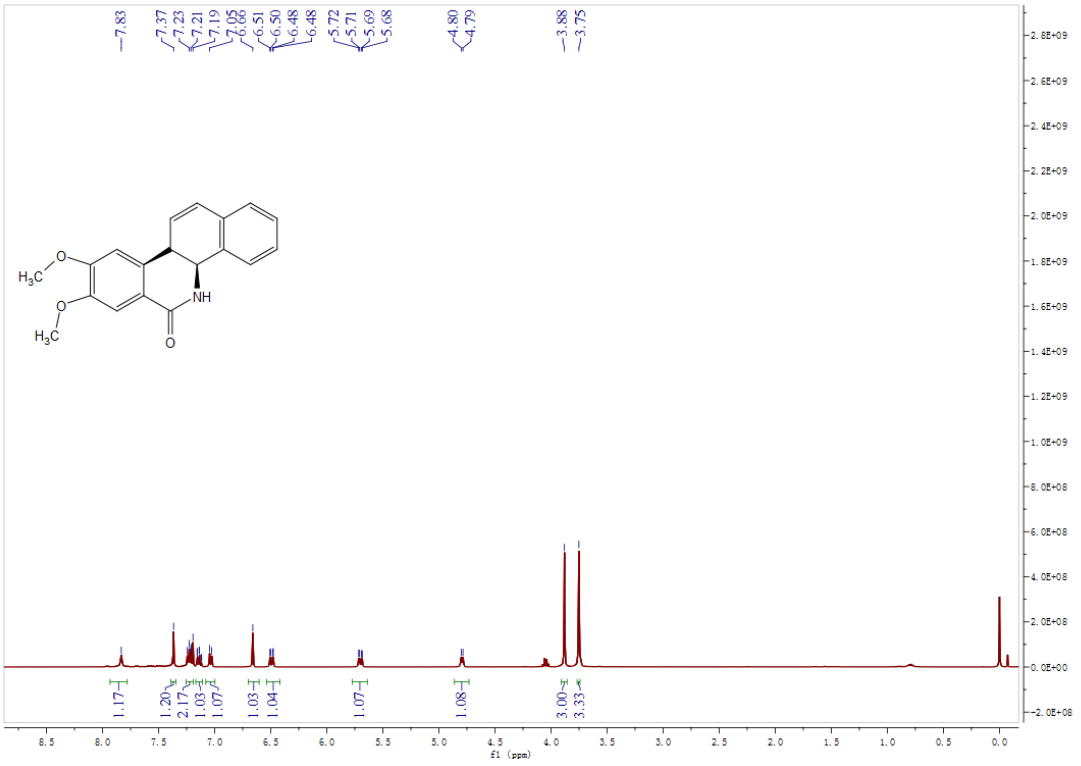
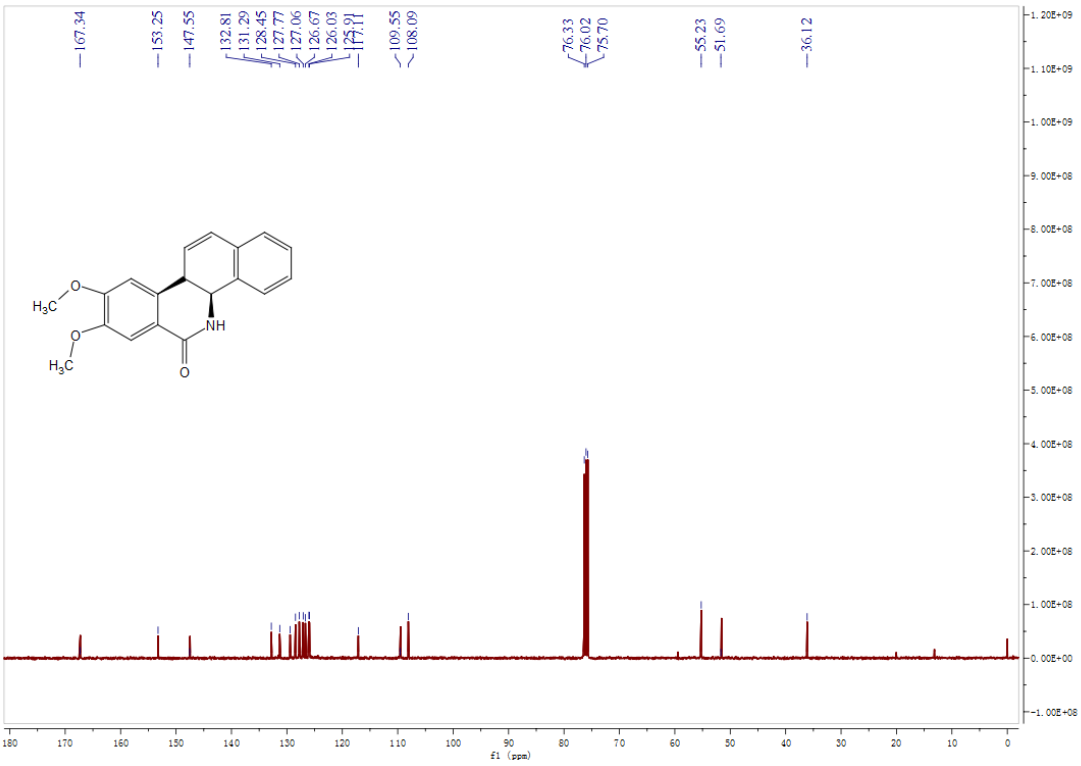
3az





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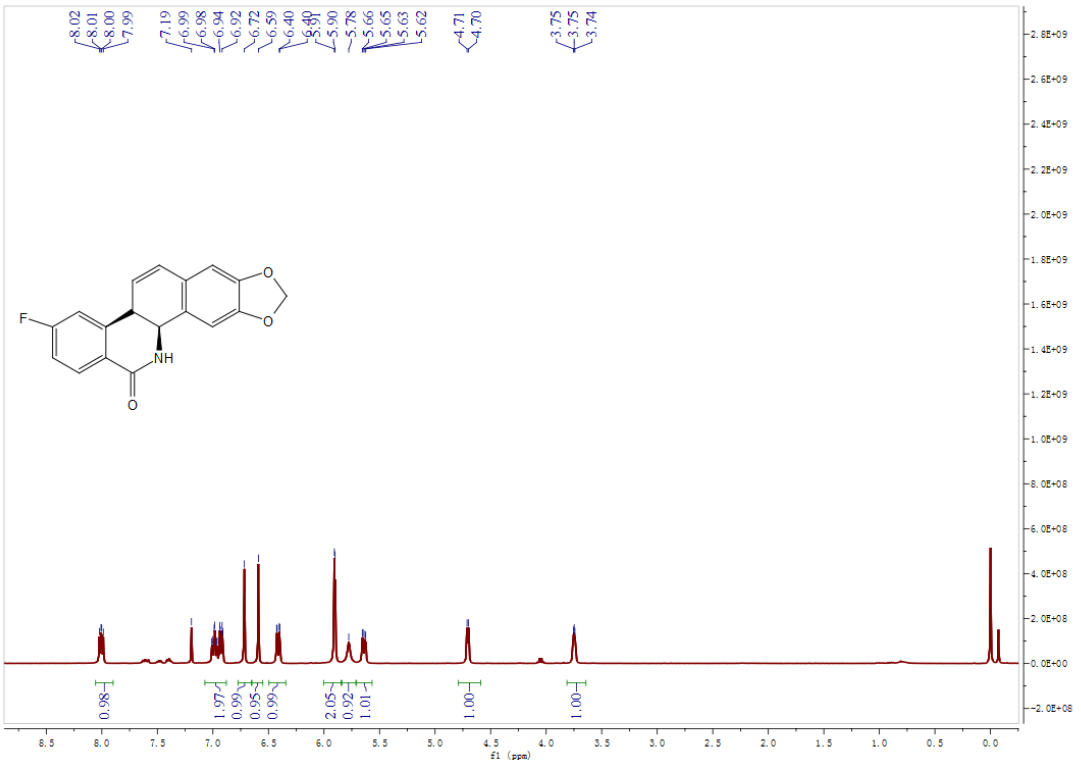
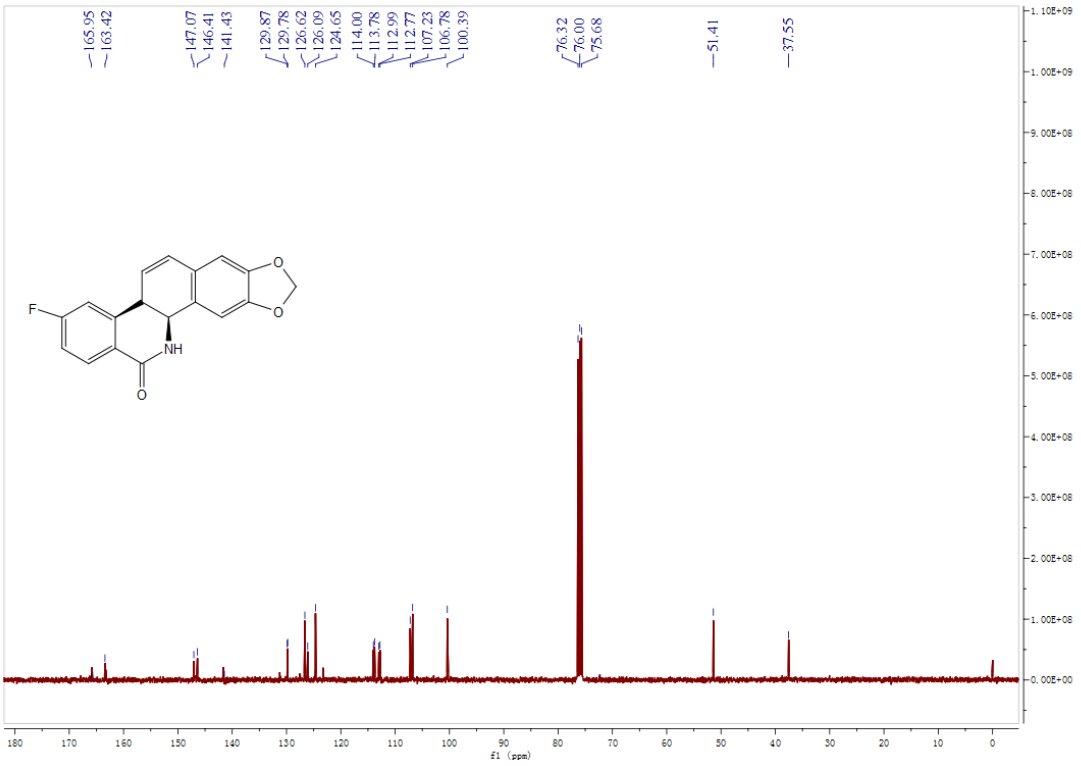
3ba





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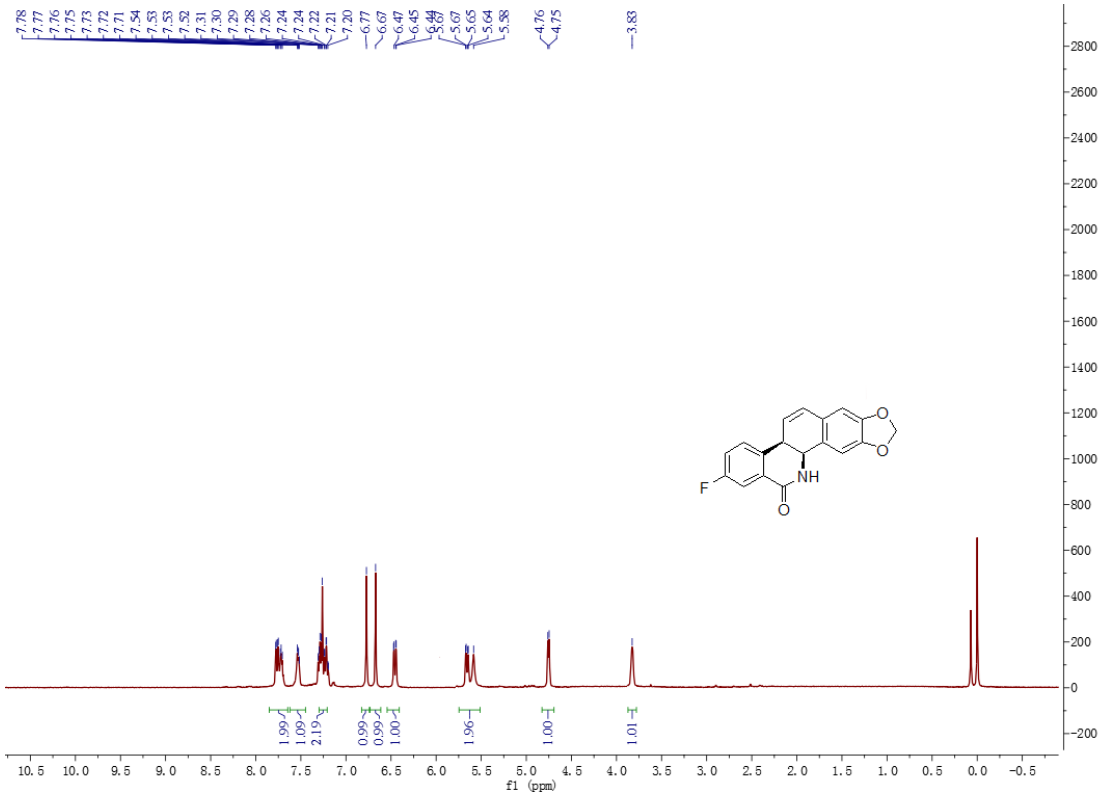
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7.72
7.71
7.54
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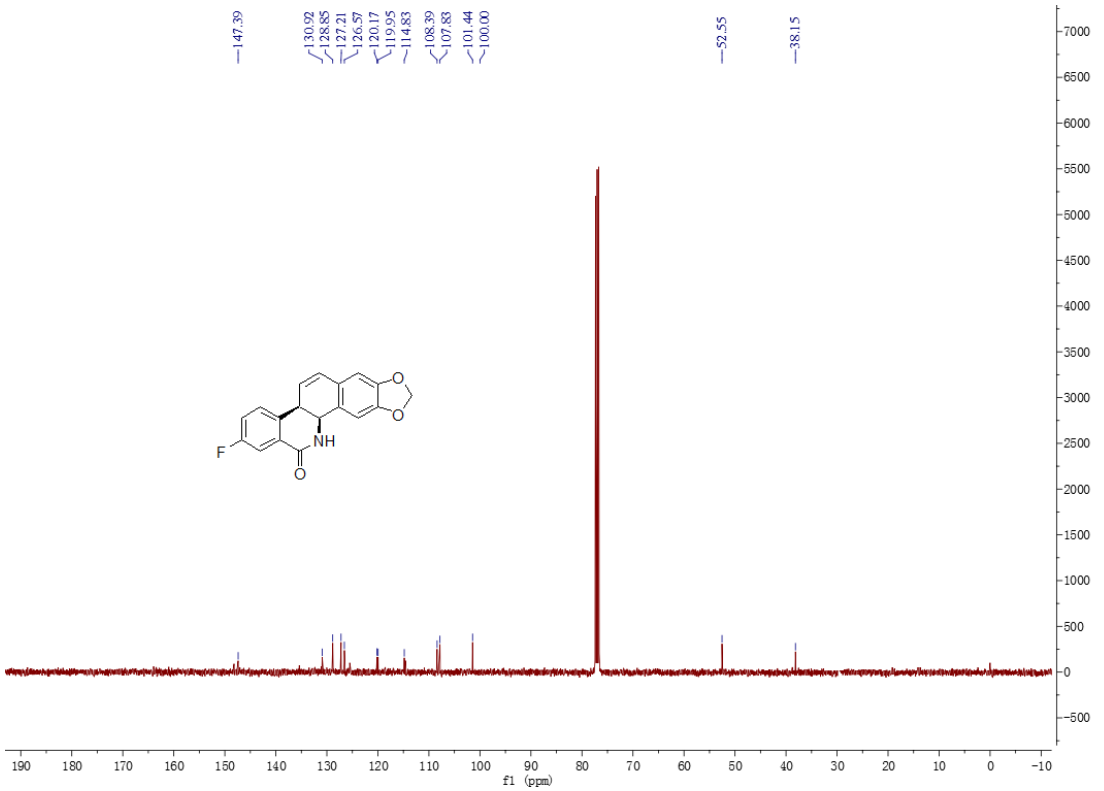
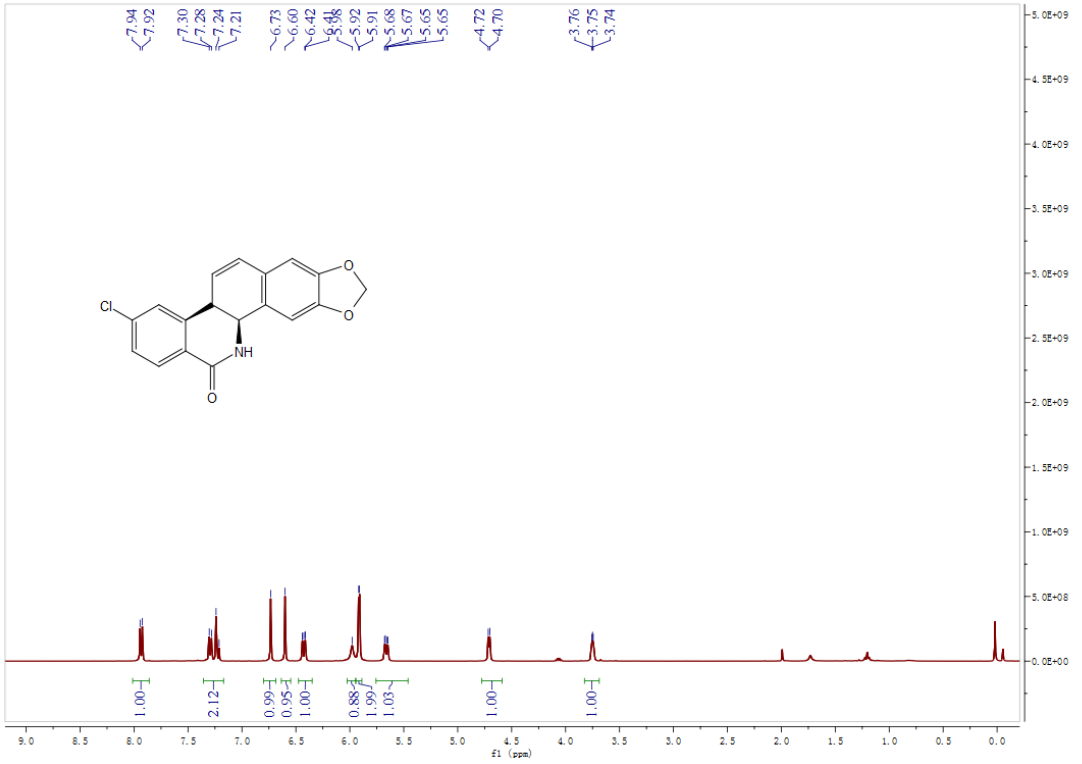
7.53
7.52
7.31
7.30
7.29
7.28
7.26
7.24
7.24
7.22
7.21
7.20
6.77
6.67
6.47
6.45
6.44
5.67
5.67
5.65
5.64
5.38
4.76
4.75
3.83
F
NH
O
O
O
1.99
1.09
2.19
0.99
0.99
1.00
1.96
1.00
1.01
f1 (ppm)


147.39
130.92
128.85
127.21
126.57
120.17
119.95
114.83
108.39
107.83
101.44
100.00
52.55
38.15
F
NH
O
O
O
f1 (ppm)

3bd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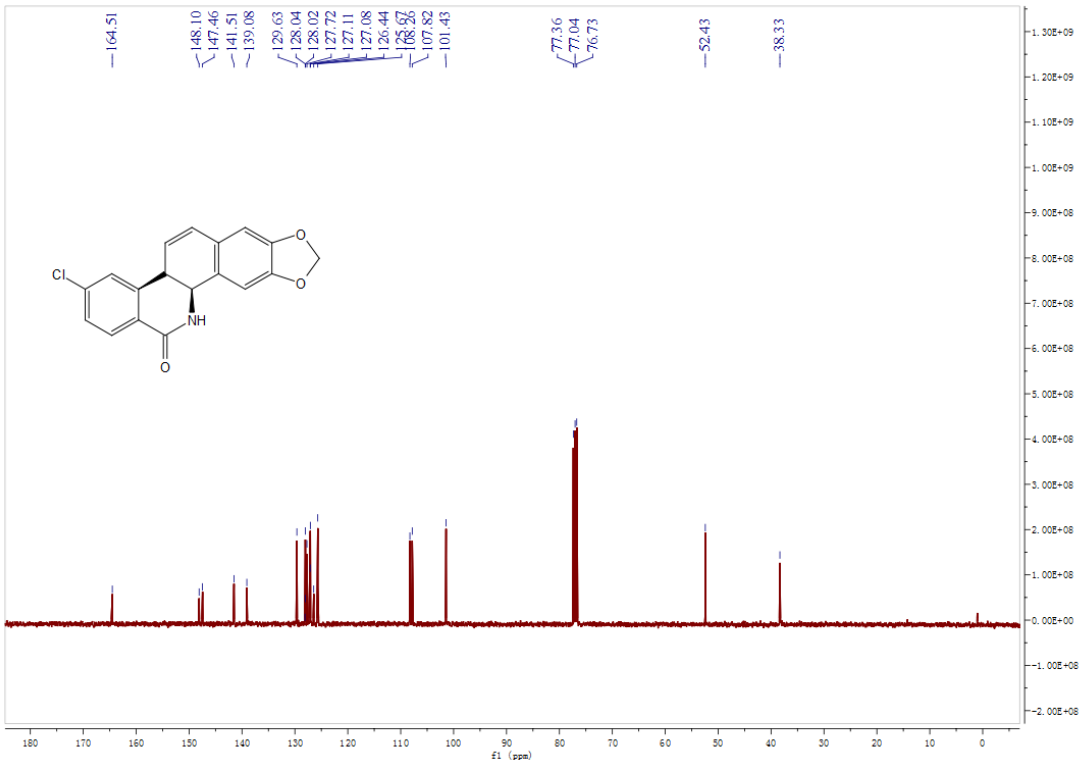
7.92
7.30
7.28
7.24
7.21
6.73
6.60
6.42
5.92
5.91
5.68
5.67
5.65
5.65
4.72
4.70
3.76
3.75
3.74
Cl
NH
O
O
O
1.00
2.12
0.99
0.95
1.00
0.88
1.99
1.03
1.00
1.00
f1 (ppm)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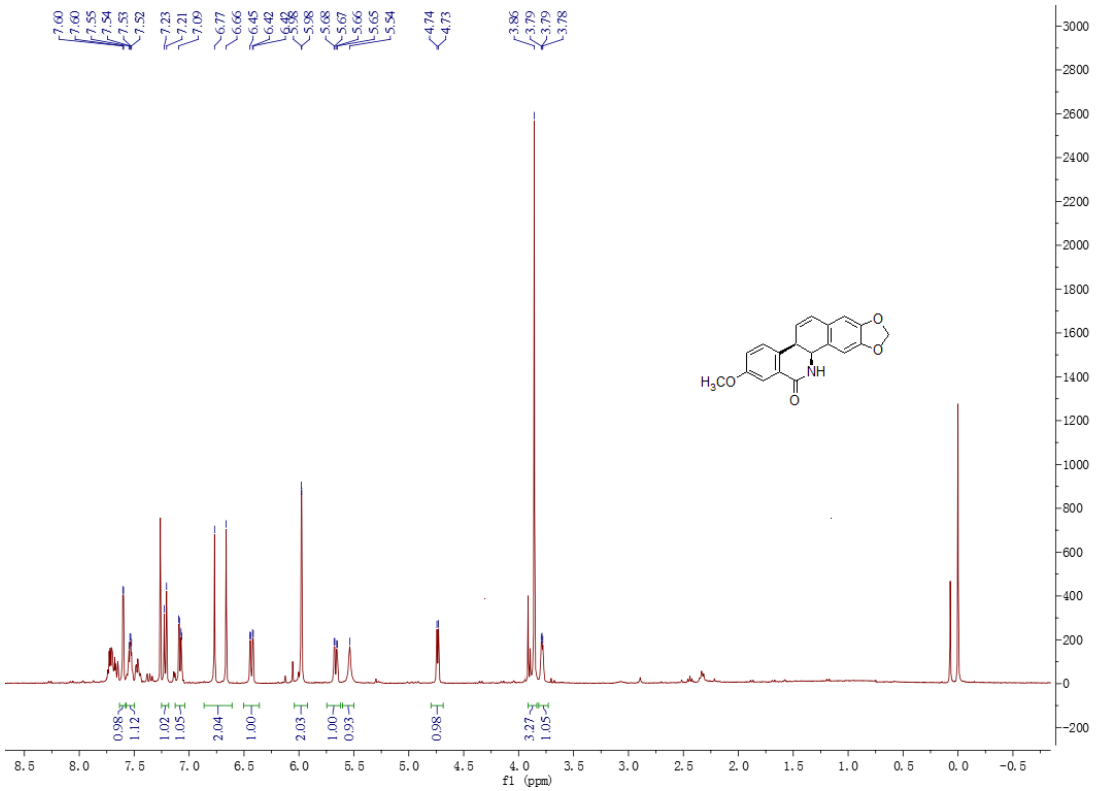
129.63
128.04
128.02
127.72
127.11
127.08
126.44
108.26
107.82
101.43
77.36
77.04
76.73
52.43
38.33
Cl
NH
O
O
O
f1 (ppm)

3bi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7.55
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7.23
7.21
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6.77
6.66
6.45
6.42
5.98
5.68
5.67
5.66
5.65
5.54
4.74
4.73
3.86
3.79
3.79
3.78
0.98
1.12
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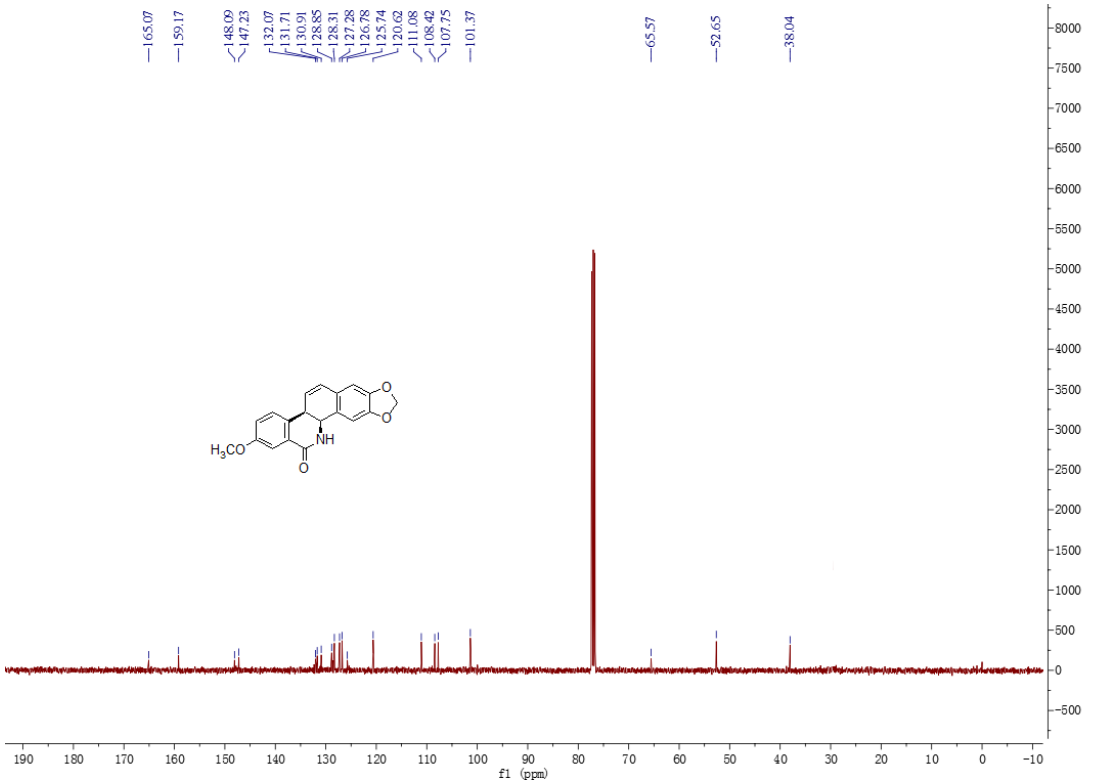
2.04
1.00
2.03
1.00
0.93
0.98
3.27
1.05
f1 (ppm)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128.31
127.28
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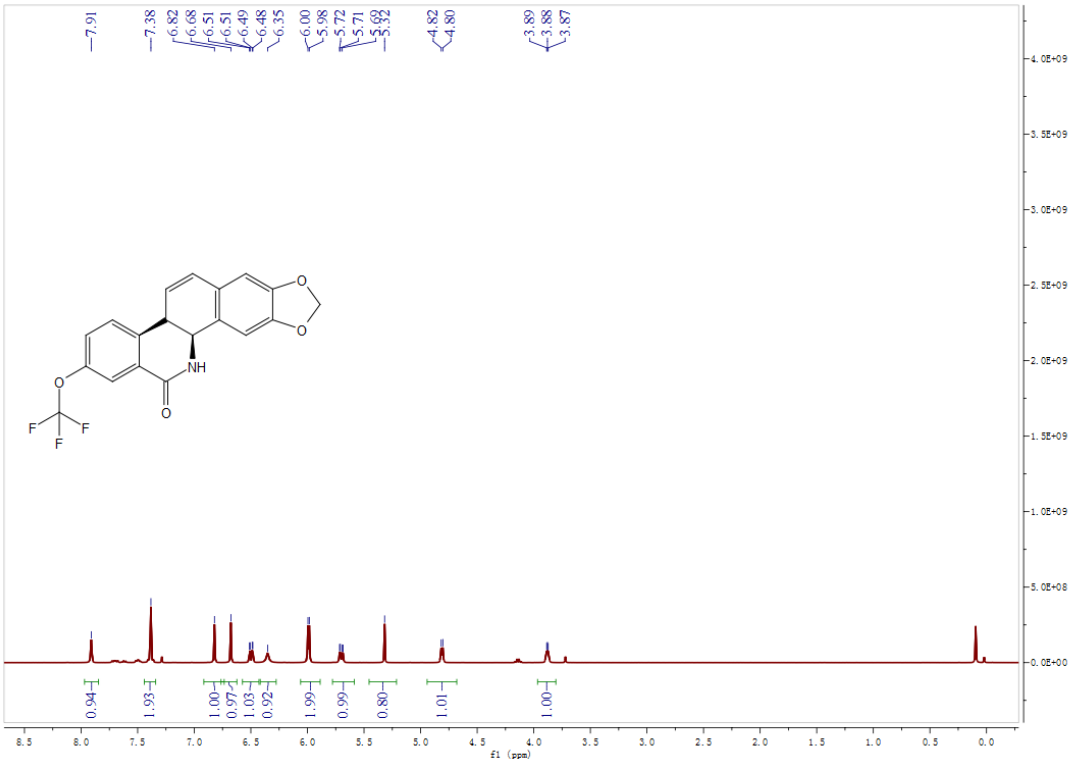
111.08
108.42
107.75
101.37
65.57
52.65
38.04
f1 (ppm)

3bk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6.48
6.35
6.00
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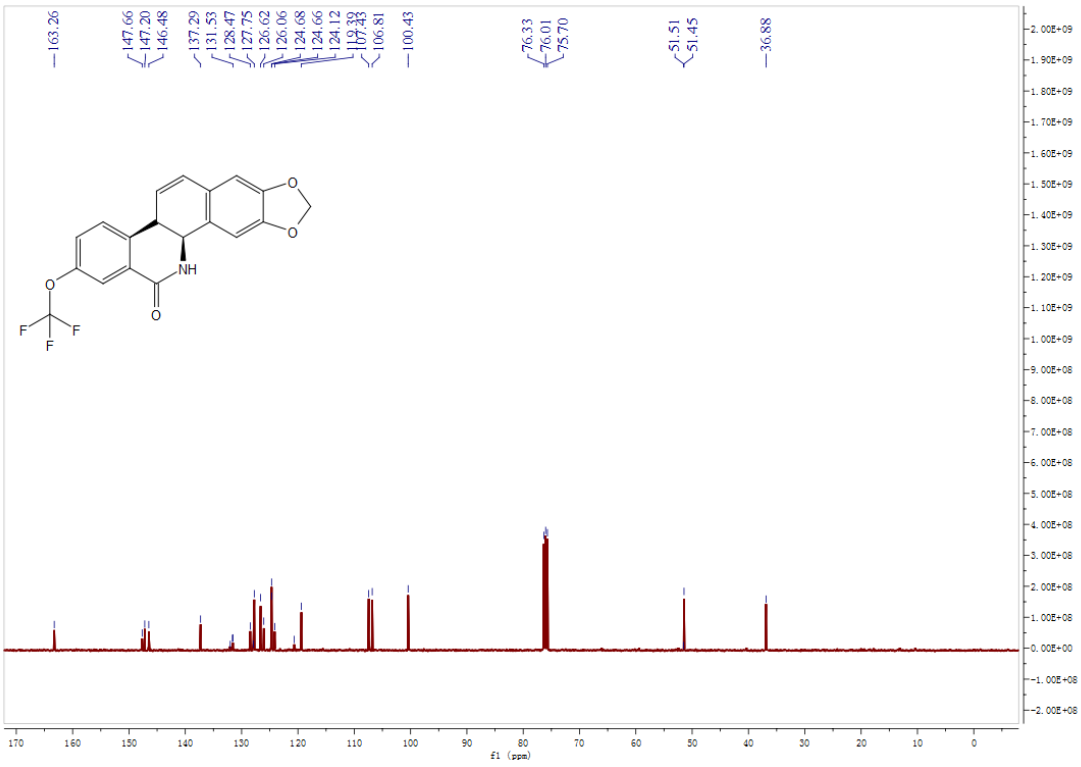
5.71
5.69
5.32
4.82
4.80
3.89
3.88
3.87
0.94
1.93
1.00
0.97
1.03
0.92
1.99
0.99
0.80
1.01
1.00
f1 (ppm)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137.29
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128.47
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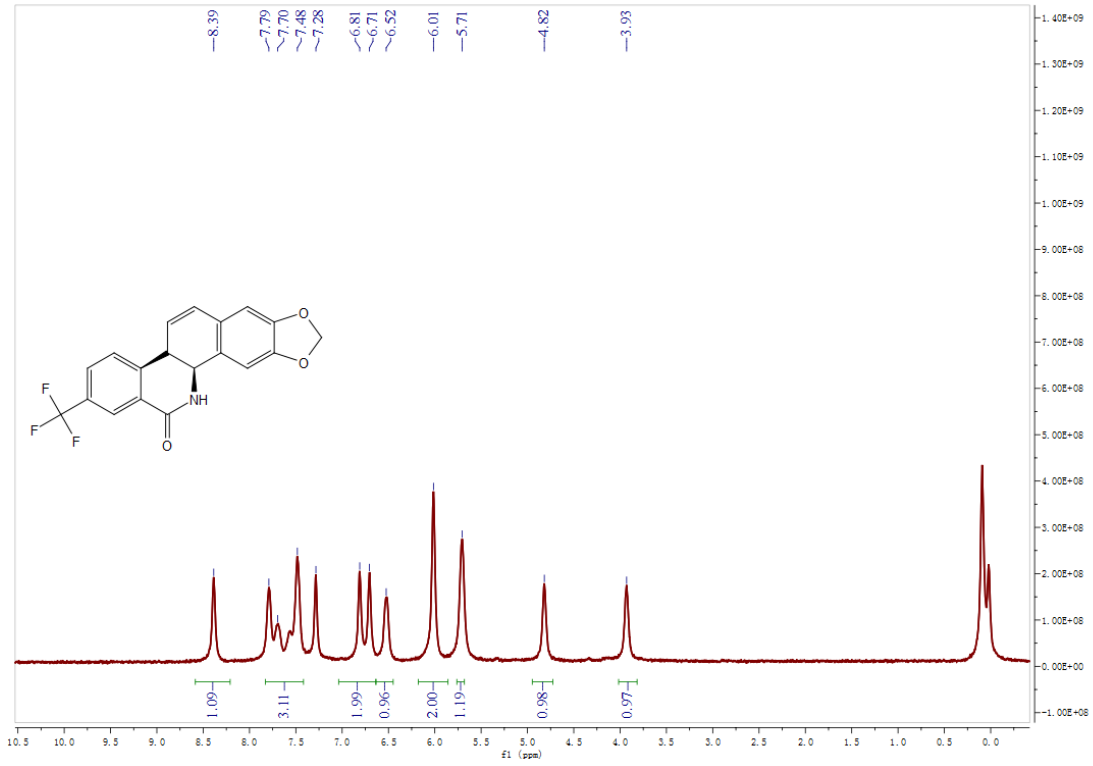
126.06
124.68
124.66
124.12
119.33
107.43
106.81
100.43
76.33
76.01
75.70
51.51
51.45
36.88
f1 (ppm)

3bx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6.52
6.01
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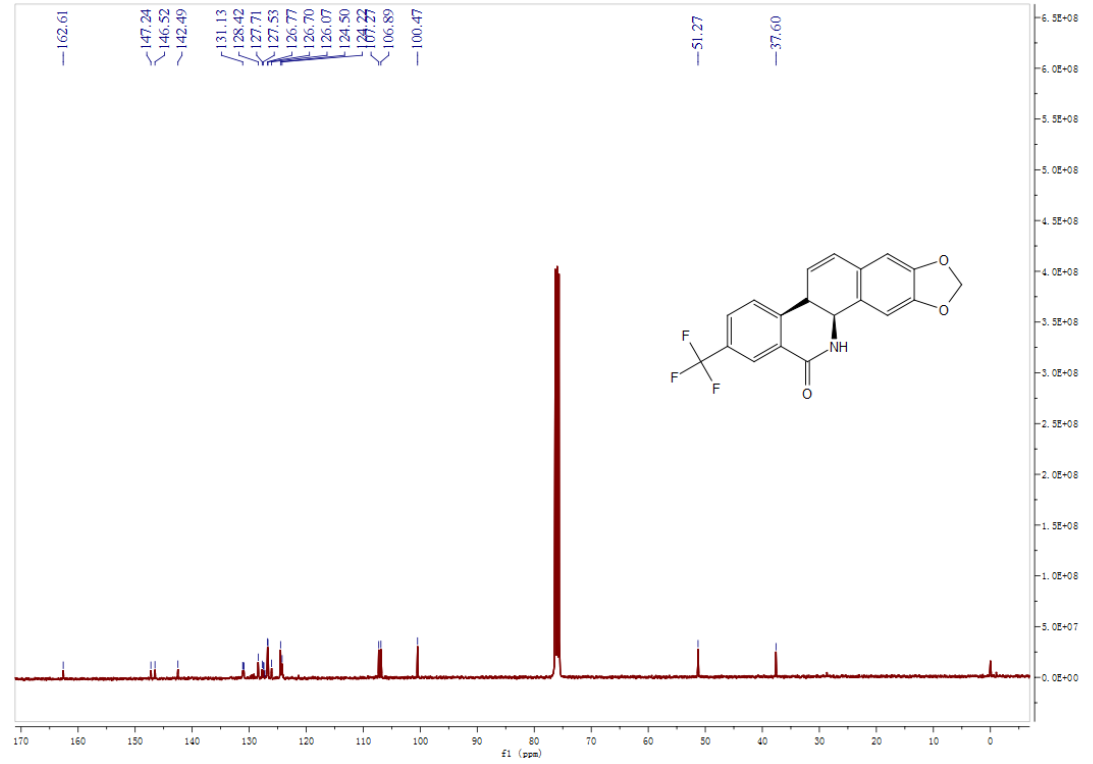
1.09
3.11
1.99
0.96
2.00
1.19
0.98
0.97
f1 (ppm)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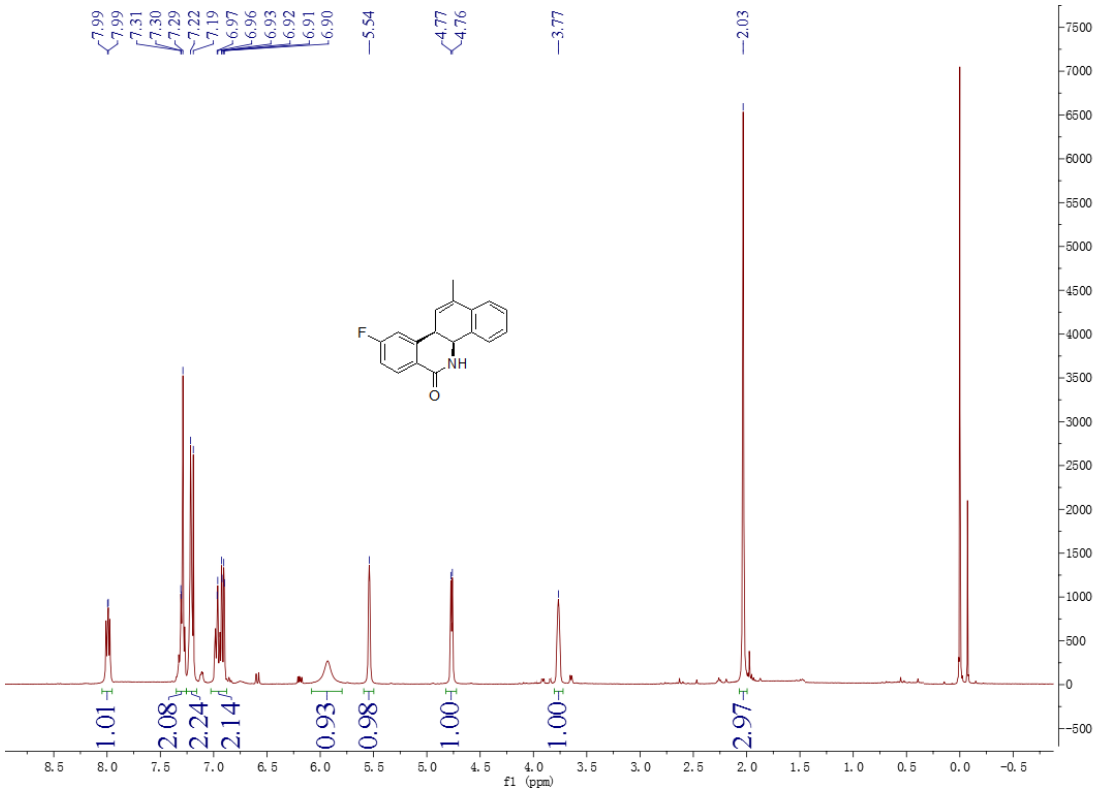
126.07
124.50
106.89
100.47
51.27
37.60
f1 (ppm)

3ca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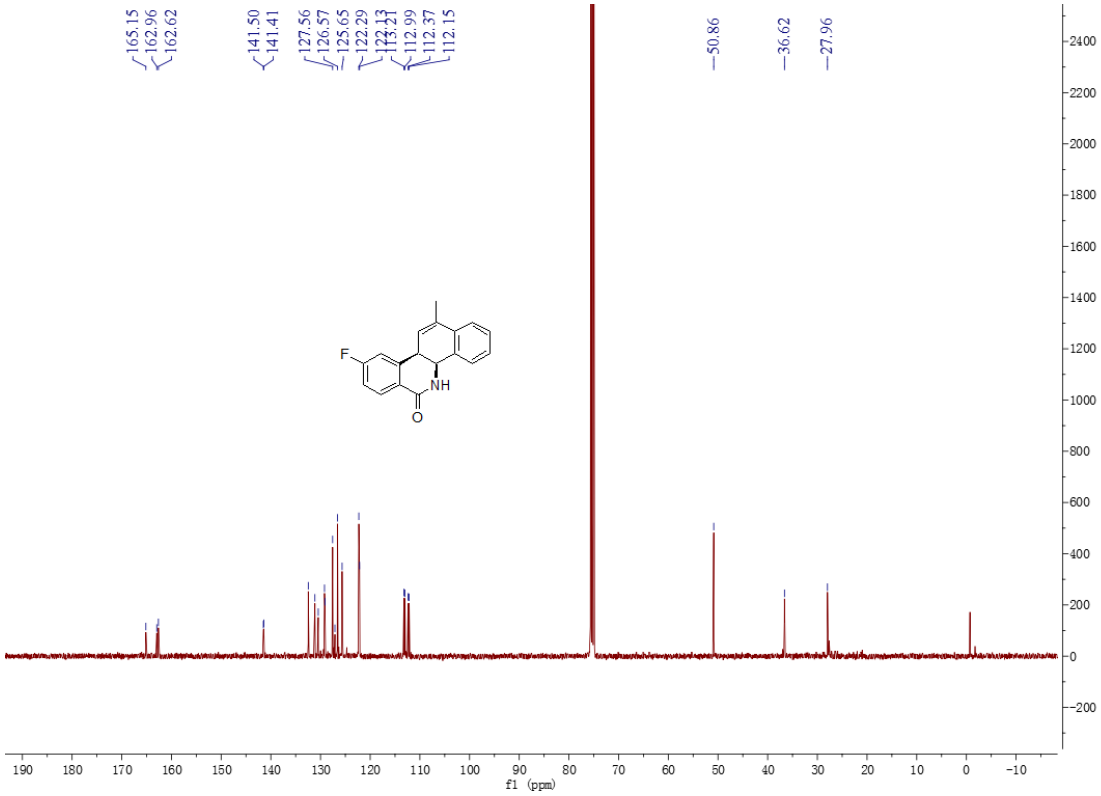
6.92
6.91
6.90
5.54
4.77
4.76
3.77
2.03
F
NH
O
1.01
2.08
2.24
2.14
0.93
0.98
1.00
1.00
2.97
f1 (ppm)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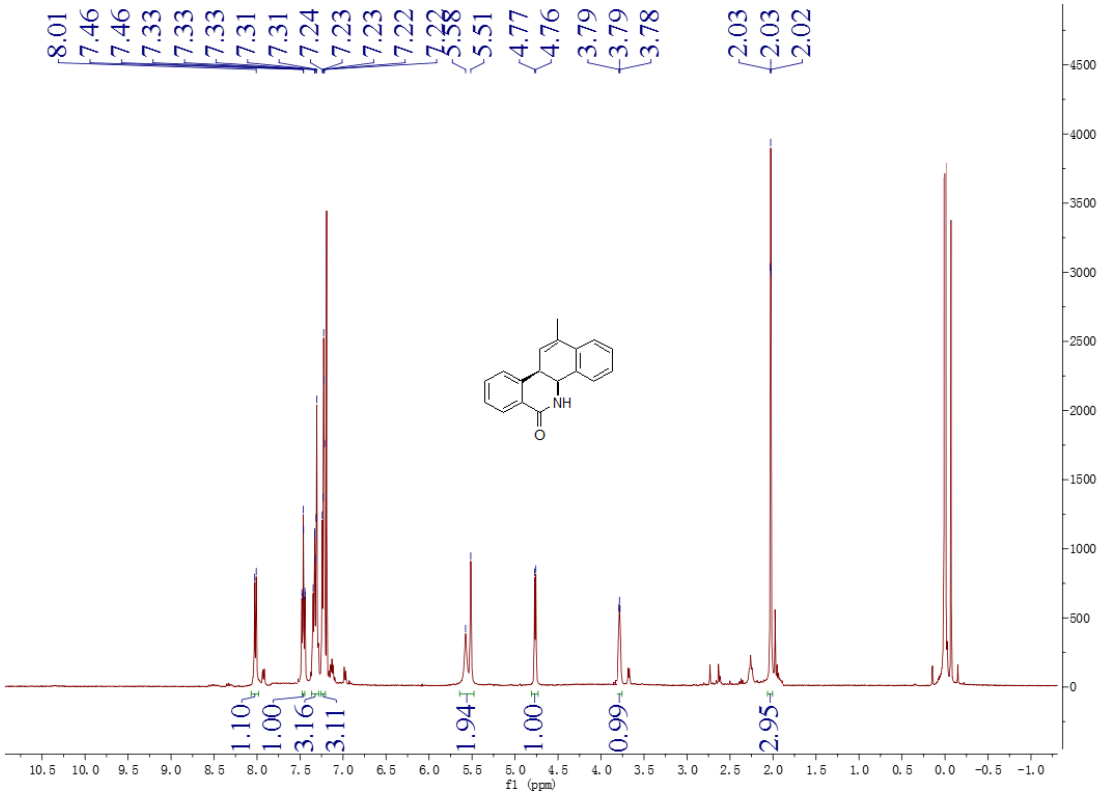
36.62
27.96
F
NH
O
f1 (ppm)

3cp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7.22
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5.58
5.51
4.77
4.76
3.79
3.79
3.78
2.03
2.03
2.02
NH
O
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3.11
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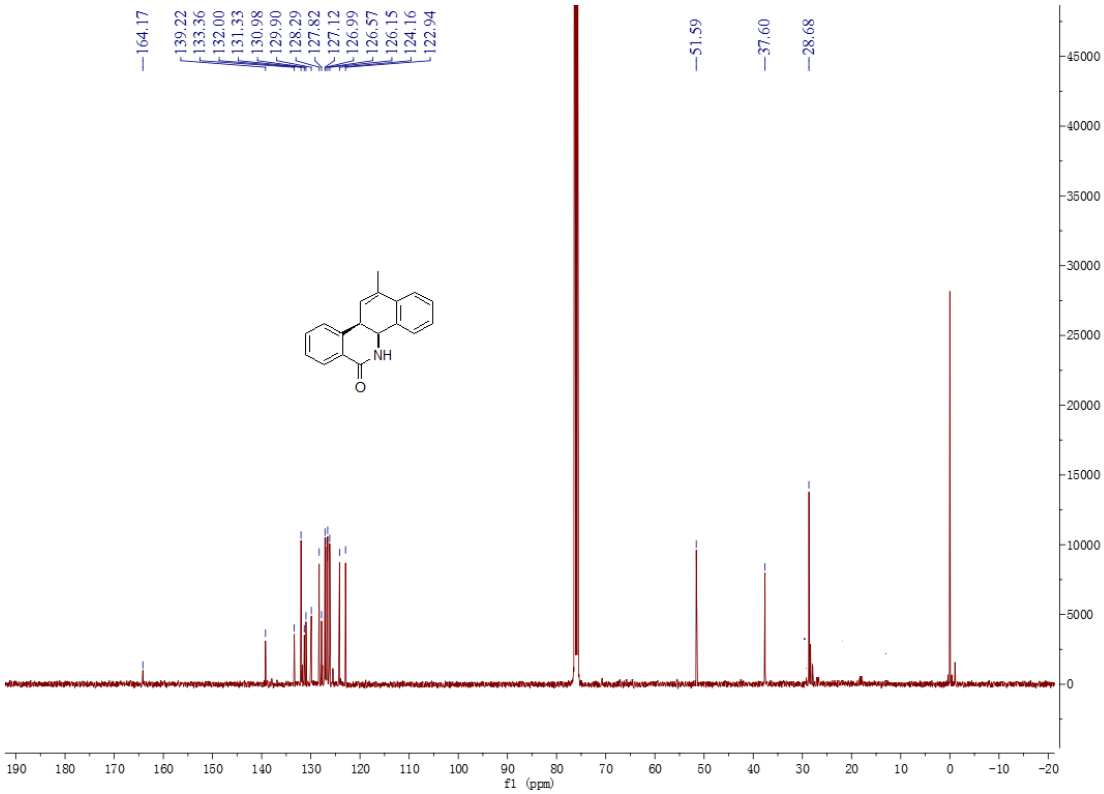
1.00
0.99
2.95
f1 (ppm)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127.82
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126.15
124.16
122.94
51.59
37.60
28.68
NH
O
f1 (ppm)