**Supporting Information for**

# Copper-mediated oxidative [3+2]-annulation of nitroalkenes and pyridinium imines: efficient synthesis of 3-fluoro- and 3-nitro-pyrazolo[1,5-a]pyridines.

Vladimir Motornov,[a,b] Andrey A. Tabolin,[*a] Yulia V. Nelyubina,[c] Valentine G. Nenajdenko,[d] Sema L. Ioffe[a]

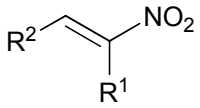
[a] *N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, Leninsky prosp. 47, Moscow, 119991, Russia. E-mail: tabolin87@mail.ru*

[b] *Higher Chemical College, D. I. Mendeleev University of Chemical Technology of Russia, Miusskaya sq. 9, Moscow 125047, Russia.*

[c] *A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, Vavilov str. 28, Moscow, 119991, Russia.*

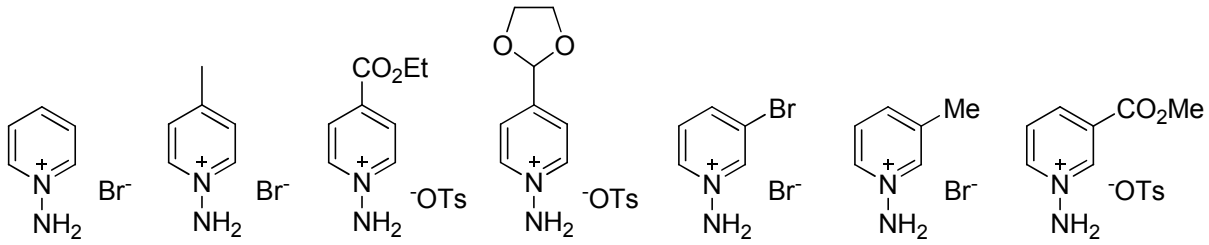
[d] *Department of Chemistry, M. V. Lomonosov Moscow State University, Leninskie Gory 1, Moscow 119991, Russia.*

**List of starting nitroalkenes and azinium salts.**

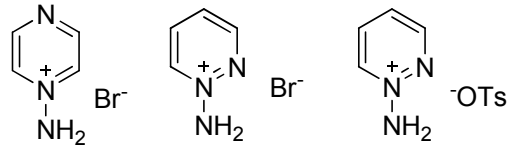


**1a**, $R^1$ = F, $R^2$ = 4-Cl-$C_6H_4$-
**1b**, $R^1$ = F, $R^2$ = 4-Br-$C_6H_4$-
**1c**, $R^1$ = F, $R^2$ = 4-F-$C_6H_4$-
**1d**, $R^1$ = F, $R^2$ = 4-Me-$C_6H_4$-
**1e**, $R^1$ = F, $R^2$ = 4-$CO_2$Me-$C_6H_4$-
**1f**, $R^1$ = F, $R^2$ = 4-$CF_3$-$C_6H_4$-
**1g**, $R^1$ = F, $R^2$ = 4-OMe-$C_6H_4$-
**1h**, $R^1$ = F, $R^2$ = 3,4-di(OMe)-$C_6H_3$-
**1i**, $R^1$ = F, $R^2$ = 3-OMe-$C_6H_4$-
**1j**, $R^1$ = F, $R^2$ = 2-Cl-$C_6H_4$-

**4a**, $R^1$ = H, $R^2$ = 4-Cl-$C_6H_4$-
**4b**, $R^1$ = H, $R^2$ = Ph-
**4c**, $R^1$ = H, $R^2$ = 4-OMe-$C_6H_4$-
**4d**, $R^1$ = H, $R^2$ = $PhCH_2CH_2$-
**4e**, $R^1$ = H, $R^2$ = t-Bu-
**4f**, $R^1$ = H, $R^2$ = 4-Br-$C_6H_4$-
**7**, $R^1$ = Cl, $R^2$ = 4-OMe-$C_6H_4$-
**9**, $R^1$ = Br, $R^2$ = 4-OMe-$C_6H_4$-



**2a** **2b** **2c** **2d** **2e** **2f** **2g**



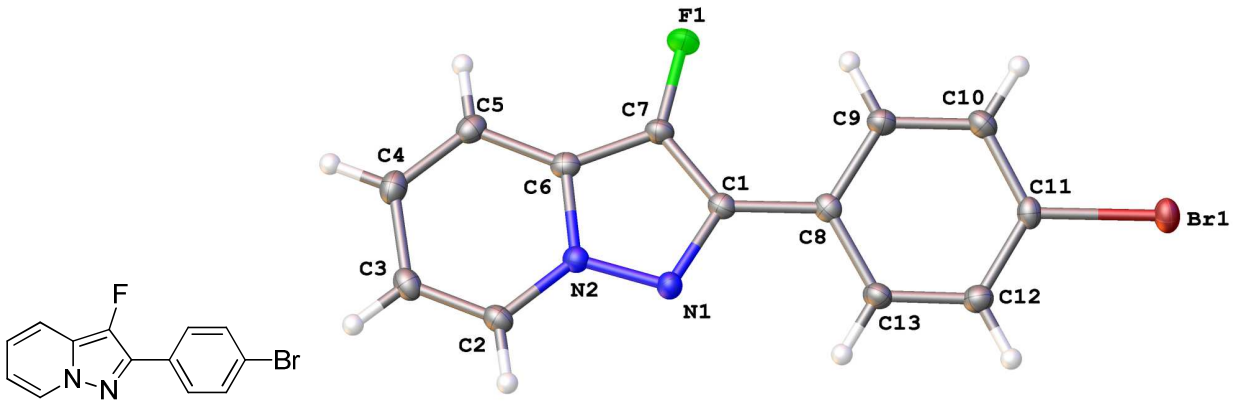
**2h** **2i** **2j**

Literature procedures for the preparation: **1a,c-e,g,h**,[s1] **1b**,[s2] **1f,i,j**,[s3] **4a-c**,**f**,[s4] **4d**,[s5] **4e**,[s6] **6**,[s7] **8**.[s8]

**References:**


s1. V. A. Motornov, V. M. Muzalevskiy, A. A. Tabolin, R. A. Novikov, Yu. V. Nelyubina, V. G. Nenajdenko and S. L. Ioffe, *J. Org. Chem.*, 2017, **82**, 5274.
s2. A. S. Aldoshin, A. A. Tabolin, S. L. Ioffe and V. G. Nenajdenko, *Eur. J. Org. Chem.*, 2018, 3816.
s3. V. A. Motornov, A. A. Tabolin, R. A. Novikov, Yu. V. Nelyubina, S. L. Ioffe, I. S. Smolyar and V. G. Nenajdenko, *Eur. J. Org. Chem.*, 2017, 6851.
s4. X. Ji, H. Tong and Y. Yuan, *Synth. Commun.*, 2011, **41**, 372.
s5. A. J. Simpson and H. W. Lam *Org. Lett.* 2003, **15**, 2586.
s6. S. E. Denmark and L. R. Marcin, *J. Org. Chem.*, 1995, **60**, 3221.
s7. V. A. Motornov, A. A. Tabolin, R. A. Novikov, Yu. V. Nelyubina, V. G. Nenajdenko and S. L. Ioffe, *Org. Chem. Front.*, 2018, **5**, 2588.
s8. L. V. Romashov, Yu. A. Khomutova, V. M. Danilenko, S. L. Ioffe and A. V. Lesiv, *Synthesis*, 2010, 407.

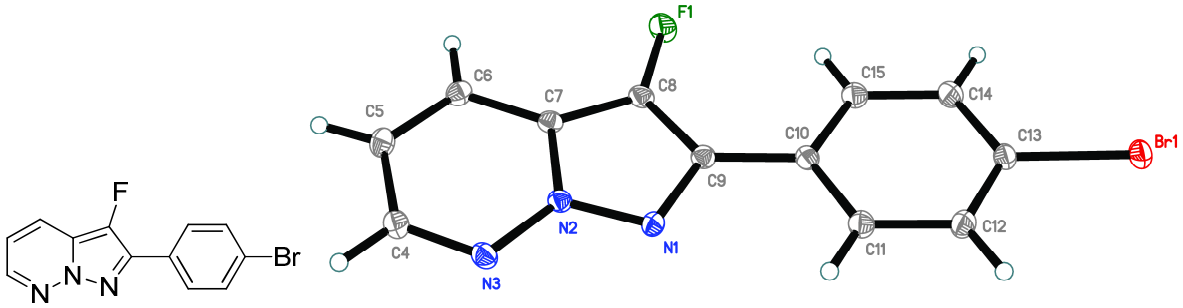
**2-(4-Bromophenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3b**




General view of the compound **3b** in representation of atoms *via* thermal ellipsoids at 50% probability level.

Crystals of **3b** ($C_{13}H_{16}N_4O_2$, M = 260.30) are monoclinic, space group $P2_1/c$, at 120 K: a = 18.5420(12), b = 4.0333(3), c = 22.2351(15) Å, β = 138.9436(10)°, V = 1092.17(13) $Å^3$, Z = 4 (Z' = 1), $d_{calc}$ = 1.770 $gcm^{-3}$, μ(MoKα) = 37.52 $cm^{-1}$, F(000) = 576. Intensities of 23407 reflections were measured with a Bruker APEX2 DUO CCD diffractometer [λ(MoKα) = 0.71073 Å, ω-scans, 2θ<58°], and 2911 independent reflections [$R_{int}$ = 0.0411] were used in further refinement. Using Olex2,[s9] the structure was solved with the ShelXT[s10] structure solution program using Intrinsic Phasing and refined with the "olex2.refine" refinement package using Gauss-Newton minimisation.[s11] Positions of hydrogen atoms were calculated, and they were refined in the isotropic approximation within the riding model. The refinement converged to wR2 = 0.0573 and GOF = 1.021 for all the independent reflections (R1 = 0.0228 was calculated against F for 2551 observed reflections with I>2σ(I)). CCDC 1969138 contains the supplementary crystallographic information for **3b.**

**2-(4-Bromophenyl)-3-fluoro-pyrazolo[1,5-a]pyridazine 10c**




General view of the compound **10c** in representation of atoms *via* thermal ellipsoids at 50% probability level.

X-ray diffraction data for **10** were collected at 100K on a Bruker Quest D8 diffractometer equipped with a Photon-III area-detector (graphite monochromator, φ- and ω-scan technique), using Mo $K_\alpha$-radiation (0.71073 Å). The intensity data were integrated by the SAINT program[s12] and were corrected for absorption and decay using SADABS.[s13] The structure was solved by direct methods using SHELXS,[s10,s14] and were refined on $F^2$ using SHELXL-2018.[s10,5] All non-hydrogen atoms were refined with individual anisotropic displacement parameters. Positions of all hydrogen atoms were found from the electron density-difference map, these atoms were refined with individual isotropic displacement parameters. The SHELXTL program suite[s10] was

used for molecular graphics. CCDC 1969358 contains the supplementary crystallographic information for **10c.**

**References:**


s9. O.V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard, and H. Puschmann, *J. Appl. Cryst.*, 2009, **42,** 339.

s10. G. M. Sheldrick, *Acta Cryst. A***,** 2015, **71**, 3.

s11. L. J. Bourhis, O.V. Dolomanov, R. J. Gildea, J. A. K. Howard, and H. Puschmann, *Acta Cryst. A***,** 2015, **71**, 59.

s12. Bruker. APEX-III. *Bruker AXS Inc.*, Madison, Wisconsin, USA., 2016.

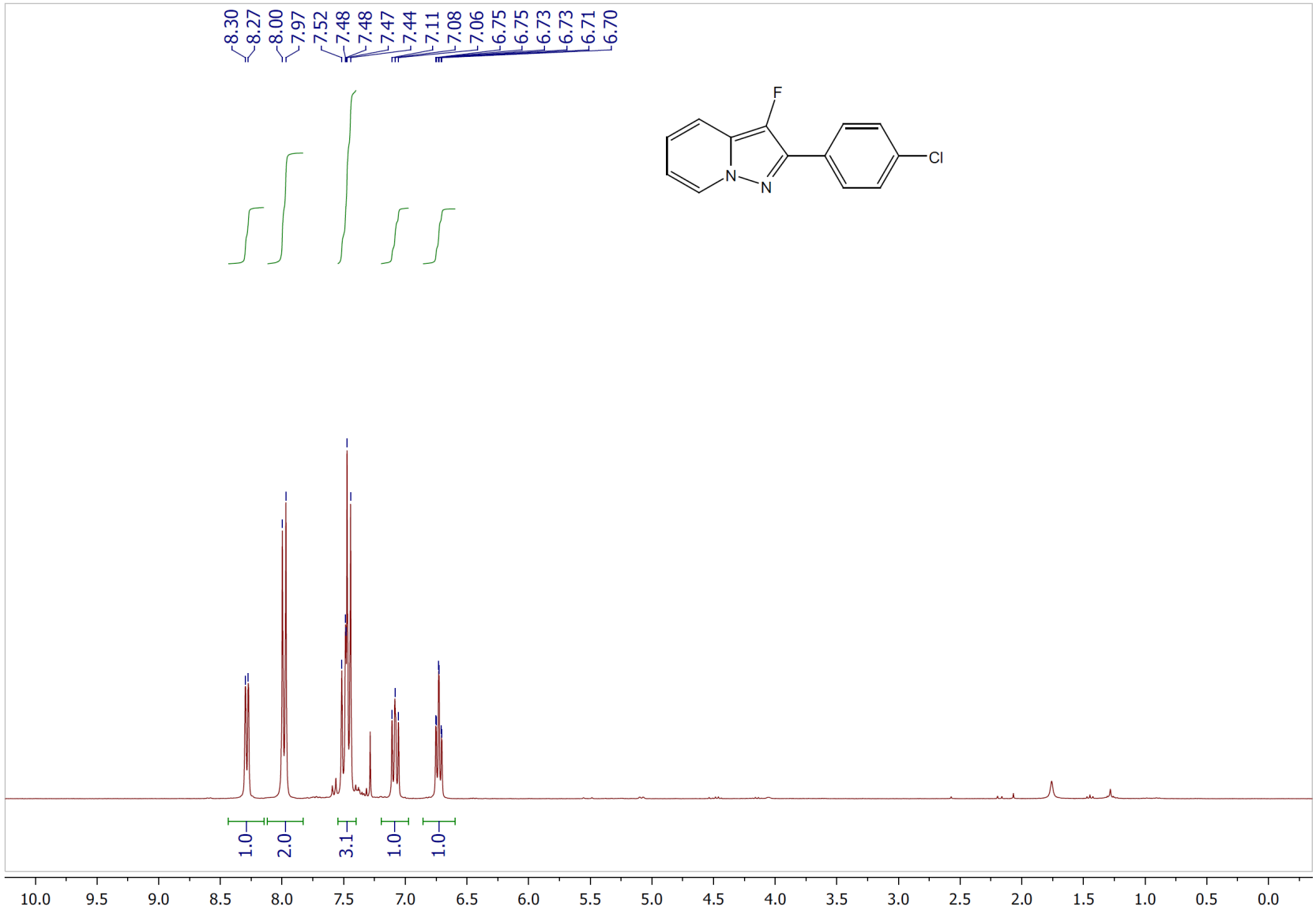
s13. L. Krause, R. Herbst-Irmer, G. M. Sheldrick, and D. Stalke, D, *J. Appl. Cryst.*, 2015, **48**, 3.

s14. G. M. Sheldrick, *Acta Cryst. A*, 2008, **64**, 112.

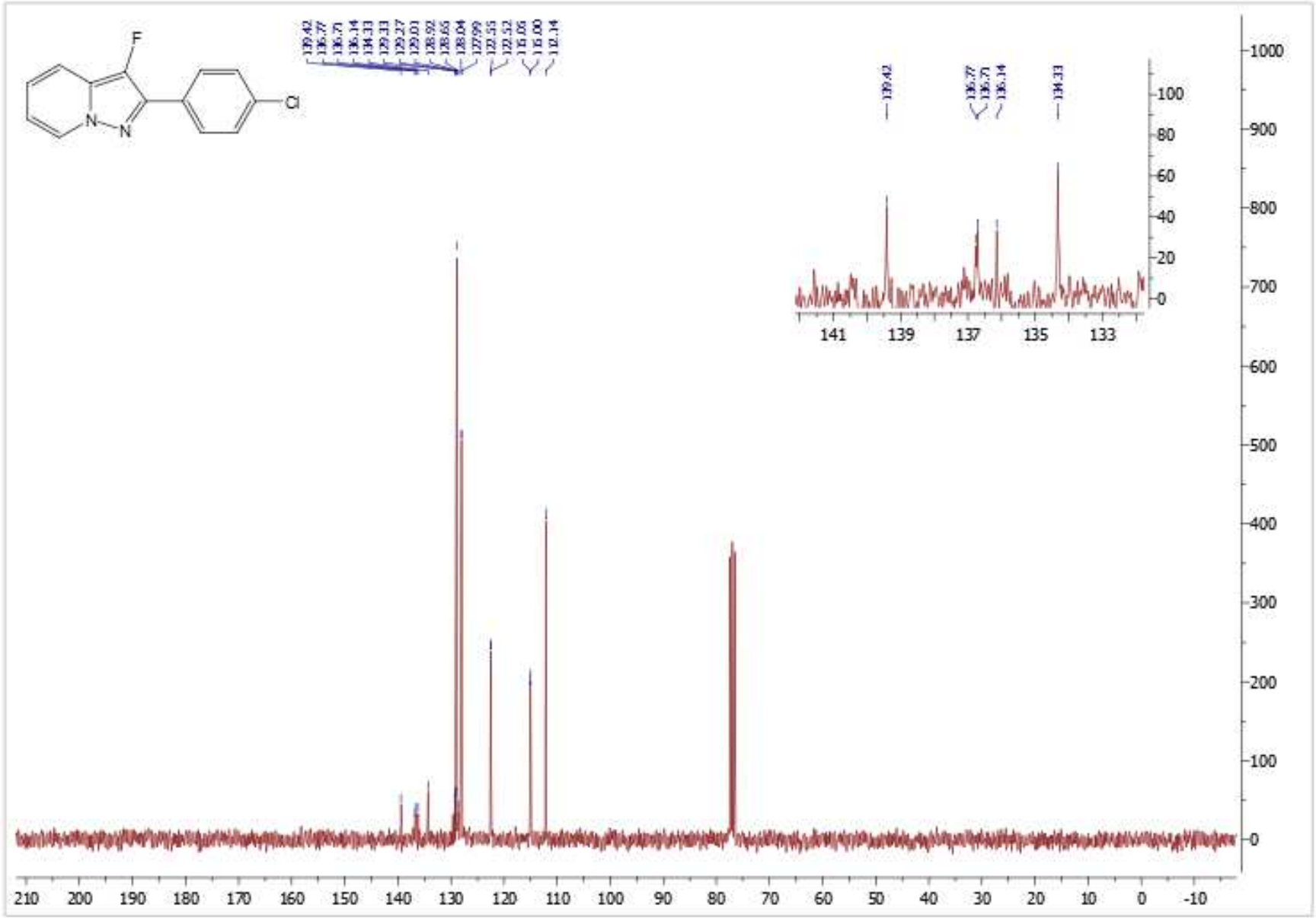
s15. G. M. Sheldrick, *Acta Cryst. C*, 2015, **71**, 3.

**2-(4-Chlorophenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3a**

$^{1}H$ NMR



$^{13}$C NMR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N
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129.33
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129.01
128.92
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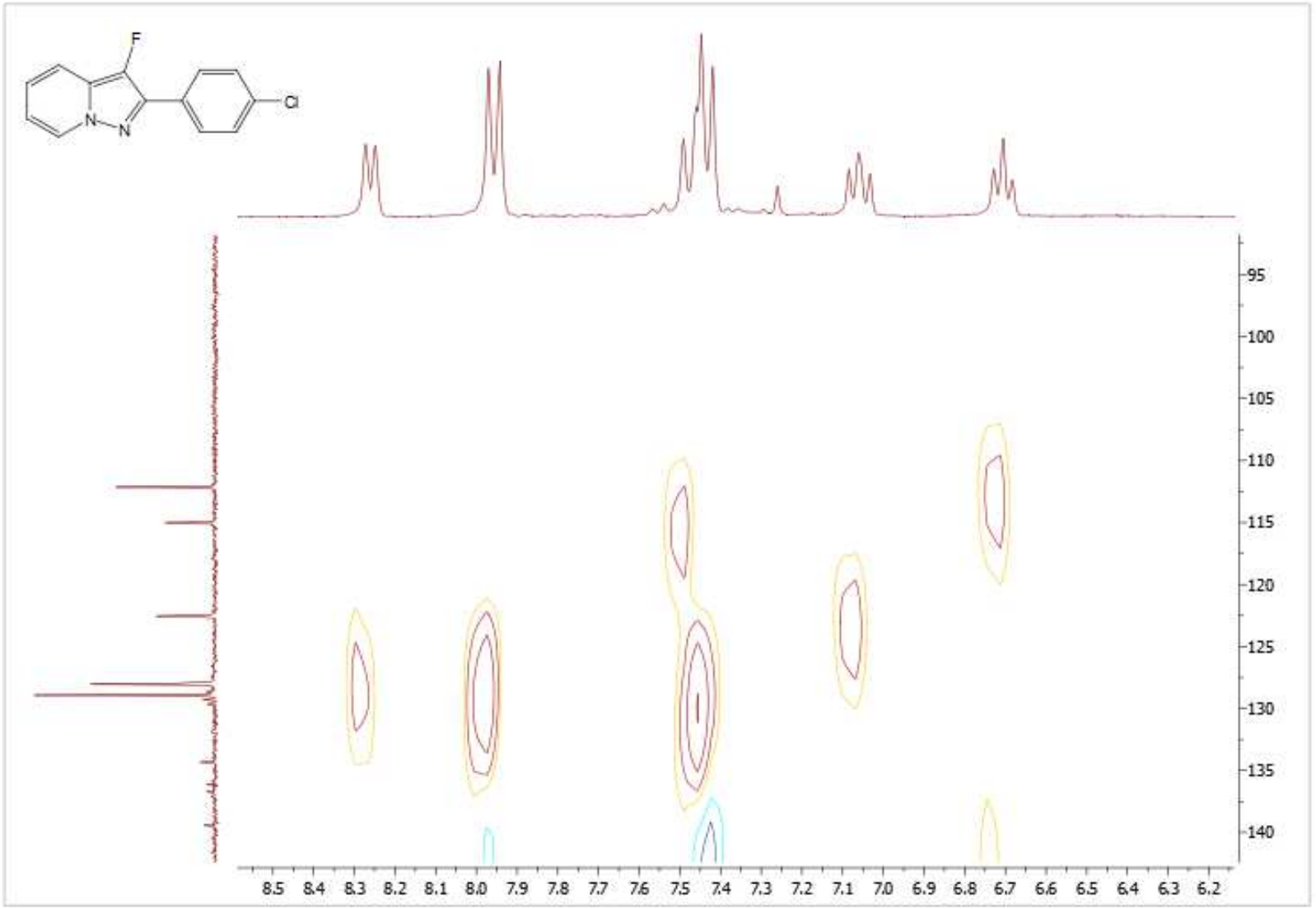
128.04
127.99
122.55
122.52
116.05
116.00
112.14
1000
900
800
700
600
500
400
300
200
100
0
100
80
60
40
20
0
141
139
137
135
133
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

$^{1}H$-$^{13}C$ HSQC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Cl
N
N
95
100
105
110
115
120
125
130
135
140
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8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
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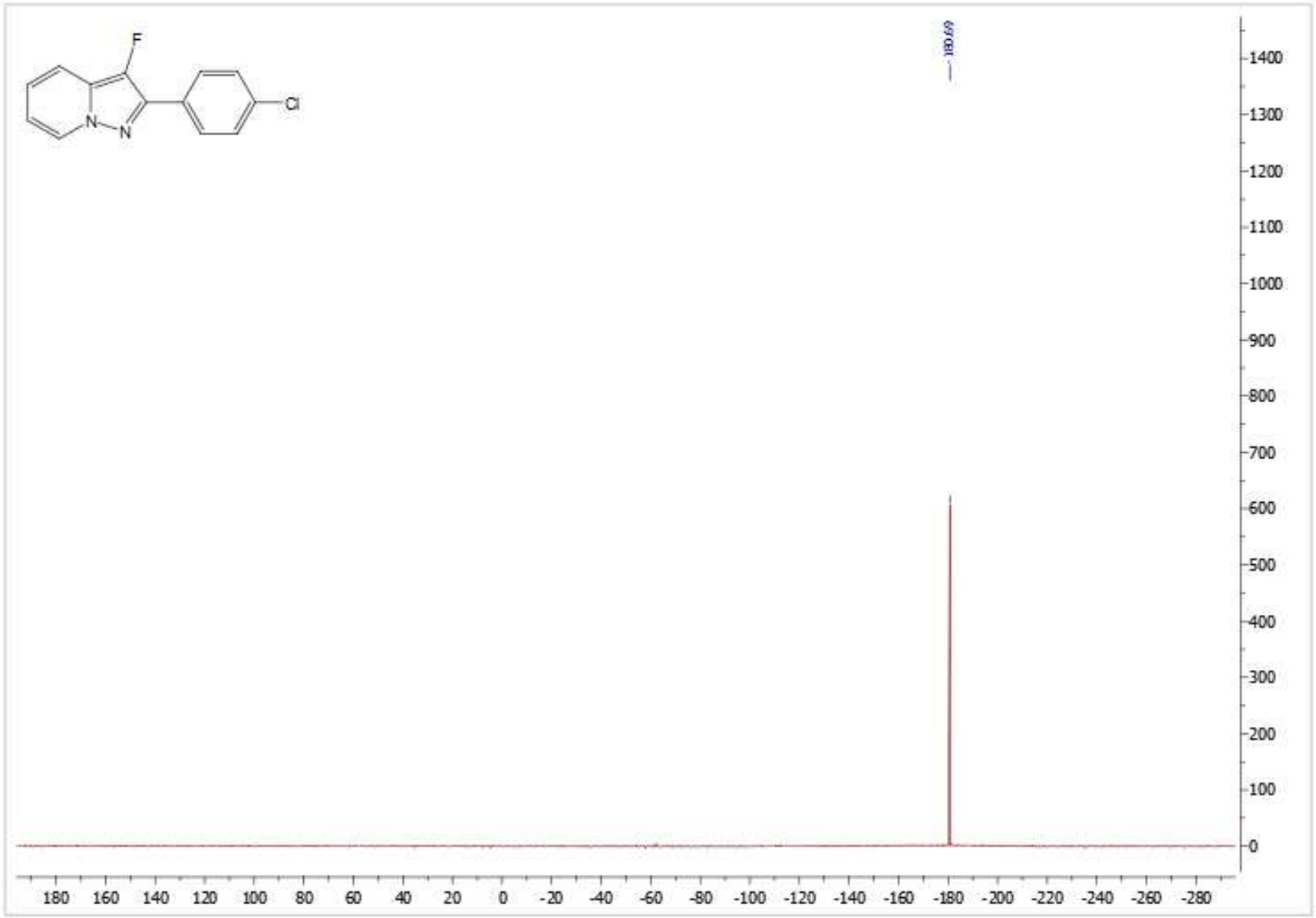
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2

$^{19}$F NMR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1300
1200
1100
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900
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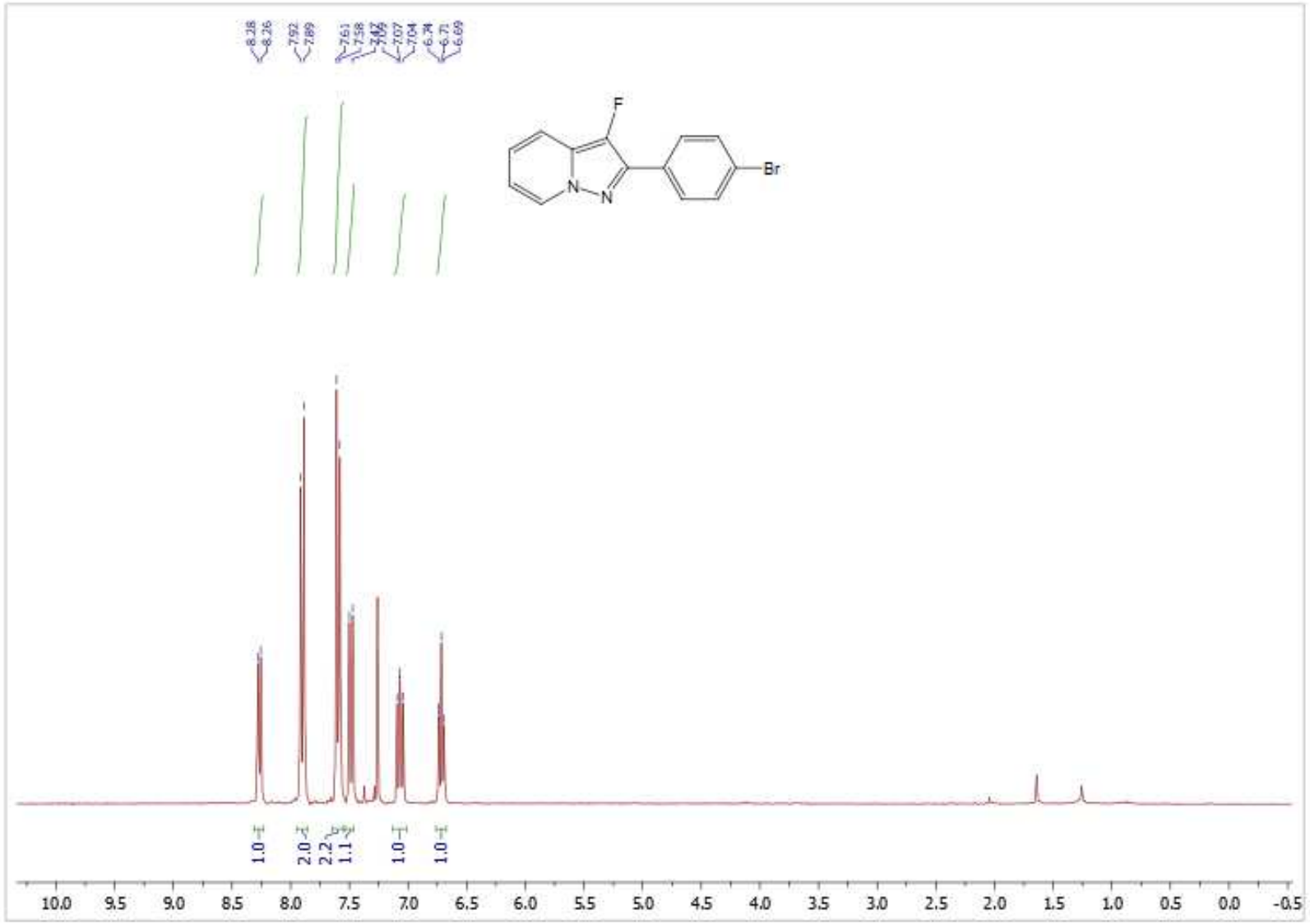
700
600
500
400
300
200
100
0
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**2-(4-Bromophenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3b**

$^{1}$H NMR



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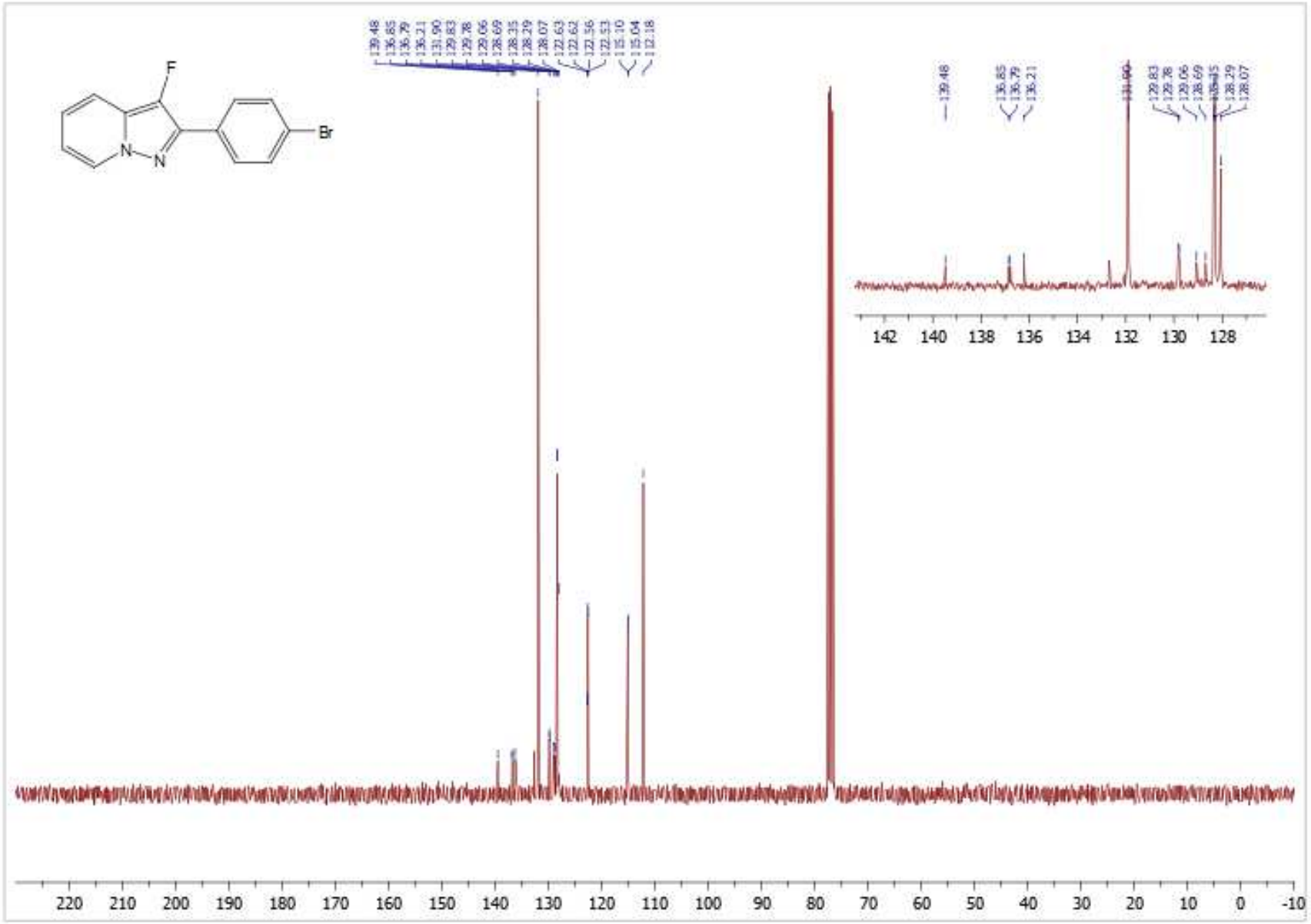
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Br
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128.35
128.29
128.07
122.63
122.62
122.56
122.53
115.10
115.04
112.18
142
140
138
136
134
132
130
128
220
210
200
190
180
170
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150
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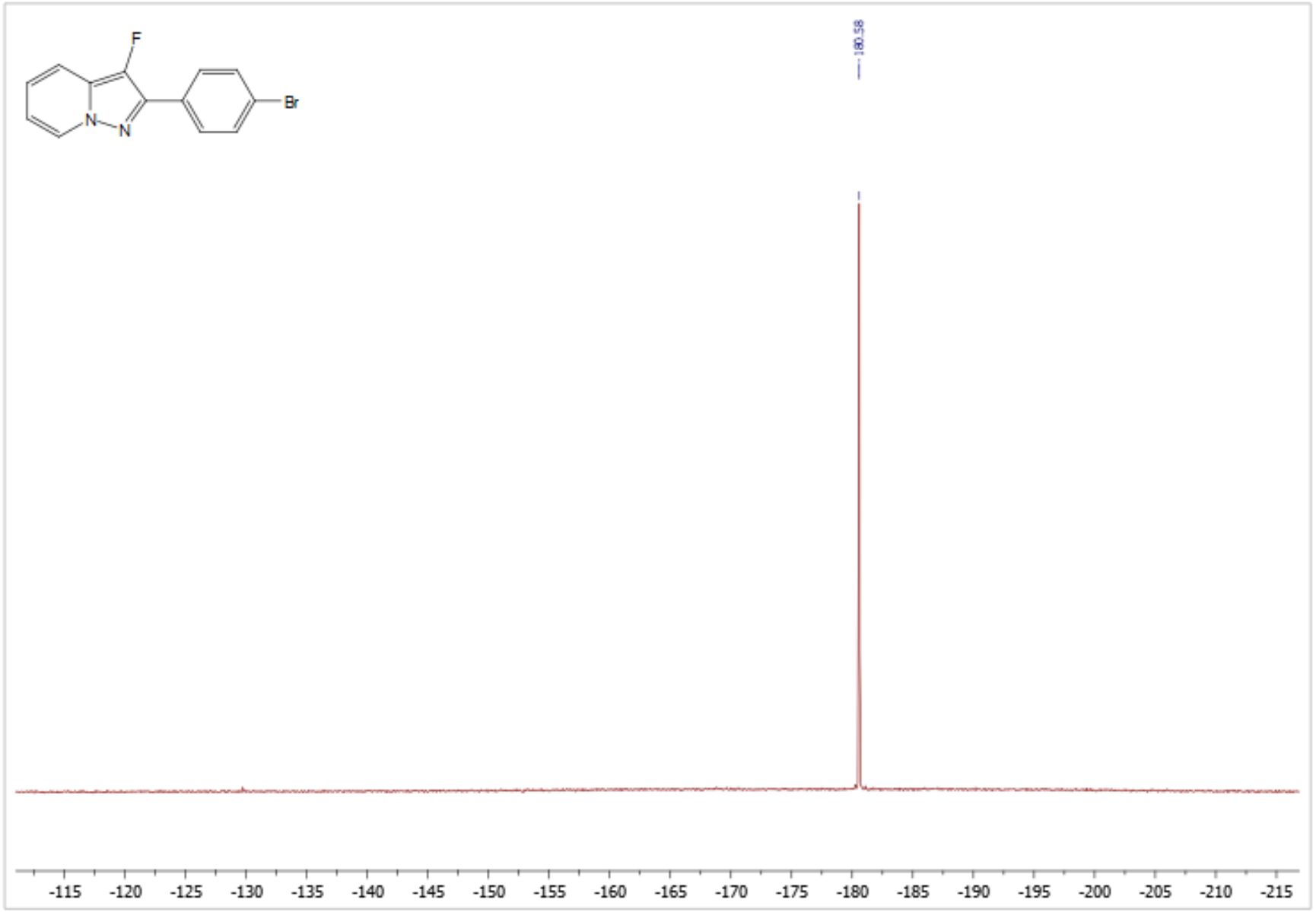
90
80
70
60
50
40
30
20
10
0
-10

$^{19}$F NMR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-150
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-160
-165
-170
-175
-180
-185
-190
-195
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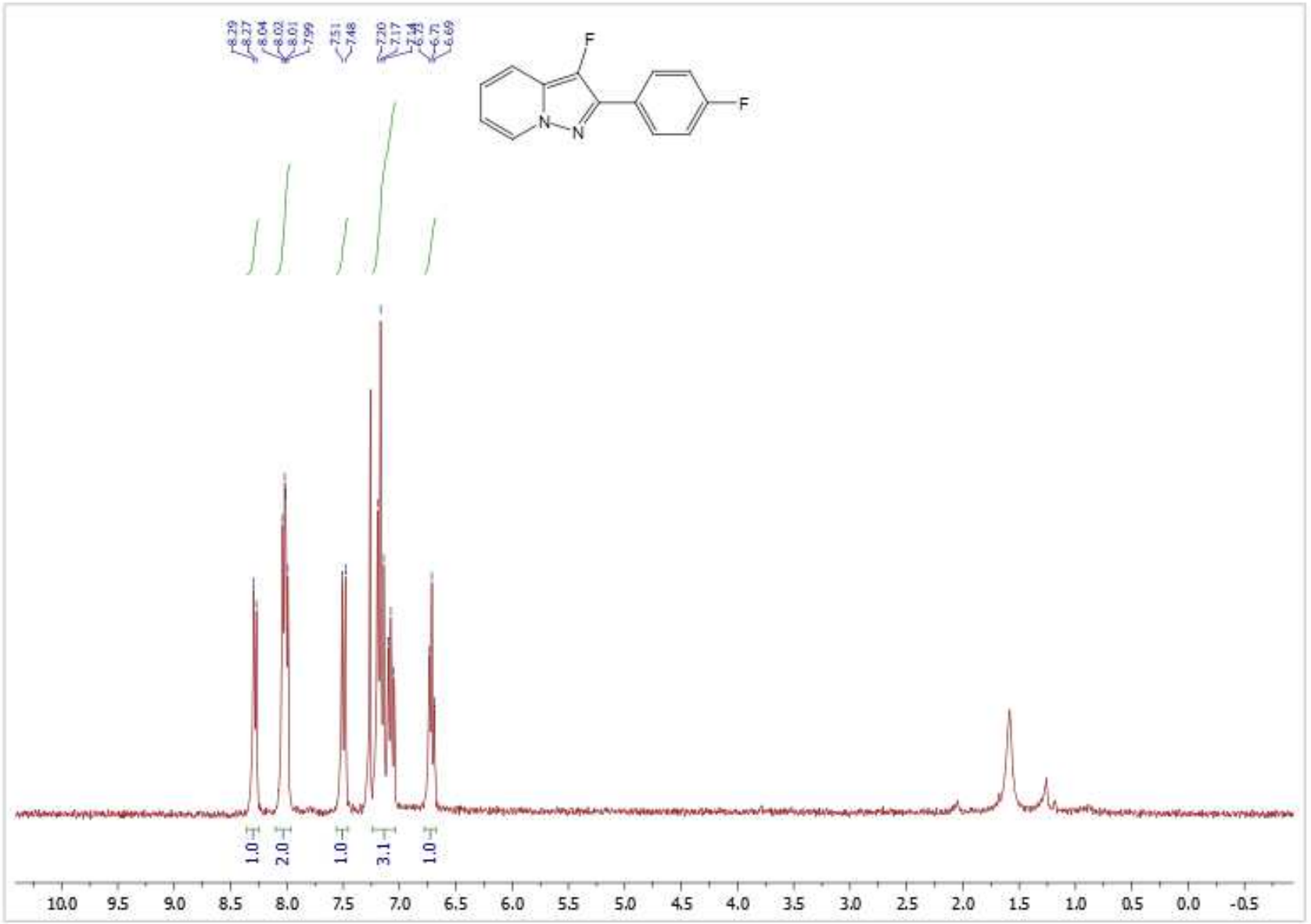
-205
-210
-215

**2-(4-Fluorophenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3c**

$^{1}$H NMR



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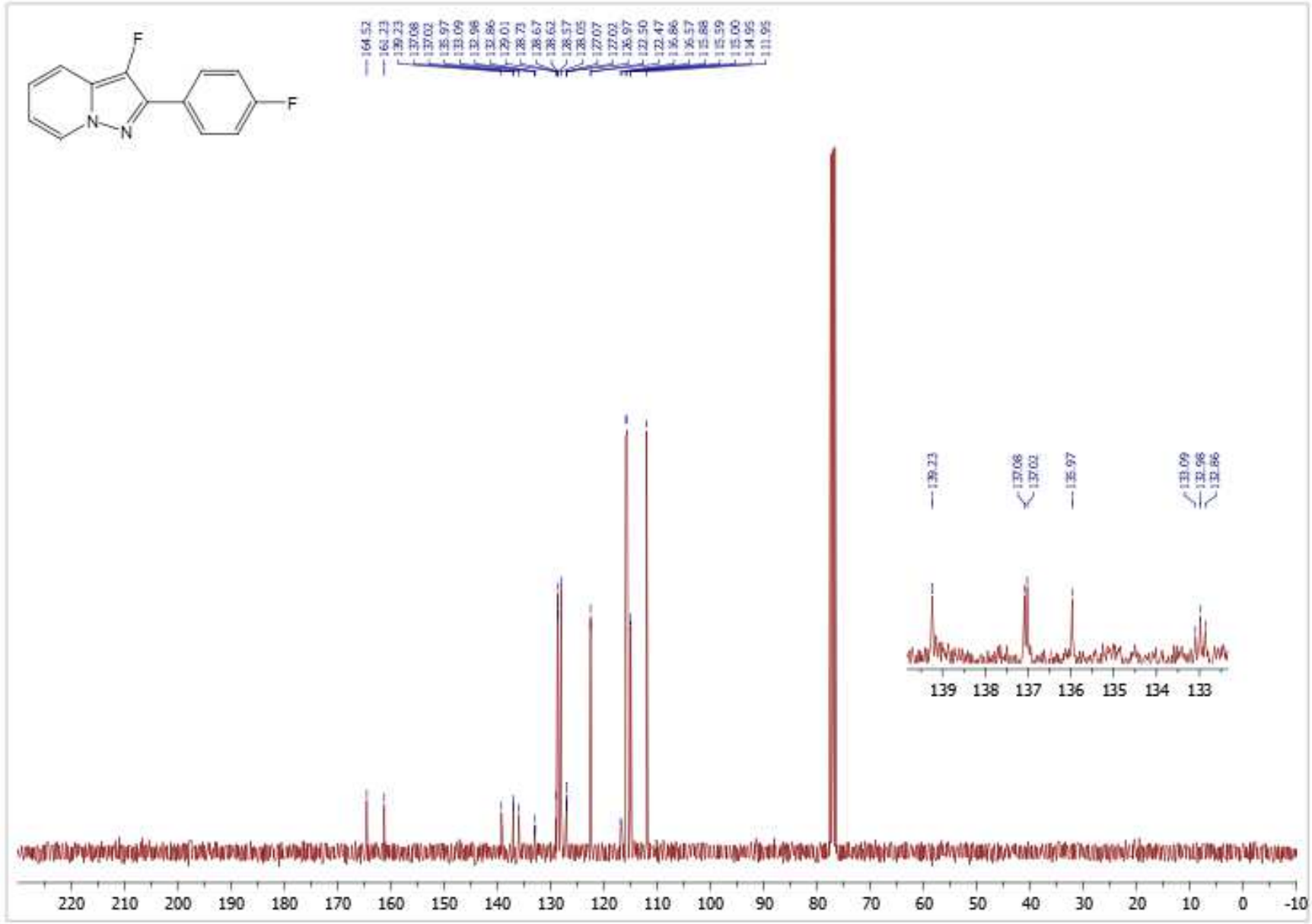
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132.98
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129.01
128.73
128.67
128.62
128.57
128.05
127.07
127.02
126.97
122.50
122.47
116.86
116.57
115.88
115.59
115.00
114.95
111.95
139.23
137.08
137.02
135.97
133.09
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132.86
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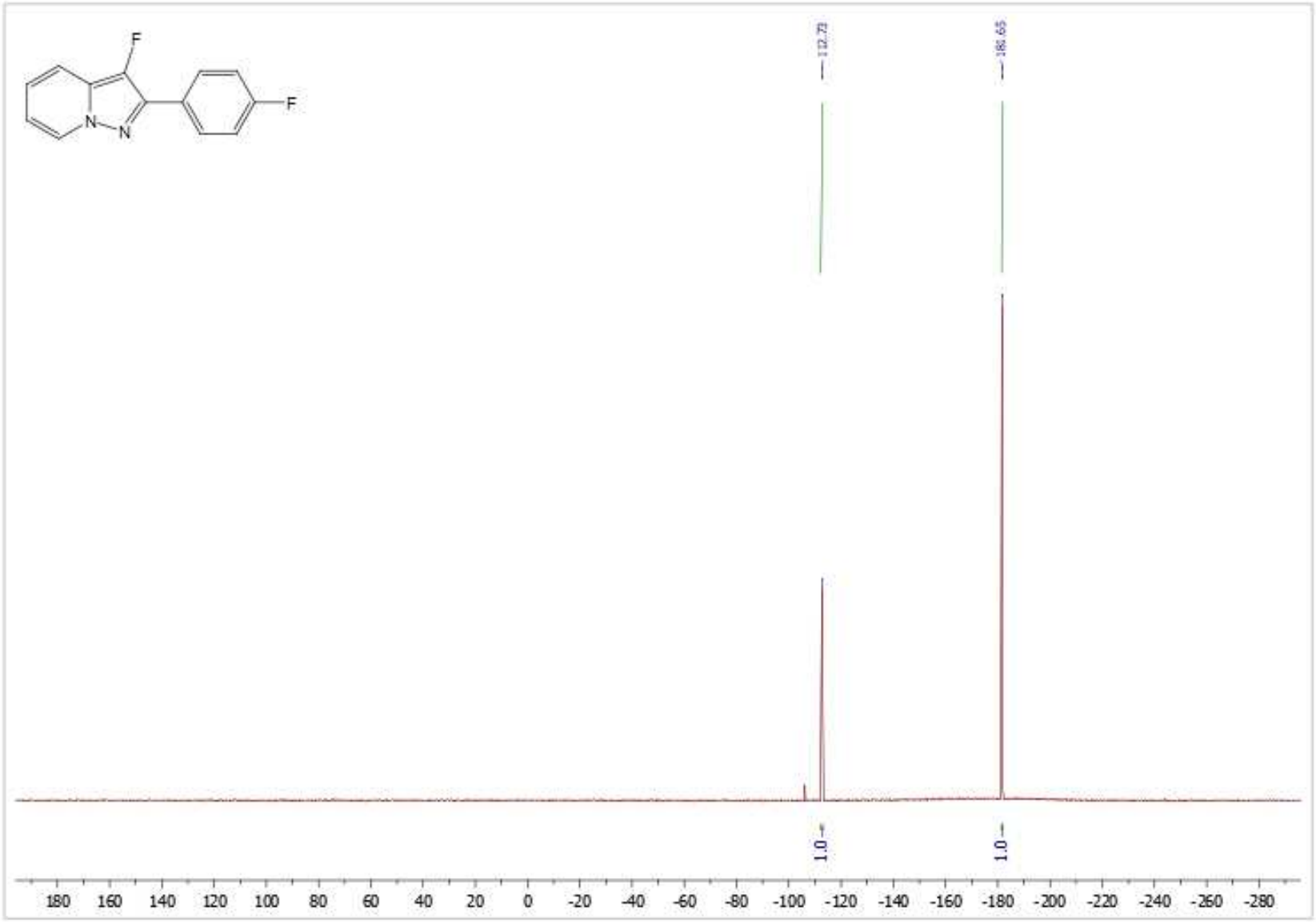
$^{19}$F NMR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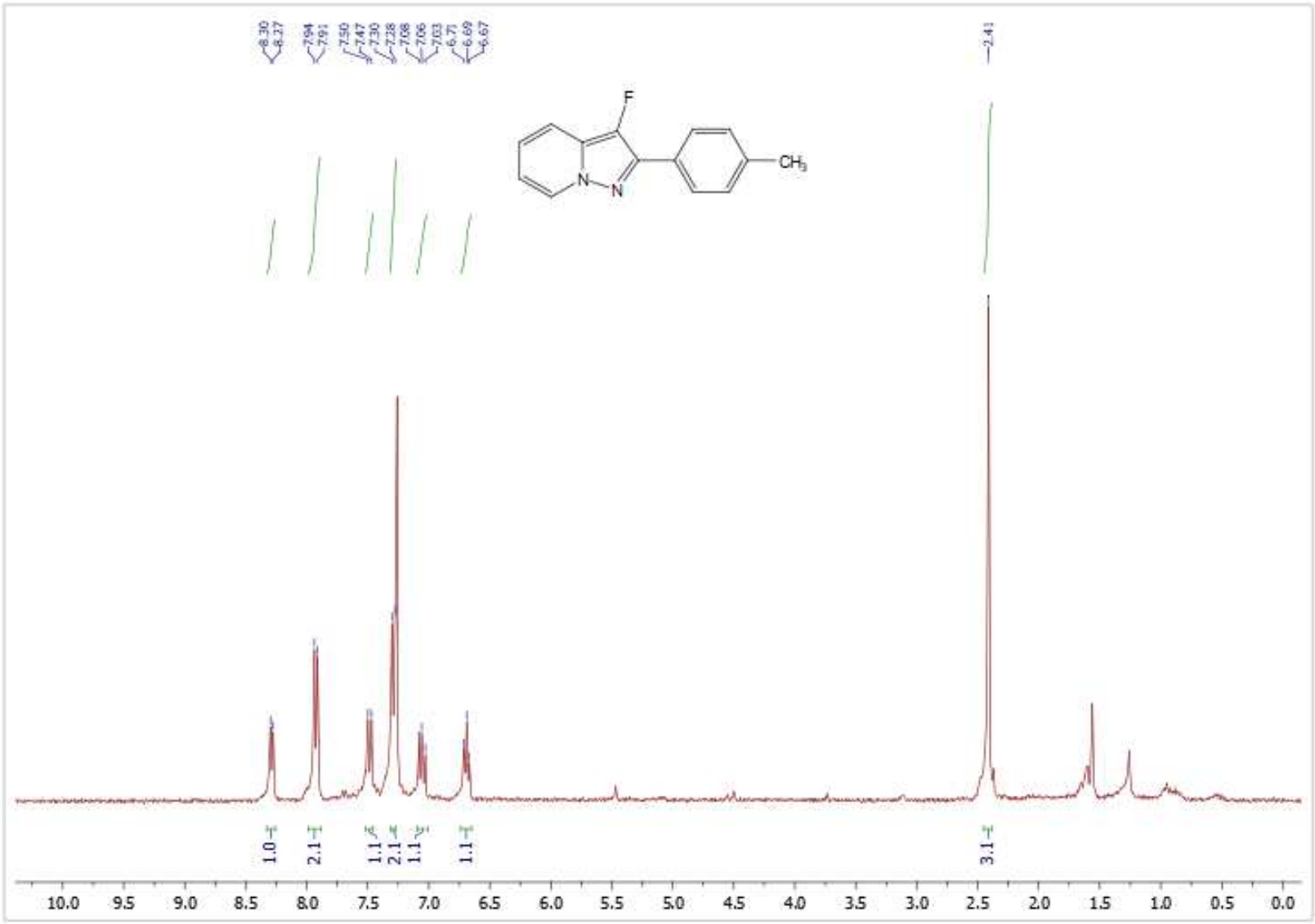
**2-(4-Methylphenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3d**

$^{1}$H NMR



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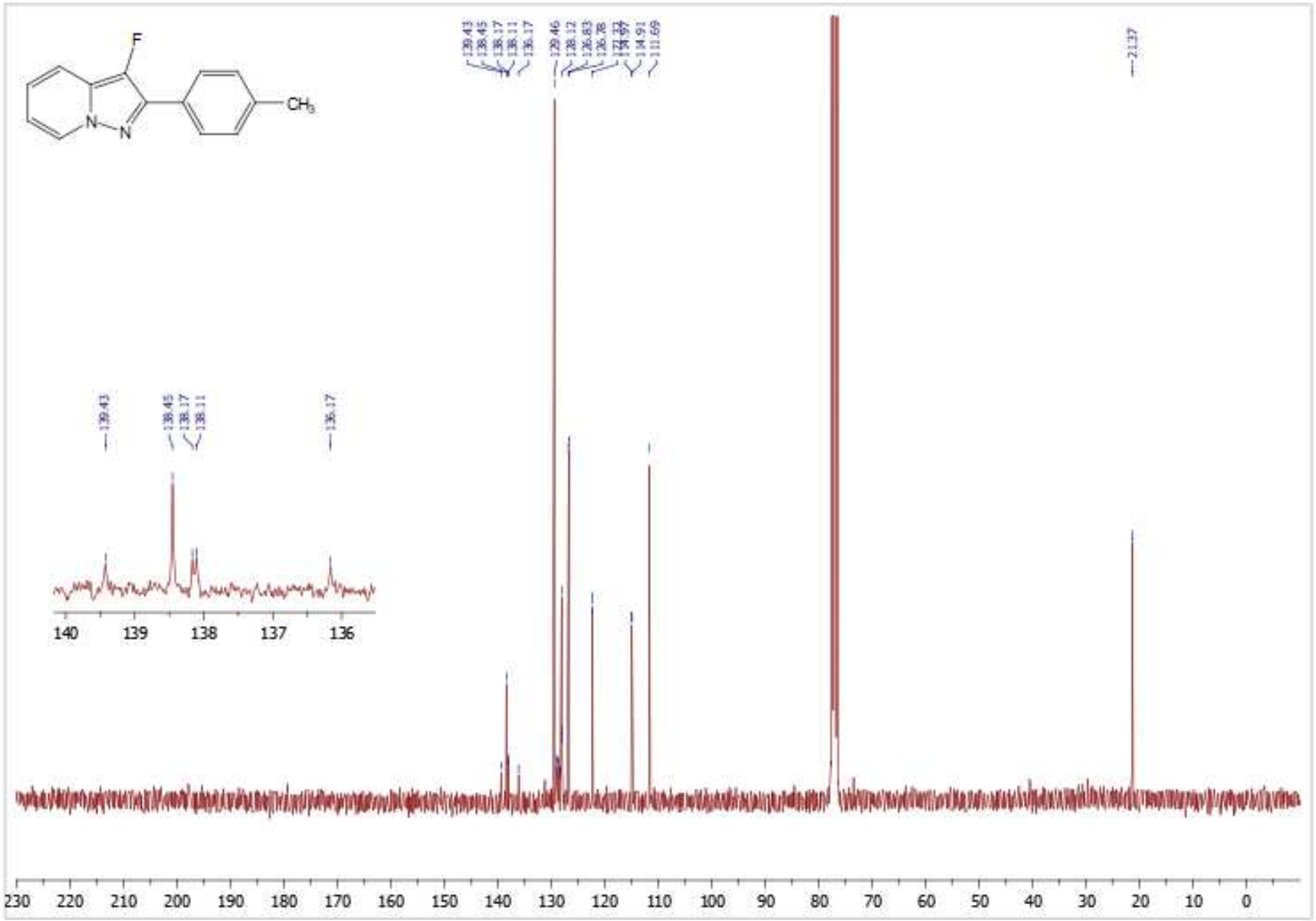
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137
136
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200
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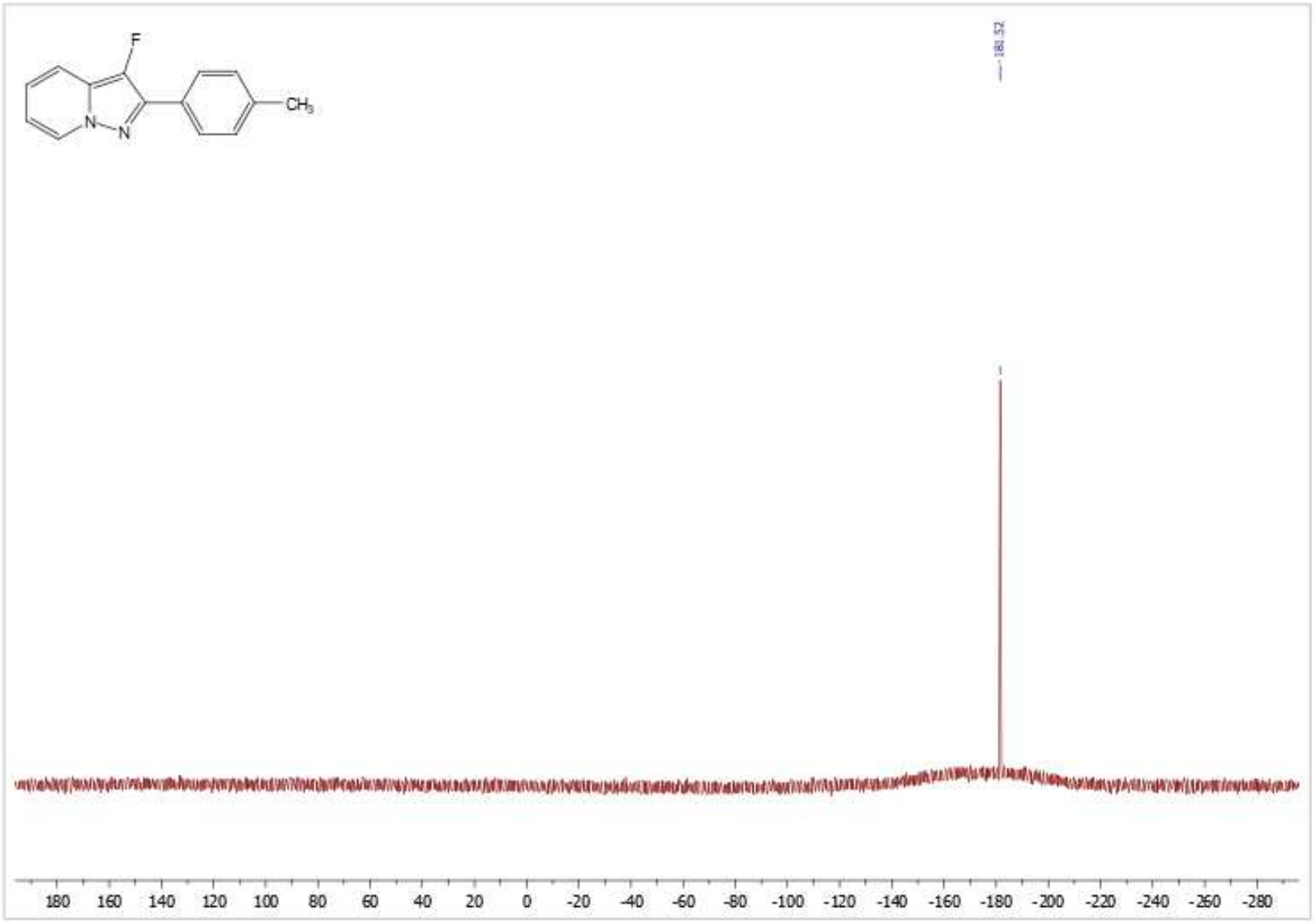
$^{19}$F NMR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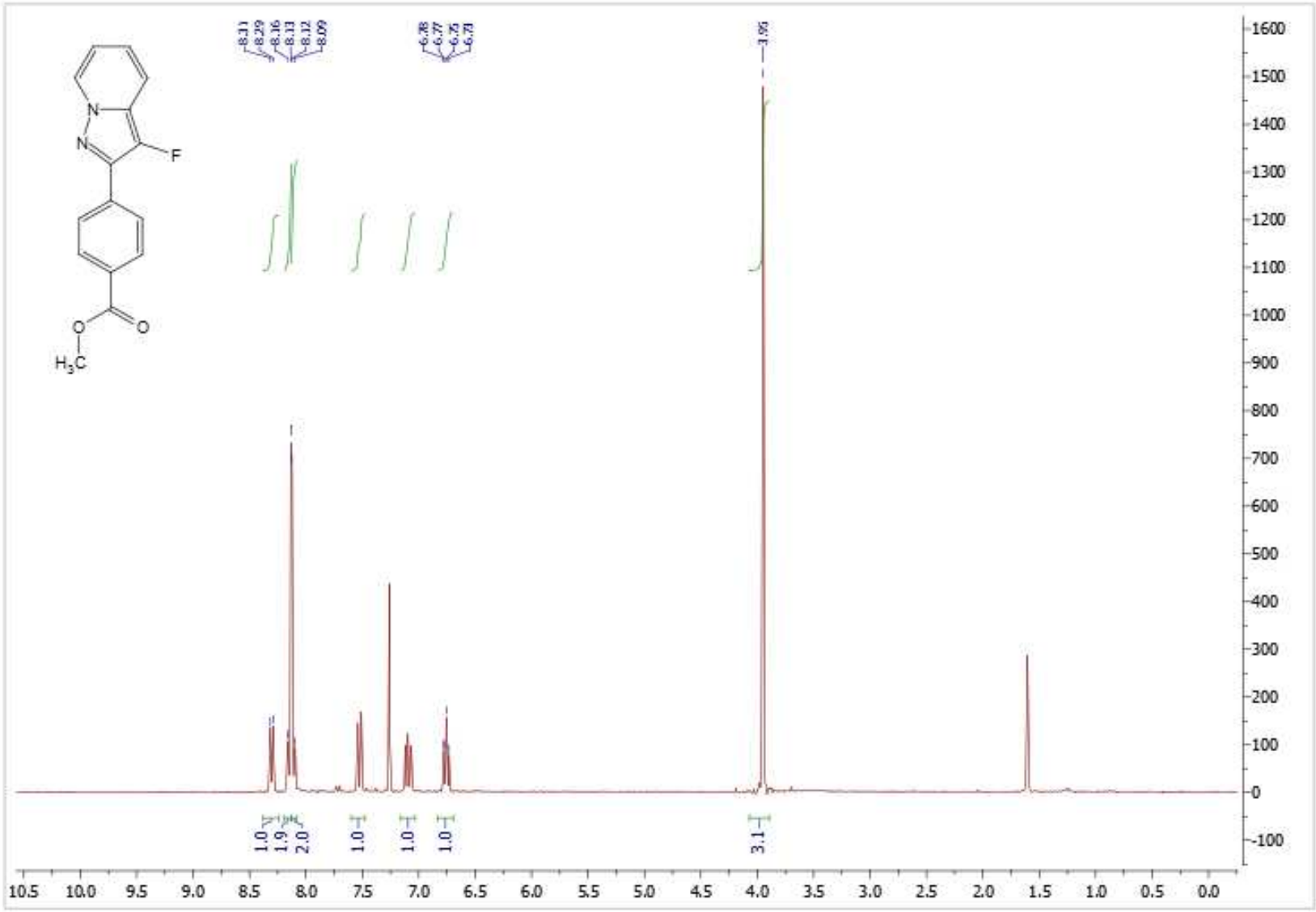
**2-(4-(Methyloxycarbonyl)phenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3e**

$^{1}$H NMR



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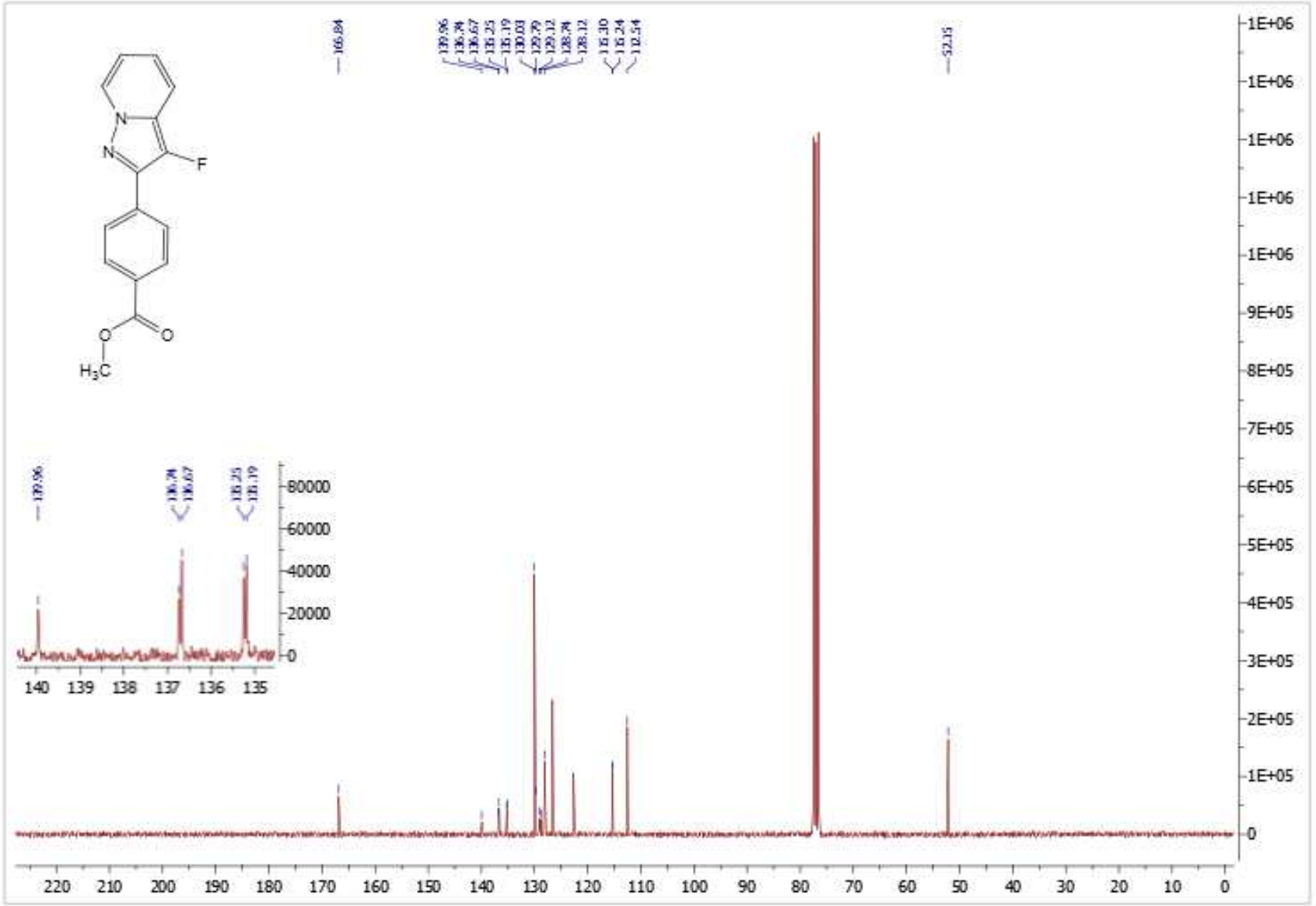
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135.19
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128.74
128.12
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116.24
112.54
52.15
N
N
F
O
O
H3C
1E+06
9E+05
8E+05
7E+05
6E+05
5E+05
4E+05
3E+05
2E+05
1E+05
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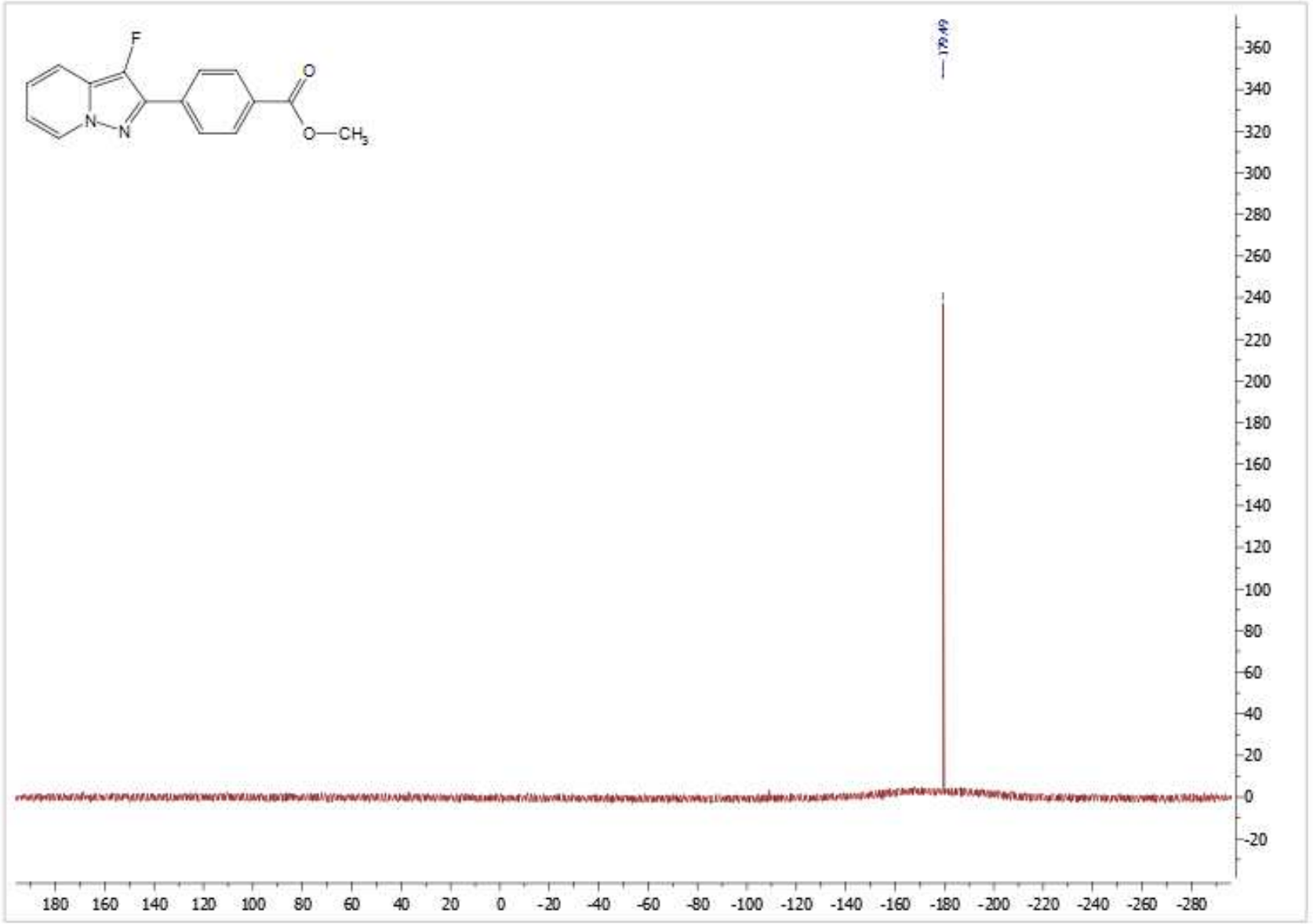
$^{19}$F NMR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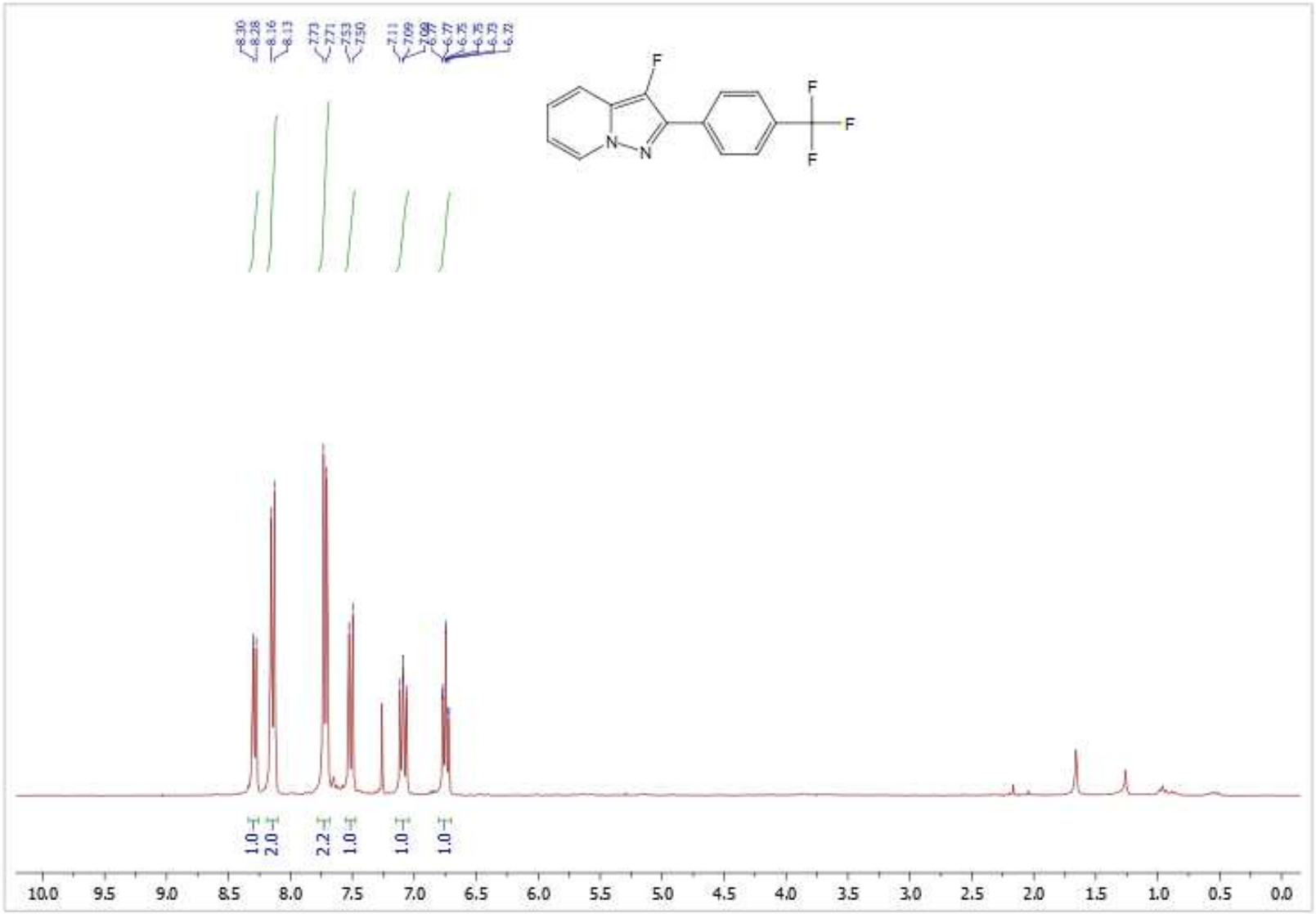
120
100
80
60
40
20
0
-20
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**2-(4-(Trifluoromethyl)phenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3f**

$^{1}$H NMR



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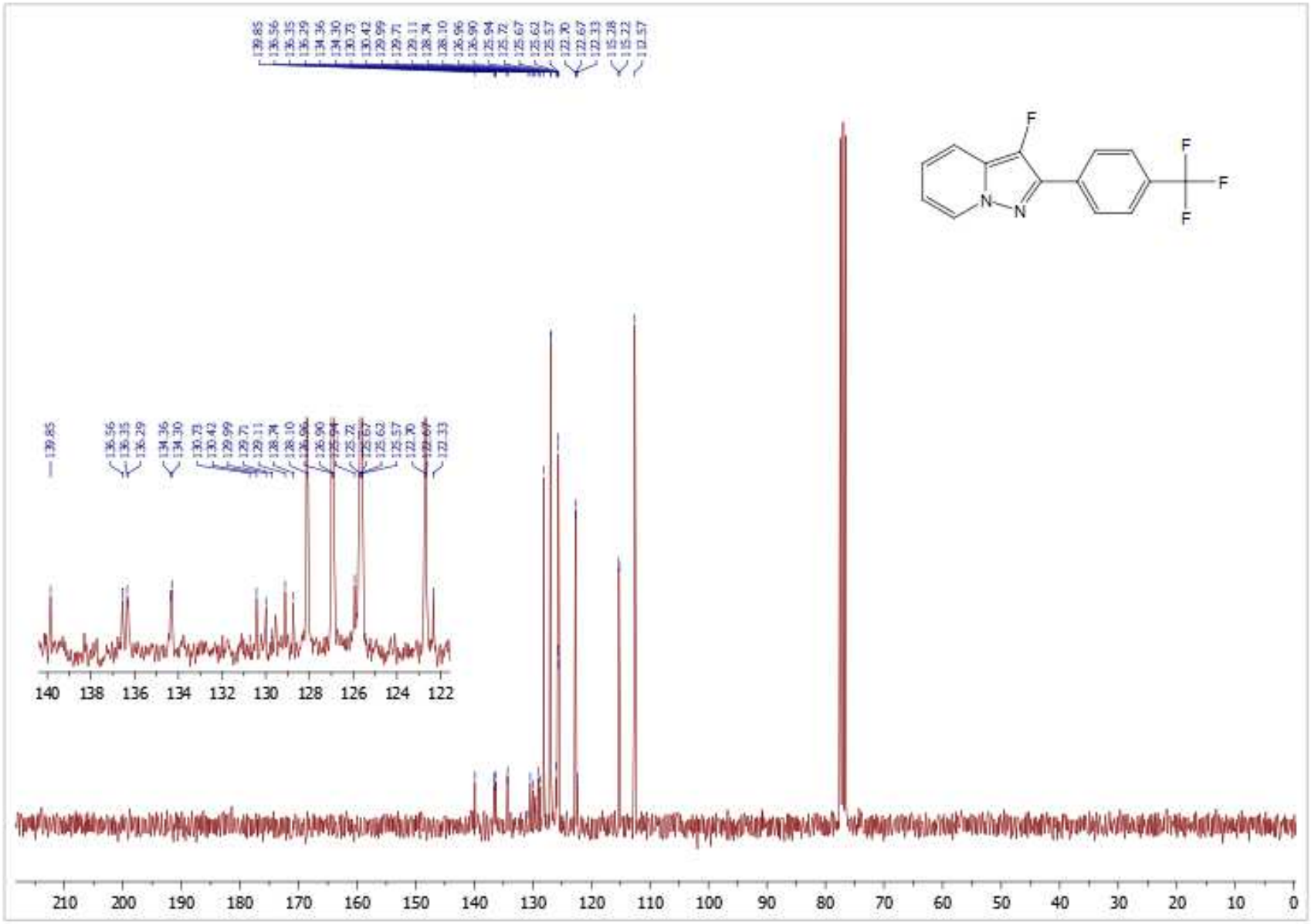
F
F
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F
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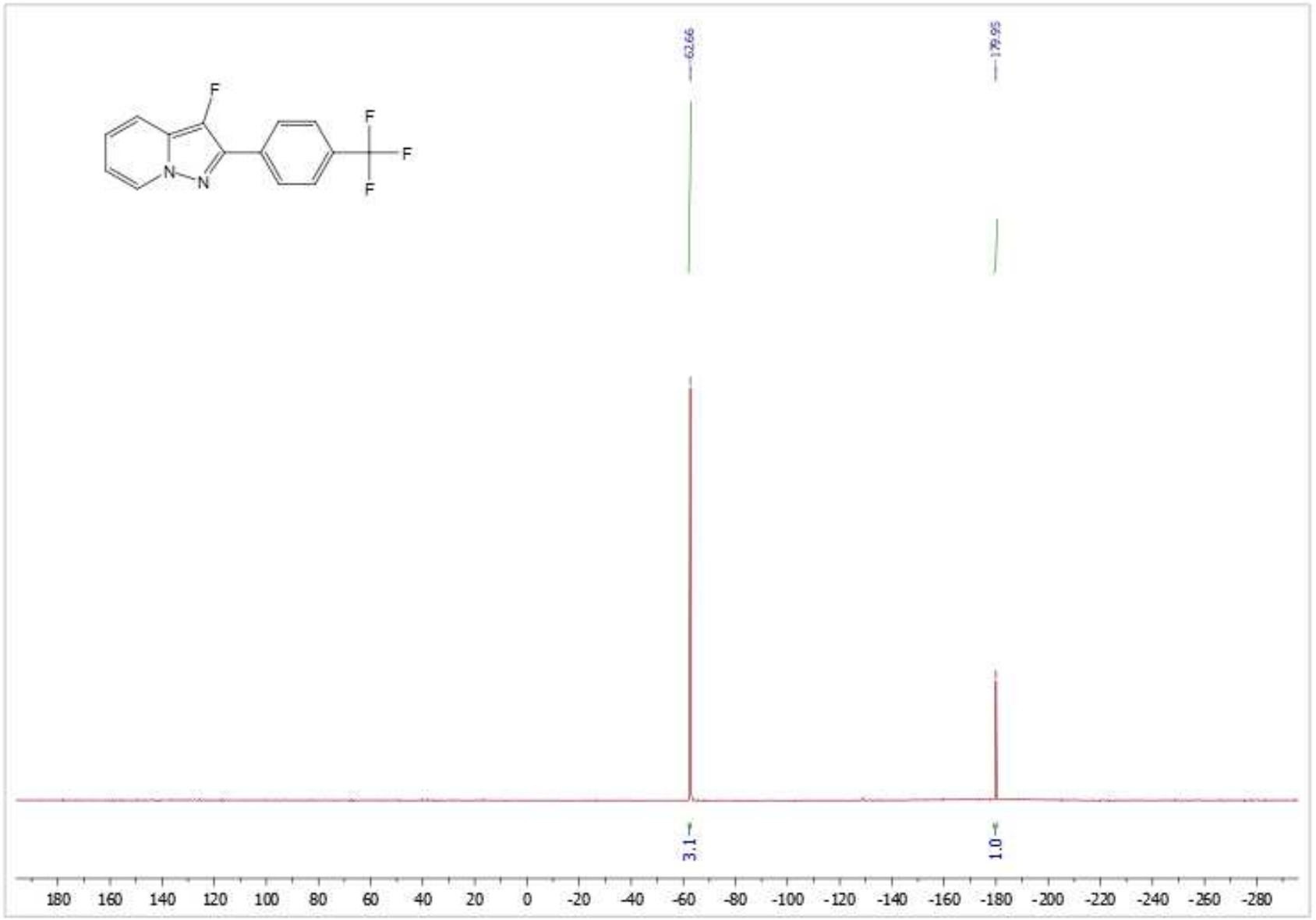
$^{19}$F NMR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F
F
F
N
N
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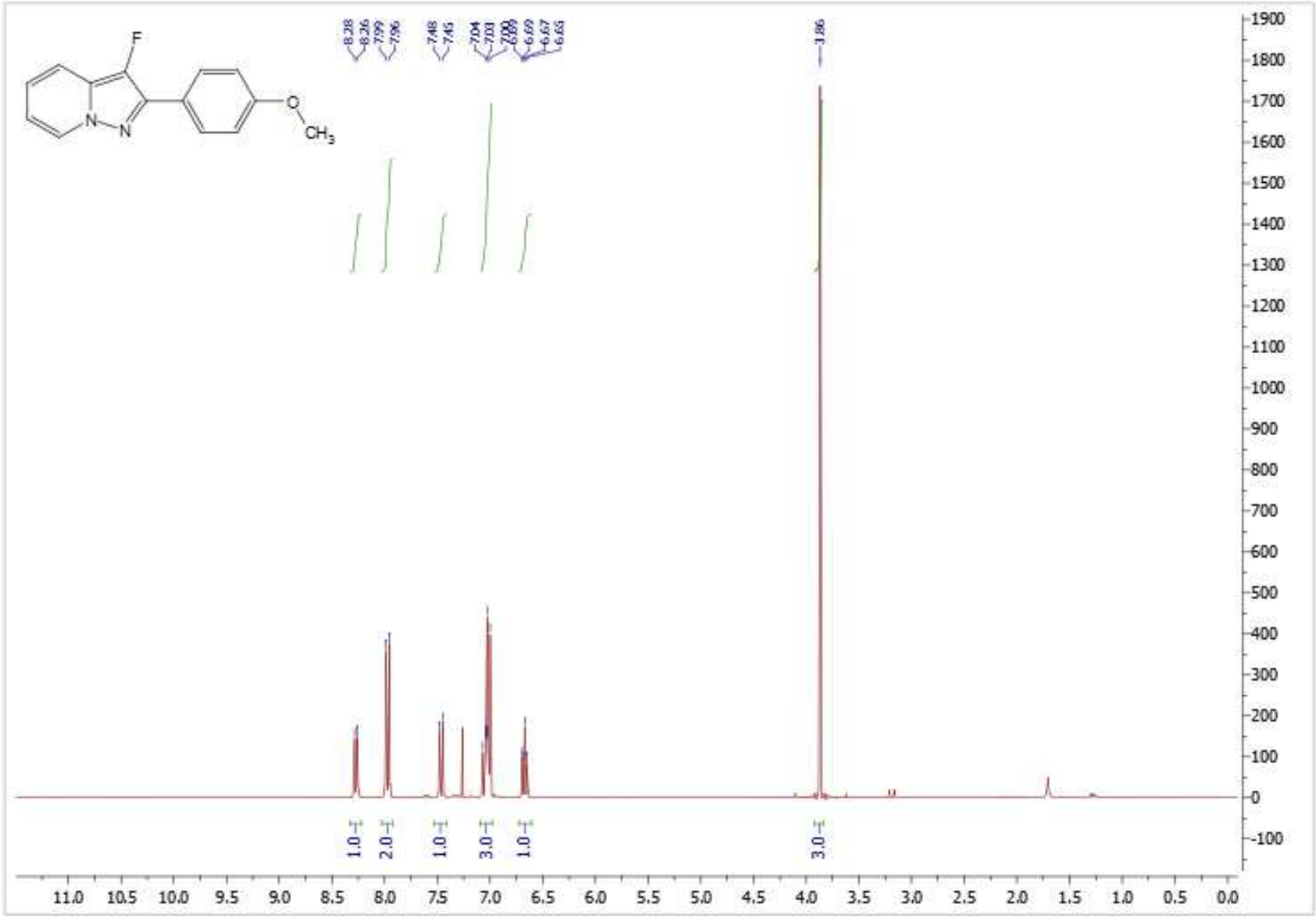
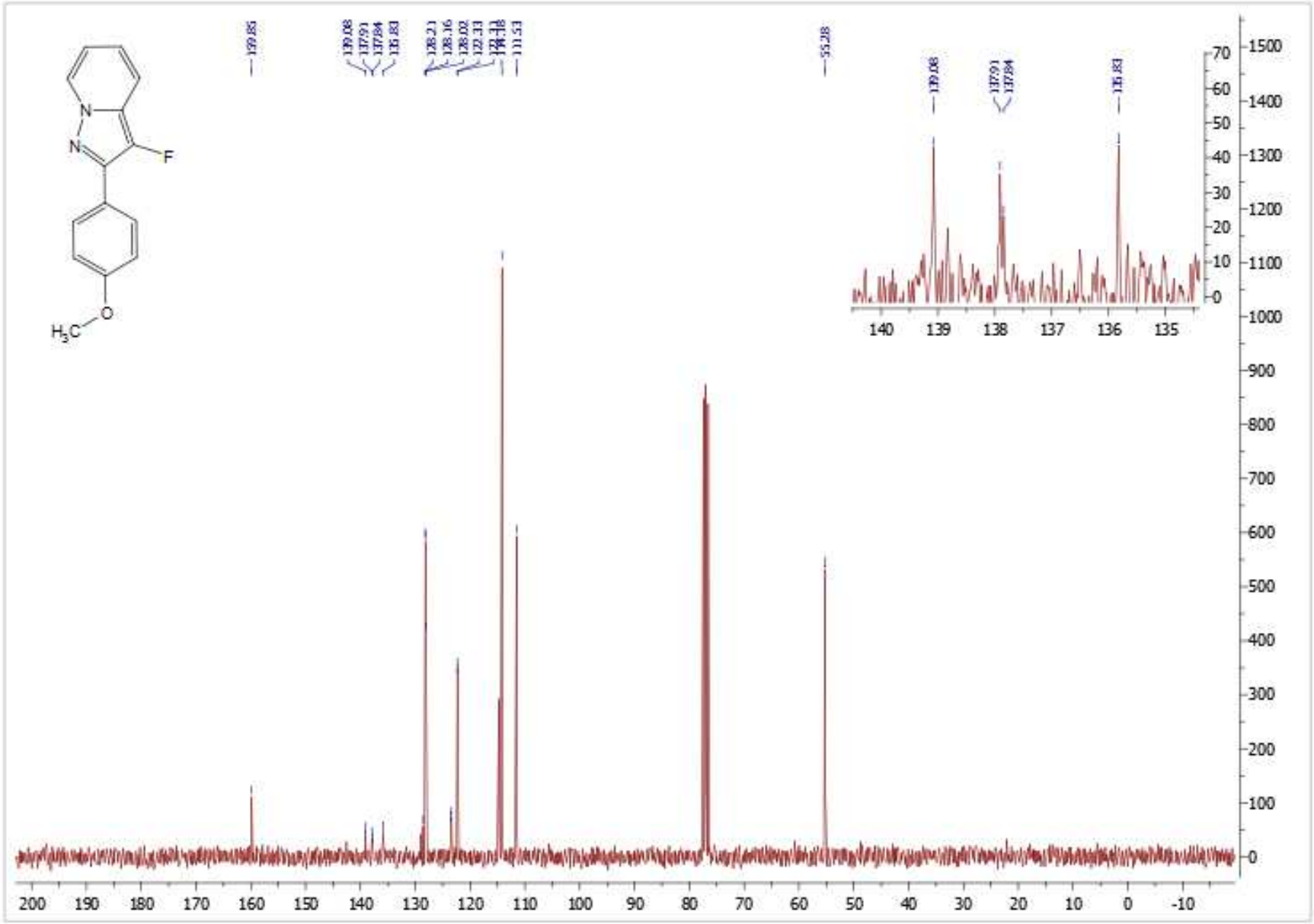
3.1
1.0
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**2-(4-Methoxyphenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3g**

$^{1}$H NMR



$^{13}$C NMR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128.21
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128.02
122.33
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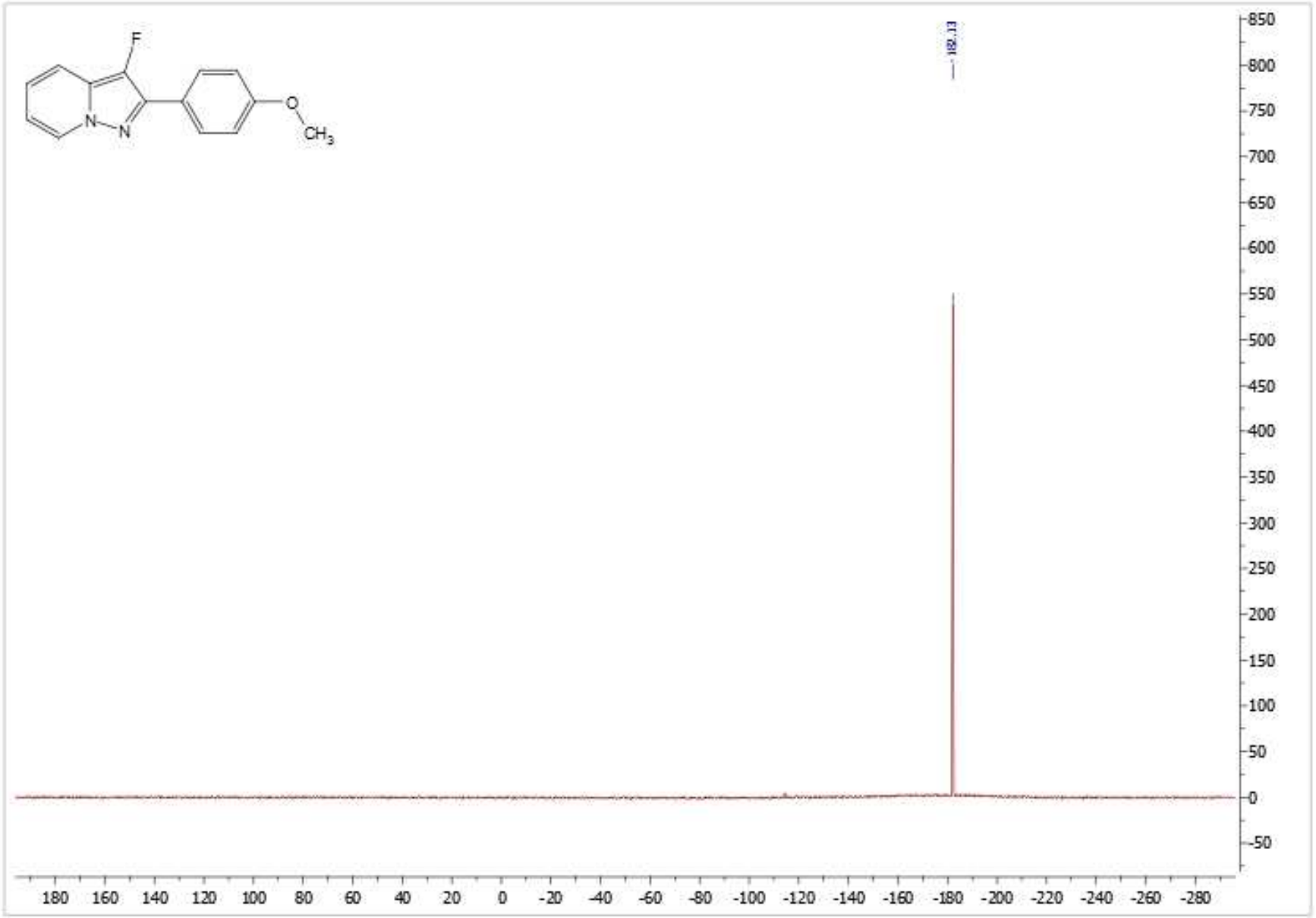
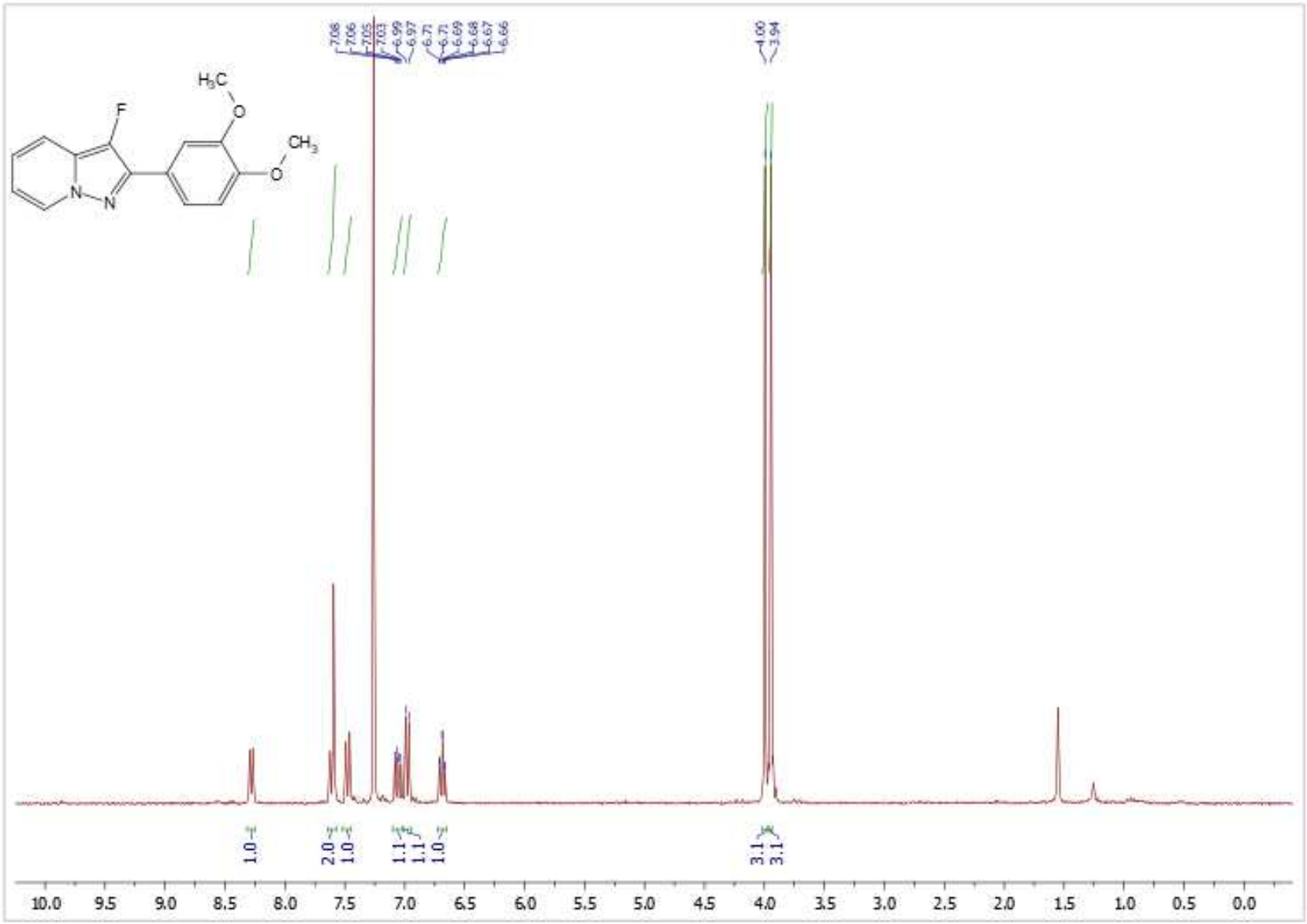
140
139
138
137
136
135
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

$^{19}$F NMR

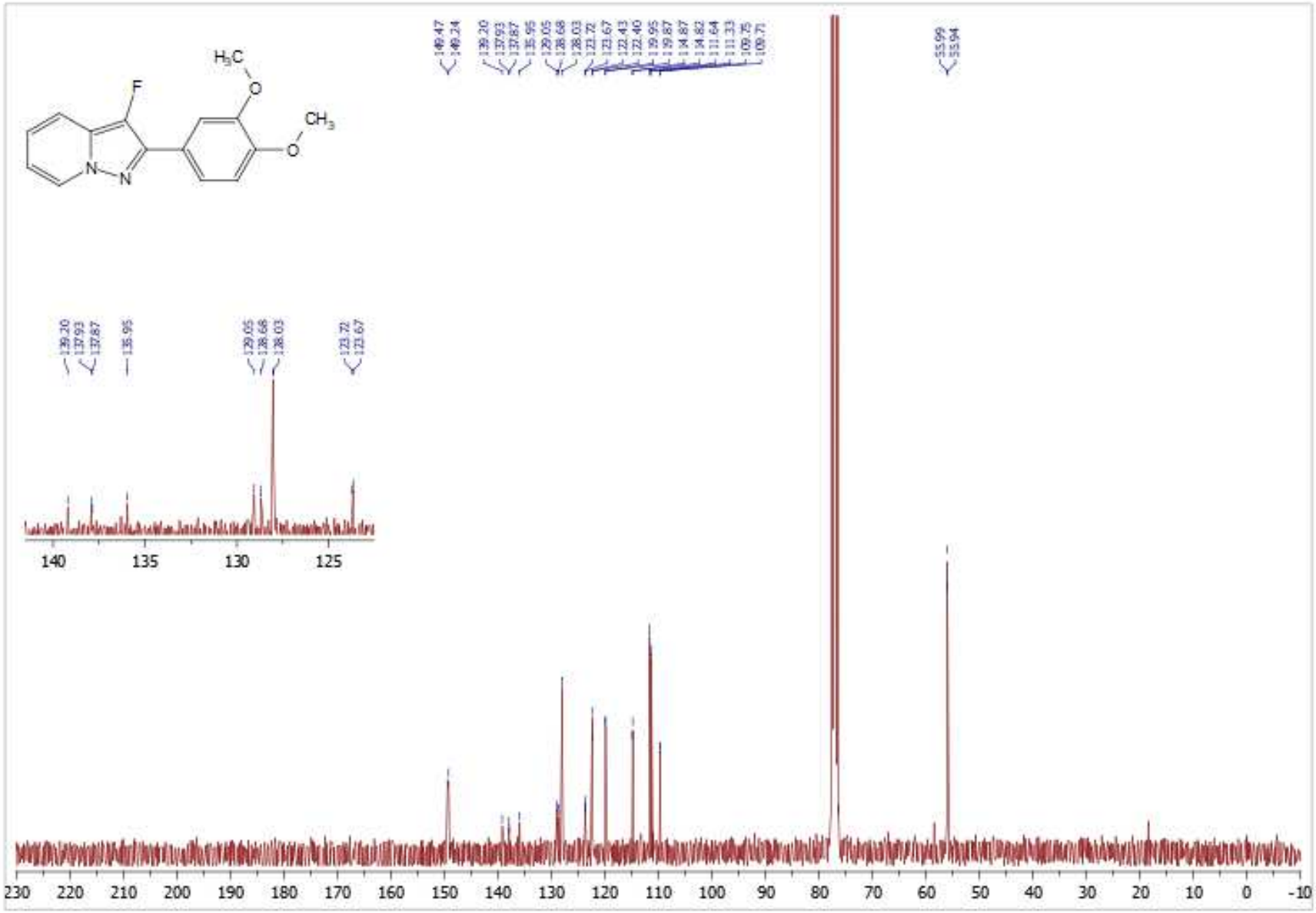

F
N
N
O
CH3
-182.13
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**2-(3,4-Dimethoxyphenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3h**

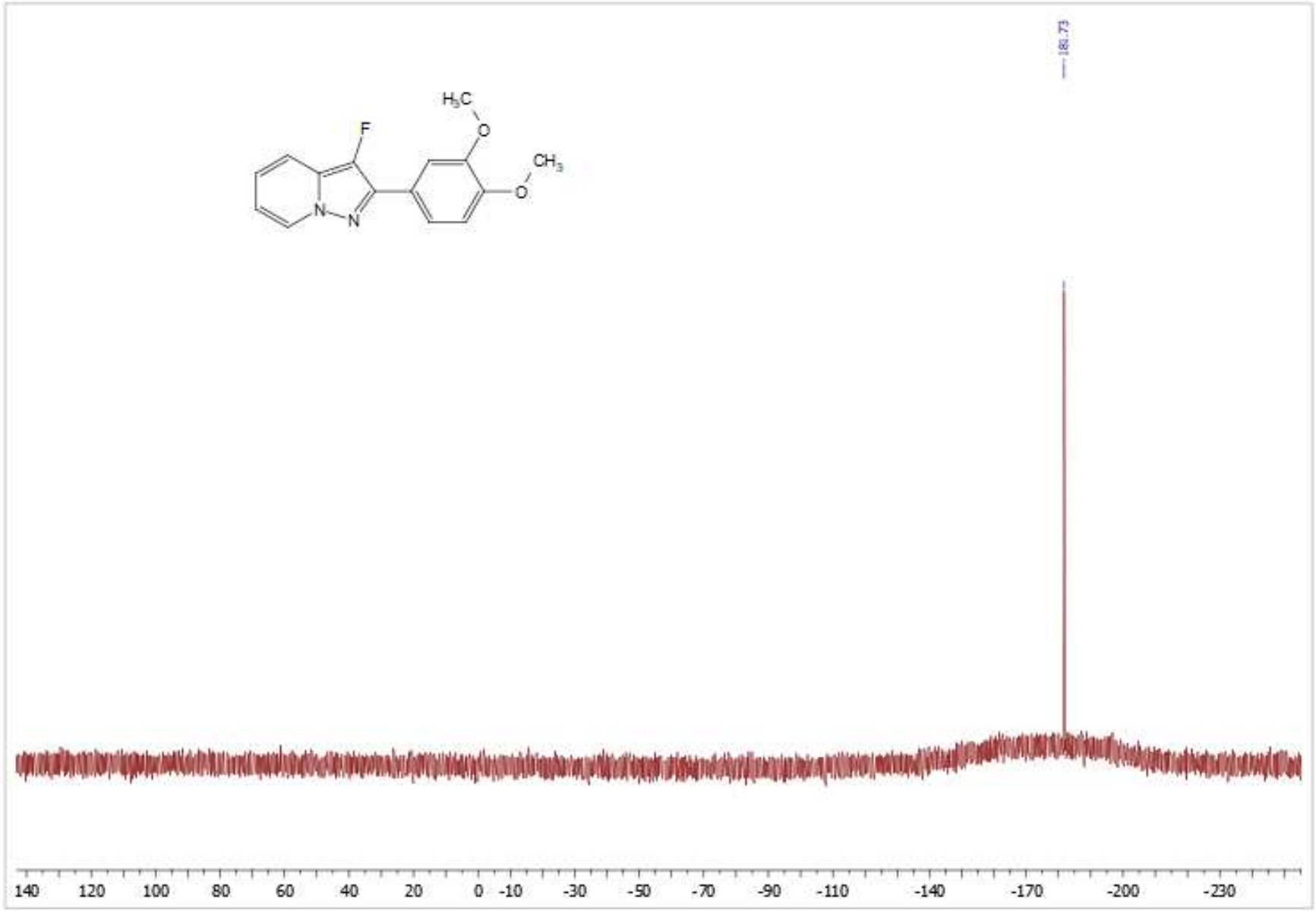
$^{1}$H NMR



$^{13}$C NMR

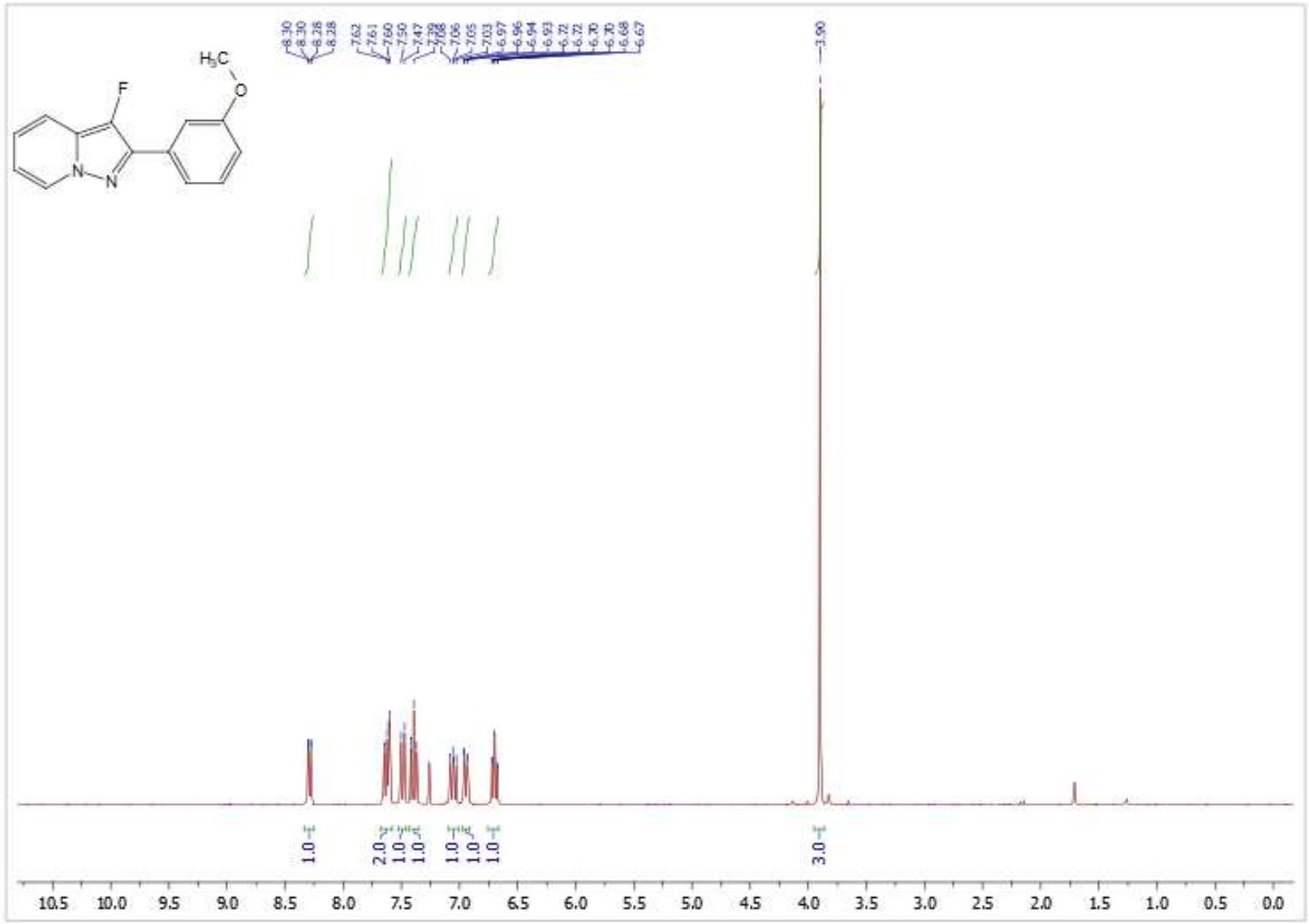

H3C
O
F
CH3
O
N
N
149.47
149.24
139.20
137.93
137.87
135.95
129.05
128.68
128.03
123.72
123.67
122.43
122.40
119.95
119.87
114.87
114.82
111.64
111.33
109.75
109.71
55.99
55.94
140
135
130
125
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

$^{19}$F NMR

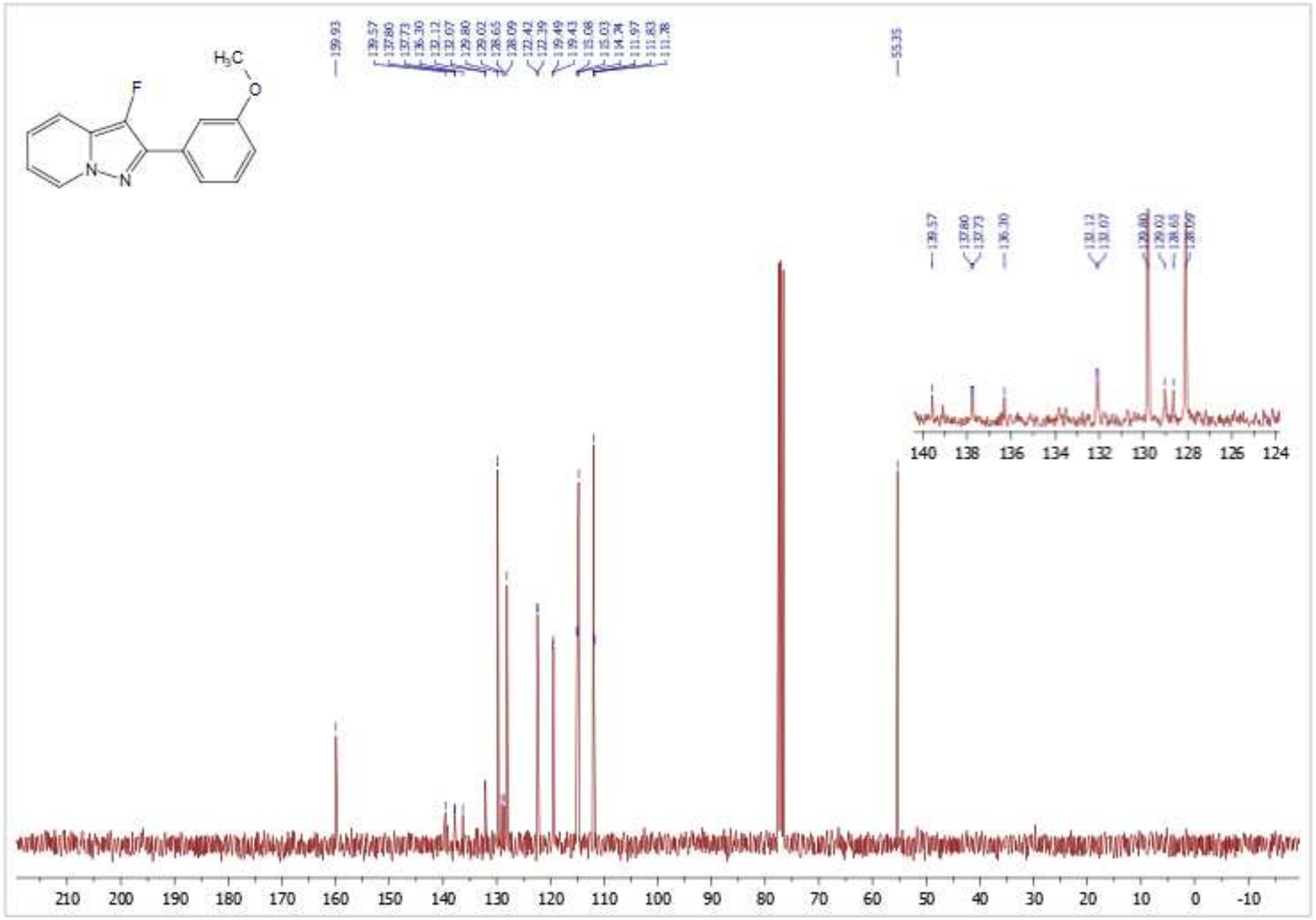

-181.73
F
H3C
O
CH3
O
N
N
140
120
100
80
60
40
20
0
-10
-30
-50
-70
-90
-110
-140
-170
-200
-230

**2-(3-Methoxyphenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3i**

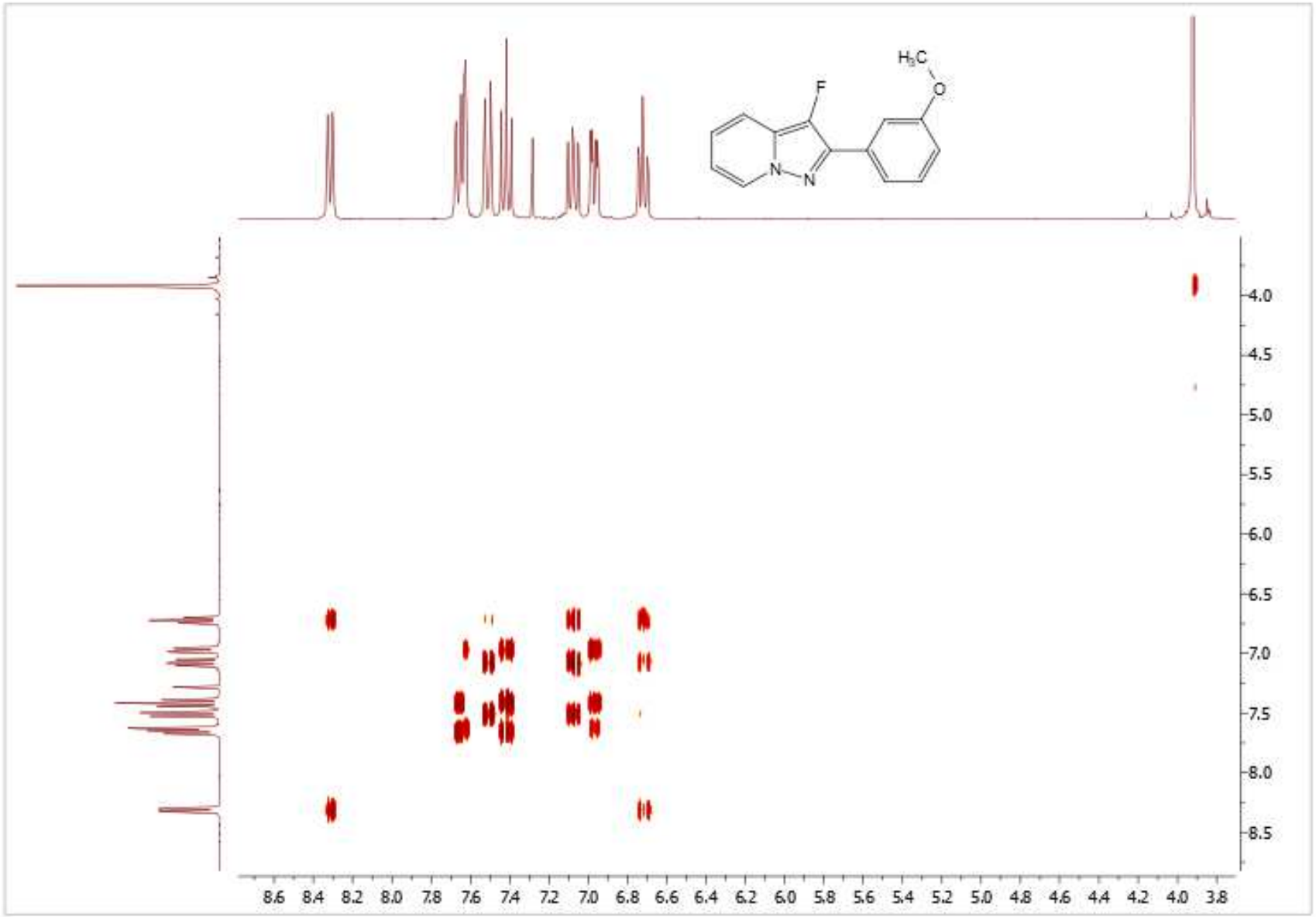
$^{1}$H NMR



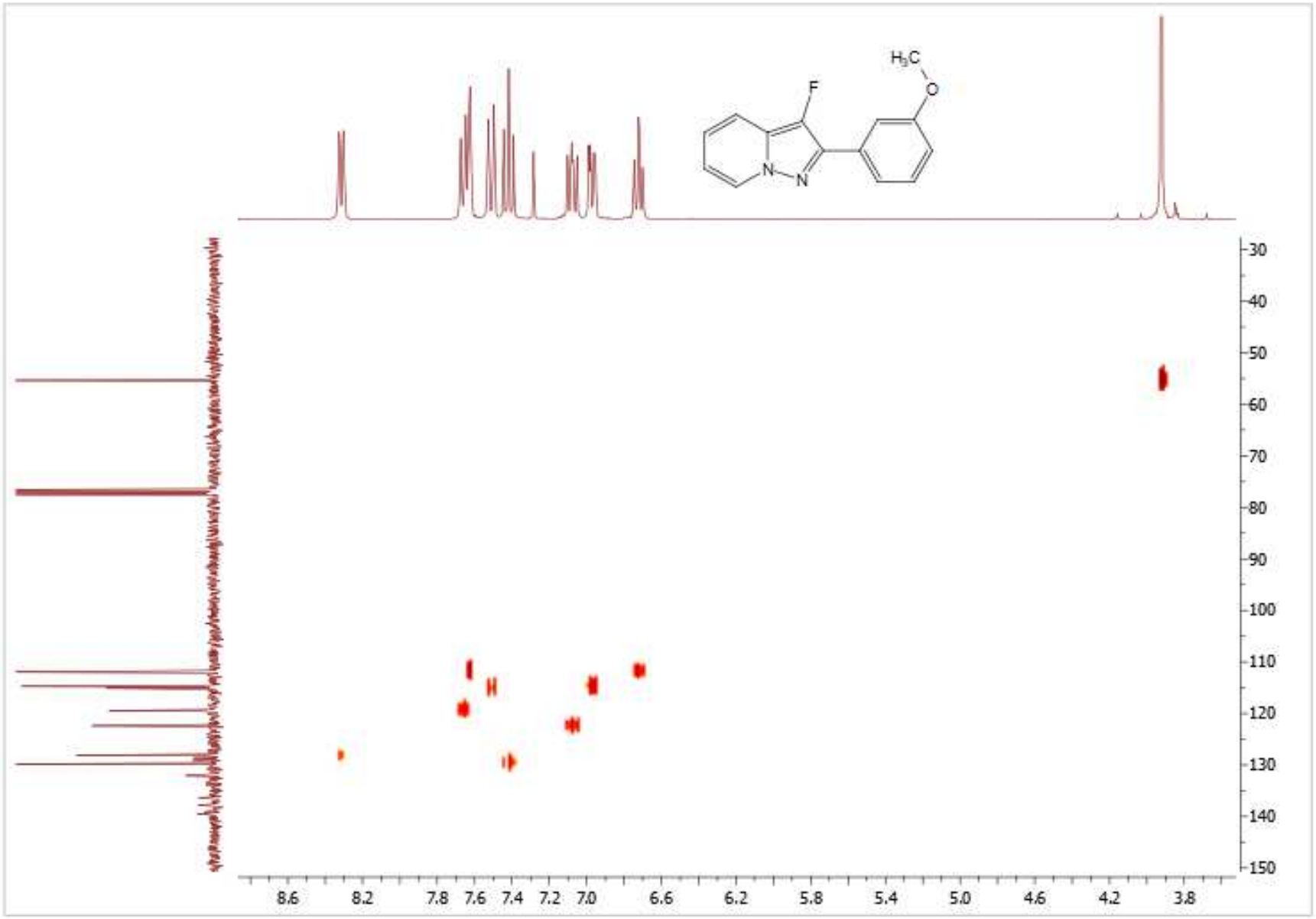
$^{13}$C NMR


159.93
139.57
137.80
137.73
136.30
132.12
132.07
129.80
129.02
128.65
128.09
122.42
122.39
119.49
119.43
115.08
115.03
114.74
111.97
111.83
111.78
55.35
F
H3C
O
N
N
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
140 138 136 134 132 130 128 126 124

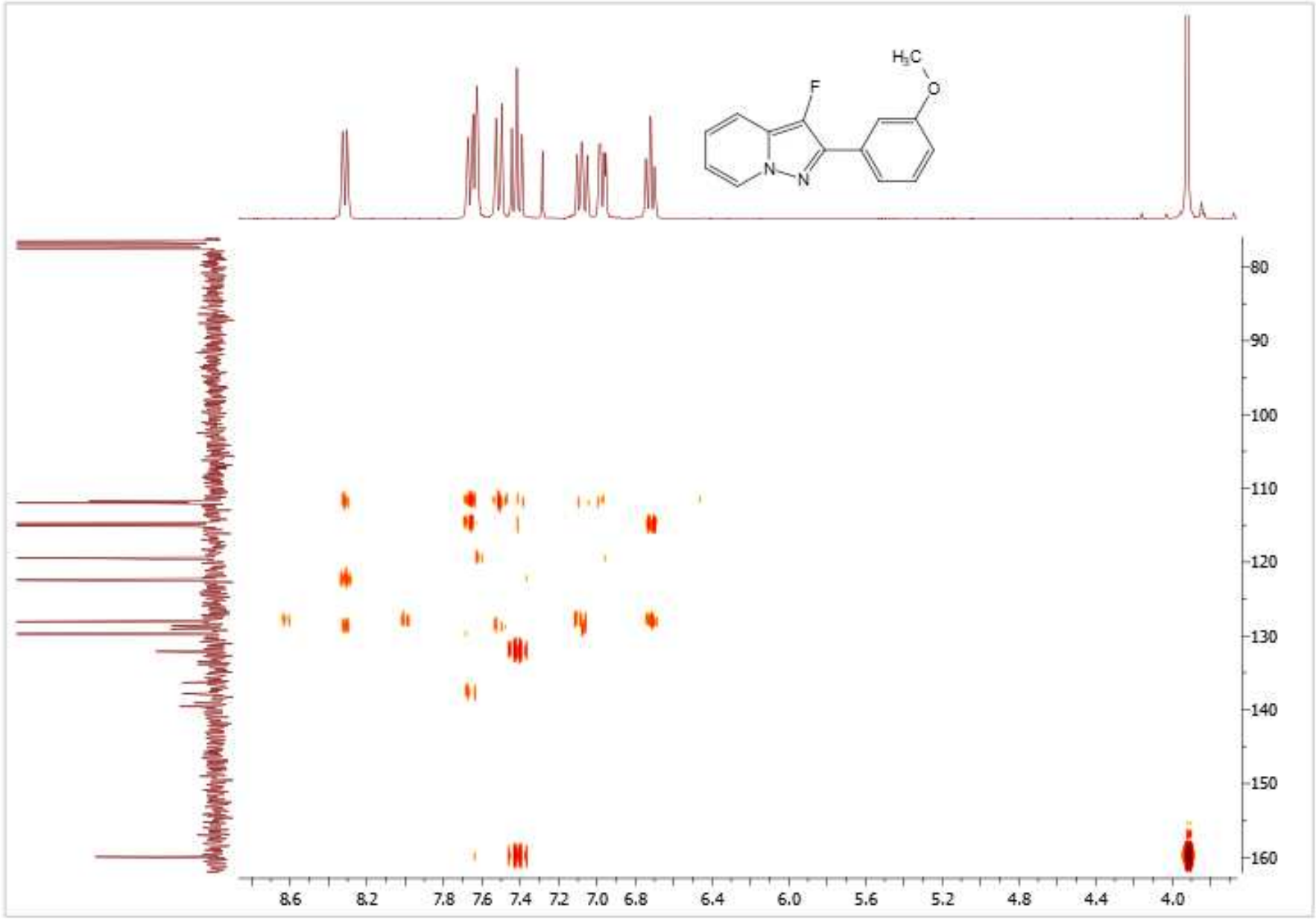
$^{1}$H-$^{1}$H COSY


H3C
O
F
N
N
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2 7.0 6.8 6.6 6.4 6.2 6.0 5.8 5.6 5.4 5.2 5.0 4.8 4.6 4.4 4.2 4.0 3.8

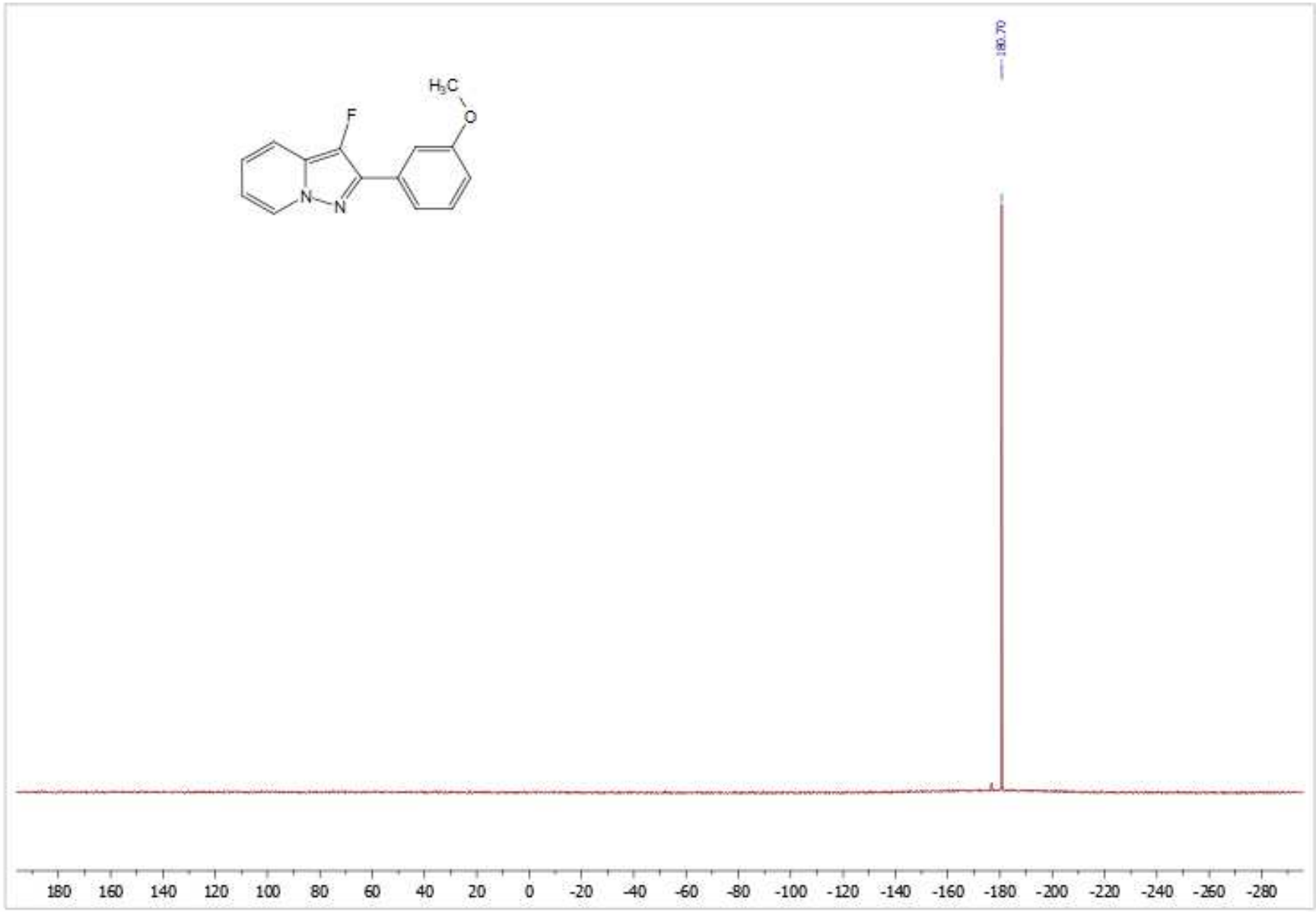
$^{1}H$-$^{13}C$ HSQC


H3C
O
F
N
N
30
40
50
60
70
80
90
100
110
120
130
140
150
8.6
8.2
7.8
7.6
7.4
7.2
7.0
6.6
6.2
5.8
5.4
5.0
4.6
4.2
3.8

$^{1}H$-$^{13}C$ HMBC

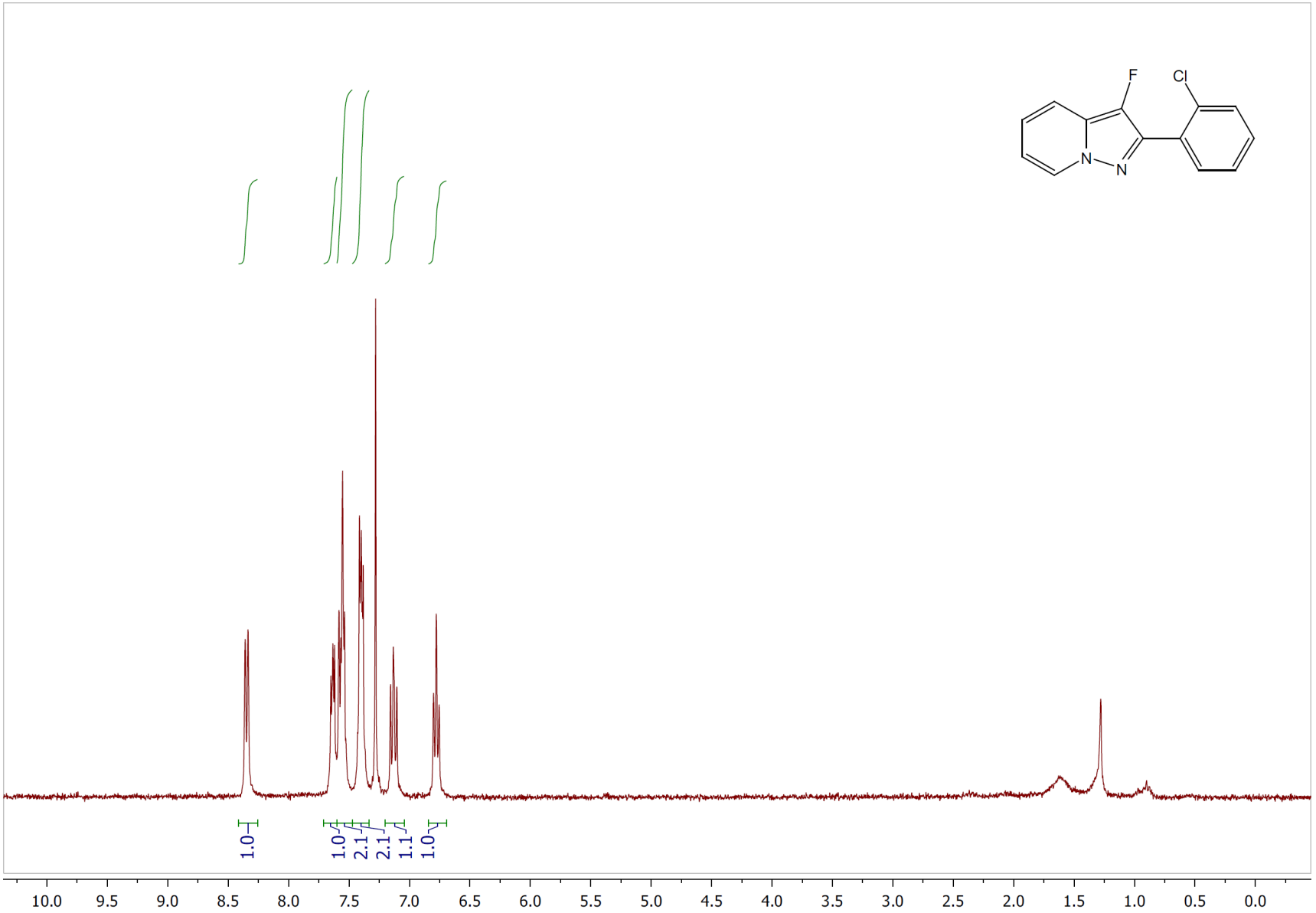

H3C
O
F
N
N
80
90
100
110
120
130
140
150
160
8.6
8.2
7.8
7.6
7.4
7.2
7.0
6.8
6.4
6.0
5.6
5.2
4.8
4.4
4.0

$^{19}$F NMR

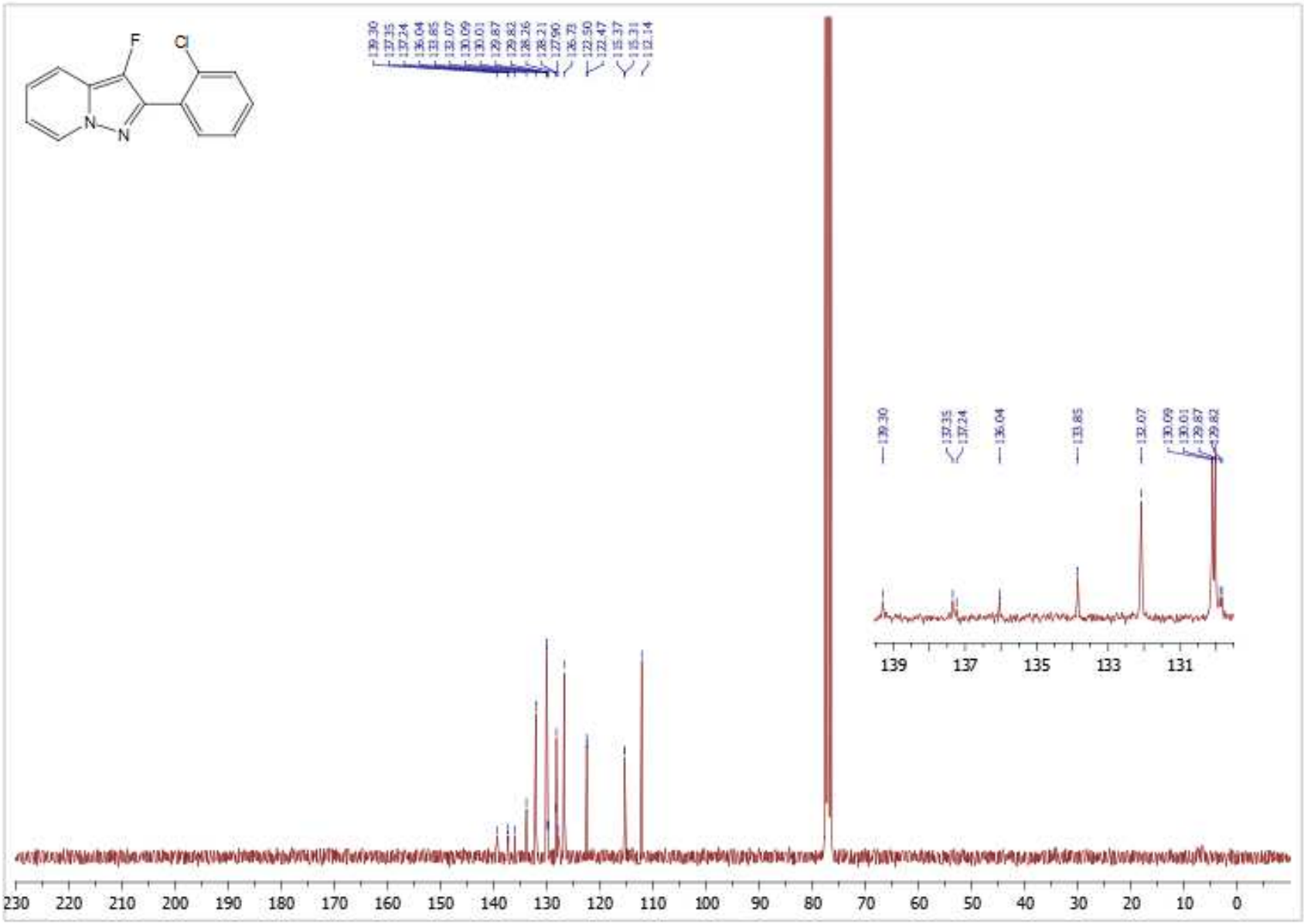

-180.70
H3C
O
F
N
N
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**2-(2-Chlorophenyl)-3-fluoro-pyrazolo[1,5-a]pyridine 3j**

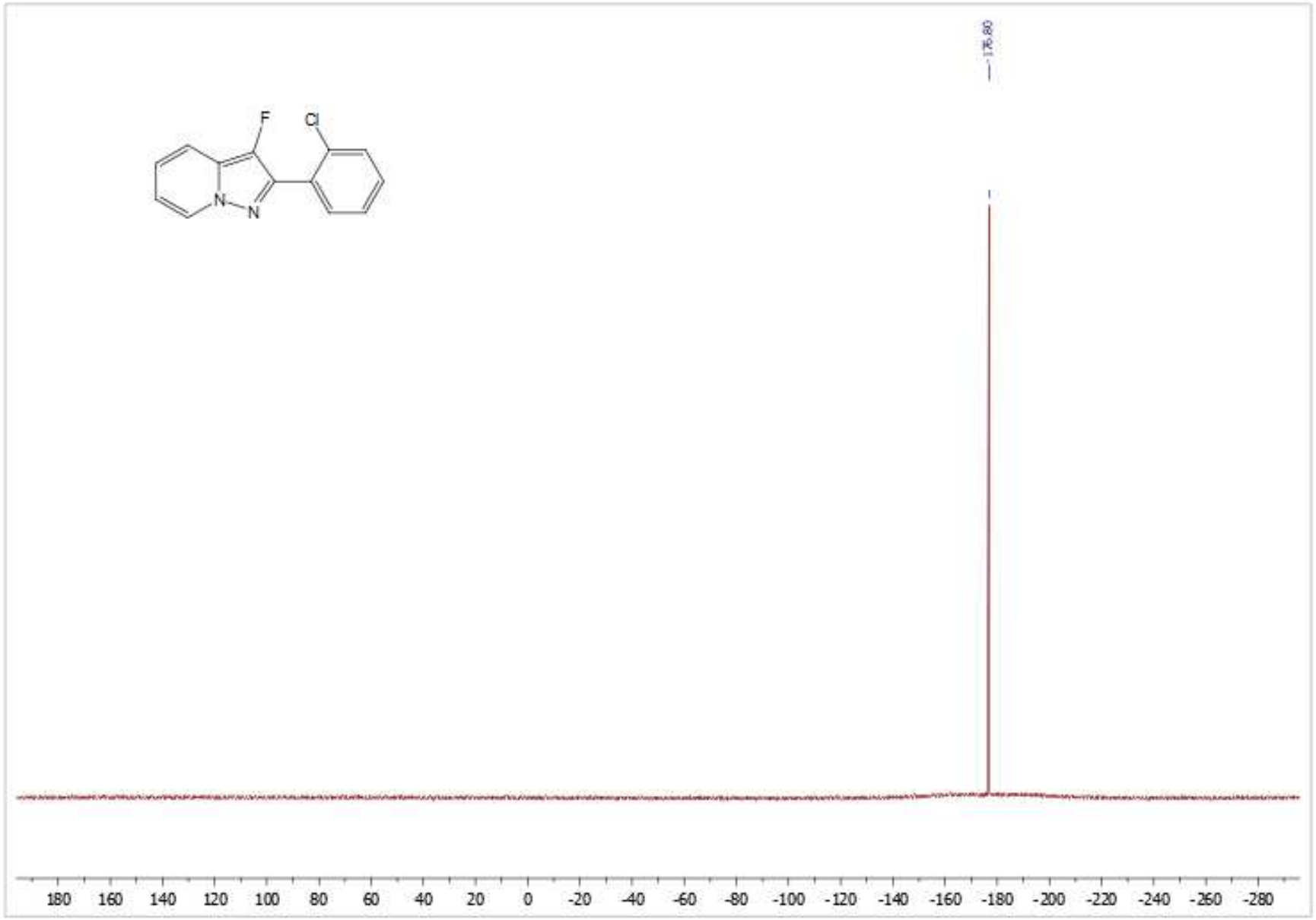
$^{1}$H NMR



$^{13}$C NMR

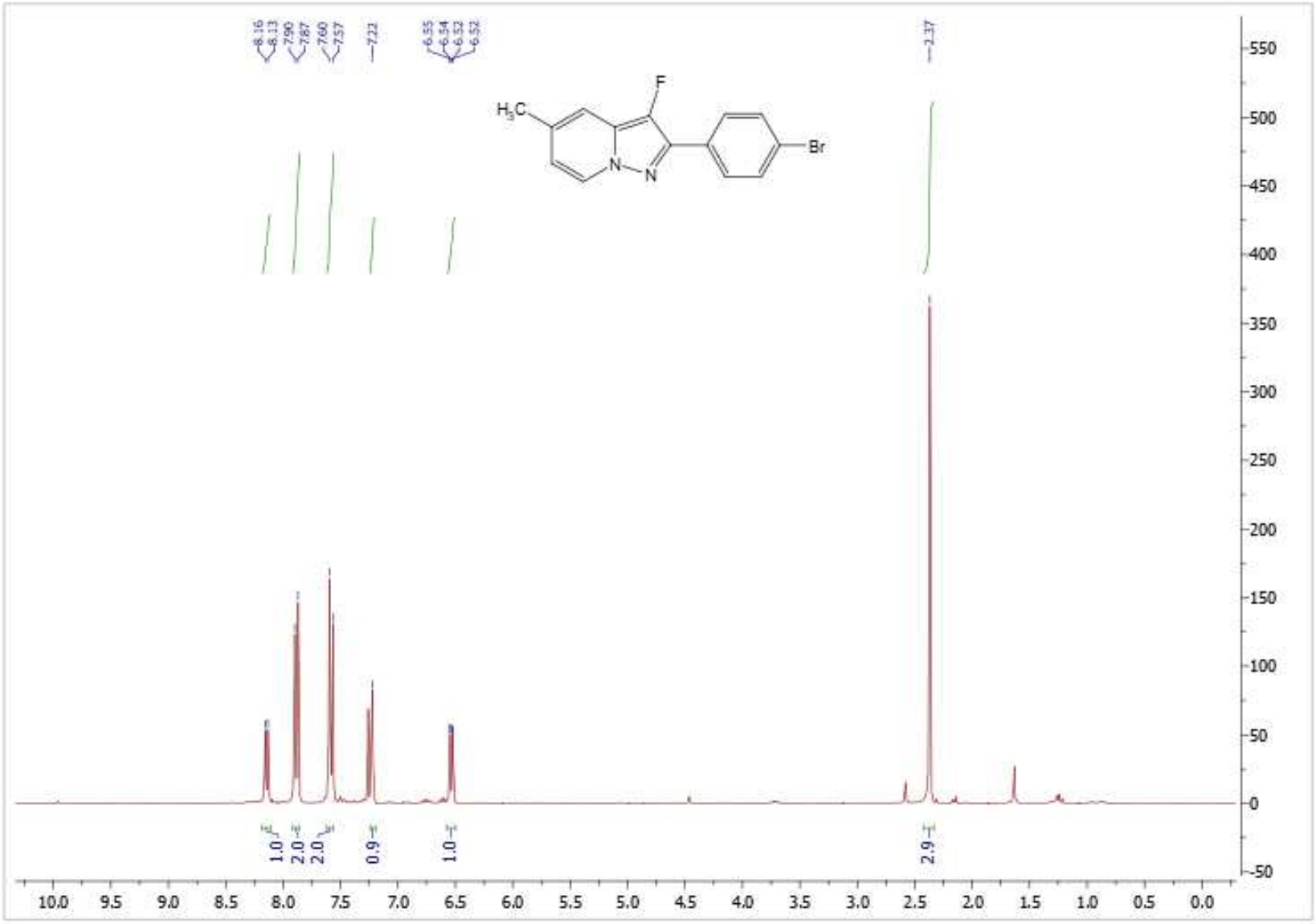

F
Cl
N
N
139.30
137.35
137.24
136.04
133.85
133.07
130.09
130.01
129.87
129.82
128.26
128.21
127.90
126.73
122.50
122.47
115.37
115.31
112.14
139.30
137.35
137.24
136.04
133.85
133.07
130.09
130.01
129.87
129.82
139
137
135
133
131
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{19}$F NMR

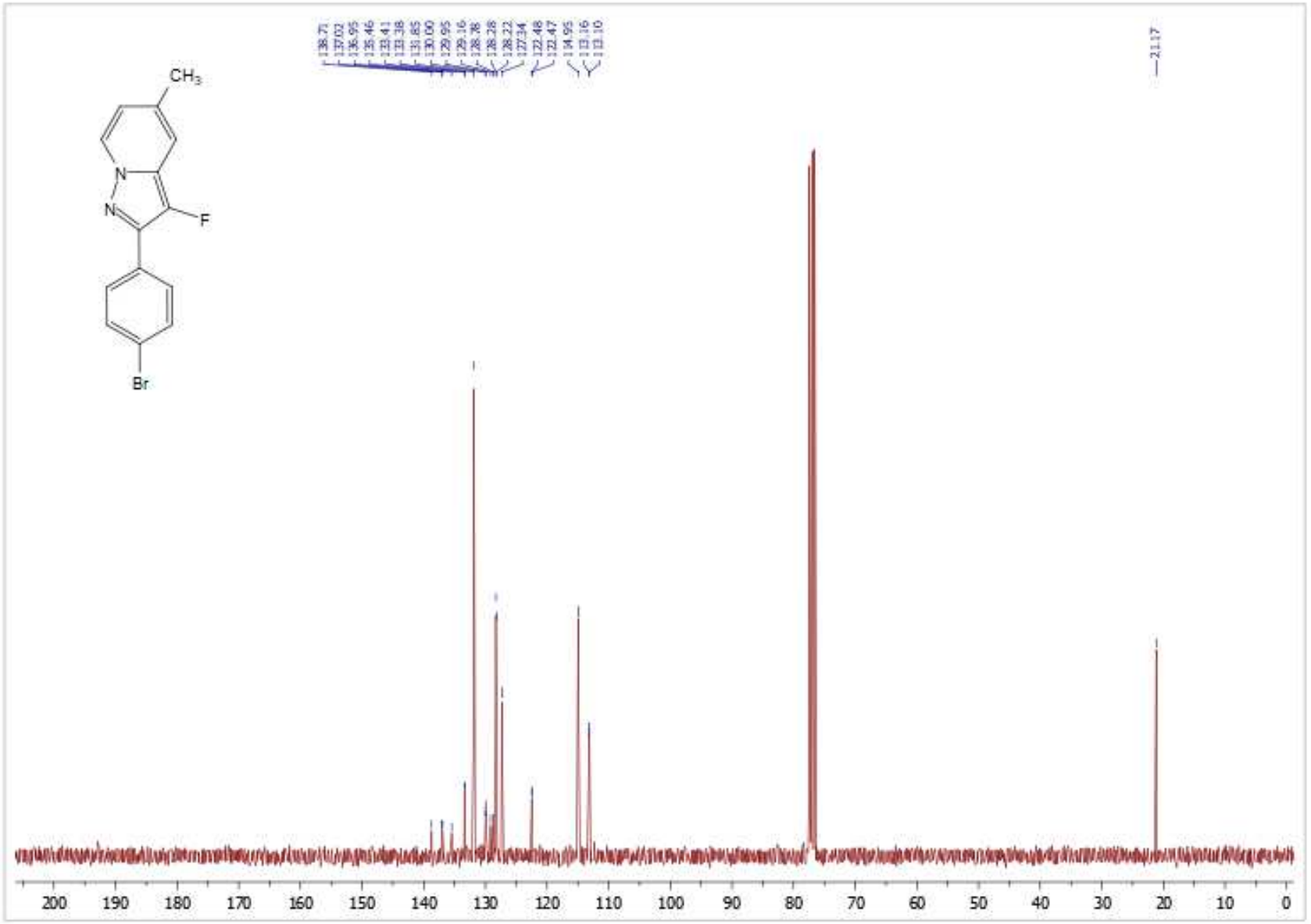

F
Cl
N
N
-176.80
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280

**2-(4-Bromophenyl)-3-fluoro-5-methyl-pyrazolo[1,5-a]pyridine 3k**

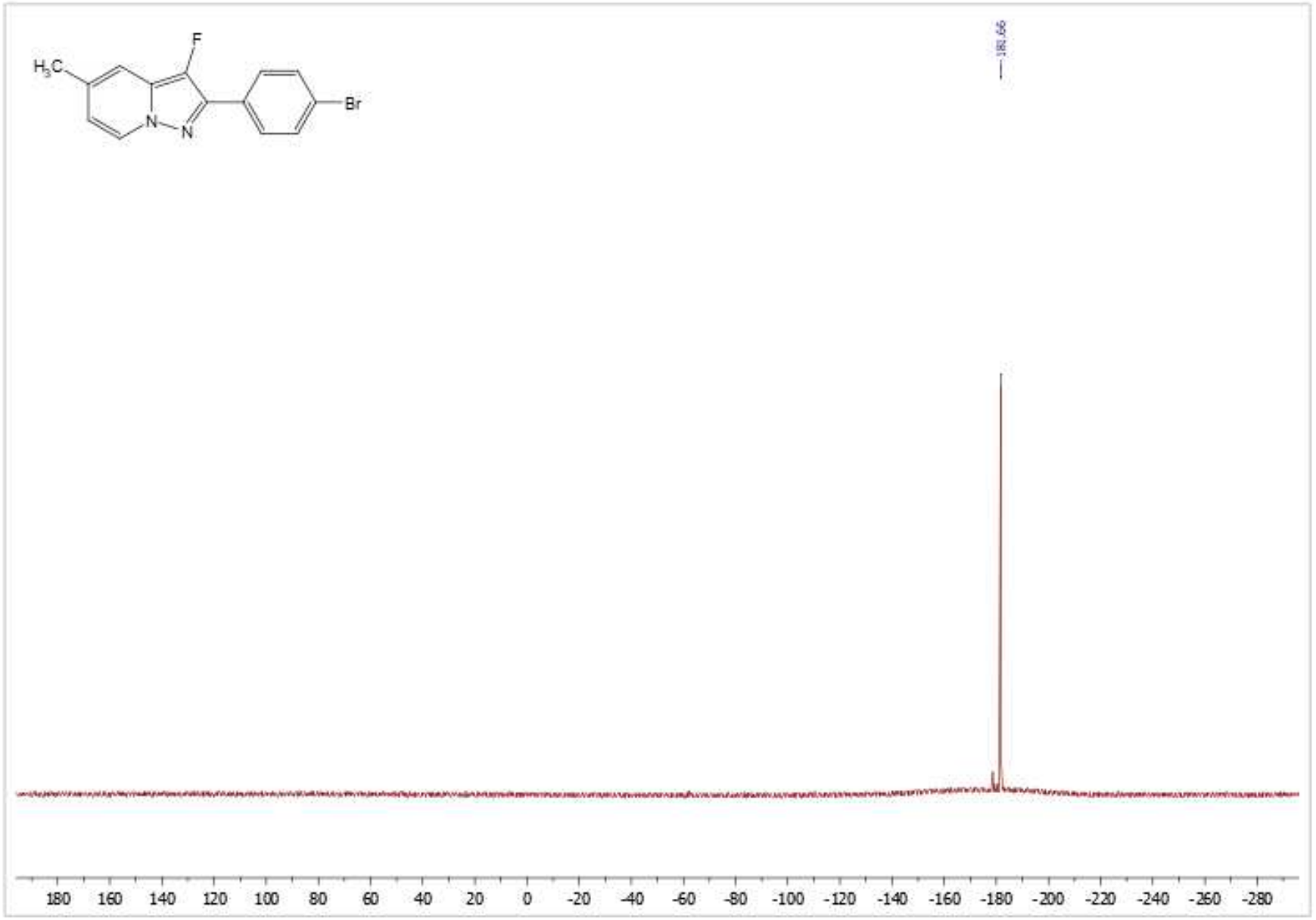
$^{1}$H NMR



$^{13}$C NMR

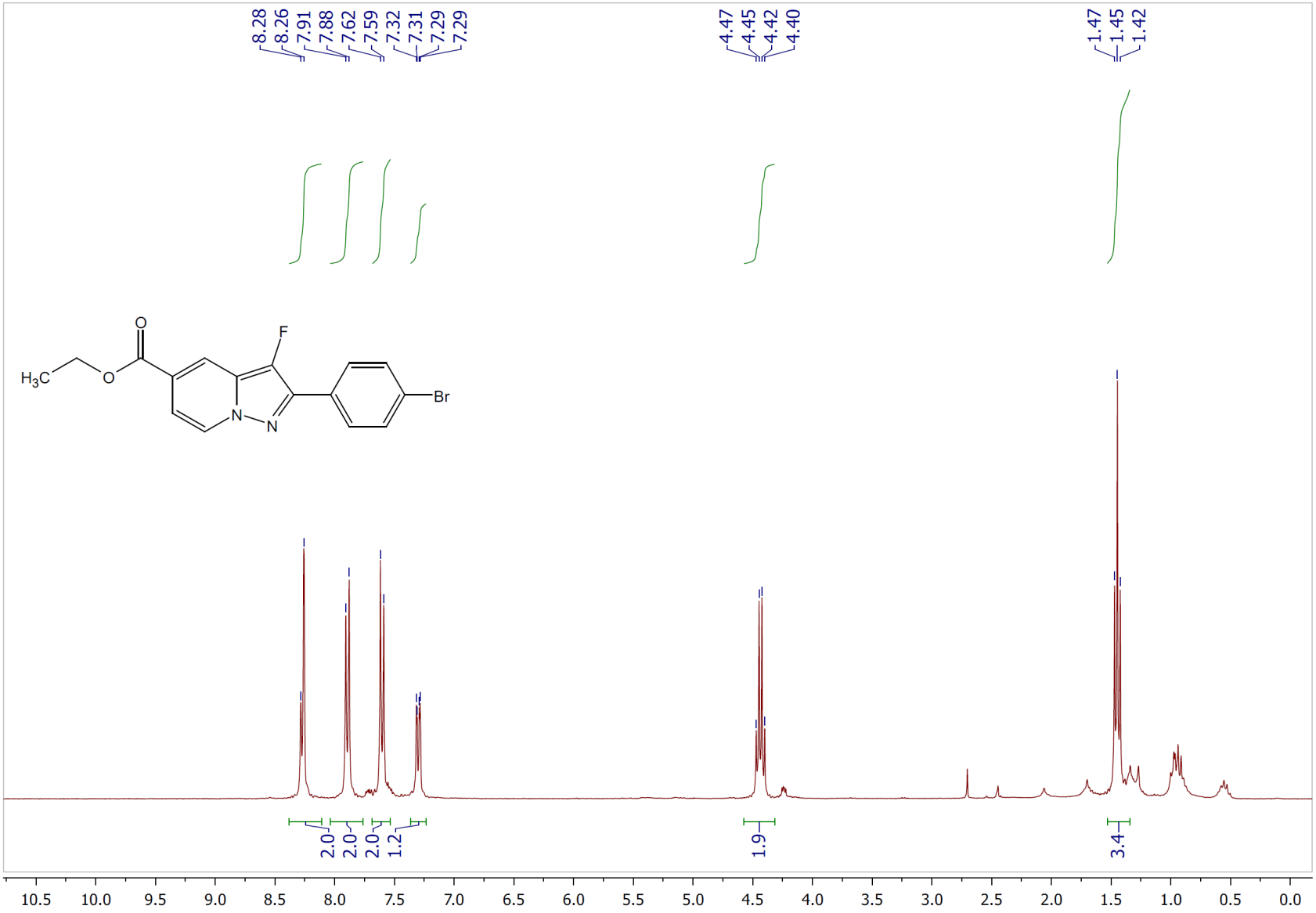

CH3
N
N
F
Br
21.17
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{19}$F NMR

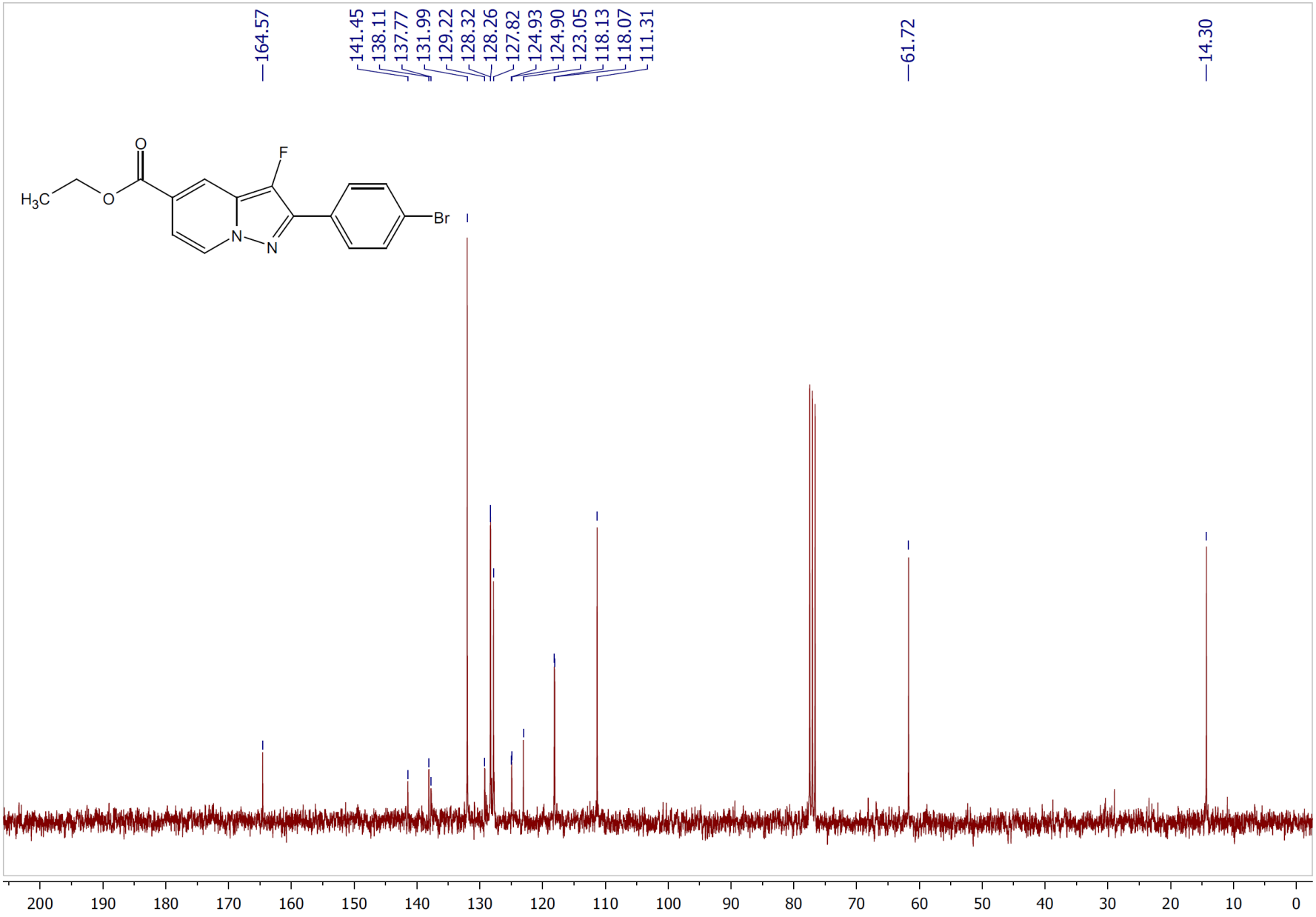

F
H3C
Br
N
N
-183.66
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**Ethyl 2-(4-bromophenyl)-3-fluoropyrazolo[1,5-a]pyridine-5-carboxylate 3l**

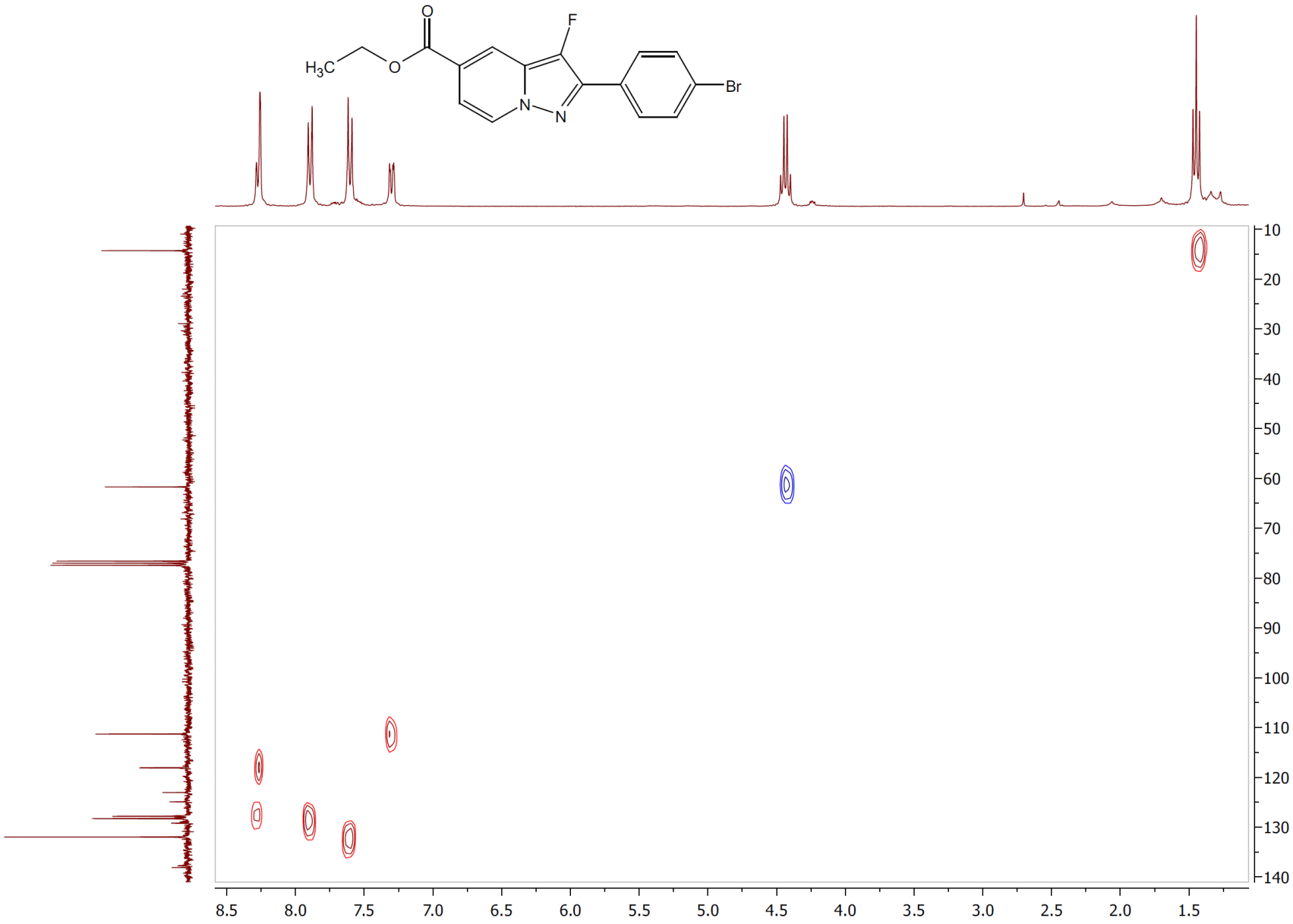
$^{1}$H NMR



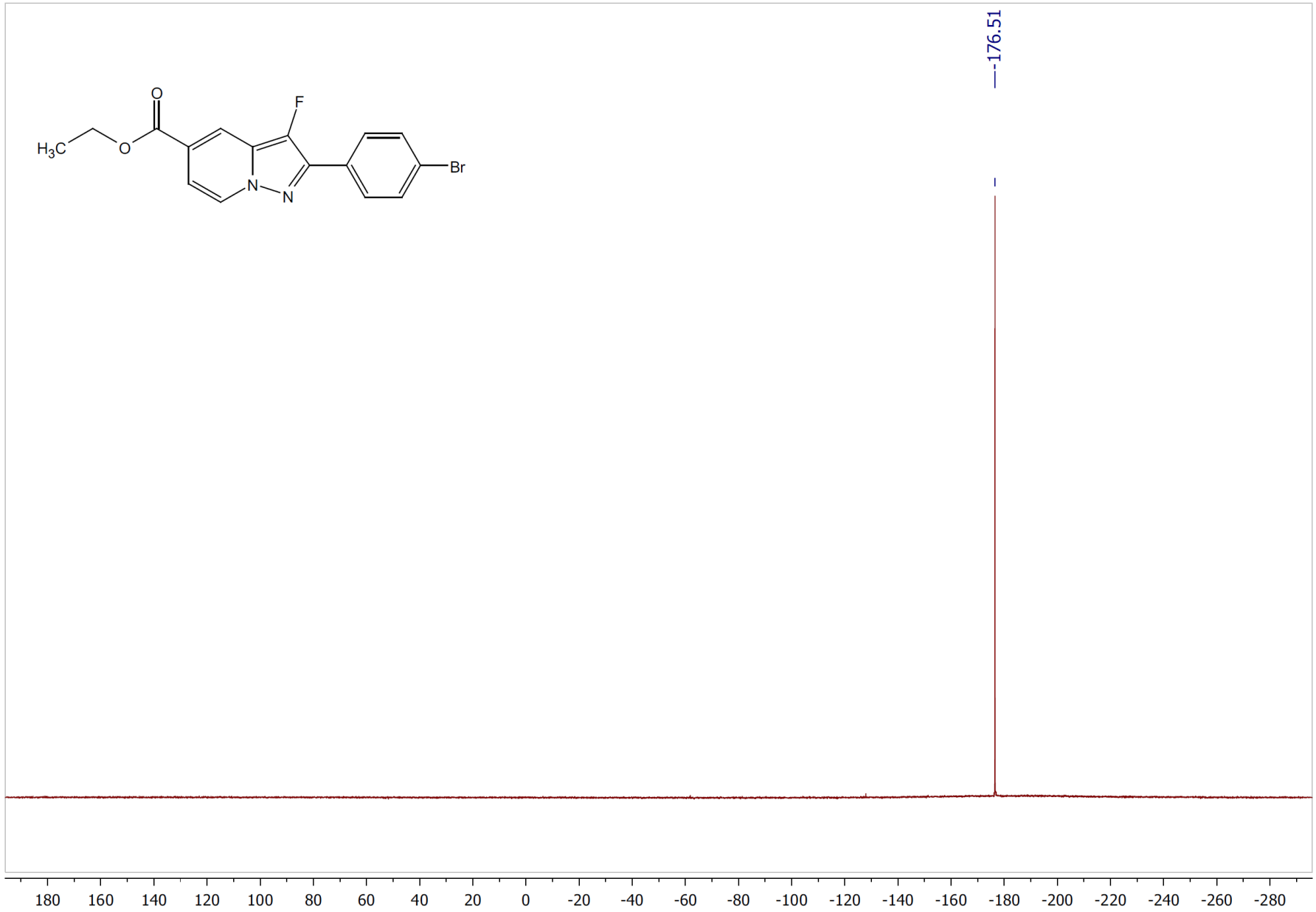
$^{13}$C NMR


164.57
141.45
138.11
137.77
131.99
129.22
128.32
128.26
127.82
124.93
124.90
123.05
118.13
118.07
111.31
61.72
14.30
O
F
H3C
O
Br
N
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC

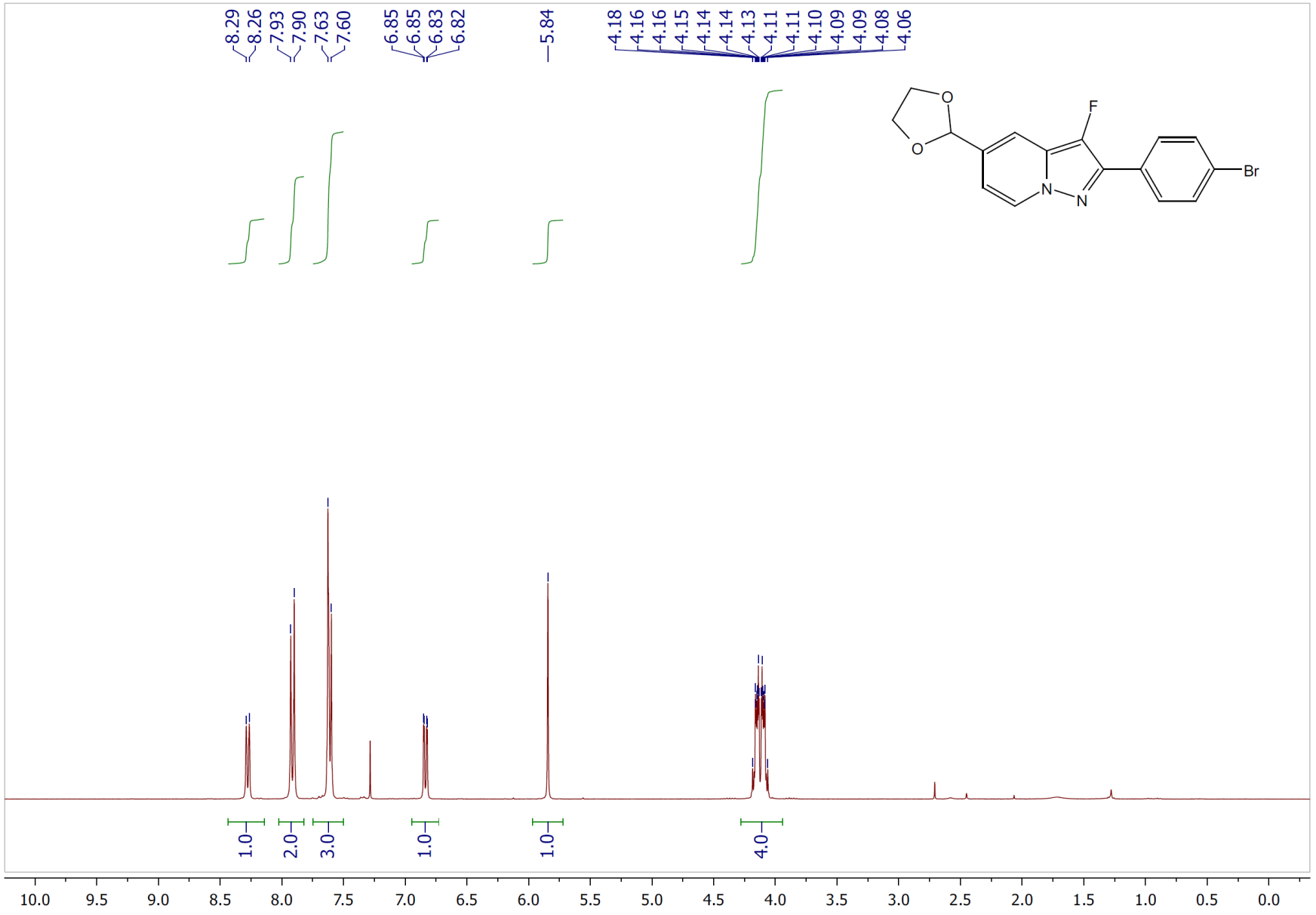

O
F
H3C
O
Br
N
N
10
20
30
40
50
60
70
80
90
100
110
120
130
140
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5

$^{19}$F NMR

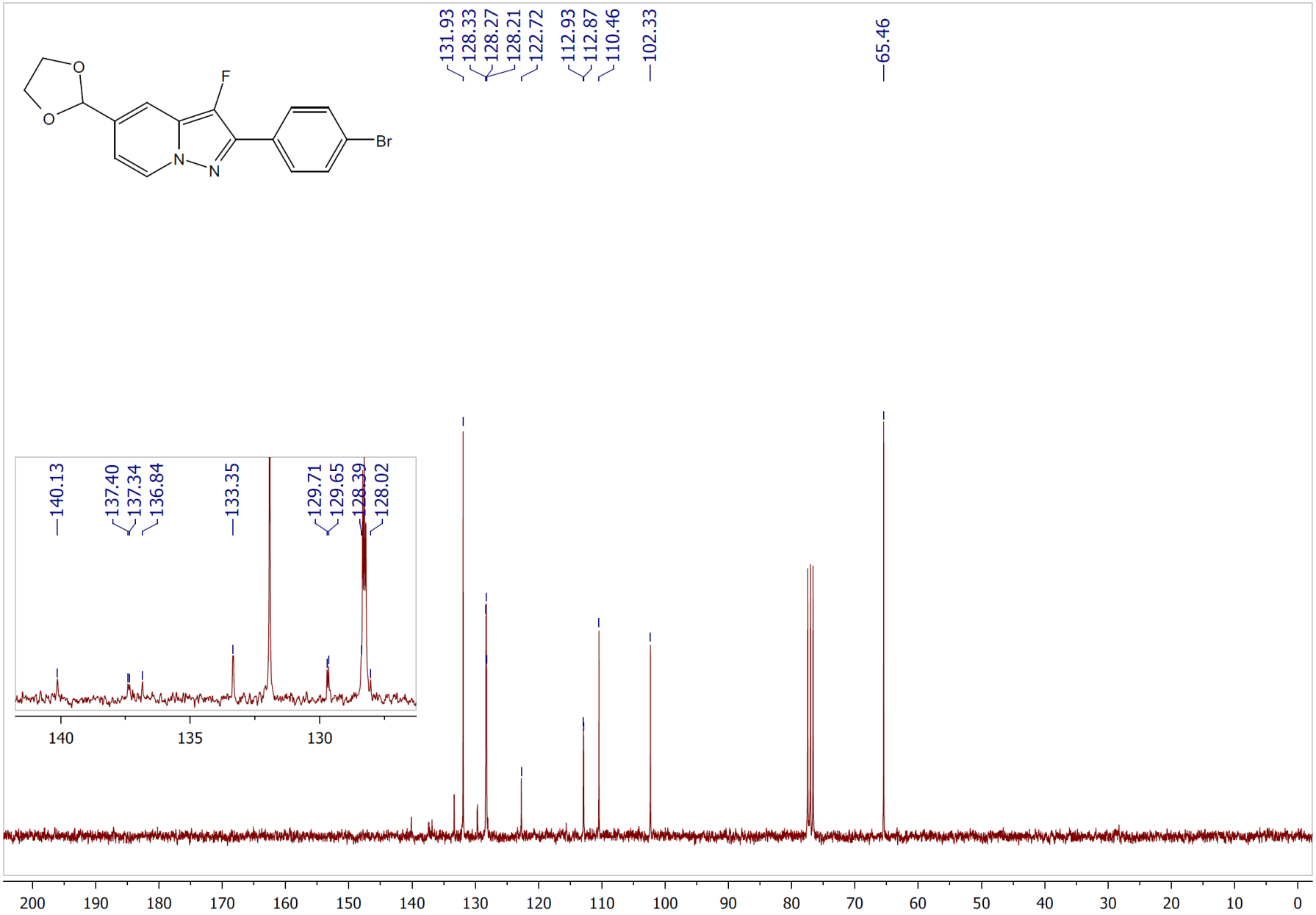

-176.51
O
F
H3C
O
N
N
Br
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280

**2-(4-Bromophenyl)-5-(1,3-dioxolan-2-yl)-3-fluoropyrazolo[1,5-a]pyridine 3m**

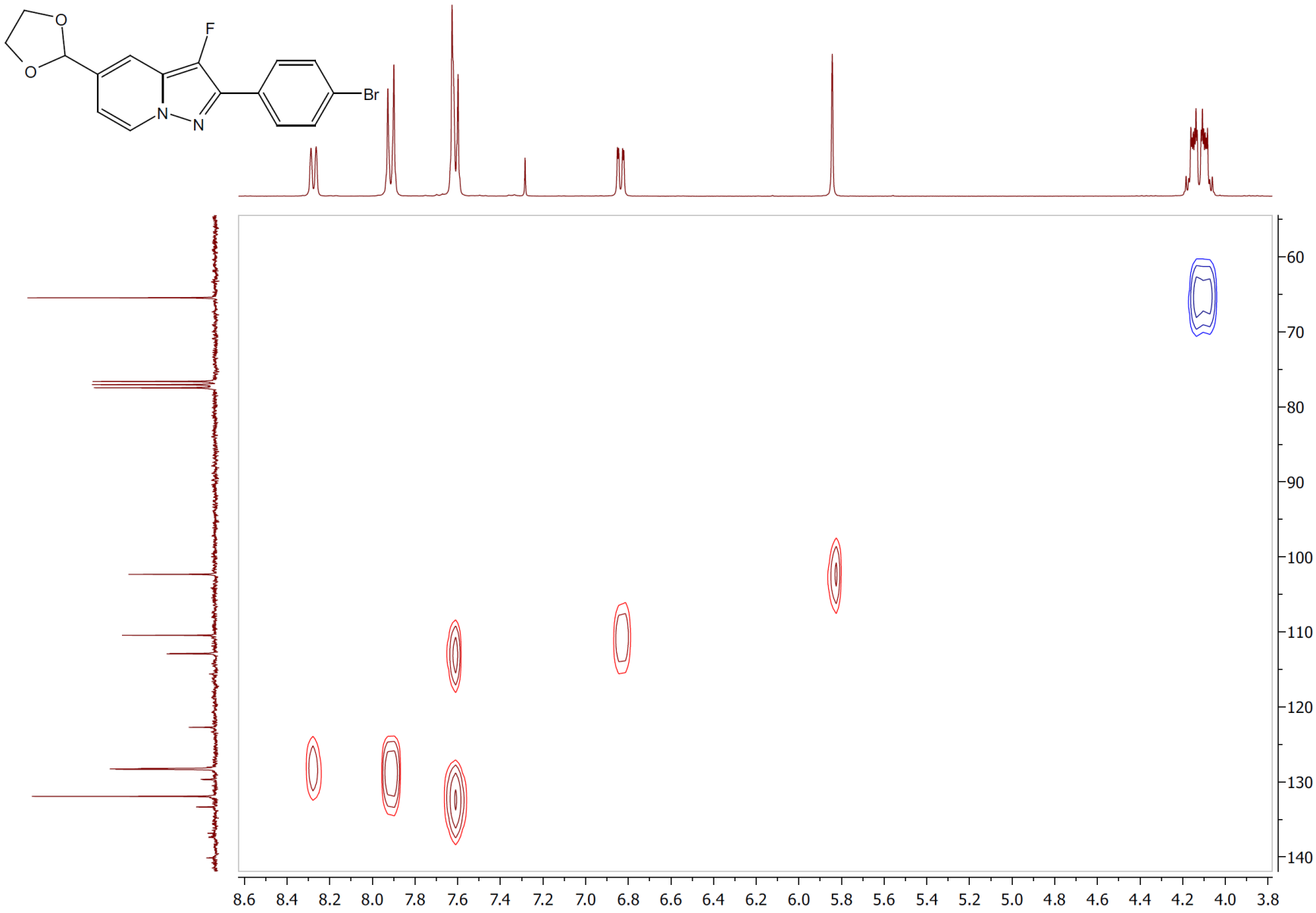
$^{1}$H NMR



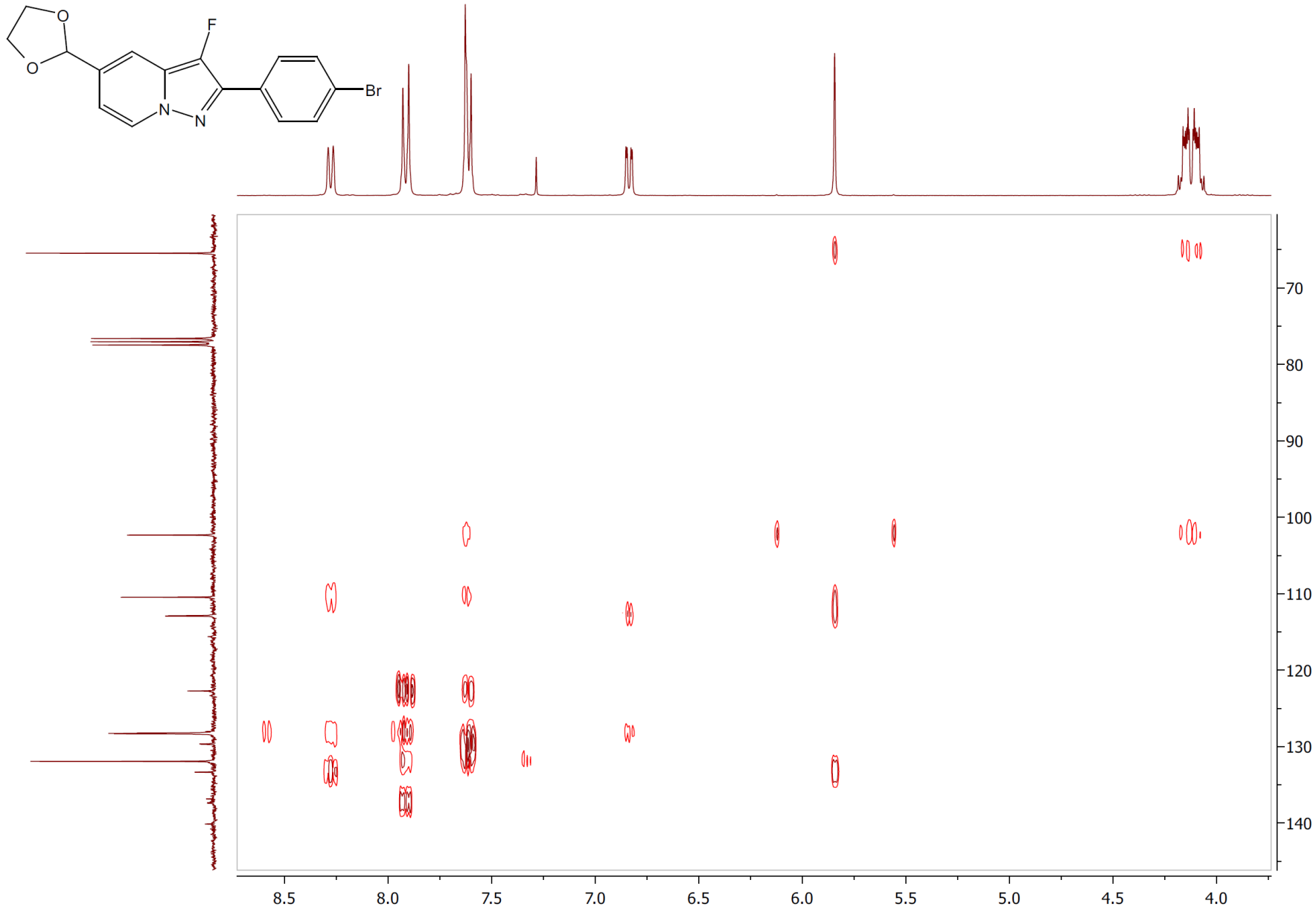
$^{13}$C NMR


131.93
128.33
128.27
128.21
122.72
112.93
112.87
110.46
102.33
65.46
O
O
F
N
N
Br
140.13
137.40
137.34
136.84
133.35
129.71
129.65
128.39
128.02
140
135
130
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

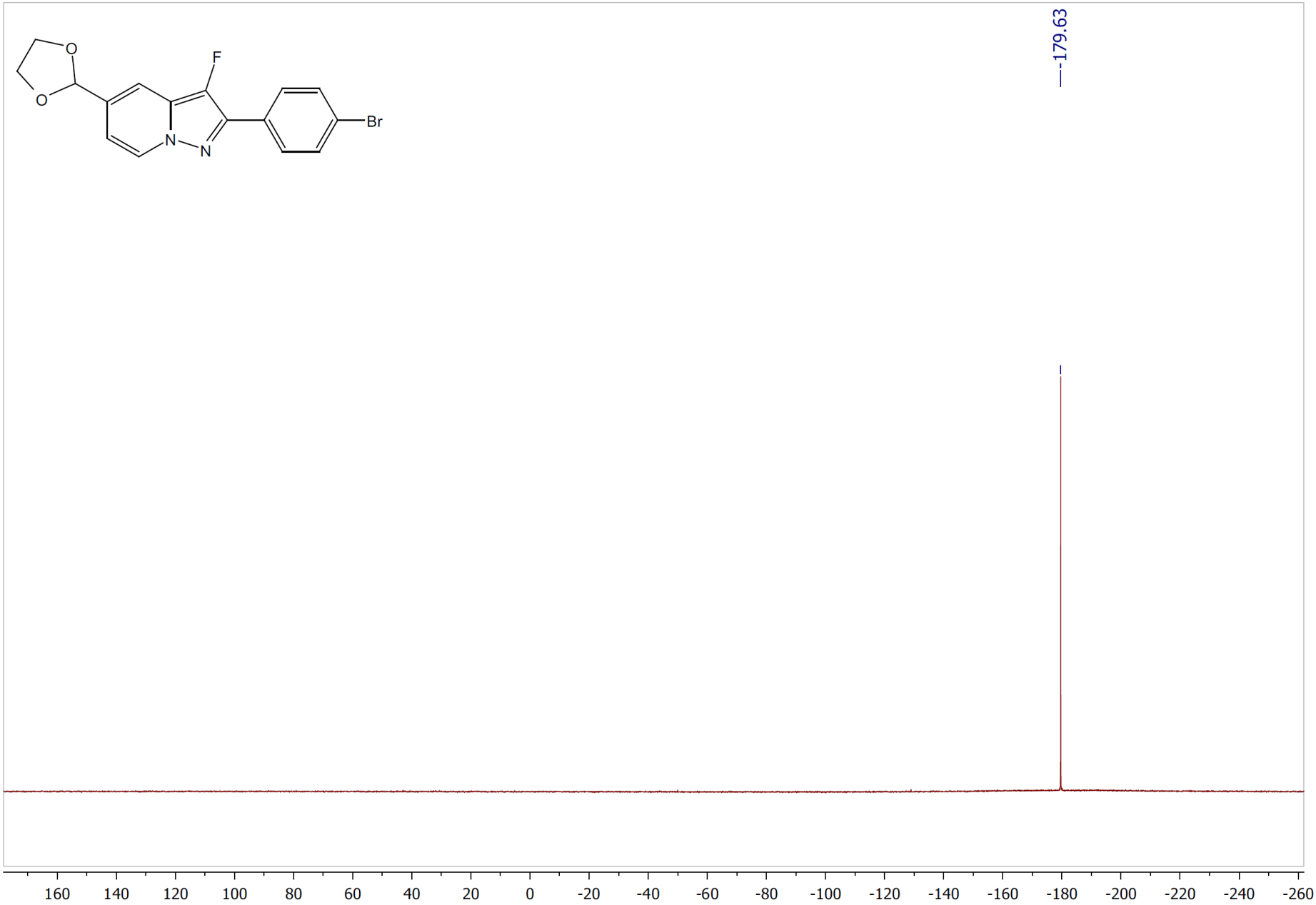
$^{1}$H-$^{13}$C HSQC


O
O
F
Br
N
N
60
70
80
90
100
110
120
130
140
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8

$^{1}H$-$^{13}C$ HMBC

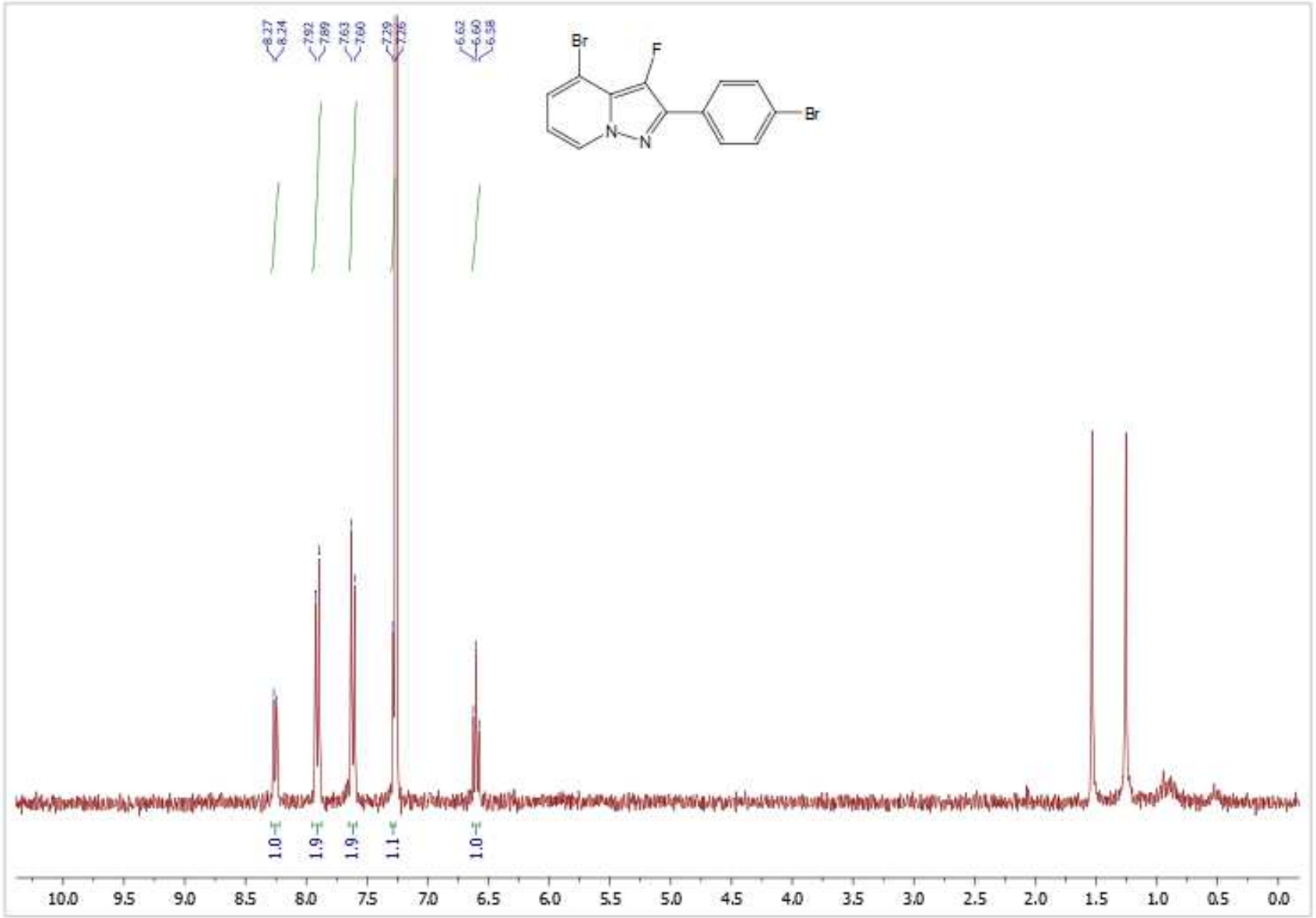


$^{19}$F NMR

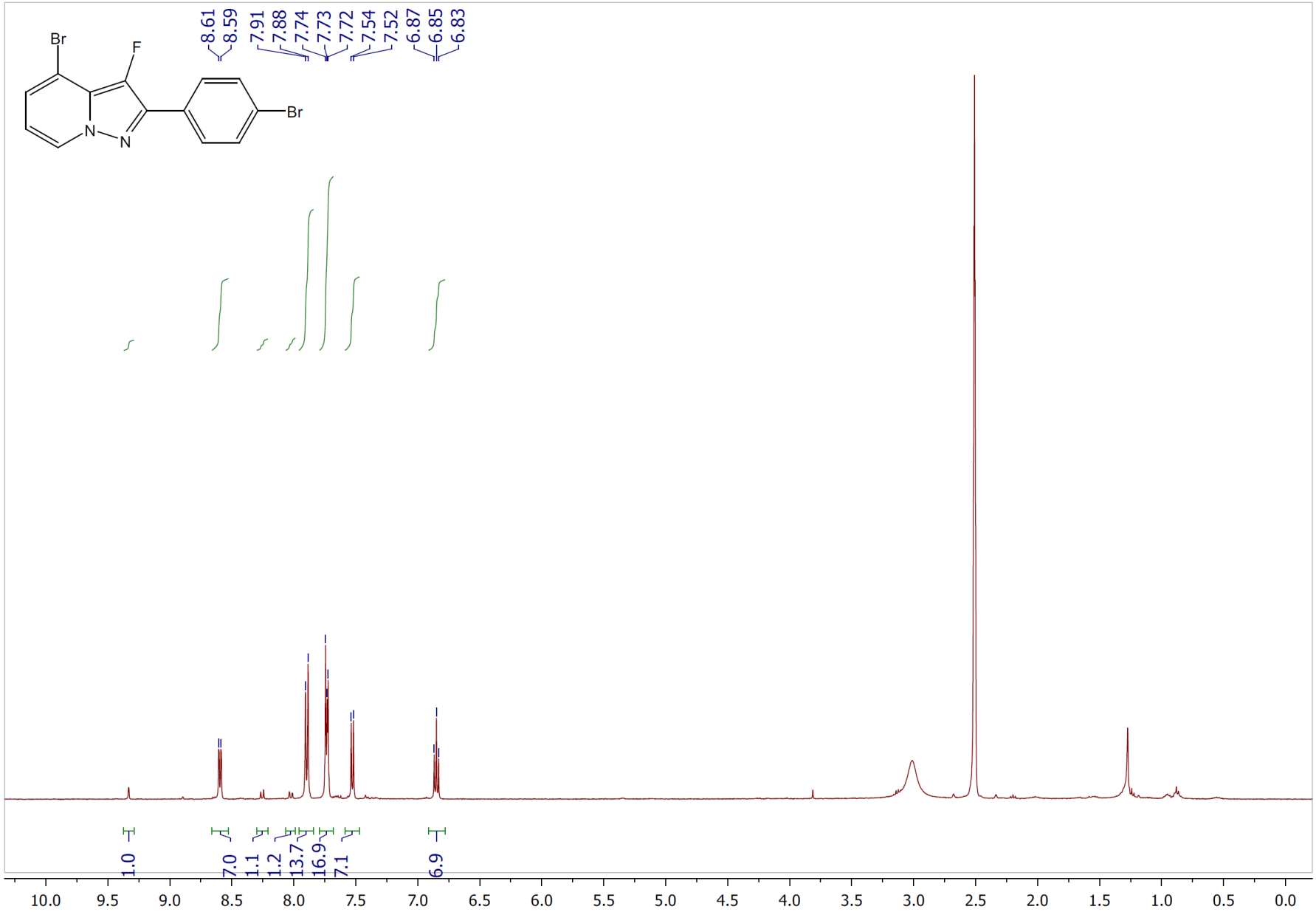

-179.63
O
O
F
N
N
Br
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260

**4-Bromo-2-(4-bromophenyl)-3-fluoropyrazolo[1,5-a]pyridine 3n**

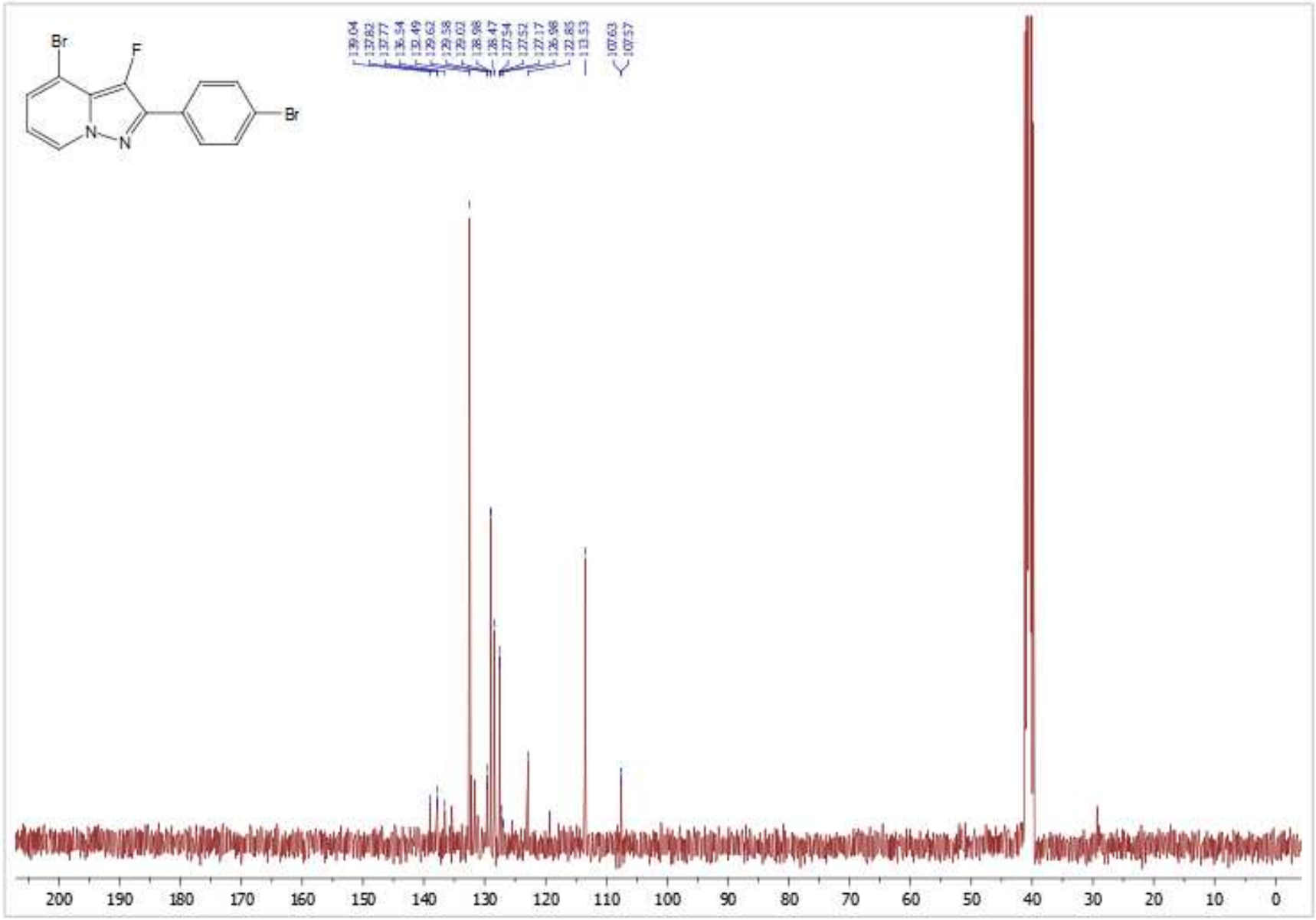
$^{1}H$ NMR ($CDCl_3$, 300 K)



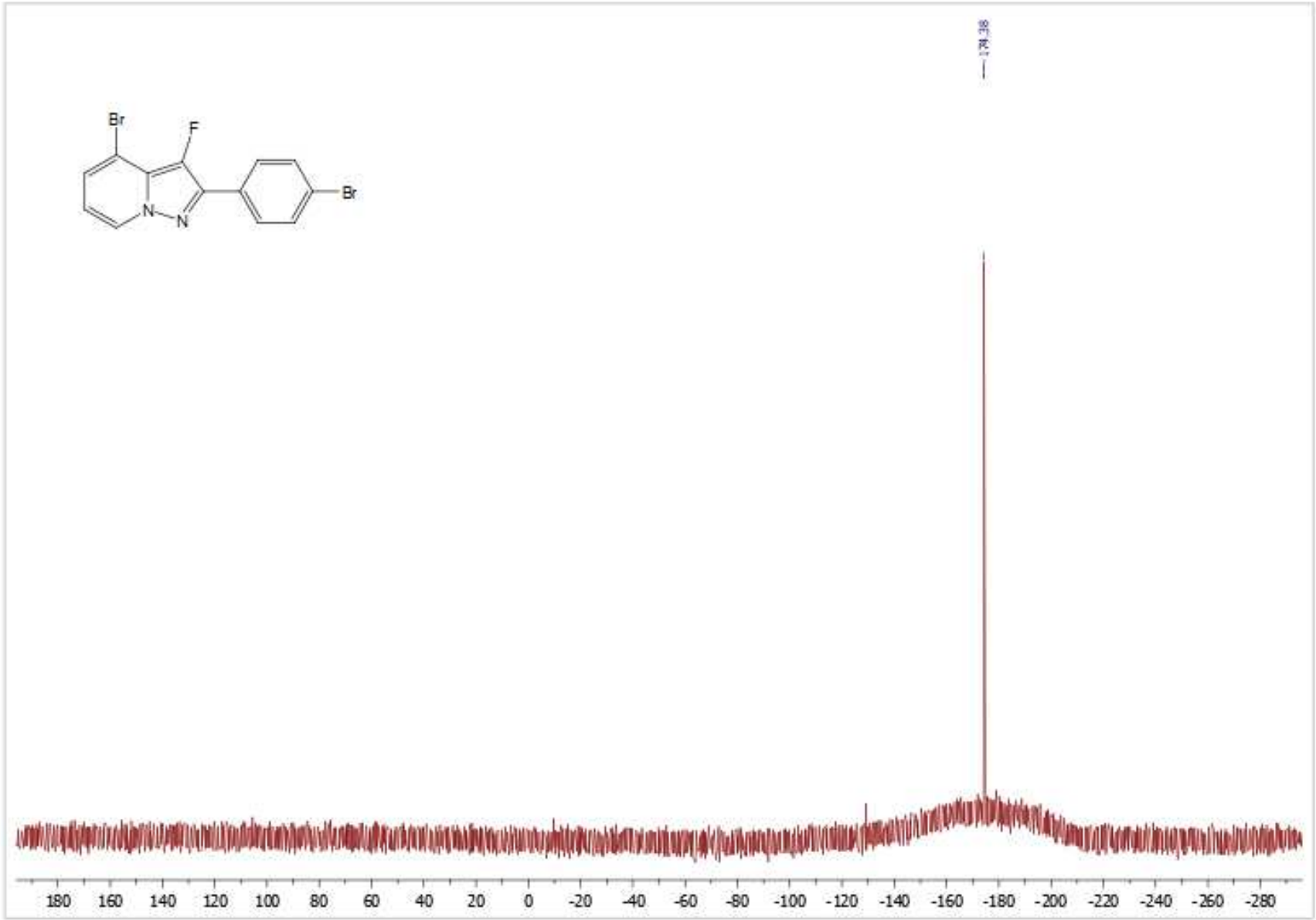
$^{1}$H NMR (DMSO-$d_6$, 363 K)



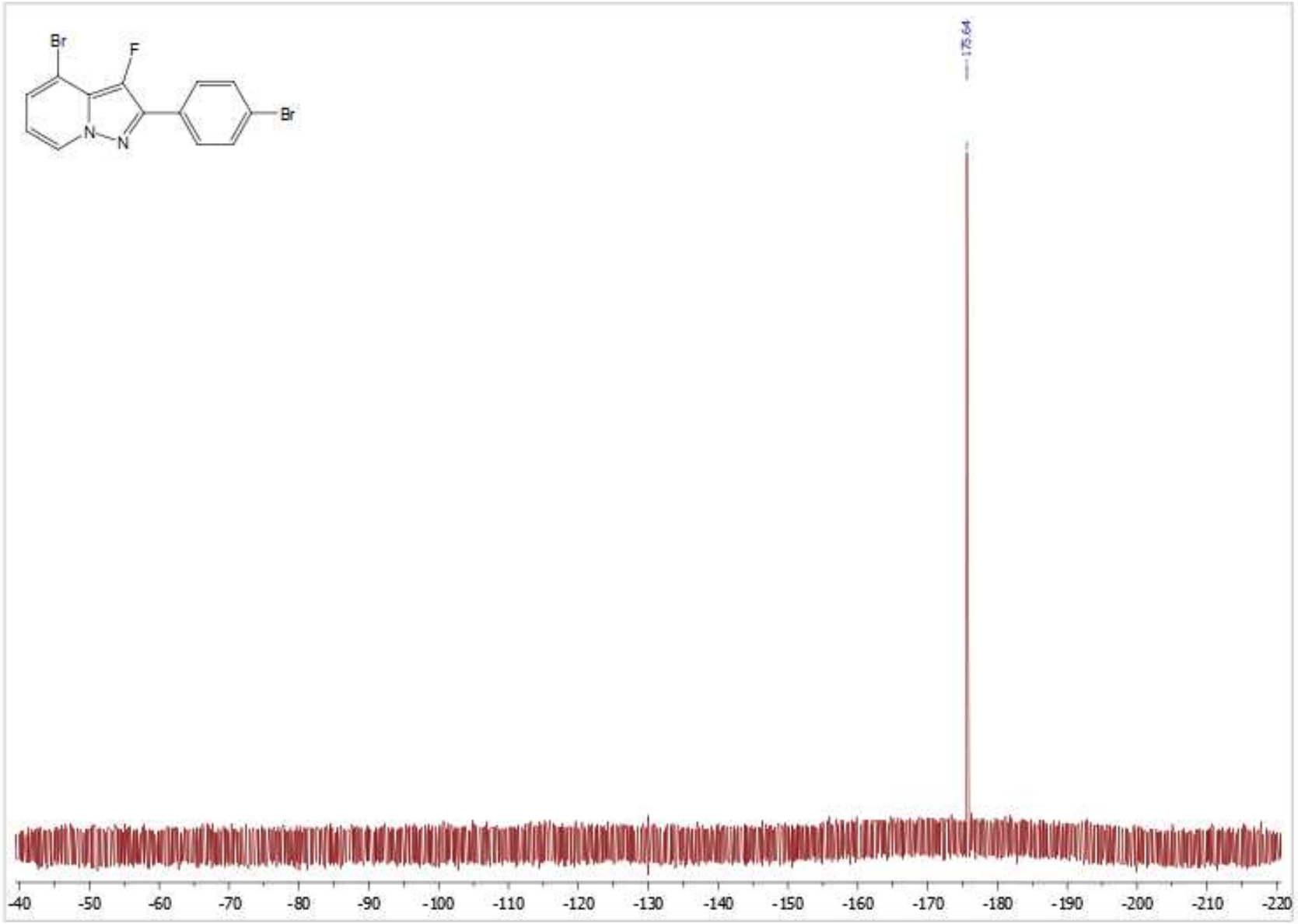
$^{13}$C NMR (DMSO-$d_6$, 363 K)



$^{19}F$ NMR ($CDCl_3$, 300K)

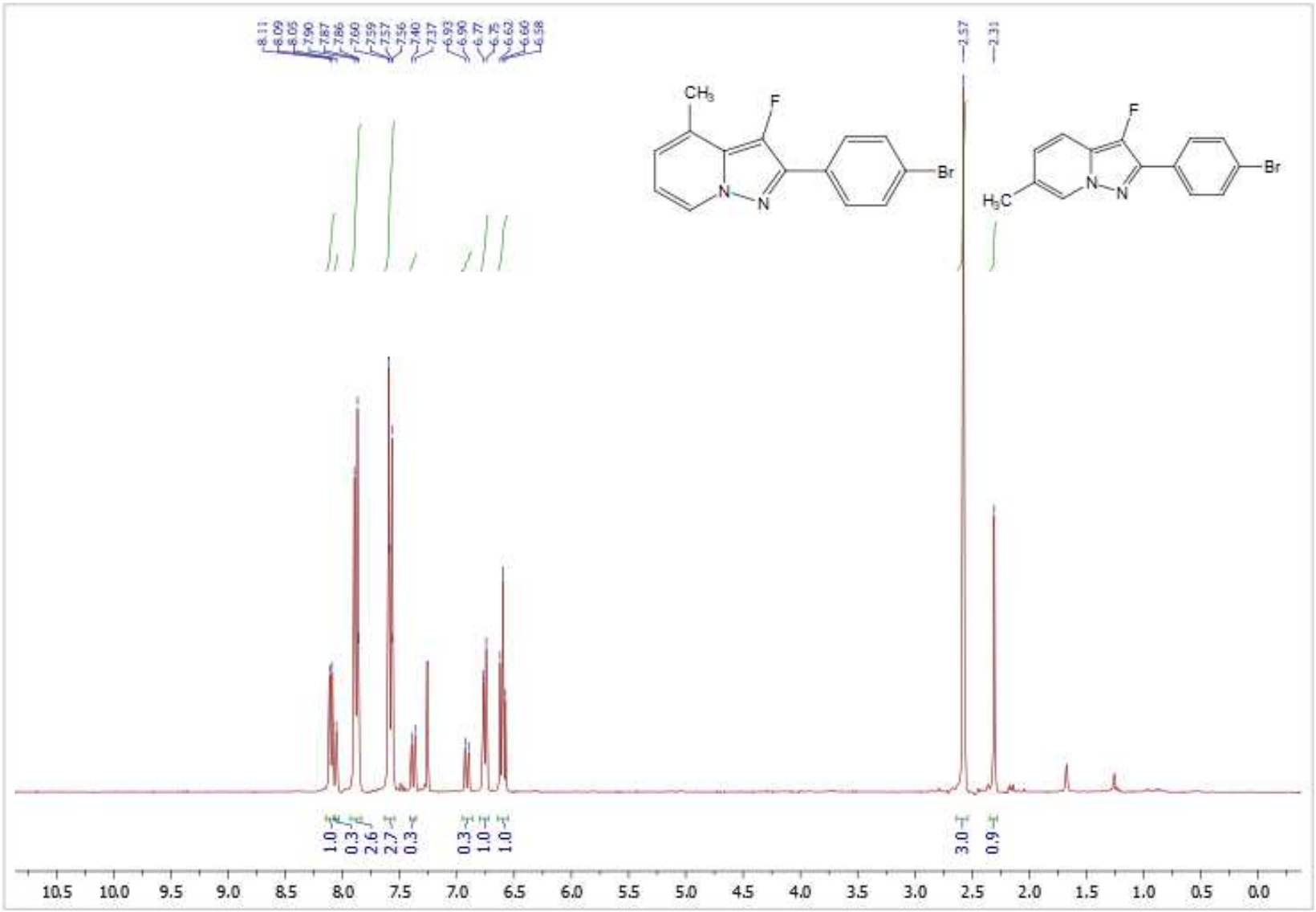


$^{19}$F NMR (DMSO-$d_6$, 363K)

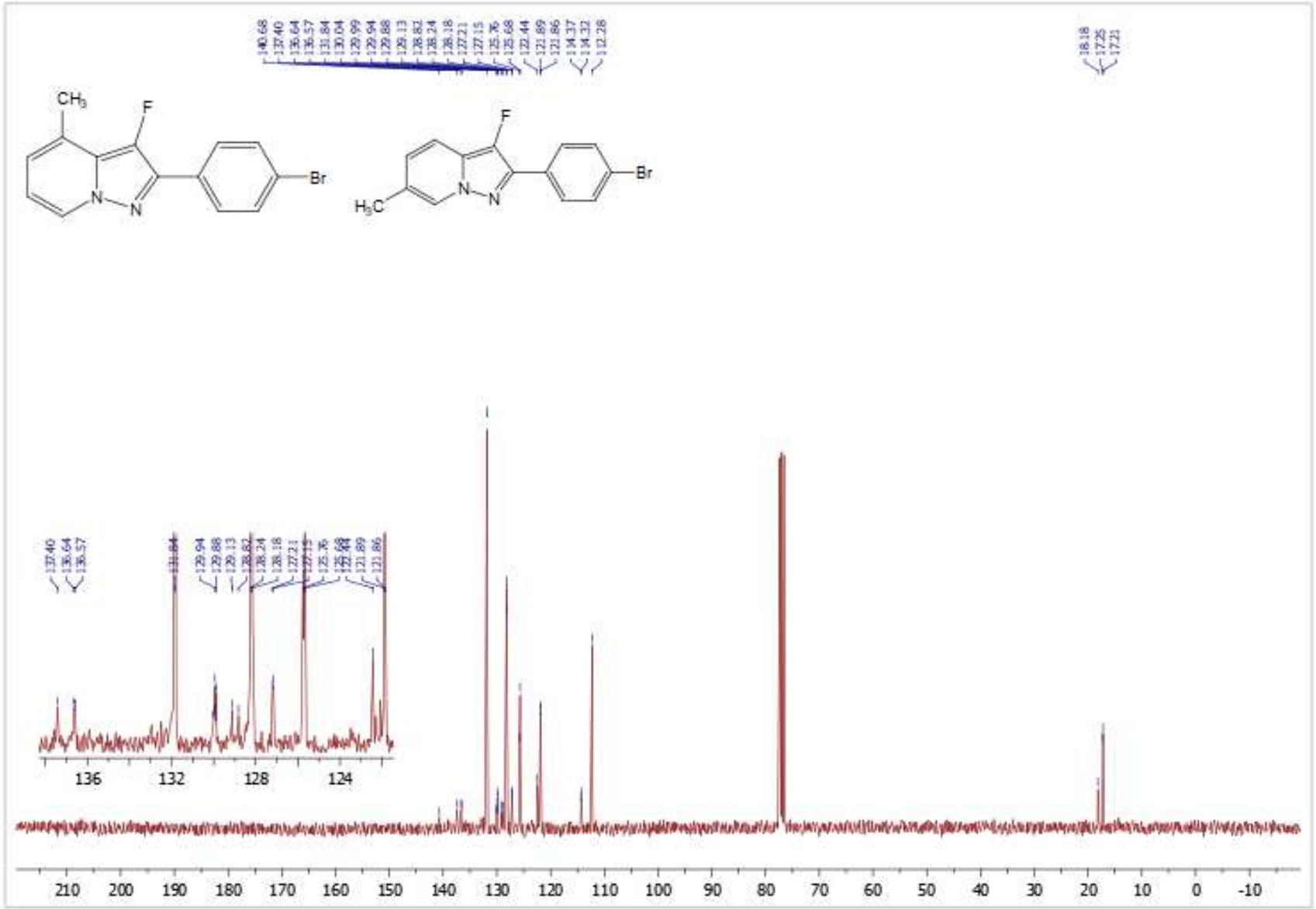


**2-(4-Bromophenyl)-4-methyl-3-fluoro-pyrazolo[1,5-a]pyridine 3o and 2-(4-bromophenyl)-6-methyl-3-fluoro-pyrazolo[1,5-a]pyridine 3o' (3:1 mixture)**

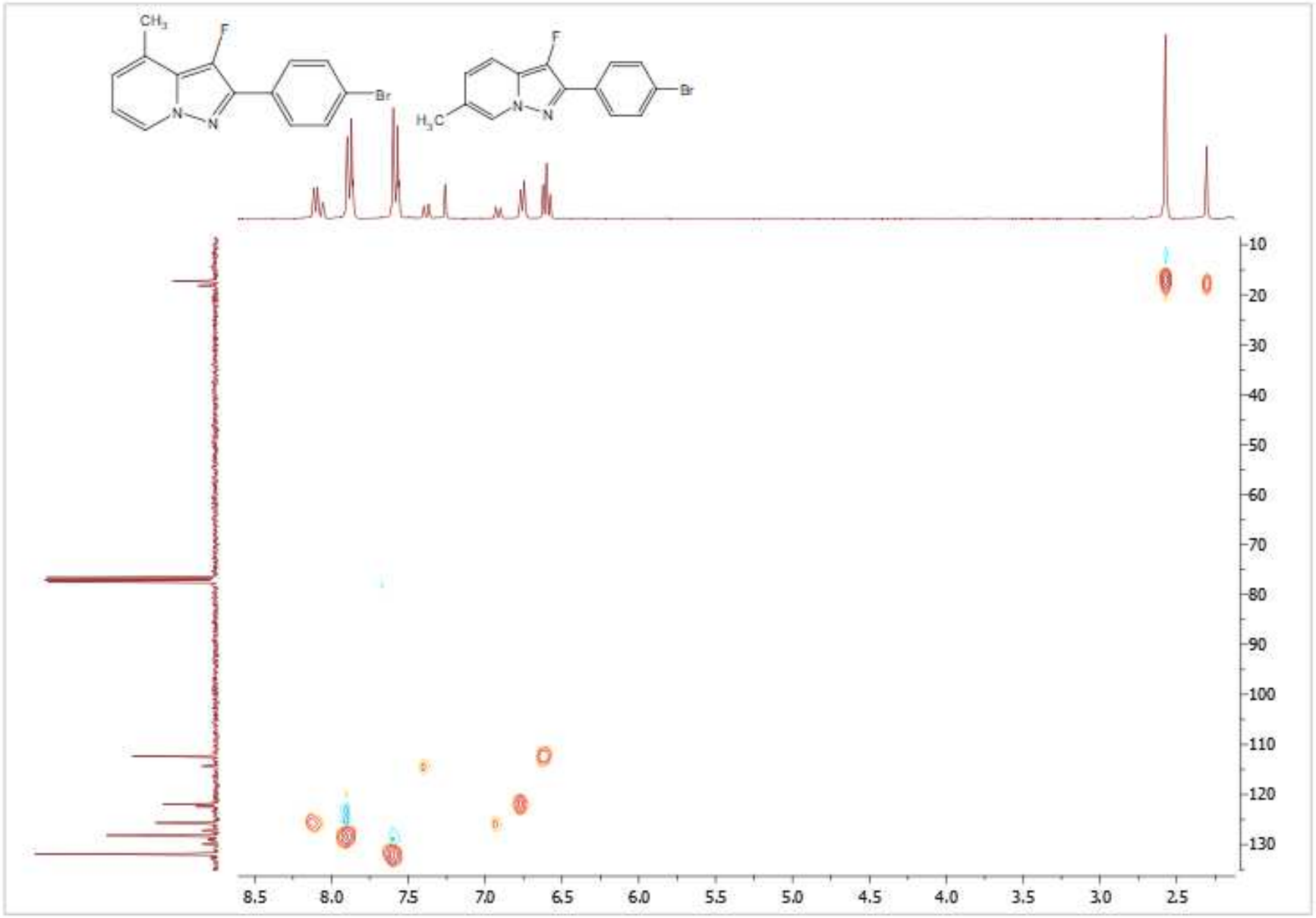
$^{1}$H NMR



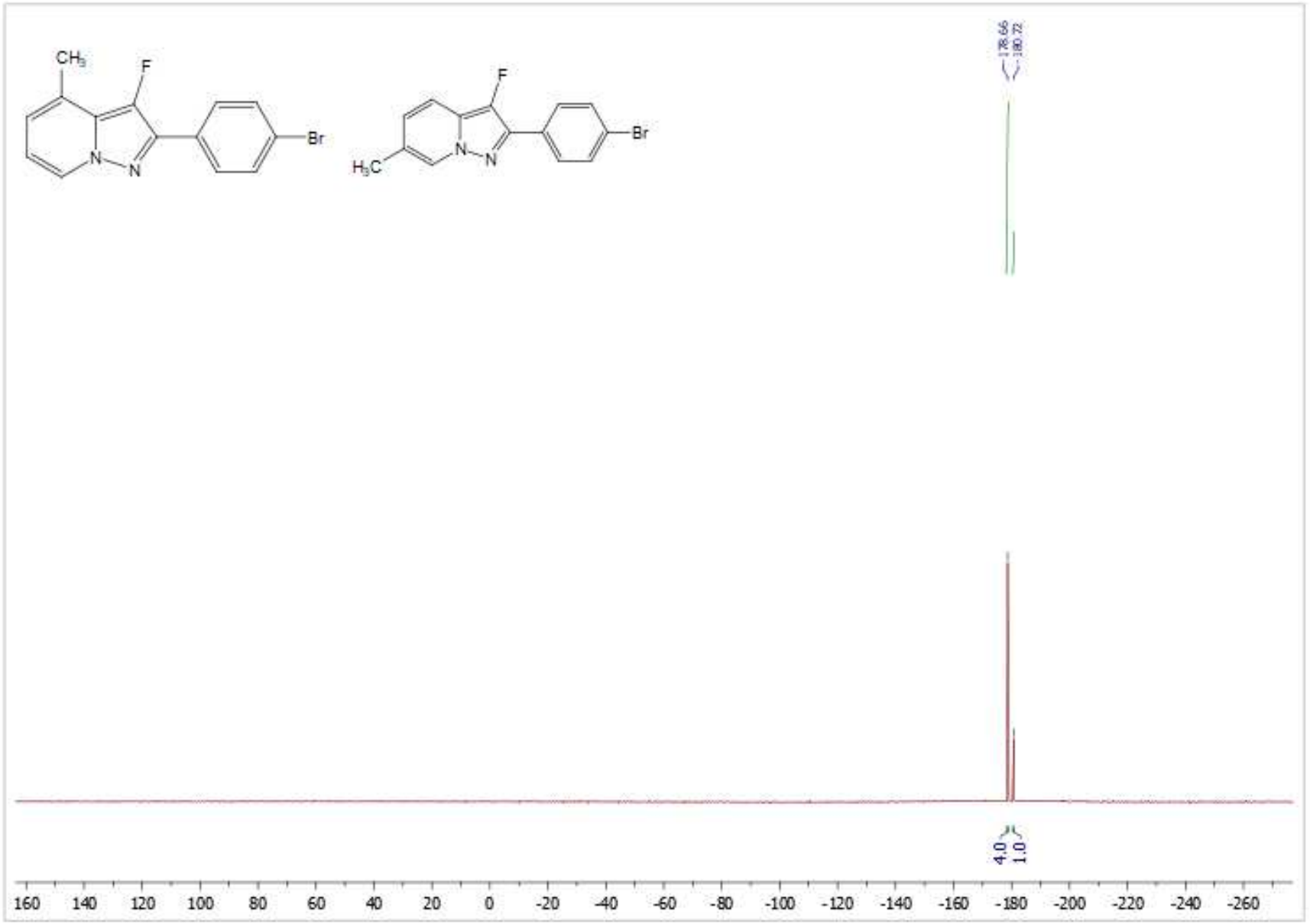
$^{13}$C NMR


CH3
F
Br
N
N
H3C
F
Br
N
N
140.68
137.40
136.64
136.57
131.84
130.04
129.99
129.94
129.88
129.13
128.82
128.24
128.18
127.21
127.15
125.76
125.68
122.44
121.89
121.86
114.37
114.32
112.28
18.18
17.25
17.21
136
132
128
124
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

$^{1}H$-$^{13}C$ HSQC

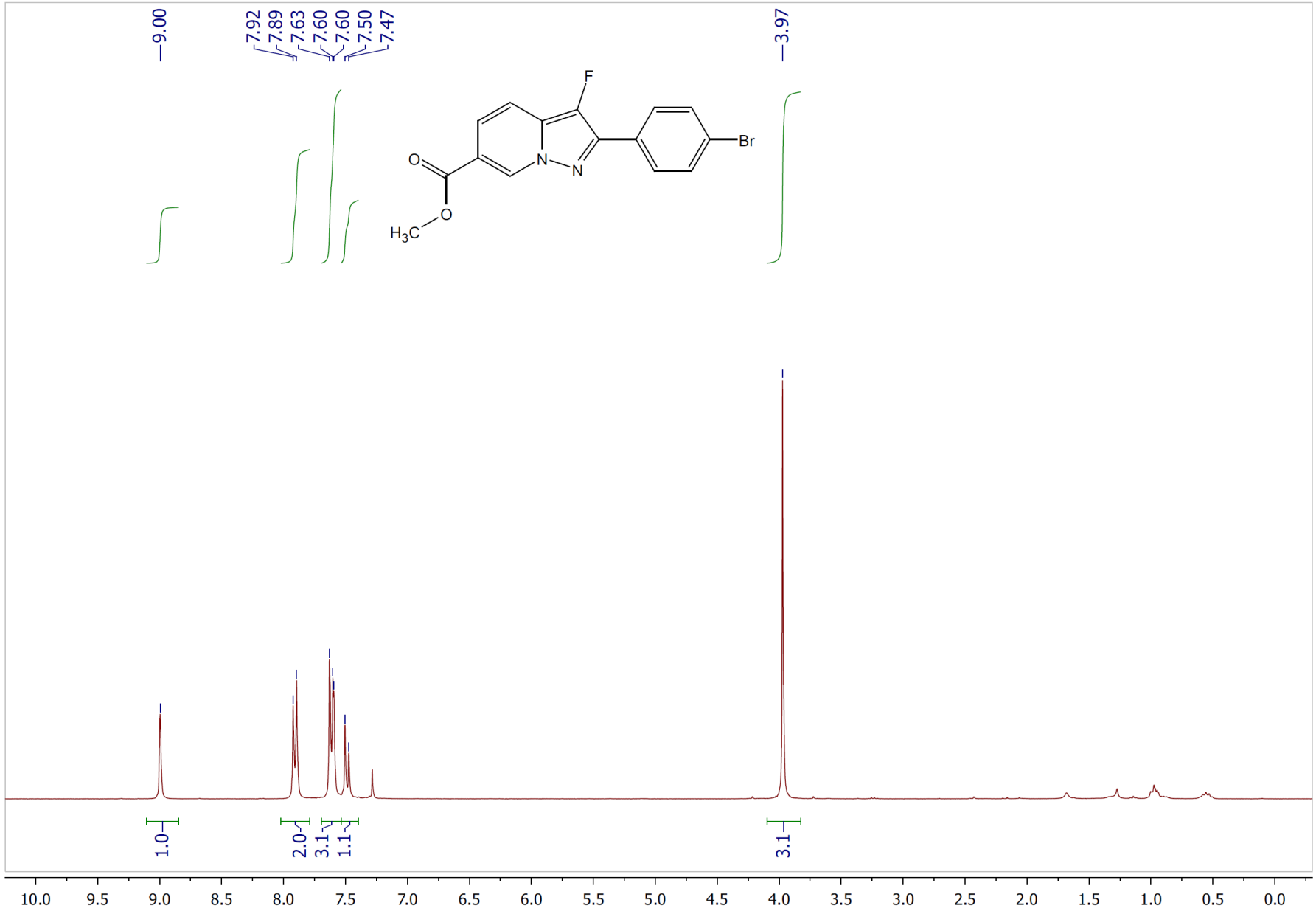

CH3
F
Br
N
N
H3C
F
Br
N
N
10
20
30
40
50
60
70
80
90
100
110
120
130
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5

$^{19}$F NMR

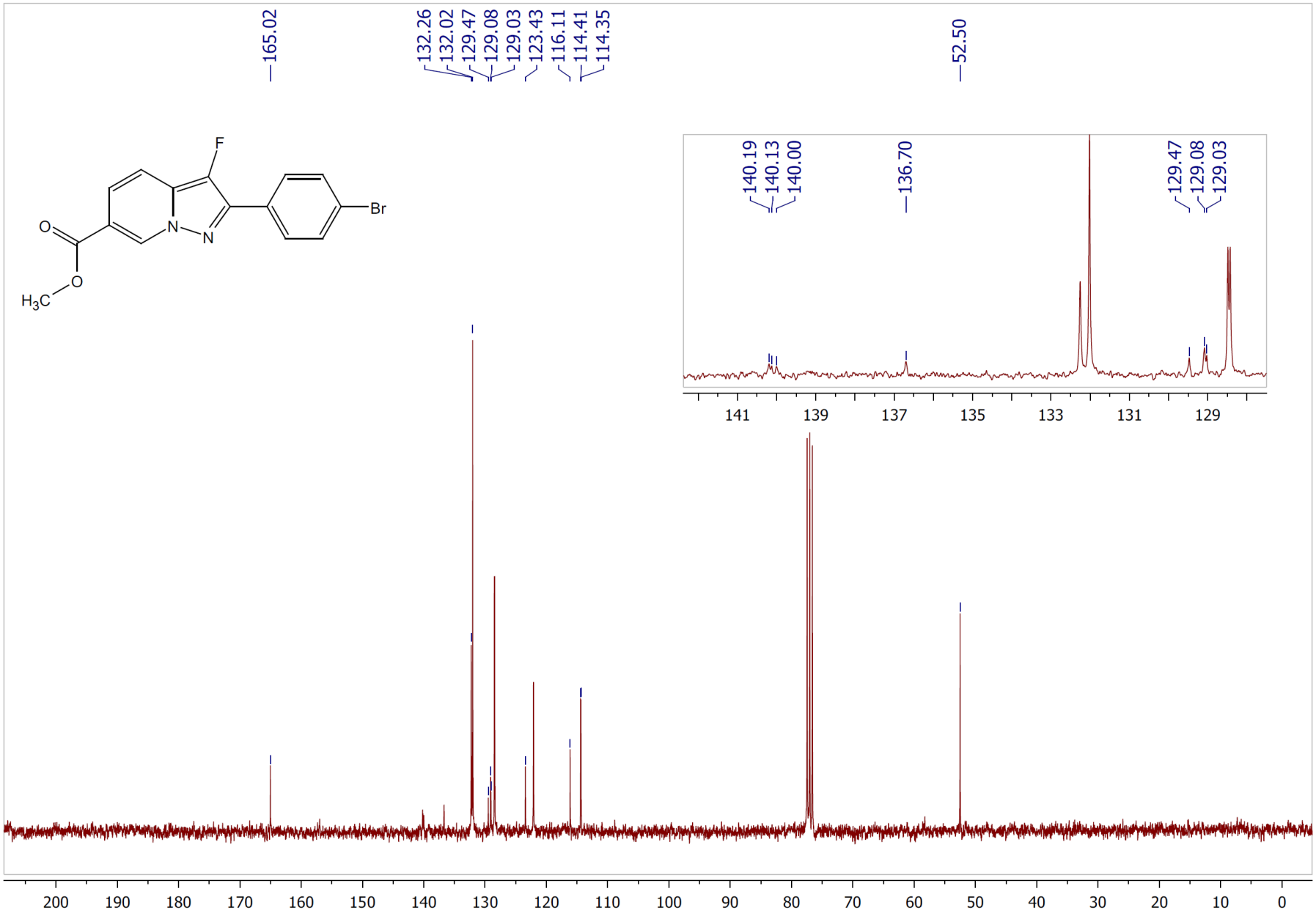

CH3
F
Br
N
N
F
Br
H3C
N
N
-178.66
-180.72
4.0
1.0
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260

**Methyl 2-(4-bromophenyl)-3-fluoropyrazolo[1,5-a]pyridine-6-carboxylate 3p**

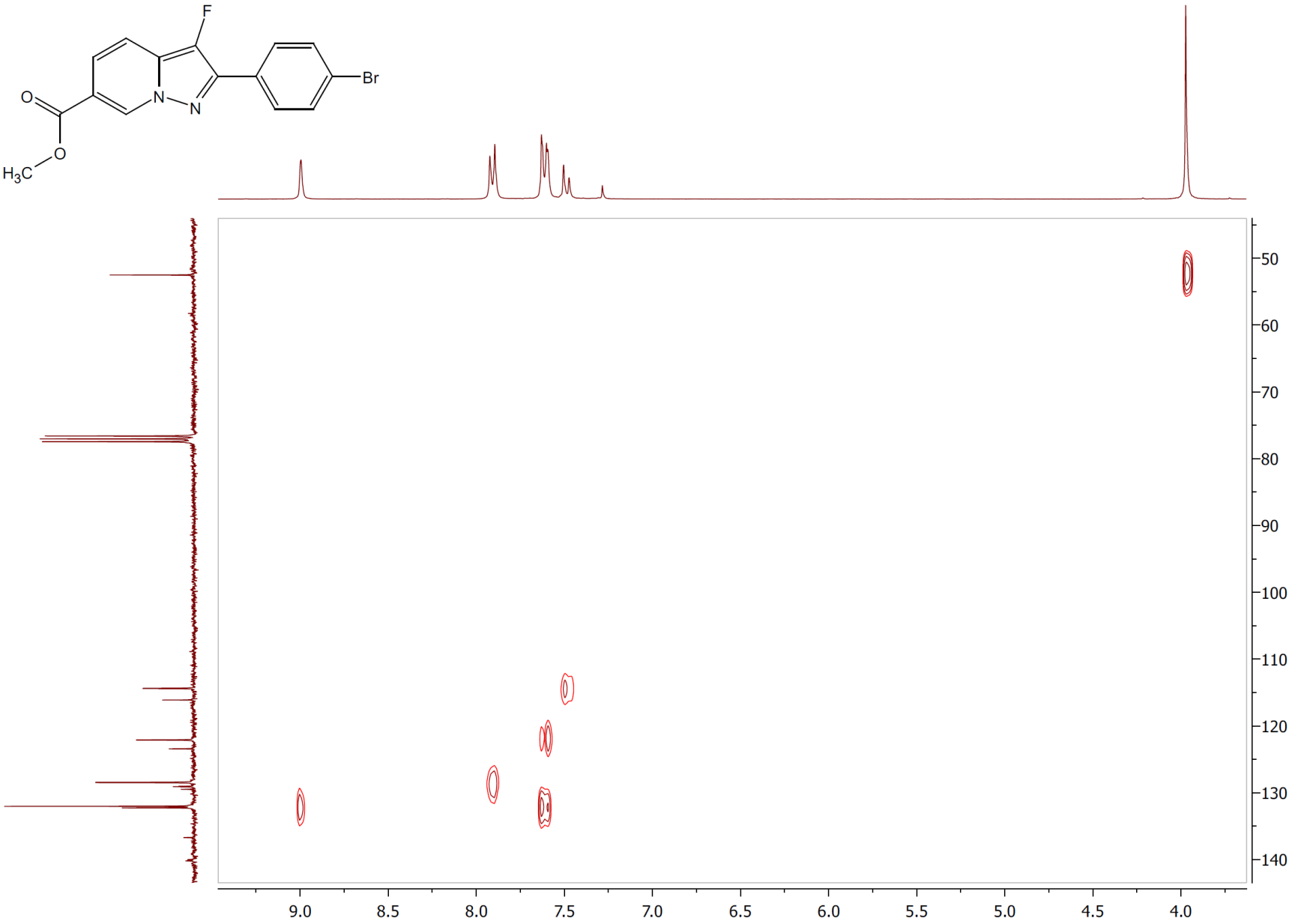
$^{1}$H NMR



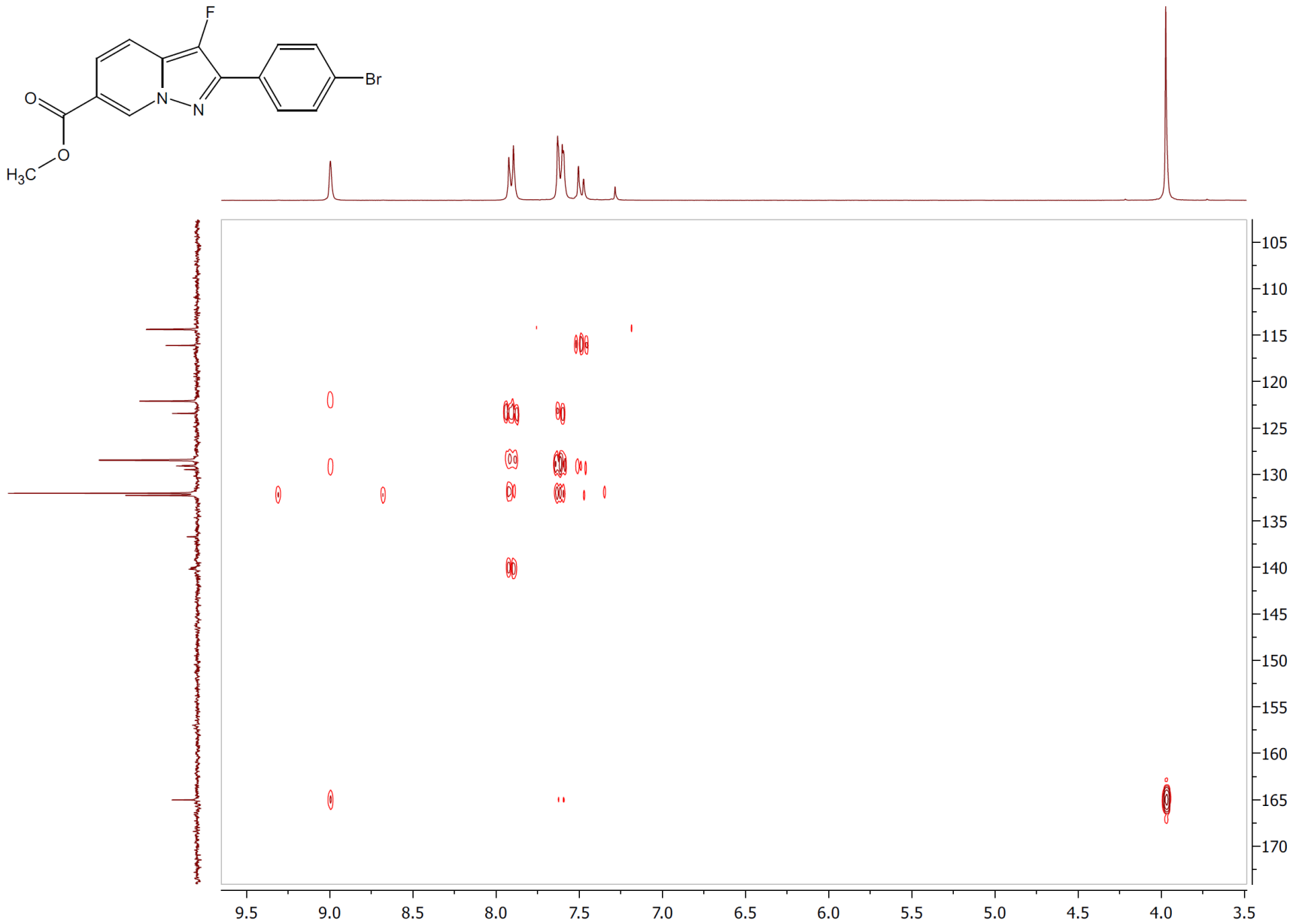
$^{13}$C NMR


165.02
132.26
132.02
129.47
129.08
129.03
123.43
116.11
114.41
114.35
52.50
F
Br
O
O
N
N
H3C
140.19
140.13
140.00
136.70
129.47
129.08
129.03
141
139
137
135
133
131
129
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

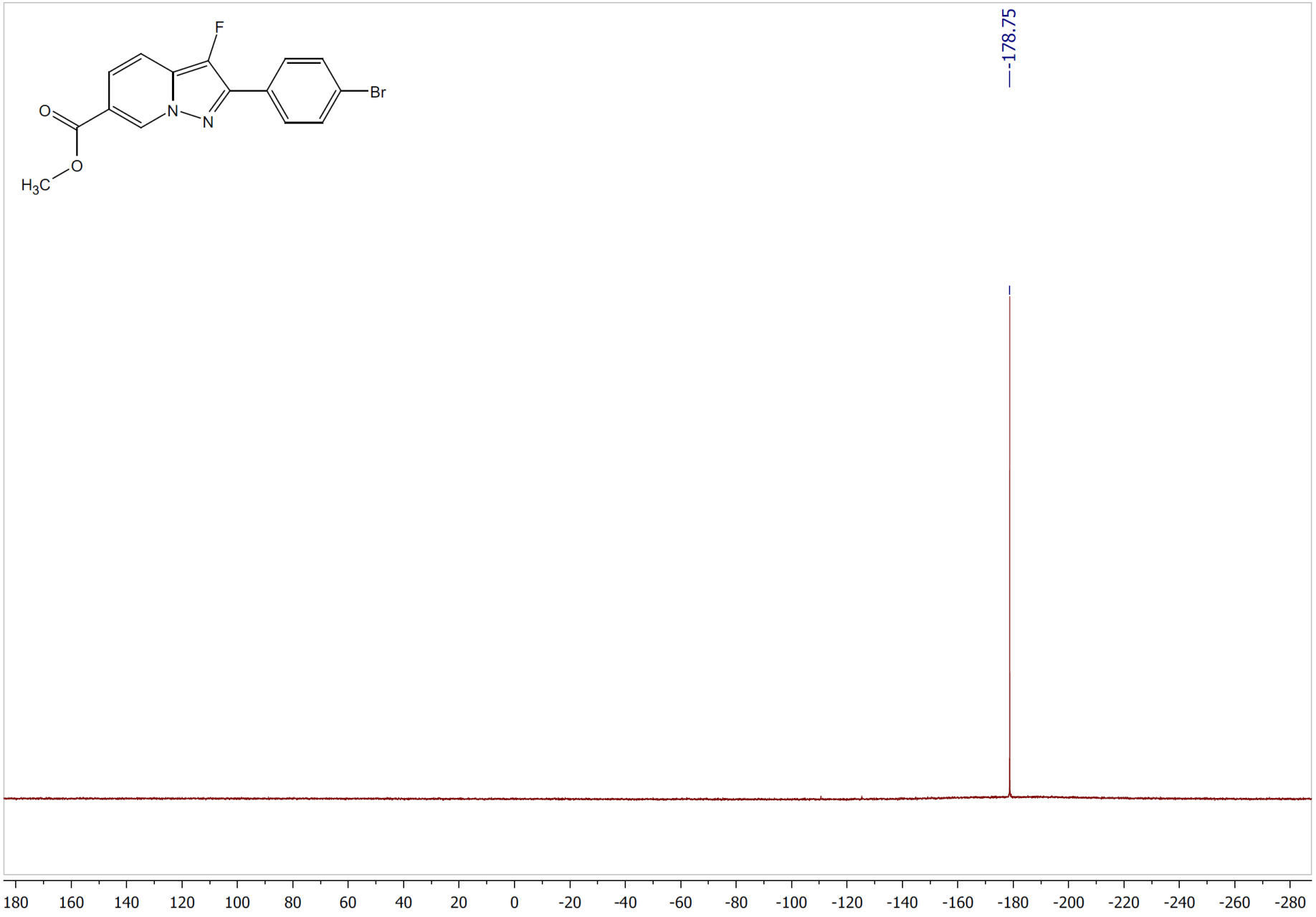
$^{1}H$-$^{13}C$ HSQC


F
Br
O
N
N
O
$H_3C$
50
60
70
80
90
100
110
120
130
140
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

$^{1}H$-$^{13}C$ HMBC

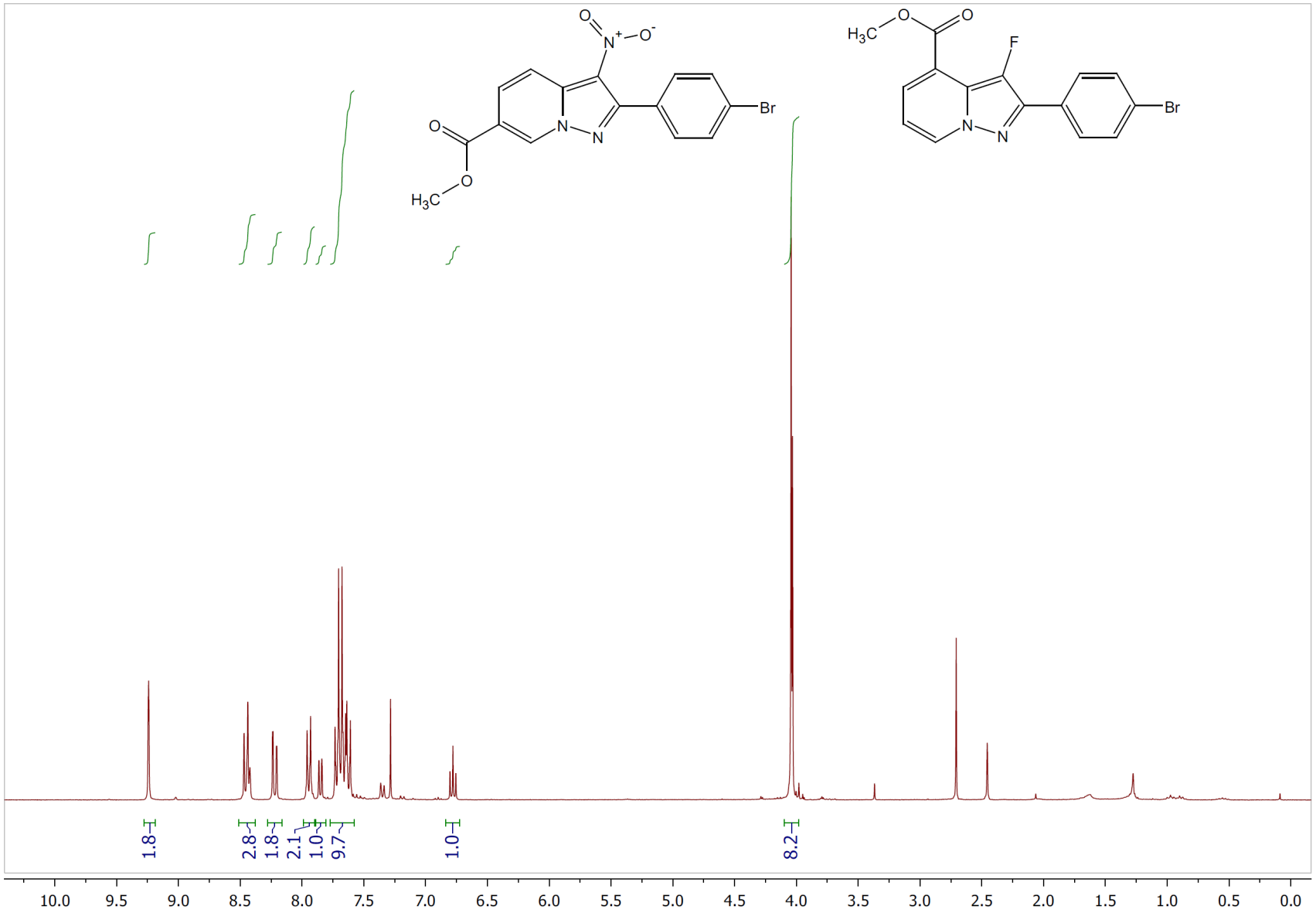

F
Br
O
N
N
O
H3C
105
110
115
120
125
130
135
140
145
150
155
160
165
170
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5

$^{19}$F NMR

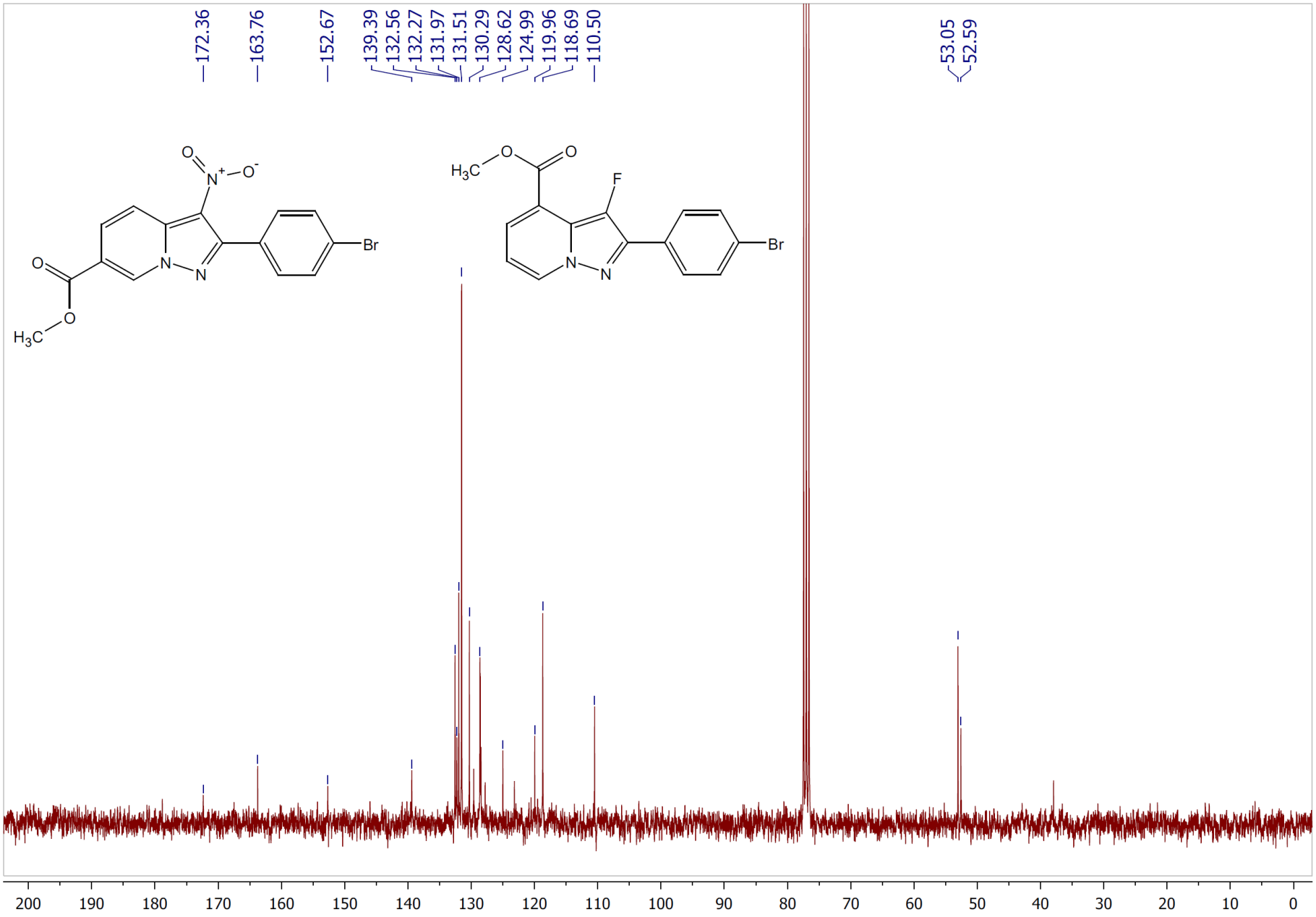

F
Br
O
N
N
O
H3C
-178.75
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280

**Methyl 2-(4-bromophenyl)-3-fluoropyrazolo[1,5-a]pyridine-4-carboxylate 3p' and methyl 2-(4-bromophenyl)-3-nitropyrazolo[1,5-a]pyridine-6-carboxylate 5g (mixture 3p' : 5g = 1:1.8)**

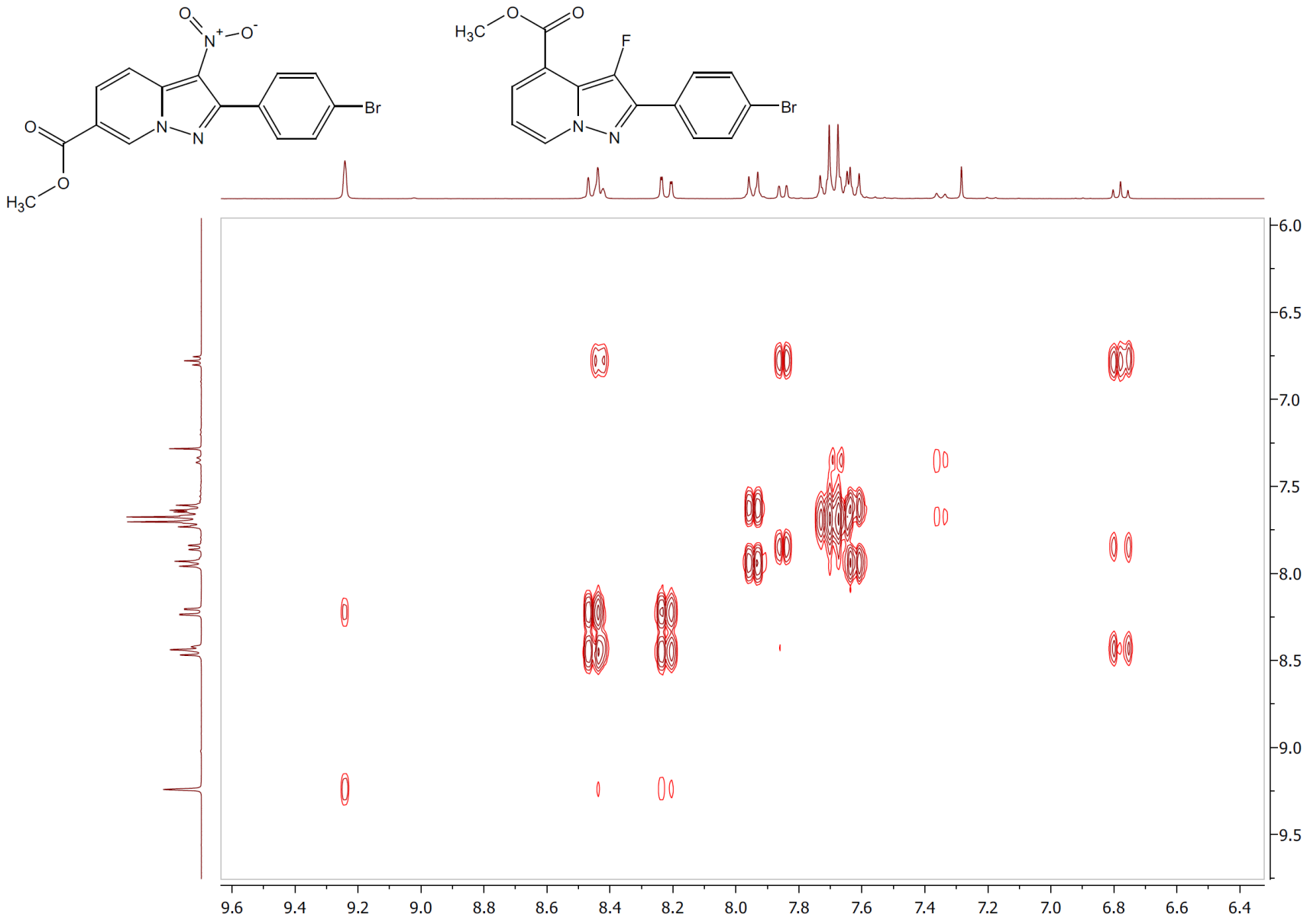
$^1$H NMR



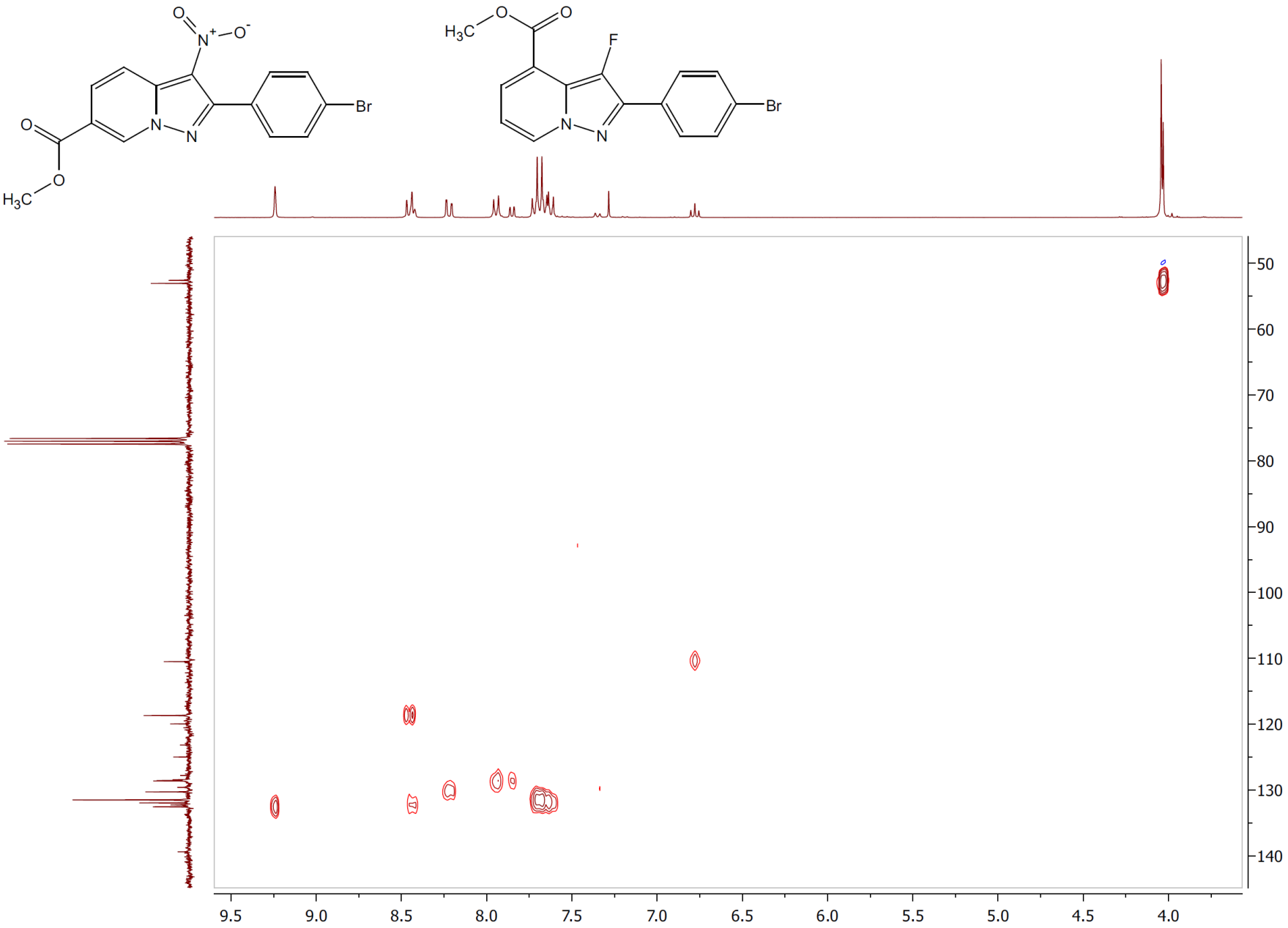
$^{13}$C NMR


172.36
163.76
152.67
139.39
132.56
132.27
131.97
131.51
130.29
128.62
124.99
119.96
118.69
110.50
53.05
52.59
O
N+
O-
Br
N
N
O
O
H3C
O
O
H3C
F
Br
N
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

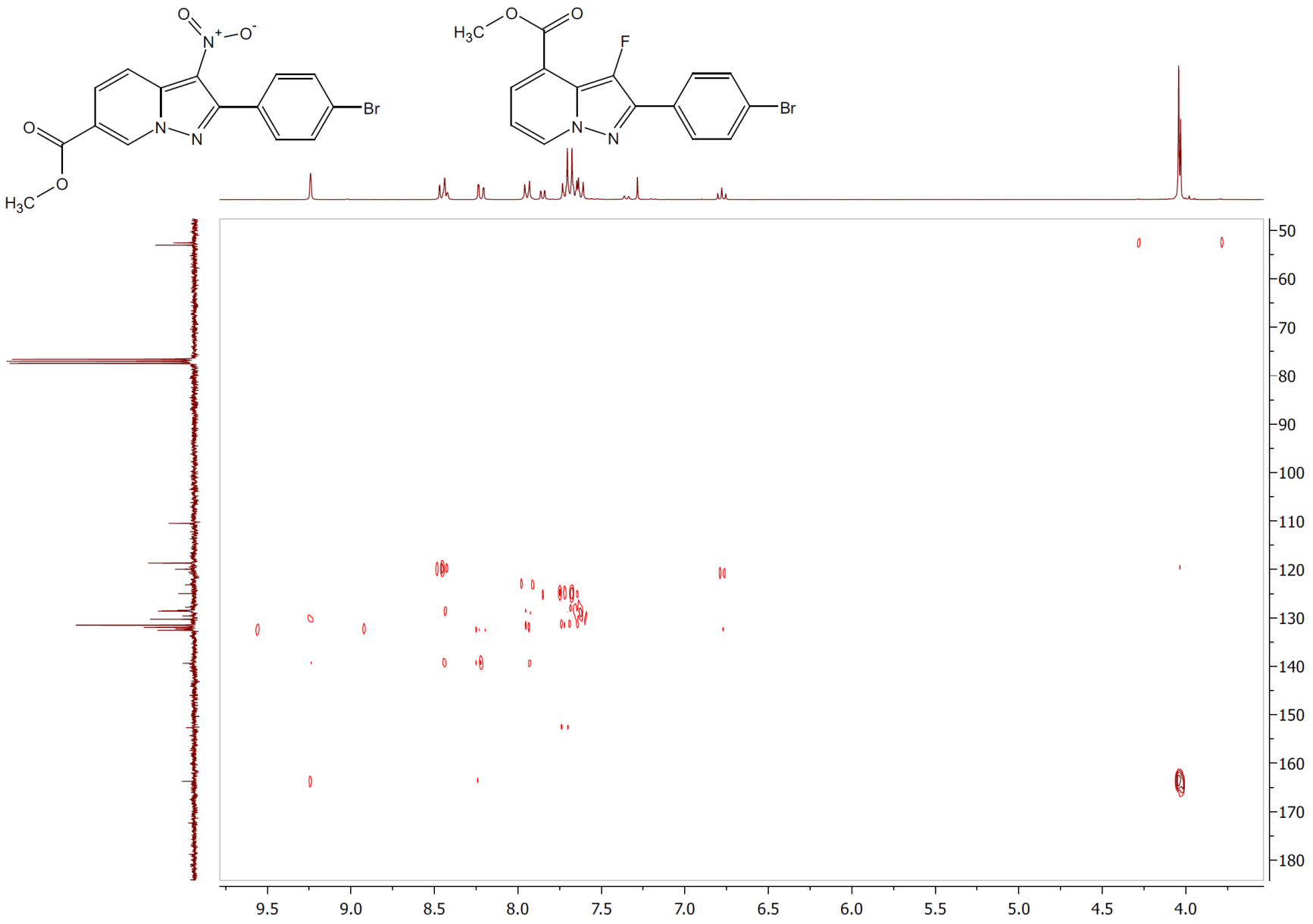
$^{1}$H-$^{1}$H COSY


O
N+
O-
Br
N
N
O
O
H3C
H3C
O
O
F
Br
N
N
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4

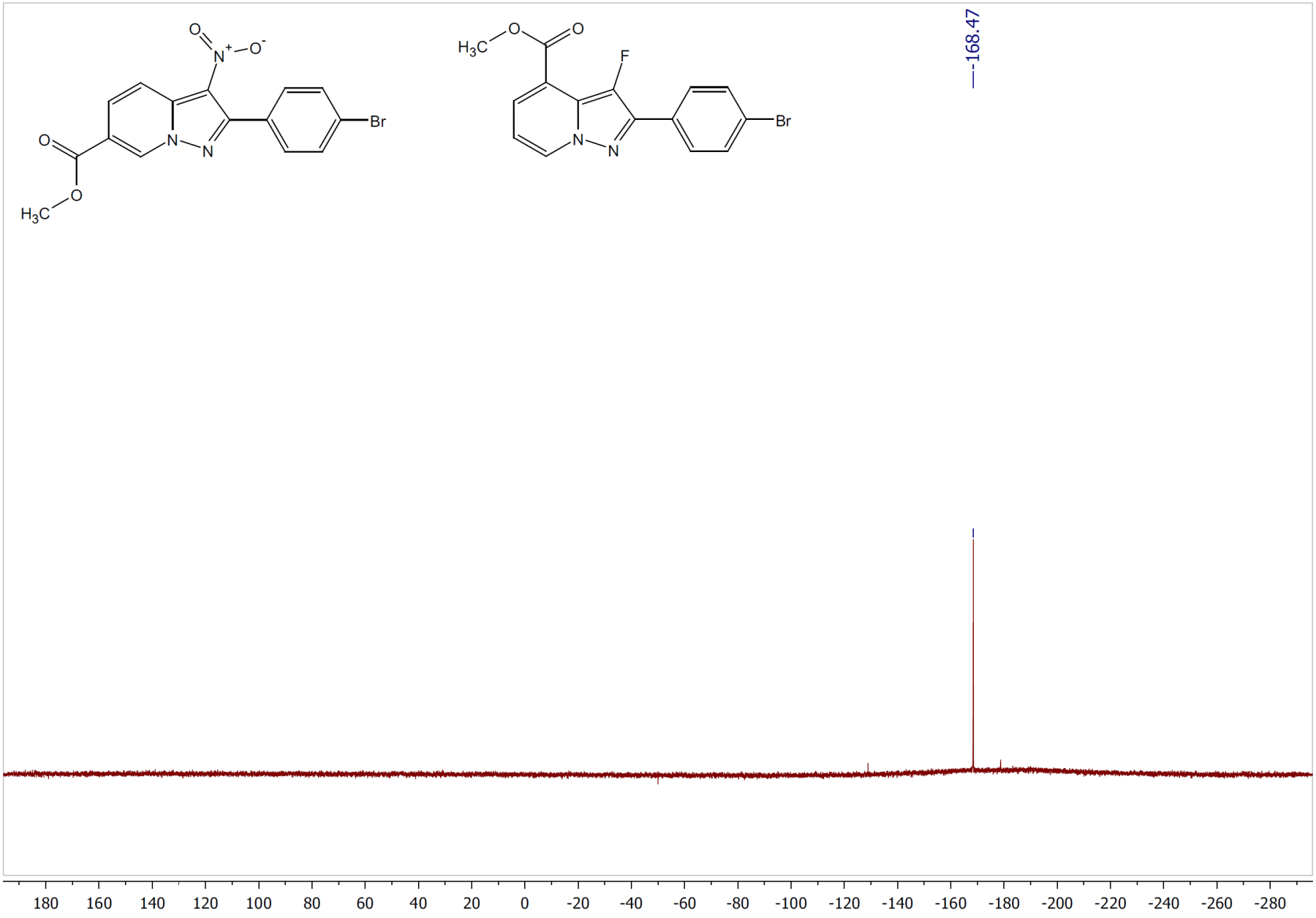
$^{1}$H-$^{13}$C HSQC


O
N+
O-
Br
N
N
O
O
H3C
O
O
H3C
F
Br
N
N
50
60
70
80
90
100
110
120
130
140
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

$^{1}H$-$^{13}C$ HMBC

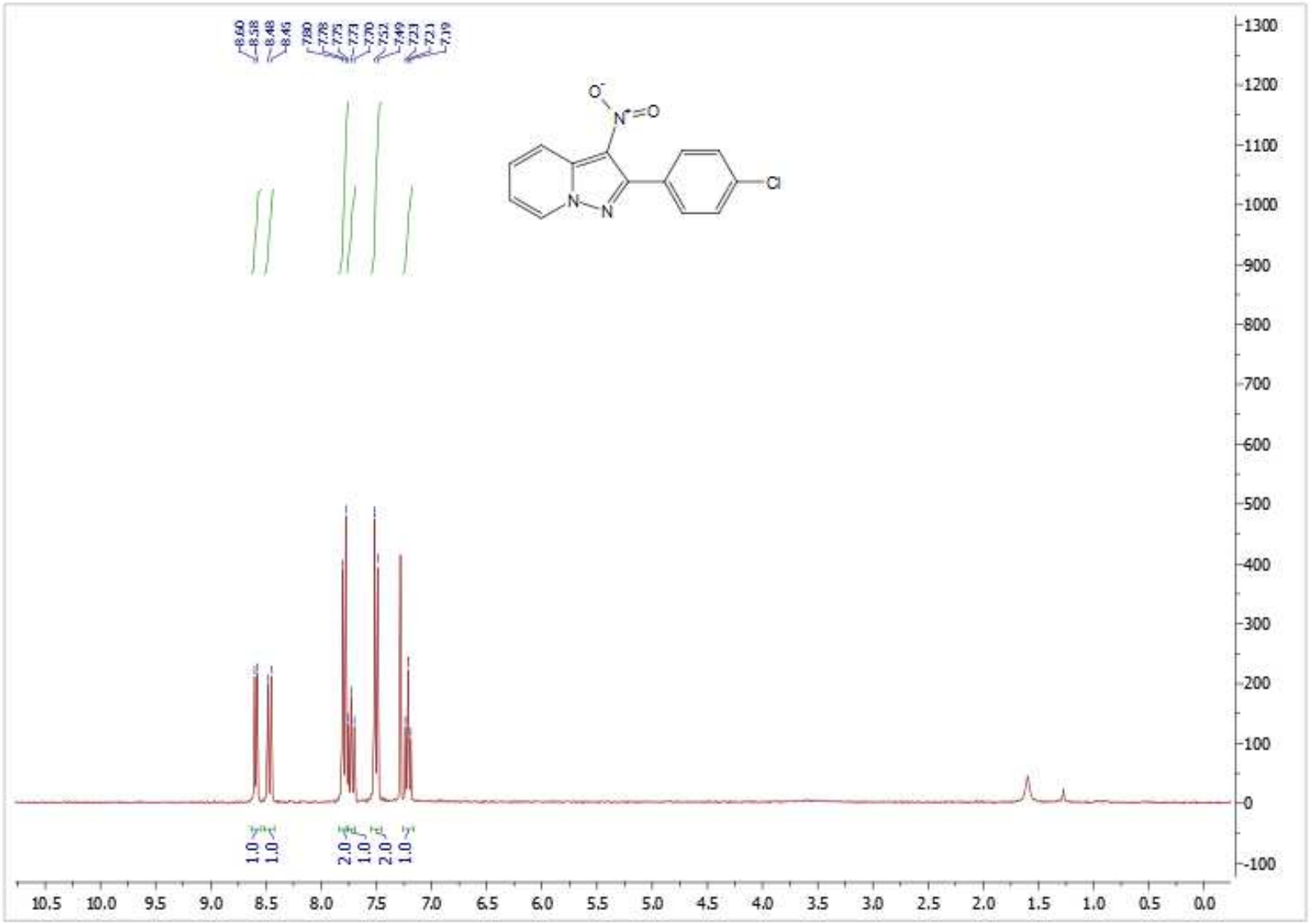

O
N+
O-
Br
N
N
O
O
H3C
H3C
O
O
F
Br
N
N
50
60
70
80
90
100
110
120
130
140
150
160
170
180
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

$^{19}$F NMR


O
N+
O-
Br
N
N
O
O
H3C
H3C
O
O
F
Br
N
N
-168.47
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280

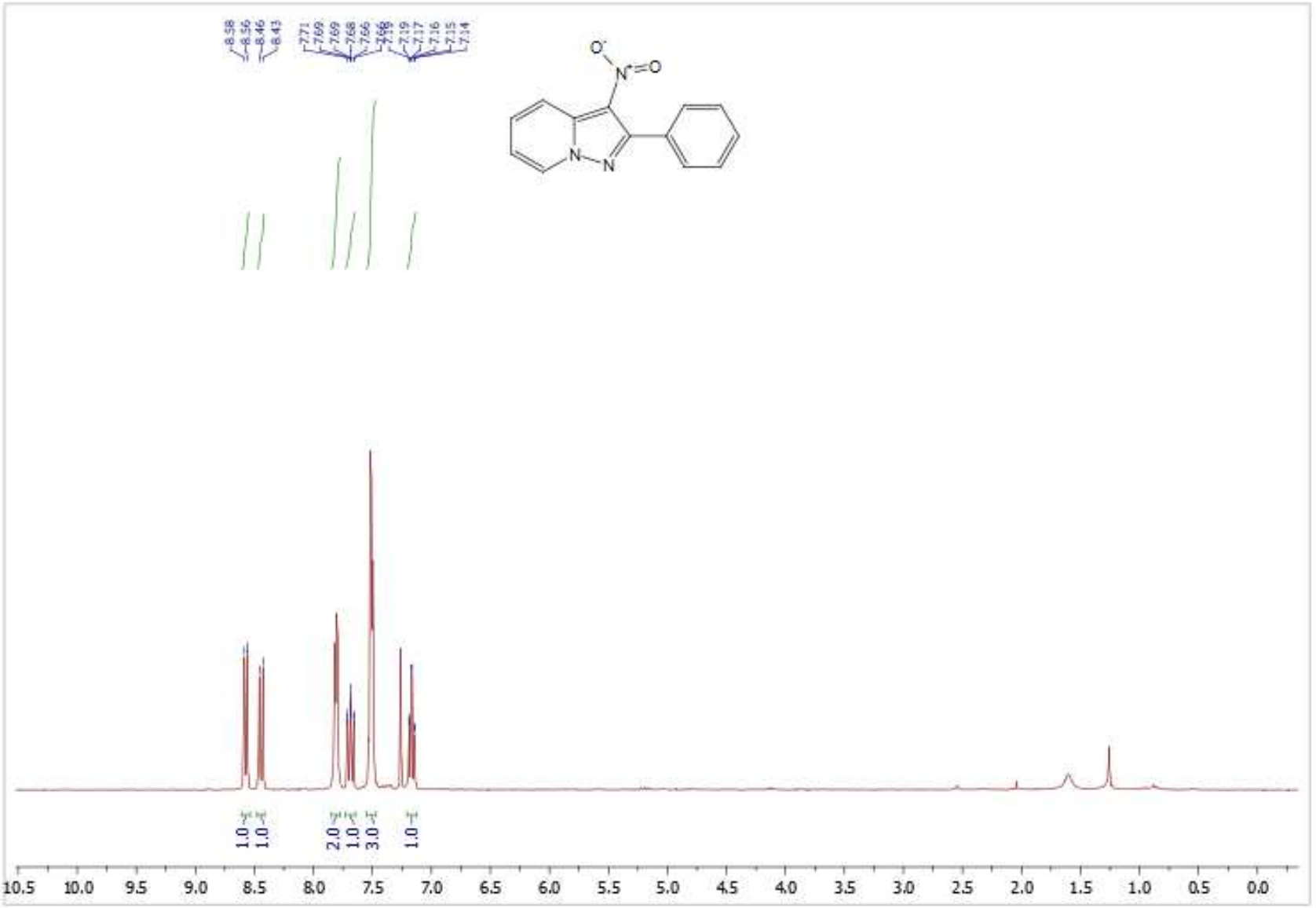
**2-(4-Chlorophenyl)-3-nitro-pyrazolo[1,5-a]pyridine 5a**

$^{1}$H NMR



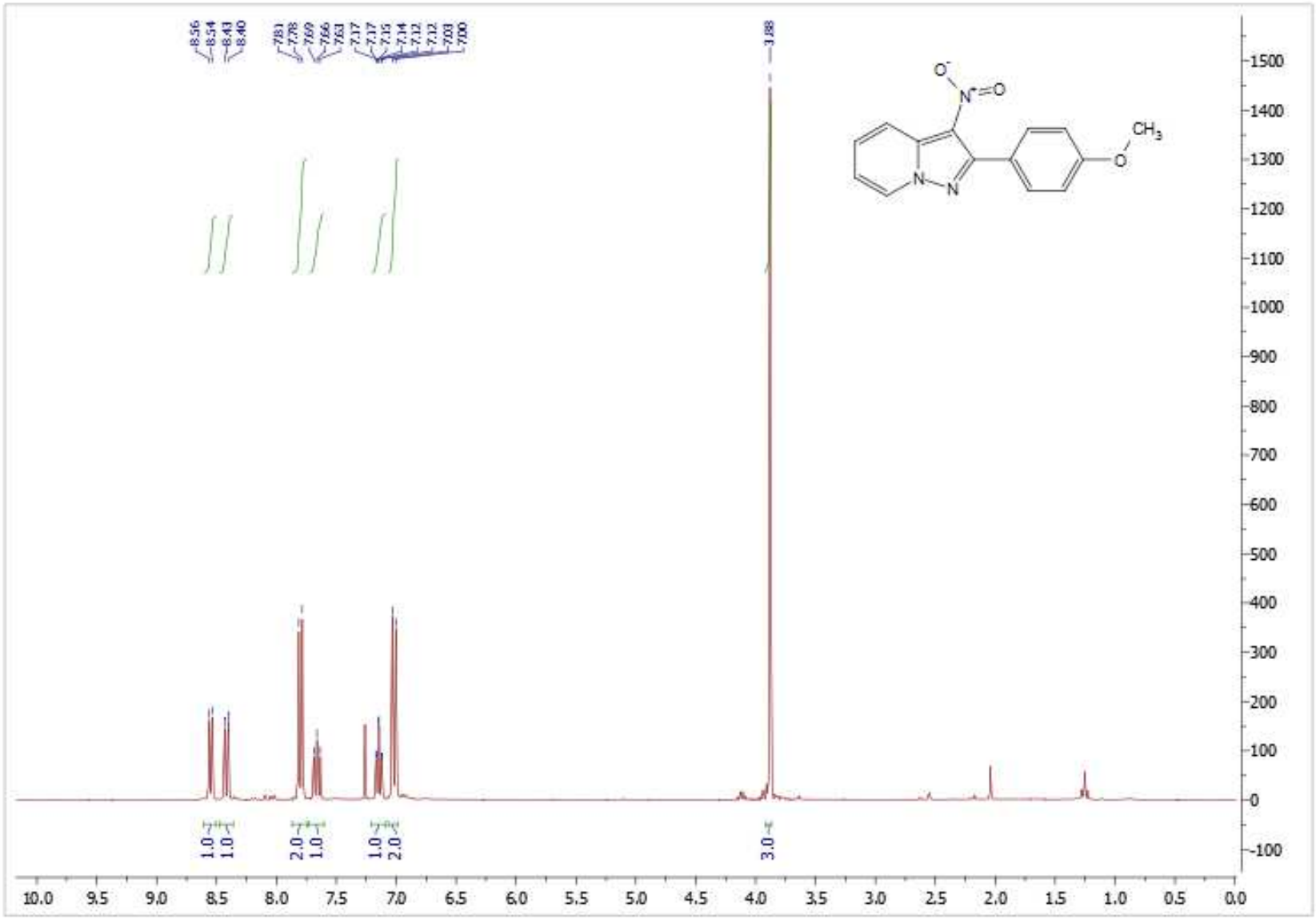
**2-Phenyl-3-nitro-pyrazolo[1,5-a]pyridine 5b**

$^{1}$H NMR



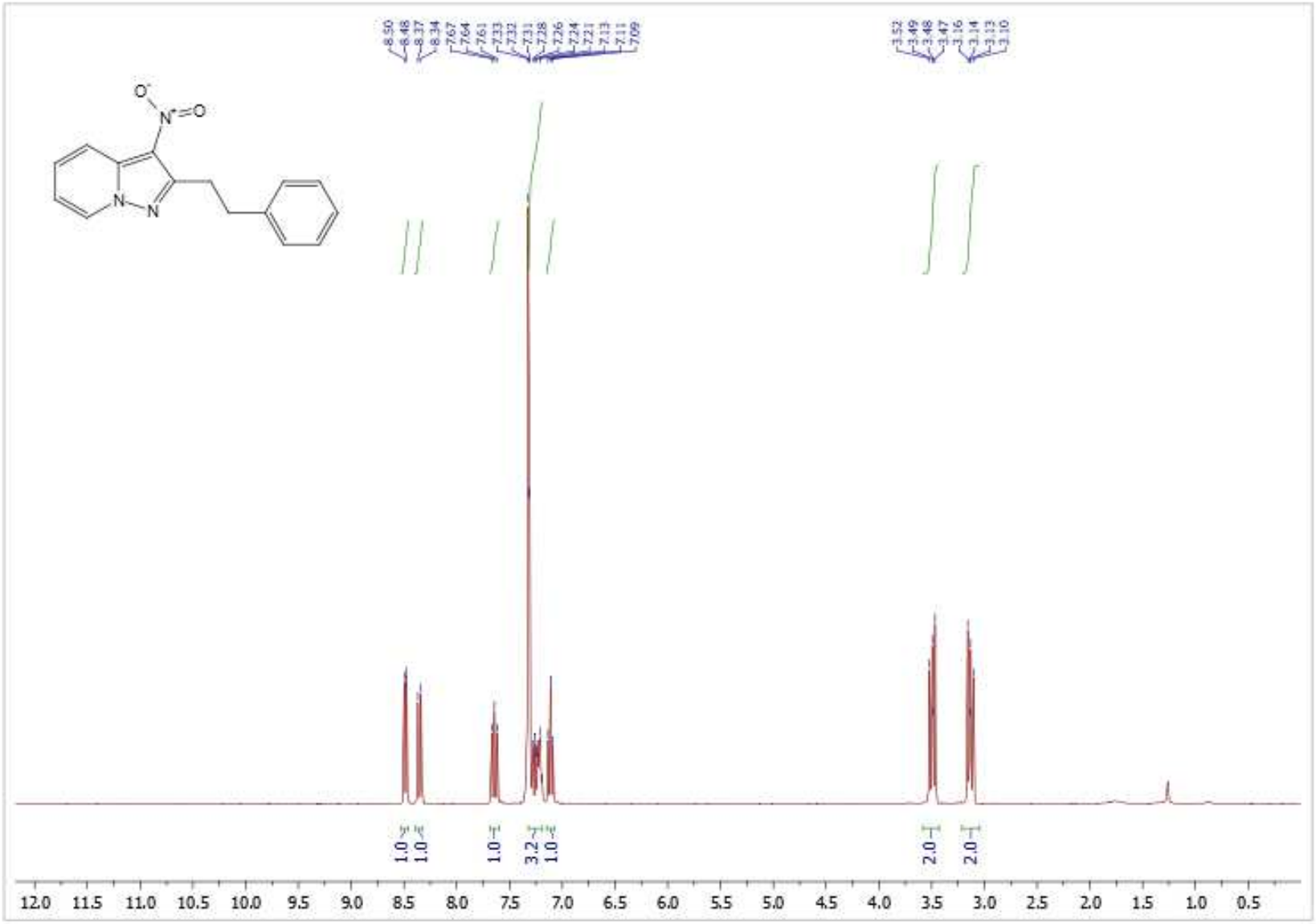
**2-(4-Methoxyphenyl)-3-nitro-pyrazolo[1,5-a]pyridine 5c**

$^{1}$H NMR

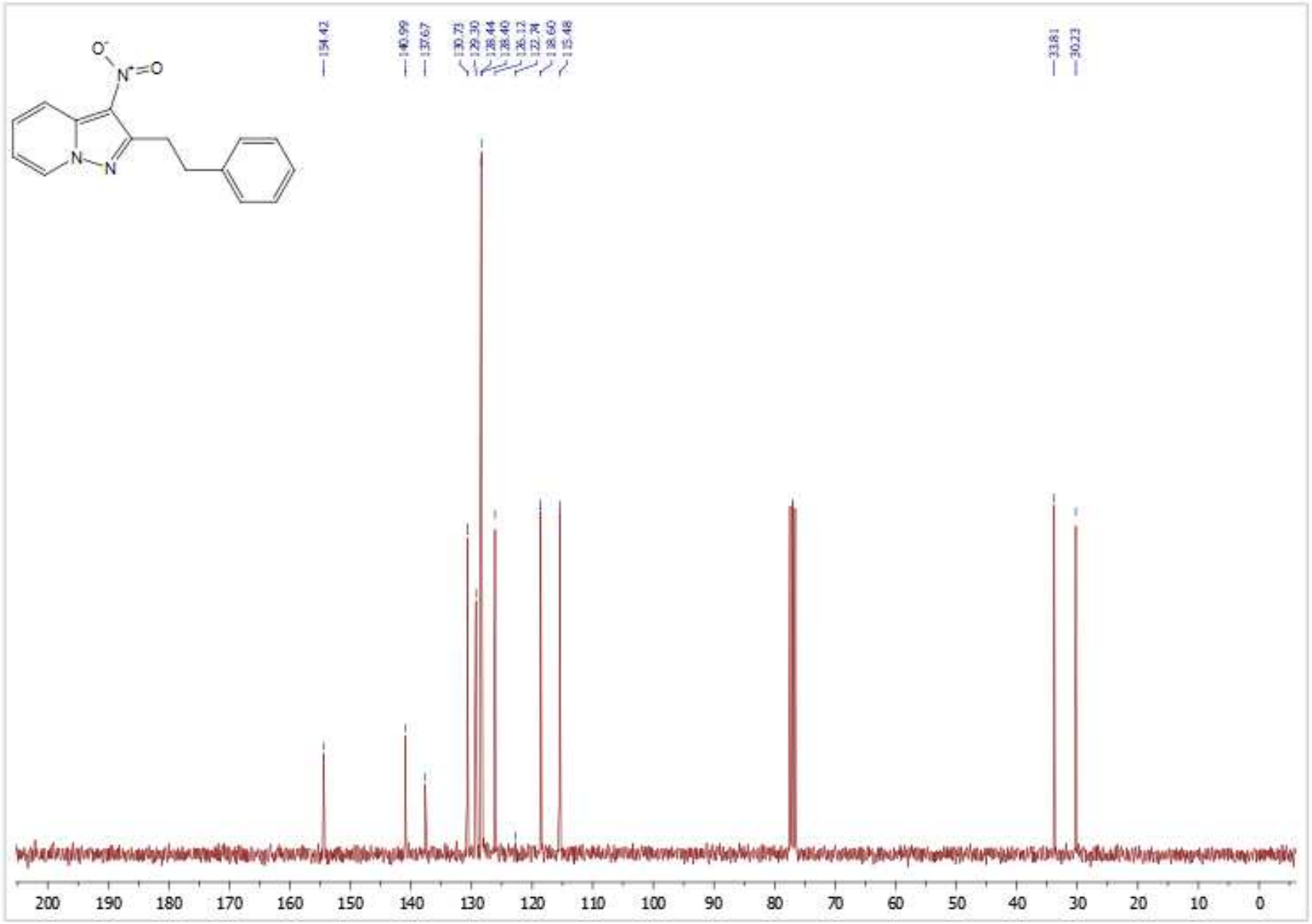


**2-(2-Phenylethyl)-3-nitro-pyrazolo[1,5-a]pyridine 5d**

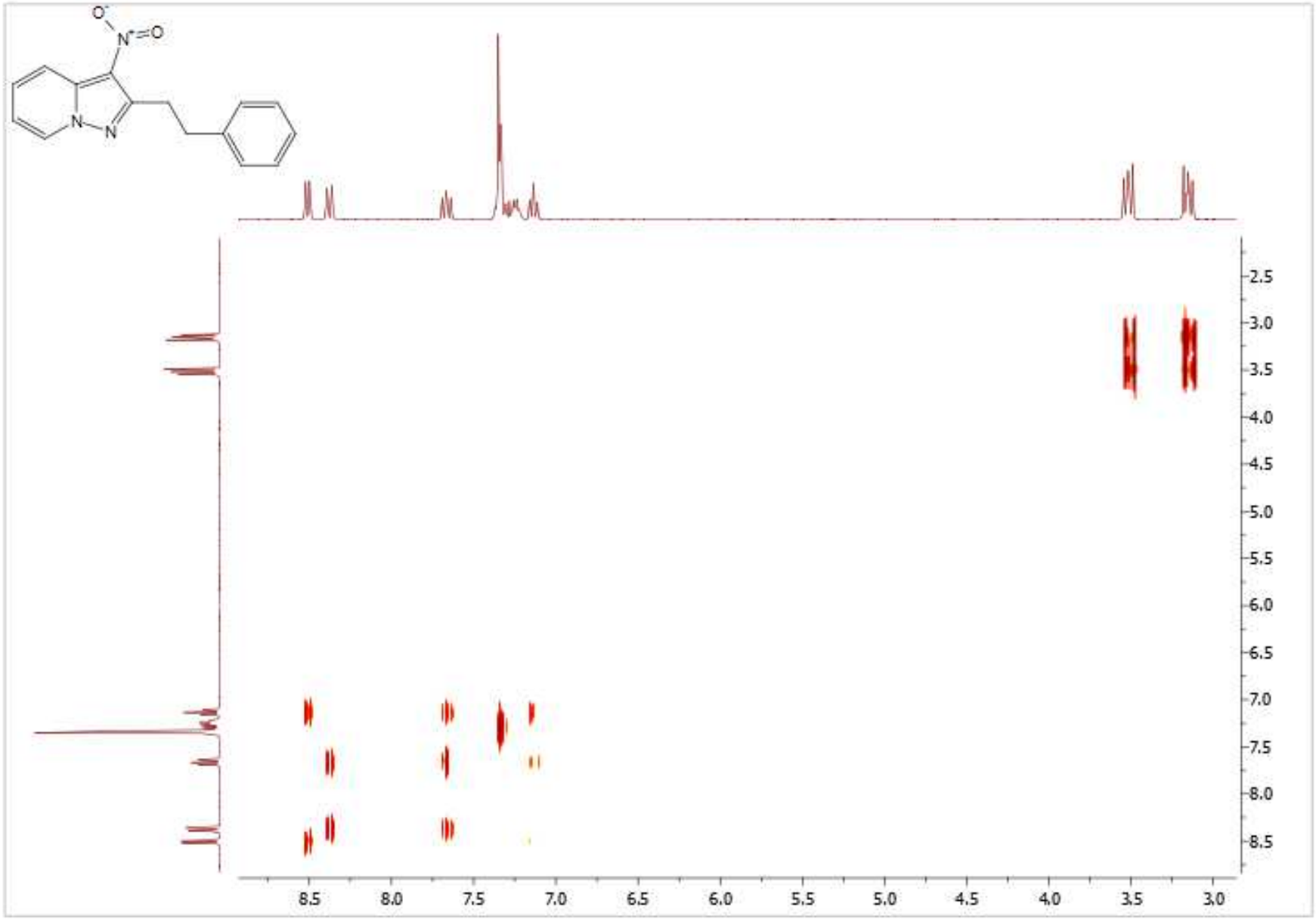
$^{1}$H NMR



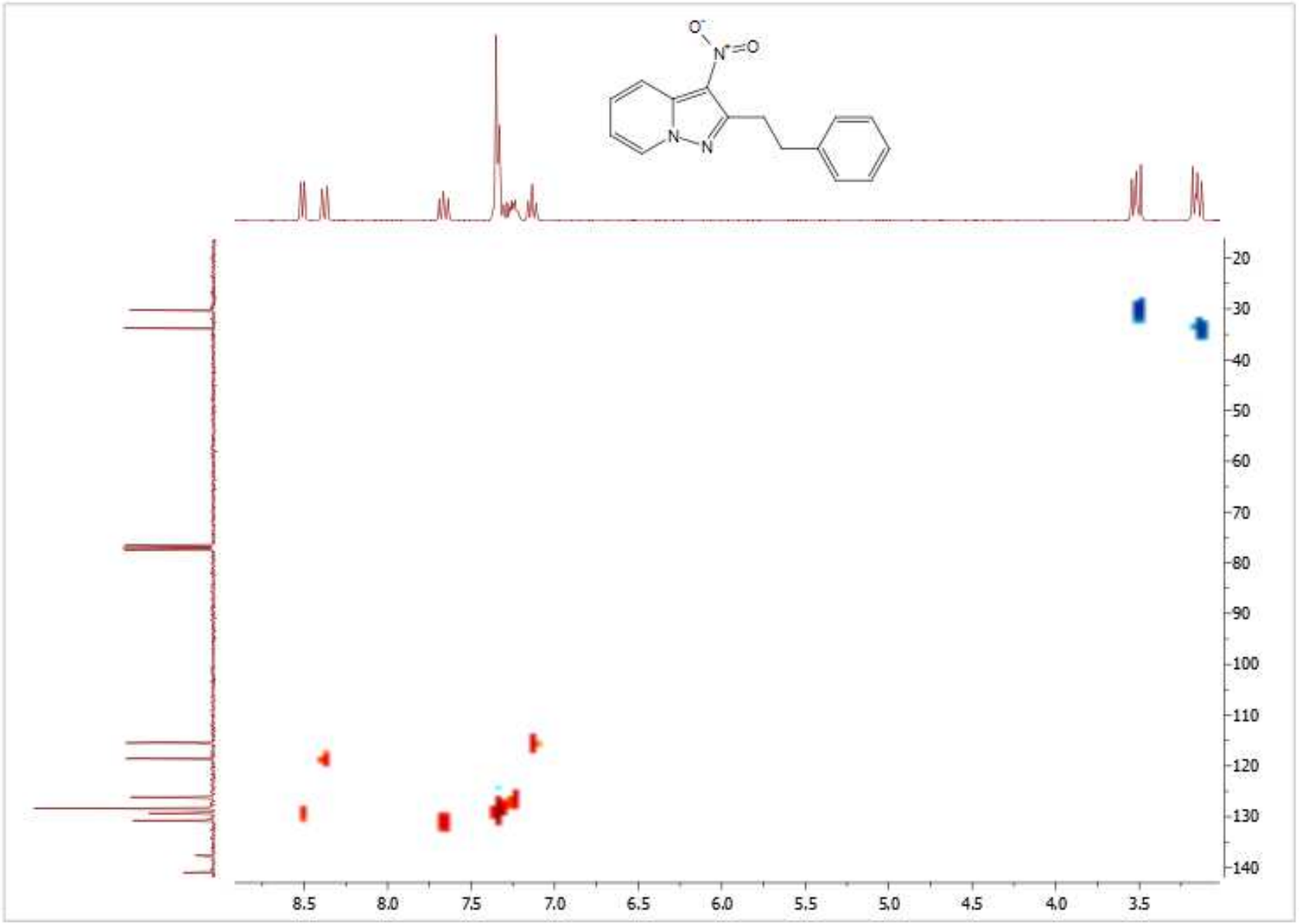
$^{13}$C NMR


154.42
140.99
137.67
130.73
129.30
128.44
128.40
126.13
122.24
118.60
115.48
33.81
30.23
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

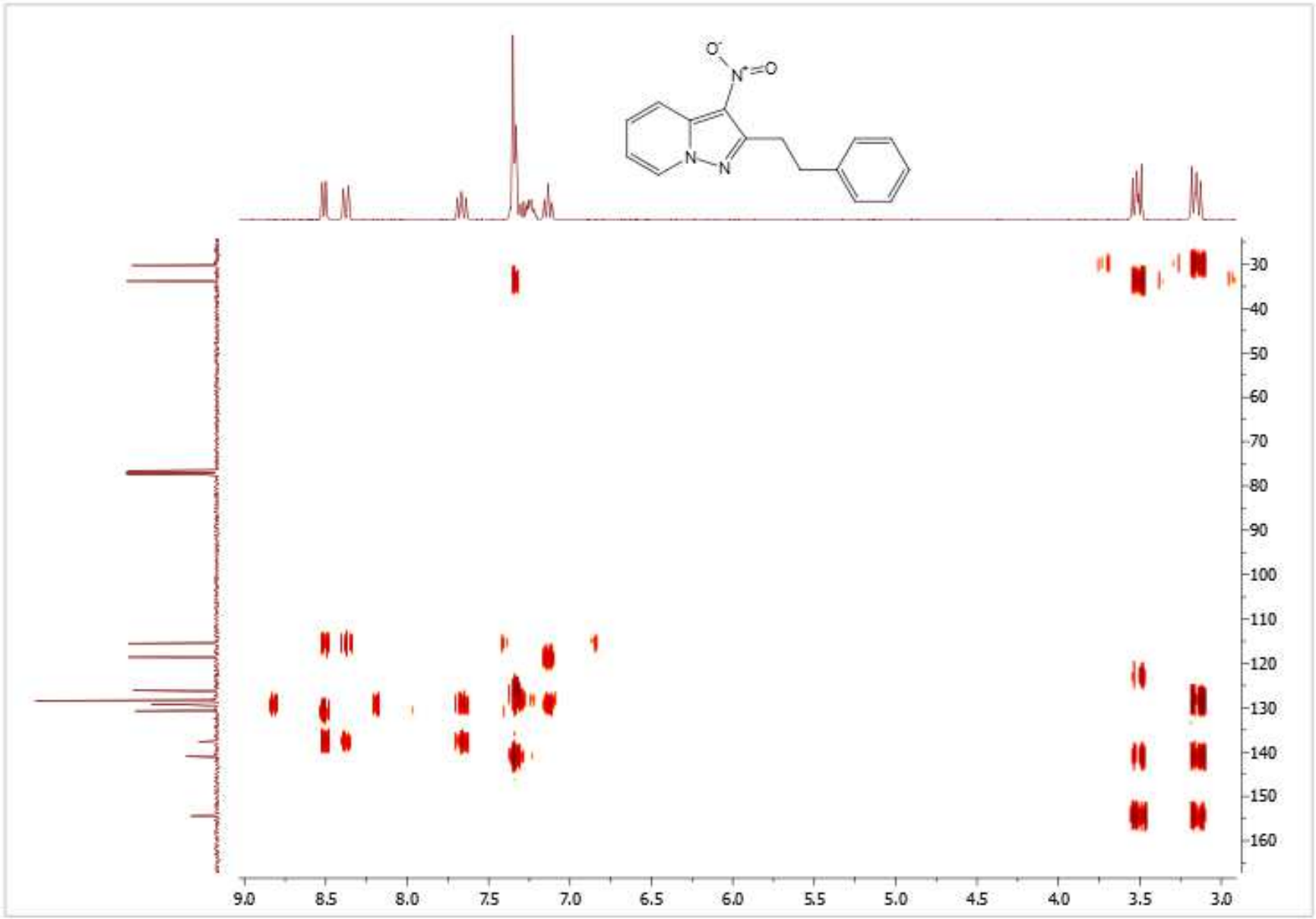
$^{1}$H-$^{1}$H COSY


O
N
O
N
N
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0

$^{1}H$-$^{13}C$ HSQC

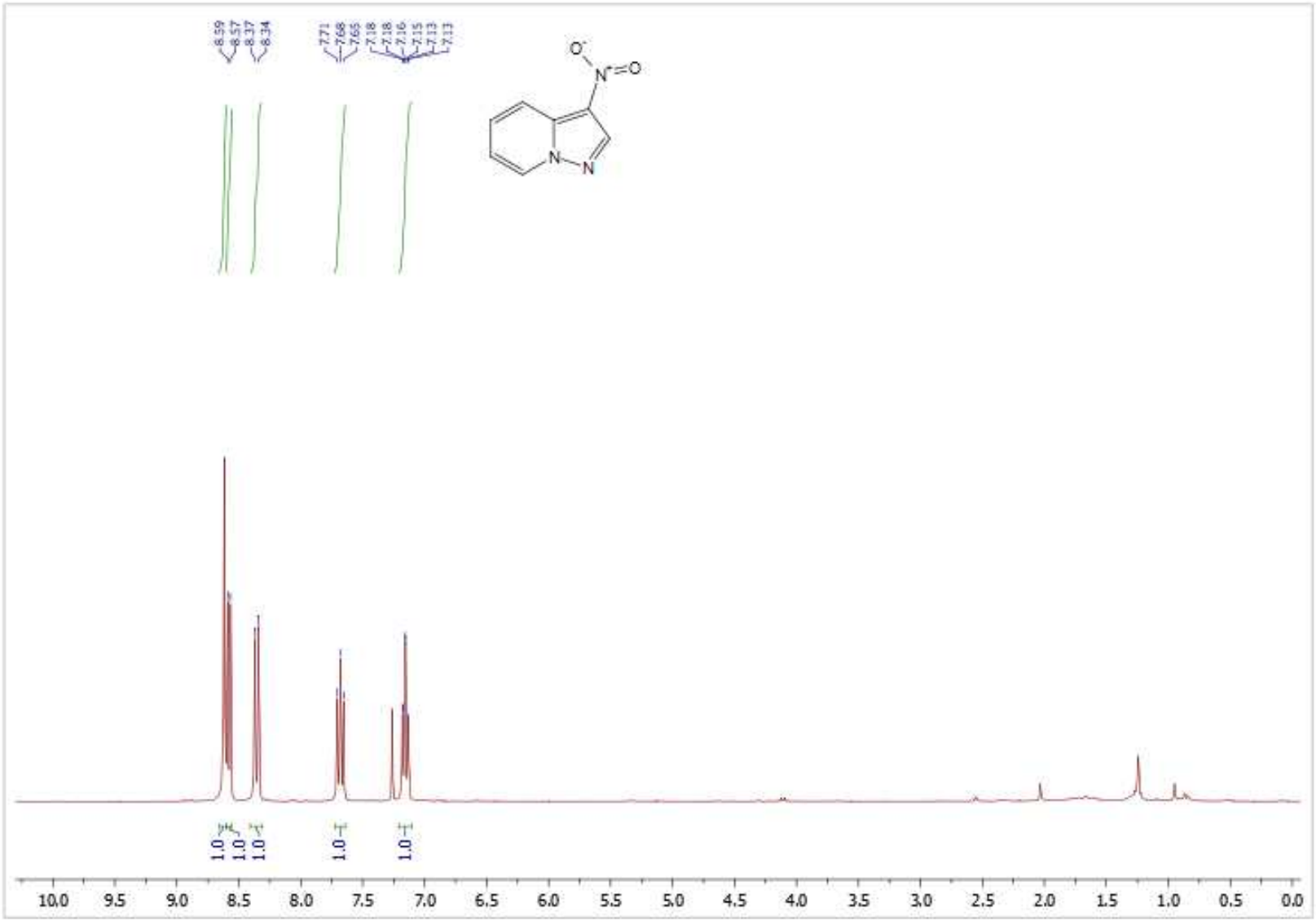

O⁻
N⁺=O
N
N
20
30
40
50
60
70
80
90
100
110
120
130
140
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5

$^{1}H$-$^{13}C$ HMBC

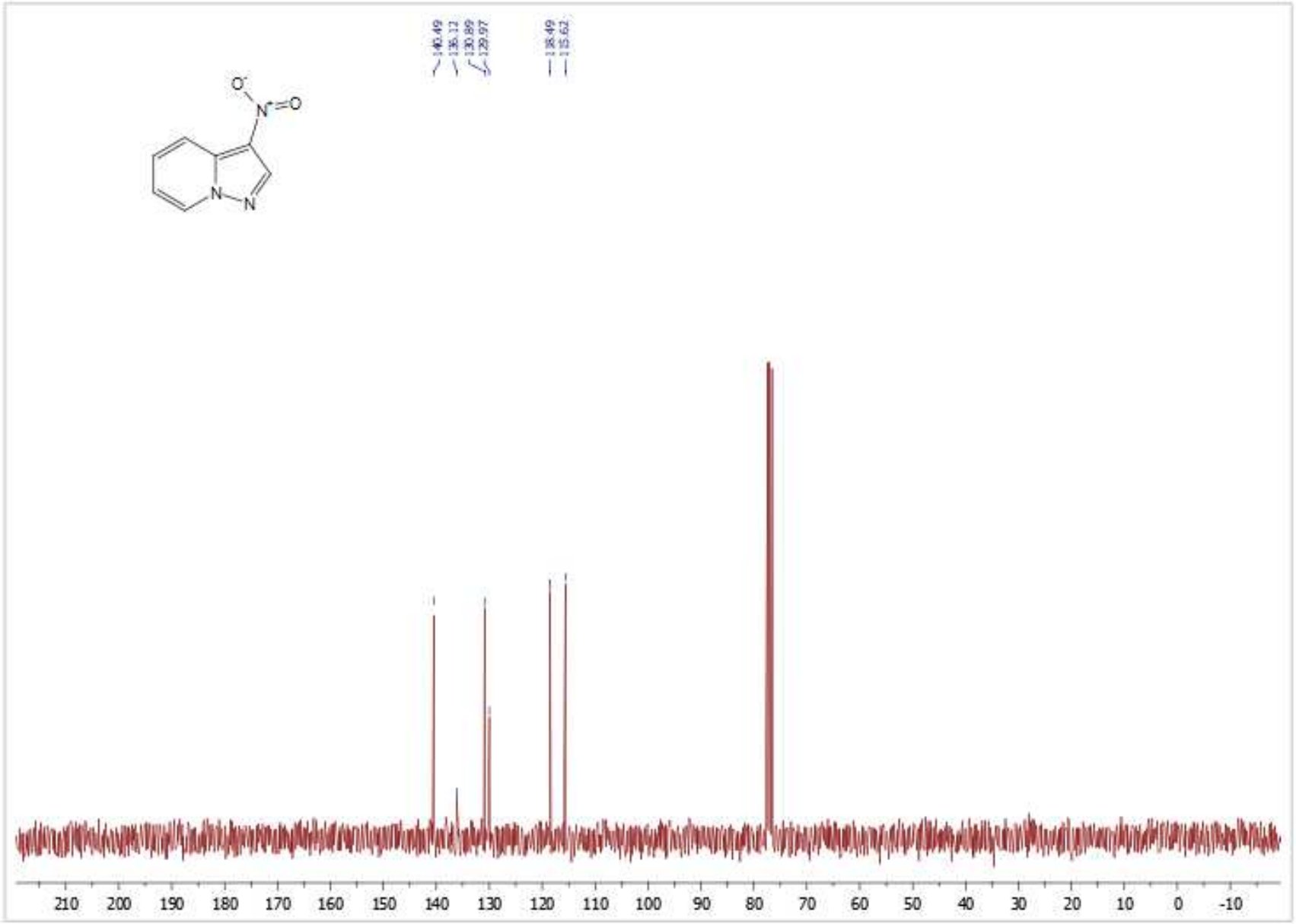

O
N
O
N
N
30
40
50
60
70
80
90
100
110
120
130
140
150
160
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0

**3-Nitro-pyrazolo[1,5-a]pyridine 5e**

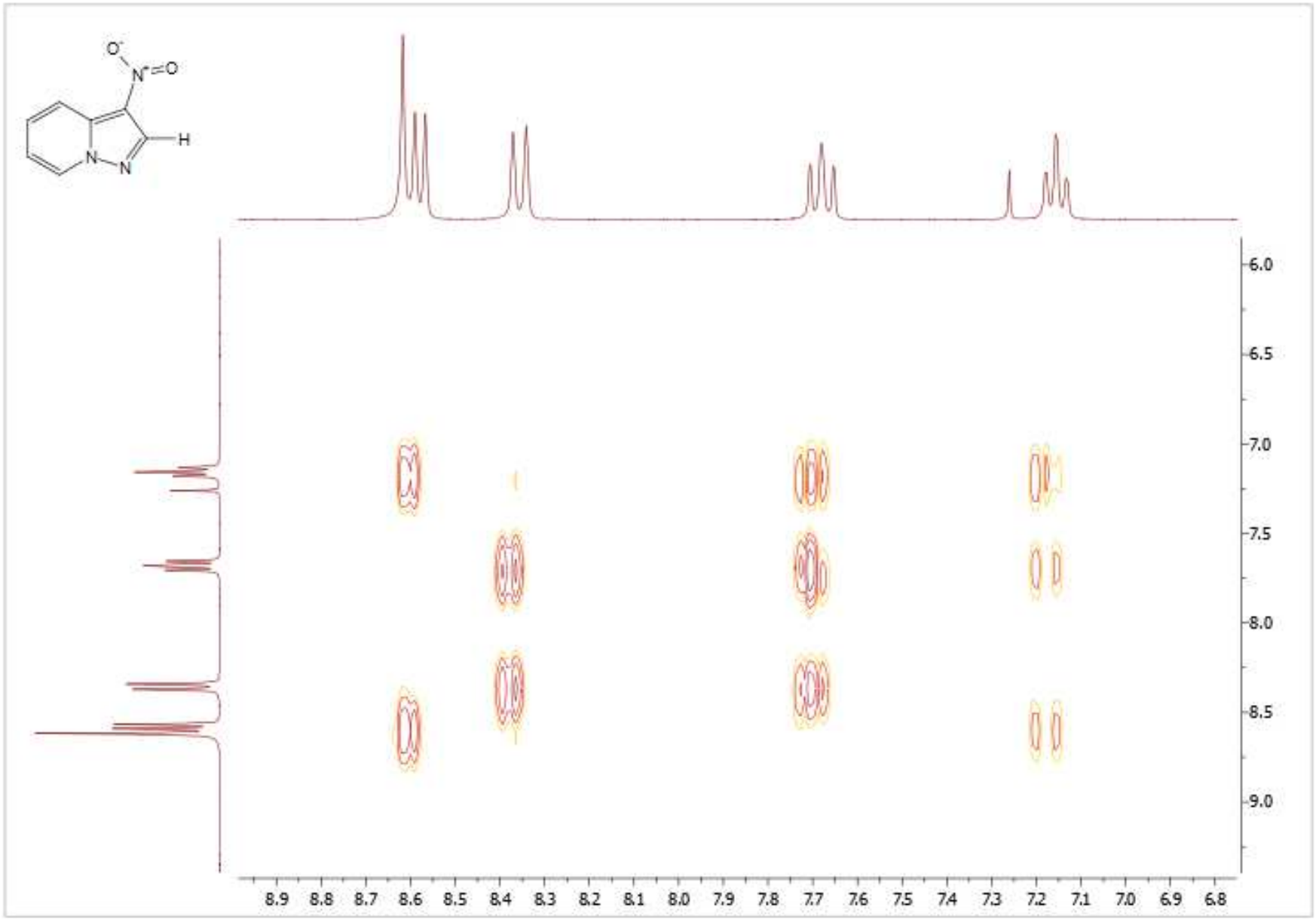
$^{1}$H NMR



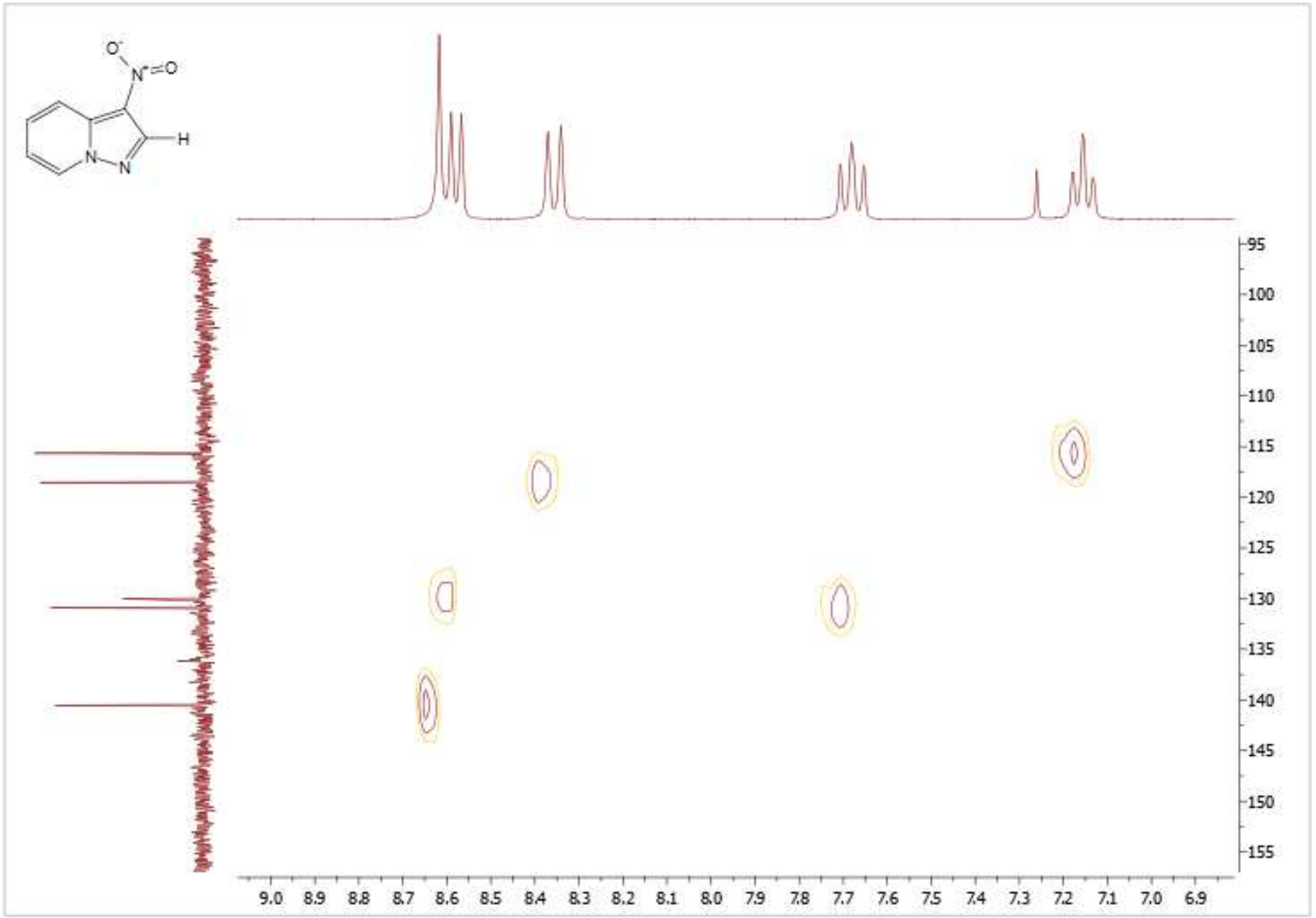
$^{13}$C NMR


140.49
136.12
130.89
129.97
118.49
115.62
O
N
O
N
N
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

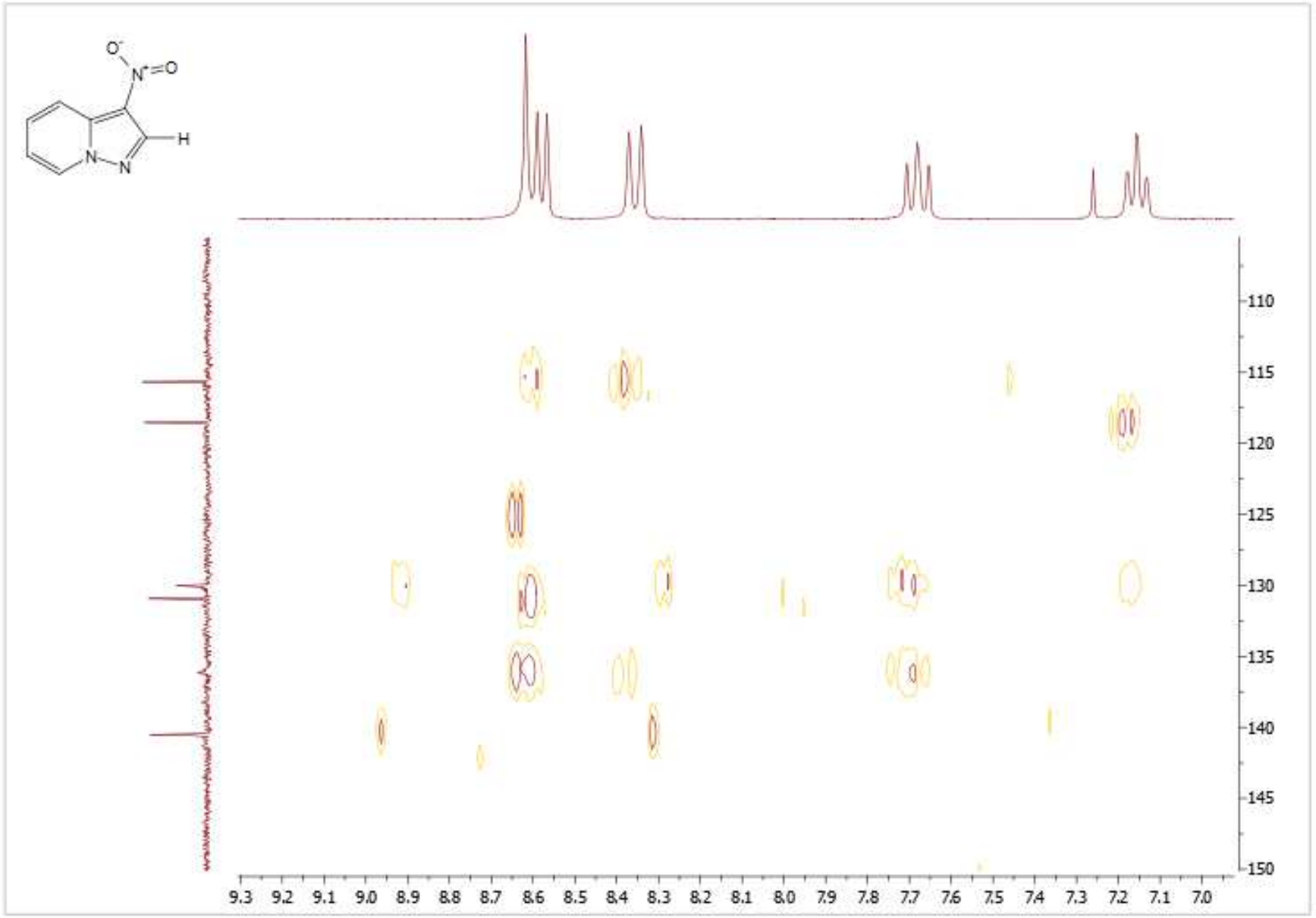
$^{1}$H-$^{1}$H COSY


O
N
O
H
N
N
6.0
6.5
7.0
7.5
8.0
8.5
9.0
8.9 8.8 8.7 8.6 8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8

$^{1}H$-$^{13}C$ HSQC

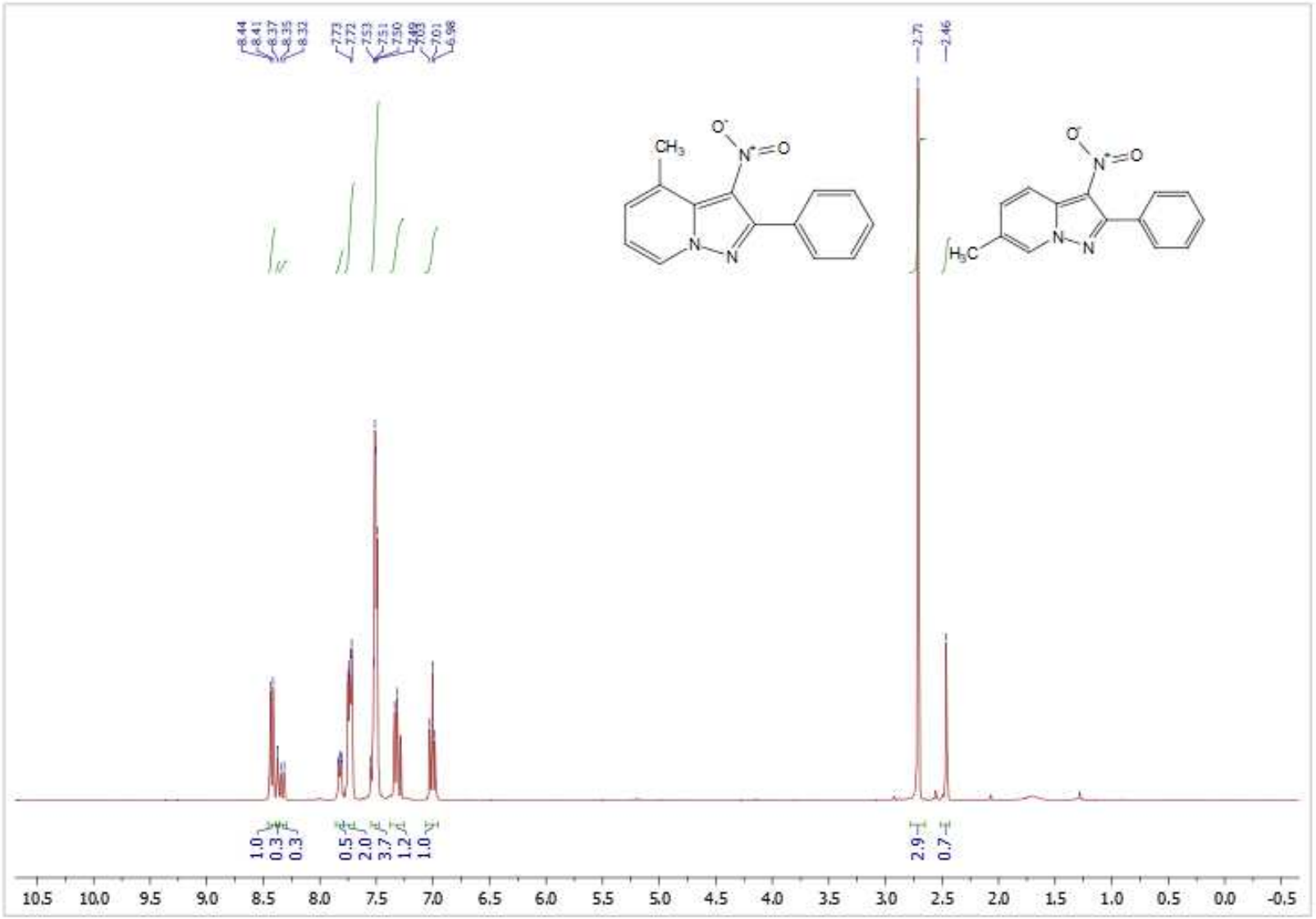

O
N
O
H
N
N
95
100
105
110
115
120
125
130
135
140
145
150
155
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9

$^{1}H$-$^{13}C$ HMBC

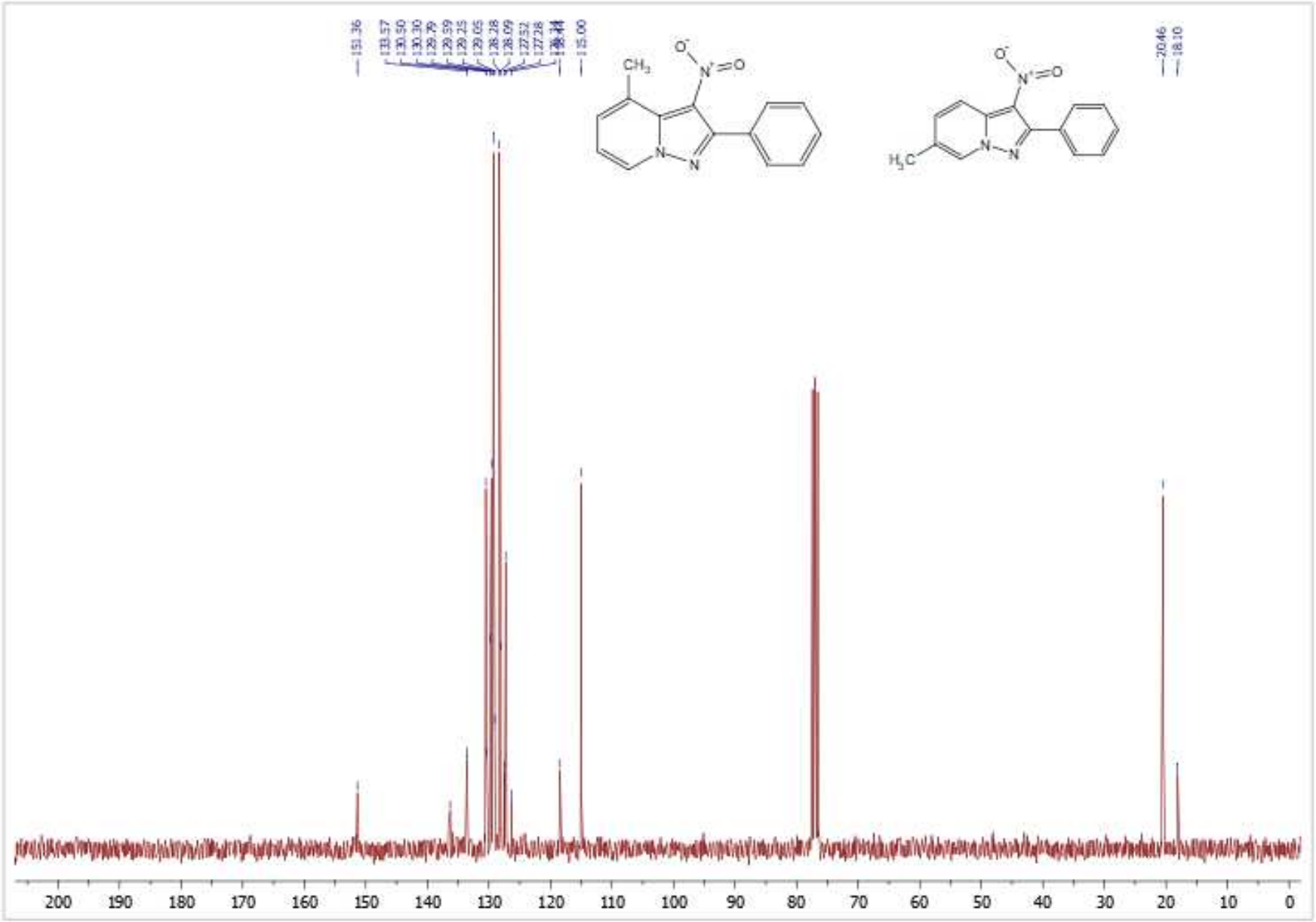

O
N
O
H
N
N
110
115
120
125
130
135
140
145
150
9.3
9.2
9.1
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0

**2-Phenyl-3-nitro-4-methyl-pyrazolo[1,5-a]pyridine 5f and 2-phenyl-3-nitro-6-methyl-pyrazolo[1,5-a]pyridine 5f' (4:1 mixture)**

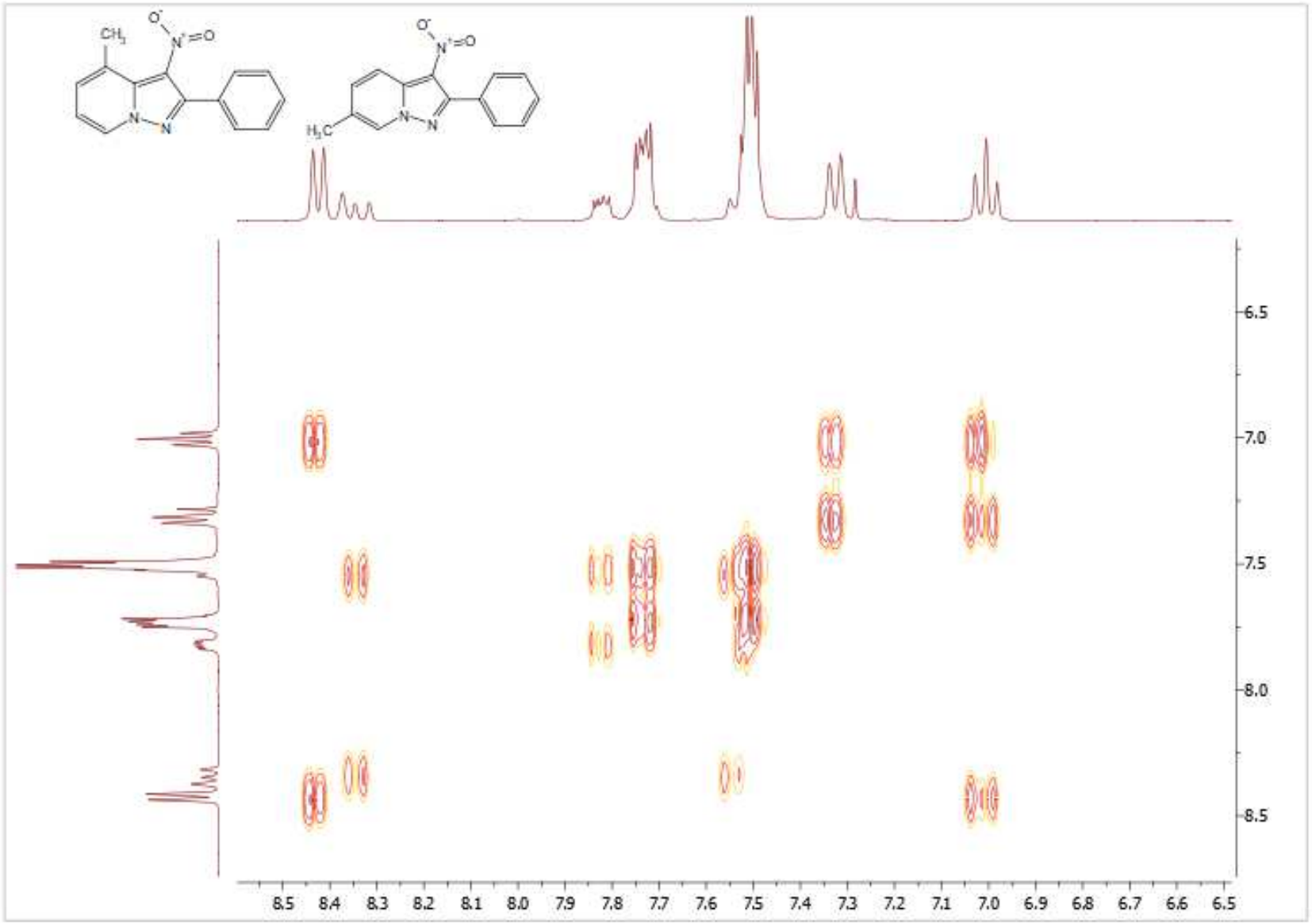
$^{1}$H NMR



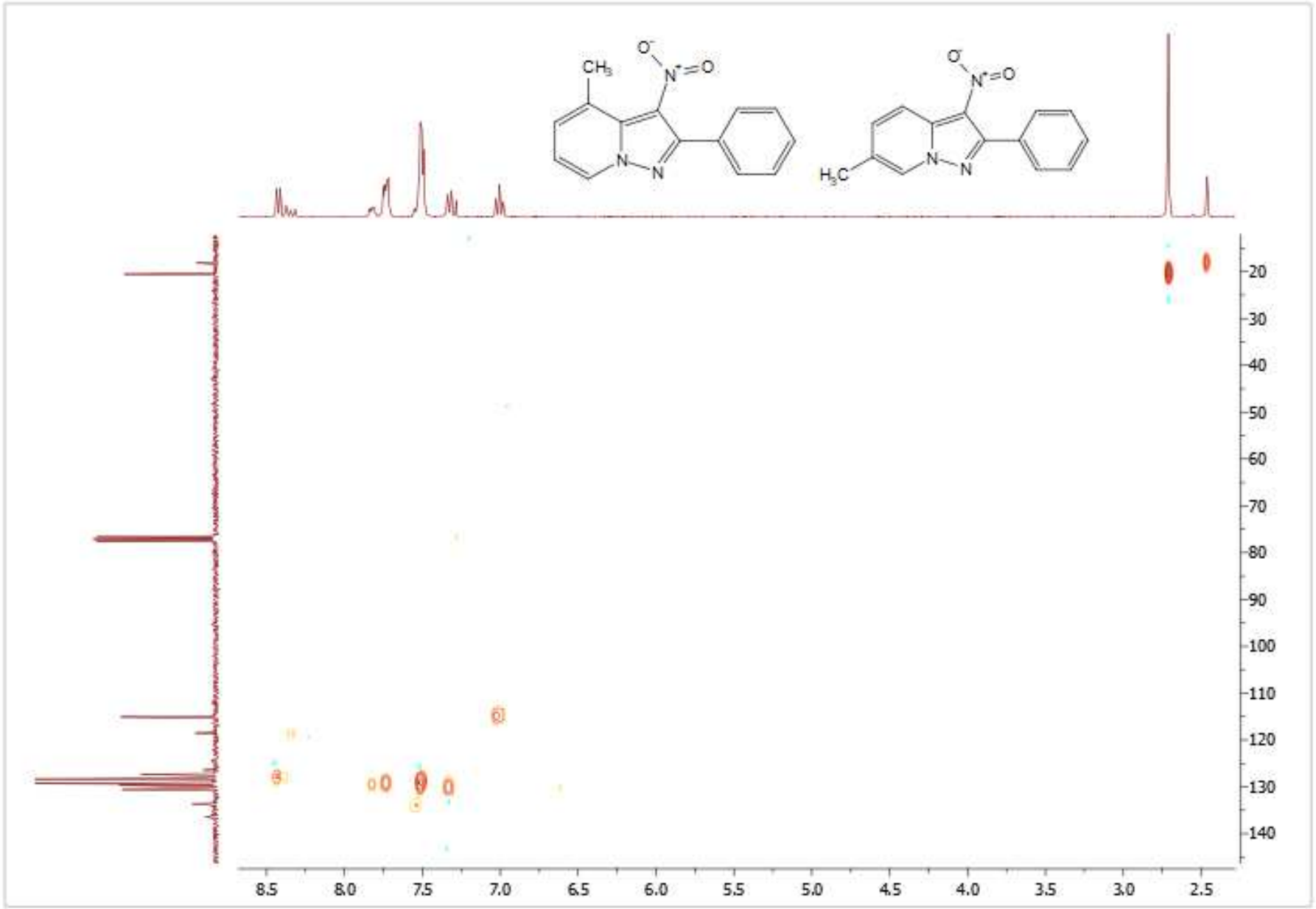
$^{13}$C NMR


151.36
133.57
130.50
130.30
129.79
129.59
129.25
129.05
128.28
128.09
127.52
127.28
115.00
20.46
18.10
CH3
O
N+=O
H3C
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

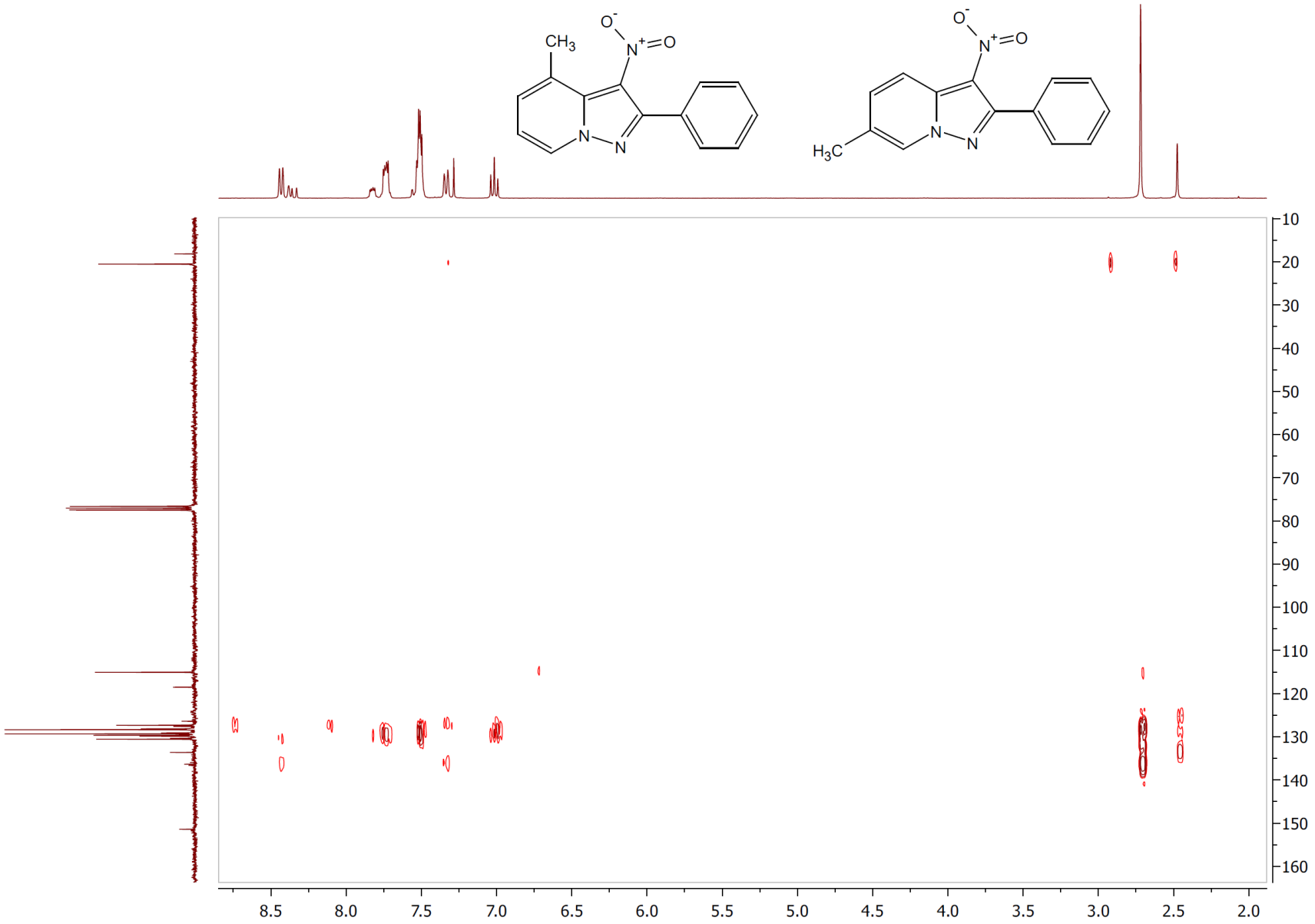
$^{1}$H-$^{1}$H COSY


CH3
O-
N+=O
N
N
H3C
6.5
7.0
7.5
8.0
8.5
8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6 6.5

$^{1}H$-$^{13}C$ HSQC

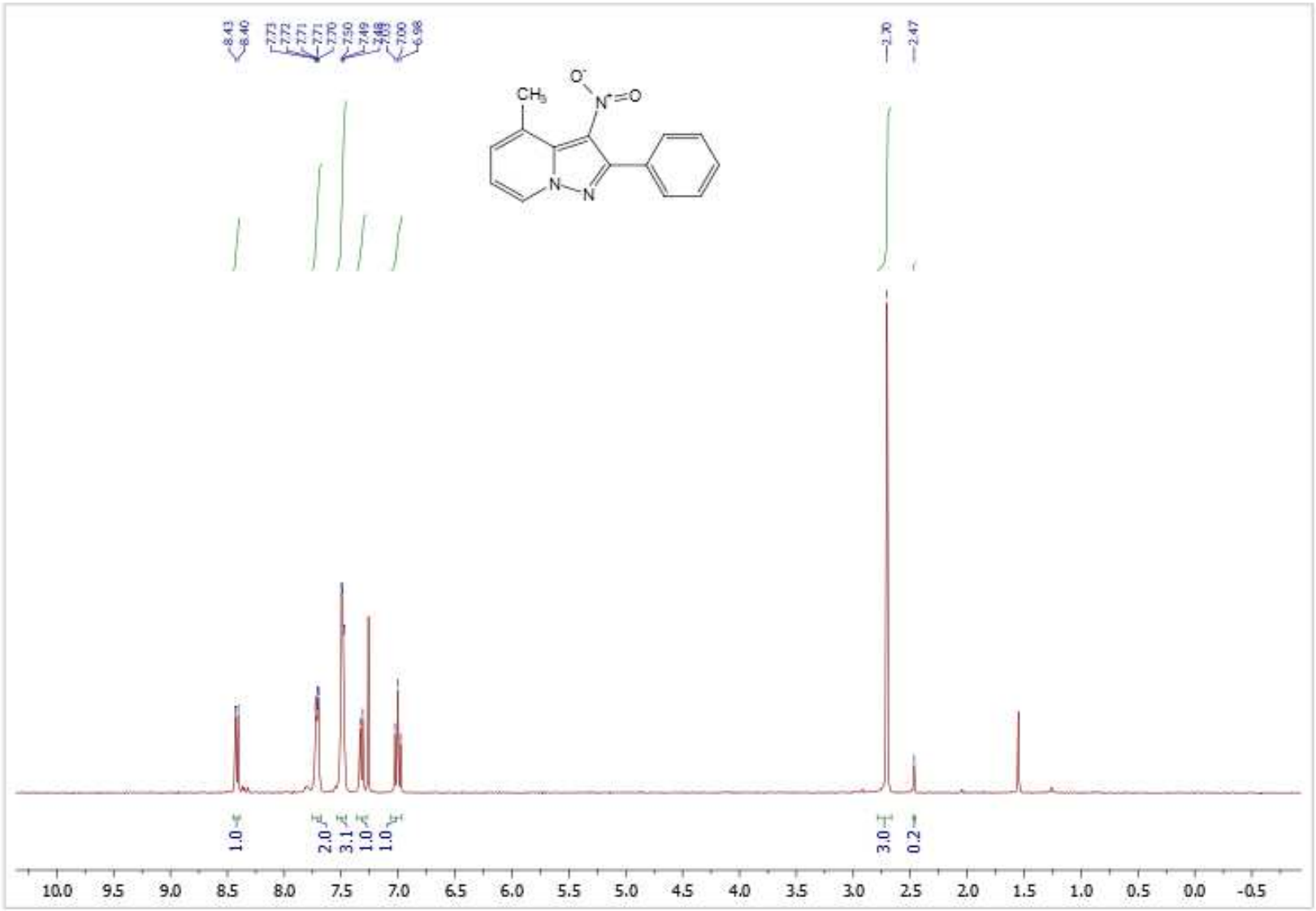

CH3
O-
N+=O
N
N
H3C
O-
N+=O
N
N
20
30
40
50
60
70
80
90
100
110
120
130
140
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5

$^{1}H$-$^{13}C$ HMBC

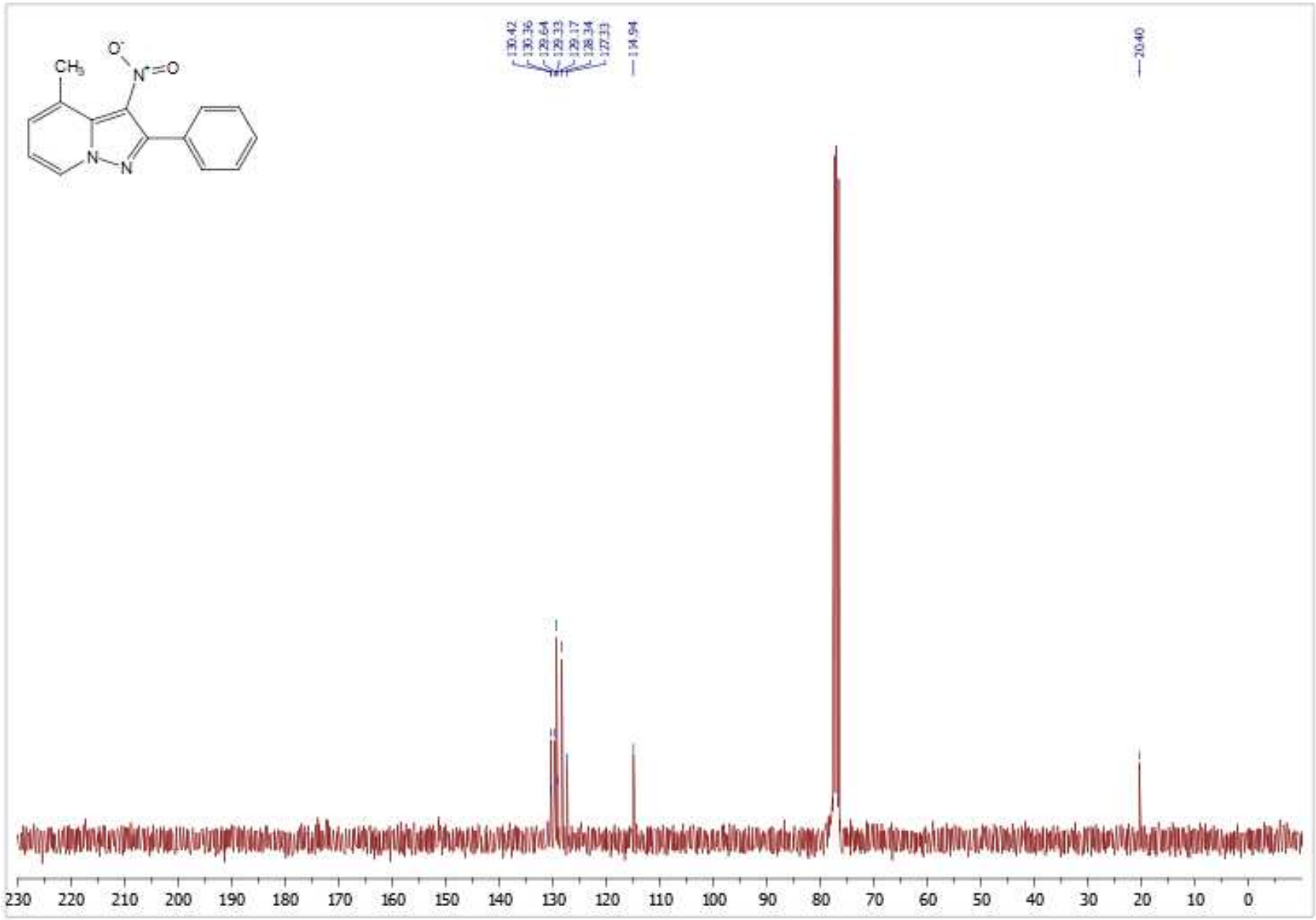

CH3
O-
N+=O
N
N
H3C
O-
N+=O
N
N
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0

**2-Phenyl-3-nitro-4-methyl-pyrazolo[1,5-a]pyridine 5f** (after crystalization)

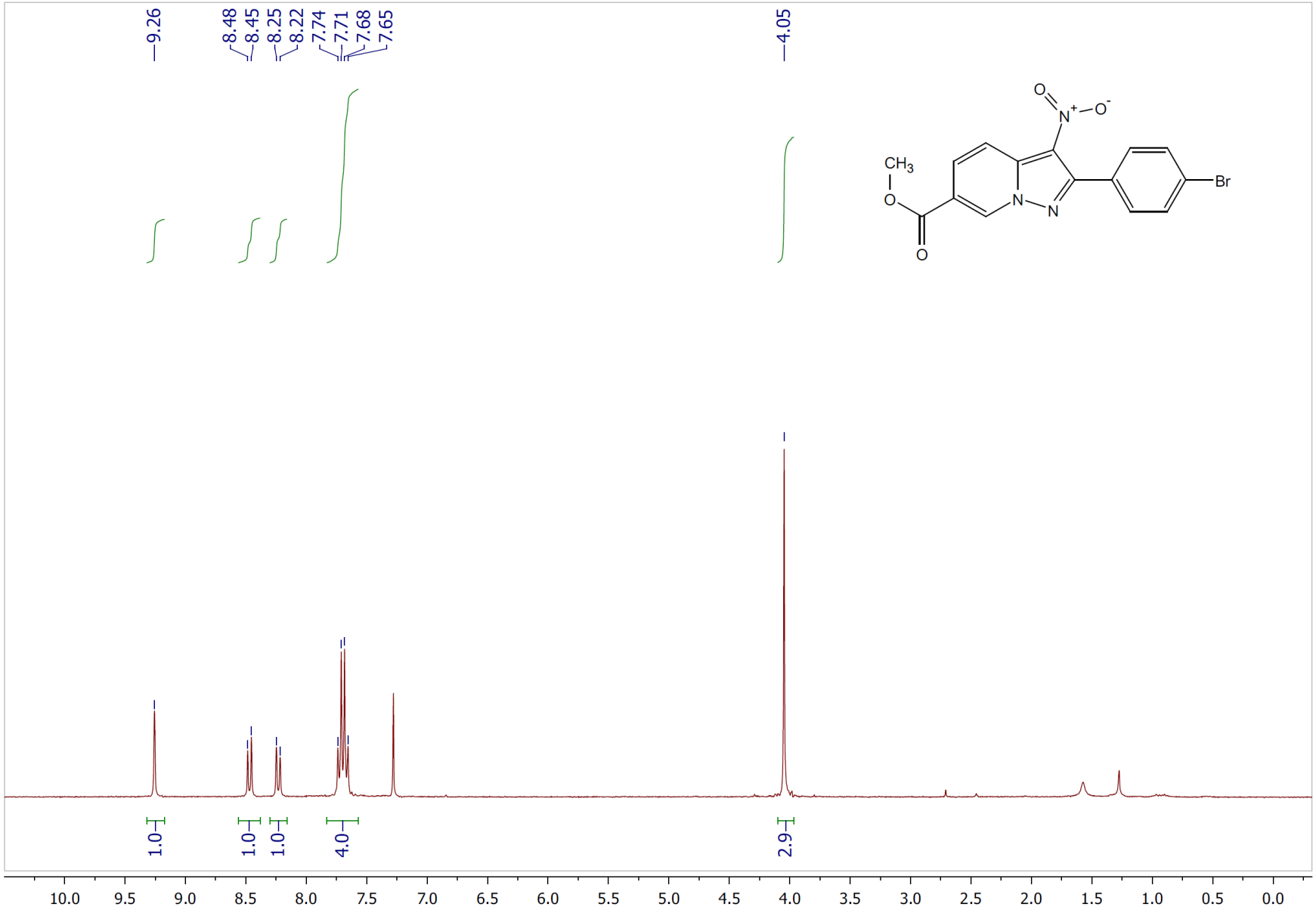
$^{1}$H NMR



$^{13}$C NMR

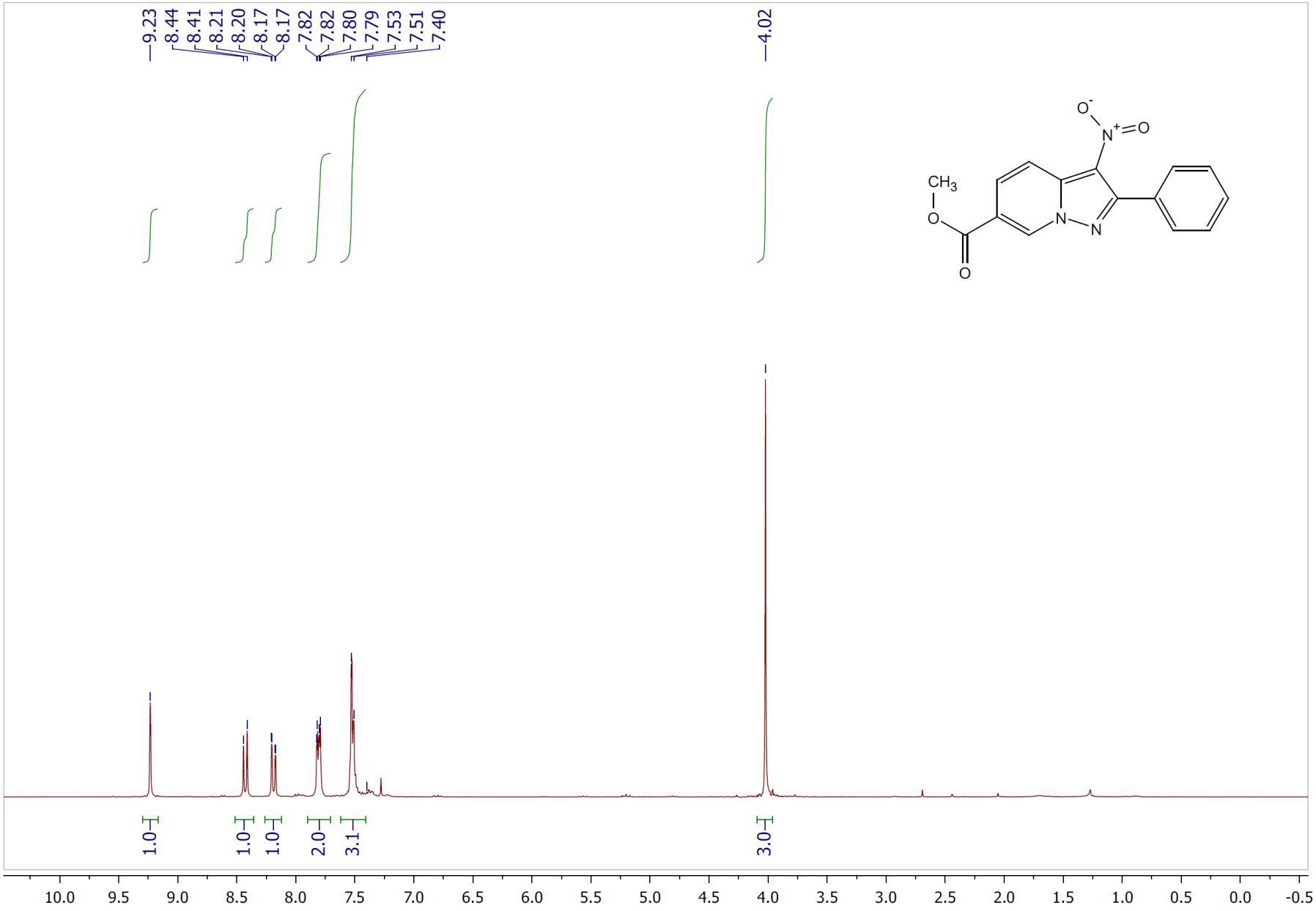

CH3
O
N
O
N
N
130.42
130.36
129.64
129.33
129.17
128.34
127.33
114.94
20.40
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

**Methyl 2-(4-bromophenyl)-3-nitropyrazolo[1,5-a]pyridine-6-carboxylate 5g** (see also above its mixture with **3p'**)
$^{1}$H NMR

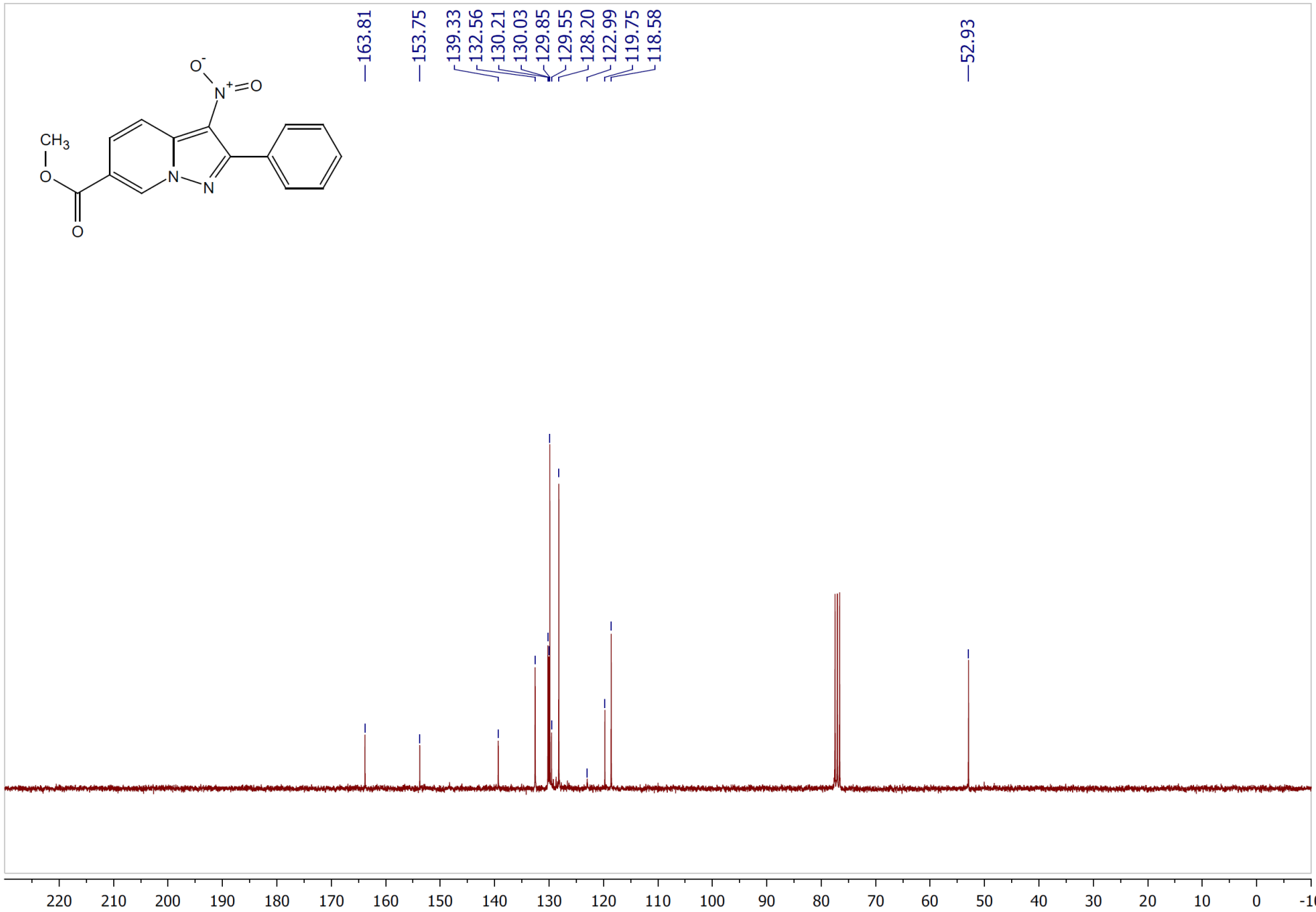


**Methyl 3-nitro-2-phenylpyrazolo[1,5-a]pyridine-6-carboxylate 5h**

$^{1}$H NMR

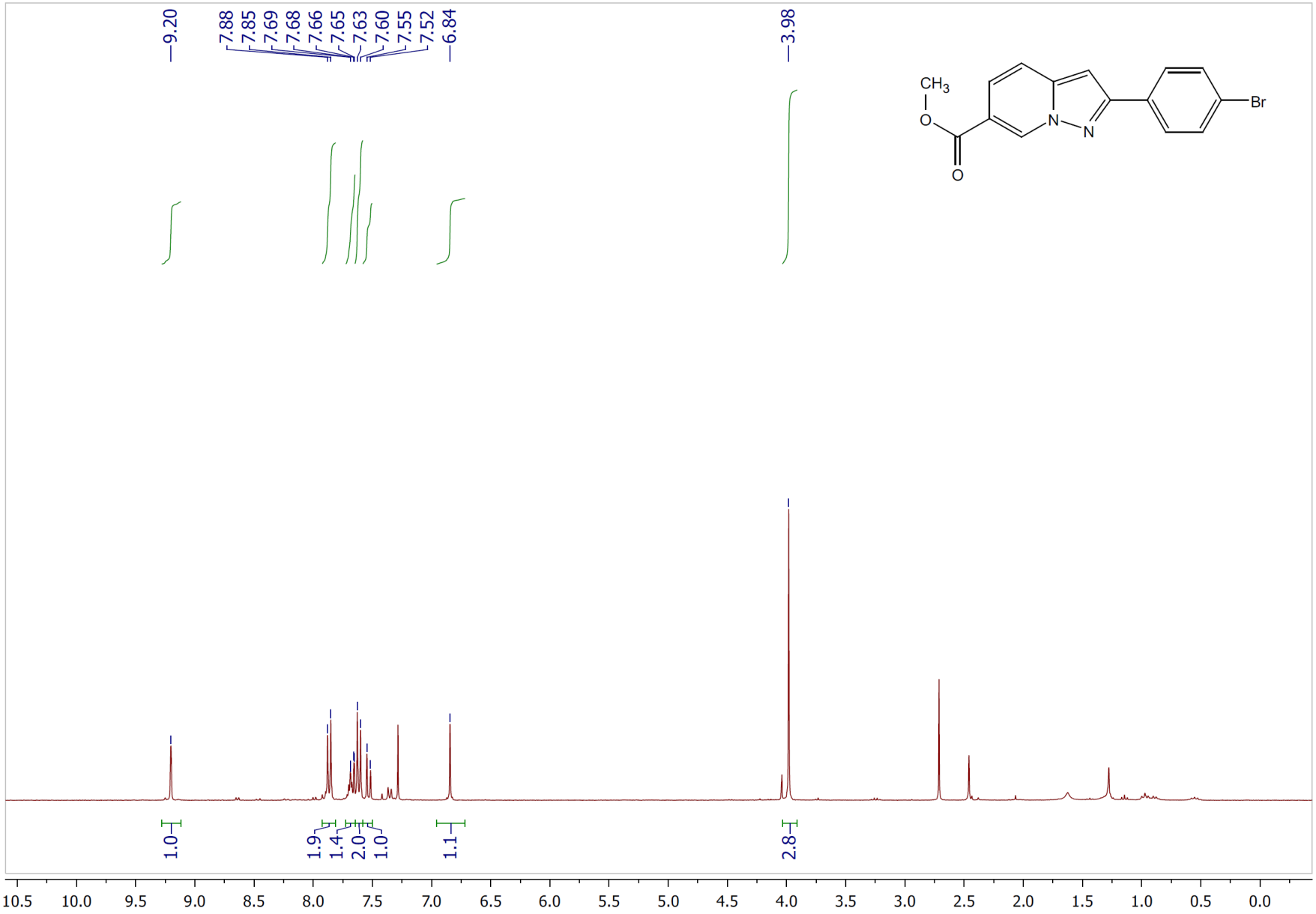


$^{13}$C NMR

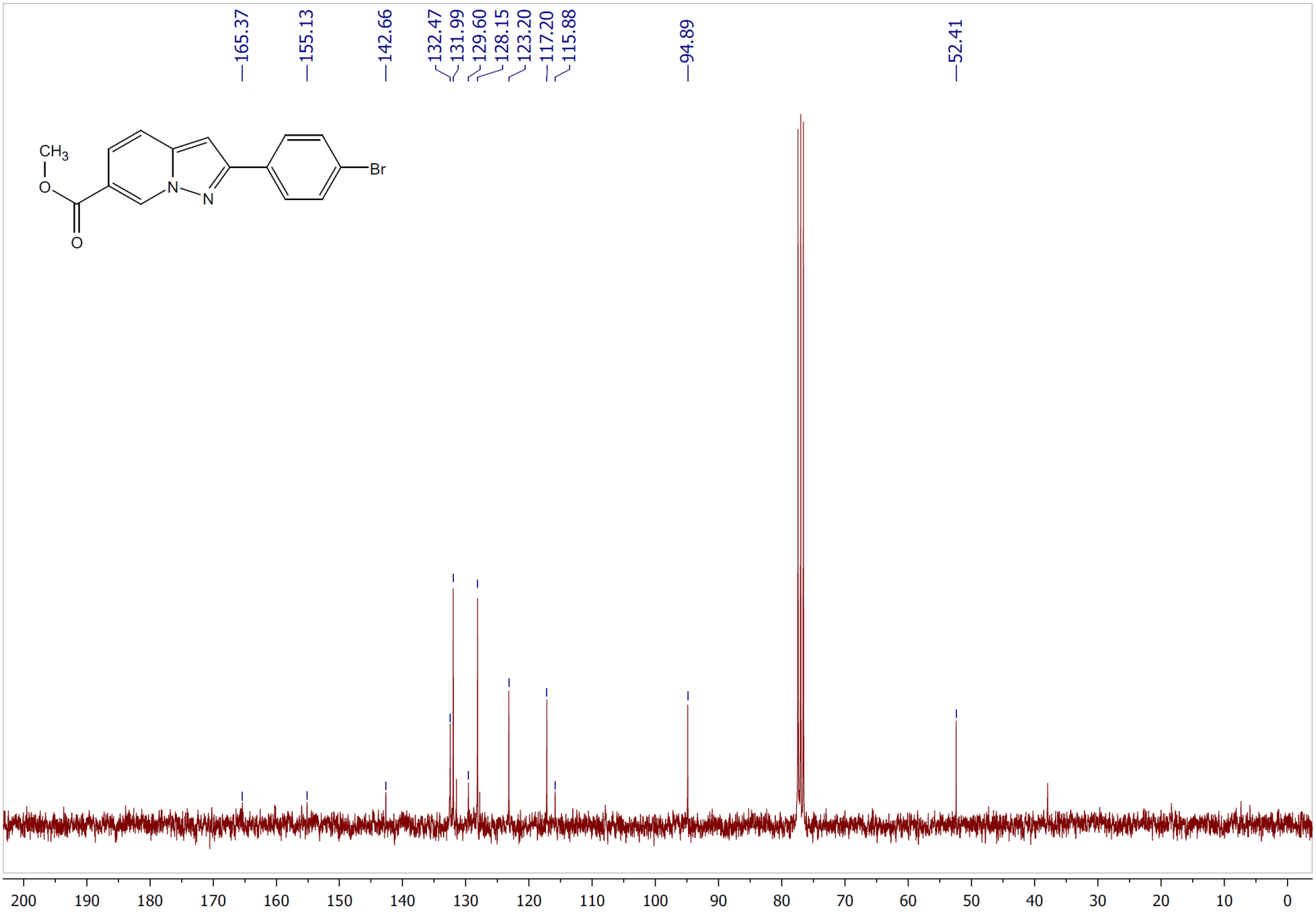

163.81
153.75
139.33
132.56
130.21
130.03
129.85
129.55
128.20
122.99
119.75
118.58
52.93
CH3
O
O
O
N+=O
O-
N
N
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

**Methyl 2-(4-bromophenyl)pyrazolo[1,5-a]pyridine-6-carboxylate 6a**

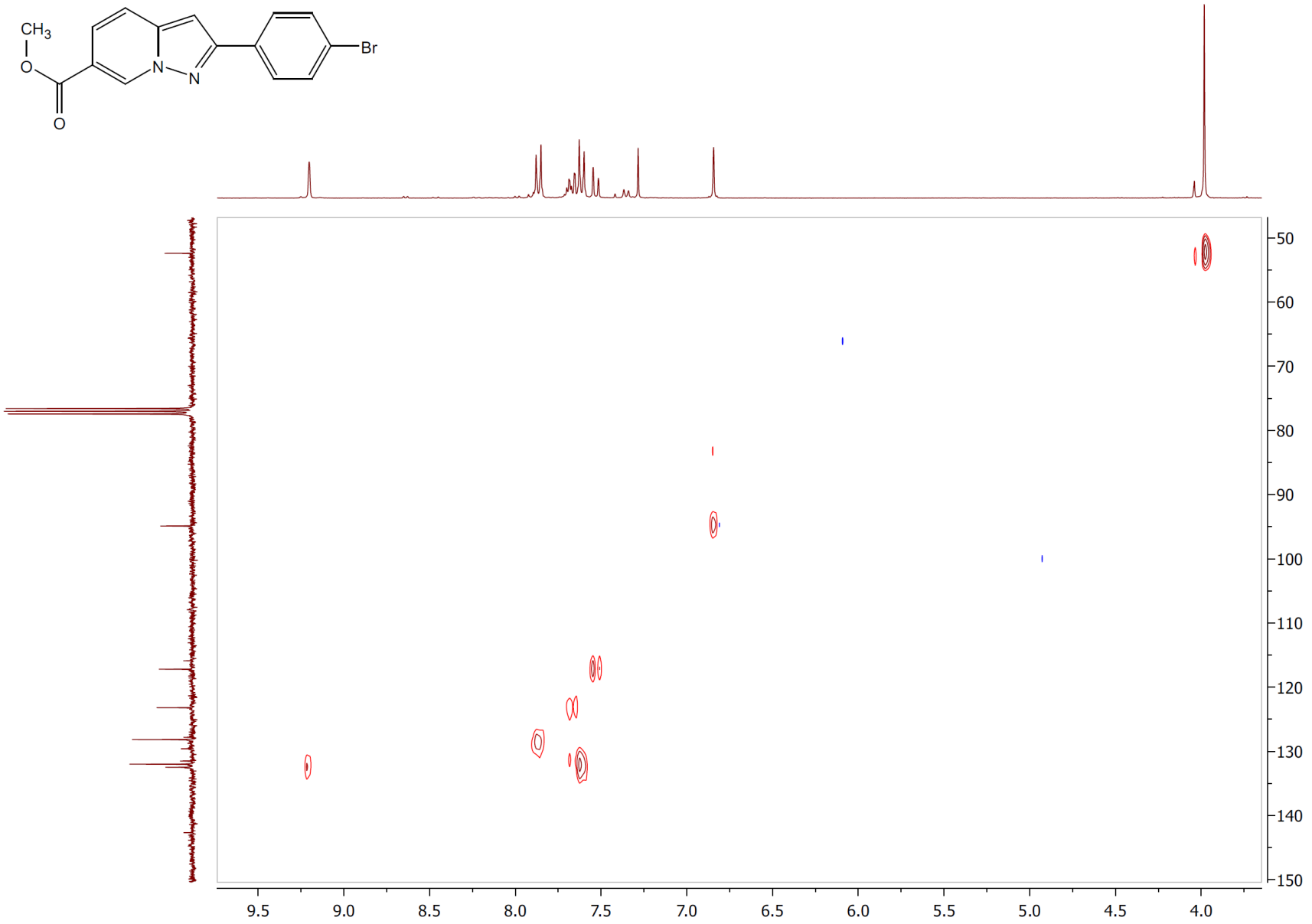
$^{1}$H NMR



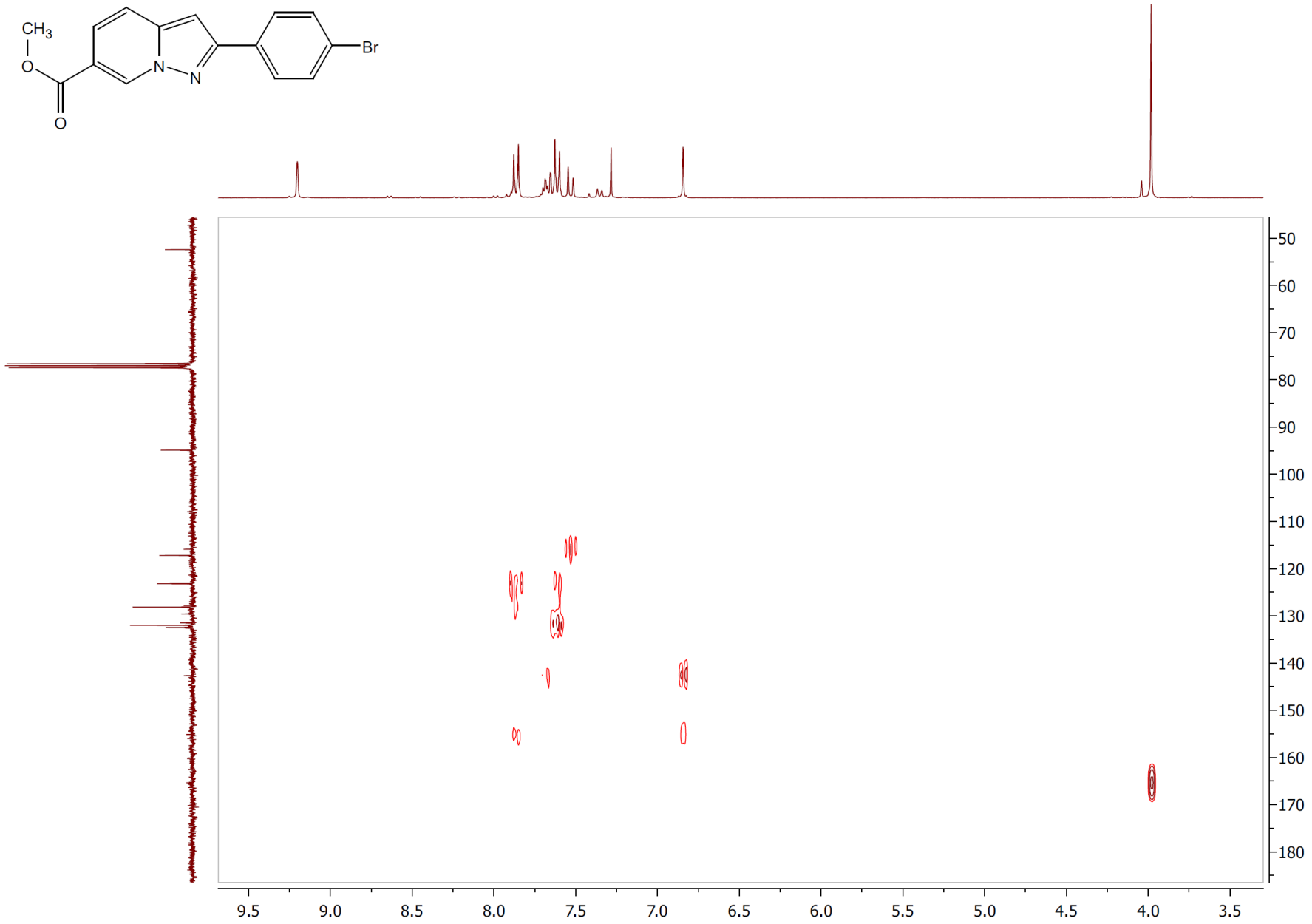
$^{13}$C NMR


165.37
155.13
142.66
132.47
131.99
129.60
128.15
123.20
117.20
115.88
94.89
52.41
CH3
O
O
N
N
Br
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC

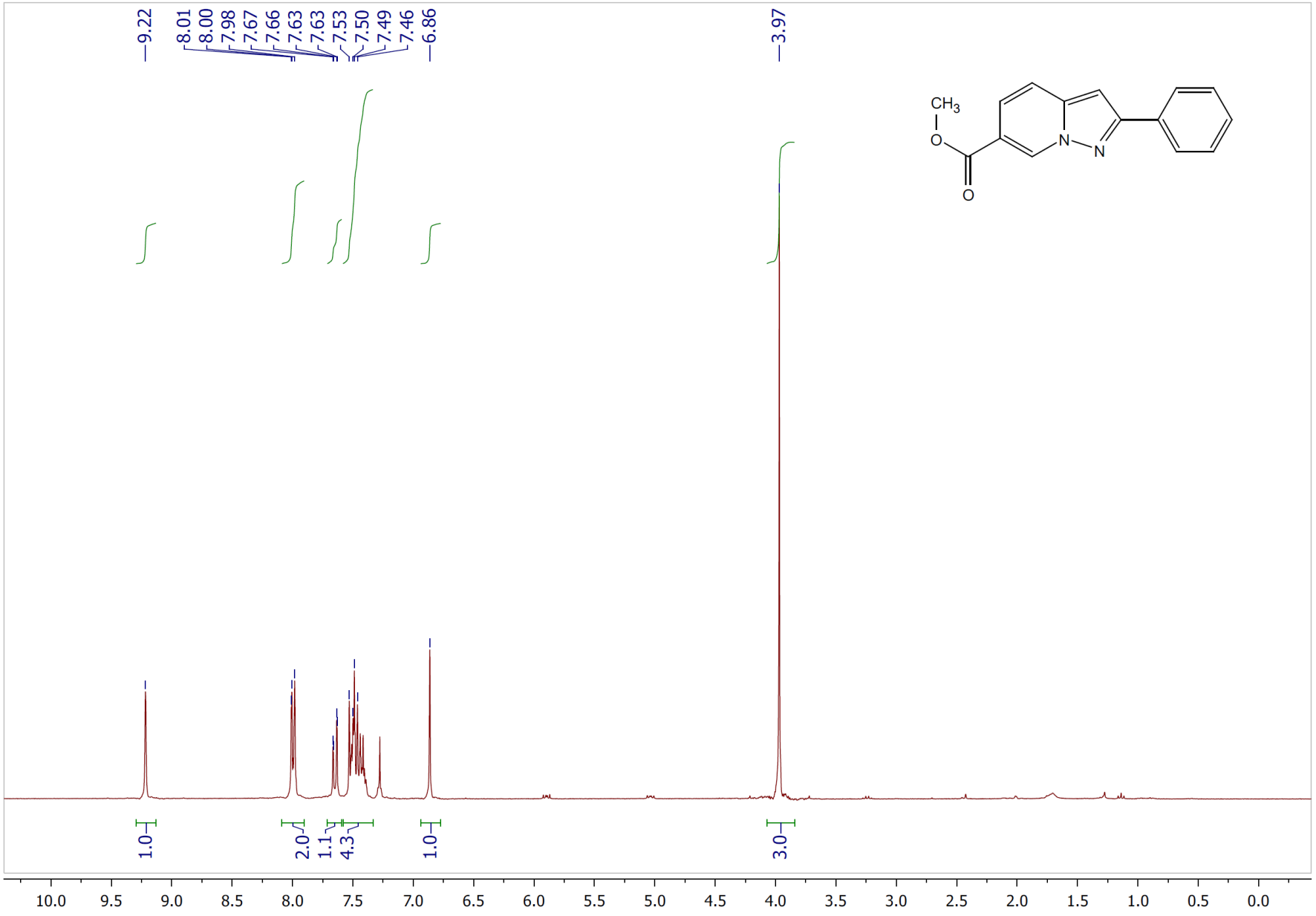

CH3
O
O
N
N
Br
50
60
70
80
90
100
110
120
130
140
150
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

$^{1}H$-$^{13}C$ HMBC


CH3
O
O
N
N
Br
50
60
70
80
90
100
110
120
130
140
150
160
170
180
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5

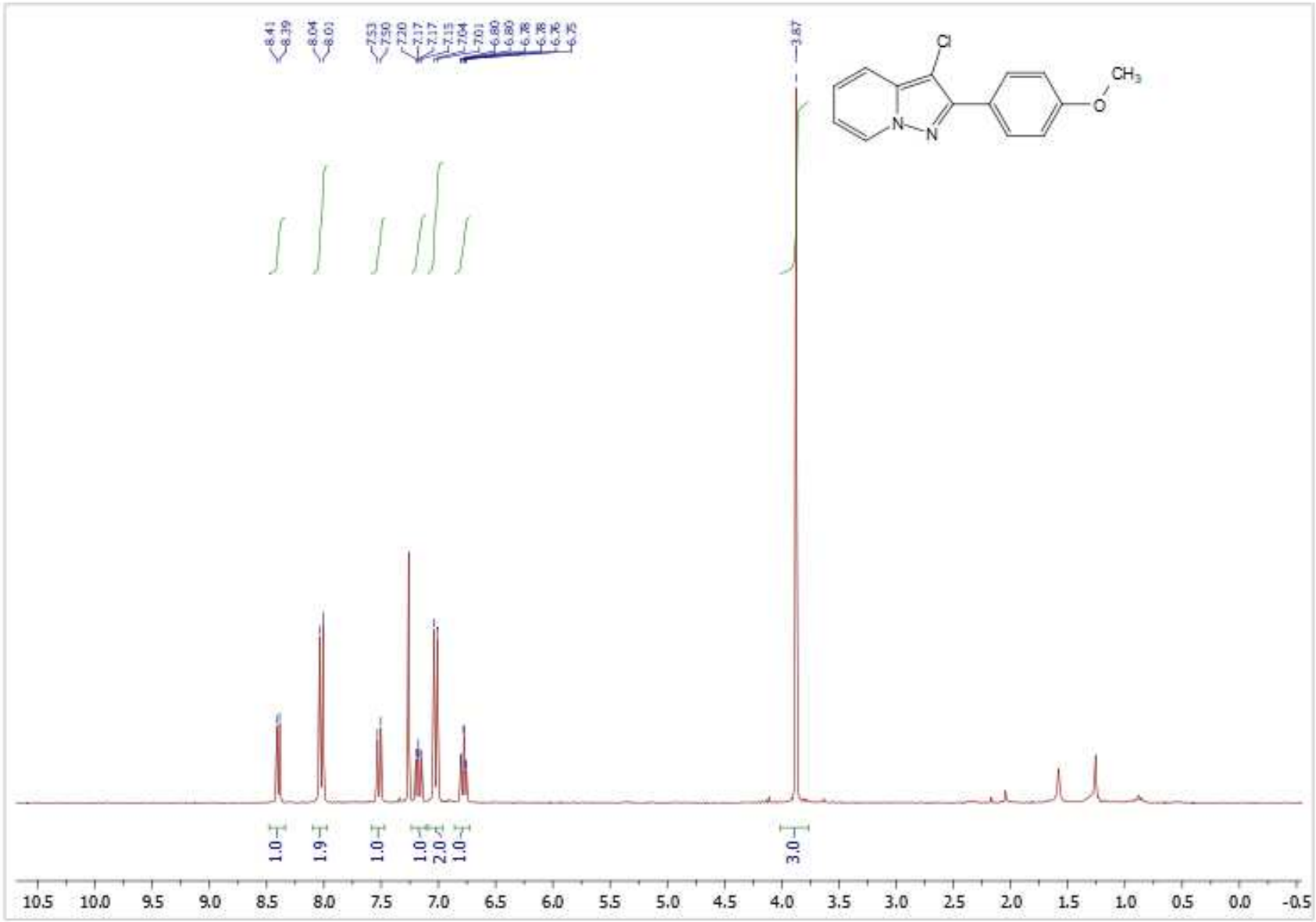
**Methyl 2-phenylpyrazolo[1,5-a]pyridine-6-carboxylate 6b**

$^{1}$H NMR

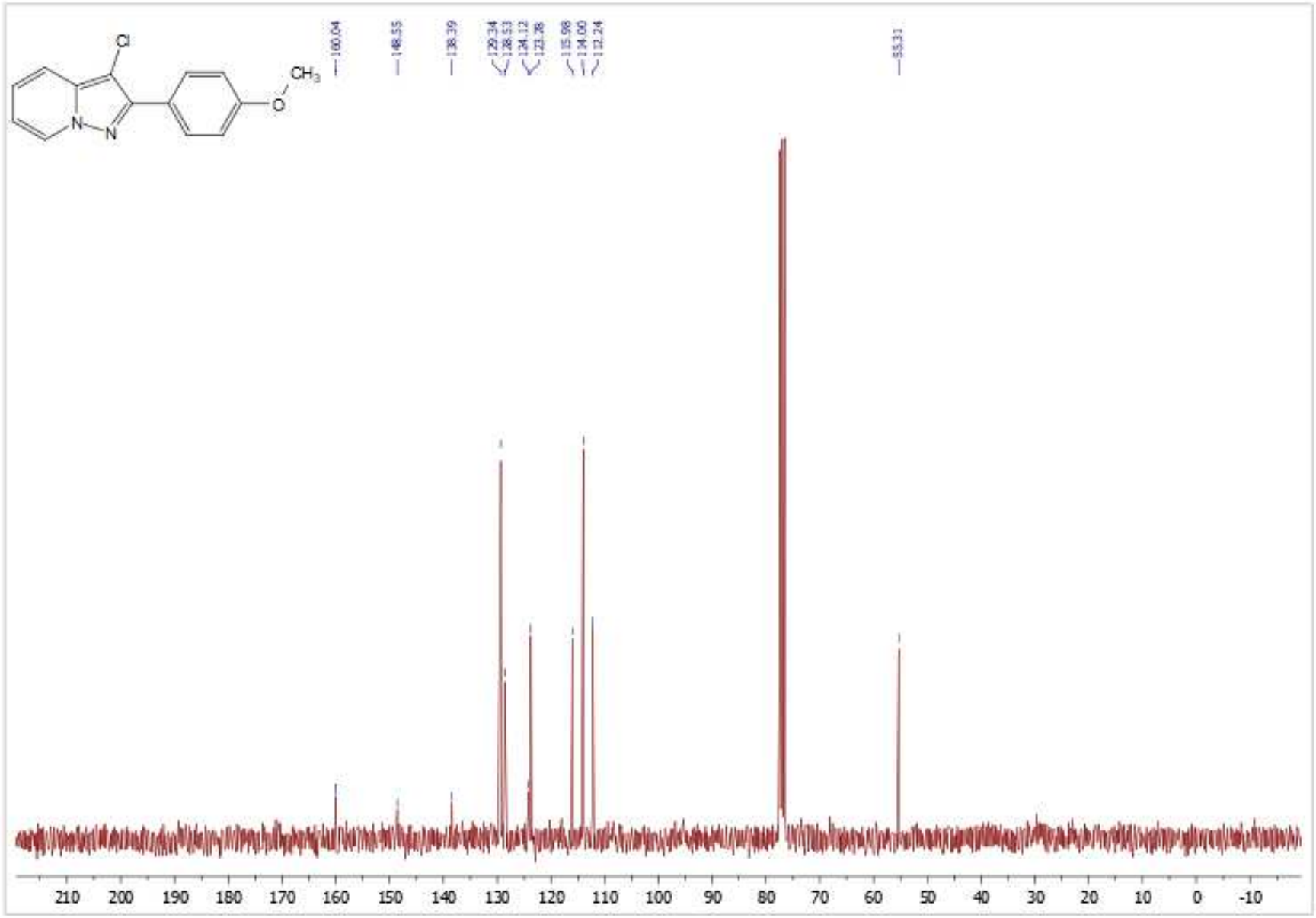


**3-Chloro-2-(4-methoxyphenyl)-pyrazolo[1,5-a]pyridine 8**

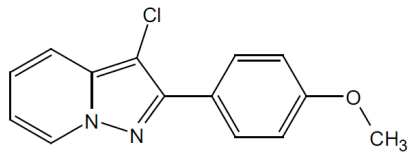
$^{1}$H NMR

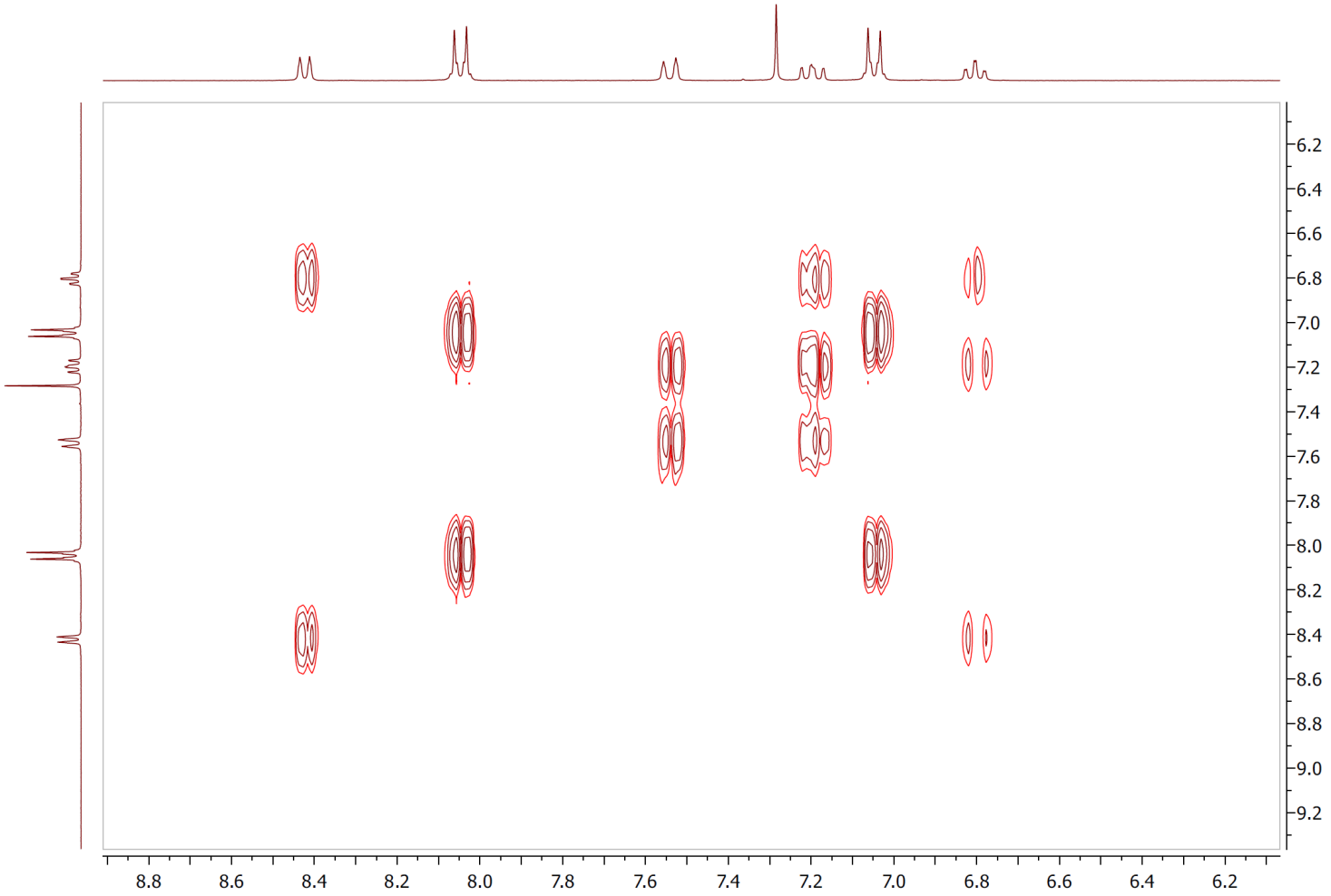


$^{13}$C NMR

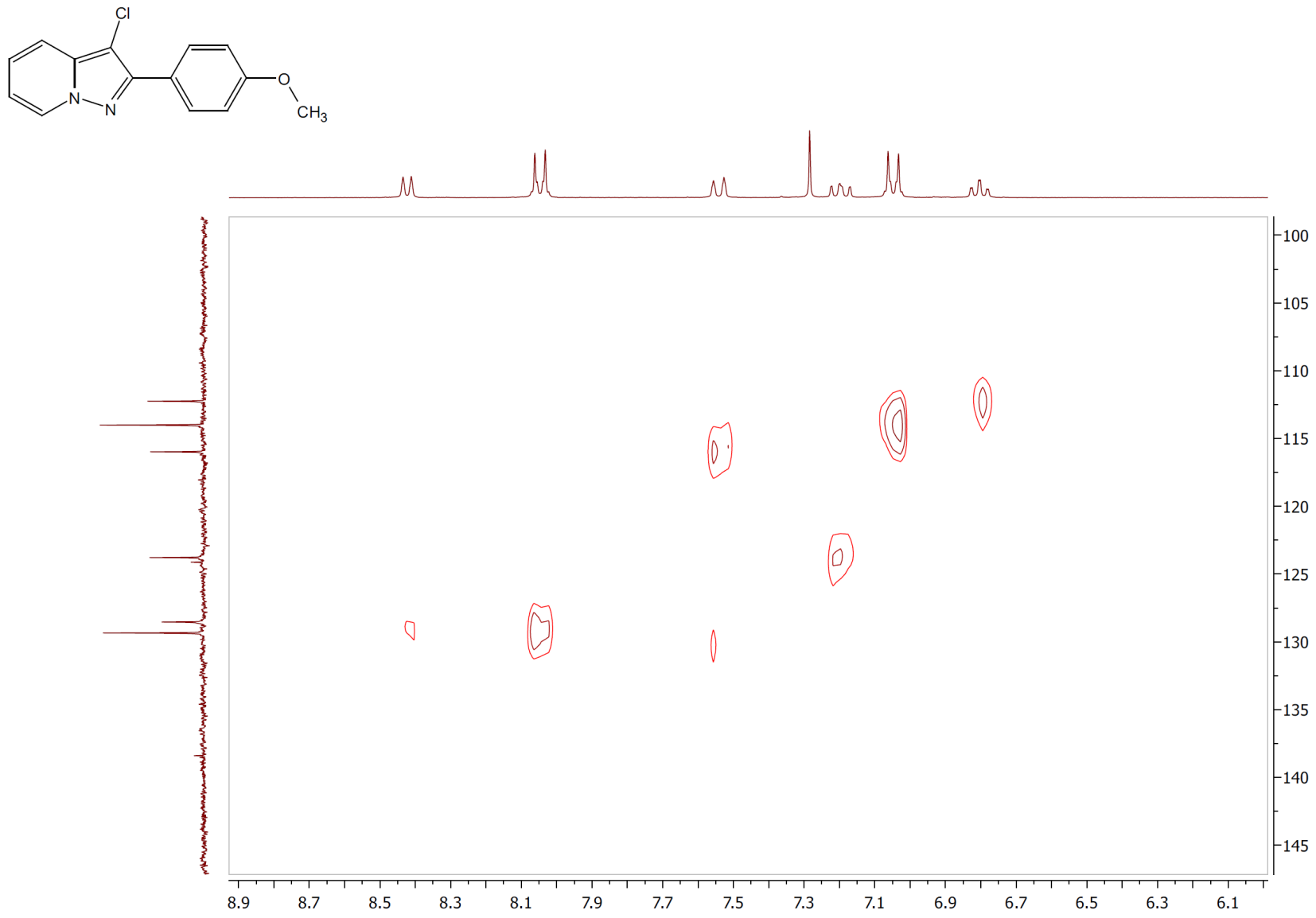

Cl
CH3
O
N
N
160.04
148.55
138.39
129.34
128.53
124.12
123.78
115.98
114.00
112.24
55.31
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

$^{1}$H-$^{1}$H COSY

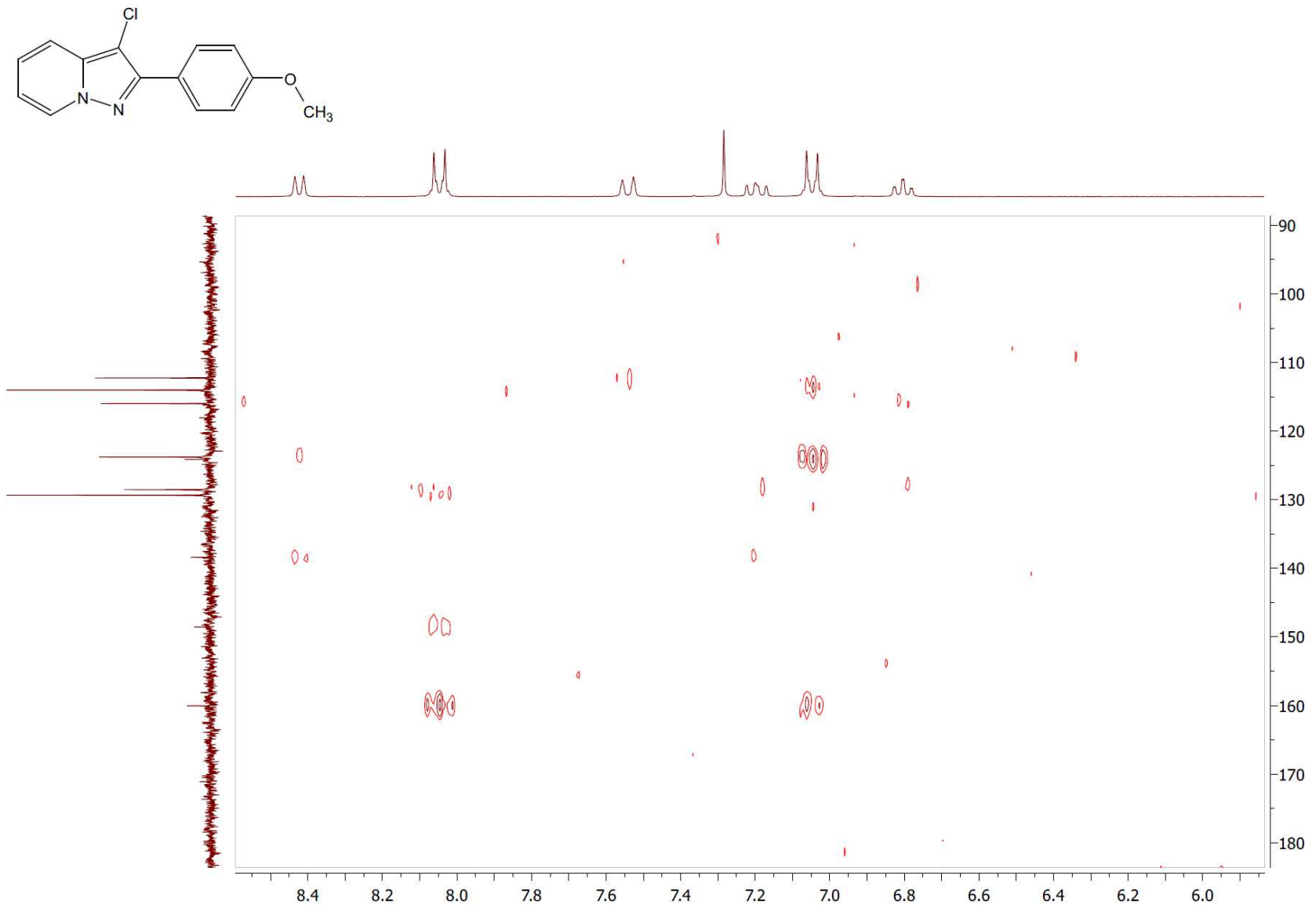

Cl
N
N
O
CH3


8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
9.2

$^{1}H$-$^{13}C$ HSQC

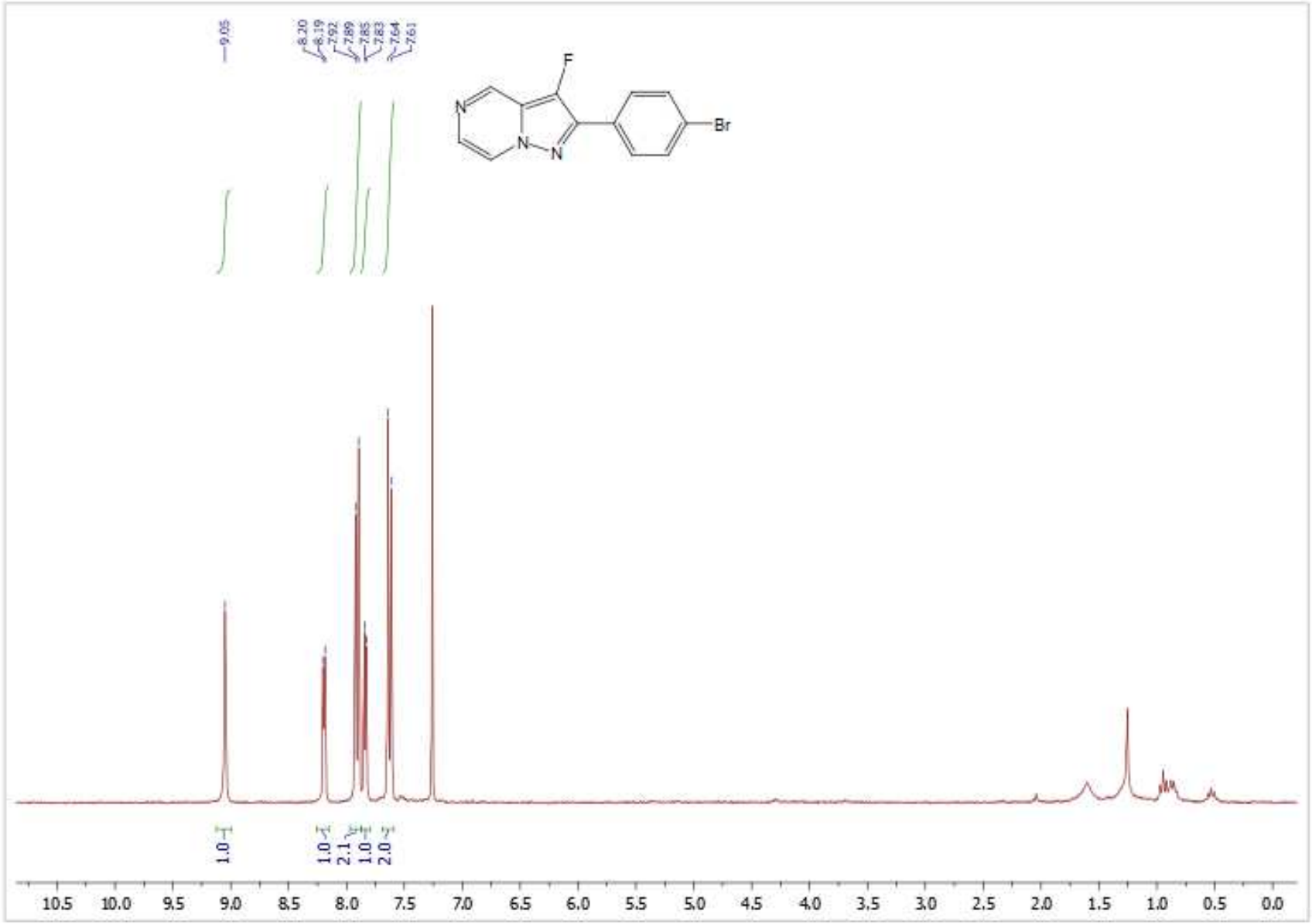

Cl
N
N
O
CH3
100
105
110
115
120
125
130
135
140
145
8.9
8.7
8.5
8.3
8.1
7.9
7.7
7.5
7.3
7.1
6.9
6.7
6.5
6.3
6.1

$^{1}H$-$^{13}C$ HMBC

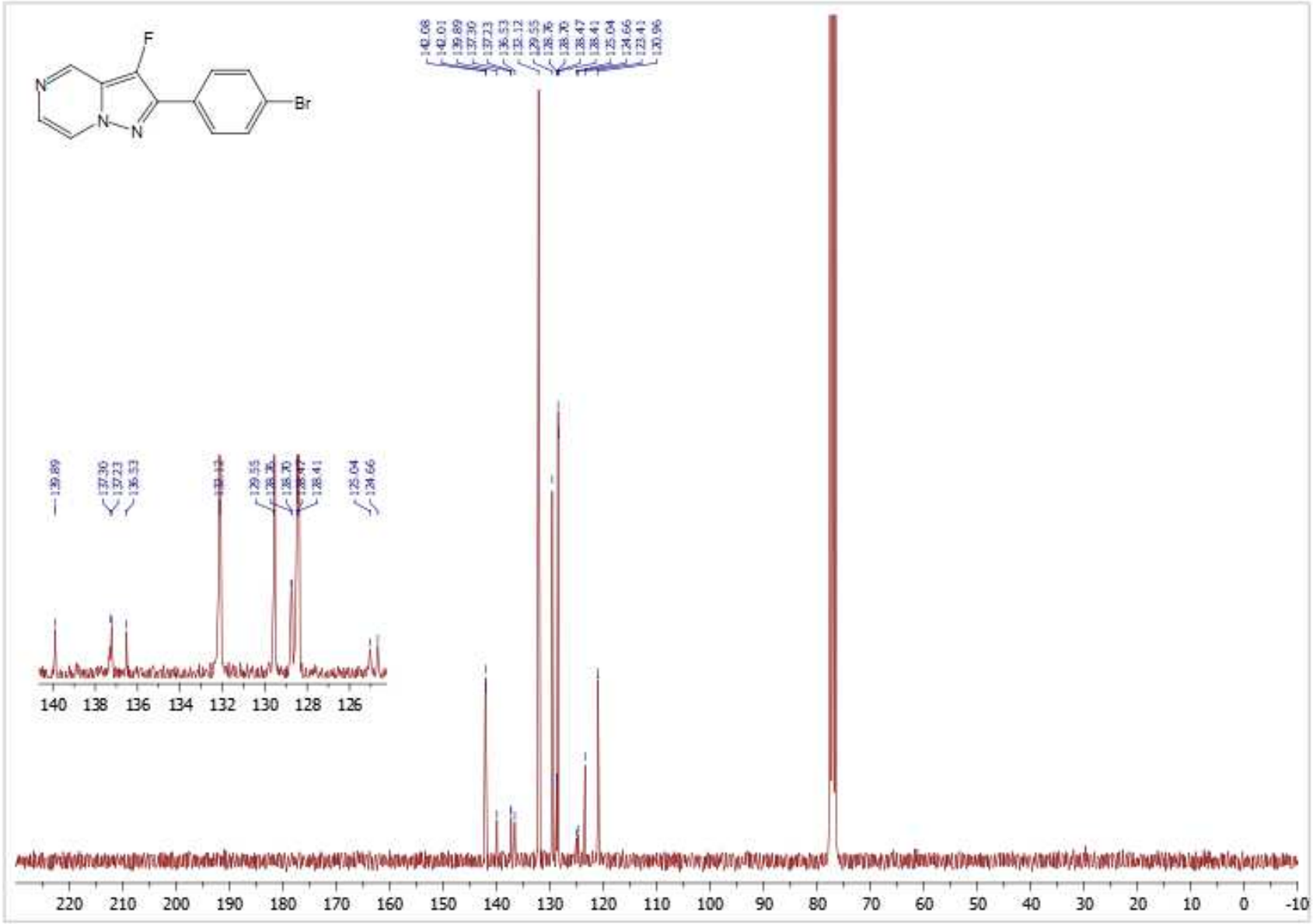

Cl
N
N
O
CH3
90
100
110
120
130
140
150
160
170
180
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0

**2-(4-Bromophenyl)-3-fluoro-pyrazolo[1,5-a]pyrazine 10a**

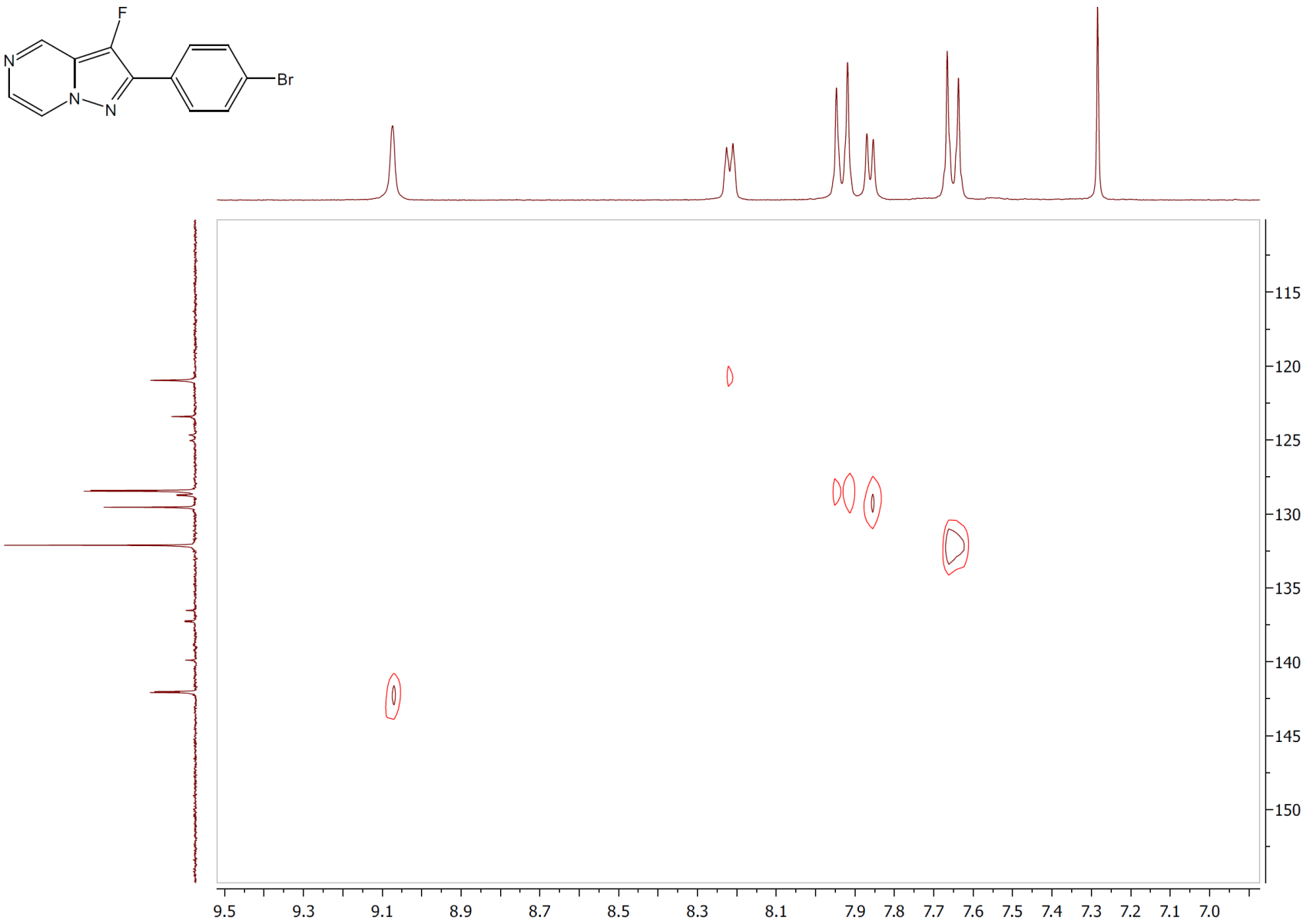
$^{1}$H NMR



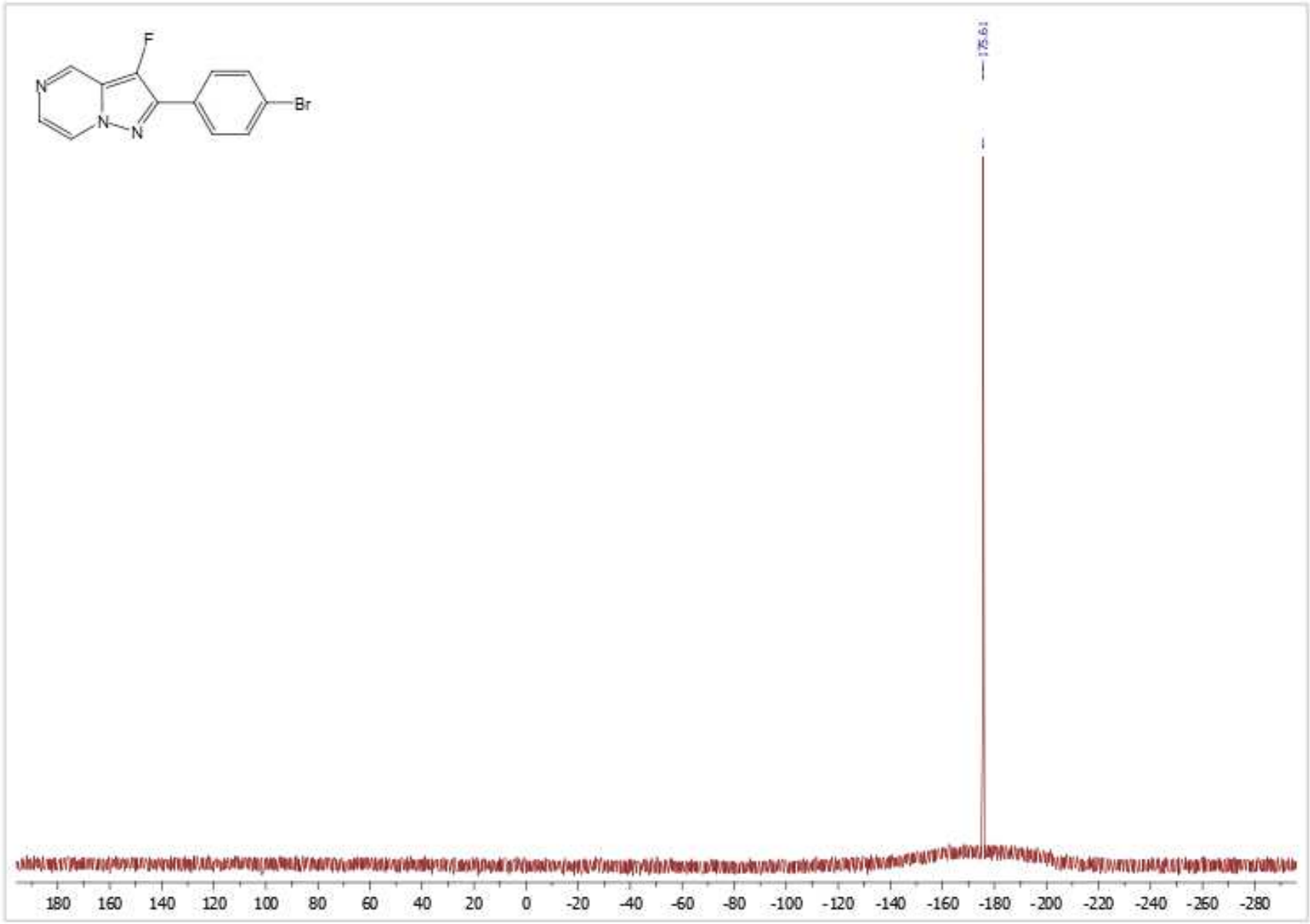
$^{13}$C NMR


F
N
N
N
Br
140.08
140.01
139.89
137.30
137.23
136.53
132.12
129.55
128.76
128.70
128.47
128.41
125.04
124.66
123.41
120.96
139.89
137.30
137.23
136.53
132.12
129.55
128.76
128.70
128.47
128.41
125.04
124.66
140 138 136 134 132 130 128 126
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

$^{1}H$-$^{13}C$ HSQC

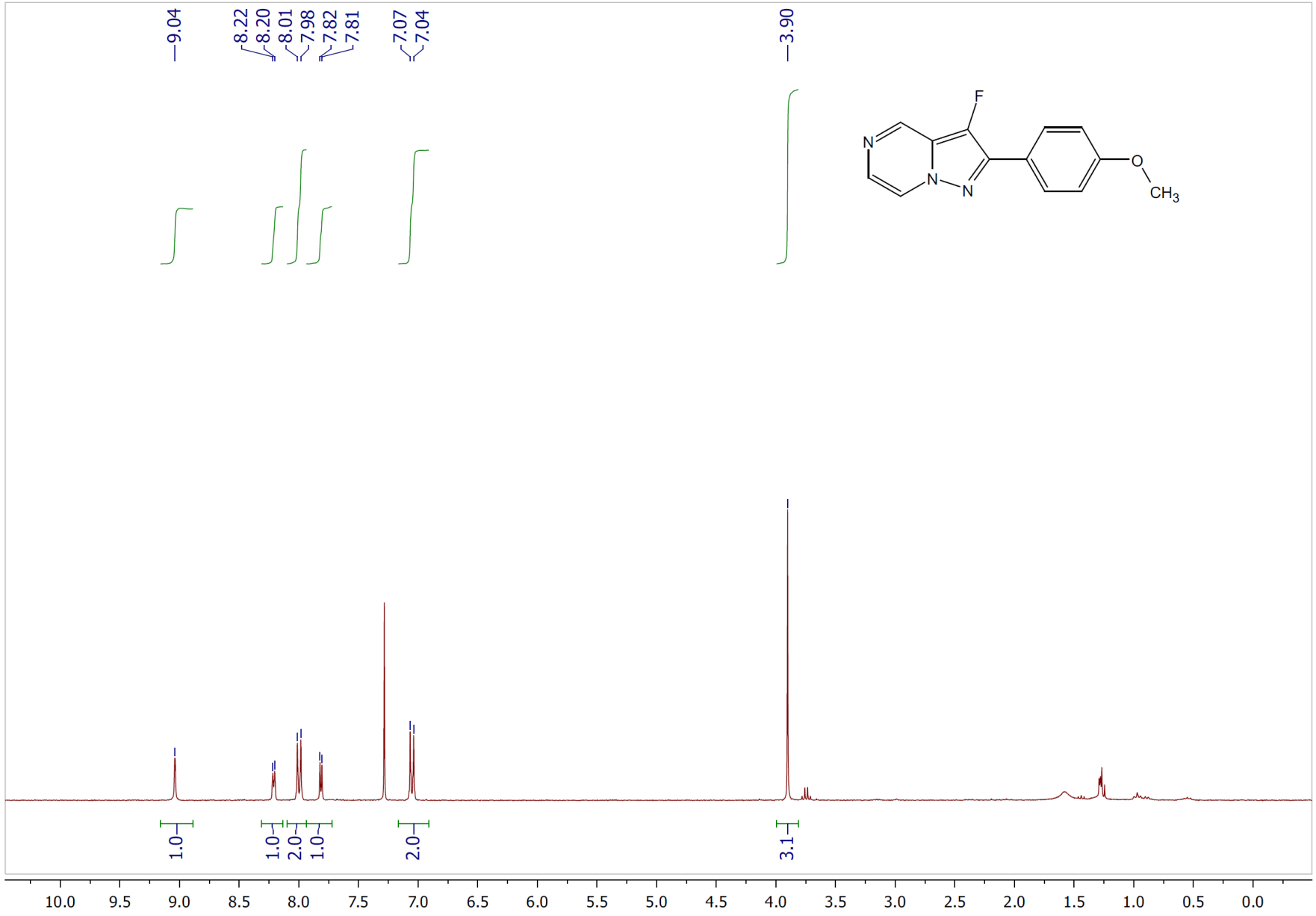

F
N
N
N
Br
115
120
125
130
135
140
145
150
9.5
9.3
9.1
8.9
8.7
8.5
8.3
8.1
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0

$^{19}$F NMR

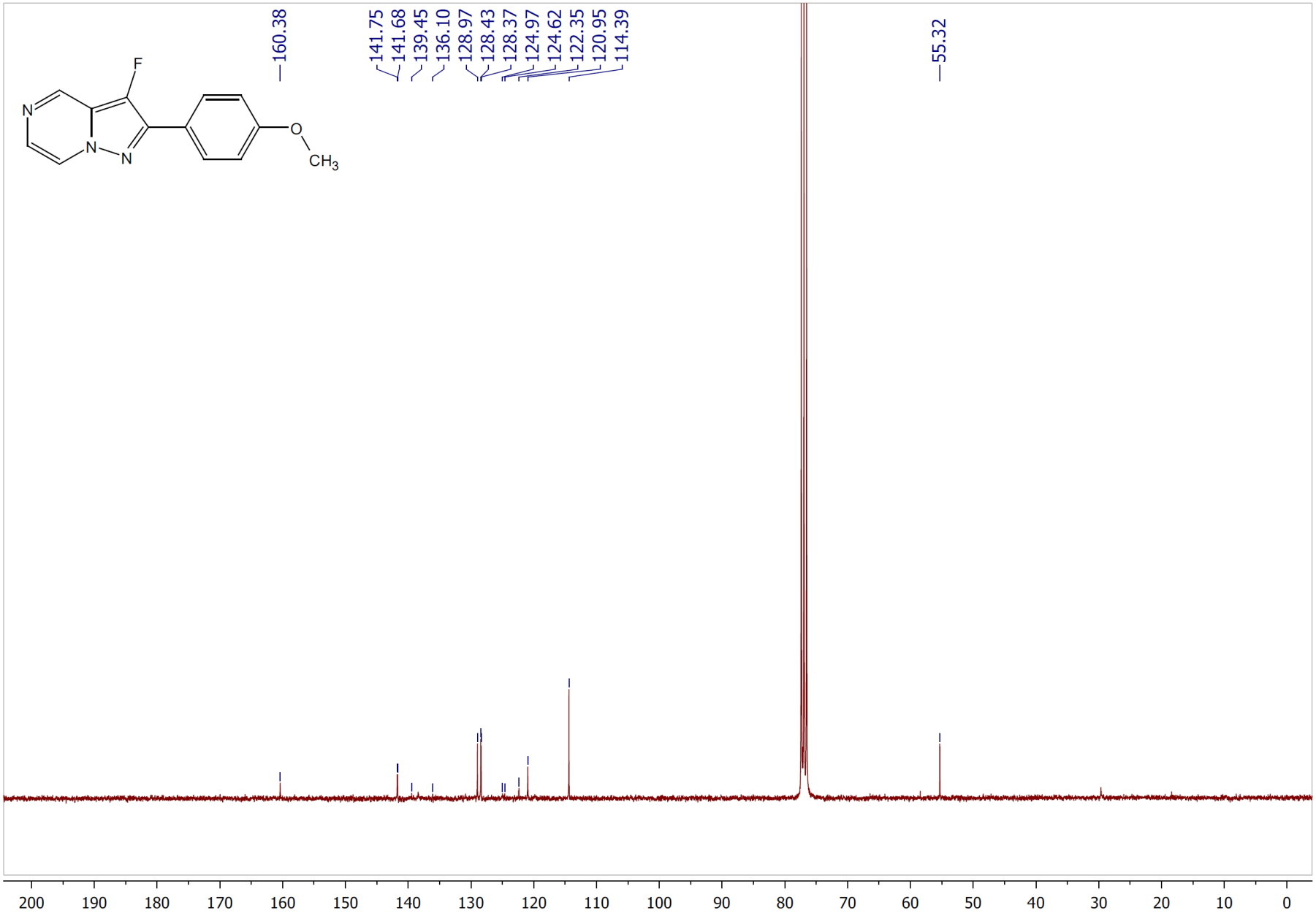

F
N
N
N
Br
-175.61
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**3-Fluoro-2-(4-methoxyphenyl)pyrazolo[1,5-a]pyrazine 10b**

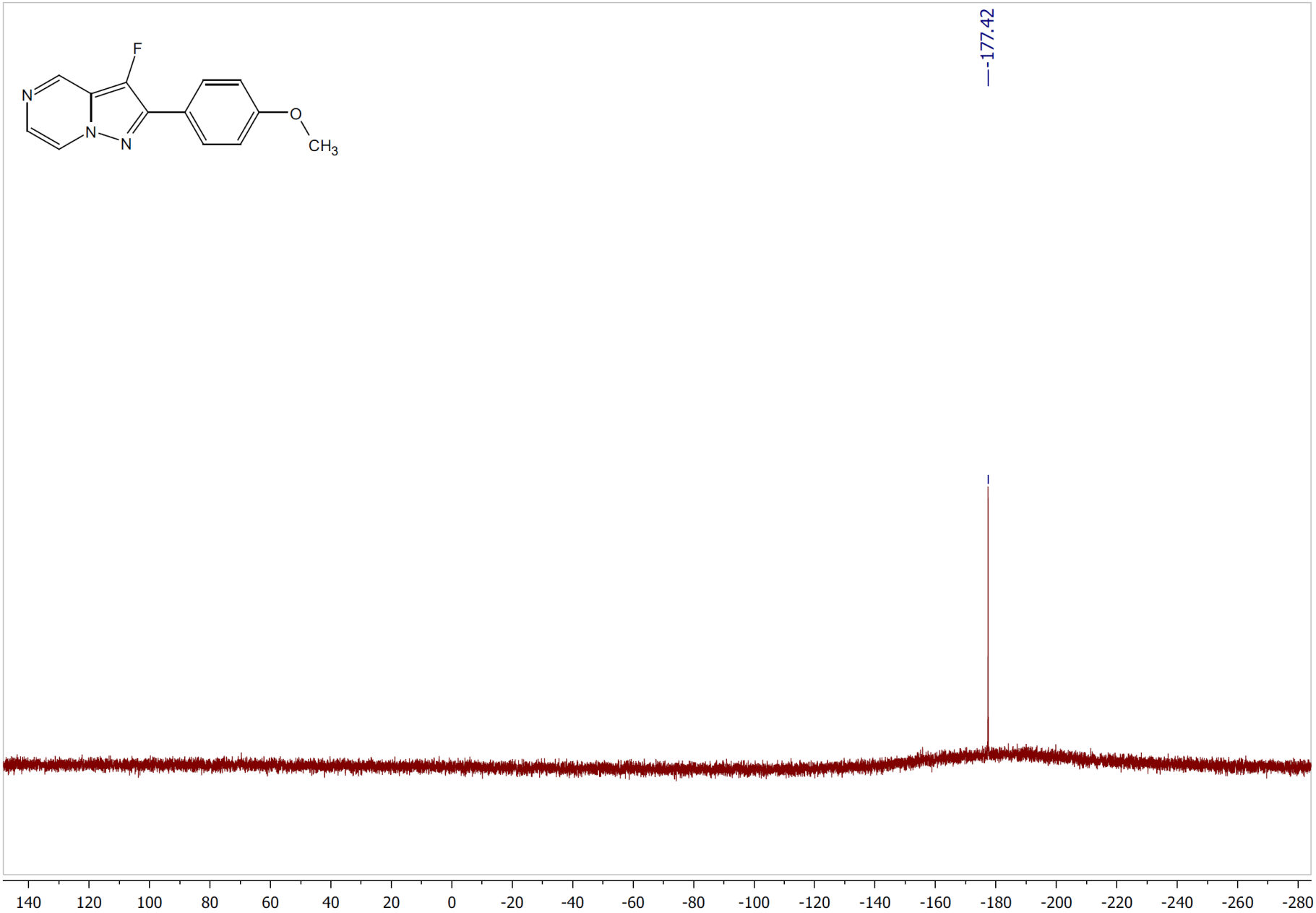
$^{1}$H NMR



$^{13}$C NMR

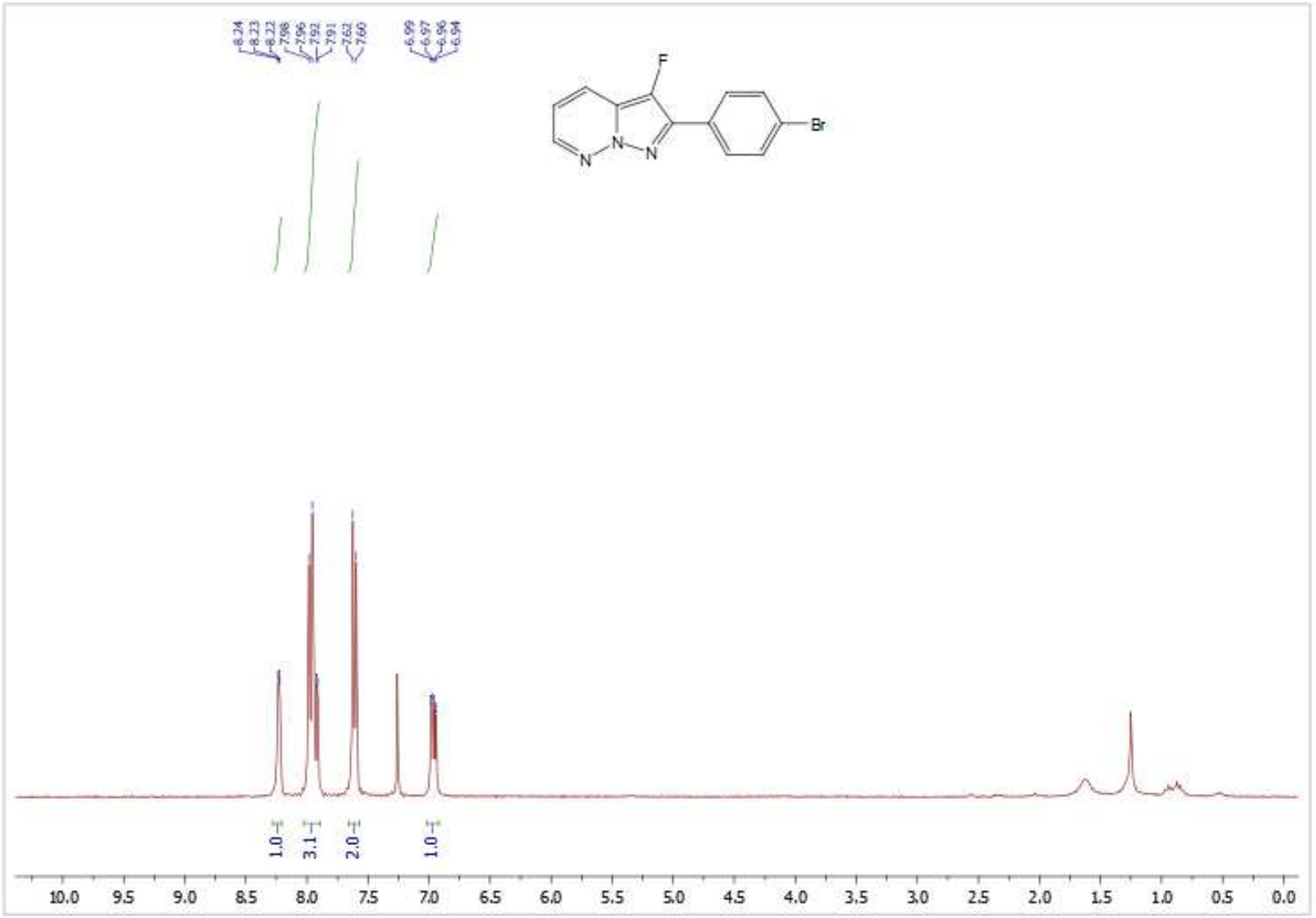

160.38
141.75
141.68
139.45
136.10
128.97
128.43
128.37
124.97
124.62
122.35
120.95
114.39
55.32
F
N
N
N
O
CH3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{19}$F NMR

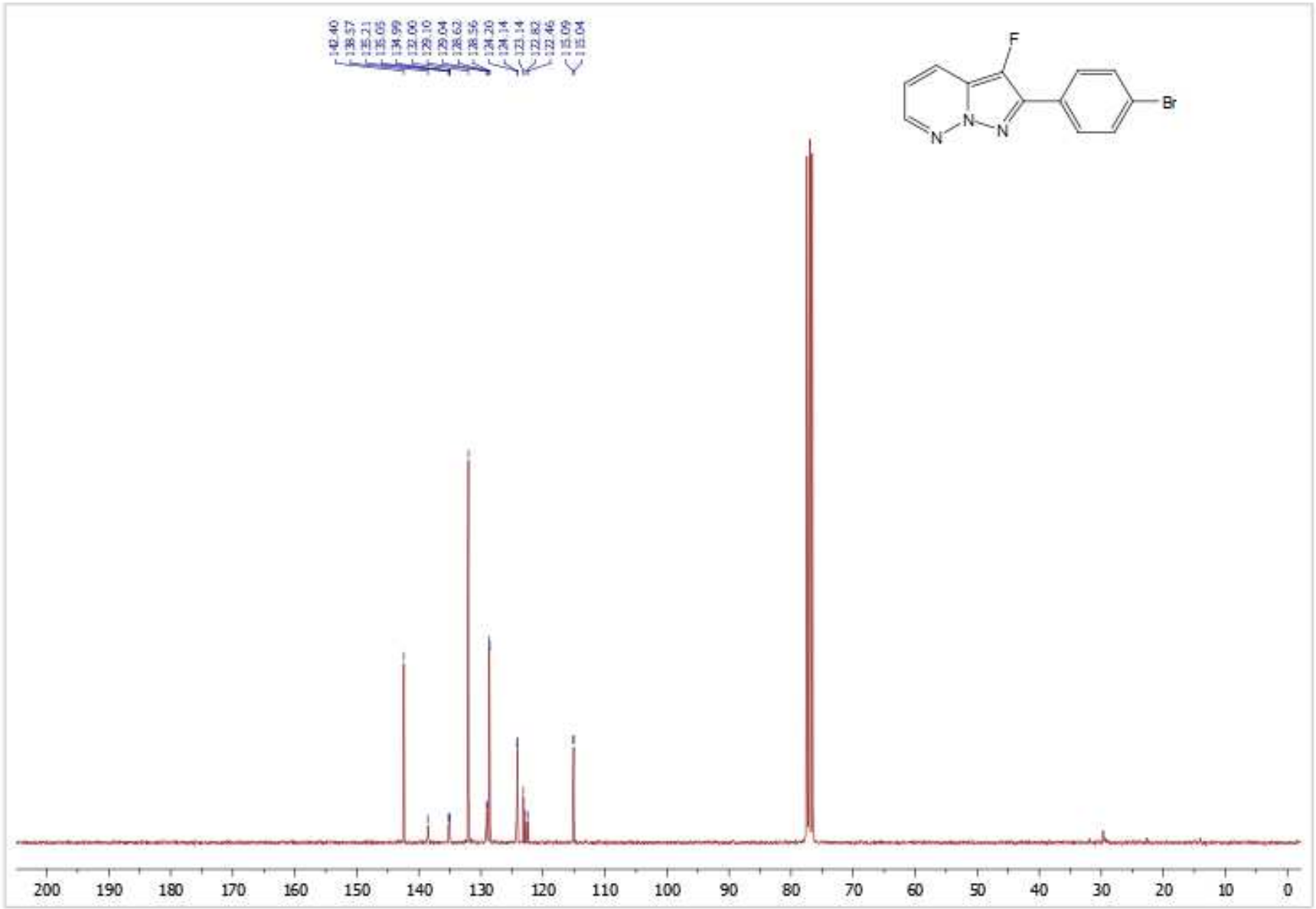

F
N
N
N
O
CH3
-177.42
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280

**2-(4-Bromophenyl)-3-fluoro-pyrazolo[1,5-a]pyridazine 10c**

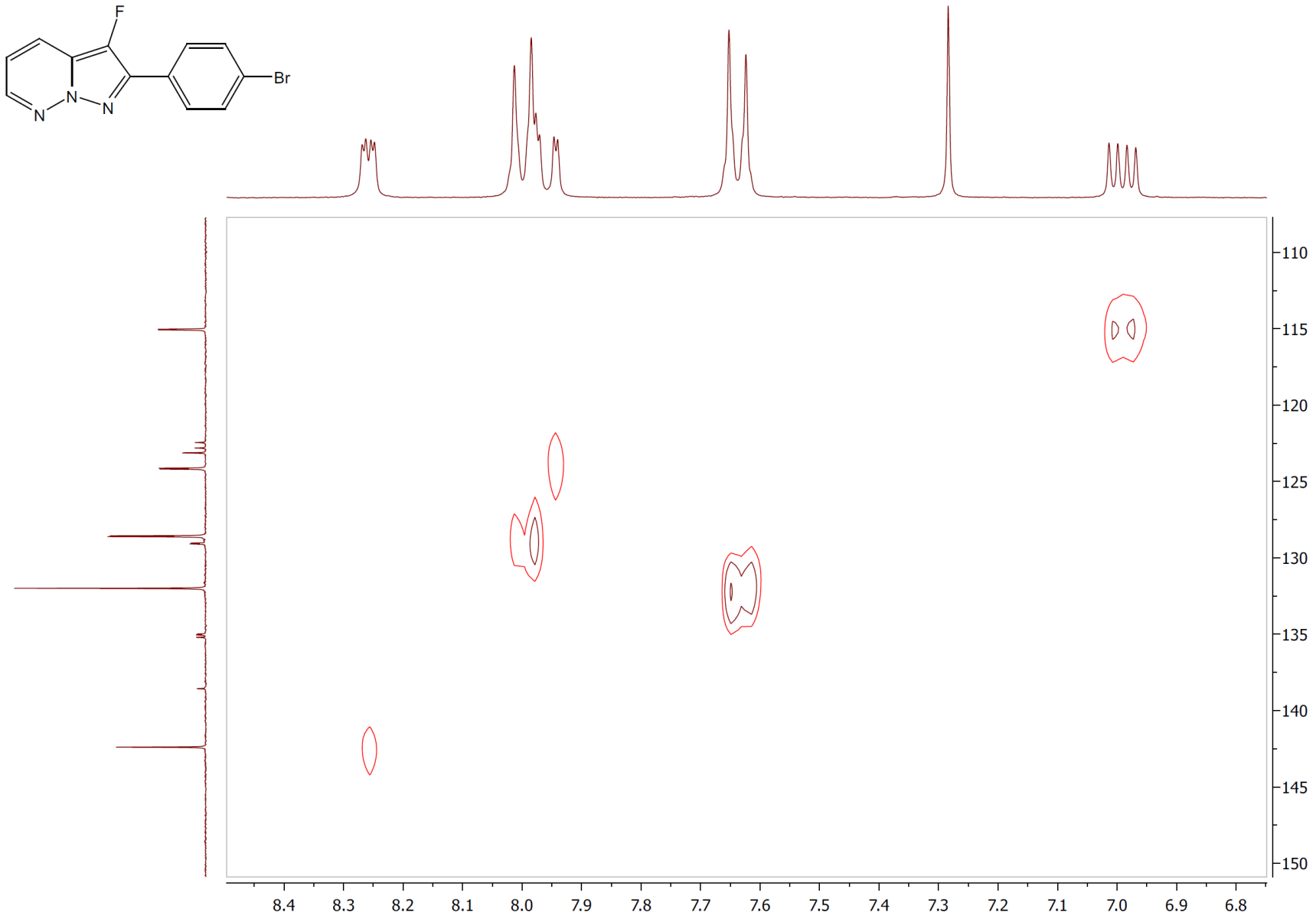
$^{1}$H NMR



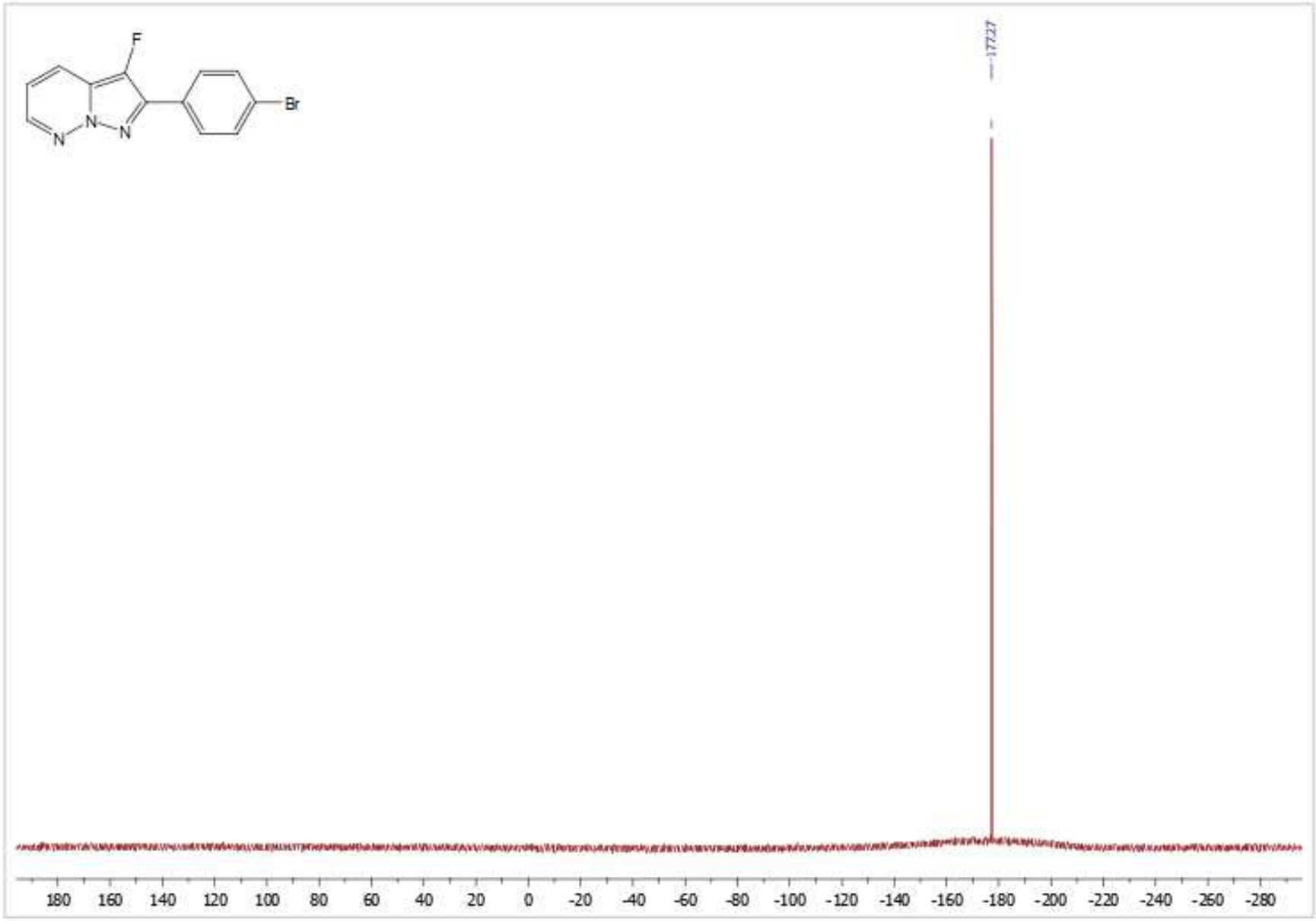
$^{13}$C NMR


142.40
138.57
135.21
135.05
134.99
132.60
129.10
129.04
128.62
128.56
124.20
124.14
123.14
122.82
122.46
115.09
115.04
F
Br
N
N
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC

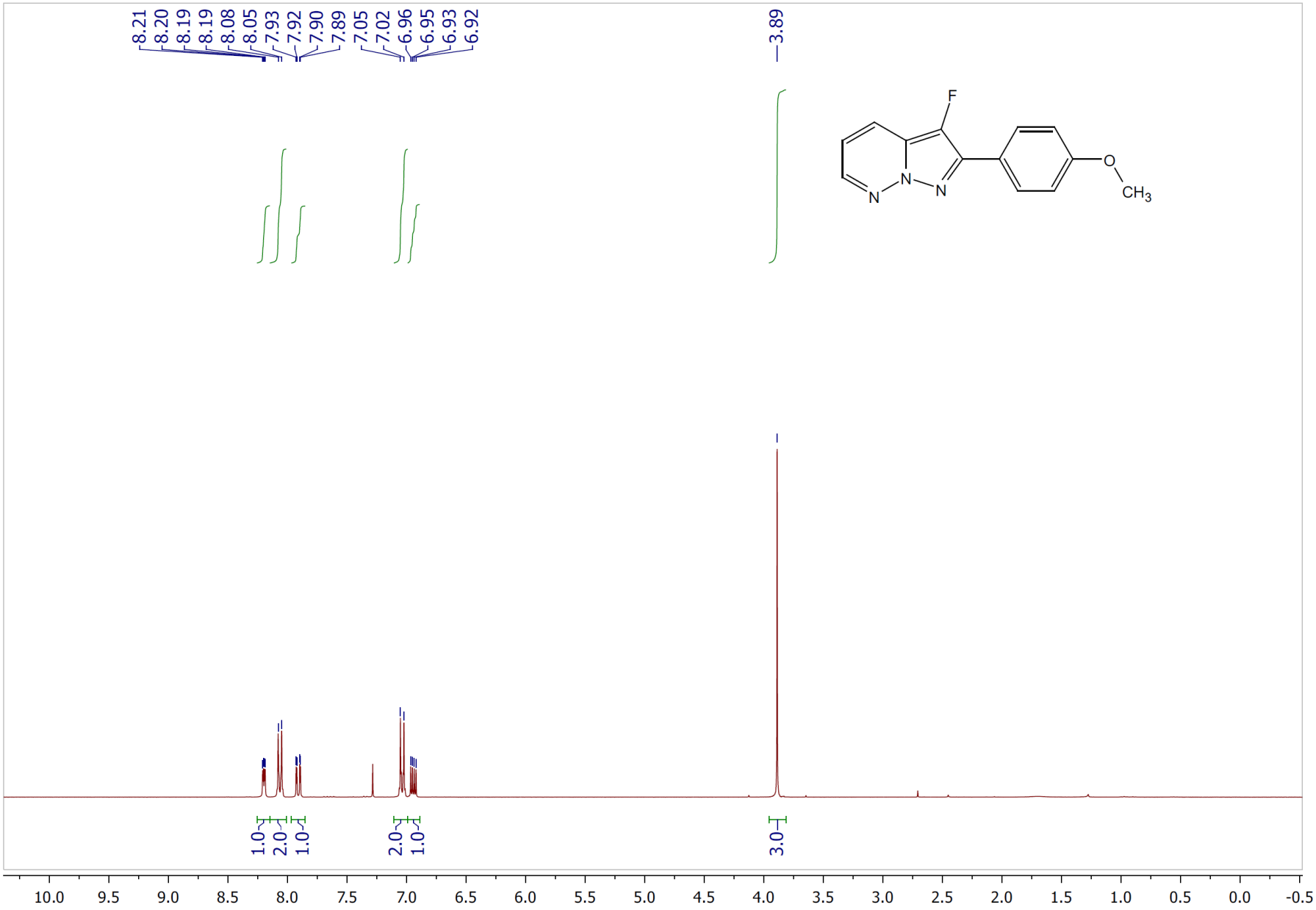

F
Br
N
N
N
110
115
120
125
130
135
140
145
150
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8

$^{19}$F NMR

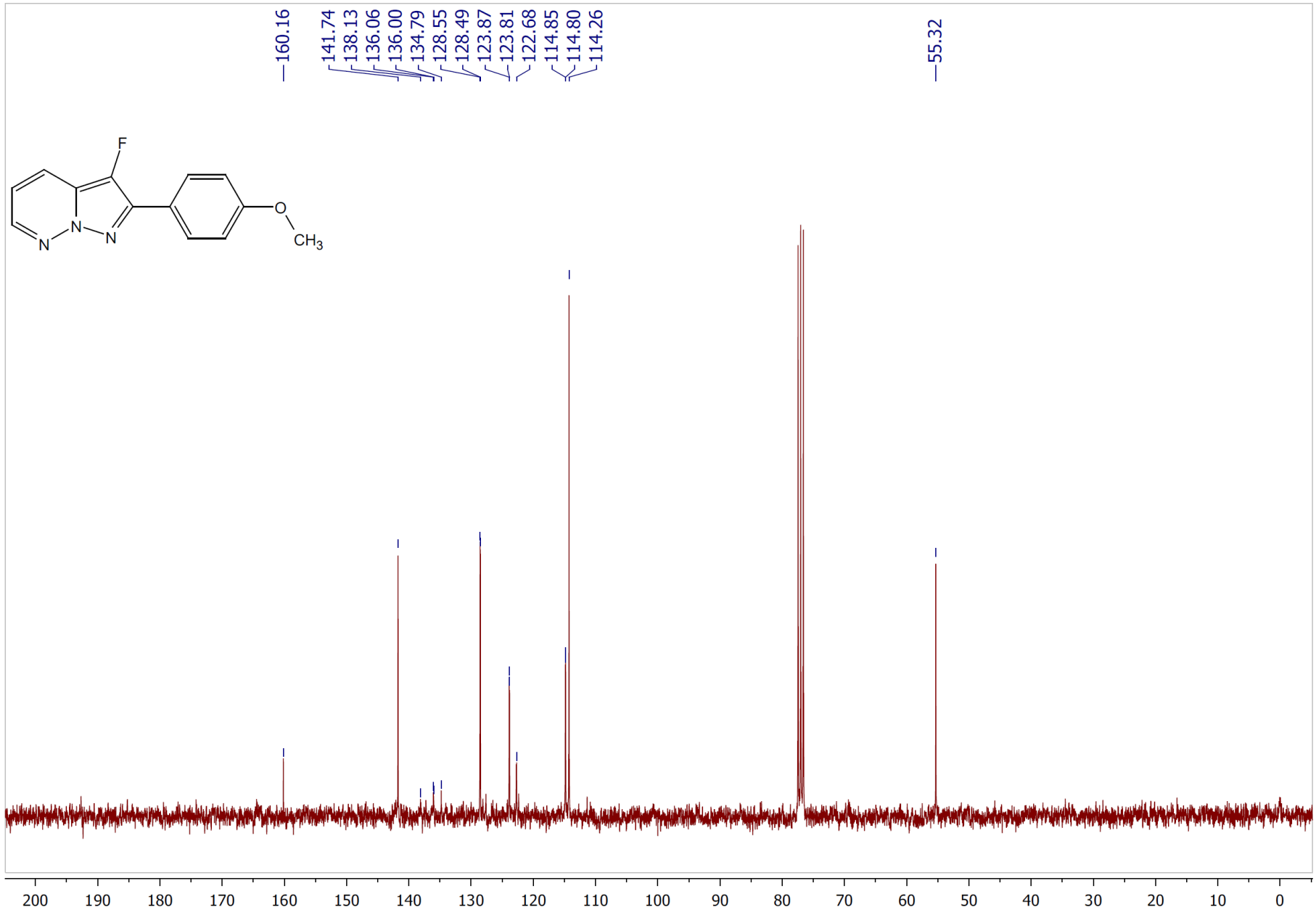

F
Br
N
N
N
-177.27
180 160 140 120 100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280

**3-Fluoro-2-(4-methoxyphenyl)pyrazolo[1,5-b]pyridazine 10d**

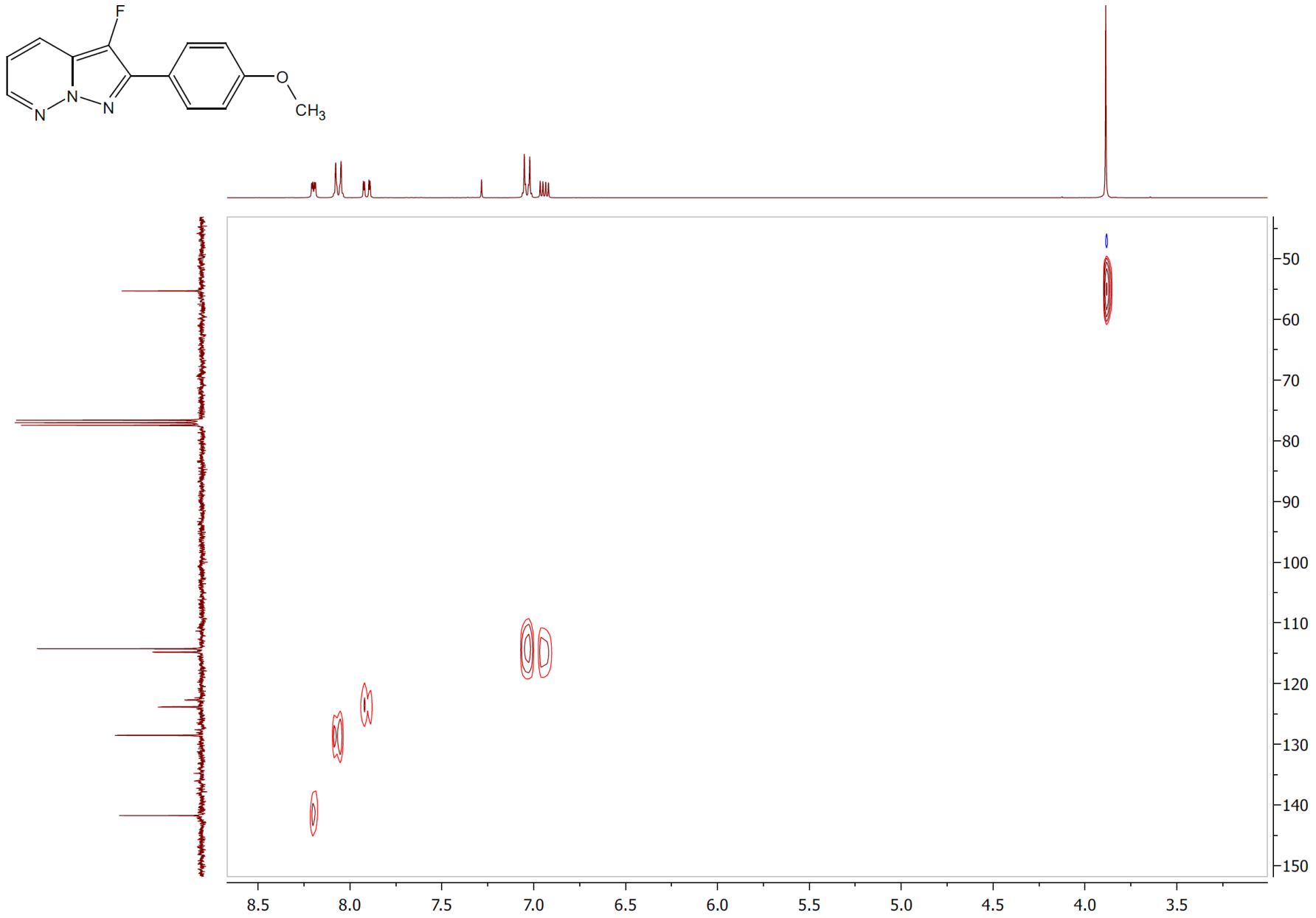
$^{1}$H NMR



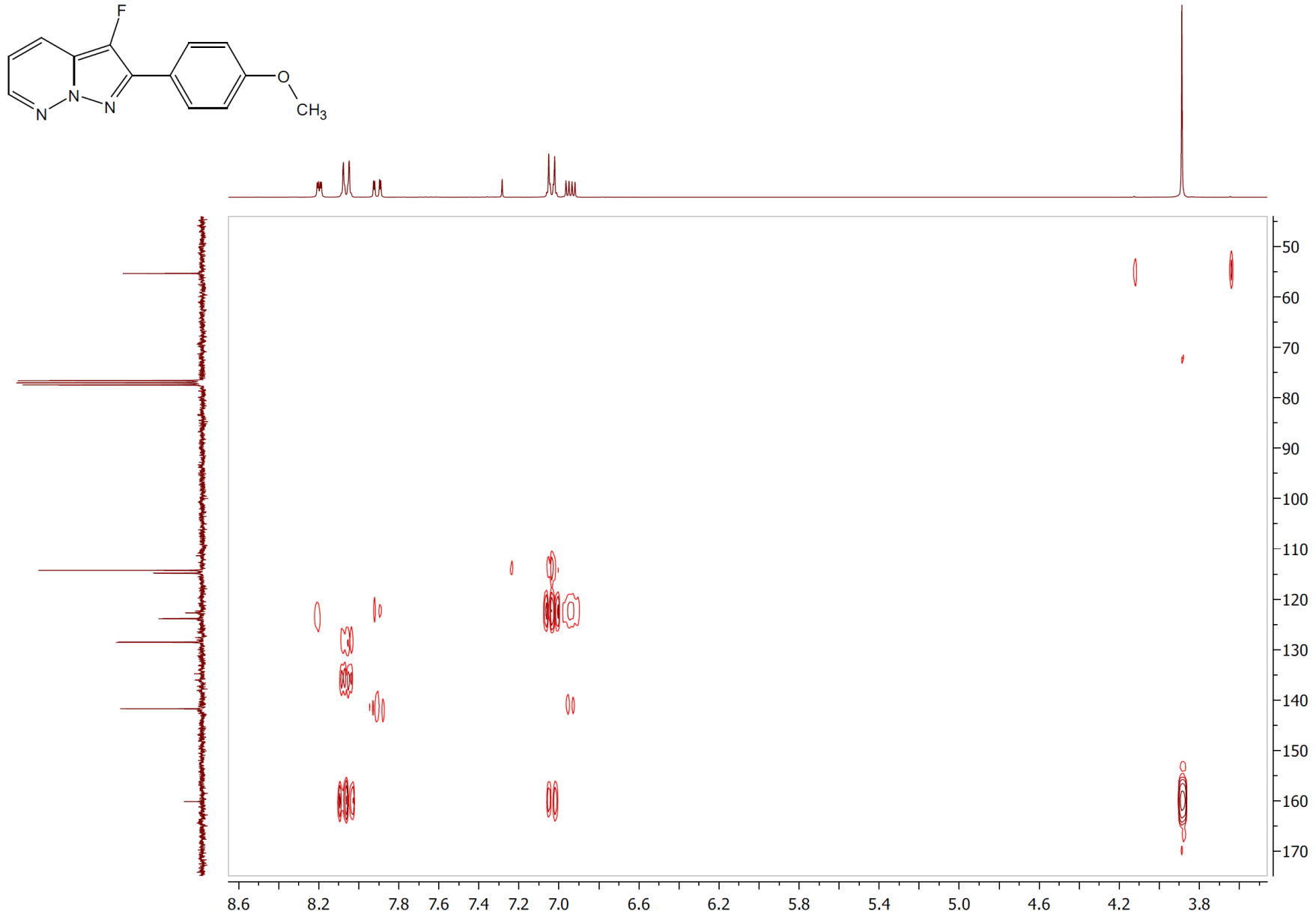
$^{13}$C NMR


160.16
141.74
138.13
136.06
136.00
134.79
128.55
128.49
123.87
123.81
122.68
114.85
114.80
114.26
55.32
F
N
N
N
O
CH3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

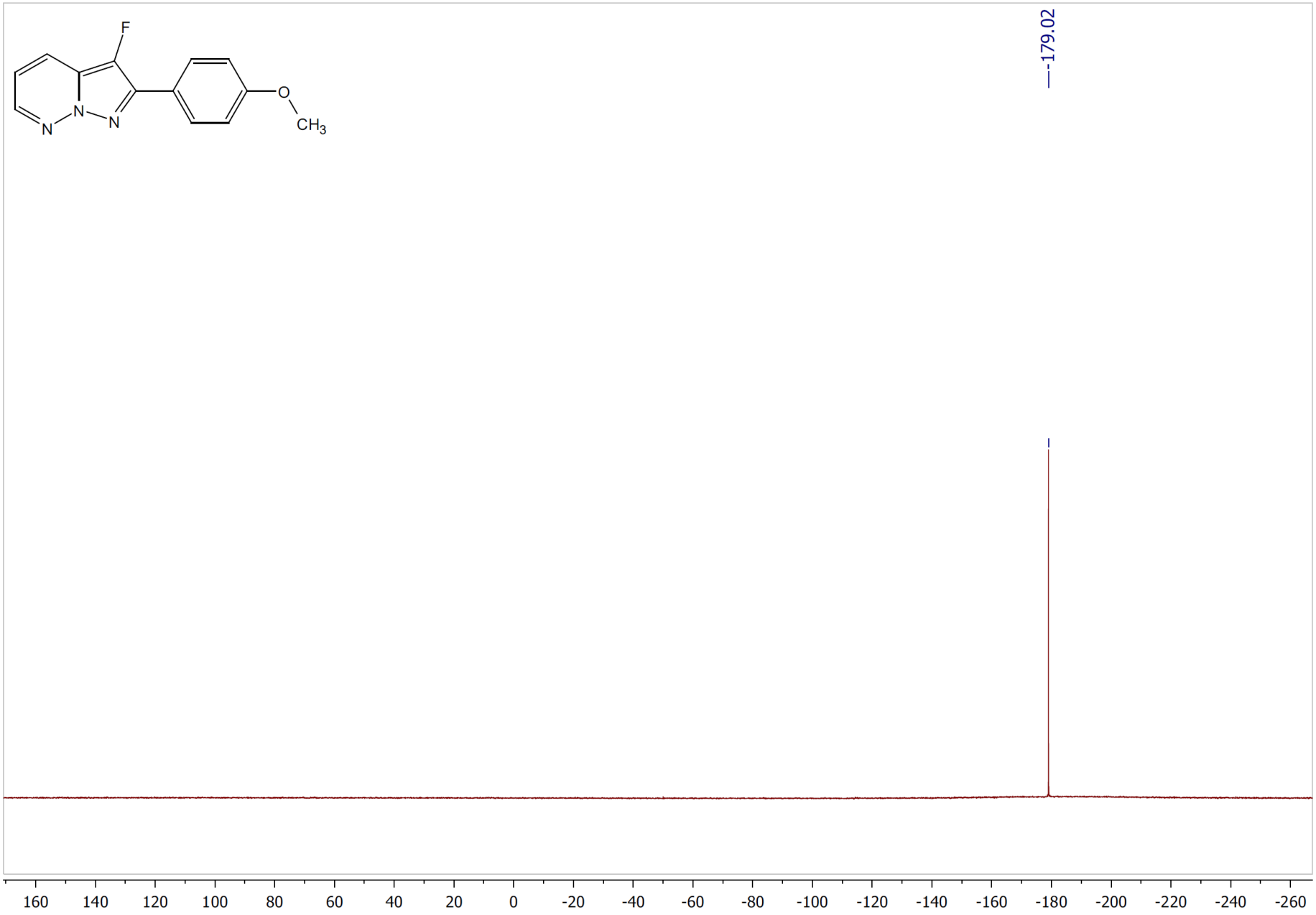
$^{1}H$-$^{13}C$ HSQC


F
N
N
N
O
CH3
50
60
70
80
90
100
110
120
130
140
150
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5

$^{1}H$-$^{13}C$ HMBC

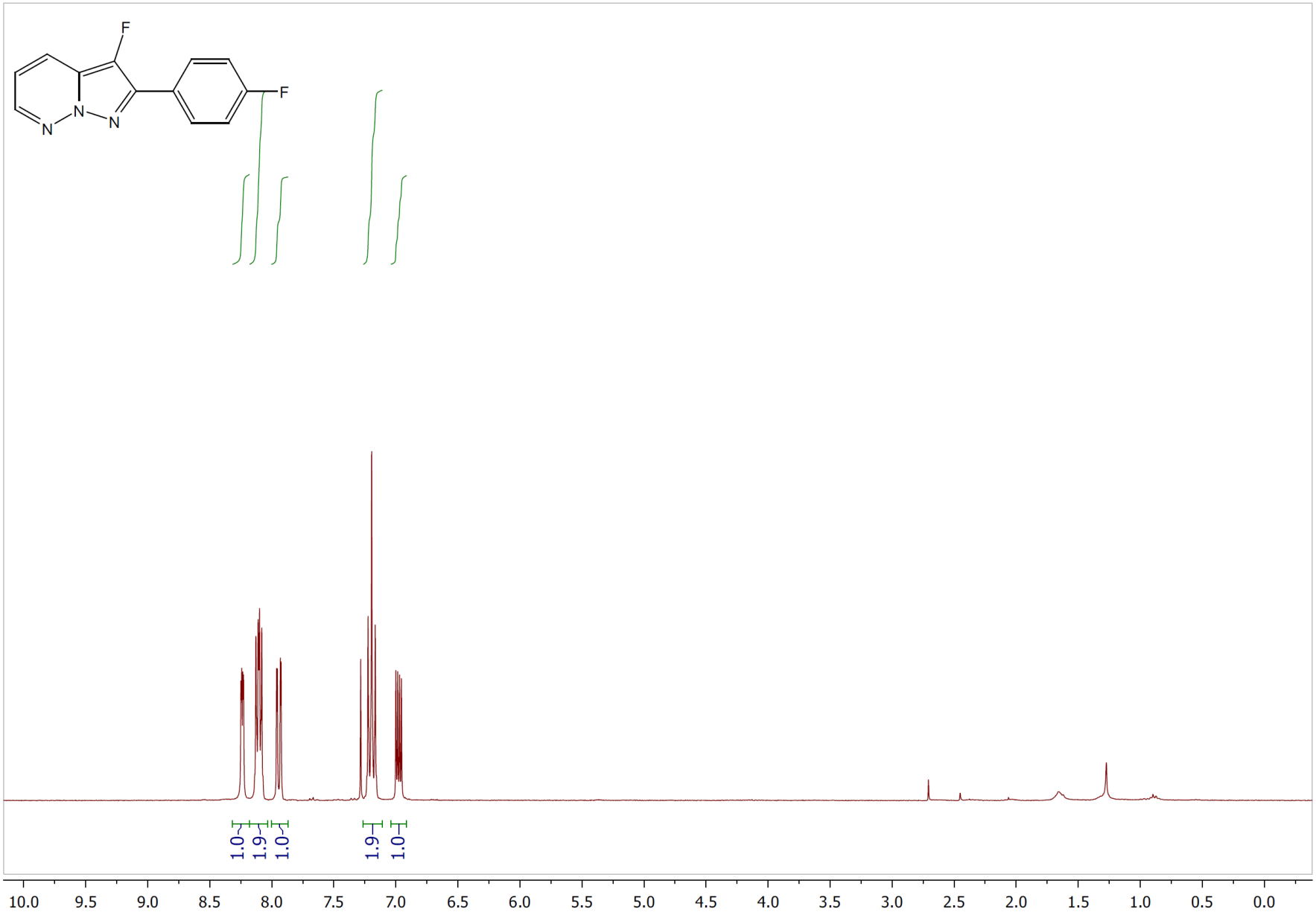

F
N
N
N
O
CH3
50
60
70
80
90
100
110
120
130
140
150
160
170
8.6
8.2
7.8
7.6
7.4
7.2
7.0
6.6
6.2
5.8
5.4
5.0
4.6
4.2
3.8

$^{19}$F NMR

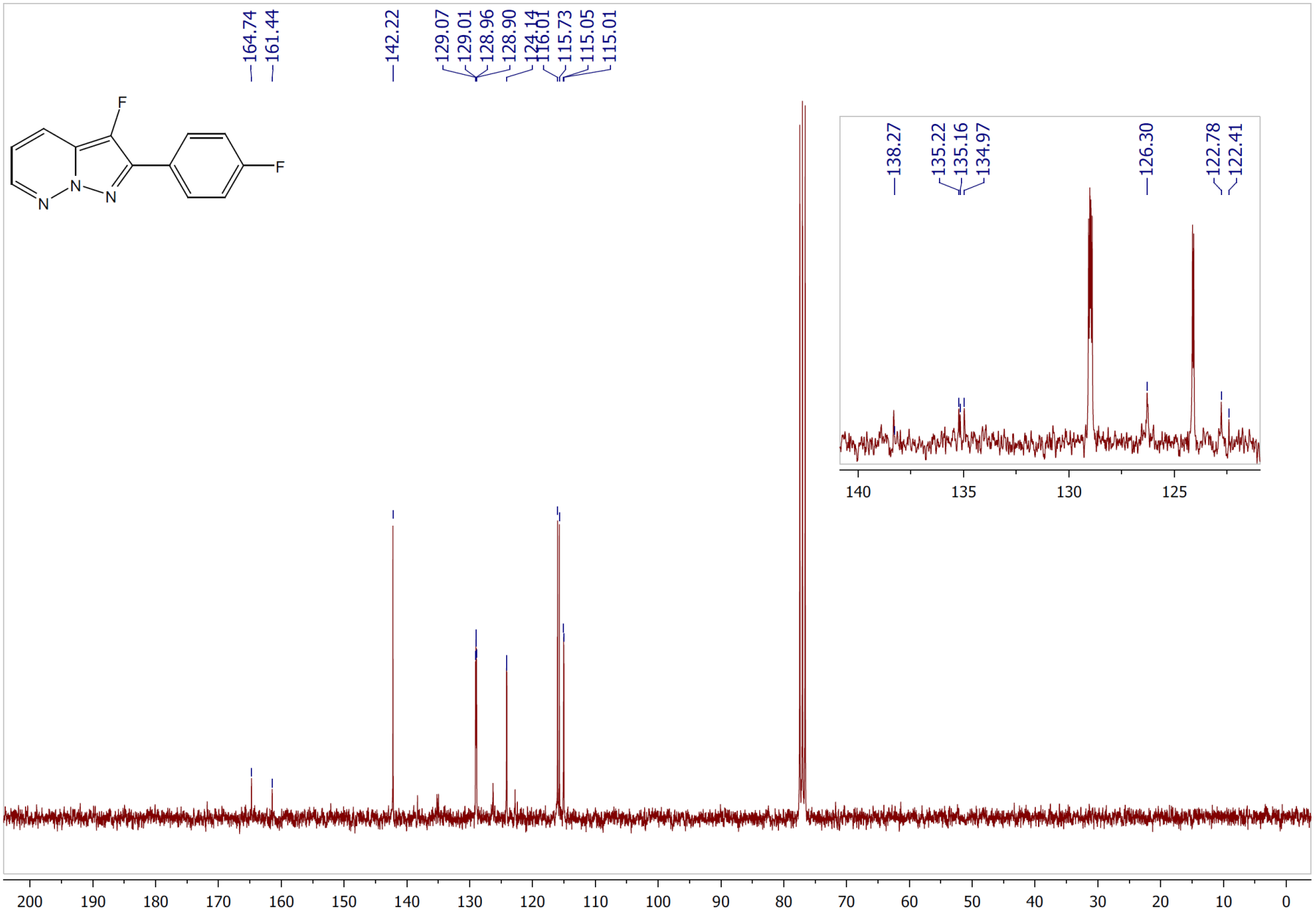

F
N
N
N
O
CH3
-179.02
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260

**3-Fluoro-2-(4-fluorophenyl)pyrazolo[1,5-b]pyridazine 10e**

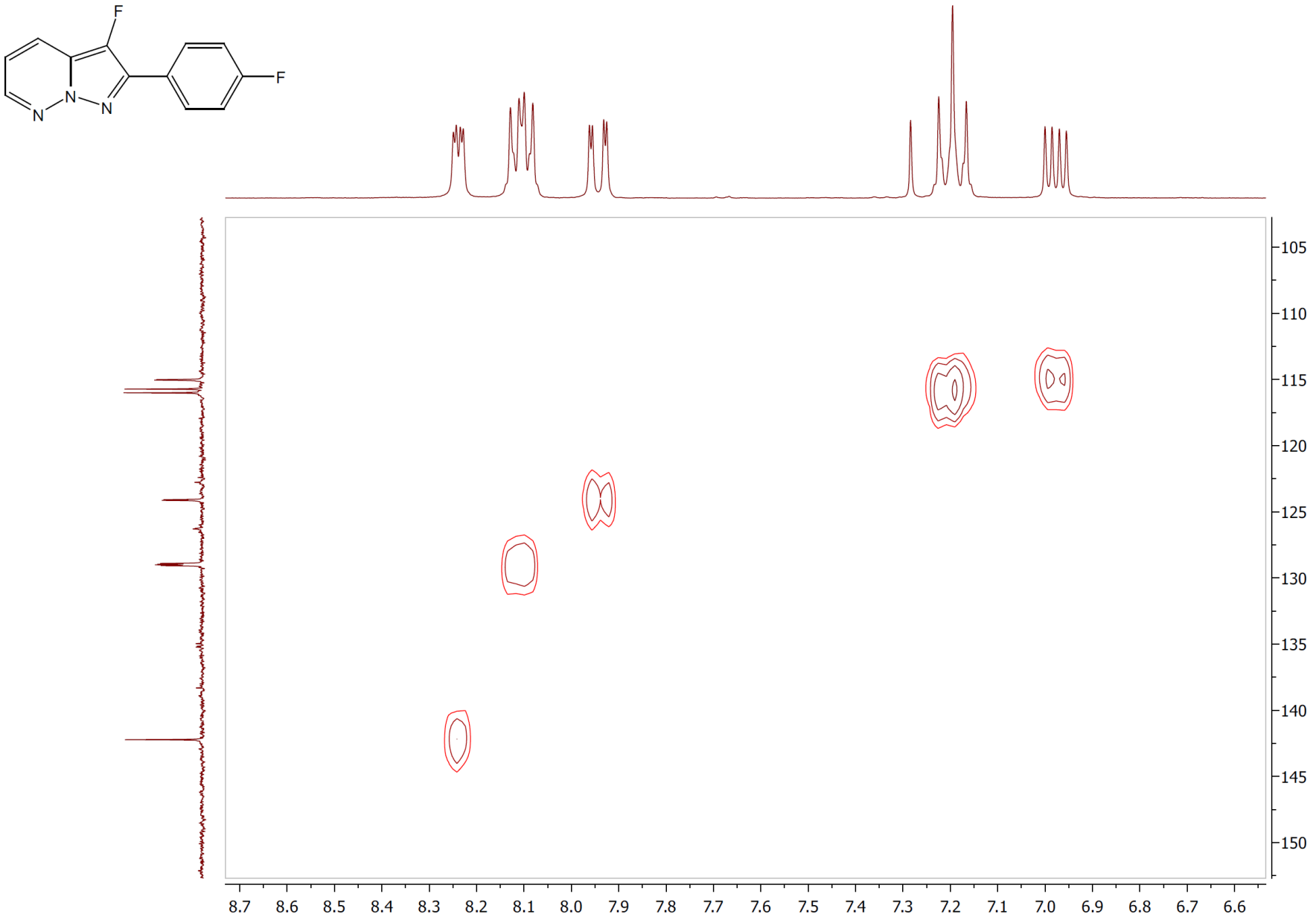
$^{1}$H NMR



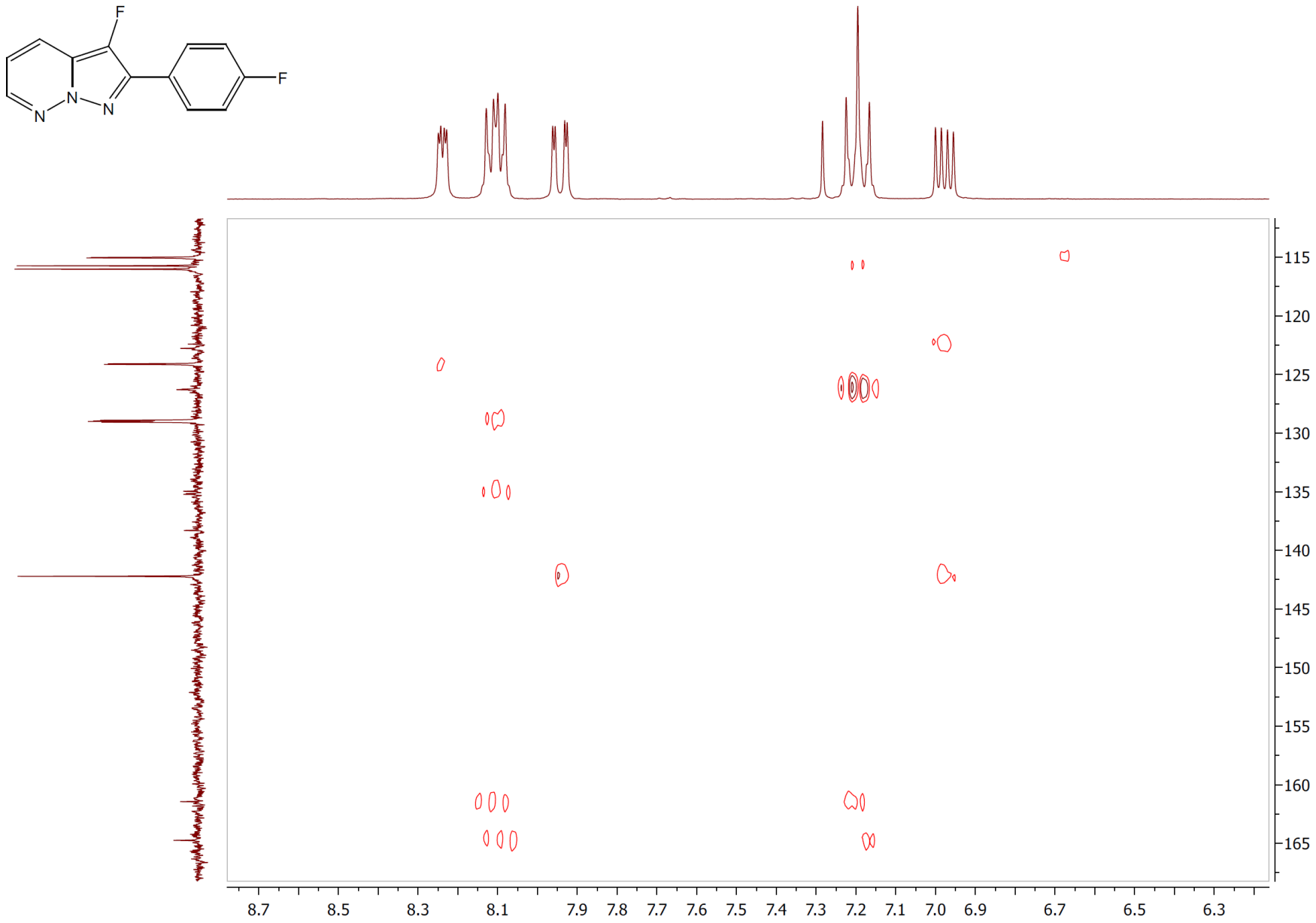
$^{13}$C NMR


164.74
161.44
142.22
129.07
129.01
128.96
128.90
124.14
116.01
115.73
115.05
115.01
F
F
N
N
N
138.27
135.22
135.16
134.97
126.30
122.78
122.41
140
135
130
125
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

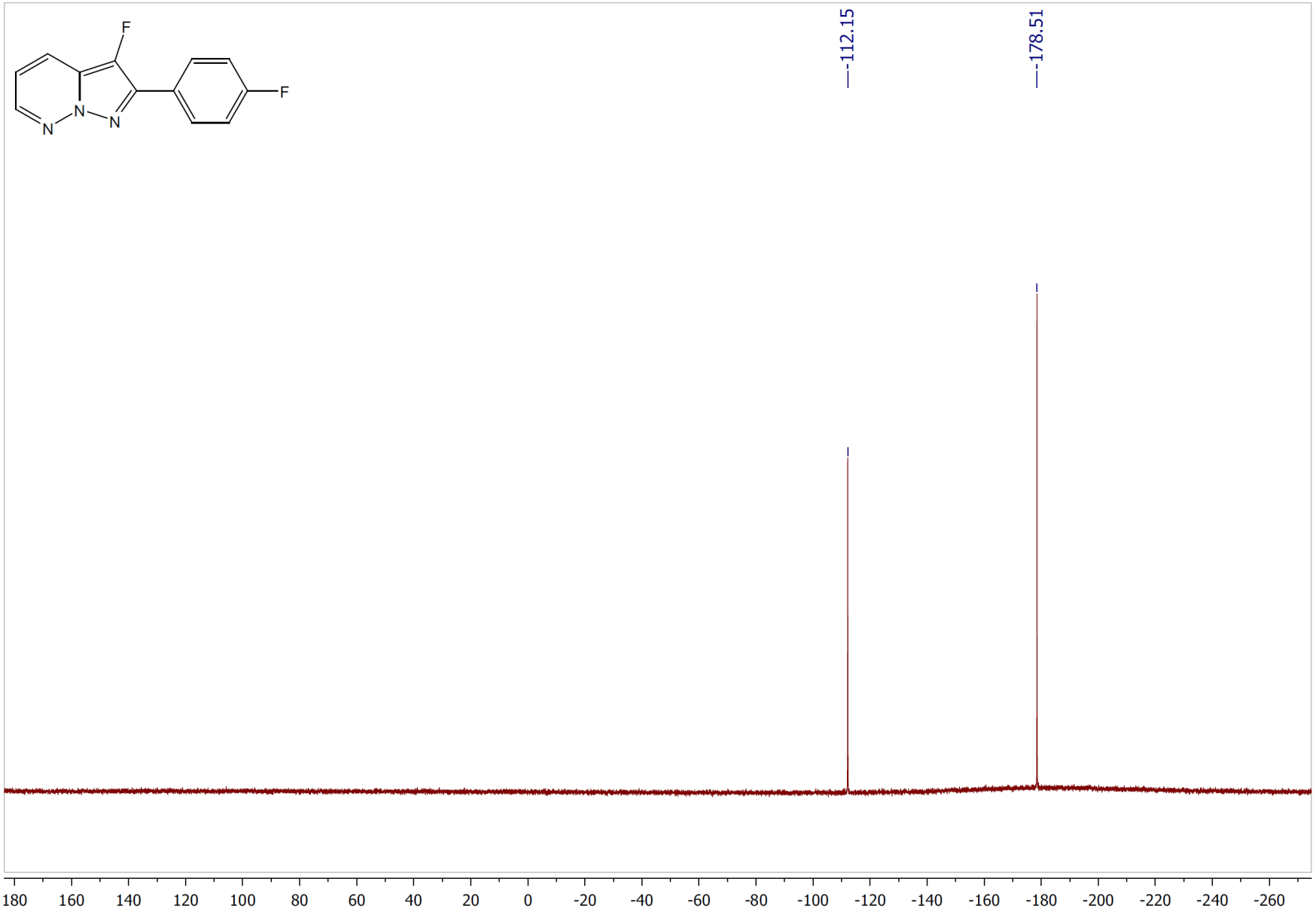
$^{1}H$-$^{13}C$ HSQC


F
F
N
N
N
105
110
115
120
125
130
135
140
145
150
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
6.6

$^{1}H$-$^{13}C$ HMBC

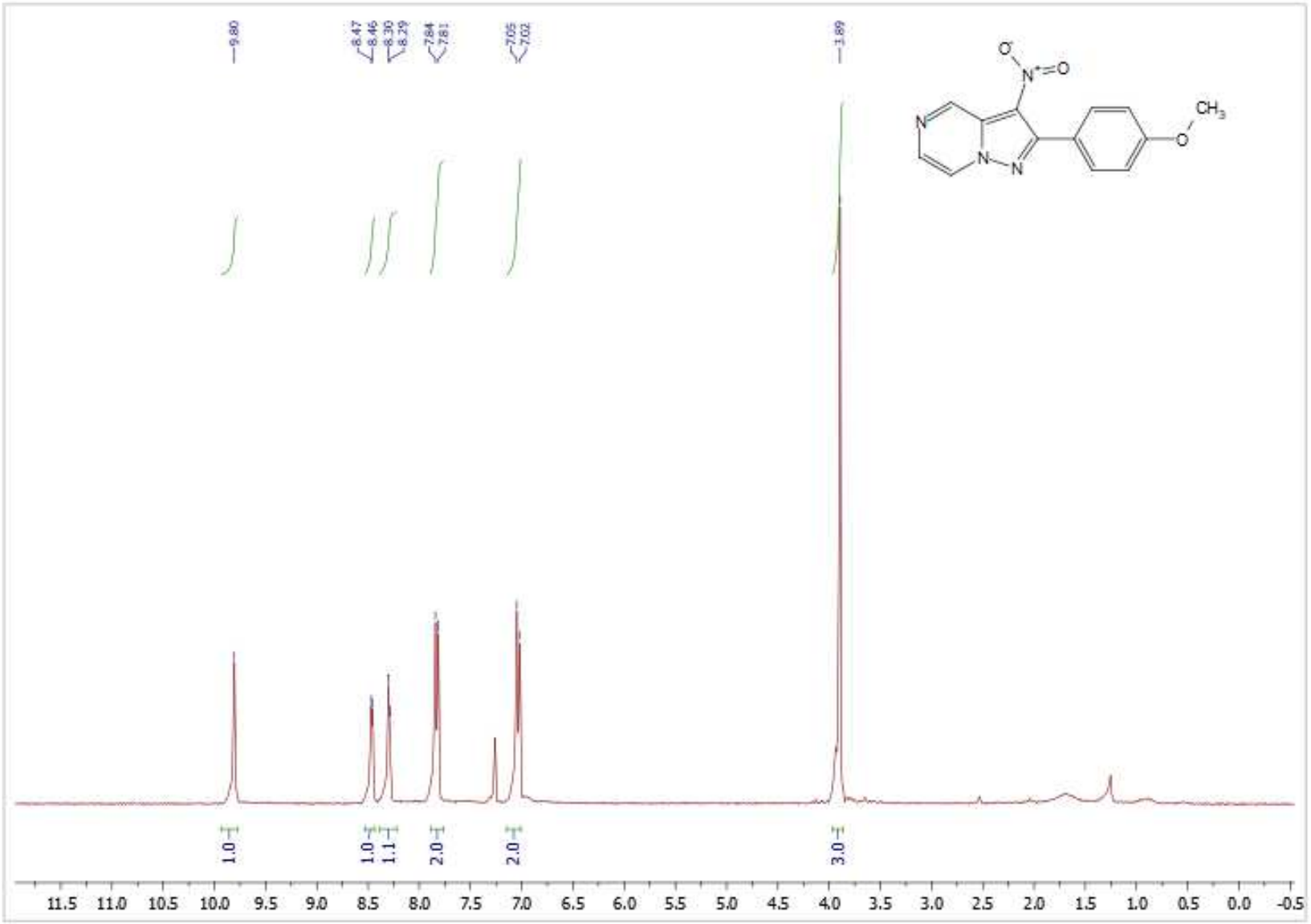

F
F
N
N
N
115
120
125
130
135
140
145
150
155
160
165
8.7
8.5
8.3
8.1
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.7
6.5
6.3

$^{19}$F NMR

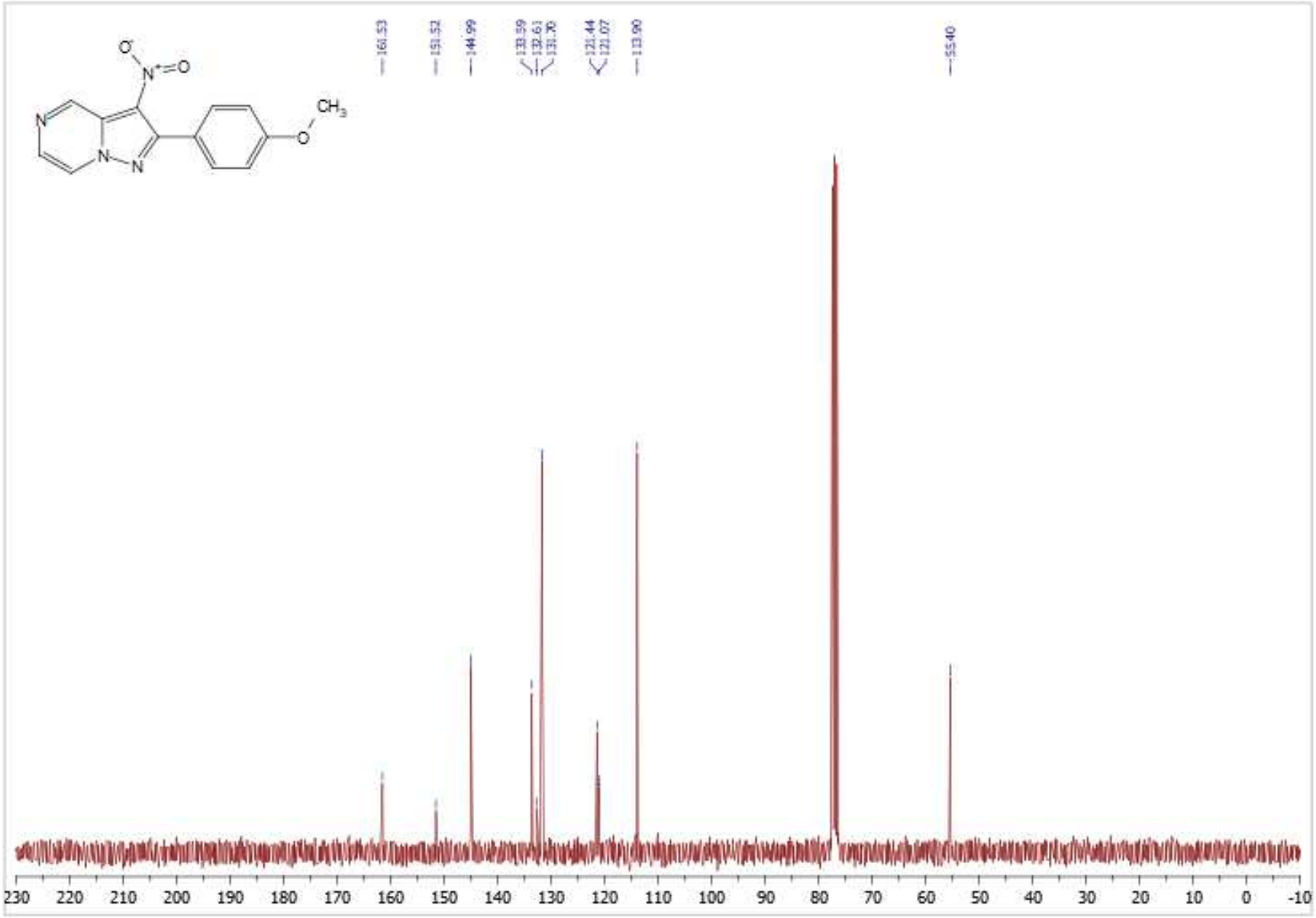

F
F
N
N
N
-112.15
-178.51
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260

**2-(4-Methoxyphenyl)-3-nitro-pyrazolo[1,5-a]pyrazine 11a**

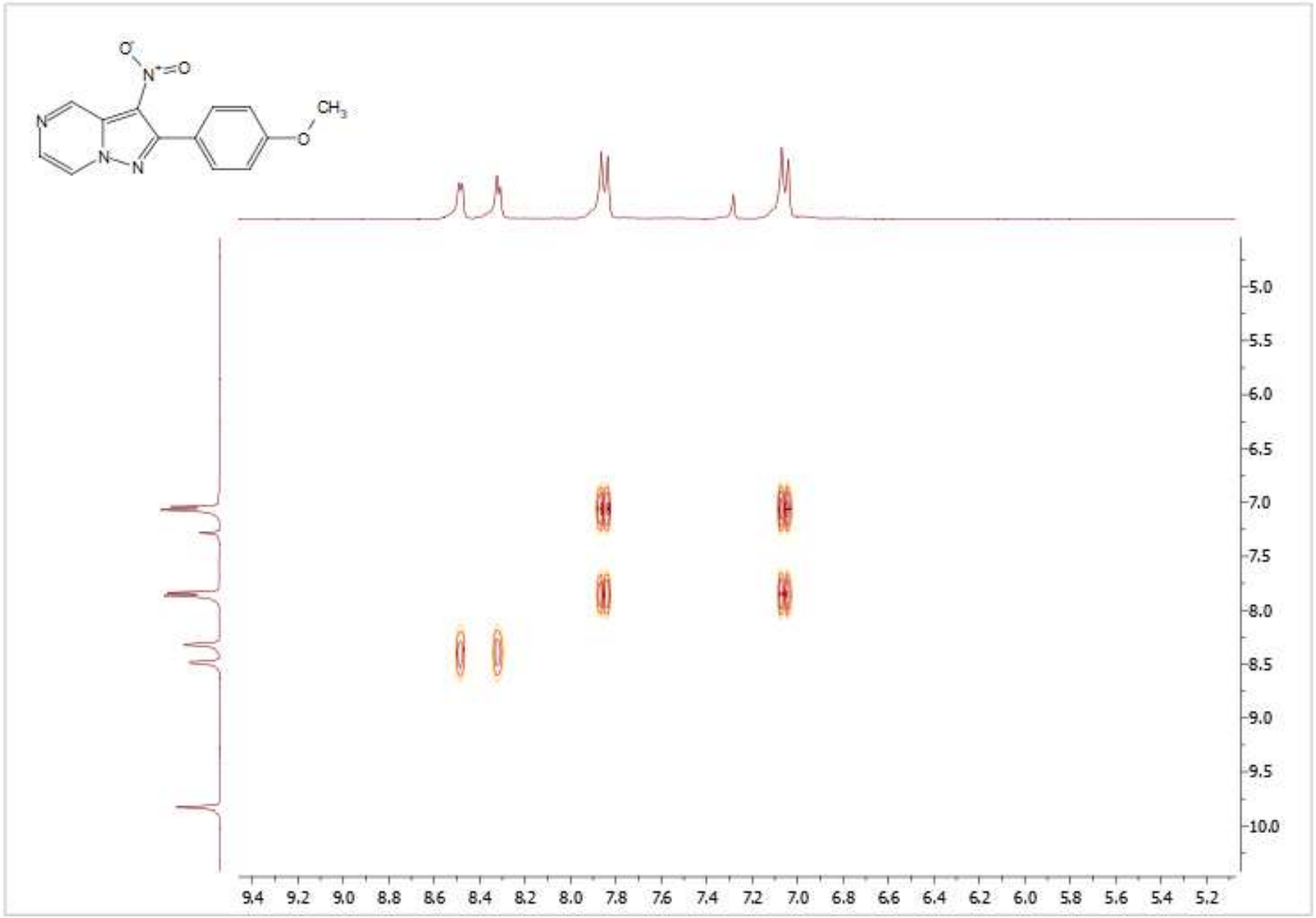
$^{1}$H NMR



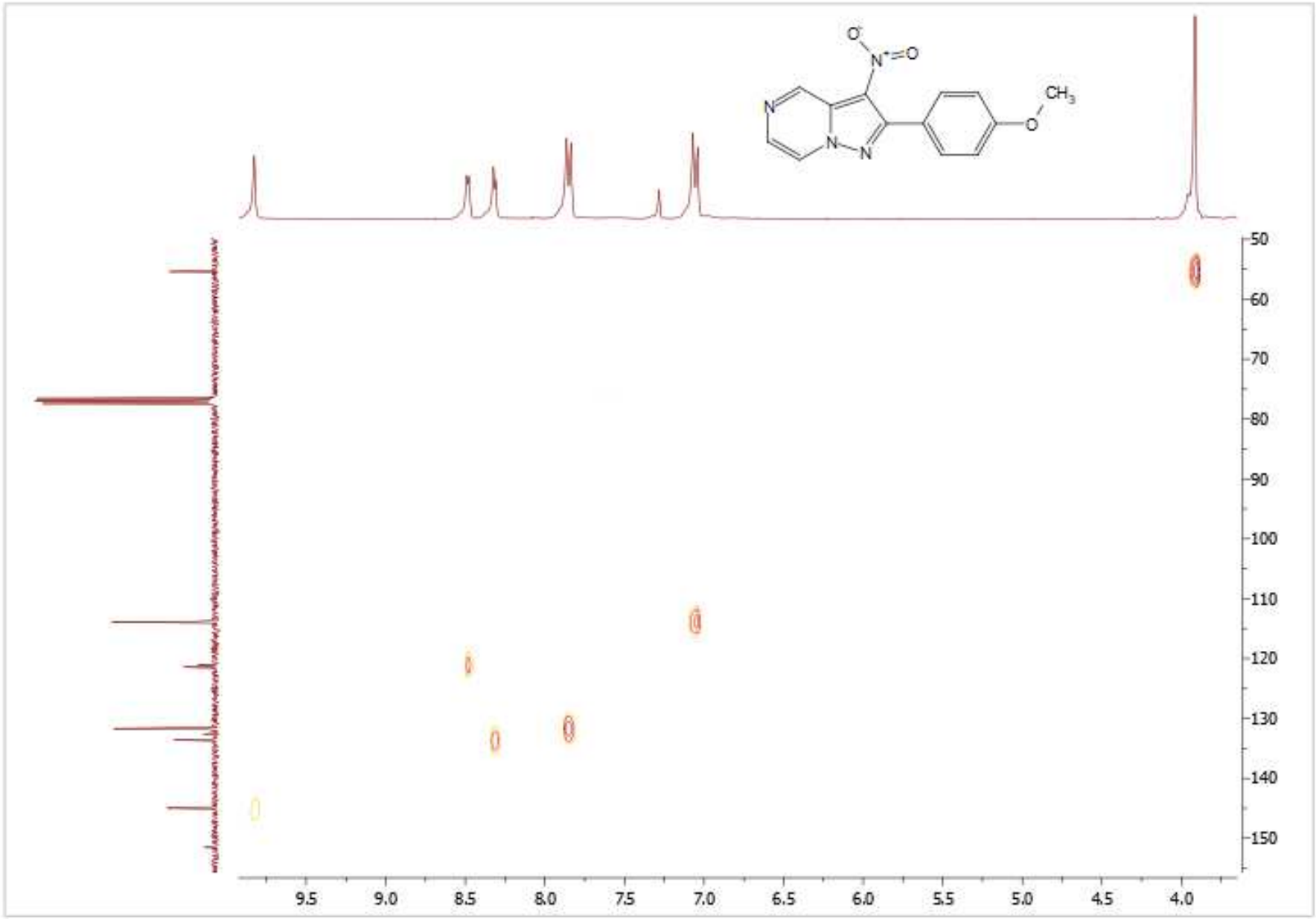
$^{13}$C NMR


161.53
151.52
144.99
133.59
132.61
131.76
121.44
121.07
113.90
55.40
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

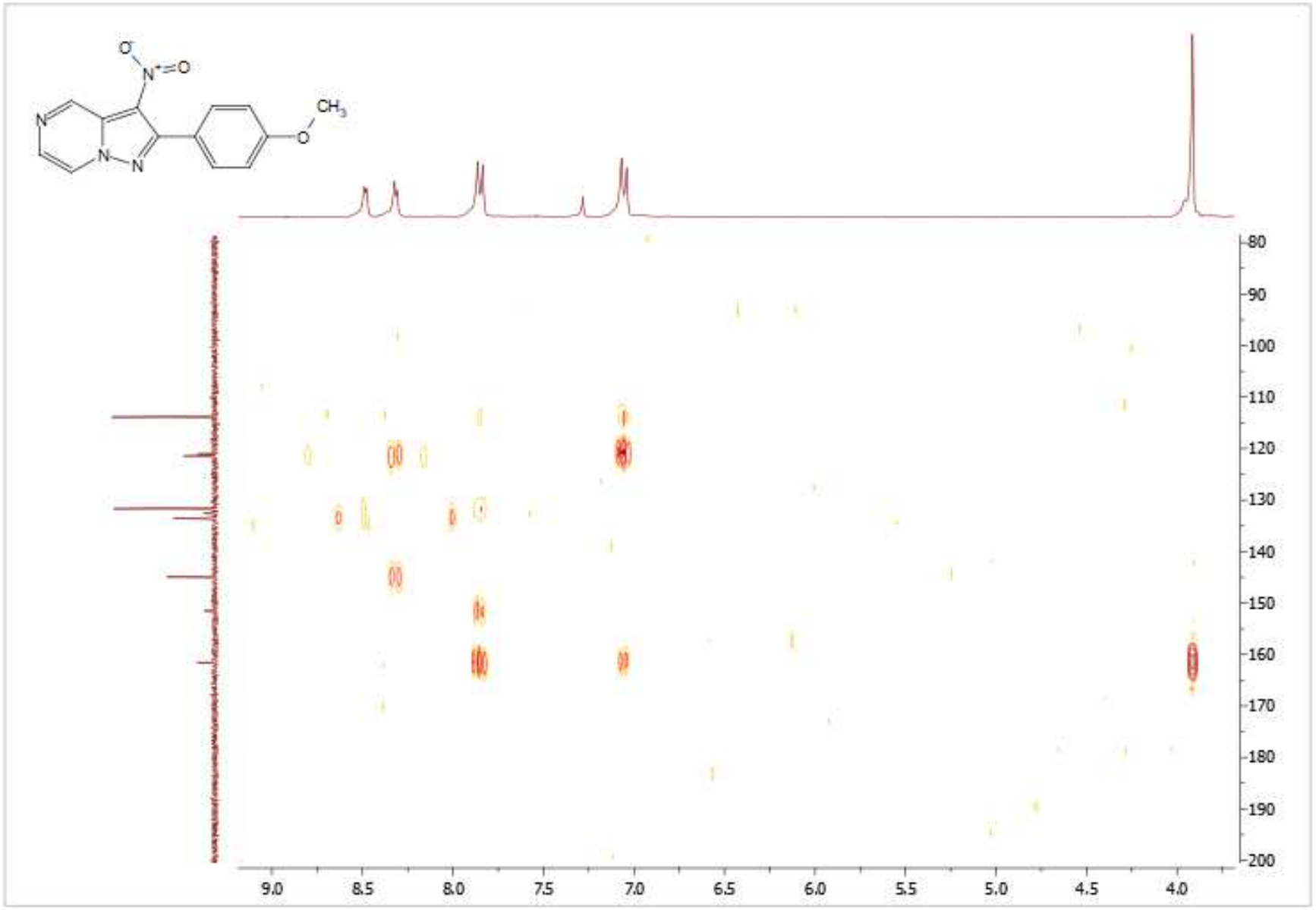
$^{1}$H-$^{1}$H COSY


O
N+=O
N
N
N
O
CH3
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
9.4 9.2 9.0 8.8 8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2 7.0 6.8 6.6 6.4 6.2 6.0 5.8 5.6 5.4 5.2

$^{1}H$-$^{13}C$ HSQC

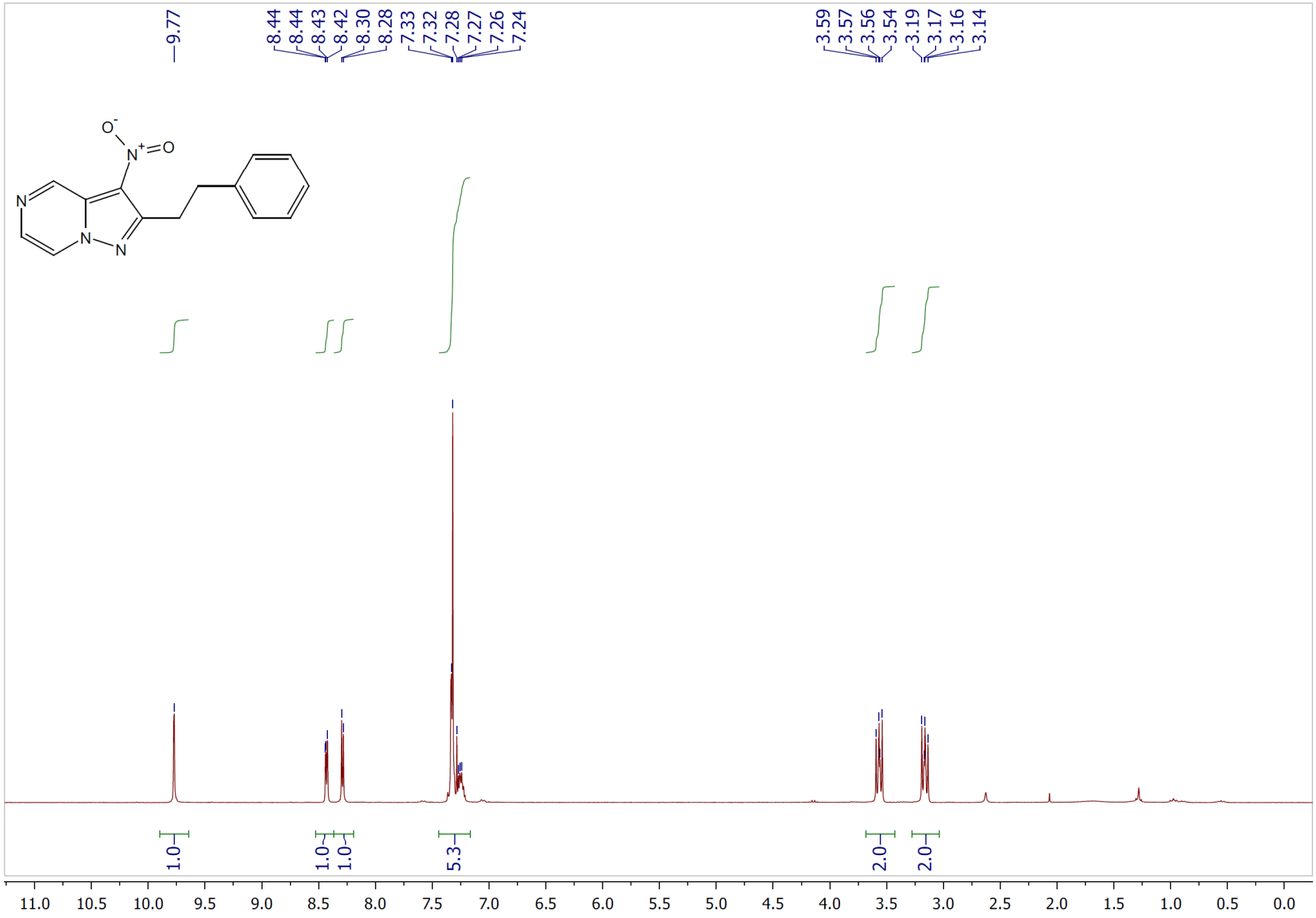

O
N+=O
N
N
N
CH3
O
50
60
70
80
90
100
110
120
130
140
150
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

$^{1}H$-$^{13}C$ HMBC

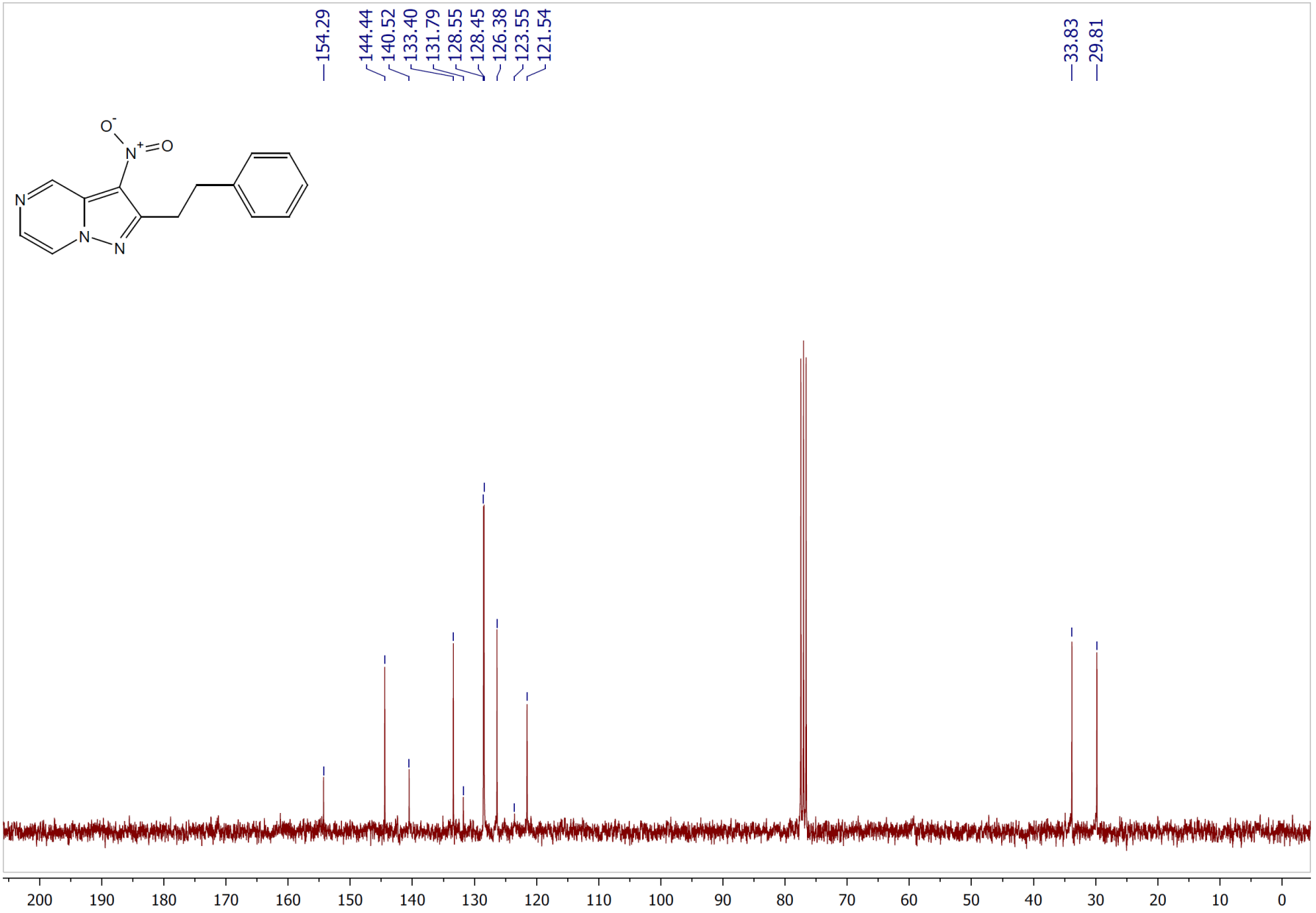

O
N
O
N
N
N
O
CH3
80
90
100
110
120
130
140
150
160
170
180
190
200
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0

**3-Nitro-2-(2-phenylethyl)pyrazolo[1,5-a]pyrazine 11b**

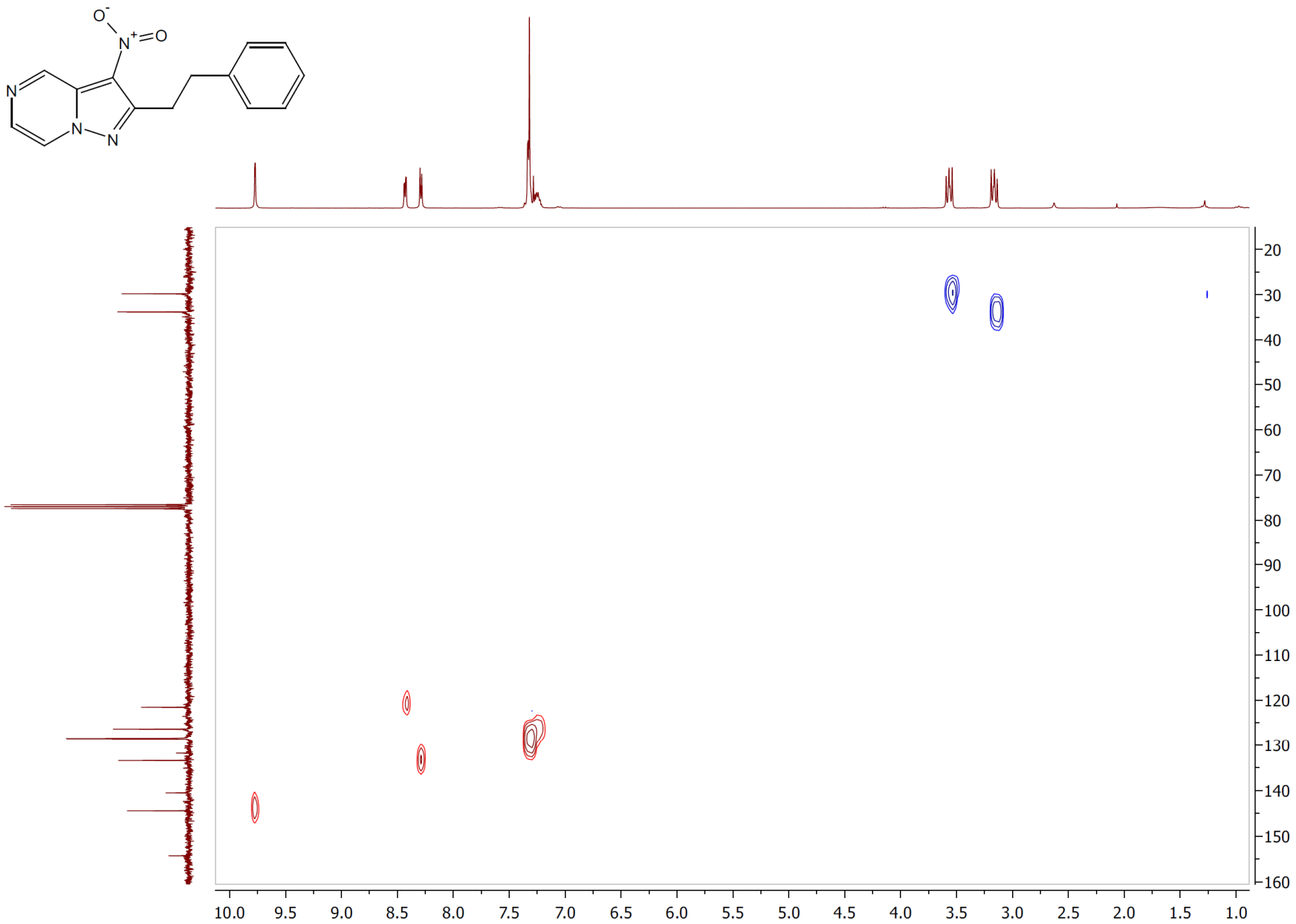
$^{1}$H NMR



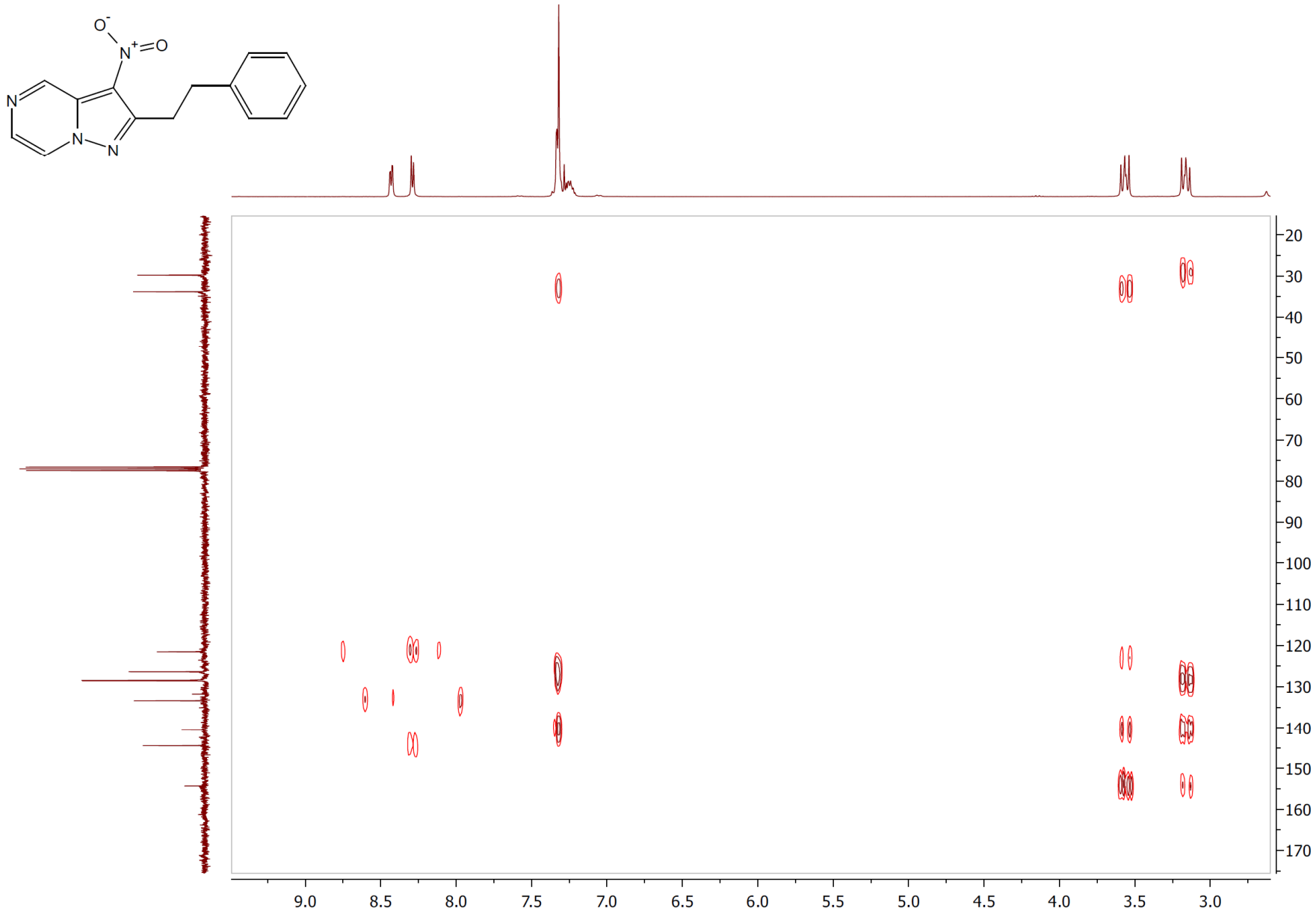
$^{13}$C NMR


154.29
144.44
140.52
133.40
131.79
128.55
128.45
126.38
123.55
121.54
33.83
29.81
O
N
O
N
N
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC

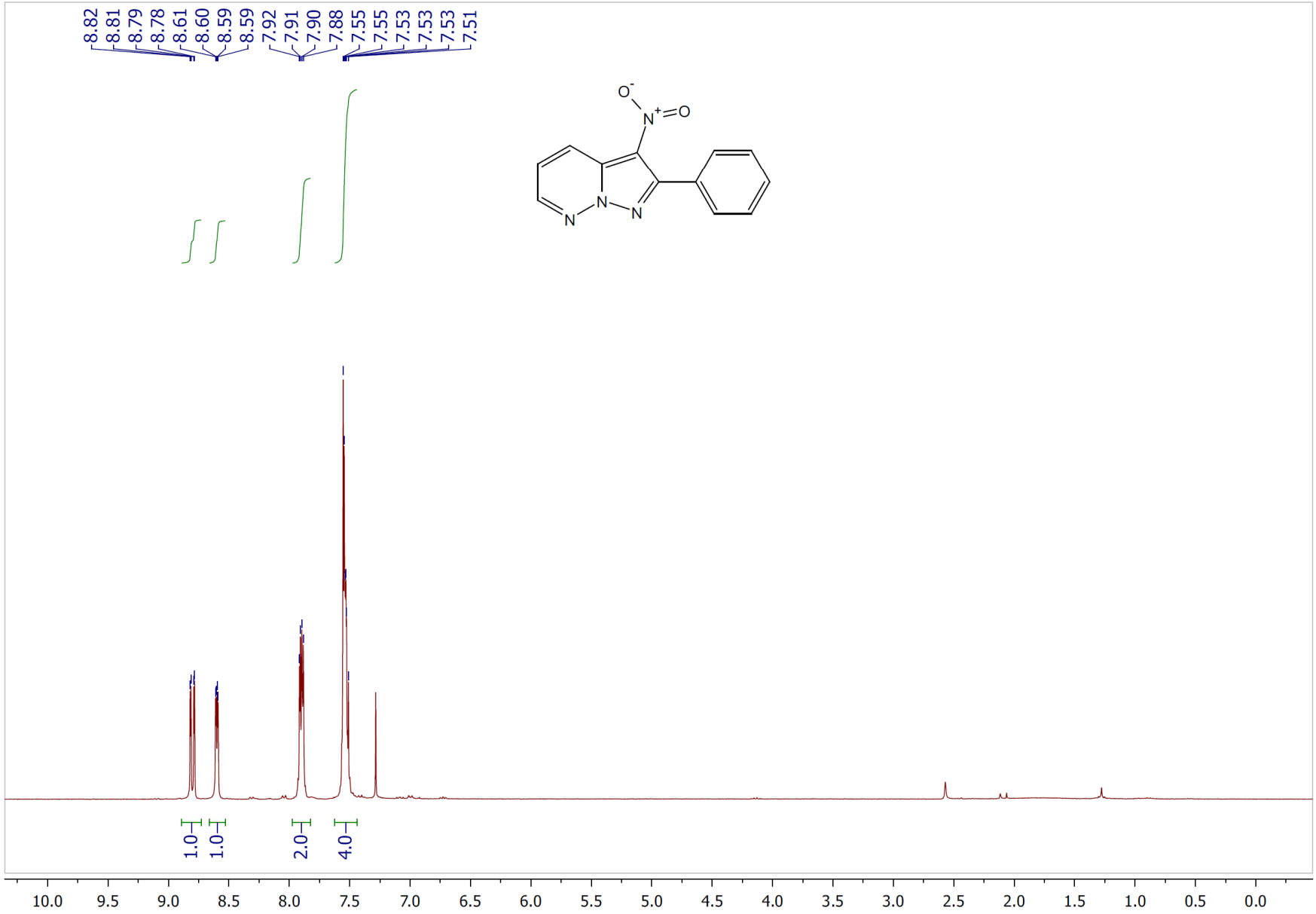

O
N+=O
N
N
N
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0

$^{1}H$-$^{13}C$ HMBC

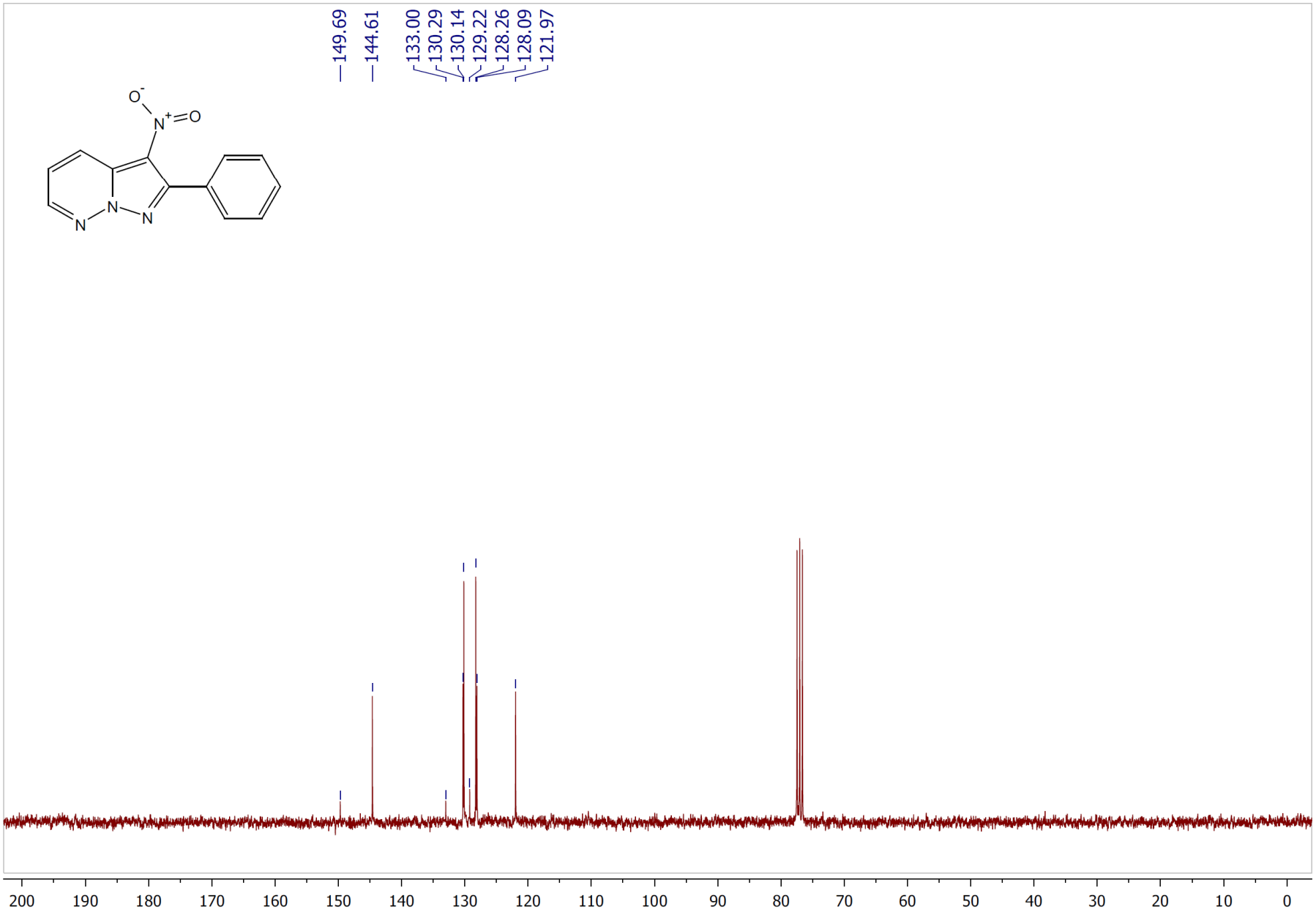

O-
N+=O
N
N
N
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

**3-Nitro-2-phenylpyrazolo[1,5-b]pyridazine 11c**

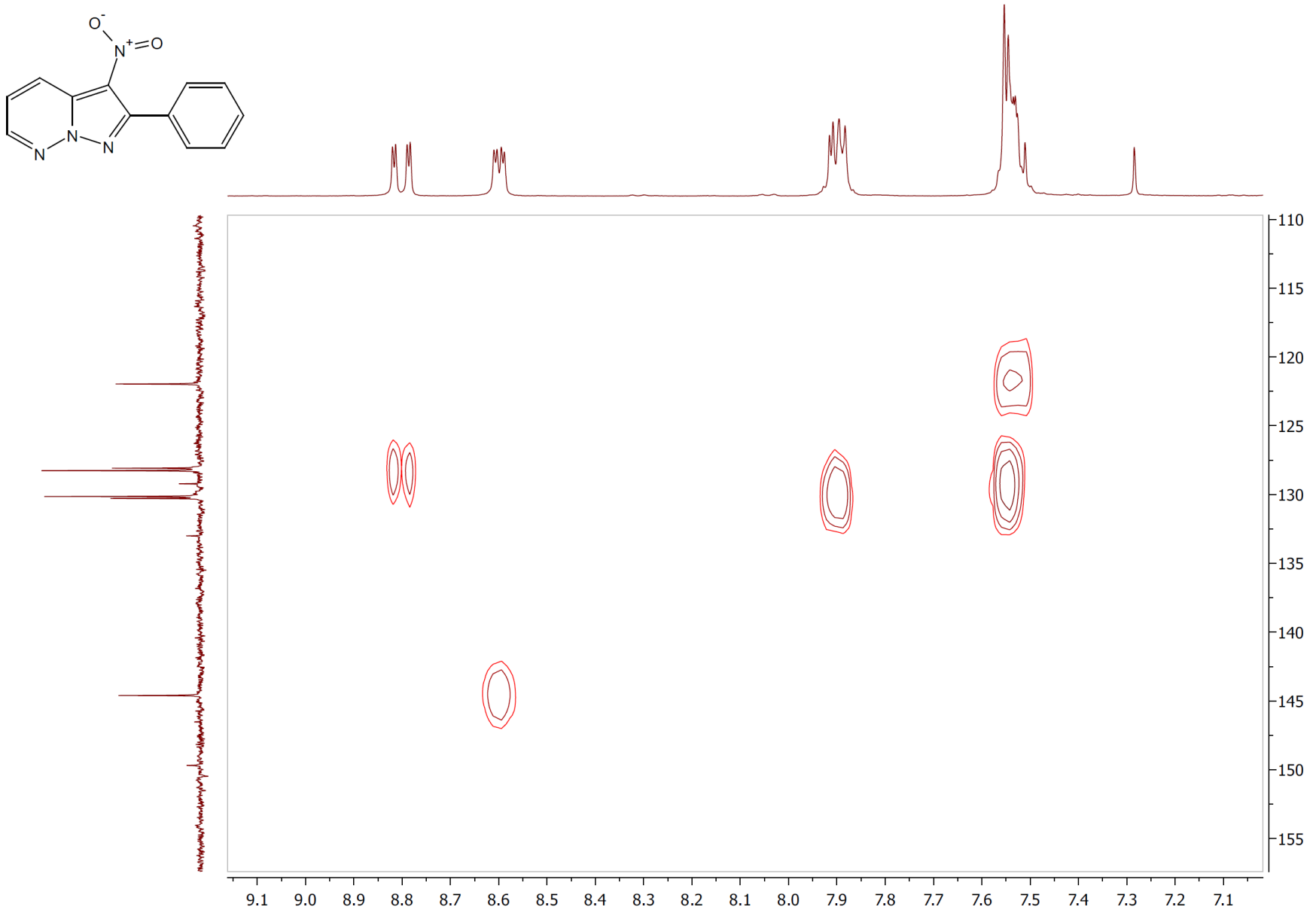
$^{1}$H NMR



$^{13}$C NMR

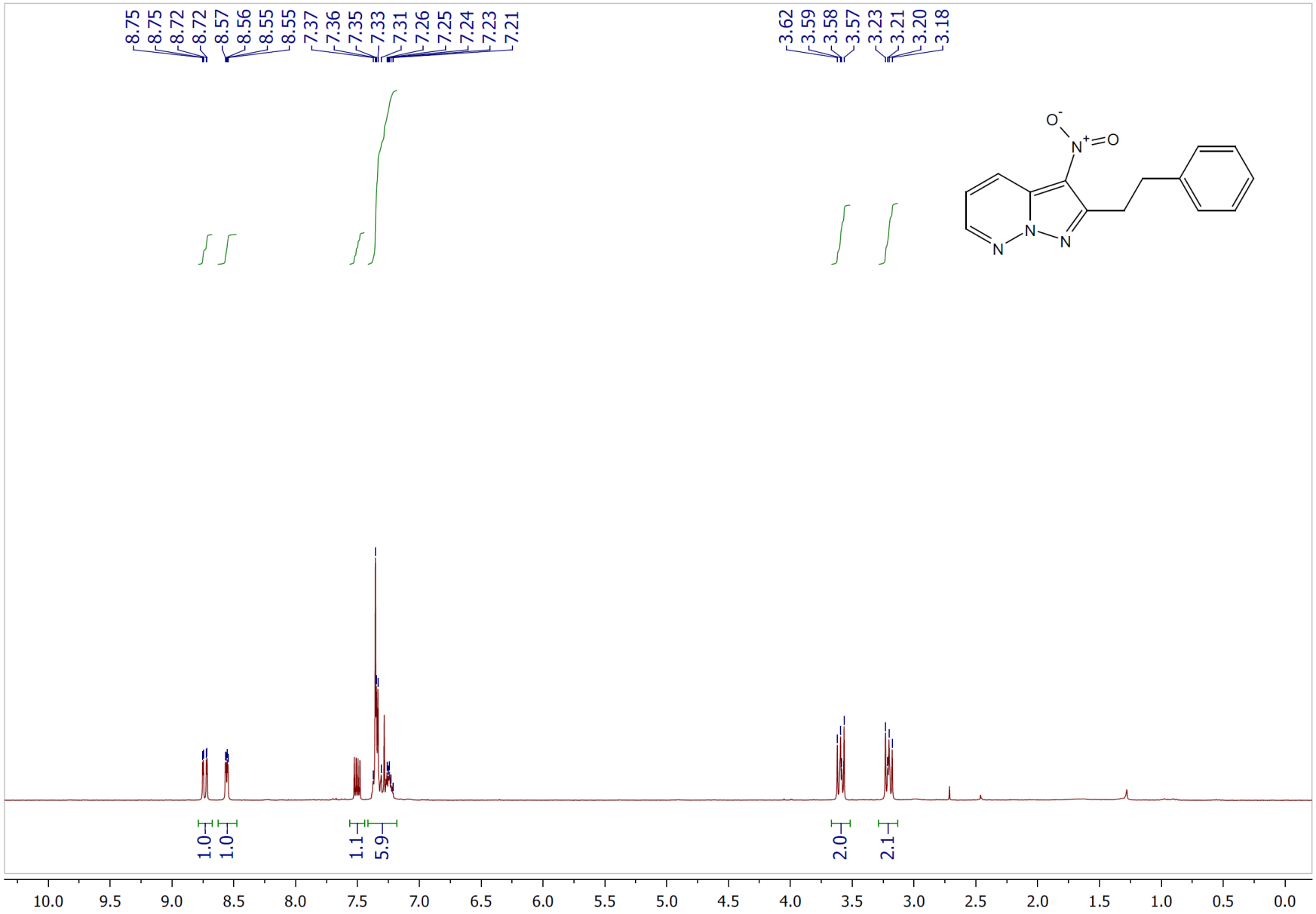

149.69
144.61
133.00
130.29
130.14
129.22
128.26
128.09
121.97
O
N
O
N
N
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC

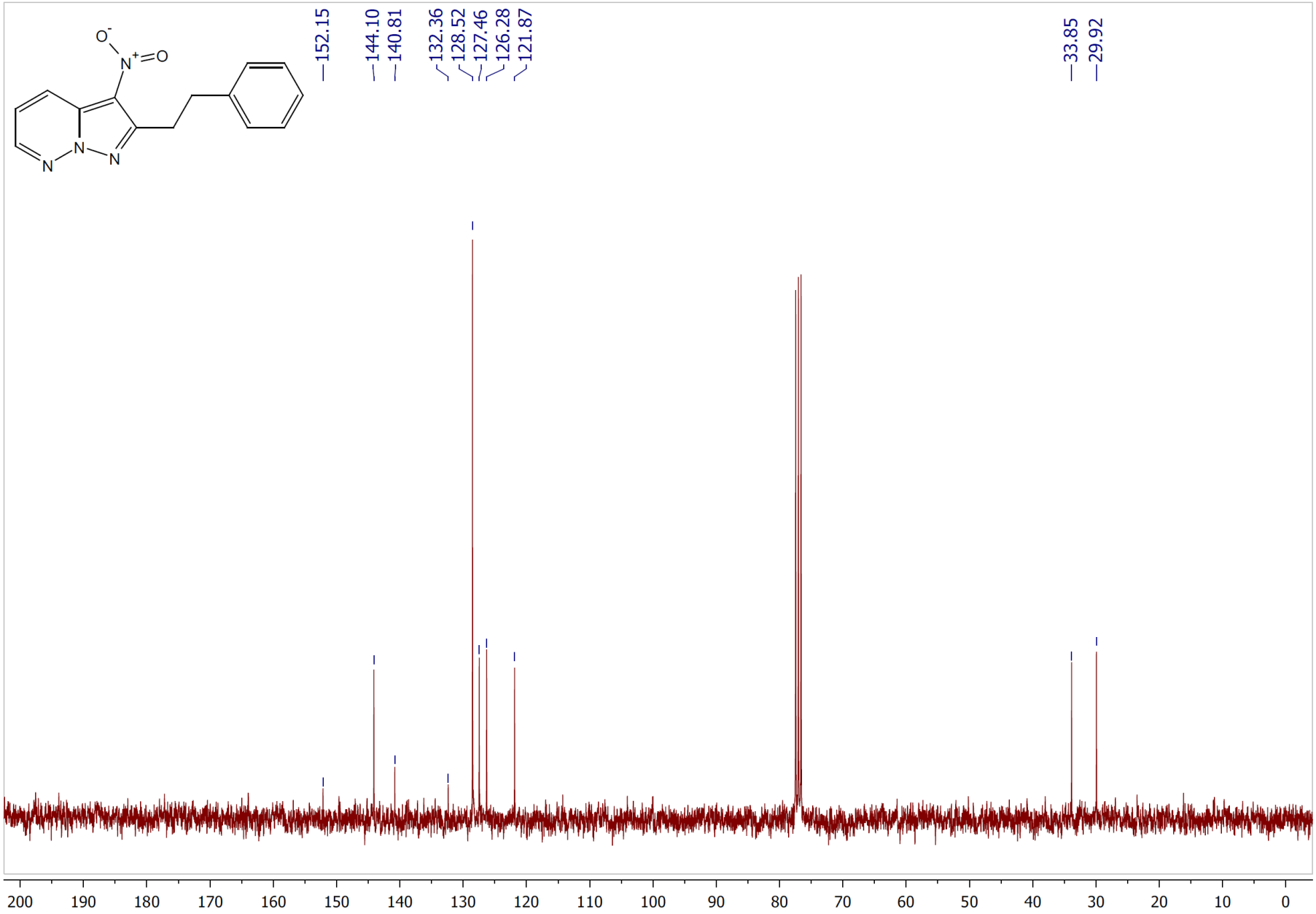

O
N+=O
N
N
N
110
115
120
125
130
135
140
145
150
155
9.1
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1

**3-Nitro-2-phenethylpyrazolo[1,5-b]pyridazine 11d**

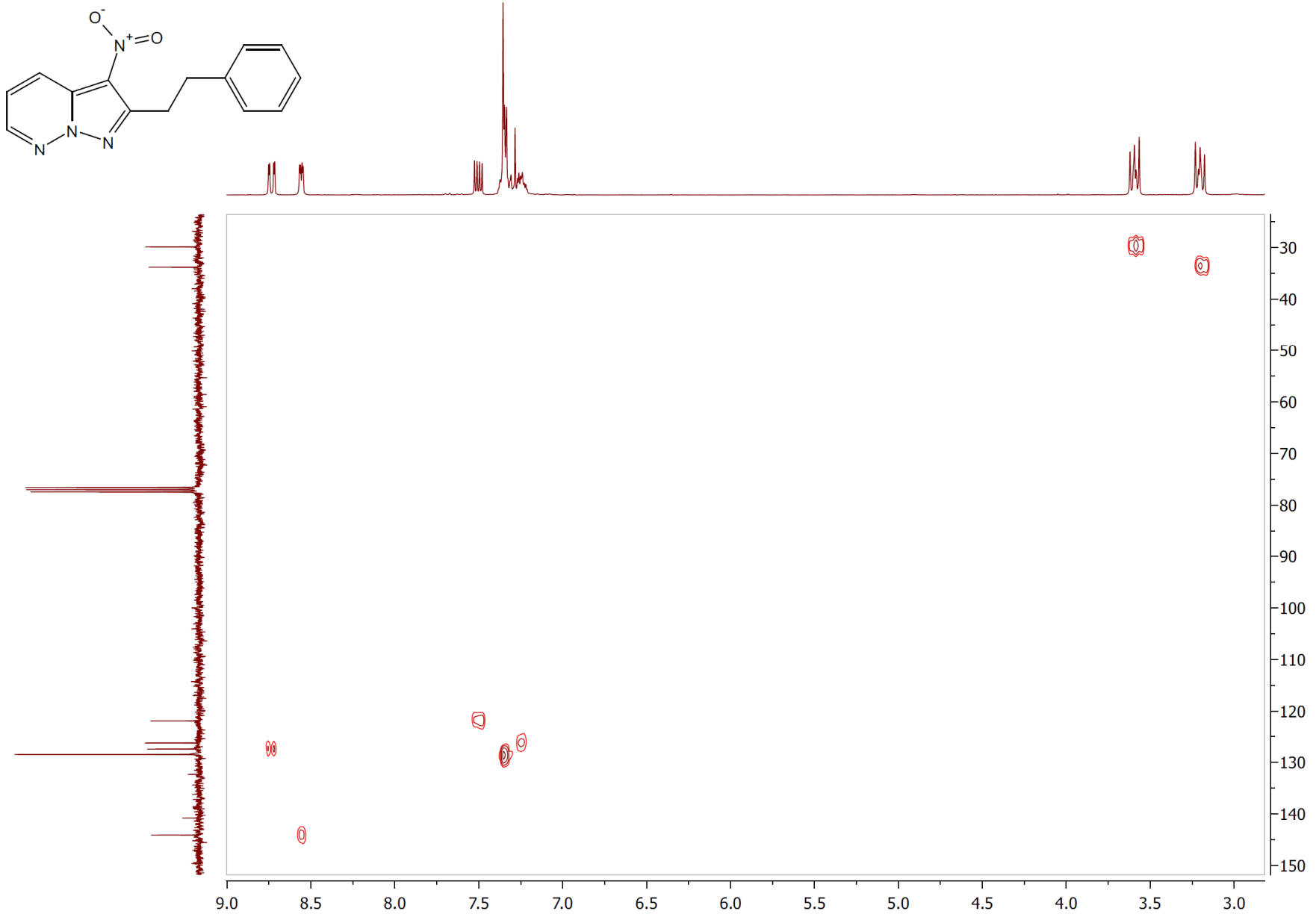
$^{1}$H NMR



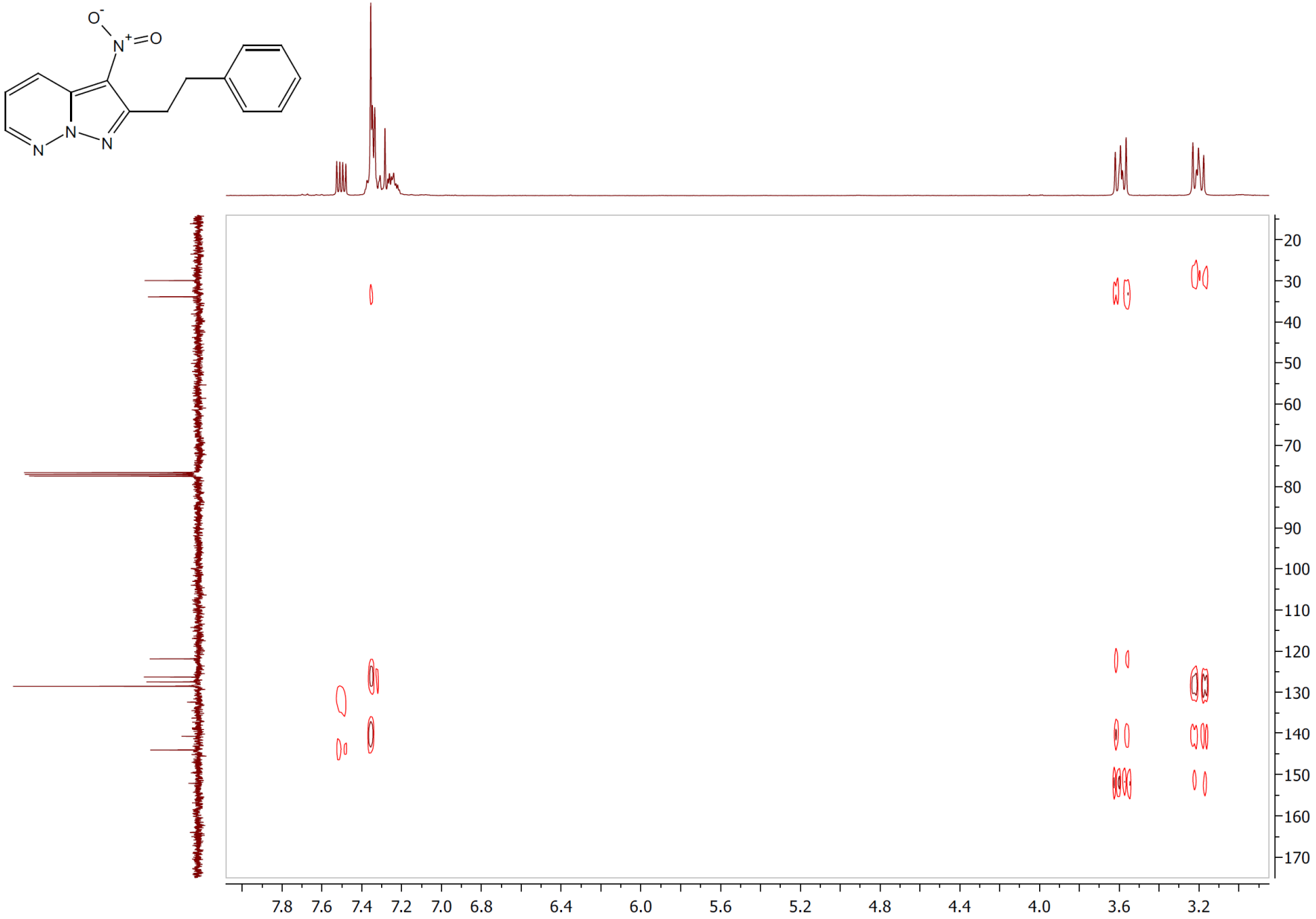
$^{13}$C NMR


152.15
144.10
140.81
132.36
128.52
127.46
126.28
121.87
33.85
29.92
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

$^{1}H$-$^{13}C$ HSQC


O
N
O
N
N
N
30
40
50
60
70
80
90
100
110
120
130
140
150
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0

$^{1}H$-$^{13}C$ HMBC


O-
N+=O
N
N
N
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
7.8
7.6
7.4
7.2
7.0
6.8
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2