Ruthenium-Catalyzed *N*-Alkylation of Amines and Sulfonamides Using Borrowing Hydrogen Methodology

M. Haniti S. A. Hamid,[†] C. Liana Allen, [†] Gareth W. Lamb, [†] Hannah C. Maytum, [†] Aoife C. Maxwell,[‡] Andrew J. A. Watson[†] and Jonathan M. J. Williams,[†]

[†]*Department of Chemistry, University of Bath, Claverton Down, Bath, BA2 7AY, UK*

[‡]*GlaxoSmithKline Research and Development, Gunnels Wood Road, Stevenage, SG1 2NY, UK*

Spectroscopic Data for Synthesized Compounds
Compounds from Table 6 on.

Table 6, Entry 1

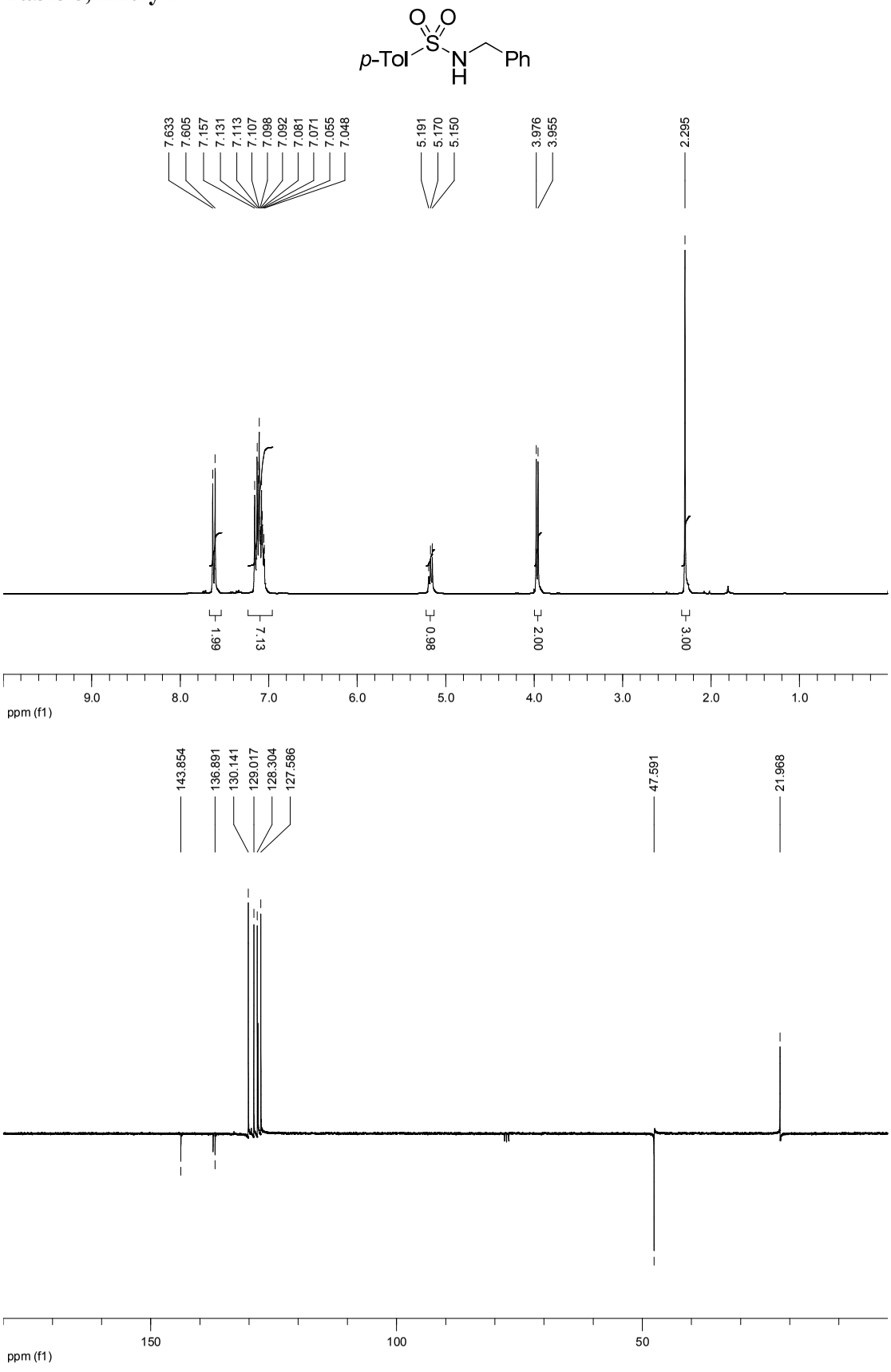


Table 6, Entry 2

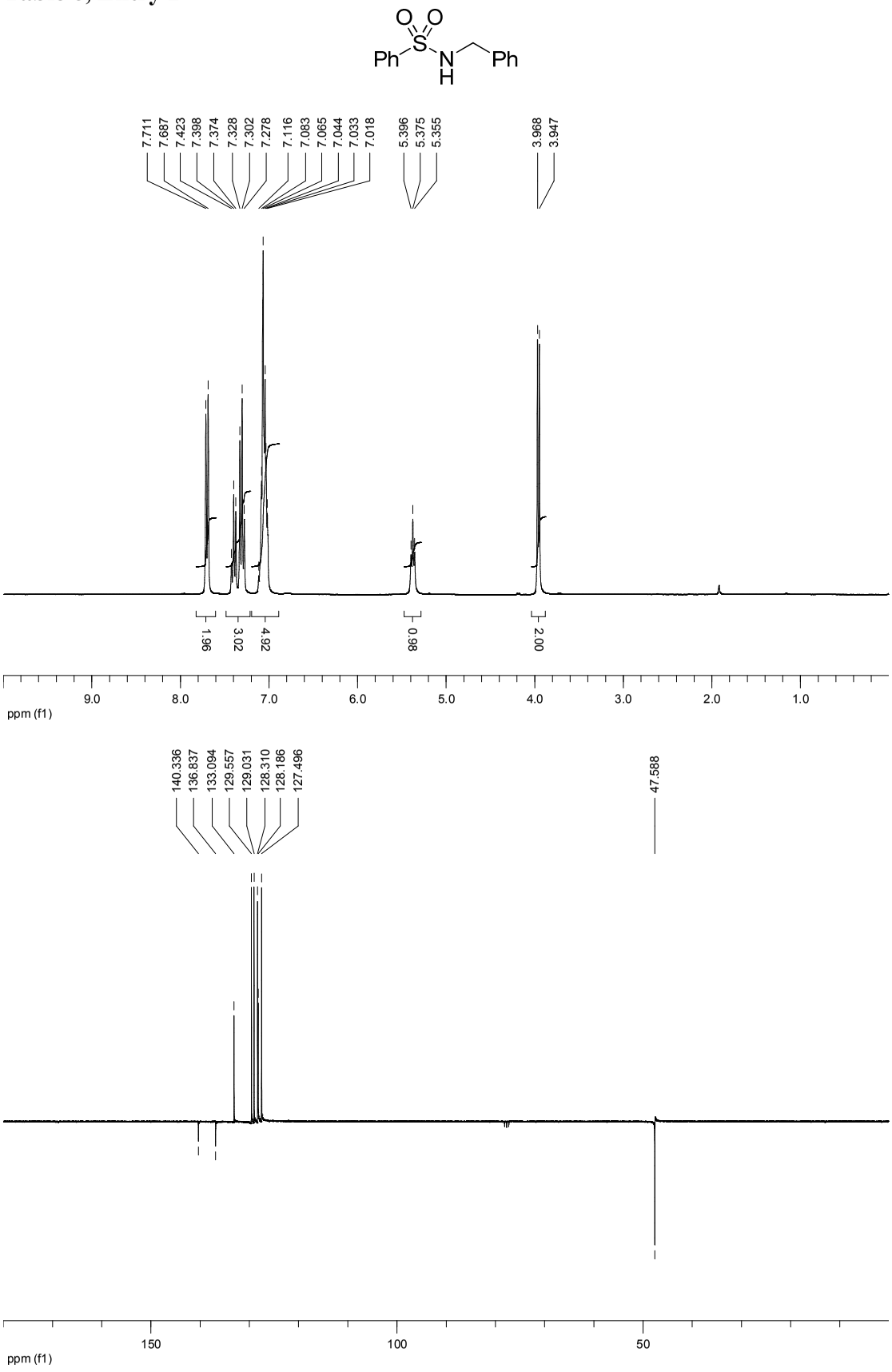


Table 6, Entry 3

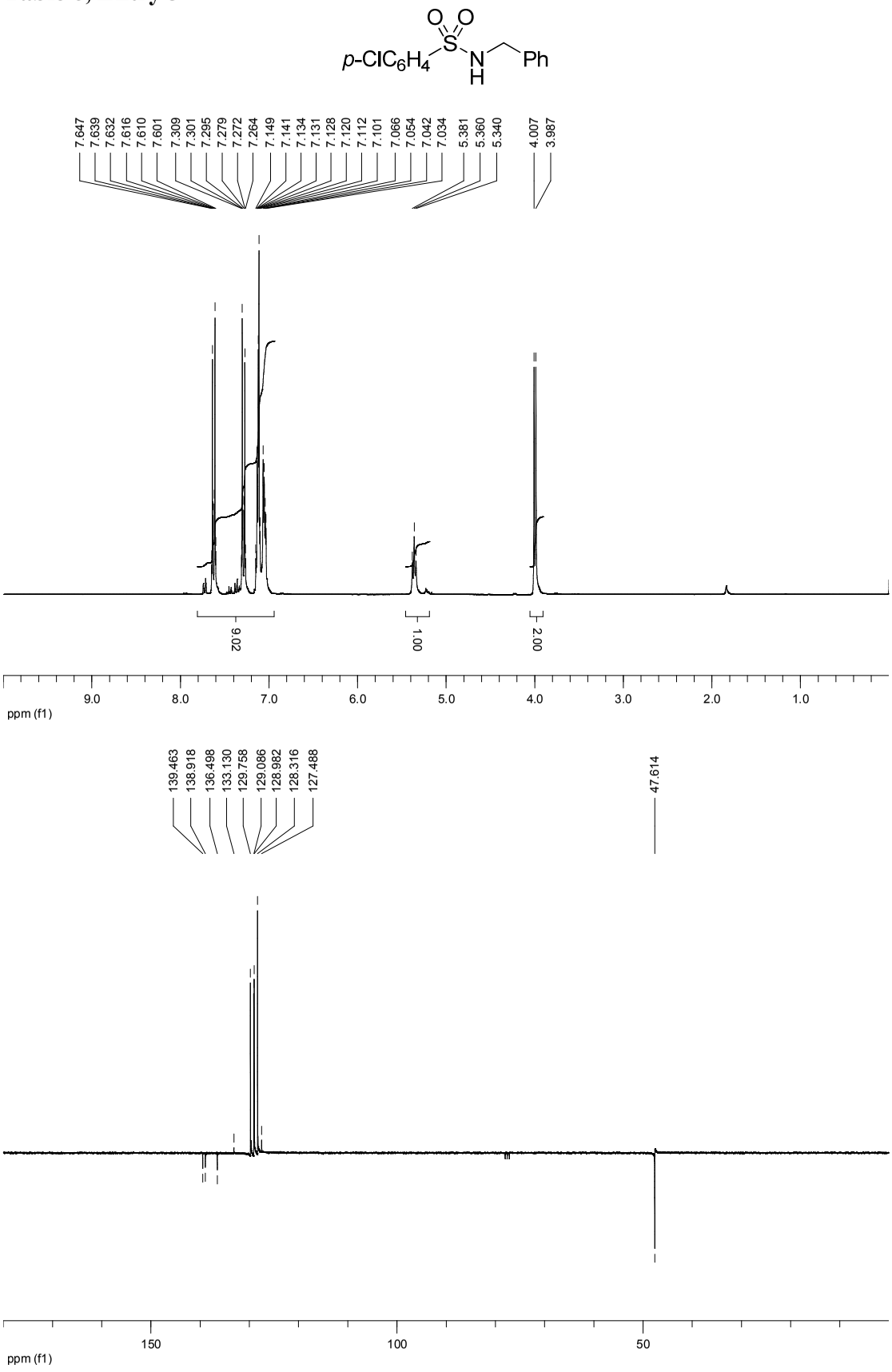


Table 6, Entry 4

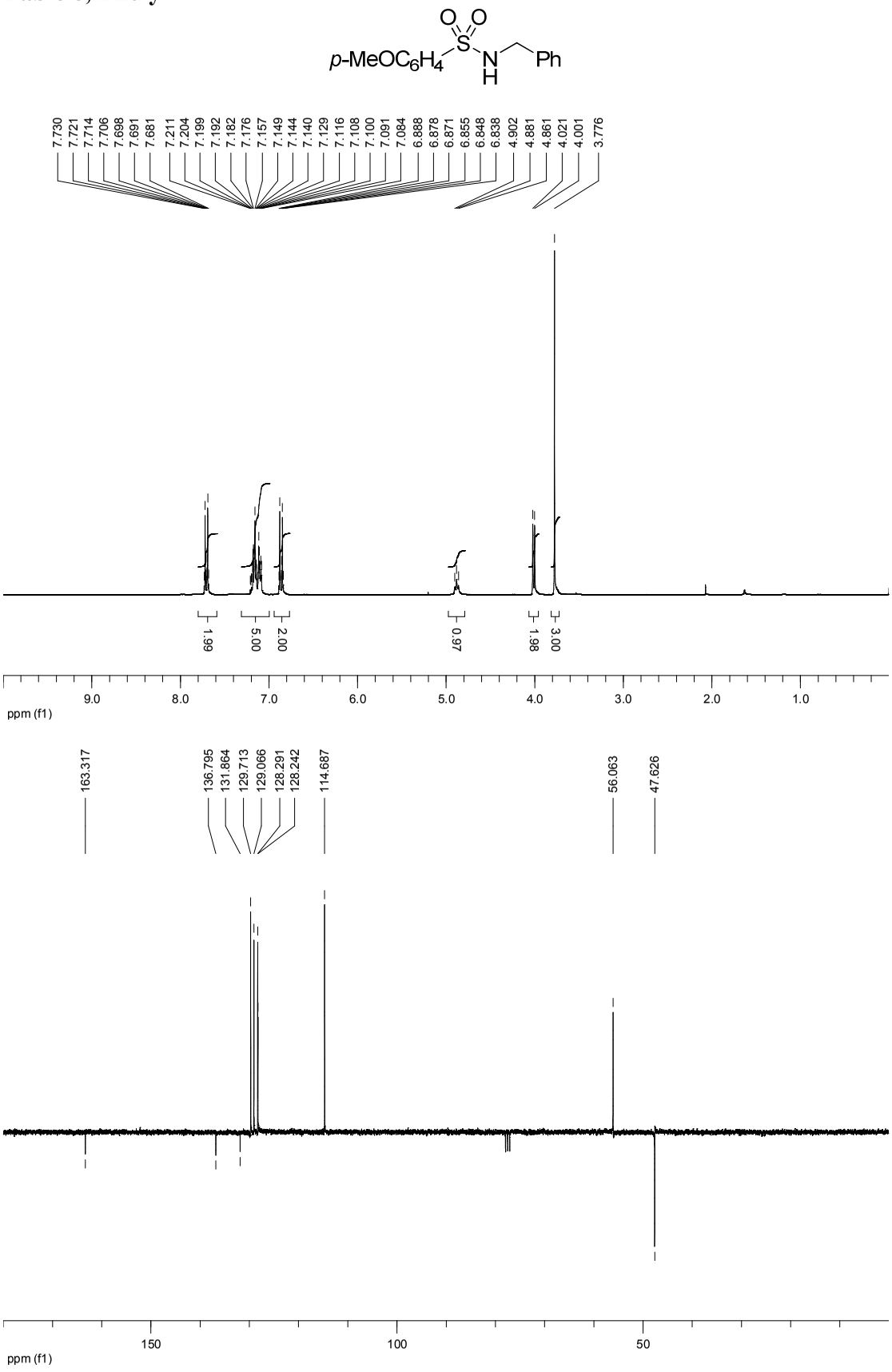


Table 6, Entry 5

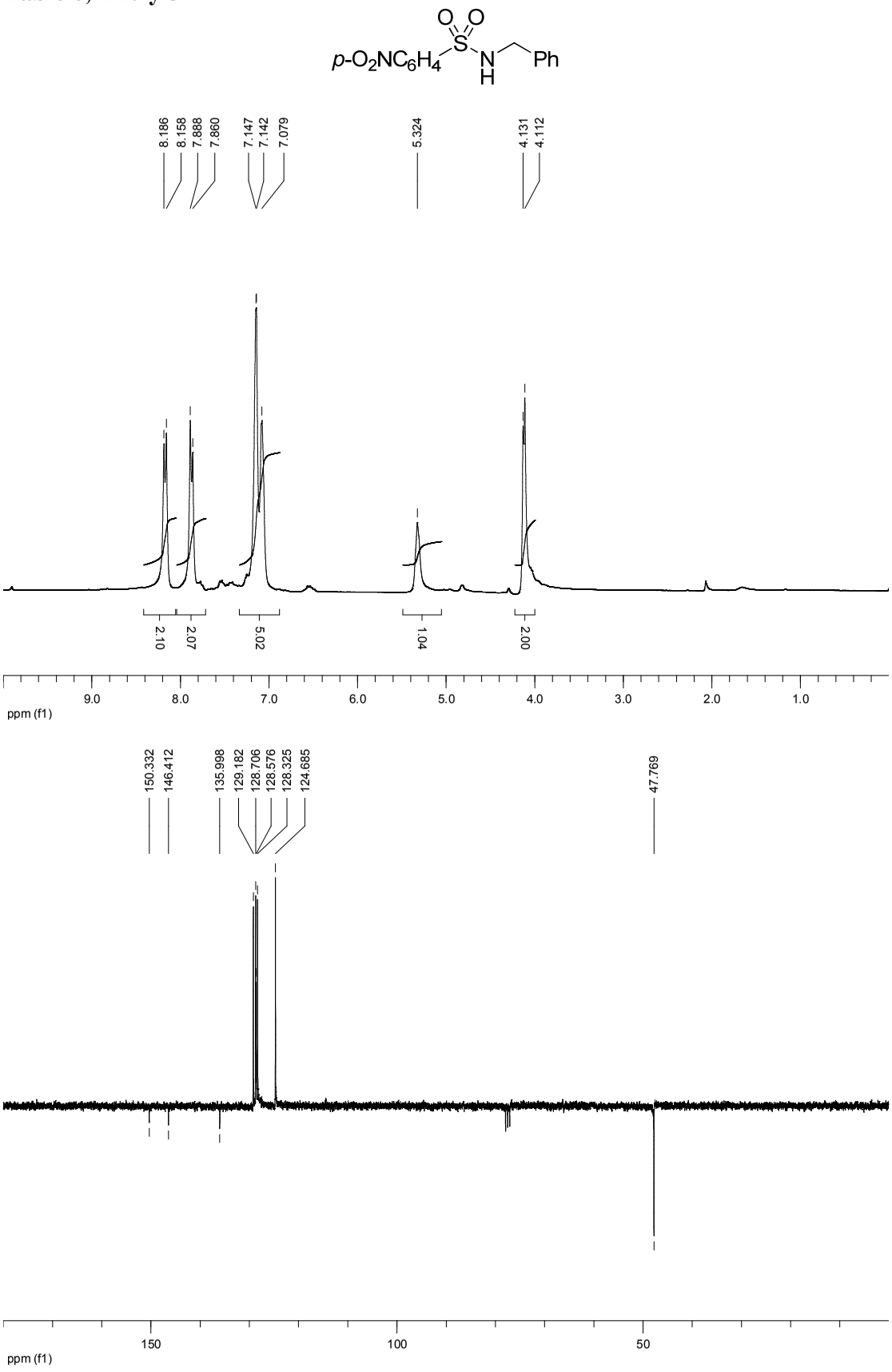
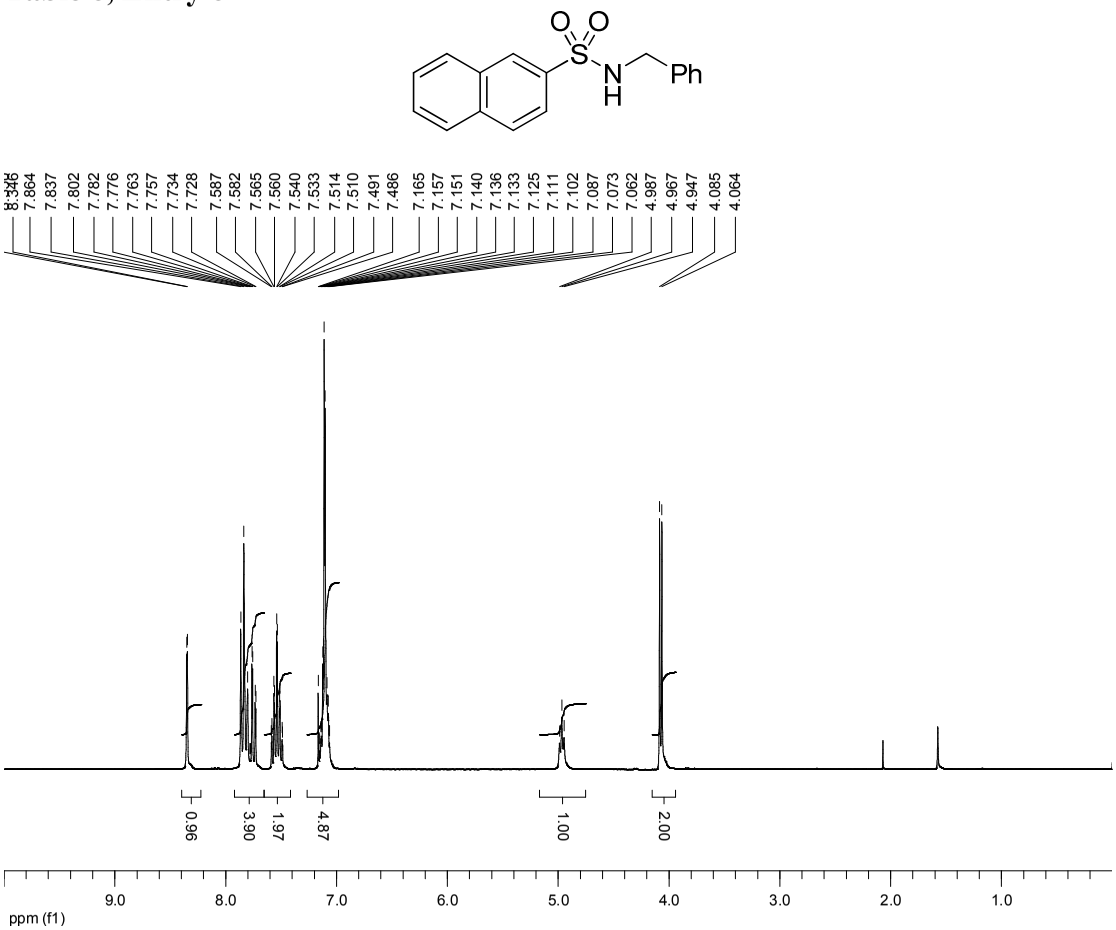


Table 6, Entry 6



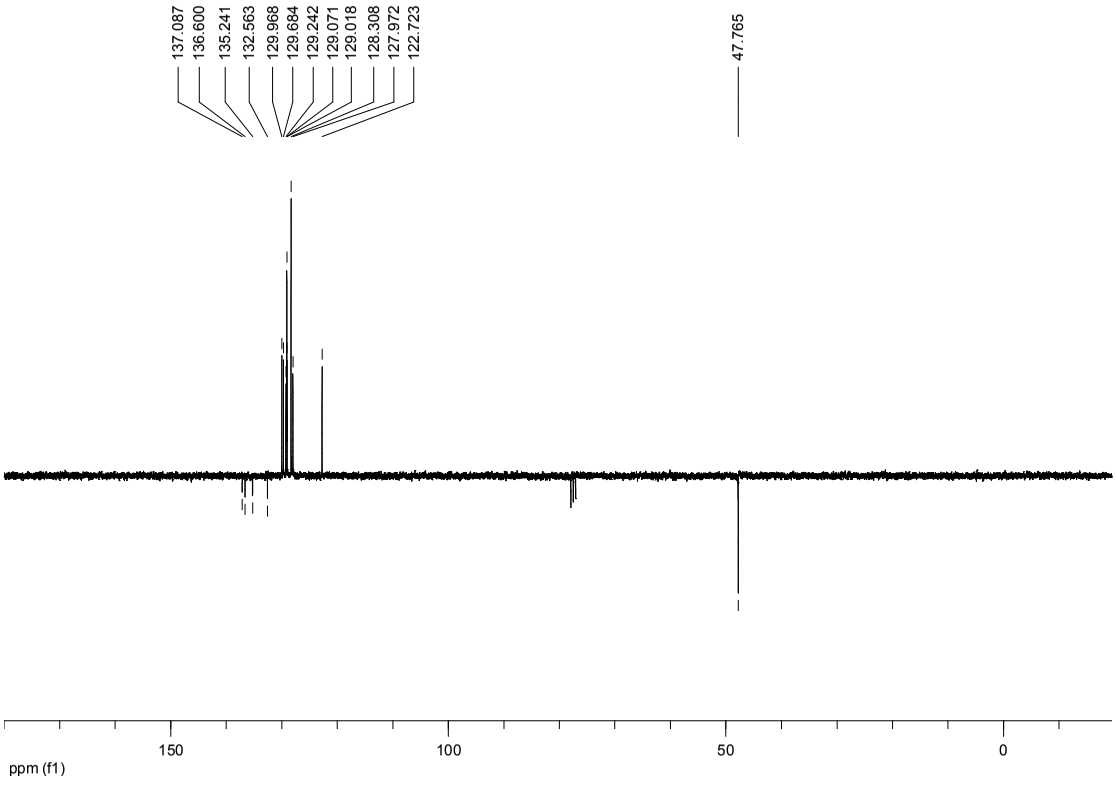


Table 6, Entry 7

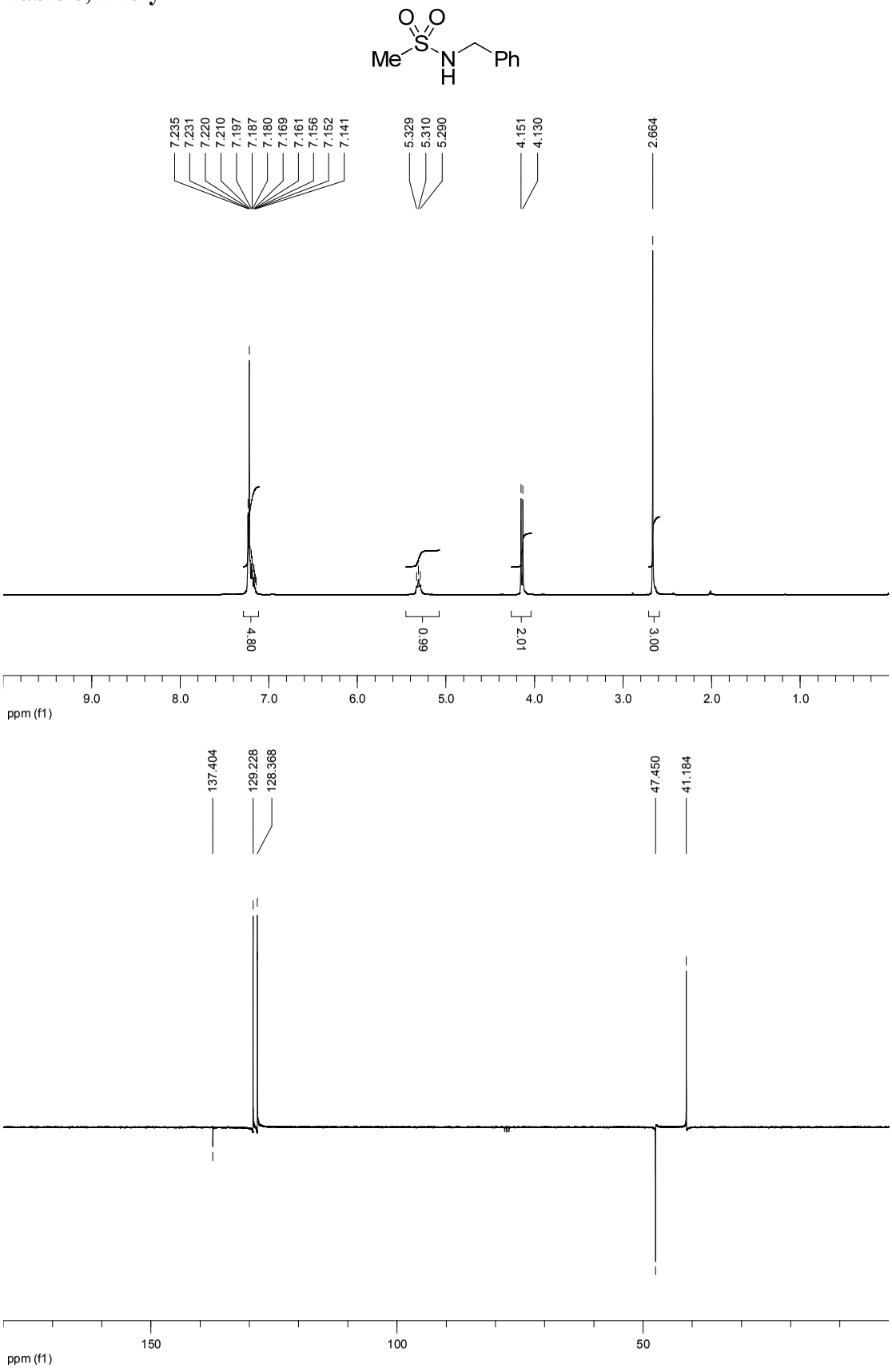
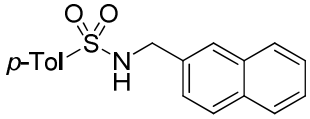
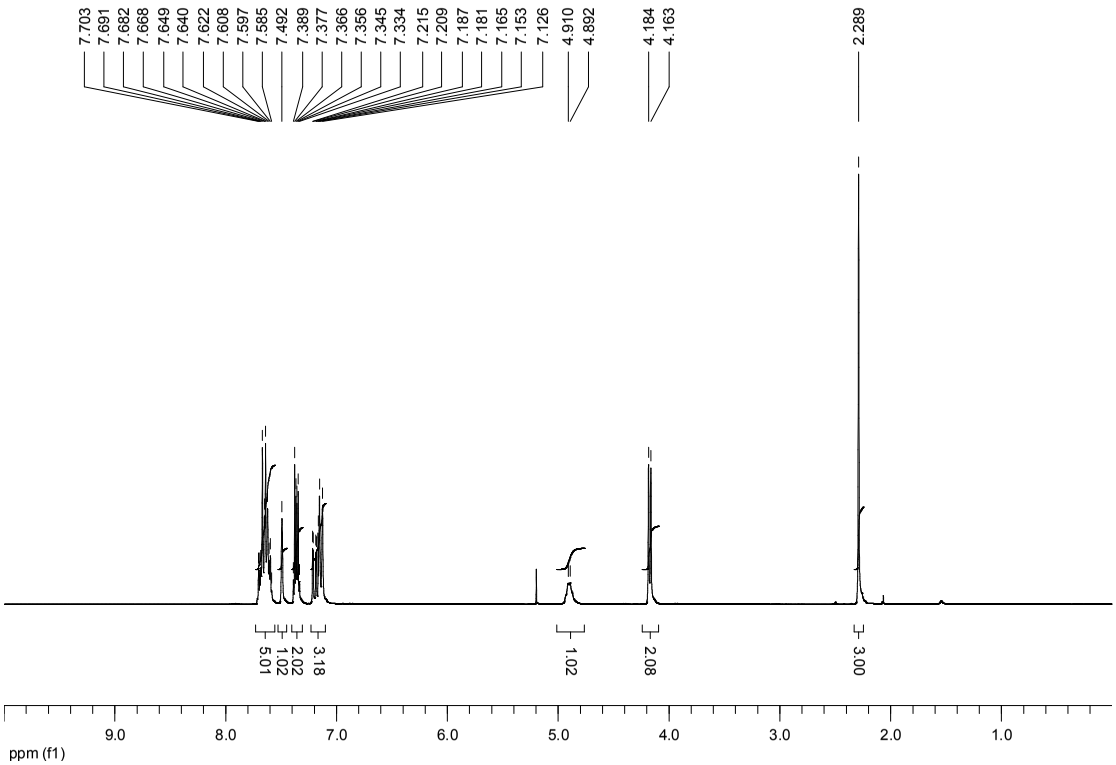


Table 6, Entry 8





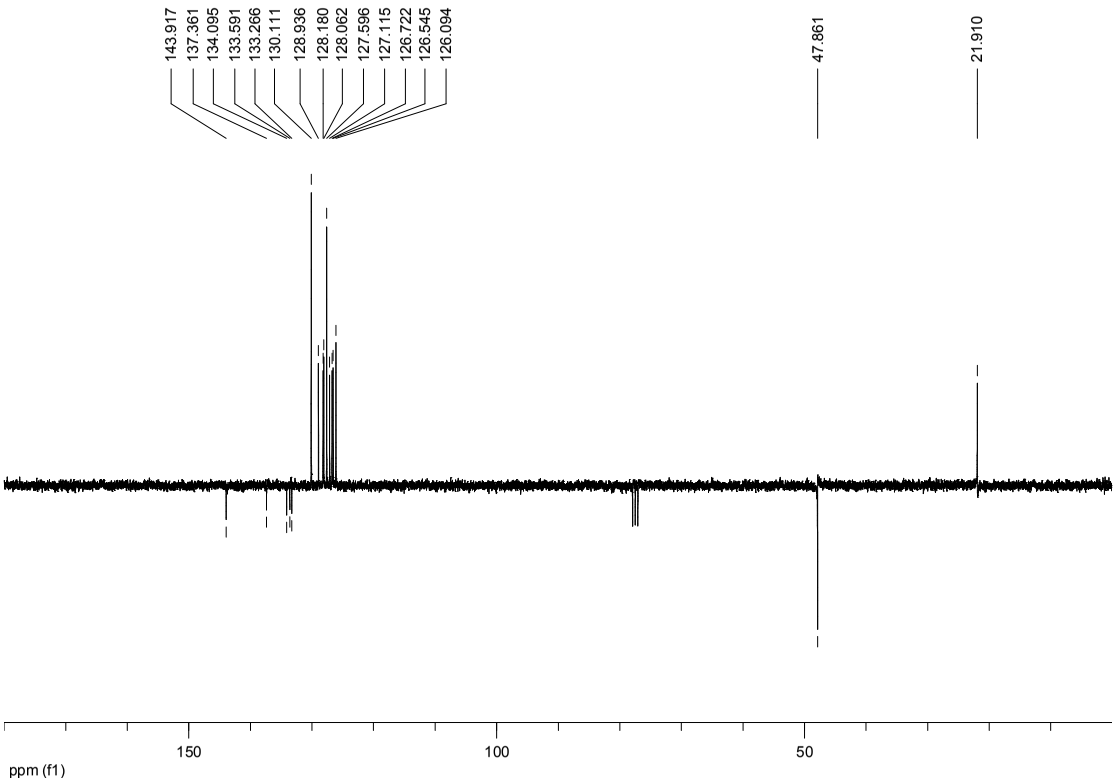


Table 6, Entry 9

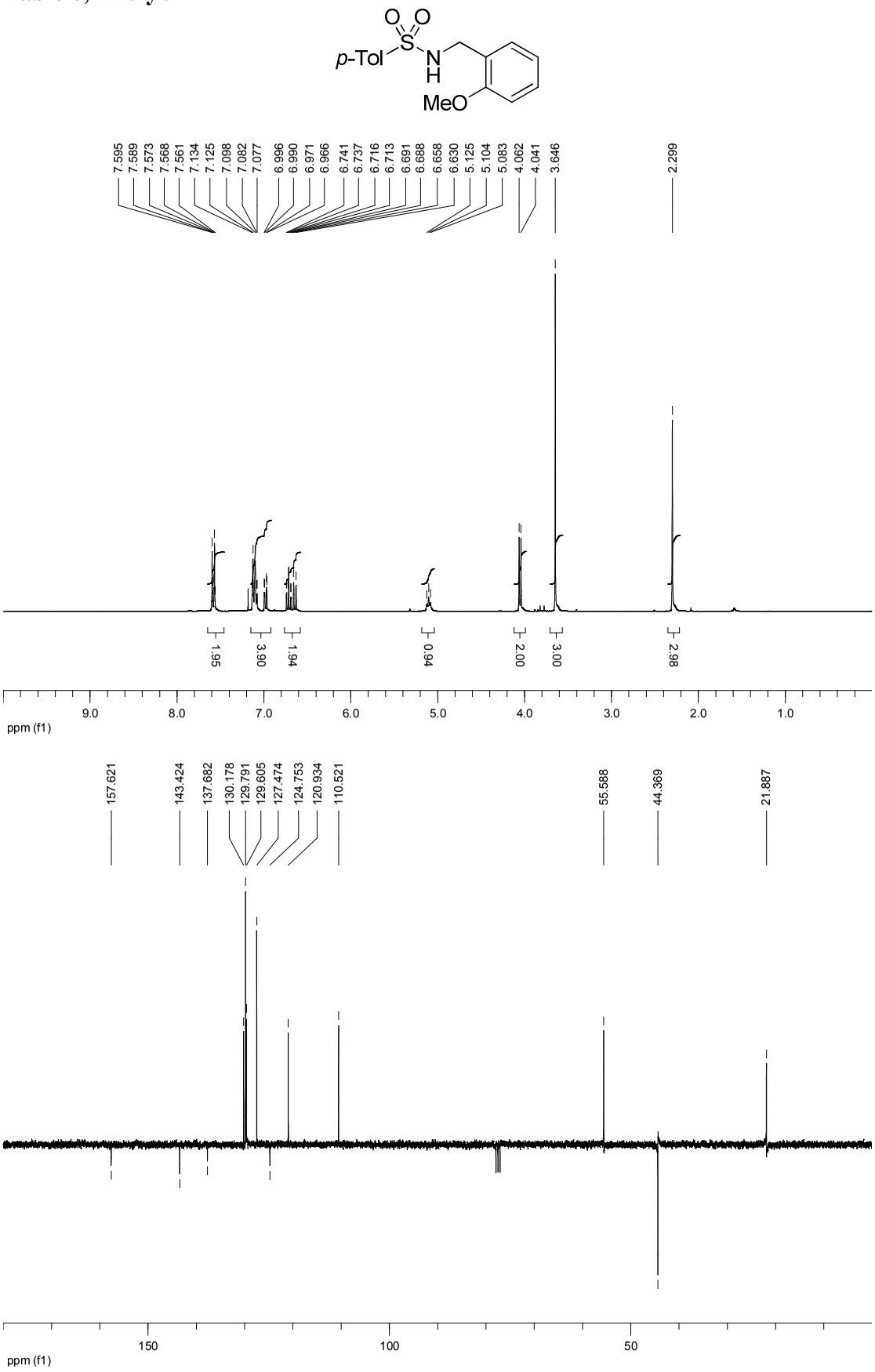


Table 6, Entry 10

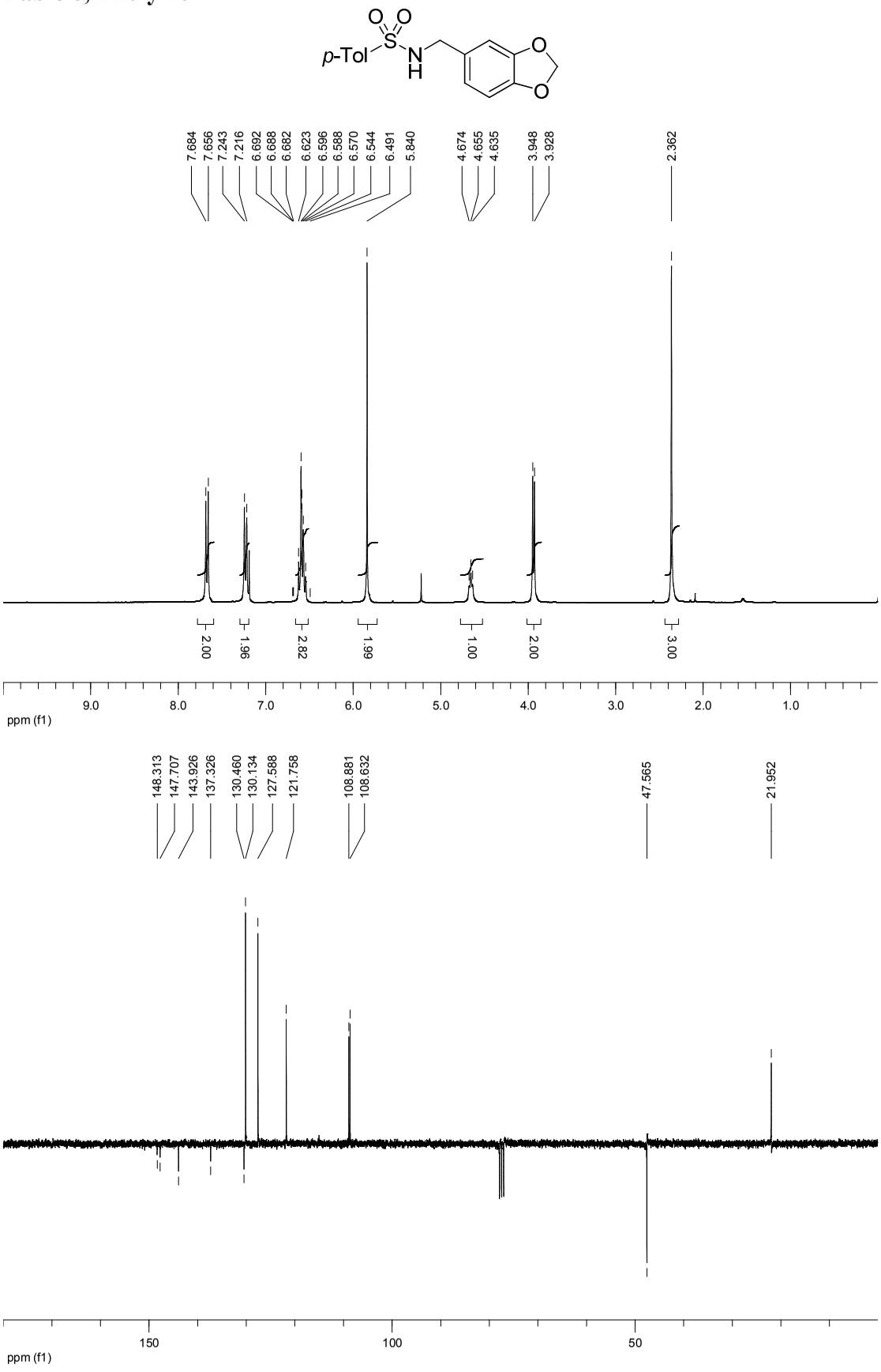
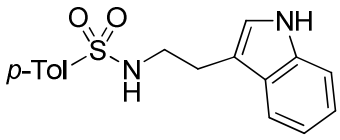
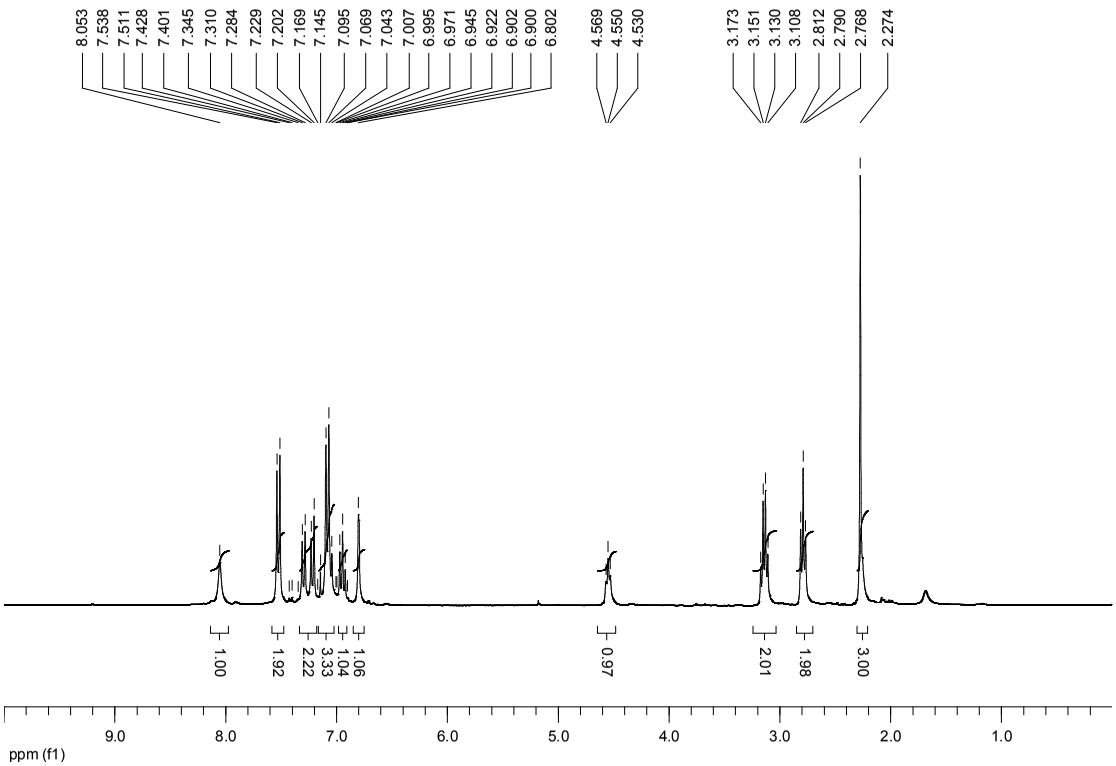


Table 6, Entry 11





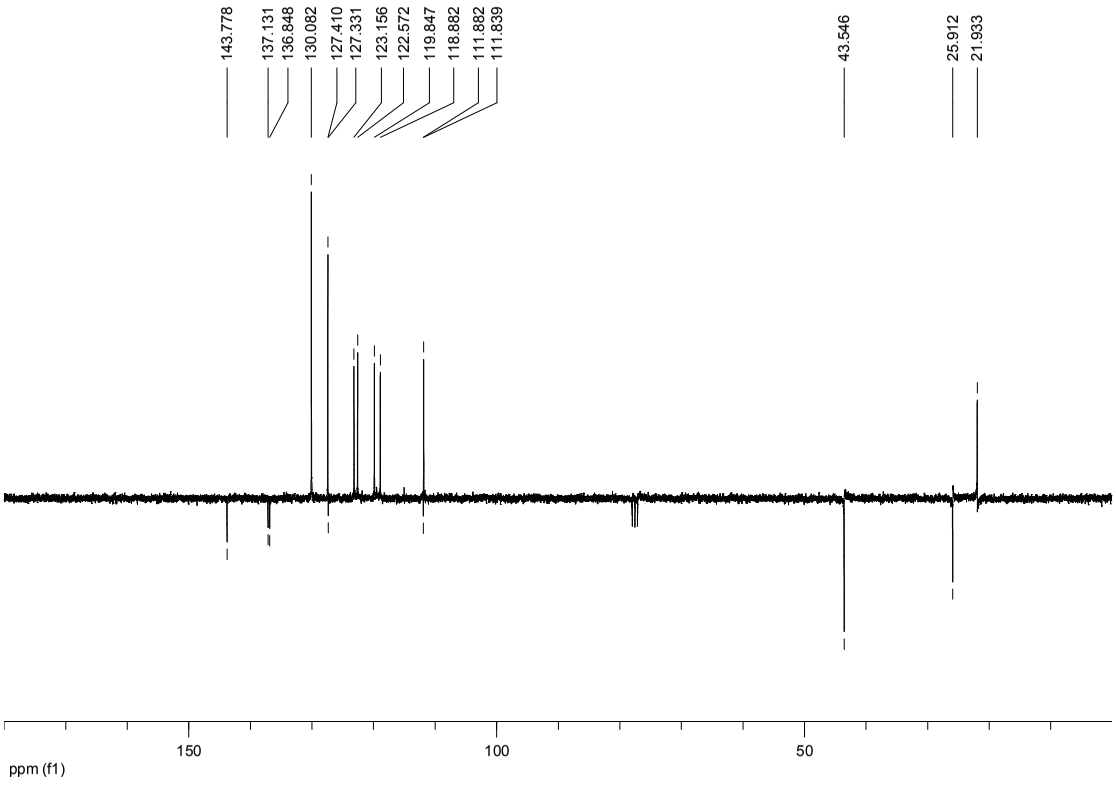
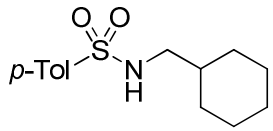
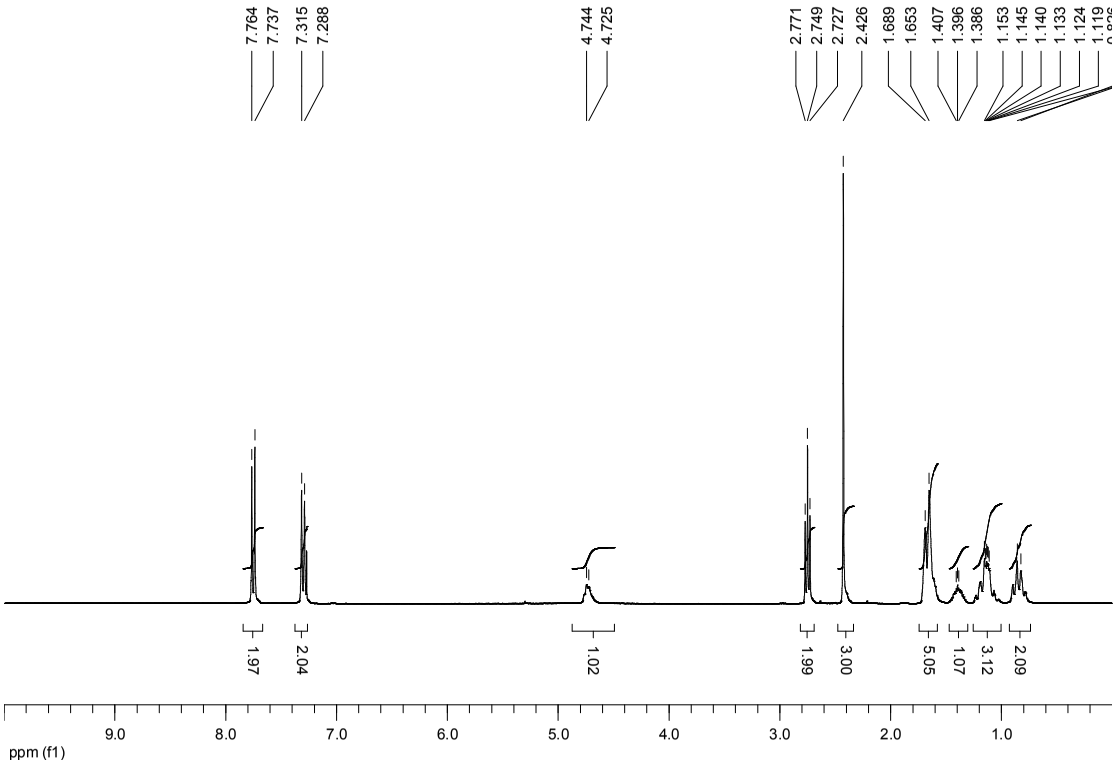


Table 6, Entry 12





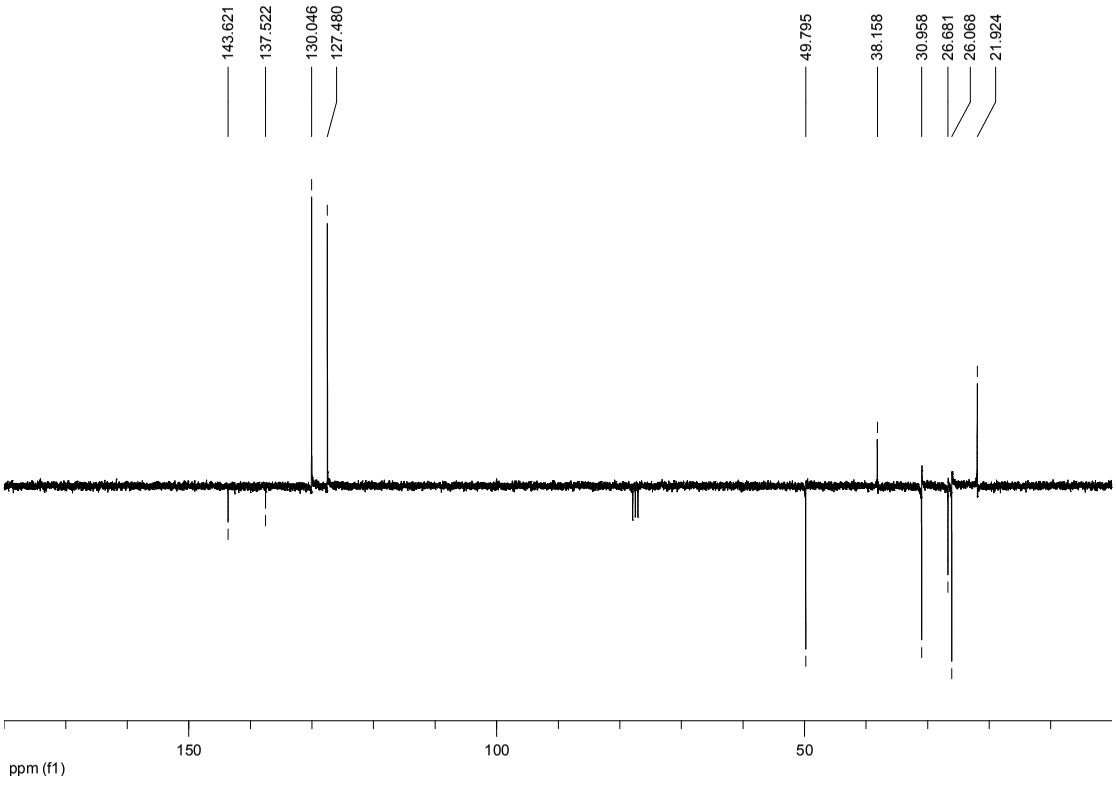
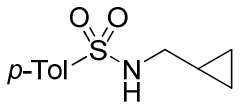
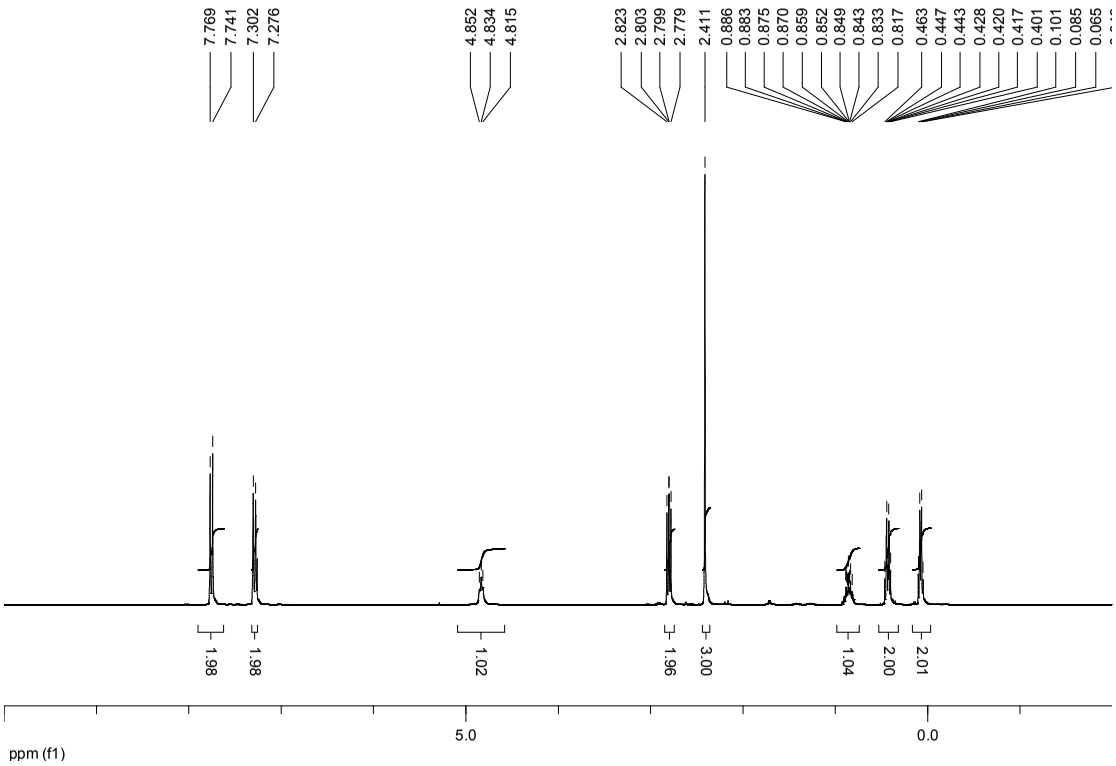


Table 6, Entry 13





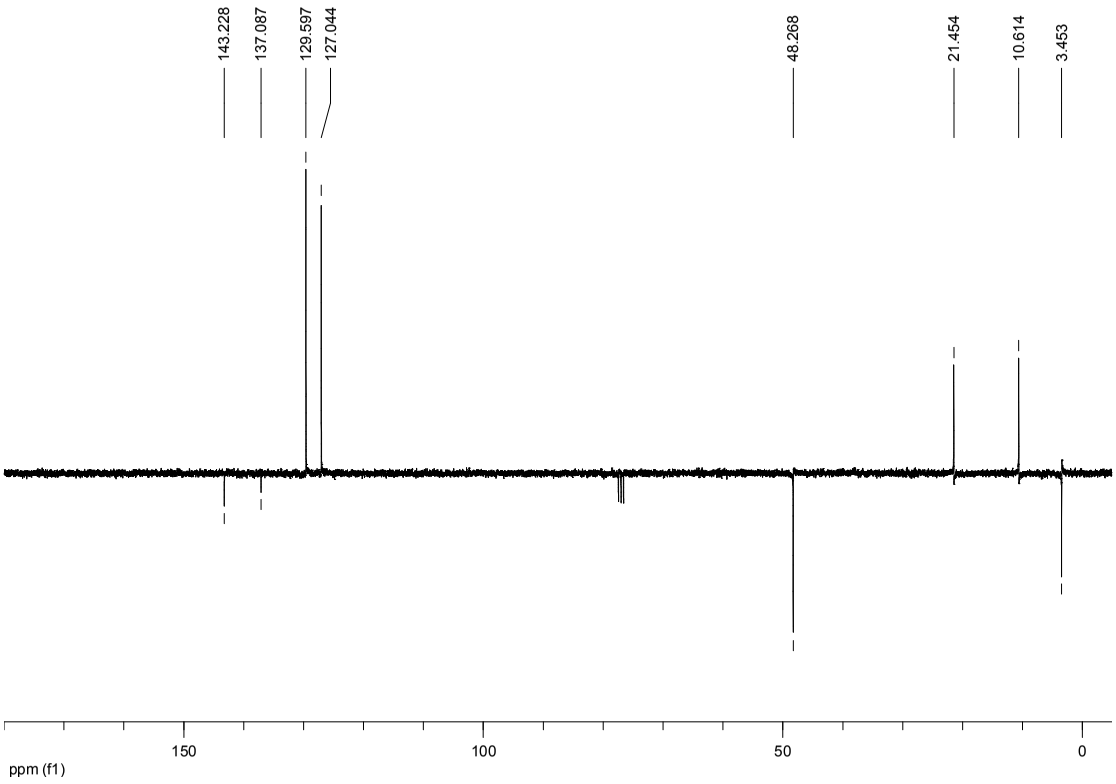
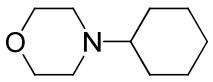
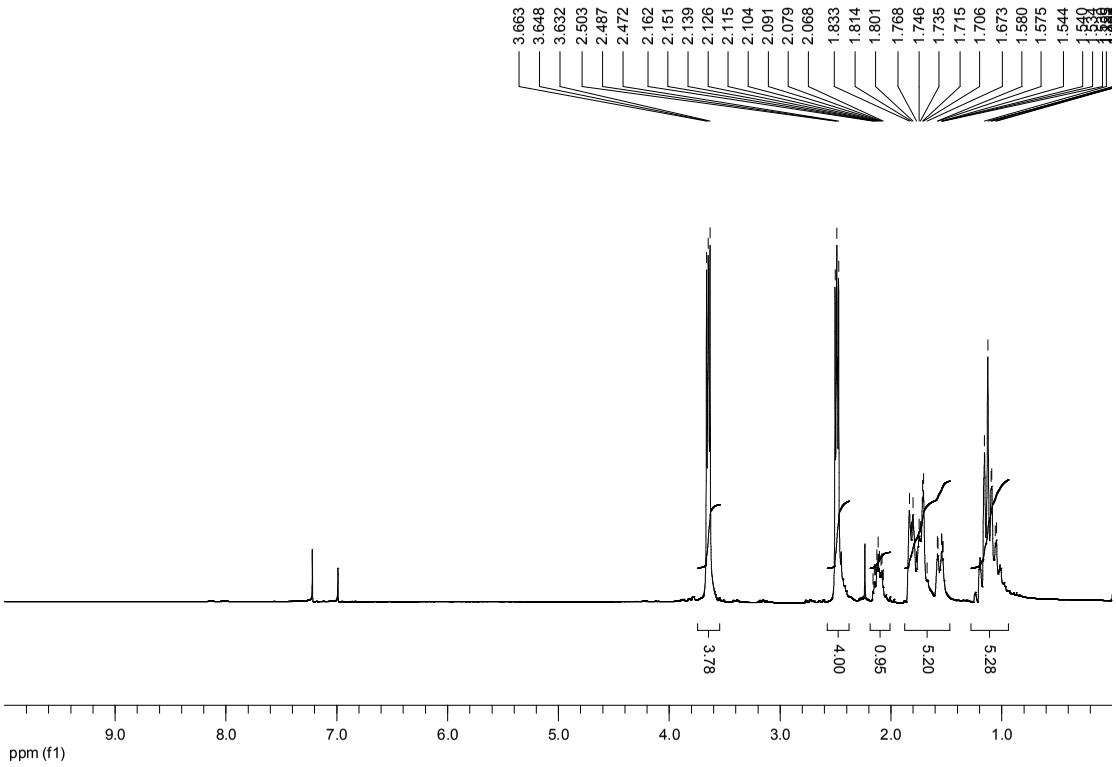


Table 7, Entry 1





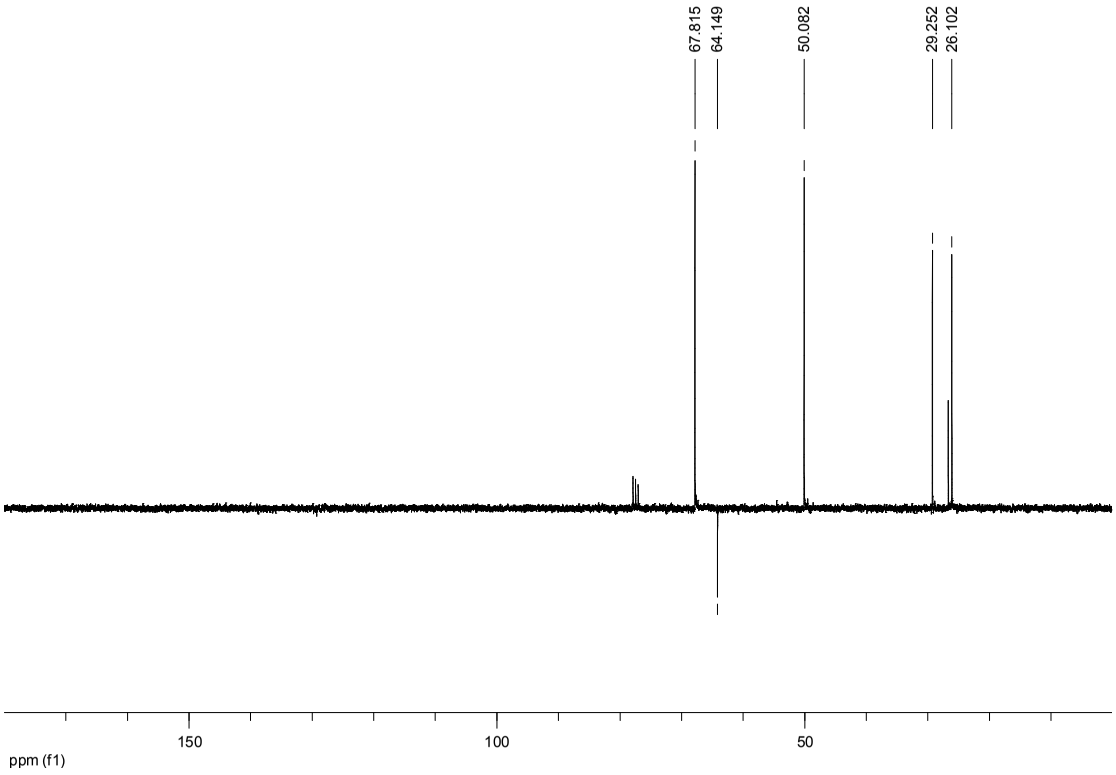
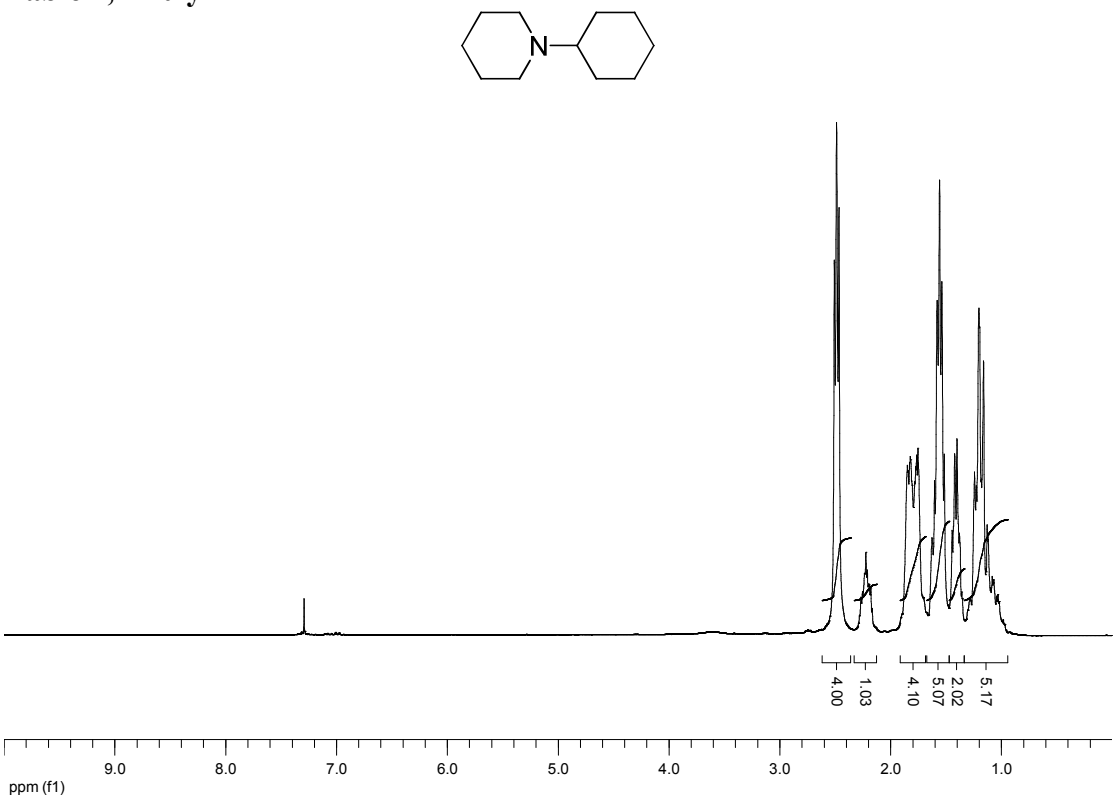


Table 7, Entry 2



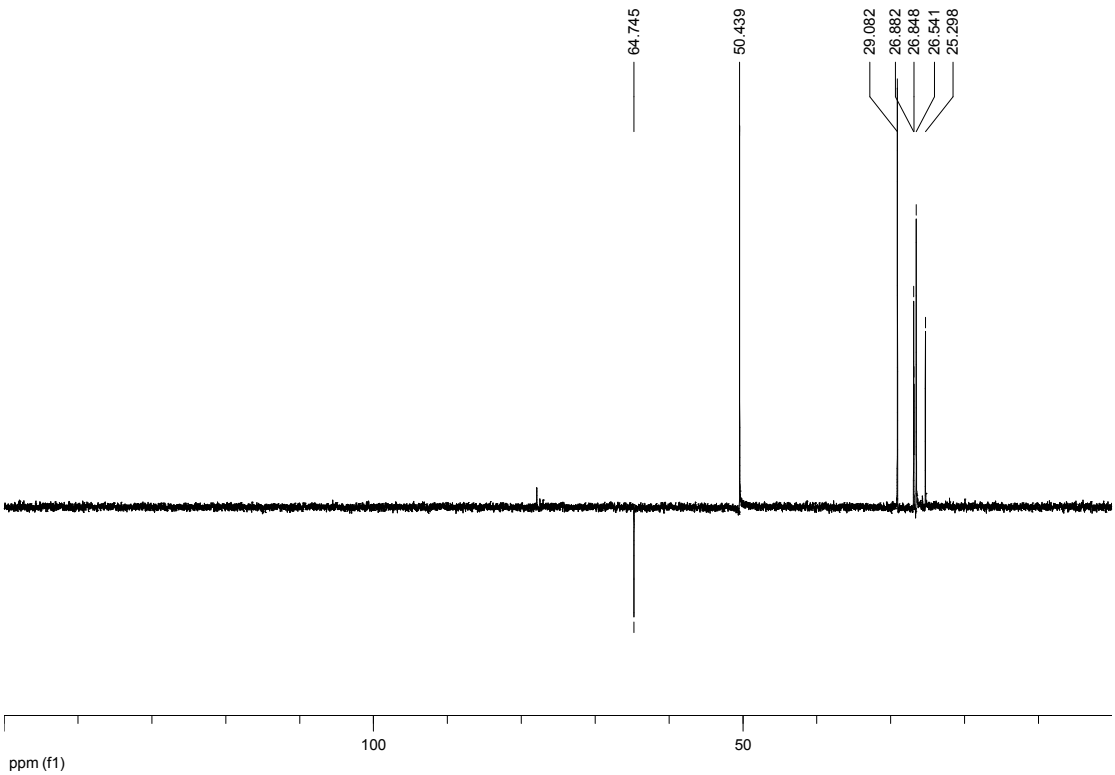
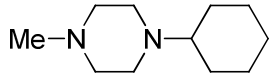
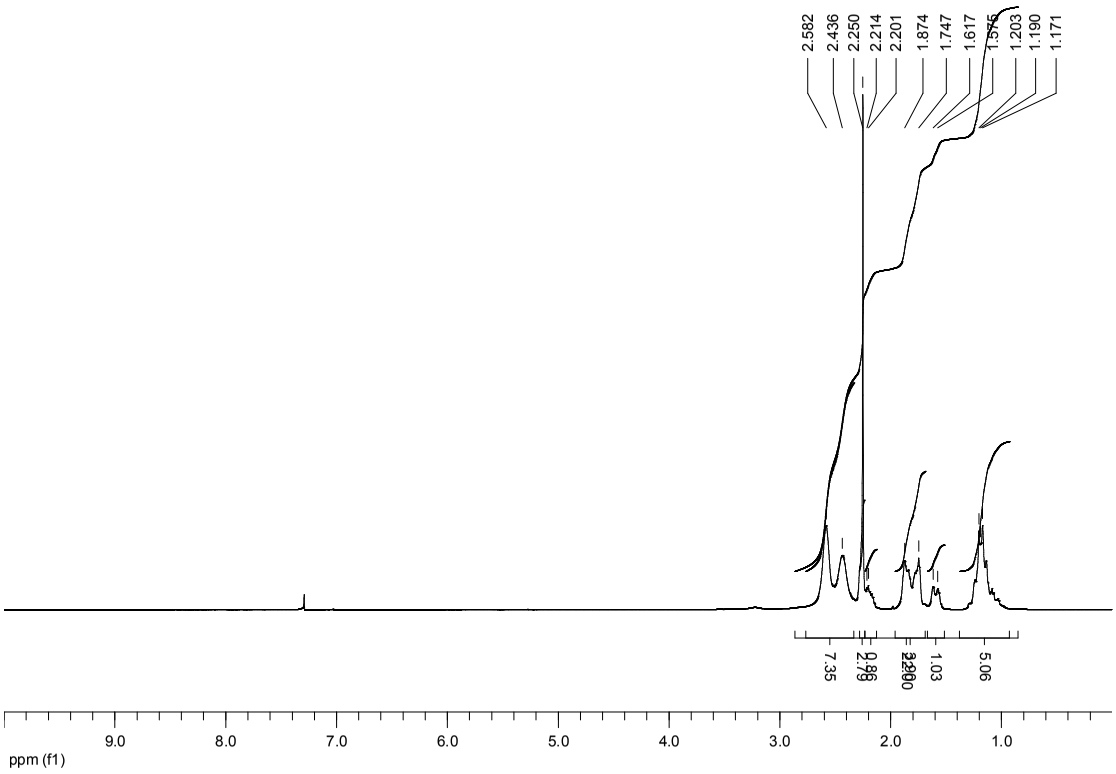


Table 7, Entry 3





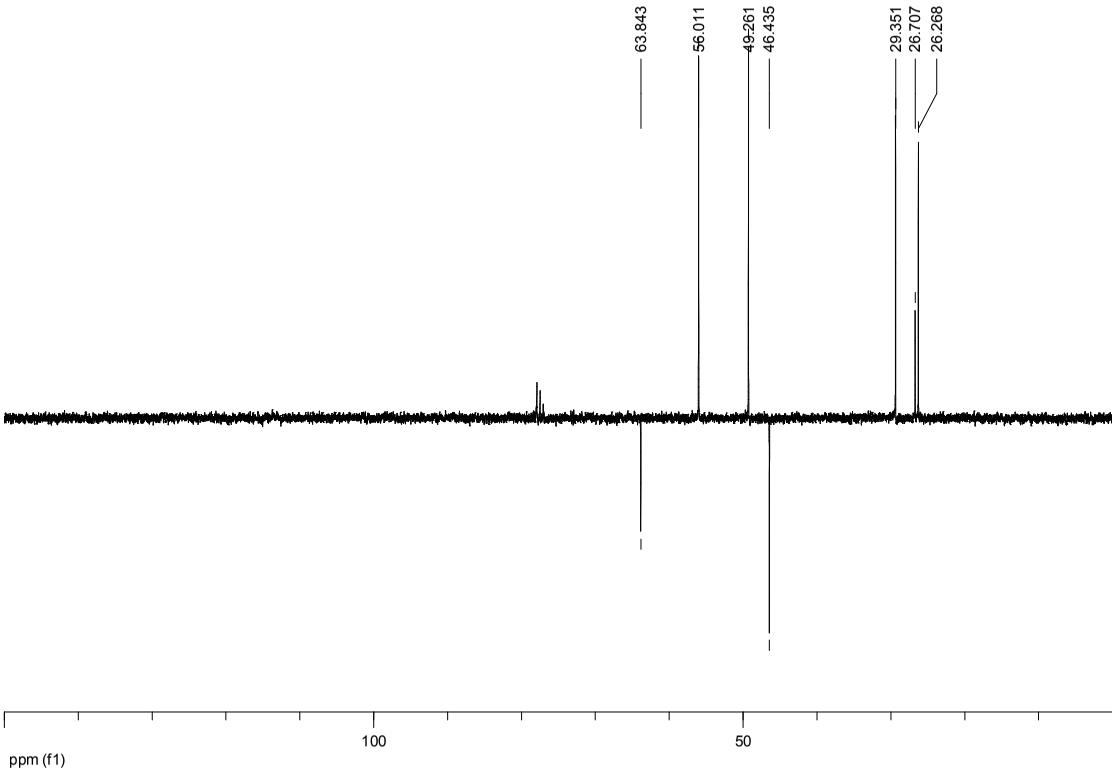
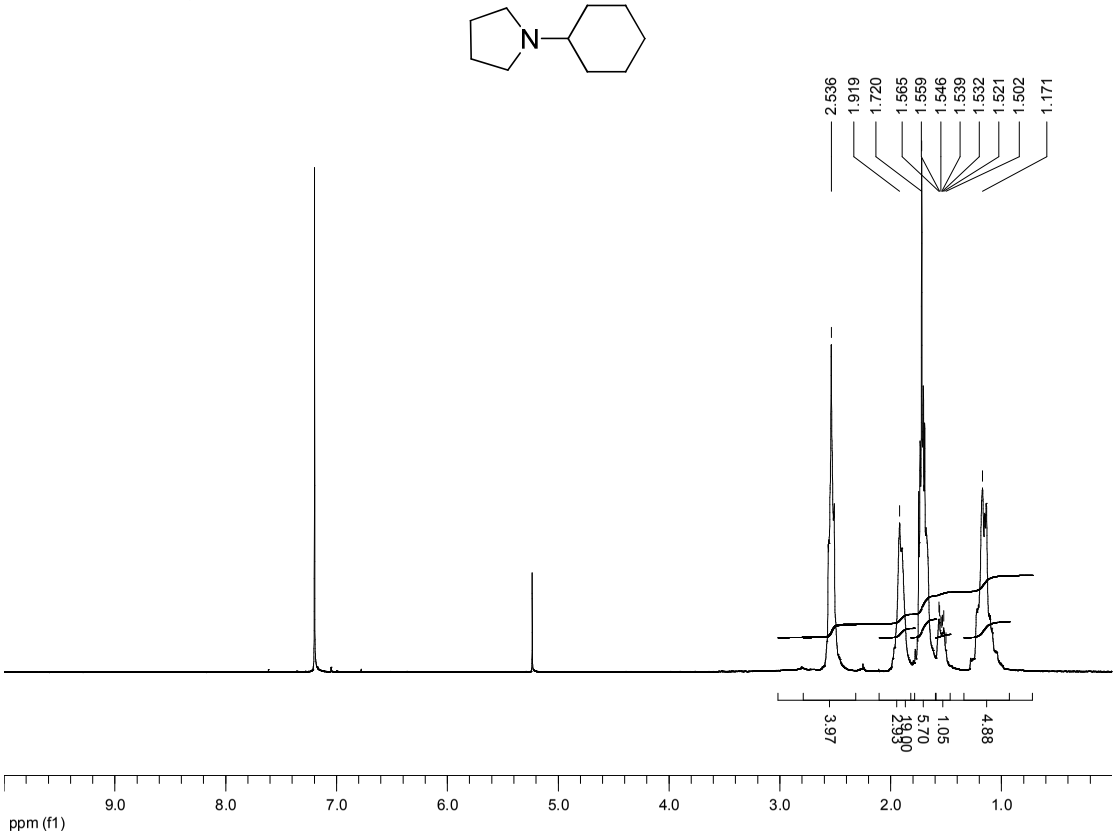


Table 7, Entry 4



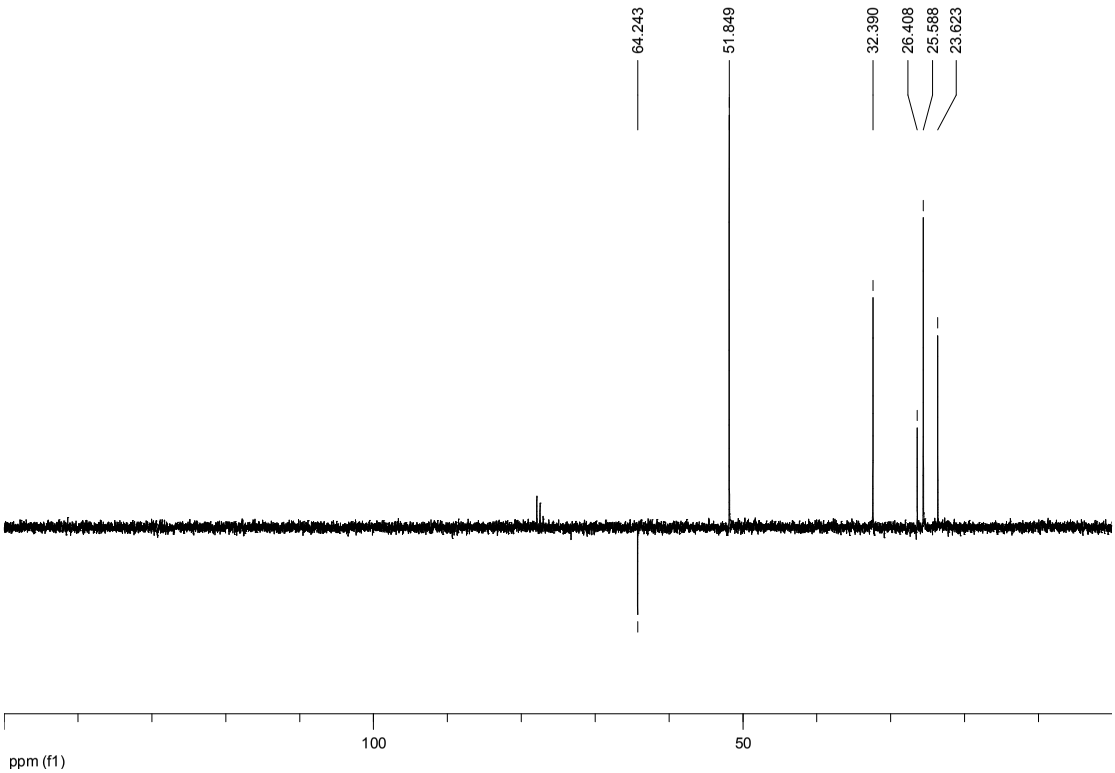


Table 7, Entry 5

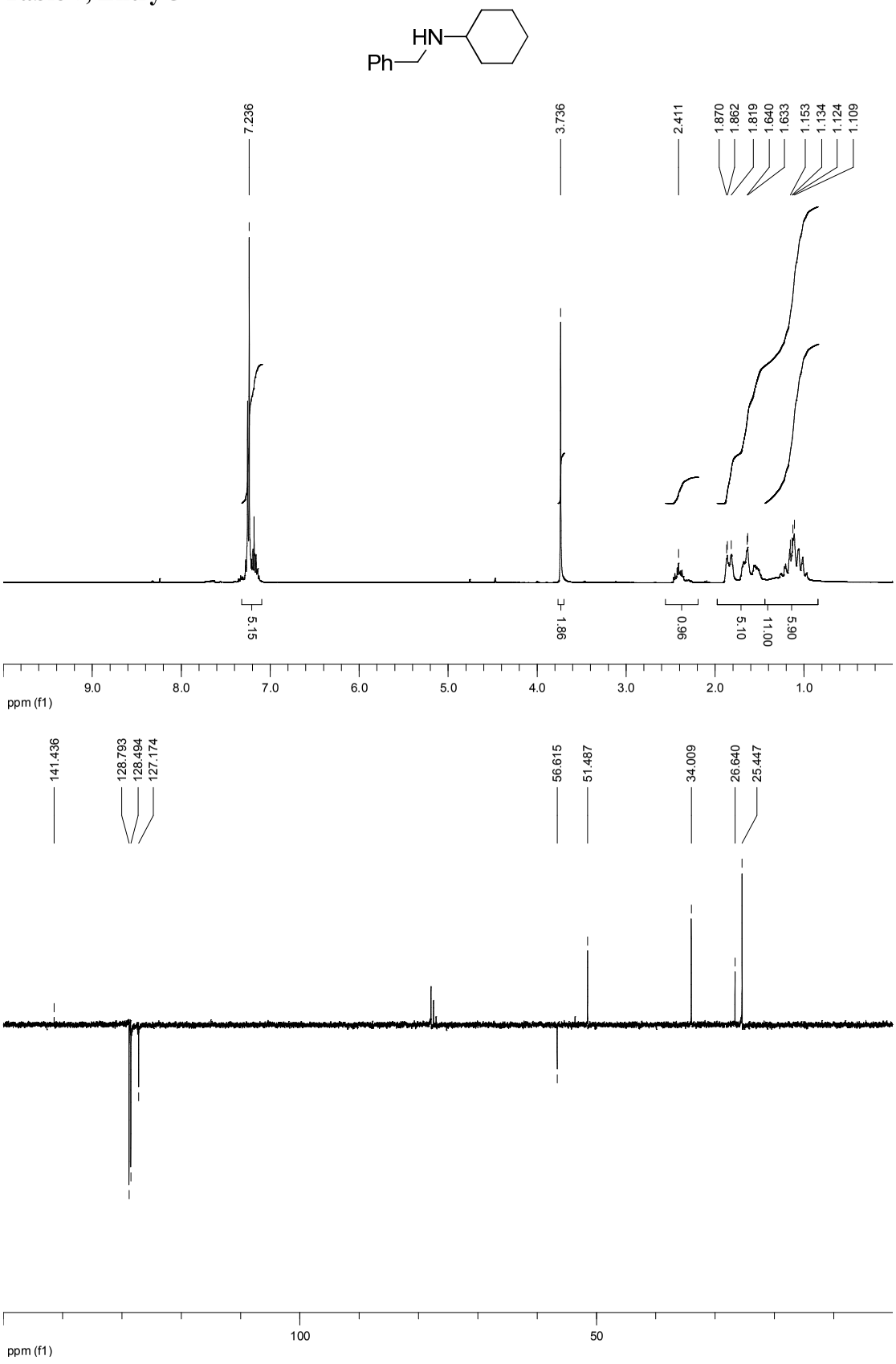
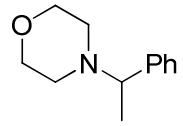
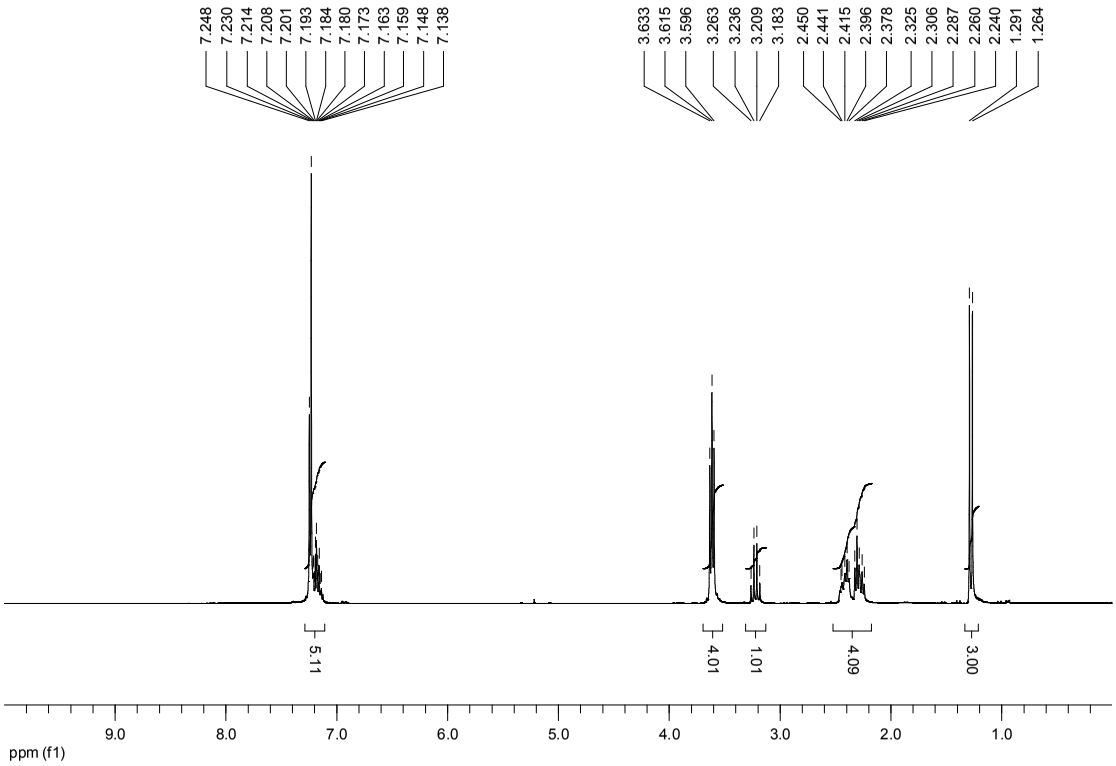


Table 8, Entry 1





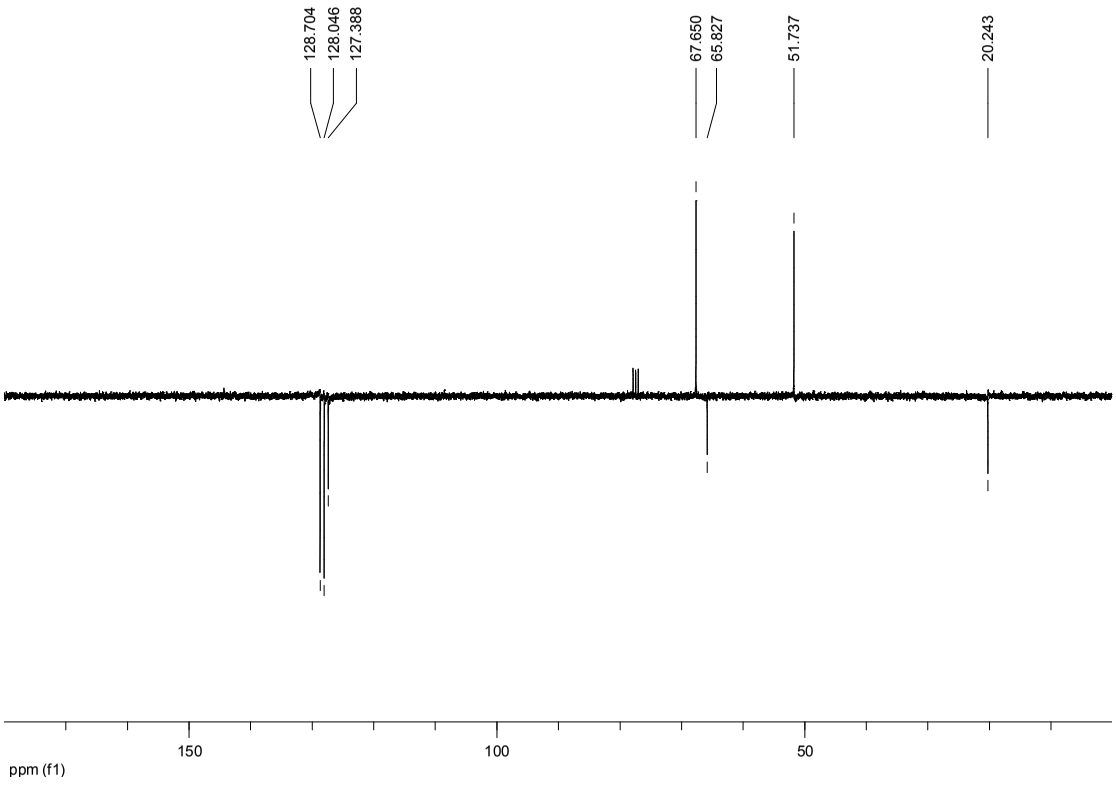
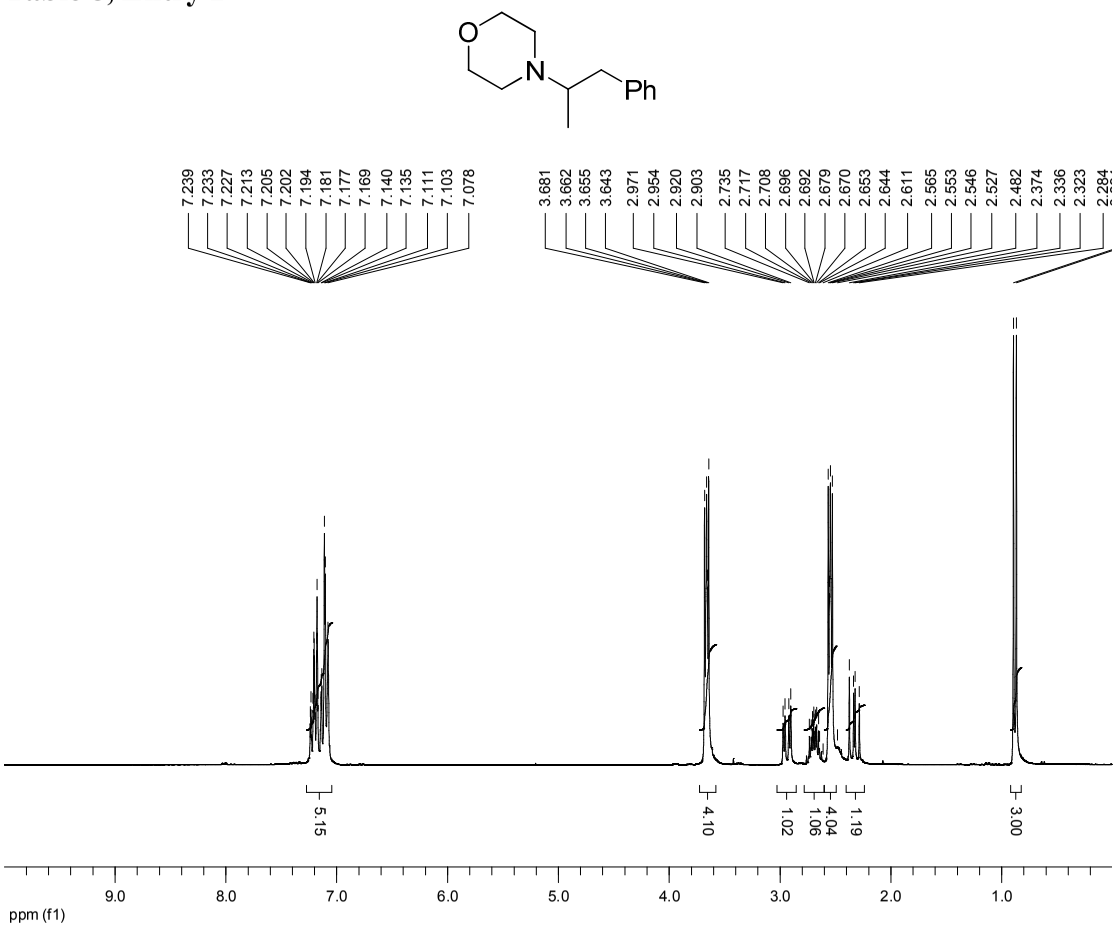


Table 8, Entry 2



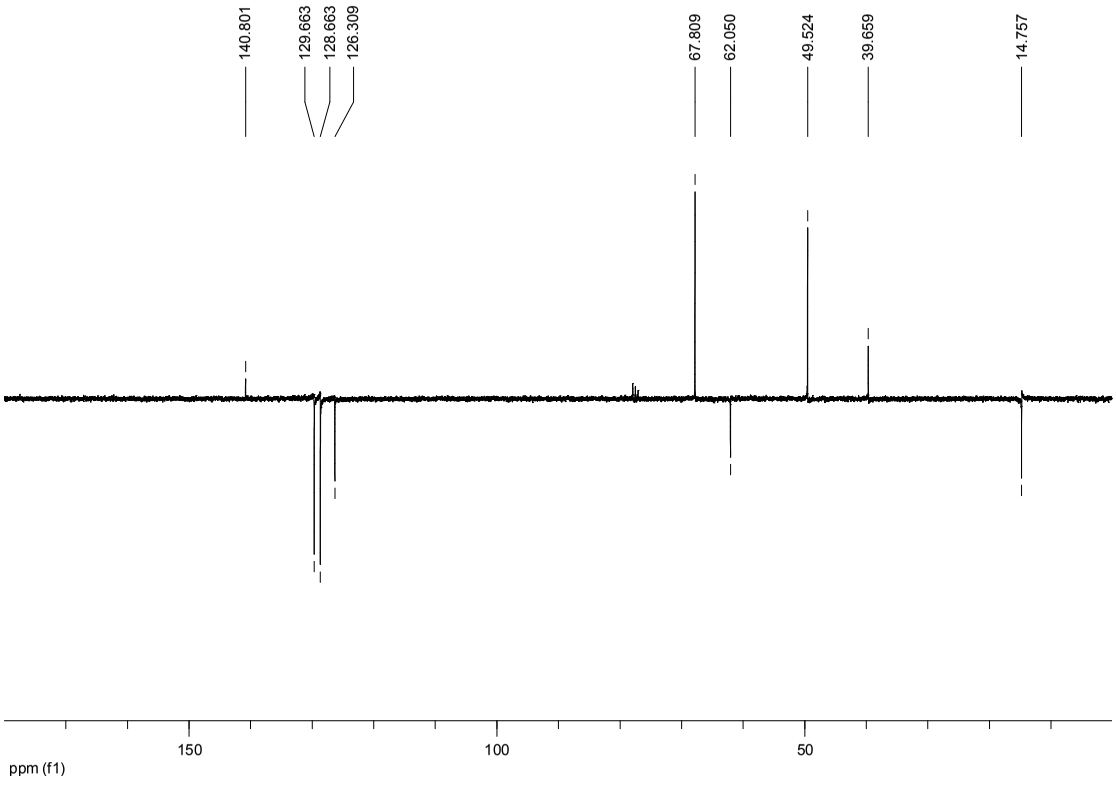
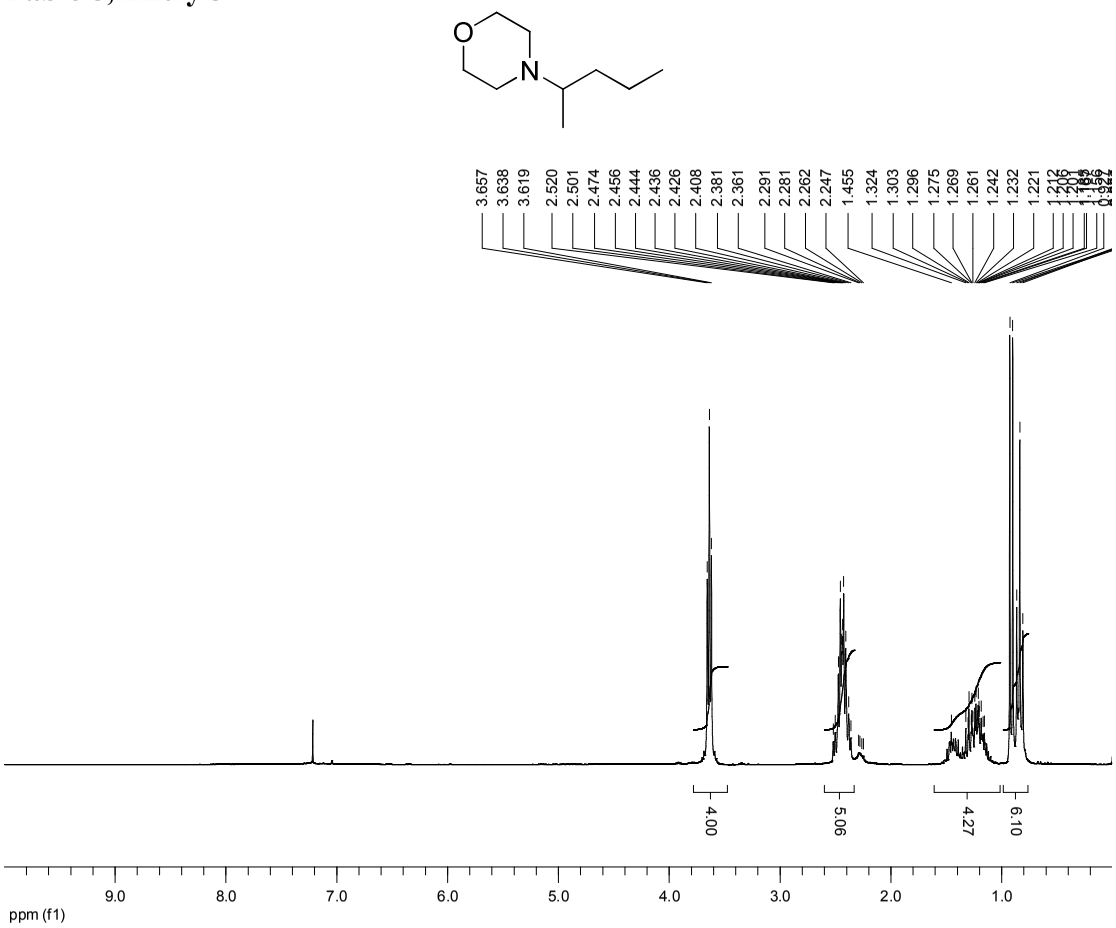


Table 8, Entry 3



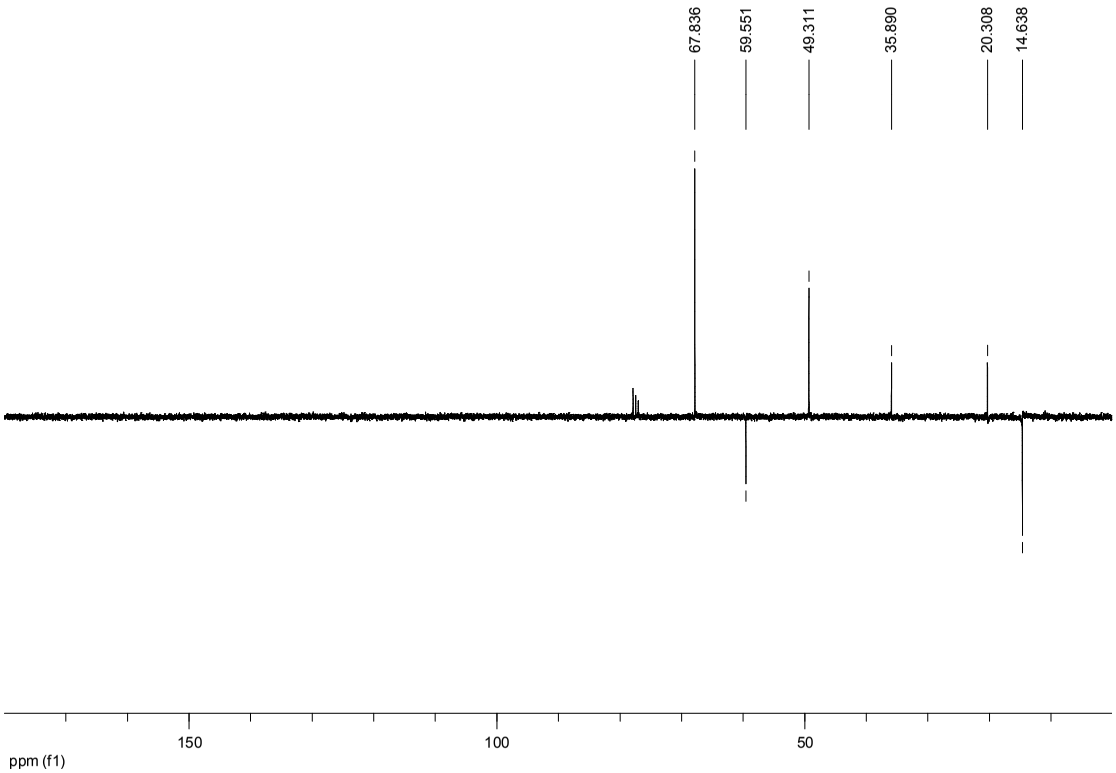
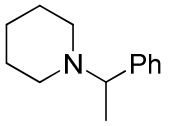
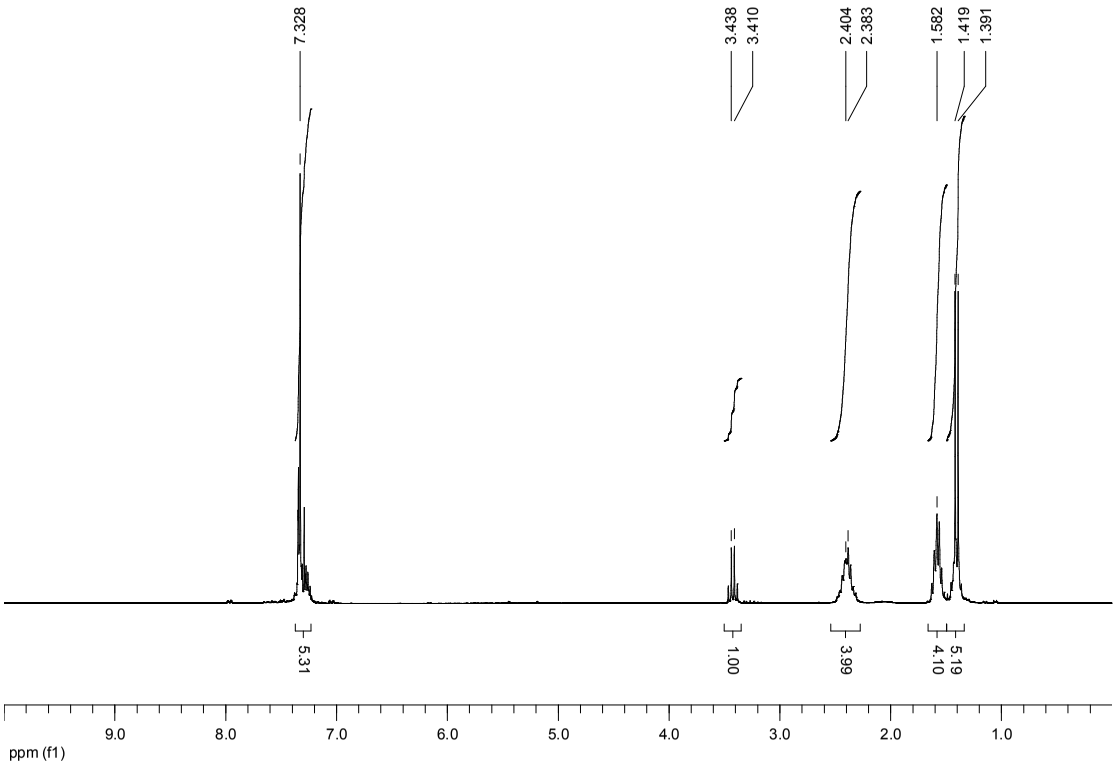


Table 8, Entry 4





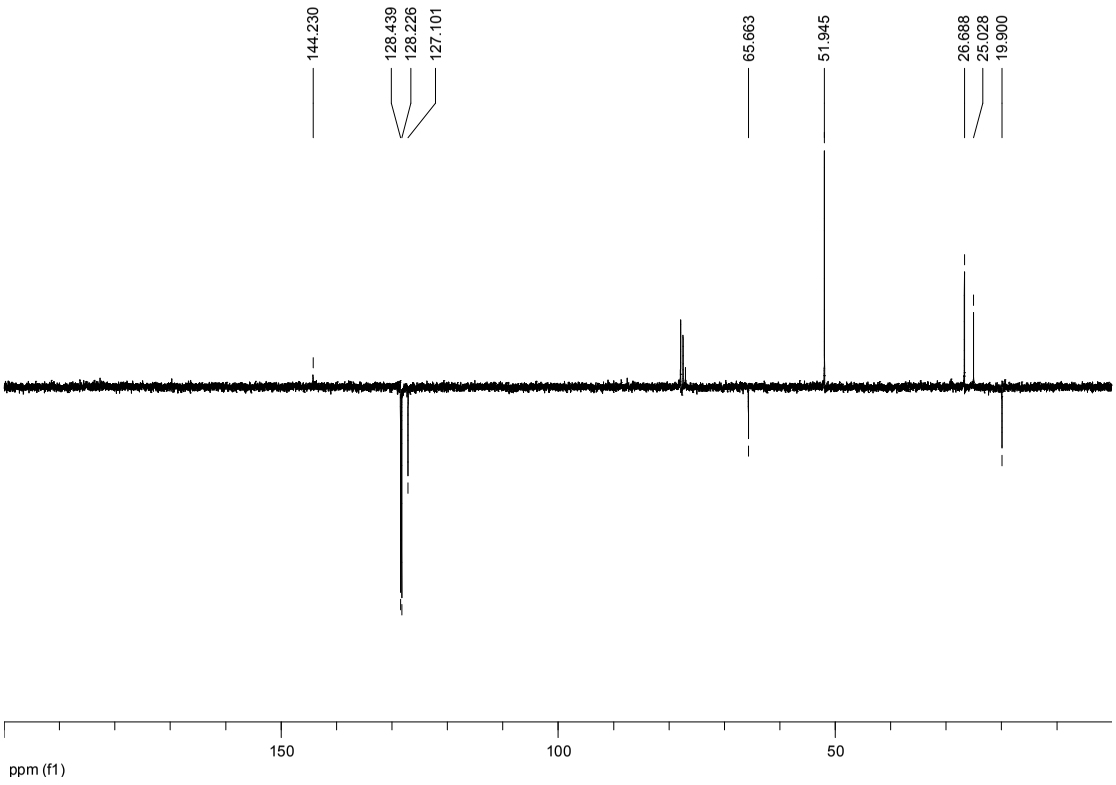
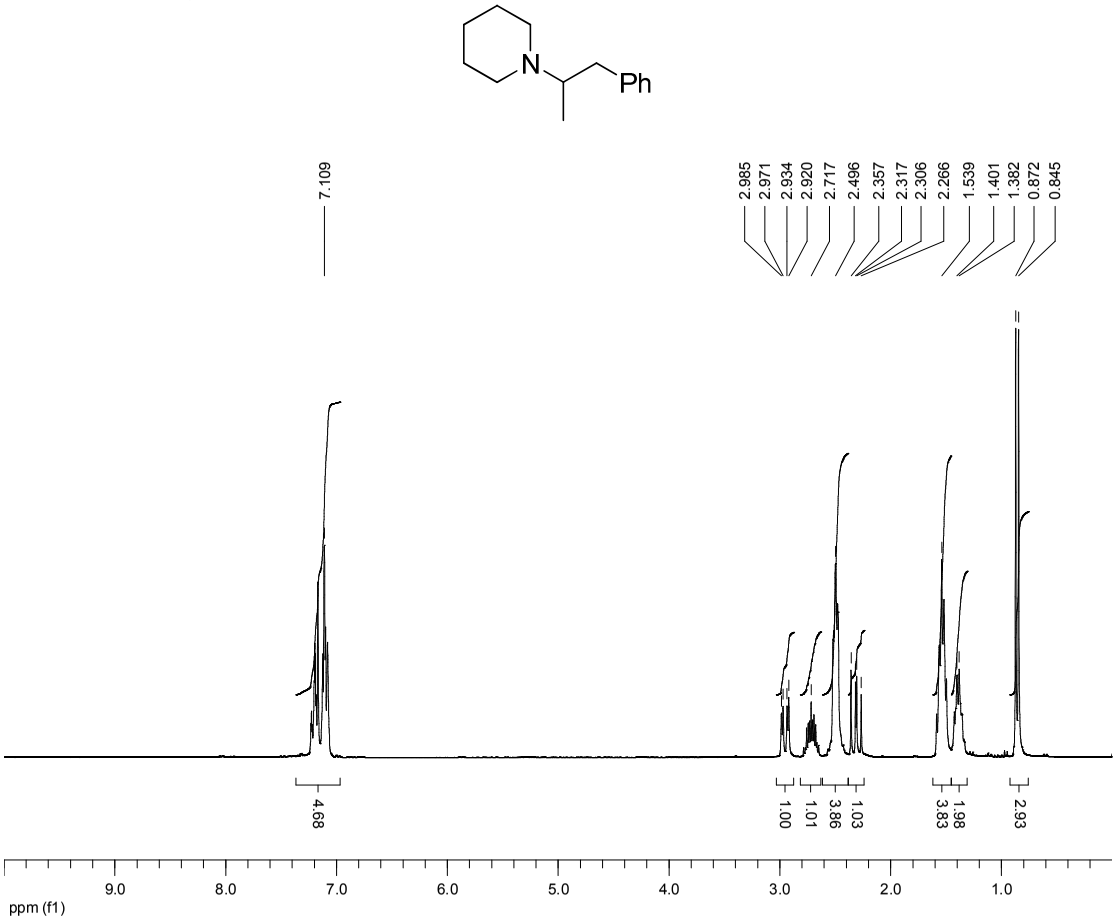


Table 8, Entry 5



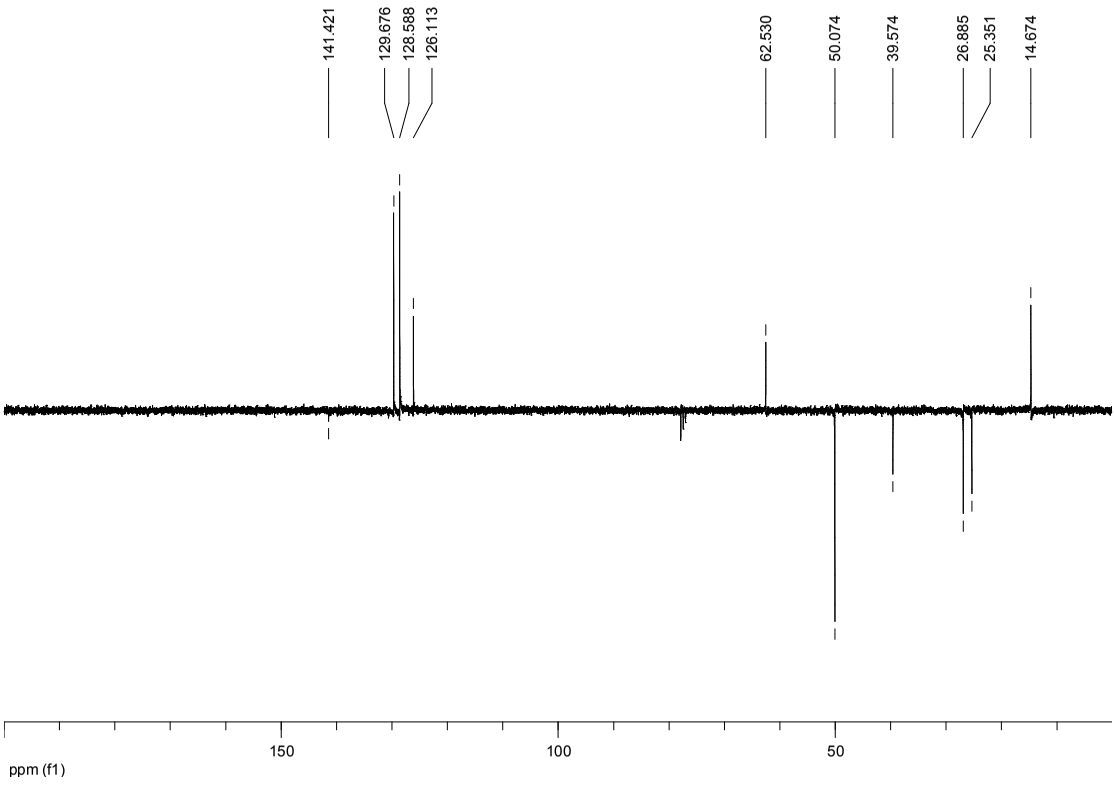
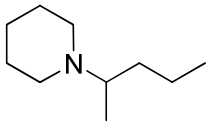
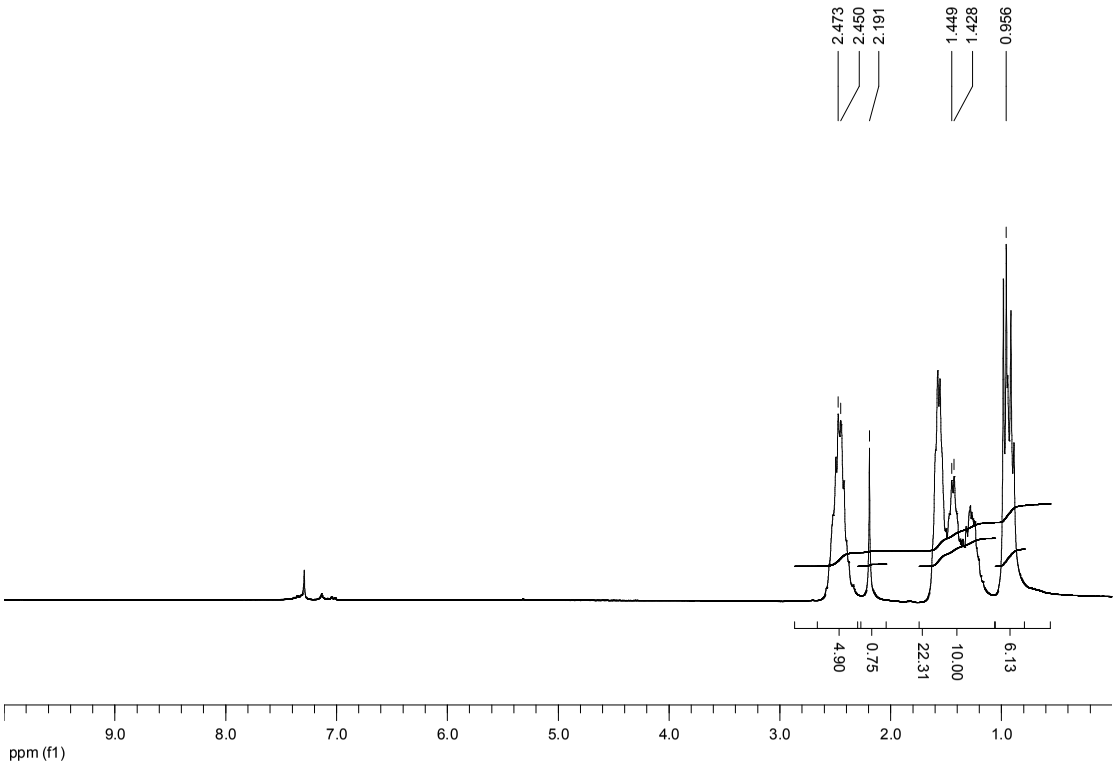


Table 8, Entry 6





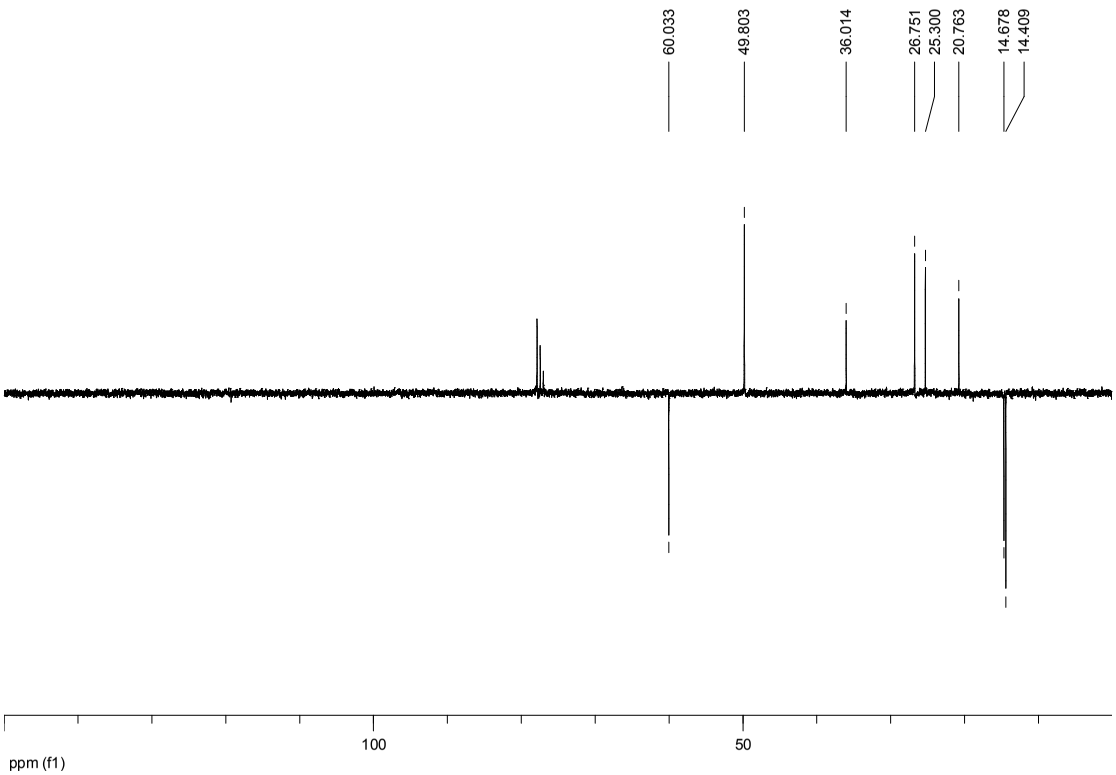
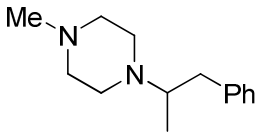
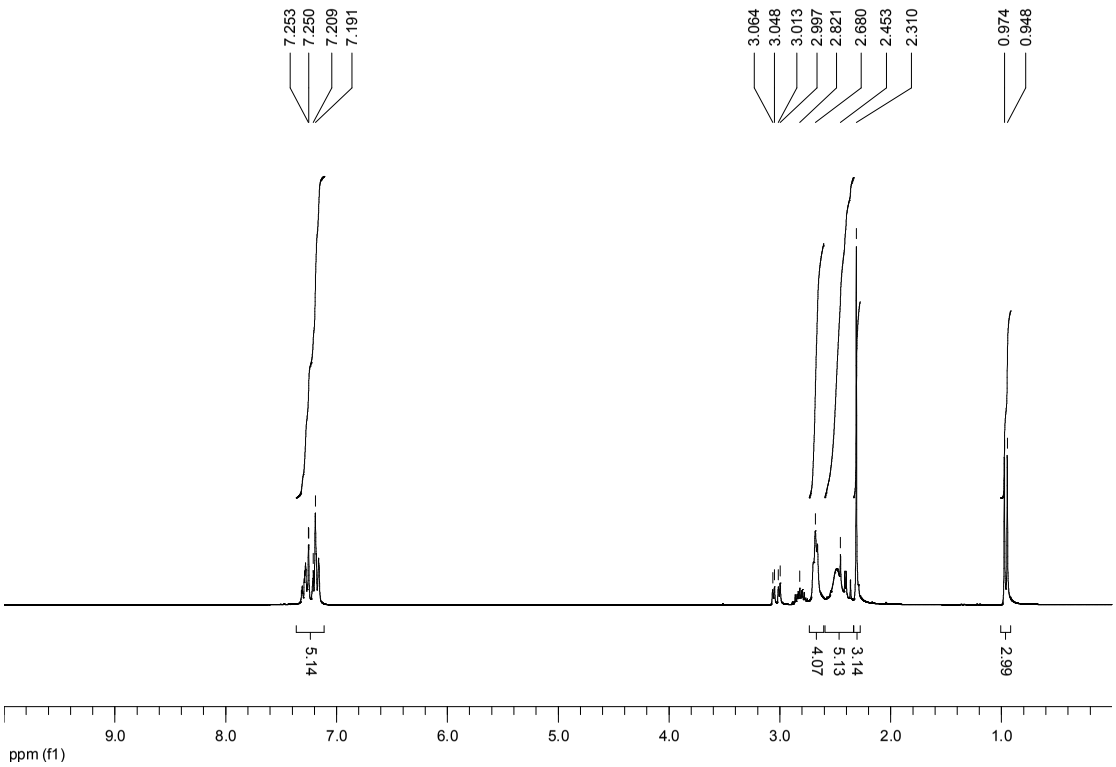


Table 8, Entry 8





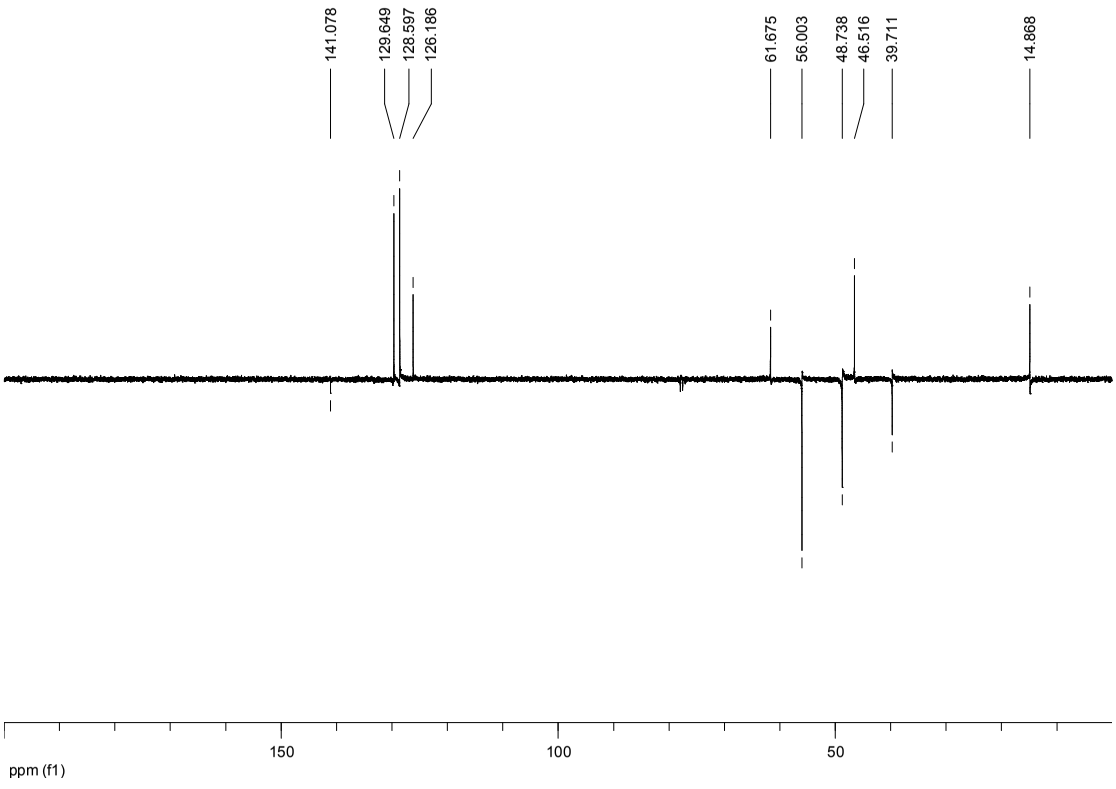
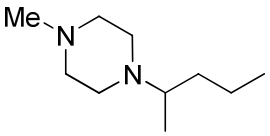
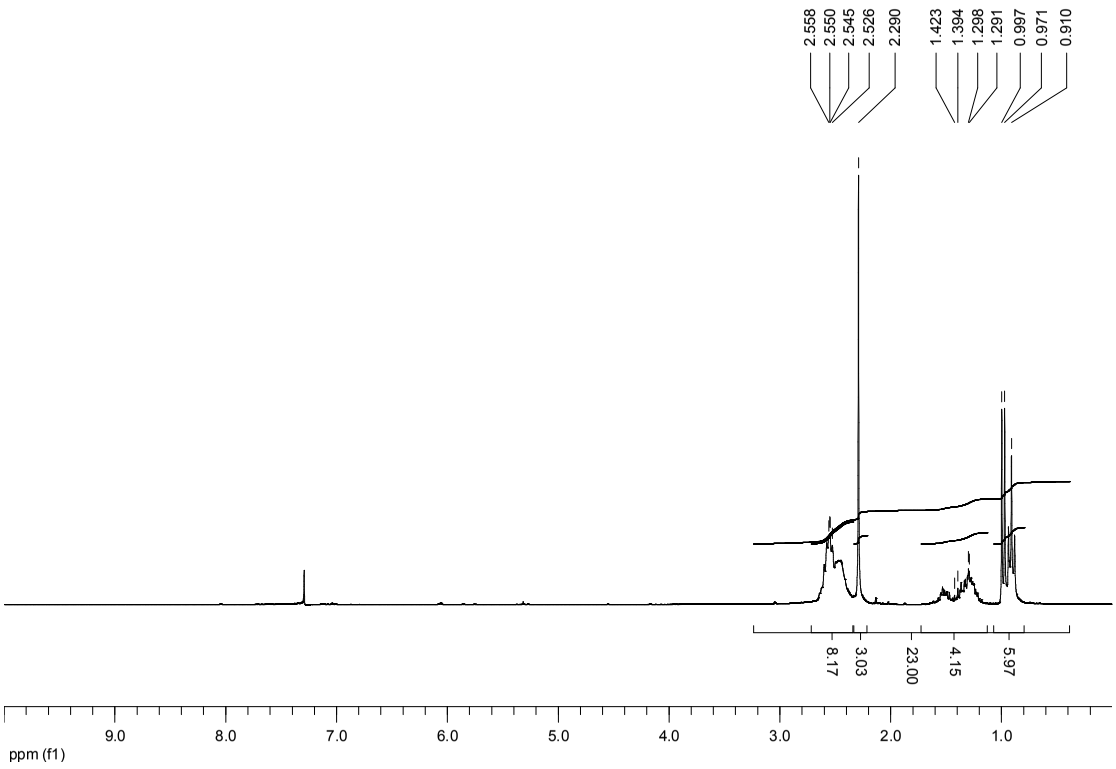


Table 8, Entry 9





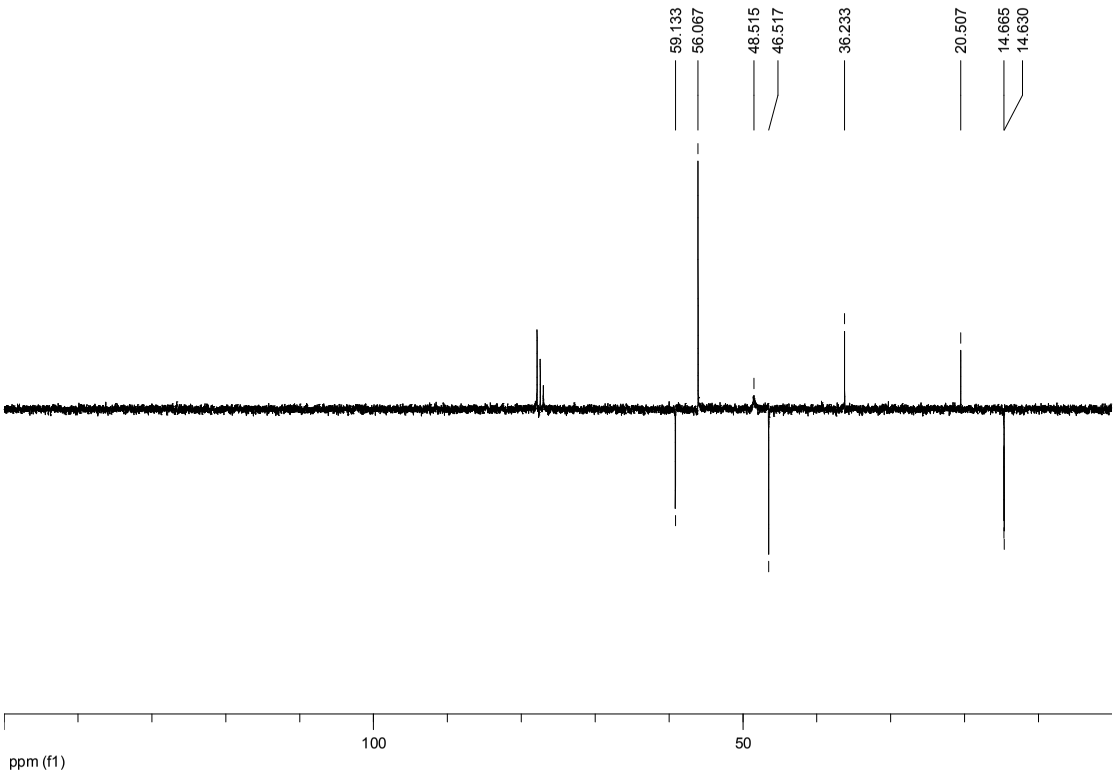


Table 8, Entry 11

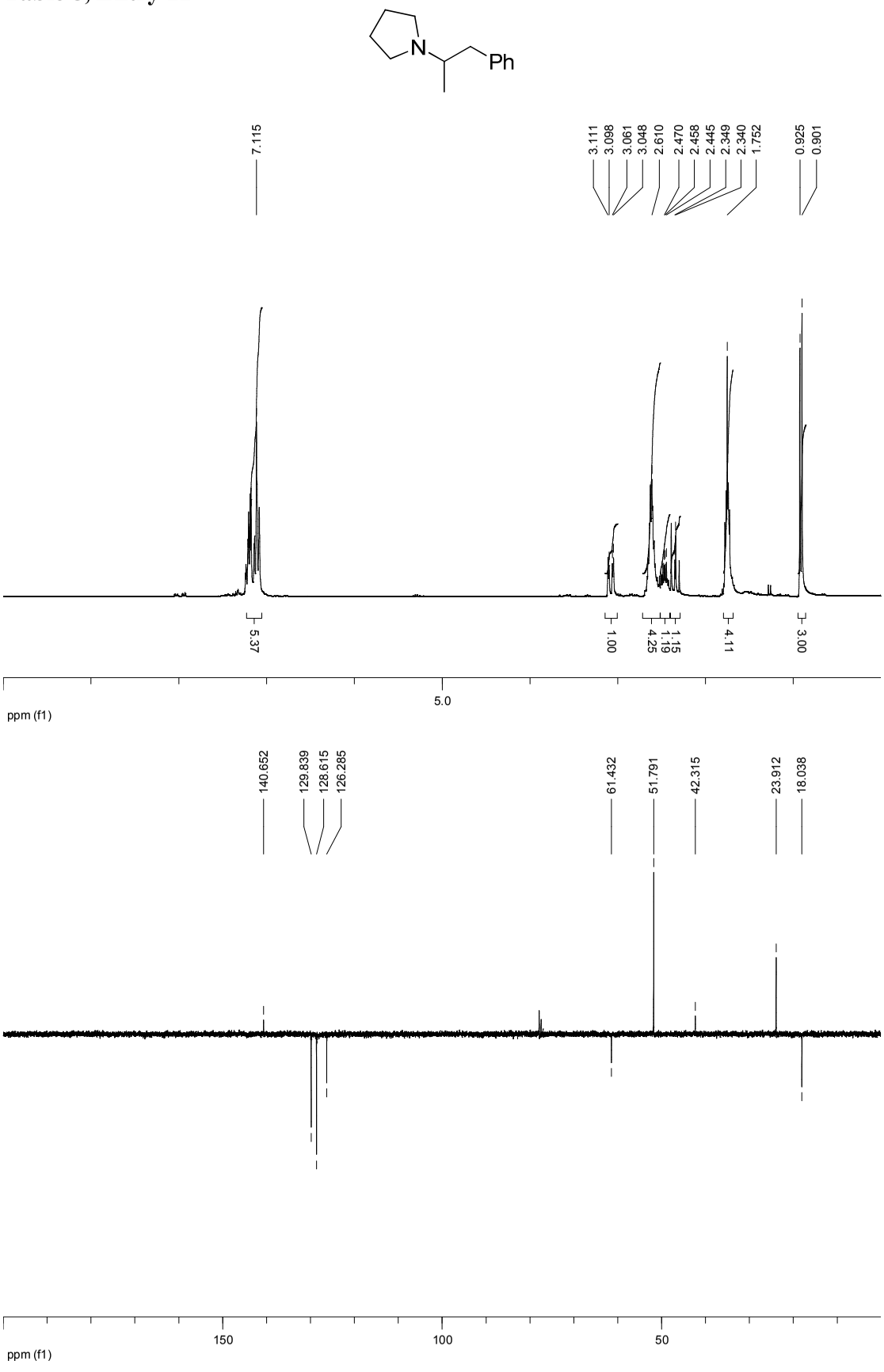
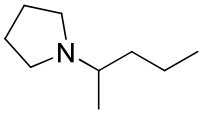
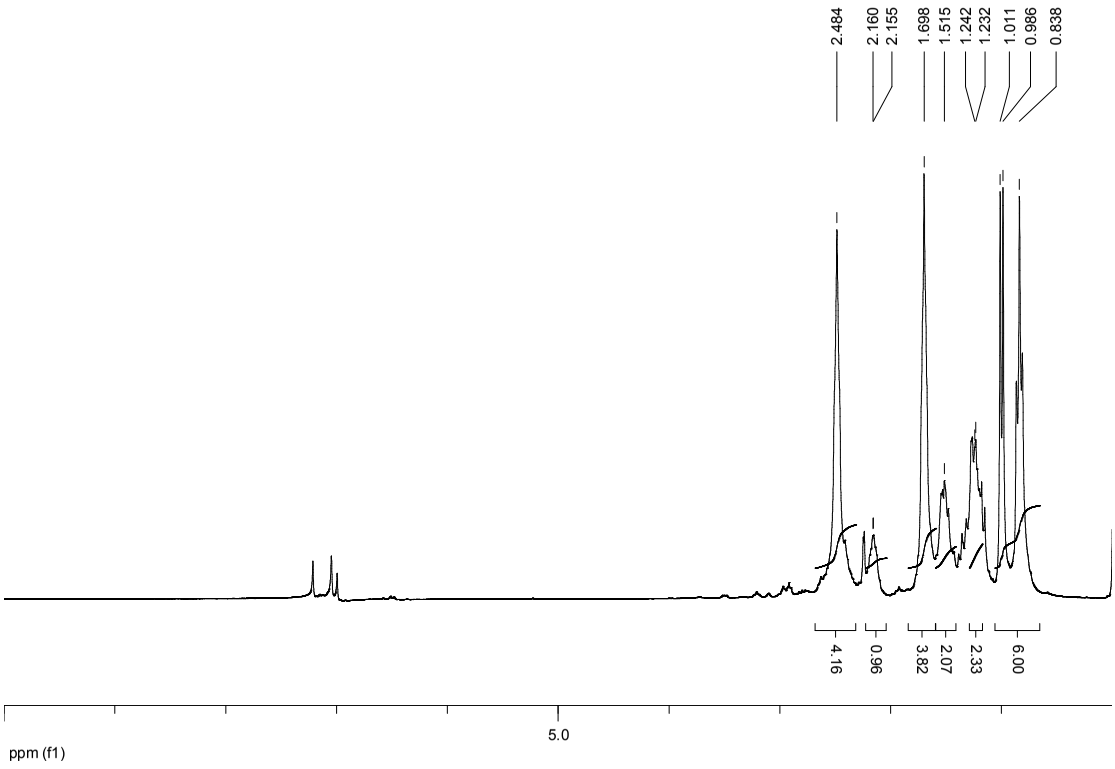
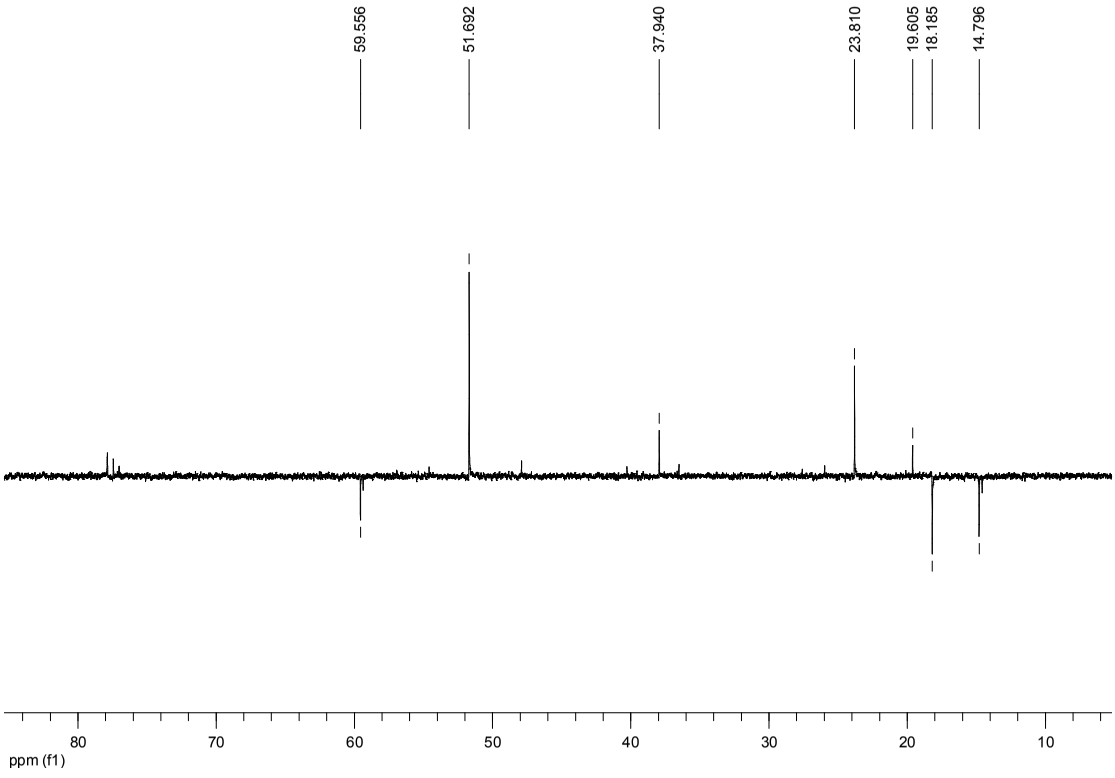
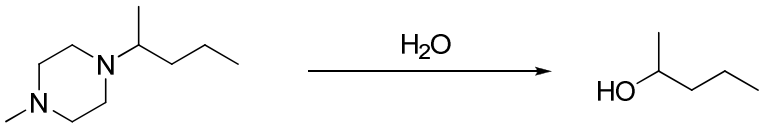


Table 8, Entry 12

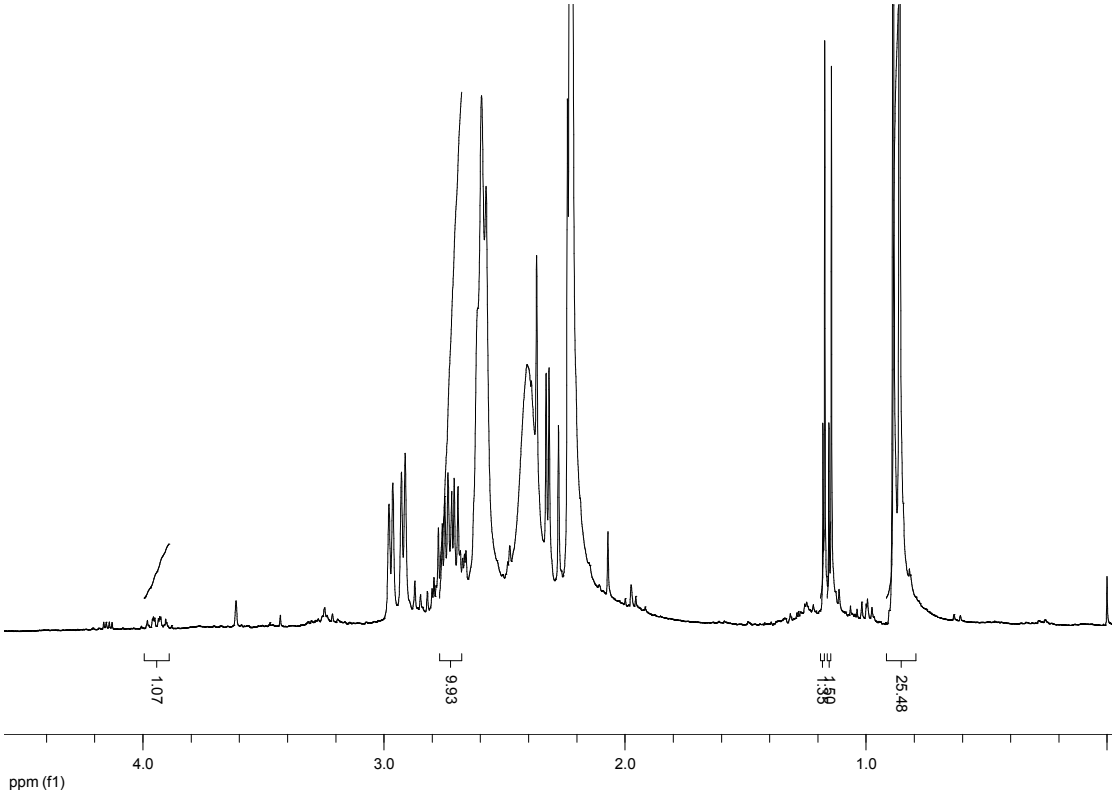


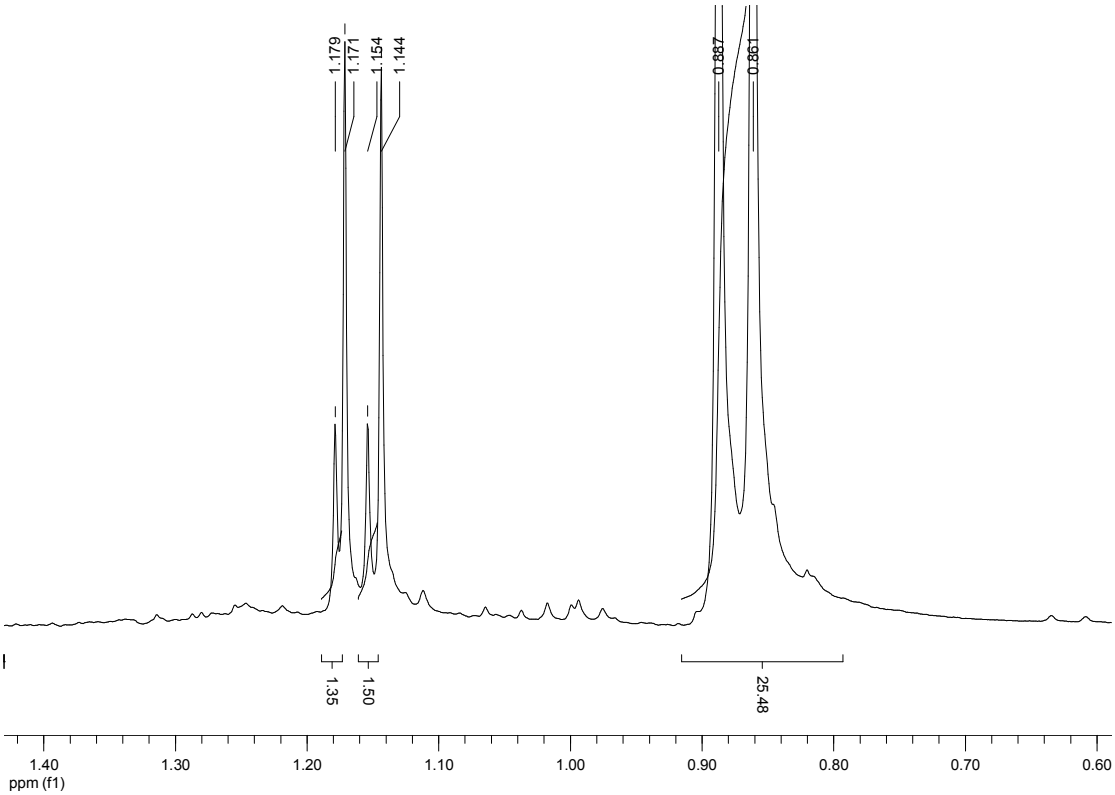






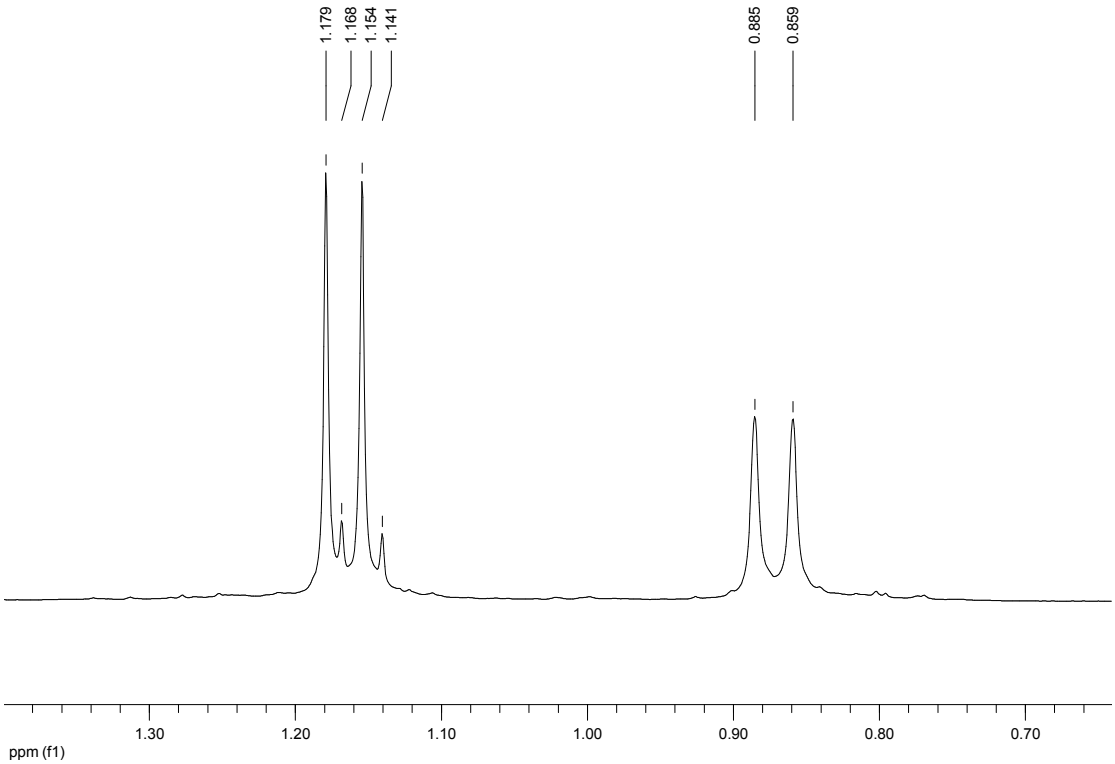
Conversion: (10% to alcohol)



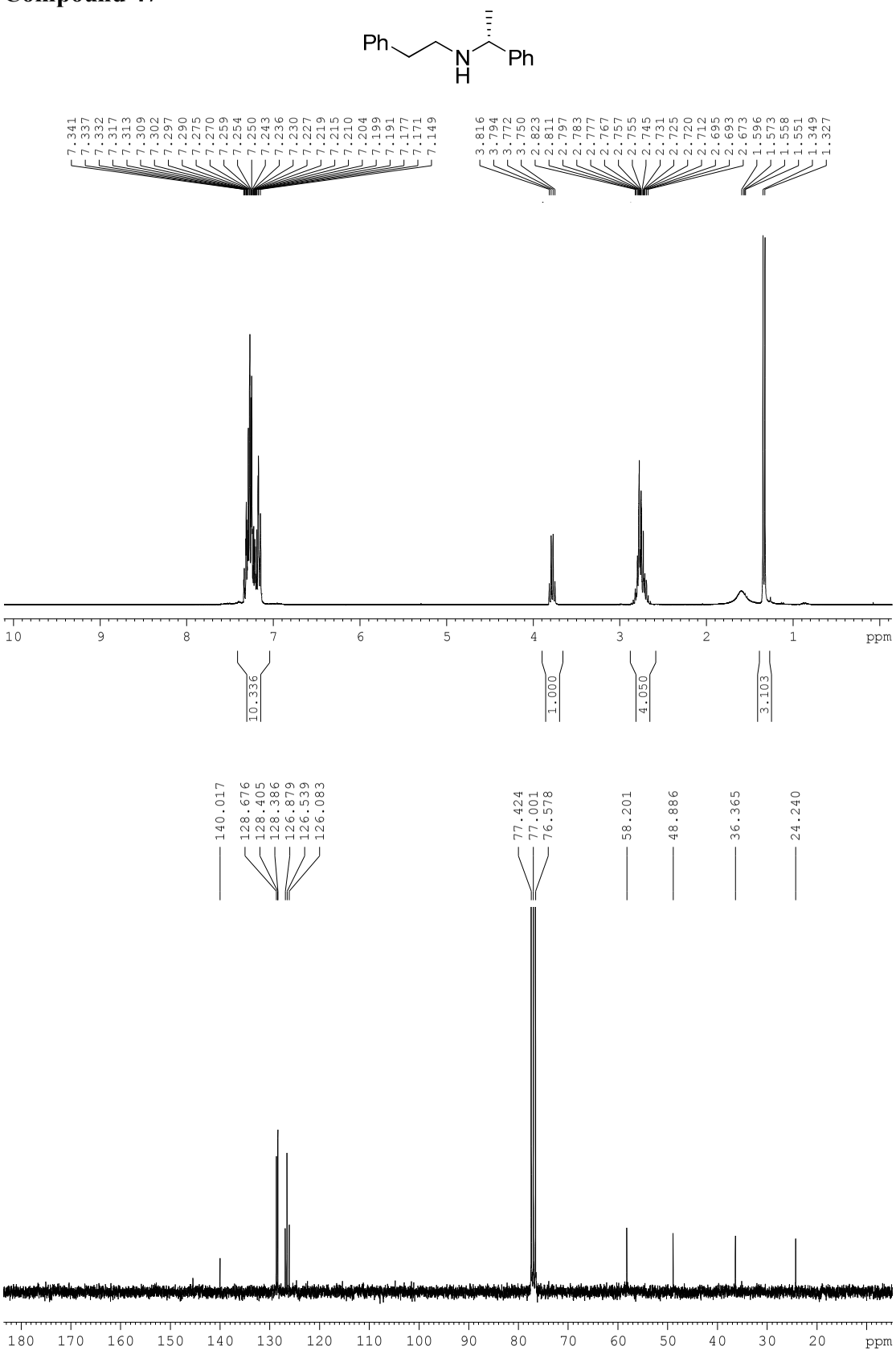


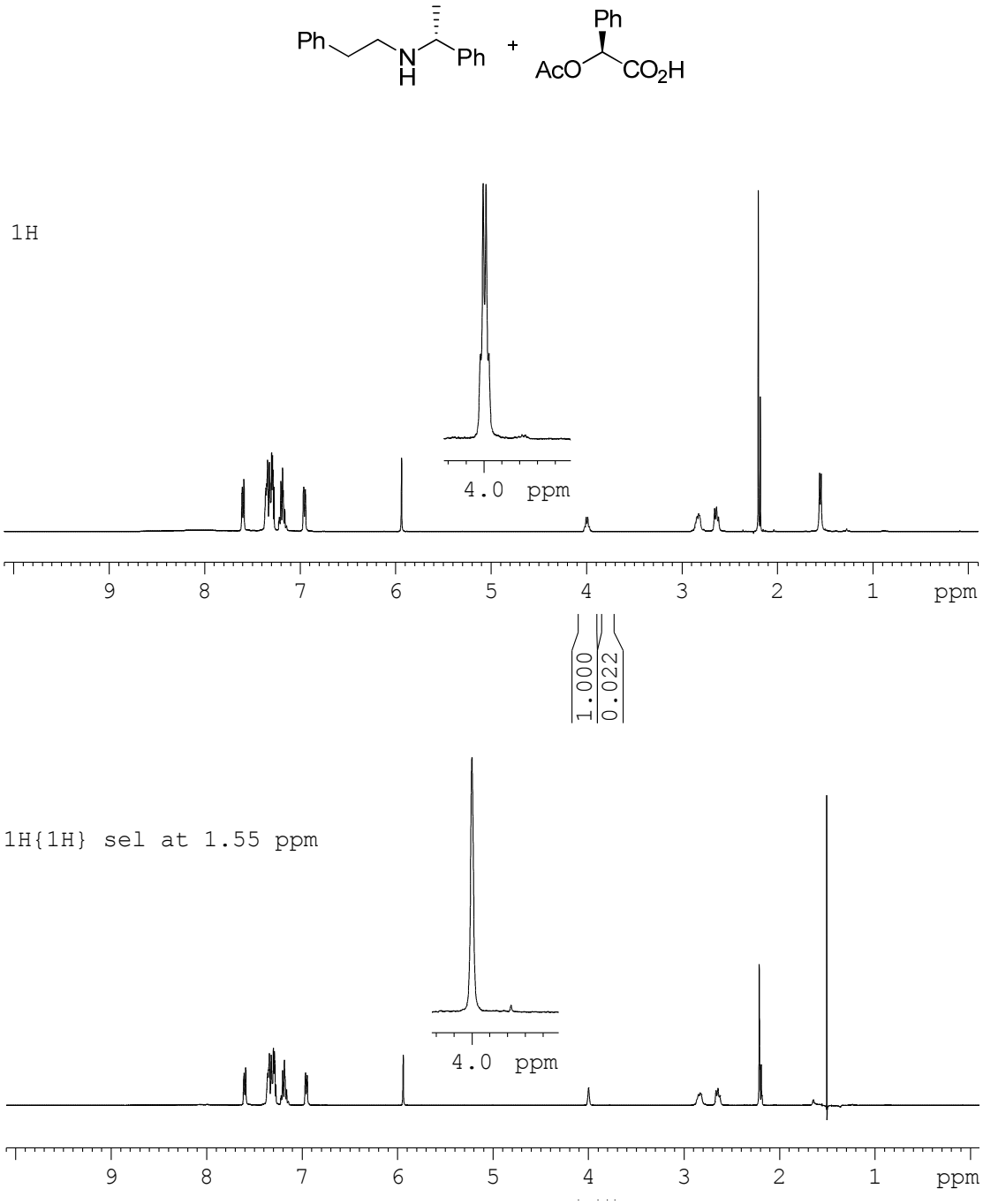
Note: signal at 1.16 ppm is free cymene from catalyst decomposition.

Previous spectra doped with 1-phenylpropan-2-ol:

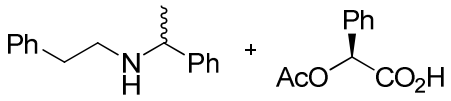


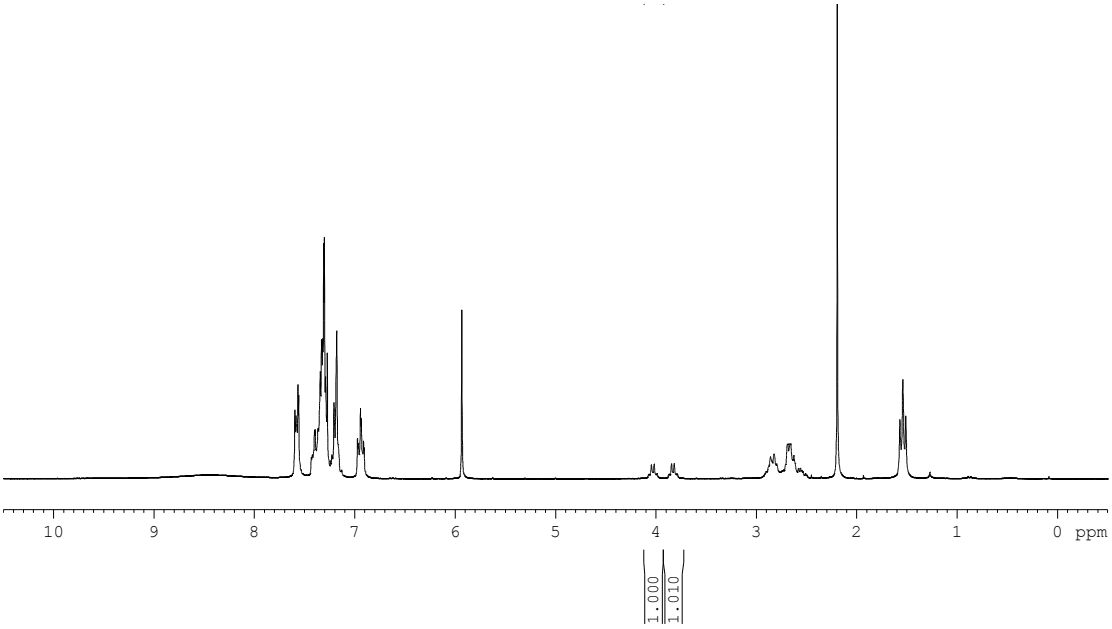
Compound 47


Ph
N
H
Ph
7.341
7.337
7.332
7.317
7.313
7.309
7.302
7.297
7.290
7.275
7.270
7.259
7.254
7.250
7.243
7.236
7.230
7.227
7.219
7.215
7.210
7.204
7.199
7.191
7.177
7.171
7.149
3.816
3.794
3.772
3.750
2.823
2.811
2.797
2.783
2.777
2.767
2.757
2.755
2.745
2.731
2.725
2.720
2.712
2.695
2.693
2.673
1.596
1.573
1.558
1.551
1.349
1.327
10
9
8
7
6
5
4
3
2
1
ppm
10.336
1.000
4.050
3.103
140.017
128.676
128.405
128.386
126.879
126.539
126.083
77.424
77.001
76.578
58.201
48.886
36.365
24.240
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

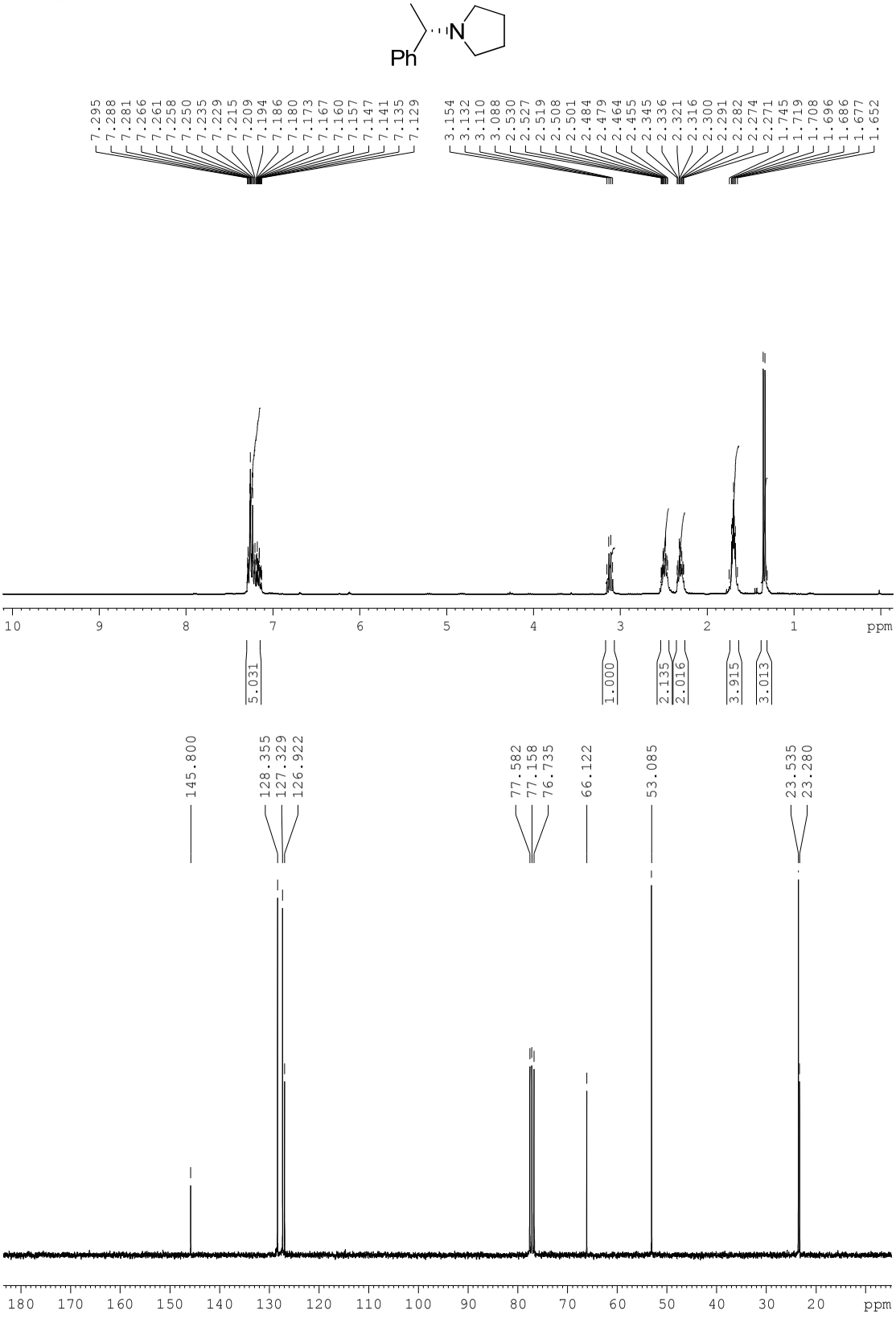


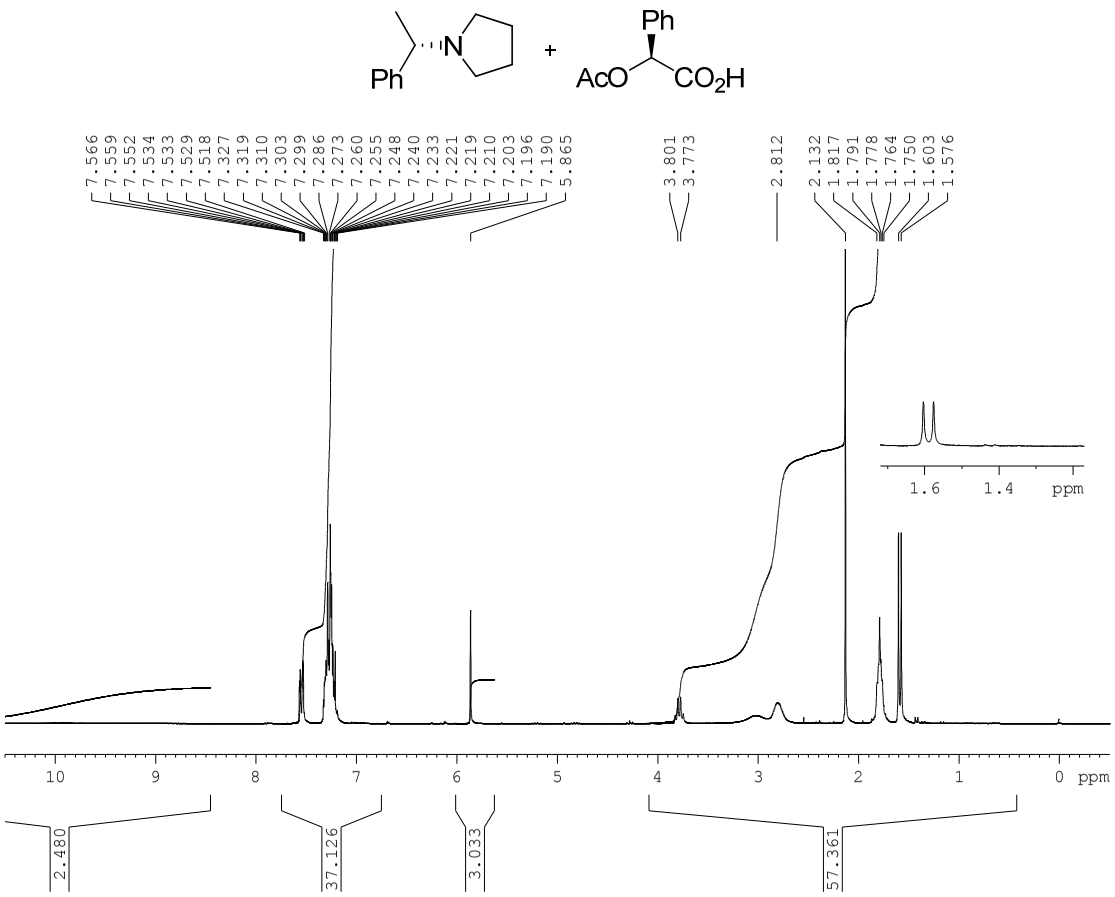
Spectrum (a) shows a quartet at δ4.00 allowing a rough integration of 1.000:0.022 for the enantiomers. Since the original spectrum was difficult to resolve, we irradiated at δ1.55 to give 2 singlets at an integration of 1.000:0.016 shown in spectrum (b) from which the ee was calculated and found to be 98% ee.

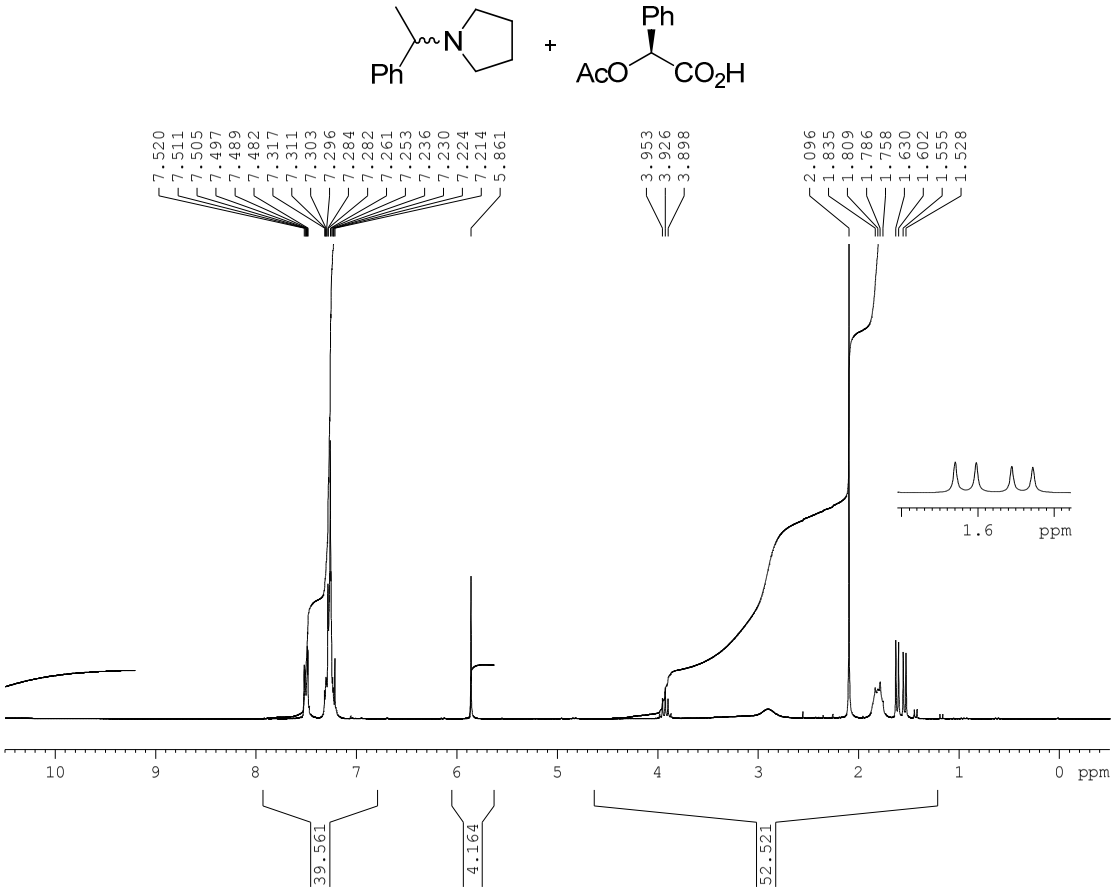

Ph
N
H
Ph
+
Ph
AcO
CO2H


10
9
8
7
6
5
4
3
2
1
0 ppm
1.000
1.010

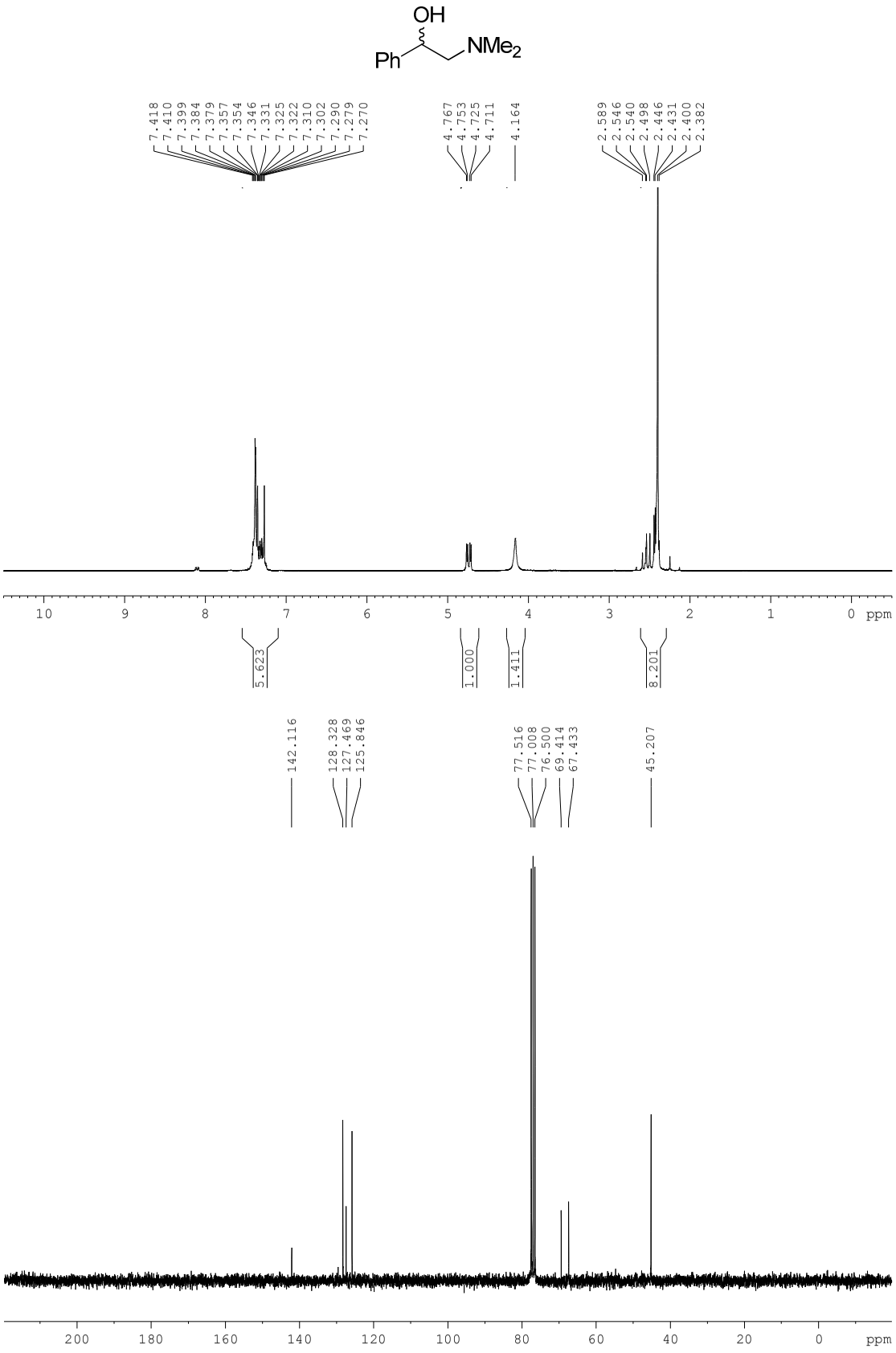
Compound 48


Ph
N
7.295
7.288
7.281
7.266
7.261
7.258
7.250
7.235
7.229
7.215
7.209
7.194
7.186
7.180
7.173
7.167
7.160
7.157
7.147
7.141
7.135
7.129
3.154
3.132
3.110
3.088
2.530
2.527
2.519
2.508
2.501
2.484
2.479
2.464
2.455
2.345
2.336
2.321
2.316
2.300
2.291
2.282
2.274
2.271
1.745
1.719
1.708
1.696
1.686
1.677
1.652
10
9
8
7
6
5
4
3
2
1
ppm
5.031
1.000
2.135
2.016
3.915
3.013
145.800
128.355
127.329
126.922
77.582
77.158
76.735
66.122
53.085
23.535
23.280
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

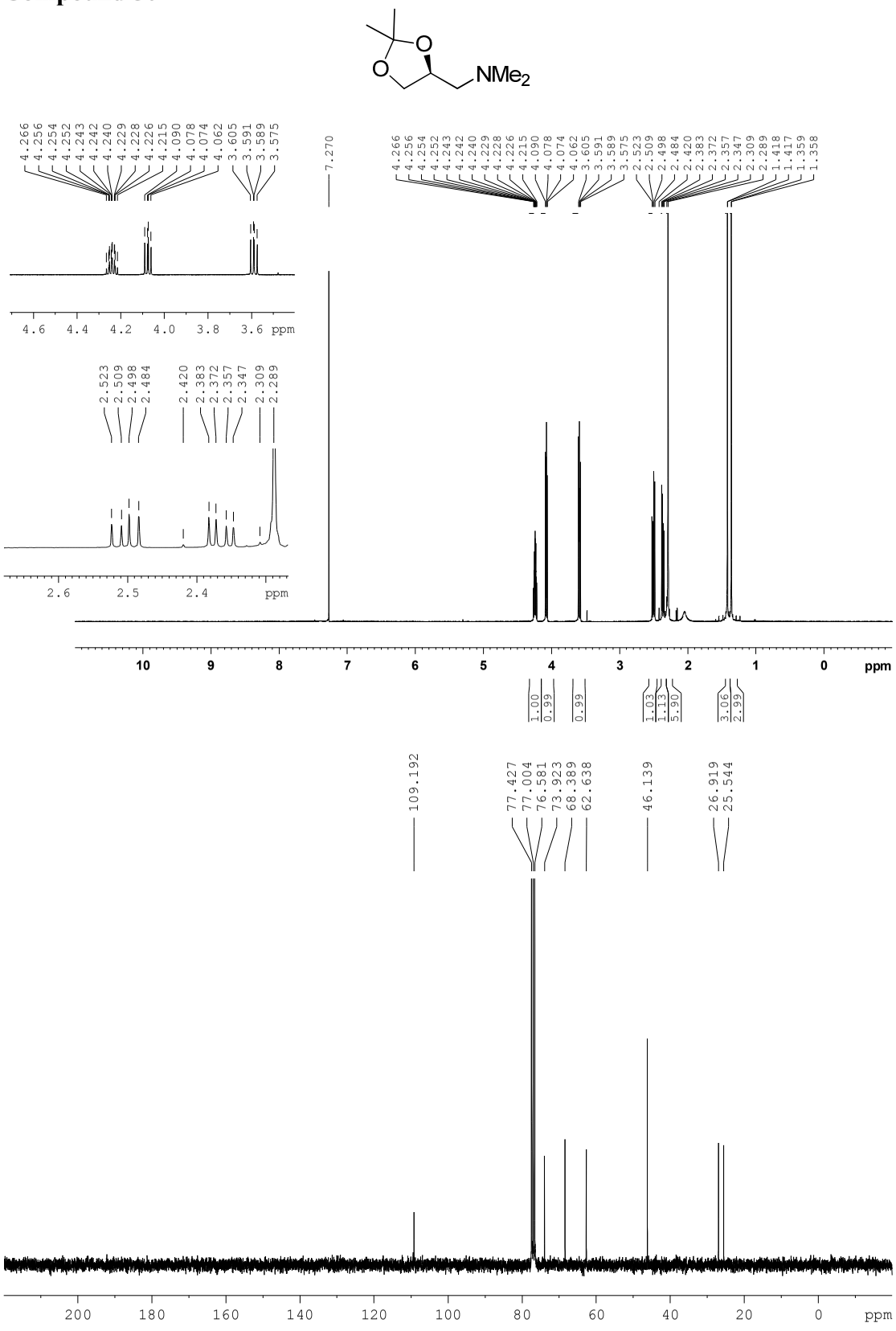

Ph
N
+
Ph
AcO
CO2H
7.566
7.559
7.552
7.534
7.533
7.529
7.518
7.327
7.319
7.310
7.303
7.299
7.286
7.273
7.260
7.255
7.248
7.240
7.233
7.221
7.219
7.210
7.203
7.196
7.190
5.865
3.801
3.773
2.812
2.132
1.817
1.791
1.778
1.764
1.750
1.603
1.576
1.6
1.4
ppm
10
9
8
7
6
5
4
3
2
1
0 ppm
2.480
37.126
3.033
57.361


Ph
N
+
Ph
AcO
CO2H
7.520
7.511
7.505
7.497
7.489
7.482
7.317
7.311
7.303
7.296
7.284
7.282
7.261
7.253
7.236
7.230
7.224
7.214
5.861
3.953
3.926
3.898
2.096
1.835
1.809
1.786
1.758
1.630
1.602
1.555
1.528
1.6
ppm
10
9
8
7
6
5
4
3
2
1
0 ppm
39.561
4.164
52.521

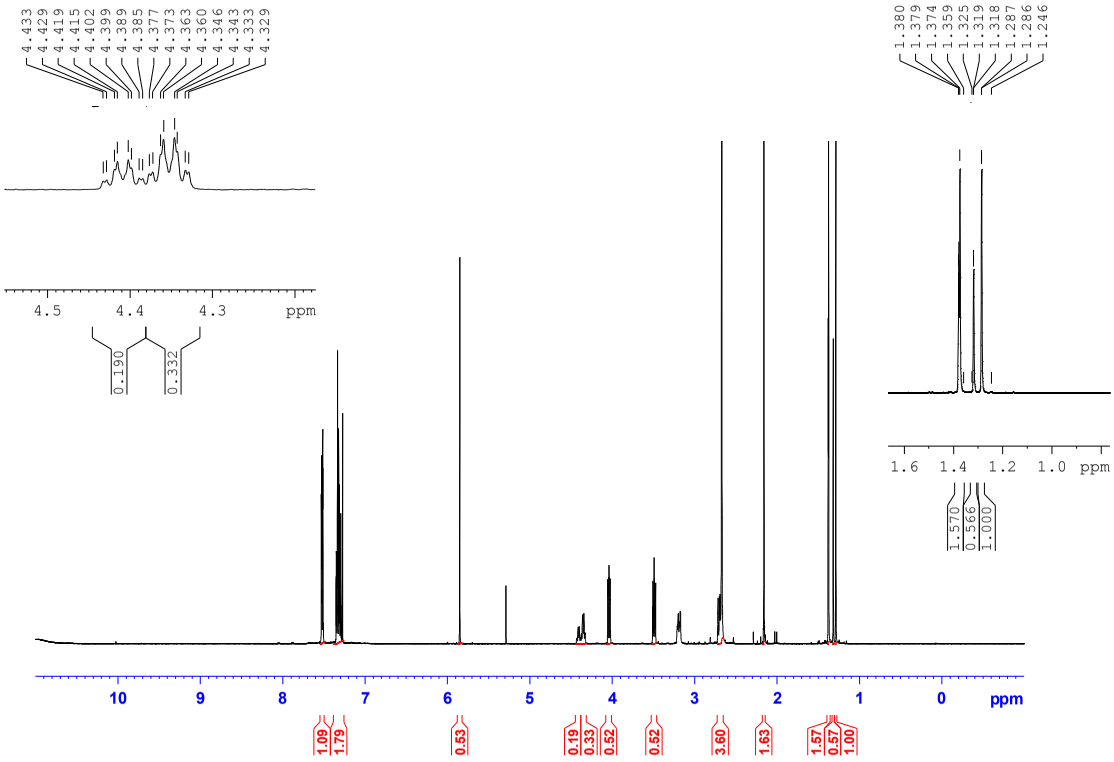
Compound 49


OH
Ph
NMe2
7.418
7.410
7.399
7.384
7.379
7.357
7.354
7.346
7.331
7.325
7.322
7.310
7.302
7.290
7.279
7.270
4.767
4.753
4.725
4.711
4.164
2.589
2.546
2.540
2.498
2.446
2.431
2.400
2.382
10
9
8
7
6
5
4
3
2
1
0 ppm
5.623
1.000
1.411
8.201
142.116
128.328
127.469
125.846
77.516
77.008
76.500
69.414
67.433
45.207
200
180
160
140
120
100
80
60
40
20
0
ppm

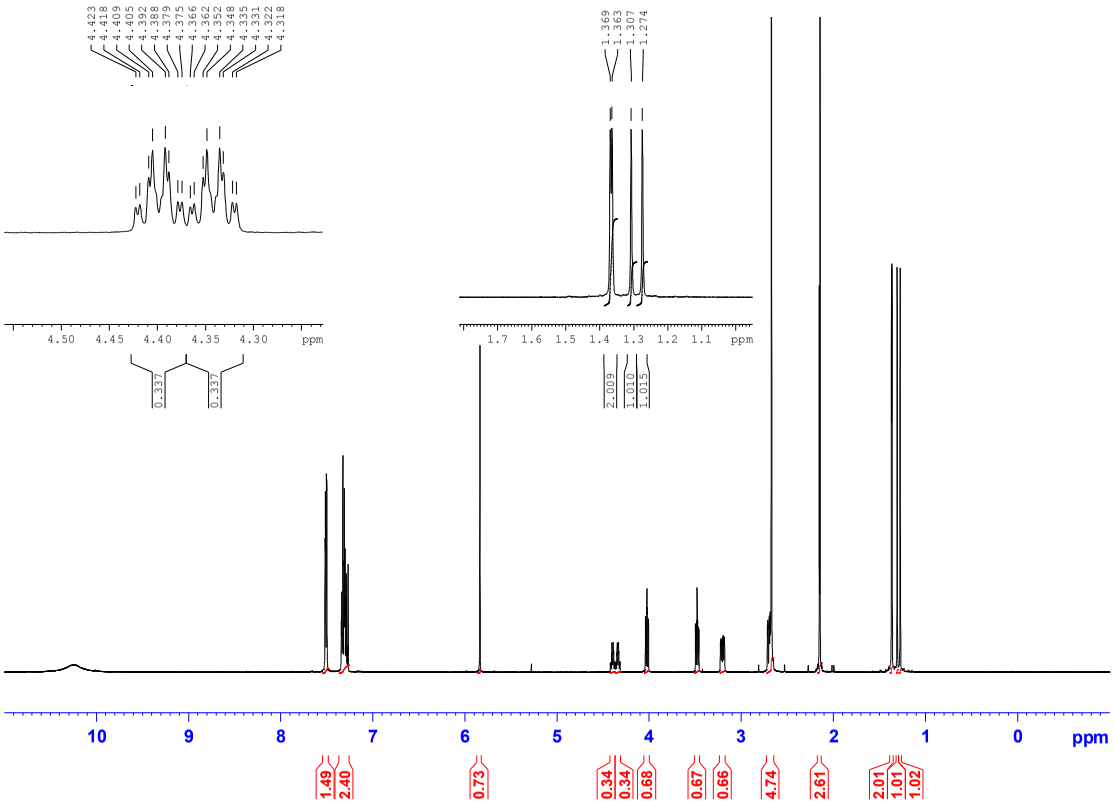
Compound 50


NMe2
4.266
4.256
4.254
4.252
4.243
4.242
4.240
4.229
4.228
4.226
4.215
4.090
4.078
4.074
4.062
3.605
3.591
3.589
3.575
7.270
2.523
2.509
2.498
2.484
2.420
2.383
2.372
2.357
2.347
2.309
2.289
1.418
1.417
1.359
1.358
4.6 4.4 4.2 4.0 3.8 3.6 ppm
2.6 2.5 2.4 ppm
10 9 8 7 6 5 4 3 2 1 0 ppm
1.00
0.99
0.99
1.03
1.13
5.90
3.06
2.99
109.192
77.427
77.004
76.581
73.923
68.389
62.638
46.139
26.919
25.544
200 180 160 140 120 100 80 60 40 20 0 ppm

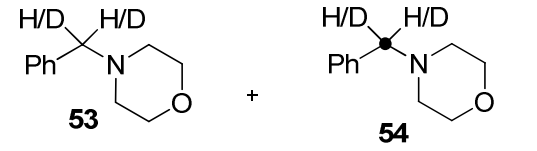
Compound 50 (28% ee) with acetylmandelic acid



Compound 50 (0% ee) with acetylmandelic acid



Compound 53 & Compound 54



46% D incorporation 31% D incorporation