Supplementary Information for

Hydrogen peroxide/dimethyl carbonate: a green system for epoxidation of *N*-alkylimines and *N*-sulfonylimines. One-pot synthesis of *N*-alkyloxaziridines from *N*-alkylamines and (hetero)aromatic aldehydes

Jamil Kraiem,[a,b] Donia Ghedira,[b] Thierry Ollevier[a]*

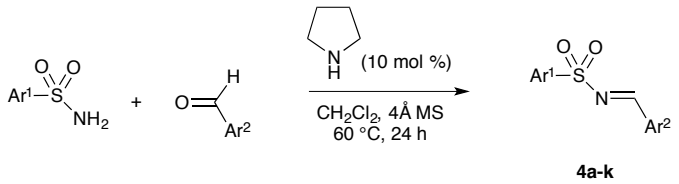
a Département de chimie, Université Laval, 1045 avenue de la Médecine Québec, QC, G1V 0A6, Canada.

b Laboratoire de Développement Chimique, Galénique et Pharmacologique des Médicaments, Faculté de Pharmacie de Monastir, Université de Monastir, Rue Avicenne, 5000 Monastir, Tunisia.

General methods

NMR spectra were acquired using $CDCl_3$ as solvent, running at 300 and 75 MHz for ^1H and ^{13}C respectively. Chemical shifts (δ) are reported in ppm relative to residual solvent signals ($CHCl_3$, 7.28 ppm and CH_2Cl_2, 5.32 ppm, H_2O 1.61 ppm for ^1H NMR; $CDCl_3$, 76.5 ppm for ^{13}C NMR). In all ^1H NMR spectra, multiplicity is indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet) or m (multiplet). Coupling constant values (in Hertz) and number of protons for each signal are also indicated. Melting points were determined on a Büchi SMP-20 capillary apparatus and are uncorrected. TLC was carried out on Merck 60F-254 precoated silica gel plates (0.25 mm). Dimethyl carbonate (Reagent plus®, 99%) and hydrogen peroxide (30 % wt in water) were purchased from Sigma-Aldrich. All starting materials purchased from commercial suppliers were used without further purification, except alkylamines and aromatic aldehydes which were distilled or recrystallized (solid reagents) before use. *N*-Sulfonylimines were prepared according to the eco-friendly procedure reported by Morales.[1]

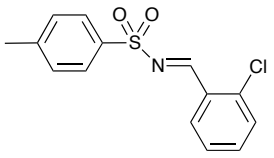
Synthesis of *N*-sulfonylimines



4a-k

Typical procedure: 2-chlorobenzaldehyde (2.4 mmol), pyrrolidine (0.2 mmol) and molecular sieves 4 Å (2 g) were added to a solution of *p*-toluenesulfonamide (2 mmol) in dry dichloromethane (1 mL). The mixture was stirred in a sealed vial at 60 °C for 24 h. Then, the reaction was filtered through a short pad of silica gel, the solvent was evaporated under reduced pressure and the residue was recrystallized with ethyl acetate/petroleum ether (20:80) to yield pure *N*-(2-chlorobenzylidene)-*p*-toluenesulfonamide **4h** as a white solid; mp 131–132 °C; yield 89%; δ_H ($CDCl_3$) 2.43 (s, 1H, CH_3), 7.30-7.53 (m, 5H, CH–Ar), 7.89 (d,

J = 8.1 Hz, 2H, CH–Ar), 8.13 (d, J = 7.8 Hz, 1H, CH–Ar); δ_C ($CDCl_3$) 21.17 (CH_3), 126.88, 127.77, 129.26, 129.39, 129.66, 129.98, 134.19, 135.16, 138.40, 144.37, 166.25 (CH=N).

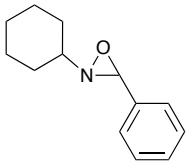


4h

Compounds **4a**,[2] **4b**,[3] **4c**,[4] **4d**,[5] **4e**,[6] **4f**,[7] **4g**,[6] **4h**,[6] **4i**,[6] **4j**,[6] and **4k** [8] were characterized by comparing their NMR spectra with literature data.

Synthesis of *N*-alkyloxaziridines

Typical procedure: To a solution of benzaldehyde (1 mmol) in DMC (1 mL) was added cyclohexylamine (1.5 mmol). The mixture was stirred for 10 min. An hydrogen peroxide solution (30 % wt, 5 mmol) was then added over a period of 5 min. The mixture was stirred at room temperature until disappearance of aldehyde (15 h, reaction monitored by TLC). The reaction mixture was then diluted with ethyl acetate (5 mL), washed with a solution of sodium sulfite (5 mL) and extracted with ethyl acetate (3 × 2 mL). The combined organic phases were dried ($MgSO_4$) and concentrated under reduced pressure to yield pure 2-cyclohexyl-3-phenyloxaziridine **3g**. Colorless oil; Yield 96%; δ_H ($CDCl_3$) 1.15–2.15 (m, 11H, cyclohexyl), 4.56 (s, 1H, O–CH–N, *trans* 91%), 5.31 (s, H, O–CH–N, *cis* 9%), 7.39–7.47 (m, 5H, Ar); δ_C ($CDCl_3$) *trans*-isomer: 24.08 (CH_2), 24.56 (CH_2), 25.77 (CH_2), 29.21 (CH_2), 31.60 (CH_2), 70.18 (CH–cyclohexyl), 79.84 (O–CH–N), 127.45 (CH–Ar), 128.49 (CH–Ar), 129.90 (CH–Ar), 135.26 (C–Ar); *cis*-isomer: 23.92 (CH_2), 23.98 (CH_2), 25.65 (CH_2), 28.15 (CH_2), 31.71 (CH_2), 59.25 (CH–cyclohexyl), 79.70 (O–CH–N), 127.95 (CH–Ar), 128.11 (CH–Ar), 129.36 (CH–Ar), 131.90 (C–Ar).

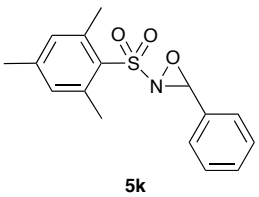


3g

N-Alkyloxaziridines **3a**,[9] **3b**,[10] **3c**,[10] **3d**,[5] **3e**,[11] **3f**,[10] **3g**,[12] **3h**,[13] **3i**,[14] **3j**,[15] **3k** [16] and **3l** [17] were characterized by comparing their NMR spectra with literature data.

Synthesis of *N*-sulfonyloxaziridines

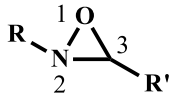
Typical procedure: To a solution of *N*-benzylidene-2,4,6-benzenesulfonamide **4k** (0.5 mmol) in DMC (1.5 mL) was added Na_2CO_3 (0.6 mmol) and $Zn(OAc)_2{\cdot}2H_2O$ (0.025 mmol). An hydrogen peroxide solution (30 % wt, 5 mmol) was then added over a period of 5 min. The mixture was stirred at room temperature until disappearance of the imine (14 h, TLC). The reaction mixture was then diluted with ethyl acetate (5 mL), washed with a solution of sodium sulfite (5 mL) and extracted with ethyl acetate (3 × 2 mL). The combined organic phases were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was filtered through a short pad of silica gel to yield pure 2-(2,4,6-trimethylbenzenesulfonyl)-3-phenyloxaziridine **5k** as white solid; mp 104–106 °C; yield 93%; δ_H ($CDCl_3$) 2.36 (s, 3H, CH_3), 2.78 (s, 6H, 2 CH_3), 5.52 (s, 1H, O–CH–N), 7.06 (s, 2H, CH–Ar), 7.43–7.50 (m, 5H, CH–Ar); δ_C ($CDCl_3$) 21.09 (CH_3), 23.06 (2 CH_3), 75.47 (O–CH–N), 128.20, 128.68, 129.74, 130.78, 131.18, 132.11, 141.94, 144.72.

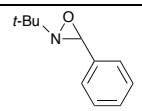
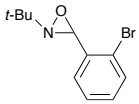
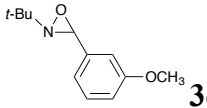
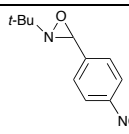
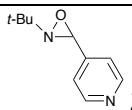
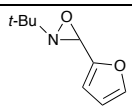
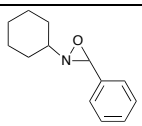
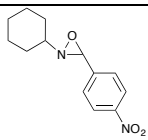
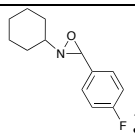
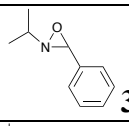
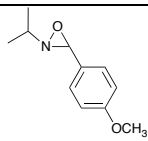
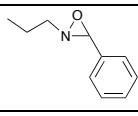


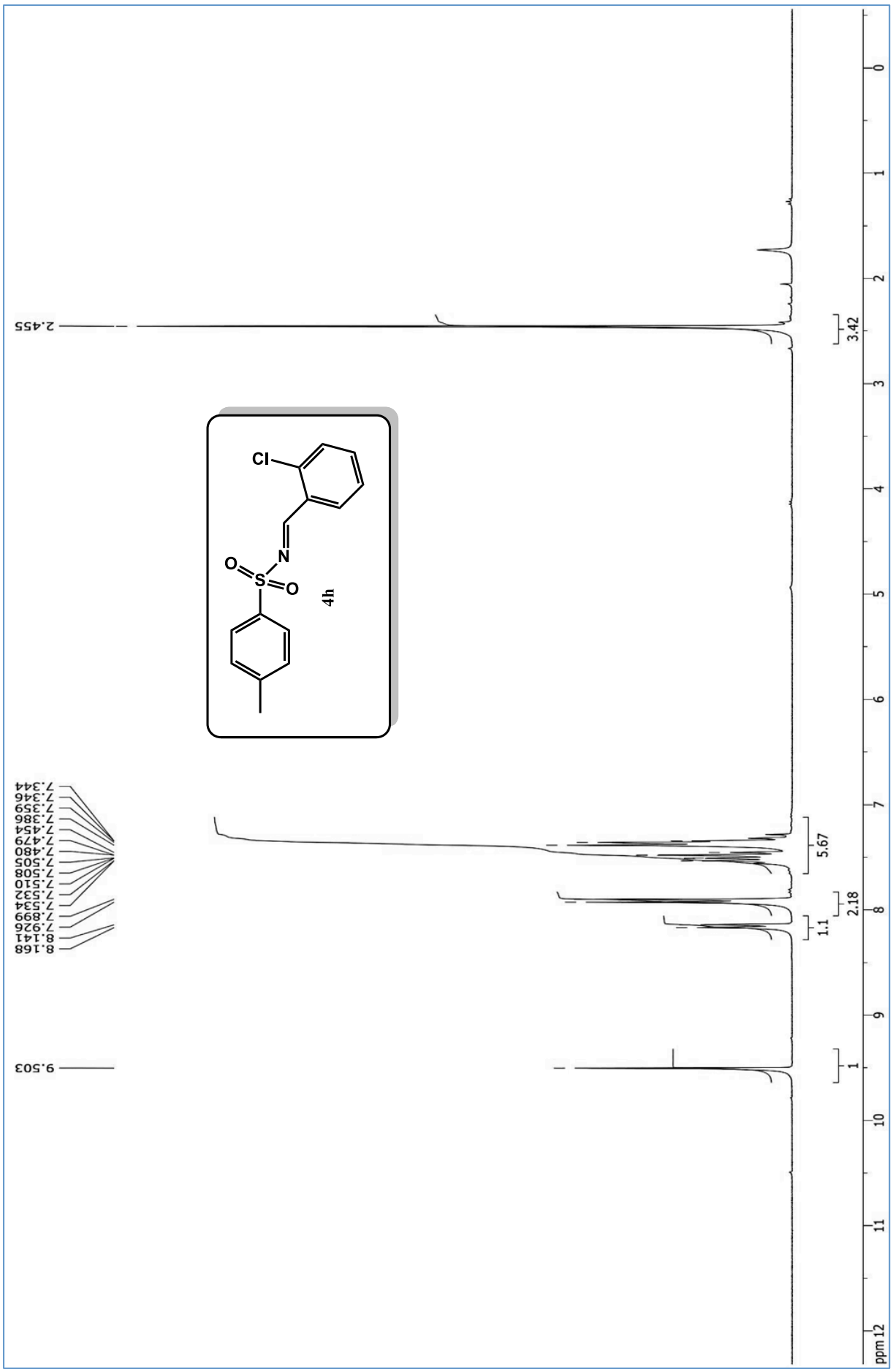
5k

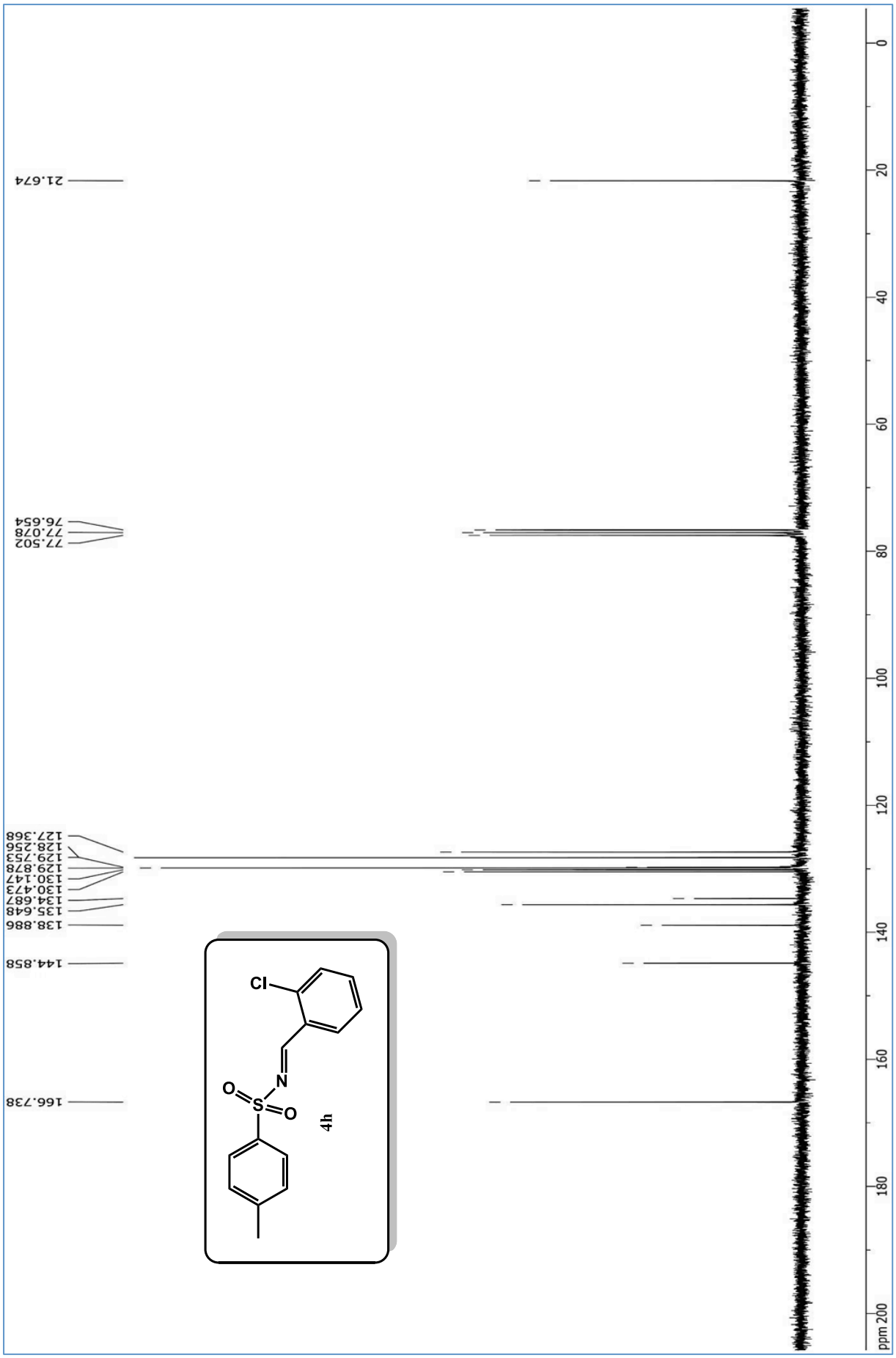
N-Sulfonyloxaziridines **5a**,[18] **5b**,[19] **5c**,[20] **5d**,[18] **5e**,[21] **5f**,[20] **5g**,[20] **5h**,[22] **5i**,[20] **5j**,[18] and **5k** [23] were characterized by comparing their NMR spectra with literature data.

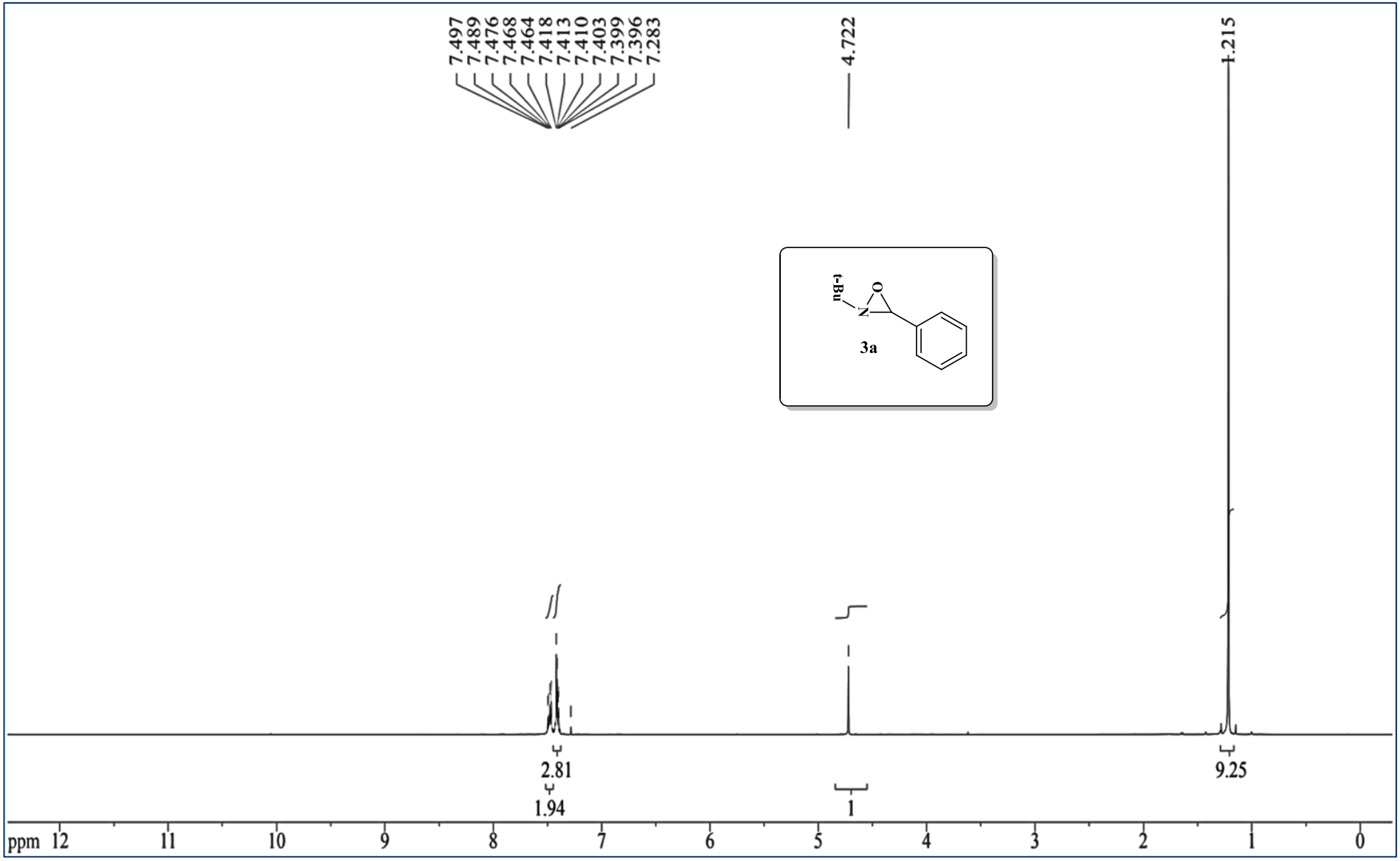
Table: Characteristic NMR chemical shifts of *cis* and *trans*-*N*-alkyloxaziridines.



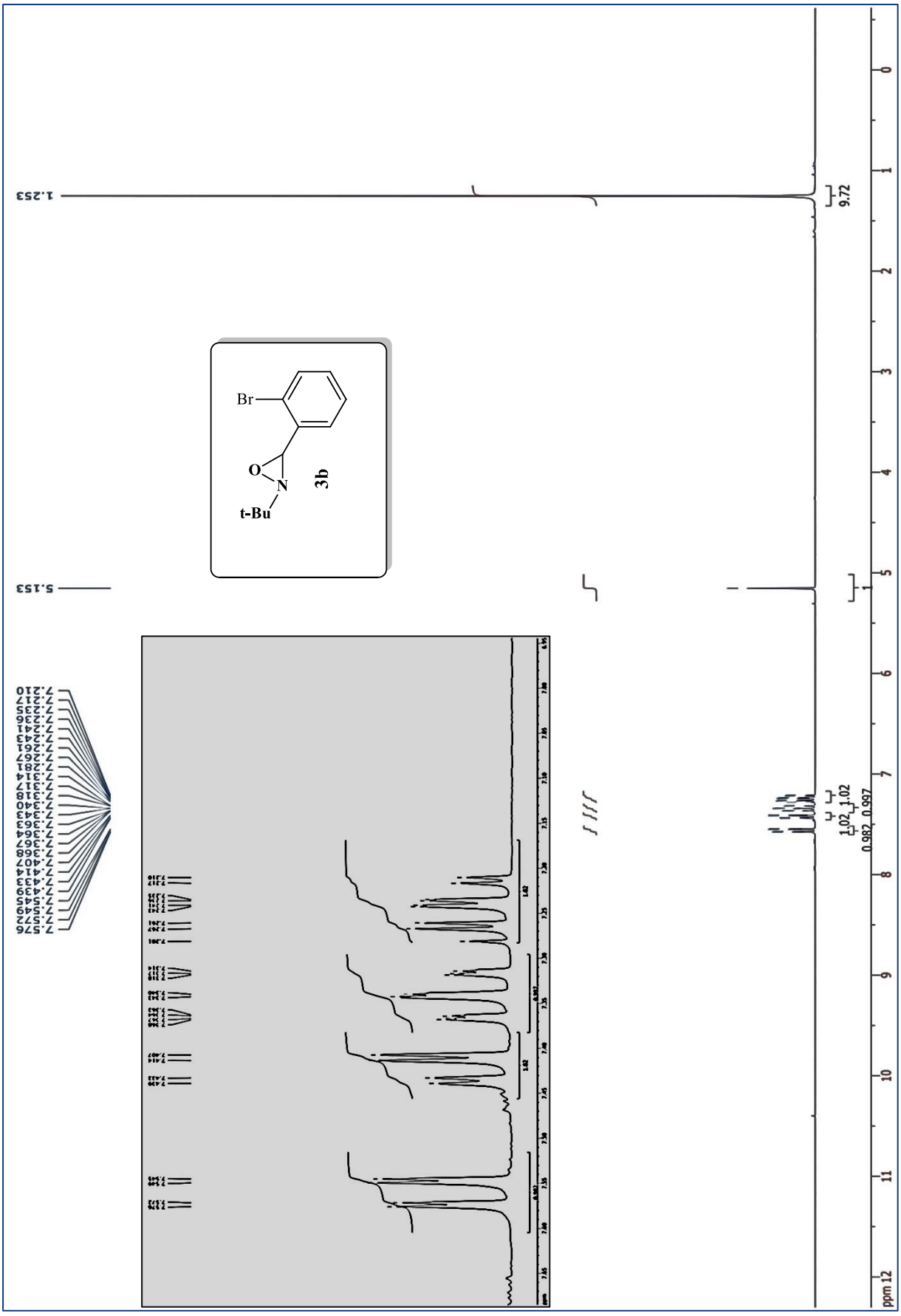
Oxaziridine	$\delta_{H\text{-}3}$ (ppm)		$\delta_{C\text{-}3}$ (ppm)		*Trans/Cis*
	Trans	*Cis*	*Trans*	*Cis*	
 **3a**	4.72	-	73.68	-	100:0
 **3b**	5.15	-	73.45	-	100:0
 **3c**	4.68	-	73.59	-	100:0
 **3d**	4.76	-	71.82	-	100:0
 **3e**	4.65	-	72.15	-	100:0
 **3f**	4.78	-	67.93	-	100:0
 **3g**	4.56	5.31	79.84	79.70	91:9
 **3h**	4.61	5.33	77.70	78.20	92:8
 **3i**	4.51	5.26	79.02	79.09	91:9
 **3j**	4.52	5.29	80.03	79.87	92:8
 **3k**	4.46	5.23	79.91	79.69	90:10
 **3l**	4.50	5.28	8.046	79.47	90:10

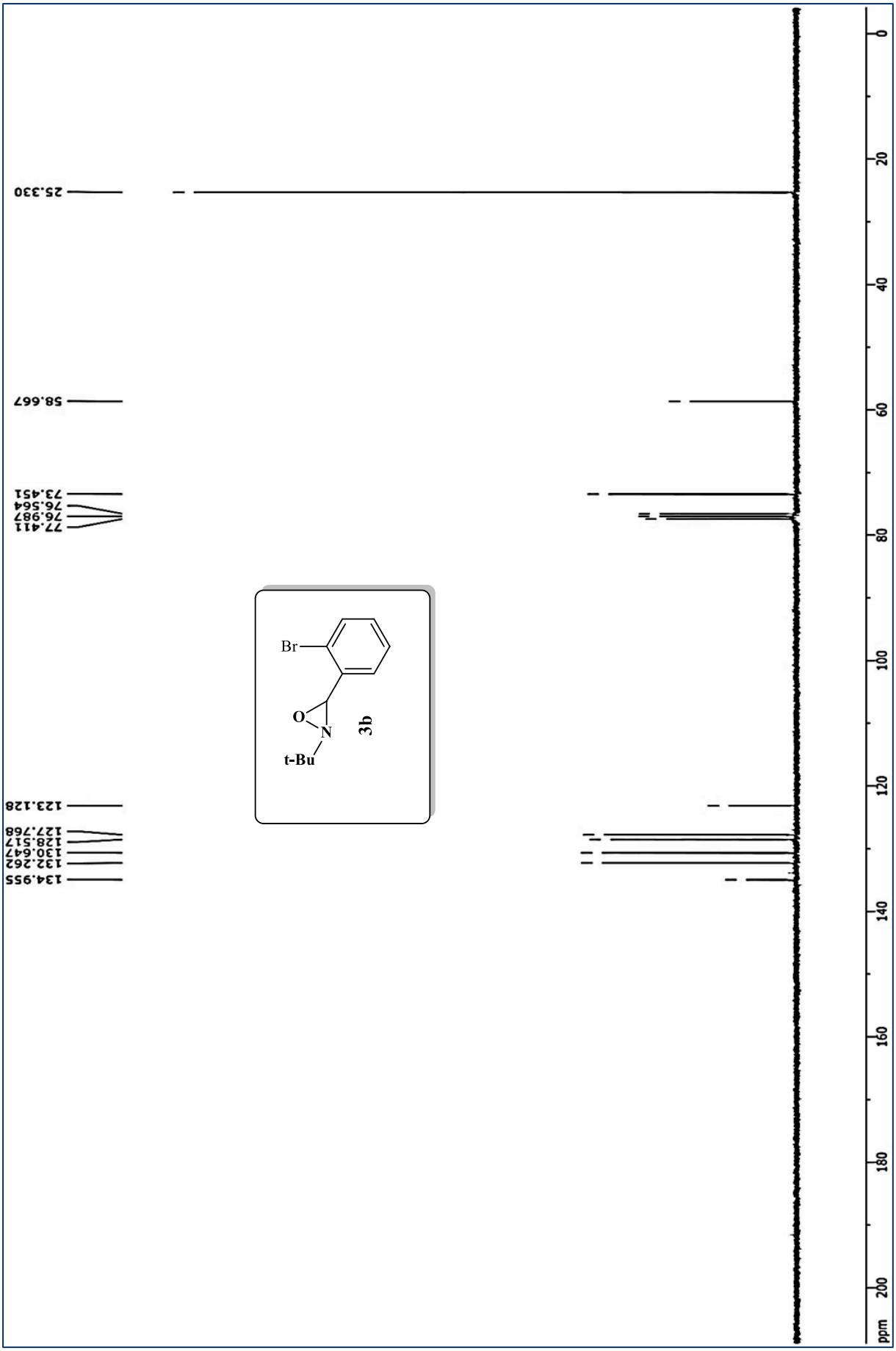

Cl
N
O
S
O
4h
2.455
9.503
8.168
8.141
7.926
7.899
7.534
7.532
7.510
7.508
7.505
7.480
7.479
7.454
7.386
7.359
7.346
7.344
3.42
5.67
2.18
1.1
1
ppm

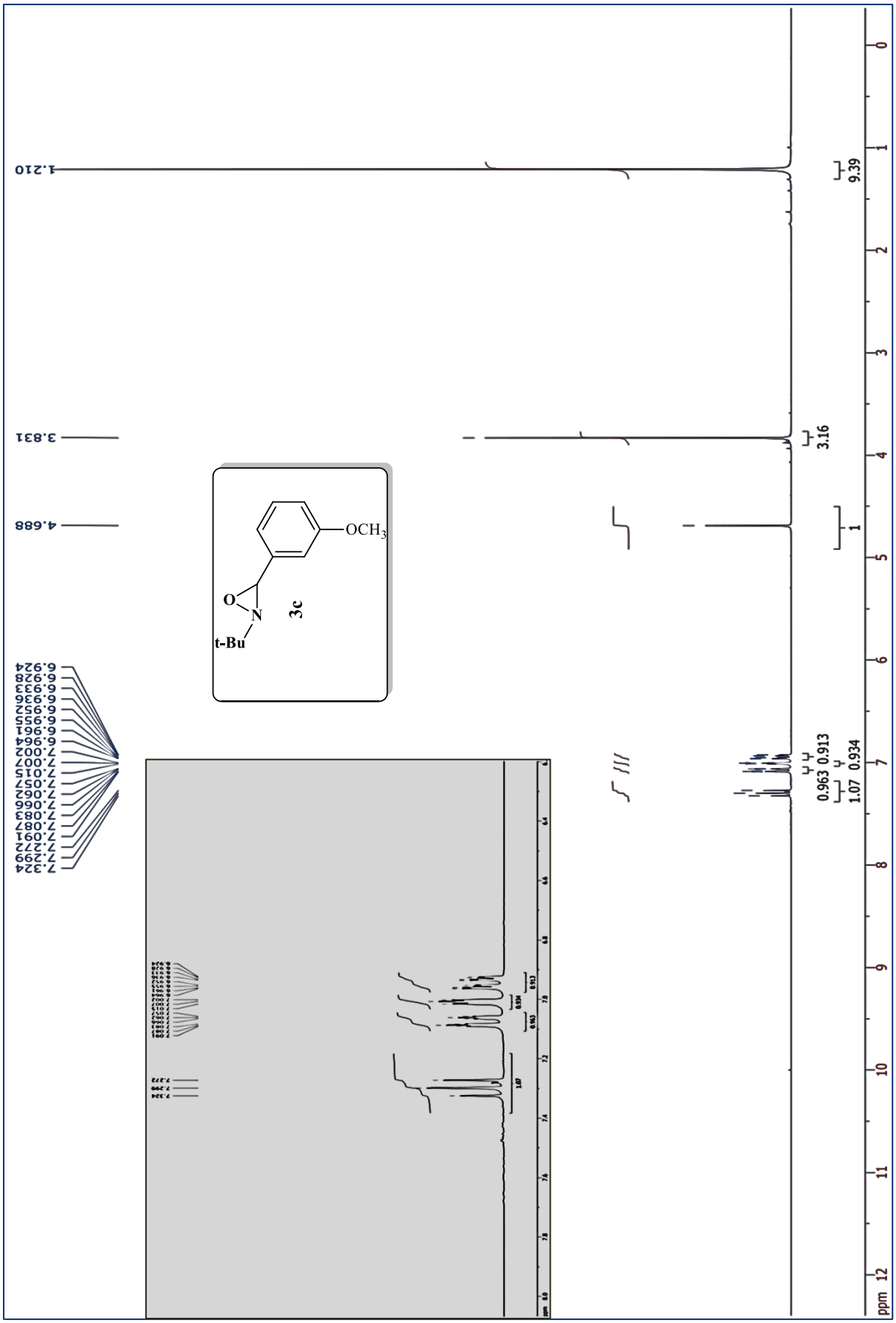

21.674
76.654
77.078
77.502
127.368
128.256
129.753
129.878
130.147
130.473
134.687
135.648
138.886
144.858
166.738
Cl
N
O
S
O
4h
0
20
40
60
80
100
120
140
160
180
200
ppm

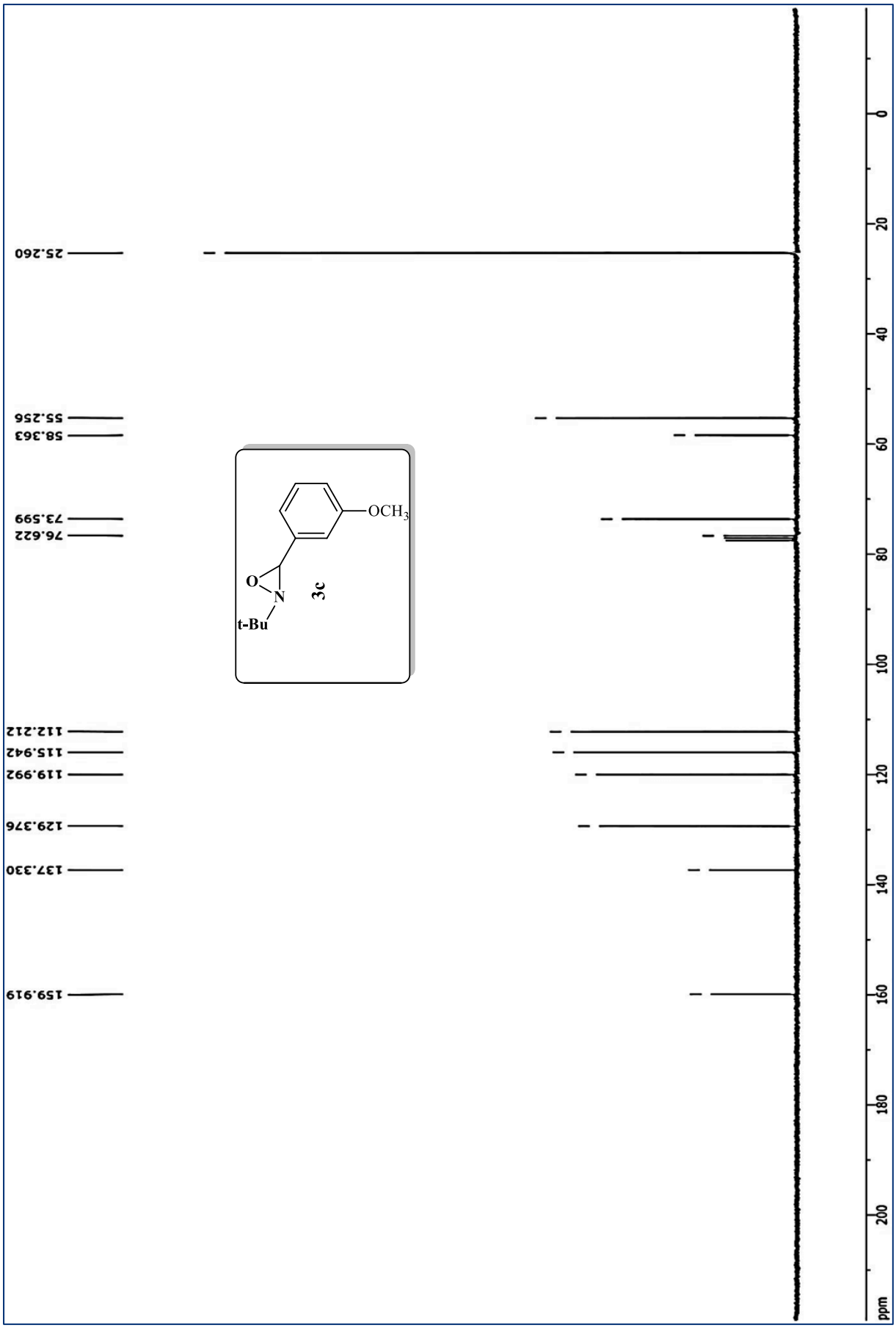

7.497
7.489
7.476
7.468
7.464
7.418
7.413
7.410
7.403
7.399
7.396
7.283
4.722
1.215
t-Bu
O
N
3a
2.81
1.94
1
9.25
ppm 12 11 10 9 8 7 6 5 4 3 2 1 0

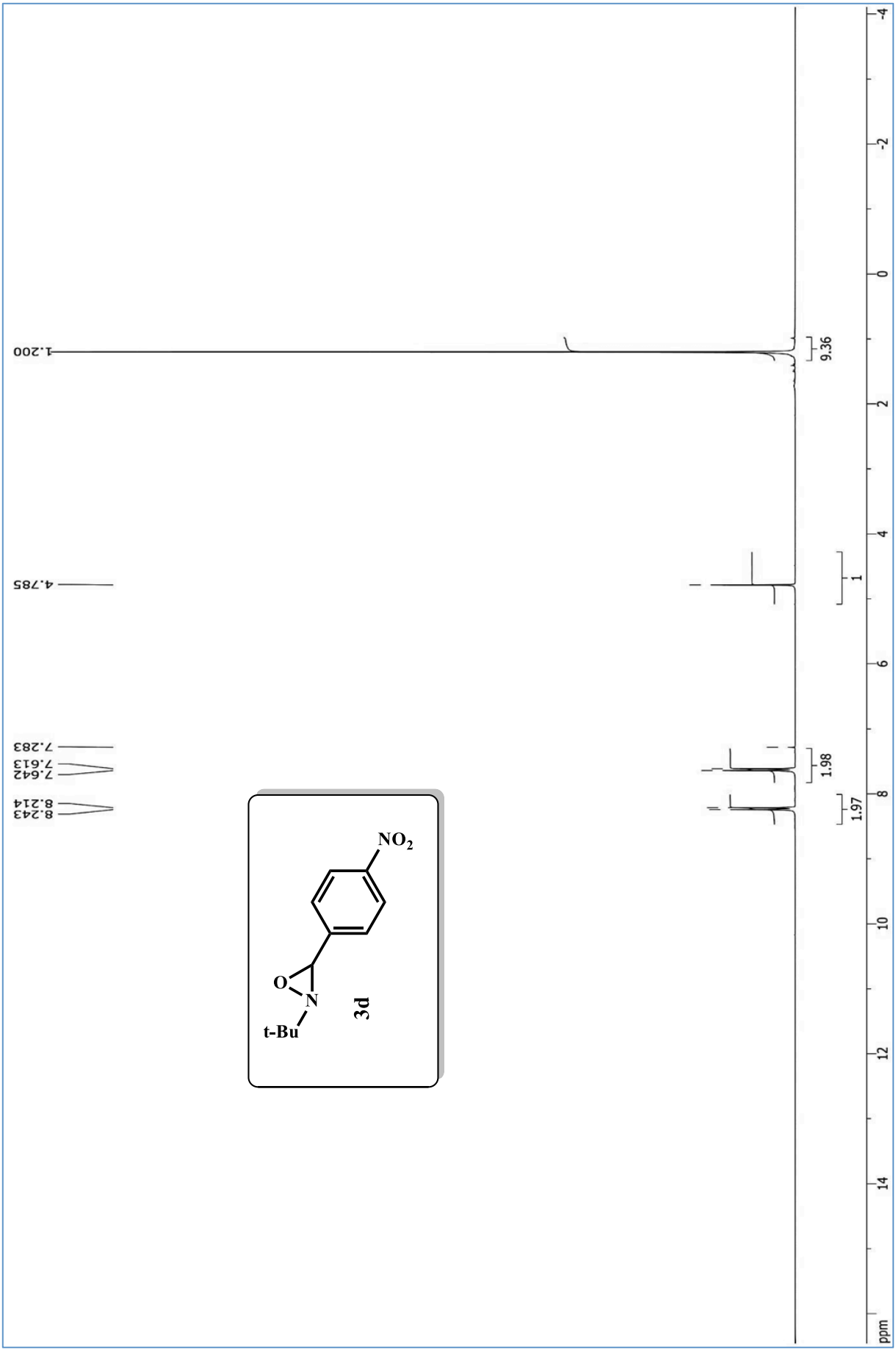
25.302
58.461
73.684
76.649
77.072
77.495
127.521
128.459
129.775
135.582
O
N
t-Bu
3a
0
20
40
60
80
100
120
140
160
180
ppm

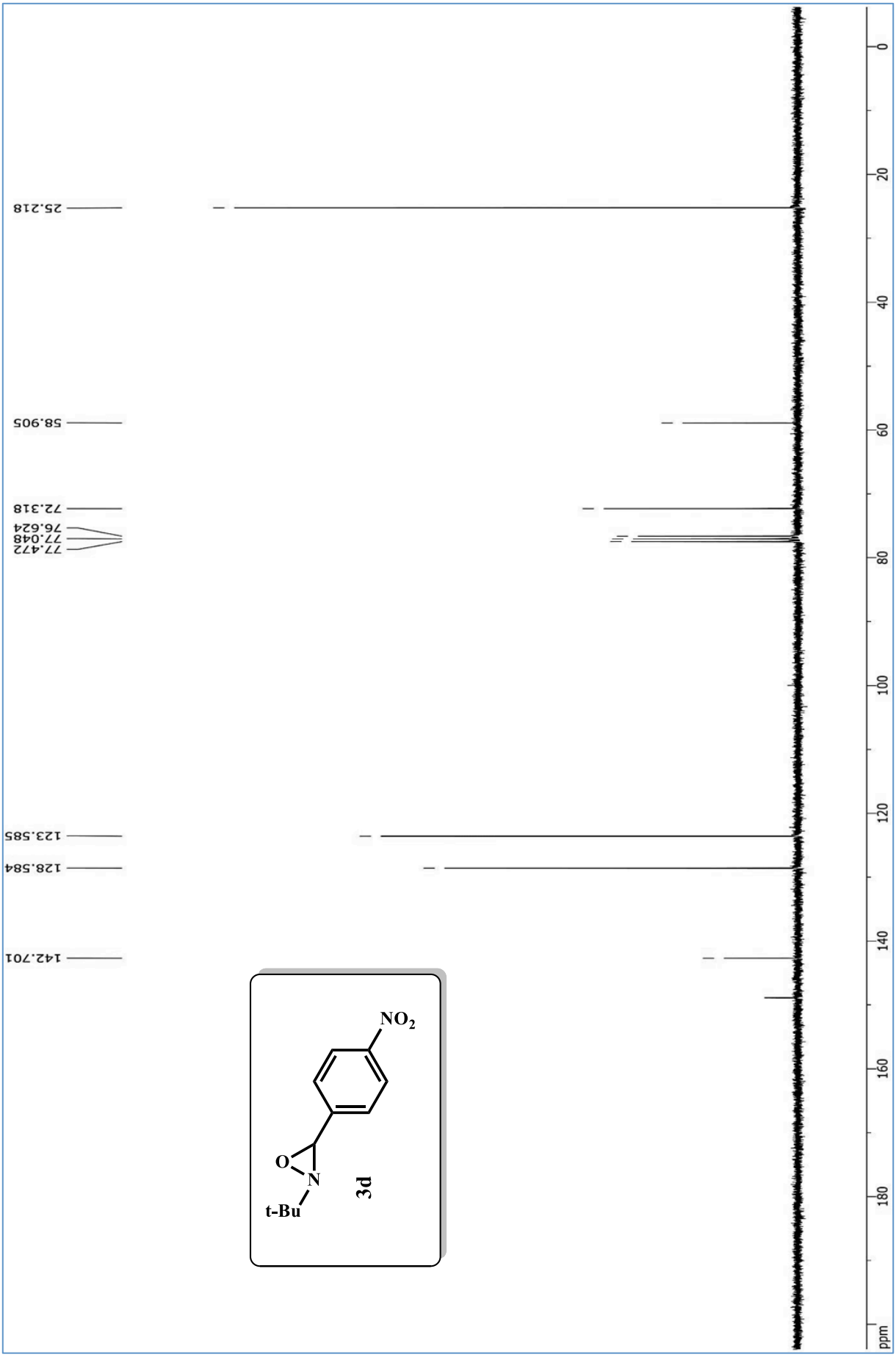

Br
O
N
t-Bu
3b
1.253
9.72
5.153
1.02
1.02
0.982
0.997
ppm

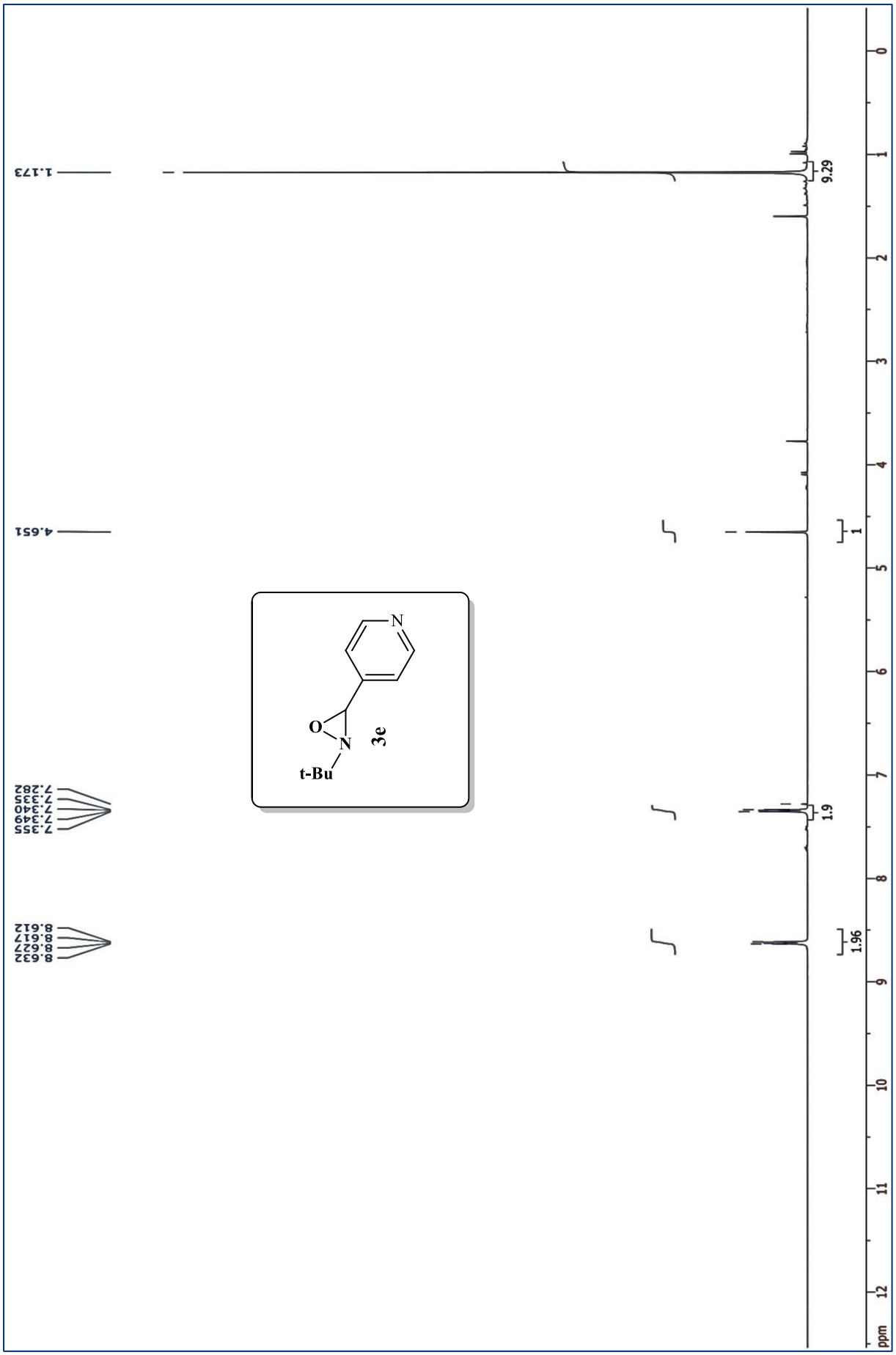

25.330
58.667
73.451
76.564
76.987
77.411
123.128
127.768
128.517
130.647
132.262
134.955
Br
O
N
t-Bu
3b
0
20
40
60
80
100
120
140
160
180
200
ppm

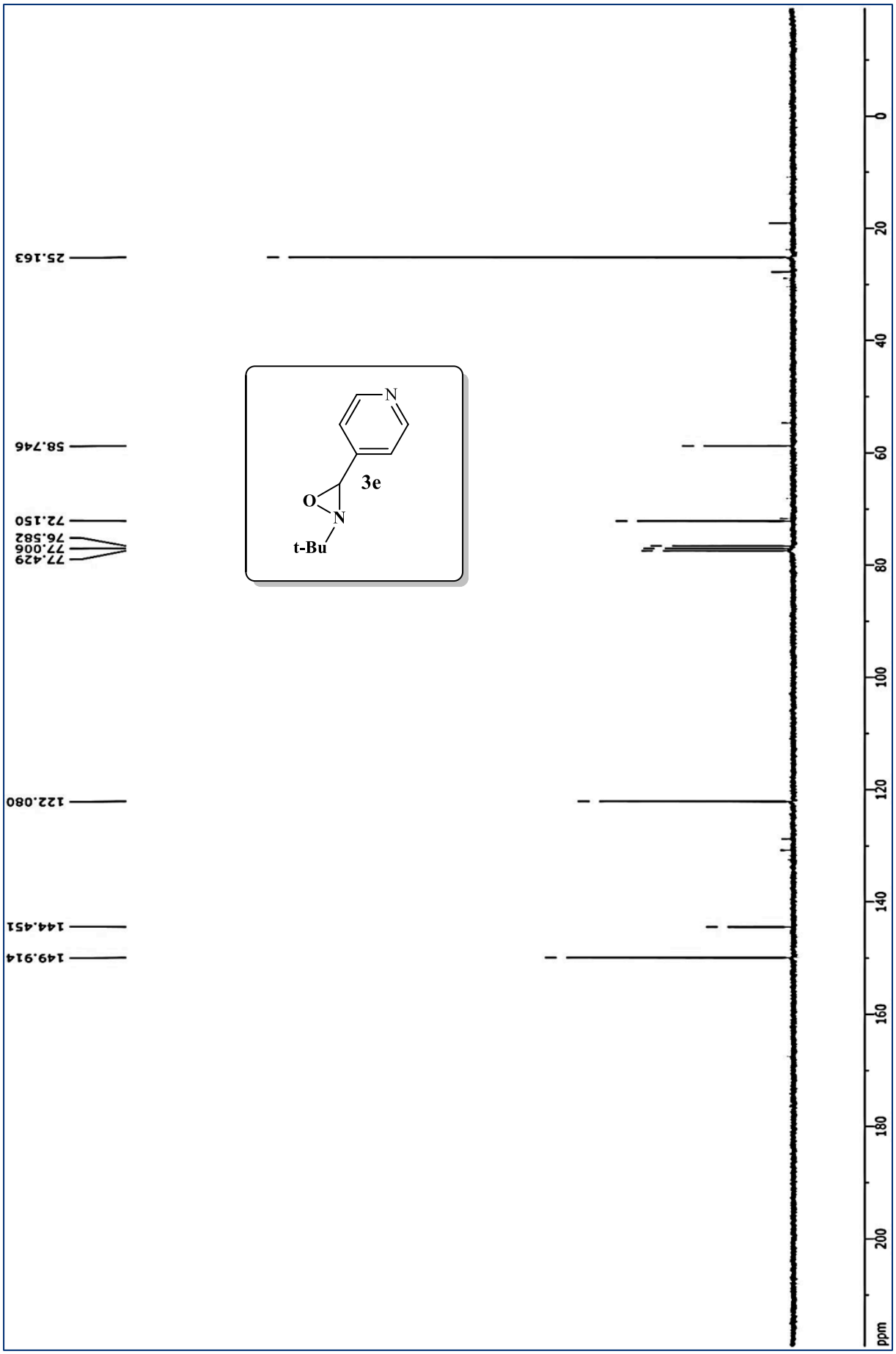

1.210
3.831
4.688
7.324
7.299
7.272
7.091
7.087
7.083
7.066
7.062
7.057
7.015
7.007
7.002
6.964
6.961
6.955
6.952
6.936
6.933
6.928
6.924
9.39
3.16
1
0.963 0.913
1.07 0.934
OCH3
O
N
t-Bu
3c
ppm

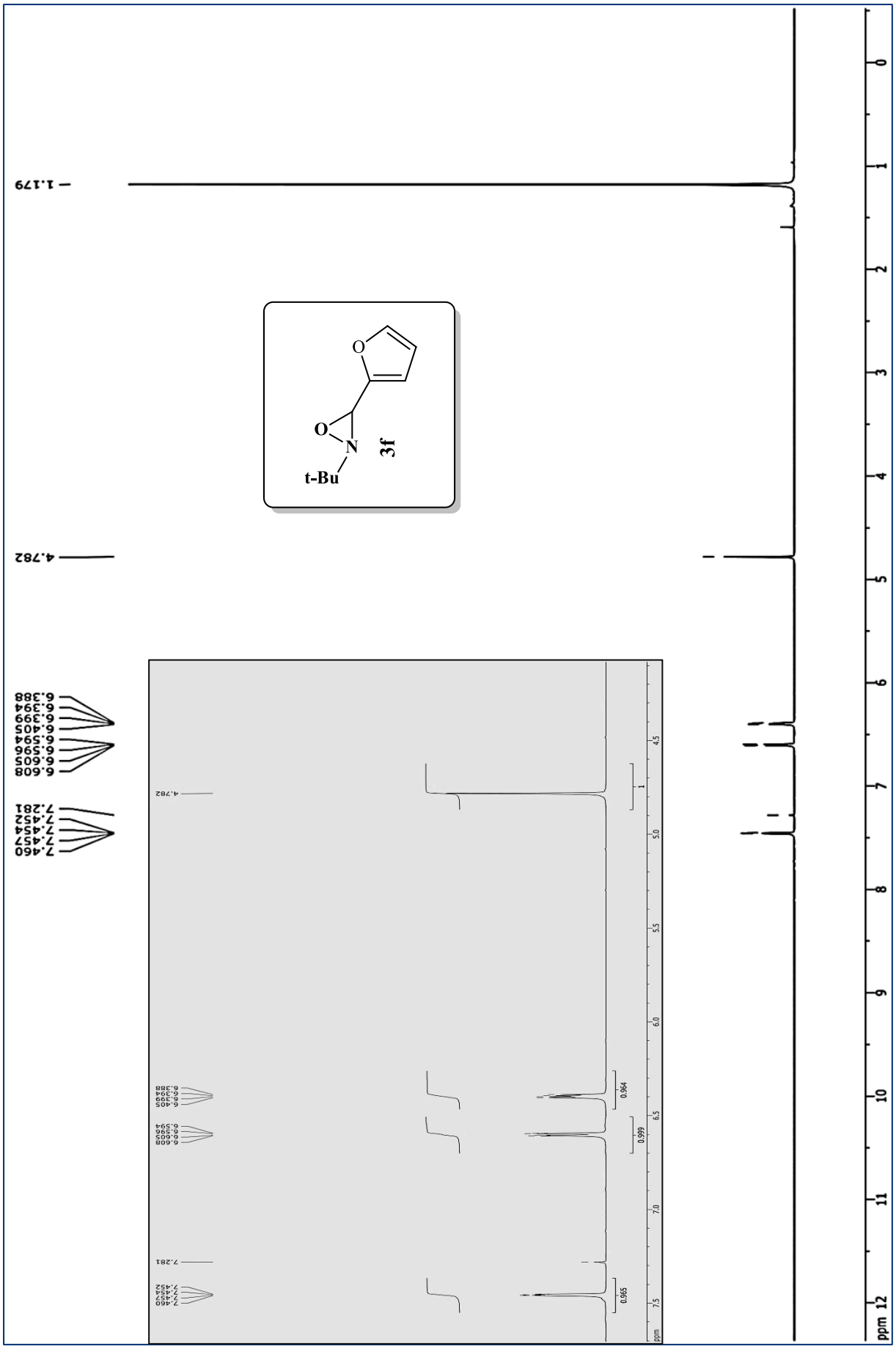

25.260
55.256
58.363
73.599
76.622
112.212
115.942
119.992
129.376
137.330
159.919
OCH3
O
N
t-Bu
3c
0
20
40
60
80
100
120
140
160
180
200
ppm

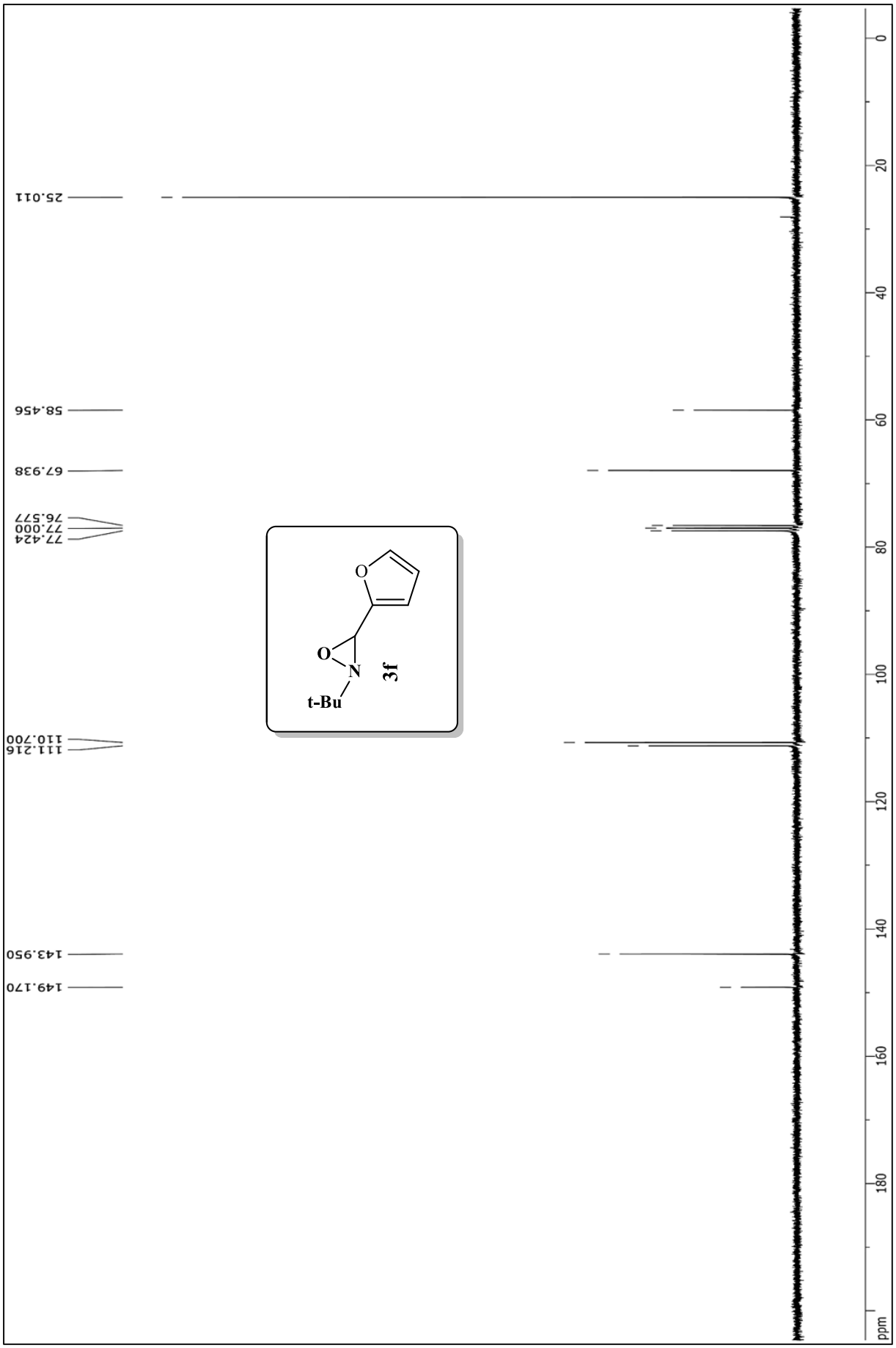

1.200
4.785
7.283
7.642
7.613
8.243
8.214
9.36
1
1.98
1.97
ppm
NO2
O
N
t-Bu
3d

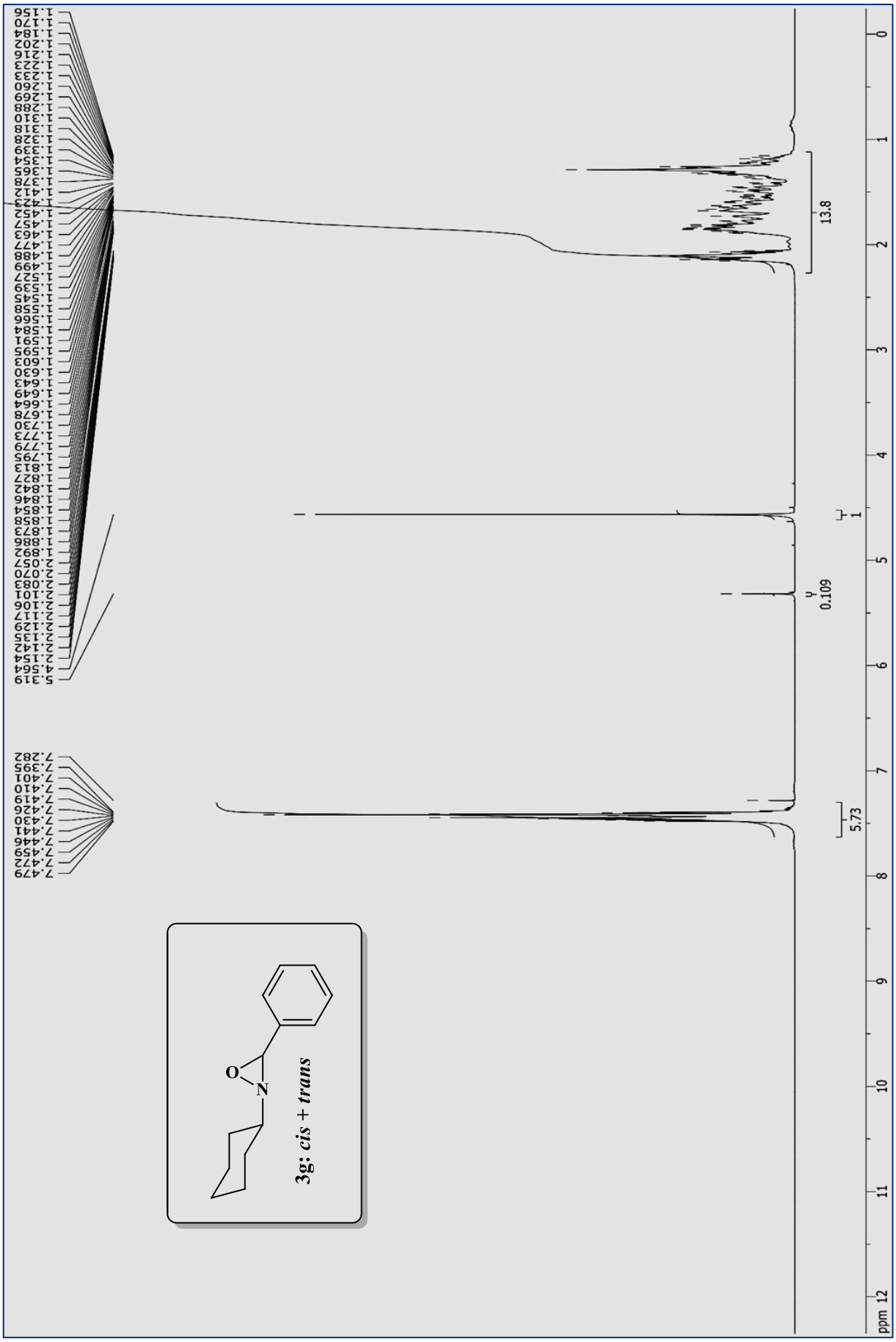

25.218
58.905
72.318
76.624
77.048
77.472
123.585
128.584
142.701
NO2
O
N
t-Bu
3d
0
20
40
60
80
100
120
140
160
180
ppm

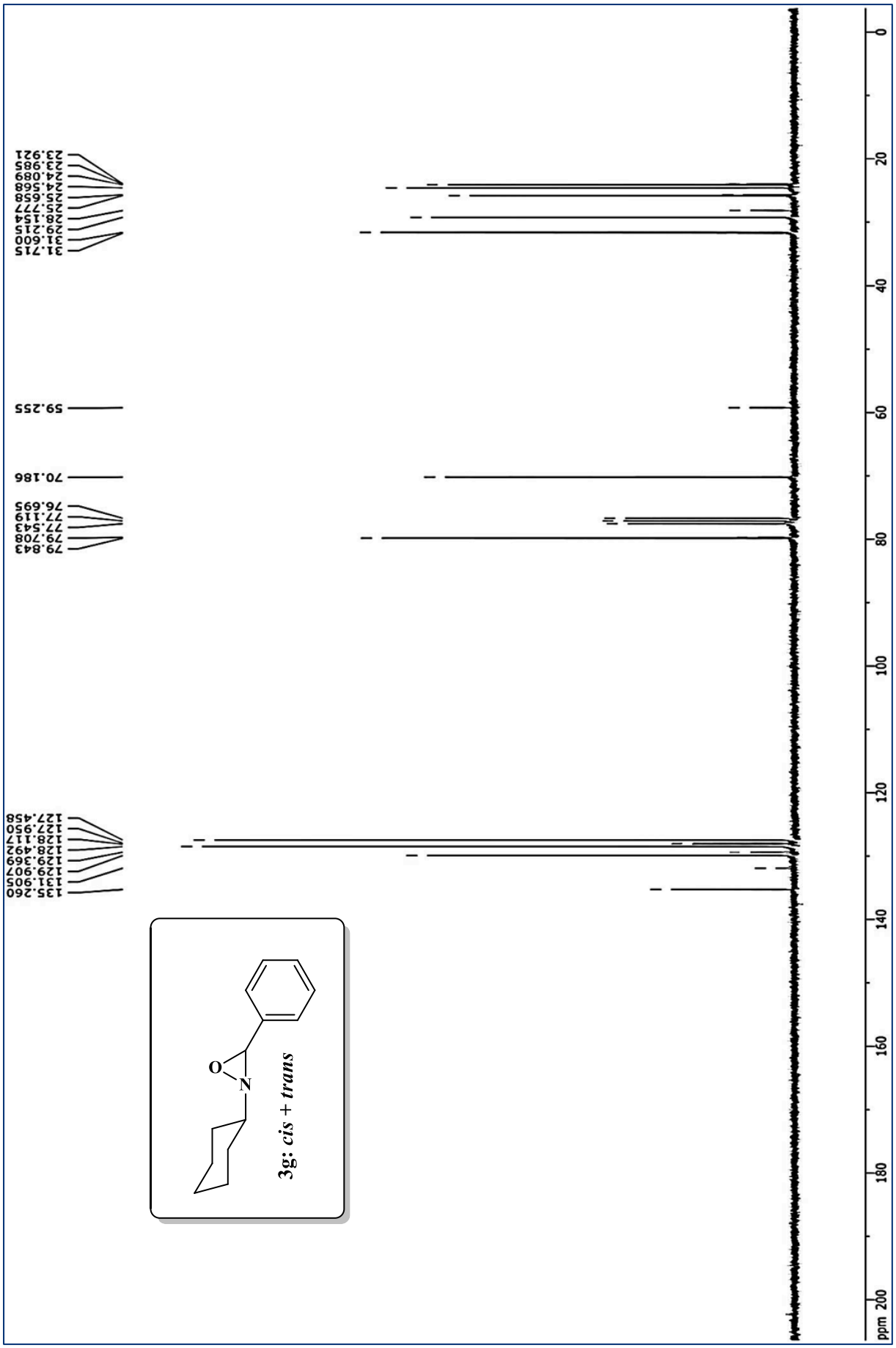

1.173
4.651
7.282
7.335
7.340
7.349
7.355
8.612
8.617
8.627
8.632
9.29
1
1.9
1.96
ppm
O
N
t-Bu
3e

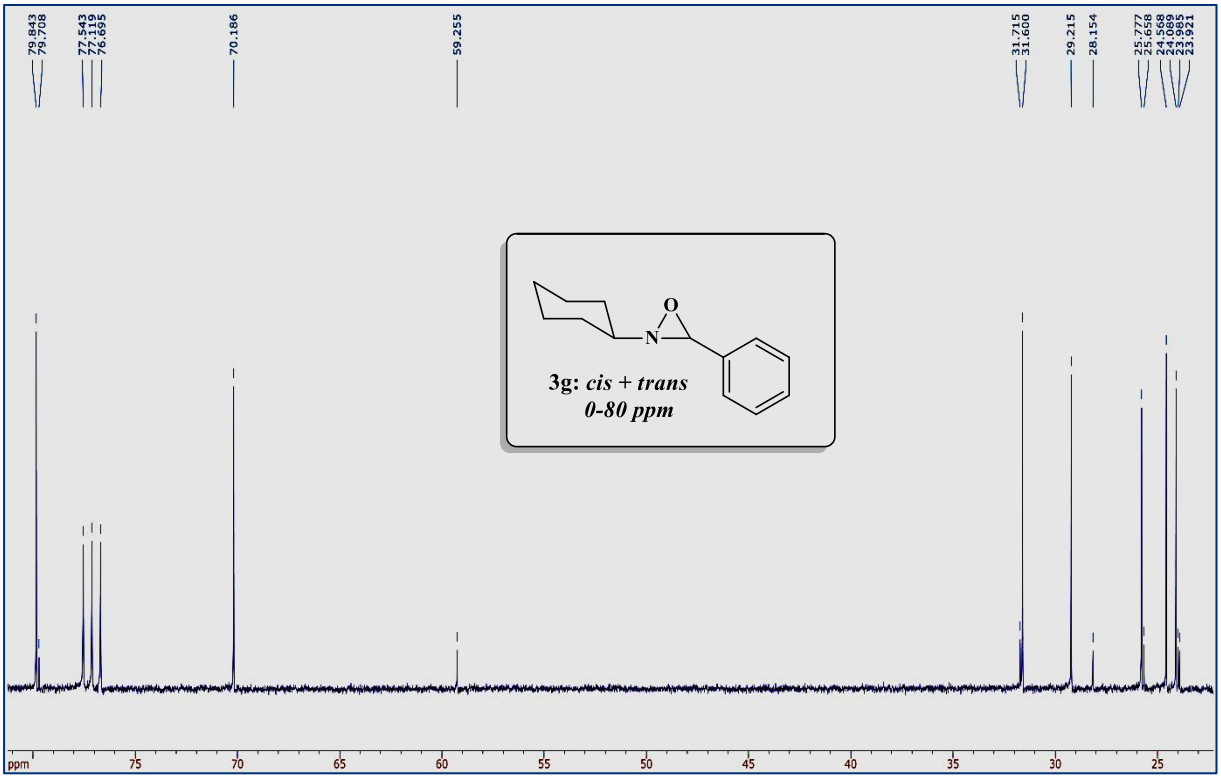

25.163
58.746
72.150
76.582
77.006
77.429
122.080
144.451
149.914
3e
t-Bu
N
O
N
0
20
40
60
80
100
120
140
160
180
200
ppm

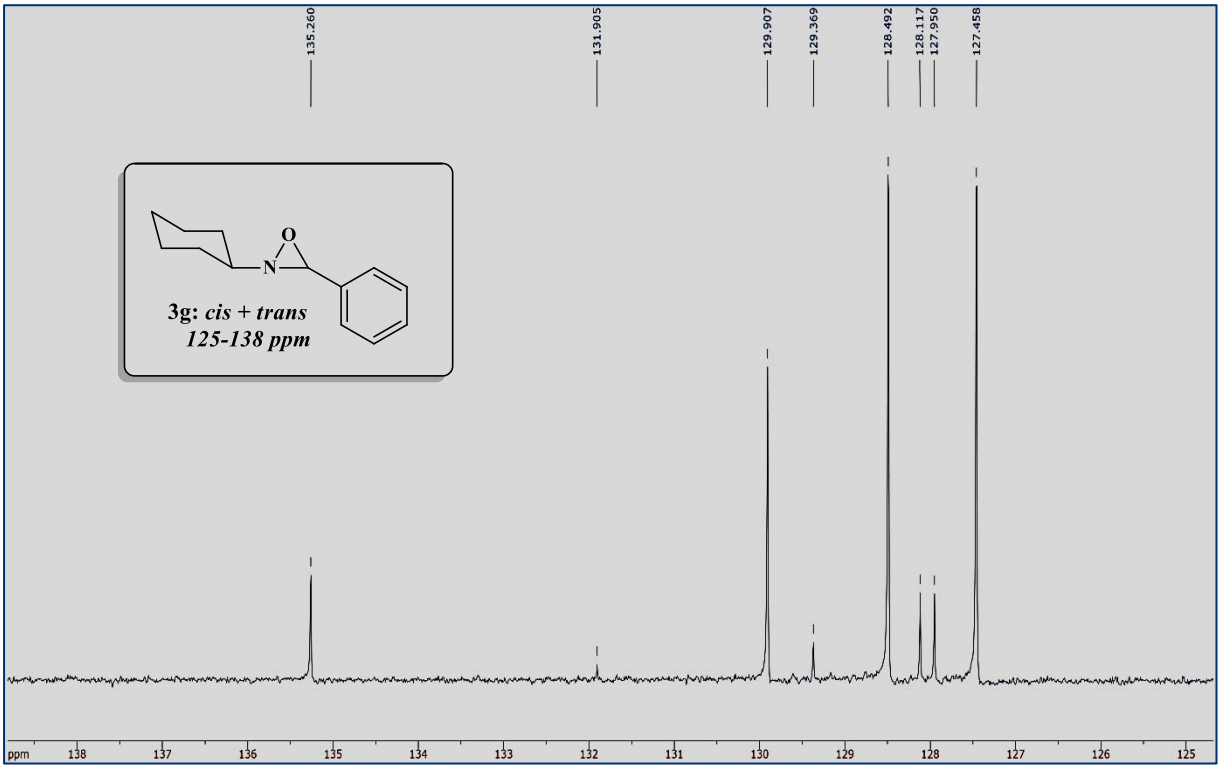

1.179
4.782
6.608
6.605
6.596
6.594
6.405
6.399
6.394
6.388
7.460
7.457
7.454
7.452
7.281
O
O
N
t-Bu
3f
ppm

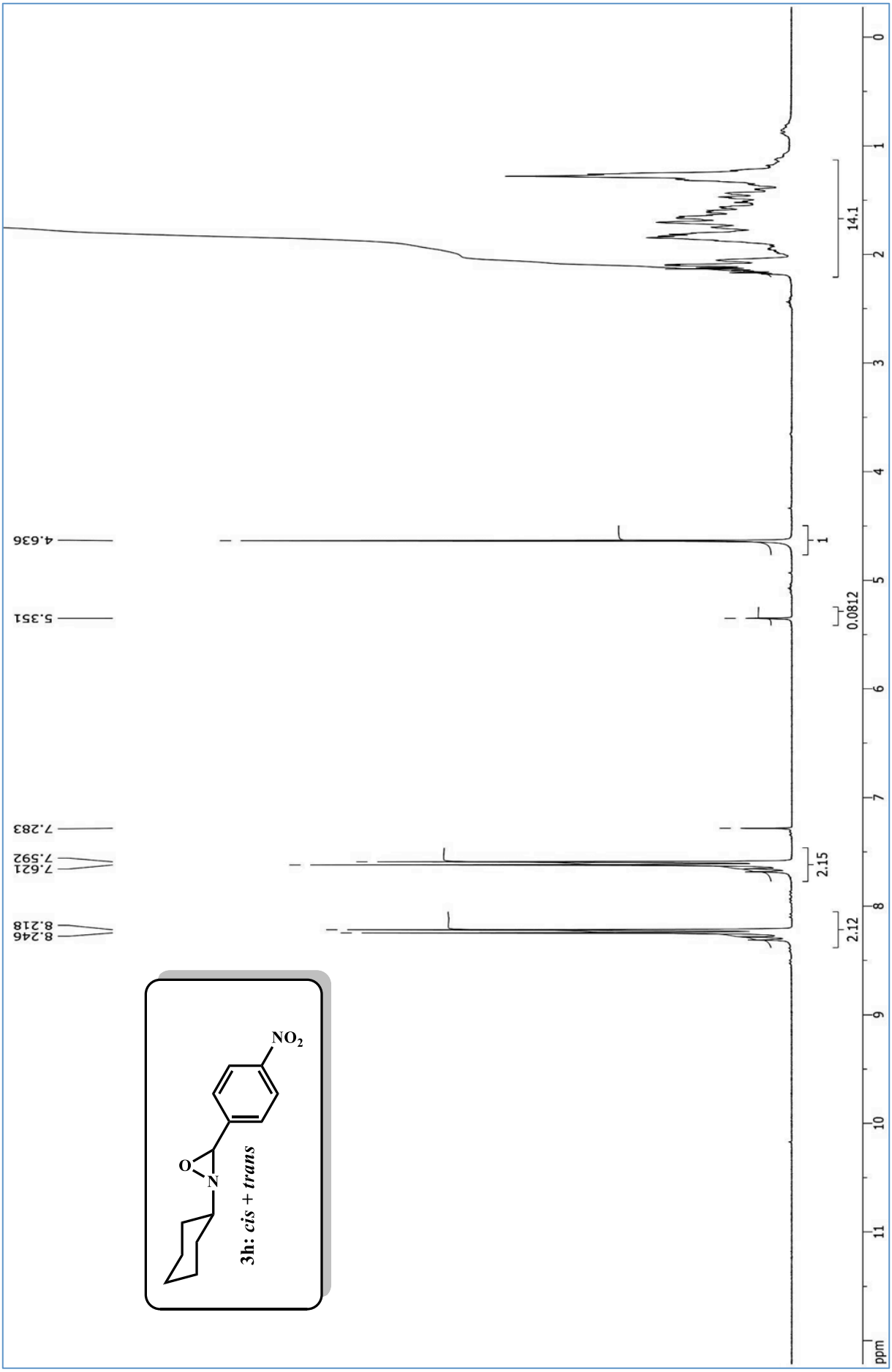

25.011
58.456
67.938
76.577
77.000
77.424
110.700
111.216
143.950
149.170
O
O
N
t-Bu
3f
0
20
40
60
80
100
120
140
160
180
ppm

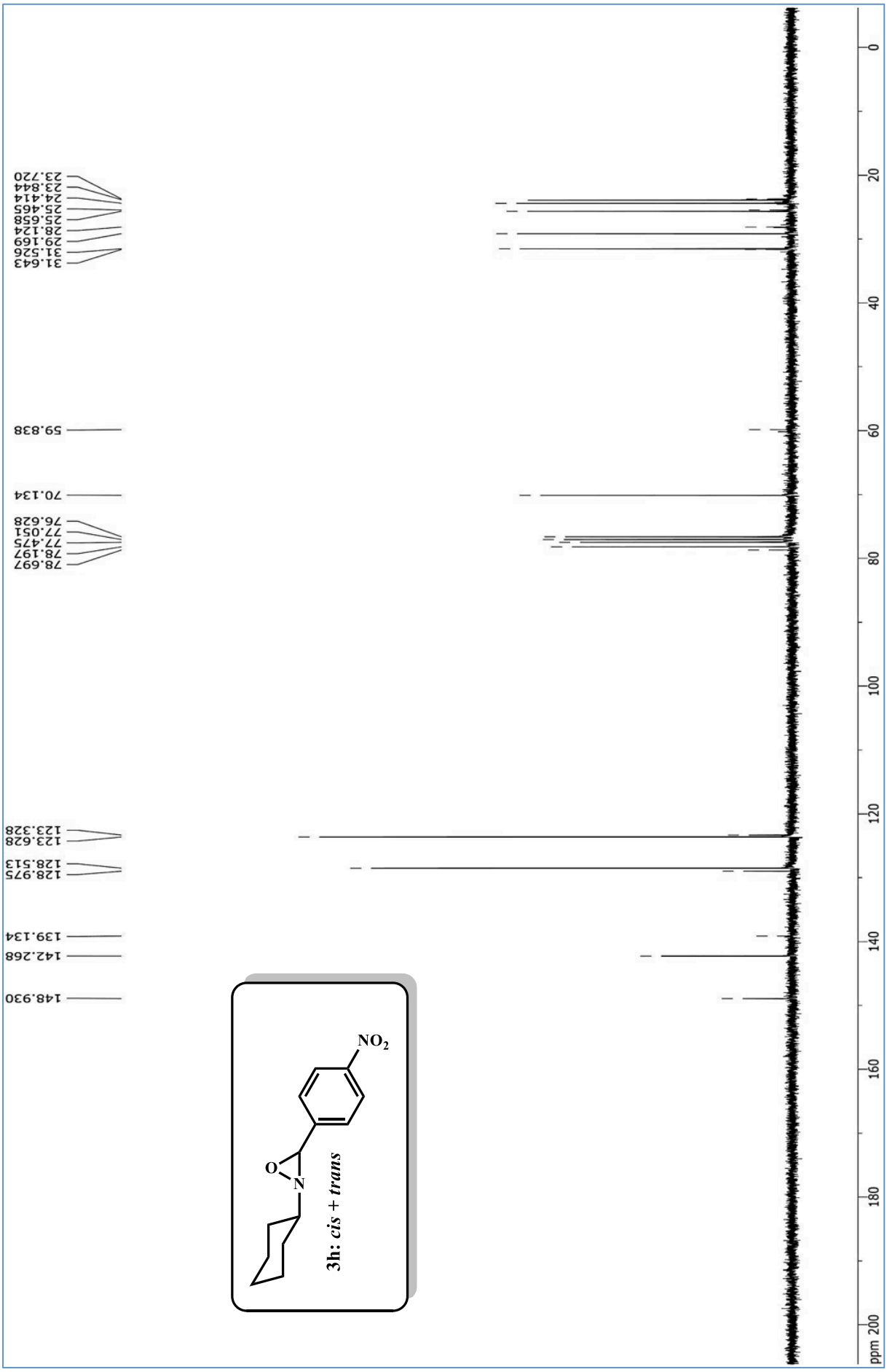

3g: *cis* + *trans*
O
N
13.8
0.109
1
5.73
ppm 12

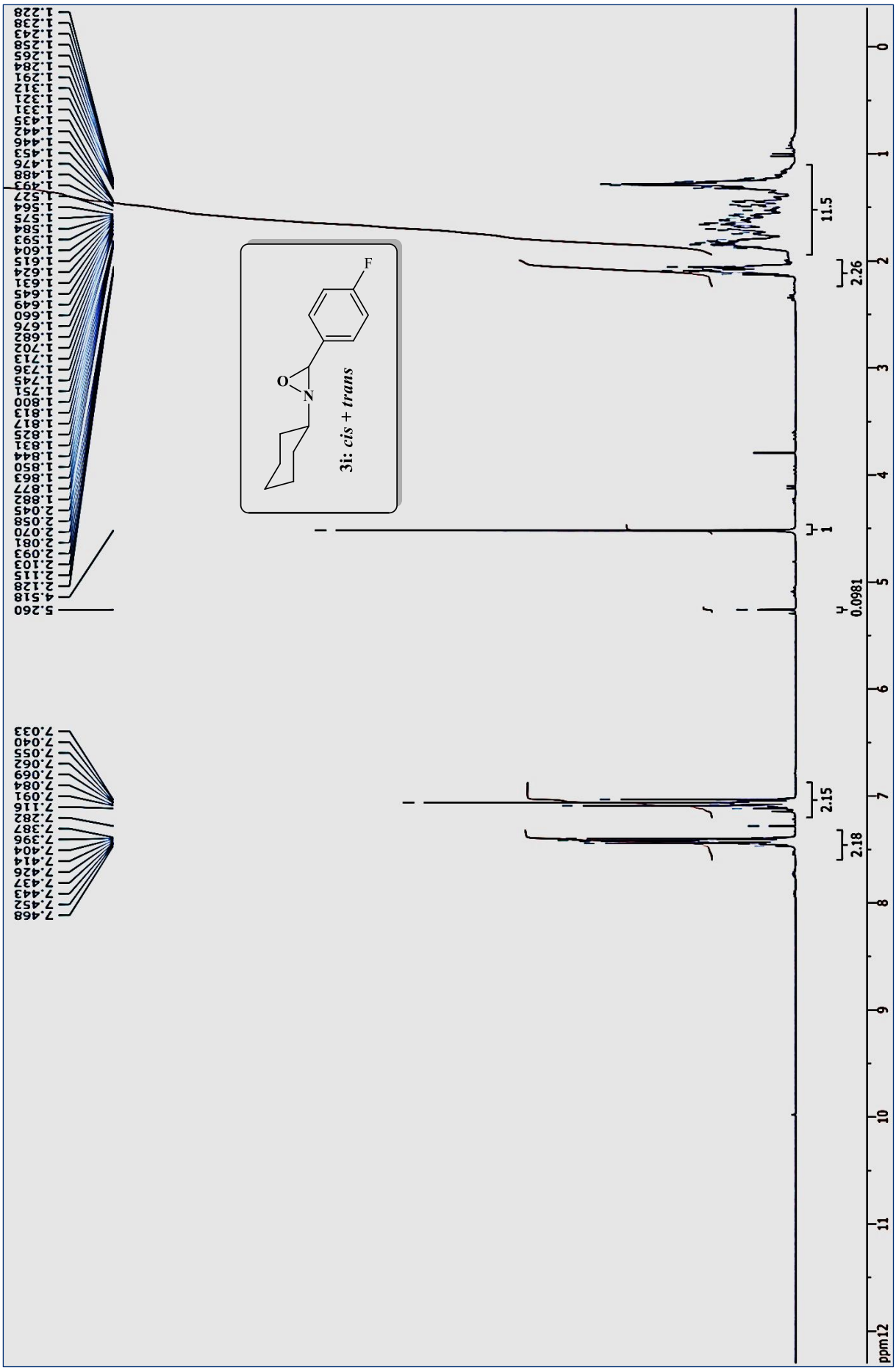

135.260
131.905
129.907
129.369
128.492
128.117
127.950
127.458
79.843
79.708
77.543
77.119
76.695
70.186
59.255
31.715
31.600
29.215
28.154
25.777
25.658
24.568
24.089
23.985
23.921
O
N
3g: cis + trans
ppm 200
180
160
140
120
100
80
60
40
20
0

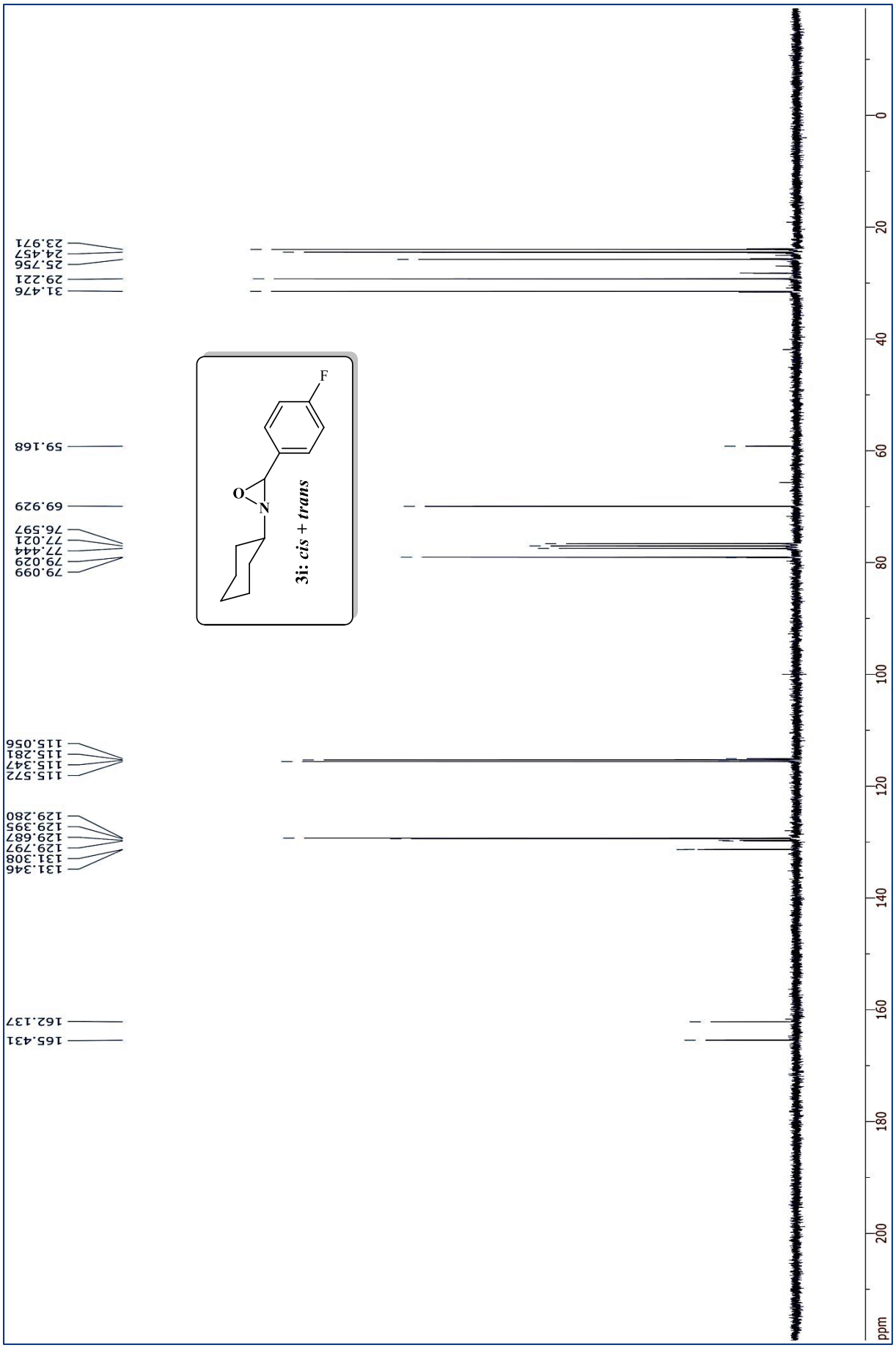

79.843
79.708
77.543
77.119
76.695
70.186
59.255
31.715
31.600
29.215
28.154
25.777
25.658
24.568
24.069
23.985
23.921
O
N
3g: cis + trans
0-80 ppm
ppm
75
70
65
60
55
50
45
40
35
30
25

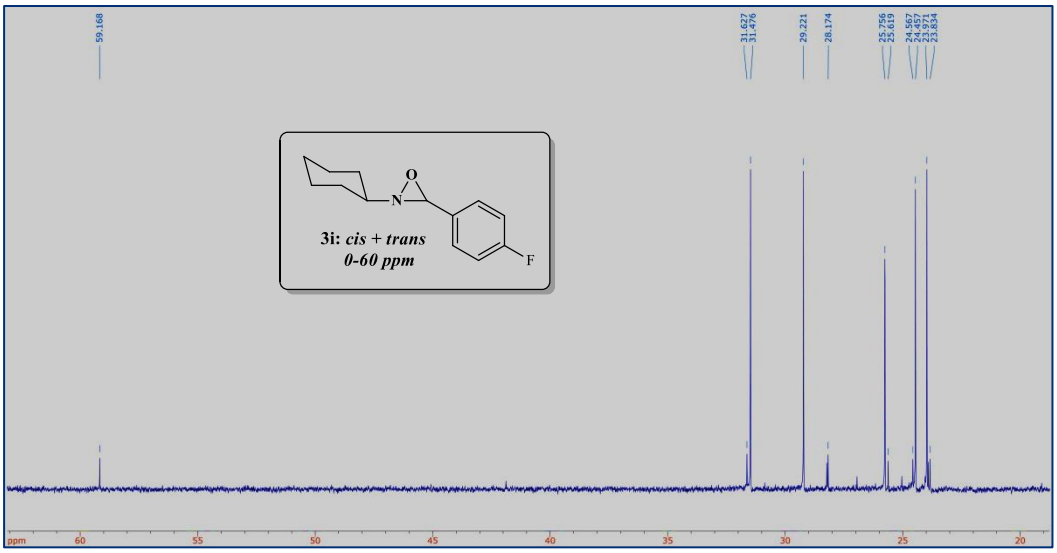

135.260
131.905
129.907
129.369
128.492
128.117
127.950
127.458
O
N
3g: cis + trans
125-138 ppm
ppm
138
137
136
135
134
133
132
131
130
129
128
127
126
125

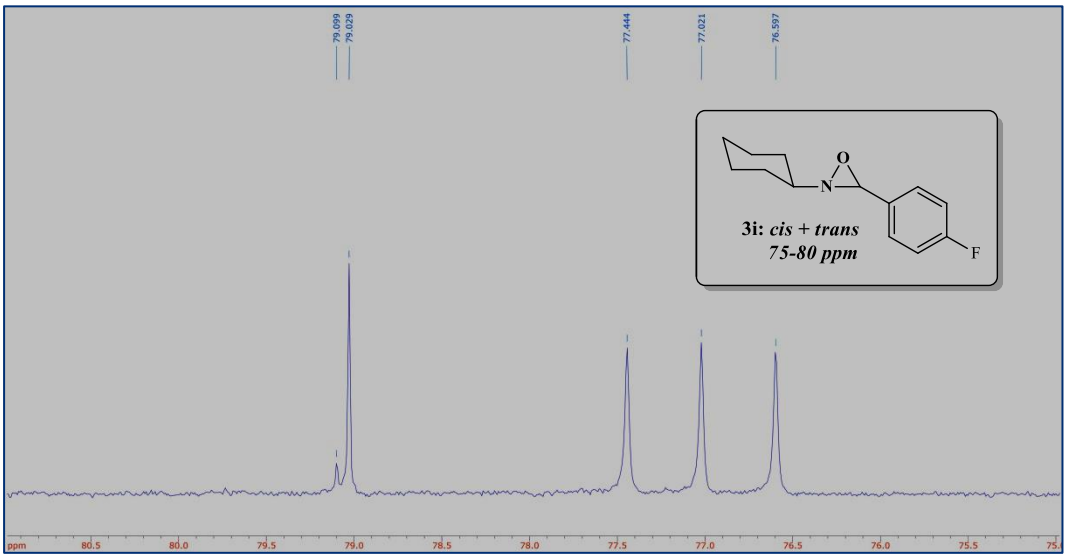

NO2
O
N
3h: cis + trans
8.246
8.218
7.621
7.592
7.283
5.351
4.636
14.1
1
0.0812
2.15
2.12
ppm

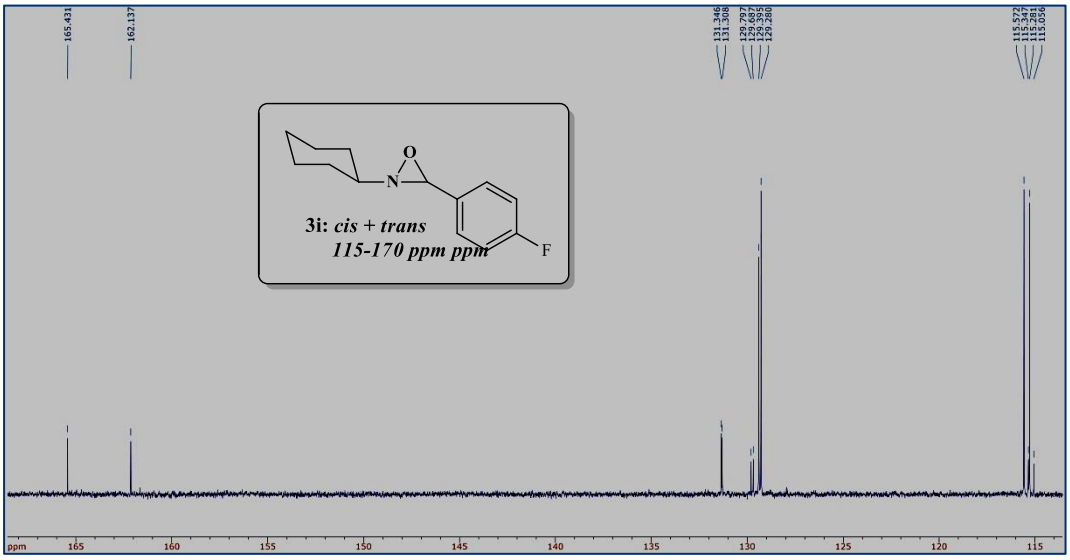

23.720
23.844
24.414
25.465
25.658
28.124
29.169
31.526
31.643
59.838
70.134
76.628
77.051
77.475
78.197
78.697
123.328
123.628
128.513
128.975
139.134
142.268
148.930
NO2
O
N
3h: cis + trans
0
20
40
60
80
100
120
140
160
180
200
ppm

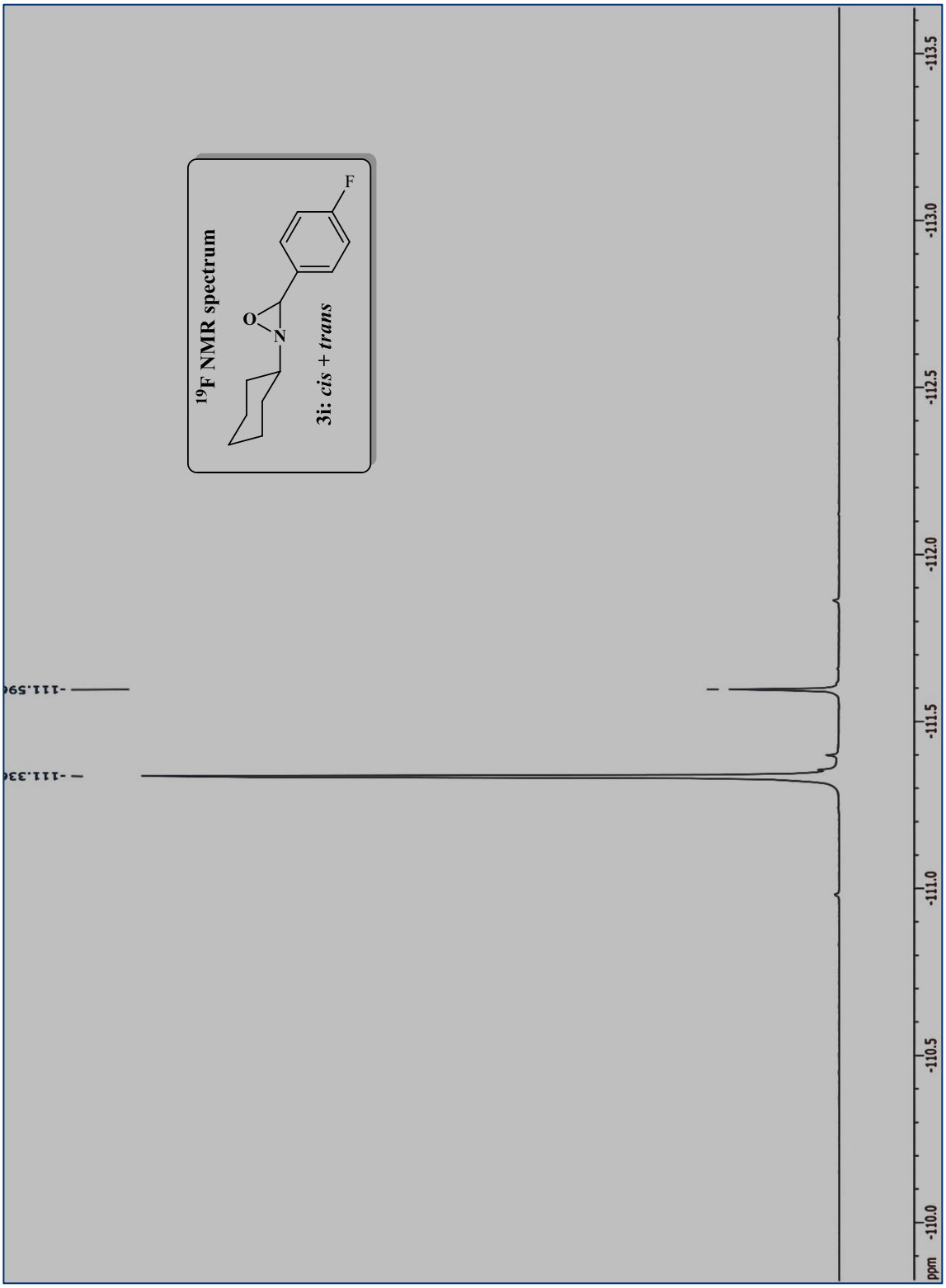

F
O
N
3i: *cis* + *trans*
11.5
2.26
1
0.0981
2.15
2.18
ppm

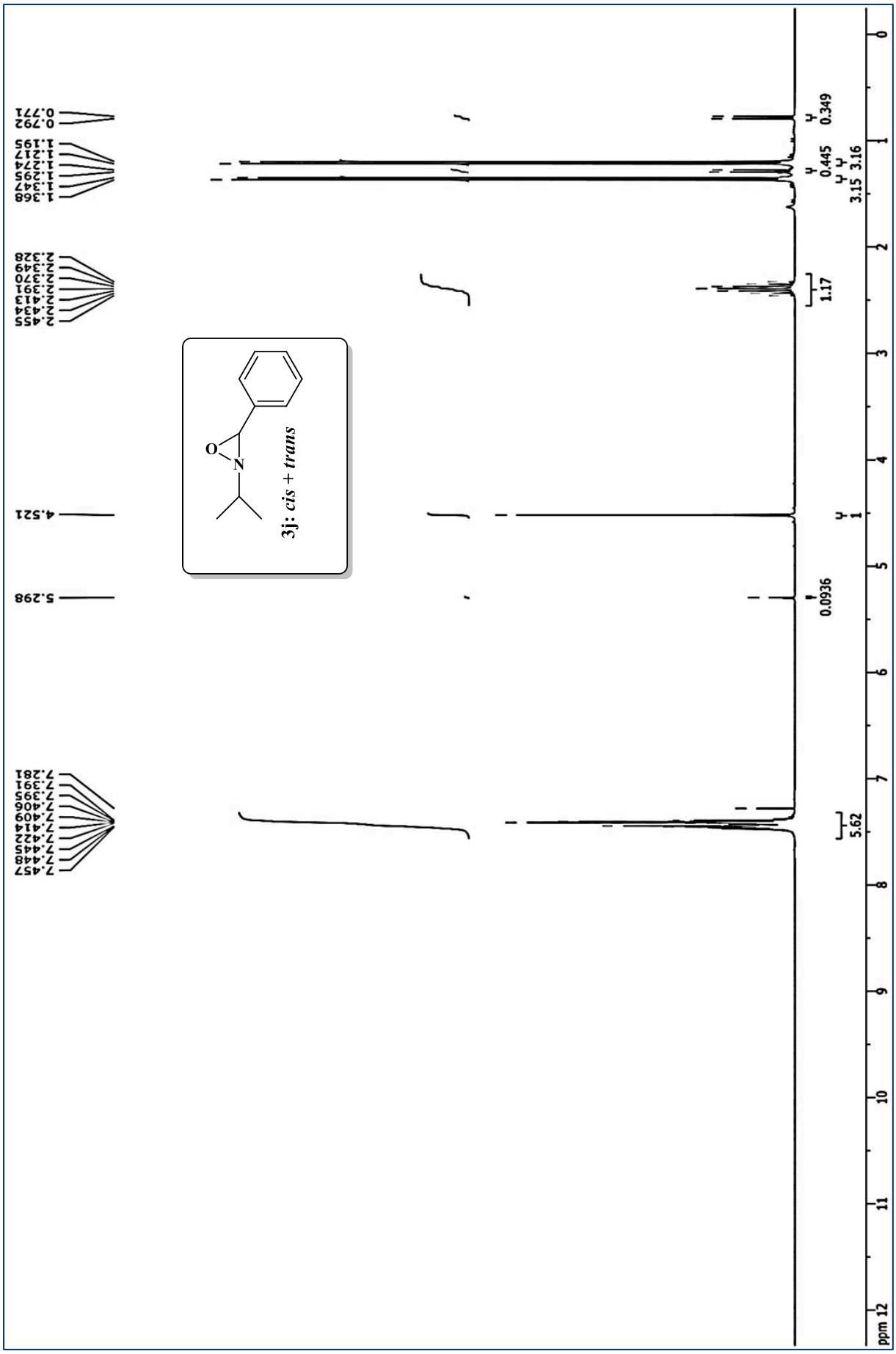

F
O
N
3i: cis + trans
23.971
24.457
25.756
29.221
31.476
59.168
69.929
76.597
77.021
77.444
79.029
79.099
115.056
115.281
115.347
115.572
129.280
129.395
129.687
129.797
131.308
131.346
162.137
165.431
ppm

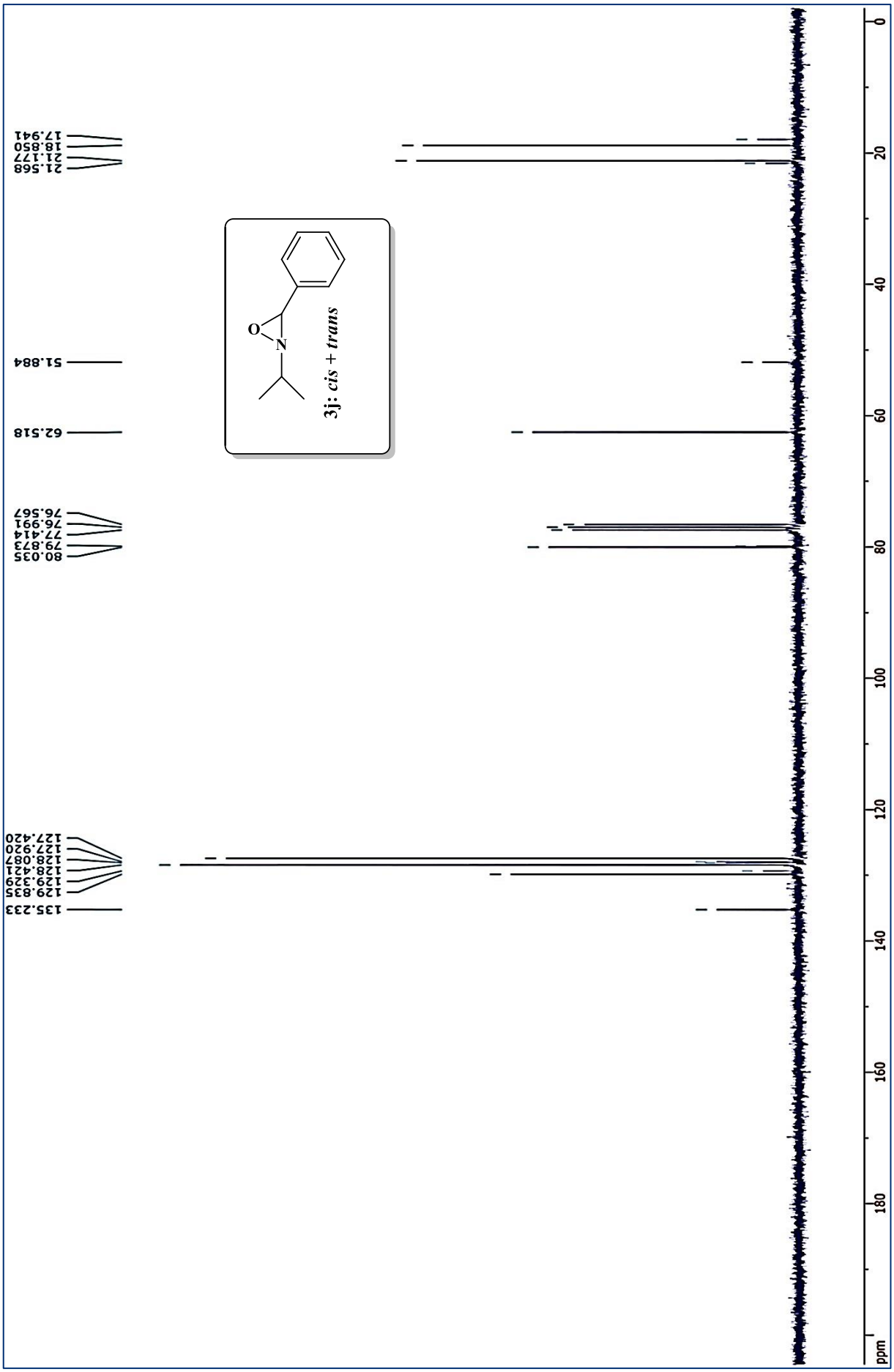

59.168
31.627
31.476
29.221
28.174
25.756
25.619
24.567
24.457
23.871
23.834
O
N
F
3i: cis + trans
0-60 ppm
ppm
60
55
50
45
40
35
30
25
20

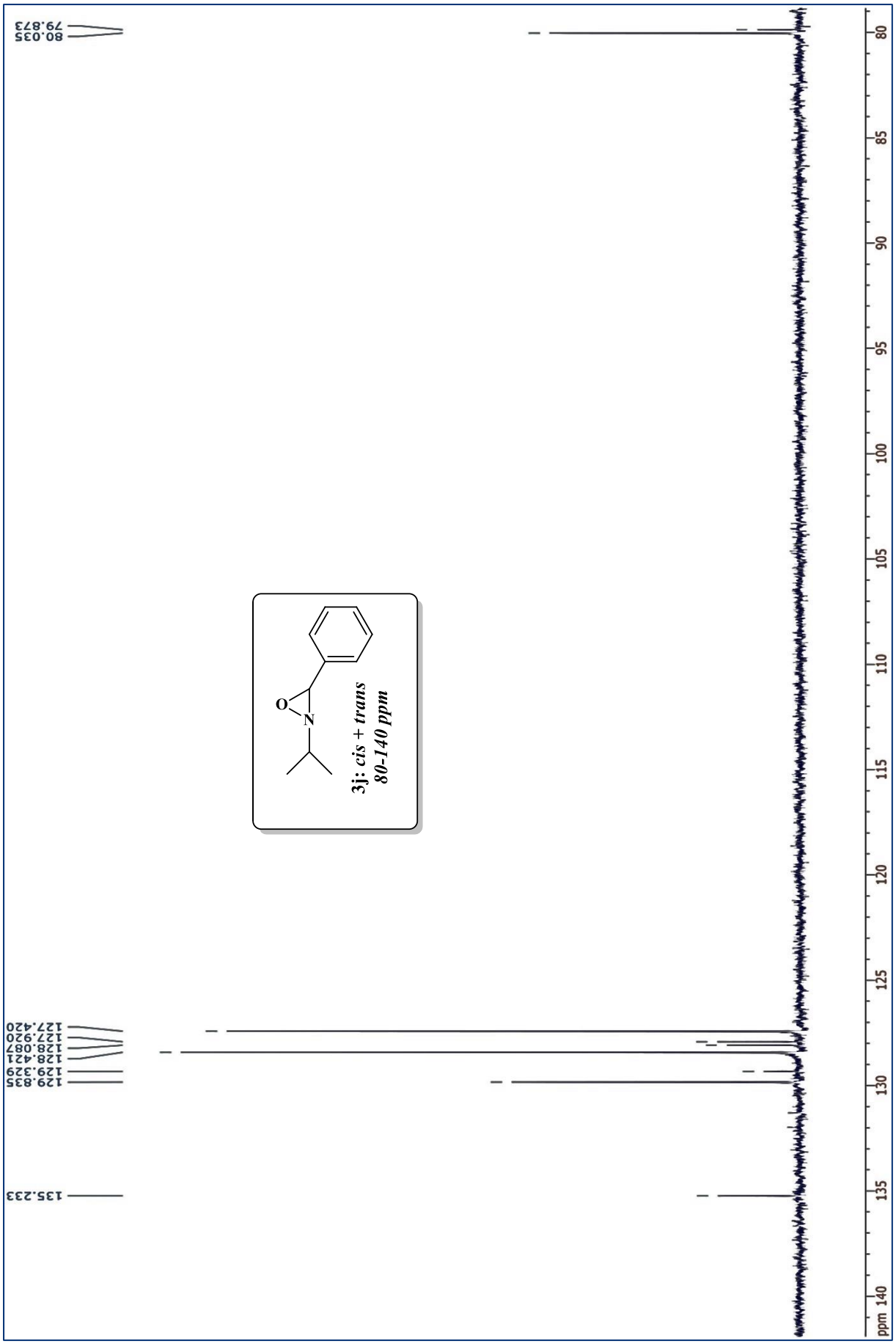

79.099
79.029
77.444
77.021
76.597
O
N
F
3i: cis + trans
75-80 ppm
ppm
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
75.5

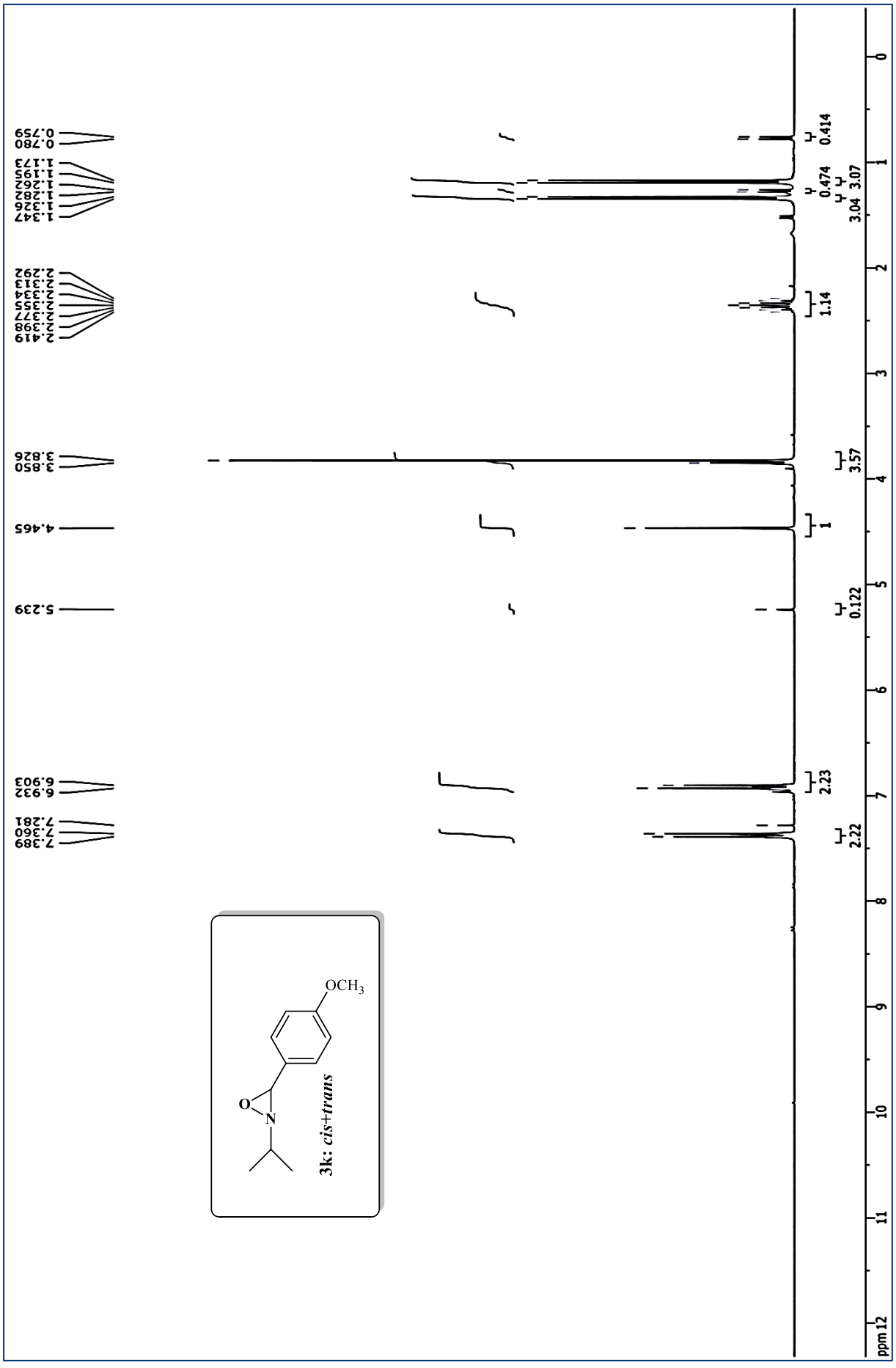

165.431
162.137
131.346
131.308
129.797
129.690
129.395
129.286
115.572
115.347
115.338
115.056
O
N
F
3i: cis + trans
115-170 ppm ppm
ppm
165
160
155
150
145
140
135
130
125
120
115

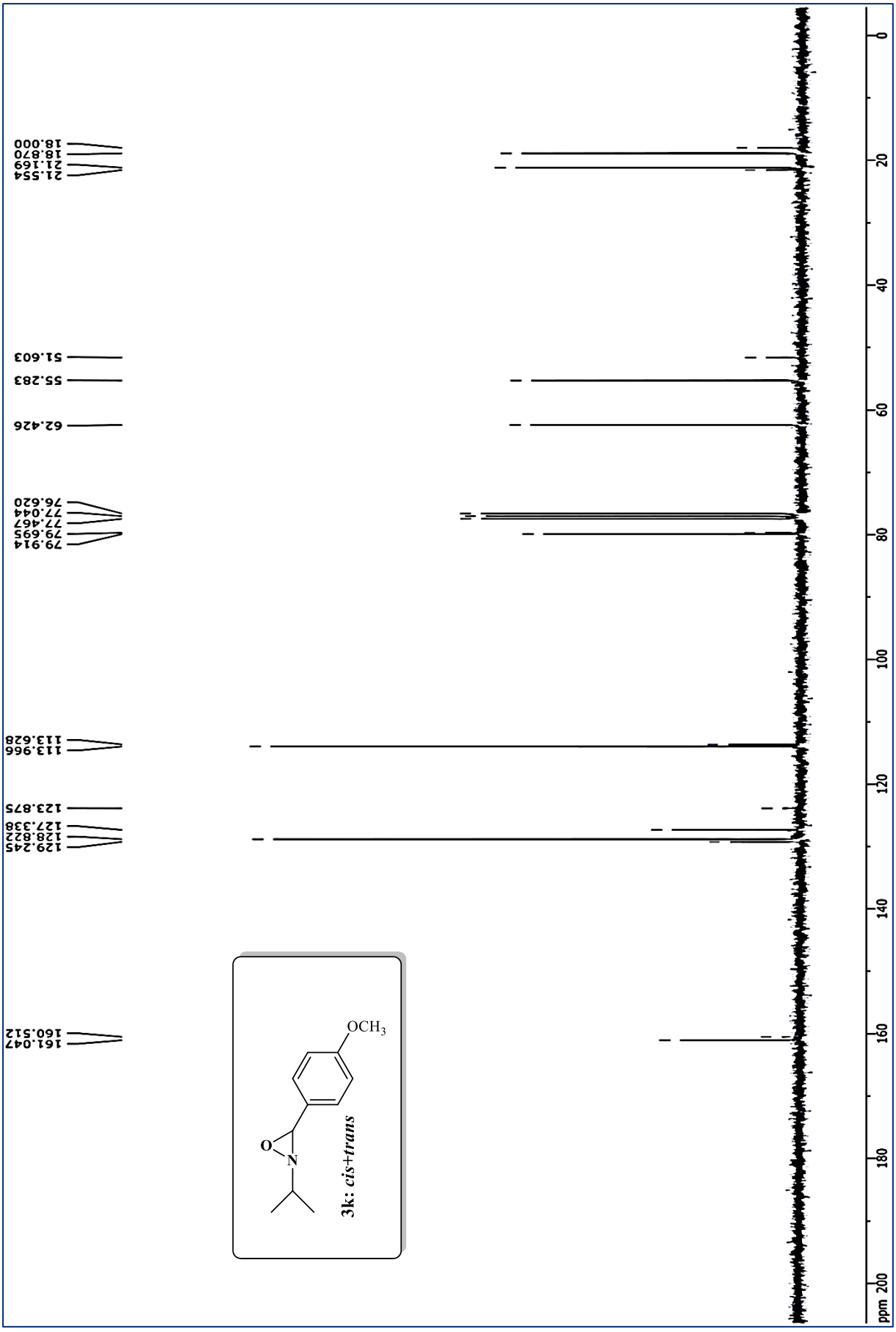

^{19}F NMR spectrum
3i: *cis* + *trans*
F
O
N
-111.596
-111.330
ppm
-110.0
-110.5
-111.0
-111.5
-112.0
-112.5
-113.0
-113.5

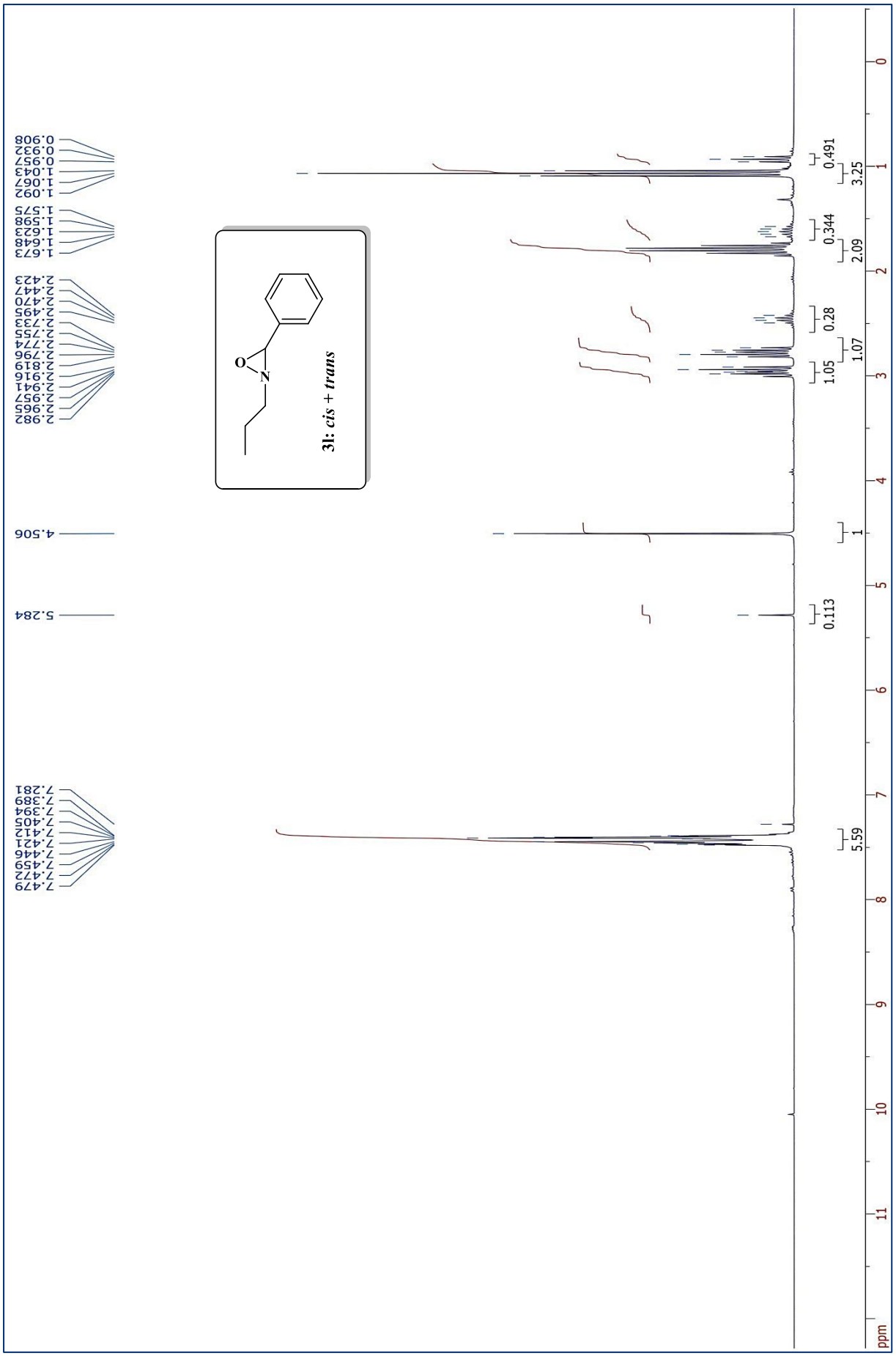

3j: *cis* + *trans*
O
N
7.457
7.448
7.445
7.422
7.414
7.409
7.406
7.395
7.391
7.281
5.298
4.521
2.455
2.434
2.413
2.391
2.370
2.349
2.328
1.368
1.347
1.295
1.274
1.217
1.195
0.792
0.771
5.62
0.0936
1.17
3.15
0.445
3.16
0.349
ppm 12

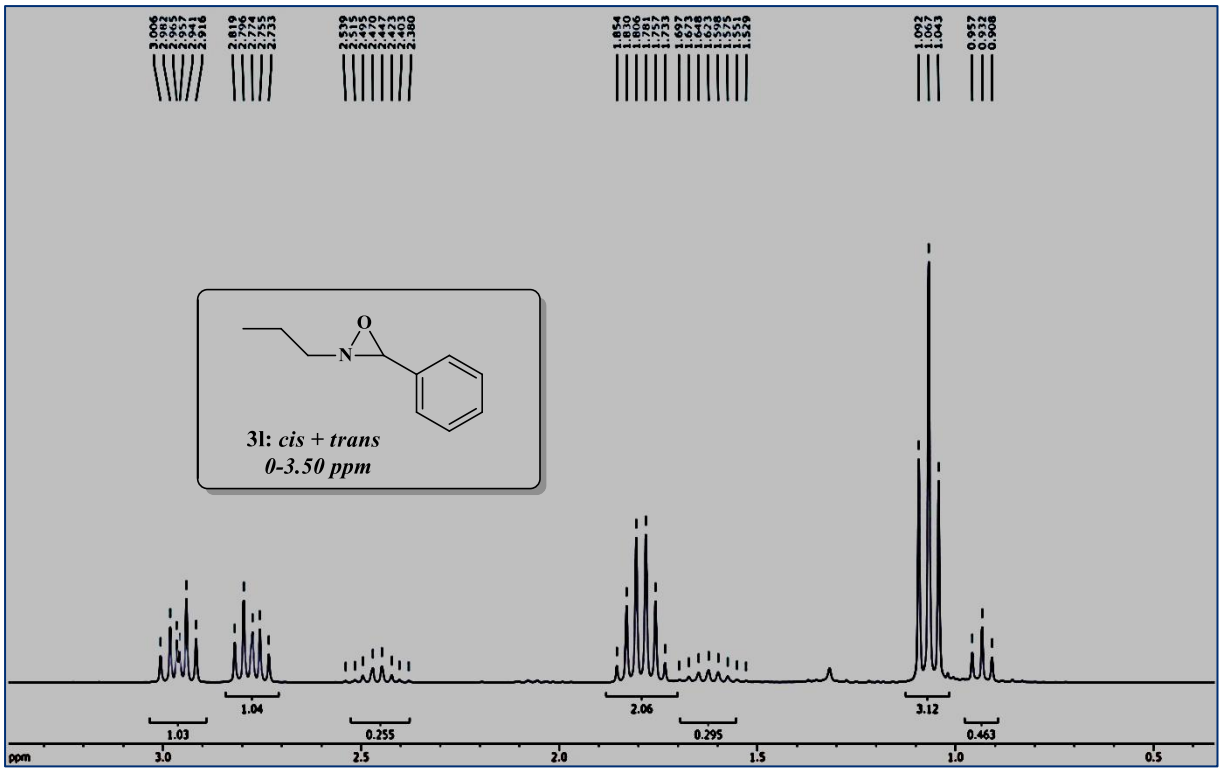

3j: *cis* + *trans*
O
N
135.233
129.835
129.329
128.421
128.087
127.920
127.420
80.035
79.873
77.414
76.991
76.567
62.518
51.884
21.568
21.177
18.850
17.941
0
20
40
60
80
100
120
140
160
180
ppm

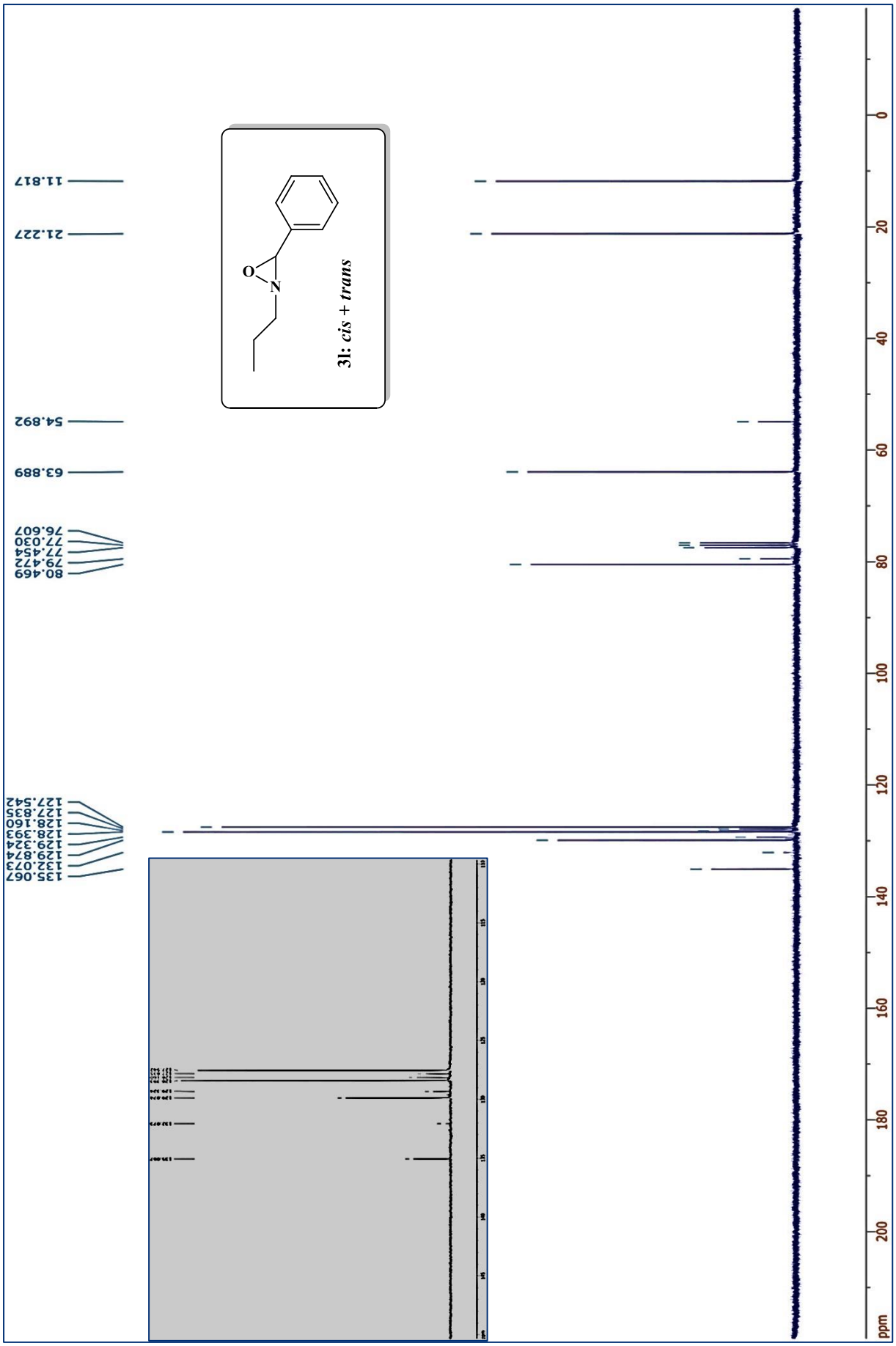

3j: cis + trans
80-140 ppm
135.233
129.835
129.329
128.421
128.087
127.920
127.420
80.035
79.873
ppm 140
135
130
125
120
115
110
105
100
95
90
85
80

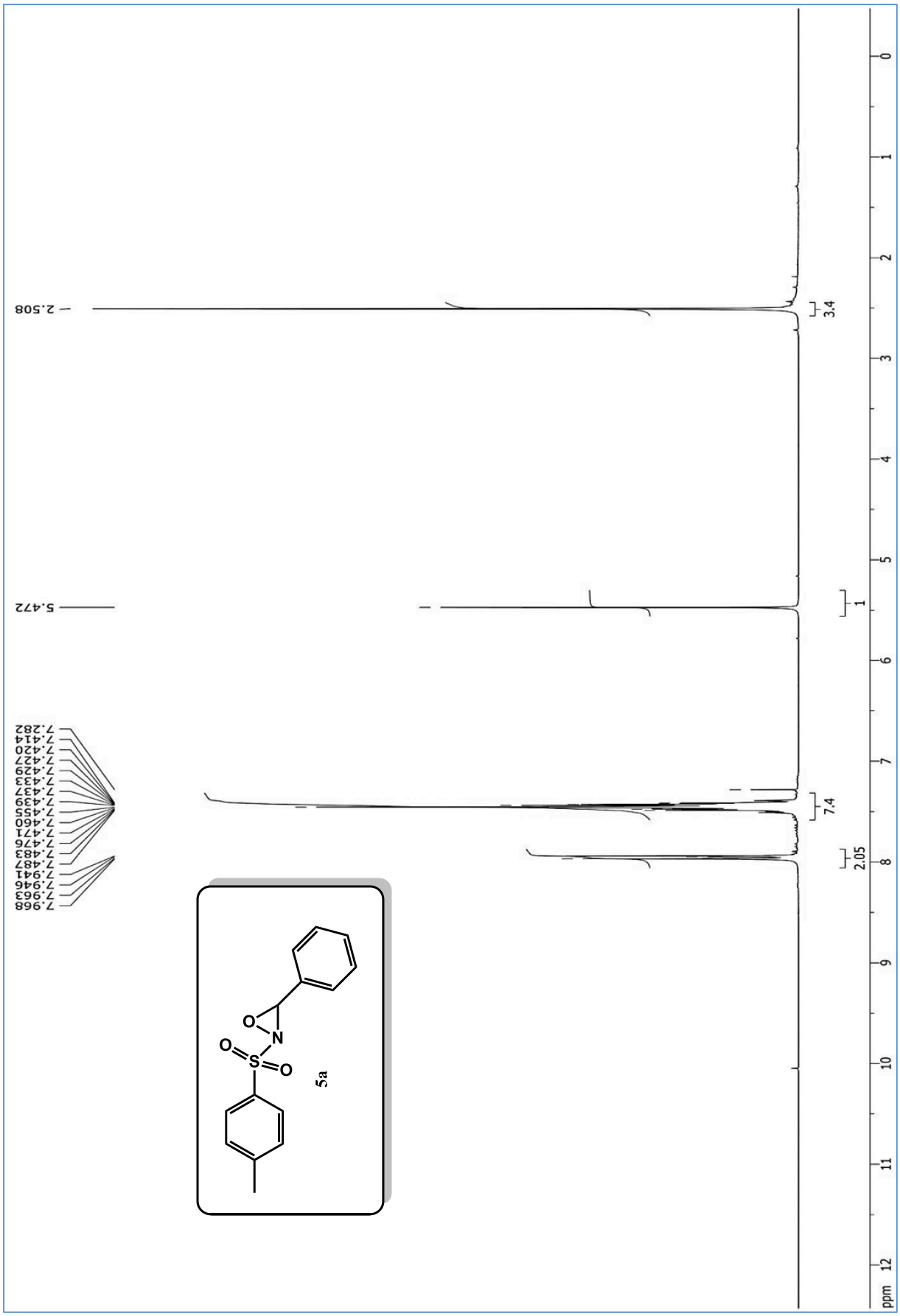

OCH3
O
N
3k: cis+trans

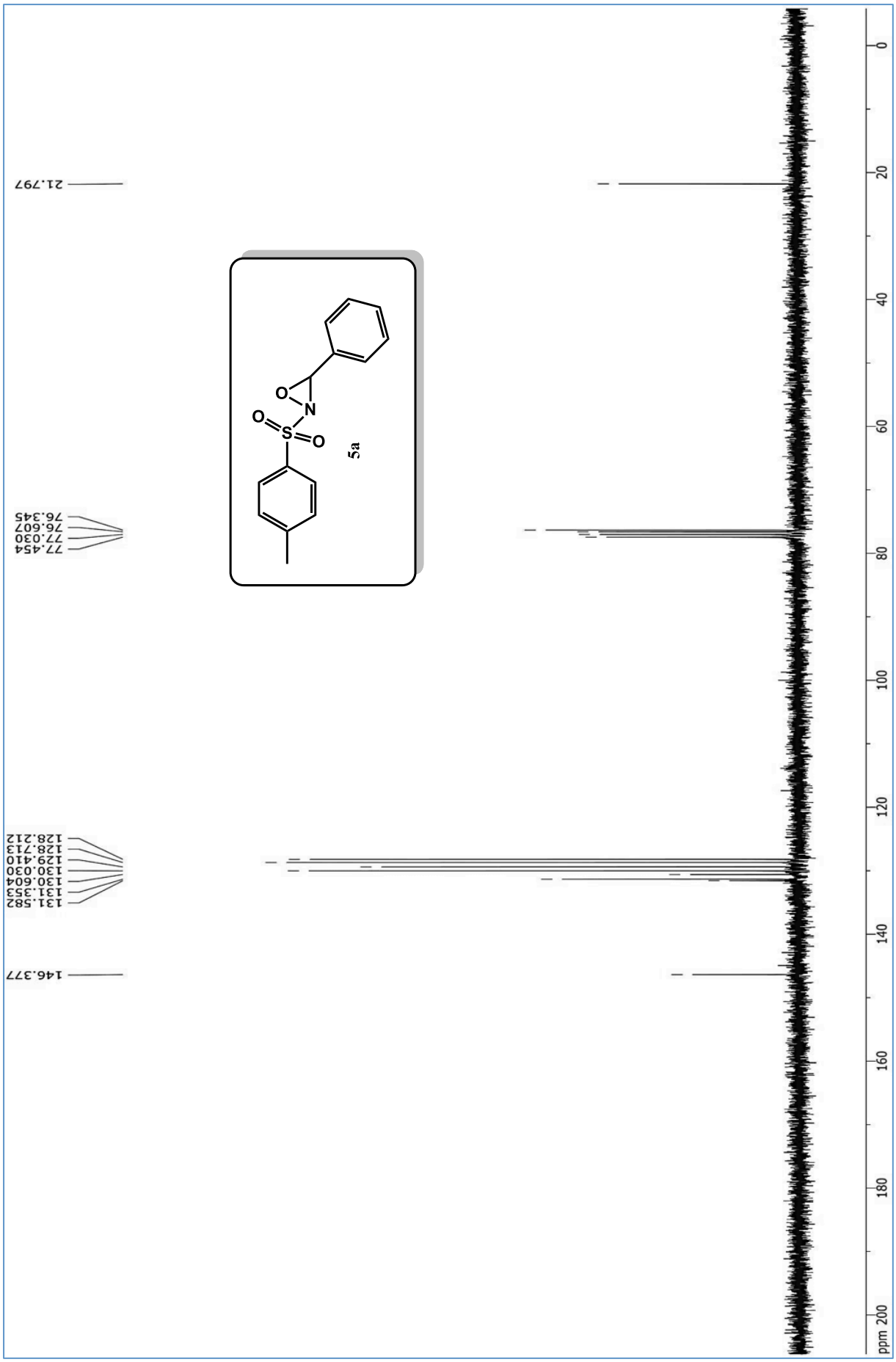

18.000
18.870
21.169
21.554
51.603
55.283
62.426
76.620
77.044
77.467
79.695
79.914
113.628
113.966
123.875
127.338
128.822
129.245
160.512
161.047
OCH3
O
N
3k: cis+trans
ppm 200
180
160
140
120
100
80
60
40
20
0

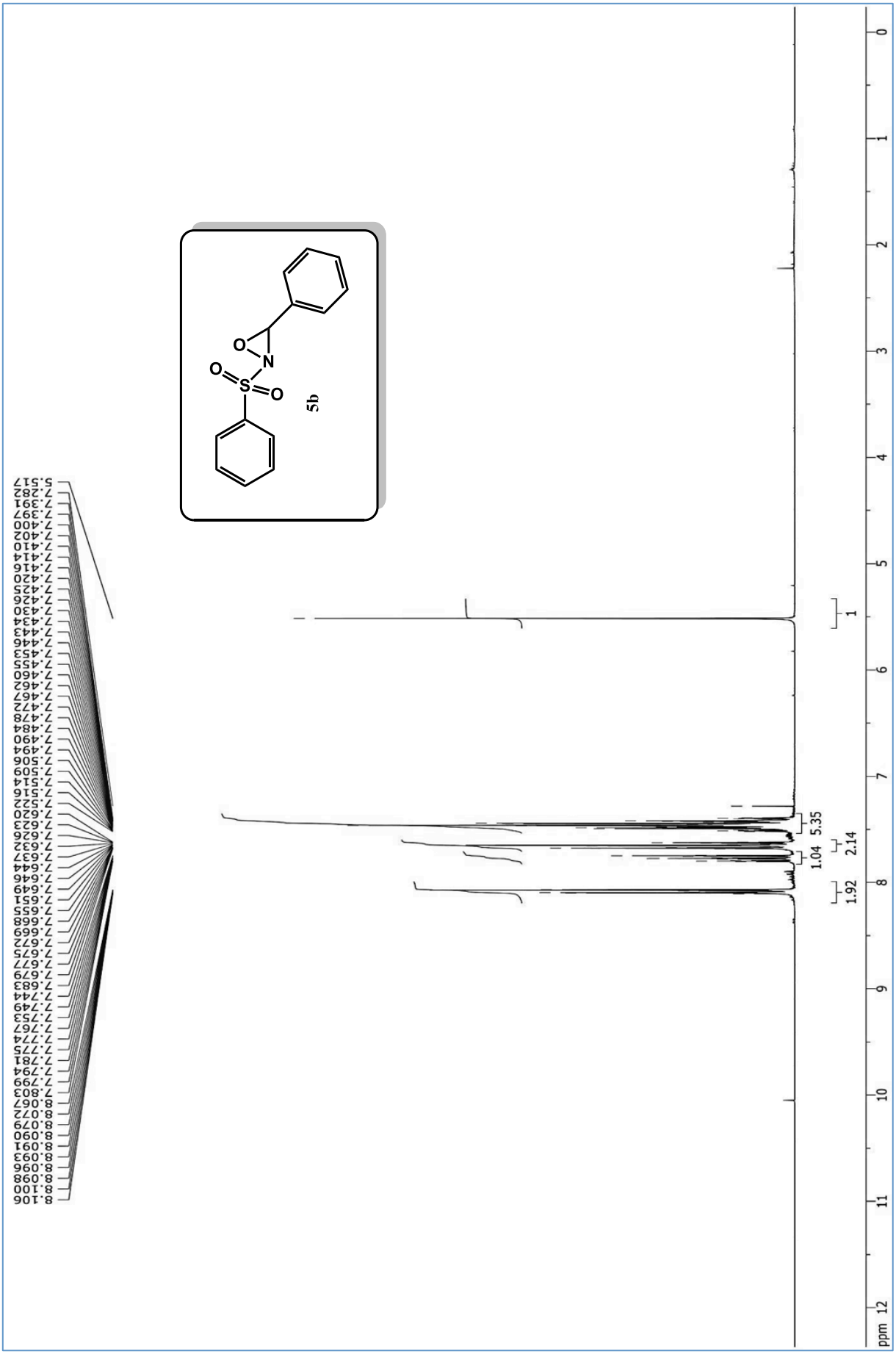

3l: *cis* + *trans*
O
N
7.479
7.472
7.459
7.446
7.421
7.412
7.405
7.394
7.389
7.281
5.284
4.506
2.982
2.965
2.957
2.941
2.916
2.819
2.796
2.774
2.755
2.733
2.495
2.470
2.447
2.423
1.673
1.648
1.623
1.598
1.575
1.092
1.067
1.043
0.957
0.932
0.908
5.59
0.113
1
1.05
0.28
1.07
0.344
2.09
0.491
3.25
ppm

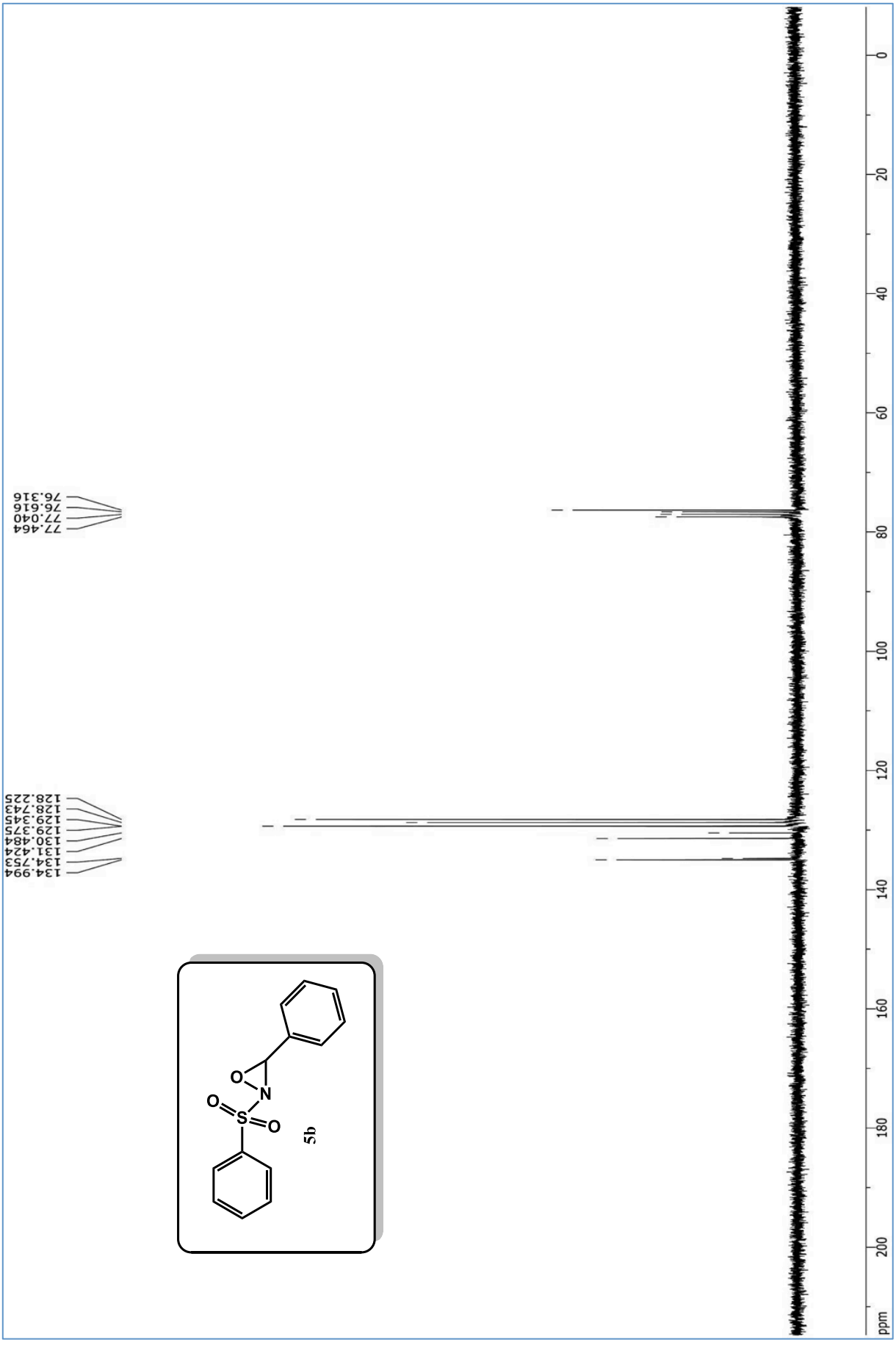

3.006
2.982
2.965
2.947
2.931
2.916
2.819
2.796
2.774
2.755
2.733
2.539
2.515
2.493
2.470
2.447
2.403
2.380
1.854
1.830
1.806
1.781
1.757
1.733
1.697
1.673
1.648
1.623
1.598
1.575
1.551
1.529
1.092
1.067
1.043
0.957
0.932
0.908
O
N
3l: cis + trans
0-3.50 ppm
1.03
1.04
0.255
2.06
0.295
3.12
0.463
ppm
3.0
2.5
2.0
1.5
1.0
0.5

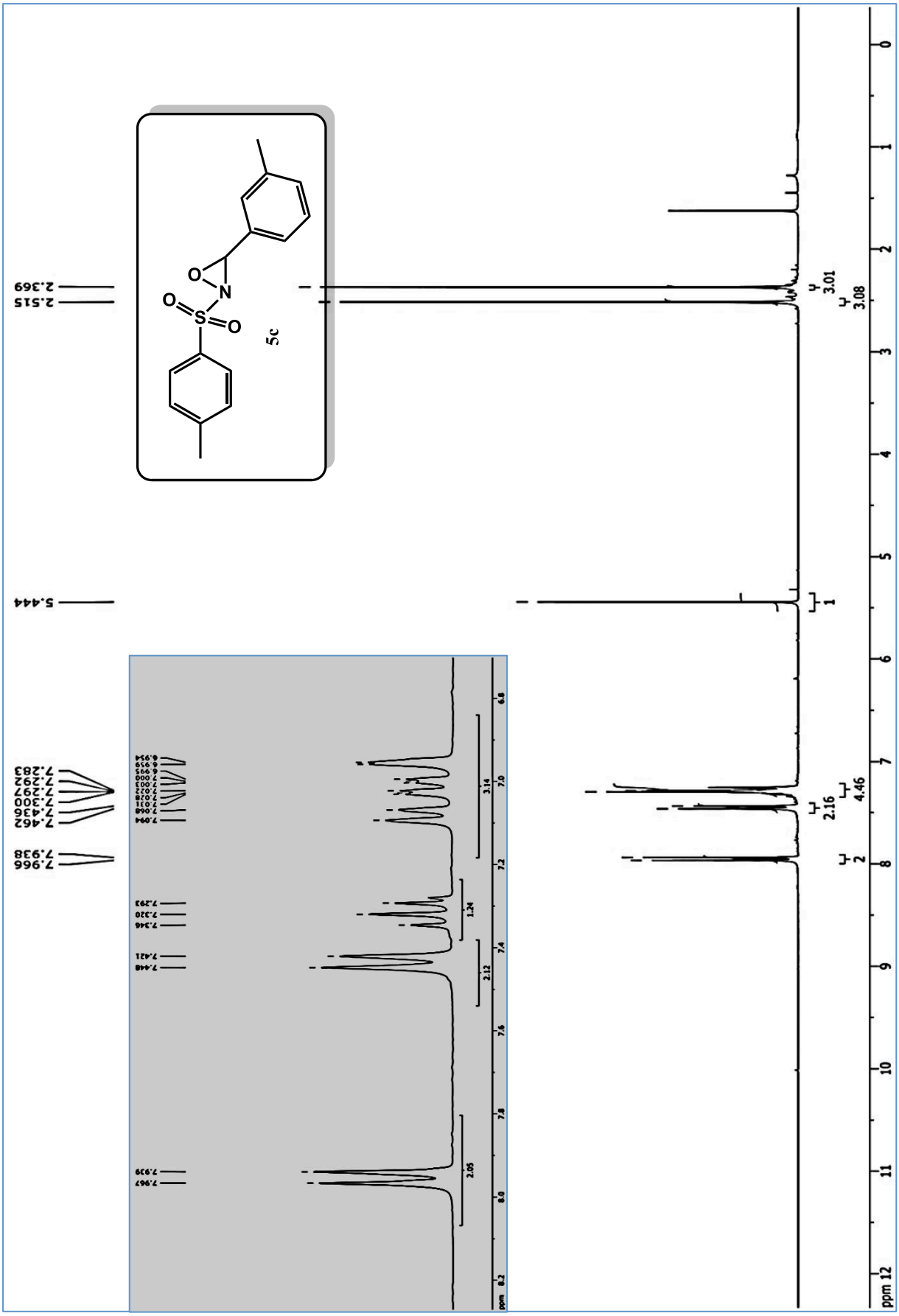

11.817
21.227
54.892
63.889
76.607
77.030
77.454
79.472
80.469
127.542
127.835
128.160
128.393
129.324
129.874
132.073
135.067
O
N
31: cis + trans
ppm

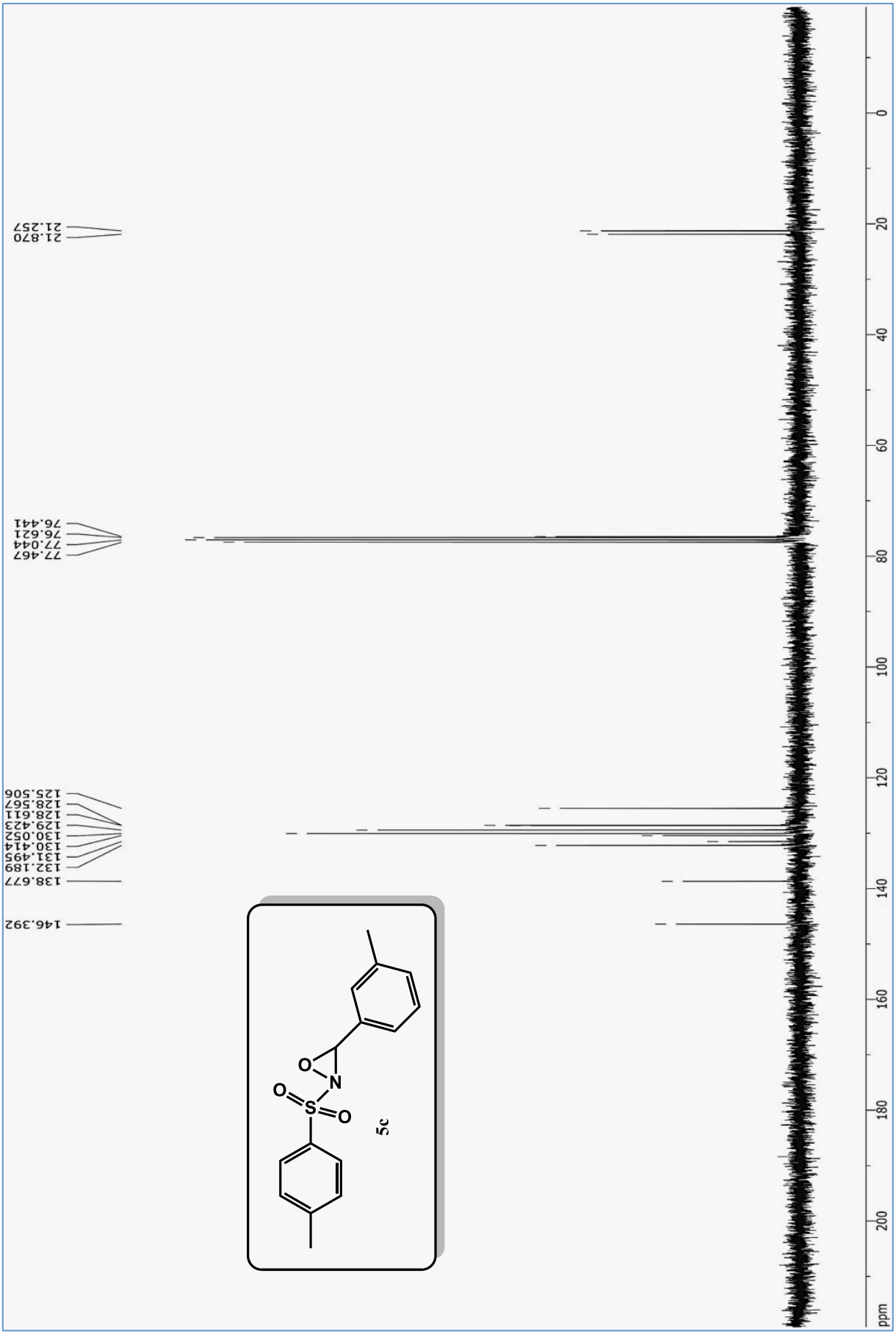

2.508
5.472
7.968
7.963
7.946
7.941
7.487
7.483
7.476
7.471
7.460
7.455
7.439
7.437
7.433
7.429
7.427
7.420
7.414
7.282
3.4
1
7.4
2.05
ppm
5a

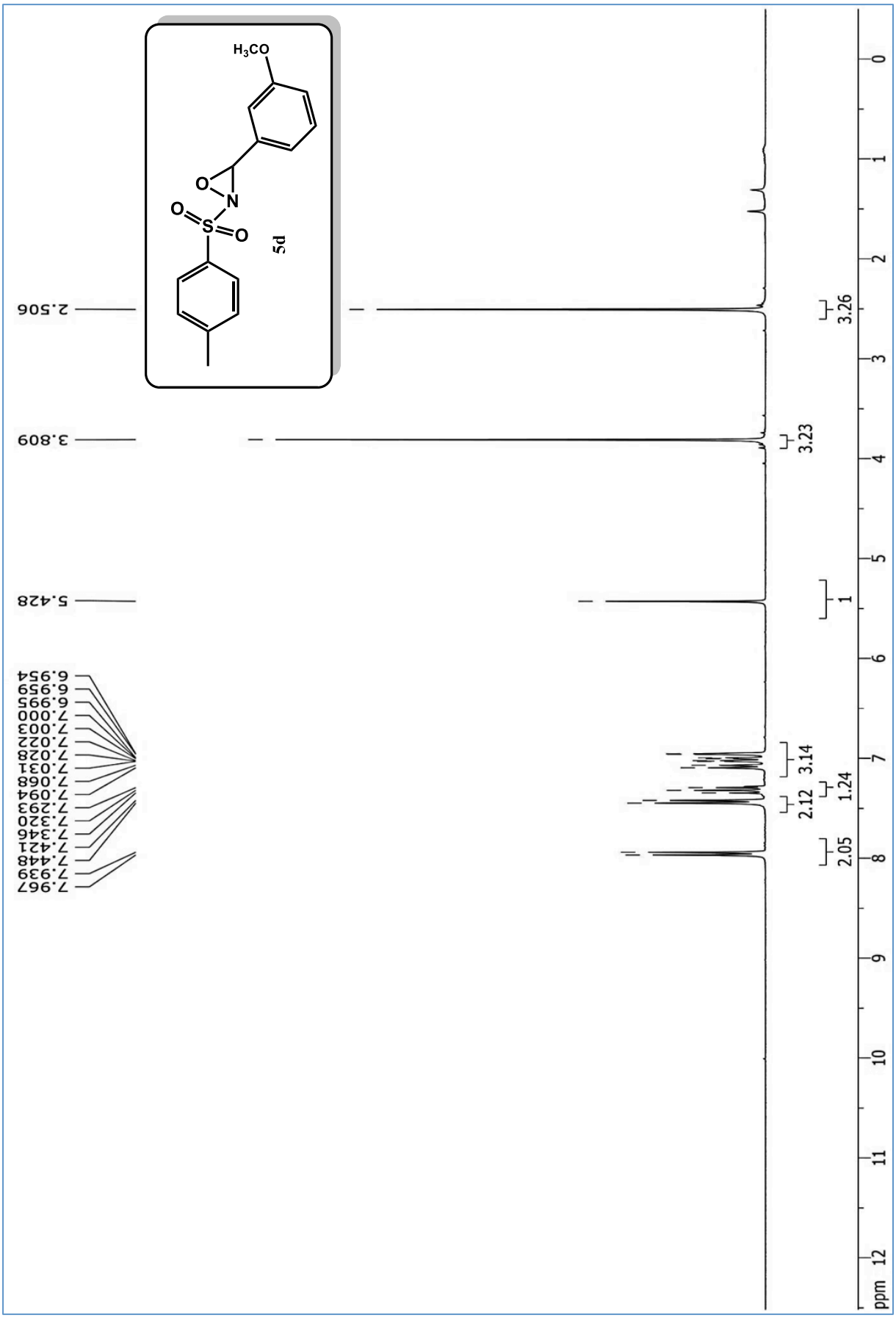

21.797
76.345
76.607
77.030
77.454
128.212
128.713
129.410
130.030
130.604
131.353
131.582
146.377
5a
ppm 200
180
160
140
120
100
80
60
40
20
0

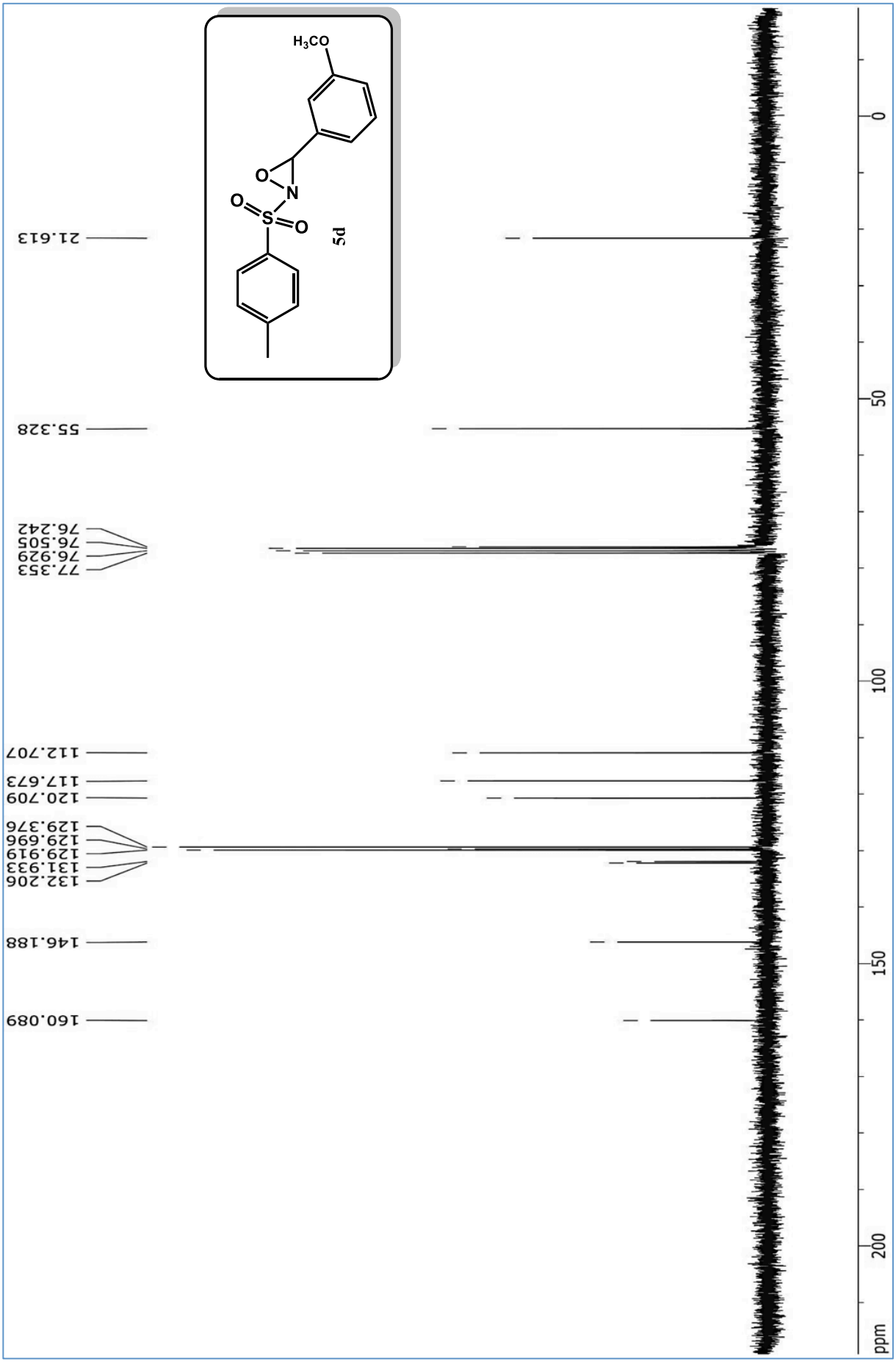

5b
1
5.35
1.04
2.14
1.92
ppm

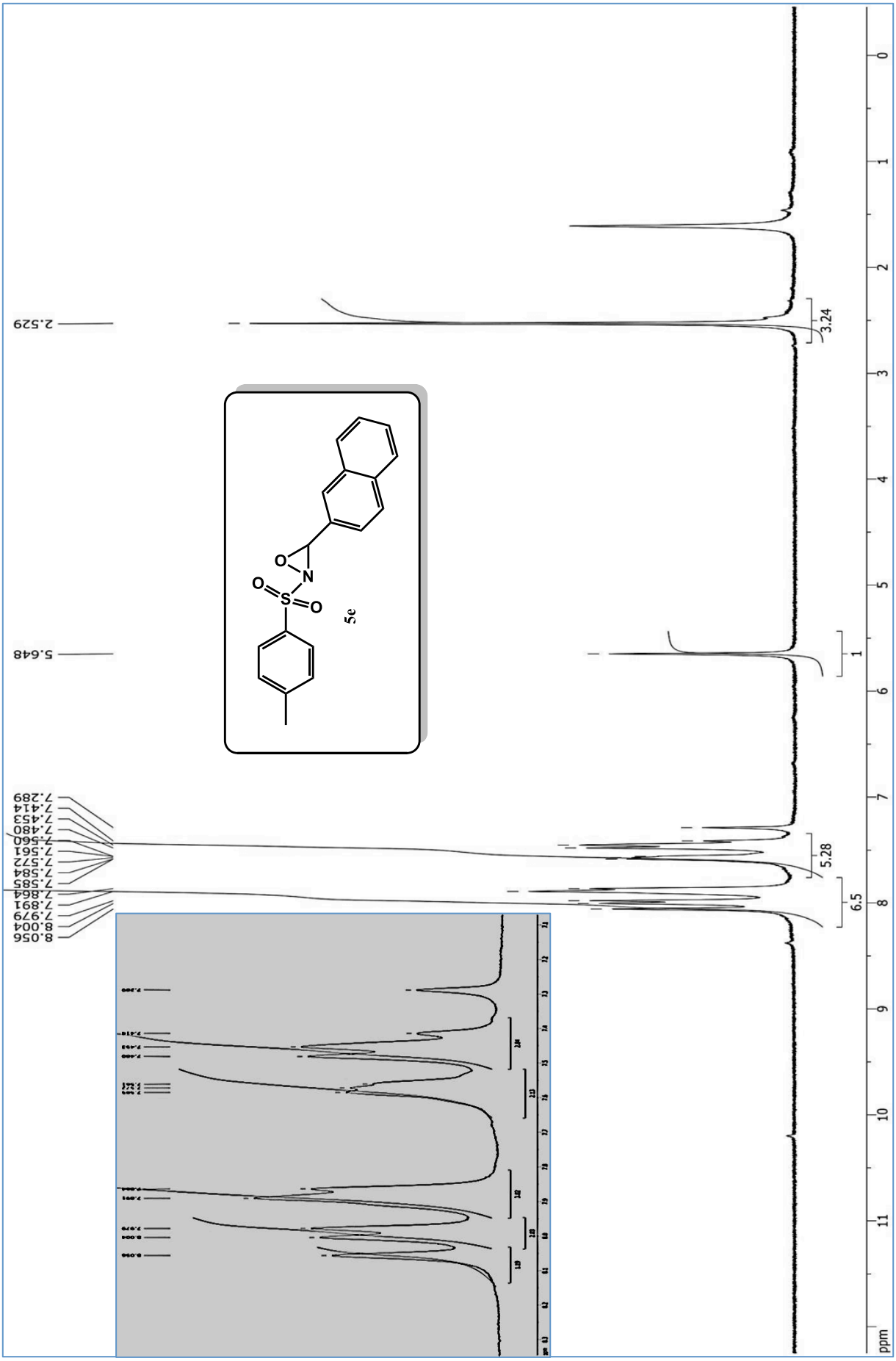

134.994
134.753
131.424
130.484
129.375
129.345
128.743
128.225
77.464
77.040
76.616
76.316
5b
ppm

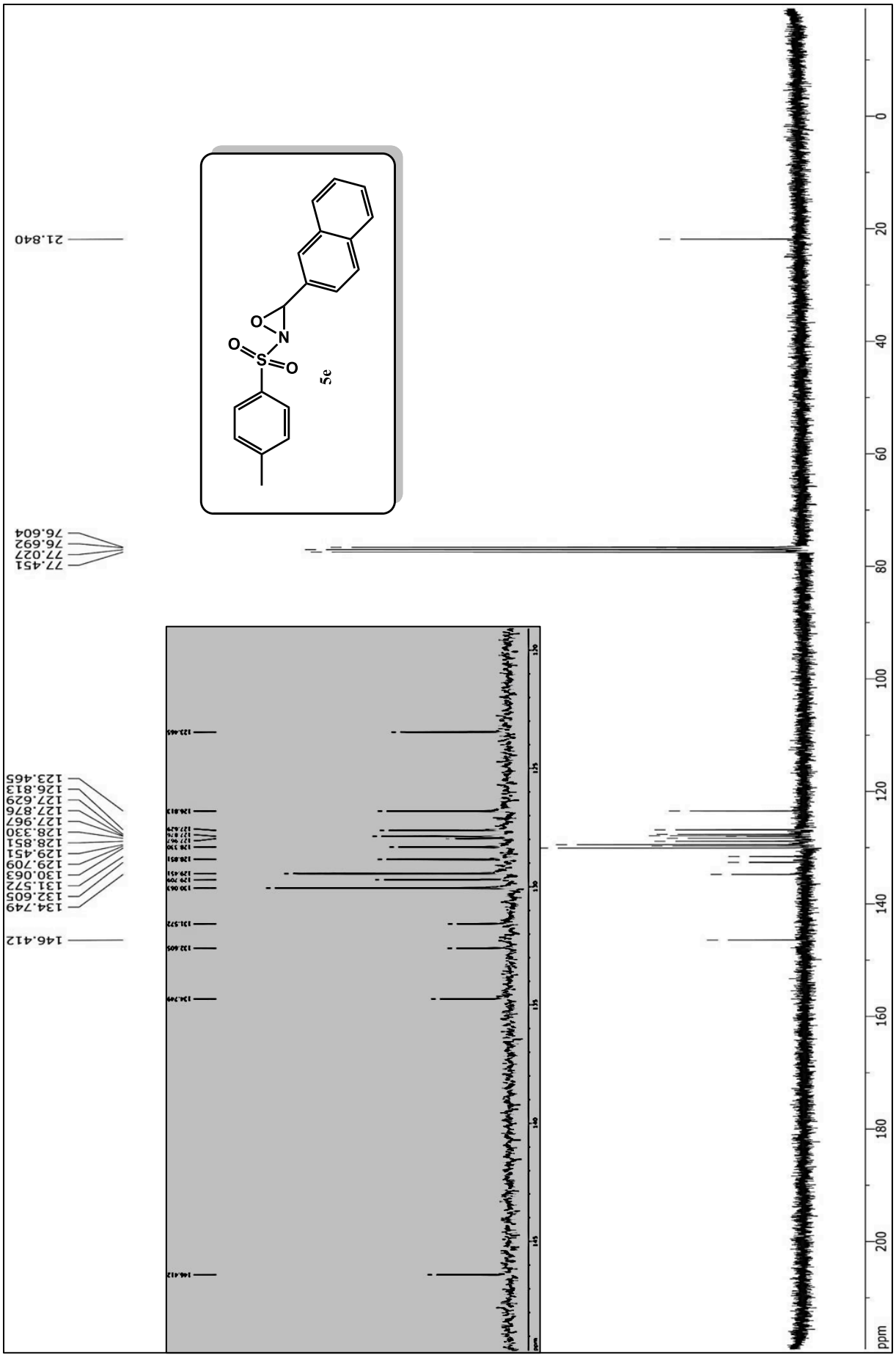

5c
2.369
2.515
5.444
7.966
7.938
7.462
7.436
7.306
7.297
7.293
7.283
7.967
7.939
7.448
7.421
7.346
7.320
7.293
7.094
7.068
7.031
7.028
7.027
7.003
7.000
6.995
6.939
6.934
3.01
3.08
2.16
4.46
2.05
1.24
2.12
3.14
1
2
ppm 12

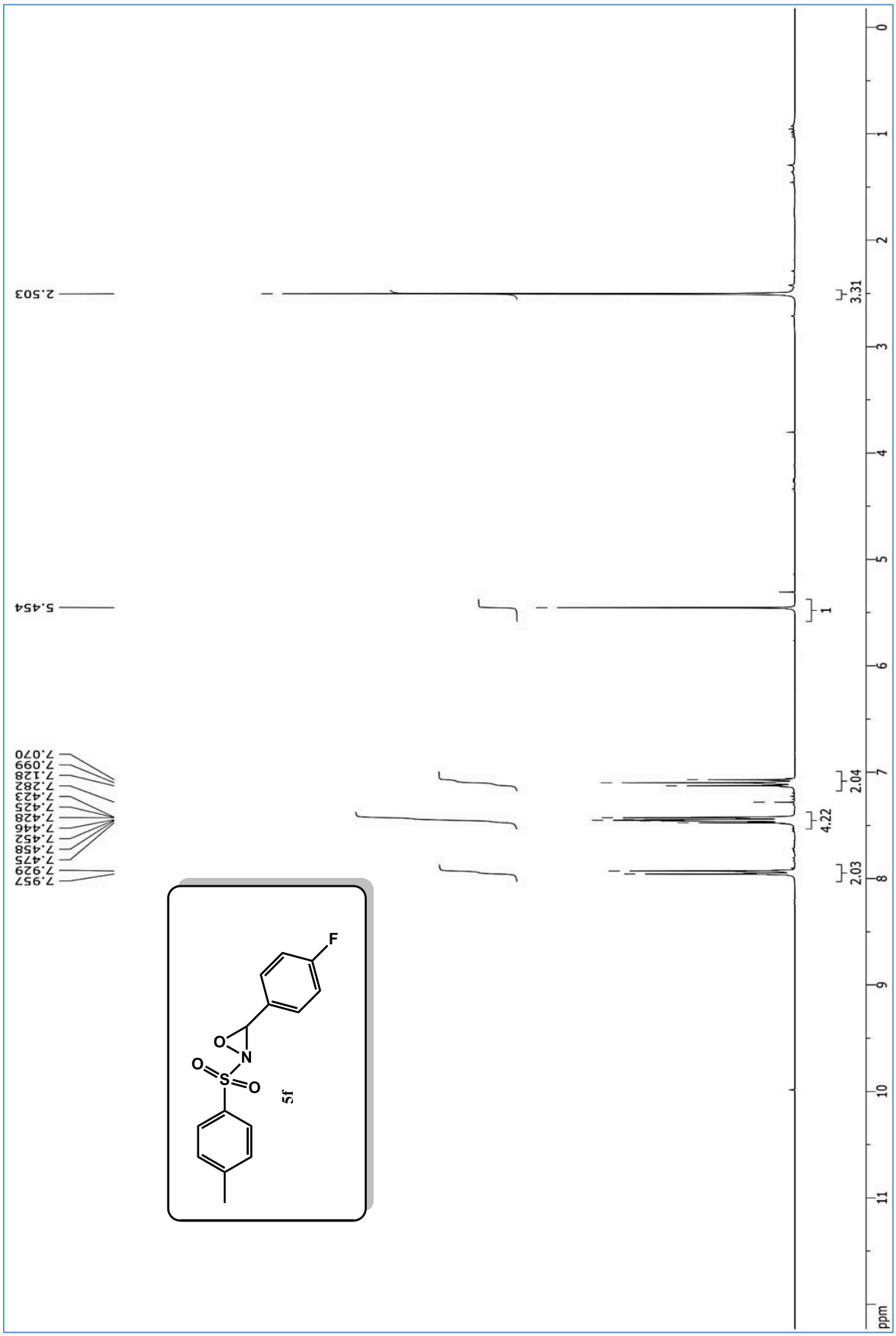

21.870
21.257
77.467
77.044
76.621
76.441
125.506
128.567
128.611
129.423
130.052
130.414
131.495
132.189
138.677
146.392
O
N
O
S
O
O
5c
0
20
40
60
80
100
120
140
160
180
200
ppm

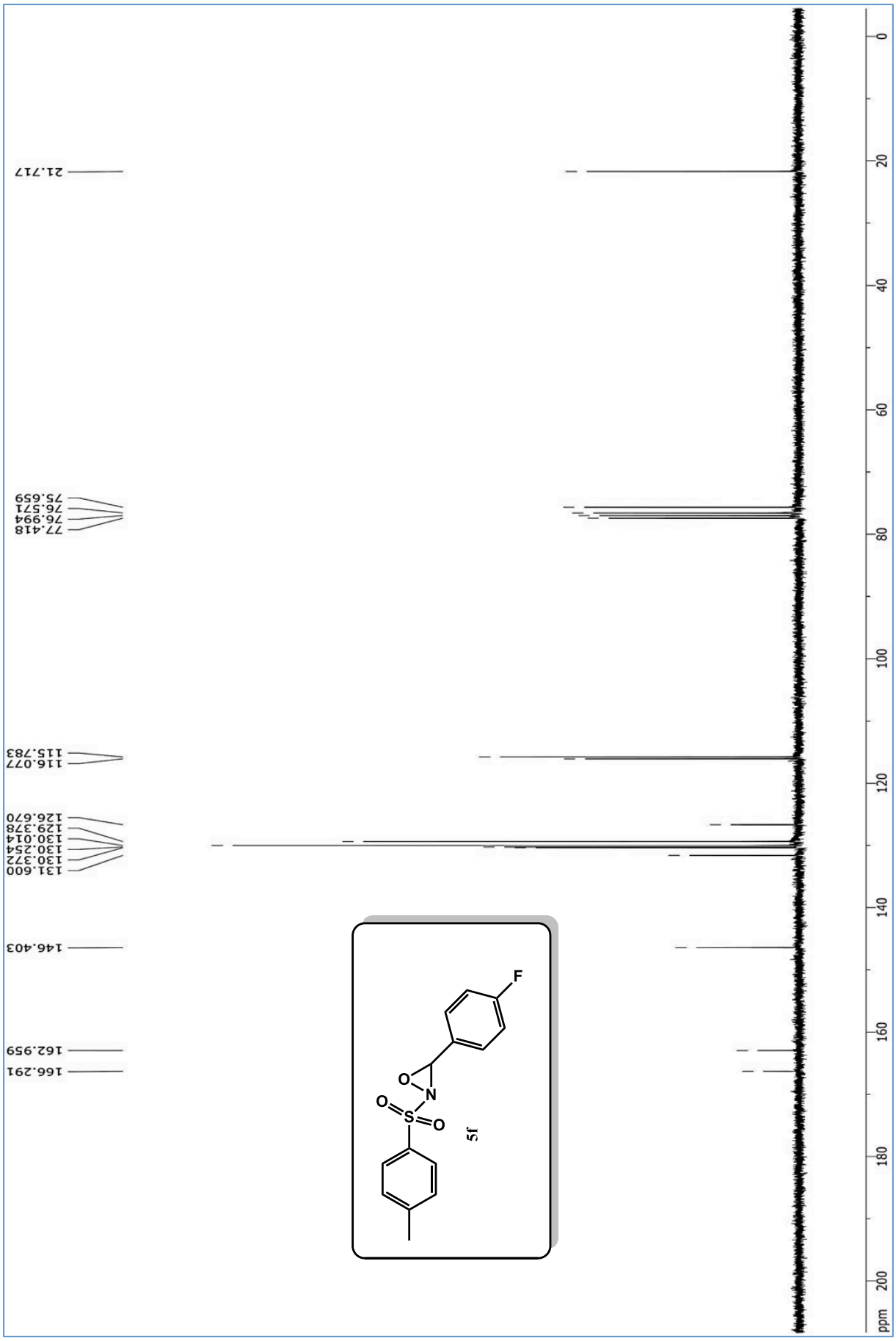

H3CO
O
N
O
S
O
5d
2.506
3.809
5.428
7.967
7.939
7.448
7.421
7.346
7.320
7.293
7.094
7.068
7.031
7.028
7.022
7.003
7.000
6.995
6.959
6.954
3.26
3.23
1
3.14
1.24
2.12
2.05
ppm

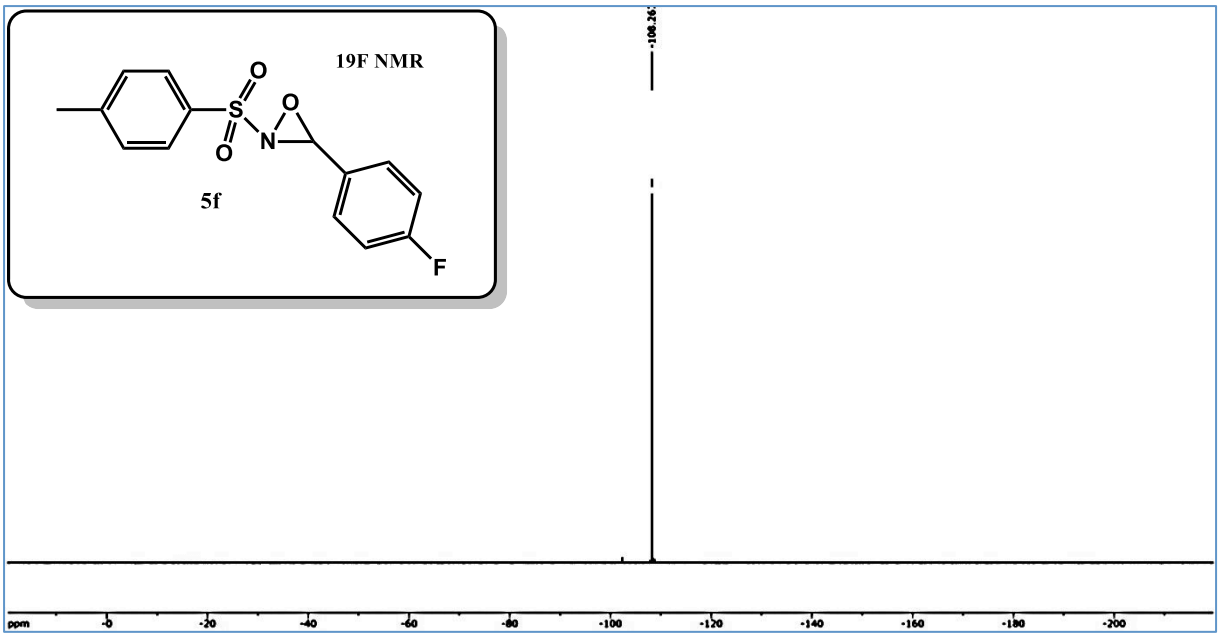

H3CO
O
N
O
S
O
5d
21.613
55.328
77.353
76.929
76.505
76.242
112.707
117.673
120.709
129.376
129.696
129.919
131.933
132.206
146.188
160.089
0
50
100
150
200
ppm

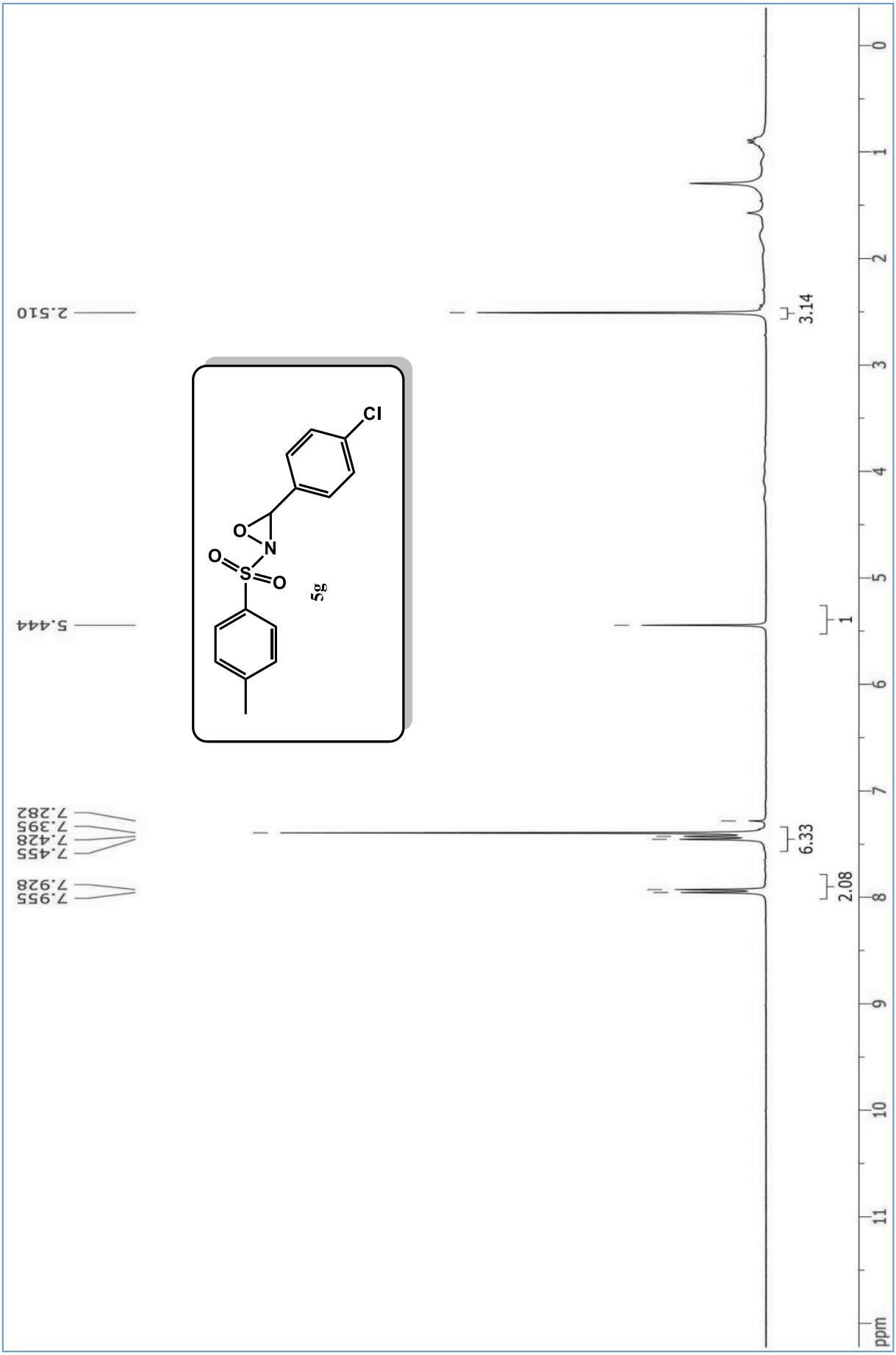

8.056
8.004
7.979
7.891
7.864
7.585
7.584
7.572
7.561
7.560
7.480
7.453
7.414
7.289
5.648
2.529
3.24
1
5.28
6.5
ppm
5e

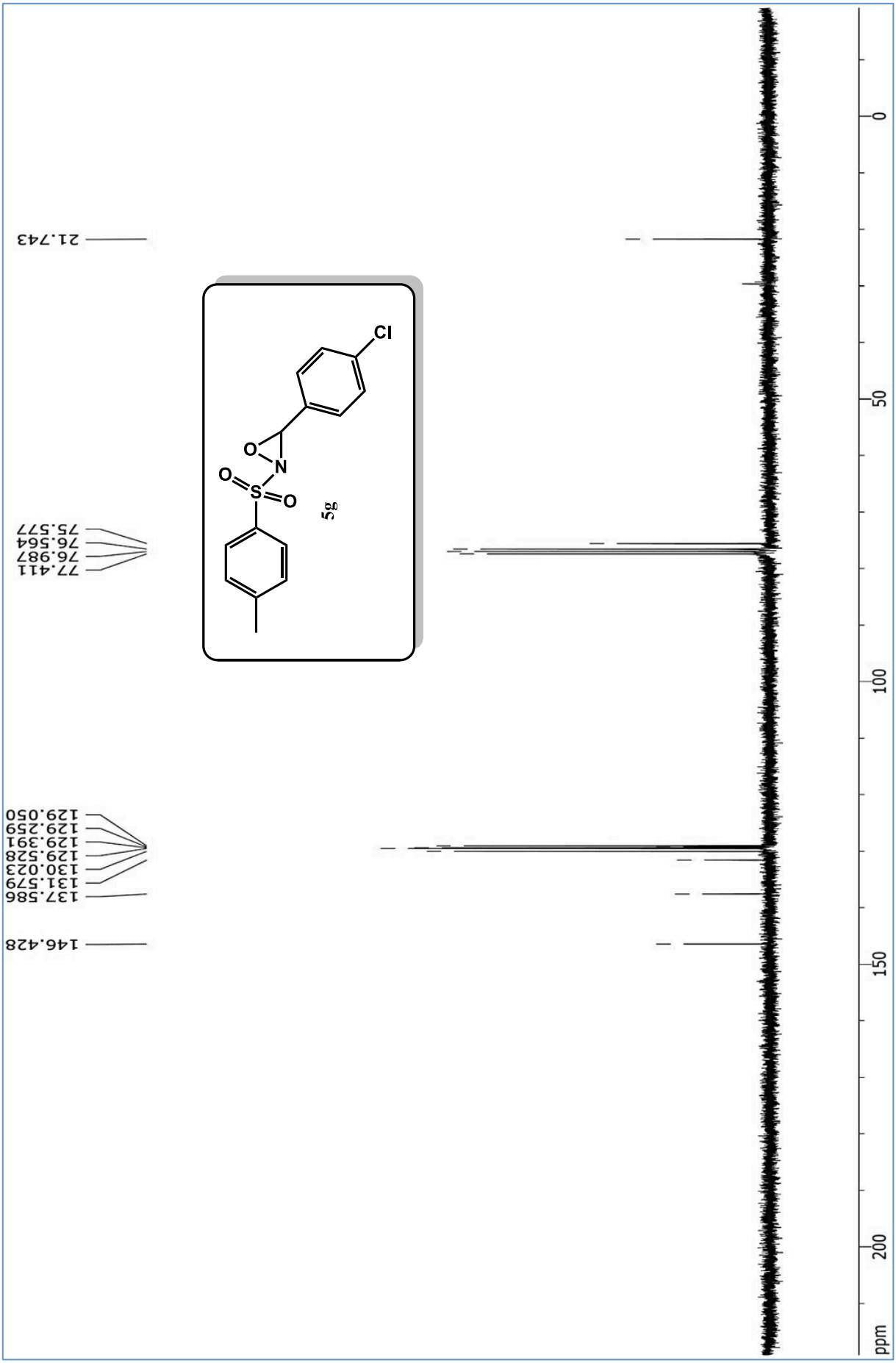

21.840
76.604
76.692
77.027
77.451
123.465
126.813
127.629
127.876
127.967
128.330
128.851
129.451
129.709
130.063
131.572
132.605
134.749
146.412
5e
ppm

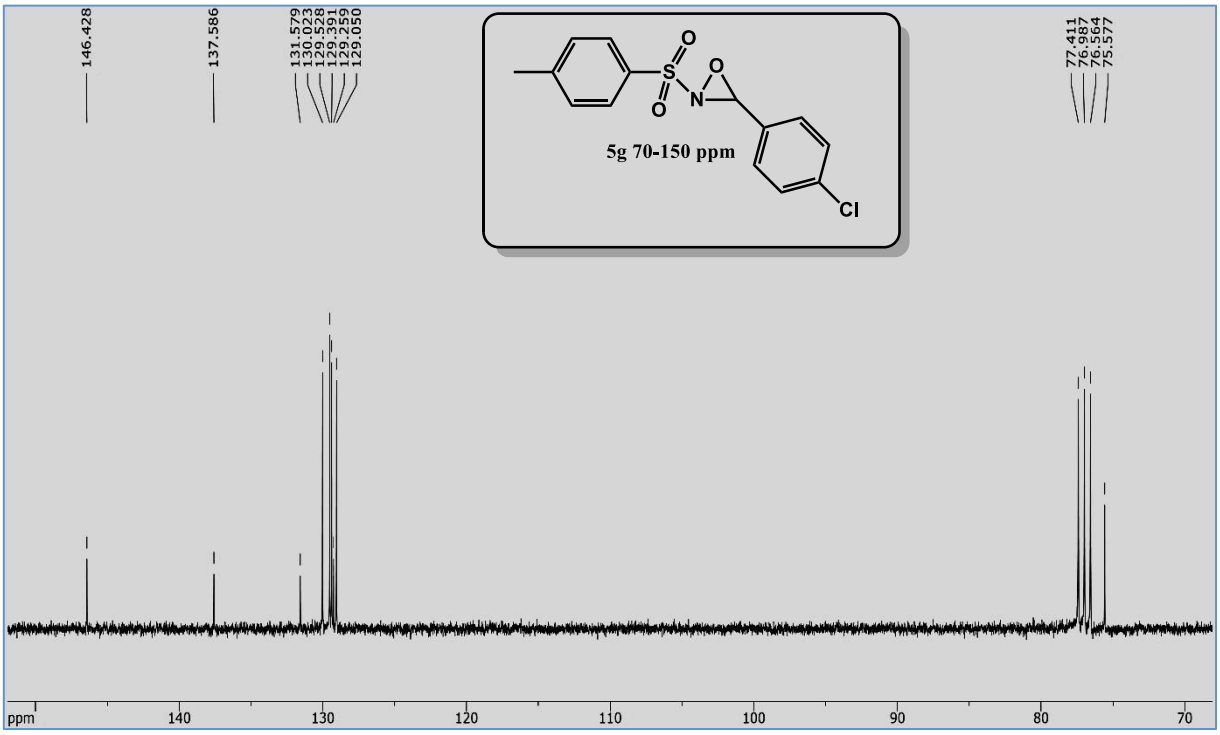

2.503
5.454
7.957
7.929
7.475
7.458
7.452
7.446
7.428
7.425
7.423
7.282
7.128
7.099
7.070
3.31
1
2.04
4.22
2.03
ppm
F
O
N
O
S
O
5f

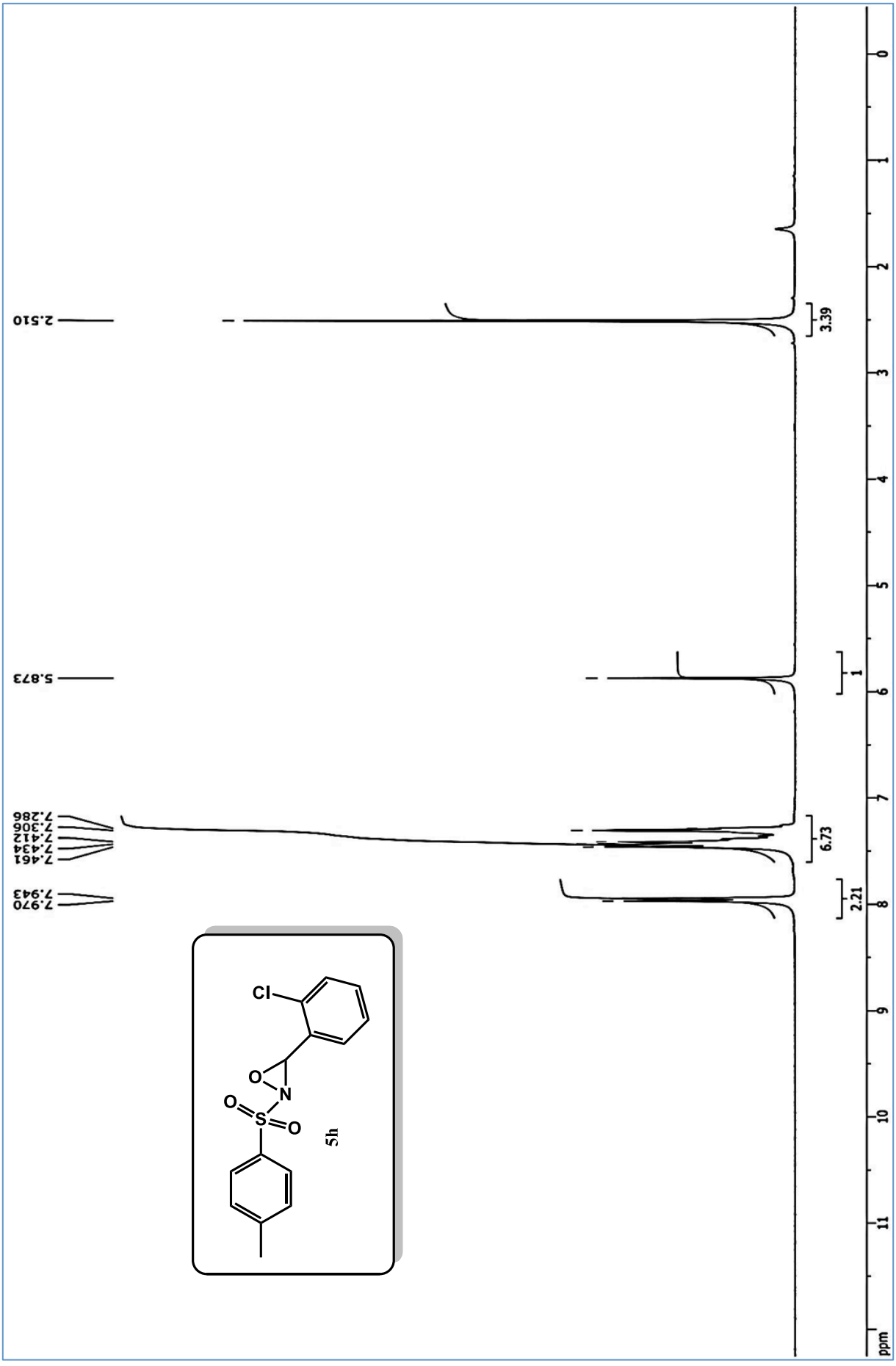

21.717
75.659
76.571
76.994
77.418
115.783
116.077
126.670
129.378
130.014
130.254
130.372
131.600
146.403
162.959
166.291
F
O
N
O
S
O
5f
0
20
40
60
80
100
120
140
160
180
200
ppm

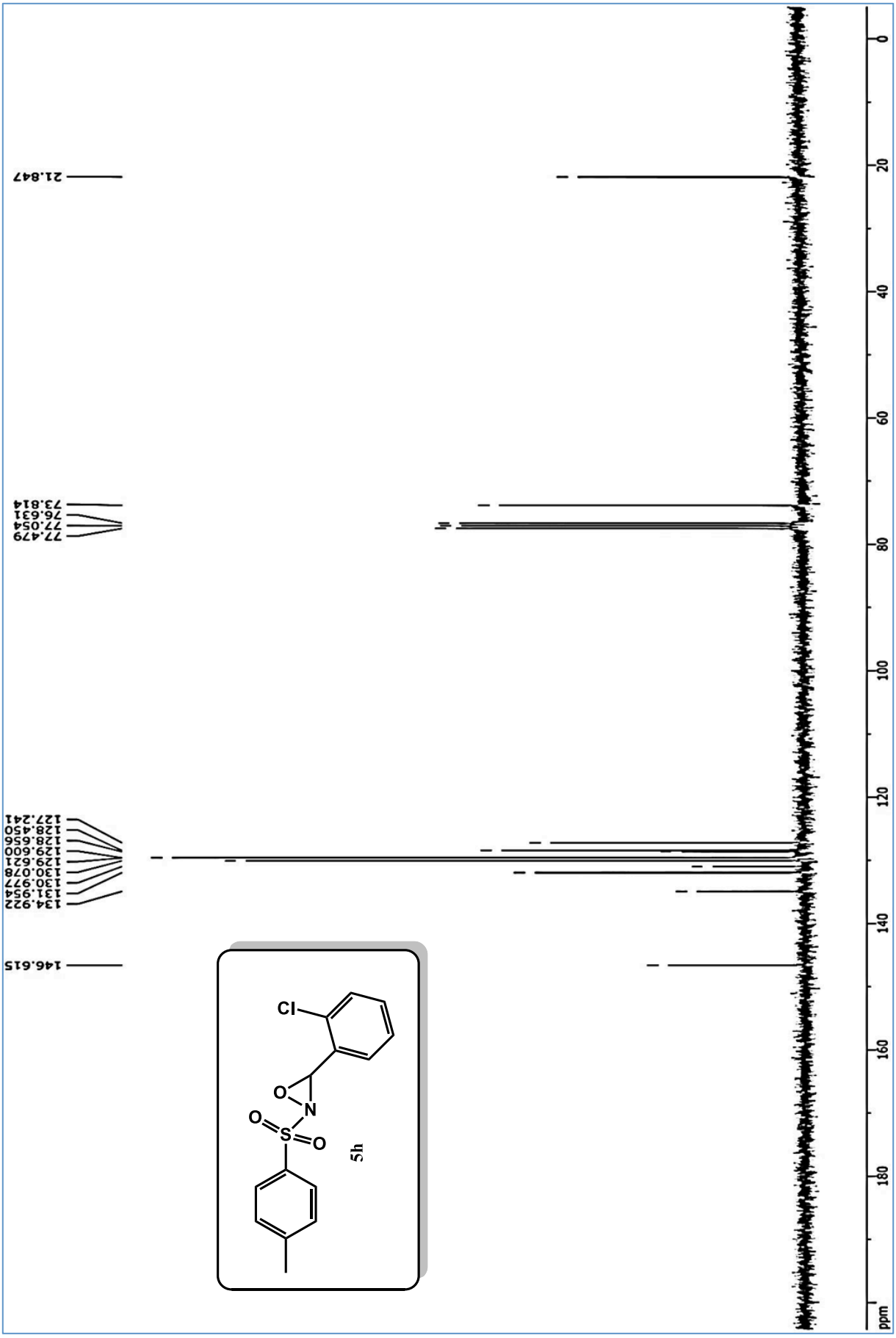

19F NMR
O
S
O
O
N
5f
F
-108.26
ppm
-0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200

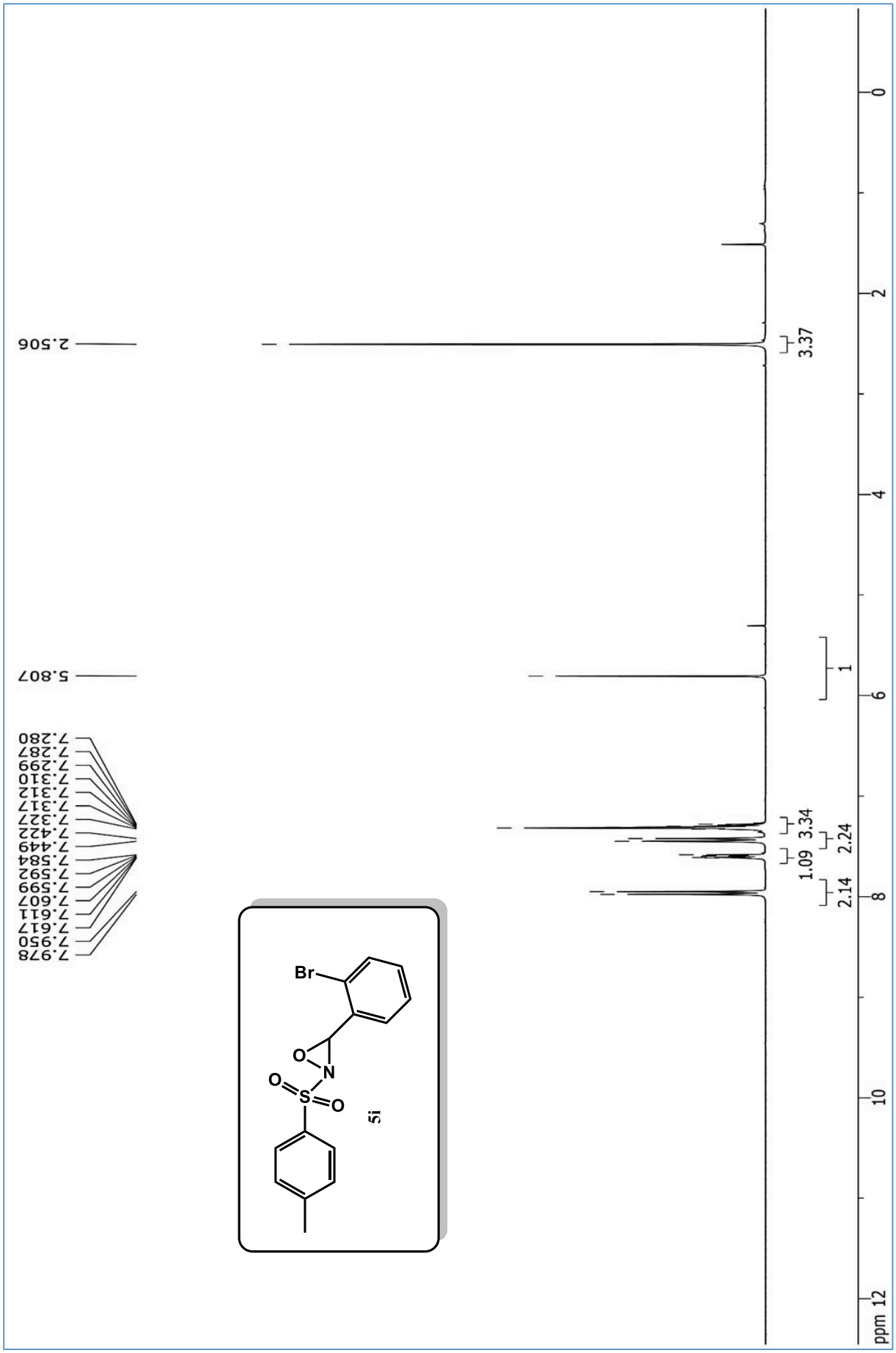

2.510
5.444
7.955
7.928
7.455
7.428
7.395
7.282
3.14
1
6.33
2.08
ppm
Cl
O
N
O
S
O
5g

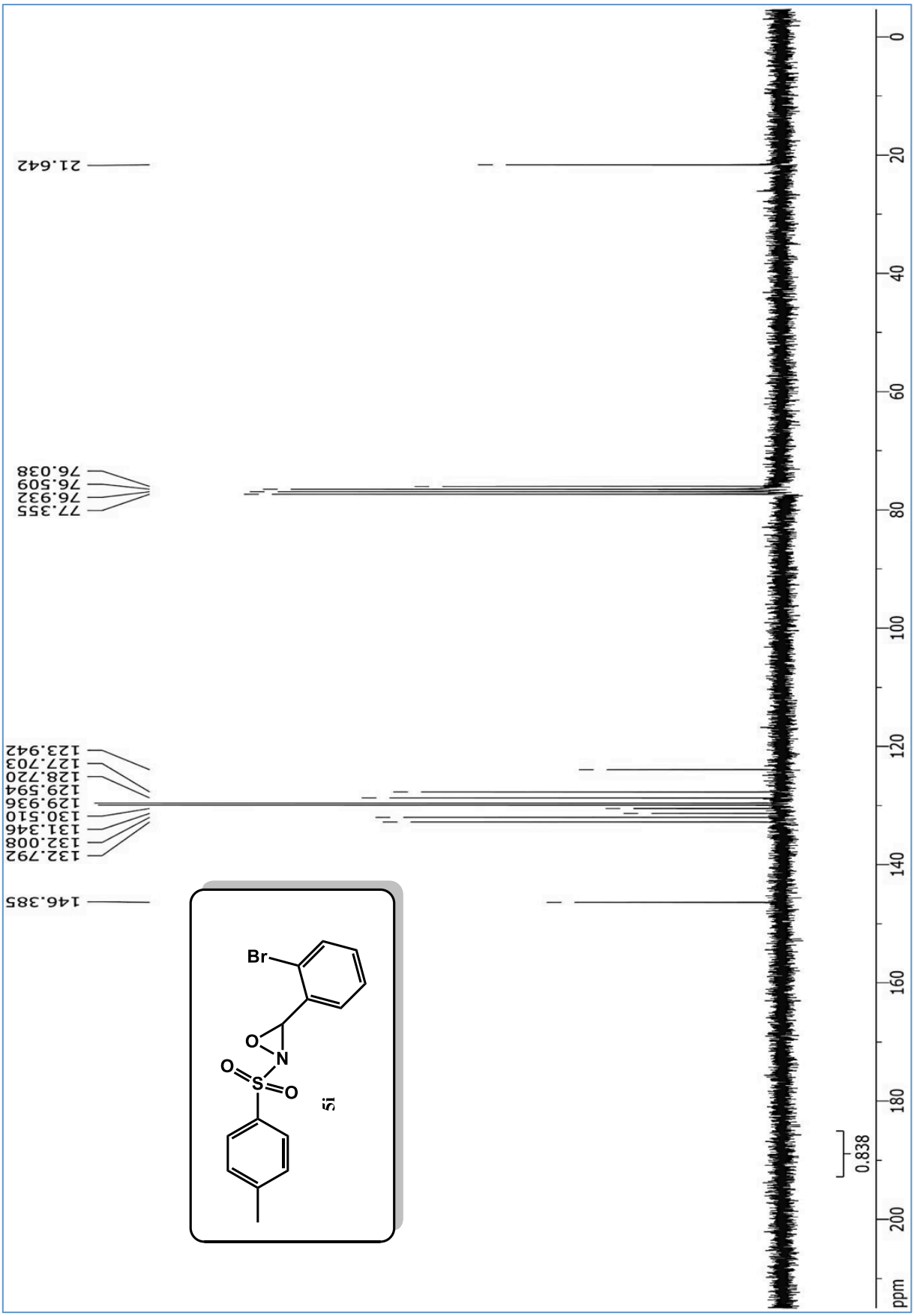

21.743
77.411
76.987
76.564
75.577
129.050
129.259
129.391
129.528
130.023
131.579
137.586
146.428
Cl
O
N
O
S
O
O
5g
ppm
0
50
100
150
200

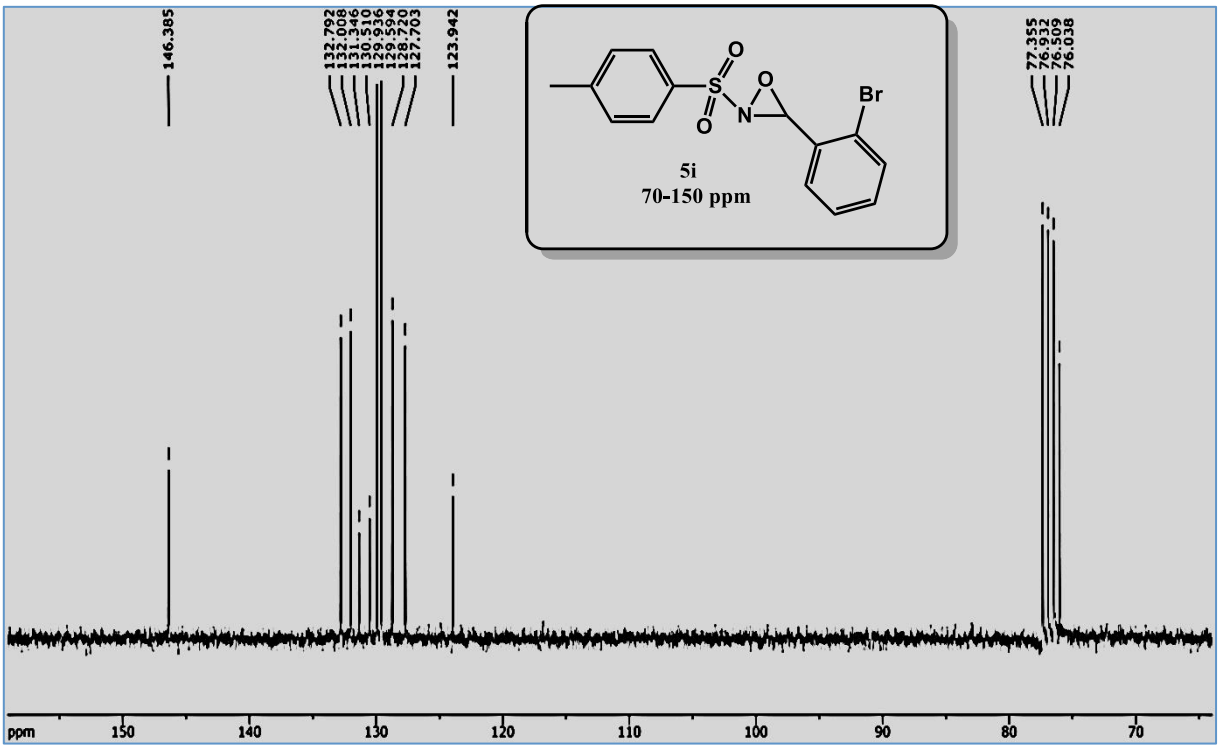

146.428
137.586
131.579
130.023
129.528
129.291
129.150
129.050
77.411
76.987
76.564
75.577
5g 70-150 ppm
O
S
O
O
N
Cl
ppm
140
130
120
110
100
90
80
70

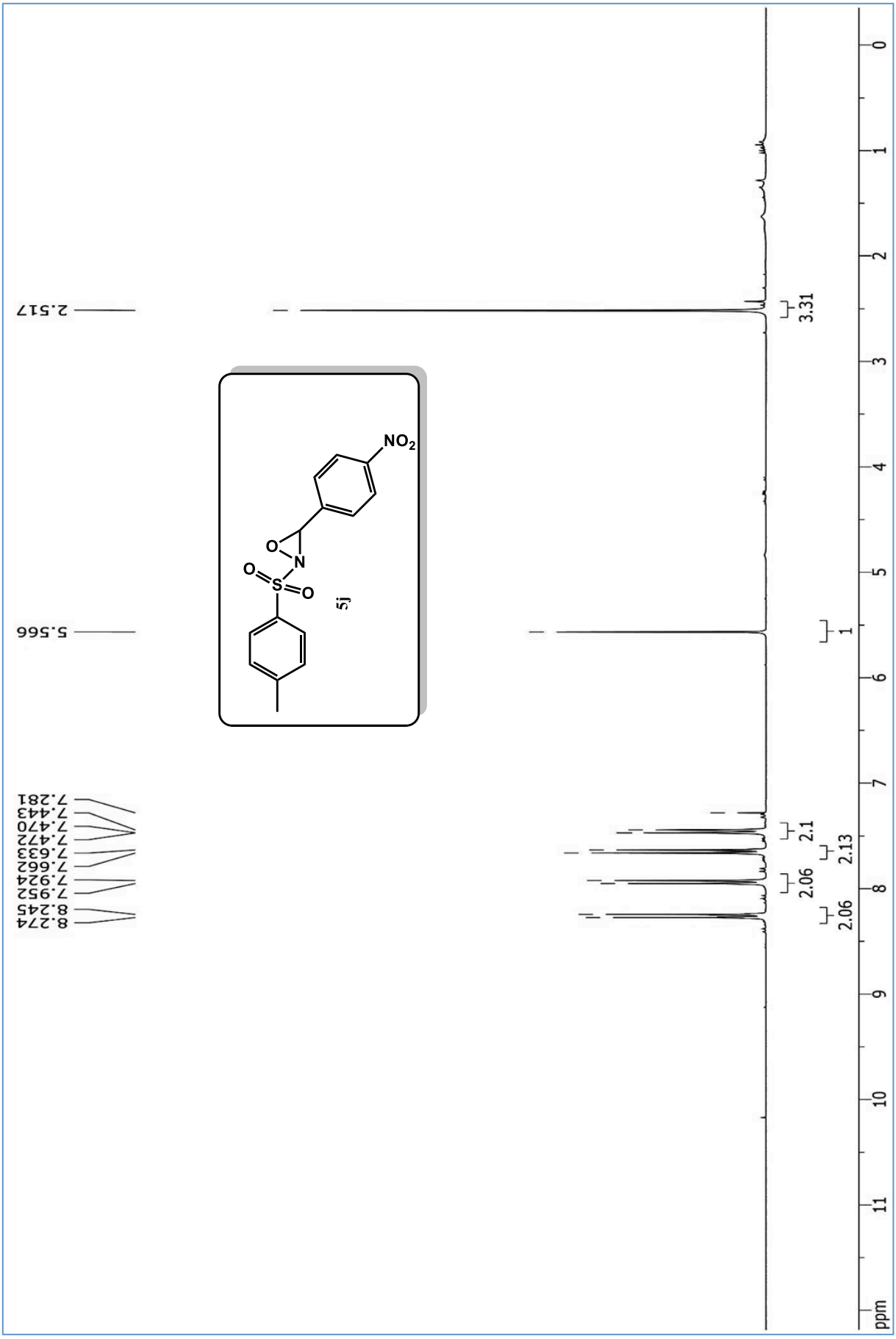

2.510
5.873
7.970
7.943
7.461
7.434
7.412
7.306
7.286
3.39
1
6.73
2.21
ppm
Cl
O
N
O
S
O
5h

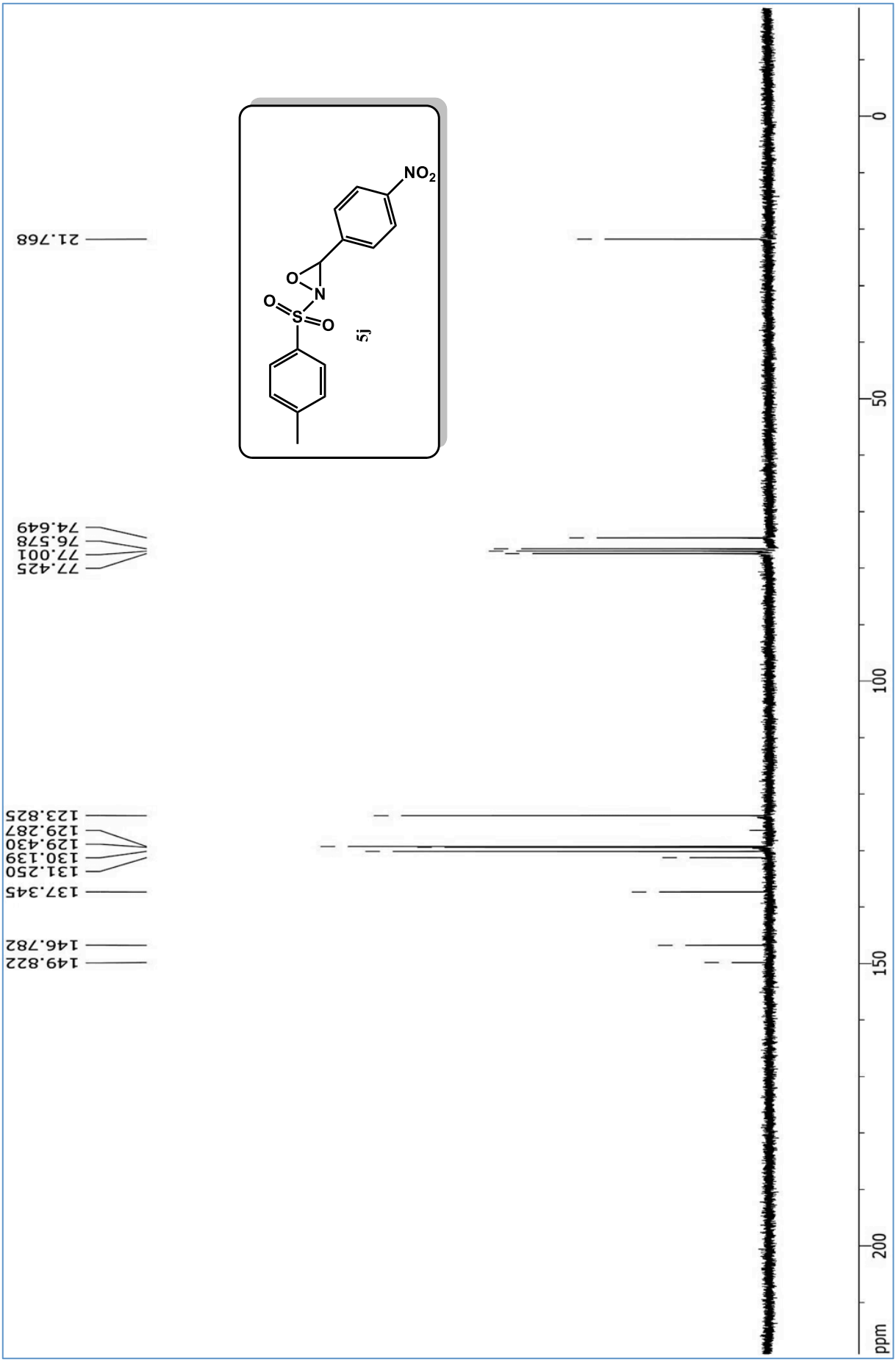

21.847
73.814
76.631
77.054
77.479
127.241
128.450
128.656
129.600
129.621
130.078
130.977
131.954
134.922
146.615
Cl
O
N
O
S
O
5h
0
20
40
60
80
100
120
140
160
180
ppm

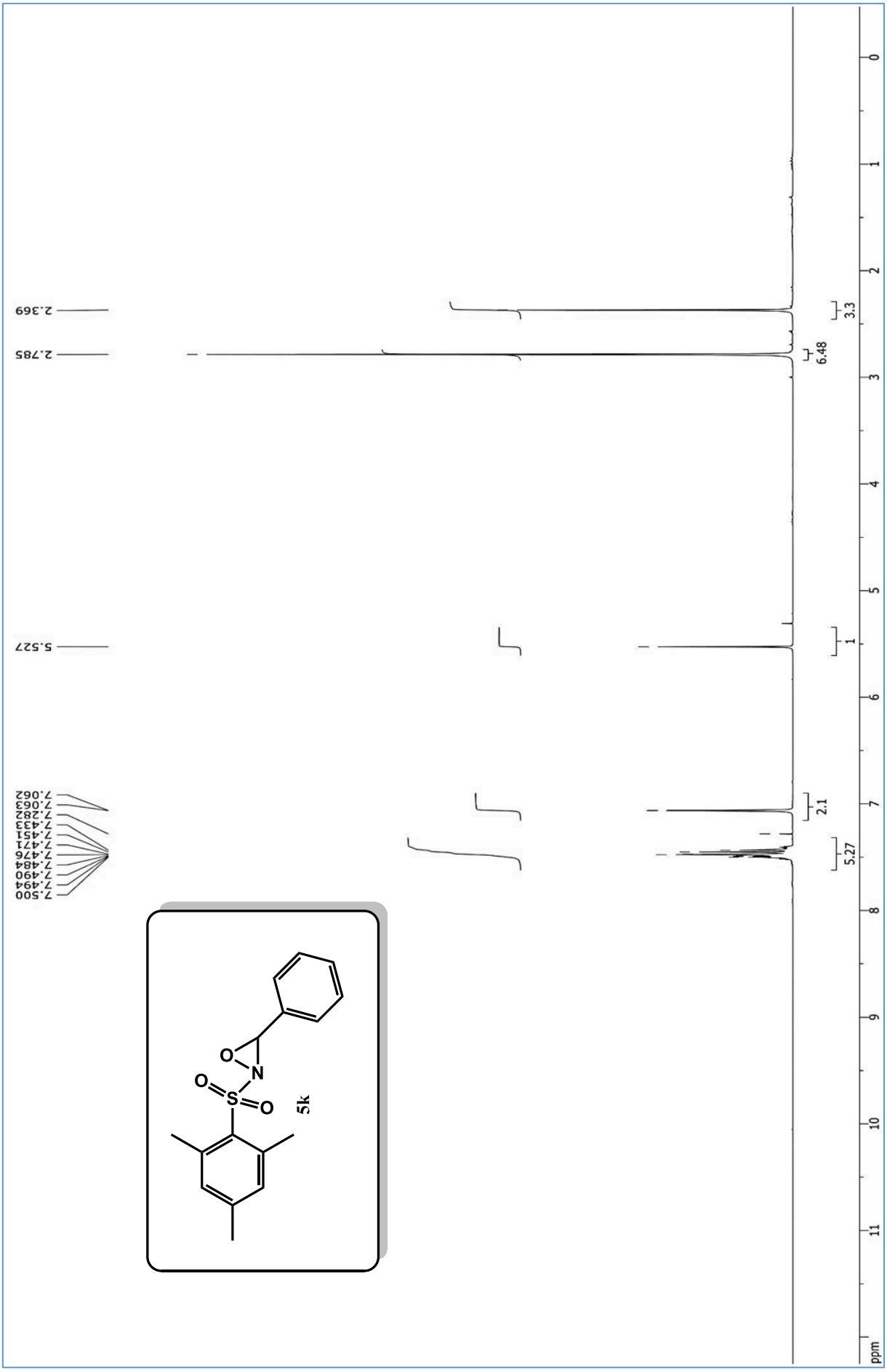

7.978
7.950
7.617
7.611
7.607
7.599
7.592
7.584
7.449
7.422
7.327
7.317
7.312
7.310
7.299
7.287
7.280
5.807
2.506
3.37
1.09
3.34
2.24
2.14
1
Br
O
N
O
S
O
5i
ppm 12
10
8
6
4
2
0

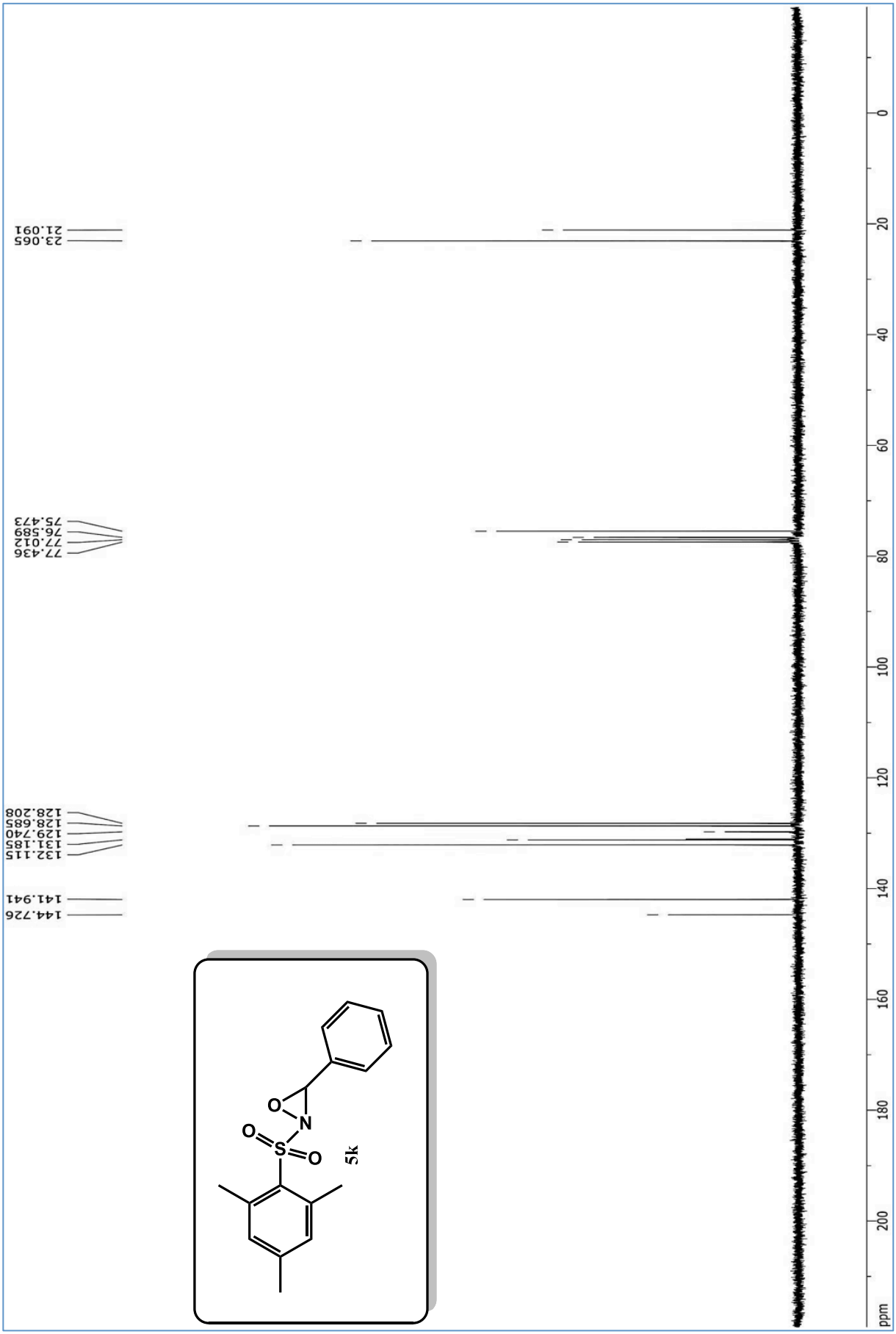

21.642
76.038
76.509
76.932
77.355
123.942
127.703
128.720
129.594
129.936
130.510
131.346
132.008
132.792
146.385
Br
O
N
O
S
O
5i
0.838
0
20
40
60
80
100
120
140
160
180
200
ppm


146.385
132.792
132.008
131.346
130.510
129.936
129.594
128.700
127.703
123.942
77.355
76.932
76.509
76.038
5i
70-150 ppm
Br
ppm
150
140
130
120
110
100
90
80
70


2.517
5.566
8.274
8.245
7.952
7.924
7.662
7.633
7.472
7.470
7.443
7.281
3.31
1
2.1
2.13
2.06
2.06
5j
NO2
O
N
S
O
O
ppm


NO2
O
N
O
S
O
5j
21.768
74.649
76.578
77.001
77.425
123.825
129.287
129.430
130.139
131.250
137.345
146.782
149.822
ppm
0
50
100
150
200


7.500
7.494
7.490
7.484
7.476
7.471
7.451
7.433
7.282
7.063
7.062
5.527
2.785
2.369
5.27
2.1
1
6.48
3.3
ppm
5k


21.091
23.065
75.473
76.589
77.012
77.436
128.208
128.685
129.740
131.185
132.115
141.941
144.726
O
N
O
S
O
O
5k
0
20
40
60
80
100
120
140
160
180
200
ppm

References

1. S. Morales, F. G. Guijarro, J. F. G. Ruano and M. B. Cid, *J. Am. Chem. Soc*. 2014, **136**, 1082.

2. R, Chawla, A. K. Singh, L. Dhar and S. Yadav, *Tetrahedron Lett.,* 2014, **55**, 3553.

3. X. Cui, F. Shi and Y. Deng, *Chem. Commun.*, 2012, **48**, 7586.

4. C-J. Wang and M. Shi, *J. Org. Chem.*, 2003, **68**, 6229.

5. D. Uraguchi, R. Tsutsumi and T. Ooi, *Tetrahedron*, 2014, **70**, 1691.

6. S. Siang-en, L. Yu-Ting, J. Yeong-Jiunn and L.Wenwei, *J. Org. Chem.*, 2011, **76**, 2888.

7. M. Barbarotto, J. Geist, S. Choppin and F. Colobert, *Tetrahedron: Asymmetry,* 2009, **20**, 2780.

8. M. Braun and K. Opdenbusch, *Liebigs Ann.,*1996, **1997**, 141.

9. C. Boudou, M. Bergès, C. Sagnes, J. Sopková-De Oliveira Santos, S. Perrio and P. Metzner, *J. Org. Chem.*, 2007, **72**, 5403.

10. A. Kivrak and R. C. Larock, *J. Org. Chem.*, 2010, **75**, 7381.

11. K. Kloc, E. Kubicz, J. Mlochowski and L. Syper, *Synthesis*, 1987, 1084.

12. H. Yositeru and W. Masamichi, *J. Org. Chem.,* 1981, **46**, 610.

13. J. Kraiem, Y. Kacem, J. Khiari and B. Ben Hassine, *Synth. Commun.,* 2001, **31**, 263.

14. M. Shailaja, A. Manjula and B. Rao, *Synlett*, 2005, 1176.

15. Y. Hata and M. Watanabe, *J. Am. Chem. Soc.,* 1979, **101**, 6671.

16. A. Klausener, R. Langer, S. Ratsch and M. Dockner, Patent : US2002/111339 A1, 2002.

17. D. Mohajer, N. Iranpood and A. Rezaeifard, *Tetrahedron Lett.,* 2004, **45**, 631.

18. R. Garcia, L. Jose, J. Aleman, C. Fajardo and A. Parra, *Org. Lett.,* 2005, **7**, 5493.

19. F. A. Davis, J. Lamendola Jr, U. Nadir, E. W. Kluger, T. C. Sedergran, T. W. Panunto, R. Billmers, R. Jenkins Jr and I. J. Turchi, *J. Am. Chem. Soc.*, 1980, **102**, 2000.

20. T. Zhang, W. He, X. Zhao and Y. Jin, *Tetrahedron*, 2013, **69**, 7416.

21. L. Lykke, C. Rodriguez-Escrich and A. K. Jœrgensen, *J. Am. Chem. Soc.,* 2011, **133**, 14932.

22. S. Pan-Lin, C. Xiang-Yu and Y. Song, *Angew. Chem . Int. Ed.,* 2010, **49**, 8412.

23. K. S. Williamson, J. W. Sawicki and T. P. Yoon, *Chem. Sci.*, 2014, **5**, 3524.