Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Facile synthesis of indolizinoindolone, indolylepoxypyrrolooxazole, indolylpyrrolooxazolone and isoindolopyrazinoindolone heterocycles from indole and imide derivatives†

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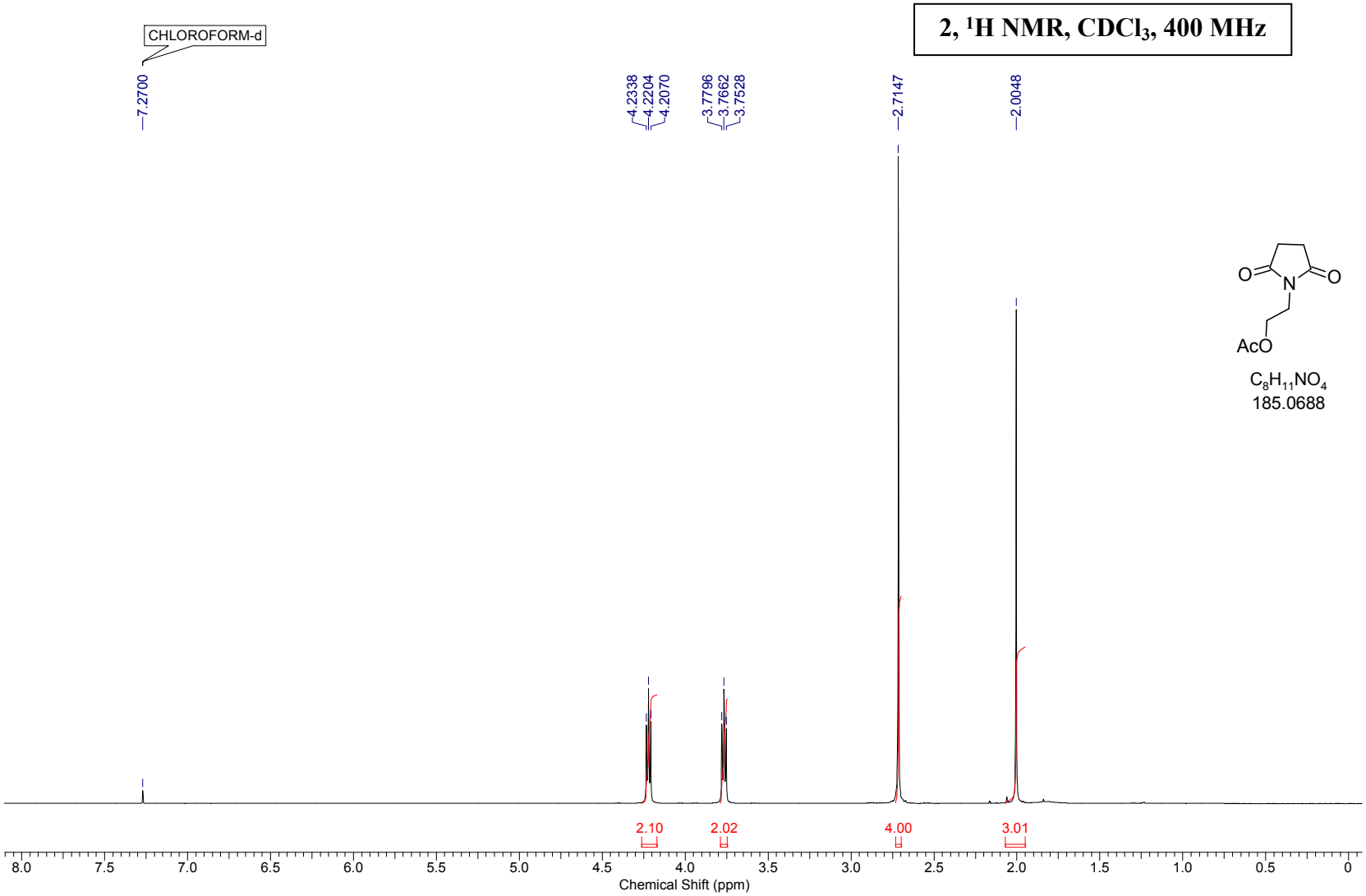
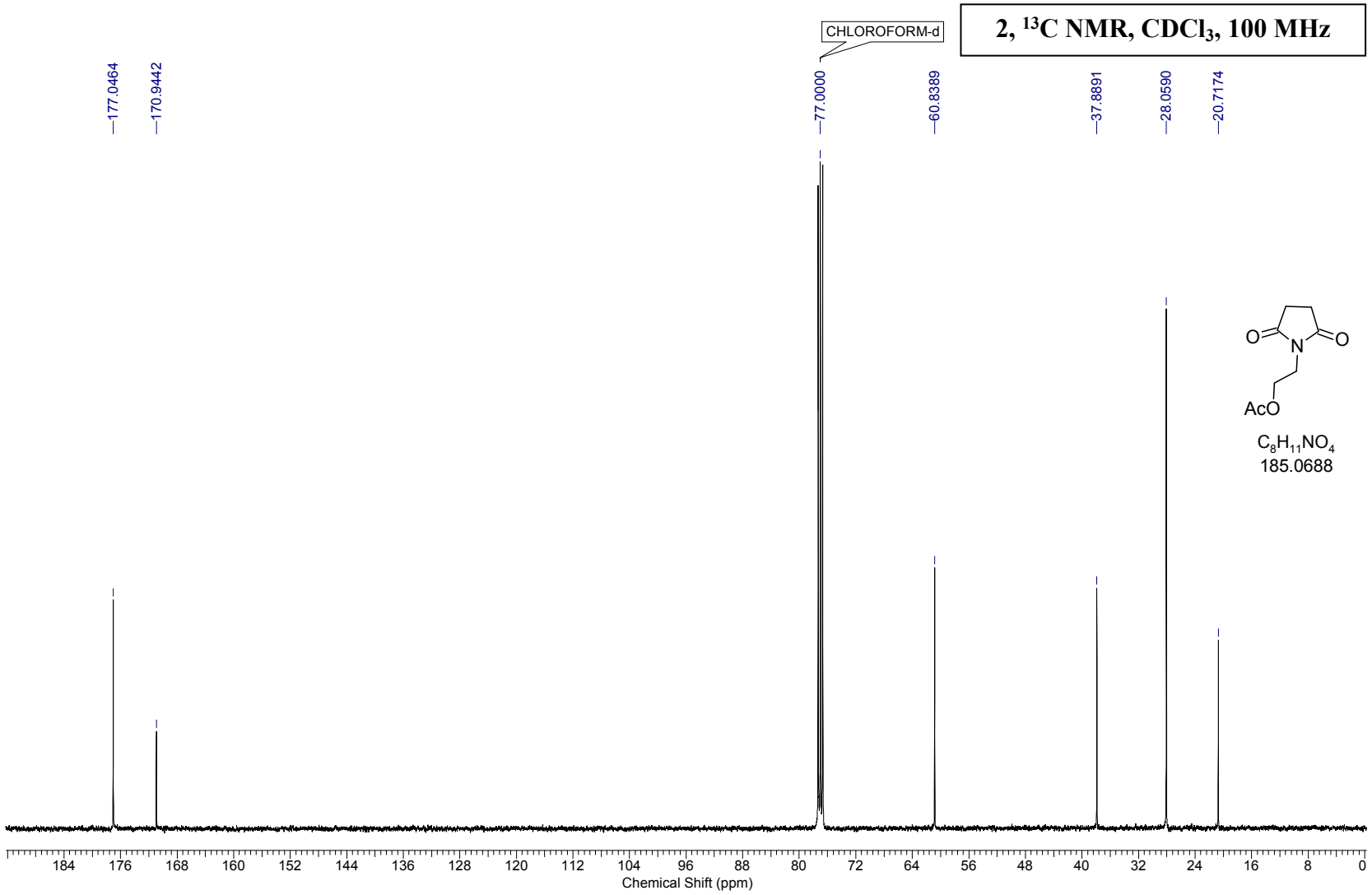
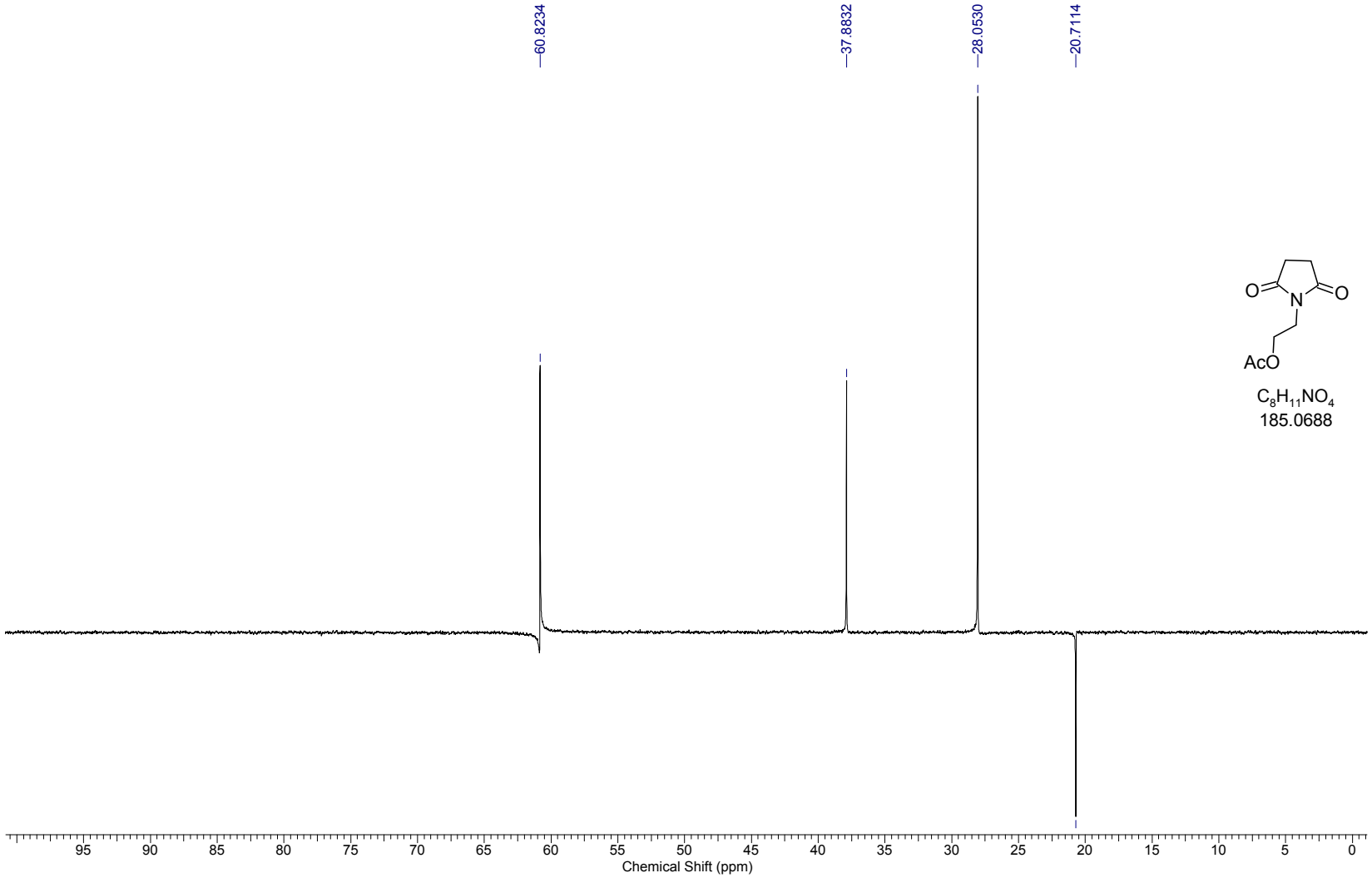
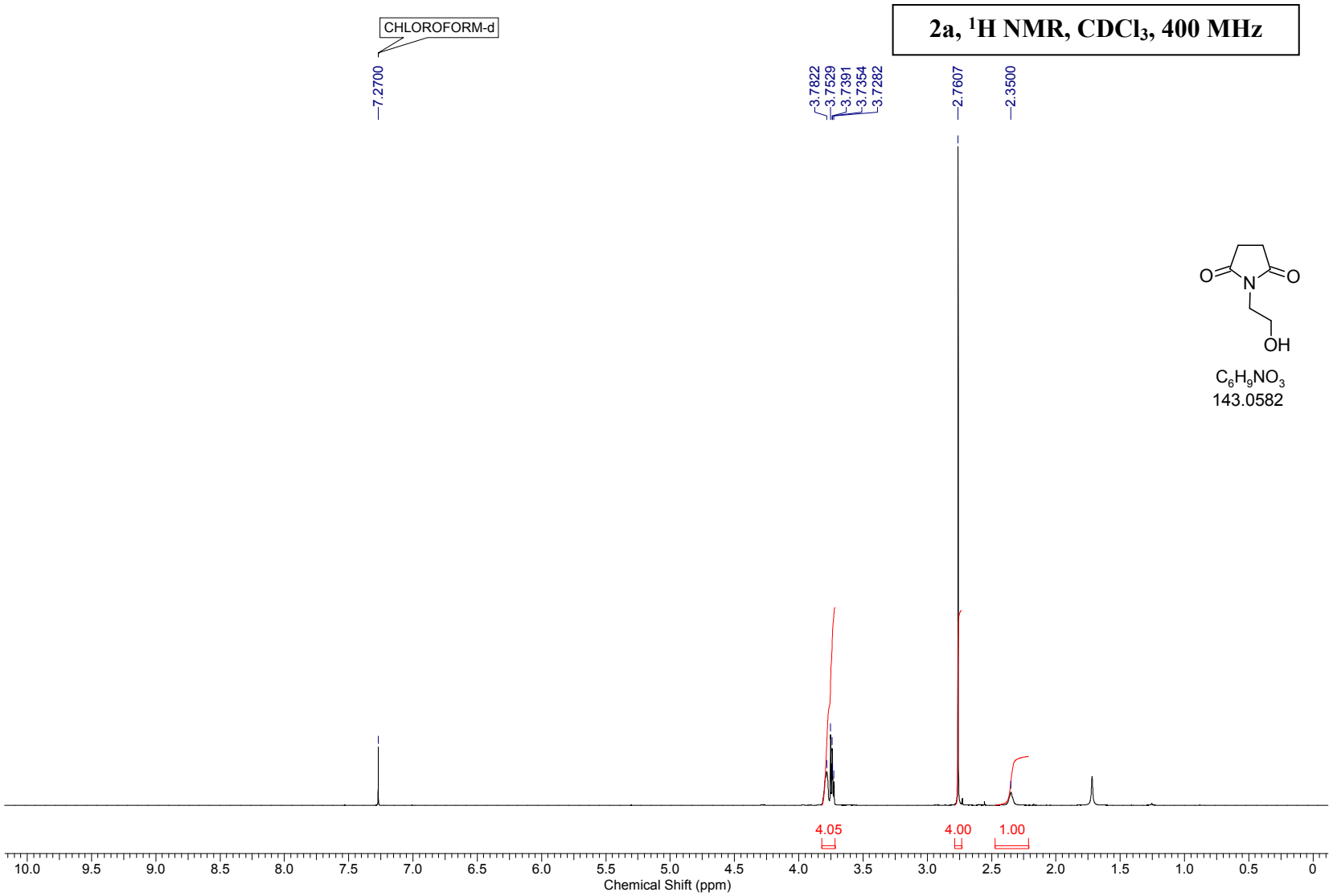

2, ^{1}H NMR, $CDCl_3$, 400 MHz
CHLOROFORM-d
7.2700
4.2338
4.2204
4.2070
3.7796
3.7662
3.7528
2.7147
2.0048
O
N
O
AcO
$C_8H_{11}NO_4$
185.0688
2.10
2.02
4.00
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)

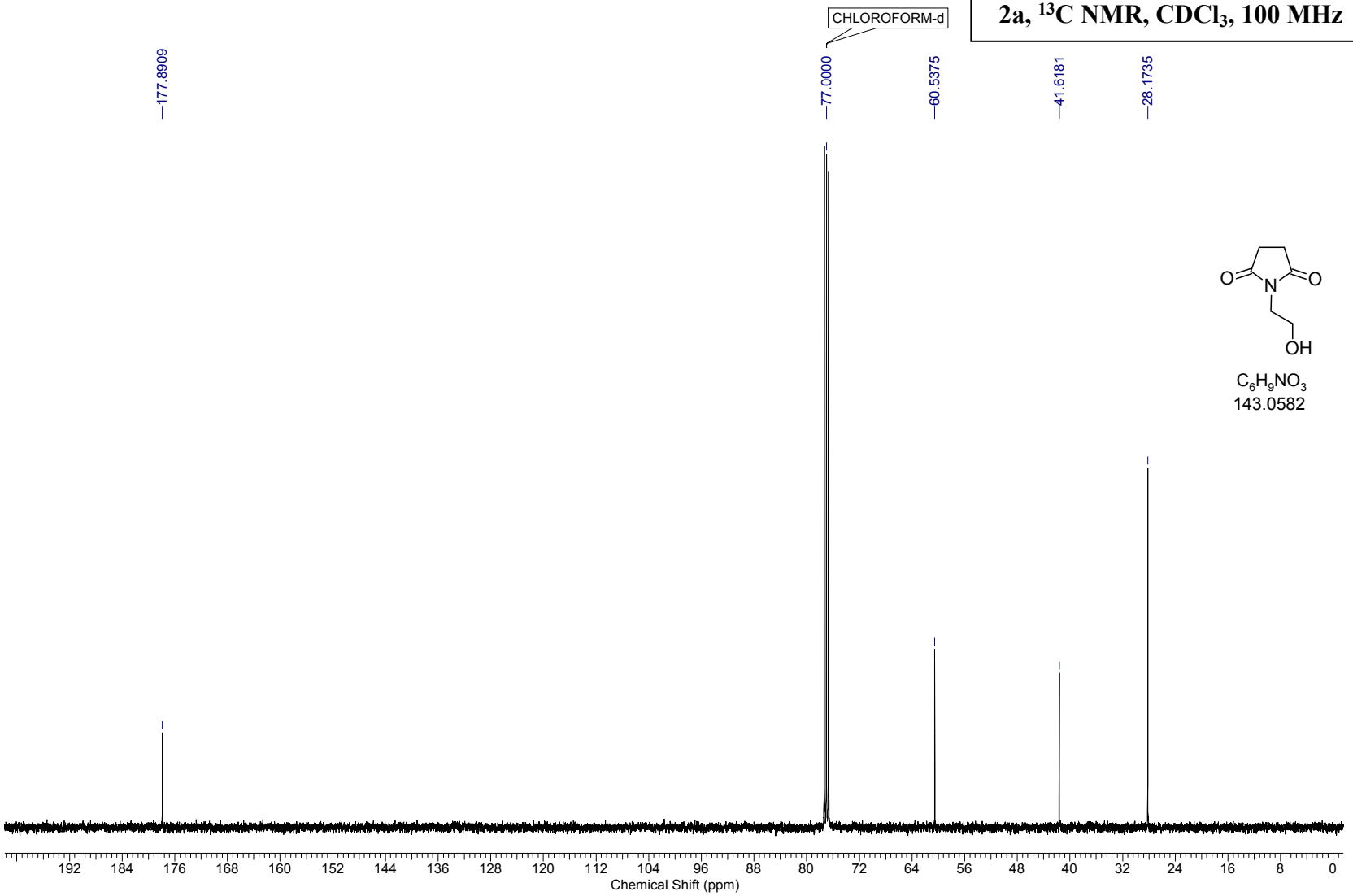

2, ^{13}C NMR, $CDCl_3$, 100 MHz
CHLOROFORM-d
177.0464
170.9442
77.0000
60.8389
37.8891
28.0590
20.7174
O
N
O
AcO
$C_8H_{11}NO_4$
185.0688
184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0
Chemical Shift (ppm)

2, DEPT, $CDCl_3$, 100 MHz

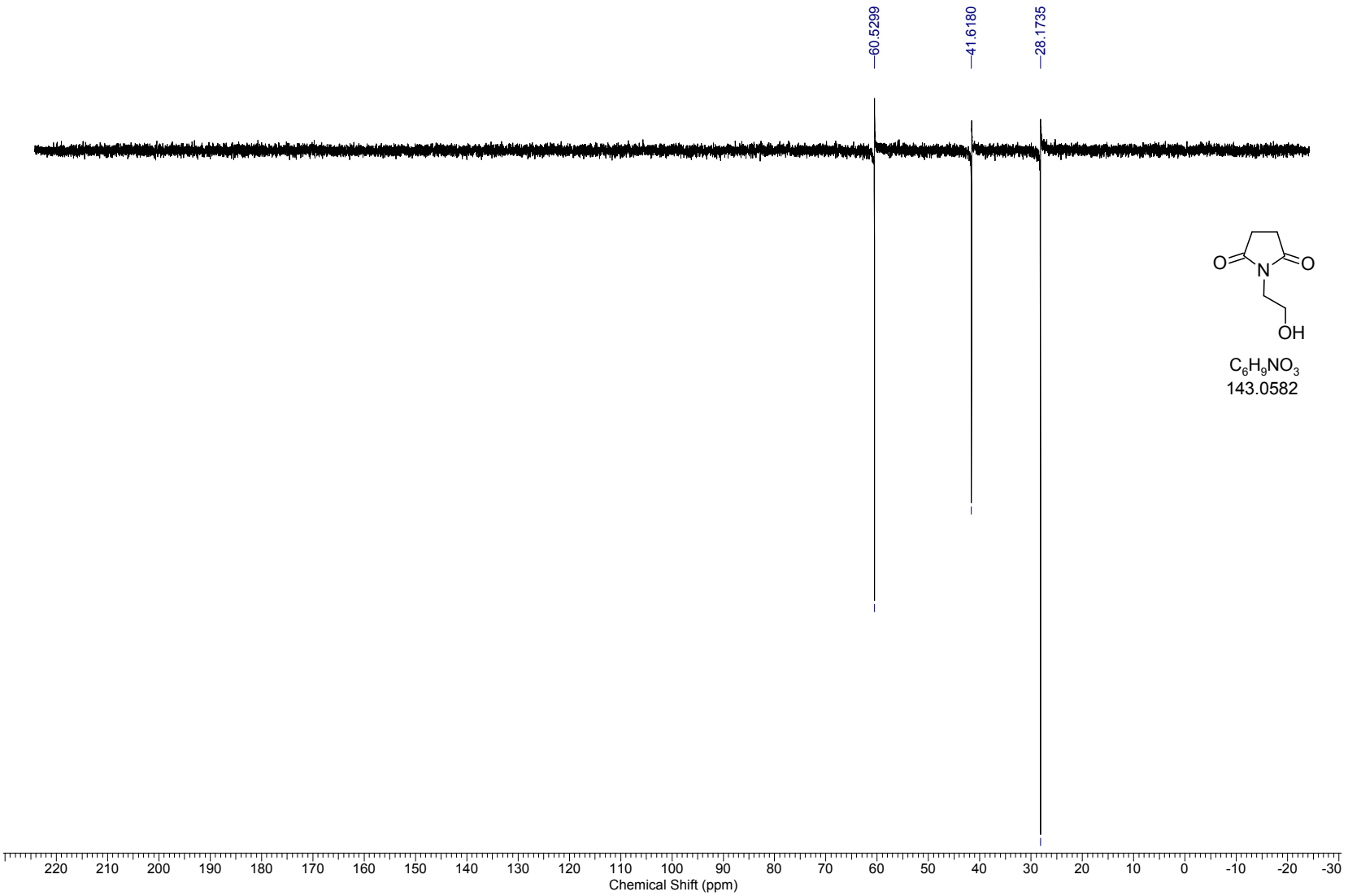


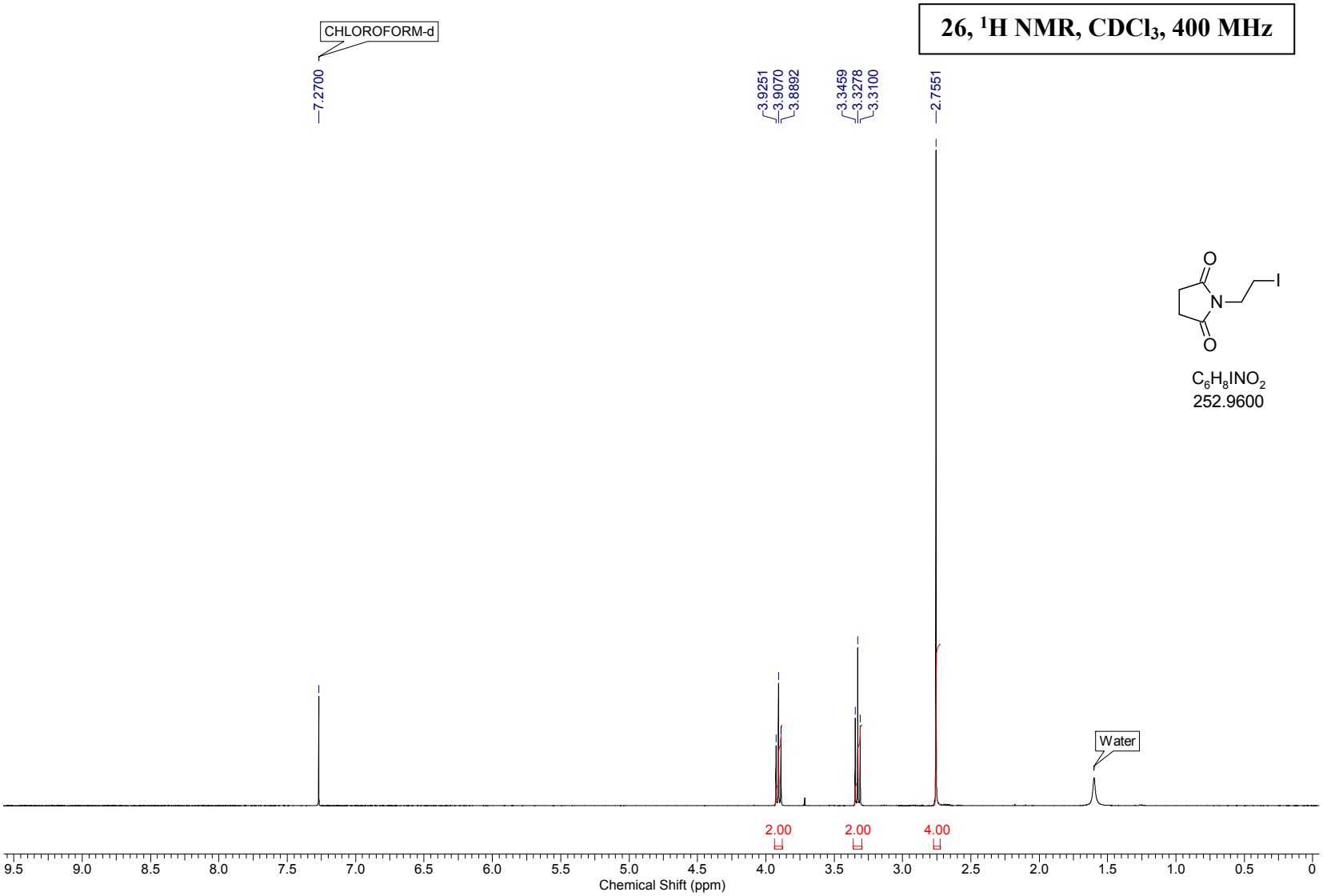

2a, ^{1}H NMR, $CDCl_3$, 400 MHz
CHLOROFORM-d
7.2700
3.7822
3.7529
3.7391
3.7354
3.7282
2.7607
2.3500
O
N
O
OH
$C_6H_9NO_3$
143.0582
4.05
4.00
1.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)

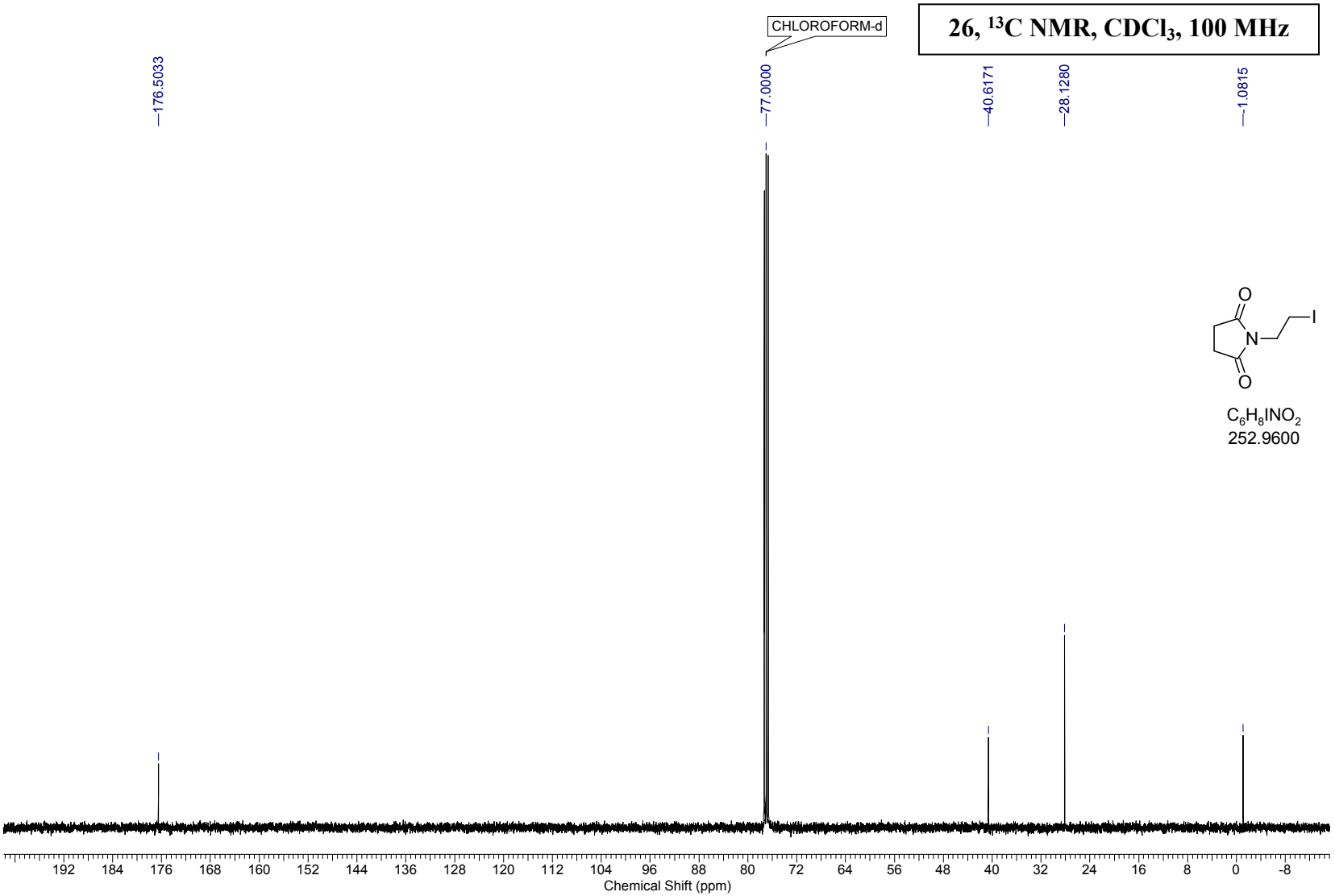
2a, ^{13}C NMR, $CDCl_3$, 100 MHz



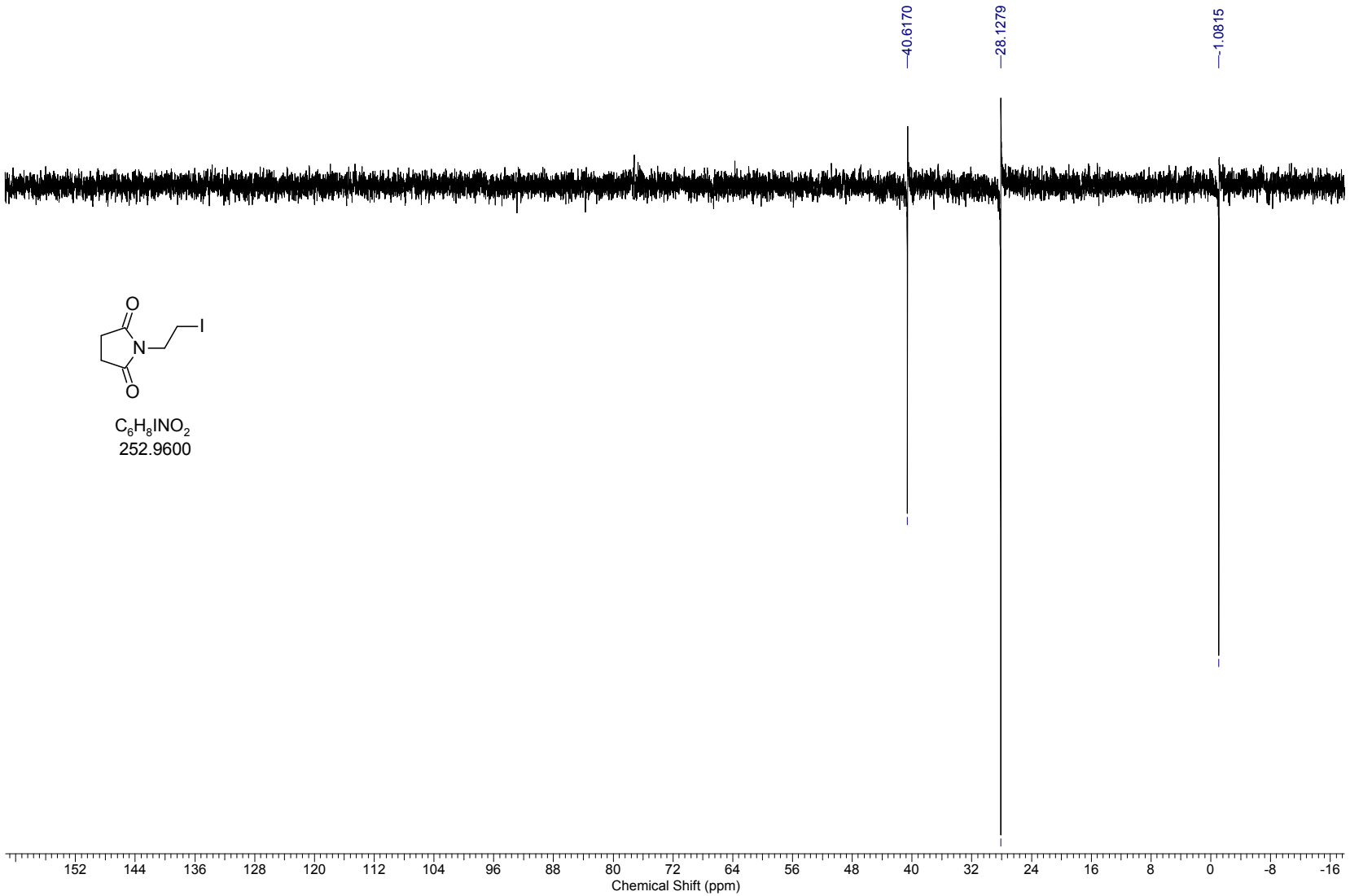
2a, DEPT, $CDCl_3$, 100 MHz



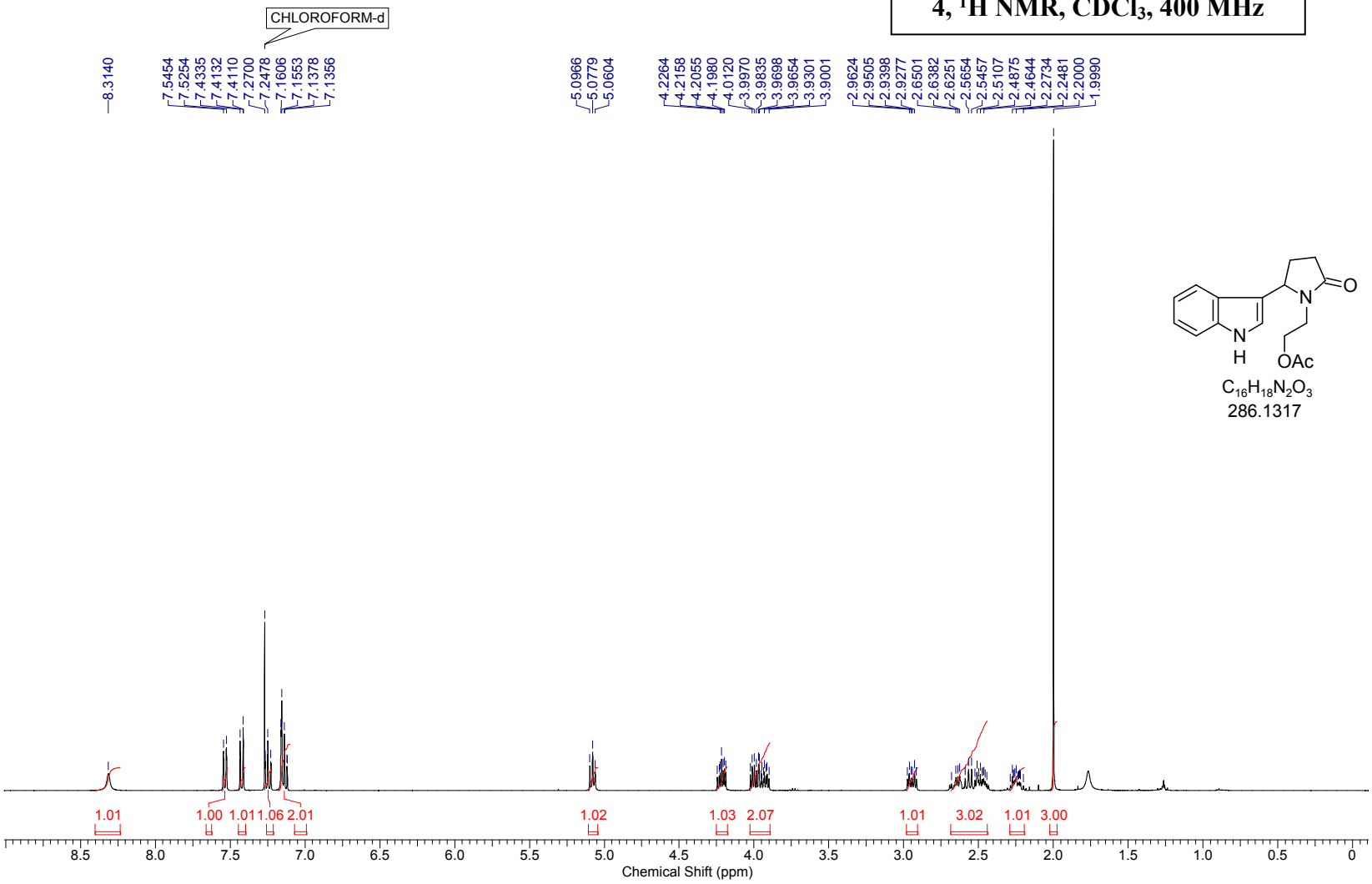

26, ^{1}H NMR, $CDCl_3$, 400 MHz
CHLOROFORM-d
7.2700
3.9251
3.9070
3.8892
3.3459
3.3278
3.3100
2.7551
Water
2.00
2.00
4.00
$C_6H_8INO_2$
252.9600
Chemical Shift (ppm)

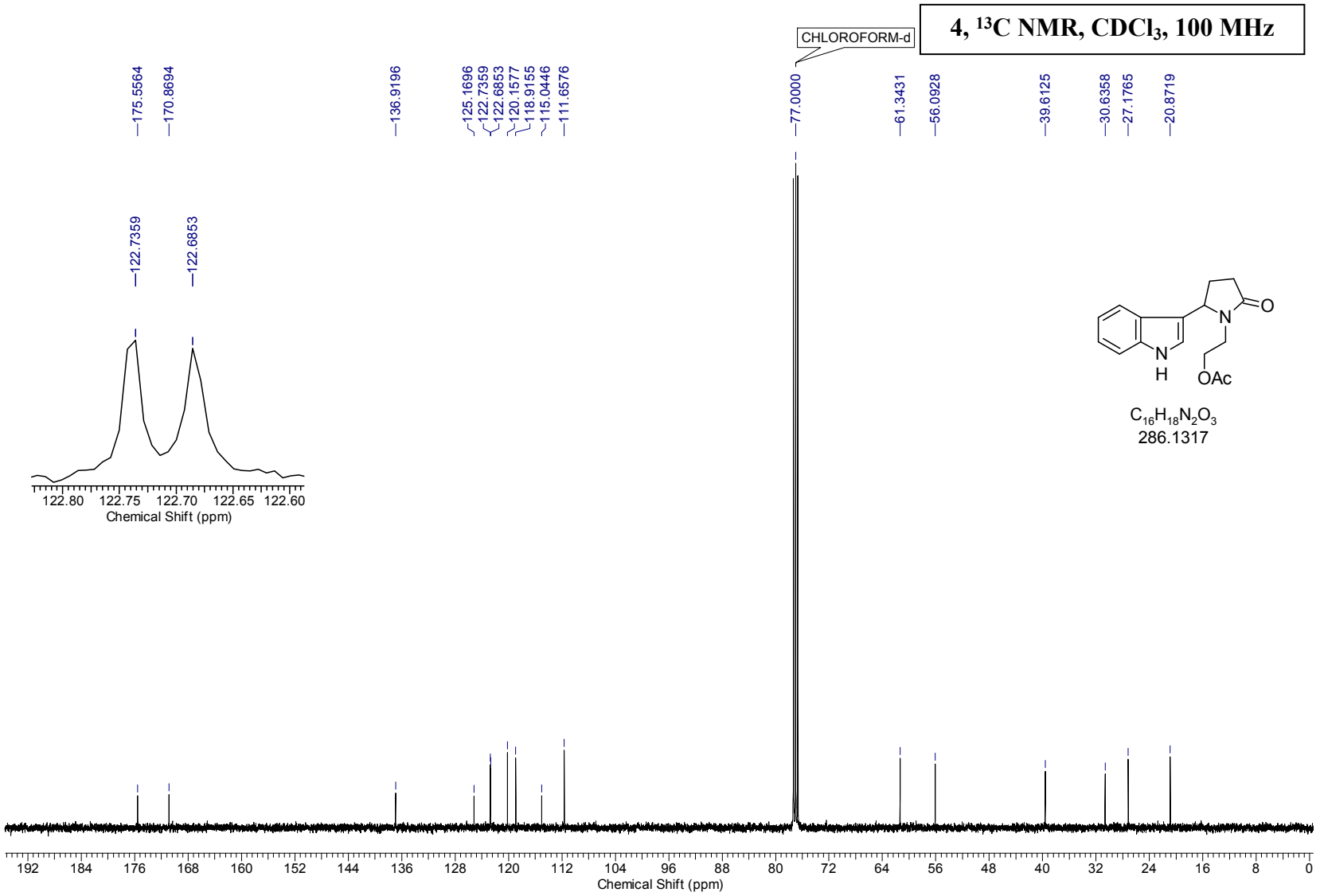

26, ^{13}C NMR, $CDCl_3$, 100 MHz
CHLOROFORM-d
176.5033
77.0000
40.6171
28.1280
1.0815
O
N
I
O
$C_6H_8INO_2$
252.9600
192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0 -8
Chemical Shift (ppm)

26, DEPT, $CDCl_3$, 100 MHz

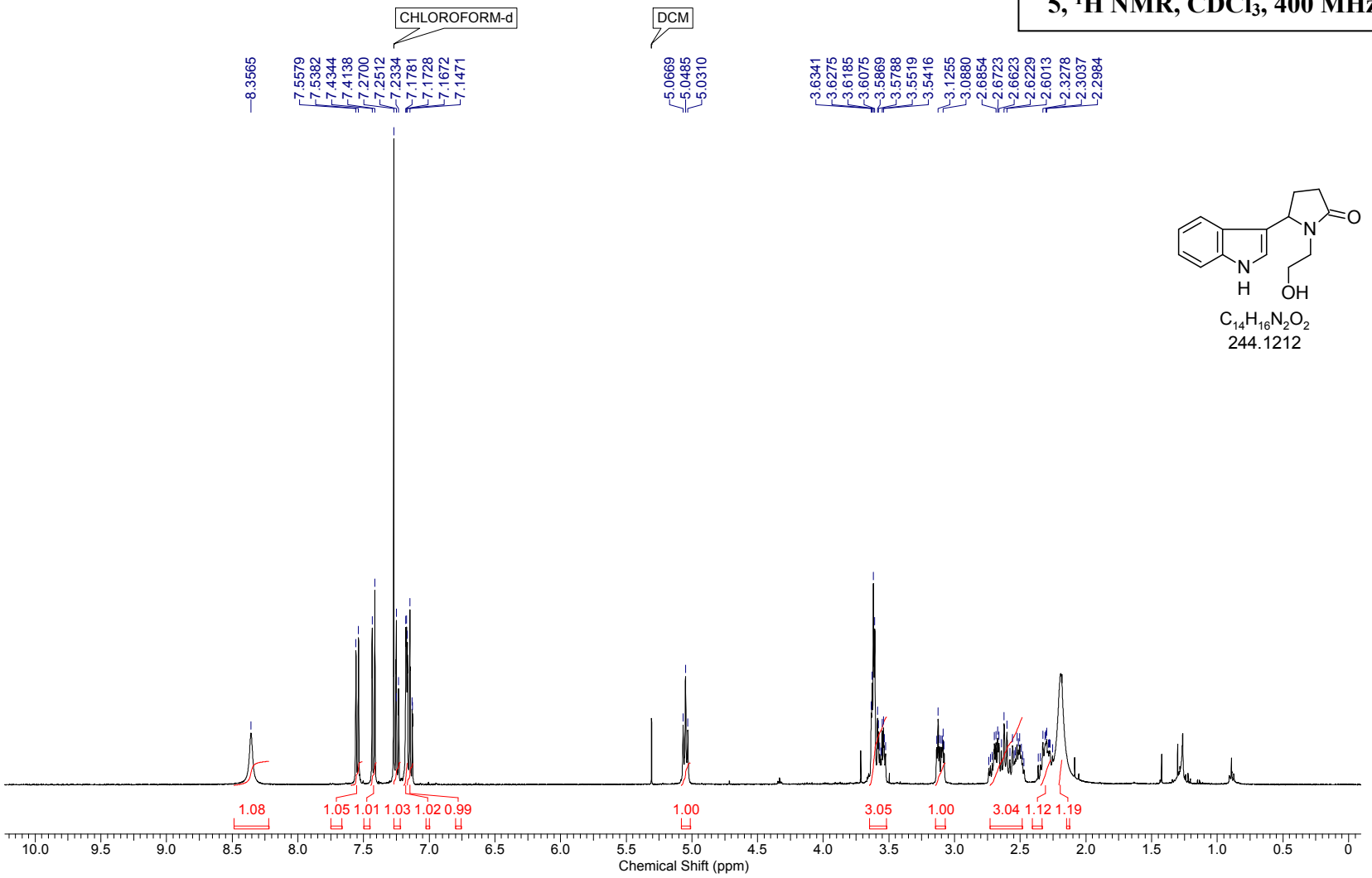


4, ^{1}H NMR, $CDCl_3$, 400 MHz



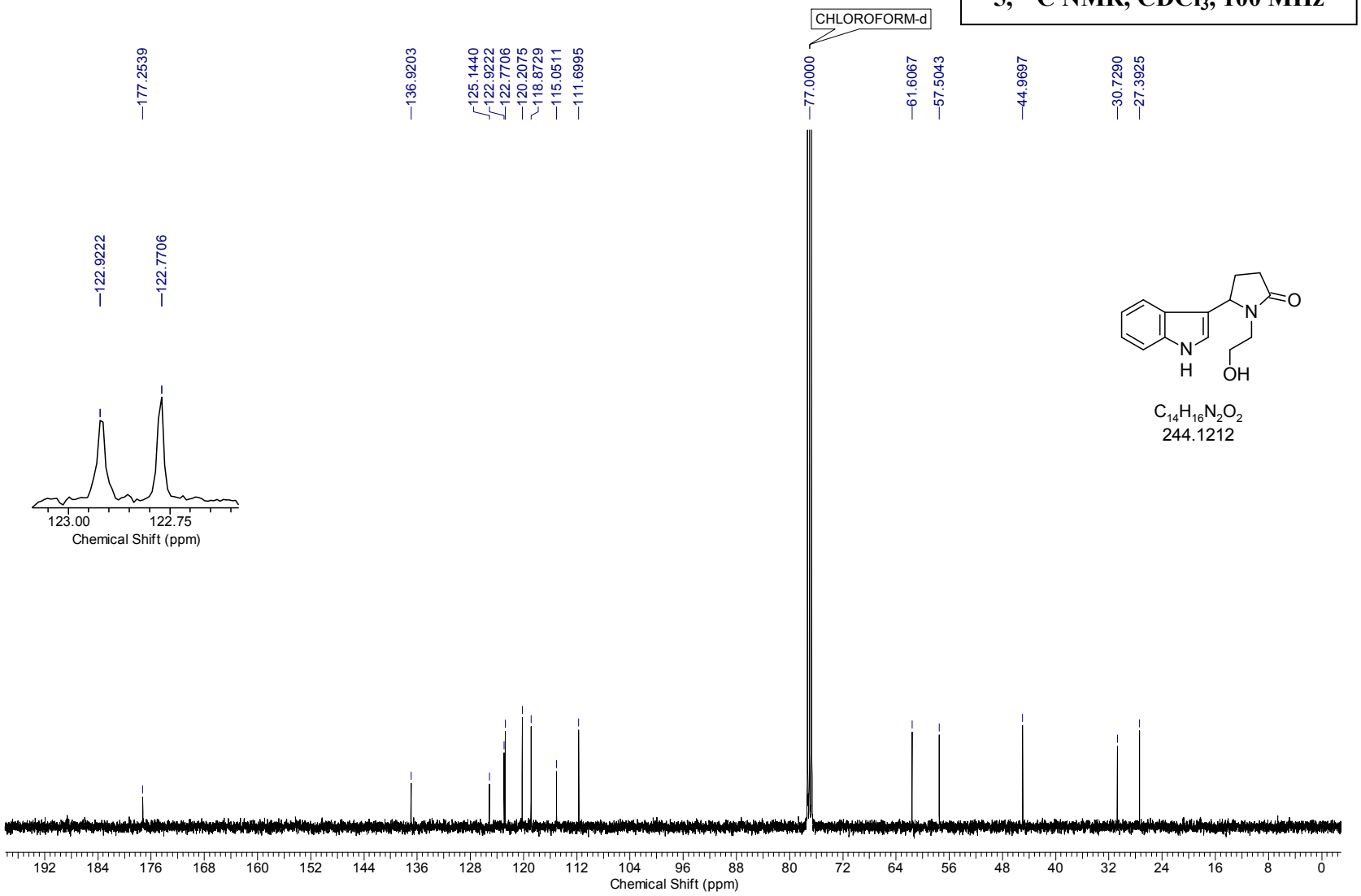

4, ^{13}C NMR, $CDCl_3$, 100 MHz
CHLOROFORM-d
175.5564
170.8694
136.9196
125.1696
122.7359
122.6853
120.1577
118.9155
115.0446
111.6576
77.0000
61.3431
56.0928
39.6125
30.6358
27.1765
20.8719
122.7359
122.6853
122.80 122.75 122.70 122.65 122.60
Chemical Shift (ppm)
O
N
N
H
OAc
$C_{16}H_{18}N_2O_3$
286.1317
192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0
Chemical Shift (ppm)

5, ^{1}H NMR, $CDCl_3$, 400 MHz



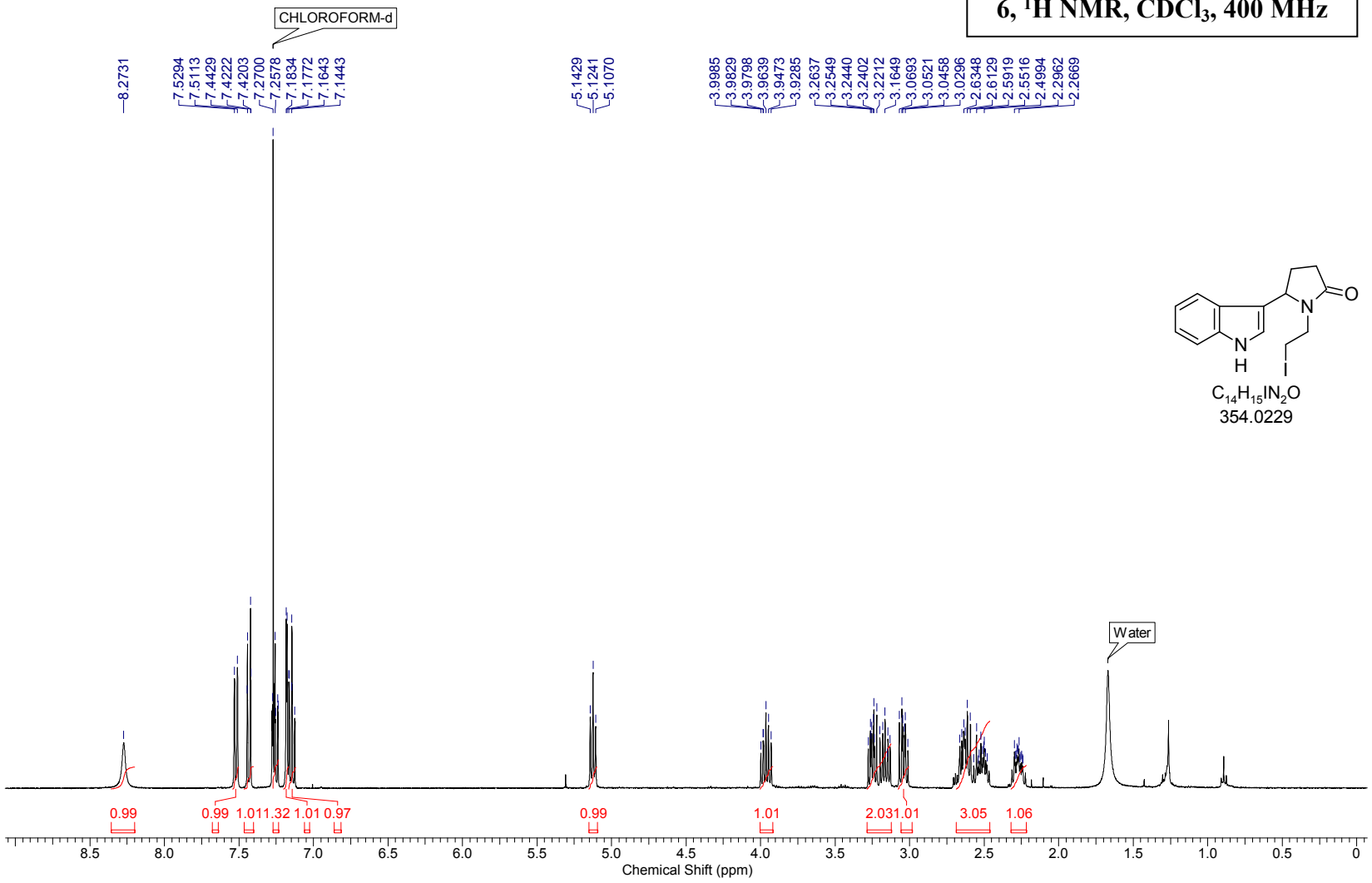
$C_{14}H_{16}N_2O_2$
244.1212

5, ^{13}C NMR, $CDCl_3$, 100 MHz



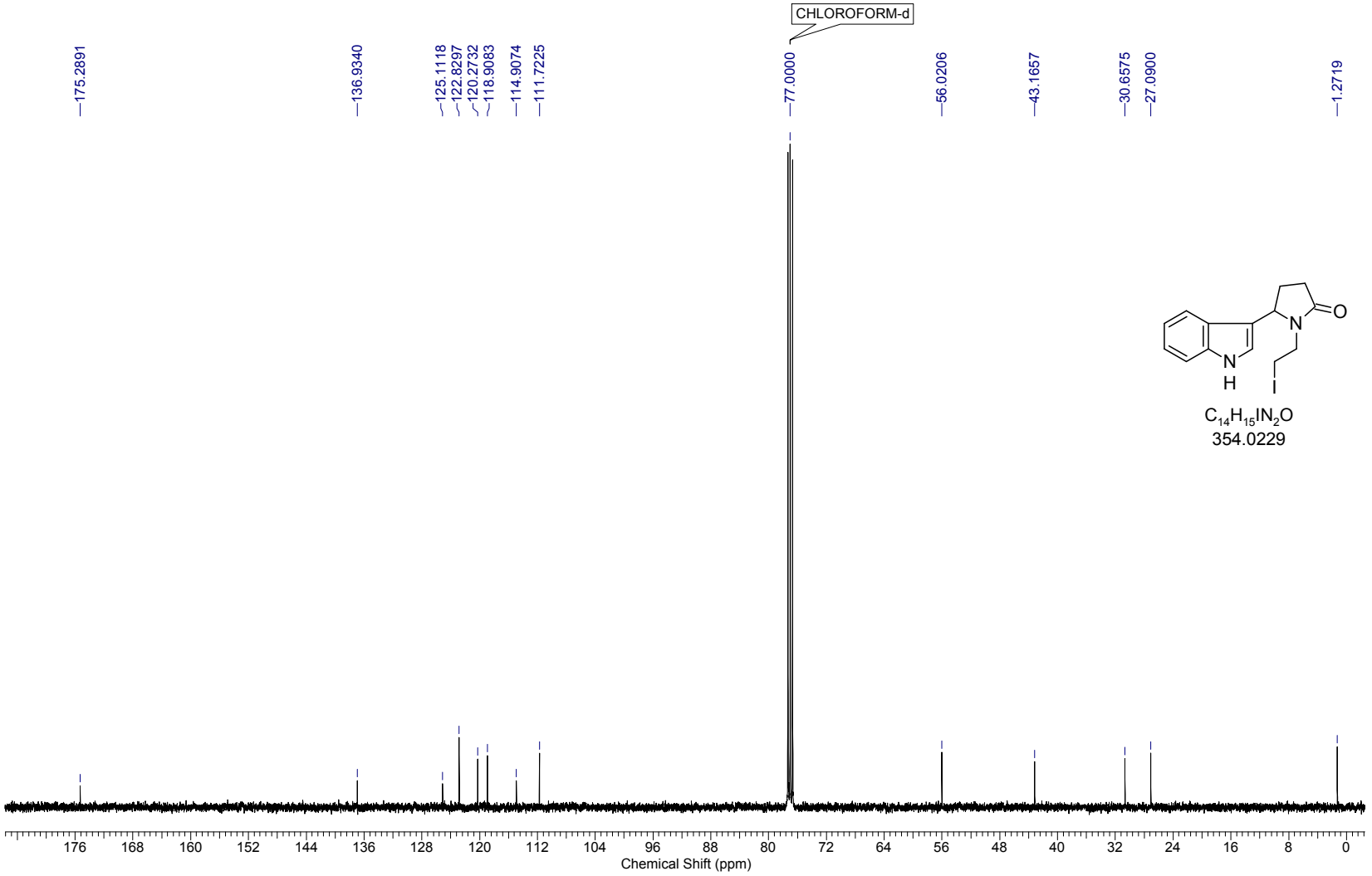
$C_{14}H_{16}N_2O_2$
244.1212

6, ^{1}H NMR, $CDCl_3$, 400 MHz

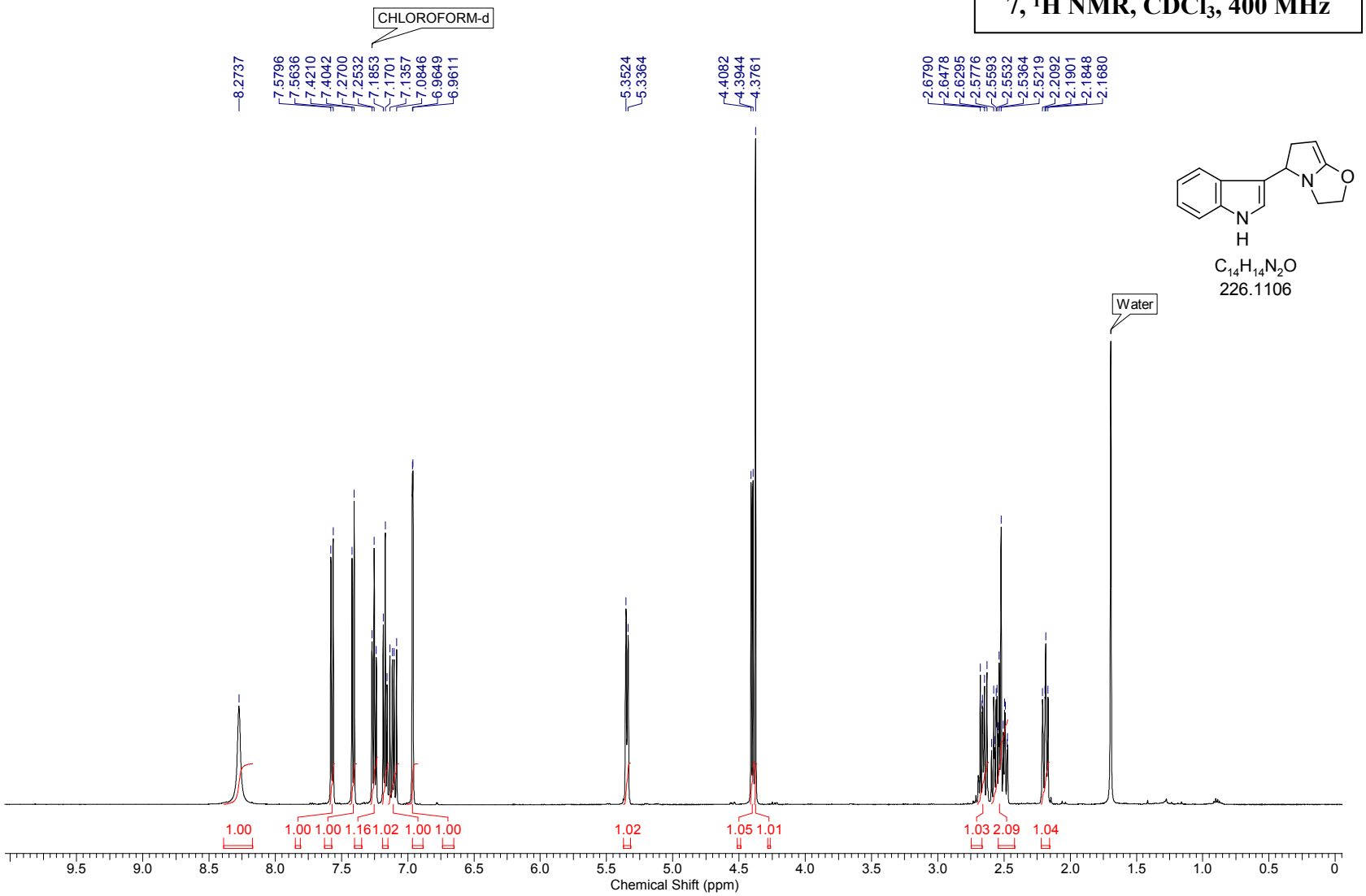


$C_{14}H_{15}IN_2O$
354.0229

6, ^{13}C NMR, $CDCl_3$, 100 MHz

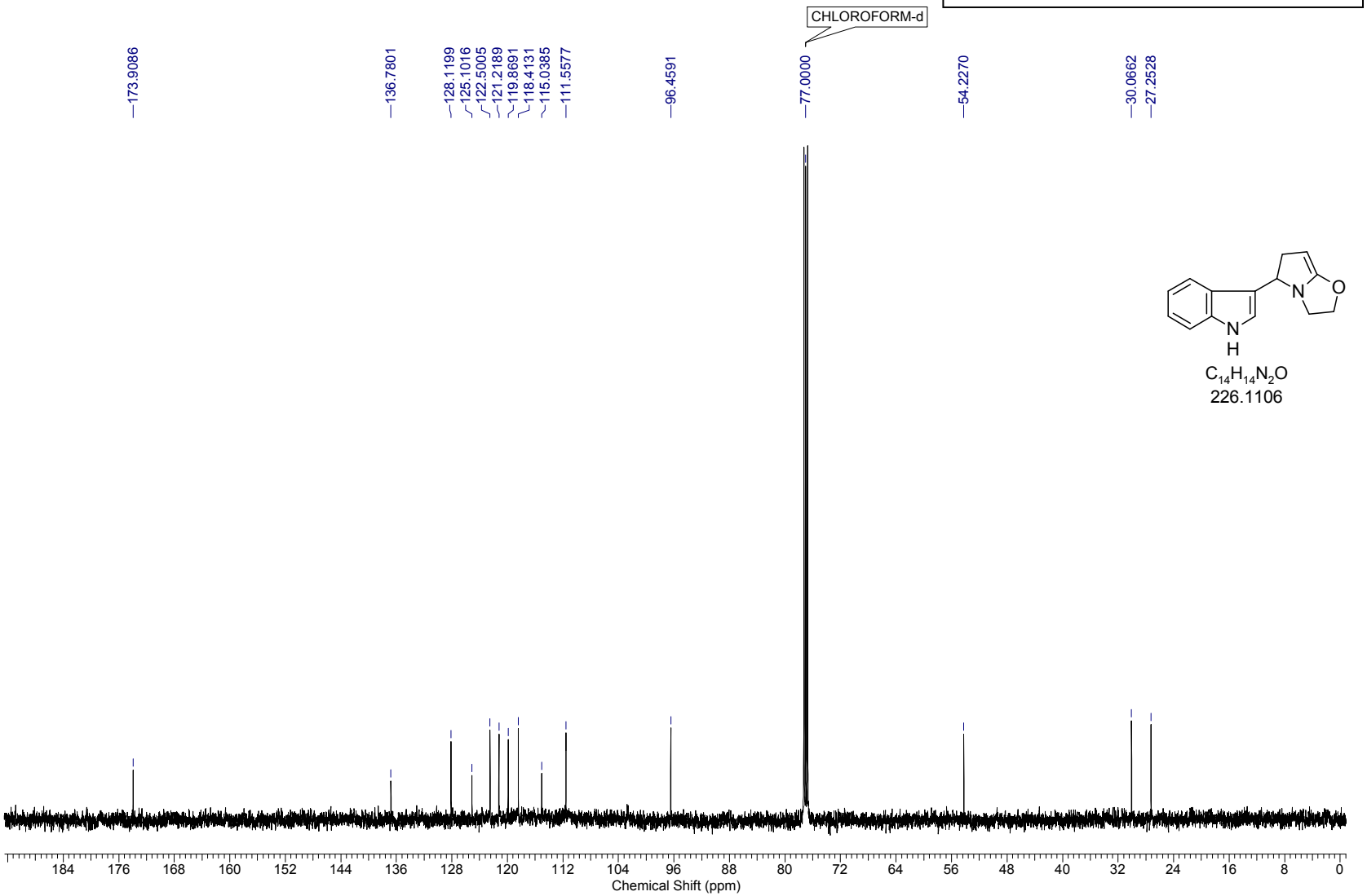


7, ^{1}H NMR, $CDCl_3$, 400 MHz

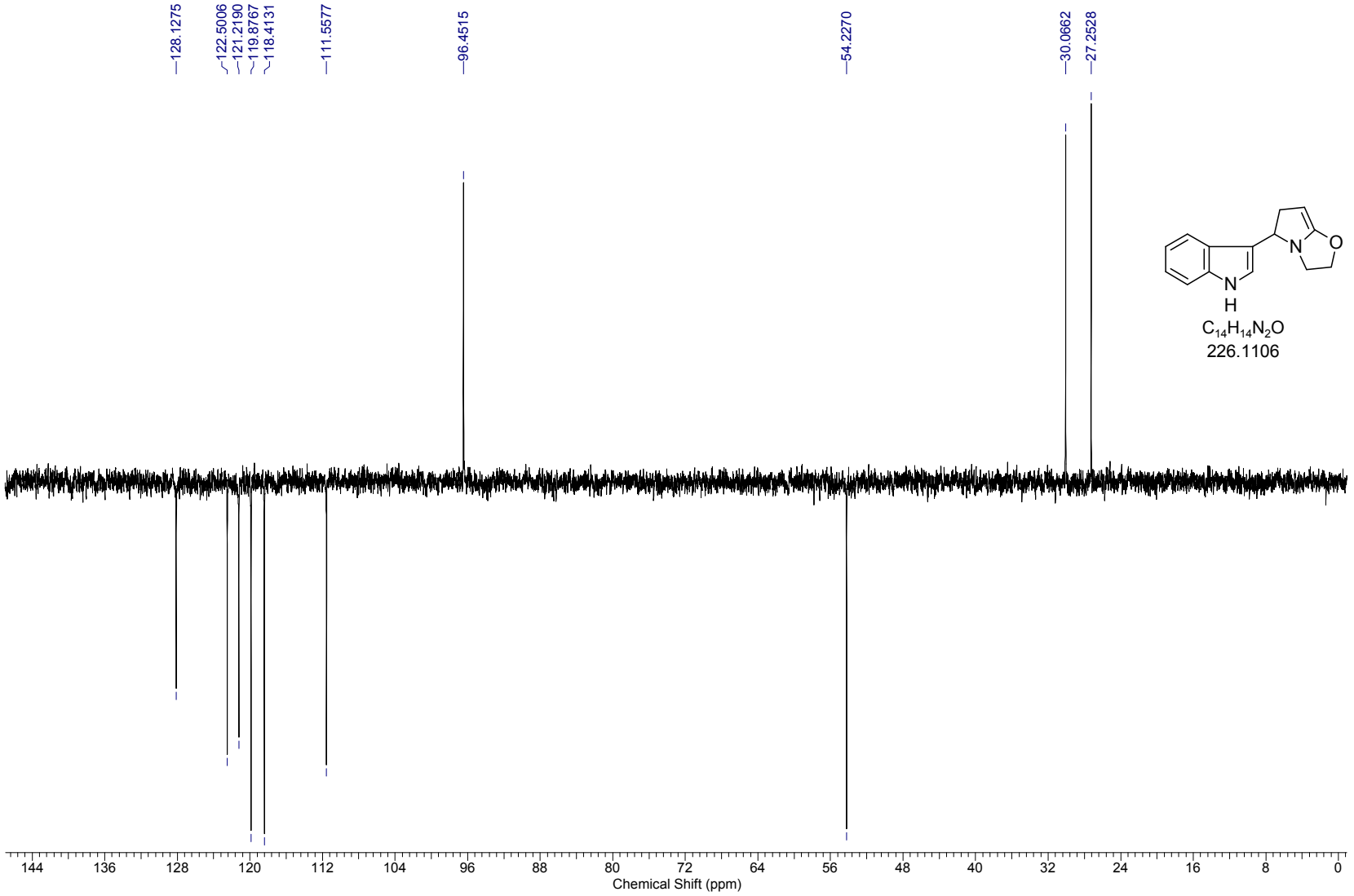


$C_{14}H_{14}N_2O$
226.1106

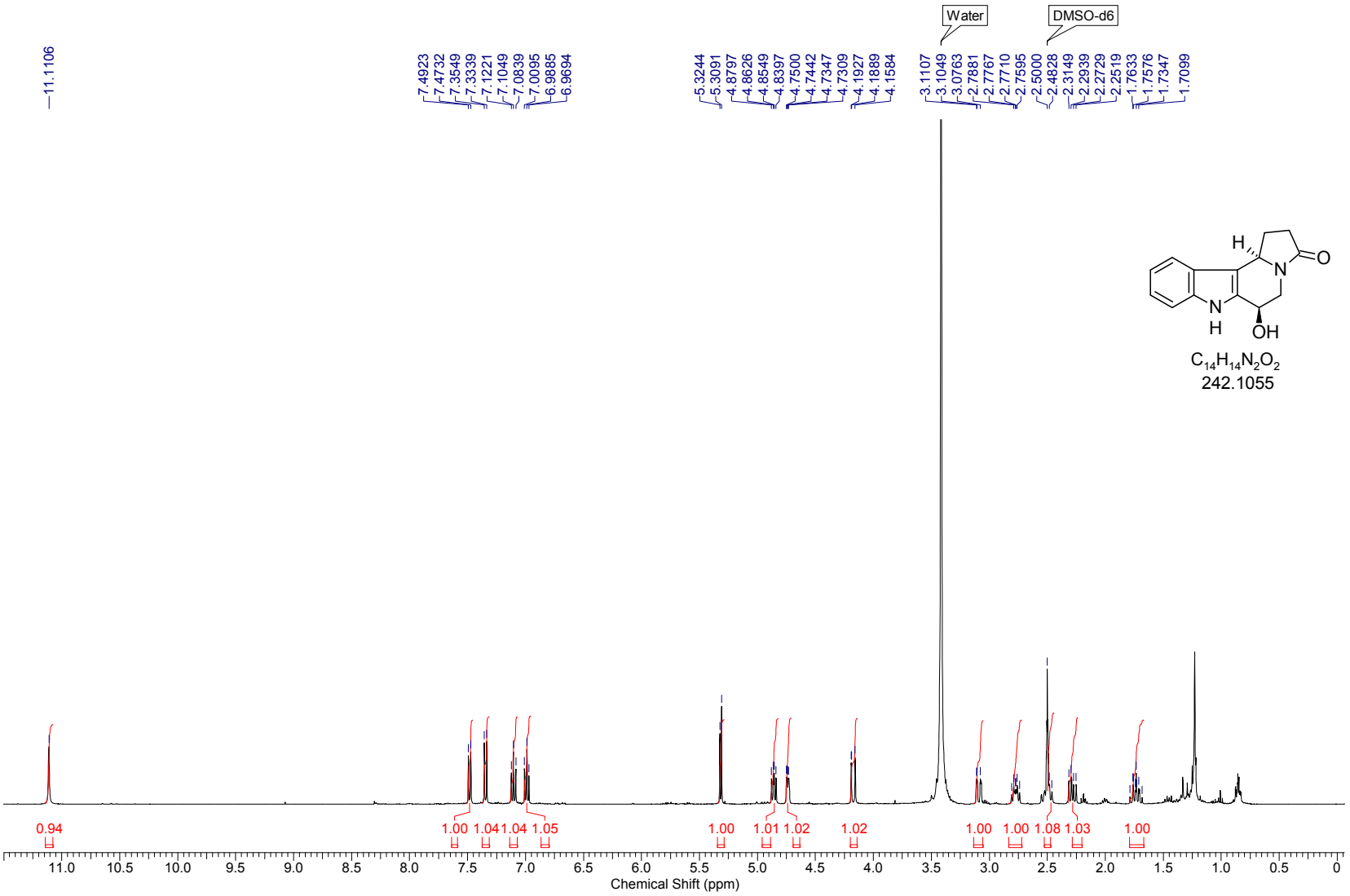
7, ^{13}C NMR, $CDCl_3$, 100 MHz



7, DEPT, $CDCl_3$, 100 MHz

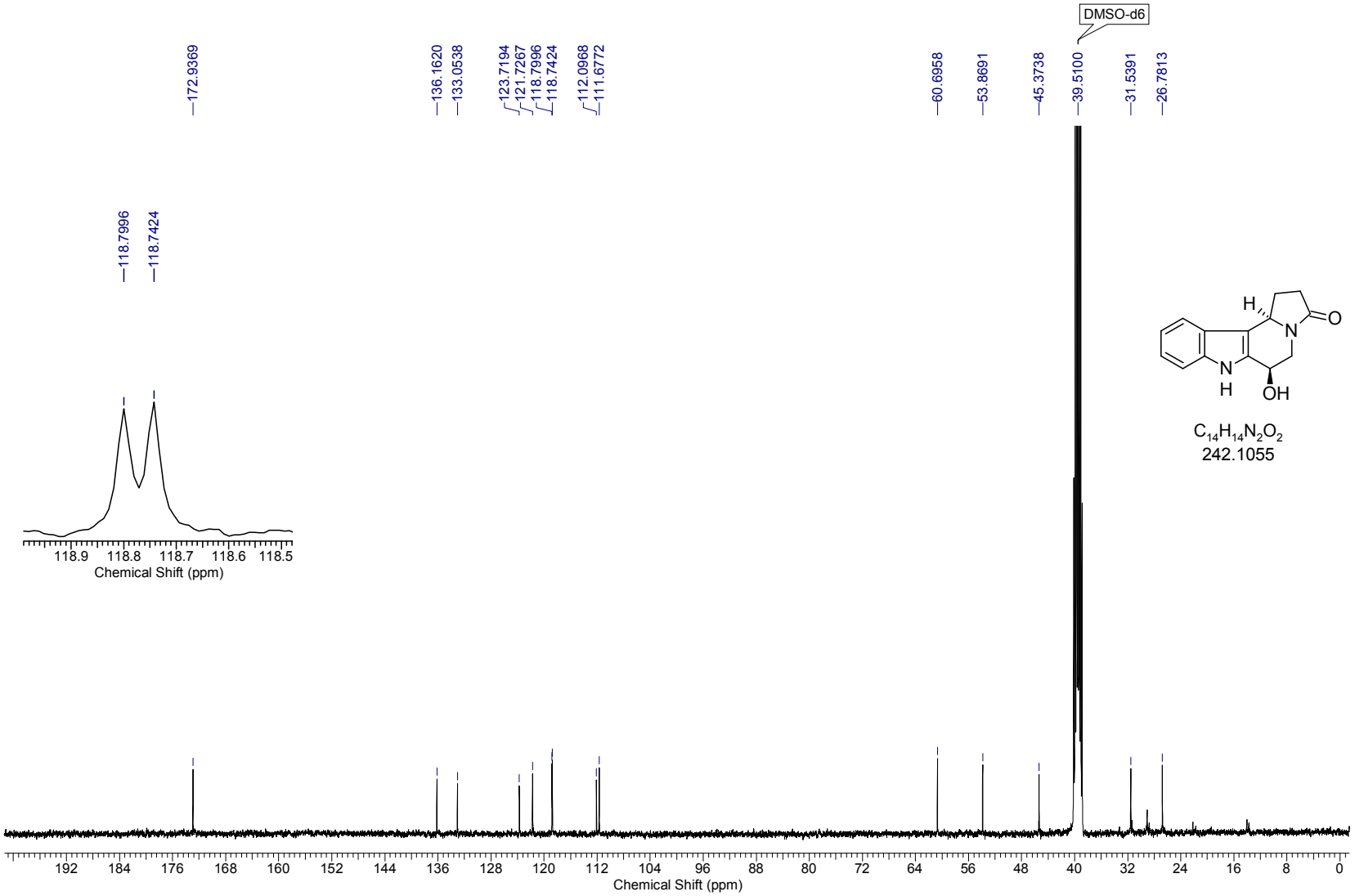


(±)-9, ^{1}H NMR, DMSO-d_6, 400 MHz

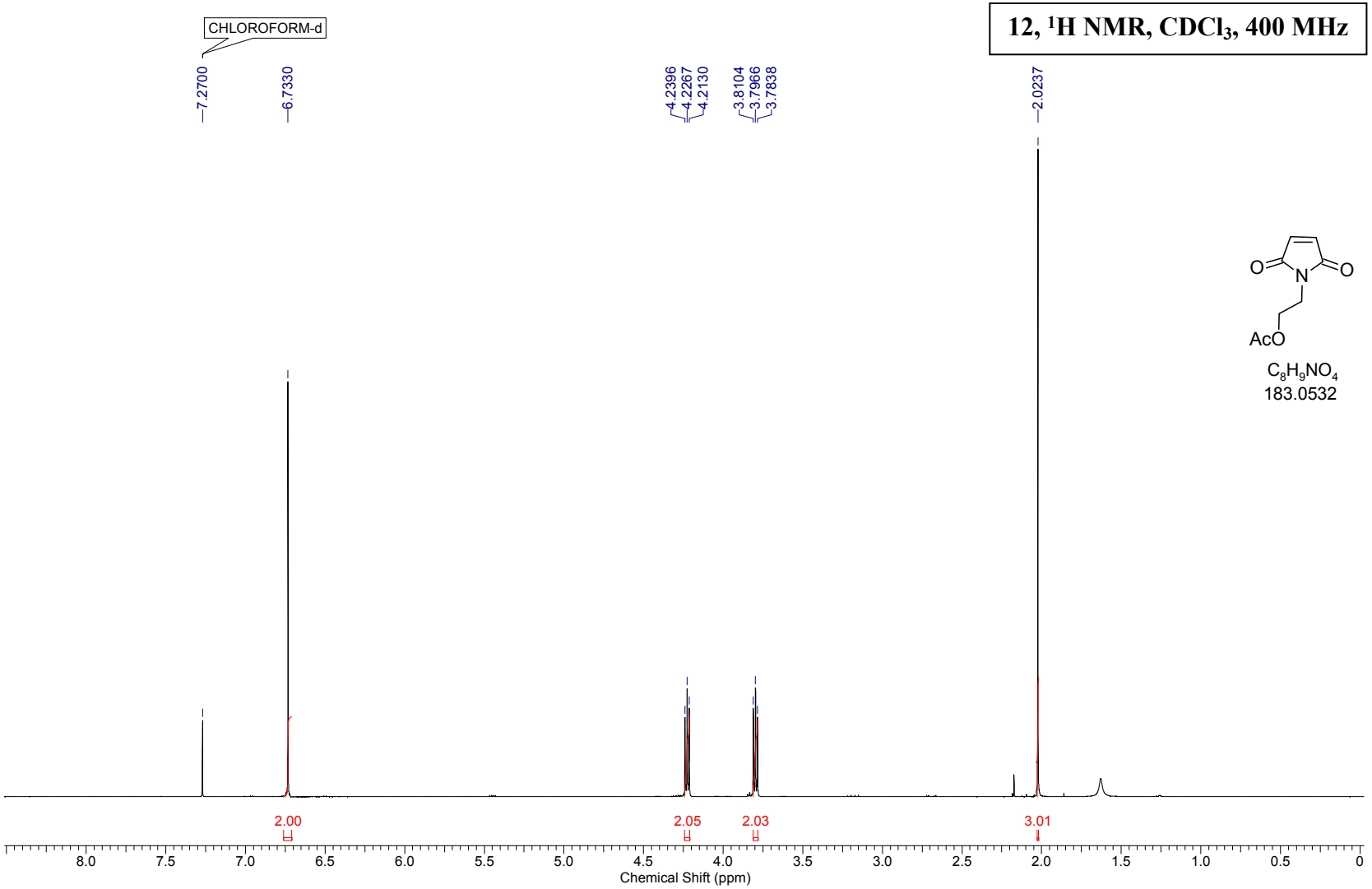


$C_{14}H_{14}N_2O_2$
242.1055

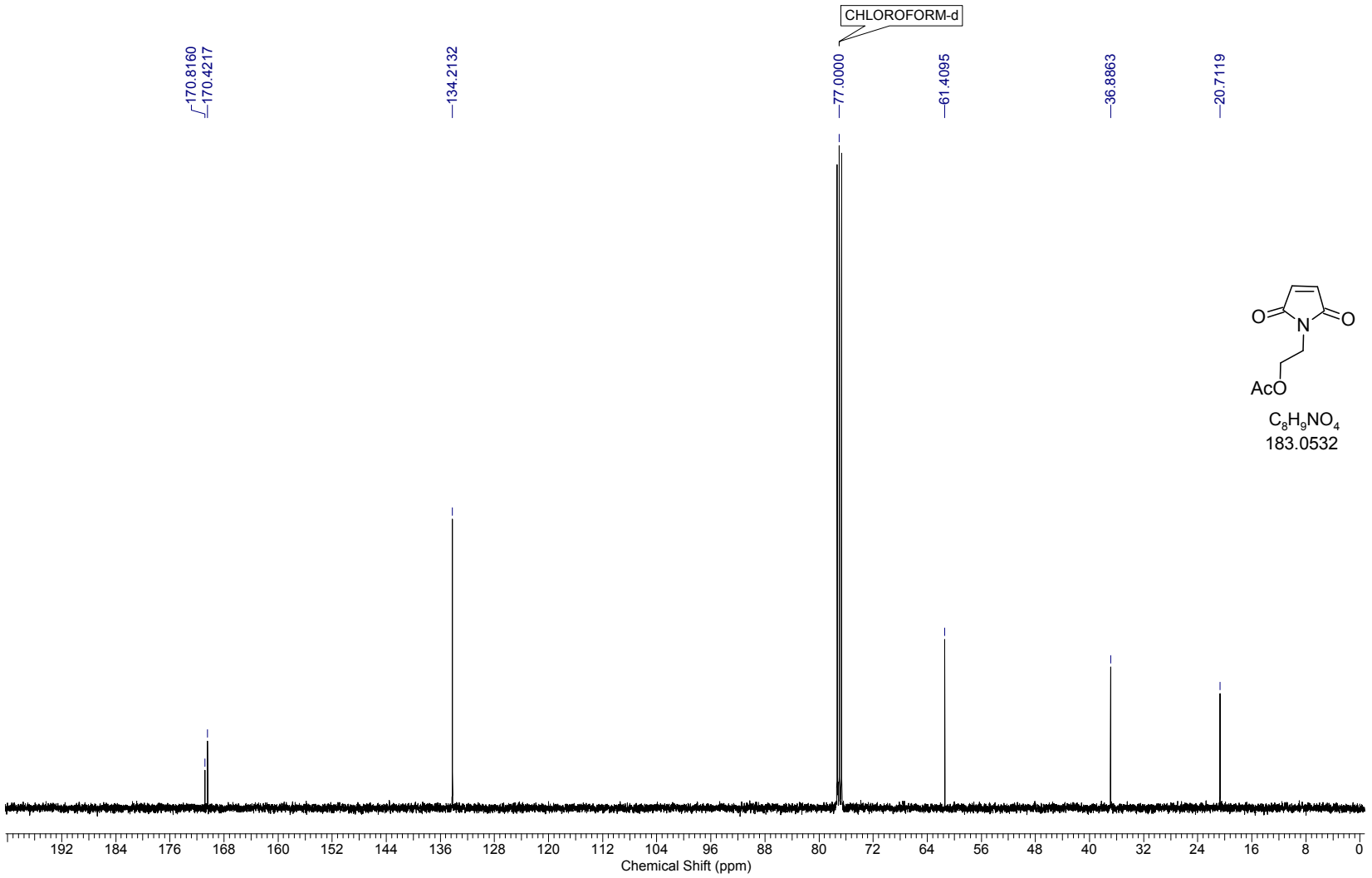
(±)-9, ^{13}C NMR, DMSO-d_6, 100 MHz



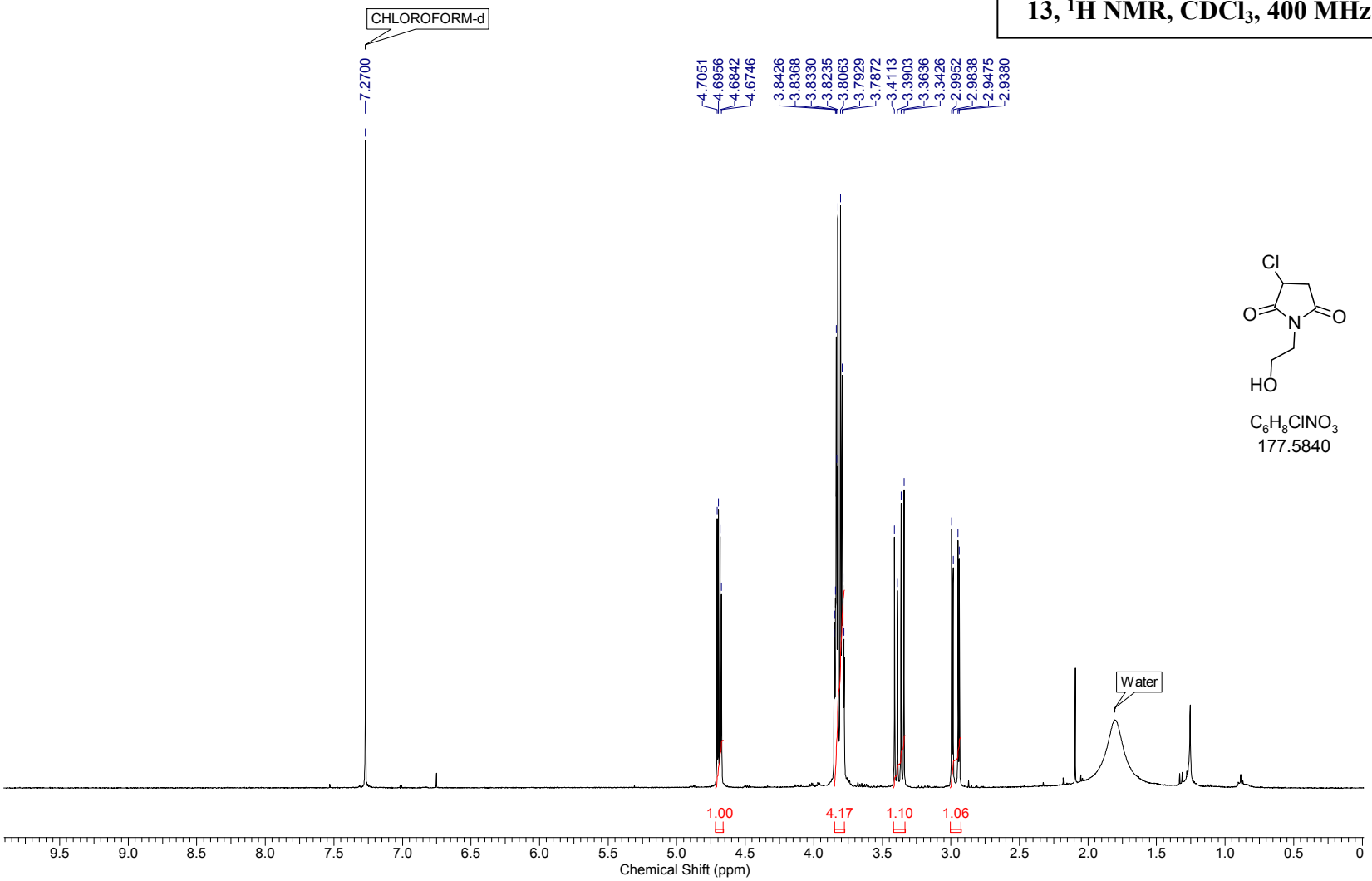
12, ^{1}H NMR, $CDCl_3$, 400 MHz



12, ^{13}C NMR, $CDCl_3$, 100 MHz

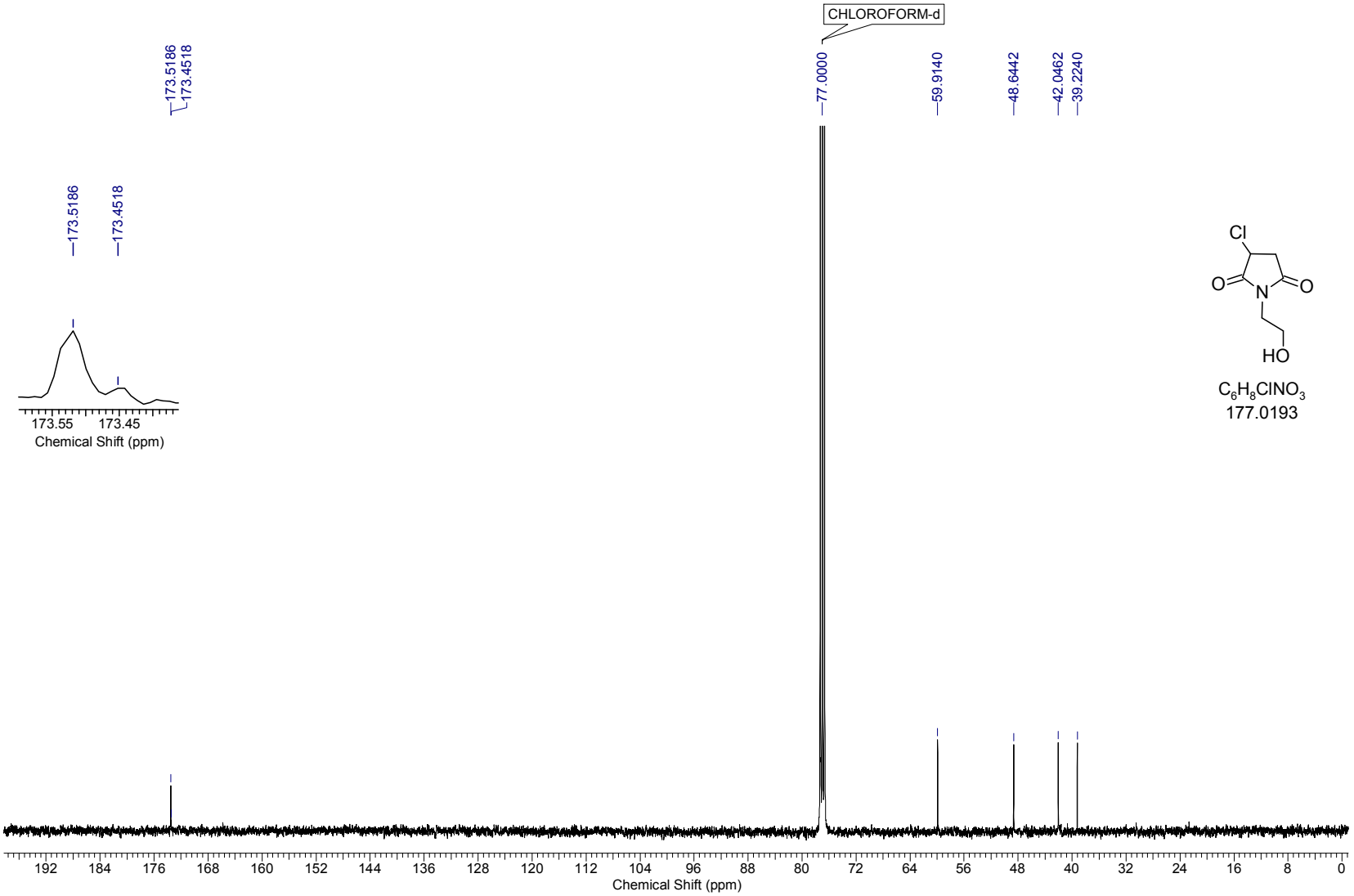


13, ^{1}H NMR, $CDCl_3$, 400 MHz

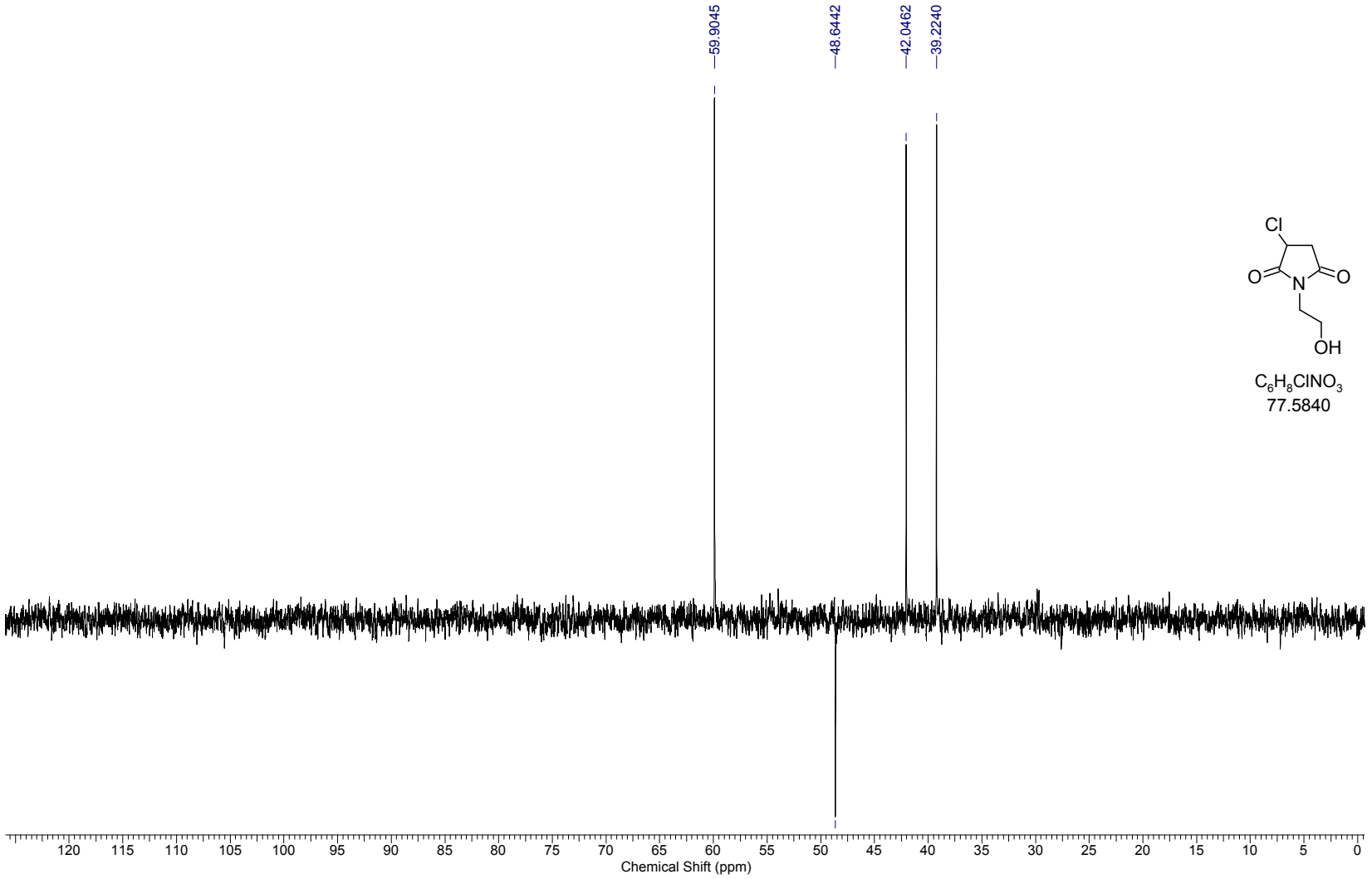


$C_6H_8ClNO_3$
177.5840

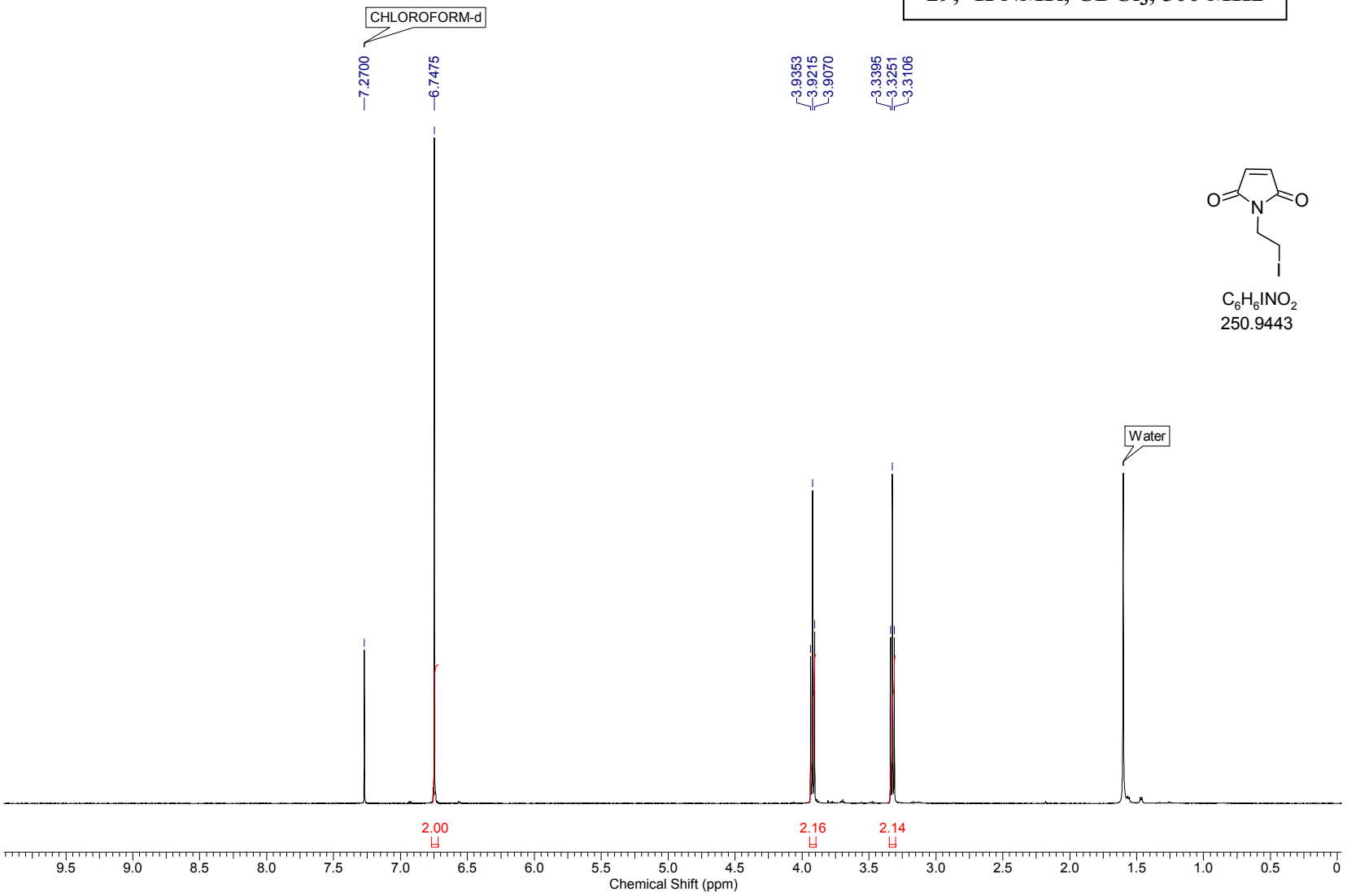
13, ^{13}C NMR, $CDCl_3$, 100 MHz



13, DEPT, $CDCl_3$, 100 MHz

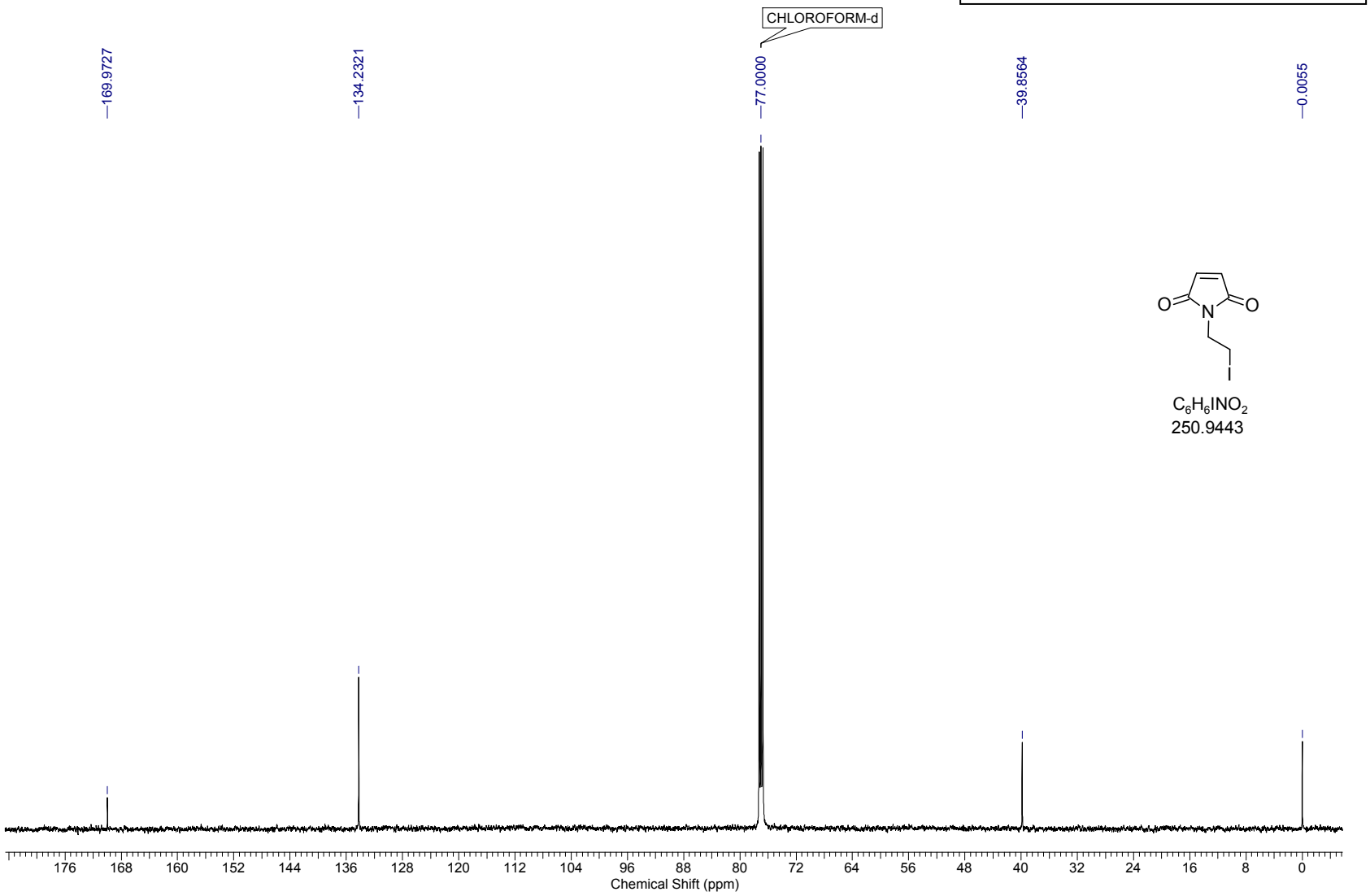


29, ^{1}H NMR, $CDCl_3$, 500 MHz

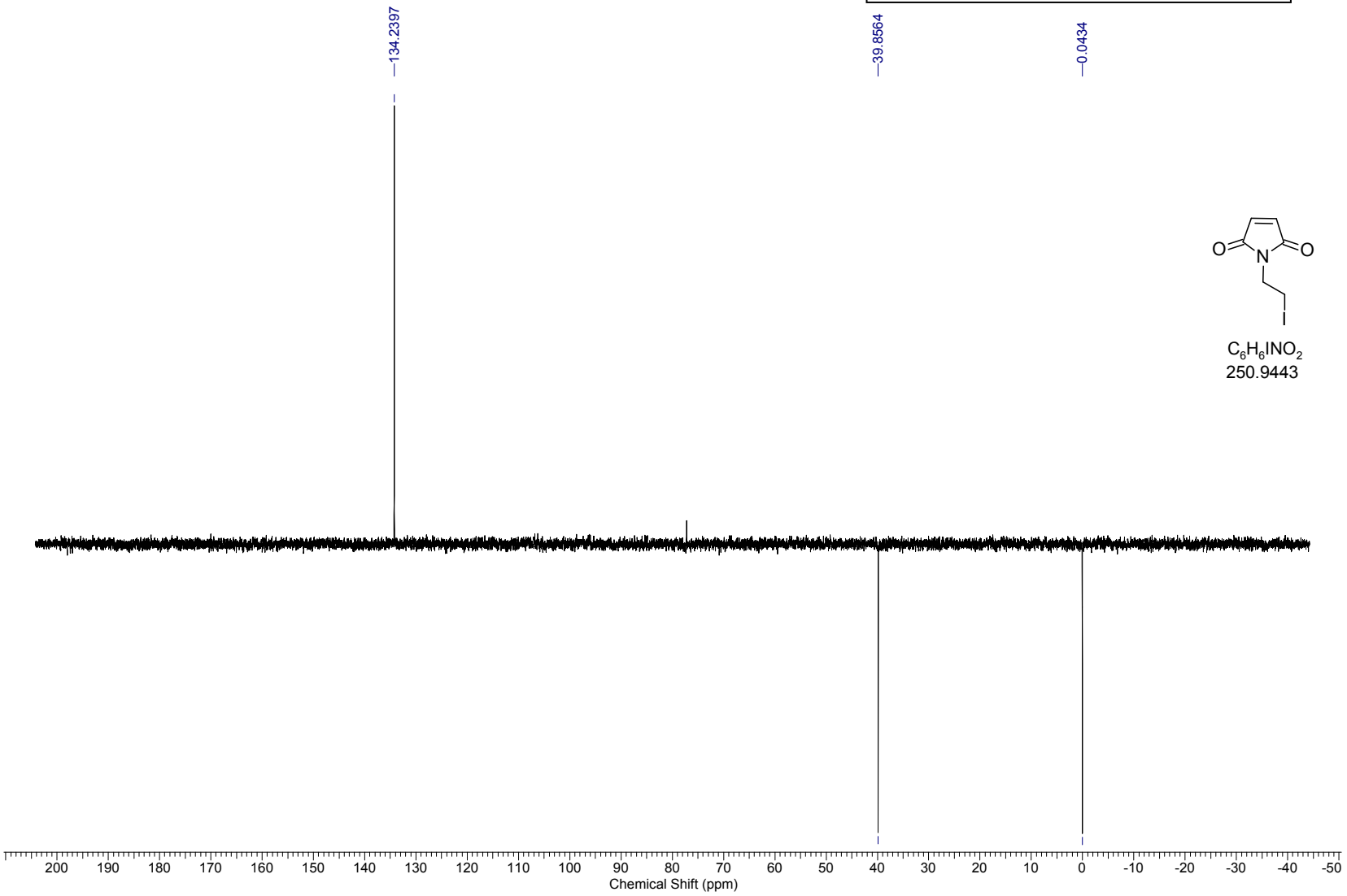


$C_6H_6INO_2$
250.9443

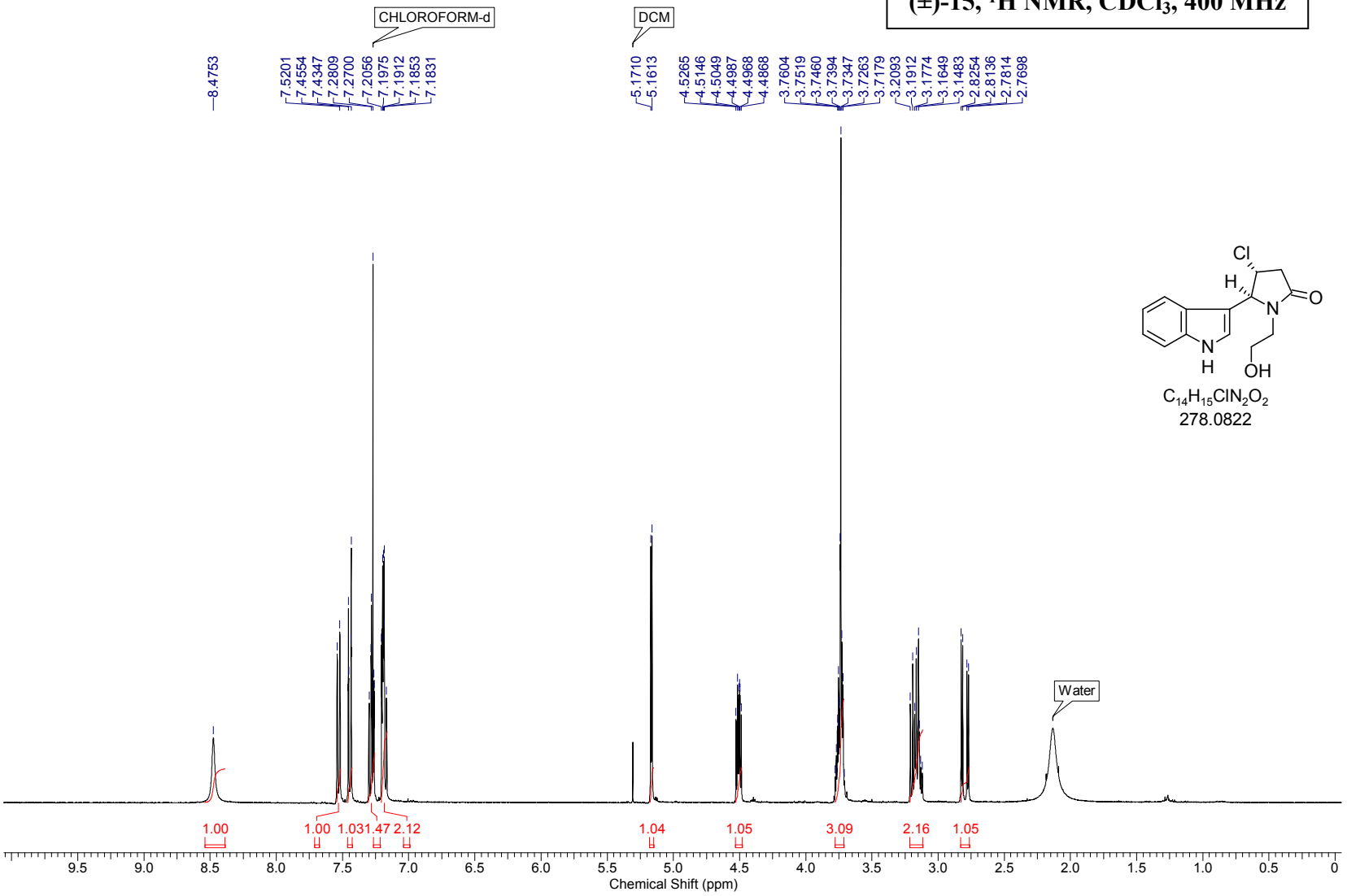
29, ^{13}C NMR, $CDCl_3$, 125 MHz



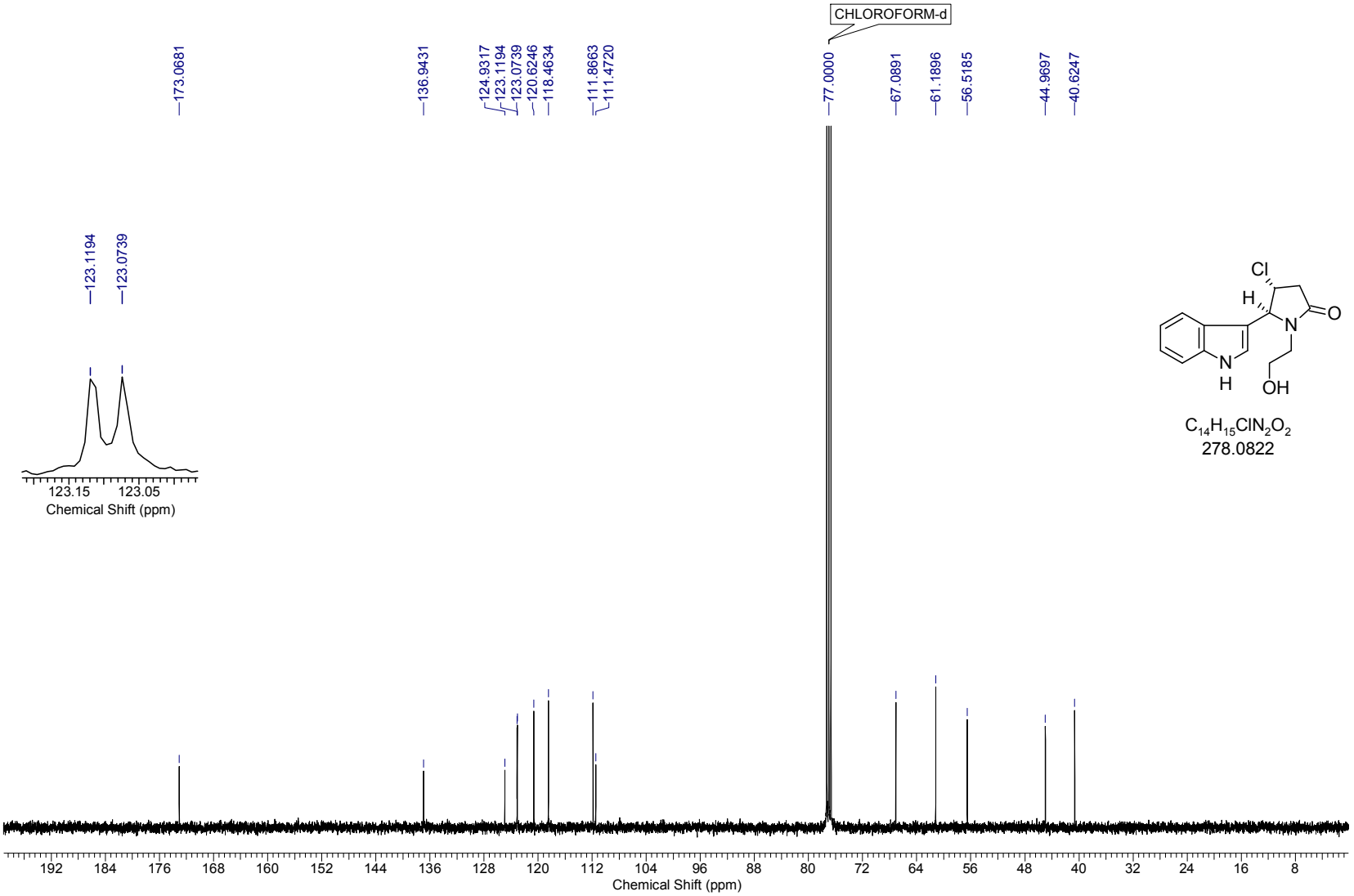
29, DEPT, $CDCl_3$, 125 MHz



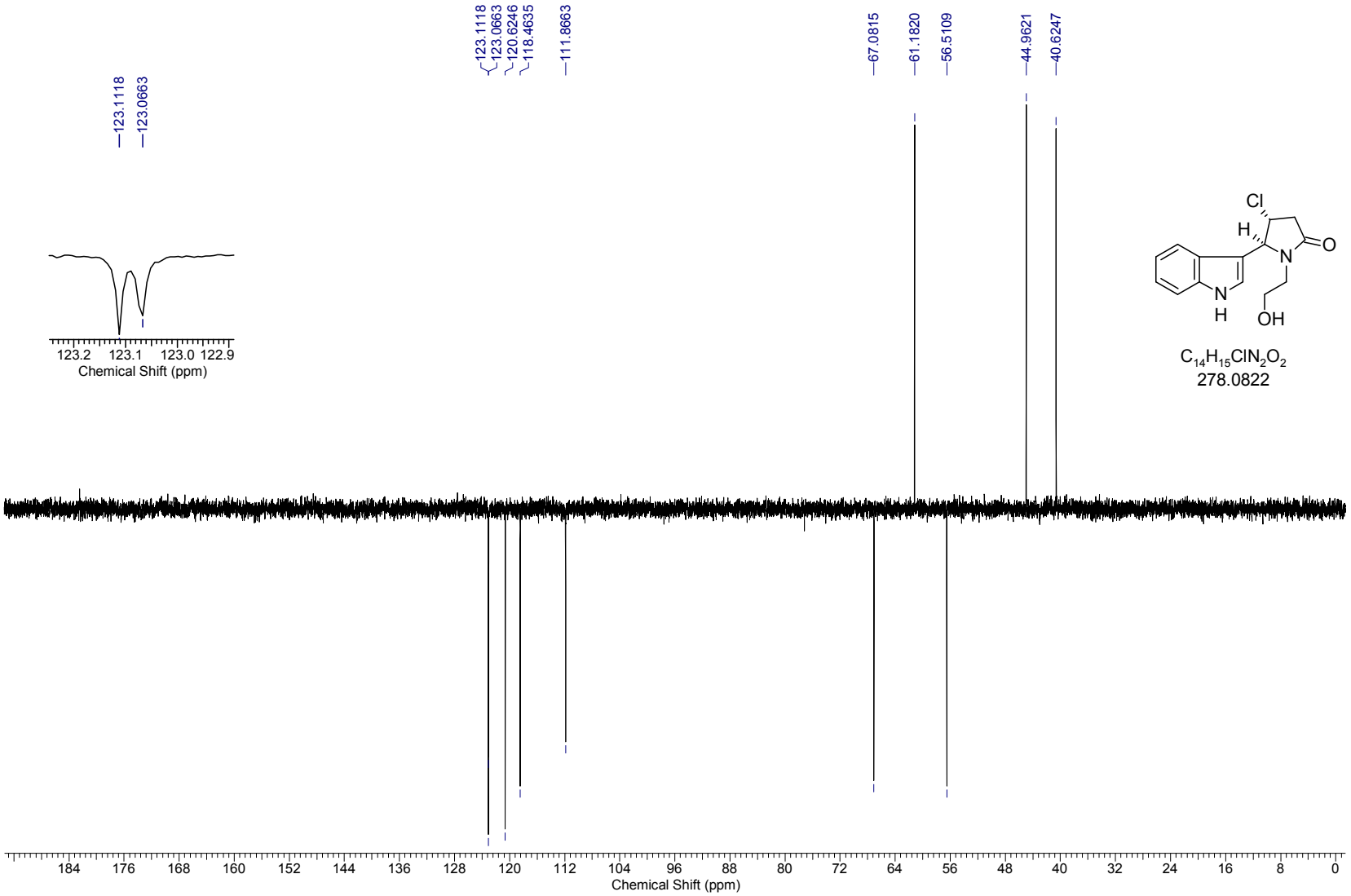
(±)-15, ^{1}H NMR, $CDCl_3$, 400 MHz



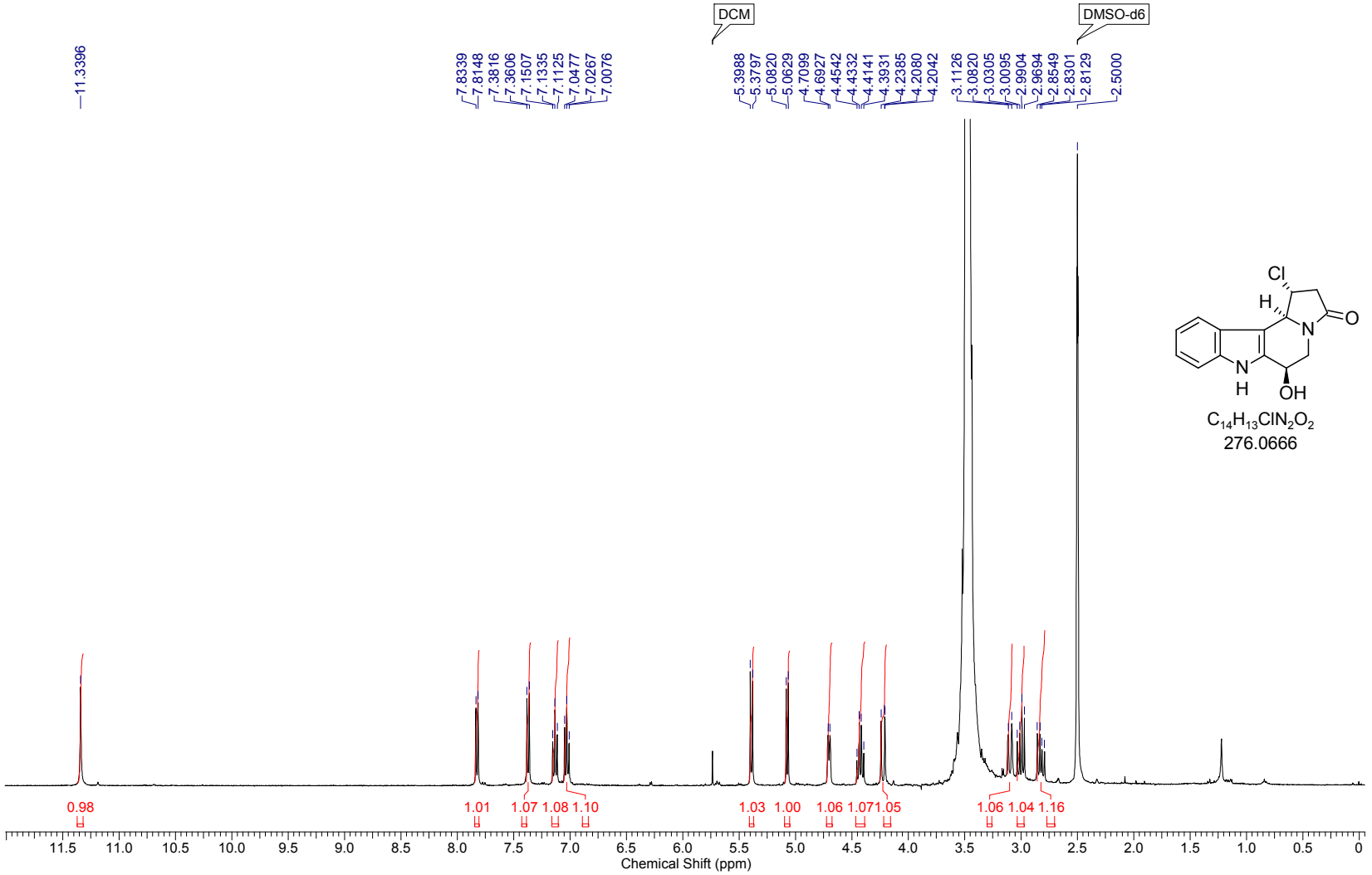
$C_{14}H_{15}ClN_2O_2$
278.0822


CHLOROFORM-d
173.0681
136.9431
124.9317
123.1194
123.0739
120.6246
118.4634
111.8663
111.4720
77.0000
67.0891
61.1896
56.5185
44.9697
40.6247
123.1194
123.0739
123.15
123.05
Chemical Shift (ppm)
Cl
H
N
O
N
H
OH
C14H15ClN2O2
278.0822
192
184
176
168
160
152
144
136
128
120
112
104
96
88
80
72
64
56
48
40
32
24
16
8
Chemical Shift (ppm)

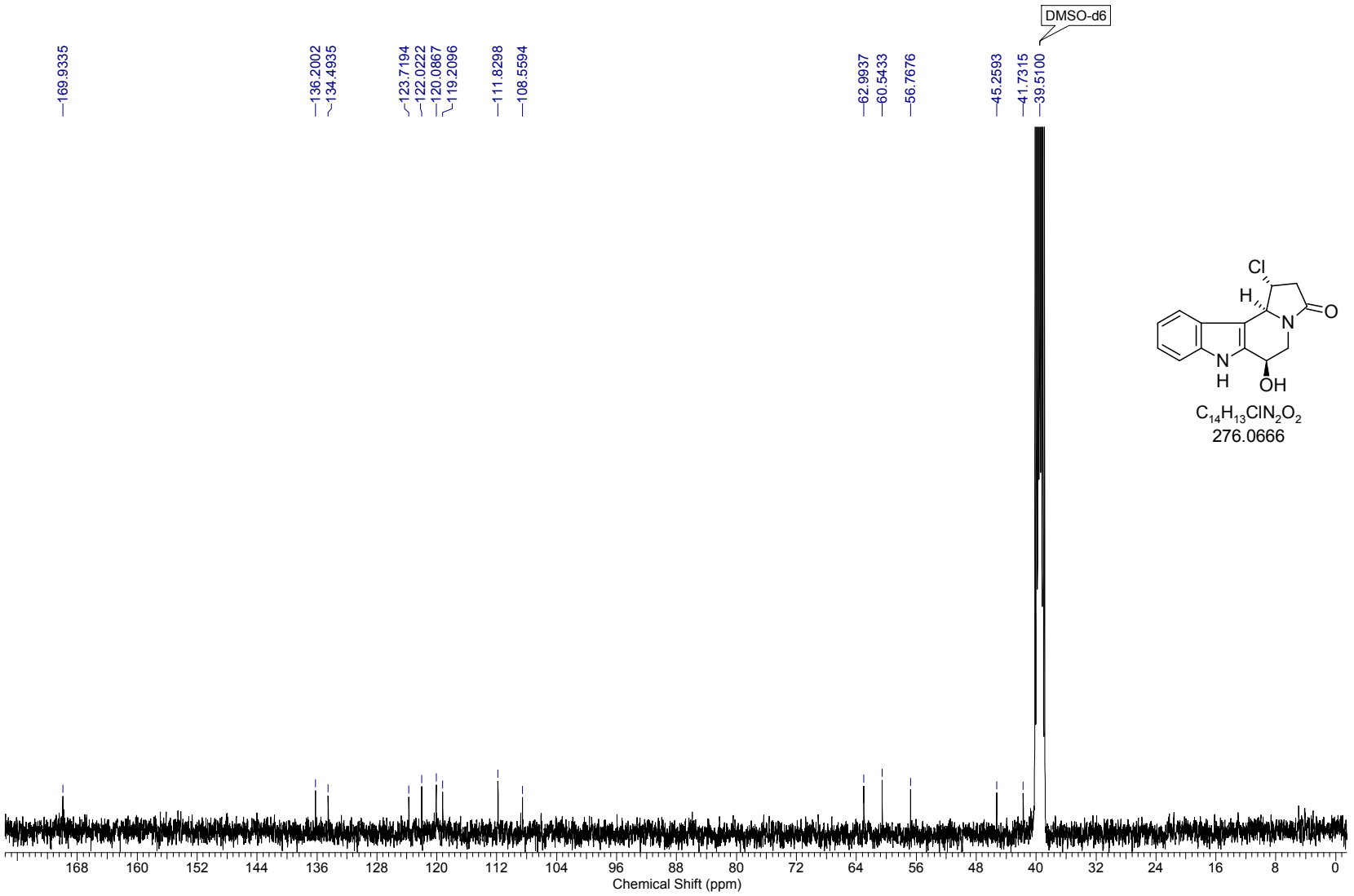
(±)-15, DEPT, $CDCl_3$, 100 MHz



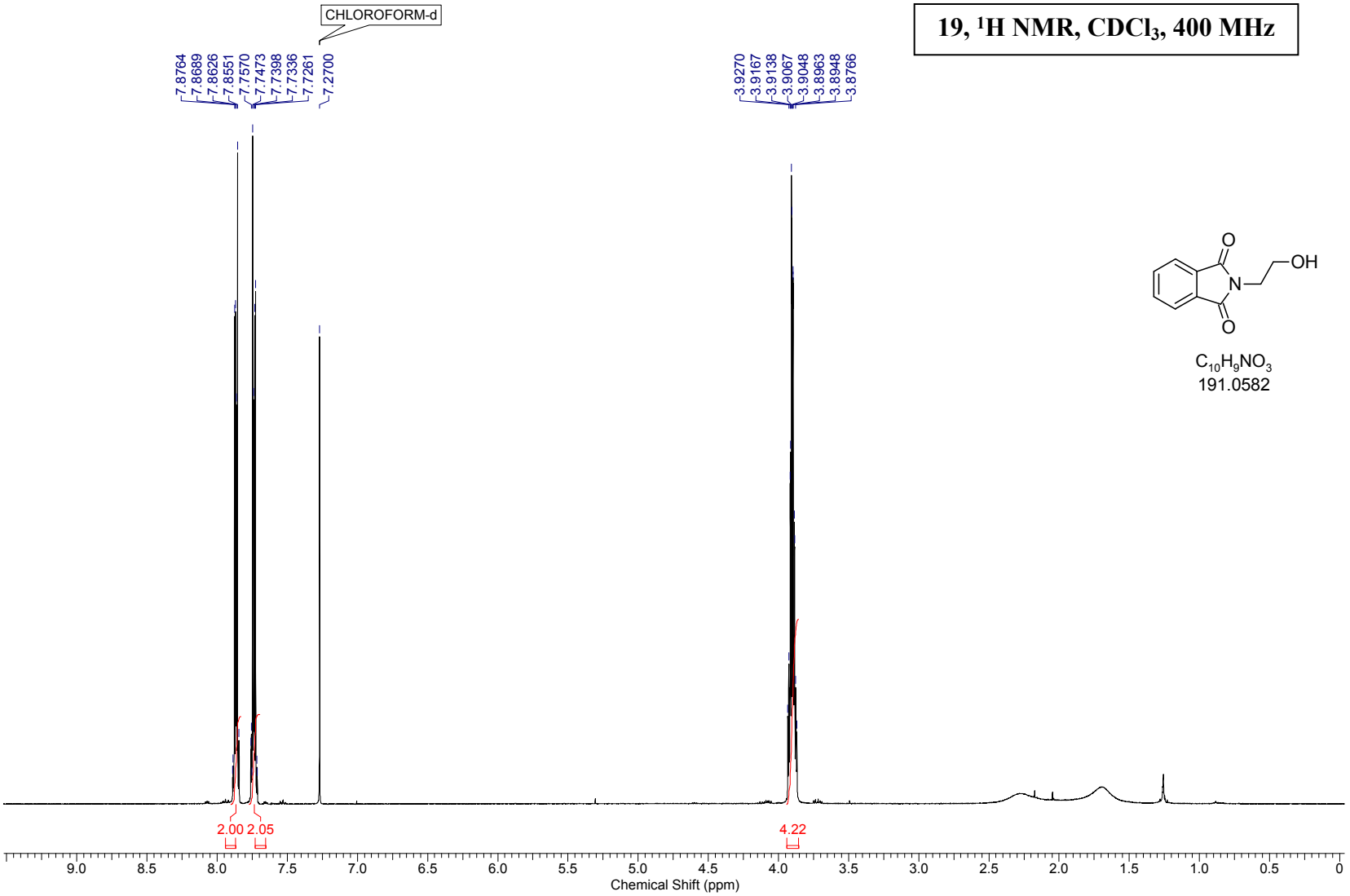
(±)-17, ^{1}H NMR, DMSO-d_6, 400 MHz



(±)-17, ^{13}C NMR, DMSO-d_6, 100 MHz

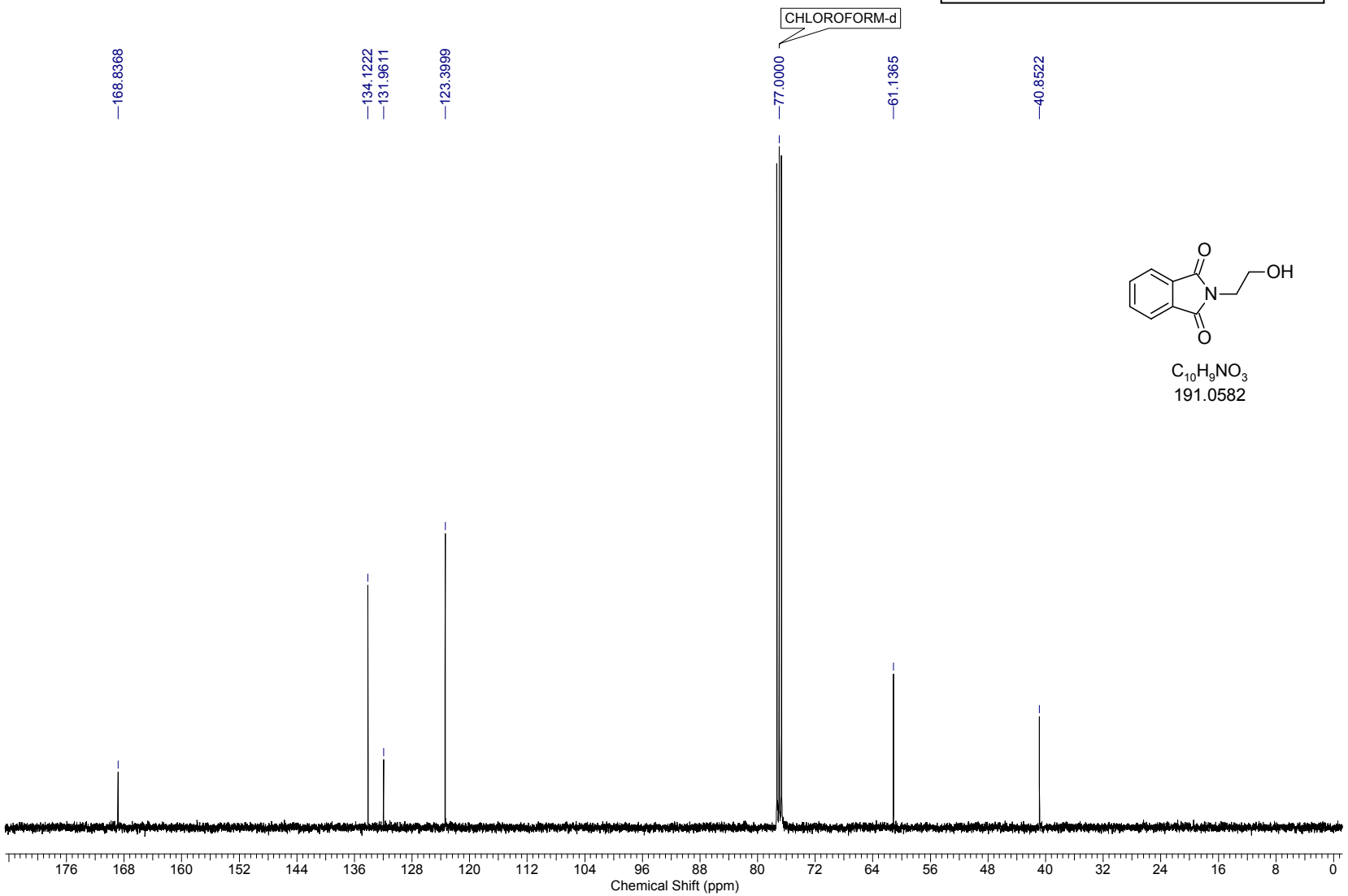


19, ^{1}H NMR, $CDCl_3$, 400 MHz

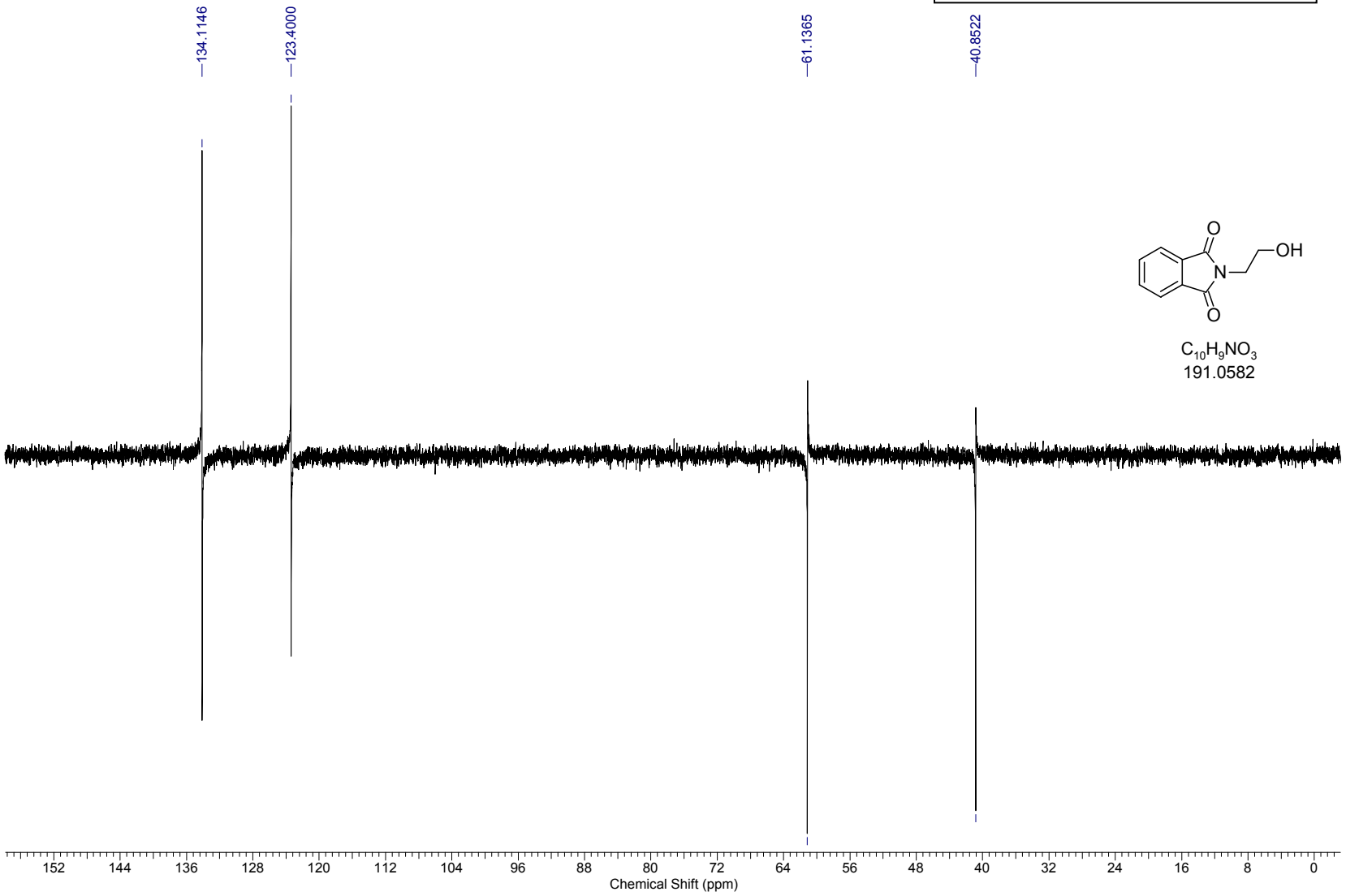


$C_{10}H_9NO_3$
191.0582

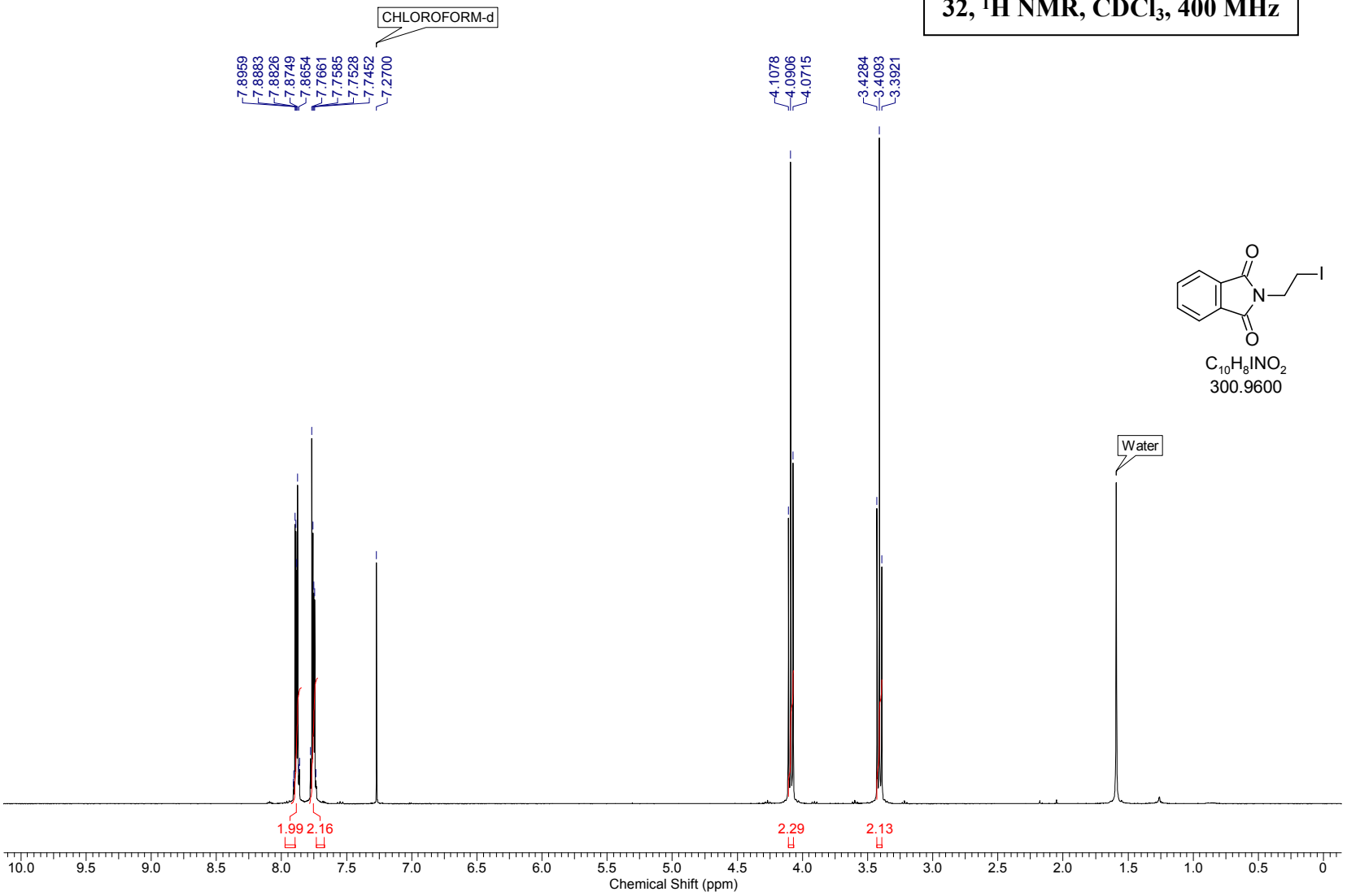
19, ^{13}C NMR, $CDCl_3$, 100 MHz



19, DEPT, $CDCl_3$, 100 MHz

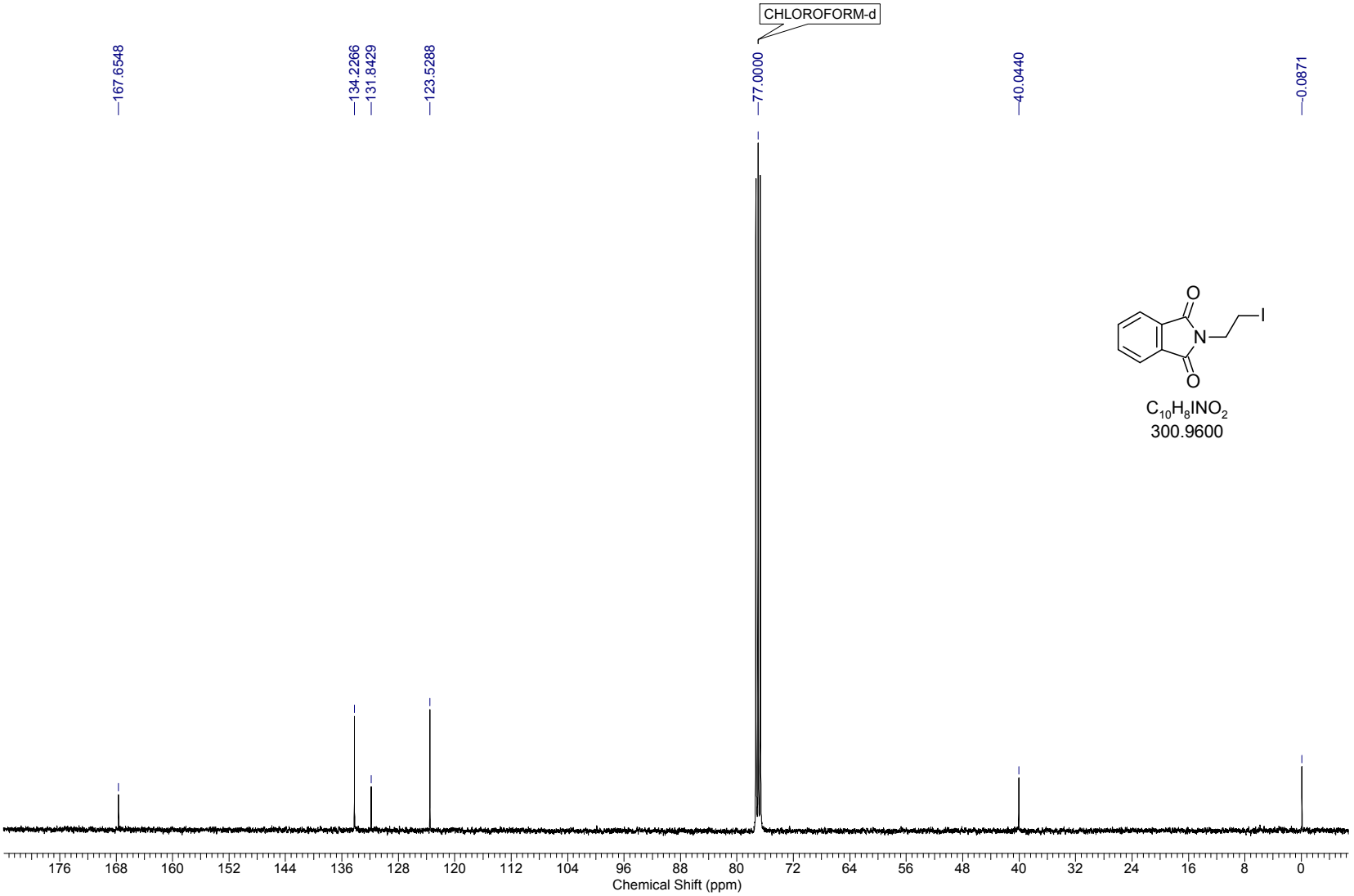


32, ^{1}H NMR, $CDCl_3$, 400 MHz

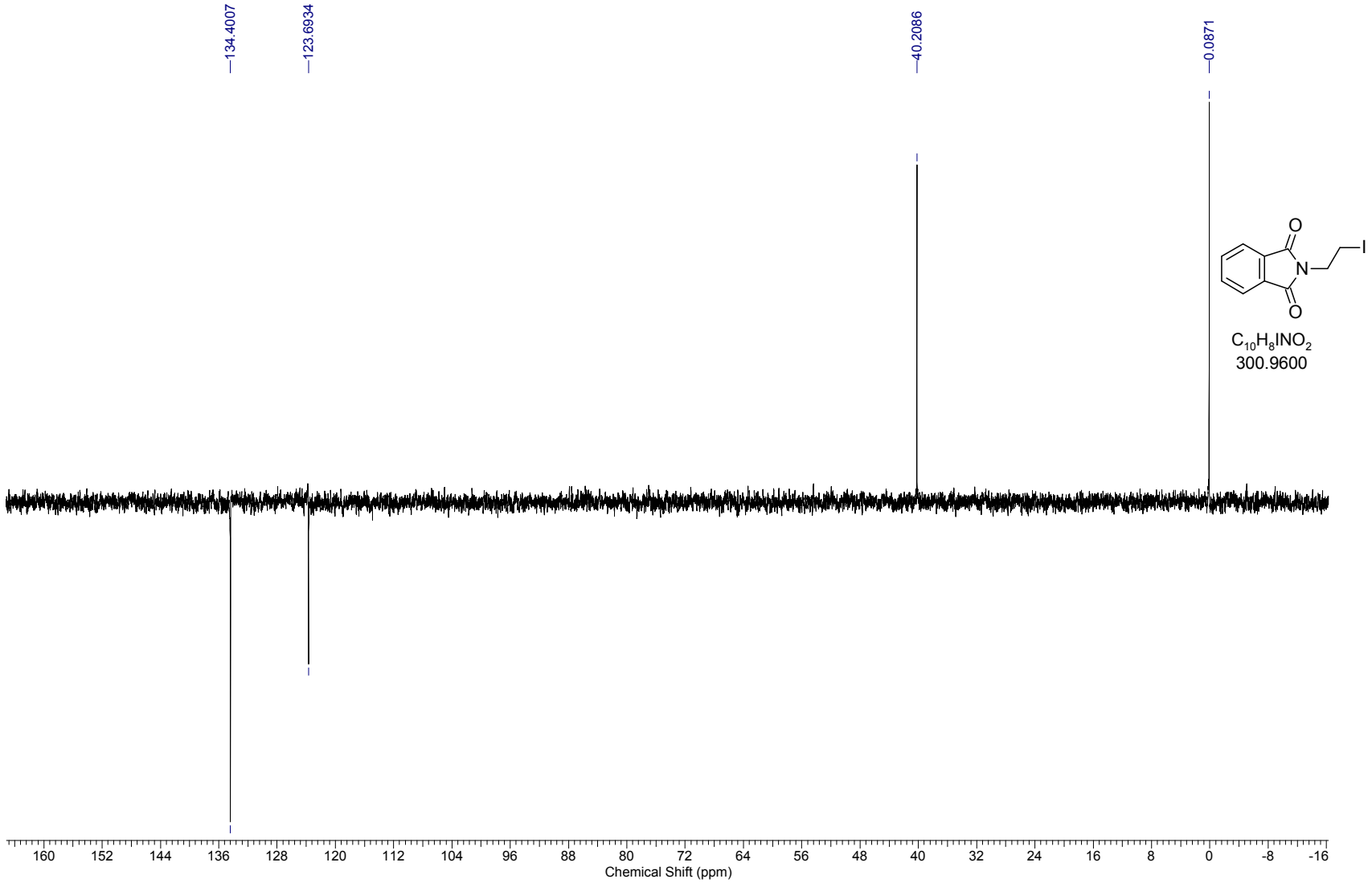


$C_{10}H_8INO_2$
300.9600

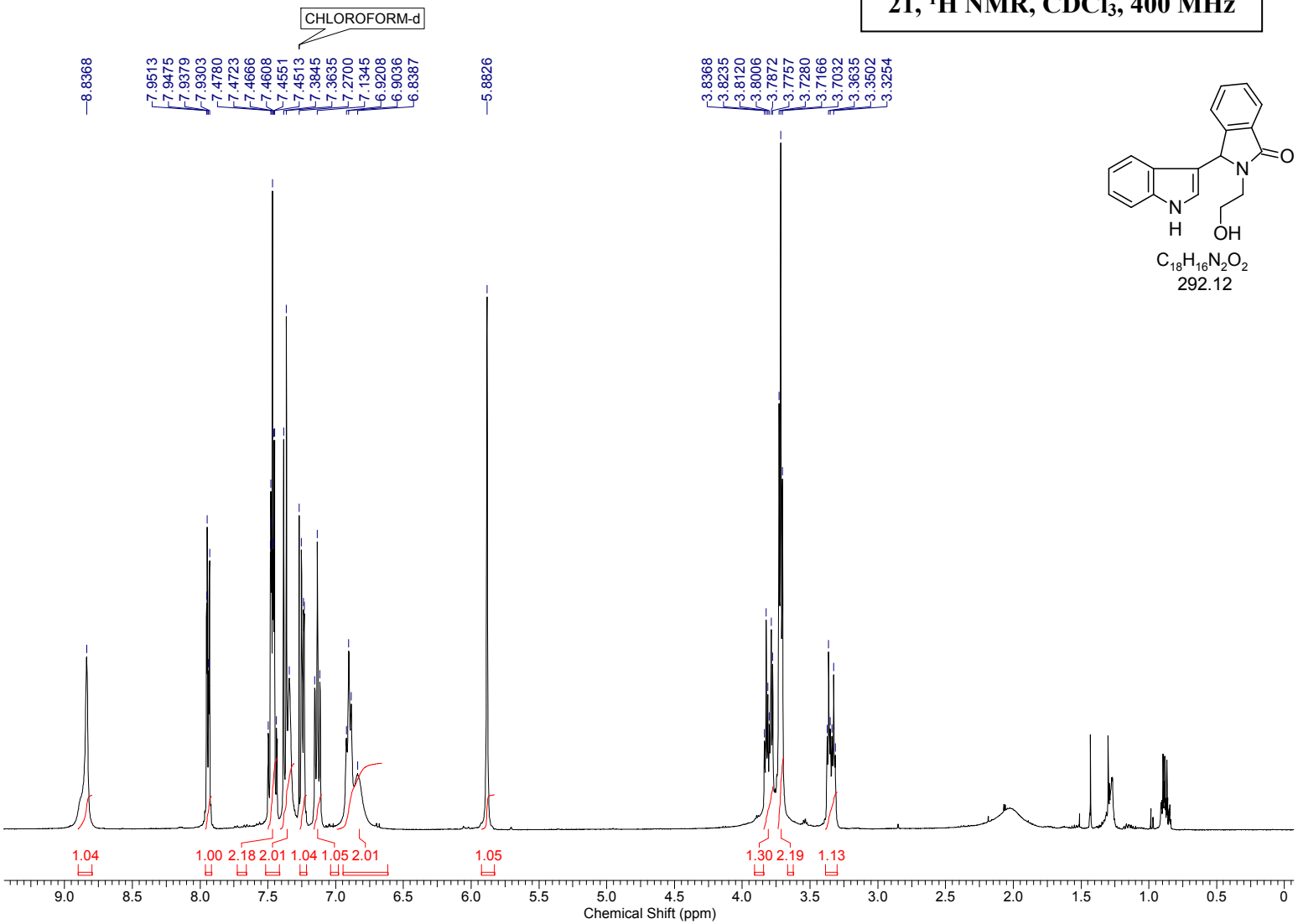
32, ^{13}C NMR, $CDCl_3$, 100 MHz



32, DEPT, $CDCl_3$, 100 MHz

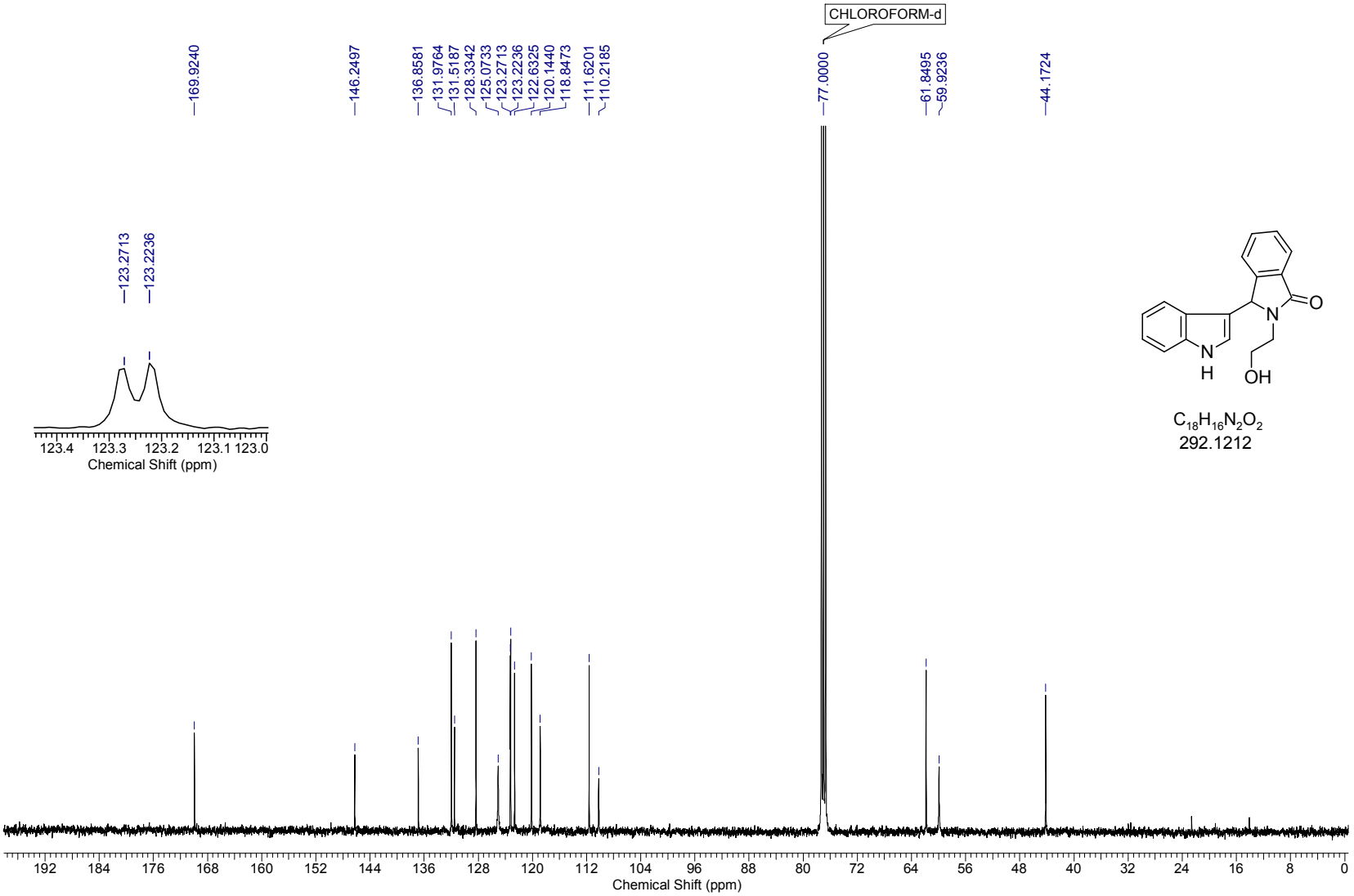


21, ^{1}H NMR, $CDCl_3$, 400 MHz



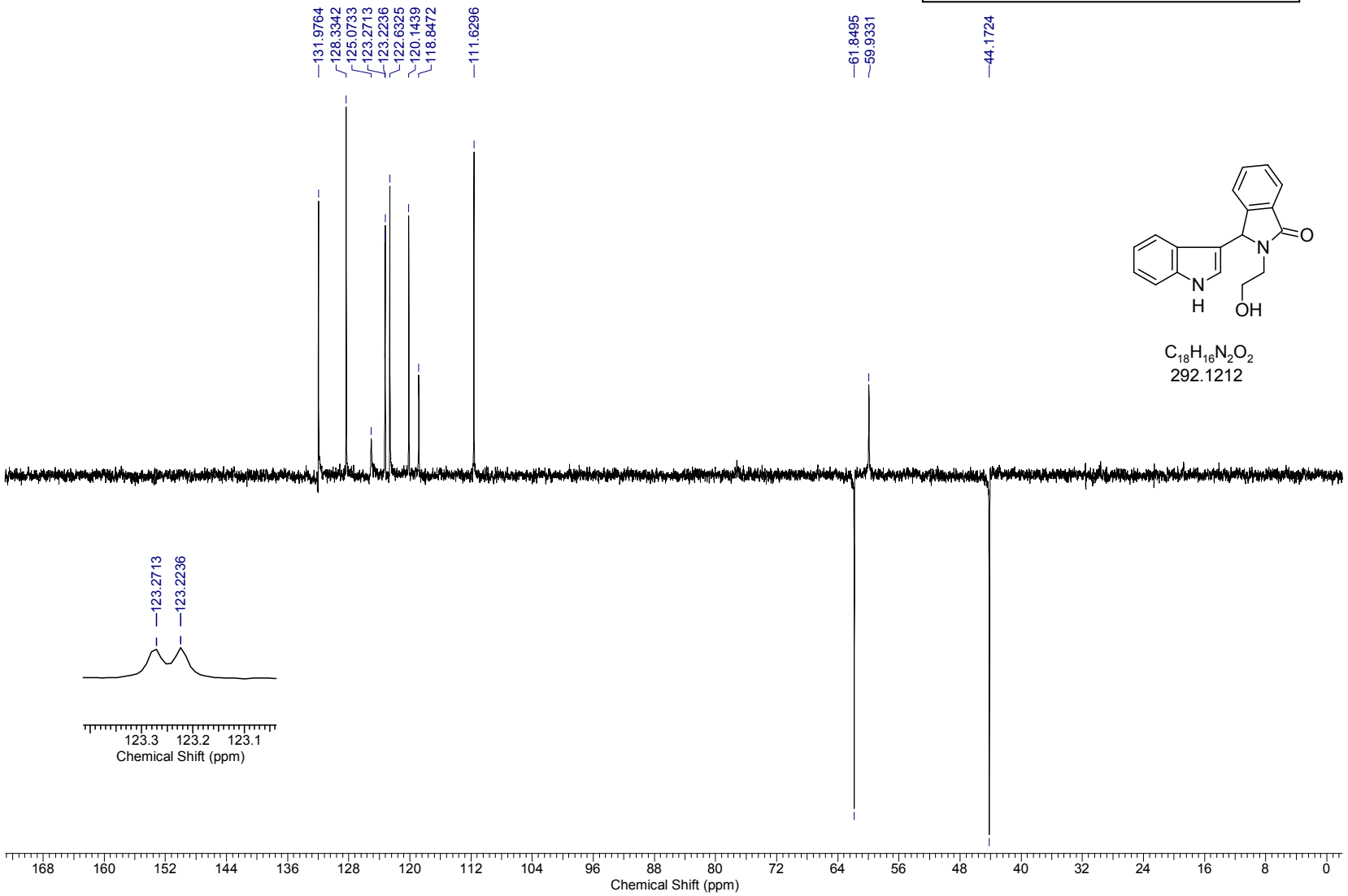
$C_{18}H_{16}N_2O_2$
292.12

21, ^{13}C NMR, $CDCl_3$, 100 MHz

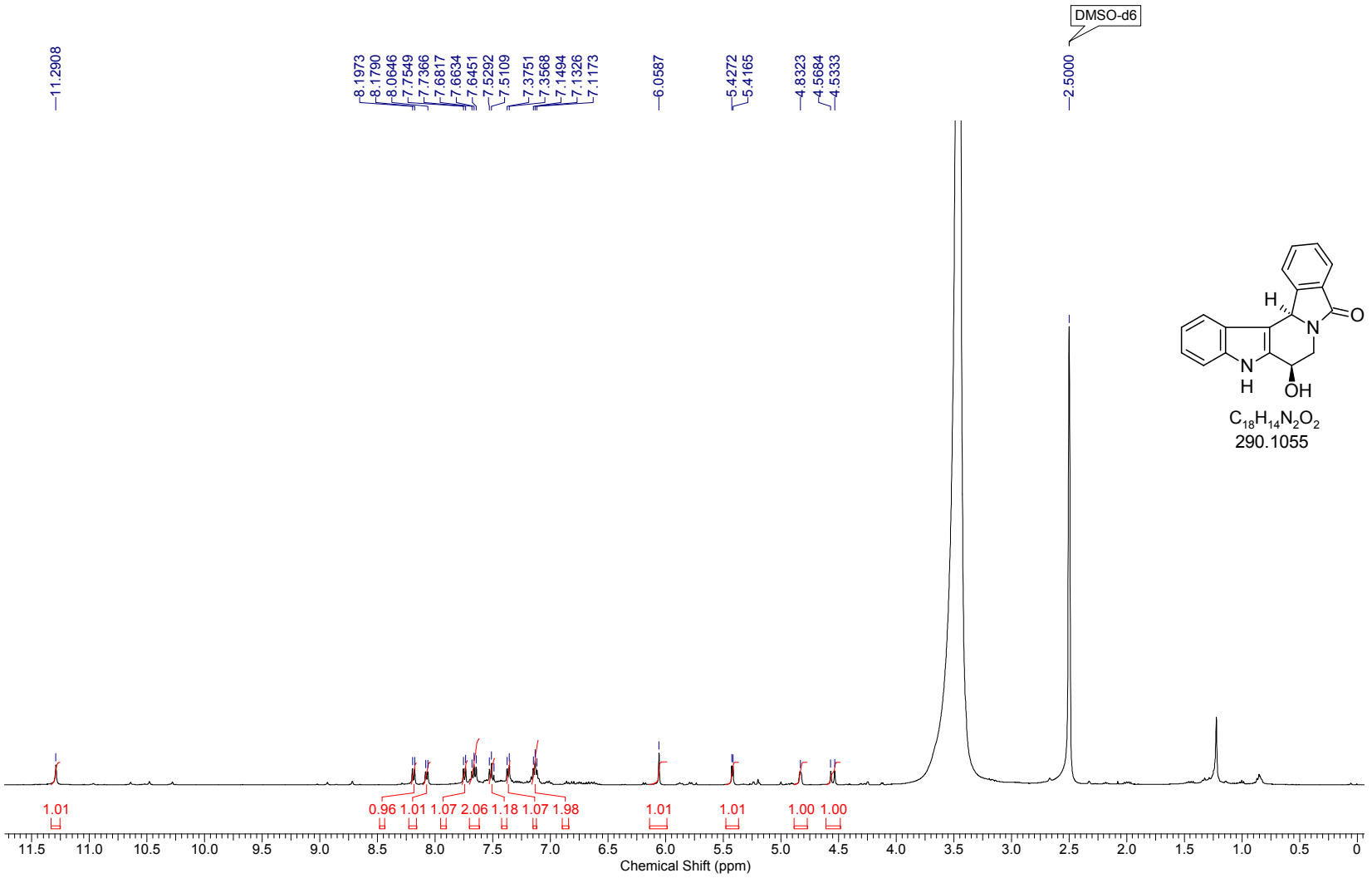


$C_{18}H_{16}N_2O_2$
292.1212

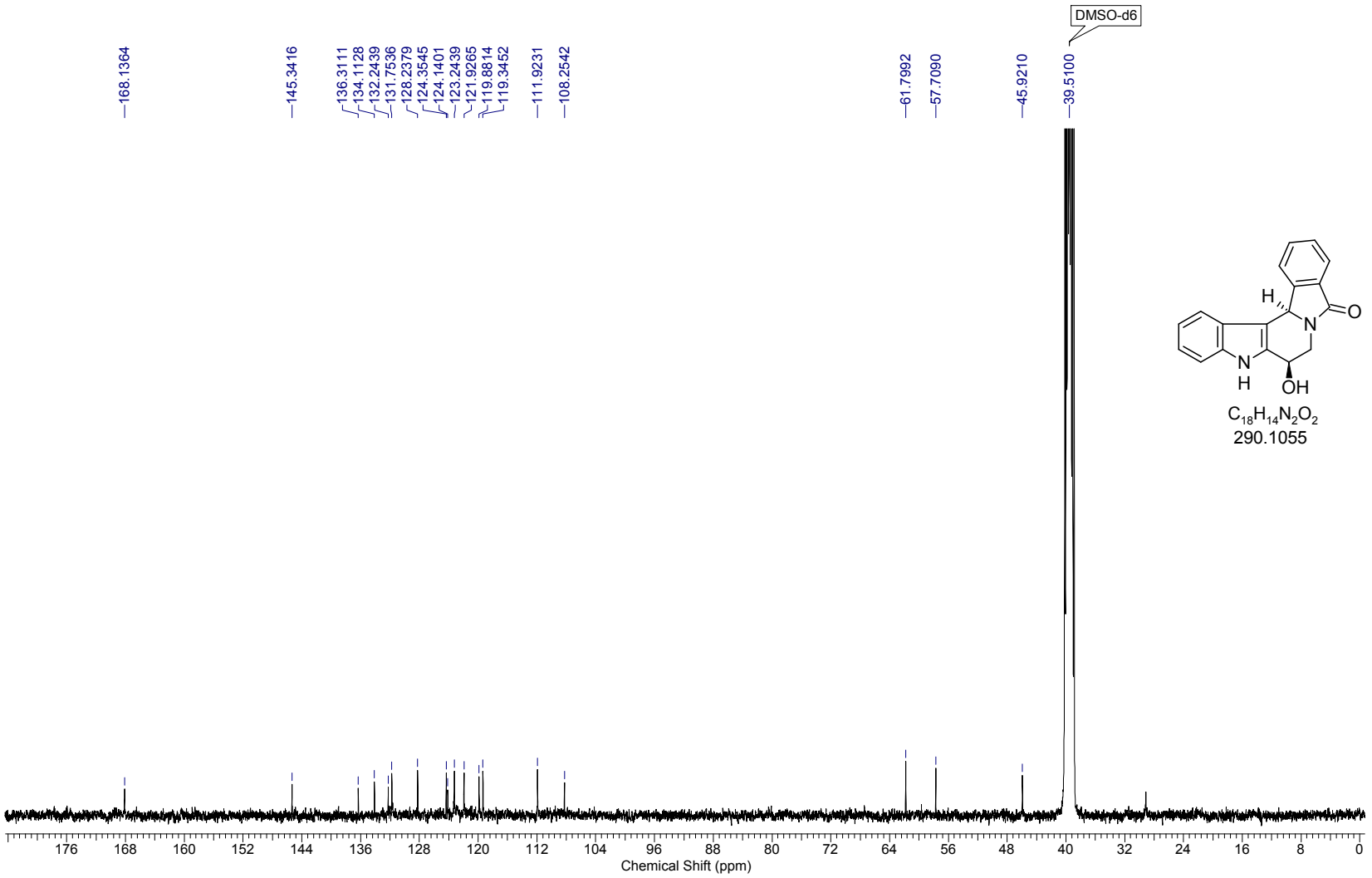
21, DEPT, $CDCl_3$, 100 MHz



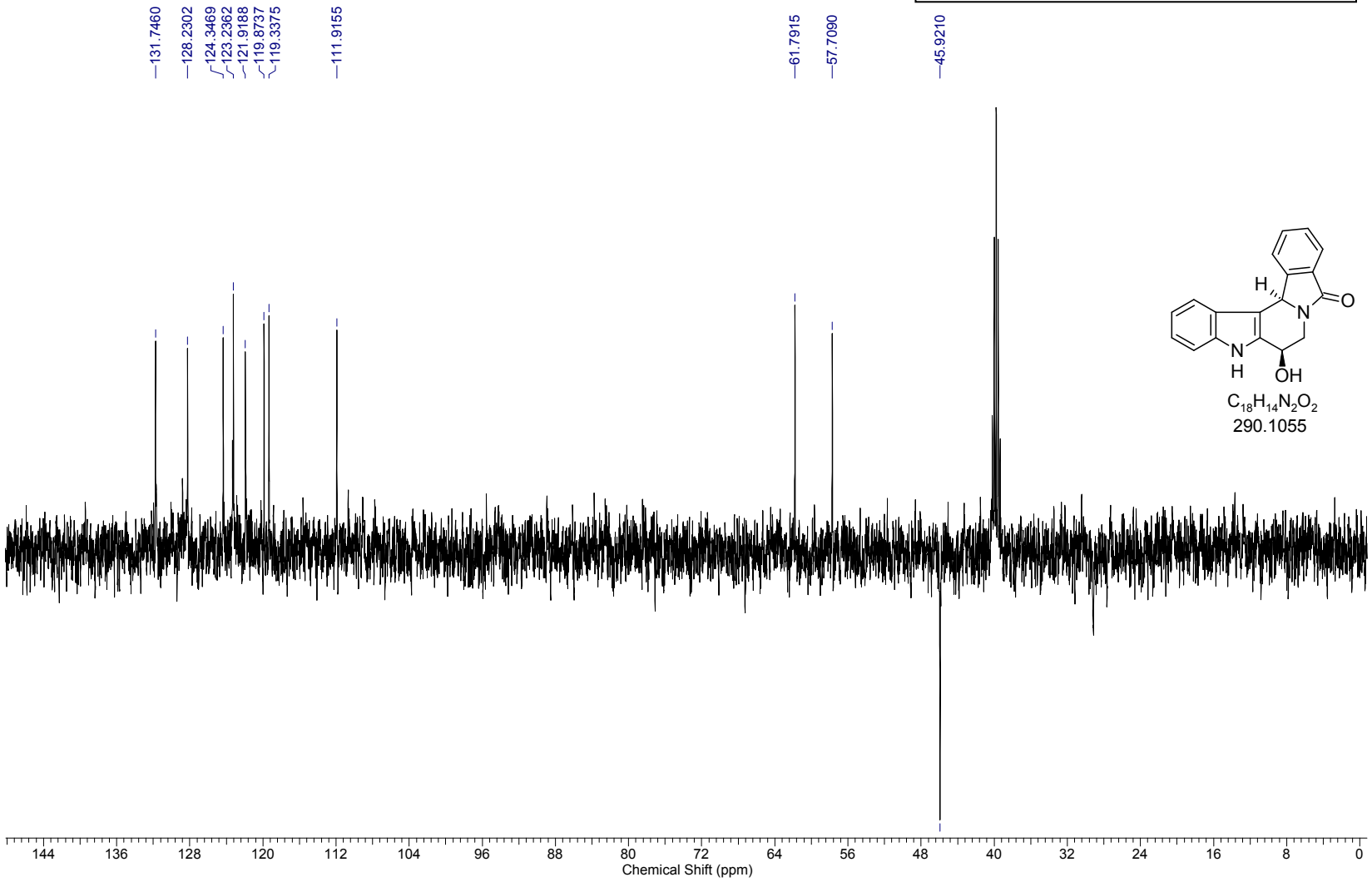
(±)-23, ^{1}H NMR, DMSO-d_6, 400 MHz



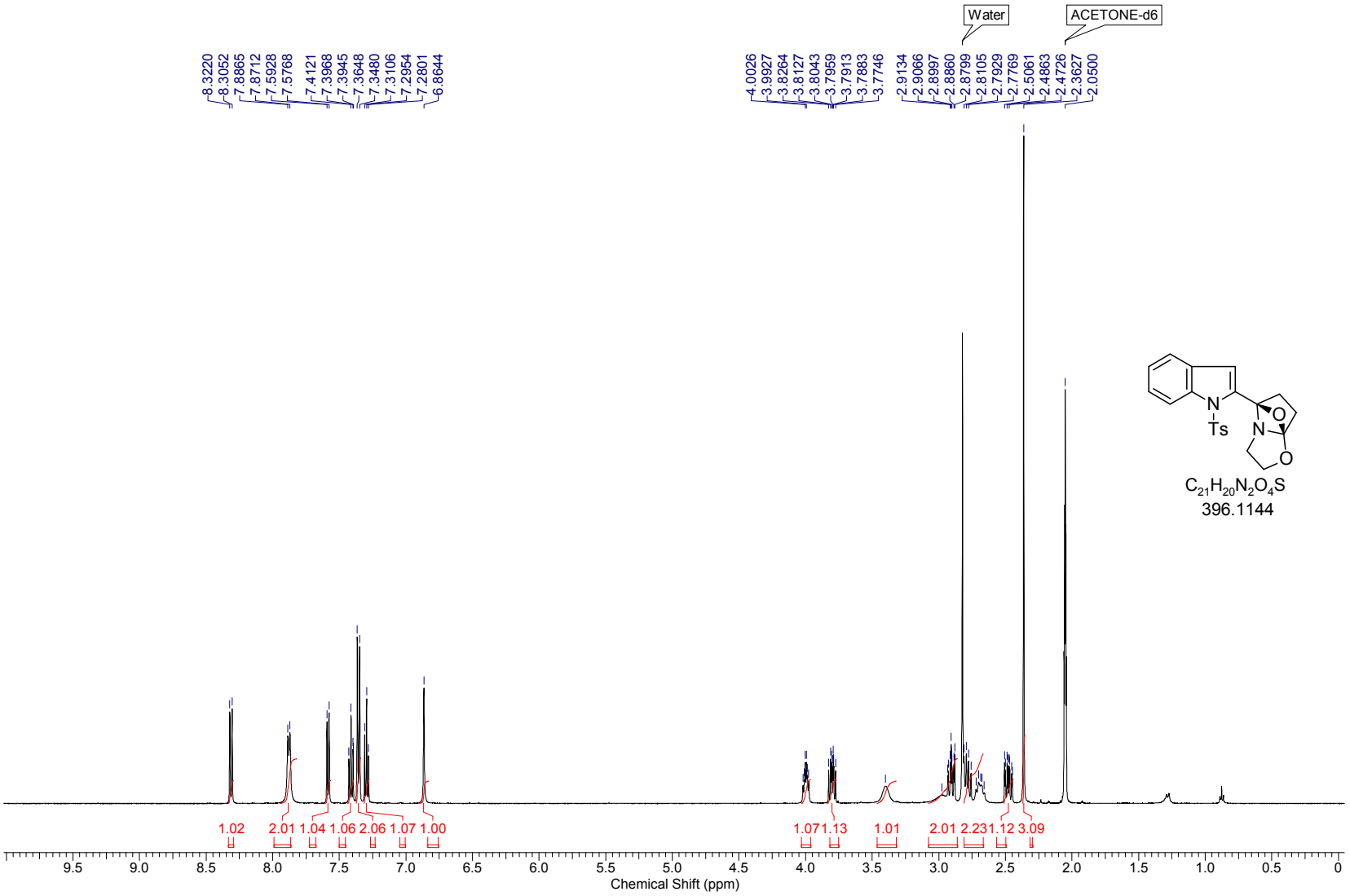
(±)-23, ^{13}C NMR, DMSO-d_6, 100 MHz



(±)-23, DEPT, DMSO-d_6, 100 MHz

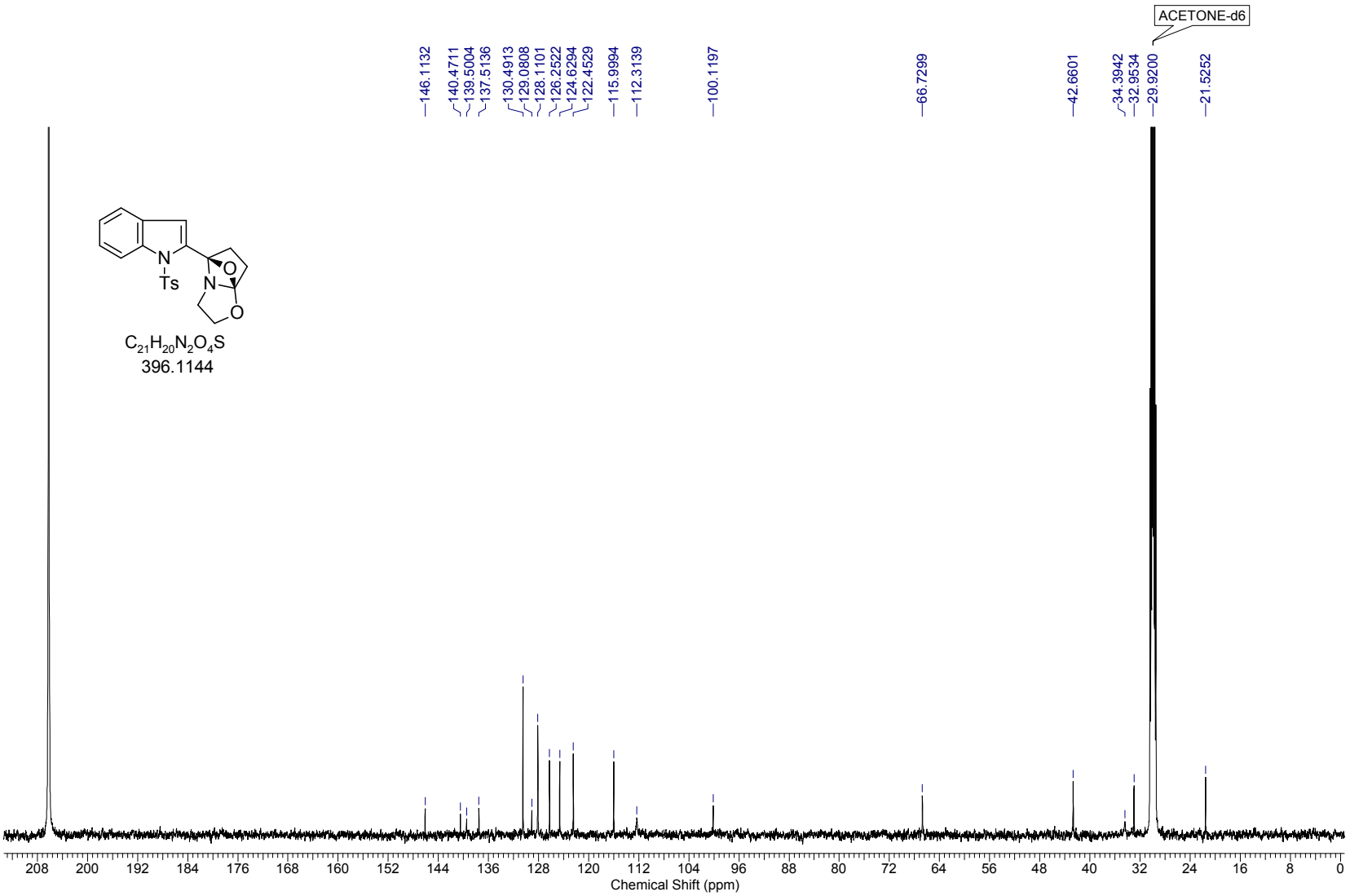


28, ^{1}H NMR, acetone-d_6, 500 MHz

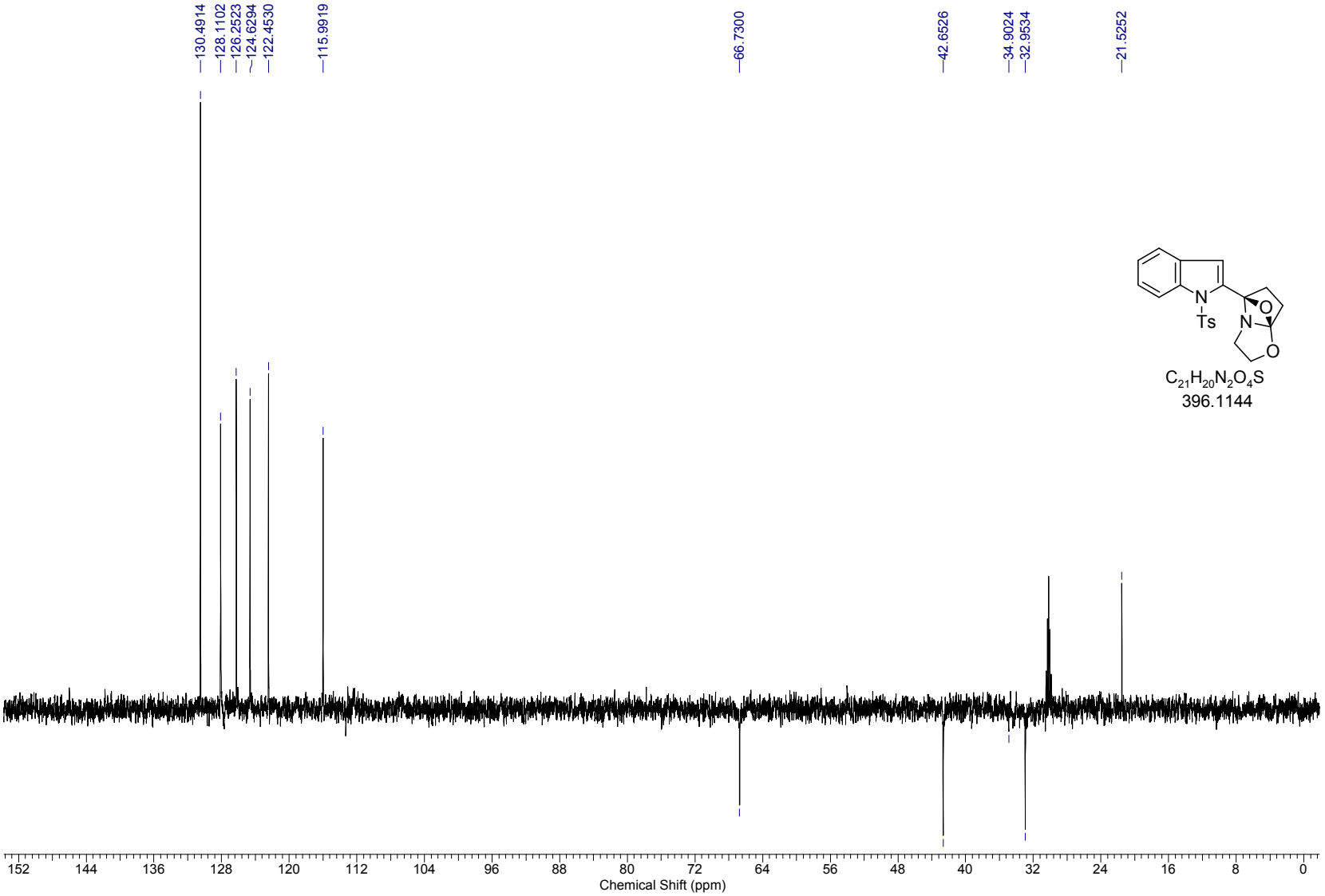


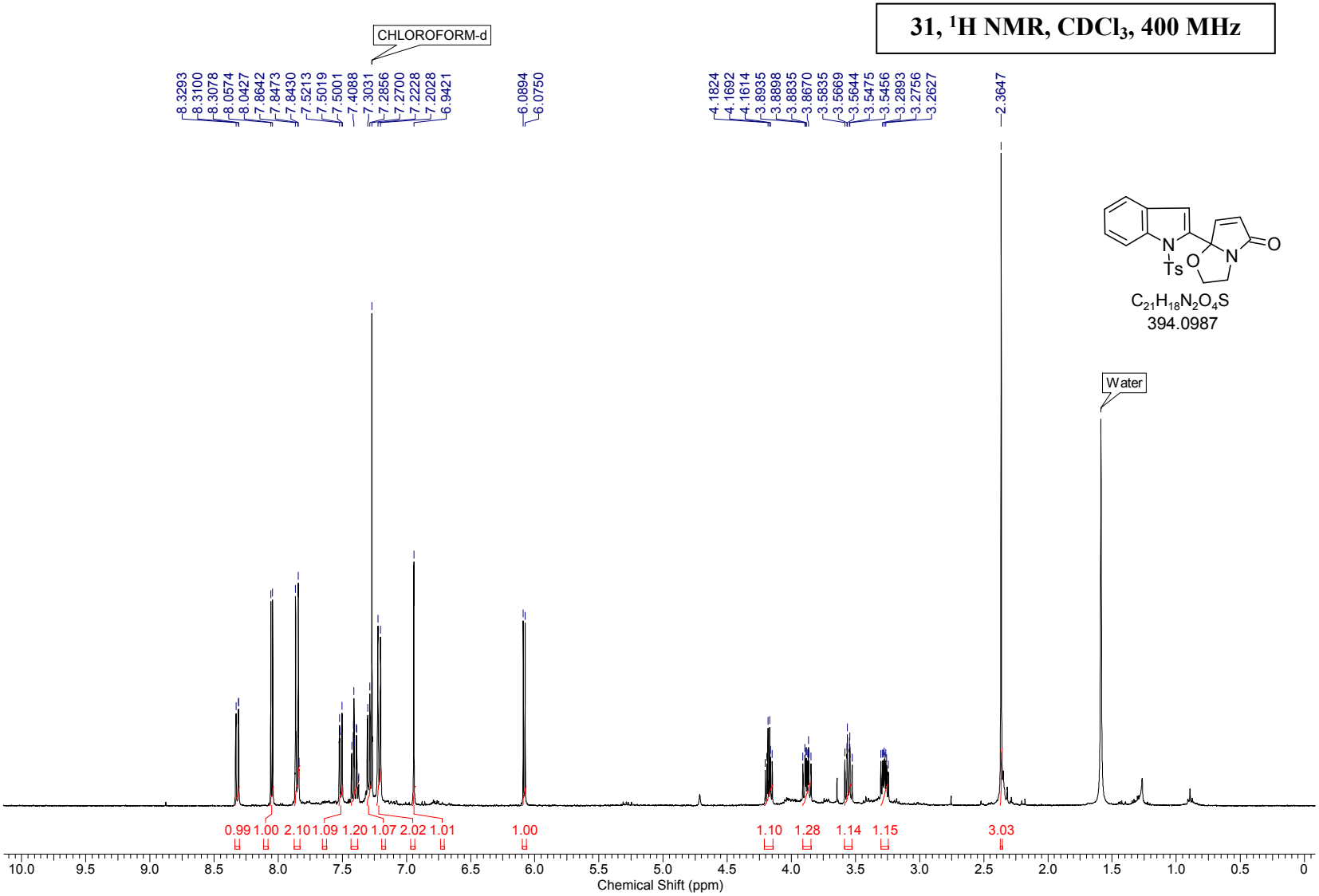
$C_{21}H_{20}N_2O_4S$
396.1144

28, ^{13}C NMR, acetone-d_6, 125 MHz

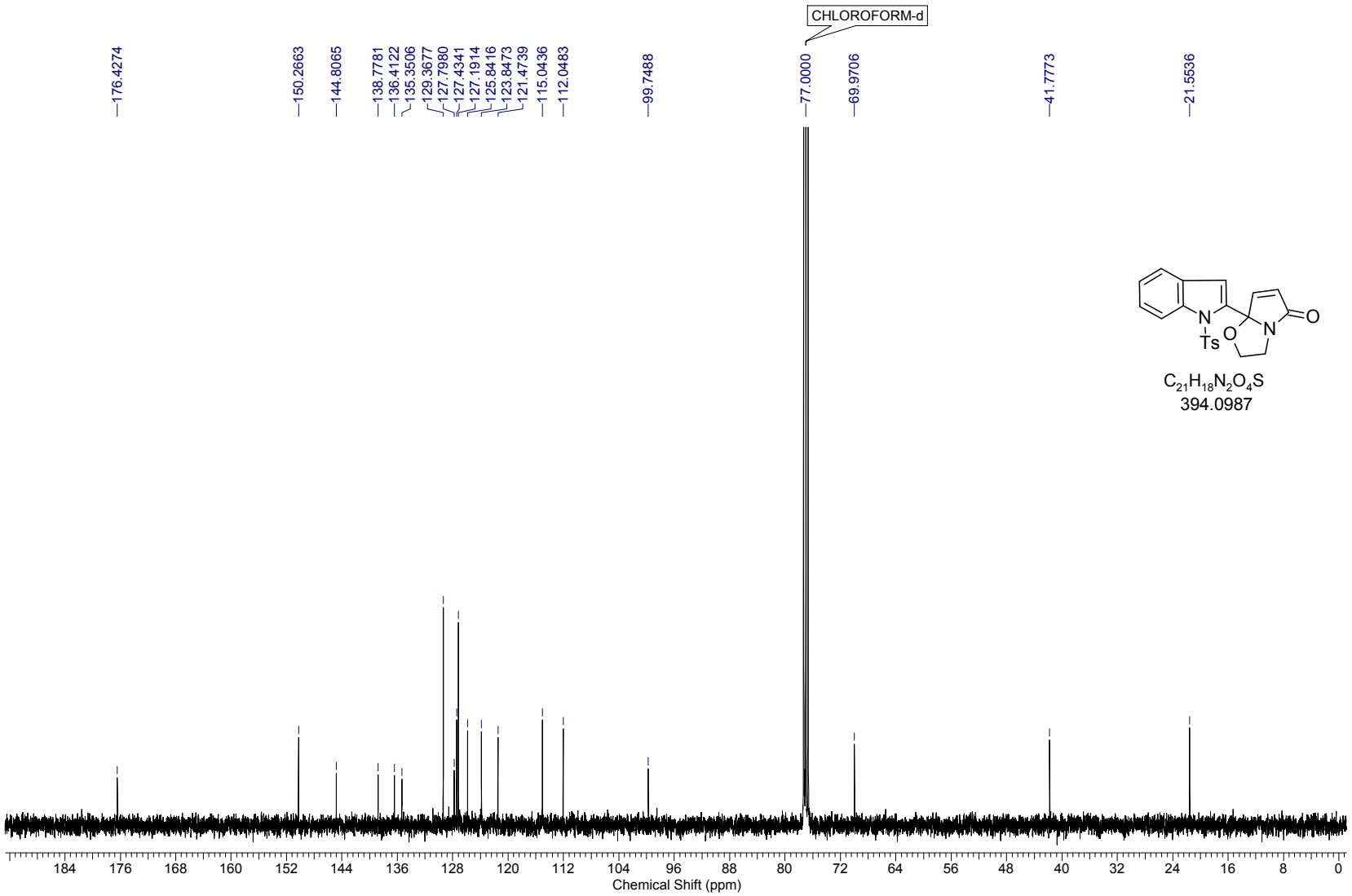


28, DEPT, acetone-d_6, 125 MHz

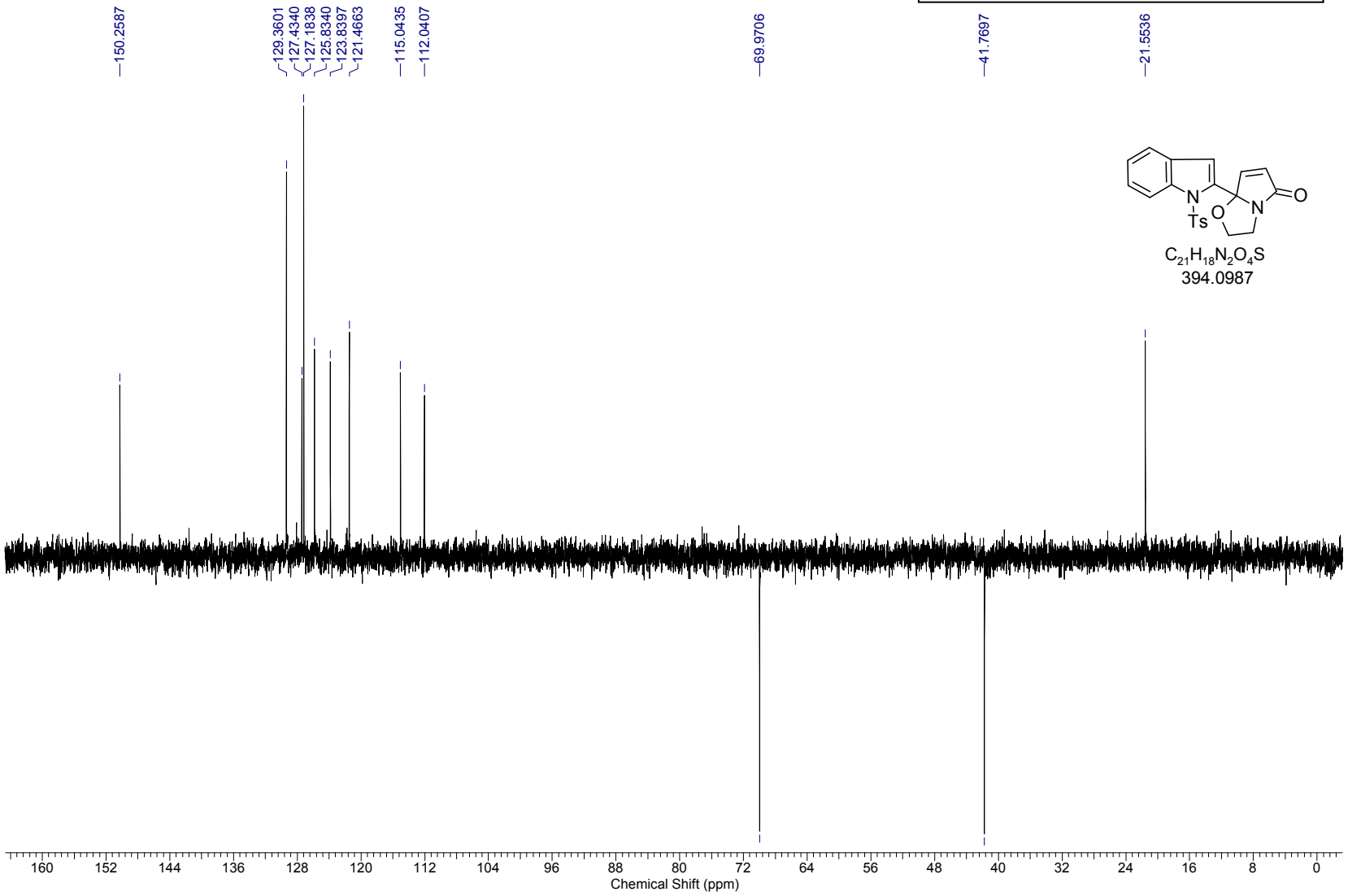



31, ^{1}H NMR, $CDCl_3$, 400 MHz
CHLOROFORM-d
8.3293
8.3100
8.3078
8.0574
8.0427
7.8642
7.8473
7.8430
7.5213
7.5019
7.5001
7.4088
7.3031
7.2856
7.2700
7.2228
7.2028
6.9421
6.0894
6.0750
4.1824
4.1692
4.1614
3.8935
3.8898
3.8835
3.8670
3.5835
3.5669
3.5644
3.5475
3.5456
3.2893
3.2756
3.2627
2.3647
Water
$C_{21}H_{18}N_2O_4S$
394.0987
0.99 1.00 2.10 1.09 1.20 1.07 2.02 1.01
1.00
1.10 1.28 1.14 1.15
3.03
Chemical Shift (ppm)

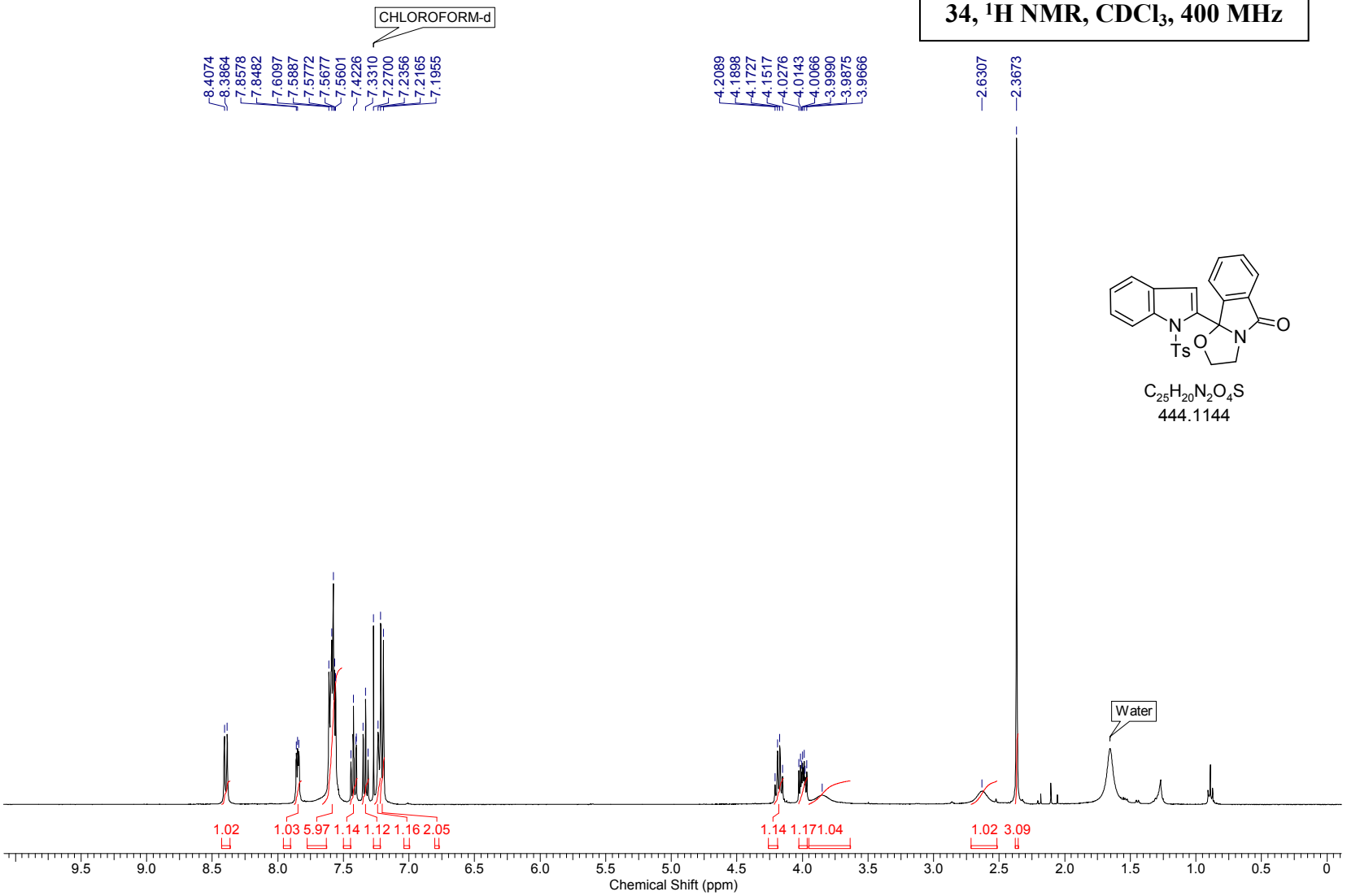
31, ^{13}C NMR, $CDCl_3$, 100 MHz



31, DEPT, $CDCl_3$, 100 MHz

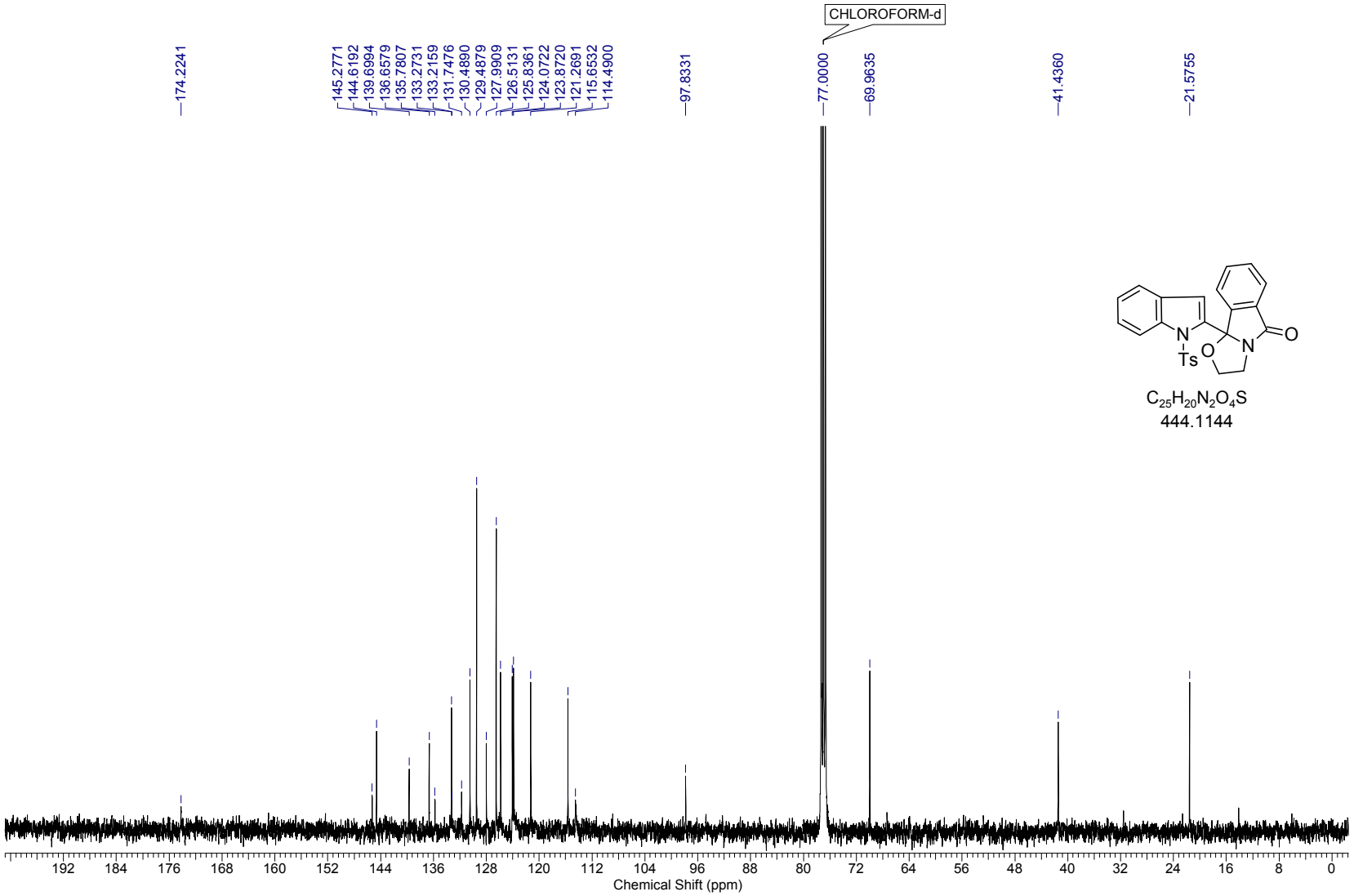


34, ^{1}H NMR, $CDCl_3$, 400 MHz

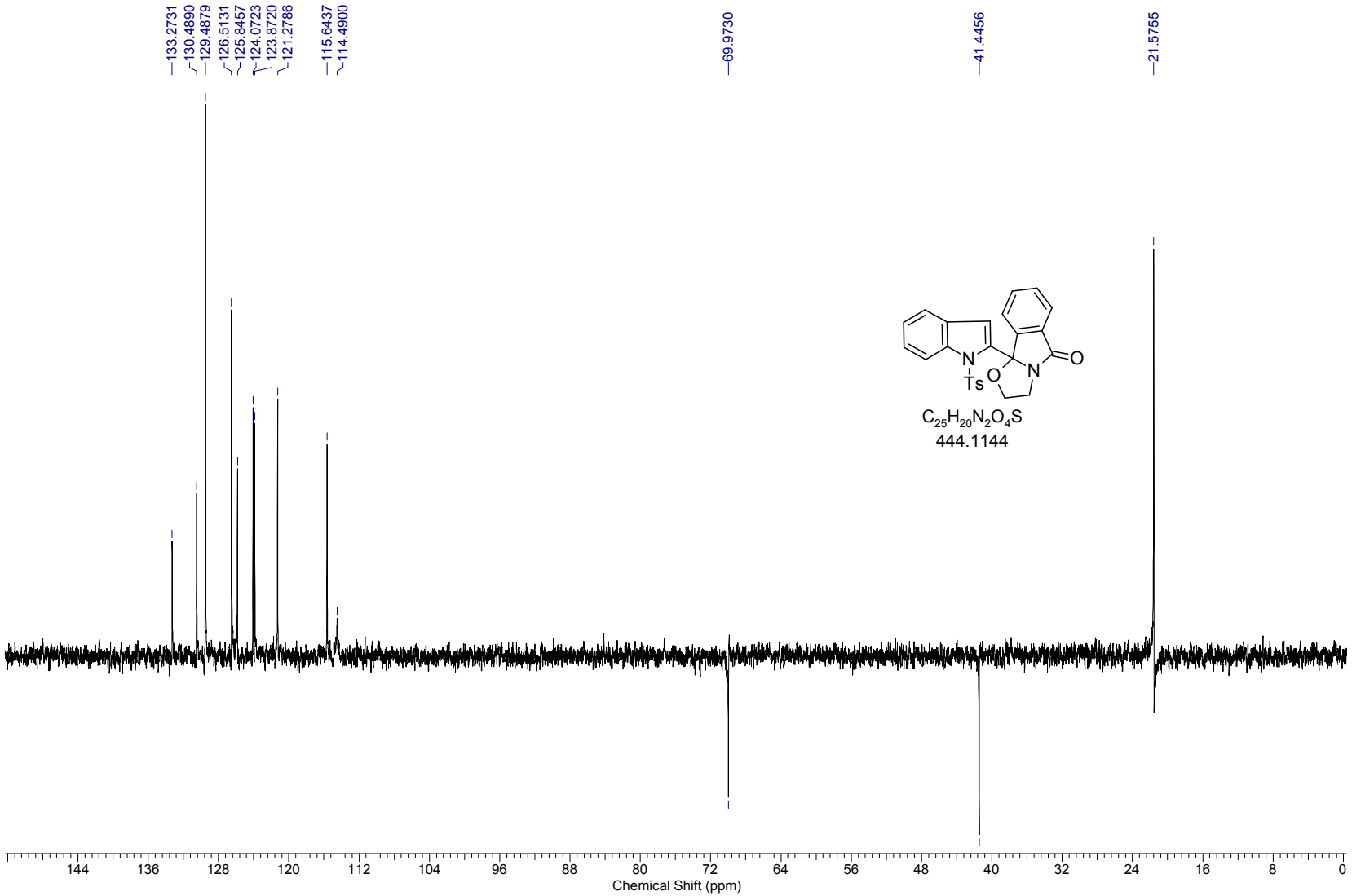


$C_{25}H_{20}N_2O_4S$
444.1144

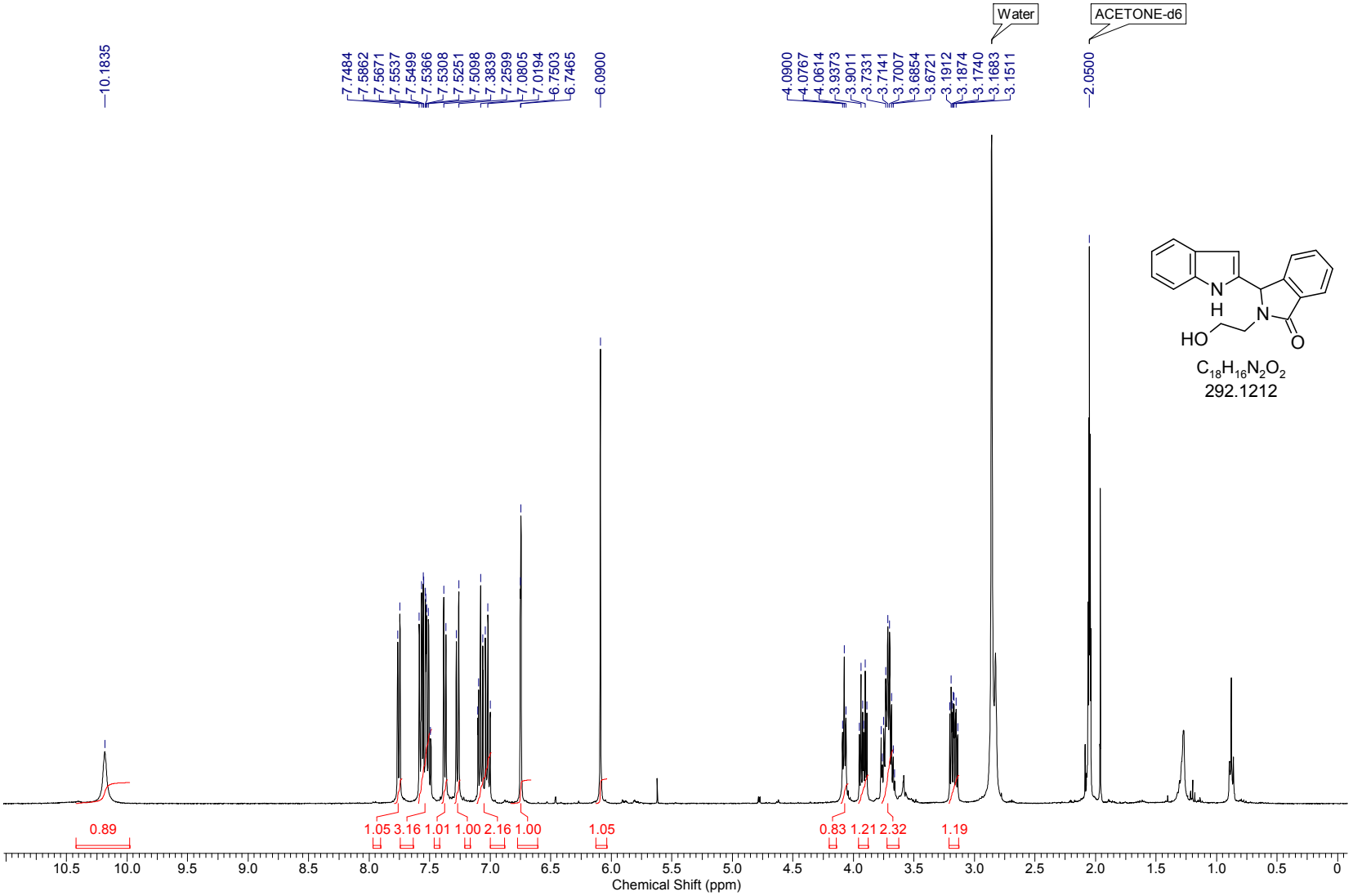
34, ^{13}C NMR, $CDCl_3$, 100 MHz



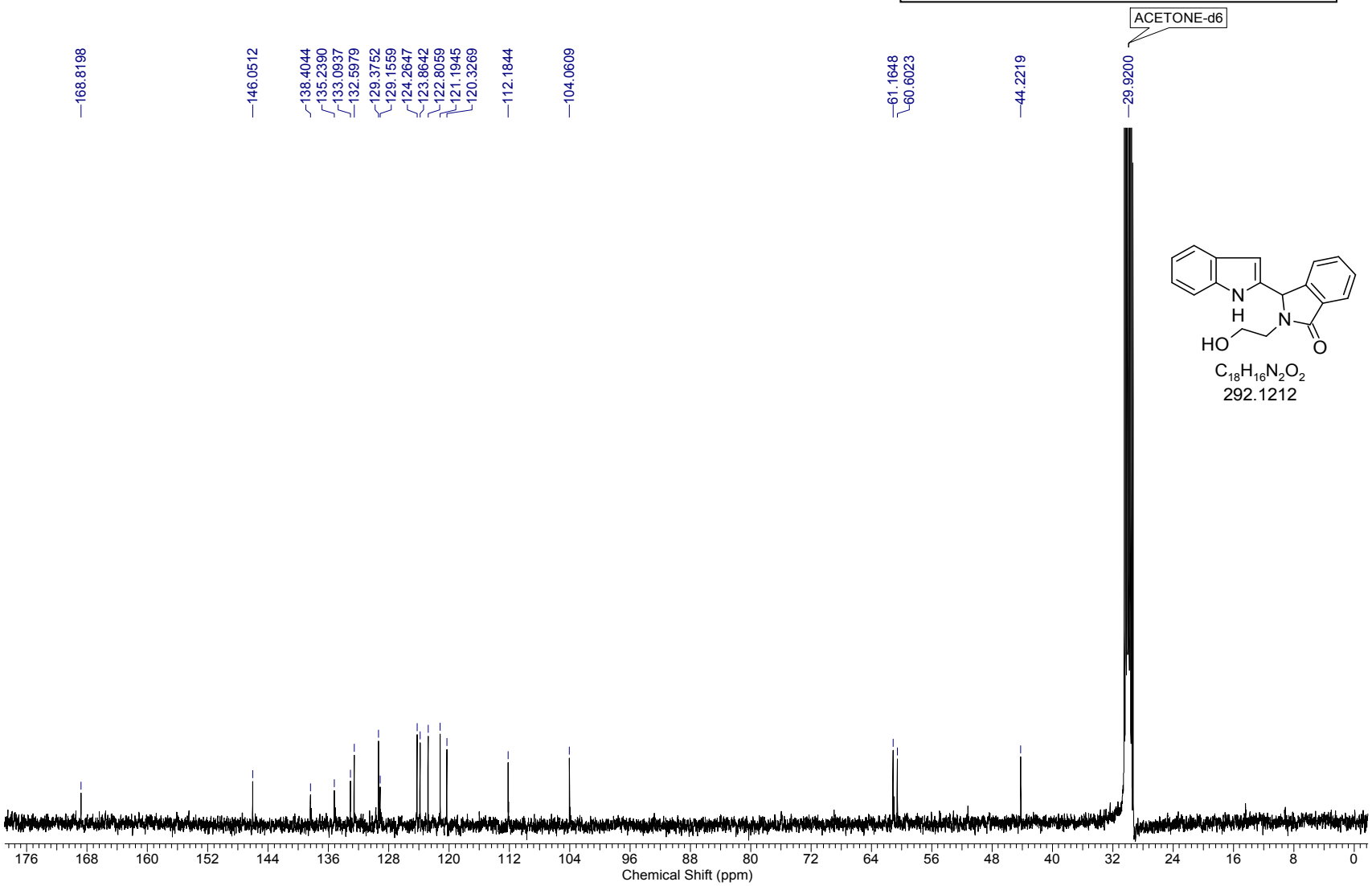
34, DEPT, $CDCl_3$, 100 MHz



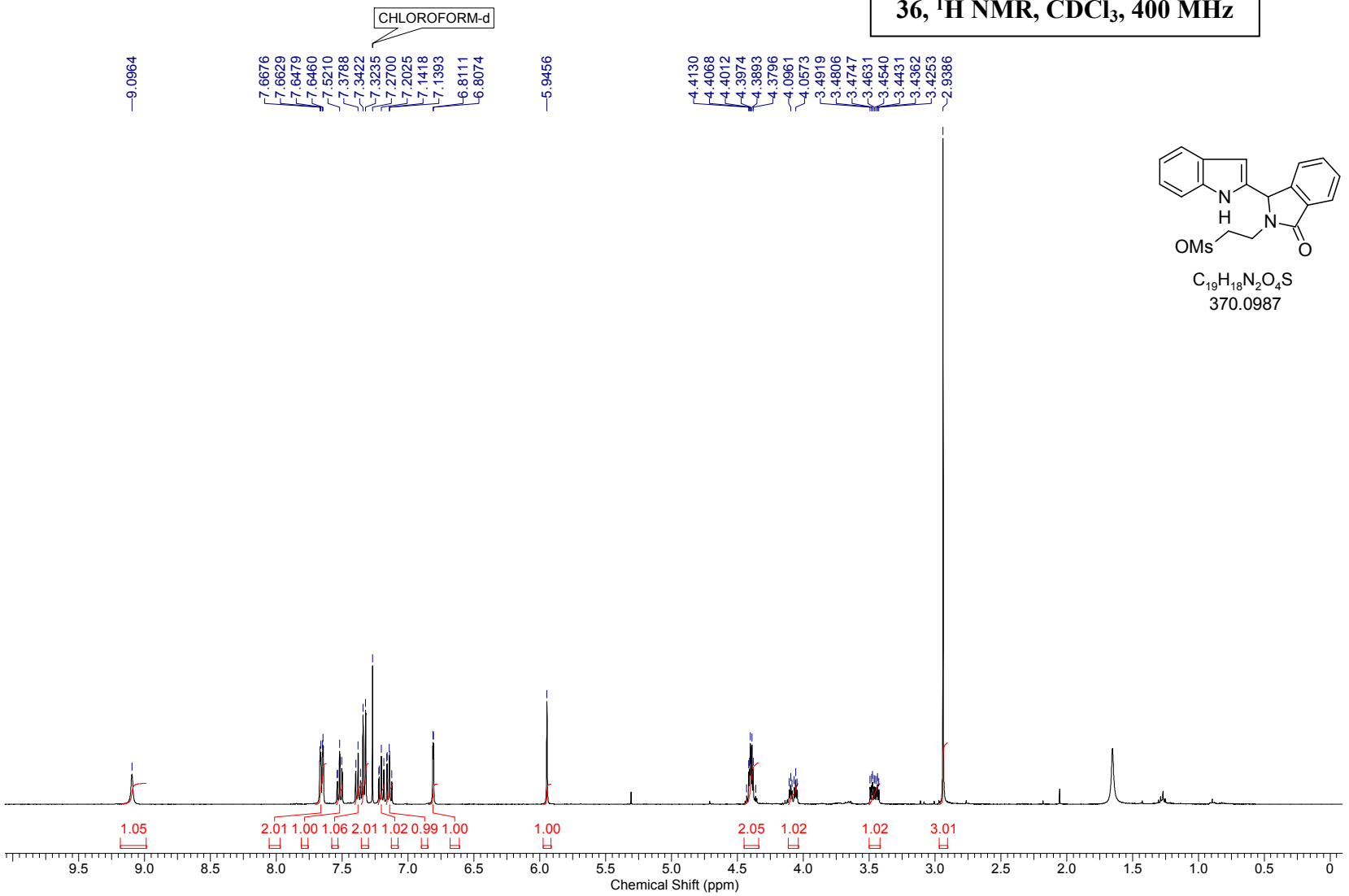
35, ^{1}H NMR, acetone-d_6, 400 MHz



35, ^{13}C NMR, acetone-d_6, 100 MHz

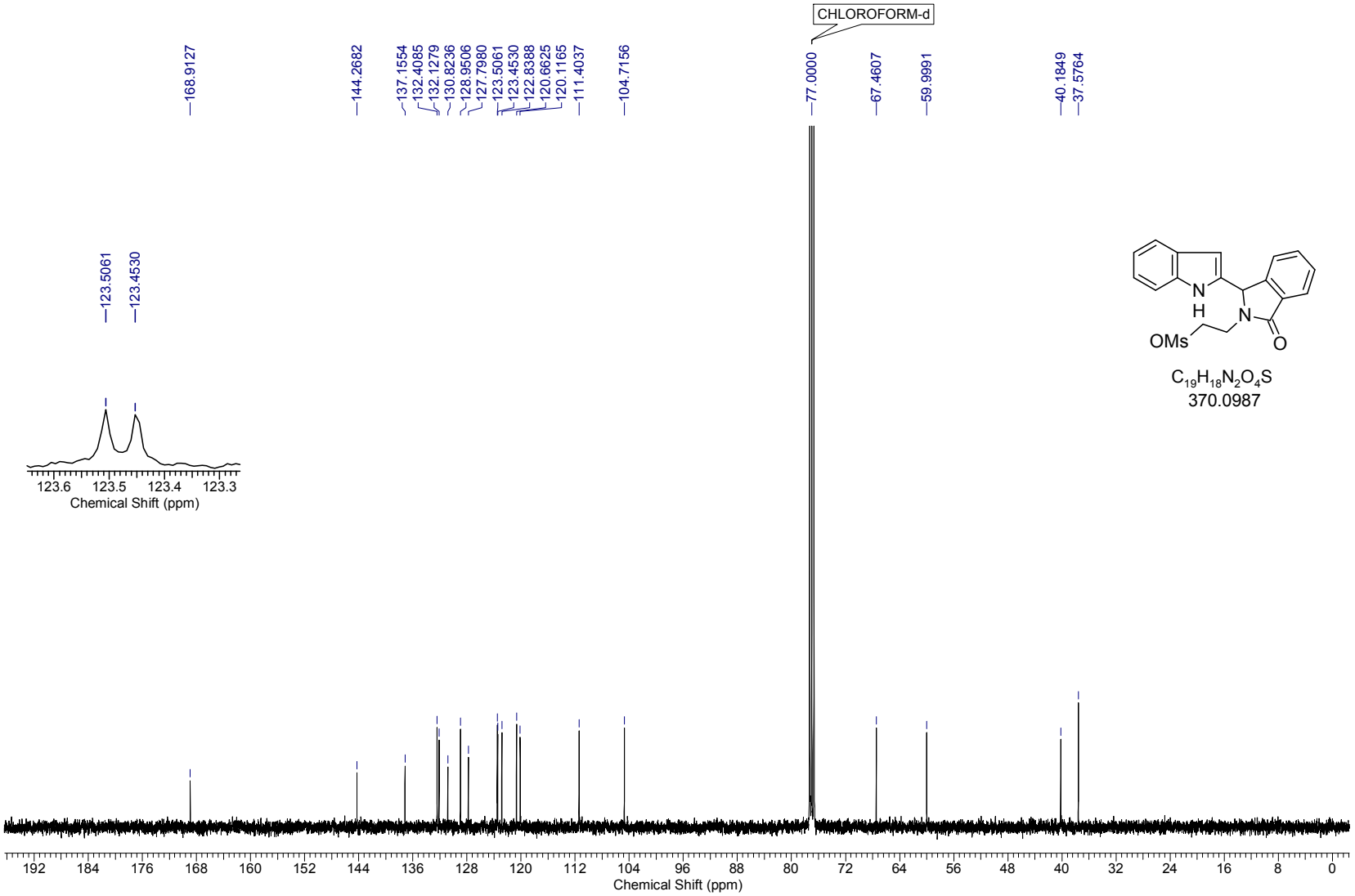


36, ^{1}H NMR, $CDCl_3$, 400 MHz

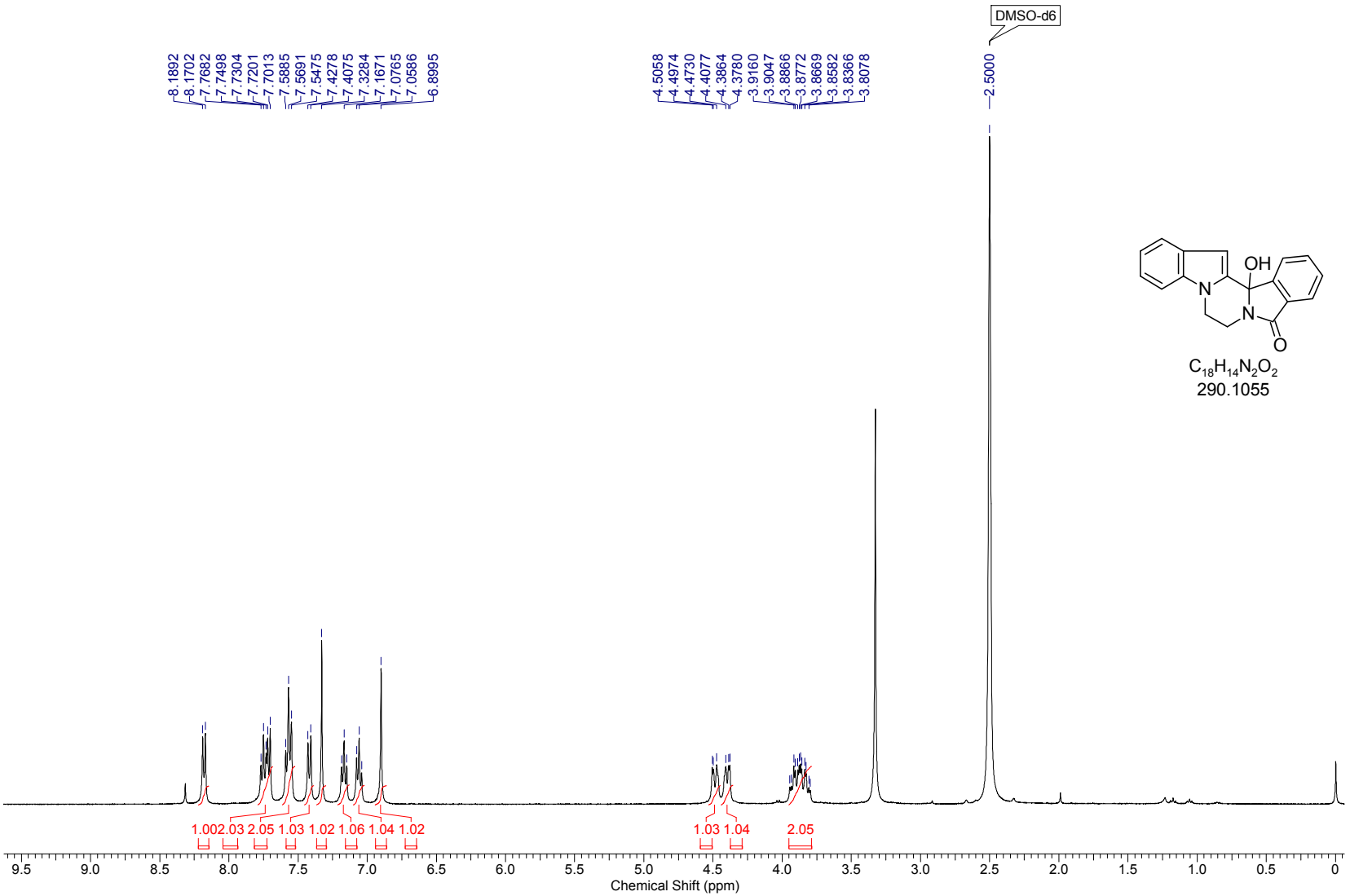


$C_{19}H_{18}N_2O_4S$
370.0987

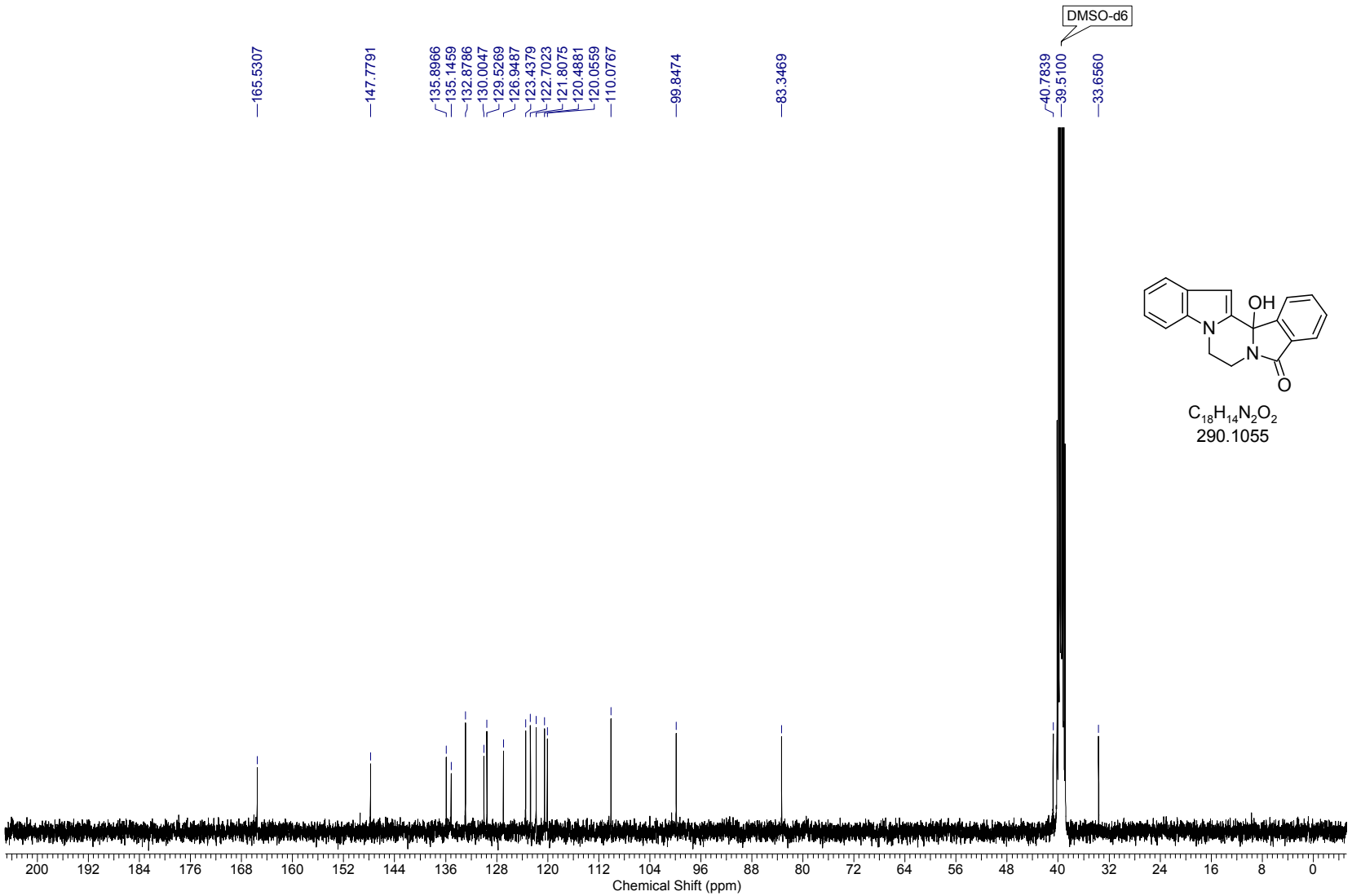
36, ^{13}C NMR, $CDCl_3$, 100 MHz



38, ^{1}H NMR, DMSO-d_6, 400 MHz

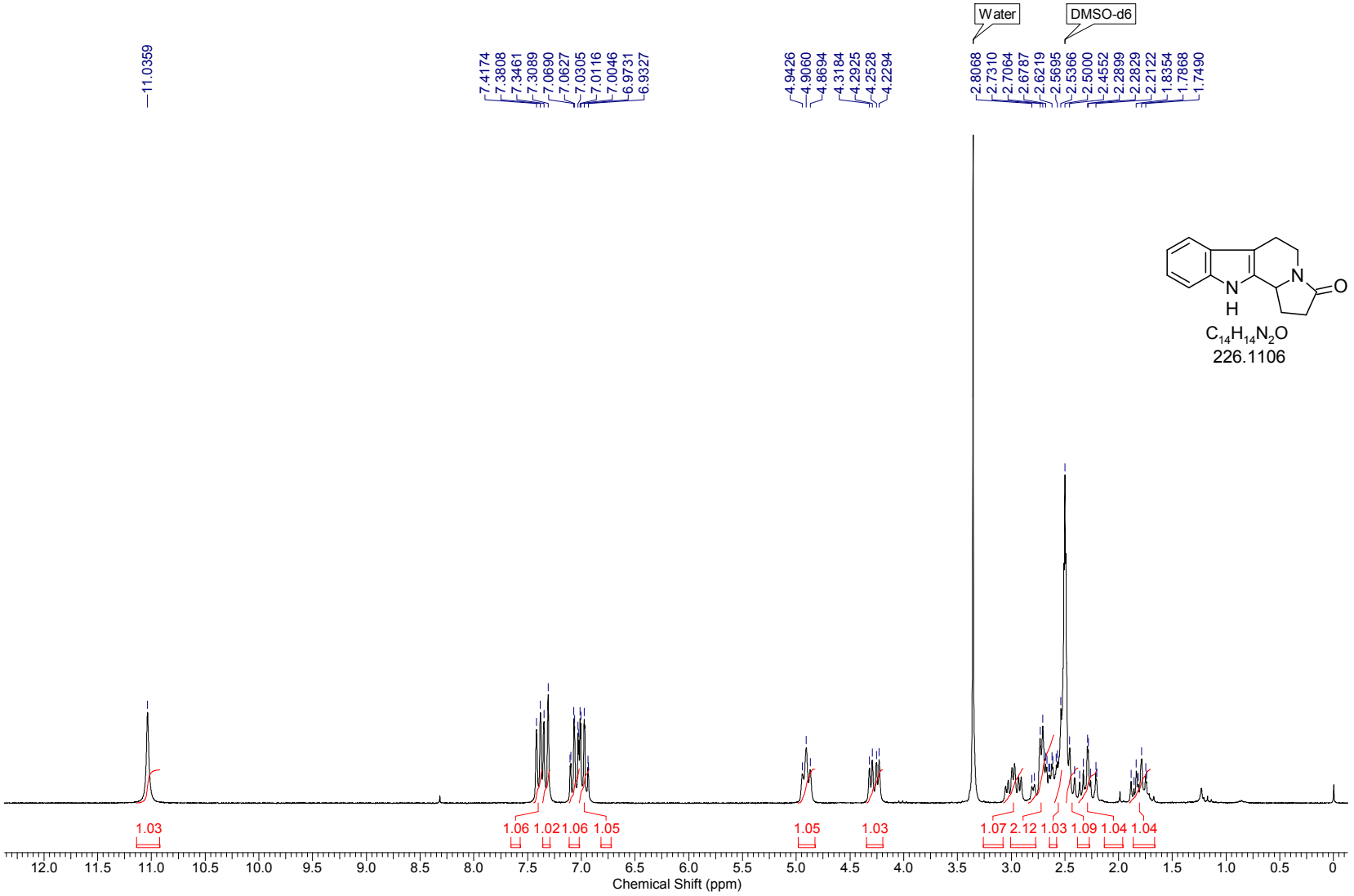


38, ^{13}C NMR, DMSO-d_6, 100 MHz

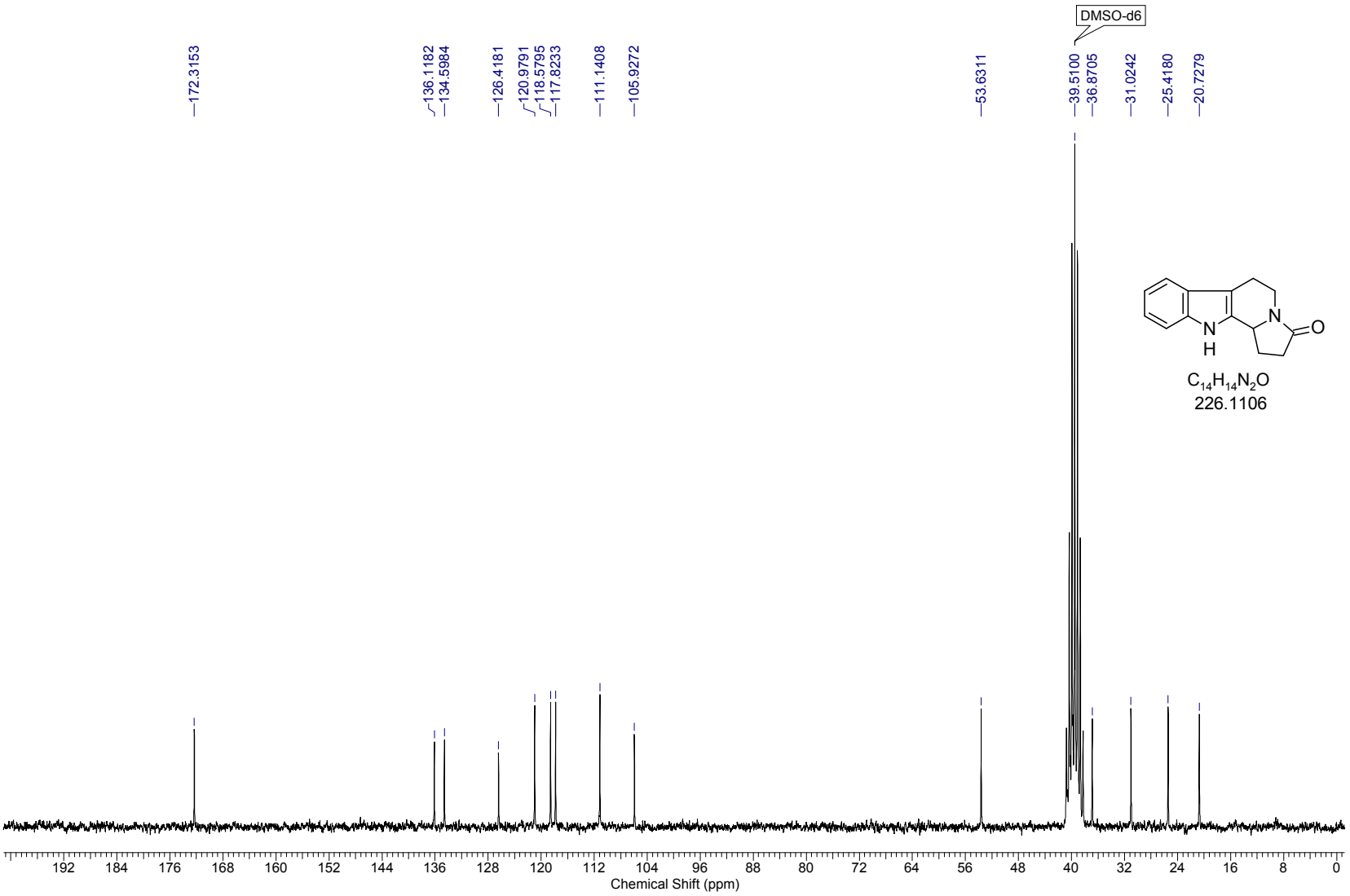


$C_{18}H_{14}N_2O_2$
290.1055

10a, ^{1}H NMR, DMSO-d_6, 200 MHz



10a, ^{13}C NMR, DMSO-d_6, 50 MHz



■ Table 1: Comparison ^{1}H and ^{13}C NMR spectral data of proposed natural product 10 and revised natural product (+)-10a

Proposed natural product 10 (reference 40 in manuscript)			Revised natural product 10a (present work)	
^{1}H NMR (DMSO-d_6, 400 MHz) δ	^{13}C NMR (DMSO-d_6, 100 MHz) δ (δ40.0 ref. lock)†	^{13}C NMR (DMSO-d_6, 100 MHz) δ (δ39.5 ref. lock)	^{1}H NMR (DMSO-d_6, 200 MHz) δ	^{13}C NMR (DMSO-d_6, 50 MHz) δ (δ39.5 ref. lock)
1.77 (m, 1H)	21.2	20.7	1.70–1.91 (m, 1H)	20.7
2.25 (m, 1H)	25.9	25.4	2.20–2.37 (m, 1H)	25.4
2.49 (m, 1H)	31.5	31.0		31.0
2.54 (m, 1H)	37.3	36.8	2.38–2.84 (m, 4H)	36.9
2.63 (m, 1H)	54.1	53.6		53.6
2.73 (dd, *J* = 15.2, 4.0 Hz, 1H)	106.4	105.9		105.9
2.95 (ddd, *J* = 12.4, 12.4, 4.0 Hz, 1H)	111.6	111.1	2.98 (dt, *J* = 12.1 and 4.9 Hz, 1H)	111.1
4.26 (dd, *J* = 12.4, 6.0 Hz, 1H)	118.3	117.8	4.27 (dd, *J* = 12.9 and 4.7 Hz, 1H)	117.8
4.89 (m, 1H)	119.1	118.6	4.91 (t, *J* = 7.3 Hz, 1H)	118.6
6.95 (br dd, *J* = 7.6, 7.2 Hz, 1H)	121.5	121.0	6.97 (dt, *J* = 7.1 and 0.9 Hz, 1H)	121.0
7.04 (br dd, *J* = 8.0, 7.2 Hz, 1H)	126.9	126.4	7.07 (dt, *J* = 6.9 and 1.3 Hz, 1H)	126.4
7.30 (br d, *J* = 8.0 Hz, 1H)	135.1	134.6	7.33 (d, *J* = 7.4 Hz, 1H)	134.6
7.38 (br d, *J* = 7.6 Hz, 1H)	136.6	136.1	7.40 (d, *J* = 7.3 Hz, 1H)	136.1
11.00 (br s, 1H)	172.8	172.3	11.04 (br s, 1H)	172.3

† **In the isolation paper authors have locked the DMSO-d_6 signal at δ40.00 (ref. 40)**

■ General X-ray Crystallography Analysis

Single crystal data of all crystals were collected on Bruker SMART APEX II single crystal X-ray CCD diffractometer having graphite-monochromatized (Mo-Kα = 0.71073 Å) radiation at 100 K. The X-ray data acquisition was monitored by APEX2 program suit. The data were corrected for Lorentz-polarization and absorption effects using SAINT and SADABS programs which are integral part of APEX2 package. The structures were solved by direct methods and refined by full matrix least squares, based on F2, using SHELXL. Crystal structures were refined using Olex software. PLATON was used to check any higher symmetry of crystal, and mercury software was utilized for molecular representations and packing diagrams. Refinement of coordinates and anisotropic thermal parameters of non-hydrogen atoms were performed with the full-matrix least-squares method. Most of hydrogen atoms in NH/OH groups were located from the difference in Fourier maps. The hydrogen atoms of CH were calculated using the riding model[1-4].

■ X-ray crystallography data and crystal structure of compound (±)-9

The compound **(±)-9** (5 mg) was dissolved in methanol (2 mL), and two drops of chloroform added to obtain a clear solution and allowed to evaporate at room temperature in a vial. After 24h, colourless crystals were formed. Crystal analysis studies were done by Bruker APEX-II CCD (Figure 1 *vide infra*).

Crystal Structure was deposited at the Cambridge Crystallographic Data Centre. The data have been assigned the following deposition number.

Compound Code: **(±)-9** [CCDC number **2070970**]

■ Table 2. Crystal data and structure refinement for compound (±)-9

Compound 9	X-ray crystallography data
Empirical Formula	$C_{14}H_{14}N_2O_2$
Formula weight	242.27
Crystal System	Orthorhombic
Space Group	*Pca2₁*
T (K)	100
a (Å)	24.406 (2)
b (Å)	5.0265 (4)
c (Å)	9.4136 (8)
α (°)	90
β (°)	90
γ (°)	90
V (Å^3)	1154.83 (17)
D_{cal} (g cm^{-3})	1.393 Mg m^{-3}
Z	4
μ (mm^{-1})	0.10
R_{int}	0.060
$R[F^2 > 2\sigma(F^2)]$	0.036
$wR(F^2)$	0.106
$(\sin\theta/\lambda)max$ (Å^{-1})	0.647
Crystal size (mm)	0.18 × 0.12 × 0.06
Measured reflections	38269
Independent reflections	2610
Reflections with $I > 2\sigma(I)$	2525
Goodness of fit (S)	1.19
X–ray Diffractometer	Bruker APEX-II CCD

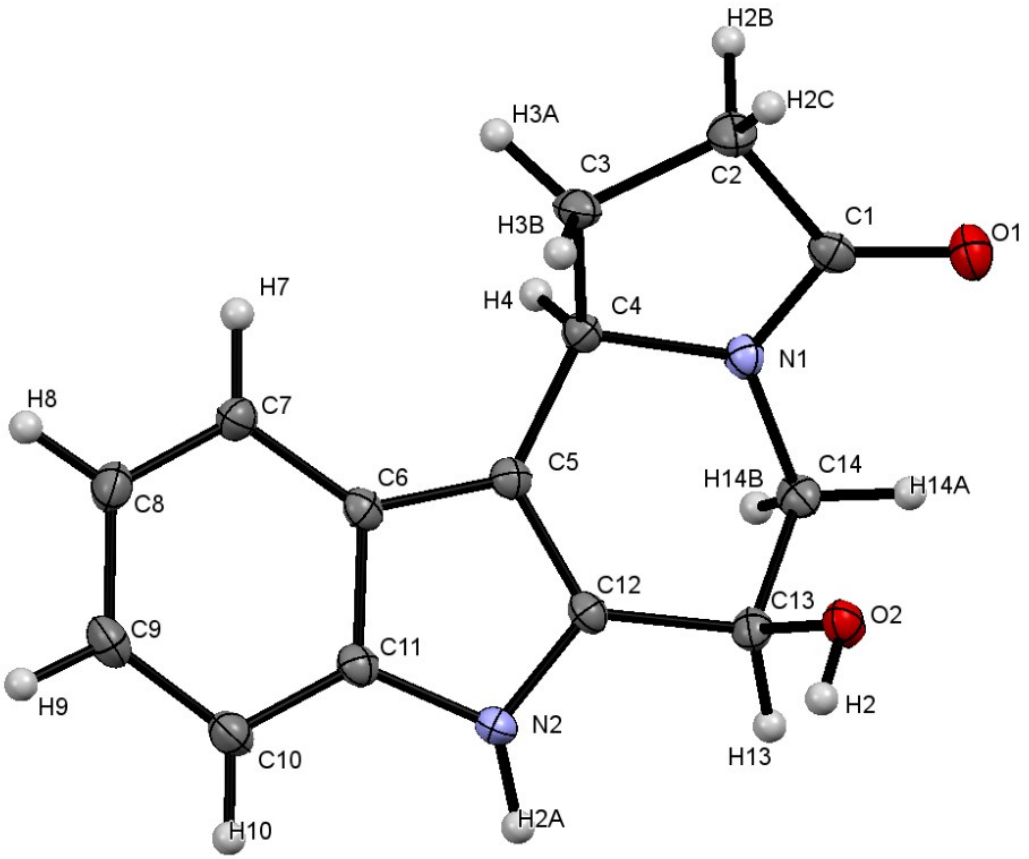


Figure S1: Molecular structure (ORTEP diagram) of compound (±)-**9** Ellipsoids are shown at 50% probability

■ X-ray crystallography data and crystal structure of compound 38

The compound **38** (3 mg) was dissolved in ethyl acetate (2 mL) and two drops of acetonitrile added to obtain a clear solution and allowed to evaporate at room temperature in a vial. After 12h, colourless crystals were formed. Crystal analysis studies were done by Bruker APEX-II CCD (Figure 1 *vide infra*).

Crystal Structure was deposited at the Cambridge Crystallographic Data Centre. The data have been assigned the following deposition number.

Compound Code: **38** [CCDC number **2070969**]

■ Table 3. Crystal data and structure refinement for compound 38

Compound 9	**X-ray crystallography data**
Empirical Formula	$C_{18}H_{14}N_2O_2$
Formula weight	290.31
Crystal System	Triclinic
Space Group	P^i
T (K)	100
a (Å)	7.2558 (7)
b (Å)	9.8044 (10)
c (Å)	10.5031 (10)
α (°)	99.055 (4)
β (°)	105.174 (4)
γ (°)	103.419 (4)
V (Å^3)	682.24 (12)
D_{cal} (g cm^{-3})	1.413 Mg m^{-3}
μ (mm^{-1})	0.09
Z	2
R[F2 > 2σ(F2)]	0.047
R int	0.065
$(\sin \theta/\lambda)_{max}$ (Å^{-1})	0.628
R[F2 > 2σ(F2)]	0.047
wR(F^2)	0.131
Crystal size (mm)	0.12 × 0.12 × 0.08
Measured reflections	13705
Independent reflections	2806
Reflections with *I*> 2σ(*I*)	2473
Goodness of fit (S)	1.11
X–ray Diffractometer	Bruker D8 VENTURE Kappa Duo PHOTON II CPAD

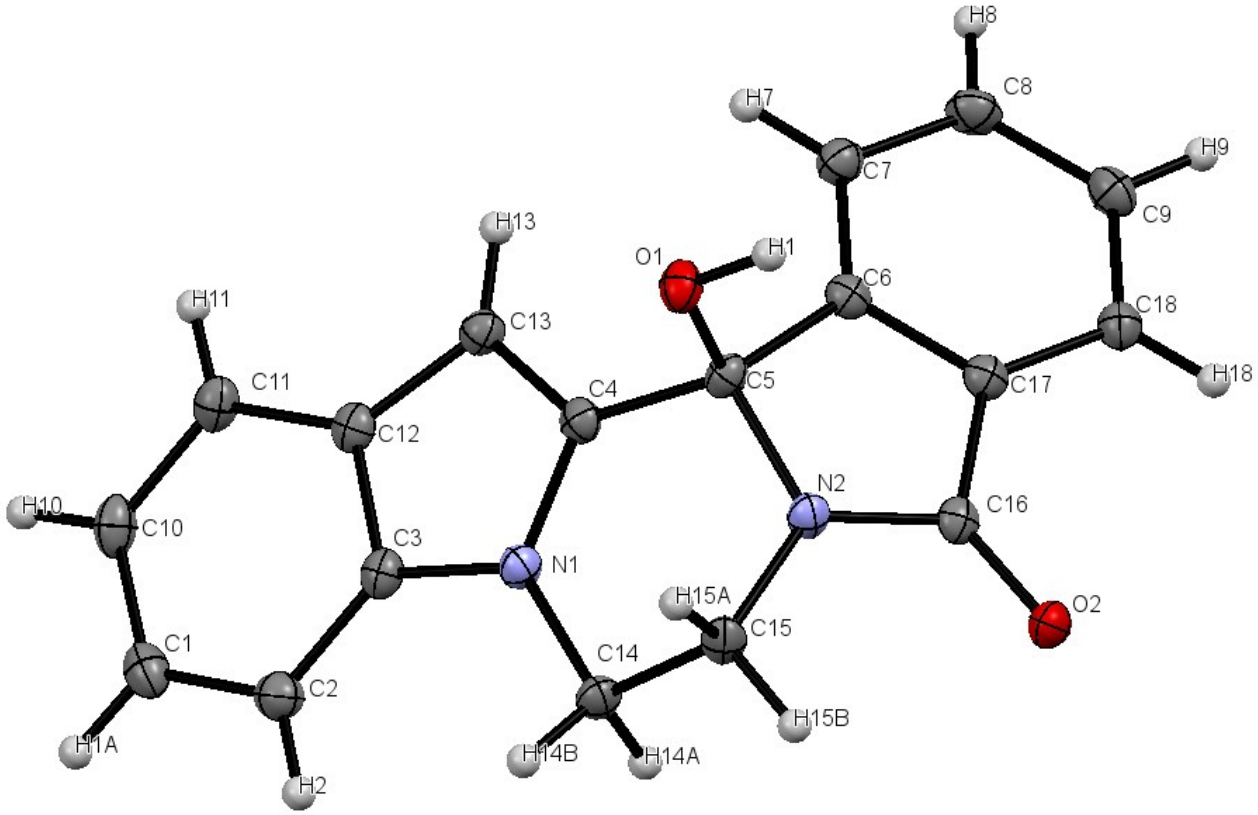


Figure S2: Molecular structure (ORTEP diagram) of compound **38** Ellipsoids are shown at 50% probability

■ References:

1. APEX2; SAINT; SADABS In *Bruker AXS Inc*; Bruker Madison, Wisconsin, USA, 2006.
2. O. V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard and H. Puschmann, *J. Appl. Cryst*., 2009, 339–341.
3. G. M. Sheldrick, *Acta Cryst*., 2015, **A71**, 3–8.
4. C. F. Macrae, P. R. Edgington, P. McCabe, E. Pidcock, G. P. Shields, R. Taylor, M. Towler and J. van de Streek, *J. Appl. Cryst*., 2006, **39**, 453–457.