Supporting Information for

Ag(I)-Catalyzed Tandem [6 + 3] Annulation/Isomerization of Isocyanoacetates with Fulvenes: An Expedient Approach to Fused Dihydropyridines

Zhao-Lin He, Chun-Jiang Wang*

E-mail: cjwang@whu.edu.cn

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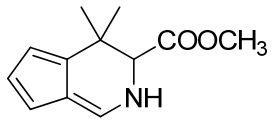
I. General Remarks

^{1}H NMR spectra were recorded on a VARIAN Mercury 300 MHz or Bruker 400 MHz spectrometer in $CDCl_3$. Chemical shifts are reported in ppm with the internal TMS signal at 0.0 ppm as a standard. The data are reported as (s = single, d = double, t = triple, q = quarte, m = multiple or unresolved, brs = broad single, coupling constant(s) in Hz, integration). ^{13}C NMR spectra were recorded on a VARIAN Mercury 75 MHz or Bruker 100 MHz spectrometer in $CDCl_3$. Chemical shifts are reported in ppm with the internal chloroform signal at 77.0 ppm as a standard. Commercially obtained reagentswere used without further purification. All reactionswere monitored by TLC with silica gel-coated plates. Enantiomeric ratios were determined by HPLC, using a chiralpak AS-H column with hexane and *i*-PrOH as solvents. Fulvenes[1] and isocyanoacetates[2] were prepared according to the literature procedure. Chiral ligand TF-BiphamPhos was prepared according our previous procedure.[3]

II. General Procedure for Ag(I)-Catalyzed [6 + 3] Cycloaddition/Isomerization of Isocyanoacetates 1 with Fulvenes 2

Under argon atmosphere, AgOAc (2.0 mg, 0.012 mmol) and PPh_3 (6.9 mg, 0.026 mmol) were dissolved in 2 mL DCM, and stirred at room temperature for about 30 min. Then, isocyanoacetate **2** (0.4 mmol), Et_3N (0.06 mmol) and fulvene **1** (0.6 mmol) was added sequentially. Once starting material was consumed (monitored by TLC), then the organic solvent was removed and the residue was purified by column chromatography to give the product.

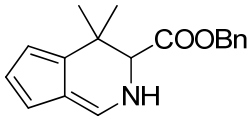


(3a)

Methyl 4,4-dimethyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

The title compound was prepared according to the general procedure as described above in 90% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.29 (d, J = 5.7 Hz, 1H), 6.28 (m, 2H), 6.08 (s, 1H), 5.82 (br, 1H), 4.13 (s, 1H), 3.85 (s, 3H), 1.56 (s, 3H), 1.01 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 171.1, 139.4, 135.1, 124.2, 116.2, 114.7, 65.6, 52.4, 36.8, 25.1, 24.0; HRMS Calcd.

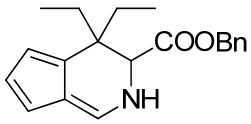
For $C_{12}H_{15}NO_2^+$: 205.1103, found: 205.1104.



(3b)

Benzyl 4,4-dimethyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

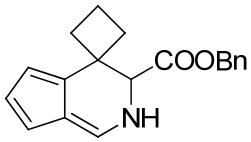
The title compound was prepared according to the general procedure as described above in 95% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.40-7.33 (m, 5H), 7.28-7.25 (m, 1H), 6.26 (s, 2H), 6.05 (s, 1H), 5.81 (br, 1H), 5.32 (d, J = 12.0 Hz, 1H), 5.22 (d, J = 12.0 Hz, 1H), 4.14 (s, 1H), 1.53 (s, 3H), 0.97 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 172.0, 139.5, 135.0, 124.0, 117.5, 116.1, 114.6, 65.6, 52.3, 36.7, 25.2, 24.0; HRMS Calcd. For $C_{18}H_{19}NO_2^+$: 281.1416, found: 281.1414.



(3c)

Benzyl 4,4-diethyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

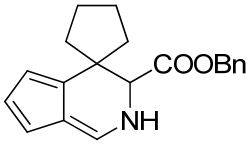
The title compound was prepared according to the general procedure as described above in 78% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.39 (m, 5H), 7.20 (d, J = 6.0 Hz, 1H), 6.29-6.28 (m, 2H), 5.97 (s, 1H), 5.70 (br, 1H), 4.50 (s, 1H), 2.09-2.02 (m, 1H), 1.75-1.57 (m, 3H), 1.07 (t, J = 7.5 Hz, 3H), 0.64 (t, J = 7.5 Hz, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.7, 138.9, 134.8, 133.7, 133.5, 128.6, 128.3, 123.7, 118.8, 117.4, 116.3, 67.4, 61.3, 44.7, 27.7, 26.0, 8.8, 8.0; HRMS Calcd. For $C_{20}H_{23}NO_2^+$: 309.1731, found: 309.1729.



(3d)

Benzyl 2',3'-dihydrospiro[cyclobutane-1,4'-cyclopenta[c]pyridine]-3'-carboxylate The title compound was prepared according to the general procedure as described above in 81% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.35 (m, 5H), 7.22 (d, J = 6.0 Hz, 1H), 6.30-6.23 (m, 3H), 5.49 (br, 1H), 5.23 (dd, J_1 = 12.0 Hz, J_2 = 16.8 Hz, 2H), 4.14 (s, 1H), 2.58-2.51 (m,

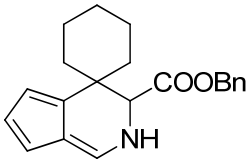
1H), 2.35-2.21 (m, 2H), 2.06-2.02 (m, 1H), 1.74-1.68 (m, 1H), 1.03 (t, J = 7.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.8, 140.2, 135.0, 133.6, 128.5, 128.4, 128.3, 124.3, 118.1, 116.7, 114.9, 67.4, 64.2, 42.4, 31.9, 29.9, 15.2.



(3e)

Benzyl 2,3-dihydrospiro[cyclopenta[c]pyridine-4,1'-cyclopentane]-3-carboxylate

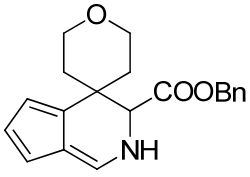
The title compound was prepared according to the general procedure as described above in 86% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.38-7.34 (m, 5H), 7.25-7.23 (m, 1H), 6.25 (m, 2H), 5.97 (s, 1H), 5.69 (br, 1H), 5.25-5.22 (m, 2H), 4.27 (s, 1H), 2.28-2.25 (m, 1H), 2.02-2.00 (m, 1H), 1.67-1.45 (m, 6H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 171.9, 139.6, 135.8, 134.8, 133.7, 128.4, 123.8, 117.9, 116.4, 115.5, 88.2, 67.4, 64.3, 47.9, 36.5, 34.9, 25.2.



(3f)

Benzyl 2',3'-dihydrospiro[cyclohexane-1,4'-cyclopenta[c]pyridine]-3'-carboxylate

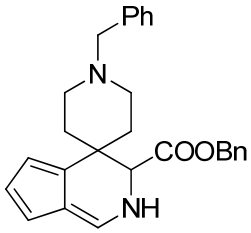
The title compound was prepared according to the general procedure as described above in 78% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.38-7.25 (m, 5H), 7.15-7.13 (m, 1H), 6.25 (m, 2H), 6.17 (s, 1H), 5.31 (br, 1H), 5.14 (dd, J_1 = 12.6 Hz, J_2 = 14.7 Hz, 2H), 4.20-4.19 (m, 1H), 1.94-1.40 (m, 10H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.7, 139.2, 135.1, 133.3, 128.4, 128.2, 128.1, 123.4, 118.4, 117.2, 116.5, 66.7, 62.1, 39.5, 36.4, 31.4, 25.7, 22.5, 21.8; HRMS Calcd. For $C_{21}H_{23}NO_2^+$: 321.1739, found: 321.1729.



(3g)

Benzyl 2,2',3,3',5',6'-hexahydrospiro[cyclopenta[c]pyridine-4,4'-pyran]-3-carboxylate

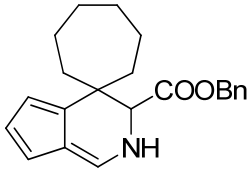
The title compound was prepared according to the general procedure as described above in 67% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.35-7.26 (m, 5H), 7.18 (d, J = 5.7 Hz, 1H), 6.28-6.27 (m, 3H), 5.45 (br, 1H), 5.22 (d, J = 6.3 Hz, 1H), 5.12 (d, J = 6.3 Hz, 1H), 4.17-4.16 (m, 1H), 3.88-3.74 (m, 4H), 2.12-2.08 (m, 1H), 1.83-1.66 (m, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 169.9, 139.3, 128.5, 128.1, 123.6, 118.7, 117.0, 67.1, 64.3, 64.1, 46.0, 37.5, 35.4, 31.6; HRMS Calcd. For $C_{20}H_{21}NO_3^+$: 323.1528, found: 323.1525.



(3h)

Benzyl 1'-benzyl-2,3-dihydrospiro[cyclopenta[c]pyridine-4,4'-piperidine]-3-carboxylate

The title compound was prepared according to the general procedure as described above in 75% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.39-7.26 (m, 10H), 7.15 (d, J = 5.1 Hz, 1H), 6.25-6.20 (m, 3H), 5.35 (br, 1H), 5.14 (dd, J_1 = 12.3 Hz, J_2 = 24.3 Hz, 2H), 4.18-4.17 (m, 1H), 3.53 (m, 2H), 2.55-2.52 (m, 4H), 2.08-1.98 (m, 2H), 1.77-1.72 (m, 2H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.3, 139.0, 133.9, 133.7, 129.5, 129.2, 128.7, 128.54, 128.49, 128.2, 128.1, 128.0, 126.9, 123.7, 116.9, 66.9, 63.2, 50.0, 49.7, 37.9, 35.4, 31.2; HRMS Calcd. For $C_{27}H_{28}N_2O_2^+$: 412.2151, found: 412.2155.

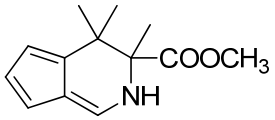


(3i)

Benzyl 2',3'-dihydrospiro[cycloheptane-1,4'-cyclopenta[c]pyridine]-3'-carboxylate

The title compound was prepared according to the general procedure as described above in 77% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.37 (m, 5H), 7.19 (d, J = 6.0 Hz, 1H), 6.26-6.25 (m, 2H), 6.14 (m, 1H), 5.60 (br, 1H), 5.30 (d, J = 12.3 Hz, 1H), 5.15 (d, J = 12.3 Hz, 1H), 4.17 (s, 1H), 2.23-2.20 (m, 1H), 2.06-1.98 (m, 1H), 1.66-1.26 (m, 10H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 171.0, 155.6, 138.9, 135.3, 131.9, 128.6, 123.7, 118.3, 117.2, 116.8, 67.4, 67.0,

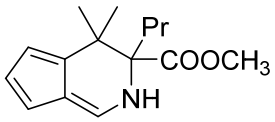
44.4, 37.8, 32.3, 31.9, 24.8, 22.9.



(3j)

Methyl 3,4,4-trimethyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

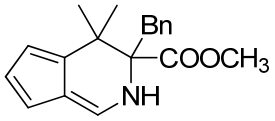
The title compound was prepared according to the general procedure as described above in 81% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.13 (d, J = 6.3 Hz, 1H), 6.24 (m, 2H), 6.07 (s, 1H), 5.94 (br, 1H), 3.84 (s, 3H), 1.51 (m, 6H), 1.09 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 174.4, 137.6, 134.5, 123.5, 116.4, 116.0, 155.8, 67.5, 52.6, 39.3, 26.8, 21.7, 19.1; HRMS Calcd. For $C_{13}H_{17}NO_2^+$: 219.1259, found: 219.1255.



(3k)

Methyl 4,4-dimethyl-3-propyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

The title compound was prepared according to the general procedure as described above in 73% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.12 (d, J = 5.7 Hz, 1H), 6.23 (m, 2H), 6.04 (s, 1H), 5.98 (br, 1H), 3.84 (s, 3H), 2.13-2.12 (m, 1H), 1.88-1.78 (m, 1H), 1.51 (m, 3H), 1.28-1.21 (m, 1H), 1.07 (s, 3H), 0.84 (t, J = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 173.8, 137.2, 135.0, 128.7, 123.4, 116.0, 155.5, 71.2, 52.5, 39.6, 31.8, 27.3, 18.2, 13.9.

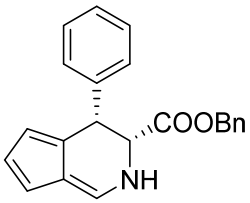


(3l)

Methyl 3-benzyl-4,4-dimethyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

The title compound was prepared according to the general procedure as described above in 72% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.32-7.23 (m, 2H), 7.13 (d, J = 6.0 Hz, 1H), 6.96-6.94 (m, 2H), 6.30 (m, 2H), 6.12 (s, 1H), 5.49-5.47 (m, 1H), 3.82 (s, 3H), 3.37 (d, J = 13.2 Hz, 1H), 3.22 (d, J = 13.2 Hz, 1H), 1.65 (m, 3H), 1.11 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 172.5, 137.1, 136.4, 129.7, 128.2, 126.6, 123.7, 117.2, 116.3, 116.2, 72.1, 52.3, 40.1, 34.9,

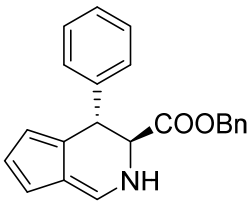
27.3, 21.4.



(4a)

Benzyl 4-phenyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

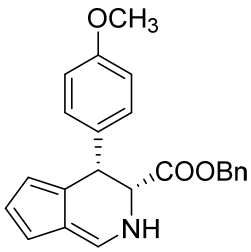
The title compound was prepared according to the general procedure as described above in 32% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.35-7.18 (m, 8H), 7.08-7.07 (m, 2H), 6.37-6.35 (m, 1H), 6.31-6.29 (m, 1H), 5.81 (s, 1H), 5.46 (br, 1H), 5.06 (dd, J_1 = 12.3 Hz, J_2 = 22.5 Hz, 2H), 4.57 (d, J = 7.8 Hz, 1H), 4.30 (d, J = 7.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.9, 140.9, 140.5, 134.8, 128.4, 128.3, 128.1, 128.0, 126.8, 125.9, 124.8, 119.9, 117.0, 67.4, 62.4, 44.7;. For $C_{22}H_{19}NO_2^+$: 329.1423, found: 329.1420.



(5a)

Benzyl 4-phenyl-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

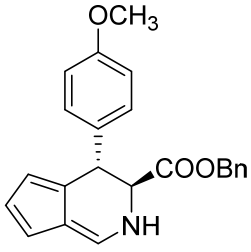
The title compound was prepared according to the general procedure as described above in 32% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.46-7.26 (m, 5H), 7.13-7.11 (m, 3H), 6.93-6.92 (m, 2H), 6.38-6.37 (m, 1H), 6.31 (m, 1H), 5.97 (s, 1H), 5.81 (br, 1H), 5.08 (dd, J_1 = 12.0 Hz, J_2 = 17.1 Hz, 2H), 4.71 (d, J = 5.4 Hz, 1H), 4.55 (d, J = 5.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 169.6, 140.2, 139.5, 134.5, 132.0, 128.8, 128.7, 128.2, 127.9, 127.0, 126.8, 125.1, 120.2, 118.5, 116.4, 67.5, 60.6, 43.5; HRMS Calcd. For $C_{22}H_{19}NO_2^+$: 329.1416, found: 329.1413.



(4b)

Benzyl 4-(4-methoxyphenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

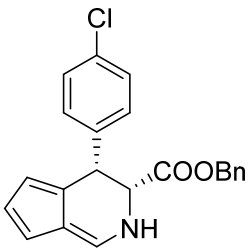
The title compound was prepared according to the general procedure as described above in 35% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.34-7.29 (m, 4H), 7.13-7.08 (m, 3H), 6.80 (d, J = 8.4 Hz, 2H), 6.36-6.35 (m, 1H), 6.31-6.29 (m, 1H), 5.80 (s, 1H), 5.51 (br, 1H), 5.05 (dd, J_1 = 12.3 Hz, J_2 = 15.0 Hz, 2H), 4.50 (d, J = 8.1 Hz, 1H), 4.26 (d, J = 8.1 Hz, 1H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 171.0, 158.4, 140.4, 134.8, 133.7, 129.2, 128.4, 128.3, 128.0, 126.5, 124.8, 120.1, 119.8, 117.0, 113.7, 67.3, 62.8, 55.1, 44.2; HRMS Calcd. For $C_{23}H_{21}NO_3^{+}$: 359.1521, found: 359.1522.



(5b)

Benzyl 4-(4-methoxyphenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

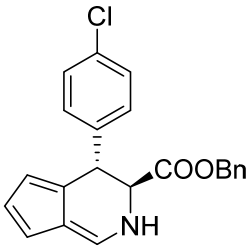
The title compound was prepared according to the general procedure as described above in 35% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.40-7.30 (m, 5H), 6.82 (d, J = 8.7 Hz, 2H), 6.62 (d, J = 8.7 Hz, 2H), 6.36-6.35 (m, 1H), 6.31-6.28 (m, 1H), 5.95 (s, 1H), 5.86-5.84 (m, 1H), 5.09 (dd, J_1 = 12.3 Hz, J_2 = 13.8 Hz, 2H), 4.66 (d, J = 5.1 Hz, 1H), 4.51 (d, J = 5.1 Hz, 1H), 3.71 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 169.7, 158.2, 140.1, 134.6, 131.7, 128.9, 128.8, 128.7, 128.5, 127.4, 125.1, 120.1, 118.2, 116.3, 113.5, 67.5, 60.7, 55.0, 42.7; HRMS Calcd. For $C_{23}H_{21}NO_3^{+}$: 359.1521, found: 359.1516.



(4c)

Benzyl 4-(4-chlorophenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

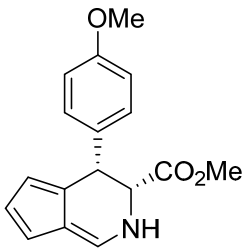
The title compound was prepared according to the general procedure as described above in 40% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.36-7.31 (m, 3H), 7.21 (d, J = 8.4 Hz, 2H), 7.13 (d, J = 8.4 Hz, 2H), 7.06 (m, 2H), 6.37-6.35 (m, 1H), 6.30-6.26 (m, 1H), 5.76 (s, 1H), 5.54 (br, 1H), 5.05 (m, 2H), 4.49 (d, J = 8.4 Hz, 1H), 4.27 (d, J = 8.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.6, 140.4, 140.2, 134.5, 132.6, 129.6, 128.5, 128.1, 125.8, 124.9, 120.1, 117.2, 67.6, 62.3, 44.4; HRMS Calcd. For $C_{22}H_{18}ClNO_2^+$: 363.1026, found: 363.1029.



(5c)

Benzyl 4-(4-chlorophenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

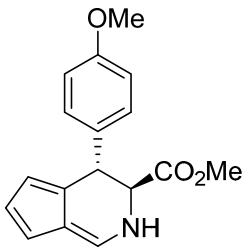
The title compound was prepared according to the general procedure as described above in 40% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.45-7.26 (m, 5H), 7.03 (d, J = 8.4 Hz, 2H), 6.82 (d, J = 8.4 Hz, 2H), 6.38-6.36 (m, 1H), 6.31-6.30 (m, 1H), 5.95 (s, 1H), 5.83 (br, 1H), 5.10 (dd, J_1 = 12.0 Hz, J_2 = 16.2 Hz, 2H), 4.69 (d, J = 5.1 Hz, 1H), 4.51 (d, J = 5.1 Hz, 1H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 169.3, 140.1, 138.0, 134.3, 133.5, 132.4, 129.2, 1289, 128.7, 128.3, 126.5, 125.2, 120.0, 118.7, 116.7, 67.7, 60.3, 42.7; HRMS Calcd. For $C_{22}H_{18}ClNO_2^+$: 363.1026, found: 363.1027.



(4d)

Methyl 4-(4-methoxyphenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

The title compound was prepared according to the general procedure as described above in 35% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.34 (d, J = 6.0 Hz, 1H), 7.12 (d, J = 8.1 Hz, 2H), 6.83 (d, J = 9.0 Hz, 2H), 6.35-6.31 (m, 1H), 6.30-6.29 (m, 1H), 5.84 (s, 1H), 5.47-5.46 (br, 1H), 4.52 (d, J = 5.1 Hz, 1H), 4.20-4.17 (m, 1H), 3.78 (s, 3H), 3.64 (s, 3H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 171.5, 158.4, 140.5, 134.1, 129.0, 126.1, 124.7, 119.9, 119.6, 116.9, 113.6, 62.6, 55.1, 52.6, 43.8.

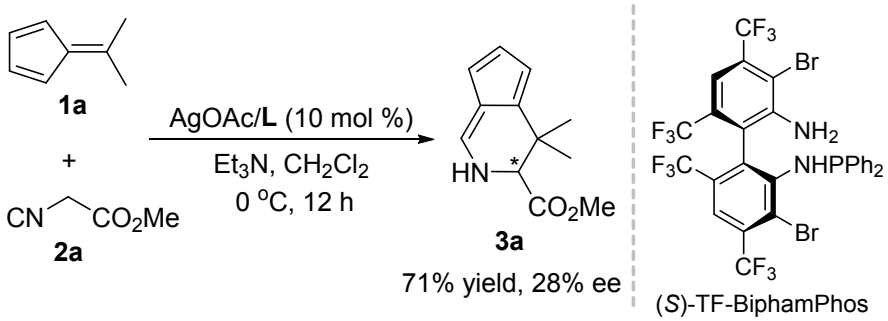


(5d)

Methyl 4-(4-methoxyphenyl)-3,4-dihydro-2H-cyclopenta[c]pyridine-3-carboxylate

The title compound was prepared according to the general procedure as described above in 35% yield. ^{1}H NMR ($CDCl_3$, TMS, 300 MHz) δ 7.42 (d, J = 6.0 Hz, 1H), 6.88 (d, J = 9.0 Hz, 2H), 6.71 (d, J = 8.7 Hz, 2H), 6.38-6.33 (m, 1H), 6.32-6.31 (m, 1H), 5.99 (s, 1H), 5.82-5.80 (m, 1H), 4.64 (d, J = 5.1 Hz, 1H), 4.52 (d, J = 5.4 Hz, 1H), 3.72 (m, 6H); ^{13}C NMR ($CDCl_3$, TMS, 75 MHz) δ 170.3, 158.3, 140.3, 131.8, 128.8, 127.2, 125.0, 120.1, 118.1, 116.2, 113.5, 60.7, 55.0, 52.3, 42.7.

III. Preliminary Results for Catalytic asymmetric [6 + 3] Cycloaddition/Isomer-ization of Isocyanoacetate 1a with Fulvene 2a



Under argon atmosphere, AgOAc (3.3 mg, 0.02 mmol) and TF-Biphamphos (14.1 mg, 0.022 mmol) and were dissolved in 2 mL DCM, and stirred at room temperature for about 30min. Isocyanoacetate **2a** (0.2 mmol), Et_3N (0.03 mmol) were added sequentially. Then, the mixture was dropped to 0 °C and fulvene **1a** (0.3 mmol) was added. Once starting material was consumed (monitored by TLC), then the organic solvent was removed and the residue was purified by column chromatography to afford the product **3a** in 71% yield. The product was analyzed by HPLC to determine the enantiomeric excess: 28% ee (Chiralpak AS-H, *i*-propanol/hexane = 10/90, flow rate 1.0 mL/min, λ = 220 nm); t_r = 8.59 and 10.61 min.

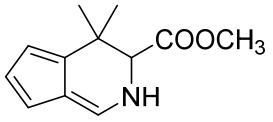
V. References

1 (a) Stone, K. J.; Little, R. D. *J. Org. Chem.* **1984**, 49, 1849. (b) Erden, I.; Xu, F.-P.; Sadoun, A.; Smith, W.; Sheff, G.; Ossun, M. *J. Org. Chem.* **1995**, *60*, 813. (c) Bandar, J. S.; Coscia, R. W.; Lambert, T. H. *Tetrahedron* **2011**, *67*, 4364.

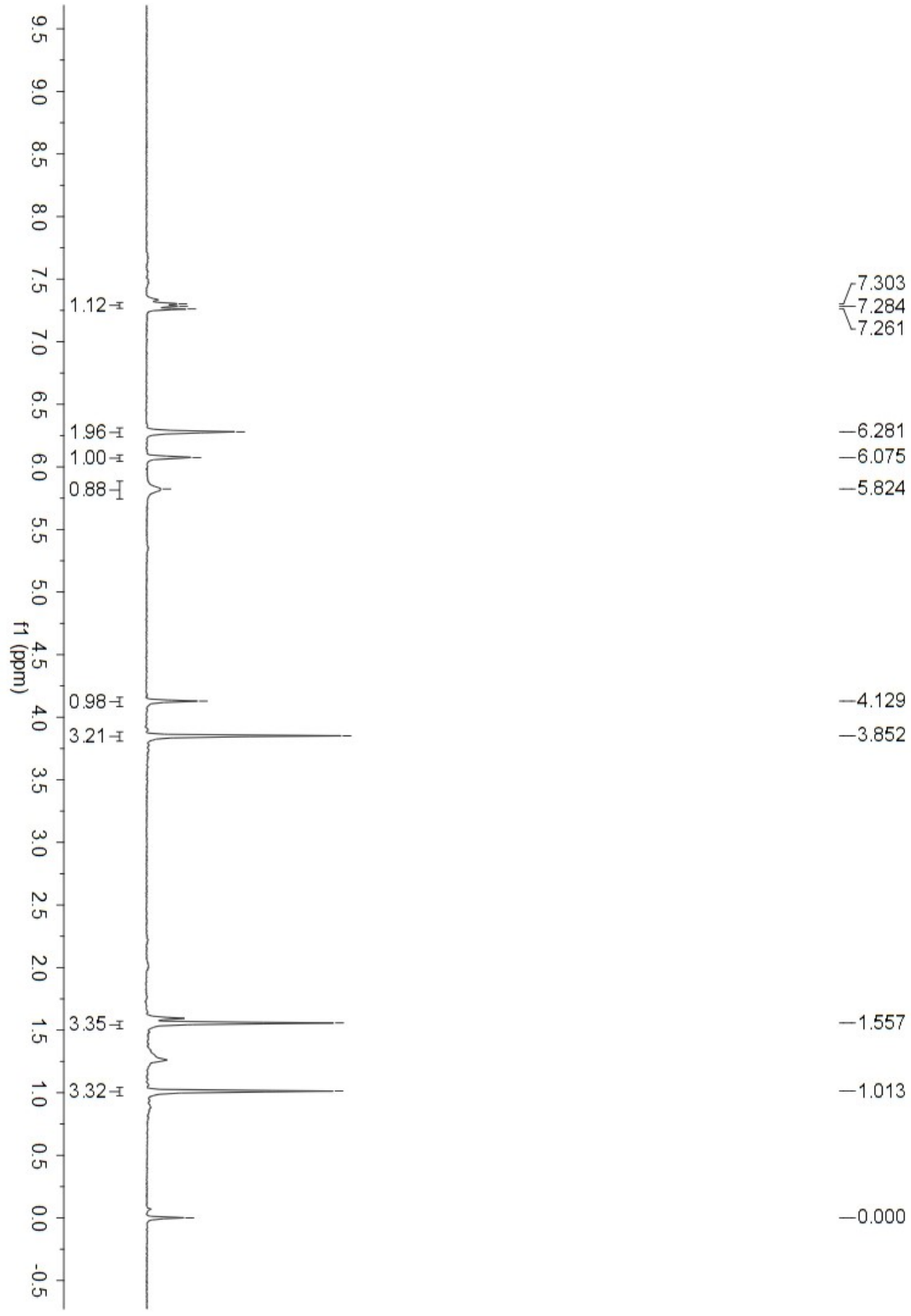
2. (a) Galan, B. R.; Kalbarczyk, K. P.; Szczepankiewicz, S.; Keister, J. B.; Diver, S. T. *Org. Lett.* **2007**, 9, 1203. (b) Elders, N.; Schmitz, R. F.; de Kanter, F. J. J.; Ruijter, E.; Groen, M. B.; Orru, R. V. A. *J. Org. Chem.* **2007**, 72, 6135.

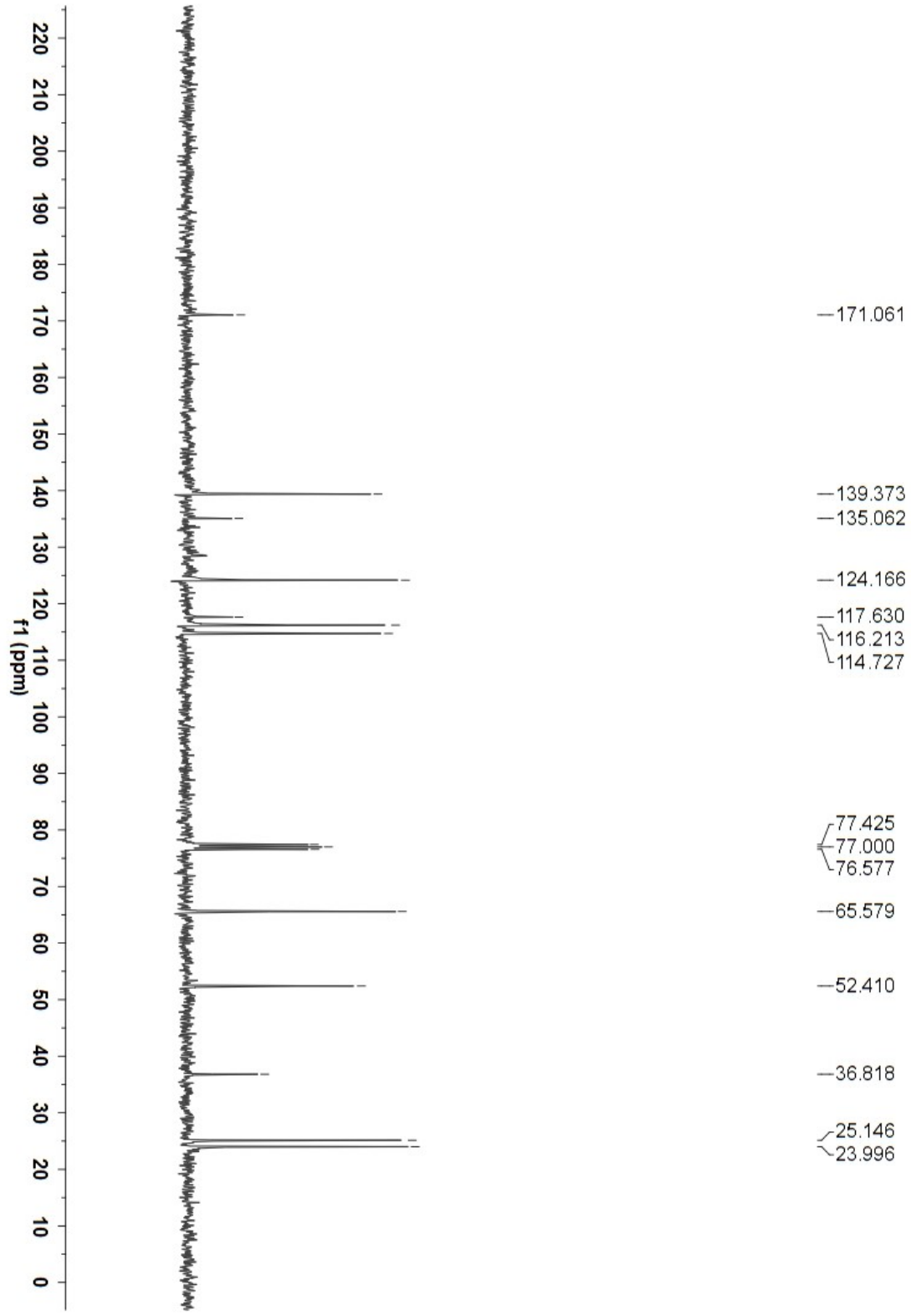
3. Wang, C.-J.; Liang, G.; Xue, Z.-Y.; Gao, F. *J. Am. Chem. Soc.* **2008**, *130*, 17250.

IV. ^{1}H NMR and ^{13}C NMR Spectra



(3a)

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150
140
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100
90
80
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50
40
30
20
10
0
171.061
139.373
135.062
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77.425
77.000
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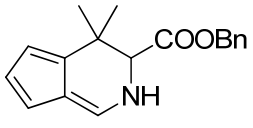
52.410
36.818
25.146
23.996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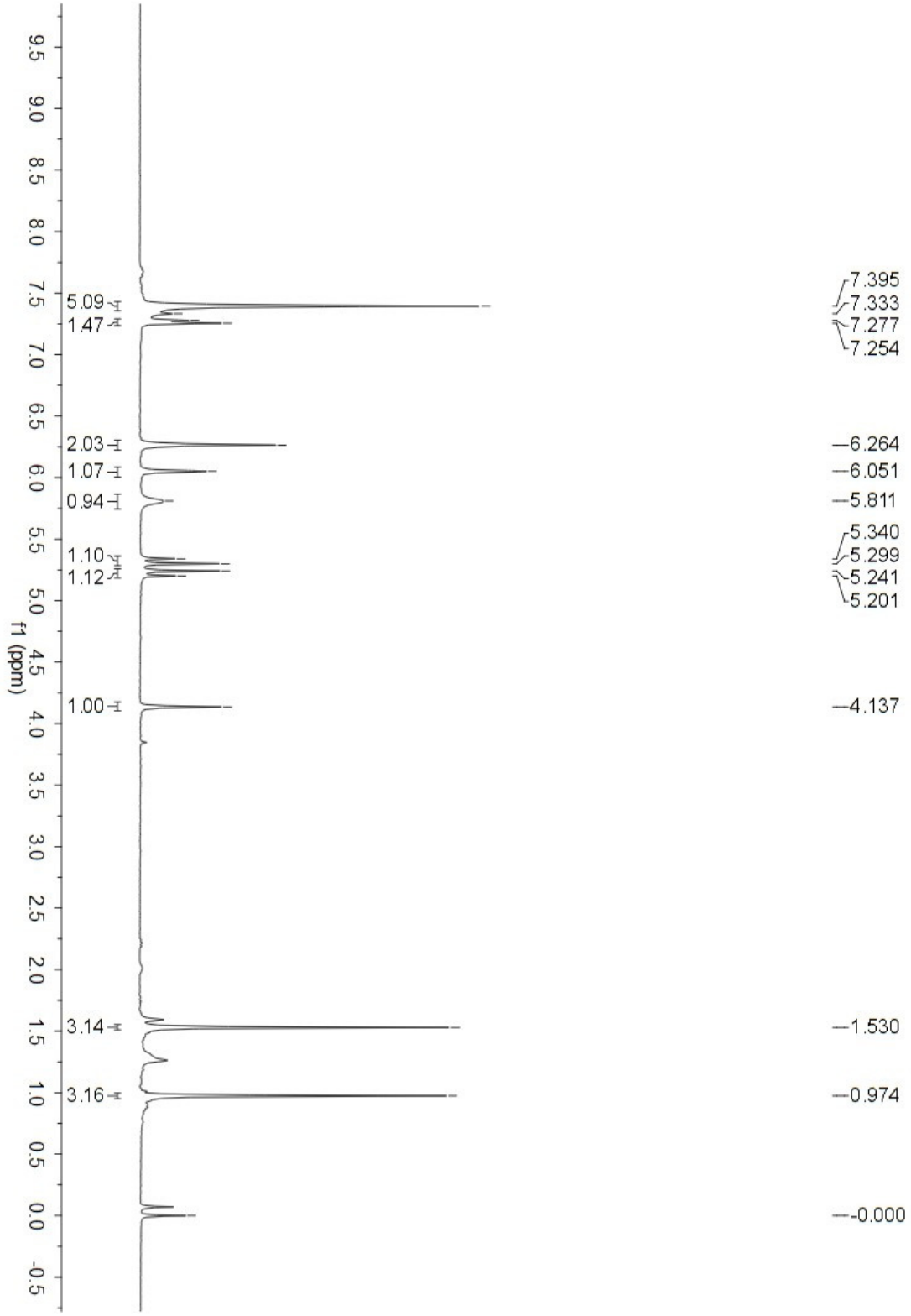
NH

(3b)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5.09
1.47
2.03
1.07
0.94
1.10
1.12
1.00
3.14
3.16
7.395
7.333
7.277
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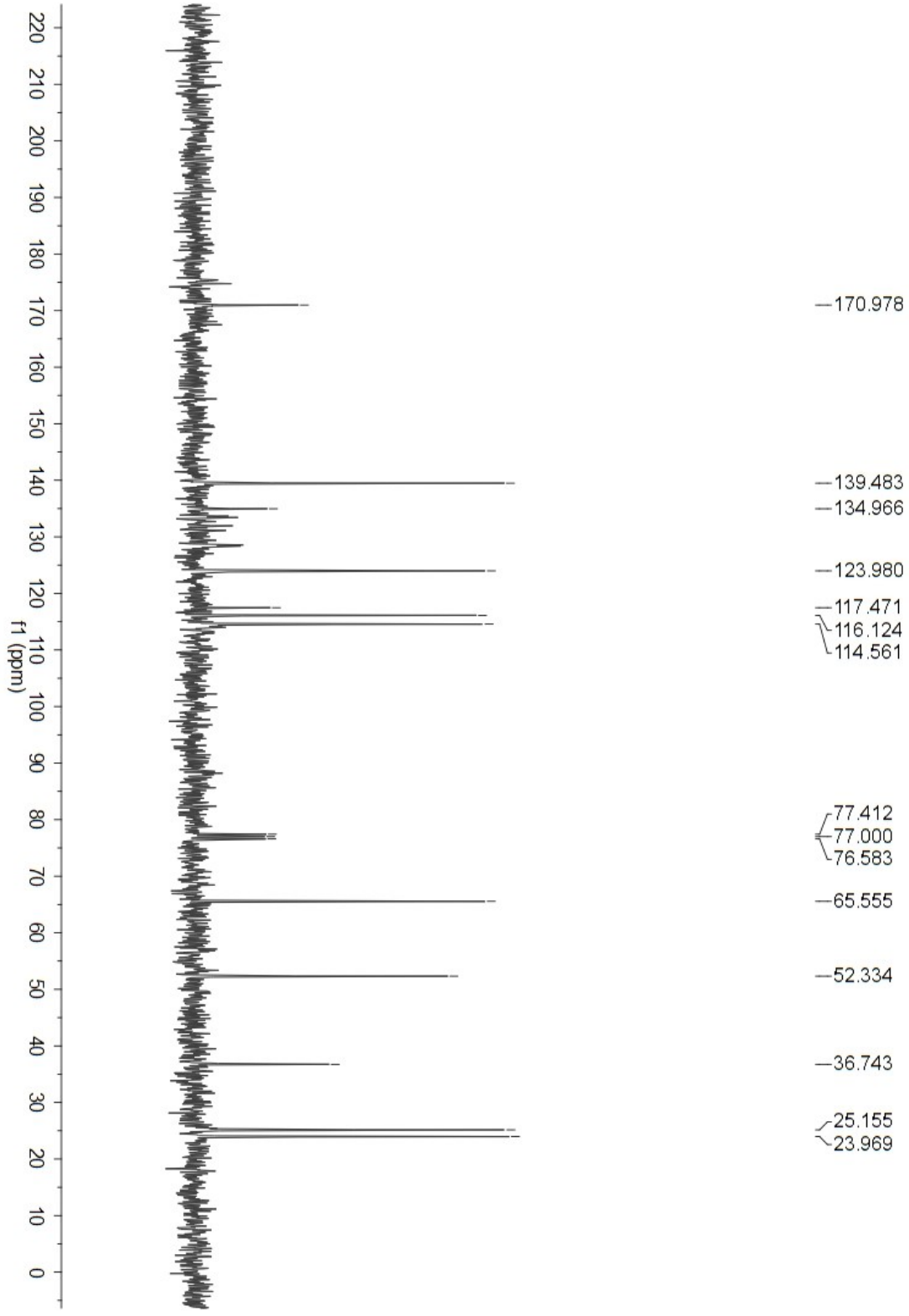
-0.000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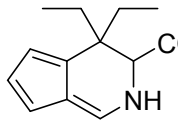
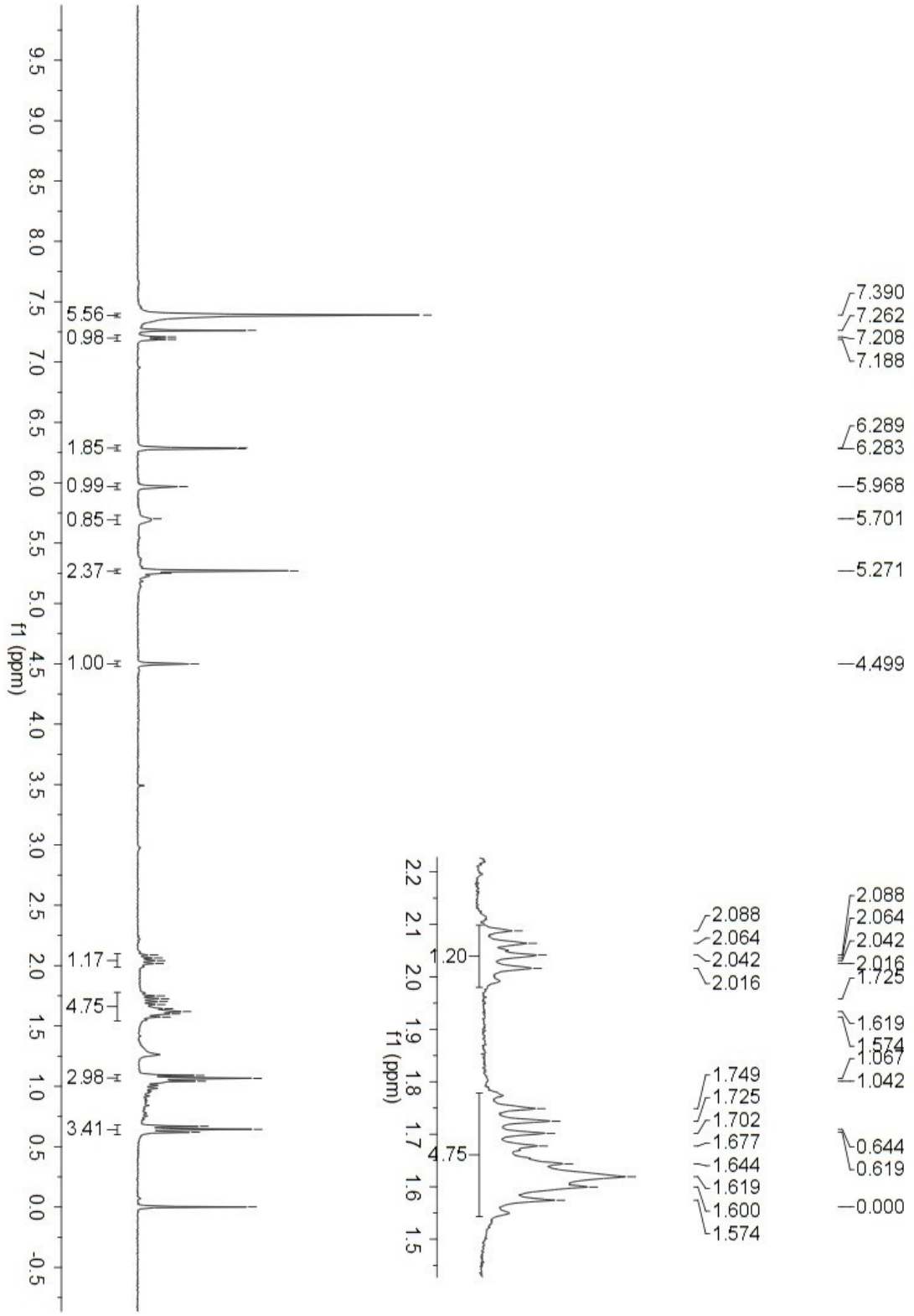
f1 (ppm)


COOBn
NH

(3c)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7.262
7.208
7.188
6.289
6.283
5.968
5.701
5.271
4.499
2.088
2.064
2.042
2.016
1.749
1.725
1.702
1.677
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1.574
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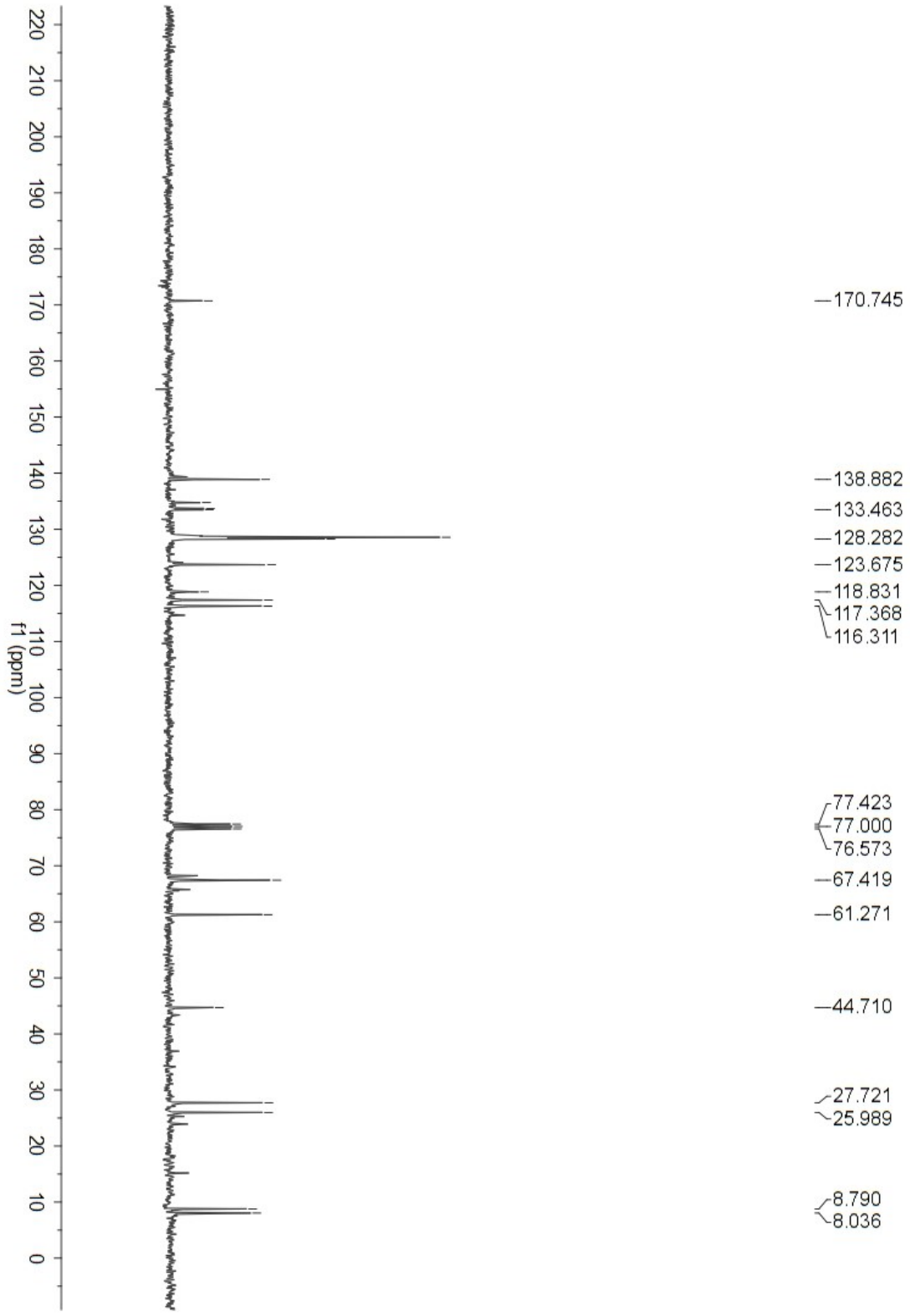
0.000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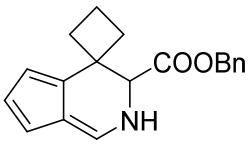
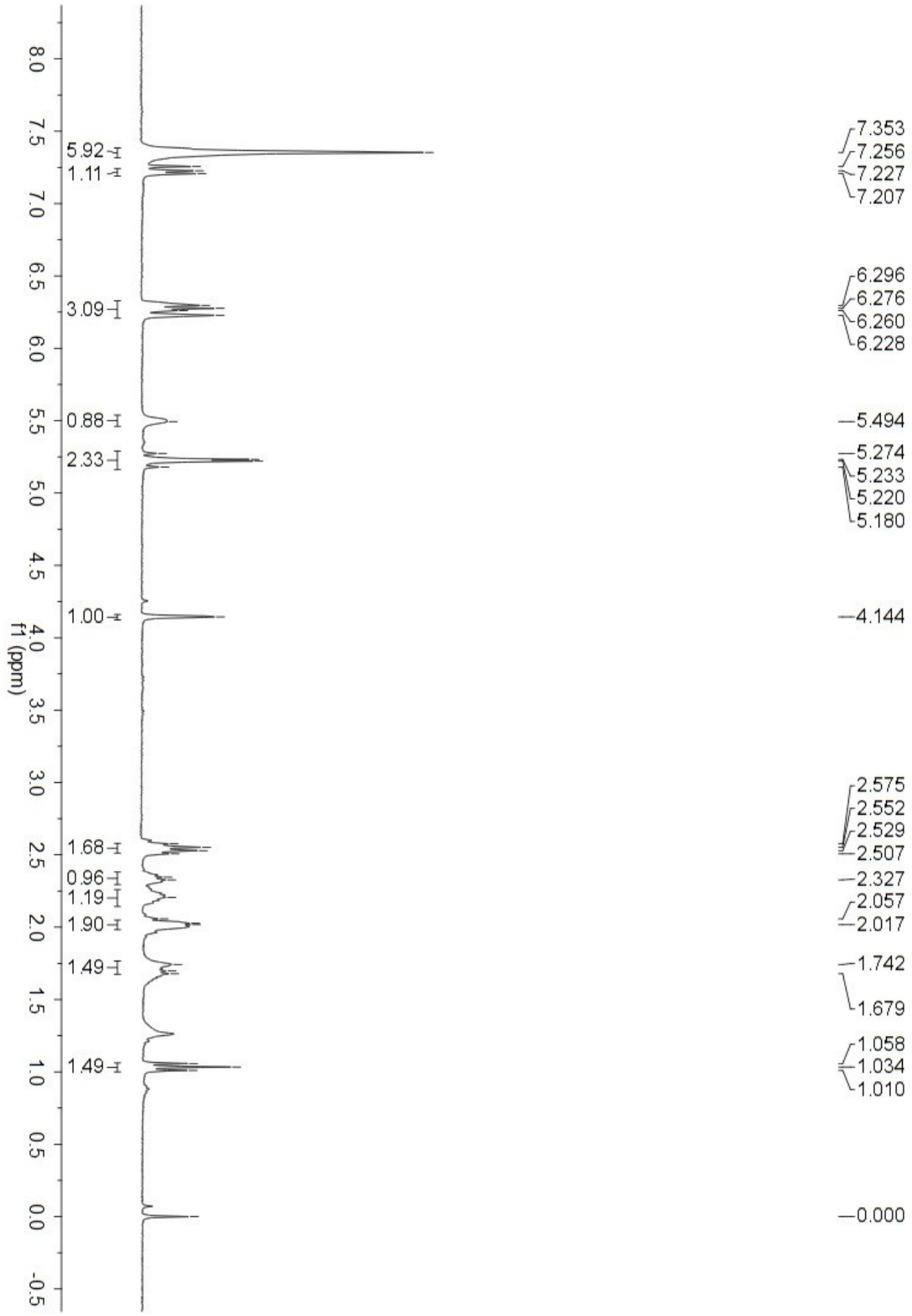
8.036
f1 (ppm)


COOBn
NH

(3d)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1.0
0.5
0.0
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3.09
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6.260
6.228
5.494
5.274
5.233
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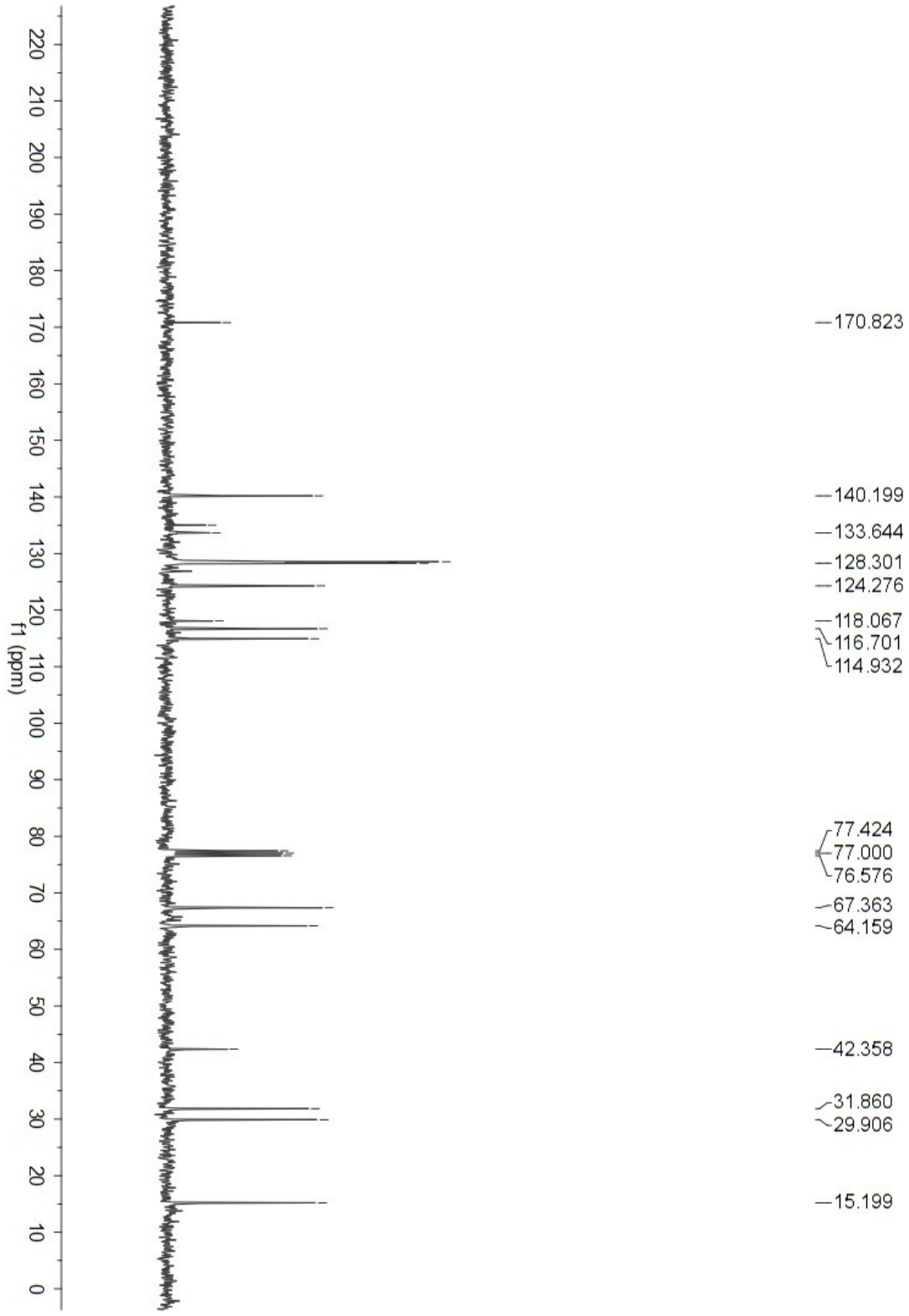
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80
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40
30
20
10
0
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140.199
133.644
128.301
124.276
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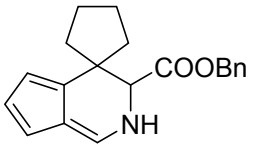
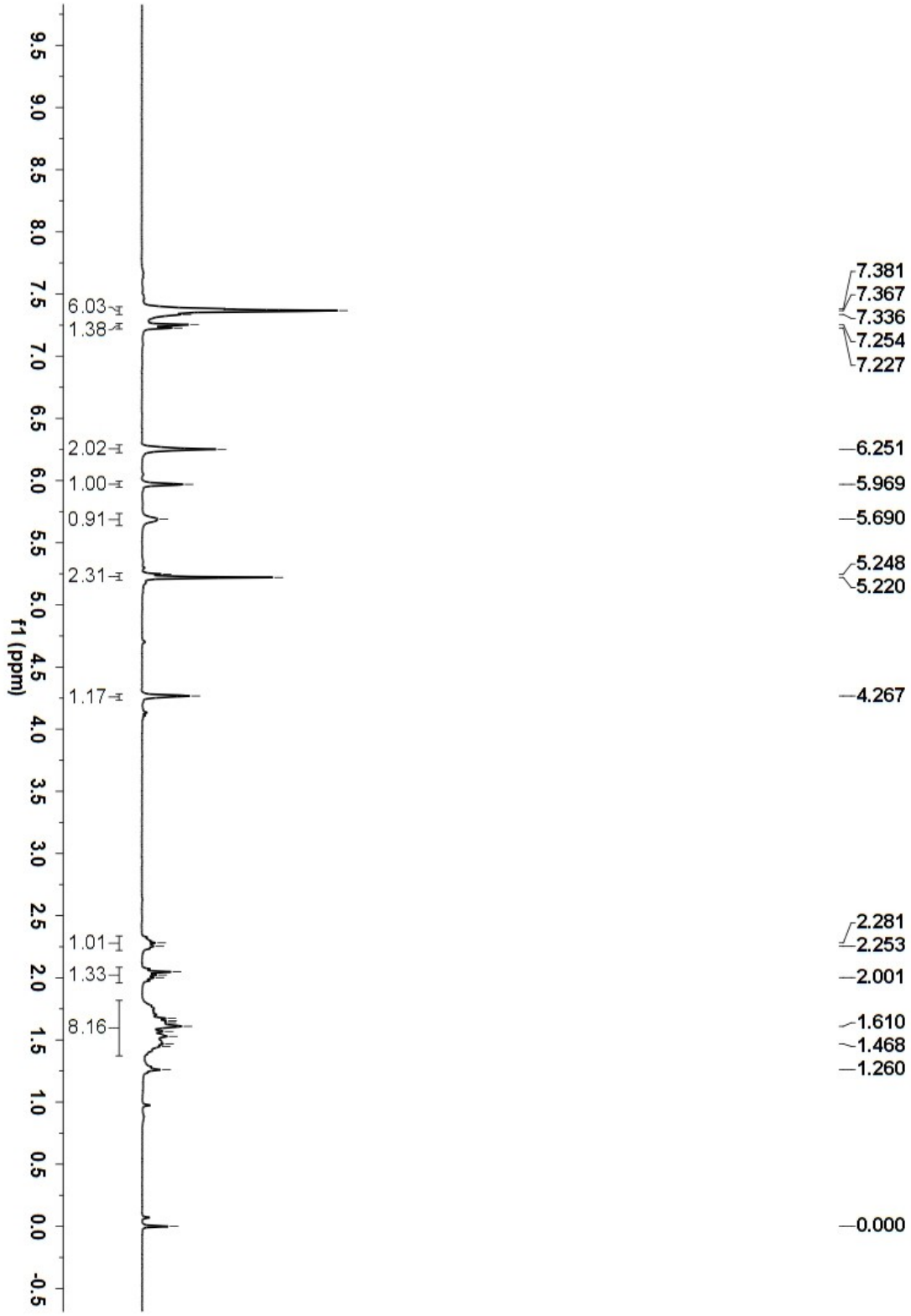
15.199


COOBn
NH

(3e)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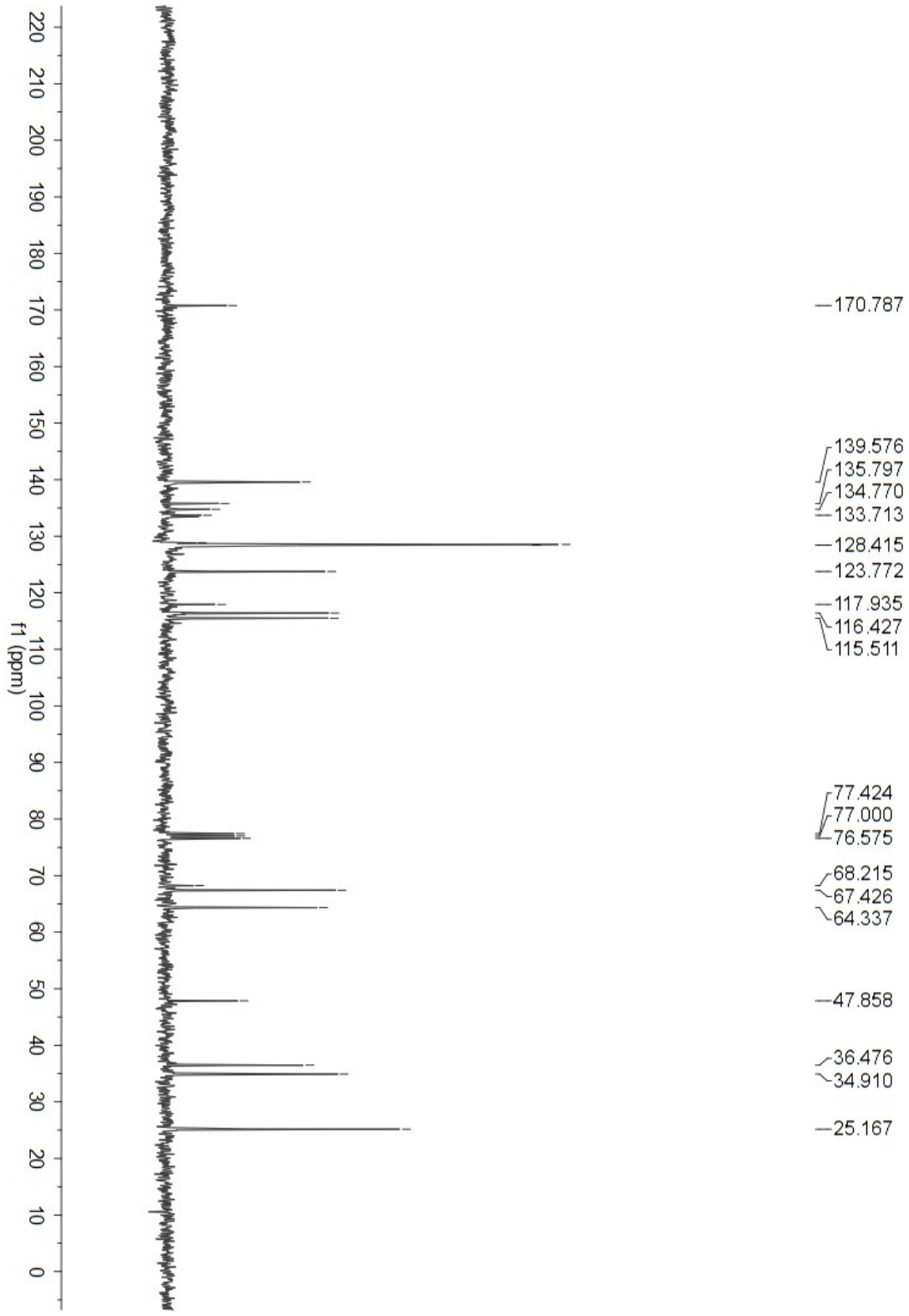
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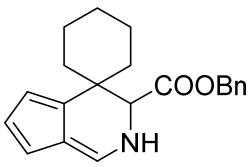
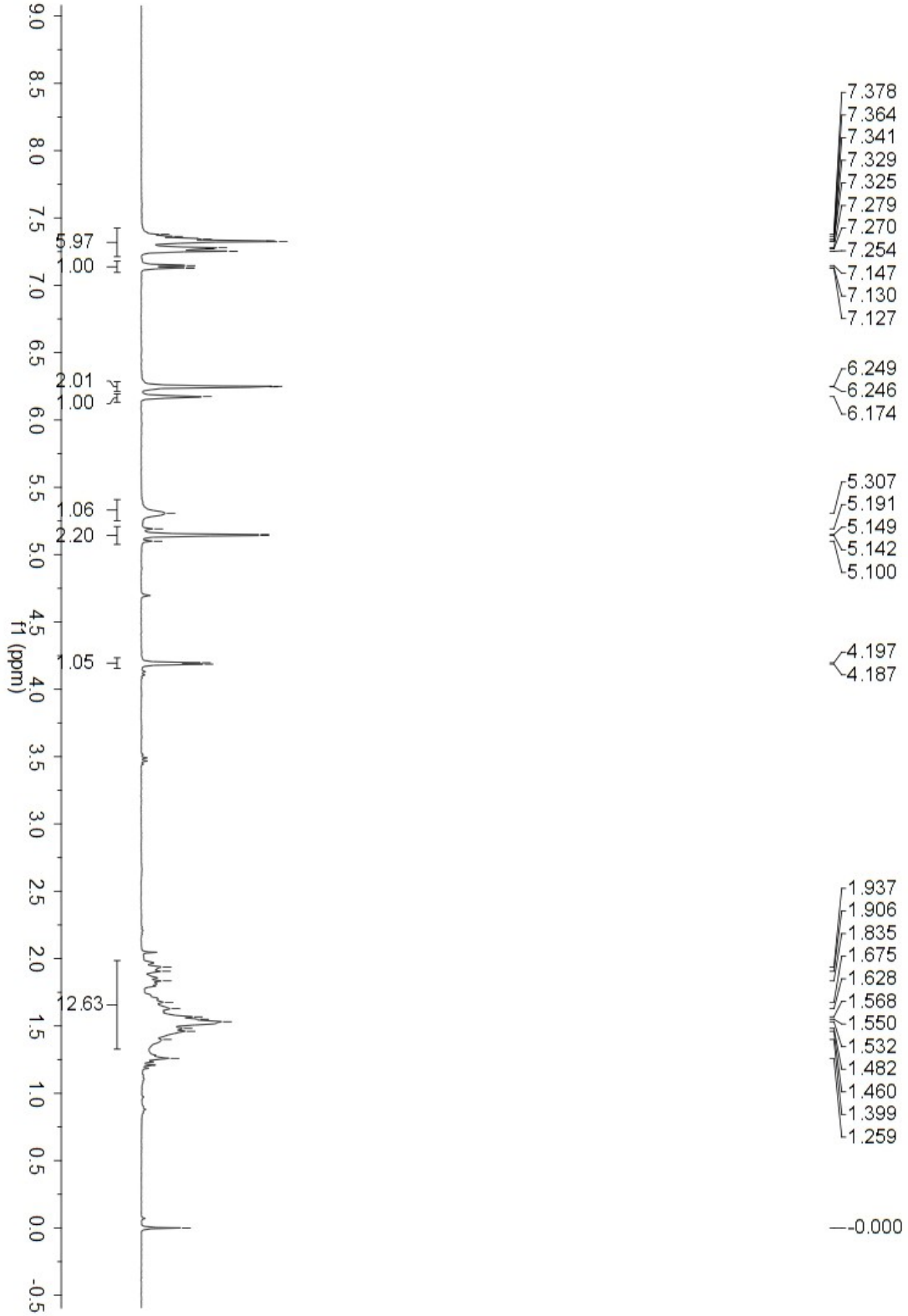

COOBn
NH

(3f)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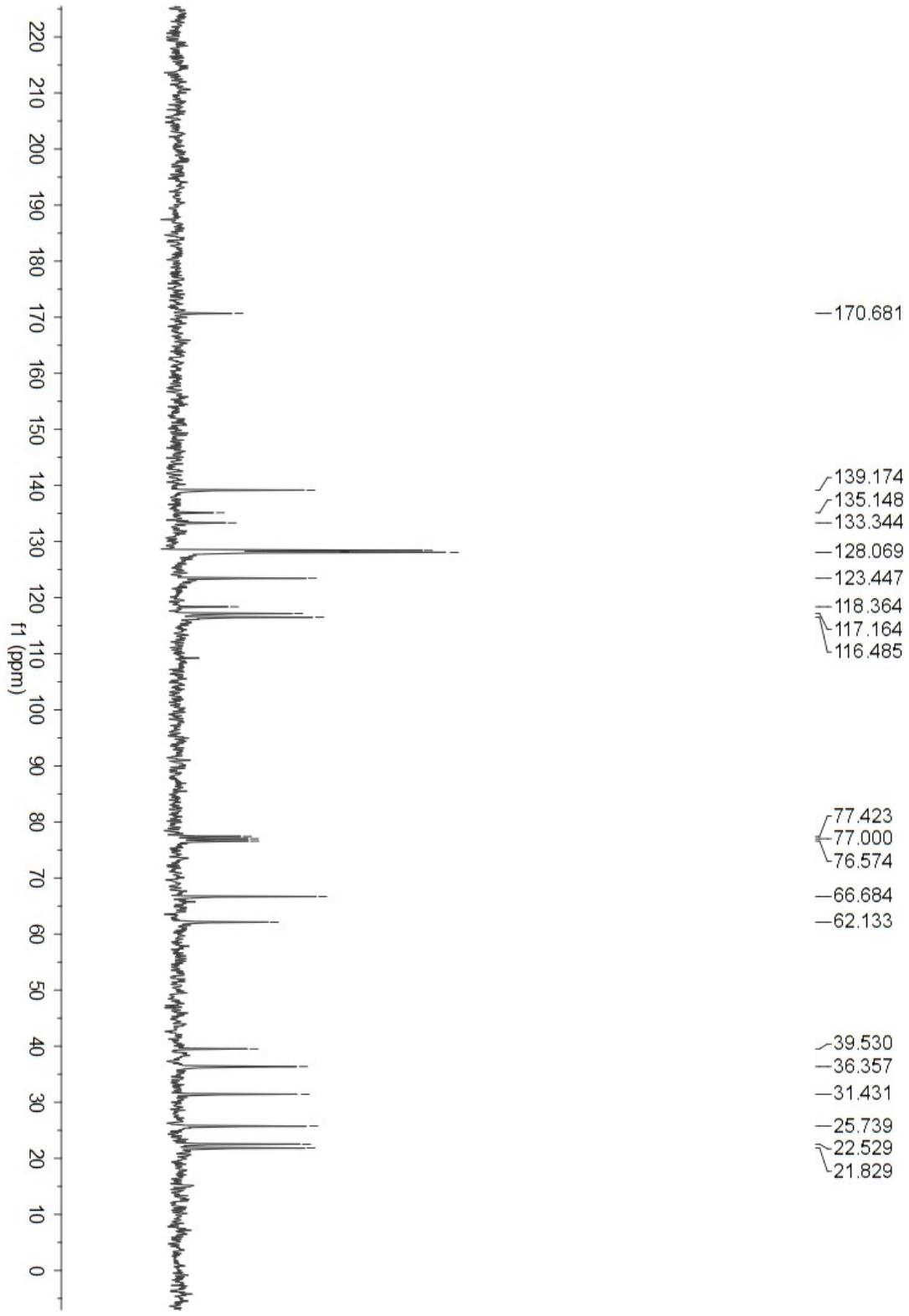
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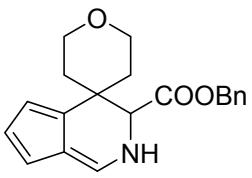
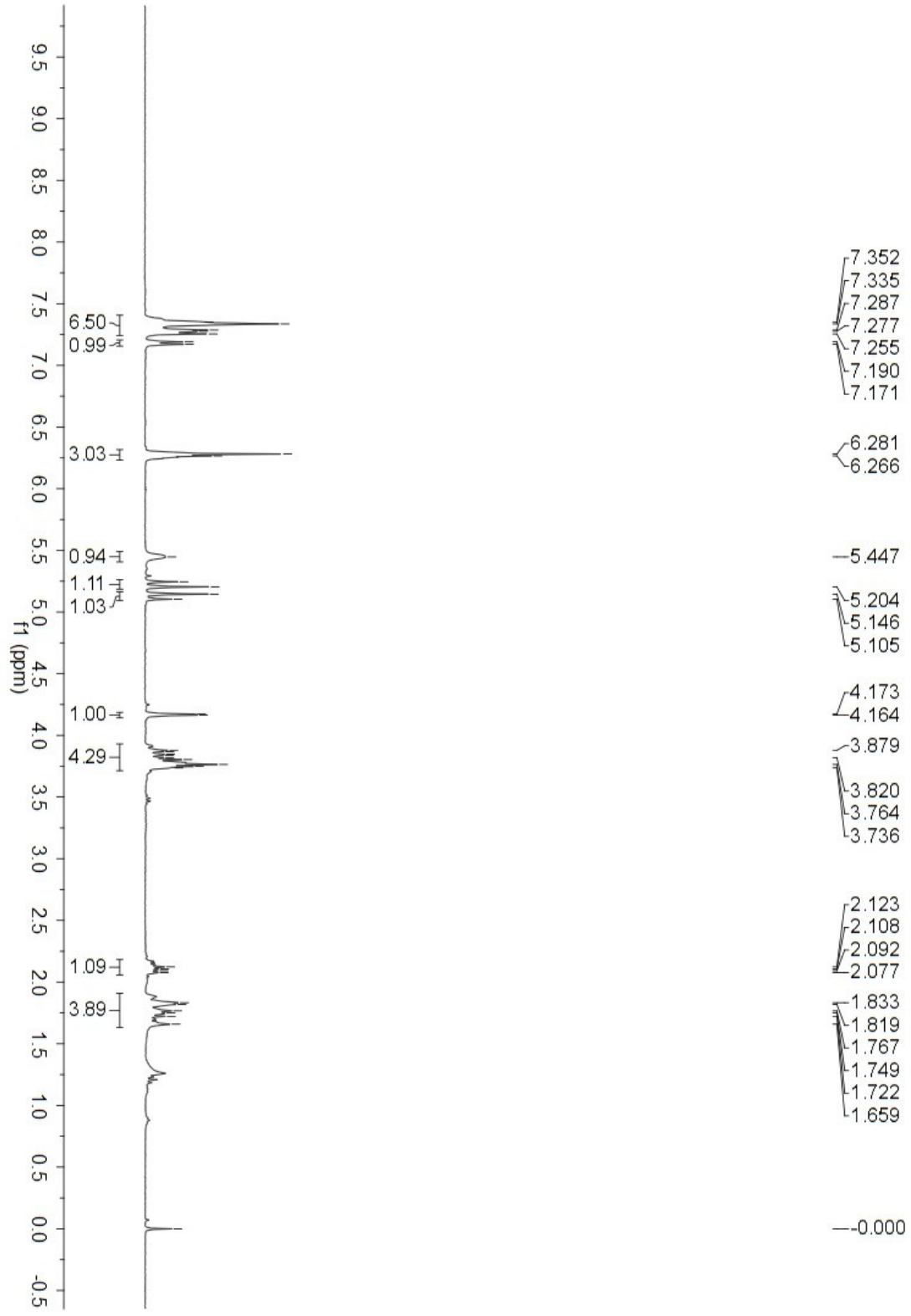
f1 (ppm)


O
COOBn
NH

(3g)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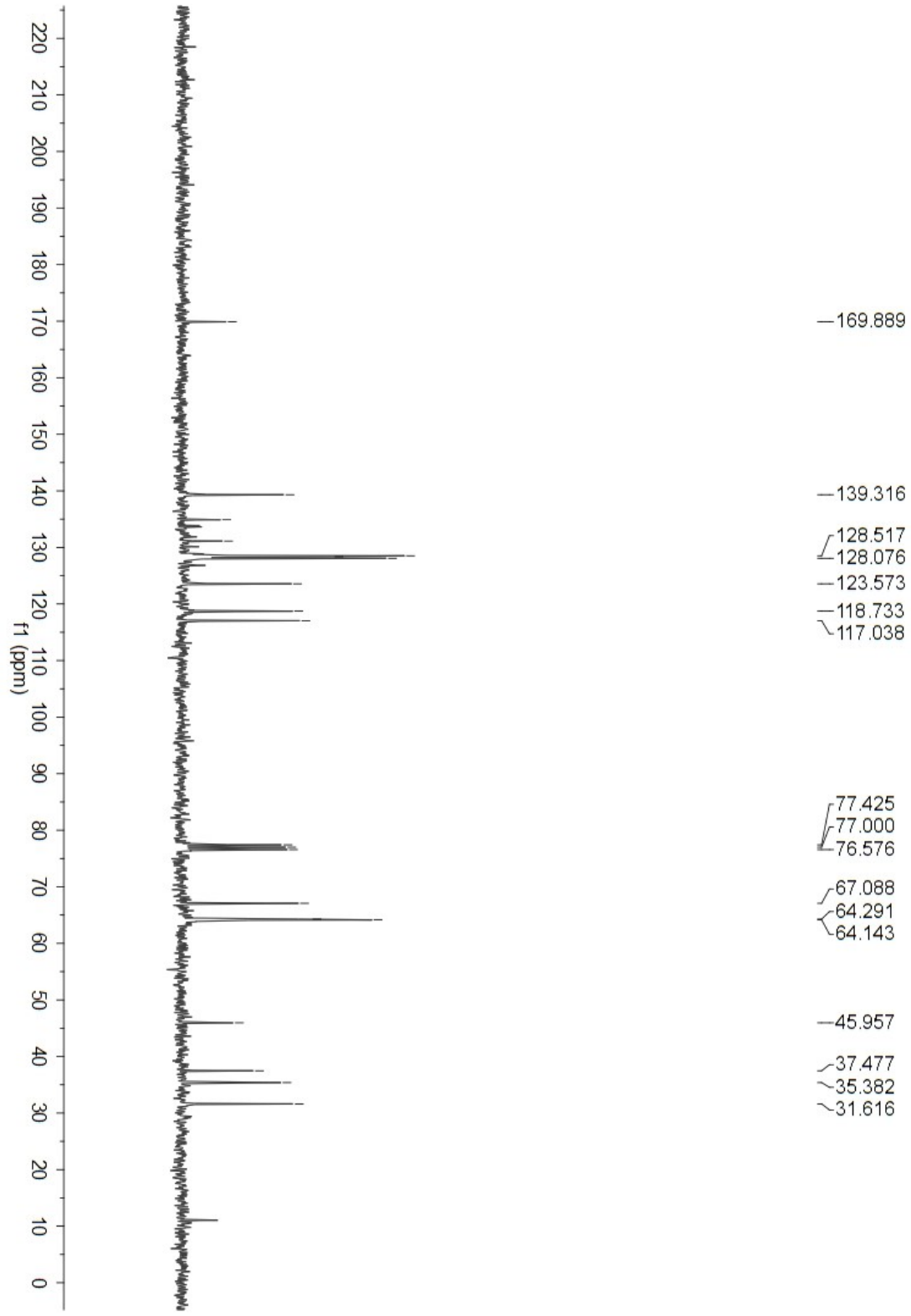
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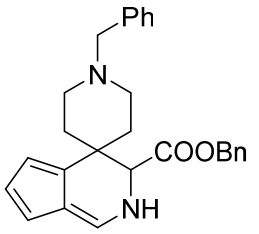
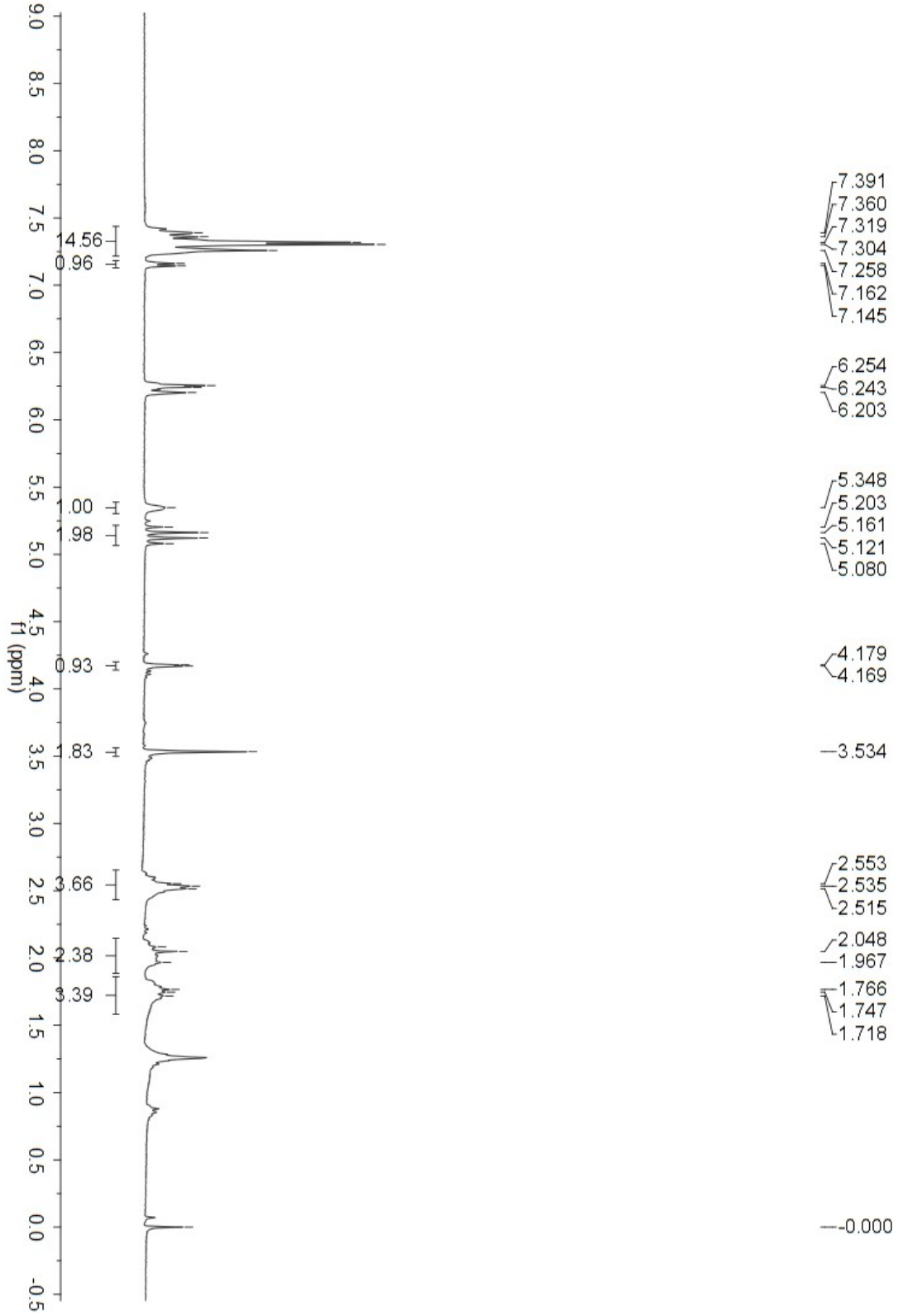
31.616
f1 (ppm)


Ph
N
COOBn
NH

(3h)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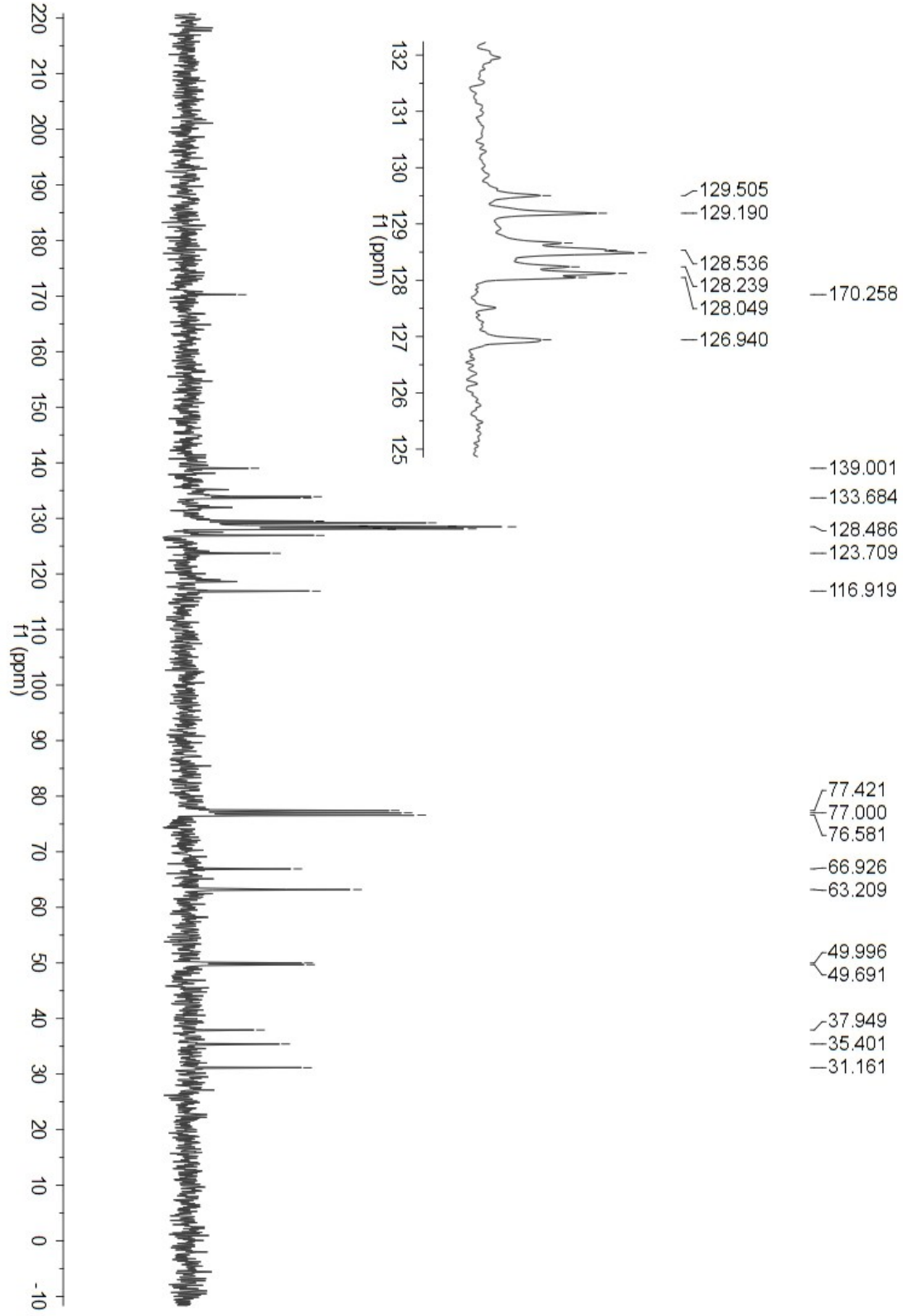
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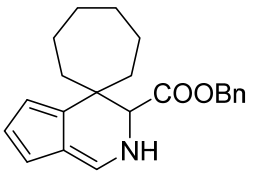
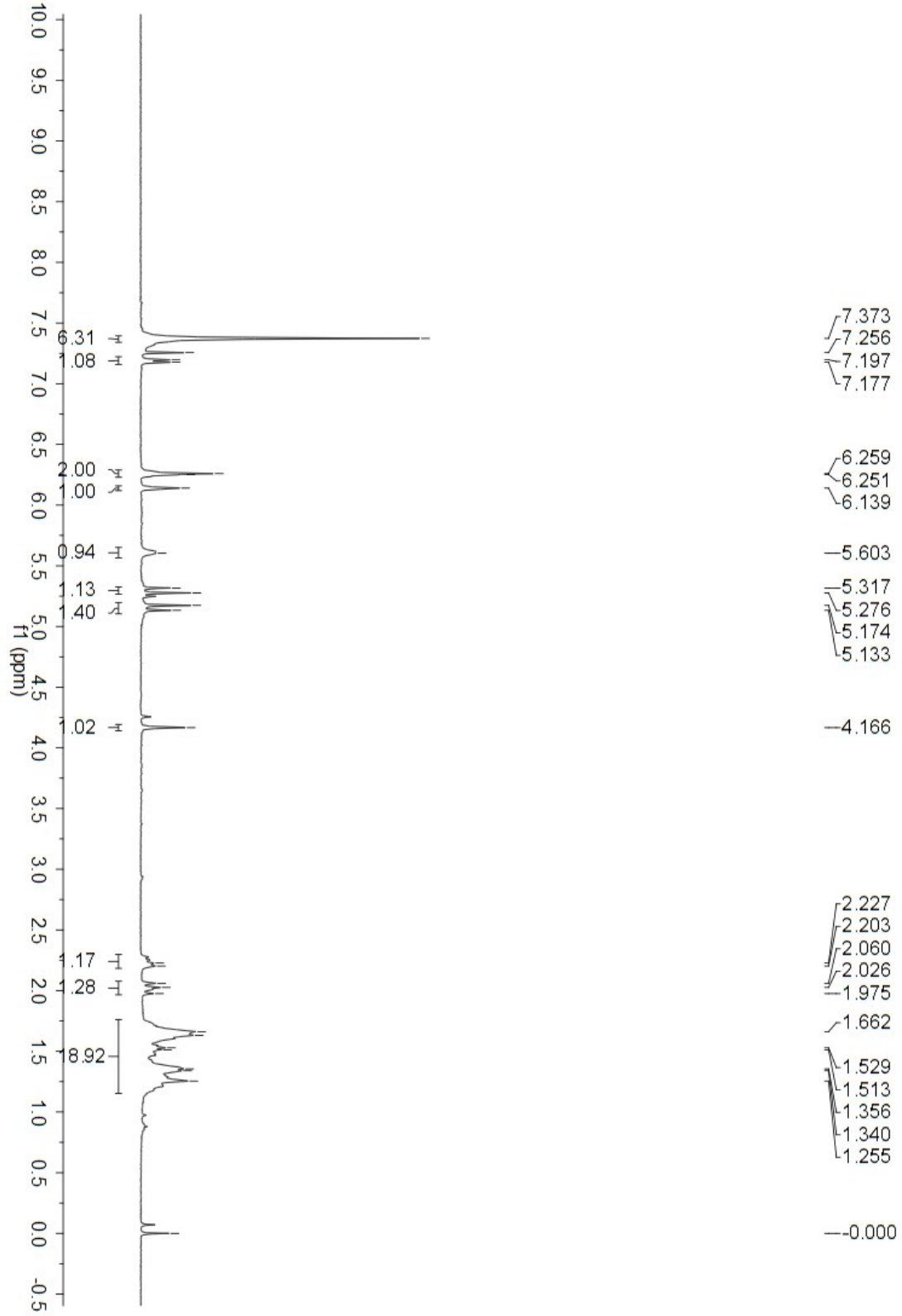

COOBn
NH

(3i)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7.197
7.177
6.259
6.251
6.139
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5.317
5.276
5.174
5.133
4.166
2.227
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1.529
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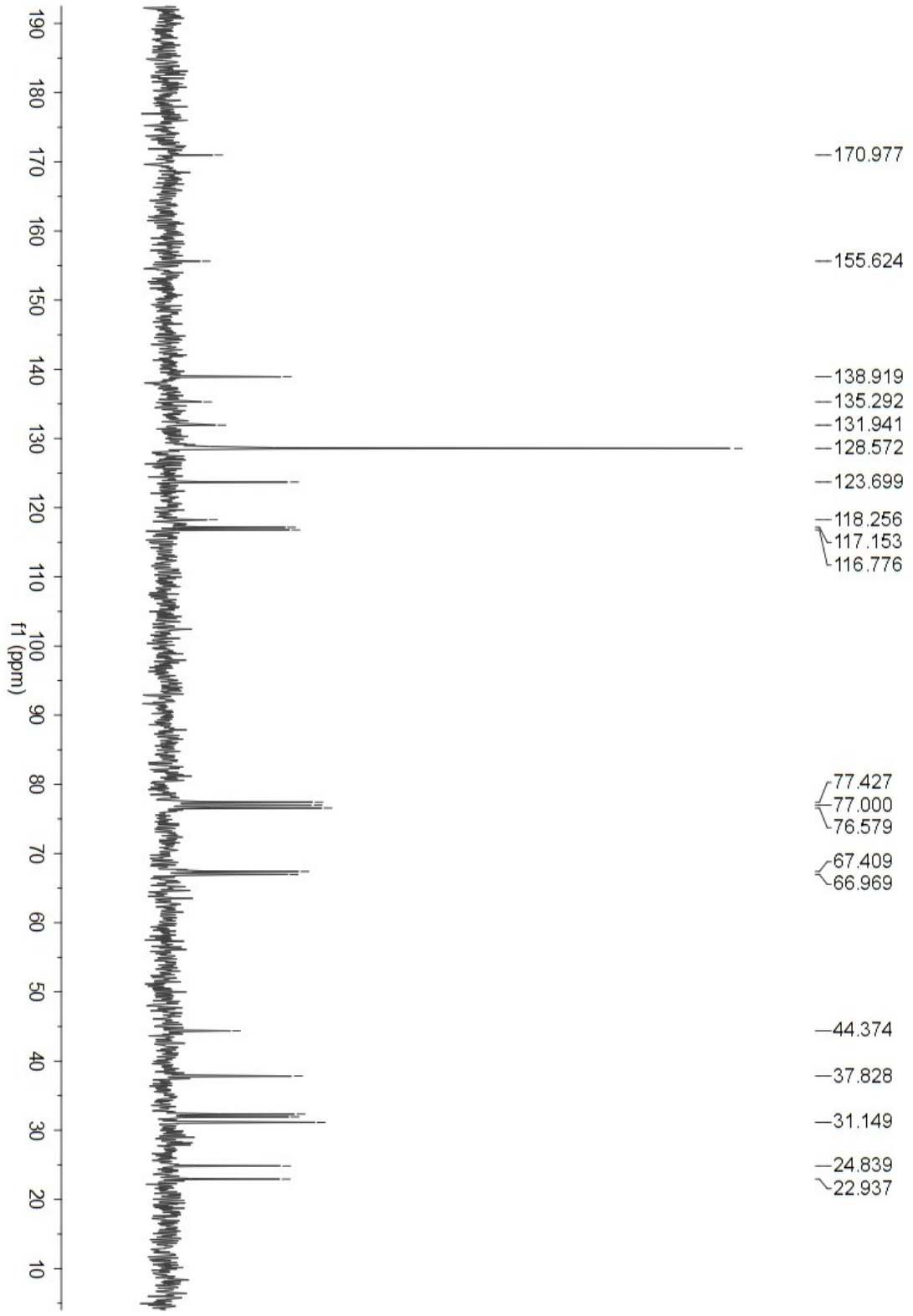
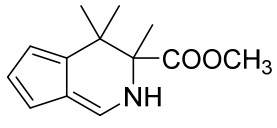
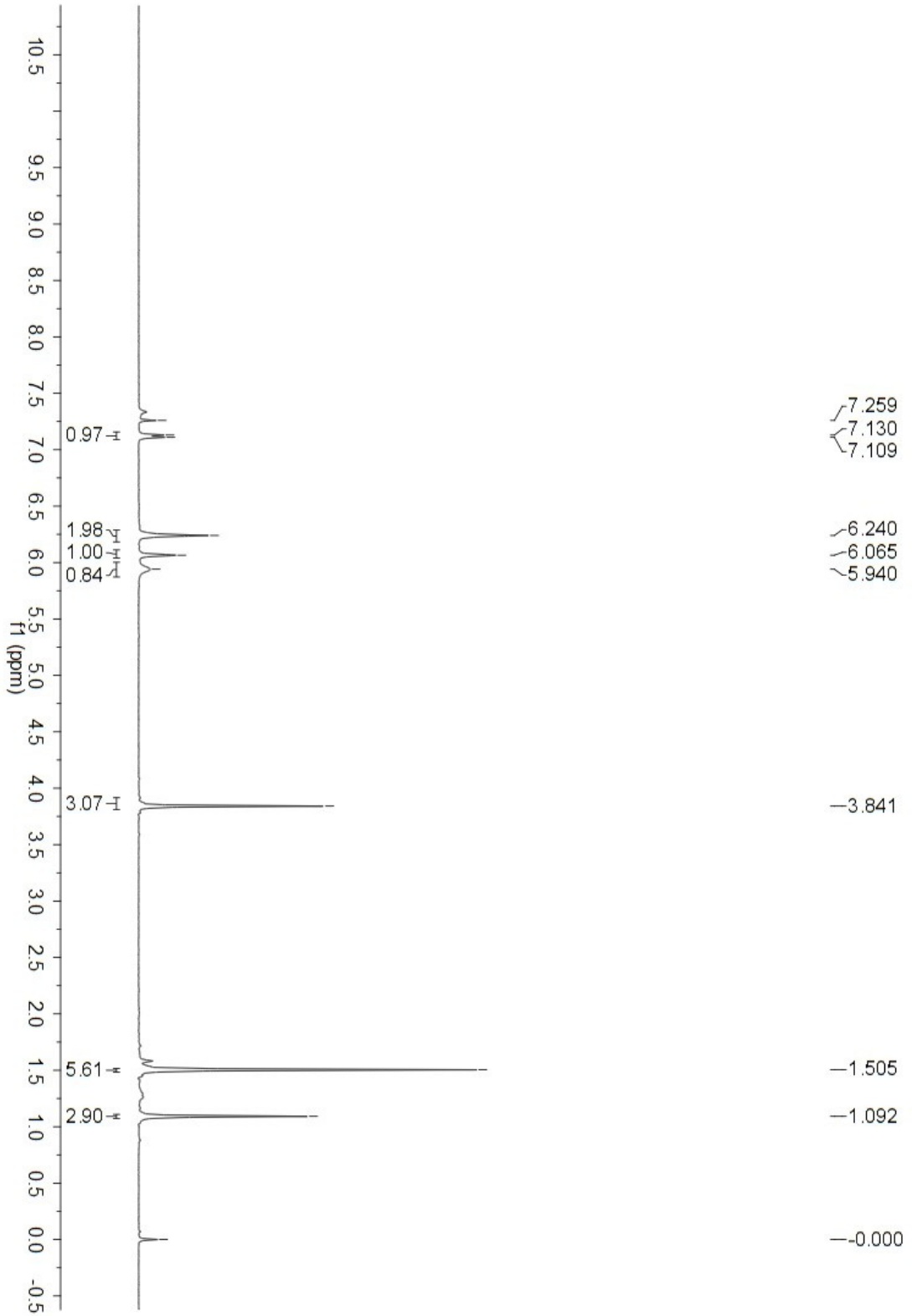
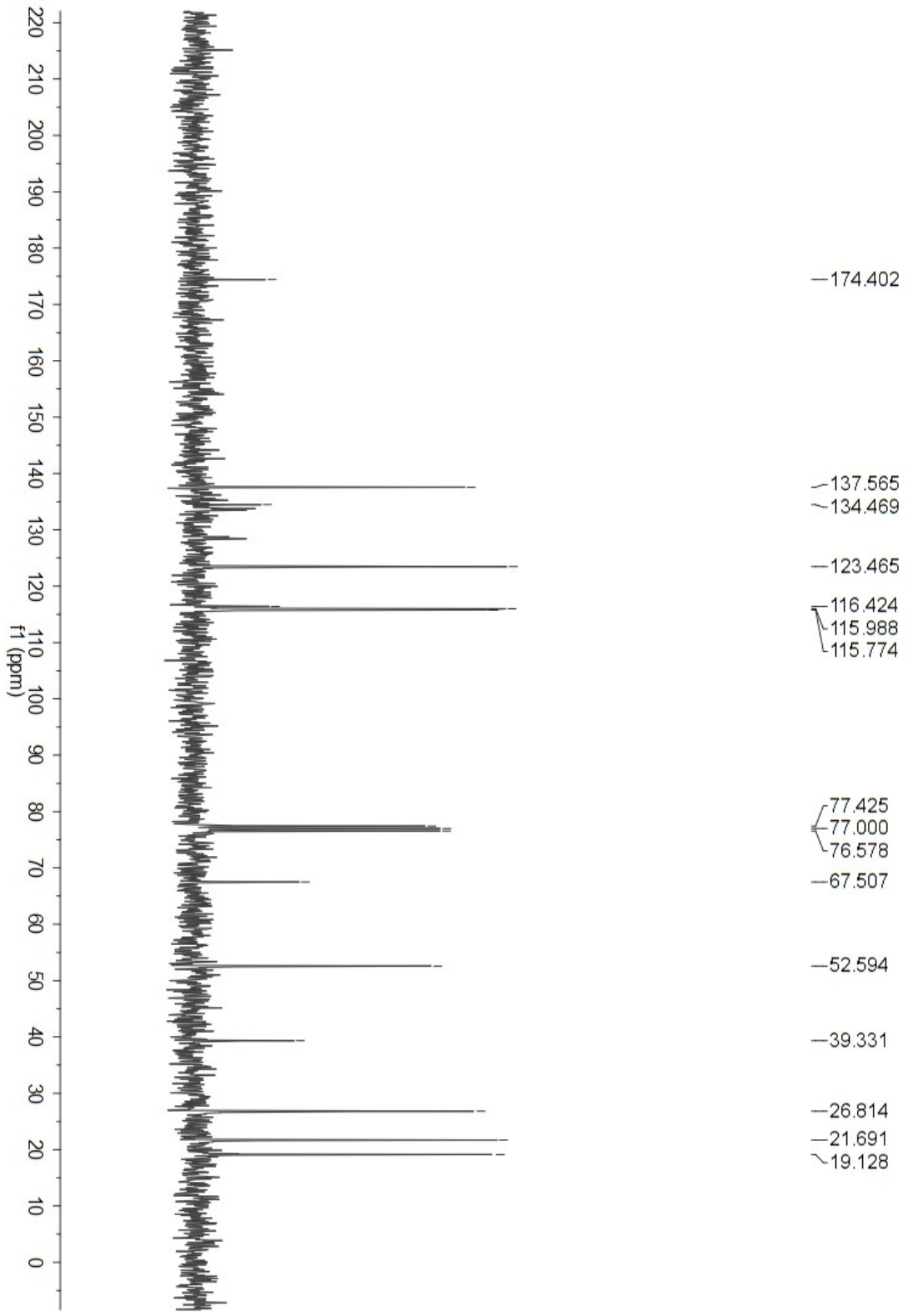
1.255
0.000

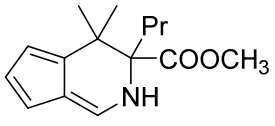

170.977
155.624
138.919
135.292
131.941
128.572
123.699
118.256
117.153
116.776
77.427
77.000
76.579
67.409
66.969
44.374
37.828
31.149
24.839
22.937
f1 (ppm)


COOCH3
NH

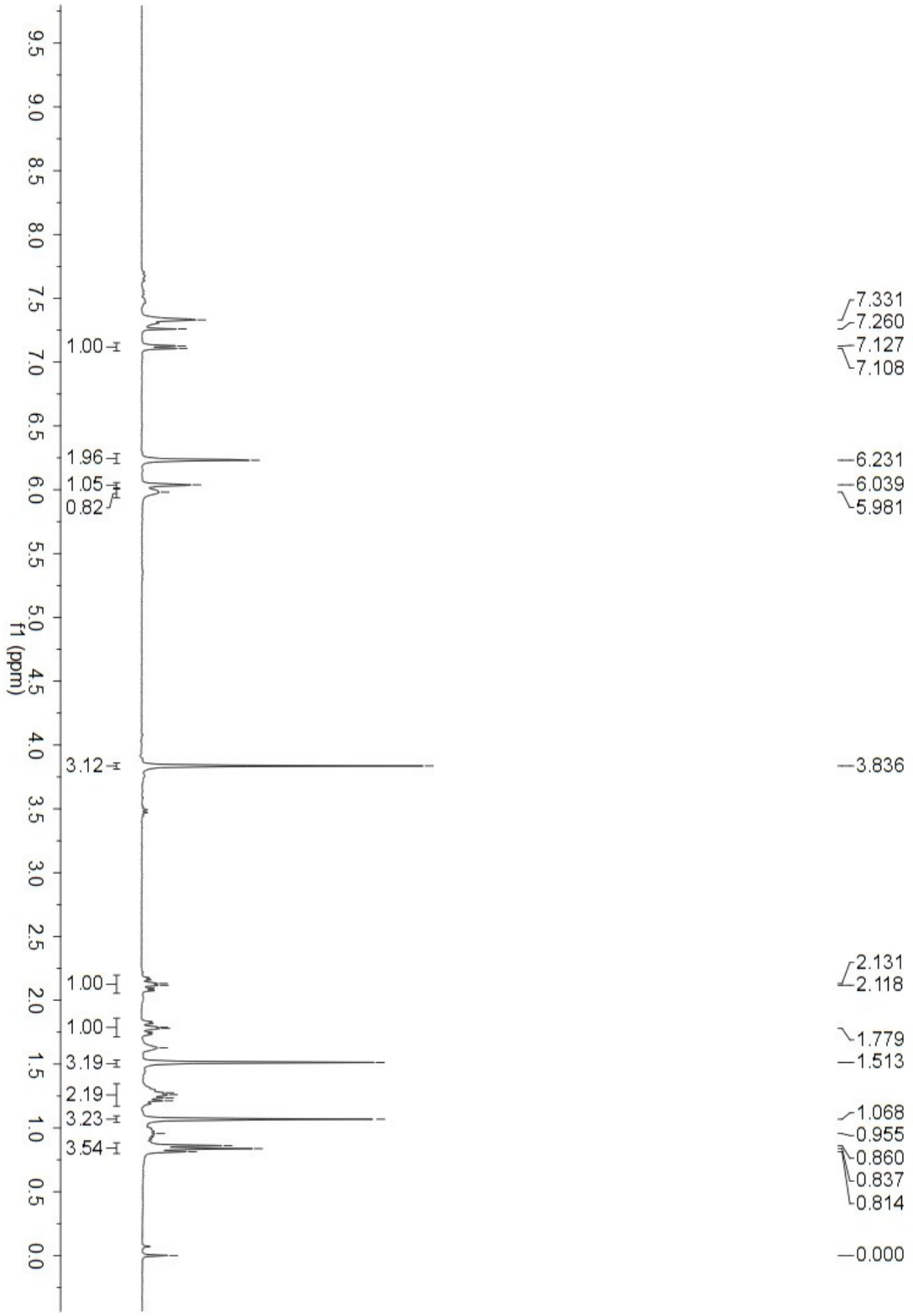
(3j)

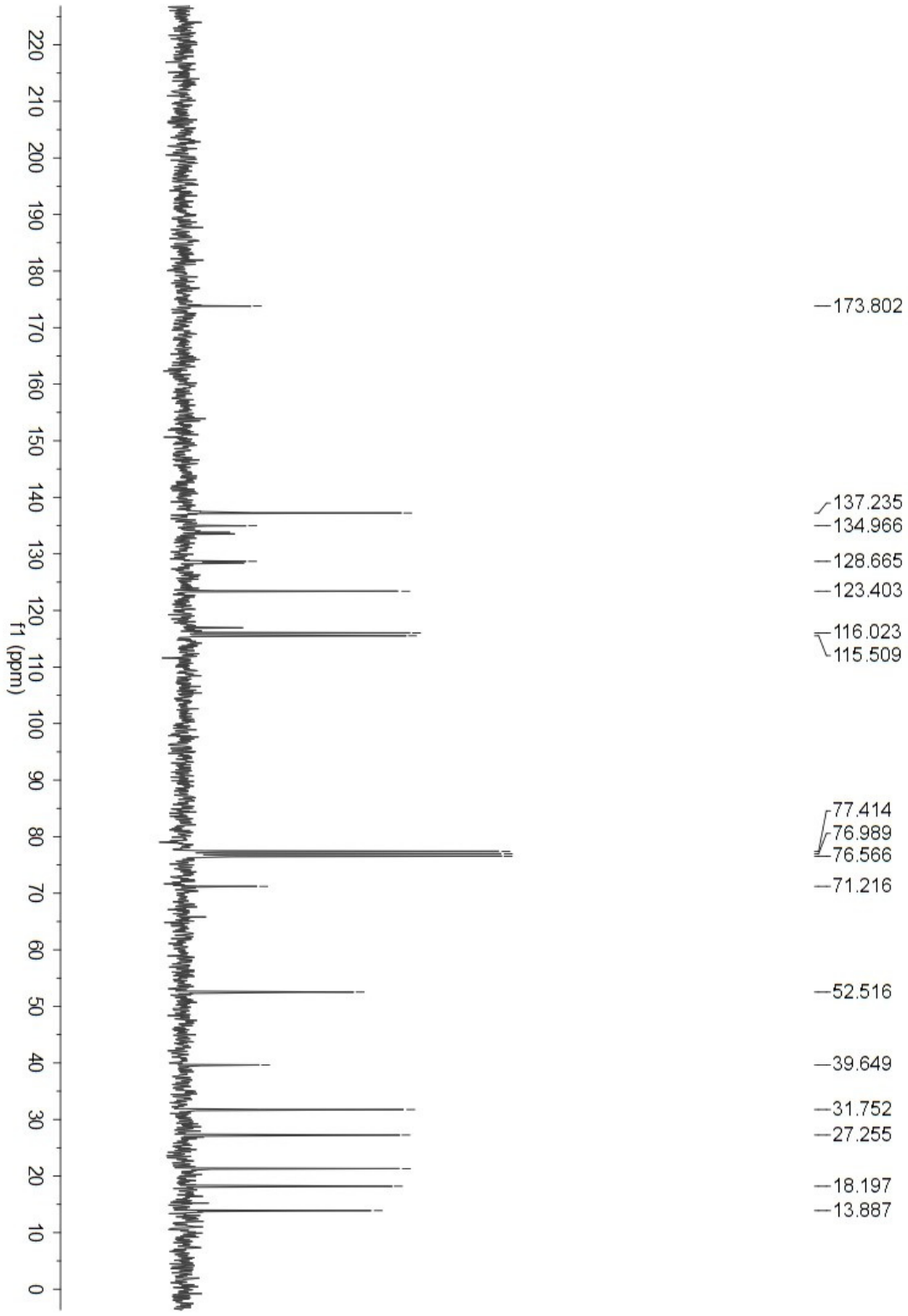

f1 (ppm)
0.97
1.98
1.00
0.84
3.07
5.61
2.90
7.259
7.130
7.109
6.240
6.065
5.940
3.841
1.505
1.092
-0.000


174.402
137.565
134.469
123.465
116.424
115.988
115.774
77.425
77.000
76.578
67.507
52.594
39.331
26.814
21.691
19.128
f1 (ppm)

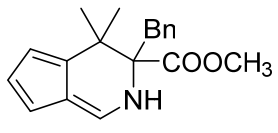

Pr
COOCH3
NH

(3k)

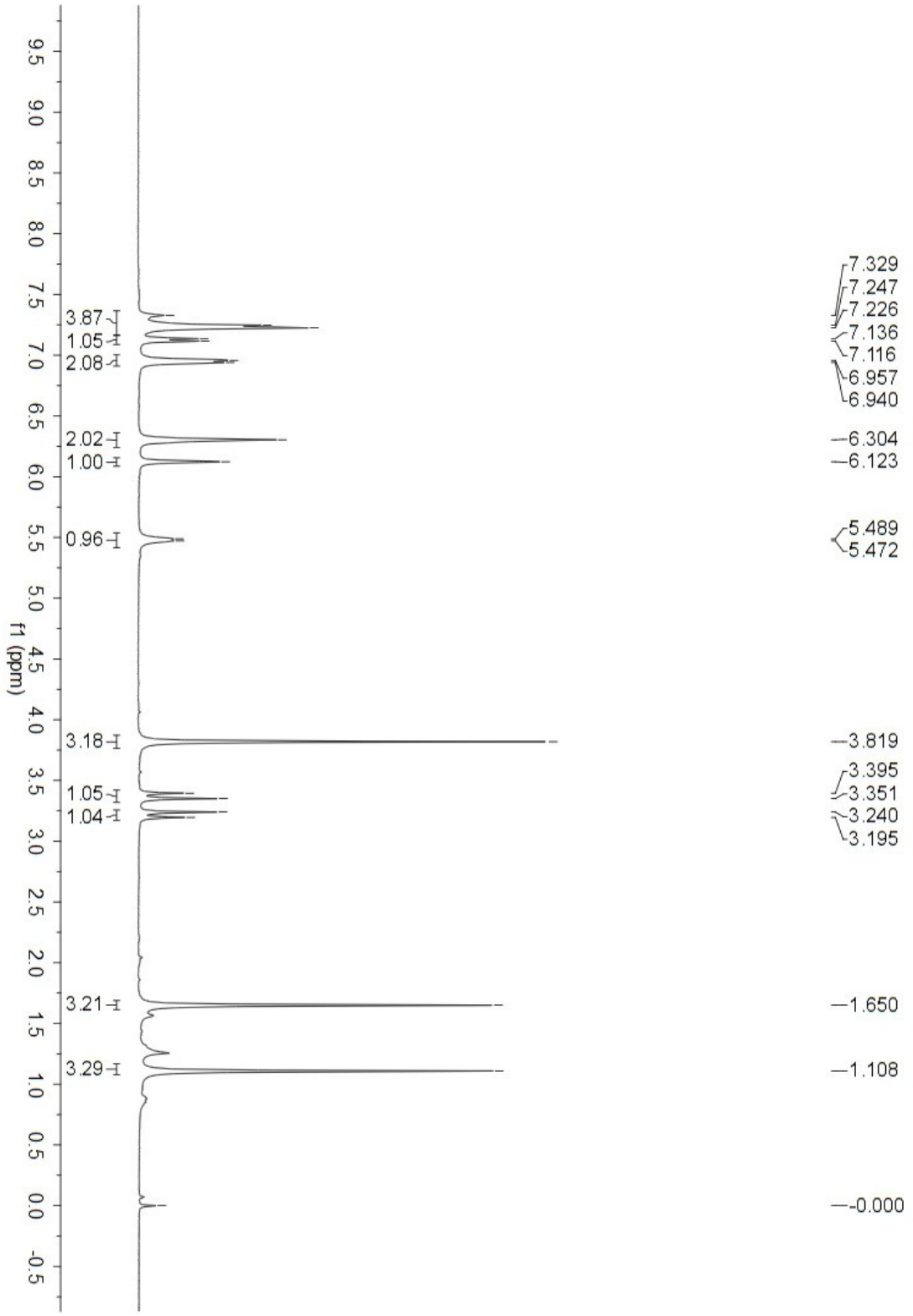

f1 (ppm)
1.00
1.96
1.05
0.82
3.12
1.00
1.00
3.19
2.19
3.23
3.54
7.331
7.260
7.127
7.108
6.231
6.039
5.981
3.836
2.131
2.118
1.779
1.513
1.068
0.955
0.860
0.837
0.814
0.000

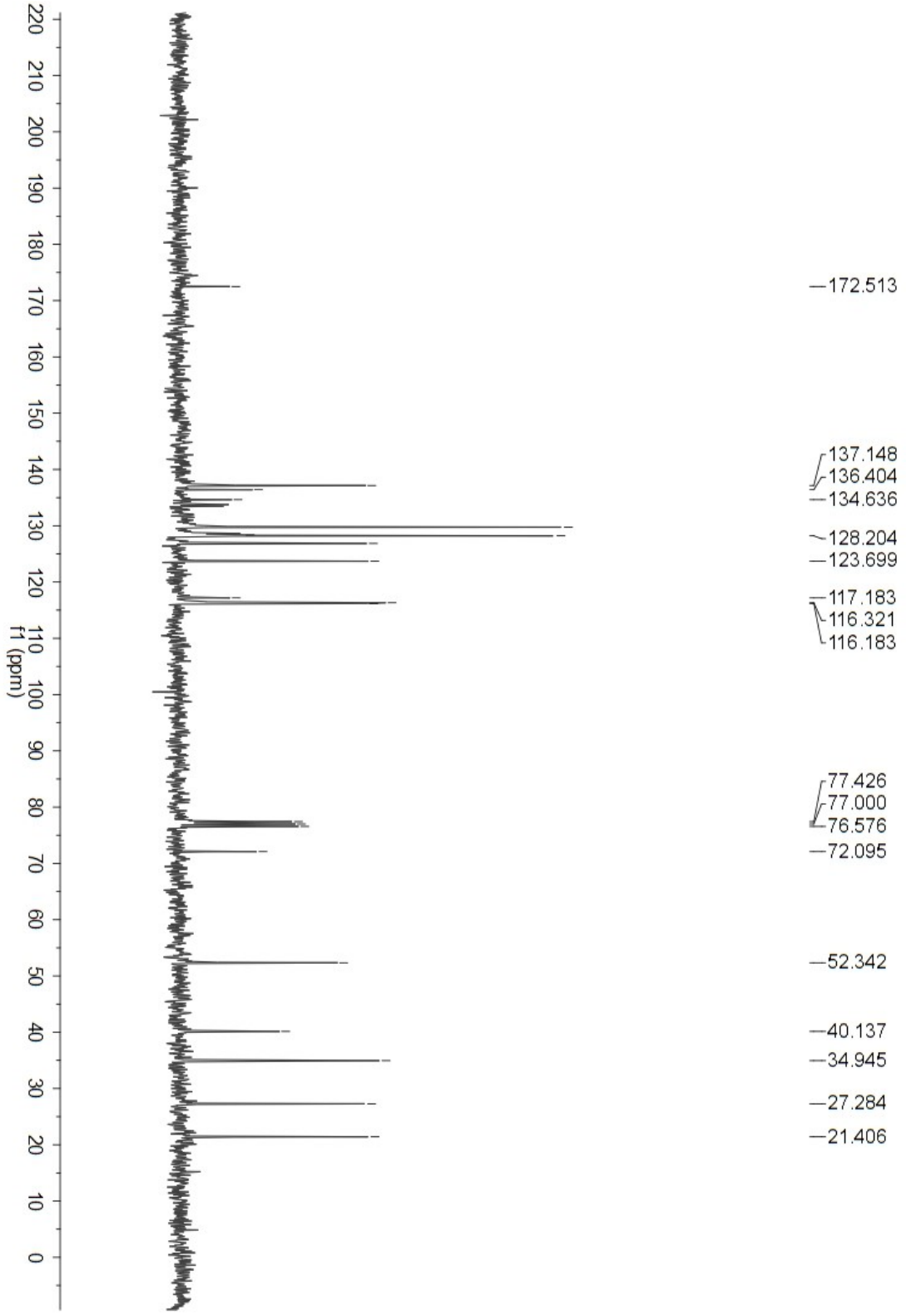

f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
173.802
137.235
134.966
128.665
123.403
116.023
115.509
77.414
76.989
76.566
71.216
52.516
39.649
31.752
27.255
18.197
13.887

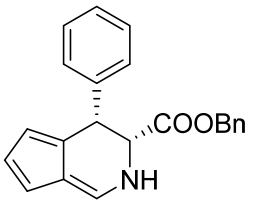
\


Bn
COOCH3
NH

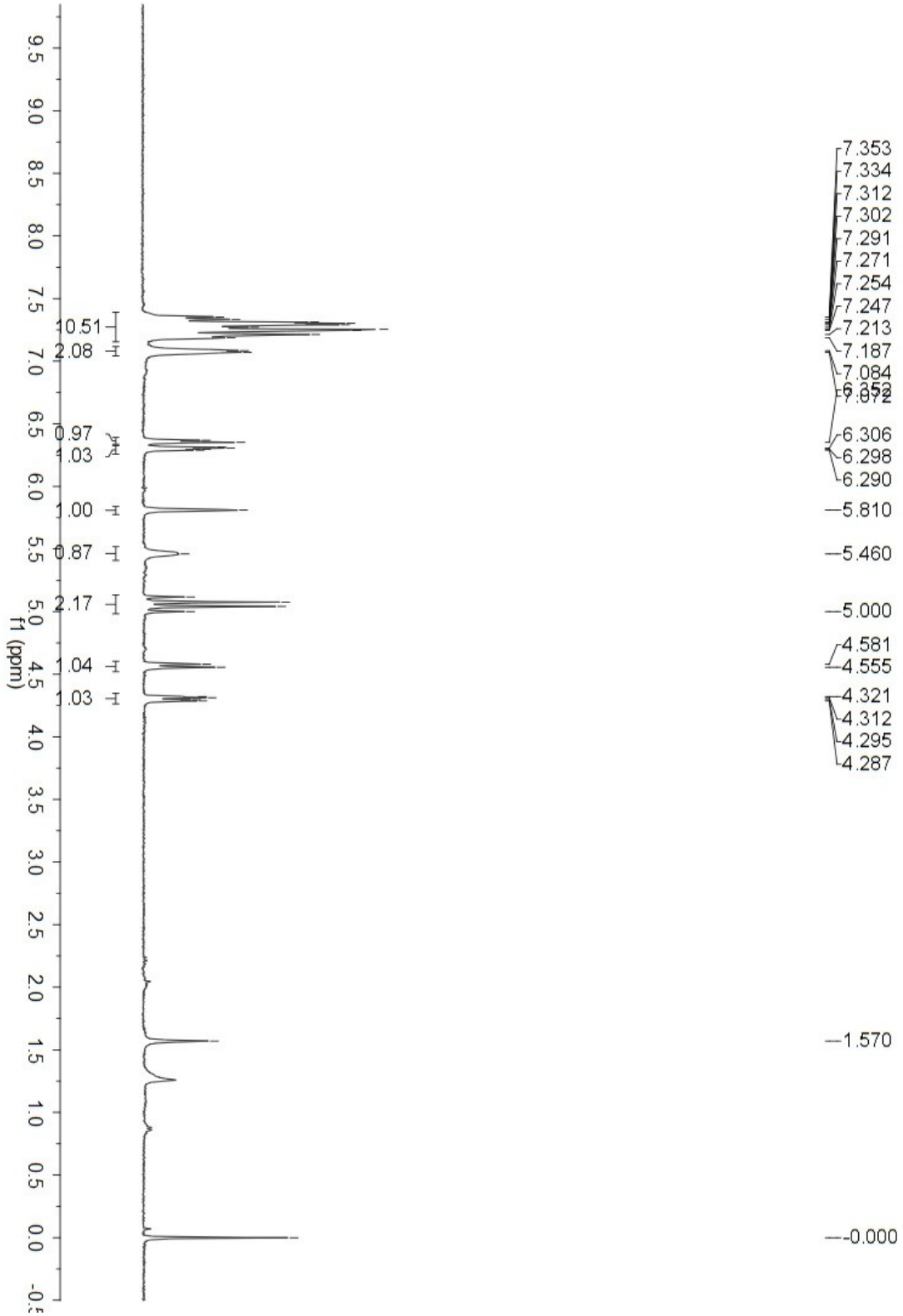
(3l)

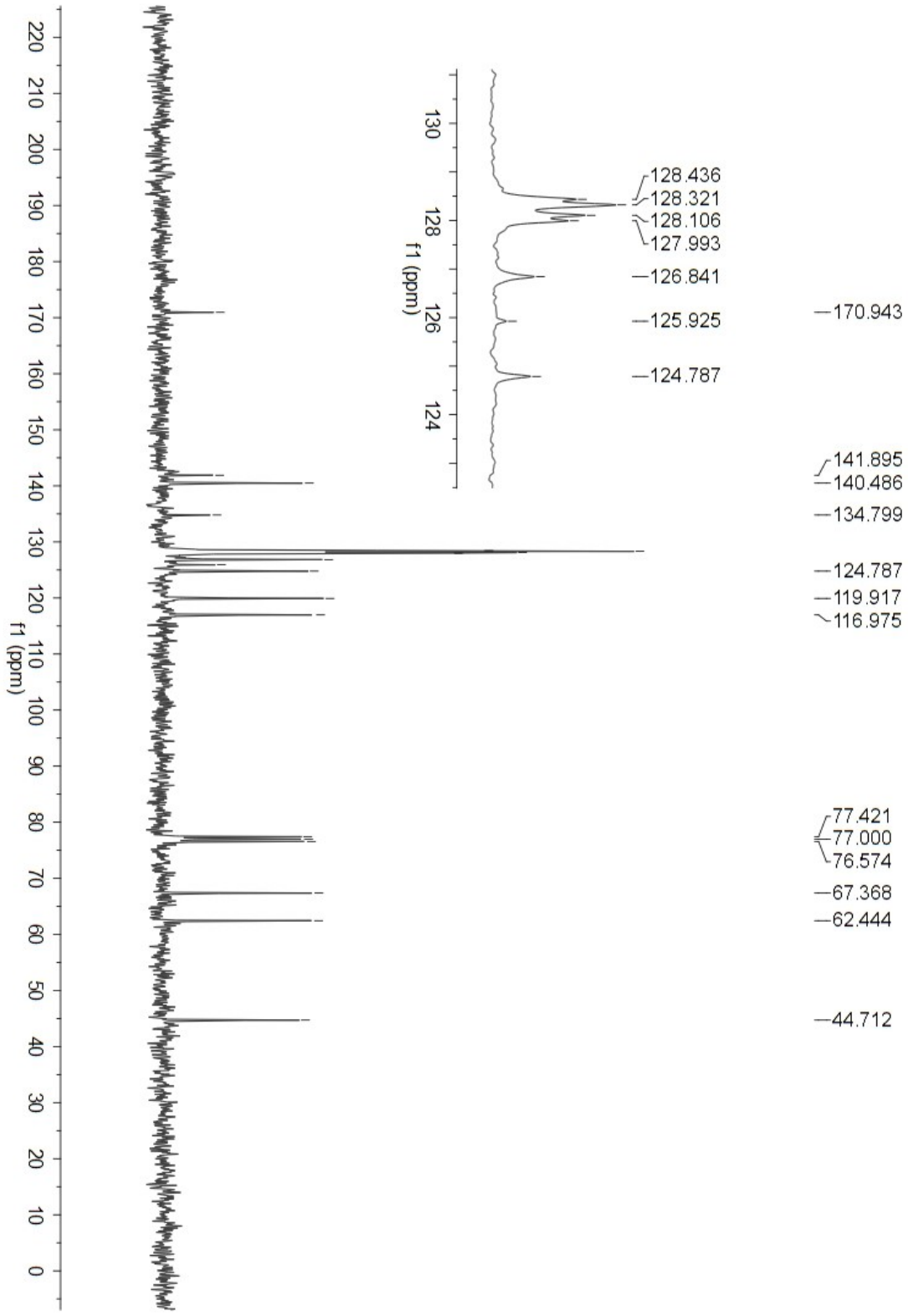

f1 (ppm)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
3.87
1.05
2.08
2.02
1.00
0.96
3.18
1.05
1.04
3.21
3.29
7.329
7.247
7.226
7.136
7.116
6.957
6.940
6.304
6.123
5.489
5.472
3.819
3.395
3.351
3.240
3.195
1.650
1.108
-0.000

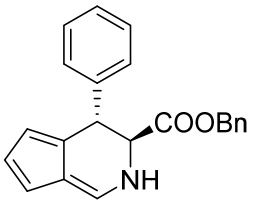

220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)
172.513
137.148
136.404
134.636
128.204
123.699
117.183
116.321
116.183
77.426
77.000
76.576
72.095
52.342
40.137
34.945
27.284
21.406


COOBn
NH

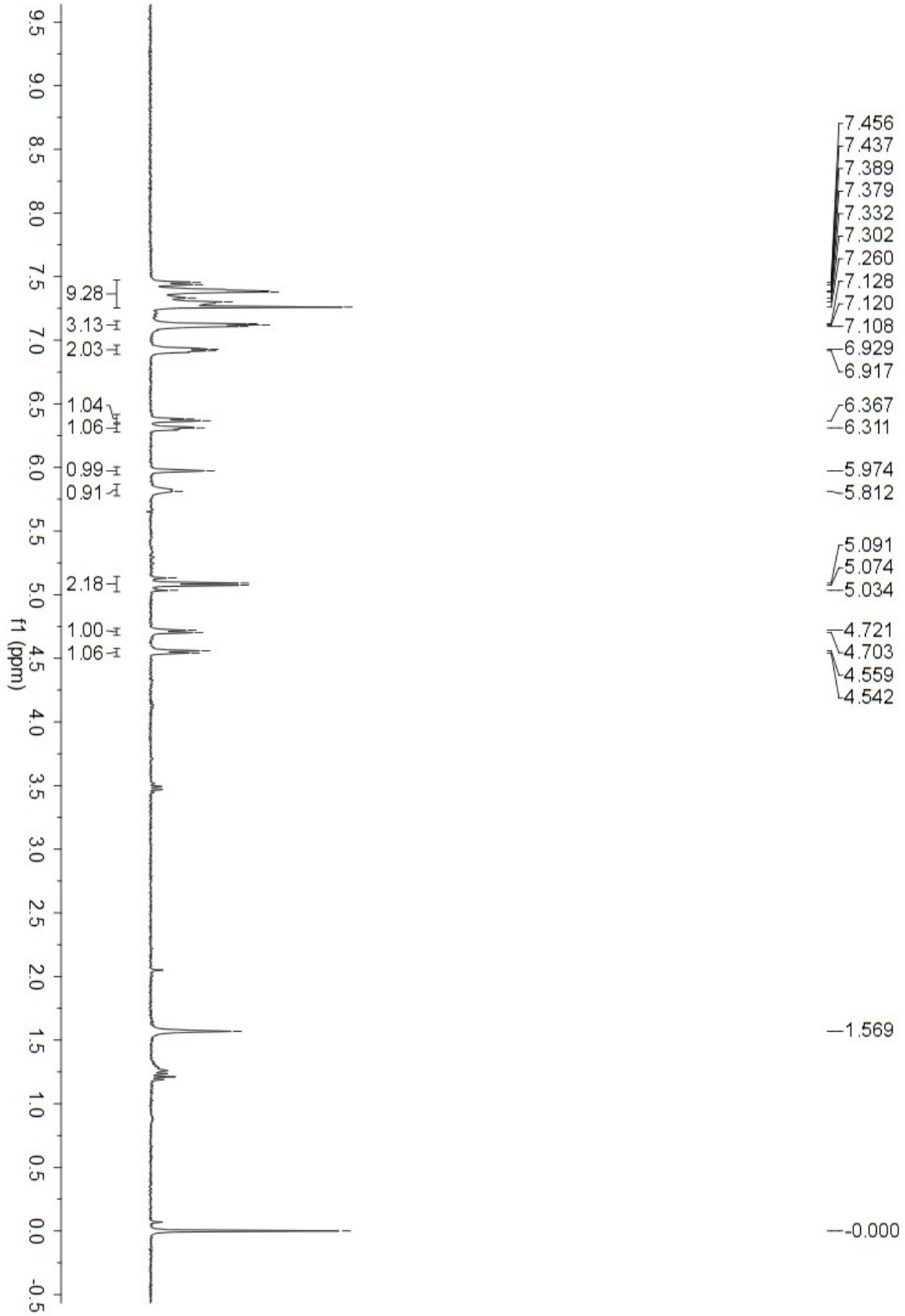
(4a)

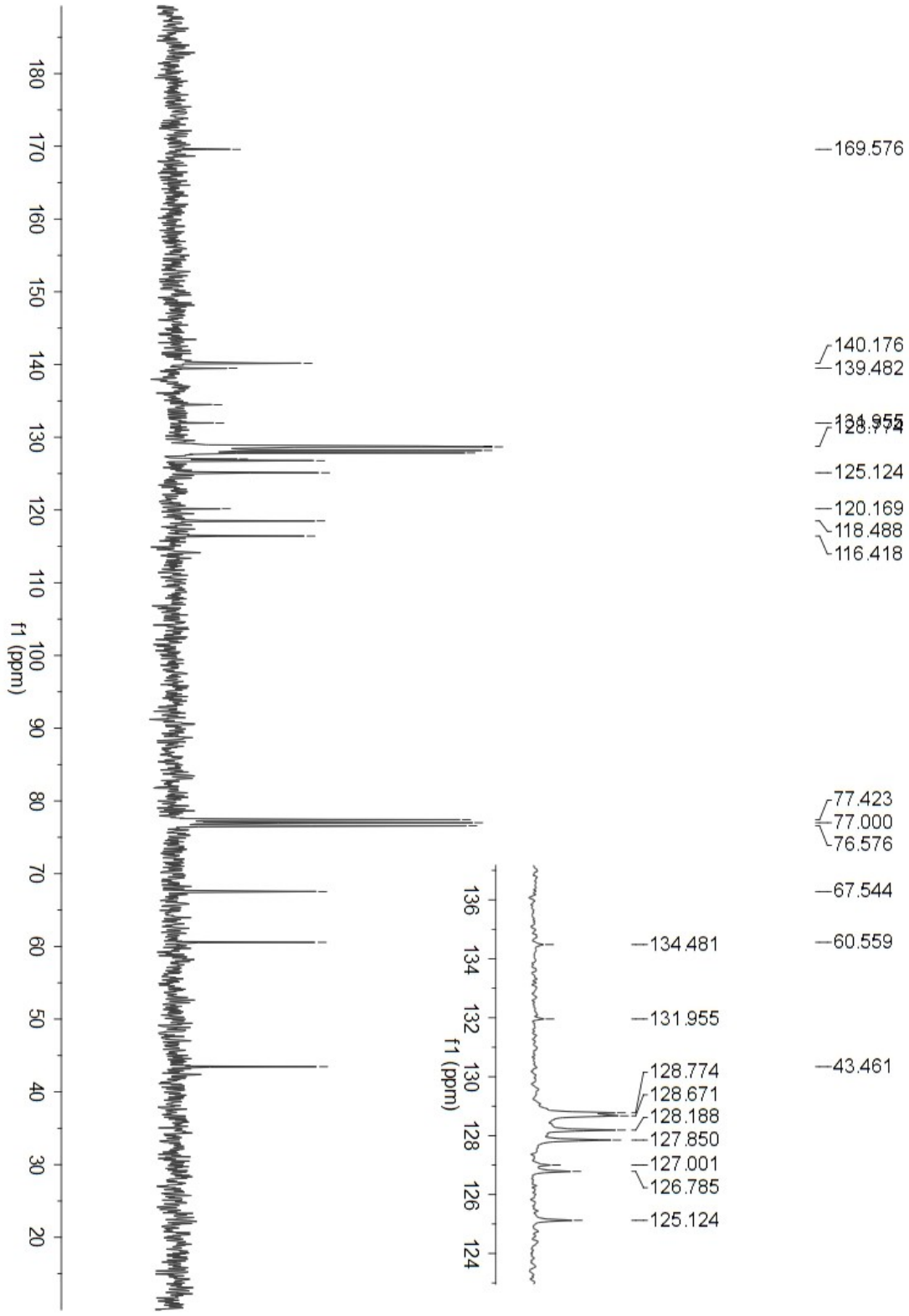

f1 (ppm)
10.51
2.08
0.97
1.03
1.00
0.87
2.17
1.04
1.03
7.353
7.334
7.312
7.302
7.291
7.271
7.254
7.247
7.213
7.187
7.084
6.306
6.298
6.290
5.810
5.460
5.000
4.581
4.555
4.321
4.312
4.295
4.287
1.570
-0.000

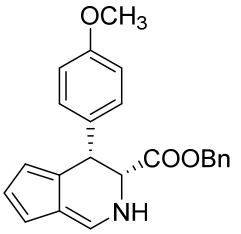

f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
130 128 126 124
128.436
128.321
128.106
127.993
126.841
125.925
124.787
170.943
141.895
140.486
134.799
124.787
119.917
116.975
77.421
77.000
76.574
67.368
62.444
44.712


COOBn
NH

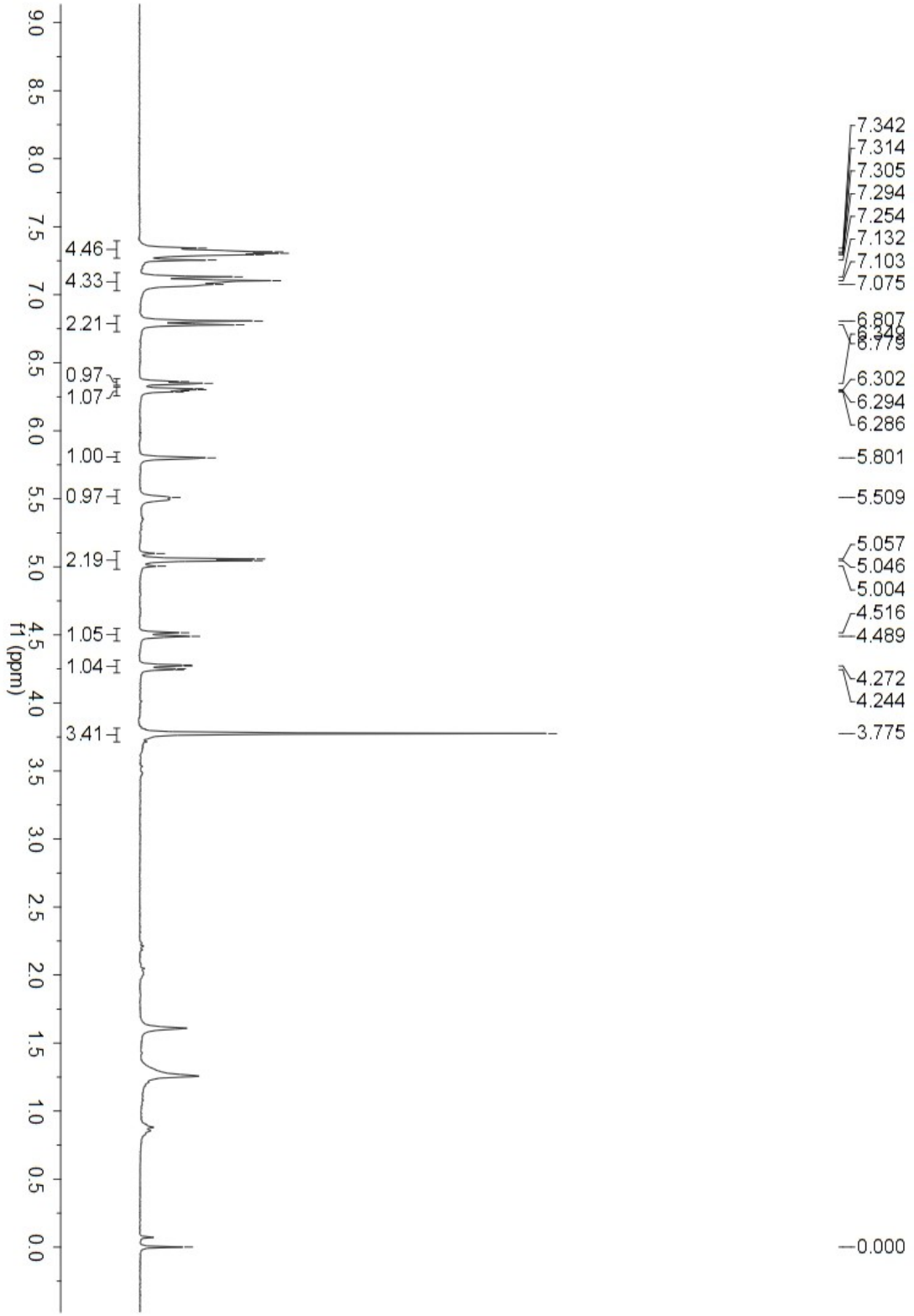
(5a)

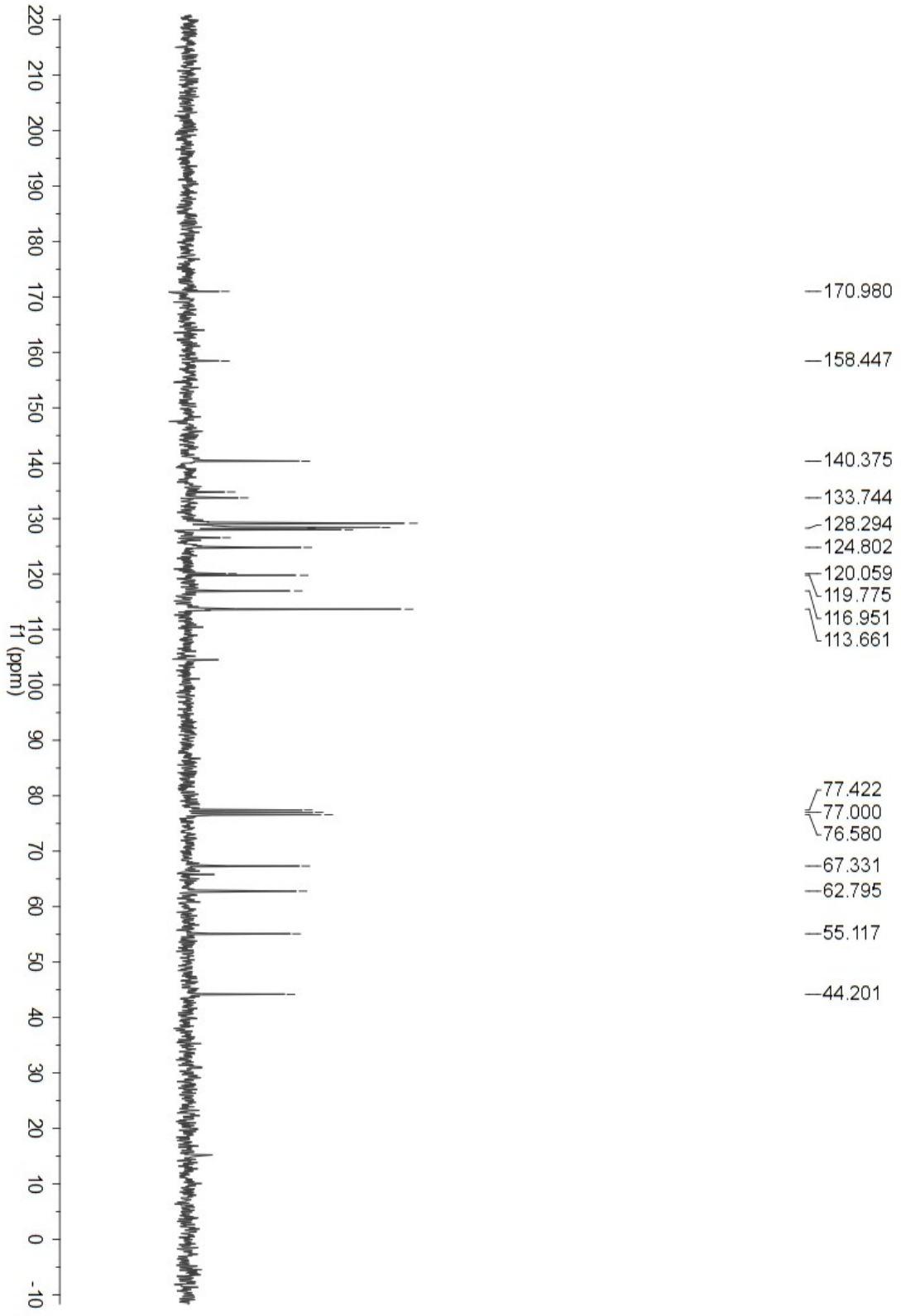

9.28
3.13
2.03
1.04
1.06
0.99
0.91
2.18
1.00
1.06
f1 (ppm)
7.456
7.437
7.389
7.379
7.332
7.302
7.260
7.128
7.120
7.108
6.929
6.917
6.367
6.311
5.974
5.812
5.091
5.074
5.034
4.721
4.703
4.559
4.542
1.569
-0.000

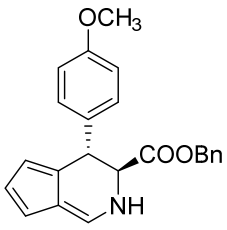

169.576
140.176
139.482
134.955
128.774
125.124
120.169
118.488
116.418
77.423
77.000
76.576
67.544
60.559
43.461
f1 (ppm)
134.481
131.955
128.774
128.671
128.188
127.850
127.001
126.785
125.124
f1 (ppm)


OCH3
COOBn
NH

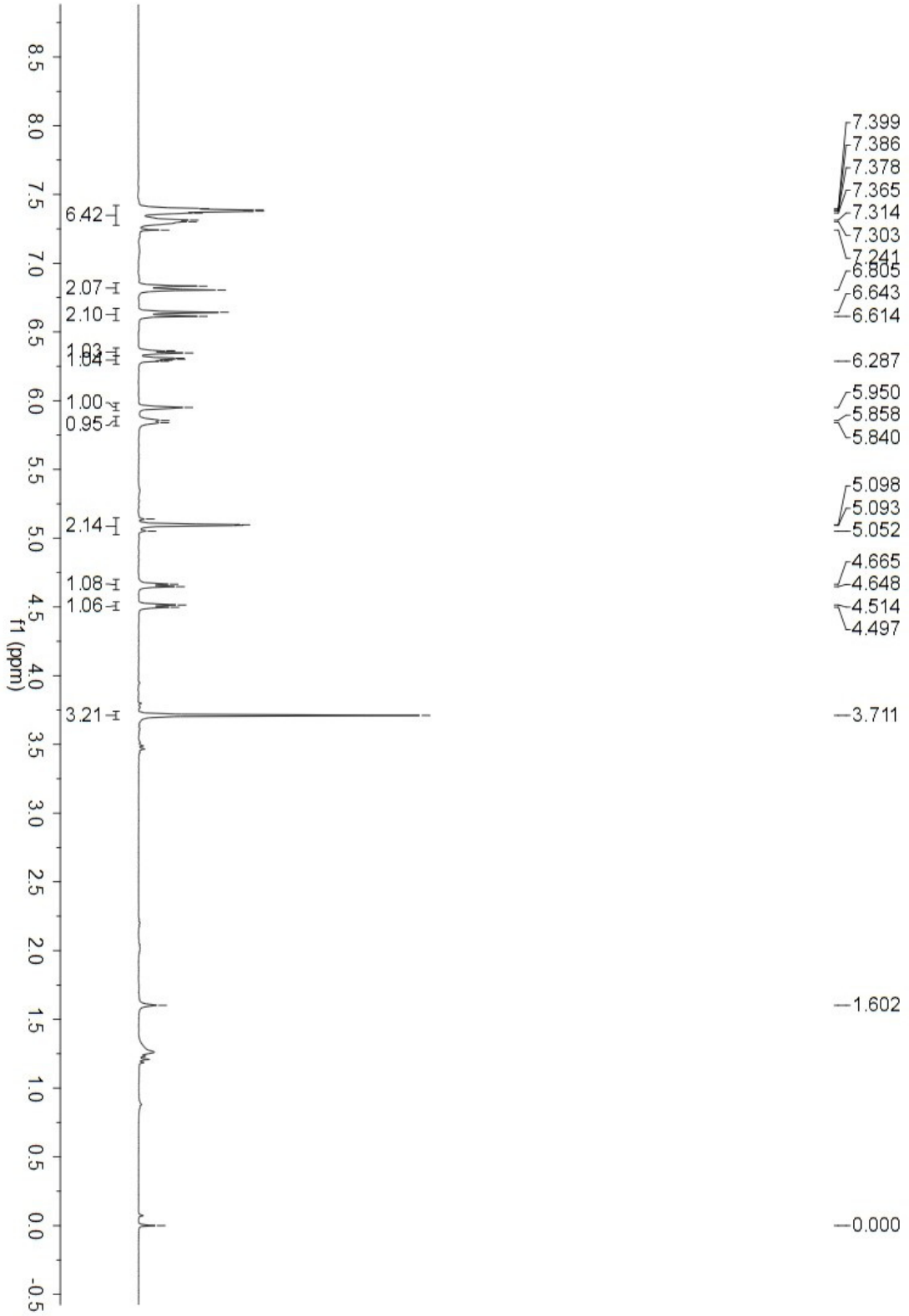
(4b)

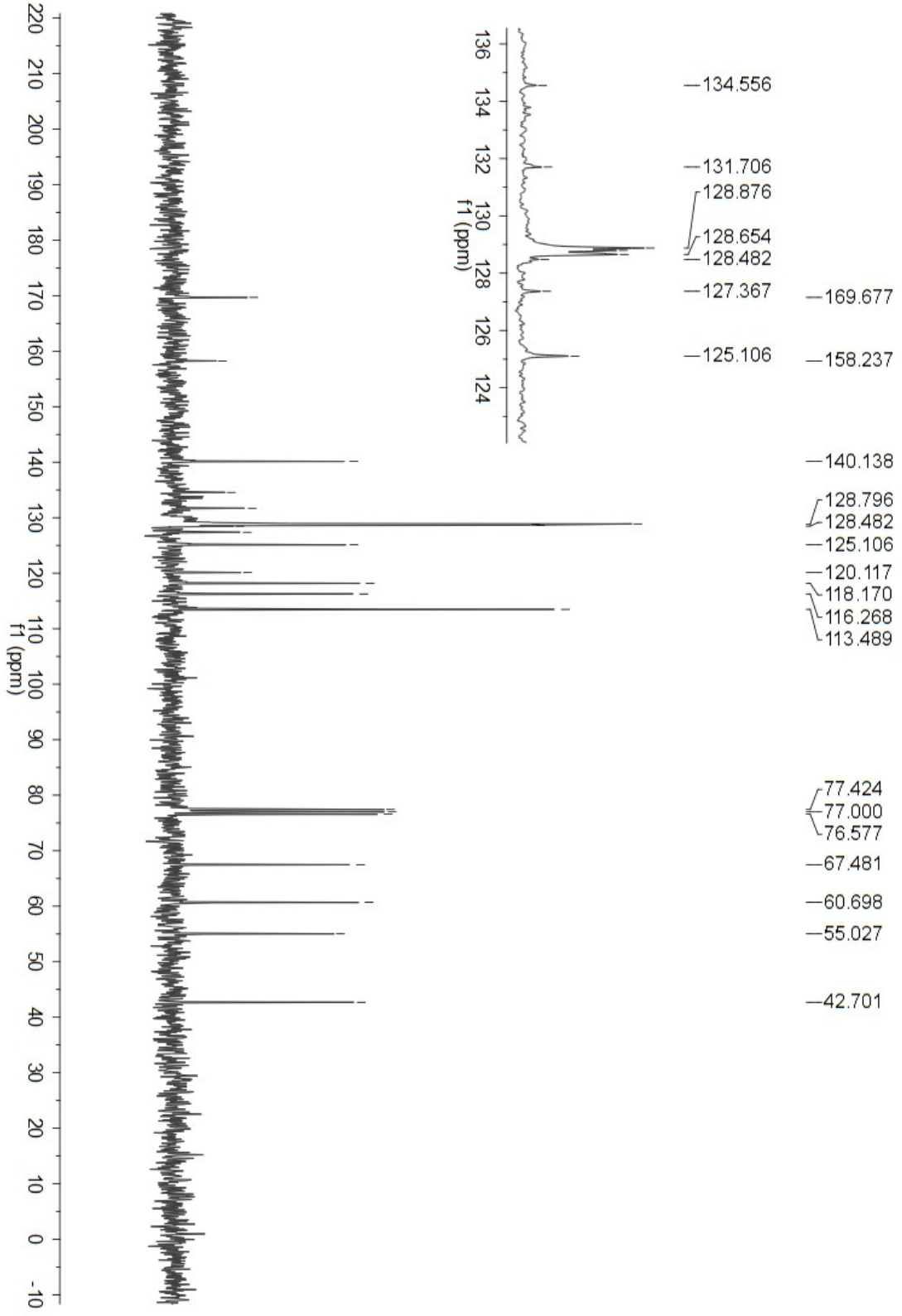

f1 (ppm)
4.46
4.33
2.21
0.97
1.07
1.00
0.97
2.19
1.05
1.04
3.41
7.342
7.314
7.305
7.294
7.254
7.132
7.103
7.075
6.807
6.779
6.302
6.294
6.286
5.801
5.509
5.057
5.046
5.004
4.516
4.489
4.272
4.244
3.775
0.000

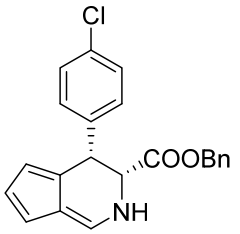

220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)
170.980
158.447
140.375
133.744
128.294
124.802
120.059
119.775
116.951
113.661
77.422
77.000
76.580
67.331
62.795
55.117
44.201


OCH3
COOBn
NH

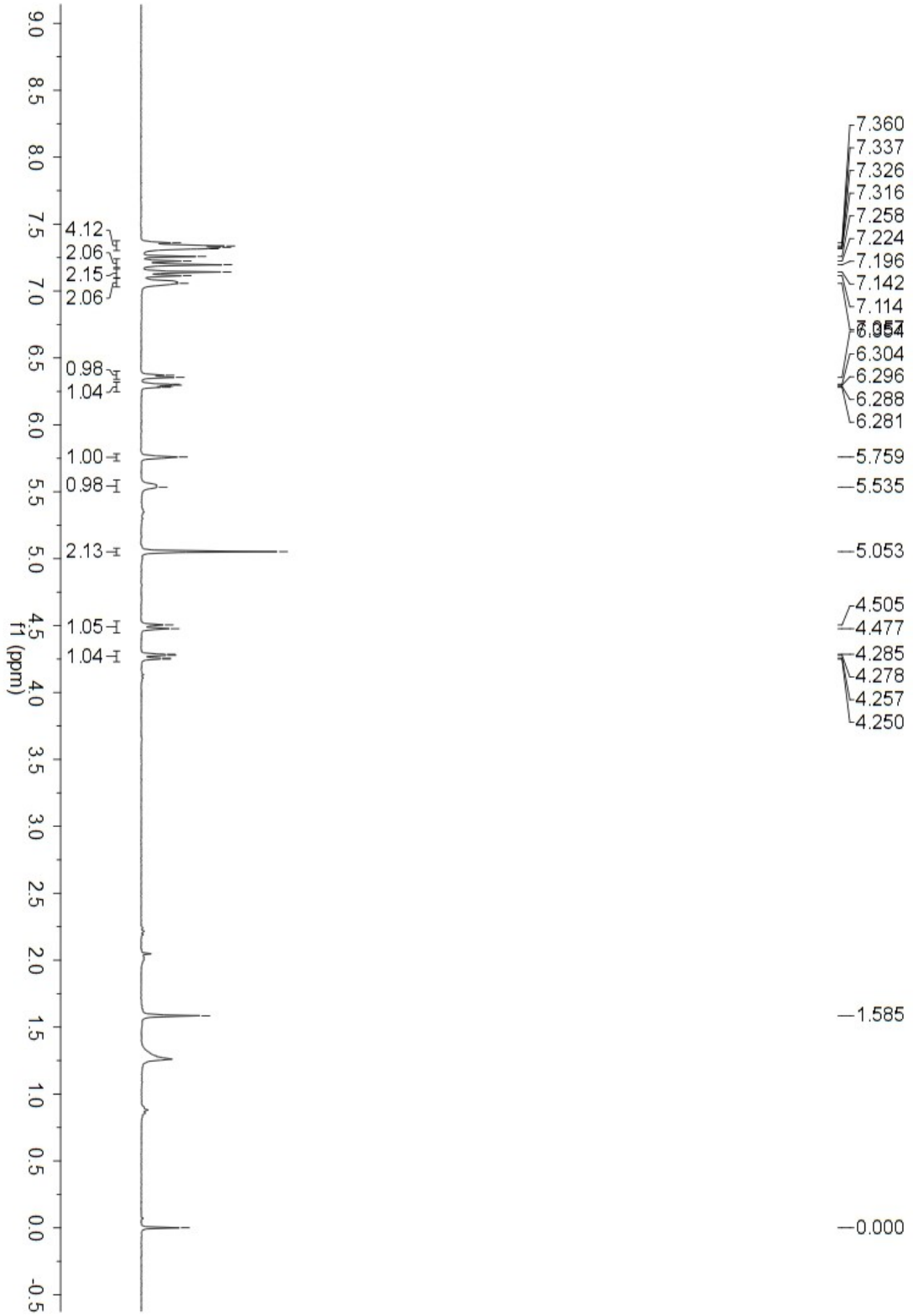
(5b)

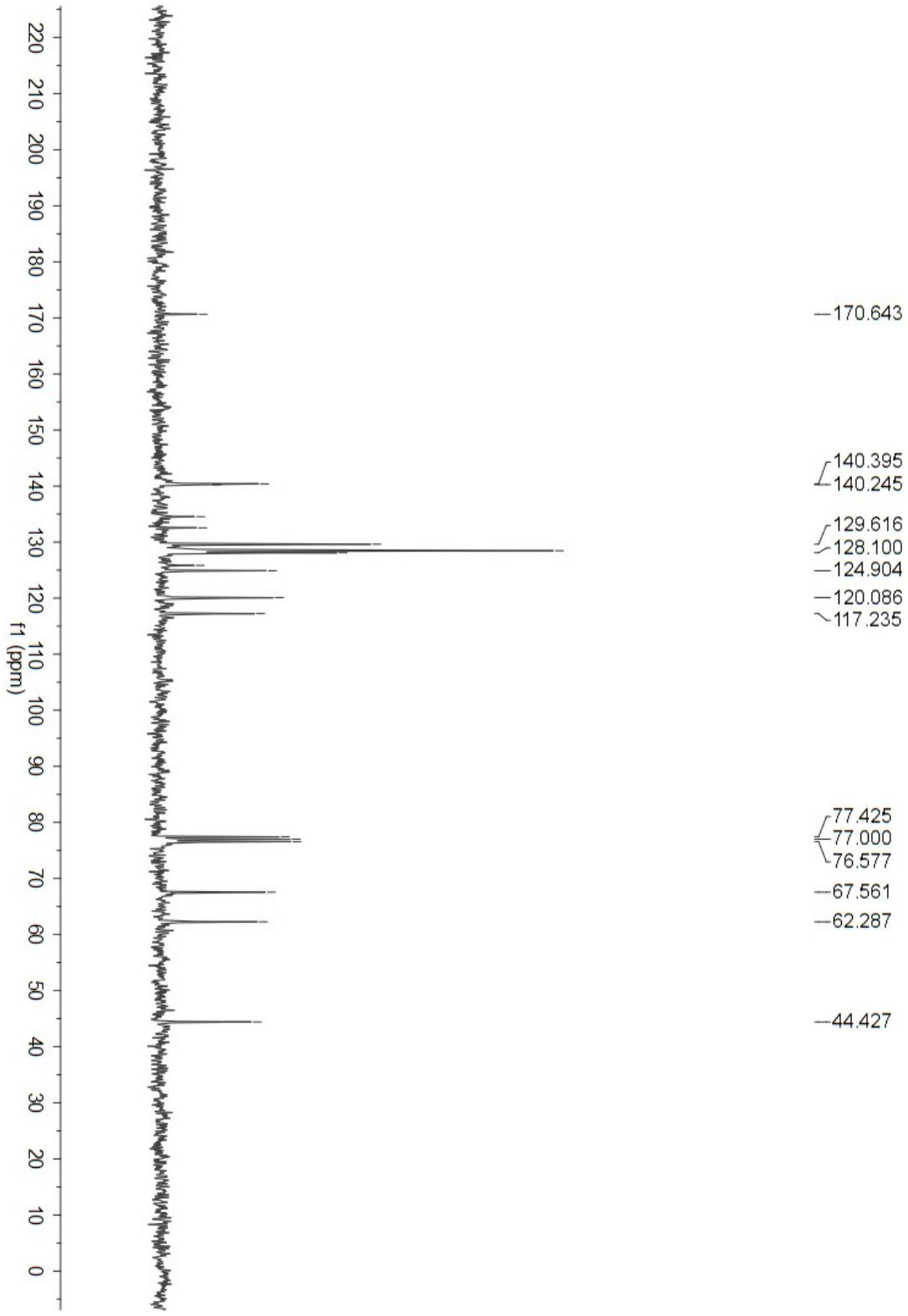

f1 (ppm)
6.42
2.07
2.10
1.03
1.04
1.00
0.95
2.14
1.08
1.06
3.21
7.399
7.386
7.378
7.365
7.314
7.303
7.241
6.605
6.643
6.614
6.287
5.950
5.858
5.840
5.098
5.093
5.052
4.665
4.648
4.514
4.497
3.711
1.602
0.000

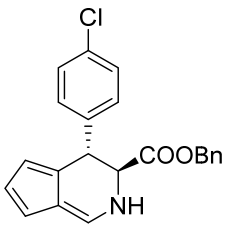

f1 (ppm)
f1 (ppm)
134.556
131.706
128.876
128.654
128.482
127.367
125.106
169.677
158.237
140.138
128.796
128.482
125.106
120.117
118.170
116.268
113.489
77.424
77.000
76.577
67.481
60.698
55.027
42.701


Cl
COOBn
NH

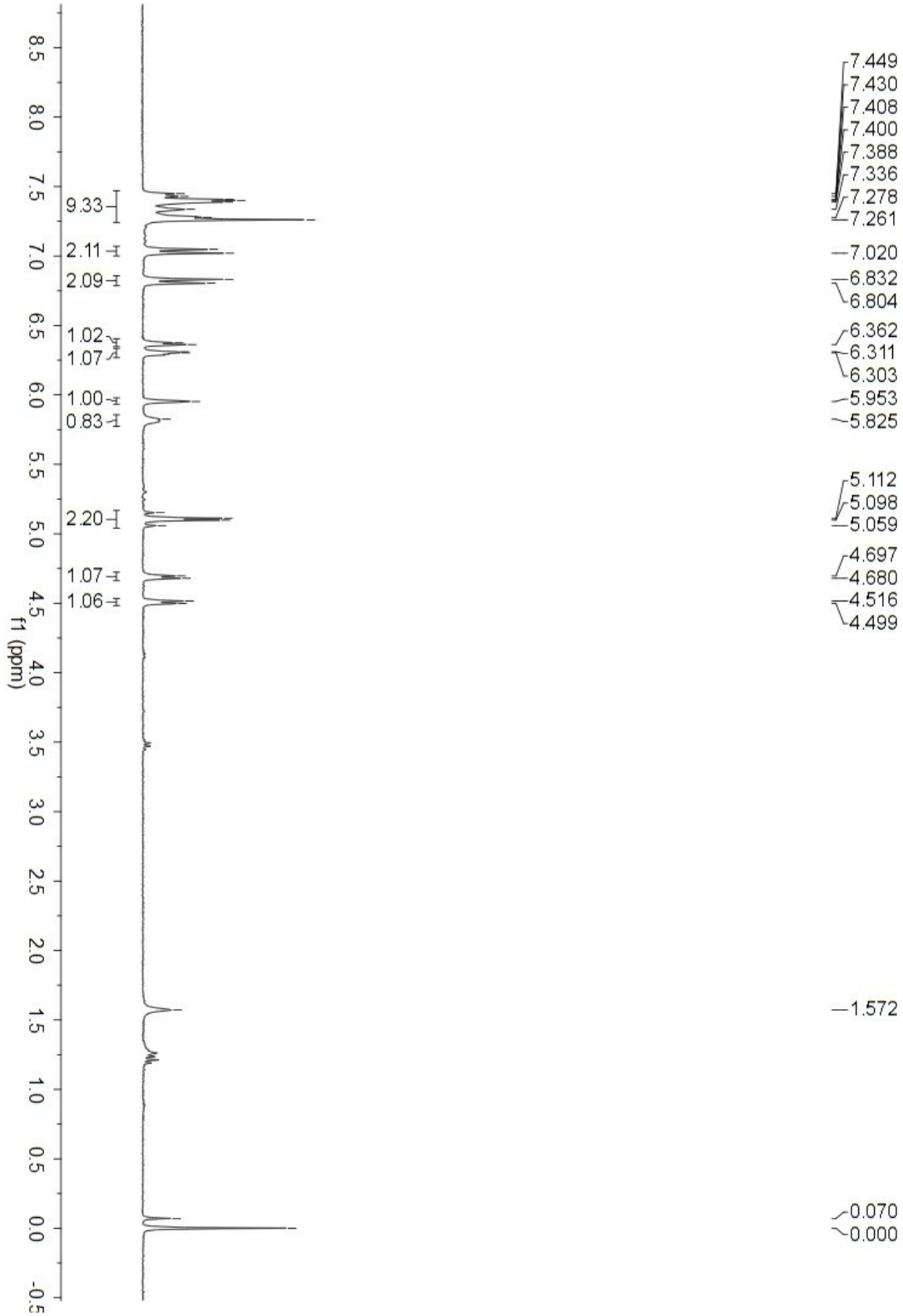
(4c)

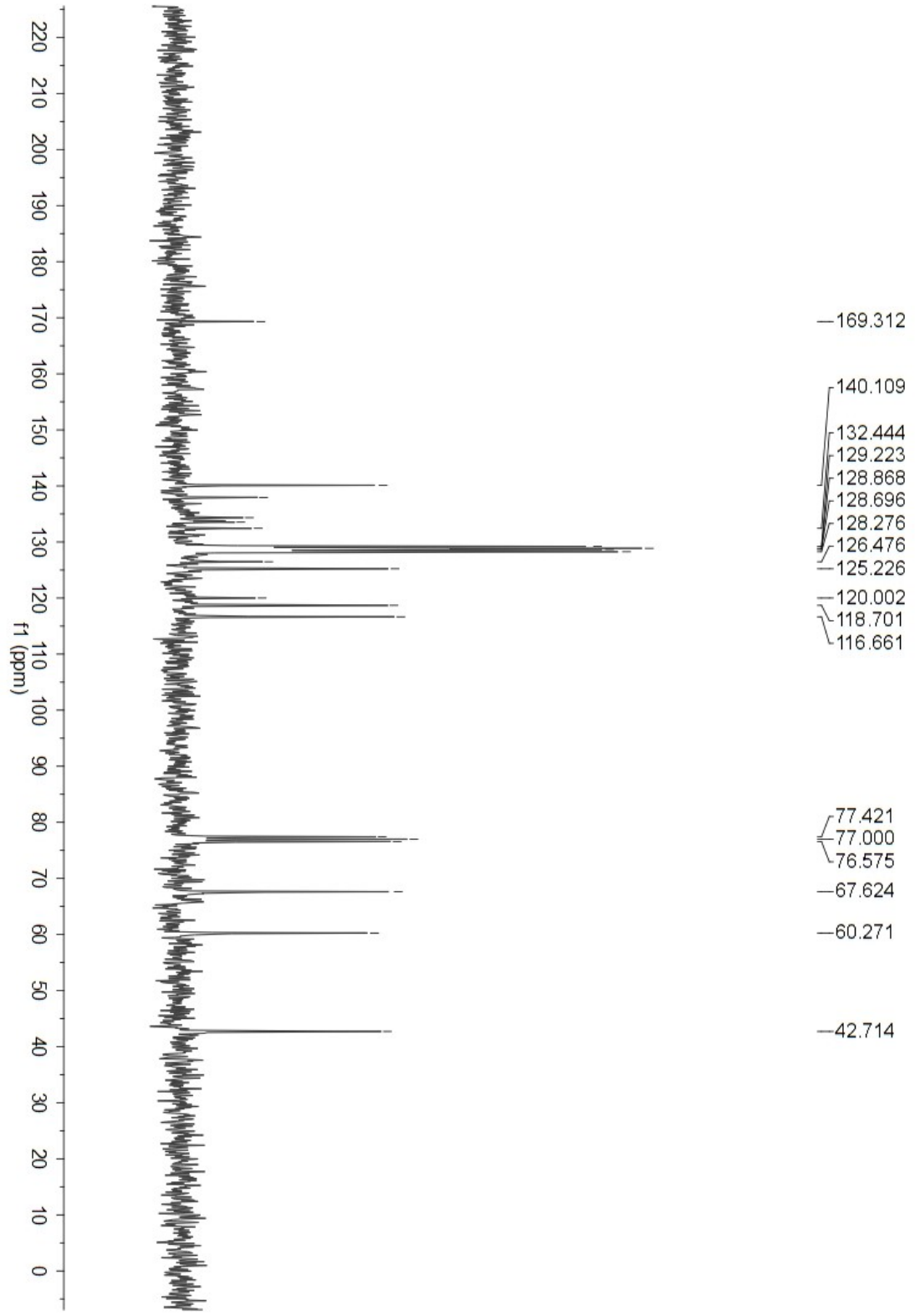

f1 (ppm)
4.12
2.06
2.15
2.06
0.98
1.04
1.00
0.98
2.13
1.05
1.04
7.360
7.337
7.326
7.316
7.258
7.224
7.196
7.142
7.114
6.304
6.296
6.288
6.281
5.759
5.535
5.053
4.505
4.477
4.285
4.278
4.257
4.250
1.585
0.000

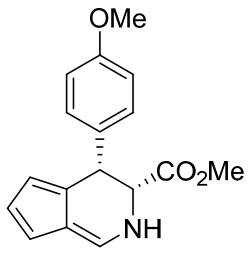

170.643
140.395
140.245
129.616
128.100
124.904
120.086
117.235
77.425
77.000
76.577
67.561
62.287
44.427
f1 (ppm)


Cl
COOBn
NH

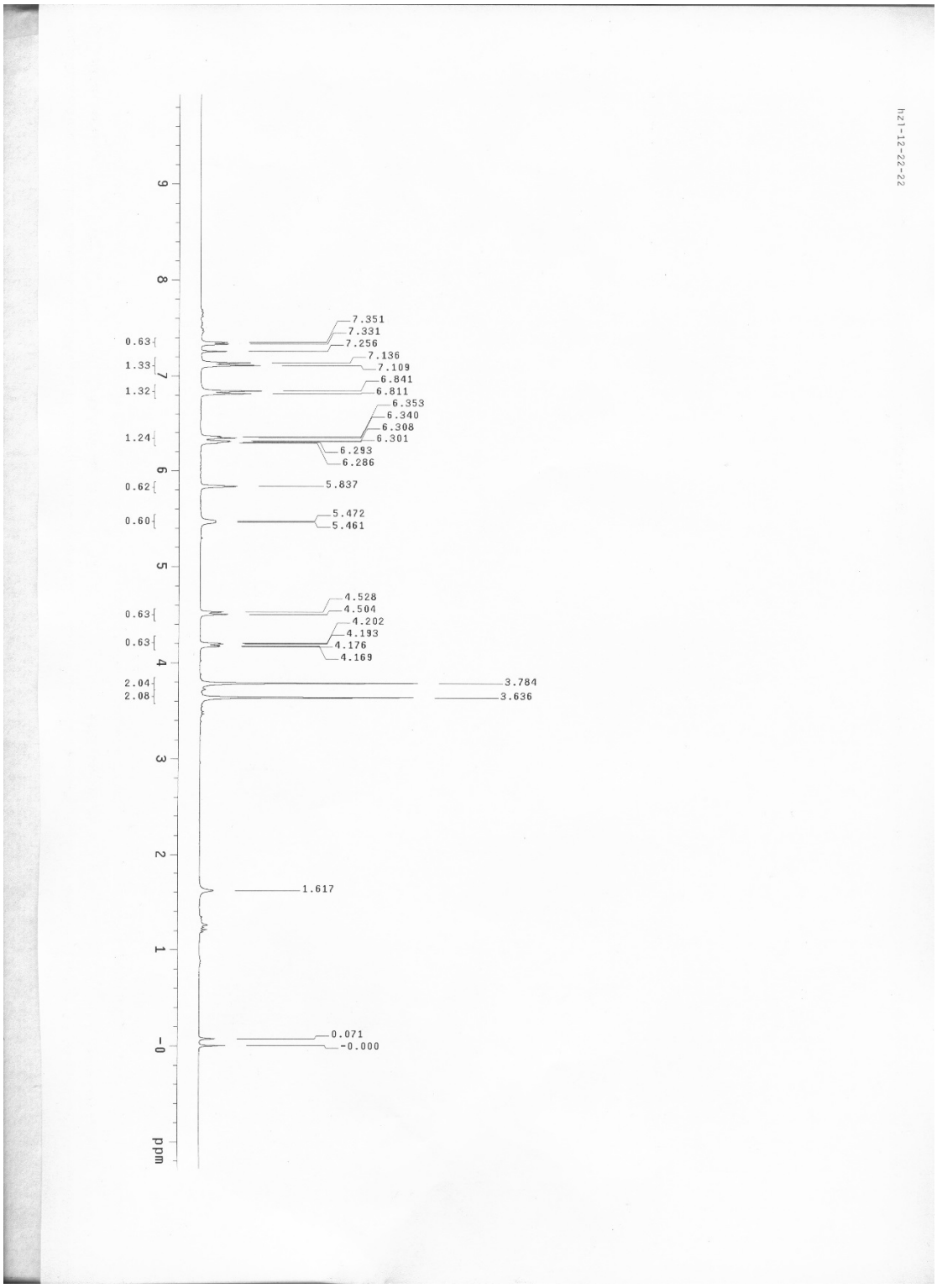
(5c)

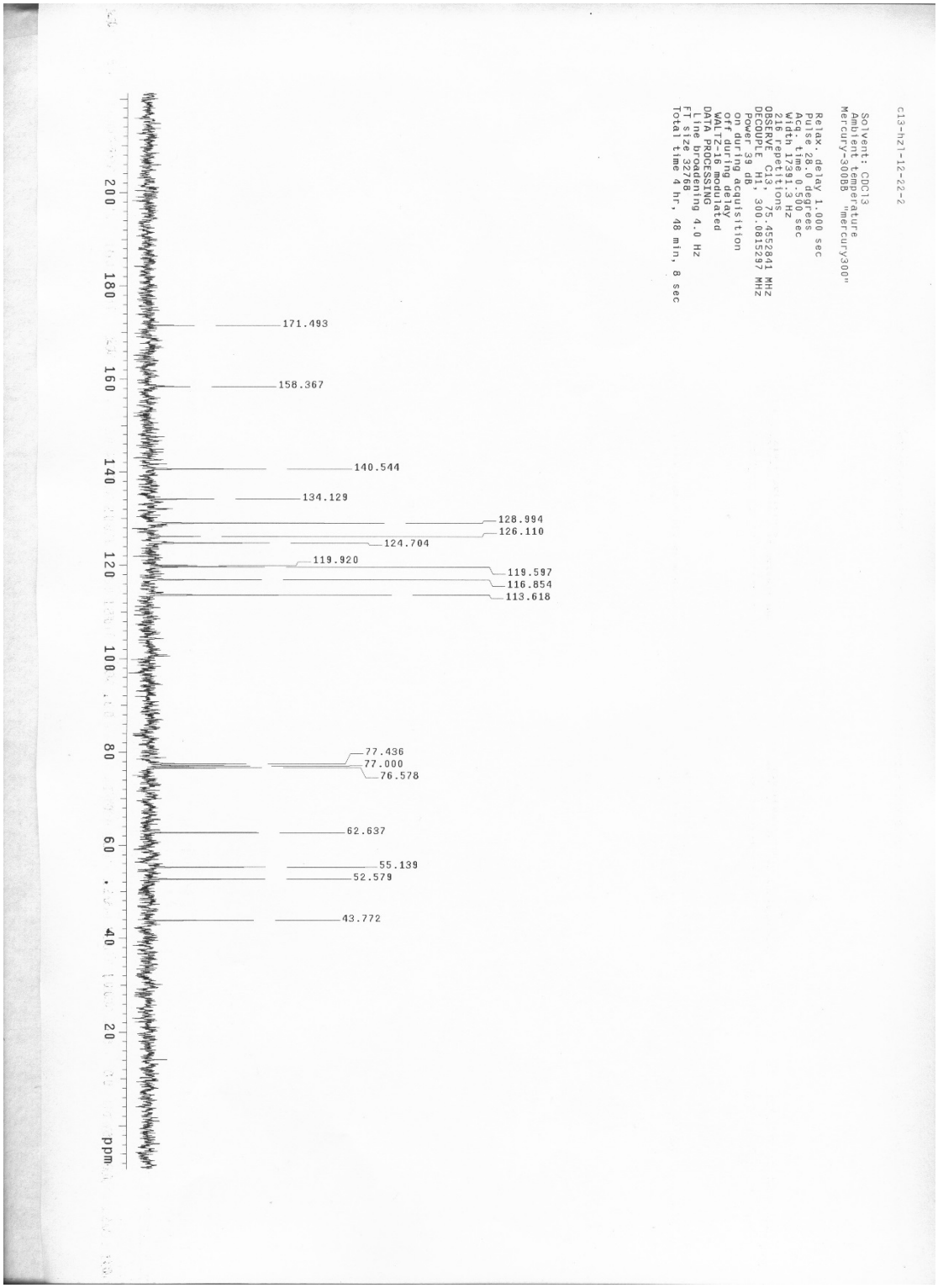

9.33
2.11
2.09
1.02
1.07
1.00
0.83
2.20
1.07
1.06
f1 (ppm)
7.449
7.430
7.408
7.400
7.388
7.336
7.278
7.261
7.020
6.832
6.804
6.362
6.311
6.303
5.953
5.825
5.112
5.098
5.059
4.697
4.680
4.516
4.499
1.572
0.070
0.000

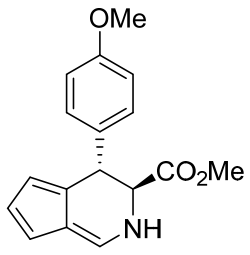

169.312
140.109
132.444
129.223
128.868
128.696
128.276
126.476
125.226
120.002
118.701
116.661
77.421
77.000
76.575
67.624
60.271
42.714
f1 (ppm)


OMe
CO2Me
NH

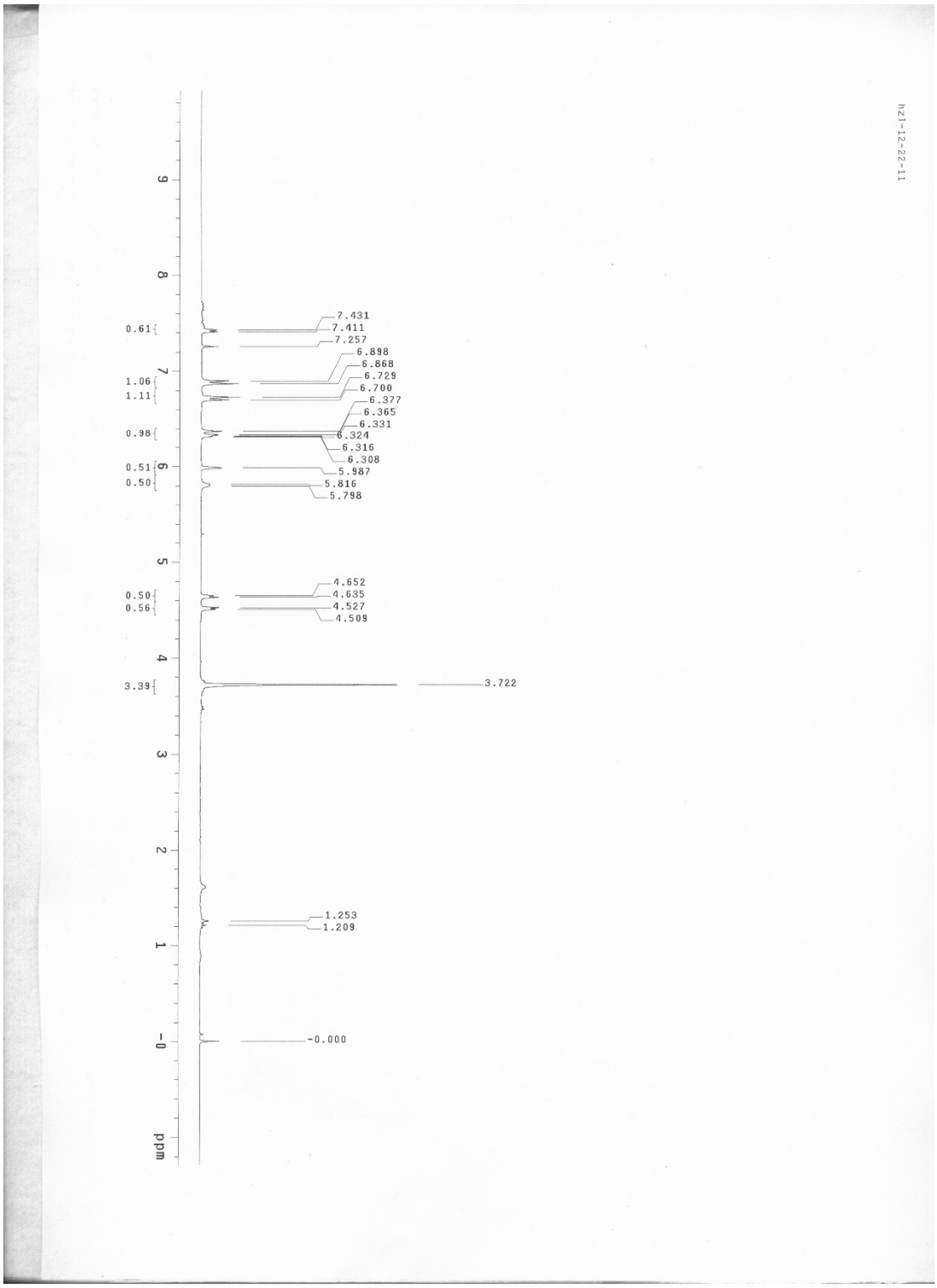
(4d)

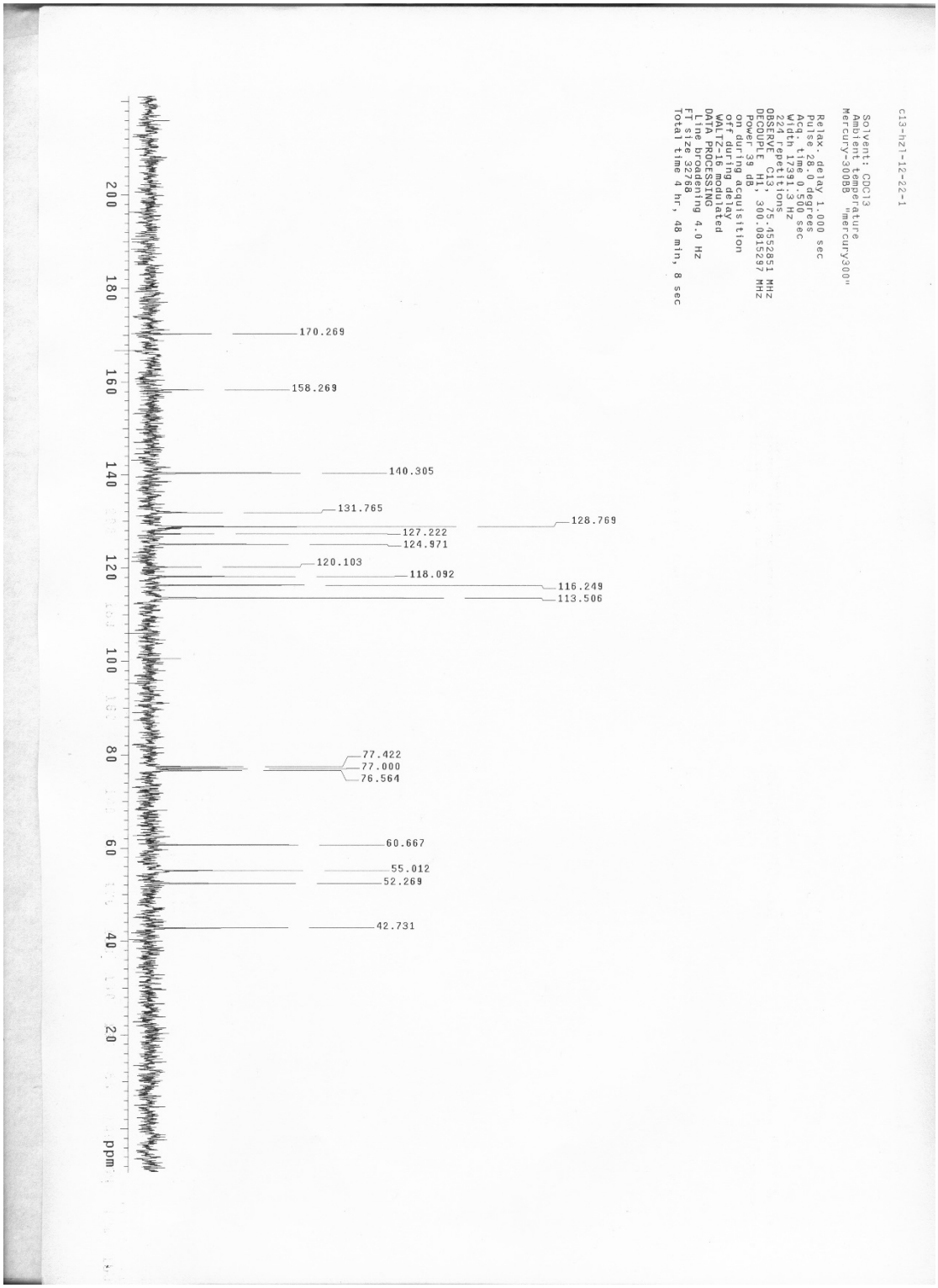

hz1-12-22-2
7.351
7.331
7.256
7.136
7.109
6.841
6.811
6.353
6.340
6.308
6.301
6.293
6.286
5.837
5.472
5.461
4.528
4.504
4.202
4.193
4.176
4.169
3.784
3.636
1.617
0.071
-0.000
0.63
1.33
1.32
1.24
0.62
0.60
0.63
0.63
2.04
2.08
ppm


c13-hzl-12-22-2
Solvent: CDCl3
Ambient temperature
Mercury-300BB "mercury300"
Relax. delay 1.000 sec
Pulse 28.0 degrees
Acq. time 0.500 sec
width 17391.3 Hz
216 repetitions
OBSERVE C13, 75.4552841 MHz
DECOUPLE H1, 300.0815297 MHz
Power 39 dB
on during acquisition
off during delay
WALTZ-16 modulated
DATA PROCESSING
Line broadening 4.0 Hz
FT size 32768
Total time 4 hr, 48 min, 8 sec
171.493
158.367
140.544
134.129
128.994
126.110
124.704
119.920
119.597
116.854
113.618
77.436
77.000
76.578
62.637
55.139
52.579
43.772
200
180
160
140
120
100
80
60
40
20
ppm

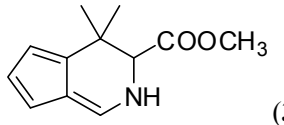

OMe
CO2Me
NH

(5d)


hz1-12-22-11
7.431
7.411
7.257
6.898
6.868
6.729
6.700
6.377
6.365
6.331
6.324
6.316
6.308
5.987
5.816
5.798
4.652
4.635
4.527
4.509
3.722
1.253
1.209
-0.000
0.61
1.06
1.11
0.98
0.51
0.50
0.50
0.56
3.39
ppm


c13-hz1-12-22-1
Solvent: CDCl3
Ambient temperature
Mercury-300BB "mercury300"
Relax. delay 1.000 sec
Pulse 28.0 degrees
Acq. time 0.500 sec
Width 17391.3 Hz
224 repetitions
OBSERVE C13, 75.455851 MHz
DECOUPLE H1, 300.081297 MHz
Power 39 dB
on during acquisition
off during delay
WALTZ-16 modulated
DATA PROCESSING
Line broadening 4.0 Hz
FT size 32768
Total time 4 hr, 48 min, 8 sec
170.269
158.269
140.305
131.765
128.769
127.222
124.971
120.103
118.092
116.249
113.506
77.422
77.000
76.564
60.667
55.012
52.269
42.731
200
180
160
140
120
100
80
60
40
20
ppm

V. HPLC Chromatograms



(3a)

Data File D:\LC\DATA\HZL\HZL-8-79\HZL-8-79-2 2013-04-13 09-39-20\002-0101.D
Sample Name: HZL-8-79

```
    ================================================================
    Acq. Operator   : TMC                          Seq. Line :   1
    Acq. Instrument : Instrument 1                  Location : Vial 2
    Injection Date  : 4/14/2013 12:40:16 AM            Inj :   1
                                                   Inj Volume : 5 µl
    Acq. Method     : D:\LC\DATA\HZL\HZL-8-79\HZL-8-79-2 2013-04-13 09-39-20\ASH-10-90-10ML-
                      220NM.M
    Last changed    : 1/14/2012 6:45:00 AM by HZL
    Analysis Method : D:\LC\DATA\HZL\HZL-8-79\HZL-8-79-2 2013-04-13 09-39-20\002-0101.D\DA.M (
                      ASH-10-90-10ML-220NM.M)
    Last changed    : 10/21/2014 4:32:38 PM by HR
                      (modified after loading)
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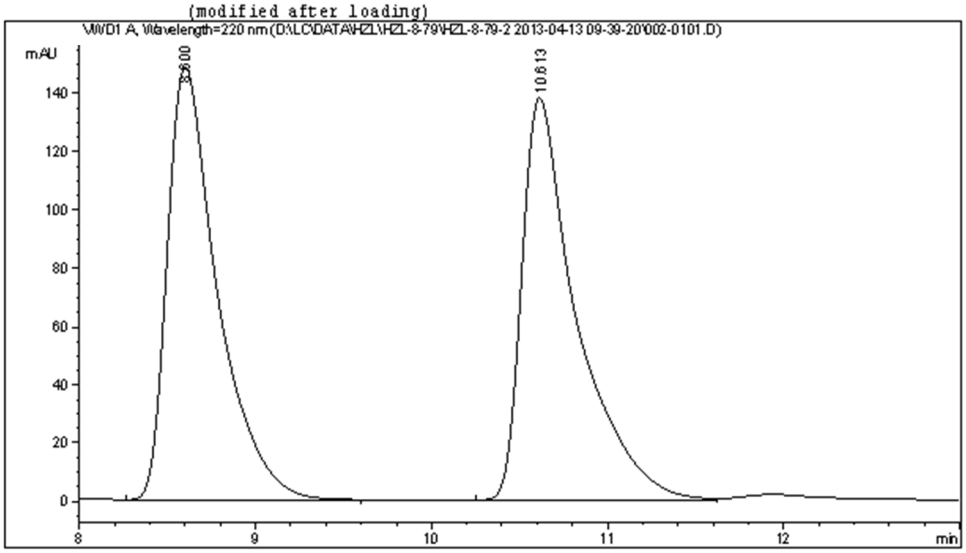


```
    ================================================================
                            Area Percent Report
    ================================================================

    Sorted By             :      Signal
    Multiplier            :      1.0000
    Dilution              :      1.0000
    Use Multiplier & Dilution Factor with ISTDs


    Signal 1: VWD1 A, Wavelength=220 nm

    Peak RetTime Type  Width     Area      Height     Area
      #   [min]        [min]  mAU   *s   [mAU   ]      %
    ----|------|----|------|----------|----------|-------|
       1   8.600 VB    0.2919 2939.99219  148.67641  49.6720
       2  10.613 BV    0.3099 2978.82544  138.08510  50.3280

    Totals :                  5918.81763  286.76151

    ================================================================
```

Instrument 1 10/21/2014 4:32:47 PM HR Page 1 of 1

Data File D:\LC\DATA\HZL\HZL-8-80\HZL-8-80A 2013-04-13 15-55-44\041-0101.D
Sample Name: HZL-8-80A

```
    ====================================================================
    Acq. Operator   : TMC                          Seq. Line :   1
    Acq. Instrument : Instrument 1                  Location : Vial 41
    Injection Date  : 4/14/2013 6:57:01 AM               Inj :   1
                                                   Inj Volume : 5 µl
    Acq. Method     : D:\LC\DATA\HZL\HZL-8-80\HZL-8-80A 2013-04-13 15-55-44\ASH-10-90-10ML-
                      220NM-15MIN.M
    Last changed    : 8/6/2012 2:28:33 AM by THL
    Analysis Method : D:\LC\DATA\HZL\HZL-8-80\HZL-8-80A 2013-04-13 15-55-44\041-0101.D\DA.M (
                      ASH-10-90-10ML-220NM-15MIN.M)
    Last changed    : 10/23/2014 5:07:14 PM by HR
                      (modified after loading)
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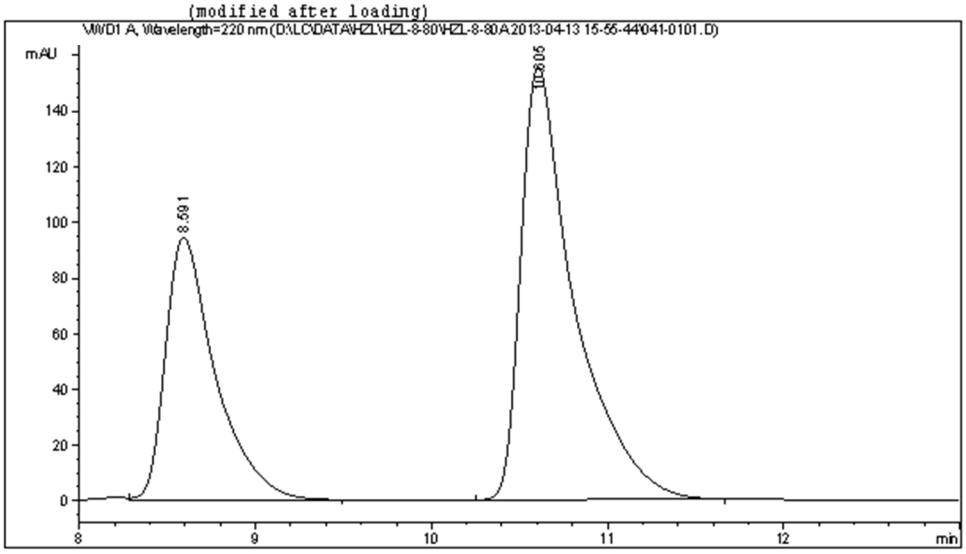


```
    ====================================================================
                            Area Percent Report
    ====================================================================

    Sorted By             :      Signal
    Multiplier            :      1.0000
    Dilution              :      1.0000
    Use Multiplier & Dilution Factor with ISTDs


    Signal 1: VWD1 A, Wavelength=220 nm

    Peak RetTime Type  Width     Area      Height     Area
      #   [min]        [min]  mAU   *s    [mAU   ]      %
    ----|-------|----|-------|----------|----------|--------|
       1   8.591 VB    0.2906 1859.17334   94.54090  36.1726
       2  10.605 BB    0.3029 3280.55444  155.51765  63.8274

    Totals :                  5139.72778  250.05856


    ====================================================================
```