

Supporting Information

Cu(OTf)₂-Catalyzed C3 *Aza*-Friedel-Crafts Alkylation of Indoles with *N, O*-Acetals

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I. X-Ray Crystallographic Structure for compounds **6k** and **6y**

ORTEP drawing of the X-ray crystallographic structure of **6k** (50% probability ellipsoids, **dd21044** is the original test number for **6k**): The single crystal of **6k** was prepared from its solution in ethylacetate /methanol (6:1) by slow evaporation of the solvent (**Table S1**)

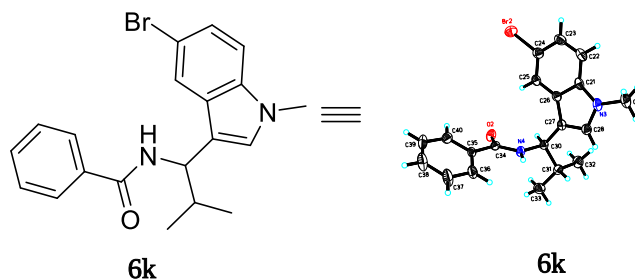


Table S1. Crystal data and structure refinement for **6k**.

Identification code	6k
Empirical formula	C ₂₀ H ₂₁ BrN ₂ O
Formula weight	385.30
Temperature	213(2) K
Wavelength	0.71073 Å
Crystal system	Triclinic
Space group	P -1
Unit cell dimensions	a = 9.7774(6) Å α = 91.317(2)° b = 10.6374(7) Å β = 95.348(2)° c = 18.9895(14) Å γ = 108.325(2)°
Volume	1863.8(2) Å ³
Z	4
Density (calculated)	1.373 Mg/m ³
Absorption coefficient	2.214 mm ⁻¹
F(000)	792
Crystal size	0.160 x 0.110 x 0.100 mm ³
Theta range for data collection	2.342 to 26.000°
Index ranges	-12 ≤ h ≤ 12, -13 ≤ k ≤ 13, -23 ≤ l ≤ 23
Reflections collected	36864
Independent reflections	7312 [R(int) = 0.0659]
Completeness to theta = 25.242°	99.9 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7456 and 0.5427
Refinement method	Full-matrix least-squares on F ²
Data / restraints / parameters	7312 / 0 / 439
Goodness-of-fit on F ²	1.006
Final R indices [I > 2σ(I)]	R1 = 0.0452, wR2 = 0.0984
R indices (all data)	R1 = 0.0854, wR2 = 0.1174
Extinction coefficient	n/a
Largest diff. peak and hole	0.568 and -0.544 e. Å ⁻³
CCDC-2117863. For detailed crystallographic data, please refer to the Cambridge	

Crystallographic Data Centre at <http://ccdc.cam.ac.uk/>

ORTEP drawing of the X-ray crystallographic structure of **6y** (50% probability ellipsoids, **dd21019** is the original test number for **6y**): The single crystal of **6y** was prepared from its solution in petroleum ether/ethylacetate (1:1) by slow evaporation of the solvent (**Table S2**)

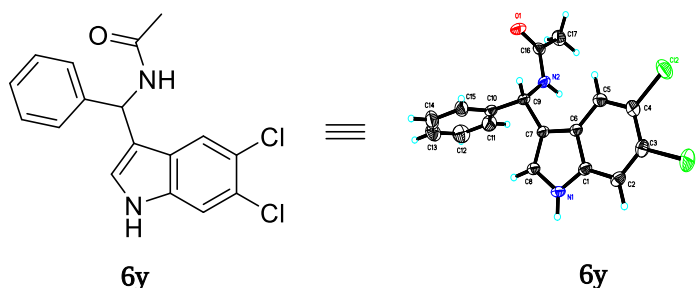


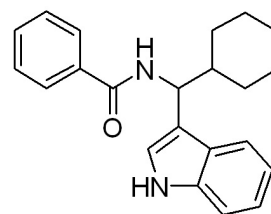
Table S2. Crystal data and structure refinement for **6y**.

Identification code	6y
Empirical formula	C ₂₁ H ₂₂ Cl ₂ N ₂ O ₃
Formula weight	421.30
Temperature	293(2) K
Wavelength	0.71073 Å
Crystal system	Triclinic
Space group	P -1
Unit cell dimensions	a = 9.2206(5) Å α = 112.905(2)° b = 11.1857(6) Å β = 103.286(2)° c = 11.8704(7) Å γ = 96.447(2)°
Volume	1069.43(10) Å ³
Z	2
Density (calculated)	1.308 Mg/m ³
Absorption coefficient	0.327 mm ⁻¹
F(000)	440
Crystal size	0.160 x 0.140 x 0.110 mm ³
Theta range for data collection	2.127 to 25.997°
Index ranges	-11 ≤ h ≤ 11, -13 ≤ k ≤ 13, -14 ≤ l ≤ 14
Reflections collected	20962
Independent reflections	4192 [R(int) = 0.0337]
Completeness to theta = 25.242°	99.6 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7456 and 0.7061
Refinement method	Full-matrix least-squares on F ²
Data / restraints / parameters	4192 / 0 / 257
Goodness-of-fit on F ²	1.018

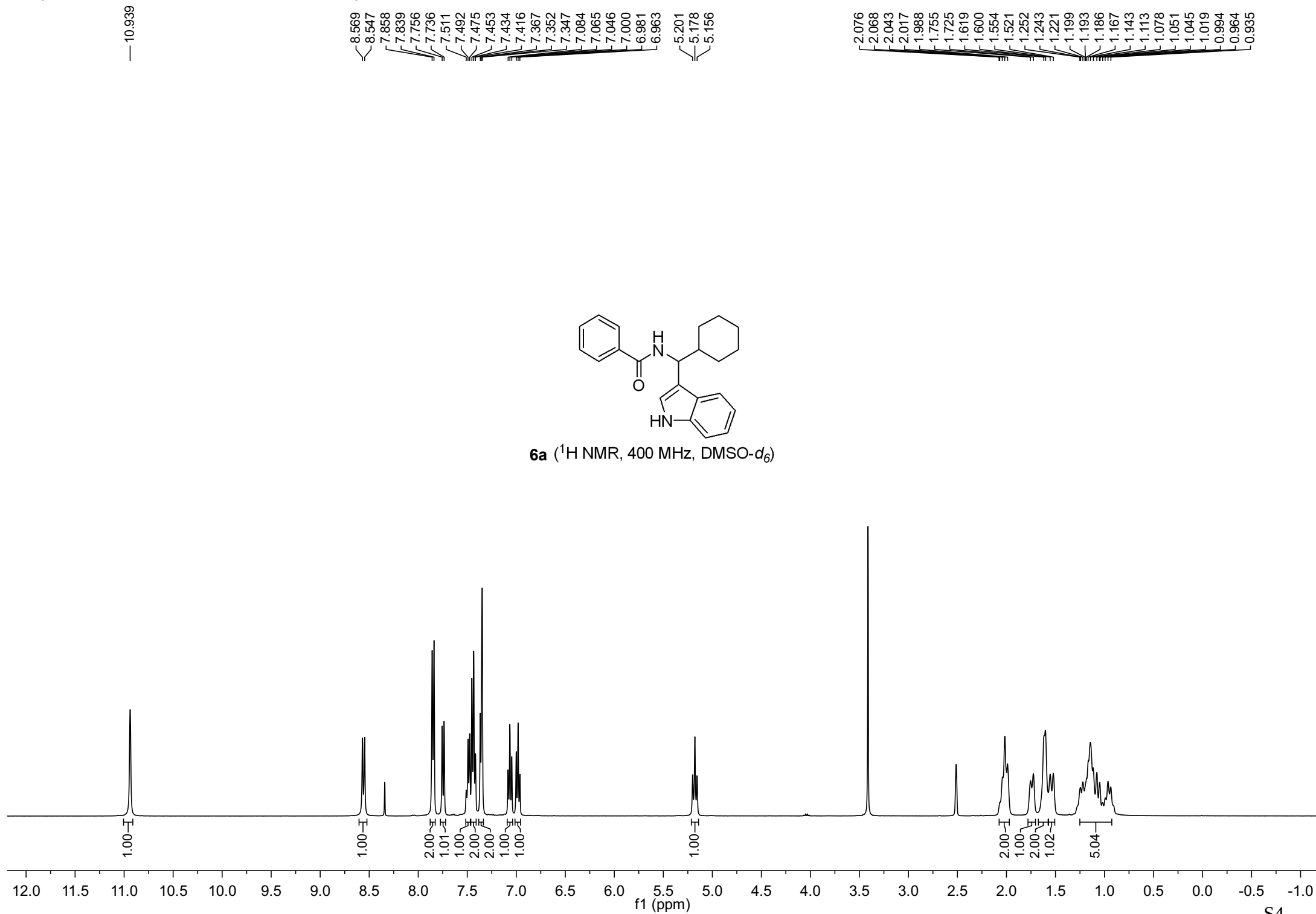
Final R indices [$I > 2\sigma(I)$]	R1 = 0.0435, wR2 = 0.1076
R indices (all data)	R1 = 0.0583, wR2 = 0.1191
Extinction coefficient	0.019(4)
Largest diff. peak and hole	0.208 and -0.258 e. Å ⁻³

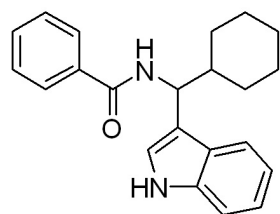
CCDC-2117862. For detailed crystallographic data, please refer to the Cambridge Crystallographic Data Centre at <http://ccdc.cam.ac.uk/>

II. Copies of ^1H NMR, ^{13}C NMR and ^{19}F NMR Spectrum

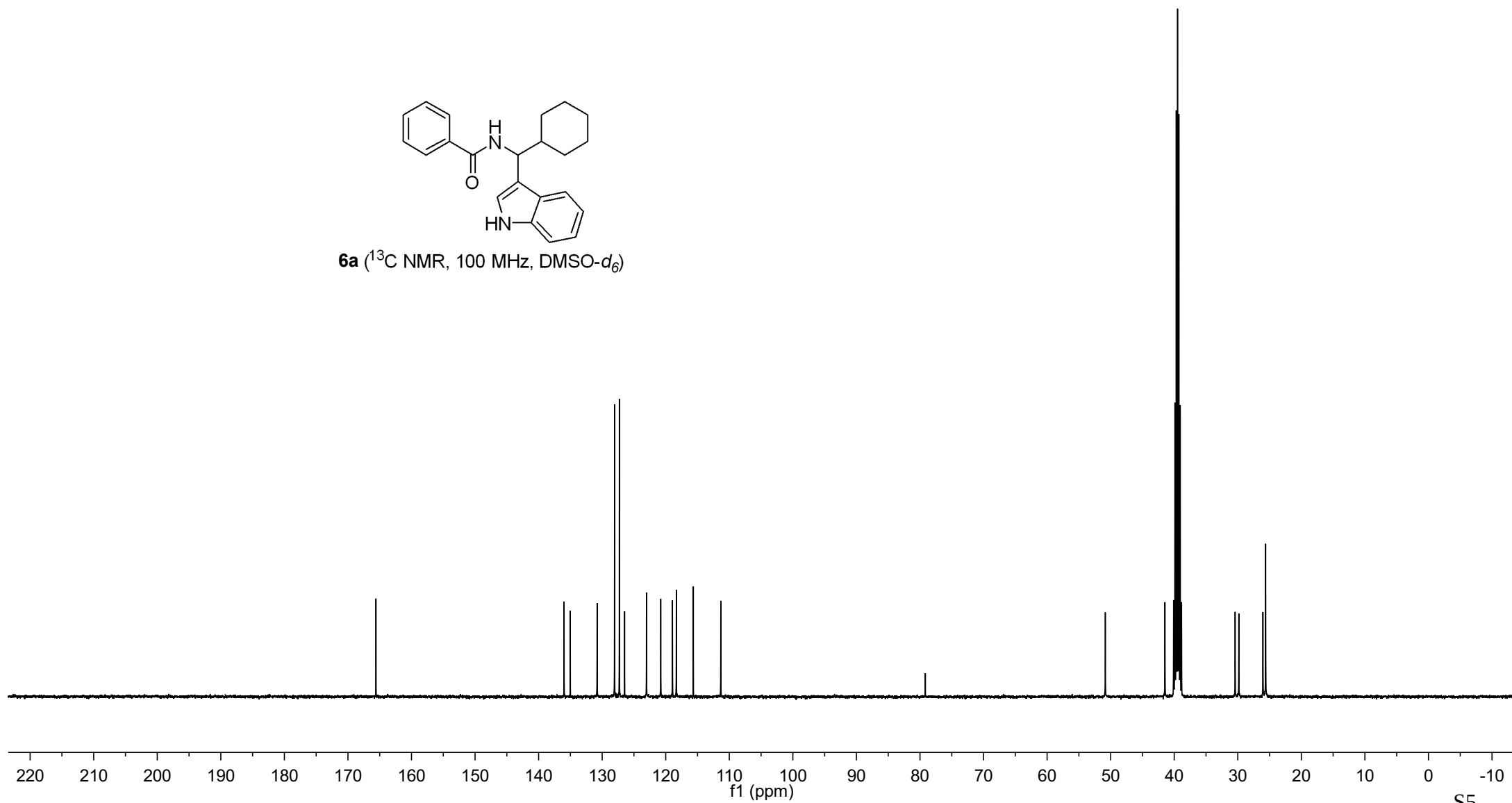


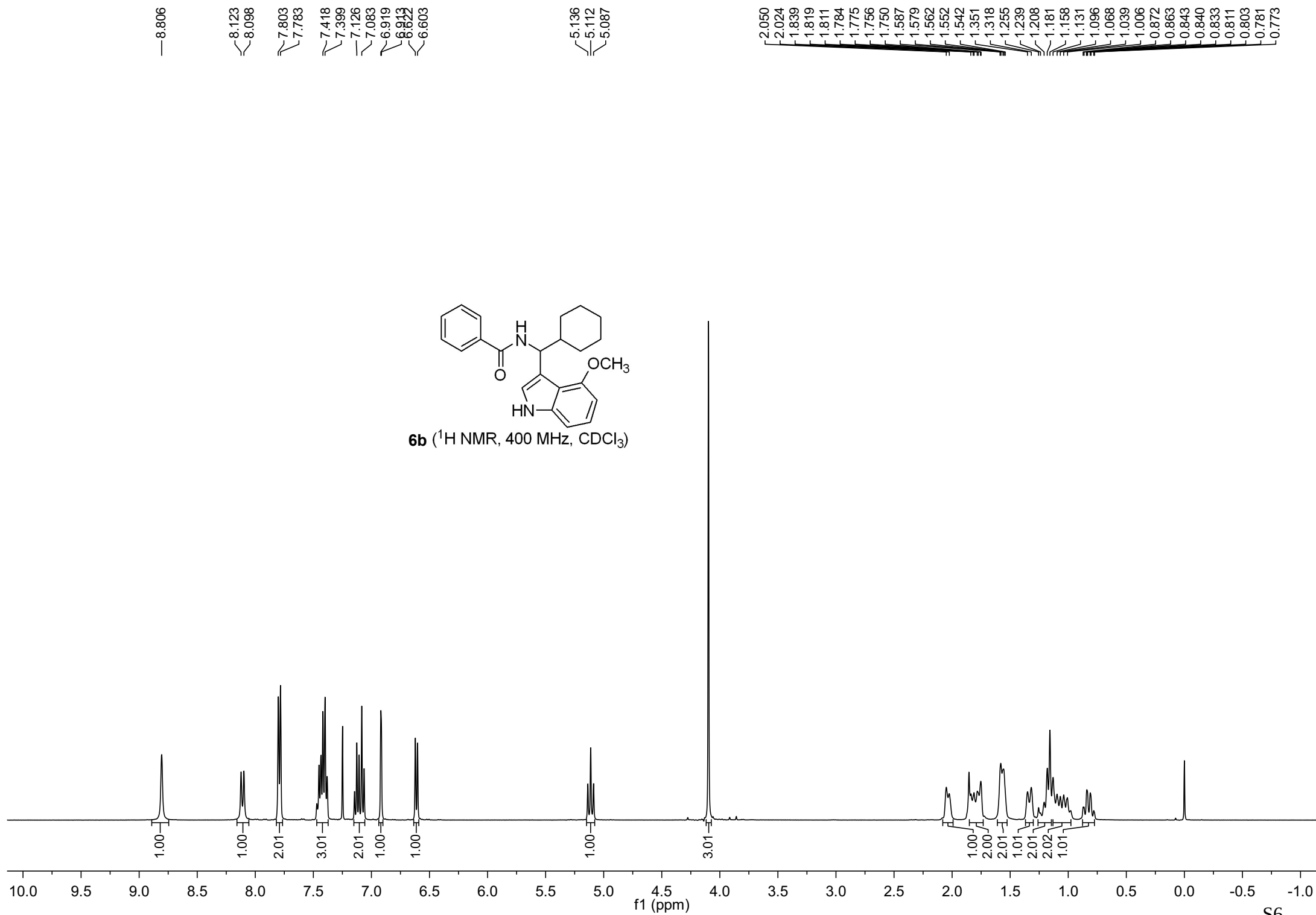
6a (^1H NMR, 400 MHz, $\text{DMSO-}d_6$)

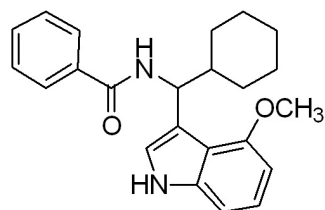




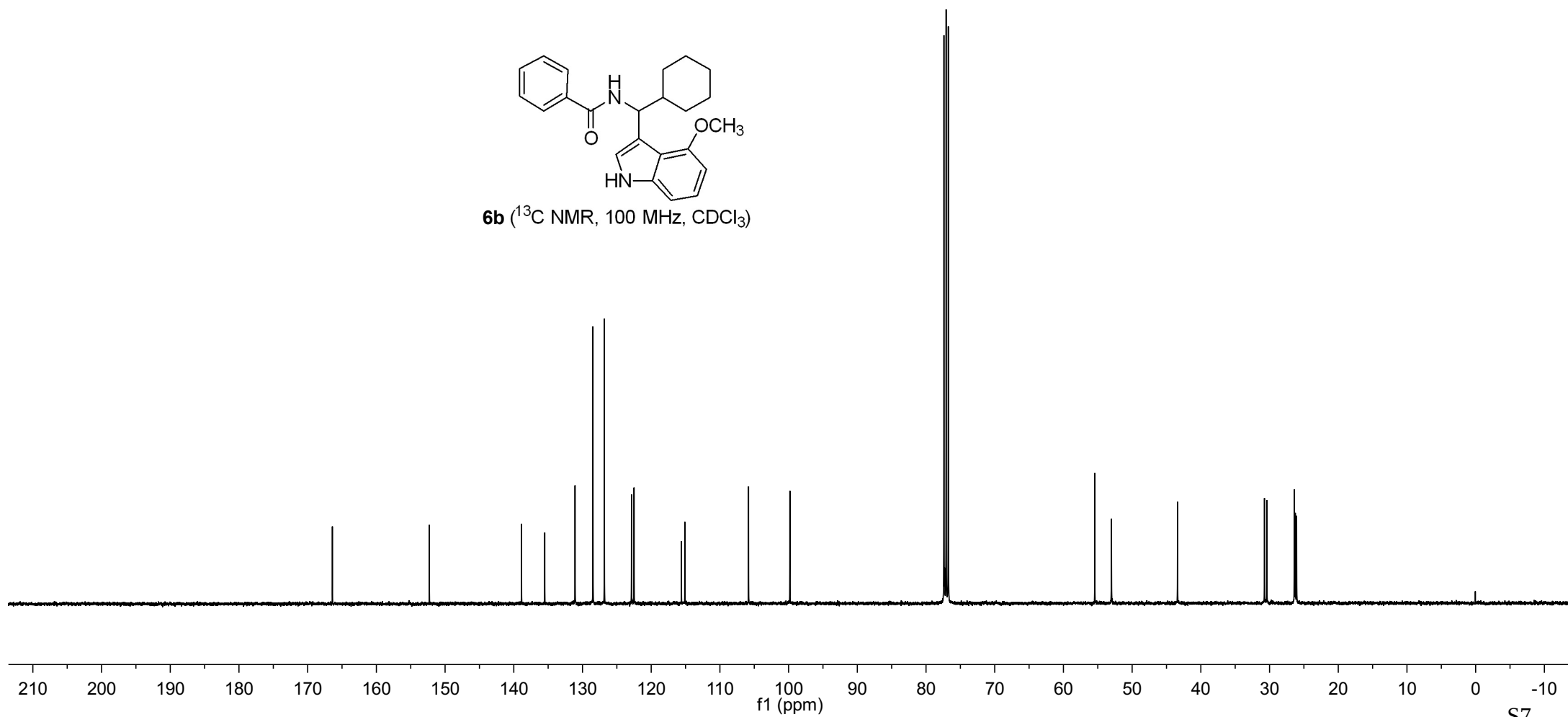
6a (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

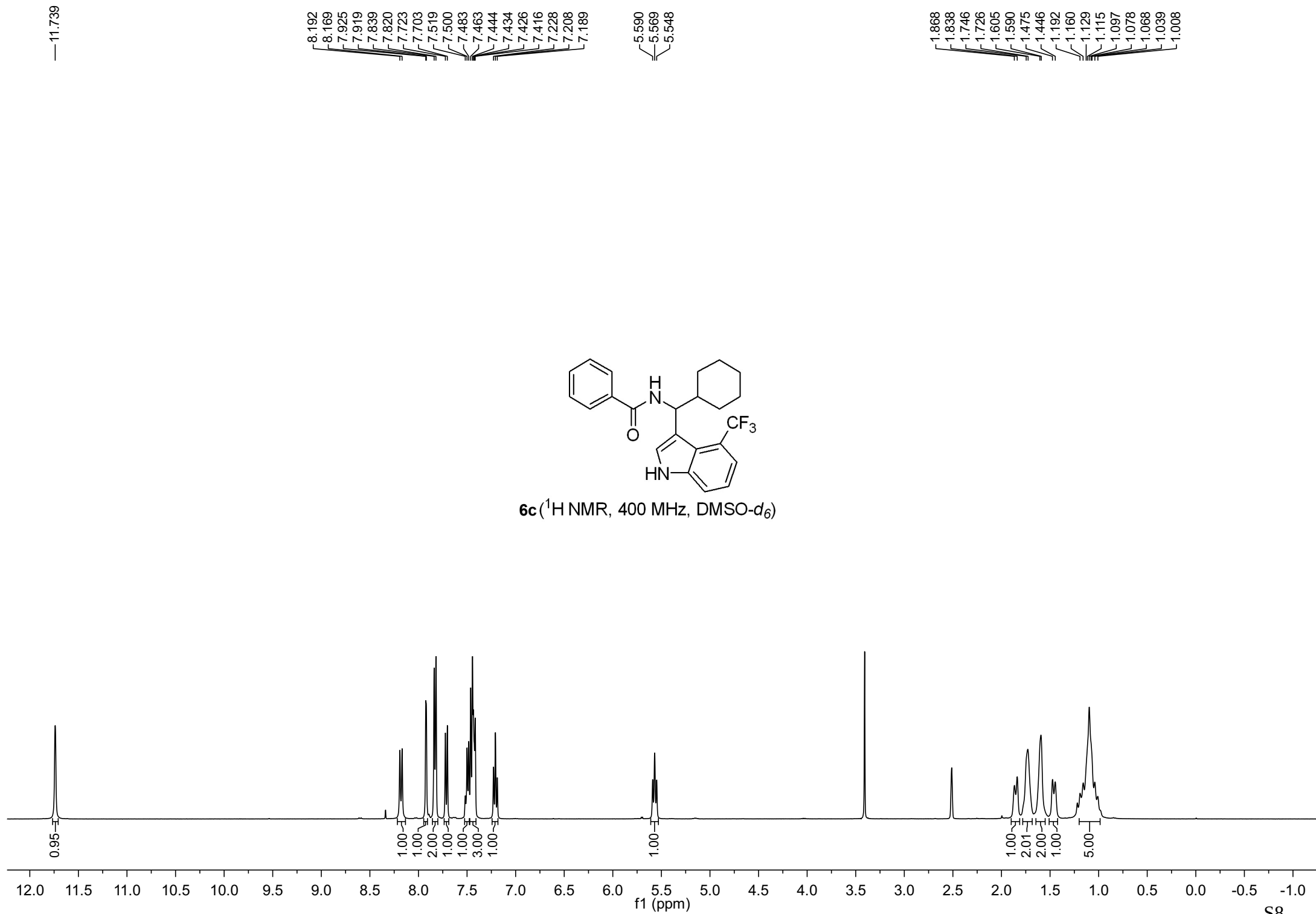


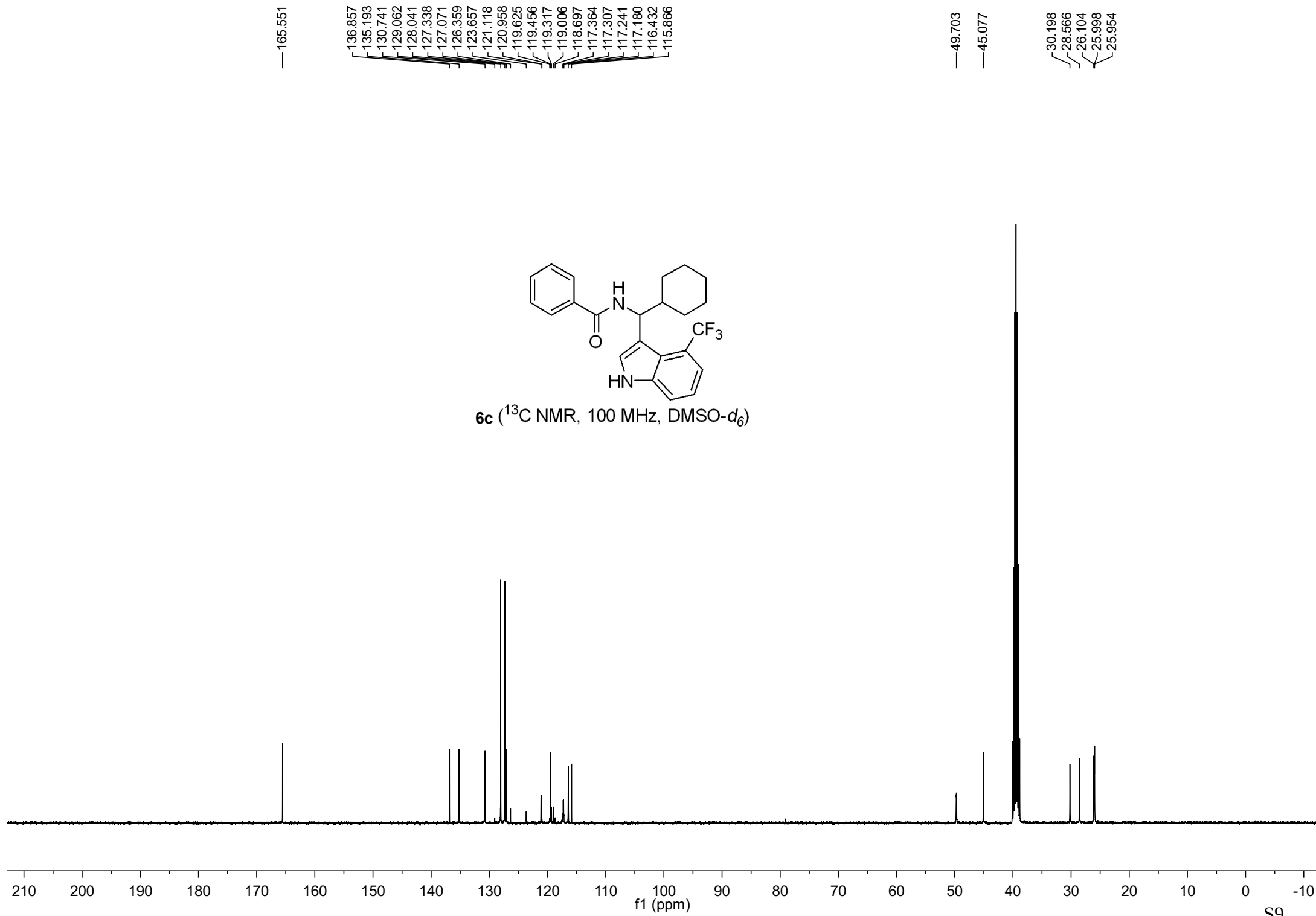


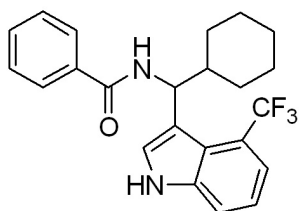


6b (^{13}C NMR, 100 MHz, CDCl_3)



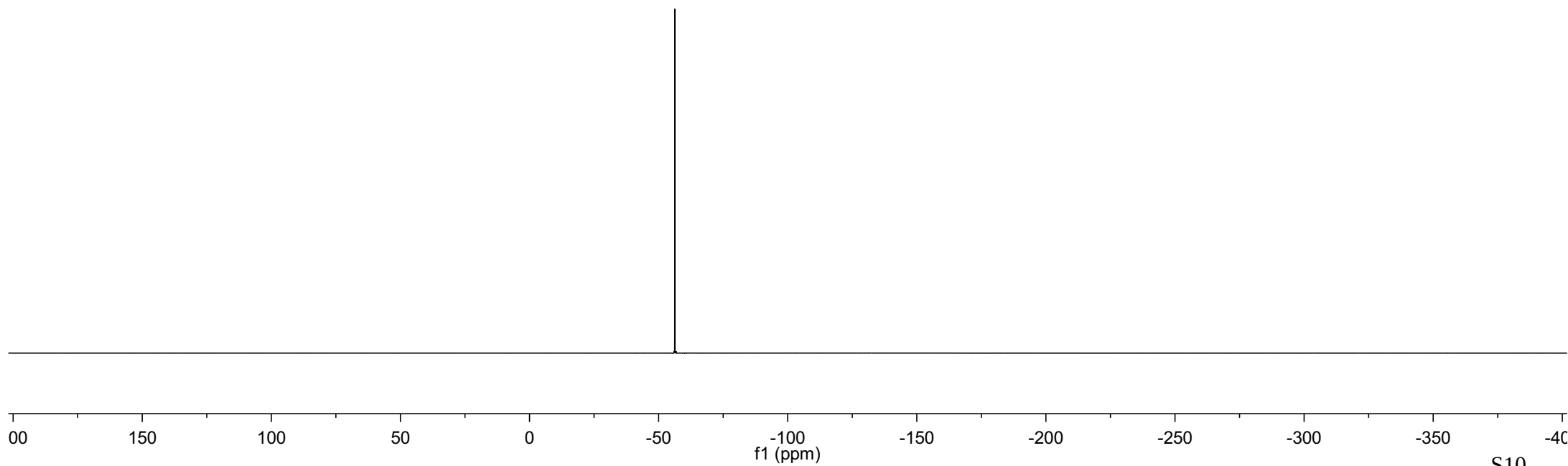


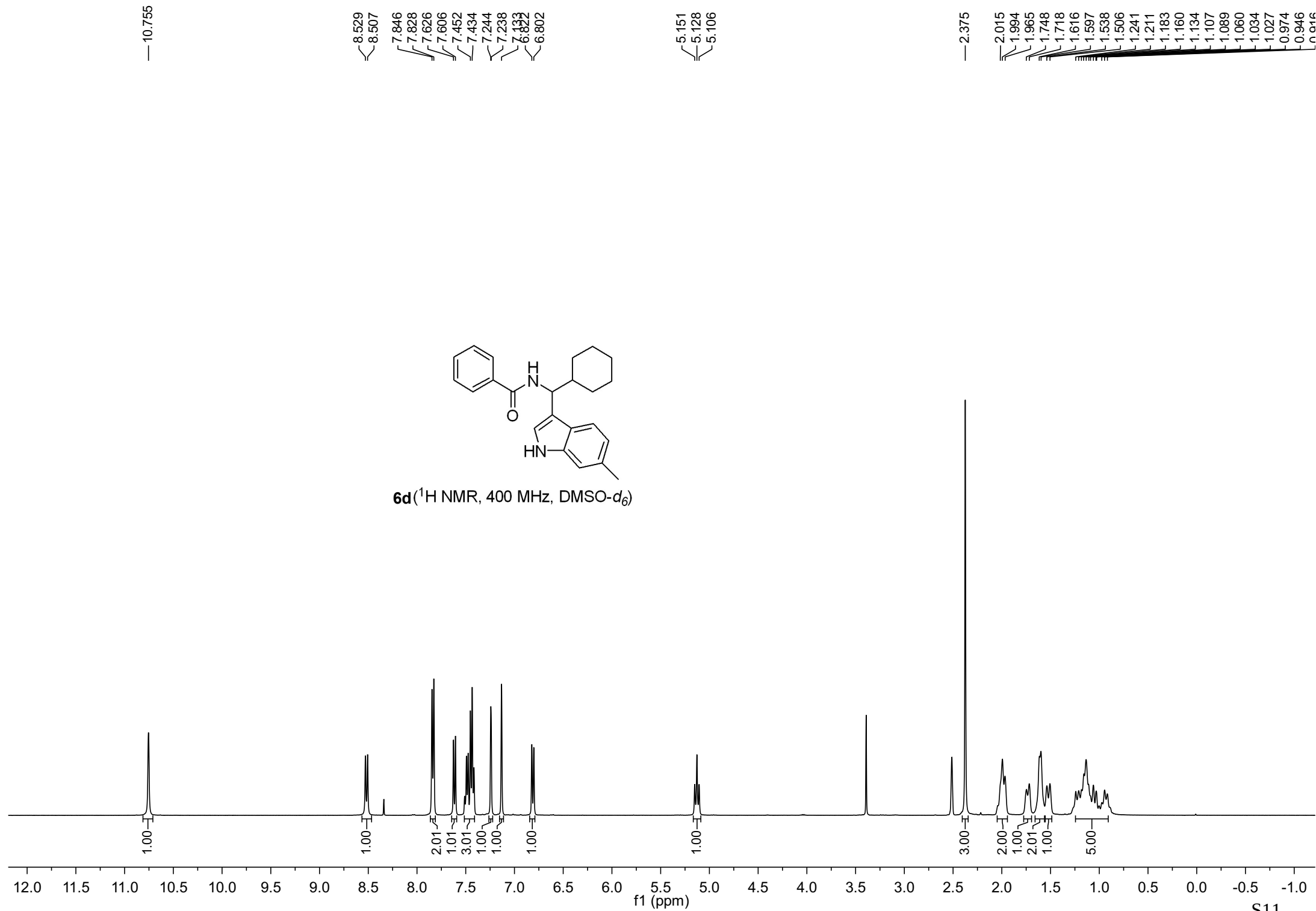


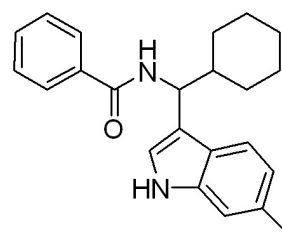


6c (^{19}F NMR, 376 MHz, $\text{DMSO-}d_6$)

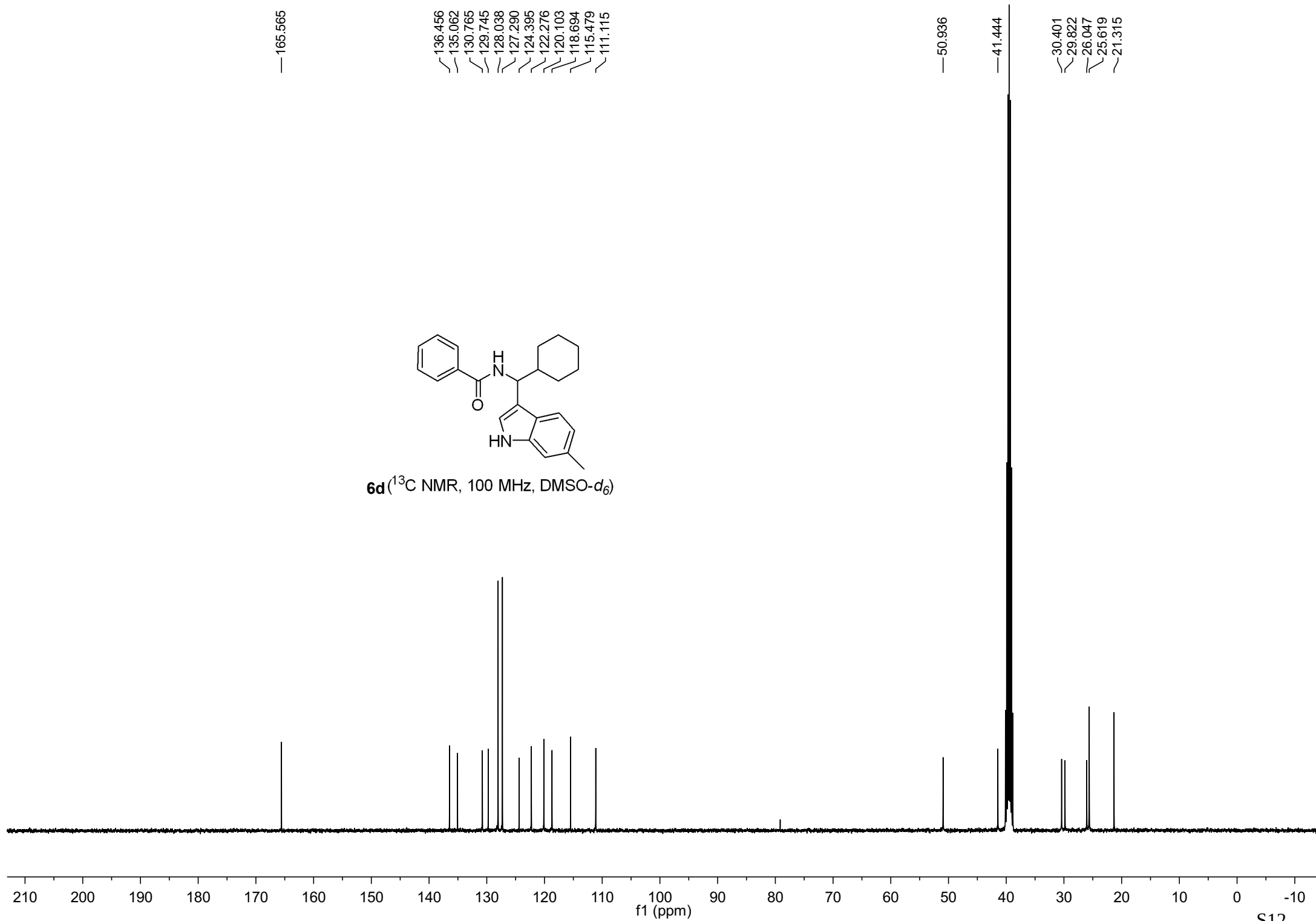
— -56.261

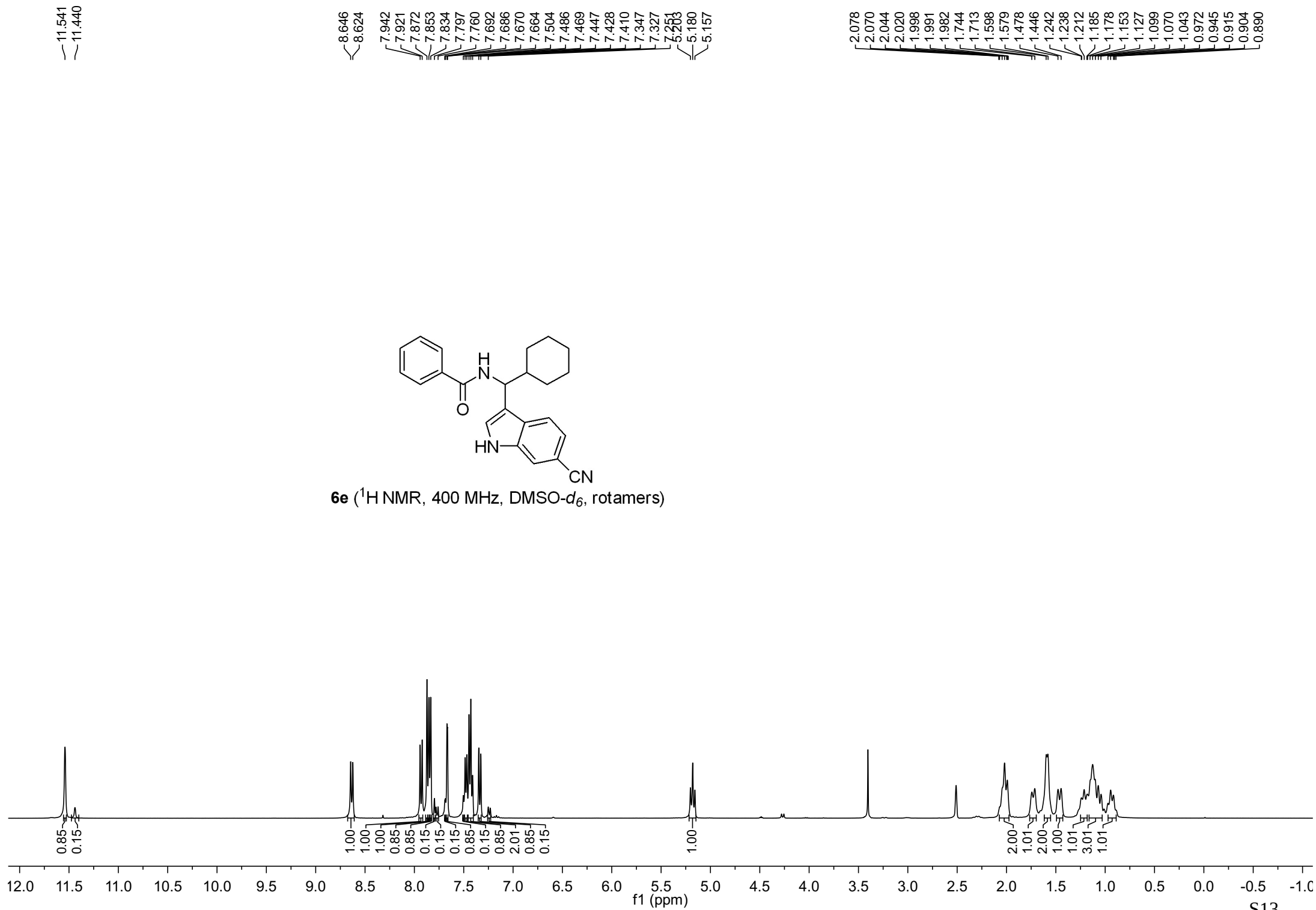


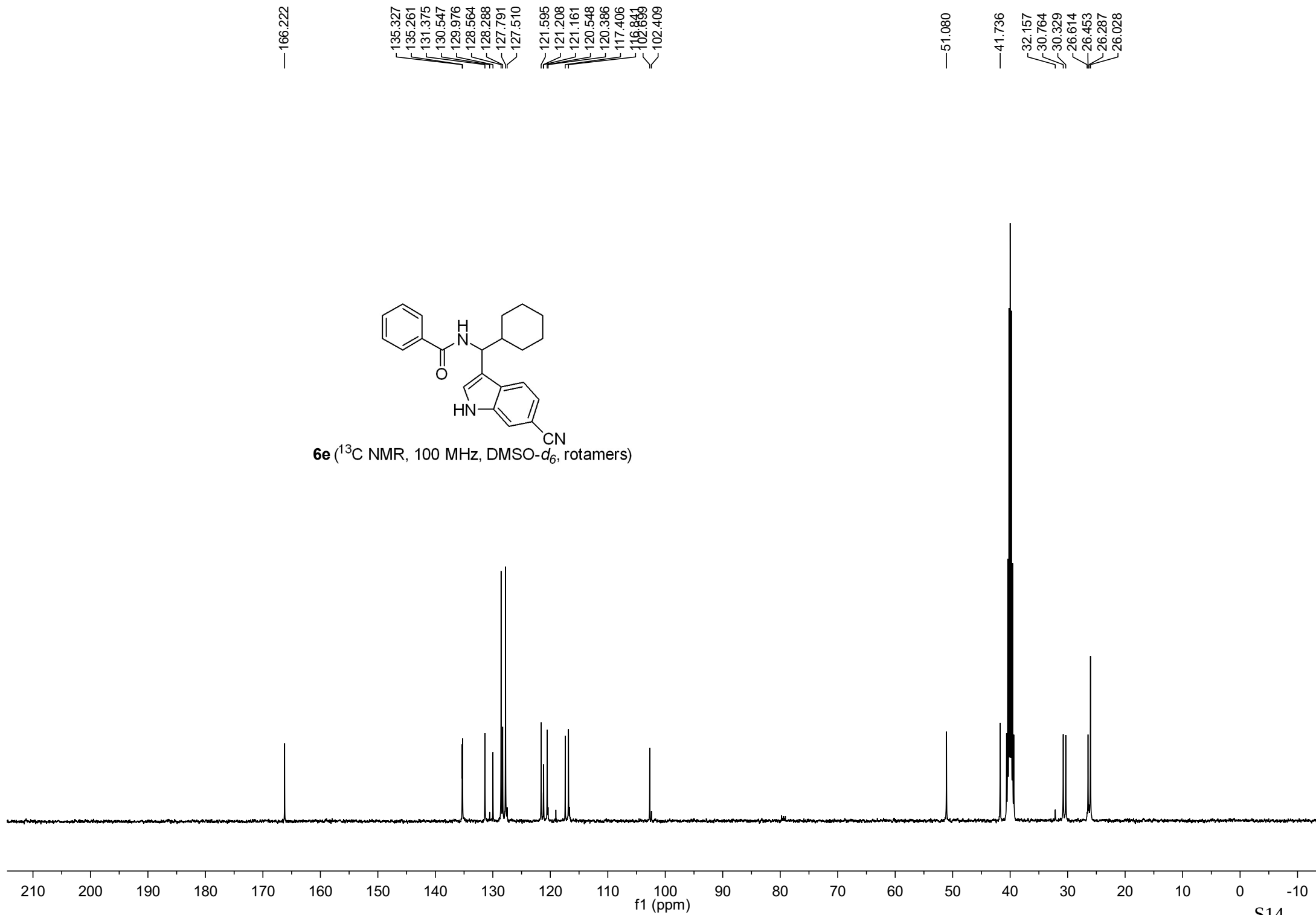
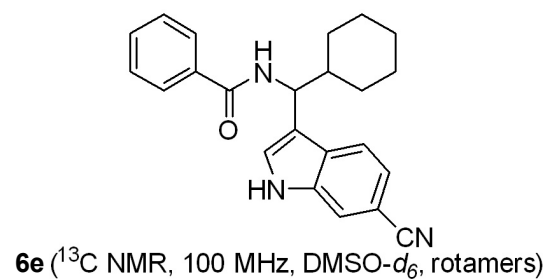




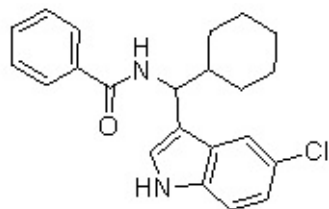
6d (^{13}C NMR, 100 MHz, $\text{DMSO-}d_6$)



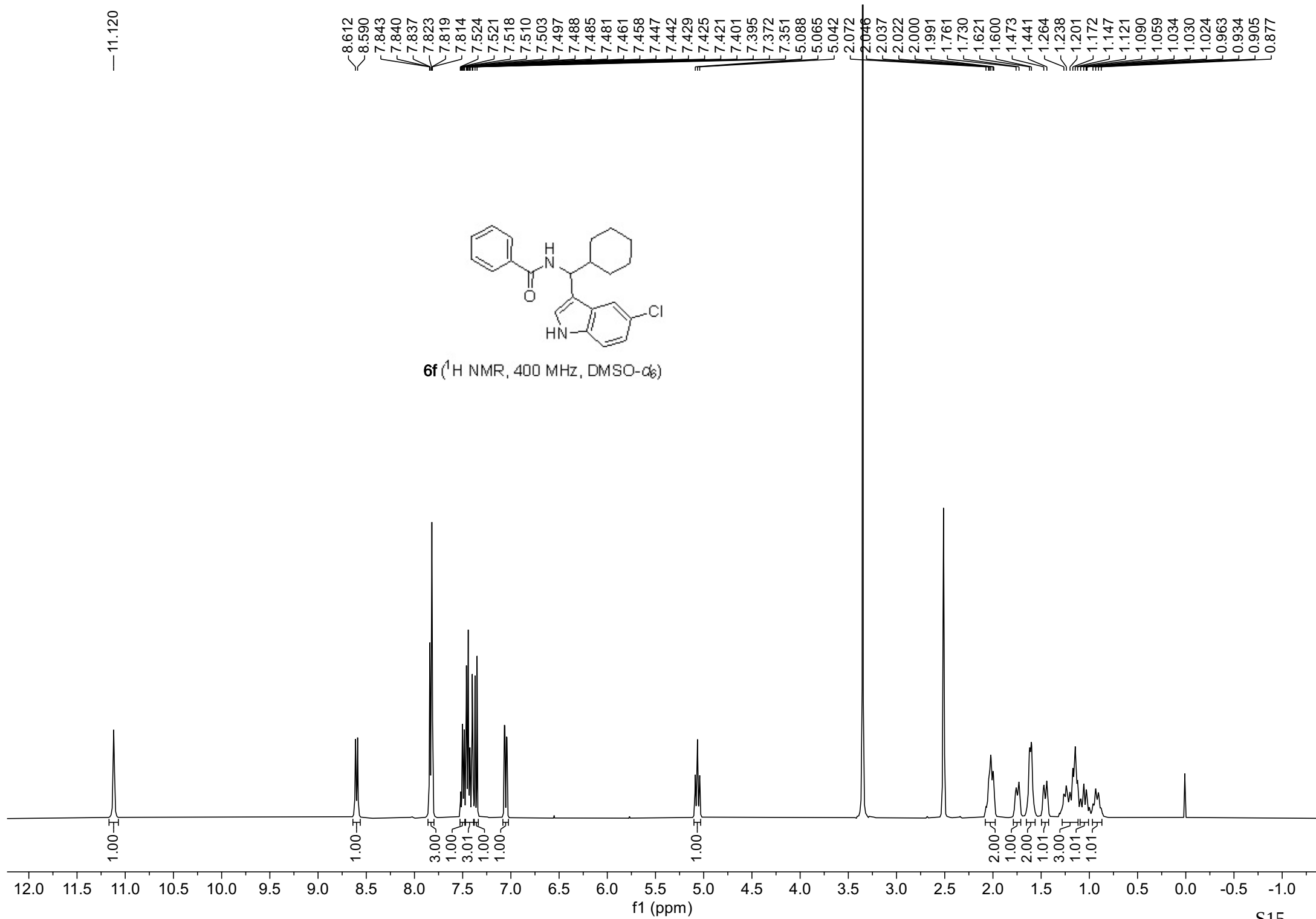


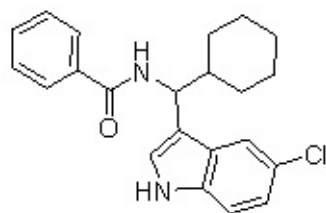


— 11.120

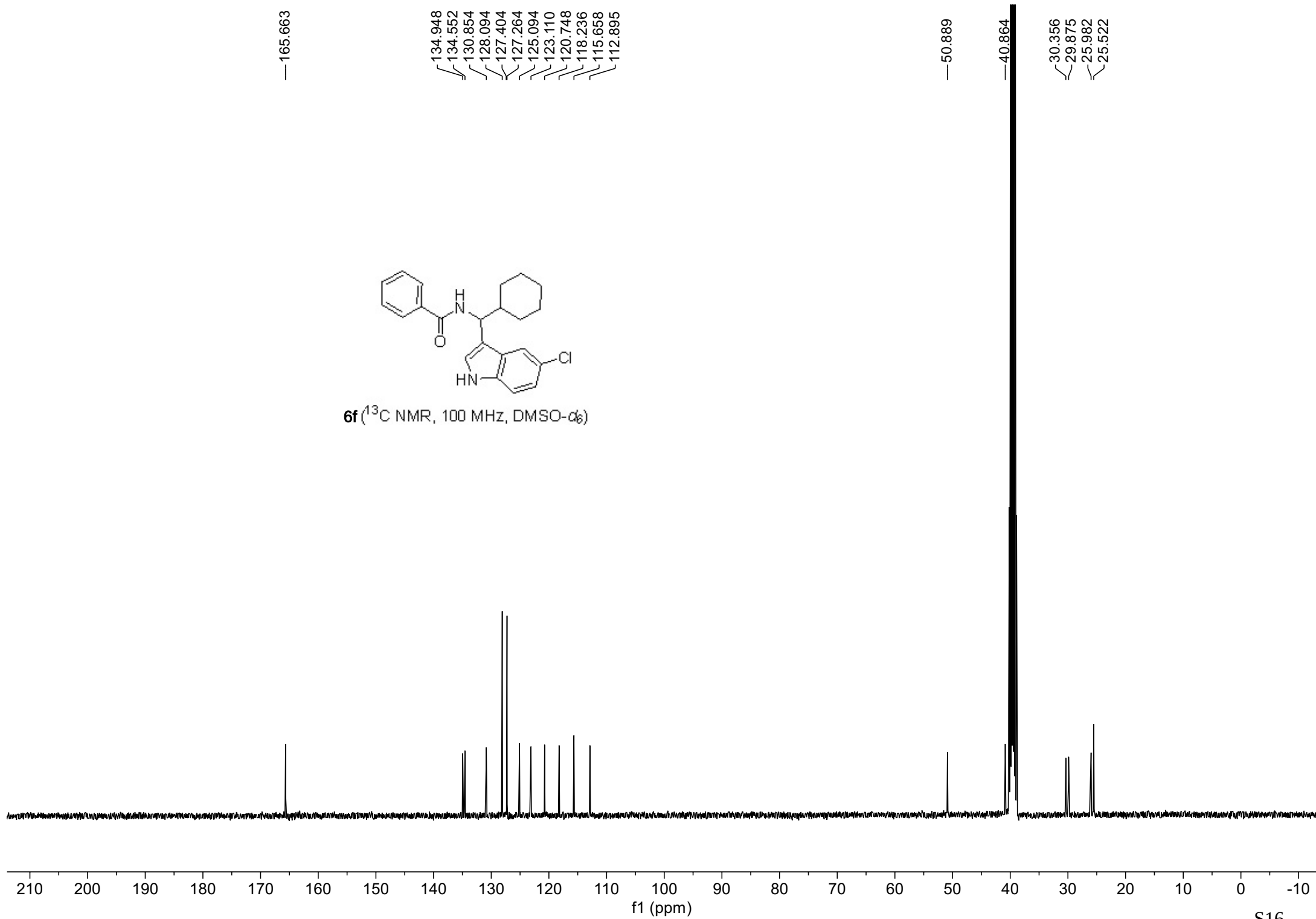


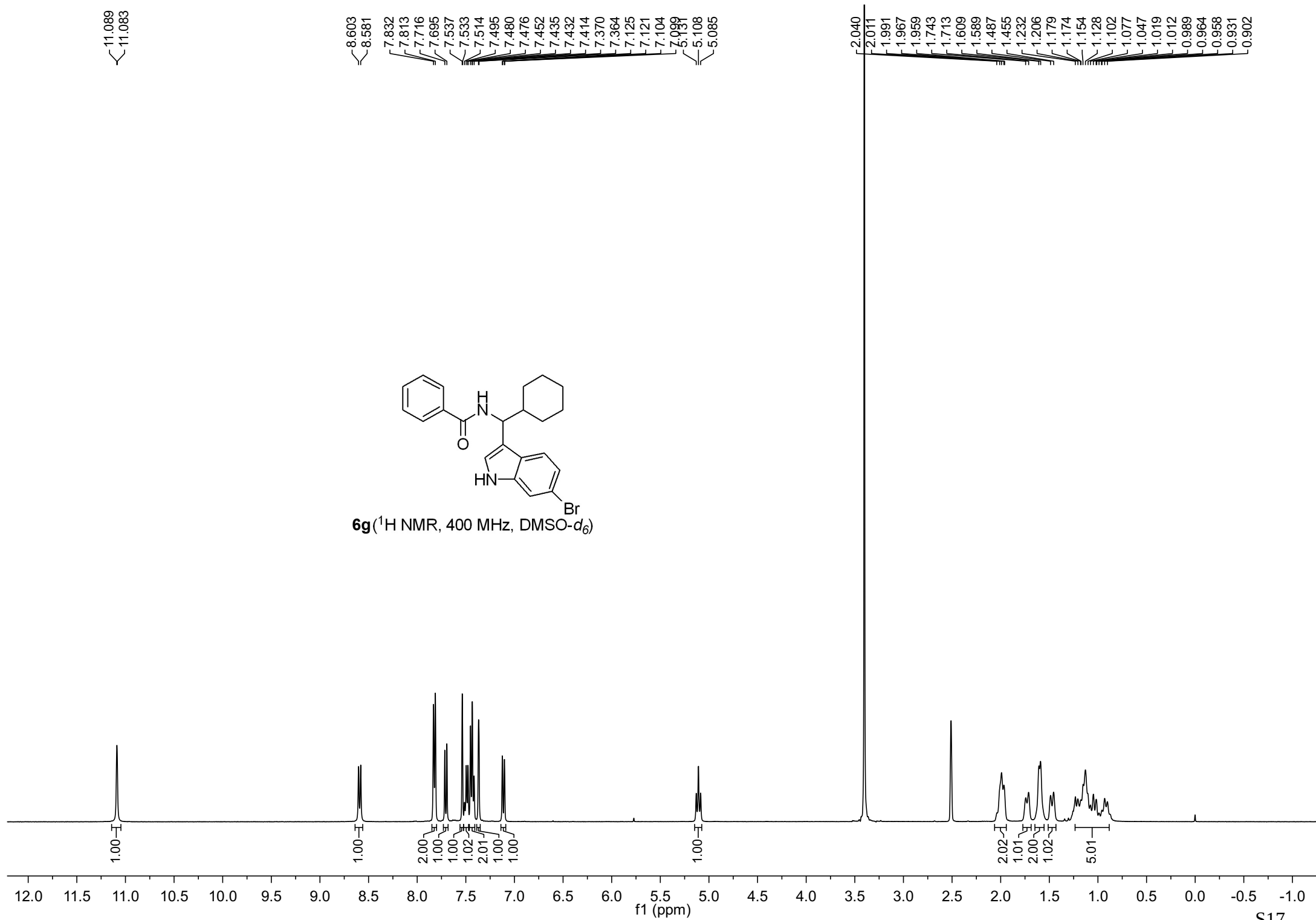
6f (^1H NMR, 400 MHz, $\text{DMSO}-d_6$)

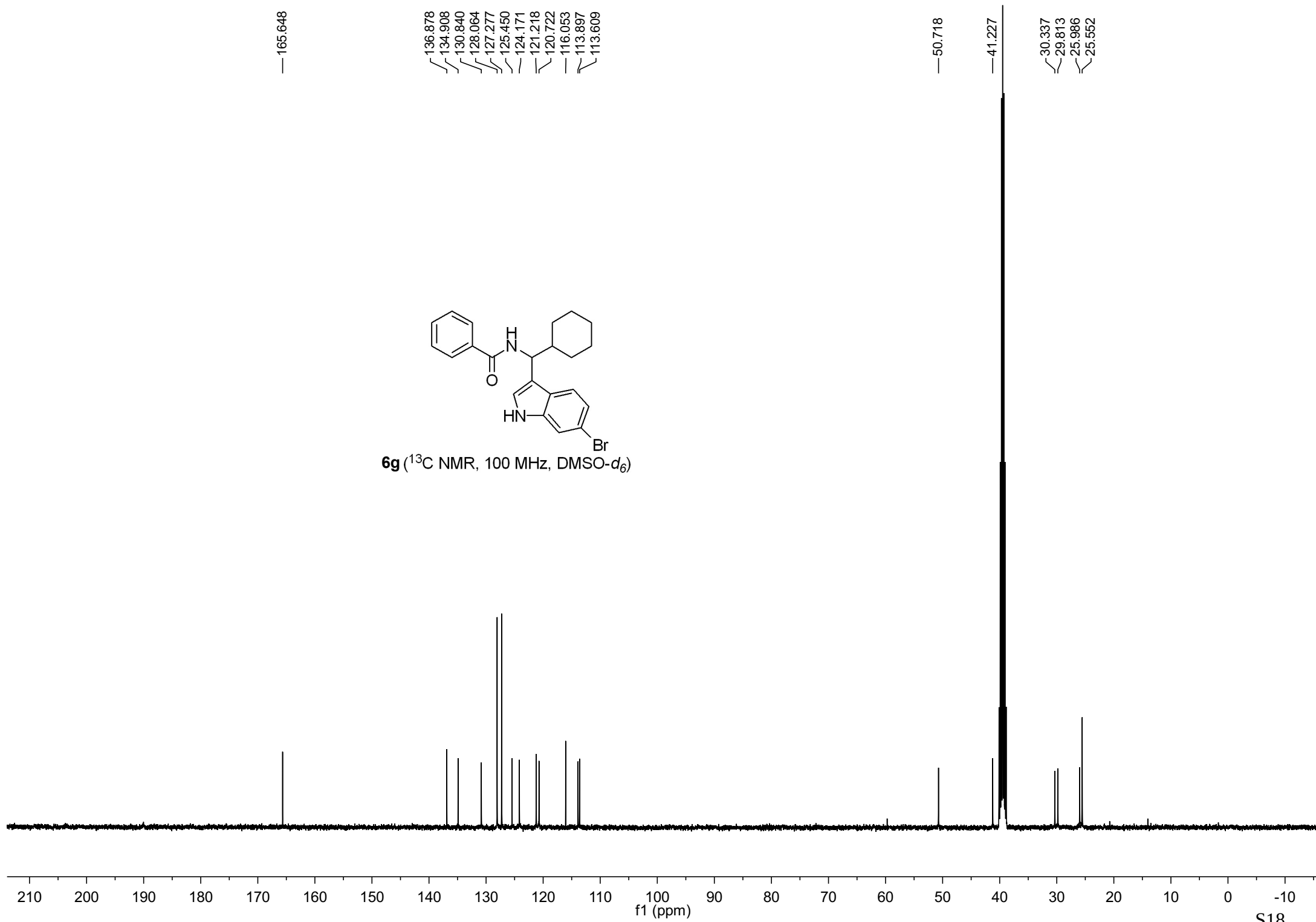


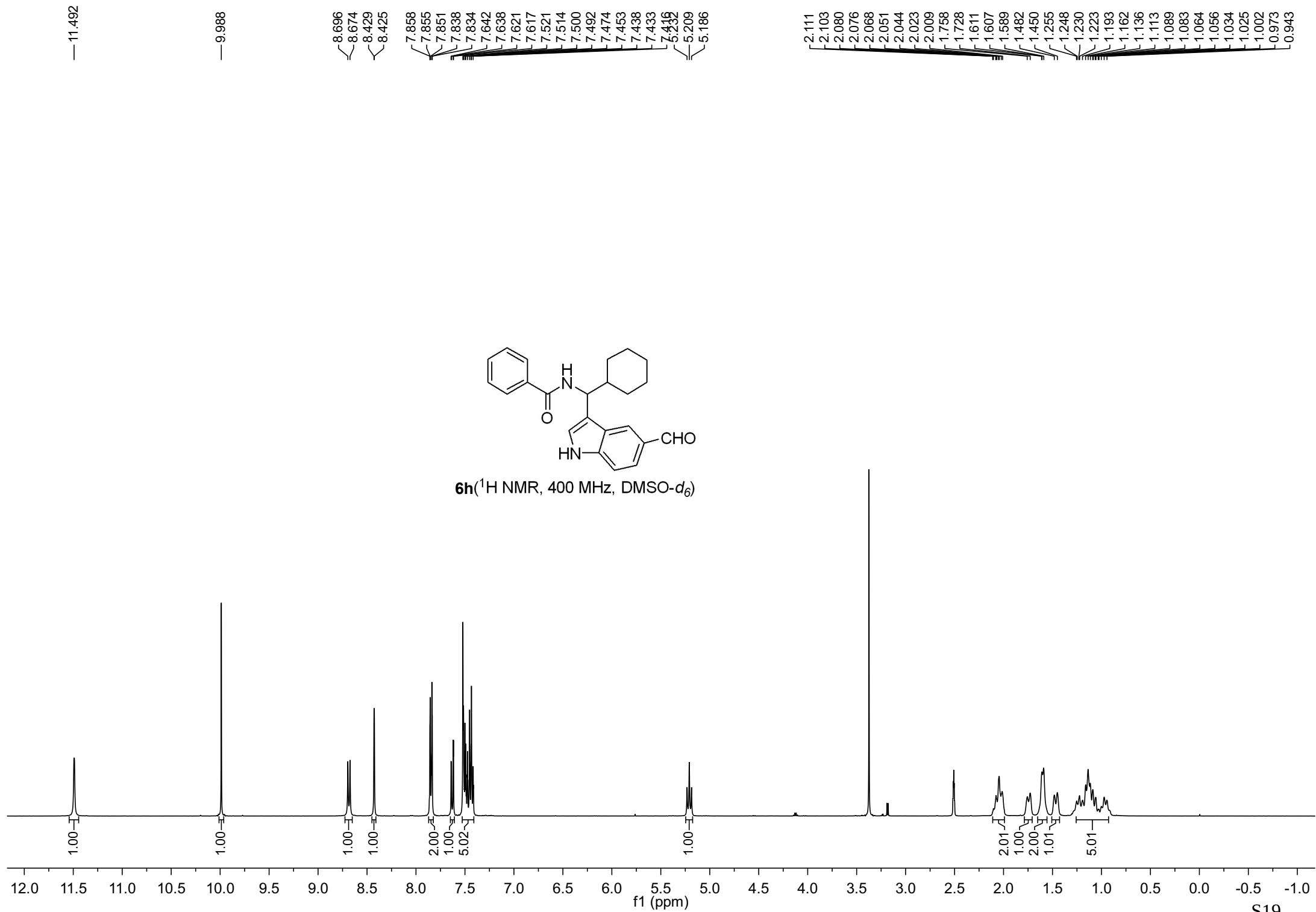


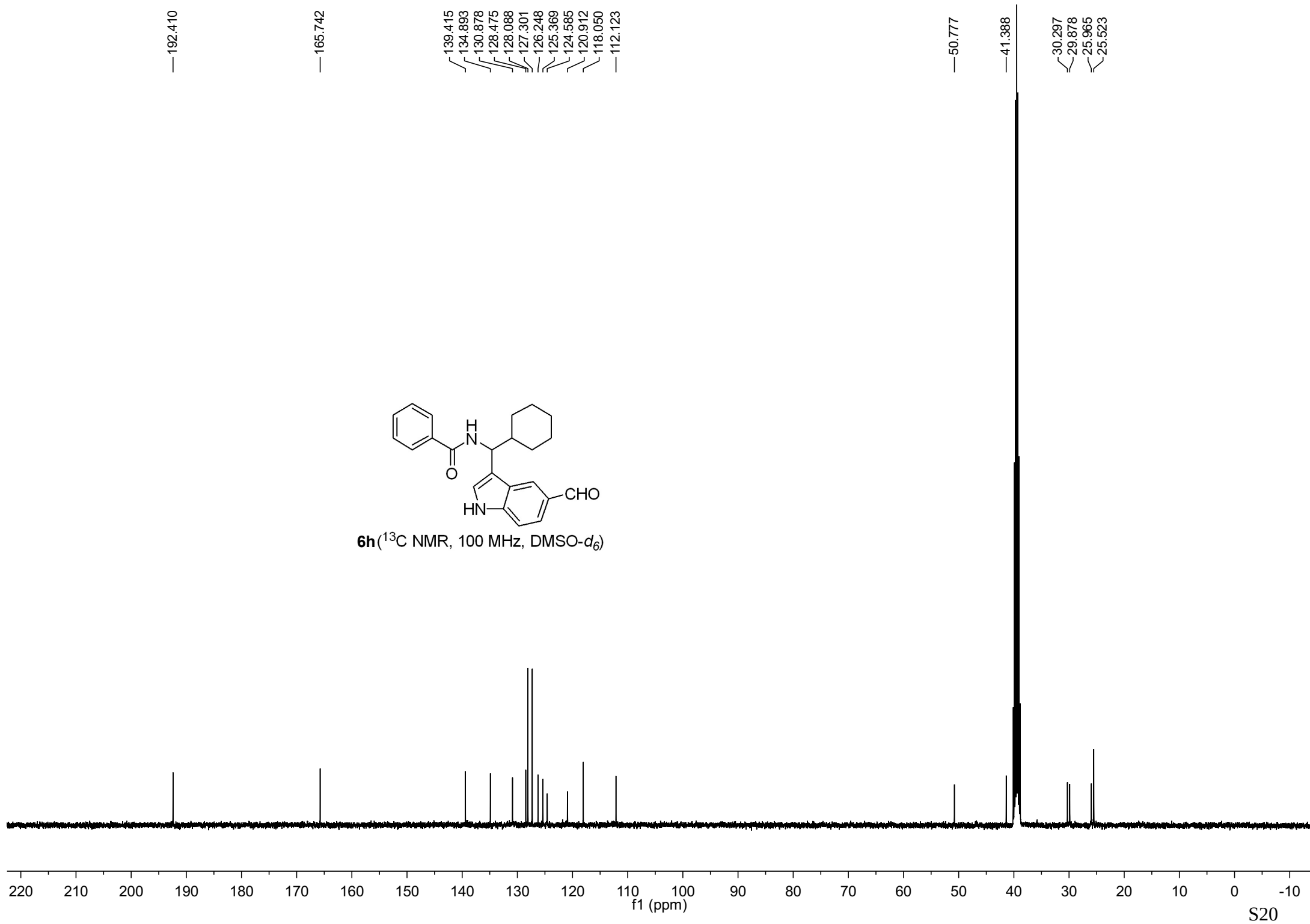
6f (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

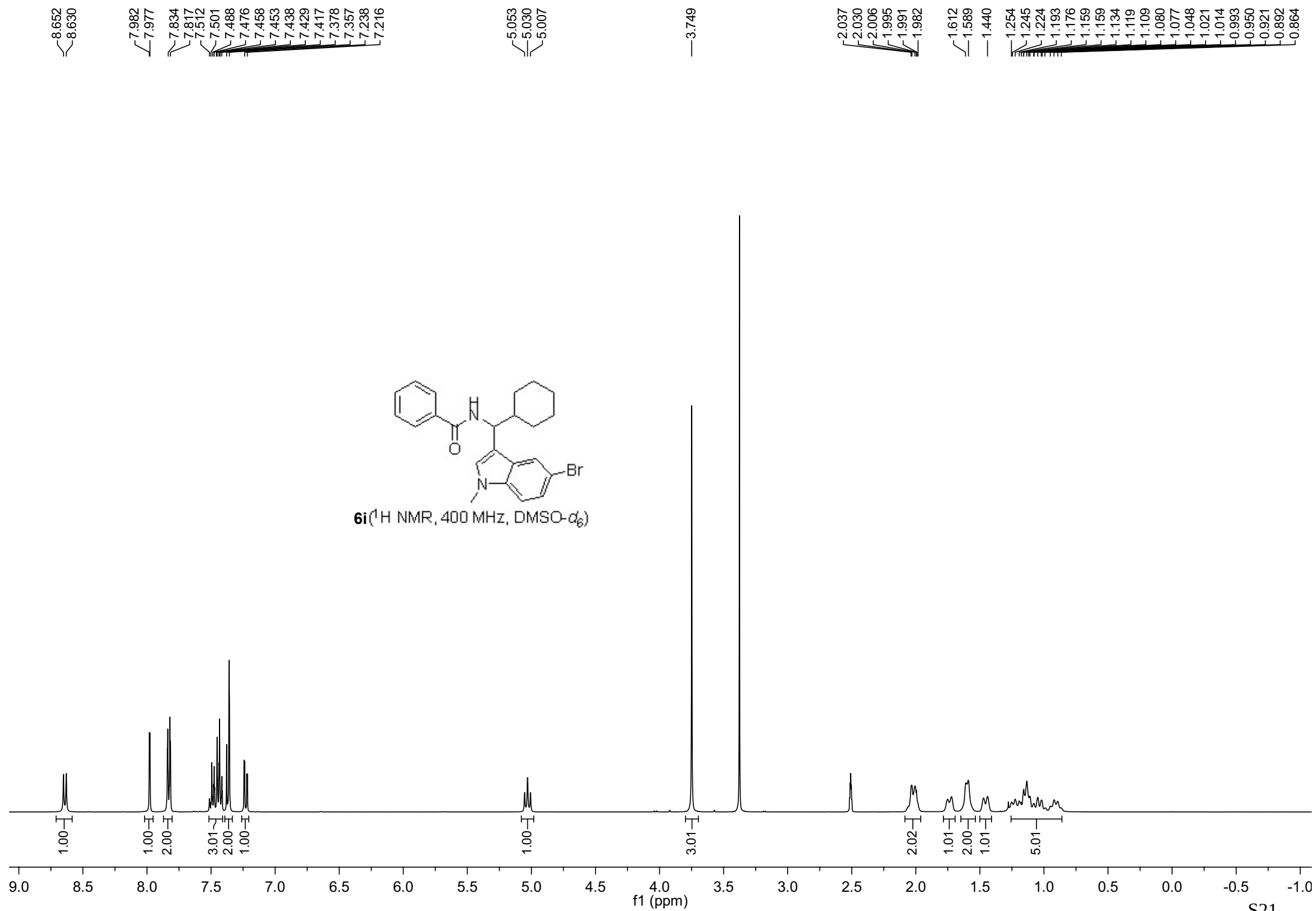


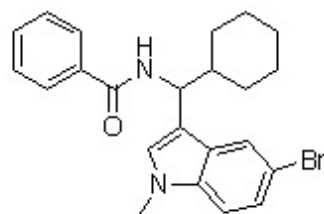




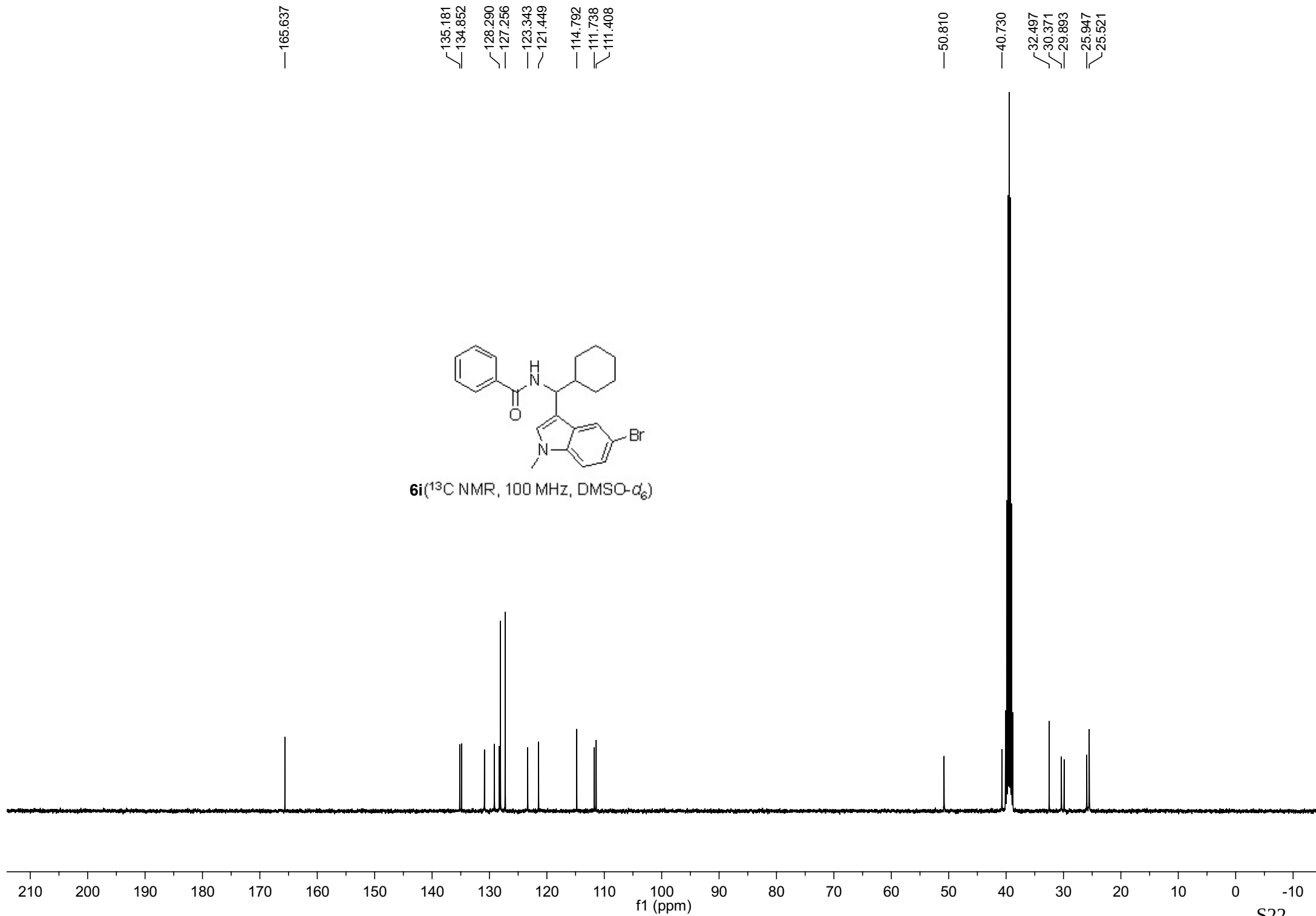


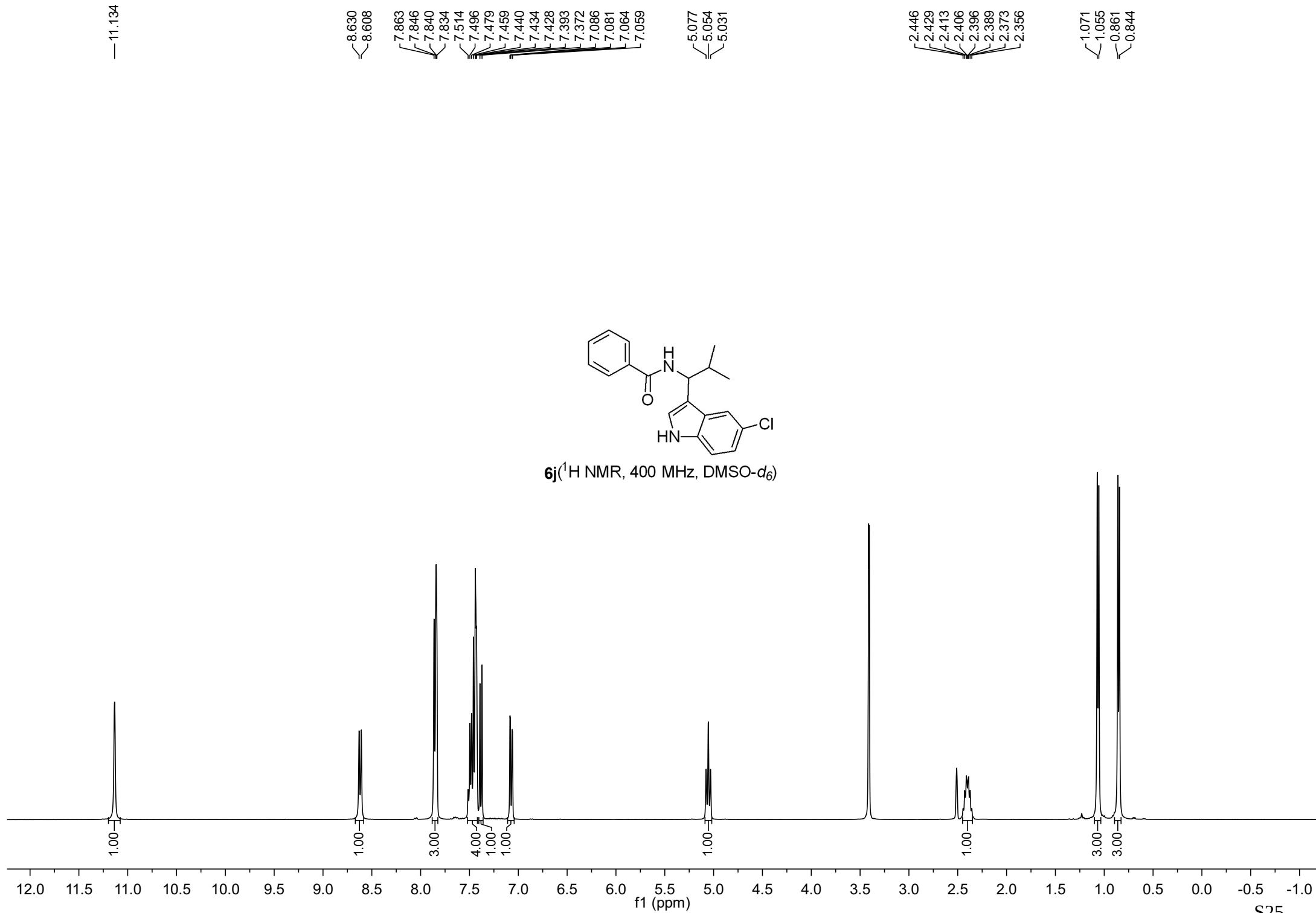


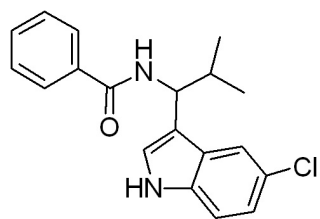




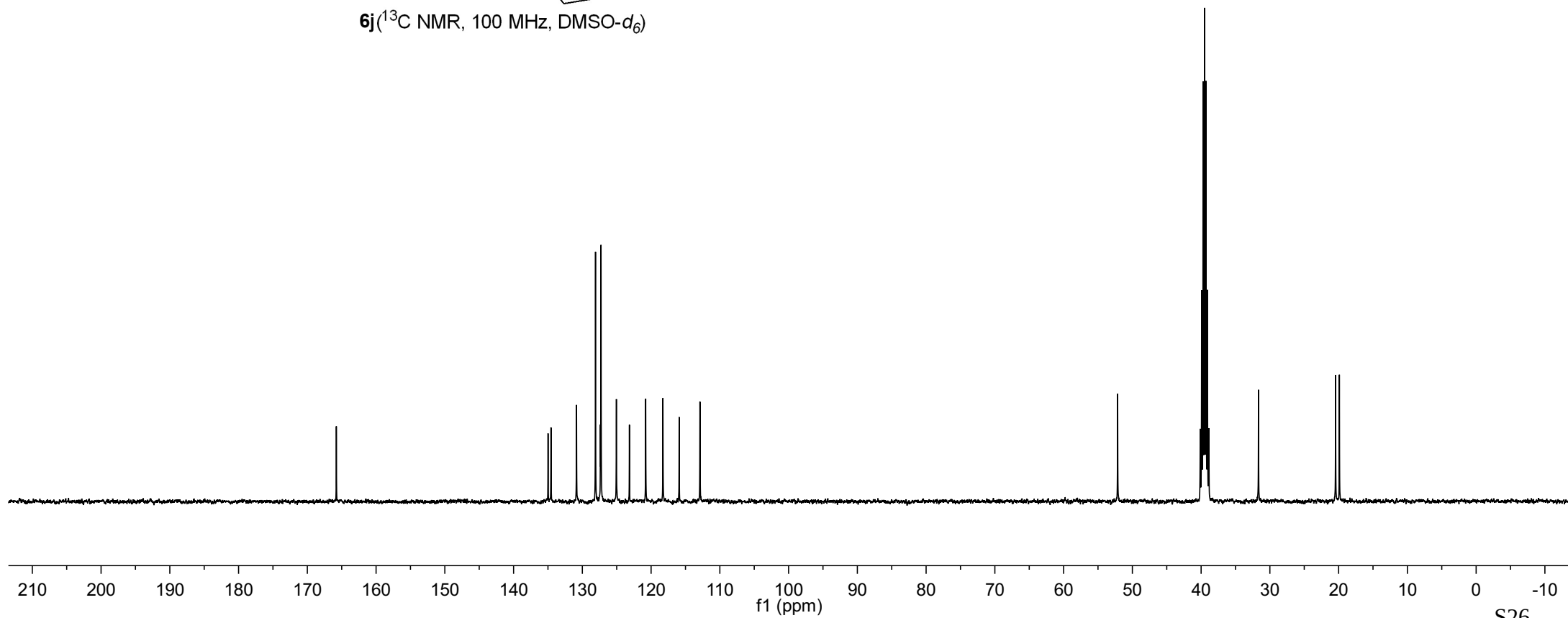
6i(^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

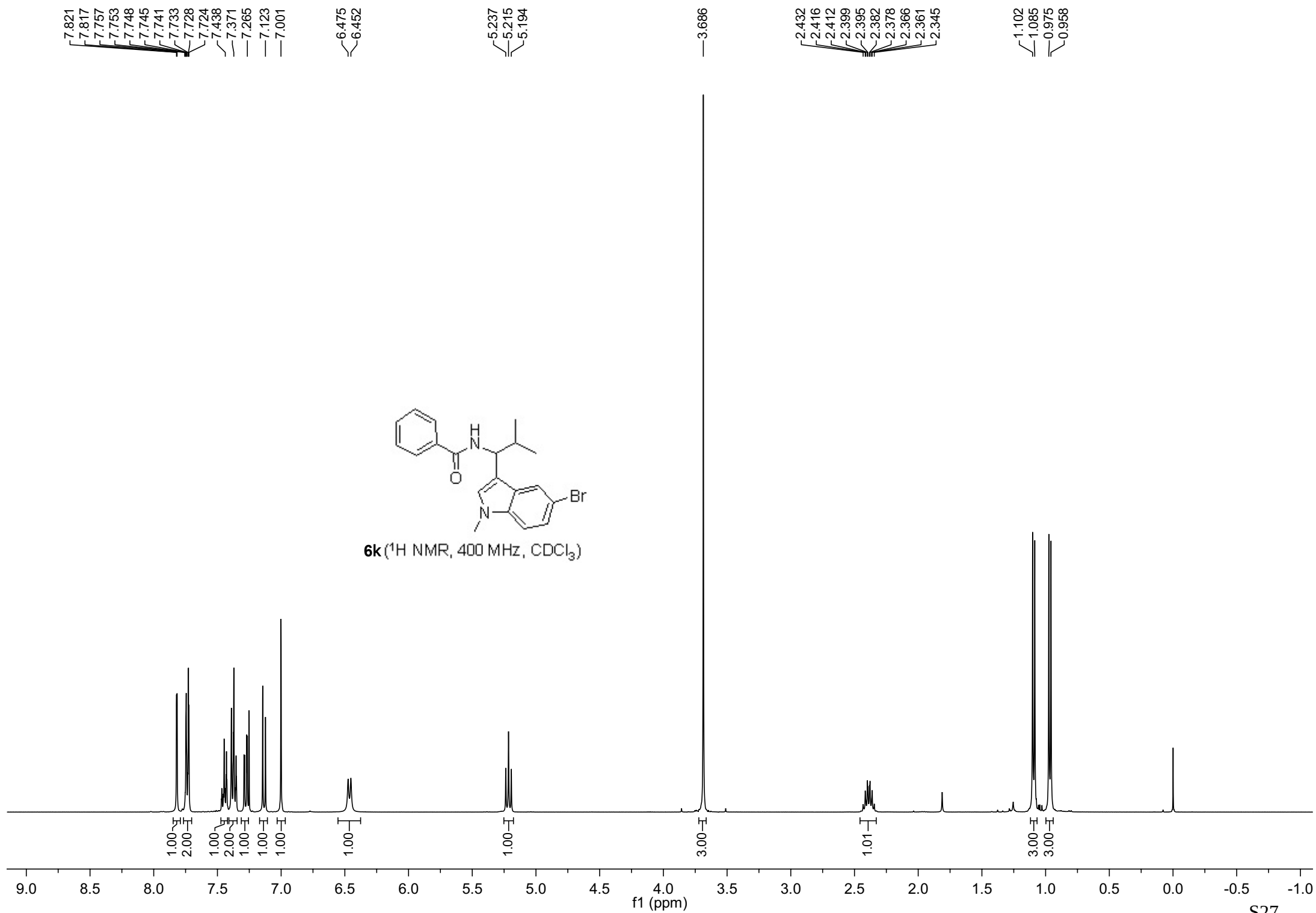


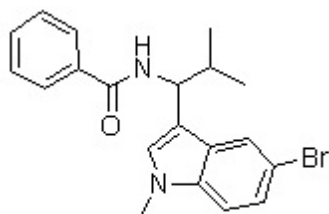




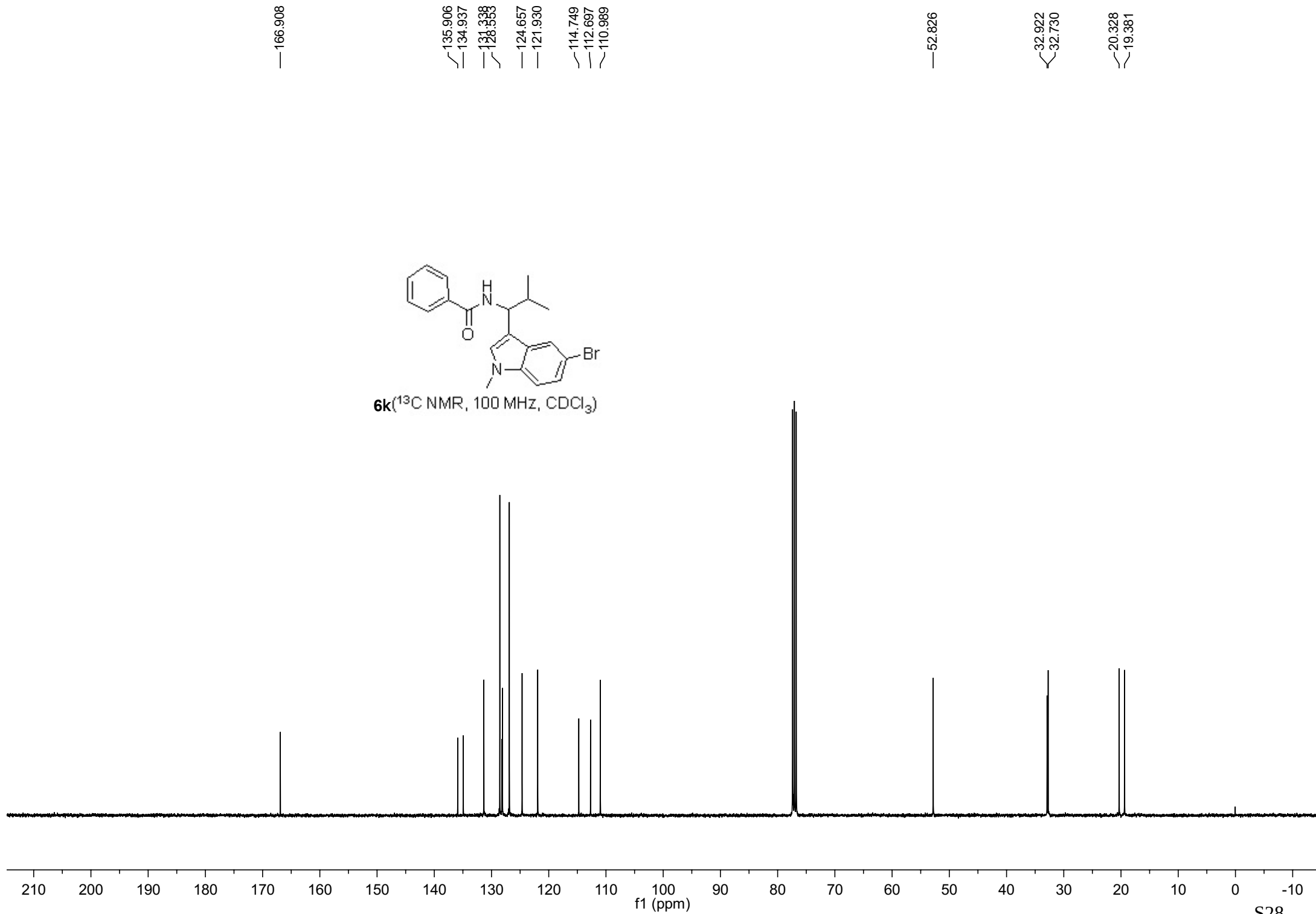
6j (^{13}C NMR, 100 MHz, $\text{DMSO-}d_6$)

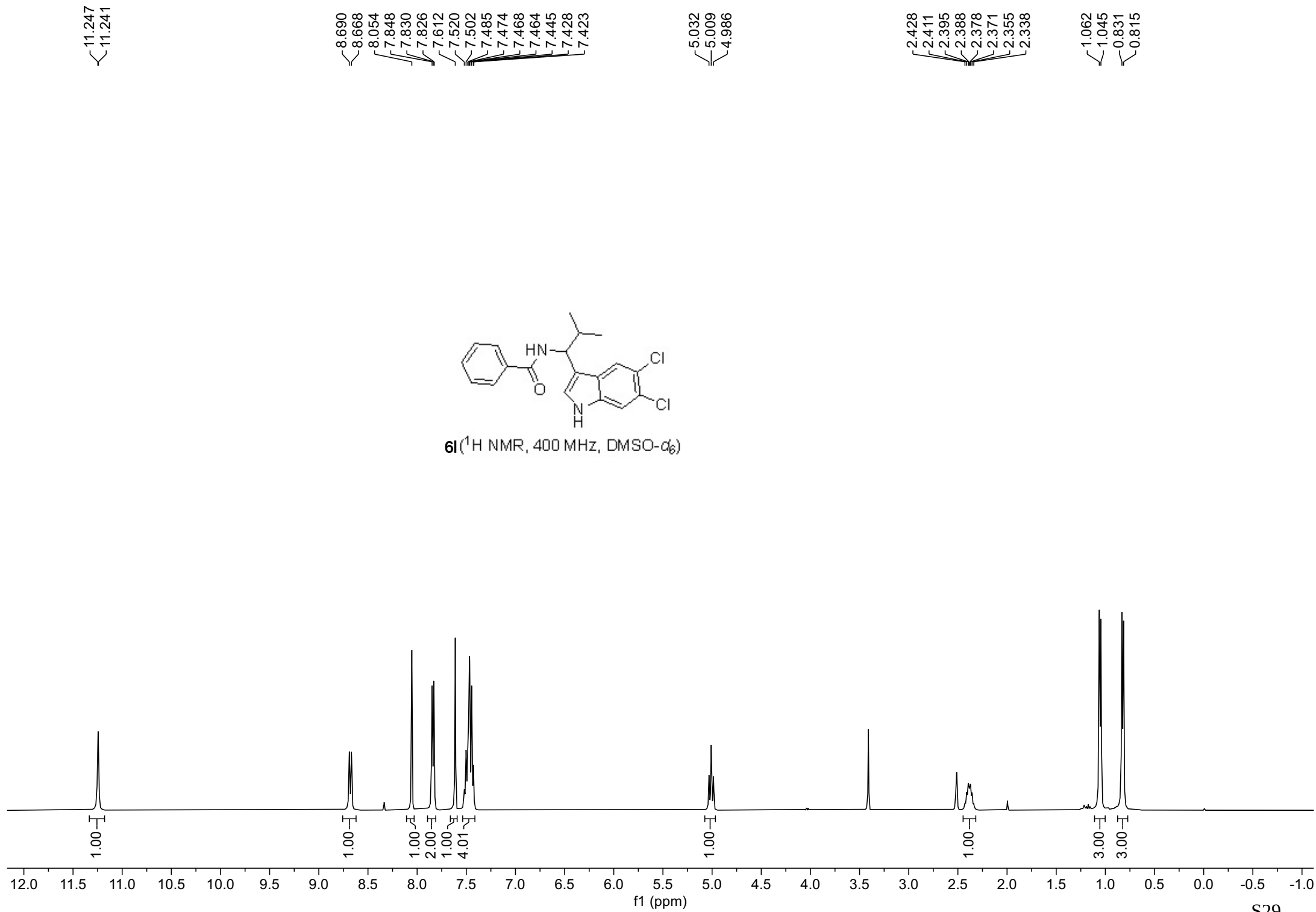


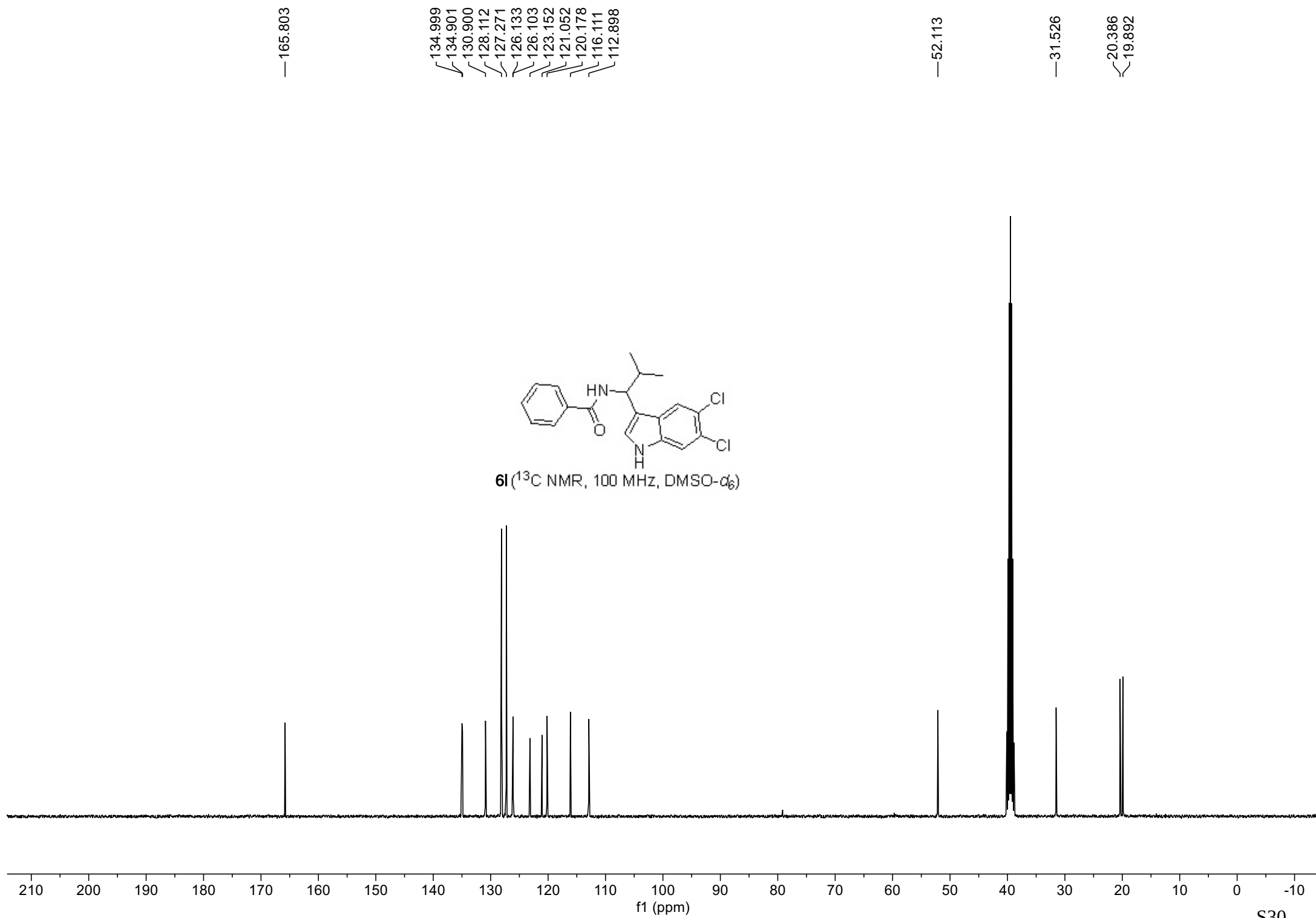


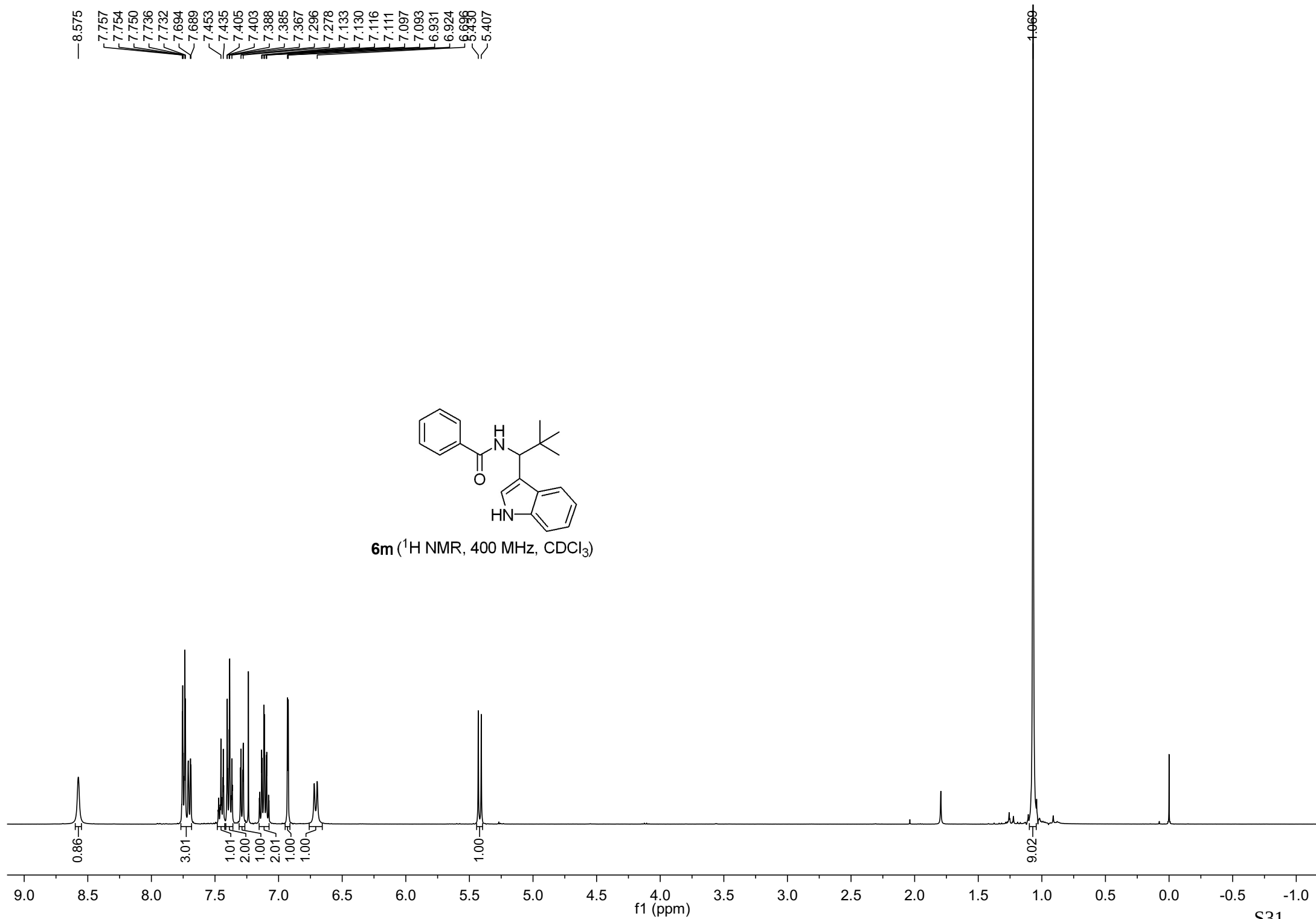


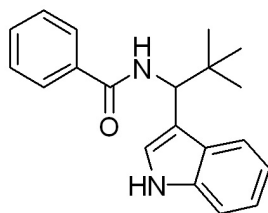
6k(¹³C NMR, 100 MHz, CDCl₃)



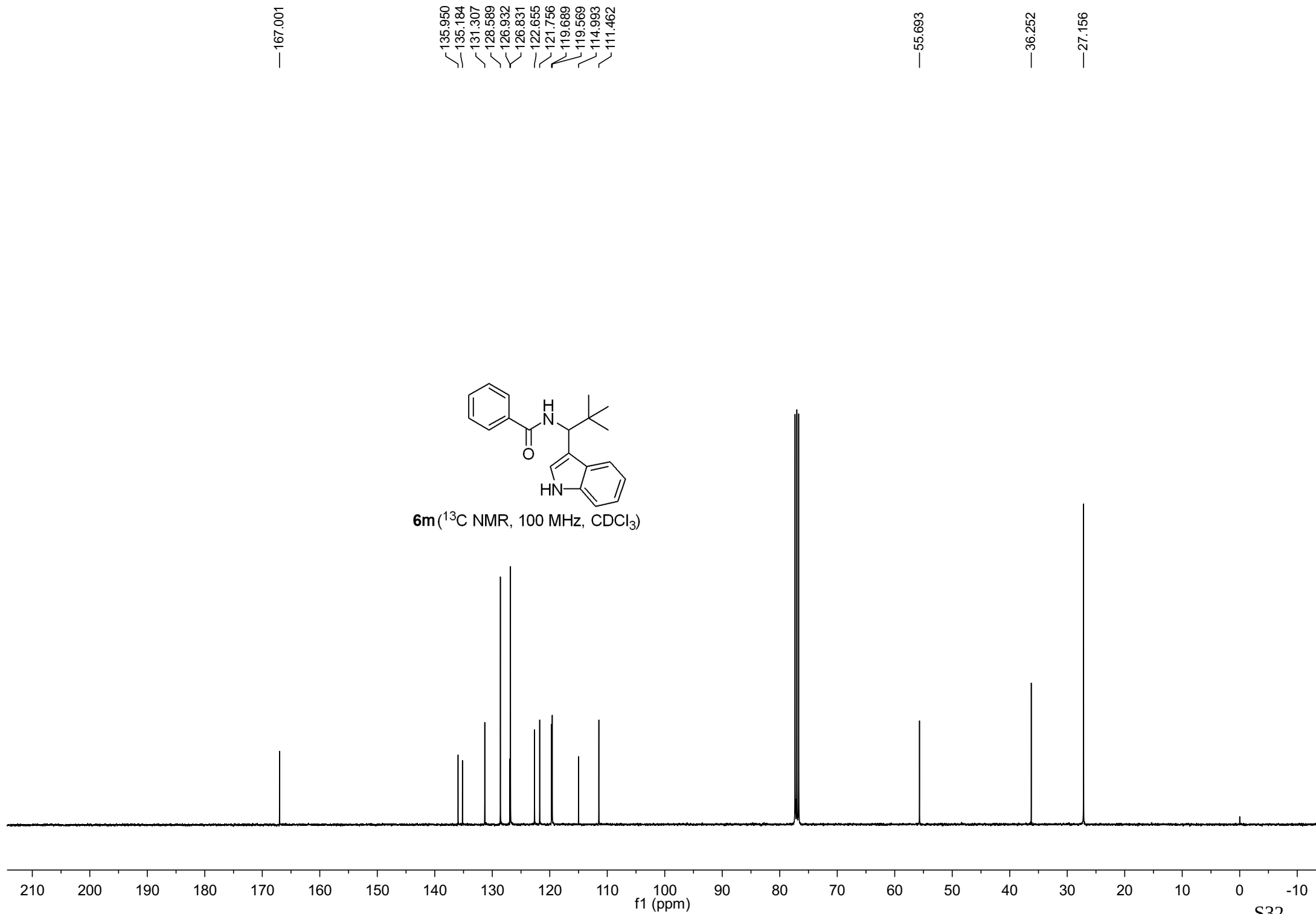


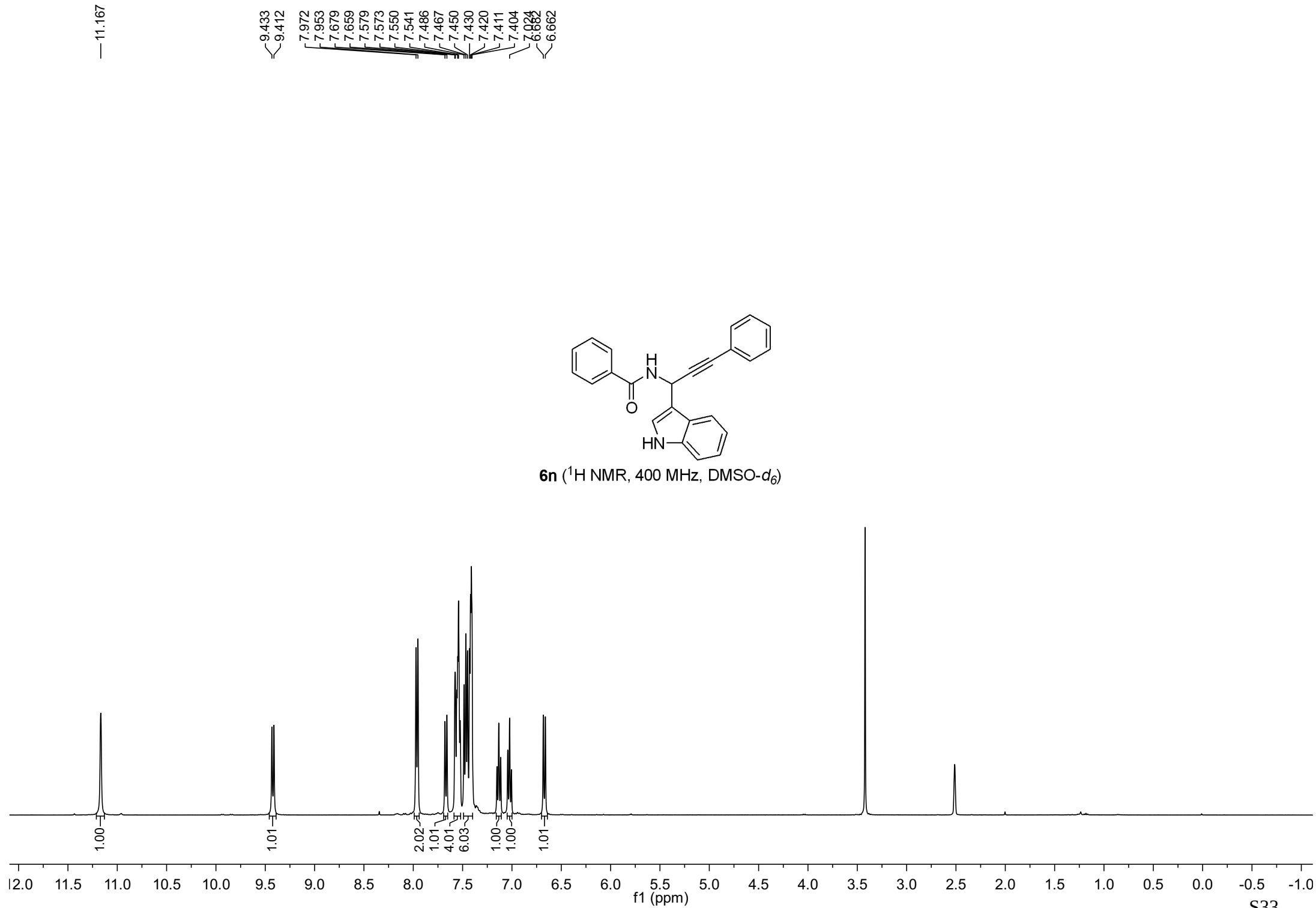


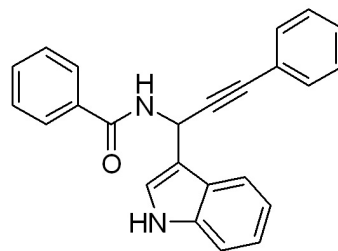




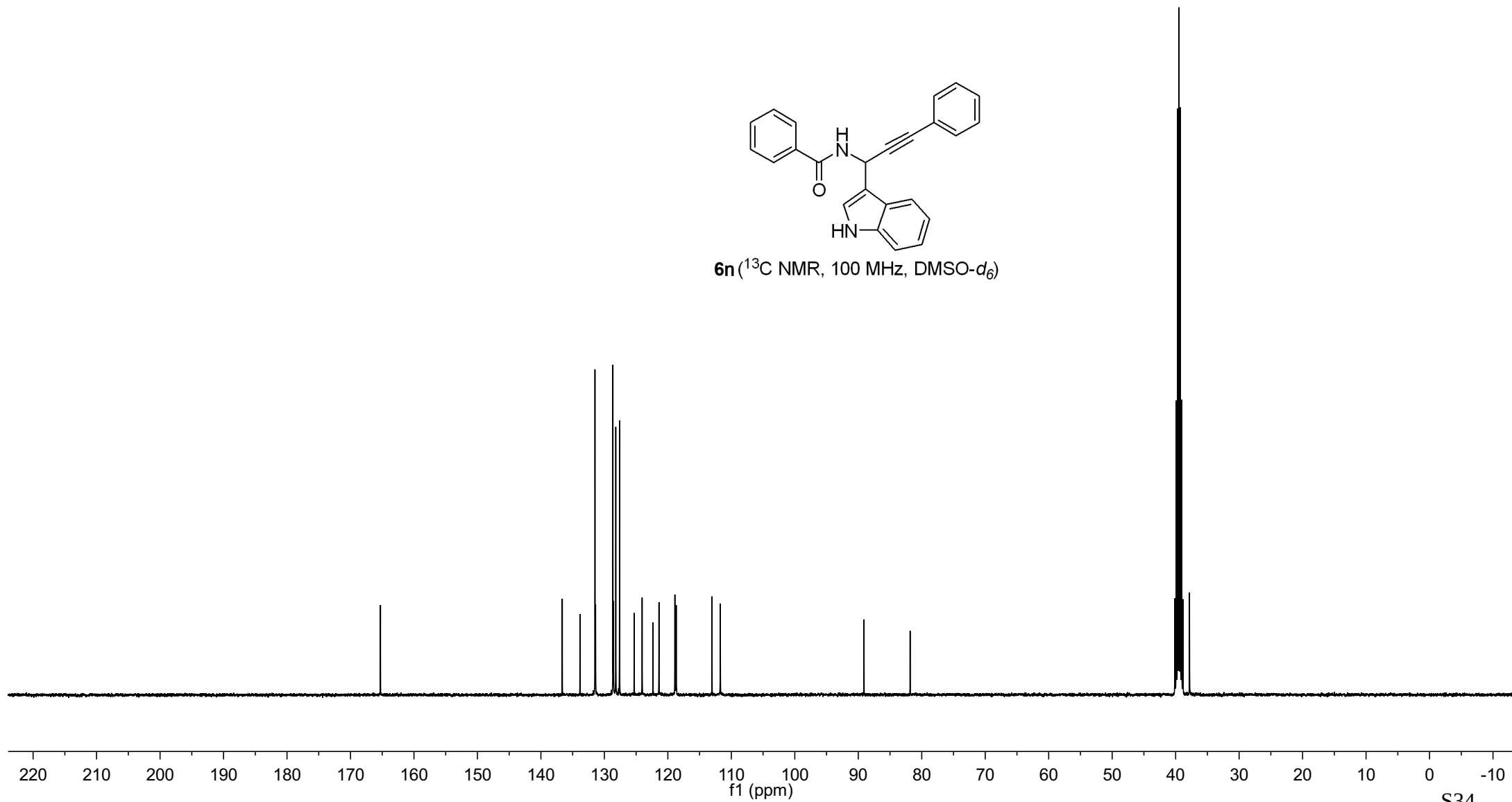
6m (^{13}C NMR, 100 MHz, CDCl_3)

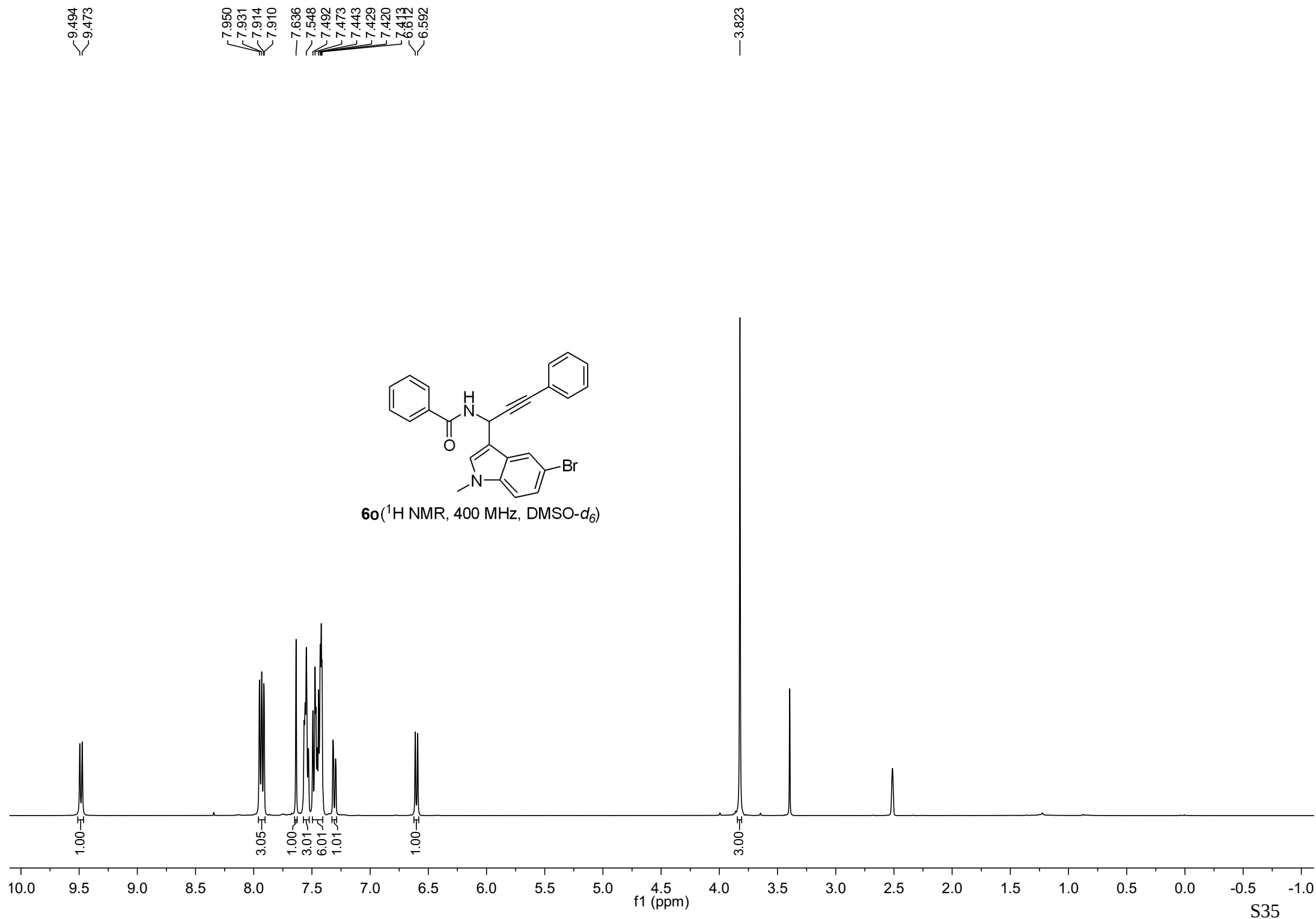


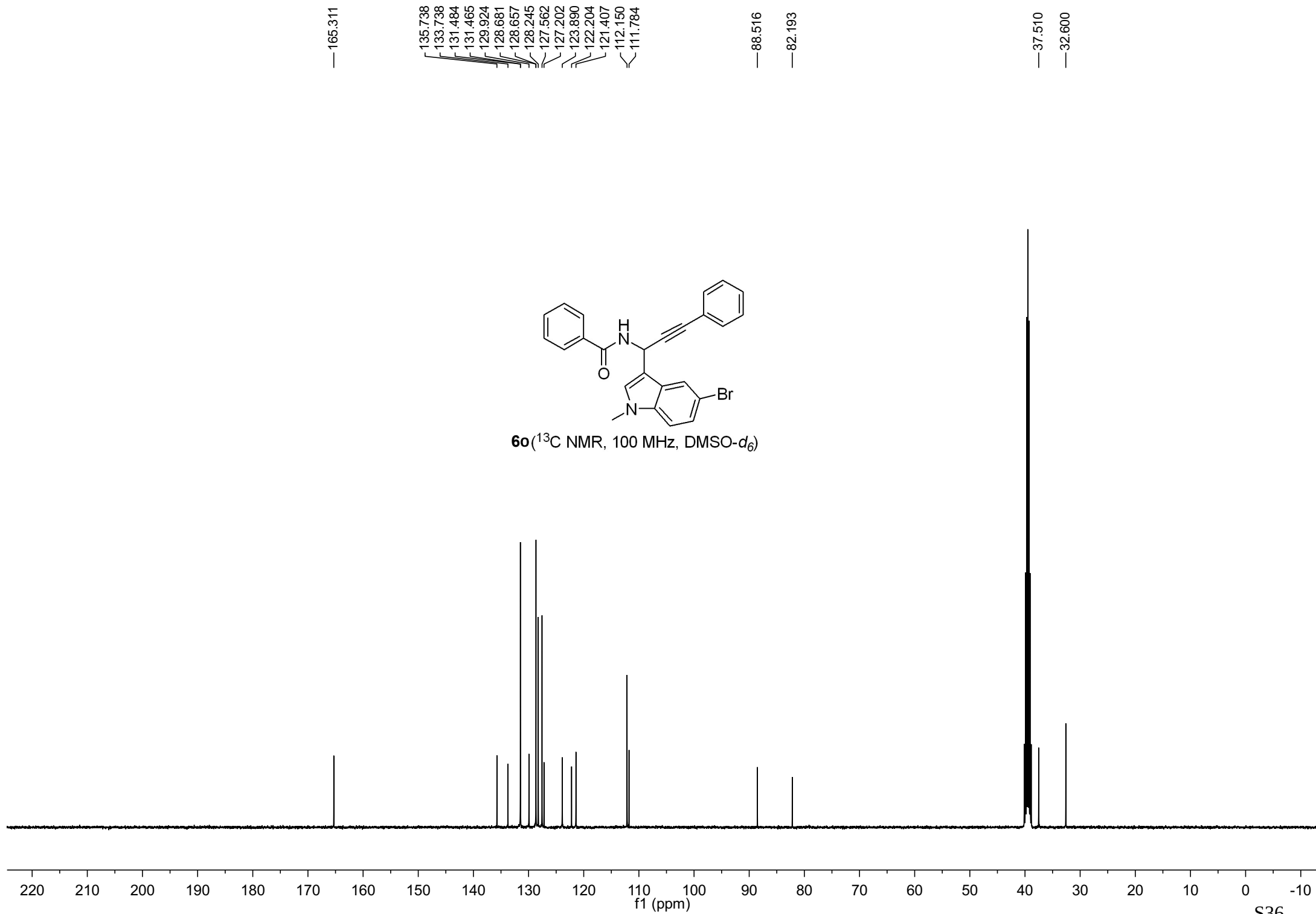


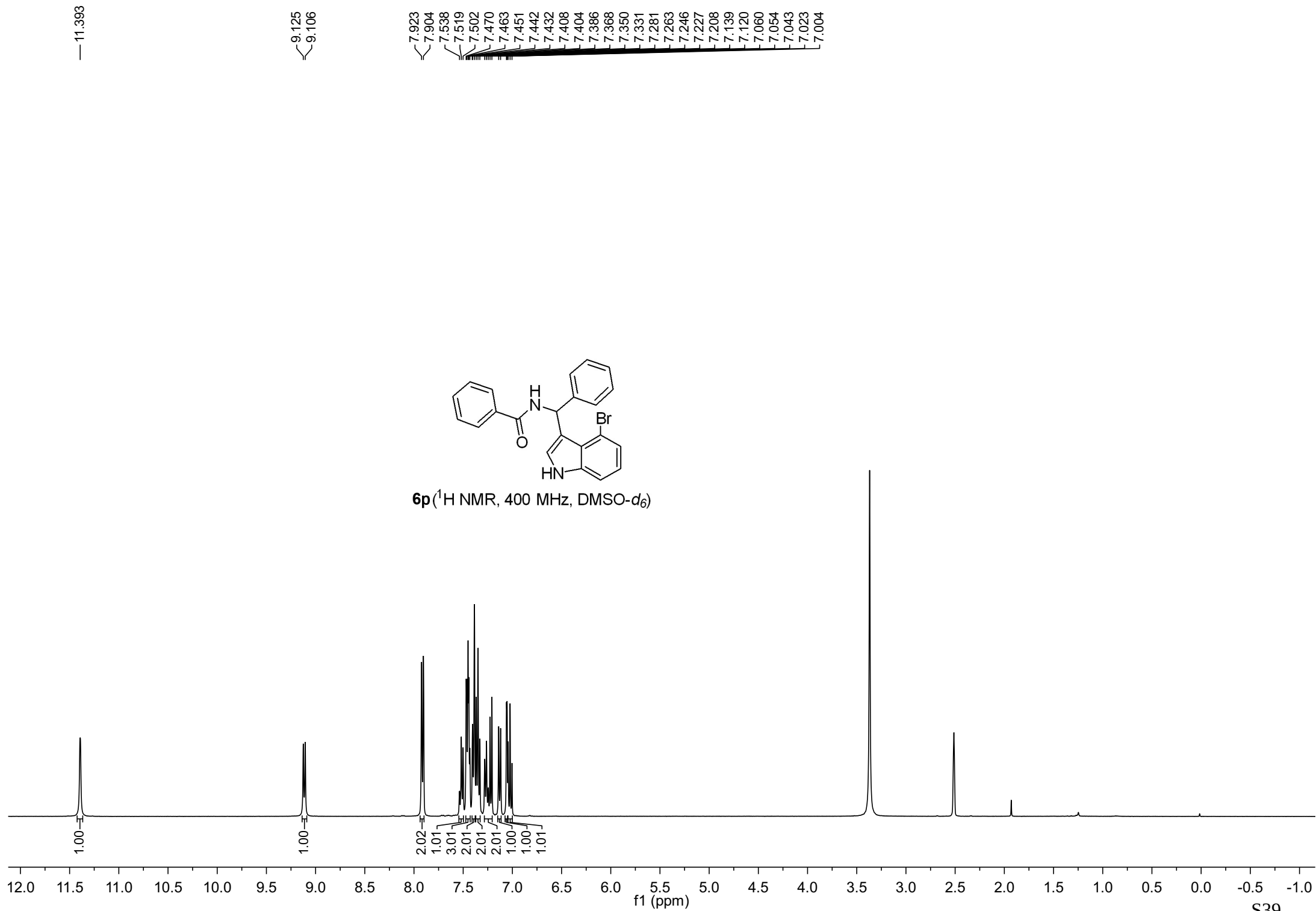


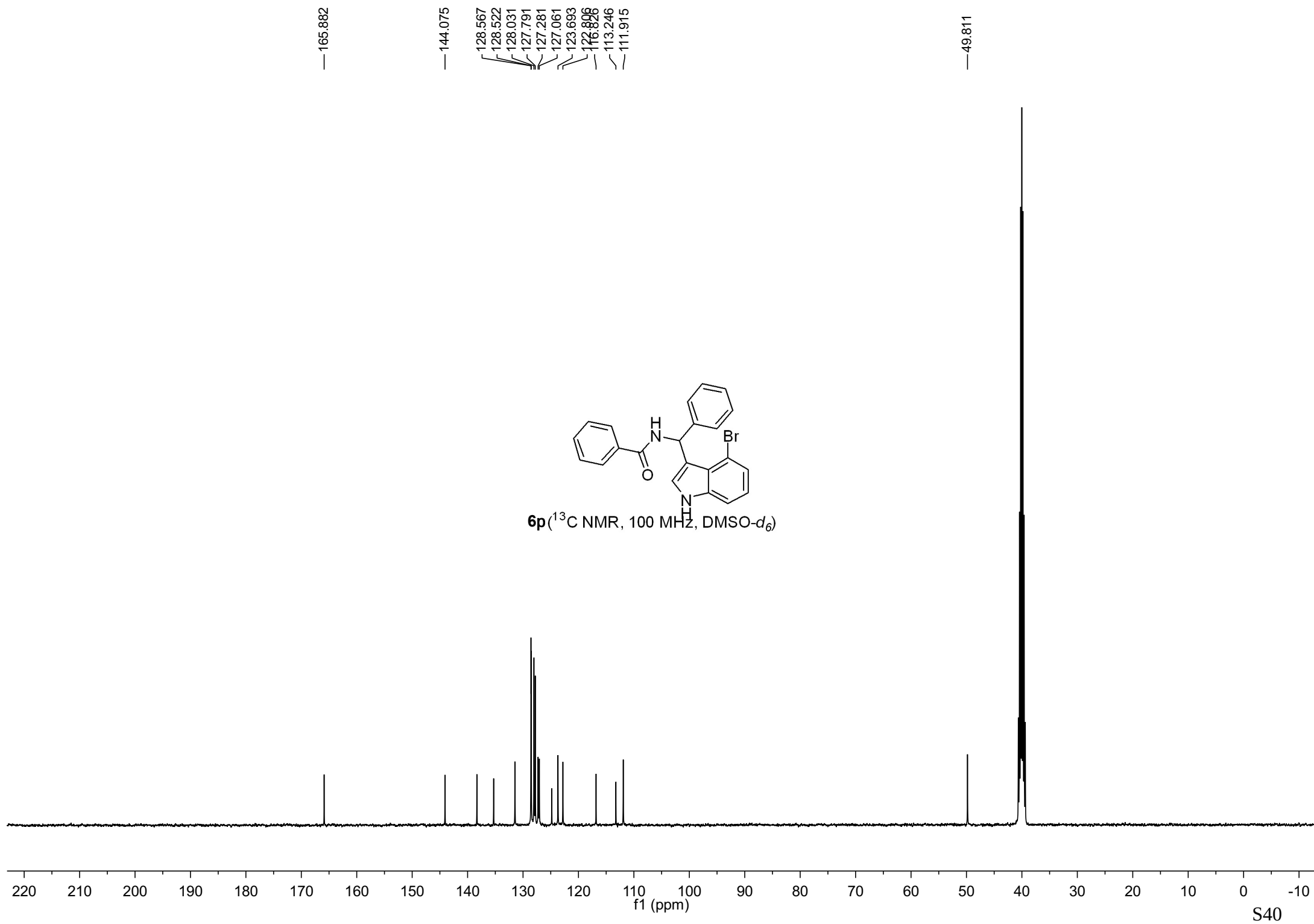
6n (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

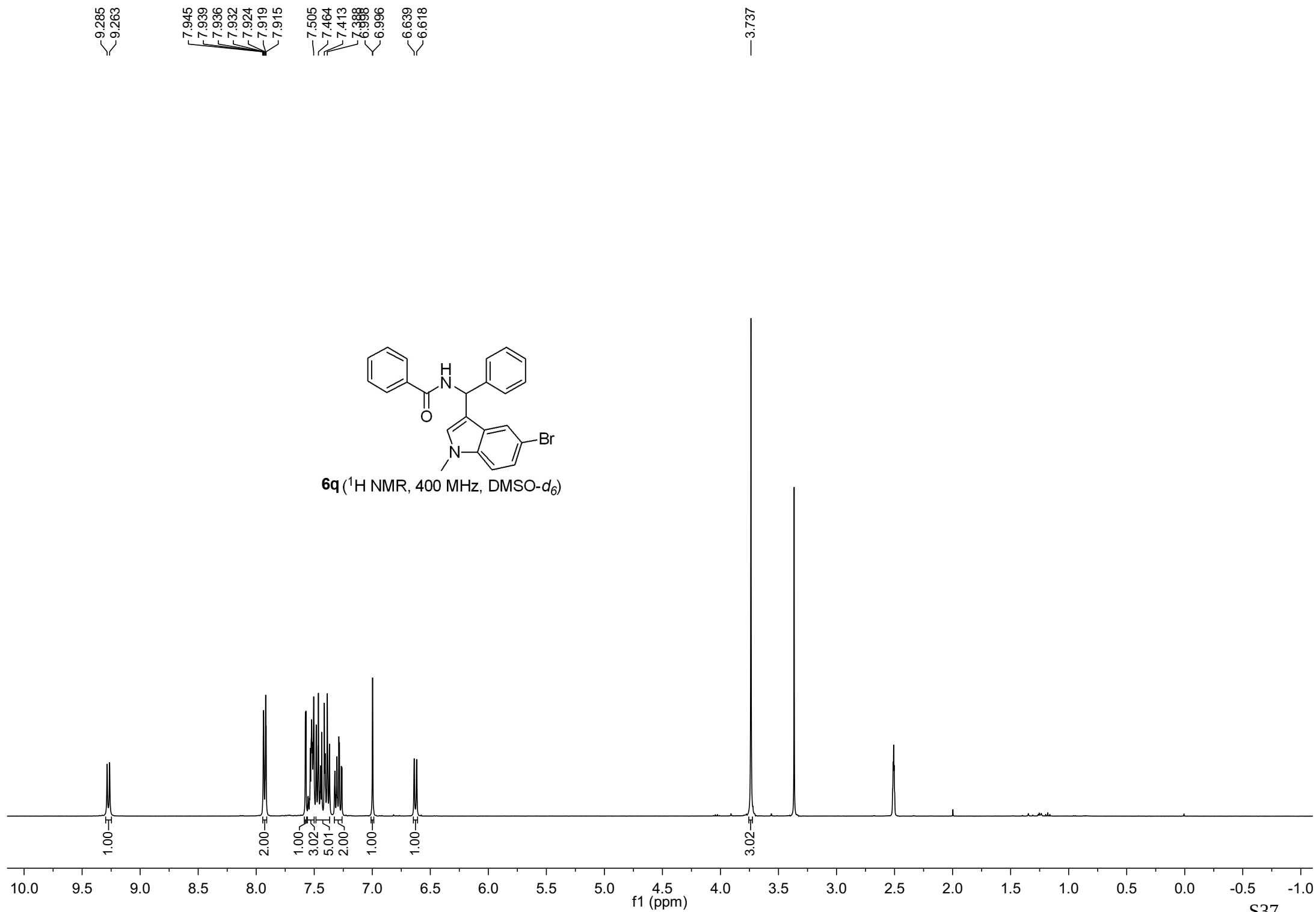


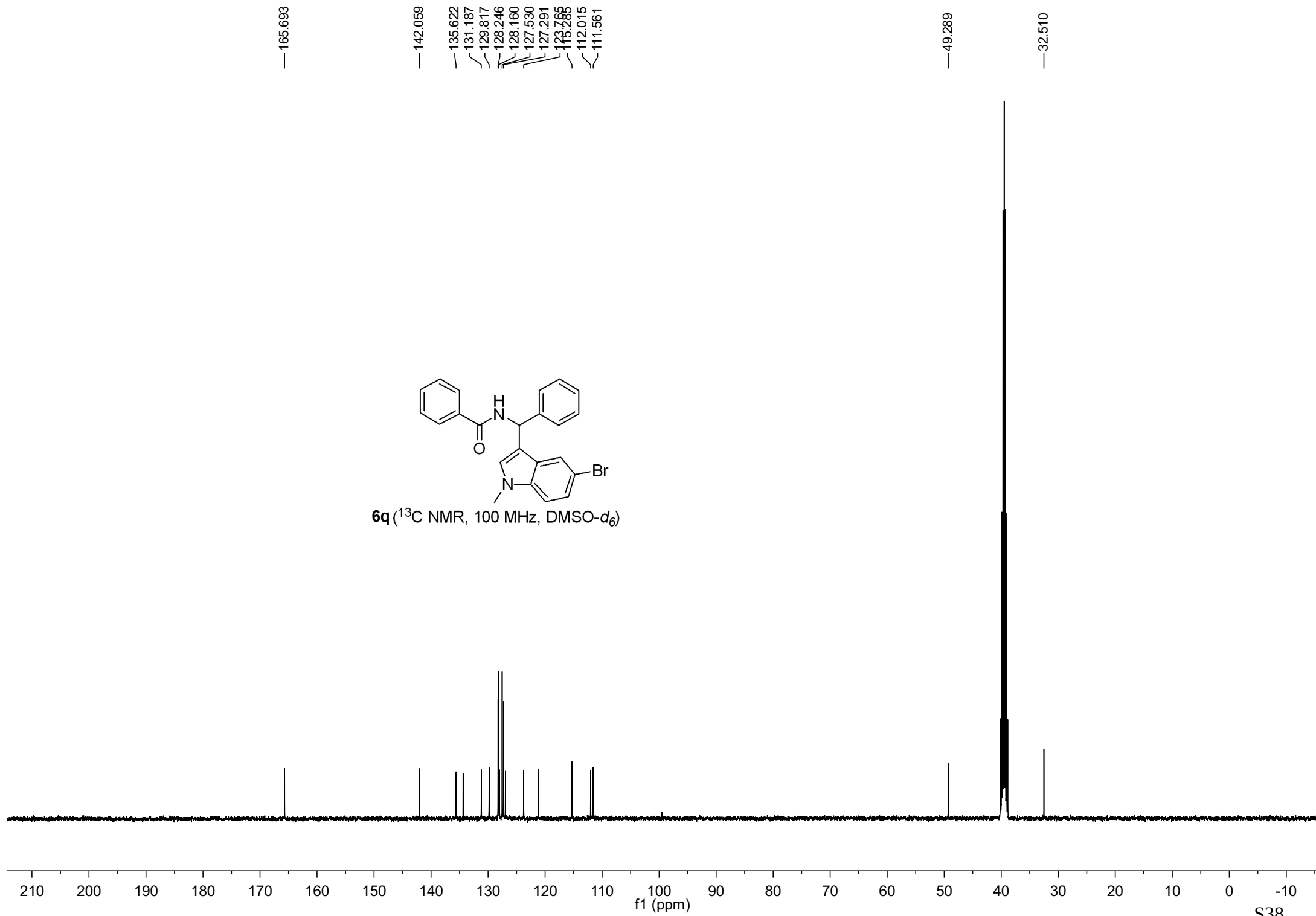


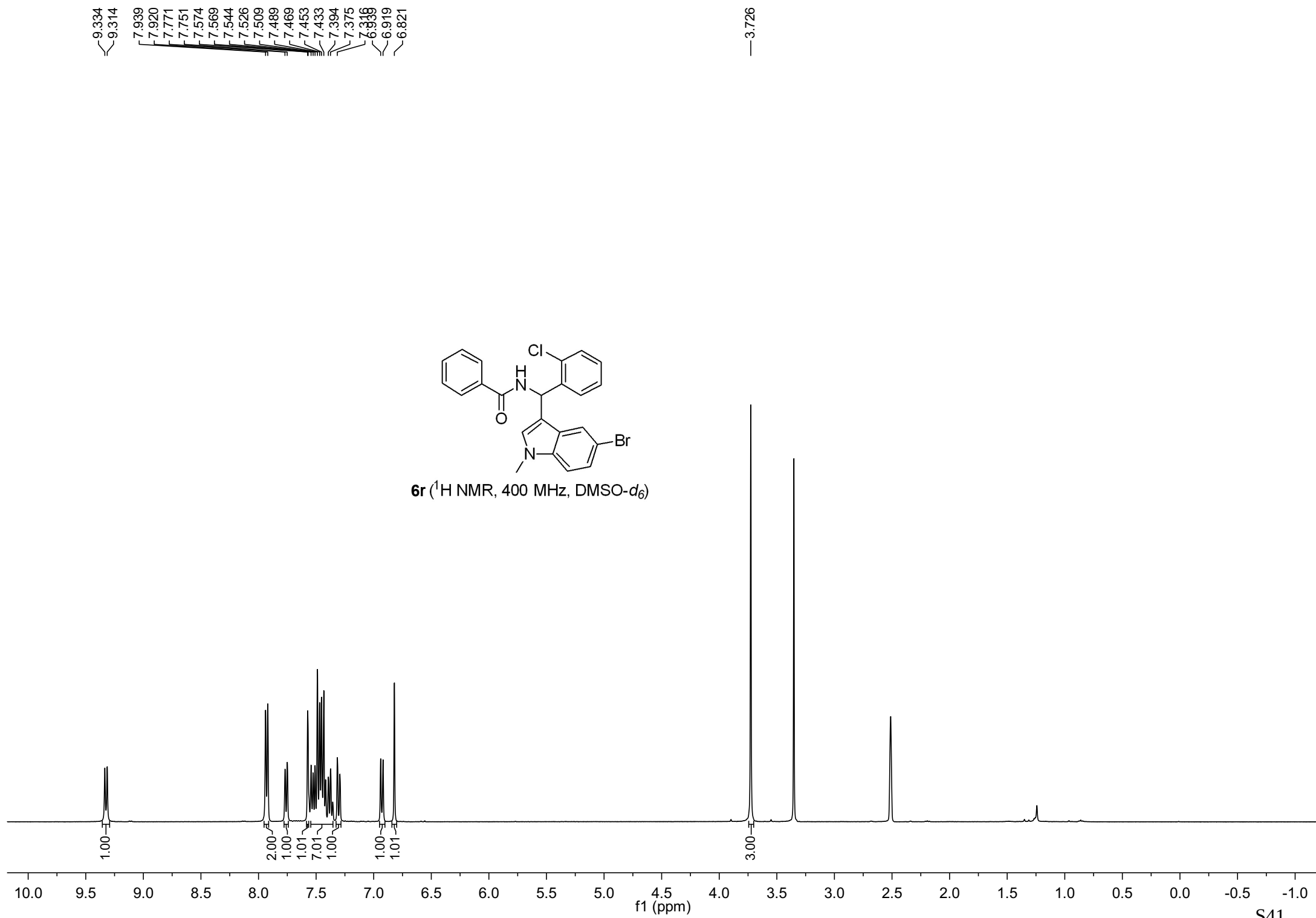


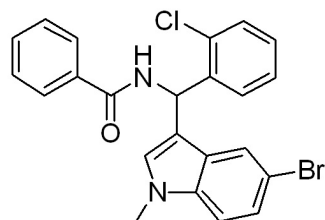




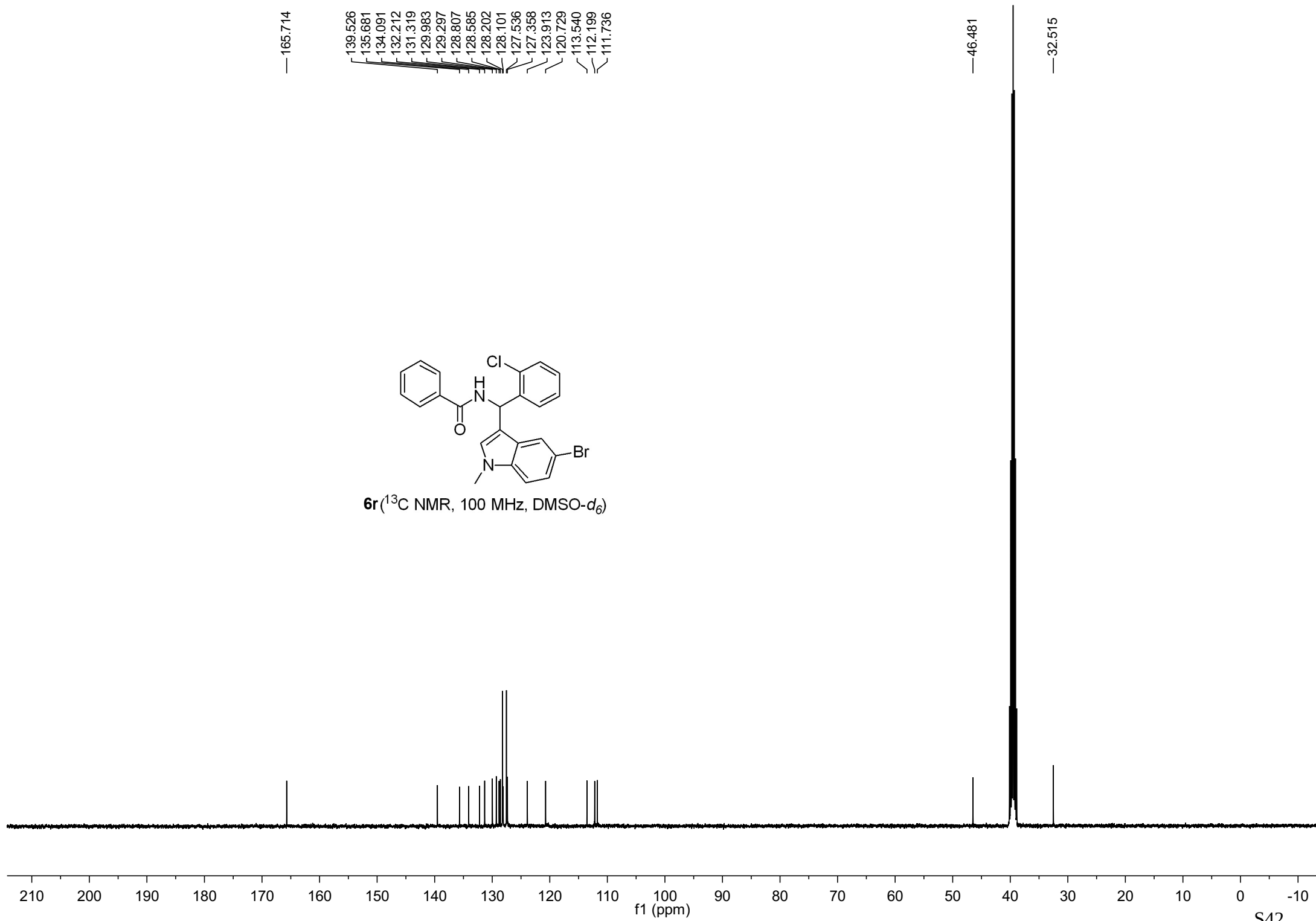


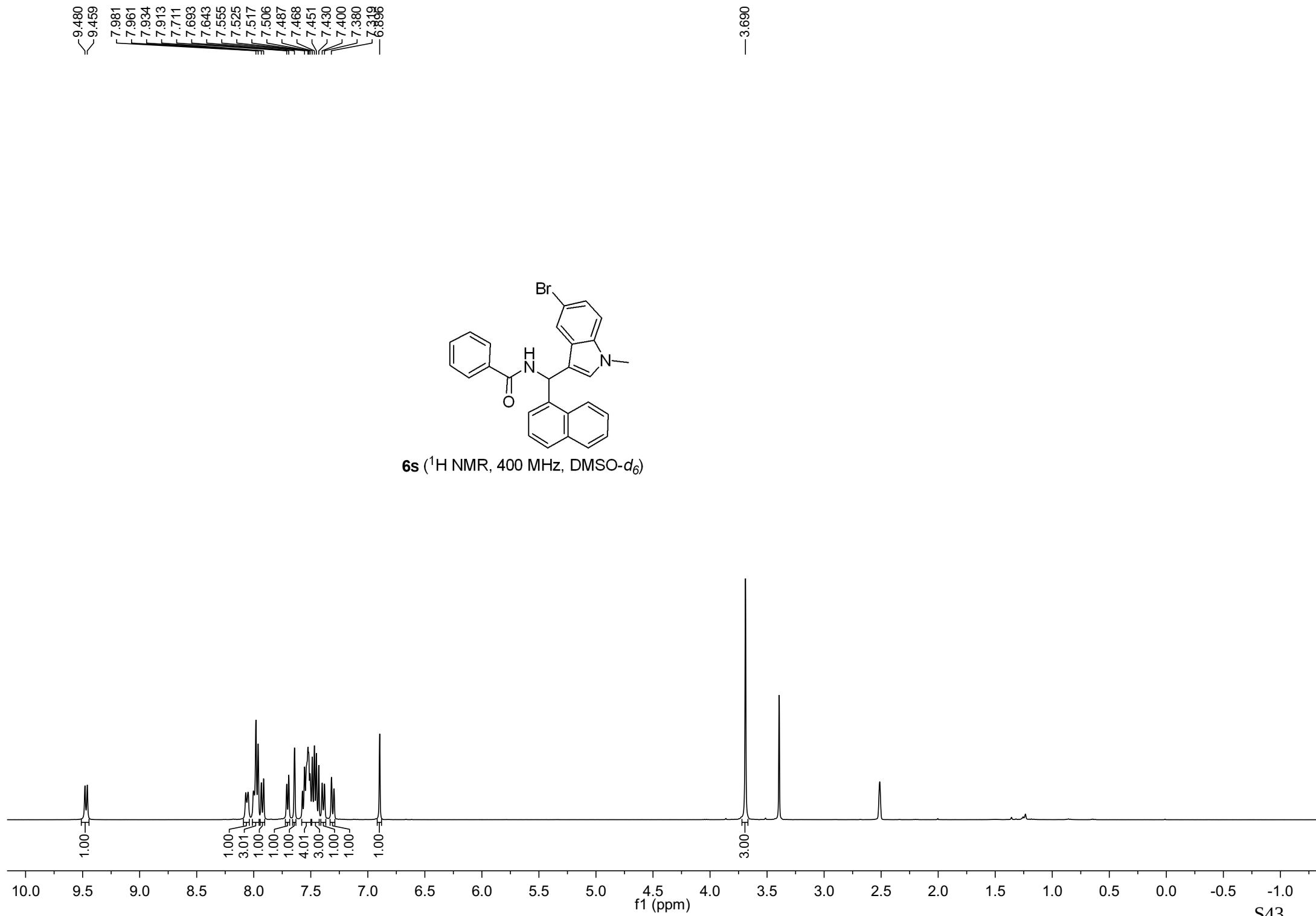


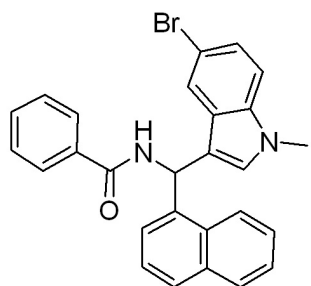




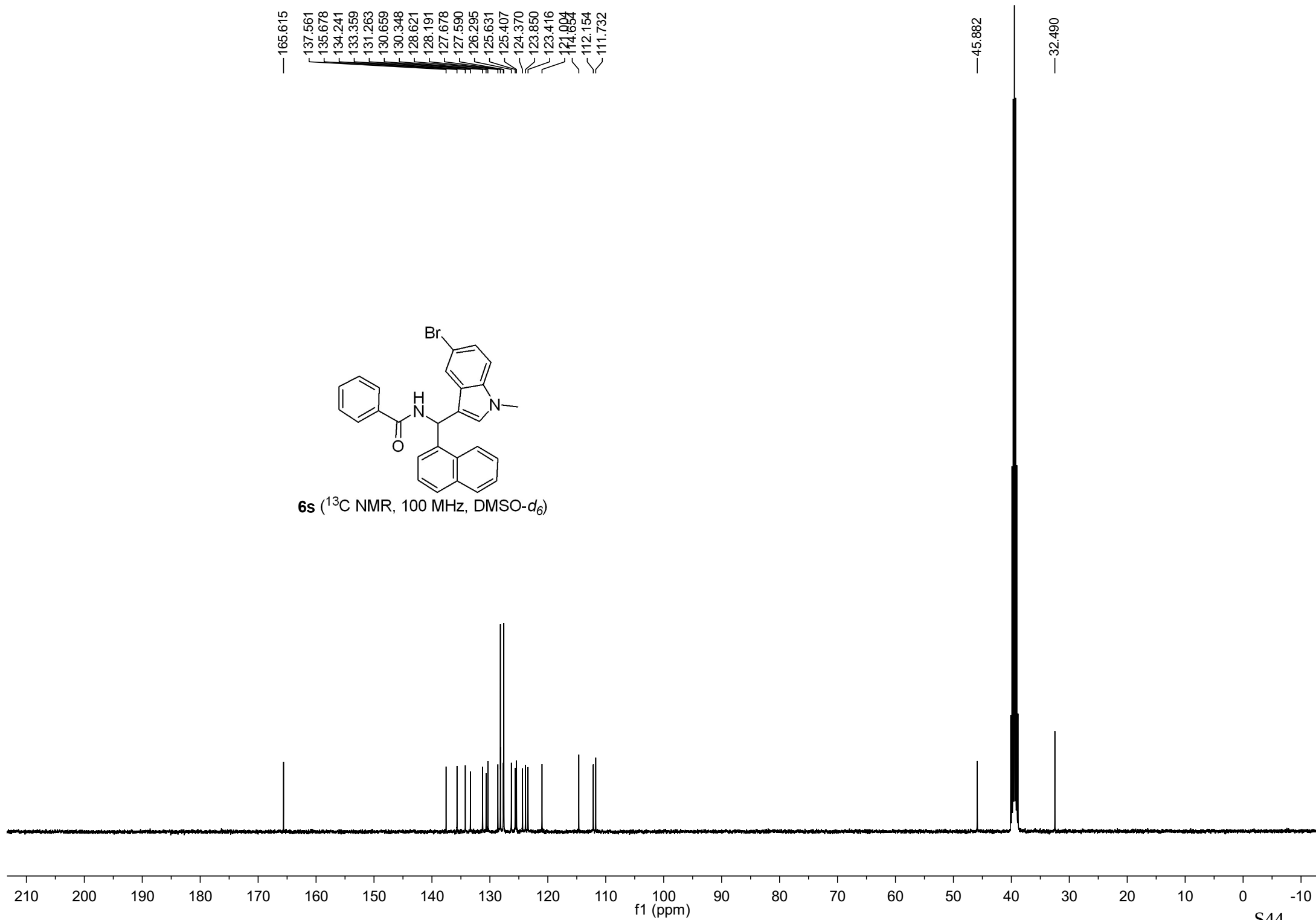
6r (^{13}C NMR, 100 MHz, $\text{DMSO-}d_6$)

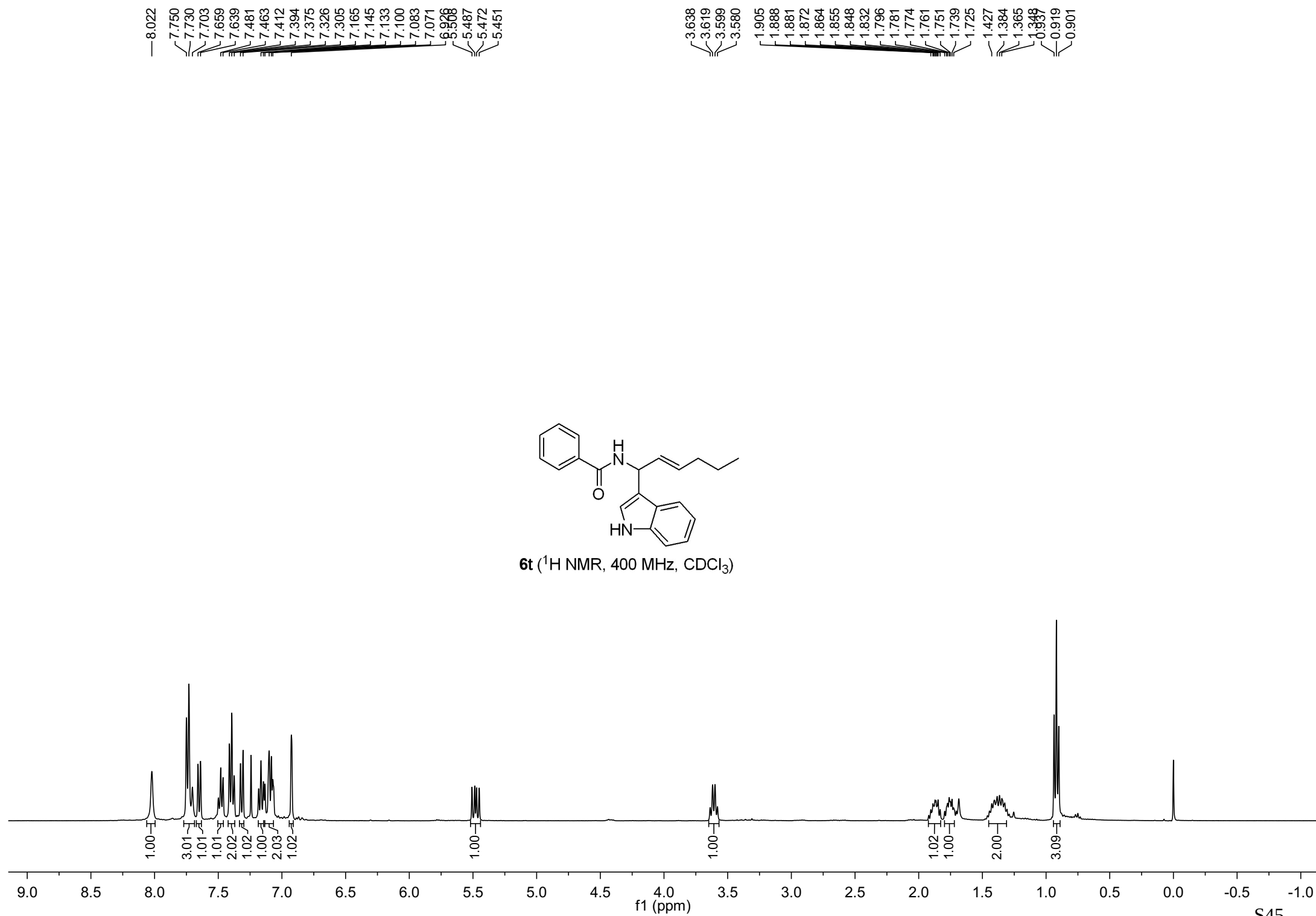


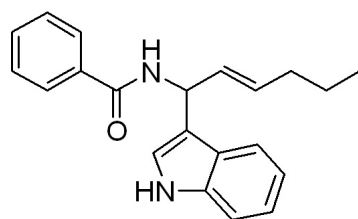




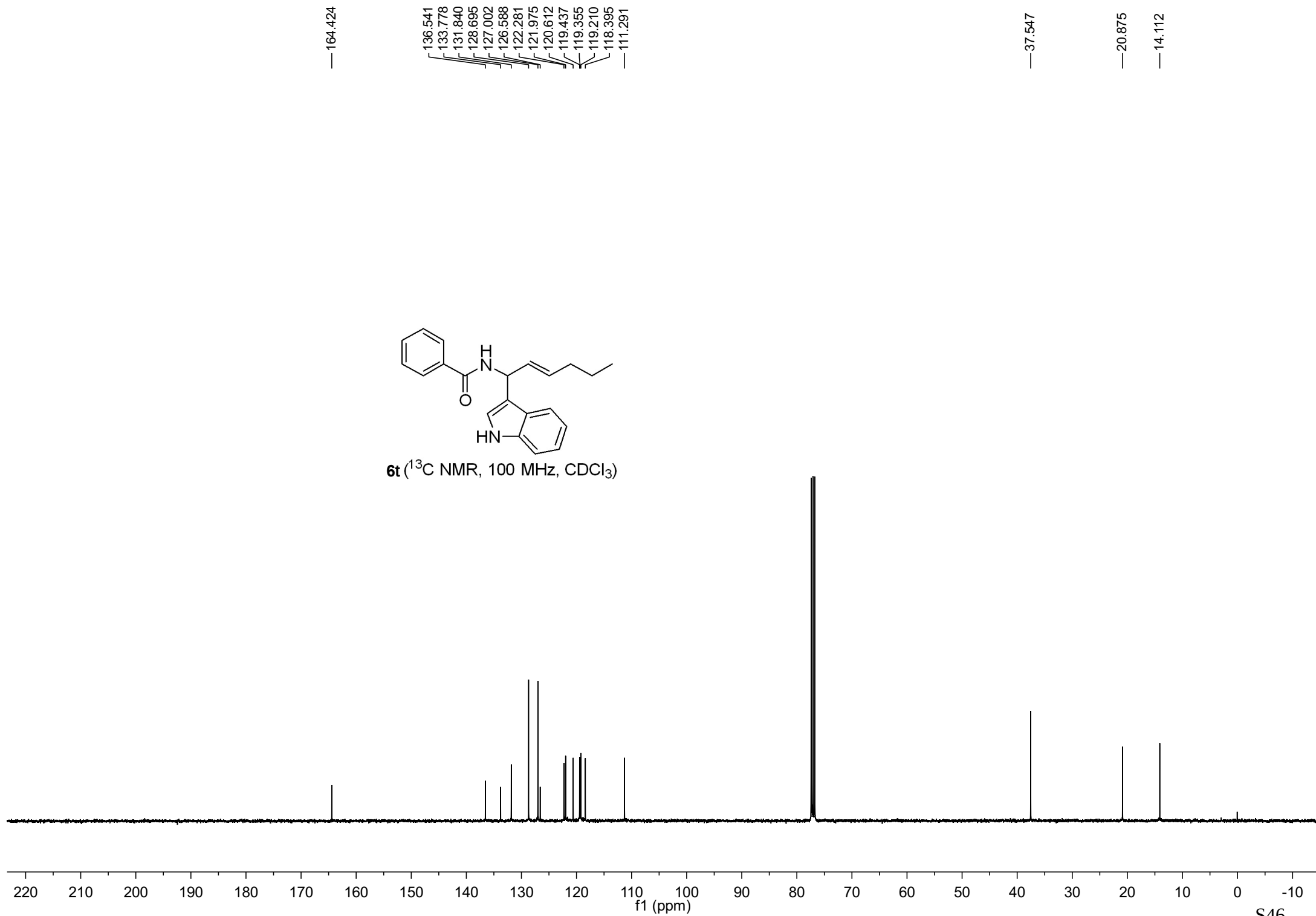
6s (^{13}C NMR, 100 MHz, $\text{DMSO-}d_6$)

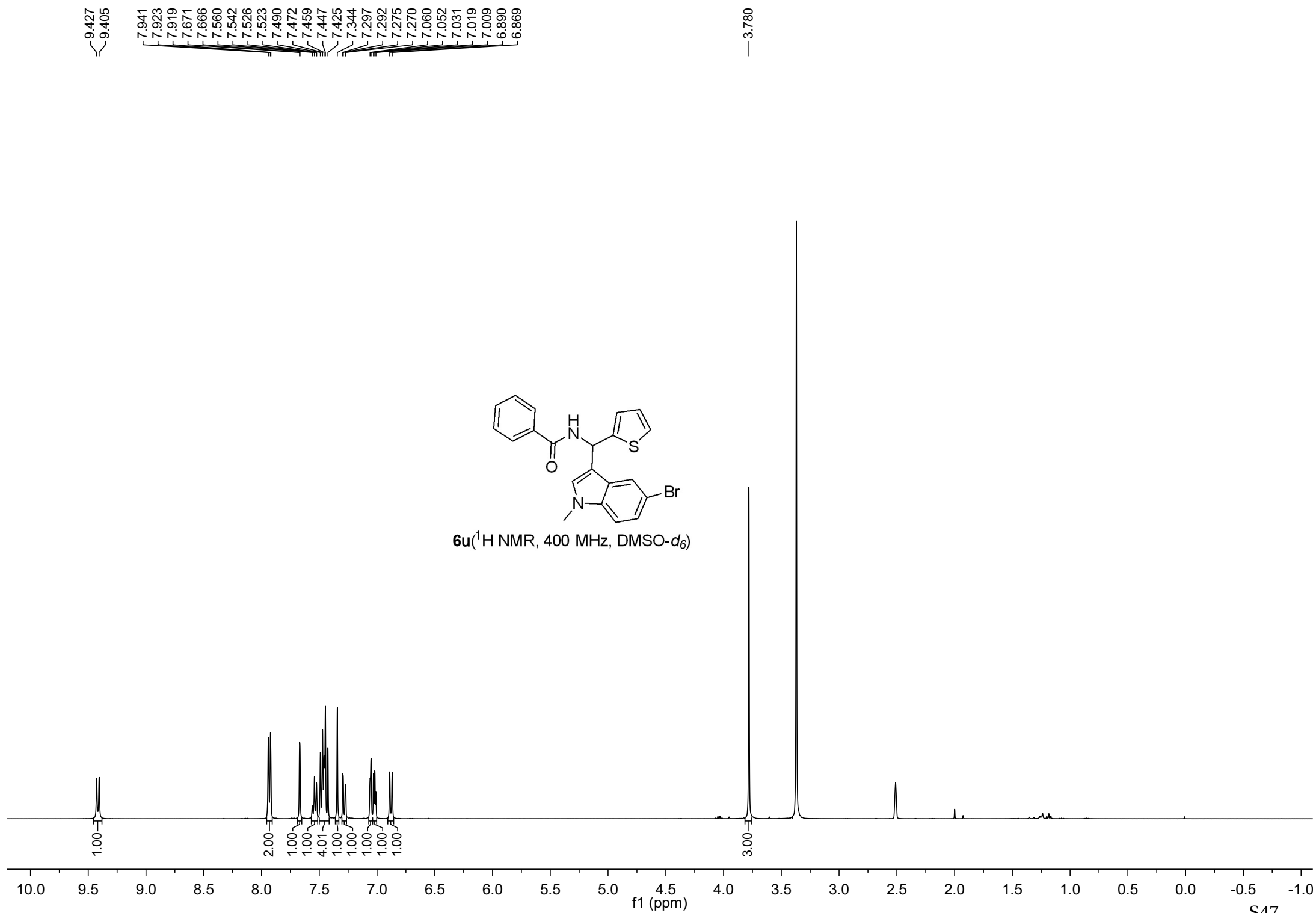


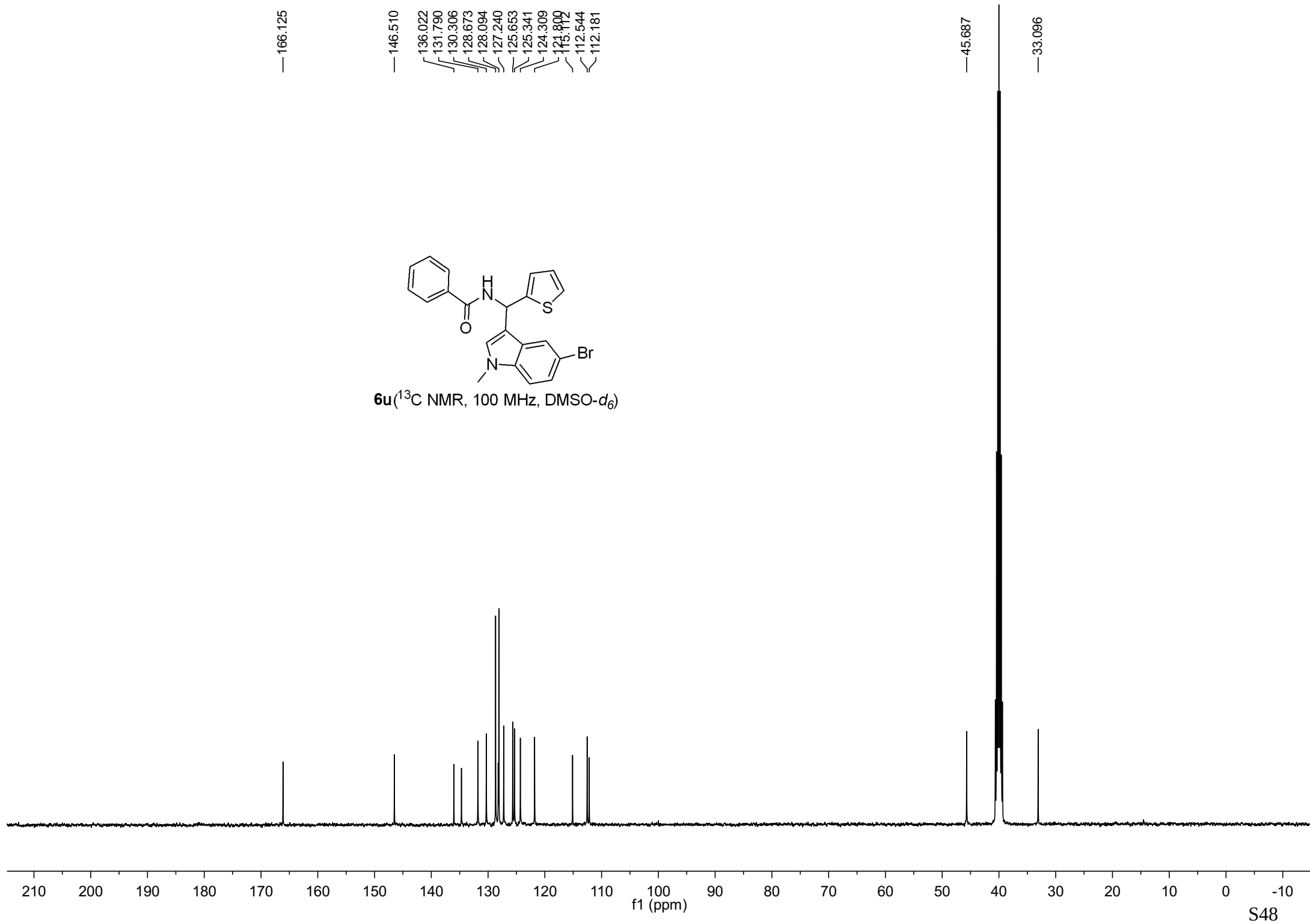


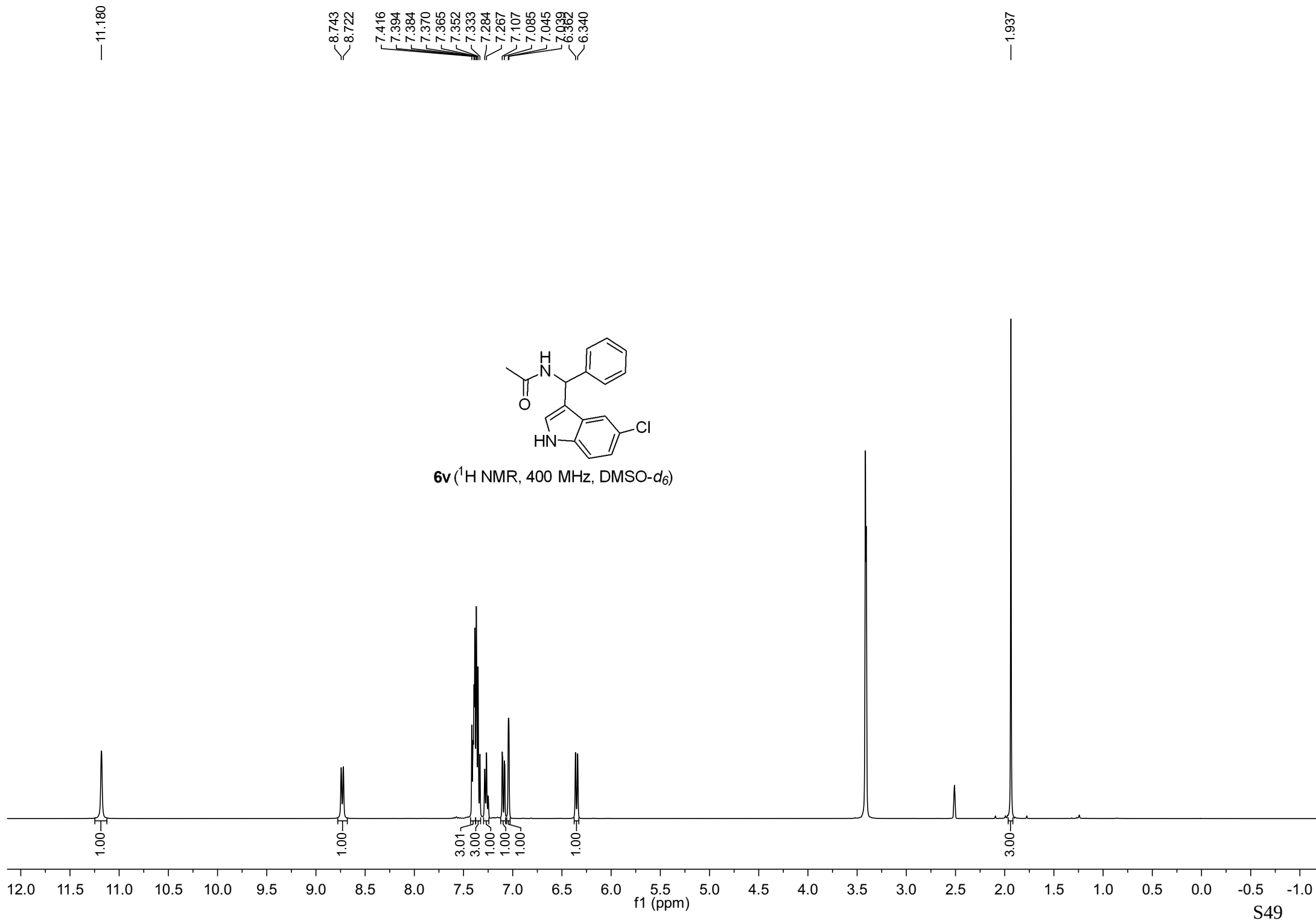


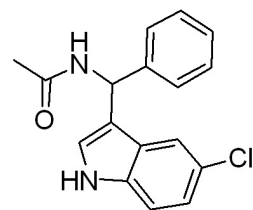
6t (^{13}C NMR, 100 MHz, CDCl_3)











6v (^{13}C NMR, 100 MHz, $\text{DMSO-}d_6$)

— 168.845

— 142.986

— 135.492

— 128.671

— 127.469

— 127.336

— 127.261

— 125.877

— 123.750

— 121.686

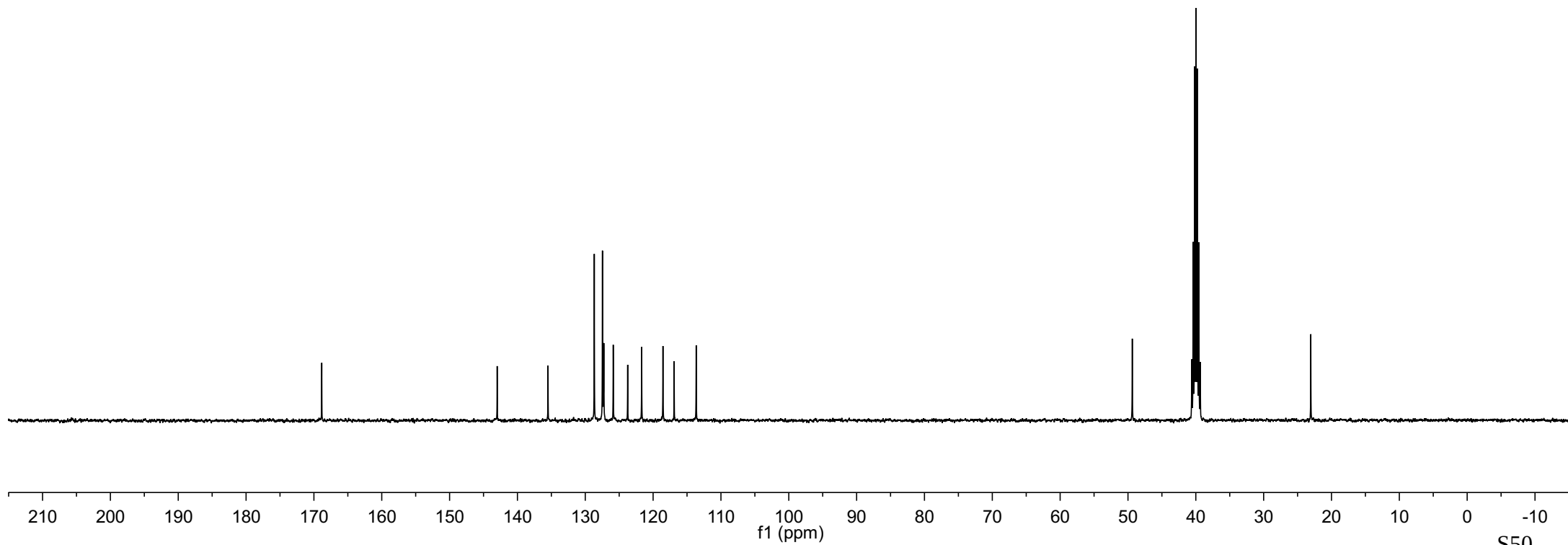
— 118.548

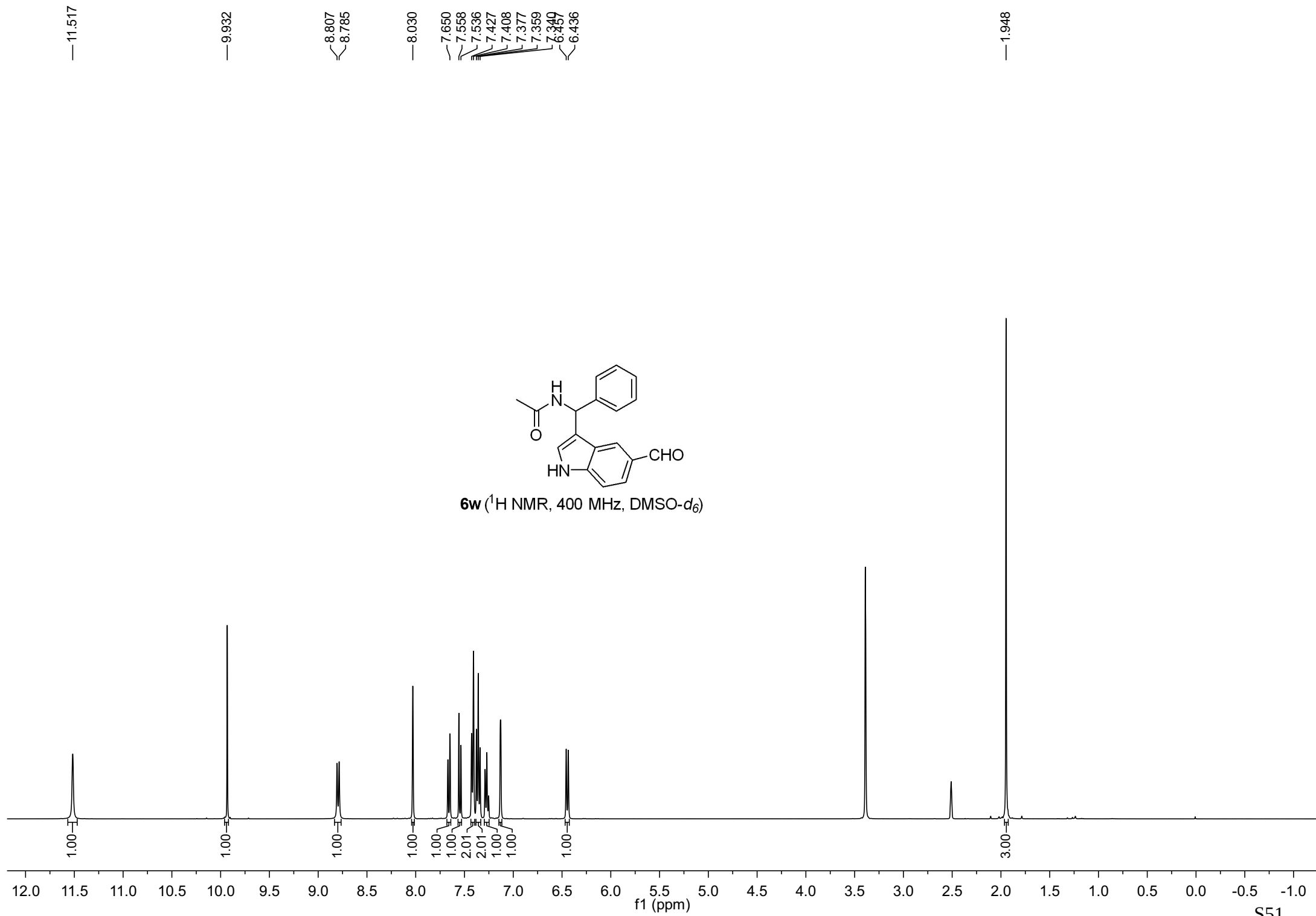
— 116.899

— 113.648

— 49.365

— 23.051





—192.858

—168.874

—143.042

—140.455

129.033

128.721

127.495

127.326

126.243

126.165

124.547

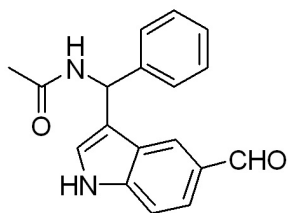
121.957

119.161

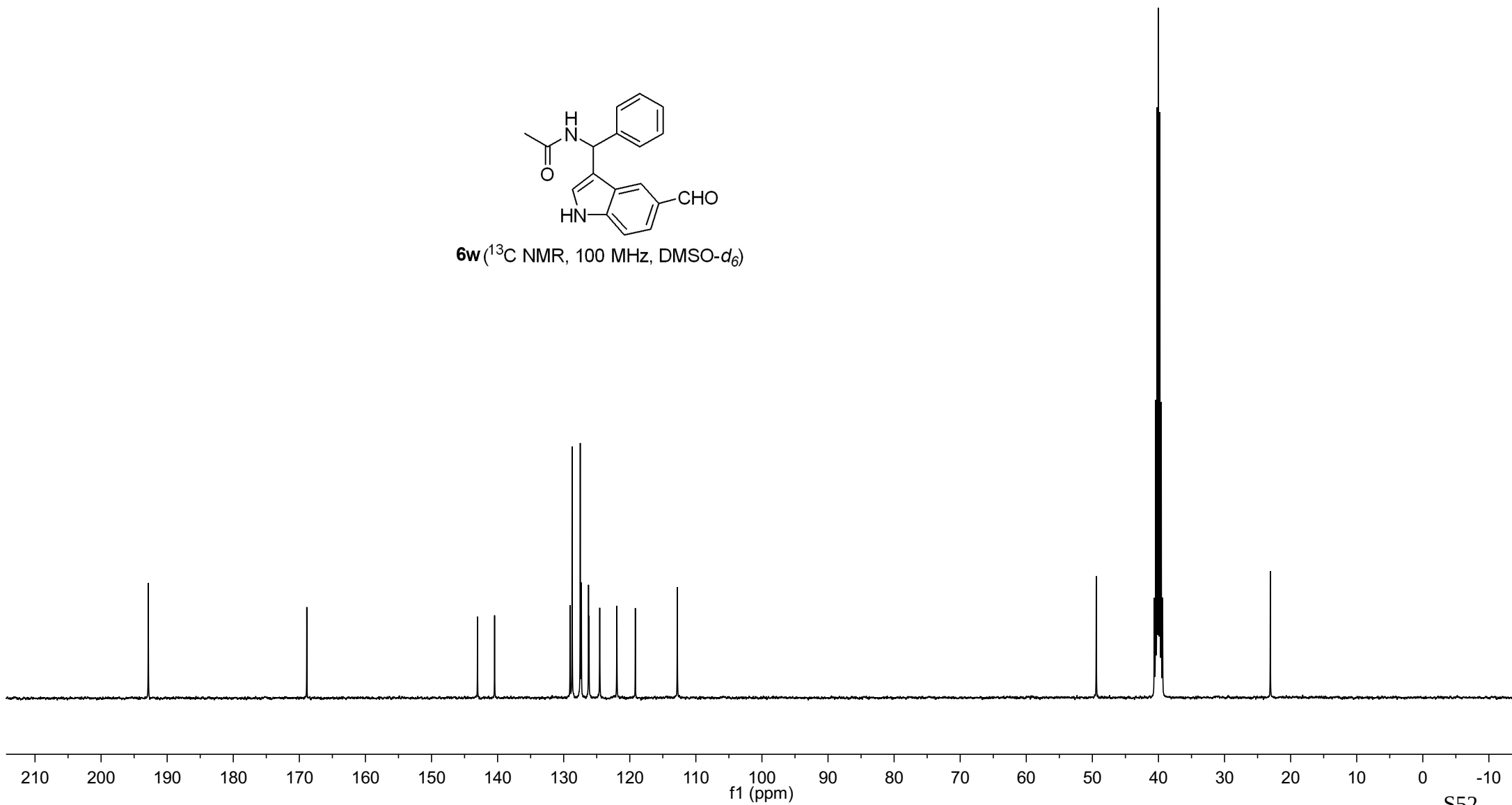
—112.807

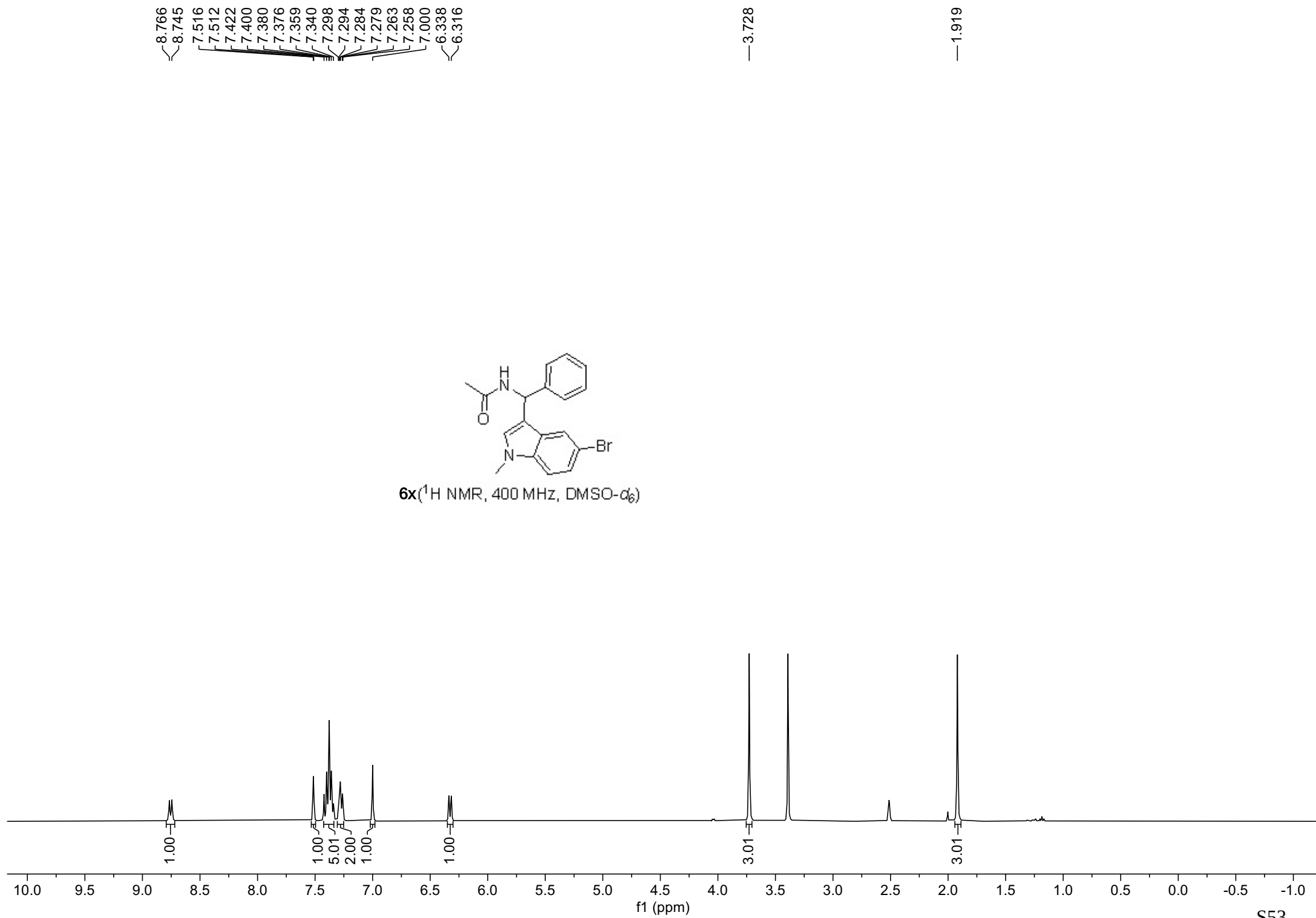
—49.408

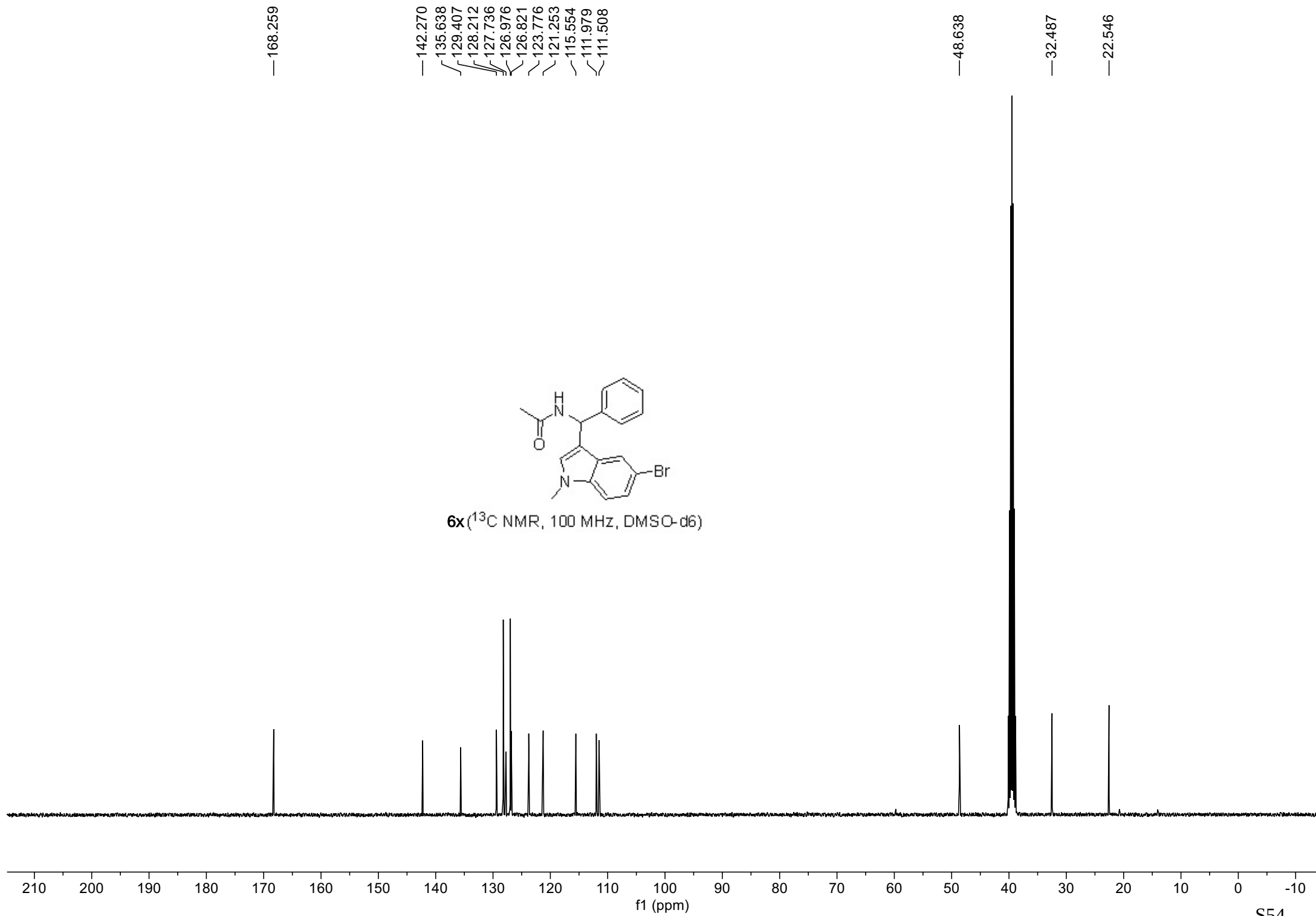
—23.070

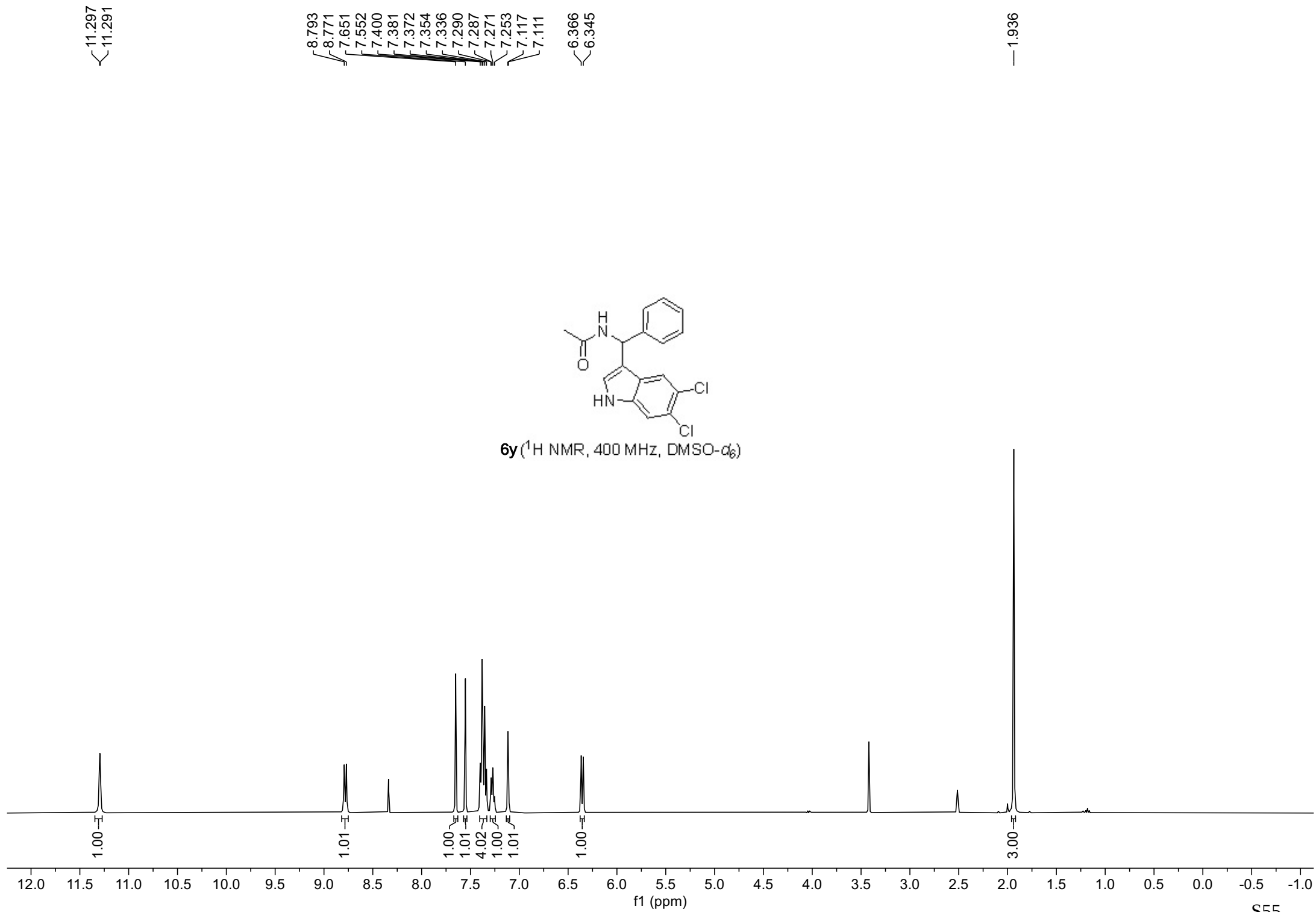


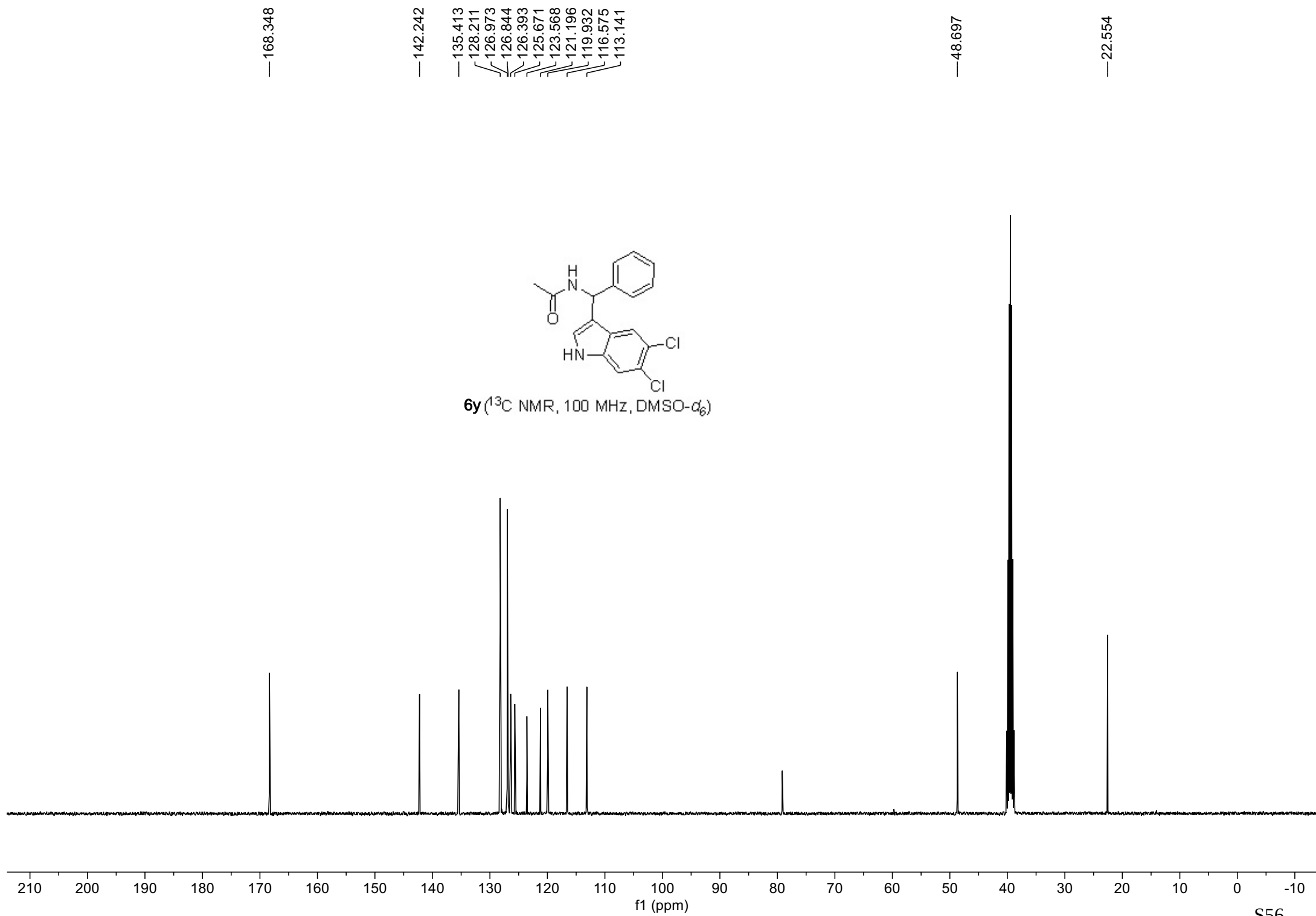
6w (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

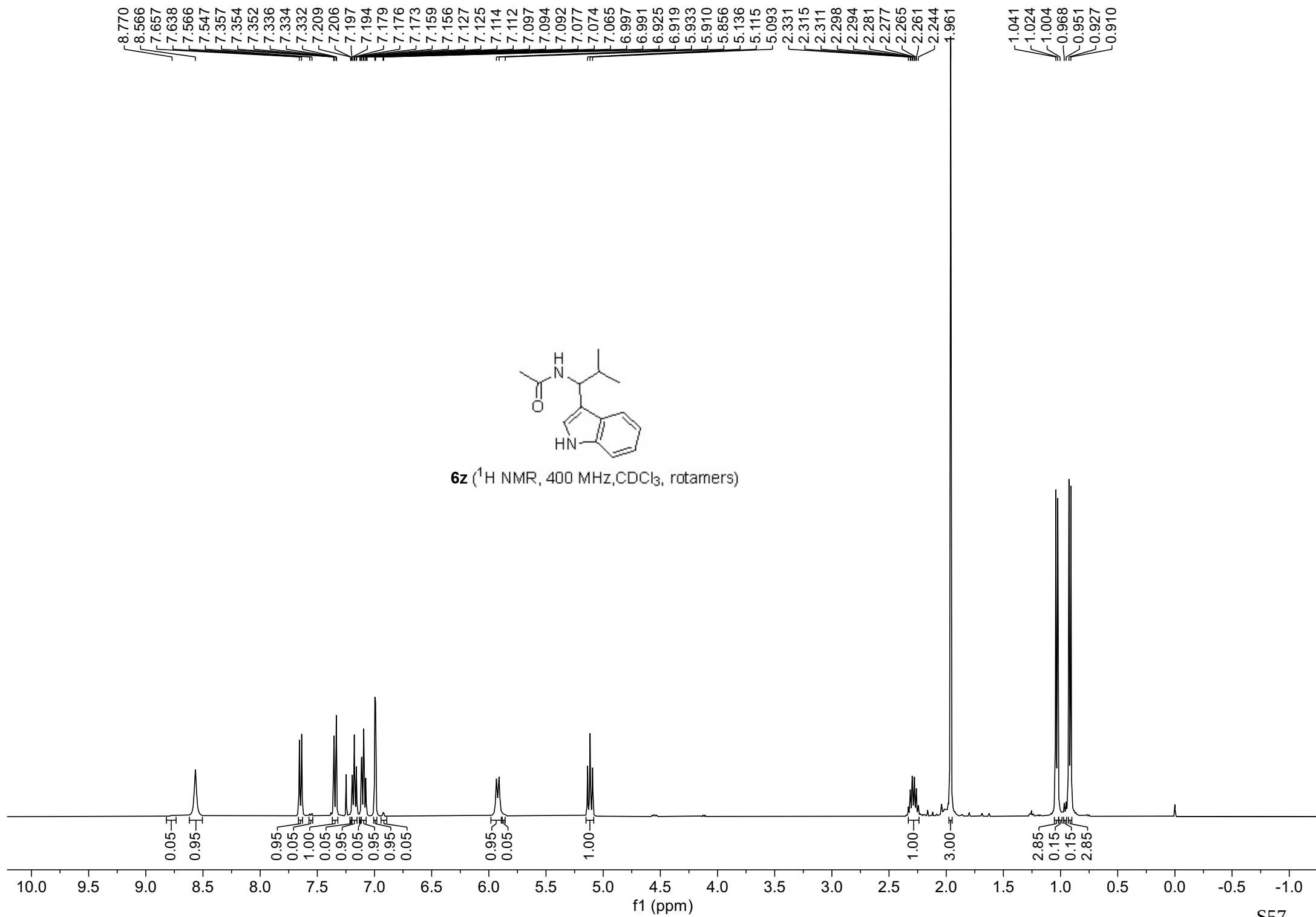


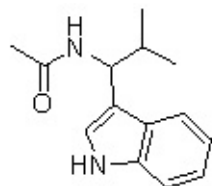












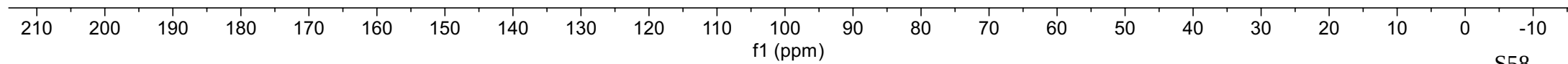
6z (^{13}C NMR, 100 MHz, CDCl_3 , rotamers)

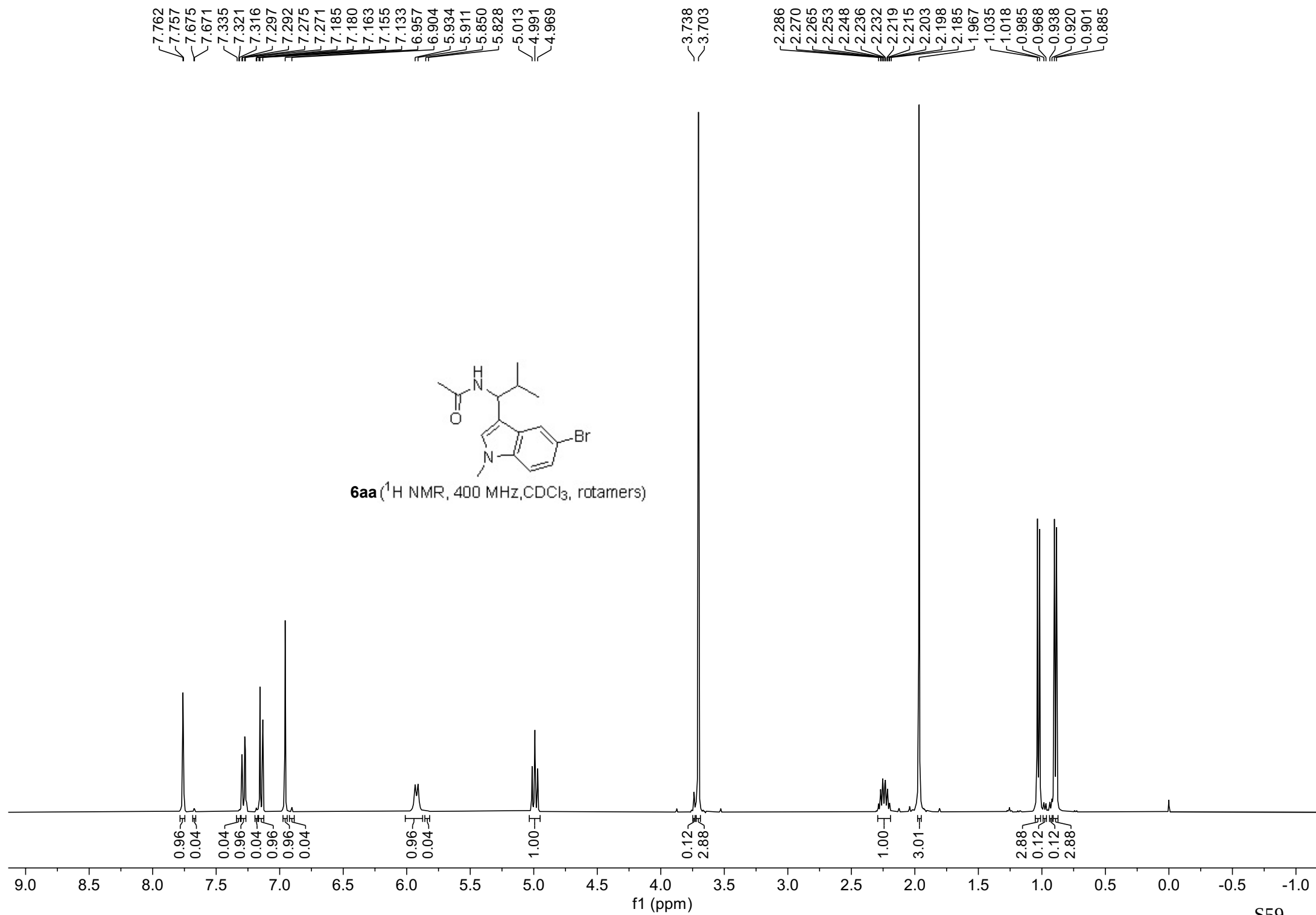
—173.414
—169.572

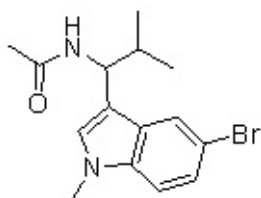
—136.549
—126.166
—125.681
—122.231
—122.174
—122.126
—121.780
—119.622
—119.547
—119.301
—118.784
—116.645
—116.246
—111.684
—111.520

—57.248
—52.556

—33.445
—32.545
—23.518
—20.583
—20.223
—19.813
—19.262
—18.060







6aa (^{13}C NMR, 100 MHz, CDCl_3 , rotamers)

—169.324

135.894

128.105

128.040

127.424

124.855

124.633

121.967

121.476

115.337

114.887

112.611

111.152

110.953

—56.872

—52.410

33.511

33.025

32.884

32.521

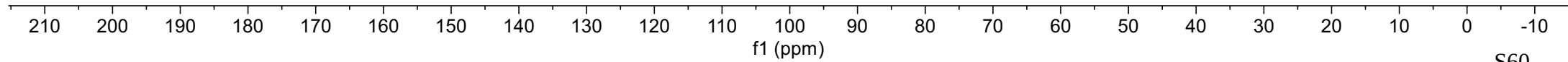
23.496

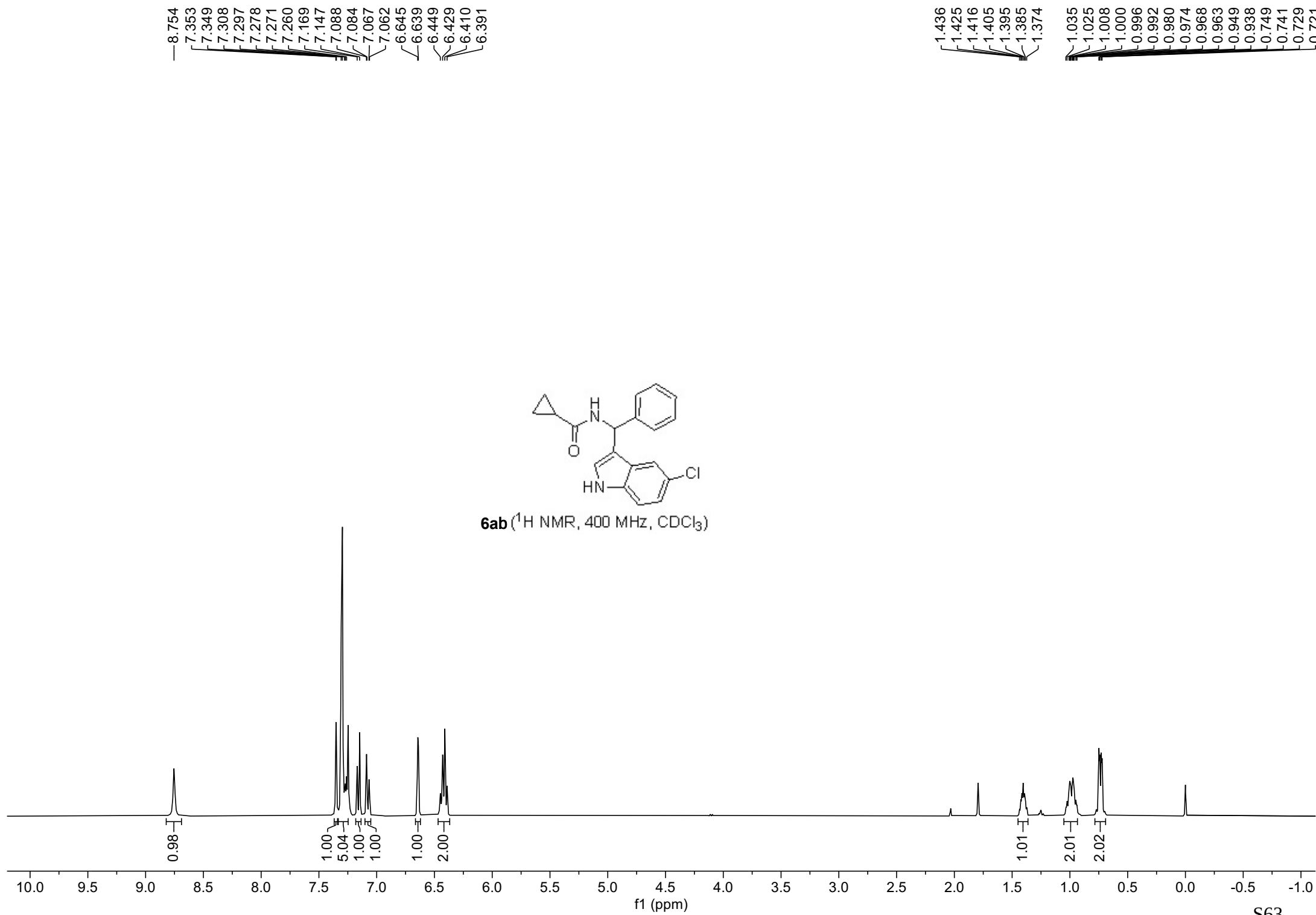
20.210

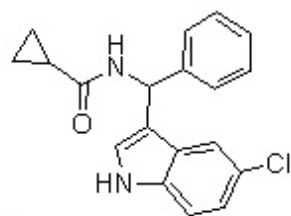
19.782

19.329

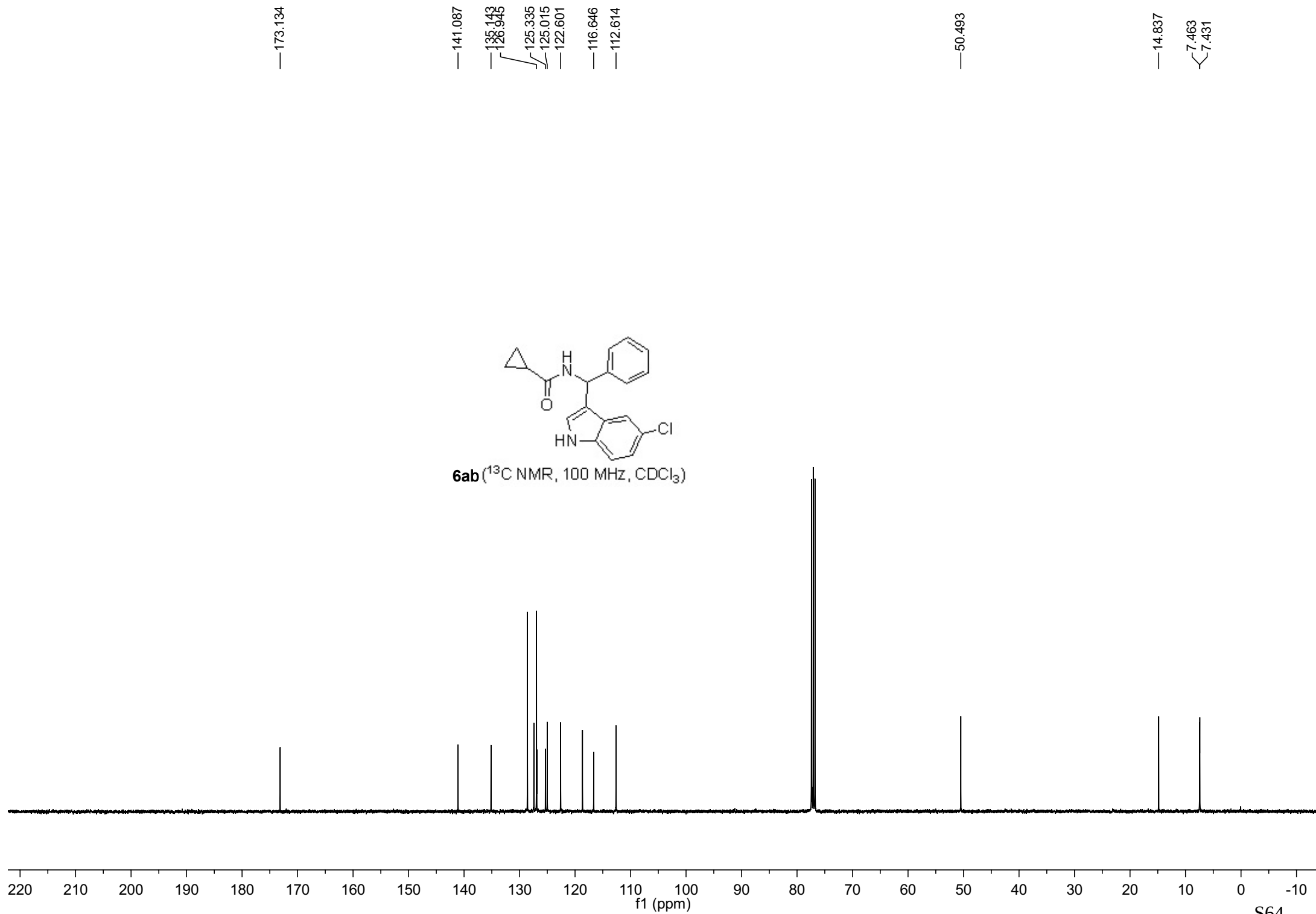
17.943







6ab (^{13}C NMR, 100 MHz, CDCl_3)



8.999
8.977

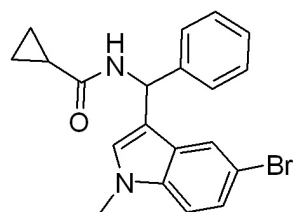
7.524
7.423
7.417
7.400
7.392
7.374
7.355
7.306
7.288
7.267
6.953

6.387
6.366

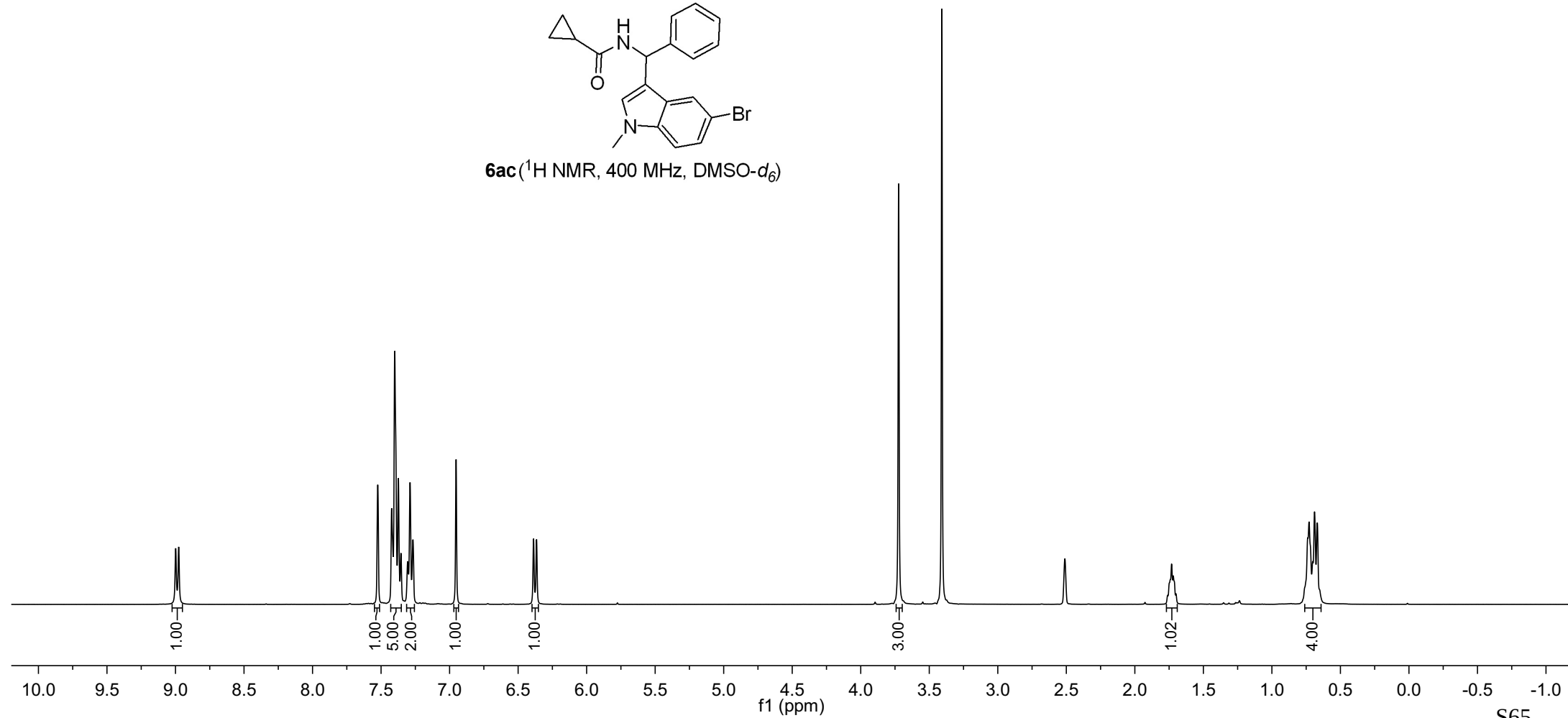
3.724

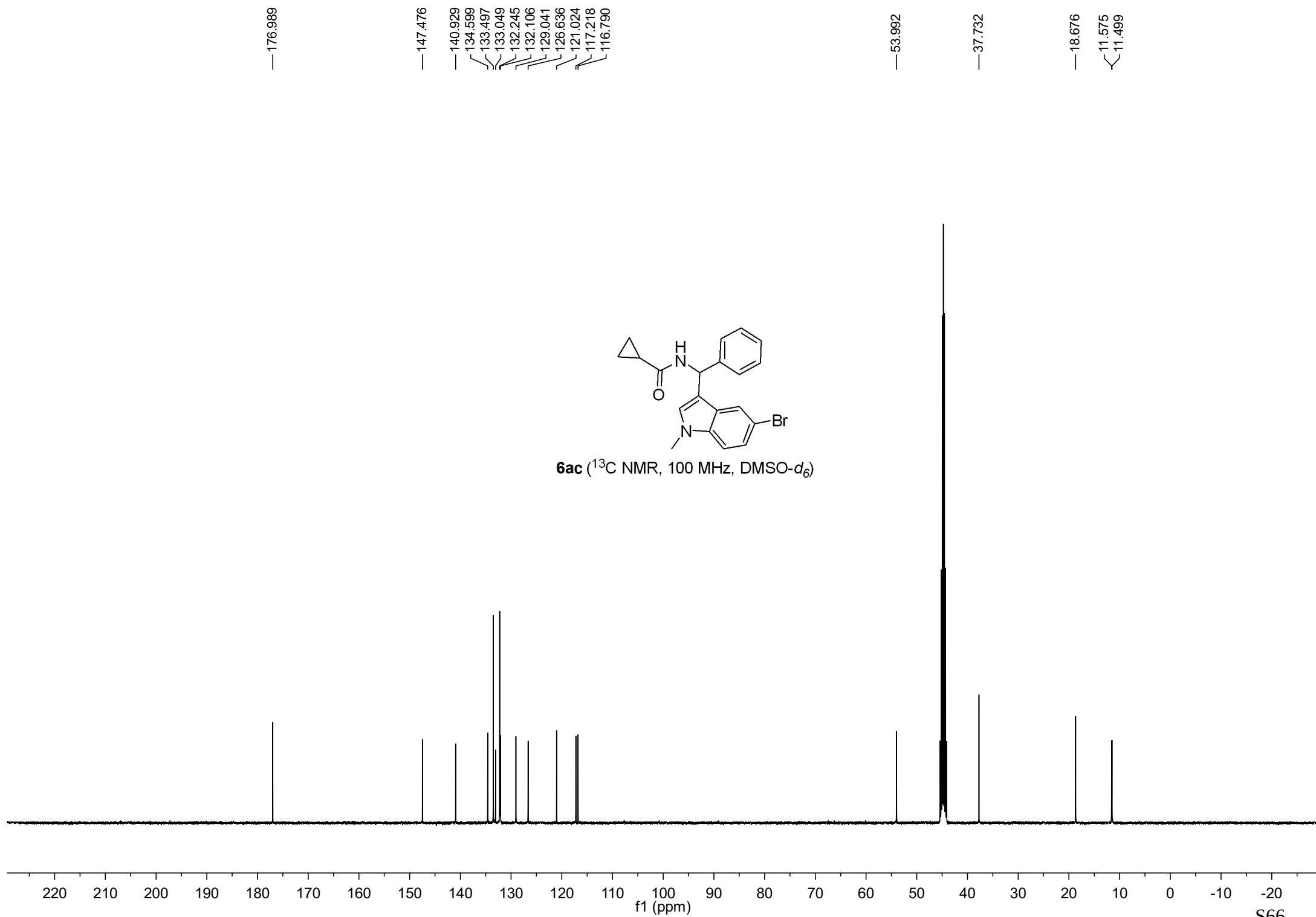
1.762
1.750
1.742
1.732
1.719
1.711
1.699

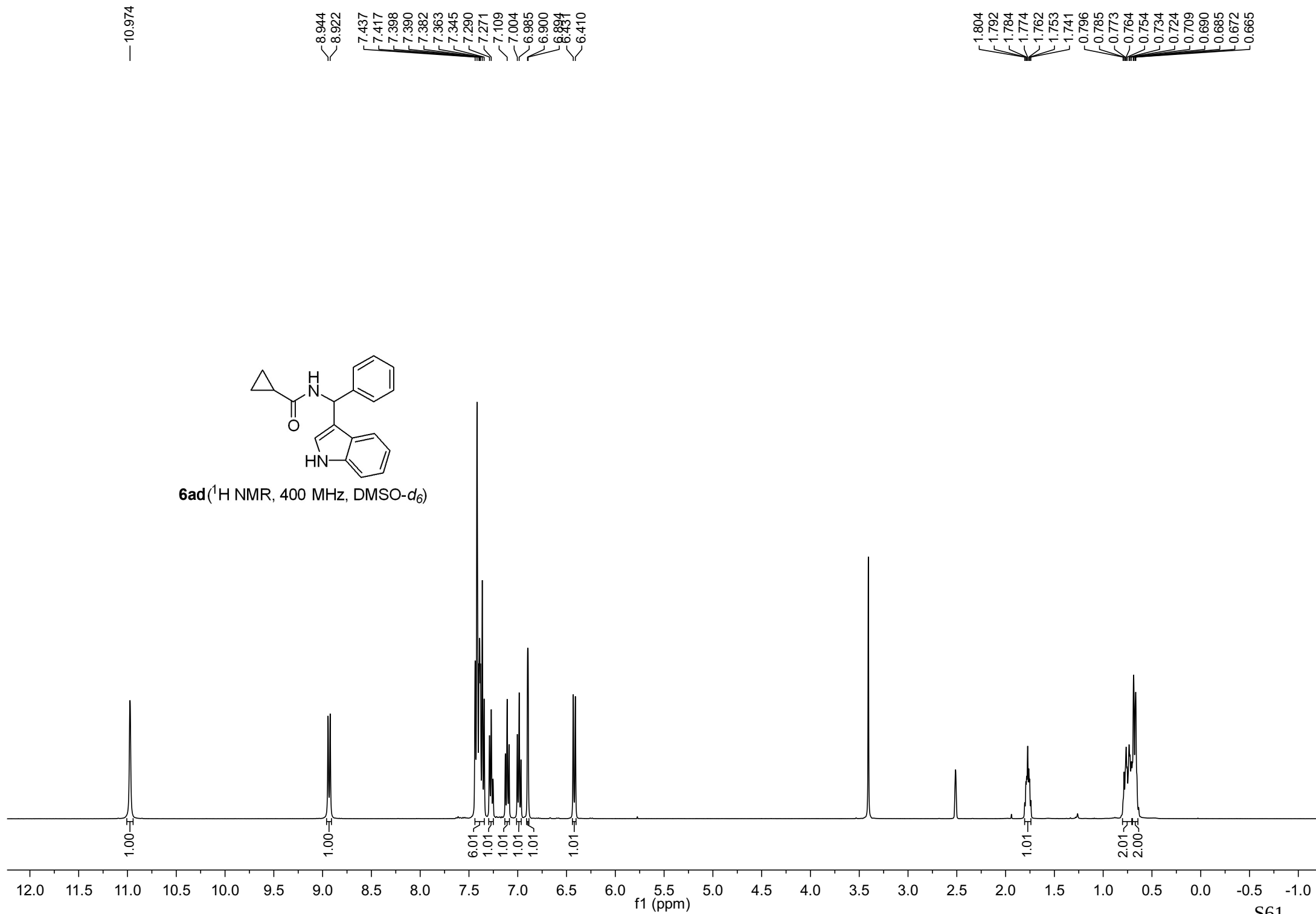
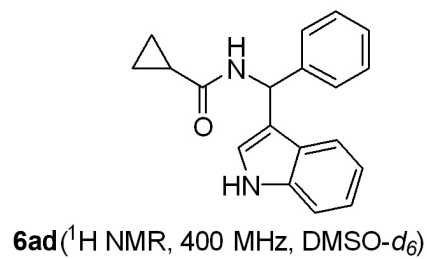
0.761
0.740
0.729
0.718
0.703
0.689
0.669

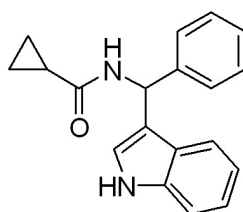


6ac (^1H NMR, 400 MHz, $\text{DMSO}-d_6$)

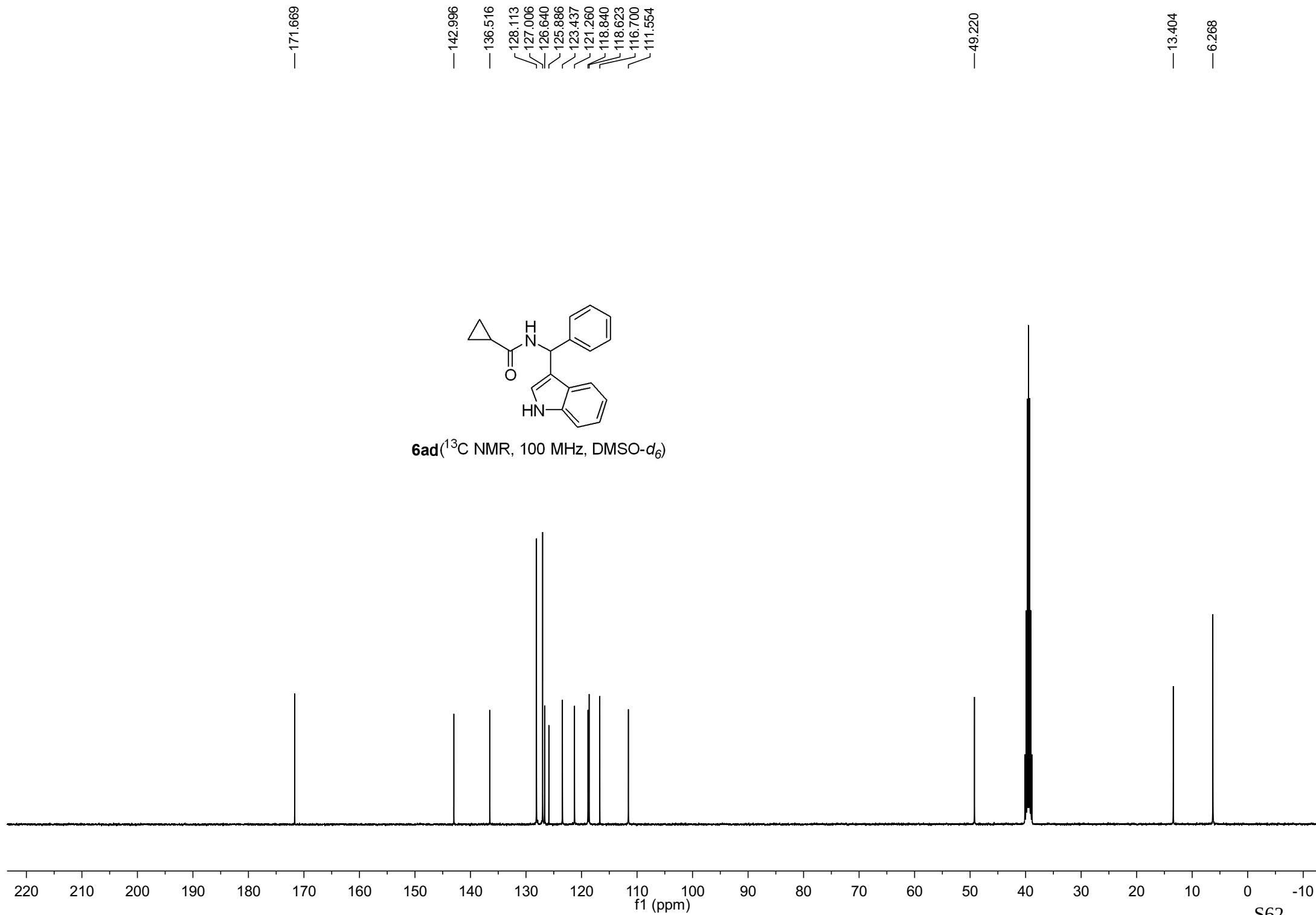


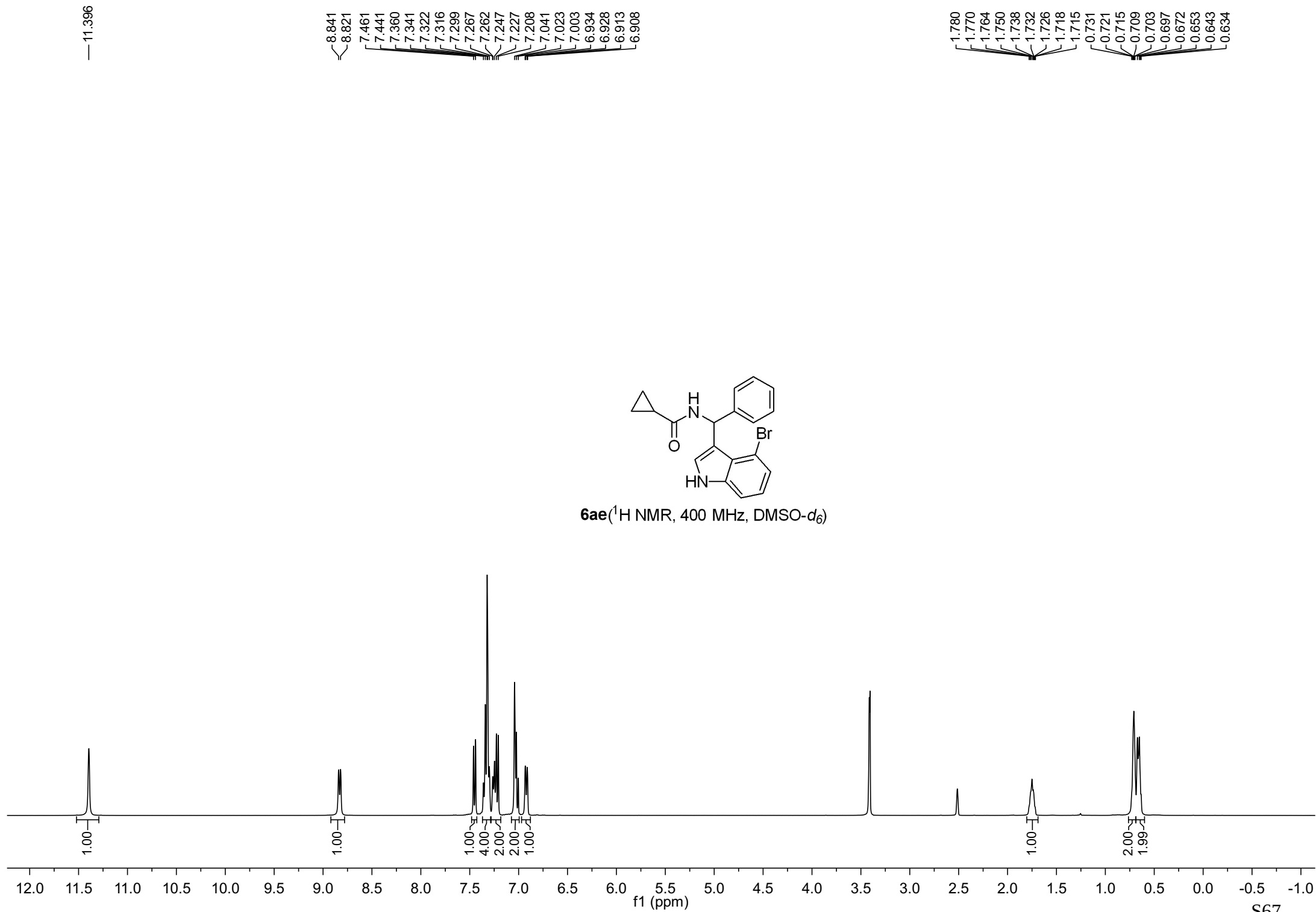


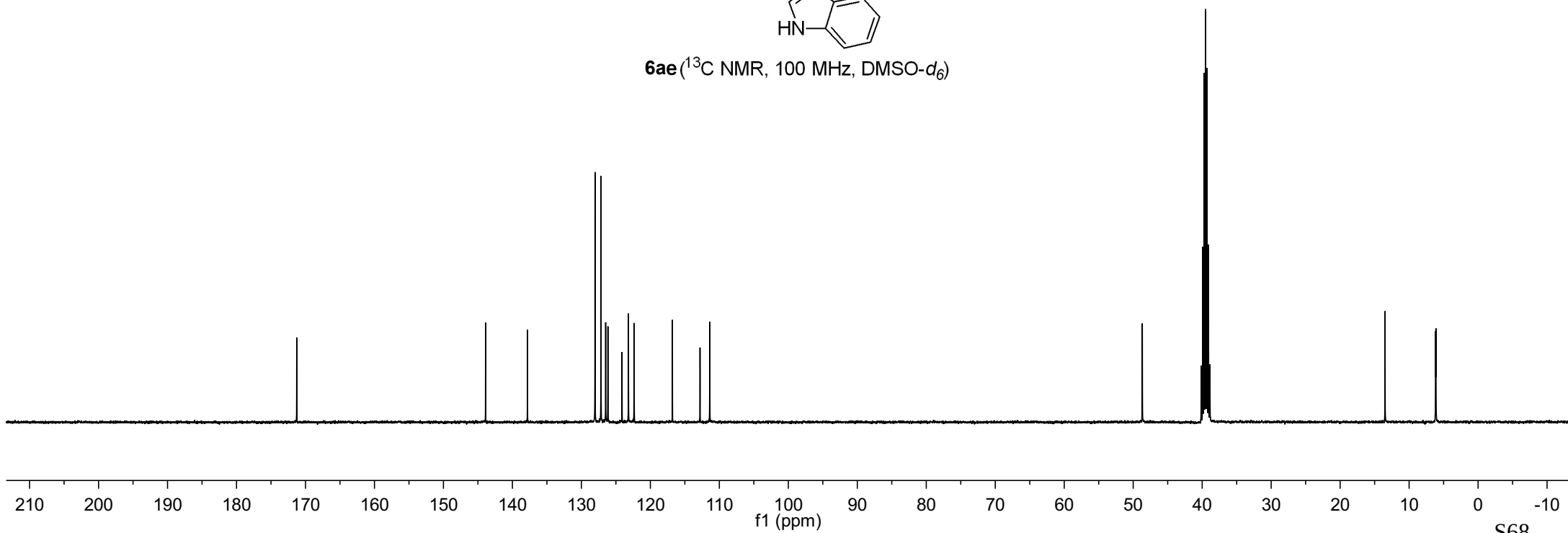
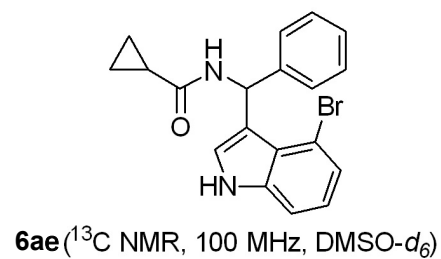


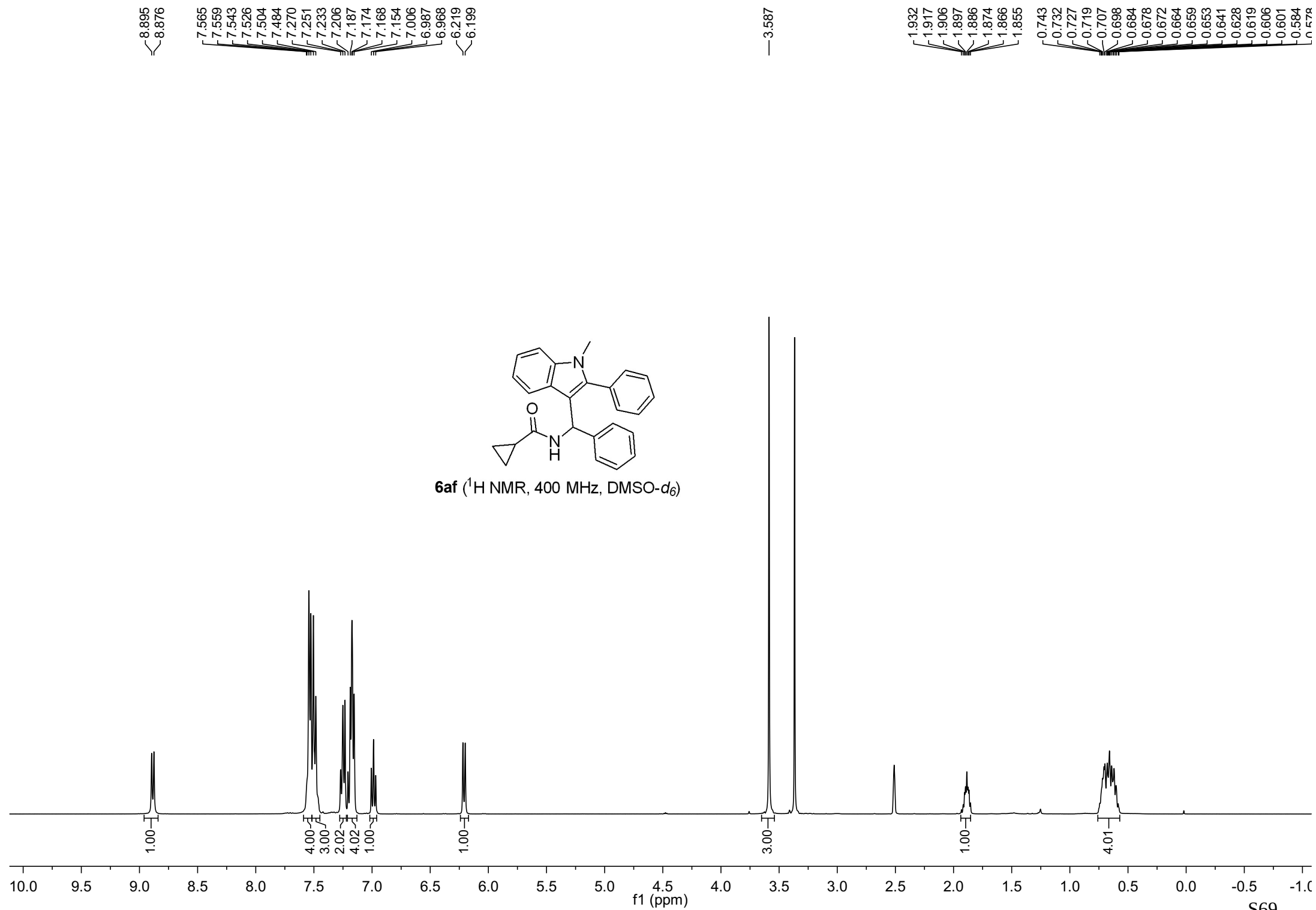


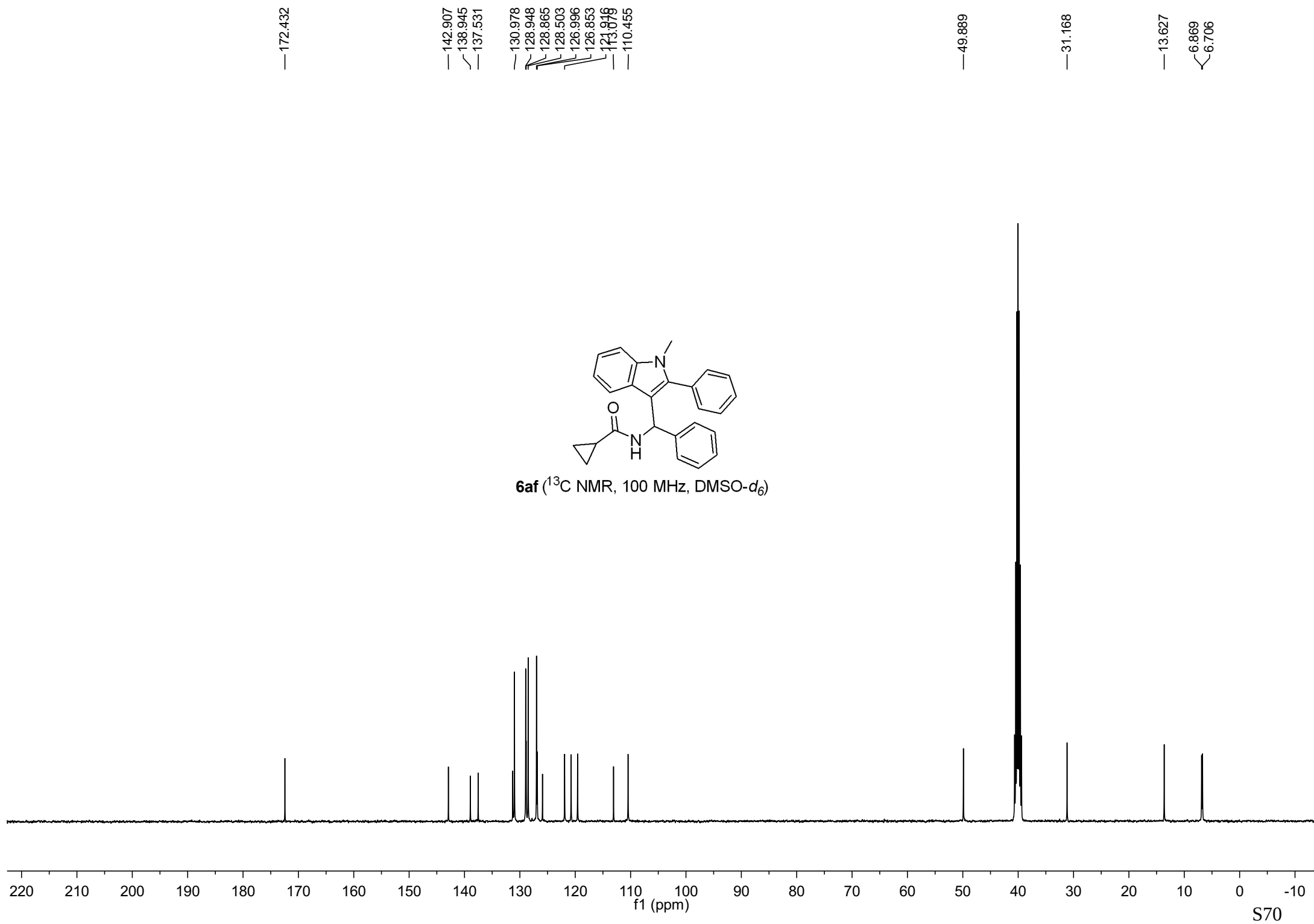
6ad (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)

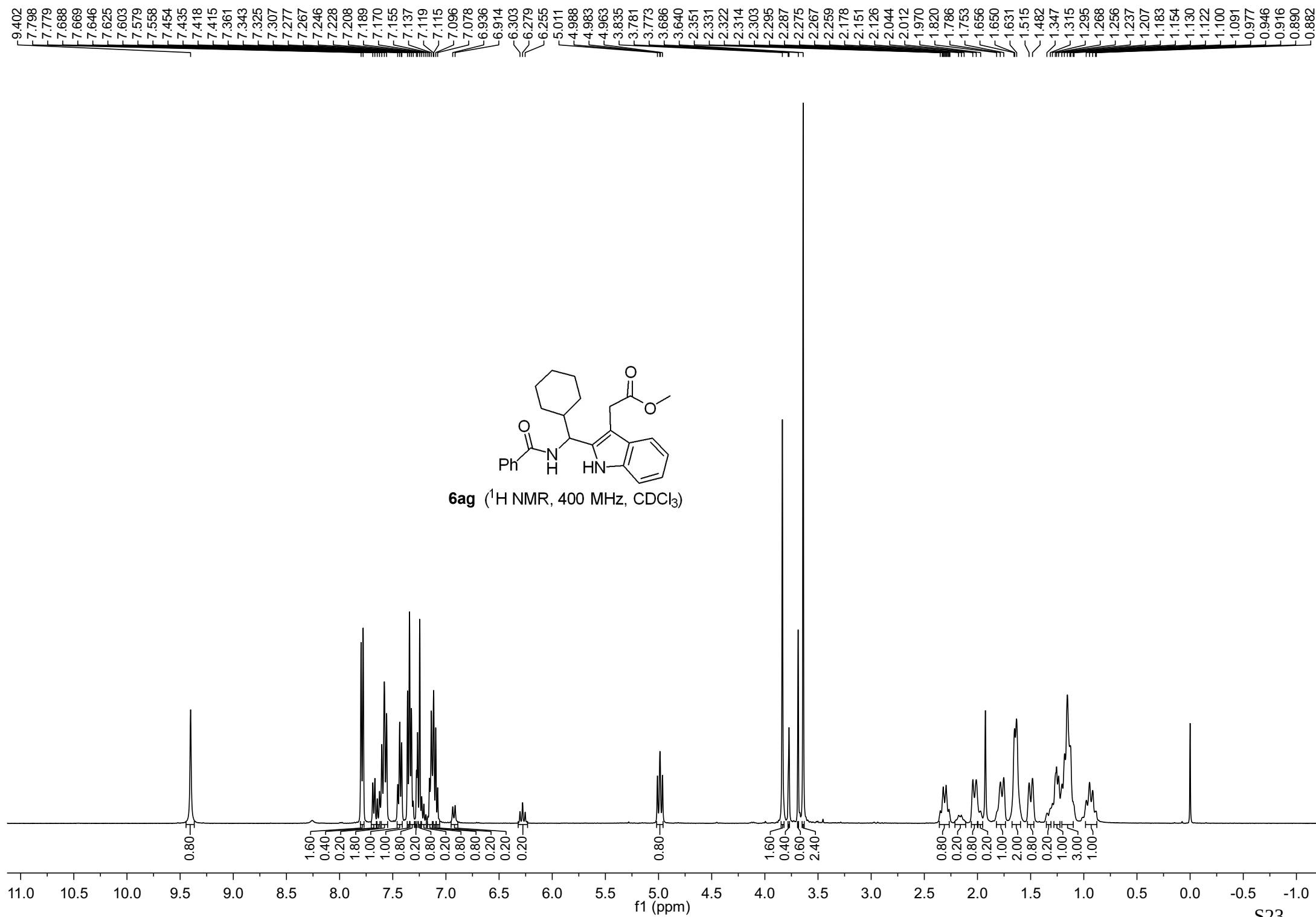


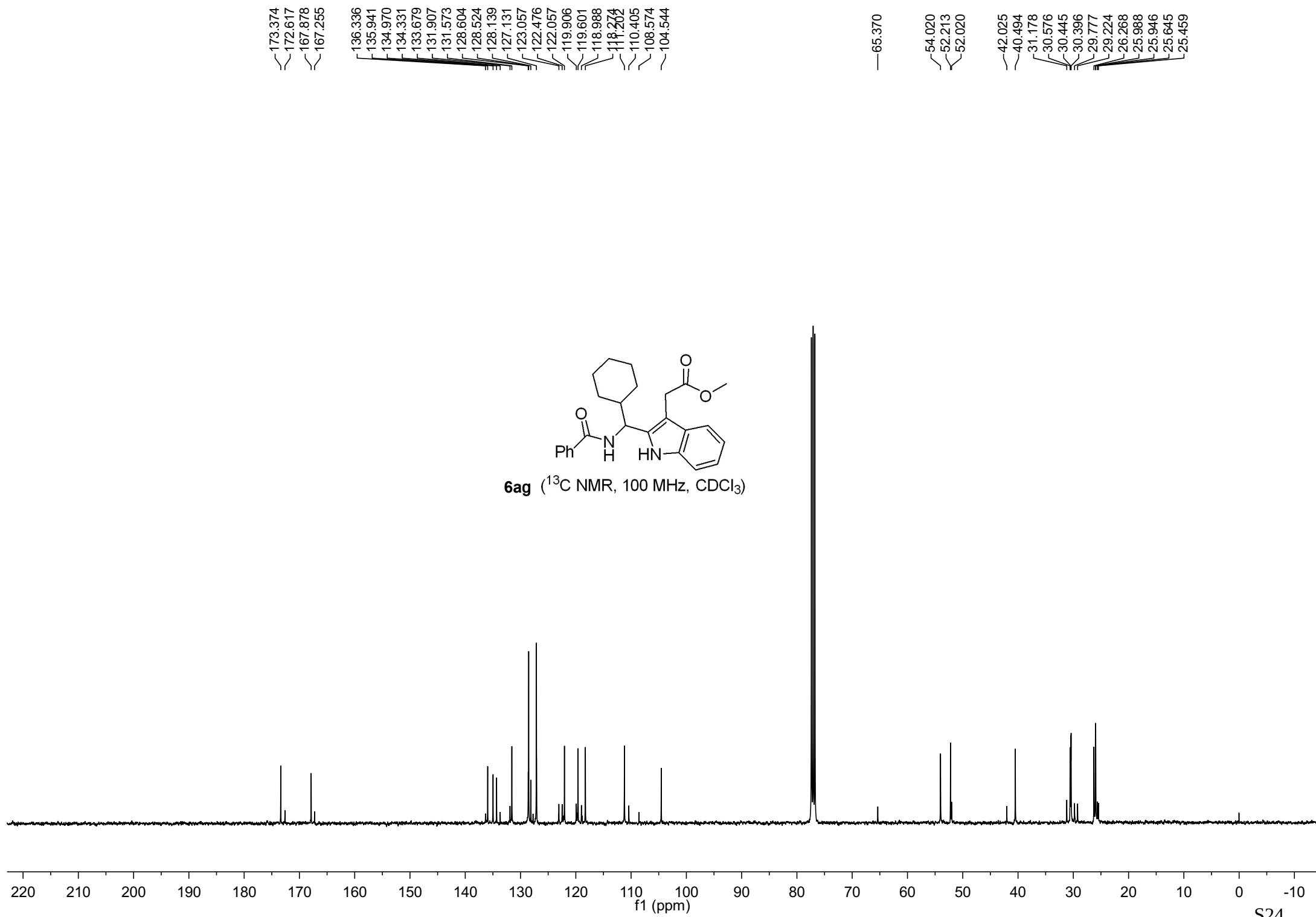












8.936
8.914

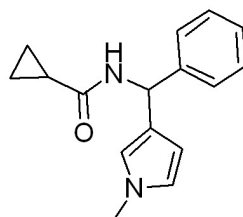
7.380
7.361
7.343
7.337
7.322
7.300
7.297
7.294
7.278
7.260
6.718
6.711
6.705

6.182
6.160

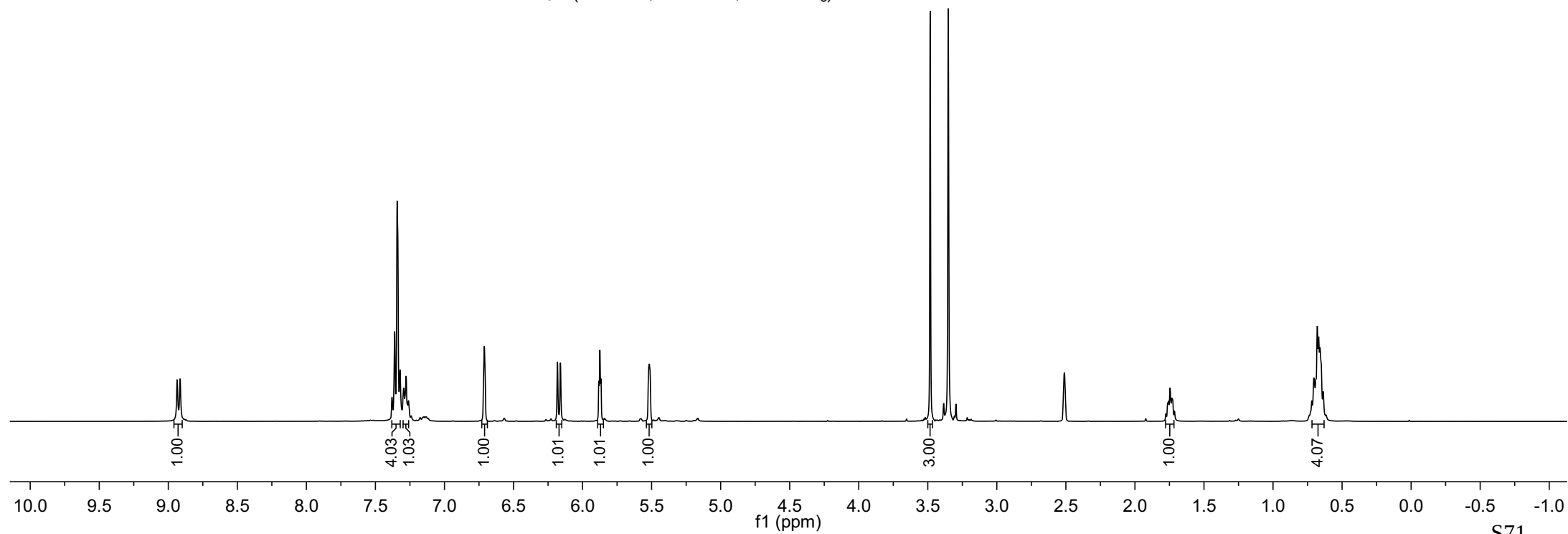
5.875
5.866
5.523
5.517
5.511

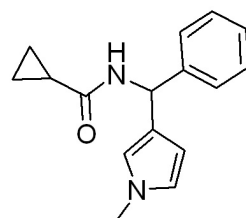
3.483

1.776
1.764
1.757
1.746
1.733
1.726
1.713
0.729
0.720
0.704
0.698
0.691
0.680
0.670
0.660
0.651
0.636

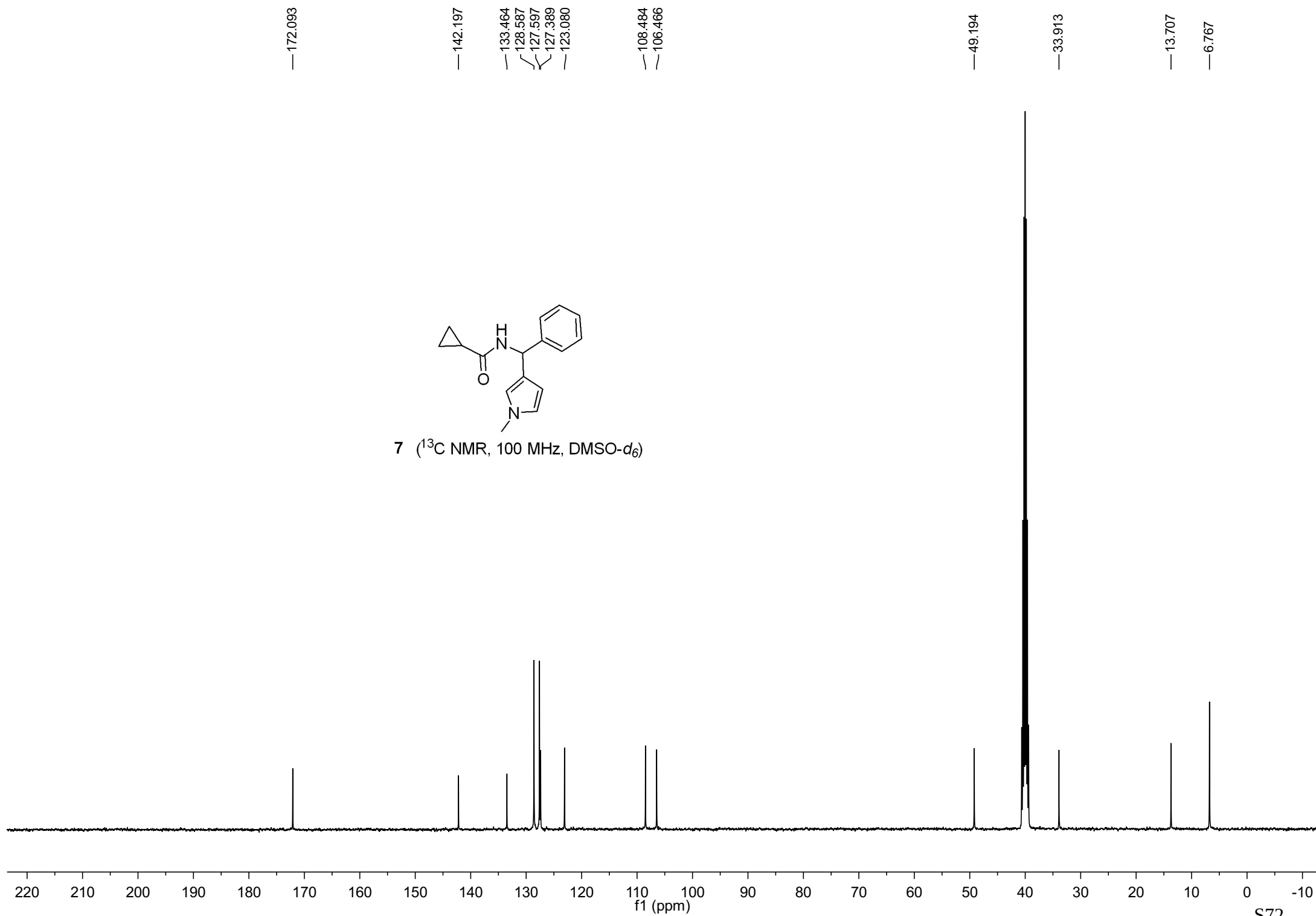


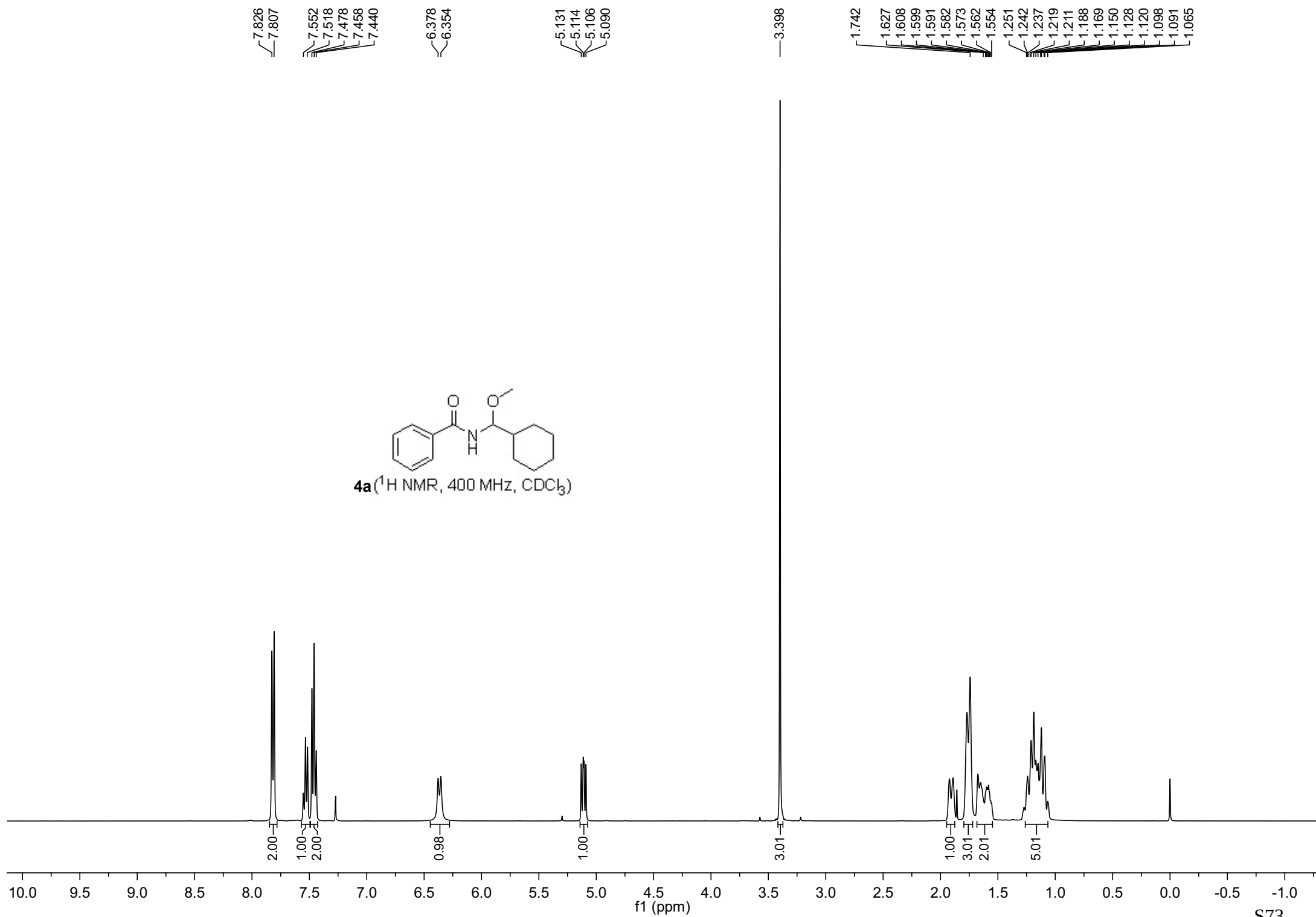
7 (¹H NMR, 400 MHz, DMSO-*d*₆)

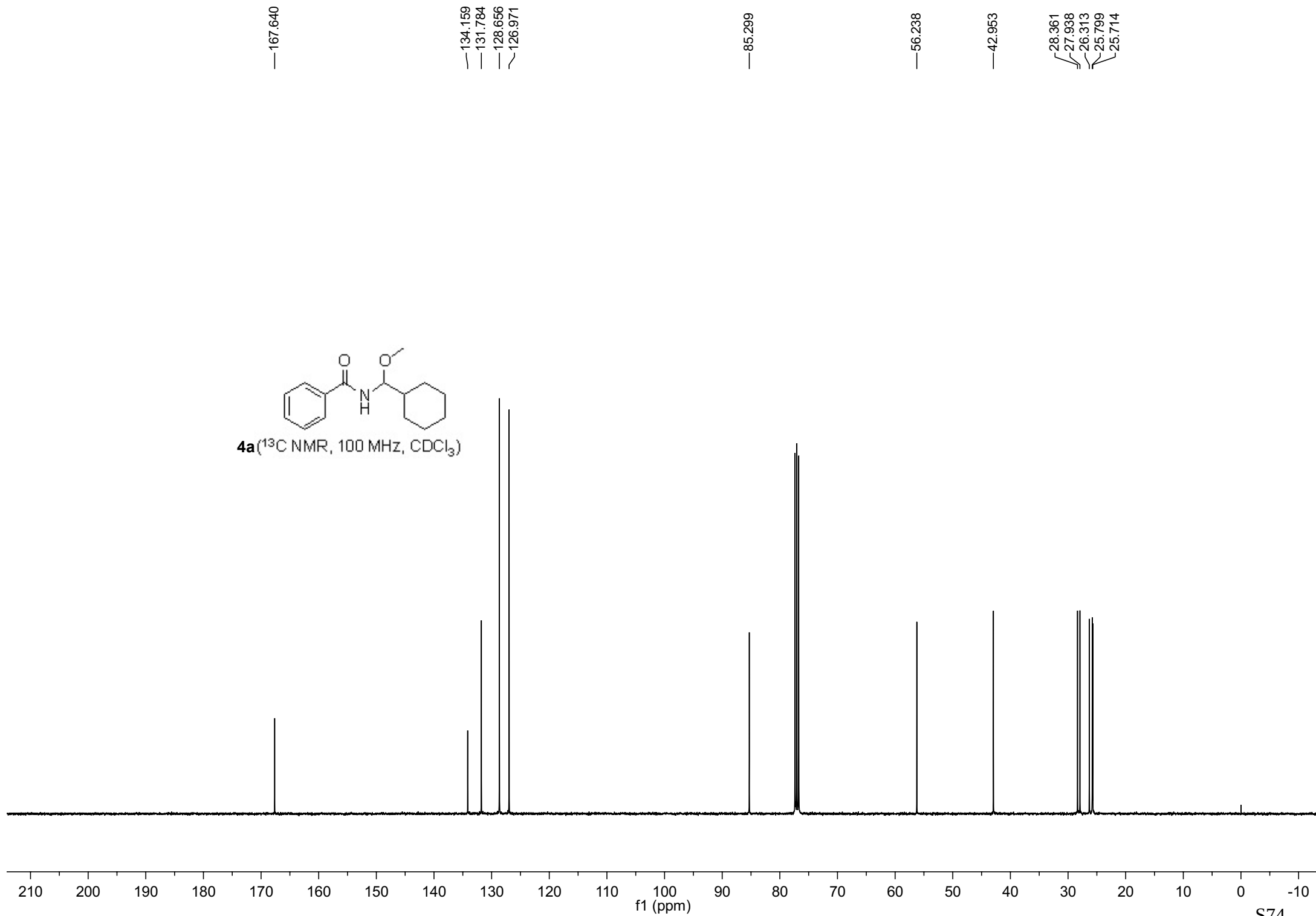
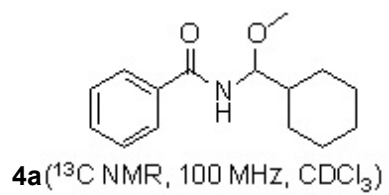


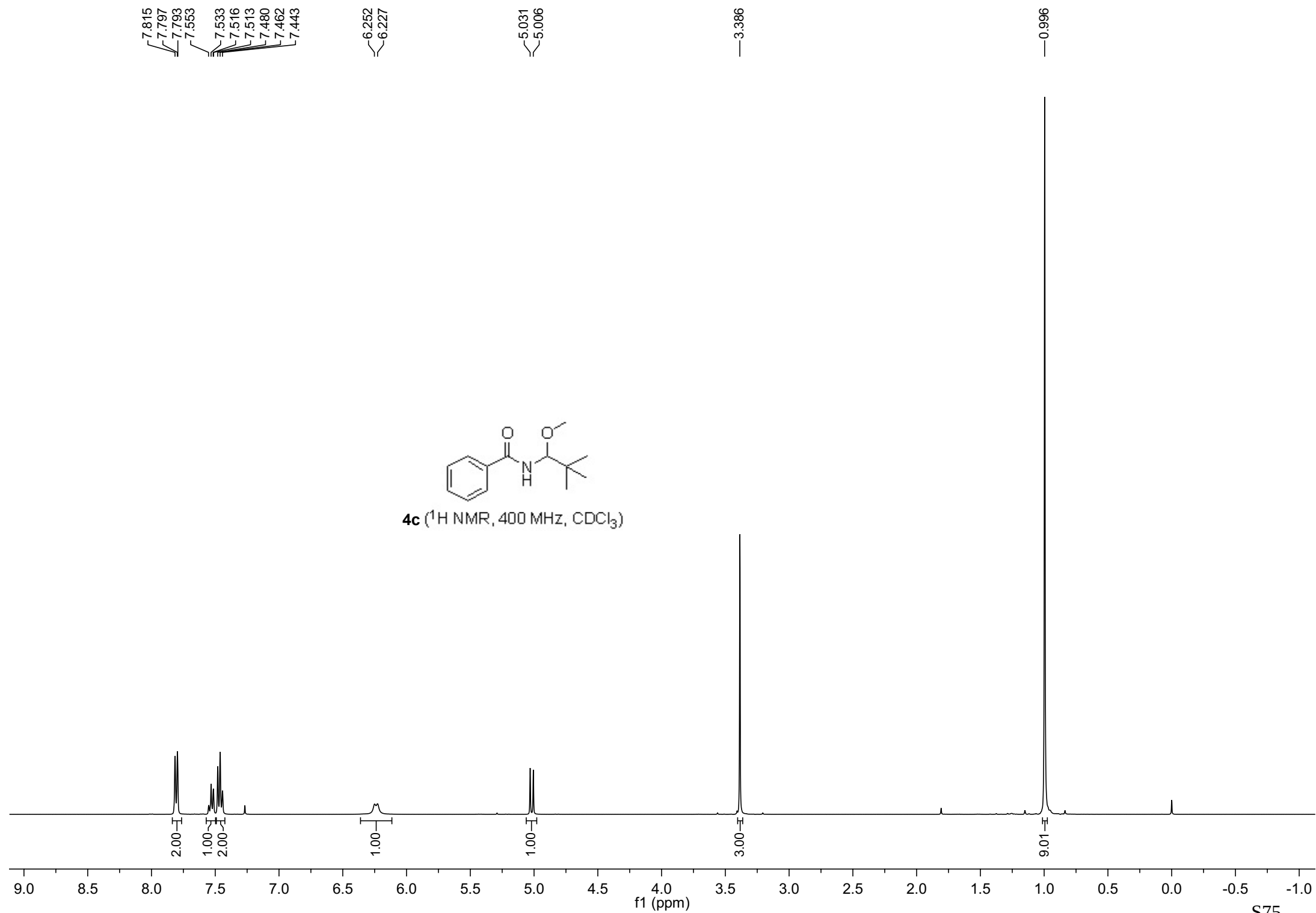


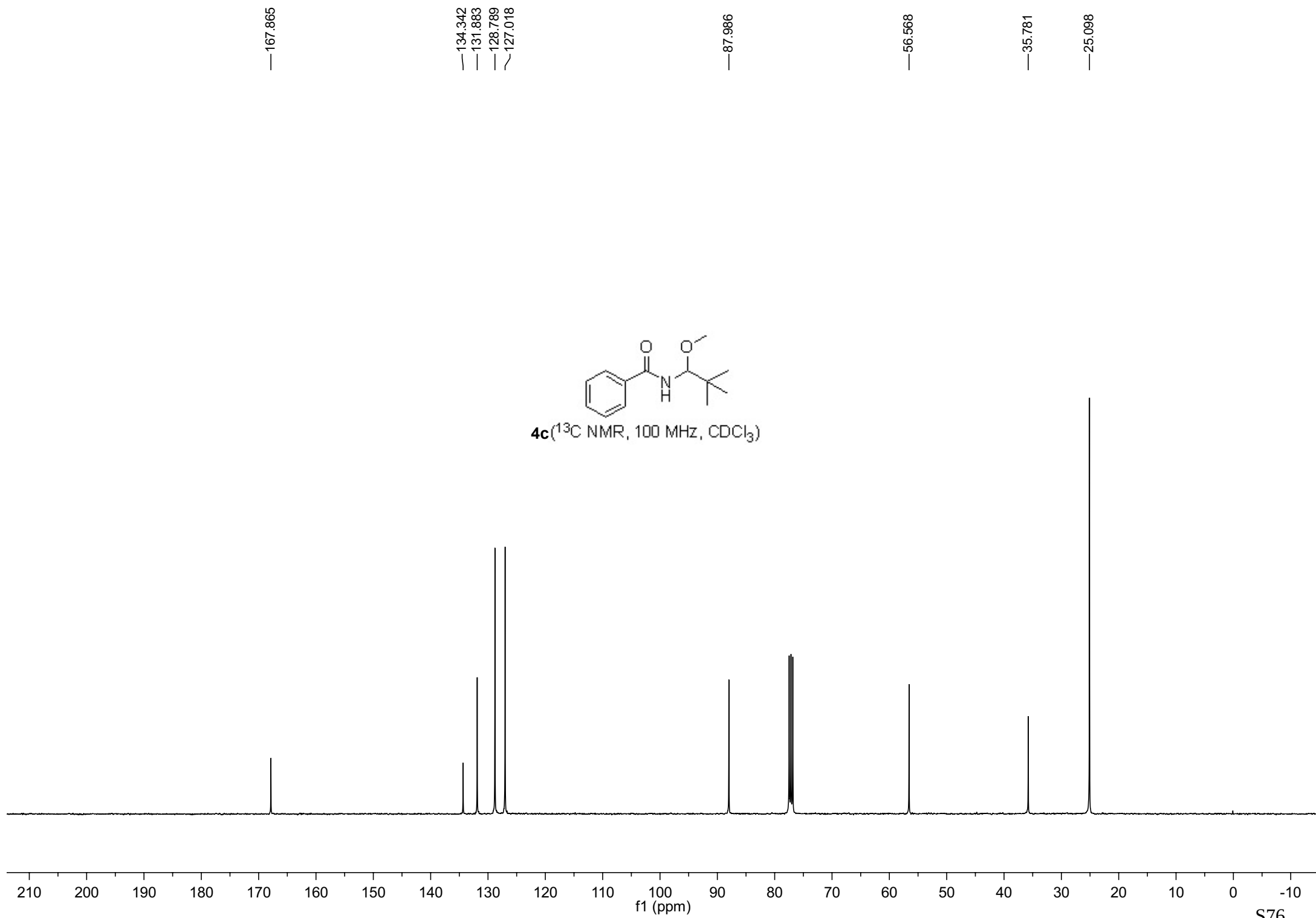
7 (^{13}C NMR, 100 MHz, $\text{DMSO}-d_6$)







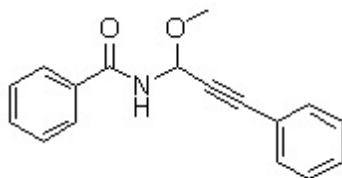




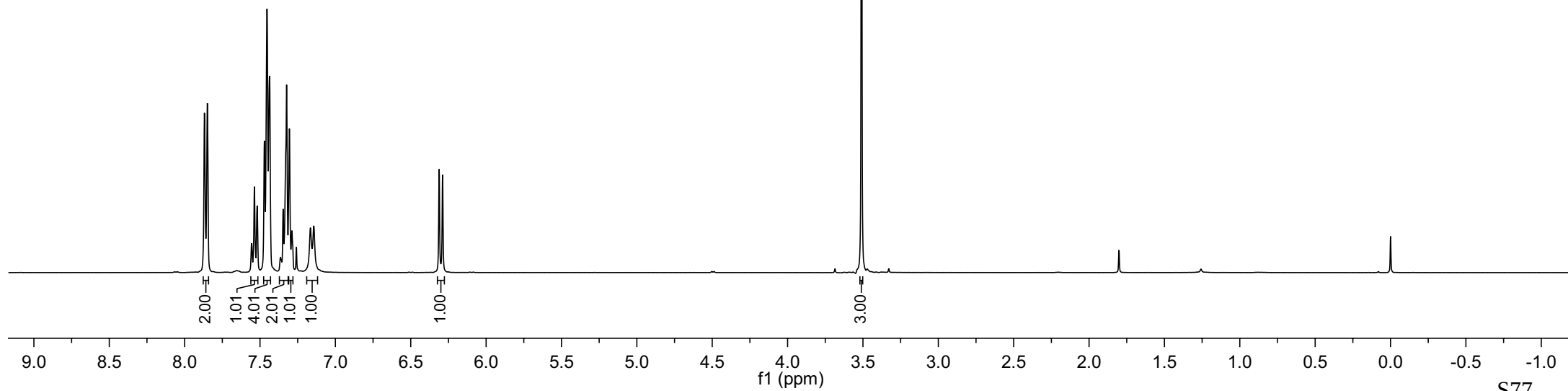
7.869
7.850
7.846
7.471
7.453
7.435
7.359
7.330
7.305
7.283
7.143

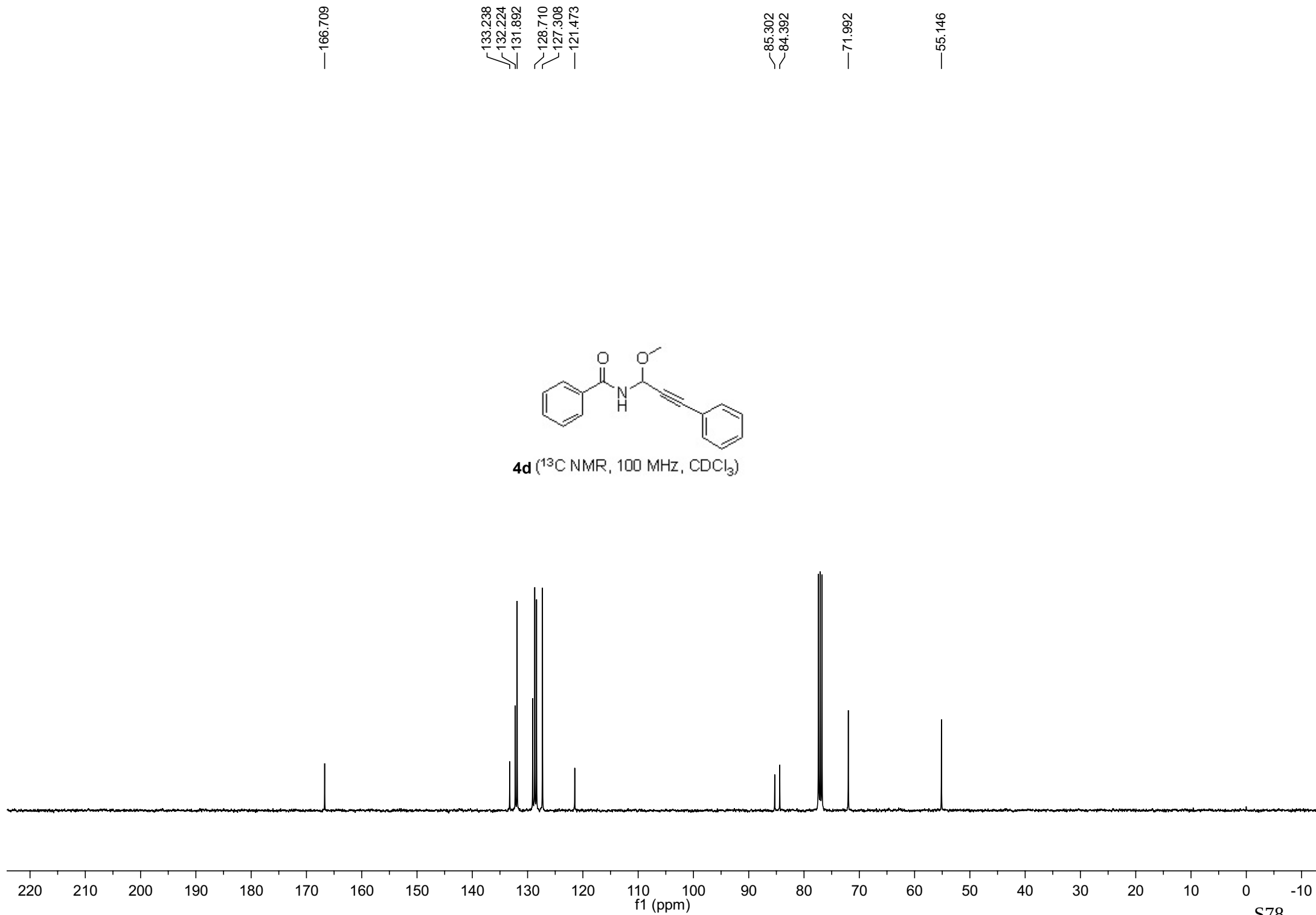
6.312
6.289

3.510



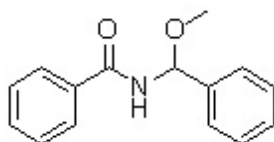
4d (^1H NMR, 400 MHz, CDCl_3)



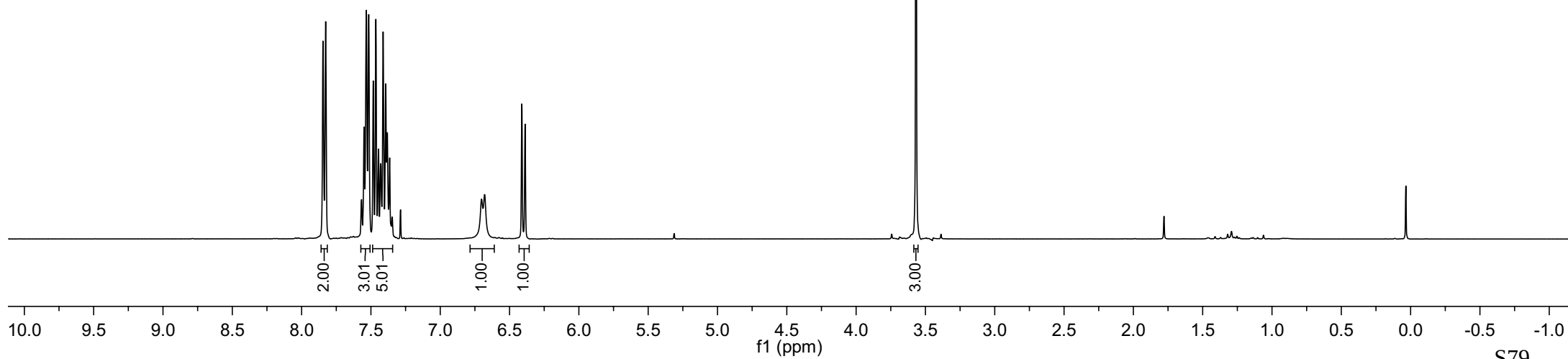


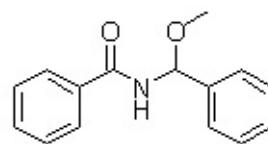
7.846
7.827
7.823
7.483
7.435
7.393
7.345
6.703
6.679
6.412
6.388

3.568

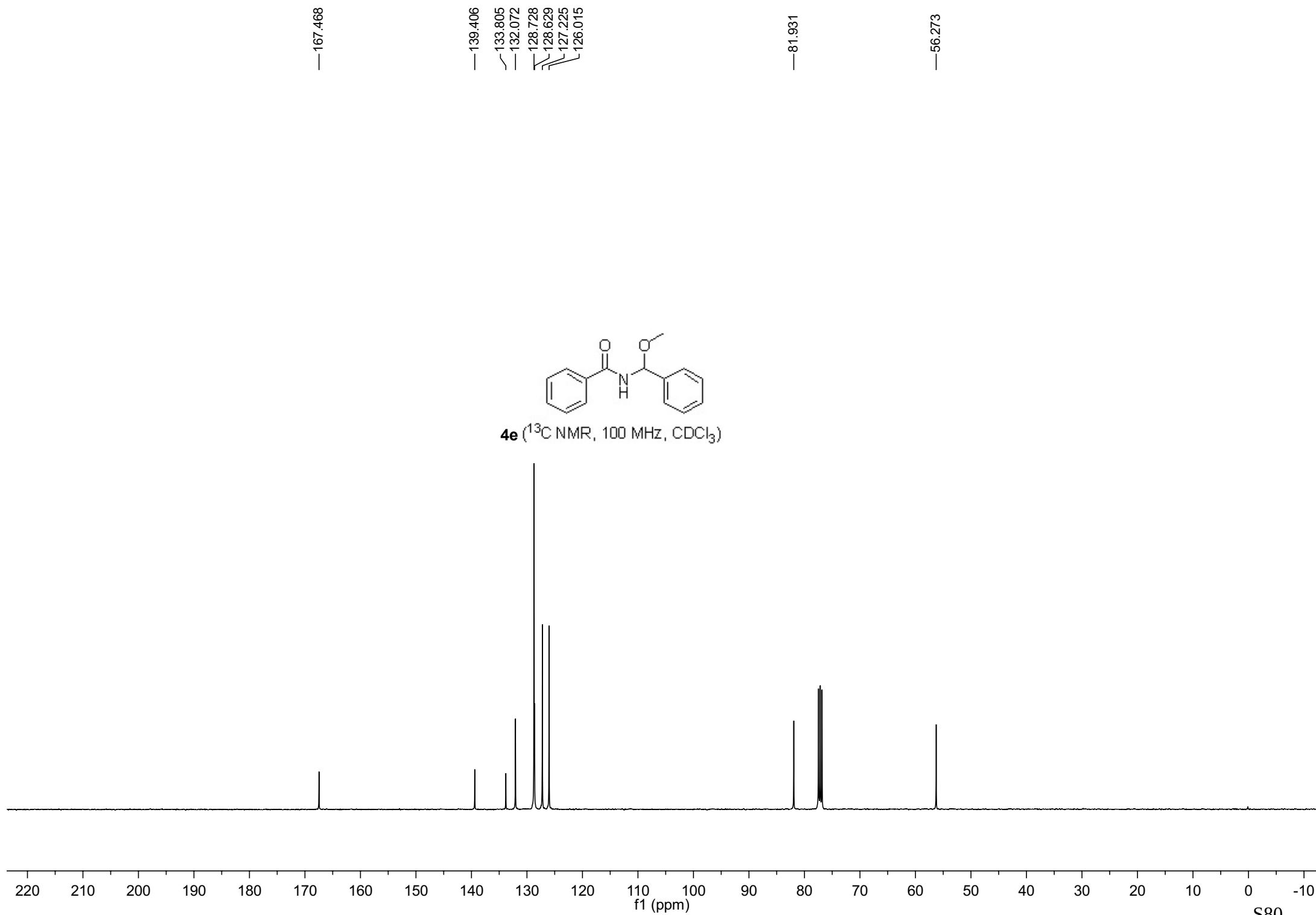


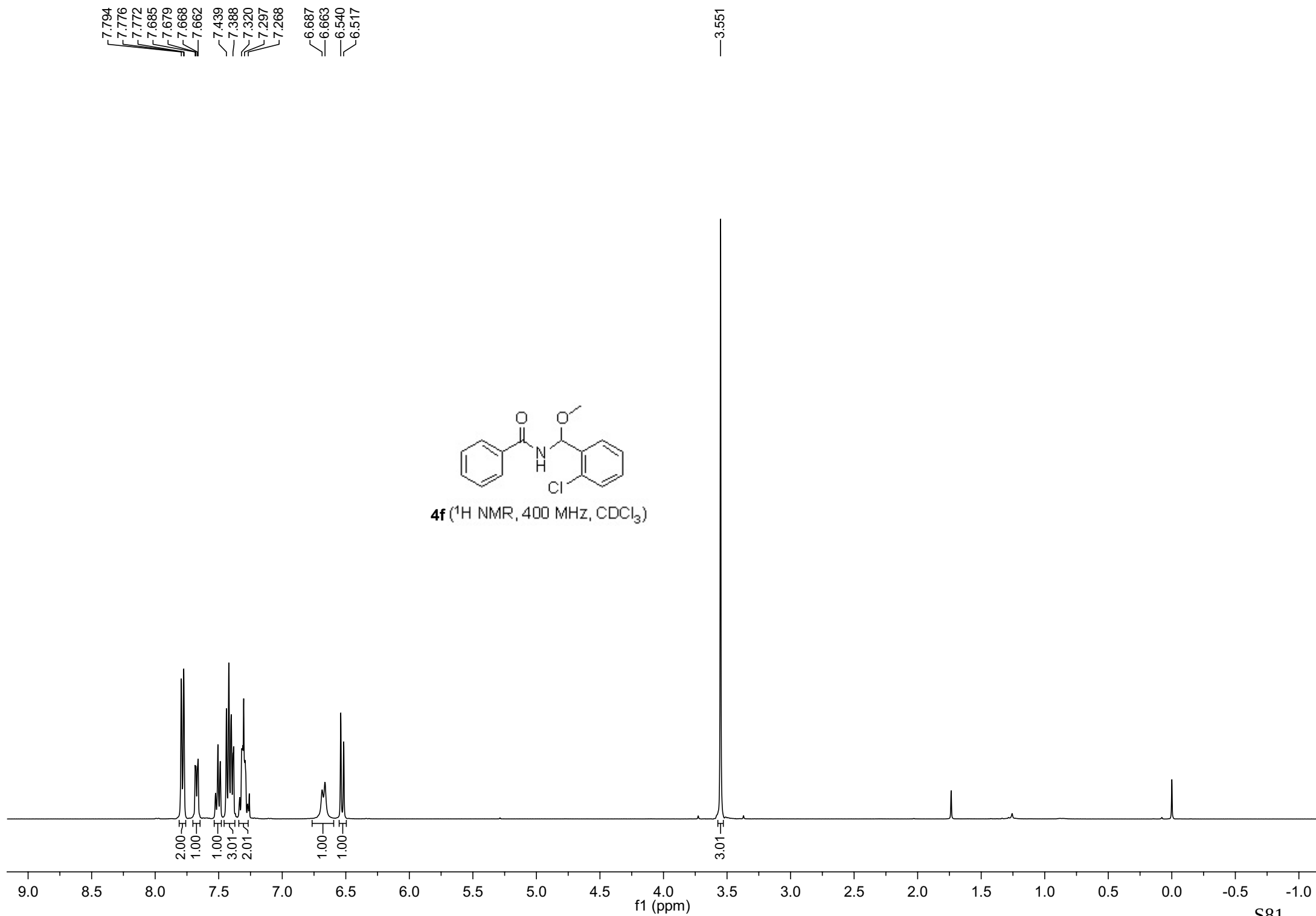
4e (^1H NMR, 400 MHz, CDCl_3)





4e (^{13}C NMR, 100 MHz, CDCl_3)

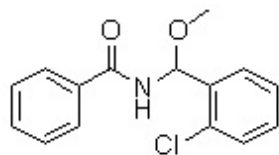




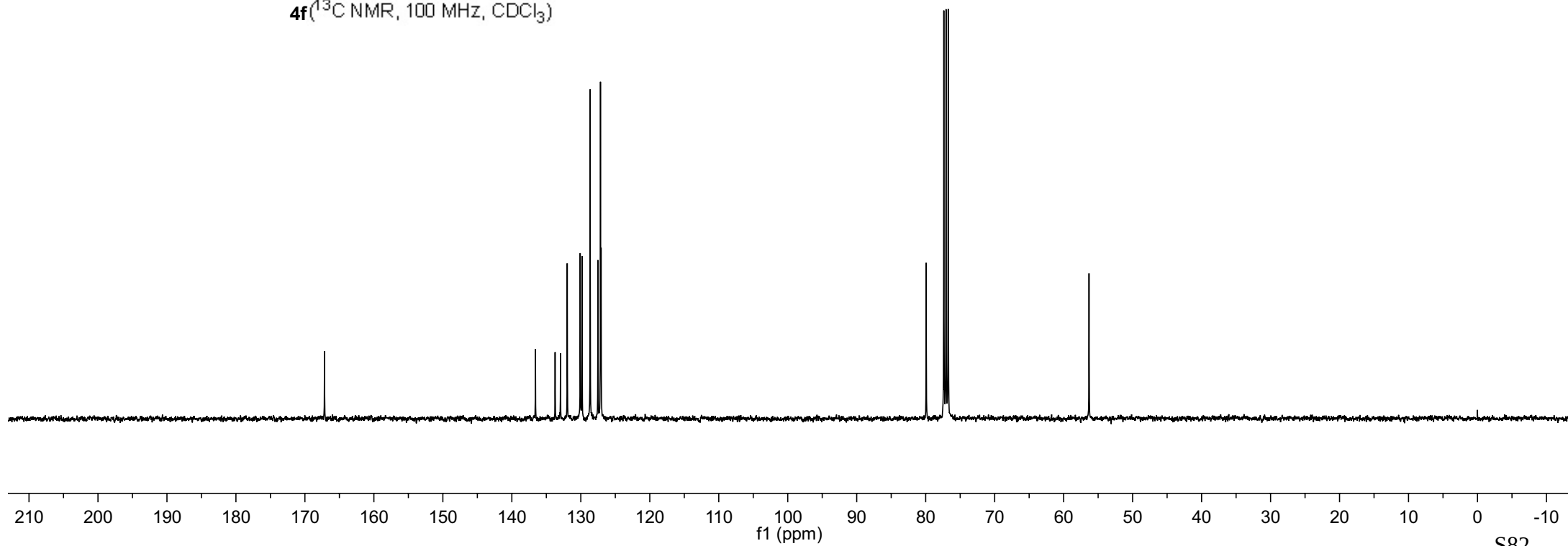
167.159
136.580
133.726
132.946
131.966
130.088
129.817
128.645
127.516
127.150
127.059

79.929

56.320

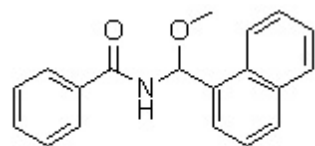


4f (^{13}C NMR, 100 MHz, CDCl_3)

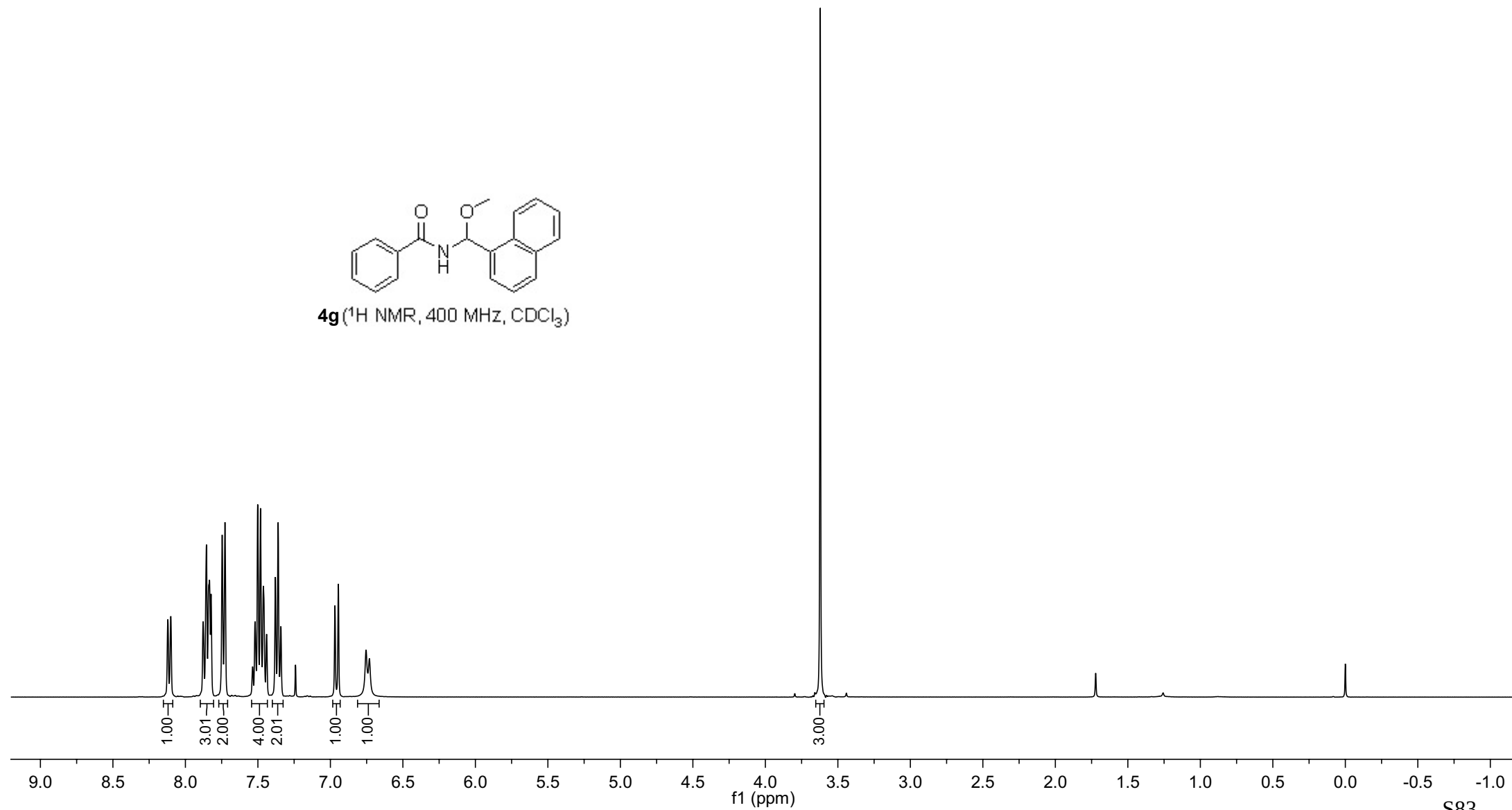


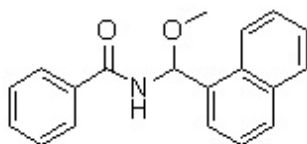
8.121
8.101
7.833
7.723
7.501
7.442
7.342
6.969
6.945
6.754
6.731

3.622

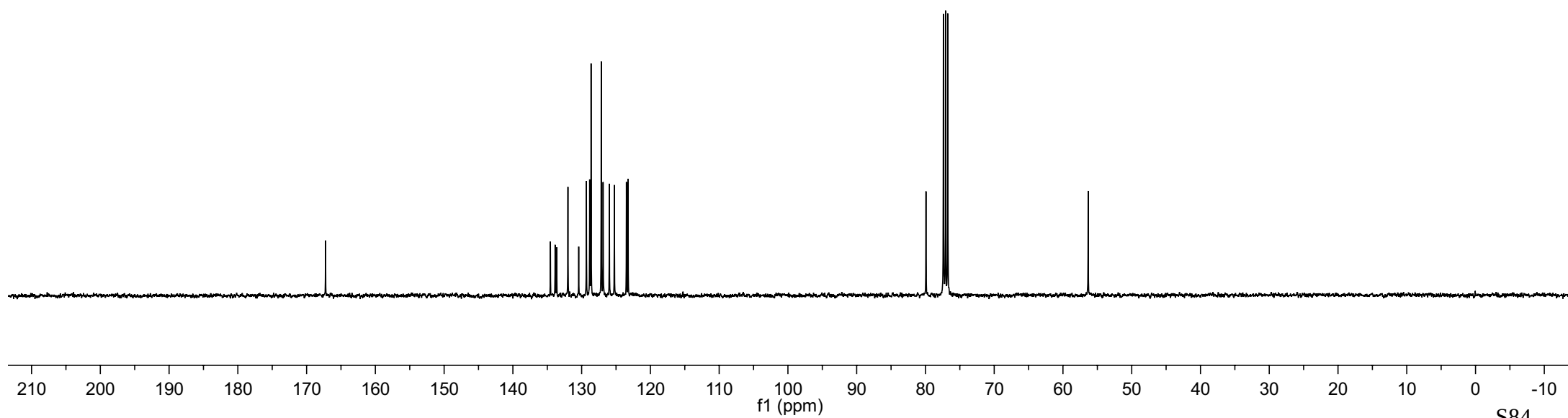


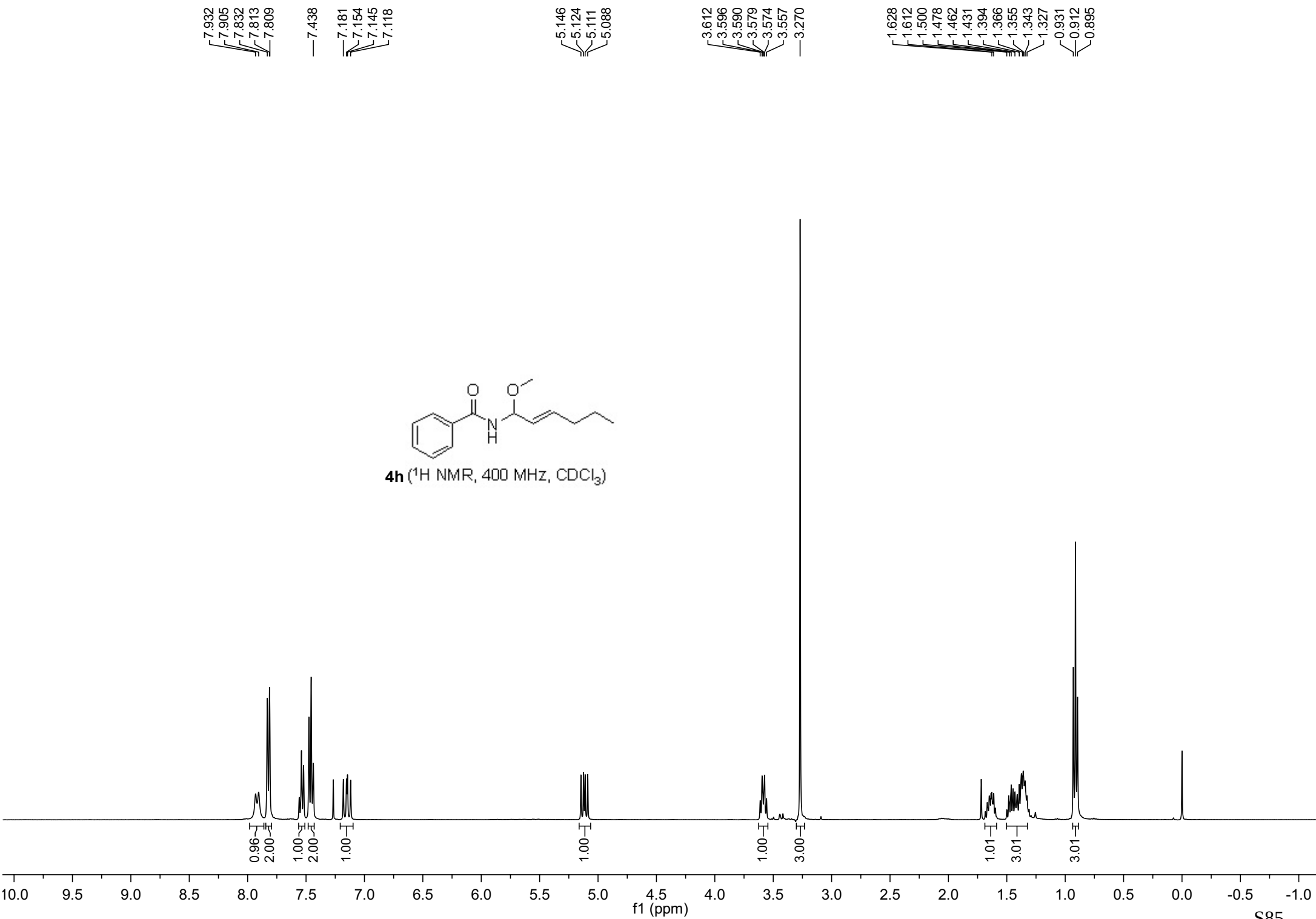
4g (¹H NMR, 400 MHz, CDCl₃)

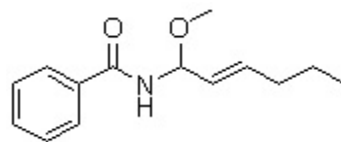




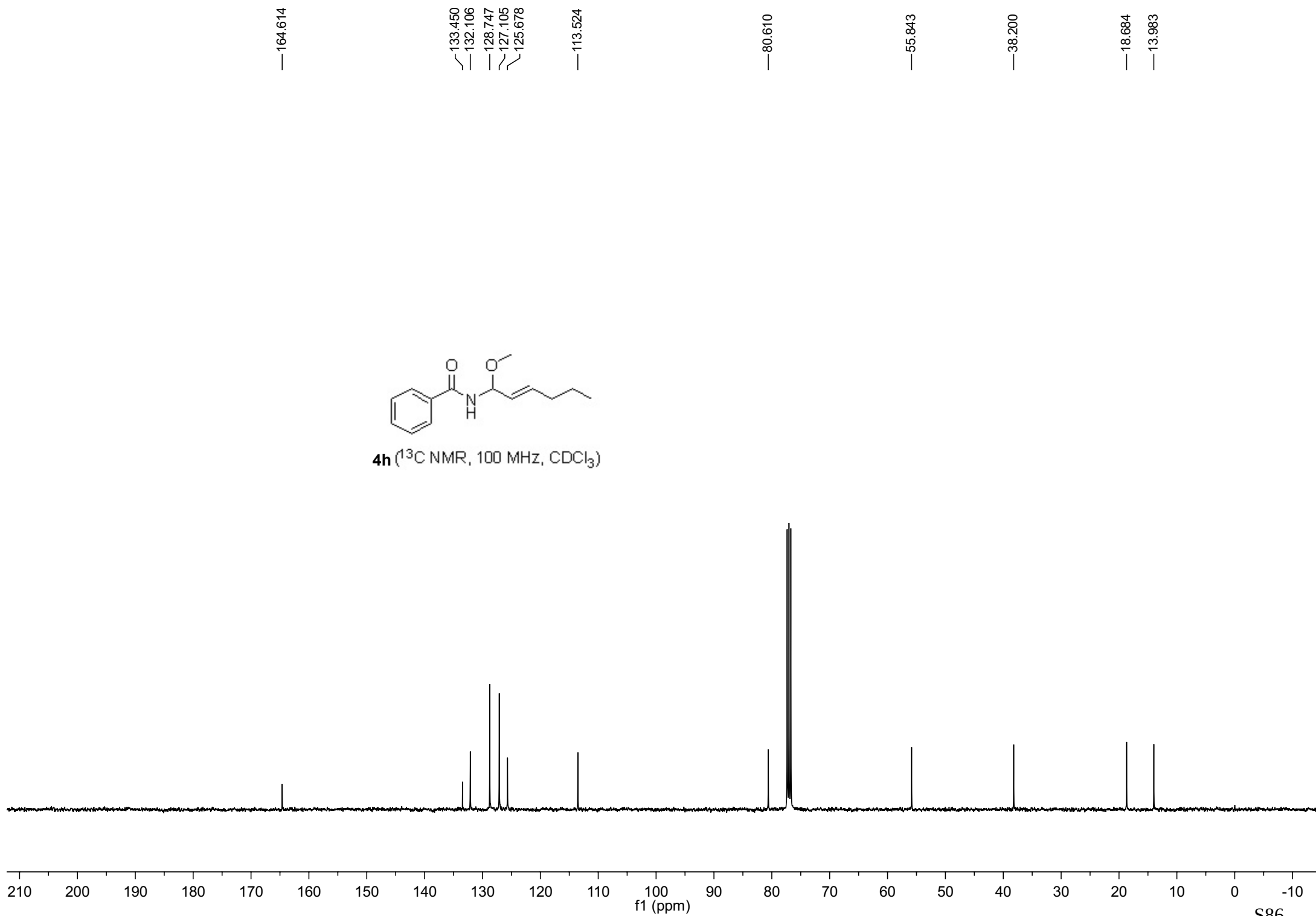
4g (^{13}C NMR, 100 MHz, CDCl_3)





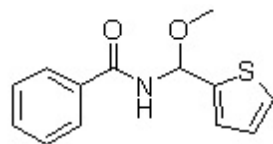


4h (^{13}C NMR, 100 MHz, CDCl_3)

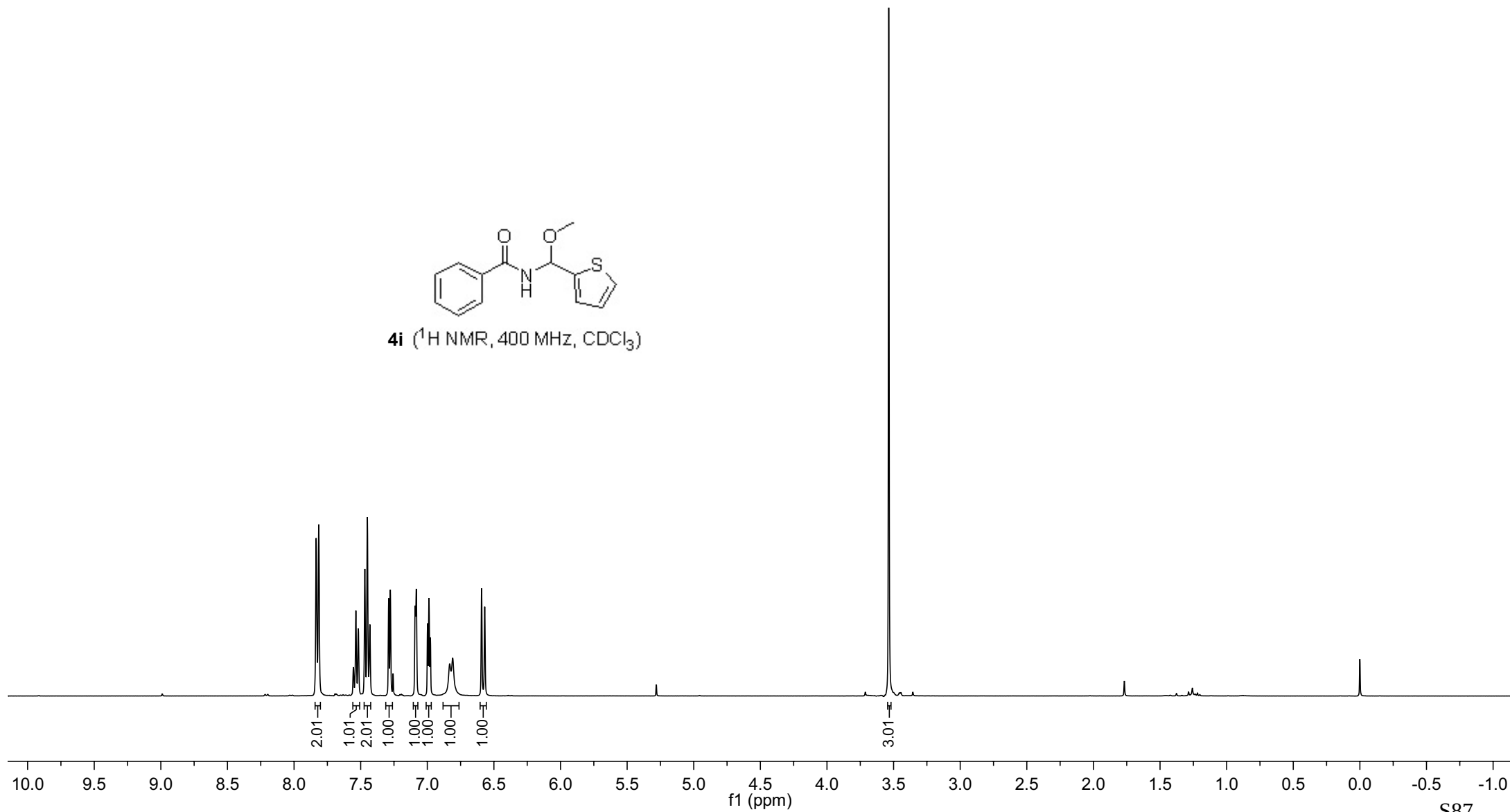


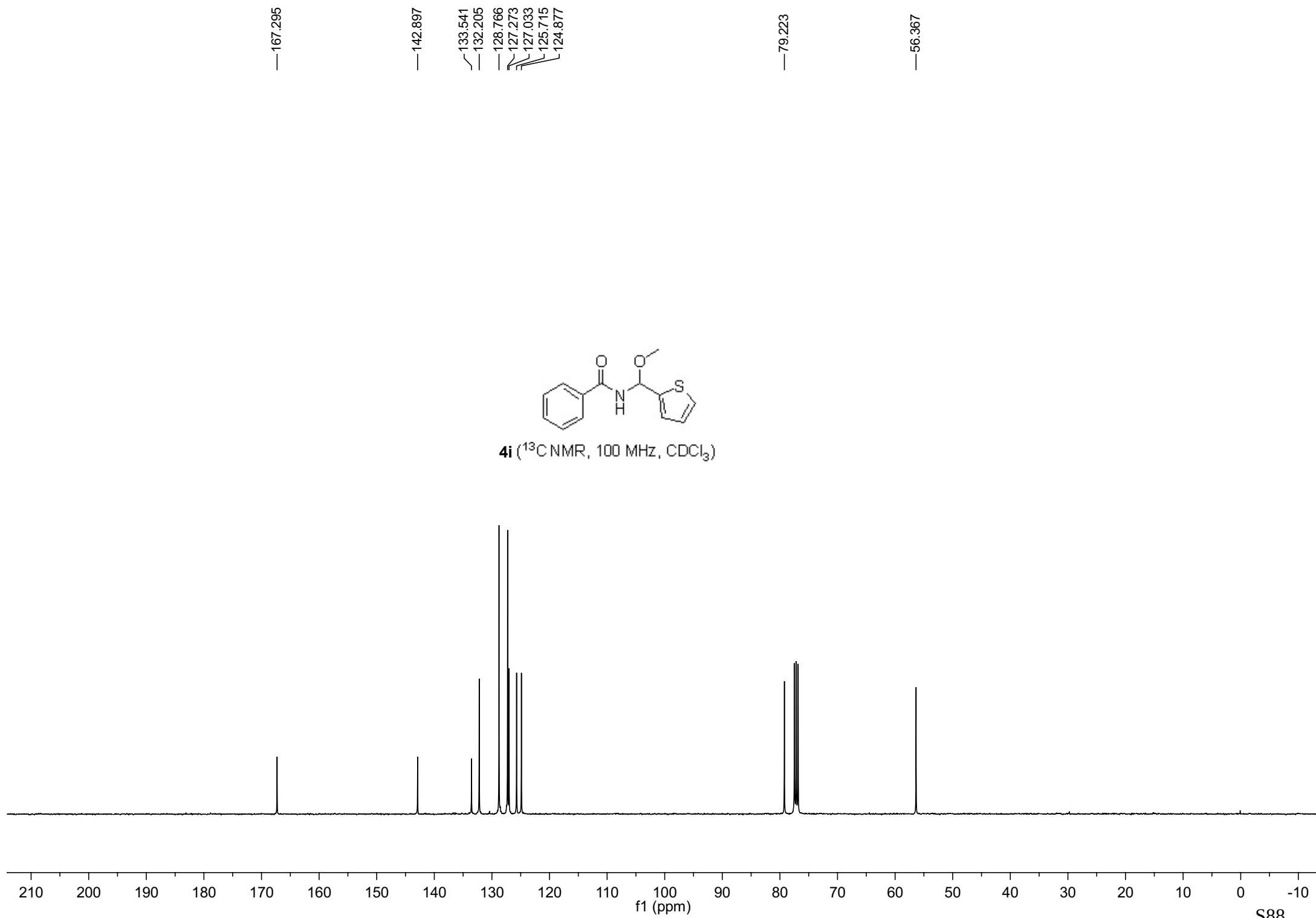
7.834
7.815
7.811
7.431
7.257
6.977
6.809
6.592
6.569

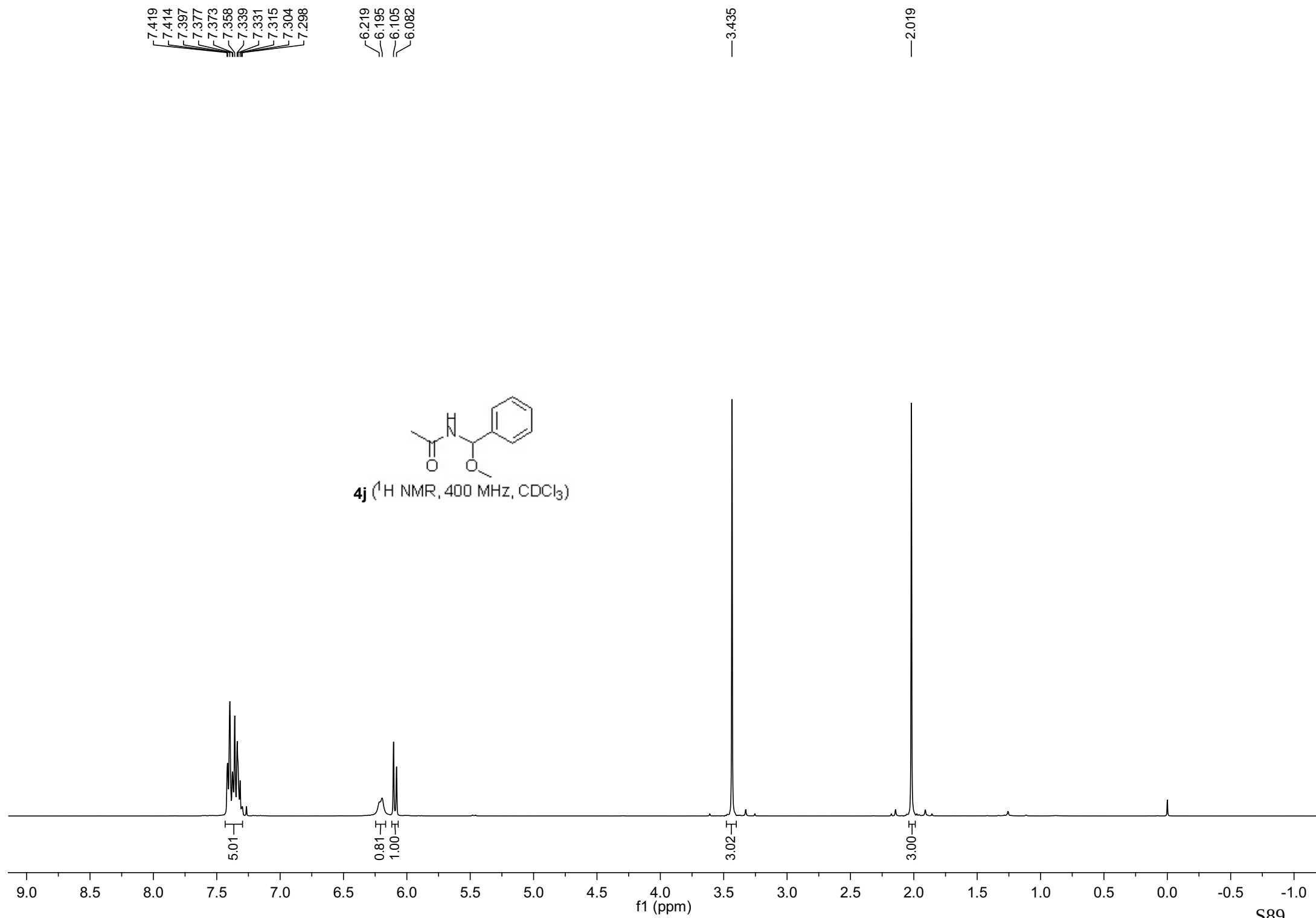
3.536

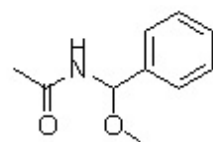


4i (^1H NMR, 400 MHz, CDCl_3)









4j (^{13}C NMR, 100 MHz, CDCl_3)

—170.239

—139.282

—128.595

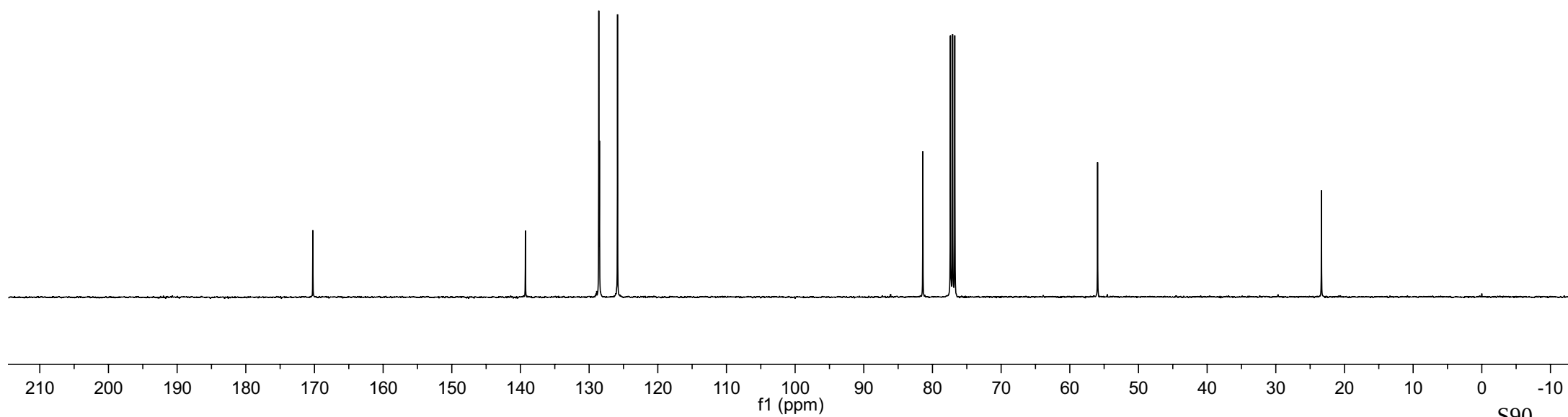
—128.497

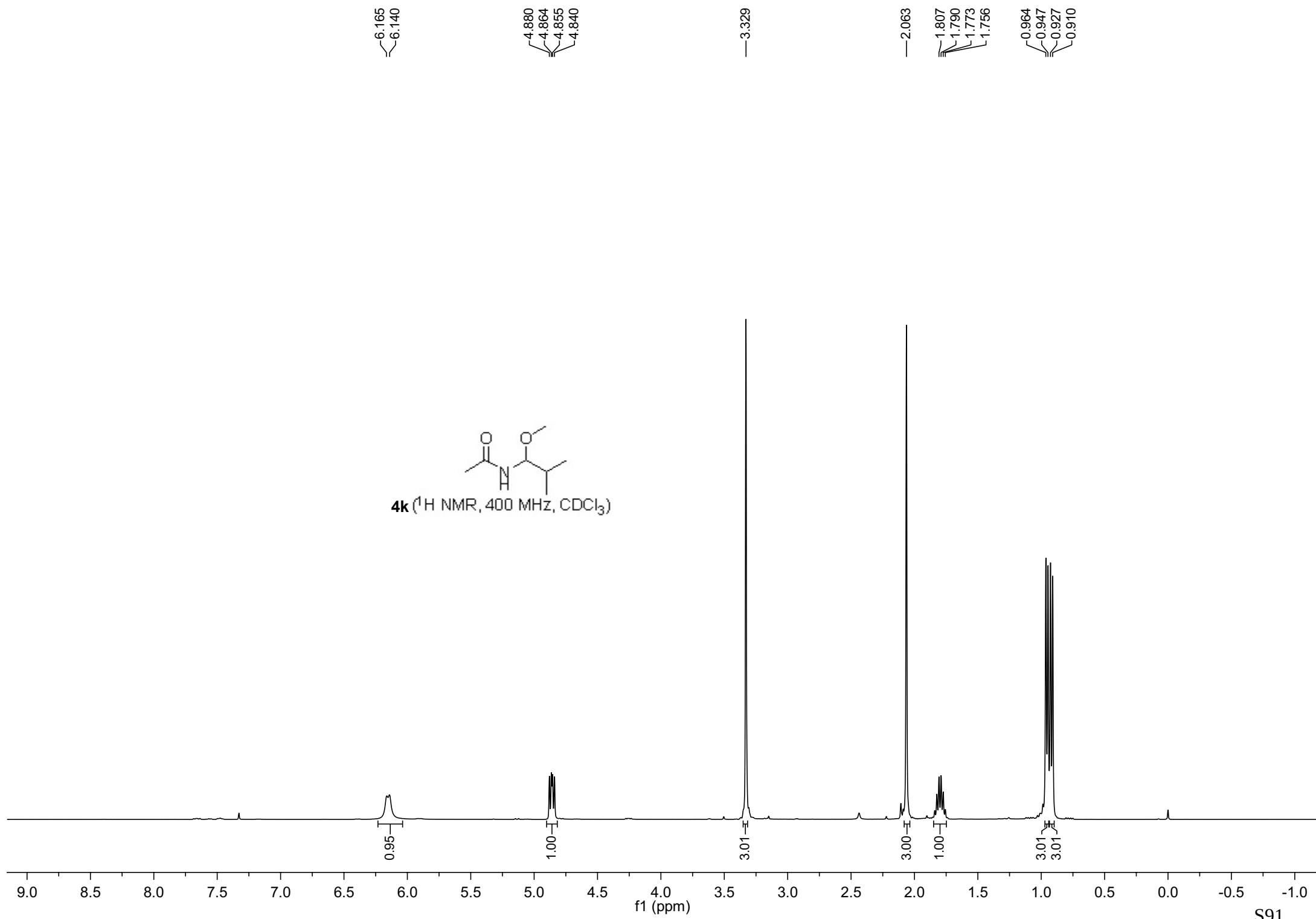
—125.869

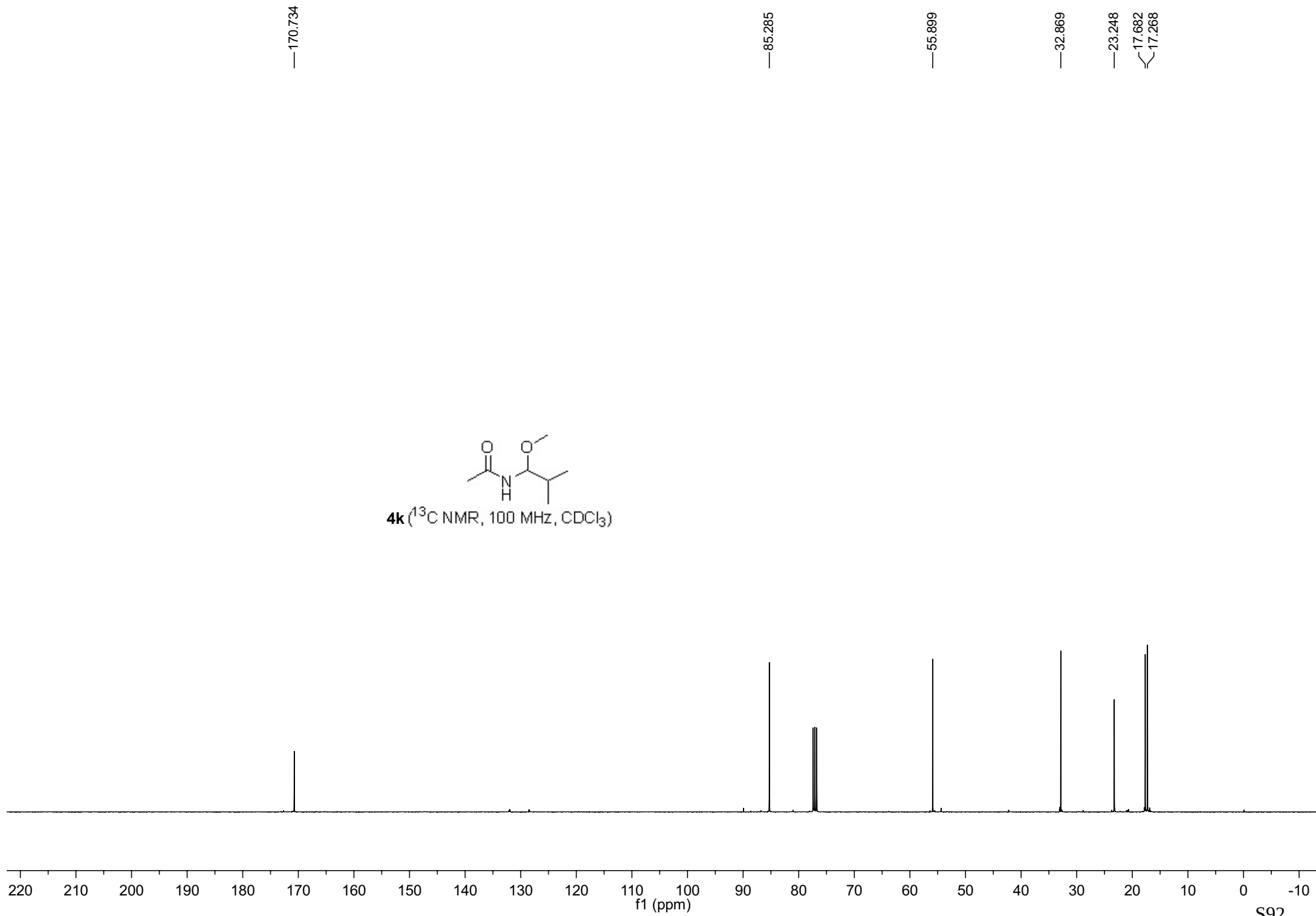
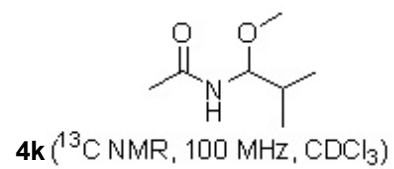
—81.405

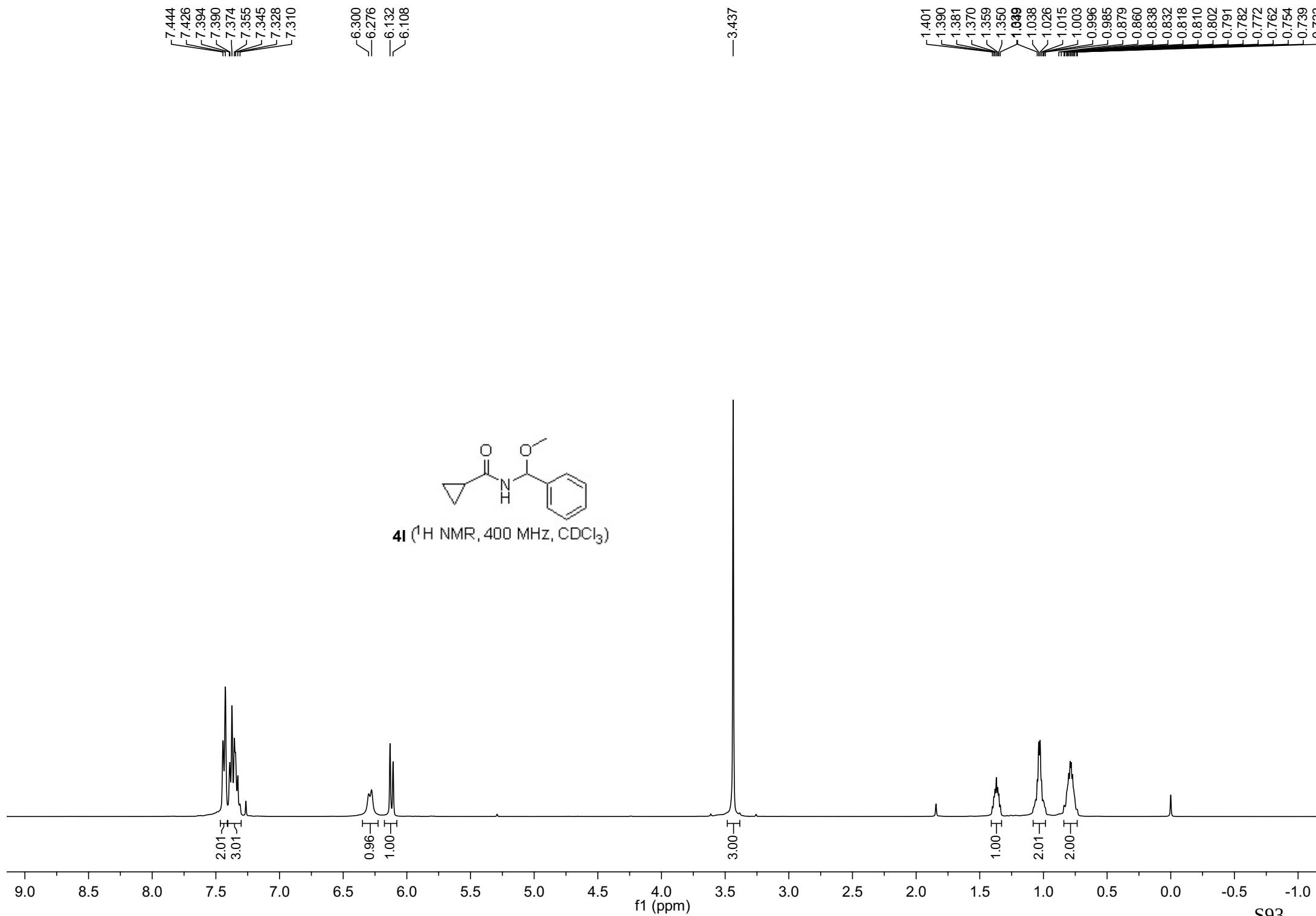
—55.959

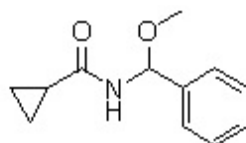
—23.356











4I (^{13}C NMR, 100 MHz, CDCl_3)

—173.919

—139.429

128.590
128.456

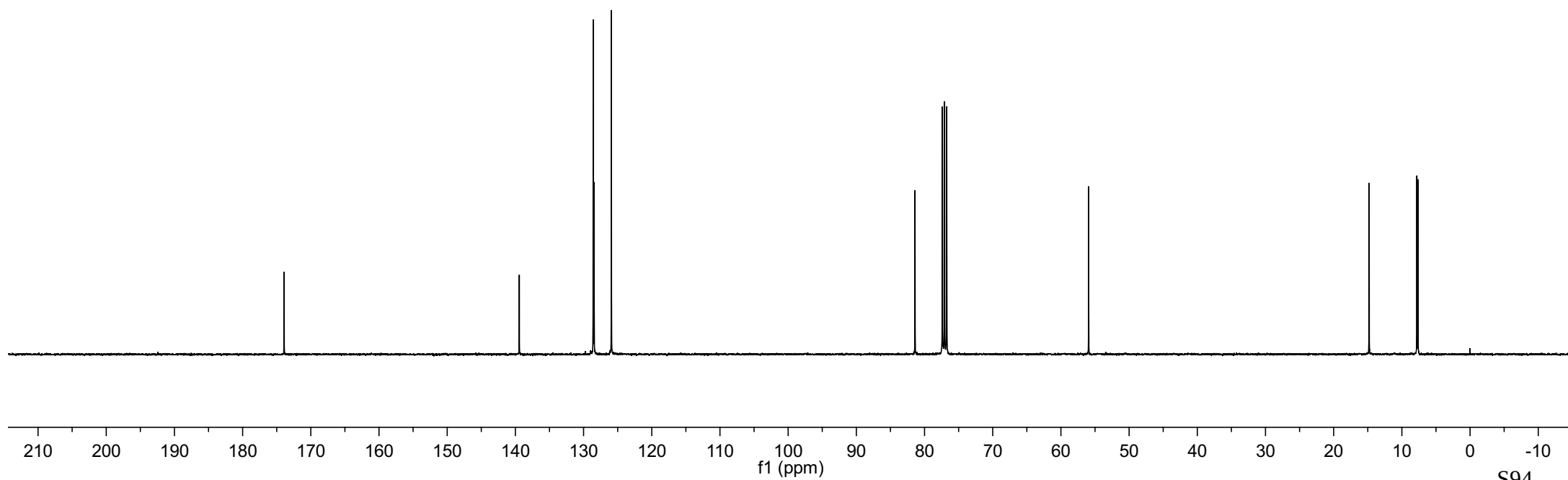
125.920

—81.396

—55.934

—14.804

7.807
7.638



Analysis Report

<Sample Information>

Sample Name: 6e

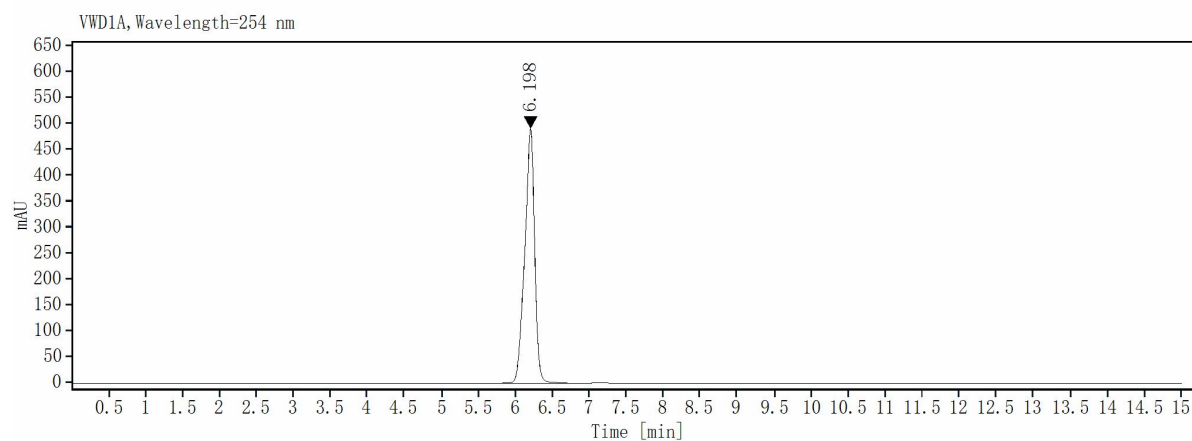
Injection Volume: 3.000

Sample Vial Number: P1-A3

Sequence Acquired Date: 2022-01-19 18:44:49+08:00

Injection Acq Method Name: Methods-2.amx

Injection Acquired By: System Administrator



Peak #	Ret.Time	Area	Height	Area%
1	6.198	4575.21	491.37	100%
Total		4575.21	491.37	100%

Analysis Report

<Sample Information>

Sample Name: **6z**

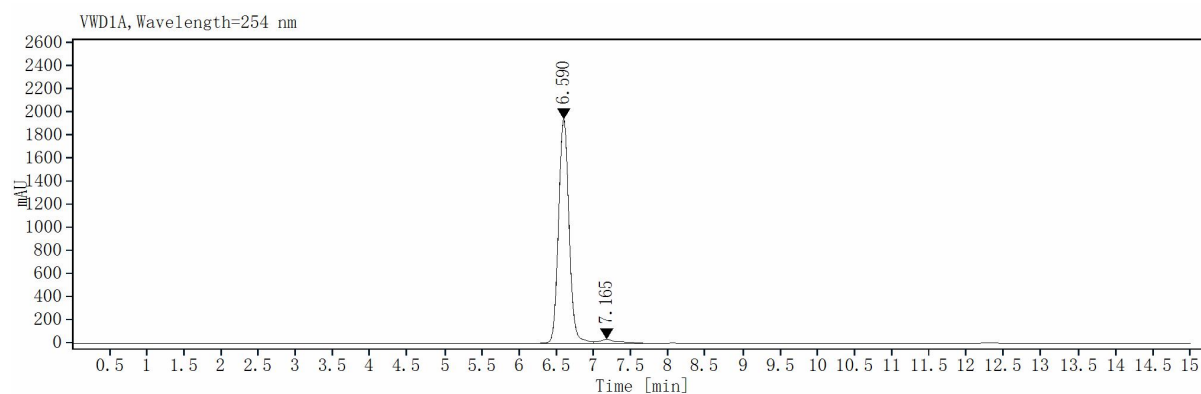
Injection Volume: 3.000

Sample Vial Number: P1-A1

Sequence Acquired Date: 2022-01-19 16:44:59+08:00

Injection Acq Method Name: Methods-1.amx

Injection Acquired By: System Administrator



Peak #	Ret.Time	Area	Height	Area%
1	6.590	19628.00	1944.58	98.92%
2	7.165	241.30	35.54	1.08%
Total		19842.30	1980.12	100%

Analysis Report

<Sample Information>

Sample Name: **6aa**

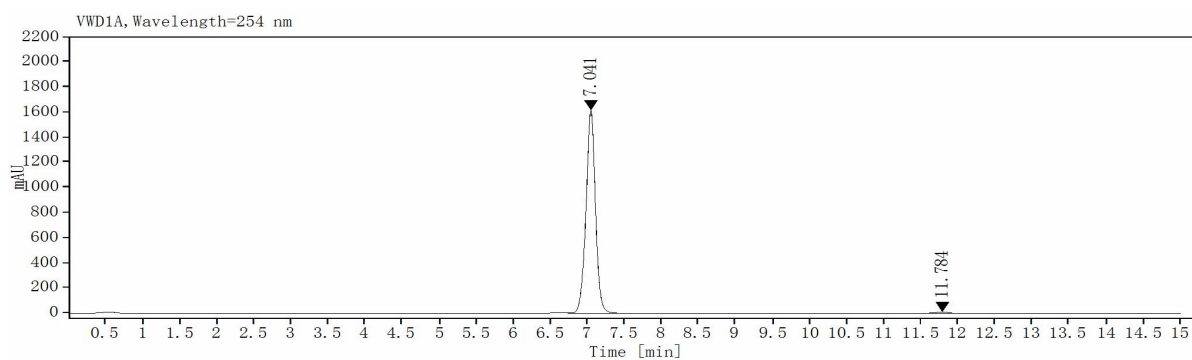
Injection Volume: 3.000

Sample Vial Number: P1-A2

Sequence Acquired Date: 2022-01-19 17:19:52+08:00

Injection Acq Method Name: Methods-1.amx

Injection Acquired By: System Administrator



Peak #	Ret.Time	Area	Height	Area%
1	7.041	14501.50	1615.51	99.32%
2	11.784	99.29	11.01	0.68%
Total		14600.79	1626.52	100%

Analysis Report

<Sample Information>

Sample Name: **6ag**

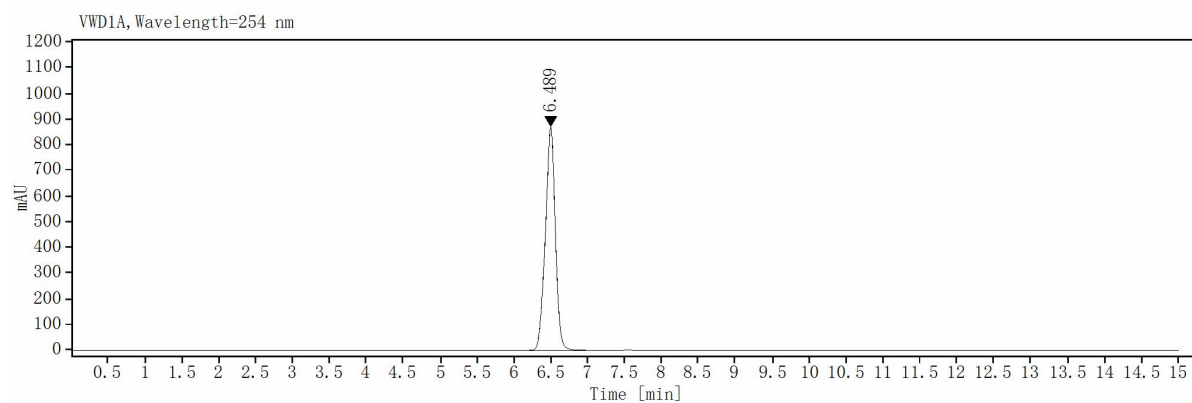
Injection Volume: 3.000

Sample Vial Number: P1-A4

Sequence Acquired Date: 2022-01-19 19:07:05+08:00

Injection Acq Method Name: Methods-2.amx

Injection Acquired By: System Administrator



Peak #	Ret.Time	Area	Height	Area%
1	6.489	8205.32	870.13	100%
Total		8205.32	870.13	100%