Supplementary Information

Novel Asymmetric Synthesis of (+)-Castanospermine Through Enol Ether Metathesis–Hydroboration/Oxidation

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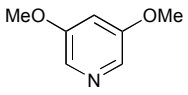
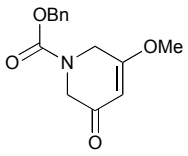
Reactions were generally carried out under argon in oven-dried glassware. Standard inert atmosphere techniques were used in handling all air and moisture sensitive reagents. Dry THF was obtained by filtration through activated molecular sieves and dry CH_2Cl_2 by filtration through activated aluminium oxide. Thin-layer chromatography was performed on (0.2 mm) silica sheets, which were visualized under ultraviolet light and by heating the plate after treatment with phosphomolybdic acid in ethanol, a p-anisaldehyde staining solution (80 mL of 95% ethanol, 2.9 mL of sulfuric acid, 0.86 mL of acetic acid, 2.1 mL of p-anisaldehyde), ninhydrin in ethanol, ceric ammonium molybdate in ethanol, or basic, aqueous $KMnO_4$. Silica gel (0.040-0.063 mm) was employed for flash column chromatography. A Fourier transform infrared spectrometer was used to record IR spectra. ^{1}H NMR and ^{13}C NMR spectra were recorded on either an AV 300, 400, or 500 MHz apparatus. All shifts for ^{1}H spectra were referenced to the residual solvent peak and are reported in ppm. When ambiguous, proton and carbon assignments were established through COSY, HMQC, and/or DEPT experiments. Mass spectra were recorded using either DCI (ammonia/isobutane 63/37), EI, or ESI techniques. HRMS were recorded on an Orbitrap apparatus (ESI). Microanalyses were performed by the microanalysis service of the DCM.



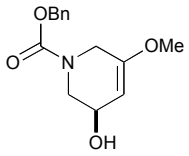
2

3,5-Dimethoxypyridine[12] **(2):** colorless oil: IR (neat) 3399, 2940, 2840, 1589, 1426, 1302, 1211, 1167, 1051 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.9 (d, *J*= 2.4 Hz, 2H), 6.7 (t, *J*= 2.4 Hz, 1H), 3.8 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 156.4, 129.4, 106.5, 55.5; MS (DCI) *m/z* 140.16 $[M+H]^+$.



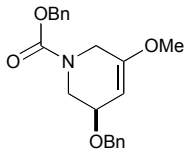
3

Benzyl 3-Methoxy-5-oxo-5,6-dihydropyridine-1(2*H*)-carboxylate (3): yellow solid: mp 47 – 48 °C; IR (neat) 3031, 2945, 2848, 1706, 1665, 1616, 1433, 1390, 1330, 1225, 1104, 1012, 824, 764, 699 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 (m, 5H), 5.48 (s, 1H), 5.14 (s, 2H), 4.23 (s, 2H), 4.08 (s, 2H), 3.73 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 192.9, 154.6, 135.8, 128.4, 128.2, 128.0, 100.8, 67.7, 56.1, 50.5, 44.3; MS (ESI) *m/z* 262.0 $[M+H]^+$, 284.0 $[M+Na]^+$; Anal. Calcd. for $C_{14}H_{15}NO_4$: C, 64.36; H, 5.79; N, 5.37. Found: C, 64.20; H, 5.86; N, 5.56.



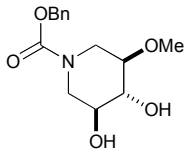
4

Benzyl 5-Hydroxy-3-methoxy-5,6-dihyydropyridine-1(2*H*)-carboxylate (4): colorless oil: IR (neat) 3425 (br), 2905, 1703, 1668, 1435, 1362, 1234, 1121, 1079, 1054, 1015, 830, 764, 699 cm^{-1}; ^1H NMR (300MHz, $CDCl_3$) δ 7.37-7.30 (m, 5H), 5.15 (s, 2H), 4.92 (d, *J* = 5.1 Hz, 1H), 4.31 (br s, 1H), 4.25-4.10 (br m, 1H), 3.91 (dd, *J* = 13.5, 3.6 Hz, 1H), 3.68 (br d, *J* = 17.1 Hz, 1H), 3.56 (s, 3H), 3.28 (dd, *J* = 13.5, 3.6 Hz, 1H), 1.72 (br, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.7, 136.4, 128.5, 128.0, 127.9, 95.3, 67.4, 63.6, 54.6, 48.5, 44.4; MS (ESI) *m/z* 286.1 $[M+Na]^+$, 302.0 $[M+K]^+$, 549.1 $[2M+Na]^+$; Anal. Calcd. for $C_{14}H_{17}NO_4$: C, 63.87; H, 6.51; N, 5.32. Found: C, 63.76; H, 6.76; N, 5.28.



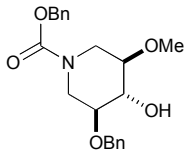
5

Benzyl 5-(Benzyloxy)-3-methoxy-5,6-dihyydropyridine-1(2*H*)-carboxylate (5): colorless oil: IR (neat) 3063, 3030, 2858, 1704, 1669, 1497, 1453, 1432, 1388, 1360, 1282, 1234, 1124, 1091, 1066, 1027, 810, 736, 698 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$, mixture of rotamers) δ 7.36-7.31 (m, 10H), 5.18 (m, 2H), 4.93 (d, *J* = 3.6 Hz, 1H), 4.75-4.52 (br m, 2H), 4.30-4.09 (br m, 3H), 3.79-3.73 (br d, *J* = 17.1 Hz, 1H), 3.58 (s, 3H), 3.37-3.29 (br m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$, mixture of rotamers) δ 156.7, 156.0, 155.3, 138.2, 136.4, 128.3, 128.2, 127.9, 127.8, 127.5, 93.5, 92.9, 70.3, 70.1, 69.8, 67.2, 54.4, 44.7, 44.2, 44.0; MS (ESI) *m/z* 376.1 $[M+Na]^+$, 342.0 $[M+K]^+$; Anal. Calcd. for $C_{21}H_{23}NO_4$: C, 71.37; H, 6.56; N, 3.97. Found: C, 71.41; H, 6.76; N, 3.97.



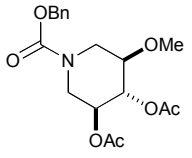
6

(3*R,4*S**,5*S**)-benzyl 3,4-Dihydroxy-5-methoxypiperidine-1-carboxylate (6)**: colorless oil: IR (neat) 3430 (br), 2929 (br), 1698, 1433, 1365, 1218, 1100, 969, 877, 765, 699 cm^{-1}; ^1H NMR (300MHz, $CDCl_3$, mixture of rotamers) δ 7.50-7.26 (m, 5H), 5.13 (s, 2H), 4.42-4.08 (m, 2H), 3.58-3.40 (m, 2H), 3.45 (s, 3H), 3.20-3.05 (br s, 1H), 3.05-2.74 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$, mixture of rotamers) δ 155.4, 136.3, 128.5, 128.2, 127.9, 78.7, 76.7, 69.5, 67.6, 57.9, 47.3, 44.4; MS (ESI) *m/z* 282.1 $[M+H]^+$, 304.1 $[M+Na]^+$, 585.2 $[2M+Na]^+$; HRMS (FT, ESI) calcd for $C_{14}H_{19}NO_5Na$: 304.11554. Found: 304.11588.



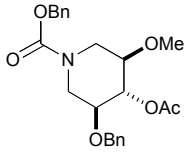
7

(3*R,4*R**,5*S**)-Benzyl 3-(Benzyloxy)-4-hydroxy-5-methoxypiperidine-1-carboxylate (7)**: colorless oil: IR (neat) 3449 (br), 3030, 2918 (br), 1703, 1497, 1454, 1431, 1363, 1316, 1248, 1217, 1103, 1029, 737, 698 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$, mixture of rotamers) δ 7.50-7.26 (m, 10H), 5.13 (br s, 2H), 4.69 (br s, 2H), 4.60-4.15 (br s, 2H), 3.55-3.48 (m, 1H), 3.48 (s, 3H), 3.14 (br s, 1H), 3.14-306 (m, 1H), 2.74 (br s, 1H), 2.63-2.40 (br t, 2H); ^{13}C NMR (75 MHz, $CDCl_3$, mixture of rotamers) δ 155.0, 137.9, 136.4, 128.6, 128.5, 128.2, 128.0, 127.9, 127.9, 127.8, 78.8, 77.6, 77.1, 72.7, 67.6, 58.2, 45.7, 45.1; MS (ESI) *m/z* 372.1 $[M+H]^+$, 394.1 $[M+Na]^+$, 410.1 $[M+K]^+$; HRMS (FT, ESI) calcd for $C_{21}H_{25}NO_5Na$: 394.16249. Found: 394.16286.



8

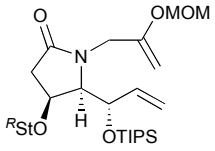
(3*R,4*R**,5*S**)-1-(Benzyloxycarbonyl)-5-methoxypiperidine-3,4-diyl Diethanoate (8)**: colorless oil: IR (neat) 2942 (br), 1745, 1701, 1432, 1359, 1233, 1163, 1107, 1042, 960, 886, 699 cm^{-1}; ^1H NMR (400 MHz, Toluene d_8, 85 °C) δ 7.24-6.99 (m, 5H), 5.06 (app. t, *J*=8.4 Hz, 1H), 5.05 (s, 2H), 4.82 (ddd, *J*=9.2, 8.3, 5.2 Hz, 1H); 4.16-4.08 (m br, 2H) ; 3.10 (s, 3H) ; 3.05 (ddd, *J*=9.2, 8.4, 5.2 Hz, 1H), 2.75 (dd, *J*=12.8, 9.2 Hz, 1H), 2.65 (dd, *J*=13.2, 9.2 Hz, 1H), 1.75 (s, 3H), 1.68 (s, 3H); ^{13}C NMR (100 MHz, toluene d_8, 85°C) δ 168.6, 168.3, 154.6, 137.0, 128.1, 127.7, 127.6, 76.8, 74.5, 69.0, 67.2, 57.0, 45.0, 44.9, 19.7, 19.5; MS (ESI) *m/z* 366.1 $[M+H]^+$, 388.1 $[M+Na]^+$, 404.1 $[M+K]^+$, 753 $[2M+Na]^+$; HRMS (FT, ESI) calcd for $C_{18}H_{23}NO_7Na$: 388.13667. Found: 388.13709.



9

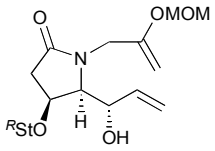
(3*R,4*R**,5*S**)-Benzyl 3-(Benzyloxy)-4-(ethanoyloxy)-5-methoxypiperidine-1-carboxylate (9)**: colorless oil: IR (neat) 2924 (br), 1740, 1701, 1450, 1428, 1363, 1315, 1233, 1172, 1098, 1055, 886, 734, 699 cm^{-1}; ^1H NMR (400 MHz, toluene d_8, at 85°C) δ 7.25-6.95 (m, 10H), 5.12 (app. t, *J* = 8.4 Hz, 1H), 5.04 (d, *J* = 12.4 Hz, 2H), 4.44 (d, *J* = 12 Hz, 2H), 4.19 (m, 2H), 3.28 (ddd, *J* = 9.6, 8.4, 5.2 Hz, 1H), 3.12 (s, 3H), 3.02 (ddd, *J* = 9.6, 8.4, 5.0 Hz, 1H), 2.59 (dd, *J* = 13, 9.6 Hz, 1H), 2.55 (dd, *J* = 13.3, 9.6 Hz, 1H), 1.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1, 155.0, 137.8, 136.3, 128.5, 128.4, 128.2, 127.9, 127.8, 127.6, 77.2, 76.3, 75.0, 72.2, 67.6, 65.8, 58.1, 45.7, 45.3,

21.0; MS (ESI) *m/z* 414.1 $[M+H]^+$, 436.1 $[M+Na]^+$, 849 $[2M+Na]^+$; HRMS (FT, ESI) calcd for $C_{23}H_{27}NO_6Na$: 436.17306. Found: 436.17326.



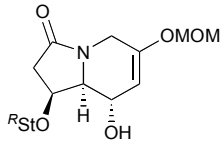
16

(4*S*,5*R*)-1-(2-(Methoxymethoxy)allyl)-4-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)-5-((*S*)-1-(triisopropylsilyloxy)allyl)pyrrolidin-2-one (16): $[\alpha]^{23}_D$ +15.8 (*c* 1.0, $CHCl_3$); IR (neat) 2959, 2867, 1705, 1462, 1154, 1102, 1015 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.04 (s, 1H), 6.95 (d, *J* = 1.6 Hz, 1H), 6.00 (ddd, *J* = 17.3, 10.6, 6.6 Hz, 1H), 5.40 (app. d, *J* = 17.3 Hz, 1H), 5.25 (app. dd, *J* = 10.6, 1.1 Hz, 1H), 5.09 (q, *J* = 6.7 Hz, 1H), 4.89 (app. d, *J* = 6.6 Hz, 1H), 4.86 (d, *J* = 11.0 Hz, 1H), 4.84 (d, *J* = 11.0 Hz, 1H), 4.54 (d, *J* = 15.5 Hz, 1H), 4.20 (d, *J* = 2.1 Hz, 1H), 4.12 (dt, *J* = 9.7, 8.3 Hz, 1H), 4.05-3.92 (m, 3H), 3.87 (d, *J* = 15.5 Hz, 1H), 3.25 (s, 3H), 3.14 (sept, *J* = 6.6 Hz, 1H), 2.86 (sept, *J* = 6.8 Hz, 1H), 2.56 (dd, *J* = 15.6, 9.7 Hz, 1H), 2.37 (dd, *J* = 15.6, 8.3 Hz, 1H), 1.55 (d, *J* = 6.7 Hz, 3H), 1.30-1.11 (m, 18H), 1.07 (s, 21H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 155.5, 148.6, 177.8, 146.3, 137.7, 131.0, 123.1, 121.0, 93.7, 85.8, 74.4, 71.3, 70.0, 65.4, 56.0, 44.1, 36.6, 33.9, 29.0, 27.8, 25.3, 25.2, 25.1, 24.1, 23.8, 23.4, 18.0, 12.3; MS (DCI) *m/z* 644.2 $[M+H]^+$; Anal. Calcd. for $C_{38}H_{65}NO_5Si$: C, 70.87; H, 10.17; N, 2.17. Found: C, 70.53; H, 9.89; N, 2.34.



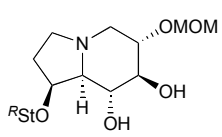
16′

(4*S*,5*S*)-5-((*S*)-1-Hydroxyallyl)-1-(2-(methoxymethoxy)allyl)-4-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)pyrrolidin-2-one (16′): $[\alpha]^{23}_D$ +32.3 (*c* 1.0, $CHCl_3$); IR (neat) 3427, 2960, 2930, 2869, 1681, 1454, 1154, 1018 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.04 (s, 1H), 6.97 (s, 1H), 5.99 (ddd, *J* = 17.3, 10.6, 6.2 Hz, 1H), 5.34 (dt, *J* = 17.3, 1.4 Hz, 1H), 5.23 (dt, *J* = 10.6, 1.4 Hz, 1H), 5.16 (q, *J* = 6.8 Hz, 1H), 4.85 (s, 2H), 4.57-4.51 (m, 1H), 4.49 (d, *J* = 15.3 Hz, 1H), 4.28 (d, *J* = 2.3 Hz, 1H), 4.23 (q, *J* = 7.9 Hz, 1H), 4.14 (d, *J* = 2.3 Hz, 1H), 3.75 (sept, *J* = 6.7 Hz, 1H), 3.70 (dd, *J* = 7.9, 4.6 Hz, 1H), 3.58 (d, *J* = 15.3 Hz, 1H), 3.24 (s, 3H), 3.20 (d, *J* = 5.9 Hz, 1H), 3.14 (sept, *J* = 6.7 Hz, 1H), 2.85 (sept, *J* = 6.9 Hz, 1H), 2.67 (dd, *J* = 16.0, 7.9 Hz, 1H), 2.54 (dd, *J* = 16.0, 7.9 Hz, 1H), 1.58 (d, *J* = 6.8 Hz, 3H), 1.32-1.14 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 154.8, 148.6, 148.2, 146.1, 137.6, 130.7, 123.3, 121.0, 117.1, 93.7, 87.9, 72.4, 72.3, 63.6, 56.1, 44.6, 37.1, 34.0, 29.2, 28.2, 25.4, 25.2, 24.9, 24.0, 23.9, 23.8, 23.1; MS (ESI) *m/z* 510.4 $[M+Na]^+$; Anal. Calcd. for $C_{29}H_{45}NO_5$: C, 71.42; H, 9.30; N, 2.87. Found: C, 71.62; H, 9.61; N, 2.78.

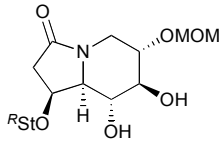


17

(1*S*,8*S*,8a*S*)-8-Hydroxy-6-(methoxymethoxy)-1-((*R*)-1-(2,4,6-triisopropylphenyl)-ethoxy)-8,8a-dihydroindolizin-3(1*H*,2*H*,5*H*)-one (17): light yellow oil: $[\alpha]^{23}_{D}$ +53.1 (*c* 1.0, $CHCl_3$); IR (neat) 3435, 2960, 2929, 2868, 2243, 1698, 1667, 1445, 1383, 1154, 732 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.06 (s, 1H), 6.98 (d, *J* = 1.7 Hz, 1H), 5.19 (q, *J* = 6.8 Hz, 1H), 5.03 (d, *J* = 6.2 Hz, 1H), 5.00 (app. d, *J* = 1.7 Hz, 1H), 4.91 (d, *J* = 6.2 Hz, 1H), 4.65-4.60 (m, 1H), 4.38 (q, *J* = 8.1 Hz, 1H), 4.33 (dt, *J* = 17.3, 1.7 Hz, 1H), 3.68 (sept, *J* = 6.8 Hz, 1H), 3.45 (app. d, *J* = 8.1 Hz, 1H), 3.41 (s, 3H), 3.33 (app. d, *J* = 17.2 Hz, 1H), 3.16 (sept, *J* = 6.7 Hz, 1H), 3.10 (d, *J* = 2.3 Hz, 1H), 2.86 (sept, *J* = 6.8 Hz, 1H), 2.66 (ddd, *J* = 16.6, 8.1, 0.9 Hz, 1H), 2.53 (dd, *J* = 16.6, 8.1 Hz, 1H), 1.62 (d, *J* = 6.8 Hz, 3H), 1.32-1.16 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 149.9, 148.7, 148.3, 146.3, 130.6, 123.4, 121.0, 100.9, 94.0, 72.4, 70.7, 63.9, 61.3, 56.4, 40.0, 36.5, 34.0, 29.2, 28.8, 25.3, 25.0, 24.2, 28.8, 23.1; MS (DCI) *m/z* 460.0 $[M+H]^+$; Anal. Calcd. for $C_{27}H_{41}NO_5$: C, 70.56; H, 9.00; N, 3.05. Found: C, 70.42; H, 8.96; N, 3.19.



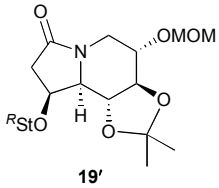
18



19

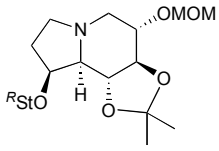
(1*S*,6*S*,7*S*,8*R*,8a*S*)-6-(Methoxymethoxy)-1-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)-octahydroindolizine-7,8-diol (18) and (1*S*,6*S*,7*S*,8*R*,8a*S*)-7,8-Dihydroxy-6-(methoxy-methoxy)-1-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)hexahydroindolizin-3(5*H*)-one (19). **Amino diol 18**: colorless liquid; $[\alpha]^{23}_{D}$ +67.4 (*c* 1.0, $CHCl_3$); IR (neat) 3449, 2959, 2927, 2867, 1697, 1103, 1070, 1036; ^1H NMR (400 MHz, $CDCl_3$) δ 7.06 (d, *J* = 1.7 Hz, 1H), 6.97 (d, *J* = 1.7 Hz, 1H), 5.18 (q, *J* = 6.8 Hz, 1H), 4.77 (d, *J* = 6.8 Hz, 1H), 4.73 (d, *J* = 6.8 Hz, 1H), 4.38-4.31 (m, 2H), 3.73 (dt, *J* = 9.3, 1.9 Hz, 1H), 3.64 (sept, *J* = 7.0 Hz, 1H), 3.54 (dt, *J* = 8.9, 1.4 Hz, 1H), 3.49-3.35 (m, 2H), 3.44 (d, *J* = 1.4 Hz, 1H), 3.33 (d, *J* = 1.9 Hz, 1H), 3.15 (sept, *J* = 6.8 Hz, 1H), 2.85 (sept, *J* = 6.9 Hz, 1H), 2.66 (ddd, *J* = 17.0, 7.8, 1.2 Hz, 1H), 2.56 (dd, *J* = 17.0, 7.0 Hz, 1H), 2.58-2.49 (m, 1H), 1.60 (d, *J* = 6.8 Hz, 3H), 1.31-1.16 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 148.7, 146.1, 123.4, 121.0, 97.2, 76.8, 72.6, 70.2, 61.6, 55.8, 41.6, 37.0, 34.0, 29.2, 28.9, 25.2, 25.1, 24.2, 23.9, 22.9; MS (DCI, NH3/isobutane) *m/z* 478 $[M+H_4^+$, 100%], 478 $[M+H^+]$, 430, 279, 248, 231. HRMS (FT, ESI) calcd for $C_{27}H_{43}NO_6Na$: 500,29881. Found: 500.29826. **Amide diol 19**: colorless liquid; $[\alpha]^{23}_{D}$ +62.0 (*c* 0.8, $CHCl_3$); IR (neat) 3452, 2868, 2797, 1461, 1149, 1108, 1072, 1033 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.05 (d, *J* = 1.6 Hz, 1H), 6.94 (d, *J* = 1.6 Hz, 1H), 5.12 (q, *J* = 7.2 Hz, 1H), 4.75 (d, *J* = 13.6 Hz, 1H), 4.73 (d, *J* = 13.6 Hz, 1H), 4.10-4.06 (m, 1H), 3.83-3.75 (m 2H), 3.63 (ddd, *J* = 10.1, 8.8, 5.3 Hz, 1H), 3.43-3.37 (m,

2H), 3.40 (s, 3H), 3.38 (dd, *J* = 11.1, 5.2 Hz, 1H), 3.25 (sept, *J* = 6.8 Hz, 1H), 3.11 (dt, *J* = 8.6, 1.7 Hz, 1H), 2.84 (sept, *J* = 6.9 Hz, 1H), 2.31 (OH, 1H), 2.23-2.00 (m, 5H), 1.56 (d, *J* = 6.8 Hz, 3H), 1.30-1.15 (m, 18H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.8, 147.7, 145.5, 132.8, 123.2, 120.7, 97.3, 79.1, 77.8, 77.1, 71.2, 69.8, 55.6, 54.3, 51.9, 34.0, 31.9, 29.3, 28.7, 25.9, 25.1, 24.6, 24.13, 23.9, 23.8, 23.3; MS (ESI) *m/z* 464.2 $[M+H]^+$; HRMS (FT, ESI) calcd for $C_{27}H_{46}NO_5$: 464.33760. Found: 464.33705.



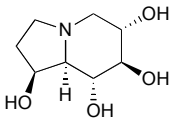
19′

Acetonide of (1*S*,6*S*,7*S*,8*R*,8a*S*)-7,8-Dihydroxy-6-(methoxymethoxy)-1-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)hexahydroindolizin-3(5*H*)-one (19′): $[\alpha]^{23}_D$ –18 (*c* 1.2, $CHCl_3$); IR (neat) 2959, 2927, 2866, 1703, 1370, 1231, 1152, 1106, 1078, 1028 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 (s, 1H), 6.93 (s, 1H), 5.14 (q, *J* = 6.8 Hz, 1H), 4.84 (d, *J* = 6.8 Hz, 1H), 4.68 (d, *J* = 6.8 Hz, 1H), 4.52 (dd, *J* = 13.4, 5.7 Hz, 1H), 4.21 (dt, *J* = 5.9, 3.1 Hz, 1H), 3.87 (sept, *J* = 6.8 Hz, 1H), 3.77-3.66 (m, 2H), 3.61-3.45 (m, 2H), 3.38 (s, 3H), 3.15 (sept, *J* = 6.8 Hz, 1H), 2.84 (sept *J* = 6.8 Hz, 1H), 2.68-2.465 (m, 3H), 1.52 (d, *J* = 6.8 Hz, 3H), 1.39 (s, 3H), 1.30-1.17 (m, 21H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 148.9, 147.5, 145.5, 132.1, 123.2, 120.5, 111.0, 96.1, 82.1, 72.6, 72.5, 72.4, 69.0, 63.8, 55.6, 42.8, 38.0, 34.0, 29.1, 28.1, 26.7, 26.3, 25.6, 25.3, 24.8, 24.3, 23.9, 23.9, 22.6; MS (ESI) *m/z* 518.2 $[M+H]^+$, 540.0 $[M+Na]^+$; HRMS (FT, ESI) calcd for $C_{30}H_{47}NO_6Na$ 540.32956 Found: 540.32828.



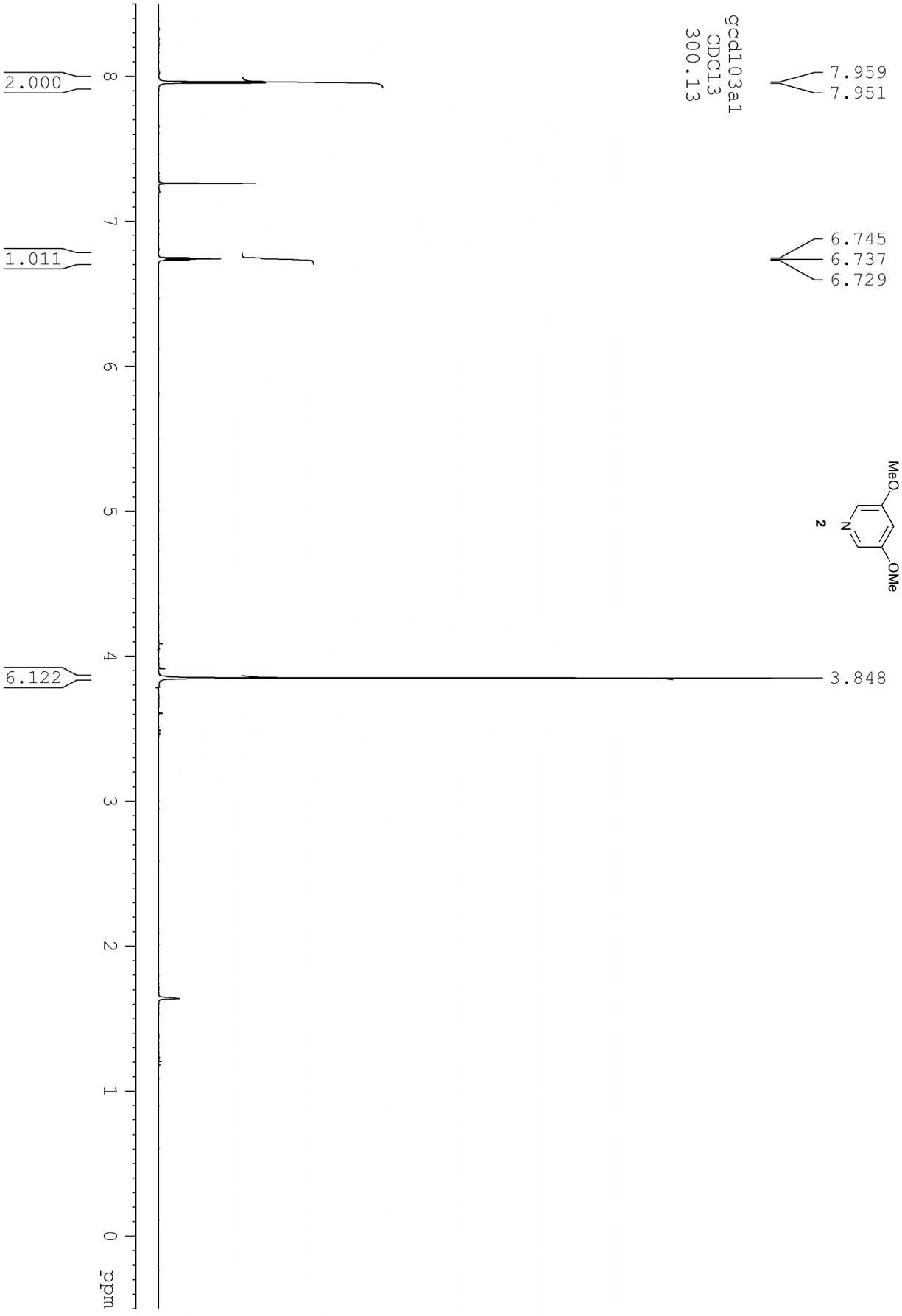
19″

Acetonide of (1*S*,6*S*,7*S*,8*R*,8a*S*)-6-(Methoxymethoxy)-1-((*R*)-1-(2,4,6-triisopropylphenyl)ethoxy)octahydroindolizine-7,8-diol (19″): $[\alpha]^{23}_D$ + 5.9 (*c* 0.4, $CHCl_3$); IR (neat) 2958, 2926, 2867, 1153, 1086, 1029 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.03 (s, 1H), 6.91 (s, 1H), 5.16 (q, *J* = 6.4 Hz, 1H), 4.84 (d, *J* = 6.8 Hz, 1H), 4.69 (d, *J* = 6.8 Hz, 1H), 4.04-4.00 (m, 1H), 3.95-3.89 (m, 2H), 3.67 (t, *J* = 9.0 Hz, 1H), 3.41 (dd, *J* = 5.2, 11.2 Hz, 1H), 3.36 (s, 3H), 3.34 (t, *J* = 9.6 Hz, 1H), 3.25-3.18 (m, 1H), 3.12 (dt, *J* = 2.8, 8.4 Hz, 1H), 2.83 (sept., *J* = 6.8 Hz, 1H), 2.25 (q, *J* = 8.4 Hz, 1H), 2.19 (dd, *J* = 5.2, 9.2 Hz, 1H), 2.11-1.98 (m, 3H), 1.51 (d, *J* = 6.8 Hz, 3H), 1.39 (s, 3H), 1.35 (s, 3H), 1.34-1.17 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.3, 147.1, 145.6, 132.9, 123.1, 120.4, 110.5, 96.3, 83.5, 74.8, 74.3, 73.4, 70.3, 69.0, 55.5, 54.8, 51.6, 34.0, 31.3, 29.0, 28.0, 26.8, 26.6, 25.8, 25.7, 25.2, 24.1, 24.0, 23.9, 22.9; MS (ESI) *m/z* 504.3 $[M+H]^+$; HRMS (FT, ESI) calcd for $C_{30}H_{50}NO_5$ 504.36835. Found: 504.36721.



(+)-Castanospermine (**1**)

(1*S*,6*S*,7*R*,8*R*,8a*R*)-Octahydroindolizine-1,6,7,8-tetraol ((+)-castanospermine) (1): white solid: mp 204 – 206 °C (dec); $[\alpha]^{23}_{D}$ + 78 (*c* 0.75, H_2O); ^{1}H NMR (400 MHz, D_2O) 4.42 (m, 1H), 3.67-3.58 (m, 2H), 3.33 (t, *J* = 9.1 Hz, 1H), 3.19 (dd, *J* = 10.8, 5.1 Hz, 1H), 3.09 (dt, *J* = 8.9, 1.9 Hz, 1H), 2.39-2.30 (m, 1H), 2.23 (q, *J* = 9.0 Hz, 1H), 2.07 (t, *J* = 10.7 Hz, 1H), 2.04 (dd, *J* = 9.9, 4.4 Hz, 1H), 1.72 (ddt, *J* = 14.1, 8.8, 1.6 Hz, 1H); ^{13}C NMR (100 MHz, D_2O) δ 78.9, 71.3, 70.0, 69.5, 68.8, 55.3, 51.5, 32.6; MS (ESI) *m*/*z* 189.9 $[M+H]^+$.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6.745
6.737
6.729
3.848
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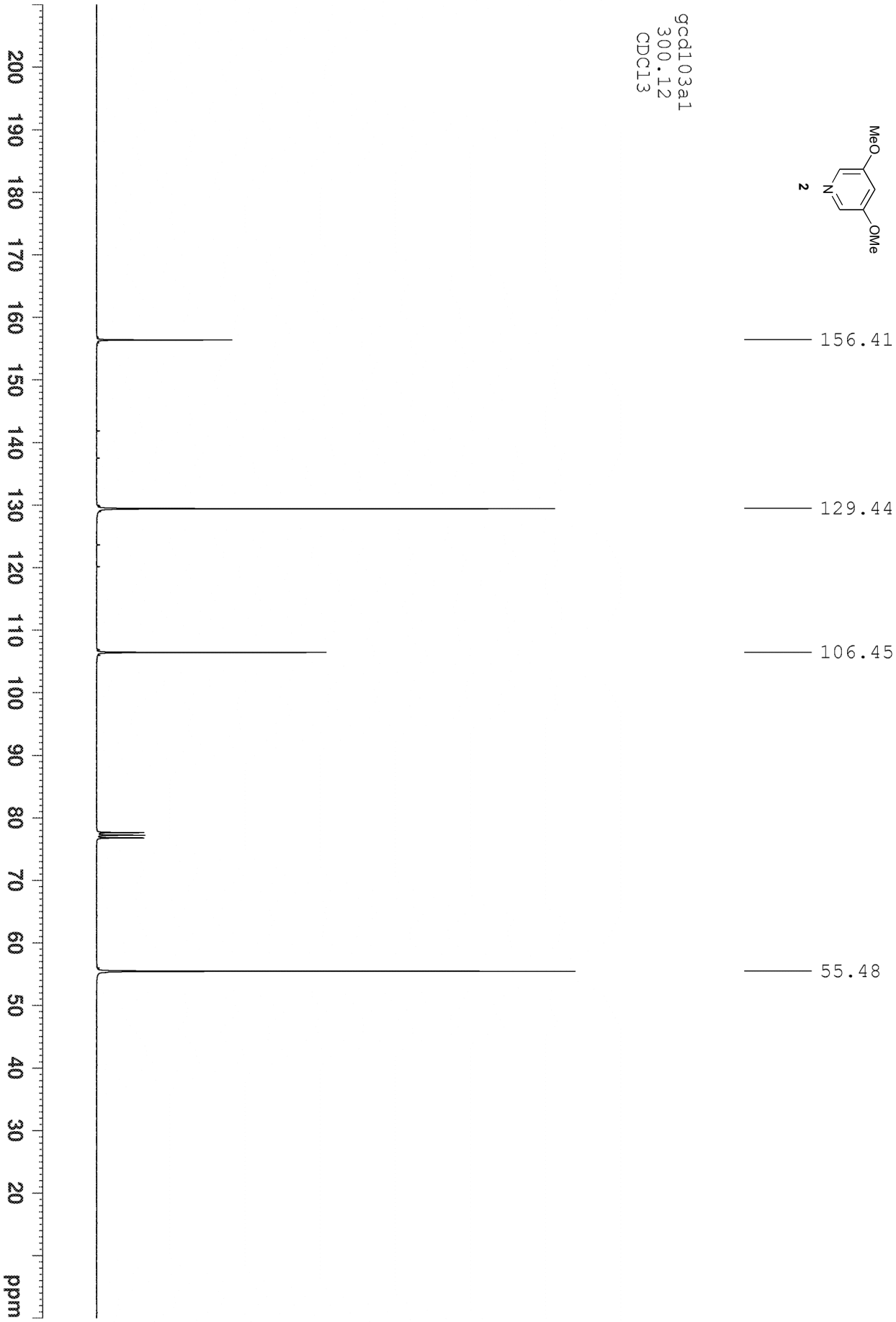
MeO
OMe
N
2
8
7
6
5
4
3
2
1
0
ppm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CDC13
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OMe
N
2
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106.45
55.48
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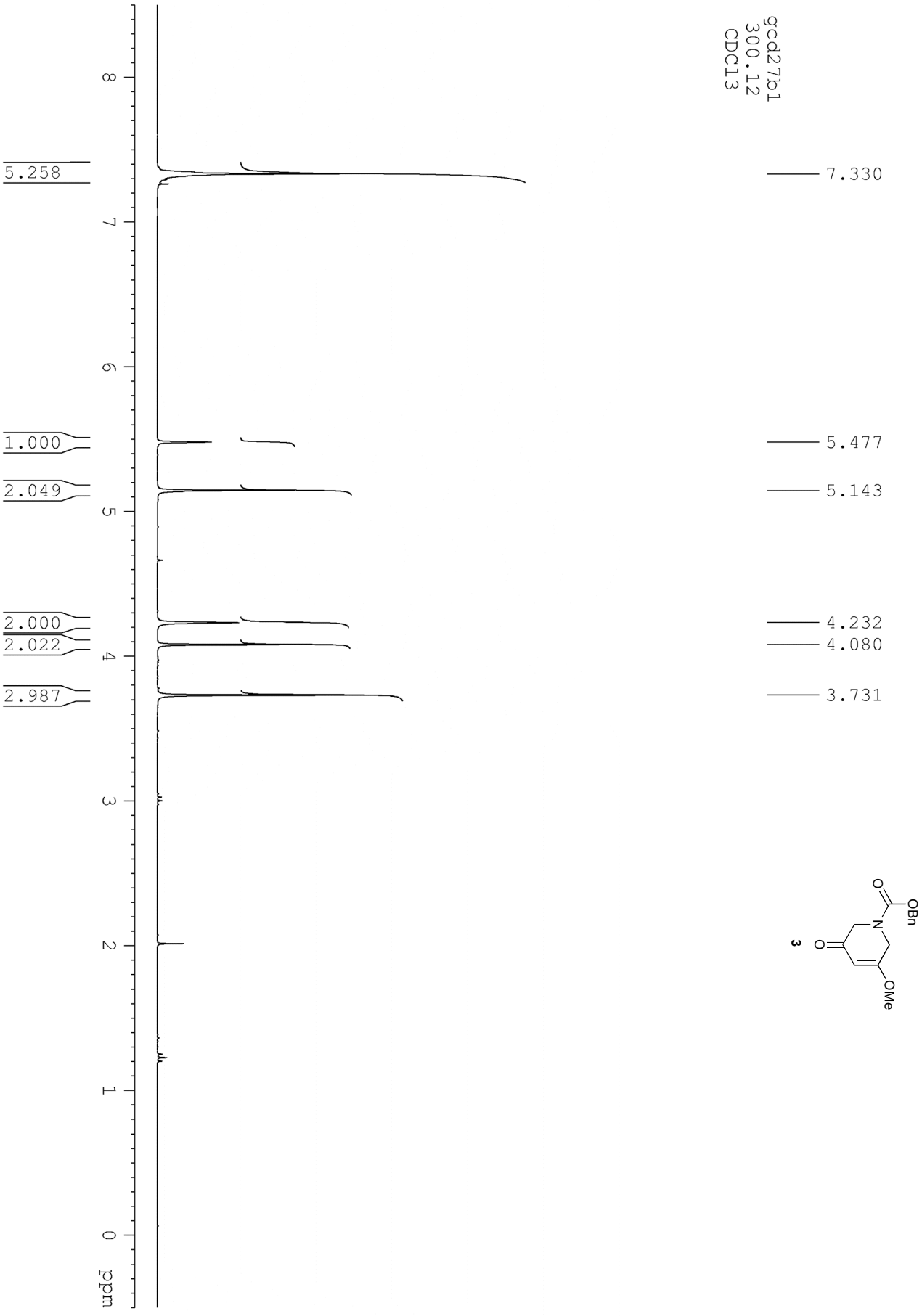
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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CDC13
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2.000
2.022
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7.330
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5.143
4.232
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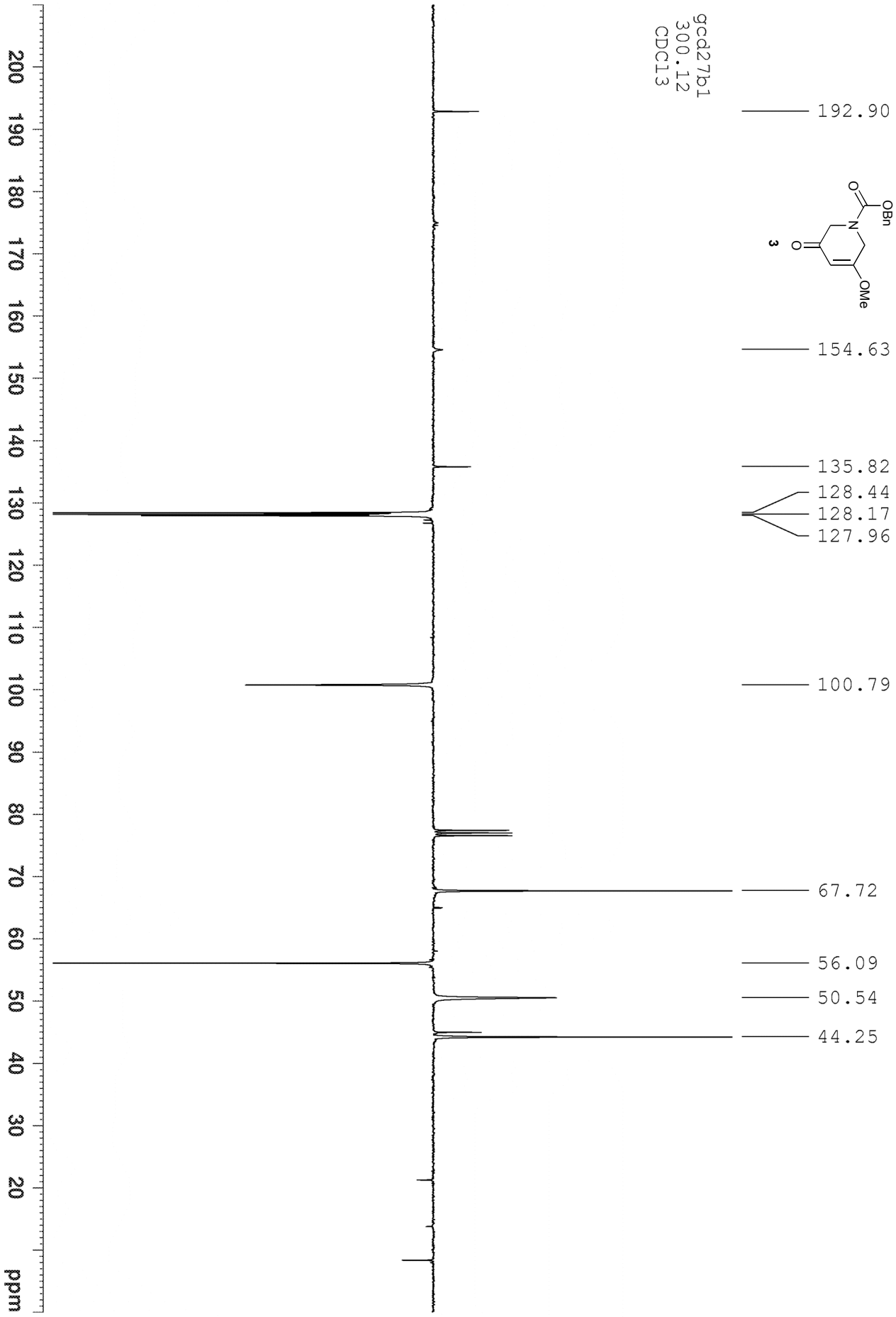
ppm
0
1
2
3
4
5
6
7
8
OBn
N
O
O
OMe
3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CDCl3
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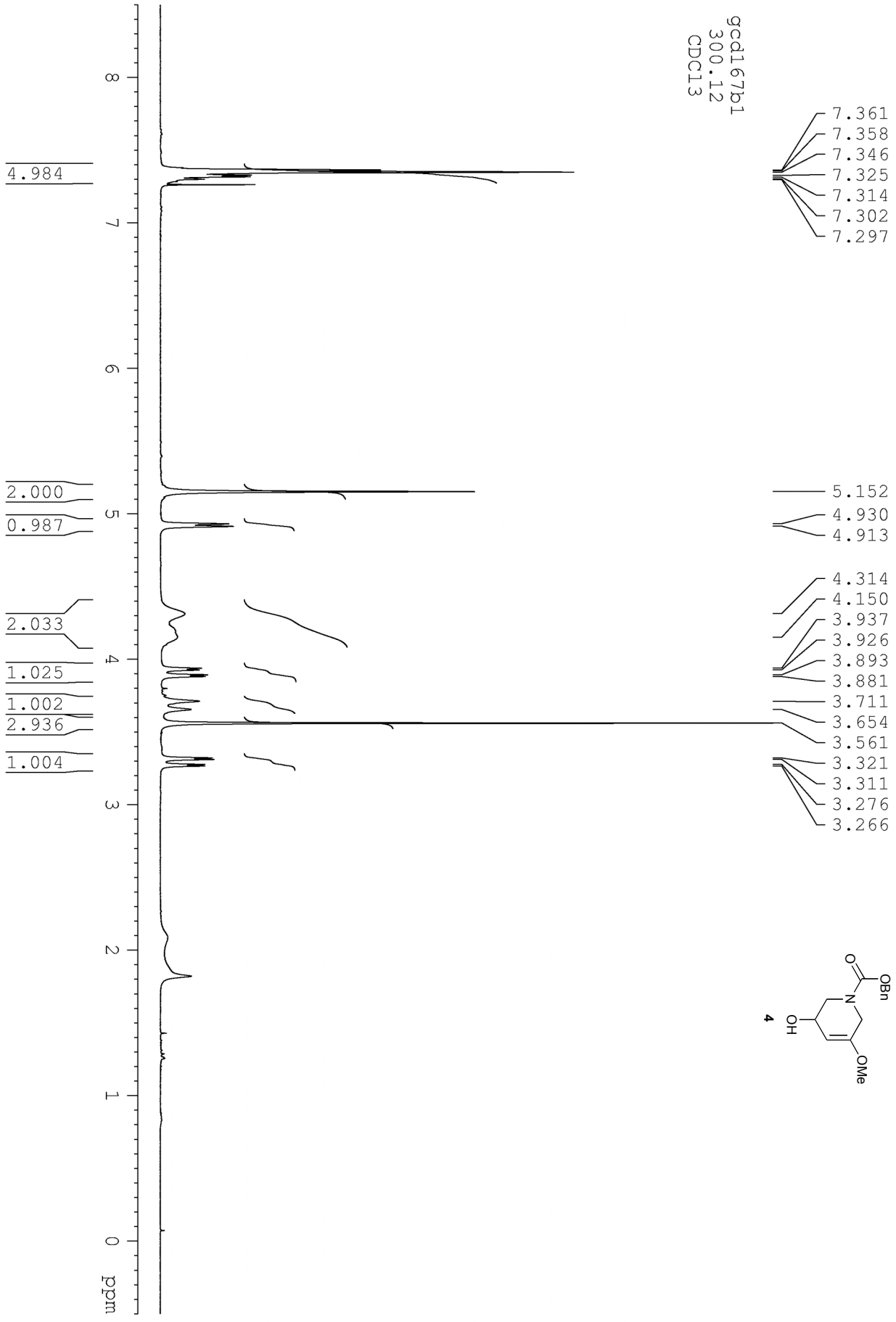
135.82
128.44
128.17
127.96
100.79
67.72
56.09
50.54
44.25
OBn
OMe
O
N
O
3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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CDC13
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7.346
7.325
7.314
7.302
7.297
5.152
4.930
4.913
4.314
4.150
3.937
3.926
3.893
3.881
3.711
3.654
3.561
3.321
3.311
3.276
3.266
4.984
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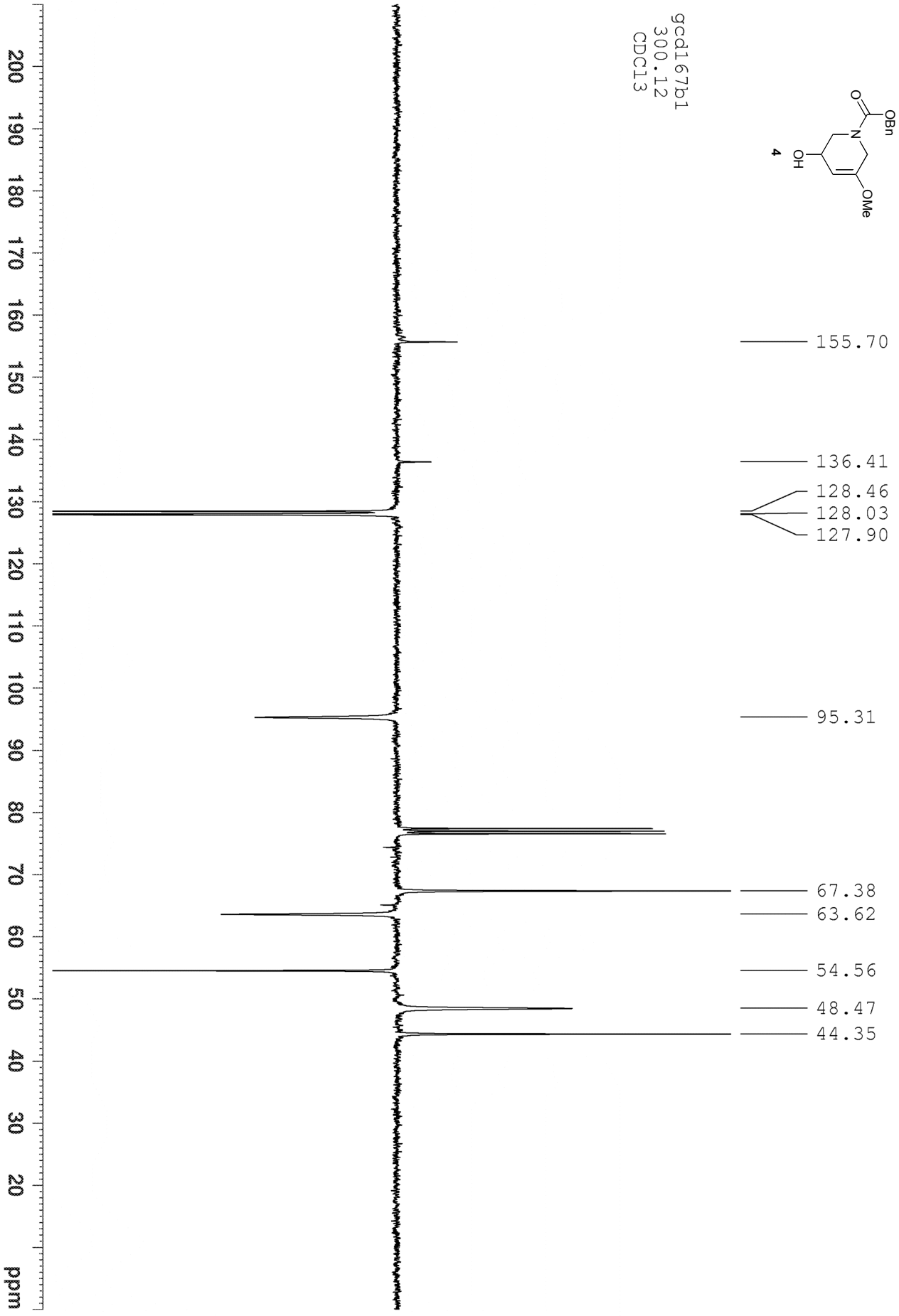
0.987
2.033
1.025
1.002
2.936
1.004
ppm
OBn
OH
OMe
4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N
OH
OMe
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63.62
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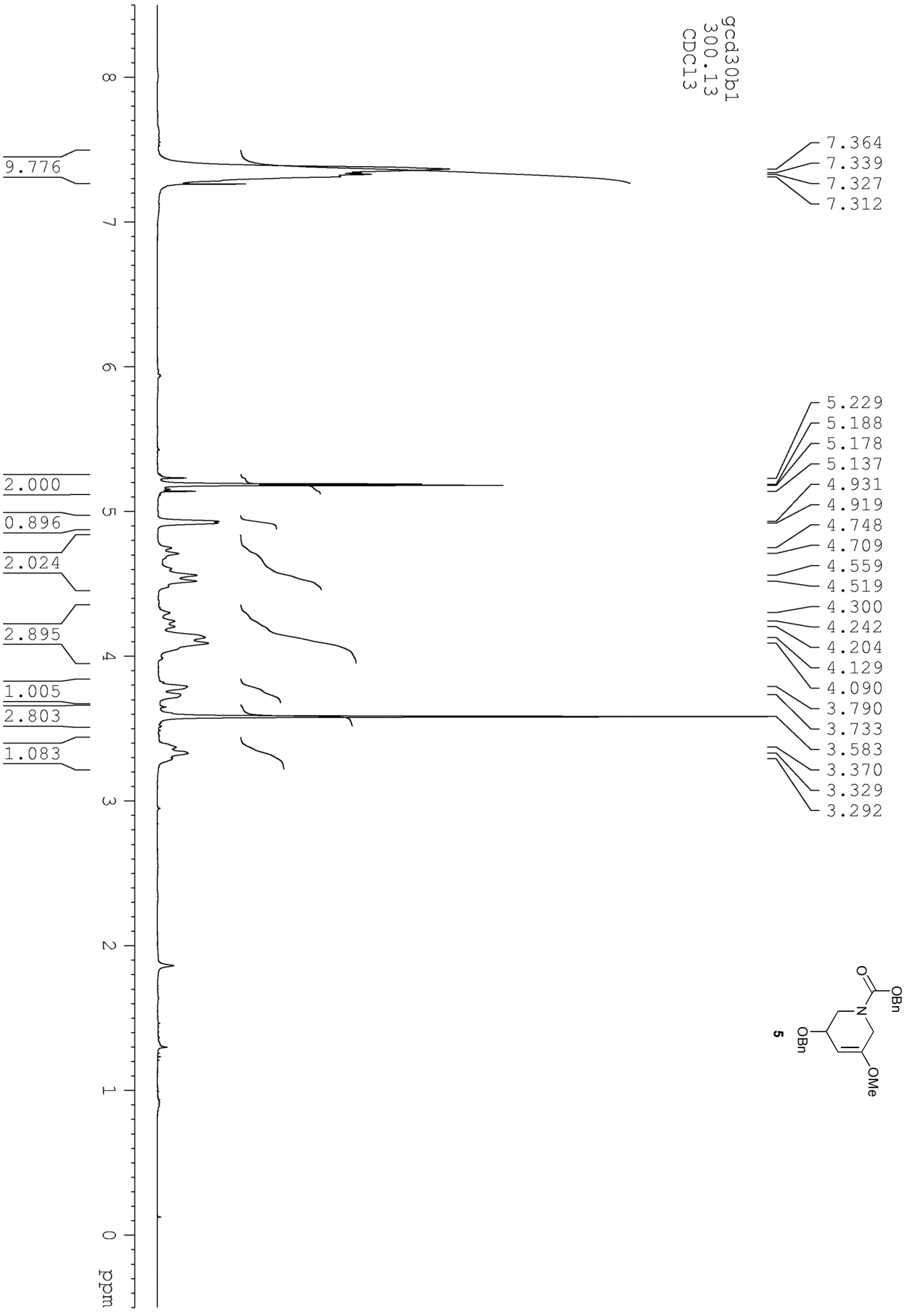
44.35
ppm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2.895
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2.803
1.083
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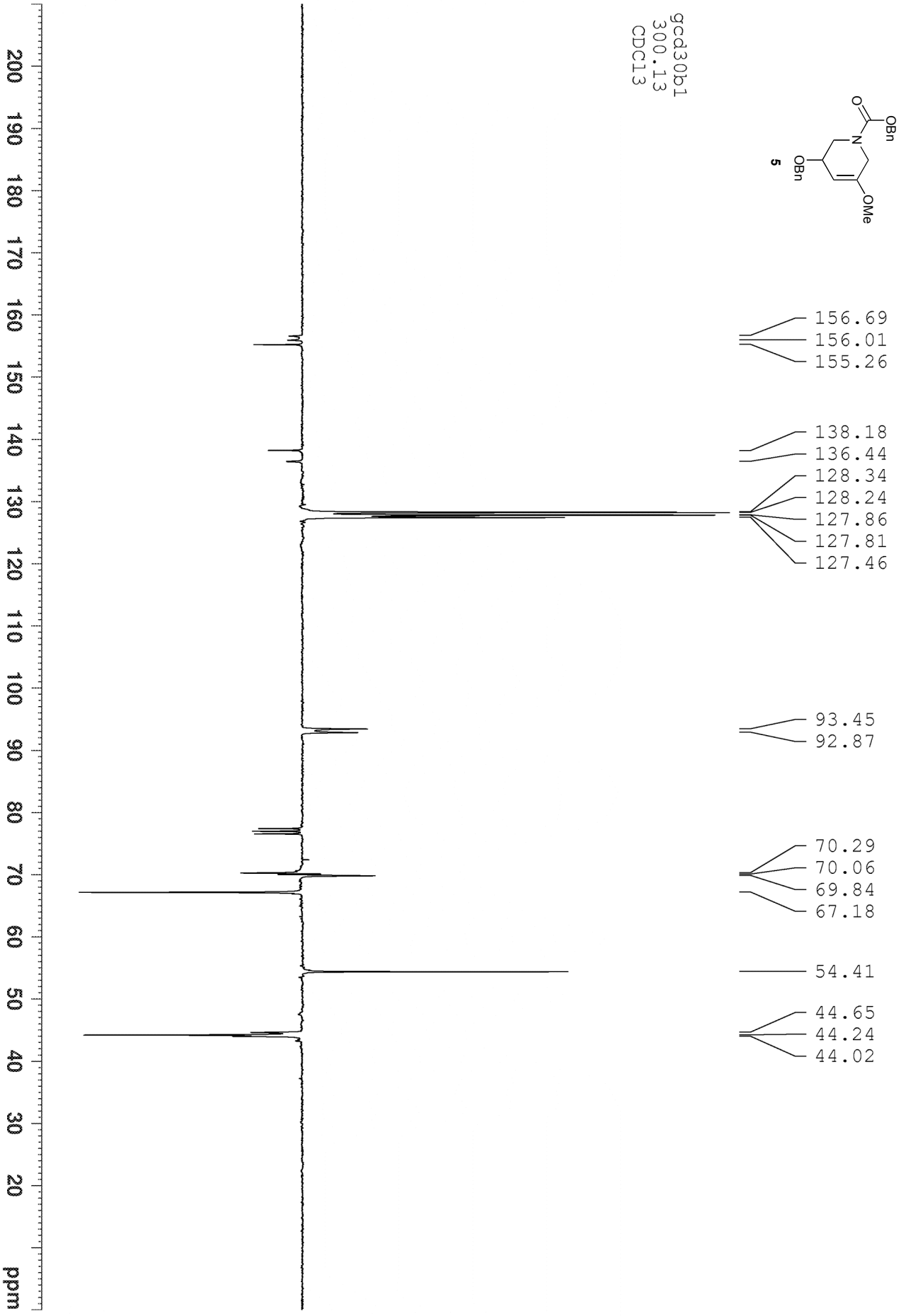
7.339
7.327
7.312
5.229
5.188
5.178
5.137
4.931
4.919
4.748
4.709
4.559
4.519
4.300
4.242
4.204
4.129
4.090
3.790
3.733
3.583
3.370
3.329
3.292
ppm
OBn
OBn
OMe
5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CDCl3
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N
O
OBn
OMe
5
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156.01
155.26
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136.44
128.34
128.24
127.86
127.81
127.46
93.45
92.87
70.29
70.06
69.84
67.18
54.41
44.65
44.24
44.02
200
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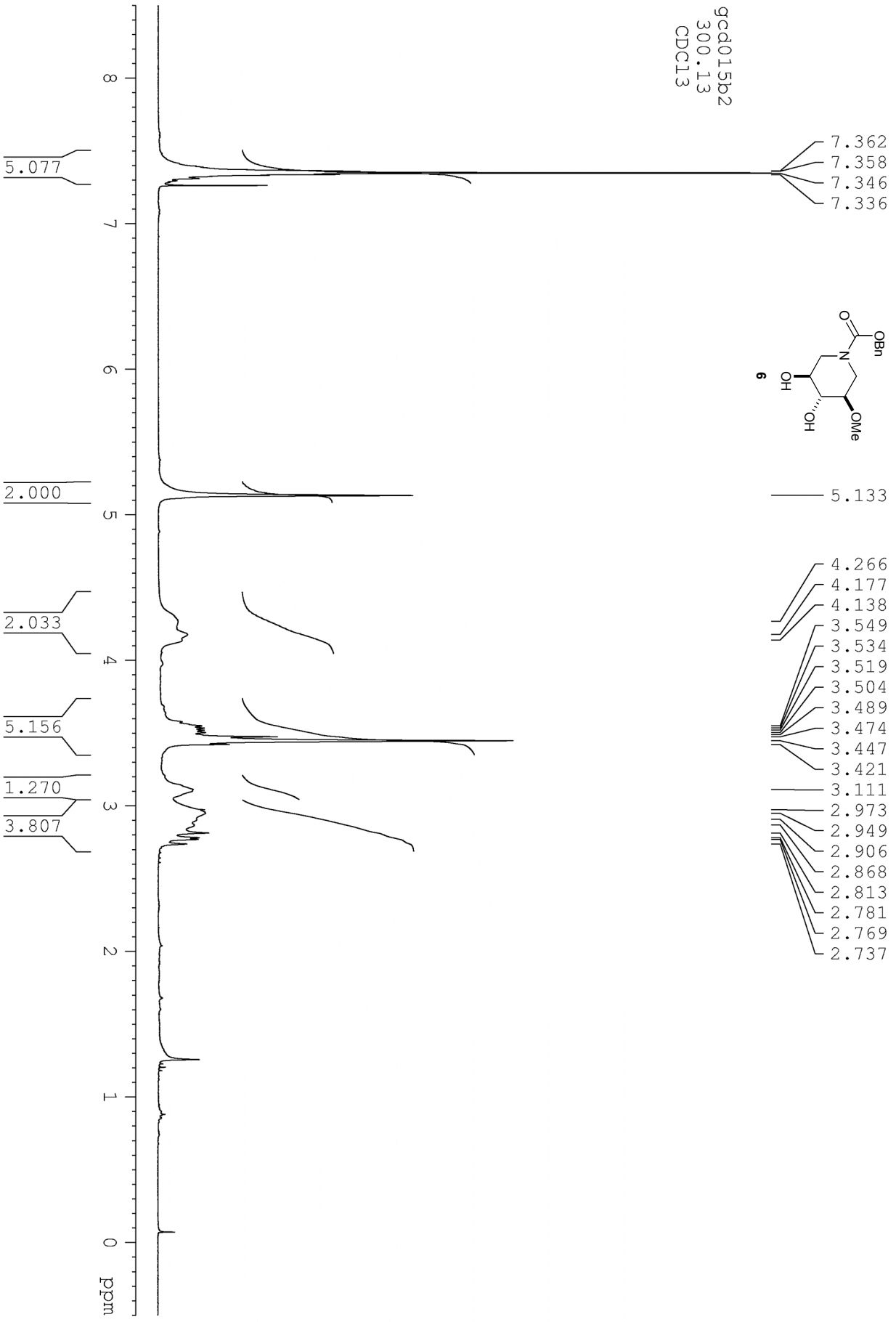
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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3.534
3.519
3.504
3.489
3.474
3.447
3.421
3.111
2.973
2.949
2.906
2.868
2.813
2.781
2.769
2.737
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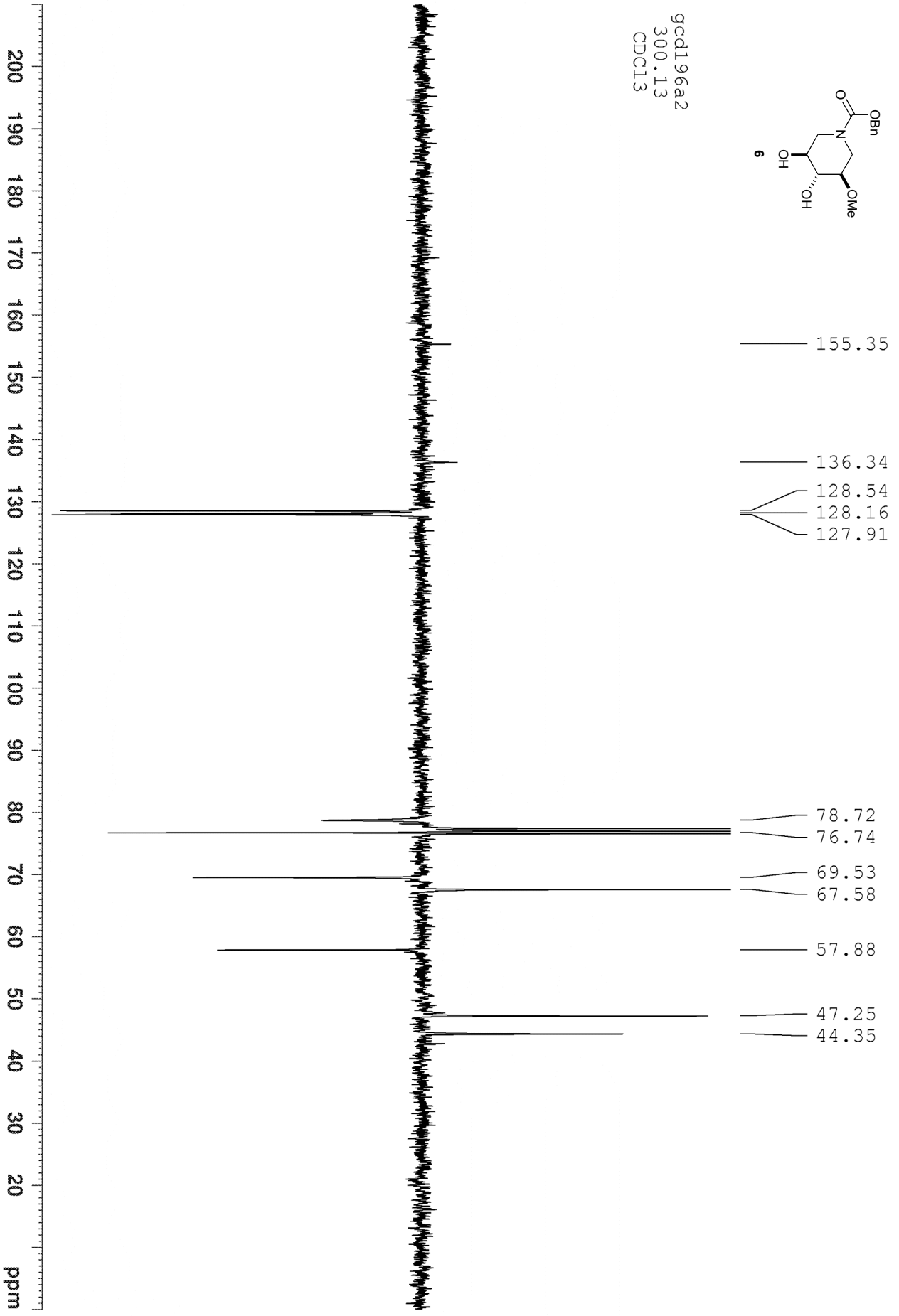
2.000
2.033
5.156
1.270
3.807
OBn
OH
OH
OMe
6
ppm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CDC13
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OH
OH
OMe
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67.58
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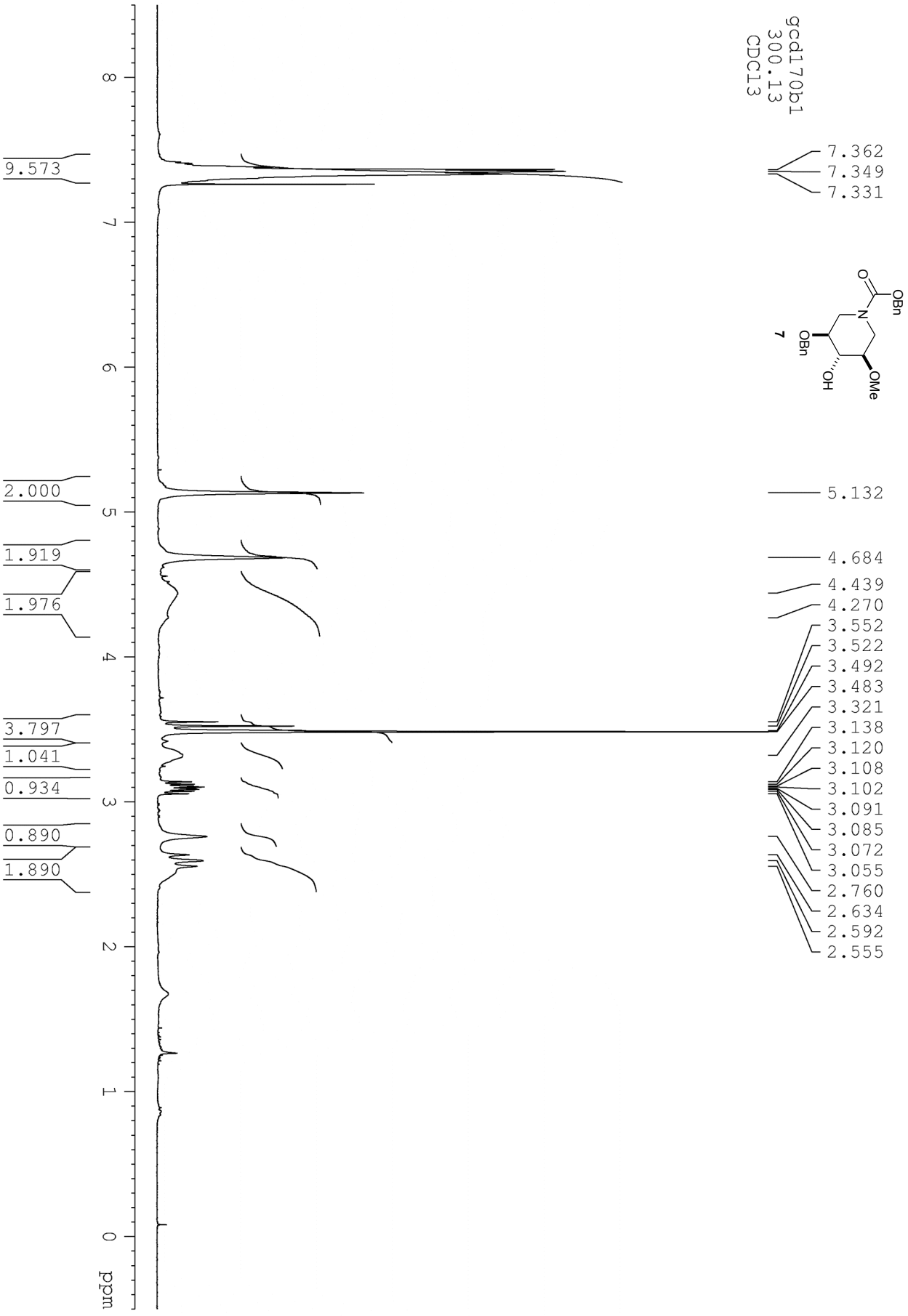
47.25
44.35
ppm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4.270
3.552
3.522
3.492
3.483
3.321
3.138
3.120
3.108
3.102
3.091
3.085
3.072
3.055
2.760
2.634
2.592
2.555
9.573
2.000
1.919
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1.041
0.934
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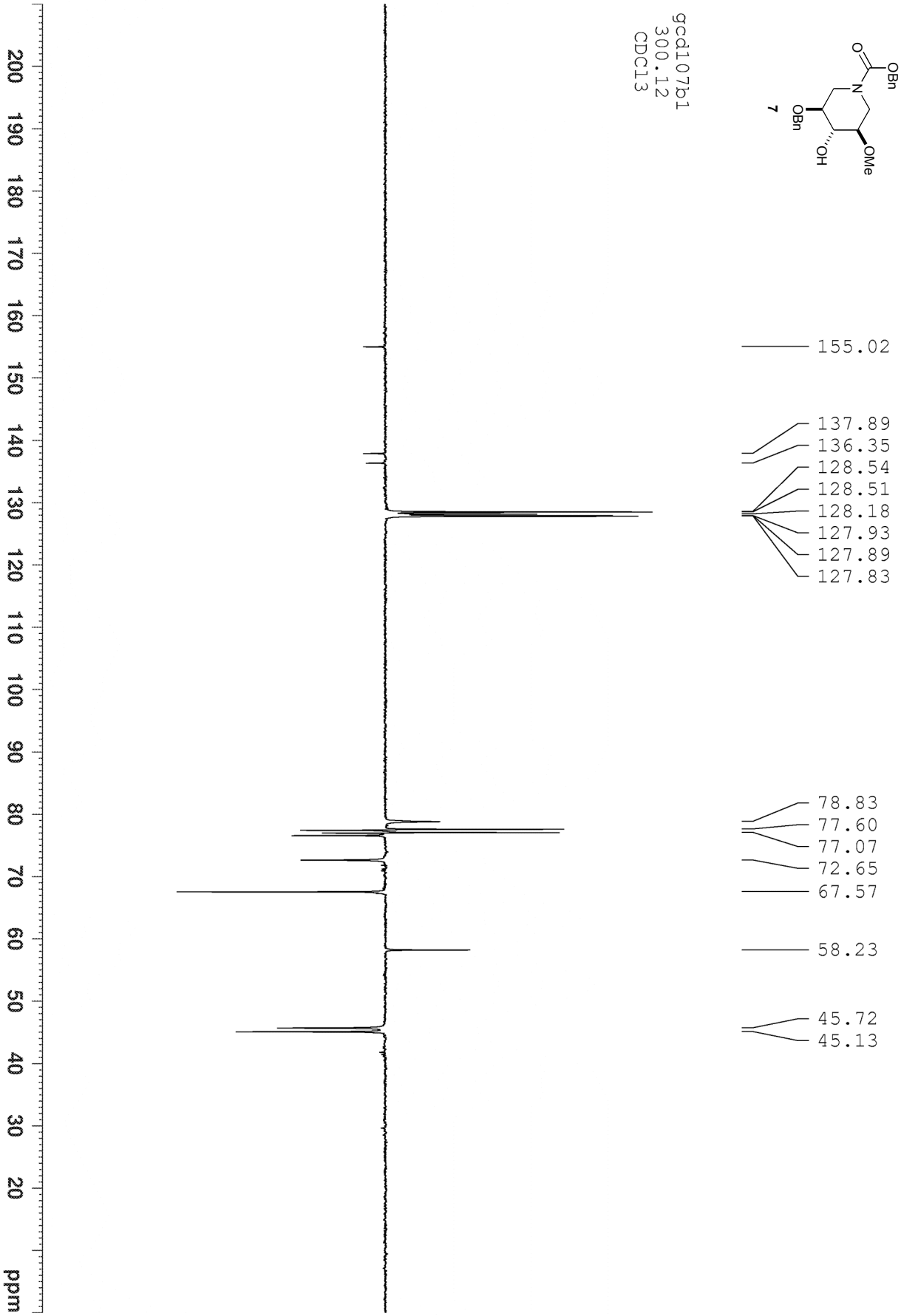
1.890
ppm
OBn
OBn
OH
OMe
7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OH
OMe
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128.18
127.93
127.89
127.83
78.83
77.60
77.07
72.65
67.57
58.23
45.72
45.13
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180
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160
150
140
130
120
110
100
90
80
70
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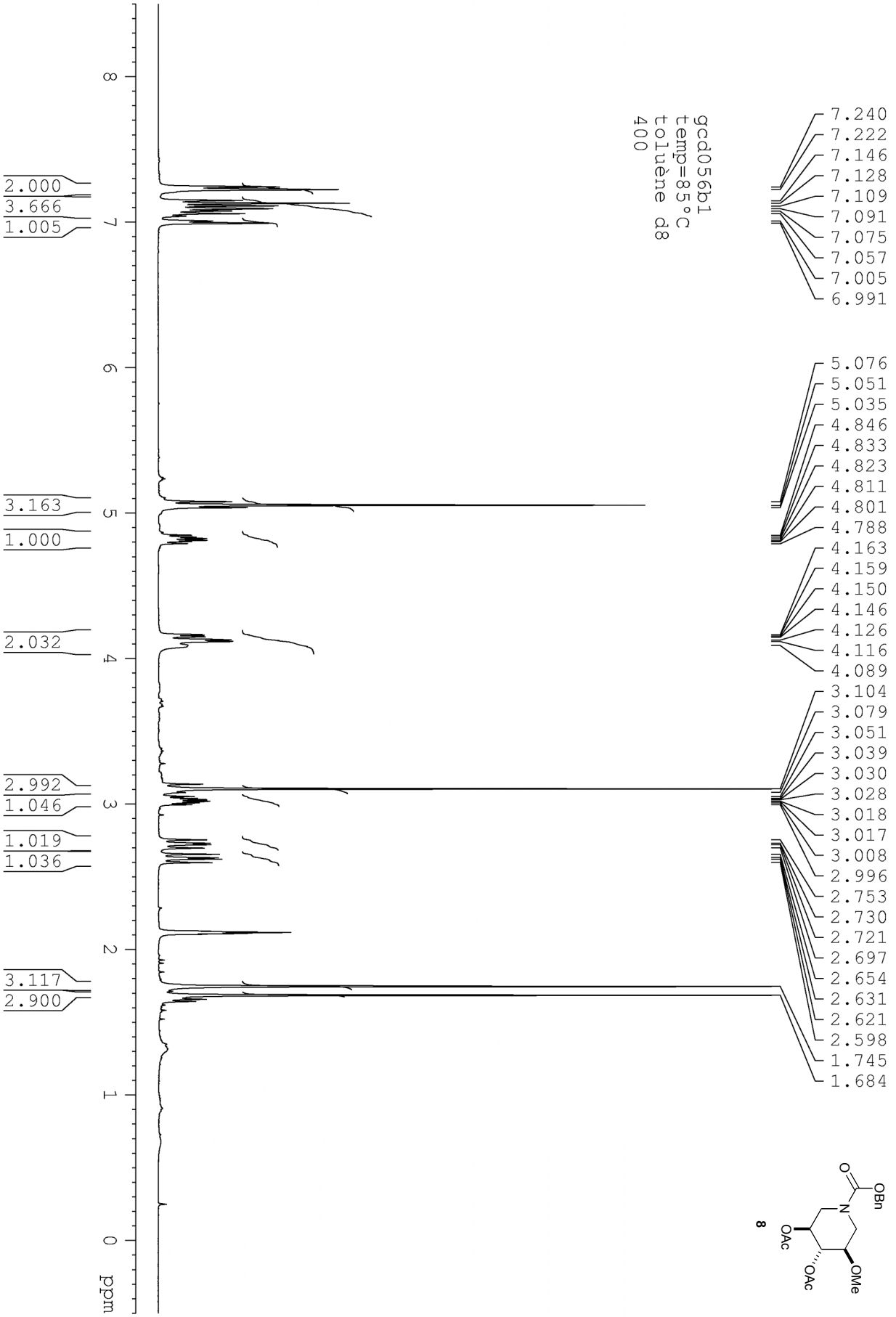
40
30
20
ppm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toluène d8
400
7.240
7.222
7.146
7.128
7.109
7.091
7.075
7.057
7.005
6.991
5.076
5.051
5.035
4.846
4.833
4.823
4.811
4.801
4.788
4.163
4.159
4.150
4.146
4.126
4.116
4.089
3.104
3.079
3.051
3.039
3.030
3.028
3.018
3.017
3.008
2.996
2.753
2.730
2.721
2.697
2.654
2.631
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3.163
1.000
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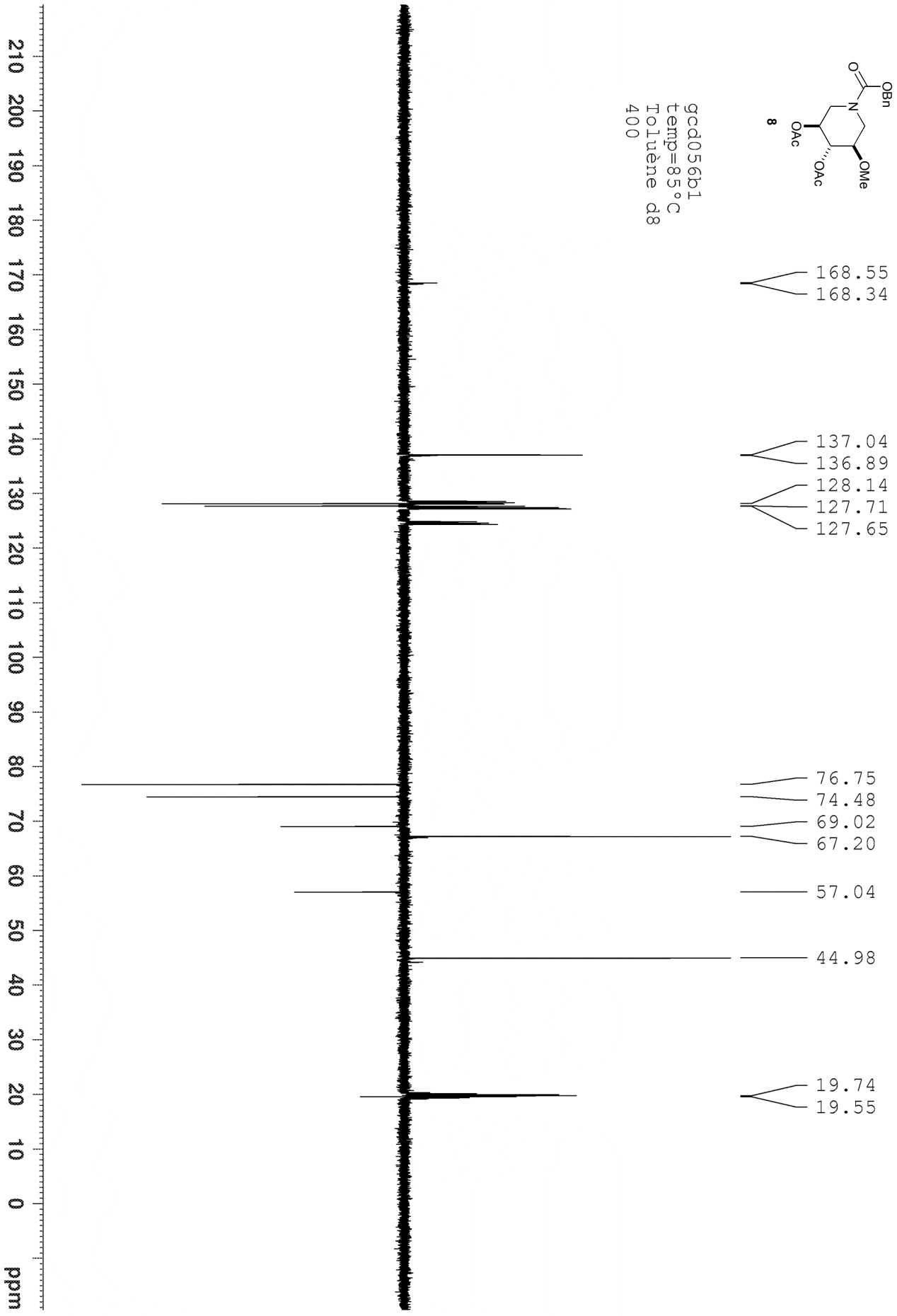
1.046
1.019
1.036
3.117
2.900
ppm
OBn
OAc
OAc
OMe
8


gcd056b1
temp=85°C
Toluène d8
400
8
OBn
OMe
OAc
OAc
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137.04
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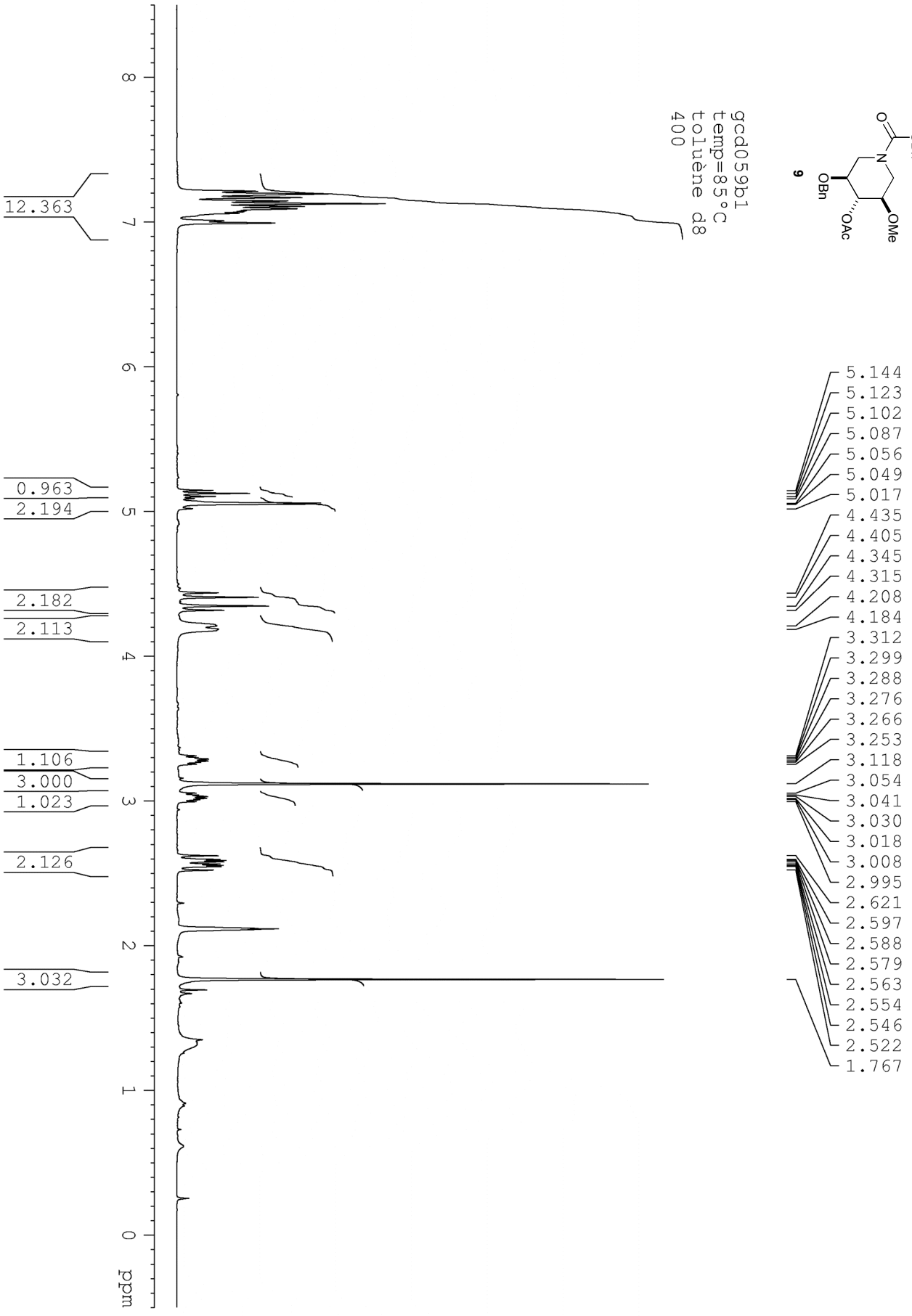
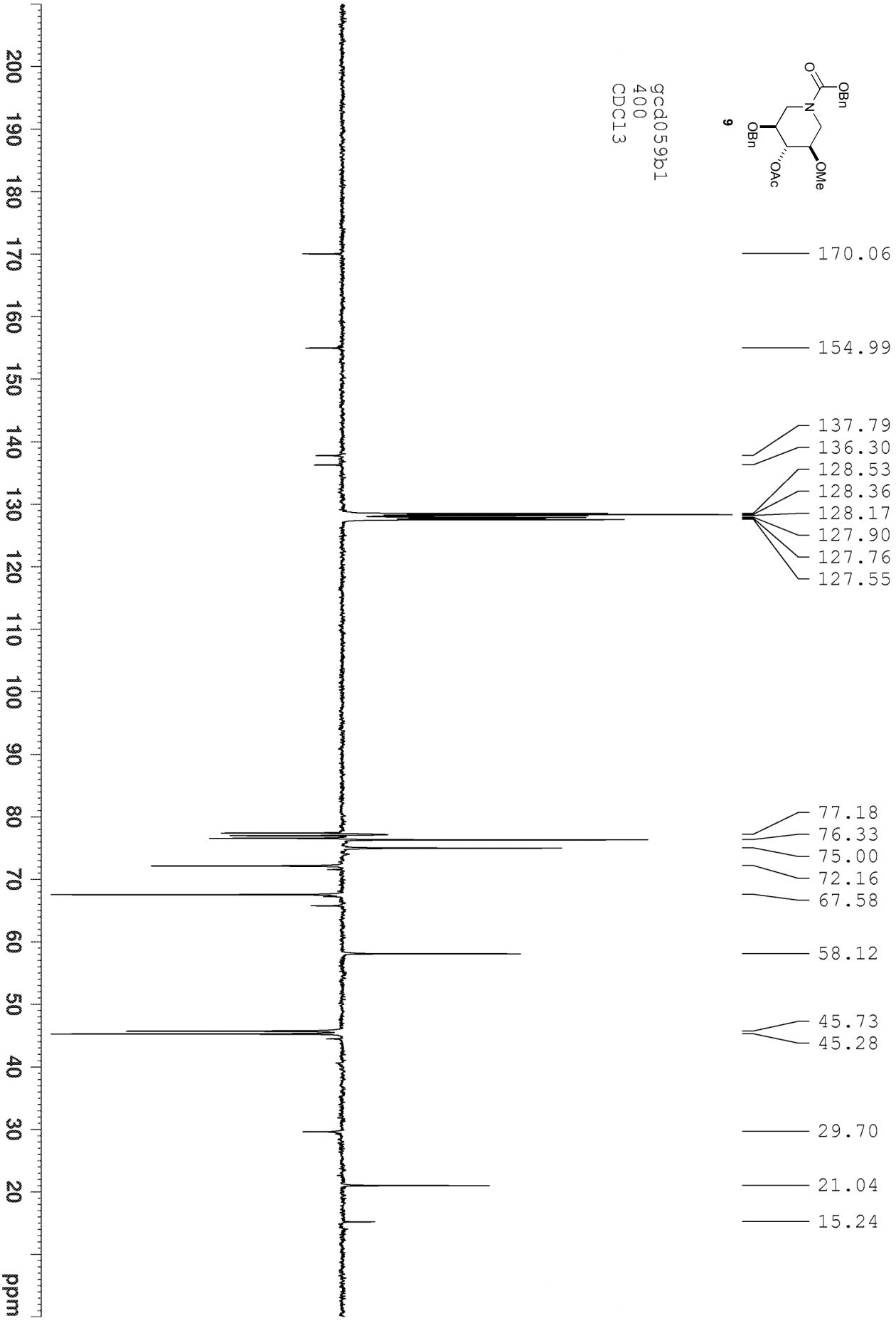
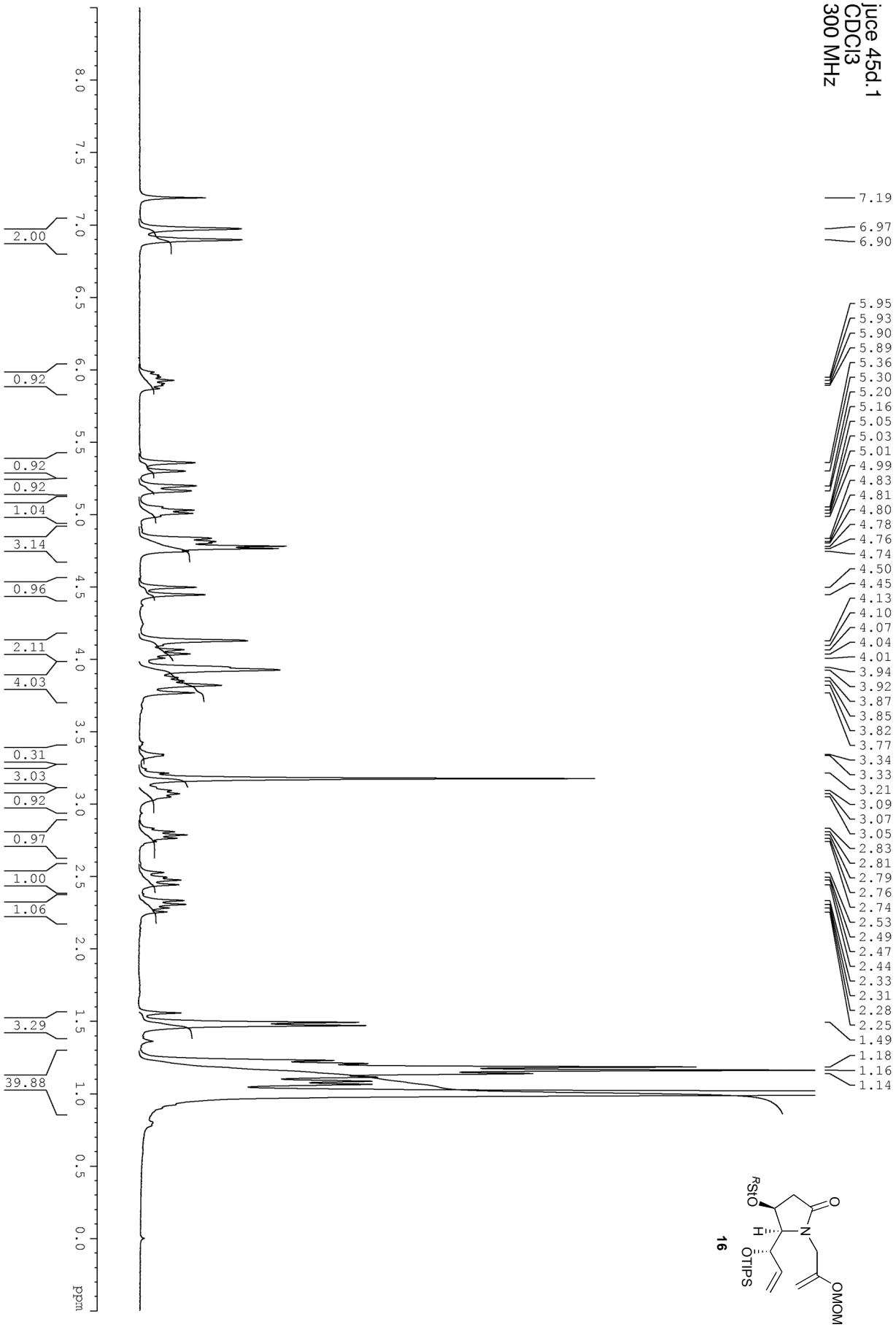
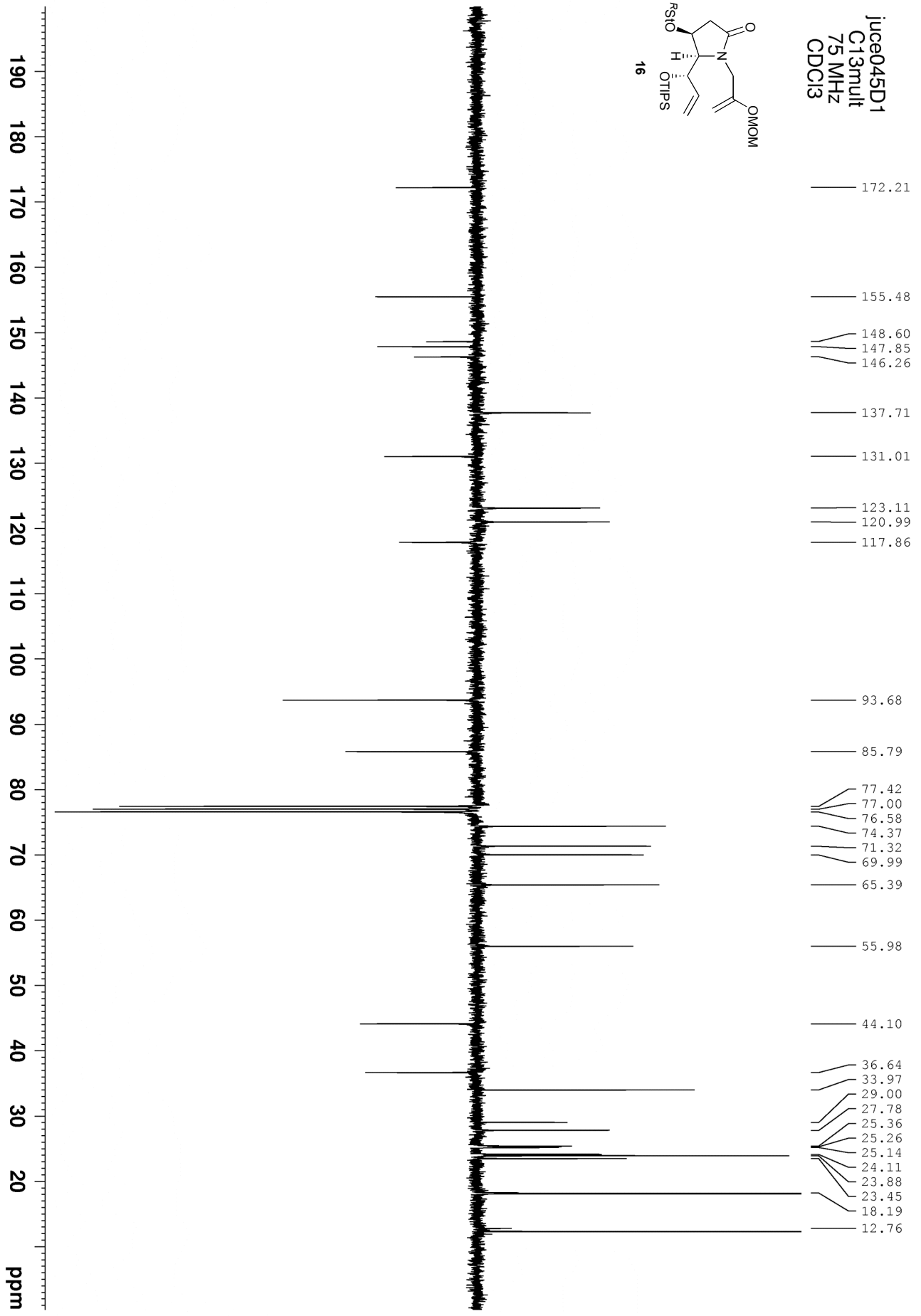
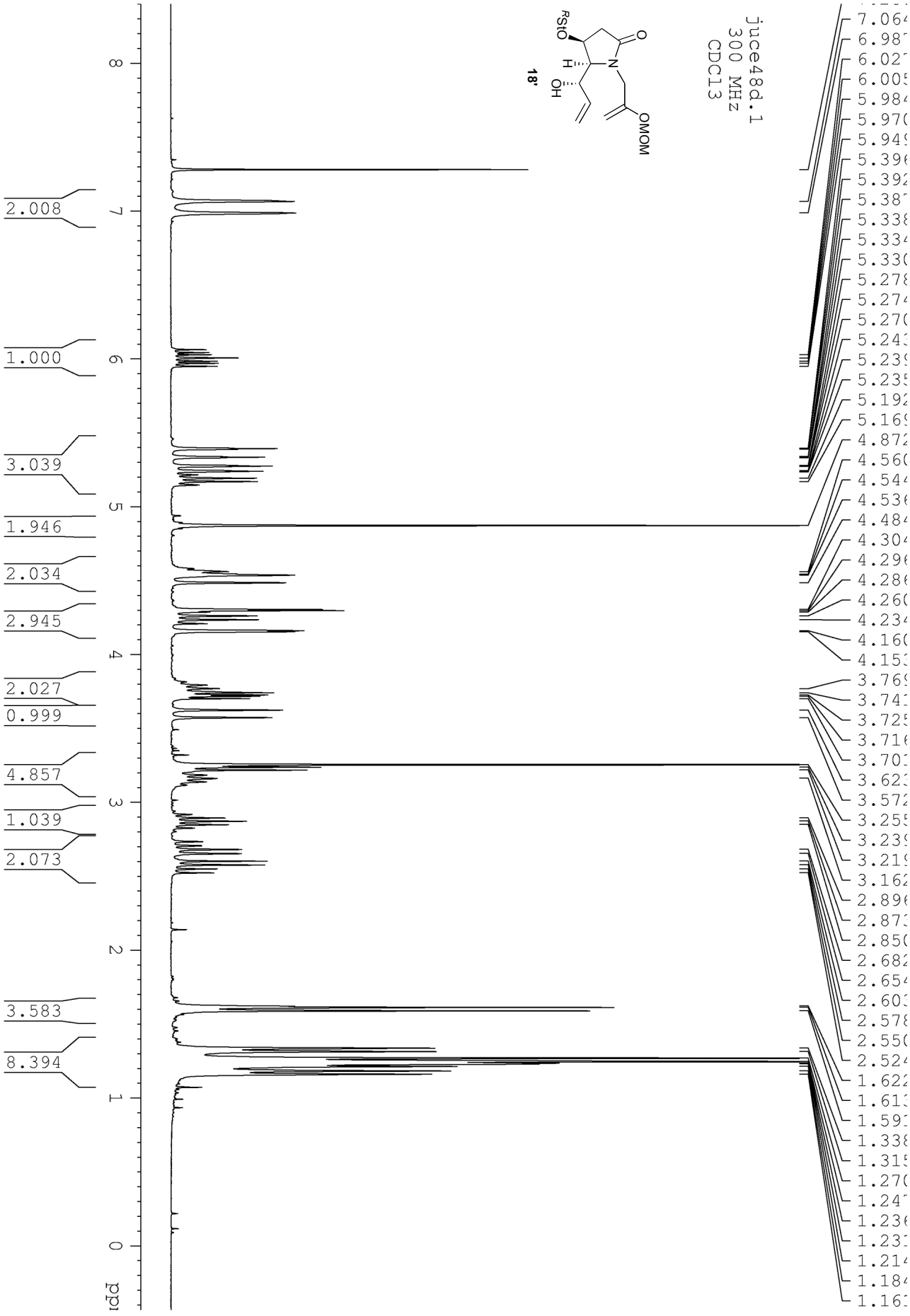
127.65
76.75
74.48
69.02
67.20
57.04
44.98
19.74
19.55
ppm

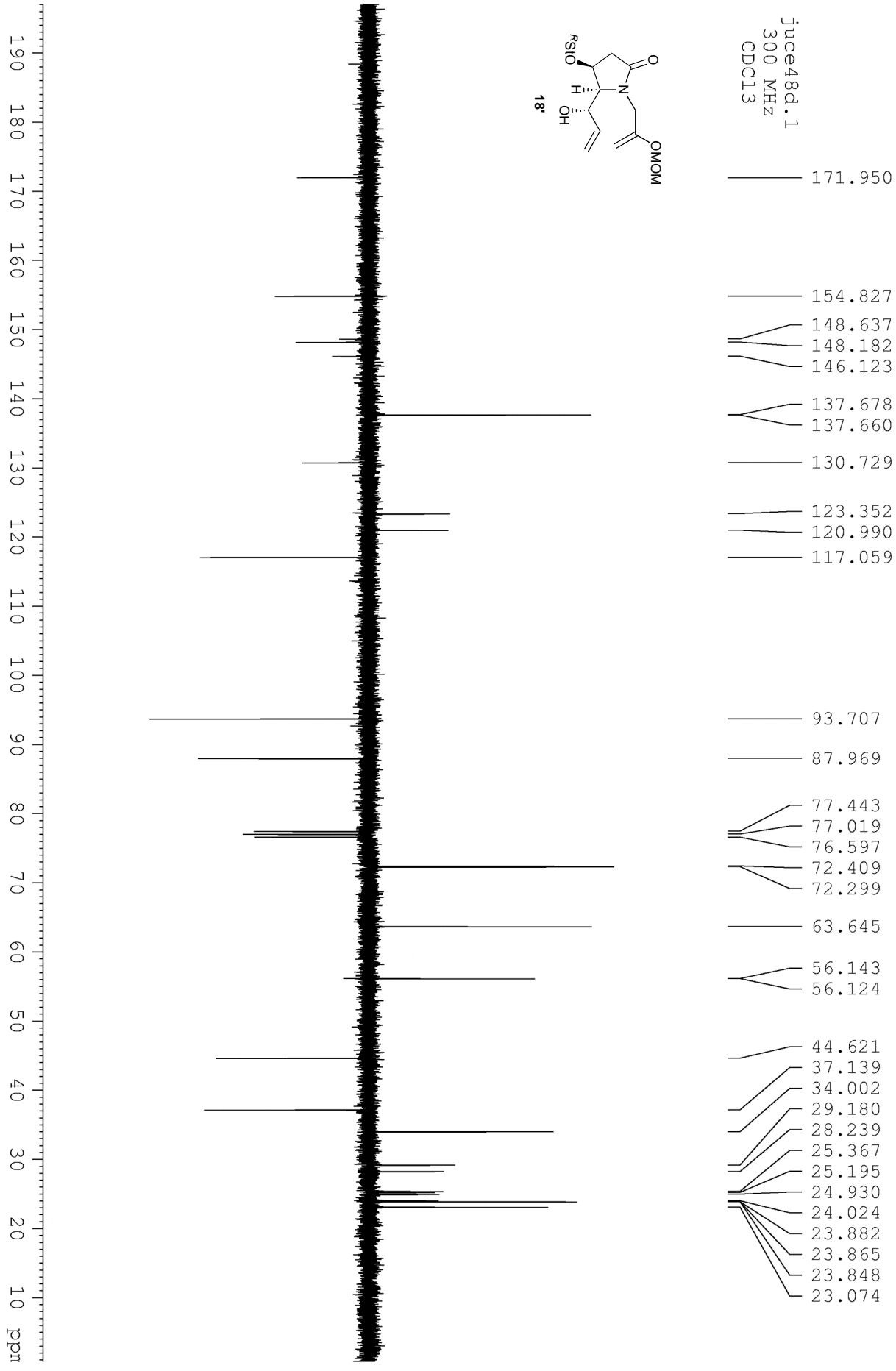

gcd059b1
temp=85°C
toluène d8
400
9
OBn
OBn
OAc
OMe
12.363
0.963
2.194
2.182
2.113
1.106
3.000
1.023
2.126
3.032
5.144
5.123
5.102
5.087
5.056
5.049
5.017
4.435
4.405
4.345
4.315
4.208
4.184
3.312
3.299
3.288
3.276
3.266
3.253
3.118
3.054
3.041
3.030
3.018
3.008
2.995
2.621
2.597
2.588
2.579
2.563
2.554
2.546
2.522
1.767
ppm

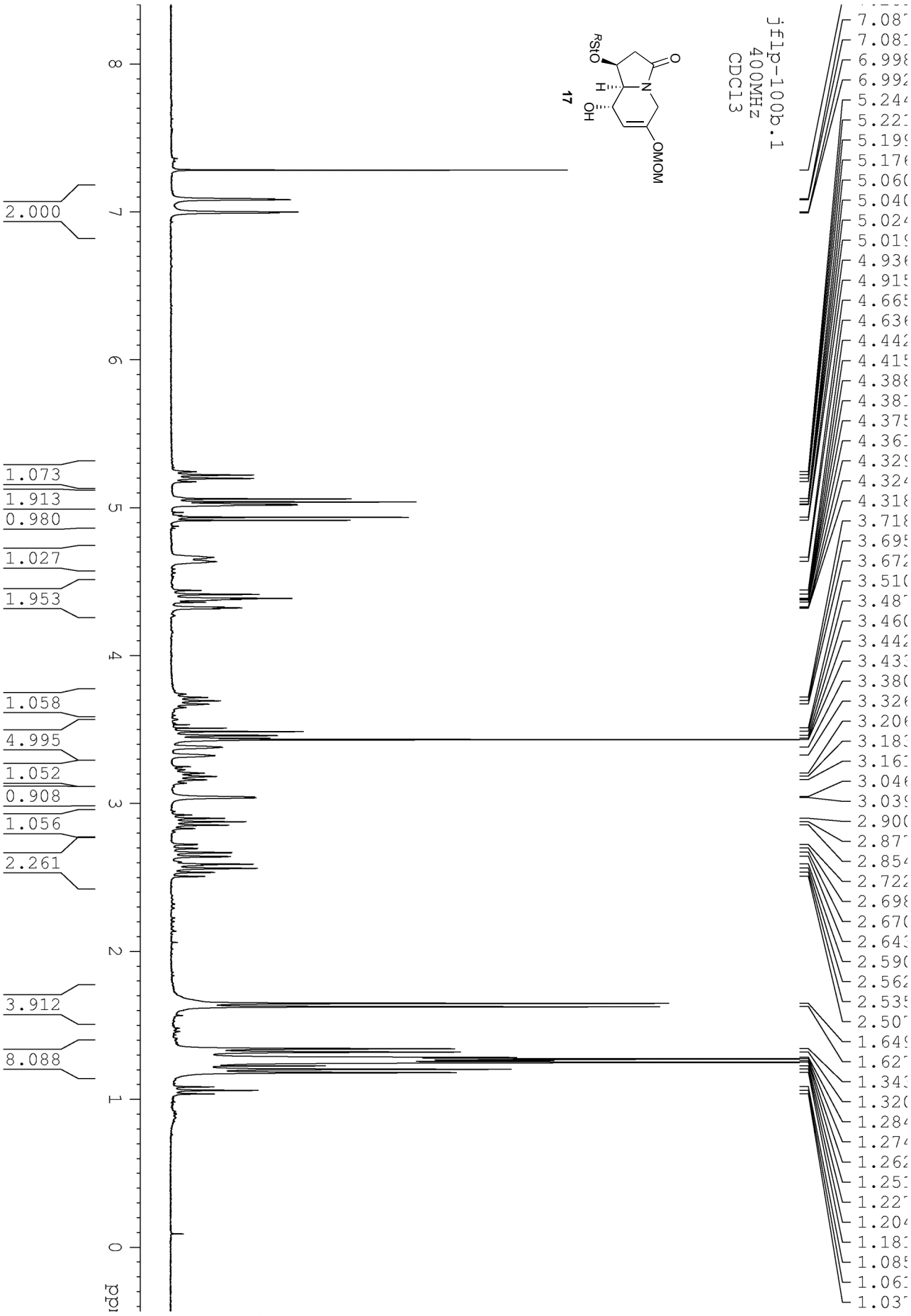

gcd059b1
400
CDC13
9
OBn
OBn
OAc
OMe
170.06
154.99
137.79
136.30
128.53
128.36
128.17
127.90
127.76
127.55
77.18
76.33
75.00
72.16
67.58
58.12
45.73
45.28
29.70
21.04
15.24
ppm

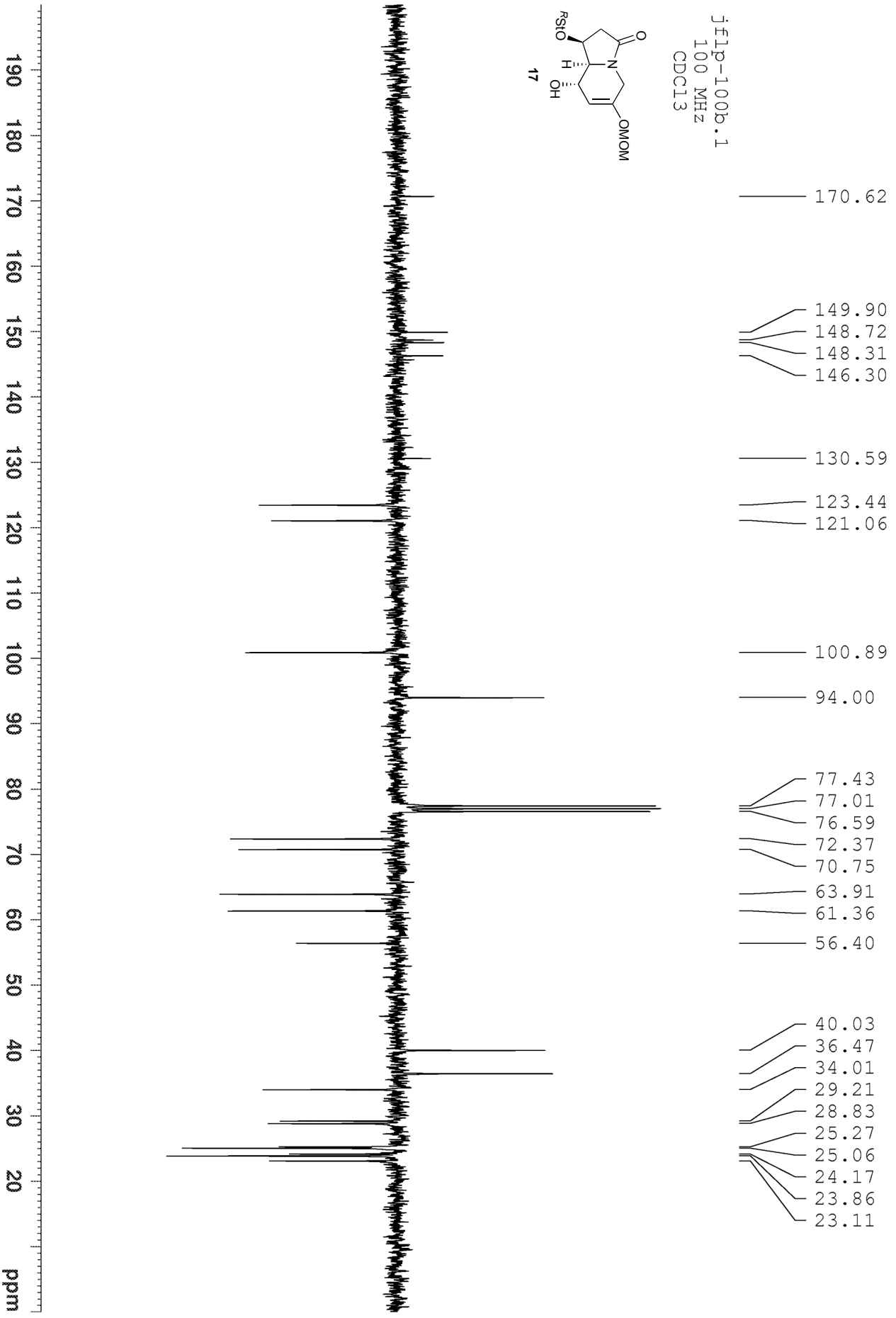

juce 45d.1
CDCl3
300 MHz
7.19
6.97
6.90
5.95
5.93
5.90
5.89
5.36
5.30
5.20
5.16
5.05
5.03
5.01
4.99
4.83
4.81
4.80
4.78
4.76
4.74
4.50
4.45
4.13
4.10
4.07
4.04
4.01
3.94
3.92
3.87
3.85
3.82
3.77
3.34
3.33
3.21
3.09
3.07
3.05
2.83
2.81
2.79
2.76
2.74
2.53
2.49
2.47
2.44
2.33
2.31
2.28
2.25
1.49
1.18
1.16
1.14
2.00
0.92
0.92
0.92
1.04
3.14
0.96
2.11
4.03
0.31
3.03
0.92
0.97
1.00
1.06
3.29
39.88
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
ppm
RStO
H
OTIPS
O
N
OMOM
16

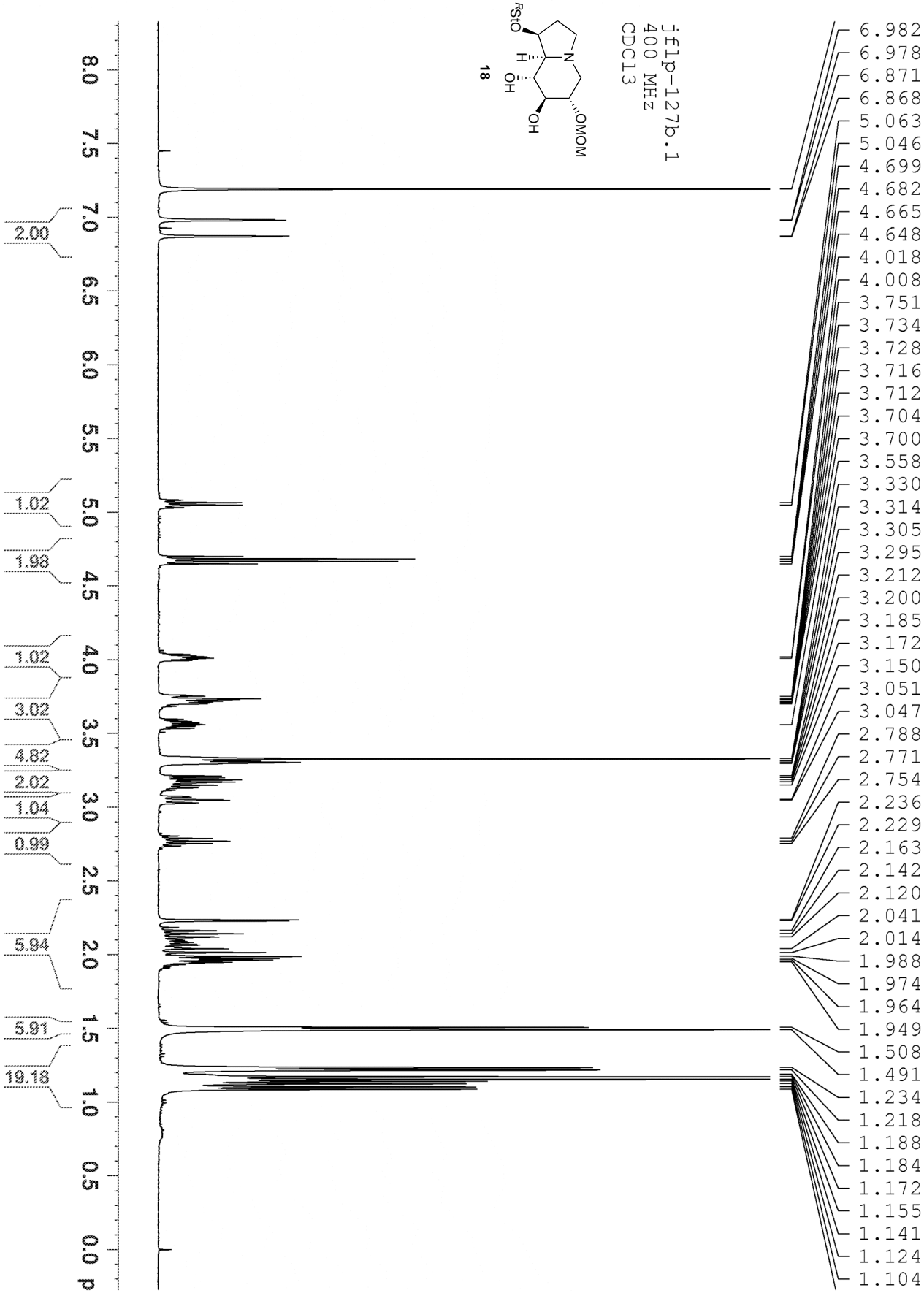

juce045D1
C13mult
75 MHz
CDCl3
16
OMOM
OTIPS
172.21
155.48
148.60
147.85
146.26
137.71
131.01
123.11
120.99
117.86
93.68
85.79
77.42
77.00
76.58
74.37
71.32
69.99
65.39
55.98
44.10
36.64
33.97
29.00
27.78
25.36
25.26
25.14
24.11
23.88
23.45
18.19
12.76
ppm


juce48d.1
300 MHz
CDC13
18'
OMOM
2.008
1.000
3.039
1.946
2.034
2.945
2.027
0.999
4.857
1.039
2.073
3.583
8.394
ppm

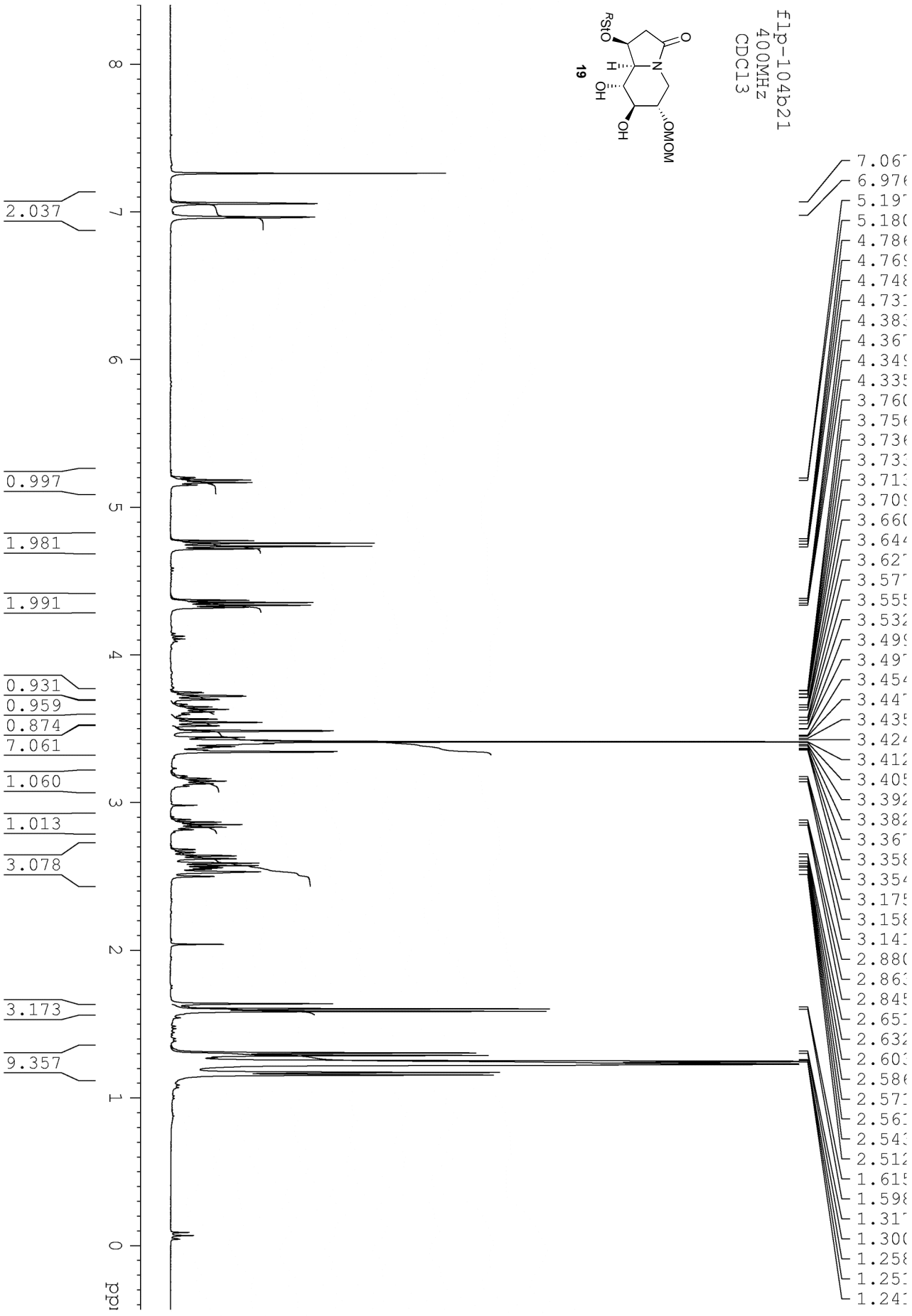

juce48d.1
300 MHz
CDC13
171.950
154.827
148.637
148.182
146.123
137.678
137.660
130.729
123.352
120.990
117.059
93.707
87.969
77.443
77.019
76.597
72.409
72.299
63.645
56.143
56.124
44.621
37.139
34.002
29.180
28.239
25.367
25.195
24.930
24.024
23.882
23.865
23.848
23.074
OMOM
18'
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


jflp-100b.1
400MHz
CDCl3
17
OMOM
OH
RSiO
2.000
1.073
1.913
0.980
1.027
1.953
1.058
4.995
1.052
0.908
1.056
2.261
3.912
8.088
ppm


jflp-100b.1
100 MHz
CDCl3
17
OMOM
OH
RsiO
170.62
149.90
148.72
148.31
146.30
130.59
123.44
121.06
100.89
94.00
77.43
77.01
76.59
72.37
70.75
63.91
61.36
56.40
40.03
36.47
34.01
29.21
28.83
25.27
25.06
24.17
23.86
23.11
ppm


jflp-127b.1
400 MHz
CDCl3
18
OMOM
OH
OH
RStO
2.00
1.02
1.98
1.02
3.02
4.82
2.02
1.04
0.99
5.94
5.91
19.18
6.982
6.978
6.871
6.868
5.063
5.046
4.699
4.682
4.665
4.648
4.018
4.008
3.751
3.734
3.728
3.716
3.712
3.704
3.700
3.558
3.330
3.314
3.305
3.295
3.212
3.200
3.185
3.172
3.150
3.051
3.047
2.788
2.771
2.754
2.236
2.229
2.163
2.142
2.120
2.041
2.014
1.988
1.974
1.964
1.949
1.508
1.491
1.234
1.218
1.188
1.184
1.172
1.155
1.141
1.124
1.104

ilp-104b.21
400 MHz
CDC13
170.79
148.72
146.11
123.44
121.03
97.22
77.44
77.02
76.76
76.72
76.59
72.66
70.17
61.59
55.82
41.59
37.02
34.01
29.24
28.91
25.20
25.08
24.17
23.87
22.93
18
RStO
H
OH
OH
OMOM
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


flp-104b21
400MHz
CDC13
19
OMOM
OH
OH
RStO
2.037
0.997
1.981
1.991
0.931
0.959
0.874
7.061
1.060
1.013
3.078
3.173
9.357
ppm

flp-aminPcast 127b.1
100MHz
CDCl3

19

148.81
147.68
145.52

132.81

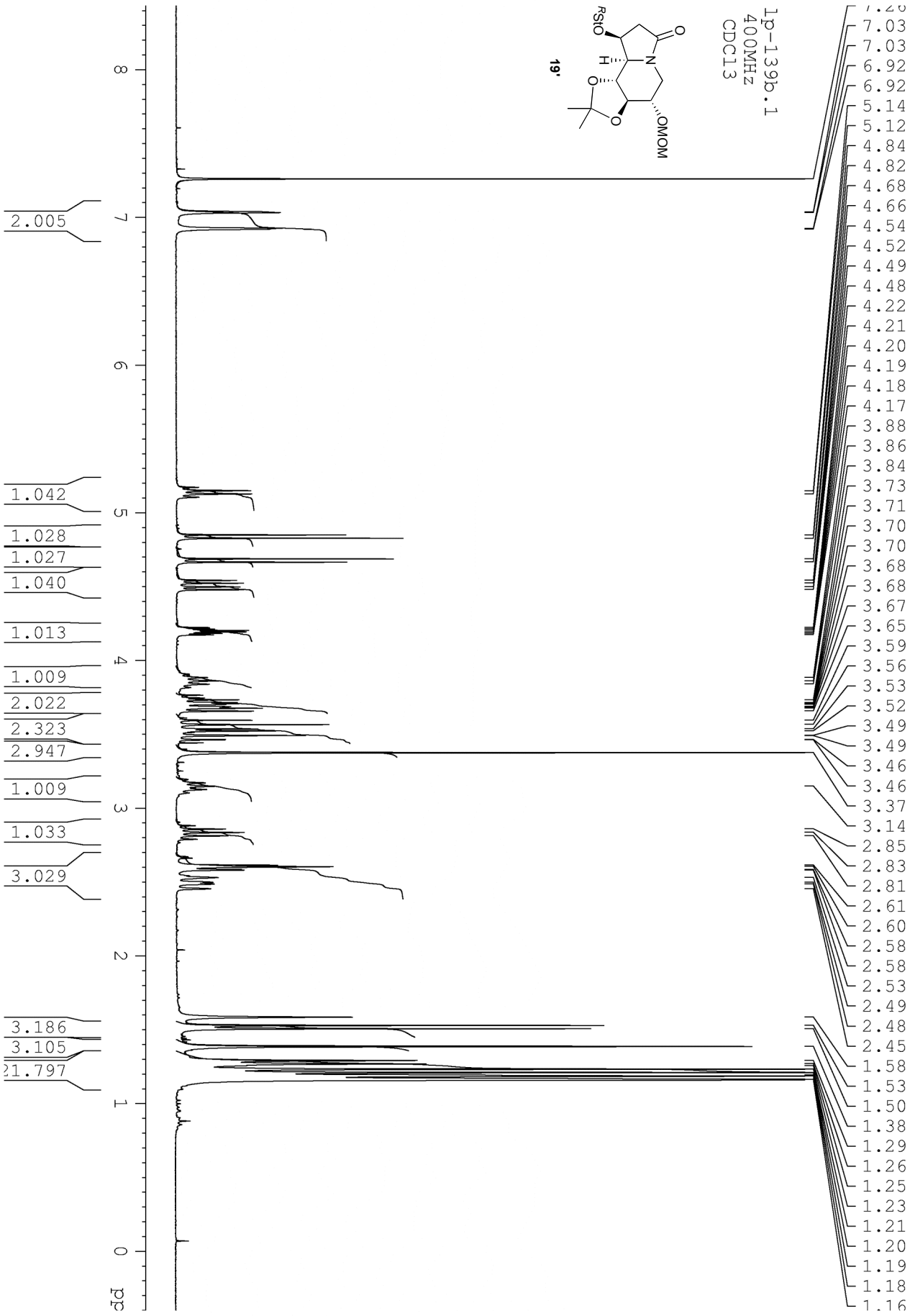
123.19
120.69

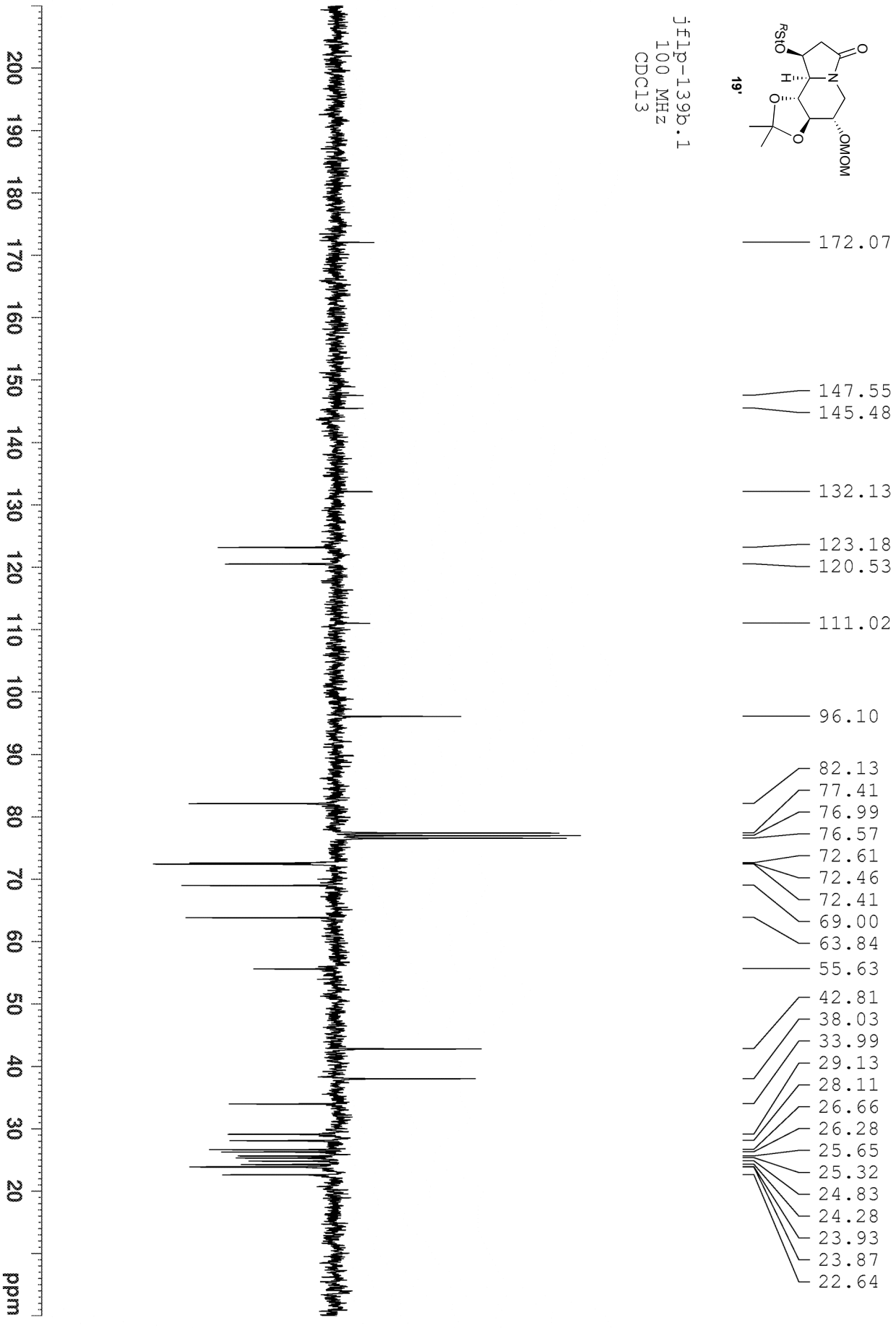
97.34

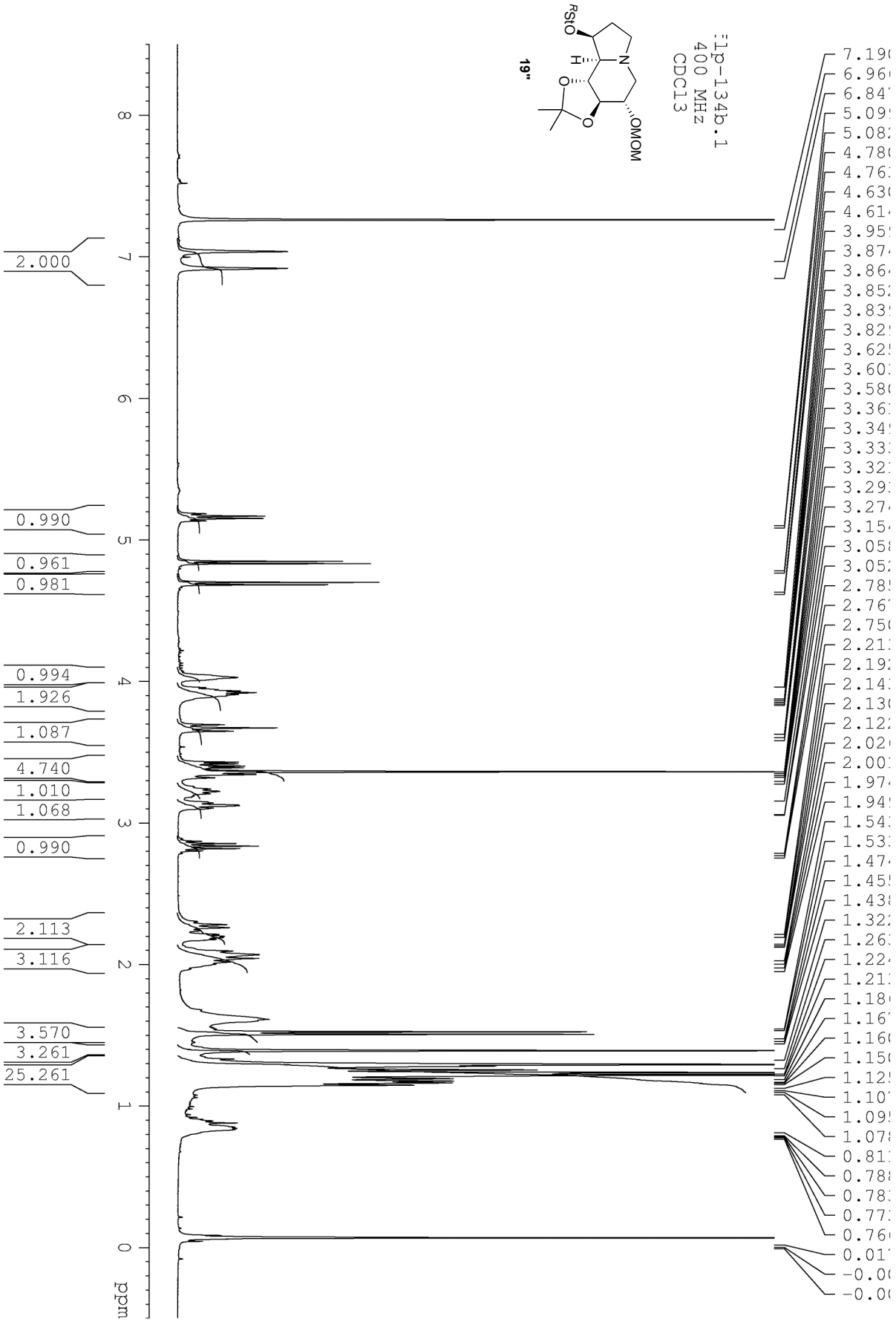
79.13
77.76
77.33
77.08
77.01
76.70
71.81
69.81

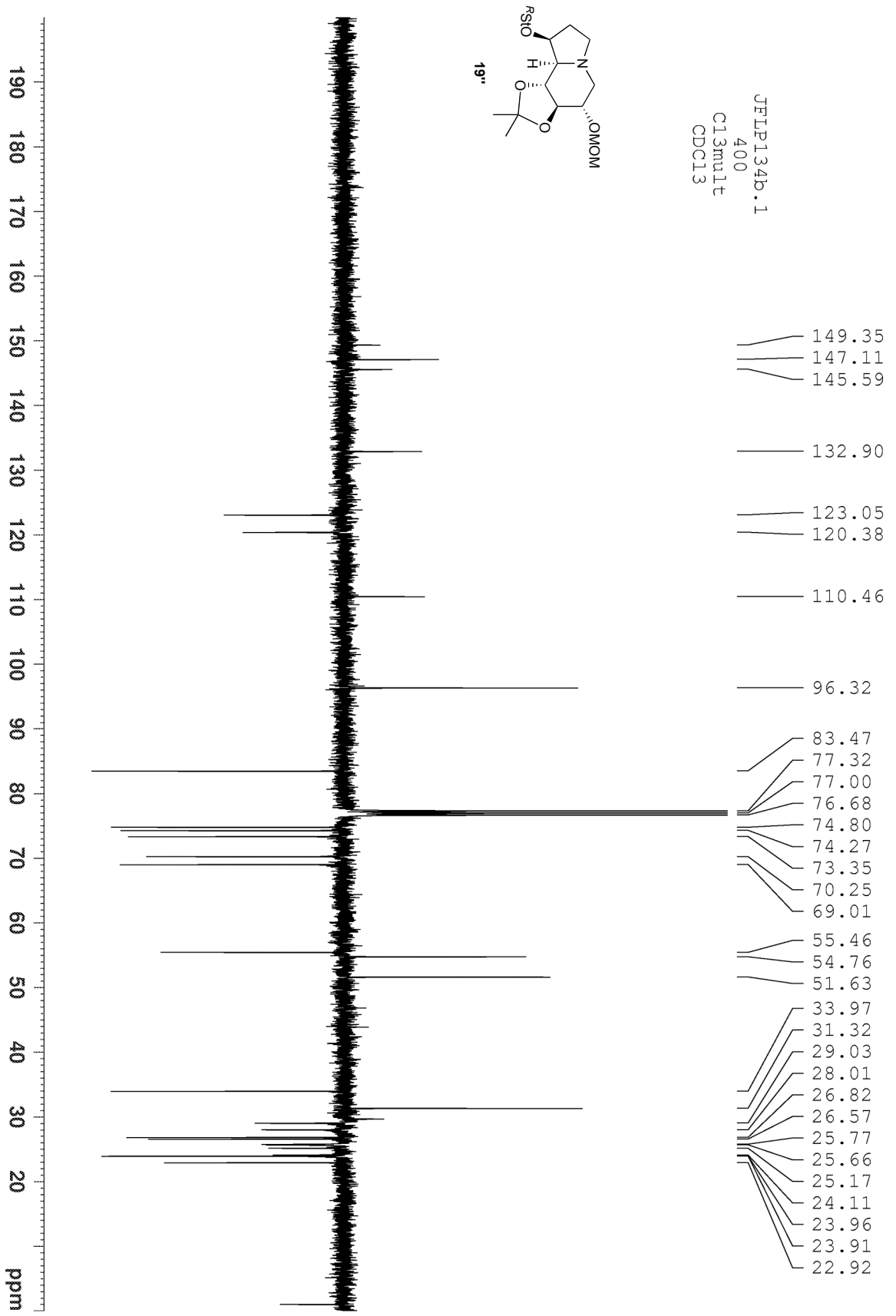
55.61
54.31
51.97

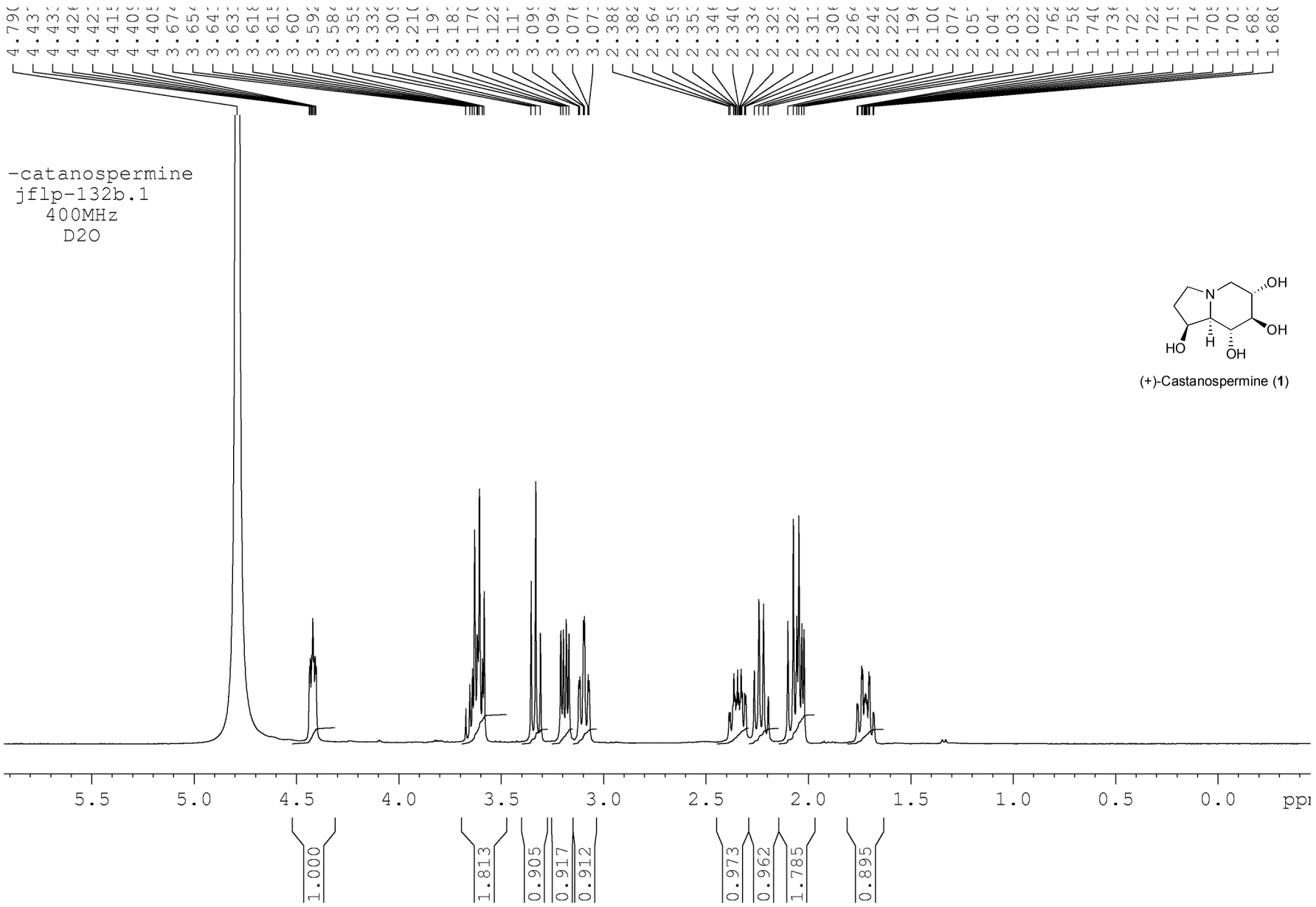
33.99
31.97
29.26
28.67
25.93
25.11
24.61
24.13
23.93
23.87
23.26


lp-139b.1
400MHz
CDCl3
19'
OMOM
2.005
1.042
1.028
1.027
1.040
1.013
1.009
2.022
2.323
2.947
1.009
1.033
3.029
3.186
3.105
1.797
7.03
7.03
6.92
6.92
5.14
5.12
4.84
4.82
4.68
4.66
4.54
4.52
4.49
4.48
4.22
4.21
4.20
4.19
4.18
4.17
3.88
3.86
3.84
3.73
3.71
3.70
3.70
3.68
3.68
3.67
3.65
3.59
3.56
3.53
3.52
3.49
3.49
3.46
3.46
3.37
3.14
2.85
2.83
2.81
2.61
2.60
2.58
2.58
2.53
2.49
2.48
2.45
1.58
1.53
1.50
1.38
1.29
1.26
1.25
1.23
1.21
1.20
1.19
1.18
ppm


jflp-139b.1
100 MHz
CDCl3
19'
OMOM
172.07
147.55
145.48
132.13
123.18
120.53
111.02
96.10
82.13
77.41
76.99
76.57
72.61
72.46
72.41
69.00
63.84
55.63
42.81
38.03
33.99
29.13
28.11
26.66
26.28
25.65
25.32
24.83
24.28
23.93
23.87
22.64
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
ppm


ilp-134b.1
400 MHz
CDCl3
19"
RStO
OMOM
2.000
0.990
0.961
0.981
0.994
1.926
1.087
4.740
1.010
1.068
0.990
2.113
3.116
3.570
3.261
25.261
ppm


JFILP134b.1
400
C13mult
CDC13
19"
RStO
H
O
N
OMOM
149.35
147.11
145.59
132.90
123.05
120.38
110.46
96.32
83.47
77.32
77.00
76.68
74.80
74.27
73.35
70.25
69.01
55.46
54.76
51.63
33.97
31.32
29.03
28.01
26.82
26.57
25.77
25.66
25.17
24.11
23.96
23.91
22.92
ppm



(+)-Castanospermine (**1**)

(+)-catanospermine
jflp-132b.1
100MHz
D2O
(+)-Castanospermine (1)
HO
H
OH
N
OH
OH
78.89
71.31
69.98
69.48
68.85
55.26
51.48
32.62
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm