Concise Syntheses of Δ^{12}-Prostaglandin J Natural Products via Stereoretentive Metathesis

Jiaming Li[†], Tonia S. Ahmed[†], Chen Xu[*,†,‡], Brian M. Stoltz[*,†] and Robert H Grubbs[*,†]

[†]*The Arnold and Mabel Beckman Laboratory of Chemical Synthesis, Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125, United States*

[‡]*Shenzhen Grubbs Institute and Department of Chemistry, Southern University of Science and Technology, Shenzhen, Guangdong 518000, China*

Supporting Information:

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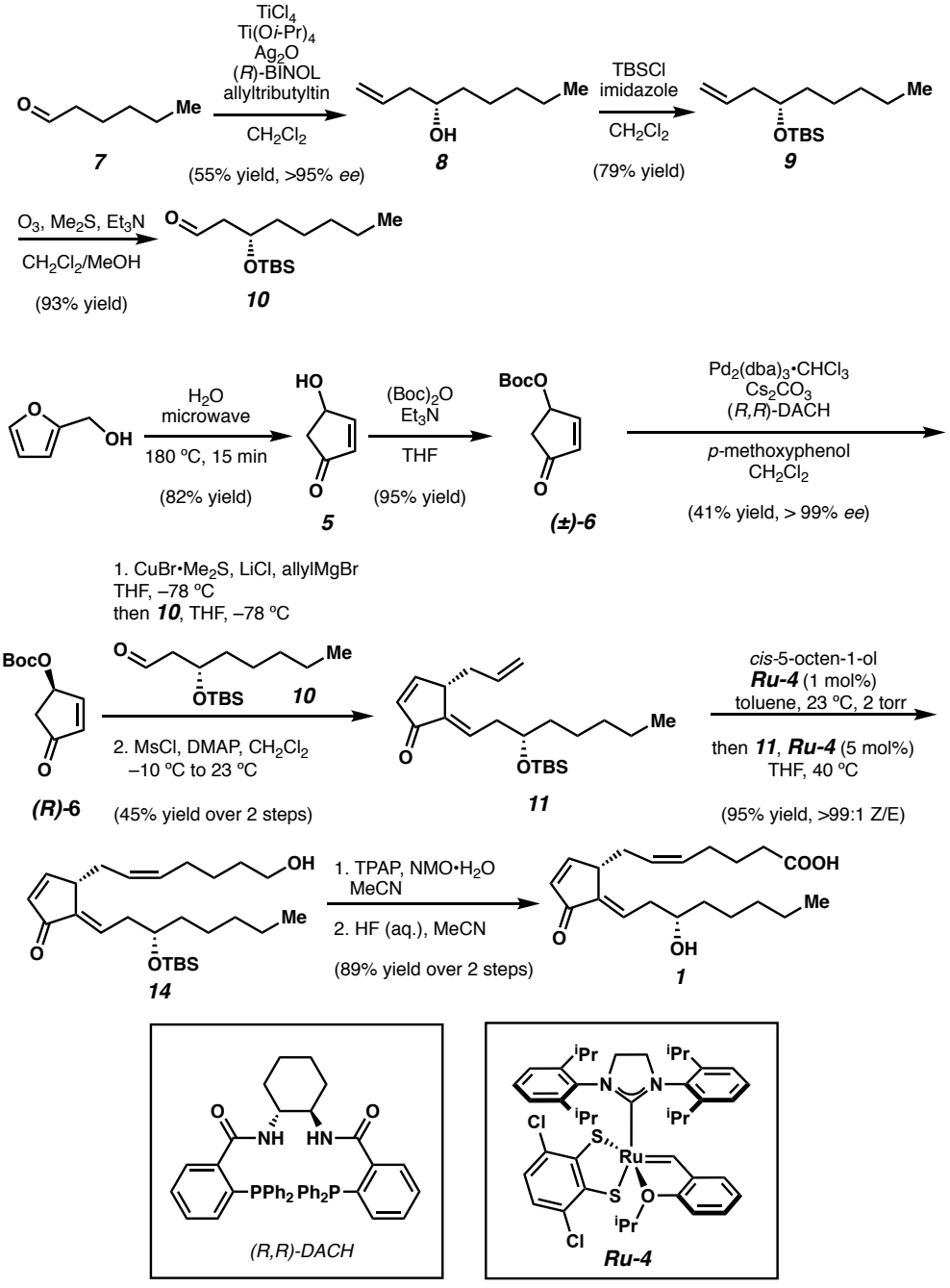
I. Materials and Methods

Unless noted in the specific procedure, reactions were performed in flame-dried glassware under argon atmosphere. All metathesis reactions were carried out under air-free conditions in dry glassware in a Vacuum Atmospheres Glovebox filled with N_2. General solvents were purified by passing through solvent purification columns. Commercially available substrates were used as received. All solvents and substrates were sparged with Ar before bringing into the glovebox and filtered over basic alumina (Brockmann I) prior to use. Reaction progress was monitored by thin-layer chromatography (TLC) using E. Merck silica gel 60 F_{254} precoated plates (0.25 mm) and visualized by UV fluorescence quenching, potassium permanganate, or *p*-anisaldehyde staining. Silicycle Silia*Flash* P60 Academic Silica gel (particle size 0.040-0.063 mm) was used for flash chromatography. Analytical chiral HPLC was performed with an Agilent 1100 Series HPLC utilizing a Chiralcel OD-H column (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd. with visualization at 254 nm. Analytical SFC was performed with a Mettler SFC supercritical CO_2 analytical chromatography system utilizing Chiralcel (IC) column (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd. with visualization at 210 nm. GC conversion data was obtained using an HP-5 capillary column with an Agilent 6850 FID gas chromatograph. ^{1}H and ^{13}C NMR spectra were recorded on a Varian Inova 500 spectrometer (500 MHz and 126 MHz, respectively), a Bruker AV III HD spectrometer equipped with a Prodigy liquid nitrogen temperature cryoprobe (400 MHz and 101 MHz, respectively), or a Varian Mercury 300 spectrometer (300 MHz and 75 MHz, respectively) and are reported in terms of chemical shift relative to residual $CHCl_3$ (δ 7.26 and δ 77.16 ppm, respectively). Data for ^{1}H NMR spectra are reported as follows: chemical shift (δ ppm) (multiplicity, coupling constant (Hz), integration). Abbreviations are used as follows: s = singlet, bs = broad singlet, d = doublet, t = triplet, q = quartet, quint = quintet, m = complex multiplet. Infrared (IR) spectra were recorded on a Perkin Elmer Paragon 1000 spectrometer using neat samples on ATR diamond, and are reported in frequency of absorption (cm^{-1}). High-resolution mass spectra HRMS were acquired from the Caltech Mass Spectral Facility using fast-atom bombardment (FAB+), electrospray ionization (TOF ES+) or electron impact (EI+). Optical rotations were measured on a Jasco P-2000 polarimeter using a 100 mm path-length cell at 589 nm.

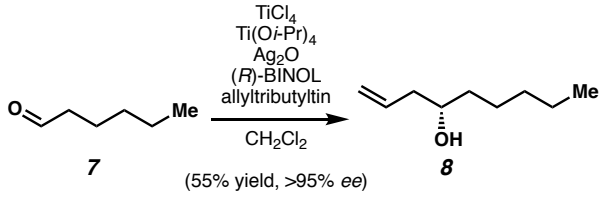
II. Experimental Procedures and Characterization Data

1. Synthesis of Δ^{12}-prostaglandin J_2 (1):

Synthetic route:



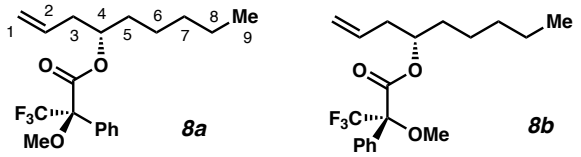
Preparation of (*S*)-non-1-en-4-ol (8):



Following the procedure by Yadav and co-workers[1], to a stirred solution of $TiCl_4$ (1.0 M solution in CH_2Cl_2, 2.5 mL, 2.5 mmol) in CH_2Cl_2 (50 mL) was added dried Ti(O*i*-Pr)$_4$ (2.24 mL,7.5 mmol) at 0 °C under argon. The solution was warmed to 23 ºC and stirred for 1 h, then Ag_2O (1.15 g, 5.0 mmol) was added, and the mixture was stirred for 5 h with the exclusion of direct light by aluminum foil. The reaction mixture was diluted with CH_2Cl_2 (80 mL) and (*R*)-binaphthol (2.86 g, 10 mmol) was added at 23 ºC. After 2 h, the reaction mixture was cooled to –15 °C and hexanal (5.0 g, 50 mmol) and allyltributyltin (17 mL, 55 mmol) was added sequentially, then the reaction mixture was warmed to 0 °C. After 8 h, saturated $NaHCO_3$ (50 mL) was added. The aqueous phase was extracted with diethyl ether (2 × 250 mL). The combined organic phases were washed with brine (1 × 200 mL), dried with anhydrous magnesium sulfate, filtered and concentrated under reduced pressure. Purification by flash column chromatography on silica gel (SiO_2, 15:1 hexanes/EtOAc) afforded compound **8** as a colorless oil (3.94 g, 55% yield, > 95% *ee* by Mosher-ester analysis).

TLC (10:1 hexanes/EtOAc): R_f= 0.22 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 5.81 (dddd, *J* = 17.6, 9.4, 7.8, 6.5 Hz, 1H), 5.17 – 5.03 (m, 2H), 3.62 (dtd, *J* = 8.0, 4.0, 2.4 Hz, 1H), 2.28 (dddt, *J* = 13.7, 6.8, 4.3, 1.3 Hz, 1H), 2.18 – 2.05 (m, 1H), 1.74 (d, *J* = 3.6 Hz, 1H), 1.50 – 1.35 (m, 3H), 1.35 – 1.21 (m, 5H), 0.87 (t, *J* = 6.8 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 135.1, 118.1, 70.8, 42.0, 36.9, 32.0, 25.5, 22.7, 14.1.
FTIR (ATR): 3355, 3077, 2956, 2929, 2859, 1641, 1467, 1435, 1378, 1124, 1027, 994, 911, 865, 725 cm^{-1}.
HRMS (EI+, m/z): calc'd for $C_9H_{18}O$ $[M]^+$ 142.1352, found: 142.1372.
$[\alpha]_D^{23}$: –7.2° (c = 1.0, $CHCl_3$).

Mosher-ester analysis of **8**:



To a stirred solution of **8** (21 mg, 0.15 mmol, 1.0 equiv) in CH_2Cl_2 (1.5 mL) in a 4 mL vial was added pyridine (0.1 mL, 1.24 mmol, 8.0 equiv) and *(S)*-(+)-Mosher chloride (100 mg, 0.40 mmol, 2.7 equiv) at 25 °C. After stirring for 2 h at the same temperature, the reaction mixture was diluted with CH_2Cl_2 (3 mL) and saturated NH_4Cl solution (3 mL) was added. The phases were separated, and the aqueous layer was extracted with CH_2Cl_2 (2 × 5 mL). The combined organic extracts were concentrated after drying over magnesium sulfate. (*R*)-MTPA ester **8a** was

obtained through column chromatography (SiO_2, 20:1 hexanes/EtOAc) as a colorless oil (50 mg, 94 %).

Compound **8b** was prepared in the same manner and on the same scale as above using *(R)*-(−)-Mosher chloride. (*S*)-MTPA ester **8b** was obtained through column chromatography (SiO_2, hexanes/EtOAc, 20:1) as a colorless oil (51 mg, 96 %).

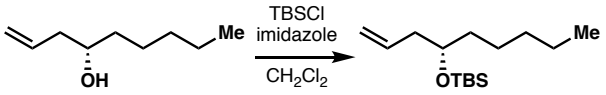
(*R*)-MTPA ester **8a**:
TLC (10:1 hexanes/EtOAc): R_f= 0.57 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57 – 7.50 (m, 2H), 7.43 – 7.31 (m, 3H), 5.73 – 5.56 (m, 1H), 5.14 (dq, *J* = 7.2, 5.7 Hz, 1H), 5.06 – 4.98 (m, 2H), 3.55 (q, *J* = 1.3 Hz, 3H), 2.35 (dddd, *J* = 6.2, 5.0, 2.5, 1.3 Hz, 2H), 1.71 – 1.54 (m, 2H), 1.39 – 1.22 (m, 6H), 0.88 (t, *J* = 6.9 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 166.4, 133.0, 132.5, 129.7, 128.4, 127.6, 123.5 (q, *J* = 288.6 Hz), 118.4, 84.7 (q, *J* = 27.5 Hz), 76.7, 55.6, 38.2, 33.4, 31.6, 25.0, 22.6, 14.1.
^{19}F NMR (282 MHz, $CDCl_3$): δ –71.3.
FTIR (ATR): 2955, 2934, 2861, 1743, 1643, 1612, 1506, 1451, 1258, 1166, 1121, 1081, 1020, 993, 912, 823, 764, 732, 716, 696, 648 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{19}H_{26}O_3F_3$ $[M+H]^+$ 359.1829, found: 359.1839.

(*S*)-MTPA ester **8b**:
TLC (10:1 hexanes/EtOAc): R_f= 0.57 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58 – 7.52 (m, 2H), 7.43 – 7.34 (m, 3H), 5.76 (ddt, *J* = 16.1, 10.4, 7.0 Hz, 1H), 5.16 (dt, *J* = 10.8, 5.2 Hz, 1H), 5.13 – 5.08 (m, 2H), 3.56 (q, *J* = 1.3 Hz, 3H), 2.42 (ddt, *J* = 7.3, 6.1, 1.3 Hz, 2H), 1.65 – 1.49 (m, 2H), 1.27 – 1.10 (m, 6H), 0.84 (t, *J* = 6.9 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 166.4, 133.4, 132.6, 129.6, 128.4, 127.5, 123.5 (q, *J* = 288.6 Hz), 118.5, 84.6 (q, *J* = 27.5 Hz), 76.7, 55.7, 38.5, 33.3, 31.6, 24.6, 22.6, 14.1.
^{19}F NMR (282 MHz, $CDCl_3$): δ –71.3.
FTIR (ATR): 2960, 2934, 2861, 1742, 1643, 1498, 1451, 1257, 1167, 1121, 1081, 1019, 992, 912, 824, 764, 732, 717, 696, 648 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{19}H_{26}O_3F_3$ $[M+H]^+$ 359.1829, found: 359.1845.

Table S1. Comparison of ^{1}H NMR data for (*R*)- and (*S*)-MTPA esters

Proton	*(S)*-MTPA ester 5b	*(R)*-MTPA ester 5a	Δδ: *(S)-(R)*
1	5.01	5.11	0.1
2	5.64	5.76	0.12
3	2.35	2.42	0.07
4	5.14	5.16	0.02
5	1.62	1.57	–0.05
6-8	1.28	1.20	–0.08
9	0.88	0.84	–0.04

Preparation of 9:

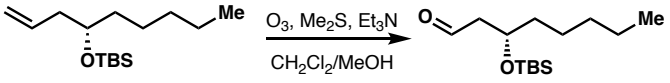


8 (79% yield) ***9***

To a stirred solution of **8** (2.0 g, 14 mmol) in CH_2Cl_2 (60 mL) was added imidazole (2.86 g, 42 mmol, 3.0 equiv) and TBSCl (4.22 g, 28 mmol, 2.0 equiv). Saturated NH_4Cl solution (50 mL) was added after stirring overnight. The aqueous layer was extracted with CH_2Cl_2 (2 × 30 mL) and the combined organic phases were dried over anhydrous magnesium sulfate, filtered and concentrated under reduced pressure. Column chromatography (SiO_2, 20:1 hexanes/EtOAc) gave **9** as a colorless oil (2.85 g, 79% yield).

TLC (10:1 hexanes/EtOAc): R_f= 0.85 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 5.82 (ddt, *J* = 17.5, 10.4, 7.1 Hz, 1H), 5.08 – 4.99 (m, 2H), 3.68 (quint, *J* = 5.7 Hz, 1H), 2.21 (dddt, *J* = 6.8, 5.3, 3.9, 1.3 Hz, 2H), 1.48 – 1.22 (m, 8H), 0.94 – 0.85 (m, 12H), 0.05 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 135.7, 116.7, 72.2, 42.1, 37.0, 32.2, 26.1, 25.2, 22.8, 18.3, 14.2, –4.2, –4.4.
FTIR (ATR): 2956, 2929, 2857, 1641, 1472, 1463, 1361, 1255, 1127, 1049, 1005, 939, 910, 834, 807, 772, 664 cm^{-1}.
HRMS (EI+, m/z): calc'd for $C_{15}H_{31}OSi$ $[M+H–H_2]^+$ 255.2138, found: 255.2174.
$[\boldsymbol{\alpha}]_{\boldsymbol{D}}^{\boldsymbol{23}}$: –15.7° (c = 1.0, $CHCl_3$).

Preparation of aldehyde 10:

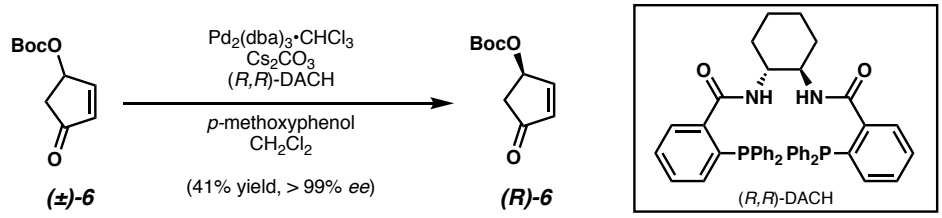


9 (93% yield) ***10***

To a stirred solution of **9** (1.6 g, 6.25 mmol) in CH_2Cl_2 (30 mL) and MeOH (30 mL) was bubbled with O_3 through a gas dispersion tube. When the color of the solution turned blue, dimethyl sulfide (13.2 mL) and triethylamine (1.2 mL) was added. The solution was stirred overnight and was concentrated under reduced pressure. Column chromatography (SiO_2, 20:1 hexenes/EtOAc) afforded **10** as a colorless oil (1.5 g, 93%)

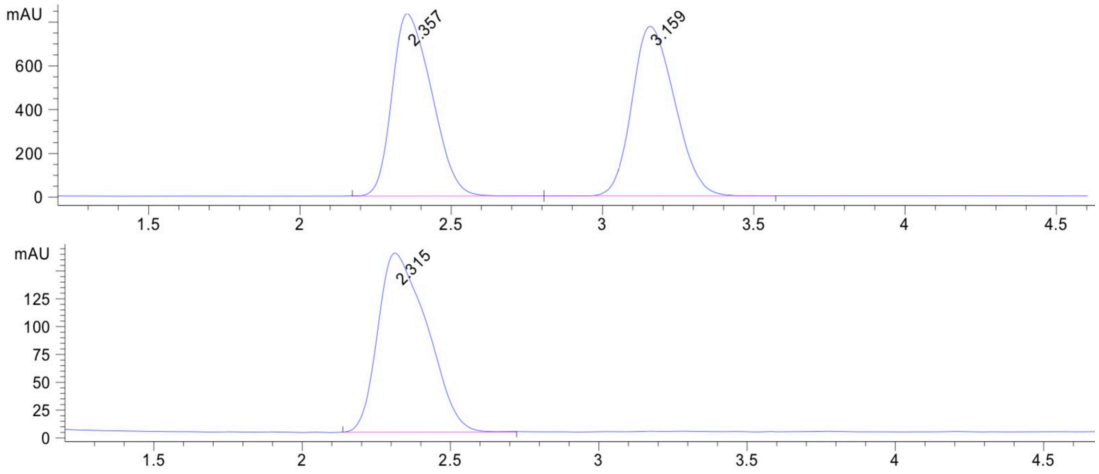
TLC (4:1 hexanes/EtOAc): R_f= 0.77 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.81 (td, *J* = 2.6, 0.7 Hz, 1H), 4.17 (quint, *J* = 5.8 Hz, 1H), 2.51 (ddd, *J* = 5.7, 2.6, 0.7 Hz, 2H), 1.56 – 1.41 (m, 2H), 1.37 – 1.22 (m, 6H), 0.96 – 0.83 (m, 12H), 0.07 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 202.7, 68.4, 51.0, 38.0, 31.9, 25.9, 25.0, 22.7, 18.1, 14.2, –4.3, –4.5.
FTIR (ATR): 2956, 2929, 2857, 1713, 1472, 1361, 1253, 1096, 1050, 1005, 939, 834, 810, 774 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{14}H_{31}O_2Si$ $[M+H]^+$ 259.2088, found: 259.2088.
$[\boldsymbol{\alpha}]_{\boldsymbol{D}}^{\boldsymbol{23}}$: –3.0° (c = 1.0, $CHCl_3$).

Preparation of enone *(R)*-6:



Under argon atmosphere, a 500 mL flask was charged with **(±)-6** (prepared through procedures by Reiser and co-workers[2]) (5.02 g, 25.4 mmol, 2.0 equiv) in CH_2Cl_2 (100 mL), *p*-methoxyphenol (1.57 g, 12.7 mmol, 1.0 equiv) and Cs_2CO_3 (1.22 g, 3.75 mmol, 0.296 equiv) was added and the solution was cooled to 0 ºC. In another 100 mL flask, $Pd_2(dba)_3$•$CHCl_3$ (131 mg, 0.127 mmol, 0.01 equiv) and ligand (*R,R*)-DACH (306 mg, 0.44 mmol, 0.035 equiv) in CH_2Cl_2 (50 mL) was stirred until the initially purple solution turned yellow brown (4–5 min), and the catalyst solution was transferred to the 500 mL flask through a cannula. The solvent was removed under reduced pressure after 2.5 h stirring at 0 ºC. The residue was purified by flash chromatography (hexanes/EtOAc 9:1 to 6:1) to give ***(R)*-6** (2.06 g, 41%, > 99% *ee* confirmed by chiral SFC analysis).

TLC (4:1 hexanes/EtOAc): R_f= 0.4 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59 (dd, *J* = 5.7, 2.4 Hz, 1H), 6.32 (dd, *J* = 5.7, 1.3 Hz, 1H), 5.70 (dtd, *J* = 6.2, 2.3, 1.3 Hz, 1H), 2.82 (dd, *J* = 18.7, 6.4 Hz, 1H), 2.39 (dd, *J* = 18.7, 2.3 Hz, 1H), 1.49 (s, 9H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 204.7, 158.7, 152.8, 137.2, 83.4, 74.3, 41.1, 27.8.
FTIR (ATR): 2981, 2937, 1722, 1591, 1475, 1459, 1395, 1369, 1334, 1272, 1253, 1152, 1104, 994, 840, 791 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{10}H_{15}O_4$ $[M+H]^+$ 199.0965, found: 199.0986.
$[\alpha]_D^{23}$: +78.7° (c = 1.0, $CHCl_3$).
SFC Conditions: 3% IPA, 4.0 mL/min, Chiralcel IC column, λ = 210 nm, t_R (min): major = 2.36, minor = 3.16



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
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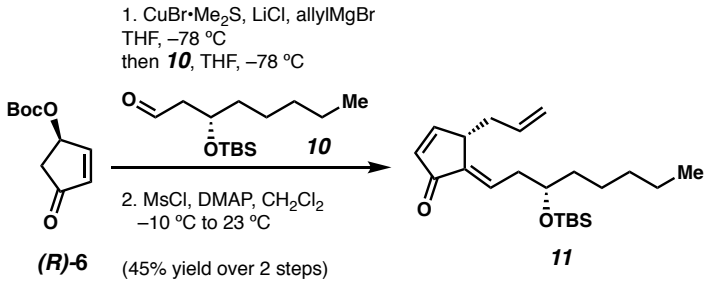
Preparation of 11:

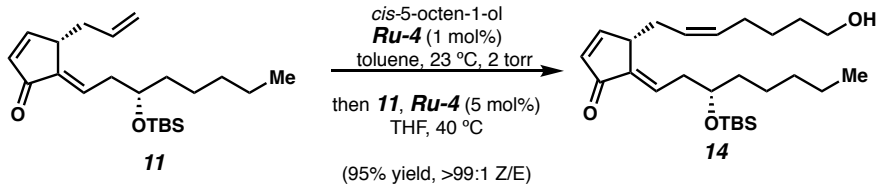


A 25 mL flask was flame dried and charged with CuBr•Me_2S (144 mg, 0.70 mmol, 2.8 equiv) and LiCl (32 mg, 0.75 mmol, 3.0 equiv) in a nitrogen-filled glove box. The flask was sealed with septum and brought out of glove box, and was heated under vacuum to remove residue water. Anhydrous THF (5 mL) was added, and the solution was vigorously stirred for 10 minutes at 23 ºC until a yellow solution was formed. At –78 ºC, allylmagnesium bromide (0.68 mL, 1.0 M solution in THF, 0.68 mmol, 2.7 equiv) was added slowly. The reaction mixture was stirred at –78 ºC for 1 hour and a solution of ***(R)*-6** (149 mg, 0.75 mmol, 3.0 equiv) in THF (1 mL) was added slowly. After 30 minutes stirring at the same temperature, a solution of **10** (65 mg, 0.25 mmol, 1.0 equiv) in THF (1 mL) was added slowly. The reaction was stirred for additional 2 hours at –78ºC before a solution of saturated NH_4Cl and $NH_3•H_2O$ (10 mL, 9:1 $NH_4Cl/NH_3•H_2O$) was added. The biphasic solution was vigorously stirred until a homogeneous dark blue solution was formed in aqueous phase. The phases were separated and the organic phase was washed with 10 mL saturated NH_4Cl solution. The combined aqueous phase was extracted with Et_2O (2 × 30 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 18:1) to give a mixture of diasteromers of the aldol product (82 mg, 0.22 mmol).

In a 25 mL flask, the crude aldol product was dissolved in CH_2Cl_2 (6 mL) and cooled to –10 ºC. DMAP (403 mg, 3.3 mmol, 15.0 equiv) and MsCl (51 μL, 0.66 mmol, 3.0 equiv) were added sequentially. The reaction mixture was slowly warmed to 23 ºC and was stirred for 12 h before diluted with 10 mL EtOAc and washed with 1 M HCl (10 mL). The aqueous phase was extracted with EtOAc (2 × 20 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (hexanes/EtOAc 15:1) to give **11** (41 mg, 45% yield over 2 steps) as colorless liquid.

TLC (9:1 hexanes/EtOAc): R_f = 0.25 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.60 (ddt, *J* = 8.3, 7.0, 1.3 Hz, 1H), 6.33 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.79 – 5.65 (m, 1H), 5.11 – 5.01 (m, 2H), 3.83 (quint, *J* = 5.8 Hz, 1H), 3.50 (ddq, *J* = 8.4, 4.0, 2.0 Hz, 1H), 2.72 – 2.61 (m, 1H), 2.51 – 2.31 (m, 2H), 2.18 (dddt, *J* = 14.3, 9.0, 7.9, 1.1 Hz, 1H), 1.53 – 1.11 (m, 8H), 0.96 – 0.79 (m, 12H), 0.05 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 196.5, 161.4, 138.5, 135.1, 134.3, 132.8, 117.8, 71.7, 43.1, 37.4, 37.1, 32.0, 26.0, 25.1, 22.8, 18.2, 14.2, –4.2, –4.5.
FTIR (ATR): 2955, 2928, 2856, 1705, 1656, 1582, 1472, 1360, 1252, 1207, 1127, 1050, 1005, 915, 863, 834, 806, 773, 726, 663 cm^{-1}.
HRMS (TOF, ES+, m/z): calc'd for $C_{22}H_{39}O_2Si$ $[M+H]^+$ 363.2714, found: 363.2711.
$[\alpha]_D^{23}$: +85.3° (c = 1.0, $CHCl_3$).

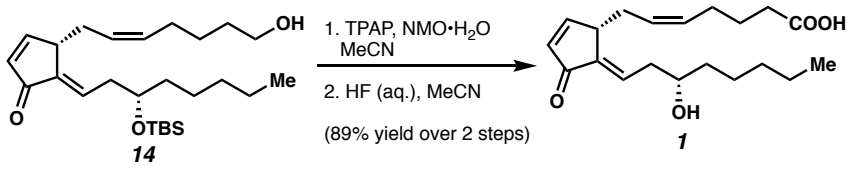
Preparation of 14:



In a nitrogen-filled glovebox, *cis*-5-octen-1-ol (150 mg, 1.17 mmol, 8.0 equiv) was dissolved in toluene (2 mL) in a 50 mL Schlenk flask, and a solution of catalyst **Ru-4** (9.9 mg, 11.7 μmol, 1 mol%) in THF (0.7 mL) was added. The Schlenk flask was sealed and brought out of the glovebox, and then connected to high vacuum. The valve was gradually opened (*Caution: open slowly and stir well to avoid splashing*). After 15 minutes stirring, the flask was refilled with argon and sealed, and was brought back into the glovebox. The residue was diluted with THF (0.5 mL), and an aliquot was taken for GC analysis (conversion of homodimerization step was >98% by GC analysis). A solution of **11** (53 mg, 0.146 mmol, 1.0 equiv) in THF (0.5 mL) was added into the Schlenk flask and an additional portion of catalyst **Ru-4** (6.2 mg, 7.3 μmol, 5 mol%) solution in THF (0.3 mL) was added. The Schlenk flask was sealed and brought out of glovebox. The reaction was stirred for 24 h at 40 ºC before a few drops of ethyl vinyl ether were added. The solvent was removed under reduced pressure. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 2:1) to give **14** (60 mg, 95%, >99:1 *Z/E*).

TLC (3:1 hexanes/EtOAc): R_f= 0.23 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.59 (ddt, *J* = 8.3, 7.0, 1.3 Hz, 1H), 6.33 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.49 (dddt, *J* = 8.6, 7.2, 5.5, 1.5 Hz, 1H), 5.35 (dtt, *J* = 11.0, 8.4, 1.6 Hz, 1H), 3.84 (quint, *J* = 5.9 Hz, 1H), 3.63 (t, *J* = 6.5 Hz, 2H), 3.46 (ddt, *J* = 11.0, 4.2, 2.2 Hz, 1H), 2.63 (dddd, *J* = 13.8, 6.5, 4.2, 1.5 Hz, 1H), 2.50 – 2.34 (m, 2H), 2.17 (dddd, *J* = 14.5, 9.4, 8.0, 1.3 Hz, 1H), 2.07 – 1.97 (m, 2H), 1.60 – 1.51 (m, 2H), 1.47 – 1.34 (m, 6H), 1.32 – 1.19 (m, 5H), 0.95 – 0.81 (m, 12H), 0.05 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 196.5, 161.8, 138.8, 135.0, 132.7, 132.5, 125.4, 71.7, 62.9, 43.6, 37.5, 37.5, 32.5, 32.0, 30.7, 27.2, 26.0, 25.8, 25.1, 22.8, 18.2, 14.2, –4.2, –4.5.
FTIR (ATR): 3443, 2956, 2928, 2856, 1703, 1652, 1580, 1472, 1360, 1251, 1206, 1127, 1048, 1005, 975, 866, 834, 806, 773, 726, 664 cm^{-1}.
HRMS (TOF, ES+, m/z): calc'd for $C_{26}H_{47}O_3Si$ $[M+H]^+$ 435.3289, found: 435.3298.
$[\alpha]_D^{23}$**:** +83.5° (c = 1.0, $CHCl_3$).

Preparation of Δ^{12}-prostaglandin J_2 (1):



To a stirred solution of **14** (26 mg, 0.06 mmol, 1.0 equiv) in MeCN (0.3 mL) was added NMO•H_2O (81 mg, 6 mmol, 10.0 equiv). Tetrapropylammonium perruthenate (2.1 mg, 6 μmol, 0.1 equiv) was added until NMO•H_2O was fully dissolved, and the reaction was stirred at 23 ºC for 3 hours. The solution was diluted with Et_2O (5 mL), passed through a short pad of silica gel, concentrated and was subjected to the next reaction without further purification.

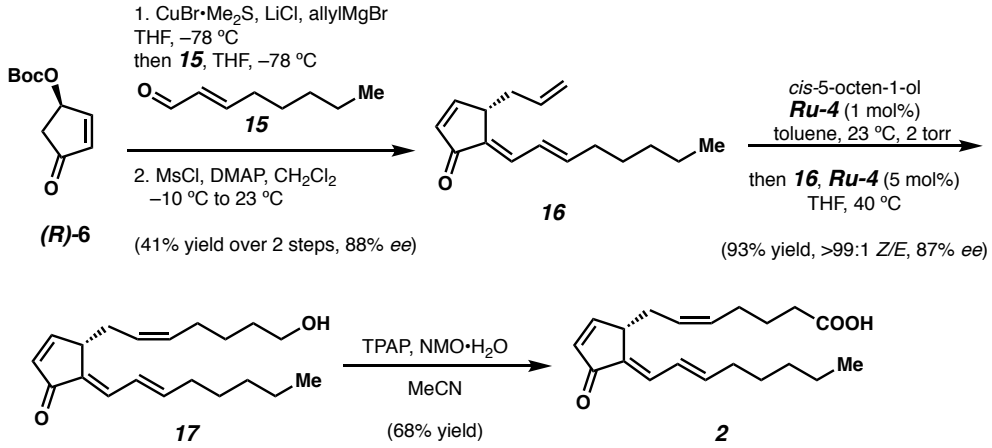
The residue was dissolved in MeCN (1.0 mL) and cooled to 0 ºC. A solution of hydrofluoric acid (48 wt. % in H_2O, 0.2 mL) in MeCN (0.4 mL) was added dropwisely. The solution was stirred in the same temperature for 30 min before saturated $NaHCO_3$ solution (1.5 mL) and brine (1.5 mL) were added. The aqueous phase was extracted with EtOAc (5 × 5 mL). The combined organic phases were dried over magnesium sulfate, filtered and concentrated (*not to dryness*). The residue was purified by flash chromatography (SiO_2, CH_2Cl_2/MeOH 20:1) to give **1** (18 mg, 89% over 2 steps) as a colorless liquid.

TLC (20:1 CH_2Cl_2/MeOH): R_f= 0.14 (UV).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.57 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.58 (ddt, *J* = 8.4, 7.2, 1.3 Hz, 1H), 6.36 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.54 – 5.38 (m, 2H), 3.86 (dtt, *J* = 7.9, 6.4, 4.0 Hz, 1H), 3.47 (ddt, *J* = 9.5, 4.0, 2.1 Hz, 1H), 2.78 – 2.68 (m, 1H), 2.57 (dt, *J* = 14.8, 6.8 Hz, 1H), 2.52 – 2.42 (m, 1H), 2.40 – 2.33 (m, 2H), 2.20 – 2.02 (m, 3H), 1.77 – 1.64 (m, 2H), 1.61 – 1.41 (m, 3H), 1.40 – 1.24 (m, 5H), 0.90 (t, *J* = 6.8 Hz, 3H).
^{13}C NMR (126 MHz, $CDCl_3$): δ 196.6, 177.3, 162.0, 139.8, 135.0, 131.8, 131.7, 126.2, 71.5, 43.9, 37.3, 36.7, 33.1, 31.9, 30.6, 26.6, 25.4, 24.6, 22.8, 14.2.
FTIR (ATR): 3445, 2960, 2929, 2858, 1699, 1646, 1579, 1463, 1406, 1265, 1237, 1135, 1084, 1033, 842, 810, 734, 702 cm^{-1}.
HRMS (TOF, ES+, m/z): calc'd for $C_{20}H_{31}O_4$ $[M+H]^+$ 335.2217, found: 335.2223.
$[\alpha]_D^{23}$: +99.5° (c = 0.2, $CHCl_3$).

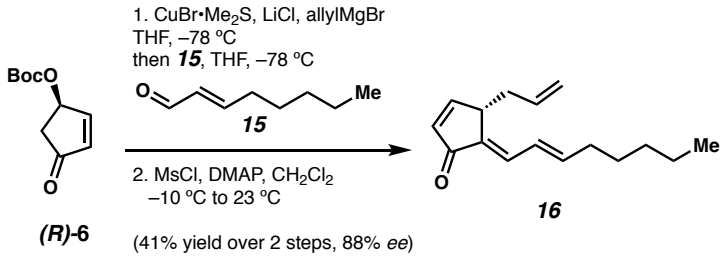
Spectral data (^{1}H NMR, ^{13}C NMR, HRMS) matched with the published data.[3]

2. Synthesis of 15-deoxy-$\Delta^{12,14}$-prostaglandin J_2 (2):

Synthetic route:



Preparation of 16:

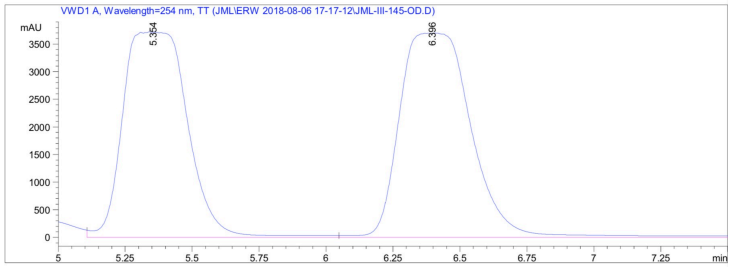


A 25 mL flask was flame dried and charged with CuBr•Me_2S (195 mg, 0.95 mmol, 3.0 equiv) and LiCl (42 mg, 1 mmol, 3.2 equiv) in a nitrogen-filled glove box. The flask was sealed with septum and brought out of glove box, and was heated under vacuum to remove residue water. Anhydrous THF (10 mL) was added, and the solution was vigorously stirred for 10 minute at 23 ºC until a yellow homogeneous solution was formed. At –78ºC, allylmagnesium bromide (0.9 mL, 1.0 M solution in THF, 0.9 mmol, 2.8 equiv) was added slowly. The reaction mixture was stirred at –78 ºC for 1 hour and a solution of ***(R)*-6** (188 mg, 0.95 mmol, 3.0 equiv) in THF (1 mL) was added slowly. After 30 minutes stirring at the same temperature, a solution of *trans*-2-octenal (**15**, 40 mg, 0.32 mmol, 1.0 equiv) in THF (1 mL) was added slowly. The reaction was stirred for additional 2 hours at –78 ºC before a solution of saturated NH_4Cl and NH_3•H_2O (10 mL, 9:1 NH_4Cl/NH_3•H_2O) was added. The biphasic solution was vigorously stirred until a homogeneous dark blue solution was formed in aqueous phase. The phases were separated and the organic phase was washed with 10 mL saturated NH_4Cl solution. The combined aqueous phase was extracted with Et_2O (2 × 30 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 15:1) to give a mixture of diasteromers of the aldol products (57 mg, 0.23 mmol).

In a 25 mL flask, the crude aldol product was dissolved in CH_2Cl_2 (6 mL) and cooled to –10 ºC. DMAP (421 mg, 3.45 mmol, 15.0 equiv) and MsCl (53 μL, 0.69 mmol, 3.0 equiv) was added sequentially. The reaction mixture was slowly warmed to 23 ºC and was stirred for 2 h before

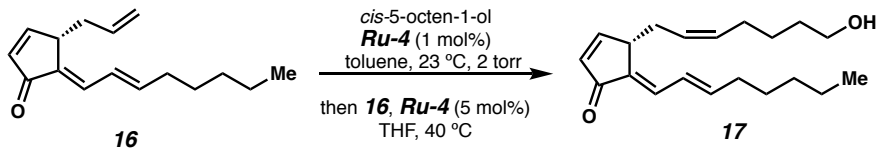
diluted with 10 mL EtOAc and washed with 1 M HCl (10 mL). The aqueous phase was extracted with EtOAc (2 × 20 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 15:1) to give **16** (30 mg, 41% yield over 2 steps, 88% *ee* by chiral HPLC analysis) as a colorless liquid.

TLC (4:1 hexanes/EtOAc): R_f= 0.56 (UV).
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.50 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.95 (dt, *J* = 10.7, 1.2 Hz, 1H), 6.35 (dd, *J* = 6.0, 1.8 Hz, 1H), 6.33 – 6.15 (m, 2H), 5.81 – 5.64 (m, 1H), 5.11 – 5.01 (m, 2H), 3.60 (ddq, *J* = 8.5, 4.1, 1.9 Hz, 1H), 2.73 – 2.58 (m, 1H), 2.24 (dddd, *J* = 13.4, 9.7, 6.8, 1.5 Hz, 3H), 1.54 – 1.37 (m, 2H), 1.38 – 1.22 (m, 4H), 0.89 (t, 3H, *J* = 6.9 Hz).
^{13}C NMR (75 MHz, $CDCl_3$): δ 197.5, 160.6, 147.1, 135.4, 134.9, 134.3, 131.8, 125.7, 117.8, 43.2, 37.4, 33.6, 31.5, 28.6, 22.6, 14.1.
FTIR (ATR): 2954, 2928, 2859, 1699, 1642, 1581, 1458, 1344, 1194, 994, 918, 829, 734 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{16}H_{21}O$ $[M+H-H_2]^+$ 229.1586, found: 229.1581.
$[\alpha]_D^{23}$: +65.4° (c = 1.0, $CHCl_3$).
HPLC Conditions: 10% IPA, 1.0 mL/min, Chiralcel OD-H column, λ = 254 nm, t_R (min): major = 5.37, minor = 6.44



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	5.372	VV	0.2135	4.77187e4	3584.78198	93.8133
2	6.441	VV	0.2467	3146.90283	188.99858	6.1867

Preparation of 17:

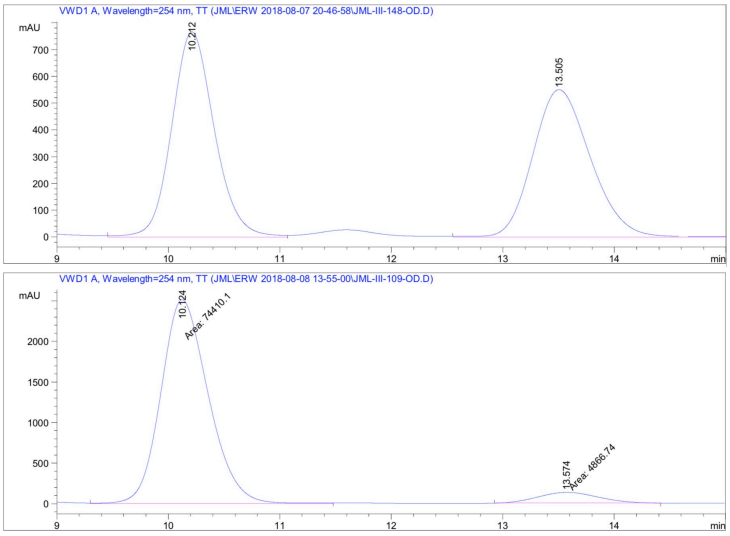


(93% yield, >99:1 *Z*/*E*, 87% *ee*)

In a nitrogen-filled glovebox, *cis*-5-octen-1-ol (113 mg, 0.88 mmol, 8.0 equiv) was dissolved in toluene (1 mL) in a 50 mL Schlenk flask and a solution of catalyst **Ru-4** (7.5 mg, 8.8 μmol, 1

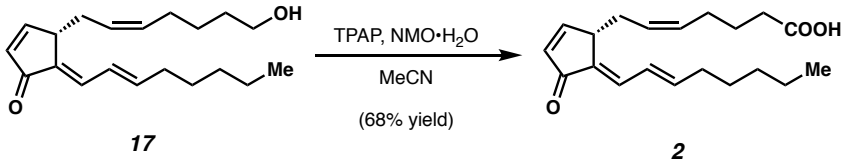
mol%) in THF (0.6 mL) was added. The Schlenk flask was sealed and brought out of the glovebox, and then connected to high vacuum. The valve was gradually opened (*Caution: open slowly and stir well to avoid splashing*). After 15 minutes stirring, the flask was refilled with argon and sealed, and was brought back into the glovebox. The residue was diluted with THF (0.5 mL), and an aliquot was taken for GC analysis (conversion of homodimerization step was >98% by GC analysis). A solution of **16** (25 mg, 0.11 mmol, 1.0 equiv) in THF (0.5 mL) was added into the Schlenk flask and an additional portion of catalyst **Ru-4** (4.6 mg, 5.5 µmol, 5 mol%) solution in THF (0.2 mL) was added. The Schlenk flask was sealed and brought out of glovebox. The reaction was stirred for 24 h at 40 ºC before a few drops of ethyl vinyl ether were added. The solvent was removed under reduced pressure. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 2:1) to give **17** (31 mg, 93%, >99:1 *Z/E*, 87% *ee* by chiral HPLC analysis).

TLC (4:1 hexanes/EtOAc): R_f= 0.2 (UV).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.95 (dt, *J* = 11.0, 1.3 Hz, 1H), 6.35 (dd, *J* = 6.0, 1.8 Hz, 1H), 6.34 – 6.19 (m, 2H), 5.52 – 5.44 (m, 1H), 5.38 – 5.30 (m, 1H), 3.63 (t, *J* = 6.5 Hz, 2H), 3.60 – 3.55 (m, 1H), 2.60 (dddd, *J* = 14.0, 6.2, 4.3, 1.4 Hz, 1H), 2.30 (dtd, *J* = 14.4, 8.6, 1.2 Hz, 1H), 2.25 – 2.17 (m, 2H), 2.01 (qd, *J* = 7.3, 1.4 Hz, 2H), 1.59 – 1.49 (m, 2H), 1.48 – 1.37 (m, 5H), 1.34 – 1.29 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 197.6, 160.9, 147.0, 135.4, 135.3, 132.6, 131.8, 125.8, 125.3, 62.9, 43.7, 33.6, 32.5, 31.5, 30.9, 28.6, 27.2, 25.8, 22.6, 14.2.
FTIR (ATR): 3445, 2960, 2930, 2862, 1690, 1629, 1580, 1447, 1264, 1207, 1054, 979, 732 cm^{-1}.
HRMS (TOF, ES+, m/z): calc'd for $C_{20}H_{31}O_2$ $[M+H]^+$ 303.2319, found: 303.2320.
$[\alpha]_D^{23}$: +115.8° (c = 0.5, $CHCl_3$).
HPLC Conditions: 10% IPA, 1.0 mL/min, Chiralcel OD-H column, λ = 254 nm, t_R (min): major = 10.12, minor = 13.57



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.124	MM	0.4934	7.44101e4	2513.44019	93.8611
2	13.574	MM	0.6177	4866.74170	131.31406	6.1389

Preparation of 15-deoxy-$\Delta^{12,14}$-prostaglandin J_2 (2):



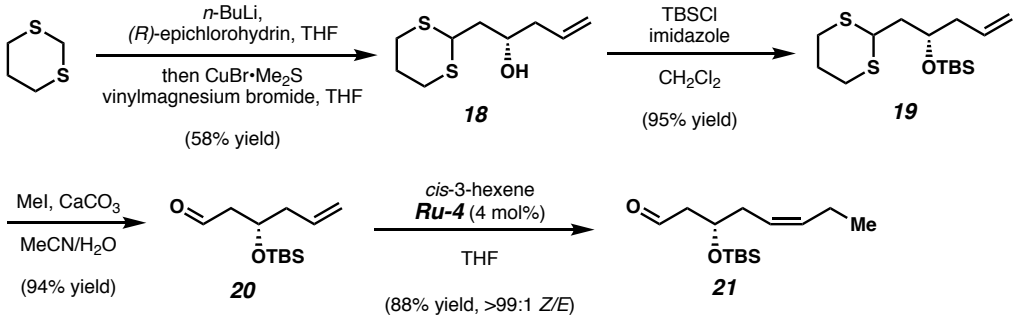
17 ***2***

To a stirred solution of **17** (14 mg, 0.046 mmol, 1.0 equiv) in MeCN (0.5 mL) was added NMO•H_2O (65 mg, 0.46 mmol, 10.0 equiv). Tetrapropylammonium perruthenate (1.7 mg, 4.6 μmol, 0.1 equiv) was added until NMO•H_2O was fully dissolved and the reaction was stirred at 23 ºC for 3 hours. The reaction mixture was stirred for 3 hours and the solvent was removed *in vacuo*. The residue was loaded onto a silica gel column, flushed with CH_2Cl_2 then CH_2Cl_2/MeOH (20:1). 15-deoxy-$\Delta^{12,14}$-prostaglandin J_2 (**2**) was obtained as a colorless oil (10 mg, 68% yield).

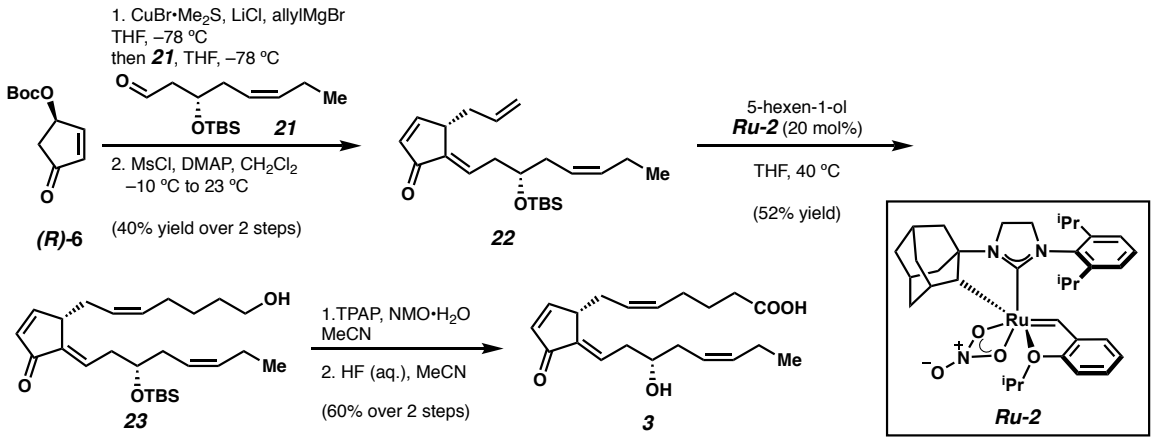
TLC (100% EtOAc): R_f= 0.70 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.95 (d, *J* = 11.0 Hz, 1H), 6.38 – 6.35 (m, 1H), 6.33 – 6.20 (m, 2H), 5.50 – 5.33 (m, 2H), 3.59 (ddd, *J* = 8.4, 4.1, 2.2 Hz, 1H), 2.59 (m, 1H), 2.36 – 2.19 (m, 5H), 2.05 (q, *J* = 7.3 Hz, 2H), 1.68 (quint, *J* = 7.5 Hz, 2H), 1.50 – 1.41 (m, 2H), 1.34 – 1.28 (m, 4H), 0.90 (t, *J* = 7.0 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 197.6, 177.9, 160.8, 147.2, 135.5, 135.1, 131.9, 131.5, 126.2, 125.8, 43.6, 33.6, 33.2, 31.6, 30.8, 28.6, 26.7, 24.6, 22.6, 14.2.
FTIR (ATR): 2960, 2928, 2850, 1708, 1692, 1629, 1456, 1265, 1207, 978, 734, 703 cm^{-1}.
HRMS (TOF, ES+, m/z): calc'd for $C_{20}H_{29}O_3$ $[M+H]^+$ 317.2111, found: 317.2127.
$[\alpha]_D^{23}$**:** +106.2° (c = 0.2, $CHCl_3$).

Spectral data (^{1}H NMR, ^{13}C NMR, HRMS) matched with the published data.[3,4]

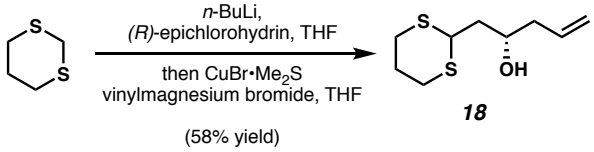
3. Synthesis of Δ^{12}-prostaglandin J_3 (3):
Synthetic route:



18 ***19*** ***20*** ***21***



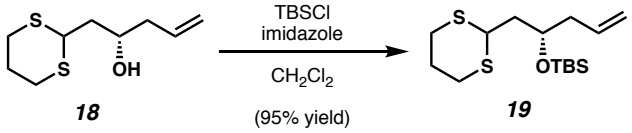
Preparation of 18:



Procedures are same as Dai and co-workers.[5] 1,3-dithiane (1.2 g, 10 mmol, 1.0 equiv) was dissolved in THF (15 mL) and cooled to –78 ºC. *n*-BuLi (2.5 M solution in hexanes, 4.4 mL, 11 mmol, 1.1 equiv) was added and the solution was stirred at the same temperature for 15 min, then warmed up to –20 °C and stirred for 1 h. The reaction mixture was cooled down to –78 °C and *(R)*-epichlorohydrin (1.1 mL, 14 mmol, 1.4 equiv) was added dropwisely. The reaction mixture was stirred at –78 °C for 1 h, then slowly warmed to 23 ºC and stirred overnight and then cooled to –40 ºC. In another flame-dried flask, vinyl magnesium bromide (28 mL, 1.0 M in THF, 28 mmol, 2.8 equiv) was added to a stirred solution of CuBr•Me_2S (124 mg, 0.6 mmol, 0.06 equiv) in THF (20 mL), and the resulting solution was transferred into the reaction mixture through a cannula at –40 ºC. The reaction mixture was slowly warmed to 23 ºC and stirred overnight before 1 M HCl (50 mL) was added. The biphasic mixture was extracted with EtOAc (3 × 50 mL). The combined organic extract was washed with brine, dried with anhydrous magnesium sulfate, filtered and concentrated under reduced pressure. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc = 9:1) to afford **18** (1.20 g, 58% yield) as colorless liquid.

TLC (4:1 hexanes/EtOAc): R_f = 0.27 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 5.89 – 5.72 (m, 1H), 5.14 (m, 2H), 4.26 (dd, *J* = 7.8, 6.6 Hz, 1H), 4.02 – 3.94 (m, 1H), 2.96 – 2.78 (m, 4H), 2.33 – 2.24 (m, 1H), 2.24 – 2.16 (m, 1H), 2.16 – 2.06 (m, 1H), 2.01 (d, *J* = 4.2 Hz, 1H), 1.95 – 1.82 (m, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 134.2, 118.7, 67.6, 44.3, 42.2, 42.1, 30.5, 30.2, 26.0.
FTIR (ATR): 3413, 3073, 2930, 2900, 2851, 2827, 1640, 1422, 1275, 1242, 1172, 1123, 1062, 1027, 993, 908, 866, 770, 664 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_9H_{16}OS_2$ $[M]^+$ 204.0637, found: 204.0657.
$[\alpha]_D^{23}$: +22.2° (c = 1.0, $CHCl_3$).

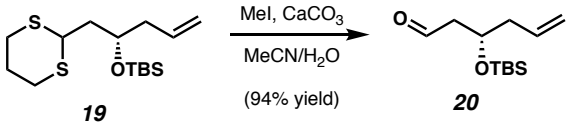
Preparation of 19:



To a stirred solution of **18** (0.70 g, 3.43 mmol) in CH_2Cl_2 (20 mL) was added imidazole (0.70 g, 10.29 mmol, 3.0 equiv) and TBSCl (1.03 g, 6.86 mmol, 2.0 equiv). Saturated NH_4Cl solution (20 mL) was added after stirring overnight. The aqueous layer was extracted with CH_2Cl_2 (3 × 20 mL) and the combined organic phase was dried over anhydrous magnesium sulfate, filtered and concentrated under reduced pressure. Column chromatography (SiO_2, 20:1 hexanes/EtOAc) gave **19** as a colorless oil (1.04 g, 95% yield).

TLC (10:1 hexanes/EtOAc): R_f= 0.54 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 5.83 – 5.71 (m, 1H), 5.07 – 5.00 (m, 2H), 4.08 (dd, *J* = 7.8, 6.9 Hz, 1H), 4.00 (qd, *J* = 6.2, 4.9 Hz, 1H), 2.92 – 2.75 (m, 4H), 2.23 (dtt, *J* = 7.5, 5.1, 1.3 Hz, 2H), 2.09 (dddt, *J* = 10.6, 5.0, 4.2, 2.8 Hz, 1H), 1.93 – 1.83 (m, 1H), 1.83 – 1.78 (m, 2H), 0.88 (s, 9H), 0.09 (s, 3H), 0.07 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 134.3, 117.6, 68.1, 44.1, 42.3, 42.3, 30.7, 30.1, 26.2, 26.0, 18.2, –4.3, –4.5.
FTIR (ATR): 2952, 2928, 2896, 2855, 1640, 1472, 1423, 1360, 1254, 1185, 1070, 1004, 940, 915, 834, 808, 773, 666 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{15}H_{31}OS_2Si$ $[M+H]^+$ 319.1580, found: 319.1583.
$[\alpha]_D^{23}$: +41.1° (c = 1.0, $CHCl_3$).

Preparation of aldehyde 20:

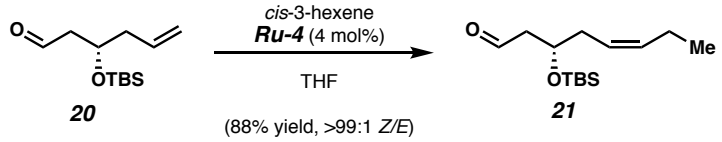


To a solution of **19** (636 mg, 2 mmol, 1.0 equiv) in $MeCN/H_2O$ (20 mL, 9:1) was added $CaCO_3$ (1.0 g, 10 mmol, 5.0 equiv) and MeI (1.87 mL, 30 mmol, 15.0 equiv). The reaction mixture was stirred at 50 ºC for 6 h, then diluted with water (20 mL) and extracted with EtOAc (3 × 20 mL). The combined organic extract was dried over anhydrous magnesium sulfate, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (SiO_2, 20:1 hexanes/EtOAc) to afford **20** (430 mg, 94%) as a colorless liquid.

TLC (10:1 hexanes/EtOAc): R_f= 0.45 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.80 (td, *J* = 2.4, 0.8 Hz, 1H), 5.78 (ddt, *J* = 16.5, 10.8, 7.2 Hz, 1H), 5.12 – 5.03 (m, 2H), 4.26 (quint, *J* = 5.9 Hz, 1H), 2.55 – 2.52 (m, 2H), 2.30 (ddt, *J* = 7.1, 6.0, 1.2 Hz, 2H), 0.87 (s, 9H), 0.08 (s, 3H), 0.06 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 202.3, 133.9, 118.3, 67.9, 50.5, 42.5, 25.9, 18.1, –4.2, –4.7.

FTIR (ATR): 2955, 2929, 2890, 2857, 1726, 1641, 1472, 1361, 1254, 1098, 1041, 1005, 915, 834, 810, 774, 680 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{12}H_{25}O_2Si$ $[M+H]^+$ 229.1618, found: 229.1629.
$[\alpha]_D^{23}$: +22.0° (c = 1.0, $CHCl_3$).

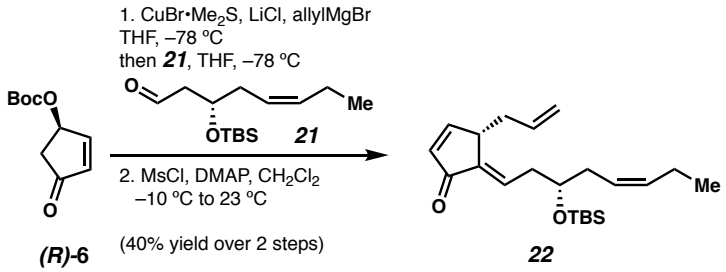
Preparation of aldehyde 21:



In a nitrogen-filled glovebox, **20** (146 mg, 0.64 mmol, 1 equiv) and *cis*-3-hexene (215 mg, 2.56 mmol, 4 equiv) were weighed into a 4 mL vial. A solution of catalyst **Ru-4** (22 mg, 25.6 μmol, 4 mol%) in THF (1.5 mL) was transferred into the vial. The reaction mixture was stirred for 1 h at 23 ºC. An aliquot was taken for GC analysis to monitor the conversion. Then the vial was brought out of the glovebox, concentrated *in vacuo*. The residue was purified by column chromatography (SiO_2, hexanes/EtOAc 20:1) to afford **21** (145 mg, 88%) as a colorless liquid.

TLC (10:1 hexanes/EtOAc): R_f= 0.45 (*p*-anisaldehyde).
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.80 (t, *J* = 2.4 Hz, 1H), 5.54 – 5.41 (m, 1H), 5.32 (dtt, *J* = 10.8, 7.5, 1.6 Hz, 1H), 4.22 (dq, *J* = 7.1, 5.7 Hz, 1H), 2.51 (dd, *J* = 5.8, 2.4 Hz, 2H), 2.38 – 2.17 (m, 2H), 2.10 – 1.92 (m, 2H), 0.96 (t, *J* = 7.5 Hz, 3H), 0.87 (s, 9H), 0.08 (s, 3H), 0.06 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 202.4, 134.8, 123.7, 68.3, 50.6, 35.7, 25.9, 20.9, 18.1, 14.3, –4.2, –4.7.
FTIR (ATR): 2957, 2930, 2890, 2857, 1726, 1472, 1361, 1253, 1096, 1005, 938, 834, 811, 774, 680 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{14}H_{27}O_2Si$ $[M+H-H_2]^+$ 255.1774, found: 255.1780.
$[\alpha]_D^{23}$: +22.0° (c = 0.4, C_6H_6).

Preparation of 22:



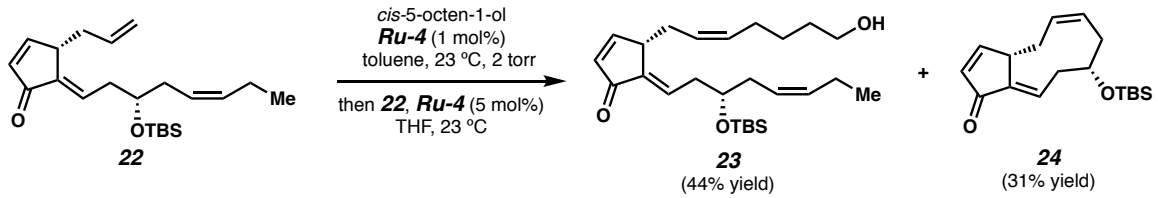
A 25 mL flask was flame dried and charged with CuBr•Me_2S (142 mg, 0.69 mmol, 3.0 equiv) and LiCl (31 mg, 0.74 mmol, 3.2 equiv) in a nitrogen-filled glove box. The flask was sealed with septum and brought out of glove box, and was heated under vacuum to remove residue water. Anhydrous THF (5 mL) was added, and the solution was vigorously stirred for 10 minute at 23 ºC

until a yellow solution was formed. At –78ºC, allylmagnesium bromide (0.65 mL, 1.0 M solution in THF, 0.65 mmol, 2.8 equiv) was added slowly. The reaction mixture was stirred at –78 ºC for 1 hour and a solution of ***(R)*-6** (137 mg, 0.69 mmol, 3.0 equiv) in THF (1 mL) was added slowly. After 30 minutes stirring at the same temperature, a solution of **21** (59 mg, 0.23 mmol, 1.0 equiv) in THF (1 mL) was added slowly. The reaction was stirred for additional 2 hours at –78 ºC before a solution of saturated NH_4Cl and $NH_3•H_2O$ (10 mL, 9:1 $NH_4Cl/NH_3•H_2O$) was added. The biphasic solution was vigorously stirred until a homogeneous dark blue solution was formed in aqueous phase. The phases were separated and the organic phase was washed with 10 mL saturated NH_4Cl solution. The combined aqueous phase was extracted with Et_2O (2 × 30 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 18:1) to give a mixture of diasteromers of the aldol products (50 mg, 0.13 mmol).

In a 25 mL flask, the crude aldol product was dissolved in CH_2Cl_2 (5 mL) and cooled to –10 ºC. DMAP (242 mg, 2.0 mmol, 15.0 equiv) and MsCl (31 μL, 0.4 mmol, 3.0 equiv) was added sequentially. The reaction mixture was slowly warmed to 23 ºC and was stirred for 12 h before diluted with 10 mL EtOAc and washed with 1 M HCl (5 mL). The aqueous phase was extracted with EtOAc (2 × 10 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (hexanes/EtOAc 15:1) to give **22** (33 mg, 40% yield over 2 steps) as a colorless liquid.

TLC (4:1 hexenes/EtOAc): R_f= 0.67 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51 (ddd, *J* = 6.1, 2.6, 1.0 Hz, 1H), 6.61 (ddt, *J* = 9.0, 8.0, 1.3 Hz, 1H), 6.33 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.79 – 5.64 (m, 1H), 5.52 – 5.41 (m, 1H), 5.42 – 5.30 (m, 1H), 5.10 – 5.01 (m, 2H), 3.88 (quint, *J* = 6.0 Hz, 1H), 3.48 (ddd, *J* = 8.8, 4.0, 2.0 Hz, 1H), 2.72 – 2.61 (m, 1H), 2.46 – 2.38 (m, 2H), 2.30 – 2.11 (m, 3H), 2.05 – 1.95 (m, 2H), 0.93 (t, *J* = 7.5 Hz, 3H), 0.87 (s, 9H), 0.06 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4, 161.4, 138.6, 135.1, 134.4, 134.1, 132.7, 124.4, 117.7, 71.7, 43.1, 37.1, 36.9, 35.3, 26.0, 20.9, 18.2, 14.3, –4.4, –4.4.
FTIR (ATR): 2957, 2929, 2894, 2856, 1706, 1657, 1582, 1472, 1366, 1253, 1148, 1083, 1005, 966, 915, 835, 808, 775 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{22}H_{37}O_2Si$ $[M+H]^+$ 361.2557, found: 361.2576.
$[\alpha]_D^{23}$**:** +122.3° (c = 1.0, $CHCl_3$).

Preparation of 23 using Ru-4:



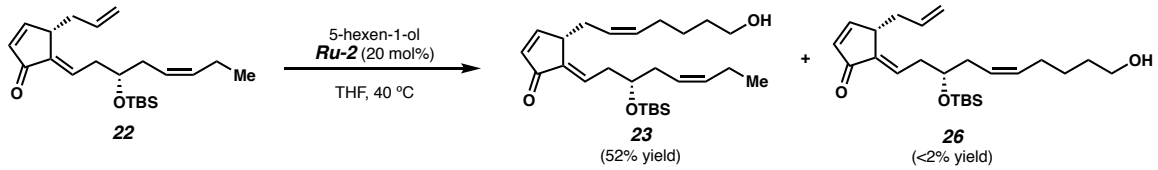
In a nitrogen-filled glovebox, *cis*-5-octen-1-ol (72 mg, 0.55 mmol, 6.7 equiv) was dissolved in toluene (1 mL) in a 50 mL Schlenk flask and a solution of catalyst **Ru-4** (4.7 mg, 5.6 μmol, 1 mol%) in THF (0.6 mL) was added. The Schlenk flask was sealed and brought out of the

glovebox, and then connected to high vacuum. The valve was gradually opened (*Caution: open slowly and stir well to avoid splashing*). After 15 minutes stirring, the flask was refilled with argon and sealed, and was brought back into the glovebox. The residue was diluted with 0.5 mL THF, and an aliquot was taken for GC analysis (conversion of homodimerization step was >98% by GC analysis). A solution of **22** (30 mg, 0.083 mmol, 1 equiv) in 0.5 mL THF was added into the Schlenk flask and an additional 0.4 mL of catalyst solution with **Ru-4** (2.9 mg, 3.5 μmol, 5 mol%) was added. The Schlenk flask was sealed and brought out of glovebox. The reaction was stirred for 12 h at 23 ºC before a few drops of ethyl vinyl ether were added. The solvent was removed under reduced pressure. The residue was purified by flash chromatography (hexanes/EtOAc 10:1 to 2:1). **23** (16 mg, 44%) and **24** (8 mg, 31%) was isolated as two products.

Compound **23**:
TLC (2:1 hexanes/EtOAc): R_f= 0.28 (UV).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (ddd, *J* = 6.0, 2.7, 1.0 Hz, 1H), 6.60 (ddt, *J* = 8.2, 7.0, 1.3 Hz, 1H), 6.32 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.53 – 5.43 (m, 2H), 5.41 – 5.31 (m, 2H), 3.89 (quint, *J* = 6.1 Hz, 1H), 3.64 (t, *J* = 6.5 Hz, 2H), 3.45 (ddq, *J* = 8.4, 4.3, 2.2 Hz, 1H), 2.68 – 2.55 (m, 1H), 2.43 (ddd, *J* = 7.7, 6.4, 2.3 Hz, 2H), 2.29 – 2.11 (m, 3H), 2.08 – 1.91 (m, 4H), 1.62 – 1.51 (m, 2H), 1.48 – 1.36 (m, 2H), 0.94 (t, *J* = 7.6 Hz, 3H), 0.88 (s, 9H), 0.06 (s, 3H), 0.05 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 196.5, 161.8, 138.9, 135.0, 134.2, 132.7, 132.5, 125.5, 124.4, 71.7, 62.9, 43.6, 37.0, 35.3, 32.5, 30.8, 27.2, 26.0, 25.9, 20.9, 18.2, 14.3, –4.4, –4.4.
FTIR (ATR): 3429, 2956, 2928, 2856, 2361, 2327, 1702, 1652, 1580, 1472, 1360, 1251, 1213, 1066, 1005, 968, 834, 807, 774, 721, 668 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{26}H_{45}O_3Si$ $[M+H]^+$ 433.3132, found: 433.3121.
$[\alpha]_D^{23}$: +136.3° (c = 1.0, C_6H_6).

Compound **24**:
TLC (2:1 hexanes/EtOAc): R_f= 0.6 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (ddd, *J* = 5.9, 2.8, 1.0 Hz, 1H), 6.80 (ddt, *J* = 10.8, 8.8, 1.3 Hz, 1H), 6.31 (dd, *J* = 5.9, 1.7 Hz, 1H), 5.76 (q, *J* = 9.1 Hz, 1H), 5.61 (dddd, *J* = 11.9, 10.7, 5.2, 1.2 Hz, 1H), 4.08 – 4.02 (m, 1H), 3.27 (d, *J* = 9.6 Hz, 1H), 2.38 (dd, *J* = 9.5, 3.0 Hz, 2H), 2.24 (q, *J* = 11.6 Hz, 2H), 2.17 – 1.95 (m, 2H), 0.91 (s, 9H), 0.11 (s, 3H), 0.08 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4, 162.3, 141.3, 134.0, 132.4, 130.6, 129.6, 73.1, 44.2, 34.7, 34.5, 32.6, 26.0, 18.3, –4.6, –4.7.
FTIR (ATR): 2952, 2926, 2886, 2855, 2359, 2339, 1705, 1654, 1586, 1471, 1369, 1251, 1190, 1077, 1039, 997, 980, 938, 855, 835, 808, 790, 774, 727, 668 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{18}H_{29}O_2Si$ $[M+H]^+$ 305.1931, found: 305.1942.
$[\alpha]_D^{23}$: –27.8° (c = 0.8, $CHCl_3$)

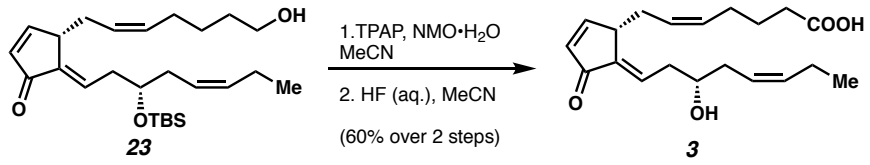
Preparation of 23 using Ru-2:



In a nitrogen-filled glovebox, **22** (64 mg, 0.18 mmol, 1.0 equiv) and 5-hexen-1-ol (142 mg, 1.42 mmol, 8.0 equiv) were weighed into a 4 mL vial. THF (0.3 mL) was added to dissolve the mixture. Catalyst **Ru-2** (24 mg, 20 mol%) was dissolved in THF (0.4 mL) and 0.1 mL of this catalyst solution was transferred into the vial. The vial was sealed with a 14/20 septum and brought out of the glovebox. The reaction was stirred at 40 ºC with a stream of argon (saturated with anhydrous THF) bubbling through a needle. A portion of the catalyst solution (0.1 mL) was added into the vial in each 1 hour. After all the catalyst was added, the reaction mixture was continued to stir for 4 h with argon bubbling. A few drops of ethyl vinyl ether were added, and the reaction mixture was concentrated *in vacuo*. The residue was purified by column chromatography (SiO_2, hexanes/EtOAc 2:1) to afford **23** (40 mg, 52%) as a colorless liquid. Compund **26** was the proposed by-product (molar ratio of **23**:**26** was 32:1 as determined by crude NMR analysis).

Compound **23**: Characterization data were in agreement with previously obtained data.
Compound **26**: Characterization data not available due to the difficulty in separation, mass data was obtained by LC-MS (TOF, ES+, m/z): calc'd for $C_{24}H_{41}O_3Si$ $[M+H]^+$ 405.2819, found: 405.2801.

Preparation of Δ^{12}-prostaglandin J_3 (3):



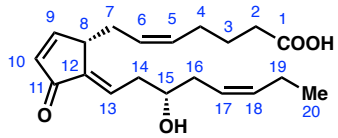
To a stirred solution of **23** (21.6 mg, 0.05 mmol, 1.0 equiv) in MeCN (0.5 mL) was added NMO•H_2O (67.5 mg, 0.5 mmol, 10.0 equiv). Tetrapropylammonium perruthenate (1.8 mg, 5 μmol, 0.1 equiv) was added until NMO•H_2O was fully dissolved and the reaction was stirred at 23 ºC for 3 hours. The solution was diluted with Et_2O (5 mL), passed through a short pad of silica gel, concentrated and was subjected to the next reaction without further purification.

The residue was dissolved in MeCN (1.0 mL) and cooled to 0 ºC. A solution of hydrofluoric acid (48 wt. % in H_2O, 0.2 mL) in MeCN (0.4 mL) was added dropwisely. The solution was stirred in the same temperature for 30 min before saturated $NaHCO_3$ solution (1.5 mL) and brine (1.5 mL) were added. The aqueous phase was extracted with EtOAc (5 × 5 mL). The combined organic phase was dried over magnesium sulfate, filtered and concentrated (*not to dryness*). The residue was purified by flash chromatography (SiO_2, CH_2Cl_2/MeOH 20:1) and through Biotage® SNAP Ultra C18 column (H_2O/MeOH) to give **3** (10 mg, 60% over 2 steps) as a colorless liquid.

TLC (100% EtOAc): R_f= 0.55 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58 (ddd, *J* = 6.0, 2.6, 1.0 Hz, 1H), 6.57 (ddt, *J* = 8.4, 7.0, 1.2 Hz, 1H), 6.36 (dd, *J* = 6.0, 1.8 Hz, 1H), 5.69 – 5.60 (m, 1H), 5.60 – 5.45 (m, 2H), 5.45 – 5.35 (m, 1H), 3.91 (quint, *J* = 6.8 Hz, 1H), 3.50 – 3.44 (m, 1H), 2.75 (ddd, *J* = 13.9, 6.9, 4.4 Hz, 1H), 2.68 – 2.58 (m, 1H), 2.49 (ddd, *J* = 15.2, 8.4, 7.0 Hz, 1H), 2.36 (t, *J* = 6.8 Hz, 2H), 2.33 – 2.28 (m, 2H), 2.20 – 1.98 (m, 5H), 1.68 (quint, *J* = 7.0 Hz, 2H), 0.96 (t, *J* = 7.5 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4, 175.8, 161.8, 139.9, 136.4, 135.1, 131.7, 131.2, 126.3, 123.6, 71.1, 44.0, 36.3, 34.5, 32.9, 30.7, 26.6, 24.7, 20.9, 14.4.
FTIR (ATR): 3449, 3010, 2956, 2919, 2850, 1728, 1703, 1650, 1579, 1455, 1375, 1222, 1182, 1046, 959, 838, 809, 721 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{20}H_{29}O_4$ $[M+H]^+$ 333.2060, found: 333.2060.
$[\alpha]_D^{23}$: +122.6° (c = 0.5, C_6H_6).

Spectral data (^{1}H NMR, ^{13}C NMR, HRMS) matched with the published data.[6] Comparisons of ^{1}H NMR data of natural and synthetic Δ^{12}-prostaglandin J_3 (3) are listed in **Table S2**.

Table S2. Comparison of ^{1}H NMR data for Δ^{12}-prostaglandin J_3 (3)

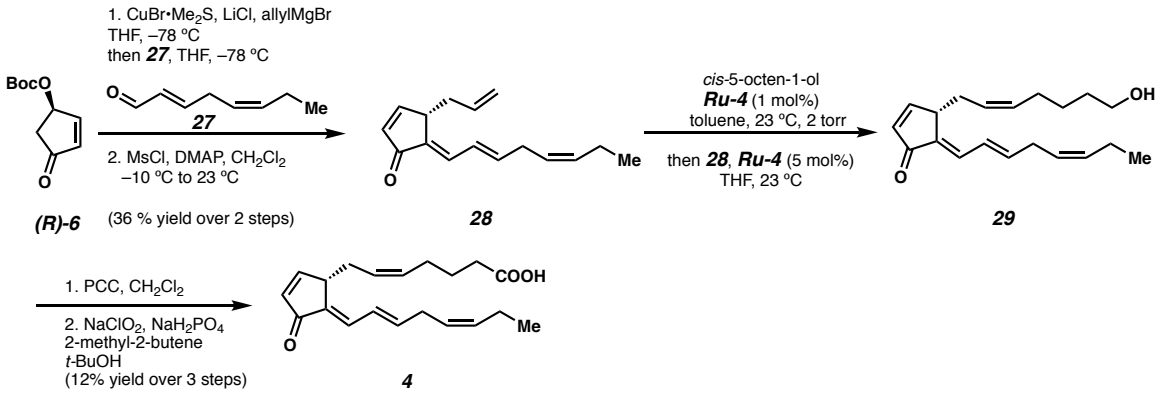


Δ^{12} -PGJ$_3$ (3)

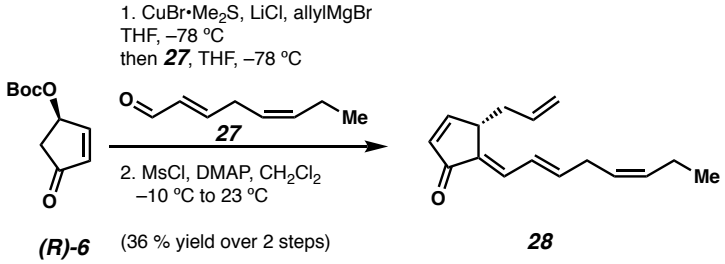
Proton Number	**Natural Δ^{12}-PGJ$_3$ ^{1}H NMR(Ref.6a)** 600 MHz, $CDCl_3$ ^{1}H [δ, multi, *J* (Hz)]	**This Work, Synthetic Δ^{12}-PGJ$_3$ ^{1}H NMR** 400 MHz, $CDCl_3$ ^{1}H [δ, multi, *J* (Hz)]
1	n.d.	
2	2.35 (t, *J* = 7.0 Hz)	2.36 (t, *J* = 6.8 Hz)
3	hidden	1.78 – 1.66 (m)
4	2.02 (m)	2.20 – 2.10 (m)
5	5.42 (m)	5.60 – 5.51 (m)
6	hidden	5.51 – 5.45 (m)
7α	2.64 (m)	2.75 (ddd, *J* = 13.9, 6.9, 4.4 Hz)
7β	2.08 (m)	2.20 – 2.10 (m)
8	3.47 (ddd, *J* = 10.0, 4.0, 2.0 Hz)	3.50 – 3.44 (m)
9	7.56 (ddd, *J* = 6.0, 2.0, 1.0 Hz)	7.58 (ddd, *J* = 6.0, 2.6, 1.0 Hz)
10	6.35 (dd, *J* = 6.0, 2.0 Hz)	6.36 (dd, *J* = 6.0, 1.8 Hz)
11	n.d.	
12	n.d.	
13	6.58 (m)	6.57 (ddt, *J* = 8.4, 7.0, 1.2 Hz)
14α	2.55 (dt, *J* = 15.0, 7.0 Hz)	2.68 – 2.57 (m)
14β	2.47 (ddd, *J* = 15.0, 8.0, 6.0 Hz)	2.49 (ddd, *J* = 15.2, 8.4, 7.0 Hz)
15	3.88 (quint, *J* = 6.0 Hz)	3.91 (quint, *J* = 6.8 Hz)
16	2.28 (m)	2.33 – 2.28 (m)
17	hidden	5.45 – 5.35 (m)
18	5.51 (m)	5.69 – 5.60 (m)
19α	2.00 (m)	2.10 – 1.98 (m)
19β	1.98 (m)	2.10 – 1.98 (m)
20	0.96 (t, *J* = 7.0 Hz)	0.96 (t, *J* = 7.5 Hz)

4. Synthesis of 15-deoxy-$\Delta^{12,14}$-prostaglandin J_3 (4):

Synthetic route:



Preparation of 28:



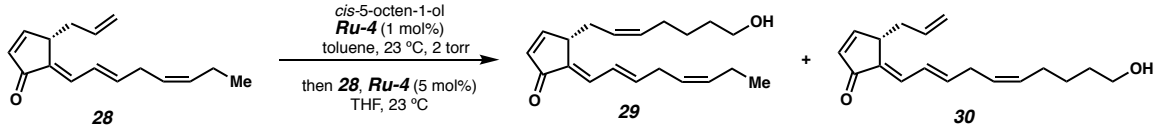
A 25 mL flask was flame dried and charged with CuBr•Me_2S (195 mg, 0.95 mmol, 1.9 equiv) and LiCl (42 mg, 1.0 mmol, 2.0 equiv) in a nitrogen-filled glove box. The flask was sealed with septum and brought out of glove box, and was heated under vacuum to remove residue water. Anhydrous THF (10 mL) was added, and the solution was vigorously stirred for 10 minute at 23 ºC until a yellow homogeneous solution was formed. At –78ºC, allyl magnesium bromide (0.9 mL, 1.0 M solution in THF, 0.9 mmol, 1.8 equiv) was added slowly. The reaction mixture was stirred at –78 ºC for 1 hour and a solution of ***(R)*-6** (198 mg, 1.0 mmol, 2.0 equiv) in THF (1 mL) was added slowly. After 30 minutes stirring at the same temperature, a solution of known compound **27** (prepared according to Honda and co-workers[7]) (62 mg, 0.5 mmol, 1.0 equiv) in THF (1 mL) was added slowly. The reaction was stirred for additional 2 hours at –78 ºC before a solution of saturated NH_4Cl and NH_3•H_2O (10 mL, 9:1 NH_4Cl/NH_3•H_2O) was added. The biphasic solution was vigorously stirred until a homogeneous dark blue solution was formed in aqueous phase. The phases were separated and the organic phase was washed with 10 mL saturated NH_4Cl solution. The combined aqueous phase was extracted with Et_2O (2 × 30 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 15:1) to give a mixture of diasteromers of the aldol products (51 mg, 0.21 mmol).

In a 25 mL flask, the crude aldol product was dissolved in CH_2Cl_2 (6 mL) and cooled to –10 ºC. DMAP (384 mg, 3.15 mmol, 15.0 equiv) and MsCl (49 μL, 0.63 mmol, 3.0 equiv) was added sequentially. The reaction mixture was slowly warmed to 23 ºC and was stirred for 2 h before diluted with 10 mL EtOAc and washed with 1 M HCl (10 mL). The aqueous phase was extracted

with EtOAc (2 × 20 mL). The combined organic phase was dried with anhydrous magnesium sulfate, and was concentrated *in vacuo*. The residue was purified by flash chromatography (hexanes/EtOAc 15:1) to give **28** (41 mg, 36% yield over 2 steps) as a colorless liquid.

TLC (4:1 hexanes/EtOAc): R_f = 0.56 (UV).
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (ddd, *J* = 5.9, 2.6, 1.0 Hz, 1H), 7.03 – 6.90 (m, 1H), 6.36 (dd, *J* = 6.1, 1.8 Hz, 1H), 6.34 – 6.29 (m, 1H), 6.21 (dt, *J* = 15.1, 6.3 Hz, 1H), 5.79 – 5.66 (m, 1H), 5.54 (dtt, *J* = 10.2, 7.2, 1.5 Hz, 1H), 5.37 (dtt, *J* = 10.5, 7.3, 1.6 Hz, 1H), 5.10 – 5.02 (m, 2H), 3.60 (ddq, *J* = 8.5, 4.0, 1.9 Hz, 1H), 3.00 – 2.95 (m, 2H), 2.65 (dddt, *J* = 13.7, 6.8, 4.2, 1.4 Hz, 1H), 2.25 (dddt, *J* = 14.2, 8.8, 7.7, 1.1 Hz, 1H), 2.07 (dquint, *J* = 7.5, 1.5 Hz, 2H), 0.98 (t, *J* = 7.5 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 197.5, 160.7, 144.5, 135.4, 135.4, 134.2, 134.1, 131.6, 125.8, 124.6, 117.9, 43.3, 37.4, 31.2, 20.7, 14.3.
FTIR (ATR): 3011, 2963, 2931, 2874, 2361, 2335, 1692, 1629, 1579, 1440, 1339, 1280, 1207, 1100, 989, 915, 872, 839, 729, 668 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{16}H_{21}O$ $[M+H]^+$ 229.1587, found: 229.1588.
$[\alpha]_D^{23}$: +117.7° (c = 0.5, $CHCl_3$).

Preparation of 29 using Ru-4:

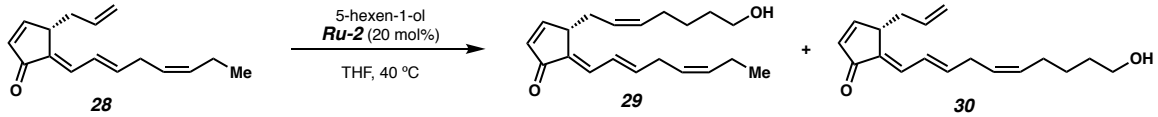


In a nitrogen-filled glovebox, *cis*-5-octen-1-ol (205 mg, 1.6 mmol, 8.0 equiv) was dissolved in toluene (1 mL) in a 50 mL Schlenk flask and a solution of catalyst **Ru-4** (13.6 mg, 16 μmol, 1 mol%) in THF (0.6 mL) was added. The Schlenk flask was sealed and brought out of the glovebox, and then connected to high vacuum. The valve was gradually opened (*Caution: open slowly and stir well to avoid splashing*). After 15 minutes stirring, the flask was refilled with argon and sealed, and was brought back into the glovebox. The residue was diluted with 0.5 mL THF, and an aliquot was taken for GC analysis (conversion of homodimerization step was >98% by GC analysis). A solution of **28** (46 mg, 0.2 mmol, 1.0 equiv) in 0.5 mL THF was added into the Schlenk flask and an additional 0.4 mL of catalyst solution with **Ru-4** (8.5 mg, 10 μmol, 5 mol%) was added. The Schlenk flask was sealed and brought out of glovebox. The reaction was stirred for 12 h at 23 °C before a few drops of ethyl vinyl ether were added. The solvent was removed under reduced pressure. The residue was purified by column chromatography (SiO_2, hexanes/EtOAc 2:1). Compounds **29** (22 mg, 36%) and **30** were separated as a mixture (28 mg, molar ratio of **29**:**30** was 3:1 as determined by crude NMR analysis).

Compound **29**: Characterization data not available due to the difficulty in separation.
Mass data was obtained by LC-MS (TOF, ES+, m/z): calc'd for $C_{20}H_{29}O_2$ $[M+H]^+$ 301.2162, found: 301.2080.

Compound **30**: Characterization data not available due to the difficulty in separation, mass data was obtained by LC-MS (TOF, ES+, m/z): calc'd for $C_{18}H_{25}O_2$ $[M+H]^+$ 273.1849, found: 273.1759.

Preparation of 29 using Ru-2:

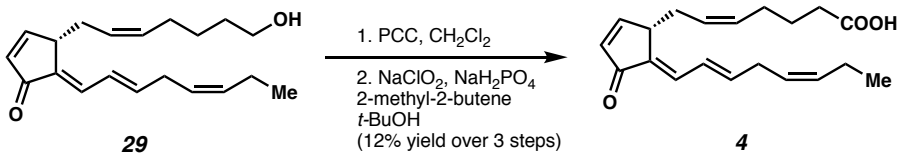


In a nitrogen-filled glovebox, **28** (23 mg, 0.1 mmol, 1.0 equiv) and 5-hexen-1-ol (80 mg, 0.8 mmol, 8.0 equiv) were weighed into a 4 mL vial. THF (0.1 mL) was added to dissolve the mixture. Catalyst **Ru-2** (13.6 mg, 20 mol%) was dissolved in THF (0.4 mL) and 0.1 mL of this catalyst solution was transferred into the vial. The vial was sealed with a 14/20 septum and brought out of the glovebox. The reaction was stirred at 40 ºC with a stream of argon (saturated with anhydrous THF) bubbling through a needle. A portion of the catalyst solution (0.1 mL) was added into the vial in each 1 hour. After all the catalyst was added, the reaction mixture was continued to stir for 2 h with argon bubbling. A few drops of ethyl vinyl ether was added, and the reaction mixture was concentrated *in vacuo*. The residue was purified by column chromatography (SiO_2, hexanes/EtOAc 2:1). Compounds **29** (9.2 mg, 31%) and **30** were separated as a mixture (12 mg, molar ratio of **29**:**30** was 3:1 as determined by crude NMR analysis).

Compound **29**: Characterization data not available due to the difficulty in separation. Mass data was obtained by LC-MS (TOF, ES+, m/z): calc'd for $C_{20}H_{29}O_2$ $[M+H]^+$ 301.2162, found: 301.2166.

Compound **30**: Characterization data not available due to the difficulty in separation, mass data was obtained by LC-MS (TOF, ES+, m/z): calc'd for $C_{18}H_{25}O_2$ $[M+H]^+$ 273.1849, found: 273.1855.

Preparation of 15-deoxy-$\Delta^{12,14}$-prostaglandin J_3 (4):



Pyridinium chlorochromate (22 mg, 0.1 mmol, 3.0 equiv) was added to a solution of **29** (mixed with by-product **30**) (10 mg, 0.033 mmol, 1.0 equiv) in CH_2Cl_2 (0.5 mL) at 23 ºC. The reaction was monitored by TLC and was diluted with Et_2O (3 mL) after stirring for 3 h. The resulting solution was filtered through a short pad of silica gel, and was subjected to the next step without further purification.

The residue was dissolved in *t*-BuOH (0.5 mL) at 23 ºC, and 2-methyl-2-butene (35 µL, 0.33 mmol, 10 equiv), a solution of $NaH_2PO_4•H_2O$ (6.9 mg, 0.05 mmol, 1.5 equiv) in H_2O (0.12 mL) and a solution of $NaClO_2$ (80 %, 5.6 mg, 0.05 mmol, 1.5 equiv) in H_2O (0.12 mL) was added sequentially. After stirring at 23 ºC for 30 minutes, the reaction mixture was diluted with a solution of $NaH_2PO_4•H_2O$ (108 mg) in H_2O (2 mL) and extracted with EtOAc (5 × 5 mL). The combined organic extracts were dried over anhydrous magnesium sulfate, filtered, and concentrated under reduced pressure. Flash column chromatography (SiO_2, CH_2Cl_2/MeOH 20:1) and purification through Biotage® SNAP Ultra C18 column (H_2O/MeOH) afforded pure compound **4** (4 mg, 0.013 mmol, 12% yield from **28**) as a colorless oil.

TLC (10:1 CH_2Cl_2/MeOH): R_f = 0.44 (UV).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 (ddd, *J* = 6.1, 2.6, 1.0 Hz, 1H), 6.96 (d, *J* = 11.5 Hz, 1H), 6.42 – 6.31 (m, 2H), 6.22 (dt, *J* = 14.9, 6.3 Hz, 1H), 5.57 – 5.51 (m, 1H), 5.50 – 5.43 (m, 1H), 5.37 (dtt, *J* = 10.1, 6.8, 1.7 Hz, 2H), 3.64 – 3.55 (m, 1H), 2.98 (t, *J* = 6.8 Hz, 2H), 2.60 (dt, *J* = 12.3, 5.9 Hz, 1H), 2.43 – 2.25 (m, 3H), 2.12 – 2.00 (m, 4H), 1.69 (quint, *J* = 7.4 Hz, 2H), 0.99 (t, *J* = 7.5 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$): δ 197.6, 176.6, 160.9, 144.5, 135.5, 135.5, 134.2, 131.6, 131.5, 126.1, 125.8, 124.6, 43.6, 33.0, 31.2, 30.9, 26.7, 24.6, 20.7, 14.3.
FTIR (ATR): 3010, 2960, 2926, 2874, 2854, 1710, 1693, 1626, 1578, 1512, 1455, 1208, 1154, 1087, 1024, 977, 817, 728 cm^{-1}.
HRMS (FAB+, m/z): calc'd for $C_{20}H_{27}O_3$ $[M+H]^+$ 315.1955, found: 315.1968.
$[\alpha]_D^{23}$: +129.6° (c = 0.07, C_6H_6).

Spectral data (^{1}H NMR, ^{13}C NMR, HRMS) matched with the published data.[8]

III. References

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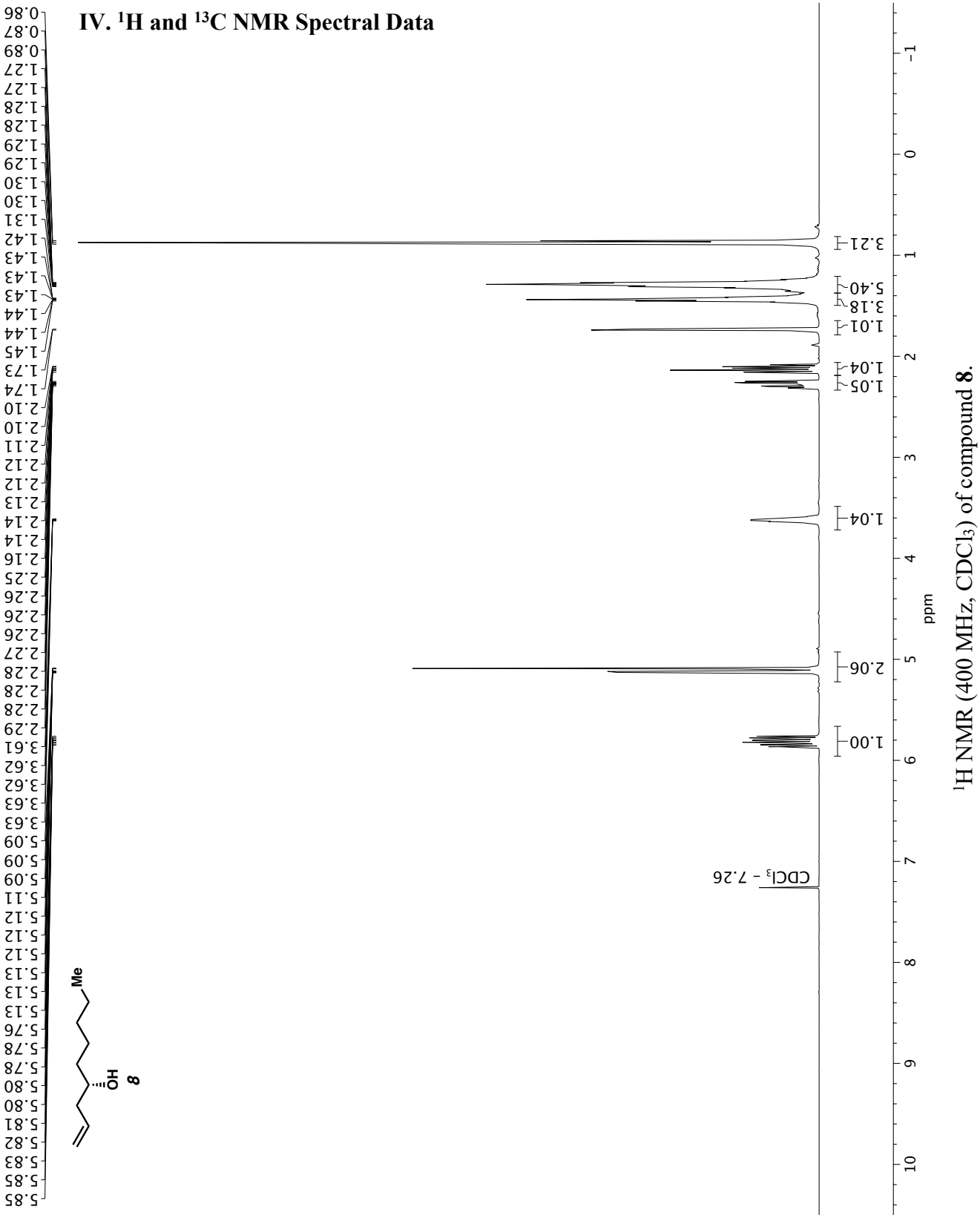
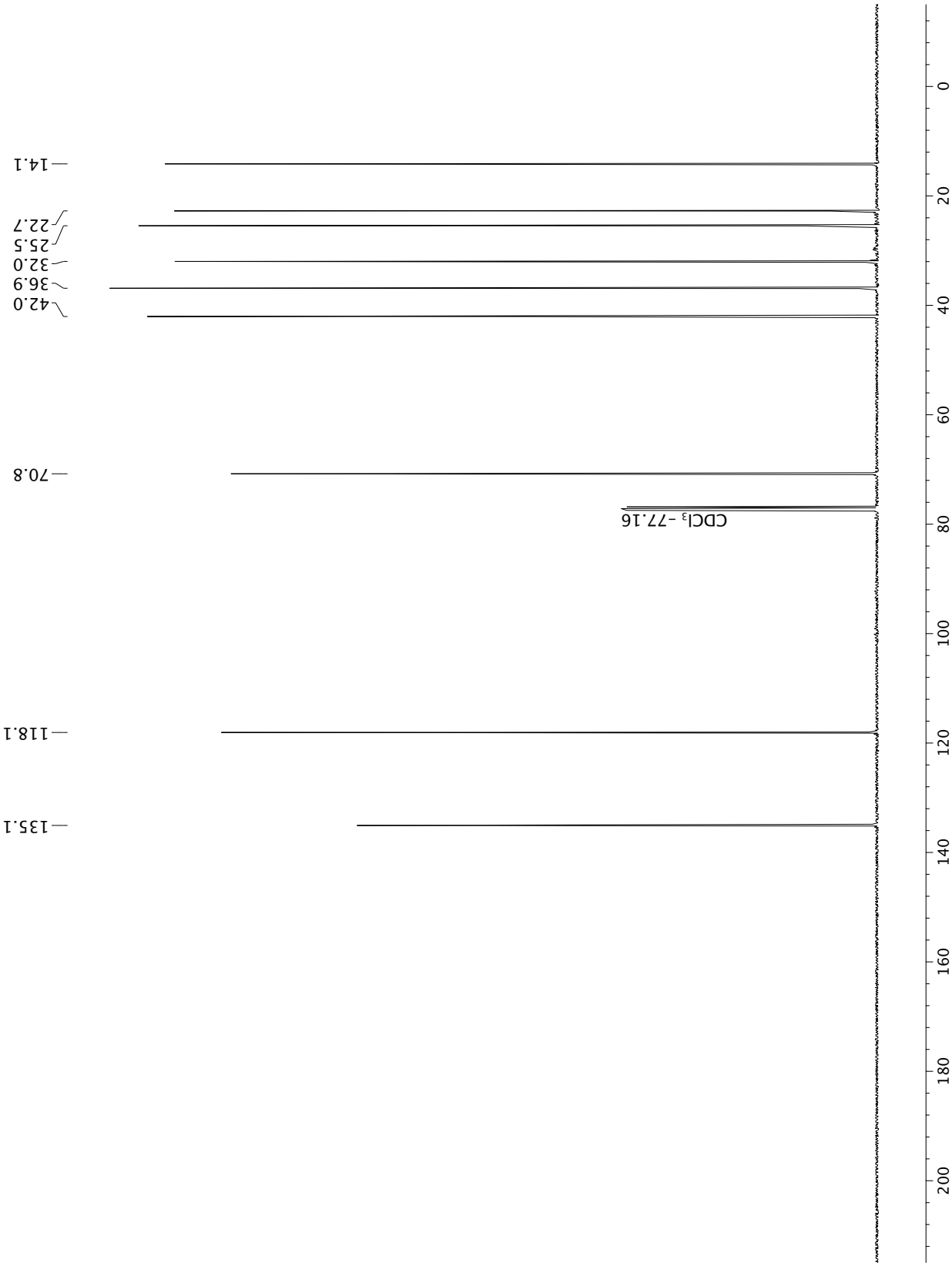
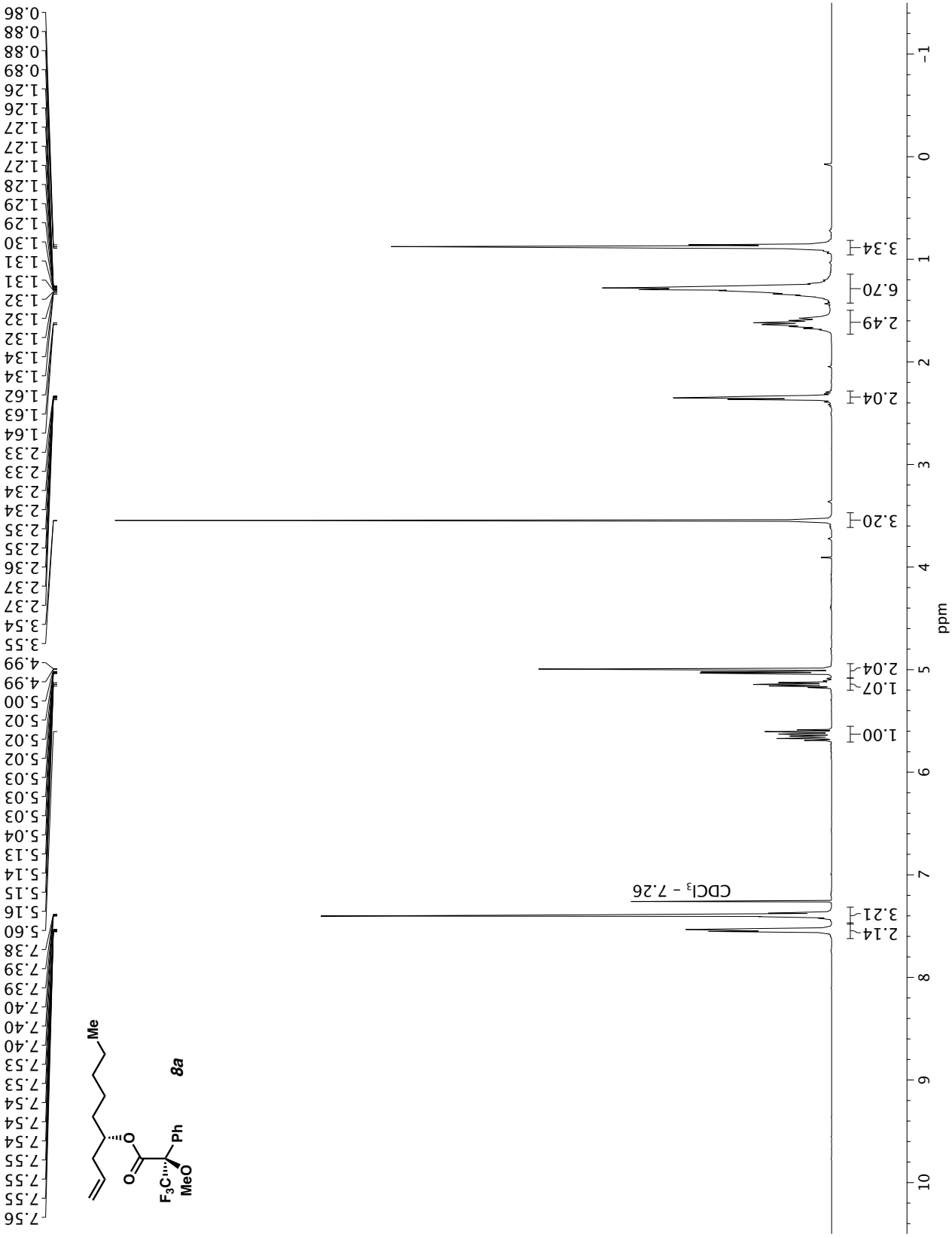
IV. ^{1}H and ^{13}C NMR Spectral Data



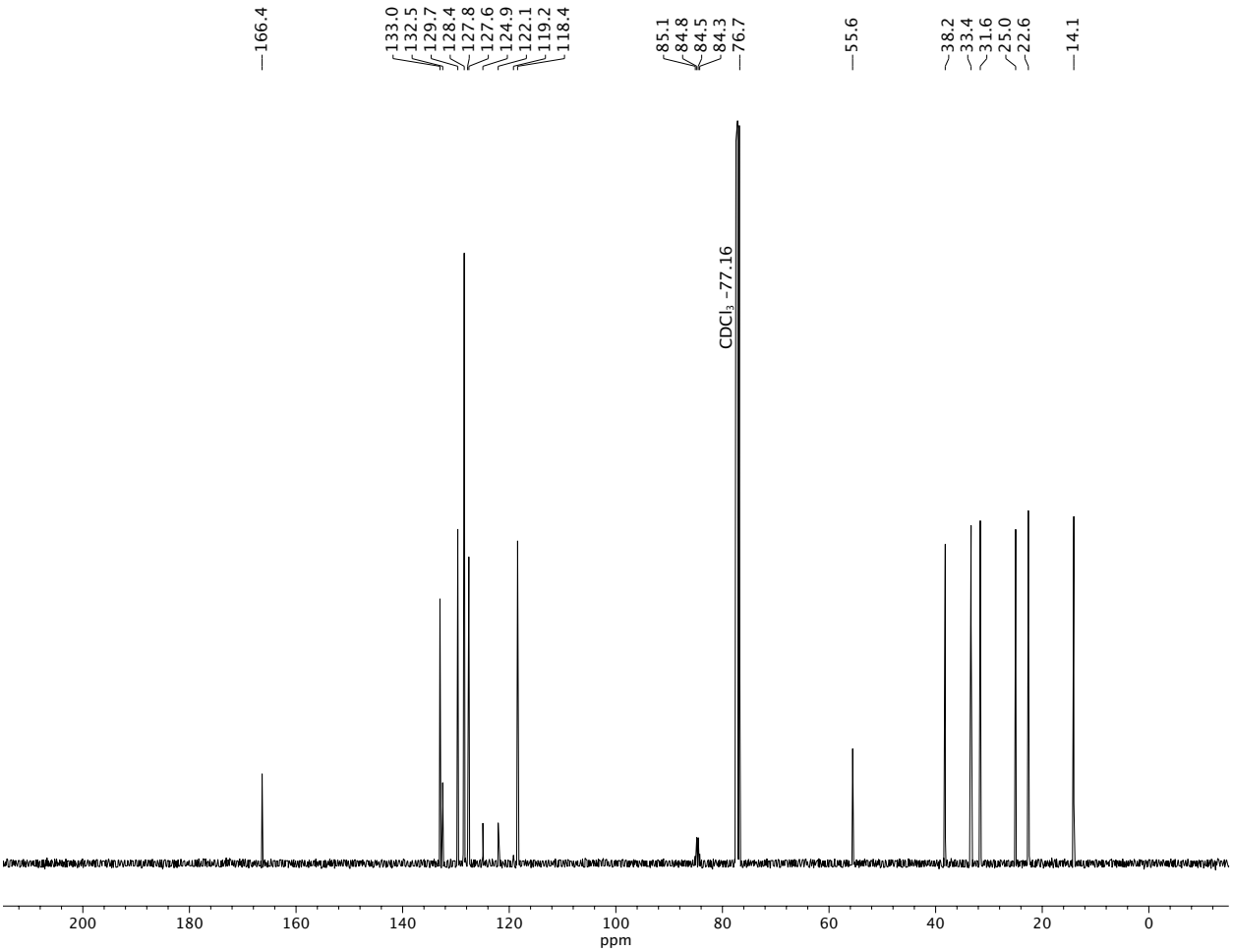
^{1}H NMR (400 MHz, $CDCl_3$) of compound **8**.



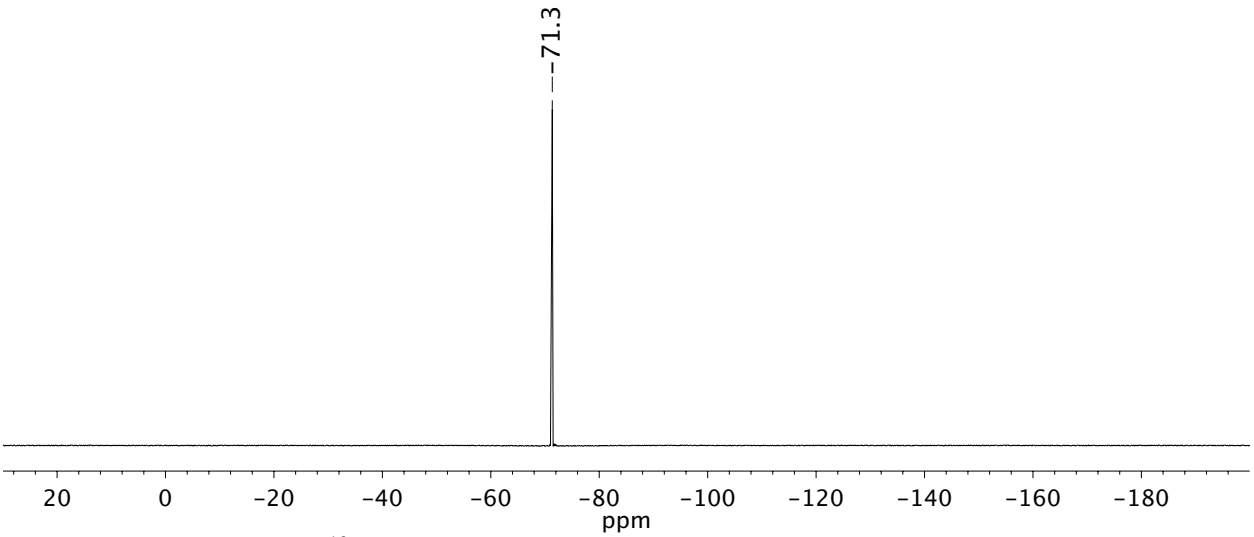
^{13}C NMR (101 MHz, $CDCl_3$) of compound **8**.



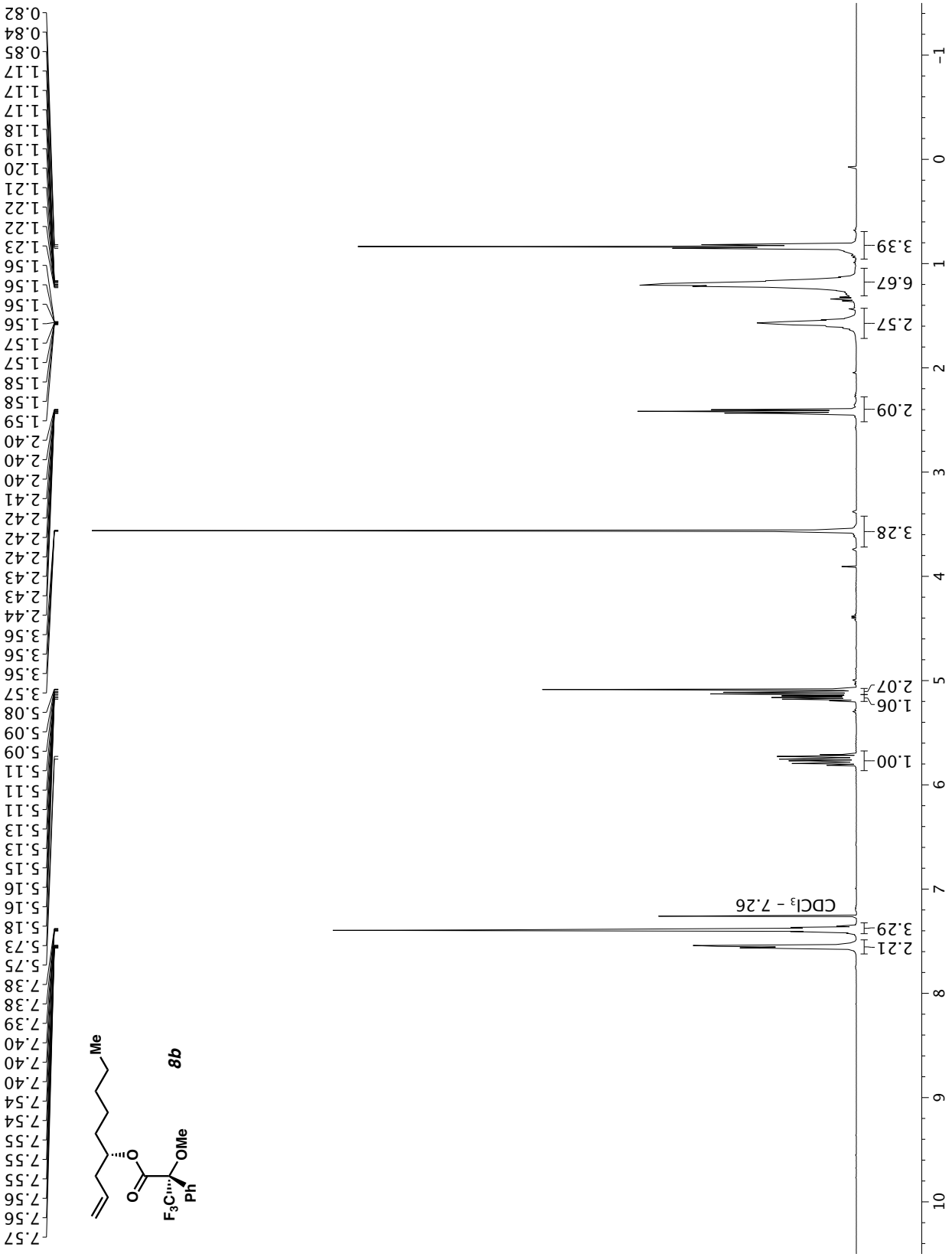
^{1}H NMR (400 MHz, $CDCl_3$) of compound **8a**.



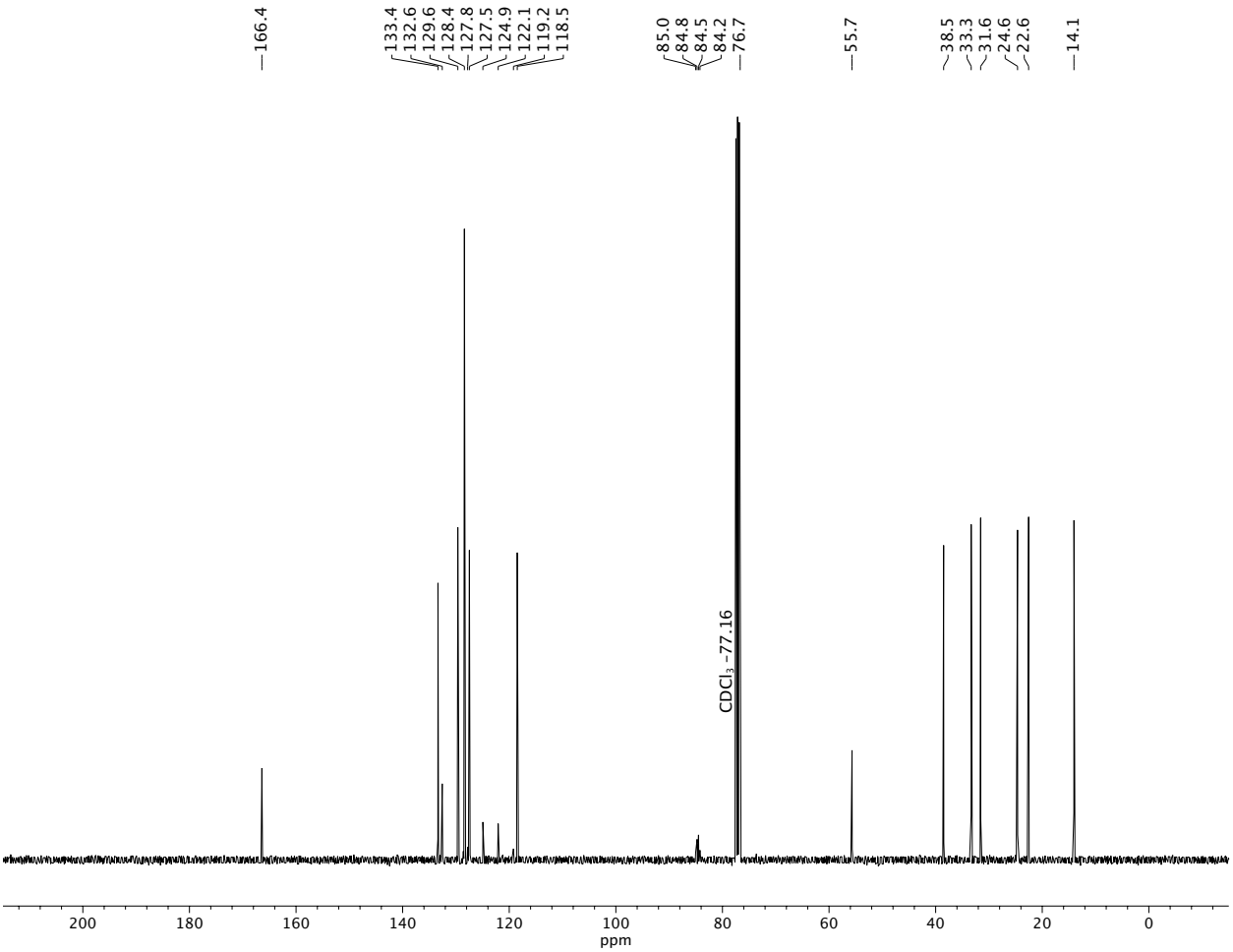
^{13}C NMR (101 MHz, $CDCl_3$) of compound **8a**.



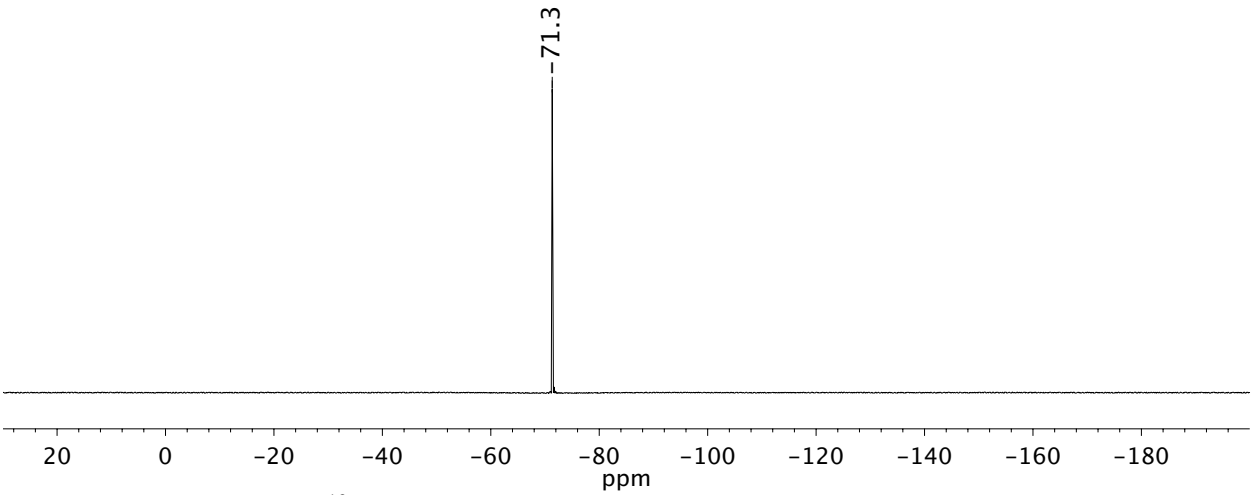
^{19}F NMR (282 MHz, $CDCl_3$) of compound **8a**.



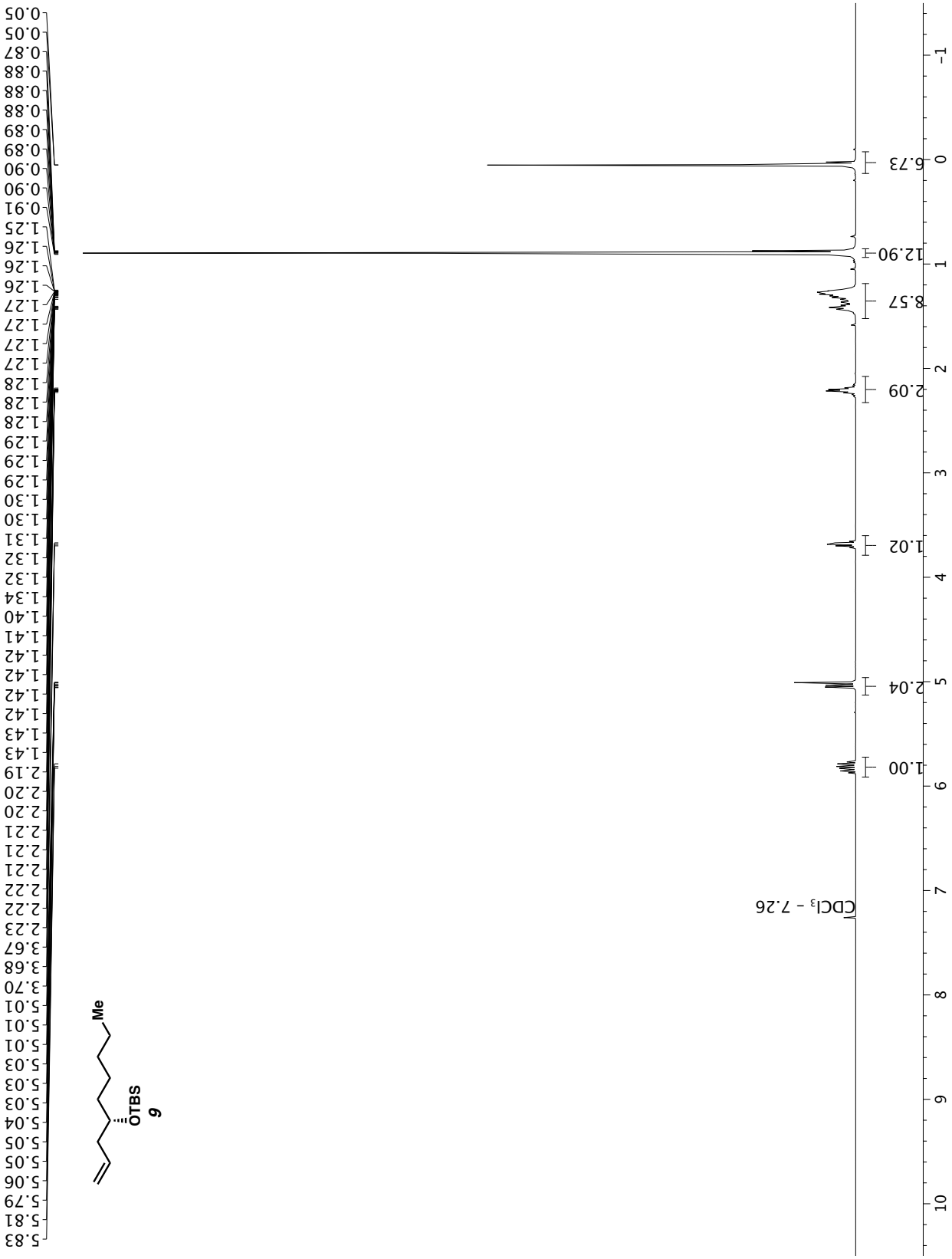
^{1}H NMR (400 MHz, $CDCl_3$) of compound **8b**.



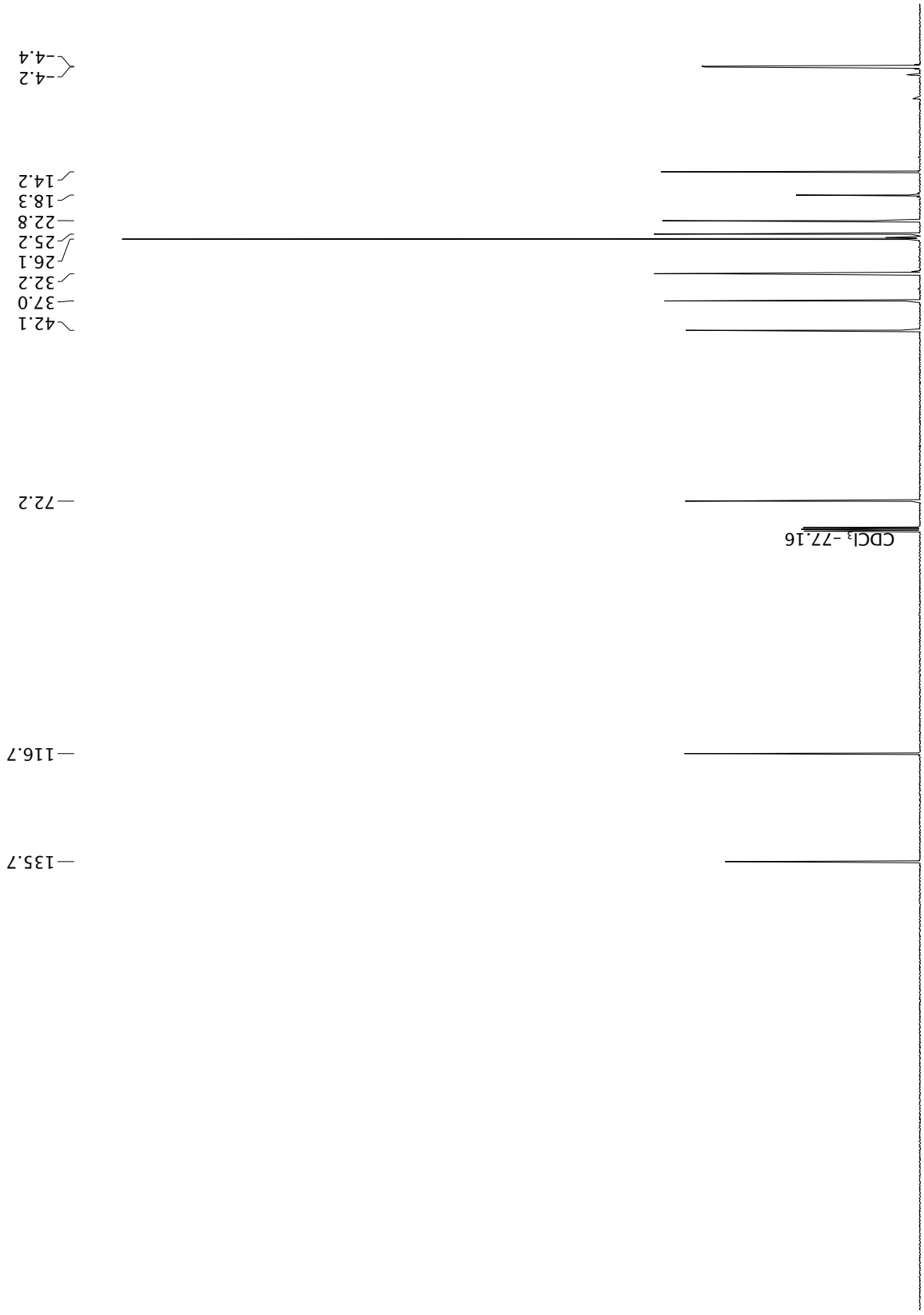
^{13}C NMR (101 MHz, $CDCl_3$) of compound **8b**.



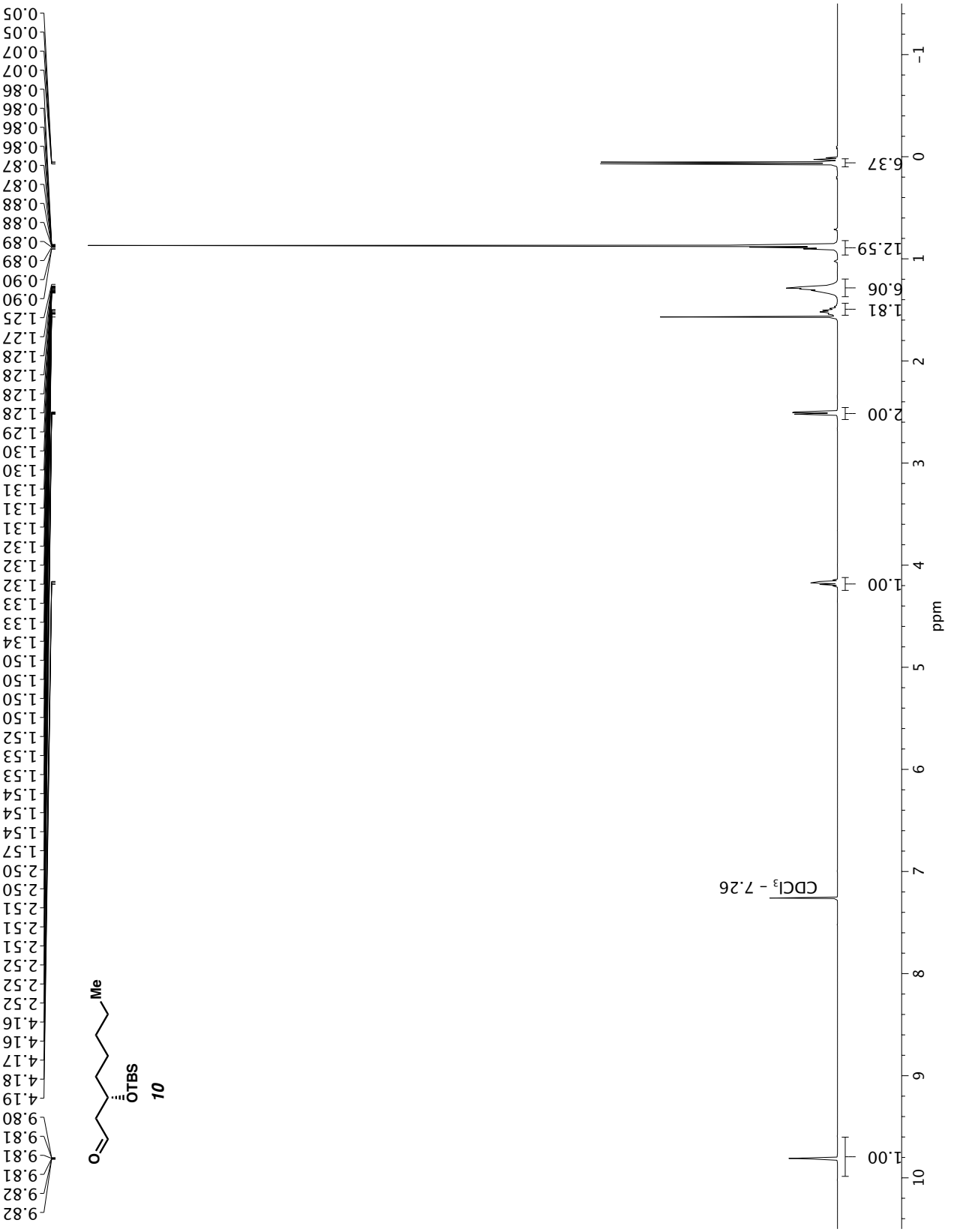
^{19}F NMR (282 MHz, $CDCl_3$) of compound **8b**.



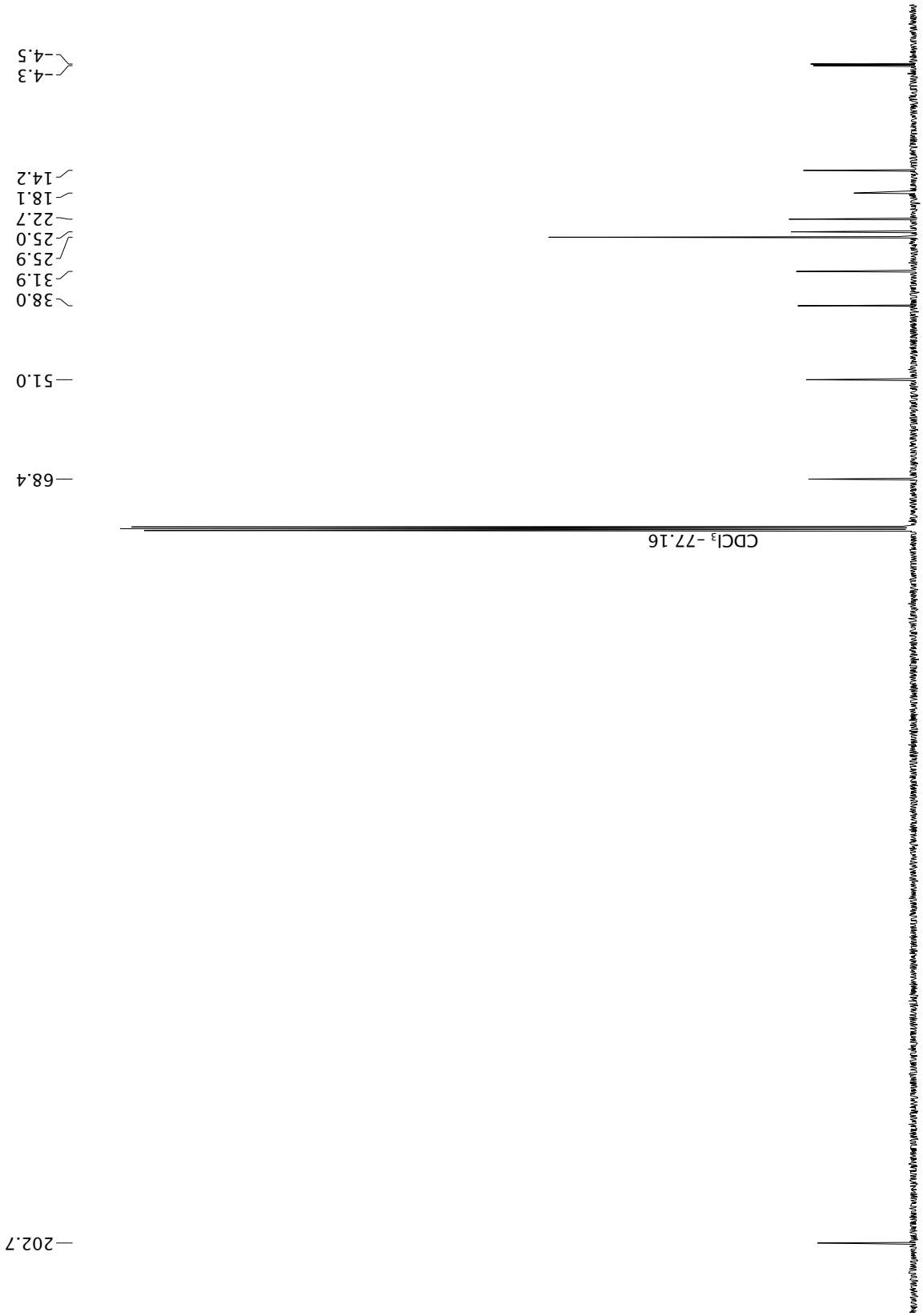
^{1}H NMR (400 MHz, $CDCl_3$) of compound **9**.



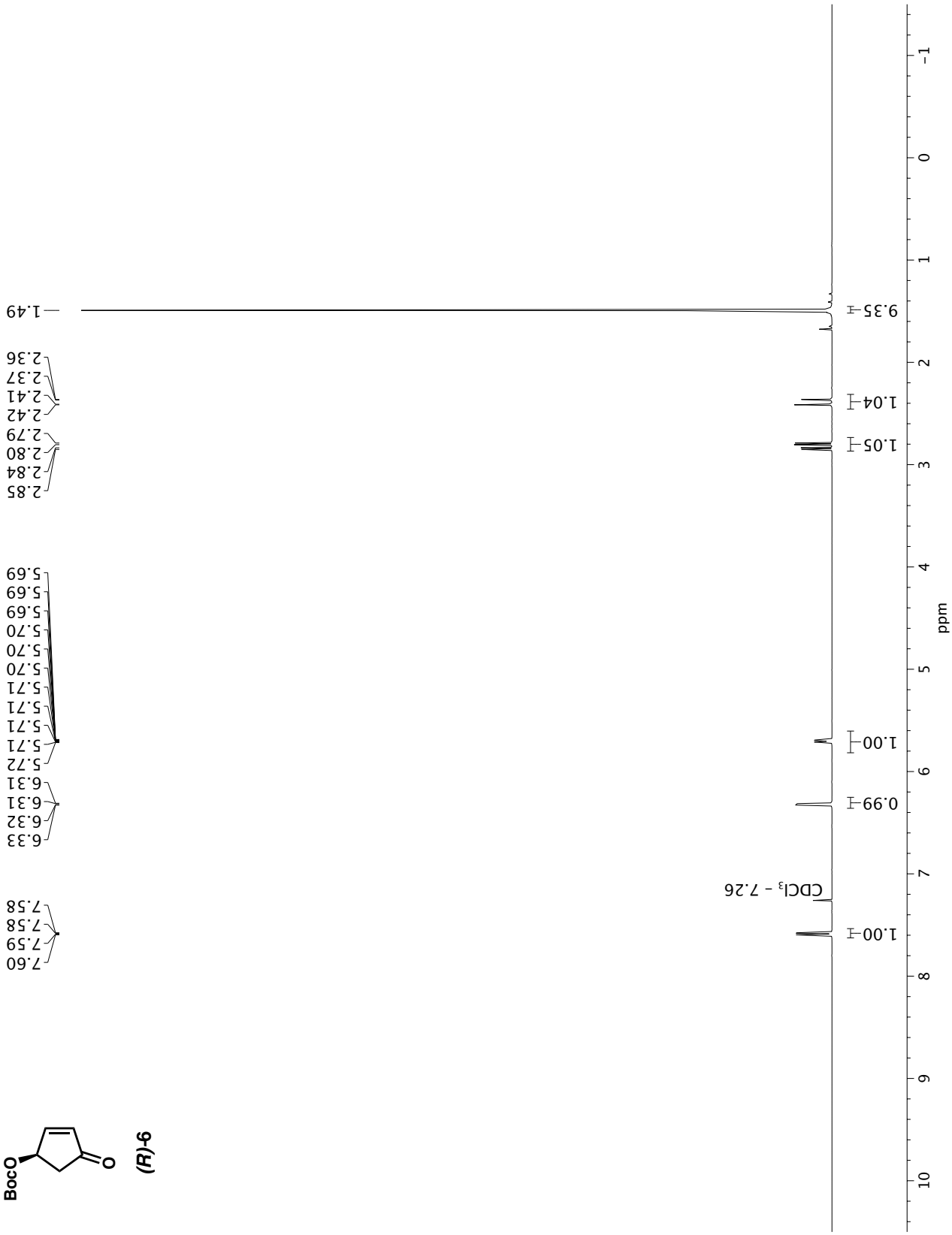
^{13}C NMR (101 MHz, $CDCl_3$) of compound **9**.



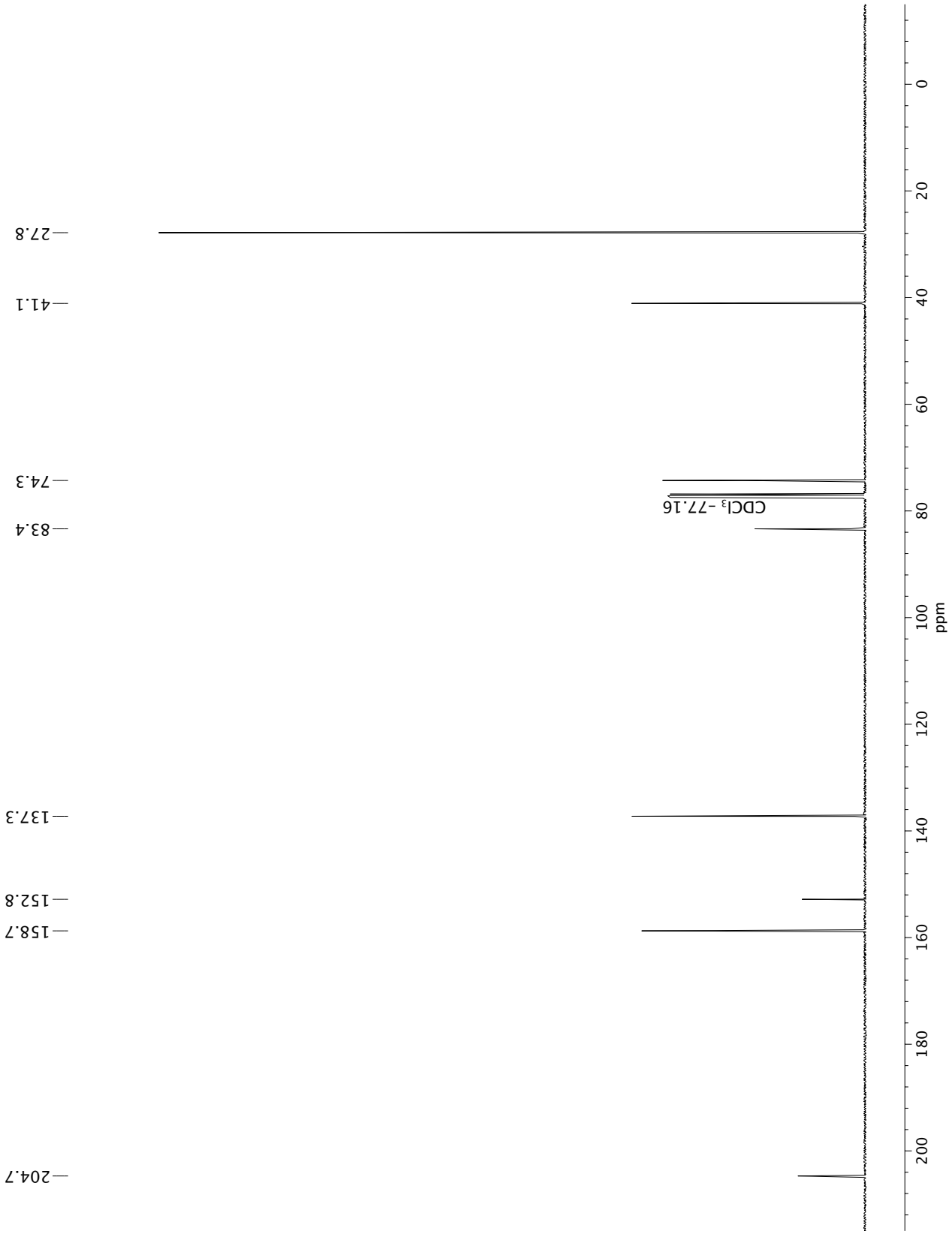
^{1}H NMR (400 MHz, $CDCl_3$) of compound **10**.



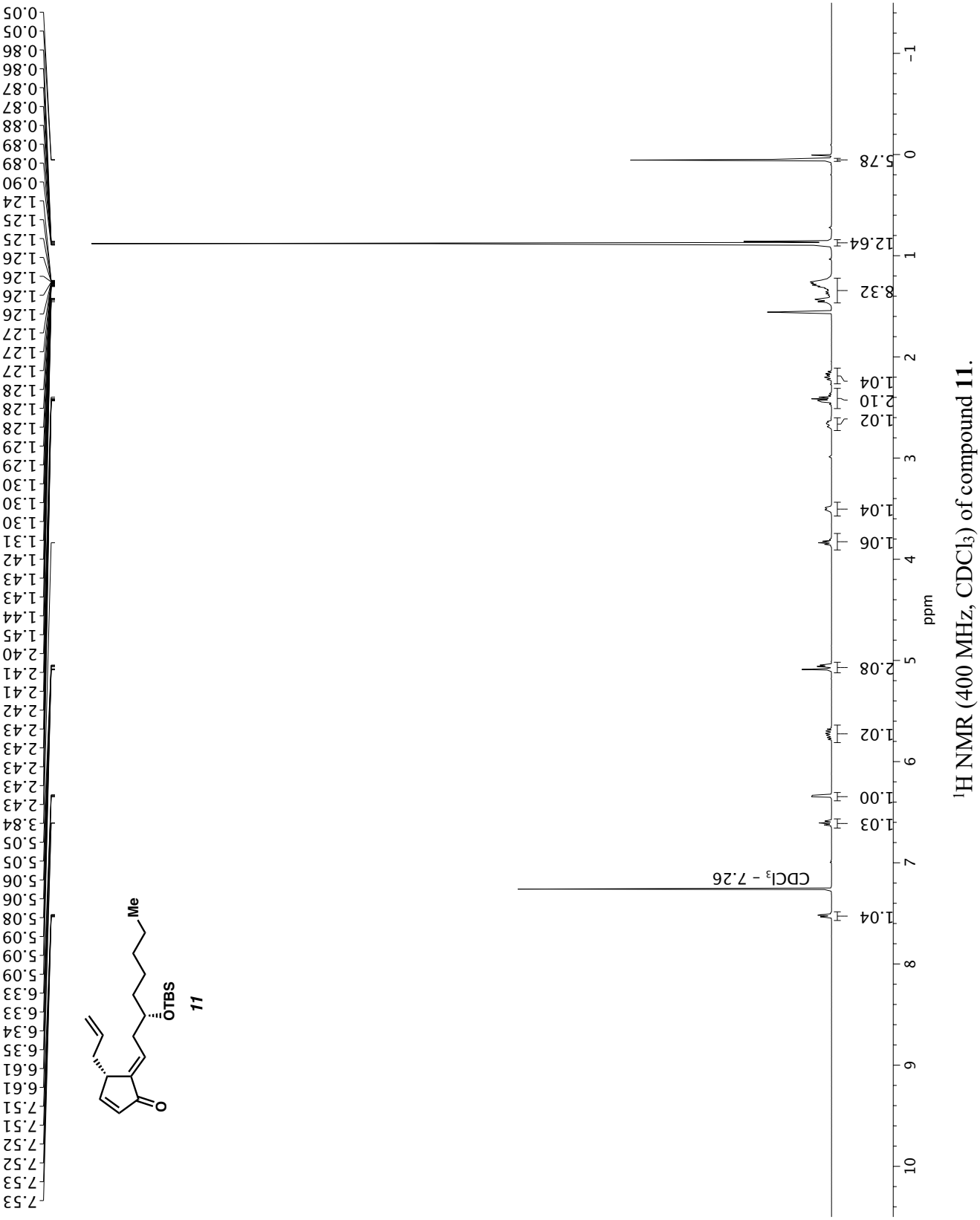
^{13}C NMR (101 MHz, $CDCl_3$) of compound **10**.



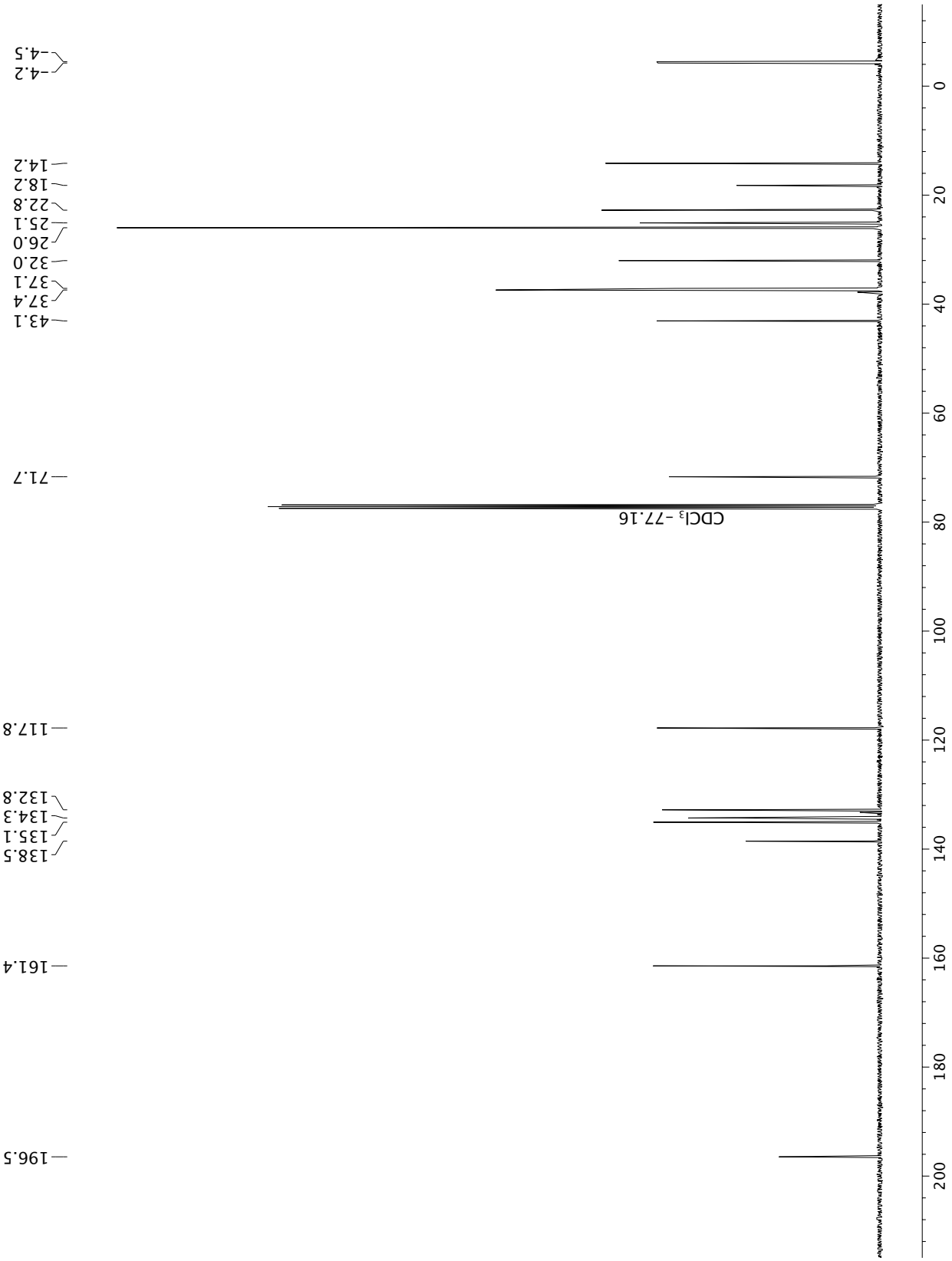
^{1}H NMR (400 MHz, $CDCl_3$) of compound ***(R)*-6**.



^{13}C NMR (101 MHz, $CDCl_3$) of compound ***(R)*-6**.



^{1}H NMR (400 MHz, $CDCl_3$) of compound **11**.



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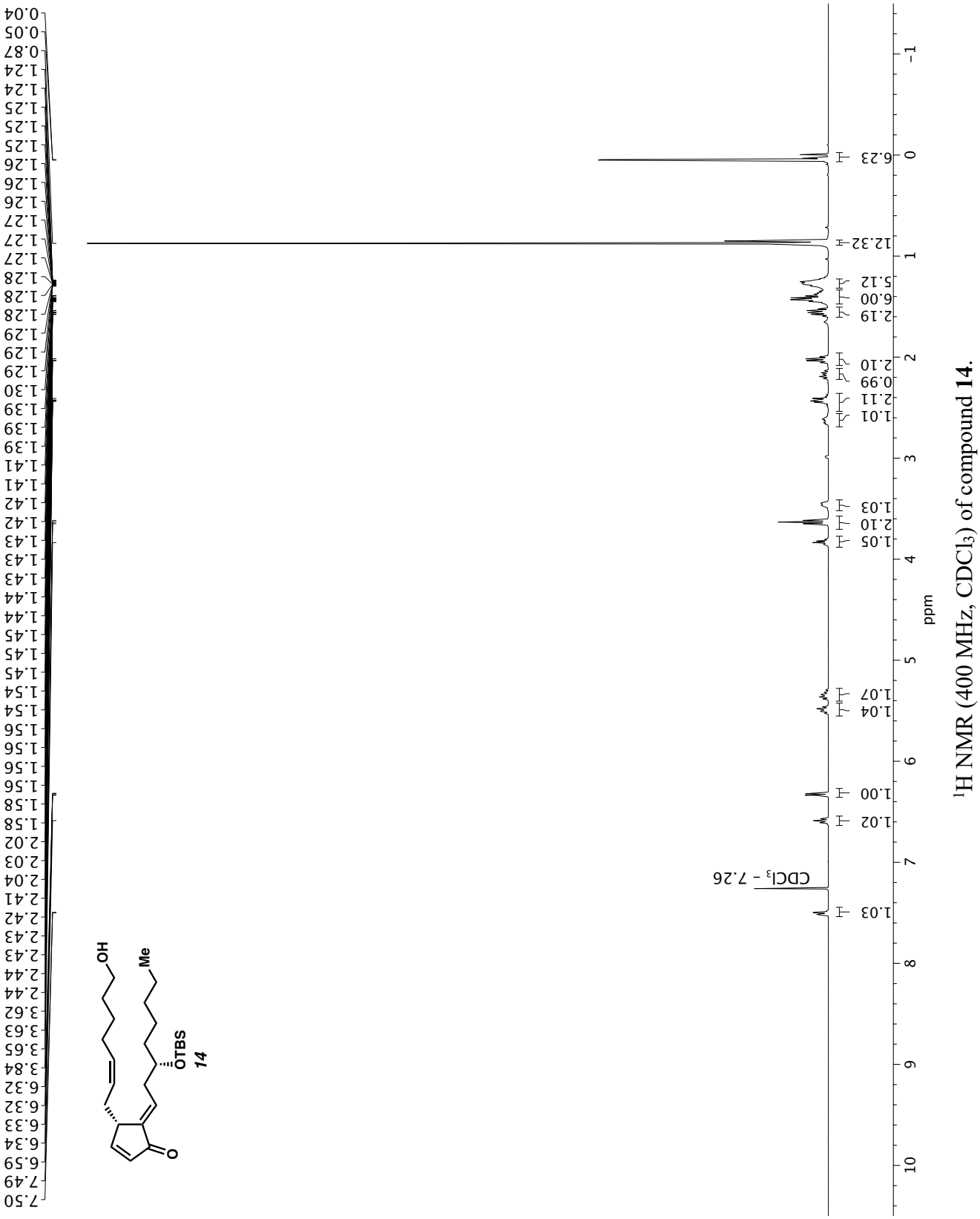
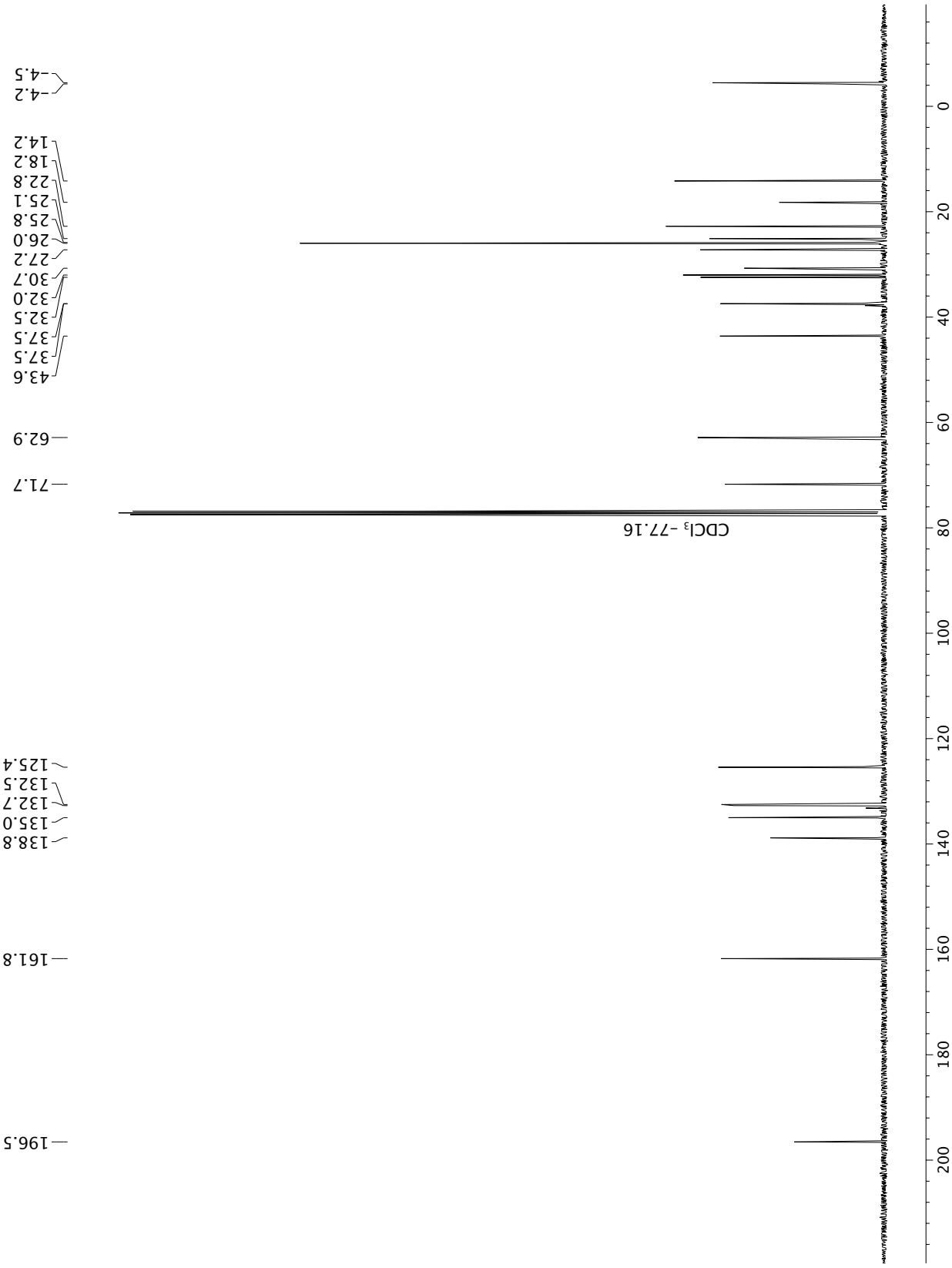
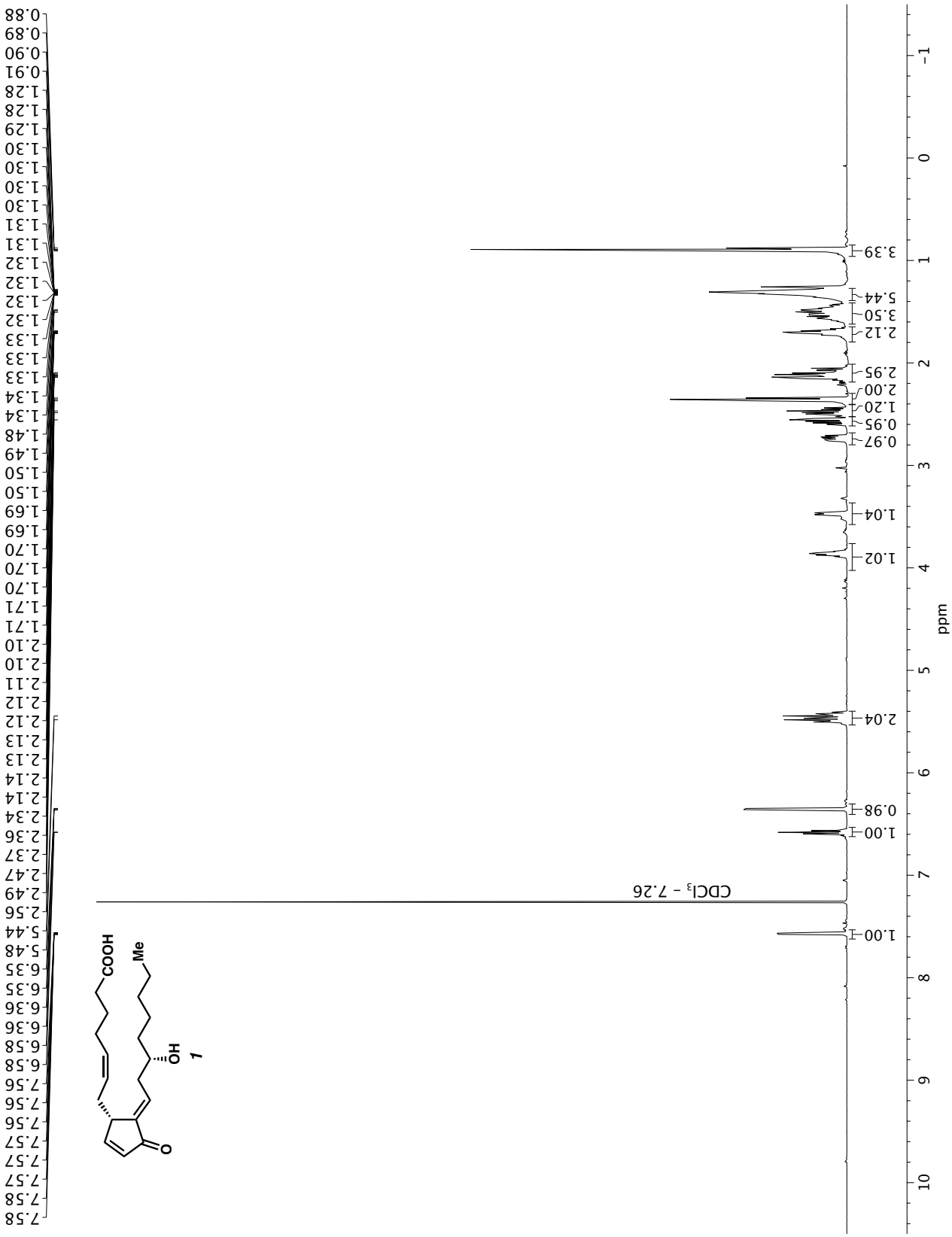


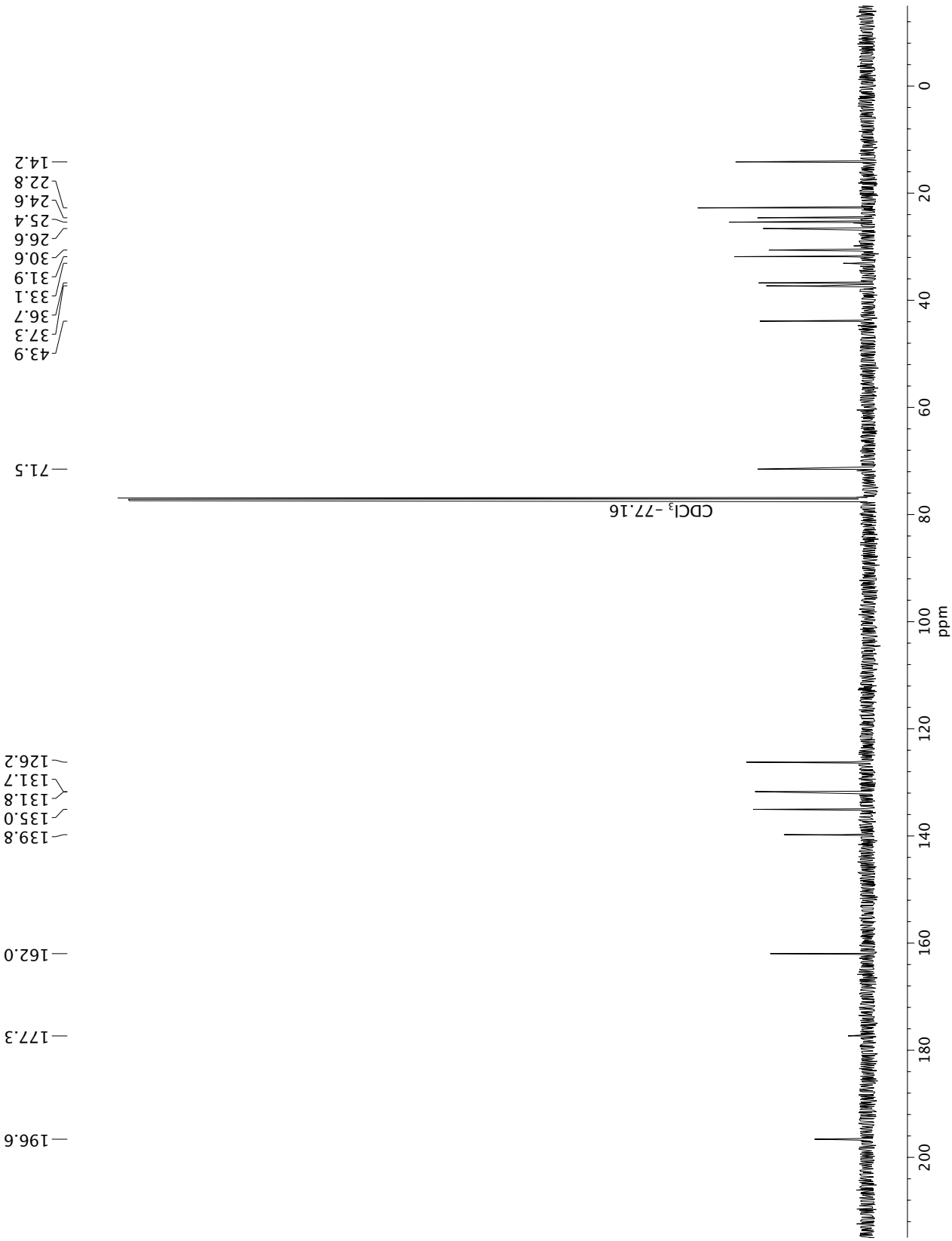
^{1}H NMR (400 MHz, $CDCl_3$) of compound **14**.



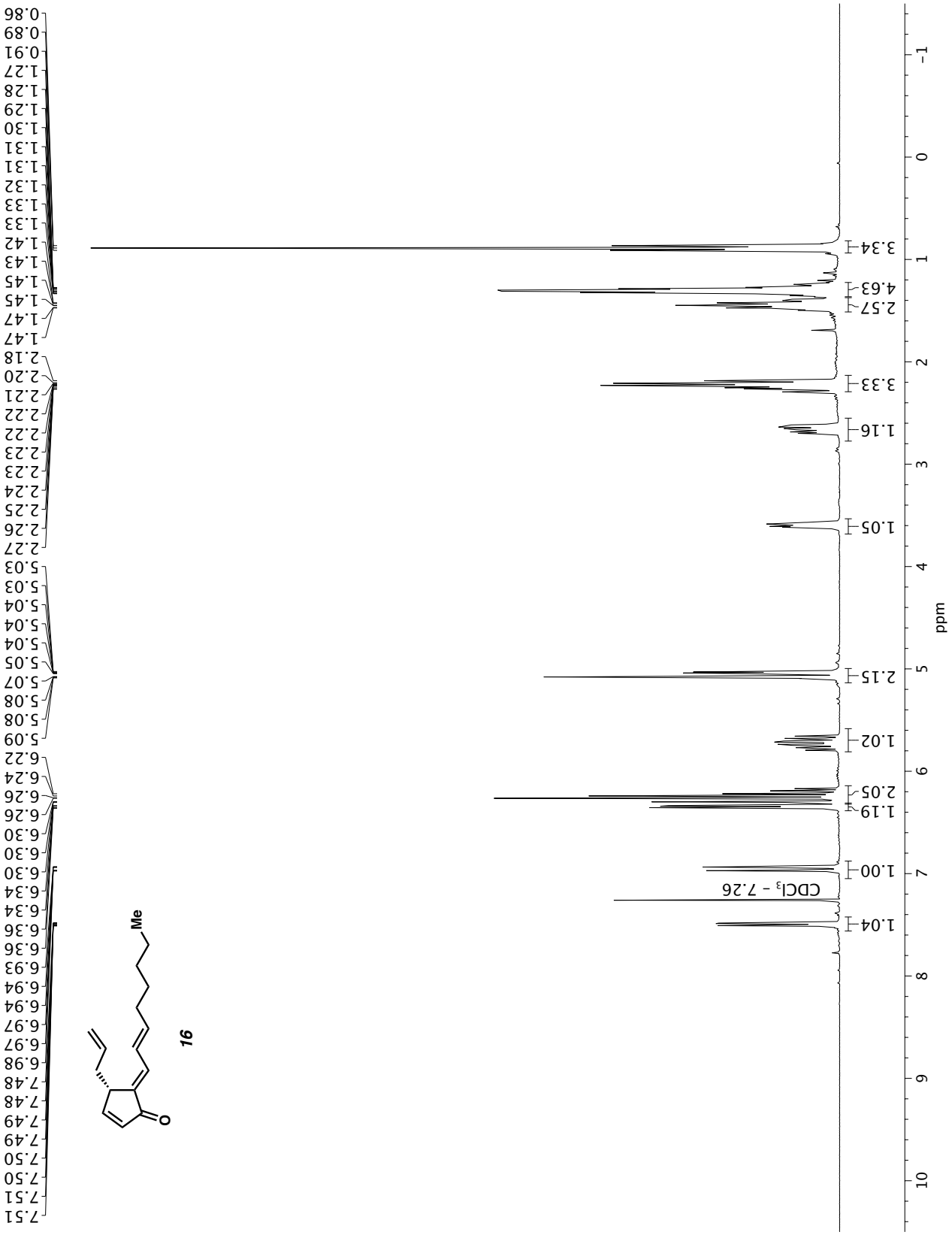
^{13}C NMR (101 MHz, $CDCl_3$) of compound **14**.



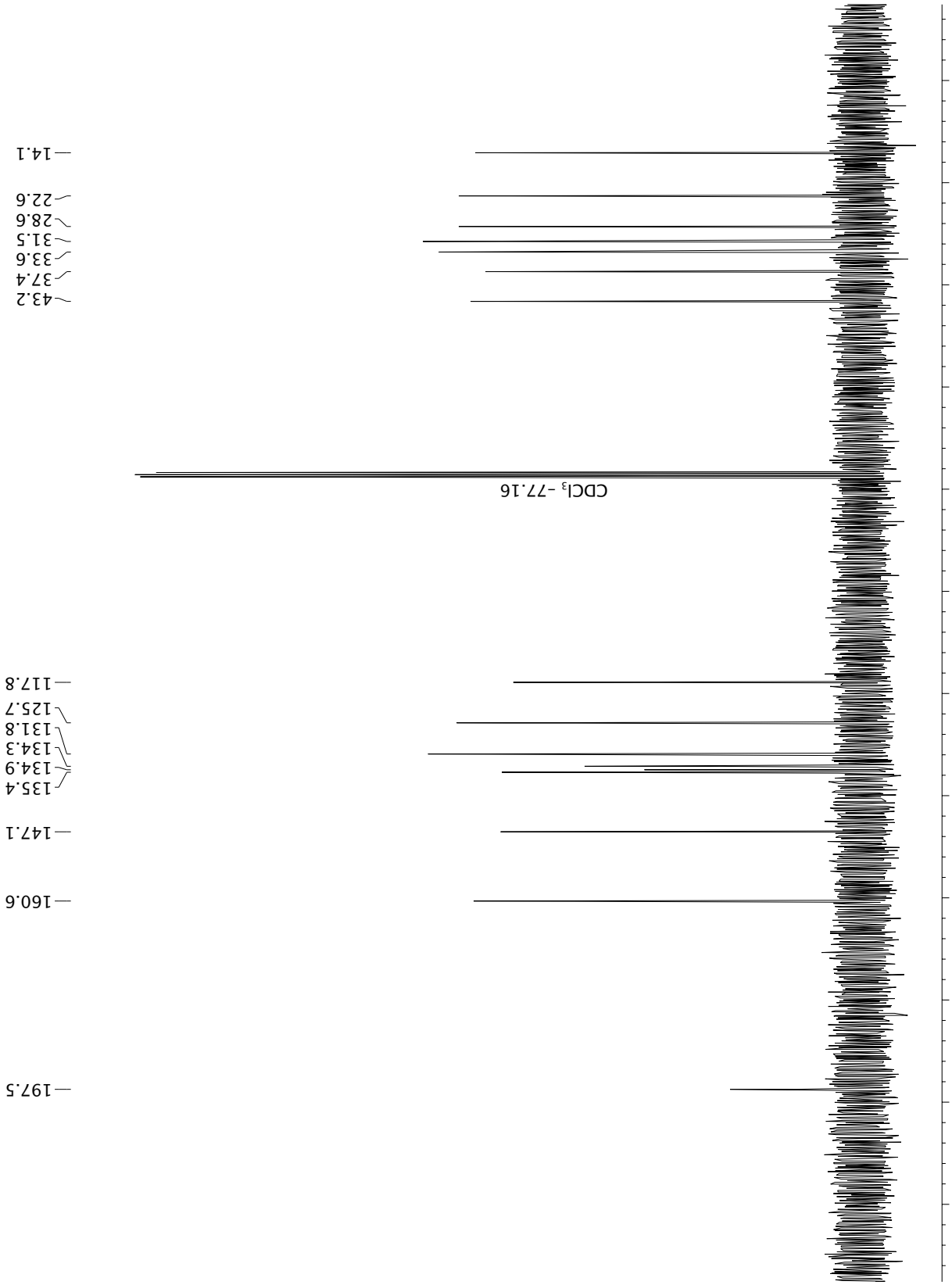
^{1}H NMR (500 MHz, $CDCl_3$) of compound **1**.



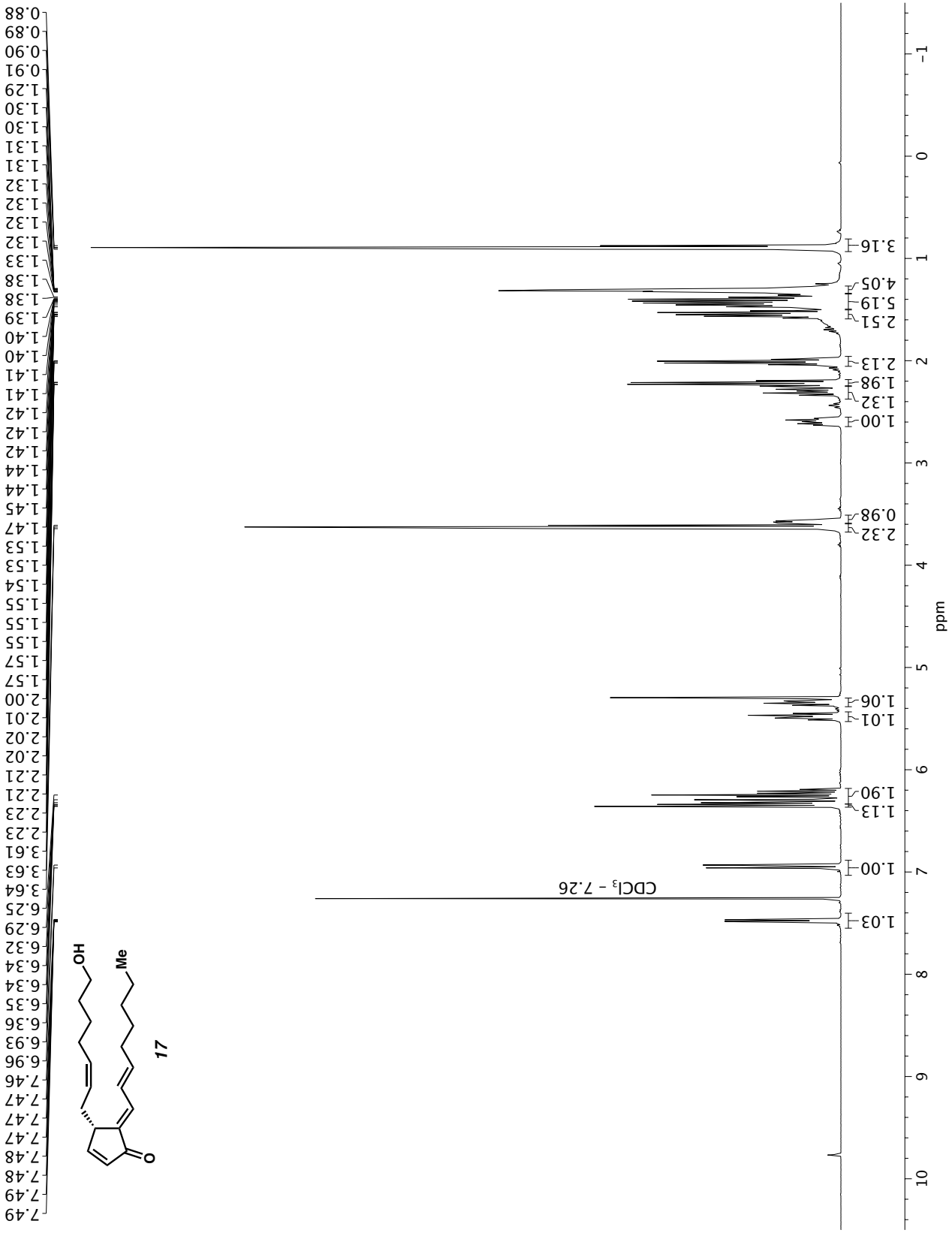
^{13}C NMR (126 MHz, $CDCl_3$) of compound **1**.



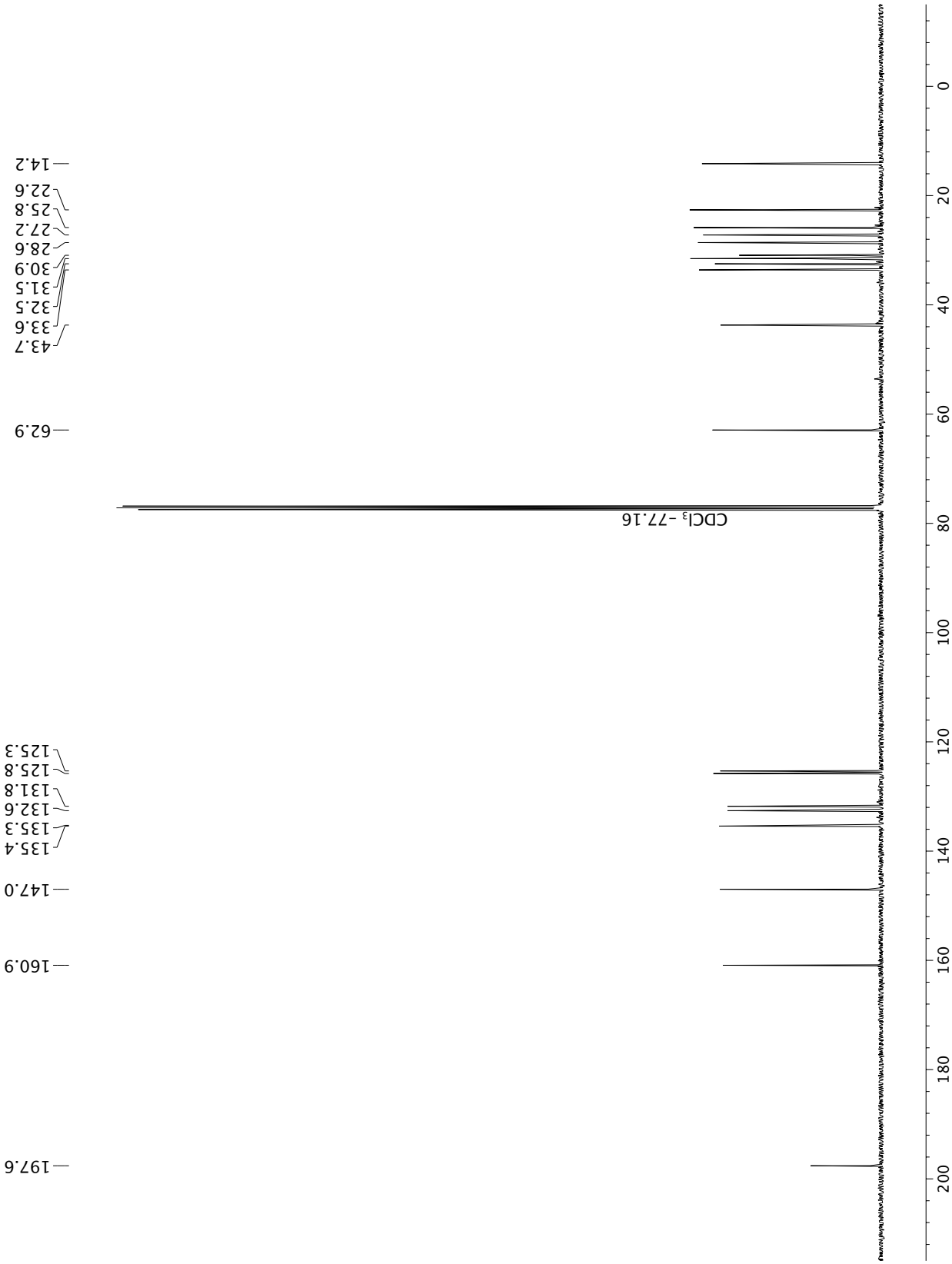
^{1}H NMR (400 MHz, $CDCl_3$) of compound **16**.



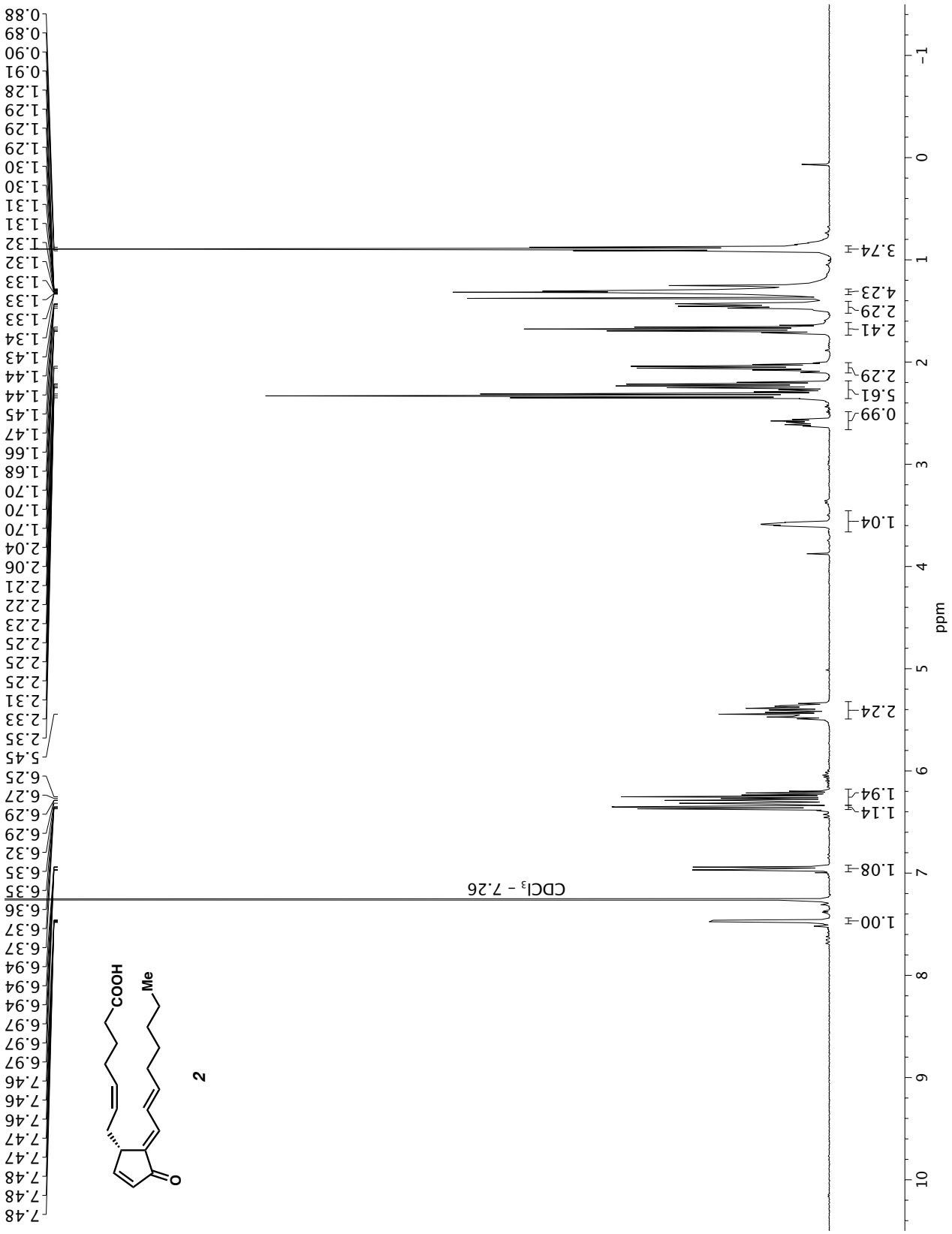
^{13}C NMR (101 MHz, $CDCl_3$) of compound **16**.



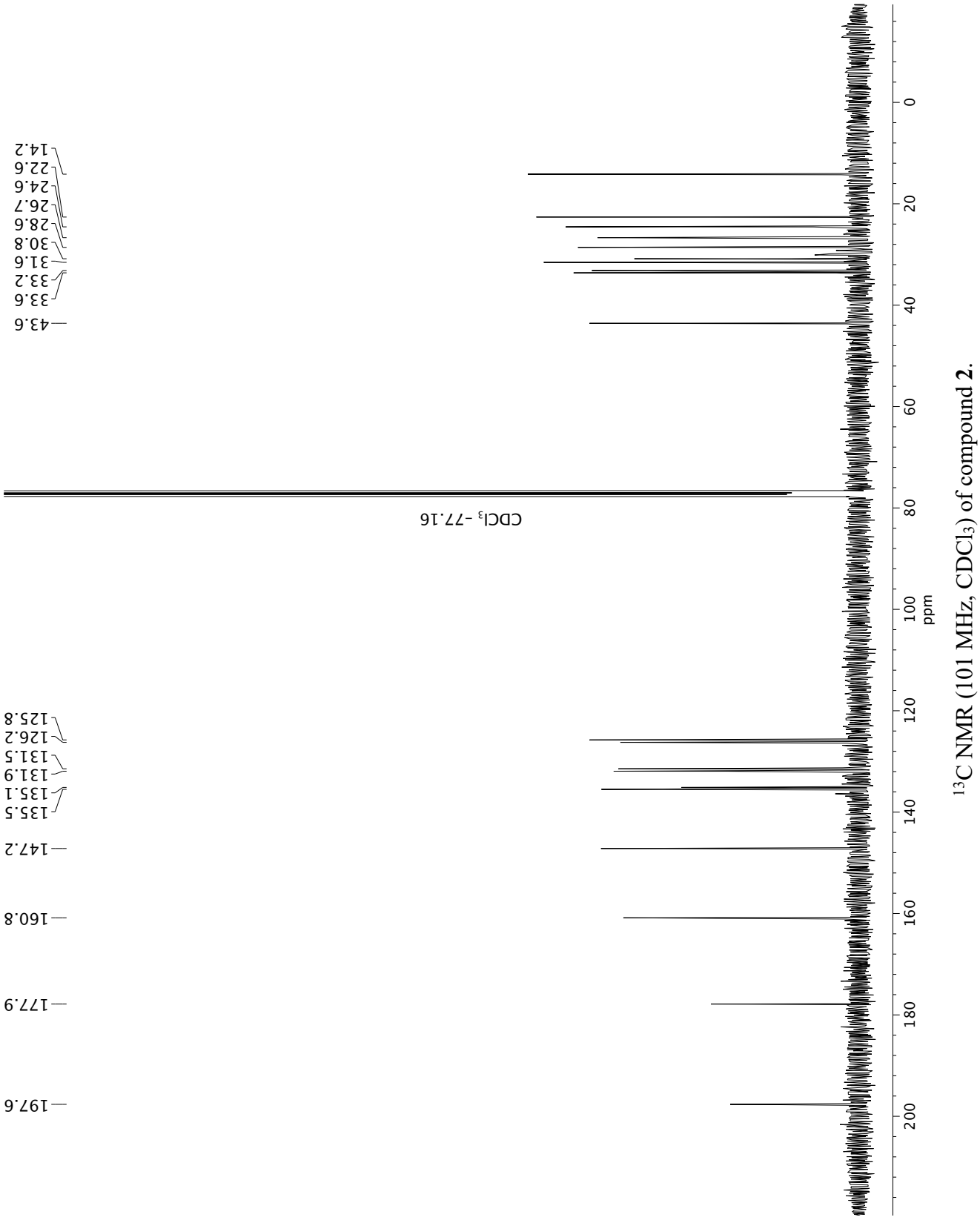
^{1}H NMR (400 MHz, $CDCl_3$) of compound **17**.



^{13}C NMR (101 MHz, $CDCl_3$) of compound **17**.



^{1}H NMR (400 MHz, $CDCl_3$) of compound **2**.



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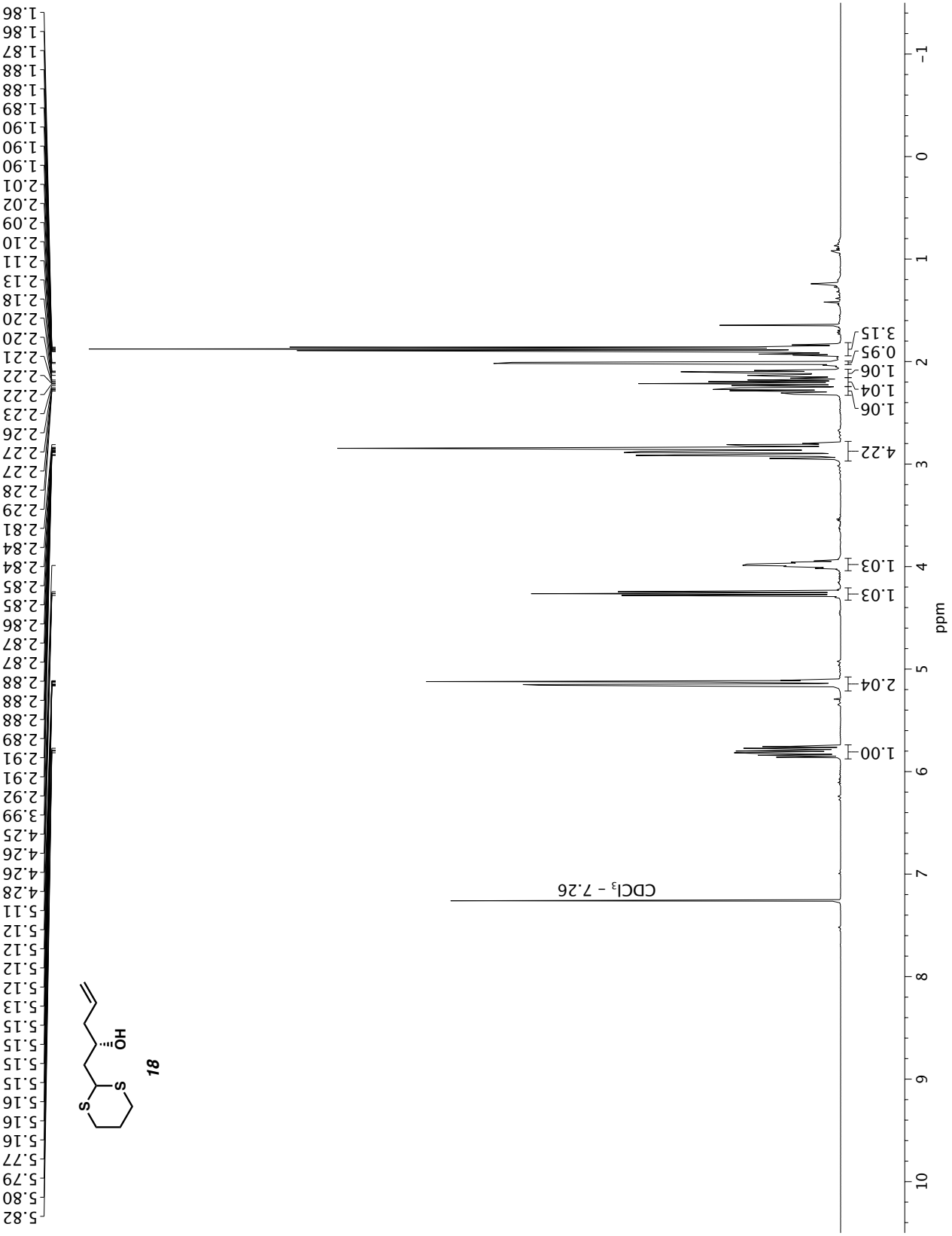
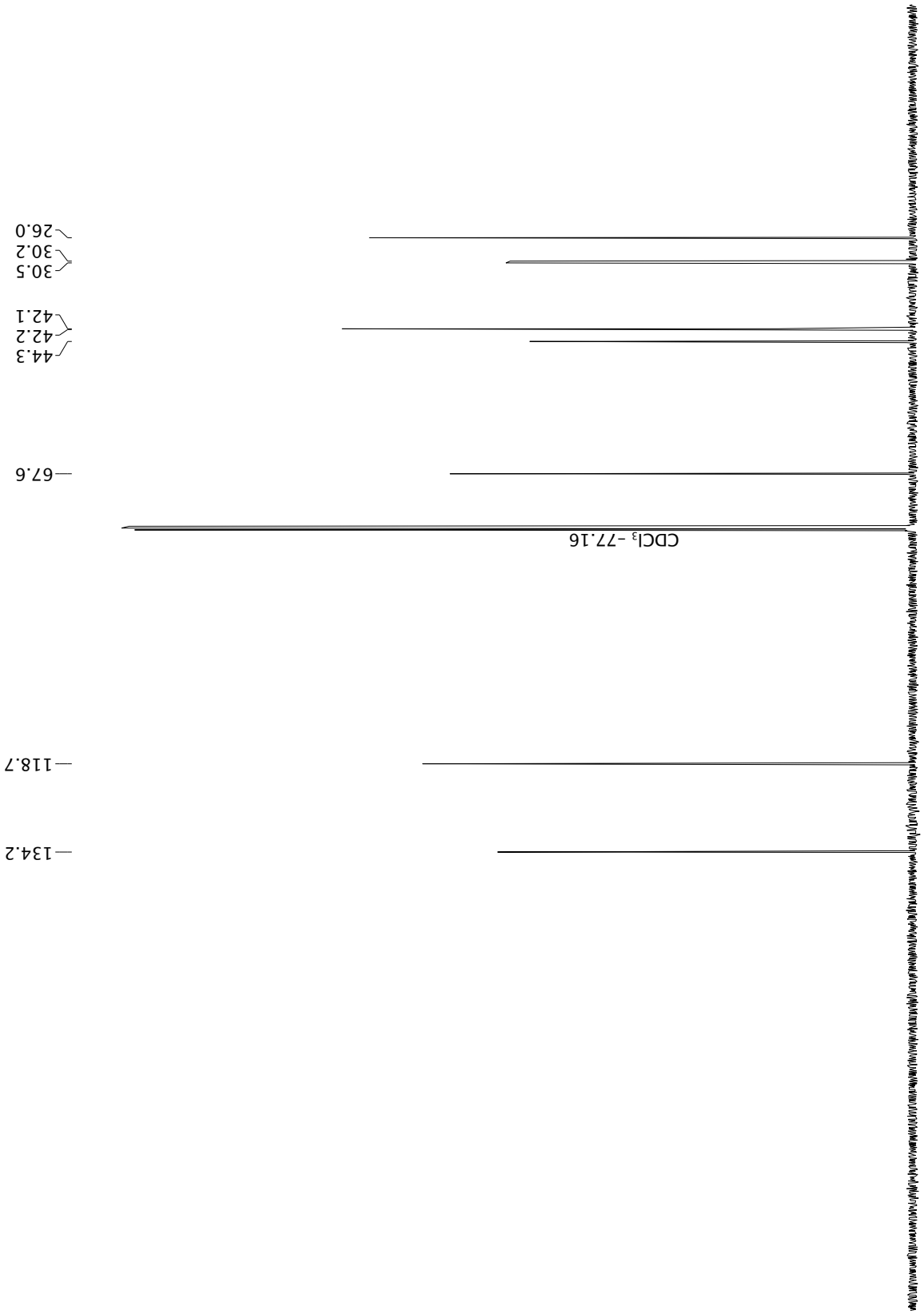
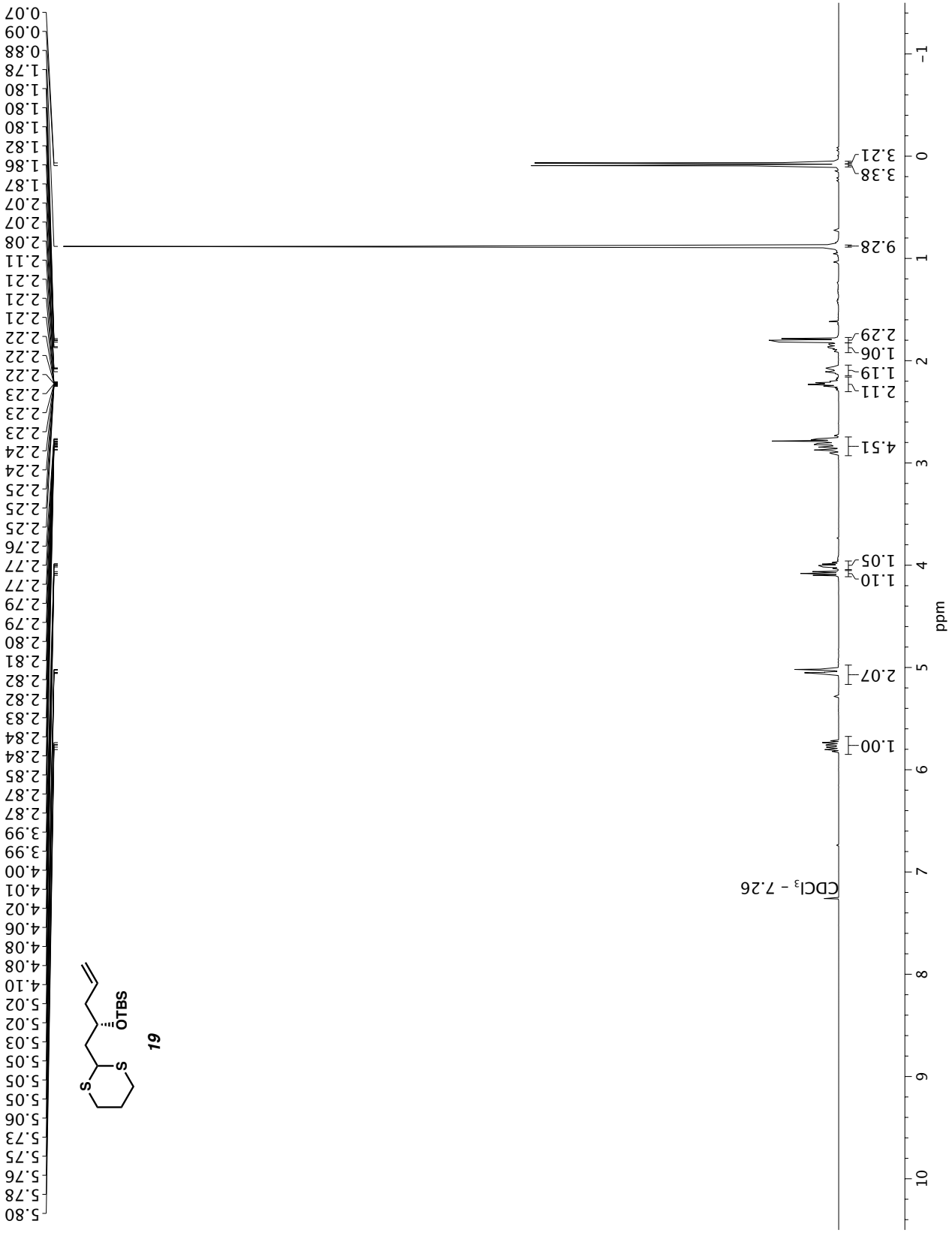


^{1}H NMR (400 MHz, $CDCl_3$) of compound **18**.



^{13}C NMR (101 MHz, $CDCl_3$) of compound **18**.



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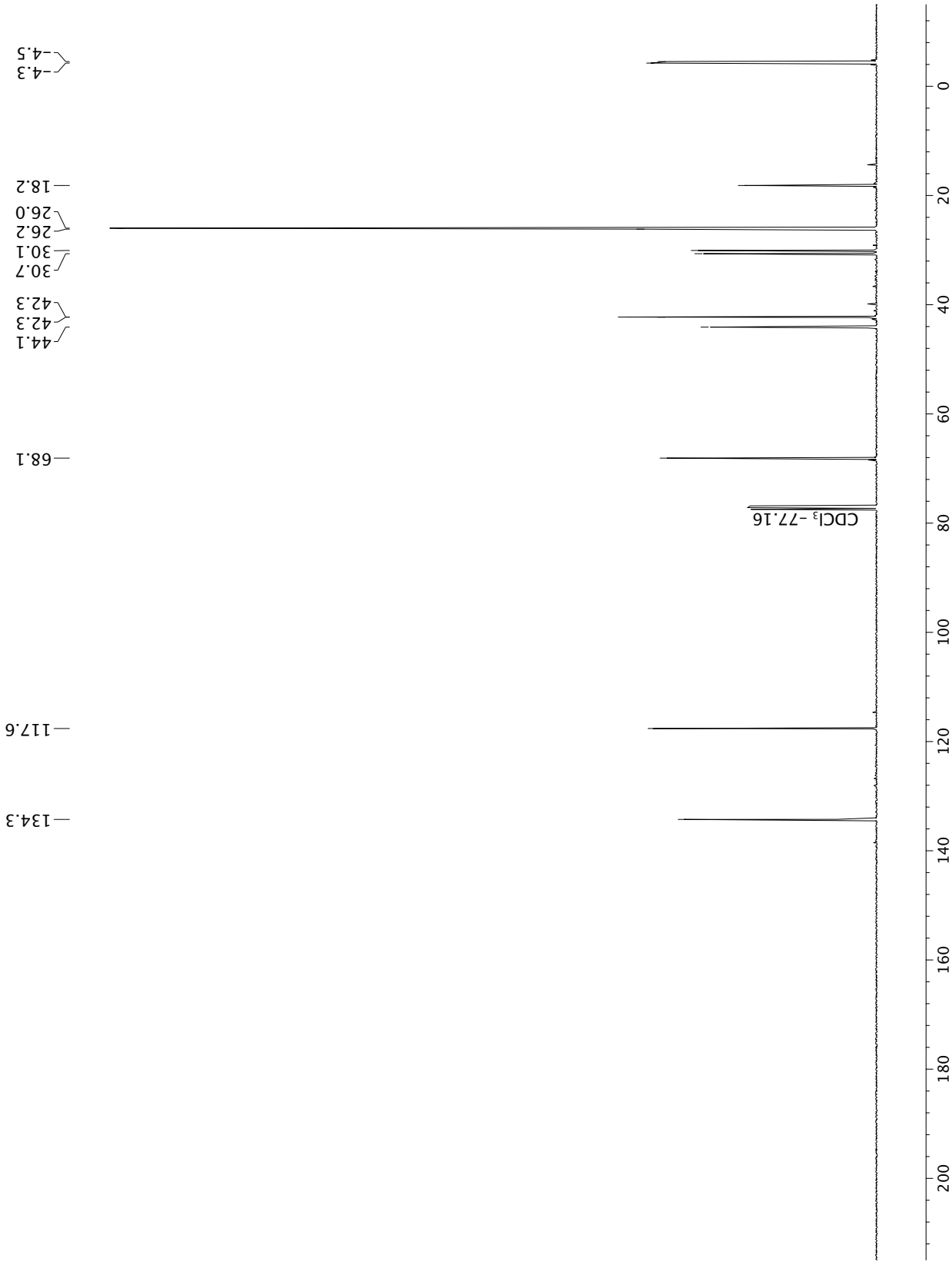
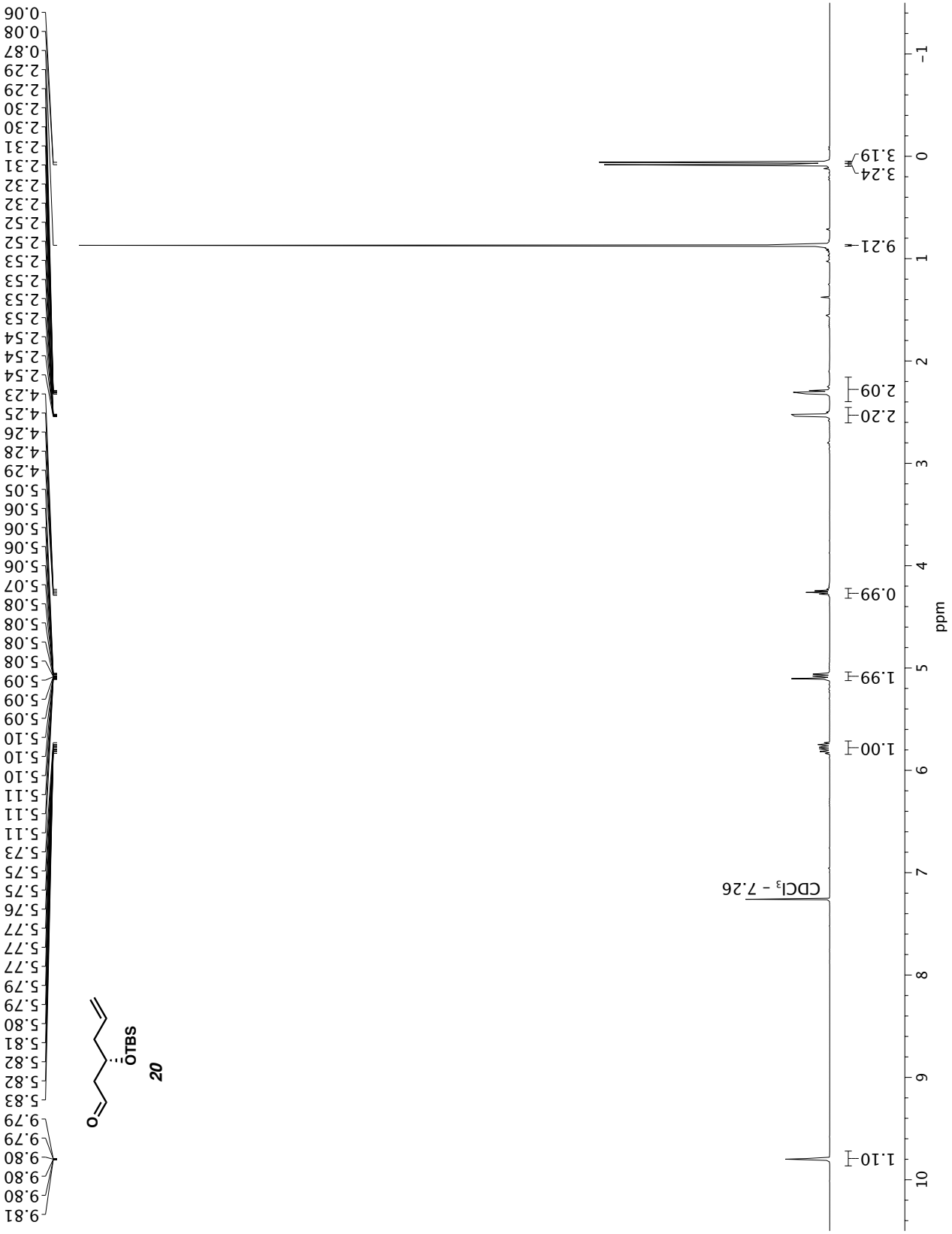
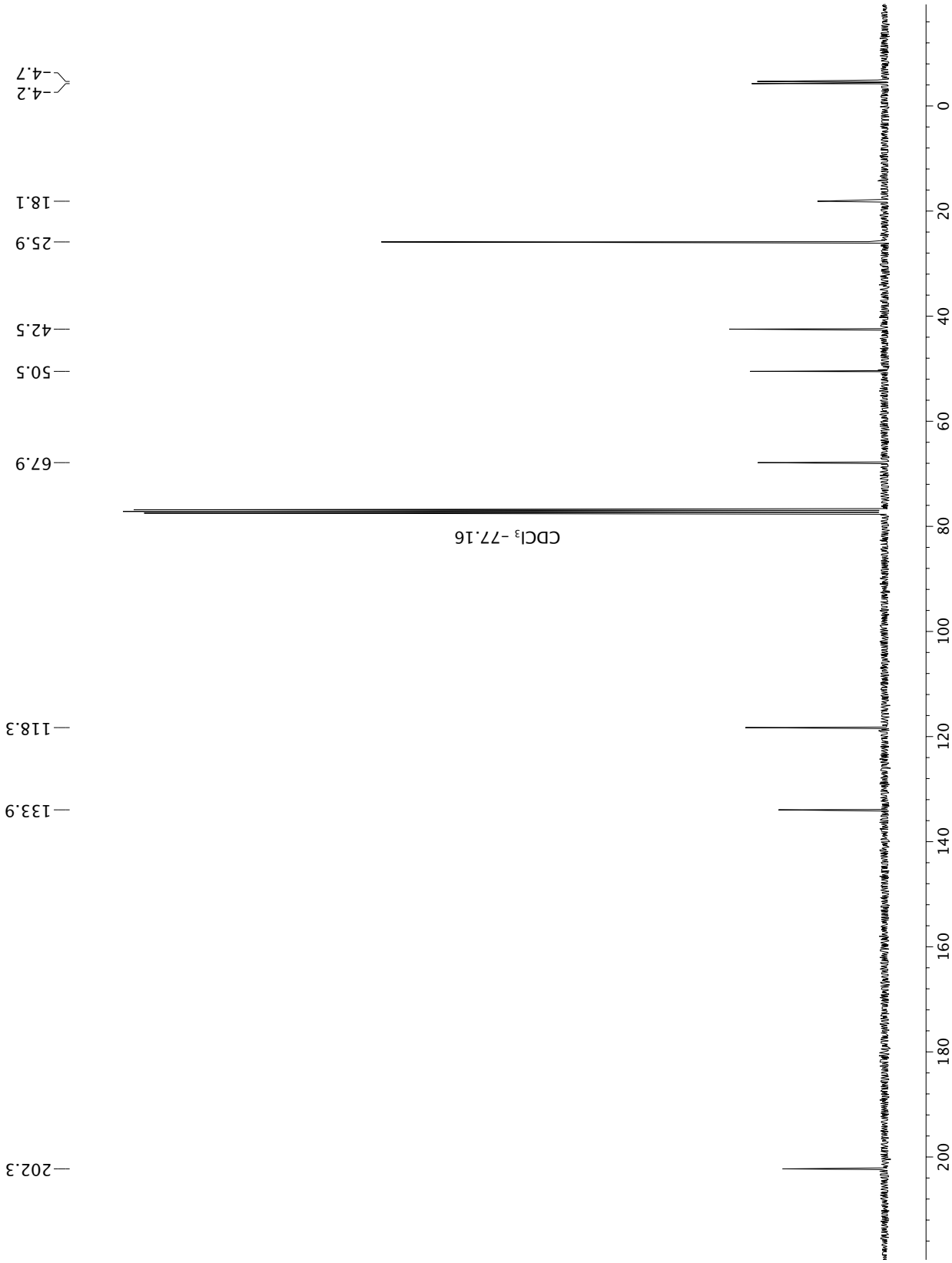


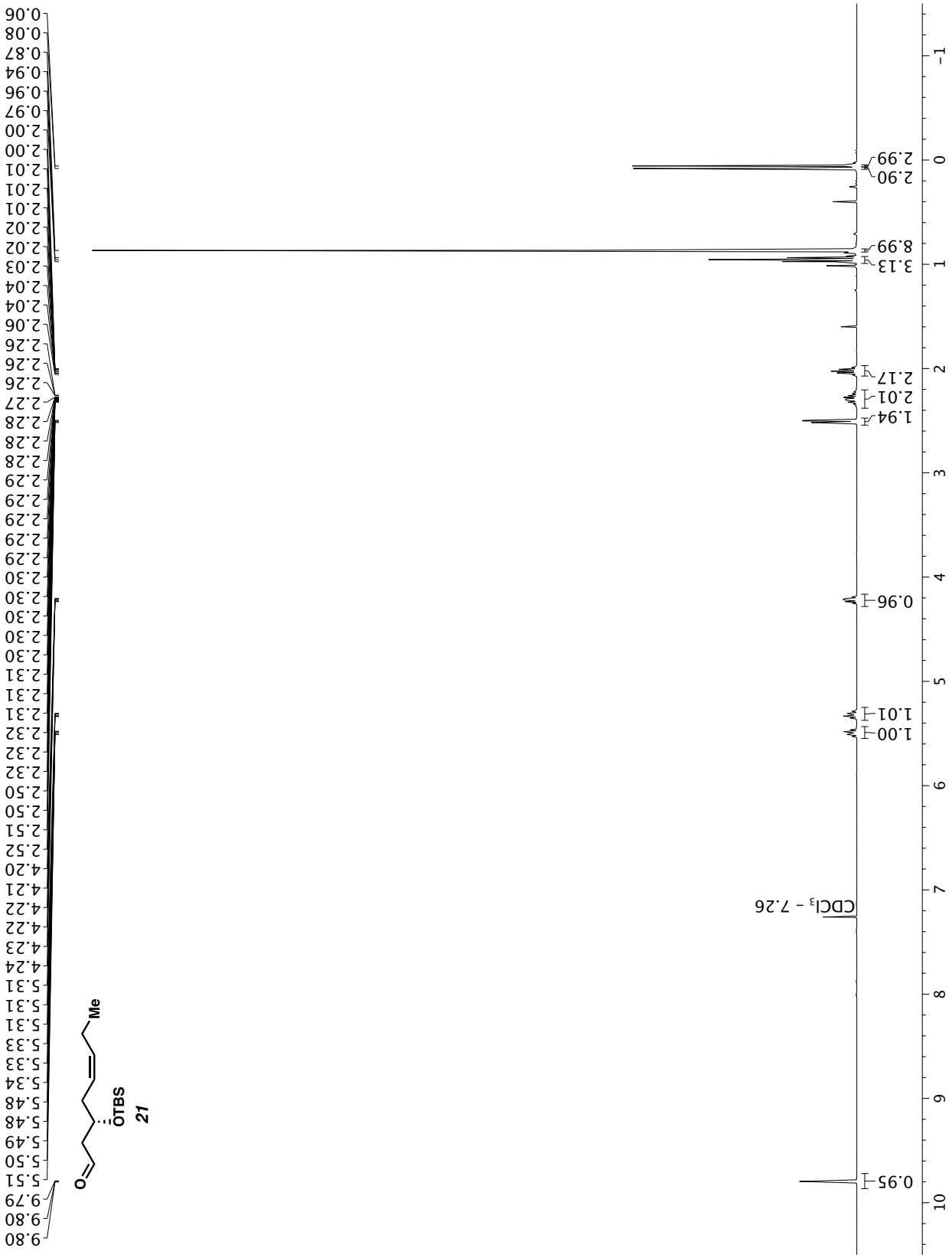
^{13}C NMR (101 MHz, $CDCl_3$) of compound **19**.



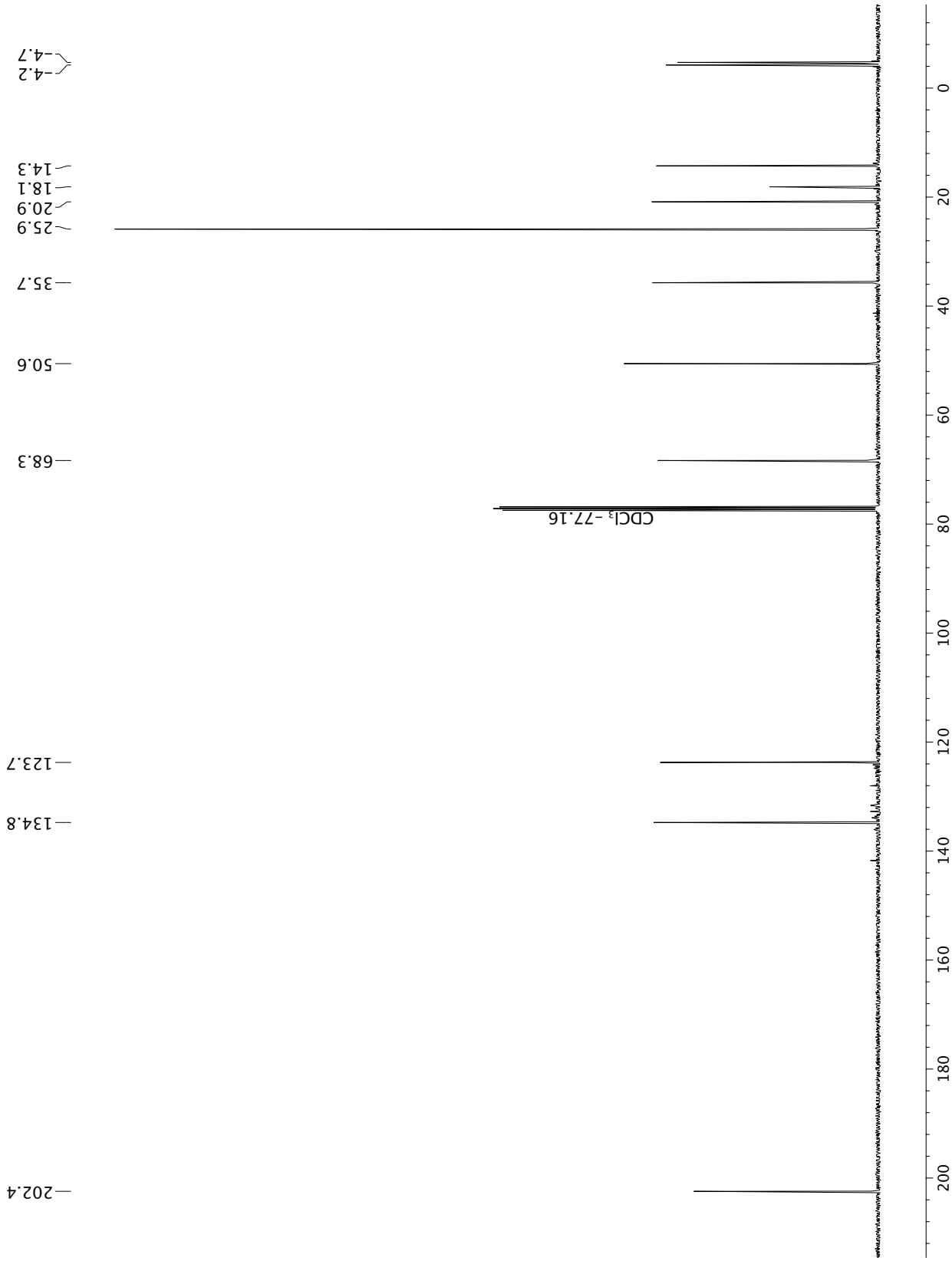
^{1}H NMR (400 MHz, $CDCl_3$) of compound **20**.



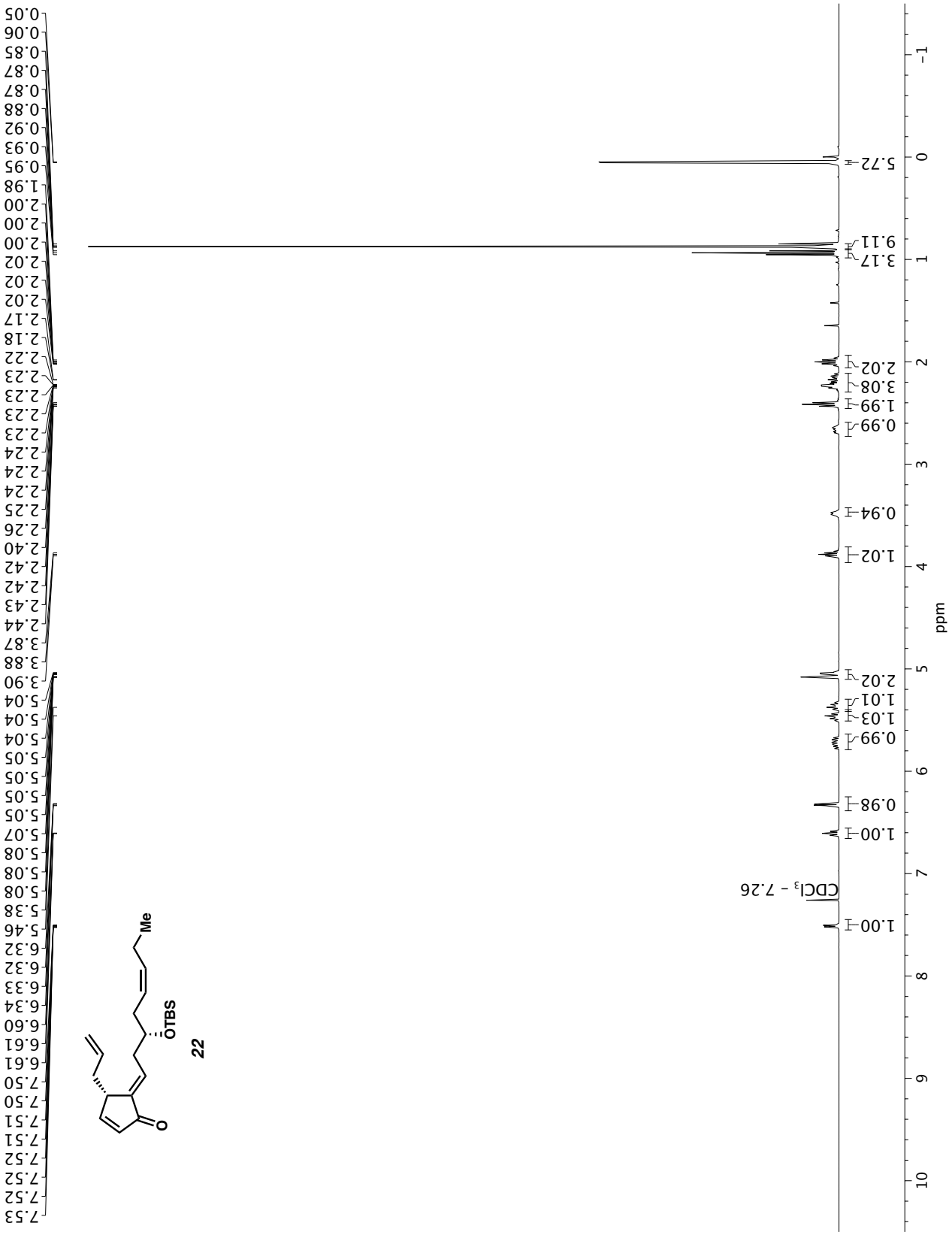
^{13}C NMR (101 MHz, $CDCl_3$) of compound **20**.



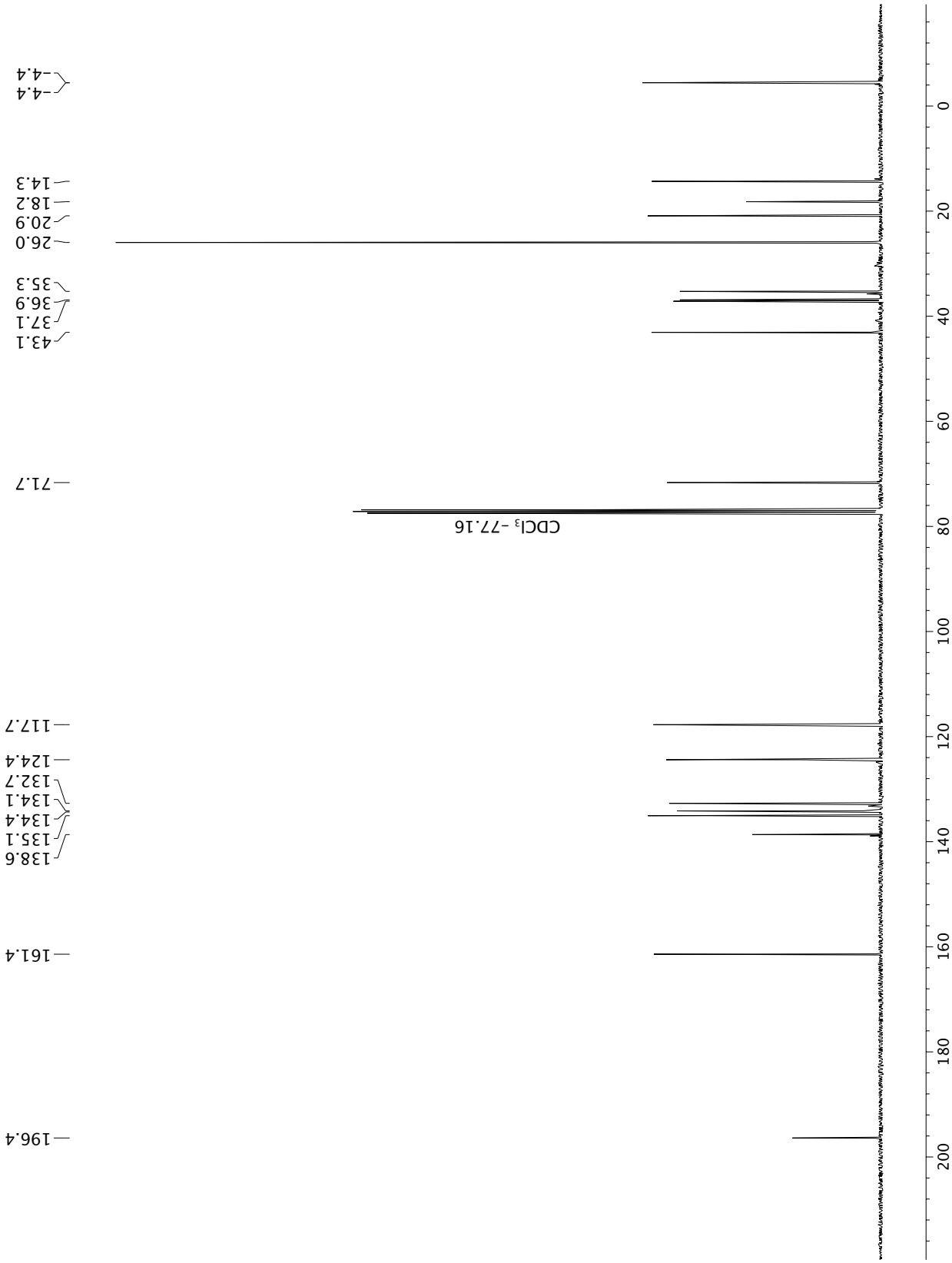
^{1}H NMR (400 MHz, $CDCl_3$) of compound **21**.



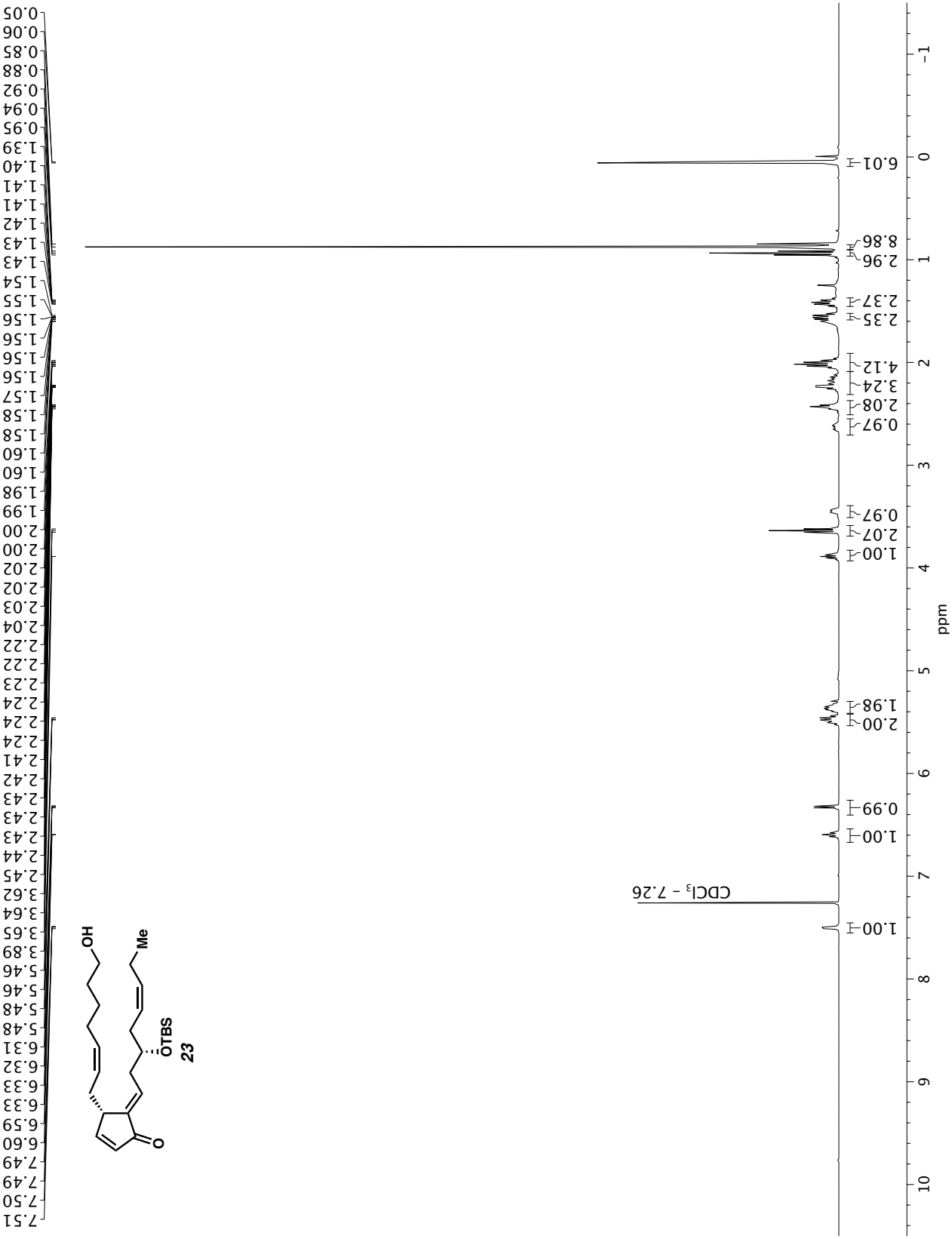
^{13}C NMR (101 MHz, $CDCl_3$) of compound **21**.



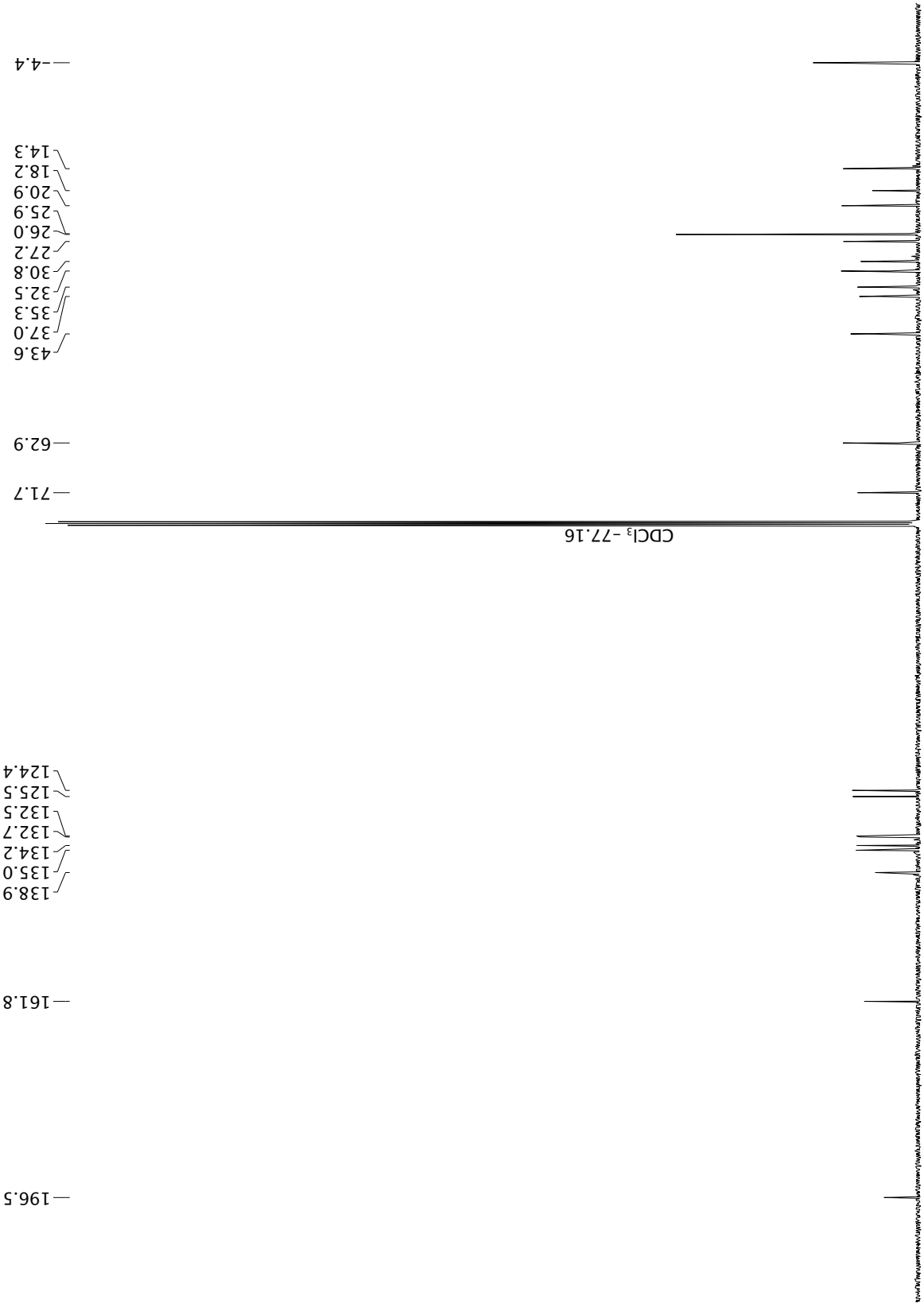
^{1}H NMR (400 MHz, $CDCl_3$) of compound **22**.



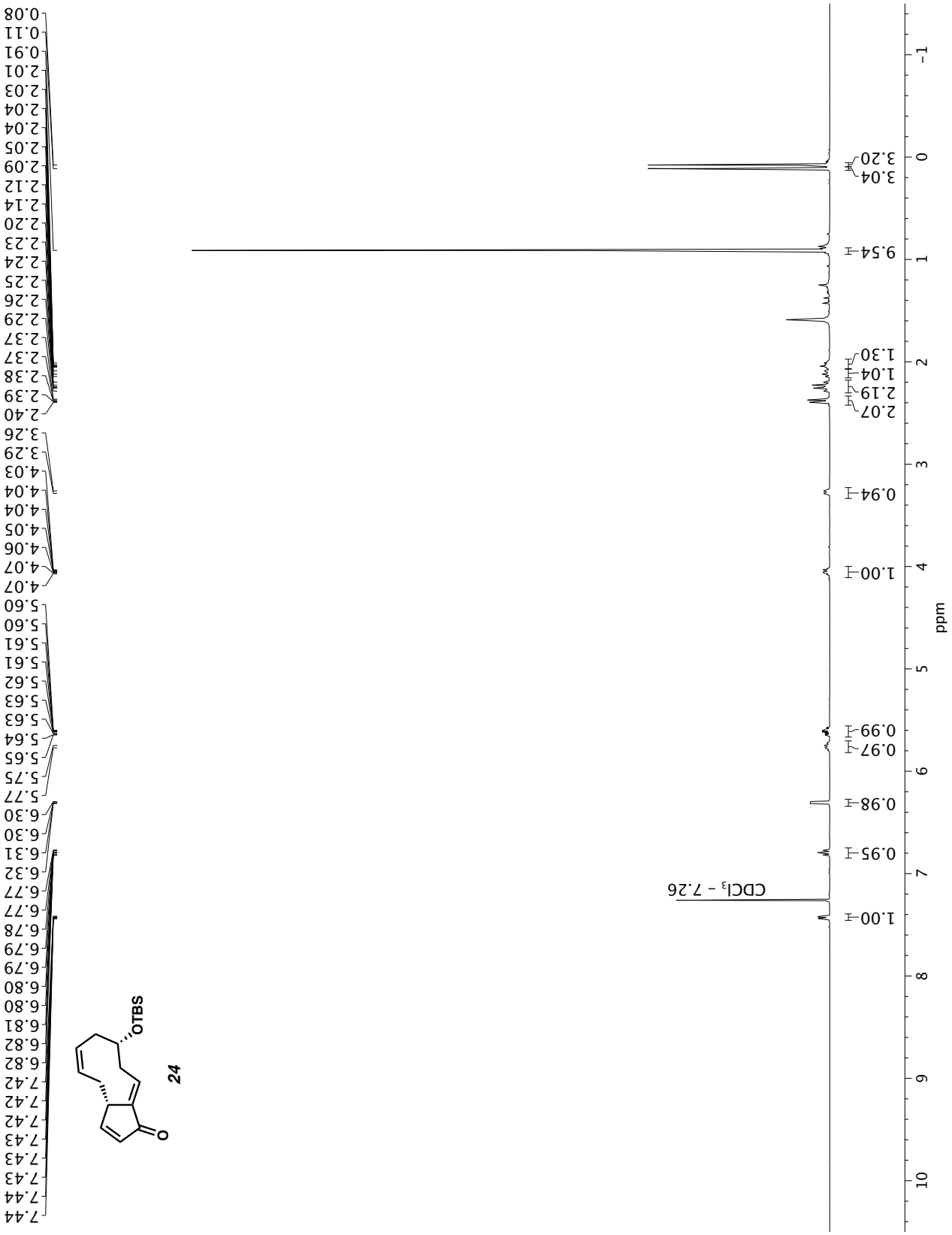
^{13}C NMR (101 MHz, $CDCl_3$) of compound **22**.



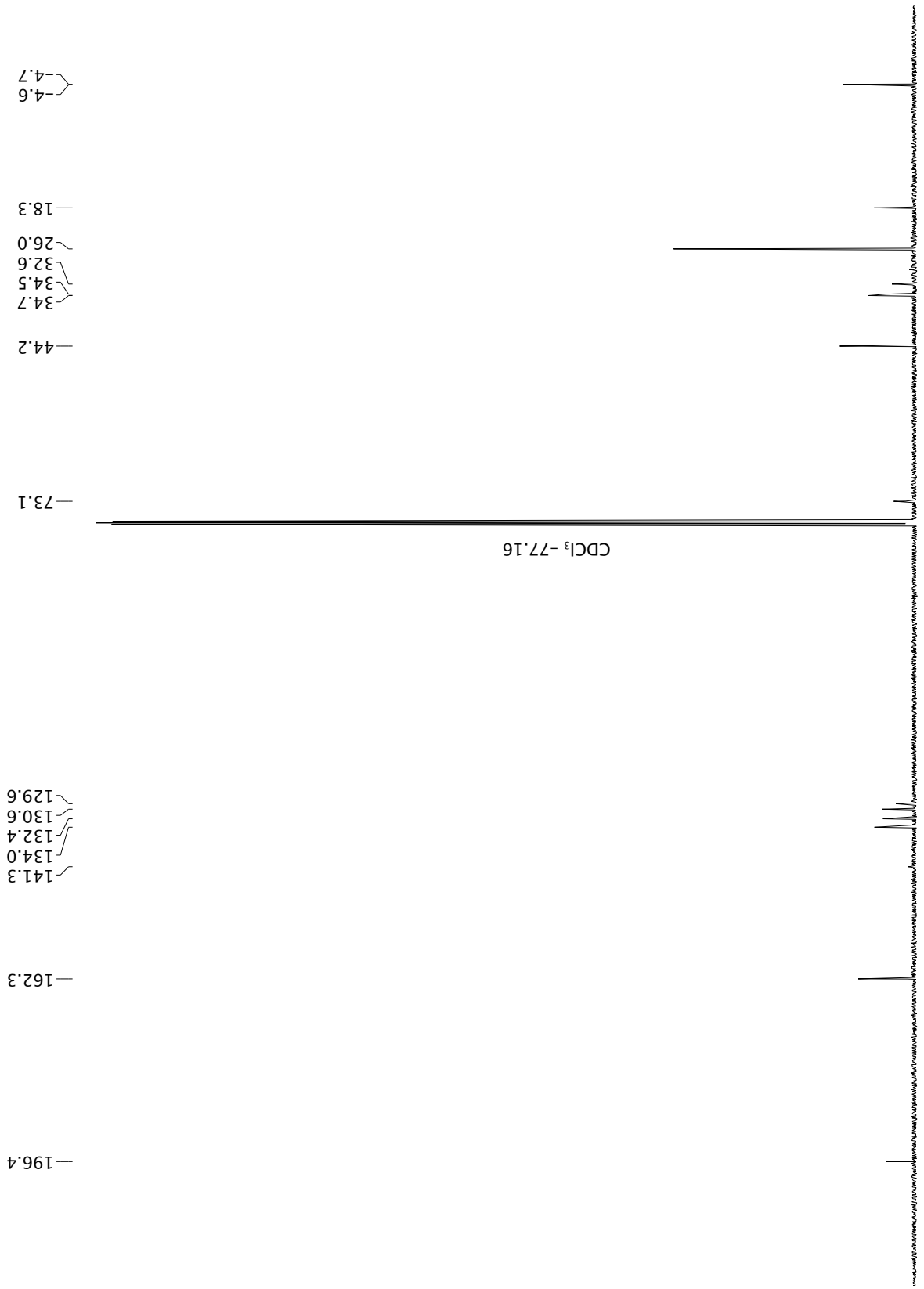
^{1}H NMR (400 MHz, $CDCl_3$) of compound **23**.



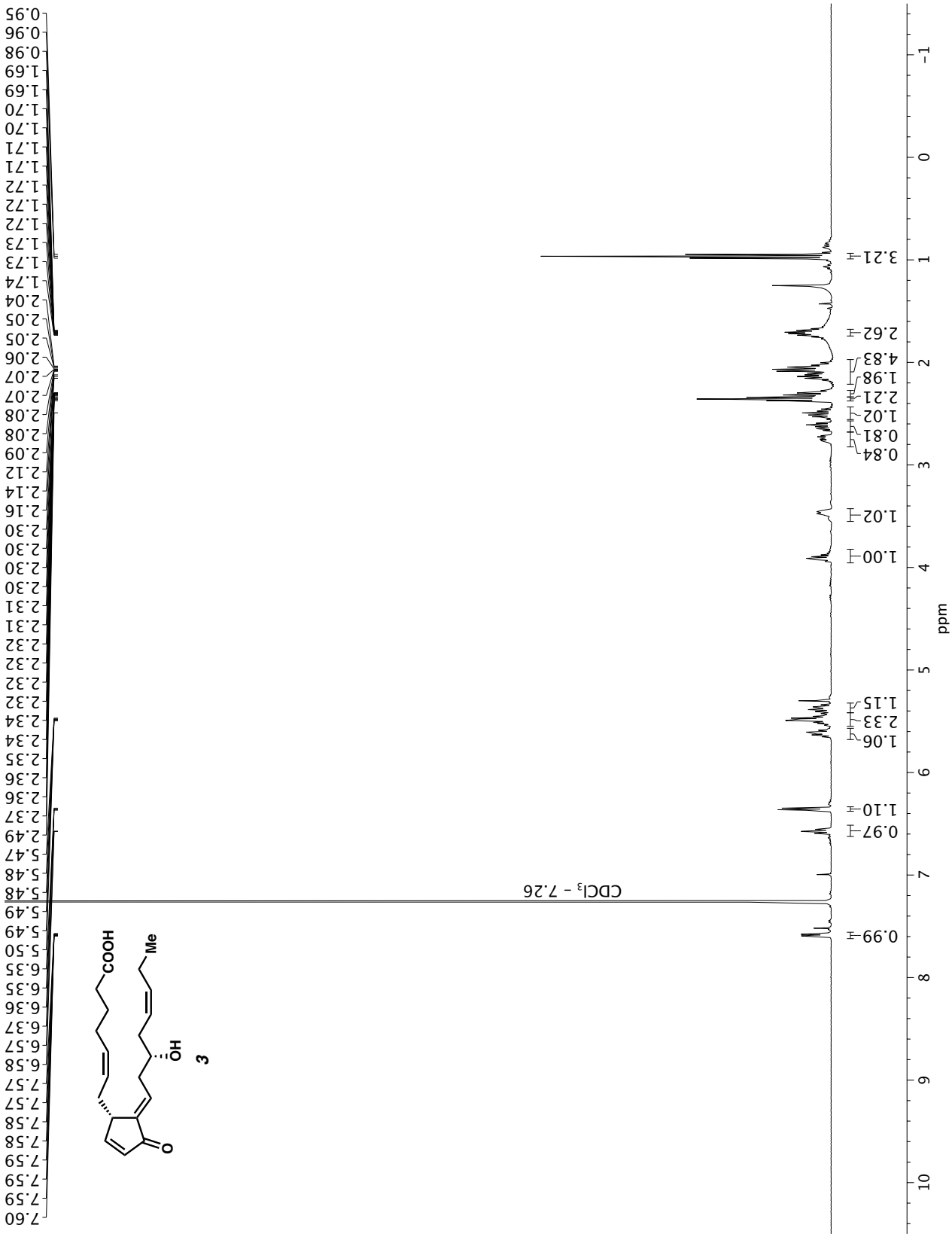
^{13}C NMR (101 MHz, $CDCl_3$) of compound **23**.



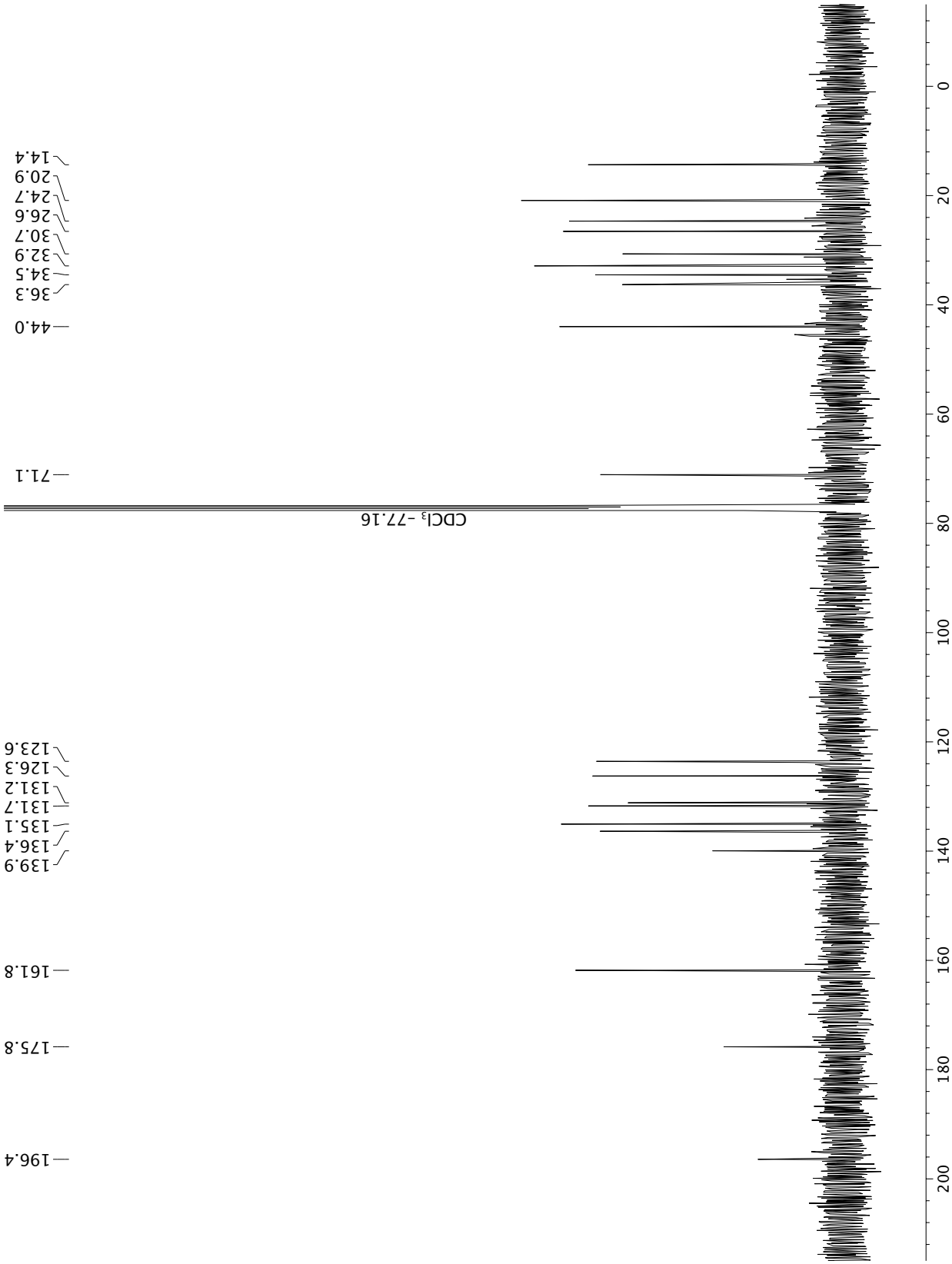
^{1}H NMR (400 MHz, $CDCl_3$) of compound **24**.



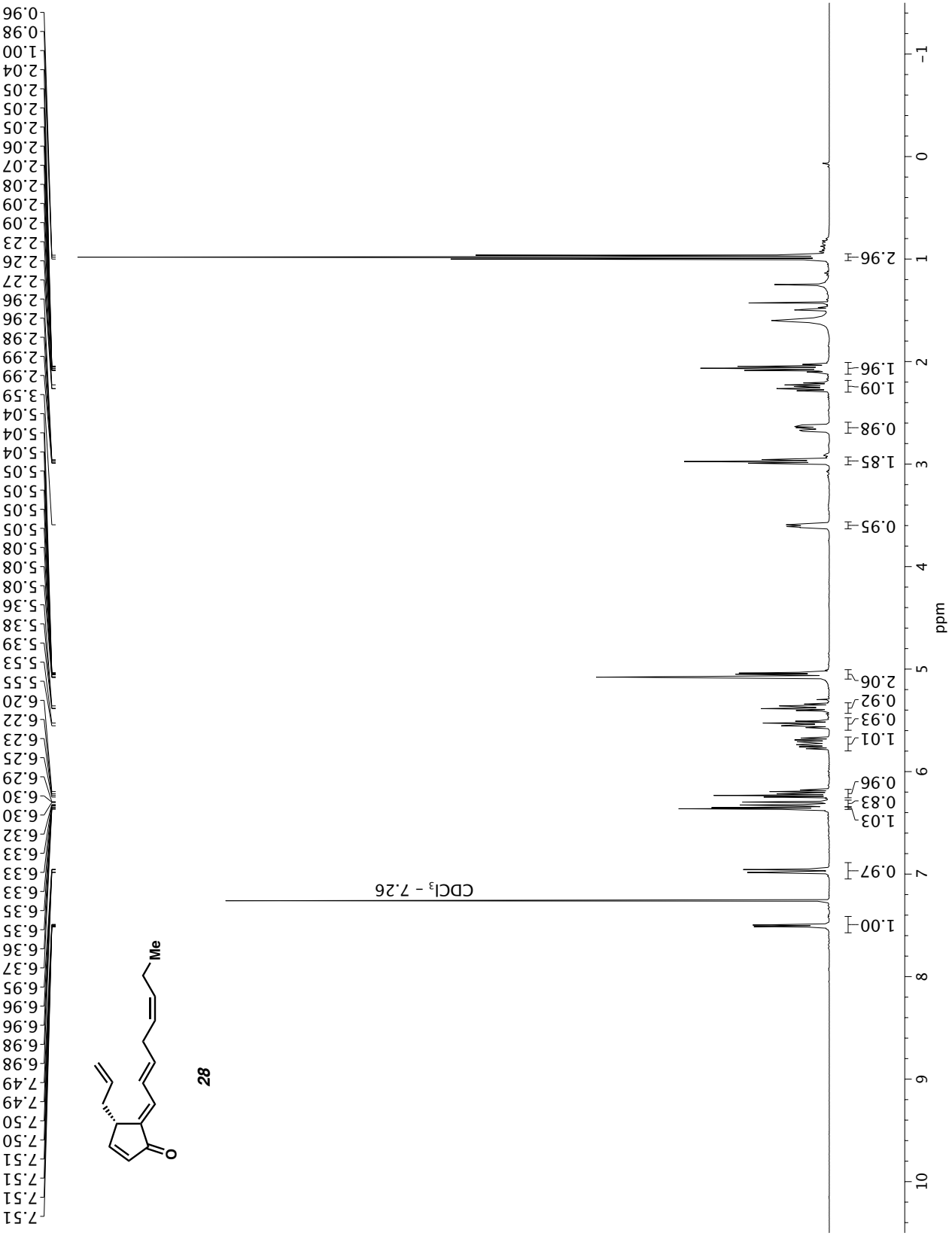
^{13}C NMR (101 MHz, $CDCl_3$) of compound **24**.



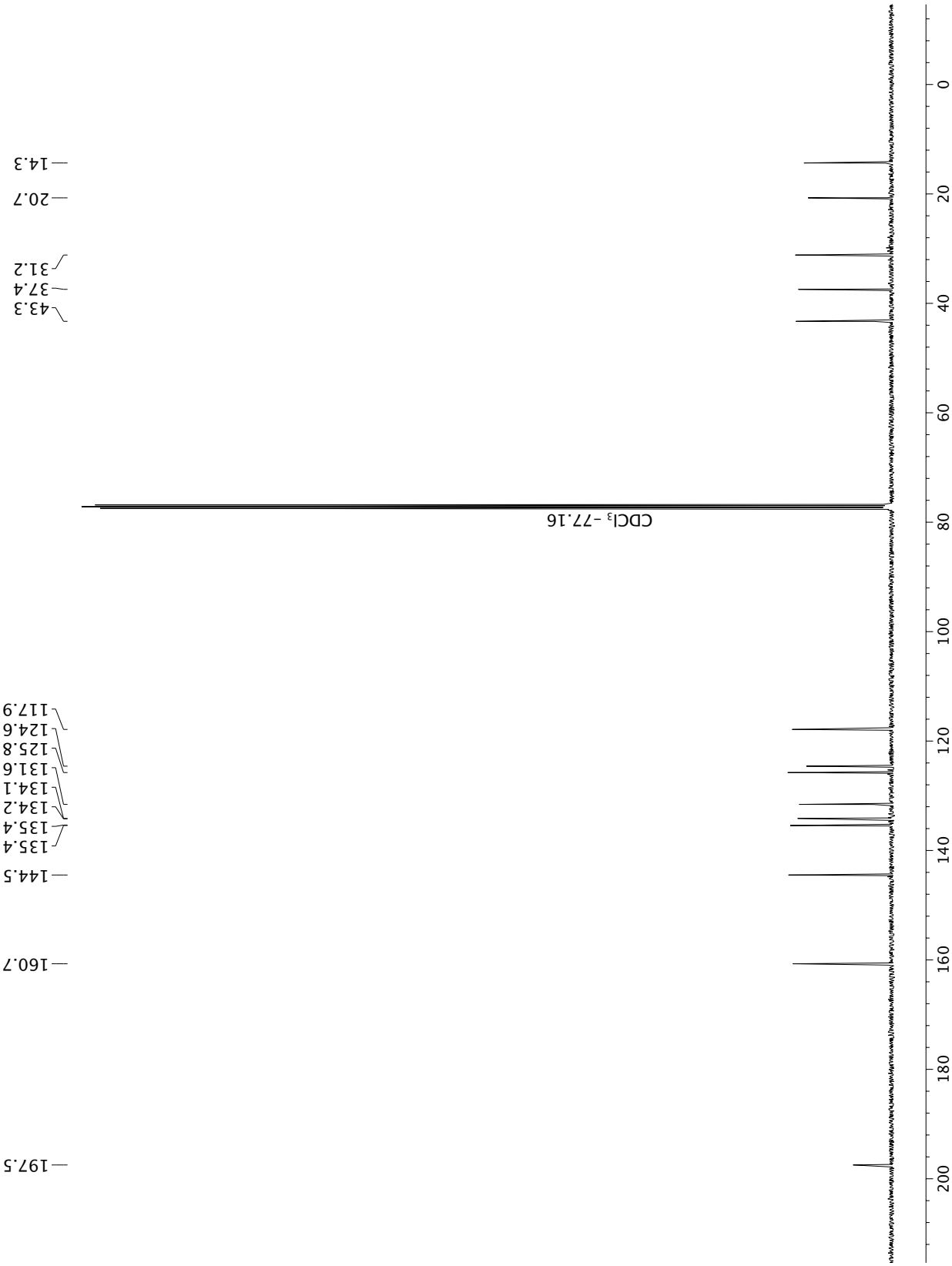
^{1}H NMR (400 MHz, $CDCl_3$) of compound **3**.



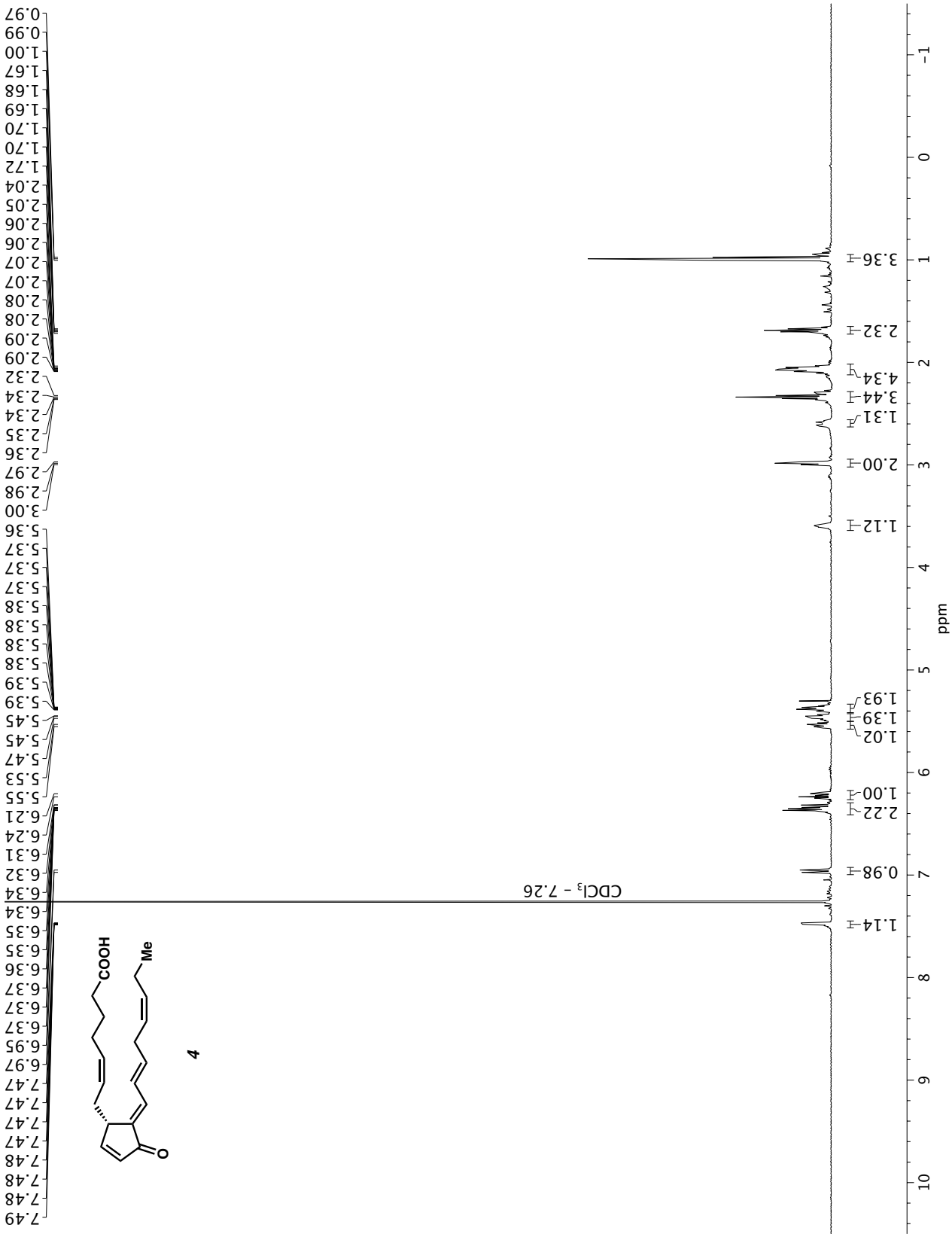
^{13}C NMR (101 MHz, $CDCl_3$) of compound **3**.



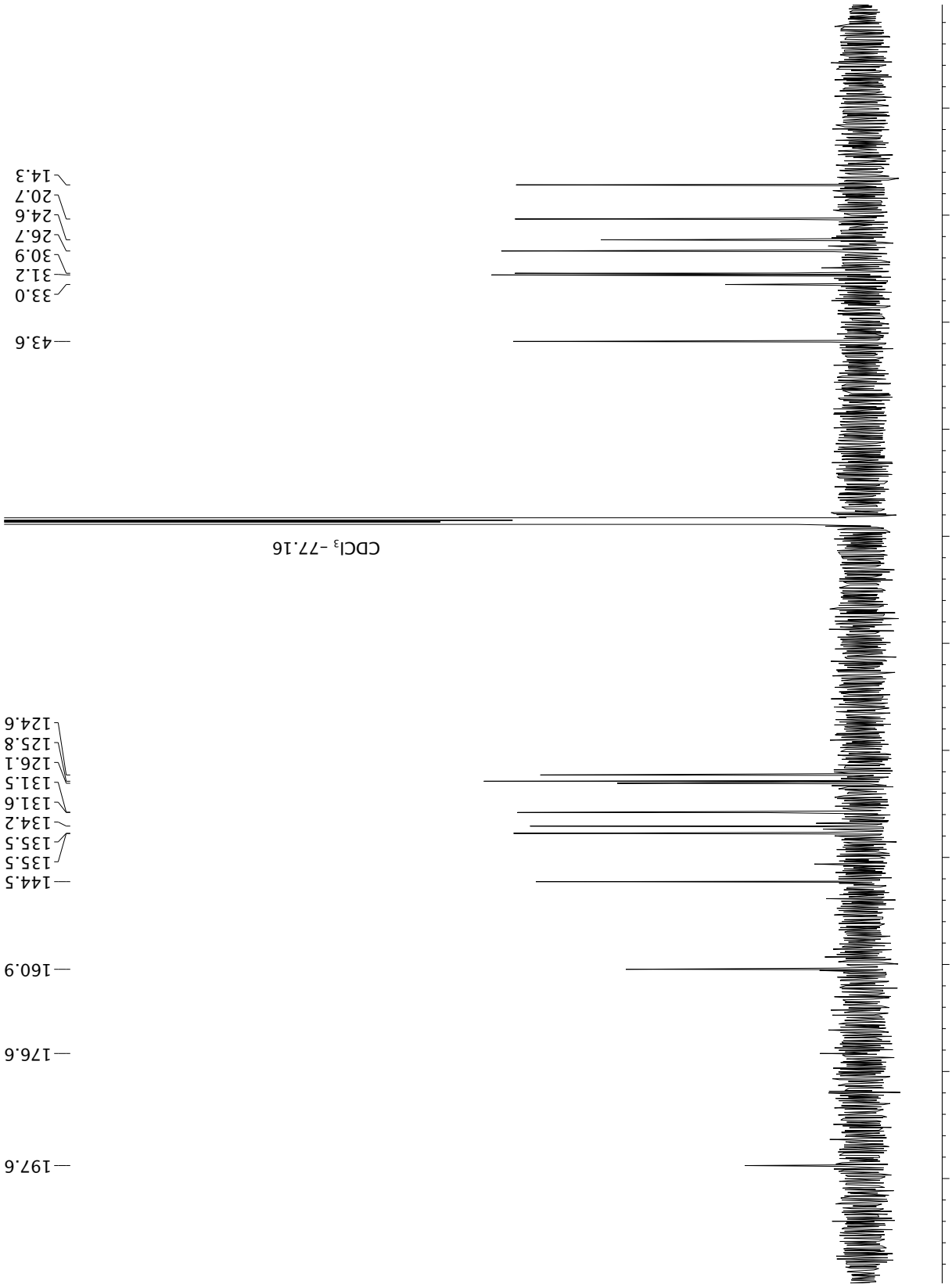
^{1}H NMR (400 MHz, $CDCl_3$) of compound **28**.



^{13}C NMR (101 MHz, $CDCl_3$) of compound **28**.



^{1}H NMR (400 MHz, $CDCl_3$) of compound **4**.



^{13}C NMR (101 MHz, $CDCl_3$) of compound **4**.