Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Electronic Supplementary Information

Damage of aromatic amino acids by the atmospheric free radical oxidant $NO_3^\bullet$ in the presence of $NO_2^\bullet$, N_2O_4, O_3 and O_2

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Contents:

1 Experimental section

1.1 General Procedures

Protection of the commercially available (Sigma-Aldrich), enatiomeric pure amino acids were performed according to literature procedures [A. J. Smallridge, M. A. Trewhella, and Z. Wang, *Aust. J. Chem*., 2002, **55**, 259; F. Giacomina, A. Meetsma, L. Panella, L. Lefort, A. H. M. de Vries, and J. G. de Vries, *Angew. Chem., Int. Ed*., 2007, **46**, 1497; K. Junge, G. Oehme, A. Monsees, T. Riermeier, U. Dingerdissen, and M. Beller, *Tetrahedron Lett*. 2002, **43**, 4977].

^{1}H and ^{13}C spectra were taken on a Varian Unity Inova 500 spectrometer [499.688 MHz (^{1}H), 125.646 (^{13}C)] in deuterated chloroform ($CDCl_3$). If possible the assignment of the chemical shifts was confirmed by utilising 2D NMR techniques.

GC/MS (EI, 70 eV) analysis was run on an Agilent 7890A GC / 5975C MSD, column from SUPELCO 30 m, 0.32 mm ID, 0.25 µm film thickness fused silica capillary column. The temperature program used was $70_5 \rightarrow 250_{17}$ heating rate 5ºC/min (40 mins in total).

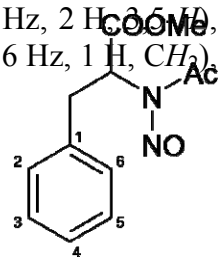
HR-MS was conducted by ionising the samples via ESI into a Thermo-Finnigan LTQ FT-ICR hybrid mass spectrometer or an Agilent 6520 LC/Q-TOF mass spectrometer with an electrospray ionizing source coupled to an Agilent 1100 LC system.

The crude products were purified by reverse-phase HPLC (Phenomenex C18, 150 × 21.2 mm, 5 micron, preparative column, 8 ml/min) using an Agilent 1100 LC system by running a gradient from 0.1 % TFA in water to 0.1 % TFA in acetonitrile within 2-3 hours. Purity was assessed by analytical RP HPLC on an Agilent Zorbax C18 5uM 150 × 4.3 mm column.

1.2 Reaction of amino acids with $NO_3^{\bullet}$

1.2.1 Reaction of phenylalanine 1a with $NO_2^{\bullet}/N_2O_4$

1b; 2-(*N*-Nitrosoacetamido)-3-phenyl-propionic acid methyl ester (*N*-nitroso-*N*-Ac-*O*-Me-phenyl alanine)

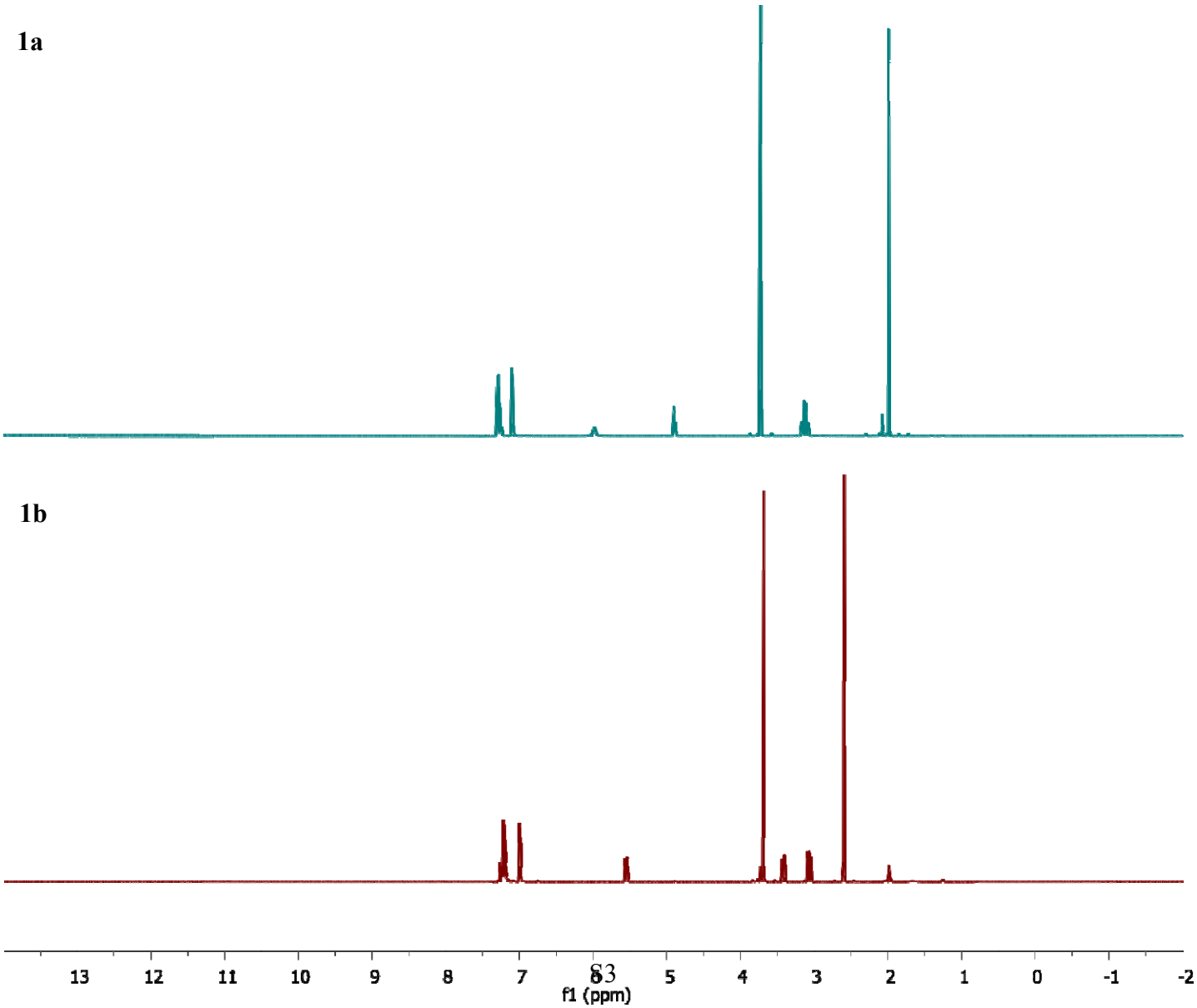


^{1}H-NMR (500 MHz, $CDCl_3$): δ = 7.20 (m, 3 H, 2,4,6-*H*), 6.99 (dd, *J* = 7.1, 1.2 Hz, 2 H, 3,5-*H*), 5.55 (dd, *J* = 10.6, 5.6 Hz, 1 H, C*H*), 3.69 (s, 3 H, COOCH_3), 3.42 (dd, *J* = 14.3, 5.6 Hz, 1 H, CH_2), 3.07 (dd, *J* = 14.3, 10.6 Hz, 1 H, CH_2), 2.60 ppm (s, 3 H, N(NO)COCH_3).

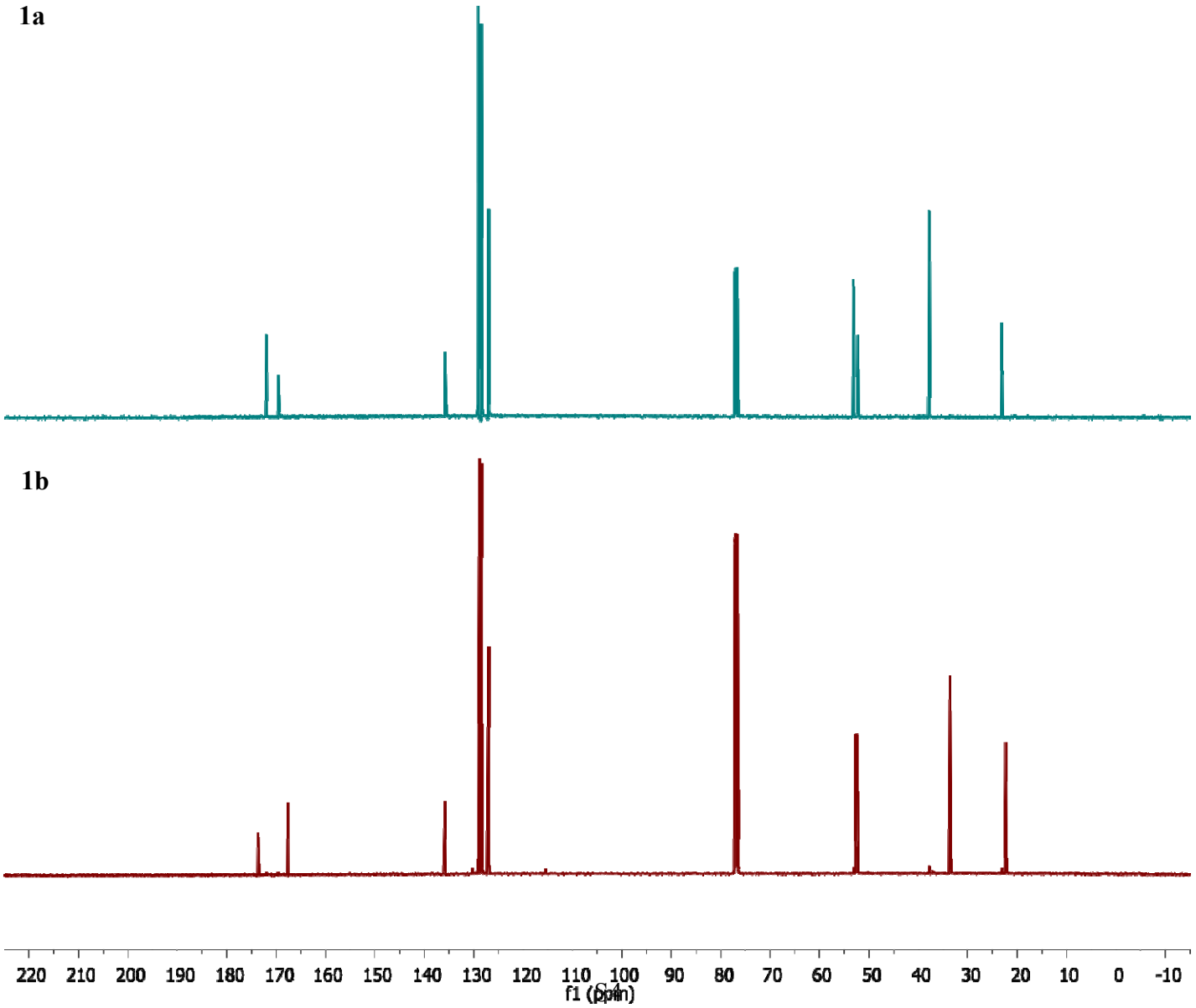
^{13}C-NMR (125 MHz, $CDCl_3$): δ = 173.9 (C_q, NH*C*OCH$_3$), 167.9 (C_q, *C*OOCH$_3$), 136.1 (C_q, *C*-1), 129.0 (C_t, *C*-3,5), 128.7 (C_t, *C*-2,6), 127.2 (C_t, *C*-4), 52.9 (C_p, COO*C*H$_3$), 52.6 (C_t, *C*H), 33.8 (C_s, *C*H$_2$), 22.5 ppm (C_p, N(NO)CO*C*H$_3$).

IR (neat): ν = 3030, 2955, 1734, 1520, 1498, 1456, 1436, 1374, 1351, 1305, 1280, 1231, 1179, 1117, 1087, 1069, 1047, 931, 810, 767, 749, 700, 671, 655 cm^{-1}.

^{1}H NMR

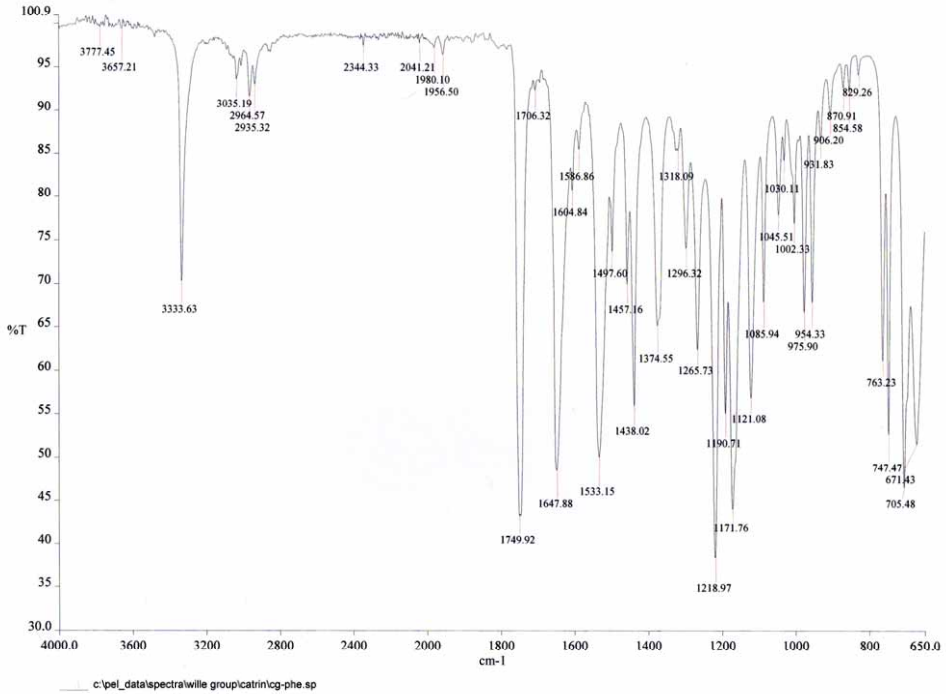


^{13}C NMR

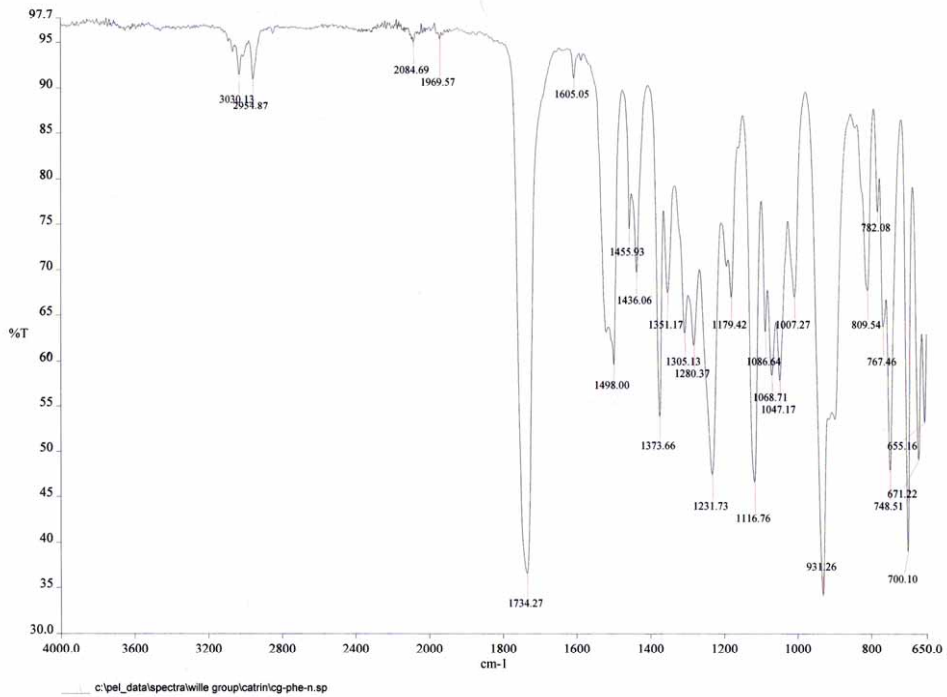

1a
1b
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

IR

1a

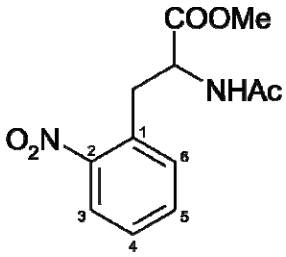

100.9
95
90
85
80
75
70
65
60
55
50
45
40
35
30.0
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
650.0
cm-1
3777.45
3657.21
3035.19
2964.57
2935.32
2344.33
2041.21
1980.10
1956.50
1706.32
1586.86
1604.84
1497.60
1457.16
1374.55
1438.02
1318.09
1296.32
1265.73
1030.11
1045.51
1002.33
1085.94
954.33
975.90
906.20
931.83
870.91
854.58
829.26
763.23
747.47
671.43
705.48
3333.63
1749.92
1647.88
1533.15
1190.71
1121.08
1171.76
1218.97
c:\pel_data\spectra\wille group\catrin\cg-phe.sp

1b


97.7
95
90
85
80
75
70
65
60
55
50
45
40
35
30.0
%T
4000.0
3600
3200
2800
2400
2000
1800
1600
1400
1200
1000
800
650.0
cm-1
3030.13
2953.87
2084.69
1969.57
1605.05
1455.93
1436.06
1351.17
1498.00
1373.66
1305.13
1280.37
1179.42
1231.73
1116.76
1086.64
1068.71
1047.17
1007.27
782.08
809.54
767.46
655.16
671.22
748.51
931.26
700.10
1734.27
c:\pel_data\spectra\wille group\catrin\cg-phe-n.sp

1.2.2 Reaction of phenylalanine 1a with $NO_3^{\bullet}$

***ortho*-6a**; 2-Acetylamino-3-(2-nitro-phenyl)-propionic acid methyl ester (*ortho*-nitro-*N*-Ac-*O*-Me-phenyl alanine)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 7.92 (dd, *J* = 8.2, 1.3 Hz, 1 H, 3-*H*), 7.57 (td, *J* = 7.6, 1.3 Hz, 1 H, 5-*H*), 7.43 (ddd, *J* = 8.2, 7.6, 1.3 Hz, 1 H, 4-*H*), 7.39 (dd, *J* = 7.6, 1.3 Hz, 1 H, 6-*H*), 6.43 (d, *J* = 7.5 Hz, 1 H, N*H*), 4.93 (td, *J* = 8.1, 5.9 Hz, 1 H, C*H*), 3.74 (s, 3 H, COOCH_3), 3.51 (dd, *J* = 13.8, 5.9 Hz, 1 H, CH_2), 3.33 (dd, *J* = 13.8, 8.2 Hz, 1 H, CH_2), 1.99 ppm (s, 3 H, NHCOCH_3).

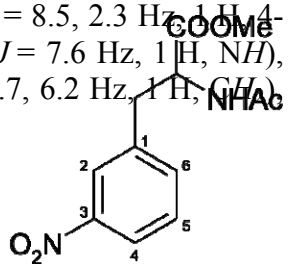
^{13}C-NMR (125 MHz, $CDCl_3$): δ = 171.5 (C_q, *C*OOCH$_3$), 171.4 (C_q, NH*C*OCH$_3$), 149.9 (C_q, *C*-2), 133.4 (C_t, *C*-5), 132.8 (C_t, *C*-6), 131.3 (C_q, *C*-1), 128.6 (C_t, *C*-4), 125.1 (C_t, *C*-3), 53.4 (C_t, *C*H), 53.0 (C_p, COO*C*H$_3$), 34.8 (C_s, *C*H$_2$), 22.9 ppm (C_p, NHCO*C*H$_3$).

MS (EI, 70 eV): *m/z* (%) = 266.0 [M^+], 220.1 [M^+- NO_2], 207.1 [M^+- COOMe].

HR-MS: $C_{12}H_{14}N_2O_5$+H: calcd 267.0981, found 267.0981.
$C_{11}{}^{13}CH_{14}N_2O_5$+H: calcd 268.1015, found 268.1010.

***meta*-6a**; 2-Acetylamino-3-(3-nitro-phenyl)-propionic acid methyl ester (*meta*-nitro-*N*-Ac-*O*-Me-phenyl alanine)

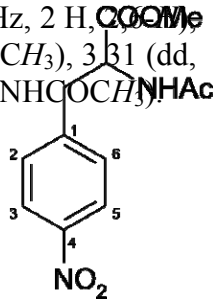
^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.78 (d, *J* = 2.3 Hz, 1 H, 3-*H*), 8.40 (dd, *J* = 8.5, 2.3 Hz, 1 H, 4-*H*), 7.68 (d, *J* = 8.5 Hz, 1 H, 6-*H*), 7.26 (d, *J* = 2.3 Hz, 1 H, 5-*H*), 6.16 (d, *J* = 7.6 Hz, 1 H, N*H*), 4.93 (dd, *J* = 14.0, 7.6 Hz, 1 H,C*H*), 3.76 (s, 3 H, COOCH_3), 3.68 (d, *J* = 13.7, 6.2 Hz, 1 H, CH_2), 3.39 (dd, *J* = 13.7, 7.8 Hz, 1 H, CH_2), 1.95 ppm (s, 3 H NHCOCH_3).



MS (EI, 70 eV): *m/z* (%) = 266.0 [M^+], 207.1 [M^+- COOMe], 165.1 [M^+- COOMe-Ac].

***para*-6a**; 2-Acetylamino-3-(4-nitro-phenyl)-propionic acid methyl ester (*para*-nitro-*N*-Ac-*O*-Me-phenyl alanine)

^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.78 (d, *J* = 8.8 Hz, 2 H, 3,5-*H*), 7.28 (d, *J* = 8.8 Hz, 2 H, 2,6-*H*), 6.19 (d, *J* = 7.0 Hz, 1 H, N*H*), 4.93 (dt, *J* = 7.4, 5.9 Hz, 1 H, C*H*), 3.76 (s, 3 H, COOCH_3), 3.31 (dd, *J* = 13.8, 6.2 Hz, 1 H, CH_2), 3.20 (dd, *J* = 13.8, 5.6 Hz, 1 H, CH_2), 2.06 ppm (s, 3 H, NHCOCH_3).

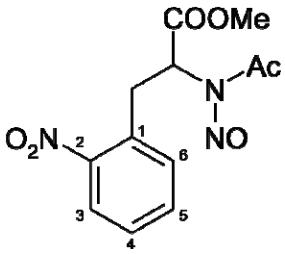


^{13}C-NMR (125 MHz, $CDCl_3$): δ = 171.4 (C_q, *C*OOCH$_3$), 171.2 (C_q, NH*C*OCH$_3$), 147.4 (C_q, *C*-4), 143.6 (C_q, *C*-1), 130.3 (C_t, *C*-2,6), 123.9 (C_t, *C*-3,5), 53.3 (C_t, *C*H), 52.9 (C_p, COO*C*H$_3$), 37.8 (C_s, *C*H$_2$), 23.0 ppm (C_p, NHCO*C*H$_3$).

MS (EI, 70 eV): *m/z* (%) = 266.1 [M^+], 207.0 [M^+- COOMe], 165.0 [M^+- COOMe-Ac].

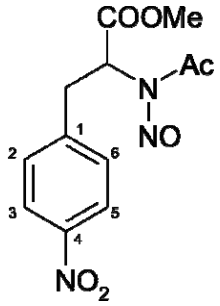
HR-MS: $C_{12}H_{14}N_2O_5$+H: calcd 267.0981, found 267.0985.
$C_{11}{}^{13}CH_{14}N_2O_5$+H: calcd 268.1015, found 268.1009.

***ortho*-6b;** 2-(*N*-Nitrosoacetamido)-3-(2-nitro-phenyl)-propionic acid methyl ester (2-nitro-*N*-nitroso-*N*-Ac-*O*-Me-phenyl alanine)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.01 (dd, *J* = 8.2, 1.4 Hz, 1 H, 3-*H*), 7.48 (td, *J* = 7.5, 1.4 Hz, 1 H, 5-*H*), 7.40 (ddd, *J* = 8.1, 7.5, 1.5 Hz, 1 H, 4-*H*), 7.04 (dd, *J* = 7.7, 1.2 Hz, 1 H, 6-*H*), 5.79 (dd, *J* = 10.4, 4.7 Hz, 1 H, C*H*), 3.94 (dd, *J* = 14.0, 4.7 Hz, 1 H, CH_2), 3.71 (s, 3 H, COOCH_3), 3.17 (dd, *J* = 14.1, 10.4 Hz, 1 H, CH_2), 2.65 ppm (s, 3 H, N(NO)COCH_3).

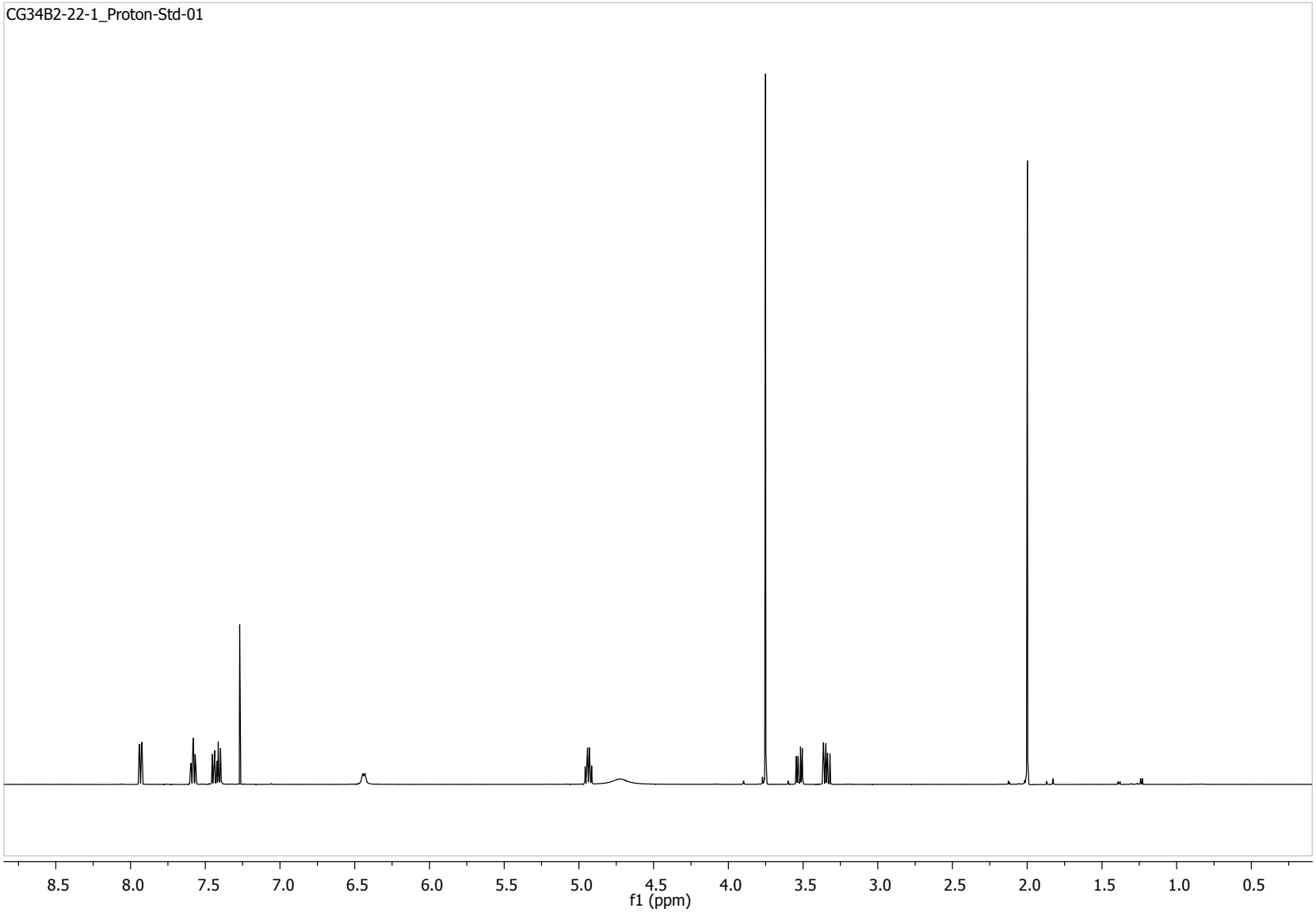
***para*-6b;** 2-(*N*-Nitrosoacetamido)-3-(4-nitro-phenyl)-propionic acid methyl ester (4-nitro-*N*-nitroso-*N*-Ac-*O*-Me-phenyl alanine)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.11 (d, *J* = 8.8 Hz, 2 H, 3,5-*H*), 7.22 (d, *J* = 8.8 Hz, 2 H, 2,6-*H*), 5.56 (dd, *J* = 9.9, 6.0 Hz, 1 H, C*H*), 3.70 (s, 3 H, COOCH_3), 3.54 (dd, *J* = 14.3, 6.0 Hz, 2 H, CH_2), 3.14 (dd, *J* = 14.3, 9.8 Hz, 2 H, CH_2), 2.67 ppm (s, 3 H, N(NO)COCH_3).

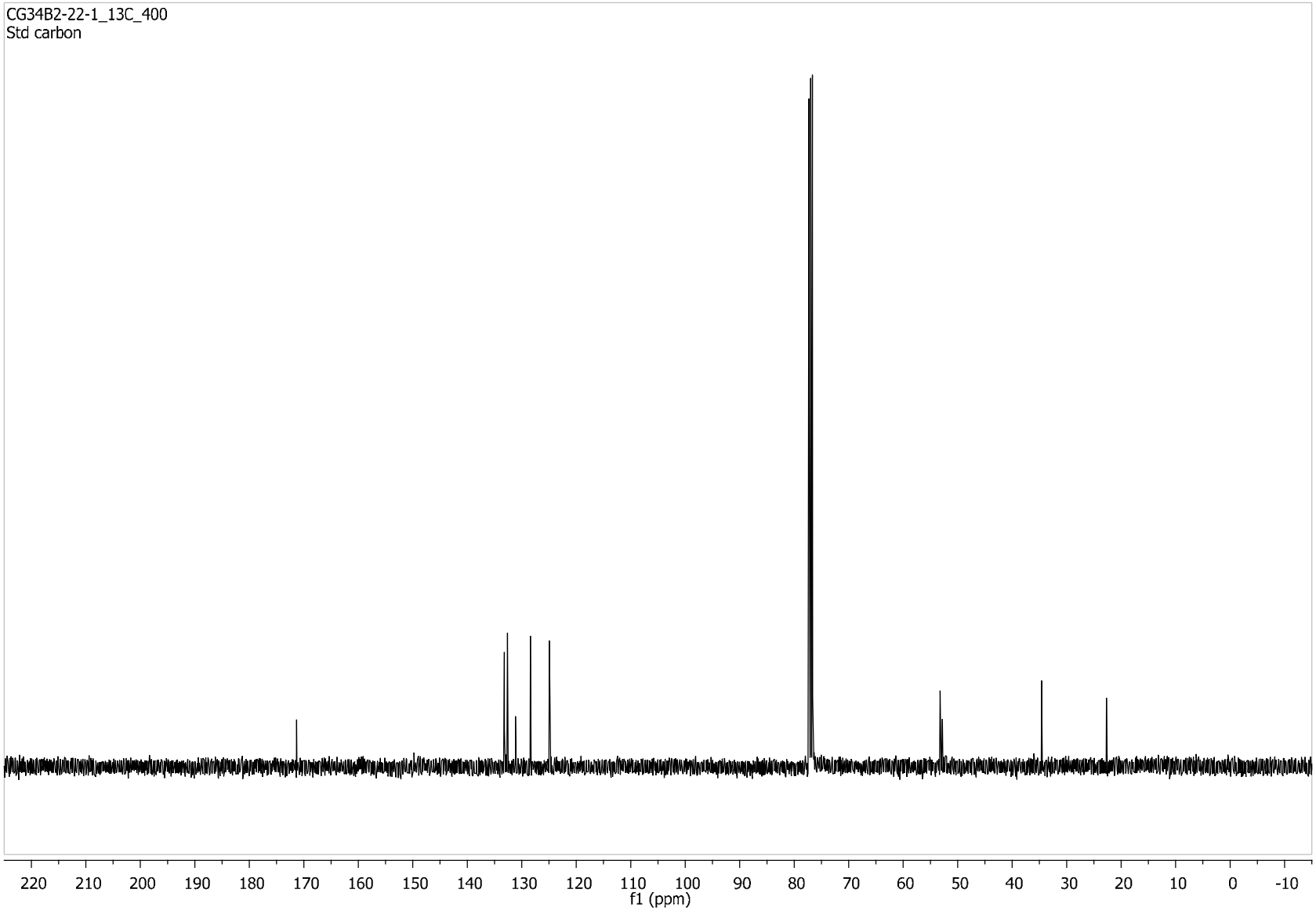
***ortho*-6a**

^{1}H NMR:



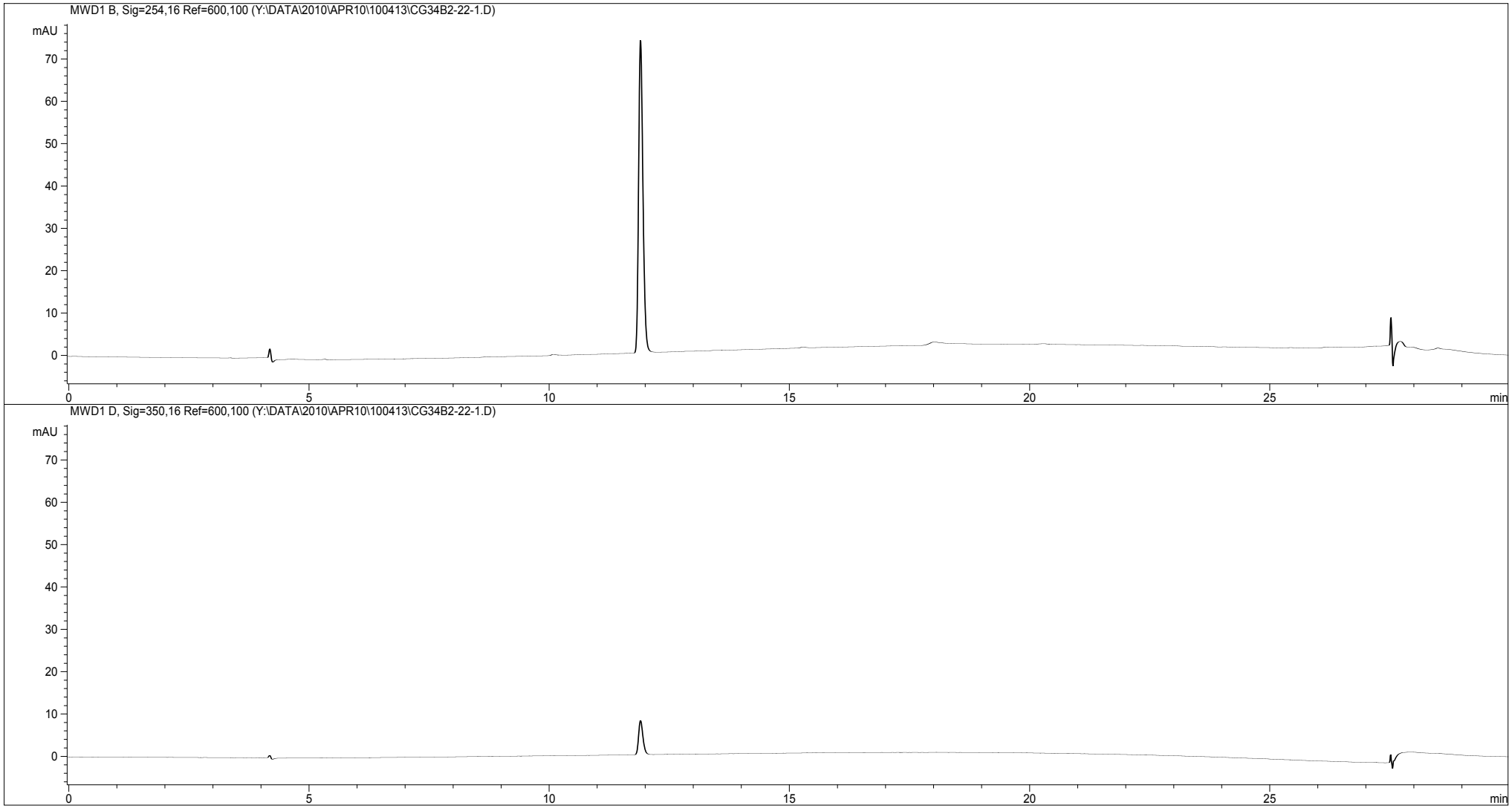
***ortho*-6a**

^{13}C NMR:



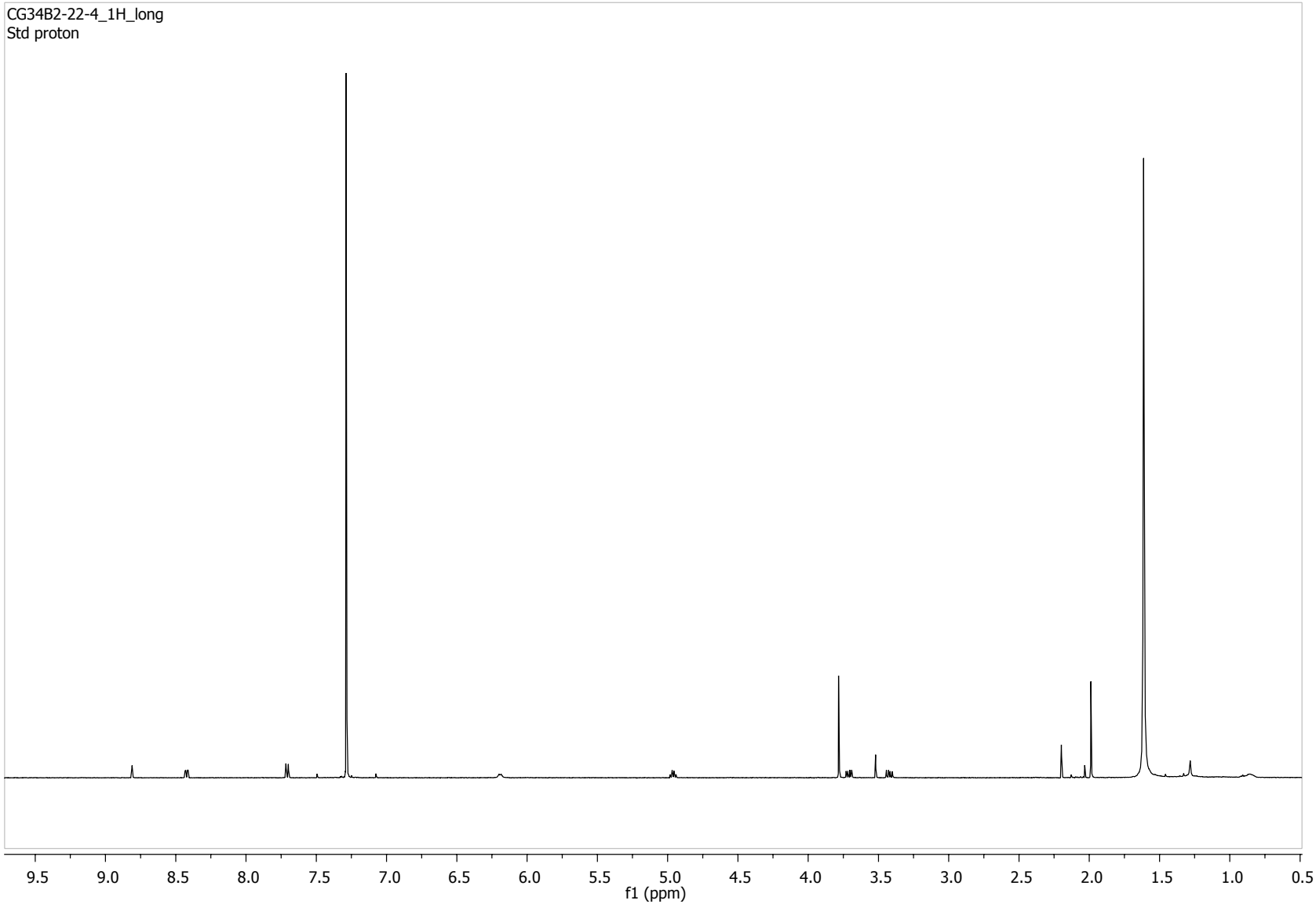
***ortho*-6a**

HPLC:



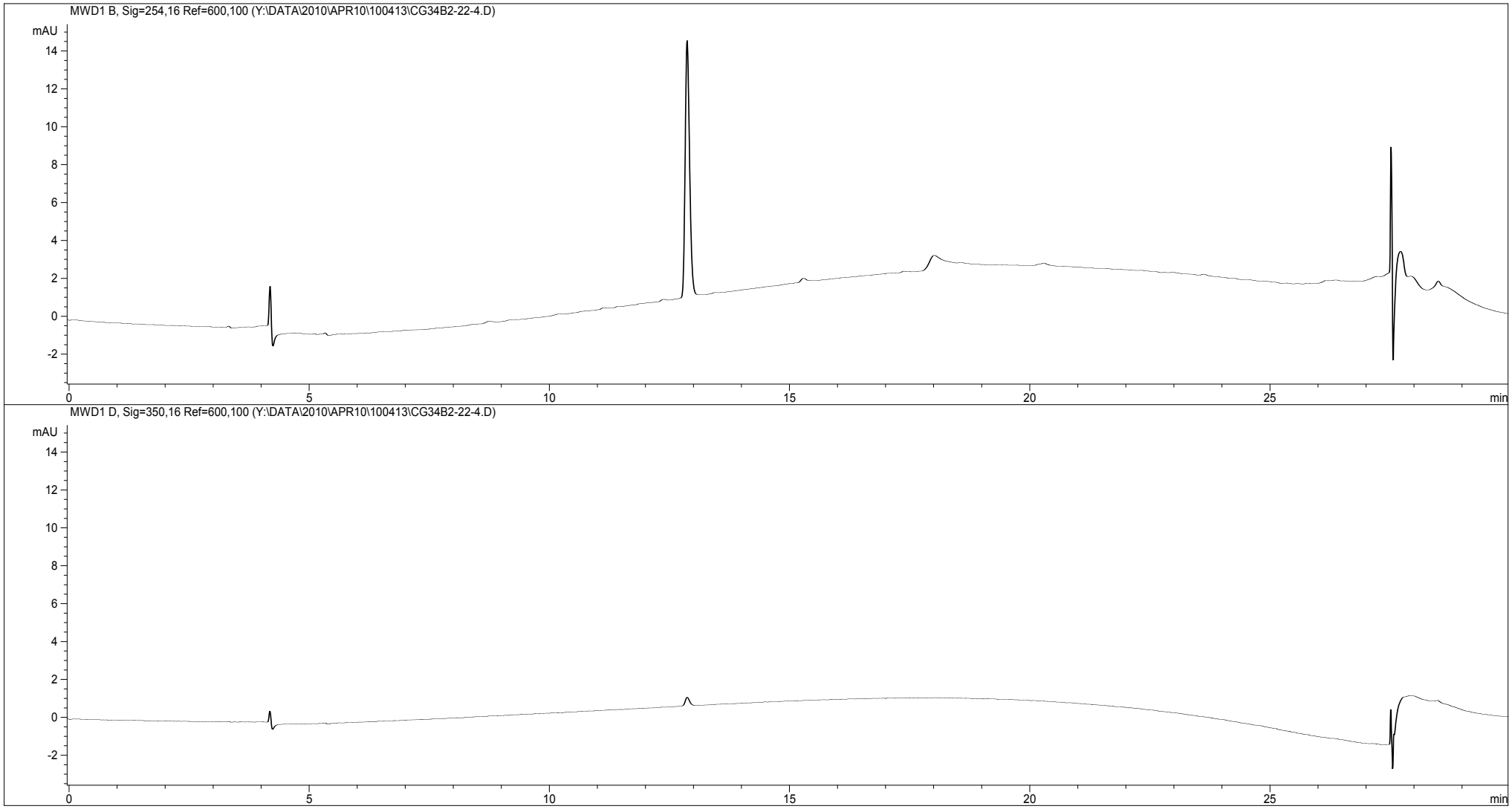
***meta*-6a**

^{1}H NMR:



***meta*-6a**

HPLC: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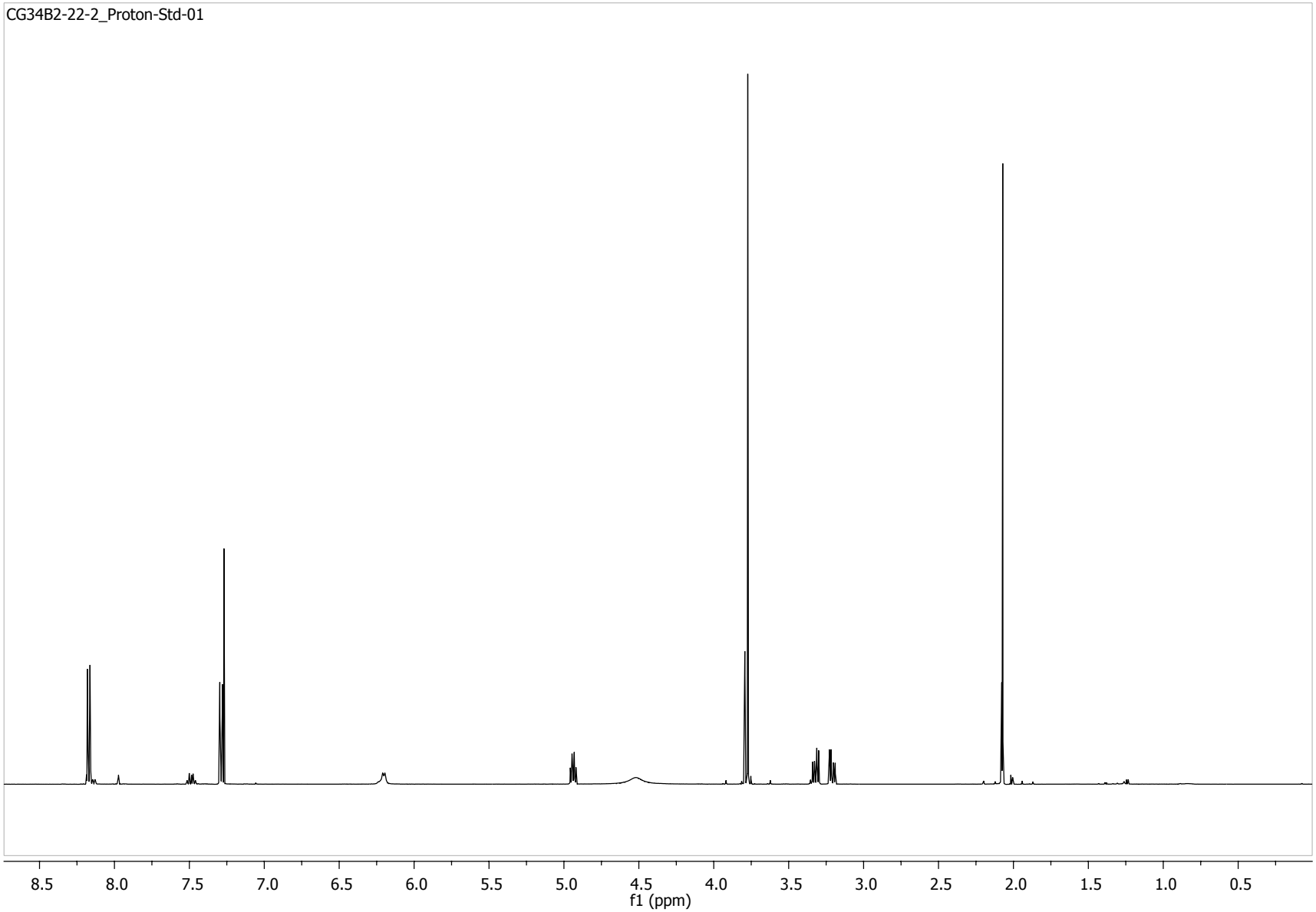
14
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
min
MWD1 D, Sig=350,16 Ref=600,100 (Y:\DATA\2010\APR10\100413\CG34B2-22-4.D)
mAU
14
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
min

***para*-6a**

^{1}H NMR: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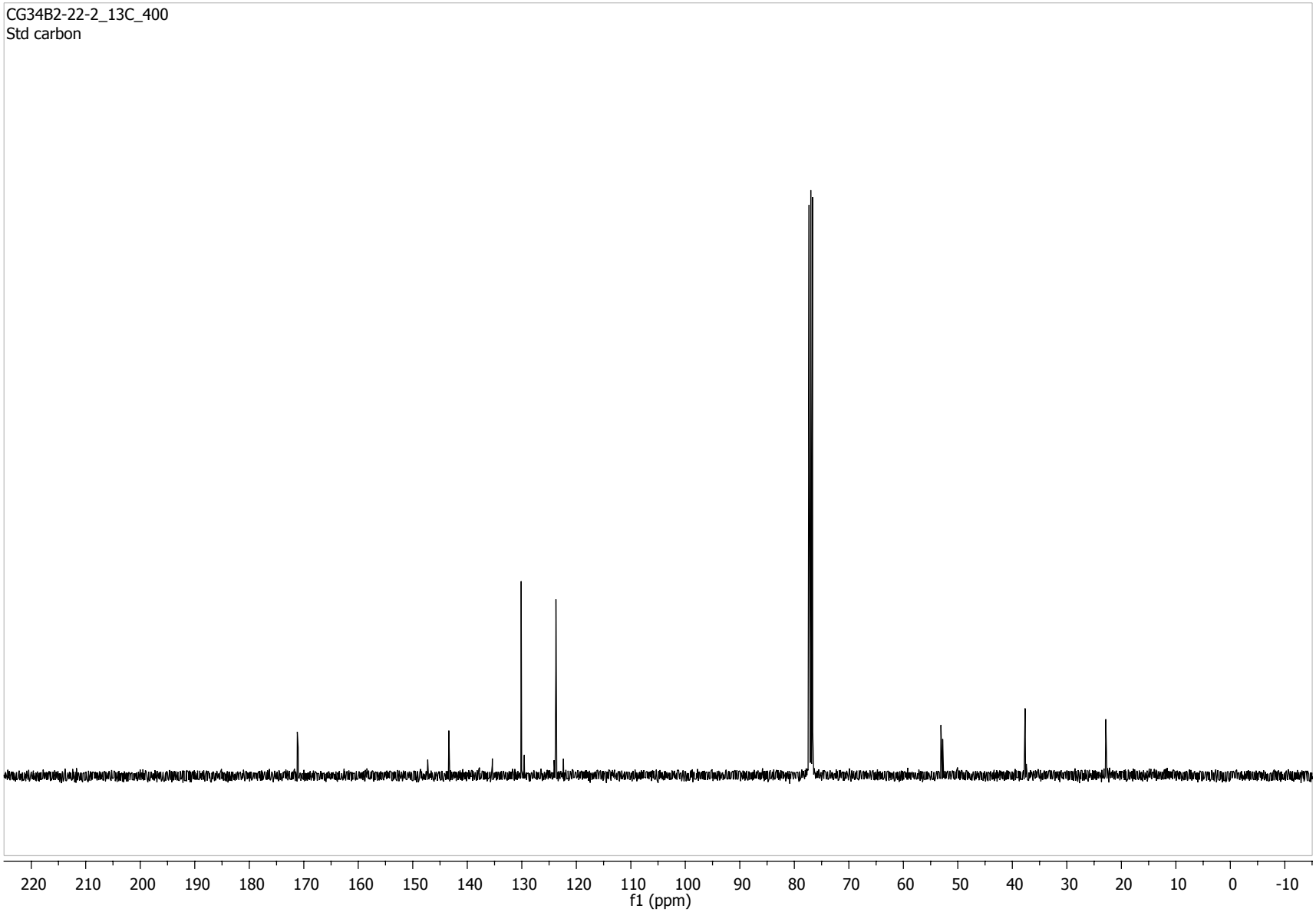
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

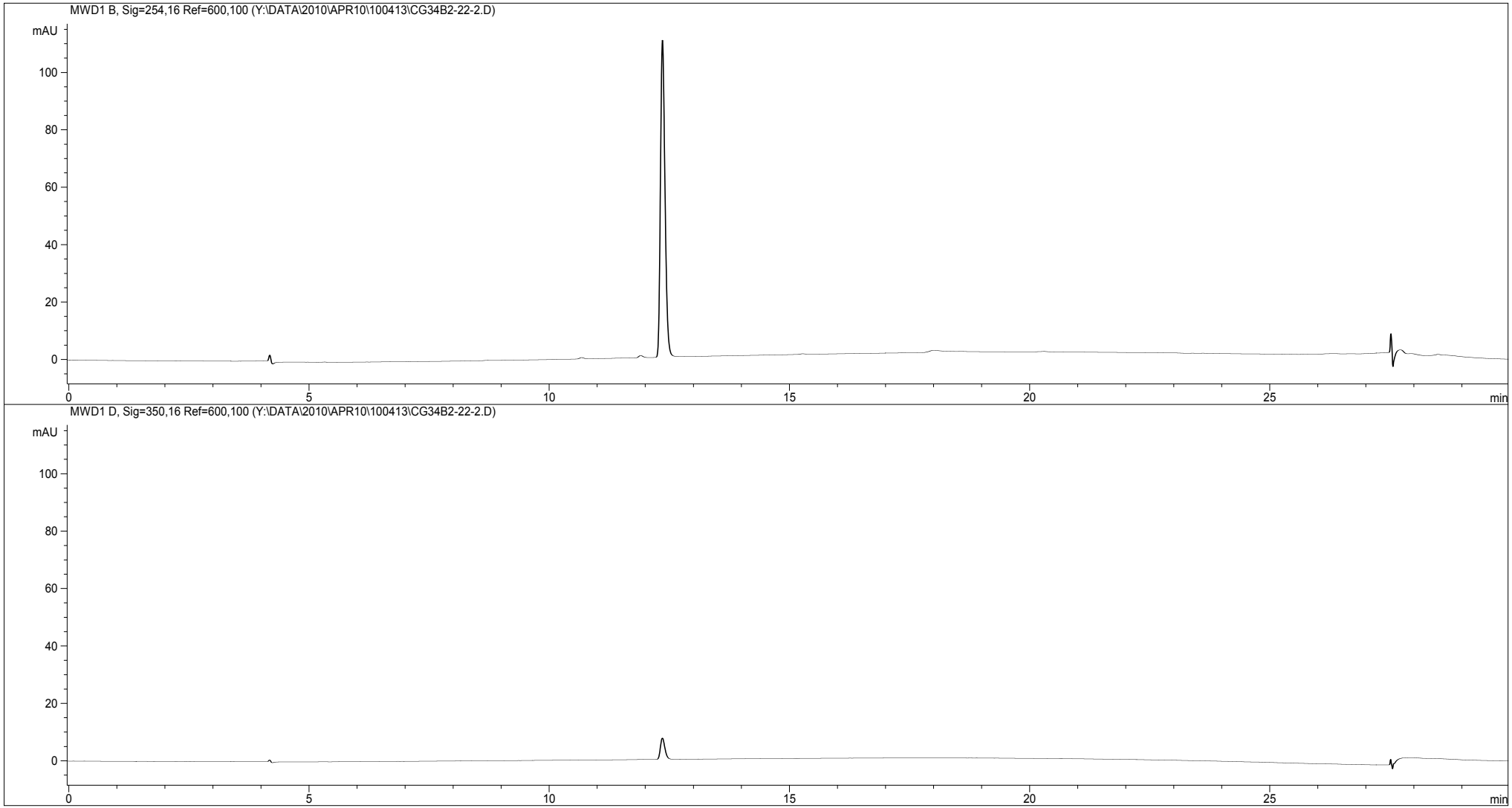
***para*-6a**

^{13}C NMR:


CG34B2-22-2_13C_400
Std carbon
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

***para*-6a**

HPLC: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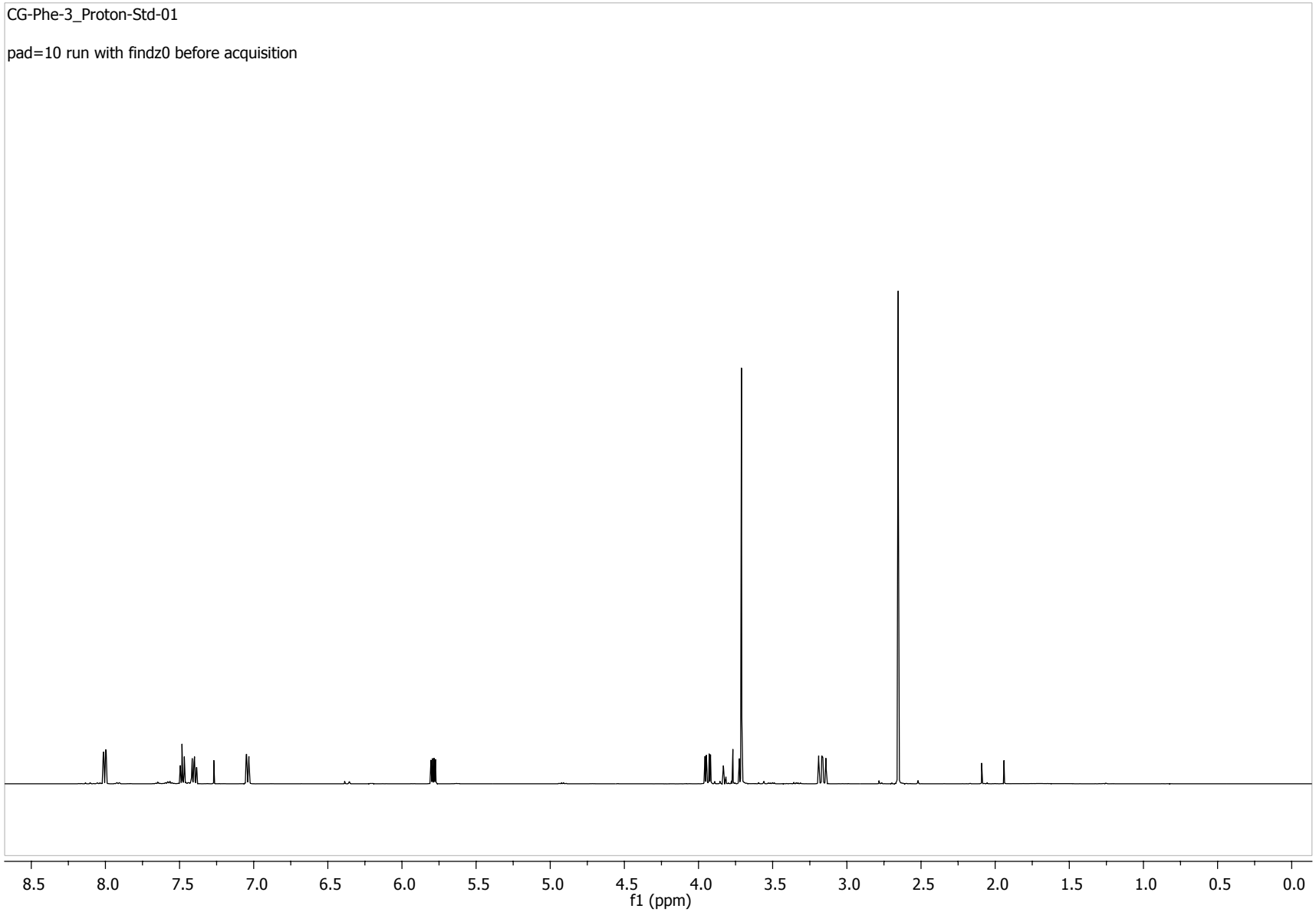
100
80
60
40
20
0
0
5
10
15
20
25
min
MWD1 D, Sig=350,16 Ref=600,100 (Y:\DATA\2010\APR10\100413\CG34B2-22-2.D)
mAU
100
80
60
40
20
0
0
5
10
15
20
25
min

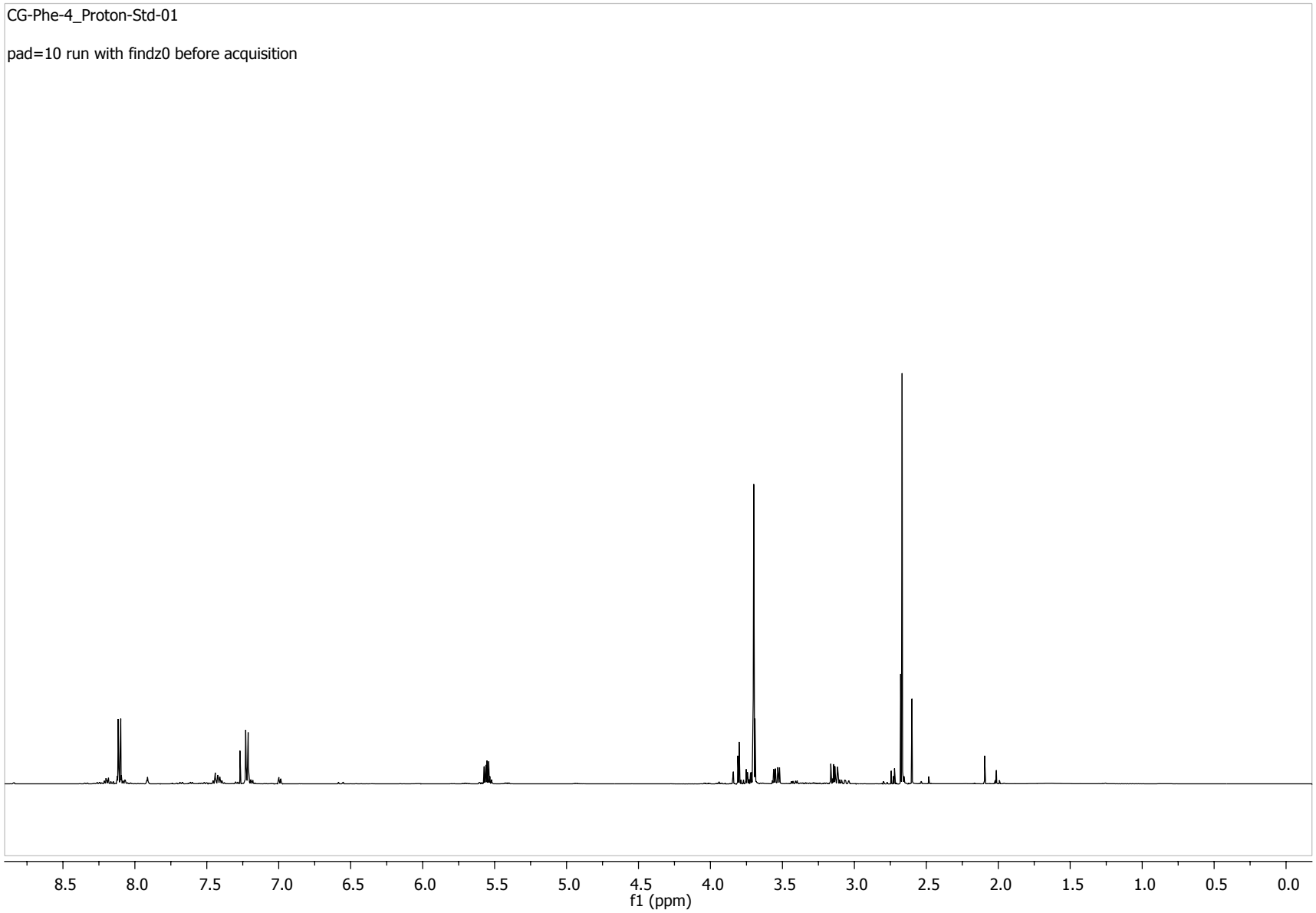
***ortho*-6b**

^{1}H NMR:


CG-Phe-3_Proton-Std-01
pad=10 run with findz0 before acquisition
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
0.0
f1 (ppm)

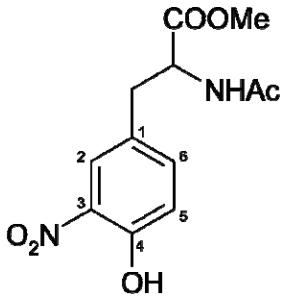
***para*-6b**

^{1}H NMR:


CG-Phe-4_Proton-Std-01
pad=10 run with findz0 before acquisition
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
0.0
f1 (ppm)

1.2.3 Reaction of tyrosine 2a with $NO_3^{\bullet}$

4a; 2-Acetylamino-3-(4-hydroxy-3-nitro-phenyl)-propionic acid methyl ester (3-nitro-*N*-Ac-*O*-Me-tyrosine)

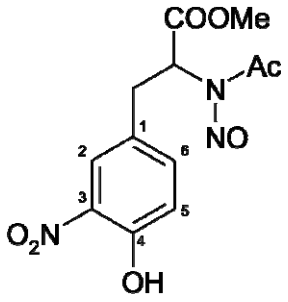


^{1}H-NMR (500 MHz, $CDCl_3$): δ = 10.45 (s, 1 H, O*H*), 7.83 (d, 1 H *J* = 1.9 Hz, 2-*H*), 7.34 (dd, *J* = 8.6, 2.2 Hz, 1 H, 6-*H*), 7.09 (d, *J* = 8.6 Hz, 1 H, 5-*H*), 6.27 (s, 1H, N*H*), 4.86 (dd, *J* = 13.1, 5.8 Hz, 1 H, C*H*), 3.77 (s, 3 H, COOCH_3), 3.19 (dd, *J* = 14.1, 5.1 Hz, 1 H, CH_2), 3.06 (dd, *J* = 14.1, 5.7 Hz, 1 H, CH_2), 2.05 ppm (s, 3 H, NHCOCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 171.5 (C_q, NH*C*OCH$_3$), 171.1 (C_q, *C*OOCH$_3$), 154.4 (C_q, *C*-4), 138.7 (C_t, *C*-6), 133.5 (C_q, *C*-3), 128.3 (C_q, *C*-1), 125.3 (C_t, *C*-2), 120.45 (C_t, *C*-5), 53.4 (C_t, *C*H), 53.0 (C_p, COO*C*H$_3$), 36.8 (C_s, *C*H$_2$), 23.0 ppm (C_p, NHCO*C*H$_3$).

HR-MS: $C_{12}H_{14}N_2O_6$+H: calcd 283.09246, found 283.09247.
$C_{11}{}^{13}CH_{14}N_2O_6$+H: calcd 284.09582, found 284.09580.

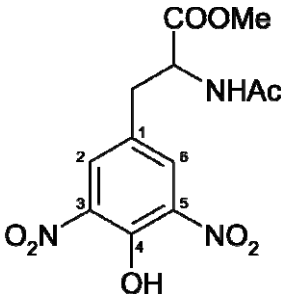
4b; 2-(*N*-Nitrosoacetamido)-3-(4-hydroxy-3-nitro-phenyl)-propionic acid methyl ester (3-nitro-*N*-nitroso-*N*-Ac-*O*-Me-tyrosine)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 10.46 (s, 1 H, O*H*), 7.77 (s, 1 H, 2-*H*), 7.29 (dd, *J* = 8.6, 1.9 Hz, 1 H, 6-*H*), 7.05 (dd, *J* = 8.6, 1.3 Hz, 1 H, 5-*H*), 5.47 (dd, *J* = 9.7, 5.8 Hz, 1 H, C*H*), 3.69 (s, 3 H, COOCH_3), 3.42 (dd, *J* = 14.6, 5.8 Hz, 3 H, CH_2), 3.00 (dd, *J* = 14.6, 9.8 Hz, 1 H, CH_2), 2.69 ppm (s, 3 H, N(NO)COCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 173.9 (C_q, NH*C*OCH$_3$), 167.4 (C_q, *C*OOCH$_3$), 154.3 (C_q, *C*-4), 138.3 (C_t, *C*-6), 133.4 (C_q, *C*-3), 128.6 (C_q, *C*-1), 125.1 (C_t, *C*-2), 120.5 (C_t, *C*-5), 53.1 (C_t, *C*H), 52.0 (C_p, COO*C*H$_3$), 32.9 (C_s, *C*H$_2$), 22.6 ppm (C_p, N(NO)COCH_3).

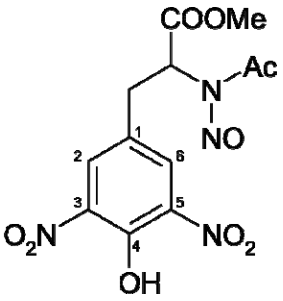
10a; 2-Acetylamino-3-(4-hydroxy-3,5-dinitro-phenyl)-propinonic acid methyl ester (*3,5*-dinitro-*N*-Ac-*O*-Me-tyrosine)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 11.34 (s, 1 H, O*H*), 8.09 (s, 1 H, N*H*), 6.16 (d, *J* = 6.4 Hz, 1 H, 2,6-*H*), 4.87 (q, *J* = 5.8 Hz, 1 H, C*H*), 3.82 (s, 3 H, COOCH_3), 3.32 (dd, *J* = 14.2, 5.7 Hz, 1 H, CH_2), 3.11 (dd, *J* = 14.2, 5.7 Hz, 1 H, CH_2), 2.06 ppm (s, 3 H, NHCOCH_3).

HR-MS: $C_{12}H_{13}N_3O_8$+H: calcd 328.0781, found 328.0779 (0.609 ppm).
$C_{11}{}^{13}CH_{13}N_3O_8$+H: calcd 329.0814, found 329.0805 (2.734 ppm).

10b; 2-(*N*-Nitrosoacetamido)-3-(4-hydroxy-3,5-dinitro-phenyl)-propinonic acid methyl ester (*3,5*-dinitro-*N*-nitroso-*N*-Ac-*O*-Me-tyrosine)



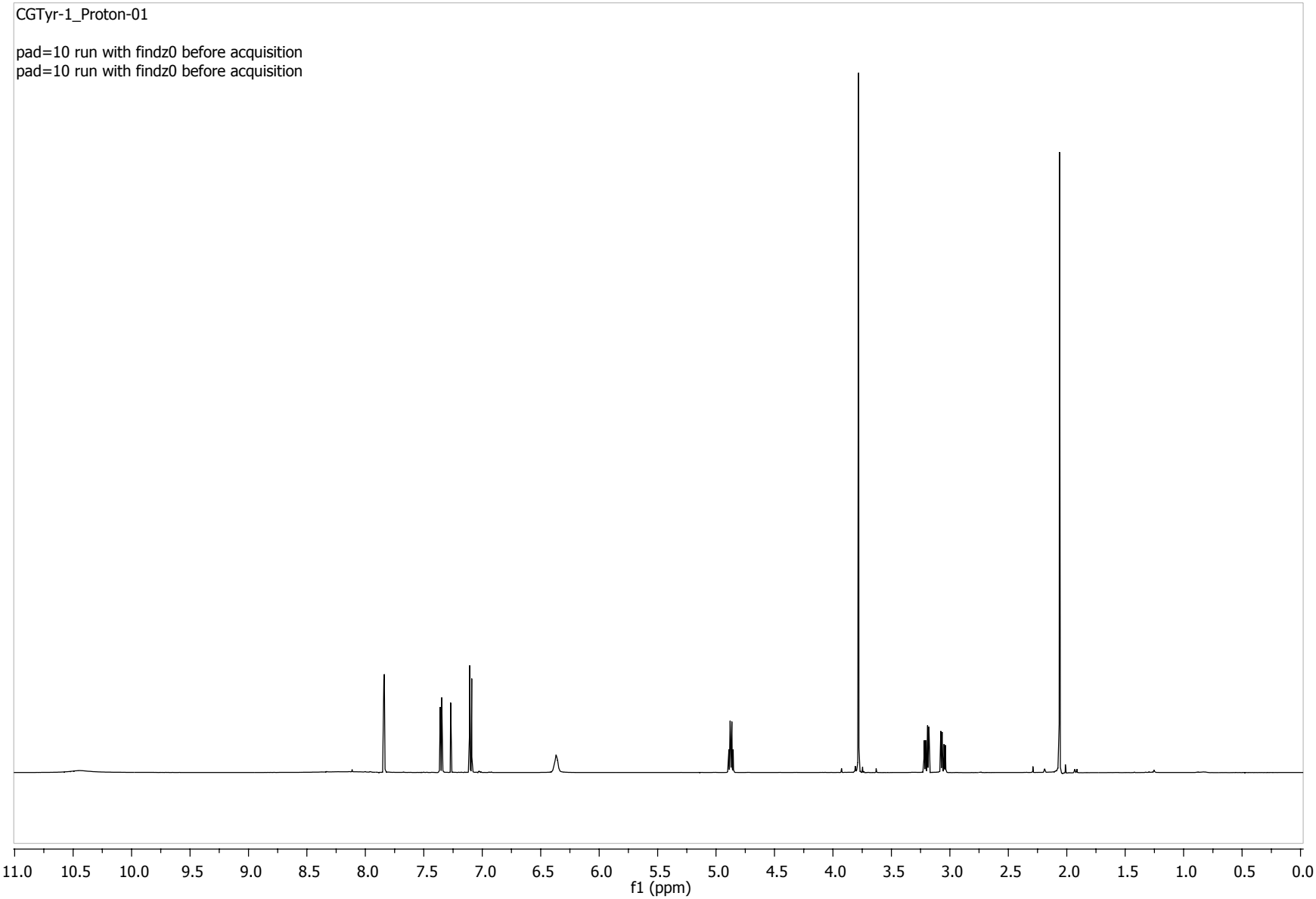
^{1}H-NMR (500 MHz, $CDCl_3$): δ = 11.32 (s, 1 H, O*H*), 8.07 (s, 2 H, 2,6-*H*), 5.43 (dd, *J* = 8.4, 6.5 Hz, 1 H, C*H*), 3.69 (s, 3 H, COOCH_3), 3.50 (dd, *J* = 14.7, 6.5 Hz, 1 H, CH_2), 2.98 (dd, *J* = 14.7, 8.4 Hz, 1 H, CH_2), 2.76 ppm (s, 3 H, NHCOCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 137.9 (C_q, *C*OOCH$_3$), 166.9 (C_q, NH*C*OCH$_3$), 148.5 (C_q, *C*-4), 137.5 (C_q, *C*-3,5), 131.9 (C_t, *C*-2,6), 128.3 (C_q, *C*-1), 53.3 (C_p, COOCH_3), 51.5 (C_s, *C*H), 33.0 (C_t, *C*H$_2$), 22.6 ppm (C_p, NHCO*C*H$_3$).

HR-MS: $C_{12}H_{12}N_4O_0$+H: calcd 357.0677, found 357.0679.
$C_{11}{}^{13}CH_{12}N_4O_9$+H: calcd 358.0716, found 358.0724.

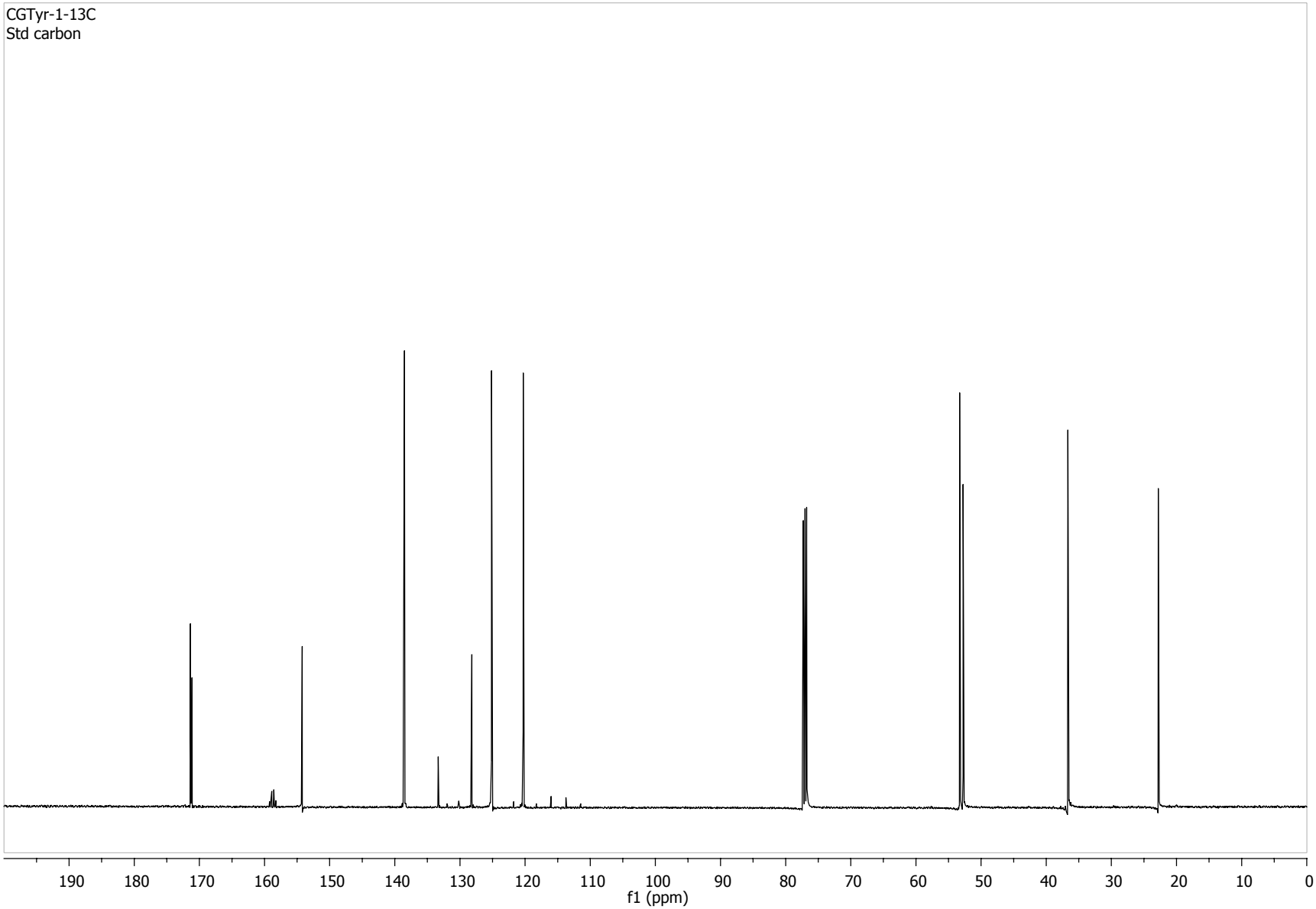
4a

^{1}H NMR:


CGTyr-1_Proton-01
pad=10 run with findz0 before acquisition
pad=10 run with findz0 before acquisition
11.0
10.5
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
0.0
f1 (ppm)

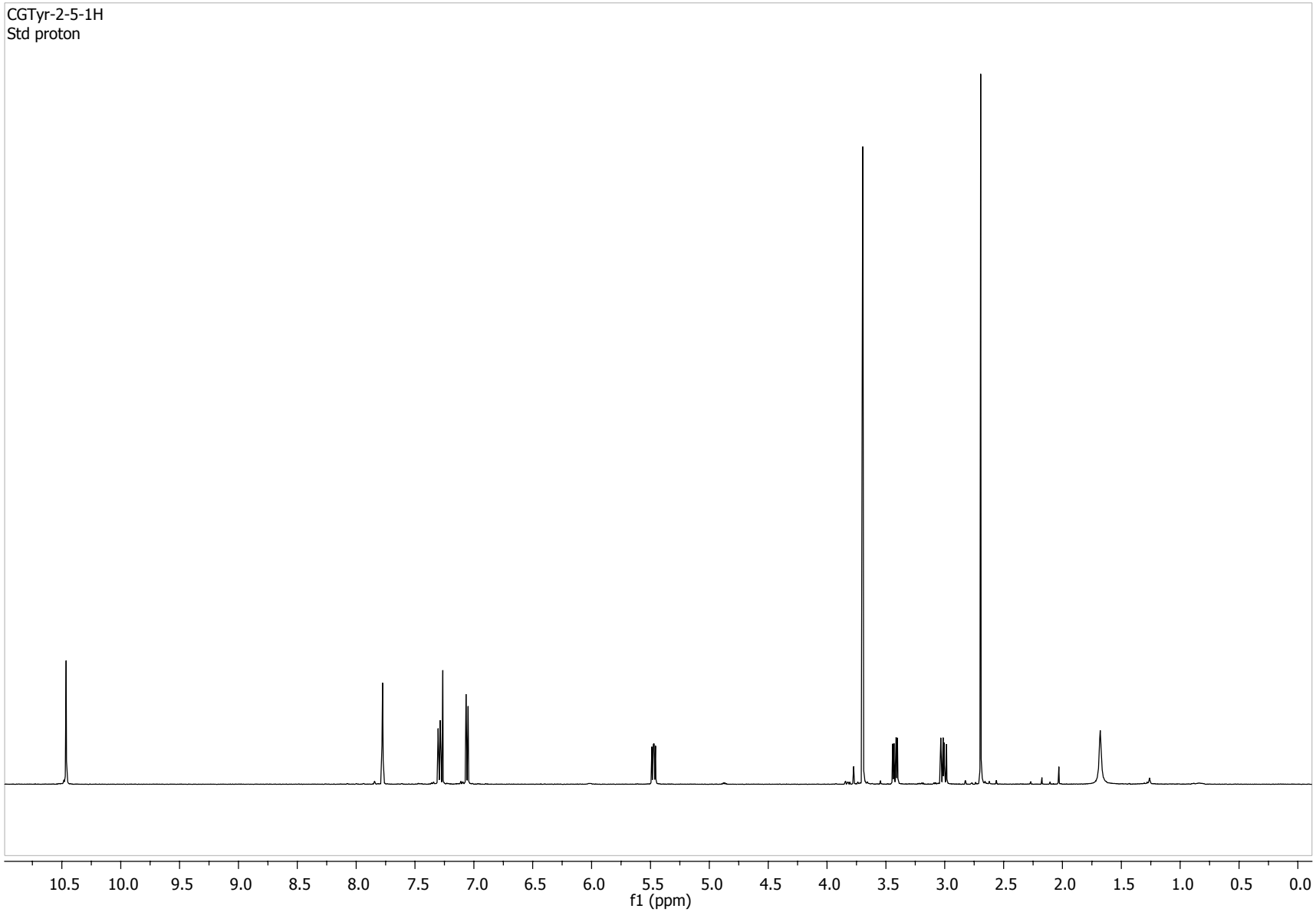
4a

^{13}C NMR:


CGTyr-1-13C
Std carbon
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

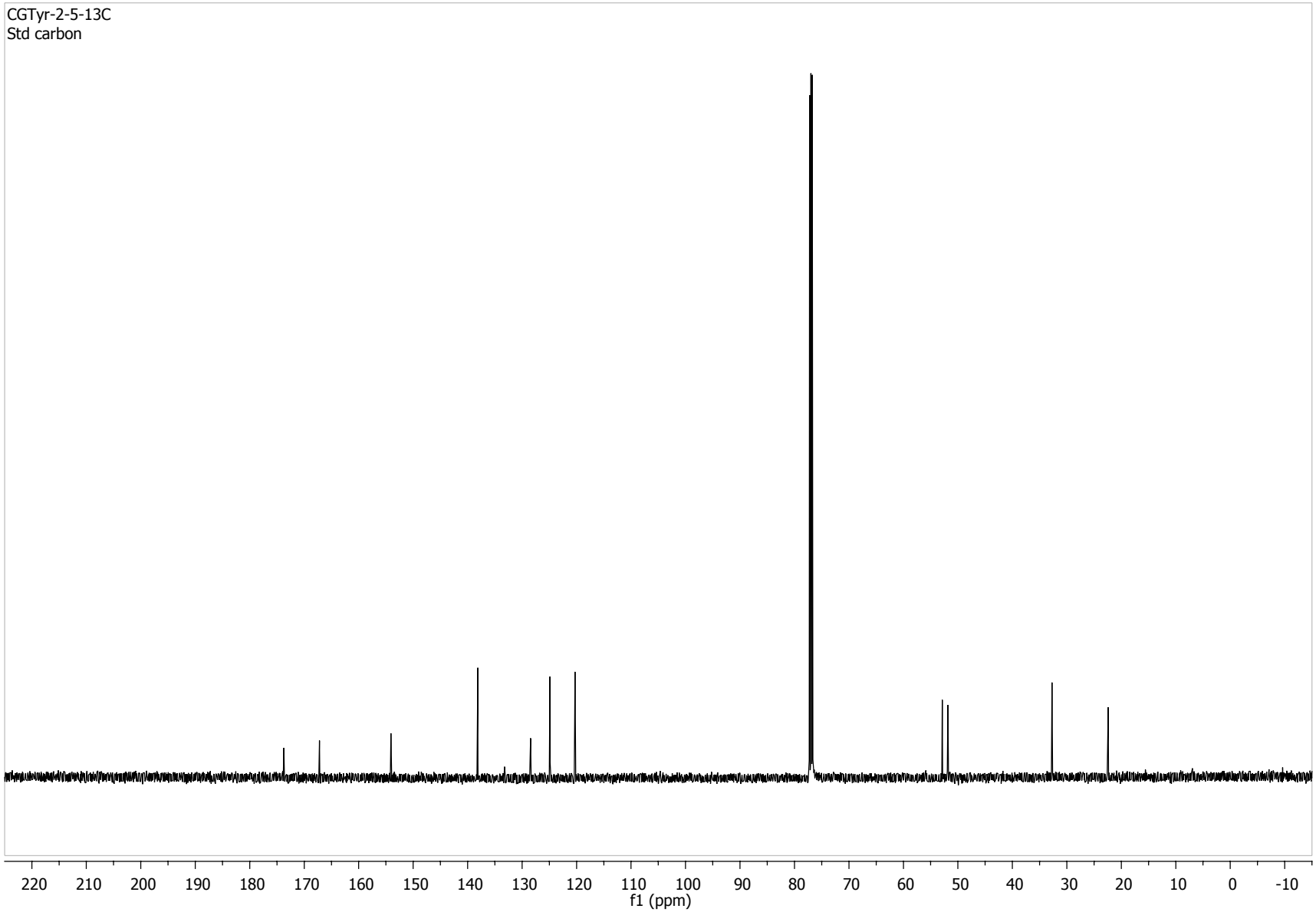
4b

^{1}H NMR:


CGTyr-2-5-1H
Std proton
10.5
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
0.0
f1 (ppm)

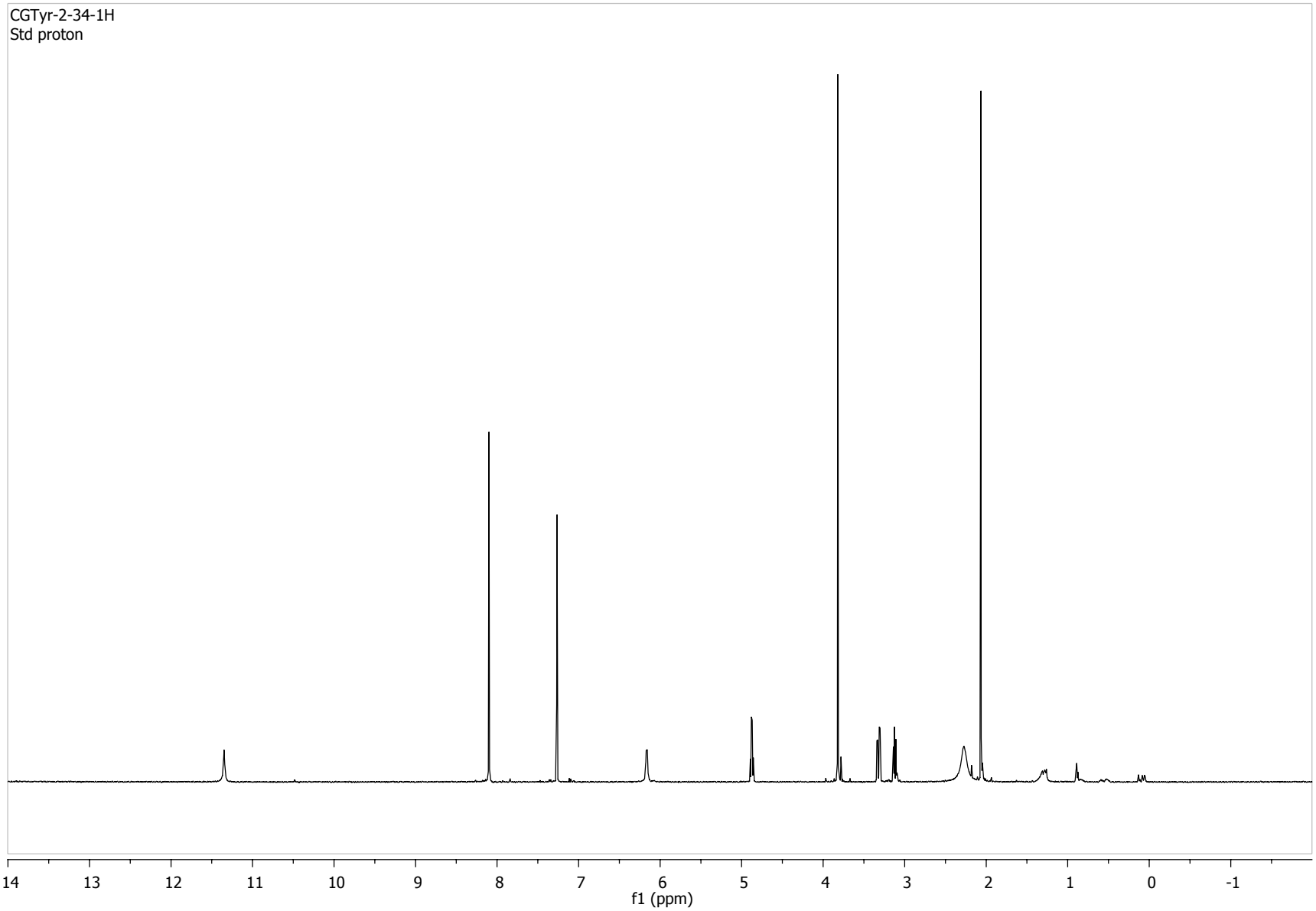
4b

^{13}C NMR:


CGTyr-2-5-13C
Std carbon
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

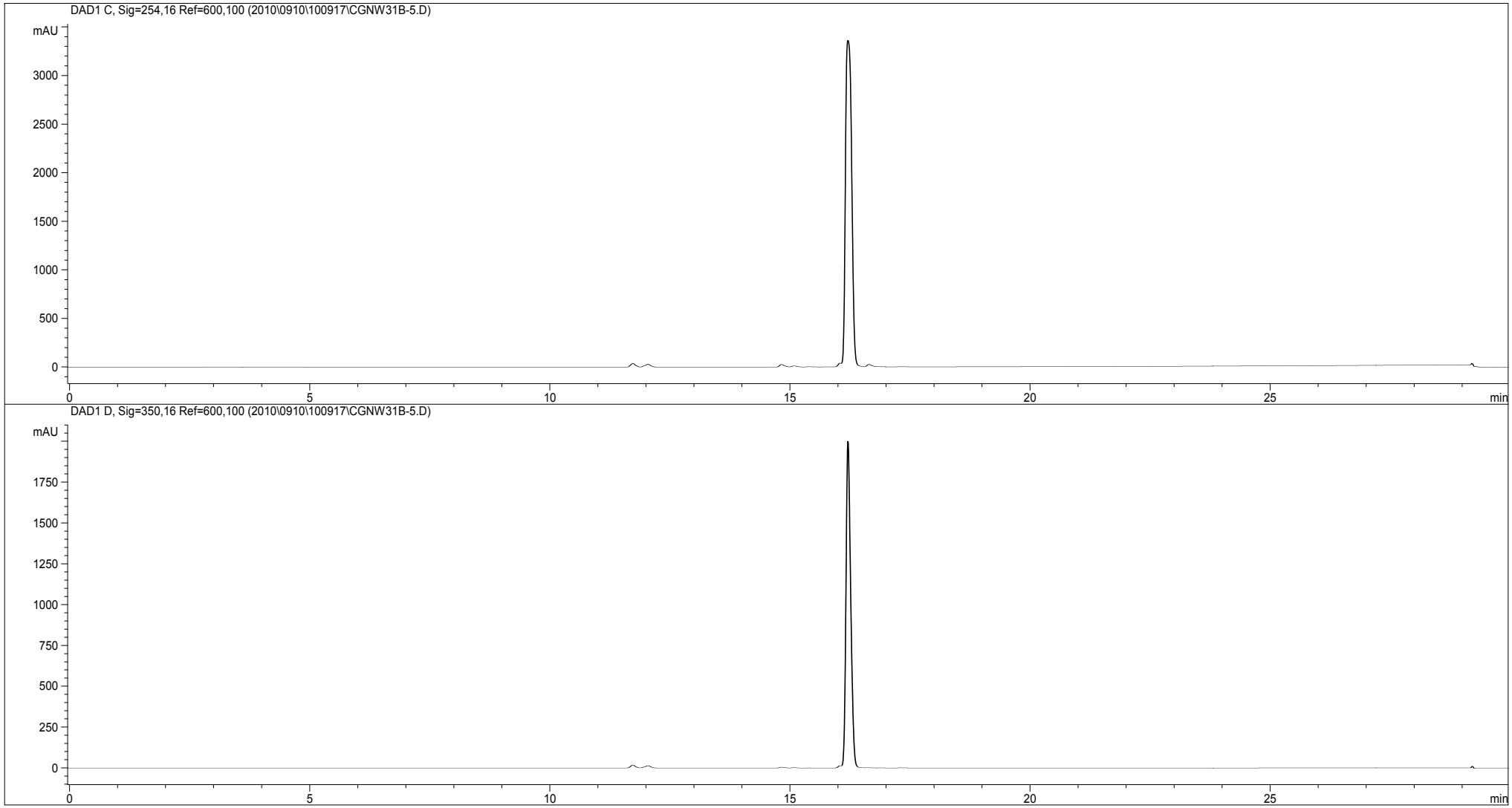
10a

^{1}H NMR:



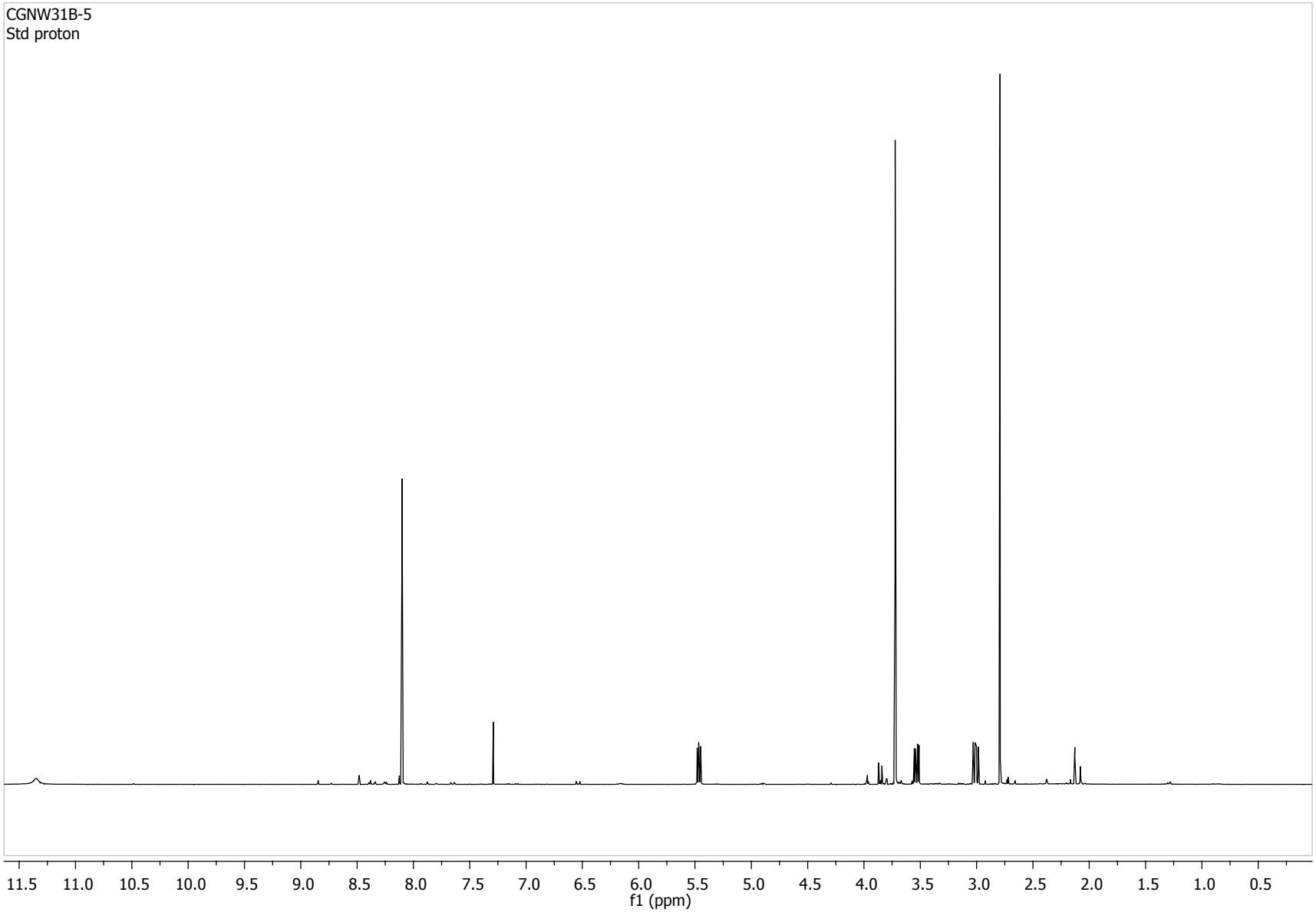
10a

HPLC:


DAD1 C, Sig=254,16 Ref=600,100 (2010\0910\100917\CGNW31B-5.D)
mAU
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
min
DAD1 D, Sig=350,16 Ref=600,100 (2010\0910\100917\CGNW31B-5.D)
mAU
1750
1500
1250
1000
750
500
250
0
0
5
10
15
20
25
min

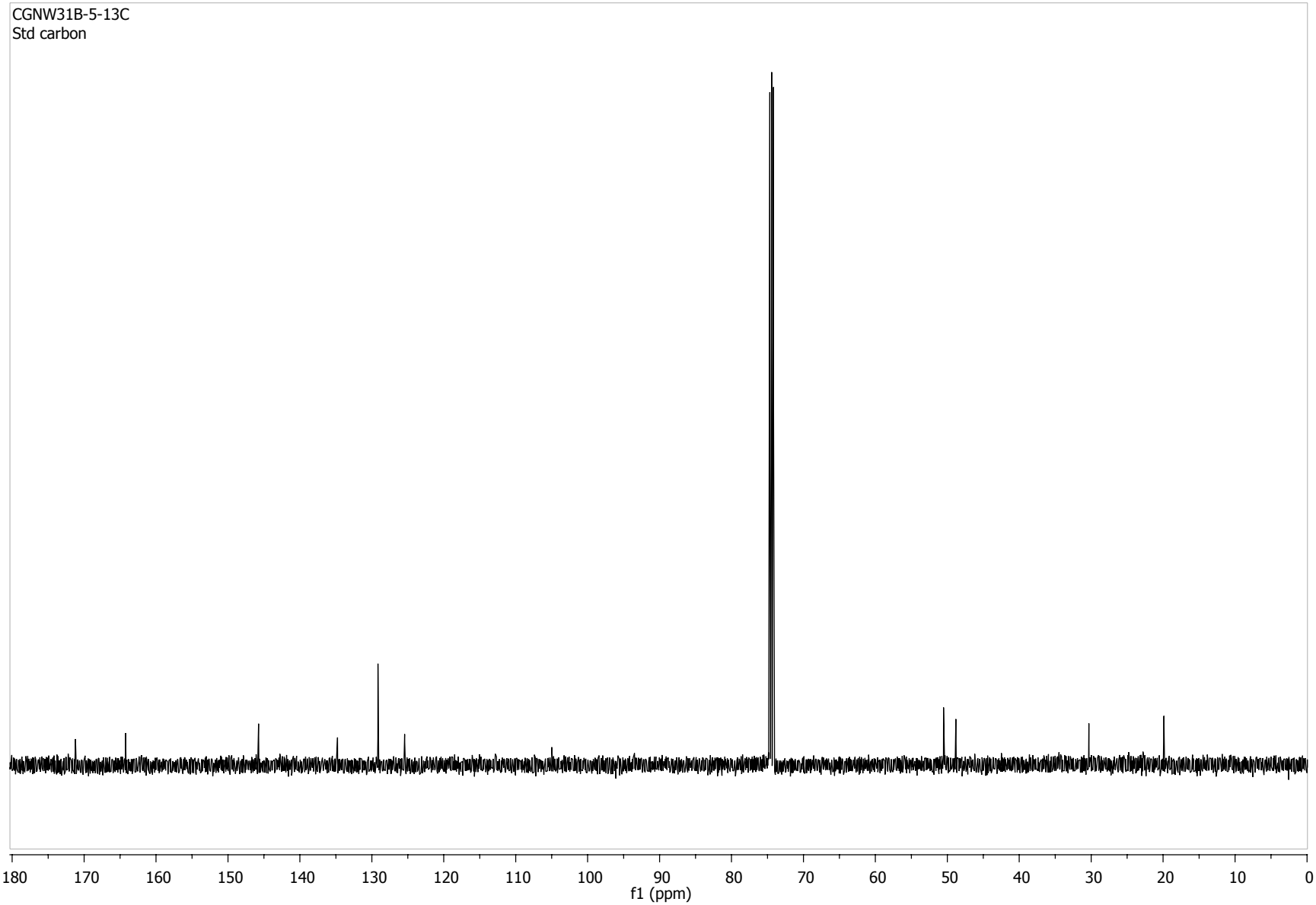
10b

^{1}H NMR:


CGNW31B-5
Std proton
11.5
11.0
10.5
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
f1 (ppm)

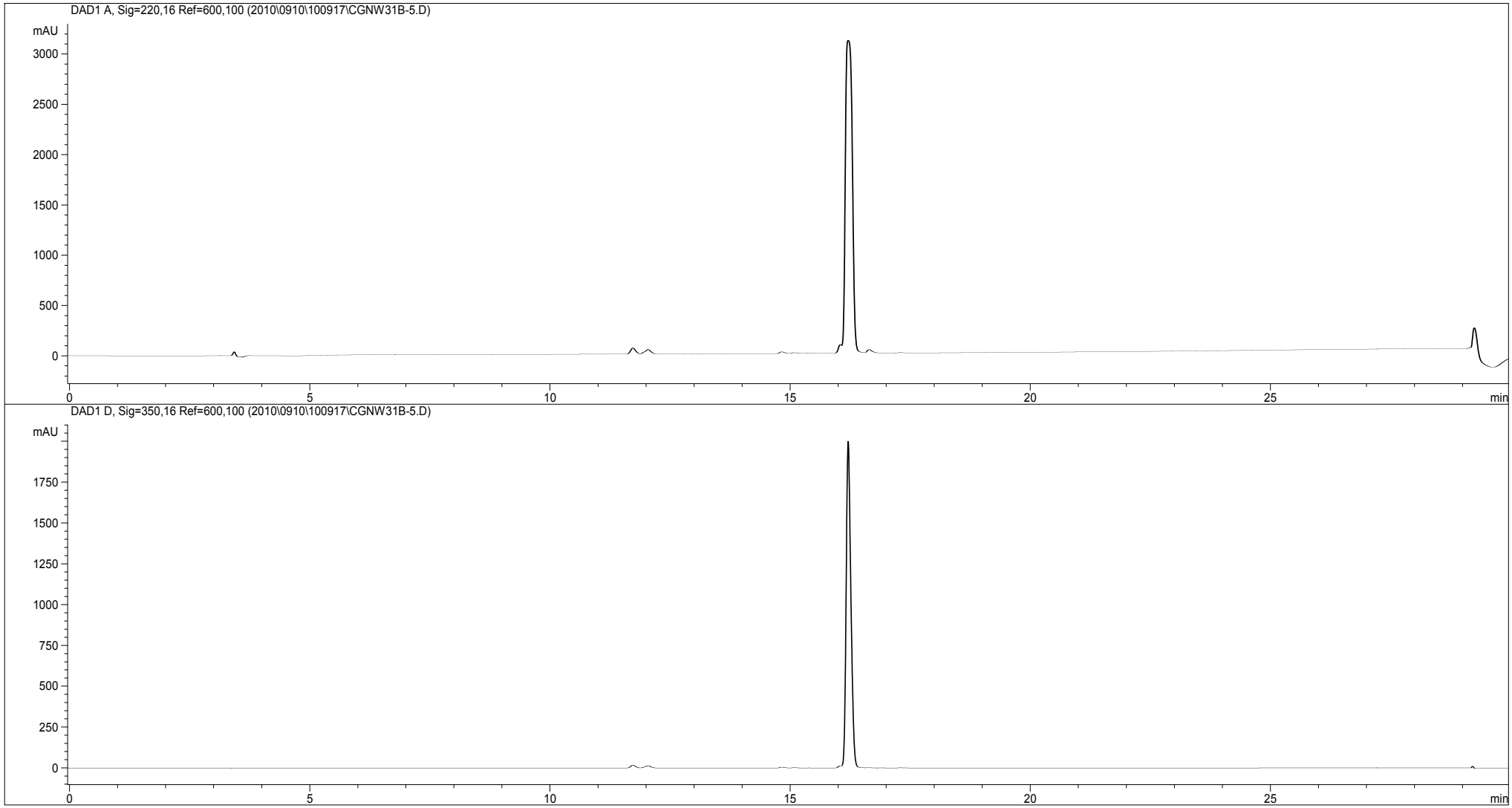
10b

^{13}C NMR:


CGNW31B-5-13C
Std carbon
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

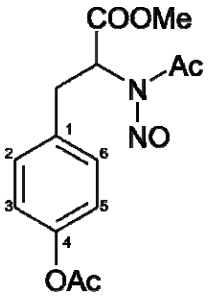
10b

HPLC:



1.2.4 Reaction of *O*-acetyltyrosine 3a with $NO_3^{\bullet}$

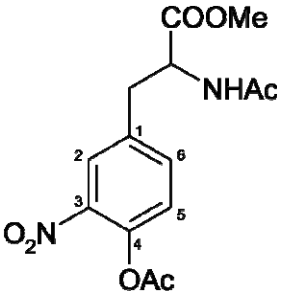
3b; 3-(4-Acetoxy-phenyl)-2-(*N*-Nitrosoacetamido)--propionic acid methyl ester (*N*-nitroso-*N*-Ac-*O*-Me-tyrosine-*O*-Ac)



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 7.02 (d, *J* = 8.5 Hz, 2 H, 2,6-*H*), 6.96 (d, *J* = 8.5 Hz, 2 H, 3,5-*H*), 5.54 (dd, *J* = 10.2, 5.9 Hz, 1 H, C*H*), 3.68 (s 3 H, COOCH_3), 3.42 (dd, *J* = 14.4, 5.9 Hz, 1 H, CH_2), 3.05 (dd, *J* = 14.4, 10.2 Hz, 1 H, CH_2), 2.62 (s,3 H, OCOCH_3), 2.26 ppm (s, 3 H, N(NO)COCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 173.8 (C_q, O*C*OCH$_3$), 169.3 (C_q, NH*C*OCH$_3$), 167.7 (C_q, *C*OOCH$_3$), 149.8 (C_q, *C*-4), 133.6 (C_q, *C*-1), 129.9 (C_t, *C*-2,6), 122.0 (C_t, *C*-3,5), 52.8 (C_t, *C*H), 52.3 (C_p, COO*C*H$_3$), 33.2 (C_s, *C*H$_2$), 22.3 (C_p, OCO*C*H$_3$), 21.1 ppm (C_p, N(NO)CO*C*H$_3$),.

11a; 3-(4-Acetoxy-3-nitro-phenyl)-2-acetylamino-propionic acid methyl ester (3-nitro-*N*-Ac-*O*-Me-tyrosine-*O*-Ac)

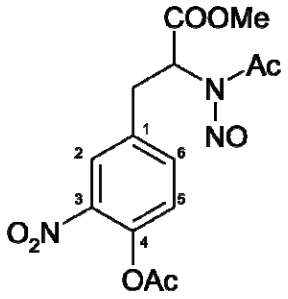


^{1}H-NMR (500 MHz, $CDCl_3$): δ = 7.82 (d, *J* = 2.1 Hz, 1 H, 2-*H*), 7.42 (dd, *J* = 8.3, 2.2 Hz, 1 H, 6-*H*), 7.17 (d, *J* = 8.3 Hz, 1 H, 5-*H*), 6.29 (d, *J* = 6.6 Hz, 1 H, N*H*), 4.90 (dt, *J* = 7.3, 5.8 Hz, 1 H, C*H*), 3.77 (s, 3 H, COOCH_3), 3.27 (dd, *J* = 14.1, 5.9 Hz, 1 H, CH_2), 3.16 (dd, *J* = 14.1, 5.6 Hz, 1 H, CH_2), 2.36 (s, 3 H, OCOCH_3), 2.06 ppm (s, 3 H, NHCOCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 171.2 (C_q, *C*OOCH$_3$), 171.1 (C_q, NH*C*OCH$_3$), 168.7 (C_q, O*C*OCH$_3$), 143.2 (C_q, *C*-4), 141.4 (C_q, *C*-3), 135.6 (C_t, *C*-6), 135.2 (C_q, *C*-1), 126.4 (C_t, *C*-2), 125.5 (C_t, *C*-5), 53.2 (C_t, *C*H), 52.9 (C_p, COO*C*H$_3$), 36.9 (C_s, *C*H$_2$), 22.9 (C_p, NHCO*C*H$_3$), 20.9 ppm (C_p, OCO*C*H$_3$).

HR-MS: $C_{14}H_{16}N_2O_7$+H: calcd 325.10303, found 325.10297.
$C_{13}{}^{13}CH_{16}N_2O_7$+H: calcd 326.10638, found 326.10641.

11b; 3-(4-Acetoxy-3-nitro-phenyl)-2-(*N*-Nitrosoacetamido)-propionic acid methyl ester (3-nitro-*N*-nitroso-*N*-Ac-*O*-Me-tyrosine-*O*-Ac)

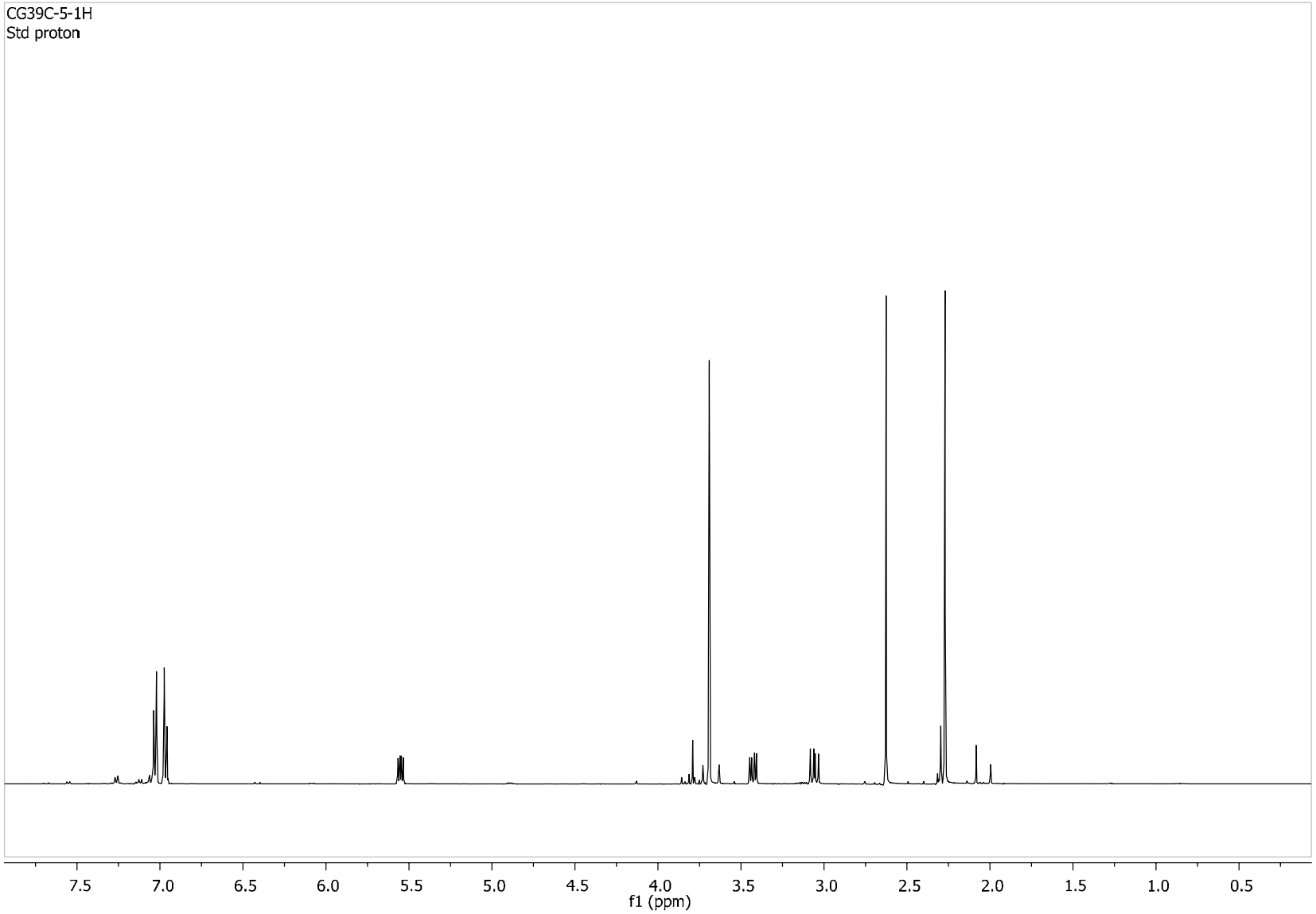


^{1}H-NMR (500 MHz, $CDCl_3$): δ = 7.77 (d, *J* = 2.2 Hz, 1 H, 3-*H*), 7.37 (dd, *J* = 8.3, 2.2 Hz, 1 H, 5-*H*), 7.13 (d, *J* = 8.3 Hz, 1 H, 6-*H*), 5.50 (dd, *J* = 9.2, 6.2 Hz, 1 H, C*H*), 3.69 (s, 3 H, COOCH_3), 3.51 (dd, *J* = 14.5, 6.2 Hz, 1 H, CH_2), 3.05 (dd, *J* = 14.5, 9.2 Hz, 1 H, CH_2), 2.70 (s, 3 H, OCOCH_3), 2.35 ppm (s, 3 H, NHCOCH_3).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 173.9 (C_q, *C*OOCH$_3$), 168.6 (C_q, NH*C*OCH$_3$), 167.3 (C_q, O*C*OCH$_3$), 143.2 (C_q, *C*-4), 141.5 (C_q, *C*-2), 135.6 (C_q, *C*-1), 135.3 (C_t, *C*-6), 126.2 (C_t, *C*-5), 125.6 (C_t, *C*-3), 53.1 (C_t, *C*H), 51.8 (C_p COO*C*H$_3$), 33.3 (C_s, *C*H$_2$), 22.5 (C_p, NHCO*C*H$_3$), 20.9 ppm (C_p, OCO*C*H$_3$).

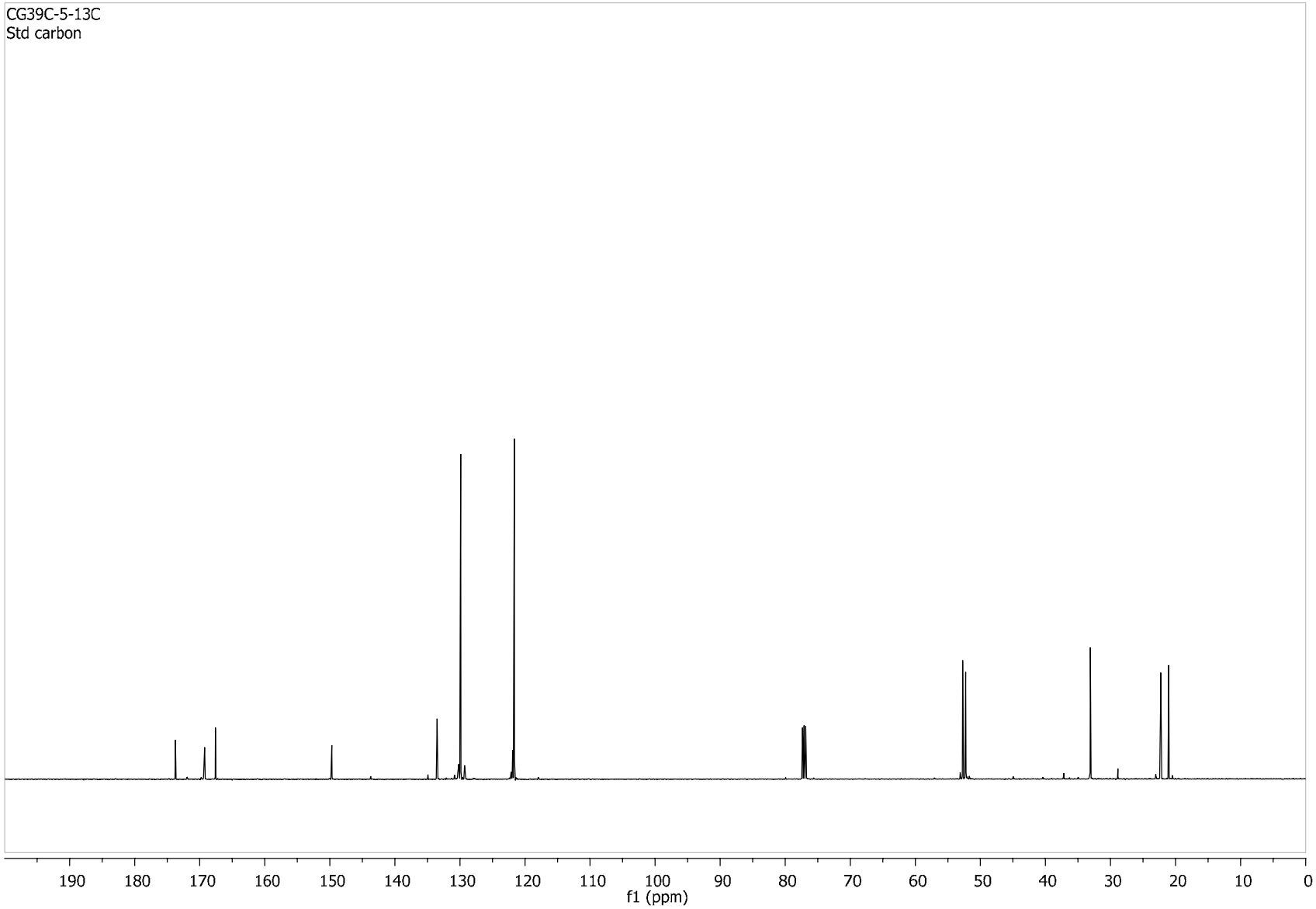
3b

^{1}H NMR:


CG39C-5-1H
Std proton
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
f1 (ppm)

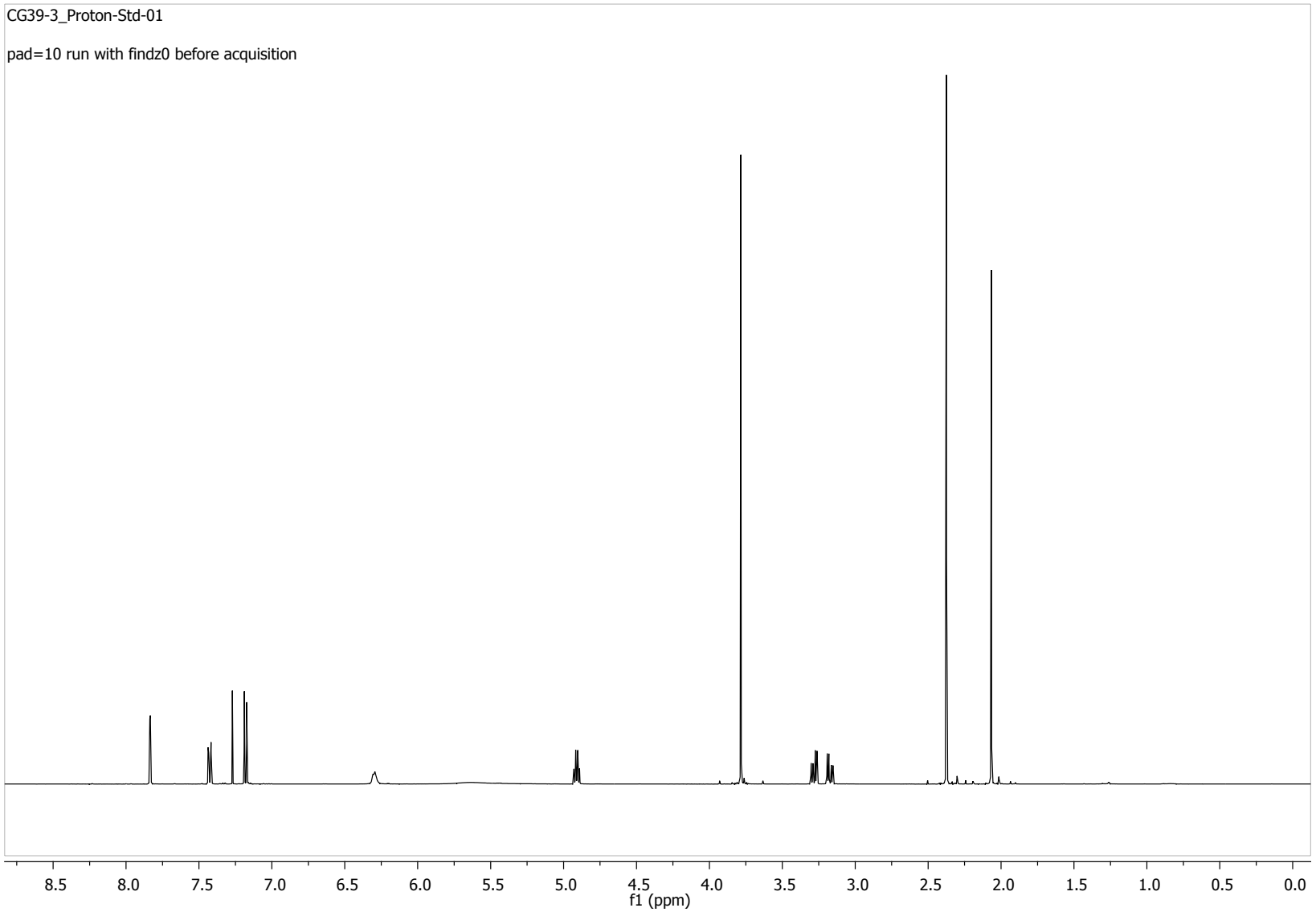
3b

^{13}C NMR:

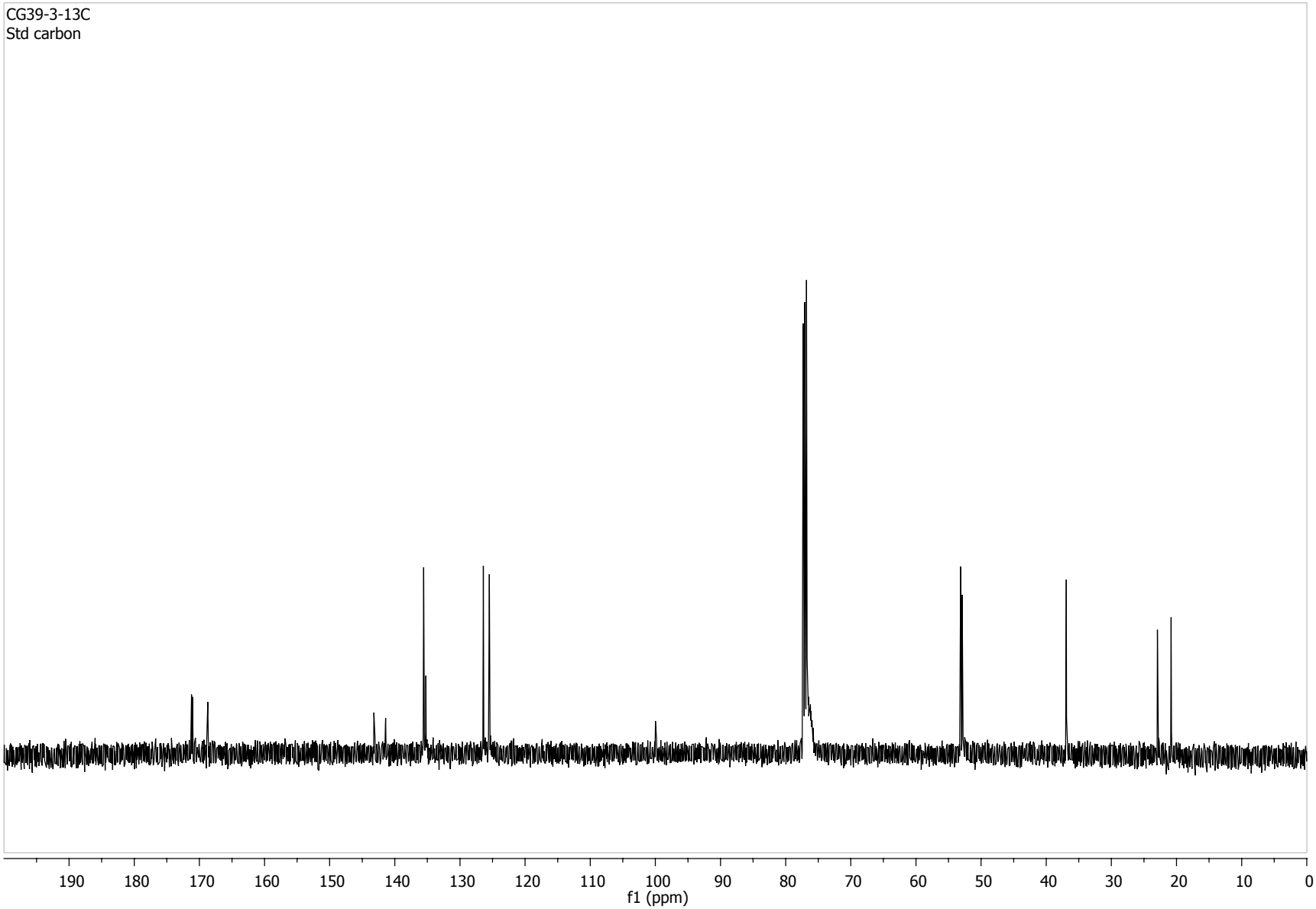

CG39C-5-13C
Std carbon
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

11a

^{1}H NMR:

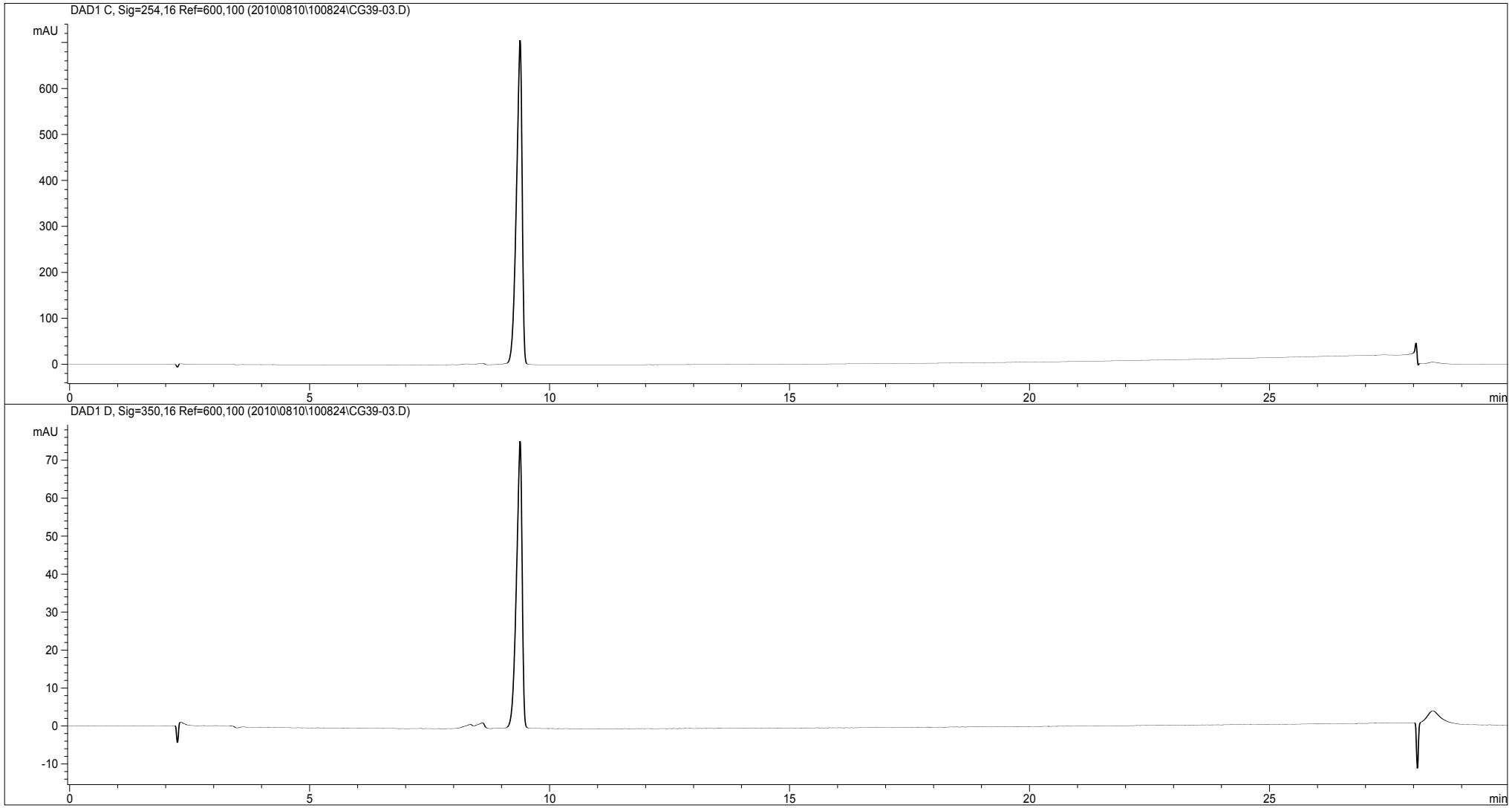

CG39-3_Proton-Std-01
pad=10 run with findz0 before acquisition
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

11a
^{13}C NMR:


CG39-3-13C
Std carbon
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

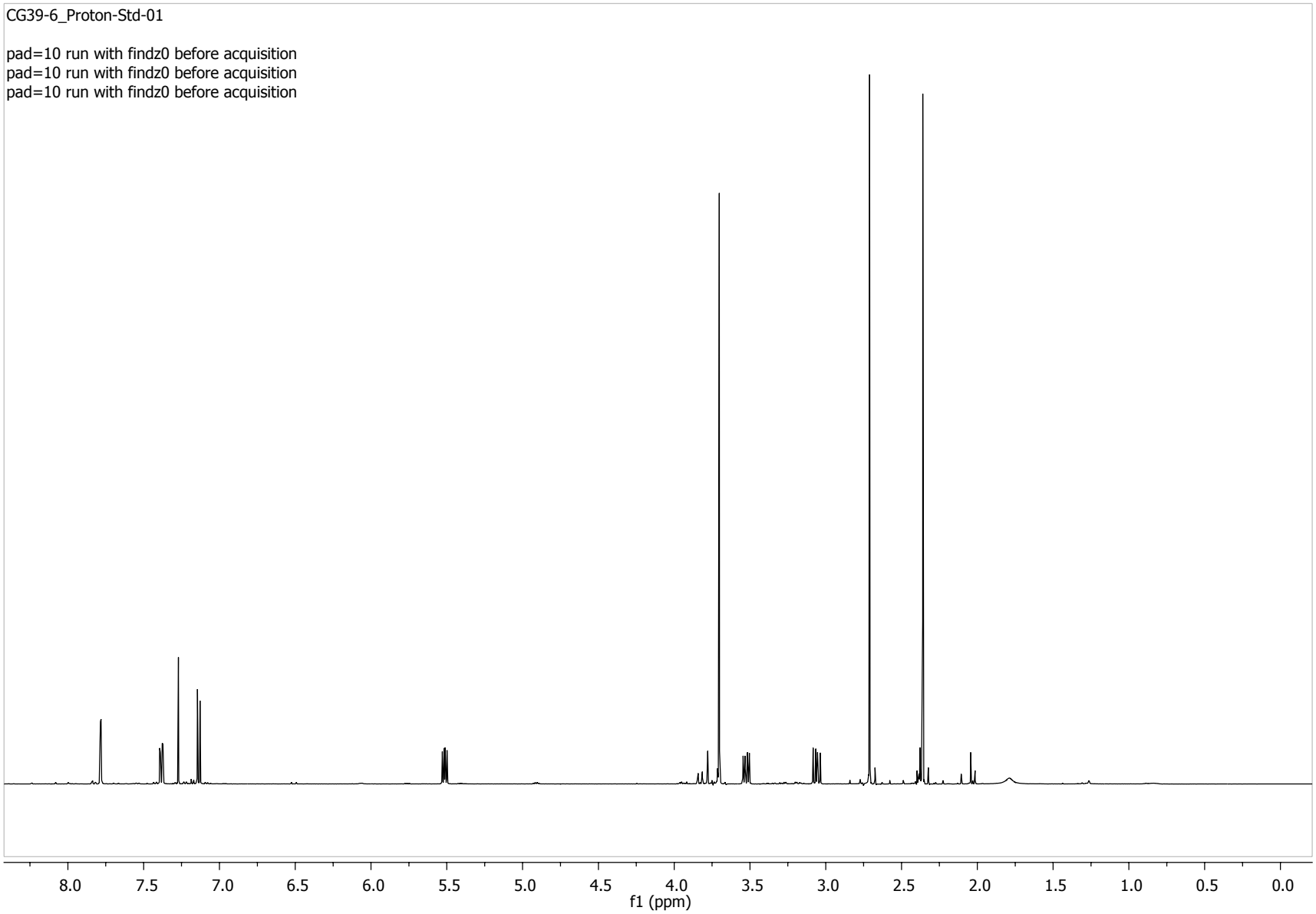
11a

HPLC:


DAD1 C, Sig=254,16 Ref=600,100 (2010\0810\100824\CG39-03.D)
mAU
600
500
400
300
200
100
0
0
5
10
15
20
25
min
DAD1 D, Sig=350,16 Ref=600,100 (2010\0810\100824\CG39-03.D)
mAU
70
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
min

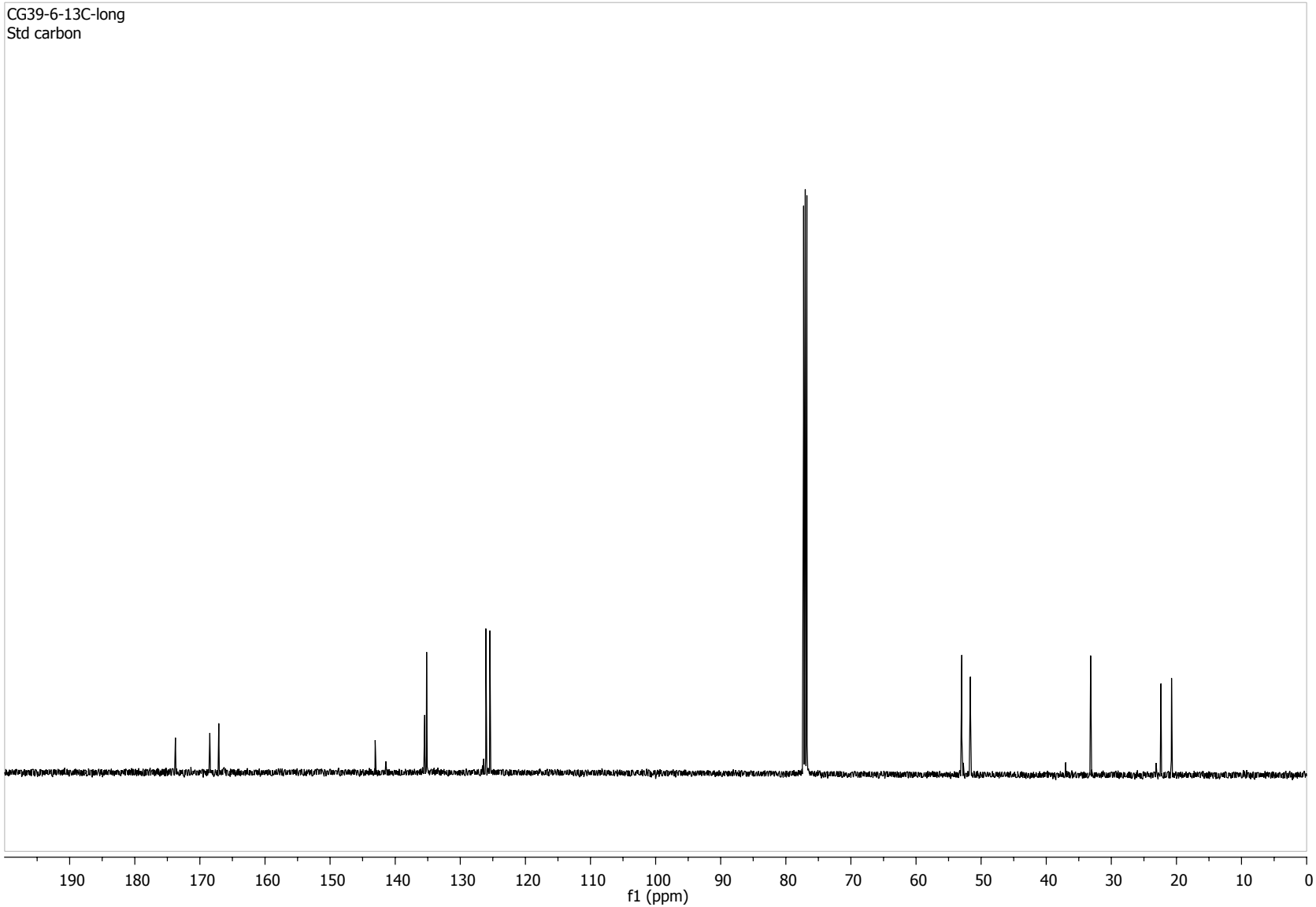
11b

^{1}H NMR:



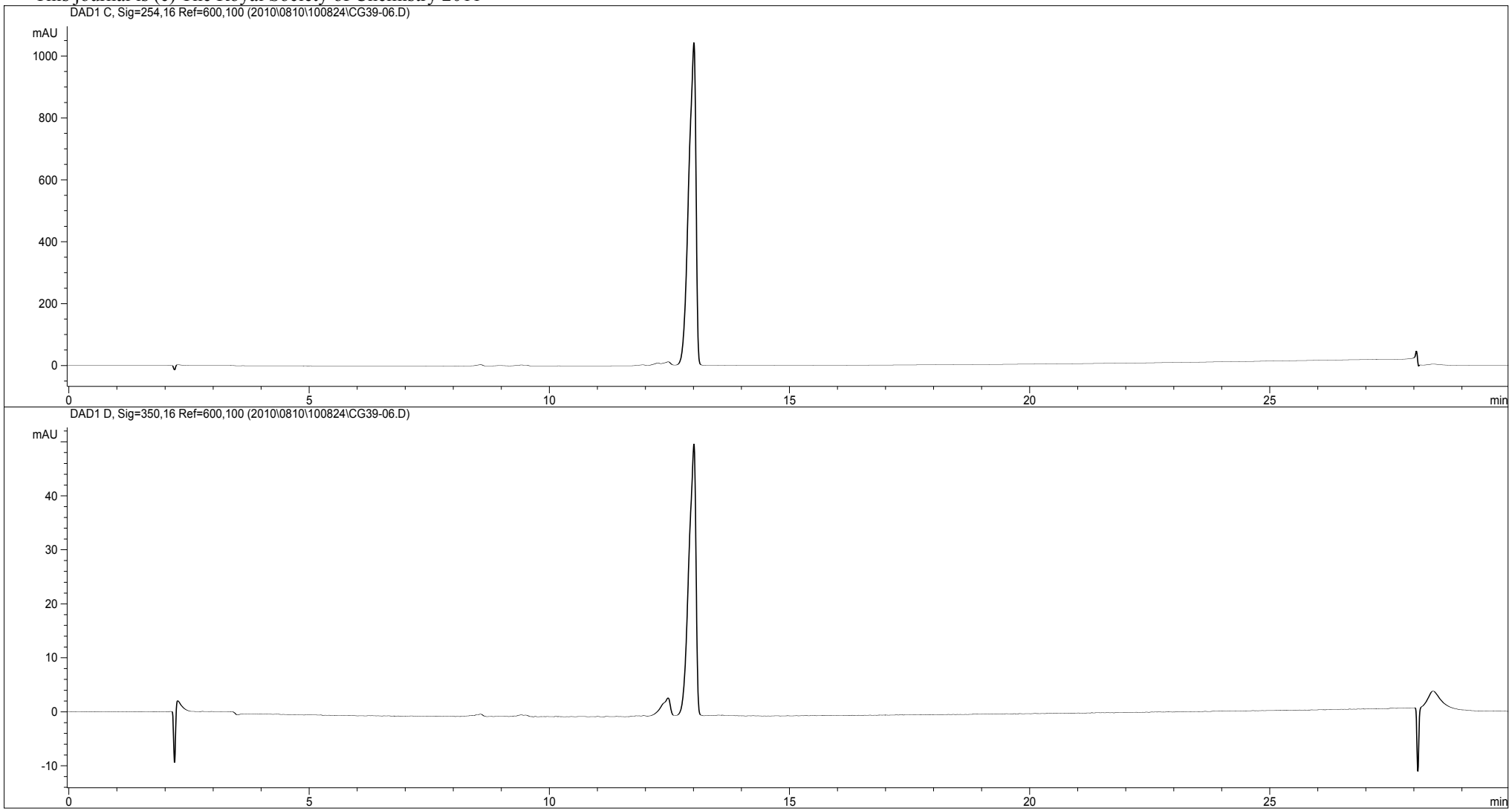
11b

^{13}C NMR:


CG39-6-13C-long
Std carbon
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

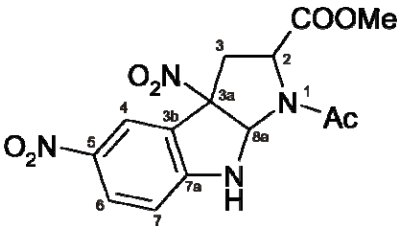
11b

HPLC:


DAD1 C, Sig=254,16 Ref=600,100 (2010\0810\100824\CG39-06.D)
mAU
1000
800
600
400
200
0
0
5
10
15
20
25
min
DAD1 D, Sig=350,16 Ref=600,100 (2010\0810\100824\CG39-06.D)
mAU
40
30
20
10
0
-10
0
5
10
15
20
25
min

1.2.5 Reaction of tryptophan 5 with $NO_3^{\bullet}$

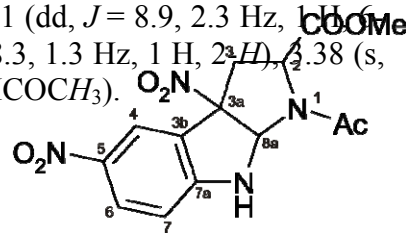
12a; (2S,3aR,8aR)-1-Acetyl-3a,5-dinitro-1,2,3,3a,8,8a-hexahydro-pyrrolo[2,3-b]indole-2-carboxylic acid methyl ester



^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.22 (m, 2 H, 4,6-*H*), 6.68 (d, *J* = 8.7 Hz, 1 H, 7-*H*), 6.51 (s, 1 H, 8a-*H*), 4.59 (dd, *J* = 9.1, 2.0 Hz, 1 H, 2-*H*), 2.96 (s, 3 H, $COOCH_3$), 3.66 (dd, *J* = 15.1, 2.1 Hz, 1 H, 3-*H*), 2.94 (dd, *J* = 15.1, 9.1 Hz, 1 H, 3-*H*), 2.06 ppm (s, 3 H, $NHCOCH_3$).

HR-MS: $C_{14}H_{14}N_4O_7$-H: calcd 349.07897, found 349.07852.
$C_{13}{}^{13}CH_{14}N_4O_7$-H: calcd 350.08233, found 350.08194.

12b; (2S)-1-Acetyl-3a,5-dinitro-1,2,3,3a,8,8a-hexahydro-pyrrolo[2,3-b]indole-2-carboxylic acid methyl ester

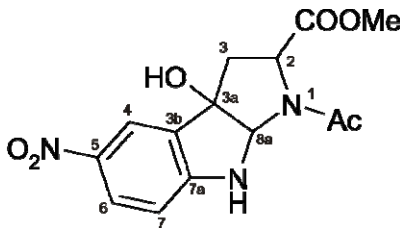


^{1}H-NMR (500 MHz, $CDCl_3$): δ = 8.31 (d, *J* = 2.3 Hz, 1 H, 4-*H*), 8.21 (dd, *J* = 8.9, 2.3 Hz, 1 H, 6-*H*), 6.68 (d, *J* = 8.9 Hz, 1 H, 7-*H*), 6.37 (s, 1 H, 8a-*H*), 4.75 (dd, *J* = 8.3, 1.3 Hz, 1 H, 2-*H*), 3.38 (s, 3H, $COOCH_3$), 3.37 (qd, *J* = 13.3, 4.7 Hz, 3-*H*), 2.09 ppm (s, 3 H, $NHCOCH_3$).

^{13}C-NMR (125 MHz, $CDCl_3$): δ = 171.4 (C_q, $NHCOCH_3$), 169.4 (C_q, $COOCH_3$), 155.6 (C_q, *C*-7a), 140.3 (C_q, *C*-5), 130.1 (C_t, *C*-6), 122.8 (C_t, *C*-4), 121.2 (C_q, *C*-3b), 108.9 (C_t, *C*-7), 96.3 (C_q, *C*-3a), 79.7 (C_t, *C*-8a), 60.6 (C_t, *C*-2), 53.3 (C_p, *C*- $COOCH_3$), 39.8 (C_s, *C*-3), 21.6 ppm (C_p, *C*-$NHCOCH_3$).

HR-MS: $C_{14}H_{14}N_4O_7$+H: calcd 351.09353, found 351.09348.
$C_{13}{}^{13}CH_{14}N_4O_7$+H: calcd 352.09688, found 352.09692.

13; (2S)-1-Acetyl-3a-hydroxy-5-nitro-1,2,3,3a,8,8a-hexahydro-pyrrolo[2,3-b]indole-2-carboxylic acid methyl ester

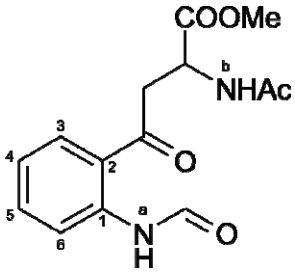


^{1}H-NMR (500 MHz, $CDCl_3$): δ= 8.15 (d, *J* = 2.2 Hz, 1 H, 4-*H*), 8.12 (dd, *J* = 8.8, 2.3 Hz, 1 H, 6-*H*), 6.61 (d, *J* = 8.8 Hz, 1 H, 7-*H*), 5.49 (s, 1 H, 8a-*H*), 4.60 (sd, *J* = 8.0, 1.5 Hz, 1 H, 2-*H*), 3.33 (s, 3 H, $COOCH_3$), 2.95 (m, 2 H, 3-*H*), 2.03 ppm (s, 3 H, $NHCOCH_3$).

^{13}C-NMR (125 MHz, $CDCl_3$): δ= 172.6 (C_q, $COOCH_3$), 170.1 (C_q, $NHCOCH_3$), 155.5 (C_q, *C*-7a), 139.9 (C_q, *C*-5), 128.9 (C_t, *C*-6), 128.5 (C_q, *C*-3b), 121.3 (C_t, *C*-4), 108.4 (C_t, *C*-7), 84.5 (C_q, *C*-3a), 81.9 (C_t, *C*-8a), 60.5 (C_t, *C*-2), 53.0 (C_p, $COOCH_3$), 40.6 (C_s, *C*-3), 21.4 ppm (C_p, $NHCOCH_3$).

HR-MS: $C_{14}H_{15}N_3O_6$+H: calcd 322.10336, found 322.10336.
$C_{13}{}^{13}CH_{15}N_3O_6$+H: calcd 323.10672, found 323.10672.

14; N_a-Formyl-N_b-acetylkynurenine methyl ester (from the reaction of **5** with O_3)



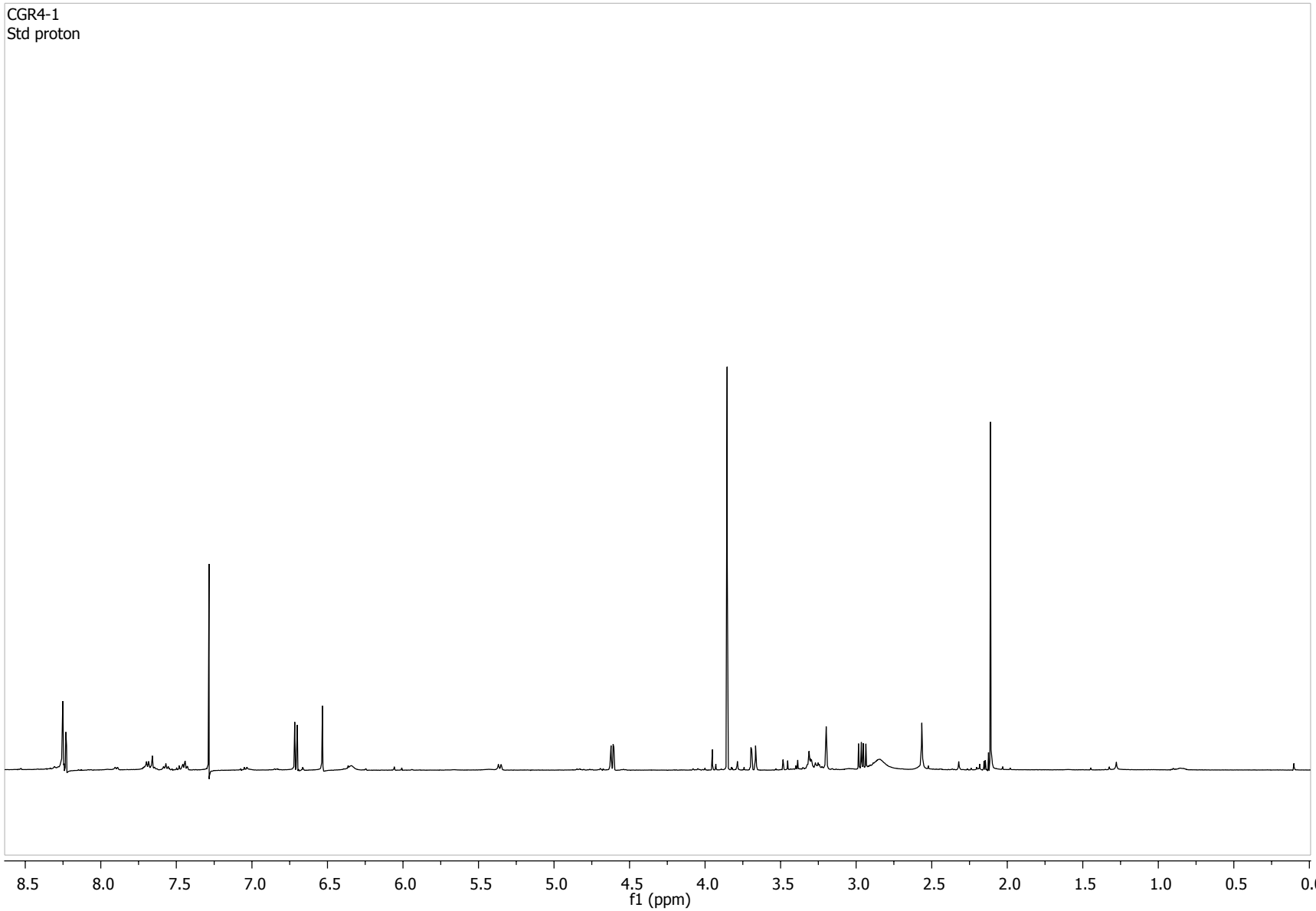
^{1}H-NMR (500 MHz, $CDCl_3$): δ = 11.37 (s, 1 H, C*H*O), 8.76 (d, *J* = 8.4 Hz, 1 H, 3-*H*), 8.49 (s, 1 H, N_aH), 7.91 (dd, *J* = 8.1, 1.5 Hz, 1 H, 6-*H*), 7.60 (t, *J* = 7.8 Hz, 1 H, 5-*H*), 7.18 (t, *J* = 7.6 Hz, 1 H, 4-*H*), 6.51 (d, *J* = 7.0 Hz, 1 H, N_bH), 4.96 (dt, *J* = 7.7, 4.0 Hz, 1 H, C*H*), 3.82-3.69 (m, 2 H, CH_2), 3.77 (s, 3 H, COOCH_3), 2.03 ppm (s, 3 H, NHCOCH_3).*

HR-MS: $C_{14}H_{16}N_2O_5$+H: calcd 293.1138, found 293.1142.
$C_{13}{}^{13}CH_{16}N_2O_5$+H: calcd 294.1171, found 294.1168.

* Data in accordance with literature: X. Fang, F. Jin, H. Jin, and C. v. Sonntag, *J. Chem. Soc., Perkin Trans. 2,* 1998, 259.

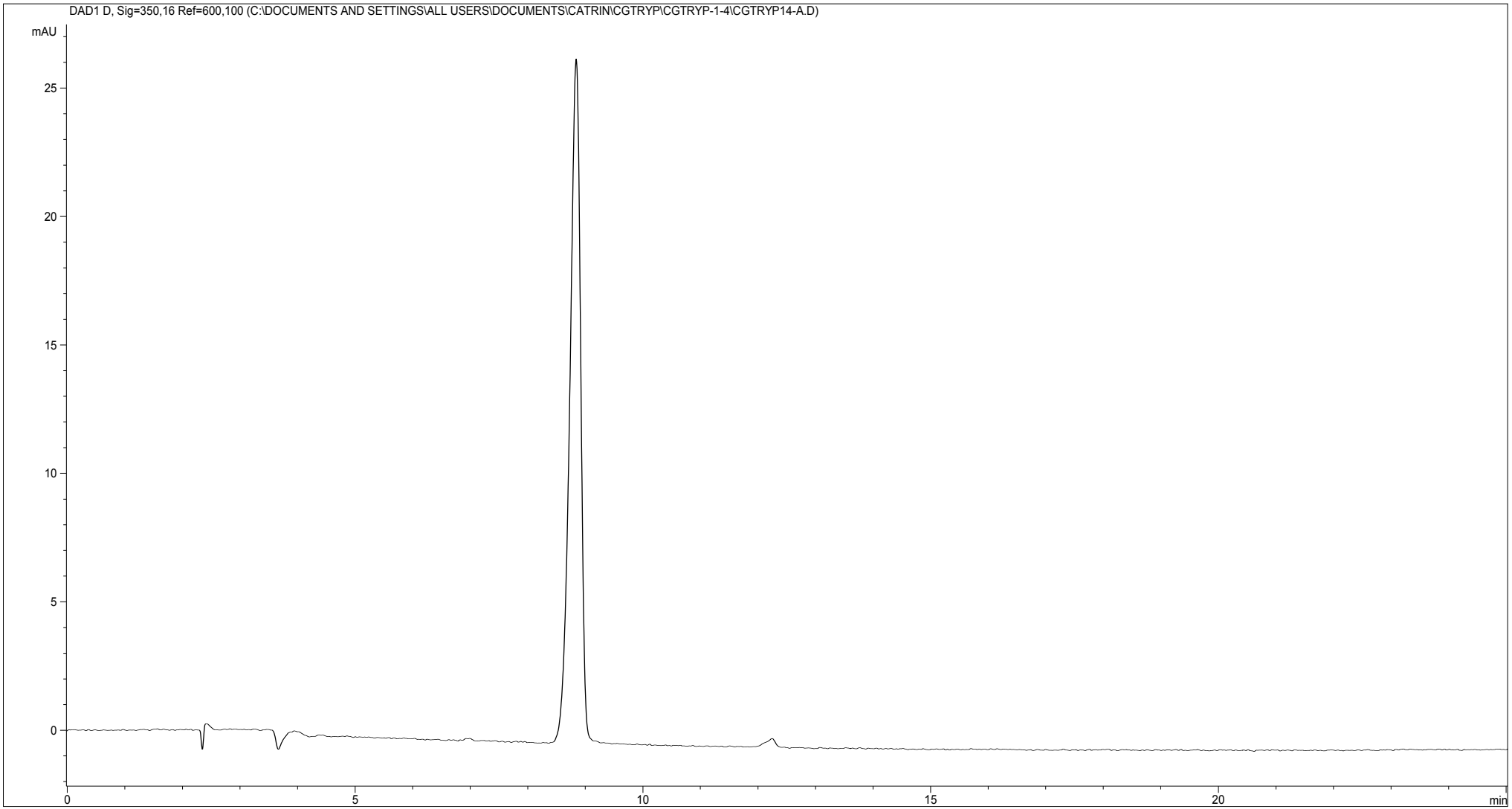
12a

^{1}H NMR:



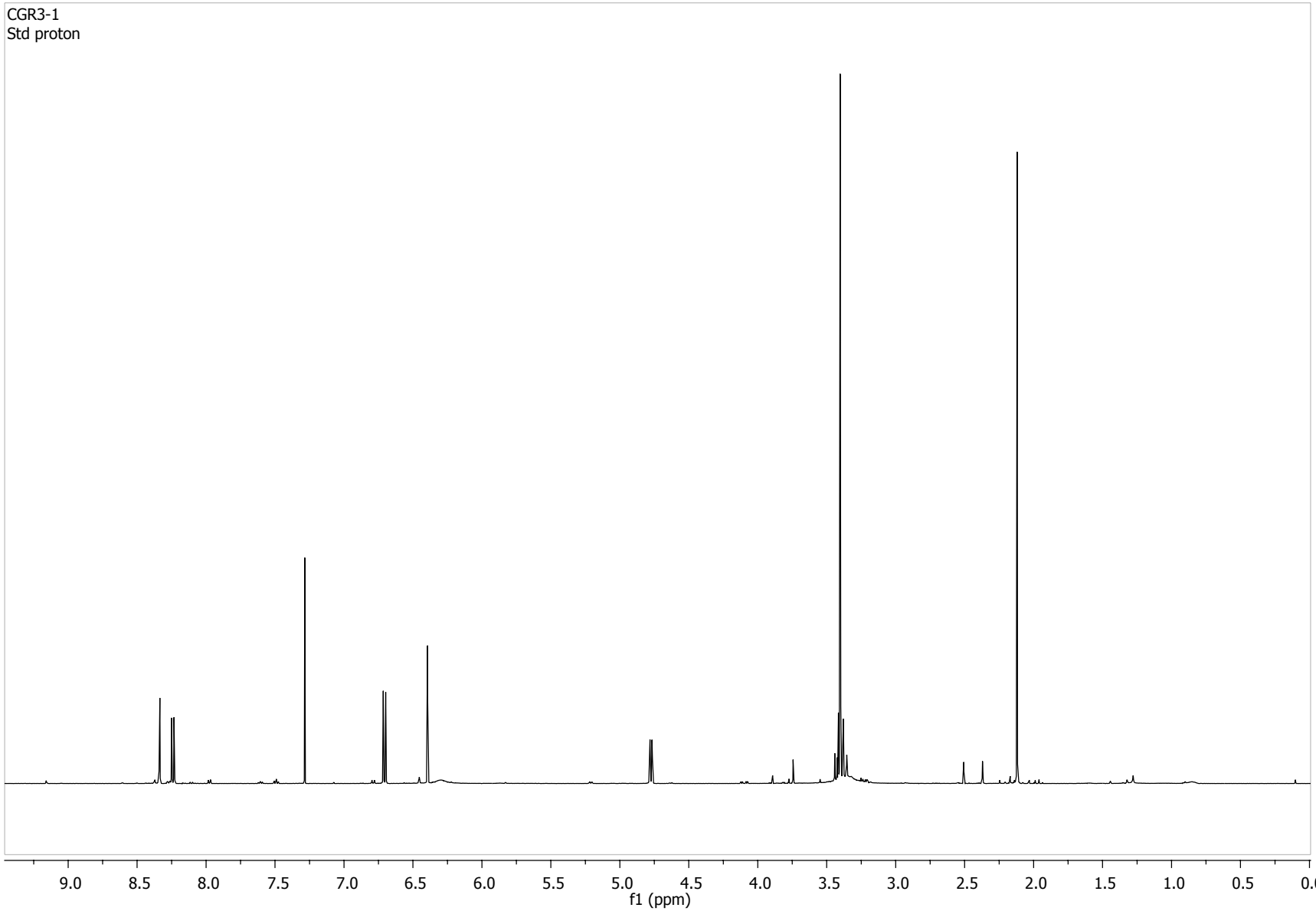
12a

HPLC:



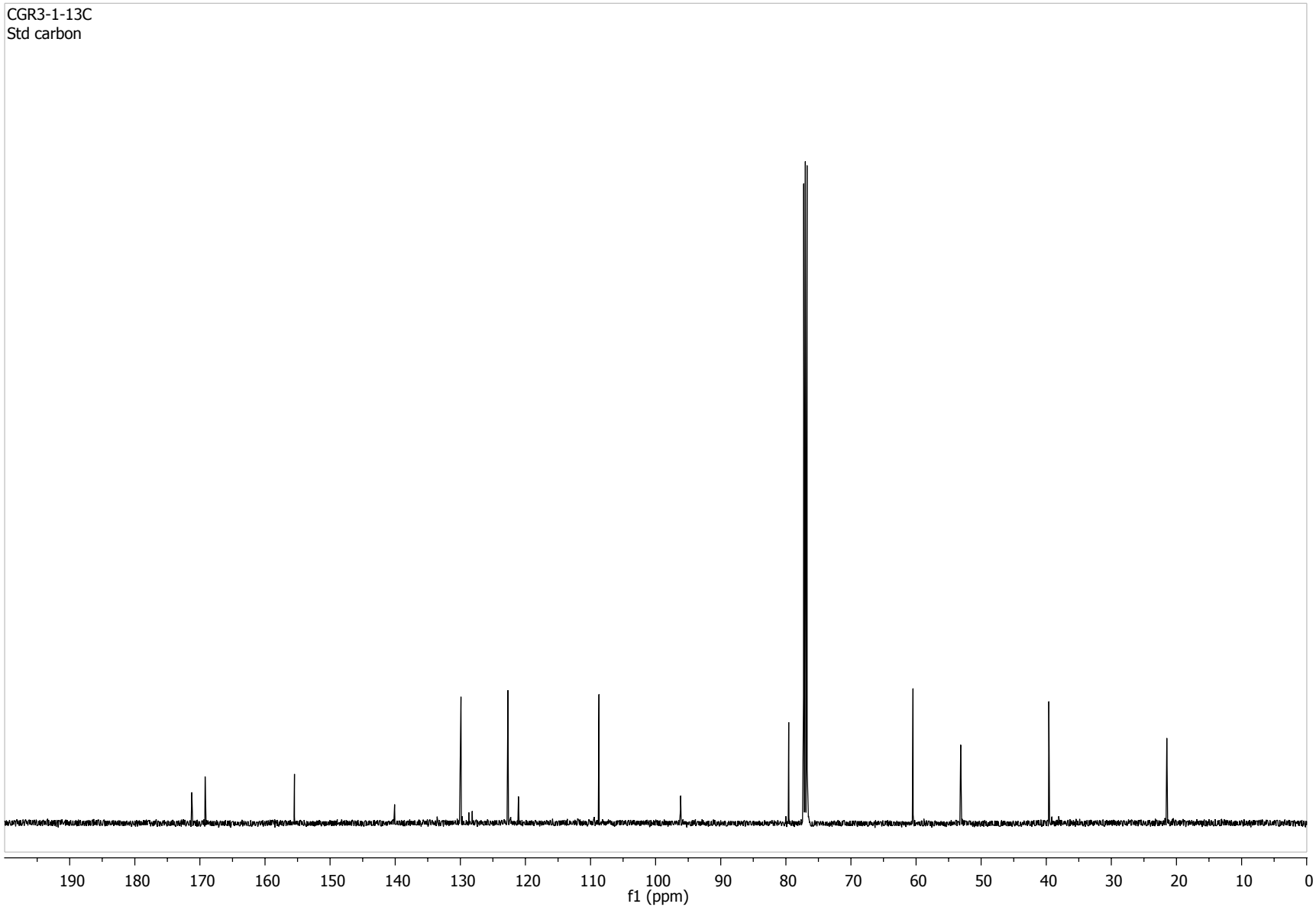
12b

^{1}H NMR:


CGR3-1
Std proton
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
0.0
f1 (ppm)

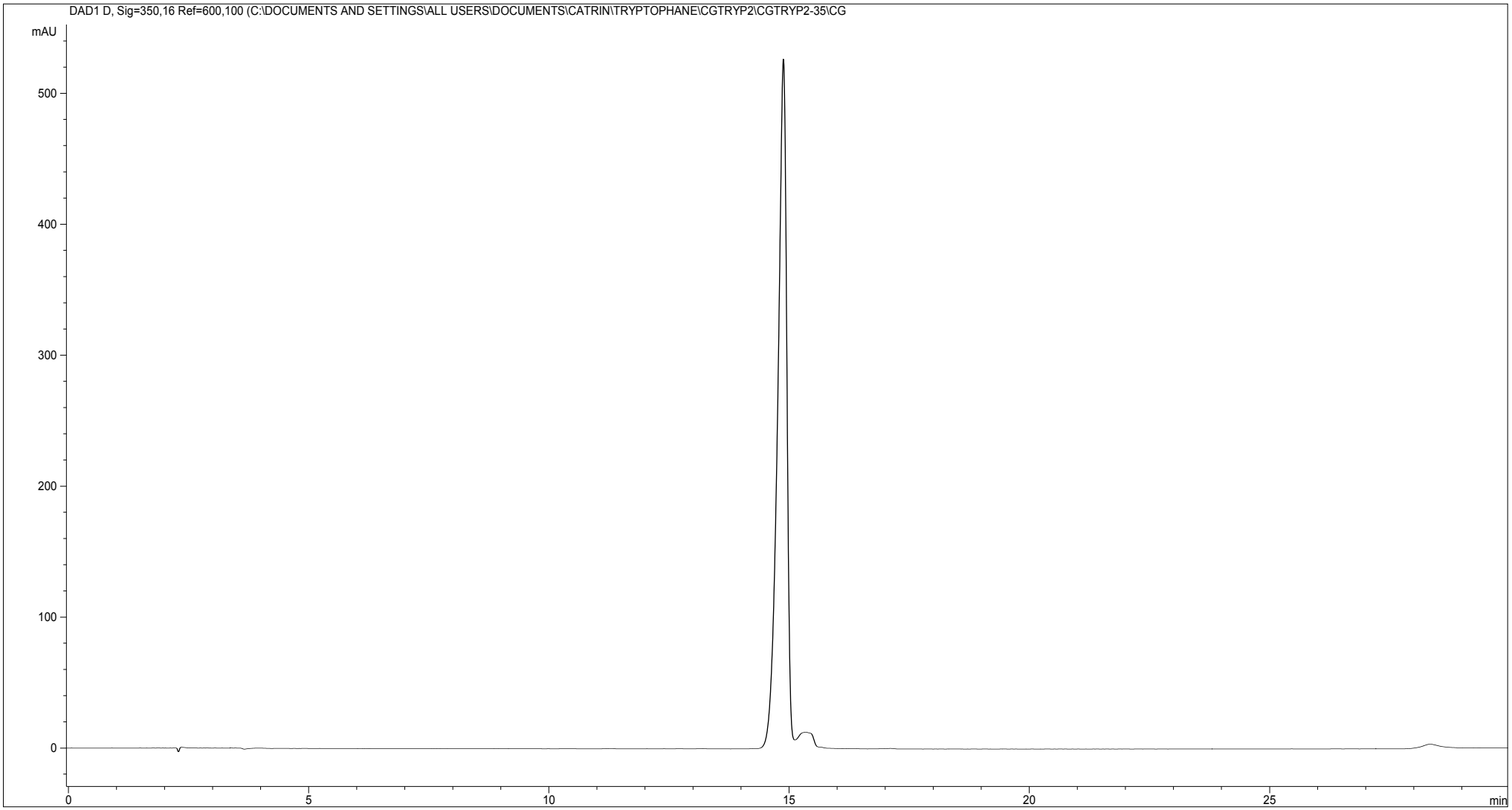
12b

^{13}C NMR:



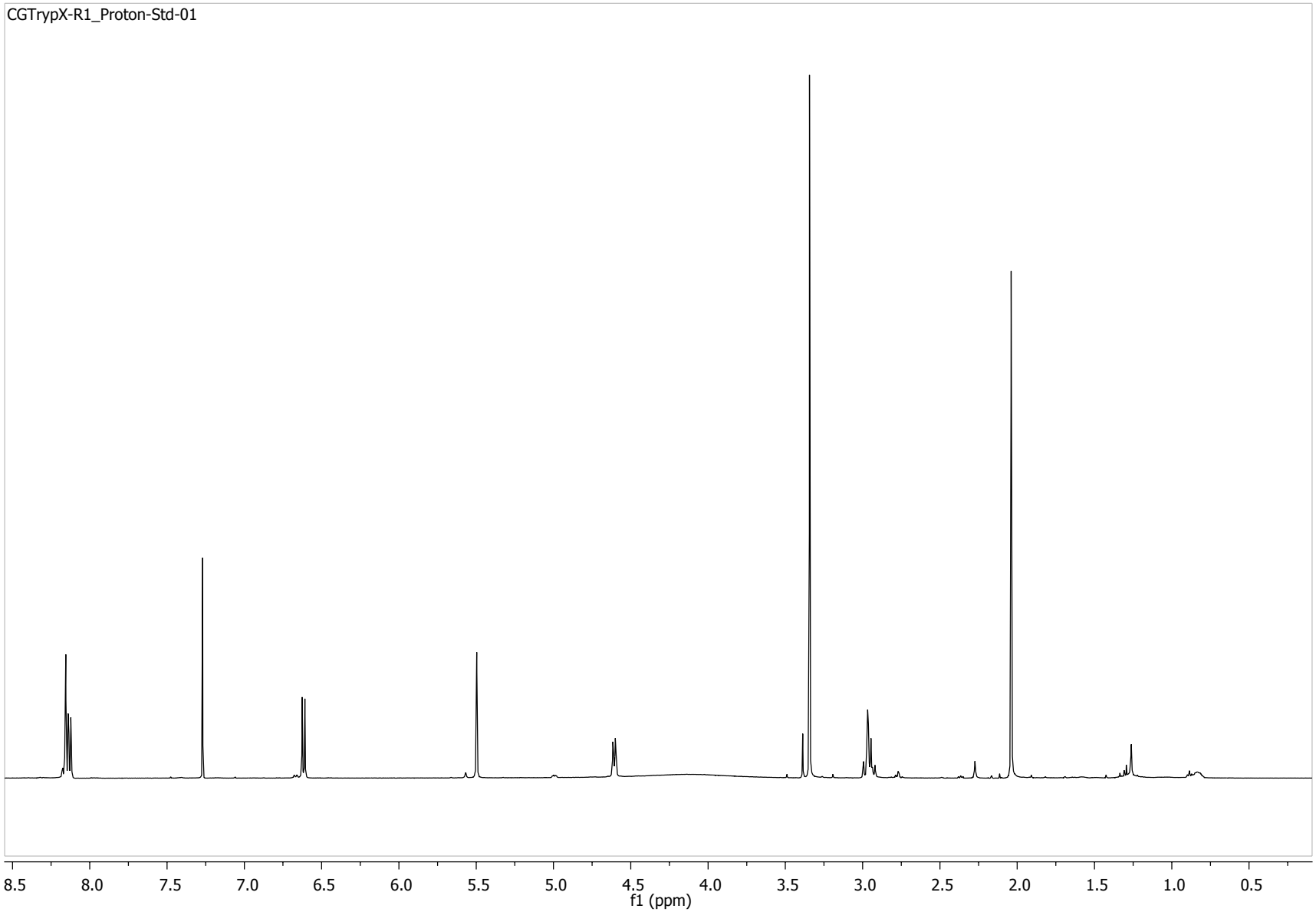
12b

HPLC:



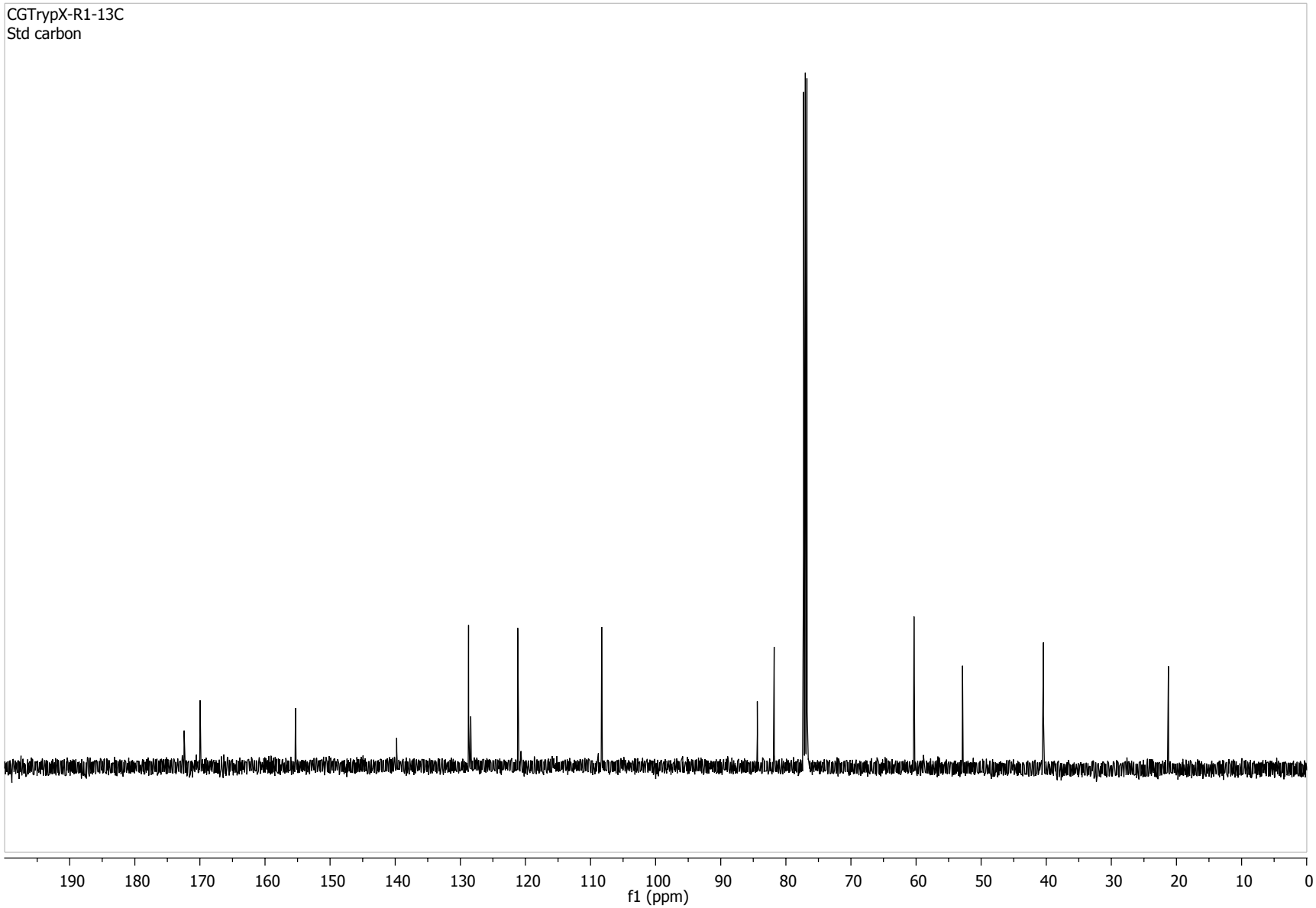
13

^{1}H NMR:


CGTrypX-R1_Proton-Std-01
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
f1 (ppm)

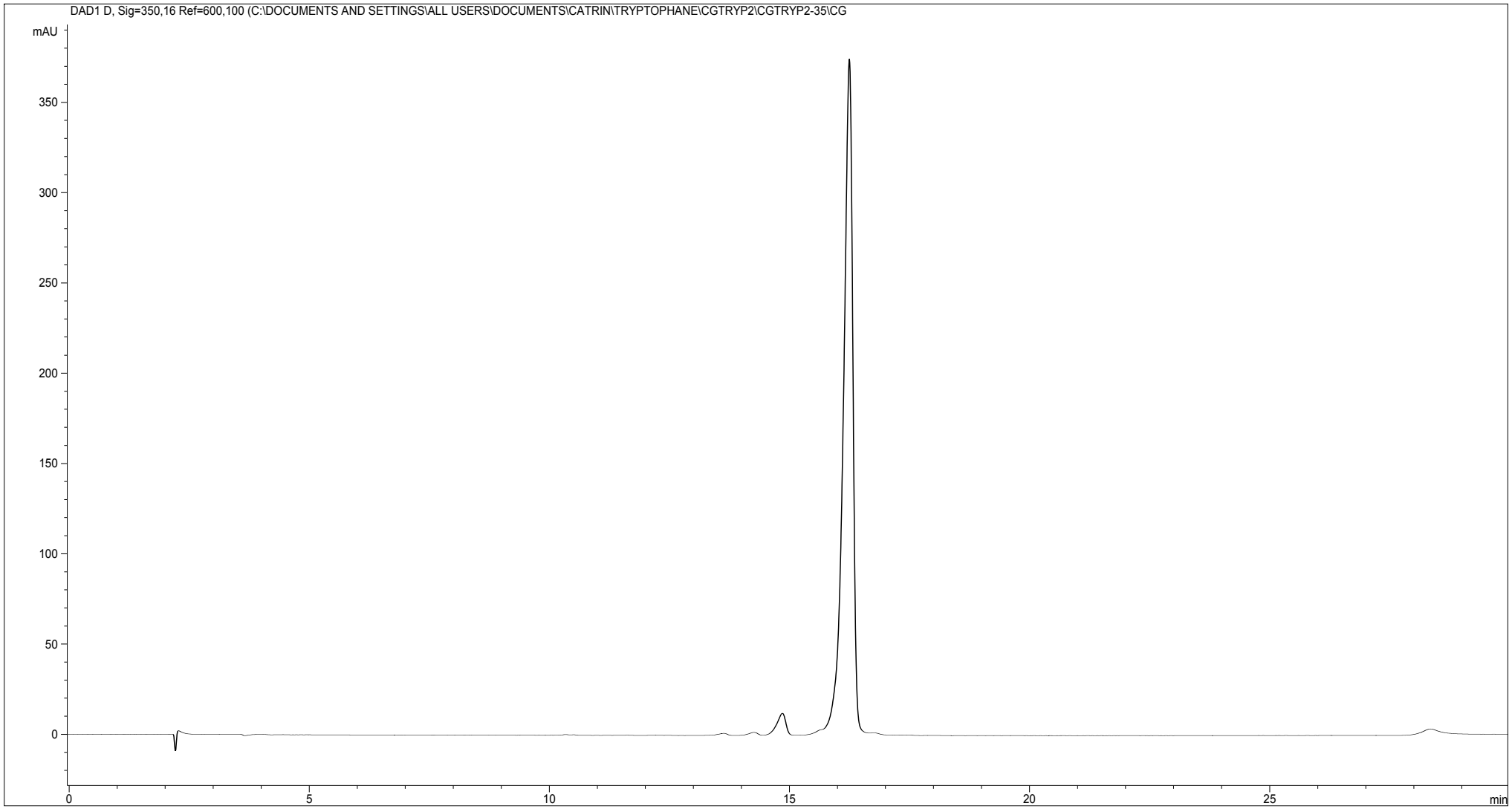
13

^{13}C NMR:


CGTrypX-R1-13C
Std carbon
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

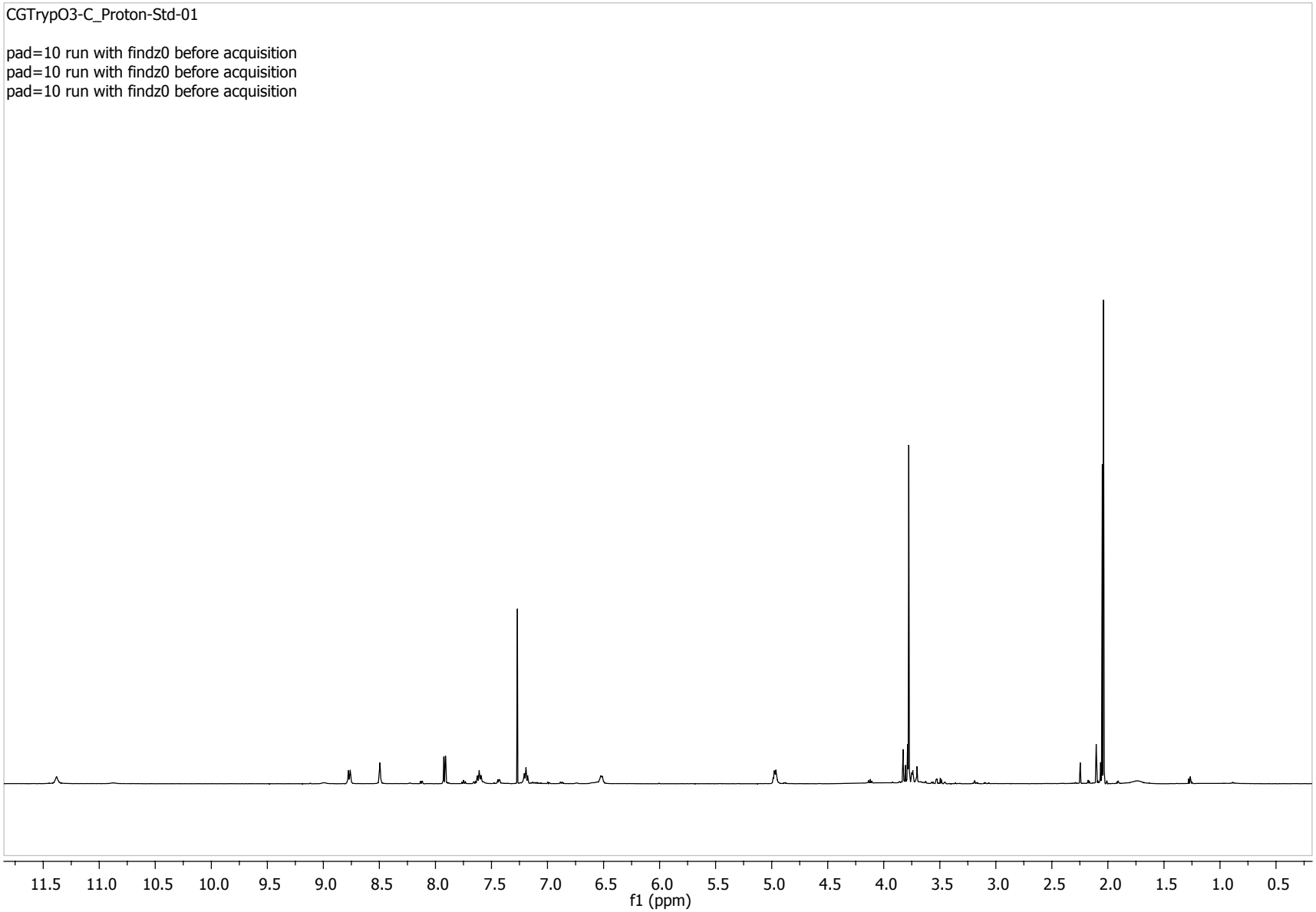
13

HPLC:



14

^{1}H NMR:


CGTrypO3-C_Proton-Std-01
pad=10 run with findz0 before acquisition
pad=10 run with findz0 before acquisition
pad=10 run with findz0 before acquisition
11.5 11.0 10.5 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
f1 (ppm)

2 Crystallographic data

Intensity data were collected with an Oxford Diffraction Sapphire CCD diffractometer using Cu-Kα radiation (graphite crystal monochromator λ = 1.54184), The temperature during the data collections was maintained at 130.0(1). Structure solution,[1] and refinement[2] were implemented within the WingX suite of programs.[3]

Crystal data for **12a**. $C_{14}H_{14}N_4O_7$, *M* =350.29, *T* = 130.0(2) K, λ = 1.5418 Å, Monoclinic, space group $P2_12_12_1$ *a* = 6.3831(14)*, b* = 7.837(3) *c* =15.410(3)*, Å*), *β* = 90.91(3)°, *V* 770.7(3) *Å*^{3}, Z = 2, D_c = 1.509 Mg M^{-3} μ(Cu-Kα) 1.061 mm^{-1}, F(000) = 364, crystal size 0.16 x 0.08 x 0.02 mm. 2249 reflections measured, 1784 independent reflections (R_{int} = 0. 11) the final R was 0.0570 [I > 2σ(I)] and *w*R(F^2) was 0.0838 (all data).

Table 1. Crystal data and structure refinement for **12a**.

Identification code	uta1	
Empirical formula	C14 H14 N4 O7	
Formula weight	350.29	
Temperature	130(2) K	
Wavelength	1.54184 ≈	
Crystal system	Monoclinic	
Space group	P 1 21 1	
Unit cell dimensions	a = 6.3831(14) ≈	α= 90∞.
	b = 7.837(3) ≈	β= 90.91(3)∞.
	c = 15.410(3) ≈	γ = 90∞.
Volume	770.7(3) ≈^{3}	
Z	2	
Density (calculated)	1.509 Mg/m^3	
Absorption coefficient	1.061 mm^{-1}	
F(000)	364	
Crystal size	0.1600 x 0.0800 x 0.0200 mm^3	
Theta range for data collection	5.74 to 64.99∞.	
Index ranges	-3<=h<=7, -9<=k<=8, -18<=l<=16	
Reflections collected	2249	
Independent reflections	1784 [R(int) = 0.1101]	
Completeness to theta = 64.99∞	97.6 %	
Absorption correction	Gaussian	
Max. and min. transmission	0.979 and 0.860	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	1784 / 1 / 227	
Goodness-of-fit on F^2	0.615	
Final R indices [I>2sigma(I)]	R1 = 0.0570, wR2 = 0.0620	
R indices (all data)	R1 = 0.2038, wR2 = 0.0838	
Absolute structure parameter	0.6(7)	
Largest diff. peak and hole	0.212 and -0.226 e.≈$^{-3}$	

[1] G. M. Sheldrick, '*SHELXS-86; Crystallographic Computing 3*', University of Göttingen, Germany, 1986.
[2] G. M. Sheldrick, '*SHELXL-97; A Program for the Refinement of Crystal Structures*' University of Göttingen, Germany, 1997.
[3] L. J. Farrugia, *J. Appl. Crystallogr.*, 1999, **32**, 837.

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (≈^{2}x 10^3) for **12a**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(3)	5418(10)	1796(10)	3188(4)	40(2)
O(2)	2660(11)	4336(9)	4249(5)	45(2)
O(1)	1387(11)	1711(10)	4557(5)	47(2)
O(4)	5721(11)	-150(9)	2194(5)	44(2)
O(7)	1775(12)	7080(8)	2274(5)	48(2)
O(6)	2461(10)	-1782(8)	-1465(4)	35(2)
N(2)	2754(13)	4320(10)	1160(6)	34(3)
N(1)	1230(15)	4352(10)	2606(6)	30(3)
N(3)	4887(15)	1076(11)	2499(7)	44(3)
N(4)	2454(13)	-1791(11)	-659(7)	34(3)
C(9)	507(15)	2925(14)	3155(6)	33(3)
C(11)	1587(16)	2900(16)	4059(6)	32(3)
C(1)	2626(15)	2948(15)	625(7)	26(3)
C(7)	2916(16)	1817(13)	2060(7)	36(3)
C(3)	2660(15)	-167(13)	697(7)	32(3)
C(4)	2460(16)	-127(14)	-183(7)	27(3)
C(10)	1010(16)	1320(11)	2624(7)	32(3)
C(6)	2518(15)	2886(15)	-272(7)	32(3)
C(13)	3555(14)	4386(17)	5126(7)	71(5)
C(2)	2772(16)	1410(13)	1116(7)	30(3)
C(14)	-1120(14)	6454(13)	3203(7)	48(3)
C(5)	2442(15)	1373(13)	-692(7)	31(3)
C(8)	3035(18)	3864(11)	2064(8)	29(3)
C(12)	730(20)	6064(14)	2678(9)	49(4)
O(5)	2356(11)	-3143(8)	-216(5)	37(2)

Table 3. Bond lengths [≈] and angles [∞] for **12a**.

O(3)-N(3)	1.244(10)
O(2)-C(11)	1.347(12)
O(2)-C(13)	1.460(10)
O(1)-C(11)	1.215(12)
O(4)-N(3)	1.198(10)
O(7)-C(12)	1.215(14)
O(6)-N(4)	1.243(10)
N(2)-C(1)	1.356(13)
N(2)-C(8)	1.447(12)
N(1)-C(12)	1.383(12)
N(1)-C(8)	1.484(12)
N(1)-C(9)	1.481(12)
N(3)-C(7)	1.533(12)
N(4)-O(5)	1.262(10)
N(4)-C(4)	1.496(12)
C(9)-C(10)	1.538(12)
C(9)-C(11)	1.545(12)
C(1)-C(6)	1.383(14)
C(1)-C(2)	1.426(14)
C(7)-C(2)	1.491(14)
C(7)-C(10)	1.556(13)
C(7)-C(8)	1.606(11)
C(3)-C(4)	1.361(13)
C(3)-C(2)	1.395(13)
C(4)-C(5)	1.413(13)
C(6)-C(5)	1.352(13)
C(14)-C(12)	1.476(14)

C(11)-O(2)-C(13)	114.4(9)
C(1)-N(2)-C(8)	113.3(8)
C(12)-N(1)-C(8)	118.4(10)
C(12)-N(1)-C(9)	127.8(11)
C(8)-N(1)-C(9)	112.3(8)
O(4)-N(3)-O(3)	125.6(10)
O(4)-N(3)-C(7)	119.8(10)
O(3)-N(3)-C(7)	114.6(9)
O(6)-N(4)-O(5)	123.1(9)
O(6)-N(4)-C(4)	119.0(10)
O(5)-N(4)-C(4)	117.8(9)
N(1)-C(9)-C(10)	104.1(8)
N(1)-C(9)-C(11)	112.8(9)
C(10)-C(9)-C(11)	112.1(9)
O(1)-C(11)-O(2)	124.1(9)
O(1)-C(11)-C(9)	122.0(11)
O(2)-C(11)-C(9)	113.8(10)
N(2)-C(1)-C(6)	129.5(11)
N(2)-C(1)-C(2)	110.2(8)
C(6)-C(1)-C(2)	120.1(12)
C(2)-C(7)-N(3)	112.8(9)
C(2)-C(7)-C(10)	117.1(9)
N(3)-C(7)-C(10)	107.6(9)

C(2)-C(7)-C(8)	102.7(9)
N(3)-C(7)-C(8)	109.7(9)
C(10)-C(7)-C(8)	106.6(10)
C(4)-C(3)-C(2)	116.3(11)
C(3)-C(4)-C(5)	124.9(10)
C(3)-C(4)-N(4)	117.9(10)
C(5)-C(4)-N(4)	116.9(9)
C(9)-C(10)-C(7)	105.3(8)
C(5)-C(6)-C(1)	120.7(12)
C(3)-C(2)-C(1)	120.1(10)
C(3)-C(2)-C(7)	130.0(10)
C(1)-C(2)-C(7)	109.8(9)
C(6)-C(5)-C(4)	117.7(10)
N(2)-C(8)-N(1)	113.1(9)
N(2)-C(8)-C(7)	103.8(9)
N(1)-C(8)-C(7)	102.8(9)
O(7)-C(12)-N(1)	117.8(12)
O(7)-C(12)-C(14)	126.5(11)
N(1)-C(12)-C(14)	115.6(13)

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters ($\approx^2$x 10^3) for **12a**. The anisotropic displacement factor exponent takes the form: $-2\pi^2[\ h^2a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(3)	46(5)	33(5)	40(5)	9(5)	2(4)	1(4)
O(2)	44(5)	44(5)	45(5)	-3(4)	-15(5)	-18(4)
O(1)	66(6)	36(5)	39(5)	2(5)	3(4)	-8(4)
O(4)	46(5)	24(4)	62(6)	3(5)	0(4)	-4(4)
O(7)	76(6)	13(4)	55(6)	1(4)	9(5)	5(4)
O(6)	50(5)	22(4)	32(5)	-7(4)	2(4)	0(4)
N(2)	38(7)	23(5)	41(7)	2(5)	3(6)	-1(5)
N(1)	31(6)	31(5)	29(6)	-4(5)	-11(5)	0(5)
N(3)	50(8)	32(6)	51(8)	8(6)	12(6)	-5(5)
N(4)	9(6)	32(6)	61(8)	-17(6)	4(5)	-13(4)
C(9)	40(8)	29(6)	31(7)	2(7)	-1(6)	1(7)
C(11)	36(8)	40(7)	21(6)	-16(7)	5(6)	-4(7)
C(1)	19(7)	24(5)	36(7)	7(6)	-10(5)	3(6)
C(7)	23(7)	19(5)	64(9)	4(7)	-30(7)	2(5)
C(3)	42(8)	17(5)	37(7)	-4(6)	-9(6)	4(6)
C(4)	27(7)	19(5)	36(8)	-11(6)	-3(6)	7(5)
C(10)	42(8)	17(6)	38(8)	-3(6)	15(7)	-13(6)
C(6)	40(8)	26(6)	30(8)	-4(7)	-6(6)	0(6)
C(13)	87(11)	64(9)	61(11)	-2(9)	-32(9)	-30(9)
C(2)	25(8)	30(7)	36(8)	-11(6)	2(6)	5(6)
C(14)	59(8)	22(5)	63(8)	-8(6)	3(7)	4(6)
C(5)	32(7)	45(7)	17(6)	4(6)	-10(5)	3(6)
C(8)	28(8)	10(5)	49(8)	-10(5)	-1(7)	-7(5)
C(12)	51(10)	34(7)	60(10)	-13(7)	-19(8)	22(7)
O(5)	62(6)	15(4)	36(5)	1(4)	12(4)	-1(4)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (≈^{2}x 10^3) for **12a**.

	x	y	z	U(eq)
H(2)	2675	5357	979	41
H(9)	-1013	3011	3225	40
H(3)	2718	-1189	1003	38
H(10A)	-179	998	2259	39
H(10B)	1362	372	3004	39
H(6)	2498	3896	-589	39
H(13A)	4288	5444	5211	106
H(13B)	4513	3452	5203	106
H(13C)	2453	4296	5540	106
H(14A)	-753	6376	3808	72
H(14B)	-2215	5652	3069	72
H(14C)	-1599	7589	3073	72
H(5)	2379	1321	-1294	38
H(8)	4368	4283	2305	35