Chiral pyridyl phosphinites with large aryl substituents as efficient ligands for the asymmetric iridium-catalyzed hydrogenation of difficult substrates

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Supporting Information

1

1.0 General information, 3

2

2.0 Synthesis of Complexes, 5
2.1. catalyst *S*-**7a**, 5
2.1. catalyst *S*-**7b**, 6
2.1. catalyst *S*-**7c**, 7
2.1. catalyst *S*-**7d**, 8
2.1. catalyst *S*-**7e**, 9
2.1. catalyst *R*-**7f**, 10
2.1. catalyst *S*-**7g**, 12
2.1. catalyst *S*-**7h**, 13
2.1. catalyst *S*-**9a**, 14
2.1. catalyst *R*-**9a**, 15
2.1. catalyst *S*-**9b**, 15
2.1. catalyst *S*-**9c**, 16
2.2. synthesis of reagent **17**, 17

3

3.0 Synthesis of pyridyl alcohols 12a-g, 18
3.1 alcohol *R*-**12c**, 20
3.1 alcohol *R*-**12g**, 23
3.1 alcohol *S*-**12a**, 18
3.1 alcohol *S*-**12b**, 19
3.1 alcohol *S*-**12d**, 20
3.1 alcohol *S*-**12e**, 21
3.1 alcohol *S*-**12f**, 22
3.1 alcohol *S*-**12g**^{1}, 22

4

4.1 acetate **11a**, 24
4.1 acetate **11b**, 25
4.1 synthesis and separation of **11a-b**, 24
4.2 CALB resolution of racemic **12c-d** and **13a-b**, 25
4.2.1 (*R*)-**12c**-OAc, 27
4.2.1 (*R*)-**12d**-OAc, 26
4.2.1 (*S*)-**14a**, 27
4.2.1 (*S*)-**14b**, 26
4.2.2 (*R*)-**13b**-OAc, 30
4.2.2 (*S*)-**15a**, 29
4.2.2 (*S*)-**15b**, 30

4.2.2 CALB resolution of racemic **13a-b**, 28
4.3 Asymmetric reduction of 2-chloro-4-methyl-5H-cyclopenta[b]pyridin-7(6H)-one with R-methyl-CBS and catecholborane or (-)B-Chlorodiisopinocamphylborane, 31
4.3. (*S*)-**13a**[2, 3], 31

5

5.0 Suzuki cross coupling, 32
5.1 Suzuki reaction of hindered boronic acids and esters with 2-chloropyridines **10a-b**, 32
5.1. **10a-**2-mesityl, 33
5.1. **10b-**2-mesityl, 33
5.2 Suzuki reaction of hindered boronic acids and esters with 2-chloropyridine-O-terbutyldimethylsilyl ether derivatives., 34
5.2. (*S*)-**12g** OTBDMS, 37
5.2. (*S*)-**12e** OTBDMS, 35
5.2. (*S*)-**12f** OTBDMS, 36
5.2. (*S*)-**12g** OTBDMS, 37
5.2. racemic-**14a**, 37
5.2. racemic-**14b**, 38

6

6.0 Chlorination of 2-pyridones, 39
6.1. **10a**, 39
6.1. **10b**, 40

7

7.0 Oxidation of ortho substituted pyridines to pyridine-N-oxides, 40

8

8.0 Boekelheide rearrangement of pyridines of N-oxides, 42
8.1. **13a**-OAc, 43
8.1. **13b**-OAc, 43

9

9.0 synthesis of 13a-b and Swern oxidation of 13a and formation of racemic 15a-b, 43
9.1 rac-**13a**, 44
9.1 rac-**13b**, 44
9.2. **13a**-ketone, 45
9.3. racemic **15a**, 45
9.3. racemic **15b**, 46

R

References, 55

10

10.0 Synthesis of 2-pyridones, 46

11

11.0 General procedures for asymmetric reduction and characterization for hydrogenation substrates and products, 48
11.1 synthesis of **22a**, 49
11.1 (*E*)-**26**, 51
11.1 **22b**, 48
11.1 conjugate reduction product of **27**, 52
11.1 product *R*-**29a**, 52
11.1 product *R*-**29b**, 53
11.1 product *R*-**29c**, 53
11.1 stereoselective synthesis of **26**, 50

12

12.0 Chromatograms, 56
12.1 GC of **21a** hydrogenation, 57
12.1 GC of **25** hydrogenation with catalyst *S*-**7e**, 61
12.1 HPLC of **20a** hydrogenation, 56
12.1 HPLC of **22a** hydrogenation, 58
12.1 HPLC of **24** hydrogenation, 60
12.1 HPLC of **26** hydrogenation, 62

12.1 HPLC of **27** hydrogenation, 63
12.1 HPLC of **29a**, 64
12.1 HPLC of **29b**, 65
12.1 HPLC of **29c**, 66
12.2 HPLC of **11a** resolution, 67
12.2 HPLC of **11b** resolution, 68
12.2 HPLC of **13a** DIPCl reduction, 69
12.2 HPLC of **13a** resolution, 69
12.2 HPLC of **13b** resolution, 70
13
13. ^{1}H & ^{13}C spectra, 71
13. **10a-2-mesityl** ^{1}H & ^{13}C, 125
13. **10a-2-mesityl-*N*-oxide** ^{1}H & ^{13}C, 129
13. **10b-2-mesityl** ^{1}H & ^{13}C, 127
13. **10b-2-mesityl-*N*-oxide** ^{1}H & ^{13}C, 131
13. **11a** ^{1}H & ^{13}C, 107
13. **11b** ^{1}H & ^{13}C, 109
13. **12a** ^{1}H & ^{13}C, 93
13. **12b** ^{1}H & ^{13}C, 95
13. **12c** ^{1}H & ^{13}C, 97
13. **12c-OAc** ^{1}H & ^{13}C, 111
13. **12d** ^{1}H & ^{13}C, 99
13. **12d-OAc** ^{1}H & ^{13}C, 113
13. **12e**^{1}H & ^{13}C, 101
13. **12e-OTBDMS** ^{1}H & ^{13}C, 119
13. **12f** ^{1}H & ^{13}C, 103
13. **12f-OTBDMS** ^{1}H & ^{13}C, 121
13. **12g** ^{1}H & ^{13}C, 105
13. **12g-OTBDMS** ^{1}H & ^{13}C, 123
13. **14a** ^{1}H & ^{13}C, 115
13. **14b** ^{1}H & ^{13}C, 117
13. **15a** ^{1}H & ^{13}C, 133
13. **15b** ^{1}H & ^{13}C, 135
13. *R*-**7f** ^{1}H & ^{13}C, 81
13. *S*-**7a** ^{1}H & ^{13}C, 71
13. *S*-**7b** ^{1}H & ^{13}C, 73
13. *S*-**7c** ^{1}H & ^{13}C, 75
13. *S*-**7d** ^{1}H & ^{13}C, 77
13. *S*-**7e** ^{1}H & ^{13}C, 79
13. *S*-**7g** ^{1}H & ^{13}C, 83
13. *S*-**7h** ^{1}H & ^{13}C, 85
13. *S*-**9a** ^{1}H & ^{13}C, 87
13. *S*-**9b** ^{1}H & ^{13}C, 89
13. *S*-**9c** ^{1}H & ^{13}C, 91

1.0 General information

NMR-Spectroscopy: NMR spectra were measured either on a Bruker Advance 400 (400 MHz) or a Bruker Advance DRX 500 (500MHz) spectrometer equipped with BBO broadband probe heads. The chemical shift δ value is given in ppm. The chemical shift δ values were corrected to 7.26 ppm (^{1}H NMR) and 77.0 ppm (^{13}C NMR) for $CHCl_3$, 5.32 ppm (^{1}H NMR) and 54.0 ppm (^{13}C NMR) for CH_2Cl_2, 4.78 ppm and 3.35 ppm (^{1}H NMR) and 49.3 ppm (^{13}C NMR) for CH_3OH, 7.16 ppm (^{1}H NMR) and 128.0 ppm (^{13}C NMR) for C_6H_6, 2.50 ppm (^{1}H NMR) and 39.5 ppm (^{13}C NMR) for $(CH_3)_2SO$. The assignment of ^{1}H and ^{13}C signals was partly made by 2D-NMR, namely COSY, HMQC, HMBC and NOSY. ^{13}C were recorded in ^{1}H decoupled mode. Multiplets were assigned with s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sext (sextet), m (multiplet). The index br stands for broad.

Mass Spectrometry (MS): Mass spectra were measured by Dr. H. Nadig (Department of Chemistry, University of Basel) on a VG70-250 (electron ionization (EI)) mass spectrometer or a MAR 312 (fast atom bombardment (FAB)) mass spectrometer. FAB was preformed with 3-nitrobenzyl alcohol (NBA) as matrix. ESI MS spectra were measured on a Finnigan MAT LCQ and a on a Varian 1200L triple Quad MS/MS. The signals are given in mass to charge ratio (m/z). The fragment and intensities are given in brackets. All values are rounded to the nearest whole number.

Infrared Spectroscopy (IR): Infrared spectra were measured on a Perkin Elmer 1600 series FTIR spectrometer. Solid samples were measured as KBr discs or as thin films on NaCl plates. Absorption bands are given in wave numbers $\tilde{\nu}$ (cm^{-1}). The peak intensity is assigned with s (strong), m (medium) and w (weak). The index br stands for broad.

Melting Point (MP): Melting points were measured on a Büchi 535 melting point apparatus and are uncorrected.

Optical Rotation ($[\alpha]_D^{20}$): Optical rotations were measured on a Perkin Elmer Polarimeter 341 in a 1 dm cuvette at 20˚C. The concentration (c) is given in g/100 mL.

Gas Chromatography (GC): Gas chromatograms were collected on a Carlo Erba HRGC Mega2 Series 800 (HRGS Mega2) instruments. Achiral separations were performed on a Restek Rtx-1701 column (30m x 0.25mm x 0.25µm) and for chiral separations β and γ cyclodexterine columns (30m x 0.25mm x 0.25µm) were used.

High Performance Liquid Chromatography (HPLC): HPLC analyses were measured on Shimadzu systems with SCL-10A system controller, CTO-10AC column oven, LC10-AD pump system, DGU-14a degasser and SPD-M10A Diode Array or UV/VIS detector. Chiralcel brand chiral columns from Daicel Chemical Industries were used with models OD-H, OJ-H, AD-H, OB-H or IC in 4.6 x 250 mm size.

Semipreparative High Performance Liquid Chromatography (HPLC): Seperations by semipreparative HPLC were performed on a Shimadzu system with SIL 10Advp autosampler, CTO 10 Asvp column oven, LC 10 Atvp pump system, FCV 10 Alvp degasser and SPD M10 avp diode array detector. Chiralcel brand columns from Diacel Chemical Industries were used with models OD and AD in size 2 x 25 cm.

Thin Layer Chromatography (TLC): TLC plates were obtained from Whatman (Partisil, 250 µm x 20 cm x 20 cm, florescent model K6F) and the glass was scored and plates broken into 20 x 100 mm size with a glass cutter. TLC were visualized with UV light (254 nm, 366 nm) or with basic permanganate solution or ceric ammonium molybdate solution.

Gas Chromatography with Mass Spectrum detection (GC/MS): HP6890 gas chromatograph with a HP5970A detector equipped with a Machery and Nagel Optima5 5% polyphenylmethylsiloxane column, 25 m x 0.2 mm id and 35 µM film thickness, flow set to 20 psi of hydrogen carrier gas, a 20/1 split ratio. The oven was programmed for a starting temperature of 100 ˚C, a 2 minute holding time at that temperature, a 10 ˚C/minute ramp with a final temperature of 270 ˚C and a holding time of 10 minutes at that temperature.

Elemental Analysis (EA): Elemental analyses were measured at the Department of Chemistry University of Basel Microanalytical Laboratory by Mr. W. Kirsch on a Leco CHN-900 analyser.

2.0 Synthesis of Complexes

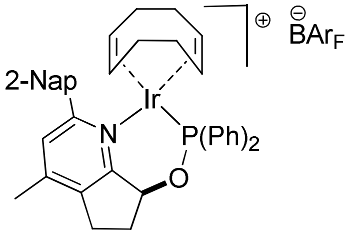
2.1 Phosphonite formation and iridium complexation

General method: Pyridyl alcohol (87.9 µmol) and DMAP (10.7 mg, 87.9 µmol) were added to a 4 mL vial with a small stir bar. The vial was loosely capped and brought inside the box. Absolute THF (500 µL) was added to the vial and the contents were stirred into solution. Chlorodiphenylphosphine (19.4 mg, 87.9 µmol) was weighed into a separate vial and (500 µL) was added. The solution was transferred to the stirring mixture of DMAP and pyridyl alcohol with a syringe and the contents of the vial and syringe were washed into the reaction mixture with THF (3 x 250 µL). An immediate white precipitate was formed on addition of the chlorophosphine and the reaction was stirred for 30 minutes. The slurry was filtered through a small pipette plug of silica and the silica washed with additional THF (2 x 1 mL) into a young tube with a stir bar. The tube was sealed, brought outside the box and the volatiles were removed on a Schlenk line. Absolute DCM (5 mL) was added to the tube under argon followed by solid iridium(I), bis[(1,2,5,6-η)-1,5-cyclooctadiene]-, tetrakis[3,5-bis(trifluoromethyl)phenyl]borate) (112.7 mg, 88.6 µmol). The tube is sealed and resulting solution is stirred for 2.5 hours at 45˚C. The reaction is then cooled and the contents are rotary evaporated onto silica, loaded onto a column of silica prepared with hexane and chromatographed with the appropriate combination of ether/hexane and then DCM. The resulting red solids are recrystallized from DCM/ hexane to obtain solid X-ray quality crystals.

Note* Catalysts with *o*-tolyl-phosphines and large groups in the 2-position of the pyridine ring require very extended acquisition time to observe the ^{31}P peak(s) which tend to be quite broad at room temperature. Increasing the line broadening to reduce noise greatly assists observations of these broad resonances.

2.1. catalyst *S*-**7a**

(+)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][(S)-7-(diphenylphosphinooxy-κP)-4-methyl-2-(naphthalen-2-yl)-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method to yield 107 mg (65.9 µmol, 73%) from **12e**. Chromatographed with 30% ether in hexane to remove byproducts, 50% DCM hexane and final elution with pure DCM.

Chemical Formula: $C_{71}H_{50}BF_{24}IrNOP$ Molecular Weight: 1623.1

MP: 198-200 ˚C

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (s, 1H), 7.95 – 7.82 (m, 3H), 7.71 – 7.62 (m, 11H), 7.62 – 7.54 (m, 2H), 7.51 – 7.44 (m, 3H), 7.42 (s, 4H), 7.41 – 7.32 (m, 6H), 6.40 – 6.22 (m, 1H), 4.48 (s, 1H), 4.22 (s, 1H), 3.01 (dddd, *J* = 17.3, 14.1, 9.2, 2.4 Hz, 2H), 2.86 (ddt, *J* = 24.3, 16.0, 8.1 Hz, 2H), 2.69 – 2.58 (m, 1H), 2.57 – 2.45 (m, 1H), 2.29 (s, 3H), 2.08 – 1.94 (m, 1H), 1.83 (dd, *J*

= 15.3, 7.8 Hz, 2H), 1.71 (dt, *J* = 13.7, 9.2 Hz, 1H), 1.60 – 1.48 (m, 1H), 1.22 – 1.12 (m, 1H), 1.06 – 0.93 (m, 1H), 0.53 (dt, *J* = 13.3, 9.2 Hz, 1H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 162.1 (dd, J_{BC} = 99.6, 49.9 Hz), 161.0, 160.2 (d, J_{PC} = 3.6 Hz), 150.1, 138.3, 136.5, 136.1, 135.6, 135.2, 134.6, 133.4, 132.6, 132.2, 131.7, 130.7 (d, J_{PC} = 14.1 Hz), 130.1, 129.7 (d, J_{PC} = 11.0 Hz), 129.4 (d, *J* = 10.9 Hz), 129.2, 128.9, 128.7 (dd, J_{FC} = 18.5, 12.6 Hz), 128.2, 126.0, 125.8, 124.7, 123.9, 121.7, 117.9, 99.4 (d, J_{PC} = 9.5 Hz), 90.4 (d, J_{PC} = 14.9 Hz), 85.7, 69.5, 63.8, 36.3, 34.4, 30.1 (d, J_{CP} = 10.2 Hz), 28.7, 26.7, 24.5, 19.2.

^{31}P NMR (162 MHz, CDCl$_3$) δ 146.2. ^{19}F NMR (376 MHz, CDCl$_3$) δ -63.5.

MS (FAB, NBA): 763.3 (2), 762.3 (10), 761.3 (41.5%), 760.2 (100), 759.2 (31),758.2 (62).

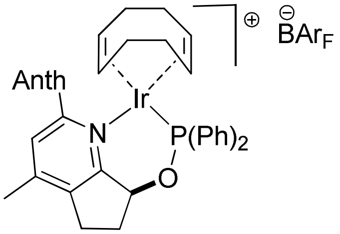
IR (neat, $\tilde{\nu}$): 2955w, 1611, 1481, 1456, 1437, 1354, 1277, 1125, 1043, 1016, 999, 965, 927, 886, 854, 838, 743, 712, 682, 669 cm^{-1}.

$[\alpha]_D^{20}$ = +20.4 at a concentration of 0.71.

Elemental Analysis: for $C_{71}H_{50}BF_{24}IrNOP$ calculated C, 52.54; H, 3.10; N, 0.86; found C, 52.46; H, 3.07; N, 0.72.

2.1. catalyst *S*-**7b**

(+)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][(S)-2-(anthracen-9-yl)-7-(diphenylphosphinooxy κP)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 23.6 mg (72.6 µmol) of pyridyl alcohol **12f**, 8.8 mg (72.6 µmol) of DMAP, 16 mg (72.6 µmol) of chlorodiphenylphosphine and 71.2 mg (72.6 µmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 89 mg (49.0 µmol, 68%).
Chemical Formula: $C_{75}H_{52}BF_{24}IrNOP$ Molecular Weight: 1673.2
MP: 98-101 ˚C
^{1}H NMR (400 MHz, CDCl$_3$) δ 8.71 (s, 1H), 8.11 (dd, *J* = 8.2, 5.1 Hz, 2H), 7.72 (s, 8H), 7.61 (qd, *J* = 6.7, 4.0 Hz, 4H), 7.55 (td, *J* = 6.0, 2.4 Hz, 2H), 7.50 (dd, *J* = 9.6, 3.9 Hz, 7H), 7.49 – 7.41 (m, 5H), 7.40 – 7.33 (m, 4H), 6.73 (d, *J* = 8.7 Hz, 1H), 6.30 – 6.19 (m, 2H), 5.13 (s, 1H), 3.75 (s, 1H), 3.35 – 3.20 (m, 1H), 3.04 (ddd, *J* = 17.2, 9.5, 4.4 Hz, 1H), 2.99 – 2.88 (m, 1H), 2.89 – 2.74 (m, 1H), 2.70 – 2.55 (m, 1H), 2.47 (s, 3H), 2.27 – 2.09 (m, 1H), 2.05 (t, *J* = 7.4 Hz, 1H), 1.63 (dd, *J* = 14.5, 9.0 Hz, 2H), 1.46 – 1.40 (m, 2H), 1.01 (dd, *J* = 15.7, 9.9 Hz, 2H), 0.66 – 0.47 (m, 2H), 0.21 – 0.05 (m, 1H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 163.5 – 160.7 (dd, J_{BC} = 99.6, 49.9 Hz), 159.0, 150.1, 139.4, 135.2, 134.0, 133.5 (d, J_{PC} = 6.5 Hz), 132.9, 132.4 (d, J_{PC} = 14.7 Hz), 132.1, 131.2 (d, J_{PC} = 5.1

Hz), 131.1, 130.94 (d, J_{PC} = 11.4 Hz), 130.6 (d, J_{PC} = 13.2 Hz), 130.4 (d, J_{PC} = 5.6 Hz), 129.7 (d, J_{PC} = 10.7 Hz), 129.5, 129.3 (d, J_{PC} = 2.5 Hz), 129.2, 129.1, 129.0 (m $_{BC}$), 128.9 – 128.8 (m $_{FC}$), 128.6, 127.7, 126.4 (d $_{PC}$, J = 17.5 Hz), 124.8, 123.7 (d, J = 12.8 Hz), 120.9, 117.9, 95.1 (d, J_{PC} = 7.8 Hz), 87.5 (d, J_{PC} = 18.7 Hz), 84.63 (s, 1H), 69.4, 68.1 , 36.3, 35.8, 29.8 (d, J_{PC} = 10.0 Hz), 27.8, 27.5, 24.6, 19.2.

^{31}P NMR (162 MHz, $CDCl_3$) δ 149.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.1.

MS (FAB, NBA): m/z: 813.3 (2), 812.3 (12), 811.3 (48), 810.2 (100), 808.2 (65), 809.2 (37).

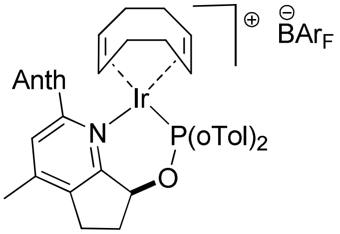
IR (neat, $\tilde{\nu}$): 2887w, 1737w, 1608, 1485, 1463, 1438, 1352s, 1272s, 1157, 1112s, 1093, 999w, 958, 885, 838, 738, 711, 696, 680, 669, 642, 619 cm^{-1}.

$[\alpha]_D^{20}$ = +39.4 at a concentration of 0.60.

Elemental Analysis: for $C_{75}H_{52}BF_{24}IrNOP$ calculated C, 53.84; H, 3.13; N, 0.84; found C, 53.78; H, 3.17; N, 0.77.

2.1. catalyst *S*-**7c**

(+)-Iridium(I)[(1,2,5,6-η)-1,5-cyclooctadiene][((S)-2-(anthracen-9-yl)-7-(dio-tolylphosphinooxy-κP)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 24.2 mg (74.5 µmol) of pyridyl alcohol **12f**, 9.1 mg (74.5 µmol) of DMAP, 18.5 mg (74.5 µmol) of chlorodiphenylphosphine and 94 mg (74.5 µmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 87 mg (51.1 µmol, 69%).
Chemical Formula: $C_{77}H_{56}BF_{24}IrNOP$ Molecular Weight: 1701.2

MP: 103-105 ˚C

^{1}H NMR (500 MHz, CDCl3) δ 8.64 (s, 1H), 8.10 (d, J = 8.5 Hz, 1H), 8.00 (d, J = 8.5 Hz, 1H), 7.69 (s, 8H), 7.55 (s, 1H), 7.45 (d, J = 12.4 Hz, 5H), 7.43 – 7.37 (m, 2H), 7.33 – 7.28 (m, 2H), 7.21 (dd, J = 21.2, 13.3 Hz, 3H), 7.10 (dd, J = 24.6, 16.6 Hz, 1H), 6.93 (s, 2H), 6.20 (m2H), 5.02 (s, 1H), 3.13 (d, J = 7.5 Hz, 1H), 2.98 (dd, J = 16.2, 8.5 Hz, 2H), 2.82 – 2.48 (m, 4H), 2.38 – 2.24 (m, 4H), 2.24 – 1.90 (m, 6H), 1.85 (dd, J = 15.8, 8.0 Hz, 1H), 1.78 – 1.39 (m, 3H), 1.29 – 1.08 (m, 2H), 0.84 (ddd, J = 31.4, 25.0, 19.3 Hz, 2H), 0.51 (d, J = 9.9 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 162.1 (dd, J_{BC} = 99.7, 49.8 Hz), 159.9, 150.4, 141.4 (d, J_{PC} = 30.5 Hz), 139.6, 135.2, 133.3, 132.5, 131.3, 131.0, 130.8, 130.3, 129.7-129.6 (m), 129.5, 129.3, 129.2 (dd, J_{PC} = 21, 10 Hz), 128.9 (dd, J_{PC} = 22.5, 11.5 Hz), 128.1 (d, J_{FC} = 21.6 Hz), 126.4 (d, J

$_{PC}$ = 6.9 Hz), 126.1, 124.7, 123.9, 121.7, 117.9 (t, J_{PC} = 14.6 Hz), 85.0, 36.4 – 36.1 (m), 33.6, 29.8 (d, J_{PC} = 10.2 Hz), 27.6, 25.4, 23.1(d, J_{PC}= 10.5 Hz), 19.1.

^{31}P NMR (162 MHz, $CDCl_3$) δ 149.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.1.

MS (FAB, NBA): m/z: 841.3 (3), 840.3 (13), 839.3 (50), 838.3 (100.0), 837.3 (34), 836.3 (66).

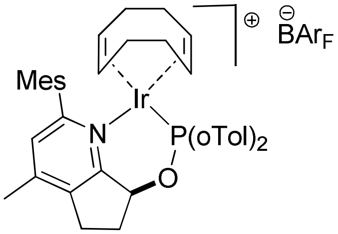
IR ($\tilde{\nu}$): 2882w, 1737w, 1608, 1463, 1354s, 1273s, 1157, 1112s, 1037, 960, 885, 839, 738, 712, 669, 622 cm^{-1}.

$[\alpha]_D^{20}$= +44.0 at a concentration of 0.92.

Elemental Analysis: for $C_{77}H_{56}BF_{24}IrNOP$ calculated C, 54.36; H, 3.32; N, 0.82; found C, 53.98; H, 3.35; N, 0.67.

2.1. catalyst *S*-**7d**

(+)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][(S)-7-(dio-tolylphosphinooxy-κP)-2-mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 31.0 mg (115.9 µmol) of pyridyl alcohol **12a**, 14.1 mg (115.9 µmol) of DMAP, 24 mg (115.9 µmol) of chlorodiphenylphosphine and 147.5 mg (115.9 µmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 139 mg (84.6 µmol, 73%).
Chemical Formula: $C_{72}H_{58}BF_{24}IrNOP$ Molecular Weight: 1643.2

MP: 162-165 ˚C

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (d, *J* = 79.0 Hz, 1H), 7.64 (s, 8H), 7.44 (s, 4H), 7.27 (dd, *J* = 17.3, 9.4 Hz, 3H), 7.16 (d, *J* = 25.9 Hz, 3H), 6.96 (s, 3H), 6.82 (s, 1H), 6.26 (s, 2H), 5.25 (d, *J* = 28.2 Hz, 1H), 3.47 (s, 1H), 3.20 (d, *J* = 3.1 Hz, 1H), 2.99 (s, 1H), 2.91 – 2.78 (m, 1H), 2.65 (s, 4H), 2.50 – 2.30 (m, 2H), 2.25 (d, *J* = 9.0 Hz, 3H), 2.21 (d, *J* = 18.7 Hz, 4H), 2.07 (t, *J* = 35.5 Hz, 5H), 1.77 (s, 4H), 1.49 (s, 2H), 1.27 (dd, *J* = 14.5, 7.4 Hz, 2H), 1.18 (s, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 162.1 (dd, J_{BC} = 99.5, 49.9 Hz), 141.57 – 141.27 (m), 140.8, 138.7, 135.2, 132.6, 131.7, 129.7 – 128.8 (m$_{PC}$), 128.8, 128.2, 126.6 – 126.4 (m), 126.0, 123.8 121.7, 117.8, 33.6, 29.7, 28.0 – 27.9 (m$_{PC}$), 27.2, 26.1, 23.2 (d, J_{PC} = 16 Hz), 21.4, 21.0, 19.0.

^{31}P NMR (202 MHz, $CDCl_3$) δ 163.8, 151.0. ^{11}B NMR (160 MHz, $CDCl_3$) δ -6.58.

MS (FAB, NBA): m/z: 783.3 (2), 782.3 (10), 781.3 (43), 780.3 (100), 779.3 (30), 778.3 (60).

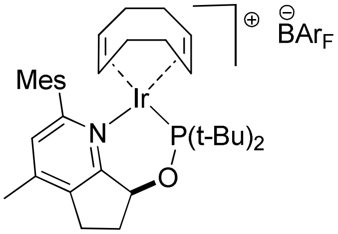
IR ($\tilde{\nu}$): 2929w, 2357, 1737w, 1614, 1460, 1352s, 1271s, 1159, 1117s, 1037, 960, 931, 877, 854, 839, 757, 744, 711, 692, 680, 668, 638, 619 cm^{-1}.

$[\alpha]_D^{20}$ = +32.0 at a concentration of 0.34.

Elemental Analysis: for $C_{72}H_{58}BF_{24}IrNOP$ calculated C, 52.63; H, 3.56; N, 0.85; found C, 52.59; H, 3.50; N, 1.08.

2.1. catalyst *S*-**7e**

(-)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][(S)-7-(di-tert-butylphosphinooxy-κP)-2-mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



In the glove box the alcohol **12a** (50 mg, 189.0 μmol) is added to a dry Young tube with a stir bar. Potassium hydride (11.1 mg, 280.5 μmol) was carefully added to reaction vessel followed by di-tert-butylchlorophosphine (34.0 mg, 189.0 μmol) added as a solution in dry DMF (150 μL). The sides of the vessel were rinsed with dry DMF (2 x 150 μL), the reaction vessel was sealed and brought outside the box. The reaction was stirred for 48 hours, at which time a liquid nitrogen cold trap was attached with a short line directly to the reaction vessel. The flask was cooled to 0 ˚C and carefully evacuated to avoid bumping. After the gas bubbles had ceased the vessel was placed in a mildly warm water bath to assist removal of DMF, periodically changing the bath for more warm water. The flask was left at high vacuum in a warm water bath for 3 hours to result in a red foam. The flask was sealed under vacuum and brought back inside the glove box. Dry THF (500 μL) was added to the Young tube and the liquid was filtered into a vial containing a solution of $Ir(cod)_2BAr_F$ (240 mg, 189.0 μmol) in 1 mL of THF with the use of a syringe and micron filter. The reaction vessel was washed and filtered into the vial with additional THF (2 x 500 μL). The resulting dark red solution was stirred for 6 hours and then brought outside the box, stripped onto silica gel and chromatographed with 50/50 hexane/ ether followed by elution of the product with DCM. The resulting dark red material was recrystallized from 1 mL of DCM/ 4 mL of hexane layered carefully and allowed to stand in the refrigerator for 48 hours to yield dark red crystals of X-ray quality. Yield 120 mg (76. 2 μmol, 40%). The mother liquor was concentrated and a second batch of crystals was obtained from DCM/ hexane (25 mg, 15.9 μmol, 8.4%).
Chemical Formula: $C_{66}H_{62}BF_{24}IrNOP$ Molecular Weight: 1575.2

MP: 113-115 ˚C

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.71 (s, 8H), 7.52 (s, 4H), 7.16 (s, 1H), 7.06 (s, 1H), 6.92 (s, 1H), 5.48 (t, *J* = 5.8 Hz, 1H), 5.44 (s, *J* = 16.7, 10.8 Hz, 1H), 5.02 (s, 1H), 4.08 – 3.82 (m, 1H), 3.16 (p, *J* = 7.8 Hz, 1H), 3.06 (dt, *J* = 16.9, 8.3 Hz, 1H), 2.91 (dd, *J* = 17.2, 8.4 Hz, 1H), 2.64 (s, 3H), 2.45 (ddd, *J* = 33.2, 15.0, 8.1 Hz, 2H), 2.36 (d, *J* = 3.3 Hz, 6H), 2.25 – 2.11 (m, 1H), 2.04 (tdd, *J* = 16.3, 10.9, 5.7 Hz, 1H), 1.99 – 1.91 (m, 1H), 1.80 (dd, *J* = 15.5, 7.5 Hz, 1H), 1.74 – 1.62 (m, 4H), 1.45 (d, *J* = 13.4 Hz, 9H), 1.23 – 0.98 (m, 3H), 0.82 (d, *J* = 14.3 Hz, 10H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 162.5 (dd, J_{BC} = 99.5, 49.9 Hz), 160.6, 150.0, 140.2, 138.1, 137.5, 136.0 (d, J_{PC} = 30.9 Hz), 134.8, 132.4, 129.3 (d, J_{PC} = 5.2 Hz), 129.0, 128.8 (m $_{BC}$), 128.5, 127.8, 125.6, 123.4, 121.3, 117.4, 92.7 (d, J_{PC} = 5.7 Hz), 85.8, 80.8 (d, J_{PC} = 18.1 Hz), 71.1, 57.6, 53.4, 40.3 (dd, J_{PC} = 70.1, 19.7 Hz), 37.5 (d, J_{PC} = 3.8 Hz,), 35.3, 31.6, 29.8 – 29.4 (m$_{PC}$), 28.6, 28.0 (d, *J* = 6.3 Hz), 27.7, 27.3, 24.9, 24.3, 22.6, 20.8 (d, *J* = 21.9 Hz), 18.5, 14.10.

^{31}P NMR (162 MHz, CDCl$_3$) δ 139.5.

MS (FAB, NBA): m/z: 714.3 (7), 713.3 (36), 712.3 (100), 711.3 (26), 710.3 (60).

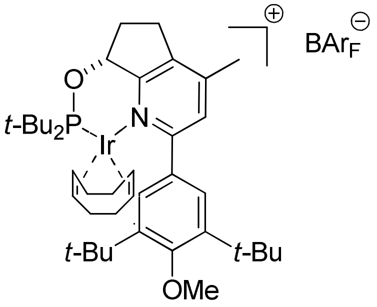
IR ($\tilde{\nu}$): 2929, 2879w, 2354, 1737w, 1610, 1463, 1456s, 1352, 1271s, 1164, 1122s, 1047, 1037, 962, 885, 838, 808, 715, 667, 636 cm^{-1}.

$[\alpha]_D^{20}$ = -9.0 at a concentration of 0.52.

Elemental Analysis: for $C_{66}H_{62}BF_{24}IrNOP$ calculated C, 50.33; H, 3.97; N, 0.89; found C, 50.01; H, 4.18; N, 0.92.

2.1. catalyst *R*-**7f**

(+)-Iridium(I) [[(1,2,5,6-η)-1,5-cyclooctadiene]-[2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-7-((*R*) -(di-*tert*-butylphosphinit-κP)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN-]-tetrakis(3,5-bis(trifluoromethyl)phenyl)borate(-)



Pyridine alcohol **12c** (50 mg, 136 µmol, 1.0 eq.) was added to a dry Young tube which was evacuated and backfilled with argon three times. KH (8.2 mg, 189 µmol, 1.5 eq.) and di-*tert*-butylchlorophosphine (24.5 mg, 136 µmol, 1.0 eq.) were added and rinsed down with DMF (0.45 mL). The increasingly dark solution was stirred for 120 h at rt. DMF was completely evaporated on high vacuo with a 60 °C hot water bath to assist complete removal of solvent. The brown residue was taken up in toluene (2 mL) and filtered through a plug of celite (2 × 2 cm). Toluene was evaporated in vacuo and the resulting violet residue was taken up in abs. DCM (2 mL). $[IrCODCl]_2$ (46 mg, 136 µmol, 1.0 eq.) was added and the solution was stirred for 1 h at rt. $NaBAr_F$ (142 mg, 163 µmol, 1.2 eq.) was added and the brownish solution was stirred for 14 h at rt. The solution was adsorbed and concentrated onto silica (2 g). Purification by column chromatography (SiO_2, hexane/DCM (1:1), 3 × 20 cm) yielded the complex **7f** (117 mg, 70 µmol, 51%) as a red solid. TLC (SiO_2, hexane/DCM (1:1), UV): $R_f = 0.39$.

MP: 142-143 °C.

^{1}H-NMR (500 MHz, CD_2Cl_2) δ 7.71 (s, 8H, BAr_F), 7.66 (s, 2H), 7.54 (s, 4H, BAr_F), 7.34 (s, 1H), 5.70-5.60 (m, 1H), 5.23-5.19 (m, 1H), 4.67-4.75 (m, 1H), 4.05-4.00 (m, 1H) 3.80 (s, 3H), 3.06-3.00 (m, 1H) 2.90-2.74 (m, 3H), 2.38 (s, 3H), 2.38-2.32 (m, 1H), 2.14-1.93 (m, 3H), 1.83 (dd, J_{HH} = 15.0 Hz, J_{HH} = 7.6 Hz, 1H), 1.53–1.45 (m, 1H), 1.48 (s, 18H), 1.47 (d, J_{PH} = 14.5 Hz, 9H), 1.29-1.21 (m, 1H), 1.18-1.09 (m, 1H), 1.10 (d, J_{PH} = 14.5 Hz, 9H), 0.95-89 (m, 1H).

^{13}C-NMR (126 MHz, CD_2Cl_2) δ 162.3 (q, J_{BC} = 50 Hz, BAr_F) 162.3, 159.5 (d, J_{PC} = 2 Hz, ar-*C*), 149.9, 145.6, 138.1, 135.4 (s, BAr_F), 135.0, 132.0, 129.5 (qq, J_{CF} = 32 Hz, J_{BC} = 3 Hz, BAr_F), 127.5, 127.5, 125.1 (q, J_{CF} = 268 Hz, BAr_F CF_3), 118.1 (m, BAr_F), 91.1 (d, J_{PC} = 5 Hz), 85.2 (d, J_{CP} = 2 Hz), 78.6 (d, J_{PC} = 19 Hz), 75.1, 64.9, 61.3, 41.7 (d, J_{PC} = 19 Hz), 40.3 (d, J_{PC} = 21 Hz), 38.4 (d, J_{PC} = 4 Hz), 36.8, 35.6, 32.4, 30.0 (d, J_{CP} = 8 Hz), 29.1 (d, J_{CP} = 7 Hz), 28.6, 26.9, 24.2 (d, J_{PC} = 4 Hz), 19.2.

^{31}P-NMR (161 MHz, $CDCl_3$) δ 143.7. ^{19}F-NMR (376 MHz, $CDCl_3$) δ -63.1. ^{11}B-NMR (160 MHz, $CDCl_3$) δ -5.6.

MS (FAB NBA) *m/z* (%): 812.4 (100).

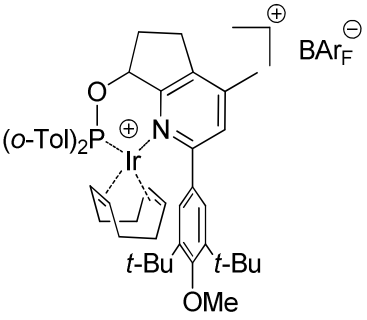
IR (neat, $\tilde{\nu}$): 2963m, 2881w, 1609w, 1458w, 1353m, 1273s, 1158m, 1200s, 1007w, 885m, 836m, 809m, 712m, 671m cm^{-1}.

$[\alpha]_D^{20}$ = +10.5 (c = 0.53).

EA ($C_{72}H_{74}BF_{24}IrNO_2P$): calculated C, 51.62; H, 4.45; N, 0.84; found: C, 51.67; H, 4.46; N, 1.00.

2.1. catalyst *S*-**7g**

(*S*)-(+)-[1,5-Cyclooctadien-[2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-7-((di-*ortho*-tolylphosphinit)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-iridium(I)]-tetrakis(3,5-bis(trifluoromethyl)phenyl)borate



The reaction was set up as in the general procedure except using the pyridyl alcohol (*S*)-**12c** (40 mg, 109 µmol, 1.0 eq), 4-dimethylaminopyridine (17 mg, 130 µmol, 1.2 eq) and chloro-di-(2-methylphenyl)-phosphine (34 mg, 130 µmol, 1.2 eq) in absolute DCM (2 mL). This solution was filtered into $[Ir(COD)Cl]_2$ (37 mg, 109 µmol, 1.00 eq) and $NaBar_F$ (117 mg, 130 µmol, 1.20 eq). Column chromatography (SiO_2, hexane/DCM (1:1), 3 × 20 cm) yielded the desired product **7g** (130 mg, 75 µmol, 68%) as an orange solid. TLC (SiO_2, hexane/DCM (1:2), UV): R_f = 0.58.

MP: 96-99 °C.

^{1}H-NMR (500 MHz, CD_2Cl_2): δ 8.32 (d, J_{HH} = 14 Hz, 1H), 7.75 (s, 8H, BAr_F) 7.57 (s, 6H, BAr_F), 7.45 (s, 2H), 7.39-7.36 (m, 1H), 7.33 (s, 2H), 7.23 (s, 1H), 7.15-7.11 (m, 1H), 6.69 (s, 1H), 6.36 (s br, 1H), 4.98 (s, 1H), 3.83 (s, 3H), 3.80 (s, 1H), 3.14-3.0 (m, 2H), 2.95-2.85 (m, 2H), 2.67 (s, 1H), 2.59 (s, 3H), 2.51-2.49 (m, 1H), 2.35 (s, 4H), 2.28-2.21 (m, 2H), 2.11 (s, 3H), 2.10-2.04 (m, 1H), 1.89-1.83 (m, 1H), 1.58 (s, 18H), 1.45-1.30 (m, 3H).

^{13}C-NMR (126 MHz, CD_2Cl_2): δ 162.8, 162.5, 162.3 (q, J_{BC} = 50 Hz, BAr_F), 159.3 (d, J_{PC} = 5 Hz), 150.1, 145.7, 143.3, 141.4 (d, J_{PC} = 8 Hz), 138.9, 137.1 (d, J_{PC} = 34 Hz) 136.0, 135.4, 134.3, 133.6 (d, J_{PC} = 8 Hz), 133.3 (d, J_{PC} = 1 Hz), 132.5 (d, J_{PC} = 8 Hz, ar-*C*), 132.4 (d, J_{PC} = 2 Hz, ar-*C*), 131.4 (d, J_{PC} = 14 Hz), 131.1, 129.5 (qq, J_{FC} = 32 Hz, J_{FC} = 4 Hz, BAr_F), 128.9, 128.2, 126.6 (d, J_{PC} = 11 Hz), 125.9 (d, J_{PC} = 17 Hz), 125.2 (d, J_{FC} = 272 Hz, BAr_F CF_3), 118.1 (sept, J_{FC} = 4 Hz, BAr_F), 100.0 (d, J_{PC} = 10 Hz), 94.0 (d, J_{PC} = 14 Hz), 84.5, 67.9, 65.4, 63.1, 37.8 (d, J_{PC} = 3 Hz), 36.8, 34.1, 32.5, 29.9 (d, J_{PC} = 10 Hz) 28.5, 26.9, 26.0, 23.0 (d, J_{PC} = 4 Hz), 21.9 (d, J_{PC} = 3 Hz), 19.1.

^{31}P-NMR (161 MHz, CD_2Cl_2): δ/ppm = 111.1 (s).

^{19}F-NMR (376 MHz, CD_2Cl_2): δ/ppm = -63.1 (s).

^{11}B-NMR (160 MHz, CD_2Cl_2): δ/ppm = -5.7 (s).

MS (FAB NBA) *m/z* (%): 882.3 (13), 881.3 (49), 880.3 (100), 879.3 (31), 878.3 (58).

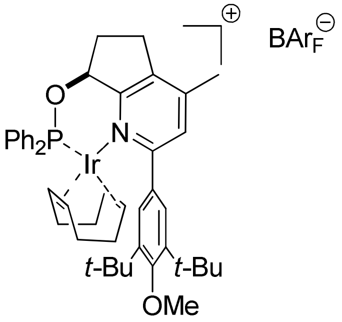
IR (neat, $\tilde{v}$): 2957, 1611, 1461, 1352, 1271, 1115, 1012, 959, 886, 824, 719, 670 cm^{-1}.

$[\alpha]_D^{20}$ = +63.3 (c = 0.94, $CHCl_3$).

EA ($C_{78}H_{20}BF_{24}IrNO_2P$) calculated: C, 53.74; H, 4.05; N, 0.80; found: C, 53.80; H, 4.14; N, 0.95.

2.1. catalyst *S*-**7h**

(+)-Iridium(I)- [[(1,2,5,6-η)-1,5-cyclooctadiene]-[2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-7-((*S*)-(di-phenylphosphinite-κP)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-κN]-tetrakis(3,5-bis(trifluoromethyl)phenyl)borate(-)



The reaction was set up as in the general procedure except using the pyridyl alcohol **12c** (35 mg, 95 µmol, 1.0 eq.), 4-dimethylaminopyridine (14 mg, 114 µmol, 1.20 eq.) and chloro-di-phenyl-phosphine (21 µL, 114 µmol, 1.2 eq.) in DCM (2 mL). This solution was filtered in to $[Ir(COD)Cl]_2$ (34 mg, 95 µmol, 1.0 eq.), NaBAr$_F$ (104 mg, 114 µmol, 1.2 eq.). Column chromatography (SiO_2, hexane/DCM (1:1), 3 × 20 cm) yielded the desired product (47 mg, 28 µmol, 29%) as an orange solid. TLC (SiO_2, hexane/DCM (1:1), UV): R_f = 0.43.

MP: 81-84 °C.

^{1}H-NMR (500 MHz, CD_2Cl_2) δ 7.75 (s, 8H, BAr$_F$), 7.57-7.54 (m, 9H), 7.46 (s, 1H) 7.43-7.40 (m, 5H), 7.35-7.32 (m, 2H), 6.43-6.39 (m, 1H), 4.65 (s br, 1H), 4.21 (s br, 1H), 3.77 (s, 3H), 3.23-3.12 (m, 3H) 3.07-2.98 (m, 2H), 2.66-2.59 (m, 1H), 2.46 (s, 3H), 2.27-2.23 (m, 2H), 2.17-2.08 (m, 1H), 1.97-1.85 (m, 2H), 1.40 (s, 18H), 1.34-1.22 (m, 2H) 0.90- 0.83 (m, 1H).

^{13}C-NMR (126 MHz, CD_2Cl_2) δ 162.9, 162.4 (q, J_{CB} = 50 Hz, BAr$_F$), 162.4, 159.9 (d, J_{PC} = 4 Hz), 150.3, 146.2, 138.6, 136.4 (d, J_{PC} = 56 Hz), 135.4 (s, BAr$_F$), 134.0, 132.4 (d, J_{PC} = 2 Hz), 132.3 (d, J_{PC} = 2 Hz), 131.1 (d, J_{PC} = 62 Hz), 130.6 (d, J_{PC} = 13 Hz), 130.2 (d, J_{PC} = 11 Hz), 129.9 (d, J_{PC} = 7 Hz), 129.9, 129.6 (d, J_{PC} = 11 Hz), 129.5 (qq, J_{FC} = 30 Hz, J_{FC} = 3 Hz, BAr$_F$), 127.0, 125.2 (q, J_{FC} = 272 Hz, BAr$_F$ CF_3), 118.1 (sept, J_{FC} = 4 Hz, BAr$_F$) 100.3 (d, J_{PC} = 10 Hz), 92.8 (d, J_{PC} = 14 Hz), 85.6, 69.3, 65.3, 61.9, 37.1 (d, J_{PC} = 3 Hz), 36.6, 33.6, 32.3, 30.2 (d, J_{PC} = 3 Hz, CH_2), 29.4, 27.1, 25.9, 19.3.

^{31}P-NMR (161 MHz, CD_2Cl_2) δ 96.5. ^{19}F-NMR (376 MHz, CD_2Cl_2) δ -63.1. ^{11}B-NMR (160 MHz, CD_2Cl_2) δ -6.6.

MS (FAB NBA) *m/z* (%): 854.3 (13), 853.3 (47), 852.3 (100), 851.3 (34), 850.2 (65).

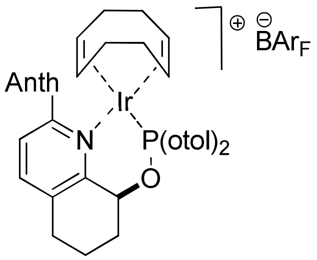
IR (neat, $\tilde{\nu}$): 2962w, 1920w, 2851w, 1716m, 1597m, 1387m, 1352m, 1278s, 1258m, 1163m, 1120s, 1024m, 894m, 678m cm^{-1}.

$[\alpha]_D^{20}$ = 16.5 (c = 0.41, $CHCl_3$).

EA ($C_{76}H_{66}BF_{24}IrNO_2P$): calc.: C 53.22, H 3.88, N 0.82; found: C 53.44, H 4.15, N 1.01.

2.1. catalyst *S*-**9a**

(+)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][((S)-2-(anthracen-9-yl)-8-(dio-tolylphosphinooxy-κP)-5,6,7,8-tetrahydroquinoline-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 31.0 mg (115.9 µmol) of pyridyl alcohol **12g**, 14.1 mg (115.9 µmol) of DMAP, 24 mg (115.9 µmol) of chlorodiphenylphosphine and 147.5 mg (115.9 µmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 139 mg (84.6 µmol, 73%).
Chemical Formula: $C_{77}H_{56}BF_{24}IrNOP$ Molecular Weight: 1701.2

MP: 231-232 ˚C

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (s, 1H), 8.18 (d, *J* = 8.6 Hz, 1H), 8.09 (d, *J* = 8.5 Hz, 1H), 7.81 – 7.69 (m, 9H), 7.69 – 7.56 (m, 2H), 7.56 – 7.46 (m, 6H), 7.46 – 7.27 (m, 6H), 7.13 – 7.02 (m, 1H), 6.89 (d, *J* = 7.8 Hz, 1H), 6.60 (s, 1H), 6.34 (t, *J* = 11.0 Hz, 1H), 5.26 (d, *J* = 26.9 Hz, 1H), 3.51 (s, 1H), 3.07 (d, *J* = 17.1 Hz, 1H), 2.94 (ddd, *J* = 17.5, 13.5, 7.6 Hz, 1H), 2.78 – 2.52 (m, 4H), 2.39 – 2.17 (m, 3H), 2.13 (d, *J* = 15.5 Hz, 3H), 2.02 (dd, *J* = 24.2, 7.4 Hz, 2H), 1.65 (ddd, *J* = 78.0, 27.9, 9.5 Hz, 4H), 1.24 (dd, *J* = 27.5, 6.3 Hz, 1H), 1.07 – 0.90 (m, 1H), 0.88 – 0.64 (m, 2H), 0.27 (dd, *J* = 11.1, 7.8 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 162.1 (dd, J_{BC} = 99.5, 49.9 Hz), 159.8, 141.6, 136.4 – 136.2 (m_{BC}), 135.2, 134.4 – 133.6 (m_{PC}), 132.8 (d, J_{PC} = 9.75 Hz), 132.2, 131.4, 131.0, 130.4, 129.7, 129.4, 129.3, 129.1, 129.1 – 129.0 (m_{PC}), 128.9 – 128.7 (m_{PC}), 128.2, 127.9 – 127.8 (m_{FC}), 126.7, 126.5, 126.3, 124.7, 123.6, 120.9, 117.9, 66.5, 36.6, 34.7, 30.9 – 29.6 (d, J_{PC} = 9.75 Hz), 28.7, 27.6, 24.7, 22.7 – 21.9 (d, J_{PC} = 4.6 Hz), 17.4.

^{31}P NMR (162 MHz, $CDCl_3$) δ 149.2. ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.1.

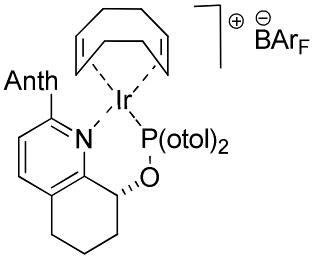
MS (FAB, NBA): m/z: 841.3 (4), 840.3 (13), 839.3 (49), 838.3 (100.0), 837.3 (33), 836.3 (62).

IR (neat, $\tilde{\nu}$): 2882w, 2359, 1737w, 1608, 1463, 1352s, 1274s, 1159, 1117s, 1064, 970, 958, 885, 869, 838, 804, 712, 669, 621 cm^{-1}.
$[\alpha]_D^{20}$ = +69.0 at a concentration of 0.28.

Elemental Analysis: for $C_{77}H_{56}BF_{24}IrNOP$ calculated C, 54.36; H, 3.32; N, 0.82; found C, 54.35; H, 3.37; N, 0.71.

2.1. catalyst *R*-**9a**

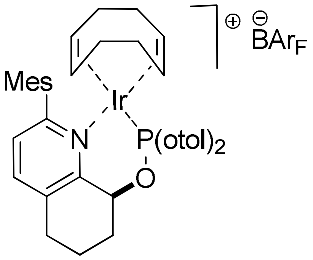
(-)-Iridium(I) [(1,2,5,6-η)-1,5-cyclooctadiene][((R)-2-(anthracen-9-yl)-8-(dio-tolylphosphinooxy-κP)-5,6,7,8-tetrahydroquinoline-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 127.0 mg (390.0 μmol) of pyridyl alcohol **12g**, 47.5 mg (390.0 μmol) of DMAP, 97 mg (390.0 μmol) of chlorodiphenylphosphine and 595.0 mg (468.0 μmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 400 mg (235.1 μmol, 60%). The physical properties matched the opposite enantiomer.
Chemical Formula: $C_{77}H_{56}BF_{24}IrNOP$ Molecular Weight: 1701.2
$[\alpha]_D^{20}$ = -71.0 at a concentration of 0.25.

2.1. catalyst *S*-**9b**

(+) Iridium(I)- [(1,2,5,6-η)-1,5-cyclooctadiene][(S)-8-(dio-tolylphosphinooxy-κP)-2-mesityl-5,6,7,8-tetrahydroquinoline-κN]-tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Synthesized by the general method except using 25.8 mg (96.8 μmol) of pyridyl alcohol **12b**, 11.8 mg (96.8 μmol) of DMAP, 24 mg (96.8 μmol) of chlorodiphenylphosphine and 122.7 mg (96.8 μmol) of iridium(I)(COD)$_2$BAr$_F$ to yield 128 mg (77.8 μmol, 81%).
Chemical Formula: $C_{72}H_{58}BF_{24}IrNOP$ Molecular Weight: 1643.2

MP: 203-04 ˚C

^{1}H NMR (500 MHz, CDCl3) δ 7.76 (s, 8H), 7.65 (d, *J* = 7.9 Hz, 1H), 7.56 (s, 4H), 7.40 (dt, *J* = 13.1, 7.3 Hz, 3H), 7.24 (s, 1H), 7.22 – 7.11 (m, 3H), 7.08 (d, *J* = 15.9 Hz, 1H), 6.95 (s, 1H), 6.73

(d, J = 52.5 Hz, 1H), 6.42 (d, J = 5.0 Hz, 1H), 5.58 (s, 1H), 3.88 (s, 1H), 3.46 (d, J = 45.0 Hz, 1H), 3.19 – 2.72 (m, 6H), 2.67 (d, J = 12.9 Hz, 1H), 2.53 – 2.23 (m, 7H), 2.23 – 1.86 (m, 9H), 1.81 (s, 4H), 1.27 (dd, J = 19.8, 12.6 Hz, 4H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1 (dd, J_{BC} = 102.0, 46.9 Hz), 141.7, 140.9, 137.0, 135.3 (d, J_{PC} = 26.4 Hz, 6H), 132.7, 130.8, 129.6 (d, J_{PC} = 30.7 Hz), 128.9 (t, J_{FC} = 13.4 Hz), 126.7 (d, J = 11.1 Hz), 126.3, 123.6, 120.9 – 120.6 (m$_{PC}$), 117.8, 99.2, 64.9, 37.2 (d, J_{PC} = 27.5 Hz), 34.6, 30.3 (d, J_{PC} = 9.6 Hz), 28.5, 27.9, 25.3, 22.5, 21.4, 21.0, 17.3.

^{31}P NMR (202 MHz, $CDCl_3$) δ 158.2 (broad), 146.4 (broad).

MS (FAB, NBA): m/z: 783.3 (2), 782.3 (10), 781.3 (43), 780.3 (100), 779.3 (29), 778.3 (60).

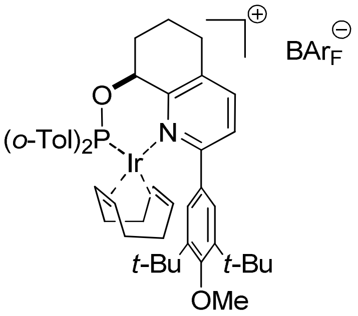
IR (neat, $\tilde{\nu}$): 2929w, 2357, 1737w, 1614, 1460, 1352s, 1271s, 1159, 1117s, 1037, 960, 931, 877, 854, 839, 757, 744, 711, 692, 680, 668, 638, 619 cm^{-1}.

$[\alpha]_D^{20}$ = +37.0 at a concentration of 0.38.

Elemental Analysis: for $C_{72}H_{58}BF_{24}IrNOP$ calculated C, 52.63; H, 3.56; N, 0.85; found C, 52.49; H, 3.66; N, 0.70.

2.1. catalyst *S*-**9c**

(+)-Iridium(I)-[(1,2,5,6-η)-1,5-cyclooctadiene]-8-((*S*)-(di-*ortho*-tolylphosphinite-κP)-2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-4-methyl-5,6,7,8-tetrahydroquinoline- κN]-tetrakis(3,5-bis(trifluoromethyl)phenyl)borate(-)



The pyridyl alcohol (*S*)-**12d** (60 mg, 163 µmol, 1.0 eq.), 4-dimethylaminopyridine (25 mg, 196 µmol, 1.2 eq.) and chloro-di-(2-methylphenyl)-phosphine (50 mg, 196 µmol, 1.2 eq.) were added in a dry Schlenk flask. This flask was evacuated and backfilled three times with argon. DCM (1.4 mL) was added to obtain a colorless solution which was stirred for 7 h at rt. A second predryed Schlenk flask was filled with $[Ir(COD)Cl]_2$ (55 mg, 163 µmol, 1.0 eq.), NaBAr$_F$ (175 mg, 196 µmol, 1.2 eq.) and equipped with a Schlenk frit. The frit was charged with aluminum oxide (d × h, 3 × 2 cm). The equipment was evaporated and backfilled with argon three times.

The ligand containing solution was filtered through the frit and the alumina was washed with degassed absolute DCM (5 mL). The new orange solution was stirred for 18 h at rt. The solvent was evaporated in vacuo and the crude iridium complex was concentrated and adsorbed onto silica (4 g). Column chromatography (SiO_2, hexane/DCM (1:1), 3 × 20 cm) yielded the desired product **9c** (208 mg, 119 µmol, 73%) as an orange solid. TLC (SiO_2, hexane/DCM (1:1), UV): R_f = 0.29.

MP: 90-91 °C.

^{1}H-NMR (500 MHz, $CDCl_3$) δ 7.96 (dd, J_{HH} = 18 Hz, J_{HH} = 7 Hz, 1H, ar-*H*), 7.70 (s, 8H, BAr_F), 7.61 (s, 2H), 7.49 (s, 4H, BAr_F) 7.49-7.47 (m, 1H), 7.36-7.32 (m, 3H), 7.26-7.22 (m, 2H), 7.18 (t, J_{HH} = 7.6 Hz, 1H), 7.14 (dd, J_{HH} = 7.3 Hz, J_{HH} = 2.0 Hz, 1H), 6.92-6.89 (m, 1H), 6.37-6.36 (m, 1H), 5.02 (s br, 1H), 3.96 (s br, 1H), 3.82 (s, 3H), 3.12-3.06 (m, 1H), 2.85-2.75 (m, 2H), 2.70-2.63 (m, 2H), 2.36 (s, 3H), 2.25-2.18 (m, 2H), 2.12-2.08 (m, 2H), 2.05 (s, 3H), 1.94-1.78 (m, 4H), 1.53 (s, 18H), 1.30-1.19 (m, 3H).

^{13}C-NMR (126 MHz, $CDCl_3$) δ 162.2, 161.9 (q, J_{BC} = 50 Hz, BAr_F), 161.7, 153.3 (d, J_{PC} = 3 Hz), 145.4, 142.6, 141.0, 140.2 (d, J_{PC} = 9 Hz), 135.7, 135.3, 135.0, 134.6, 134.1, 133.8, 133.3 (d, J_{PC} = 7 Hz), 132.9, 132.2, 132.1, 130.8 (d, J_{PC} = 12 Hz), 129.9, 129.1 (qq, J_{FC} = 30 Hz, J_{FC} = 3 Hz, BAr_F), 127.1, 126.5 (d, J_{PC} = 11 Hz), 125.2 (d, J_{PC} = 17 Hz), 124.7 (q, J_{FC} = 273 Hz, BAr_F *C*F_3), 117.6 (sept, J_{FC} = 4 Hz, BAr_F), 97.6 (d, J_{PC} = 8 Hz, *C*H COD), 90.5 (d, J_{PC} = 15 Hz, *C*H COD), 76.1, 69.2, 64.8, 64.0, 37.3 (d, J_{PC} = 10 Hz, *C*H_2), 36.5, 33.9, 32.1, 30.5 (d, J_{PC} = 10 Hz, *C*H_2, COD), 28.6 (s, *C*H_2 COD), 28.2, 25.1 (s, *C*H_2 COD), 22.0 (d, J_{PC} = 5 Hz), 21.4 (d, J_{PC} = 3 Hz), 17.3.

^{31}P-NMR (161 MHz, $CDCl_3$): δ = 103.3 (s). ^{19}F-NMR (376 MHz, $CDCl_3$): δ = -62.7 (s). ^{11}B NMR (160 MHz, $CDCl_3$): δ = -6.6 (s).

MS (FAB NBA): *m/z* (%): 880.3 (100).

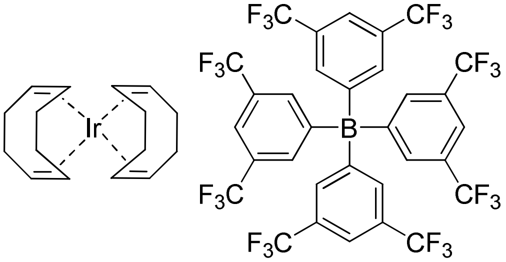
IR (neat, $\tilde{\nu}$): 2961w, 2939w, 2889w, 2876w, 1609w, 1454w, 1353m, 1273s, 1160m, 1117s, 1003m, 930m, 885m, 838m, 713m, 669m cm^{-1}.

$[\alpha]_D^{20}$ = +68.2 (c = 0.92)

EA ($C_{78}H_{20}BF_{24}IrNO_2P$): calculated C, 53.74; H, 4.05; N, 0.80; found: C, 53.97; H, 4.22; N, 0.91.

2.2. synthesis of reagent **17**

Iridium(I) bis[(1,2,5,6-η)-1,5-cyclooctadiene]- tetrakis[3,5-bis(trifluoromethyl)phenyl]borate(-)



Chloro(1,5-cyclooctadiene)iridium(I) dimer (130.7 mg, 194.6 µmol) was added to a dry 25 mL flask and dissolved by stirring in 8 mL of absolute DCM. Cyclooctadiene (63.1 mg, 71.7 µL, 584 µmol) was added by syringe and the reaction was stirred for 30 minutes at room temperature.

Sodium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate (362 mg, 408.6 µmol) was added as a solid and the very dark red solution was stirred for 2 hours at room temperature. The solution was filtered through a 2 gram silica pipette column which was washed with an additional 7 mL of DCM. The solvent was concentrated at a rotovap to dryness. The resulting crude mixture was taken up in 5 mL of DCM, filtered through a micron filter and layered with 5 ml of hexane. Crystallization at -20 ˚C overnight followed by cold vacuum filtration and washing with -20˚C hexane (2 x 25 mL) provided very large dark red high symmetry crystals of X-ray diffraction quality which were dried on a high vacuum for 3 hours to provide 470 mg of pure product (370 µmol, 95%).
Chemical Formula: $C_{48}H_{36}BF_{24}Ir$ Molecular Weight: 1271.8

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, J = 2.3 Hz, 2H), 7.54 (s, 1H), 4.99 (s, 2H), 2.49 – 2.33 (m, 2H), 2.33 – 2.16 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.0 (dd, J_{BC} = 99.7, 50.0 Hz), 135.2, 129.3 (ddd, J_{BC} = 57.5, 18.7, 15.6 Hz), 124.9 (d, $^{1}J_{FC}$ = 272.7 Hz), 118.2 – 117.7 (m_{BC}), 101.5, 30.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -63.5.

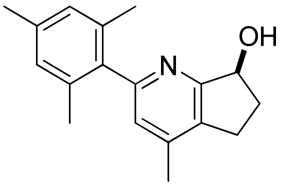
3.0 Synthesis of pyridyl alcohols 12a-g

General method A, cleavage of tert-butyldimethylsilyl ethers: The 2-arylpyridyl silyl ether (0.200 mmol) was taken up in 5 mL of dry THF and solid tetrabutylammonium fluoride trihydrate (195 mg, 0.600 mmol) was added. The reaction was heated to 50 ˚C for 4 hours. The reaction was monitored by TLC, if the conversion was incomplete and additional amount of TBAF was added and the heating continued (100 mg, 0.307 mmol). The heating was stopped when full conversion was achieved by pouring the reaction after cooling to room temperature into an appropriately sized separatory funnel, addition and washing of the flask into the funnel with 25 mLs of ethyl acetate and extraction with water (3 x 30 mL). The organic layer was washed with brine (2 x 25 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated at the rotovap to provide the pure product.

General method B: The parent acetate ester (0.565 mmol) was deprotected by placing the starting material into an oven dried round bottom flask with 10 mL of THF with 1 mL of 4M sodium hydroxide. The reaction was heated to 65 ˚C at a high rate of mixing and the reaction was monitored with TLC. When the starting material was completely consumed the reaction was diluted with ethyl acetate (20 mLs) and transferred to a separatory funnel. The organic layer was washed with water (2 x 20 mL) and the aqueous layer was back extracted with ethyl acetate (5 mL). The organic layer was washed with brine (2 x 20 mL), dried over magnesium sulfate, filtered and concentrated at a rotovap to yield the product. If further purification was necessary the product was chromatographed on silica gel with ethyl acetate/ hexane 1:4.

3.1 alcohol *S*-**12a**

(*S*)-2-mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



Synthesize by general method B from 165 mg of the *S* ester to yield 135 mg (0.505 mmol, 89%) of product after chromatography with 20% ethyl acetate to remove trace impurities.

Chemical Formula: $C_{18}H_{21}NO$ Molecular Weight: 267.4

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.91 (s, 2H), 6.88 (s, 1H), 5.38 – 4.97 (m, 1H), 3.77 (s, 1H), 2.96 (ddd, *J* = 16.1, 9.1, 3.9 Hz, 1H), 2.86 – 2.66 (m, 1H), 2.61 – 2.42 (m, 1H), 2.31 (d, *J* = 5.9 Hz, 6H), 2.12 – 1.78 (m, 7H).

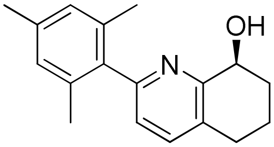
^{13}C NMR (126 MHz, $CDCl_3$) δ 164.4, 158.9, 144.5, 137.9, 137.6, 136.2, 133.7, 128.5, 124.9, 75.3, 32.5, 26.2, 21.4, 20.6, 19.0.

MS (e.i. 70 eV): m/z (%) 268.2 (7), 267.2 (37), 266.2 (48).

IR (neat, $\tilde{\nu}$): 3185, 2923, 1597, 1574, 1451, 1373, 1341, 1279, 1220, 1173, 1149, 1109, 957, 852, 732 cm^{-1}.

3.1 alcohol *S*-**12b**

(S)-2-mesityl-5,6,7,8-tetrahydroquinolin-8-ol



Synthesized by general method B from 158 mg (0.511 mmol) ester. Yield 129 mg (0.482 mmol, 94%).

Chemical Formula: $C_{18}H_{21}NO$ Molecular Weight: 267.4

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.8 Hz, 1H), 7.06 (d, *J* = 7.8 Hz, 1H), 6.95 (s, 2H), 4.72 (t, *J* = 6.9 Hz, 1H), 4.08 (s, 1H), 3.00 – 2.76 (m, 2H), 2.34 (d, *J* = 10.0 Hz, 4H), 2.05 (d, *J* = 13.4 Hz, 7H), 1.98 – 1.75 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 158.1, 157.1, 138.0, 137.9, 137.5, 136.3, 129.5, 128.8, 123.8, 69.4, 30.9, 28.5, 21.5, 20.7, 20.1.

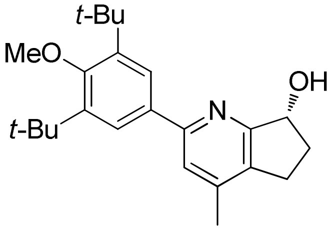
MS (e.i. 70 eV): m/z (%) 268.2 (8), 267.2 (38), 266.2 (39), 250.2 (8), 249.2 (28), 248.2 (100), 235.2 (2), 234.2 (10), 233.1 (6), 232.1 (6).

IR (neat, $\tilde{\nu}$): 3217, 2940, 1592, 1444, 1369, 1339, 1271, 1217, 1178, 1145, 1111, 957, 849 cm^{-1}.

$[\alpha]_D^{20}$ = +57.4 at a concentration of 0.51.

3.1 alcohol *R*-**12c**

(*R*)-2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



The reaction was set up as in the general procedure B except using acetate (*R*)-**12c** (200 mg, 0.48 mmol, 1.0 eq.) in a mixture of MeOH/THF ((1:1), 4 mL) and 2 M NaOH (1.8 mL). Extraction and drying on HV yielded the alcohol (*R*)-**12c** (175 mg, 0.48 mmol, 98%, 98.6% *ee*) as a colorless solid. Recrystallization out of hexane (8.5 mL) filtration of the scalemic crystals and evaporation of the solvent yielded the desired product (*R*)-**12c** (167 mg, 0.46 mmol, 95%) in enriched enantioselectivity (99.2% *ee*) from the solution. TLC (SiO_2, hexane/ethyl acetate (5:1), UV): $R_f = 0.16$.

HPLC**:** column: *Daicel*, Chiralcel AD-H (250 × 4.6 mm); eluent: heptane/*i*-propanol 98:02, 0.5 mL/min; T = 25 °C, R_t = 11.4 min and 13.3 min.

Mp: 153-155 °C.

^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.77 (s, 2H), 7.30 (s, 1H), 5.25 (t, J_{HH} = 6.4 Hz, 1H), 4.21 (s br, 1H), 3.72 (s, 3H), 2.96 (ddd, J_{HH} = 16.1 Hz, J_{HH} = 8.9 Hz, J_{HH} = 4.2 Hz, 1H), 2.77-2.69 (m, 1H), 2.54-2.46 (m, 1H), 2.33 (s, 3H), 2.07-1.99 (m, 1H), 1.47 (s, 18 H).

^{13}C-NMR (101 MHz, $CDCl_3$): δ 164.2, 160.4, 157.9, 144.5, 143.8, 134.1, 133.6, 125.8, 121.3, 74.9, 64.4, 36.0, 32.5, 32.21, 26.0, 18.9.

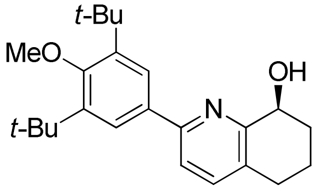
MS (EI, 70 eV, 200 °C) *m/z* (%): 367.3.

IR (KBr, $\tilde{\nu}$) = 3197m br, 3004m, 2960s, 1597m, 1442m, 1405m, 1216s, 1114m, 1002m, 867m cm^{-1}.

$[\alpha]_D^{20}$ = -14.9 (c = 0.75, $CHCl_3$).

3.1 alcohol *S*-**12d**

(*S*)-2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-5,6,7,8-tetrahydroquinolin-8-ol



The reaction was setup as in the general deprotection procedure a of the racemic silyl ethers. Deprotection of the silyl ether (*S*)-**14b** (300 mg, 6.23 mmol) yielded the alcohol (*S*)-**12d** (190 mg, 5.17 mmol, 83%, 99.8% *ee*) as a colorless solid. TLC (SiO_2, DCM, UV): $R_f = 0.49$.

HPLC: column: *Daicel*, Chiralcel AD-H (250 × 4.6 mm); eluent: heptane/*i*-propanol 98:02, 0.5 mL/min; T = 40 °C, $R_t = 13.2$ min and 15.6 min.

Mp: 188-189 °C.

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.84 (s, 2H, ar-*H*), 7.51 (d, $J_{HH} = 8.0$ Hz, 1H, ar-*H*), 7.46 (d, $J_{HH} = 8.0$ Hz, 1H, ar-*H*), 4.74 (dd, $J_{HH} = 9.0$ Hz, $J_{HH} = 4.4$ Hz, 1H, *H*COH), 4.34 (s, 1H, O*H*), 3.72 (s, 3H, OCH_3), 2.91-2.78 (m, 2H, CH_2), 2.40-2.34 (m, 1H, CH_2) 2.06-2.03 (m, 1H, CH_2), 1.91-1.75 (m, 2H, CH_2), 1.49 (s, 18H, 2 × $C(CH_3)_3$).

^{13}C-NMR (101 MHz, $CDCl_3$) δ160.8, 157.6, 155.2, 144.1, 137.8, 133.3, 129.2, 125.4, 119.4, 69.2, 64.5, 36.1, 32.2, 30.8, 28.1, 19.8.

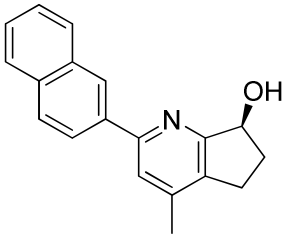
MS (EI, 70 eV, 200 °C) *m/z* (%): 367.3.

IR (KBr, $\tilde{\nu}$) = 3475m, 2944s, 2866m, 1589m, 1472m, 1450s, 1414s, 1248m, 1225s, 1117m, 1066m, 1013m, 824m cm^{-1}.

$[\alpha]_D^{20} = +97.5$ (c = 0.83, $CHCl_3$).

3.1 alcohol *S*-**12e**

(S)-4-methyl-2-(naphthalen-2-yl)-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



Synthesized by general method A except using 40 mg (0.103 mmol) of starting silyl ether and producing 25.1 mg of alcohol (91.2 µmol, 89%).

m.p.: 145-147 °C.

Chemical Formula: $C_{19}H_{17}NO$ Molecular Weight: 275.3

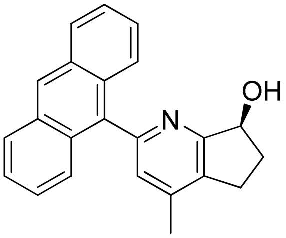
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44 (s, 1H), 8.11 (dd, *J* = 8.6, 1.8 Hz, 1H), 7.96 – 7.89 (m, 2H), 7.86 (dd, *J* = 5.2, 4.2 Hz, 1H), 7.55 (s, 1H), 7.53 – 7.46 (m, 2H), 5.29 (dd, *J* = 7.2, 6.1 Hz, 1H), 3.27 (s, 1H), 3.00 (ddd, *J* = 16.2, 9.0, 3.9 Hz, 1H), 2.89 – 2.68 (m, 1H), 2.68 – 2.48 (m, 1H), 2.35 (s, 3H), 2.20 – 1.98 (m, 1H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 164.2, 156.7, 144.6, 136.9, 134.2, 133.5, 128.6, 128.3, 127.6, 126.3, 126.2, 126.1, 124.8, 121.3, 75.2, 32.6, 25.9, 18.8.

MS (e.i. 70 eV): 277.1 (1), 276.1 (4), 275.2 (25).

3.1 alcohol *S*-**12f**

(S)-2-(Anthracen-9-yl)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



Synthesized by method B from 94 mg (0.214 mmol) of TBDMS ether. Yield after chromatography using 5% ether in DCM is 55 mg (0.169 mmol, 79%).

Chemical Formula: $C_{23}H_{19}NO$ Molecular Weight: 325.4

m.p.: 182-185 ˚C.

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.52 (s, 1H), 8.04 (dd, *J* = 8.5, 3.0 Hz, 2H), 7.66 – 7.52 (m, 2H), 7.50 – 7.40 (m, 2H), 7.38 – 7.33 (m, 1H), 7.33 – 7.29 (m, 1H), 7.18 (s, 1H), 5.24 (t, *J* = 6.3 Hz, 1H), 4.04 – 3.53 (m, 1H), 3.10 – 2.92 (m, 1H), 2.87 – 2.71 (m, 1H), 2.46 (dd, *J* = 19.2, 14.7 Hz, 1H), 2.36 (s, 3H), 2.04 – 1.88 (m, 1H).

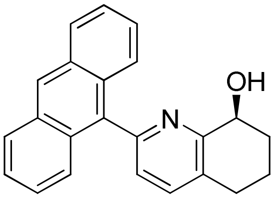
^{13}C NMR (126 MHz, CDCl$_3$) δ 164.9, 156.9, 144.7, 135.4, 134.7, 131.7, 130.6, 130.5, 128.8, 128.7, 127.7, 127.1, 126.6, 126.5, 126.0, 125.4, 125.3, 75.3, 32.4, 26.3, 19.0.

MS (e.i. 70 eV): m/z (%) 327.1 (5), 326.1 (21), 325.1 (100), 324.1 (68).

IR (neat, $\tilde{\nu}$): 3381, 3050, 2937, 1670, 1623, 1591, 1457, 1367, 1288, 1236, 1160, 1052, 1023, 983, 885, 735 cm^{-1}.

3.1 alcohol *S*-**12g**[1]

(S)-2-(anthracen-9-yl)-5,6,7,8-tetrahydroquinolin-8-ol



Synthesized by general method A except using 700 mg (1.59 mmol) of the silyl ether, 2 g (6.36 mmol) of tetrabutyl ammonium fluoride trihydrate in 50 mL of absolute THF and stirring for 18 hours under argon followed by heating to 60 ˚C for 2 hours to remove the last traces of starting material. A small trace of the *R* enantiomer was present in the HPLC so the product was purified by fractional recrystallization from toluene (500 mg in 20 mL). Scalemic product crystallizes while enantiopure remains in solution. Yield of enantiopure 350 mg (1.07 mmol, 68%). X-ray quality crystals were grown from 300 mg in 12 mls of boiling isopropanol followed by cooling to -20 ˚C overnight for quantitative return of material.

HPLC conditions: ODH column, 30% isopropanol in heptanes with a flow rate of 0.5 mLs/min and a temperature of 25 ˚C. Elution times $T_s = 9$ minutes and $T_r = 18$.

Chemical Formula: $C_{23}H_{19}NO$ Molecular Weight: 325.4

m.p.: 198.2-198.7 ˚C

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.55 (s, 1H), 8.06 (d, *J* = 8.4 Hz, 2H), 7.64 (t, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.8 Hz, 1H), 7.48 (dd, *J* = 17.6, 10.5 Hz, 2H), 7.42 – 7.31 (m, 3H), 4.84 (t, *J* = 7.0 Hz, 1H), 3.98 (s, 1H), 3.23 – 2.82 (m, 2H), 2.56 – 2.28 (m, 1H), 2.29 – 2.06 (m, 1H), 2.06 – 1.85 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 155.5, 137.6, 135.2, 131.8, 130.6, 130.5, 130.4, 128.9, 128.8, 127.9, 126.6, 126.4, 126.3, 126.2, 126.0, 125.6, 125.5, 69.4, 31.0, 28.7, 20.0.

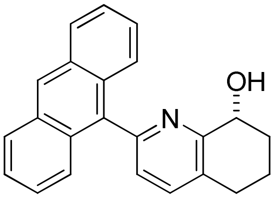
MS (e.i. 70 eV): m/z (%) 327.1 (3), 326.1 (23), 325.1 (100), 324.1 (73).

IR (neat, $\tilde{\nu}$): 3381, 3048, 2920, 1675, 1616, 1592, 1489, 1316, 1288, 1217, 1170, 1145, 1081, 955, 885, 724 cm^{-1}.

$[\alpha]_D^{20}$ = +4.0 at a concentration of 1.10.

3.1 alcohol *R*-**12g**

(*R*)-2-(anthracen-9-yl)-5,6,7,8-tetrahydroquinolin-8-ol



Synthesized by general method A except using 420 mg (0.957 mmol) of the silyl ether, 3 g (9.5 mmol) of tetrabutyl ammonium fluoride trihydrate in 50 mL of absolute THF and heating to 60 ˚C for 6 hours. Fractional recrystallization from 12 mL of toluene to precipitate the scalemic product yields the enantiopure product in the remaining solvent, 268 mg (0.824 mmol, 86%). The product matched the opposite enantiomer in its spectral and physical properties.

HPLC conditions: ODH column, 30% isopropanol in heptanes with a flow rate of 0.5 mLs/min and a temperature of 25 ˚C Elution times $T_s = 9$ minutes and $T_r = 18$.

Chemical Formula: $C_{23}H_{19}NO$ Molecular Weight: 325.4

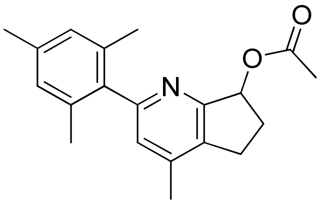
4.0 Asymmetric synthesis of scaffolds: Chiral HPLC separation of **11a-b,** Asymmetric CALB resolution of rac **12c-d**, and rac **13a-b** and synthesis of *S*-**13**a by asymmetric reduction

4.1 synthesis and separation of **11a-b**

Boekelheide rearrangement of pyridine *N*-oxides general synthesis method: Pyridine-*N*-oxide (37.3 mmol) was added to a round bottom flask with 60 mLs of acetic anhydride. The reaction was stirred for 1 hour at room temperature and then a reflux condenser was placed on the reaction vessel followed by heating to 80˚C for 5 hours. The reaction was cooled and the condenser was exchanged for a vacuum distillation head. The volatiles were vacuum distilled off and the resulting viscous oil was taken up in 100 mLs of DCM and washed with saturated sodium bicarbonate (3 x 100 mLs), brine (100 mLs), dried over magnesium sulfate, filtered and concentrated to dryness at a rotovap. The crude product can be purified by silica gel chromatography or carried through to ester hydrolysis.

4.1 acetate **11a**

2-Mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-yl acetate



Produced by the general method except 1.00g (3.74 mmol) of the pyridine-*N*-oxide was dissolved in 10 mLs of acetic anhydride and heated to 107 ˚C for 20 hours. Workup is identical to the general procedure accept the product was additionally purified by chromatography on silica gel with a gradient of ether and DCM starting from 0% ether and working to 5% changing the concentration by 2.5% for every two column lengths. Product R_f = 0.7 in 2% ether in DCM and streaks badly. Yield after column is 650 mg (2.10 mmol, 56%).

HPLC conditions: ADH column, 1% isopropanol in heptanes with a flow rate of 0.75 mLs/min and a temperature of 25 ˚C. Elution times 11.7 and 23.7 minutes. Semiprep conditions AD column, 1% isopropanol in hexanes with a flow rate of 6.0 mLs/min and a temperature of 25 ˚C min T_s = 20.3 min and T_r= 39.0.

Chemical Formula: $C_{20}H_{23}NO_2$ Molecular Weight: 309.4

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.96 (s, 1H), 6.90 (s, 2H), 6.08 (dd, *J* = 7.4, 3.7 Hz, 1H), 3.12 – 3.00 (m, 1H), 2.88 (tt, *J* = 9.0, 5.5 Hz, 1H), 2.76 – 2.63 (m, 1H), 2.33 (s, 3H), 2.30 (s, 3H), 2.24 – 2.09 (m, 1H), 2.07 (s, 3H), 2.02 (s, 6H).

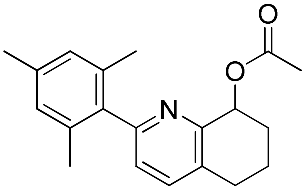
^{13}C NMR (126 MHz, $CDCl_3$) δ 171.0, 159.6, 159.5, 144.1, 137.6, 137.3, 135.8, 135.1, 128.3, 125.3, 78.1, 30.4, 26.5, 21.4, 21.1, 20.3, 18.8.

MS (e.i. 70 eV): m/z 309.1.

IR (neat, $\tilde{\nu}$): 2952, 2902, 1752, 1608, 1567, 1472, 1368, 1242, 1165, 1058, 972, 849, 734 cm^{-1}.

4.1 acetate **11b**

2-Mesityl-5,6,7,8-tetrahydroquinolin-8-yl acetate



Produced by the general method except 800mg (3.00 mmol) of the pyridine-N-oxide was dissolved in 10 mLs of acetic anhydride and heated to 107 ˚C for 20 hours. Workup is identical to the general procedure accept the product was additionally purified by chromatography on silica gel with a gradient of ether and DCM starting from 0% ether and working to 5% changing the concentration by 2.5% for every two column lengths. Product $R_f = 0.65$ in 2% ether in DCM and streaks badly. Yield after column is 750 mg (2.42 mmol, 81%).

HPLC conditions: OD column, 5% isopropanol in heptanes with a flow rate of 1.0 mLs/min and a temperature of 25 ˚C. Elution times 5.7 and 6.5 minutes. Semiprep conditions OD column, 0.5% isopropanol in hexanes with a flow rate of 6.0 mLs/min and a temperature of 25 ˚C T_s= 30.8 min and T_r= 39.2 min.

Chemical Formula: $C_{20}H_{23}NO_2$ Molecular Weight: 309.4

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (d, *J* = 7.9 Hz, 1H), 7.09 (d, *J* = 7.9 Hz, 1H), 6.92 (s, 2H), 5.91 (t, *J* = 4.1 Hz, 1H), 2.91 (dt, *J* = 16.7, 4.6 Hz, 1H), 2.85 – 2.76 (m, 1H), 2.30 (s, 3H), 2.26 (dd, *J* = 6.4, 3.5 Hz, 1H), 2.11 – 2.06 (m, 1H), 2.04 (s, 9H), 2.01 – 1.91 (m, 1H), 1.91 – 1.82 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.2, 157.7, 152.8, 137.4, 137.2, 135.9, 131.2, 128.4, 124.3, 71.5, 28.8, 28.2, 21.4, 21.0, 20.2, 18.2.

MS (e.i. 70 eV): m/z 309.1.

IR (neat, $\tilde{\nu}$): 2946, 2866, 1734, 1612, 1592, 1560, 1464, 1369, 1288, 1237, 1195, 1153, 1064, 1046, 970, 849, 734 cm^{-1}.

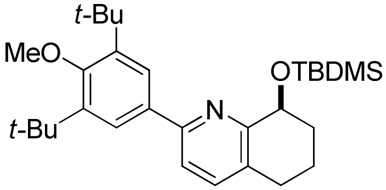
4.2 CALB resolution of racemic **12c-d** and **13a-b**

4.2.1 Resolution of racemic-**12d**, synthesis of (*S*)-**14b** and (*R*)-**12d**-OAc: Vinyl acetate (1.30 mL, 21.1 mmol, 15.0 eq.) and CAL-B [250 mg, immobilized on acrylic resin from Sigma (L47777)] was added to a solution of the racemic alcohol **12d** (514 mg, 1.40 mmol, 1.0 eq.) in dry *i*-Pr_2O (60 mL). The resulting solution was stirred at 60 °C for 5.5 h until chiral HPLC showed full disappearance of one enantiomer. The enzyme was filtered off and washed with EtOAc (3 × 20 mL). Evaporation of the solvent yielded a pale yellow residue which was dissolved in DMF (5 mL). Imidazole (160 mg, 2.35 mmol, 1.7 eq.) and TBDMSCl (170 mg, 1.12 mmol, 0.8 eq.) were added under argon. The resulting colorless solution was stirred for 18 h at rt. The solvent

was evaporated on HV and the resulting pale yellow residue was taken up in DCM (10 mL) and H_2O (10 mL) was added. The organic layer was separated and the aqueous layer was extracted with DCM (2 × 10 mL). The combined organic layers were dried over $MgSO_4$, filtered and the solvent evaporated in vacuo to afford a colorless residue. Column chromatography (SiO_2, hexane/ethyl acetate (1:20 → 1:1),
6 × 30 cm) yielded the TBDMS ether (*S*)-**14b** (310 mg, 0.64 mmol, 46%) as a colorless solid and the acetate (*R*)-**12d**-OAc (250 mg, 0.61 mmol, 44%) as a colorless oil.

4.2.1 (*S*)-**14b**

(*S*)-8-(tert-butyldimethylsilyloxy)-2-(3,5-di-tert-butyl-4-methoxyphenyl)-5,6,7,8-tetrahydroquinoline

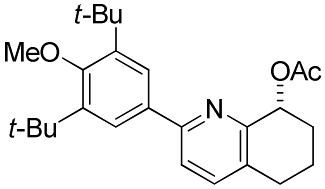


$[\alpha]_D^{20} = +30.8$ (c = 0.73, $CHCl_3$).

Analytical data matches the racemic silyl ether **14b.**

4.2.1 (*R*)-**12d**-OAc

(R)-2-(3,5-di-tert-butyl-4-methoxyphenyl)-5,6,7,8-tetrahydroquinolin-8-yl acetate



HPLC: column: *Daicel*, Chiralcel OD-H (250 × 4.6 mm); eluent: heptane/*i*-propanol 99.5:0.5, 0.5 mL/min; T = 25 °C, R_t = 26.4 min and 32.1 min.

TLC (SiO_2, DCM, UV): $R_f = 0.64$.

^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.86 (s, 2H), 7.53 (d, J_{HH} = 8.0 Hz, 1H), 7.45 (d, J_{HH} = 8.0 Hz, 1H), 6.08 (t, J_{HH} = 5.7 Hz, 1H), 3.71 (s, 3H), 2.87 (dt, J_{HH} = 16.7 Hz, J_{HH} = 6.2 Hz, 1H), 2.77 (dt, J_{HH} = 16.7 Hz, J_{HH} = 6.2 Hz, 1H), 2.17-2.10 (m, 2H, CH_2), 2.15 (s, 3H), 2.03-1.95 (m, 1H), 1.91-1.83 (m, 1H), 1.47 (s, 18H).

^{13}C-NMR (101 MHz, $CDCl_3$) δ 170.6, 160.5, 155.7, 153.1, 143.7, 137.5, 133.4, 130.7, 125.3, 119.3, 71.0, 64.3, 35.9, 32.1, 29.1, 28.1, 21.5, 19.2.

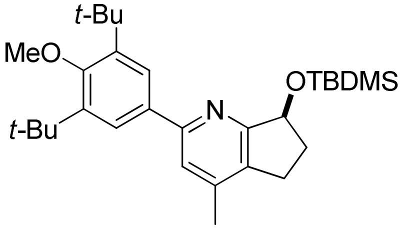
MS (EI, 70 eV, 200 °C) *m/z* (%): 409.3.

IR (NaCl, $\tilde{\nu}$): 2956, 1739, 1593, 1559, 1412, 1369, 1236, 1115, 1012, 756 cm^{-1}.

$[\alpha]_D^{20} = +19.6$ (c = 0.53, $CHCl_3$).

4.2.1 Resolution of racemic-**12c**, synthesis of (*S*)-**14a** and (*R*)-**12c**-OAc: The reaction was set up as for racemic **12d** except using vinyl acetate (2.0 mL, 32.5 mmol, 32.5 eq.), CAL-B (200 mg) and the racemic alcohol **12c** (370 mg, 1.00 mmol, 1.0 eq.) in dry *i*-Pr_2O (80 mL) stirred at 60 °C for 4.5 h. After workup the mixture was dissolved in DMF (8 mL). Imidazole (115 mg, 1.69 mmol, 1.7 eq.) and TBDMSCl (125 mg, 0.82 mmol, 0.8 eq.) were added to the solution under argon and the reaction was stirred for 18 h. Evaporation of the solvent, extraction and column chromatography (SiO_2, hexane/ethyl acetate (1:20 → 1:3), 6 × 30 cm) yielded the TBDMS ether (*S*)-**14c** (240 mg, 0.49 mmol, 49%) as a colorless solid and the acetate (*R*)-**12c**-OAc (200 mg, 0.48 mmol, 48%) as a colorless oil.

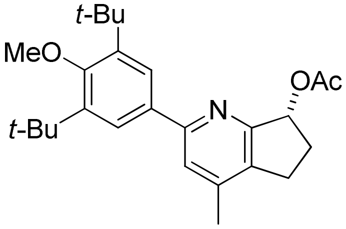
4.2.1 (*S*)-**14a**



$[\alpha]_D^{20} = +12.1$ (c = 0.94, $CHCl_3$).

Other analytical data matches silyl ether **14b**.

4.2.1 (*R*)-**12c-**OAc



HPLC**:** column: *Daicel*, Chiralcel IC (250 × 4.6 mm); eluent: heptane/*i*-propanol 50:50, 0.5 mL/min; T = 25 °C, R_t = 22.5 min and 23.5 min.

TLC (SiO_2, hexane/ethyl acetate (5:1), UV): $R_f = 0.26$.

^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.78 (s, 2H), 7.35 (s, 1H), 6.17 (dd, J_{HH} = 7.3 Hz, J_{HH} = 4.4 Hz, 1H), 3.71 (s, 3H), 3.02 (ddd, J_{HH} = 16.1 Hz, J_{HH} = 8.8 Hz, J_{HH} = 5.4 Hz, 1H), 3.83 (ddd, J_{HH} = 16.0 Hz, J_{HH} = 8.6 Hz, J_{HH} = 5.3 Hz, 1H), 2.68-2.59 (m, 1H), 2.35 (s, 3H), 2.16-2.08 (m, 1H), 2.13 (s, 3H), 1.48 (s, 18H).

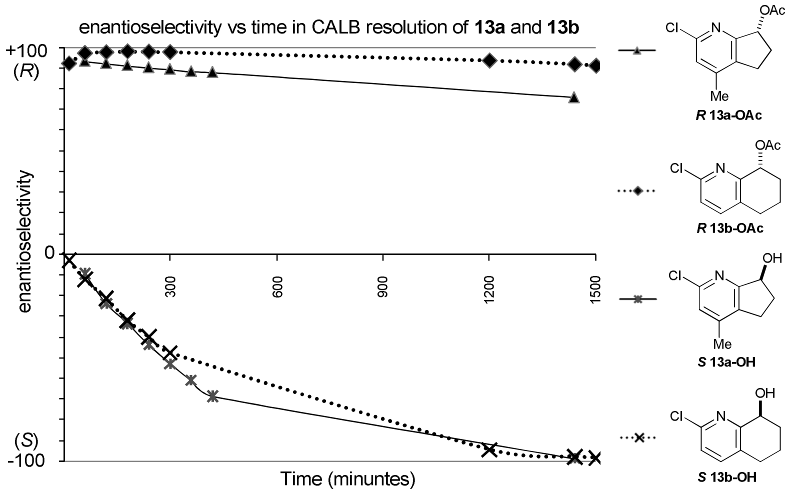
^{13}C-NMR (101 MHz, $CDCl_3$): δ 171.1, 160.6, 160.0, 158.5, 144.3, 143.8, 134.9, 134.3, 125.8, 121.7, 77.9, 64.5, 36.0, 32.2, 30.7, 26.4, 21.5, 19.0.

MS (EI, 70 eV, 200 °C) *m/z* (%): 409.3.

IR (NaCl, $\tilde{\nu}$): 2965m, 1734s, 1597w, 1444w, 1405m, 1363m, 1242s, 1219s, 1115w, 1003m, 889w cm^{-1}.

$[\alpha]_D^{20} = -29.2$ (c = 0.84, CHCl$_3$).

4.2.2 CALB resolution of racemic **13a-b**



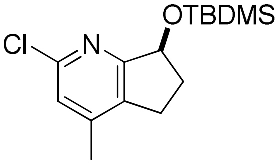
Graph 1 enantioselectivity vs time in resolution of **13a-b** with CALB

General procedure A: A 25 mL Schlenk flask equipped with a micro stir bar and rubber septum was dried under vacuum with a heat gun. The flask was placed under argon and the pressure was turned off to prevent the unwanted aerosol of the dry reagents. Racemic pyridyl alcohol (50 mg, 0.272 mmol) and *Candida Antarctica Lipase B* immobilized on resin, Novozyme® 435 (5 mg), were added quickly in succesion and the flask was placed under vacuum and then backfilled with argon for three cycles. Dry, degased diisopropyl ether (10 mL, inhibited with BHT) was transferred to the flask by syringe under argon. The flask was placed into a 67 ˚C oil bath and 1 mL of vinyl acetate was added. The reaction was stirred at this temperature and aliquots of 100 µL were taken at regular intervals with a syringe. The aliquot was passed through a micronfilter into an HPLC vial, the volatiles were dried under a stream of nitrogen and 1 mL of HPLC grade isopropanol was added and the aliquot analyzed by chiral HPLC. The reaction was removed from the heat after the enantioselectivity had reached 99% for either the alcohol or ester and cooled in an ice bath. The contents were removed with a needle and syringe and filtered through a large micronfilter. The volatiles were removed at the rotovap and tert-butyldimethylsilyl chloride (106 mg, 0.680 mmol) and imidazole (55.5 mg, 0.816 mmol) were added to the flask with a stir bar and septum. The contents were purged with an inert atmosphere through needles in the septum and dry DMF (1 mL) was added. The reaction was stirred overnight and the reaction was worked up by the addition of 3 mLs of ethyl acetate, extracted with water (4 x 4 mL), saturated ammonium chloride (2 x 2 mL), dried over magnesium sulfate, filtered and concentrated to dryness. A small column with a three solvent gradient was used to purify the products starting with 25% DCM in hexane and working to 100% DCM in steps of 25% every two column lengths followed by 10% ethyl acetate/ DCM to move the ester. Reaction is selective for the *R* acetate and *S* alcohol.

General procedure B: A 500 mL 4 neck reactor equipped with an overhead stirrer, condenser, inert gas inlet and bubbler was flame dried under a purge of argon. Racemic pyridyl alcohol (830 mg, 4.52 mmol) and *Candida Antarctica Lipase B* immobilized on resin, Novozyme® 435 (130 mg), were added under gentle argon purge in succesion and the flask was sealed with a ruber septum. Dry, degased diisopropyl ether (120 mL, inhibited with BHT) was transferred to the reactor by a double ended cannula pressure transfer under argon. The flask was placed into a 67 ˚C oil bath and 20 mL of vinyl acetate was added. The reaction was stirred at 900 rpm at this temperature and aliquots were taken and treated the same as in the general procedure A in the text above. The reaction was removed from the heat after the enantioselectivity had reached 99% for either the alcohol or ester and allowed to cool for ease of manipulation, filtered, the filter was washed with ethyl acetate (20mL), and the resin was recovered. The volatiles were removed at the rotovap and tert-butyldimethylsilyl chloride (1.75 g, 11.4 mmol) and imidazole (930 mg, 13.7mmol) were added to the flask with a stir bar and septum. The contents were purged with an inert atmosphere through needles in the septum and dry DMF (20 mL) was added. The reaction was stirred overnight and was worked up by the addition of 50mLs of ethyl acetate, extracted with water (4 x 100 mL), saturated ammonium chloride (2 x 50 mL), dried over magnesium sulfate, filtered and concentrated to dryness. Purified by column chromatography with silica gel, TBDMS ether elutes very rapidly in 50% DCM/ hexane, acetyl ester was eluted with 30% ethylacetate hexane. The TBDMS protecting group could be removed by heating the protected ether with 3 equivalents of TBAF trihydrate in dry THF with heating to 50 ˚C for 5 hours followed by aqueous workup. The acetate protecting group could be removed by using the same conditions for the racemate (K_2CO_3, $MeOH_{abs}$).

4.2.2 (*S*)-**15a**

(*S*)-7-(tert-butyldimethylsilyloxy)-2-chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine



Produced by general method A, yield 31.5 mg (0.106 mmol, 40%). 99.3% Enantioselectivity measured from the parent alcohol.

HPLC: Separated the parent alcohol on a chiral ADH column with a mobile phase of 5% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 40 ˚C, $T_{(R)\text{-acetate}}$ = 12.69 minutes, $T_{(S)\text{-acetate}}$= 13.68 minutes, $T_{(S)\text{-alcohol}}$= 17.2 minutes, $T_{(R)\text{- alcohol}}$ = 19.49 minutes.

Chemical Formula: $C_{15}H_{24}ClNOSi$ Molecular Weight: 297.9

TLC (SiO_2, hexane/ethyl acetate (5:1), UV): R_f = 0.68.

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.82 (s, 1H), 4.96 (t, *J* = 5.3 Hz, 1H), 2.78 (dt, *J* = 14.7, 10.8 Hz, 1H), 2.55 – 2.43 (m, 1H), 2.32 – 2.20 (m, 1H), 2.08 (s, 3H), 1.86 (dq, *J* = 8.7, 4.7 Hz, 1H), 0.77 (s, 9H), 0.05 (s, 3H), -0.00 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 150.6, 146.8, 135.0, 123.7, 76.2, 34.1, 26.3, 26.0, 18.8, -3.8, -4.3.

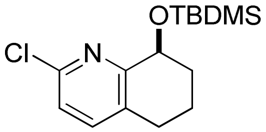
MS (FAB NBA): m/z (%): 299.1 (12), 297.1(52).

IR (NaCl): 2950s, 2929s, 2855s, 1580m, 1472m, 1443s, 1360w, 1253m, 1135m, 1089s, 991s, 881m, 835s, 778s.

Elemental Analysis: for $C_{15}H_{24}ClNOSi$ calculated C, 60.48; H, 8.12; N, 4.70 found C, 60.62; H, 8.39; N, 4.59.

4.2.2 (*S*)-**15b**

(*S*)-8-(tert-butyldimethylsilyloxy)-2-chloro-5,6,7,8-tetrahydroquinoline



Synthesized with general procedure B in identical detail. Yield of the protected silyl ether 563 mg (1.90 mmol, 41.7% yield) 99% enantioselectivity based on HPLC analysis of parent alcohol.

HPLC: Separated on a chiral ADH column with a mobile phase of 5% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 40˚C, $T_{(R)\text{-acetate}}$ = 12.05 minutes, $T_{(S)\text{-acetate}}$=13.82 minutes, $T_{(S)\text{-alcohol}}$= 15.8 minutes, $T_{(R)\text{- alcohol}}$ = 17.23 minutes.

Chemical Formula: $C_{15}H_{24}ClNOSi$ Molecular Weight: 297.9

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 8.1 Hz, 1H), 7.10 (d, *J* = 8.1 Hz, 1H), 4.74 (t, *J* = 4.5 Hz, 1H), 2.78 (dt, *J* = 17.0, 5.3 Hz, 1H), 2.72 – 2.57 (m, 1H), 2.13 – 1.94 (m, 2H), 1.94 – 1.81 (m, 1H), 1.73 (tdd, *J* = 8.3, 6.0, 2.9 Hz, 1H), 0.91 – 0.87 (m, 9H), 0.21 (d, *J* = 3.1 Hz, 3H), 0.10 (d, *J* = 3.1 Hz, 3H).

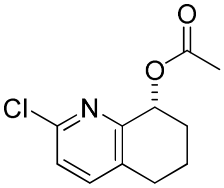
^{13}C NMR (126 MHz, $CDCl_3$) δ 158.5, 148.6, 140.0, 131.4, 123.2, 69.8, 32.5, 28.3, 26.3, 26.1, 18.7, -3.7, -4.6.

MS (FAB NBA): m/z (%): 299.1 (22), 297.1(80).

EA ($C_{15}H_{24}ClNOSi$): calculated: C, 60.48; H, 8.12; N, 4.70; found: C, 60.46; H, 8.34; N, 4.60;

4.2.2 (*R*)-**13b**-OAc

(*R*)-2-Chloro-5,6,7,8-tetrahydroquinolin-8-yl acetate



Synthesized by general method B. Isolated enantiopure product after chromatography and enantio enrichment by recrystallization of the parent ester (432 mg, 1.92 mmol, 97% ee) from 7 mLs of hot hexane cooled to -20 ˚C overnight to result in ester in 284 mg (1.26 mmol, 28% yield, 56% recovery) in 99% enantioselectivity.

Chemical Formula: $C_{11}H_{12}ClNO_2$ Molecular Weight: 225.7

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.1 Hz, 1H), 7.19 (d, *J* = 8.1 Hz, 1H), 5.85 (t, *J* = 4.4 Hz, 1H), 2.83 (dt, *J* = 17.0, 5.0 Hz, 2H), 2.76 – 2.65 (m, 1H), 2.21 – 2.12 (m, 1H), 2.10 (s, 3H), 2.04 – 1.95 (m, 1H), 1.95 – 1.88 (m, 1H), 1.88 – 1.78 (m, 1H).

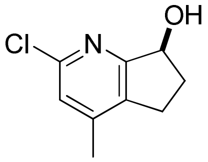
^{13}C NMR (101 MHz, $CDCl_3$) δ 170.6, 154.1, 149.2, 140.3, 132.9, 124.3, 70.8, 29.0, 28.1, 21.8, 18.5.

MS (EI, 70 eV): m/z (%): 227 (2), 225 (7).

4.3 Asymmetric reduction of 2-chloro-4-methyl-5H-cyclopenta[b]pyridin-7(6H)-one with R-methyl-CBS and catecholborane or (-)B-Chlorodiisopinocamphylborane

4.3. (*S*)-**13a**[2, 3]

(*S*)-2-chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



4.3.1 CBS reduction: Ketone (88 mg, 0.485 mmol) and *R*-methyl-CBS are added together in a 50 mL Schlenk flask in the glove box with a stir bar. The flask is equipped with a rubber septum and brought outside the glove box. Absolute DCM (20 mL) was added and the reaction was cooled to -20 ˚C in an isopropanol bath cooled with a digital refrigerated circulator. Catecholborane (116 mg, 0.967 mmol) was diluted in 2 mLs of absolute DCM and added dropwise over 15 minutes. The reaction was stirred for 48 hours at that temperature. The reaction was quenched with 4M lithium hydroxide (2 mL) and the reaction was removed from the cold bath and stirred for 30 minutes at that temperature. Water was added (10 mL), the layers were separated and the organic layer was passed through a short filtration column of silica, the silica was washed with ethyl acetate and the organics were combined and concentrated to yield essentially pure product in 90.8% ee (*S* selective),

HPLC: Separated on a chiral ADH column with a mobile phase of 10% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 25 ˚C, T_s = 13.2 minutes, T_R = 14.8 minutes.

(-)B-Chlorodiisopinocamphylborane reduction: Optimized conditions: Ketone (0.5 grams, 2.76 mmol) was added to a Schlenk flask in the glove box with absolute THF (20 mL). The flask was brought outside the box and cooled in a circulated bath at -50 ˚C for thirty minutes. (-)DIP-Cl (1.3 g, 4.06 mmol) was added as a solid under argon at that temperature, the flask was sealed and stirred at that temperature for two days. Diethanolamine (426 mg, 391μL, 4.06 mmol) was added cold and the reaction was allowed to stir for 1 hour while the diethylolaminoboranate is precipitated. The solution is filtered on a Schlenk frit under argon and the filtrate washed with 5 mLs of THF. The solution is worked up with 4 mLs of 4M lithium hydroxide, transferred to a separatory funnel and DCM is added (200mL). The solution is extracted with water (2 x 200 mL), followed by brine (100 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated to yield the crude product. The product was purified by silica gel chromatography with a gradient of ethyl acetate/ hexanes starting from pure hexanes and ending with 30% ethyl acetate. Yield of 256 mg (1.39 mmol, 50.6%). Product ee of 99.1% using HPLC conditions above.

Chemical Formula: $C_9H_{10}ClNO$ Molecular Weight: 183.6

MP: 108 ˚C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.03 (s, 1H), 5.17 (dd, *J* = 7.4, 5.8 Hz, 1H), 2.94 (ddd, *J* = 16.3, 9.0, 4.1 Hz, 1H), 2.75 – 2.66 (m, 1H), 2.55 (dddd, *J* = 13.4, 8.5, 7.6, 4.1 Hz, 1H), 2.27 (s, 3H), 2.05 (dddd, *J* = 13.6, 9.1, 6.6, 5.8 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.6, 149.9, 147.3, 134.7, 123.5, 74.2, 32.2, 25.5, 18.5.

MS (e.i. 70 eV): m/z (%) 182.

IR ($\tilde{\nu}$): 3420s, 2970w, 1589m, 1535m, 1435m, 1373m, 1188s, 1096s, 1065m, 1018m, 957m, 887w, 856s cm^{-1}.

$[\alpha]_D^{20}$ = -25 (c = 0.12)

Elemental Analysis: for $C_9H_{10}ClNO$ calculated C, 58.86; H, 5.49; N, 7.63; found C, 58.84; H, 5.42; N, 7.51

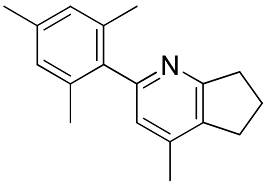
5.0 Suzuki cross coupling

5.1 Suzuki reaction of hindered boronic acids and esters with 2-chloropyridines **10a-b**.

General method:[4] A 5 mL microwave tube was charged with 2-pyridylchloride (167 mg, 1 mmol), 2-aryl boronic acid or ester (1.15 mmol) and the Nolan palladium NHC carbene catalyst chloro[(1,2,3-n)-3-phenyl-2-propenyl][1,3-bis(2,6-di-i-propylphenyl)-4,5-dihydroimidazol-2-ylidene]palladium(II) (1.9 mg, 2.92 μmol, 0.3 mol%). A stir bar was added and the microwave tube was sealed with a high presure microwave septum. The reaction vessel was purged with argon for 15 minutes by a needle inlet and release needle through the septum. Degassed isopropanol (3 mLs) was added via syringe and the contents were stirred and briefly sonicated until all had dissolved. Degassed aqueous sodium hydroxide (120 mg, 3 mmol) in 250 μL of water was added, the needles were removed and the reaction was heated to 100 ˚C for 48 hours. The vial is then cooled and decapped. The contents were washed into a round bottom flask and the volatiles were removed at a rotovap. The crude solids were taken up in dichloromethane, washed with saturated sodium bicarbonate (3 x 20 mLs), brine (1 x 20 mLs) and the organics were dried over magnesium sulfate. The volatiles were removed at a rotovap and the solids were taken up in dry hydrochloric acid in ether resulting in the immediate precipitation of a powder which was collected on a glass frit, washed with hexane and the hydrochloride pyridine salt was collected by dissolving in chloroform. The chloroform solution was neutralized with saturated bicarbonate, dried over magnesium sulfate and concentrated to yield the pure 2-arylpyridine.

5.1. **10a-**2-mesityl

2-Mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine



Synthesized by general method with the following modifications to the amounts used and purification: 2-pyridylchloride (850 mg, 5.09 mmol), 2,4,6-mesitylboronic acid (959 mg, 5.85 mmol), Nolan NHC catalyst (64 mg, 9.98 µmol, 2 mol%), 12 mLs of isopropanol, and 4M NaOH (3.8 mLs, 15.3 mmol) were used. Heated to 115 ˚C to overcome the insolubility of resulting boric eight complex, precipitate becomes loose and reaction mixture becomes less cloudy at higher temperature. Dry hydrochloric acid in ethanol (3 mLs of acetyl chloride in 30 mLs of absolute ethanol) was added to the crude solid after aqueous workup and removed at the rotovap followed by toluene (20 mLs) with subsequent removal by rotovap of the solvent to aid in crystallization. Isolation was identical to general method in all other regards yielding 1.1 grams (86%) of free pyridine after basic workup as an oil. Product can be purified by flash chromatography, 30% ethyl acetate in hexane, R_f of product = 0.5.

Chemical Formula: $C_{18}H_{21}N$ Molecular Weight: 251.4

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.89 (s, 2H), 6.77 (s, 2H), 3.05 (t, *J* = 7.8 Hz, 2H), 2.92 (t, *J* = 7.5 Hz, 2H), 2.29 (s, 3H), 2.27 (s, 3H), 2.16 (dt, *J* = 11.0, 7.7 Hz, 2H), 2.01 (s, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.8, 157.8, 142.8, 138.2, 136.8, 135.8, 133.7, 128.1, 122.8, 34.4, 29.1, 22.4, 21.0, 20.2, 18.9.

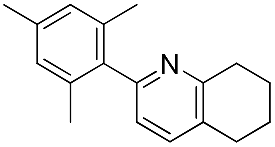
MS (e.i. 70 eV): m/z (%) 252.3 (6), 251.2 (37), 250.0 (100), 237.2 (1.3), 236.2 (8), 235.2 (7), 234.2 (5).

IR (neat ,$\tilde{\nu}$): 2930, 2858, 1612, 1590, 1563, 1460, 1393, 1258, 1181, 1116, 957, 849 cm^{-1}.

Elemental Analysis: for $C_{18}H_{21}N$ calculated C, 86.01; H, 8.42; N, 5.57 found C, 85.59; H, 8.52; N, 5.74.

5.1. **10b-**2-mesityl

2-Mesityl-5,6,7,8-tetrahydroquinoline



Synthesized by general method with the following modifications to the amounts used and purification: 2-pyridylchloride (954 mg, 5.70 mmol), 2,4,6-mesitylboronic acid (1.11 mg, 5.85 mmol), Nolan NHC catalyst (74 mg, 11.4 µmol, 2 mol%), 12 mLs of isopropanol, and 4M NaOH (3.8 mLs, 15.26 mmol) were used. Heated to 115 ˚C to overcome the insolubility of resulting boric eight complex, precipitate becomes loose and reaction mixture becomes less cloudy at higher temperature. Dry hydrochloric acid in ethanol (3 mLs of acetyl chloride in 30 mLs of absolute ethanol) was added to the crude solid after aqueous workup and removed at the rotovap followed by toluene (20 mLs) with subsequent removal by rotovap of the solvent to aid in crystallization. Isolation was identical to general method in all other regards yielding 1.25 grams (87%) of free pyridine after basic workup as an oil. Product can be purified by flash chromatography, 30% ethyl acetate in hexane.

Chemical Formula: $C_{18}H_{21}N$ Molecular Weight: 251.4

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 7.7 Hz, 1H), 6.93 (d, *J* = 7.8 Hz, 1H), 6.91 – 6.88 (s, 2H), 2.95 (t, *J* = 6.4 Hz, 2H), 2.81 (t, *J* = 6.3 Hz, 2H), 2.29 (s, 3H), 2.02 (s, 6H), 1.97 – 1.90 (m, 2H), 1.89 – 1.82 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 156.9, 156.8, 137.9, 137.0, 136.9, 135.8, 129.7, 128.2, 121.7, 32.5, 28.6, 23.2, 22.8, 21.0, 20.2.

MS (e.i. 70 eV): m/z (%) 252.3 (6), 251.2 (41), 250.0 (100), 236.2 (1.7), 235.2 (7), 234.2 (5), 223.2 (2.7), 222.2 (9), 221.3 (2).

IR (neat ,$\tilde{\nu}$): 2924, 2850, 1614, 1591, 1561, 1458, 1393, 1252, 1181, 1111, 957, 842 cm^{-1}.

Elemental Analysis: for $C_{18}H_{21}N$ calculated C, 86.01; H, 8.42; N, 5.57 found C, 86.13; H, 8.42; N, 5.52.

5.2 Suzuki reaction of hindered boronic acids and esters with 2-chloropyridine-O-terbutyldimethylsilyl ether derivatives.

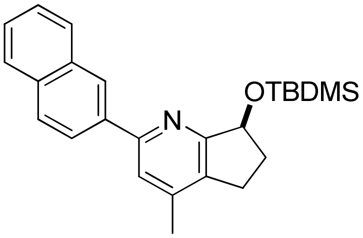
General procedure A: 2-Chloropyridine-O-TBDMS ether **15a** or **15b** (100 mg, 0.336 mmol), boronic acid (0.672 mmol), and Nolan NHC catalyst (8.6 mg, 13.7 µmol, 4 mol%) were added to a 5 mL microwave tube with a stir bar, the tube was sealed with a microwave septum and the contents were thoroughly purged with 2 bars of argon through a needle inlet/outlet for 15 minutes. Sodium tert-butoxide (0.29 M, 2.5 mL, 0.725 mmol) was added under purge. The purge needles were removed and the contents of the flask were pulverized with a sonicator for 15 minutes. The reaction was stirred at 60 ˚C for 24 hours. The reaction was worked up by extraction with DCM (25 mL) and water (2 x 25 mL), followed by brine (1 x 25 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated at the rotovap to provide crude product which was purified by column chromatography on a small column with a hexane/ DCM gradient starting from pure hexane and working in 20% change in solvent every 2 column lengths. Product typically elutes in the 40-60% range of DCM while the byproduct from protonation of the boronic acid reagent comes earlier.

General procedure B: 2-Chloropyridine-O-TBDMS ether (100 mg, 0.336 mmol), boronic acid (1.08 mmol), and Nolan NHC catalyst **16** (8.6 mg, 13.7 µmol, 4 mol%) were added to a 20 mL microwave tube with a stir bar, the tube was sealed with a microwave septum and the contents were thoroughly purged with 2 bars of argon through a needle inlet/outlet for 15 minutes. Isopropanol was degassed by bubbling argon through the solvent in a septumed flask with needles and with stirring for 20 minutes, 10.0 mL was added to the microwave tube by syringe and the contents were sonicated with stirring for 20 minutes. Thoroughly degassed (as for the isopropanol) aqueous sodium hydroxide (4.0 M, 500 µL, 2.0 mmol) was added under purge. The purge needles were removed and the contents of the flask were pulverized with a sonicator for 5 minutes. The reaction was stirred at 60 ˚C for 24 hours. The reaction was worked up by extraction with DCM (50 mL) and water (2 x 50 mL), followed by brine (1 x 50 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated at the rotovap to provide crude product which was purified by column chromatography on a small column with a hexane/ ethyl acetate gradient starting from pure hexane and working in 15% change in solvent every 2 column lengths until 75% ethyl acetate is reached.

General procedure C: 2-Chloropyridine-O-TBDMS ether (315 mg, 1.06 mmol), boronic acid (2.12 mmol), and Nolan NHC catalyst (27 mg, 42.4 µmol, 4 mol%) were added to a 20 mL microwave tube with a stir bar, the tube was sealed with a microwave septum and the contents were thoroughly purged with 2 bars of argon through a needle inlet/outlet for 15 minutes. Isopropanol was degassed by bubbling argon through the solvent in a septumed flask with needles and with stirring for 20 minutes, 14.0 mL was added to the microwave tube by syringe and the contents were sonicated with stirring for 20 minutes. Thoroughly degassed (as for the isopropanol) aqueous sodium hydroxide (4.0 M, 795 µL, 3.18 mmol) was added under purge. The purge needles were removed and the contents of the flask were pulverized with a sonicator for 5 minutes. The reaction was stirred at 60 ˚C for 24 hours. The reaction was worked up by extraction with DCM (100 mL) and water (2 x 100 mL), followed by brine (1 x 100 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated at the rotovap to provide crude product which was purified by column chromatography with a hexane/ DCM gradient starting from pure hexane and working in 20% change in solvent every 2 column lengths until pure DCM is reached.

5.2. (*S*)-**12e** OTBDMS

(*S*)-7-(tert-butyldimethylsilyloxy)-4-methyl-2-(naphthalen-2-yl)-6,7-dihydro-5H-cyclopenta[b]pyridine



Synthesized by general method A with enantiopure 2-chloropyridine. All spectral properties matched those of the racemate. Yield 122 mg (0.313 mmol, 93%).

Chemical Formula: $C_{25}H_{31}NOSi$ Molecular Weight: 389.6

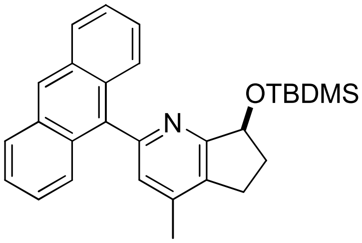
^{1}H NMR (500 MHz, CDCl$_3$) δ 8.54 (s, 1H), 8.24 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.92 (d, *J* = 8.3 Hz, 2H), 7.89 – 7.82 (m, 1H), 7.58 (s, 1H), 7.54 – 7.43 (m, 2H), 5.28 (dd, *J* = 7.1, 5.3 Hz, 1H), 3.02 (ddd, *J* = 16.0, 8.7, 4.7 Hz, 1H), 2.82 – 2.67 (m, 1H), 2.59 – 2.42 (m, 1H), 2.35 (s, 3H), 2.14 – 1.97 (m, 1H), 1.02 (s, 9H), 0.30 (s, 3H), 0.25 (s, 3H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 164.6, 156.5, 144.3, 137.6, 134.6, 133.9, 133.8, 129.0, 128.5, 128.0, 126.5, 126.4, 126.3, 125.2, 120.8, 76.8, 34.3, 26.4, 26.2, 19.2, 19.1, -3.89, -4.1.

MS (FAB NBA): m/z (%): 389.3.

5.2. (*S*)-**12f** OTBDMS

(*S*)-2-(anthracen-9-yl)-7-(tert-butyldimethylsilyloxy)-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine



Synthesized by general method A with enantiopure *S*-**15a**. Yield 139 mg (0.316 mmol, 94%) as an oil.

Chemical Formula: $C_{29}H_{33}NOSi$ Molecular Weight: 439.7

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.51 (s, 1H), 8.02 (t, *J* = 9.6 Hz, 2H), 7.80 (d, *J* = 8.8 Hz, 1H), 7.70 (d, *J* = 8.8 Hz, 1H), 7.49 – 7.40 (m, 2H), 7.38 – 7.30 (m, 2H), 7.16 (d, *J* = 8.0 Hz, 1H), 5.28 (dd, *J* = 6.6, 3.0 Hz, 1H), 3.27 – 3.12 (m, 1H), 2.94 – 2.82 (m, 1H), 2.48 (ddt, *J* = 13.5, 8.6, 6.7 Hz, 1H), 2.37 (s, 3H), 2.24 – 2.13 (m, 1H), 0.90 (d, *J* = 5.7 Hz, 9H), 0.14 (s, 3H), 0.08 (d, *J* = 5.9 Hz, 3H).

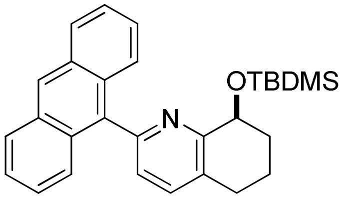
^{13}C NMR (126 MHz, CDCl$_3$) δ 165.0, 156.9, 143.9, 136.3, 134.9, 131.9, 131.8, 130.7, 130.5, 128.8, 128.5, 127.6, 127.5, 127.3, 126.9, 125.7, 125.7, 125.5, 125.3, 76.9, 34.1, 26.8, 26.3, 22.7, 19.1, 18.8, 14.5, -3.8, -4.2.

IR (neat ,$\tilde{\nu}$): 2927, 2854, 1669, 1591, 1459, 1360, 1316, 1254, 1084, 1027, 1113, 881 cm^{-1}.

MS (FAB NBA+KCl): m/z (%): 440.1.

5.2. (*S*)-**12g** OTBDMS

(*S*)-2-(anthracen-9-yl)-8-(tert-butyldimethylsilyloxy)-5,6,7,8-tetrahydroquinoline



Synthesized by general method C with 550 mg (1.85 mmol) enantiopure (S)-8-(tert-butyldimethylsilyloxy)-2-chloro-5,6,7,8-tetrahydroquinoline. Product is a clear high viscosity oil. Yield 760 mg (1.73 mmol, 93%).

Chemical Formula: $C_{29}H_{33}NOSi$ Molecular Weight: 439.7

^1H NMR (500 MHz, $CDCl_3$) δ 8.52 (s, 1H), 8.04 (dd, *J* = 8.4, 2.9 Hz, 2H), 7.74 (d, *J* = 8.8 Hz, 1H), 7.66 (d, *J* = 8.8 Hz, 1H), 7.59 (d, *J* = 7.7 Hz, 1H), 7.45 (dd, *J* = 14.7, 7.2 Hz, 2H), 7.34 (dd, *J* = 13.9, 6.0 Hz, 2H), 7.30 (d, *J* = 7.7 Hz, 1H), 4.92 (s, 1H), 3.01 (dt, *J* = 16.8, 4.6 Hz, 1H), 2.94 – 2.80 (m, 1H), 2.25 (dd, *J* = 22.8, 18.1 Hz, 1H), 2.19 – 2.08 (m, 1H), 2.02 (dd, *J* = 24.7, 12.0 Hz, 1H), 1.86 (dd, *J* = 9.4, 3.5 Hz, 1H), 0.87 (s, 9H), 0.08 (d, *J* = 6.9 Hz, 3H), -0.06 (s, 3H).

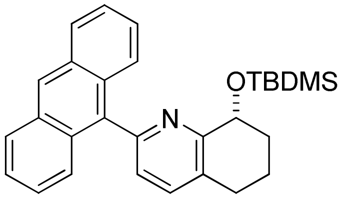
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.07, 155.46, 137.39, 136.15, 131.84, 131.77, 131.14, 130.59, 130.45, 128.80, 128.49, 127.55, 127.50, 126.79, 125.99, 125.76, 125.49, 125.31, 70.39, 32.72, 28.76, 26.28, 18.63, 17.88, -3.71, -4.45.

MS (FAB NBA+KCl): m/z (%): 440.1.

IR (neat ,$\tilde{v}$): 2928, 2854, 1671, 1593, 1458, 1354, 1311, 1251, 1085, 1027, 881, 835, 776, 753 735 cm^{-1}.

5.2. (*S*)-**12g** OTBDMS

(*R*)-2-(anthracen-9-yl)-8-(tert-butyldimethylsilyloxy)-5,6,7,8-tetrahydroquinoline

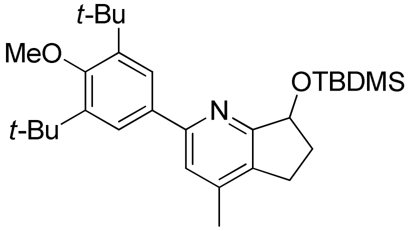


Synthesized by general method C with enantiopure (R)-8-(tert-butyldimethylsilyloxy)-2-chloro-5,6,7,8-tetrahydroquinoline **15b**. Product is a clear high viscosity oil. Yield 440 mg (1.00 mmol, 94%). Product matched the opposite enantiomer in perfect agreement in spectra and properties.

5.2. racemic-**14a**

7-((*tert*-butyldimethylsilyl)oxy)-2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-4-methyl-6,7-

dihydro-5H-cyclopenta[b]pyridine



The reaction was set up as for the procedure for **14b** except using compound **13a** (600 mg, 2.01 mmol, 1.0 eq.), 2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (1.00 g, 2.88 mmol, 1.4 eq.), the catalyst **16** (40 mg, 3 mol%), *i*-PrOH (12 mL) and 4 M NaOH-solution (1.5 mL). Extraction and column chromatography (SiO_2, hexane/DCM (20:1), 21 × 6 cm) yielded the product **14a** (840 mg, 1.77 mmol, 88%) as a colorless solid. TLC (SiO_2, hexane/ethyl acetate (5:1), UV): $R_f = 0.78$.

MP: 84-87 °C.

^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.94 (s, 2H), 7.33 (s, 1H), 5.24 (dd, $J_{HH} = 6.4$ Hz, $J_{HH} = 5.1$ Hz, 1H), 3.72 (s, 3H), 3.03-2.96 (m, 1H), 2.74-2.67 (m, 1H), 2.49-2.42 (m, 1H), 2.31 (s, 3H), 2.09-2.00 (m, 1H), 1.49 (s, 18H), 0.99 (s, 9H), 0.30 (s, 3H), 0.22 (s, 3H).

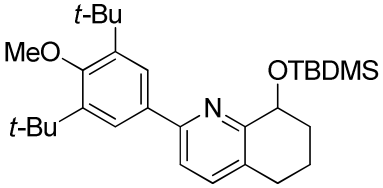
^{13}C-NMR (101 MHz, $CDCl_3$): δ 164.0, 160.3, 157.1, 143.8, 143.7, 134.3, 133.5, 125.6, 120.1, 76.6, 64.4, 36.1, 33.9, 32.3, 26.2, 26.0, 18.9, 18.8, -3.9, -4.4.

MS (FAB NBA): *m/z* (%): 482.2.

IR (KBr , $\tilde{\nu}$): 2955, 2856, 1597, 1472, 1406, 1360, 1252, 1218, 1113, 1062, 1001, 912, 867, 836, 778 cm^{-1}.

5.2. racemic-**14b**

8-((*tert*-butyldimethylsilyl)oxy)-2-(3,5-di-tert-butyl-4-methoxyphenyl)-5,6,7,8-tetrahydroquinoline



8-((*tert*-butyldimethylsilyl)oxy)-2-chloro-5,6,7,8-tetrahydroquinoline (0.70 g, 2.35 mmol, 1.0 eq.), 2-(3,5-di-*tert*-butyl-4-methoxyphenyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (1.22 g, 3.52 mmol, 1.5 eq.) and the catalyst **16** (50 mg, 3 mol%) were added to a microwave vial and sealed. The vial was purged with argon for 15 min. Afterwards degassed *i*-PrOH (12 mL) and degassed 4 M NaOH-solution (1.76 mL) were added. The solution was stirred for 18 h at 50 °C. The reaction mixture was allowed to cool down to rt and the resulting dark gel was dissolved in DCM (30 mL) and partitioned with H_2O (10 mL). The organic layer was separated and the aqueous layer was extracted with DCM (2 × 30 mL). The combined organic layers were dried over $MgSO_4$, filtered and the solvent was evaporated in vacuo to afford a dark solid. Purification by column chromatography (SiO_2, hexane/DCM (4:1), 12 × 3 cm) yielded the desired product **14b** (1.10 g, 2.28 mmol, 97%) as a colorless solid. TLC (SiO_2, DCM, UV): $R_f = 0.60$.

MP: 107-108 °C.

^{1}H-NMR (400 MHz, $CDCl_3$): δ/ppm = 7.91 (s, 2H), 7.51 (d, J_{HH} = 8.0 Hz, 1H), 7.42 (d, J_{HH} = 8 Hz, 1H), 4.92 (t, J_{HH} = 3.5 Hz, 1H), 3.74 (s, 3H), 2.89-2.83 (m, 1H), 2.72-2.68 (m, 1H), 2.23-2.16 (m, 1H), 2.14-2.09 (m, 1H), 1.92-1.82 (m, 1H), 1.79-1.75 (m, 1H), 1.52 (s, 18H), 0.94 (s, 9H), 0.36 (s, 3H), 0.12 (s, 3H).

^{13}C-NMR (101 MHz, $CDCl_3$): δ/ppm = 160.4, 156.9, 155.3, 143.8, 137.8, 134.0, 130.1, 125.5, 119.2, 70.1, 64.4, 36.1, 32.5, 32.3, 28.4, 26.1, 18.4, 17.5, -3.6, -4.6.

MS (FAB NBA): *m/z* (%): 482.3.

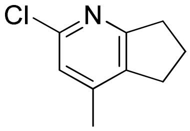
IR (KBr ,$\tilde{\nu}$): 2954, 2867, 1593, 1473, 1412, 1359, 1247, 1221, 1081, 993, 833, 776 cm^{-1}.

6.0 Chlorination of 2-pyridones

General procedure: Solid 2-pyridone (15.7 g, 0.105 mol) and phenylphosphoryl dichloride (55.7 g, 40 mL, 0.285 mol) were added to a 100 mL round bottom flask equipped with a strong egg shaped stir bar, a reflux condenser and an inert gas bubbler, a Teflon sleeve was placed between the reflux condenser and flask to prevent the joints from fusing together. The resulting slurry was heated to 135 ˚C under an argon atmosphere during which time the solids dissolved. The resulting orange solution was stirred for 16 hours at this temperature. A 3 L flask for quenching was charged with 500 grams of ice, 60 grams of potassium carbonate, 200 mLs of water, 200 mLs of chloroform and a large and powerful stir bar for mixing viscous slurries. The flask was set in a large ice water bath and the still warm (ca 80 ˚C) highly viscous black reaction mixture was poured gently into the ice/ base quench mixture with a high rate of mixing. It is important to note that the cold reaction mixture forms a black tar which is extremely difficult to work with and ground glass joints fuse together if the entire joint is not protected by a Teflon sleeve. Precautions should be taken as a very exothermic release of gas ensues with the addition of strong acid to potassium carbonate, strong mixing and cooling assist this greatly. The remains of the reaction are washed into the stirring quench mixture with chloroform and the pH is adjusted to 8.5 with the careful addition of portions of potassium carbonate and frequent checking with pH indicator strips. The mixture is poured into a large separatory funnel and the layers are separated. The aqueous layer is back extracted with chloroform (2 x 200 mLs), the layers are combined and dried over magnesium sulfate. The filtered organics were concentrated at a rotovap and the resulting black mixture was purified by Kugelrohr distillation (0.06 mbar, 120-150 ˚C, dry ice cooling) to result in a white solid which slowly darkens on contact with air and light and melts at very moderate temperatures. Note: the products are very pungent, volatile and some people develop a headache and nausea when exposed to the vapors.

6.1. **10a**

2-Chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine[3, 5, 6]



15.3 Grams of colorless waxy solid which slowly darkens in contact with air and light 87% yield. $C_9H_{10}ClN$ Molecular Weight: 167.6

MP: 51 ˚C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.91 (s, 1H), 2.99 (t, *J* = 7.8 Hz, 2H), 2.82 (t, *J* = 7.5 Hz, 2H), 2.23 (s, 3H), 2.19 – 2.05 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.2, 150.9, 148.4, 120.5, 115.0, 31.0, 28.3, 22.3, 19.7.

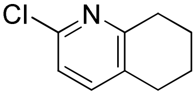
MS (e.i. 70 eV): m/z (%) 216.1 (15), 133.1 (9), 120.1 (60), 105.0 (100), 77.0 (32).

IR ($\tilde{v}$): 3271s, 2916w, 16341, 1535m, 1435m, 1219w, 1173m, 1111w, 957m cm^{-1}.

Elemental Analysis: for $C_9H_{10}ClN$ calculated C, 64.48; H, 6.01; N, 8.36 found C, 64.26; H, 6.08; N, 8.23.

6.1. **10b**

2-Chloro-5,6,7,8-tetrahydroquinoline[1, 7]



The commercially available compound was prepared using the general procedure outlined above in an identical fashion yielding 14.08 grams, 80.3% as a colorless waxy solid.

Chemical Formula: $C_9H_{10}ClN$ Molecular Weight: 167.6

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.0 Hz), 7.39 (d, *J* = 8.0 Hz), 3.23 (t, *J* = 6.4 Hz), 3.07 (t, *J* = 6.2 Hz), 2.25 – 2.18 (m), 2.17 – 2.10 (m).

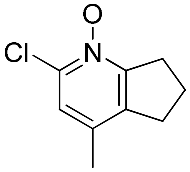
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.2, 147.7, 139.5, 131.0, 121.1, 32.2, 28.0, 22.6, 22.4.

7.0 Oxidation of ortho substituted pyridines to pyridine-N-oxides

General method A: Ortho functionalized pyridine (53.9 mmol) was dissolved in acetic acid (75 mLs) and 32% hydrogen peroxide was added to this mixture which was then heated to 100 ˚C for 18 hours. The volatiles were removed at the rotovap and the resulting slurry was dissolved in DCM (300 mLs) and partitioned with 5% sodium bicarbonate (2 x 150 mLs),water (2 x 150 mLs), and brine (2 x 100 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated to dryness to yield essentially pure product (53.6 mmol) which could be further purified by taking up in a minimal amount of toluene (ca 60 mLs) and leaving in the freezer overnight (47.3 mmol).

General method B: *Ortho* functionalized pyridine (1.62 mmol) was dissolved in 10 mLs of DCM and commercially available 77% MCPBA was added (500 mg, 2.89 mmol). The flask was equipped with a reflux condenser and the reaction was heated to 42 ˚C while monitoring the disappearance of starting material by TLC (2-4% TEA in DCM). Reaction is complete within 4 to 6 hours and quenched immediately to prevent over oxidation. The reaction was quenched with a workup by extraction with saturated bicarbonate diluted in water (1:3 v/v, 3 x 50 mL), water (2 x 50 mL) and brine (2 x 50 mL). The organic layer was dried over sodium sulfate, filtered and concentrated at the rotovap for essentially pure product in a yield range of 70-96%.

7.1 2-Chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-N-oxide[6, 8]



Produced in an identical manner to general method A. Yield 9.30 grams (50.6 mmol) of white crystalline material from 53.9 mmol of starting material (94% isolated yield).

Chemical Formula: $C_9H_{10}ClNO$ Molecular Weight: 183.6

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11 (s, 1H), 3.19 (t, *J* = 7.6 Hz, 2H), 2.92 (t, *J* = 7.6 Hz, 2H), 2.23 (s, 3H), 2.19 – 2.05 (m, 2H).

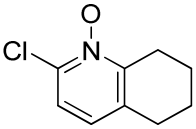
^{13}C NMR (101 MHz, $CDCl_3$) δ 163.4, 153.4, 133.8, 133.7, 125.3, 30.7, 30.4, 22.0, 18.0.

MS (e.i. 70 eV): m/z (%) 183 (83), 166 (100), 151 (18), 131 (52), 77 (18).

IR ($\tilde{\nu}$): 3032w, 1805w, 1659w, 1512w, 1458m, 1381m, 1227s, 1173s, 1072m, 910s cm^{-1}.

MP: 172˚C.

7.1 2-Chloro-5,6,7,8-tetrahydroquinoline-*N*-oxide[1, 5, 6, 9, 10]



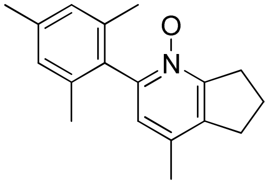
Produced in an identical manner to general method A. Yield 9.2 grams (50.3 mmol) of white crystalline material from 53.9 mmol of starting material (93% isolated yield).

Chemical Formula: $C_9H_{10}ClNO$ Molecular Weight: 183.6

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.3 Hz, 2H), 6.92 (d, *J* = 8.3 Hz, 2H), 2.95 (t, *J* = 6.6 Hz, 2H), 2.74 (t, *J* = 6.0 Hz, 2H), 1.92 – 1.84 (m, 2H), 1.78 – 1.70 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 150.5, 139.1, 134.2, 125.8, 122.9, 28.3, 25.5, 21.7, 21.4.

7.1 2-Mesityl-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine-N-oxide



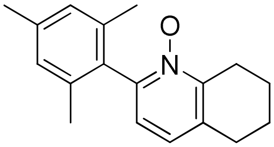
Produced by general method B except running the reaction at room temperature on 1 gram (4.00 mmol) of 2-arylpyridine, addition of 1.5 grams (6.00 mmol) MCPBA is quite exothermic. An additional 250 mg (1.41 mmol) of oxidant is added 2 hours into reaction to drive the reaction to completion, total time 5 hours. Aqueous workup was identical to that outlined in general method B, yielding 950 mg (3.55 mmol, 89%) as a viscous clear wax which crystallized on standing for a few hours.

Chemical Formula: $C_{18}H_{21}NO$ Molecular Weight: 267.4

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.92 (s, 2H), 6.83 (s, 1H), 3.24 (t, *J* = 7.7 Hz, 2H), 2.97 (t, *J* = 7.6 Hz, 2H), 2.31 (s, 3H), 2.25 (s, 3H), 2.26 – 2.17 (m, 2H), 2.05 (s, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 152.5, 147.4, 139.2, 138.3, 136.8, 132.5, 130.2, 128.2, 126.7, 30.5, 30.3, 21.9, 21.1, 19.8, 18.1.

7.1 2-Mesityl-5,6,7,8-tetrahydroquinoline-N-oxide



Produced by general method B except using 800 mg (3.18 mmol) of 2-arylpyridine and 1.17 g (4.78 mmol calculated for 70% b/w). A significant exotherm occurred on addition of the oxidant so the reaction was stirred at room temperature. Stirred for 5 hours and worked up as in general method B to yield 810 mg (3.03 mmol, 95%) as a clear solid.

Chemical Formula: $C_{18}H_{21}NO$ Molecular Weight: 267.4

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 – 6.97 (m, 2H), 6.93 (s, 2H), 2.99 (t, *J* = 6.5 Hz, 2H), 2.82 (t, *J* = 6.1 Hz, 2H), 2.31 (s, 3H), 2.04 (s, 6H), 1.98 – 1.86 (m, 2H), 1.86 – 1.76 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 149.2, 147.0, 138.3, 136.6, 134.7, 130.7, 128.2, 125.1, 123.9, 28.7, 24.9, 22.1, 21.7, 21.1, 19.7.

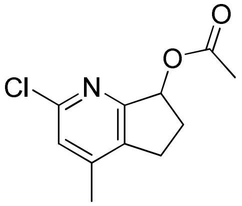
8.0 Boekelheide rearrangement of pyridines of *N*-oxides

General method: Pyridine-*N*-oxide (37.3 mmol) was added to a round bottom flask with 60 mLs of acetic anhydride. The reaction was stirred for 1 hour at room temperature and then a reflux condenser was placed on the reaction vessel followed by heating to 80 ˚C for 5 hours. The reaction was cooled and the condenser was exchanged for a vacuum distillation head. The volatiles were vacuum distilled off and the resulting viscous oil was taken up in 100 mLs of

DCM and washed with saturated sodium bicarbonate (3 x 100 mLs), brine (100 mLs), dried over magnesium sulfate, filtered and concentrated to dryness at a rotovap. The crude product can be purified by silica gel chromatography or carried through to ester hydrolysis.

8.1. **13a**-OAc

2-Chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-yl acetate



Produced in exact detail with the general method resulting in 6.85 grams (30.4 mmol, 81%) of a colorless solid in good accordance with the literature.[3, 5, 6, 8]

Chemical Formula: $C_{11}H_{12}ClNO_2$ Molecular Weight: 225.7

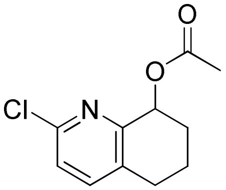
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (s, 1H), 6.03 (dd, *J* = 4.3, 4.3 Hz, 1H), 3.04-2.91 (m, 1H), 2.78 (ddd, *J* = 16.3, 8.8, 5.0 Hz, 1H), 2.66 (dddd, *J* = 14.2, 8.8, 7.5, 5.3 Hz, 1H), 2.29 (s, 3H), 2.11 (s, 3H), 2.11-2.05 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 175.8, 165.5, 149.1, 145.9, 135.1, 121.8, 61.5, 34.0, 28.6, 22.4, 18.8.
MS (e.i. 70 eV): m/z (%) 182 (100), 165 (60), 154 (10), 130 (12), 43 (16).

IR ($\tilde{\nu}$): 2955w, 2854w, 1736s, 1589m, 1435m, 1366m, 1304w, 1227s, 1103m, 1042s, 934m, 887m, 864w, 733w, 687w, 633w cm^{-1}.

8.1. **13b**-OAc

2-Chloro-5,6,7,8-tetrahydroquinolin-8-yl acetate



Produced with the general method except using 9.0 grams (49.2 mmol) of the resulting in 8.5 grams (37.7 mmol, 77%) of a colorless solid in good accordance with the literature.[1, 7, 9, 11] The analytical data matched the enantiomer 4.2.2 (*R*)-**13b**-OAc**.**

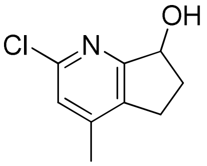
Chemical Formula: $C_{11}H_{12}ClNO_2$ Molecular Weight: 225.7

9.0 synthesis of 13a-b and Swern oxidation of 13a and formation of racemic 15a-b

9.1 General synthesis method for **13a-b**: The parent 2-chloropyridylalcohol acetate ester was deprotected by placing 27.0 mmol of the starting material into an oven dried round bottom flask with 215 mmol of finely divided potassium carbonate and 100 mLs of absolute methanol. The reaction was sealed with a septum and stirred at a high rate of mixing. The reaction was monitored with TLC. When the starting material was completely consumed the reaction was diluted with dichloromethane (200 mLs) and passed through a pad of celite. The filter was washed with DCM (2 x 50 mL) and the resulting solution was extracted with water (300 mL) and the aqueous layer was back extracted with DCM (4 x 50 mL), the organic layer was dried over magnesium sulfate, filtered and concentrated at a rotovap to yield the crude product which was then purified by chromatography.

9.1 rac-**13a**

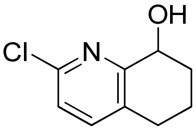
2-Chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridin-7-ol



Produced in identical fashion to the general example and in good agreement with the literature[5, 6] to yield 4.36 grams (23.8 mmol, 88%) from 6.10 grams of starting material. Chromatographed in silica gel, R_f= 0.4 for product in 1:1 ethyl acetate/ hexane. Analytical data matched the data reported for the enantiomer in section 4.2.2 (*S*)-**13a.**

9.1 rac-**13b**

2-Chloro-5,6,7,8-tetrahydroquinolin-8-ol



Produced by the general method except using 1.2 grams (5.37 mmol) of acetate, 1.2 grams (8.69 mmol) of potassium carbonate and 20% of the volumes for extraction as described. Yield after chromatography 970 mg (5.30 mmol, 97%), in good agreement with the literature.[1, 9, 10] TLC (SiO_2, hexane/ethyl acetate (5:1), UV): R_f = 0.07.

Chemical Formula: $C_9H_{10}ClNO$ Molecular Weight: 183.6

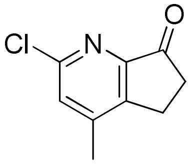
^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.37 (d, J_{HH} = 8.0 Hz), 7.13 (d, J_{HH} = 8.0 Hz), 4.68 (dd, J_{HH} = 6.0 Hz, J_{HH} = 5.2 Hz, 1H), 3.54 (s br, 1H), 2.83-2.70 (m, 2H), 2.26-2.21 (m, 1H), 2.02-1.95 (m, 1H), 1.86-1.77 (m, 2H).

^{13}C-NMR (101 MHz, $CDCl_3$): δ 158.8, 148.5, 134.0, 130.7, 123.1, 68.7, 30.4, 27.9, 19.3.

9.2 Swern oxidation of **13a**: A 500 mL Schlenk flask is dried under vacuum with a heat gun and allowed to cool to room temperature under an active vacuum. The flask is placed under an inert atmosphere and charged with 150 mL of dry chloroform (amylenes as inhibitor). Oxalyl chloride (1.37 mL, 16.3 mmol) was added and the solution was cooled to -78 °C. DMSO (3.9 mL, 54.9 mmol) was added and the reaction was stirred 10 minutes. The parent alcohol (2.50 g, 13.6 mmol) dissolved in dry chloroform (120 mL) was added and the resulting mixture was stirred at -78 ˚C for one hour. Triethylamine (9.56 mL, 68.8 mmol) was added and the reaction was allowed to come to room temperature. The reaction mixture was quenched with saturated sodium bicarbonate with slow pipette addition at first followed by pouring into sodium bicarbonate solution (200 mL), followed by extraction with brine (3 x 100 mL), drying of the organic layer over magnesium sulfate, filtration and concentration to yield a crude dark product. The crude material was purified by column chromatography with MTBE/ hexane 50:50 to yield 2.34 g (12.9 mmol, 95%) as a white solid.

9.2. **13a**-ketone

2-Chloro-4-methyl-5H-cyclopenta[b]pyridin-7(6H)-one[2, 3, 5]



Chemical Formula: C_9H_8ClNO Molecular Weight: 181.6

MP: 166 ˚C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (s, 1H), 3.01 (dd, *J* = 6.6, 4.7 Hz, 2H), 2.77 – 2.72 (m, 2H), 2.39 (s, 3H).

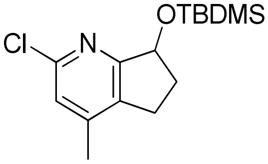
^{13}C NMR (101 MHz, $CDCl_3$) δ 203.6, 153.5, 153.0, 149.2, 148.5, 128.4, 34.8, 21.8, 17.6. MS (e.i. 70 eV): m/z (%) 181 (100), 153 (42), 139 (34), 118 (27), 91 (18), 77 (12), 51 (8).

IR ($\tilde{\nu}$): 3062w, 2988w, 1713s, 1582m, 1435m, 1389w, 1281m, 1258w, 1204m, 1111s, 914w, 872s, 733m, 648m cm^{-1}.

9.3 formation of racemic 13a-b

9.3. racemic **15a**

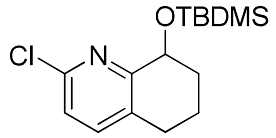
7-((*tert*-butyldimethylsilyl)oxy)-2-chloro-4-methyl-6,7-dihydro-5H-cyclopenta[b]pyridine



The alcohol **13a** (1.39 g, 7.57 mmol, 1.0 eq.), imidazole (1.56 g, 22.7 mmol, 3.0 eq.) and TBDMSCl (1.71 mg, 11.4 mmol, 1.5 eq.) were added to a round bottom flask, which was capped with a ruber septum and purged with argon for 5 min. DMF (12 mL) was added and the resulting colorless solution was stirred for 18 h at rt. DMF was evaporated on HV and DCM (90 mL) was added. The solution was extracted with H_2O (3 × 90 mL) and dried over $MgSO_4$. Filtration and evaporation of the solvent yielded the TBDMS-ether rac-**15a** (2.20 g, 7.38 mmol, 98%) as pale oil. All analytical data matched the data of the enantiomer in section 4.2.2 (*S*)-**15a**.

9.3. racemic **15b**

8-((*tert*-butyldimethylsilyl)oxy)-2-chloro-5,6,7,8-tetrahydroquinoline

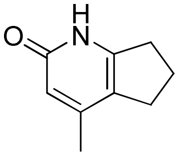


The alcohol **13b** (1.48 g, 8.05 mmol, 1.0 eq.), imidazole (1.66 g, 24.1 mmol, 3.0 eq.) and TBDMSCl (1.70 g, 11.3 mmol, 1.4 eq.) were added to a round bottom flask, which was sealed with a rubber septum and purged with argon for 5 min. DMF (8 mL) was added and the resulting colorless solution was stirred for 18 h at rt. DMF was evaporated on HV and DCM (30 mL) was added. The solution was extracted with H_2O (3 × 30 mL), dried over $MgSO_4$ and filtered. Evaporation of the solvent yielded the TBDMS-ether rac-**15b** (2.06 mg, 6.92 mmol, 86%) as a pale oil. The analytical data matches that of the enantiomer reported in section 4.2.2 (*S*)-**15b**.

10.0 Synthesis of 2-pyridones

10.1 synthesis of 2-pyridones

10.1 4-Methyl-6,7-dihydro-1H-cyclopenta[b]pyridin-2(5H)-one[3, 8, 12]



Ethyl acetoacetate (116 g, 107 mL, 1 mol), cyclopentanone (84 g, 88.5 mL, 1 mol) and ammonium acetate (77.8 g, 1 mol) were combined together in a 1000 mL flask and heated to 135 ˚C for 18 hours with a reflux condenser and water cooling. The reflux condenser was replaced with a large simple distillation head and a long cooling condenser with a vacuum adapter and 250 mL receiving flask attached at the distillate end. The reaction mixture was partially concentrated by vacuum distilling off the remaining cyclopentanone and acetic acid (ca 90 mL) to yield a very dark, high viscosity solution. The product precipitates as an orange solid overnight, collected by vacuum filtration and the filter cake is washed with 50 mLs of diethyl ether and 50 mls of water. Recrystallized from ethanol or ethyl acetate (100mL) or water (roughly 700 mLs) to yield 29 grams of a white crystalline solid.

Chemical Formula: $C_9H_{11}NO$ Molecular Weight: 149.2

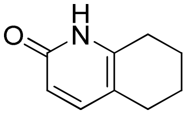
^{1}H NMR (400 MHz, $CDCl_3$) δ 6.91 (s, 1H), 2.99 (t, *J* = 7.8 Hz, 2H), 2.82 (t, *J* = 7.5 Hz, 2H), 2.23 (s, 3H), 2.18 – 2.06 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.2, 150.9, 148.4, 120.5, 115.0, 31.0, 28.3, 22.3, 19.7. MS (e.i. 70 eV): m/z (%) 216.1 (15), 133.1 (9), 120.1 (60), 105.0 (100), 77.0 (32).

IR (neat, $\tilde{\nu}$): 3271, 2916, 1634, 1535, 1435, 1219, 1173, 1111, 957 cm^{-1}.

MP: 240 ˚C.

10.1 5,6,7,8-Tetrahydroquinolin-2(1H)-one[9, 13]



The commercially available 2-pyridone was prepared according to Meyers *et. Al.* with the following procedure and notes: 3-(2-Oxocyclohexyl)propanenitrile (30 g, 198 mmol) is added to ice cold 98% sulfuric acid (200 mL) under argon with overhead stirring via a dropping funnel over a period of 45 minutes with internal temperature monitoring. On completion of the addition the orange reaction mixture is allowed to warm to room temperature, bubbling of sulfur dioxide is apparent as the reaction proceeds. If addition is carried out to quickly a large exotherm is observed and little or no product will be obtained. On warming the reaction mildly exotherms to 29 ˚C and bubbles become more prevalent. The reaction is stirred for an additional 45 minutes (ca 3 hours total time) and the reaction was carefully poured over a mixture of 1kg of crushed ice and 430 mLs of 32% ammonium hydroxide chilled in a large ice bath with vigorous stirring and cooling. The resulting aqueous solution (pH 9) is extracted with chloroform (9 x 150 mLs), the layers are combined and concentrated at the rotovap to yield 19 grams of crude product which is recrystallized from 1L of hot water which was concentrated to 600 mLs by normal distillation. The resulting long white needles are filtered off by vacuum filtration and dried by pulling air over the filtrate for 2 hours to result in 14 grams of semi-pure product which is further purified by sublimation (0.1 mbar, 100 ˚C, water cooling) to result in 13 grams of pure product as a white powder (87.2 mmol, 44%).

Chemical Formula: $C_9H_{11}NO$ Molecular Weight: 149.2

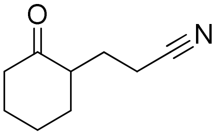
MP: 204 ˚C.

^{1}H NMR (400 MHz, DMSO) δ 13.24 (s, 1H), 7.16 (d, *J* = 9.1 Hz, 1H), 6.35 (d, *J* = 9.1 Hz, 1H), 2.67 (t, *J* = 5.9 Hz, 2H), 2.45 (t, *J* = 5.8 Hz, 2H), 1.80 – 1.68 (m, 4H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.2, 142.9, 142.5, 117.0, 111.7, 26.1, 25.4, 22.17, 21.2.

Elemental Analysis: for $C_9H_{11}NO$ calculated C, 72.46; H, 7.43; N, 9.39 found C, 72.41; H, 7.36; N, 9.39.

10.3 3-(2-Oxocyclohexyl)propanenitrile[9, 13, 14]



Cyclohexanone (120g, 128 mLs, 1.19 mol), acrylonitrile (64.8g, 80.0 mL, 1.22 mol), cyclohexylamine (4.3 g , 5.0 mL, 43.4 mmol) and acetic acid (525 mg, 0.5 mL, 8.7 mmol) were mixed together in a round bottom flask and heated to 120˚C for 3 hours. The resulting liquid is fractionally distilled under vacuum (0.6 mbar, 110˚C) to result in a clear oil (154 g, 1.02 mol, 86% yield).

Chemical Formula: $C_9H_{13}NO$ Molecular Weight: 151.2

^{1}H NMR (400 MHz, DMSO) δ 2.42 (ddd, *J* = 19.6, 12.5, 6.7 Hz, 3H), 2.20 (dd, *J* = 13.3, 4.3 Hz, 1H), 2.07 (dtd, *J* = 12.0, 6.0, 3.3 Hz, 1H), 1.99 (ddd, *J* = 9.4, 6.0, 3.0 Hz, 1H), 1.91 (dt, *J* = 21.2, 7.3 Hz, 1H), 1.82 – 1.72 (m, 1H), 1.72 – 1.48 (m, 2H), 1.42 (td, *J* = 13.6, 7.5 Hz, 1H), 1.28 (qd, *J* = 12.5, 3.8 Hz,1H).

MS (e.i. 70 eV): m/z (%) 151.1.

11.0 General procedures for asymmetric reduction and characterization for hydrogenation substrates and products

General information

Conditions for previously made substrates and the resulting asymmetric hydrogenation products can be found in prior publications for **18a, 19a, 20a, 23,** and **26;**[15] **21a**;[16] for compounds **24** and **25;**[17, 18] and for **29a**.[19]

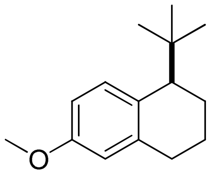
27[20] and it's conjugate reduction product**,**[21, 22] **28a** and **29a**,[23] **28b** and **29b,**[24] **28c** and **29c**[25] are known compounds. Our separation procedures as well as representative chromatograms are given for each of the products below with additional analytical data.

General procedure: The individual precatalyst metal complexes were each weighed into reaction vials (1 µmol, 1 mol%). The substrate was weighed into a separate vial (400 µmol) and absolute DCM (2000 µL) was added fresh from either a Fluka crown cap bottle or a Grubbs type solvent system. The substrate was dissolved and transferred to the reaction vials (500 µL/ reaction, 100 µmol/ reaction), followed by the addition of a stir bar and the vials were then placed into an autoclave. The autoclave was purged with hydrogen for 30 seconds and then the system was sealed and pressurized to a given pressure between 50 and 100 bar. The reaction was stirred at 900 rpm for a given length of time between 2 and 24 hours. The autoclave was vented and the individual vials were placed on a hot plate adapted with a multivial aluminum heating block set to 50 ˚C. The individual reactions were concentrated with stirring in the block for 1 hour while silica gel pipette columns were prepared. The resulting viscous oil was taken up in 0.5 mL of diethyl ether, passed through the pipette column and collected in a small vial, the column was washed with an additional amount of ether (1.5 mL) and the solution was concentrated on the same heating block. A small portion of the sample was taken in isopropanol and analyzed by chiral HPLC or in hexane and analyzed by GC.

11.1 reduction product **22b** and synthesis of **22a**

11.1 **22b**

(*R*)-1-tert-butyl-6-methoxy-1,2,3,4-tetrahydronaphthalene



HPLC conditions: Chiral OD-H with a flow rate of 1.0 mL/min and a polarity of 100% heptanes at 20 ˚C, T_{ent1} = 6.4 minutes and T_{ent2} = 8.7 minutes λ_{max} = 204, 224 nm, substrate T_{sub} = 14.7 minutes λ_{max} = 227, 282 nm, aromatic side product T_{ar} =10.8 min λ_{max} = 206, 276 nm.

Chemical Formula: $C_{15}H_{22}O$ Molecular Weight: 218.3

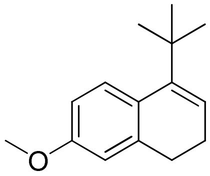
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.06 (d, *J* = 8.4 Hz, 1H), 6.66 (dd, *J* = 8.4, 2.8 Hz, 1H), 6.62 (d, *J* = 2.7 Hz, 1H), 3.79 (s, 3H), 2.75 – 2.54 (m, 3H), 2.02 – 1.89 (m, 1H), 1.89 – 1.80 (m, 2H), 1.51 – 1.37 (m, 1H), 0.90 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.6, 141.9, 132.5, 131.2, 113.6, 110.6, 55.5, 47.1, 36.3, 30.7, 28.9, 25.8, 22.8.

MS (EI, 70 eV): m/z: 218.3,

11.1 synthesis of **22a**

4-Tert-butyl-7-methoxy-1,2-dihydronaphthalene



Anhydrous zinc chloride (1 g, 7 mmol) was added to a 250 mL Schlenk flask with absolute THF (100 mL). T-butyl lithium (1.6 M, 50 mL, 80 mmol) was added at -20 ˚C and the reaction was allowed to stir at that temperature for 1 hour. 6-Methoxy-α-tetralone (12 g, 68.2 mmol) was added to the reaction mixture as a solid. The resulting reaction was stirred overnight at room temperature. The next morning the reaction was cooled to 0 ˚C and a solution of saturated ammonium chloride (40 mL) was carefully added with vigorous stirring by pipette portions over 20 minutes. The solution was allowed to warm to room temperature and stirred for an additional half hour. The contents of the flask were transferred to a separatory funnel with 100 mL of ethyl acetate, washed with additional ammonium chloride (2 x 100 mL), water (3 x 100 mL), brine (2 x 100 mL) and dried over magnesium sulfate. NMR of the crude material indicated that roughly a third of the product had been converted with half of the converted product as the desired olefin. The crude mixture of 6-methoxy-α-tetralone and tert-butylated product was partially purified by column chromatography with 100% hexane. The crude mix of desired olefin, alcohol and a slight trace of tetralone (3 grams) was taken up in 100 mL of DCM and 25 grams of activated 4Å molecular sieves and the reaction was sealed with a rubber septum and stirred overnight. Crude NMR indicated that the remaining alcohol had been converted to the olefin. Column chromatography with hexane furnished the desired product as 1.6 grams (7.4 mmol, 11%) of viscous oil which crystallized into a white solid on standing at room temperature.

Chemical Formula: $C_{15}H_{20}O$ Molecular Weight: 216.3

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.1 Hz, 1H), 6.76 – 6.72 (m, 2H), 5.98 (t, *J* = 4.9 Hz, 1H), 3.82 (s, 3H), 2.65 (t, *J* = 7.8 Hz, 2H), 2.21 – 2.11 (m, 2H), 1.34 (s, 9H).

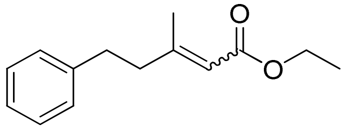
^{13}C NMR (101 MHz, $CDCl_3$) δ 157.7, 144.9, 141.0, 128.2, 127.3, 122.1, 114.1, 110.5, 55.5, 35.3, 31.4, 30.3, 23.8.

MS (EA, 70mV) m/z: 216.3.

Elemental Analysis: for $C_{15}H_{20}O$ calculated C, 83.29; H, 9.32; found C, 83.44; H, 9.50.

11.1 stereoselective synthesis of **26**

(*E,Z*)-Ethyl 3-methyl-5-phenylpent-2-enoate[26]

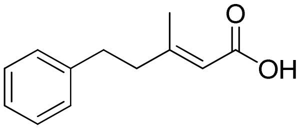


Potassium tert-butoxide (5.35 g, 55.7 mmol) was transferred to a large Young tube which was evacuated and placed under argon. Absolute THF (50 mL) was added to the tube by cannula followed by triethyl phosphonoacetate (10.4 g, 46.44 mmol) was syringed into the reaction vessel at room temperature. A mild exotherm occurred on addition and a homogenous solution was obtained after 30 minutes of stirring at ambient temperature. The reaction mixture was cooled to -50 ˚C for 30 minutes and 4-phenyl-2-butanone (6.53 g, 44.12 mmol) was added cold and the reaction allowed to warm to room temperature overnight. The reaction was quenched with water (25 mL) and washed with into ethyl acetate (100 mL) into a separatory funnel. Brine was added (50 mL) and the layers shaken and separated. The organic layer was washed with more brine (2 x 100 mL), dried over magnesium sulfate, filtered and concentrated at the rotovap to yield the crude material which was purified by kugelrohr distillation (5 mTorr, 100 ˚C) to obtain 7.0 g (32.2 mmol, 69%) as a slightly yellow oil.

Chemical Formula: $C_{14}H_{18}O_2$ Molecular Weight: 218.3

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (t, *J* = 7.3 Hz, 2H), 7.19 (dd, *J* = 13.4, 7.1 Hz, 3H), 5.70 (dd, *J* = 10.1, 1.2 Hz, 1H), 4.15 (q, *J* = 7.1 Hz, 2H), 2.85 – 2.73 (m, 2H), 2.54 – 2.38 (m, 2H), 2.21 (dd, *J* = 4.7, 1.1 Hz, 3H), 1.28 (t, *J* = 7.1 Hz, 3H).

(*E*)-3-methyl-5-phenylpent-2-enoic acid[27]



Ethyl 3-methyl-5-phenylpent-2-enoate (5.20 g, 23.8 mmol) was dissolved in 25 mL of methanol and added to a flask containing sodium hydroxide (2.80 g, 70.0 mmol) in 100 mL of water. The resulting slurry was heated to 100 ˚C for 4 hours during which time the slurry became a clear solution. The reaction was cooled to 0˚C and the solution was acidified with concentrated hydrochloric acid to a pH of 2, during which time the acid precipitated as a white powder. The resulting slurry was taken up and transferred with 200 mL of diethyl ether to a separatory funnel. The layers were thoroughly shaken, and the organic layer was separated and washed with brine (3 x 100 mL). The organic layer was dried over magnesium sulfate, filtered and concentrated to dryness at a rotovap. The resulting crude acid was taken up in ethyl acetate (ca 4 grams of crude in 50 mL) and cyclohexylamine (3.13 g, 3.6 mL, 31.5 mmol) was added dropwise to the quickly stirring solution, immediate white precipitate was formed, the solution became a thick slurry on complete addition of the cyclohexylamine. An additional 120 mL of ethyl acetate was added to the slurry followed by heating to reflux with strong stirring. On dissolution of the precipitate the solution was allowed to cool to room temperature, and then further cooled to -20 ˚C in an ice salt bath. The resulting white precipitate was filtered off by vacuum filtration and the filtrate washed with a 50 mL portion of diethyl ether cooled in the ice salt bath. A small portion of the precipitate was partitioned with 2 M HCl and ethyl acetate, the layers separated and the organic layer was dried over magnesium sulfate, concentrated and the small aliquot analyzed by GC to find a 95:5 ratio of cis/trans isomers in favor of the trans. The precipitate was (3 grams) was taken up in 100 mL of ethyl acetate and recrystallized and treated as before to find a ratio of 99 to 1. The resulting 2.4 grams of salt was taken up in DCM (50 mL) and 2 M HCl (100 mL). The slurry was mixed into solution until no precipitate was present, the layers were separated and the organic layer was washed with additional 2 M HCl (2 x 50 mL) and brine (2 x 50 mL), dried over magnesium sulfate, filtered and the solution was concentrated to dryness at a rotovap. The resulting acid (1.6 g) was taken up in hot hexane (6 mL) and allowed to stand overnight at -20 ˚C. The resulting large clear crystals were quickly isolated by vacuum filtration to yield 1.2 g (6.31 mmol).

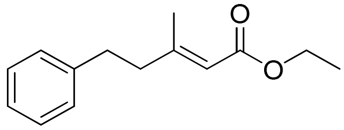
Chemical Formula: $C_{12}H_{14}O_2$ Molecular Weight: 190.2

^{1}H NMR (400 MHz, $CDCl_3$) δ 11.76 (s, 1H), 7.31 (dd, *J* = 10.1, 4.5 Hz, 6H), 7.25 – 7.14 (m, 9H), 5.71 (d, *J* = 1.2 Hz, 3H), 2.81 (dd, *J* = 9.3, 6.8 Hz, 6H), 2.59 – 2.38 (m, 6H), 2.22 (d, *J* = 1.2 Hz, 9H).

GC: General conditions, the injector was set to 270˚C, oven temperature 100 ˚C held for 3 minutes and a ramp of 7 ˚C/min to 230 ˚C for 10 minues, detector was set to 250 ˚C and a pressure of 60 kPa. T_{trans} = 27.1 min T_{cis} = 27.8 min.

11.1 (*E*)-**26**

(*E*)-ethyl 3-methyl-5-phenylpent-2-enoate[26]



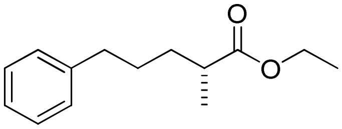
(*E*)-3-methyl-5-phenylpent-2-enoic acid (1.20 g, 6.30 mmol) was refluxed in a mixture of absolute ethanol (50 mL) and 10 grams of magnesium sulfate with a catalytic amount of p-toluene sulfonic acid. The reaction was allowed to reflux under an inert atmosphere for 8 hours after which time the reaction was cooled, filtered, concentrated and the concentrate was dissolved in ether and saturated sodium bicarbonate (50/ 100 mL). The organic layer was thoroughly shaken with the aqueous mixture, washed with brine (2 x 50 mL), dried over magnesium sulfate, filtered and concentrated at the rotovap. Kugelrohr distillation gave 750 mg (3.44 mmol, 54.6%) of pure product which was indiscernible from the cis trans miture by NMR.

Chemical Formula: $C_{14}H_{18}O_2$ Molecular Weight: 218.3

HPLC conditions for asymmetric reduction Chiralcel OJ-H heptane/isopropanol 98:2 flow rate 0.5 mL/min 20 ˚C, T_r = 14.7 min, T_r = 16.1 min.

11.1 conjugate reduction product of **27**

(*R*)-ethyl 2-methyl-5-phenylpentanoate



HPLC conditions: Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 20 ˚C, T_1 = 9.1 minutes and T_2 = 14.8 minutes. Enantiomers were identified by peak reversal between opposite configured catalysts *S*-**7e** and *R*-**9a**, conversion by GC.

Chemical Formula: $C_{14}H_{20}O_2$ Molecular Weight: 220.3

^{1}H NMR (400 MHz, C_6D_6) δ 7.18 – 7.14 (m, 2H), 7.06 (dd, *J* = 14.7, 7.2 Hz, 3H), 3.95 (q, *J* = 7.1 Hz, 2H), 2.43 (t, *J* = 7.7 Hz, 2H), 2.38 – 2.27 (m, 1H), 1.69 (dddd, *J* = 12.9, 10.6, 7.8, 5.4 Hz, 1H), 1.64 – 1.44 (m, 2H), 1.39 – 1.25 (m, 1H), 1.05 (d, *J* = 7.0 Hz, 3H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, C_6D_6) δ 175.9, 142.4, 128.7, 128.6, 126.1, 59.9, 39.6, 36.1, 33.7, 29.4, 17.3, 14.3.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 (d, *J* = 7.5 Hz, 1H), 7.26 (m, 1H), 7.18 (t, *J* = 7.9 Hz, 3H), 4.12 (q, *J* = 7.1 Hz, 2H), 2.61 (t, *J* = 7.6 Hz, 2H), 2.50 – 2.38 (m, 1H), 1.71 (dt, *J* = 14.2, 7.4 Hz, 1H), 1.62 (dt, *J* = 15.2, 7.5 Hz, 2H), 1.46 (dt, *J* = 19.7, 6.7 Hz, 1H), 1.24 (t, *J* = 7.1 Hz, 3H), 1.14 (d, *J* = 6.9 Hz, 3H).

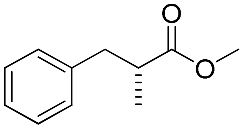
^{13}C NMR (126 MHz, $CDCl_3$) δ 177.2, 142.6, 128.8, 128.7, 126.1, 60.5, 39.8, 36.2, 33.8, 29.5, 17.5, 14.7.

MS (EI, 70 eV): m/z: 220.4.

$[\alpha]_D^{20}$ = -16.0 at a concentration of 0.14 and ee = 95.6%.

11.1 product *R*-**29a**

(*R*)-methyl 2-methyl-3-phenylpropanoate



HPLC conditions: Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 25 ˚C, T_R = 10.8 minutes and T_S = 11.6 minutes.

Chemical Formula: $C_{11}H_{14}O_2$ Molecular Weight: 178.2

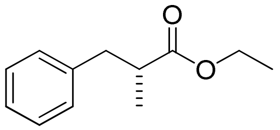
^{1}H NMR (500 MHz, CDCl$_3$) δ 7.29 - 7.26 (m, 2H), 7.20 (t, *J* = 7.2 Hz, 1H), 7.16 (d, *J* = 7.5 Hz, 2H), 3.64 (s, 3H), 3.03 (dd, *J* = 13.3, 6.7 Hz, 1H), 2.78 – 2.70 (m, 1H), 2.66 (dd, *J* = 13.3, 7.8 Hz, 1H), 1.15 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 177.0, 139.8, 129.4, 128.8, 126.7, 52.0, 41.8, 40.1, 17.1.

$[\alpha]_D^{20}$= -34.0 at a concentration of 0.16 and ee = 96.6%.

11.1 product *R*-**29b**

(*R*)-ethyl 2-methyl-3-phenylpropanoate



HPLC conditions: Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 25 ˚C, T_1 = 10.4 minutes and T_2 = 11.5 minutes.

Chemical Formula: $C_{12}H_{16}O_2$ Molecular Weight: 192.3

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.28 - 7.26 (m, 2H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.17 (d, *J* = 7.4 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.01 (dt, *J* = 21.8, 10.9 Hz, 1H), 2.78 – 2.60 (m, 2H), 1.19 (t, *J* = 7.1 Hz, 3H), 1.15 (d, *J* = 6.7 Hz, 3H).

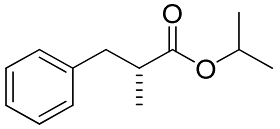
^{13}C NMR (126 MHz, CDCl$_3$) δ 176.5, 139.8, 129.4, 128.7, 126.7, 60.7, 41.9, 40.1, 17.2, 14.6.

$[\alpha]_D^{20}$ = -33.0 at a concentration of 0.17 and ee = 97%.

Elemental Analysis: for $C_{12}H_{16}O_2$ calculated C, 74.97; H, 8.39; found C, 74.58; H, 8.46.

11.1 product *R*-**29c**

(*R*)-isopropyl 2-methyl-3-phenylpropanoate



HPLC conditions: Chiral OB-H with a flow rate of 1.0 mL/min and a polarity of 100% heptanes at 20 ˚C, T_R = 7.45 minutes and T_S = 8.15 minutes, substrate T_{sub} = 9.45 minutes.

Chemical Formula: $C_{13}H_{18}O_2$ Molecular Weight: 206.3

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.28 - 7.25 (m, 2H), 7.19 (dd, *J* = 14.3, 7.2 Hz, 3H), 4.96 (hept, *J* = 6.1 Hz, 1H), 2.99 (dd, *J* = 11.9, 5.6 Hz, 1H), 2.77 – 2.58 (m, 2H), 1.19 (d, *J* = 6.2 Hz, 3H), 1.14 (d, *J* = 6.4 Hz, 3H), 1.12 (d, *J* = 6.2 Hz, 3H).

^{13}C NMR (126 MHz, CDCl$_3$) δ 176.1, 139.9, 129.4, 128.7, 126.6, 67.8, 42.0, 40.1, 22.1, 22.1, 17.2.

$[\alpha]_D^{20}$ = -43.0 at a concentration of 0.13 and ee = 99.1%.

Elemental Analysis: for $C_{13}H_{18}O_2$ calculated C, 75.69; H, 8.80; found C, 75.88; H, 8.97.

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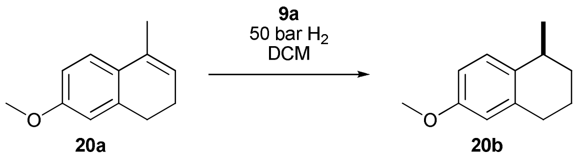
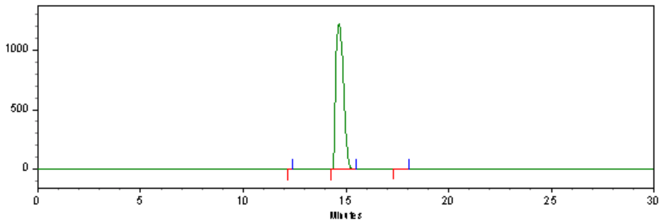
12.0 Chromatograms

<u>12.1 HPLC of **20a** hydrogenation**:**</u> Conditions ODH 99.8% heptane/ 0.2% isopropanol 0.5 mL/min at 20 °C.



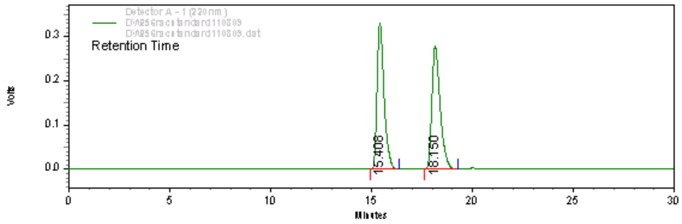
Run with *R*-**9a**



1: 230 nm, 8 nm

Retention Time	Area Percent
12.352	0.00
14.656	99.58
17.643	0.42

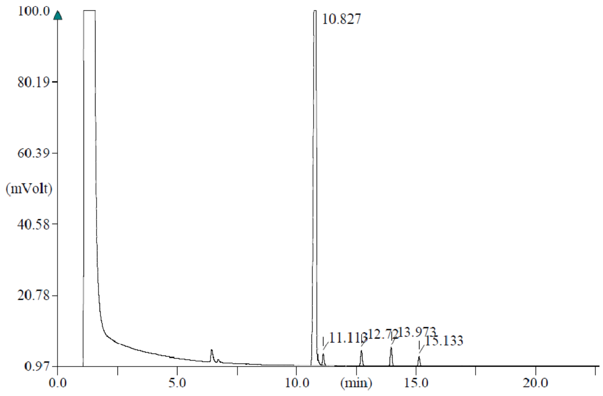
racemate



Detector A - 1 (220nm)

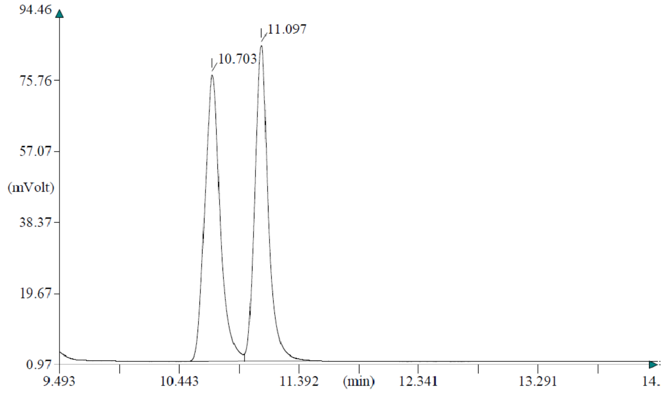
Retention Time	Area	Area Percent
15.408	7899236	49.96
18.150	7910843	50.04

<u>12.1 GC of **21a** hydrogenation</u>: (chiral, b-Cyclodextrin,DEtTButSil (Brechbühler, SE54), 0.25 mm, 0.25 µm, 25 m, 60 kPa H2, 140 °C, 0 min, 2 K/min, 180°C, 5 min): $T_{[(S)\text{-}21b]}$ = 10.8 min, $T_{[(R)\text{-}21b]}$ = 11.1 min, $T_{\text{sub}\mathbf{21a}}$ = 12.7 min, $T_{\mathbf{21c}}$ = 15.0 min.



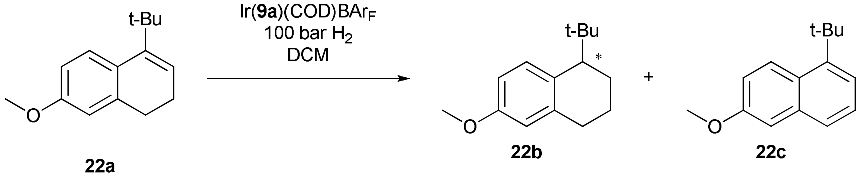
```
Retention Time   Area              Area %            Peak Type
(Min)            (æV/Sec*10)
---------------  ---------------   ---------------   ---------------
10.83            13805020          94.774            Manual integ.
11.11            141326            0.970             Manual integ.
12.72            217001            1.490             Resolved
13.97            271881            1.867             Resolved
15.13            130967            0.899             Resolved
```

racemate

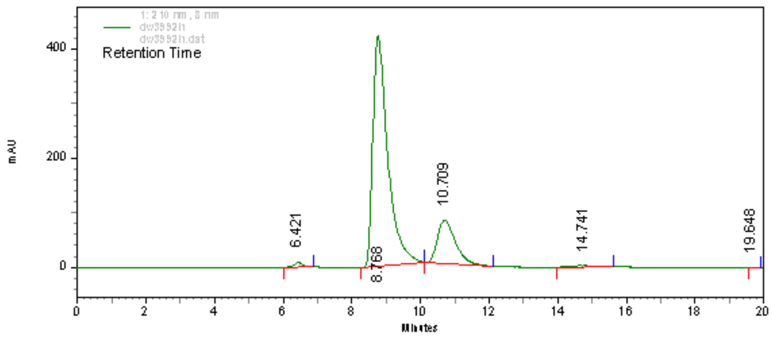


```
Retention Time   Area              Area %            Peak Type
(Min)            (æV/Sec*10)
---------------  ---------------   ---------------   ---------------
10.70            6384388           51.020            Manual integ.
11.10            6129210           48.980            Manual integ.
```

<u>12.1 HPLC of **22a** hydrogenation</u>**:** Conditions ODH 100% heptane 1.0 mL/min PDA detection (uv abs overlay given after chromatogram)



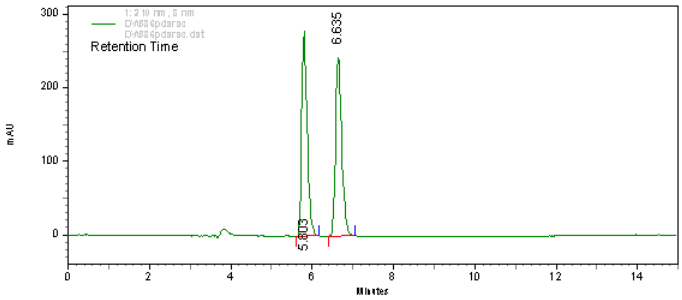
22a **22b** **22c**



1: 210 nm, 8 nm

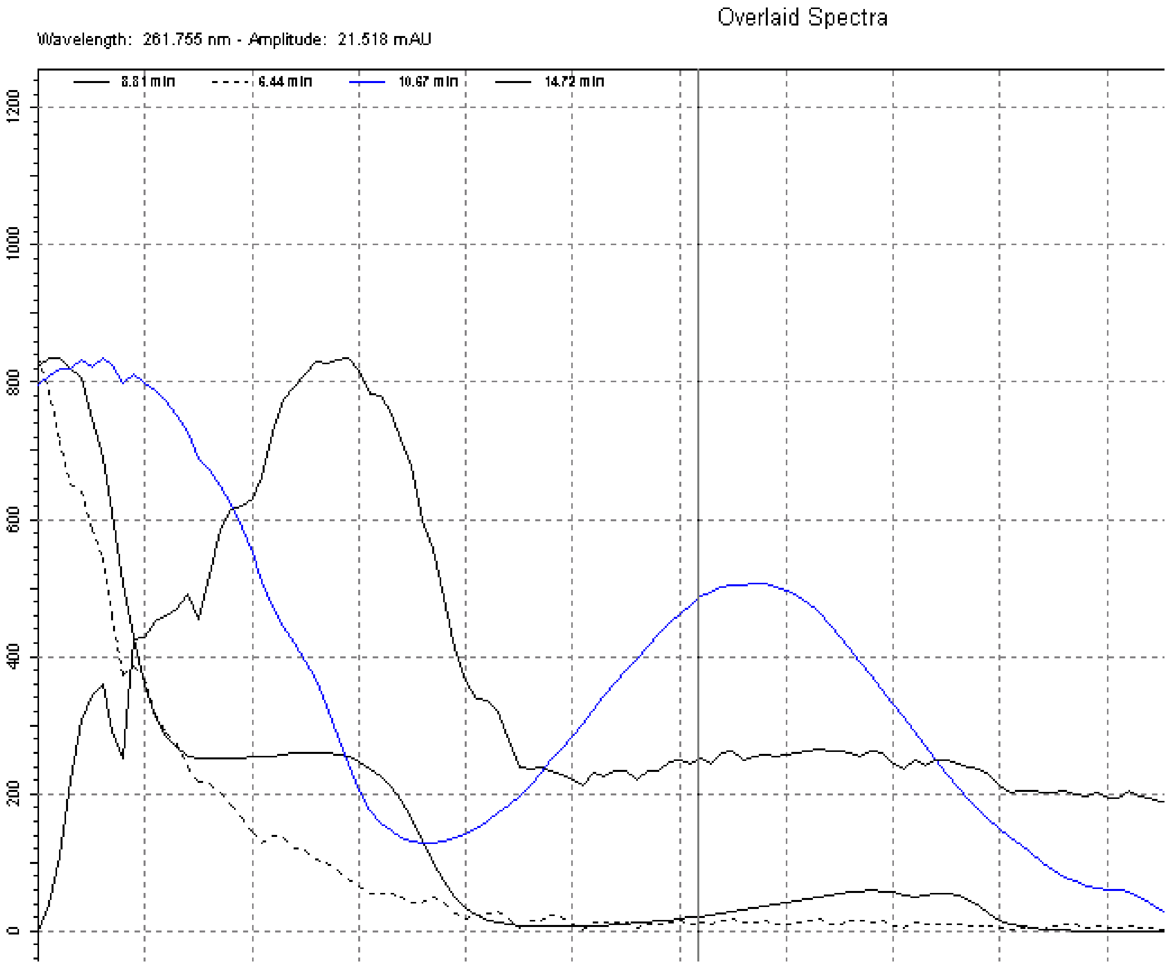
Retention Time	Area	Area Percent
6.421	161472	1.02
8.768	12689650	80.25
10.709	2823117	17.85
14.741	134986	0.85
19.648	3917	0.02

racemate, times are highly variable due to extremely nonpolar conditions and degree of contamination on the column stationary phase.



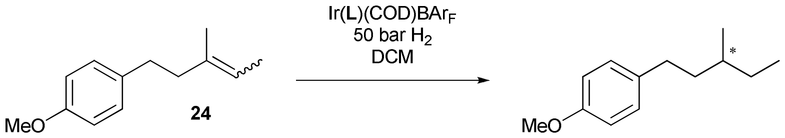
1: 210 nm, 8 nm

Retention Time	Area	Area Percent
5.803	2543979	49.78
6.635	2566486	50.22



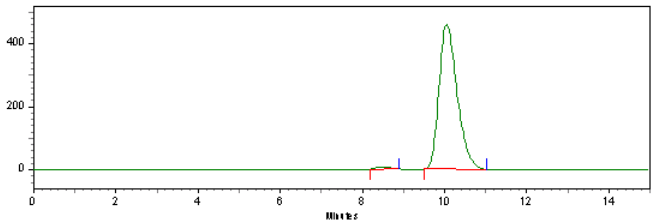
Overlay of uv vis spectrum from the reduction products of **22a,** each rectangle is 200 mAu (y axis) by 10nm (x axis) starting from 200nm and 0 mAu.

12.1 HPLC of **24** hydrogenation**:** Chiralcel OB-H column heptane/isopropanol 99:1, 0.5 ml/min): T_R = 8.4 min , T_{sub} = 10.0 min, T_S = 10.4 min.



E-**24**, *S*-**7c**: >99% Conv 97% ee (*S*) *Z*-**24**, *S*-**7c**: >99% Conv 99% ee (*R*)

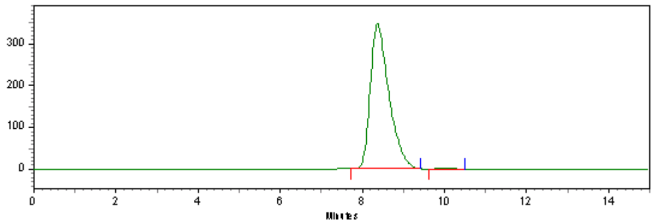
From *E*-**24** and *S*-**7c**



1: 230 nm, 8 nm

Retention Time	Area Percent
8.469	1.11
10.048	98.89

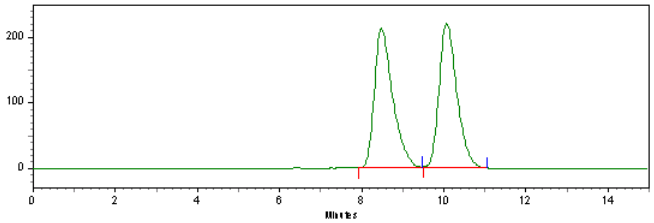
From *Z*-**24** and *S*-**7c**



1: 230 nm, 8 nm

Retention Time	Area Percent
8.363	99.48
10.027	0.52

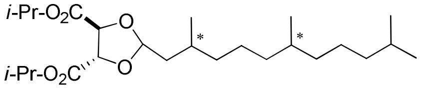
racemate



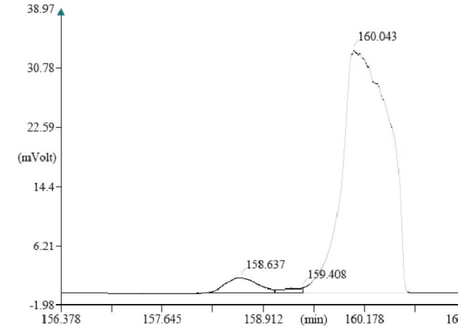
1: 230 nm, 8 nm

Retention Time	Area Percent
8.491	49.86
10.069	50.14

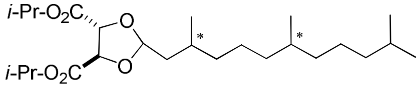
<u>12.1 GC of **25** hydrogenation with catalyst *S*-**7e**</u>: CP-sil-88, 50 kPa H_2, 250 °C (injector), 270 °C (detector); temperature program: 110 °C (0 min), 0.5 °C/min, 200 °C (0 min).



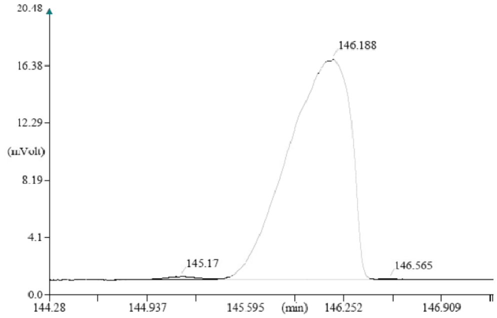
D-acetal



Retention Time (min)	Area (.1*uV*sec)	Area % (%)	Peak Type
158.637	586924	4.081	Manual integ.
159.408	117022	0.814	Manual integ.
160.043	13677620	95.105	Manual integ.

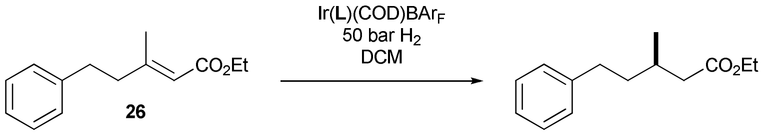


L-acetal

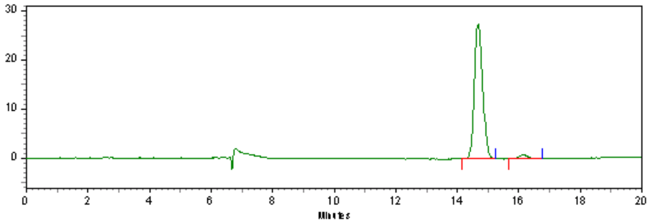


Retention Time (min)	Area (.1*uV*sec)	Area % (%)	Peak Type
145.170	38580	0.831	Manual integ.
146.188	4599620	99.057	Manual integ.
146.565	5185	0.112	Manual integ

12.1 HPLC of **26** hydrogenation: conditions for asymmetric reduction Chiralcel OJ-H heptane/isopropanol 98:2 flow rate 0.5 mL/min 20 ˚C, T_r = 14.7 min, T_r = 16.1 min.



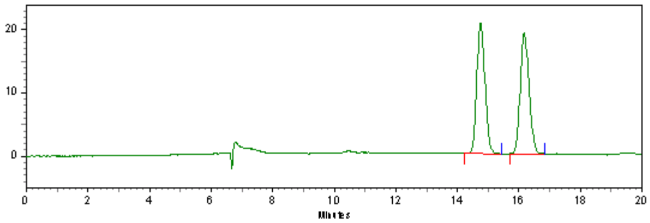
S-**7e**: >99% Conv 94% ee (*R*)
S-**7d**: >99% Conv 94% ee (*R*)



2: 260 nm, 8 nm

Retention Time	Area Percent
14.677	97.03
16.171	2.97

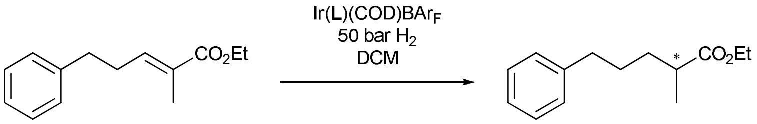
Racemic reduction of **26**



2: 260 nm, 8 nm

Retention Time	Area Percent
14.763	50.12
16.171	49.88

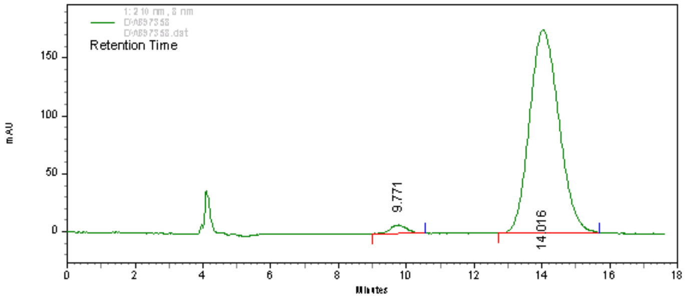
12.1 HPLC of **27** hydrogenation: Conditions Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 20 ˚C, T_1 = 9.1 minutes and T_2 = 14.8 minutes.



27

S-**7e:** >99% Conv 96% ee (-)

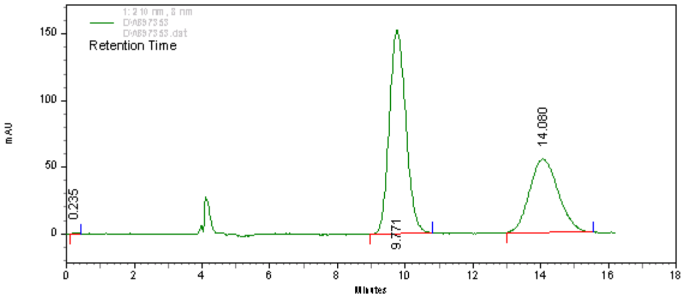
From reduction with *S*-**7e**



1: 210 nm, 8 nm

Retention Time	Area	Area Percent
9.771	231077	2.16
14.016	10487712	97.84

From reduction with *R*-**9a**

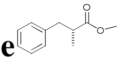


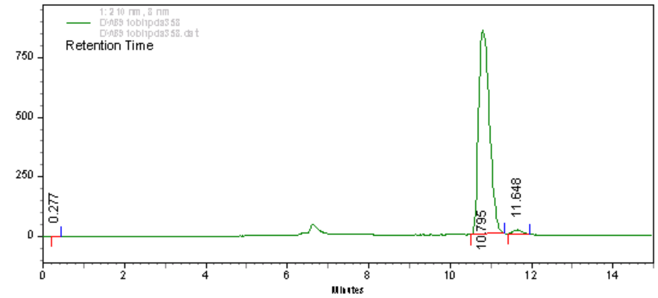
1: 210 nm, 8 nm

Retention Time	Area	Area Percent
0.235	4918	0.06
9.771	5121110	61.27
14.080	3232159	38.67

12.1 HPLC of **29a**: Conditions, Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 25 ˚C, T_1 = 10.8 minutes and T_2 = 11.6 minutes.

From reduction with *S*-**7e**

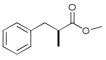


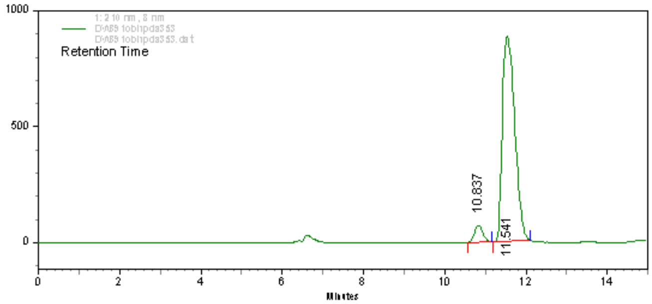


210 nm, 8 nm

Retention Time	Area	Area Percent
0.277	1541	0.01
10.795	15991178	98.38
11.648	261071	1.61

From reduction with *R*-**9a**

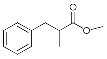


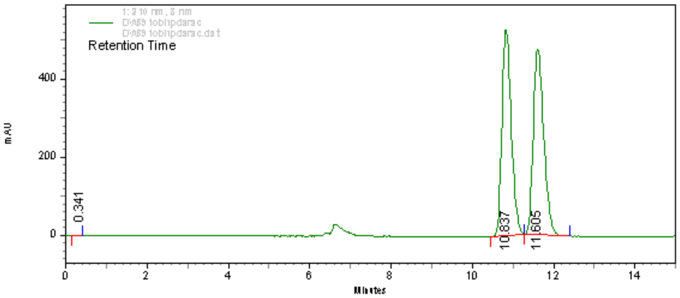


210 nm, 8 nm

Retention Time	Area	Area Percent
10.837	1052529	5.29
11.541	18837135	94.71

racemate

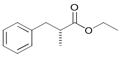


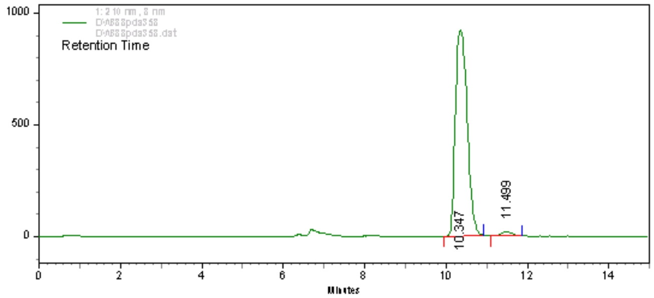


1: 210 nm, 8 nm

Retention Time	Area	Area Percent
0.341	3154	0.02
10.837	8438493	49.57
11.605	8580828	50.41

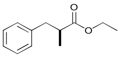
<u>12.1 HPLC of **29b**:</u> Conditions, Chiral OB-H with a flow rate of 0.8 mL/min and a polarity of 97:3 heptanes to isopropanol at 25 ˚C, T_1 = 10.4 minutes and T_2 = 11.5 minutes.

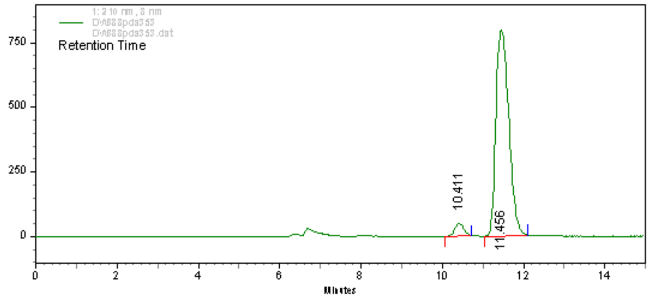
From reduction with *S*-**7e**




: 210 nm, 8 nm

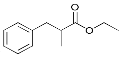
Retention Time	Area	Area Percent
10.347	18489123	98.26
11.499	328363	1.74

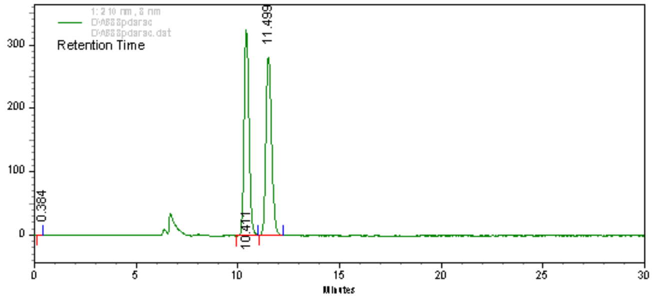
From reduction with *R*-**9a**




210 nm, 8 nm

Retention Time	Area	Area Percent
10.411	738696	4.04
11.456	17547284	95.96

racemate


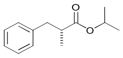


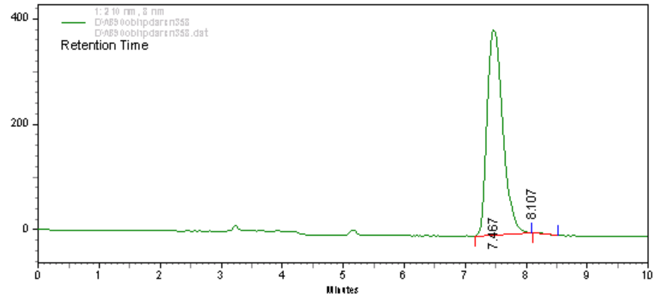
210 nm, 8 nm

Retention Time	Area	Area Percent
0.384	3529	0.03
10.411	5443766	49.81
11.499	5481730	50.16

12.1 HPLC of **29c**: Conditions: Chiral OB-H with a flow rate of 1.0 mL/min and a polarity of 100% heptanes at 20 ˚C, T_R = 7.45 minutes and T_S = 8.15 minutes, substrate T_{sub} = 9.45 minutes.

From reduction with *S*-**7e**

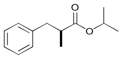


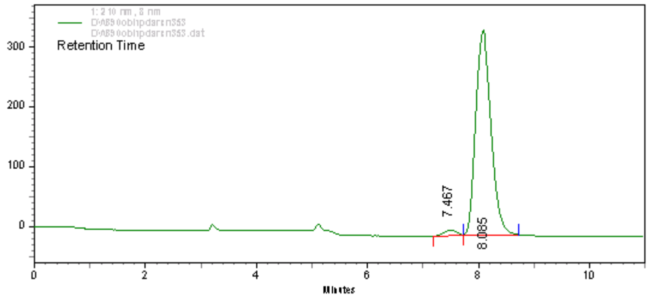


1: 210 nm, 8 nm

Retention Time	Area	Area Percent
7.467	6950413	99.89
8.107	7643	0.11

From reduction with *R*-**9a**

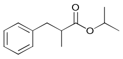


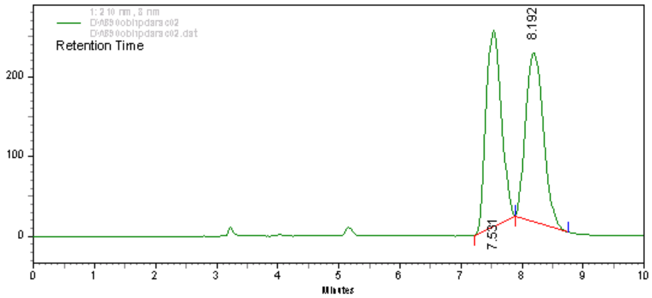


210 nm, 8 nm

Retention Time	Area	Area Percent
7.467	127444	1.83
8.085	6817968	98.17

racemate

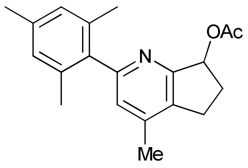


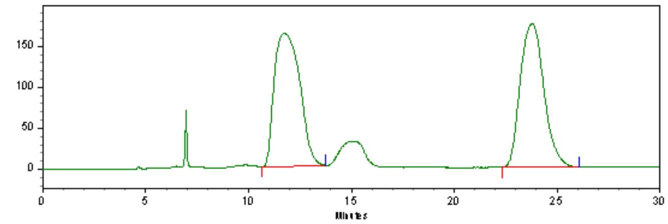


210 nm, 8 nm

Retention Time	Area	Area Percent
7.531	4270845	49.90
8.192	4287415	50.10

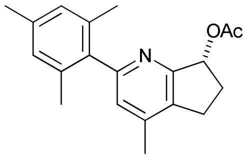
12.2 HPLC of **11a** resolution: Conditions: ADH column, 1% isopropanol in heptanes with a flow rate of 0.75 mLs/min and a temperature of 25˚C. Elution times T_S = 11.7 and T_R = 23.7 minutes.

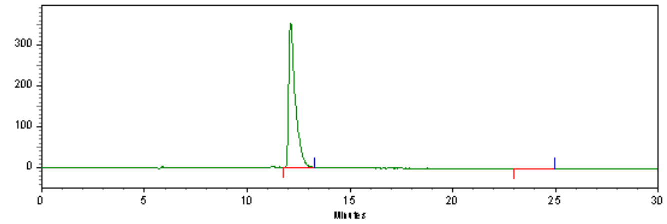




1: 230 nm, 8 nm

Retention Time	Area Percent
11.733	50.00
23.787	50.00

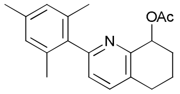


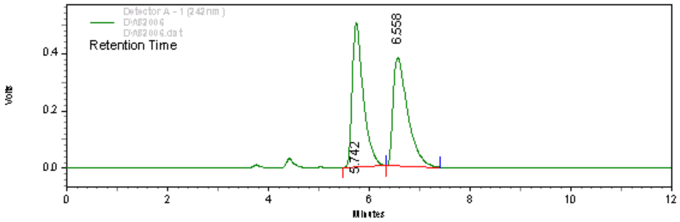


1: 230 nm, 8 nm

Retention Time	Area Percent
12.117	99.98
23.232	0.02

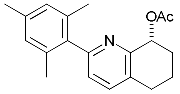
12.2 HPLC of **11b** resolution: Conditions: OD column, 5% isopropanol in heptanes with a flow rate of 1.0 mLs/min and a temperature of 25 ˚C. Elution times T_S = 5.7 and T_S = 6.5 minutes.

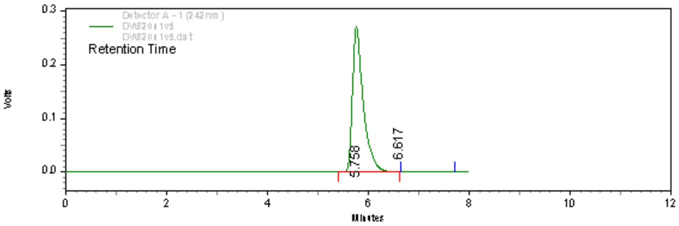




Detector A - 1 (242nm)

Retention Time	Area	Area Percent
5.742	7684257	50.24
6.558	7610211	49.76



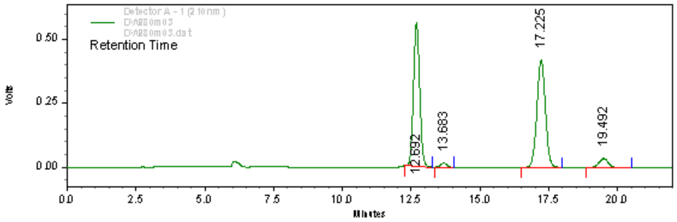


Detector A - 1 (242nm)

Retention Time	Area	Area Percent
5.758	4021672	99.79
6.617	8368	0.21

12.2 HPLC of **13a** resolution: Separated the parent alcohol on a chiral ADH column with a mobile phase of 5% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 40 ˚C, $T_{(R)\text{-acetate}}$ = 12.69 minutes, $T_{(S)\text{-acetate}}$= 13.68 minutes, $T_{(S)\text{-alcohol}}$= 17.2 minutes, $T_{(R)\text{- alcohol}}$ = 19.49 minutes.

End point of resoltion

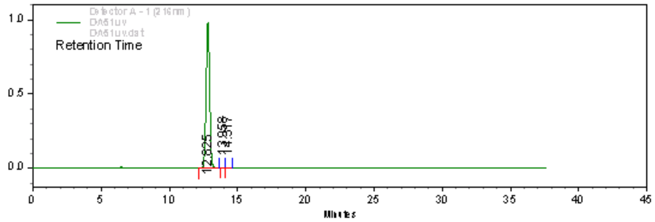


Detector A - 1 (210nm)

Retention Time	Area	Area Percent
12.692	8776176	46.53
13.683	254192	1.35
17.225	8987926	47.66
19.492	841709	4.46

12.2 HPLC of **13a** DIPCl reduction: Separated on a chiral ADH column with a mobile phase of 10% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 25 ˚C, T_s = 13.2 minutes, T_r = 14.8 minutes.

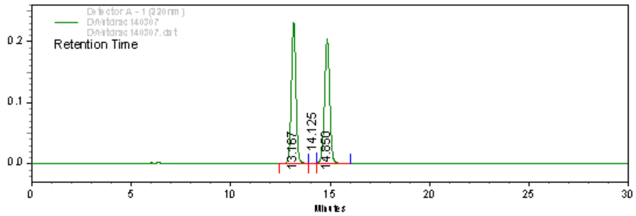
S-**13a**



Detector A - 1 (216nm)

Retention Time	Area	Area Percent
12.825	17870794	99.73
13.958	6985	0.04
14.317	40739	0.23

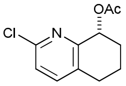
rac-**13a**

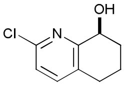


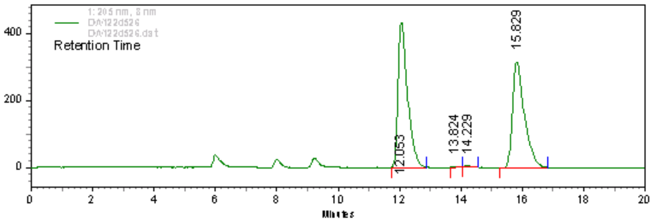
Detector A - 1 (220nm)

Retention Time	Area	Area Percent
13.167	3682973	49.94
14.125	12727	0.17
14.850	3679282	49.89

12.2 HPLC of **13b** resolution: HPLC: Separated on a chiral ADH column with a mobile phase of 5% isopropanol in heptanes with a flow rate of 0.5 mLs/minute and 40 ˚C, $T_{(R)\text{-acetate}}$ = 12.05 minutes, $T_{(S)\text{-acetate}}$=13.82 minutes, $T_{(S)\text{-alcohol}}$= 15.8 minutes, $T_{(R)\text{- alcohol}}$ = 17.23 minutes.

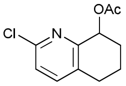


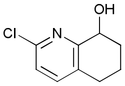


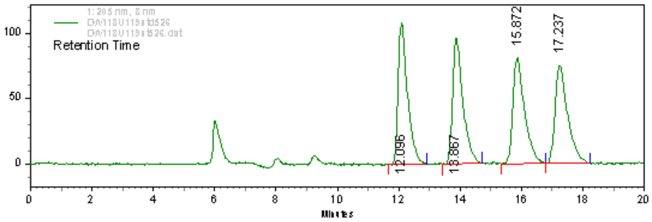


1: 205 nm, 8 nm

Retention Time	Area	Area Percent
12.053	9369950	52.25
13.824	29729	0.17
14.229	49646	0.28
15.829	8484567	47.31





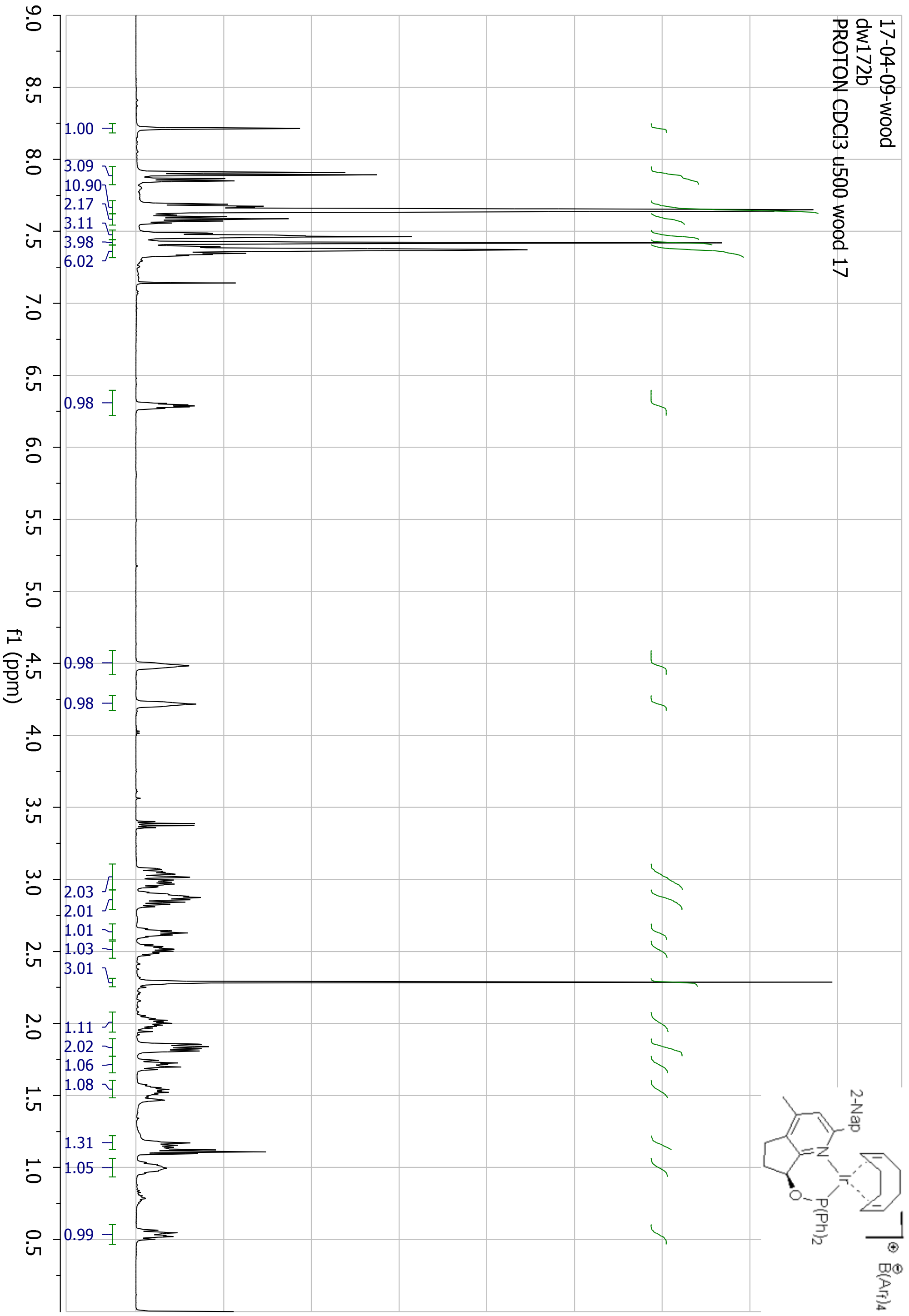


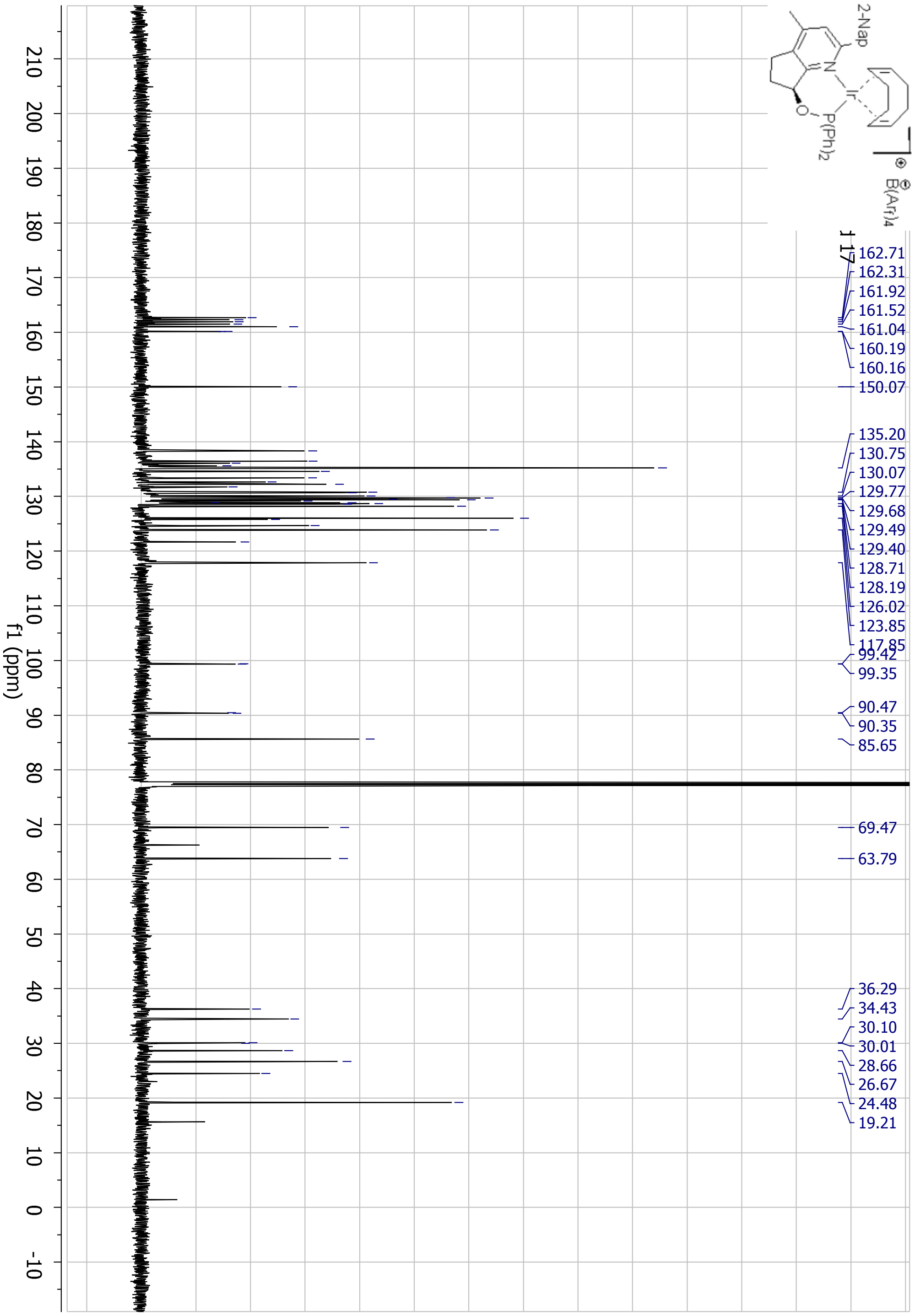
1: 205 nm, 8 nm

Retention Time	Area	Area Percent
12.096	2279990	25.99
13.867	2236967	25.50
15.872	2141286	24.41
17.237	2113952	24.10

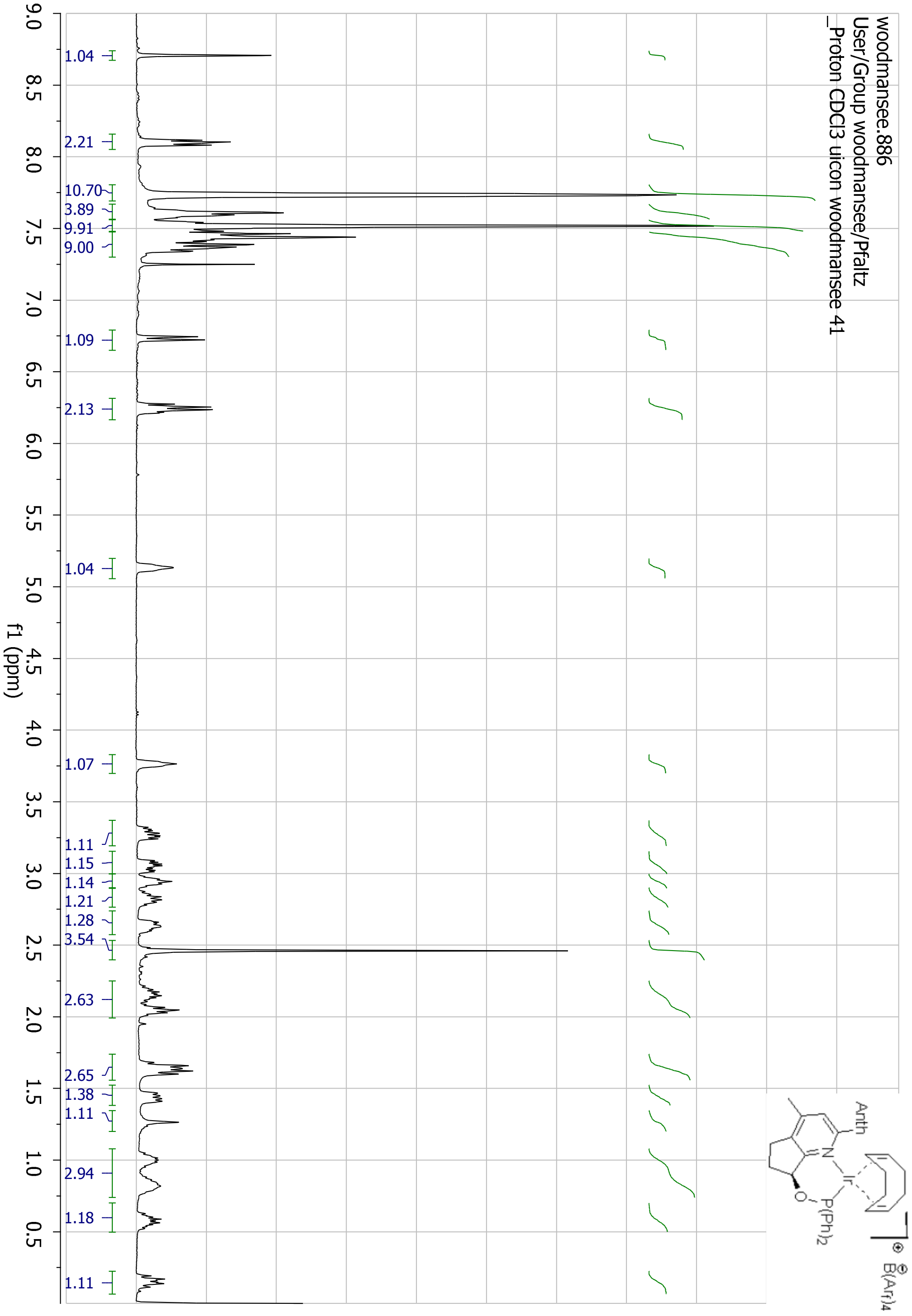
13. ^{1}H & ^{13}C spectra

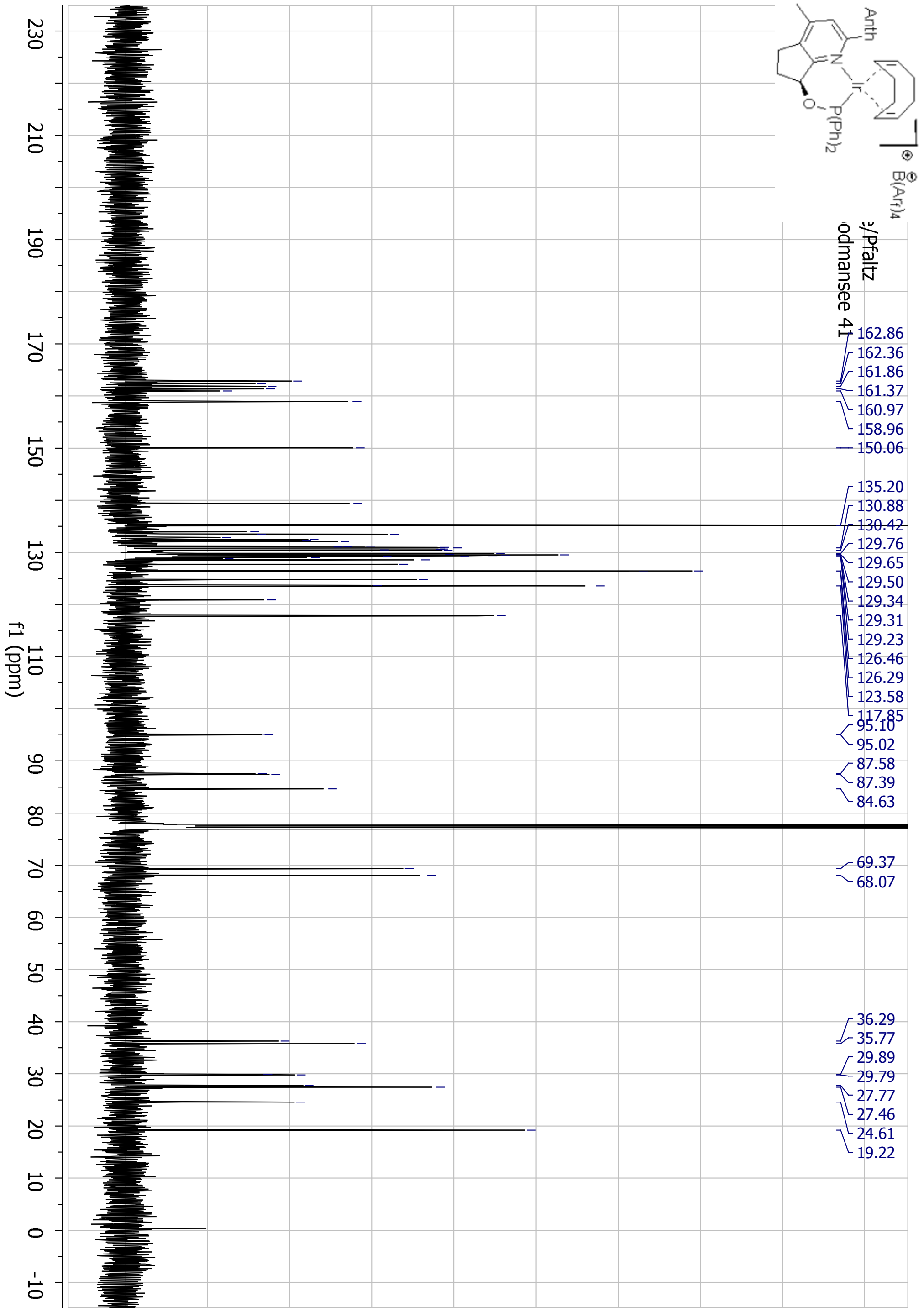
13. *S*-**7a** ^{1}H & ^{13}C



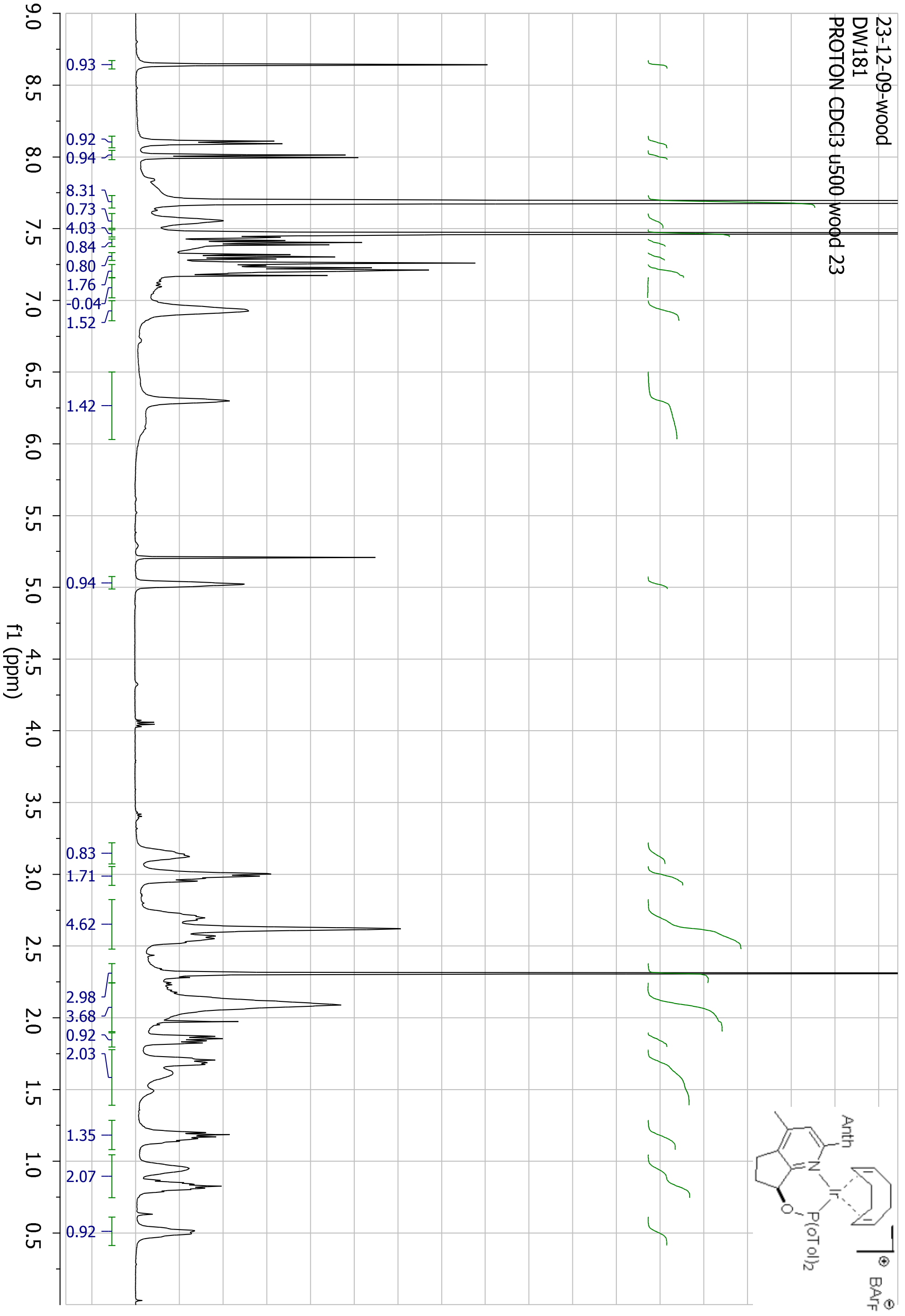

2-Nap
N
Ir
O
P(Ph)2
⊕
⊖
B(Ar)4
162.71
162.31
161.92
161.52
161.04
160.19
160.16
150.07
135.20
130.75
130.07
129.77
129.68
129.49
129.40
128.71
128.19
126.02
123.85
117.85
99.42
99.35
90.47
90.35
85.65
69.47
63.79
36.29
34.43
30.10
30.01
28.66
26.67
24.48
19.21
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

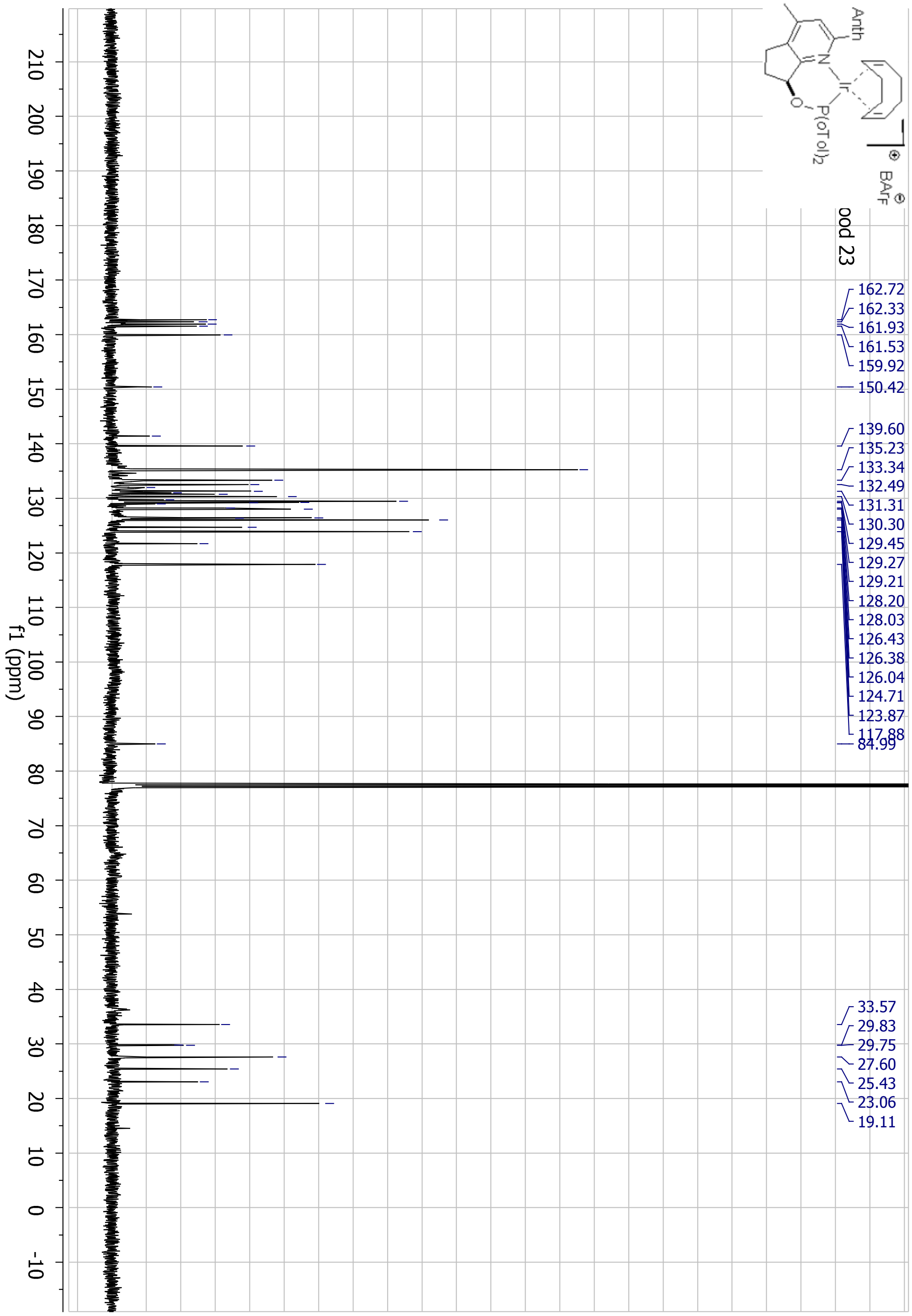
13. *S*-**7b** ^{1}H & ^{13}C


woodmansee.886
User/Group woodmansee/Pfaltz
_Proton CDCl3 uicon woodmansee 41
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)
1.04
2.21
10.70
3.89
9.91
9.00
1.09
2.13
1.04
1.07
1.11
1.15
1.14
1.21
1.28
3.54
2.63
2.65
1.38
1.11
2.94
1.18
1.11
Anth
N
Ir
P(Ph)2
O
⊕
⊖
B(Ar)4

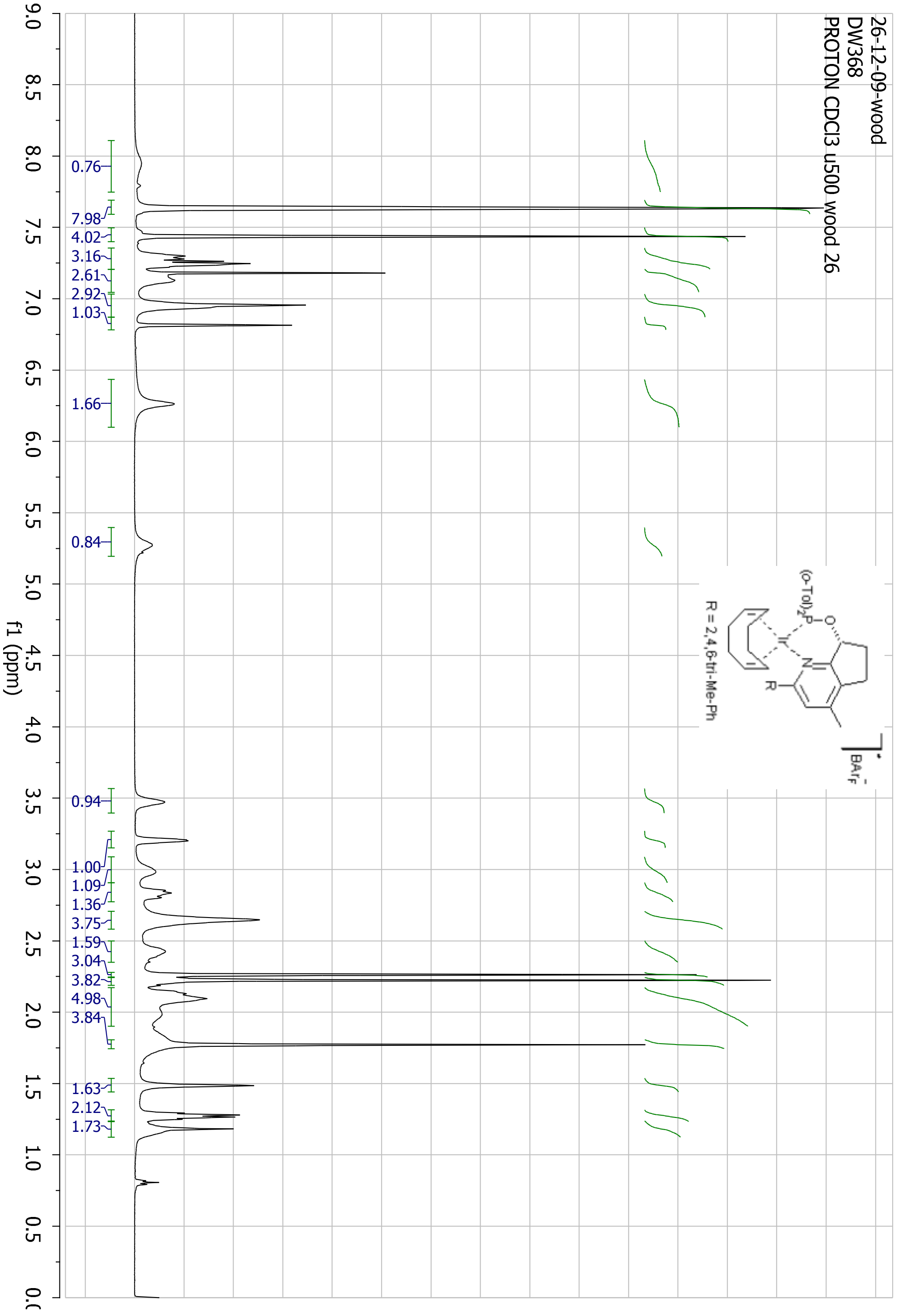

Anth
N
Ir
O
P(Ph)2
⊕
⊖
B(Ar)4
e/Pfaltz
odmansee 41
162.86
162.36
161.86
161.37
160.97
158.96
150.06
135.20
130.88
130.42
129.76
129.65
129.50
129.34
129.31
129.23
126.46
126.29
123.58
117.85
95.10
95.02
87.58
87.39
84.63
69.37
68.07
36.29
35.77
29.89
29.79
27.77
27.46
24.61
19.22
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

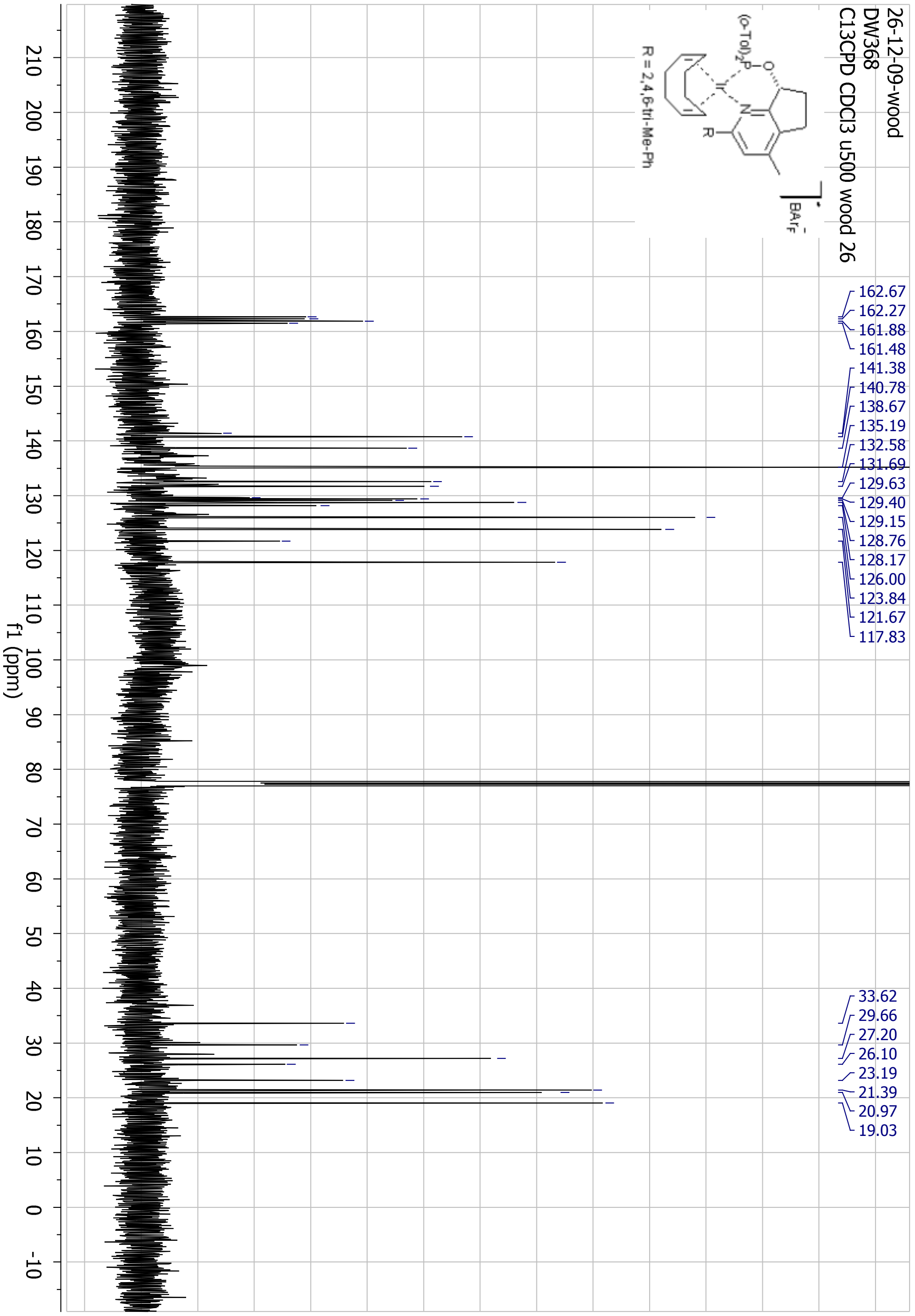
13. *S*-**7c** ^{1}H & ^{13}C


23-12-09-wood
DW181
PROTON CDCl3 u500 wood 23
0.93
0.92
0.94
8.31
0.73
4.03
0.84
0.80
1.76
-0.04
1.52
1.42
0.94
0.83
1.71
4.62
2.98
3.68
0.92
2.03
1.35
2.07
0.92
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)
Anth
N
Ir
O
P(oTol)2
⊕
BArF ⊖

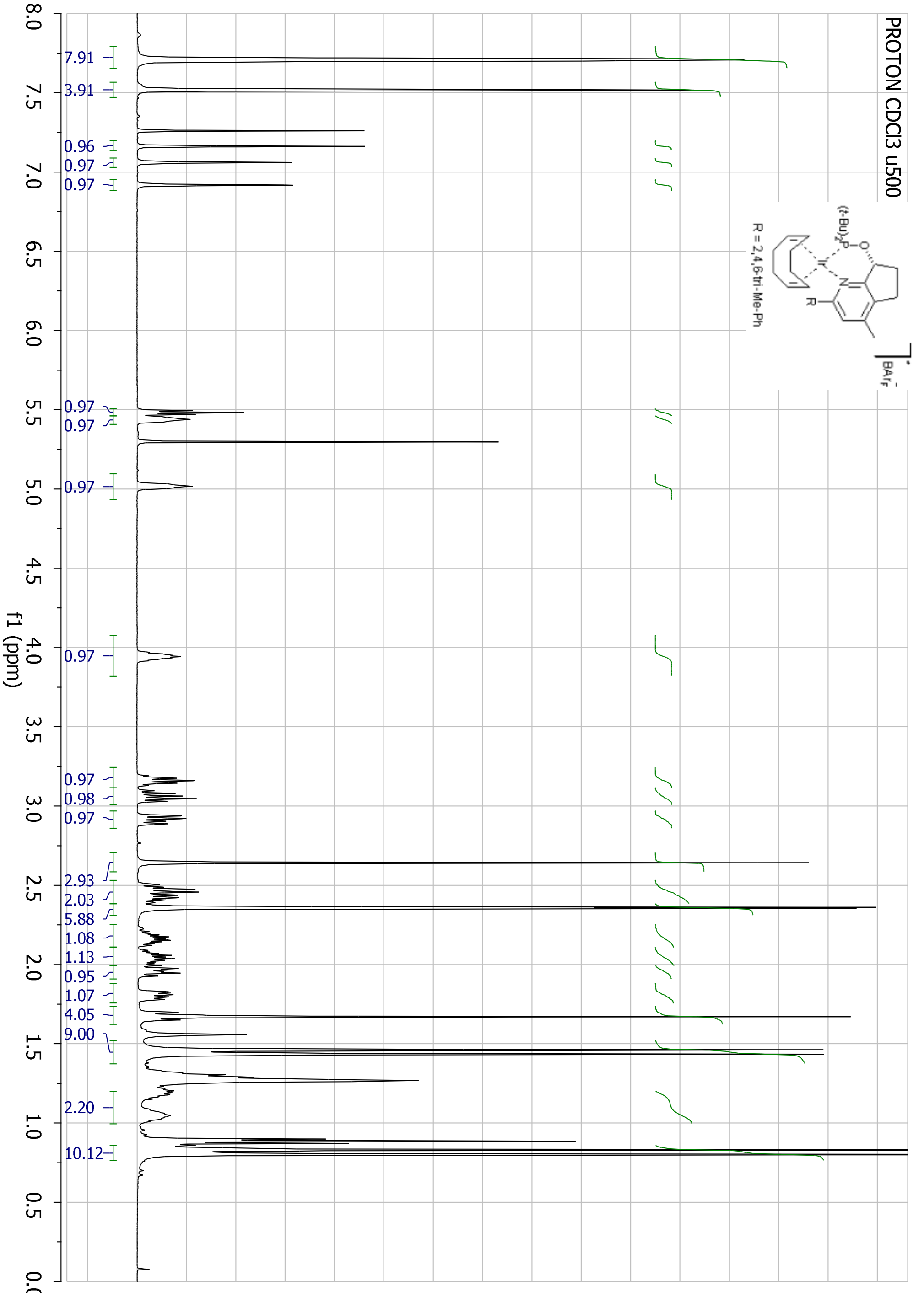

Anth
N
Ir
O
P(oTol)2
BArF
ood 23
162.72
162.33
161.93
161.53
159.92
150.42
139.60
135.23
133.34
132.49
131.31
130.30
129.45
129.27
129.21
128.20
128.03
126.43
126.38
126.04
124.71
123.87
117.88
84.99
33.57
29.83
29.75
27.60
25.43
23.06
19.11
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

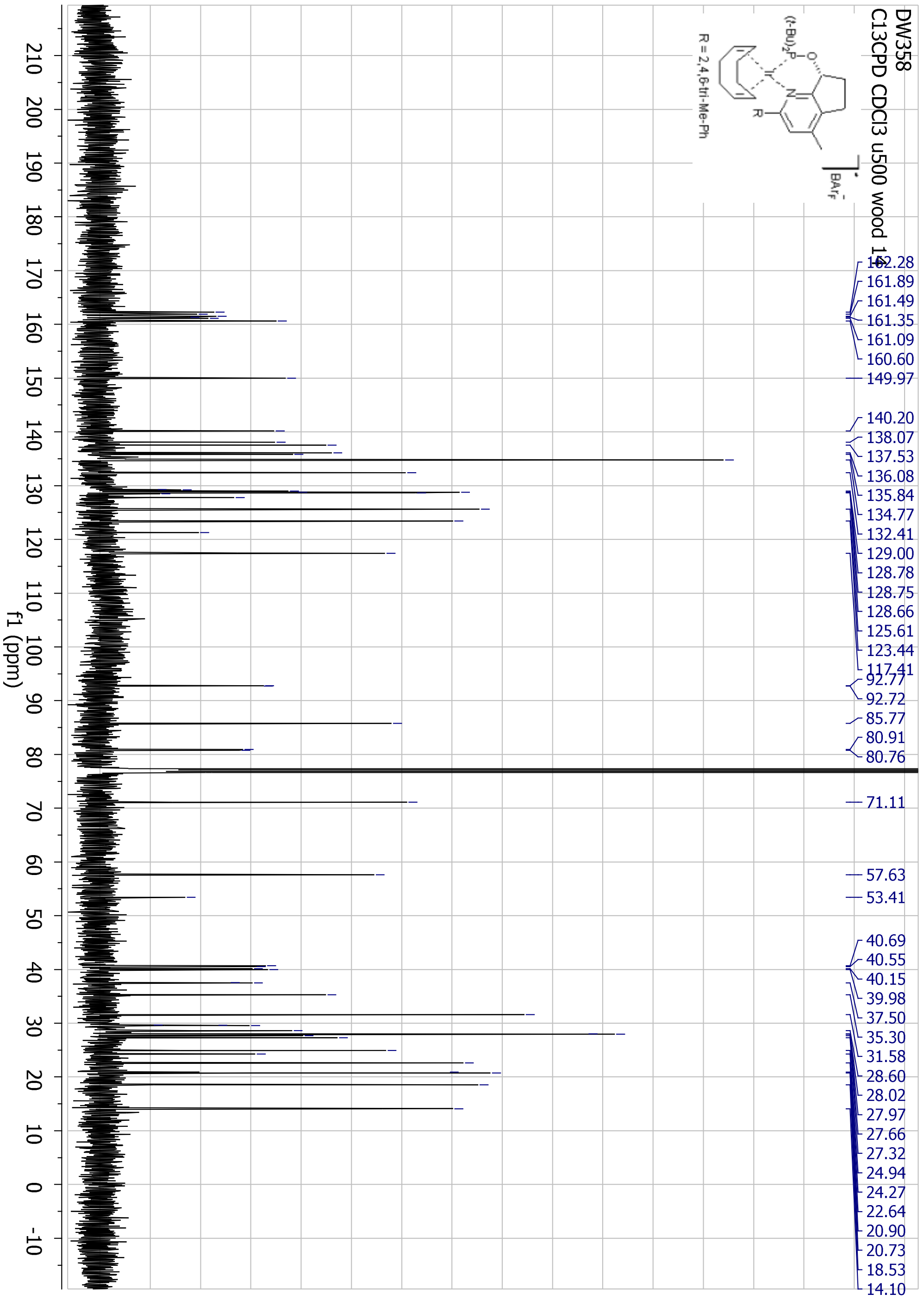
13. *S*-**7d** ^{1}H & ^{13}C (*R*-isomer drawn)



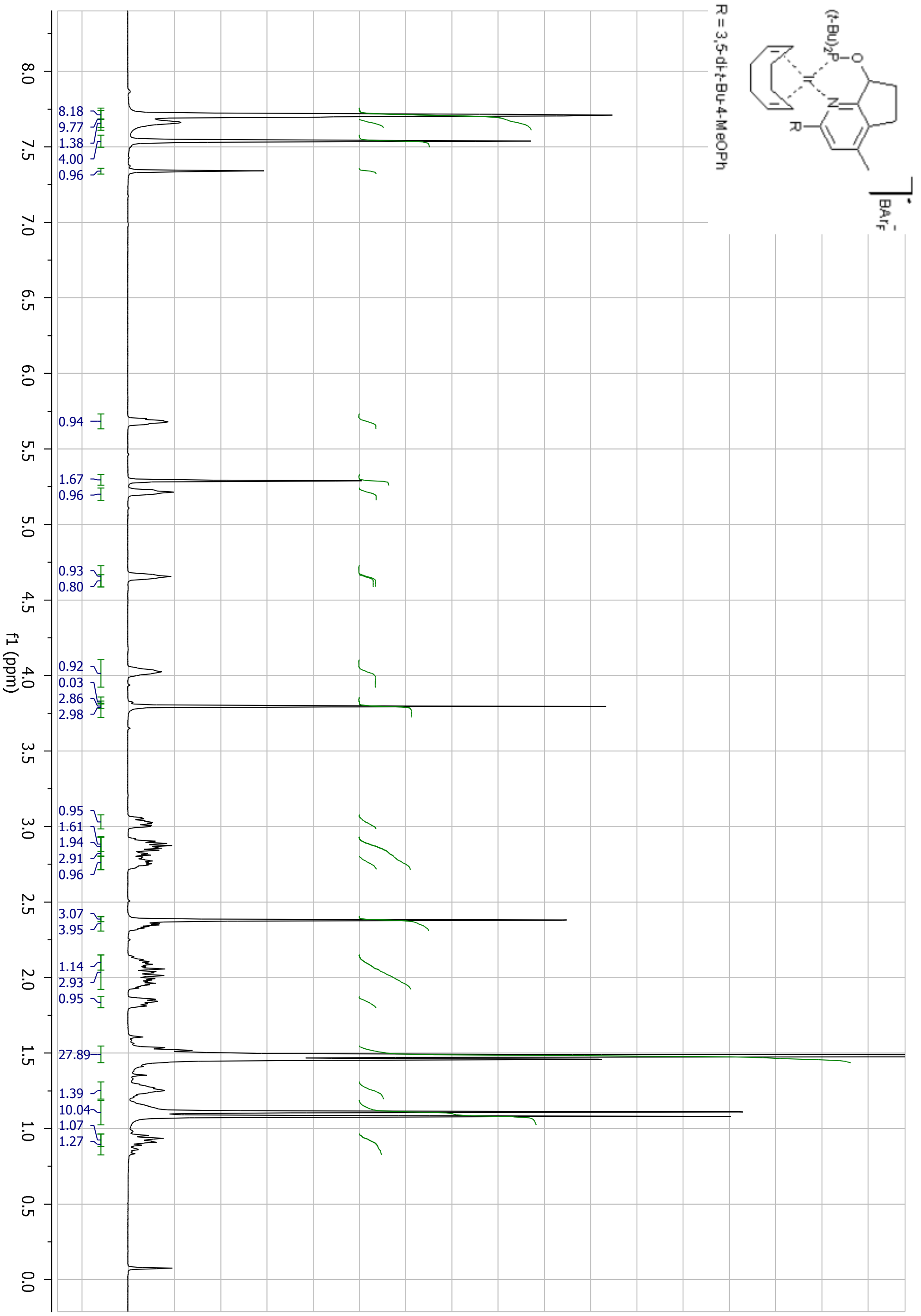

26-12-09-wood
DW368
C13CPD CDCl3 u500 wood 26
(o-Tol)2P
O
N
Ir
R
BArF
R = 2,4,6-tri-Me-Ph
162.67
162.27
161.88
161.48
141.38
140.78
138.67
135.19
132.58
131.69
129.63
129.40
129.15
128.76
128.17
126.00
123.84
121.67
117.83
33.62
29.66
27.20
26.10
23.19
21.39
20.97
19.03
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

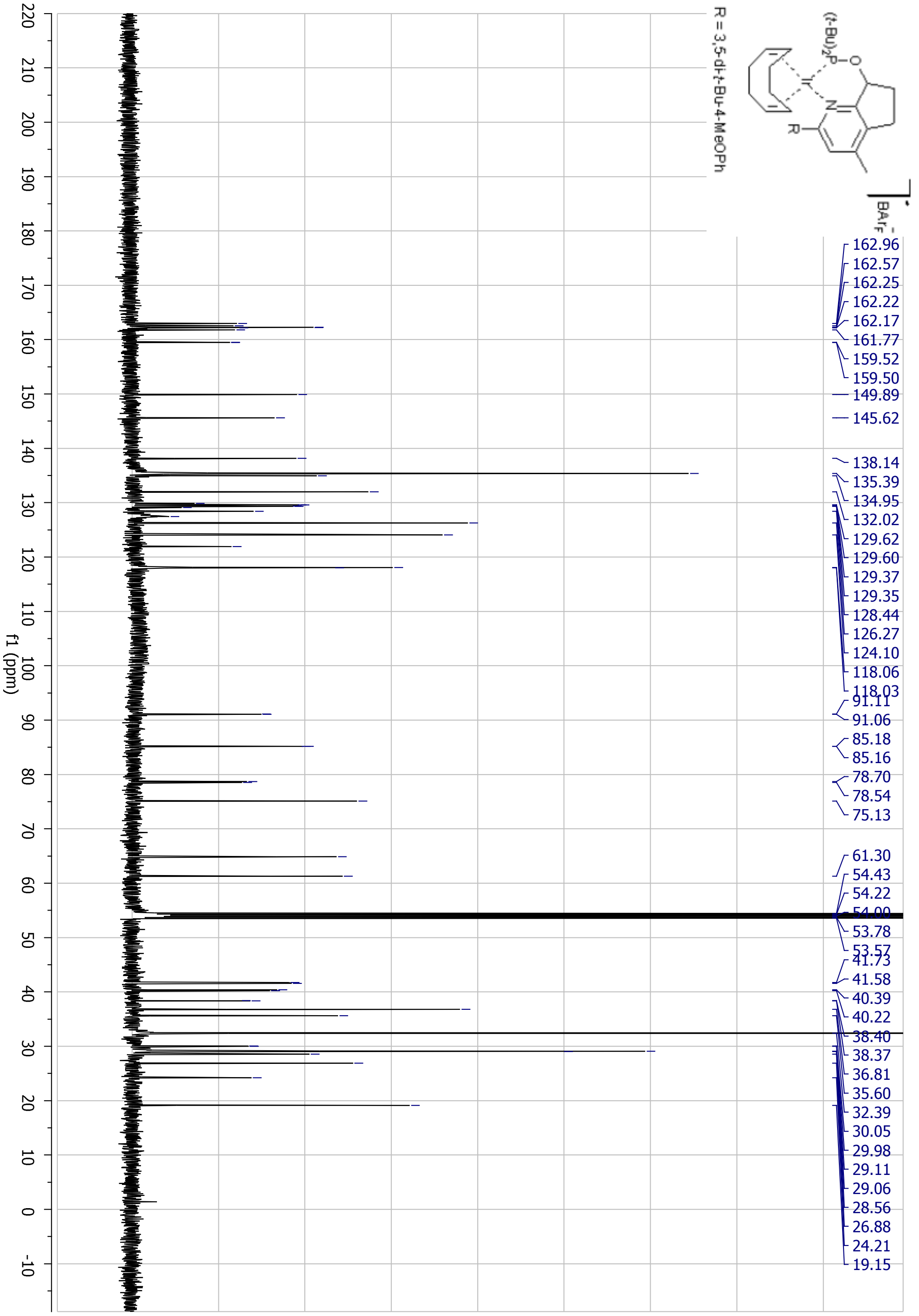
13. *S*-**7e** ^{1}H & ^{13}C (*R*-isomer drawn)



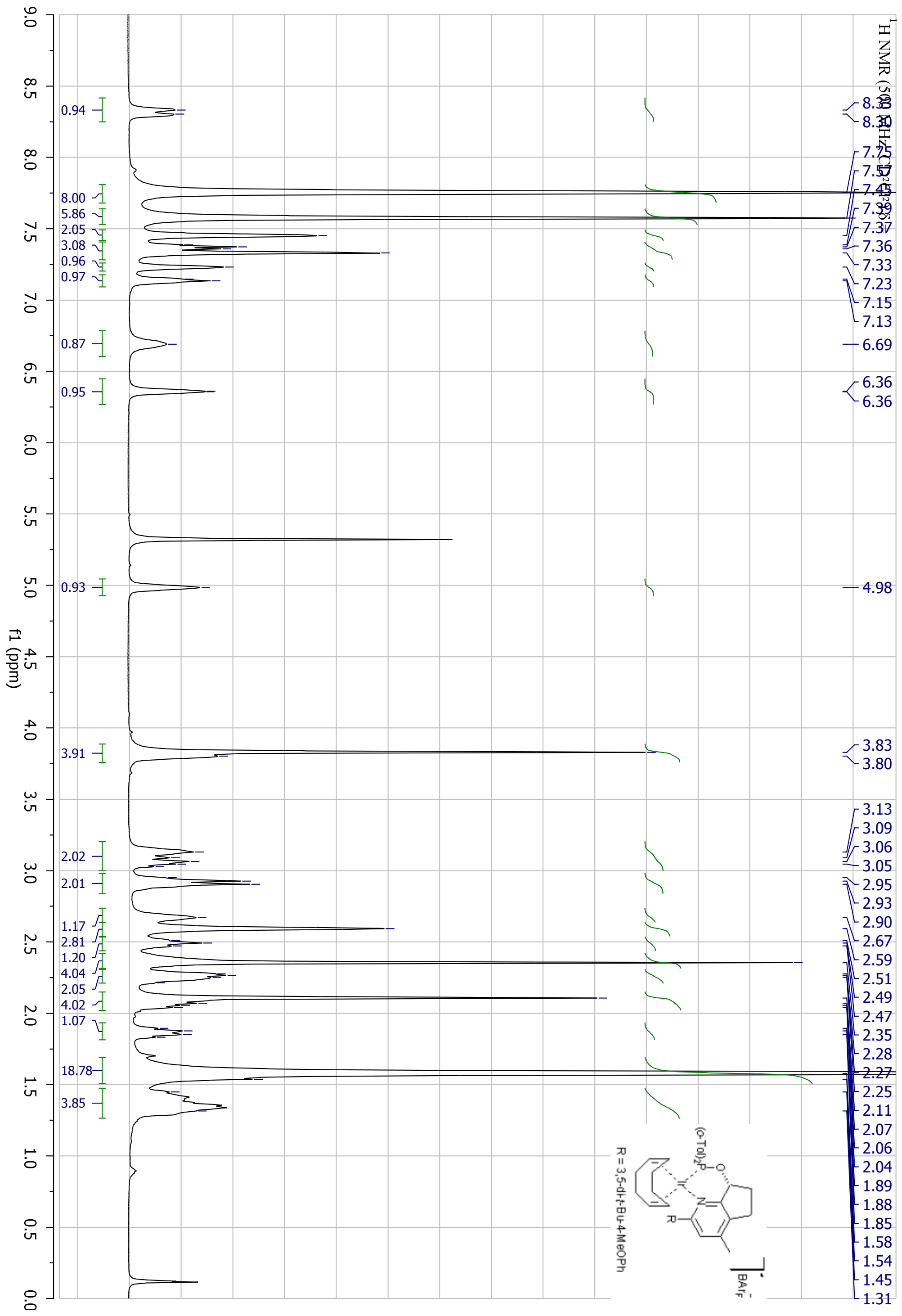

DW358
C13CPD CDCl3 u500 wood 1
(t-Bu)2P
O
Ir
N
R
BArF−
R = 2,4,6-tri-Me-Ph
162.28
161.89
161.49
161.35
161.09
160.60
149.97
140.20
138.07
137.53
136.08
135.84
134.77
132.41
129.00
128.78
128.75
128.66
125.61
123.44
117.41
92.77
92.72
85.77
80.91
80.76
71.11
57.63
53.41
40.69
40.55
40.15
39.98
37.50
35.30
31.58
28.60
28.02
27.97
27.66
27.32
24.94
24.27
22.64
20.90
20.73
18.53
14.10
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)

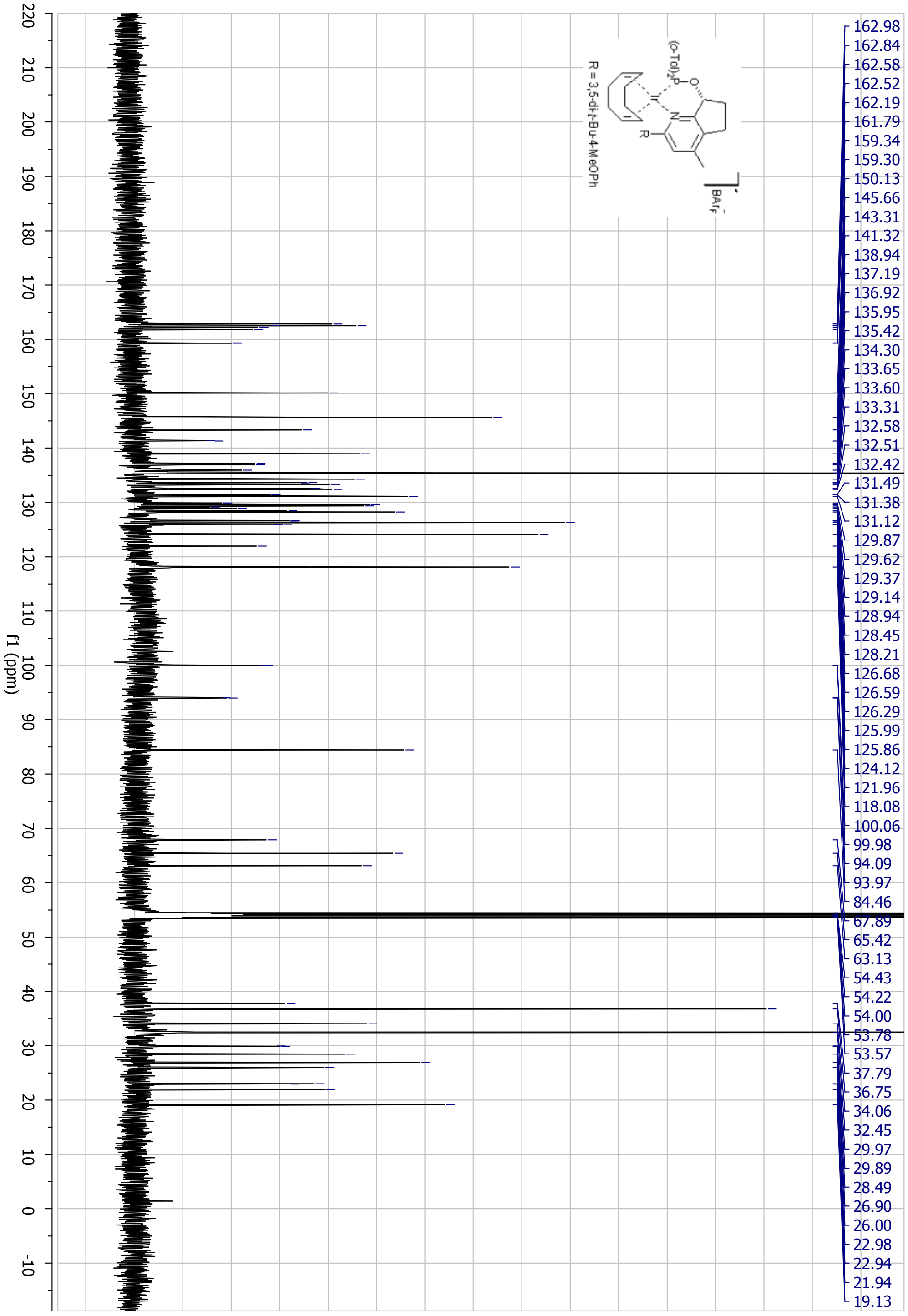
13. *R*-**7f** ^{1}H & ^{13}C


(t-Bu)2P
O
Ir
N
R
BArF−
R = 3,5-di-t-Bu-4-MeOPh
8.18
9.77
1.38
4.00
0.96
0.94
1.67
0.96
0.93
0.80
0.92
0.03
2.86
2.98
0.95
1.61
1.94
2.91
0.96
3.07
3.95
1.14
2.93
0.95
27.89
1.39
10.04
1.07
1.27
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)

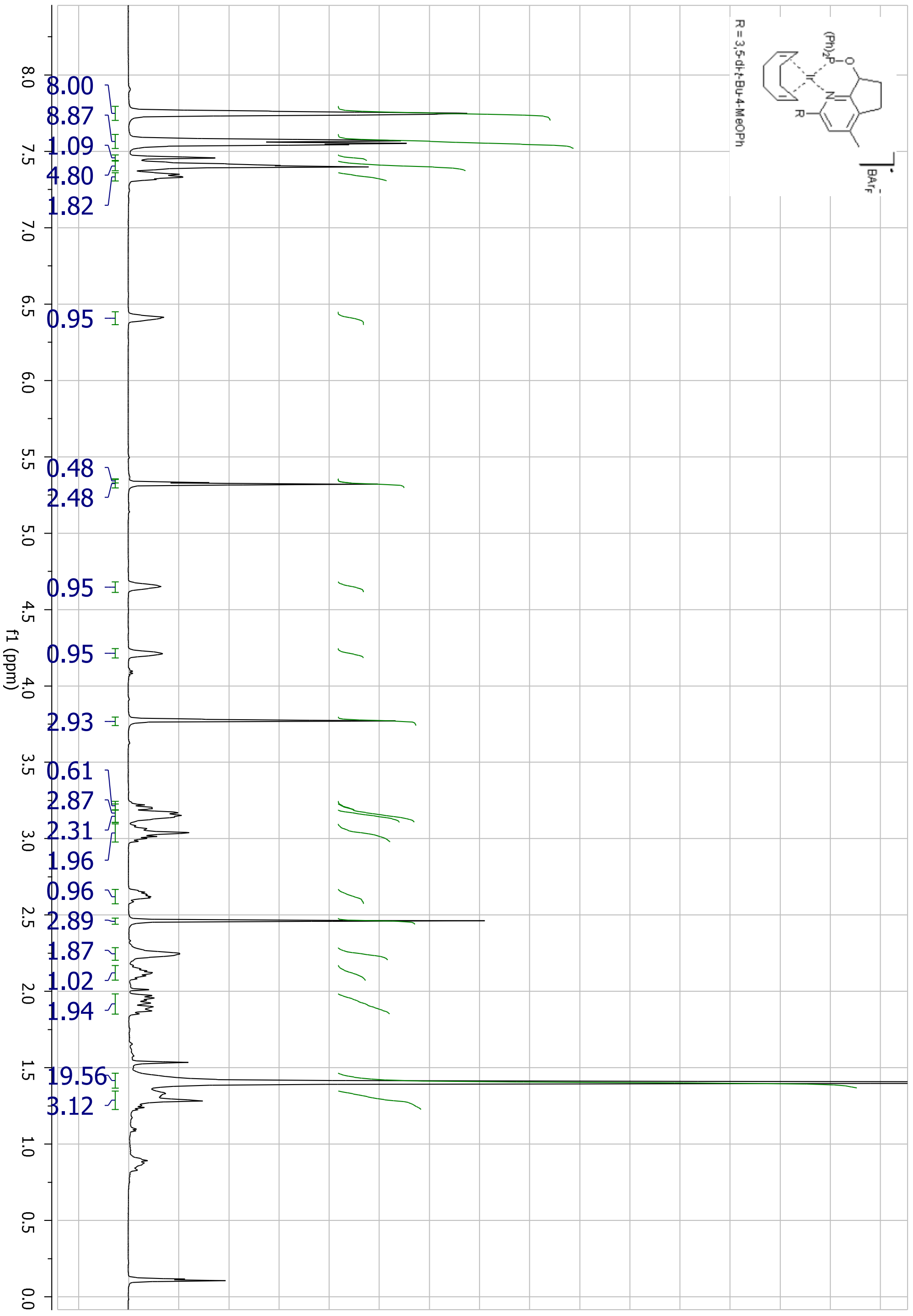

(t-Bu)$_2$P
O
Ir
N
R
BAr$_F^-$
R = 3,5-di-t-Bu-4-MeOPh
162.96
162.57
162.25
162.22
162.17
161.77
159.52
159.50
149.89
145.62
138.14
135.39
134.95
132.02
129.62
129.60
129.37
129.35
128.44
126.27
124.10
118.06
118.03
91.11
91.06
85.18
85.16
78.70
78.54
75.13
61.30
54.43
54.22
54.00
53.78
53.57
41.73
41.58
40.39
40.22
38.40
38.37
36.81
35.60
32.39
30.05
29.98
29.11
29.06
28.56
26.88
24.21
19.15
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)

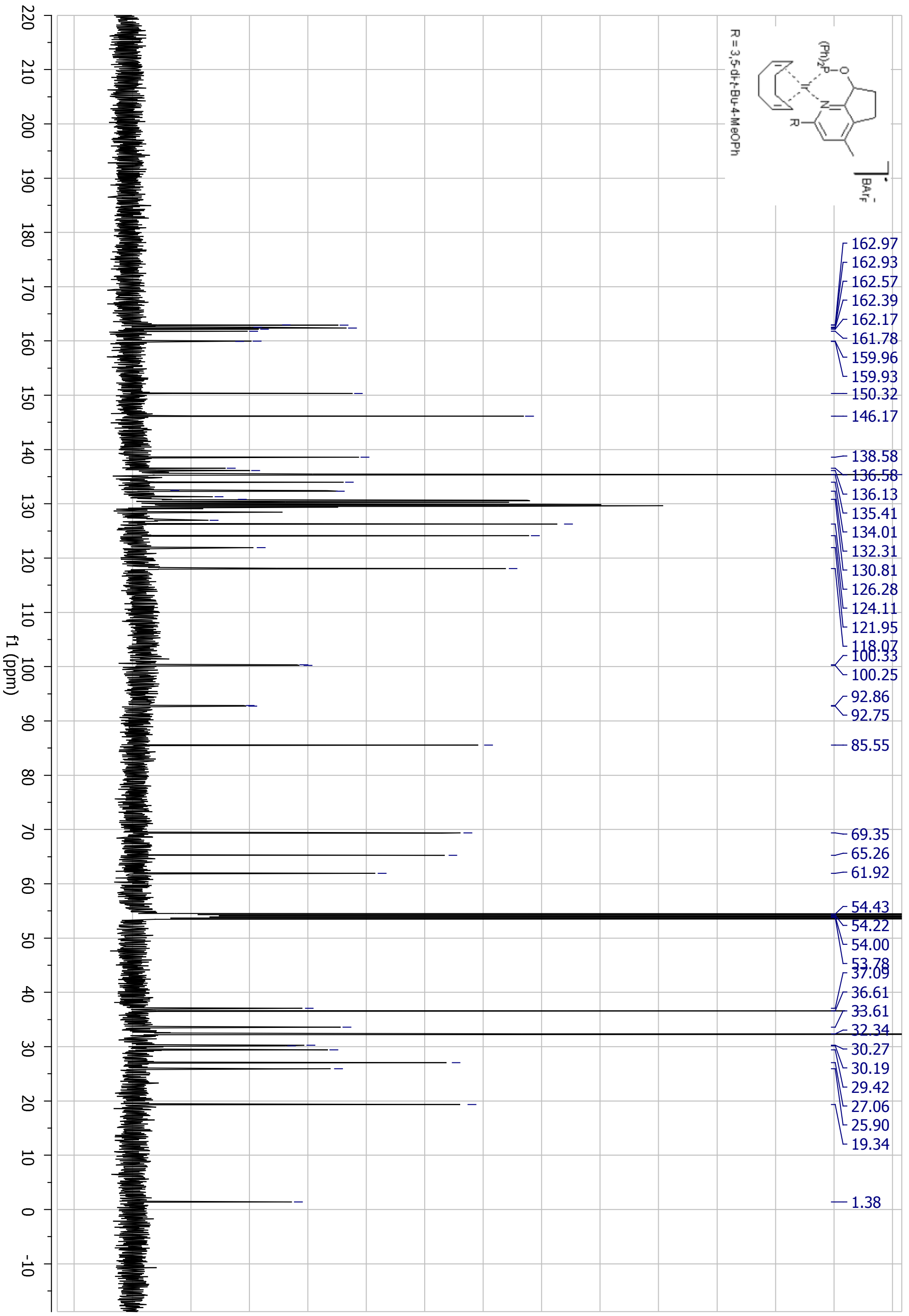
13. *S*-**7g** ^{1}H & ^{13}C (*R*-isomer drawn)



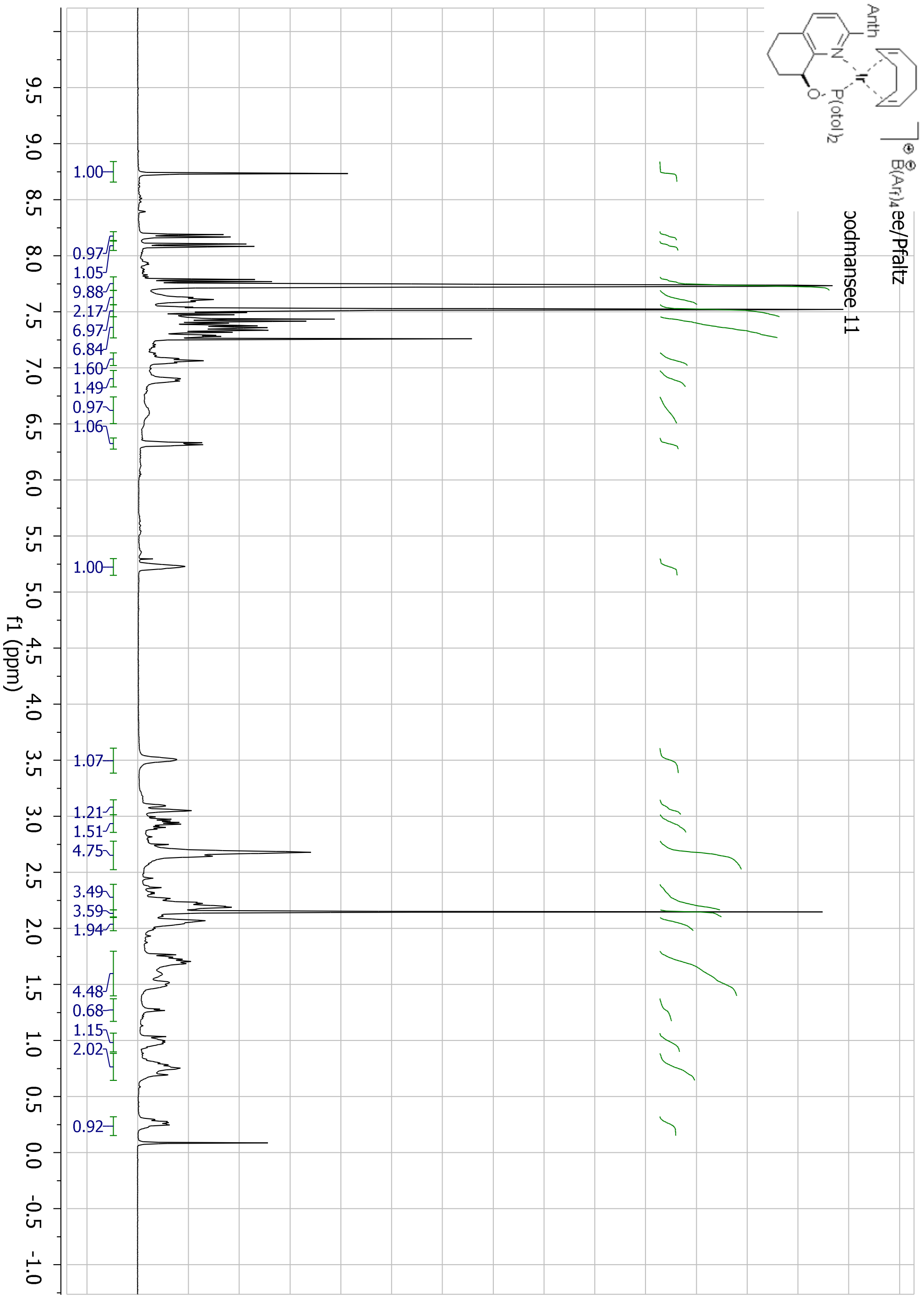

(o-Tol)$_2$P
O
N
Ir
R
BAr$_F^-$
R = 3,5-di-t-Bu-4-MeOPh
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
162.98
162.84
162.58
162.52
162.19
161.79
159.34
159.30
150.13
145.66
143.31
141.32
138.94
137.19
136.92
135.95
135.42
134.30
133.65
133.60
133.31
132.58
132.51
132.42
131.49
131.38
131.12
129.87
129.62
129.37
129.14
128.94
128.45
128.21
126.68
126.59
126.29
125.99
125.86
124.12
121.96
118.08
100.06
99.98
94.09
93.97
84.46
67.89
65.42
63.13
54.43
54.22
54.00
53.78
53.57
37.79
36.75
34.06
32.45
29.97
29.89
28.49
26.90
26.00
22.98
22.94
21.94
19.13

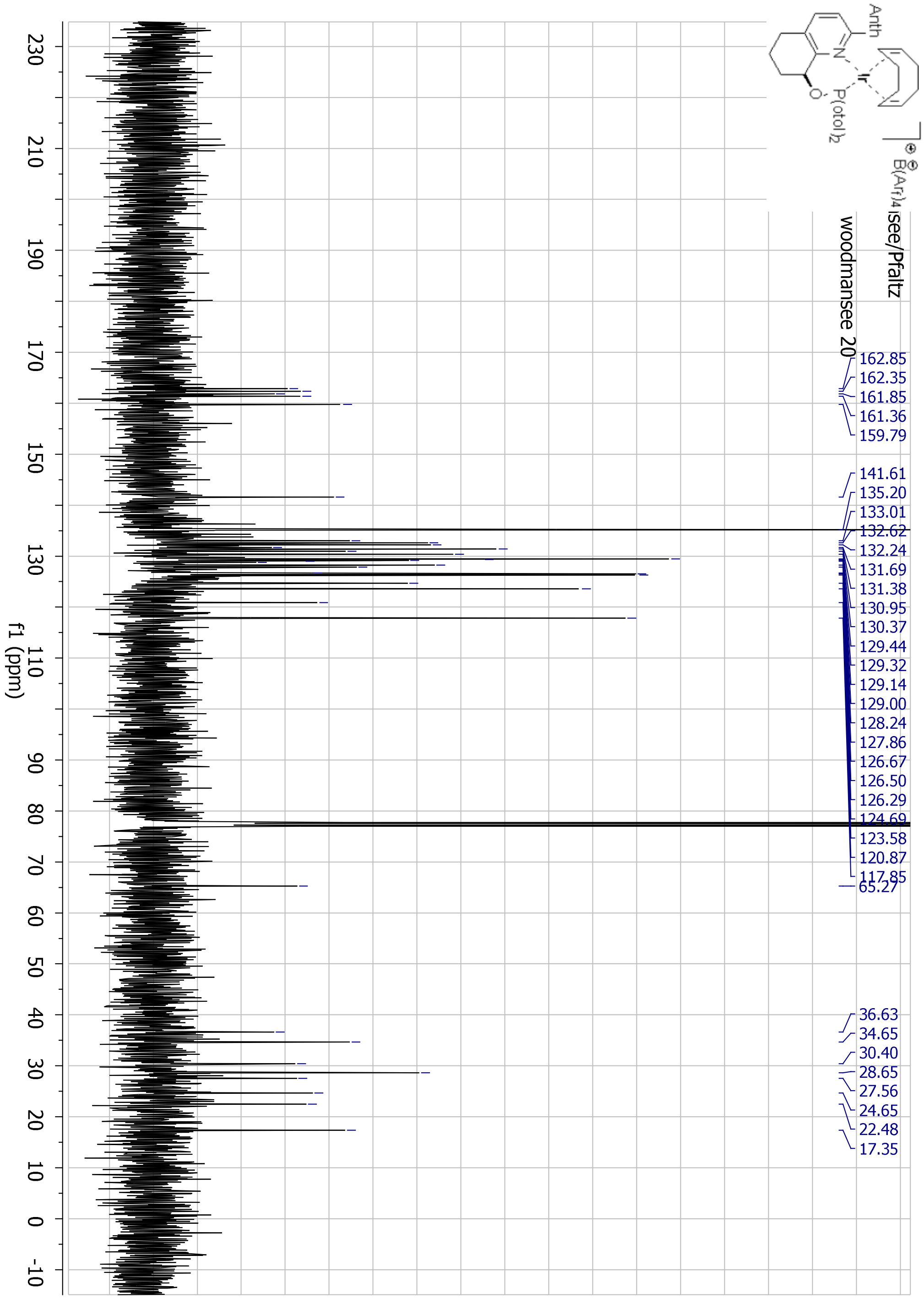
13. *S*-**7h** ^{1}H & ^{13}C


8.00
8.87
1.09
4.80
1.82
0.95
0.48
2.48
0.95
0.95
2.93
0.61
2.87
2.31
1.96
0.96
2.89
1.87
1.02
1.94
19.56
3.12
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)
(Ph)2P
O
Ir
N
R
BArF-
R = 3,5-di-t-Bu-4-MeOPh

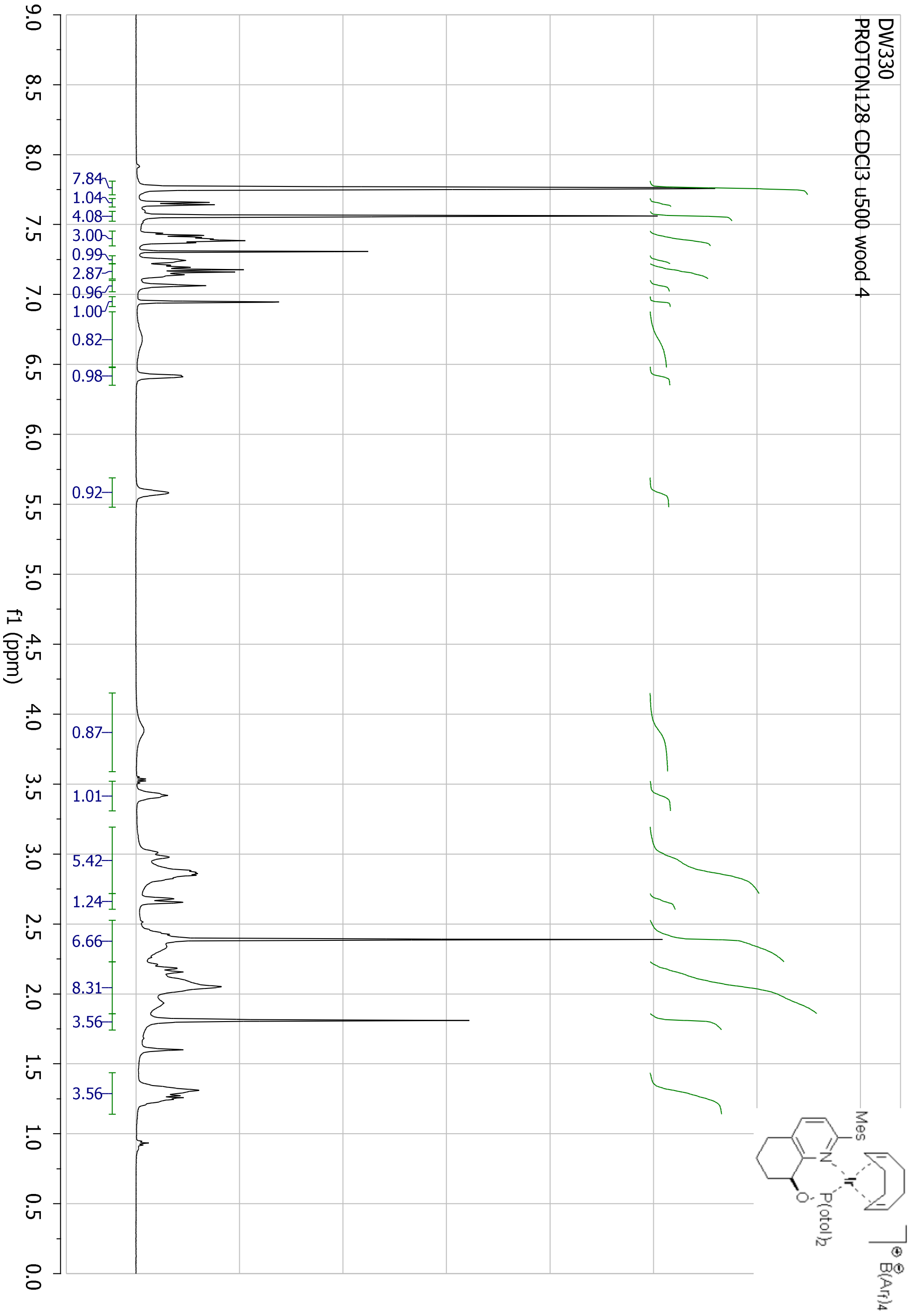

(Ph)2P
O
N
Ir
R
BArF−
R = 3,5-di-t-Bu-4-MeOPh
162.97
162.93
162.57
162.39
162.17
161.78
159.96
159.93
150.32
146.17
138.58
136.58
136.13
135.41
134.01
132.31
130.81
126.28
124.11
121.95
118.07
100.33
100.25
92.86
92.75
85.55
69.35
65.26
61.92
54.43
54.22
54.00
53.78
37.09
36.61
33.61
32.34
30.27
30.19
29.42
27.06
25.90
19.34
1.38
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

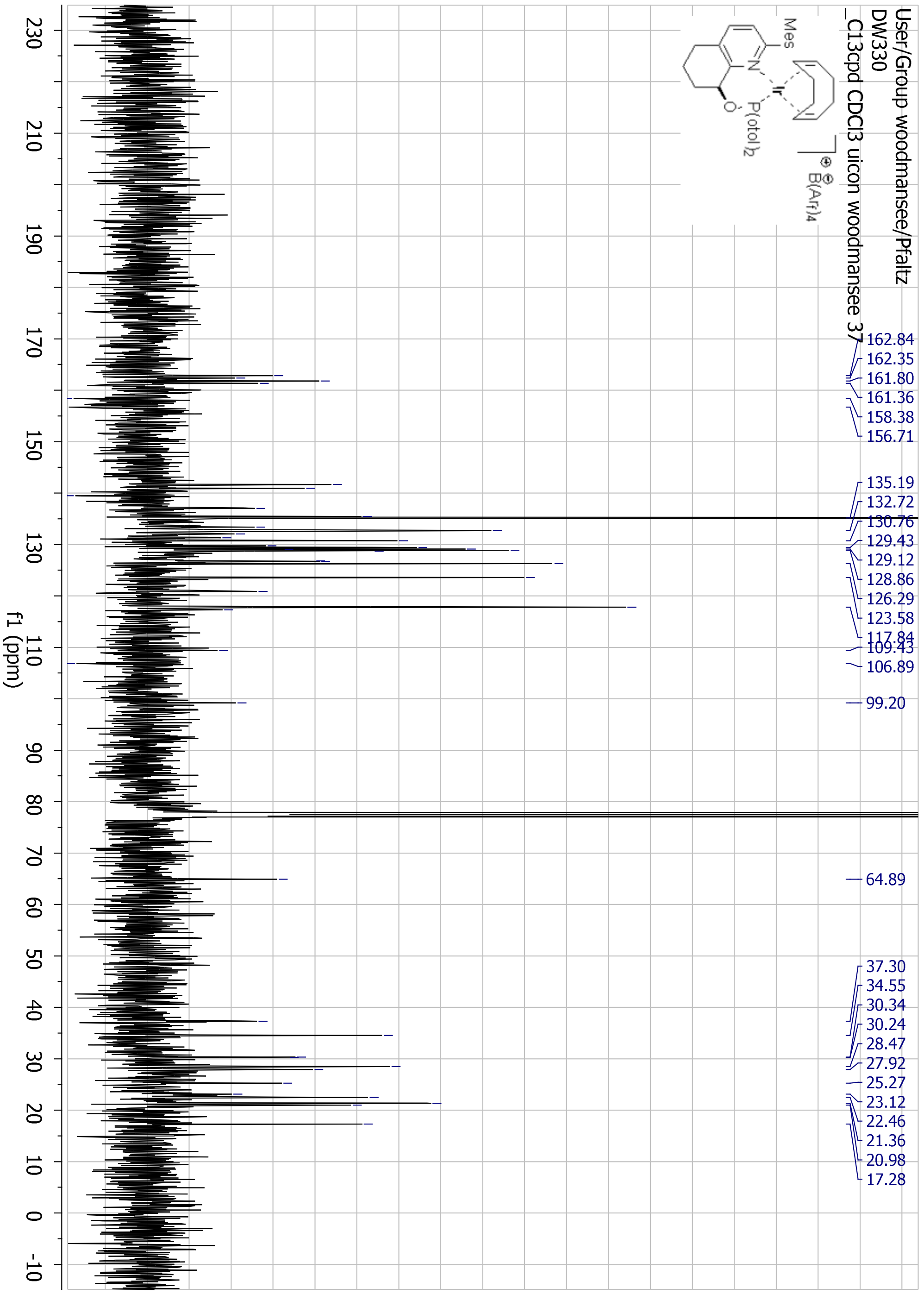
13. *S*-**9a** ^{1}H & ^{13}C


Anth
N
Ir
P(otol)2
O
B(ArF)4
ee/Pfaltz
odmansee 11
1.00
0.97
1.05
9.88
2.17
6.97
6.84
1.60
1.49
0.97
1.06
1.00
1.07
1.21
1.51
4.75
3.49
3.59
1.94
4.48
0.68
1.15
2.02
0.92
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
-0.5
-1.0
f1 (ppm)

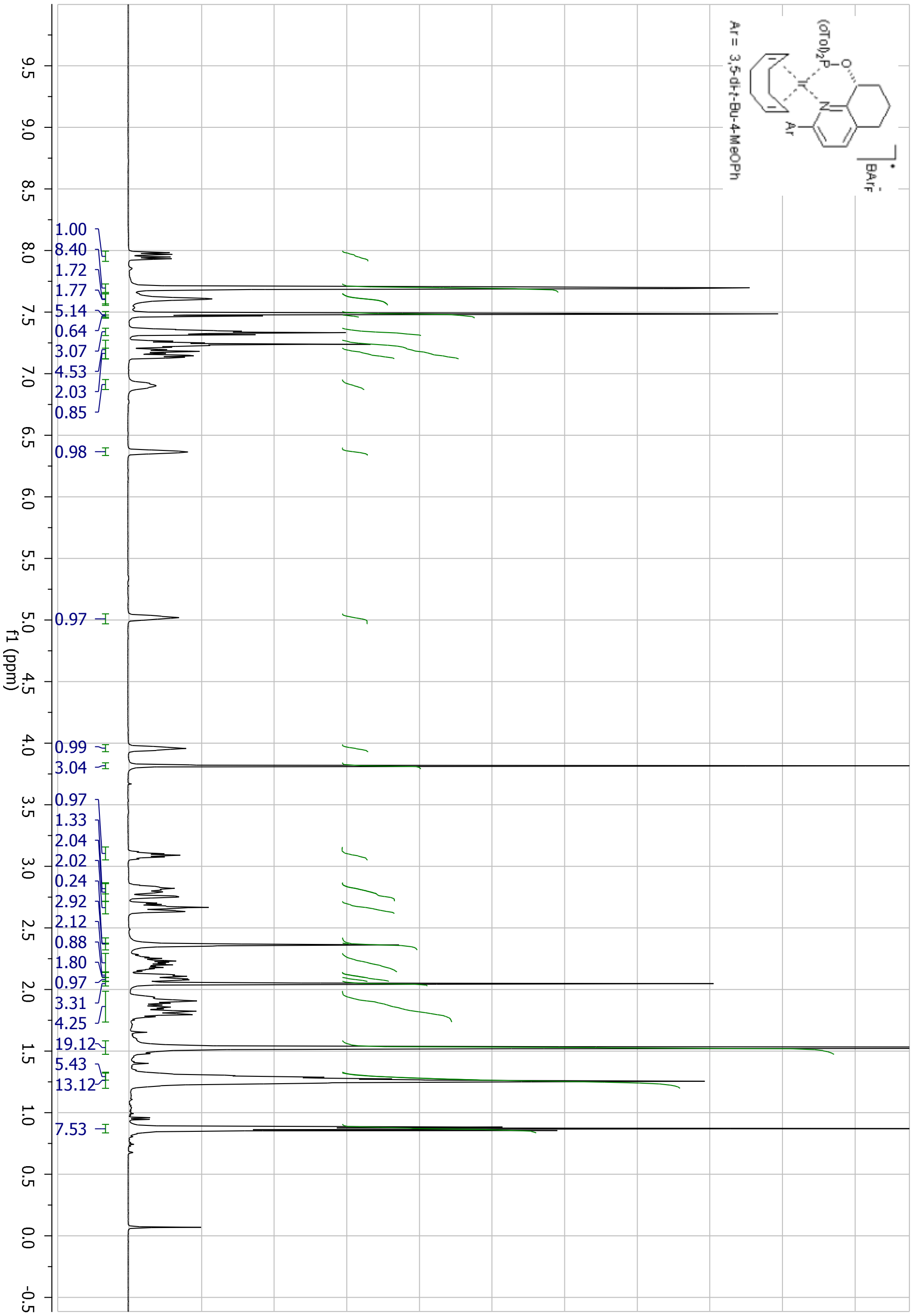

Anth
N
Ir
P(otol)2
O
B(Arf)4
isee/Pfaltz
woodmansee 20
162.85
162.35
161.85
161.36
159.79
141.61
135.20
133.01
132.62
132.24
131.69
131.38
130.95
130.37
129.44
129.32
129.14
129.00
128.24
127.86
126.67
126.50
126.29
124.69
123.58
120.87
117.85
65.27
36.63
34.65
30.40
28.65
27.56
24.65
22.48
17.35
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

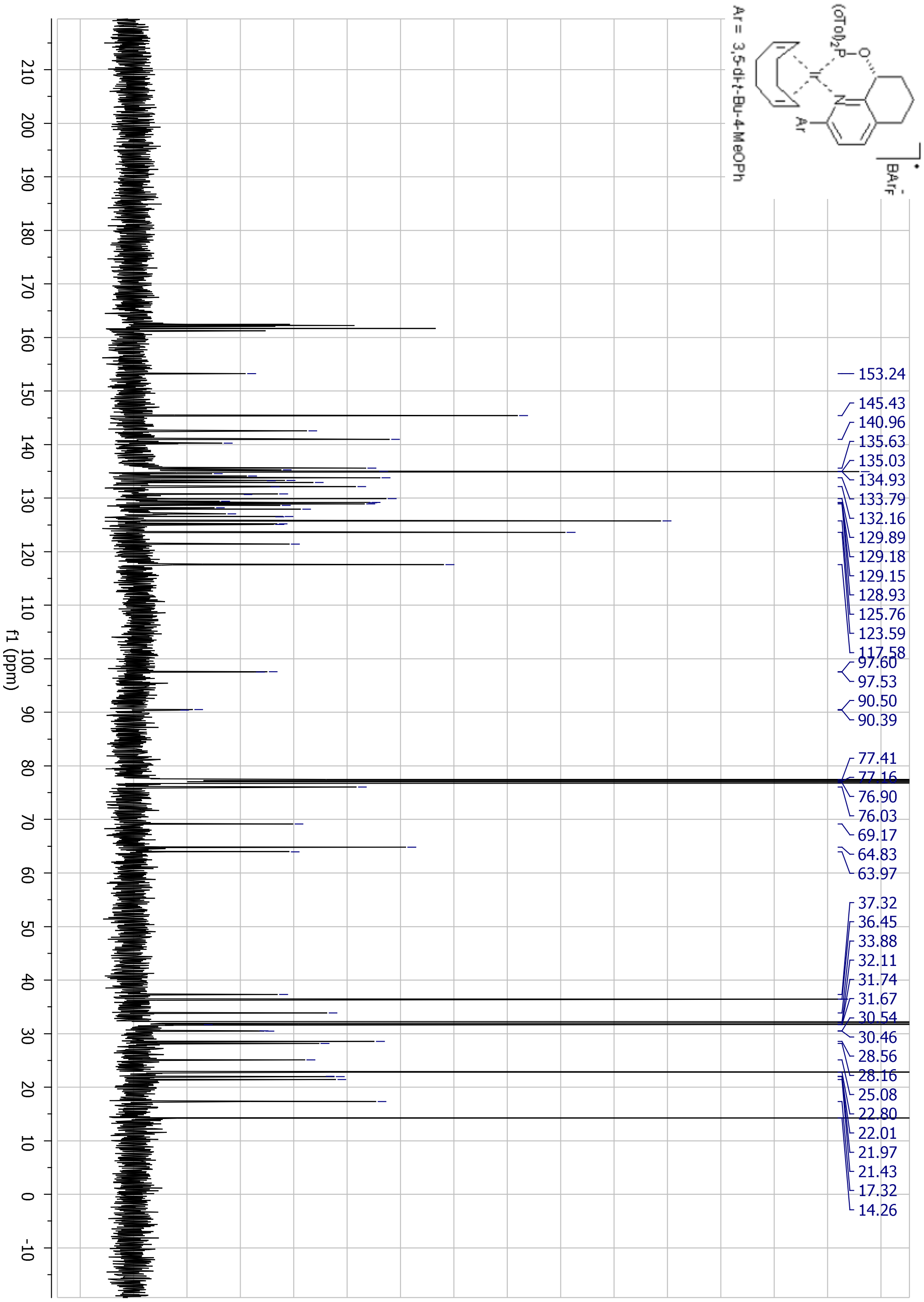
13. *S*-**9b** ^{1}H & ^{13}C


DW330
PROTON128 CDCl3 u500 wood 4
f1 (ppm)
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
7.84
1.04
4.08
3.00
0.99
2.87
0.96
1.00
0.82
0.98
0.92
0.87
1.01
5.42
1.24
6.66
8.31
3.56
3.56
Mes
N
Ir
P(otol)2
O
B(Ar)4

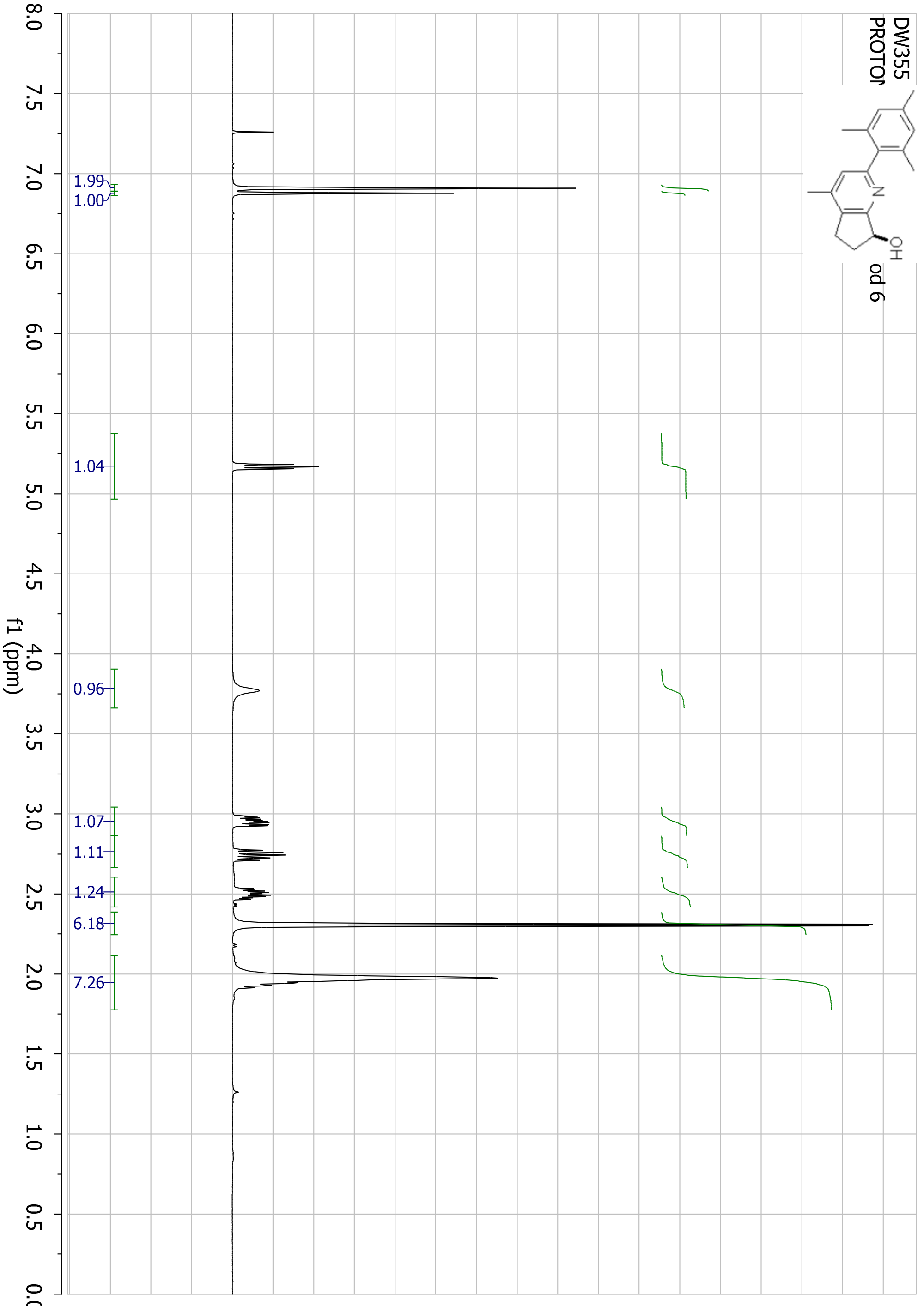

User/Group woodmansee/Pfaltz
DW330
_C13cpd CDCl3 uicon woodmansee 37
Mes
N
Ir
P(otol)2
O
B(ArF)4
162.84
162.35
161.80
161.36
158.38
156.71
135.19
132.72
130.76
129.43
129.12
128.86
126.29
123.58
117.84
109.43
106.89
99.20
64.89
37.30
34.55
30.34
30.24
28.47
27.92
25.27
23.12
22.46
21.36
20.98
17.28
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

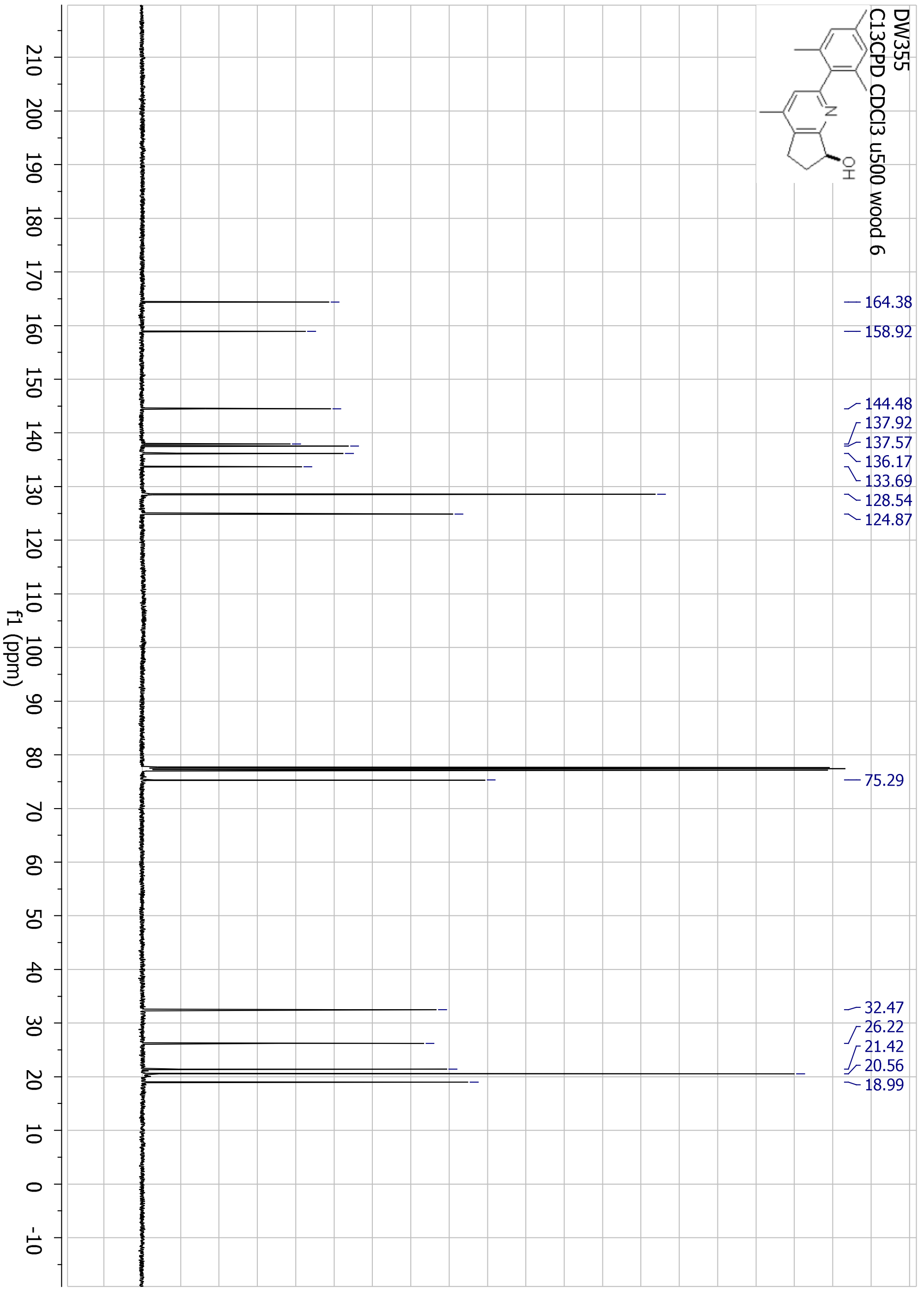
13. *S*-**9c** ^{1}H & ^{13}C


(oTol)2P
O
Ir
N
Ar
BArF
Ar = 3,5-di-t-Bu-4-MeOPh
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
-0.5
f1 (ppm)
1.00
8.40
1.72
1.77
5.14
0.64
3.07
4.53
2.03
0.85
0.98
0.97
0.99
3.04
0.97
1.33
2.04
2.02
0.24
2.92
2.12
0.88
1.80
0.97
3.31
4.25
19.12
5.43
13.12
7.53

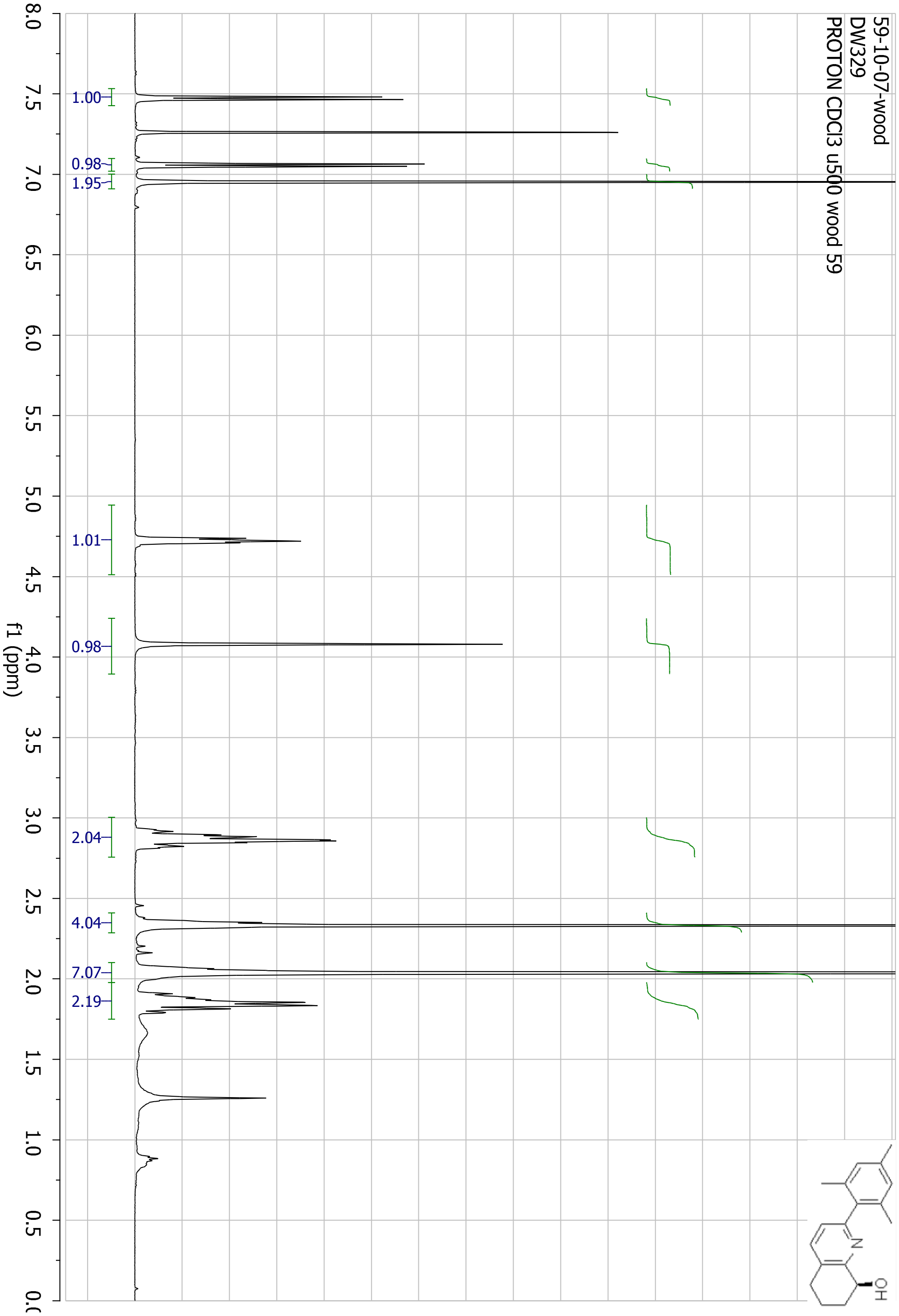

(oTol)2P
O
N
Ir
Ar
BArF
Ar = 3,5-di-t-Bu-4-MeOPh
153.24
145.43
140.96
135.63
135.03
134.93
133.79
132.16
129.89
129.18
129.15
128.93
125.76
123.59
117.58
97.60
97.53
90.50
90.39
77.41
77.16
76.90
76.03
69.17
64.83
63.97
37.32
36.45
33.88
32.11
31.74
31.67
30.54
30.46
28.56
28.16
25.08
22.80
22.01
21.97
21.43
17.32
14.26
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)

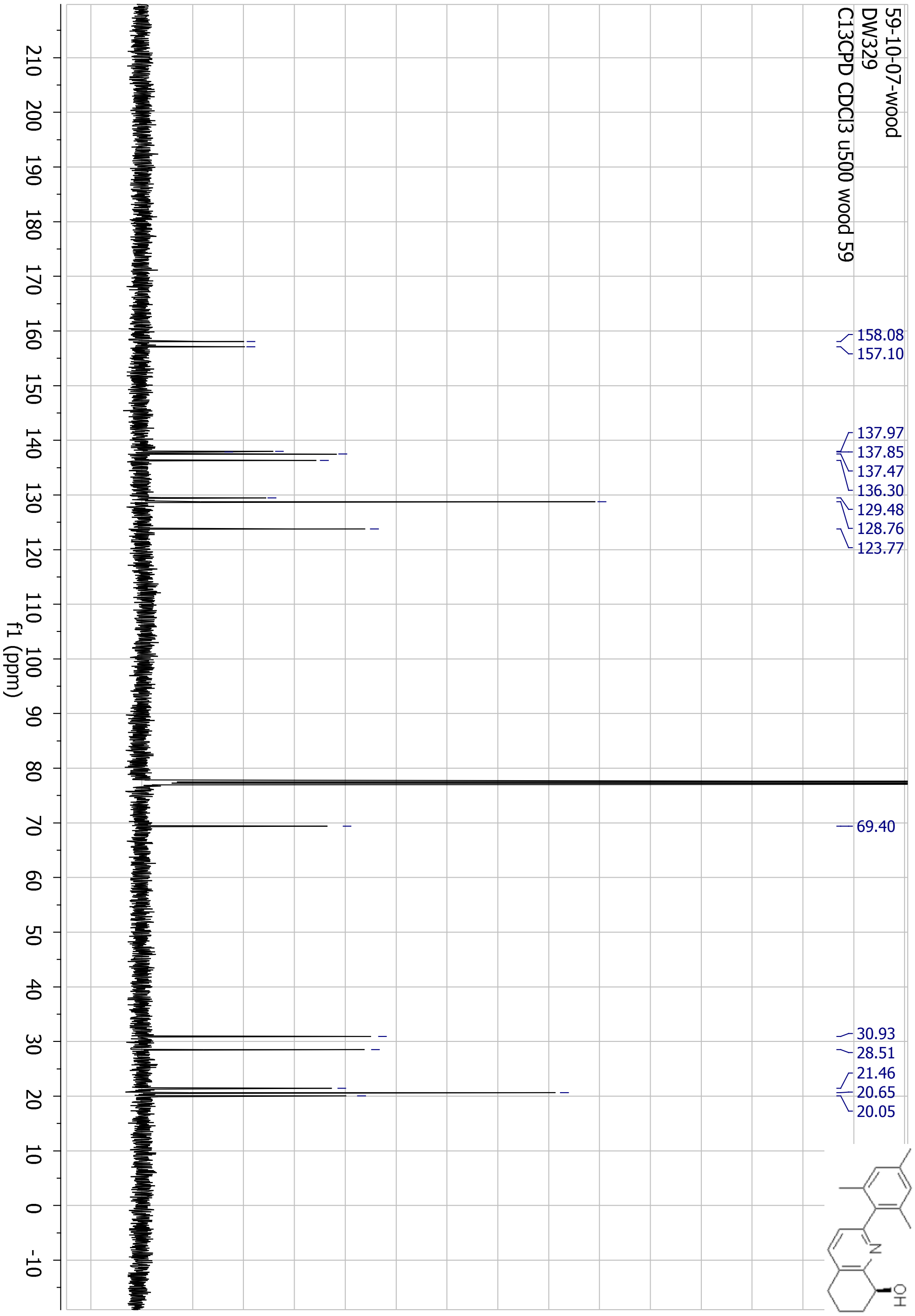
13. **12a** ^{1}H & ^{13}C


DW355
PROTOI
od 6
N
OH
1.99
1.00
1.04
0.96
1.07
1.11
1.24
6.18
7.26
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.(
f1 (ppm)

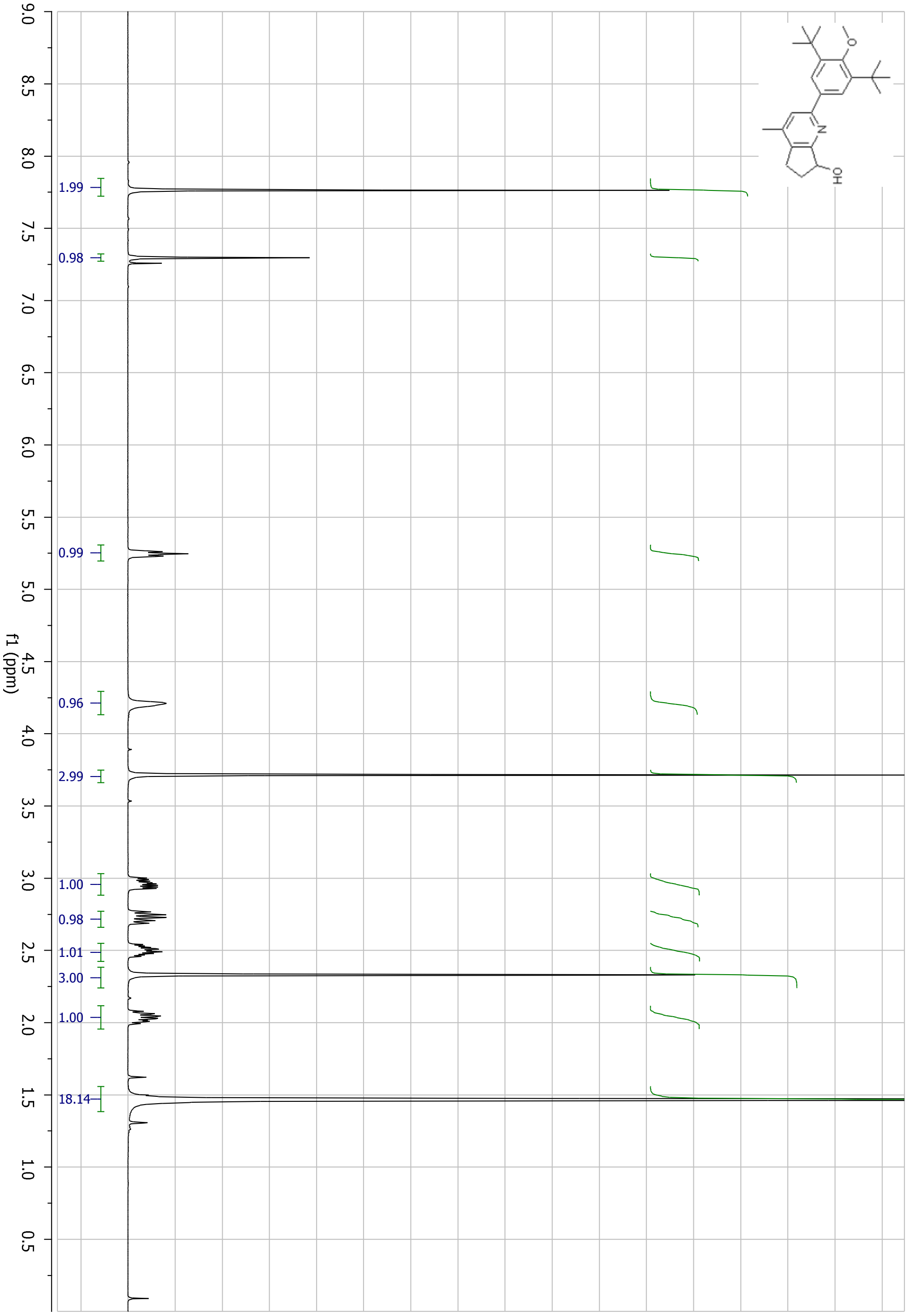

DW355
C13CPD CDCl3 u500 wood 6
N
OH
164.38
158.92
144.48
137.92
137.57
136.17
133.69
128.54
124.87
75.29
32.47
26.22
21.42
20.56
18.99
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

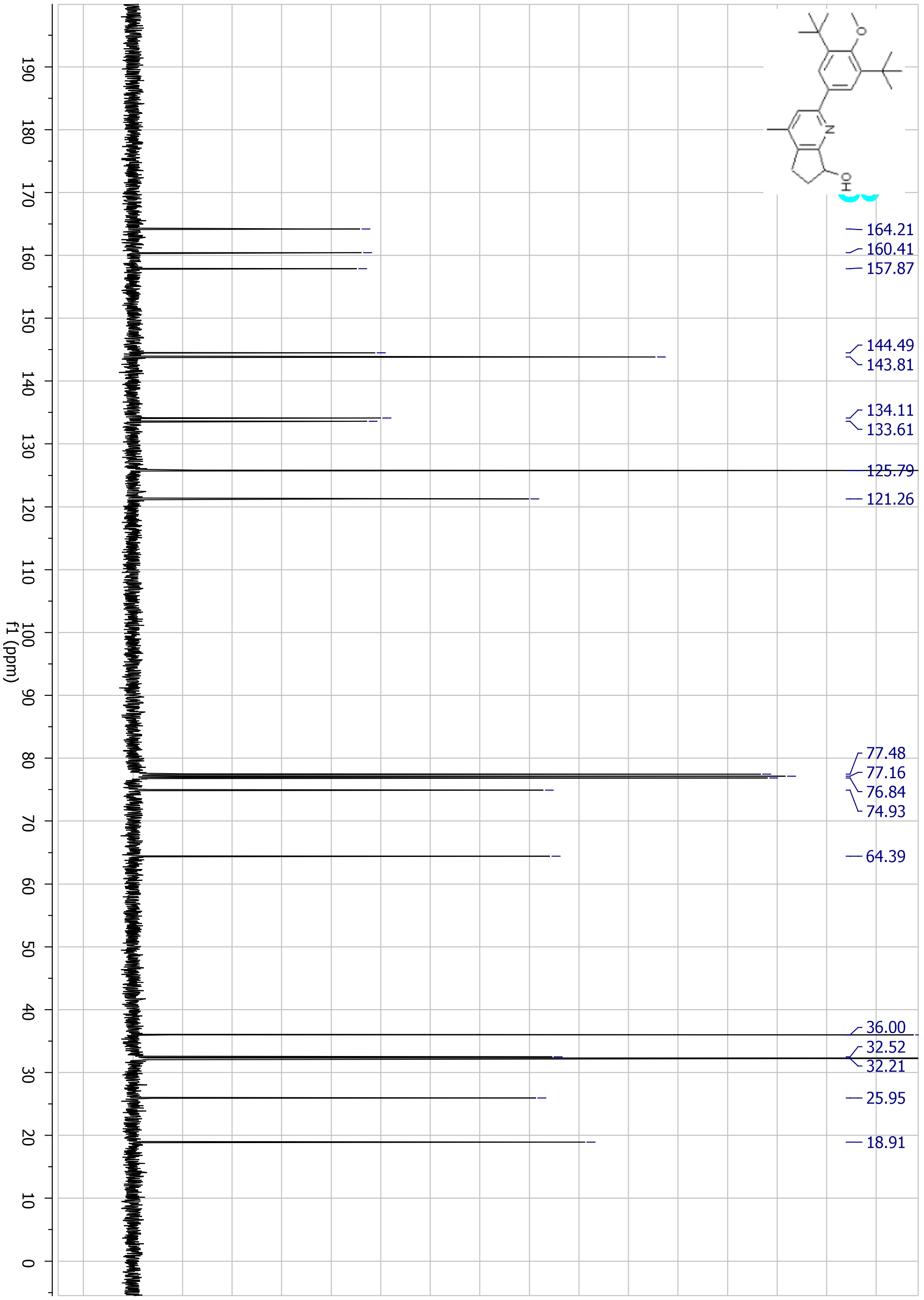
13. **12b** ^{1}H & ^{13}C


59-10-07-wood
DW329
PROTON CDCl3 u500 wood 59
1.00
0.98
1.95
1.01
0.98
2.04
4.04
7.07
2.19
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)
N
OH

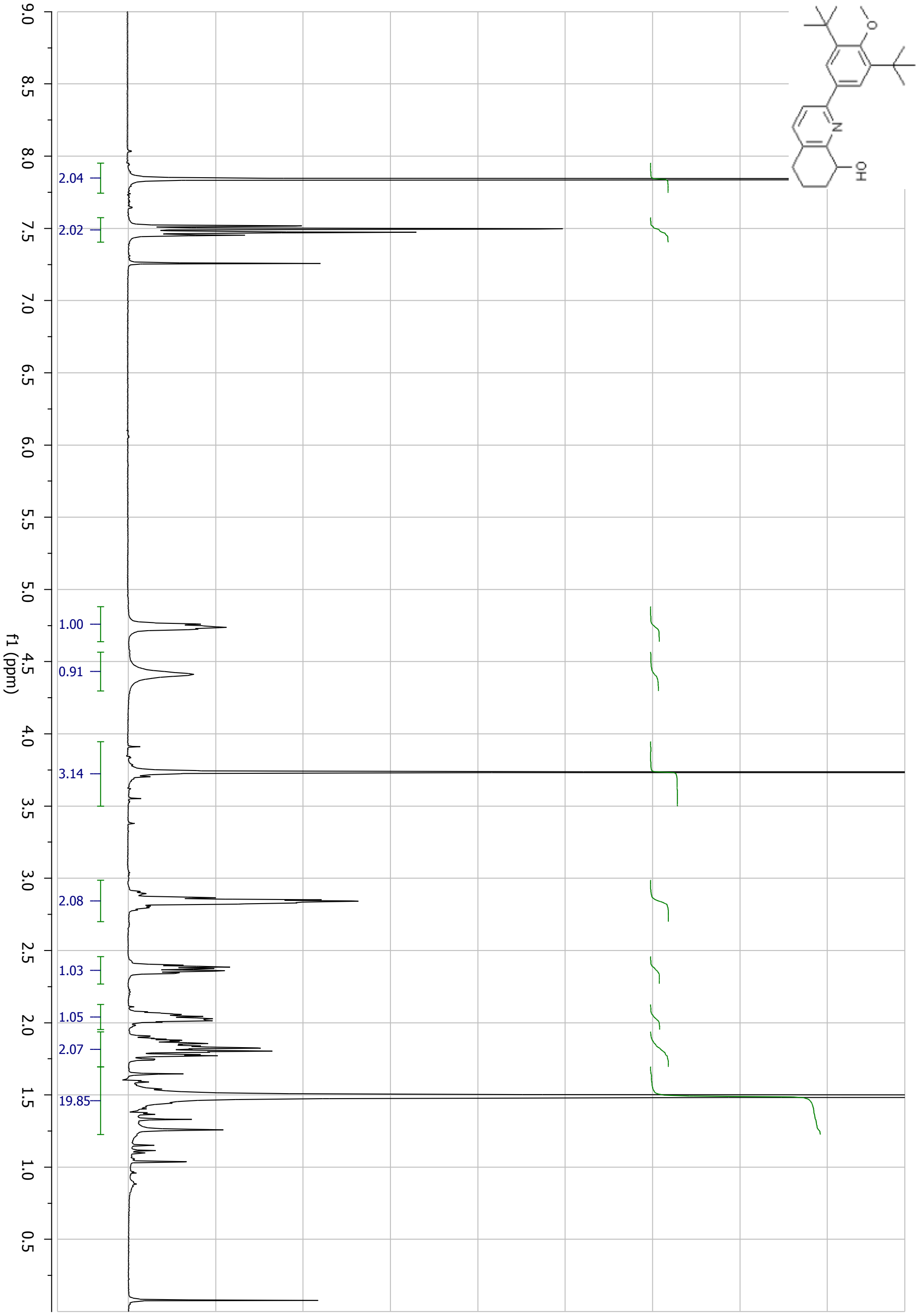

59-10-07-wood
DW329
C13CPD CDCl3 u500 wood 59
158.08
157.10
137.97
137.85
137.47
136.30
129.48
128.76
123.77
69.40
30.93
28.51
21.46
20.65
20.05
N
OH
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

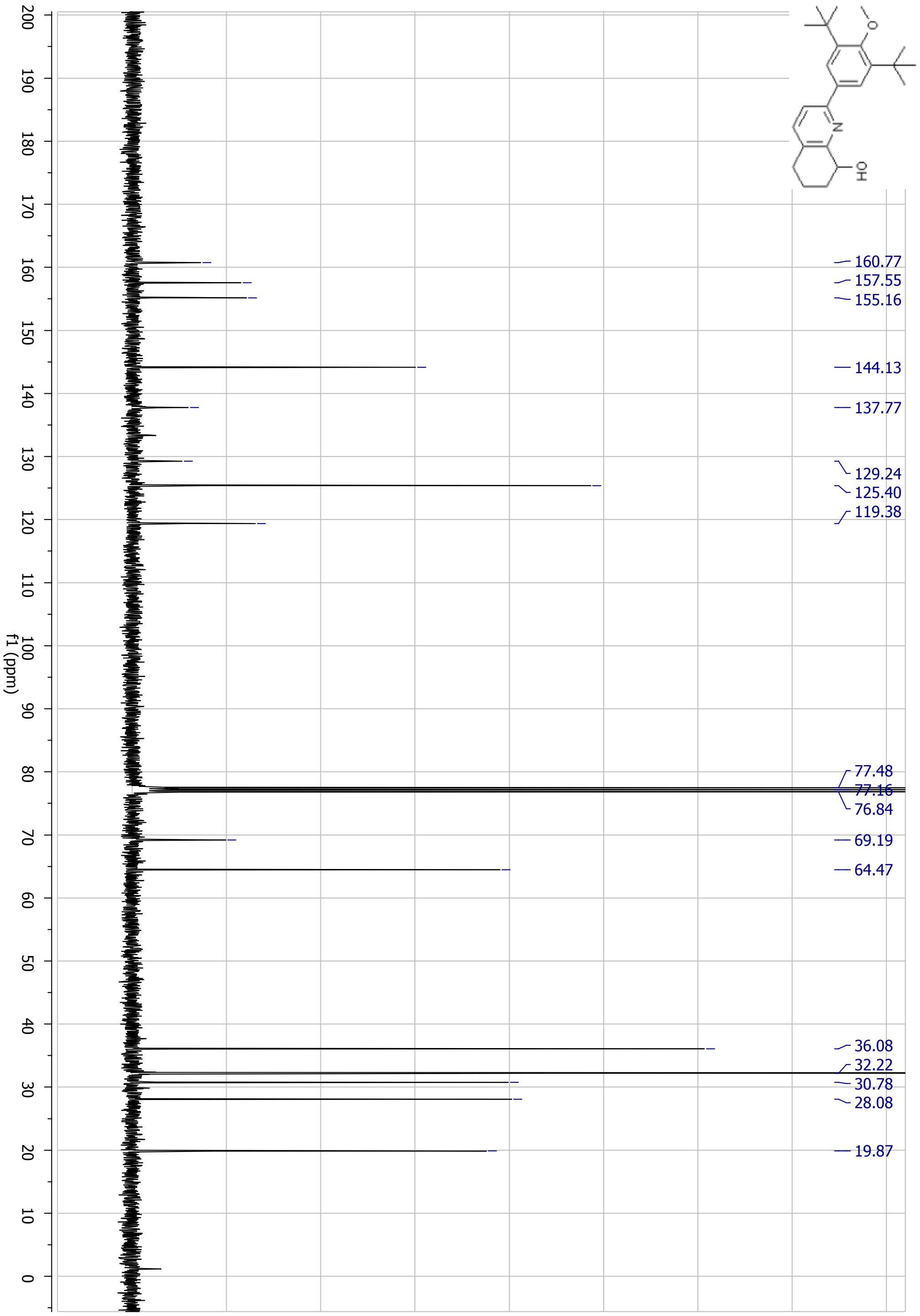
13. **12c** ^{1}H & ^{13}C


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)
1.99
0.98
0.99
0.96
2.99
1.00
0.98
1.01
3.00
1.00
18.14
O
N
OH

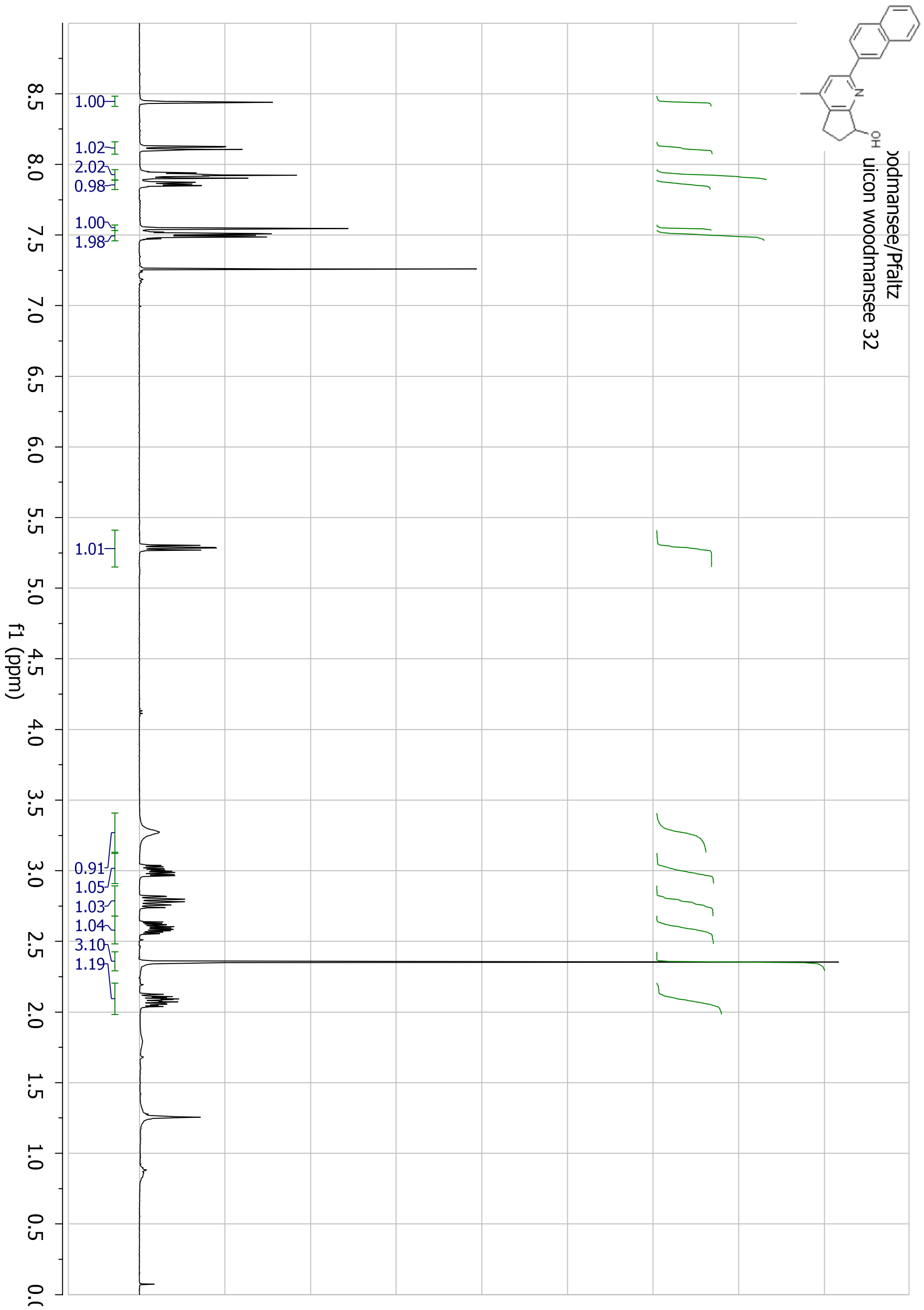

164.21
160.41
157.87
144.49
143.81
134.11
133.61
125.79
121.26
77.48
77.16
76.84
74.93
64.39
36.00
32.52
32.21
25.95
18.91
f1 (ppm)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
O
N
OH

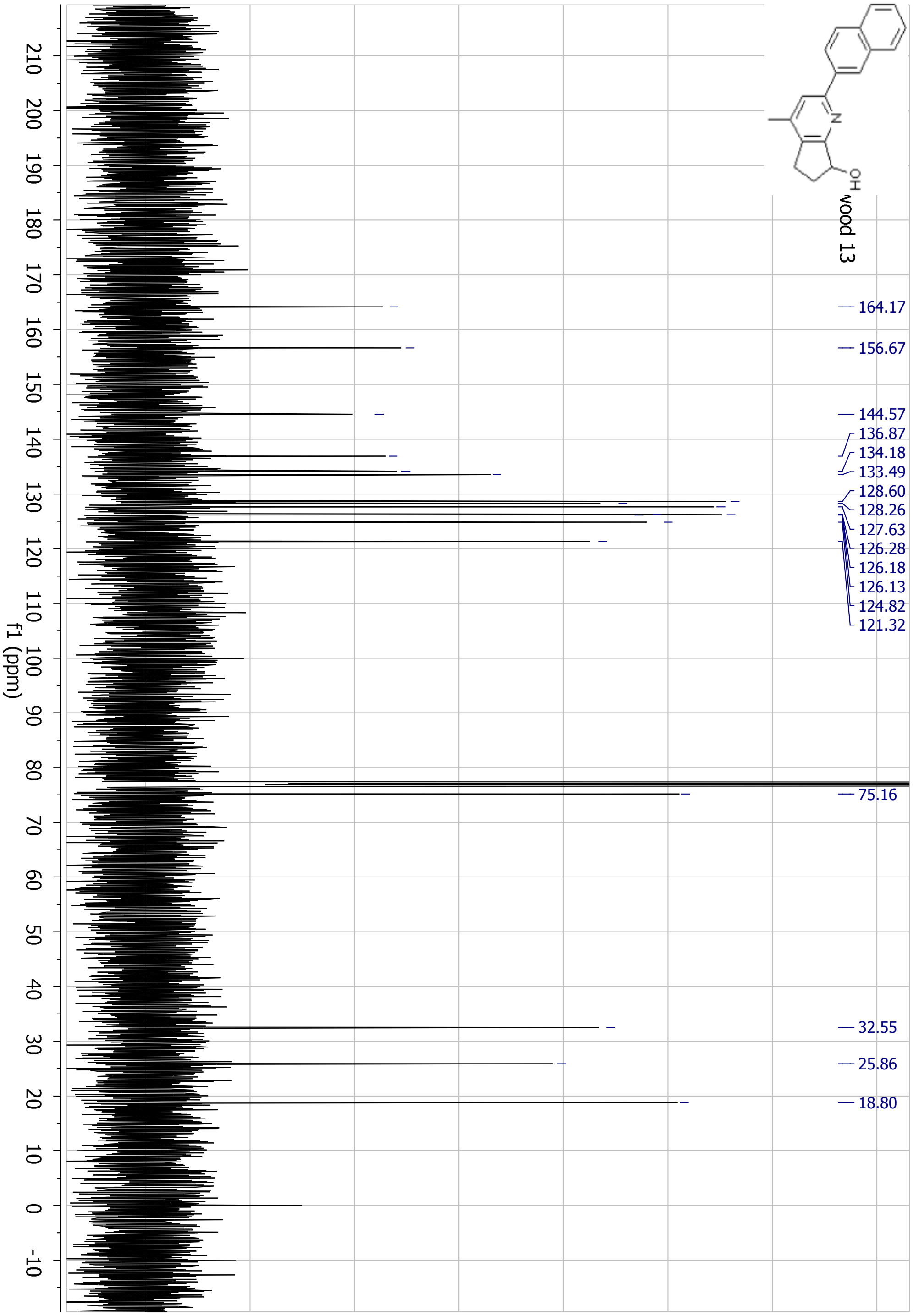
13. **12d** ^{1}H & ^{13}C


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)
2.04
2.02
1.00
0.91
3.14
2.08
1.03
1.05
2.07
19.85
O
N
OH

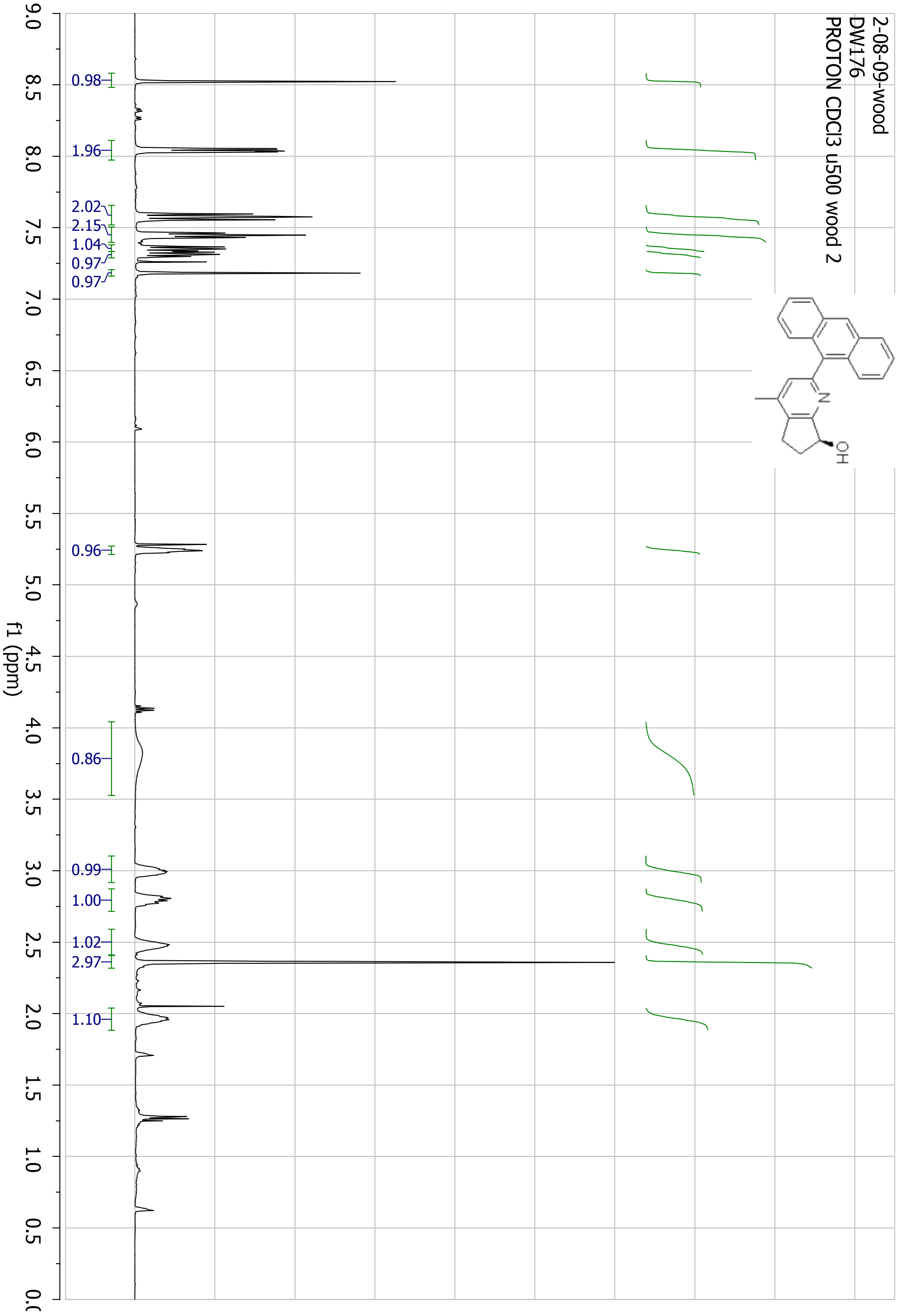

160.77
157.55
155.16
144.13
137.77
129.24
125.40
119.38
77.48
77.16
76.84
69.19
64.47
36.08
32.22
30.78
28.08
19.87
OH
N
O
f1 (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

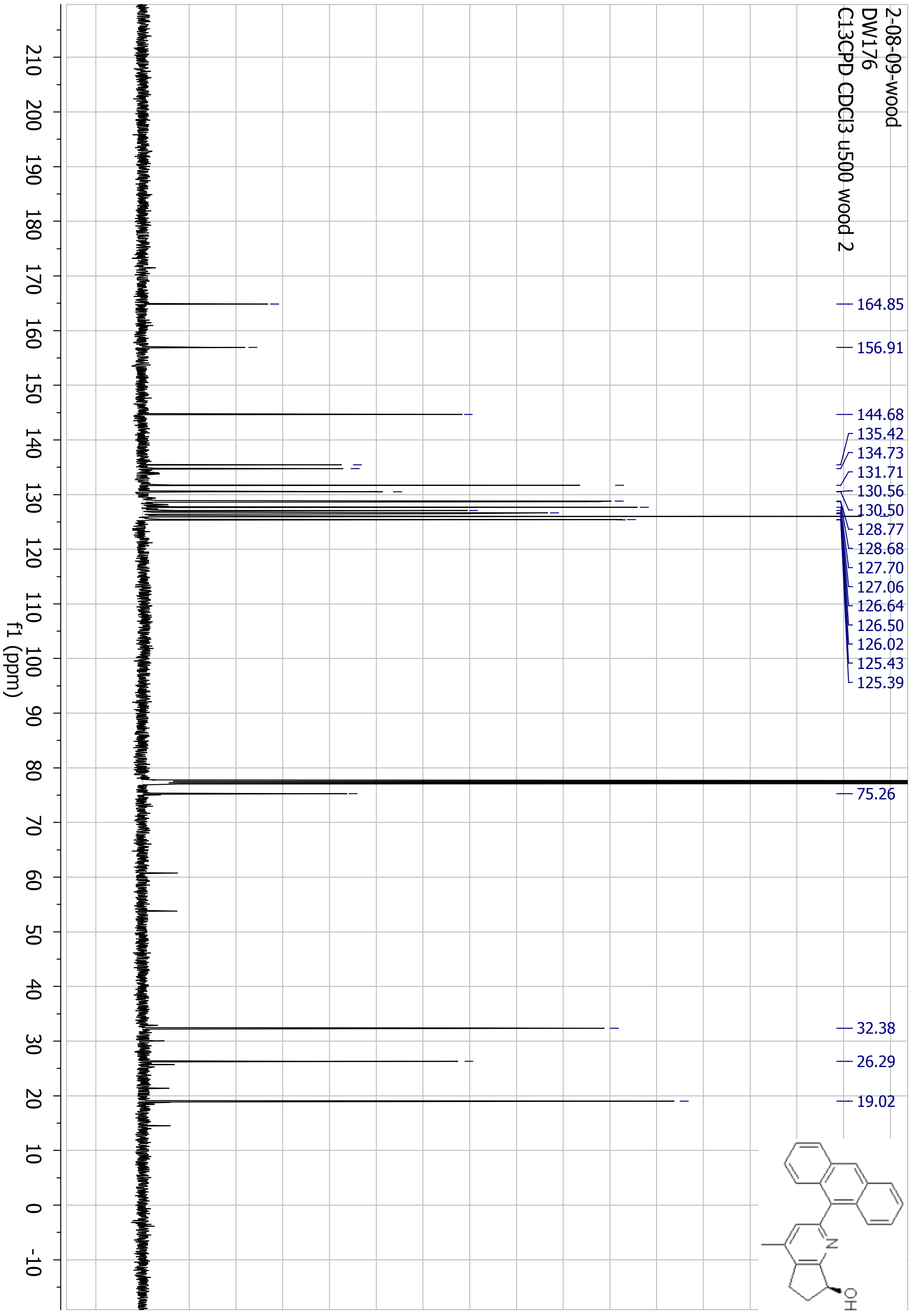
13. **12e** ^{1}H & ^{13}C


odmansee/Pfaltz
uicon woodmansee 32
N
OH
1.00
1.02
2.02
0.98
1.00
1.98
1.01
0.91
1.05
1.03
1.04
3.10
1.19
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)

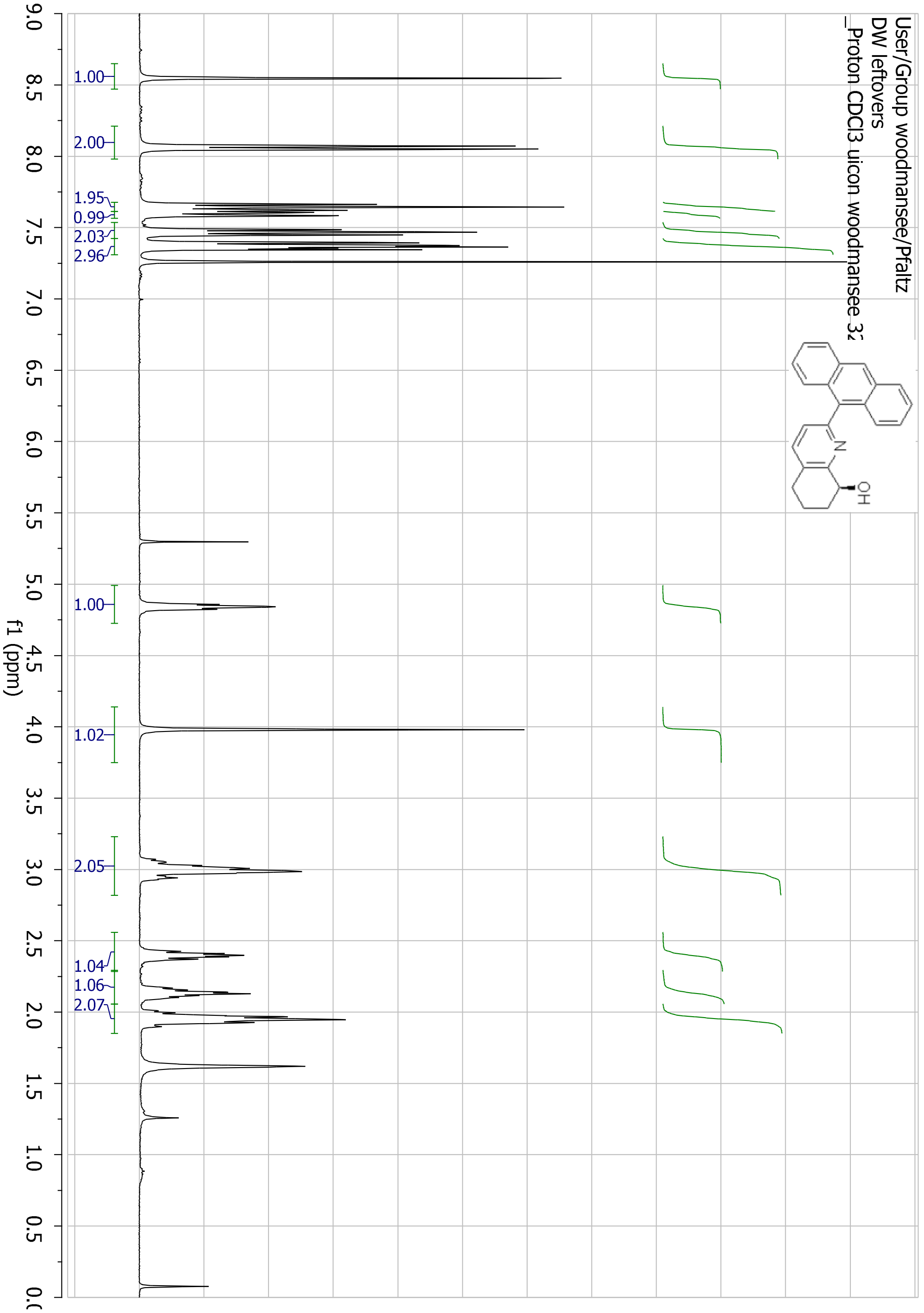

wood 13
OH
N
164.17
156.67
144.57
136.87
134.18
133.49
128.60
128.26
127.63
126.28
126.18
126.13
124.82
121.32
75.16
32.55
25.86
18.80
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

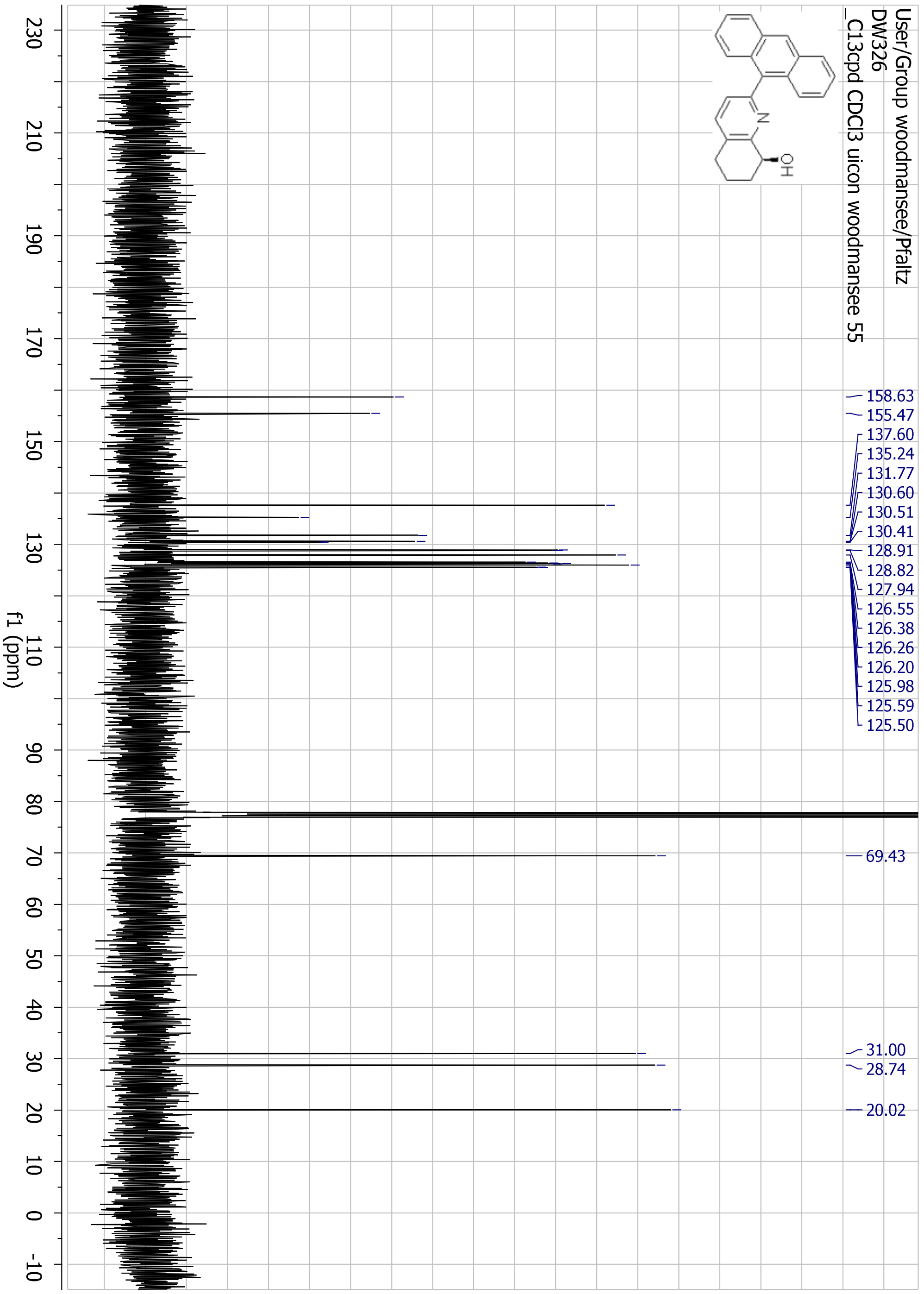
13. **12f** ^{1}H & ^{13}C


2-08-09-wood
DW176
PROTON CDCl3 u500 wood 2
0.98
1.96
2.02
2.15
1.04
0.97
0.97
0.96
0.86
0.99
1.00
1.02
2.97
1.10
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)
N
OH

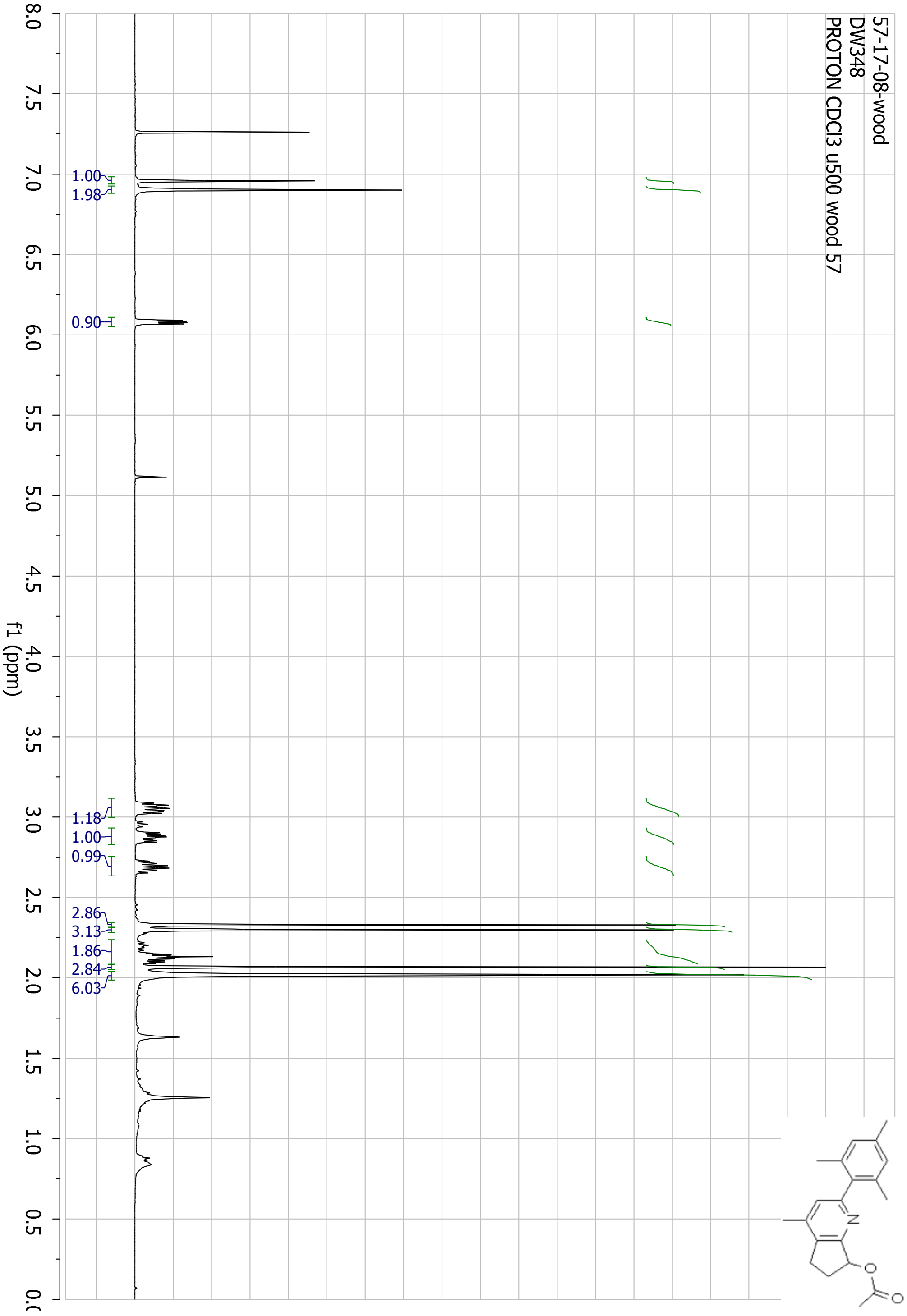

2-08-09-wood
DW176
C13CPD CDCl3 u500 wood 2
164.85
156.91
144.68
135.42
134.73
131.71
130.56
130.50
128.77
128.68
127.70
127.06
126.64
126.50
126.02
125.43
125.39
75.26
32.38
26.29
19.02
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)
N
OH

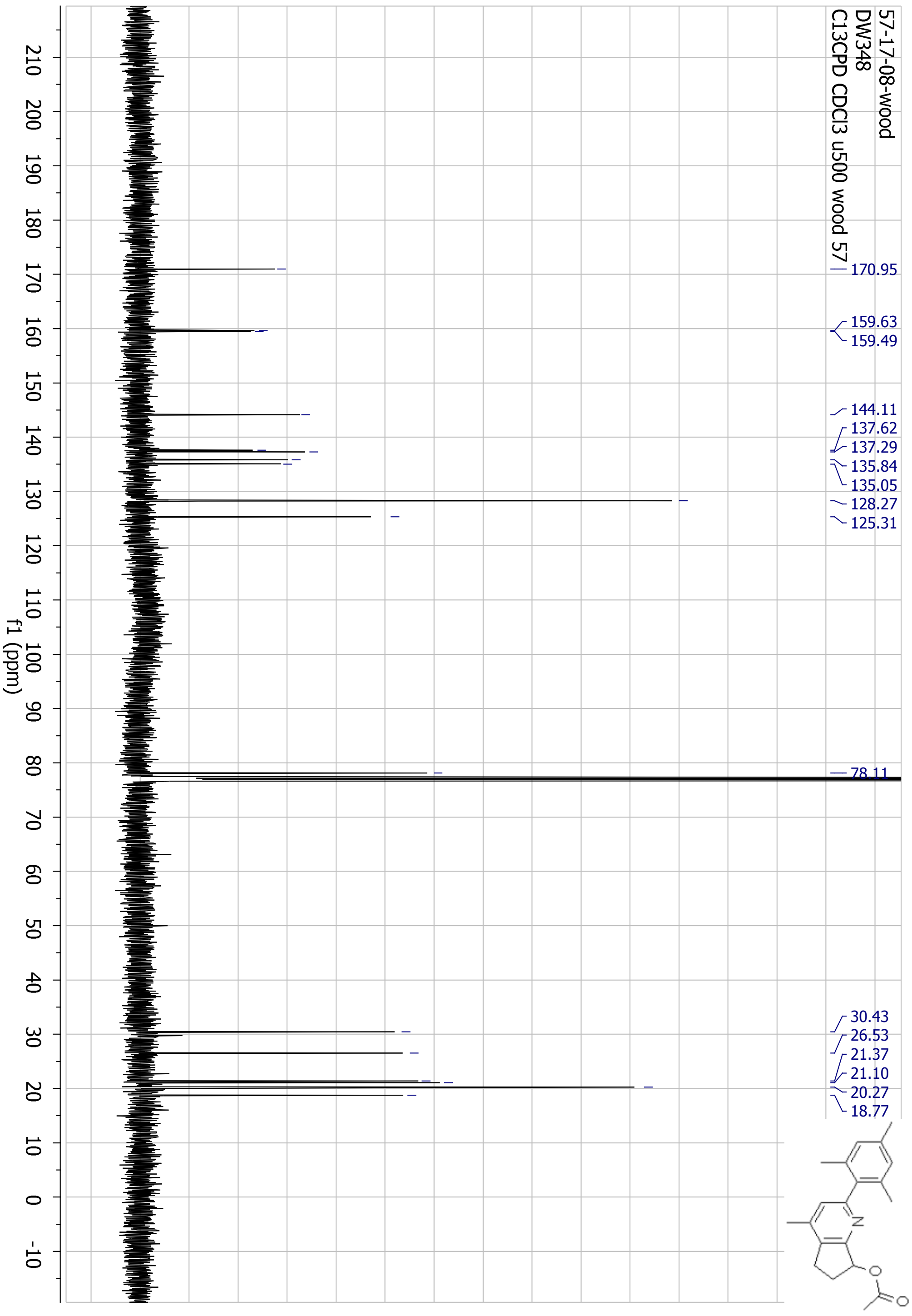
13. **12g** ^{1}H & ^{13}C


User/Group woodmansee/Pfaltz
DW leftovers
_Proton CDCl3 uicon woodmansee 3
OH
N
1.00
2.00
1.95
0.99
2.03
2.96
1.00
1.02
2.05
1.04
1.06
2.07
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)

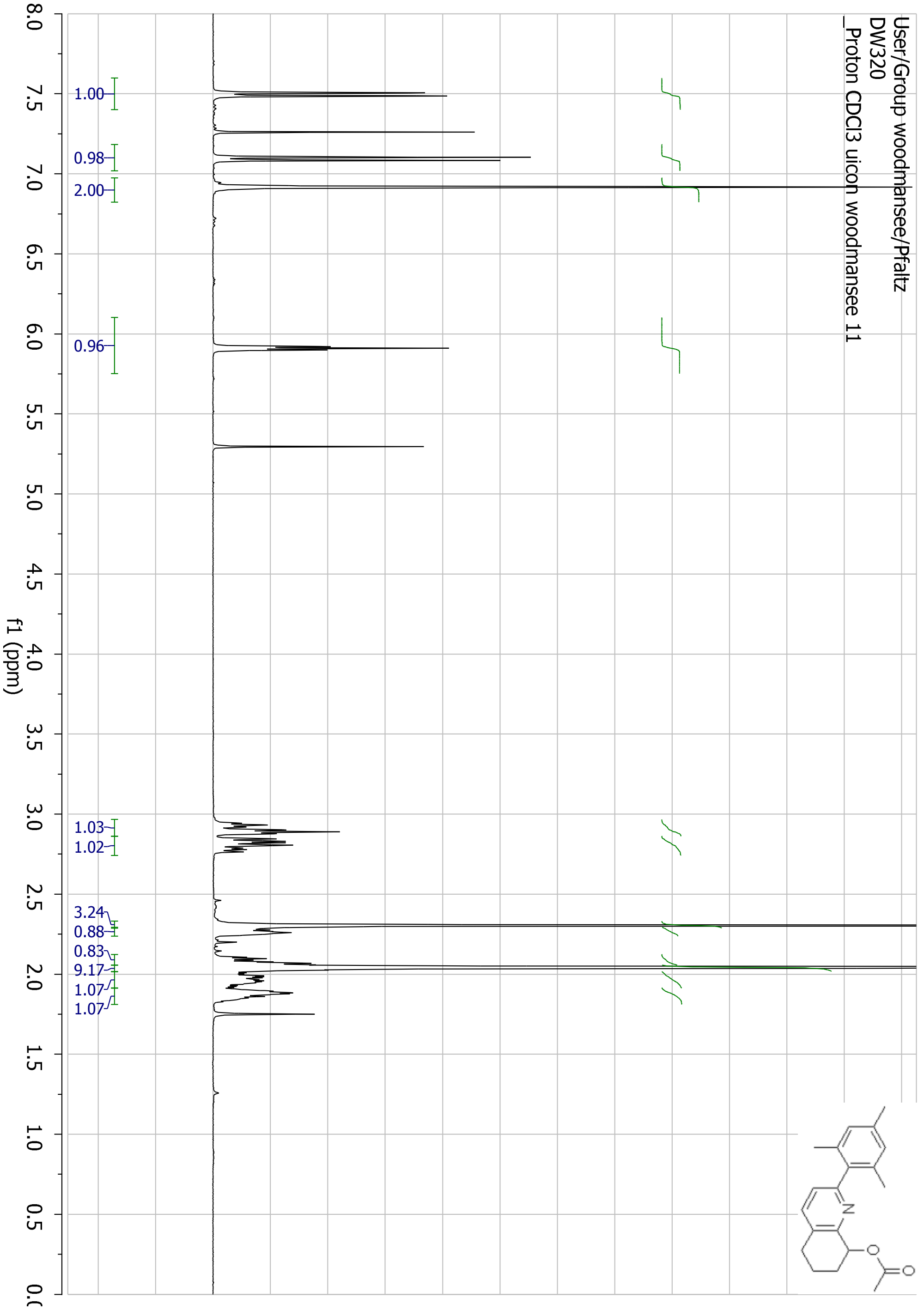

User/Group woodmansee/Pfaltz
DW326
_C13cpd CDCl3 uicon woodmansee 55
N
OH
158.63
155.47
137.60
135.24
131.77
130.60
130.51
130.41
128.91
128.82
127.94
126.55
126.38
126.26
126.20
125.98
125.59
125.50
69.43
31.00
28.74
20.02
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

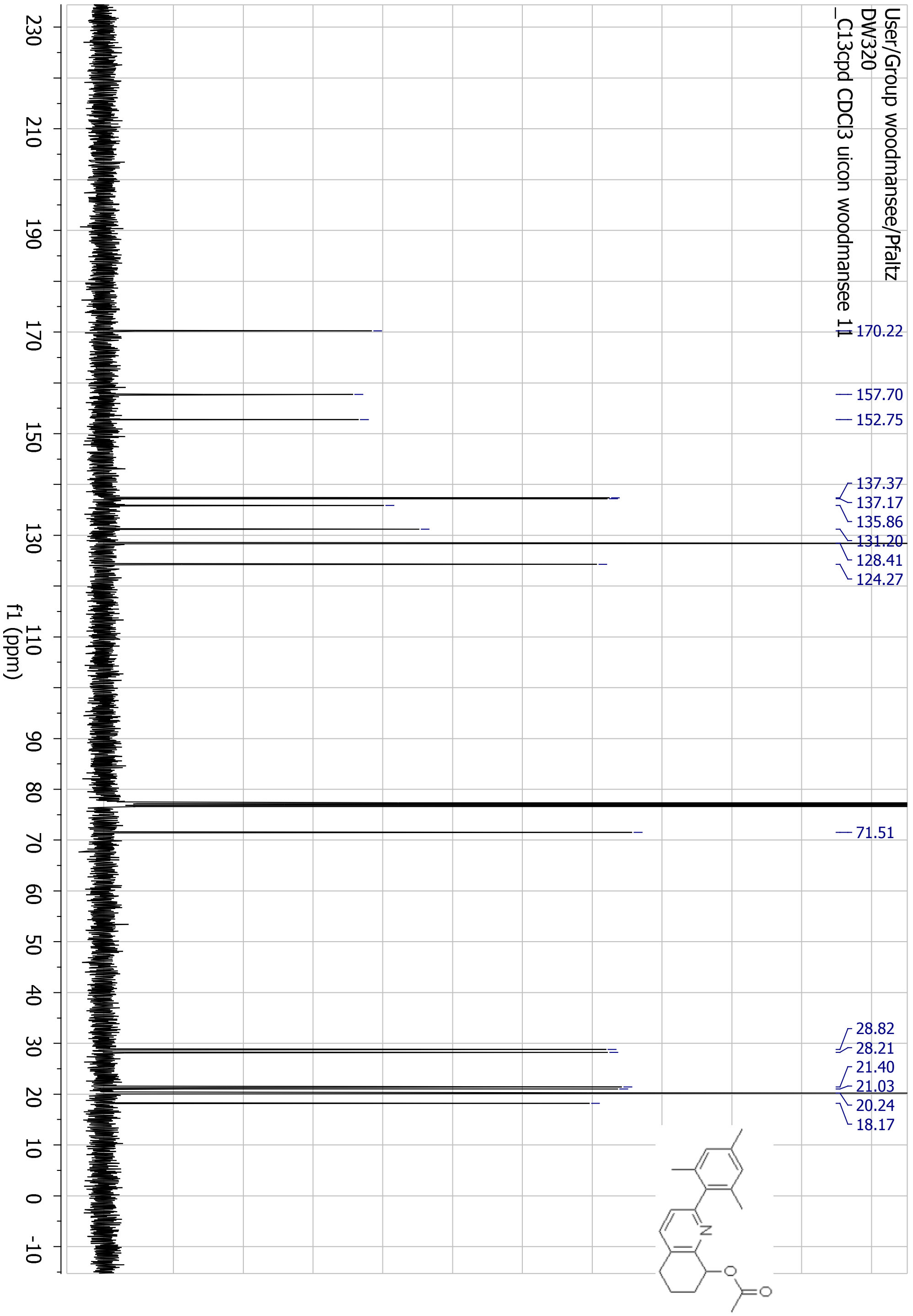
13. **11a** ^{1}H & ^{13}C


57-17-08-wood
DW348
PROTON CDCl3 u500 wood 57
1.00
1.98
0.90
1.18
1.00
0.99
2.86
3.13
1.86
2.84
6.03
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)
N
O
O

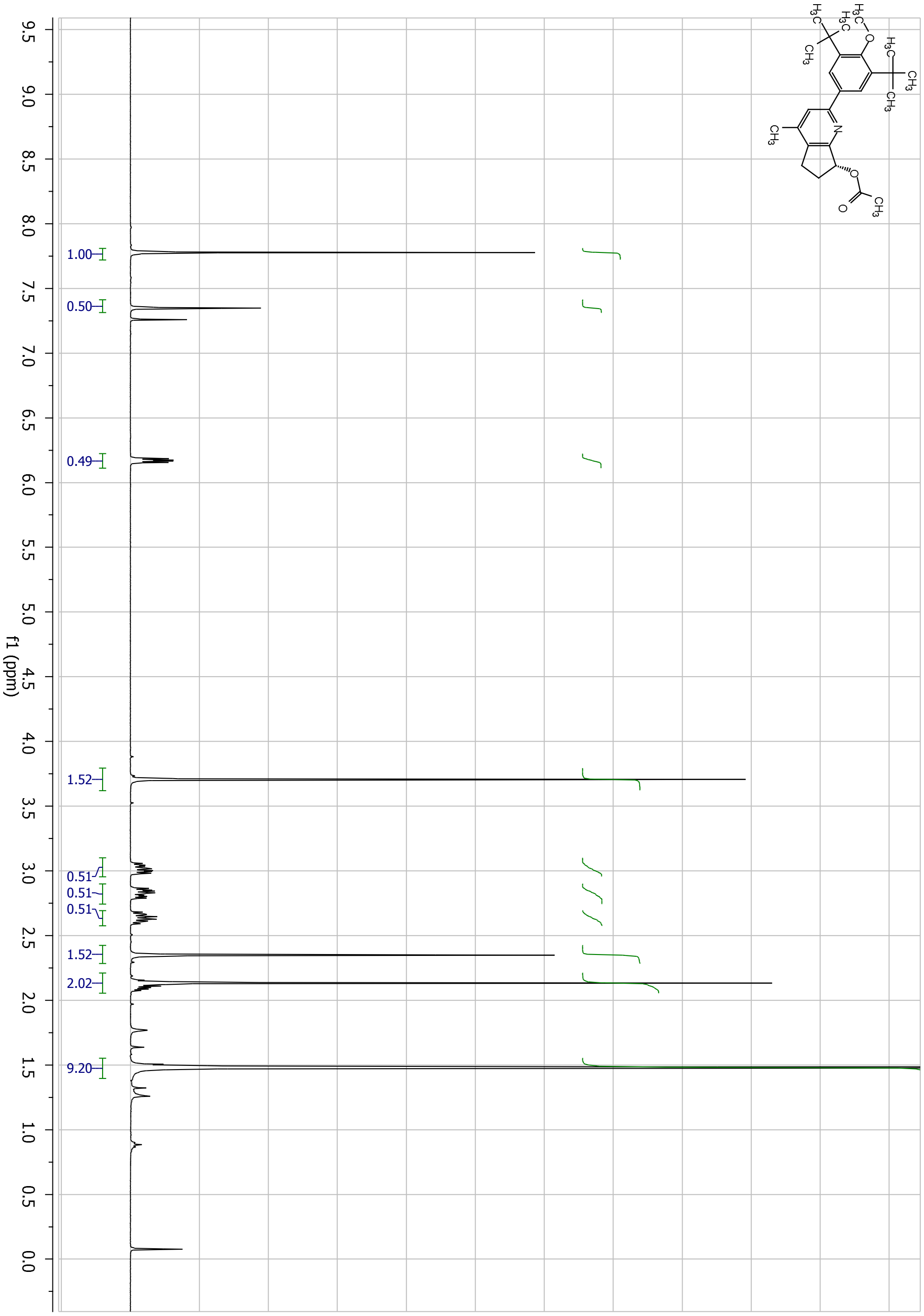

57-17-08-wood
DW348
C13CPD CDCl3 u500 wood 57
170.95
159.63
159.49
144.11
137.62
137.29
135.84
135.05
128.27
125.31
78.11
30.43
26.53
21.37
21.10
20.27
18.77
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)
N
O
O

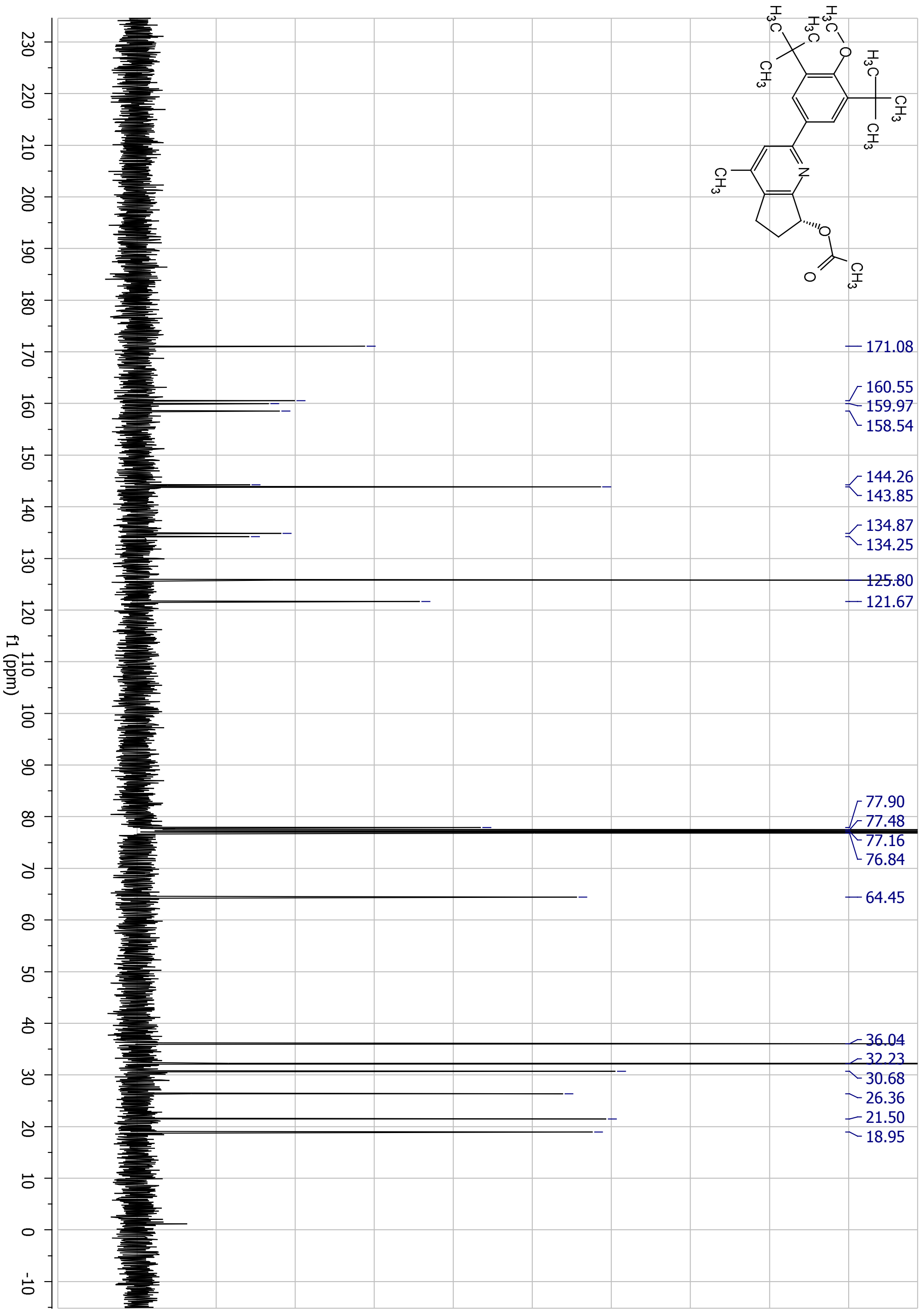
13. **11b** ^{1}H & ^{13}C


User/Group woodmansee/Pfaltz
DW320
_Proton CDCl3 uicon woodmansee 11
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)
1.00
0.98
2.00
0.96
1.03
1.02
3.24
0.88
0.83
9.17
1.07
1.07
N
O
O

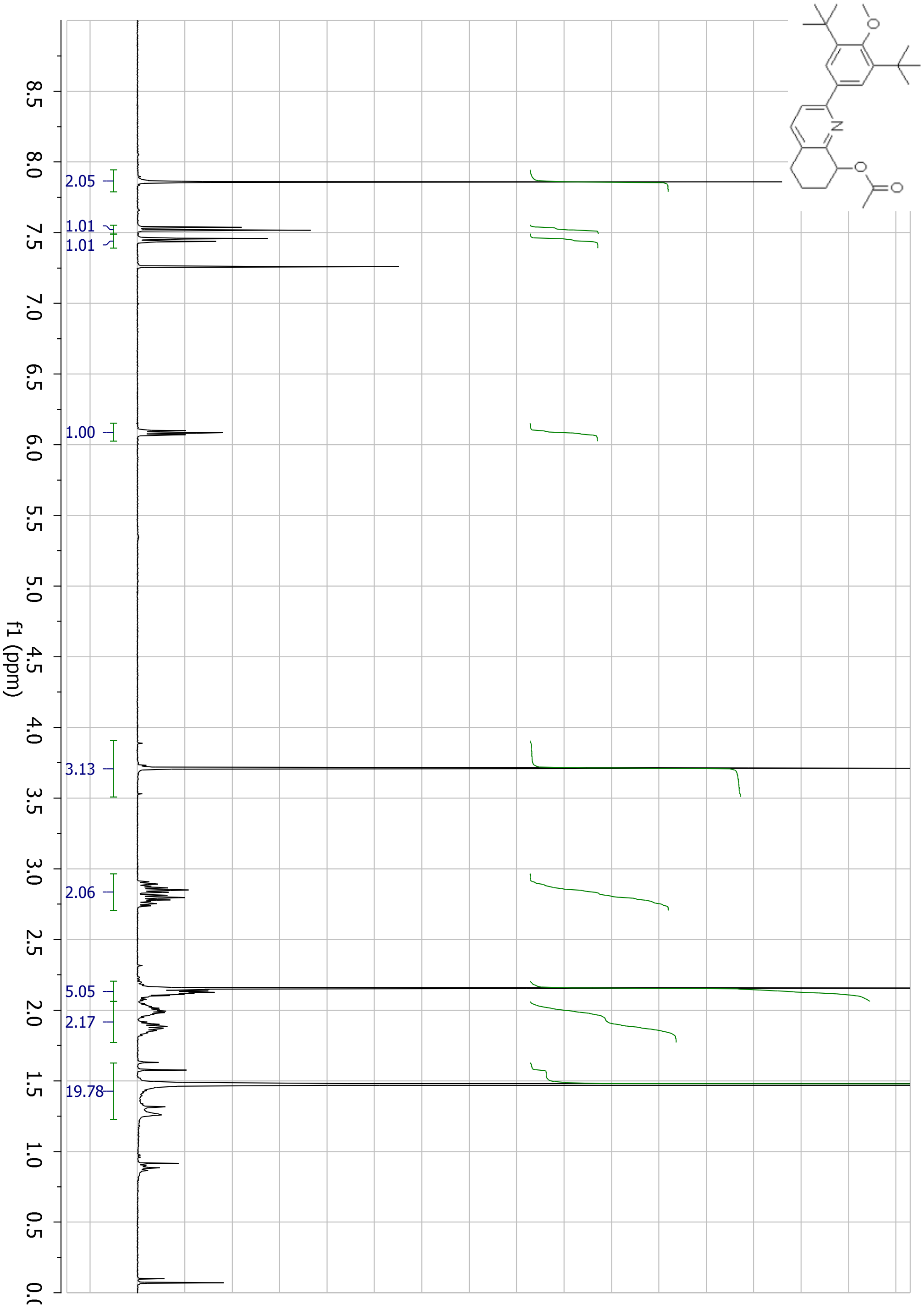

User/Group woodmansee/Pfaltz
DW320
_C13cpd CDCl3 uicon woodmansee 11
170.22
157.70
152.75
137.37
137.17
135.86
131.20
128.41
124.27
71.51
28.82
28.21
21.40
21.03
20.24
18.17
N
O
O
f1 (ppm)
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10

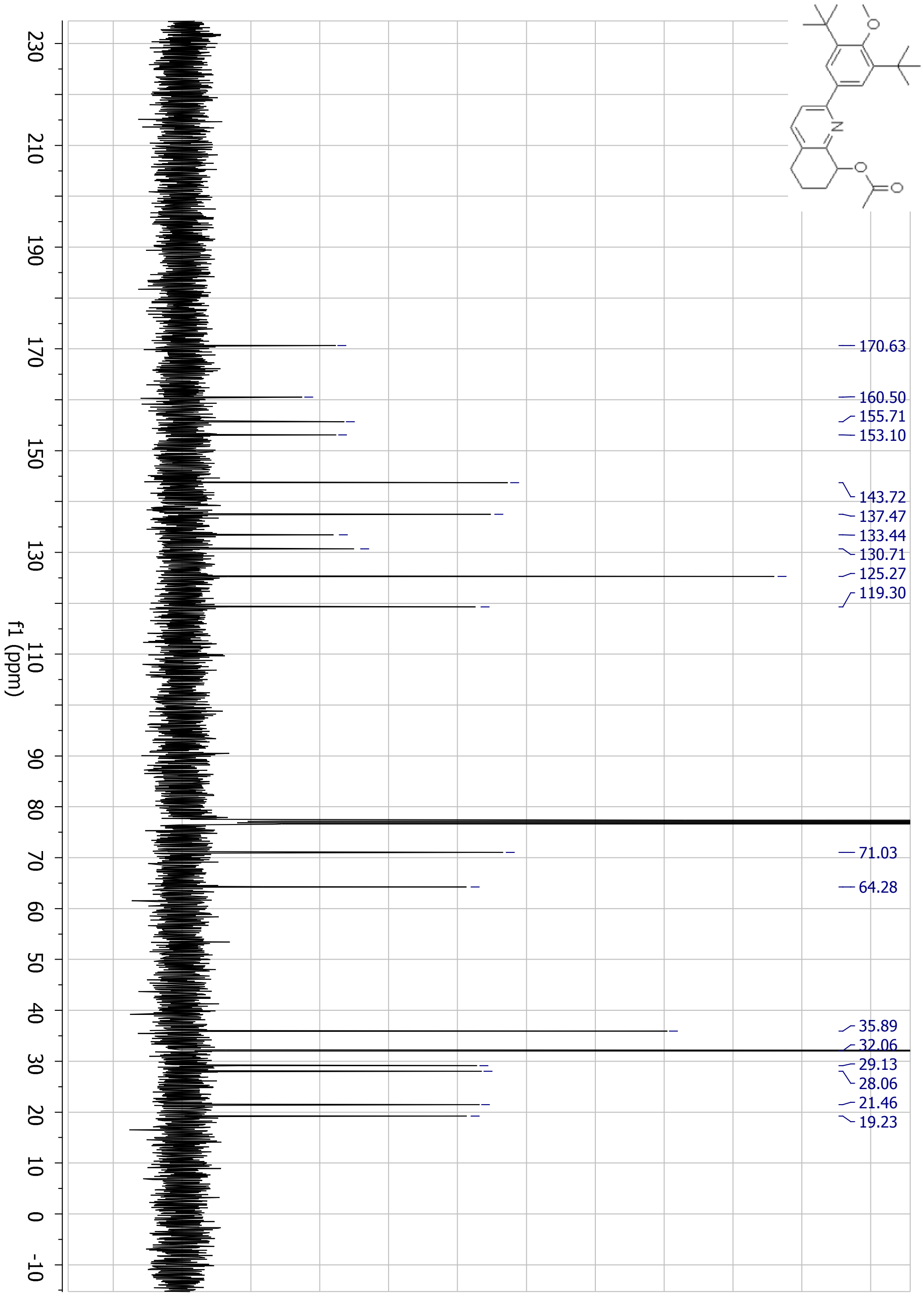
13. **12c-OAc** ^{1}H & ^{13}C



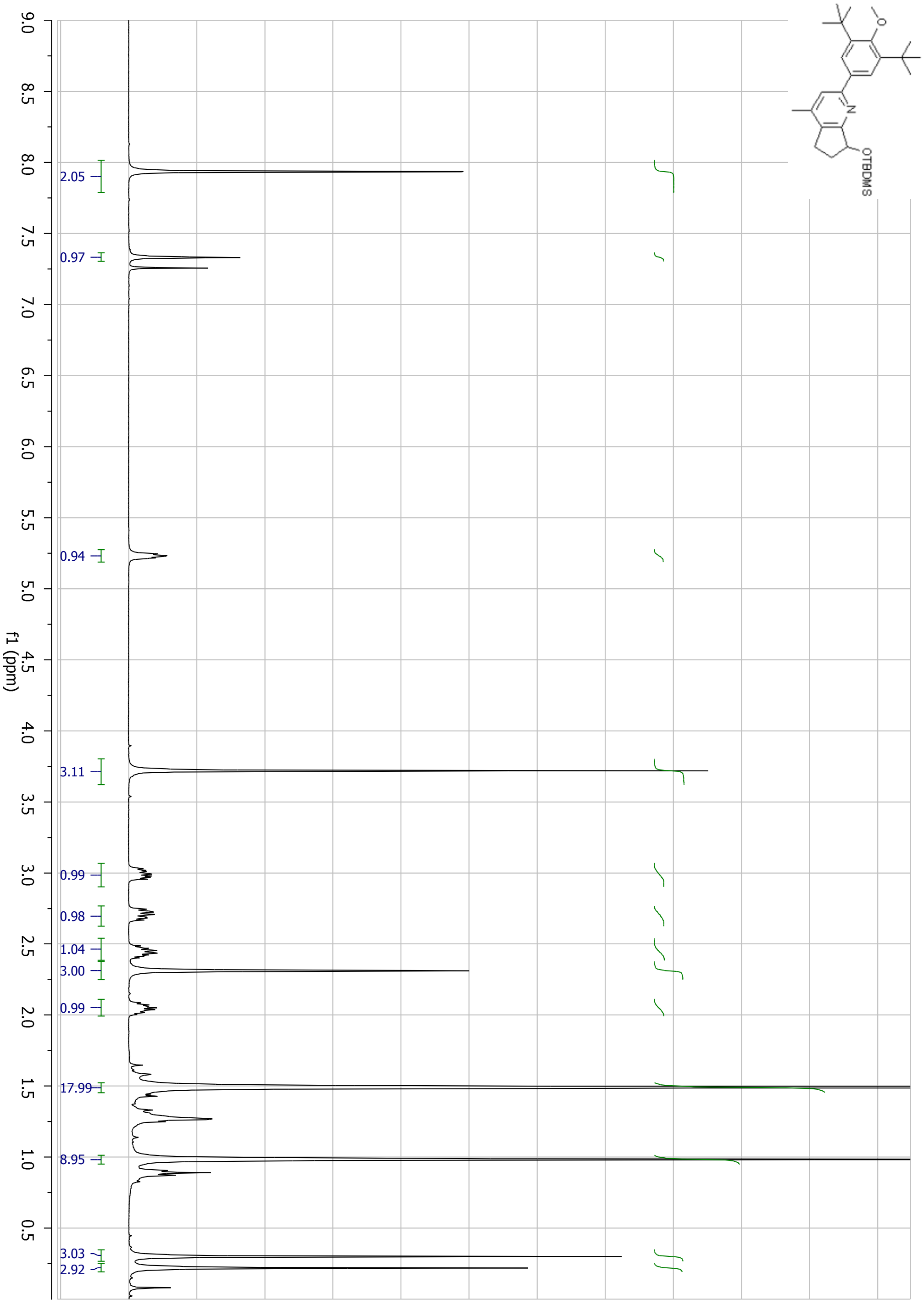

171.08
160.55
159.97
158.54
144.26
143.85
134.87
134.25
125.80
121.67
77.90
77.48
77.16
76.84
64.45
36.04
32.23
30.68
26.36
21.50
18.95
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)
H3C
CH3
O
N
CH3
CH3

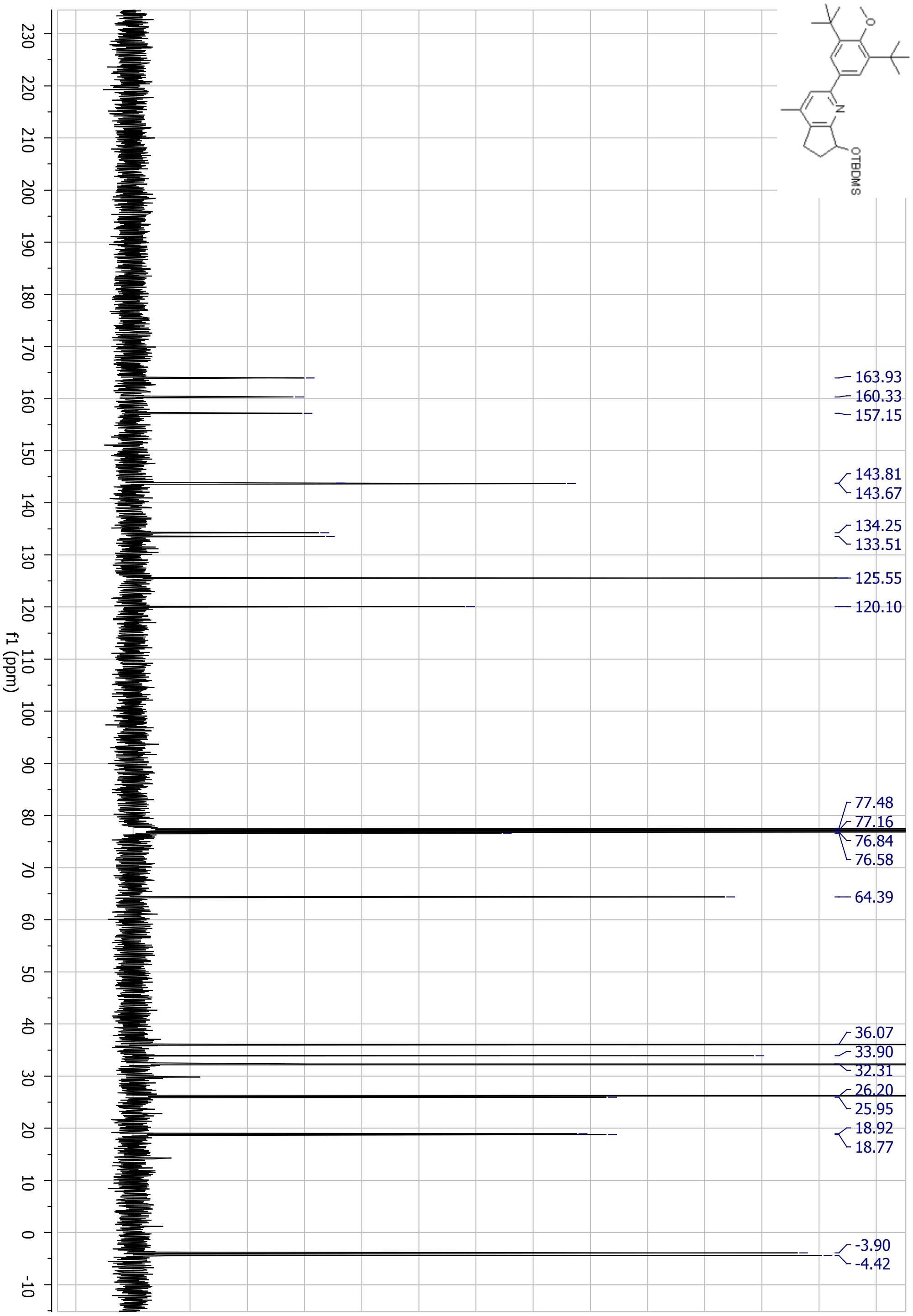
13. **12d-OAc** ^{1}H & ^{13}C



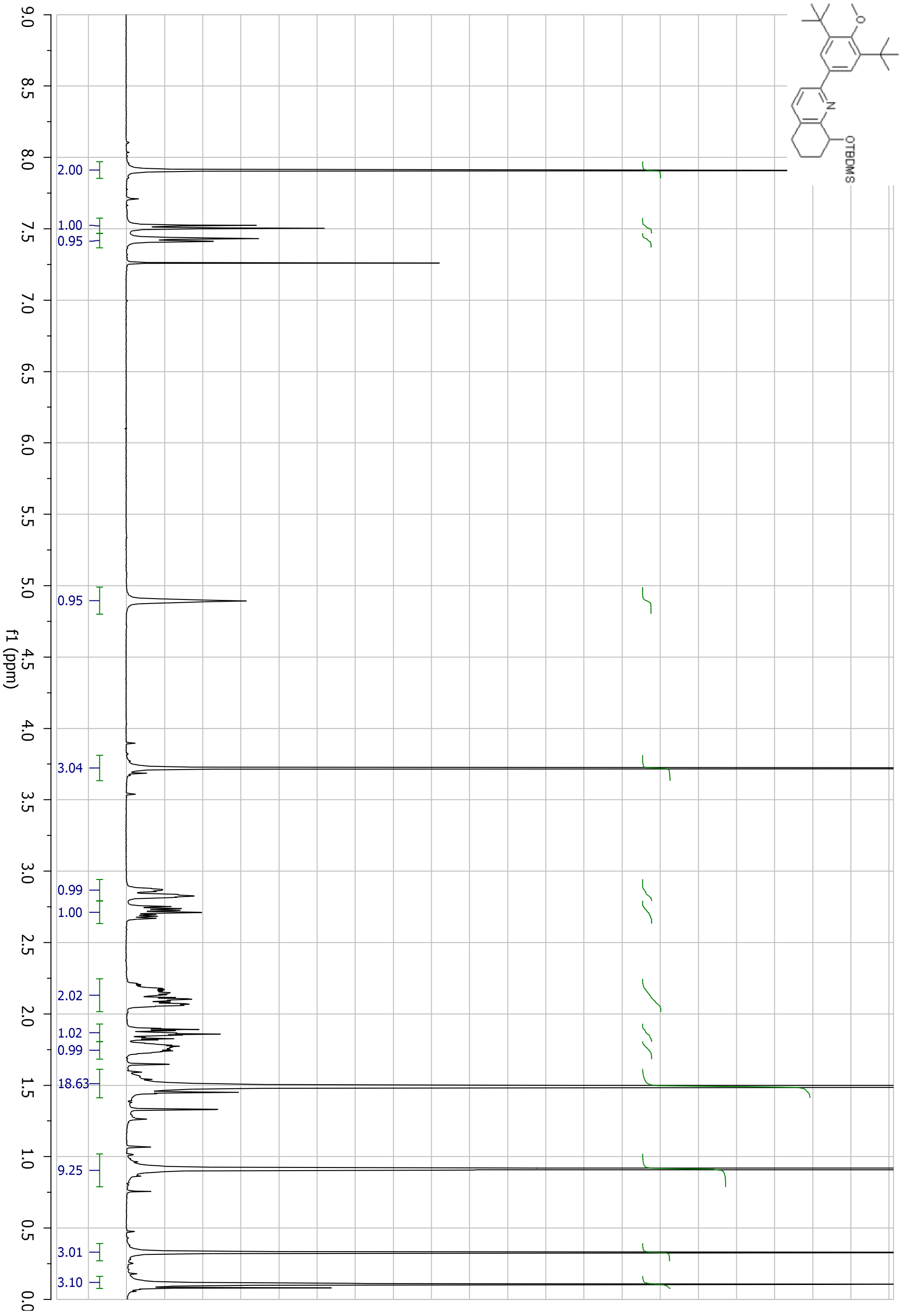

N
O
O
O
230
210
190
170
150
130
110
f1 (ppm)
90
80
70
60
50
40
30
20
10
0
-10
170.63
160.50
155.71
153.10
143.72
137.47
133.44
130.71
125.27
119.30
71.03
64.28
35.89
32.06
29.13
28.06
21.46
19.23

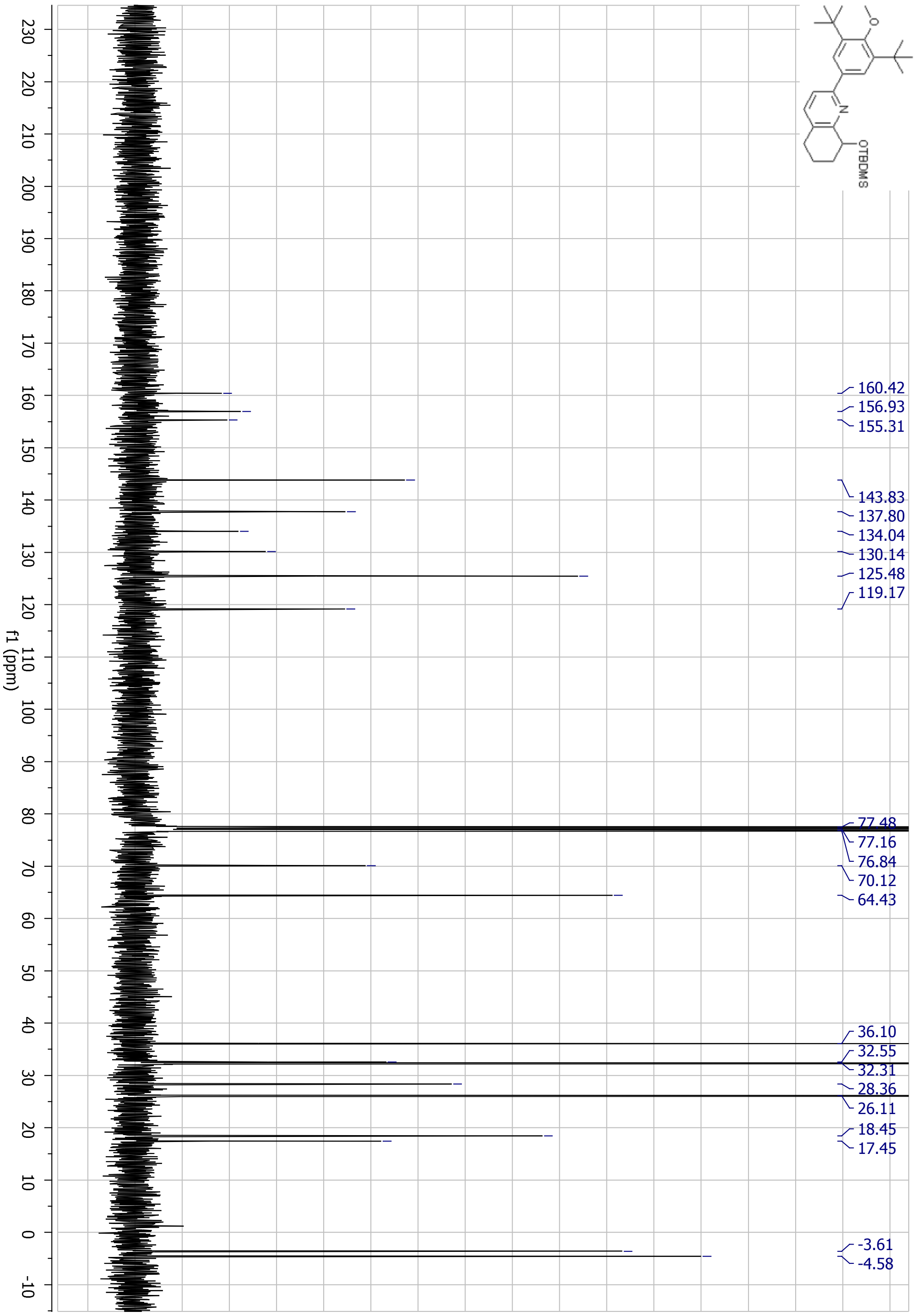
13. **14a** ^{1}H & ^{13}C


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)
2.05
0.97
0.94
3.11
0.99
0.98
1.04
3.00
0.99
17.99
8.95
3.03
2.92
N
O
OTBDMS

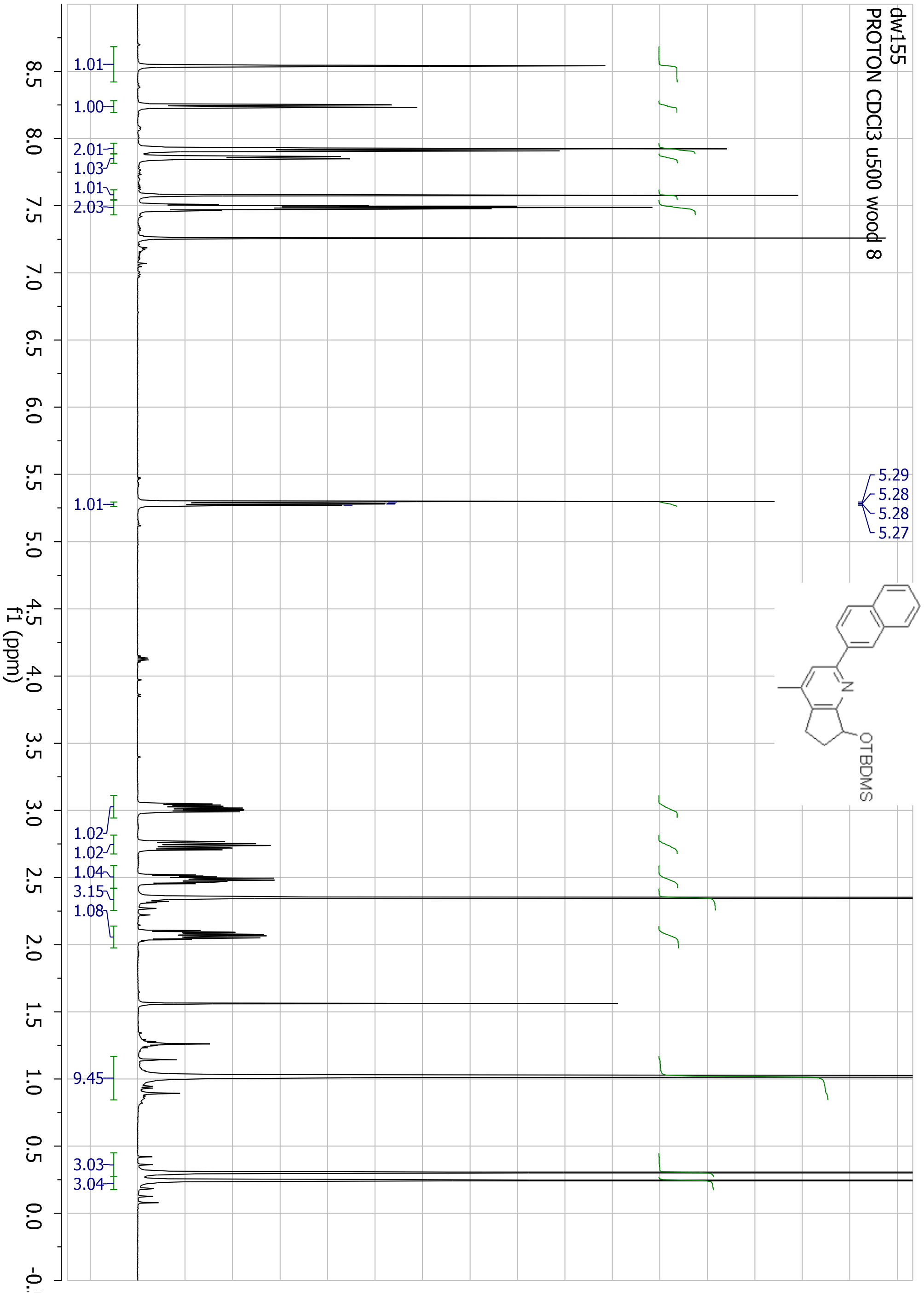

O
N
OTBDMS
163.93
160.33
157.15
143.81
143.67
134.25
133.51
125.55
120.10
77.48
77.16
76.84
76.58
64.39
36.07
33.90
32.31
26.20
25.95
18.92
18.77
-3.90
-4.42
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

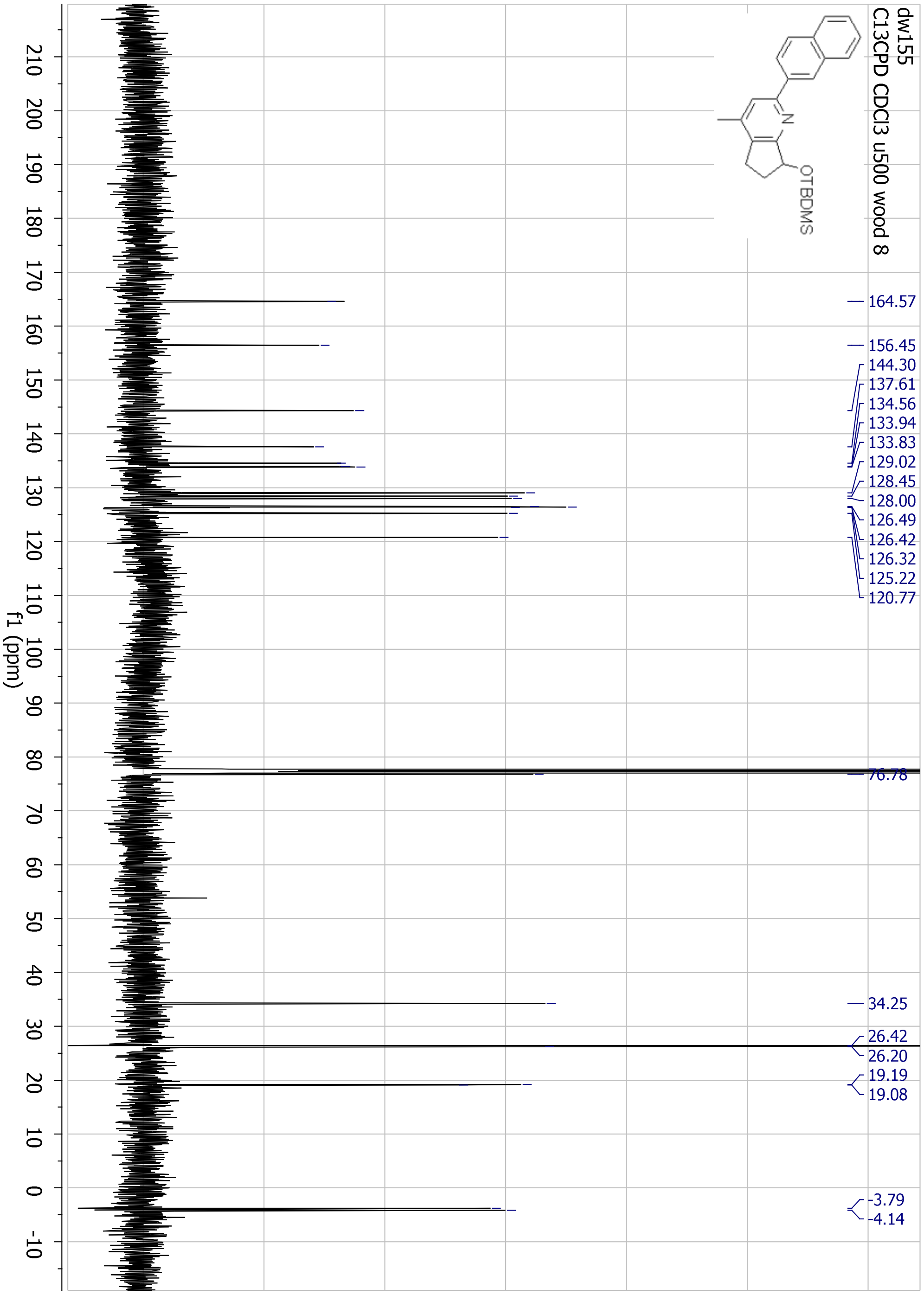
13. **14b** ^{1}H & ^{13}C


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)
2.00
1.00
0.95
0.95
3.04
0.99
1.00
2.02
1.02
0.99
18.63
9.25
3.01
3.10
O
N
OTBDMS

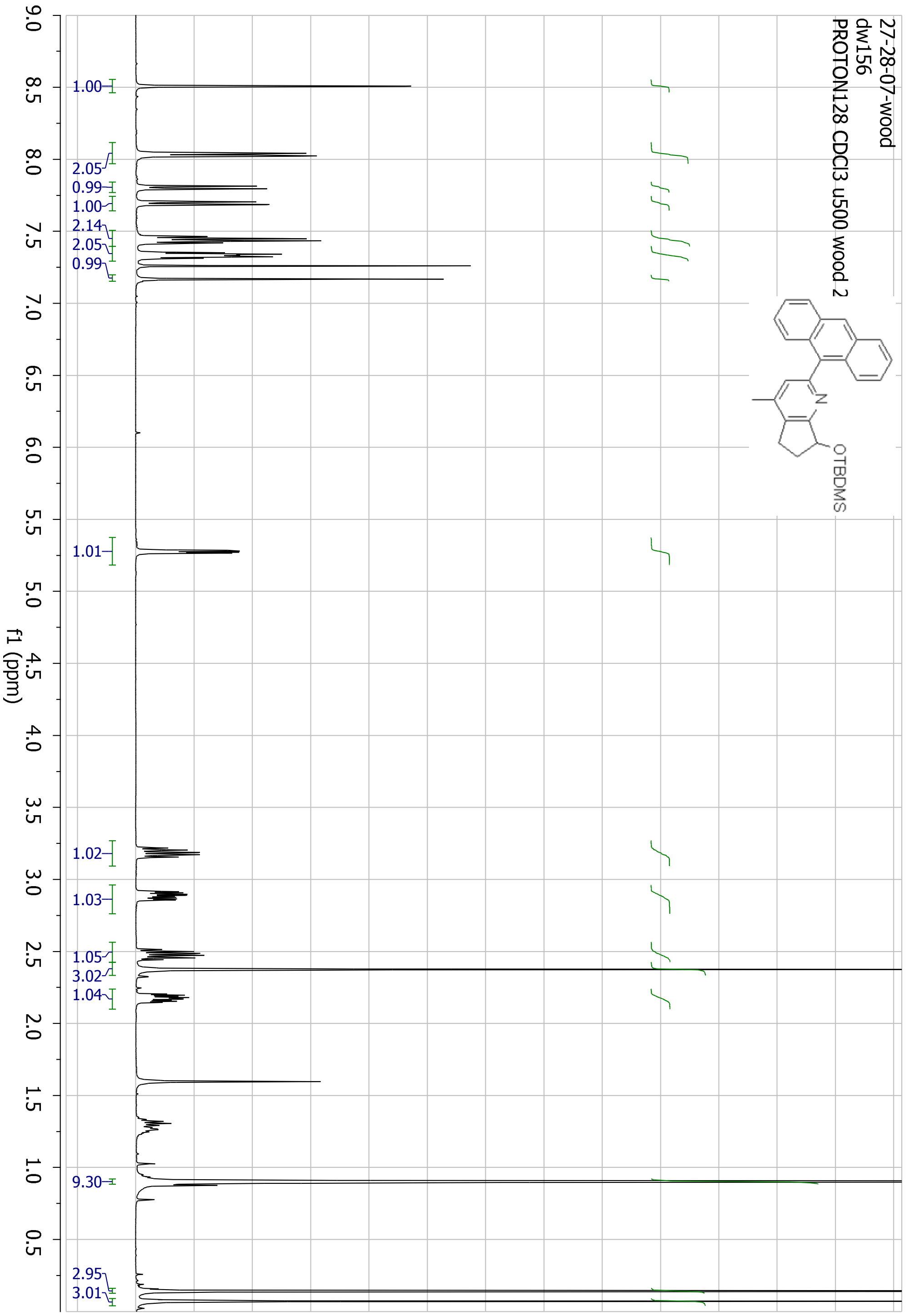

N
O
OTBDMS
160.42
156.93
155.31
143.83
137.80
134.04
130.14
125.48
119.17
77.48
77.16
76.84
70.12
64.43
36.10
32.55
32.31
28.36
26.11
18.45
17.45
-3.61
-4.58
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

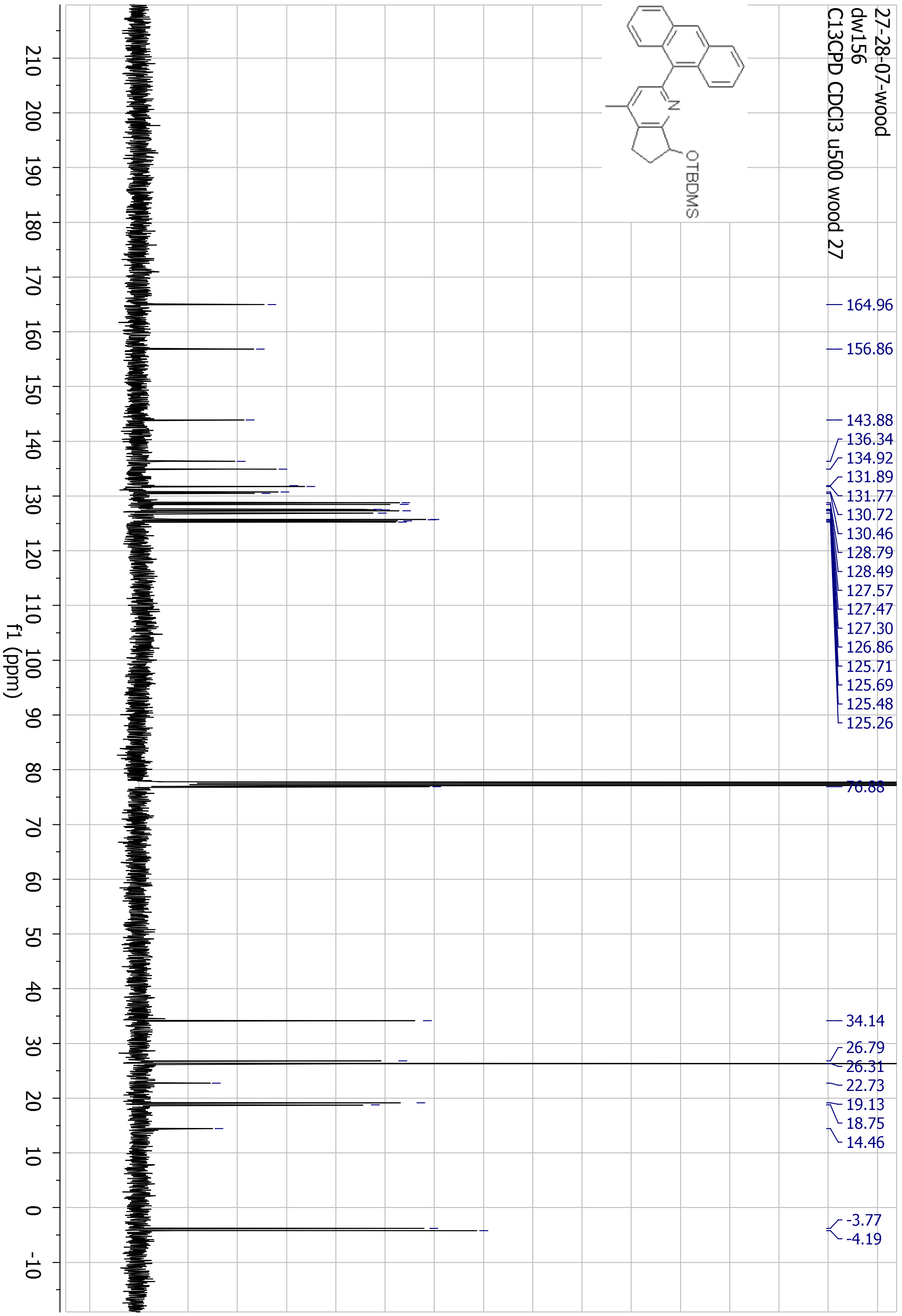
13. **12e-OTBDMS** ^{1}H & ^{13}C



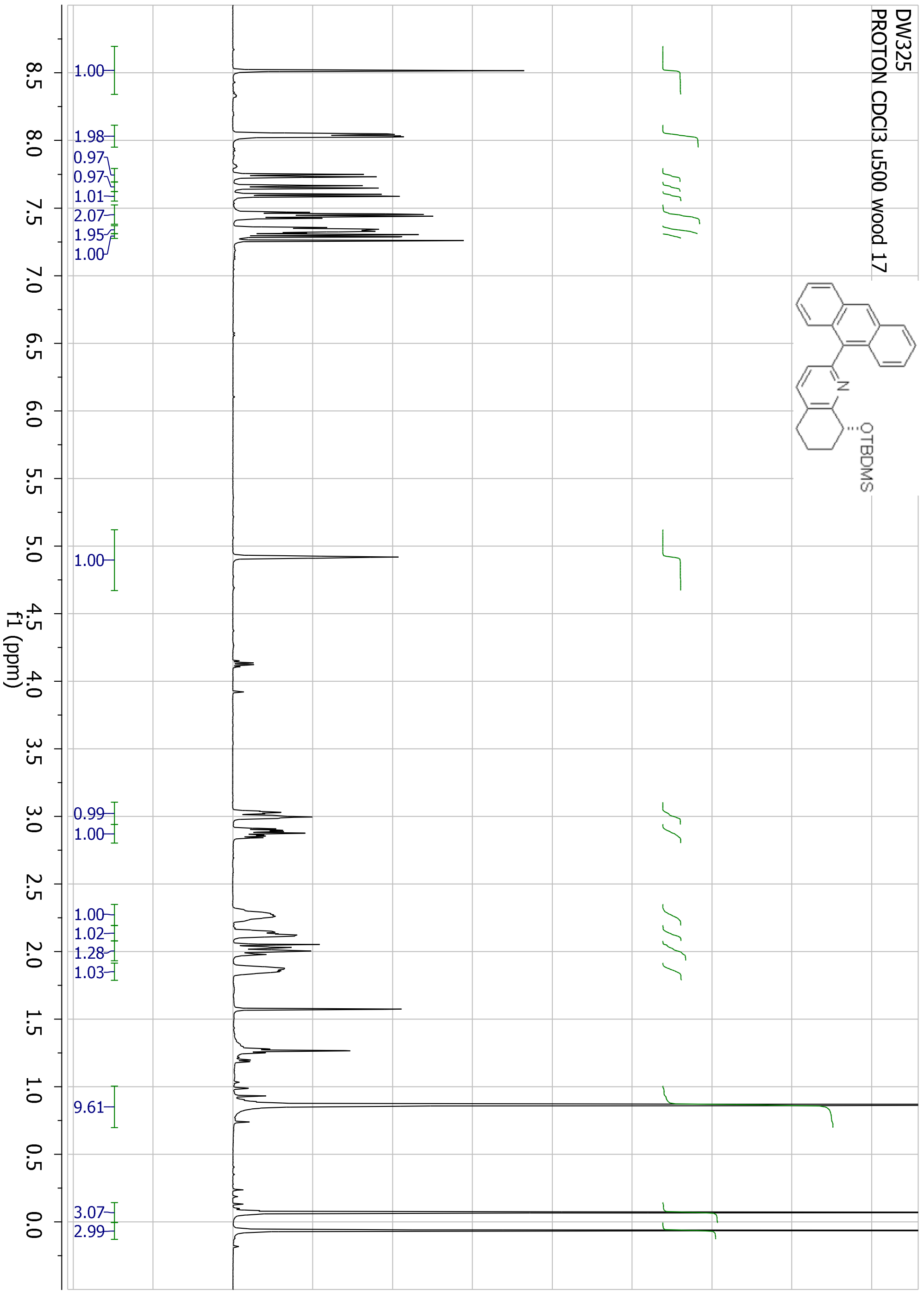

dw155
C13CPD CDCl3 u500 wood 8
N
OTBDMS
164.57
156.45
144.30
137.61
134.56
133.94
133.83
129.02
128.45
128.00
126.49
126.42
126.32
125.22
120.77
76.78
34.25
26.42
26.20
19.19
19.08
-3.79
-4.14
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

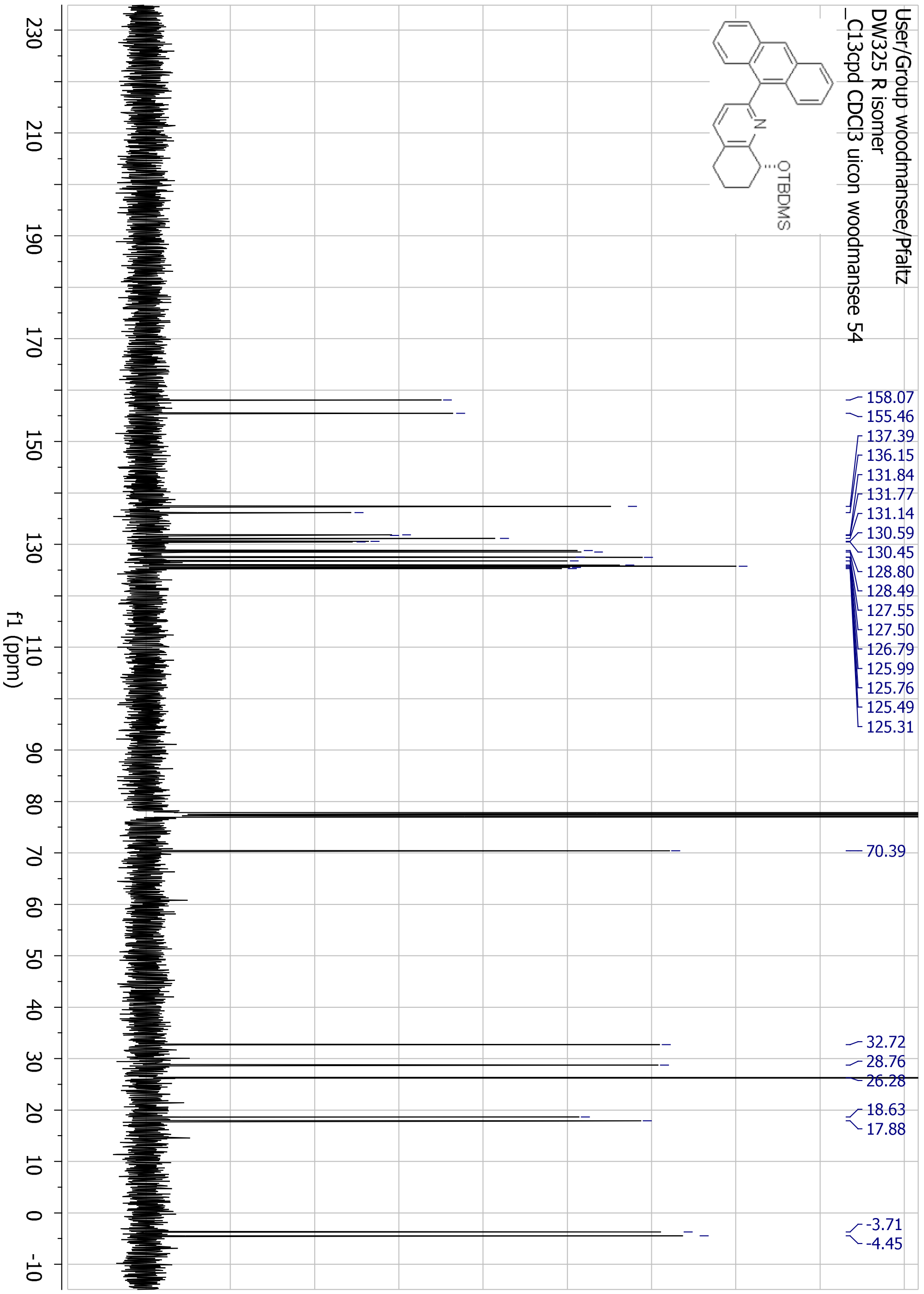
13. **12f-OTBDMS** ^{1}H & ^{13}C



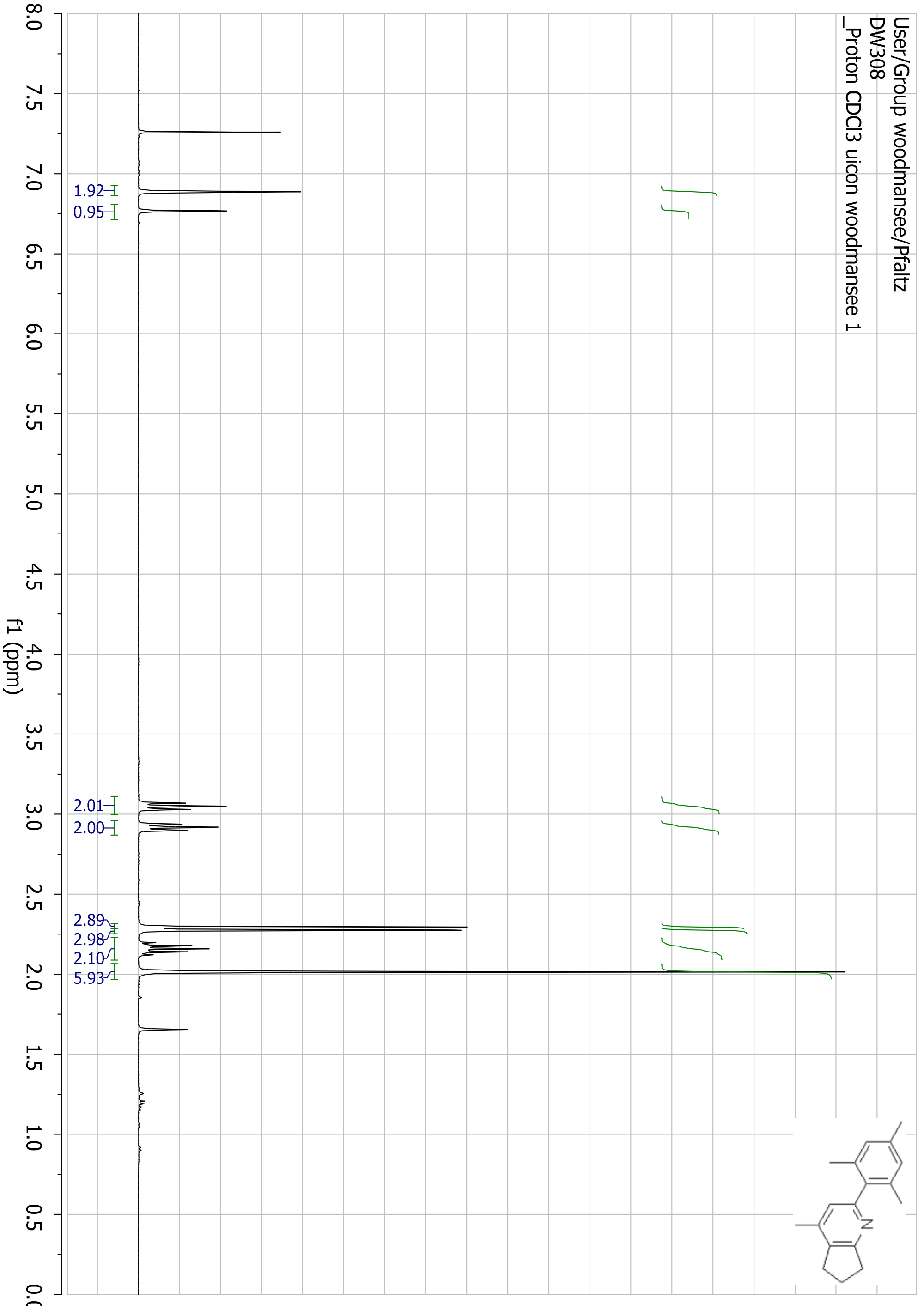

27-28-07-wood
dw156
C13CPD CDCl3 u500 wood 27
N
OTBDMS
164.96
156.86
143.88
136.34
134.92
131.89
131.77
130.72
130.46
128.79
128.49
127.57
127.47
127.30
126.86
125.71
125.69
125.48
125.26
76.88
34.14
26.79
26.31
22.73
19.13
18.75
14.46
-3.77
-4.19
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

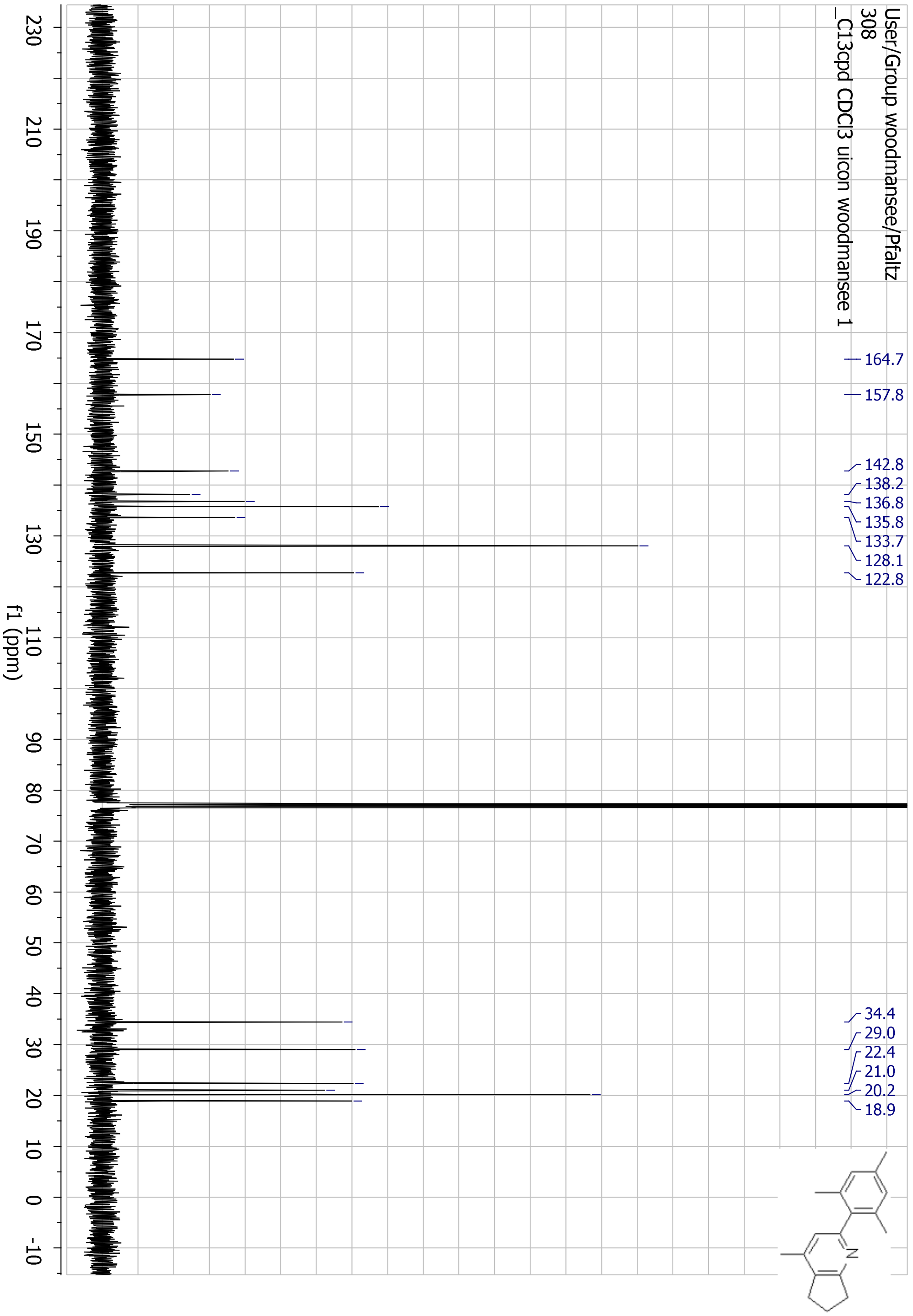
13. **12g-OTBDMS** ^{1}H & ^{13}C



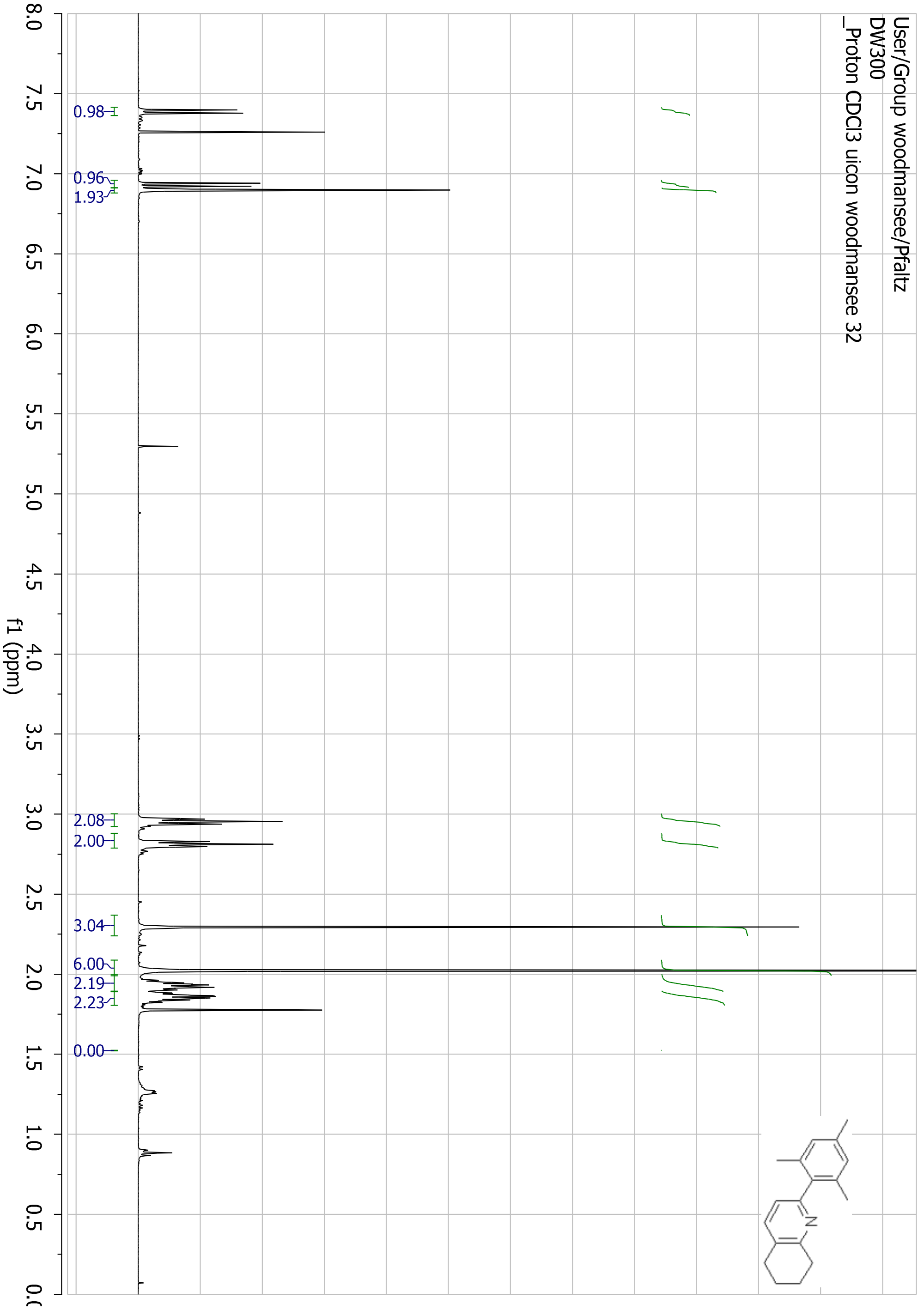

User/Group woodmansee/Pfaltz
DW325 R isomer
_C13cpd CDCl3 uicon woodmansee 54
N
OTBDMS
158.07
155.46
137.39
136.15
131.84
131.77
131.14
130.59
130.45
128.80
128.49
127.55
127.50
126.79
125.99
125.76
125.49
125.31
70.39
32.72
28.76
26.28
18.63
17.88
-3.71
-4.45
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

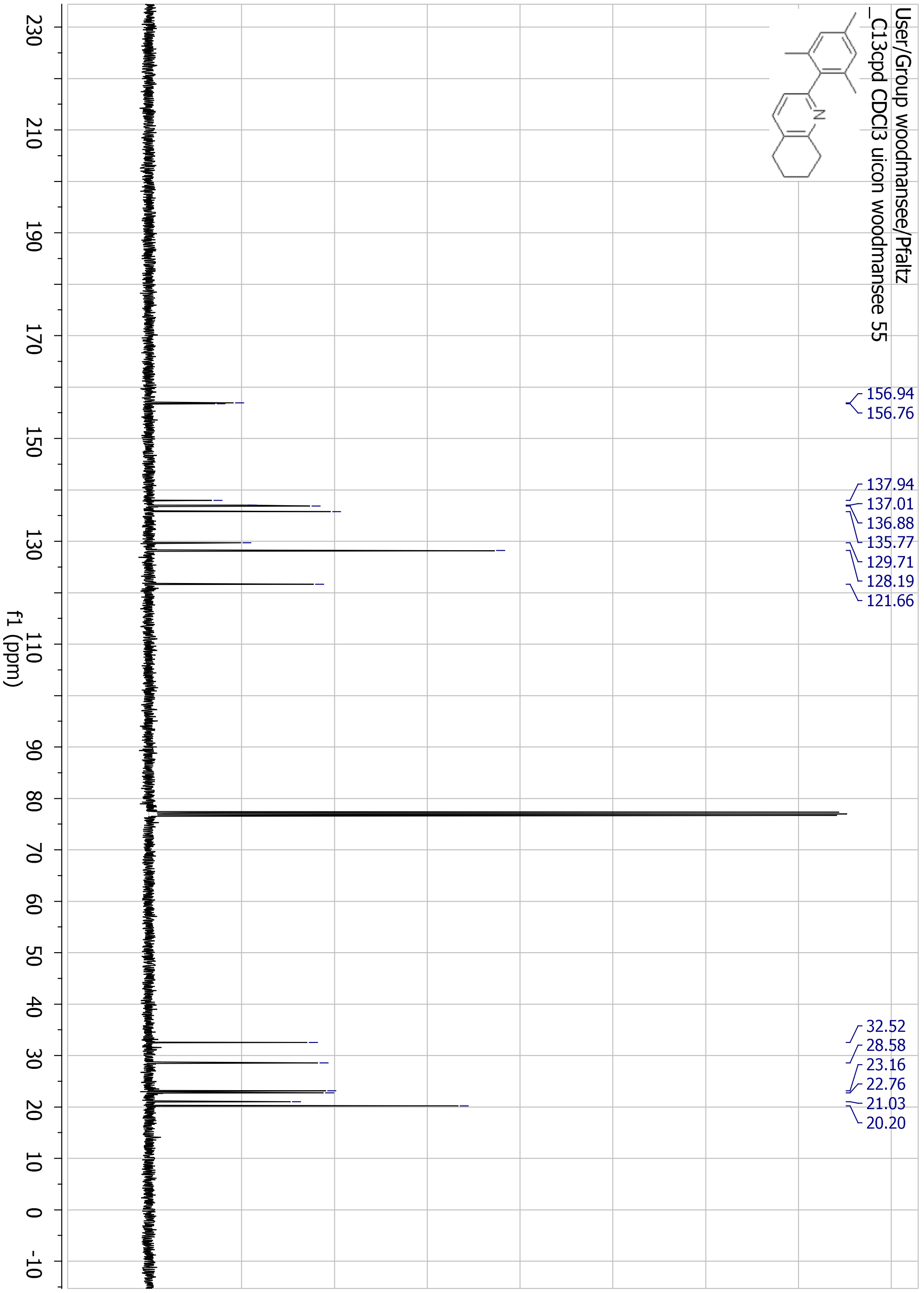
13. **10a-2-mesityl** ^{1}H & ^{13}C



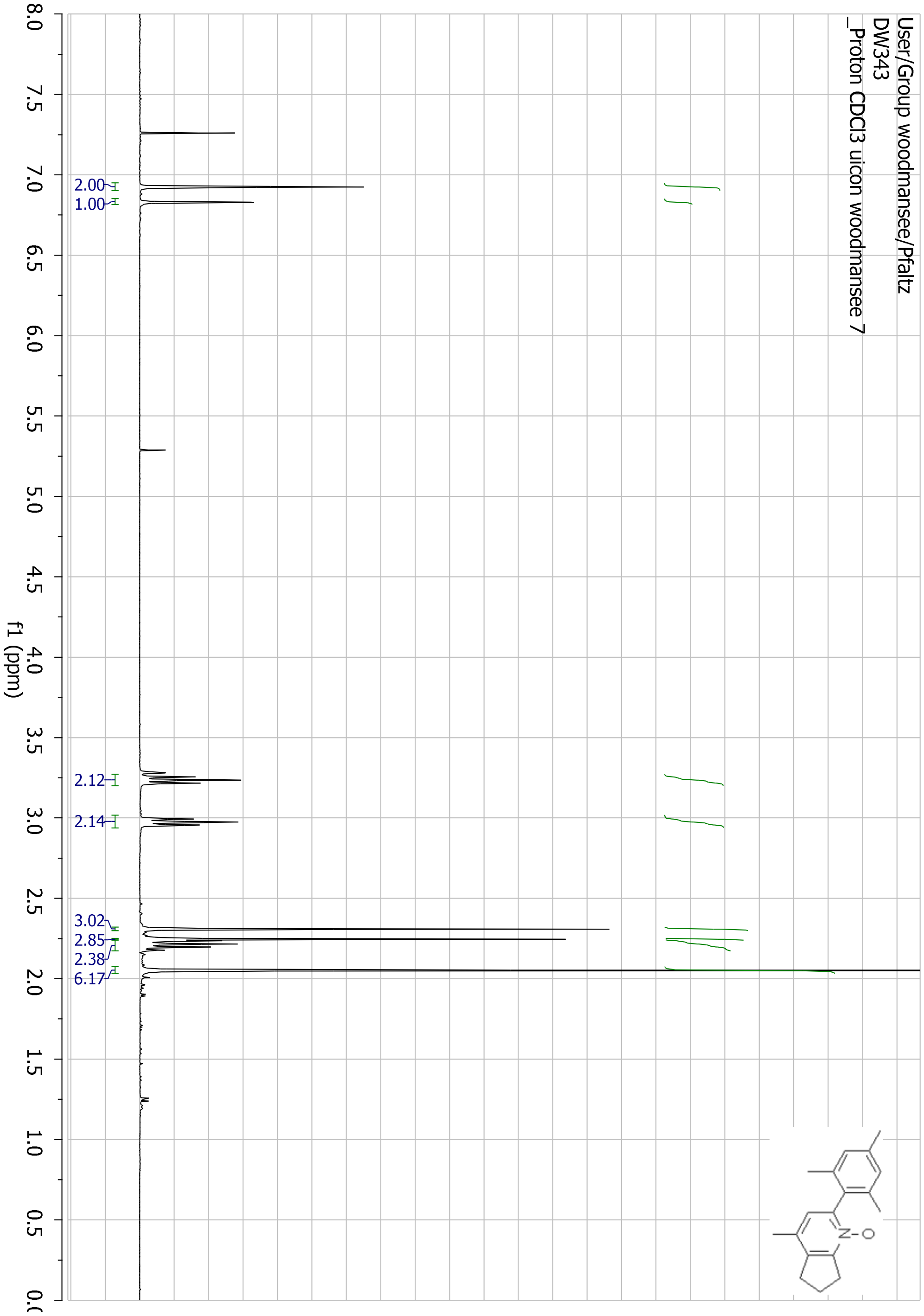

User/Group woodmansee/Pfaltz
308
_C13cpd CDCl3 uicon woodmansee 1
164.7
157.8
142.8
138.2
136.8
135.8
133.7
128.1
122.8
34.4
29.0
22.4
21.0
20.2
18.9
N
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

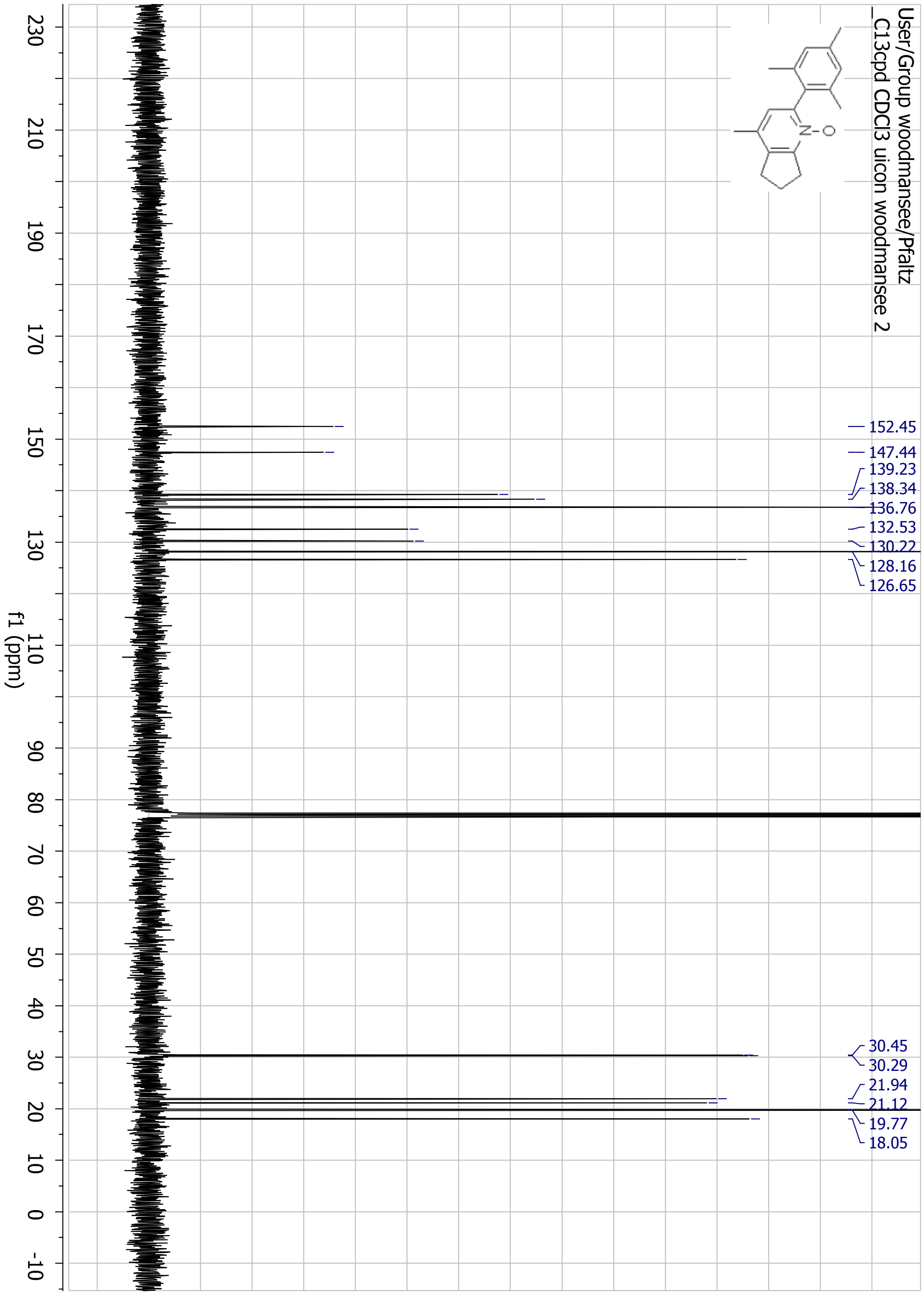
13. **10b-2-mesityl** ^{1}H & ^{13}C



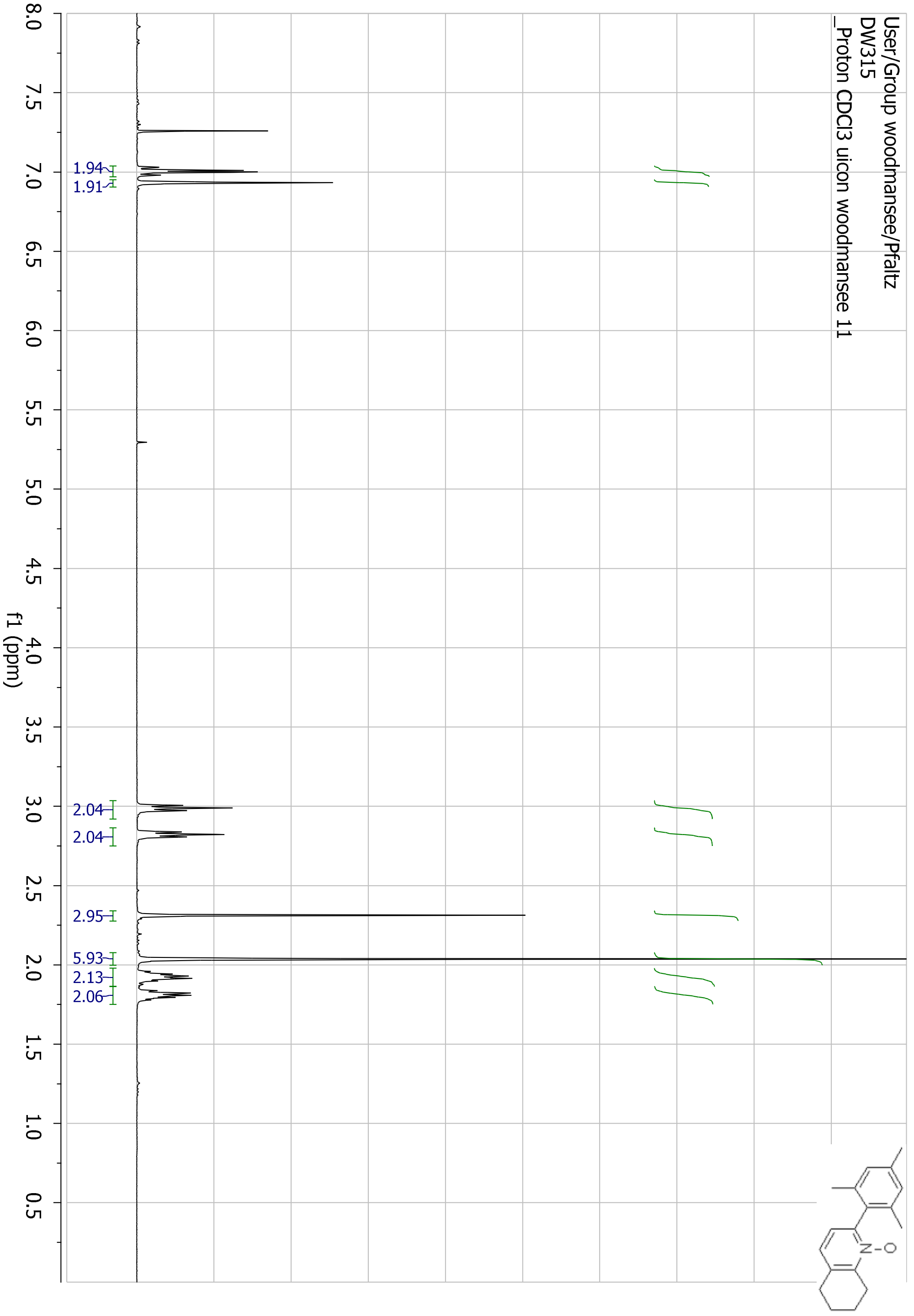

User/Group woodmansee/Pfaltz
_C13cpd CDCl3 uicon woodmansee 55
N
156.94
156.76
137.94
137.01
136.88
135.77
129.71
128.19
121.66
32.52
28.58
23.16
22.76
21.03
20.20
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

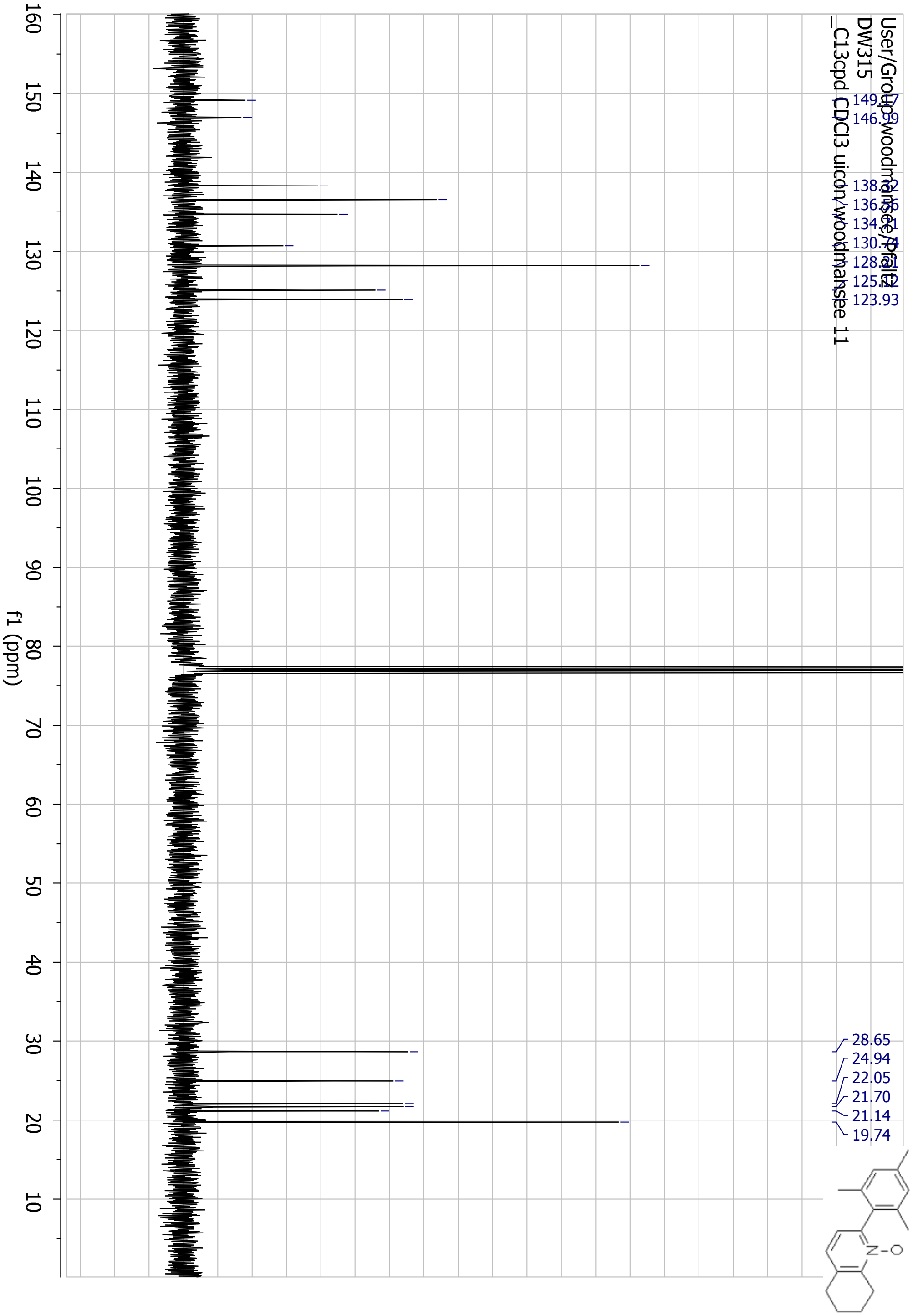
13. **10a-2-mesityl-*N*-oxide** ^{1}H & ^{13}C



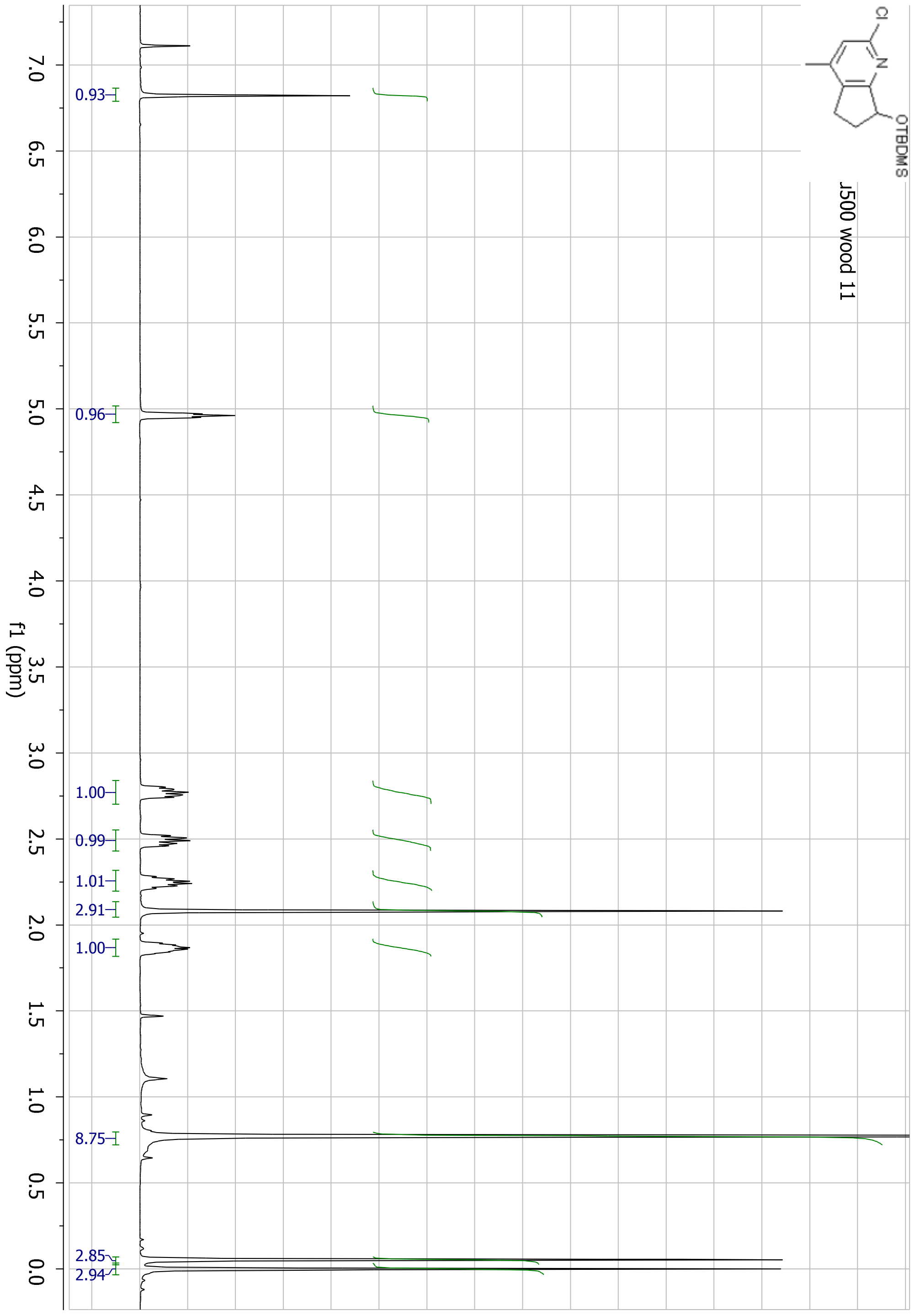

User/Group woodmansee/Pfaltz
_C13cpd CDCl3 uicon woodmansee 2
N
O
152.45
147.44
139.23
138.34
136.76
132.53
130.22
128.16
126.65
30.45
30.29
21.94
21.12
19.77
18.05
230
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

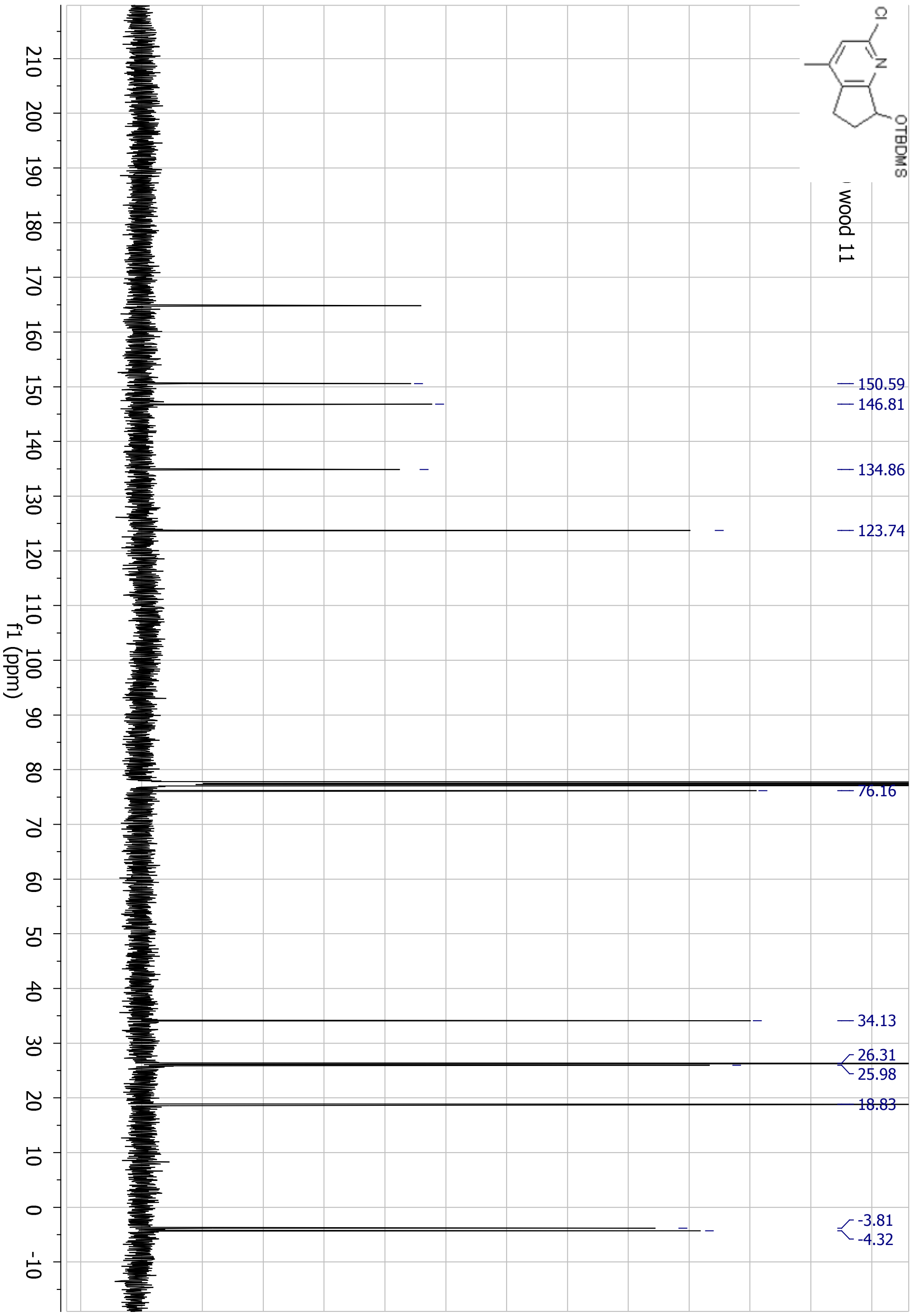
13. **10b-2-mesityl-*N*-oxide** ^{1}H & ^{13}C



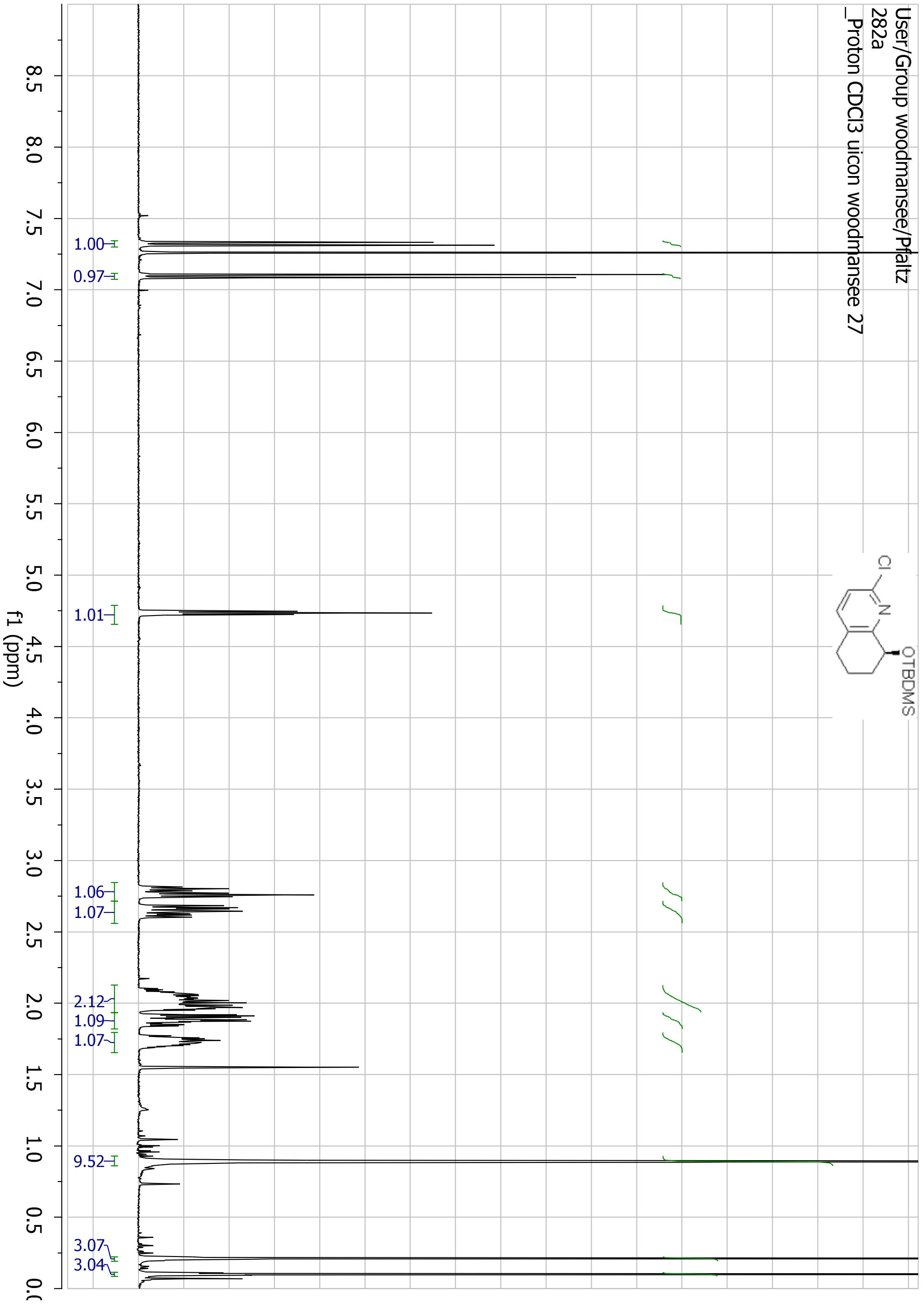

User/Groupwoodmansee/Pfaltz
DW315
_C13cpd CDCl3 uicon/woodmansee 11
149.17
146.99
138.32
136.56
134.71
130.74
128.21
125.12
123.93
28.65
24.94
22.05
21.70
21.14
19.74
N
O
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

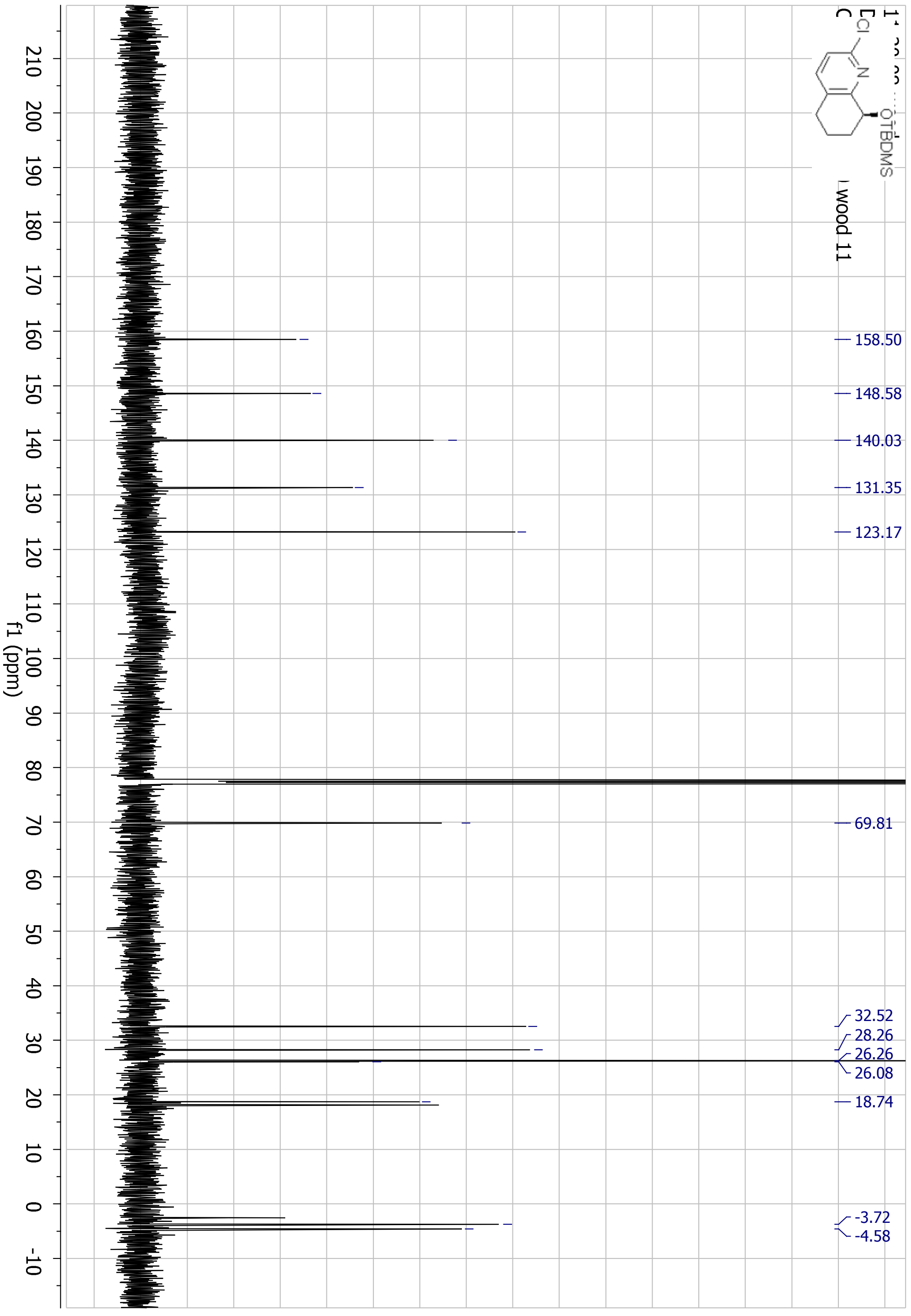
13. **15a** ^{1}H & ^{13}C


Cl
N
OTBDMS
J500 wood 11
0.93
0.96
1.00
0.99
1.01
2.91
1.00
8.75
2.85
2.94
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)


Cl
N
OTBDMS
wood 11
150.59
146.81
134.86
123.74
76.16
34.13
26.31
25.98
18.83
-3.81
-4.32
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)

13. **15b** ^{1}H & ^{13}C


User/Group woodmansee/Pfaltz
282a
_Proton CDCl3 uicon woodmansee 27
Cl
N
OTBDMS
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)
1.00
0.97
1.01
1.06
1.07
2.12
1.09
1.07
9.52
3.07
3.04


wood 11
Cl
N
OTBDMS
158.50
148.58
140.03
131.35
123.17
69.81
32.52
28.26
26.26
26.08
18.74
-3.72
-4.58
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)