

Studies toward a prebiotic protometabolism

Adam J. Coggins

UCL

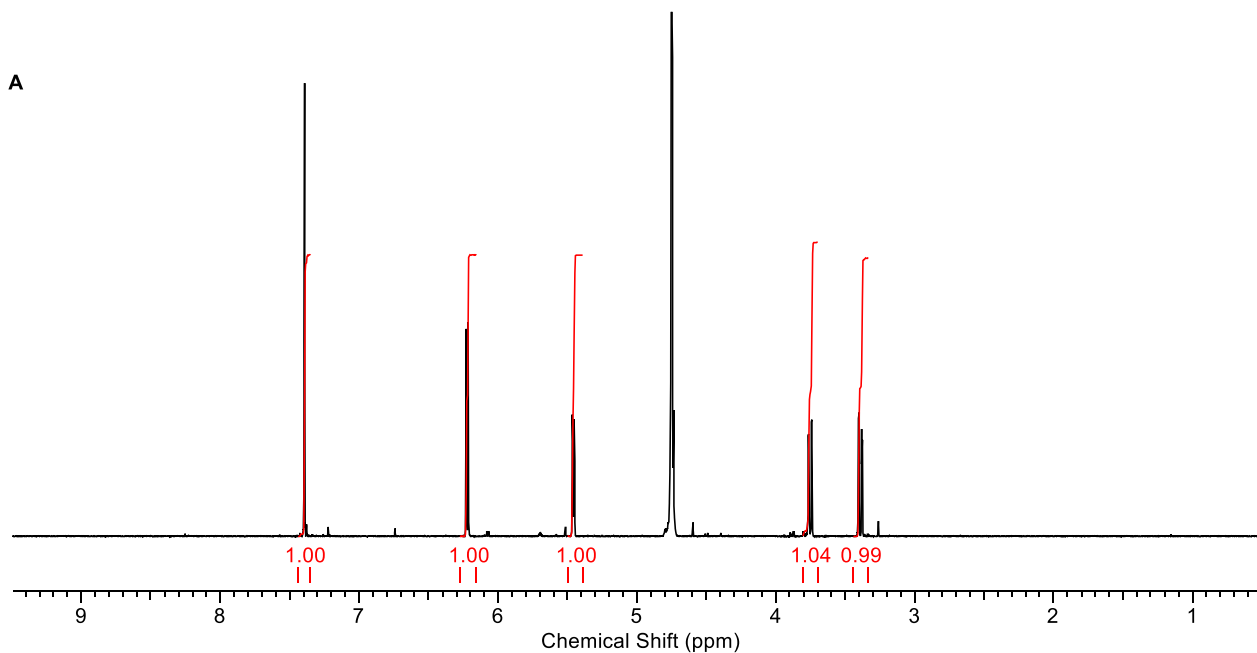
*Thesis Submitted to University College London
for the Degree of Doctor of Philosophy*

Appendix – part 3

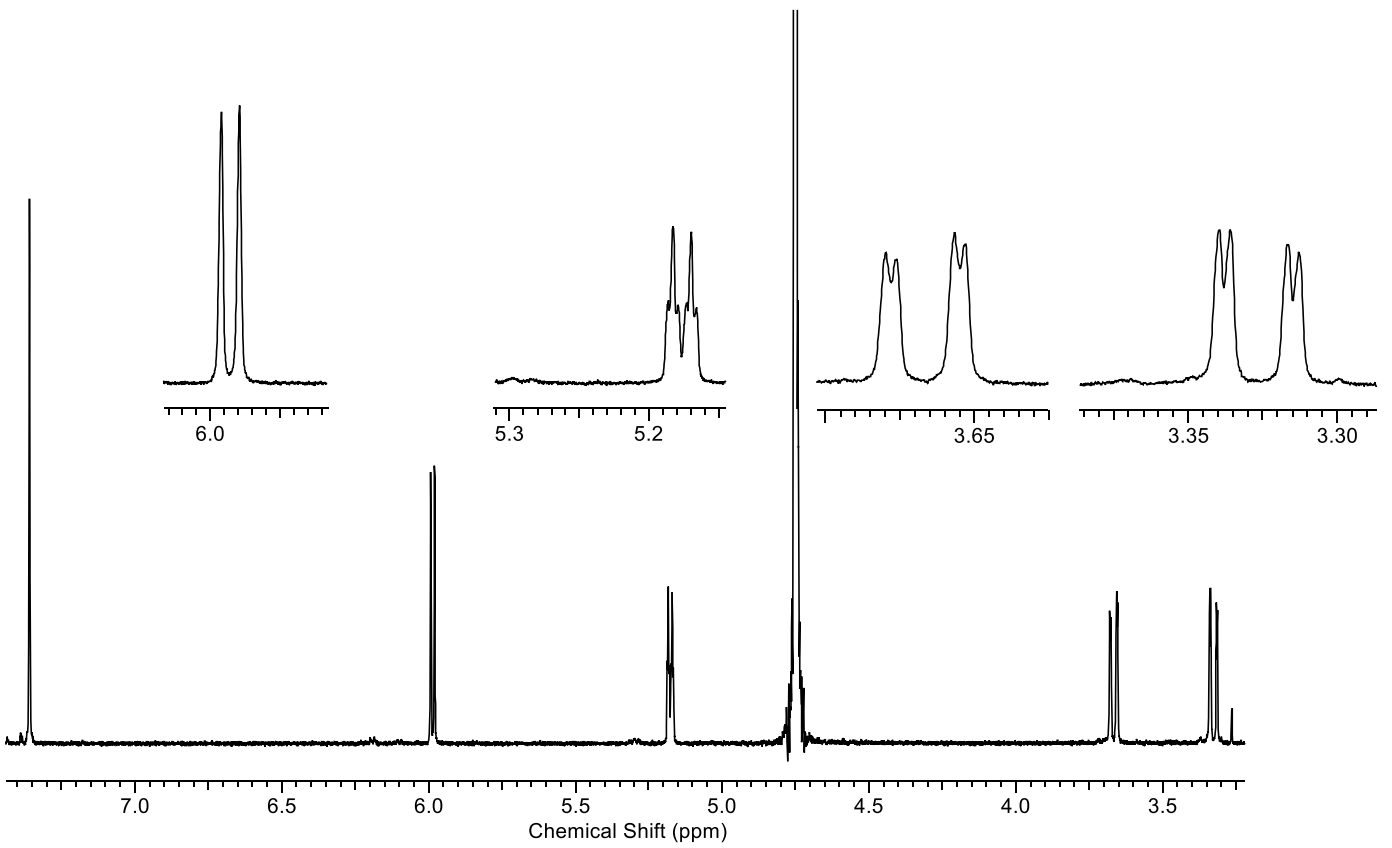
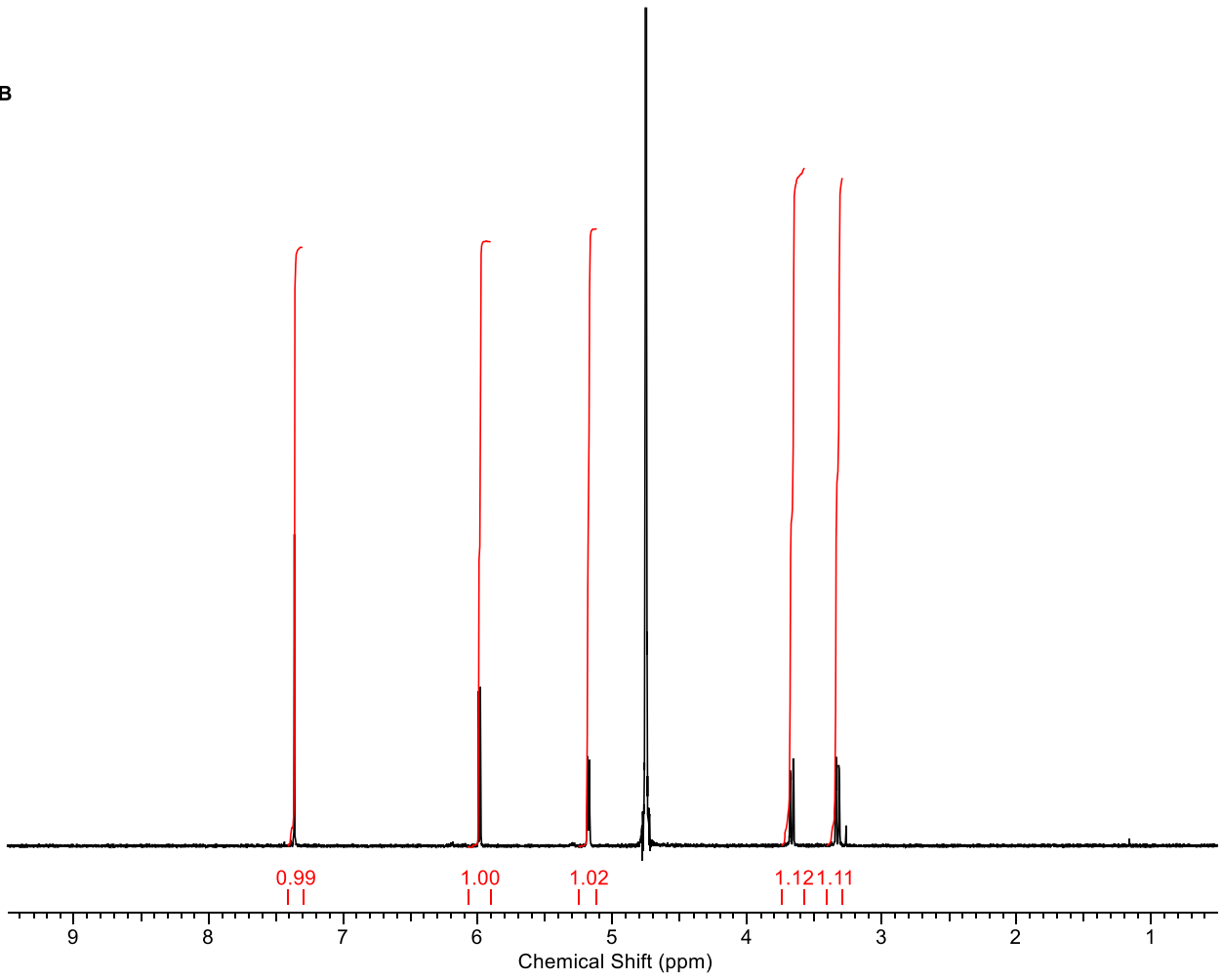
Multicomponent Purine Assembly

2-amino-3a,4,5,9a-tetrahydroimidazo[1,5-a]oxazolo[5,4-e]pyrimidine-6-carboxamide (174)

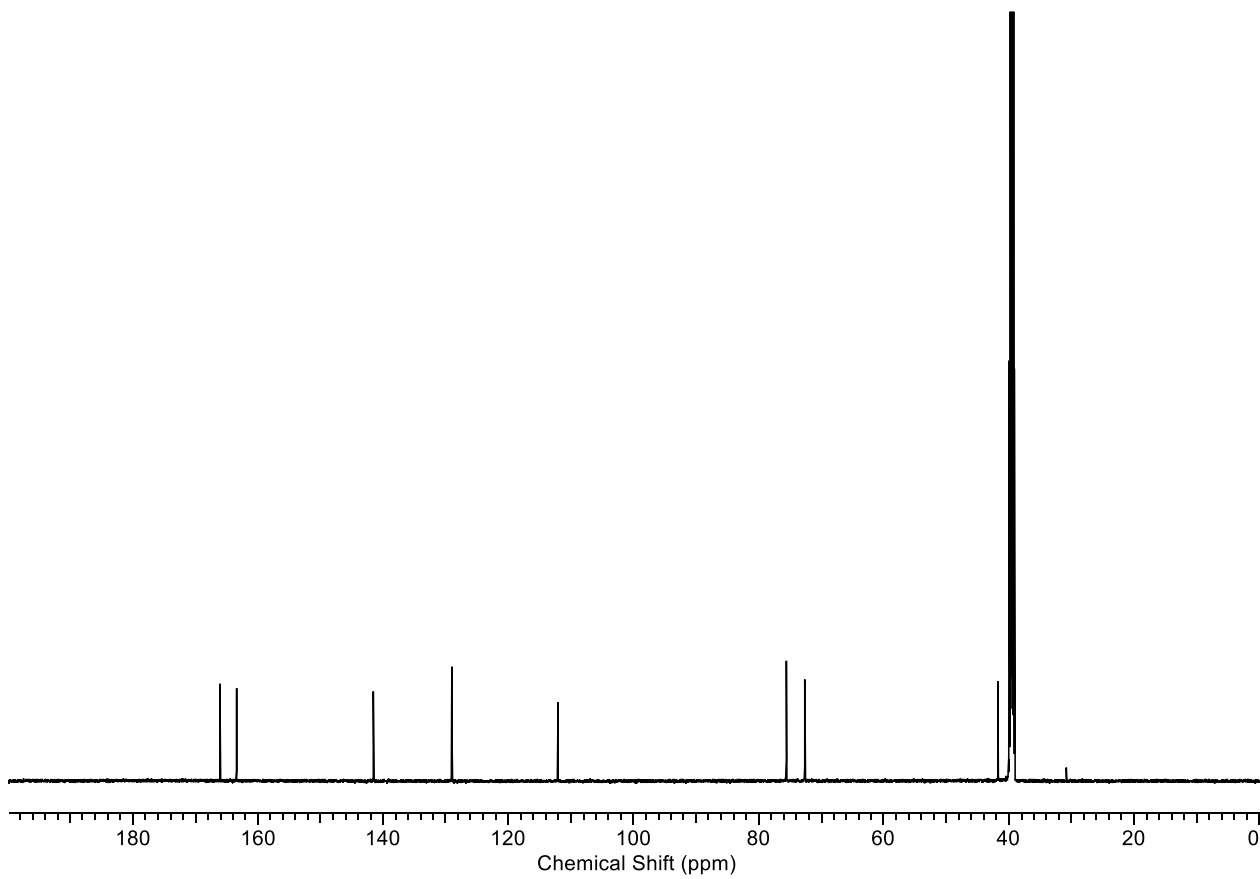
A263: ^1H NMR spectra (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **A**, un-purified **174** and **B** purified **174** with expansion below.



B

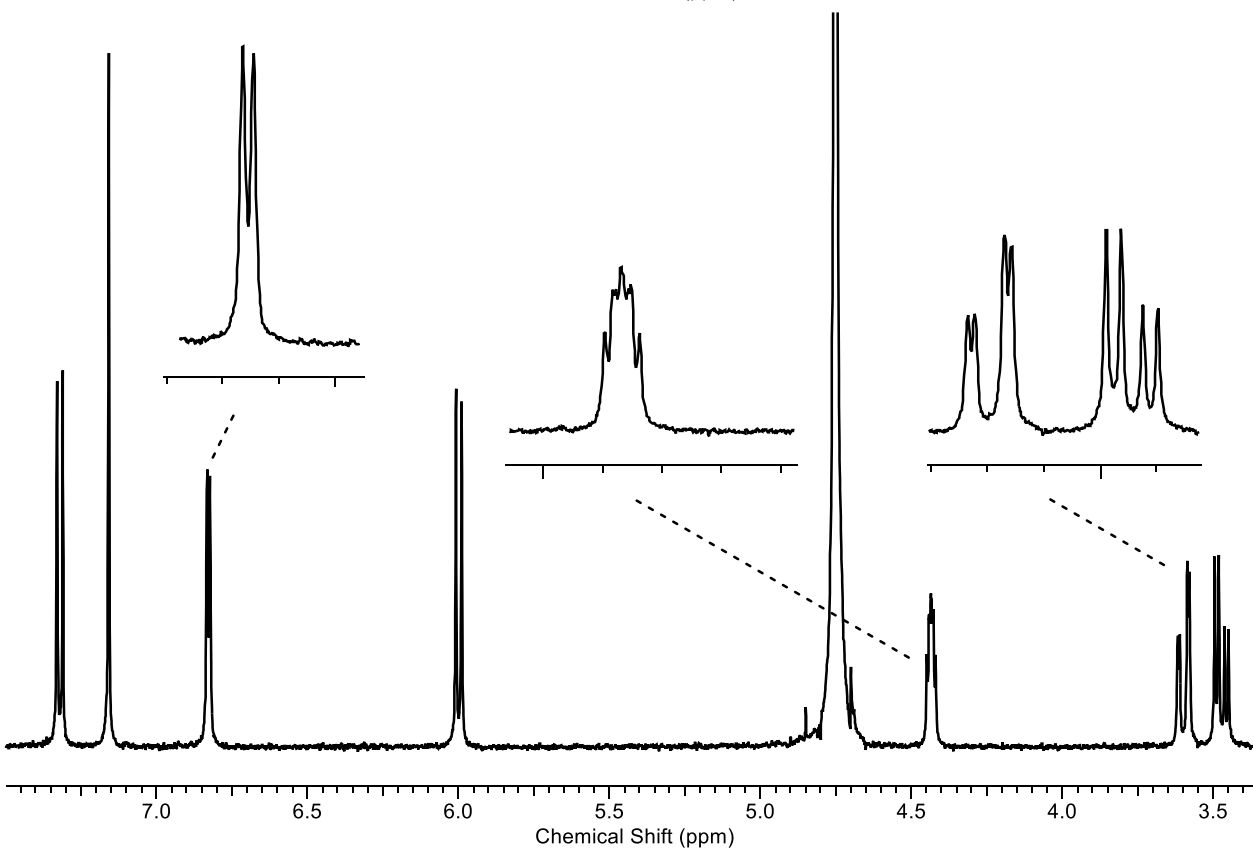
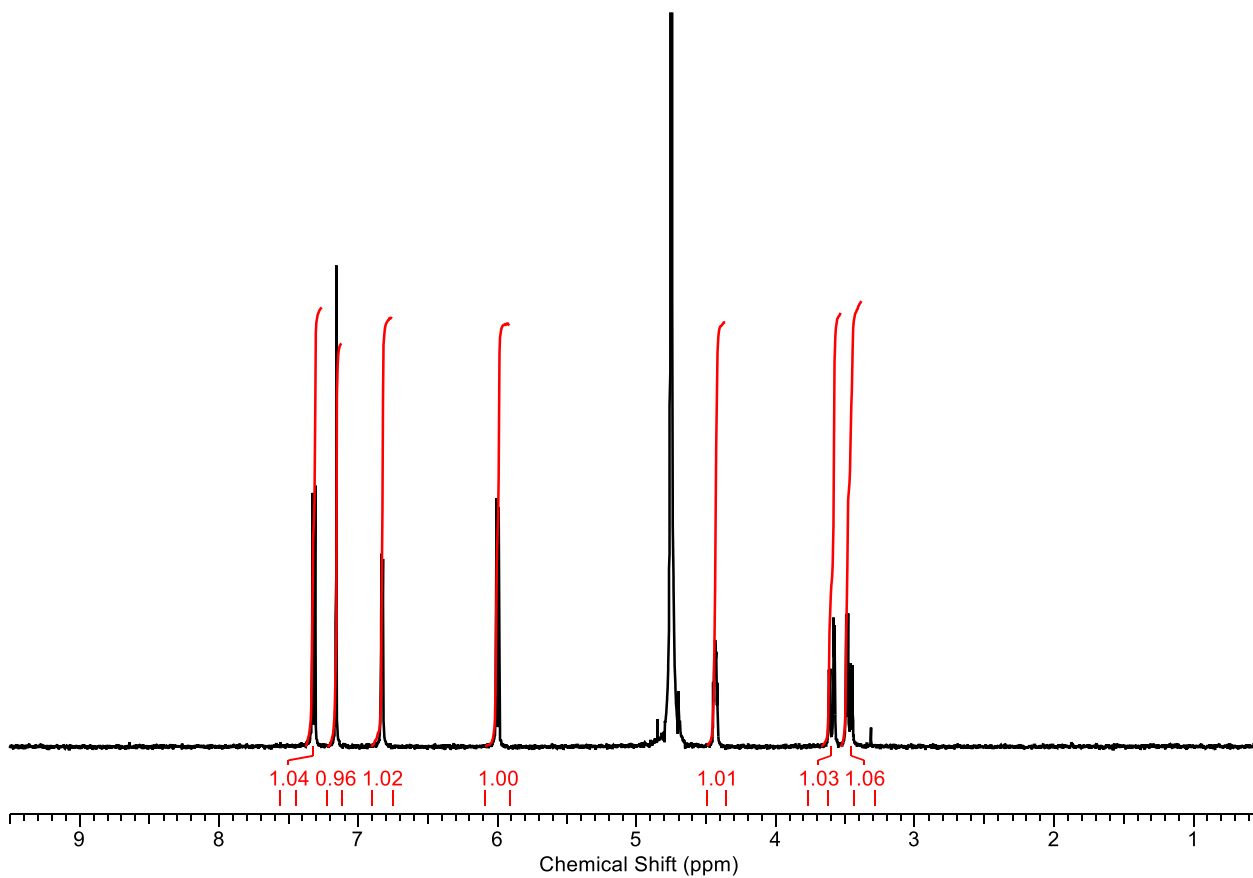


A264: ^{13}C NMR spectrum (151 MHz, {DMSO-d₆}, 200 – 0 ppm) of **174**.

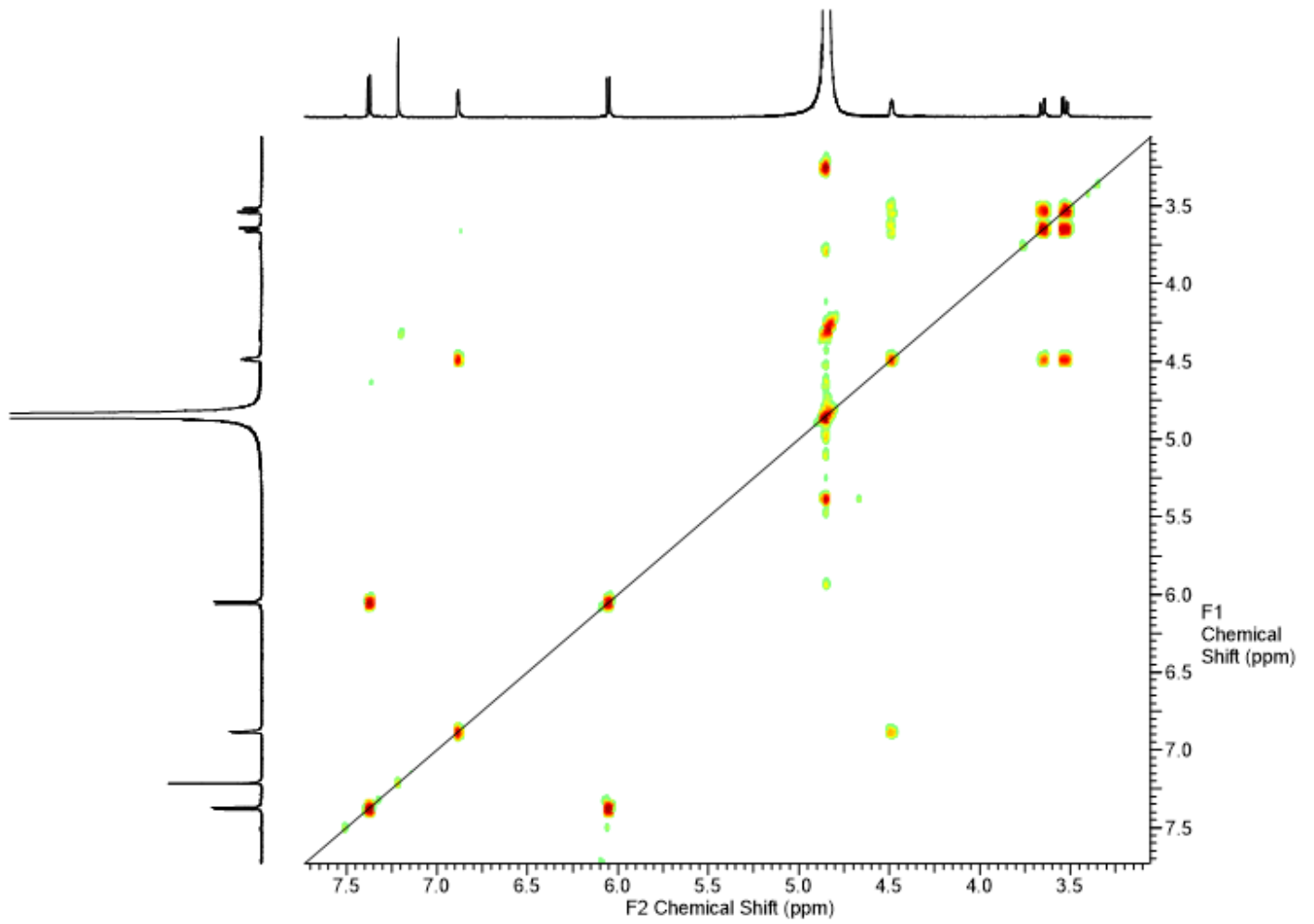


rac-4-(4-amino-2-oxopyrimidin-1(2H)-yl)-3-hydroxy-1,2,3,4-tetrahydroimidazo[1,5-a]pyrimidine-8-carboxamide (176)

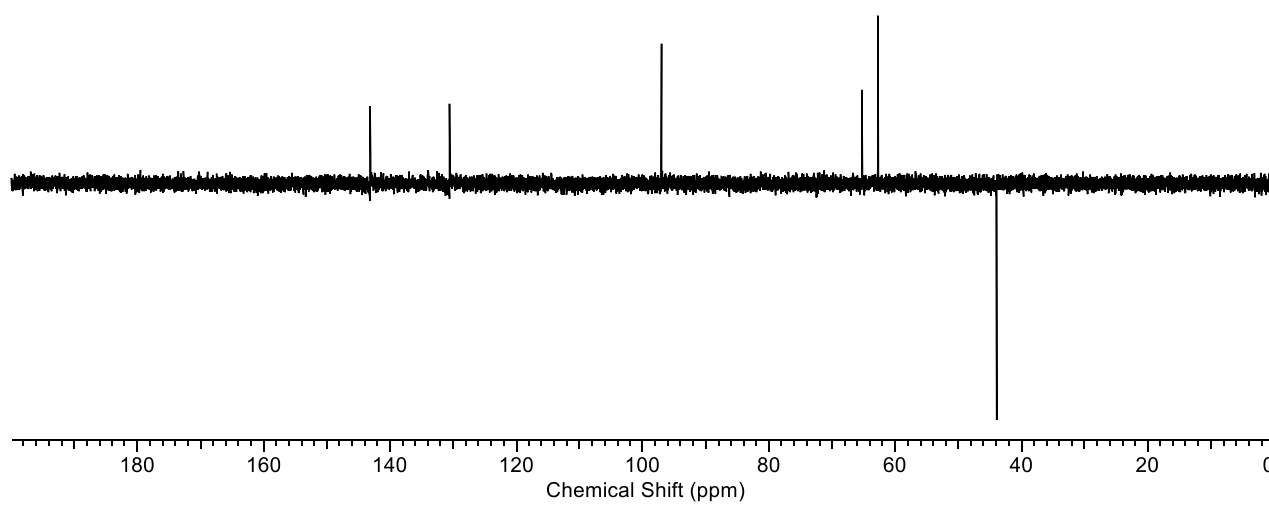
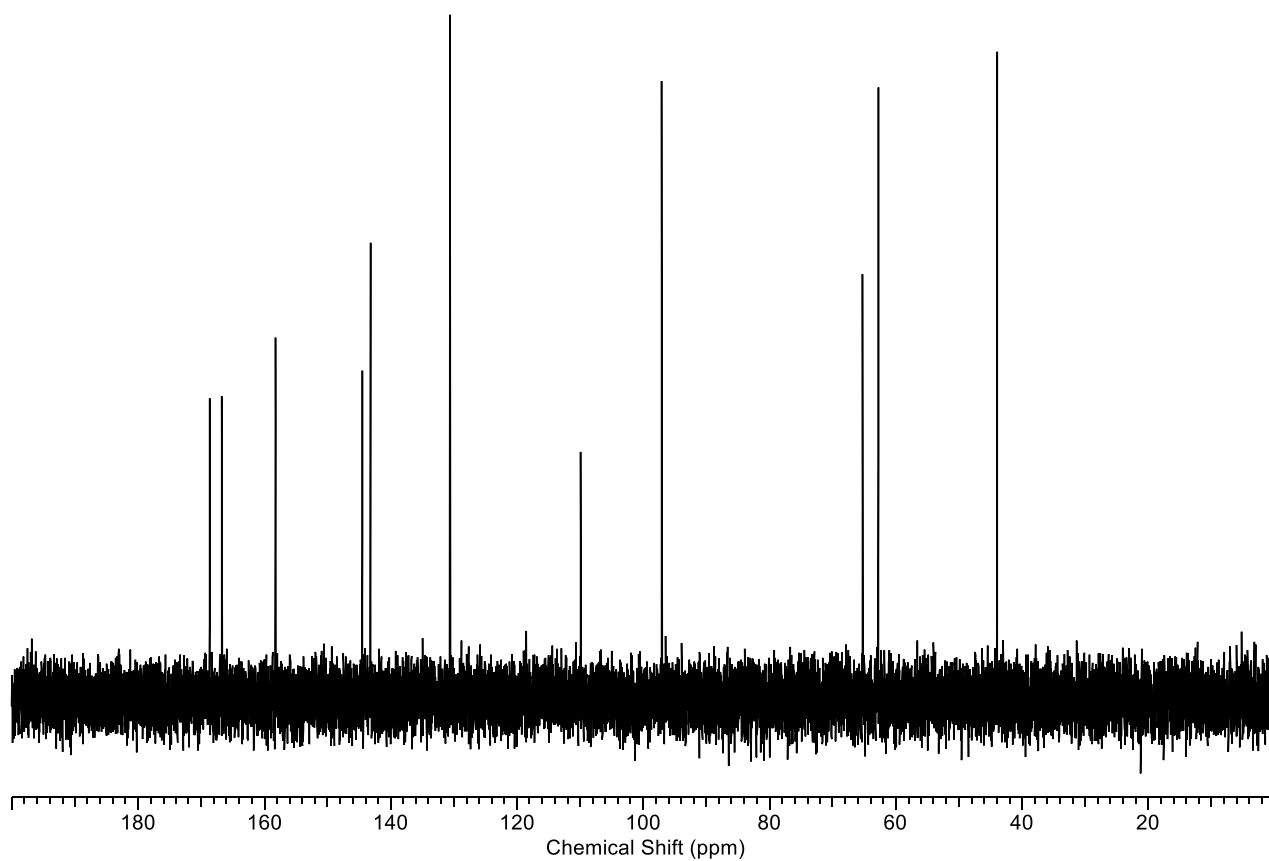
A265: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **176** with expansion below.



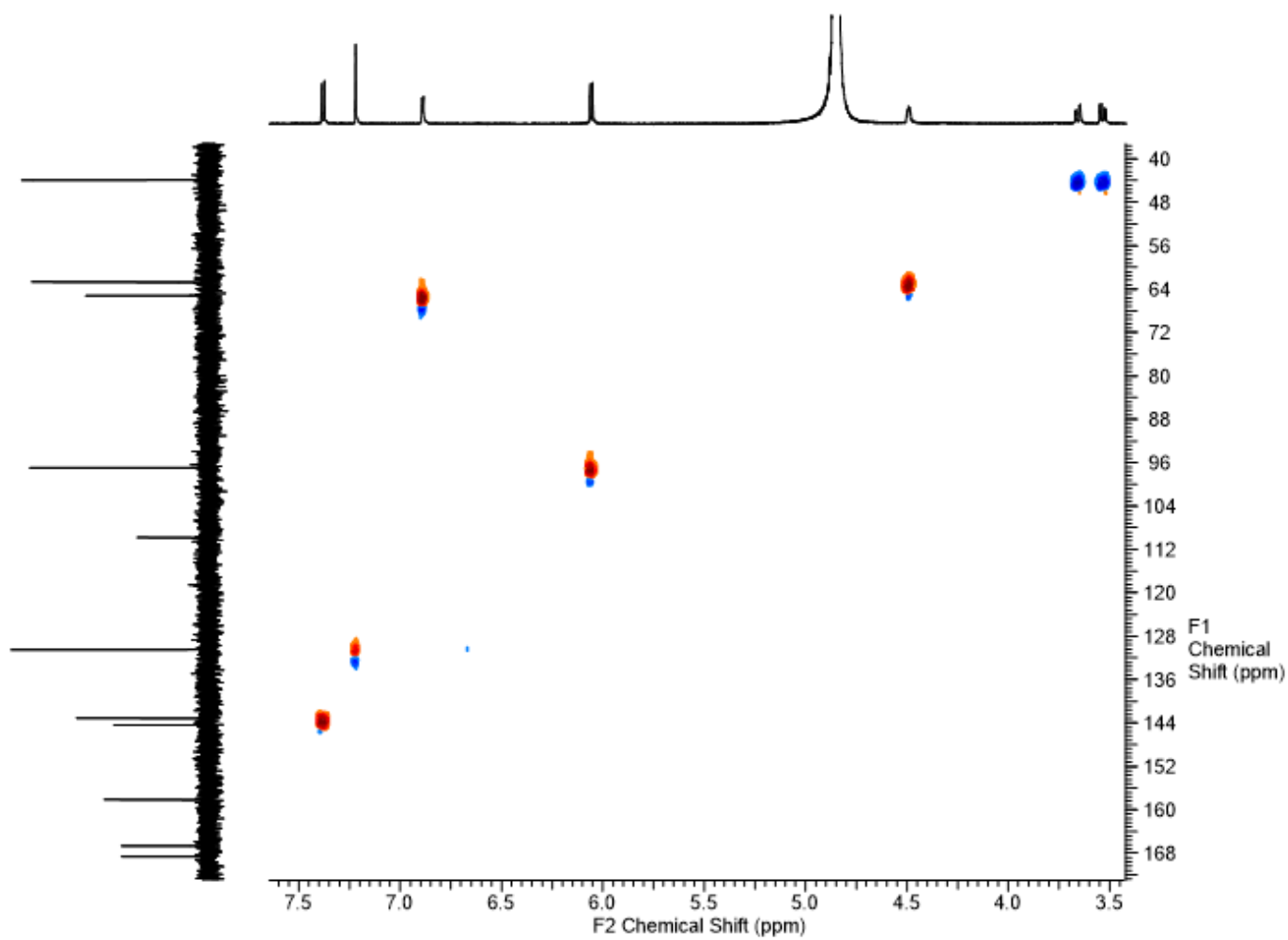
A266: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **176**.



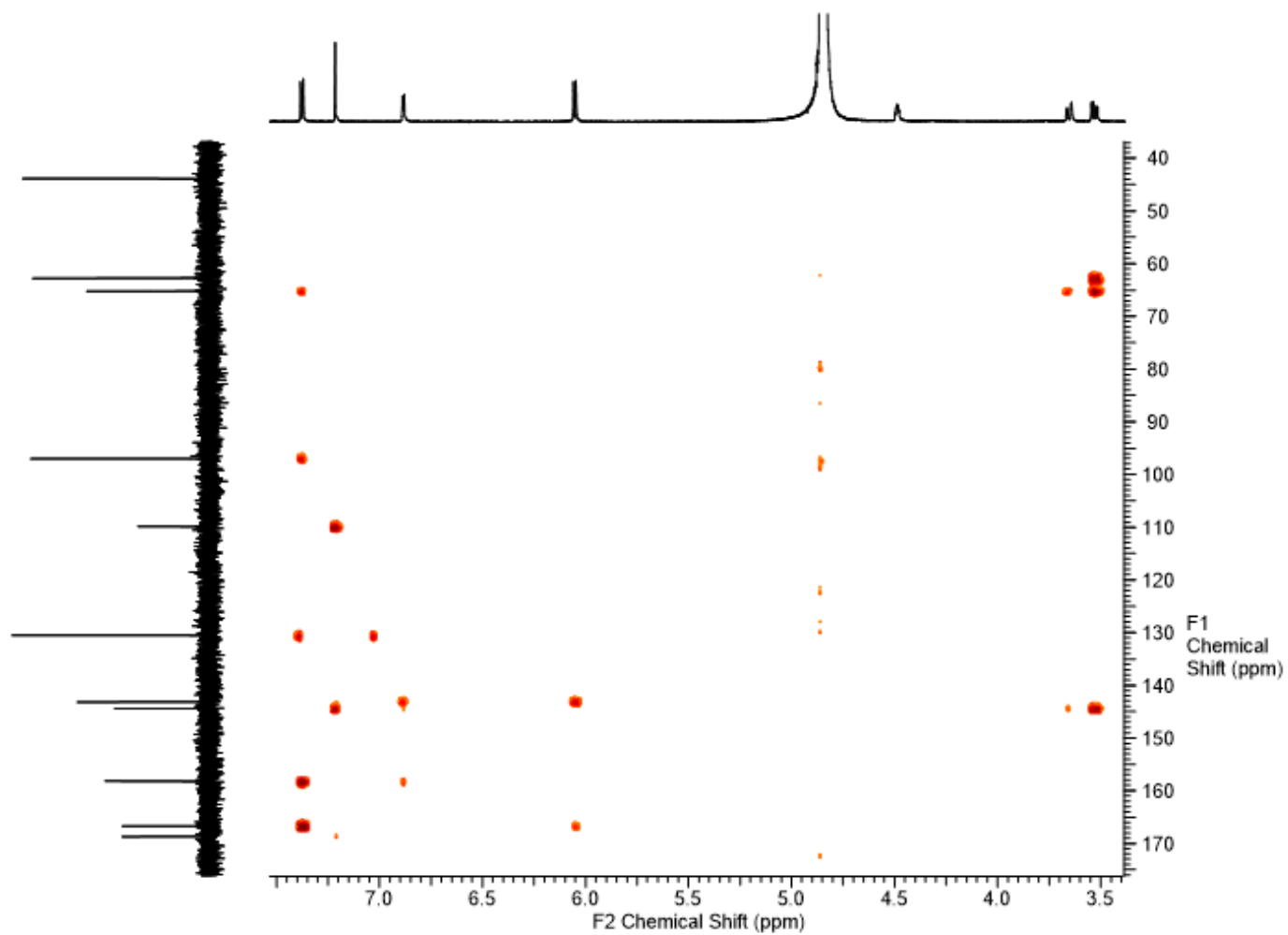
A267: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **176** with DEPT135 spectrum below.



A268: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **176**.

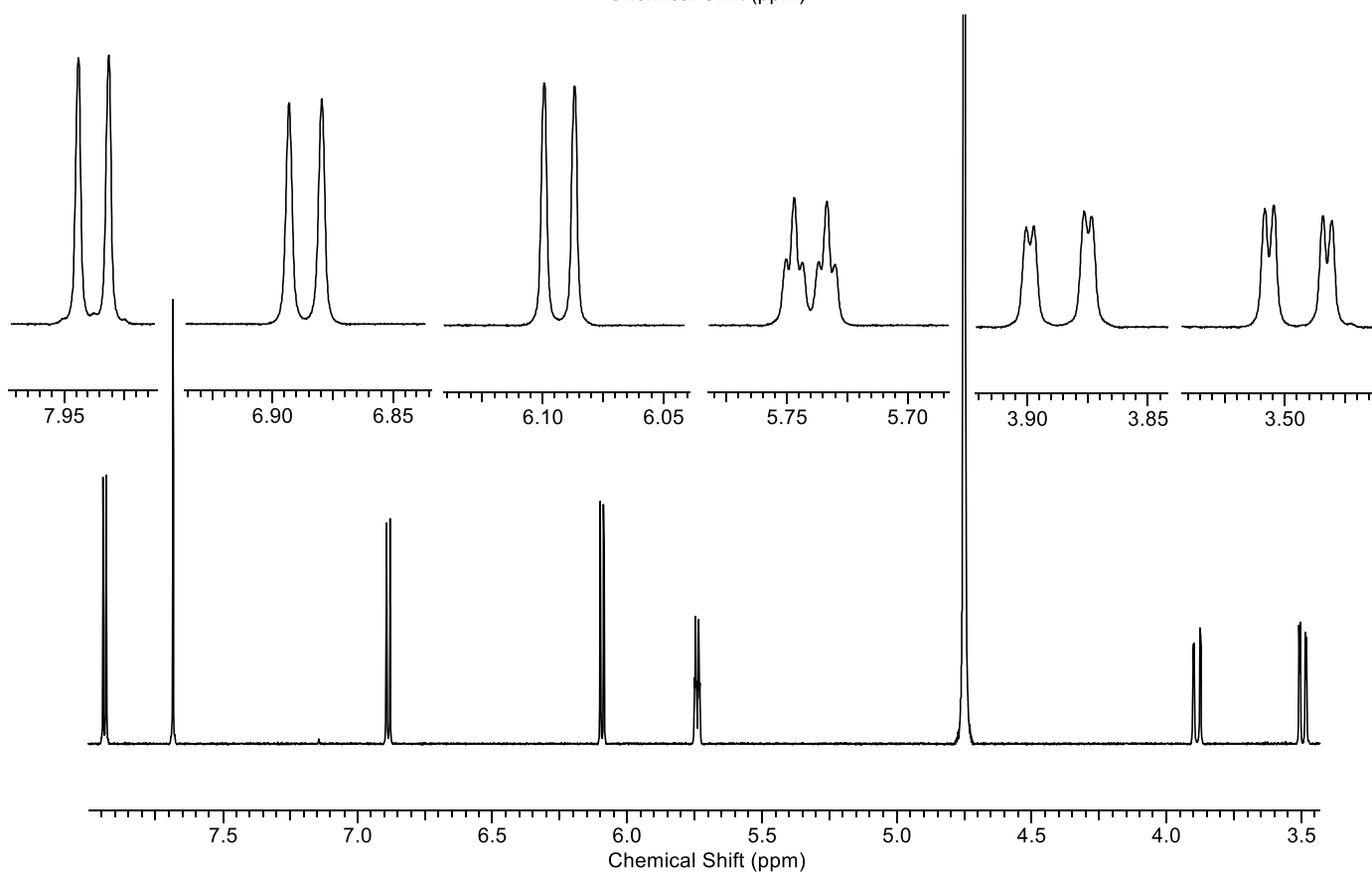
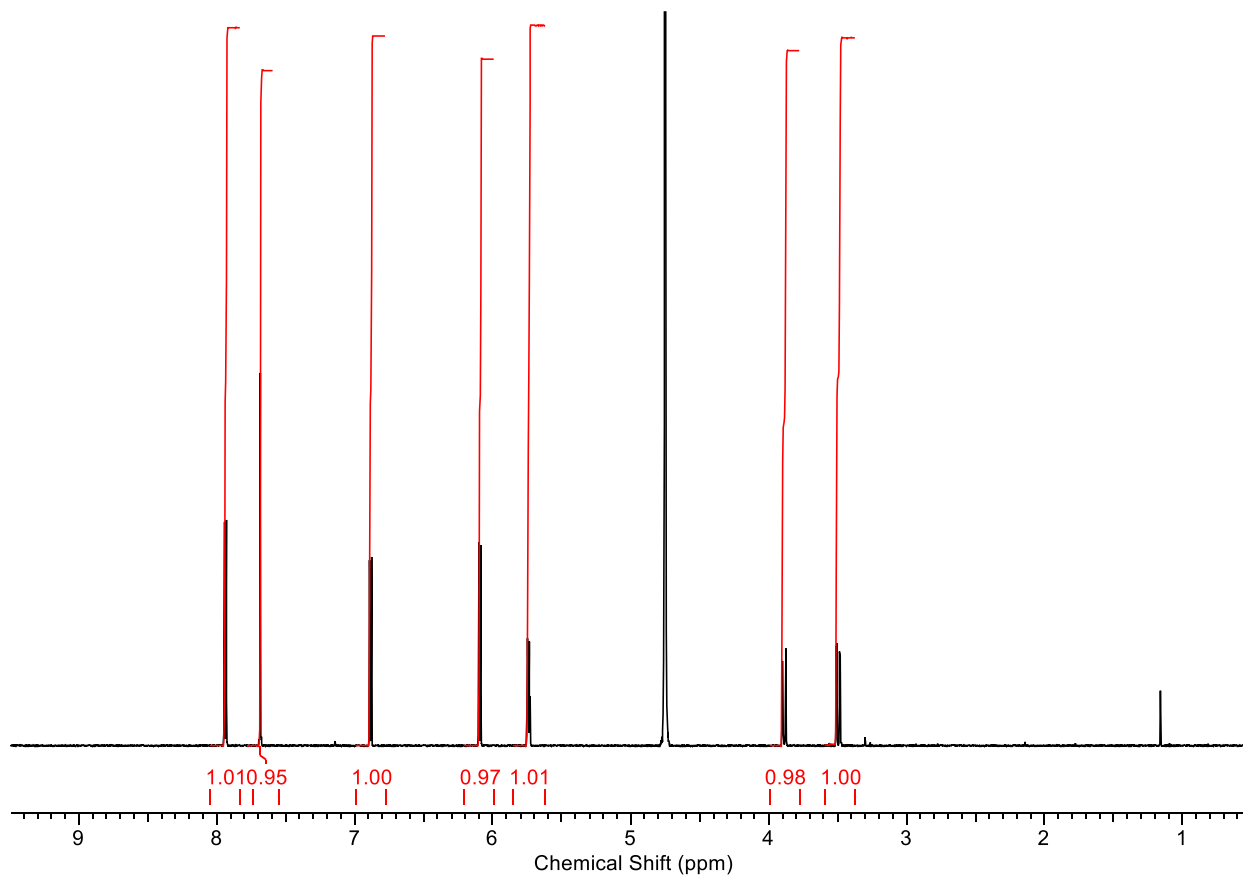


A269: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **176**.

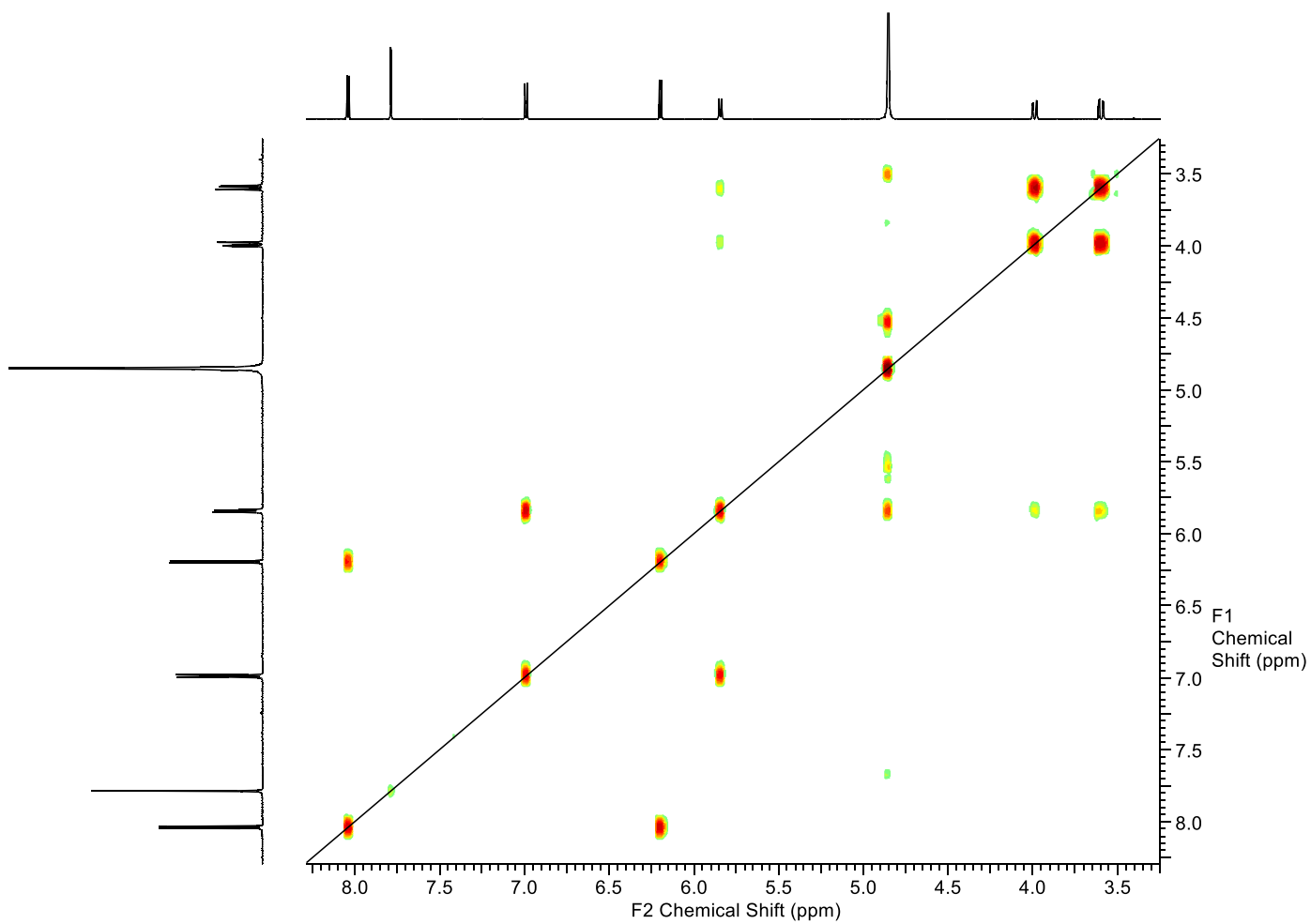


rac-Anhydro-[4-(2,4-dioxo-3,4-dihydropyrimidin-1(2H)-yl)-3-hydroxy-1,2,3,4-tetrahydroimidazo[1,5-a]pyrimidine-8-carboxamide] (185)

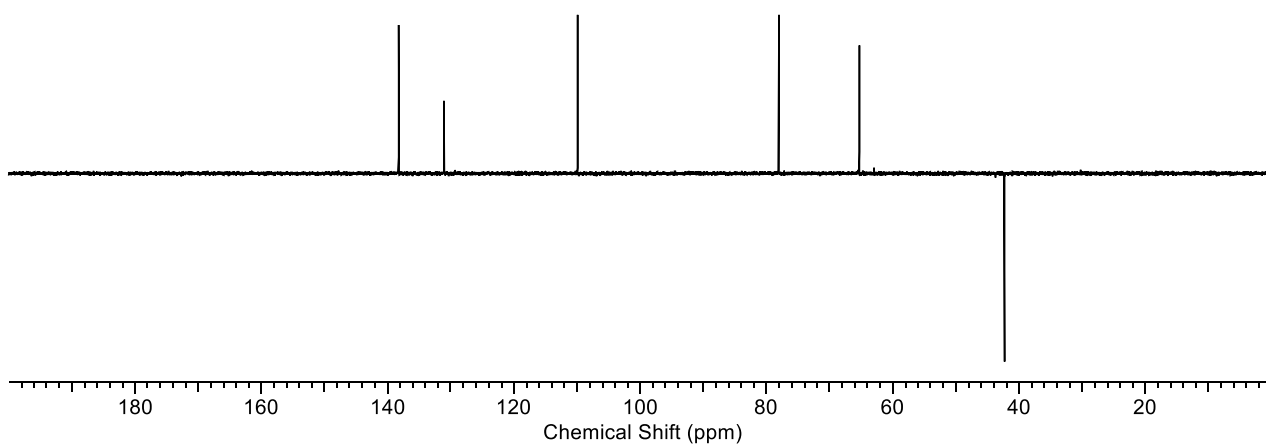
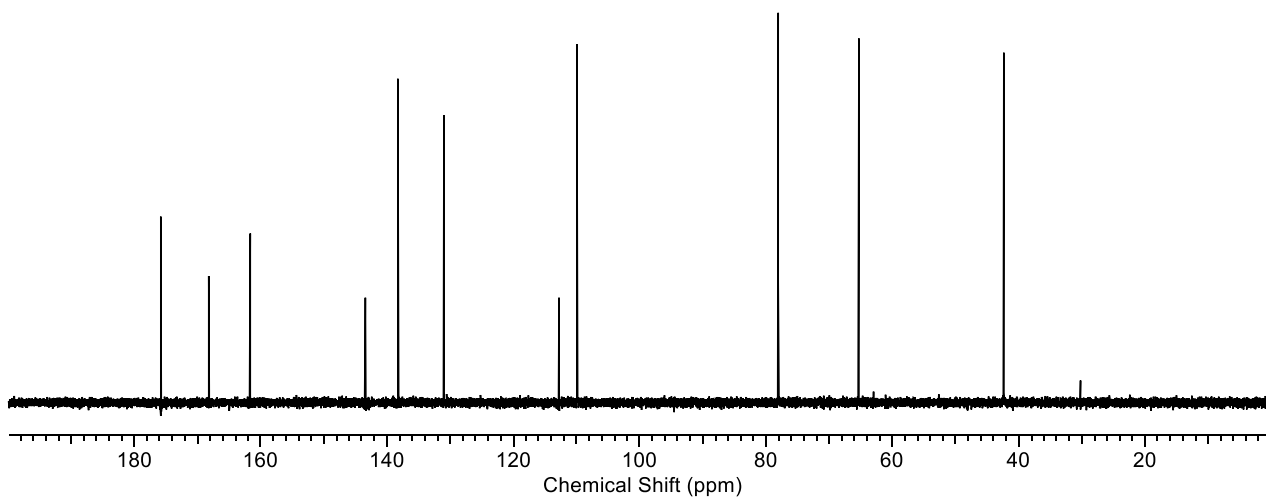
A270: ¹H NMR spectrum (600 MHz, {D₂O}, 0.5 – 9.5 ppm) of **185** with expansion below.



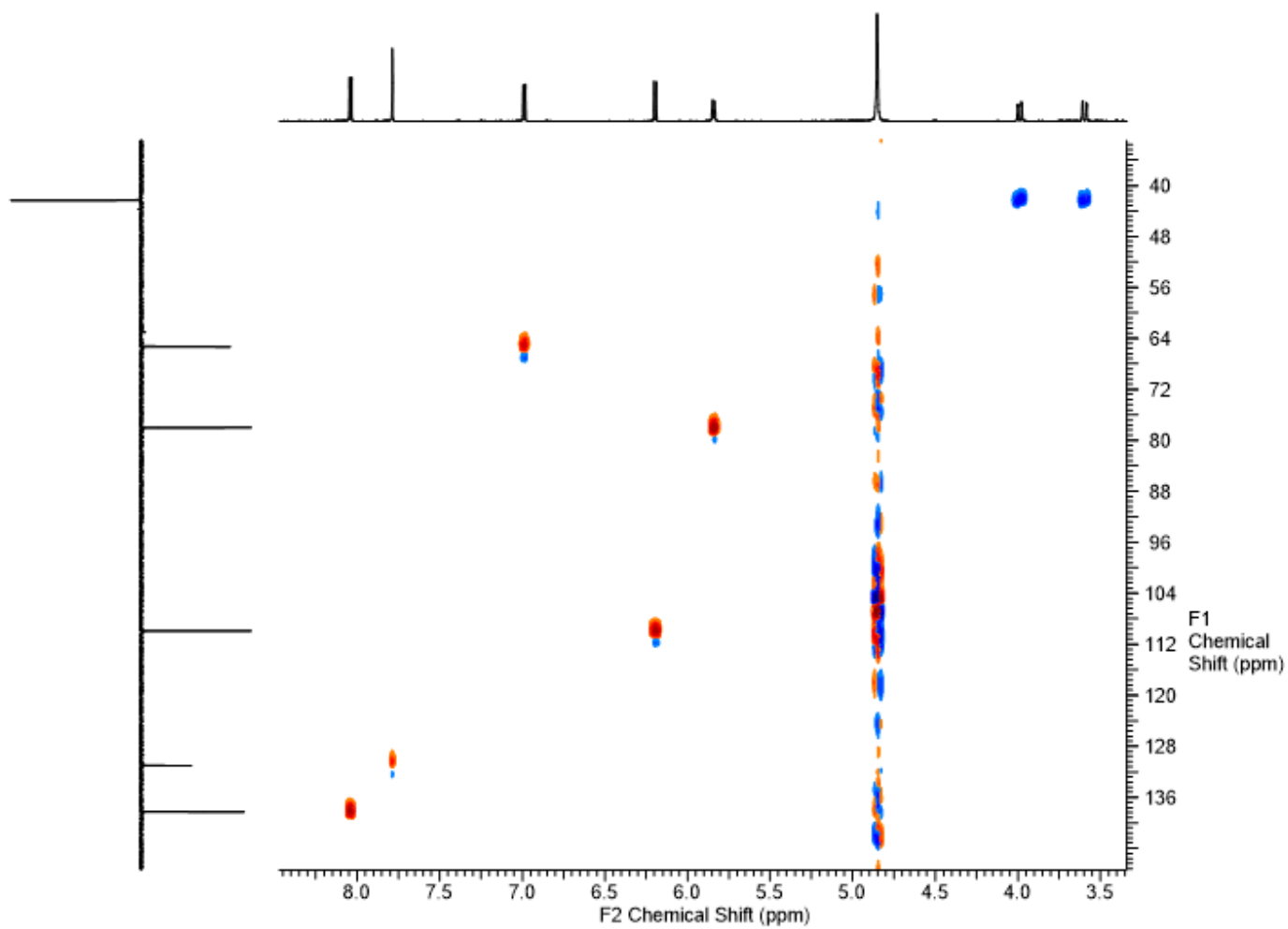
A271: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **185**.



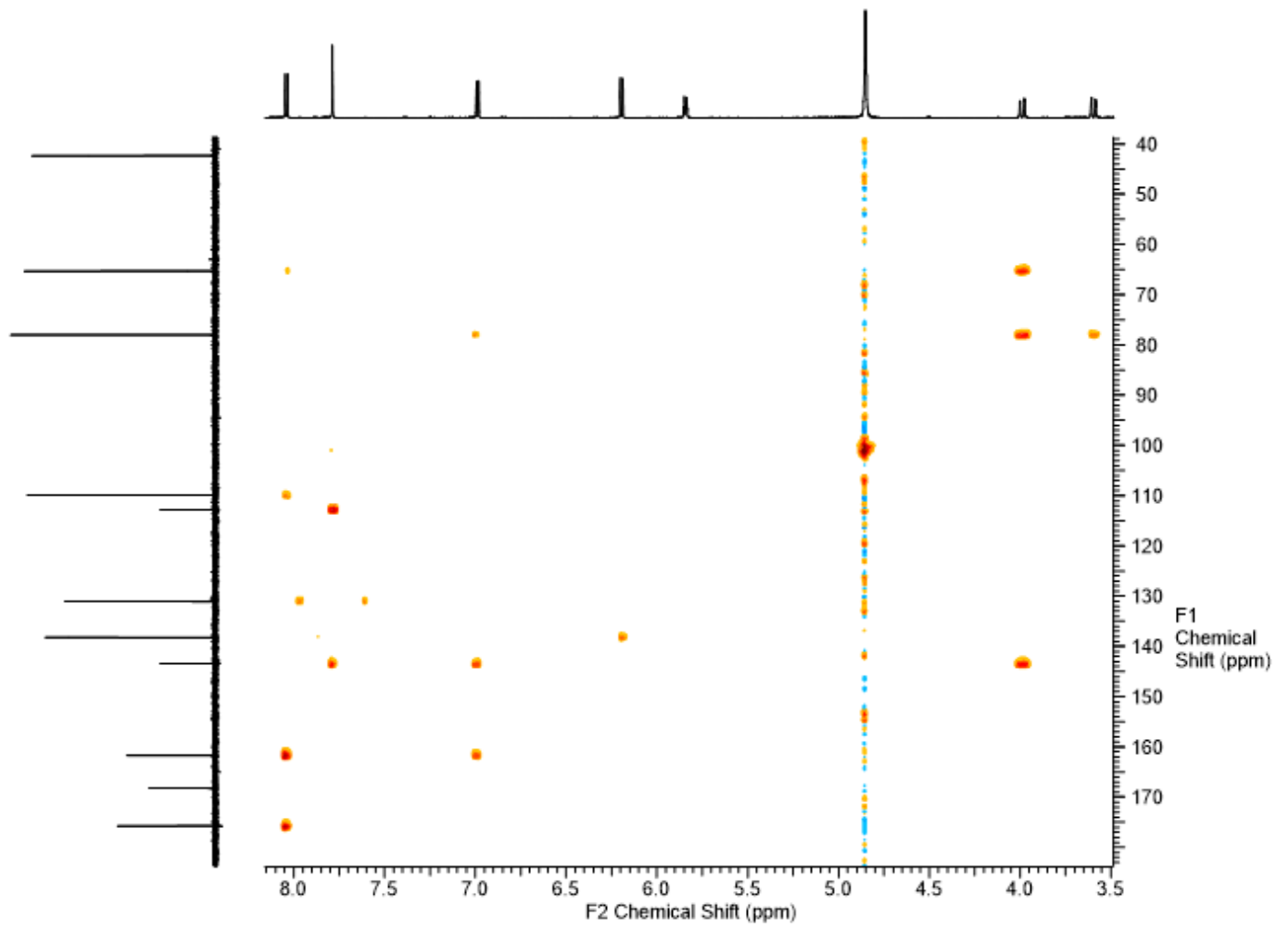
A272: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **185** with DEPT135 spectrum below.



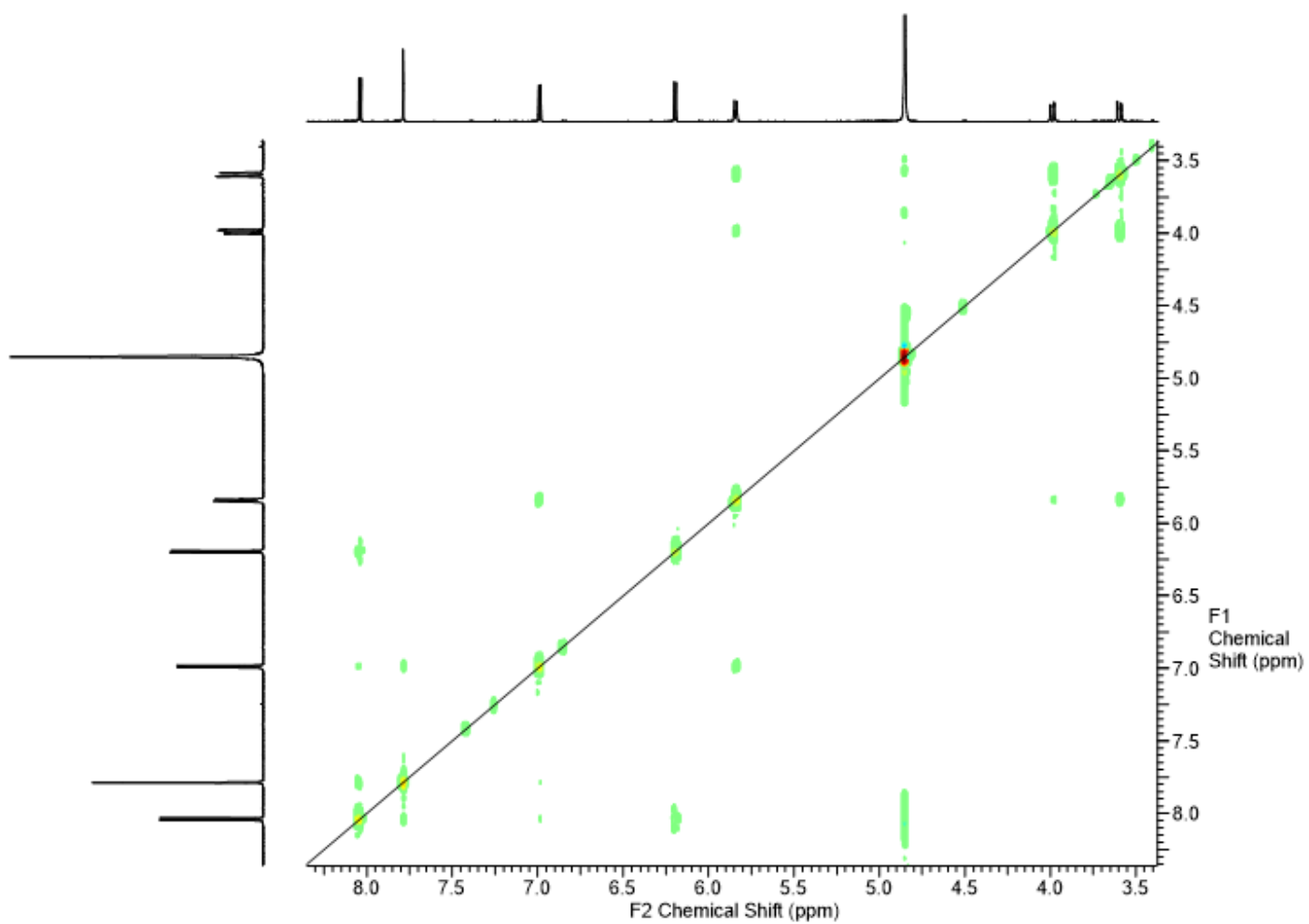
A273: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **185**.



A274: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **185**.



A275: ^1H - ^1H NOESY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **185**.



A276: ESI+ mass spectrum of 185.

Monoisotopic Mass, Even Electron Ions

47 formula(e) evaluated with 1 results within limits (up to 50 closest results for each mass)

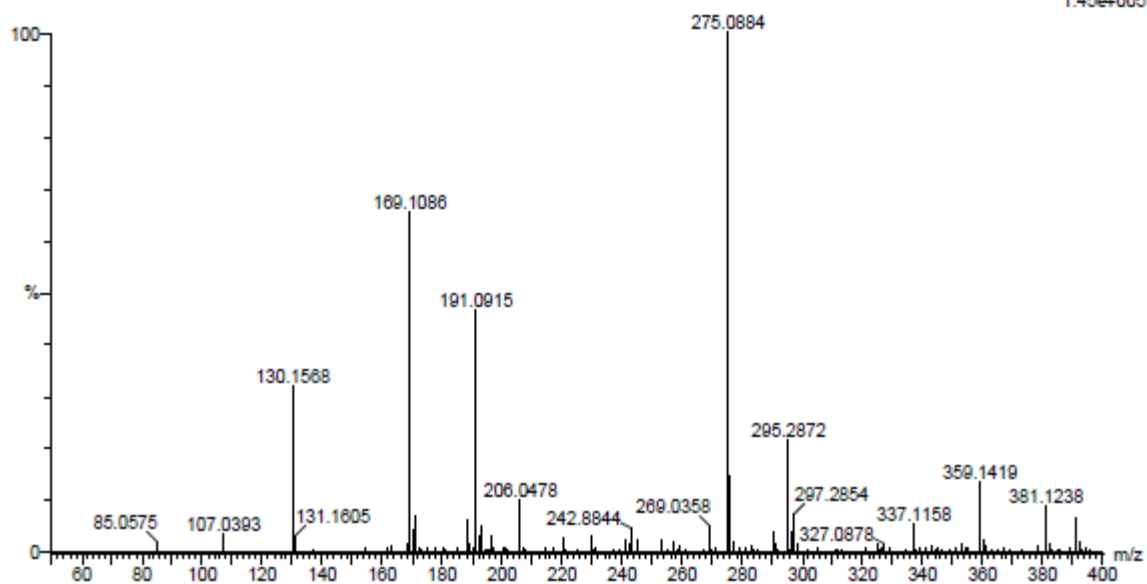
Elements Used:

C: 11-11 H: 0-11 N: 0-6 O: 0-3 Na: 0-1

LCT Premier

12-Jun-2014
ajc359 17 (0.598)

1: TOF MS ES+
1.45e+005

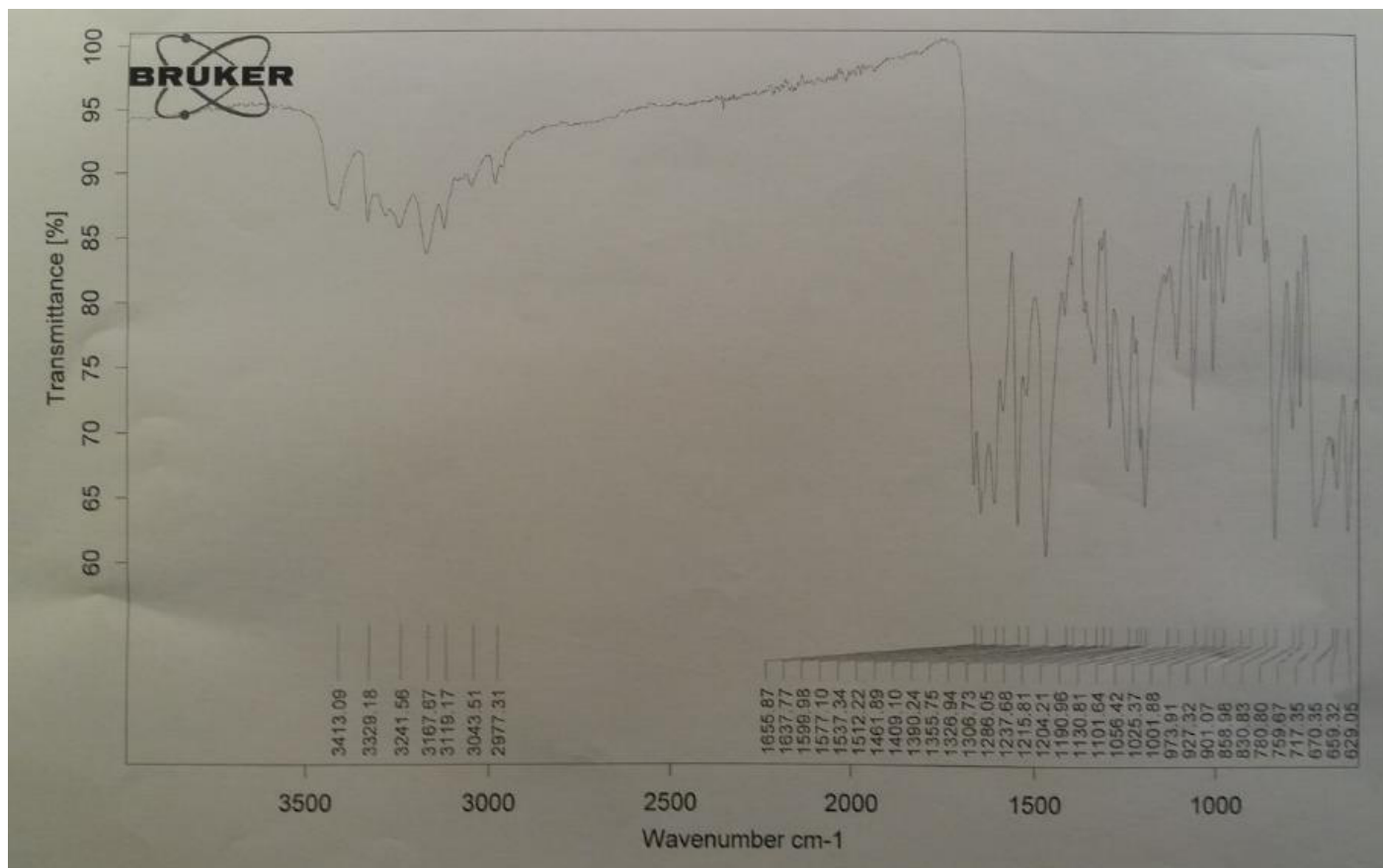


Minimum:

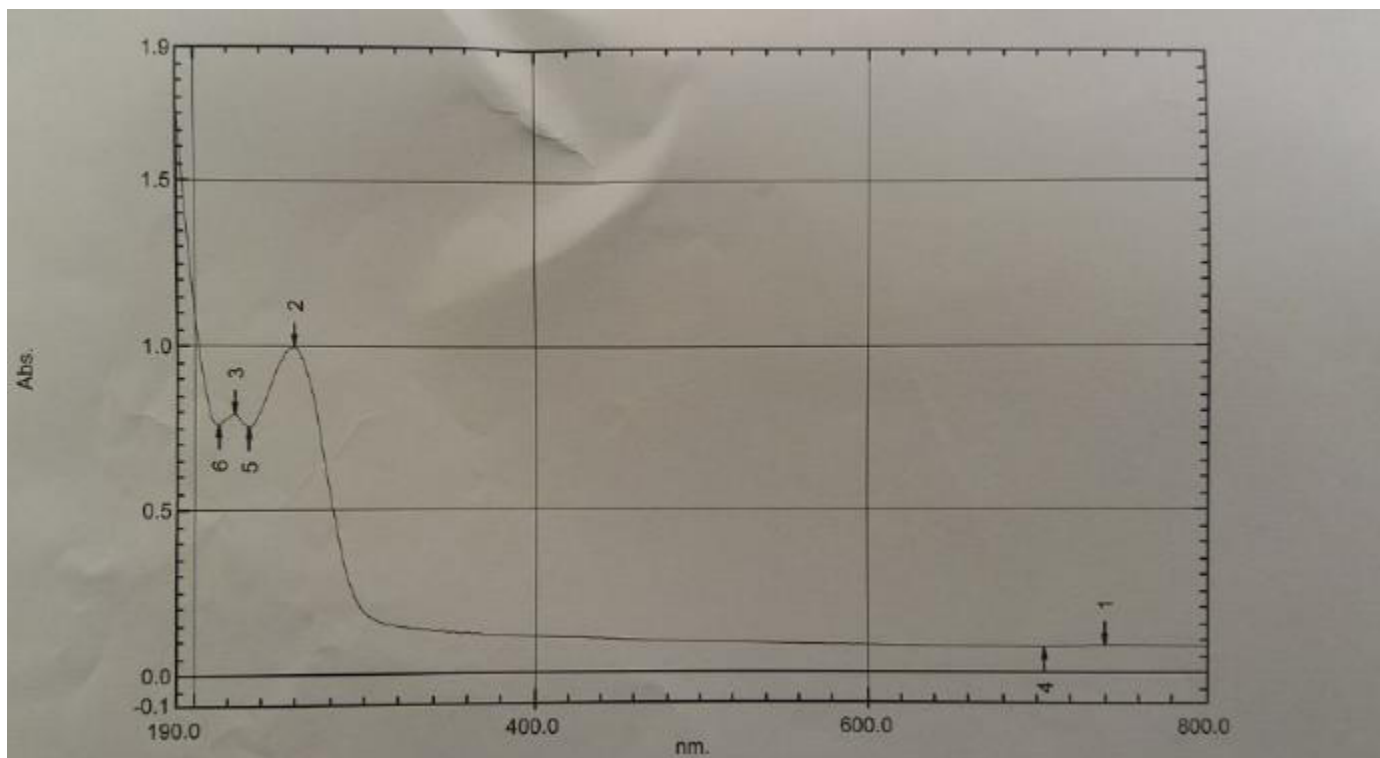
Maximum: 5.0 10.0 50.0 -1.5

Mass	Calc. Mass	mDa	PPM	DBE	i-FIT	Formula
275.0884	275.0892	-0.9	-3.3	9.5	25.9	C11 H11 N6 O3

A277: IR spectrum of 185.

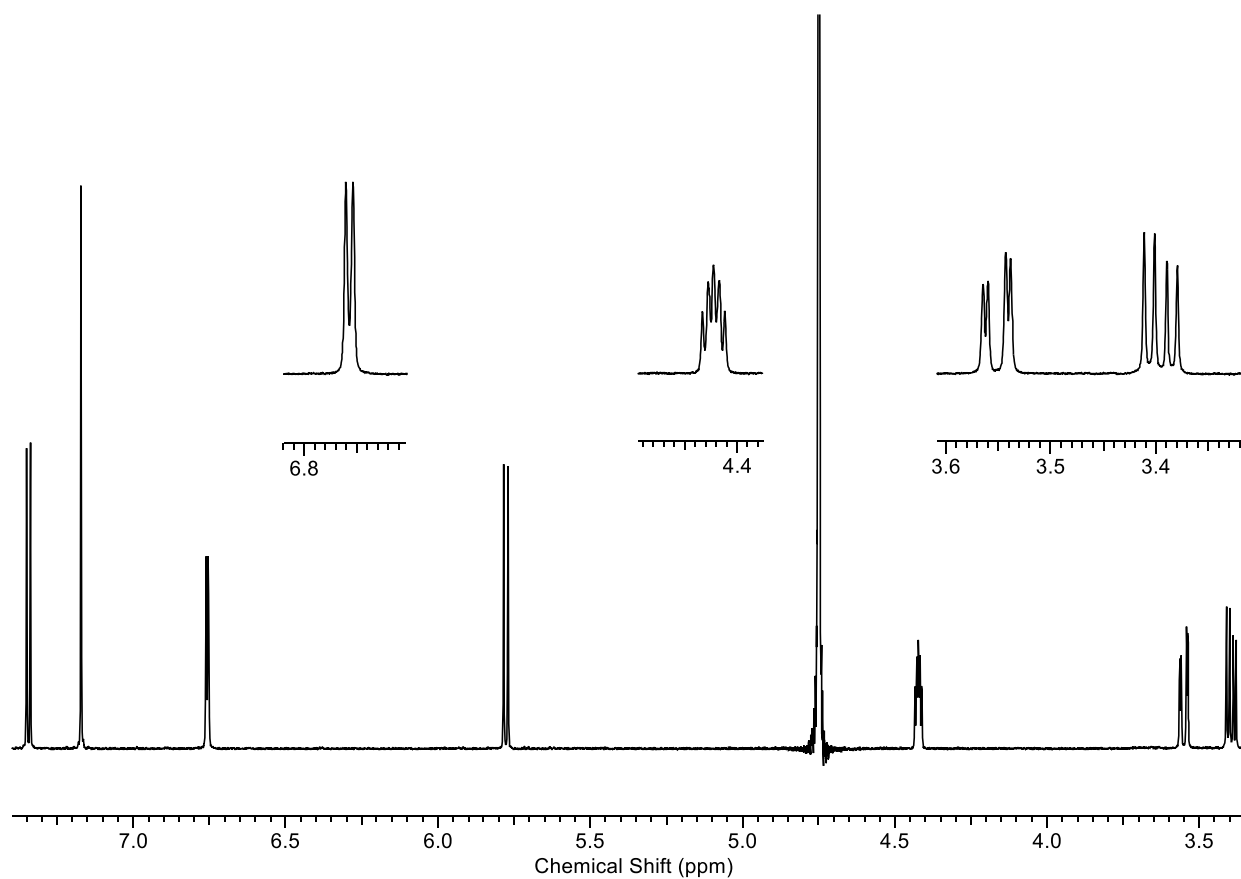
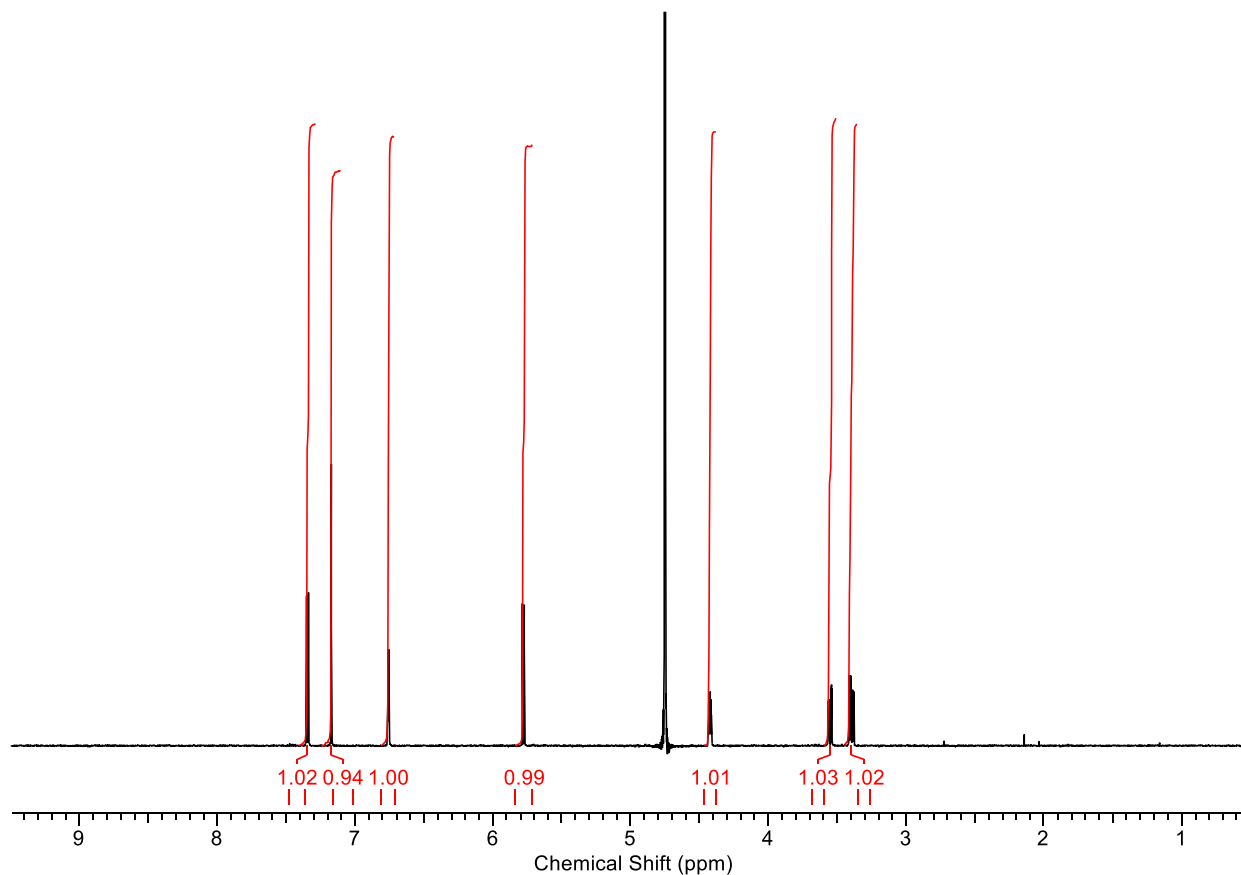


A278: UV-vis spectrum of **185**.

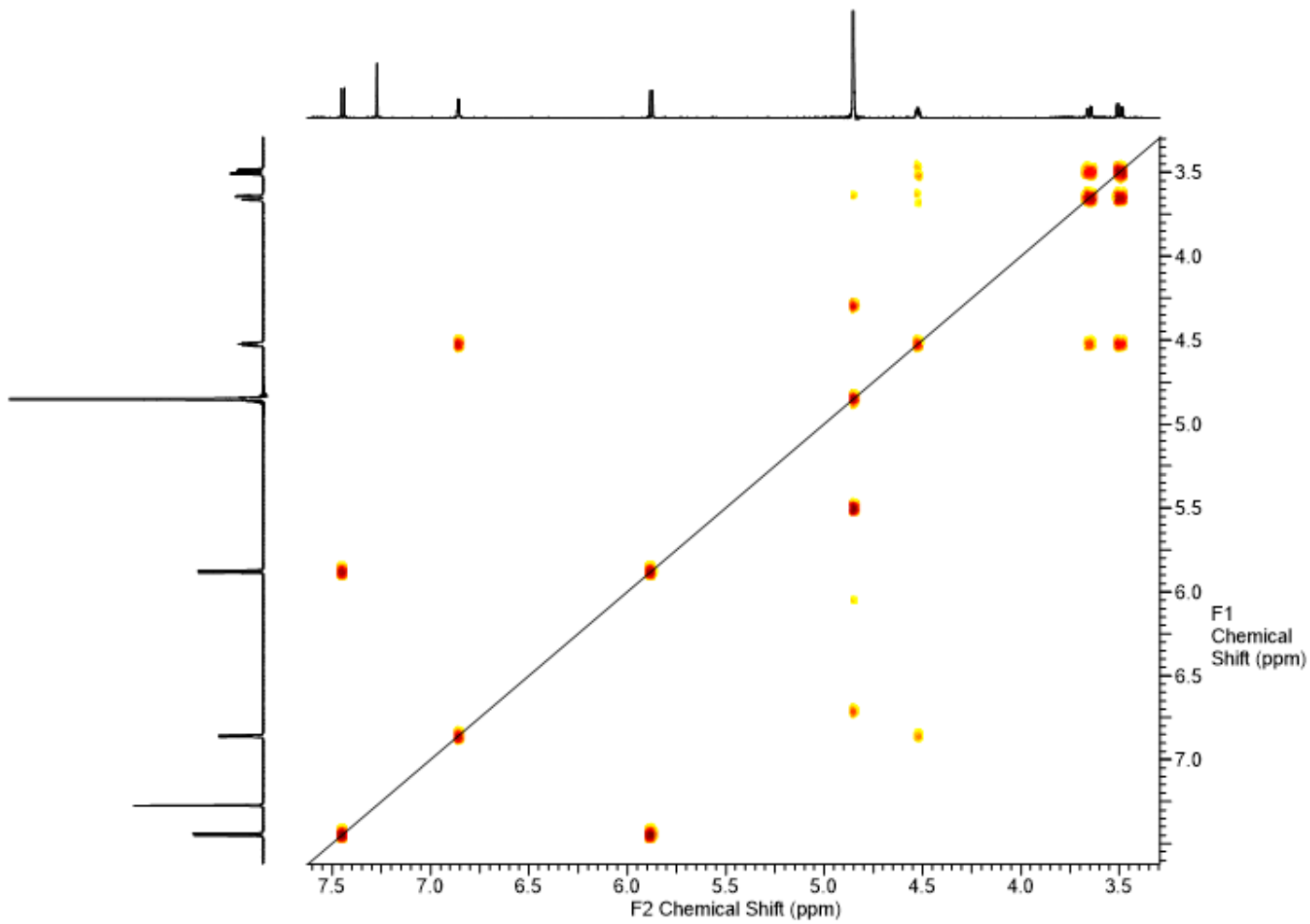


rac-4-(2,4-dioxo-3,4-dihydropyrimidin-1(2H)-yl)-3-hydroxy-1,2,3,4-tetrahydroimidazo[1,5-a]pyrimidine-8-carboxamide (184)

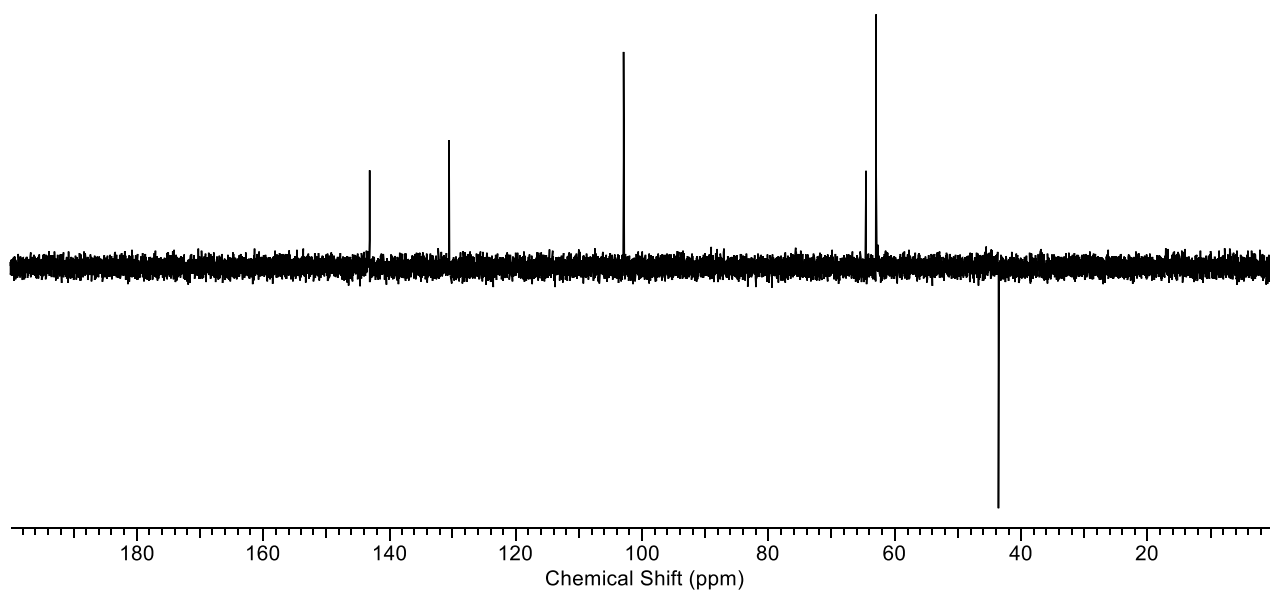
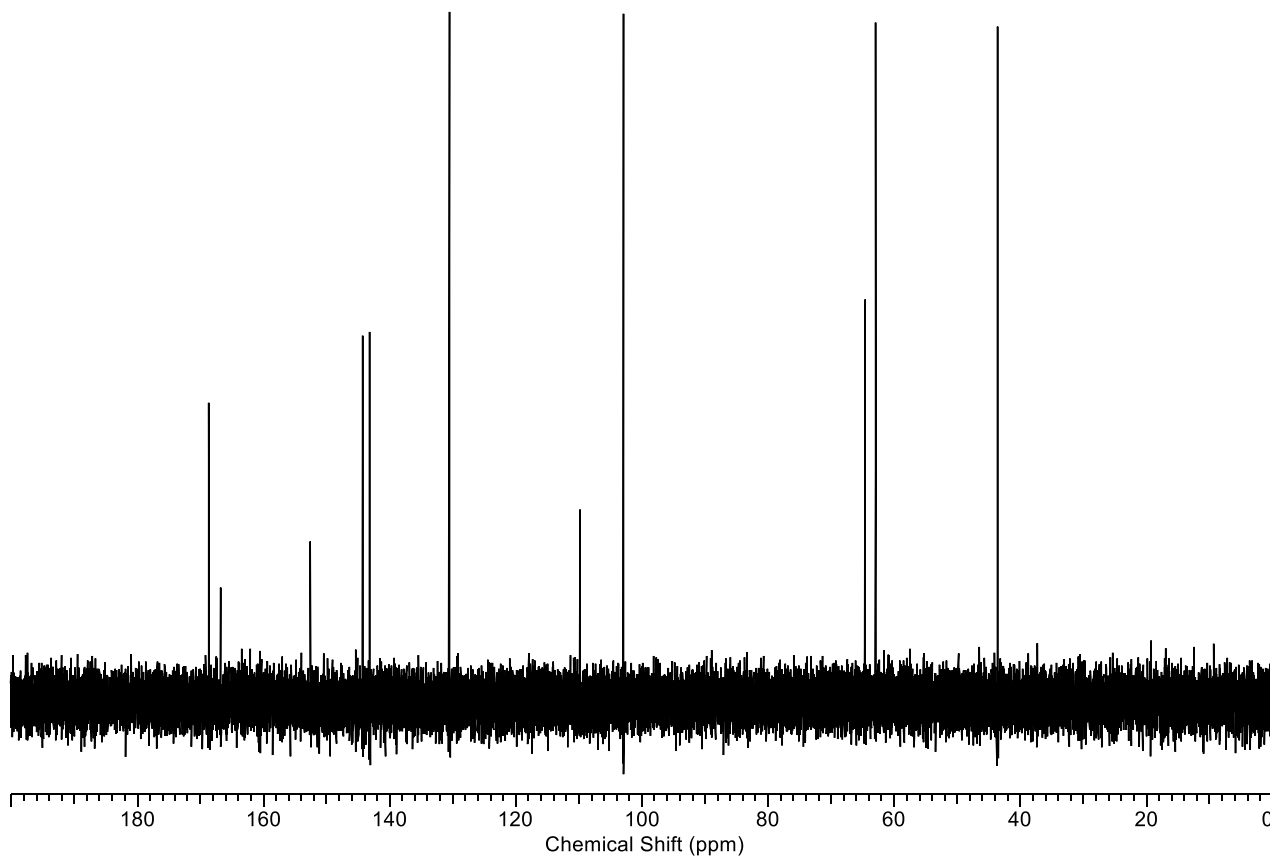
A279: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **184** with expansion below.



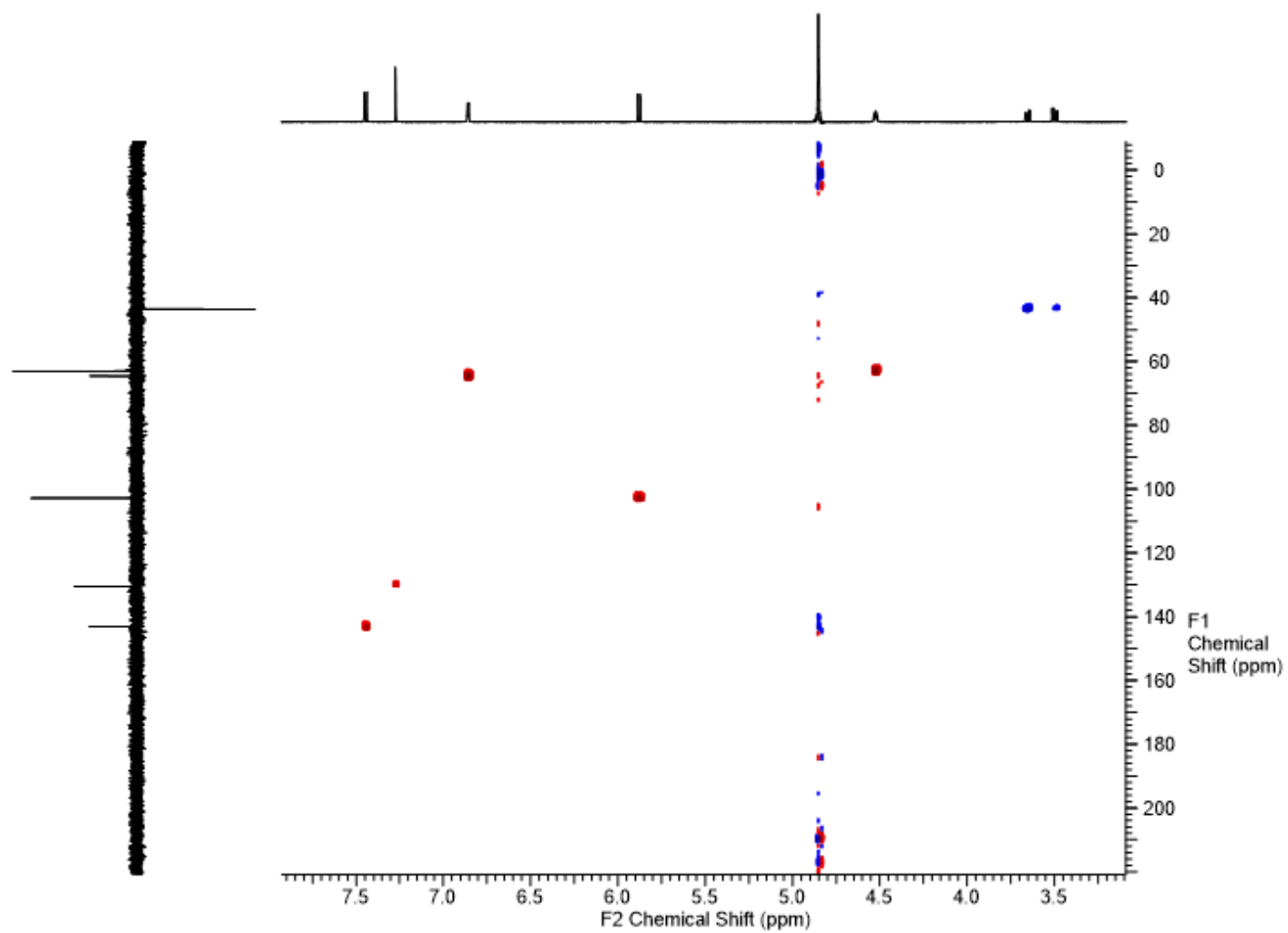
A280: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **184**.



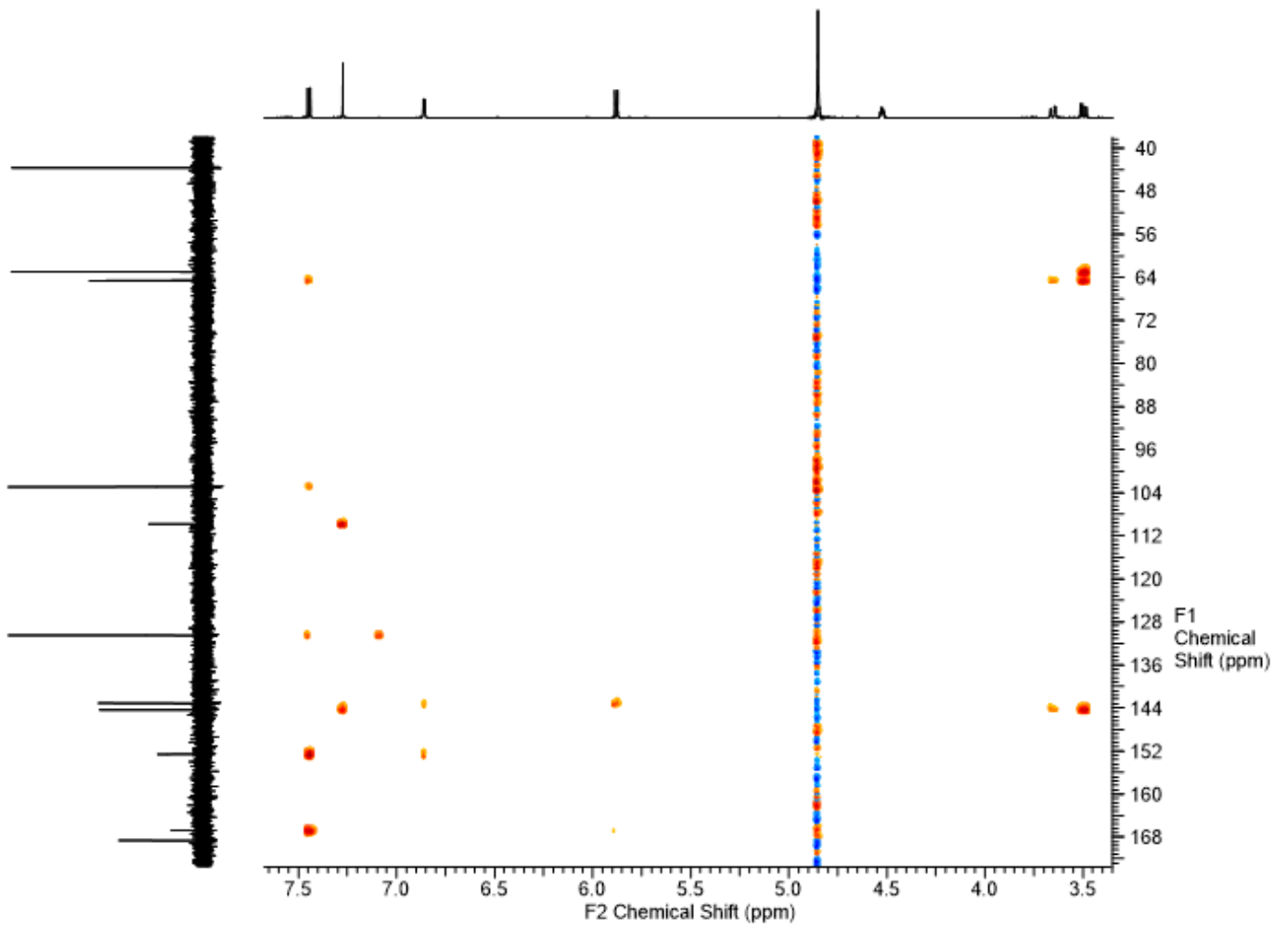
A281: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **184** with DEPT135 spectrum below.



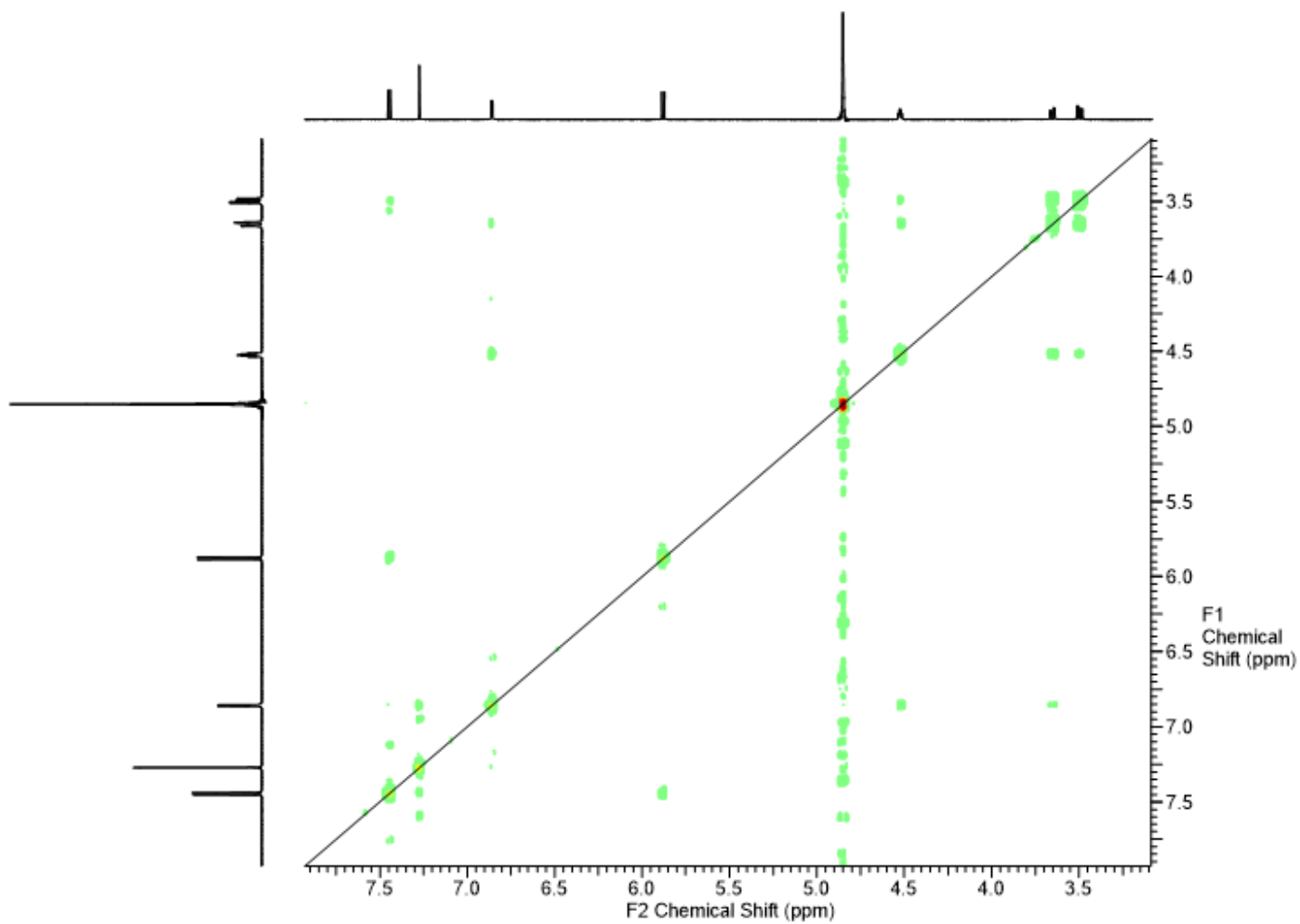
A282: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **184**.



A283: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **184**.



A284: ^1H - ^1H NOESY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **184**.



A285: ESI+ mass spectrum of 184.

Monoisotopic Mass, Even Electron Ions

287 formula(e) evaluated with 2 results within limits (up to 50 closest results for each mass)

Elements Used:

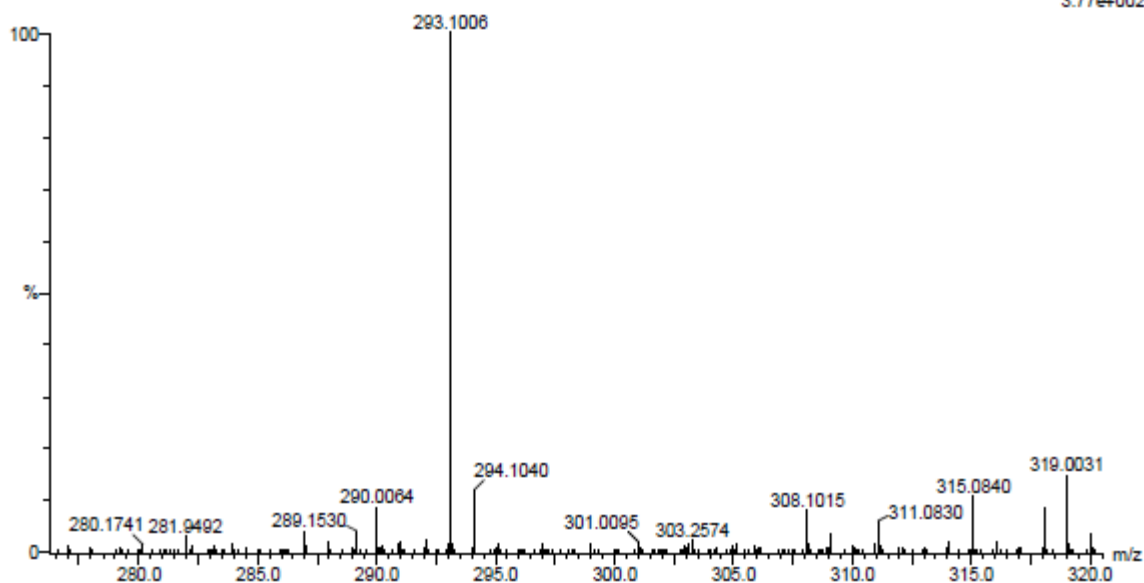
C: 0-30 H: 0-30 N: 0-8 O: 0-5 Na: 0-1

LCT Premier

24-Jun-2014

AJC363 21 (0.738)

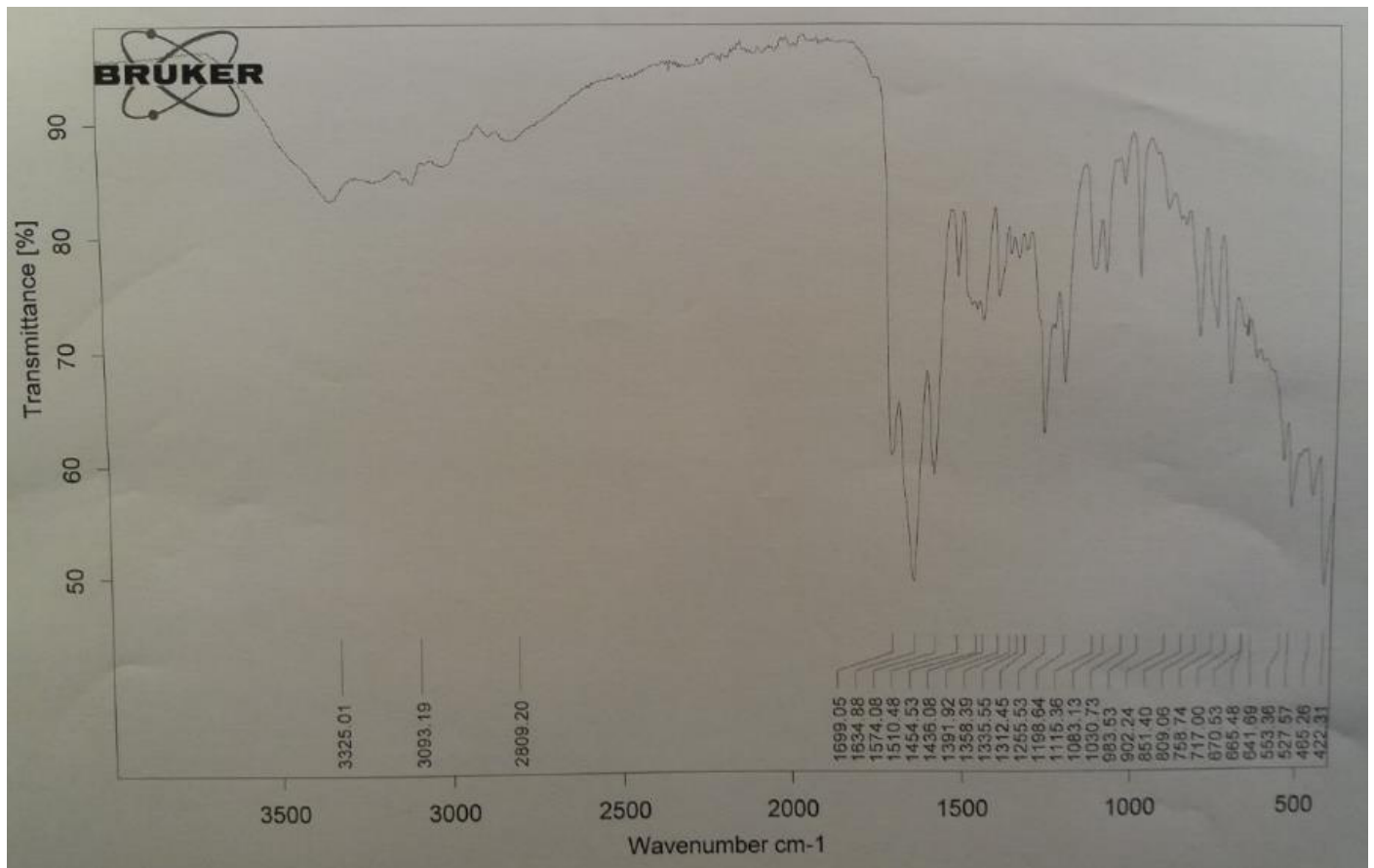
1: TOF MS ES+
3.77e+002



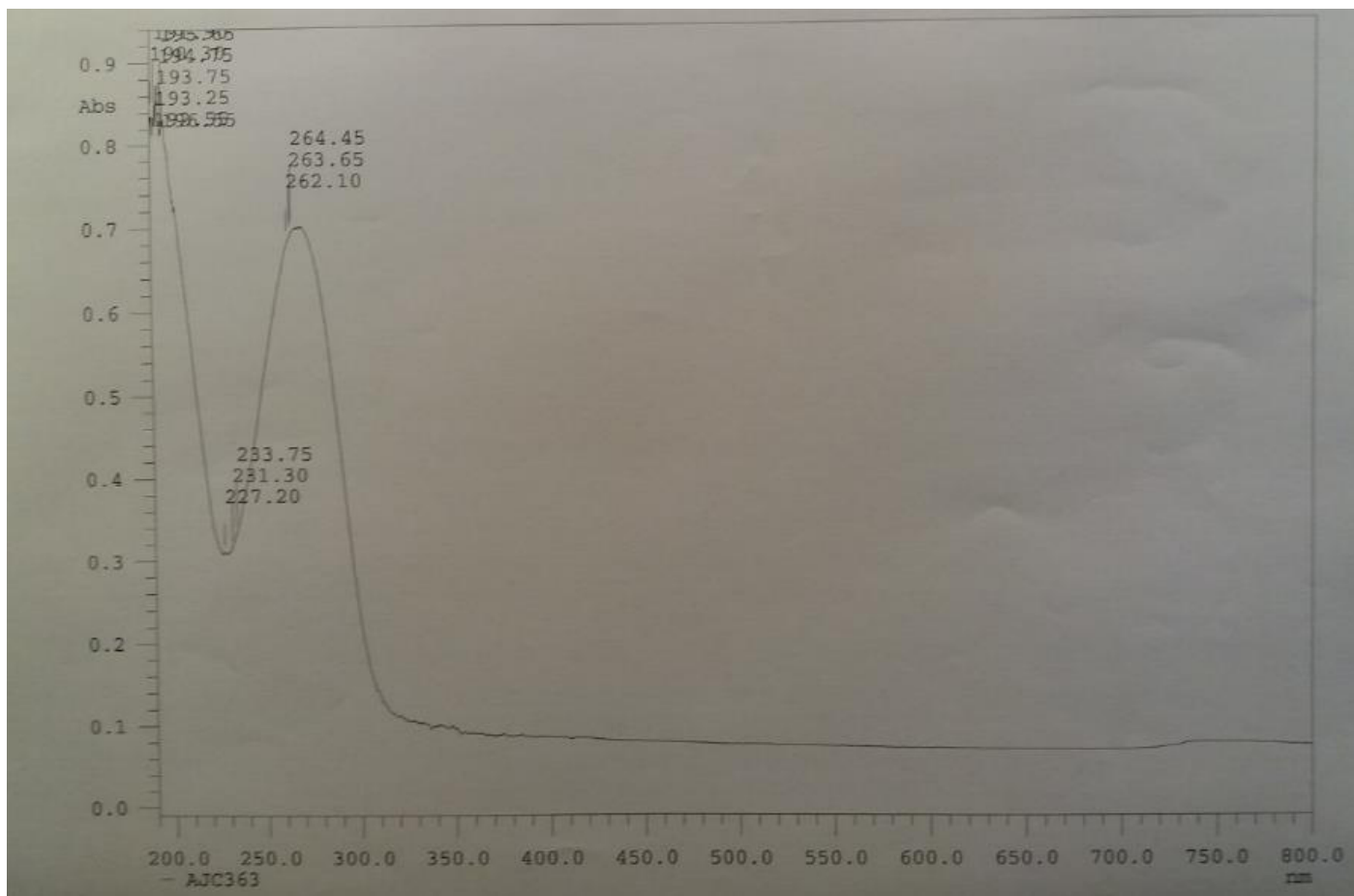
Minimum: -1.5
Maximum: 5.0 10.0 50.0

Mass	Calc. Mass	mDa	PPM	DBE	i-FIT	Formula
293.1006	293.0998	0.8	2.7	8.5	1.2	C11 H13 N6 O4
	293.1014	-0.8	-2.7	9.5	3.9	C14 H14 N4 O2 Na

A286: IR spectrum of 184.

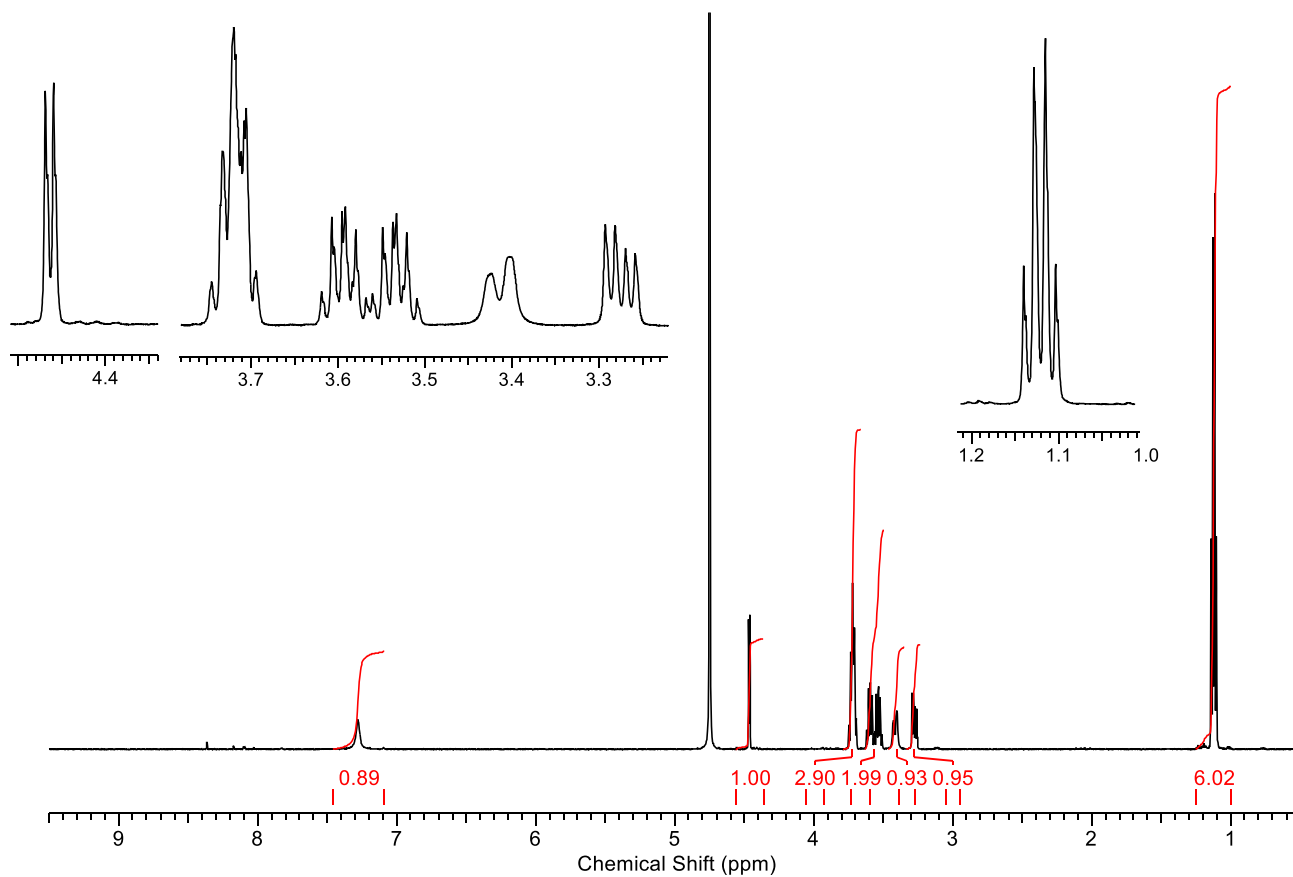


A287: UV-vis spectrum of 184.

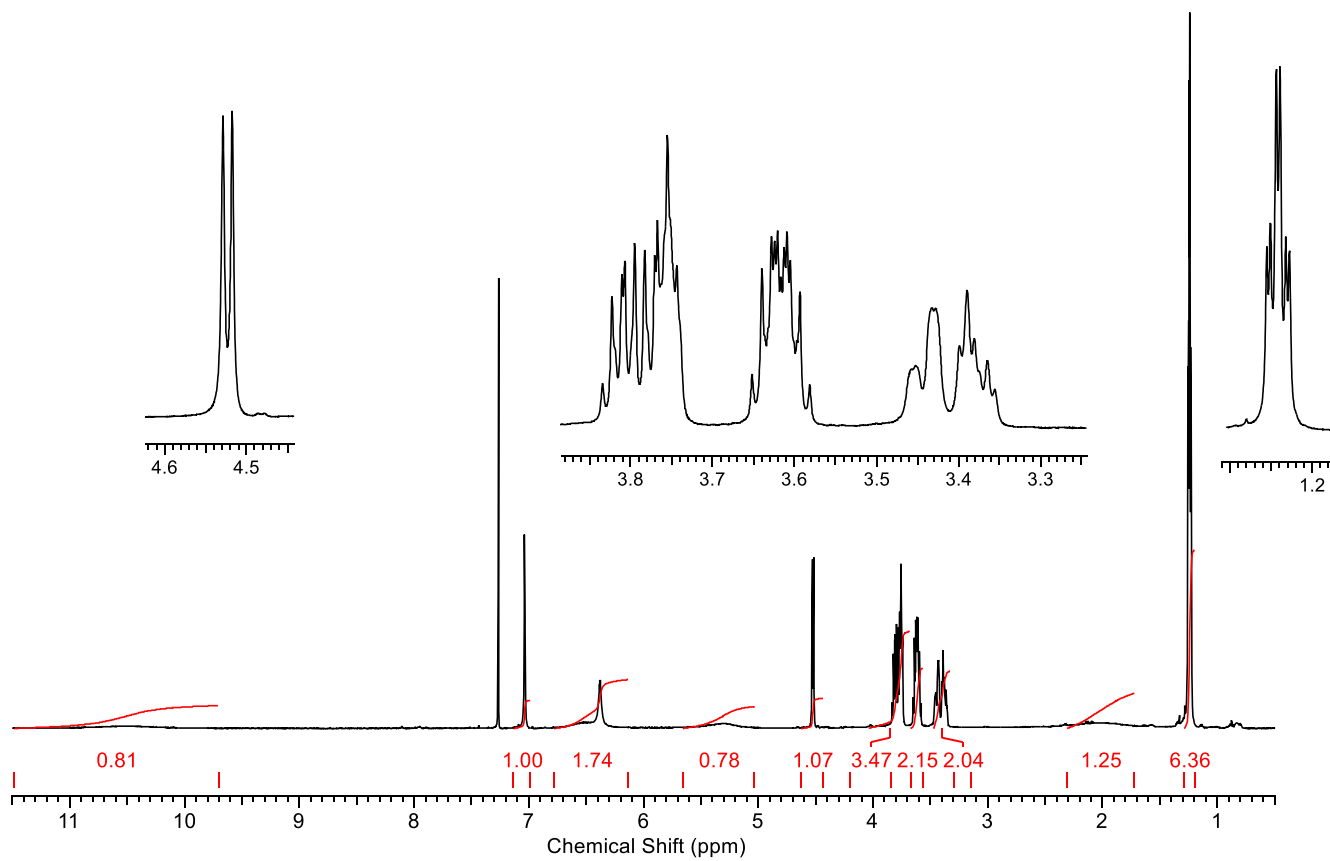


rac-5-((3,3-diethoxy-2-hydroxypropyl)amino)-1H-imidazole-4-carboxamide (191)

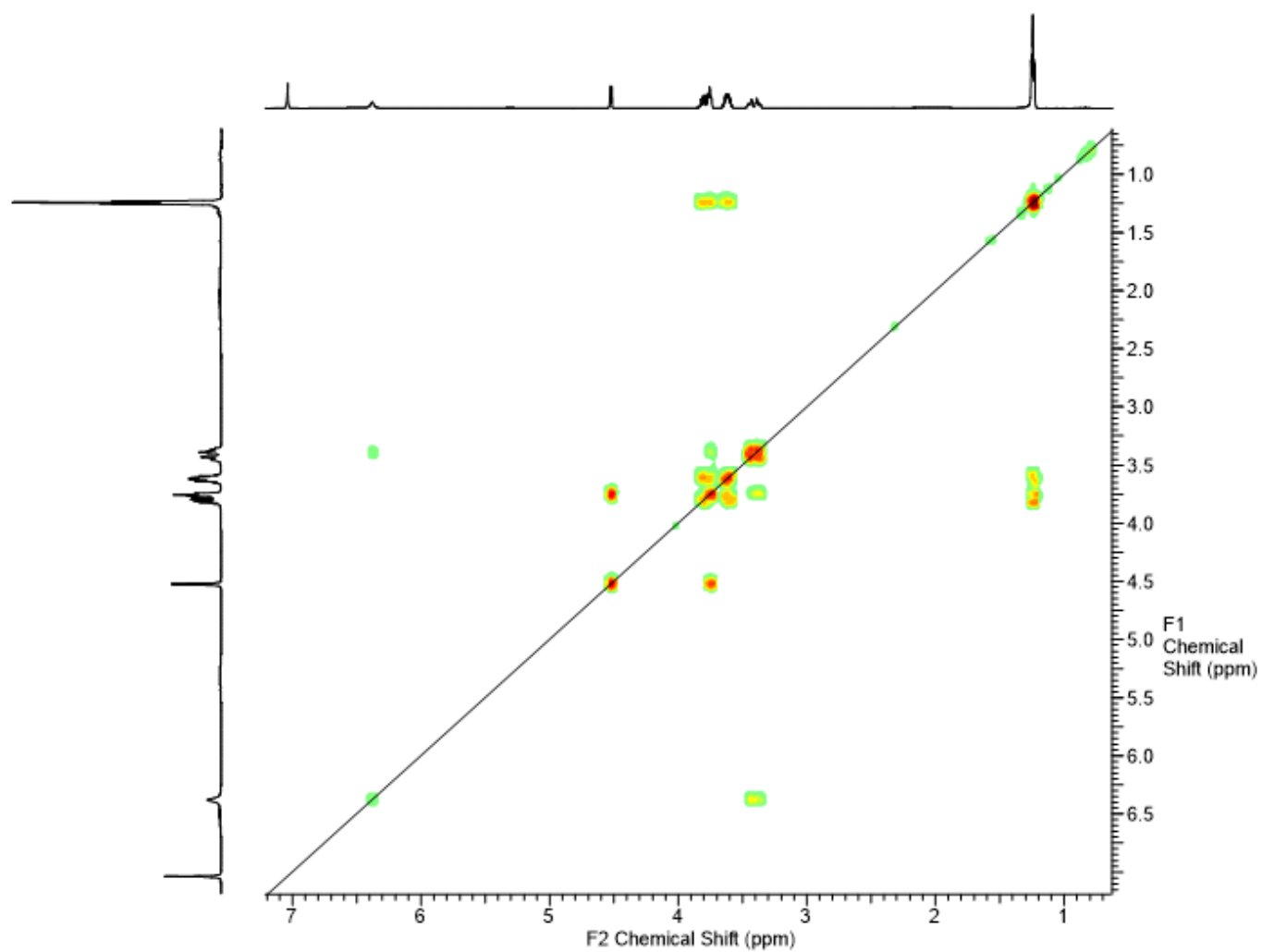
A288: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **191** with expansion overlaid.



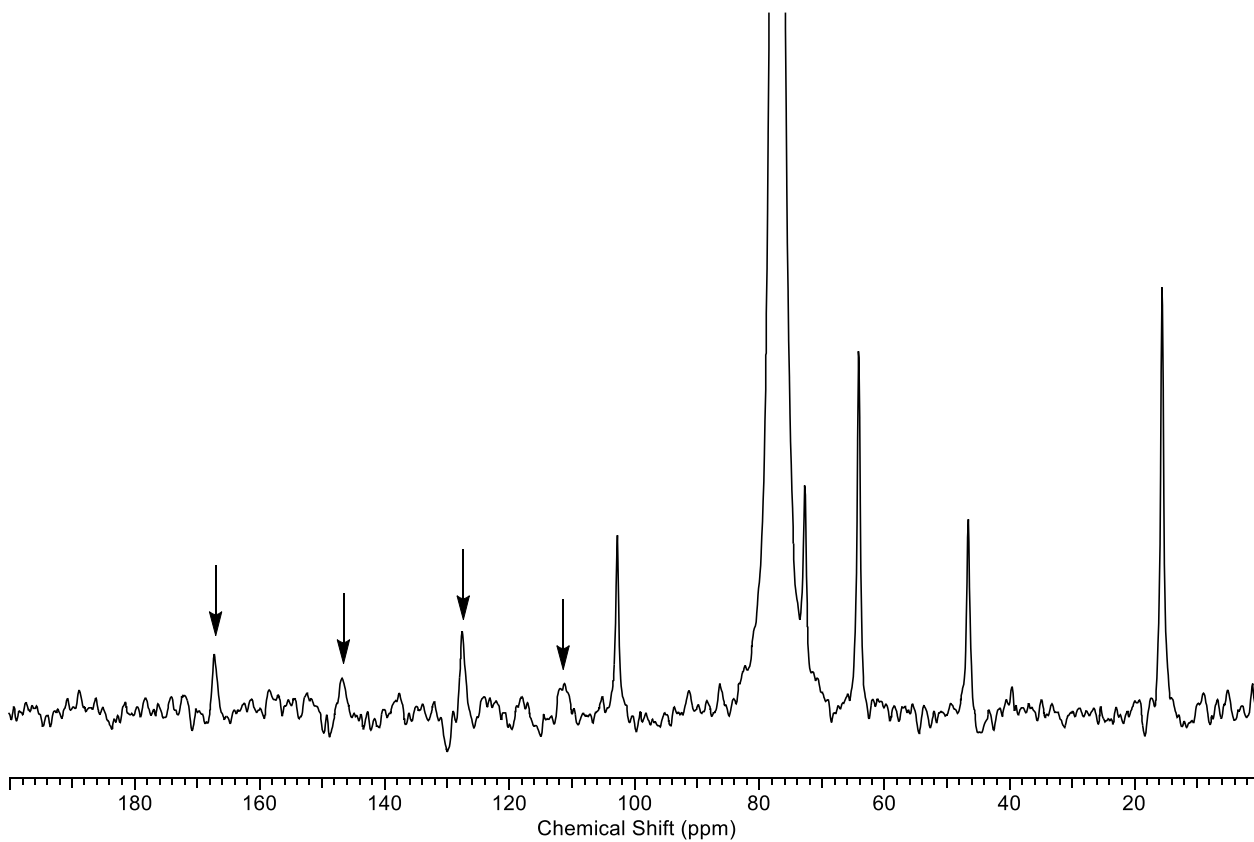
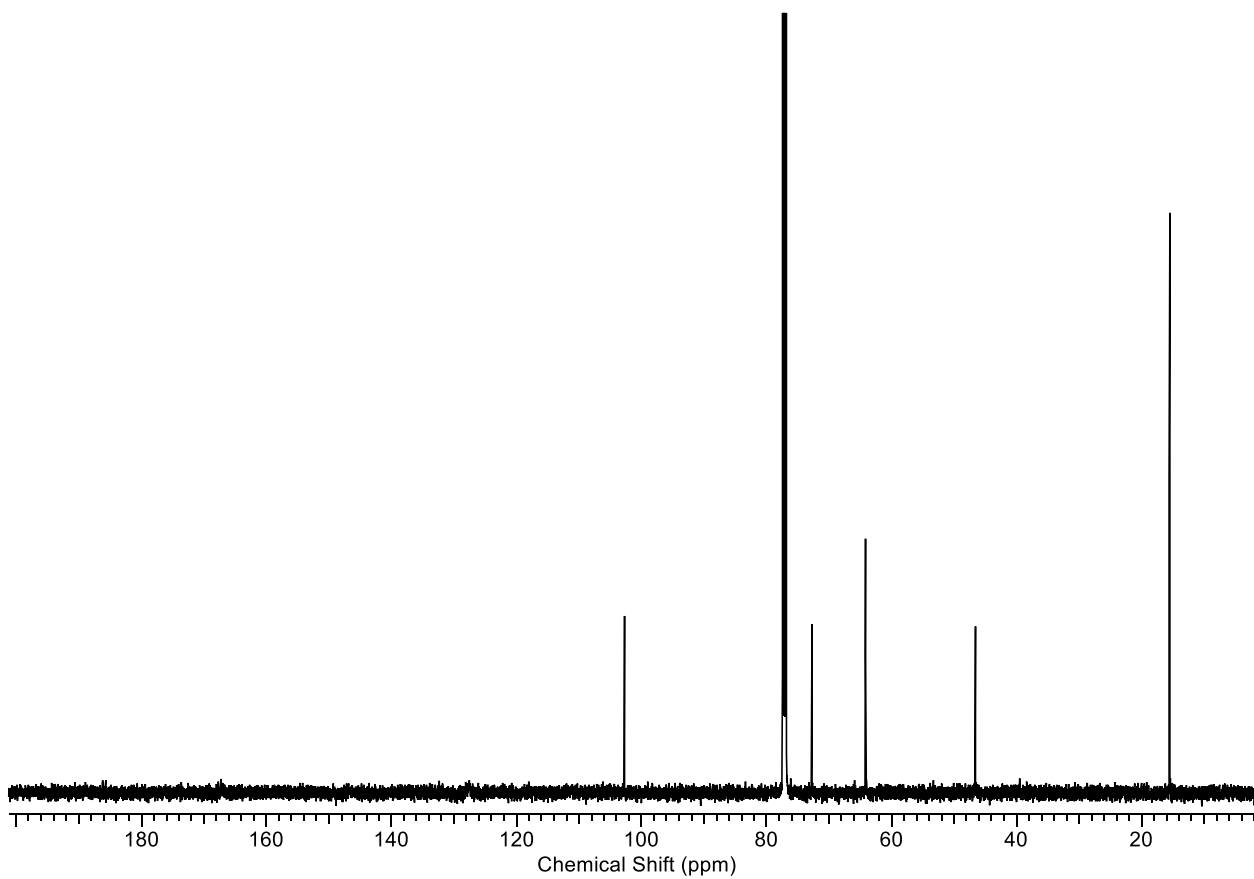
A289: ^1H NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$, 0.5 – 11.5 ppm) of **191** with expansion overlaid.



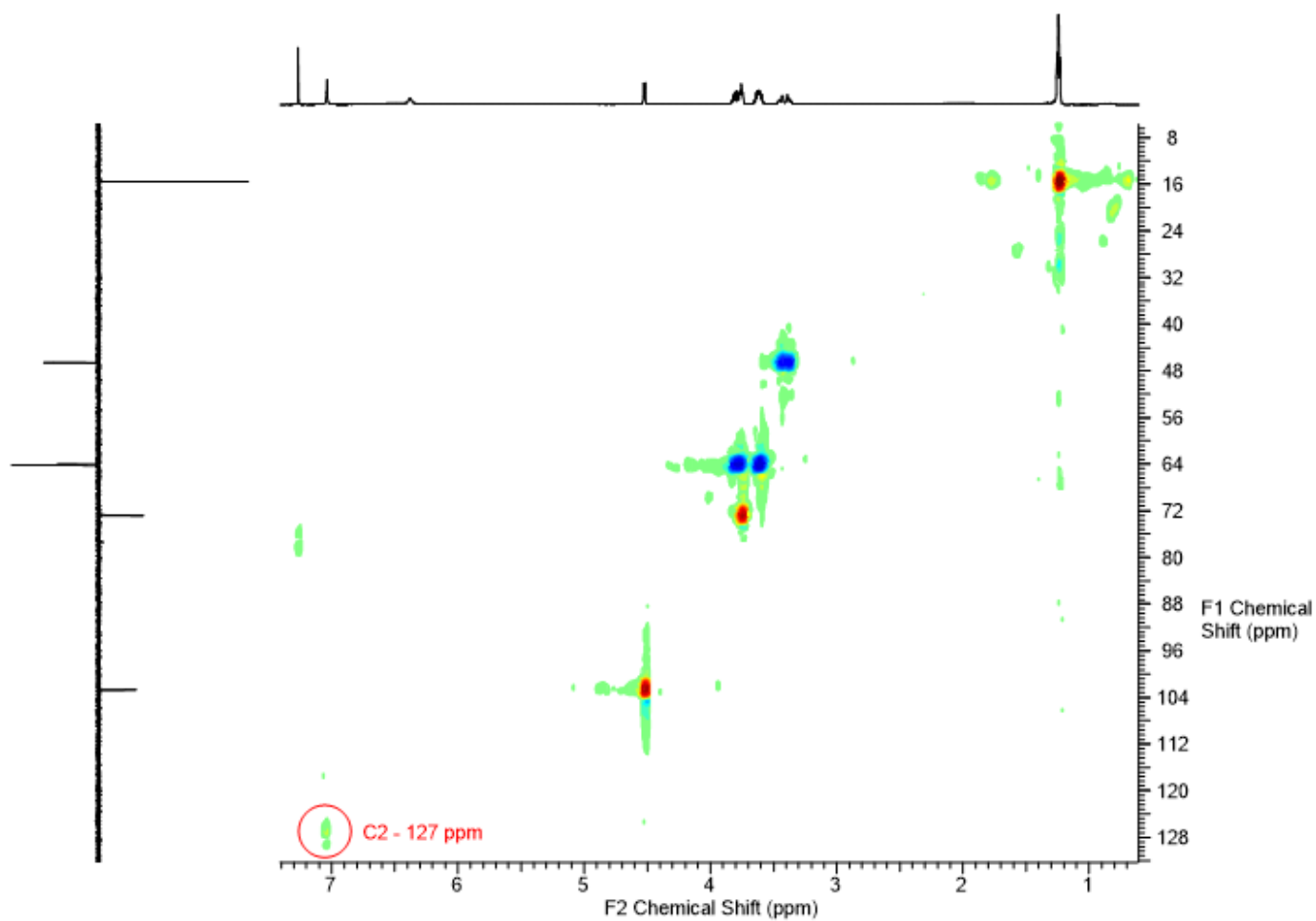
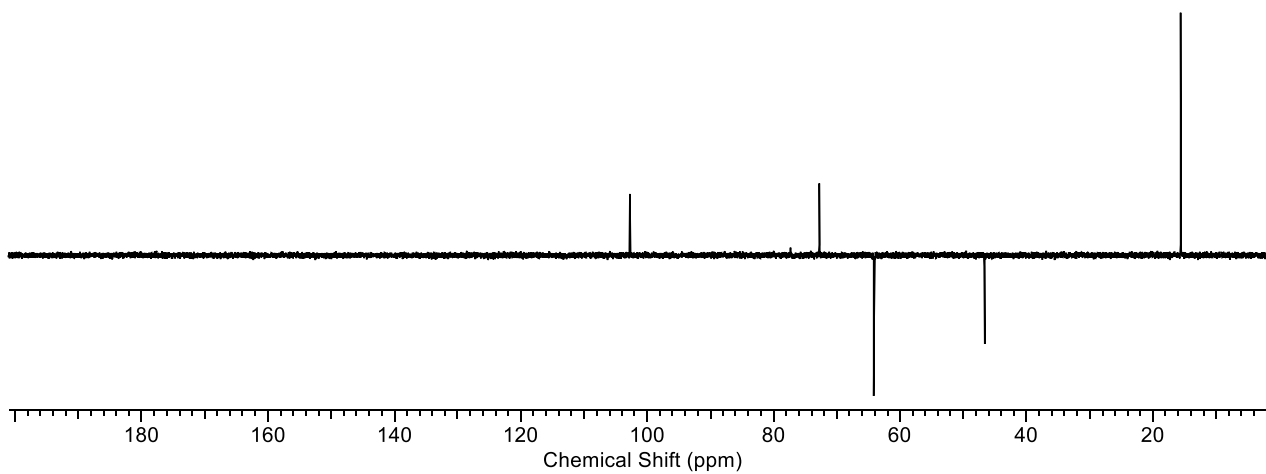
A290: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$) of **191**.



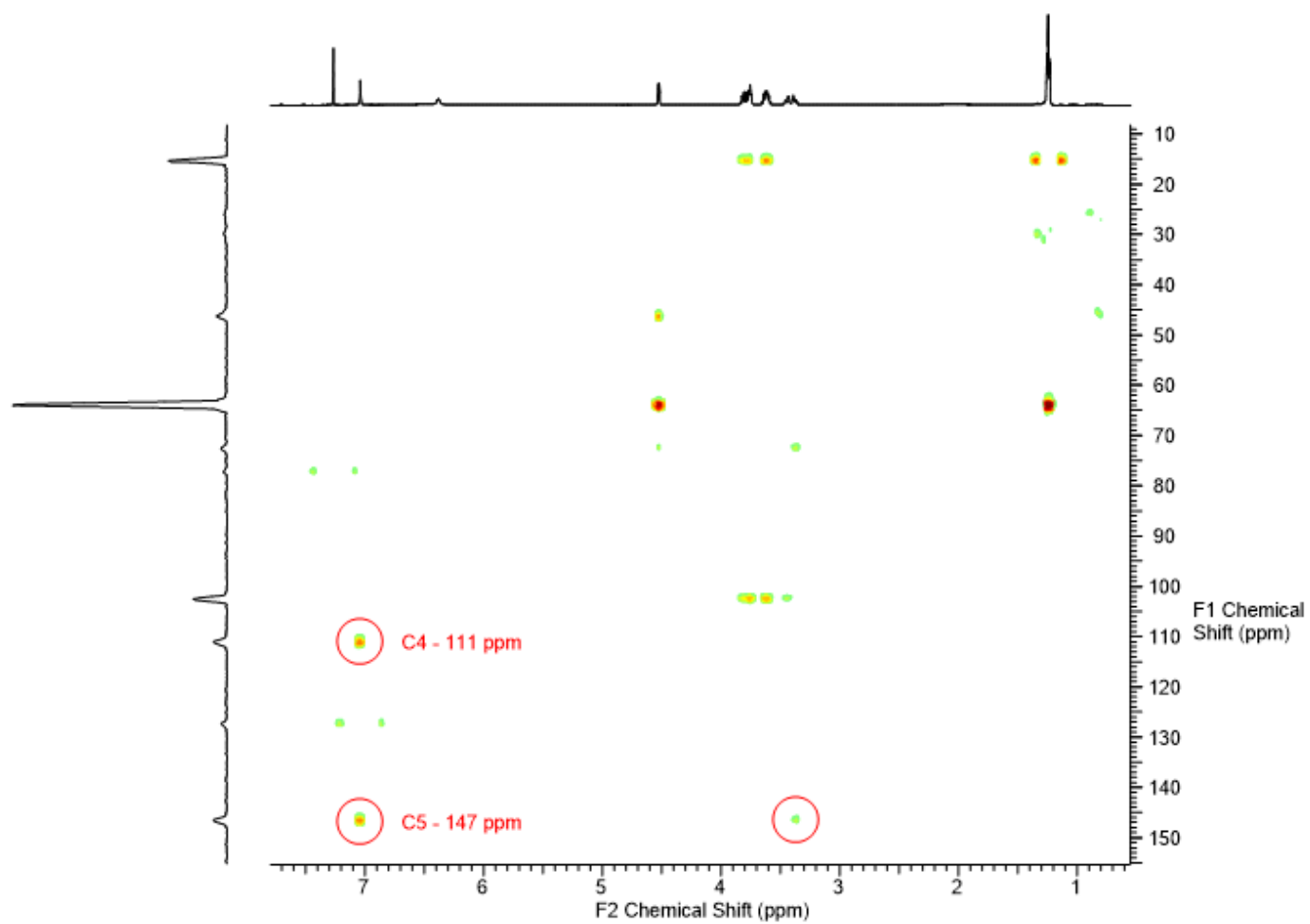
A291: ^{13}C NMR spectra (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **191**.



A292: ^{13}C DEPT135 and ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **191**.



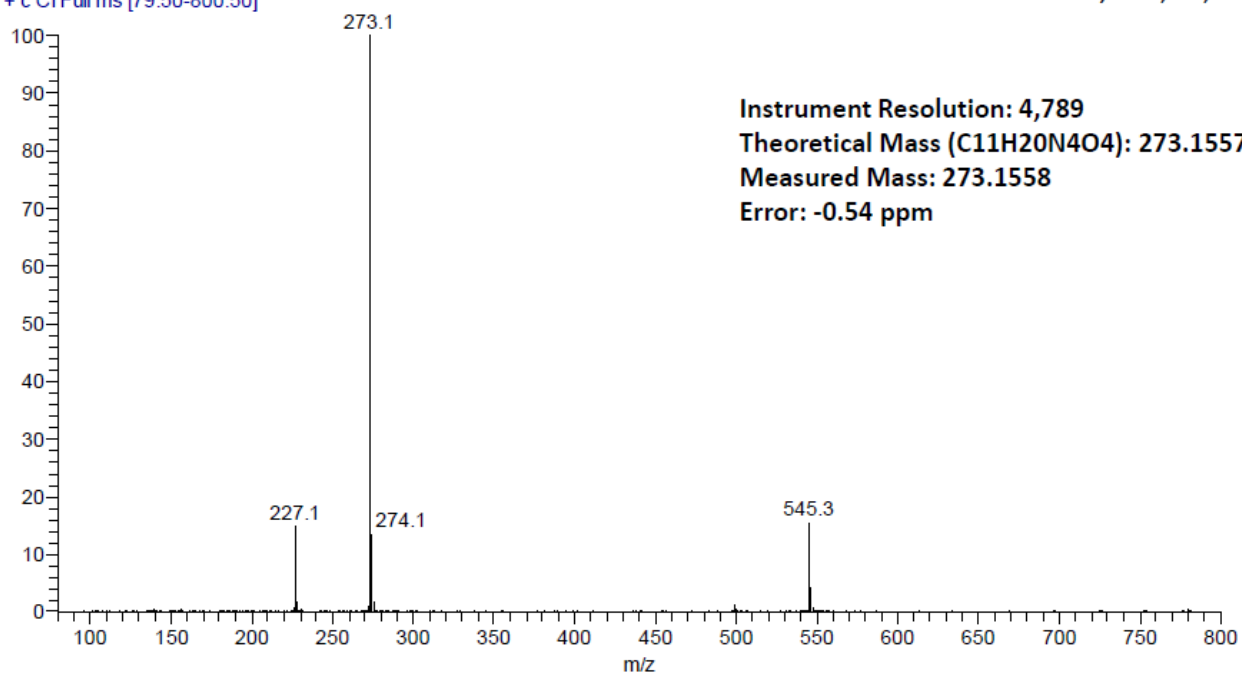
A293: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **191**.



A294: Cl⁺ mass spectrum of 191.

ajs783b_ci #19 RT: 1.73 AV: 1 NL: 8.90E6
T: + c Cl Full ms [79.50-800.50]

AMMONIA *m/z* 18, 35, 52

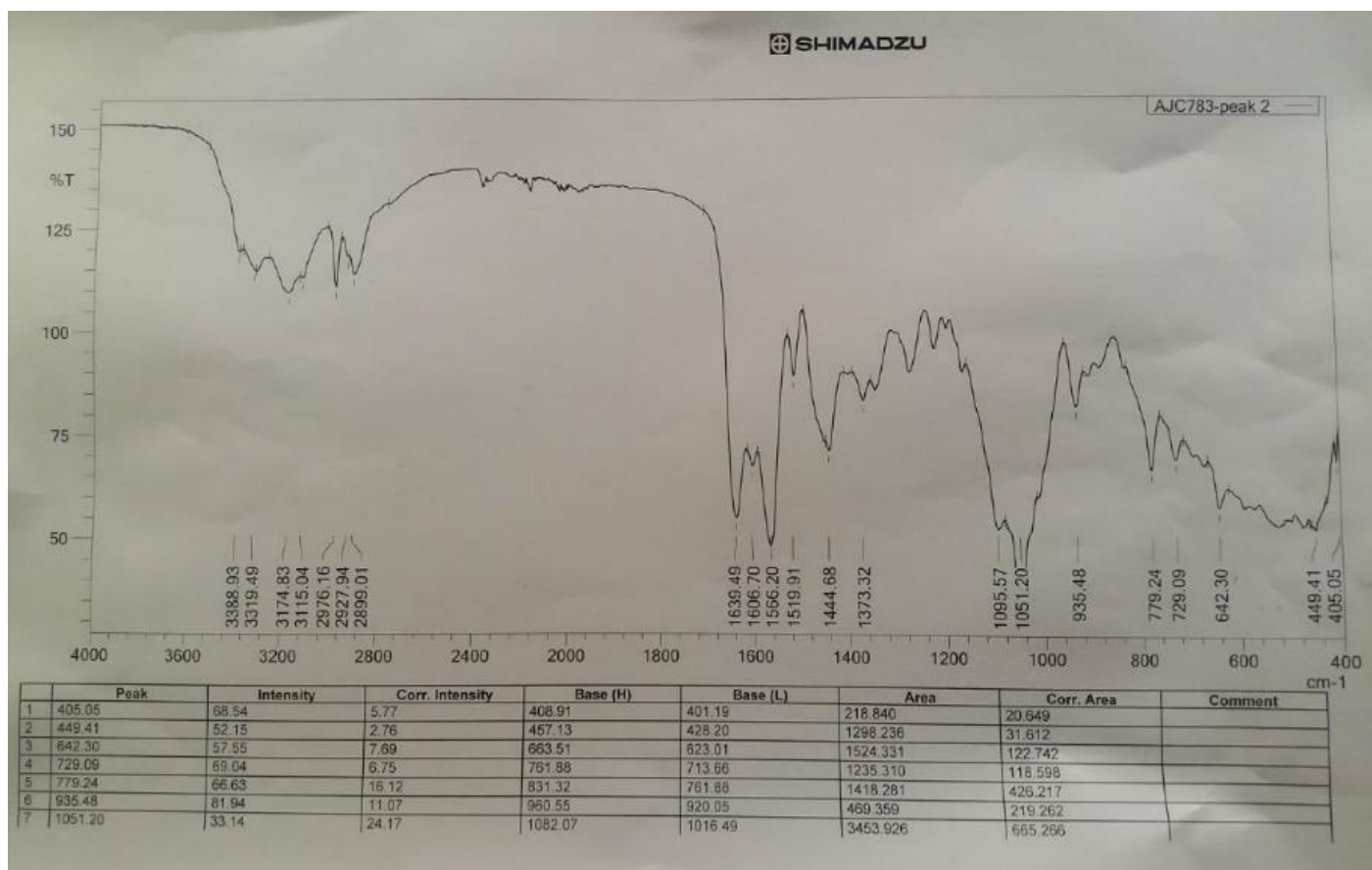


MAT900 mass spectrometer

18/08/2016

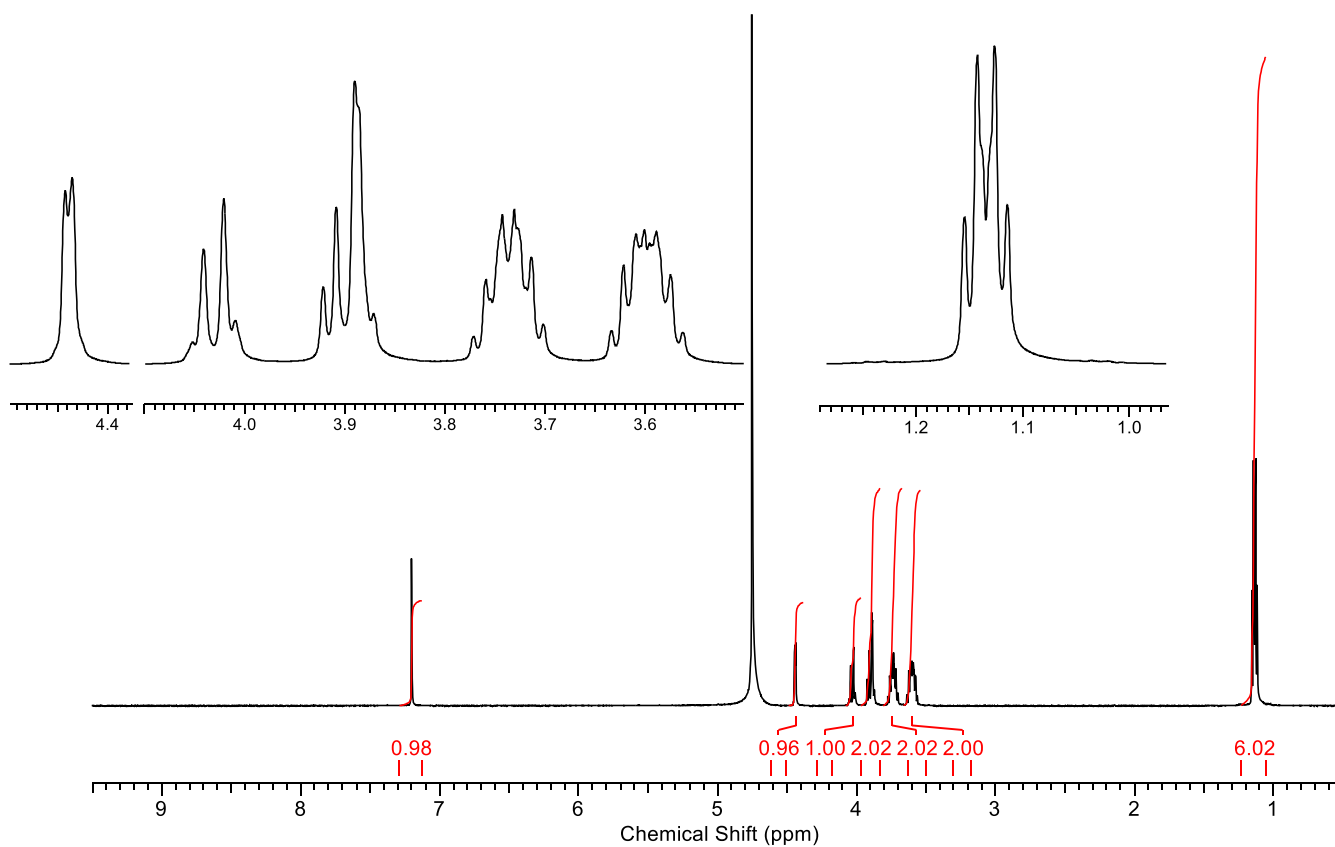
1

A295: IR spectrum of 191.

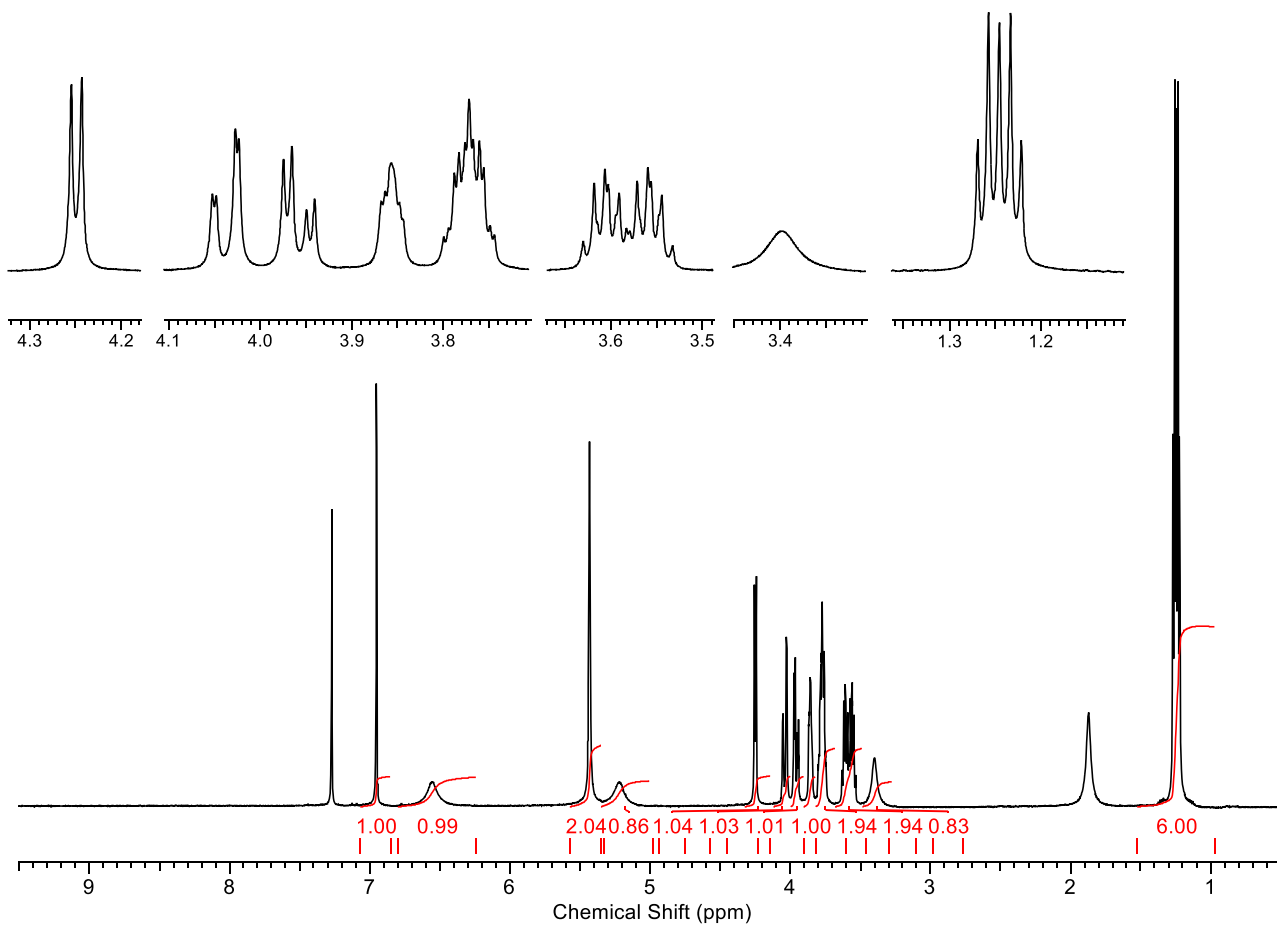


rac-5-amino-1-(3,3-diethoxy-2-hydroxypropyl)-1H-imidazole-4-carboxamide (192)

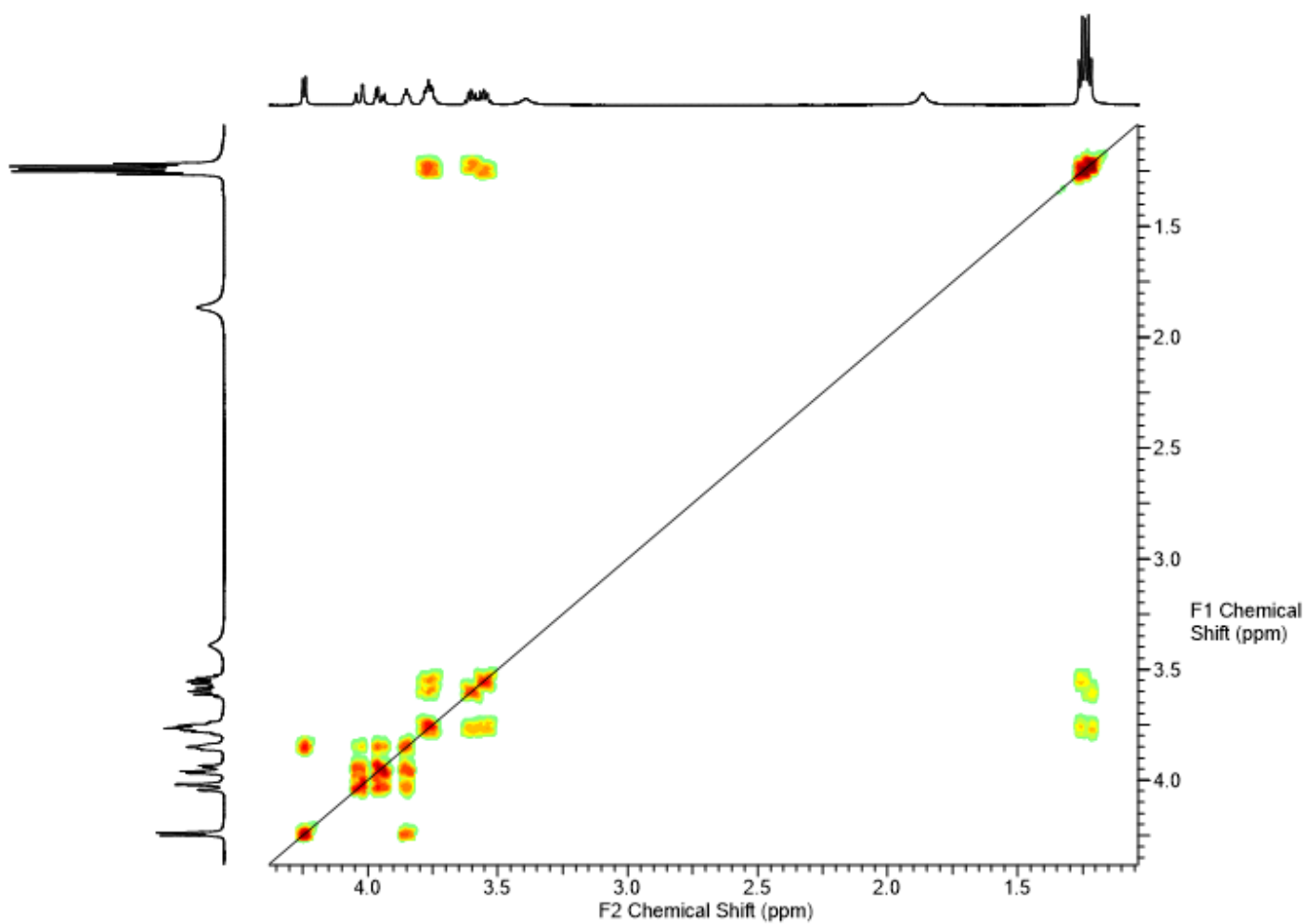
A296: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **192** with expansion overlaid.



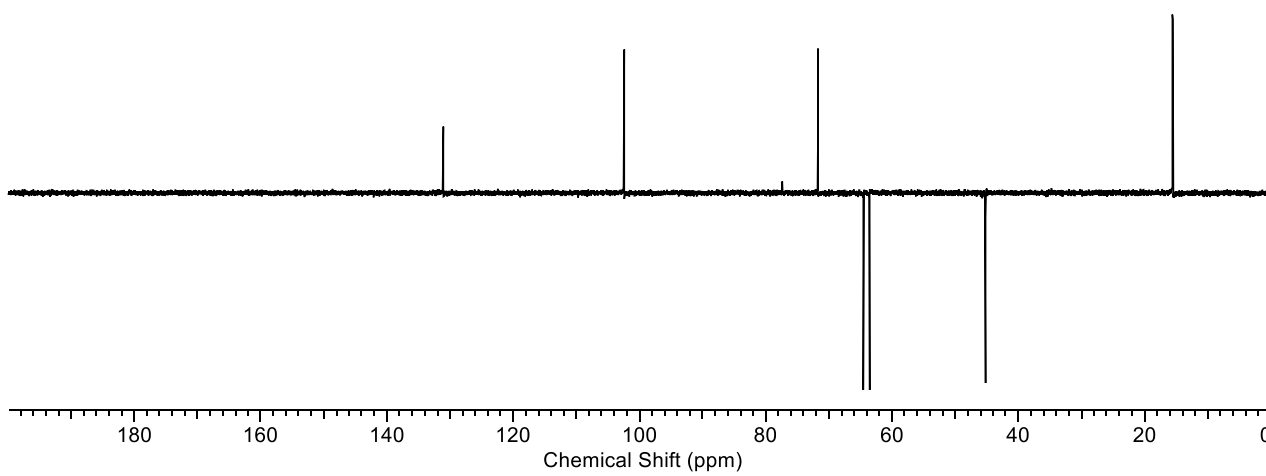
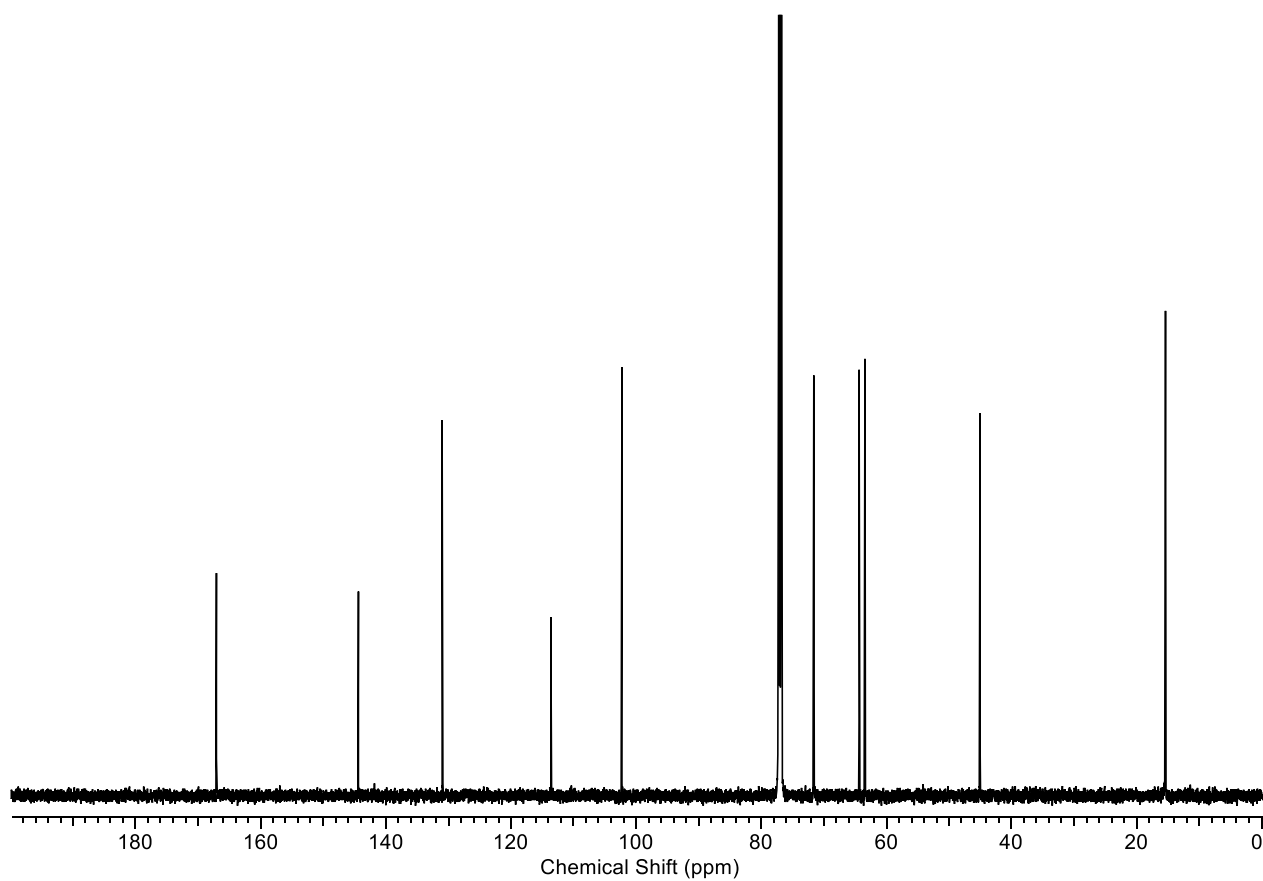
A297: ^1H NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$, 0.5 – 9.5 ppm) of **192** with expansion overlaid.



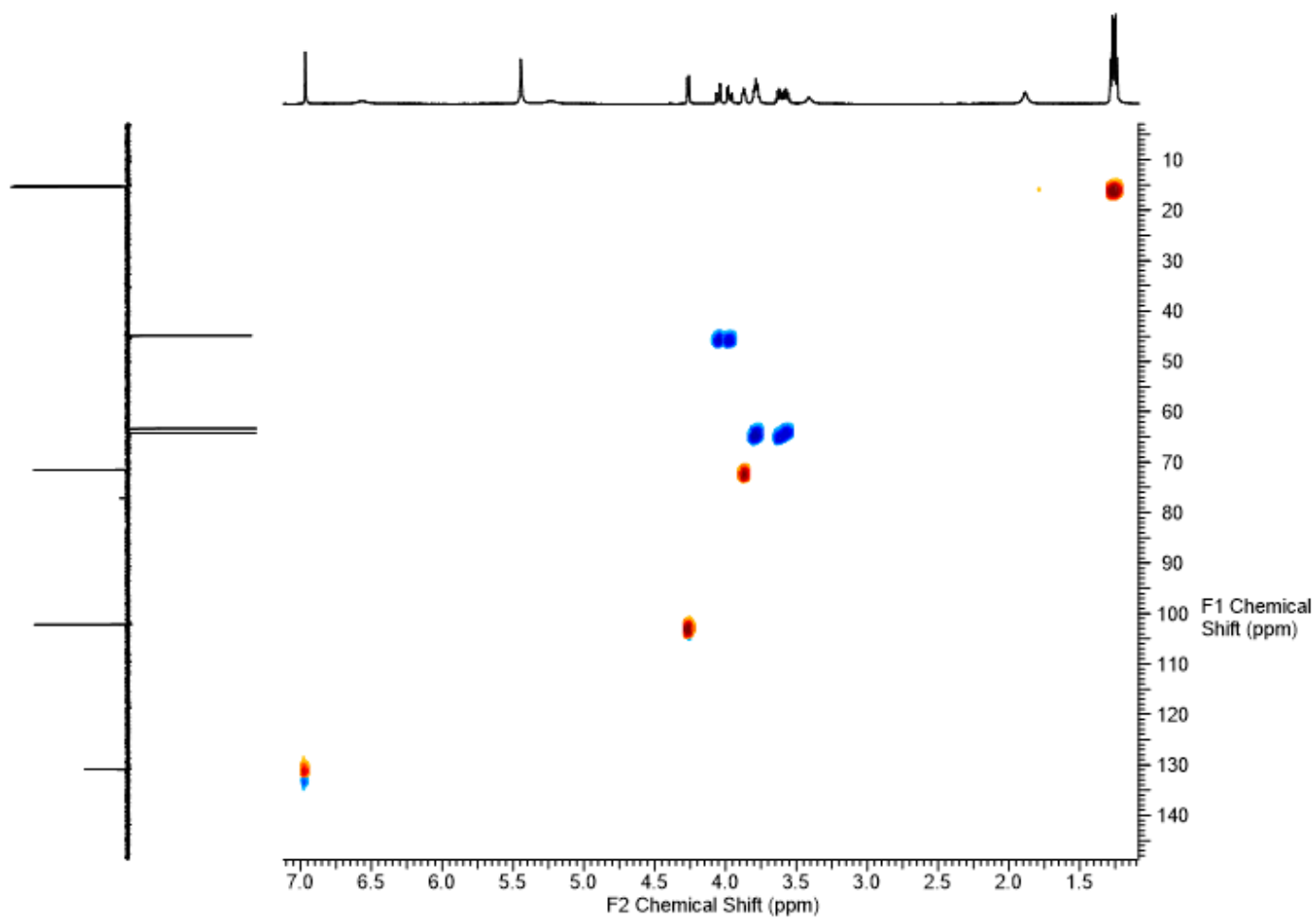
A298: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$) of **192**.



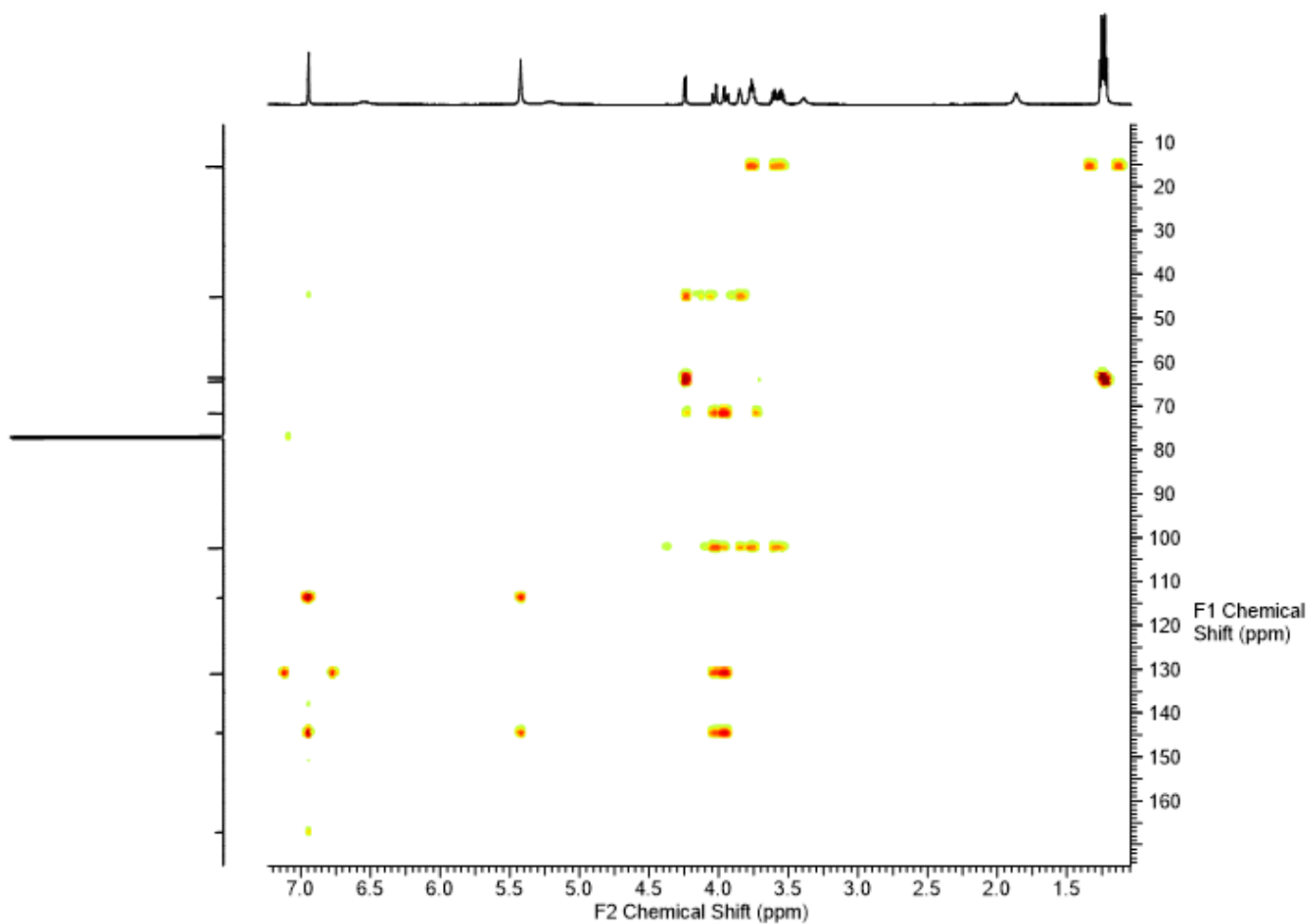
A299: ^{13}C NMR spectrum (151 MHz, $\{\text{CDCl}_3\}$, 200 – 0 ppm) of **192** with DEPT135 spectrum below.



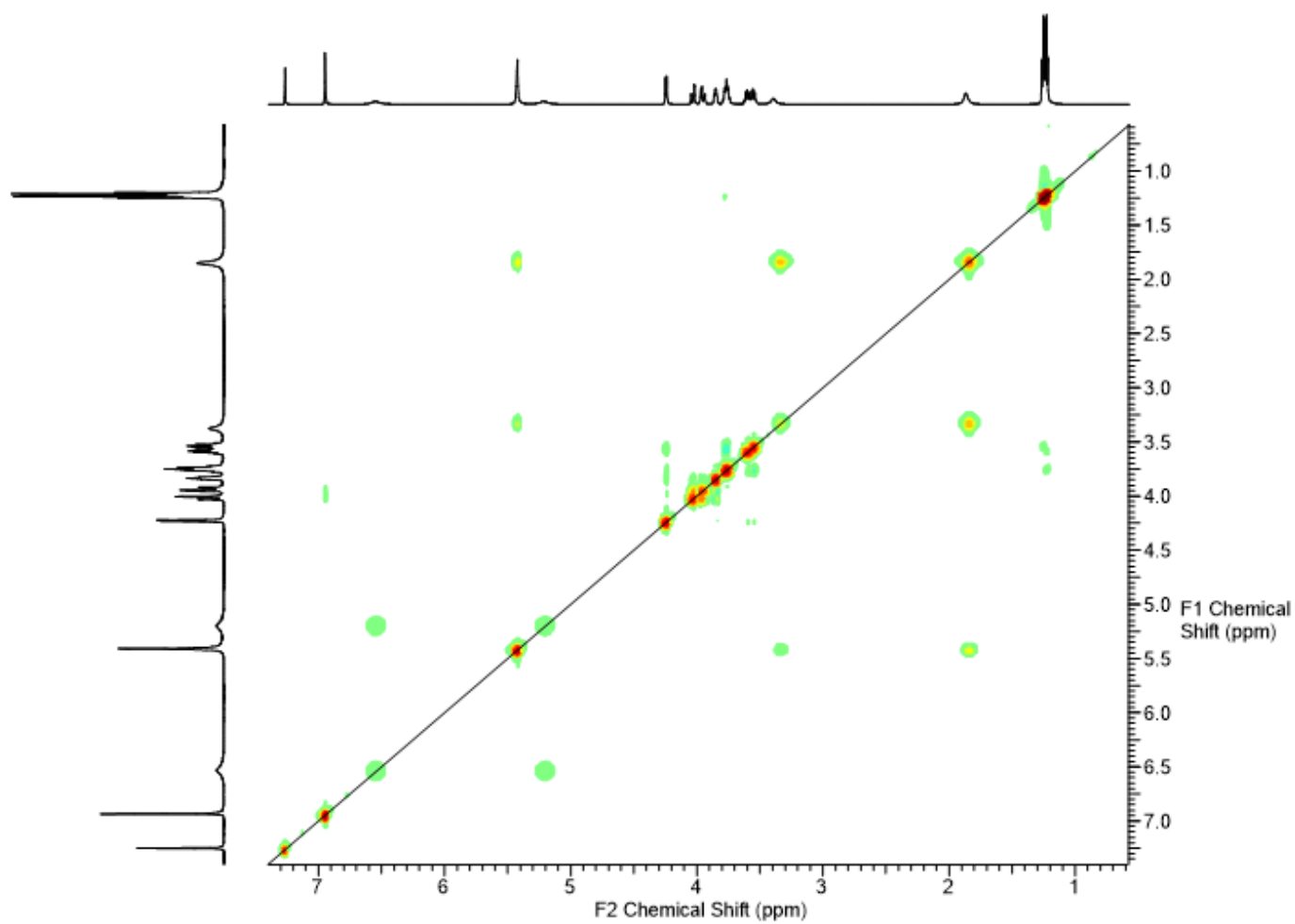
A300: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$) of **192**.



A301: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$) of **192**.



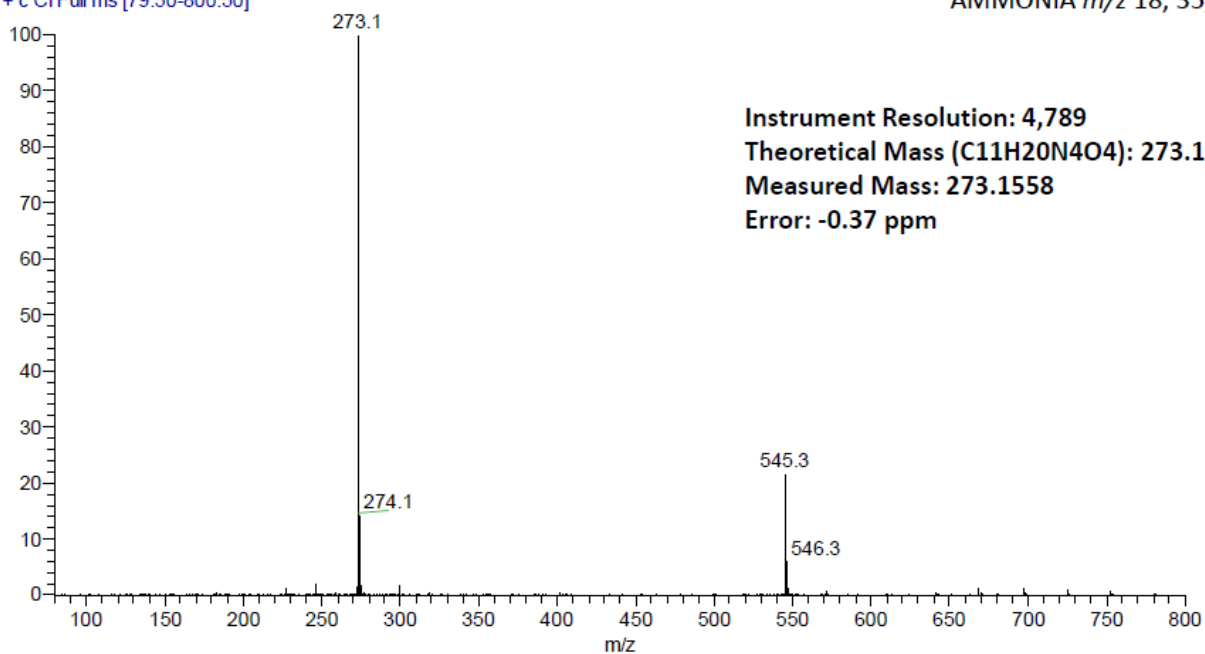
A302: ^1H - ^1H NOESY NMR spectrum (600 MHz, $\{\text{CDCl}_3\}$) of **192**.



A303: Cl⁺ mass spectrum of 192.

ajc783a ci #11 RT: 1.03 AV: 1 NL: 3.30E6
T: + c Cl Full ms [79.50-800.50]

AMMONIA *m/z* 18, 35, 52

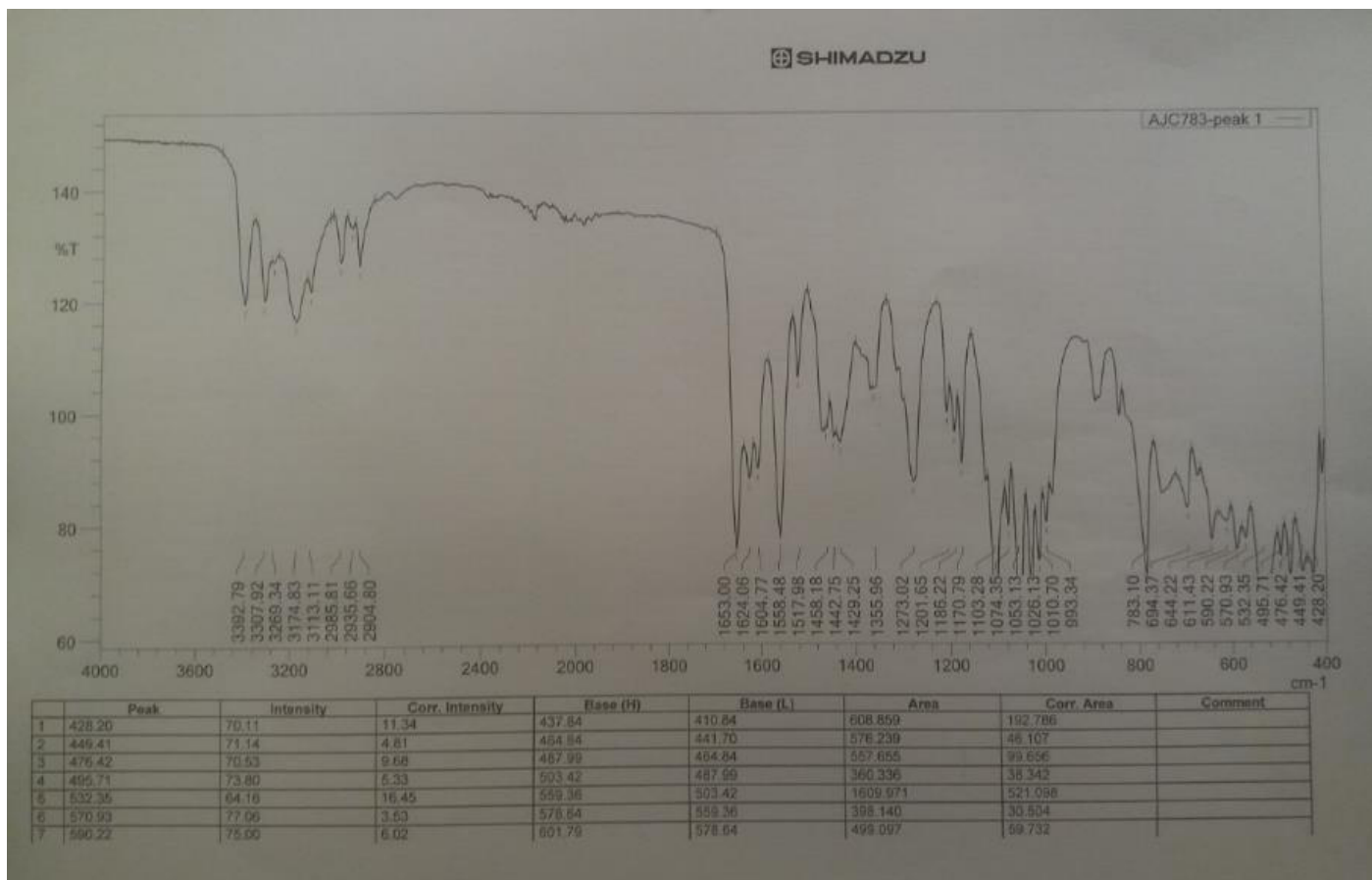


MAT900 mass spectrometer

18/08/2016

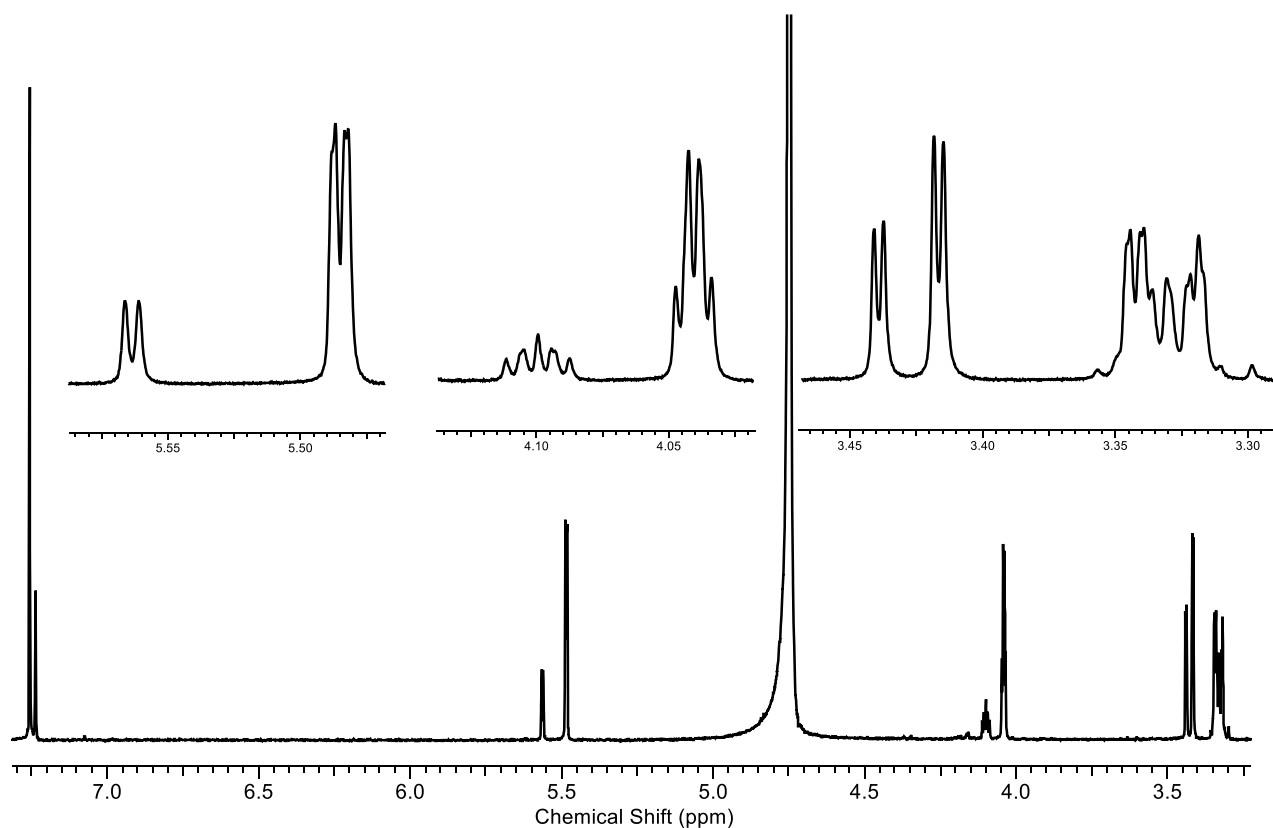
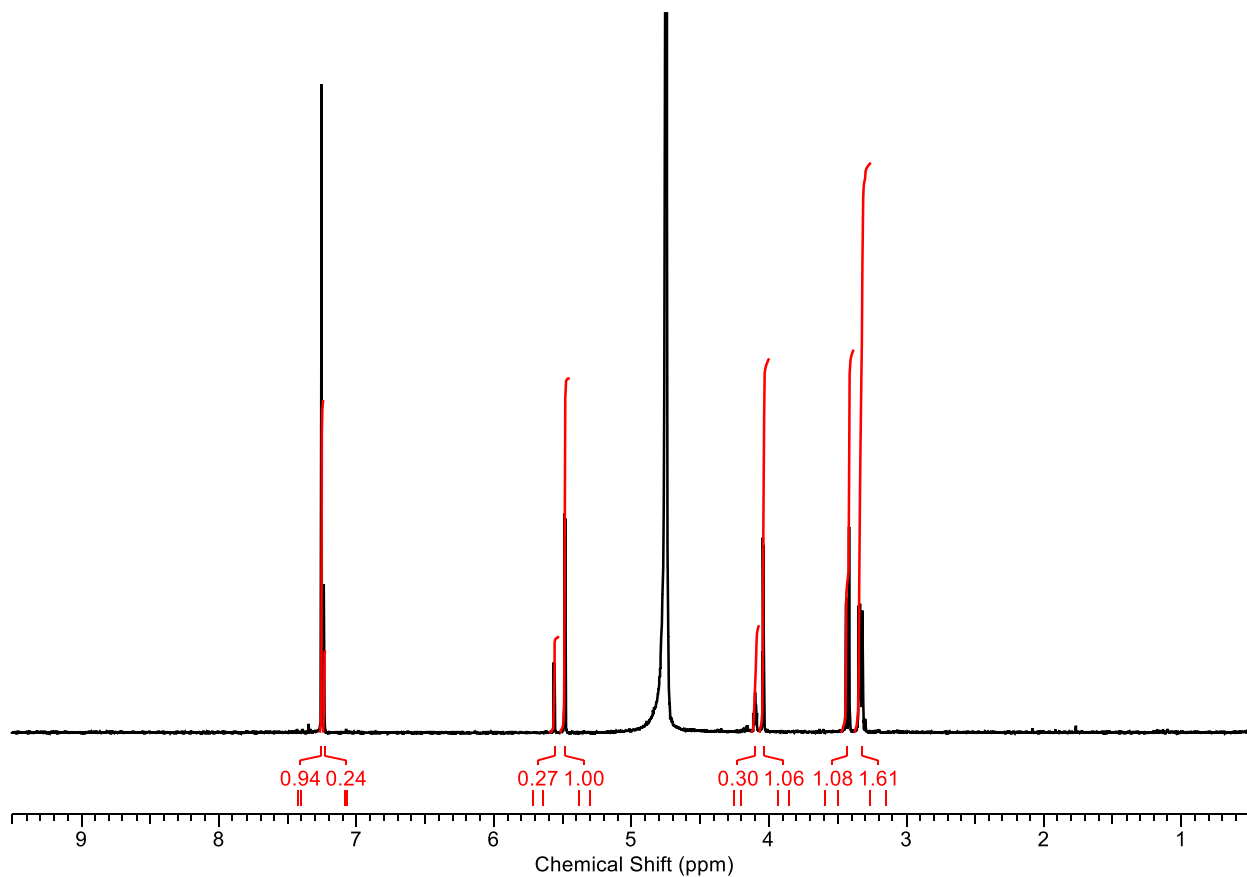
1

A304: IR spectrum of 192.

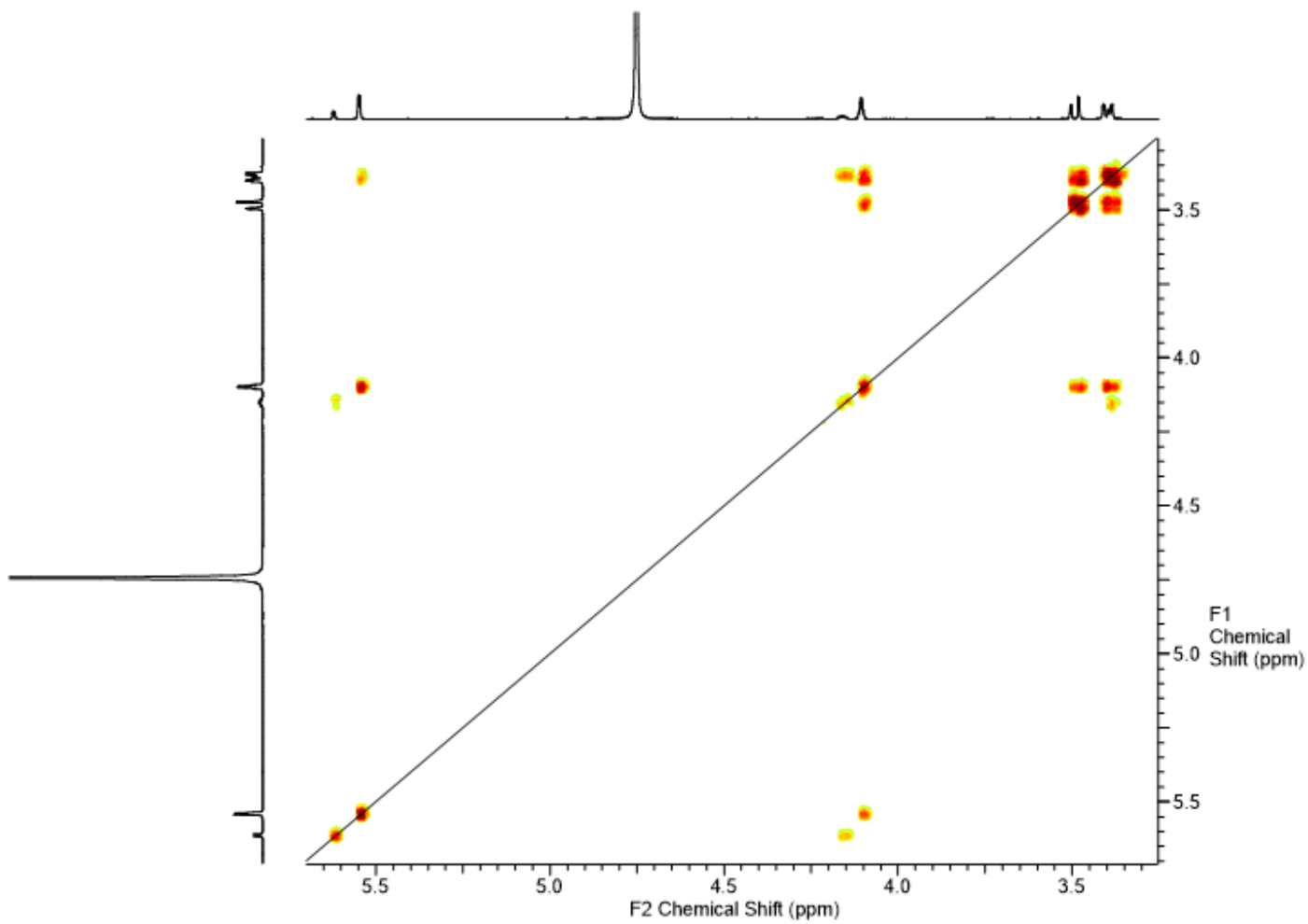


rac-3,4-dihydroxy-1,2,3,4-tetrahydroimidazo[1,5-a]pyrimidine-8-carboxamide (177)

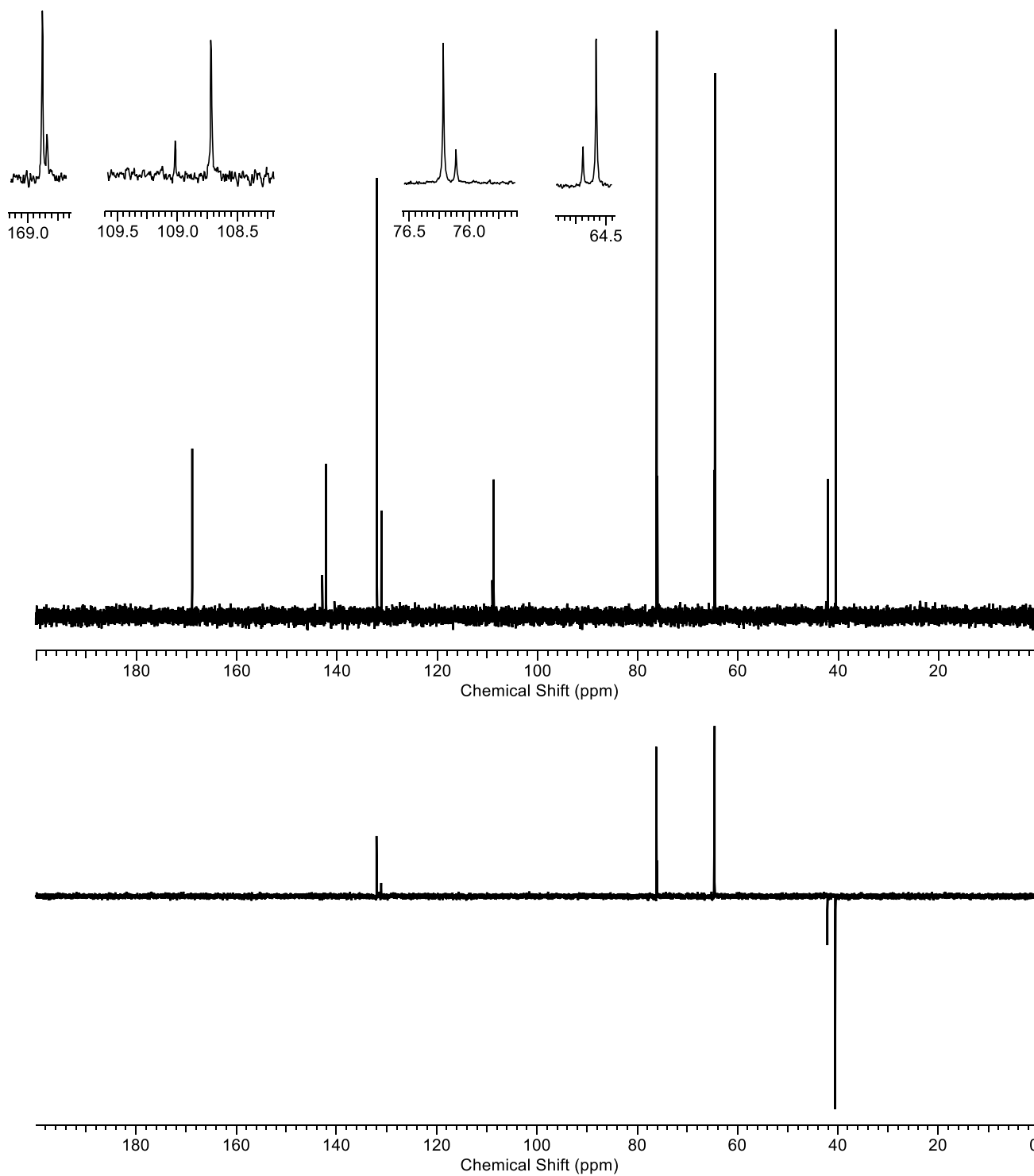
A305: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **177** with expansion below.



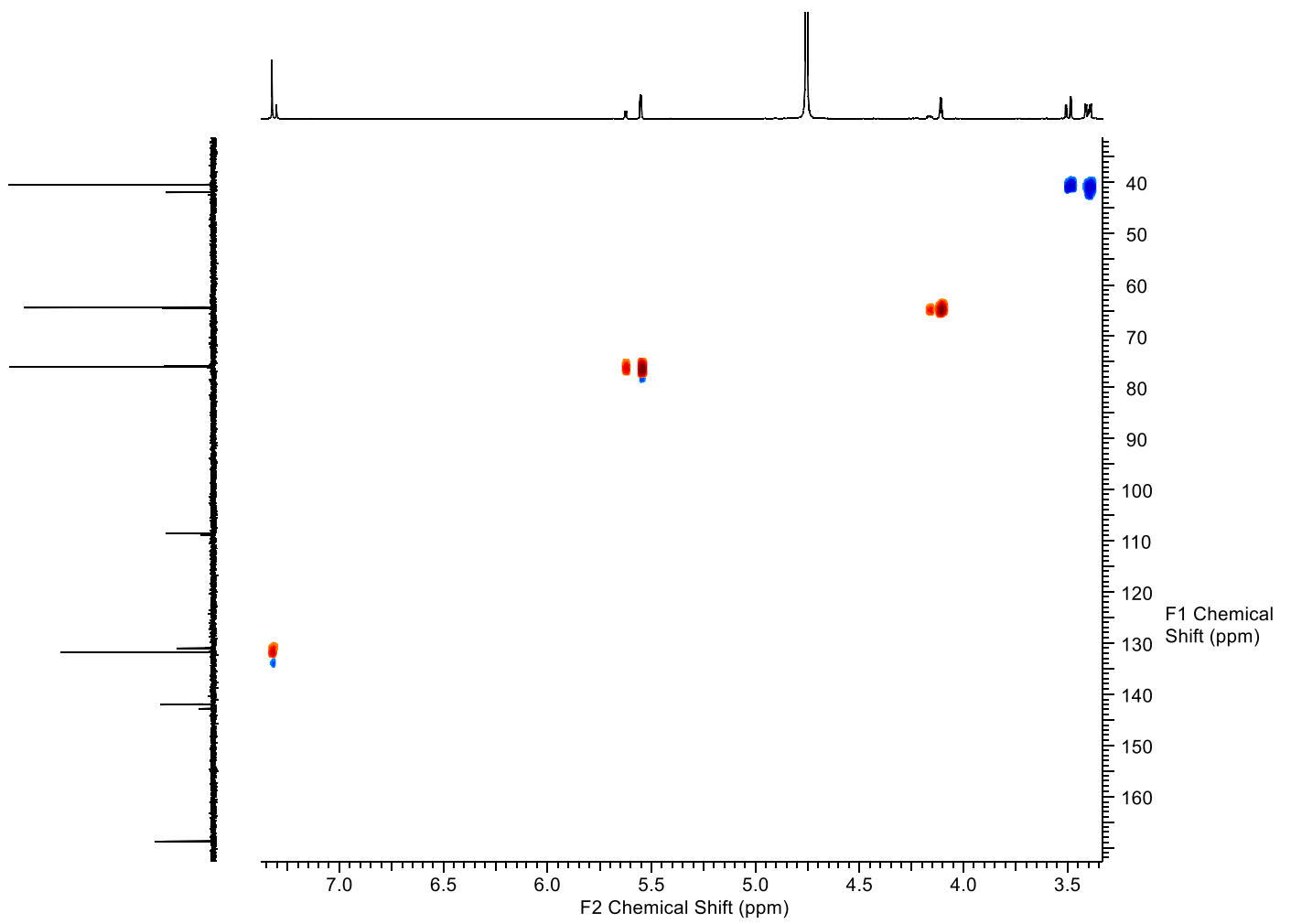
A306: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **177**.



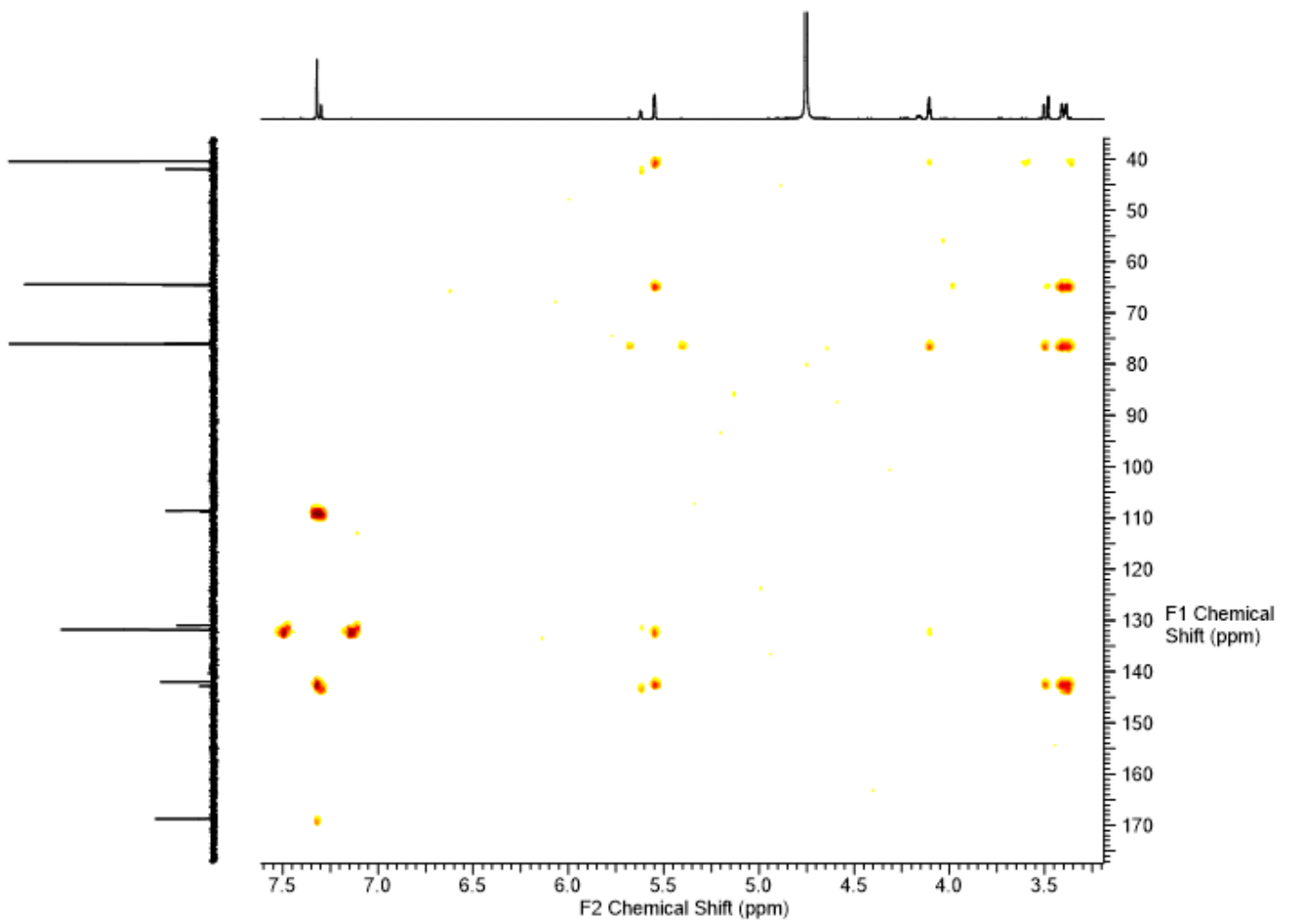
A307: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **177** with DEPT135 spectrum below.



A308: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **177**.



A309: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **177**.

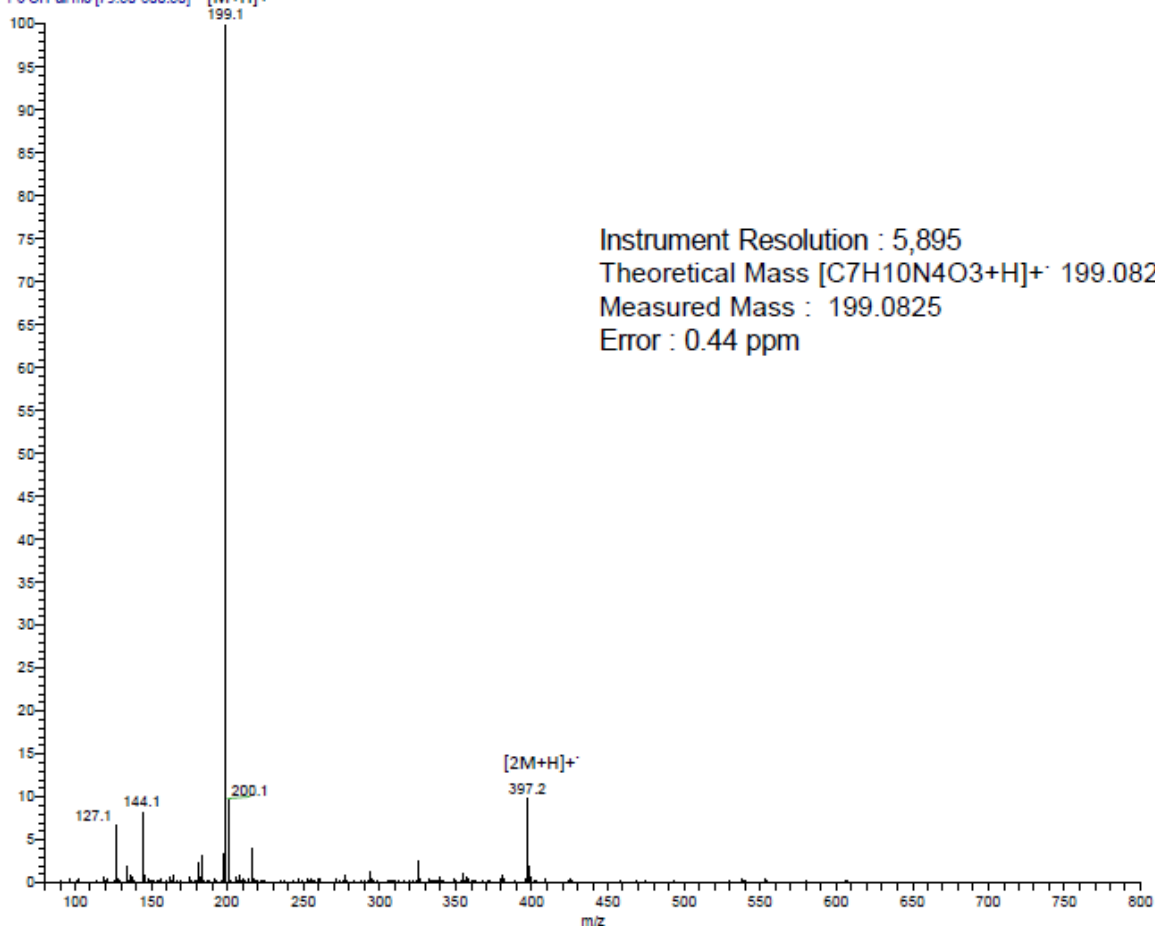


A310: Cl⁺ mass spectrum of 177.

UCL Chemistry Mass Spectrometry Facility

AMMONIA m/z 18, 35, 52

alc792b cl#99 RT: 8.67 AV: 1 NL: 1.14E7
T: + c Cl Full ms [79.50-800.50] [M+H]⁺

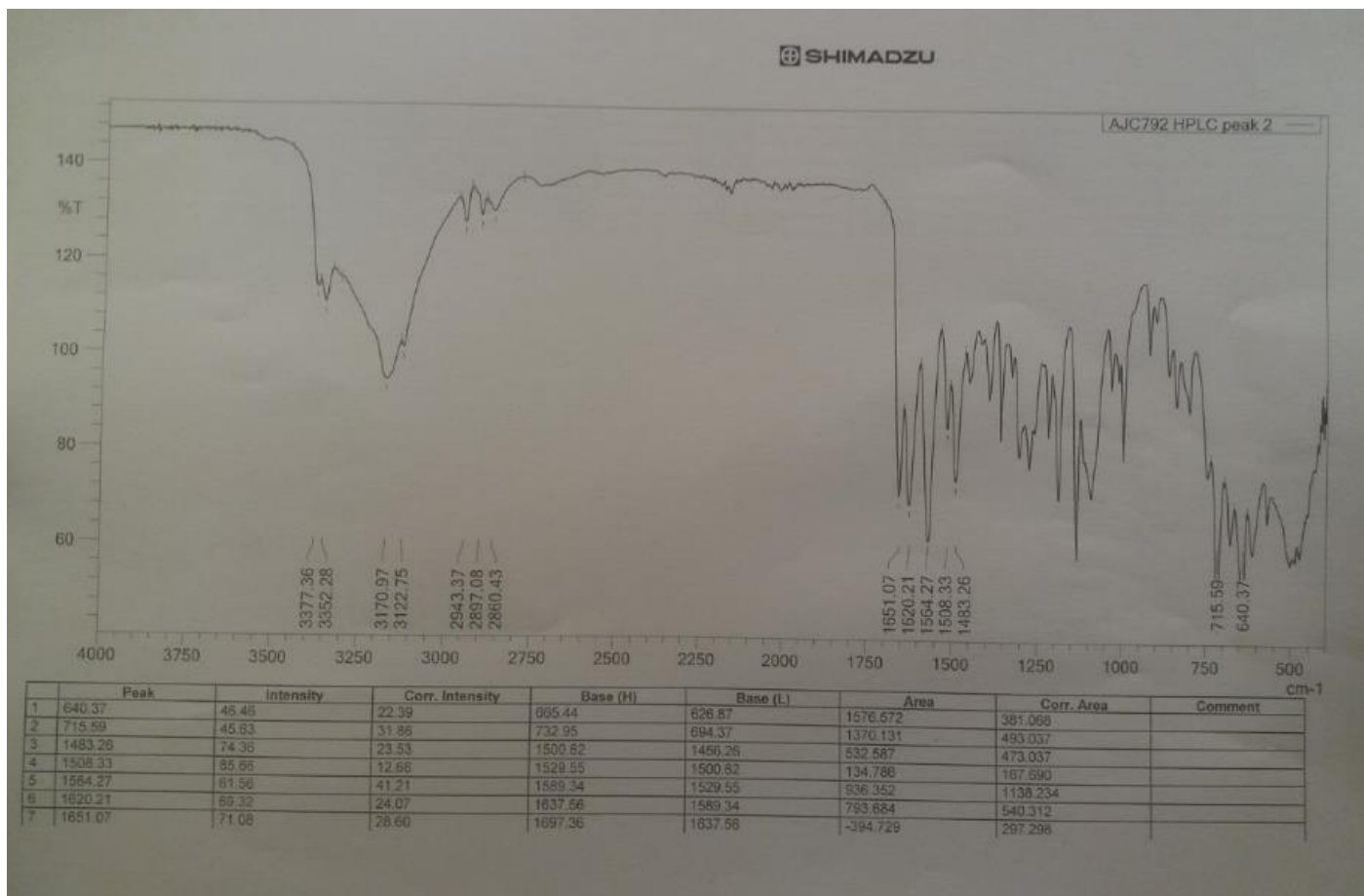


13/09/2016

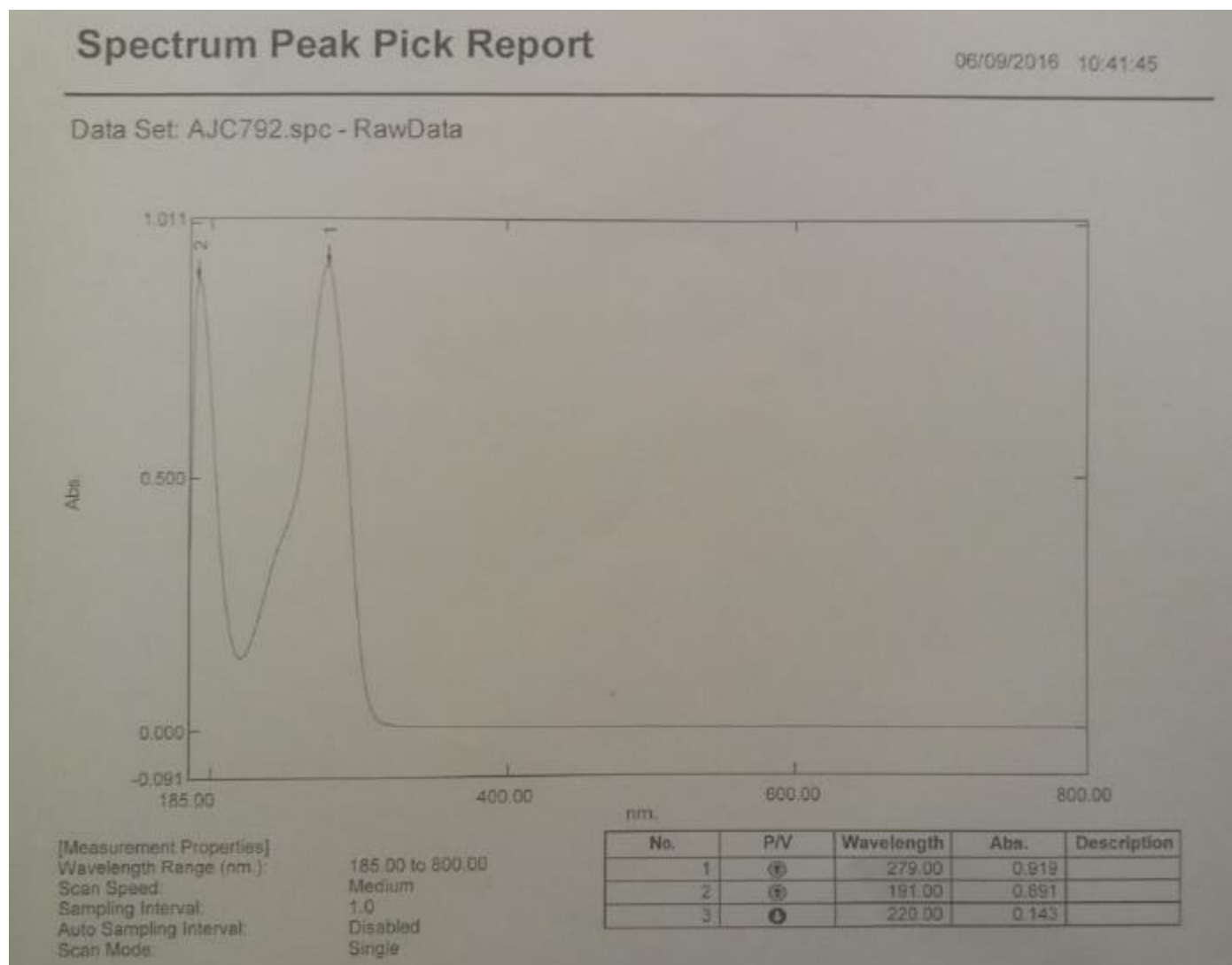
Finnigan MAT 900 XE mass spectrometer

1

A311: IR spectrum of 177.

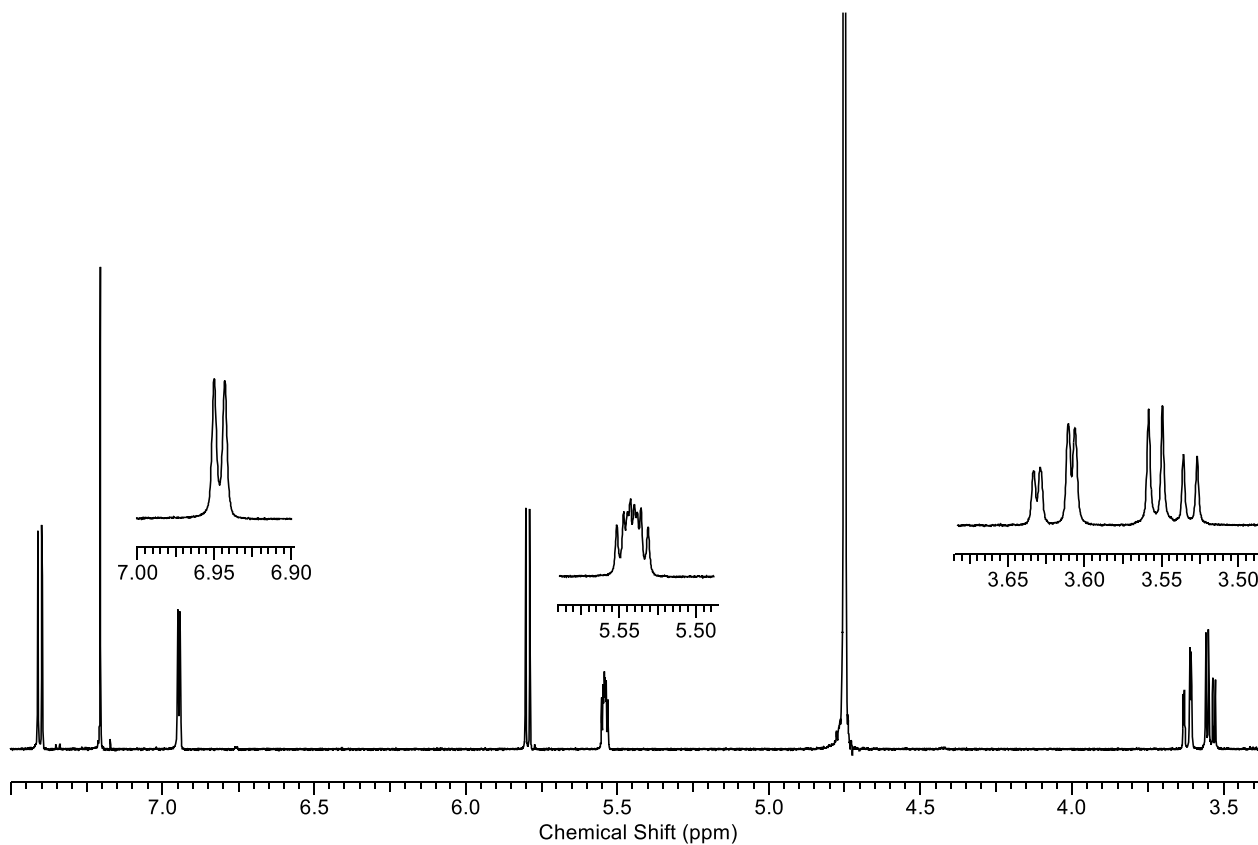
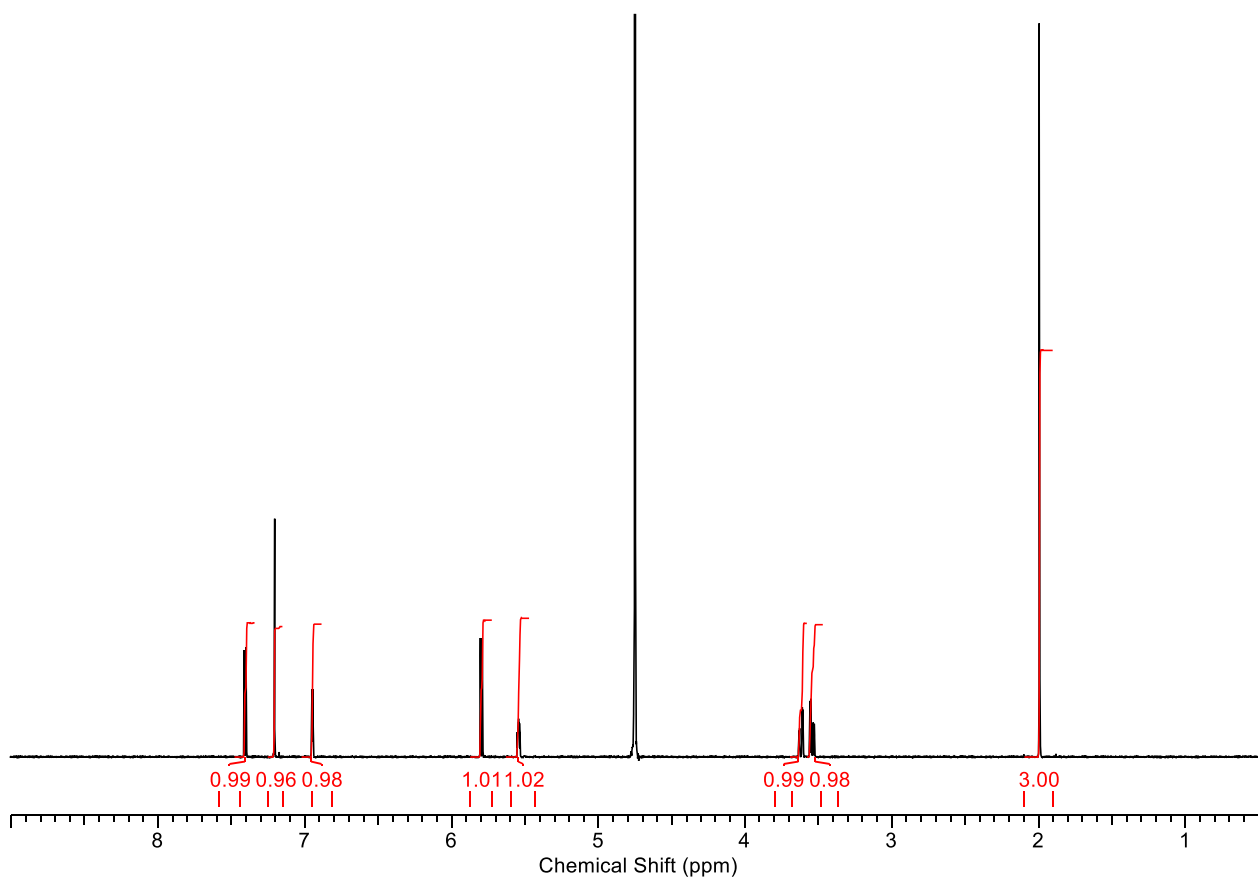


A312: UV-vis spectrum of 177.

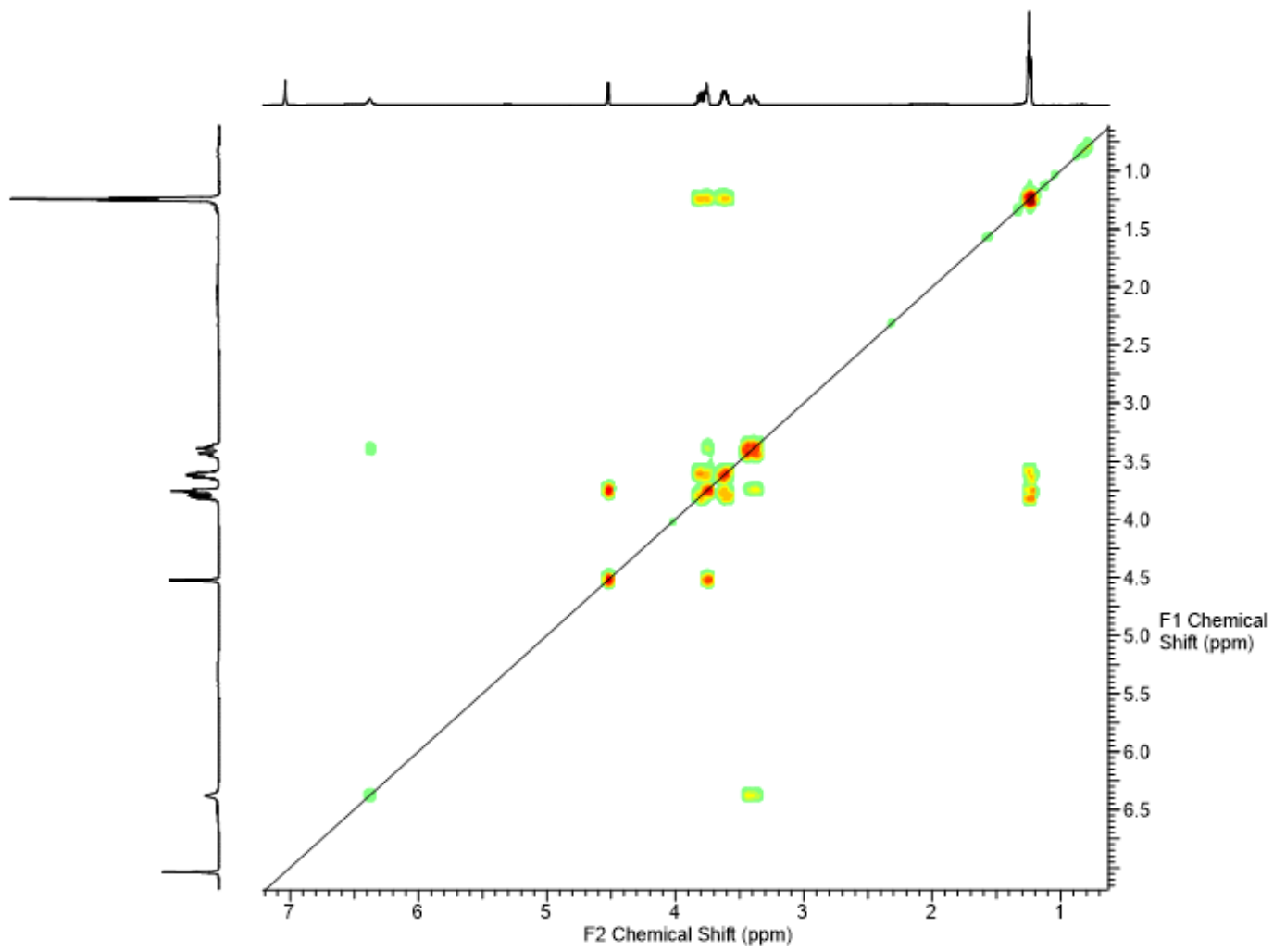


rac-8-carbamoyl-4-(2,4-dioxo-3,4-dihydropyrimidin-1(2H)-yl)-1,2,3,4-tetrahydroimidazo[1,5-a]pyrimidin-3-yl acetate (198)

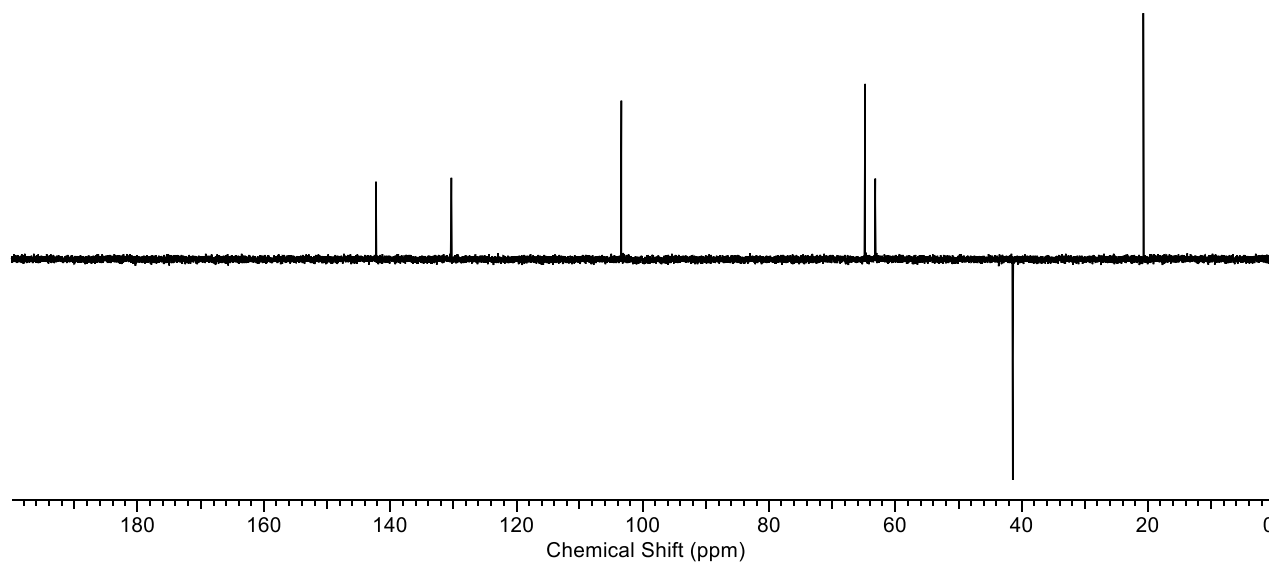
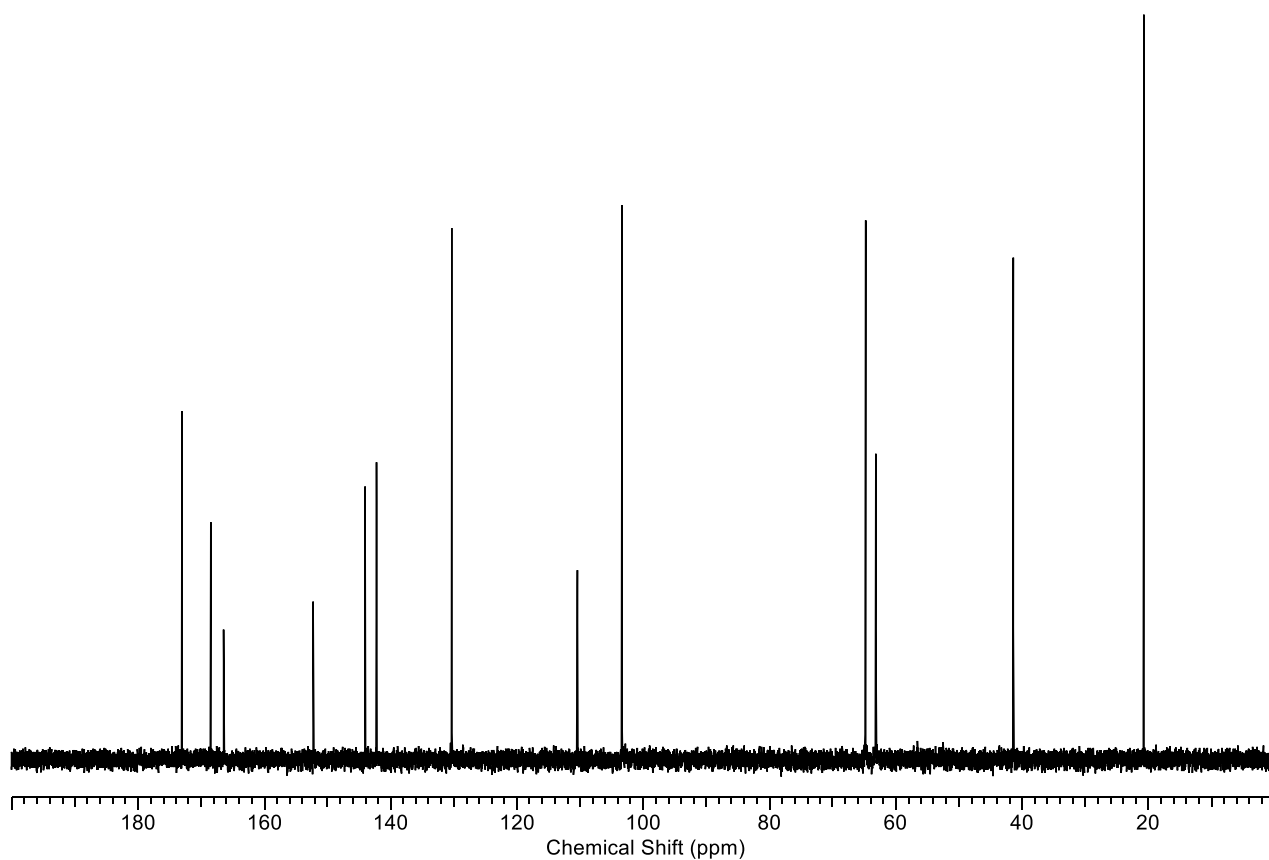
A313: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **198** with expansion below.



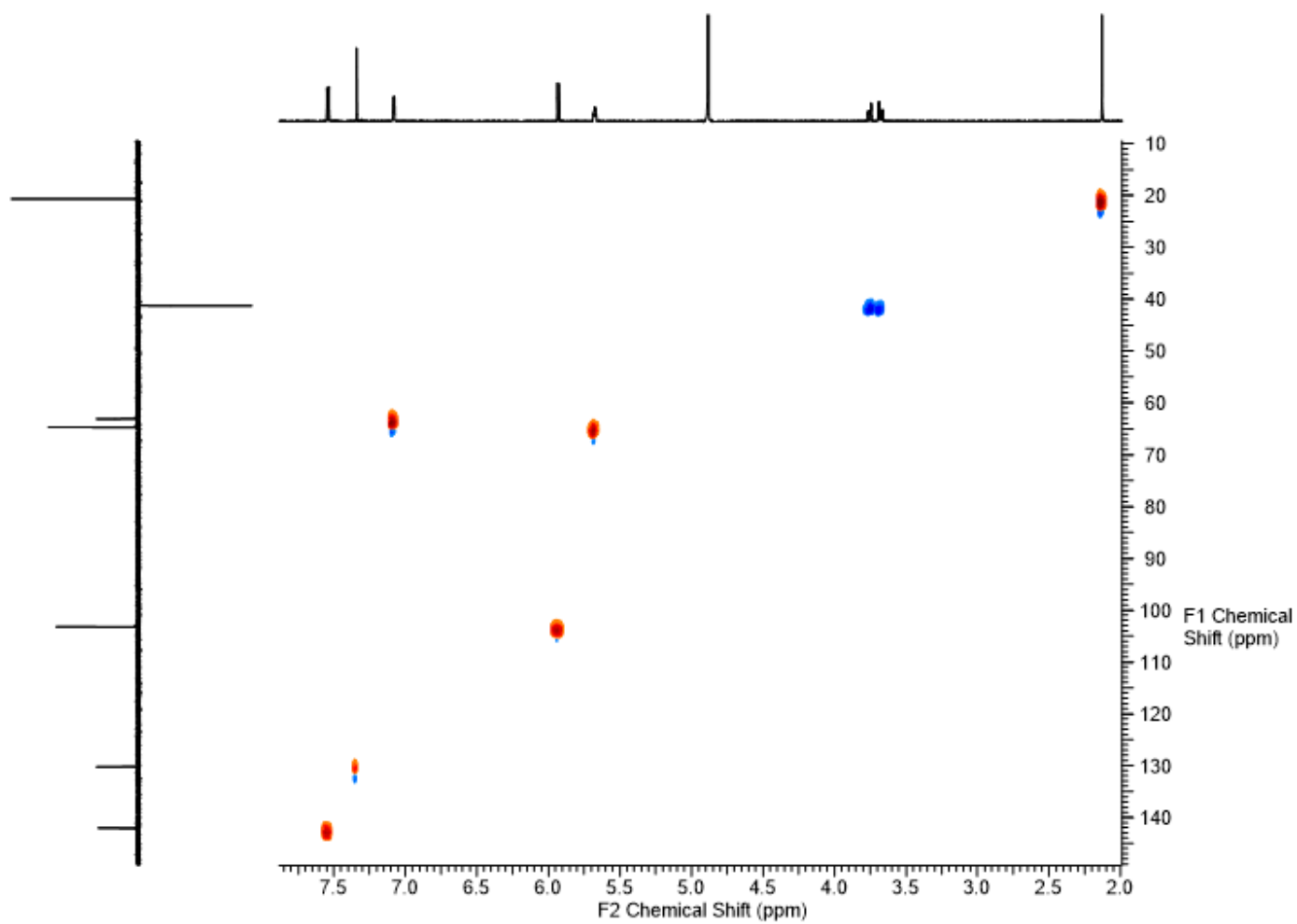
A314: ^1H - ^1H COSY NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **198**.



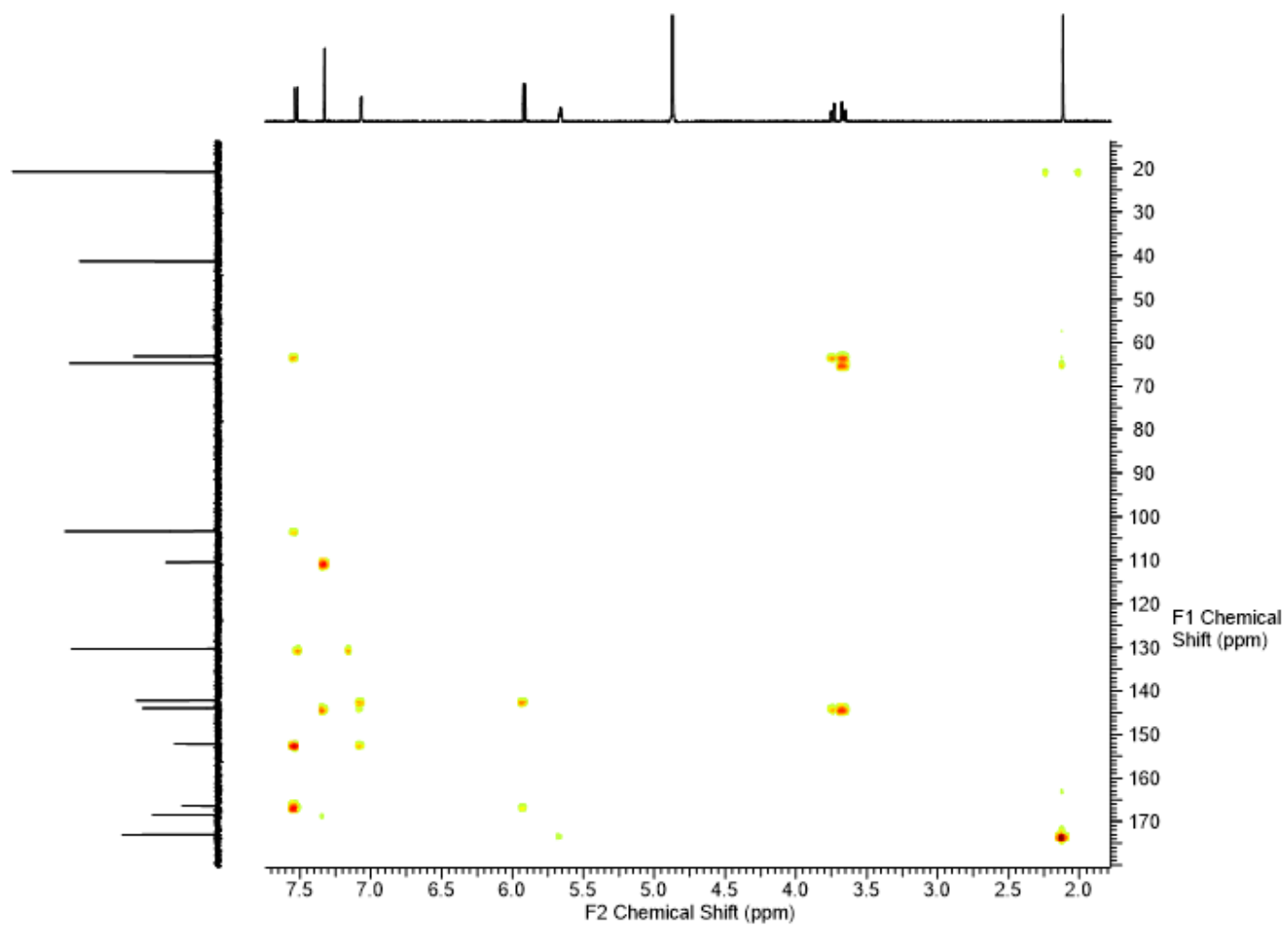
A315: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 200 – 0 ppm) of **198** with DEPT135 spectrum below.



A316: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **198**.

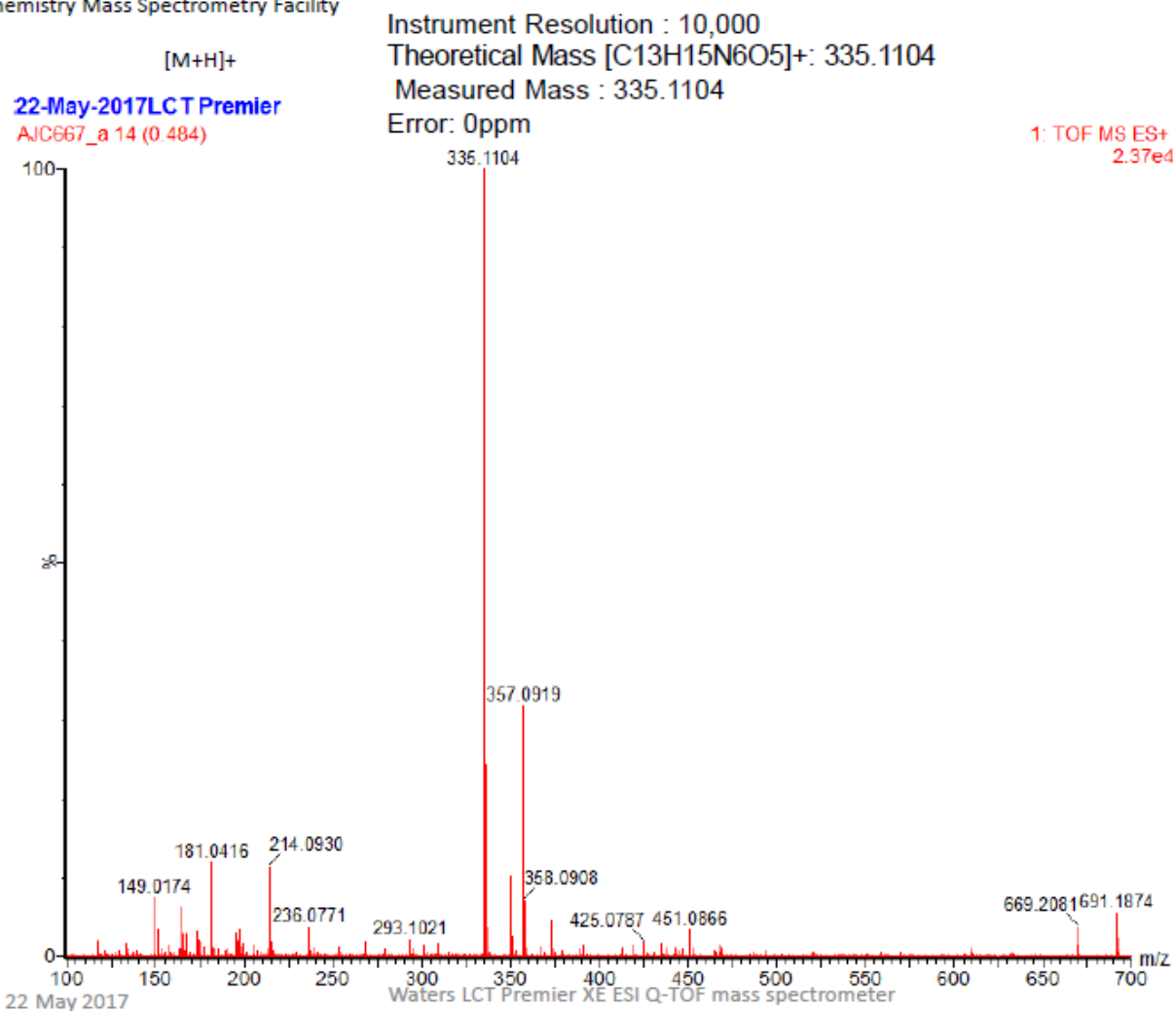


A317: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$) of **198**.

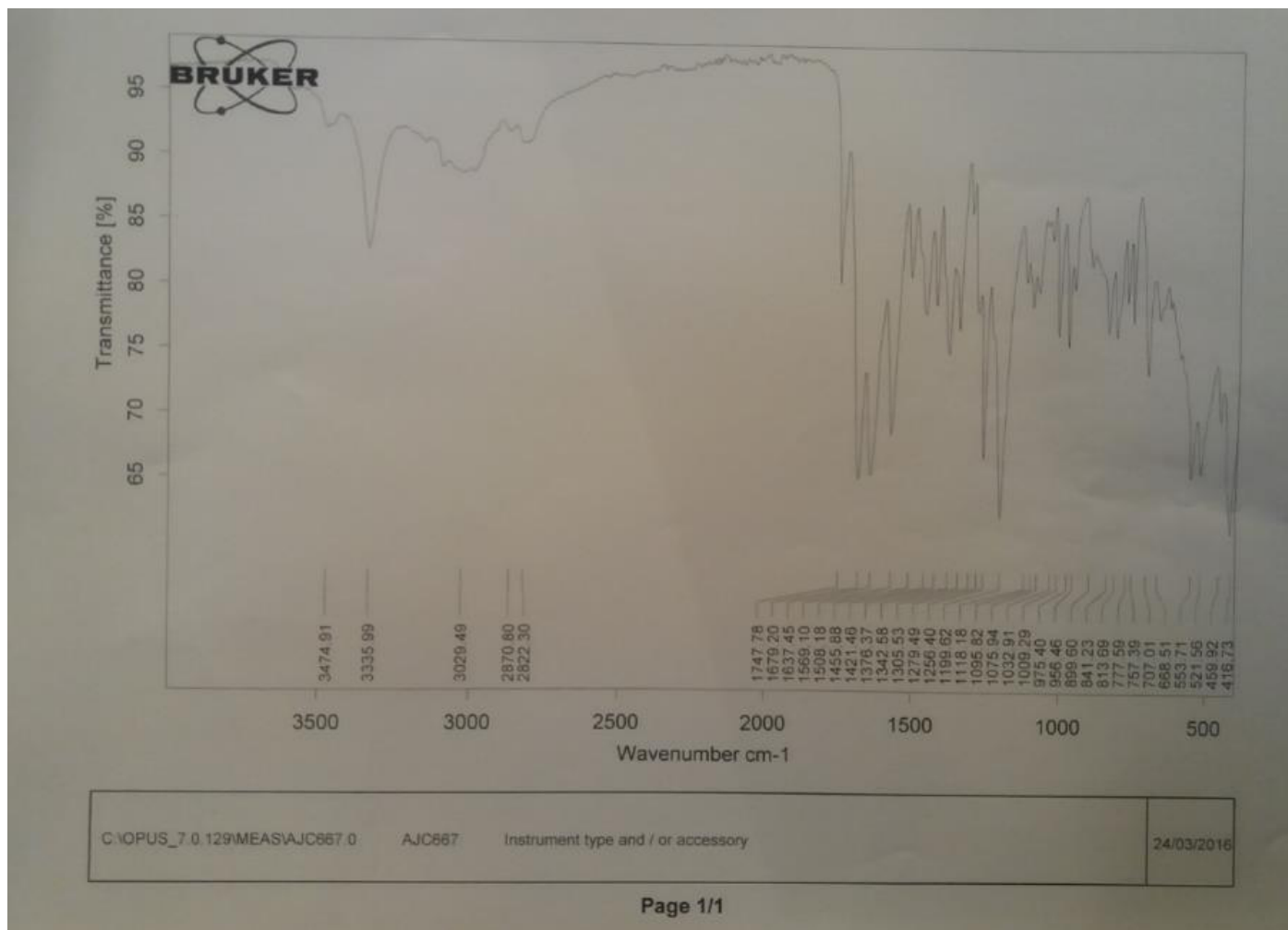


A318: ESI+ mass spectrum of 198.

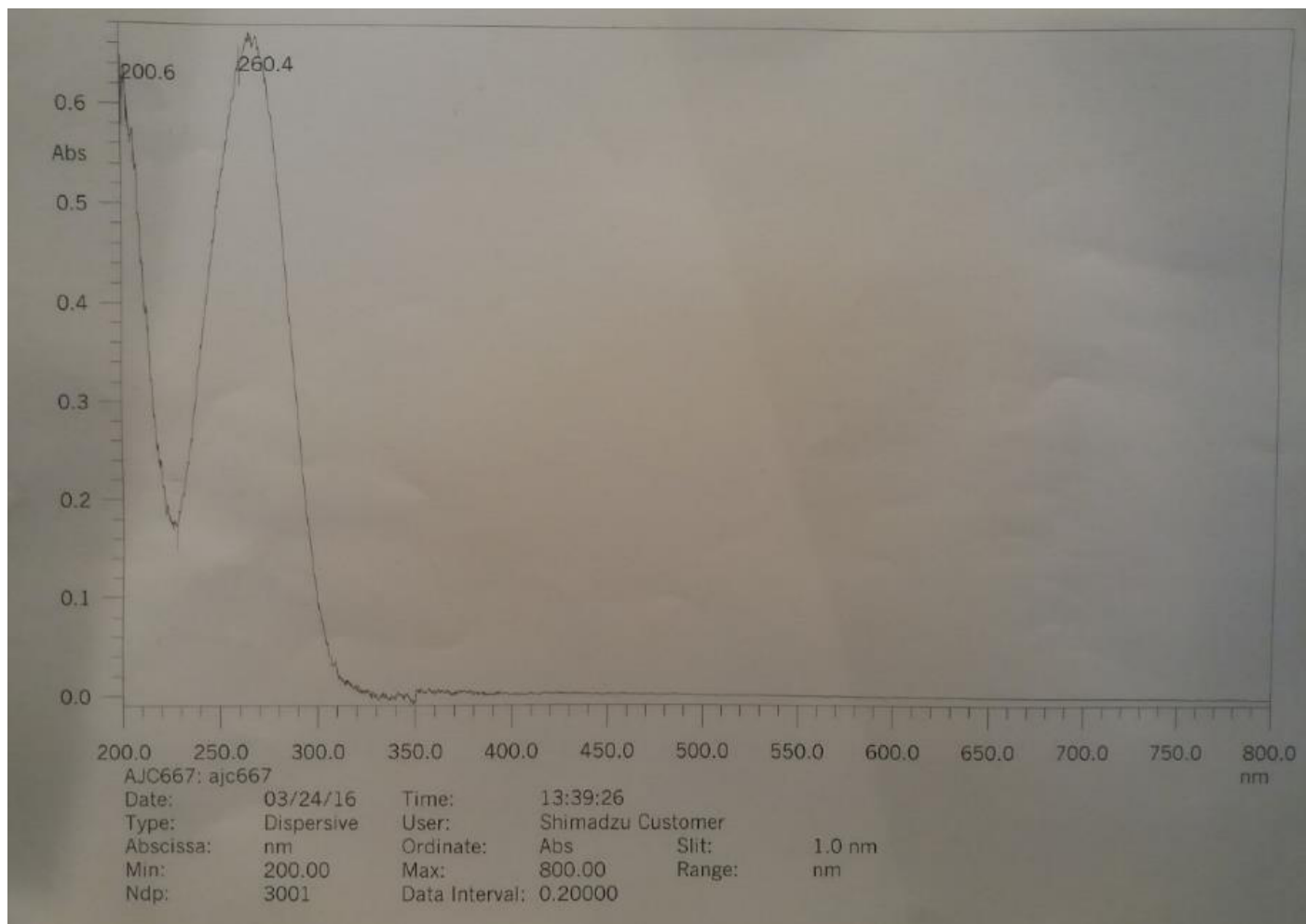
UCL Chemistry Mass Spectrometry Facility



A319: IR spectrum of 198.

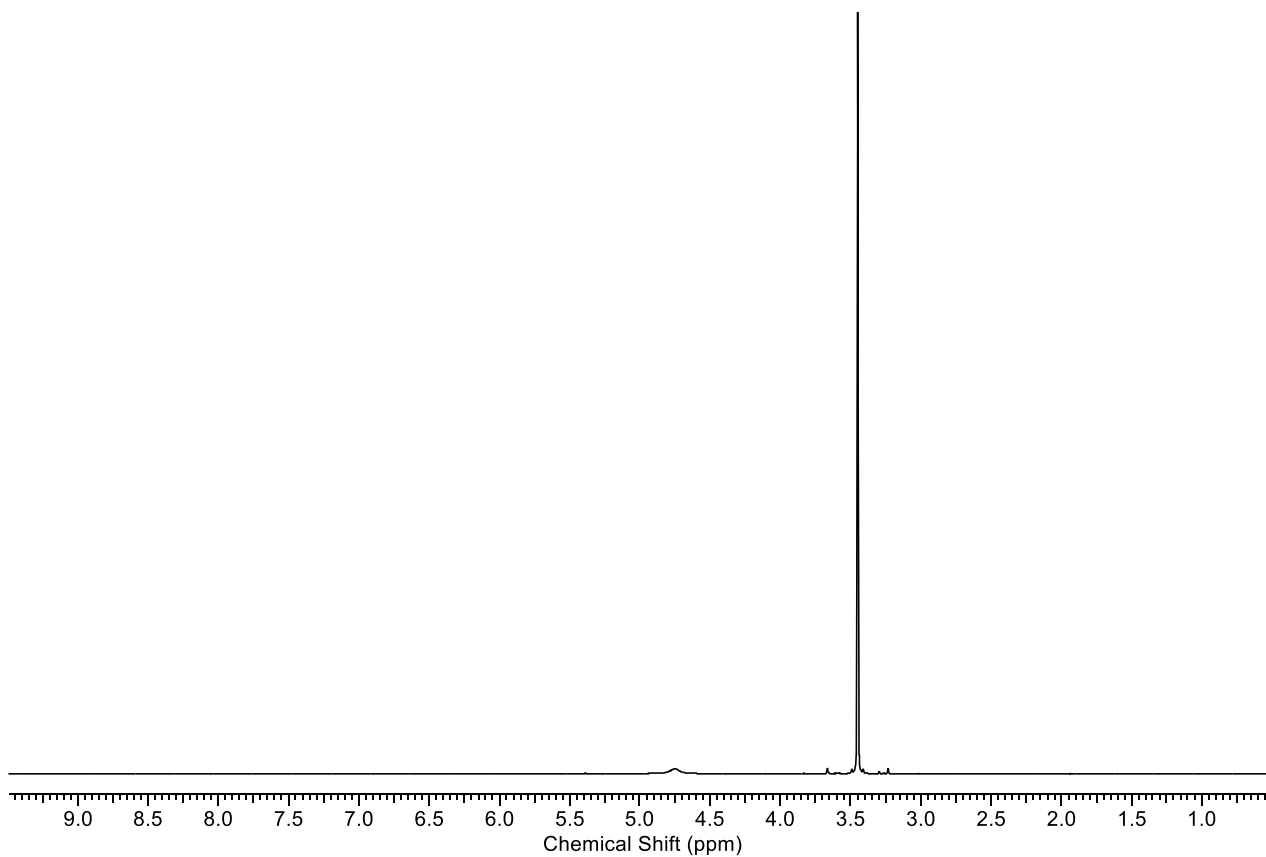


A320: UV-vis spectrum of 198.

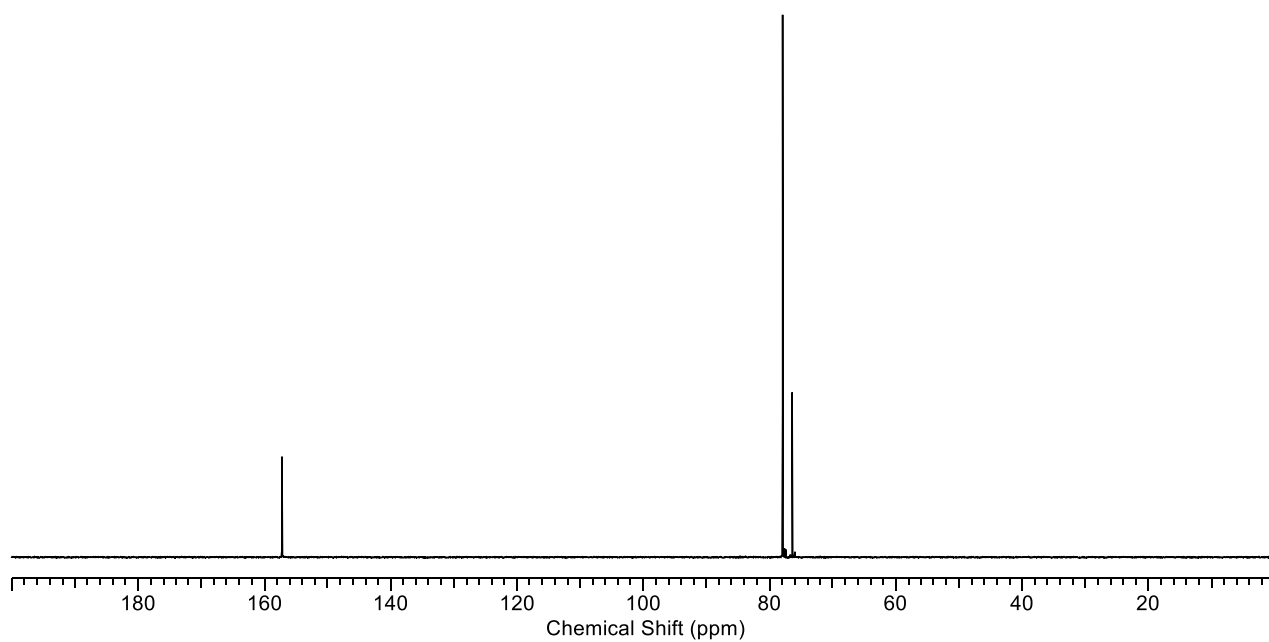


Propiolamide (182)

A321: ^1H NMR spectrum (600 MHz, $\{\text{D}_2\text{O}\}$, 0.5 – 9.5 ppm) of **182**.

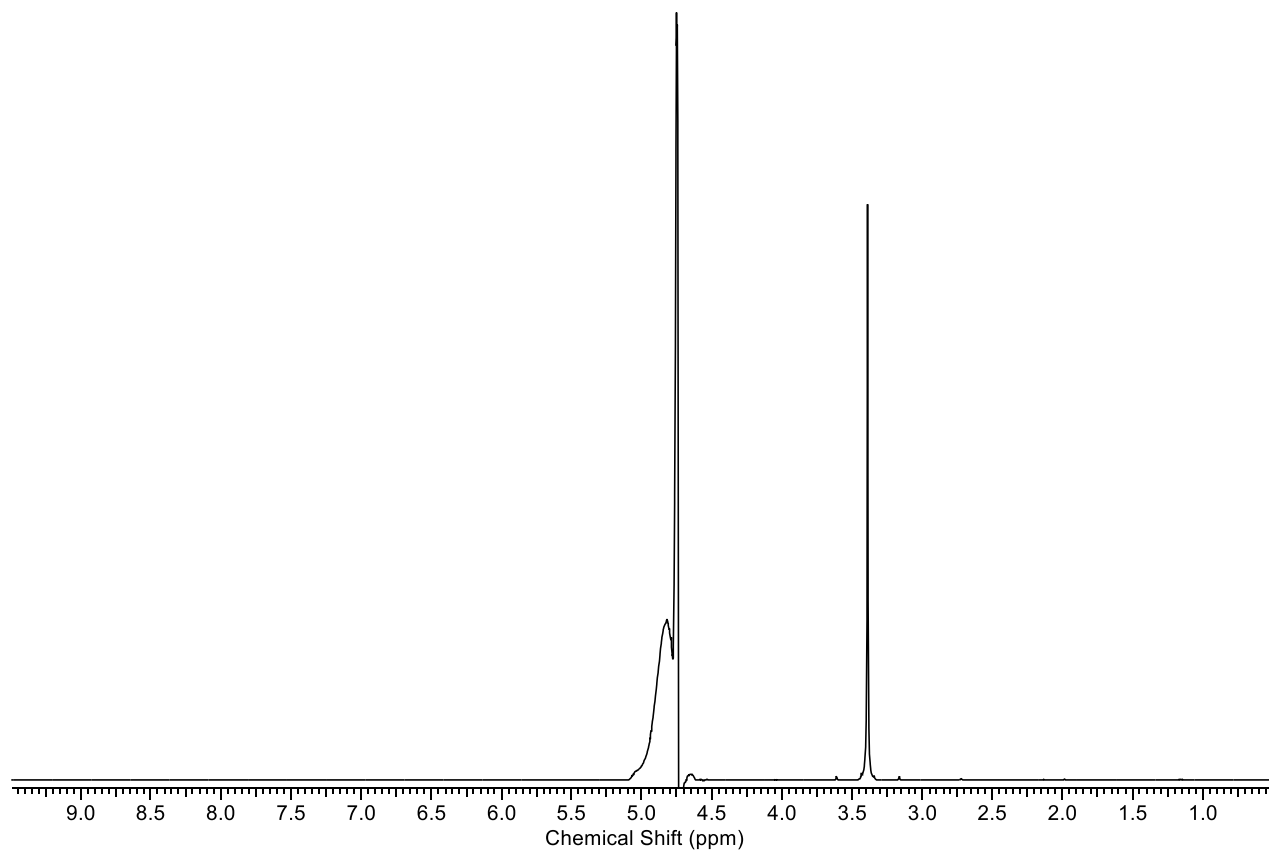


A322: ^{13}C NMR spectrum (151 MHz, $\{\text{D}_2\text{O}\}$, 0 – 200 ppm) of **182**.

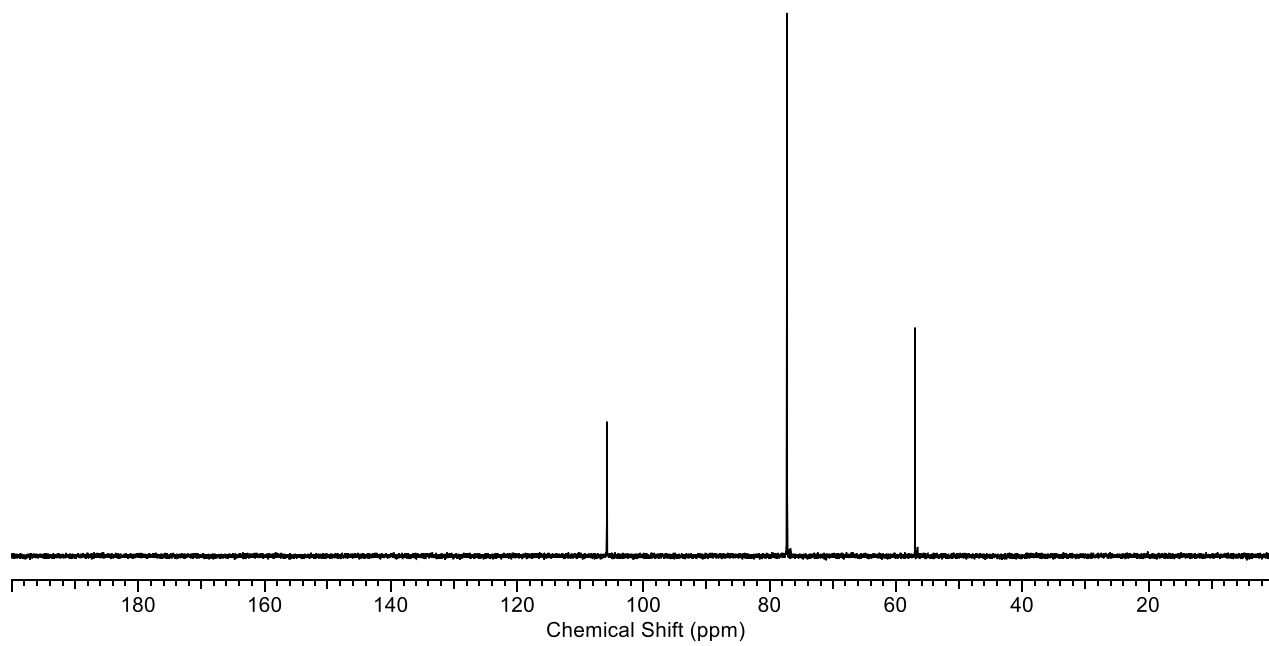


Cyanoacetylene (3)

A323: ^1H NMR spectrum (600 MHz, $\{\text{H}_2\text{O}/\text{D}_2\text{O}, 9:1\}$, 0.5 – 9.5 ppm) of **3**.

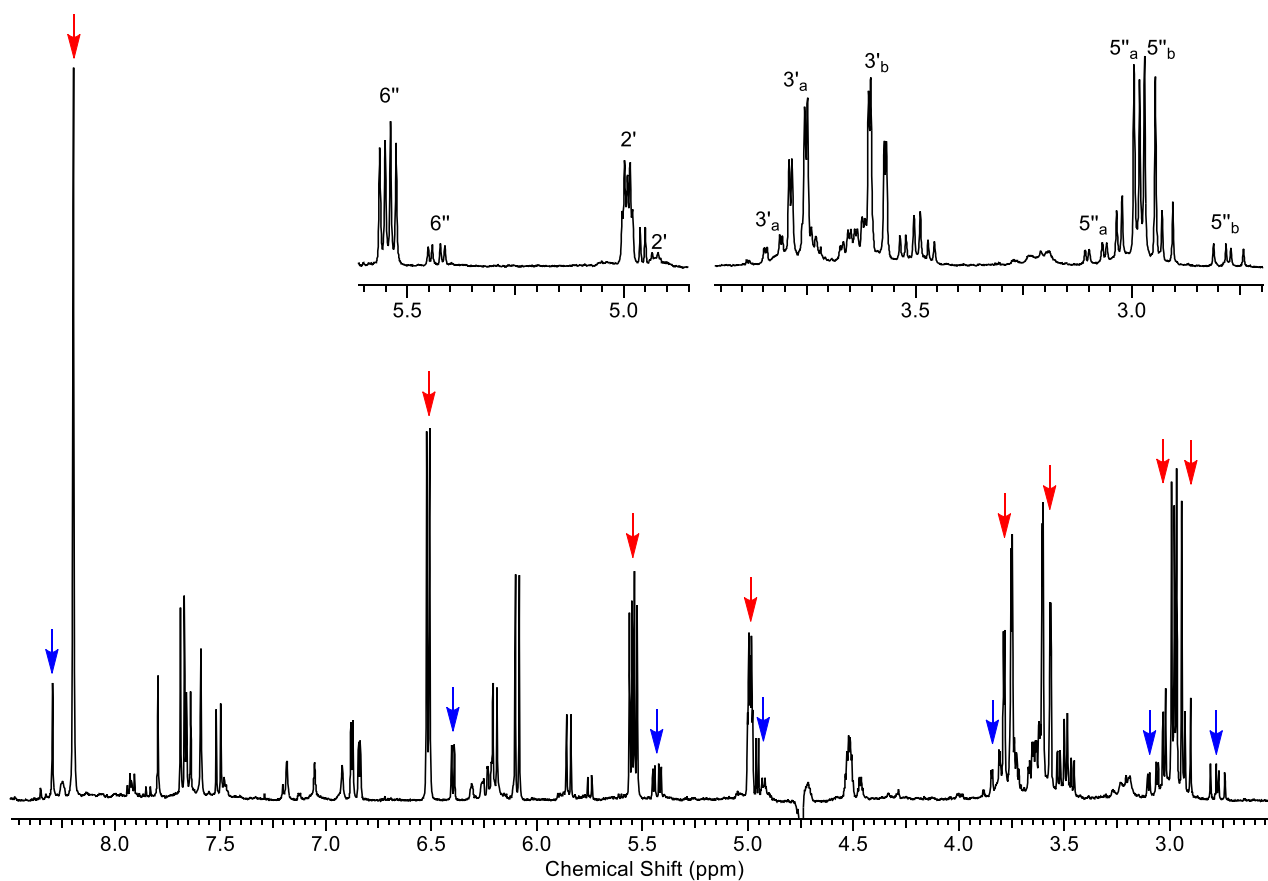


A324: ^1H NMR spectrum (600 MHz, $\{\text{H}_2\text{O}/\text{D}_2\text{O}, 9:1\}$, 0.5 – 9.5 ppm) of **3**.

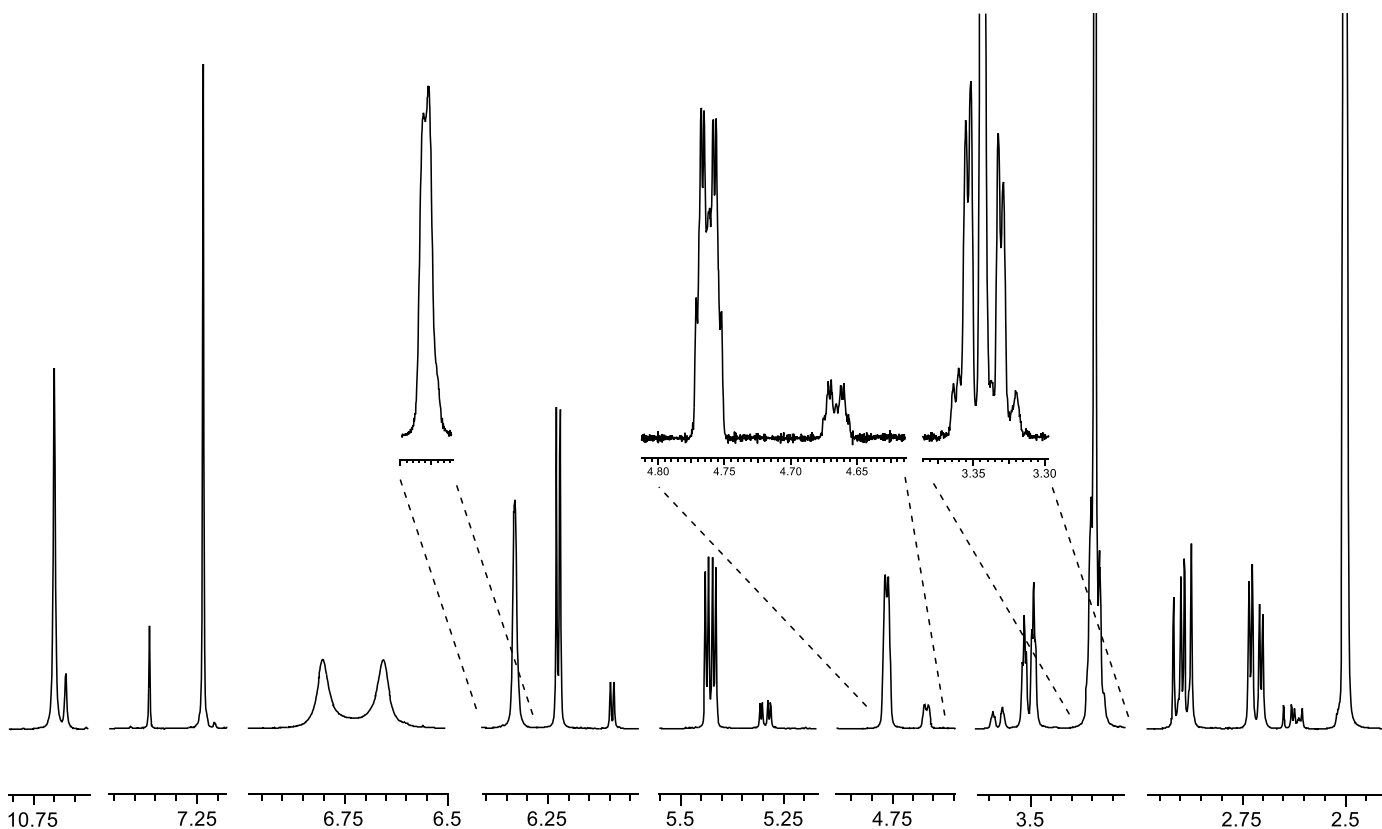
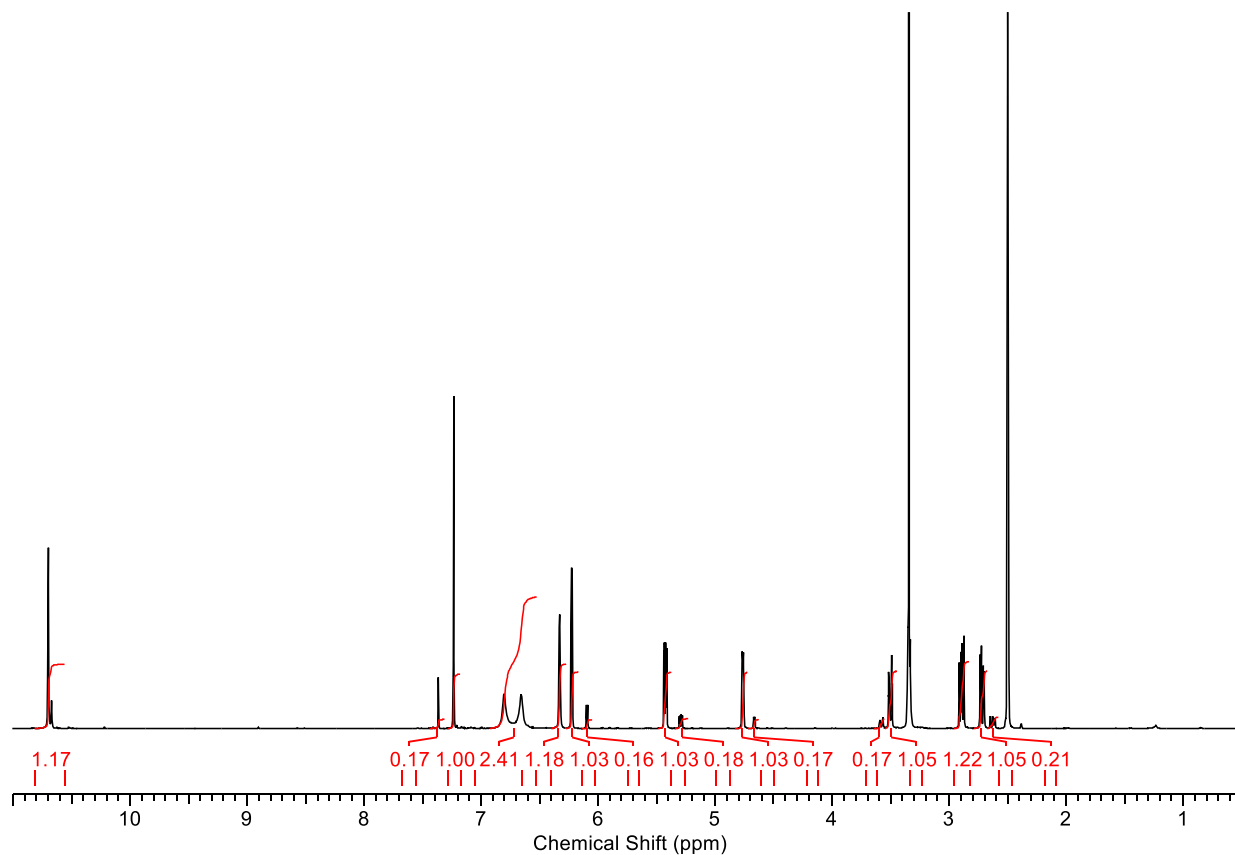


176-intra-molecular-addition product (**188**)

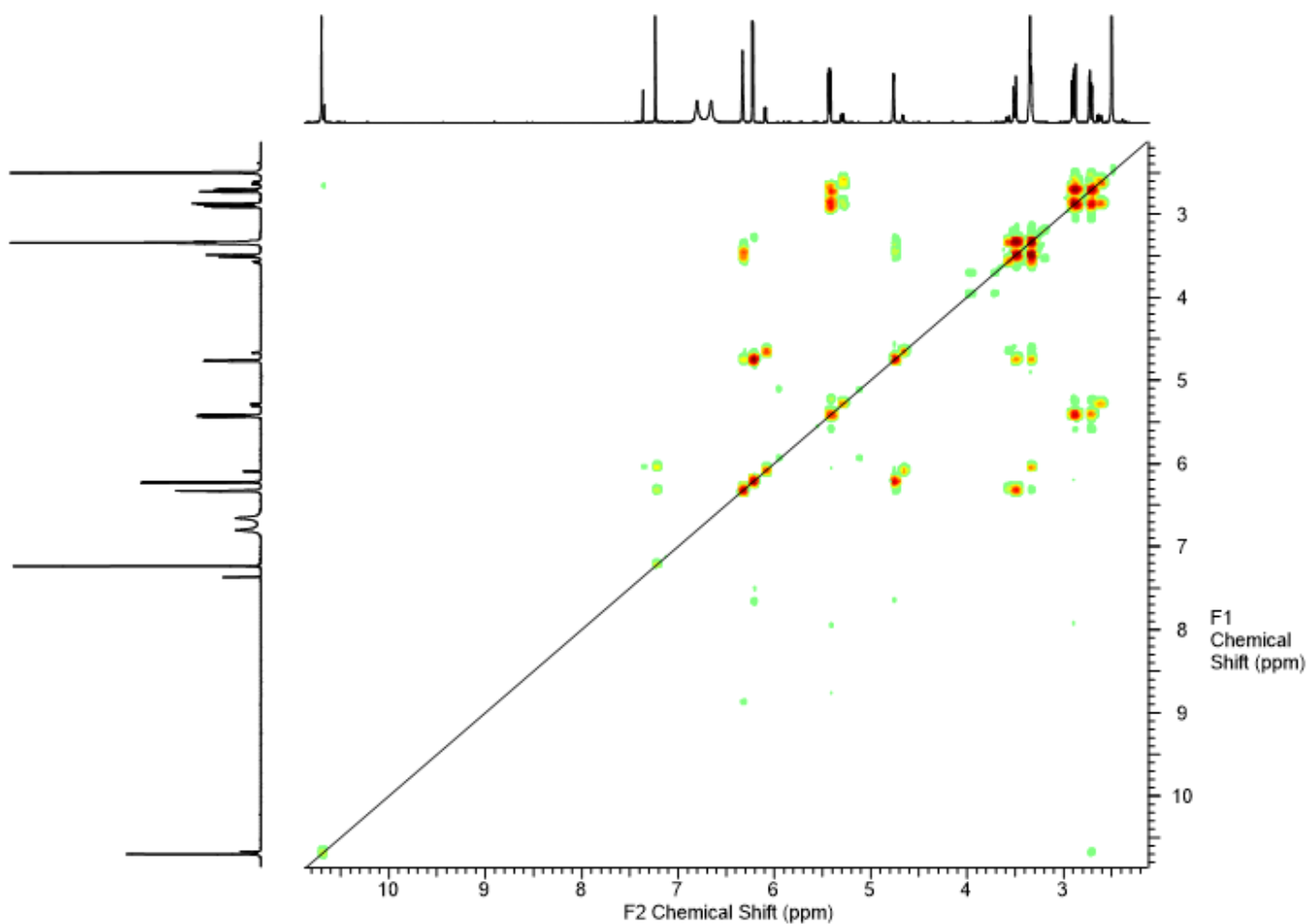
A325: ^1H NMR spectrum (400 MHz, $\{\text{H}_2\text{O}/\text{D}_2\text{O}, 9:1\}$, 2.5 – 8.5 ppm) of crude reaction product of **176** acid hydrolysis experiment after 47 h, with expansions overlaid and major and minor **188** diastereoisomer signals labelled (where discernible) with red and blue arrows respectively.



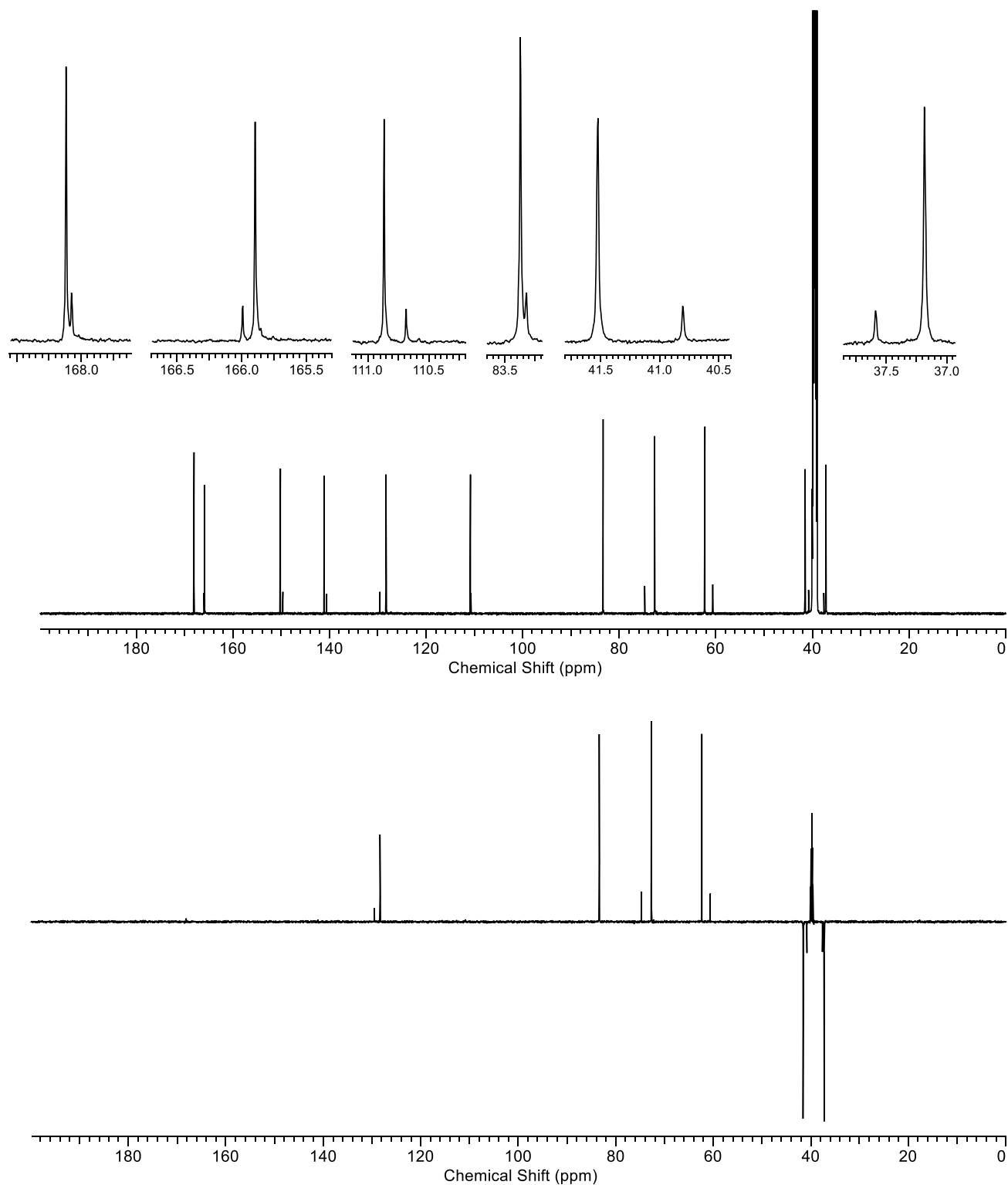
A326: ^1H NMR spectrum (600 MHz, {DMSO-d₆}, 0.5 – 11.0 ppm) of **188** as a mixture of diastereoisomers (major/minor ~6:1) with expansions below. The additionally expanded peaks are from the spectrum obtained from an FID processed with Lorentz-Gaussian apodization to improve signal resolution.



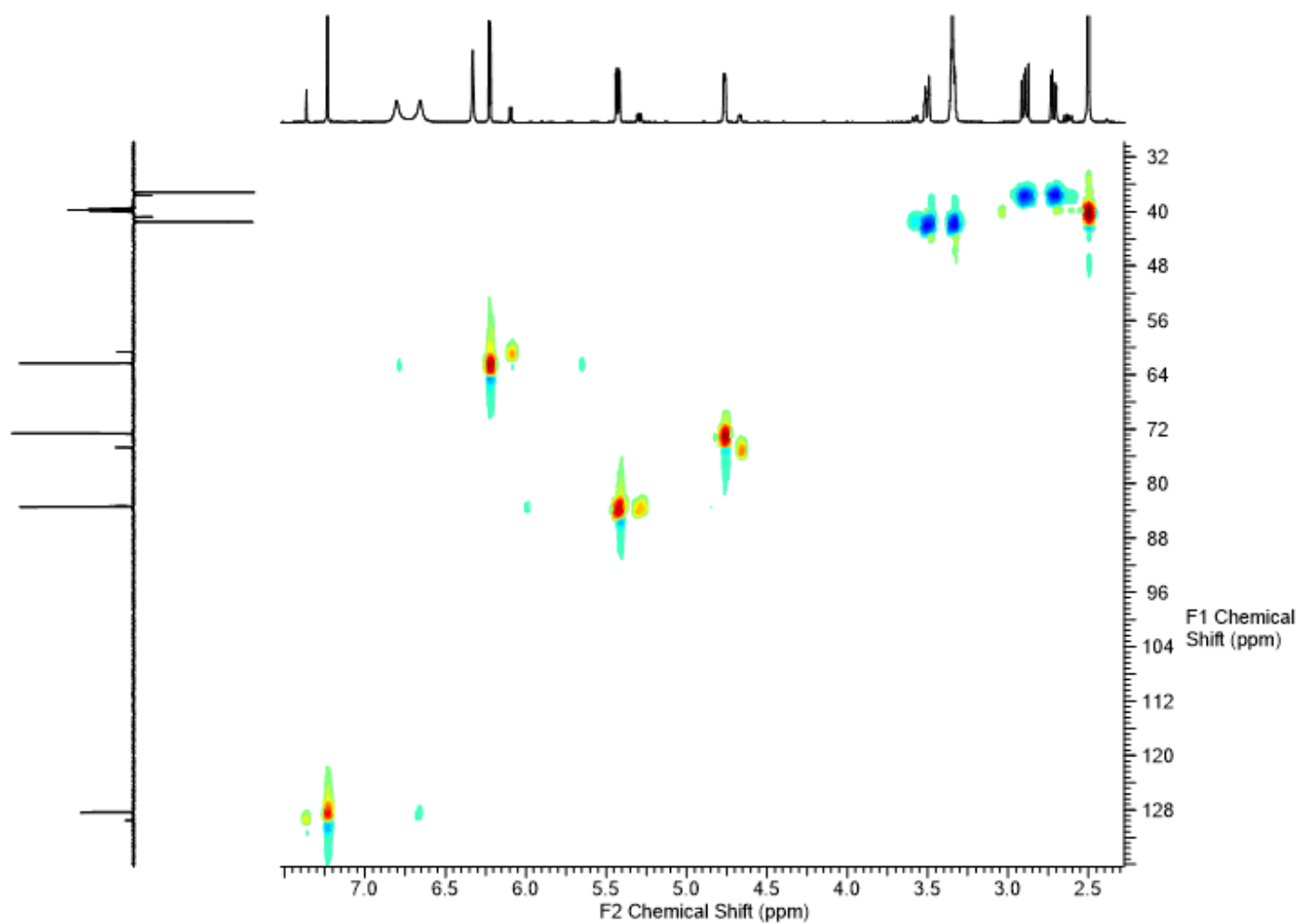
A327: ^1H - ^1H COSY NMR spectrum (600 MHz, {DMSO-d₆}) of **188** as a mixture of diastereoisomers (major/minor ~6:1).



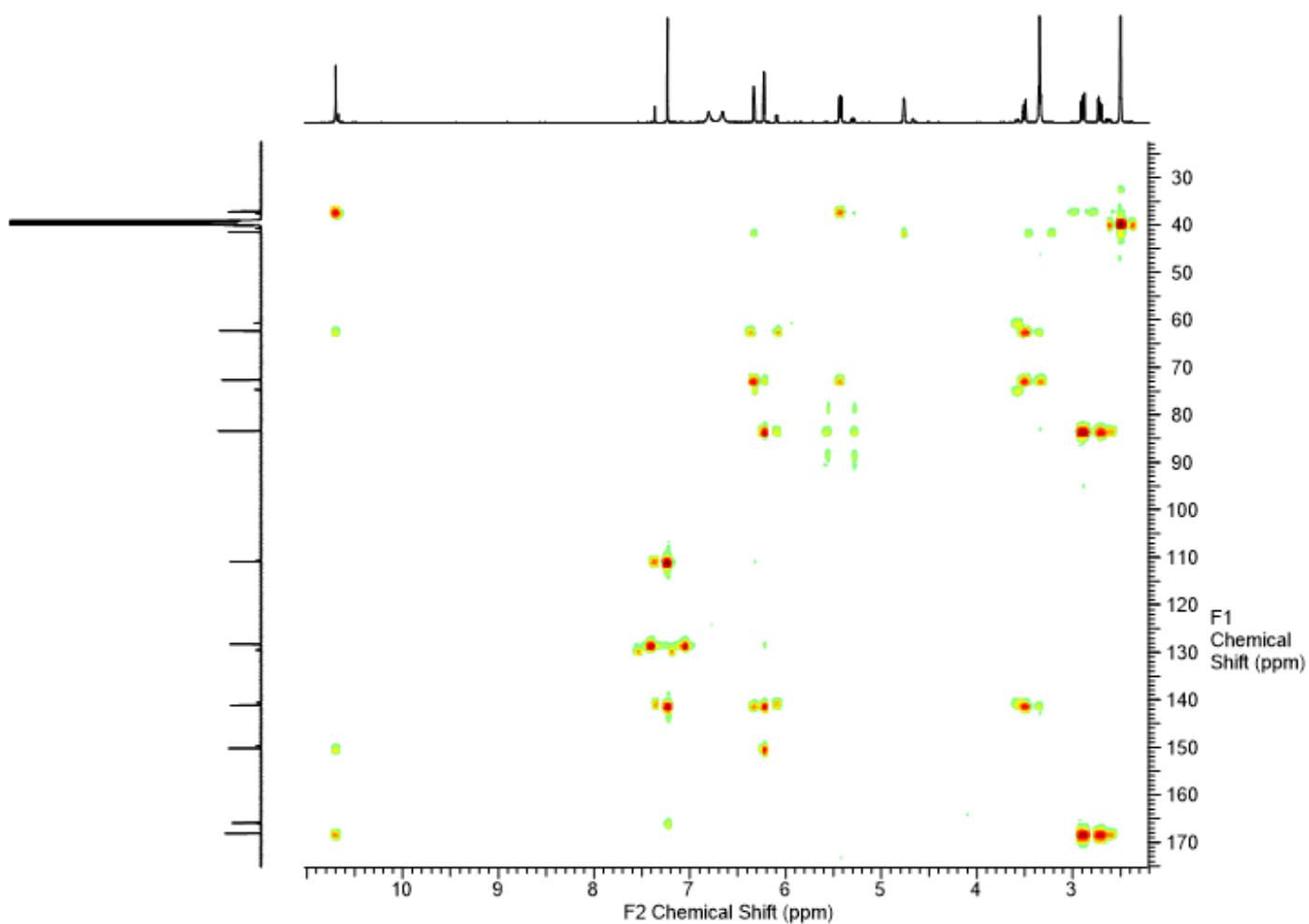
A328: ^{13}C NMR spectrum (151 MHz, {DMSO- d_6 }) of **188** as a mixture of diastereoisomers (major/minor ~6:1) with expansions overlaid and DEPT135 spectrum below.



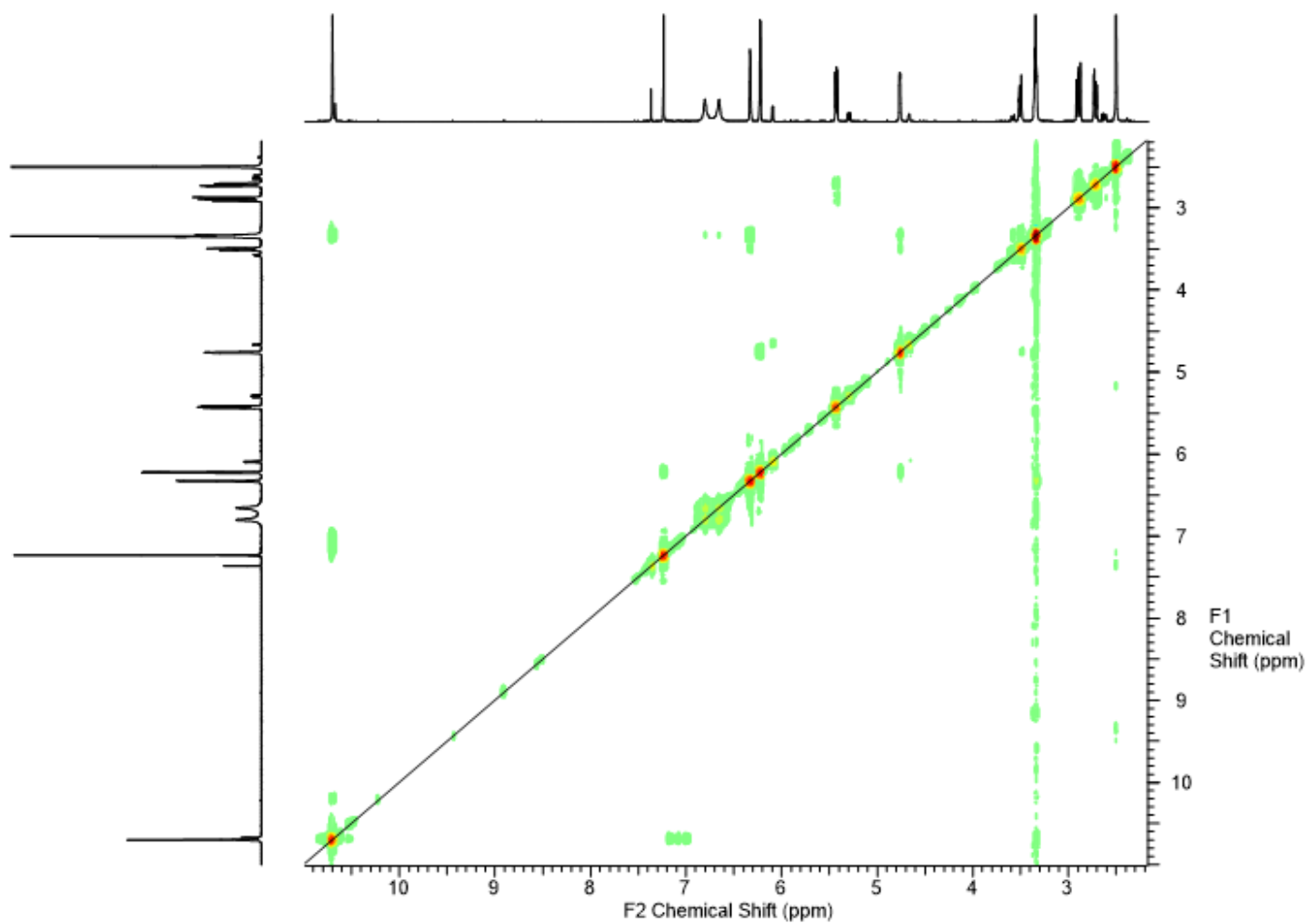
A329: ^1H - ^{13}C HSQC NMR spectrum (600 MHz, {DMSO- d_6 }) of **188** as a mixture of diastereoisomers (major/minor ~6:1).



A330: ^1H - ^{13}C HMBC NMR spectrum (600 MHz, {DMSO- d_6 }) of **188** as a mixture of diastereoisomers (major/minor ~6:1).



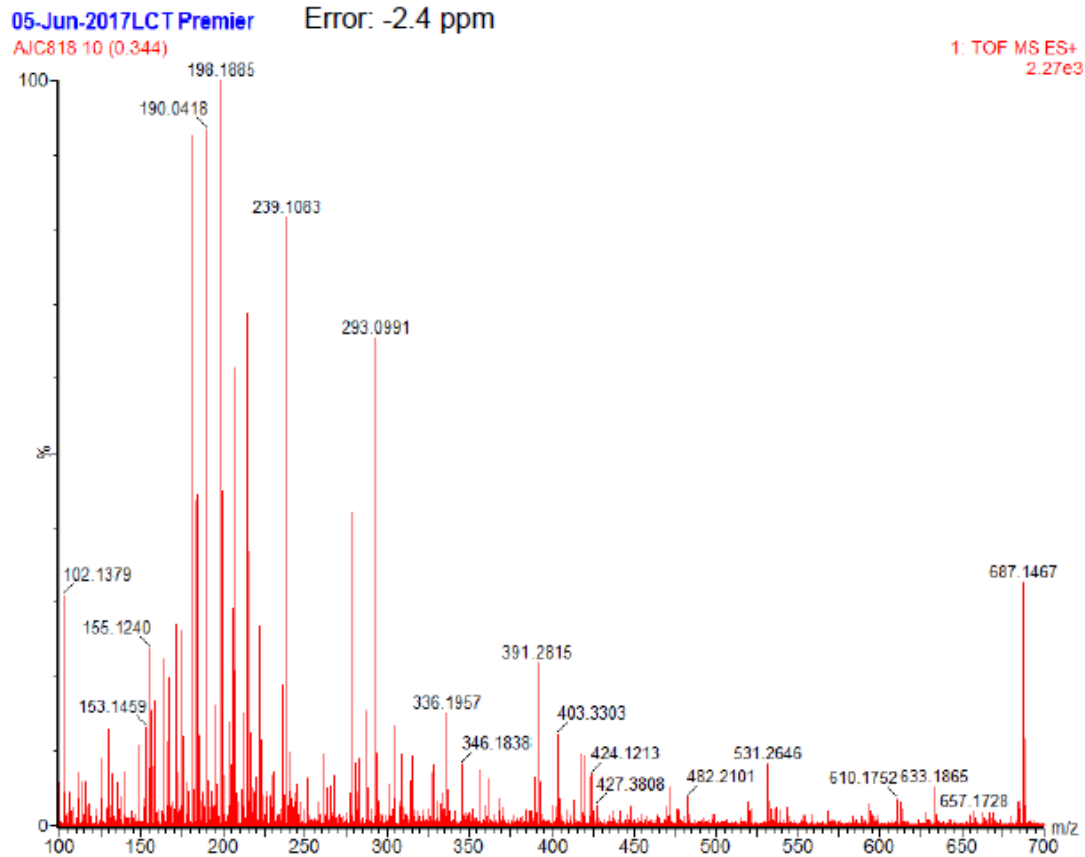
A331: ^1H - ^1H NOESY NMR spectrum (600 MHz, {DMSO- d_6 }) of **188** as a mixture of diastereoisomers (major/minor ~6:1).



A332: Mass spectrum of **188** as a mixture of diastereoisomers (major/minor ~6:1).

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Instrument Resolution: 10,000
Theoretical Mass [C₁₁H₁₃N₆O₄]⁺: 293.0998
Measured Mass : 293.0991
Error: -2.4 ppm



8 June 2017

Waters LCT Premier XE ESI Q-TOF mass spectrometer

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