Rhodium-Catalyzed Endo-Selective Epoxide-Opening Cascades: Formal Synthesis of (–)-Brevisin

Kurt W. Armbrust, Matthew G. Beaver, and Timothy F. Jamison*

Department of Chemistry, Massachusetts Institute of Technology
Cambridge, MA 02139

Supporting Information

Table of Contents:

I. General Experimental

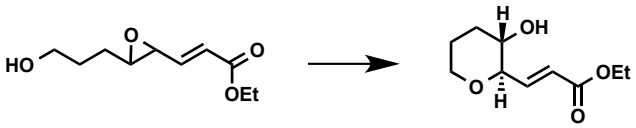
All reactions were performed under an atmosphere of argon under anhydrous conditions, unless otherwise noted. Dichloromethane, tetrahydrofuran (THF), Et_2O, benzene, dioxane, acetonitrile, dimethylformamide (DMF), pyridine, dimethylsulfoxide (DMSO) and triethylamine were purified via an SG Water USA solvent column system. Solvents used for Rh-promoted epoxide-opening reactions were sparged with argon prior to use. Unless otherwise noted, all reagents were commercially obtained and used without further purification. Analytical thin layer chromatography (TLC) was performed using EM Science silica gel 60 F_{254} plates, visualizing with a UV lamp (254 nm), $KMnO_4$, *p*-anisaldehyde, or CAM. Liquid chromatography was performed using forced flow (flash chromatography) of the indicated solvent system on Silicycle silica gel (230–400 mesh) or Biotage® Isolera flash purification system on SNAP HP-SIL columns.

^1H NMR and ^{13}C Nuclear Magnetic Resonance (NMR) spectra were recorded at ambient temperature at 600 MHz and 150 MHz, respectively, using a Bruker AVANCE-600 spectrometer or 500 MHz and 125 MHz, respectively, using a Varian Inova-500 spectrometer. The ^1H NMR data are reported as follows: chemical shift in parts per million (ppm) from an internal standard of residual $CHCl_3$ in $CDCl_3$ (7.27 ppm) on the δ scale, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in hertz (Hz), and integration (H). Chemical shifts of ^{13}C NMR spectra are reported in ppm from the central peak of $CDCl_3$ (77.2 ppm).

Infrared (IR) spectra were recorded on a Perkin-Elmer Model 2000 FT-IR or an Agilent Cary 630 FTIR Spectrometer. High resolution mass spectra (HR-MS) were acquired on a Bruker Daltronics APEXIV 4.7 Tesla Fourier Transform Ion Cyclotron Resonance Mass Spectrometer at the Massachusetts Institute of Technology Department of Chemistry Instrumentation Facility. Optical rotations were measured using a Jasco Model 1010 digital polarimeter at 589 nm and calculated using the formula: $[\alpha]_D = (\alpha_{obs}*100)/(l*c)$, where c = (g of substrate/100 mL of solvent) and l = 1 dm.

II. Procedures for Epoxide-Opening Reactions

A. Rh-promoted Epoxide-Opening:



6a **7a**

$[Rh(CO)_2Cl]_2$ promoted cyclization of epoxy alcohol 6a: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6a** (57 mg, 0.28 mmol), THF (1.4 mL), and a solution of $[Rh(CO)_2Cl]_2$ in THF (2.8 mg, 7 μmol, in 1.4 mL THF) and stirred at room temperature. After consumption of the starting material (1 h, as determined by TLC analysis), 40 mg

of polymer-bound triphenylphosphine resin was added and stirred for 30 min. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a >95:5 [*endo*(**7a**)/*exo*(**8a**)] ratio of products. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **7a** as a colorless oil (53.2 mg, 94%).

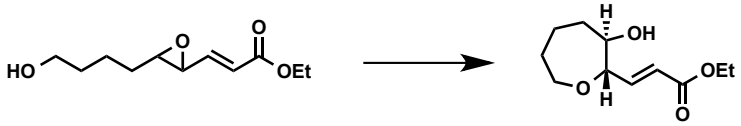
Characterization Data for 7a:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08 (dd, *J* = 15.8, 4.9 Hz, 1H), 6.09 (dd, *J* = 15.8, 1.5 Hz, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 3.95 (d, *J* = 12.1 Hz, 1H), 3.67 (ddd, *J* = 9.0, 4.9, 1.4 Hz, 1H), 3.41-3.34 (m, 2H), 2.54-2.50 (br, 1H), 2.16-2.13 (m, 1H), 1.72-1.67 (m, 2H), 1.52-1.44 (m, 1H), 1.27 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 145.4, 122.2, 81.3, 70.0, 67.5, 60.7, 32.7, 25.4, 14.4

FT-IR (ATR, cm^{-1}): 3422, 2940, 2857, 1700, 1658, 1445, 1368, 1303, 1265, 1174, 1077, 1041, 982

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{10}H_{16}O_4$: 218.1387, found 218.1385



6b **7b**

$[Rh(CO)_2Cl]_2$ promoted cyclization of epoxy alcohol 6b: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6b** (54 mg, 0.25 mmol), THF (1.25 mL), and a solution of $[Rh(CO)_2Cl]_2$ in THF (4.9 mg, 13 μmol, in 1.25 mL THF) and stirred at room temperature. After consumption of the starting material (9 h, as determined by TLC analysis), 45 mg of polymer-bound triphenylphosphine resin was added and stirred for 30 min. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a >95:5 [*endo*(**7b**)/*exo*(**8b**)] ratio of products. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **7b** as a colorless oil (43.6 mg, 81%).

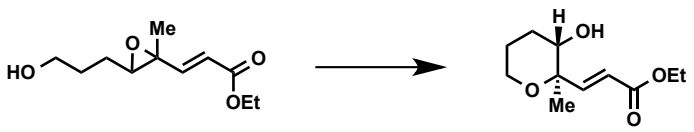
Characterization Data for 7b:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.09 (dd, *J* = 15.7, 4.4 Hz, 1H), 6.10 (dd, *J* = 15.7, 1.8 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 3.94 (dt, *J* = 12.2, 5.3 Hz, 1H), 3.88 (ddd, *J* = 8.5, 4.4, 1.8 Hz, 1H), 3.70-3.60 (m, 2H), 2.13 (br, 1H), 2.01-1.97 (m, 1H), 1.80-1.67 (m, 4H), 1.61-1.55 (m, 1H), 1.28 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 147.2, 121.1, 83.4, 74.7, 70.8, 60.6, 36.1, 30.7, 21.0, 14.4

FT-IR (ATR, cm^{-1}): 3425, 2932, 2864, 1700, 1656, 1446, 1368, 1300, 1270, 1172, 1135, 1102, 1038

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{11}H_{18}O_4$: 232.1543, found 232.1543



6c **7c**

$[Rh(CO)_2Cl]_2$ promoted cyclization of epoxy alcohol 6c: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6c** (60 mg, 0.28 mmol), THF (2.3 mL), and a solution of $[Rh(CO)_2Cl]_2$ in THF (1.1 mg, 3 μmol, in 0.5 mL THF) and stirred at room temperature. After consumption of the starting material (3 h, as determined by TLC analysis), 11 mg of polymer-bound triphenylphosphine resin was added and stirred for 30 min. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated only *endo*-**7c** present and no *exo*-**8c** was observed. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 15:85 to 35:65) to afford **7c** as a colorless oil (56 mg, 93%).

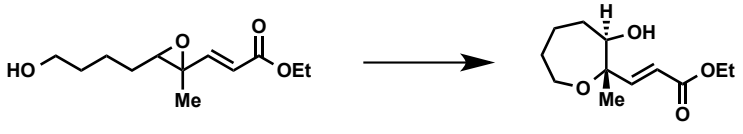
Characterization Data for 7c:

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.05 (d, *J* = 16.0 Hz, 1H), 6.04 (d, *J* = 16.0 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.72 (ddd, *J* = 11.5, 6.7, 4.5 Hz, 1H), 3.67 (ddd, *J* = 11.6, 7.4, 3.8 Hz, 1H), 3.62-3.59 (m, 1H), 1.92 (d, *J* = 6.7 Hz, 1H), 1.86-1.71 (m, 3H), 1.56-1.50 (m, 1H), 1.31 (s, 3H) 1.30 (t, *J* = 7.1 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 166.8, 151.4, 120.8, 77.07, 70.9, 61.8, 60.7, 27.7, 22.6, 19.8, 14.4

FT-IR (ATR, cm^{-1}): 3452, 2979, 2940, 2870, 1700, 1654, 1445, 1368, 1302, 1268, 1230, 1178, 1117, 1083, 1056

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{11}H_{18}O_4$: 215.1278, found 215.1278



6d **7d**

$[Rh(CO)_2Cl]_2$ promoted cyclization of epoxy alcohol 6d: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6d** (60 mg, 0.26 mmol), THF (2.0 mL), and a solution of $[Rh(CO)_2Cl]_2$ in THF (2.5 mg, 7 μmol, in 0.6 mL THF) and stirred at room temperature. After consumption of the starting material (5 h, as determined by TLC analysis), 25 mg of polymer-bound triphenylphosphine resin was added and stirred for 30 min. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated only *endo*-**7d** present and no

exo-**8d** was observed. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 35:65) to afford **7d** as a colorless oil (53 mg, 88%).

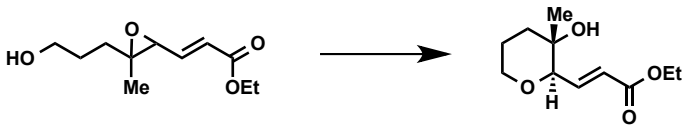
Characterization Data for 7d:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.12 (d, *J* = 15.8 Hz, 1H), 6.05 (d, *J* = 15.8 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.85 (dd, *J* = 9.7, 1.0 Hz, 1H), 3.77 (dtd, *J* = 12.5, 3.9, 0.9 Hz, 1H), 3.44 (ddd, *J* = 12.7, 7.0, 5.5 Hz, 1H), 2.02 (dddd, *J* = 13.6, 11.1, 9.7, 2.5 Hz, 1H), 1.95 (br, 1H), 1.83-1.80 (m, 1H), 1.69-1.59 (m, 3H), 1.45-1.37 (m, 1H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.25 (s, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 167.2, 152.2, 119.4, 80.2, 76.0, 64.7, 60.7, 32.5, 30.8, 24.6, 21.2, 14.4

FT-IR (ATR, cm^{-1}): 3452, 2981, 2934, 1699, 1653, 1446, 1368, 1299, 1271, 1175, 1118, 1096, 1072, 1045

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{12}H_{20}O_4$: 246.1700, found 246.1694



6e **7e**

$[Rh(CO)_2Cl]_2$ promoted cyclization of epoxy alcohol 6e: To a 100 ml round bottom flask equipped with a magnetic stir bar open to air was added epoxide **6e** (47.4 mg, 0.22 mmol) and a solution of $[Rh(CO)_2Cl]_2$ in 1,4-dioxane (8.5 mg, 22 μmol, in 4.4 mL 1,4-dioxane) and quickly heated to 80 ºC in an oil bath. After consumption of the starting material (30 min, as determined by TLC analysis), the reaction was removed from the oil bath and 150 mg of polymer-bound triphenylphosphine resin was added and stirred for 2 h. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 12.5:1 [*endo*(**7e**)/*exo*(**8e**)] ratio of products. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **7e** as a colorless oil (35.5 mg, 76%).

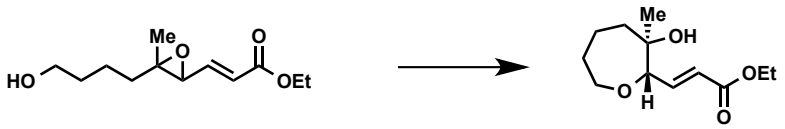
Characterization Data for 7e:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.07 (dd, *J* = 15.8, 4.2 Hz, 1H), 6.08 (dd, *J* = 15.8, 1.9 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 4.01 (ddt, *J* = 11.4, 3.1, 1.6 Hz, 1H), 3.80 (dd, *J* = 4.2, 1.9 Hz, 1H), 3.43 (td, *J* = 11.7, 2.5 Hz, 1H), 1.90-1.87 (m, 2H), 1.77-1.70 (m, 1H), 1.67-1.61 (m, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.16 (s, 3H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 144.2, 122.4, 83.3, 70.3, 68.0, 60.5, 39.2, 24.7, 21.4, 14.4

FT-IR (ATR, cm^{-1}): 3448, 2976, 2939, 2856, 1700, 1658, 1449, 1368, 1304, 1262, 1174, 1116, 1069, 1050, 1033

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{11}H_{18}O_4$: 215.1278, found 215.1292



6f **7f**

[Rh(CO)$_2$Cl]$_2$ promoted cyclization of epoxy alcohol 6f: To a 200 ml Schlenk tube equipped with a magnetic stir bar was added epoxide **6f** (53 mg, 0.23 mmol) and a solution of [Rh(CO)$_2$Cl]$_2$ in THF (8.9 mg, 23 μmol, in 4.6 mL THF), then the tube was sealed and quickly heated to 80 ºC in an oil bath. After 18 h, the reaction was removed from the oil bath and 150 mg of polymer-bound triphenylphosphine resin was added and stirred for 1 h. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et$_3$N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 4:1 [*endo*(**7f**)/*exo*(**8f**)] ratio of products. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **7f** as a colorless oil (11 mg, 21%).

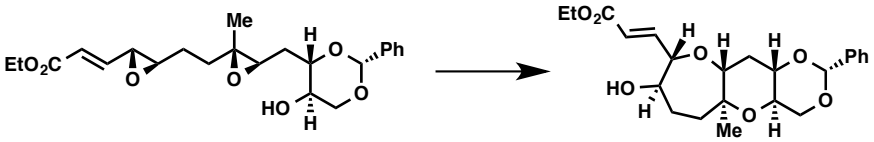
Characterization Data for 7f:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.10 (dd, *J* = 15.7, 3.9 Hz, 1H), 6.14 (d, *J* = 15.7 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 4.04 (dt, *J* = 11.8, 5.7 Hz, 1H), 3.95 (d, *J* = 1.7 Hz, 1H), 3.61-3.56 (m, 1H), 1.86-1.73 (m, 4H), 1.64-1.59 (m, 2H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.26 (br, 1H), 1.13 (s, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.8, 146.3, 121.8, 84.8, 75.5, 71.8, 60.5, 44.4, 31.1, 24.3, 20.8, 14.4

FT-IR (ATR, cm^{-1}): 3443, 2929, 2859, 1700, 1654, 1457, 1369, 1300, 1260, 1166, 1105, 1043

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{12}H_{20}O_4$: 229.1434, found 229.1441



5 **11**

[Rh(CO)$_2$Cl]$_2$ promoted cyclization of 5: To a solution of diepoxy alcohol **5** (17.1 mg, 40.9 μmol) in dioxane (1.0 mL) was added a solution of [Rh(CO)$_2$Cl]$_2$ in dioxane (0.080 mL, 0.025 M, 2.0 μmol) and the reaction mixture was heated to 65 ºC for 4 h. After cooling to room temperature, 4.0 mg of polymer-bound triphenylphosphine was added and the reaction mixture was stirred for 30 min. The solution was passed through a pad of silica gel, eluted with EtOAc, and then concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 40:60 to 60:40) to afford **11** as a colorless film (10.4 mg, 61%).

Characterization Data for 11:

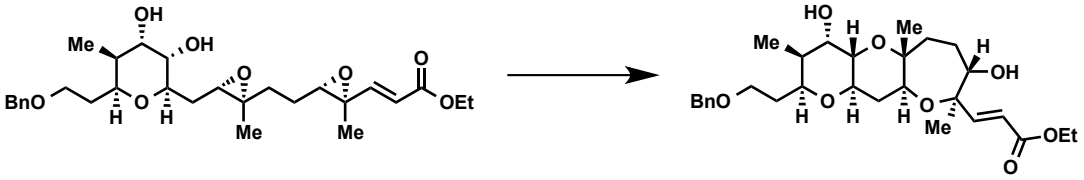
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.50 (m, 2H), 7.38 (m, 3H), 6.85 (dd, *J* = 15.5, 4.3 Hz, 1H), 6.11 (dd, *J* = 15.5, 1.9 Hz, 1H), 5.52 (s, 1H), 4.41 (m, 1H), 4.25 (dd, *J* = 9.7, 4.2 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 4.09 (m, 1H), 3.89 (dd, *J* = 11.8, 4.6 Hz, 1H), 3.66 (m, 1H), 3.61 (m, 1H), 3.50 (ddd, *J* = 12.7, 8.8, 4.3 Hz, 1H), 2.19 (dt, *J* = 11.7, 4.4 Hz, 1H), 2.00 (m, 1H), 1.83 (m, 2H), 1.70 (m, 1H), 1.61 (s, 1H), 1.59 (m, 1H), 1.33 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 166.7, 145.9, 137.6, 129.3, 128.6, 126.6, 121.5, 101.9, 83.1, 78.2, 78.0, 76.6, 73.3, 70.3, 66.2, 60.8, 34.2, 32.8, 25.5, 16.4, 14.5

FT-IR (ATR, cm^{-1}): 3447, 2963, 2925, 2859, 1718, 1654

HRMS (ESI, *m/z*): $[M+H]^+$ calculated for $C_{23}H_{30}O_7$: 419.2064, found 419.2068

$[\alpha]^{24}_D$ = +29.4 (*c* = 0.110, $CHCl_3$)



21 **22**

[Rh(CO)$_2$Cl]$_2$ promoted cyclization of 21: To a 2 dram vial equipped with a magnetic stir bar was added **21** (7.8 mg, 0.015 mmol), THF (0.5 mL), and a solution of $[Rh(CO)_2Cl]_2$ in THF (0.6 mg, 1.5 μmol, in 0.25 mL THF) and stirred at room temperature. After consumption of the starting material (3 h, as determined by TLC analysis), 10 mg of polymer-bound triphenylphosphine resin was added and stirred for 30 min. The cloudy brown solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. The resultant pale yellow film was purified by flash chromatography (EtOAc/hexanes, gradient 40:60 to 70:30) to afford **21** as a colorless oil (6.1 mg, 78%).

Characterization Data for 22:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36-7.28 (m, 5H), 6.72 (d, *J* = 15.4 Hz, 1H), 6.08 (d, *J* = 15.4 Hz, 1H), 4.55-4.47 (m, 2H), 4.25-4.16 (m, 2H), 4.02 (td, *J* = 6.1, 3.3 Hz, 1H), 3.98 (d, *J* = 6.8 Hz, 1H), 3.89 (dd, *J* = 11.9, 4.8 Hz, 1H), 3.80 (t, *J* = 2.6 Hz, 1H), 3.57 (dd, *J* = 7.4, 5.8 Hz, 2H), 3.48 (ddd, *J* = 11.9, 9.9, 4.2 Hz, 1H), 3.36 (dd, *J* = 9.8, 2.8 Hz, 1H), 1.99-1.88 (m, 4H), 1.86-1.74 (m, 3H), 1.68-1.61 (m, 2H), 1.57 (q, *J* = 11.9 Hz, 1H), 1.50 (ddd, *J* = 13.3, 5.0, 2.3 Hz, 1H), 1.36 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.26 (s, 3H), 0.98 (d, *J* = 7.4 Hz, 3H)

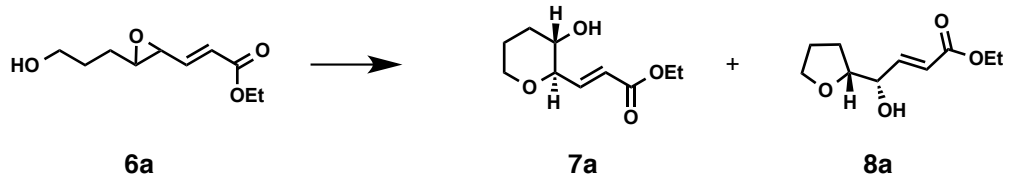
^{13}C NMR (125 MHz, $CDCl_3$) δ 167.0, 151.9, 138.8, 128.5, 127.82, 127.64, 120.3, 80.5, 78.5, 74.0, 73.0, 72.10, 71.99, 71.6, 71.0, 69.3, 67.6, 60.7, 39.0, 34.22, 34.03, 32.6, 24.9, 20.7, 16.4, 14.4, 11.2

FT-IR (ATR, cm^{-1}): 3427, 2929, 2871, 1715, 1655, 1455, 1367, 1292, 1224, 1179, 1088, 1075, 1029

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{29}H_{42}O_8$: 519.2925, found 519.2953

$[\alpha]^{24}_D$ = –50.5 (*c* = 0.30, CH_2Cl_2)

B. CSA-Promoted Epoxide-Opening:



6a **7a** **8a**

(±)-CSA Promoted cyclization of epoxy alcohol 6a: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6a** (60 mg, 0.30 mmol) in CH_2Cl_2 (15 mL) and (±)-CSA (7.0 mg, 0.03 mmol) and stirred at room temperature. After consumption of the starting material (15 h, as determined by TLC analysis), the clear solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 1:1 [*endo*(**7a**)/*exo*(**8a**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **7a** as a colorless oil (25.9 mg, 43%) and **8a** as a colorless oil (30.3 mg, 50%).

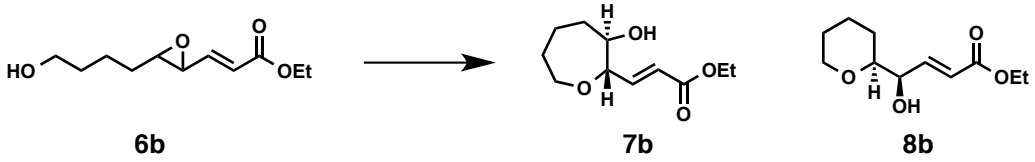
Characterization Data for 8a:

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.90 (dd, *J* = 15.7, 4.3 Hz, 1H), 6.15 (dd, *J* = 15.7, 2.0 Hz, 1H), 4.53 (td, *J* = 3.9, 1.9 Hz, 1H), 4.21 (q, *J* = 7.1Hz, 2H), 3.98 (td, *J* = 7.3, 3.7 Hz, 1H), 3.92 (dt, *J* = 8.2, 6.6 Hz, 1H), 3.80 (dt, *J* = 8.2, 6.8 Hz, 1H), 2.45-2.38 (br, 1H), 1.92-1.87 (m, 2H), 1.81-1.77 (m, 2H), 1.30 (t, *J* = 7.1 Hz, 4H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.5, 145.4, 121.8, 81.0, 71.9, 69.3, 60.6, 26.3, 25.2, 14.4

FT-IR (ATR, cm^{-1}): 3426, 2977, 2932, 2872, 1717, 1659, 1464, 1447, 1368, 1302, 1267, 1175, 1067, 1039

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{10}H_{16}O_4$: 218.1387, found 218.1380



6b **7b** **8b**

(±)-CSA Promoted cyclization of epoxy alcohol 6b: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6b** (54 mg, 0.25 mmol) in CH_2Cl_2 (12 mL) and (±)-CSA (58 mg, 0.25 mmol) and stirred at room temperature. After consumption of the starting material (7 h, as determined by TLC analysis), the clear solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 1:3 [*endo*(**7b**)/*exo*(**8b**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **8b** as a colorless oil (35.8 mg, 67%) and **7b** as a colorless oil (11.4 mg, 21%).

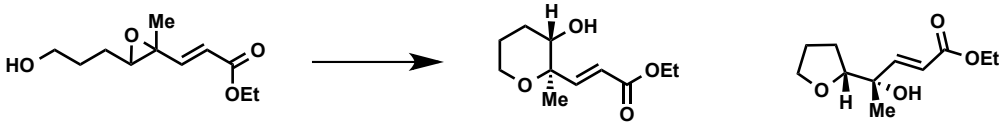
Characterization Data for 8b:

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.93 (dd, *J* = 15.7, 4.7 Hz, 1H), 6.12 (dd, *J* = 15.7, 1.9 Hz, 1H), 4.33 (br, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 4.02 (ddt, *J* = 11.4, 4.1, 2.0 Hz, 1H), 3.50-3.43 (m, 2H), 2.56 (br, 1H), 1.89-1.86 (m, 1H), 1.58-1.42 (m, 5H), 1.29 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.5, 145.8, 122.1, 79.7, 73.4, 69.0, 60.6, 26.0, 25.7, 23.1, 14.4

FT-IR (ATR, cm^{-1}): 3429, 2936, 2851, 1717, 1659, 1443, 1368, 1306, 1270, 1175, 1092, 1043

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{11}H_{18}O_4$: 232.1543, found 232.1539



6c **7c** **8c**

(±)-CSA Promoted cyclization of epoxy alcohol 6c: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6c** (54 mg, 0.25 mmol) in CH_2Cl_2 (12 mL) and (±)-CSA (6 mg, 0.025 mmol) and stirred at room temperature. After consumption of the starting material (2 h, as determined by TLC analysis), the clear solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 3.4:1 [*endo*(**7c**)/*exo*(**8c**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 30:70) to afford **8c** as a colorless oil (10.5 mg, 20%) and **7c** as a colorless oil (37 mg, 69%).

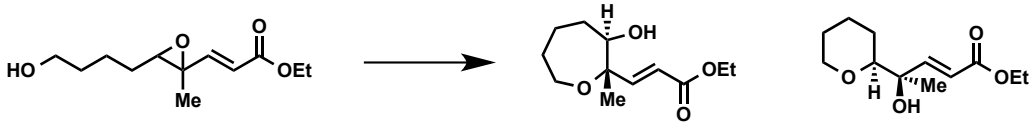
Characterization Data for 8c:

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.90 (d, *J* = 15.6 Hz, 1H), 6.12 (d, *J* = 15.6 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.88-3.79 (m, 3H), 2.39 (br, 1H), 1.91-1.79 (m, 3H), 1.72 (dq, *J* = 12.2, 8.2 Hz, 1H), 1.36 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 149.8, 120.5, 84.4, 74.2, 69.3, 60.6, 26.60, 26.51, 25.6, 14.4

FT-IR (ATR, cm^{-1}): 3481, 2979, 2933, 2874, 1716, 1657, 1456, 1368, 1304, 1256, 1178, 1072, 1034

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{11}H_{18}O_4$: 232.1543, found 232.1533



6d **7d** **8d**

(±)-CSA Promoted cyclization of epoxy alcohol 6d: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6d** (54 mg, 0.24 mmol) in CH_2Cl_2 (12 mL) and (±)-CSA (55 mg, 0.24 mmol) and stirred at room temperature. After consumption of the starting material (4 h, as determined by TLC analysis), the clear solution was filtered through a

plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 1:1.8 [*endo*(**7d**)/*exo*(**8d**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 15:85 to 35:65) to afford **8d** as a colorless oil (23.1 mg, 43%) and **7d** as a colorless oil (13.3 mg, 25%).

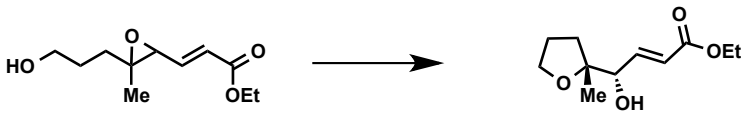
Characterization Data for 8d:

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.97 (d, *J* = 15.6 Hz, 1H), 6.10 (d, *J* = 15.6 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 4.03 (dt, *J* = 11.1, 2.1 Hz, 1H), 3.44 (td, *J* = 11.5, 2.7 Hz, 1H), 3.22 (dd, *J* = 11.3, 1.9 Hz, 1H), 2.87 (br, 1H), 1.89-1.86 (m, 1H), 1.59-1.33 (m, 5H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.28 (s, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 150.6, 120.4, 83.6, 74.5, 69.2, 60.5, 26.2, 25.9, 24.2, 23.4, 14.4

FT-IR (ATR, cm^{-1}): 3487, 2936, 2854, 1715, 1655, 1443, 1367, 1302, 1283, 1265, 1174, 1089, 1034

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{12}H_{20}O_4$: 246.1700, found 246.1694



6e **8e**

(±)-CSA promoted cyclization of epoxy alcohol 6e: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6e** (50 mg, 0.23 mmol) in CH_2Cl_2 (12 mL) and (±)-CSA (5 mg, 0.02 mmol) and stirred at room temperature. After consumption of the starting material (30 min, as determined by TLC analysis), the clear solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 1:>20 [*endo*(**7e**)/*exo*(**8e**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **8e** as a colorless oil (48 mg, 96%).

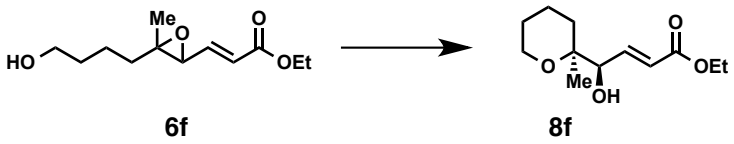
Characterization Data for 8e:

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.93 (dd, *J* = 15.6, 4.6 Hz, 1H), 6.18 (dd, *J* = 15.6, 1.9 Hz, 1H), 4.25 (dd, *J* = 4.6, 1.9 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.95-3.85 (m, 2H), 2.57 (br, 1H), 2.02-1.87 (m, 3H), 1.50-1.44 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.21 (s, 3H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 145.4, 122.5, 85.1, 76.2, 68.7, 60.6, 31.4, 26.5, 23.8, 14.4

FT-IR (ATR, cm^{-1}): 3435, 2976, 2873, 1717, 1656, 1448, 1369, 1305, 1272, 1175, 1094, 1036

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{11}H_{18}O_4$: 215.1278, found 215.1291



6f **8f**

(±)-CSA promoted cyclization of epoxy alcohol 6f: To a 20 ml vial equipped with a magnetic stir bar was added epoxide **6f** (44.6 mg, 0.20 mmol) in CH_2Cl_2 (10 mL) and (±)-CSA (10 mg, 0.04 mmol) and stirred at room temperature. After consumption of the starting material (5 h, as determined by TLC analysis), the clear solution was filtered through a plug of silica gel (pretreated with Et_3N/EtOAc 2:98 then flushed with EtOAc), eluted with EtOAc, and concentrated *in vacuo*. ^{1}H NMR spectroscopic analysis of the unpurified mixture indicated a 1:>20 [*endo*(**7f**)/*exo*(**8f**)] ratio of products. The resultant clear film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **8f** as a colorless oil (40.4 mg, 90%).

Characterization Data for 8f:

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.92 (dd, *J* = 15.6, 4.8 Hz, 1H), 6.16 (dd, *J* = 15.6, 1.9 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 4.11 (dd, *J* = 4.8, 1.8 Hz, 1H), 3.77-3.67 (m, 2H), 3.00 (br, 1H), 1.73-1.57 (m, 3H), 1.52-1.48 (m, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.22 (s, 3H), 1.19 (dt, *J* = 12.9, 3.4 Hz, 1H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.6, 145.0, 122.7, 77.51, 75.6, 62.1, 60.5, 28.4, 26.0, 19.0, 18.1, 14.4

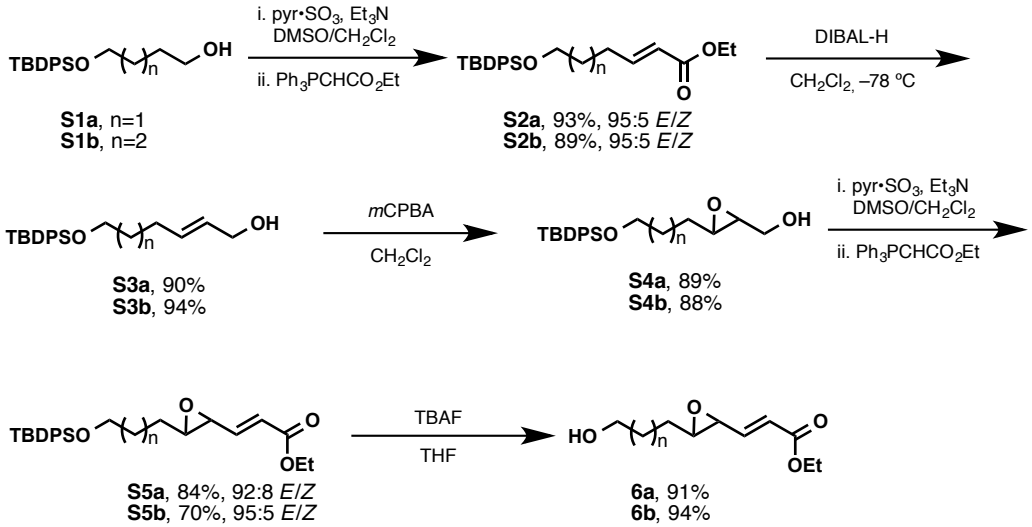
FT-IR (ATR, cm^{-1}): 3449, 2980, 2937, 2867, 1717, 1656, 1466, 1449, 1369, 1305, 1273, 1212, 1176, 1114, 1081, 1046

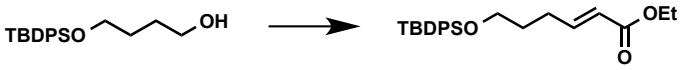
HRMS (ESI, *m/z*): $[M+Na]^+$ calculated for $C_{12}H_{20}O_4$: 251.1254, found 251.1273

III. Synthesis of Substrates

A. Synthesis of Epoxy Alcohols 6a and 6b:

Synthetic Route to Epoxy Alcohols 6a and 6b:





S1a **S2a**

(*E*)-Enoate S2a: To a solution of TBDPS-protected alcohol **S1a**[1] (2.0 g, 6.09 mmol) in CH_2Cl_2 (61 mL) was added DMSO (6.1 mL, 85.9 mmol) and Et_3N (4.3 mL, 30.5 mmol), cooled to 0 ºC, and Pyr•SO_3 (1.94 g, 12.2 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (4.25 g, 12.2 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (35 mL) and diluted with CH_2Cl_2 (35 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S2a** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S2a** as a colorless oil (2.24 g, 93%, 95:5 *E*/*Z*). The product could be purified further by flash chromatography (EtOAc/hexanes, gradient 0:100 to 6:94) to afford **S2a** as only the *E* alkene (1.98 g, 82%).

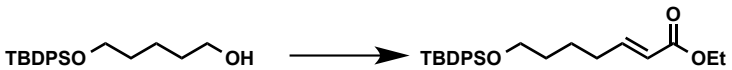
Data were consistent with those reported by Beauchemin and coworkers.[2]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.39 (m, 6H), 7.00 (dt, *J* = 15.6, 6.9 Hz, 1H), 5.84 (dt, *J* = 15.6, 1.6 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.70 (t, *J* = 6.1 Hz, 2H), 2.39-2.31 (m, 2H), 1.78-1.69 (m, 2H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.07 (s, 9H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 149.1, 135.7, 134.0, 129.8, 127.8, 121.7, 63.1, 60.3, 31.1, 28.8, 27.0, 19.4, 14.5

FT-IR (ATR, cm^{-1}): 3069, 2933, 2858, 1718, 1654, 1472, 1427, 1265, 1203, 1105, 1041

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{24}H_{32}O_3Si$: 414.2459, found 414.2460



S1b **S2b**

(*E*)-Enoate S2b: To a solution of TBDPS-protected alcohol **S1b**[1] (2.50 g, 7.30 mmol) in CH_2Cl_2 (73 mL) was added DMSO (7.3 mL, 0.10 mol) and Et_3N (5.1 mL, 36.5 mmol), cooled to 0 ºC, and Pyr•SO_3 (2.32 g, 14.6 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3h. At this point, (carbethoxymethylene)triphenylphosphorane (5.1 g, 14.6 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (50 mL) and diluted with CH_2Cl_2 (50 mL). The aqueous layer

[1] Zhu, G.; Negishi, E. *Org. Lett.* **2007**, *9*, 2771.
[2] Clavette, C.; Rocan, J.-F. V.; Beauchemin, A. M. *Angew. Chem., Int. Ed.* **2013**, *52*, 12705.

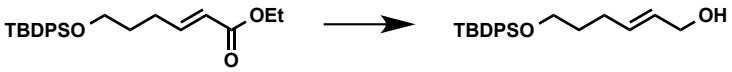
was separated and extracted twice with CH_2Cl_2 (30 mL each). The combined organics were washed with H_2O (50 mL), sat. $NaCl_{(aq)}$ (50 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S2b** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S2b** as a colorless oil (2.68 g, 89%, 95:5 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 0:100 to 3:97) to afford **S2b** enriched to 98:2 *E*/Z (1.20 g, 40%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.38 (m, 6H), 6.97 (dt, *J* = 15.6, 6.9 Hz, 1H), 5.81 (dt, *J* = 15.6, 1.5 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.68 (t, *J* = 5.9 Hz, 2H), 2.20 (qd, *J* = 7.1, 1.3 Hz, 2H), 1.63-1.55 (m, 4H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.06 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 149.4, 135.7, 134.1, 129.7, 127.8, 121.5, 63.6, 60.3, 32.11, 32.05, 27.0, 24.5, 19.4, 14.5

FT-IR (ATR, cm^{-1}): 3069, 2932, 2858, 1719, 1653, 1473, 1428, 1265, 1195, 1159, 1108, 1043

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{25}H_{34}O_3Si$: 428.2615, found 428.2617



S2a **S3a**

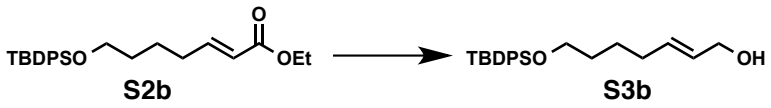
Alcohol S3a: To a solution of enoate **S2a** (1.97 g, 4.97 mmol) in CH_2Cl_2 (20 mL) at –78 ºC was added DIBAL–H (1.0 M in CH_2Cl_2, 17.4 mL, 17.4 mmol) dropwise over three min. The reaction was stirred for 20 min, and then quenched by slow addition of MeOH (5 mL) at –78 ºC. The reaction mixture was then poured into an Erlenmeyer flask containing sat. aq. Rochelle's salt (150 mL) and stirred vigorously for 2 h at room temperature. The aqueous layer was separated and extracted with CH_2Cl_2 (2x20 mL). The combined organics were dried over $MgSO_4$, filtered and concentrated *in vacuo* to afford crude alcohol **S3a** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 35:65) to afford **S3a** as a colorless oil (1.59 g, 90%).

^{1}H NMR (500 MHz, $CDCl_3$) δ7.71-7.70 (m, 4H), 7.47-7.39 (m, 6H), 5.72-5.62 (m, 2H), 4.09-4.07 (br, 2H), 3.71 (t, *J* = 6.3 Hz, 2H), 2.18 (q, *J* = 6.9 Hz, 2H), 1.69 (quint, *J* = 7.1 Hz, 2H), 1.48-1.44 (br, 1H), 1.09 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.1, 132.9, 129.7, 129.4, 127.8, 63.9, 63.3, 32.1, 28.6, 27.0, 19.4

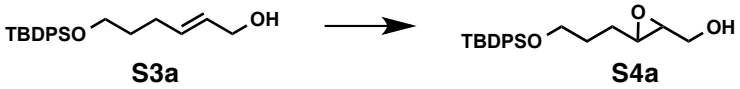
FT-IR (ATR, cm^{-1}): 3325, 3068, 2932, 2857, 1670, 1589, 1472, 1728, 1389, 1361, 1105, 998, 967

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{22}H_{30}O_2Si$: 372.2353, found 372.2346



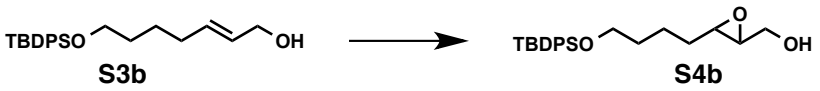
Alcohol S3b: To a solution of enoate **S2b** (1.20 g, 2.92 mmol) in CH_2Cl_2 (12 mL) at –78 ºC was added DIBAL–H (1.0 M in CH_2Cl_2, 10.5 mL, 10.5 mmol) dropwise over three min. The reaction was stirred for 25 min, and then quenched by slow addition of MeOH (3 mL) at –78 ºC. The reaction mixture was then poured into an Erlenmeyer flask containing sat. aq. Rochelle's salt (100 mL) and stirred vigorously for 2 h at room temperature. The aqueous layer was separated and extracted with CH_2Cl_2 (2x20 mL). The combined organics were dried over $MgSO_4$, filtered and concentrated *in vacuo* to afford crude alcohol **S3b** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 35:65) to afford **S3b** as a colorless oil (1.02 g, 94%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70-7.68 (m, 4H), 7.46-7.38 (m, 6H), 5.72-5.60 (m, 2H), 4.10 (br, 2H), 3.68 (t, *J* = 6.4 Hz, 2H), 2.06 (q, *J* = 6.9 Hz, 2H), 1.59 (dq, *J* = 8.7, 6.1 Hz, 2H), 1.51-1.45 (m, 2H), 1.35 (br, 1H), 1.07 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.2, 133.4, 129.7, 129.2, 127.8 63.98, 63.89, 32.20, 32.08, 27.0, 25.5, 19.4
FT-IR (ATR, cm^{-1}): 3324, 3057, 2931, 2859, 1669, 1590, 1472, 1428, 1389, 1105
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{23}H_{32}O_2Si$: 386.2510, found 386.2520



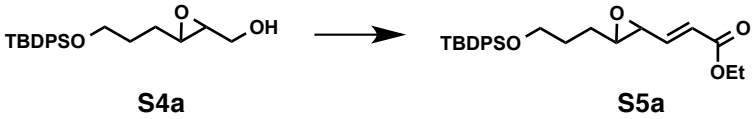
Epoxide S4a: To a solution of alcohol **S3a** (1.57 g, 4.43 mmol) in CH_2Cl_2 (44 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 1.49 g, 6.64 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (60 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (30 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (30 mL), and 10% $Na_2CO_{3(aq)}$ (30 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S3a** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 15:85 to 45:55) to afford **S3a** as a colorless oil (1.47 g, 89%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.66 (m, 4H), 7.44-7.38 (m, 6H), 3.88 (dd, *J* = 12.6, 2.5 Hz, 1H), 3.73-3.71 (m, 2H), 3.59 (dd, *J* = 12.6, 4.4 Hz, 1H), 2.98-2.96 (m, 1H), 2.91 (ddd, *J* = 4.5, 2.3, 2.3 Hz, 1H), 1.90-1.80 (br, 1H), 1.75-1.66 (m, 4H), 1.07 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 133.98, 133.97, 129.8, 127.8, 63.4, 61.8, 58.6, 55.9, 29.0, 28.2, 27.0, 19.4
FT-IR (ATR, cm^{-1}): 3407, 2932, 2858, 1472, 1428, 1389, 1361, 1307, 1105
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{22}H_{30}O_3Si$: 388.2302, found 388.2292



Epoxide S4b: To a solution of alcohol **S3b** (0.97 g, 2.63 mmol) in CH_2Cl_2 (26 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 0.88 g, 3.95 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (30 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (20 mL), and 10% $Na_2CO_{3(aq)}$ (20 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S4b** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 40:60) to afford **S4b** as a colorless oil (0.89 g, 88%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.67 (m, 4H), 7.45-7.38 (m, 6H), 3.93-3.90 (m, 1H), 3.68 (t, *J* = 6.1 Hz, 2H), 3.65-3.61 (m, 1H), 2.96-2.94 (m, 1H), 2.91 (dt, *J* = 4.4, 2.3 Hz, 1H), 1.74 (t, *J* = 5.8 Hz, 1H), 1.65-1.50 (m, 6H), 1.06 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.1, 129.7, 127.8, 63.7, 61.8, 58.5, 56.0, 32.4, 31.4, 27.0, 22.5, 19.4
FT-IR (ATR, cm^{-1}): 3420, 3069, 2931, 2858, 1589, 1472, 1428, 1389, 1361, 1188, 1105
HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{23}H_{32}O_3Si$: 402.2459, found 402.2443



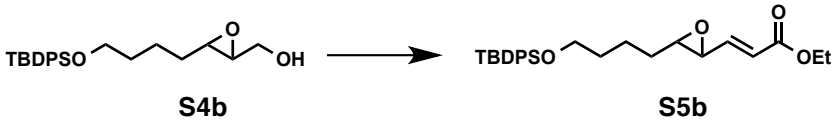
(*E*)-Epoxy Enoate S5a: To a solution of epoxy alcohol **S4a** (1.40 g, 3.78 mmol) in CH_2Cl_2 (38 mL) was added DMSO (3.8 mL, 53.5 mmol) and Et_3N (2.6 mL, 19 mmol), cooled to 0 ºC, and Pyr•SO_3 (1.20 g, 7.56 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (2.63 g, 7.56 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (25 mL) and diluted with CH_2Cl_2 (25 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5a** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, isocratic 10:90) to afford **S5a** as a colorless oil (1.39 g, 84%, 92:8 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 0:100 to 8:92) to afford **S5a** as only the (*E*)-alkene (1.07 g, 65%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.66 (m, 4H), 7.46-7.38 (m, 6H), 6.65 (dd, *J* = 15.7, 7.2 Hz, 1H), 6.11 (dd, *J* = 15.7, 0.7 Hz, 1H), 4.22 (q, *J* = 7.1 Hz, 2H), 3.71 (t, *J* = 5.4 Hz, 2H), 3.20 (ddd, *J* = 7.2, 1.9, 0.5 Hz, 1H), 2.89 (td, *J* = 5.1, 2.0 Hz, 1H), 1.76-1.69 (m, 4H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.06 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 165.8, 144.9, 135.7, 133.92, 133.89, 129.8, 127.84, 127.83, 123.8, 63.2, 61.3, 60.7, 56.5, 28.8, 28.6, 27.0, 19.4, 14.4

FT-IR (ATR, cm^{-1}): 3067, 2933, 2858, 1719, 1655, 1589, 1472, 1428, 1390, 1368, 1302, 1258, 1182, 1106

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{26}H_{34}O_4Si$: 456.2565, found 456.2557



S4b **S5b**

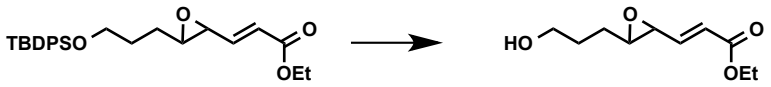
(*E*)-Epoxy Enoate S5b: To a solution of epoxy alcohol **S4b** (0.83 g, 2.16 mmol) in CH_2Cl_2 (21 mL) was added DMSO (2.2 mL, 31 mmol) and Et_3N (1.5 mL, 10.8 mmol), cooled to 0 ºC, and Pyr•SO_3 (0.69 g, 4.3 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (1.5 g, 4.3 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (25 mL) and diluted with CH_2Cl_2 (25 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5b** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S5b** as a colorless oil (0.69 g, 70%, 95:5 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 0:100 to 6:94) to afford **S5b** as only the (*E*)-alkene (0.38 g, 38%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.66 (m, 4H), 7.45-7.37 (m, 6H), 6.68 (dd, *J* = 15.7, 7.1 Hz, 1H), 6.12 (dd, *J* = 15.7, 0.6 Hz, 1H), 4.22 (q, *J* = 7.1 Hz, 2H), 3.68 (t, *J* = 5.9 Hz, 2H), 3.19 (ddd, *J* = 7.1, 2.0, 0.6 Hz, 1H), 2.89-2.86 (m, 1H), 1.62-1.52 (m, 6H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.06 (s, 9H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 144.9, 135.7, 134.1, 129.7, 127.8, 123.7, 63.7, 61.5, 60.7, 56.4, 32.3, 31.8, 27.0, 22.4, 19.4, 14.4

FT-IR (ATR, cm^{-1}): 3067, 2933, 2858, 1719, 1655, 1589, 1473, 1428, 1390, 1368, 1302, 1256, 1180, 1093, 1041

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{27}H_{36}O_4Si$: 470.2721, found 470.2703

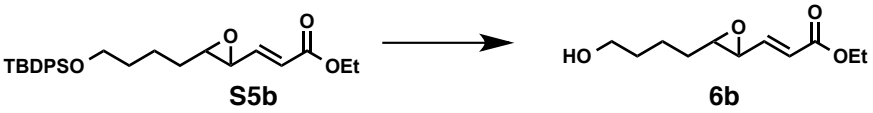


S5a **6a**

(*E*)-Epoxy Alcohol 6a: To a solution of enoate **S5a** (0.60 g, 1.37 mmol) in THF (2.7 mL) at 0 ºC was added TBAF (1.0 M in THF, 2.7 mL, 2.7 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature

over 2 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 60:40) to afford **6a** as a colorless oil (0.25 g, 91%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.67 (dd, *J* = 15.7, 7.1 Hz, 1H), 6.12 (d, *J* = 15.7 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 3.69 (t, *J* = 5.9 Hz, 2H), 3.25 (dd, *J* = 7.1, 1.5 Hz, 1H), 2.94 (td, *J* = 5.4, 1.8 Hz, 1H), 1.84-1.61 (m, 5H), 1.28 (t, *J* = 7.1 Hz, 3H)
^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 144.6, 123.9, 62.3, 61.3, 60.8, 56.6, 29.0, 28.6, 14.4
FT-IR (ATR, cm^{-1}): 3414, 2983, 2934, 2875, 1715, 1654, 1446, 1369, 1303, 1259, 1182, 1142, 1033
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{10}H_{16}O_4$: 218.1387, found 218.1391

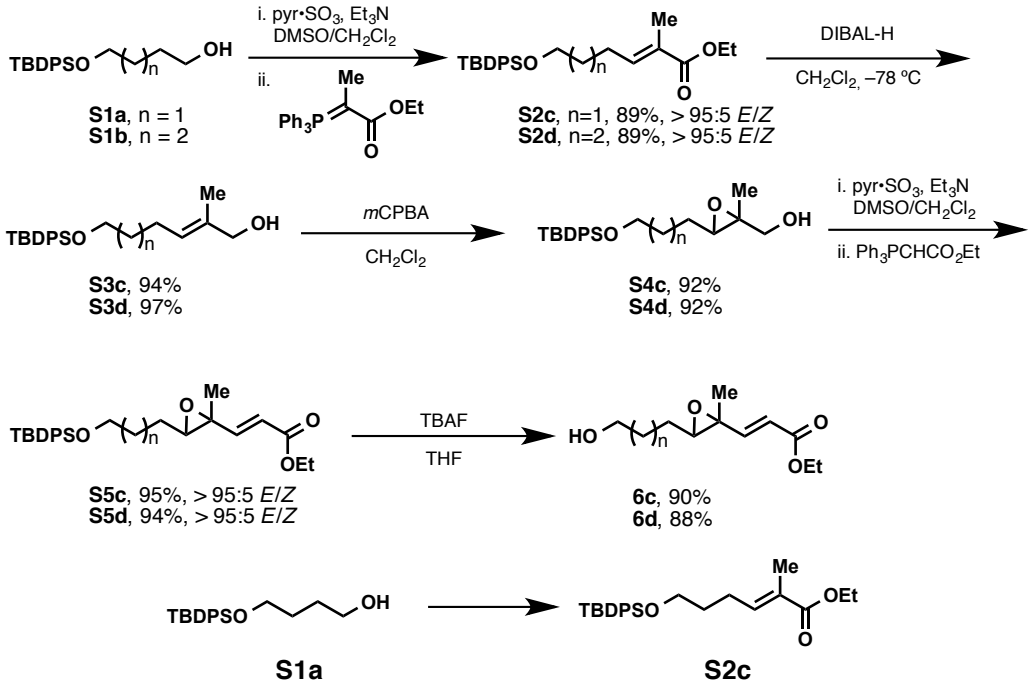


(*E*)-Epoxy Alcohol 6b: To a solution of enoate **S5b** (0.38 g, 0.84 mmol) in THF (1.7 mL) at 0 ºC was added TBAF (1.0 M in THF, 1.7 mL, 1.7 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature over 2 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 60:40) to afford **92b** as a colorless oil (0.17 g, 94%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.64 (dd, *J* = 15.7, 7.1 Hz, 1H), 6.10 (d, *J* = 15.7 Hz, 1H), 4.17 (q, *J* = 7.1 Hz, 2H), 3.62 (t, *J* = 6.2 Hz, 2H), 3.21 (dd, *J* = 7.1, 1.7 Hz, 1H), 2.90-2.87 (m, 1H), 1.91 (br, 1H), 1.65-1.50 (m, 6H), 1.26 (t, *J* = 7.1 Hz, 3H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 165.8, 144.8, 123.8, 62.5, 61.4, 60.7, 56.4, 32.3, 31.7, 22.3, 14.3
FT-IR (ATR, cm^{-1}): 3423, 2978, 2936, 2865, 1716, 1655, 1446, 1369, 1303, 1258, 1180, 1141, 1033
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{11}H_{18}O_4$: 232.1543, found 232.1541

B. Synthesis of Epoxy Alcohols 6c and 6d:

Scheme S1: Synthetic Route to epoxy alcohols 6c and 6d.



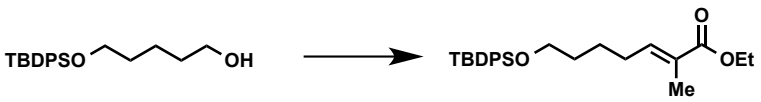
(*E*)-Enoate S2c: To a solution of TBDPS-protected alcohol **S1a**[1] (3.33 g, 10.1 mmol) in CH_2Cl_2 (100 mL) was added DMSO (10 mL, 0.14 mol) and Et_3N (7.0 mL, 50 mmol), cooled to 0 ºC, and Pyr•SO_3 (3.22 g, 20.2 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (Carbethoxyethylidene)triphenylphosphorane (7.32 g, 20.2 mmol) was added as a solid at room temperature and stirred for 12 h. The reaction was quenched by addition of H_2O (75 mL) and diluted with CH_2Cl_2 (25 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (30 mL each). The combined organics were washed with H_2O (50 mL), sat. $NaCl_{(aq)}$ (50 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S2c** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S2c** as a colorless oil (2.92 g, 89%, 96:4 *E*/*Z*). The product was purified further by flash chromatography with a gradient of solvents (EtOAc/hexanes, gradient 2:98 to 4:96) to afford **S2c** enriched to >99:1 *E*/Z (1.27 g, 39%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.66 (m, 4H), 7.46-7.38 (m, 6H), 6.77 (tq, *J* = 7.5, 1.4 Hz, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 3.69 (t, *J* = 6.1 Hz, 2H), 2.30 (q, *J* = 7.4 Hz, 2H), 1.85 (d, *J* = 1.3 Hz, 3H), 1.73-1.67 (m, 2H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.07 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 168.4, 142.0, 135.7, 134.0, 129.8, 128.2, 127.8, 63.4, 60.6, 31.6, 27.0, 25.3, 19.4, 14.5, 12.5

FT-IR (ATR, cm^{-1}): 3073, 2933, 2858, 1708, 1651, 1590, 1473, 1428, 1389, 1366, 1261, 1234, 1190, 1106, 1030

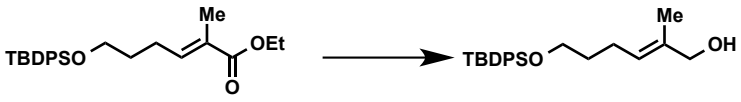
HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{25}H_{34}O_3Si$: 428.2615, found 428.2635



S1b **S2d**

(E) Enoate S2d: To a solution of TBDPS-protected alcohol **S1b**[1] (2.64 g, 7.7 mmol) in CH_2Cl_2 (77 mL) was added DMSO (7.7 mL, 0.11 mol) and Et_3N (5.4 mL, 39 mmol), cooled to 0 ºC, and Pyr•SO_3 (2.45 g, 15.4 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3h. At this point, (Carbethoxyethylidene)triphenylphosphorane (5.60 g, 15.4 mmol) was added as a solid at room temperature and stirred for 12 h. The reaction was quenched by addition of H_2O (75 mL) and diluted with CH_2Cl_2 (25 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (30 mL each). The combined organics were washed with H_2O (50 mL), sat. $NaCl_{(aq)}$ (50 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S2d** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S2d** as a colorless oil (2.92 g, 89%, 96:4 *E*/*Z*). The product was purified further by flash chromatography with a gradient of solvents (EtOAc/hexanes, gradient 2:98 to 4:96) to afford **S2d** enriched to >99:1 *E*/Z (1.27 g, 39%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.68 (m, 4H), 7.46-7.38 (m, 6H), 6.77 (d, *J* = 7.4 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.69 (t, *J* = 5.9 Hz, 2H), 2.18 (q, *J* = 7.2 Hz, 2H), 1.83 (s, 3H), 1.63-1.53 (m, 4H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.07 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 168.4, 142.3, 135.7, 134.1, 129.7, 128.0, 127.8, 63.7, 60.6, 32.4, 28.5, 27.0, 25.1, 19.4, 14.5, 12.5
FT-IR (ATR, cm^{-1}): 3055, 2932, 2858, 1708, 1651, 1590, 1472, 1428, 1389, 1365, 1254, 1223, 1185, 1104
HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{26}H_{36}O_3Si$: 442.2772, found 442.2772



S2c **S3c**

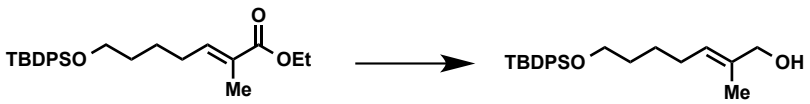
Alcohol S3c: To a solution of enoate **S2c** (2.37 g, 5.77 mmol) in CH_2Cl_2 (25 mL) at –78 ºC was added DIBAL–H (1.0 M in CH_2Cl_2, 20 mL, 20 mmol) dropwise over three min. The reaction was stirred for 2.5 h, and then quenched by slow addition of MeOH (6 mL) at –78 ºC. The reaction mixture was then poured into an Erlenmeyer flask containing sat. aq. Rochelle's salt (150 mL) and stirred vigorously for 2 h at room temperature. The aqueous layer was separated and extracted with CH_2Cl_2 (2x30 mL). The combined organics were dried over $MgSO_4$, filtered and concentrated *in vacuo* to afford crude alcohol **S3c** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 15:85 to 20:80) to afford **S3c** as a colorless oil (1.98 g, 94%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.68 (m, 4H), 7.45-7.38 (m, 6H), 5.38 (tq, *J* = 7.2, 1.3 Hz, 1H), 3.99 (d, *J* = 5.0 Hz, 2H), 3.68 (t, *J* = 6.3 Hz, 2H), 2.14 (q, *J* = 7.3 Hz, 2H), 1.67 (d, *J* = 0.4 Hz, 3H), 1.65-1.61 (m, 2H), 1.26 (t, *J* = 5.9 Hz, 1H), 1.07 (s, 9H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 135.7, 135.2, 134.2, 129.7, 127.8, 126.1, 69.2, 63.5, 32.5, 27.0, 24.0, 19.4, 13.8

FT-IR (ATR, cm^{-1}): 3300, 2931, 2858, 1472, 1428, 1388, 1109, 1007

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{23}H_{32}O_2Si$: 386.2510, found 386.2492



S2d **S3d**

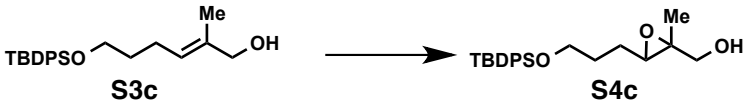
Alcohol S3d: To a solution of enoate **S2d** (1.21 g, 2.85 mmol) in CH_2Cl_2 (12 mL) at –78 ºC was added DIBAL–H (1.0 M in CH_2Cl_2, 10 mL, 10 mmol) dropwise over three min. The reaction was stirred for 2.5 h, and then quenched by slow addition of MeOH (3 mL) at –78 ºC. The reaction mixture was then poured into an Erlenmeyer flask containing sat. aq. Rochelle's salt (100 mL) and stirred vigorously for 5 h at room temperature. The aqueous layer was separated and extracted with CH_2Cl_2 (2x20 mL). The combined organics were dried over $MgSO_4$, filtered and concentrated *in vacuo* to afford crude alcohol **S3d** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 30:70) to afford **S3d** as a colorless oil (1.06 g, 2.77 mmol, 97%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (m, 4H), 7.45-7.37 (m, 6H), 5.40 (tq, *J* = 7.1, 1.2 Hz, 1H), 4.01 (s, 2H), 3.67 (t, *J* = 6.4 Hz, 2H), 2.04 (q, *J* = 7.3 Hz, 2H), 1.65 (s, 3H), 1.61-1.56 (m, 2H), 1.48-1.42 (m, 2H), 1.39 (br, 1H), 1.06 (s, 9H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 135.8, 135.0, 134.3, 129.7, 127.8, 126.6, 69.2, 64.0, 32.4, 27.5, 27.1, 25.9, 19.4, 13.9

FT-IR (ATR, cm^{-1}): 3321, 3069, 2931, 2857, 1472, 1428, 1389, 1361, 1189, 1109, 1007

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{24}H_{34}O_2Si$: 400.2666, found 400.2669

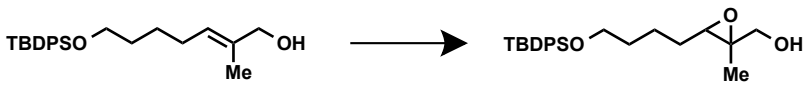


S3c **S4c**

Epoxide S4c: To a solution of alcohol **S3c** (1.94 g, 5.32 mmol) in CH_2Cl_2 (53 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 1.78 g, 8.00 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (60 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (30 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (30 mL), and 10% $Na_2CO_{3(aq)}$ (30 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S4c** as a

colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 40:60) to afford **S4c** as a colorless oil (1.87 g, 92%).

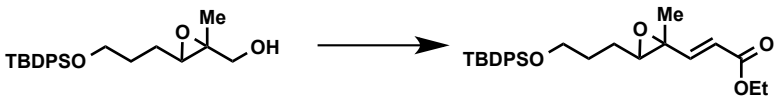
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.66 (m, 4H), 7.44-7.37 (m, 6H), 3.75-3.70 (m, 2H), 3.67 (dd, *J* = 12.1, 4.4 Hz, 1H), 3.56 (dd, *J* = 12.2, 8.7 Hz, 1H), 3.04 (t, *J* = 6.0 Hz, 1H), 1.78-1.67 (m, 4H), 1.60 (dd, *J* = 8.7, 4.4 Hz, 1H), 1.27 (s, 3H), 1.06 (s, 9H)
^{13}C NMR (150 MHz, $CDCl_3$) δ 135.73, 135.72, 134.0, 129.8, 127.8, 65.4, 63.5, 61.0, 60.0, 29.5, 27.0, 24.9, 19.4, 14.3
FT-IR (ATR, cm^{-1}): 3400, 2931, 2858, 1472, 1428, 1387, 1258, 1191, 1106, 1039
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{23}H_{32}O_3Si$: 402.2459, found 402.2450



S3d **S4d**

Epoxide S4d: To a solution of alcohol **S3d** (1.02 g, 2.67 mmol) in CH_2Cl_2 (27 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 0.90 g, 4.0 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (30 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (20 mL), and 10% $Na_2CO_{3(aq)}$ (20 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S4d** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to afford **S4d** as a colorless oil (0.98 g, 92%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70-7.67 (m, 4H), 7.45-7.38 (m, 6H), 3.71-3.68 (m, 3H), 3.58 (dd, *J* = 12.1, 8.1 Hz, 1H), 3.04 (t, *J* = 5.8 Hz, 1H), 1.87 (dd, *J* = 8.0, 4.3 Hz, 1H), 1.66-1.52 (m, 6H), 1.28 (s, 3H), 1.07 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.1, 129.7, 127.8, 65.5, 63.7, 61.0, 60.3, 32.5, 28.1, 27.0, 23.0, 19.4, 14.4
FT-IR (ATR, cm^{-1}): 3424, 3069, 2931, 2859, 1589, 1472, 1428, 1388, 1260, 1188, 1105, 1039
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{24}H_{34}O_3Si$: 416.2615, found 416.2593



S4c **S5c**

(*E*)-Epoxy Enoate S5c: To a solution of epoxy alcohol **S4c** (1.82 g, 4.78 mmol) in CH_2Cl_2 (48 mL) was added DMSO (4.8 mL, 67.6 mmol) and Et_3N (3.4 mL, 24 mmol), cooled to 0 ºC, and Pyr•SO_3 (1.53 g, 9.6 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point,

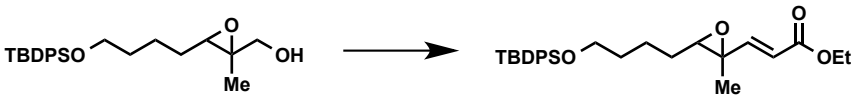
(carbethoxymethylene)triphenylphosphorane (3.34 g, 9.6 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (50 mL) and diluted with CH_2Cl_2 (25 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (25 mL each). The combined organics were washed with H_2O (30 mL), sat. $NaCl_{(aq)}$ (30 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5c** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 7:93 to 10:90) to afford **S5c** as a colorless oil (2.06 g, 95%, 95:5 *E*/*Z*).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66 (m, 4H), 7.45-7.38 (m, 6H), 6.73 (d, *J* = 15.7 Hz, 1H), 6.00 (d, *J* = 15.7 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.73-3.67 (m, 2H), 2.85 (t, *J* = 5.7 Hz, 1H), 1.76-1.65 (m, 4H), 1.42 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (s, 9H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 166.3, 150.1, 135.7, 133.89, 133.87, 129.8, 127.8, 121.7, 65.8, 63.3, 60.7, 58.7, 29.3, 27.0, 25.3, 19.4, 15.2, 14.4

FT-IR (ATR, cm^{-1}): 2932, 2858, 1719, 1654, 1473, 1428, 1389, 1366, 1304, 1270, 1175, 1111, 1035

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{27}H_{36}O_4Si$: 470.2721, found 470.2717



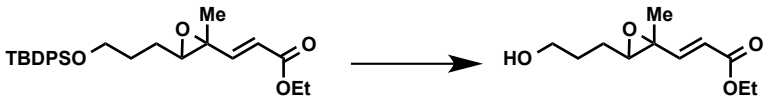
(*E*)-Epoxy Enoate S5d: To a solution of epoxy alcohol **S4d** (0.94 g, 2.36 mmol) in CH_2Cl_2 (24 mL) was added DMSO (2.4 mL, 34 mmol) and Et_3N (1.6 mL, 12 mmol), cooled to 0 ºC, and Pyr•SO_3 (0.94 g, 5.9 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (1.64 g, 4.7 mmol) was added as a solid at room temperature and stirred for 30 min. The reaction was quenched by addition of H_2O (30 mL) and diluted with CH_2Cl_2 (15 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (15 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5d** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S5d** as a colorless oil (1.04 g, 94%, 95:5 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 2:98 to 10:90) to afford **S5d** as only the (*E*)-alkene (0.50 g, 45%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.38 (m, 6H), 6.77 (d, *J* = 15.8 Hz, 1H), 6.03 (d, *J* = 15.8 Hz, 1H), 4.22 (q, *J* = 7.1, 2H), 3.69 (t, *J* = 6.0 Hz, 2H), 2.84 (t, *J* = 5.7 Hz, 1H), 1.66-1.53 (m, 6H), 1.42 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.07 (s, 9H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 150.1, 135.7, 134.1, 129.7, 127.8, 121.6, 66.0, 63.6, 60.7, 58.5, 32.4, 28.4, 27.0, 22.9, 19.4, 15.3, 14.4

FT-IR (ATR, cm^{-1}): 2933, 2858, 1718, 1654, 1472, 1428, 1388, 1366, 1303, 1262, 1210, 1166, 1105, 1033

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{28}H_{38}O_4Si$: 484.2878, found 484.2858



S5c **6c**

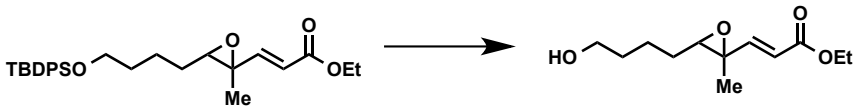
(*E*)-Epoxy Alcohol 6c: To a solution of enoate **S5c** (0.42 g, 0.93 mmol) in THF (1.9 mL) at 0 ºC was added TBAF (1.0 M in THF, 1.9 mL, 1.9 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature over 1.5 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 60:40) to afford **6c** as a colorless oil (0.18 g, 90%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 6.73 (d, *J* = 15.7 Hz, 1H), 6.00 (d, *J* = 15.7 Hz, 1H), 4.19-4.16 (m, 2H), 3.69 (br, 2H), 2.89-2.87 (m, 1H), 2.01 (br, 1H), 1.77-1.63 (m, 4H), 1.43 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 166.3, 149.8, 121.7, 65.8, 62.2, 60.7, 58.9, 29.4, 25.2, 15.3, 14.3

FT-IR (ATR, cm^{-1}): 3453, 2938, 2885, 1716, 1654, 1456, 1368, 1304, 1264, 1174, 1032

HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{11}H_{18}O_4$: 215.1278, found 215.1290



S5d **6d**

(*E*)-Epoxy Alcohol 6d: To a solution of enoate **S5d** (0.53 g, 1.14 mmol) in THF (2.3 mL) at 0 ºC was added TBAF (1.0 M in THF, 2.3 mL, 2.3 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature over 1.5 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 60:40) to afford **6d** as a colorless oil (0.21 g, 88%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.72 (d, *J* = 15.8 Hz, 1H), 5.98 (d, *J* = 15.8 Hz, 1H), 4.17 (q, *J* = 7.1 Hz, 2H), 3.63 (t, *J* = 6.1 Hz, 2H), 2.83 (t, *J* = 5.9 Hz, 1H), 1.92 (br, 1H), 1.65-1.49 (m, 6H), 1.41 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H)

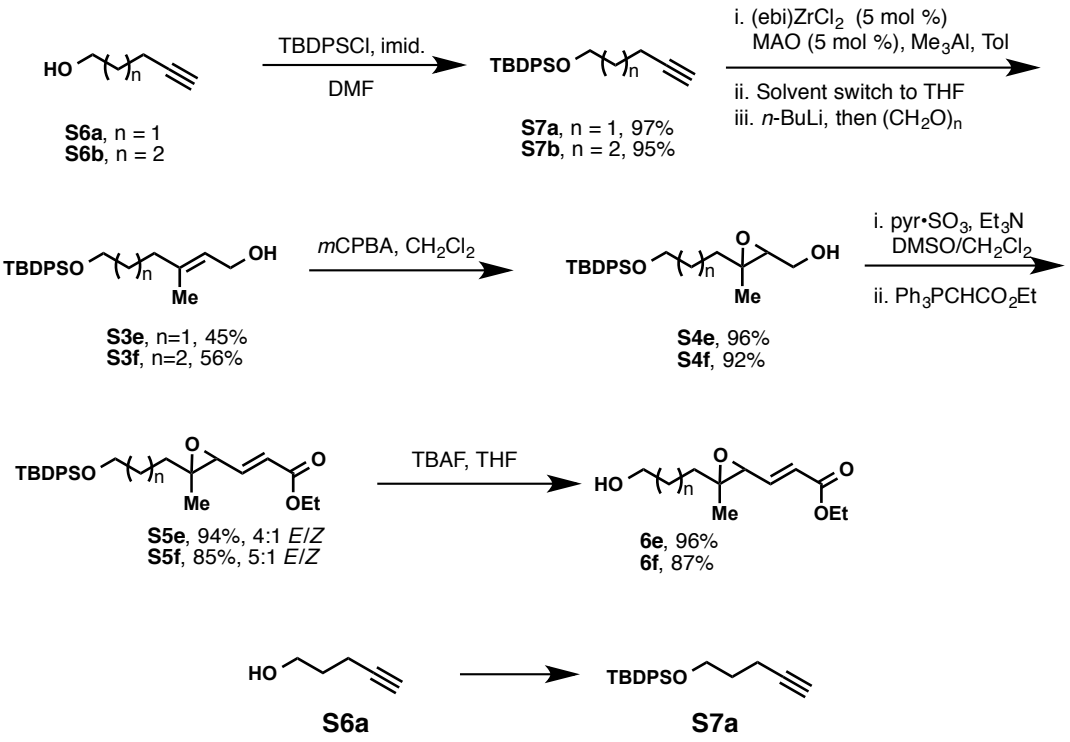
^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 150.0, 121.6, 65.9, 62.6, 60.7, 58.6, 32.4, 28.4, 22.8, 15.3, 14.3

FT-IR (ATR, cm^{-1}): 3400, 2933, 2870, 1716, 1654, 1457, 1388, 1368, 1305, 1264, 1175, 1031

HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{12}H_{20}O_4$: 246.1700, found 246.1699

C. Synthesis of Epoxy Alcohols 6e and 6f:

Scheme S2: Synthetic Route to Epoxy Alcohols 6c and 6d.



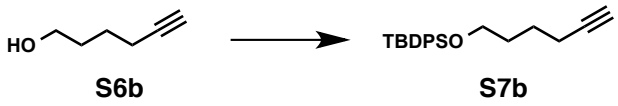
Alkyne S7a: To a solution of 4-pentyn-1-ol (**S6a**, 4.21 g, 50.0 mmol) and imidazole (4.77 g, 70.0 mmol) in DMF (50 mL) cooled to 0 ºC was added TBDPSCl (15.6 mL, 60.0 mmol). After 5 h, the reaction was quenched with the addition of H_2O (50 mL) and diluted with Et_2O (50 mL). The aqueous layer was separated and extracted twice with Et_2O (20 mL each). The combined organics were washed with H_2O (2 x 25 mL), sat. $NaCl_{(aq)}$ (25 mL), dried over Na_2SO_4, filtered, and concentrated *in vacuo* to afford crude alkyne **S7a** as a pale yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 0:100 to 5:95) to afford **S7a** as a colorless oil (16.3 g, 48.5 mmol, 97%).

^{1}H NMR (500 MHz, $CDCl_3$) δ. 7.71-7.69 (m, 4H), 7.47-7.39 (m, 6H), 3.78 (t, *J* = 6.0 Hz, 2H), 2.38 (td, *J* = 7.2, 2.6 Hz, 2H), 1.94 (t, *J* = 2.7 Hz, 1H), 1.83-1.78 (m, 2H), 1.08 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.0, 129.8, 127.8, 84.4, 68.5, 62.4, 31.6, 27.0, 19.4, 15.2

FT-IR (ATR, cm^{-1}): 3303, 3069, 2932, 2857, 1889, 1824, 1589, 1472, 1426, 189, 1361, 1259, 1189, 1104, 1007

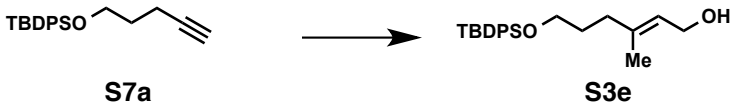
HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{21}H_{26}OSi$: 323.1826, found 323.1816



S6b **S7b**

Alkyne S7b: To a solution of 5-pentyn-1-ol (**S6b**, 3.93 g, 40.0 mmol) and imidazole (3.81 g, 56.0 mmol) in DMF (40 mL) cooled to 0 ºC was added TBDPSCl (12.5 mL, 48.0 mmol). After 5 h, the reaction was quenched with the addition of H_2O (40 mL) and diluted with Et_2O (40 mL). The aqueous layer was separated and extracted twice with Et_2O (20 mL each). The combined organics were washed with H_2O (2 x 40 mL), sat. $NaCl_{(aq)}$ (40 mL), dried over Na_2SO_4, filtered, and concentrated *in vacuo* to afford crude alkyne **S7b** as a pale yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 0:100 to 5:95) to afford **S7b** as a colorless oil (12.8 g, 95%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.38 (m, 6H), 3.69 (t, *J* = 5.9 Hz, 2H), 2.21 (td, *J* = 6.8, 2.6 Hz, 2H), 1.95 (t, *J* = 2.6 Hz, 1H), 1.72-1.62 (m, 4H), 1.06 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.1, 129.7, 127.8, 84.7, 68.4, 63.5, 31.7, 27.0, 25.1, 19.4, 18.4
FT-IR (ATR, cm^{-1}): 3306, 3069, 2932, 2858, 1888, 1824, 1589, 1472, 1427, 1389, 1361, 1261, 1188, 1106, 1008
HRMS (DART, *m/z*): $[M+H]^+$ calculated for $C_{22}H_{28}OSi$: 337.1982, found 337.1969

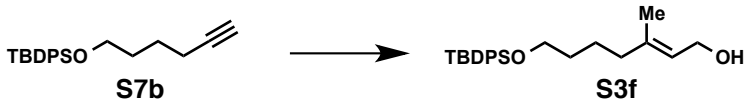


S7a **S3e**

Alcohol S3e:[3] To (±)-(ebi)$ZrCl_2$ (0.20 g, 0.48 mmol) was added $AlMe_3$ in toluene (7.2 mL, 2.0 M, 14.4 mmol), MAO in toluene (0.32 mL, 10 wt%, 0.48 mmol), and finally alkyne **S7a** (3.10 g, 9.6 mmol). The reaction, which became very viscous, was stirred at room temperature. After 20 h, the reaction mixture was concentrated *in vacuo* (25 ºC, 1 torr) and refilled with Ar. The viscous oil was diluted with THF (10 mL), and *n*-BuLi in hexanes (5.2 mL, 1.94 M, 10.1 mmol) was added dropwise over 2 min. After stirring at room temperature for 30 min, a suspension of paraformaldehyde (0.86 g, 28.8 mmol) in THF (20 mL) was added. After an additional 4 h, the reaction was diluted with hexanes (10 mL) and quenched with the dropwise addition of 1 M $HCl_{(aq)}$ (5 mL), and the combined mixture was poured into sat. Rochelle's salt in water (100 mL). After stirring vigorously for 10 min, the mixture was allowed to stand for 10 min, and the organic layer was separated from the gelatinous aqueous layer. To the aqueous layer was added hexanes (10 mL) and EtOAc (10 mL), and the combined mixture was vigorously stirred for 1 h, followed by separation of the organic layer. The combined organic layers were dried Na_2SO_4, filtered, and concentrated *in vacuo* to afford a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 45:55) to afford **S3e** as a colorless oil (1.60 g, 45%).

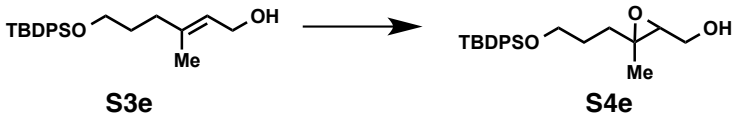
[3] Procedure adapted from the following report: Lipshutz, B. H.; Butler, T.; Lower, A. *J. Am. Chem. Soc.* **2006**, *128*, 15396.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70-7.68 (m, 4H), 7.46-7.38 (m, 6H), 5.40 (t, *J* = 6.9 Hz, 1H), 4.14 (d, *J* = 6.9 Hz, 2H), 3.67 (t, *J* = 6.4 Hz, 2H), 2.12 (t, *J* = 7.7 Hz, 2H), 1.73-1.67 (m, 2H), 1.66 (s, 3H), 1.23 (br, 1H), 1.07 (s, 9H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 139.7, 135.7, 134.2, 129.7, 127.8, 123.6, 63.6, 59.5, 35.9, 30.8, 27.0, 19.4, 16.4
FT-IR (ATR, cm^{-1}): 3326, 2068, 2931, 2856, 1888, 1825, 1668, 1589, 1472, 1427, 1388, 1304, 1253, 1188, 1106
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{23}H_{32}O_2Si$: 386.2510, found 386.2501



Alcohol S3f:[3] To (±)-(ebi)$ZrCl_2$ (0.40 g, 0.96 mmol) was added $AlMe_3$ in toluene (14.4 mL, 2.0 M, 28.8 mmol), MAO in toluene (0.64 mL, 10 wt%, 0.96 mmol), and finally alkyne **S7b** (6.46 g, 19.2 mmol). The reaction, which became very viscous, was stirred at room temperature. After 20 h, the reaction mixture was concentrated *in vacuo* (25 ºC, 1 torr) and refilled with Ar. The viscous oil was diluted with THF (19 mL), and *n*-BuLi in hexanes (9.4 mL, 2.25 M, 21.1 mmol) was added dropwise over 2 min. After stirring at room temperature for 30 min, a suspension of paraformaldehyde (1.73 g, 57.6 mmol) in THF (40 mL) was added. After an additional 4 h, the reaction was diluted with hexanes (20 mL) and quenched with the dropwise addition of 1 M $HCl_{(aq)}$ (5 mL), and the combined mixture was poured into sat. Rochelle's salt in water (200 mL). After stirring vigorously for 10 min, the mixture was allowed to stand for 10 min, and the organic layer was separated from the gelatinous aqueous layer. To the aqueous layer was added hexanes (20 mL) and EtOAc (20 mL), and the combined mixture was vigorously stirred for 2.5 h, followed by separation of the organic layer. The combined organic layers were dried Na_2SO_4, filtered, and concentrated *in vacuo* to afford a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 30:70) to afford **S3f** as a colorless oil (4.1 g, 56%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.37 (m, 6H), 5.39 (tq, *J* = 7.0, 1.3 Hz, 1H), 4.15 (d, *J* = 6.9 Hz, 2H), 3.67 (t, *J* = 6.1 Hz, 2H), 2.01 (t, *J* = 7.1 Hz, 2H), 1.66 (d, *J* = 0.4 Hz, 3H), 1.57-1.49 (m, 5H), 1.06 (s, 9H)
^{13}C NMR (150 MHz, $CDCl_3$) δ 139.7, 135.7, 134.1, 129.6, 127.7, 123.5, 63.8, 59.4, 39.3, 32.2, 27.0, 23.9, 19.3, 16.2
FT-IR (ATR, cm^{-1}): 3336, 3067, 2931, 2858, 1665, 1589, 1472, 1428, 1388, 1361, 1305, 1187, 1106
HRMS (DART, *m/z*): $[M+NH_4]^+$ calculated for $C_{24}H_{34}O_2Si$: 400.2666, found 400.2654



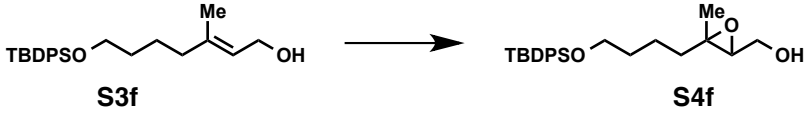
Epoxide S4e: To a solution of alcohol **S3e** (1.28 g, 3.47 mmol) in CH_2Cl_2 (34 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 1.13 g, 5.0 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (50 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (25 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (25 mL), and 10% $Na_2CO_{3(aq)}$ (25 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S4e** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 40:60) to afford **S4e** as a colorless oil (1.28 g, 96%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.65 (m, 4H), 7.45-7.38 (m, 6H), 3.80 (dd, *J* = 11.9, 3.9 Hz, 1H), 3.70-3.66 (m, 3H), 2.95 (dd, *J* = 6.6, 4.4 Hz, 1H), 1.73-1.58 (m, 5H), 1.28 (s, 3H), 1.06 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.01, 134.00, 129.79, 129.79, 127.8, 63.6, 62.9, 61.6, 61.3, 35.0, 28.3, 27.0, 19.4, 17.0

FT-IR (ATR, cm^{-1}): 3410, 3054, 2931, 2857, 1590, 1472, 1427, 1386, 1361, 1255, 1188, 1105, 1087, 1026

HRMS (ESI, *m/z*): $[M+Na]^+$ calculated for $C_{23}H_{32}O_3Si$: 407.2013, found 407.2029



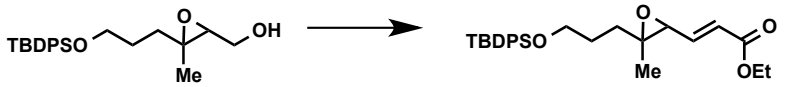
Epoxide S4f: To a solution of alcohol **S3f** (3.50 g, 9.2 mmol) in CH_2Cl_2 (92 mL) at 0 ºC was added *m*CPBA (≤ 77 wt %, 3.08 g, 13.7 mmol) as a solid in one portion. The reaction was allowed to warm to room temperature and stirred for 2 h, and then quenched by addition of 10% $Na_2CO_{3(aq)}$ (90 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (50 mL each). The combined organic layer was washed with sat. $NaHSO_{3(aq)}$ (50 mL), and 10% $Na_2CO_{3(aq)}$ (50 mL). The combined organics were dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude alcohol **S4f** as a colorless oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 40:60) to afford **S4f** as a colorless oil (3.36 g, 92%).

^{1}H NMR (MHz, $CDCl_3$) δ 7.69-7.67 (m, 4H), 7.45-7.38 (m, 6H), 3.84 (d, *J* = 11.4 Hz, 1H), 3.71-3.66 (m, 3H), 2.95 (dd, *J* = 6.7, 4.2 Hz, 1H), 1.90 (br, 1H), 1.66-1.43 (m, 6H), 1.29 (s, 3H), 1.07 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 135.7, 134.1, 129.7, 127.8, 63.7, 63.0, 61.6, 61.5, 38.3, 32.5, 27.0, 21.6, 19.4, 16.8

FT-IR (ATR, cm^{-1}): 3405, 3069, 2931, 2858, 1472, 1428, 1386, 1187, 1105, 1027

HRMS (ESI, *m/z*): $[M+Na]^+$ calculated for $C_{24}H_{34}O_3Si$: 421.2169, found 421.2186



S4e **S5e**

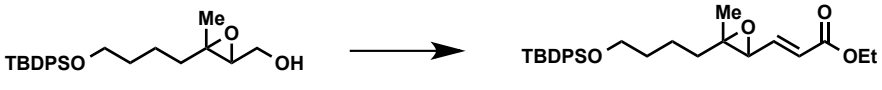
(*E*)-Epoxy Enoate S5e: To a solution of epoxy alcohol **S4e** (1.24 g, 3.21 mmol) in CH_2Cl_2 (31 mL) was added DMSO (3.1 mL, 44 mmol) and Et_3N (2.2 mL, 16 mmol), cooled to 0 ºC, and Pyr•SO_3 (0.99 g, 6.2 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (2.63 g, 7.56 mmol) was added as a solid at room temperature and stirred for 4 h. The reaction was quenched by addition of H_2O (20 mL) and diluted with CH_2Cl_2 (20 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5e** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S5e** as a colorless oil (1.36 g, 94%, 4:1 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 6:94 to 12:88) to afford **S5e** as only the (*E*)-alkene (0.77 g, 53%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68-7.66 (m, 4H), 7.46-7.38 (m, 6H), 6.82 (dd, *J* = 15.7, 6.5 Hz, 1H), 6.08 (dd, *J* = 15.7, 1.0 Hz, 1H), 4.23 (qd, *J* = 7.1, 2.3 Hz, 2H), 3.68 (t, *J* = 5.7 Hz, 2H), 3.30 (dd, *J* = 6.5, 0.7 Hz, 1H), 1.79-1.62 (m, 4H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.26 (s, 3H), 1.06 (s, 9H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 165.9, 143.0, 135.7, 133.95, 133.92, 129.82, 129.81, 127.84, 127.82, 125.0, 64.3, 63.5, 61.4, 60.7, 34.9, 28.3, 27.0, 19.4, 16.8, 14.4

FT-IR (ATR, cm^{-1}): 3069, 2932, 2858, 1718, 1653, 1589, 1472, 1428, 1387, 1366, 1301, 1259, 1175, 1105, 1038

HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{27}H_{36}O_4Si$: 470.2721, found 470.2737

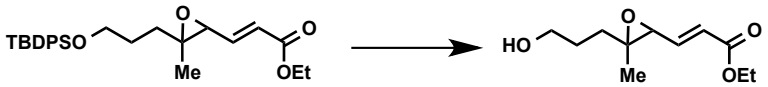


S4f **S5f**

(*E*)-Epoxy Enoate S5f: To a solution of epoxy alcohol **S4f** (1.38 g, 3.46 mmol) in CH_2Cl_2 (34 mL) was added DMSO (3.5 mL, 49 mmol) and Et_3N (2.4 mL, 17 mmol), cooled to 0 ºC, and Pyr•SO_3 (1.10 g, 6.9 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 3 h. At this point, (carbethoxymethylene)triphenylphosphorane (2.41 g, 6.9 mmol) was added as a solid at room temperature and stirred for 5 h. The reaction was quenched by addition of H_2O (20 mL) and diluted with CH_2Cl_2 (20 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (20 mL each). The combined organics were washed with H_2O (20 mL), sat. $NaCl_{(aq)}$ (20 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S5f** as a yellow oil. The

crude product was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S5f** as a colorless oil (1.37 g, 85%, 5:1 *E*/*Z*). The product was purified further by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford **S5f** as only the (*E*)-alkene (1.13 g, 70%).

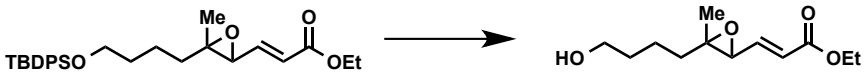
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.68-7.67 (m, 4H), 7.45-7.38 (m, 6H), 6.85 (dd, *J* = 15.7, 6.4 Hz, 1H), 6.11 (d, *J* = 15.7 Hz, 1H), 4.26-4.20 (m, 2H), 3.68 (t, *J* = 6.0 Hz, 2H), 3.29 (d, *J* = 6.5 Hz, 1H), 1.70-1.65 (m, 1H), 1.60-1.48 (m, 5H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.27 (s, 3H), 1.06 (s, 9H)
^{13}C NMR (150 MHz, $CDCl_3$) δ 165.9, 143.1, 135.7, 134.1, 129.7, 127.8, 124.9, 64.5, 63.6, 61.5, 60.8, 38.2, 32.5, 27.0, 21.6, 19.4, 16.6, 14.4
FT-IR (ATR, cm^{-1}): 2934, 2858, 1716, 1654, 1472, 1428, 1387, 1366, 1301, 1258, 1175, 1105, 1041
HRMS (ESI, *m*/*z*): $[M+Na]^+$ calculated for $C_{28}H_{38}O_4Si$: 489.2432, found 489.2423



S5e **6e**

Epoxy Alcohol 6e: To a solution of enoate **S5e** (0.77 g, 1.70 mmol) in THF (3.4 mL) at 0 ºC was added TBAF (1.0 M in THF, 3.4 mL, 3.4 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature over 2 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 60:40) to afford **6e** as a colorless oil (0.35 g, 96%).

^{1}H NMR (MHz, $CDCl_3$) δ 6.81 (dd, *J* = 15.7, 6.4 Hz, 1H), 6.08 (dd, *J* = 15.7, 0.8 Hz, 1H), 4.18 (qd, *J* = 7.1, 1.4 Hz, 2H), 3.63 (t, *J* = 4.4 Hz, 2H), 3.34 (dd, *J* = 6.4, 0.6 Hz, 1H), 2.18 (br, 1H), 1.73-1.63 (m, 4H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.26 (s, 3H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 165.8, 142.6, 125.1, 64.2, 62.3, 61.6, 60.8, 34.7, 28.0, 16.6, 14.3
FT-IR (ATR, cm^{-1}): 3421, 2941, 2877, 1716, 1654, 1449, 1387, 1368, 1302, 1259, 1177, 1134, 1095, 1032
HRMS (DART, *m*/*z*): $[M+NH_4]^+$ calculated for $C_{11}H_{18}O_4$: 232.1543, found 232.1550



S5f **6f**

Epoxy Alcohol 6f: To a solution of enoate **S5f** (0.76 g, 1.63 mmol) in THF (3.3 mL) at 0 ºC was added TBAF (1.0 M in THF, 3.3 mL, 3.3 mmol) dropwise over 1 min. The reaction was stirred and allowed to warm to room temperature over 2 h. The crude reaction mixture was purified without concentration by flash chromatography (pretreated with Et_3N/EtOAc/Hexanes 1:49:50 then gradient EtOAc/Hex, 50:50 to 70:30) to afford **6f** as a colorless oil (0.32 g, 87%).

^{1}H NMR (MHz, $CDCl_3$) δ 6.82 (dd, *J* = 15.7, 6.5 Hz, 1H), 6.09 (d, *J* = 15.7 Hz, 1H), 4.24-4.17 (m, 2H), 3.66 (t, *J* = 6.1 Hz, 2H), 3.32 (d, *J* = 6.5 Hz, 1H), 1.73-1.67 (m, 1H), 1.61-1.47 (m, 6H), 1.31-1.27 (m, 6H)

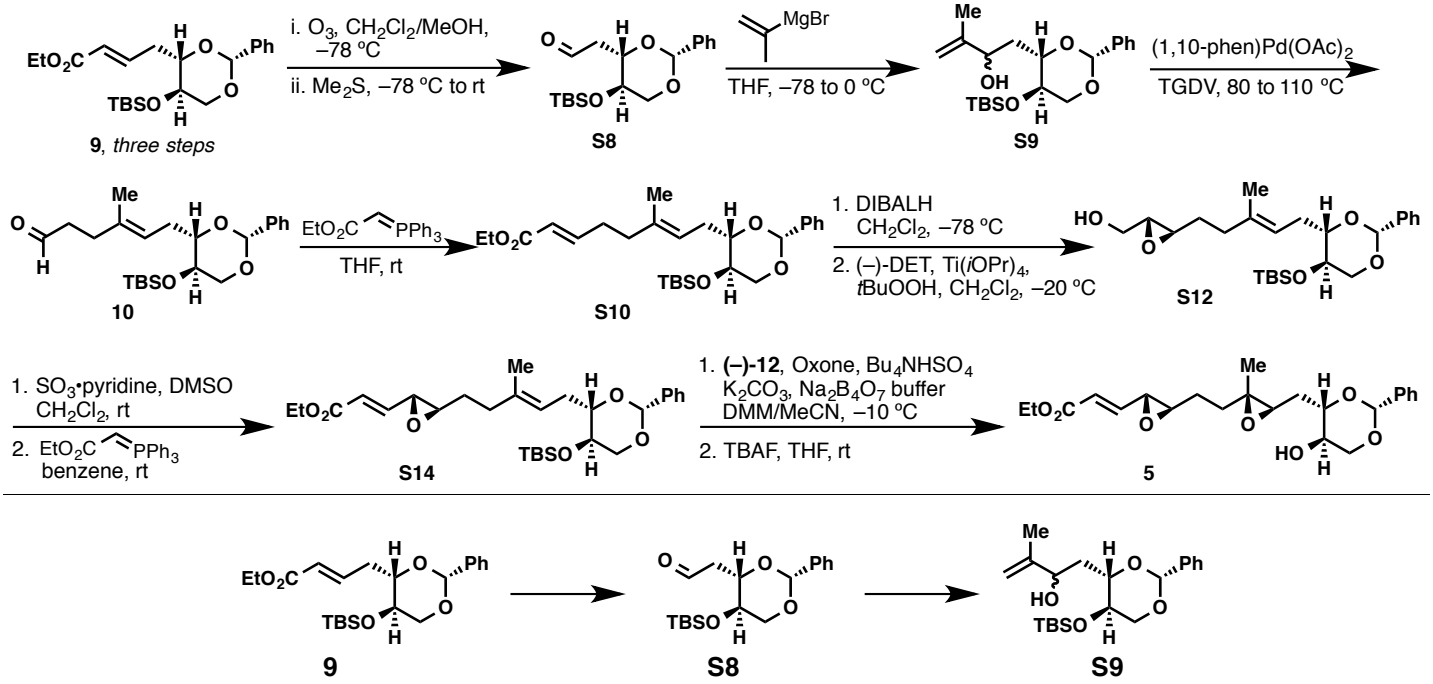
^{13}C NMR (125 MHz, $CDCl_3$) δ 165.9, 142.9, 125.1, 64.4, 62.7, 61.4, 60.8, 38.2, 32.6, 21.6, 16.7, 14.4

FT-IR (ATR, cm^{-1}): 3425, 2939, 2867, 1718, 1653, 1459, 1368, 1304, 1260, 1176, 1096, 1038

HRMS (ESI, *m/z*): $[M+Na]^+$ calculated for $C_{12}H_{20}O_4$: 251.1254, found 251.1240

D. First Generation Synthesis of Diepoxy Alcohol 11:

Scheme S3: Synthetic Route to Diepoxy Alcohol 11.



Allylic Alcohol S9: To a cooled (–78 ºC) solution of (*E*)-enoate **9**[4] (10.0 g, 24.6 mmol) in CH_2Cl_2 (50 mL) was bubbled ozone until a pale blue color persisted. The solution was purged with nitrogen and then dimethyl sulfide (9.10 mL, 123 mmol) was added dropwise. The resultant solution was allowed to warm to room temperature, stirred for 12 h, and then diluted with H_2O (50 mL). The aqueous layer was extracted with Et_2O (3 x 50mL) and the combined organic layers were dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude aldehyde **S8** was used without further purification.

To a cooled (–78 ºC) solution of crude aldehyde **S8** in THF (180 mL) was added a solution of isopropenyl magnesium bromide in THF (39.2 mL, 0.5 M, 19.6 mmol) dropwise over 20 min. The solution was allowed to warm to 0 ºC, stirred for 1.5 h, and then diluted with saturated aqueous ammonium chloride (50 mL). The aqueous layer was extracted with

[4] Van Dyke, A. R.; Jamison, T. F. *Angew. Chemie., Int. Ed.* **2009**, *48*, 4430–4432.

Et_2O (3 x 50mL) and the combined organic layers were washed with brine (50 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 20:80) to afford a diastereomeric mixture (1:1) of the title compound as a colorless oil (6.0 g, 64% over two steps).

The reported characterization was performed on a single isolated diastereomer:

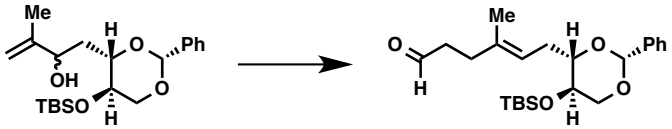
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (m, 2H), 7.37 (m, 3H), 5.52 (s, 1H), 5.03 (s, 1H), 4.88 (s, 1H), 4.40 (dd, *J* = 8.5, 4.7 Hz, 1H), 4.20 (m, 1H), 3.75 (m, 1H), 3.61 (m, 2H), 2.88, (s, 1H), 2.20 (ddd, *J* = 14.3, 4.7, 2.1 Hz, 1H), 1.74 (m, 4H), 0.90 (s, 9H), 0.11 (d, *J* = 7.8 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 146.6, 137.6, 129.3, 128.6, 126.1, 111.6, 101.1, 82.8, 75.0, 72.0, 66.7, 37.2, 25.8, 18.1, 17.8, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 3464, 3039, 2929, 2857, 1253, 1105

HRMS (ESI, *m/z*): $[M+H]^+$ calculated for $C_{21}H_{34}O_4Si$: 379.2299, found 379.2281

$[\alpha]^{24}_D$ = –36.6 (*c* = 1.13, $CHCl_3$)



Aldehyde 10: To a solution of **S9** (6.00 g, 15.9 mmol) and triethyleneglycol divinyl ether (6.48 mL, 31.7 mmol) was added 1,10-phenanthroline-$Pd(OAc)_2$[5] (0.322 g, 1.59 mmol). The reaction vessel was fitted with a reflux condenser (open to air) and the solution was heated to 80 ºC for 22 h and then to 110 ºC for an additional 24 h. The reaction mixture was cooled to room temperature and the resultant brown oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford an isomeric mixture (7:1 *E*/*Z*) of the title compound as a colorless oil (4.0 g, 63%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (m, 2H), 7.36 (m, 3H), 5.48 (s, 1H), 5.41 (t, *J* = 5.35 Hz, 1H), 4.18 (m, 1H), 3.58 (m, 3H), 2.61 (dd, *J* = 14.2, 6.3 Hz, 1H), 2.54 (ddd, *J* = 8.1, 6.9, 1.9 Hz, 2H), 2.37 (t, *J* = 8.3 Hz, 2H), 2.22 (m, 1H), 1.66 (s, 3H), 0.91 (s, 9H), 0.11 (d, *J* = 9.0 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 202.9, 138.2, 135.2, 129.0, 128.4, 126.2, 121.2, 101.0, 82.6, 71.9, 66.6, 42.4, 32.1, 30.4, 25.9, 18.1, 16.6, -4.0, -4.6

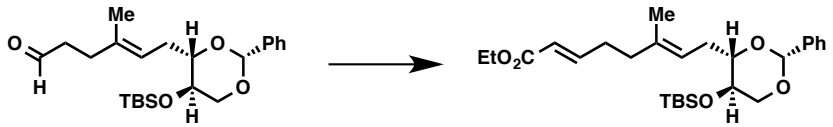
FT-IR (ATR, cm^{-1}): 3067, 3036, 2929, 2857, 1725, 1105

HRMS (ESI, *m/z*): $[M+H]^+$ calculated for $C_{23}H_{36}O_4Si$: 405.2456, found 405.2474

$[\alpha]^{24}_D$ = –67.1 (*c* = 0.495, $CHCl_3$)

---

[5] Wei, X.; Lorenz, J. C.; Kapadia, S.; Saha, A.; Haddad, N.; Busacca, C. A.; Senanayake, C. H. *J. Org. Chem.* **2007**, *72*, 4250–4253.



(*E*)-Enoate S10: To a solution of **10** (4.00 g, 9.89 mmol) in THF (49 mL) was added (carbethoxymethylene)triphenylphosphorane (4.1 g, 11.9 mmol). The reaction mixture was stirred at room temperature for 17 h and then concentrated *in vacuo*. The resultant orange slurry was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 15:85) to afford the title compound as a colorless oil (4.4 g, 94%).

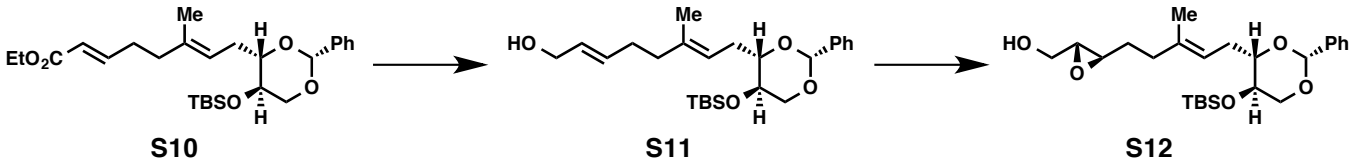
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (m, 2H), 7.36 (m, 3H), 6.97 (m, 1H), 5.83 (dd, *J* = 15.7, 1.6 Hz, 1H), 5.48 (s, 1H), 5.40 (t, *J* = 7.0 Hz, 1H), 4.17 (m, 3H), 3.57 (m, 3H), 2.61 (m, 1H), 2.15–2.35 (m, 5H), 1.65 (s, 3H), 1.27 (t, *J* = 7.2 Hz, 3H), 0.91 (s, 9H), 0.11 (d, *J* = 11.0 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 166.9, 149.1, 138.2, 135.8, 128.9, 128.6, 126.2, 121.5, 121.0, 100.9, 82.8, 71.9, 66.6, 60.4, 38.2, 31.0, 30.4, 25.9, 18.1, 16.5, 14.5, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 3066, 3037, 2929, 2857, 1722, 1655

HRMS (ESI, *m/z*): $[M+H]^+$ calculated for $C_{27}H_{42}O_5Si$: 475.2874, found 475.2890

$[\alpha]^{24}_D$ = –57.7 (*c* = 0.505, $CHCl_3$)



Epoxy Alcohol S12: To a cooled (–78 ºC) solution of **S10** (4.4 g, 9.3 mmol) in CH_2Cl_2 (92 mL) was added a solution of DIBAL–H in CH_2Cl_2 (23 mL, 1.0 M, 23 mmol) dropwise over 10 min. After 1 h, the reaction mixture was quenched with MeOH (2 mL) and then warmed to room temperature. The solution was diluted with EtOAc (200 mL) and washed with saturated aqueous sodium potassium tartrate (100 mL). The aqueous layer was extracted with EtOAc (3 x 50mL) and the combined organic layers were washed with brine (50 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude alcohol **S11** was used without further purification.

To a cooled (–20 ºC) solution of 4Å molecular sieves (1.2 g) in CH_2Cl_2 (45 mL) was added (–)-diethyl tartrate (0.18 mL, 1.1 mmol), Ti(*i*OPr)$_4$ (0.27 mL, 0.90 mmol), then a solution of crude alcohol **S11** in CH_2Cl_2 (10 mL). The solution was stirred for 20 min and then a solution of *t*BuOOH in decane (2.46 mL, 5.5 M, 13.5 mmol) was added dropwise over 5 min. The reaction mixture was stirred at –20 ºC for 20 h and then diluted with EtOAc (150 mL) and allowed to warm to room temperature. The organic layer was washed with saturated aqueous sodium sulfate and then dried over $MgSO_4$, filtered

and concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 10:90) to afford the title compound as a colorless oil (3.5 g, 84% over two steps).

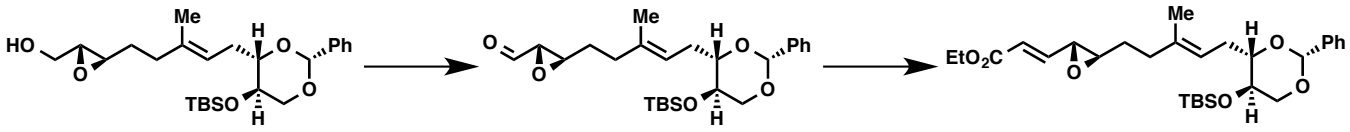
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (m, 2H), 7.36 (m, 3H), 5.48 (s, 1H), 5.41 (t, *J* = 7.0 Hz, 1H), 4.18 (dd, *J* = 10.0, 4.3 Hz, 1H), 3.82 (m, 1H), 3.60 (m, 4H), 2.94 (td, *J* = 5.8, 2.3 Hz, 1H), 2.91 (dt, *J* = 4.8, 2.6 Hz, 1H), 2.61 (m, 1H), 2.20 (m, 3H), 1.61–1.76 (m, 6H), 0.91 (s, 9H), 0.10 (d, *J* = 10.7 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 138.2, 136.1, 129.0, 128.4, 126.2, 120.8, 101.0, 82.7, 71.9, 66.5, 61.9, 58.6, 55.9, 36.0, 30.3, 30.1, 25.9, 18.1, 16.4, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 3434, 3036, 2929, 2857, 1104

HRMS (ESI, *m/z*): $[M+NH_4]^+$ calculated for $C_{25}H_{40}O_5Si$: 466.2983, found 466.2983

$[\alpha]^{24}_D$ = –34.2 (*c* = 1.26, $CHCl_3$)



S12 **S13** **S14**

(*E*)-Enoate S14: To a cooled (0 ºC) solution of **S12** (5.15 g, 11.5 mmol) in CH_2Cl_2/DMSO (4:1, 115 mL) was added Et_3N (8.0 mL, 57 mmol) then SO_3•pyridine (5.5 g, 34 mmol) in four equal portions. The solution was allowed to warm to room temperature and after 3 h was diluted with Et_2O (300 mL). The organic layer was washed with saturated aqueous ammonium chloride (100 mL) and brine (100 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude aldehyde **S13** was used without further purification.

To a solution of crude aldehyde **S13** in benzene (45 mL) was added (carbethoxymethylene)triphenylphosphorane (4.00 g, 11.5 mmol). The reaction mixture was stirred at room temperature for 17 h and then concentrated *in vacuo*. The resultant orange slurry was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 20:80) to afford an isomeric mixture (14:1 *E*/*Z*) of the title compound as a colorless oil (4.6 g, 78% over two steps).

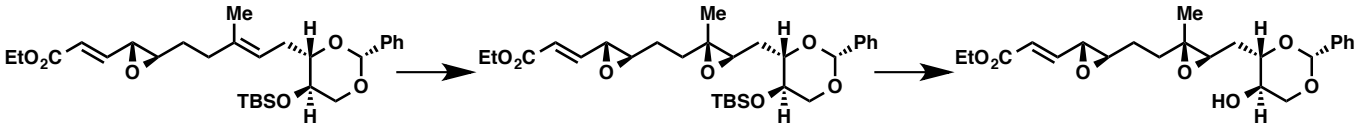
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (m, 2H), 7.36 (m, 3H), 6.66 (dd, *J* = 15.6, 7.1 Hz, 1H), 6.12 (d, *J* = 15.7 Hz, 1H), 5.47 (s, 1H), 5.41 (t, *J* = 7.0 Hz, 1H), 4.19 (m, 3H), 3.51–3.63 (m, 3H), 3.22 (d, *J* = 7.1 Hz, 1H), 2.90 (td, *J* = 5.5, 1.8 Hz, 1H), 2.61 (dd, *J* = 15.2, 7.7 Hz, 1H), 2.13–2.26 (m, 3H), 1.74 (m, 2H), 1.65 (s, 3H), 1.29 (t, *J* = 7.6 Hz, 3H), 0.92 (s, 9H), 0.11 (d, *J* = 10.8 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 165.9, 145.0, 138.2, 135.8, 128.9, 128.4, 126.2, 123.8, 121.0, 100.9, 82.7, 71.9, 66.6, 61.3, 60.8, 56.6, 35.8, 30.6, 30.4, 25.9, 18.1, 16.4, 14.4, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 3066, 3036, 2930, 2857, 1721, 1655

HRMS (ESI, *m/z*): $[M+Na]^+$ for $C_{29}H_{44}O_6Si$: 539.2799, found 539.2790

$[\alpha]^{24}_D$ = –52.3 (*c* = 0.265, $CHCl_3$)



S14 **S15** **5**

Diepoxy Alcohol 11: To a cooled (–10 ºC) solution of **S14** (3.25 g, 6.29 mmol) in DMM/MeCN (2:1, 94 mL) was added a solution of 0.05 M $Na_2B_4O_7$•$10H_2O$ in 4 x 10^{-4} Na_2EDTA (62 mL), $n$$Bu_4HSO_4$ (0.214 g, 0.629 mmol), and chiral ketone **(–)-12** (0.812 g, 3.14 mmol). To this vigorously stirred reaction mixture was added, simultaneously over 2 h via syringe pump, a solution of Oxone (5.42 g, 8.81 mmol) in 4 x 10^{-4} Na_2EDTA (41 mL) and a solution of K_2CO_3 in H_2O (41 mL, 0.89 M, 37 mmol). Upon completion of syringe pump addition, the reaction mixture was diluted with Et_2O/H_2O (1:1, 200 mL) and warmed to room temperature. The aqueous layer was extracted with EtOAc (3 x 50 mL) and the combined organic layers were washed with brine (50 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude diepoxide **S15** was used without further purification.

To a cooled (0 ºC) solution of crude diepoxide **S15** (1/3 total mass of crude mixture obtained above) in THF (25 mL) was added a solution of TBAF in THF (3.0 mL, 1.0 M, 3.0 mmol) dropwise over 10 min. The reaction mixture was allowed to warm to room temperature over 1.5 h and then diluted with Et_2O (100 mL). The solution was washed with H_2O (25 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant pale yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 50:50 to 70:30) to afford the title compound as a colorless oil (0.73 g, 77% over two steps).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (m, 2H), 7.37 (m, 3H), 6.66 (dd, *J* = 15.7, 7.1 Hz, 1H), 6.12 (d, *J* = 15.7 Hz, 1H), 5.52 (s, 1H), 4.32 (dd, *J* = 10.7, 5.1 Hz, 1H), 4.20 (m, 2H), 3.91 (m, 1H), 3.79 (ddd, *J* = 9.1, 5.1, 3.6 Hz, 1H), 3.63 (t, *J* = 10.4 Hz, 1H), 3.22 (dd, *J* = 7.1, 1.9 Hz, 1H), 3.13 (dd, *J* = 8.1, 3.9 Hz, 1H), 2.92 (ddd, *J* = 6.1, 4.5, 2.0 Hz, 1H), 2.49 (s, 1H), 2.16 (dt, *J* = 15.1, 3.8 Hz, 1H), 1.98 (ddd, *J* = 15.1, 8.0, 5.2 Hz, 1H), 1.62–1.79 (m, 4H), 1.32 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H).

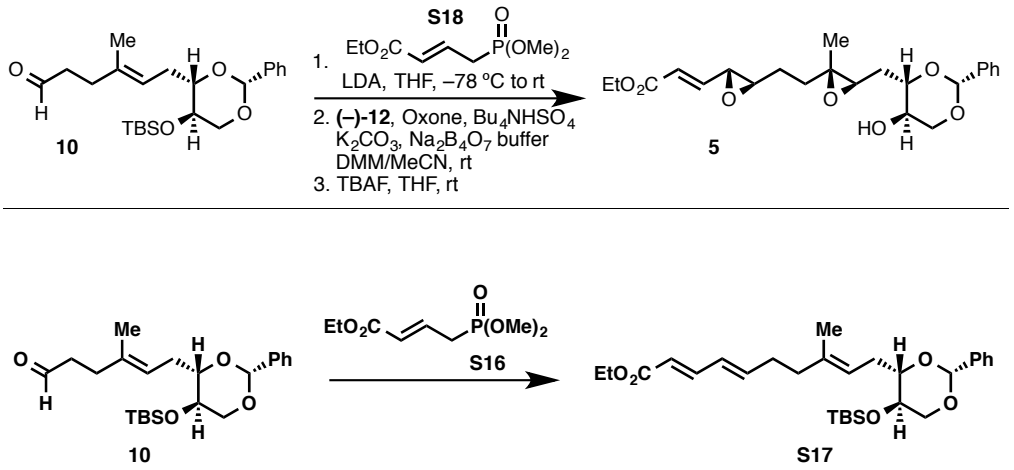
^{13}C NMR (150 MHz, $CDCl_3$) δ 165.9, 144.6, 137.8, 129.2, 128.5, 126.3, 124.1, 101.4, 80.4, 71.3, 64.9, 61.0, 60.9, 60.1, 59.7, 56.6, 34.6, 31.1, 27.6, 17.0, 14.4

FT-IR (ATR, cm^{-1}): 3447, 2925, 2859, 1718, 1654

HRMS (ESI, *m/z*): $[M+Na]^+$ for $C_{23}H_{30}O_7$: 441.1884, found 441.1902

$[\alpha]^{24}_D$ = +5.52 (*c* = 0.155, $CHCl_3$)

Scheme S4: Alternative route to diepoxide **11**.



Triene S17: To a cooled (–78 ºC) solution of diisopropylamine (0.11 mL, 0.79 mmol) in THF (7 mL) was added a solution of *n*-butyllithium (0.29 mL, 2.6 M, 0.75 mmol). The reaction mixture was allowed to warm to 0 ºC and stirred for 30 min. The reaction mixture was then cooled to –78 ºC and a solution of phosphonate ester **S16**[6] (160 mg, 0.74 mmol) in THF (1 mL) was added dropwise. After stirring at –78 ºC for 30 min, a solution of aldehyde **10** (180 mg, 0.43 mmol) in THF (1 mL) was added dropwise and the reaction mixture was allowed to warm to room temperature. After 15 h, saturated aqueous ammonium chloride (20 mL) was added dropwise. The aqueous layer was extracted with EtOAc (3 x 20 mL) and the combined organic layers were dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 1:99 to 10:90) to afford an isomeric mixture (2:1 *E*/*Z*)[7] of the title compound as a colorless oil (180 mg, 84%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (m, 2H), 7.36 (m, 3H), 7.24 (dd, *J* = 15.4, 10.5 Hz, 1H), 6.15 (m, 2H), 5.77 (d, *J* = 15.4 Hz, 1H), 5.48 (s, 1H), 5.39 (m, 1H), 4.20 (q, *J* = 7.1 Hz, 3H), 3.58 (m, 3H), 2.61 (ddd, *J* = 14.7, 7.4, 2.8 Hz, 1H), 2.30 (m, 2H), 2.23 (m, 1H), 2.15 (m, 2H), 1.65 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 0.91 (s, 9H), 0.11 (d, *J* = 11.2 Hz, 6H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 167.5, 145.2, 144.3, 138.2, 136.1, 128.9, 128.6, 128.4, 126.2, 120.8, 119.5, 101.0, 82.3, 71.9, 66.6, 60.4, 38.9, 31.7, 30.3, 25.9, 18.1, 16.4, 14.5, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 3029, 2930, 2857, 1714, 1643, 1105

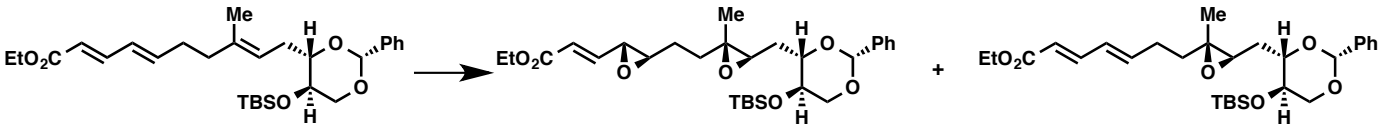
HRMS (ESI, *m*/*z*): $[M+H]^+$ for $C_{29}H_{44}O_5Si$: 501.3031, found 501.3043

$[\alpha]^{24}_D$ = –36.4 (*c* = 0.410, $CHCl_3$)

---

[6] The phosphonate ester was prepared in two steps by the literature method: Mitton-Fry, M. J.; Cullen, A. J.; Sammakia, T. *Angew. Chem., Int. Ed.* **2007**, *46*, 1066–1070.

[7] The isomeric mixture could be carried forward to the next synthetic operation or subjected to literature conditions (I_2, $CHCl_3$) to improve the isomeric ratio to 5:1 (*E*/*Z*). See, for example: (a) Nazaré, M.; Waldmann, H. *Chem. Eur. J.* **2001**, *7*, 3363–3376. (b) Xu, J.; Caro-Diaz, E. J. E.; Trzoss, L.; Theodorakis, E. A. *J. Am. Chem. Soc.* **2012**, *134*, 5072–5075.



Diepoxide S15: To a solution of **S17** (60 mg, 0.12 mmol) in DMM/MeCN (2:1, 5.3 mL) was added a solution of 0.05 M $Na_2B_4O_7$•$10H_2O$ in 4 x 10^{-4} Na_2EDTA (3.5 mL), $n$$Bu_4HSO_4$ (4.1 mg, 0.012 mmol), and chiral ketone **(–)-12** (47 mg, 0.18 mmol). To this vigorously stirred reaction mixture was added, simultaneously over 1.5 h via syringe pump, a solution of Oxone (260 mg, 0.43 mmol) in 4 x 10^{-4} Na_2EDTA (2.3 mL) and a solution of K_2CO_3 in H_2O (2.3 mL, 0.89 M, 2.1 mmol). Upon completion of syringe pump addition, the reaction mixture was diluted with EtOAc/H_2O (2:1, 10 mL). The aqueous layer was extracted with EtOAc (3 x 10 mL) and the combined organic layers were washed with brine (10 mL), dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant pale yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 20:80) to afford recovered monoepoxide **S18** (32 mg, 51%) and the title compound as a colorless oil (14 mg, 22% [45% based on recovered monoepoxide]).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (m, 2H), 7.37 (m, 3H), 6.64 (dd, J = 15.7, 7.2 Hz, 1H), 6.10 (d, J = 15.7 Hz 1H), 5.51 (s, 1H), 4.20 (m, 3H), 3.69 (m, 2H), 3.58 (m, 1H), 3.18 (d, J = Hz, 1H), 3.07 (t, J = 6.2 Hz, 1H), 2.92 (m, 1H), 1.99 (m, 2H), 1.75 (m, 2H), 1.63 (m, 2H), 1.29 (m, 6H), 0.89 (s, 9H), 0.11 (d, J = 5.7 Hz, 6H)

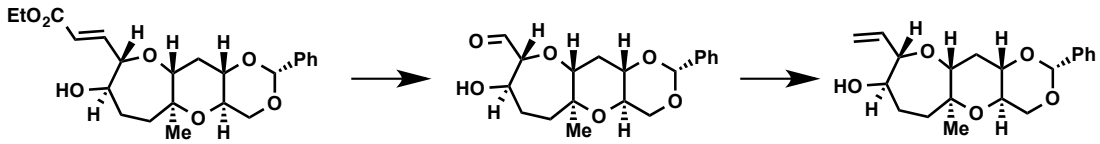
^{13}C NMR (150 MHz, $CDCl_3$) δ 165.8, 144.6, 137.9, 129.1, 128.5, 126.2, 124.0, 101.0, 80.8, 72.0, 66.0, 61.0, 60.8, 59.8, 59.7, 56.6, 34.6, 31.0, 27.8, 25.9, 18.0, 16.9, 14.4, -4.0, -4.6

FT-IR (ATR, cm^{-1}): 2932, 2858, 1718, 1656, 1102

HRMS (ESI, m/z): $[M+Na]^+$ for $C_{29}H_{44}O_7Si$: 550.3195, found 550.3187

$[\alpha]^{24}_D$ = –20.7 (c = 1.20, $CHCl_3$)

E. Completion of Formal Synthesis of 3:



Vinyl-Capped EF-Ring System 3: Through a cooled (–78 ºC) solution of **11** (13 mg, 0.031 mmol) in CH_2Cl_2/MeOH (4:1, 2.5 mL) was bubbled ozone until a blue color persisted. The solution was sparged with argon and triphenylphosphine (10 mg, 0.038 mmol) was added. The reaction mixture was allowed to warm to room temperature, stirred for 2 h, and concentrated *in vacuo*. The crude aldehyde **S18** was used without further purification.

To a solution of methyltriphenylphosphonium bromide (0.043 g, 0.12 mmol) in THF (0.5 mL) was added a solution of KO*t*Bu (9.4 mg, 0.084 mmol) in THF (0.5 mL). The reaction mixture was stirred for 30 min and then cooled to 0 ºC. A solution of crude aldehyde **S18** in THF (1 mL) was added and the reaction mixture was allowed to warm to room temperature over 16 h. Saturated aqueous ammonium chloride (2 mL) was added dropwise and the aqueous layer was extracted with Et2O (3 x 2mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant pale yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 30:70 to 50:50) to afford the title compound as a colorless amorphous solid (9.0 mg, 84% over two steps).

The spectral data correlate with the previously reported data for **3**:[8]

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51–7.49 (m, 2H), 7.39–7.35 (m, 3H), 5.78 (ddd, *J* = 16.8, 10.5, 5.8 Hz, 1H), 5.52 (s, 1H), 5.35 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.18 (dd, *J* = 10.6, 1.5 Hz, 1H), 4.25 (dd, *J* = 9.9, 4.5 Hz, 1H), 4.19–4.17 (m, 1H), 3.97–3.95 (m, 1H), 3.84 (dd, *J* = 11.9, 4.6 Hz, 1H), 3.66 (t, *J* = 9.9 Hz, 1H), 3.61 (td, *J* = 9.5, 4.3 Hz, 1H), 3.50 (ddd, *J* = 11.7, 9.0, 4.3 Hz, 1H), 2.21 (dt, *J* = 11.6, 4.4 Hz, 1H), 2.02–1.97 (m, 1H), 1.84–1.80 (m, 2H), 1.66 (d, *J* = 3.3 Hz, 1H), 1.61 (ddd, *J* = 13.7, 5.9, 3.0 Hz, 1H), 1.33 (s, 3H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 137.7, 137.1, 129.2, 128.6, 126.6, 116.4, 101.9, 85.3, 78.4, 78.1, 76.7, 74.3, 70.4, 66.3, 34.7, 33.0, 25.7, 16.6

HRMS (ESI, *m/z*): $[M+H]^+$ for $C_{20}H_{26}O_5$: 347.1853, found 347.1865

$[\alpha]^{24}_D$ = –11.4 (*c* = 0.175, $CHCl_3$)

[8] Kuranaga, T.; Ohtani, N.; Tsutsumi, R.; Baden, D. G.; Wright, J. L. C.; Satake, M.; Tachibana, K. *Org. Lett.* **2011**, *13*, 696–699.

Comparison of ^{1}H NMR data for **3** and previously reported synthesis (ref. 8)

^{1}H NMR (600 MHz, $CDCl_3$) δ **3**	**^{1}H NMR** (500 MHz, CDCl3) δ ref. 8
Referenced at $CHCl_3$ = 7.27 ppm	**Referenced at $CHCl_3$ = 7.24 ppm**
7.51–7.49 (m, 2H)	7.48–7.46 (m, 2H)
7.39–7.35 (m, 3H)	7.36–7.31 (m, 3H)
5.78 (ddd, *J* = 16.8, 10.5, 5.8 Hz, 1H)	5.75 (ddd, *J* = 16.8, 11.3, 5.6 Hz, 1H)
5.52 (s, 1H)	5.49 (s, 1H)
5.35 (dd, *J* = 17.2, 1.6 Hz, 1H)	5.32 (dd, *J* = 17.2, 1.3 Hz, 1H)
5.18 (dd, *J* = 10.6, 1.5 Hz, 1H)	5.14 (dd, *J* = 10.5, 1.3 Hz, 1H)
4.25 (dd, *J* = 9.9, 4.5 Hz, 1H)	4.22 (dd, *J* = 9.9, 4.0 Hz, 1H)
4.19–4.17 (m, 1H)	4.15–4.13 (m, 1H)
3.97–3.95 (m, 1H)	3.92–3.90 (m, 1H)
3.84 (dd, *J* = 11.9, 4.6 Hz, 1H)	3.81 (dd, *J* = 12.0, 4.4 Hz, 1H)
3.66 (t, *J* = 9.9 Hz, 1H)	3.63 (*J* = 9.9, 9.9 Hz, 1H)
3.61 (td, *J* = 9.5, 4.3 Hz, 1H)	3.58 (ddd, *J* = 9.7, 9.7, 4.6 Hz, 1H)
3.50 (ddd, *J* = 11.7, 9.0, 4.3 Hz, 1H)	3.47 (ddd, *J* = 12.0, 8.6, 3.7 Hz, 1H)
2.21 (dt, *J* = 11.6, 4.4 Hz, 1H)	2.18 (ddd, *J* = 11.8, 4.4, 4.4 Hz, 1H)
2.02–1.97 (m, 1H)	1.97 (ddd, *J* = 14.3, 10.4, 4.6 Hz, 1H)
1.84–1.80 (m, 2H),	1.84–1.76 (m, 3H)
1.66 (d, *J* = 3.3 Hz, 1H)	
1.61 (ddd, *J* = 13.7, 5.9, 3.0 Hz, 1H)	1.60–1.56 (m, 1H)
1.33 (s, 3H)	1.30 (s, 3H)

Comparison of ^{13}C NMR data for **3** and previously reported synthesis (ref. 8)

^{13}C NMR (150 MHz, $CDCl_3$) δ **3**	**^{13}C NMR** (100 MHz, CDCl3) δ ref. 8
Referenced at $CDCl_3$ center peak (77.2 ppm)	Referenced at $CDCl_3$ center peak (77.0 ppm)
137.7	137.5
137.1	136.9
129.2	129.0
128.6	128.3
[1]	128.3
126.6	126.2
[1]	126.2
116.4	116.0
101.9	101.6
85.3	85.1
78.4	78.2
78.1	77.9
76.7	76.5
74.3	74.0
70.4	70.1
66.3	66.0
34.7	34.4
33.0	32.7
25.7	25.5
16.6	16.3

[1] We ascribe the absence of these resonances to the pseudo symmetry in the aromatic ring.

F. Synthesis of Diepoxy Alcohol 21:

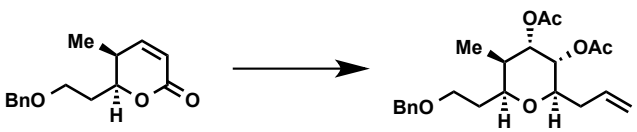
17 **18**

Epoxide 18: To a cooled (–40 ºC) solution of 3Å molecular sieves (180 mg) in CH_2Cl_2 (42 mL) was added (+)-diethyl tartrate (0.10 mL, 0.55 mmol), Ti(*i*OPr)$_4$ (0.13 mL, 0.42 mmol), then a solution of **17**[9] (0.60 g, 4.24 mmol) in CH_2Cl_2 (5 mL). The solution was stirred for 20 min and then a solution of *t*BuOOH in decane (1.16 mL, 5.5 M, 6.36 mmol) was added dropwise over 5 min. The reaction mixture was stirred at –20 ºC for 18 h and then diluted with EtOAc (75 mL) and allowed to warm to room temperature. The organic layer was washed with sat. $Na_2SO_{4(aq)}$ and then dried over $MgSO_4$, filtered and concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 50:50) to an epoxy alcohol, which was used directly in the next step.

To a solution of the epoxy alcohol in CH_2Cl_2 (22 mL) cooled to 0 ºC was added Et_3N (0.93 mL, 6.7 mmol) and TBSCl (0.40 g, 2.68 mmol), and then warmed to room temperature. After 24 h, the reaction was quenched by the addition of sat. $NH_4Cl_{(aq)}$ (25 mL) and extracted with CH_2Cl_2 (2 x 20 mL). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 20:80) to yield **18** as a colorless oil (0.53g, 46% over two steps). The ee of **18** was determined to be 93%. Determination of the ee of **18** was accomplished by formation of the benozoate ester of the intermediate epoxy alcohol, and comparison to the racemic epoxy benzoate on chiral analytical HPLC analysis (Chiracel OJ–H; 0.5% *i*PrOH in hexanes, 1.00 mL/min; t_R(major) = 13.0 min, t_R(minor) = 14.2 min.

^{1}H NMR (600 MHz, $CDCl_3$) δ 4.75 (s, 1H), 4.72 (s, 1H), 3.58 (s, 2H), 2.88 (t, *J* = 6.3 Hz, 1H), 2.20 (dt, *J* = 14.9, 7.5 Hz, 1H), 2.13 (dt, *J* = 14.9, 7.6 Hz, 1H), 1.75 (s, 3H), 1.70 (m, 2H), 1.29 (s, 3H), 0.90 (s, 9H), 0.07 (s, 3H), 0.06 (s, 3H)
^{13}C NMR (150 MHz, $CDCl_3$) δ 145.0, 110.6, 68.0, 61.2, 60.8, 34.7, 26.7, 26.0, 22.7, 18.5, 14.3, –5.2
FT-IR (ATR, cm^{-1}): 3076, 2957, 2930, 2858, 1651, 1473, 1463, 1376, 1253, 1135, 1098, 1007
HRMS (ESI, *m/z*): $[M+Na]^+$ for $C_{15}H_{30}O_2Si$: 293.1907, found 293.1907
$[\alpha]^{24}_D$ = –2.5 (*c* = 0.51, $CHCl_3$)

[9] For the synthesis of **47**, please see: Yang, D.; Xu, M. *Org. Lett.* **2001**, *3*, 1785.



14 **15**

Alkene 15: To a solution of **14**[10] (3.42 g, 13.9 mmol) and NMO (50 wt% in H_2O, 4.3 mL, 20.8 mmol) in acetone/H_2O (4:1, 139 mL) cooled to 0 ºC was added OsO_4 (2.5 wt% in *t*-BuOH, 8.7 mL, 0.70 mmol). After 10 min at 0 ºC, the reaction was allowed to warm to room temperature. After 5 h, the reaction was diluted with EtOAc (250 mL), mixed with H_2O (50 mL), and the two layers separated. The aqueous layer was extracted with EtOAc (3 x 100 mL), and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The resultant brown oil was purified via by flash chromatography (EtOAc/hexanes, gradient 70:30 to 100:0) to yield a colorless oil that was used directly in the next reaction.

The previously obtained oil was diluted in THF (700 mL), cooled –78 ºC, and allylmagnesium bromide in Et_2O (97 mL, 1.0 M, 97 mmol) was added dropwise over 1 h. After an additional 2.5 h at –78 ºC, the reaction was warmed to 0 ºC and quenched by dropwise addition of sat. $NH_4Cl_{(aq)}$ (50 mL). The reaction mixture was extracted with EtOAc (3 x 100 mL), and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated *in vacuo* to provided a yellow-brown oil that was carried forward into the next reaction.

To the previously obtained oil diluted in CH_3CN (139 mL) was added Et_3SiH (4.0 mL, 25.0 mmol), cooled to 0 ºC, and then TMSOTf (0.50 mL, 2.8 mmol) was added dropwise over 1 min. After an addition 10 min the reaction was quenched by the addition of sat. $NaHCO_{3(aq)}$ (50 mL) and extracted EtOAc (3 x 50 mL). The combined organic layers were washed with sat. $NaCl_{(aq)}$, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The resultant brown oil was purified by flash chromatography (EtOAc/hexanes, gradient 40:60 to 60:40) to yield a colorless oil that was used directly in the next reaction.

To the previously obtained oil diluted in CH_2Cl_2 (60 mL) was added DMAP (12 mg, 0.1 mmol), pyridine (4.4 mL, 55 mmol), and Ac_2O (3.4 mL, 36.4 mmol). The reaction was heated to 30 ºC for 18 h, then concentrated *in vacuo*. The resultant yellow oil was purified by flash chromatography (EtOAc/hexanes, gradient 15:85 to 30:70) to yield **15** as a colorless oil (2.02 g, 37% over 4 steps)

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36-7.29 (m, 5H), 5.83 (ddt, *J* = 17.1, 10.3, 6.8 Hz, 1H), 5.20 (t, *J* = 3.0 Hz, 1H), 5.07-5.03 (m, 2H), 4.80 (dd, *J* = 10.2, 3.1 Hz, 1H), 4.55-4.49 (m, 2H), 4.01 (dt, *J* = 9.5, 2.9 Hz, 1H), 3.74 (ddd, *J* = 10.5, 7.9, 2.9 Hz, 1H), 3.62-3.54 (m, 2H), 2.31-2.27 (m, 1H), 2.17-2.13 (m, 1H), 2.12 (s, 3H), 2.00 (s, 3H), 1.89-1.83 (m, 1H), 1.80 (ddd, *J* = 14.4, 9.6, 4.9 Hz, 1H), 1.64-1.58 (m, 1H), 1.06 (d, *J* = 7.3 Hz, 3H)

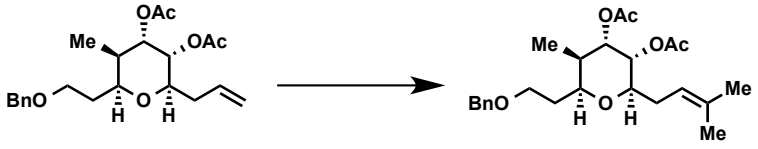
[10] Ohtani, N.; Tsutsumi, R.; Kuranaga, T.; Shirai, T.; Wright, J. L.; Baden, D. G.; Satake, M.; Tachibana, K. *Heterocycles* **2010**, *80*, 825.

^{13}C NMR (150 MHz, $CDCl_3$) δ 170.4, 170.1, 138.6, 134.3, 128.6, 127.83, 127.77, 117.0, 73.9, 73.2, 72.6, 71.3, 68.8, 67.1, 38.1, 36.4, 32.4, 21.3, 21.1, 10.6

FT-IR (ATR, cm^{-1}): 2965, 2919, 2860, 1743, 1454, 1370, 1242, 1219, 1102, 1054

HRMS (DART, *m/z*): $[M+H]^+$ for $C_{22}H_{30}O_6$: 391.2115, found 391.2114

$[\alpha]^{24}_D$ = +0.86 (*c* = 0.40, $CHCl_3$)



15 **16**

Trisubstituted Alkene 16: To a solution of **15** (417 mg, 1.07 mmol) in 2-methyl-2-butene (3.4 mL, 31.6 mmol) was added benzoquinone (17 mg, 0.16 mmol) and Hoveyda-Grubbs 2nd Generation Catalyst (15 mg, 0.024 mmol) and stirred at room temperature. After consumption of **15** (1 h, determined by ^{1}H NMR analysis of aliquot of reaction mixture), the reaction mixture was concentrated *in vacuo*. The resultant green oil was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 25:75) to afford **16** as a pale green oil (387 mg, 87%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.28 (m, 5H), 5.21-5.17 (m, 2H), 4.80 (dd, *J* = 10.2, 3.1 Hz, 1H), 4.55-4.50 (m, 2H), 4.00 (ddd, *J* = 9.5, 3.6, 2.5 Hz, 1H), 3.68 (ddd, *J* = 10.5, 7.4, 3.3 Hz, 1H), 3.62-3.54 (m, 2H), 2.25-2.20 (m, 1H), 2.13-2.08 (m, 1H), 2.11 (s, 3H), 2.00 (s, 3H), 1.87-1.77 (m, 2H), 1.69 (s, 3H), 1.63-1.60 (m, 1H), 1.57 (s, 3H), 1.06 (d, *J* = 7.3 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 170.4, 170.1, 138.7, 133.8, 128.6, 127.80, 127.77, 119.6, 74.5, 73.3, 72.8, 71.3, 69.0, 67.2, 38.2, 32.5, 30.8, 26.0, 21.3, 21.1, 18.1, 10.6

FT-IR (ATR, cm^{-1}): 2965, 2919, 2860, 1743, 1454, 1370, 1242, 1219, 1102, 1054

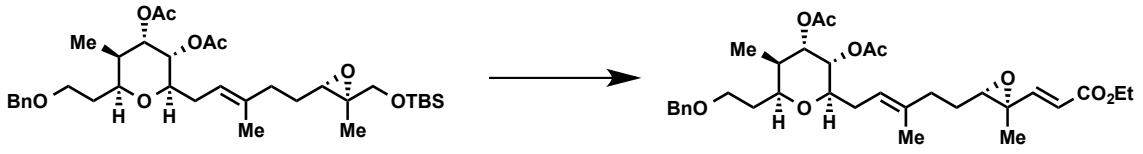
HRMS (ESI, *m/z*): $[M+Na]^+$ for $C_{24}H_{34}O_6$: 441.2248, found 441.2260

$[\alpha]^{24}_D$ = –2.1 (*c* = 1.51, CH_2Cl_2)

16 **18** **19**

Trisubstituted Alkene 19: To a 10 mL Schlenk tube containing **16** (350 mg, 0.86 mmol), **18** (465 mg, 1.72 mmol), and benzoquinone (10 mg, 0.09 mmol) was added Hoveyda-Grubbs 2nd Generation Catalyst (27 mg, 0.043 mmol) and flushed with argon. This mixture was heated with stirring on an oil bath at 80 ºC. After 18 h, the reaction mixture was transferred out of the Schlenk tube with CH_2Cl_2 (3x5 mL) and the reaction mixture was concentrated *in vacuo*. The resultant green oil was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 20:80) to afford **19** as a pale green oil (423 mg, 78%, 2:1 *E*/*Z*). Enrichment to >9:1 *E*/*Z* of **50** could be achieved through repeated flash chromatography (EtOAc/hexanes, gradient 10:90 to 20:80).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.29 (m, 5H), 5.27-5.24 (m, 1H), 5.20 (t, *J* = 3.1 Hz, 1H), 4.79 (dd, *J* = 10.2, 3.1 Hz, 1H), 4.54-4.48 (m, 2H), 4.00 (ddd, *J* = 9.4, 3.6, 2.5 Hz, 1H), 3.70 (ddd, *J* = 10.4, 7.5, 3.1 Hz, 1H), 3.60-3.55 (m, 4H), 2.85 (t, *J* = 6.3 Hz, 1H), 2.24-2.21 (m, 1H), 2.18-2.05 (m, 3H), 2.11 (s, 3H), 2.00 (s, 3H), 1.87-1.78 (m, 2H), 1.67-1.62 (m, 3H), 1.58 (s, 3H), 1.27 (s, 3H), 1.05 (d, *J* = 7.3 Hz, 3H), 0.90 (s, 9H), 0.07 (s, 3H), 0.06 (s, 3H)
^{13}C NMR (125 MHz, $CDCl_3$) δ 170.4, 170.1, 138.7, 136.6, 128.6, 127.8, 120.0, 74.4, 73.2, 72.7, 71.4, 68.9, 68.0, 67.3, 61.2, 60.8, 38.1, 36.5, 32.5, 30.6, 27.3, 26.1, 21.3, 21.1, 18.5, 16.5, 14.3, 10.6, –5.2
FT-IR (ATR, cm^{-1}): 2958, 2930, 2850, 1748, 1455, 1371, 1245, 1223, 1101, 1057
HRMS (ESI, *m*/*z*): $[M+Na]^+$ for $C_{35}H_{56}O_8Si$: 655.3637, found 655.3644
$[\alpha]^{24}_D$ = –8.0 (*c* = 0.92, CH_2Cl_2)



19 **S19**

Enoate S19: To a solution of **19** (57 mg, 0.09 mmol) in THF (0.9 mL) at 0 ºC was added TBAF (1.0 M in THF, 0.11 mL, 0.11 mmol). The reaction was stirred for 30 min, and quenched with H_2O (2 mL). The reaction was extracted with Et_2O (3x5 mL), and the combined organic layers were washed with sat. $NaCl_{(aq)}$ (10 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to provide a crude alcohol. The crude alcohol was purified by flash chromatography (30% EtOAc in hexanes to 70% EtOAc in hexanes) to provide an alcohol intermediate as a colorless oil (39 mg).

To a solution of the alcohol intermediate in CH_2Cl_2 (0.7 mL) was added DMSO (0.15 mL, 2 mmol) and Et_3N (0.10 mL, 0.73 mmol), cooled to 0 ºC, and Pyr•SO_3 (35 mg, 0.22 mmol) added as a solid. The reaction was allowed to warm to room temperature and stirred for 4 h. At this point, (carbethoxymethylene)triphenylphosphorane (77 mg, 0.22 mmol) was added as a solid at room temperature and stirred for 1 h. The reaction was quenched by addition of H_2O (5 mL) and diluted with CH_2Cl_2 (5 mL). The aqueous layer was separated and extracted twice with CH_2Cl_2 (5 mL each). The combined organics were washed with H_2O (3 mL), sat. $NaCl_{(aq)}$ (3 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to afford crude enoate **S19** as a yellow oil. The crude product was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 40:60) to afford **S19** as a colorless oil (39 mg, 91%, 95:5 *E*/*Z*).

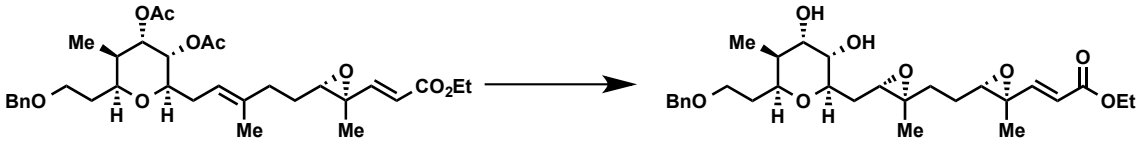
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37-7.29 (m, 5H), 6.74 (d, *J* = 15.8 Hz, 1H), 6.01 (d, *J* = 15.7 Hz, 1H), 5.25 (t, *J* = 6.4 Hz, 1H), 5.19 (t, *J* = 3.0 Hz, 1H), 4.79 (dd, *J* = 10.2, 3.1 Hz, 1H), 4.54-4.49 (m, 2H), 4.22-4.18 (m, 2H), 4.01-3.99 (m, 1H), 3.70 (ddd, *J* = 10.4, 7.5, 3.1 Hz, 1H), 3.60-3.53 (m, 2H), 2.84 (t, *J* = 6.2 Hz, 1H), 2.25-2.21 (m, 1H), 2.18-2.08 (m, 3H), 2.11 (s, 3H), 2.00 (s, 3H), 1.87-1.77 (m, 2H), 1.72-1.68 (m, 2H), 1.63-1.59 (m, 1H), 1.58 (s, 3H), 1.42 (s, 3H), 1.30-1.27 (m, 3H), 1.04 (d, *J* = 7.3 Hz, 3H)

^{13}C NMR (150 MHz, $CDCl_3$) δ 170.4, 170.1, 166.3, 150.1, 138.6, 136.2, 128.6, 127.78, 127.74, 121.7, 120.4, 74.3, 73.2, 72.6, 71.3, 68.8, 67.2, 65.6, 60.7, 58.7, 38.1, 36.3, 32.4, 30.5, 27.4, 21.3, 21.1, 16.4, 15.3, 14.4, 10.6

FT-IR (ATR, cm^{-1}): 2963, 2928, 2862, 1744, 1718, 1654, 1454, 1368, 1304, 1242, 1221, 1175, 1101, 1054, 1031

HRMS (ESI, *m*/*z*): $[M+Na]^+$ for $C_{33}H_{46}O_9$: 609.3034, found 609.3029

$[\alpha]^{24}_D$ = –3.2 (*c* = 1.95, CH_2Cl_2)



S19 **21**

Diol 21: To a solution of **S19** (36 mg, 0.06 mmol) and chiral ketone (+)-**12**[11] (16 mg, 0.061 mmol) in DMM/MeCN (2:1, 2.8 mL) was added a solution of 0.05 M $Na_2B_4O_7$•$10H_2O$ in 4 x 10^{-4} Na_2EDTA (1.85 mL) and $n$$Bu_4HSO_4$ (4 mg, 0.01 mmol), and the mixture was cooled to –10 ºC. To this vigorously stirred reaction mixture was added, simultaneously over 1 h via syringe pump, a 0.212 M solution of Oxone® in 4 x 10^{-4} Na_2EDTA (0.86 mL) and a 0.89 M solution of K_2CO_3 in H_2O (0.86 mL). Upon completion of syringe pump addition, the reaction mixture was diluted with Et_2O/H_2O (1:1, 10 mL) and warmed to room temperature. The aqueous layer was extracted with EtOAc (2 x 5 mL) and the combined organic layers were washed with sat. $NaCl_{(aq)}$ (5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo*. The crude diepoxide

[11] Jamison, T. F.; Ikeuchi, Y. Epoxidation Catalysts. U.S. Patent 8,680,303 B2, Mar. 25, 2014

was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 40:60) to provide a diepoxide intermediate as a colorless oil (31 mg).

To the previous diepoxide in EtOH (0.9 mL) at 0 ºC was added a premixed solution of EtOH (0.25 mL) containing guanidinium•HCl (0.7 mg, 7 μmol) and NaOEt (0.4 mg, 6 μmol). After 2 h, the reaction was allowed to warm to room temperature. After 6 h, the reaction was concentrated *in vacuo*, and directly purified by flash chromatography (EtOAc/hexanes, gradient 50:50 to 100:0) to provide **21** as a colorless film (19.1 mg, 72%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36-7.28 (m, 5H), 6.74 (d, *J* = 15.7 Hz, 1H), 6.01 (d, *J* = 15.7 Hz, 1H), 4.53-4.48 (m, 2H), 4.20 (q, *J* = 7.1 Hz, 2H), 4.03 (ddd, *J* = 9.3, 3.7, 2.4 Hz, 1H), 3.89 (br, 1H), 3.69-3.65 (m, 2H), 3.57 (dd, *J* = 7.3, 5.8 Hz, 2H), 3.01 (dd, *J* = 7.3, 4.5 Hz, 1H), 2.84 (t, *J* = 5.8 Hz, 1H), 2.57 (d, *J* = 6.0 Hz, 1H), 2.45 (br, 1H), 2.01-1.96 (m, 1H), 1.93-1.87 (m, 1H), 1.84-1.77 (m, 2H), 1.75-1.68 (m, 3H), 1.68-1.60 (m, 2H), 1.43 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.28 (s, 3H), 0.96 (d, *J* = 7.3 Hz, 3H)

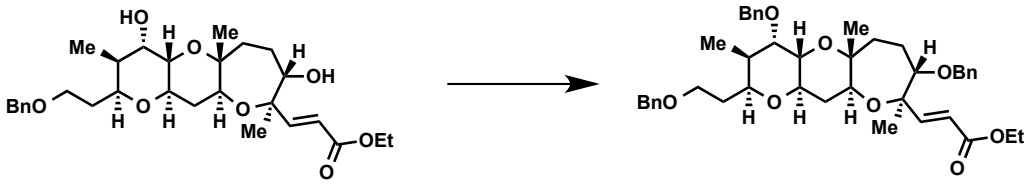
^{13}C NMR (125 MHz, $CDCl_3$) δ 166.3, 149.8, 138.7, 128.5, 127.75, 127.70, 121.8, 74.5, 73.6, 73.1, 71.0, 68.1, 67.6, 65.5, 60.8, 60.4, 59.8, 58.8, 39.7, 35.2, 32.5, 31.6, 24.4, 16.9, 15.3, 14.4, 10.8

FT-IR (ATR, cm^{-1}): 3434, 2965, 2927, 2866, 2362, 1717, 1659, 1456, 1387, 1368, 1307, 1266, 1210, 1177, 1104, 1071, 1038

HRMS (DART, *m/z*): $[M+NH_4]^+$ for $C_{29}H_{42}O_8$: 519.2925, found 519.2937

$[\alpha]^{24}_D$ = –16.0 (*c* = 0.40, CH_2Cl_2)

G. Completion of Formal Synthesis of 2:



22 **S20**

Enoate S20: To a solution of **22** (5.0 mg, 9.6 μmol) in THF (0.96 mL) was added NaH (95%, 9 mg, 0.38 mmol), TBAI (7 mg, 0.02 mmol), and BnBr (45 μL, 0.38 mmol). The reaction was heated in an oil bath at 40 ºC for 3 h, then at 60 ºC for an additional 2 h. After cooling to room temperature, the reaction was quenched by the careful addition of sat. $NH_4Cl_{(aq)}$ (2 mL) and extracted with EtOAc (3 x 3mL). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The resultant colorless film was purified by flash chromatography (EtOAc/hexanes, gradient 5:95 to 40:60) to afford **S20** as a colorless oil (5.0 mg, 75%).

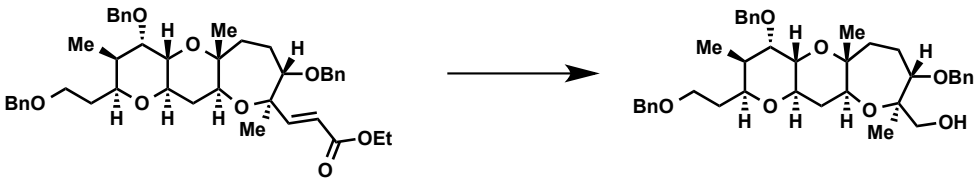
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.29 (m, 10H), 7.27-7.23 (m, 5H), 6.68 (d, *J* = 15.4 Hz, 1H), 6.08 (d, *J* = 15.4 Hz, 1H), 4.86 (d, *J* = 12.0 Hz, 1H), 4.65 (d, *J* = 11.9 Hz, 1H), 4.60 (d, *J* = 12.0 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.47 (d, *J* = 12.0 Hz, 1H), 4.32 (d, *J* = 11.9 Hz, 1H), 4.25-4.15 (m, 2H), 4.02 (dt, *J* = 9.1, 3.1 Hz, 1H), 3.96 (dd, *J* = 12.0, 4.8 Hz, 1H), 3.64 (ddd, *J* = 11.8, 10.0, 4.5 Hz, 1H), 3.60-3.52 (m, 4H), 3.45 (dd, *J* = 9.9, 2.5 Hz, 1H), 1.96-1.77 (m, 5H), 1.60-1.55 (m, 4H), 1.34 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.25 (s, 3H), 0.96 (d, *J* = 7.3 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 167.1, 152.4, 139.9, 138.8, 138.2, 128.63, 128.48, 128.32, 127.88, 127.74, 127.62, 127.53, 127.3, 120.1, 81.1, 80.7, 79.6, 76.9, 73.10, 73.07, 71.92, 71.79, 71.69, 71.4, 70.4, 67.7, 60.7, 39.3, 34.9, 34.1, 32.7, 21.32, 21.22, 16.0, 14.5, 11.8

FT-IR (ATR, cm^{-1}): 3065, 3032, 2926, 2863, 1717, 1660, 1497, 1454, 1365, 1291, 1241, 1179, 1096, 1064, 1028

HRMS (ESI, *m/z*): $[M+Na]^+$ for $C_{43}H_{54}O_8$: 721.3711, found 721.3725

$[\alpha]^{24}_D$ = –17.5 (*c* = 0.18, CH_2Cl_2)



S20 **2**

Alcohol 2: To a solution of **S20** (4.0 mg, 5.7 μmol) in *t*-BuOH/H_2O (2:1, 0.42 mL) was added citric acid monohydrate (2.4 mg, 0.012 mmol), NMO (as solid, 2.0 mg, 0.017 mmol), and $K_2OsO_2(OH)_4$•$2H_2O$ (0.4 mg, 12 μmol), and the green reaction mixture was stirred at room temperature. After 16 h, the colorless reaction was quenched by addition of 1M $HCl_{(aq)}$ (0.2 mL), then extracted EtOAc (3 x 2 mL). The combined organic layers were washed sat. $Na_2CO_{3(aq)}$ (1 x 2.5 mL), sat. $NaCl_{(aq)}$ (1 x 2.5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to provide the crude diol as a pale green oil, which was used without further purification.

To a solution of the crude diol in CH_2Cl_2 (0.3 mL) was added Ph_3BiCO_3 (17 mg, 0.034 mmol) and heated to 60 ºC in an oil bath. After 2 h, the reaction was removed from the oil bath, filtered through Celite (washed CH_2Cl_2 3 x 1 mL), and concentrated *in vacuo*. The crude beige gel was purified by flash chromatography (EtOAc/hexanes, gradient 10:90 to 30:70) to afford an aldehyde that was used immediately in the next step.

To a solution of aldehyde in MeOH (0.3 mL) at 0 ºC was added $NaBH_4$ (1.6 mg, 0.04 mmol). The reaction was quenched after 5 min by the addition of 1M $HCl_{(aq)}$ (0.1 mL), EtOAc (1 mL), and H_2O (0.2 mL). The reaction mixture was extracted with EtOAc (3 x 2 mL), and the combined organic layers were washed with sat. $NaCl_{(aq)}$ (2 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo*. The colorless film was purified by flash chromatography (EtOAc/hexanes, gradient 20:80 to 50:50) to yield **2** as a colorless film (2.1 mg, 60% over 3 steps).

The spectral data correlate with the previously reported data for **2**:[12]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36-7.28 (m, 10H), 7.27-7.22 (m, 5H), 4.84 (d, *J* = 12.0 Hz, 1H), 4.62 (d, *J* = 11.8 Hz, 1H), 4.60 (d, *J* = 11.9 Hz, 1H), 4.51 (d, *J* = 12.0 Hz, 1H), 4.47 (d, *J* = 12.0 Hz, 1H), 4.30 (d, *J* = 11.8 Hz, 1H), 4.04-4.00 (m, 1H), 3.80 (dd, *J* = 12.1, 4.7 Hz, 1H), 3.64 (ddd, *J* = 11.6, 10.0, 4.5 Hz, 1H), 3.59 (t, *J* = 2.6 Hz, 1H), 3.56-3.52 (m, 2H), 3.45-3.42 (m, 2H), 3.38 (d, *J* = 10.7 Hz, 1H), 3.24 (d, *J* = 10.7 Hz, 1H), 2.02-1.93 (m, 3H), 1.89 (dt, *J* = 11.7, 4.7 Hz, 1H), 1.80-1.77 (m, 1H), 1.72-1.67 (m, 1H), 1.60-1.58 (m, 1H), 1.57-1.53 (m, 1H), 1.52-1.49 (m, 1H), 1.29 (s, 3H), 1.21 (s, 3H), 0.95 (d, *J* = 7.3 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$): δ 139.8, 138.74, 138.57, 128.56, 128.49, 128.32, 127.88, 127.70, 127.64, 127.58, 127.54, 127.3, 81.1, 80.4, 79.6, 77.4, 73.11, 73.08, 72.08, 71.95, 71.51, 71.34, 70.4, 69.3, 67.6, 39.3, 35.1, 34.0, 32.7, 22.8, 17.5, 15.7, 11.8

FT-IR (ATR, cm^{-1}): 3427, 3030, 2925, 2858, 1718, 1670, 1605, 1496, 1453, 1361, 1260, 1215, 1156, 1089, 1062, 1027

HRMS (DART, *m/z*): $[M+H]^+$ for $C_{39}H_{50}O_7$: 631.3629, found 631.3629

$[\alpha]^{24}_D$ = –17.5 (*c* = 0.105, $CHCl_3$)

[12] Characterization data for **2** matches except the optical rotation data differs by a factor of 10 (reported: $[\alpha]^{27}_D = -168$ (*c* = 0.111, $CHCl_3$)) as reported in Kuranaga, T.; Ohtani, N.; Tsutsumi, R.; Baden, D. G.; Wright, J. L. C.; Satake, M.; Tachibana, K. *Org. Lett.* **2011**, *13*, 696.

Comparison of ^{1}H NMR data for **2** and previously reported synthesis (ref. 8)

^{1}H NMR (600 MHz, $CDCl_3$) δ **2**	**^{1}H NMR** (500 MHz, CDCl3) δ ref. 8
Referenced at $CHCl_3$ = 7.27 ppm	**Referenced at $CHCl_3$ = 7.24 ppm**
7.36-7.28 (m, 10H)	7.35–7.25 (m, 15H)
7.27-7.22 (m, 5H)	
4.84 (d, *J* = 12.0 Hz, 1H)	4.81 (d, J = 11.7 Hz, 1H)
4.62 (d, *J* = 11.8 Hz, 1H)	4.59 (d, J =12.6 Hz, 1H)
4.60 (d, *J* = 11.9 Hz, 1H)	4.58 (d, J = 12.6 Hz, 1H)
4.51 (d, *J* = 12.0 Hz, 1H)	[1]
4.47 (d, *J* = 12.0 Hz, 1H)	[1]
4.30 (d, *J* = 11.8 Hz, 1H)	4.28 (d, J = 11.8 Hz, 1H)
4.04-4.00 (m, 1H)	4.00 (ddd, J = 9.2, 2.0, 2.0 Hz, 1H)
3.80 (dd, *J* = 12.1, 4.7 Hz, 1H)	3.77 (dd, J = 11.8, 4.6 Hz, 1H),
3.64 (ddd, *J* = 11.6, 10.0, 4.5 Hz, 1H)	3.61 (ddd, J = 11.8, 10.1, 4.2 Hz, 1H)
3.59 (t, *J* = 2.6 Hz, 1H)	3.56 (dd, J = 2.5, 2.5 Hz, 1H)
3.56-3.52 (m, 2H)	3.54–3.45 (m, 2H)
3.45-3.42 (m, 2H)	3.42–3.40 (m, 2H)
3.38 (d, *J* = 10.7 Hz, 1H)	3.36 (d, J = 10.9 Hz, 1H)
3.24 (d, *J* = 10.7 Hz, 1H)	3.21 (dd, J = 10.5, 6.7 Hz, 1H)
2.02-1.93 (m, 3H)	2.01–1.90 (m, 3H)
1.89 (dt, *J* = 11.7, 4.7 Hz, 1H)	1.86 (ddd, J = 11.7, 4.6, 4.6 Hz, 1H)
1.80-1.77 (m, 1H)	1.77 (dddd, J = 14.7, 9.6, 5.5, 5.5 Hz, 1H)
1.72-1.67 (m, 1H)	1.67 (dd, J = 13.4, 13.4 Hz, 1H)
1.60-1.58 (m, 1H)	1.57 (ddd, J = 11.3, 7.1, 3.8 Hz, 1H)
1.57-1.53 (m, 1H)	1.54–1.44 (m, 2H)
1.52-1.49 (m, 1H)	
1.29 (s, 3H)	1.26 (s, 3H)
1.21 (s, 3H)	1.18 (s, 3H)
0.95 (d, *J* = 7.3 Hz, 3H)	0.93 (d, J = 7.2 Hz, 3H)

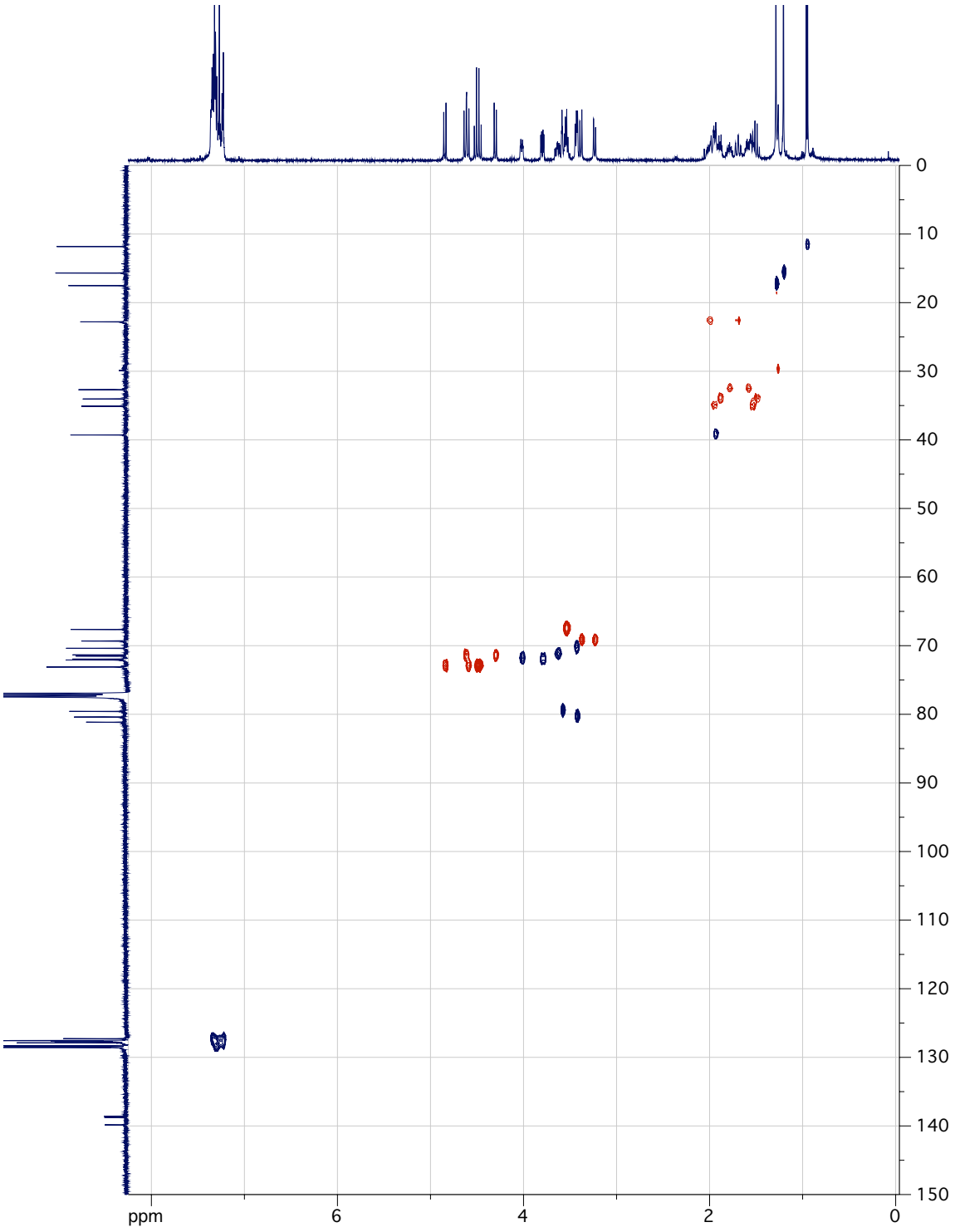
[1] While not tabulated in the reported data from ref. 8, these peaks are observed in the ^{1}H spectrum, as well as are necessary for the six benzylic protons between 4.30–4.84 ppm. Additionally, we observe coupling to reported ^{13}C peaks on the ^{1}H–^{13}C HSQC spectrum.

Comparison of ^{13}C NMR data for **2** and previously reported synthesis (ref. 8)

^{13}C NMR (150 MHz, $CDCl_3$) δ **2**	**^{13}C NMR** (100 MHz, CDCl3) δ ref. 8
Referenced at $CDCl_3$ center peak (77.2 ppm)	Referenced at $CDCl_3$ center peak (77.0 ppm)
139.8	139.7
138.74	138.5
138.57	138.4
128.56	128.4
128.49	128.3
128.32	128.1
127.88	127.7
127.70	127.5
127.64	127.4
127.58	127.4
127.54	127.4
127.3	127.1
81.1	81.0
80.4	80.2
79.6	79.4
77.4	77.2
73.11	72.9
73.08	[1]
72.08	71.9
71.95	71.8
71.51	71.3
71.34	71.1
70.4	70.2
69.3	69.1
67.6	67.4
39.3	39.1
35.1	34.9
34.0	33.8
32.7	32.5
22.8	22.6
17.5	17.3
15.7	15.5
11.8	11.6

[1] We ascribe this missing resonance from ref. 8 to be coincident with the peak listed at 72.9. This peak is necessary for the 13 C-O ^{13}C peaks, and is also observed in the ^{1}H–^{13}C HSQC to couple to listed ^{1}H resonances.

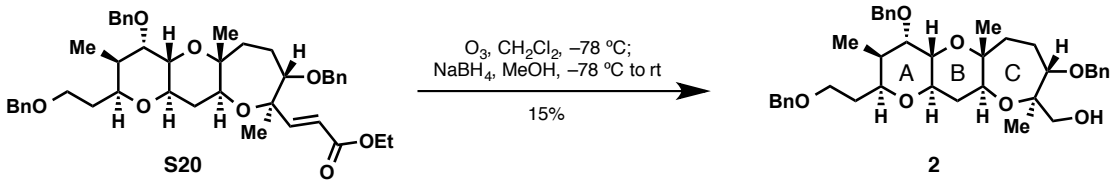
^{1}H–^{13}C HSQC spectrum of **2** (500 MHz, $CDCl_3$)



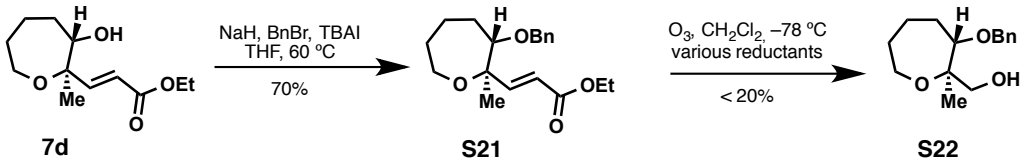
H. Studies on Enoate Oxidative Cleavage Towards **2**

Our first attempts to oxidatively cleave enoate **S20** via ozonolysis with subsequent reductive quenching with $NaBH_4$ yielded only small amounts of the desired formal synthesis intermediate **2**, with what appeared to be significant amounts of oxidation of benzyloxy to benzoate groups (Scheme S5). With limited quantities of **S20**, we synthesized **S21** for model studies to allow rapid screening of oxidation conditions (Scheme S6).

Scheme S5: Low yield from initial attempts at ozonolysis toward **2**.



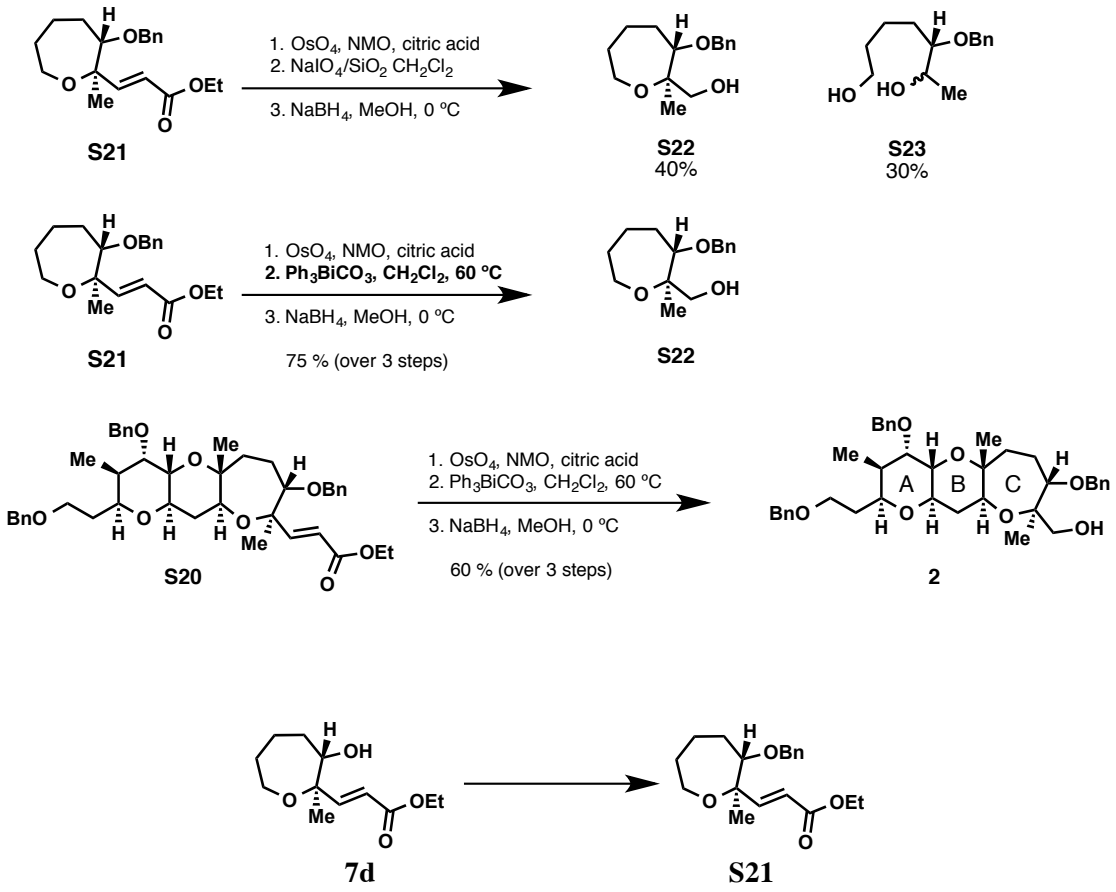
Scheme S6: Synthesis of model system **S21** and exploration of alternative ozonolysis conditions**.**



Attempts to limit undesired benzyl oxidation by reverse addition of a saturated O_3 solution in CH_2Cl_2, or use of Ph_3P to first provide an aldehyde saw no improvement in the yield of **S22**. The combination of low yields and difficulty obtaining high purity product prompted us to explore an alternative sequence of dihydroxylation, oxidative diol cleavage, and reduction (Scheme S7). Dihydroxylation of **S21**, followed by periodate cleavage and subsequent reduction with $NaBH_4$ provided the desired alcohol **S22**. In addition to the moderate yield of **S22,** a significant side product was observed: diol **S23**. We reasoned the acidic nature of $NaIO_4$ was resulting in opening the oxepane, with subsequent oxidative cleavage yielding a ketone and ultimately producing diol **S23**. Use of a neutral diol oxidative cleavage reagent, Ph_3BiCO_3, provided the desired **S23** in 75% yield.[13] Application of this three-step sequence to tricycle **S20** provided the formal synthesis target alcohol **2** in high purity and 60% yield over three steps.

[13] (a) Barton, D. H. R.; Kitchin, J. P.; Lester, D. J.; Motherwell, W. B.; Papoula, M. T. B. *Tetrahedron* **1981**, *37*, 73. (b) Anaya, J. Barton, D. H. R., Gero, S. D.; Grande, M.; Martin, N.; Tachdijian, C. *Angew. Chem., Int. Ed. Engl.* **1993**, *32*, 867.

Scheme S7: Application of dihydroxylation, oxidative diol cleavage, and reduction towards **2**.



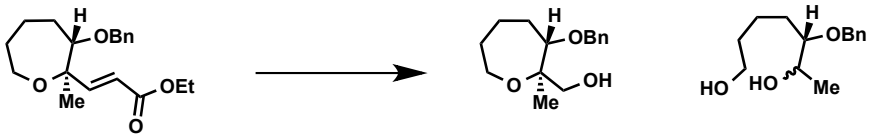
Enoate S21: To a solution of **7d** (190 mg, 0.83 mmol) in THF (8.3 mL) was added NaH (95%, 40 mg, 1.66 mmol), TBAI (30 mg, 0.08 mmol), and BnBr (217 μL, 1.83 mmol). The reaction was stirred at room temperature for 17 h then quenched by the careful addition of sat. $NH_4Cl_{(aq)}$ (5 mL) and extracted with EtOAc (3 x 10mL). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The resultant colorless film was purified by flash chromatography (5–20% EtOAc/hexanes) to afford **S21** as a colorless oil (160 mg, 60%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39-7.29 (m, 5H), 7.02 (d, *J* = 15.7 Hz, 1H), 6.04 (d, *J* = 15.7 Hz, 1H), 4.65 (d, *J* = 11.7 Hz, 1H), 4.41 (d, *J* = 11.7 Hz, 1H), 4.21 (q, *J* = 7.1 Hz, 2H), 3.83-3.78 (m, 1H), 3.51 (d, *J* = 9.1 Hz, 1H), 3.44 (ddd, *J* = 12.4, 8.2, 3.8 Hz, 1H), 1.95-1.89 (m, 1H), 1.86-1.79 (m, 2H), 1.67-1.60 (m, 2H), 1.40-1.35 (m, 1H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.29 (s, 3H)

^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 152.4, 138.4, 128.5, 127.78, 127.72, 119.3, 83.4, 80.3, 71.8, 64.7, 60.5, 31.1, 26.8, 24.6, 21.8, 14.4

FT-IR (ATR, cm^{-1}): 2980, 2934, 2875, 1715, 1654, 1497, 1453, 1366, 1298, 1272, 1214, 1173, 1115, 1096, 1067l 1029

HRMS (DART, *m/z*): $[M+H]^+$ for $C_{19}H_{26}O_4$: 319.1904, found 319.1912



S21 **S22** **S23**

Alcohol S22: To a solution of **S21** (8.9 mg, 0.028 mmol) in *t*-BuOH/H_2O (1:1, 0.56 mL) was added citric acid monohydrate (6 mg, 0.028 mmol), NMO (as solid, 7 mg, 0.056 mmol), and $K_2OsO_2(OH)_4$•$2H_2O$ (0.5 mg, 1.4 μmol), and the green reaction mixture was stirred at room temperature. After 8 h, the colorless reaction was quenched by addition of 1M $HCl_{(aq)}$ (0.2 mL), then extracted EtOAc (3 x 2 mL). The combined organic layers were washed sat. $Na_2CO_{3(aq)}$ (1 x 2.5 mL), sat. $NaCl_{(aq)}$ (1 x 2.5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to provide the crude diol as a pale green oil, which was used without further purification.

To a solution of the crude diol in CH_2Cl_2 (0.55 mL) was added $NaIO_4/SiO_2$ (1.2 g/mmol, 100 mg, 0.084 mmol) and stirred at room temperature. After 30 min, the reaction was filtered through a cotton plug and washed CH_2Cl_2 (1 x 1 mL), then Et_2O (2 x 1 mL), and concentrated *in vacuo*. The crude aldehyde was used directly without purification.

To a solution of crude aldehyde in MeOH (0.3 mL) at 0 ºC was added $NaBH_4$ (6 mg, 0.15 mmol). The reaction was quenched after 10 min by the addition of 1M $HCl_{(aq)}$ (0.3 mL), EtOAc (2 mL), and H_2O (0.4 mL). The reaction mixture was extracted with EtOAc (3 x 5 mL), and the combined organic layers were washed with sat. $NaCl_{(aq)}$ (5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo*. The resultant colorless film was purified by flash chromatography (20–60% EtOAc/hexanes) to afford **S22** as a colorless oil (4.2 mg, 60%) and **S23** as a colorless film (1.5:1 d.r., 3 mg, 43%).

Characterization Data For S22:

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.27 (m, 5H), 4.63 (d, *J* = 11.7 Hz, 1H), 4.35 (d, *J* = 11.7 Hz, 1H), 3.73 (ddd, *J* = 12.6, 6.2, 3.6 Hz, 1H), 3.60 (ddd, *J* = 12.6, 7.3, 3.6 Hz, 1H), 3.52 (d, *J* = 10.9 Hz, 1H), 3.47-3.43 (m, 2H), 1.94-1.87 (m, 2H), 1.83-1.79 (m, 1H), 1.67-1.61 (m, 2H), 1.44-1.39 (m, 1H), 1.24 (s, 3H)

^{13}C NMR (125 MHz, $CDCl_3$) δ 138.6, 128.5, 127.77, 127.74, 82.3, 79.9, 71.5, 68.6, 63.8, 31.2, 27.6, 23.3, 17.3

FT-IR (ATR, cm^{-1}): 3415, 2930, 2873, 1718, 1606, 1497, 1453, 1400, 1367, 1267, 1206, 1062, 1027

HRMS (DART, *m/z*): $[M+H]^+$for $C_{15}H_{22}O_3$: 251.1642, found 251.1653.

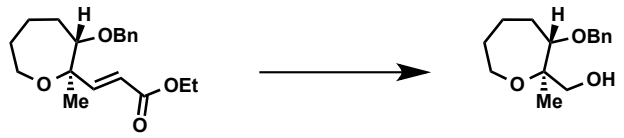
Characterization Data For S23 (major diastereomer):

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.30 (m, 5H), 4.67 (d, *J* = 11.3 Hz, 1H), 4.53 (d, *J* = 11.3 Hz, 1H), 3.77 (quintet, *J* = 6.4 Hz, 1H), 3.66 (t, *J* = 6.4 Hz, 2H), 3.25 (q, *J* = 5.4 Hz, 1H), 1.67-1.48 (m, 6H), 1.20 (d, *J* = 6.4 Hz, 3H)

^{13}C NMR (125 MHz, $CDCl_3$): δ 138.5, 128.7, 128.03, 127.95, 84.1, 72.8, 69.1, 63.0, 33.2, 30.2, 21.3, 19.3

FT-IR (ATR, cm^{-1}): 3359, 2925, 2859, 1717, 1497, 1454, 1371, 1276, 1208, 1068

HRMS (DART, *m/z*): $[M+Na]^+$ for $C_{14}H_{22}O_3$: 261.1461, found 261.1467.



S21 **S23**

Alcohol S23: To a solution of **S21** (27 mg, 0.085 mmol) in *t*-BuOH/H_2O (1:1, 0.86 mL) was added citric acid monohydrate (18 mg, 0.085 mmol), NMO (as solid, 20 mg, 0.17 mmol), and $K_2OsO_2(OH)_4$•$2H_2O$ (1.5 mg, 4 μmol), and the green reaction mixture was stirred at room temperature. After 14 h, the colorless reaction was quenched by addition of 1M $HCl_{(aq)}$ (0.4 mL), then extracted EtOAc (3 x 3 mL). The combined organic layers were washed sat. $Na_2CO_{3(aq)}$ (1 x 5 mL), sat. $NaCl_{(aq)}$ (1 x 5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to provide the crude diol as a pale green oil, which was used without further purification.

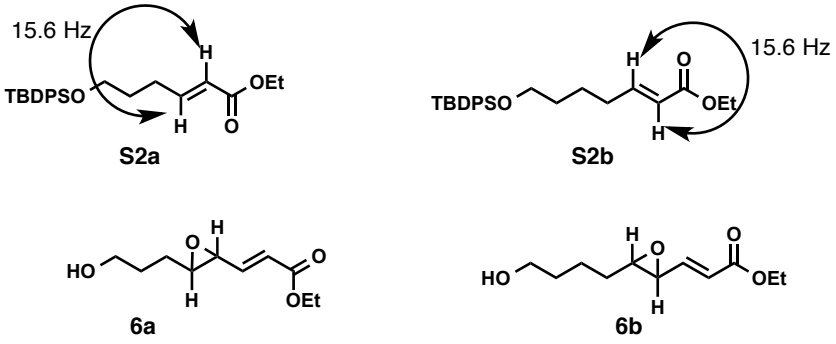
To a solution of the crude diol in CH_2Cl_2 (1 mL) was added Ph_3BiCO_3 (85 mg, 0.17 mmol) and heated to 50 ºC in an oil bath. After 3 h, the reaction was removed from the oil bath, filtered through Celite (washed CH_2Cl_2 3 x 1 mL), and concentrated *in vacuo*. The crude gel was purified by flash chromatography (100% hexanes–6% EtOAc/hexanes) to afford an aldehyde that was used immediately in the next step.

To a solution of aldehyde in MeOH (2 mL) at 0 ºC was added $NaBH_4$ (12 mg, 0.31 mmol). The reaction was quenched after 5 min by the addition of 1M $HCl_{(aq)}$ (0.4 mL), EtOAc (2 mL), and H_2O (0.4 mL). The reaction mixture was extracted with EtOAc (3 x 5 mL), and the combined organic layers were washed with sat. $NaCl_{(aq)}$ (5 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo* to yield **S23** as a colorless film (16 mg, 0.064 mmol, 75% over 3 steps).

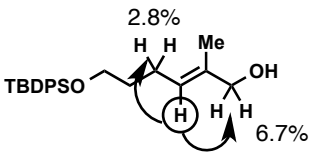
I. Stereochemical Determination

a. Cyclization Model Systems

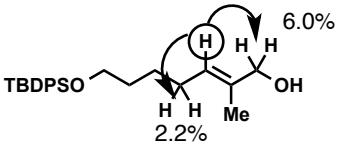
Stereochemistry of **6a** and **6b** epoxides were determined by the geometry of the underlying alkenes, from **S2a** and **S2b**, in combination with the accepted stereochemical outcome of the reactions used in the synthetic sequence. Shown below are the relevant coupling constants in S2a and S2b with corresponding **6a** and **6b**.



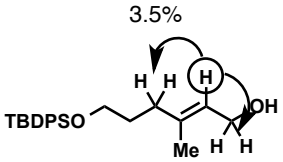
Stereochemical assignment of epoxide geometry for **6c-6f** was made at the corresponding allylic alcohols **S3c-S3f** by 1-D nOe difference spectra. The circled proton was selectively irradiated, and the corresponding nOe are shown by arrows and percentages.



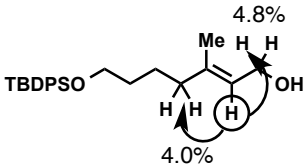
3c



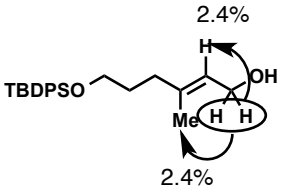
3d



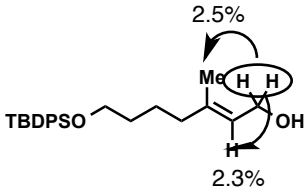
3e



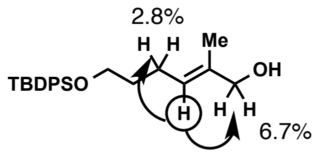
3f



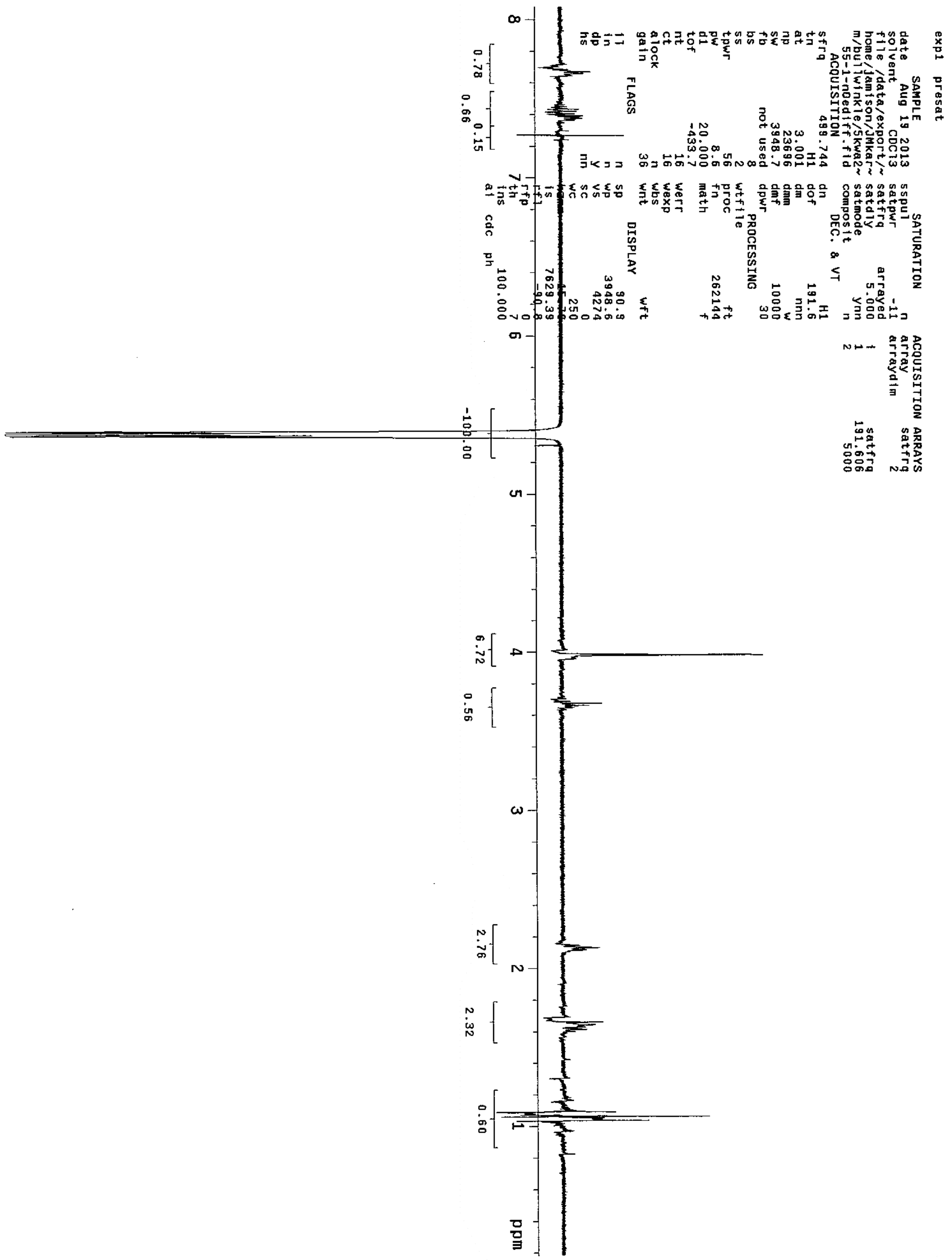
3e

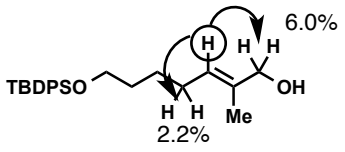


3f

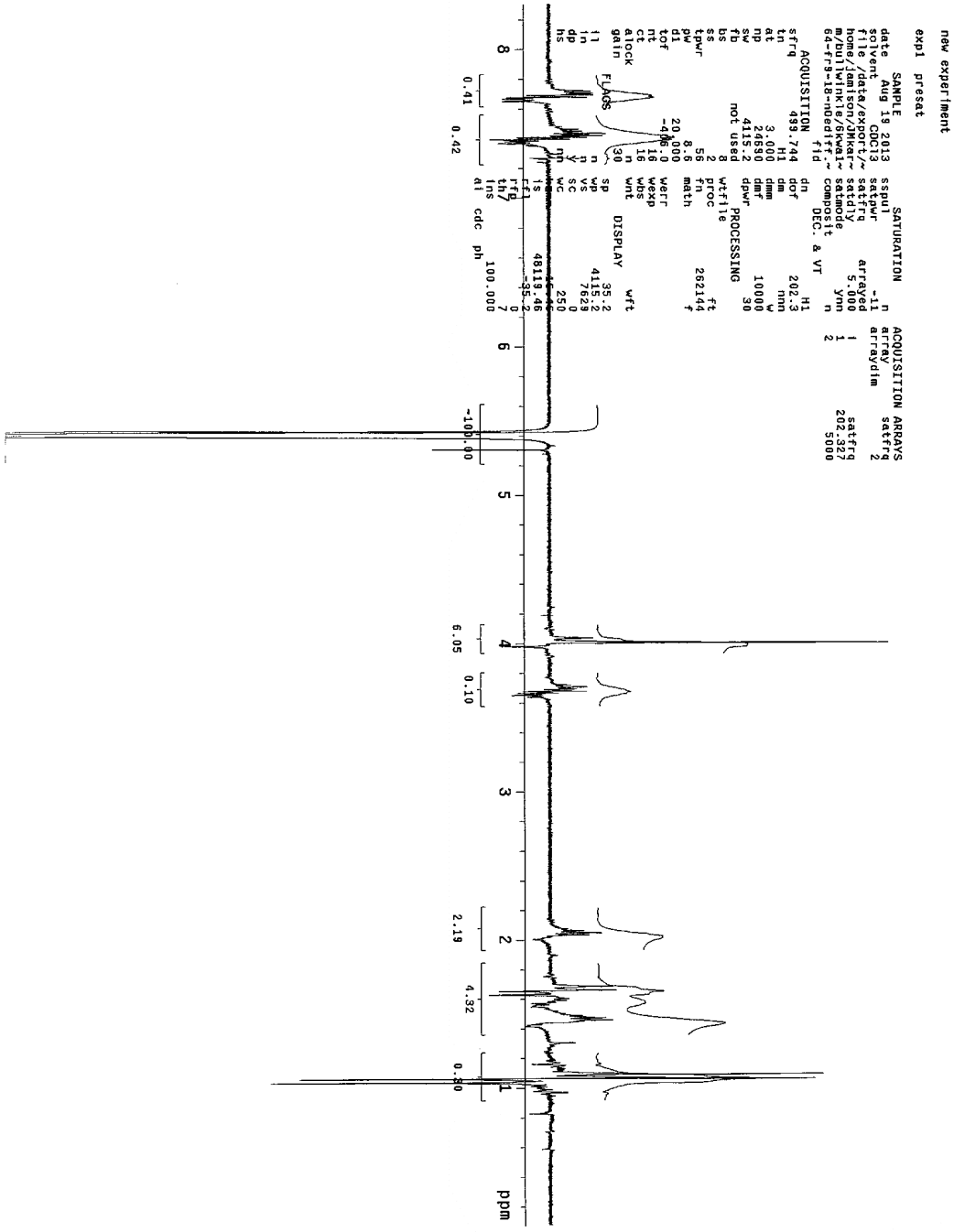


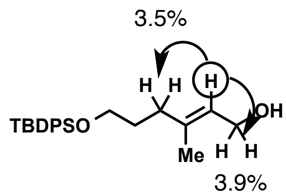
3c



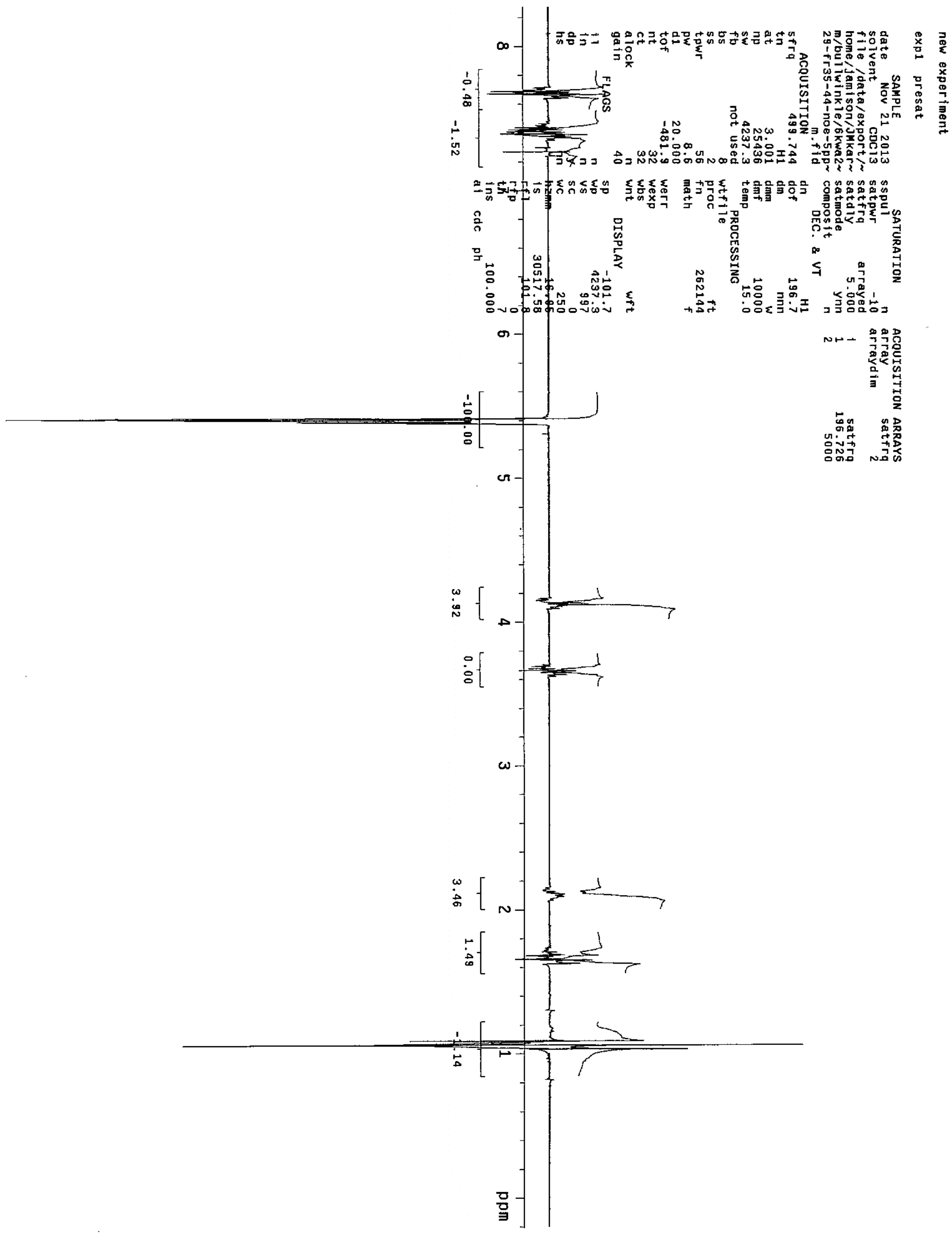

6.0%
H
H H
TBDPSO
OH
H H
Me
2.2%

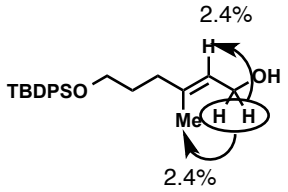
3d


new experiment
expl preset
SAMPLE
date Aug 19 2013
solvent CDCl3
file /data/export/~
home/jamison/JMker~
m/DuliWink/9kwa1~
64-frq-18-ndedit~
ACQUISITION
sfrq 499.744 H1
tn H1
at 3.000
np 24690
sw 4115.2
fb
bs
ss
tpwr
pw
dl
tof
nt
ct
alock
gain
FLAGS
SATURATION
sspul n
satpwr -11
satfrq arrayed
satdly 5.000
satmode ynn
compost n
DEC. & VT
dn H1
dof 202.3
dm nnn
dmm w
dmf 10000
dpwr 30
PROCESSING
wtfile
proc ft
math f
werr
wexp
wbs
wnt
ACQUISITION ARRAYS
array satfrq
arraydim 2
1
2
satfrq
202.327
202.3000
DISPLAY
sp 35.2
wp 4115.2
vs 7822
sc 0
wc 250
hs
wft
48119.46
-35.2
0.41
0.42
6.05
0.10
2.19
4.32
0.80
-100.00
ppm

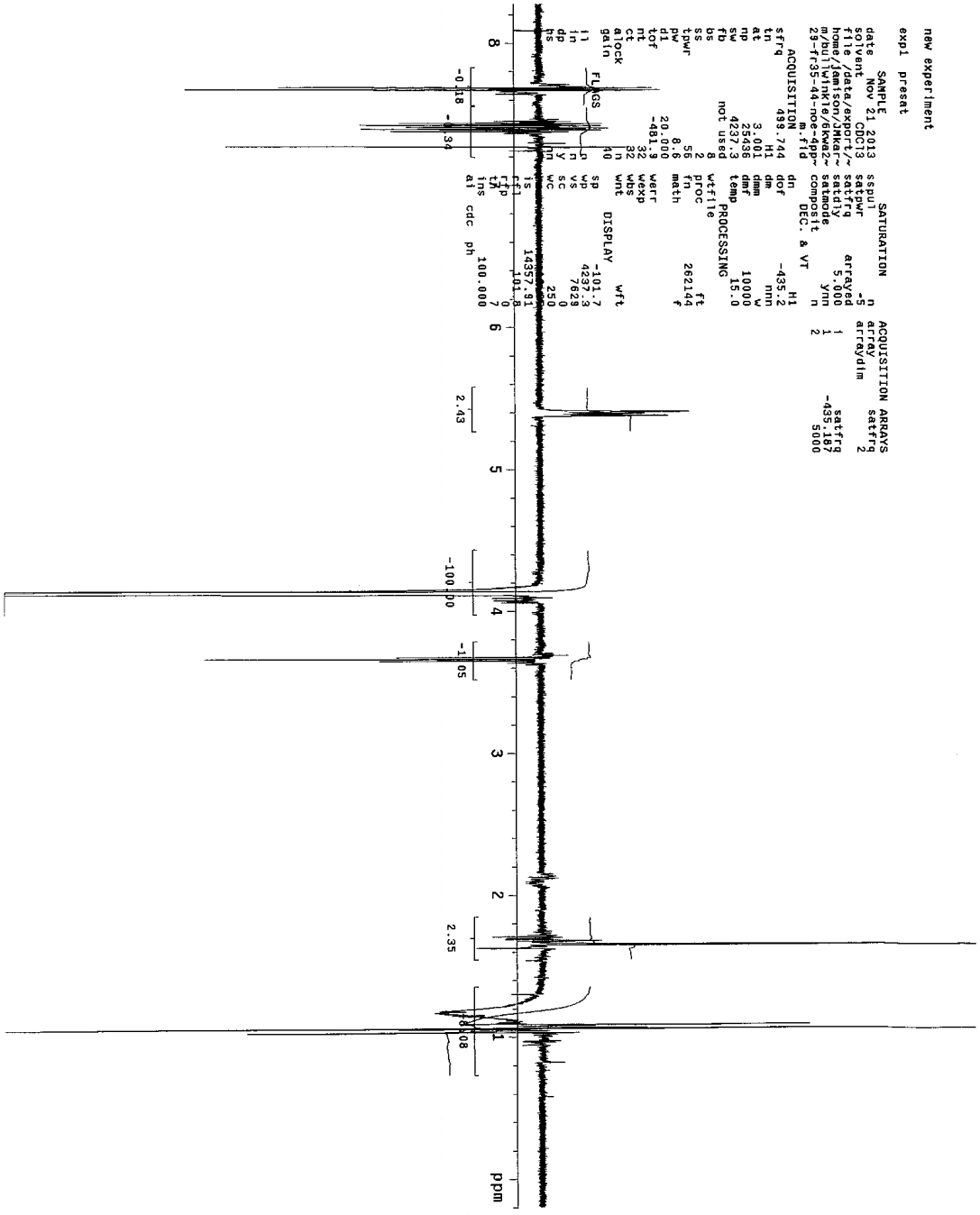


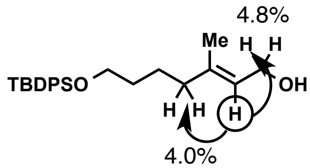
3e



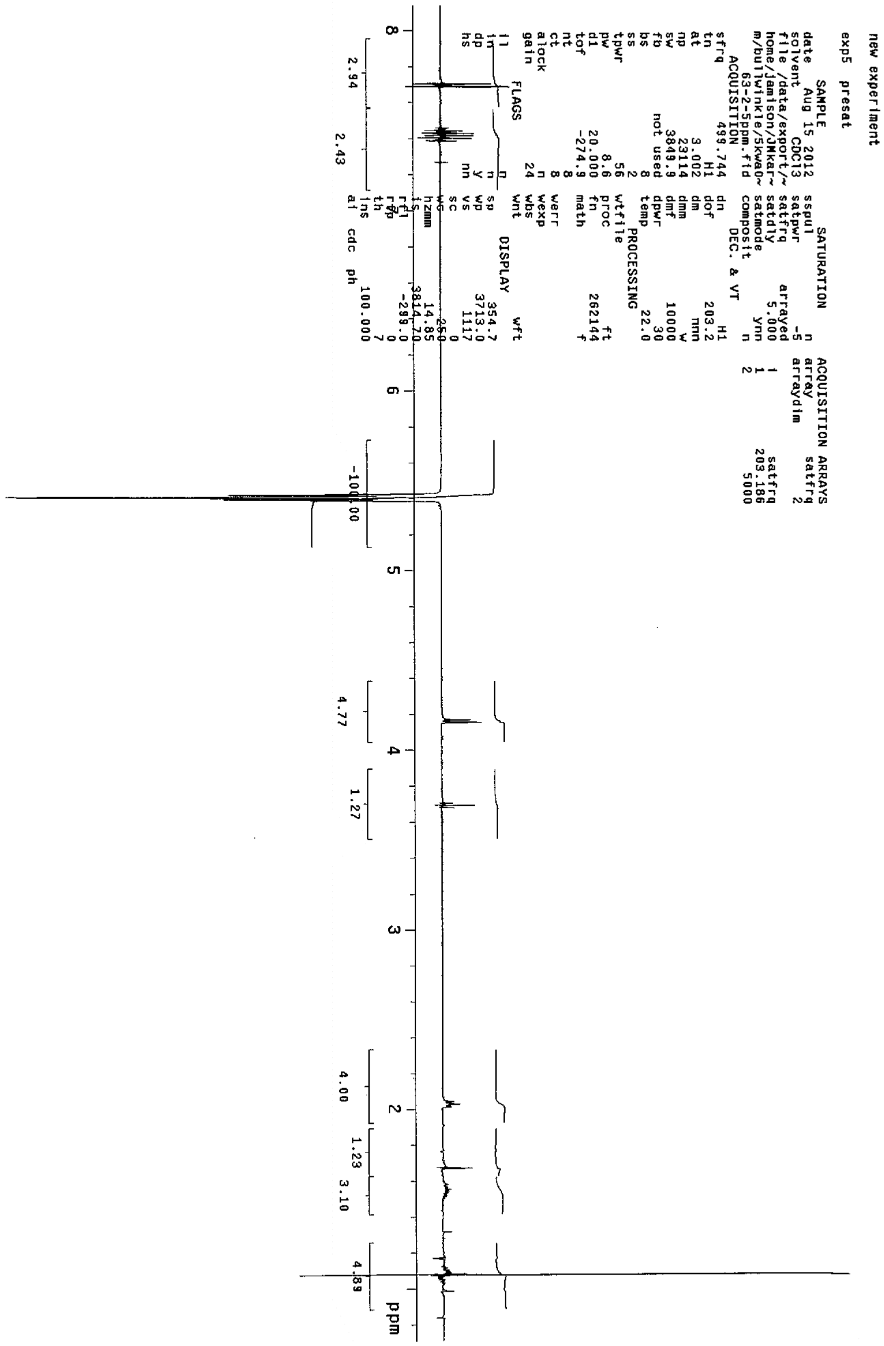


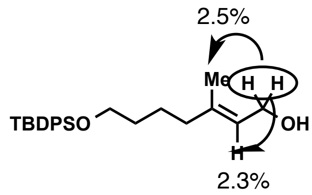
3e



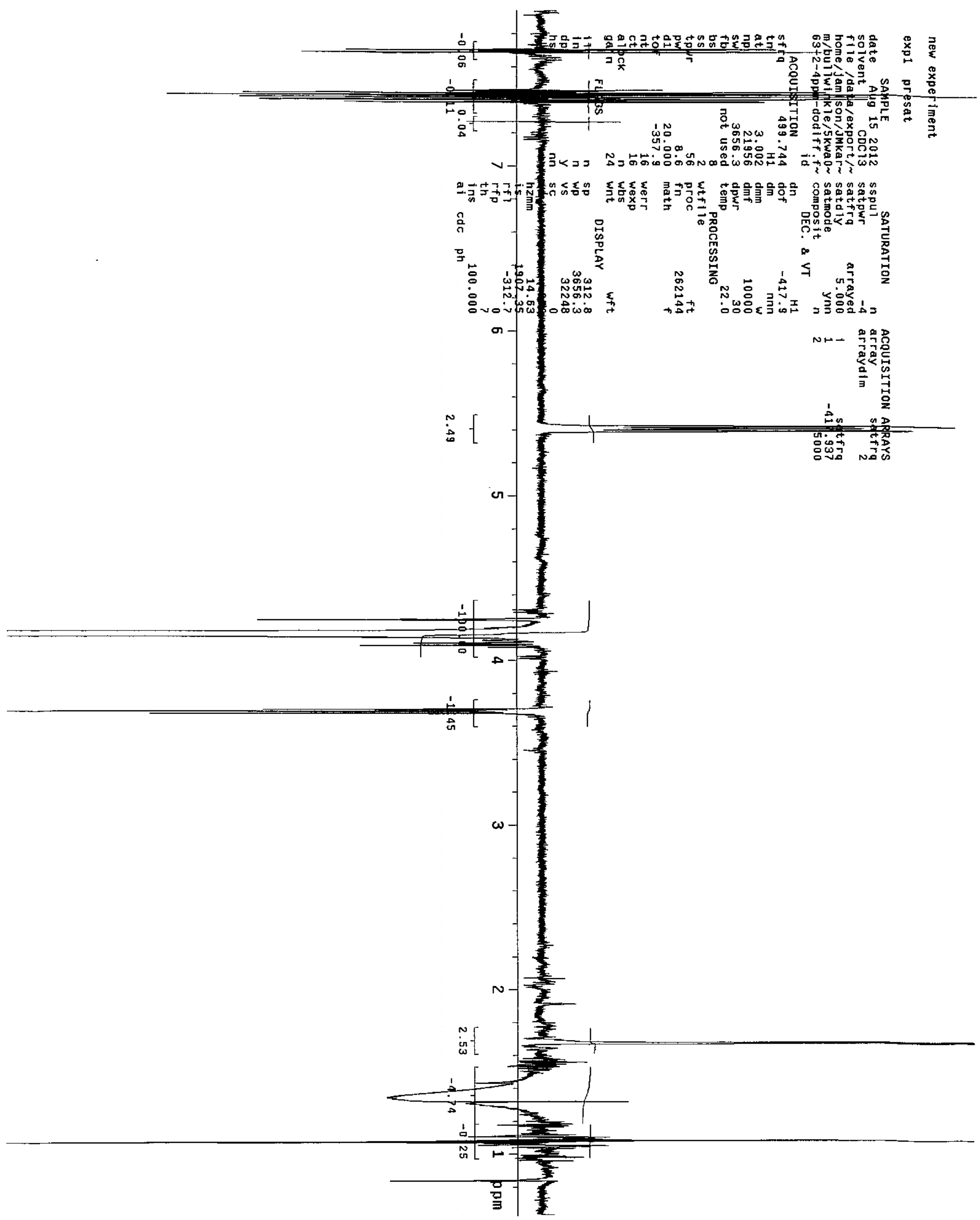


3f





3f



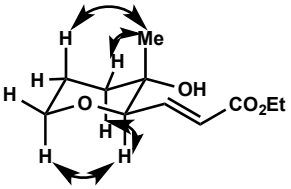
Cyclization products **7a-c** and **8a-c** were assigned by correlation to the following references, utilizing the typically small difference between methyl and ethyl esters. **7d** and **8d** were assigned by comparison to **7c** and **8c**.

References:

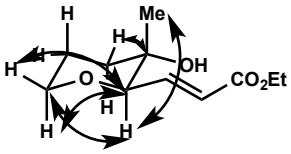
Nicolaou, K. C.; Prasad, C. V. C.; Somers, P. K.; Hwang, C.-K. *J. Am. Chem. Soc.* **1989**, *111*, 5330.

Nicolaou, K. C.; Prasad, C. V. C.; Somers, P. K.; Hwang, C.-K. *J. Am. Chem. Soc.* **1989**, *111*, 5335

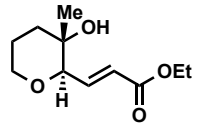
Cyclization product **7e** was assigned using 2-D NMR (gCOSY, HSQC, gHMBC, NOESY). Cyclization product **7f** was assigned by comparison to **7e**. Cyclization products **8e** and **8f** were assigned on the basis of the known stereo-inversion mechanism and exo preference for CSA mediated cyclization, as well as gCOSY analysis.



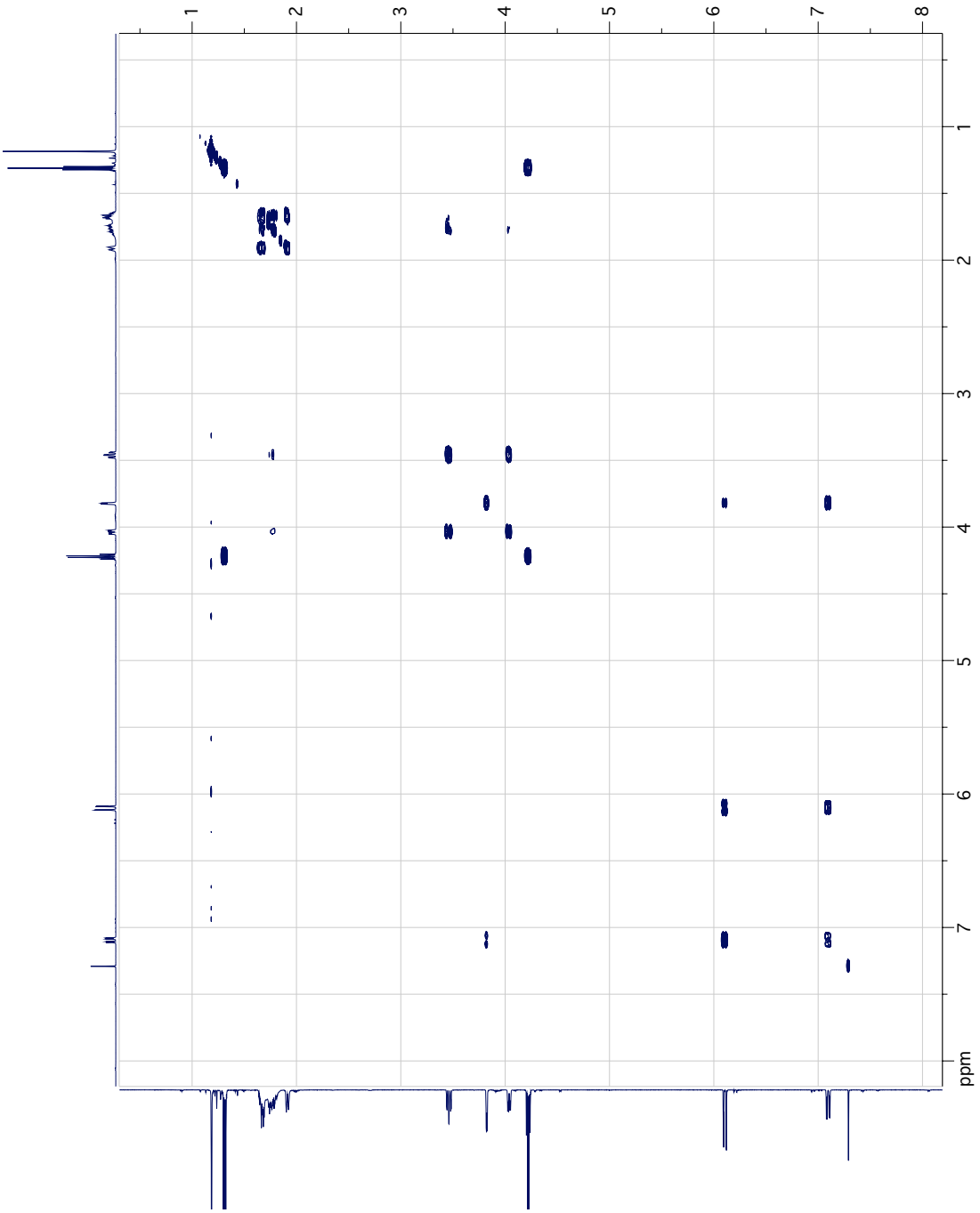
7e NOESY Correlations

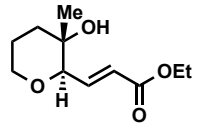


7e gHMBC Correlations

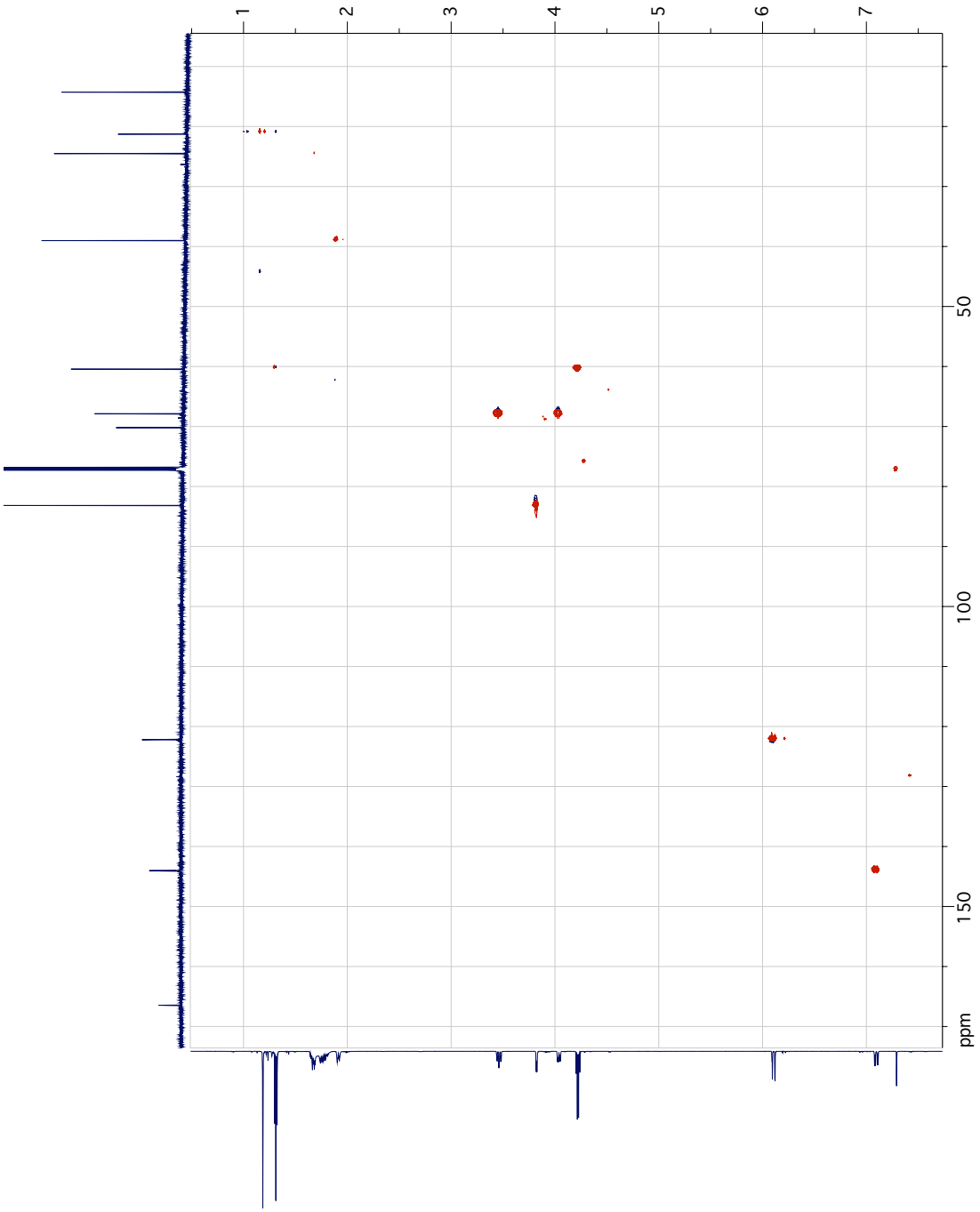


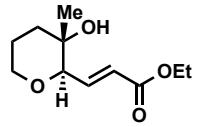
7e (gCOSY, $CDCl_3$, 600 MHz)



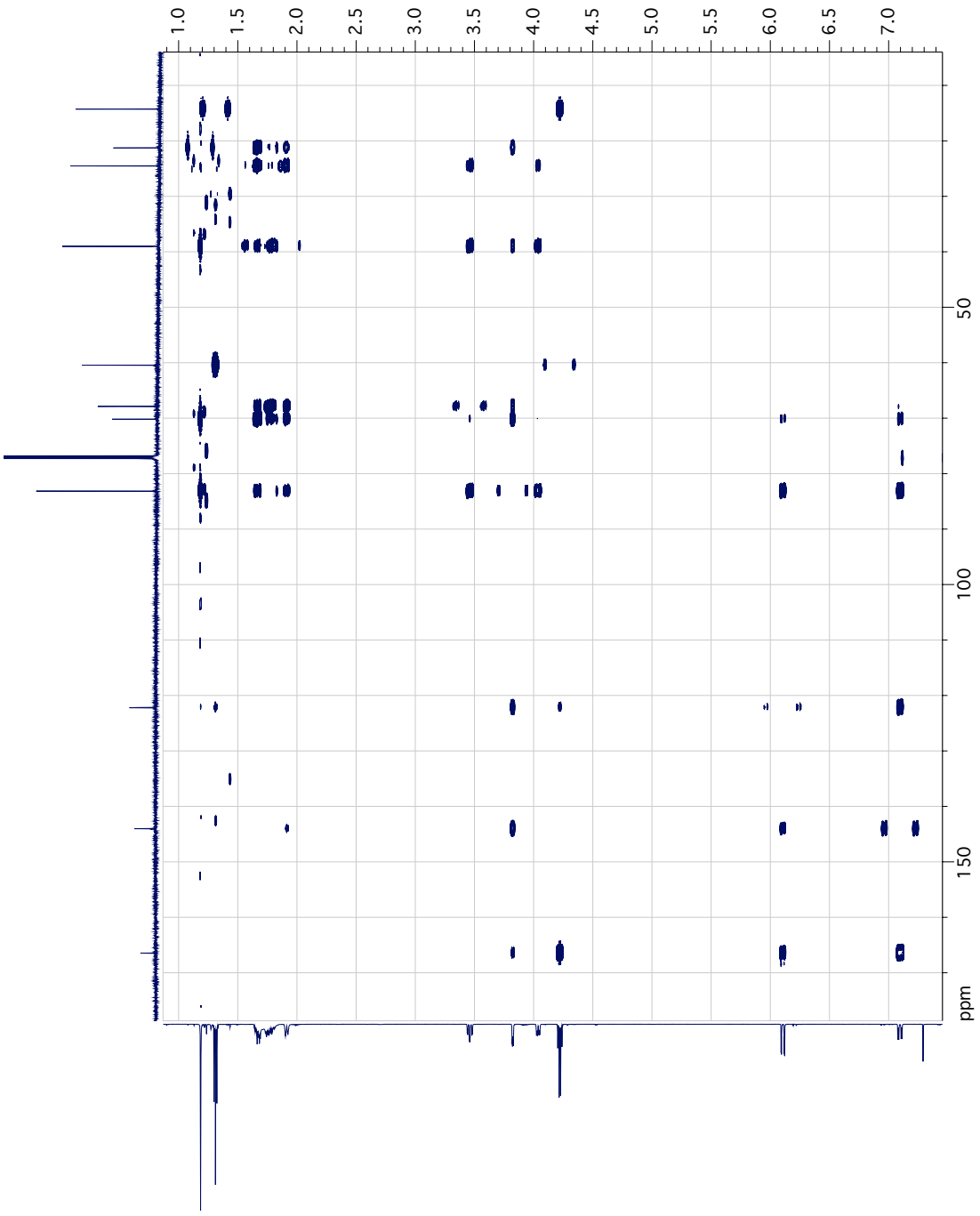


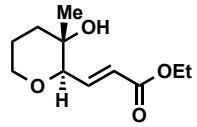
7e (HSQC, $CDCl_3$, 600 MHz)



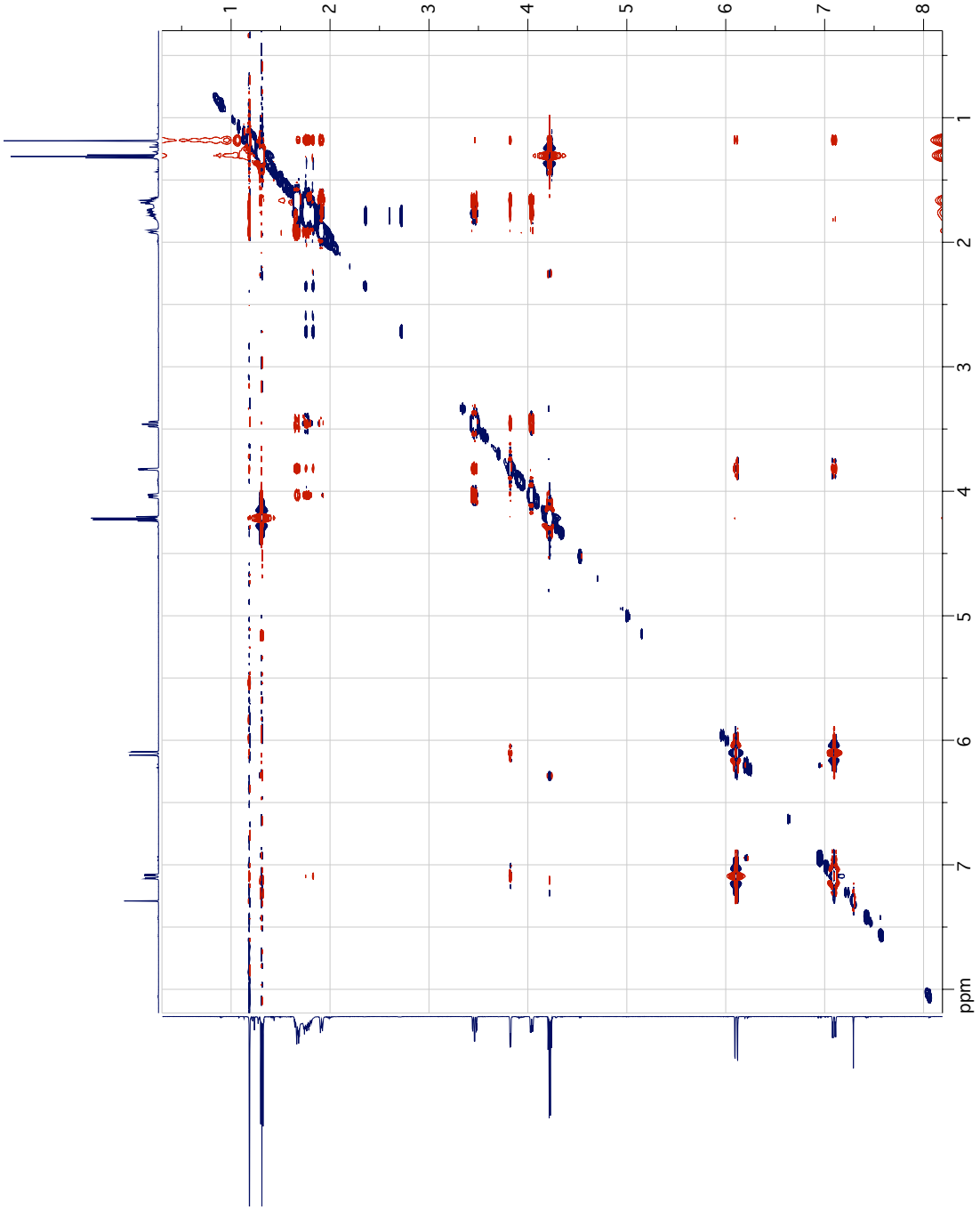


7e (gHMBC, $CDCl_3$, 600 MHz)





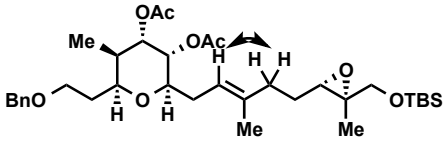
7e (NOESY, $CDCl_3$, 600 MHz)



Assignment of EF Stereochemistry: The assignment of the stereochemistry of cascade precursor **5** and **13** are based on 1-D NMR and the expected stereochemical outcomes of the Claisen [3,3] rearrangement (*E* olefin geometry predominates) and HWE olefination (*E* olefin geometry predominates), while the epoxide stereochemistry was assigned based on the known catalyst control of the Shi asymmetric epoxidation. Additional evidence to support these assignments comes from the interception of known EF tricycle **3**.

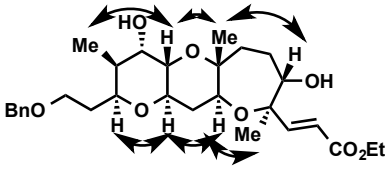
Assignment of ABC Stereochemistry: The assignment of the stereochemistry of cascade precursor **21** is based on the underlying olefin geometry assignments and the epoxide stereochemistry assigned based on the known catalyst control of the Shi and Sharpless asymmetric epoxidations.

The olefin geometry of the cross metathesis product **19** was assigned using 2-D NMR (NOESY, attached).

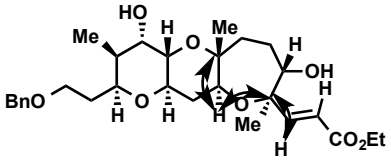


Key NOESY correlation observed in 19 for *E* olefin geometry

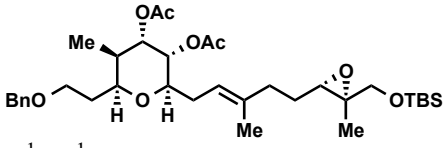
The stereochemistry of the cascade product **22** was assigned by 2-D NMR analysis (gCOSY, HSQC, gHMBC, NOESY, attached) and interception of the known compound **2**.



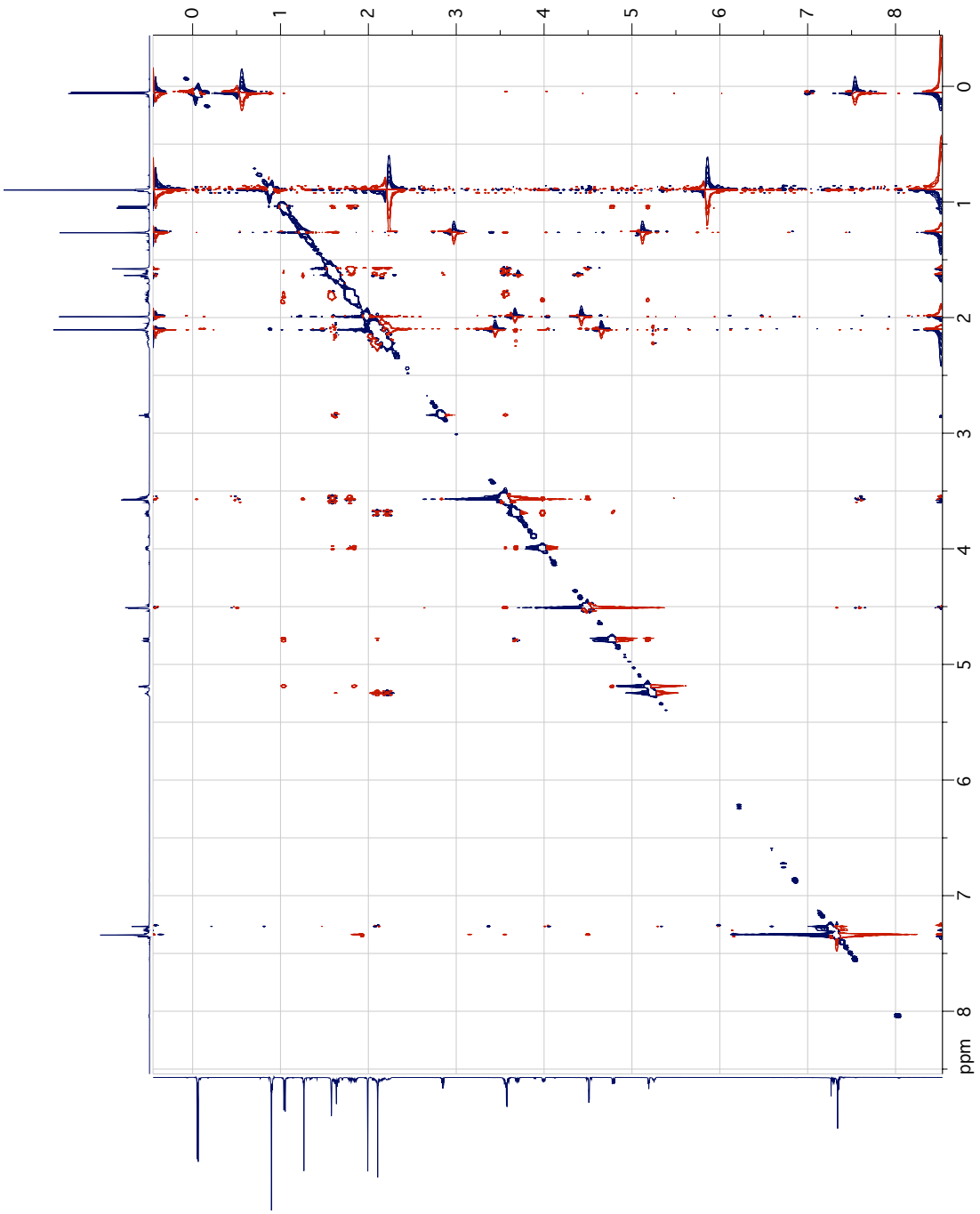
Key NOESY correlations observed in 22 to support all *trans*-fused product

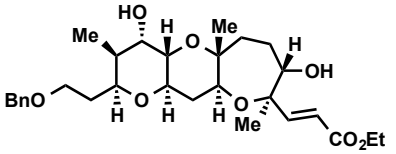


Selected gHMBC correlations observed in 22 to support formation of C-ring oxepane

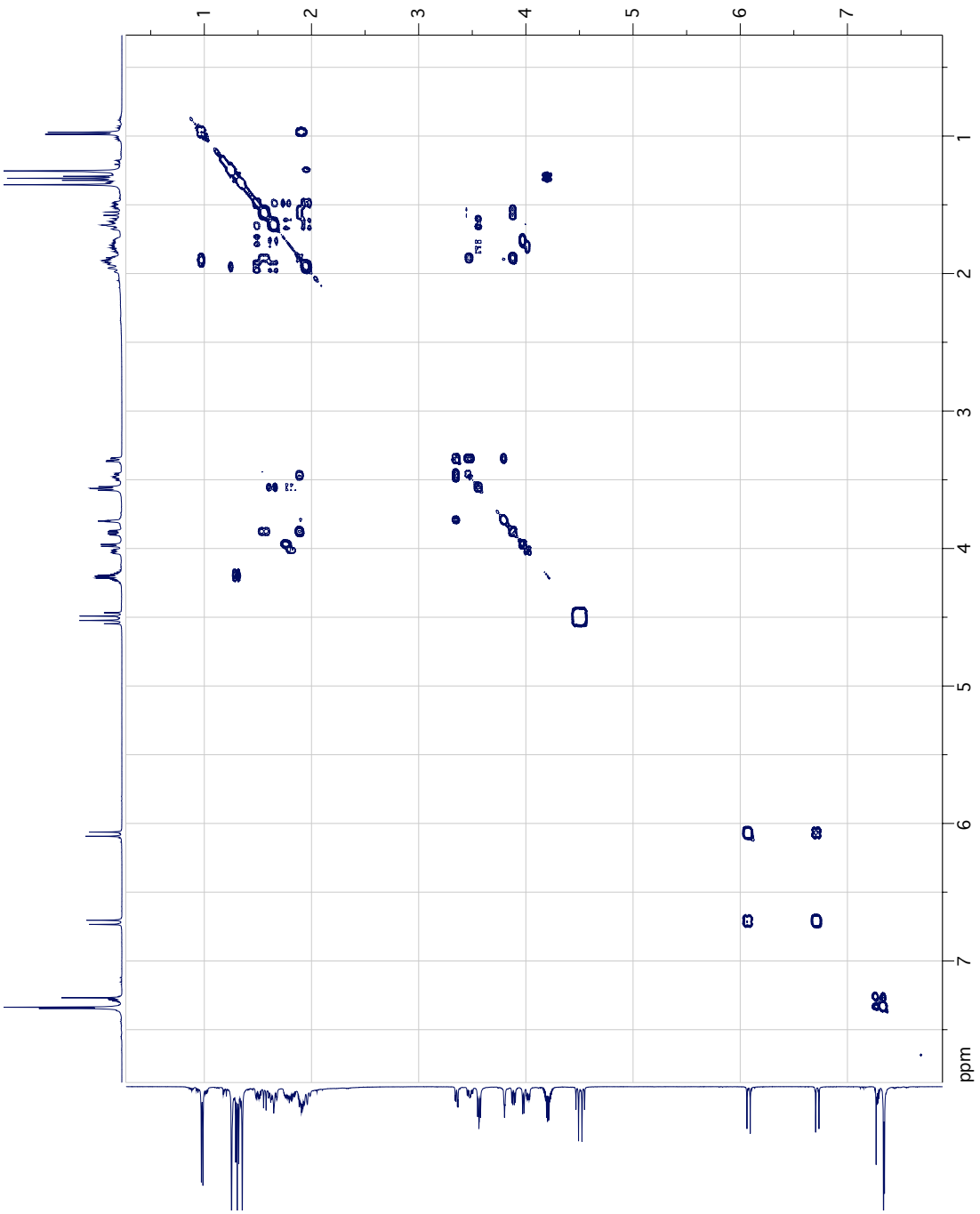


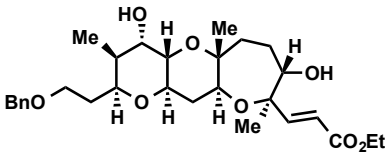
19 (^{1}H–^{1}H NOESY, 500 MHz, $CDCl_3$)



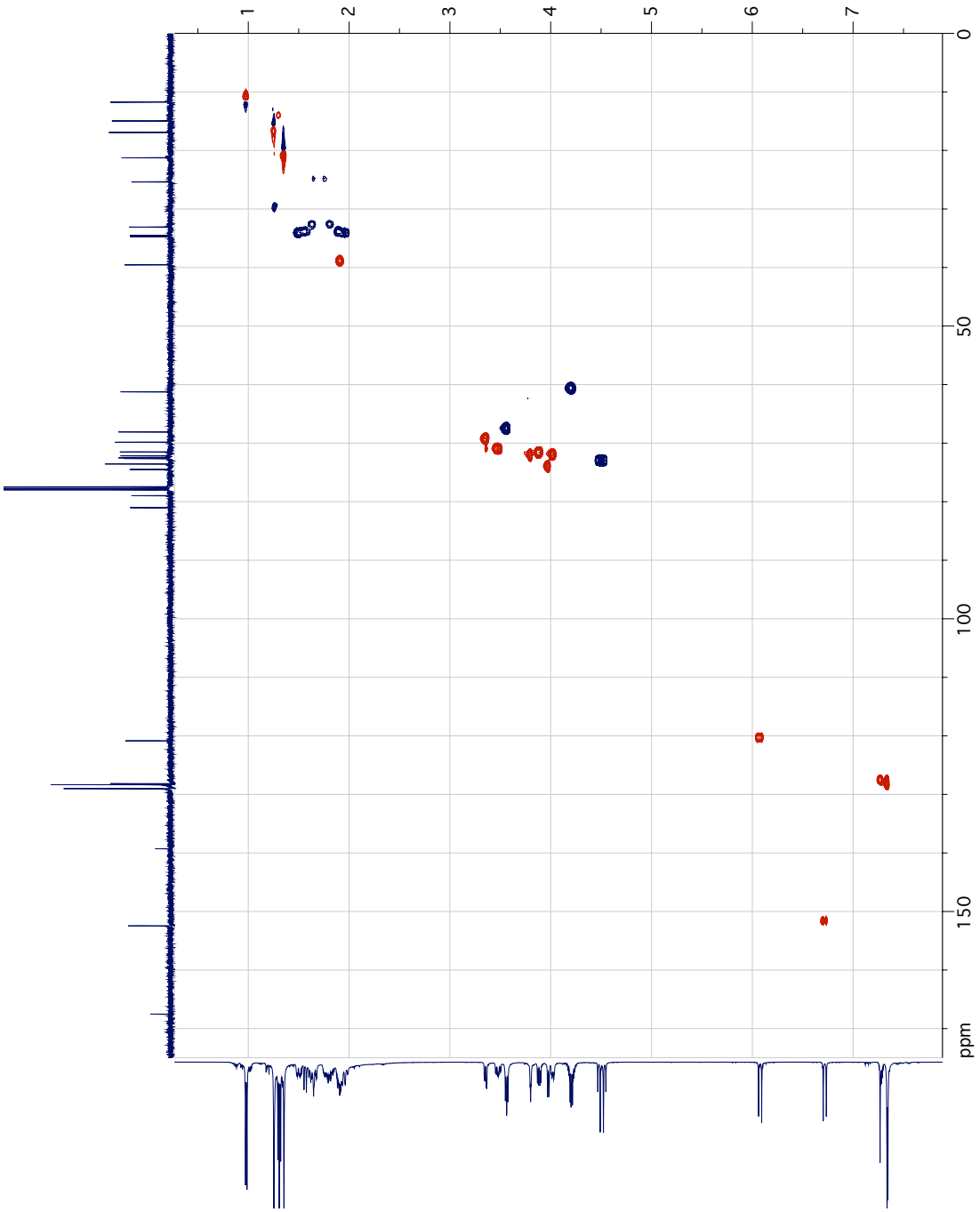


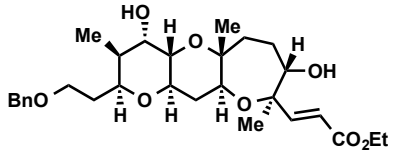
22 (^{1}H–^{1}H gCOSY, 500 MHz, $CDCl_3$)



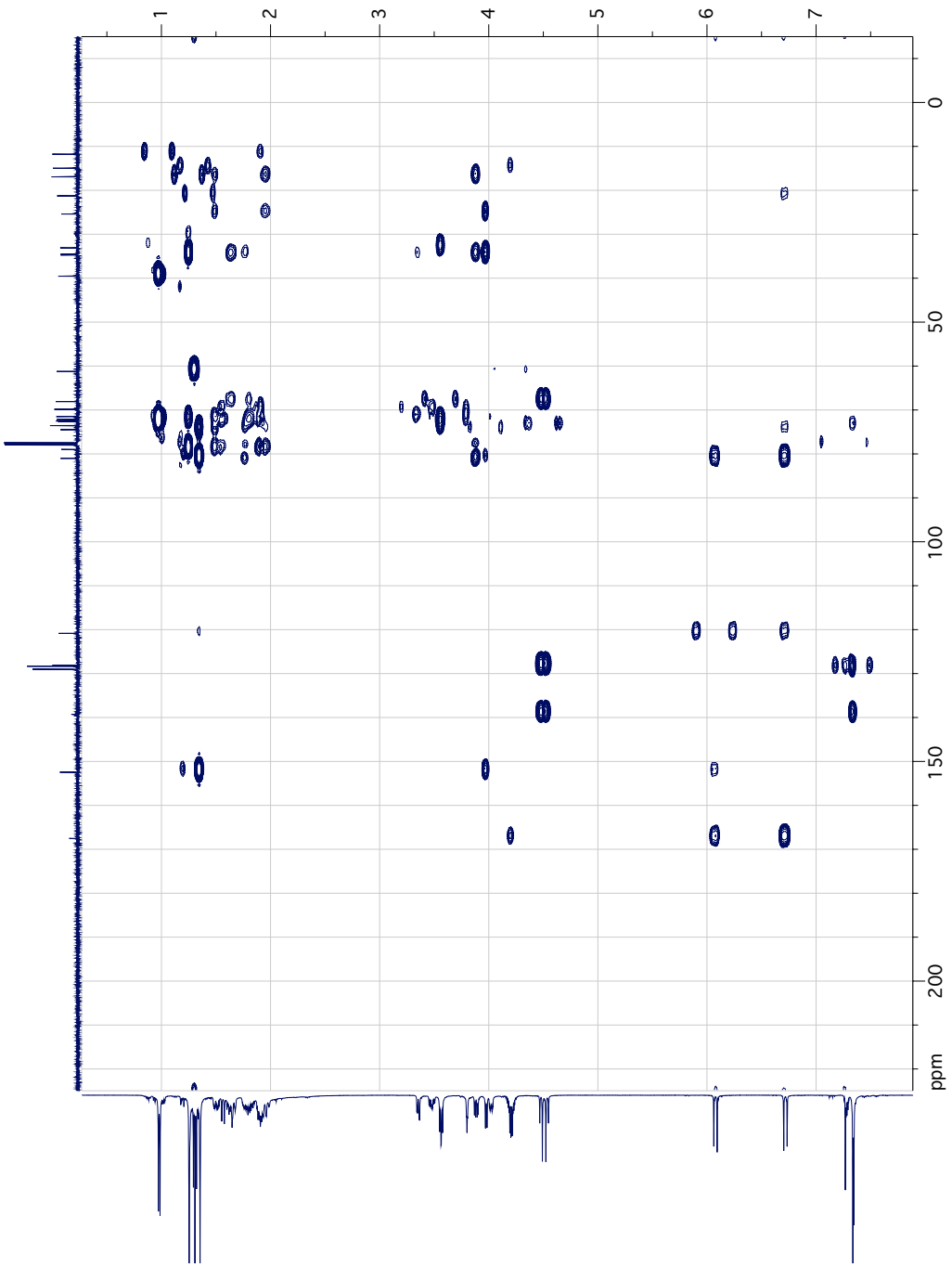


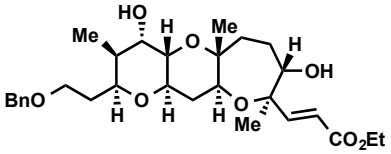
22 (^{1}H–^{13}C HSQC, 500 MHz, $CDCl_3$)



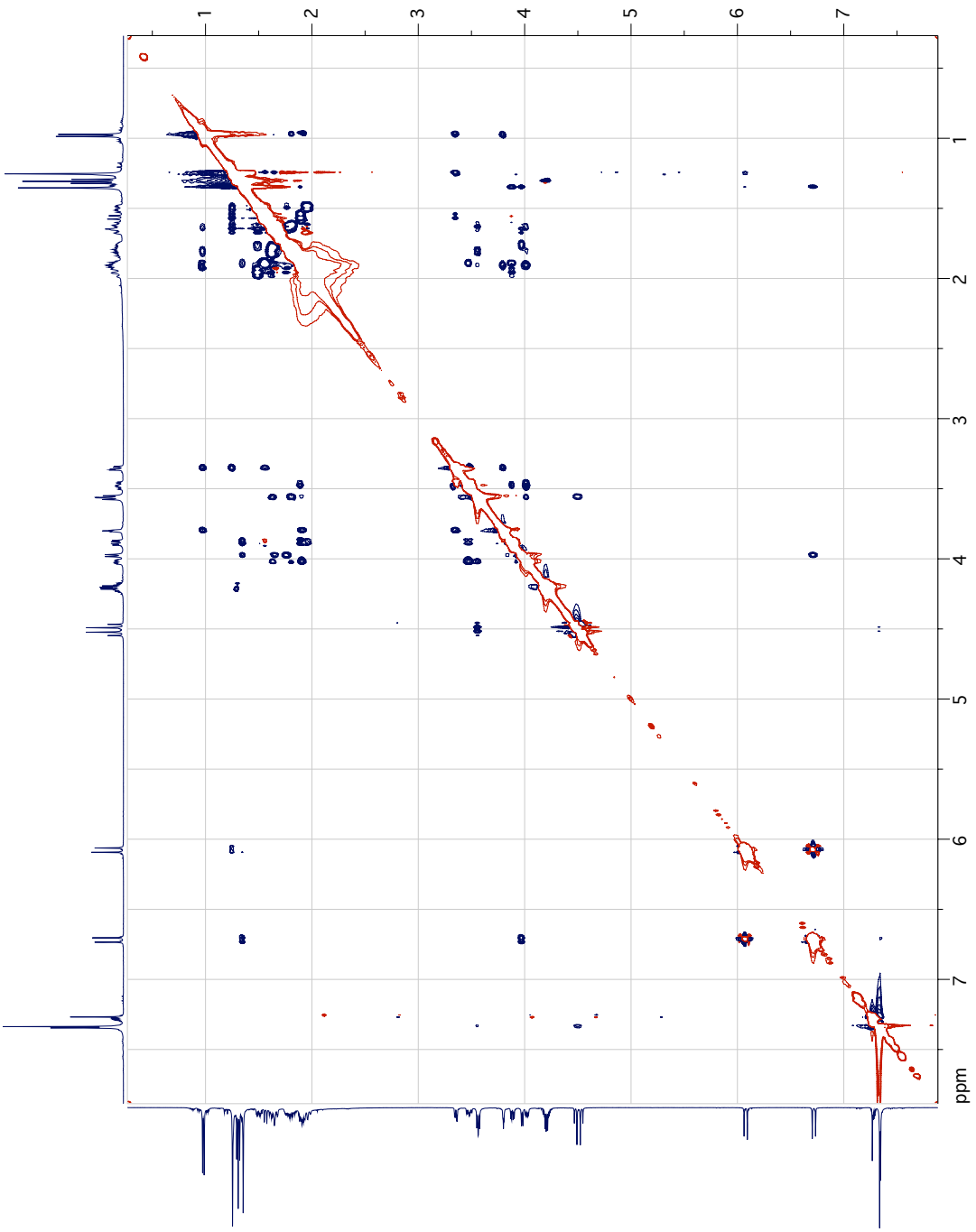


22 (^{1}H–^{13}C gHMBC, 500 MHz, $CDCl_3$)



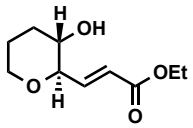


22 (^{1}H–^{1}H NOESY, 500 MHz, $CDCl_3$)

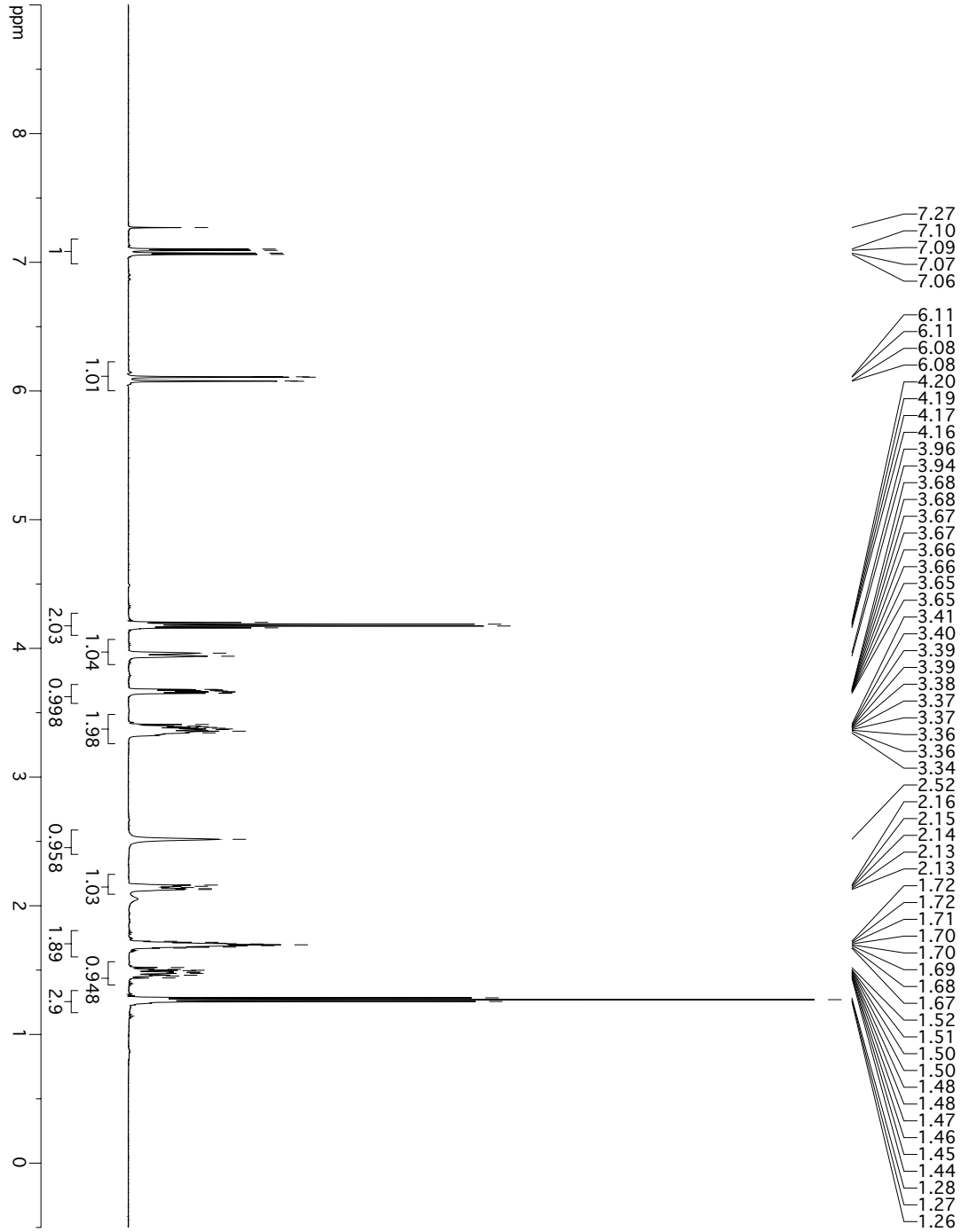


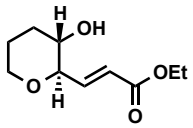
II. Analytical Data

A. ^{1}H and ^{13}C NMR Spectroscopy Data:

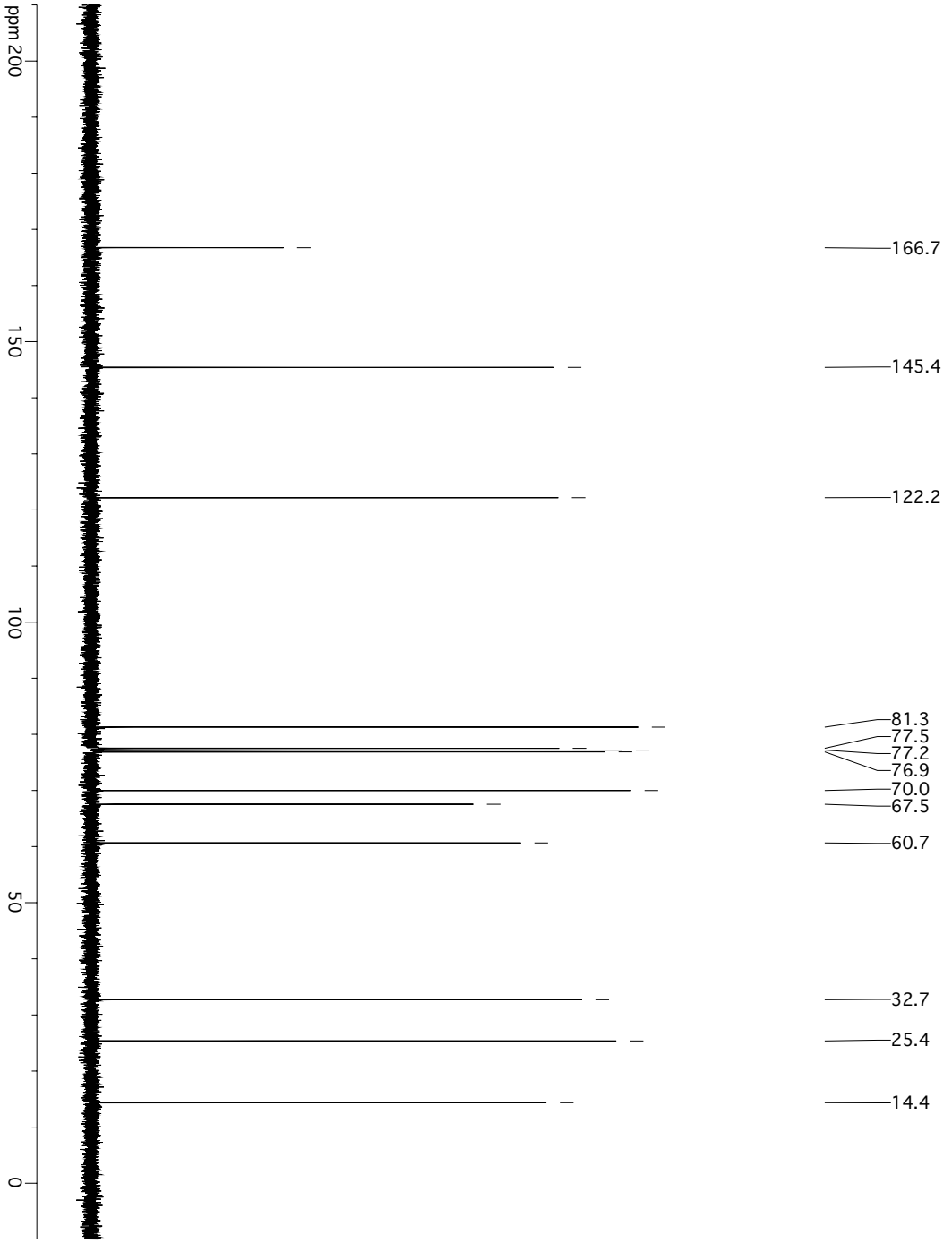

H
OH
OEt
O
H
O

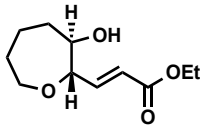
7a


ppm
8
7
6
5
4
3
2
1
0
1
1.01
2.03
1.04
0.998
1.98
0.958
1.03
1.89
0.948
2.9
7.27
7.10
7.09
7.07
7.06
6.11
6.11
6.08
6.08
4.20
4.19
4.17
4.16
3.96
3.94
3.68
3.68
3.67
3.67
3.66
3.66
3.65
3.65
3.41
3.40
3.39
3.39
3.38
3.37
3.37
3.36
3.36
3.34
2.52
2.16
2.15
2.14
2.13
2.13
1.72
1.72
1.71
1.70
1.70
1.69
1.68
1.67
1.52
1.51
1.50
1.50
1.48
1.48
1.47
1.46
1.45
1.44
1.28
1.27
1.26

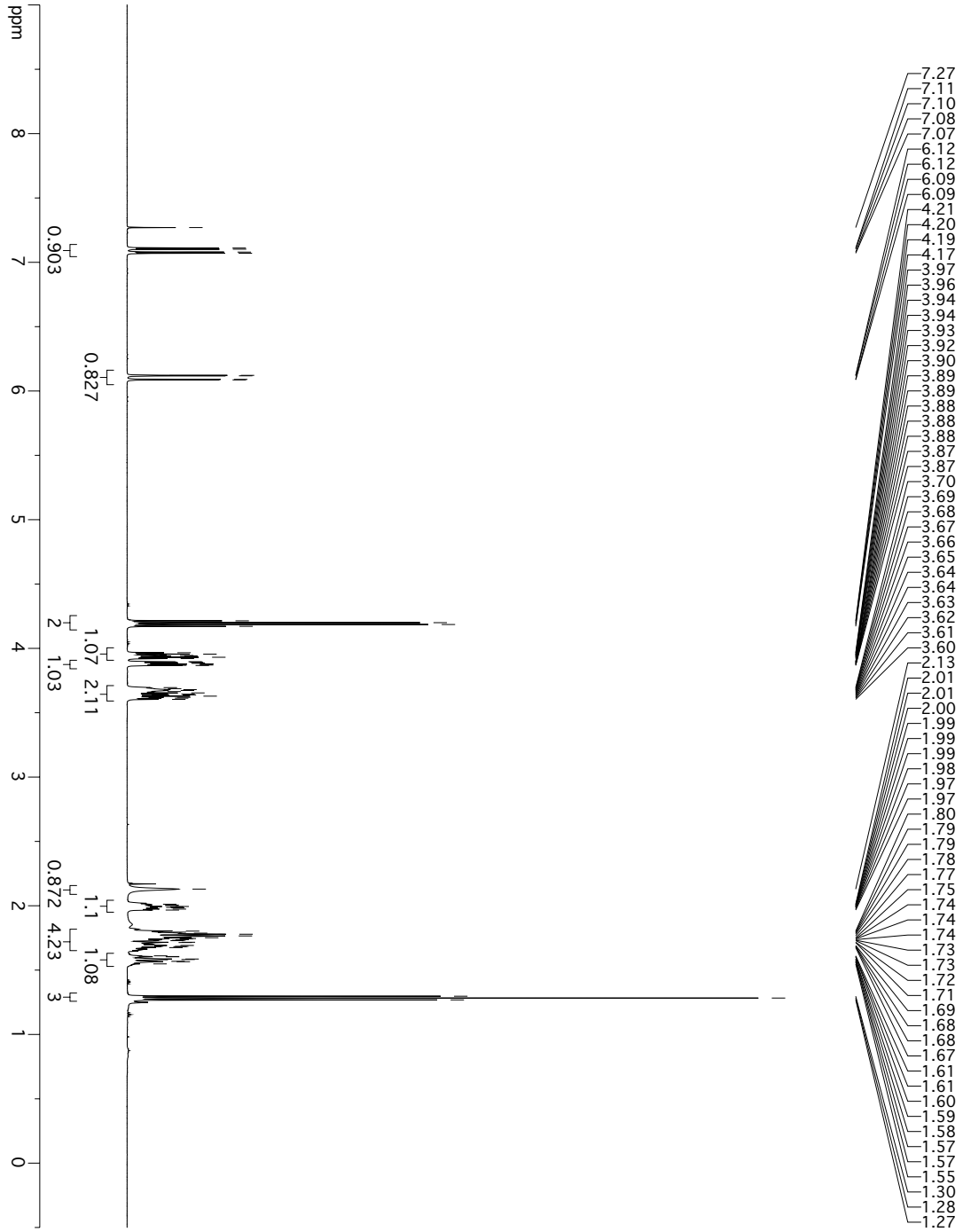

H
OH
OEt
O
H
O

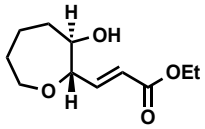
7a


ppm
200
150
100
50
0
166.7
145.4
122.2
81.3
77.5
77.2
76.9
70.0
67.5
60.7
32.7
25.4
14.4

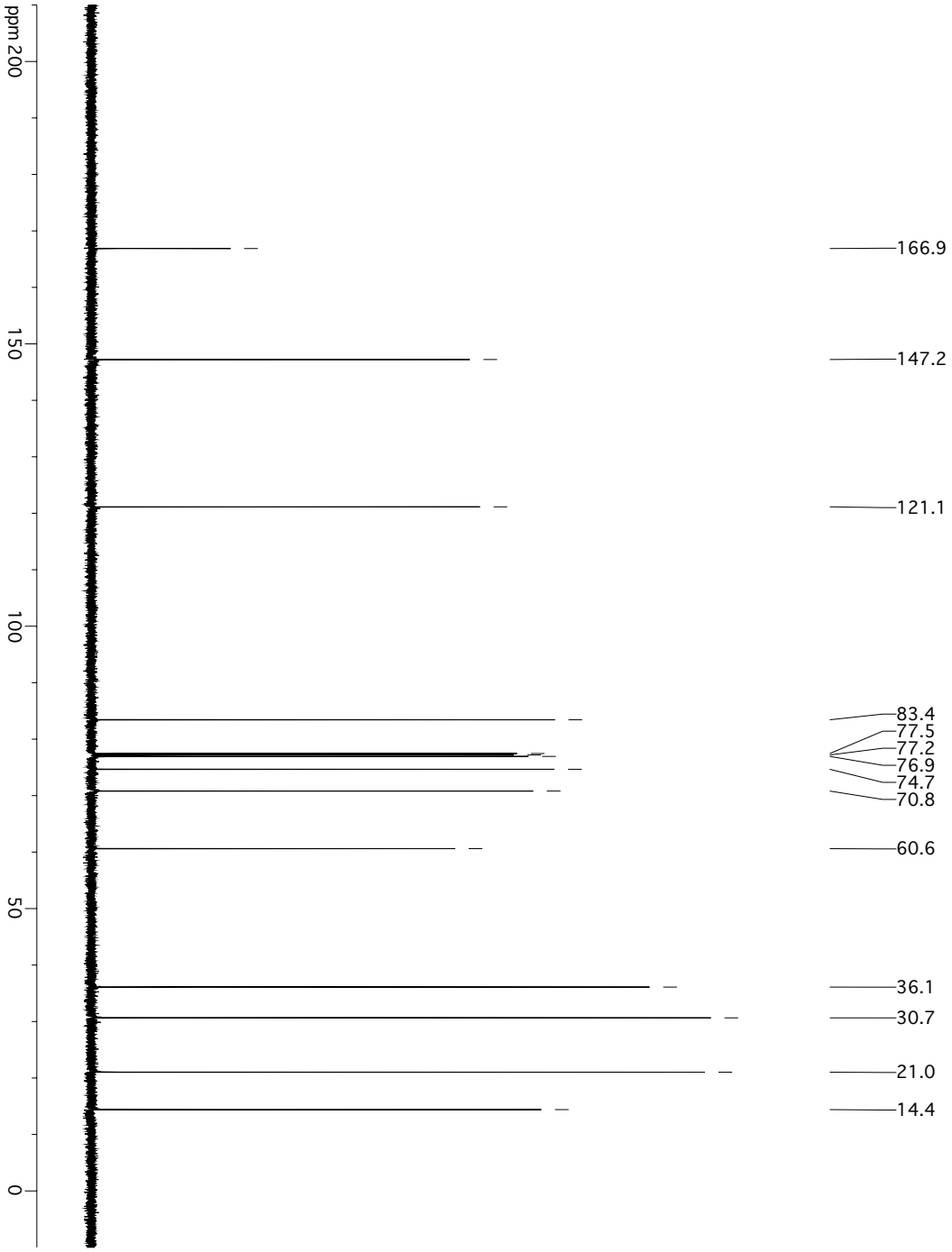

H
OH
OEt
O
H
O

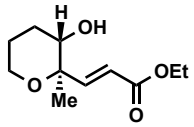
7b


ppm
0.903
0.827
1.07
2.11
1.03
0.872
1.1
4.23
1.08
7.27
7.11
7.10
7.08
7.07
6.12
6.12
6.09
6.09
4.21
4.20
4.19
4.17
3.97
3.96
3.94
3.94
3.93
3.92
3.90
3.89
3.89
3.88
3.88
3.88
3.87
3.87
3.70
3.69
3.68
3.67
3.66
3.65
3.64
3.64
3.63
3.62
3.61
3.60
2.13
2.01
2.01
2.00
1.99
1.99
1.99
1.98
1.97
1.97
1.80
1.79
1.79
1.78
1.77
1.75
1.74
1.74
1.74
1.73
1.73
1.72
1.71
1.69
1.68
1.68
1.67
1.61
1.61
1.60
1.59
1.58
1.57
1.57
1.55
1.30
1.28
1.27

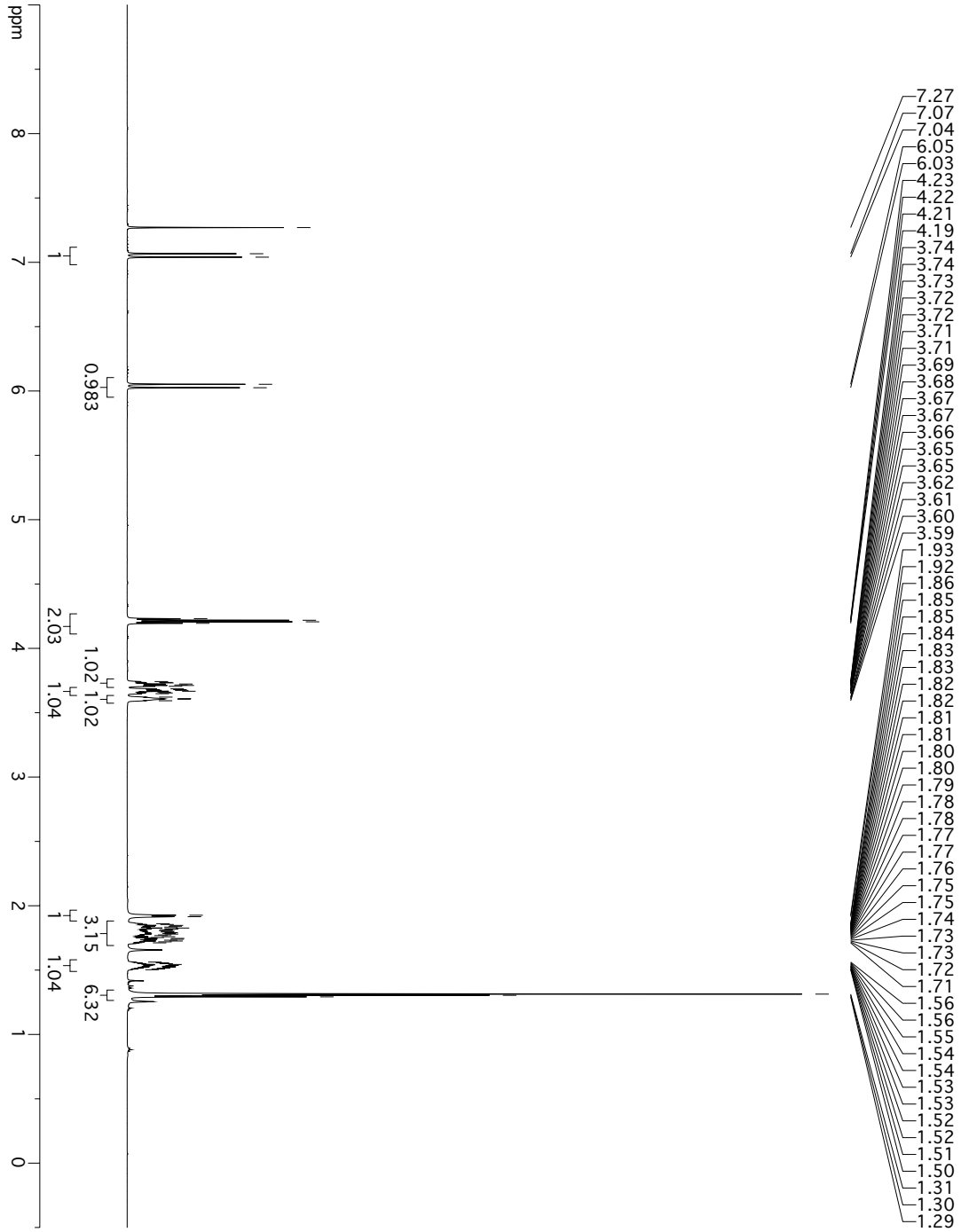

H
OH
OEt
O
H
O

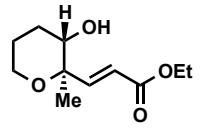
7b


ppm
200
150
100
50
0
166.9
147.2
121.1
83.4
77.5
77.2
76.9
74.7
70.8
60.6
36.1
30.7
21.0
14.4

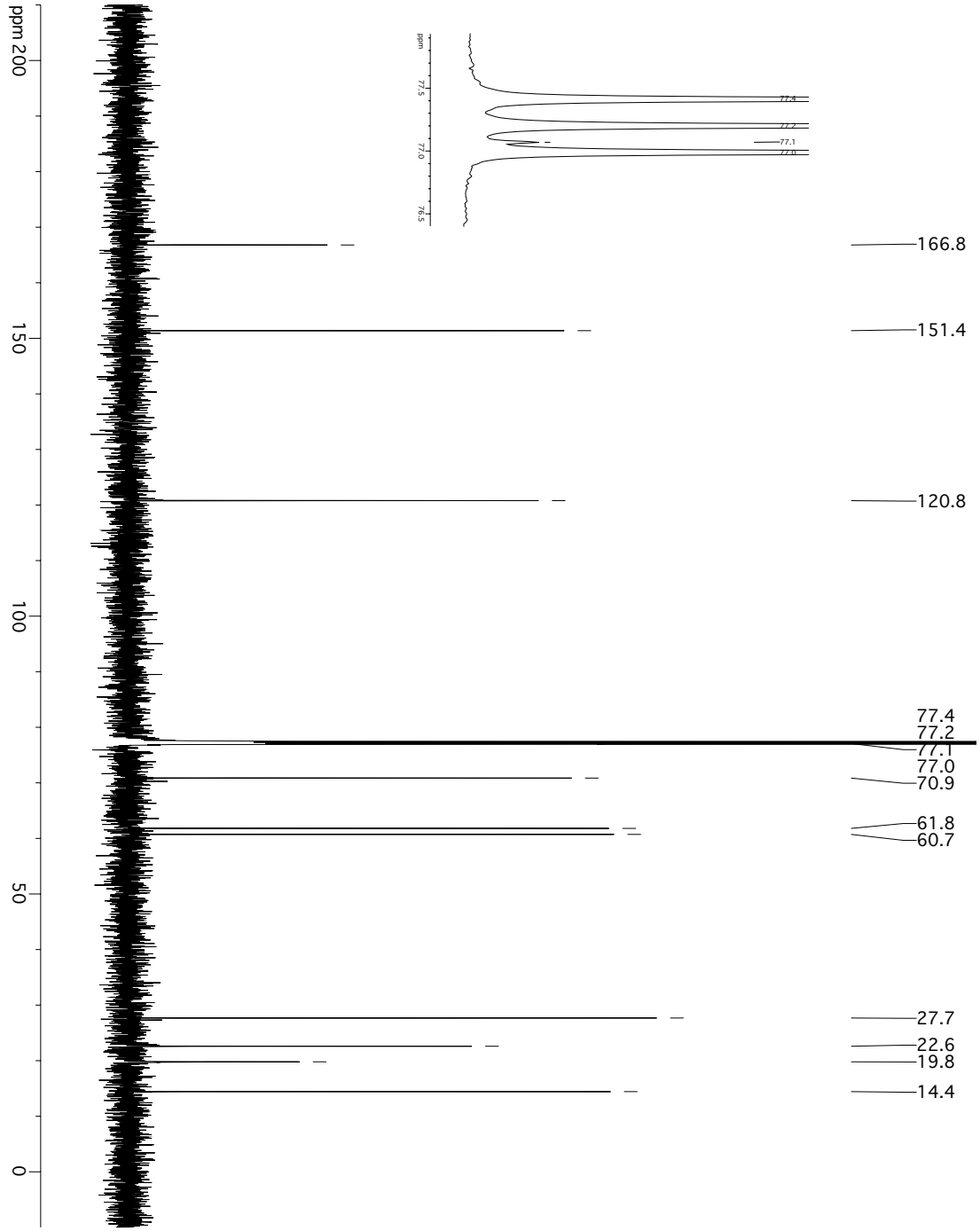

H
OH
OEt
O
Me
O

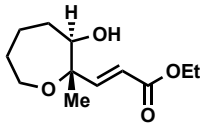
7c


ppm
8
7
6
5
4
3
2
1
0
1
0.983
2.03
1.02
1.02
1.04
1
3.15
1.04
6.32
7.27
7.07
7.04
6.05
6.03
4.23
4.22
4.21
4.19
3.74
3.74
3.73
3.72
3.72
3.71
3.71
3.69
3.68
3.67
3.67
3.66
3.65
3.65
3.62
3.61
3.60
3.59
1.93
1.92
1.86
1.85
1.85
1.84
1.83
1.83
1.82
1.82
1.81
1.81
1.80
1.80
1.79
1.78
1.78
1.77
1.77
1.76
1.75
1.75
1.74
1.73
1.73
1.72
1.71
1.56
1.56
1.55
1.54
1.54
1.53
1.53
1.52
1.52
1.51
1.50
1.31
1.30
1.29

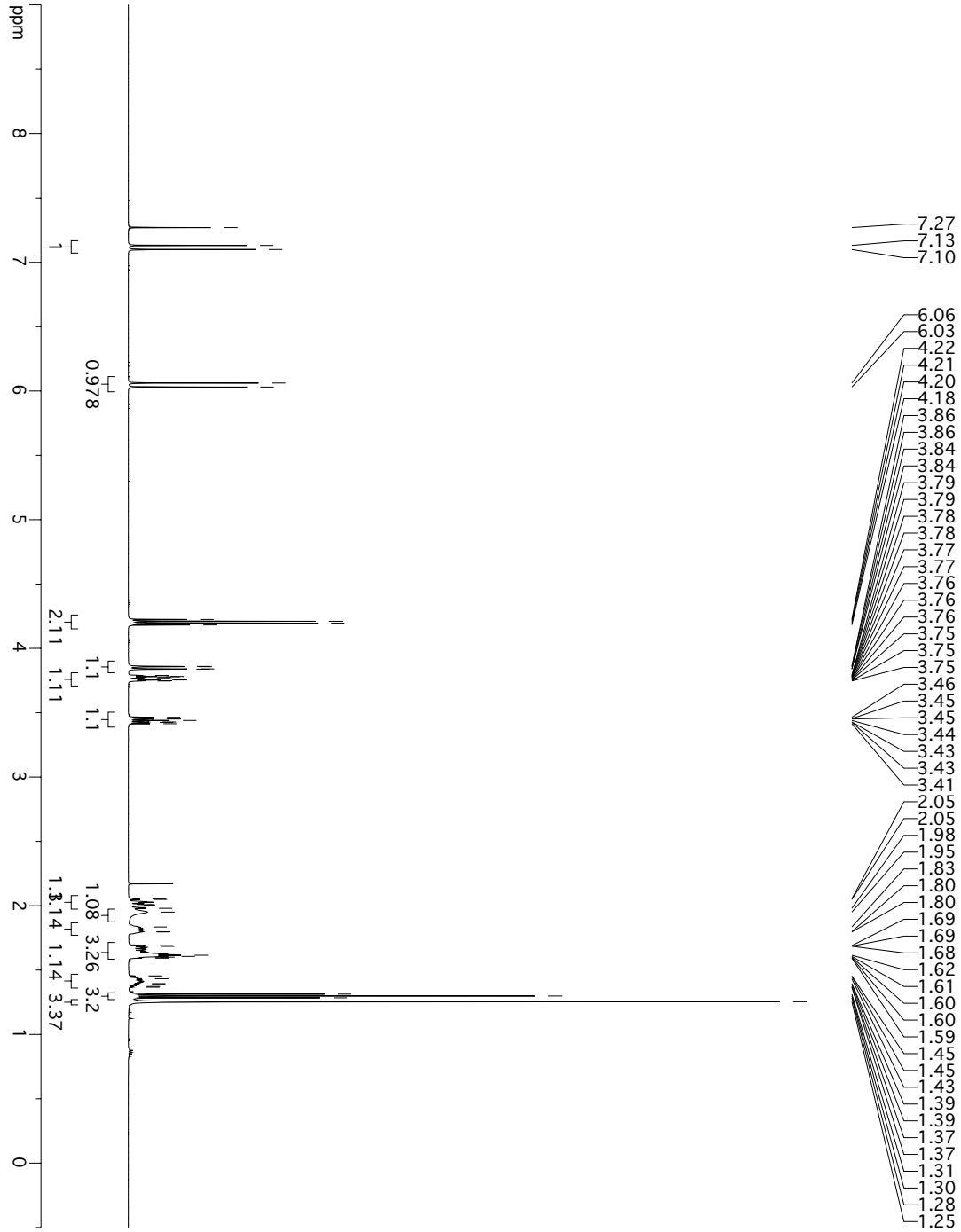

H
OH
OEt
O
Me
O

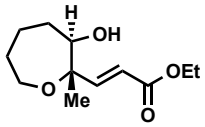
7c


ppm
200
150
100
50
0
166.8
151.4
120.8
77.4
77.2
77.1
77.0
70.9
61.8
60.7
27.7
22.6
19.8
14.4

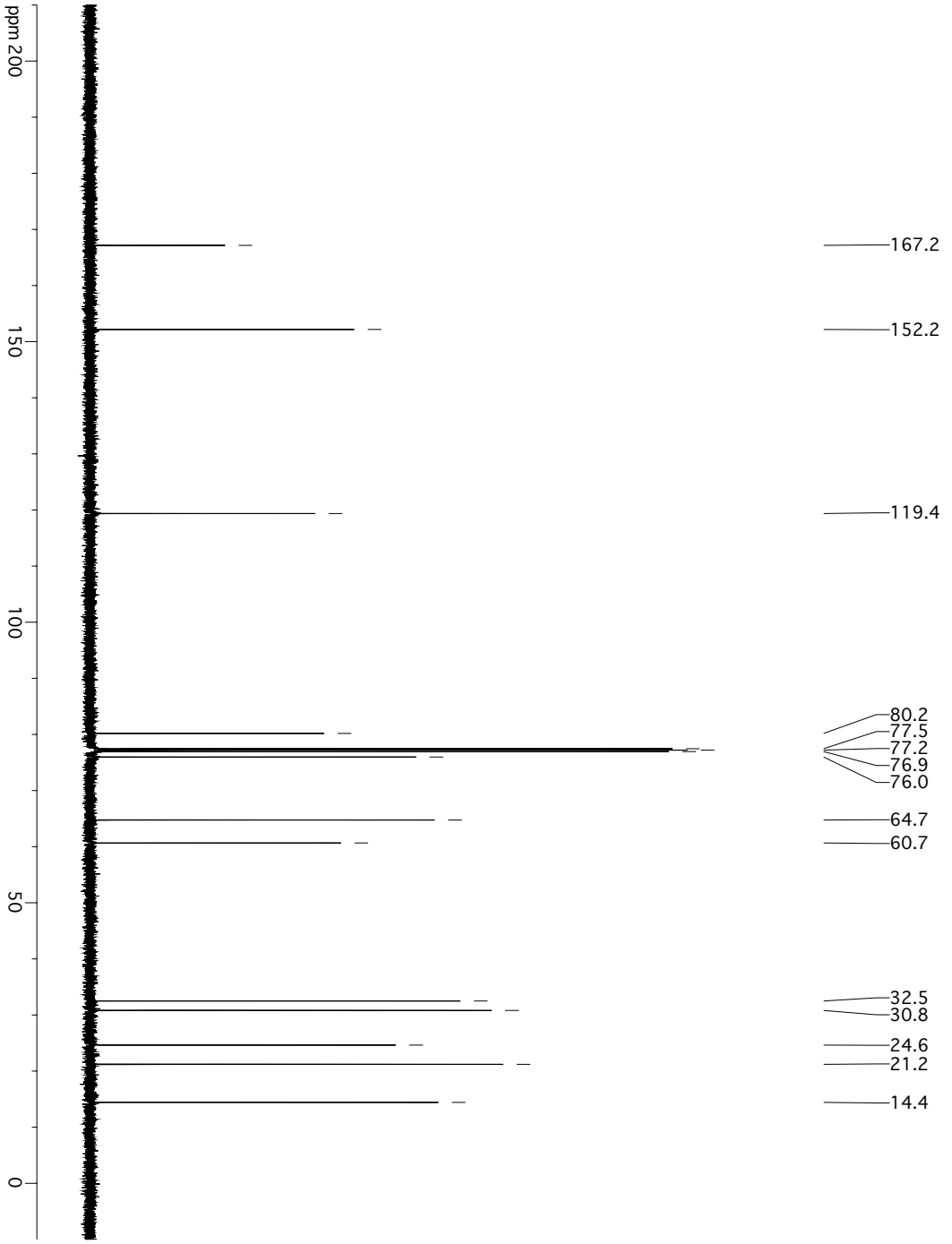

H
OH
OEt
O
Me
O

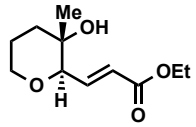
7d


ppm
8
7
6
5
4
3
2
1
0
1
0.978
2.11
1.1
1.11
1.1
1.3
1.14
1.08
3.26
1.14
3.2
3.37
7.27
7.13
7.10
6.06
6.03
4.22
4.21
4.20
4.18
3.86
3.86
3.84
3.84
3.79
3.79
3.78
3.78
3.77
3.77
3.76
3.76
3.76
3.75
3.75
3.75
3.46
3.45
3.45
3.44
3.43
3.43
3.41
2.05
2.05
1.98
1.95
1.83
1.80
1.80
1.69
1.69
1.68
1.62
1.61
1.60
1.60
1.59
1.45
1.45
1.43
1.39
1.39
1.37
1.37
1.31
1.30
1.28
1.25

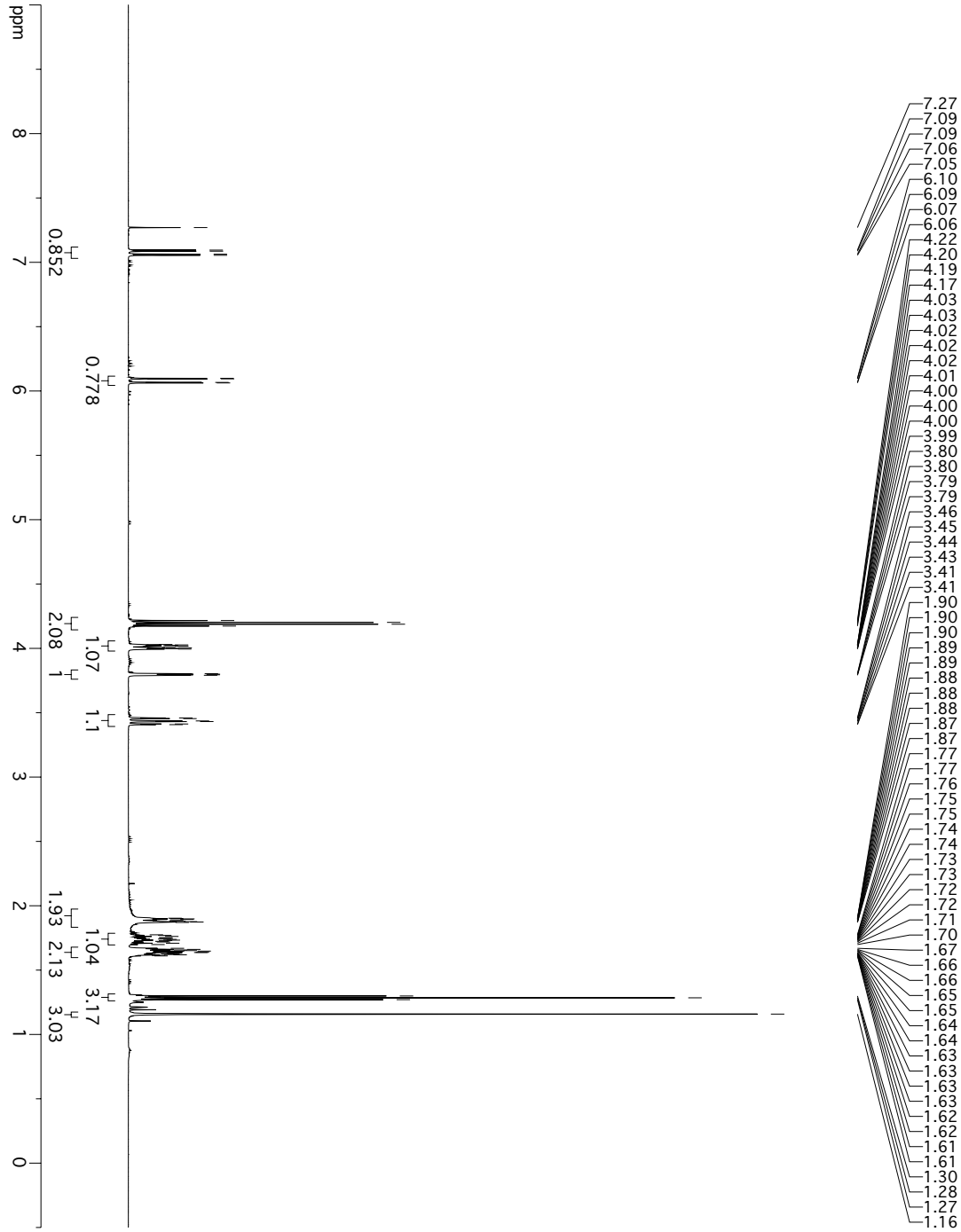

H
OH
OEt
O
Me
O

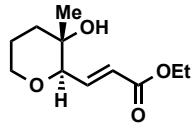
7d


ppm
200
150
100
50
0
167.2
152.2
119.4
80.2
77.5
77.2
76.9
76.0
64.7
60.7
32.5
30.8
24.6
21.2
14.4

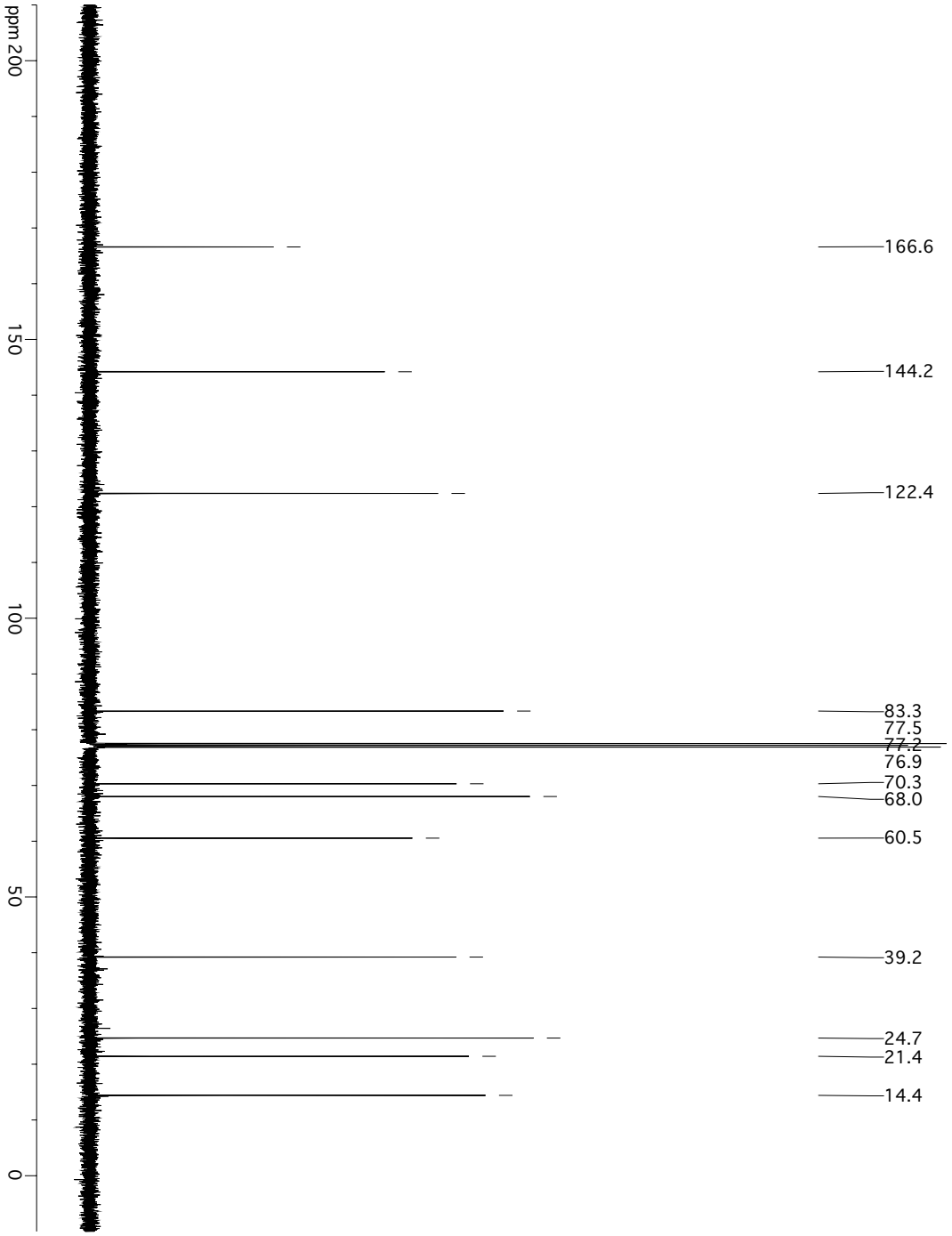

Me
OH
OEt
O
H
O

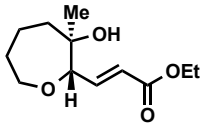
7e


ppm
8
7
6
5
4
3
2
1
0
0.852
0.778
2.08
1.07
1
1.1
1.93
1.04
2.13
3.17
3.03
7.27
7.09
7.09
7.06
7.05
6.10
6.09
6.07
6.06
4.22
4.20
4.19
4.17
4.03
4.03
4.02
4.02
4.02
4.01
4.00
4.00
4.00
3.99
3.80
3.80
3.79
3.79
3.46
3.45
3.44
3.43
3.41
3.41
1.90
1.90
1.90
1.89
1.89
1.88
1.88
1.88
1.87
1.87
1.77
1.77
1.76
1.75
1.75
1.74
1.74
1.73
1.73
1.72
1.72
1.71
1.70
1.67
1.66
1.66
1.65
1.65
1.64
1.64
1.63
1.63
1.63
1.63
1.62
1.62
1.61
1.61
1.30
1.28
1.27
1.16

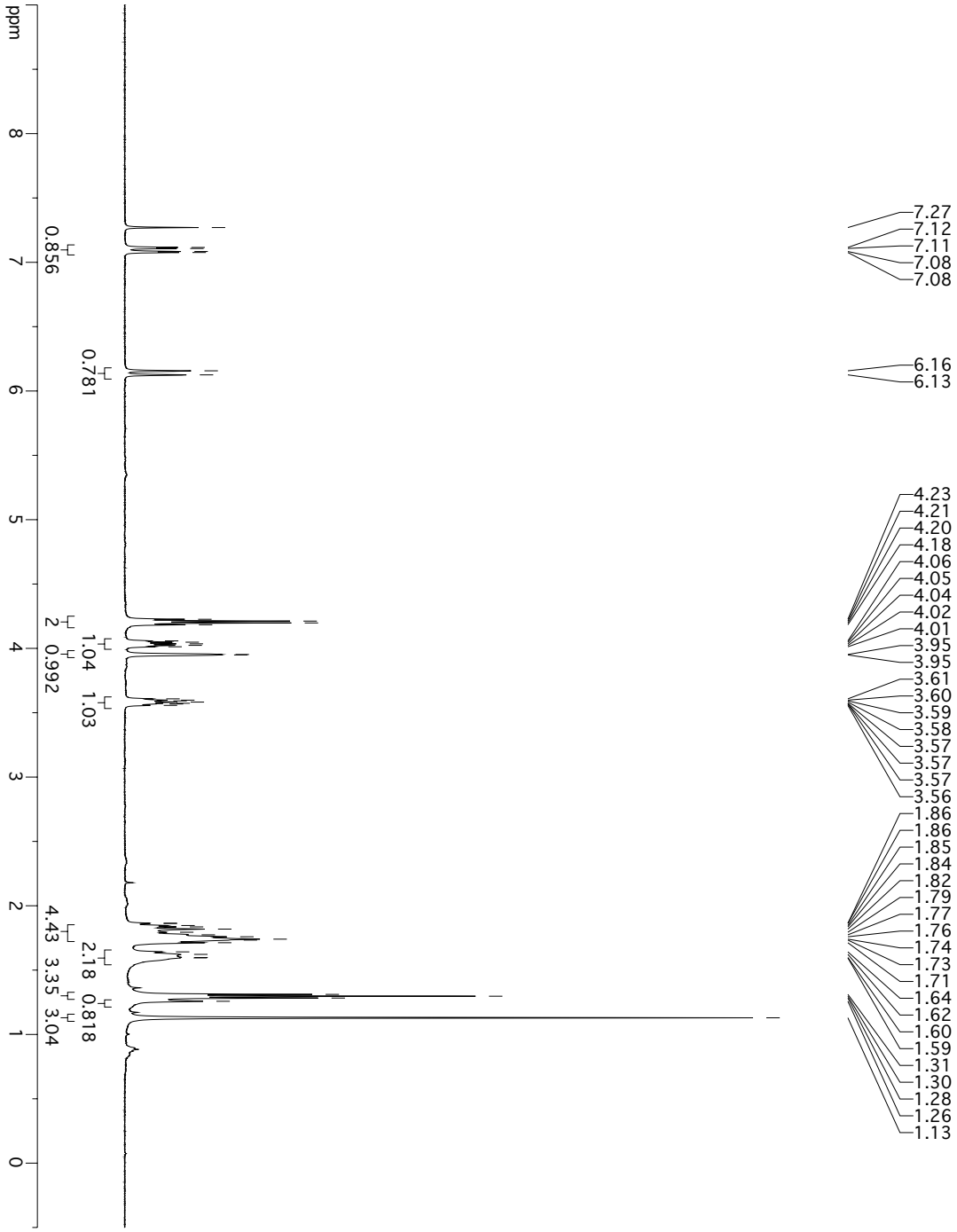

Me
OH
OEt
O
H
O

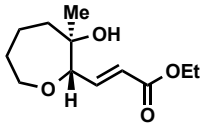
7e


ppm
200
150
100
50
0
166.6
144.2
122.4
83.3
77.5
77.2
76.9
70.3
68.0
60.5
39.2
24.7
21.4
14.4

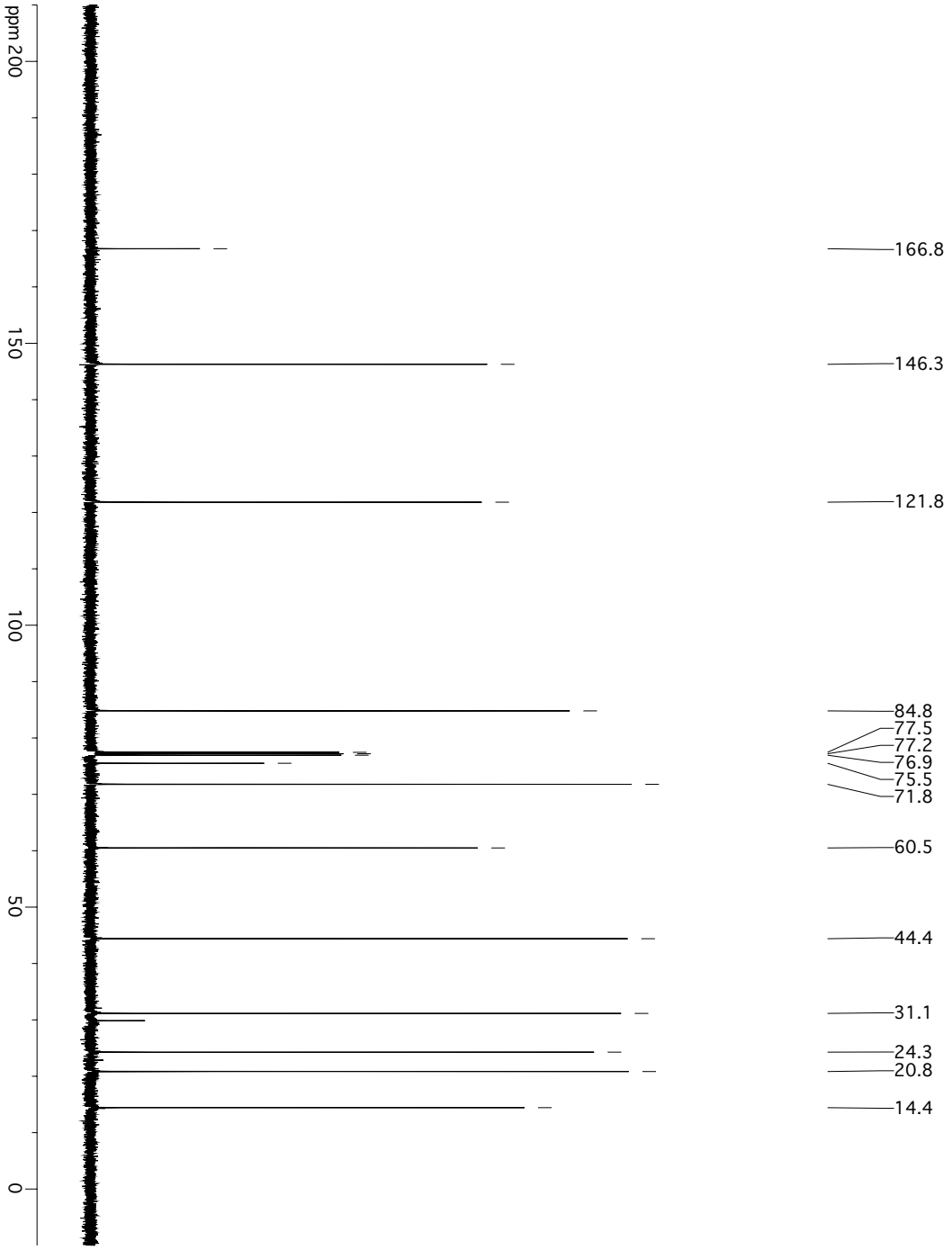

Me
OH
OEt
O
H
O

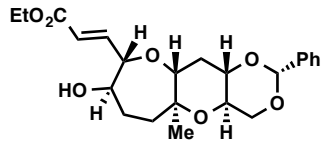
7f


ppm
8
7
6
5
4
3
2
1
0
0.856
0.781
2
0.992
1.04
1.03
4.43
3.35
2.18
0.818
3.04
7.27
7.12
7.11
7.08
7.08
6.16
6.13
4.23
4.21
4.20
4.18
4.06
4.05
4.04
4.02
4.01
3.95
3.95
3.61
3.60
3.59
3.58
3.57
3.57
3.57
3.56
1.86
1.86
1.85
1.84
1.82
1.79
1.77
1.76
1.74
1.73
1.71
1.64
1.62
1.60
1.59
1.31
1.30
1.28
1.26
1.13

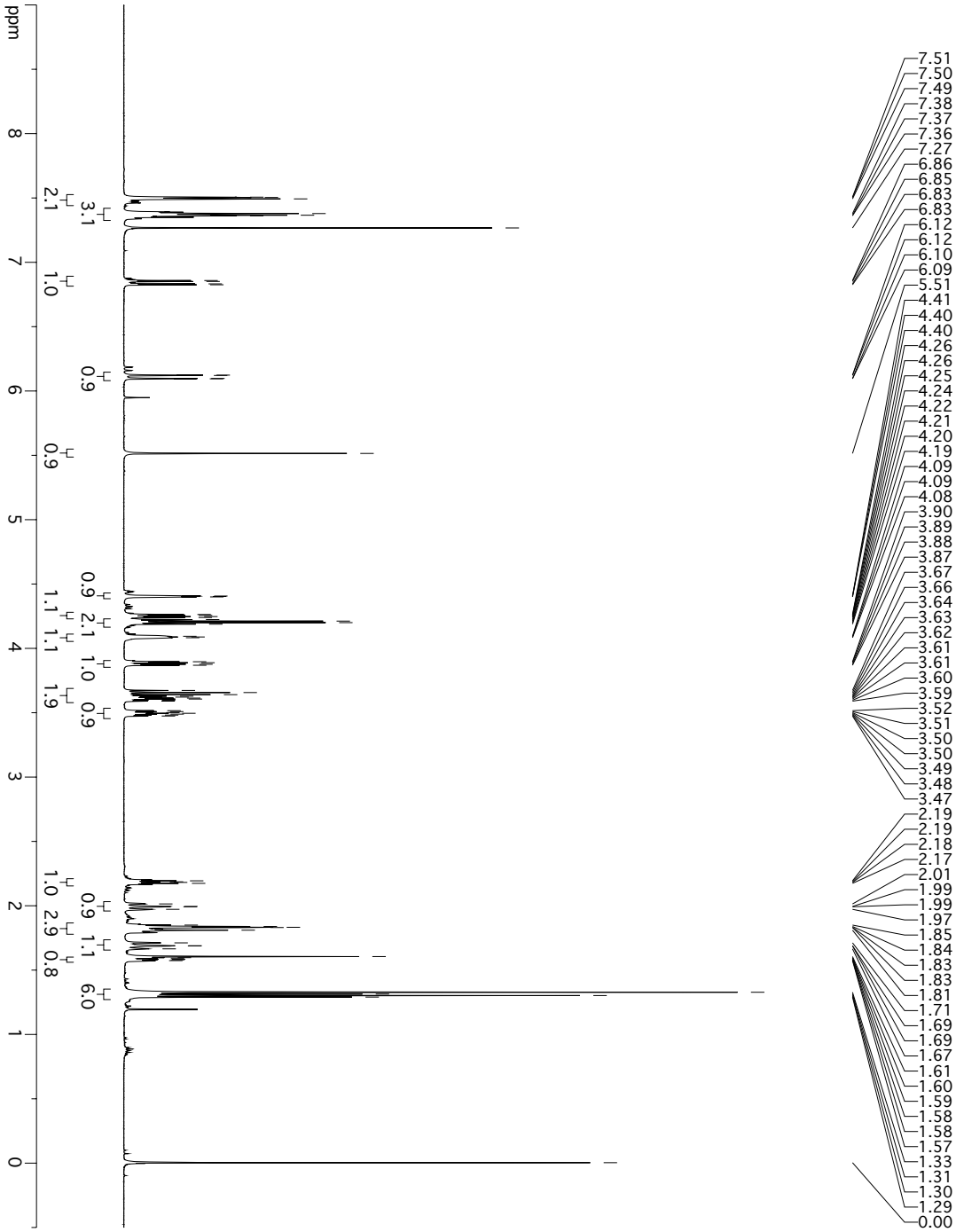

Me
OH
OEt
O
H
O

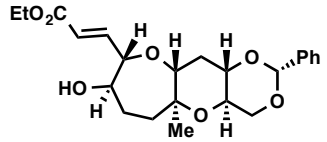
7f


ppm
200
150
100
50
0
166.8
146.3
121.8
84.8
77.5
77.2
76.9
75.5
71.8
60.5
44.4
31.1
24.3
20.8
14.4

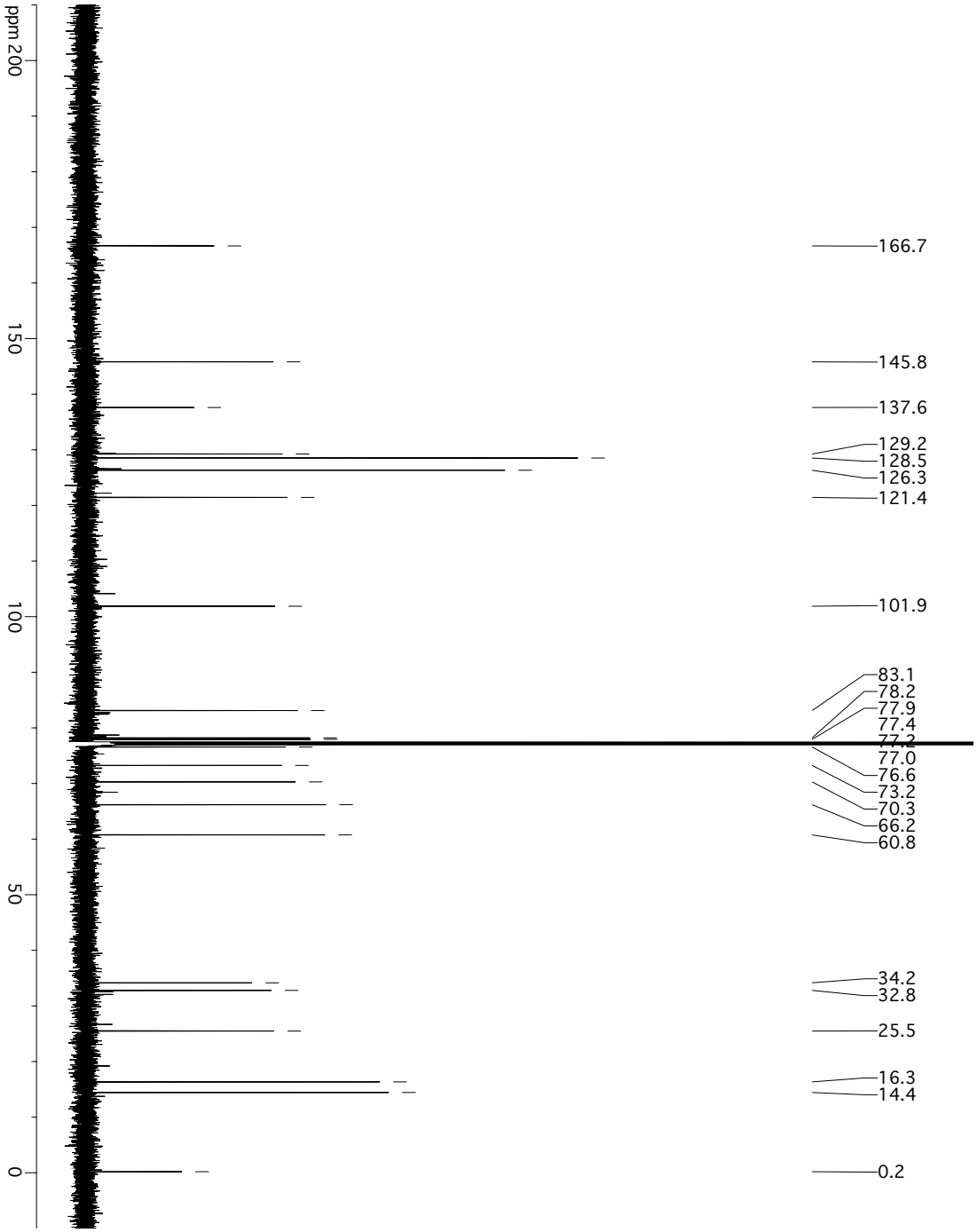

EtO2C
H
O
H
H
O
Ph
HO
H
O
O
Me
O
H

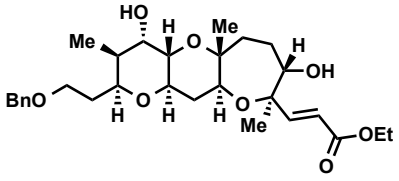
11


ppm
8
7
6
5
4
3
2
1
0
2.1
3.1
1.0
0.9
0.9
0.9
1.1
2.1
1.1
1.0
1.9
0.9
1.0
0.9
2.9
1.1
0.8
6.0
7.51
7.50
7.49
7.38
7.37
7.36
7.27
6.86
6.85
6.83
6.83
6.12
6.12
6.10
6.09
5.51
4.41
4.40
4.40
4.26
4.26
4.25
4.24
4.22
4.21
4.20
4.19
4.09
4.09
4.08
3.90
3.89
3.88
3.87
3.67
3.66
3.64
3.63
3.62
3.61
3.61
3.60
3.59
3.52
3.51
3.50
3.50
3.49
3.48
3.47
2.19
2.19
2.18
2.17
2.01
1.99
1.99
1.97
1.85
1.84
1.83
1.83
1.81
1.71
1.69
1.69
1.67
1.61
1.60
1.59
1.58
1.58
1.57
1.33
1.31
1.30
1.29
0.00

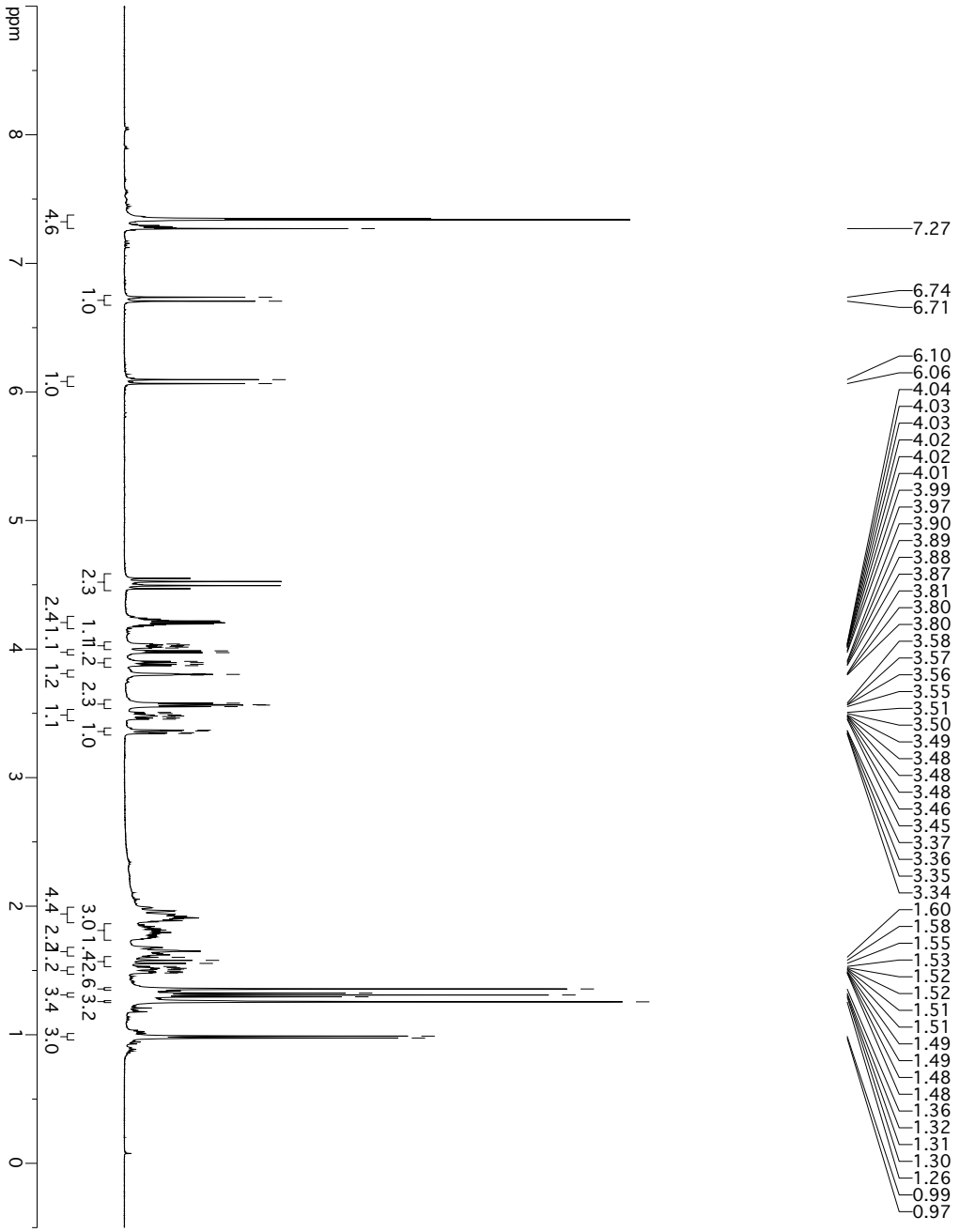

EtO2C
H
O
H
H
O
Ph
HO
H
O
O
Me
O
H

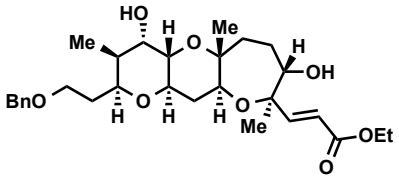
11


ppm
200
150
100
50
0
166.7
145.8
137.6
129.2
128.5
126.3
121.4
101.9
83.1
78.2
77.9
77.4
77.2
77.0
76.6
73.2
70.3
66.2
60.8
34.2
32.8
25.5
16.3
14.4
0.2

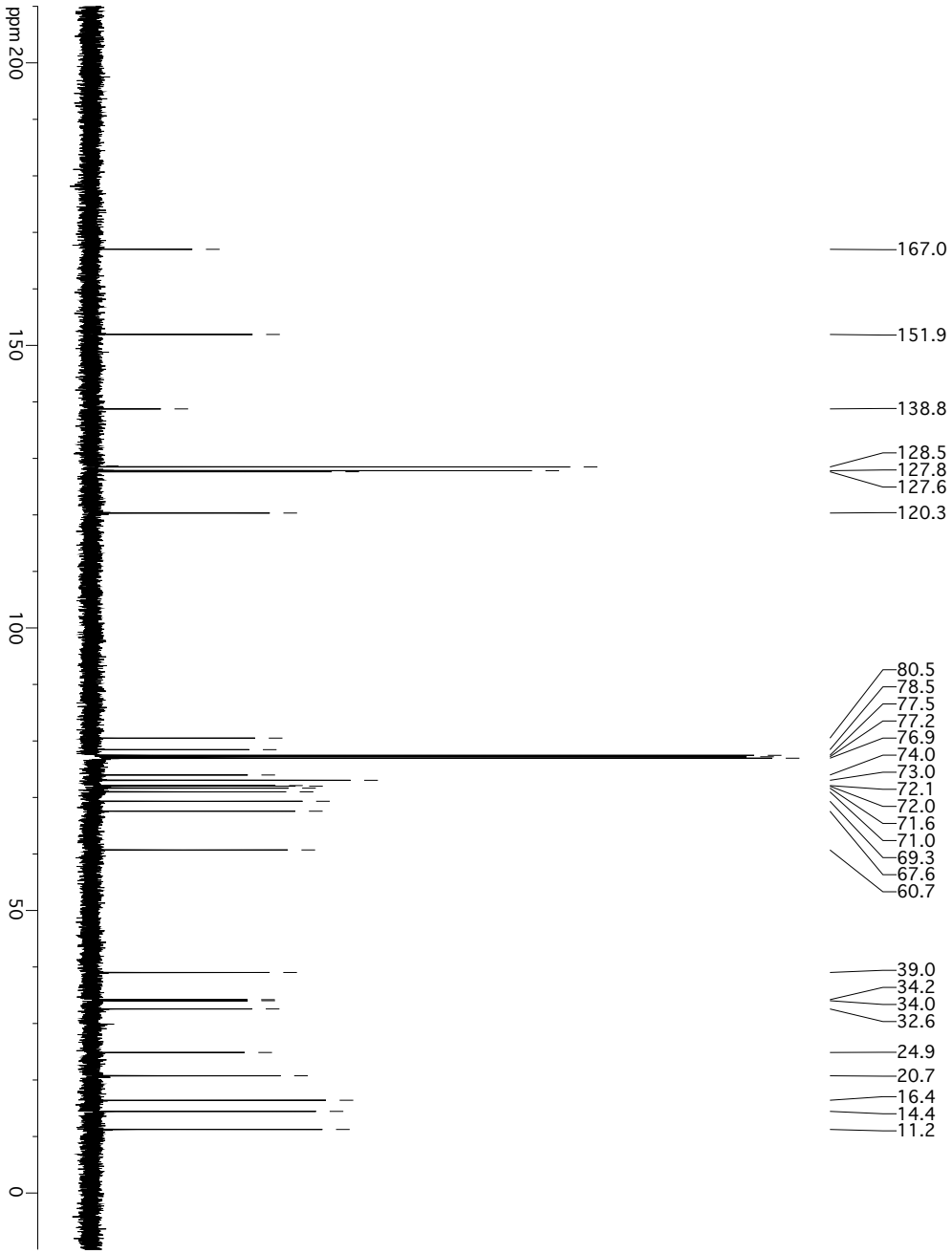

HO
H
Me
Me
O
H
OH
BnO
O
H
H
H
O
Me
OEt
O

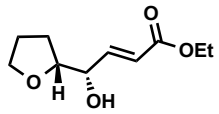
22


ppm
8
7
6
5
4
3
2
1
0
4.6
1.0
1.0
2.3
2.4
1.1
1.1
1.2
2.3
1.0
1.1
4.4
2.2
3.0
1.4
2.6
3.2
3.4
3.0
7.27
6.74
6.71
6.10
6.06
4.04
4.03
4.03
4.02
4.02
4.01
3.99
3.97
3.90
3.89
3.88
3.87
3.81
3.80
3.80
3.58
3.57
3.56
3.55
3.51
3.50
3.49
3.48
3.48
3.48
3.46
3.45
3.37
3.36
3.35
3.34
1.60
1.58
1.55
1.53
1.52
1.52
1.51
1.51
1.49
1.49
1.48
1.48
1.36
1.32
1.31
1.30
1.26
0.99
0.97

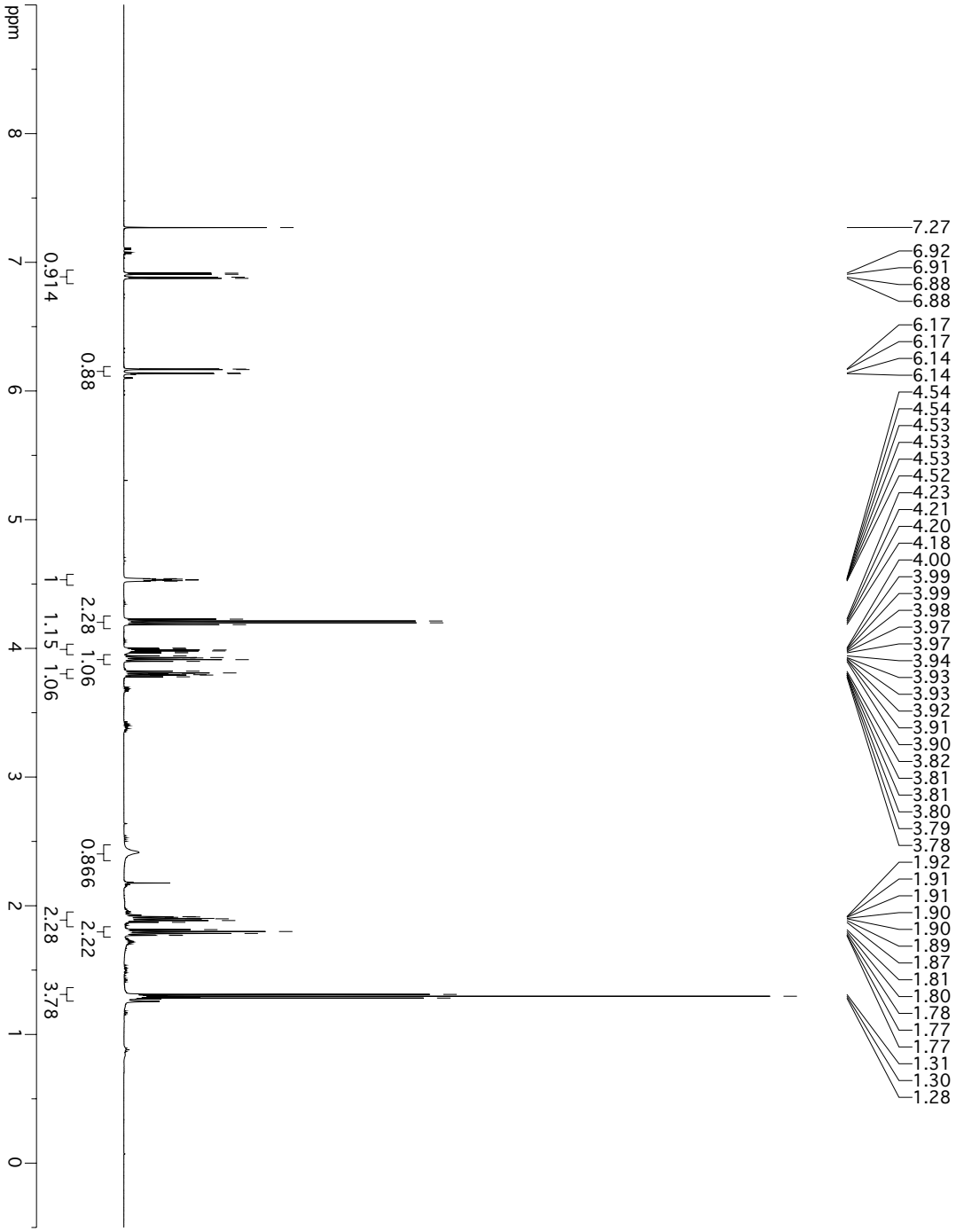

HO
H
Me
Me
O
H
OH
BnO
O
H
H
H
O
Me
OEt
O

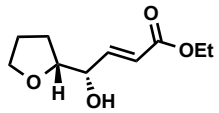
22


ppm
200
150
100
50
0
167.0
151.9
138.8
128.5
127.8
127.6
120.3
80.5
78.5
77.5
77.2
76.9
74.0
73.0
72.1
72.0
71.6
71.0
69.3
67.6
60.7
39.0
34.2
34.0
32.6
24.9
20.7
16.4
14.4
11.2

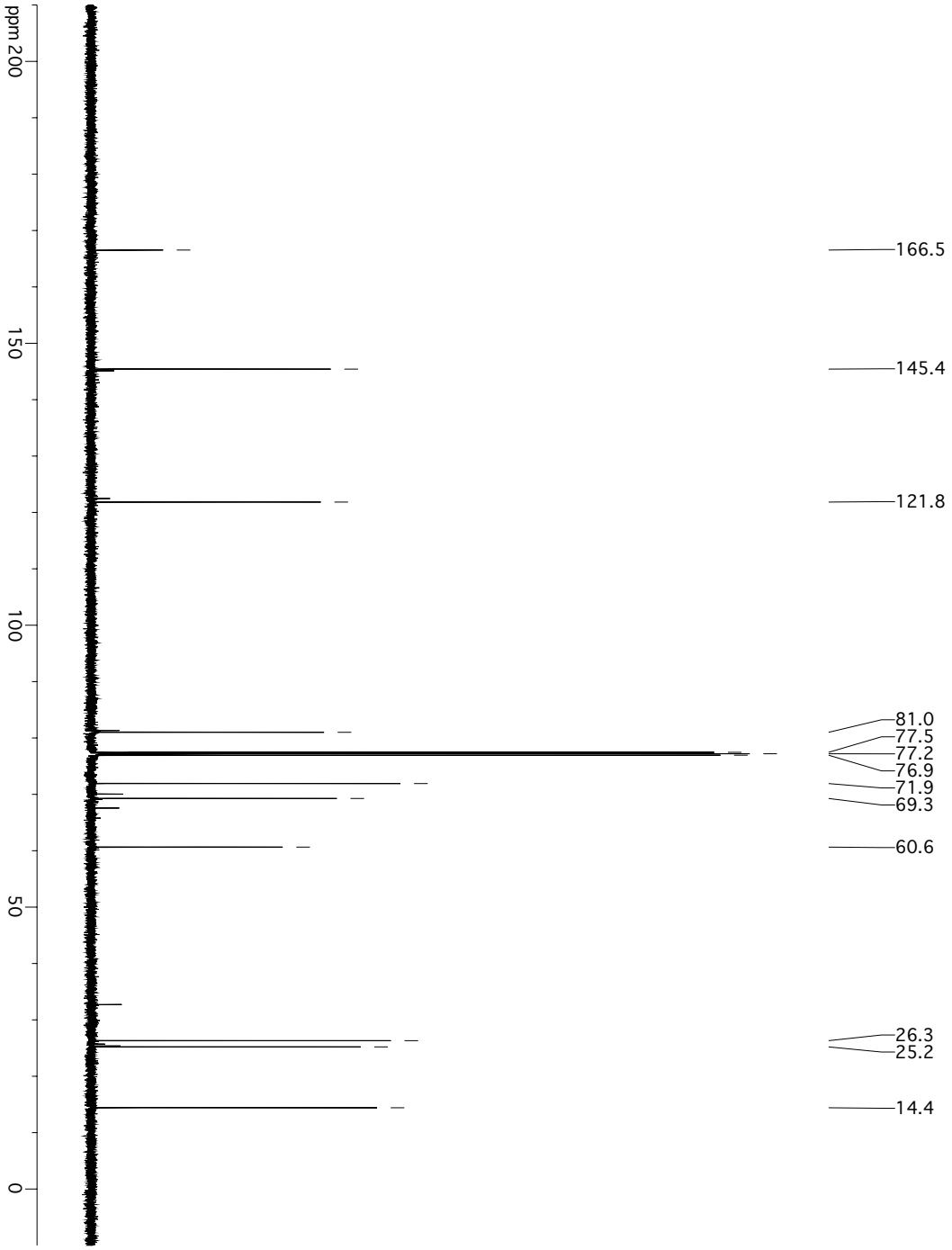

O
OEt
O
H
OH

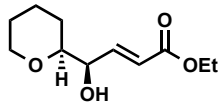
8a


ppm
8
7
6
5
4
3
2
1
0
0.914
0.88
1
2.28
1.15
1.06
1.06
0.866
2.28
2.22
3.78
7.27
6.92
6.91
6.88
6.88
6.17
6.17
6.14
6.14
4.54
4.54
4.53
4.53
4.53
4.52
4.23
4.21
4.20
4.18
4.00
3.99
3.99
3.98
3.97
3.97
3.94
3.93
3.93
3.92
3.91
3.90
3.82
3.81
3.81
3.80
3.79
3.78
1.92
1.91
1.91
1.90
1.90
1.89
1.87
1.81
1.80
1.78
1.77
1.77
1.31
1.30
1.28

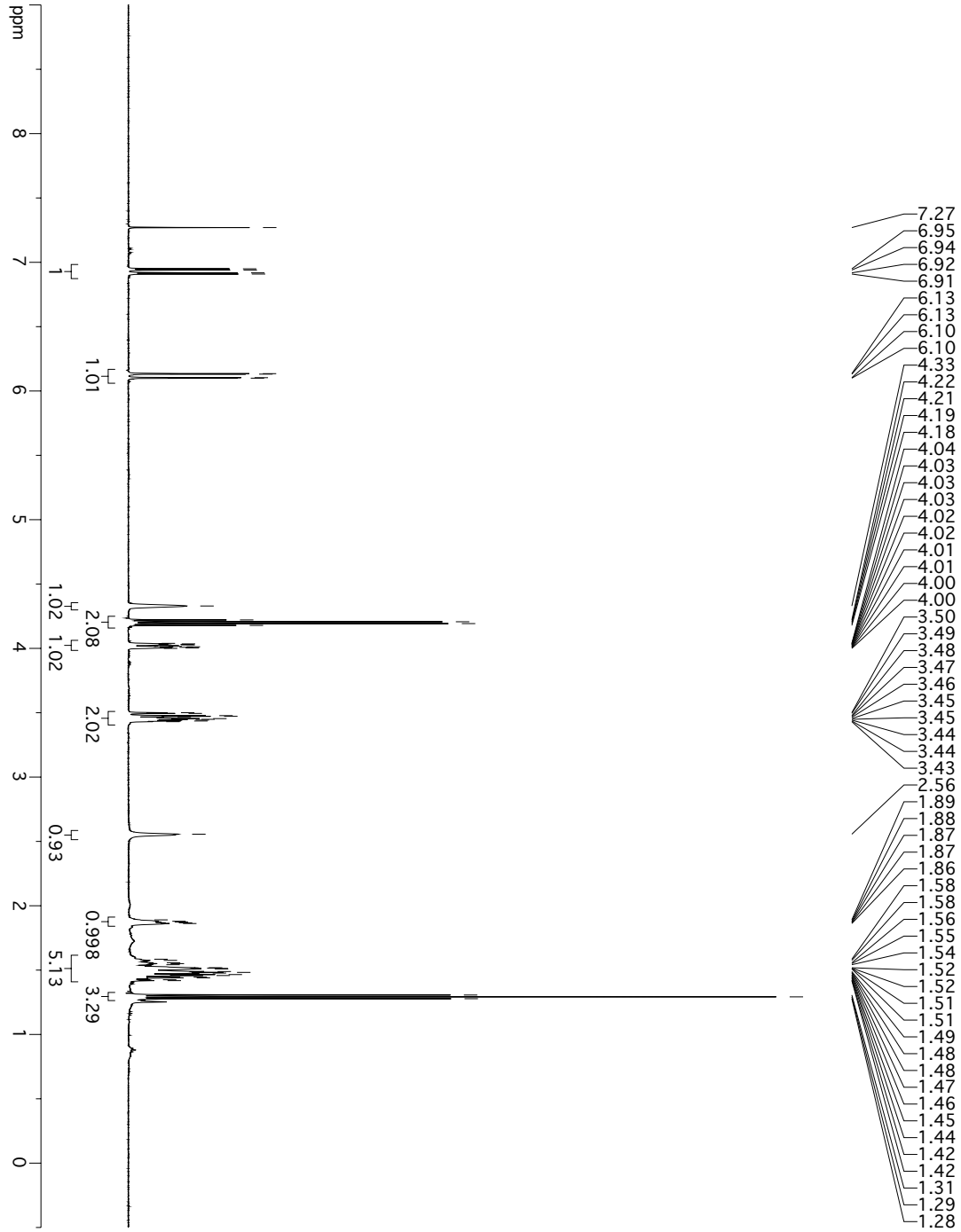

O
OEt
O
H
OH

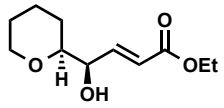
8a


ppm 200
150
100
50
0
166.5
145.4
121.8
81.0
77.5
77.2
76.9
71.9
69.3
60.6
26.3
25.2
14.4

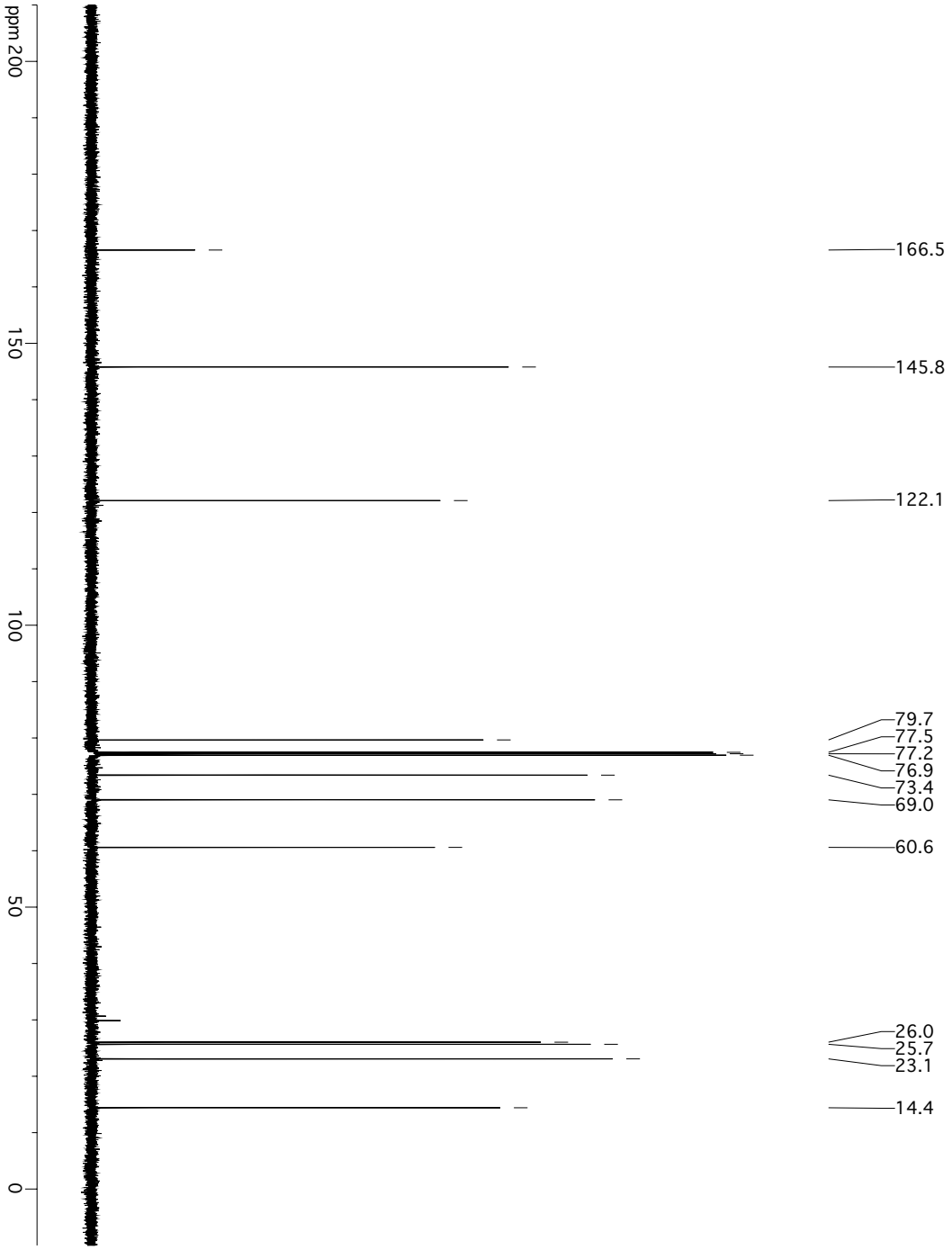

O
OEt
O
H
OH

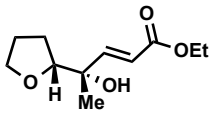
8b


ppm
8
7
6
5
4
3
2
1
0
1
1.01
1.02
1.02
2.08
2.02
0.93
0.998
5.13
3.29
7.27
6.95
6.94
6.92
6.91
6.13
6.13
6.10
6.10
4.33
4.22
4.21
4.19
4.18
4.04
4.03
4.03
4.03
4.02
4.02
4.01
4.01
4.00
4.00
3.50
3.49
3.48
3.47
3.46
3.45
3.45
3.44
3.44
3.43
2.56
1.89
1.88
1.87
1.87
1.86
1.58
1.58
1.56
1.55
1.54
1.52
1.52
1.51
1.51
1.49
1.48
1.48
1.47
1.46
1.45
1.44
1.42
1.42
1.31
1.29
1.28

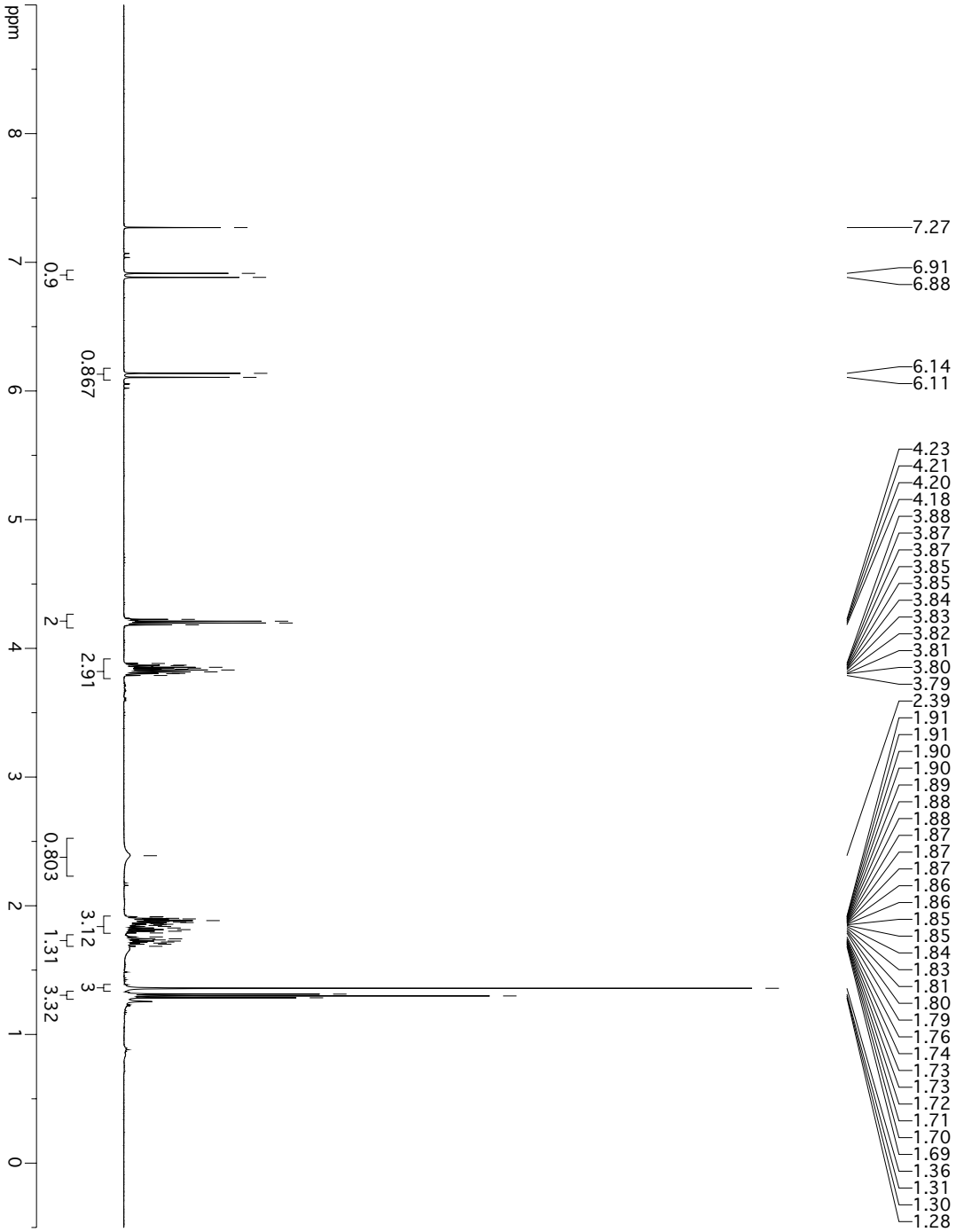

O
OEt
O
H
OH

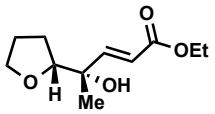
8b


ppm
200
150
100
50
0
166.5
145.8
122.1
79.7
77.5
77.2
76.9
73.4
69.0
60.6
26.0
25.7
23.1
14.4

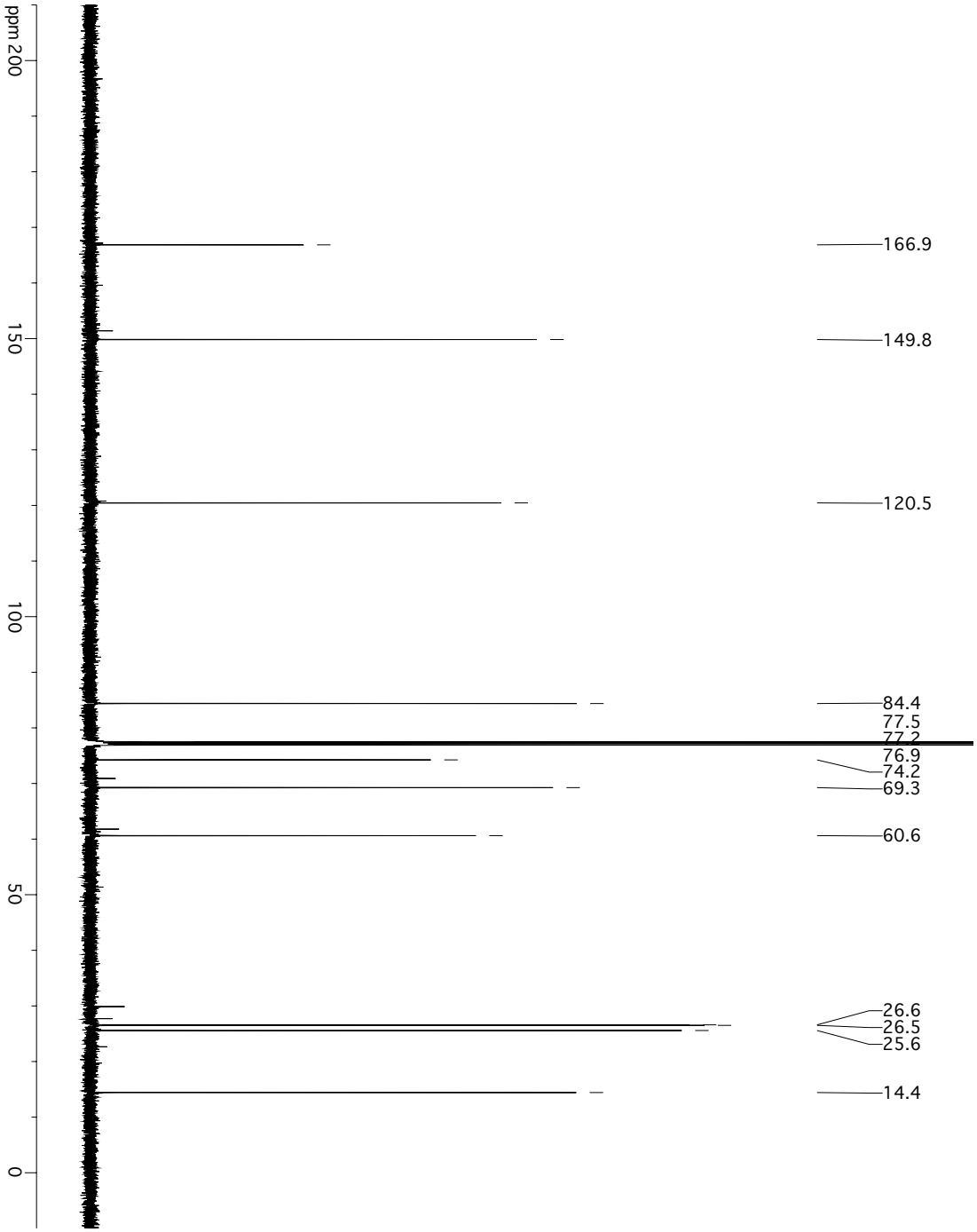

O
OEt
O
H
OH
Me

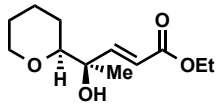
8c


ppm
0.9
0.867
2
2.91
0.803
3.12
1.31
3
3.32
7.27
6.91
6.88
6.14
6.11
4.23
4.21
4.20
4.18
3.88
3.87
3.87
3.85
3.85
3.84
3.83
3.82
3.81
3.80
3.79
2.39
1.91
1.91
1.90
1.90
1.89
1.88
1.88
1.87
1.87
1.87
1.86
1.86
1.85
1.85
1.84
1.83
1.81
1.80
1.79
1.76
1.74
1.73
1.73
1.72
1.71
1.70
1.69
1.36
1.31
1.30
1.28

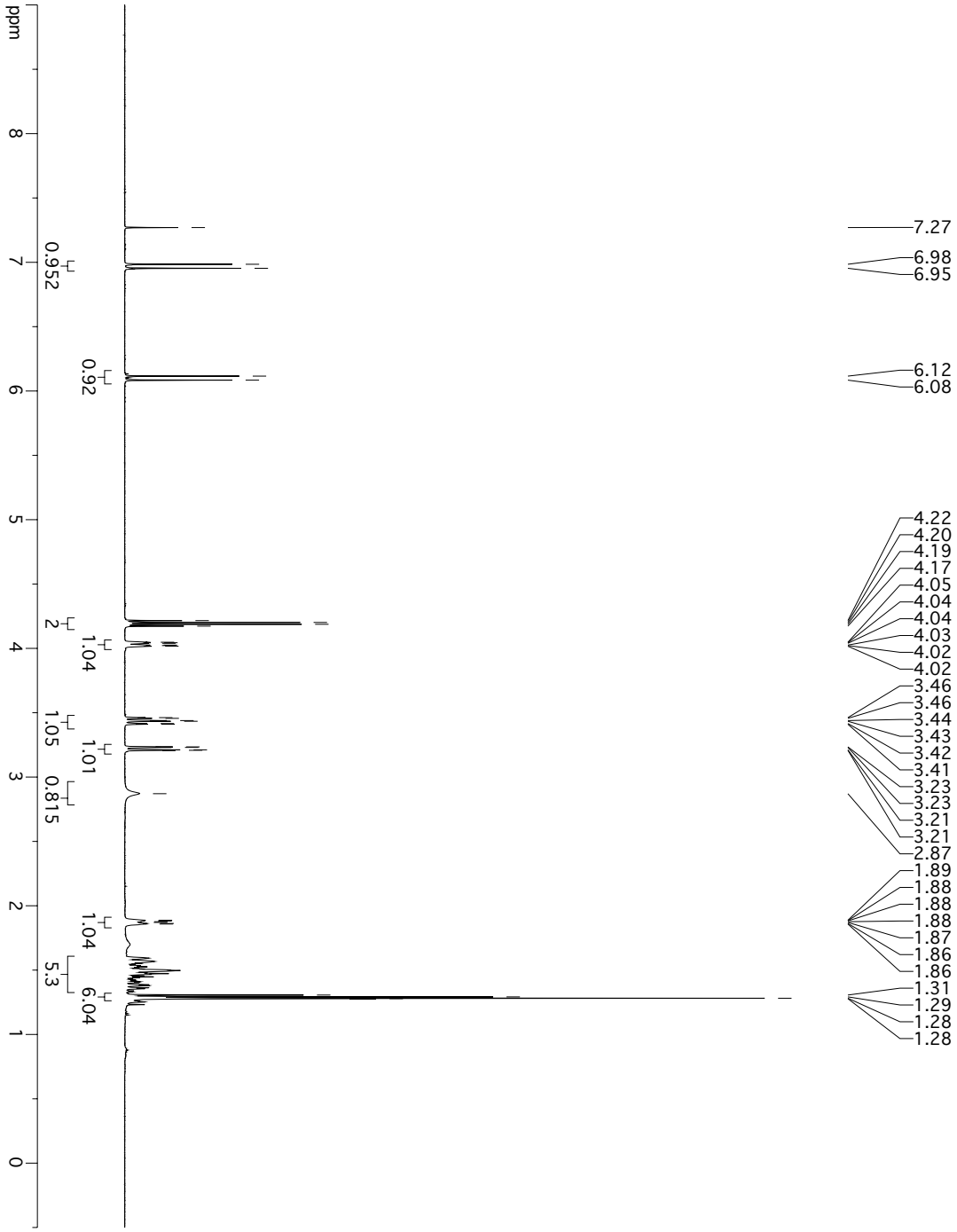

O
OEt
O
H
OH
Me

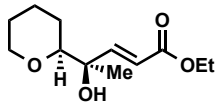
8c


ppm
200
150
100
50
0
166.9
149.8
120.5
84.4
77.5
77.2
76.9
74.2
69.3
60.6
26.6
26.5
25.6
14.4

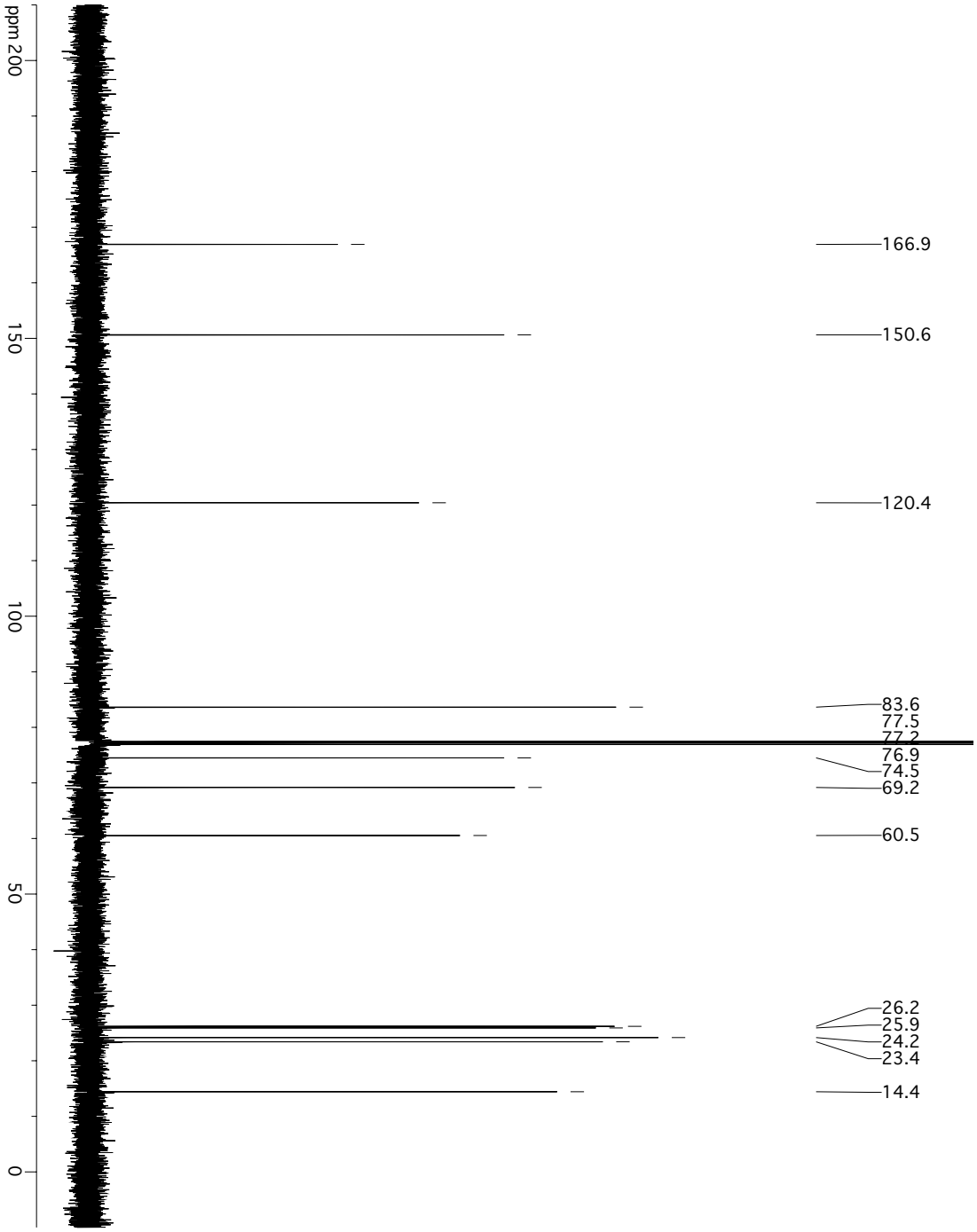

O
O
H
Me
OEt
OH

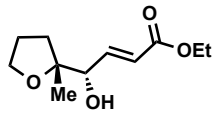
8d


ppm
8
7
6
5
4
3
2
1
0
0.952
0.92
2
1.04
1.05
1.01
0.815
1.04
5.3
6.04
7.27
6.98
6.95
6.12
6.08
4.22
4.20
4.19
4.17
4.05
4.04
4.04
4.03
4.02
4.02
3.46
3.46
3.44
3.43
3.42
3.41
3.23
3.23
3.21
3.21
2.87
1.89
1.88
1.88
1.88
1.87
1.86
1.86
1.31
1.29
1.28
1.28

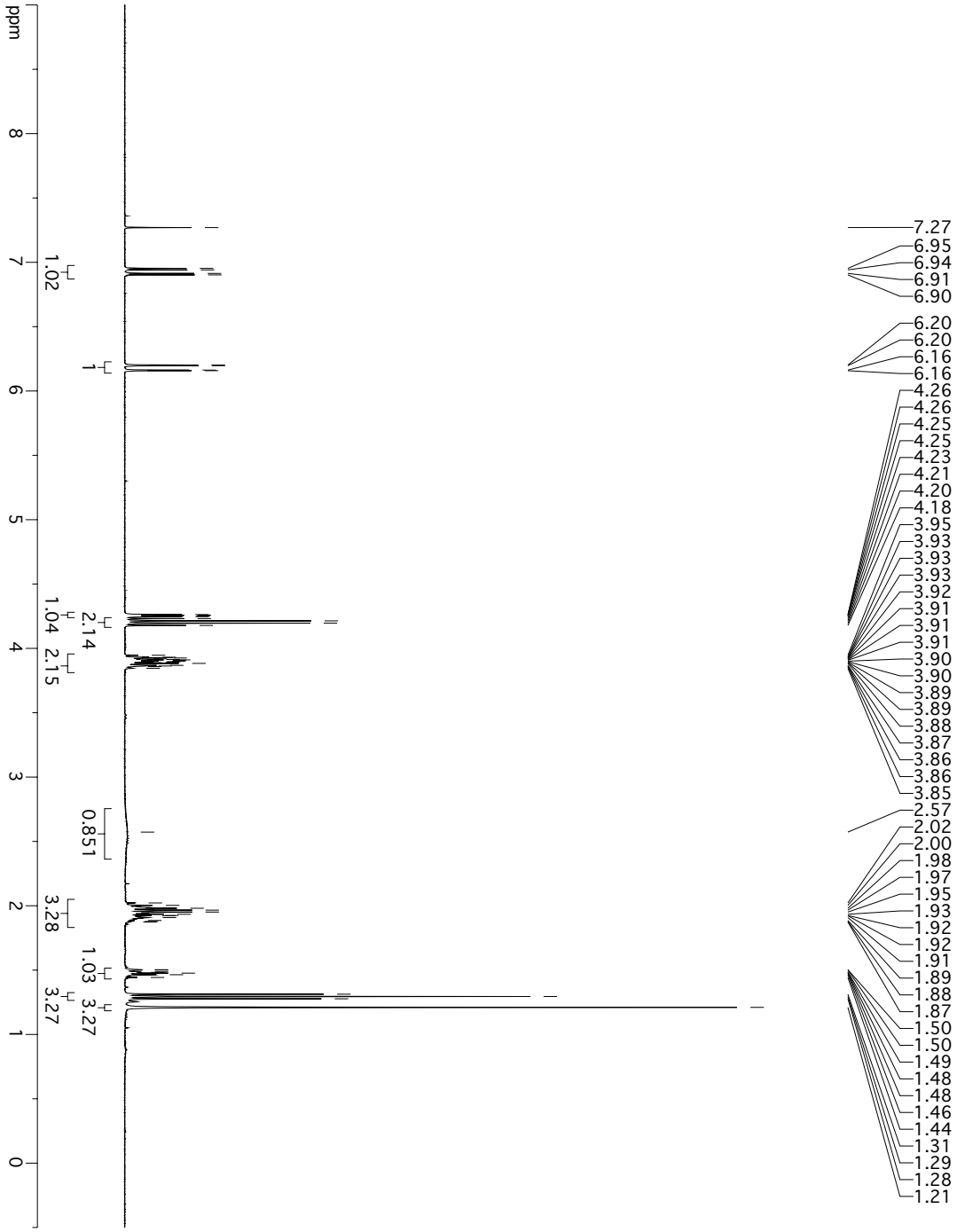

O
O
H
Me
OEt
OH

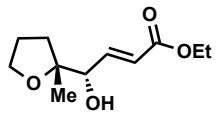
8d


ppm
200
150
100
50
0
166.9
150.6
120.4
83.6
77.5
77.2
76.9
74.5
69.2
60.5
26.2
25.9
24.2
23.4
14.4

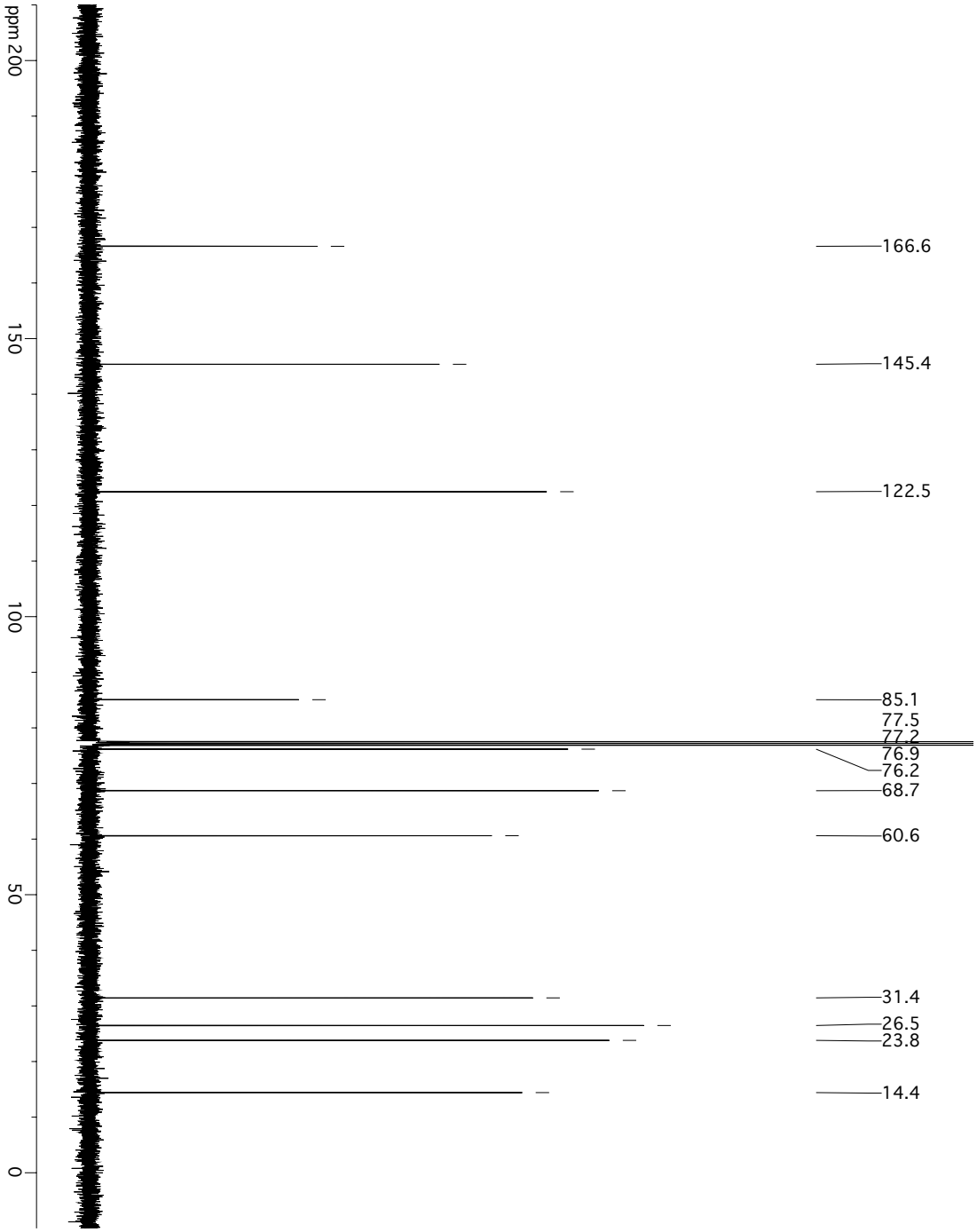

O
OEt
O
Me
OH

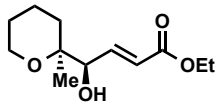
8e


ppm
8
7
6
5
4
3
2
1
0
1.02
1
2.14
1.04
2.15
0.851
3.28
1.03
3.27
3.27
7.27
6.95
6.94
6.91
6.90
6.20
6.20
6.16
6.16
4.26
4.26
4.25
4.25
4.23
4.21
4.20
4.18
3.95
3.93
3.93
3.93
3.92
3.91
3.91
3.91
3.90
3.90
3.89
3.89
3.88
3.87
3.86
3.86
3.85
2.57
2.02
2.00
1.98
1.97
1.95
1.93
1.92
1.92
1.91
1.89
1.88
1.87
1.50
1.50
1.49
1.48
1.48
1.46
1.44
1.31
1.29
1.28
1.21

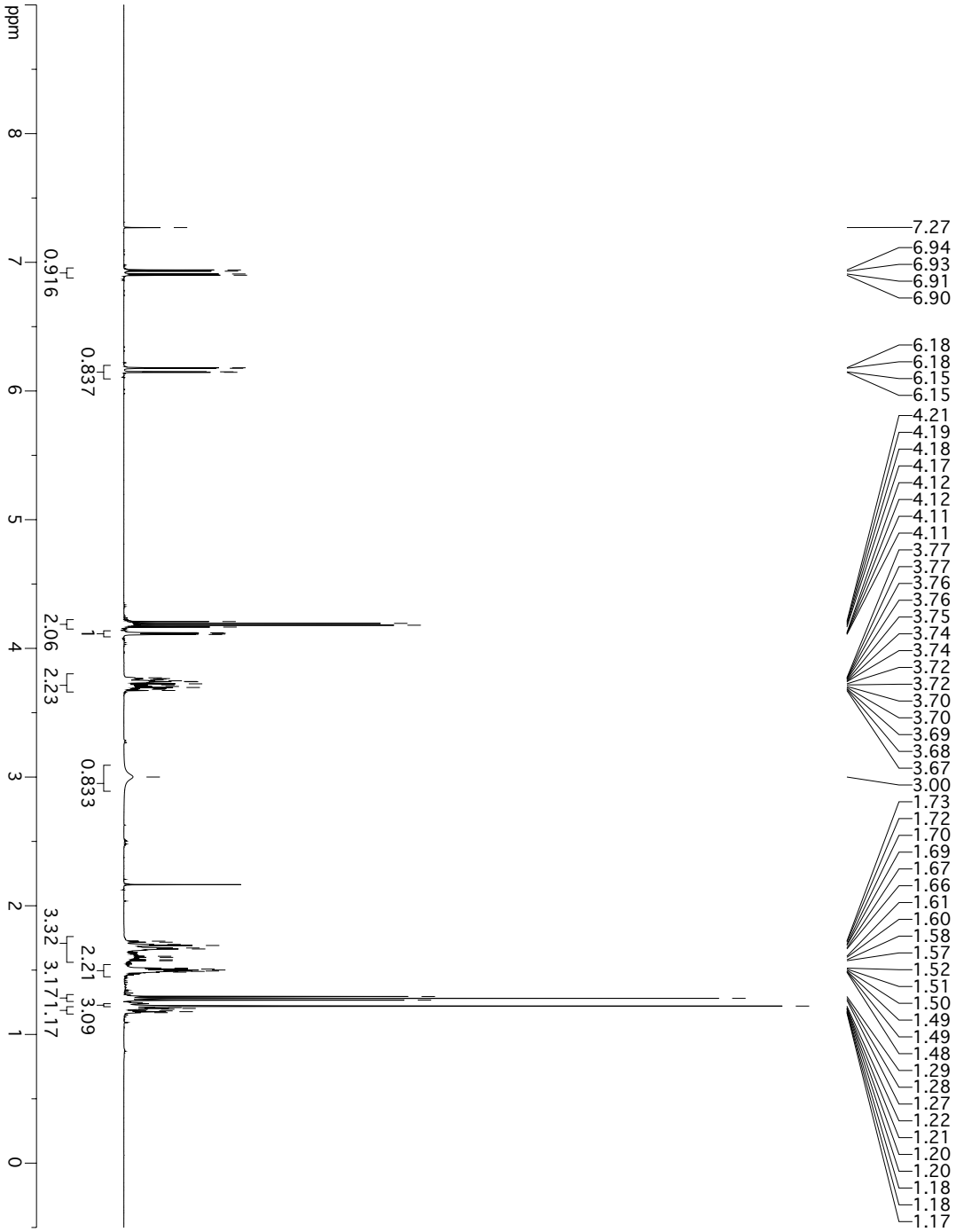

O
OEt
O
Me
OH

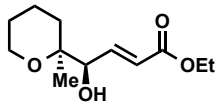
8e


ppm
200
150
100
50
0
166.6
145.4
122.5
85.1
77.5
77.2
76.9
76.2
68.7
60.6
31.4
26.5
23.8
14.4

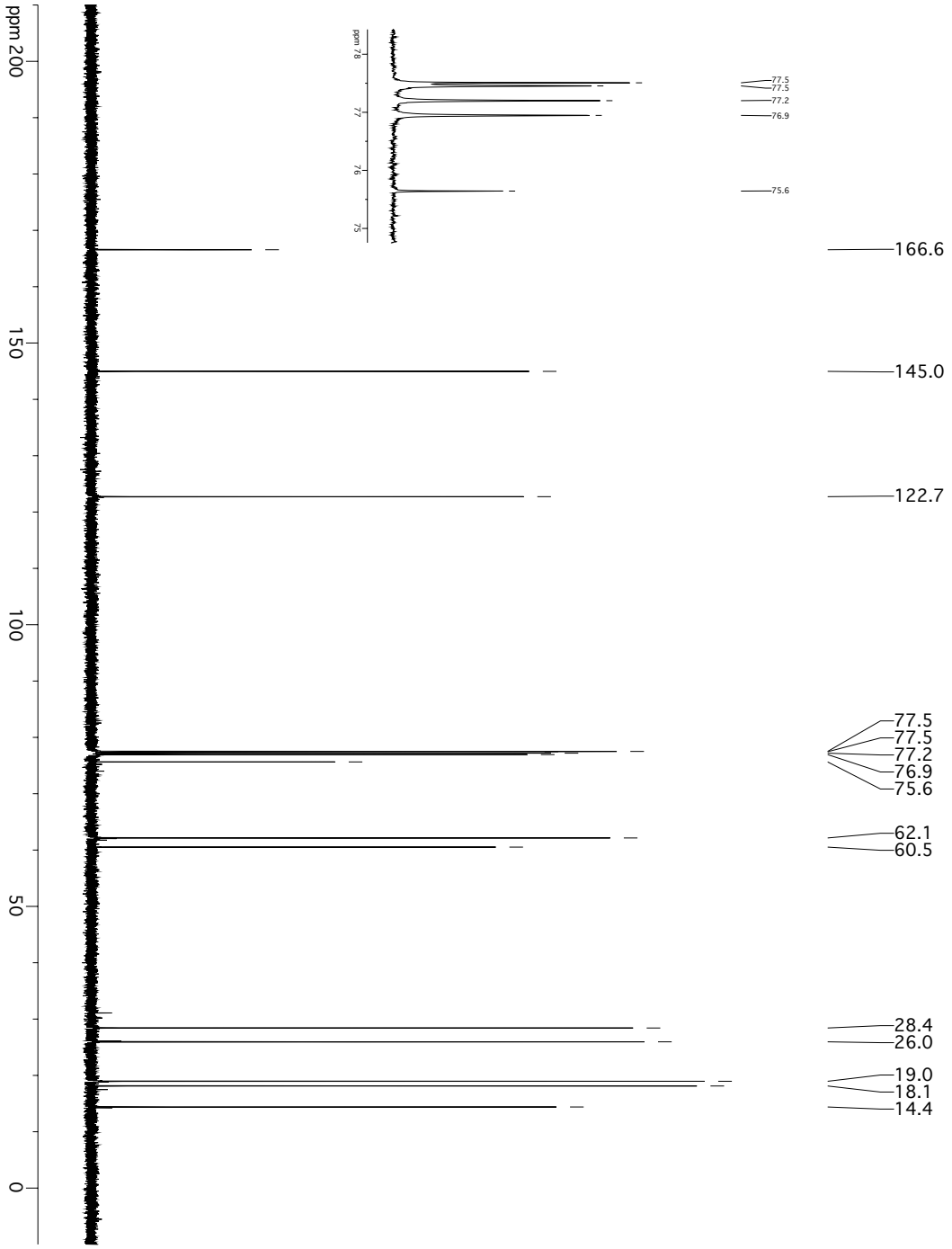

O
OEt
Me
OH

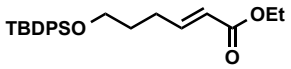
8f


ppm
8
7
6
5
4
3
2
1
0
0.916
0.837
2.06
1
2.23
0.833
3.32
2.21
3.17
3.09
1.17
7.27
6.94
6.93
6.91
6.90
6.18
6.18
6.15
6.15
4.21
4.19
4.18
4.17
4.12
4.12
4.11
4.11
3.77
3.77
3.76
3.76
3.75
3.74
3.74
3.72
3.72
3.70
3.70
3.69
3.68
3.67
3.00
1.73
1.72
1.70
1.69
1.67
1.66
1.61
1.60
1.58
1.57
1.52
1.51
1.50
1.49
1.49
1.48
1.29
1.28
1.27
1.22
1.21
1.20
1.20
1.18
1.18
1.17

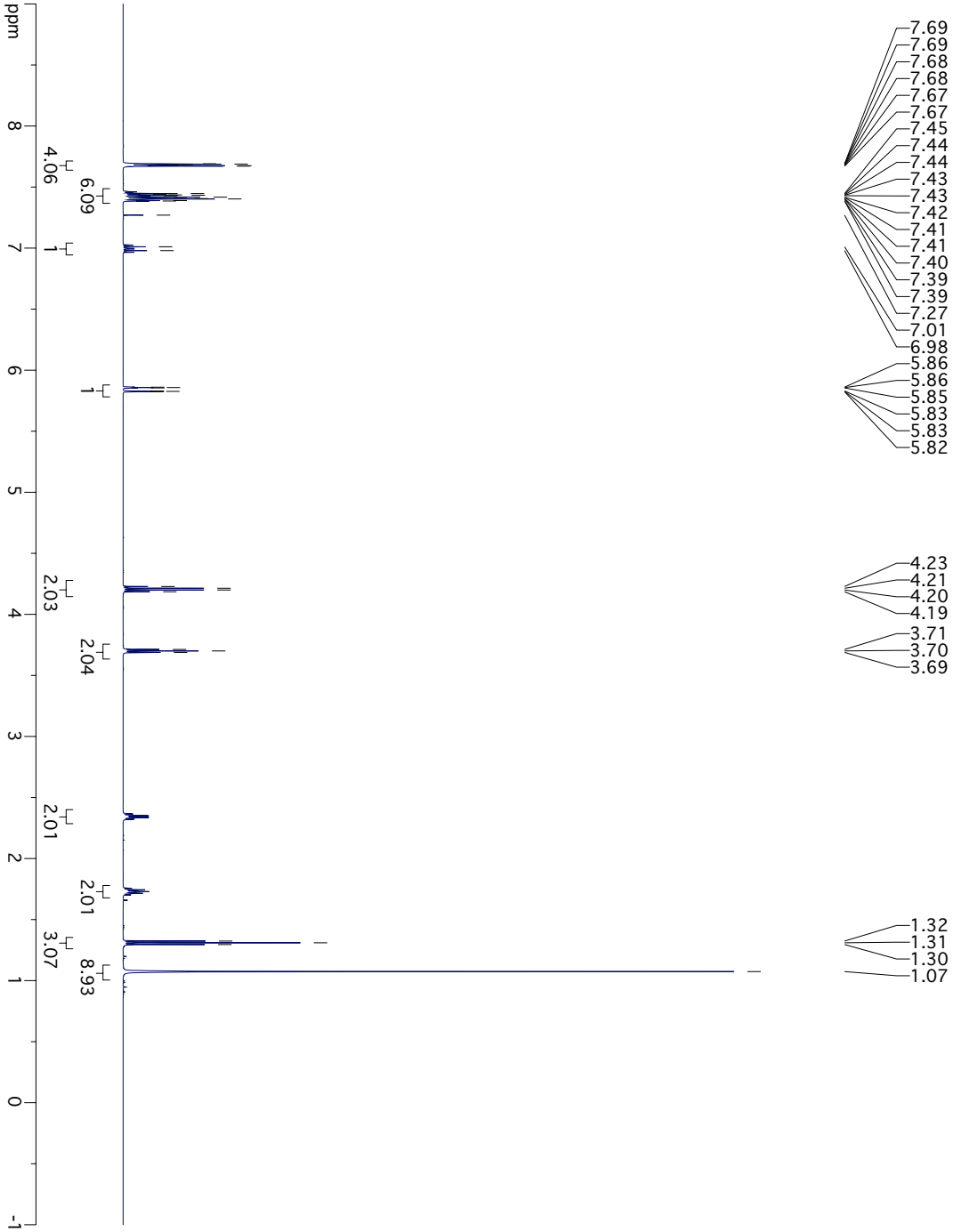

O
OEt
Me
OH

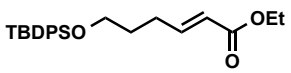
8f


ppm
200
150
100
50
0
166.6
145.0
122.7
77.5
77.5
77.2
76.9
75.6
62.1
60.5
28.4
26.0
19.0
18.1
14.4

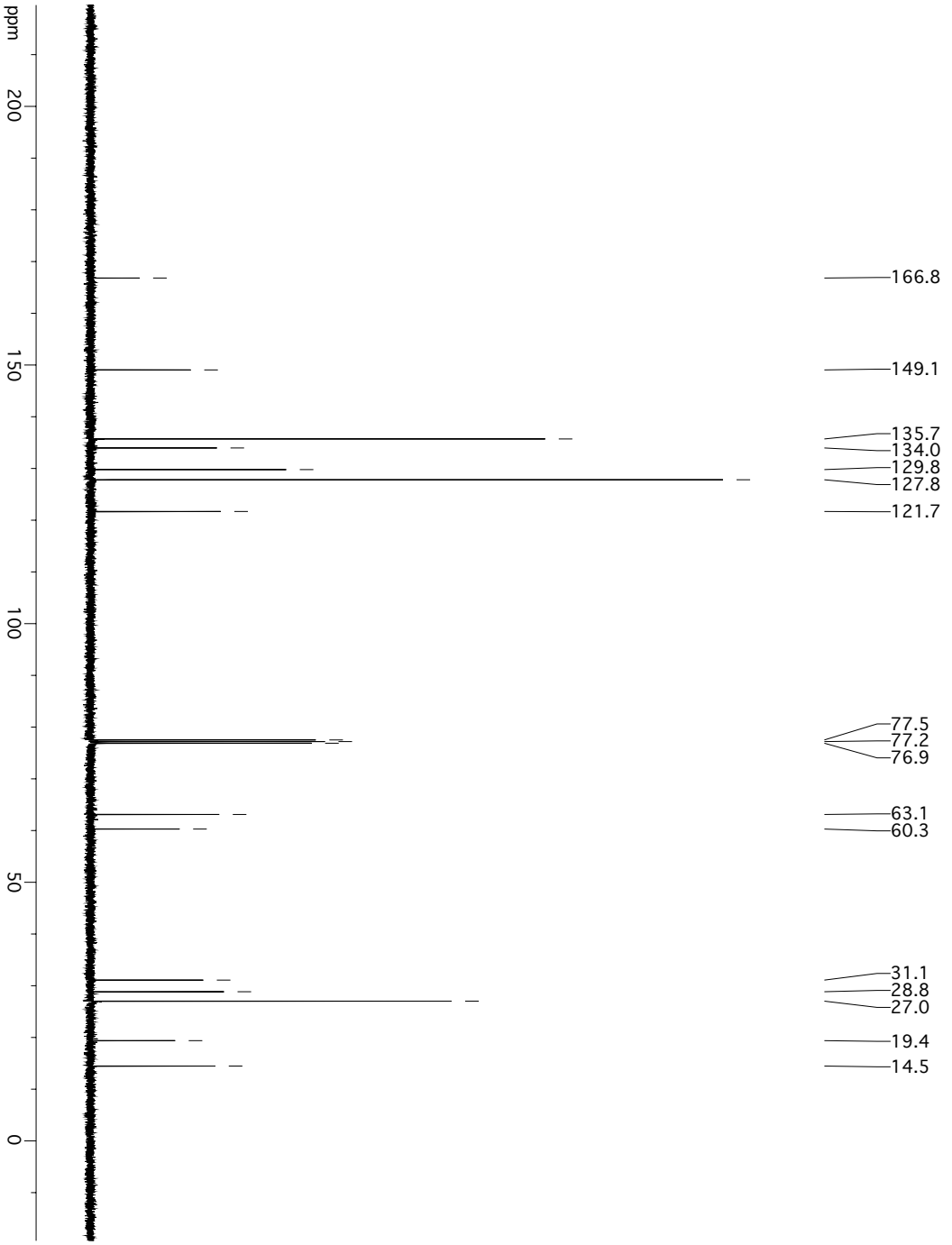

TBDPSO
OEt
O

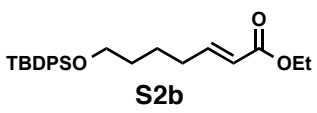
S2a


ppm
8
7
6
5
4
3
2
1
0
-1
4.06
6.09
1
1
2.03
2.04
2.01
2.01
3.07
8.93
7.69
7.69
7.68
7.68
7.67
7.67
7.45
7.44
7.44
7.43
7.43
7.42
7.41
7.41
7.40
7.39
7.39
7.27
7.01
6.98
5.86
5.86
5.85
5.83
5.83
5.82
4.23
4.21
4.20
4.19
3.71
3.70
3.69
1.32
1.31
1.30
1.07

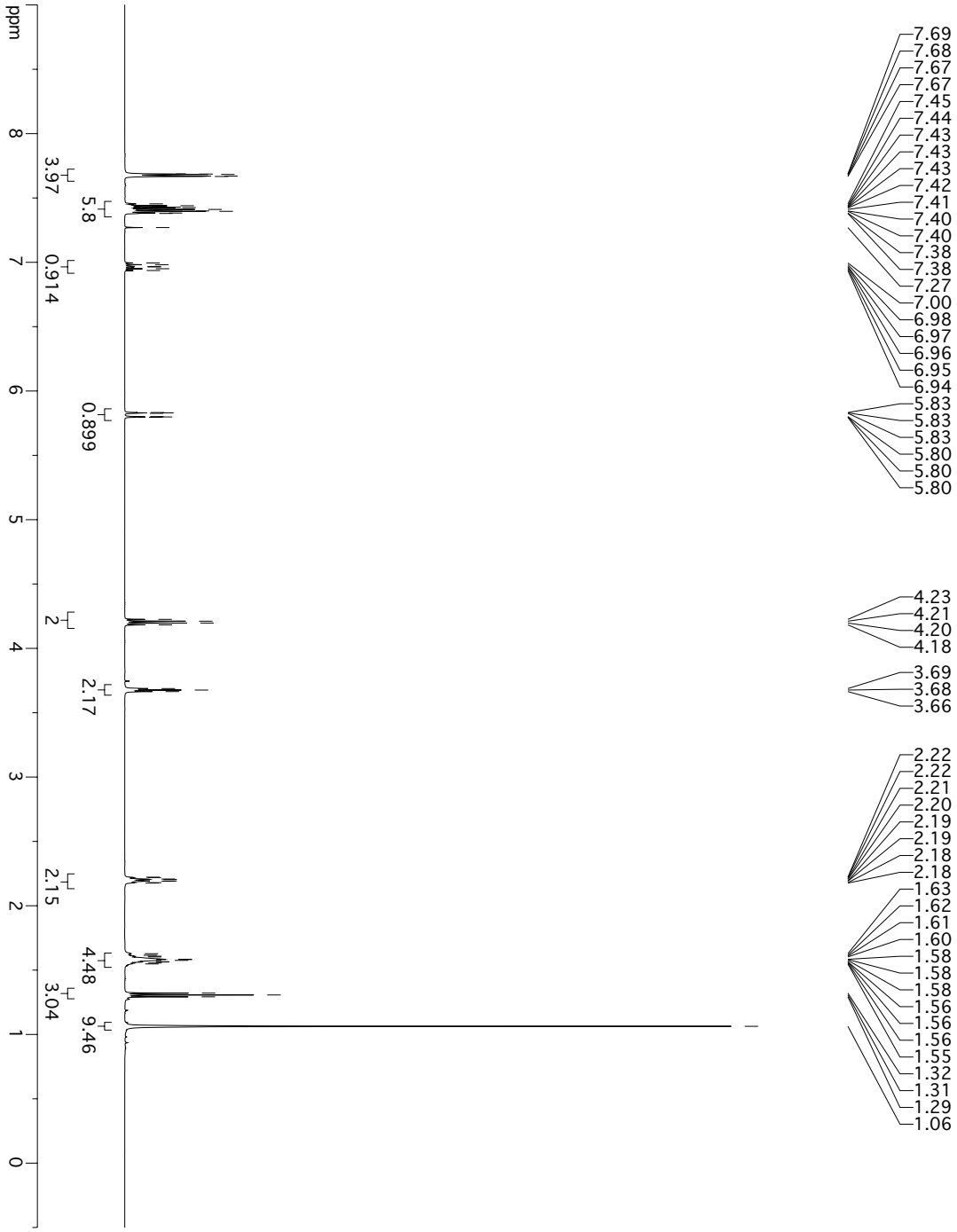

TBDPSO
OEt
O

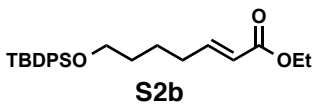
S2a


ppm
200
150
100
50
0
166.8
149.1
135.7
134.0
129.8
127.8
121.7
77.5
77.2
76.9
63.1
60.3
31.1
28.8
27.0
19.4
14.5

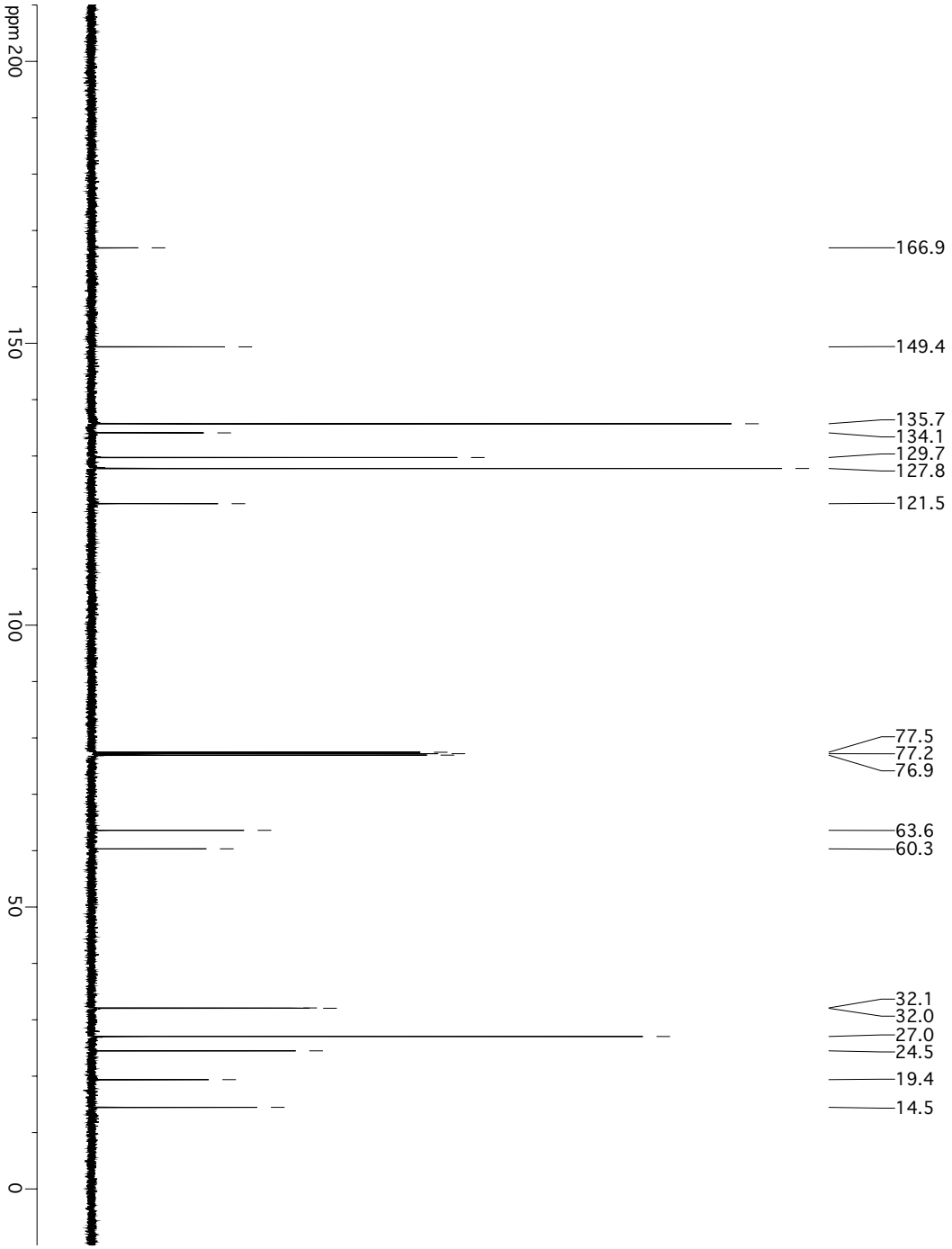

TBDPSO
O
OEt

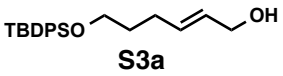
S2b


ppm
8
7
6
5
4
3
2
1
0
3.97
5.8
0.914
0.899
2
2.17
2.15
4.48
3.04
9.46
7.69
7.68
7.67
7.67
7.45
7.44
7.43
7.43
7.43
7.42
7.41
7.40
7.40
7.38
7.38
7.27
7.00
6.98
6.97
6.96
6.95
6.94
5.83
5.83
5.83
5.80
5.80
5.80
4.23
4.21
4.20
4.18
3.69
3.68
3.66
2.22
2.22
2.21
2.20
2.19
2.19
2.18
2.18
1.63
1.62
1.61
1.60
1.58
1.58
1.58
1.56
1.56
1.56
1.55
1.32
1.31
1.29
1.06

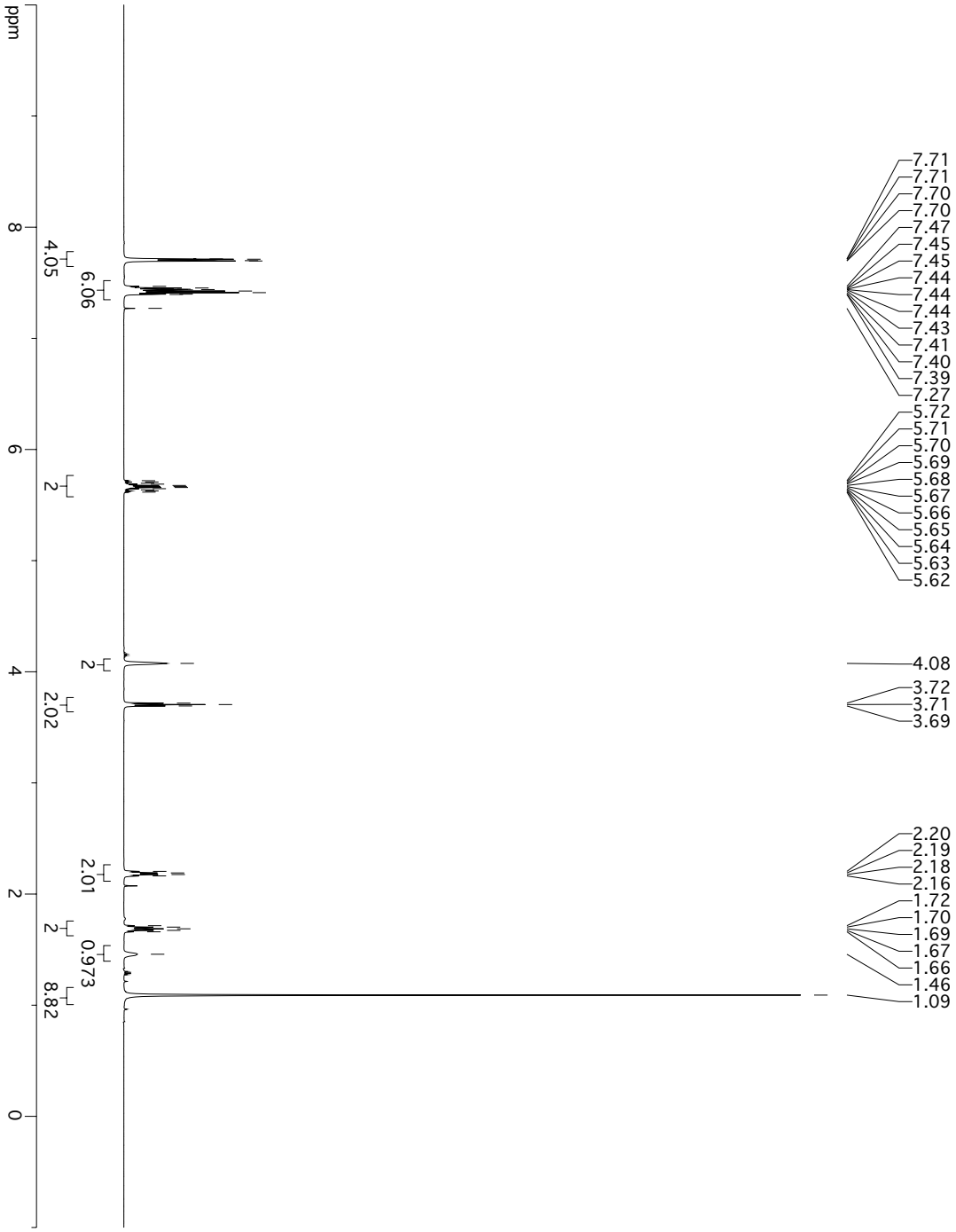

TBDPSO
O
OEt

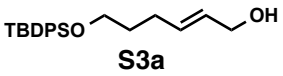
S2b


ppm
200
150
100
50
0
166.9
149.4
135.7
134.1
129.7
127.8
121.5
77.5
77.2
76.9
63.6
60.3
32.1
32.0
27.0
24.5
19.4
14.5

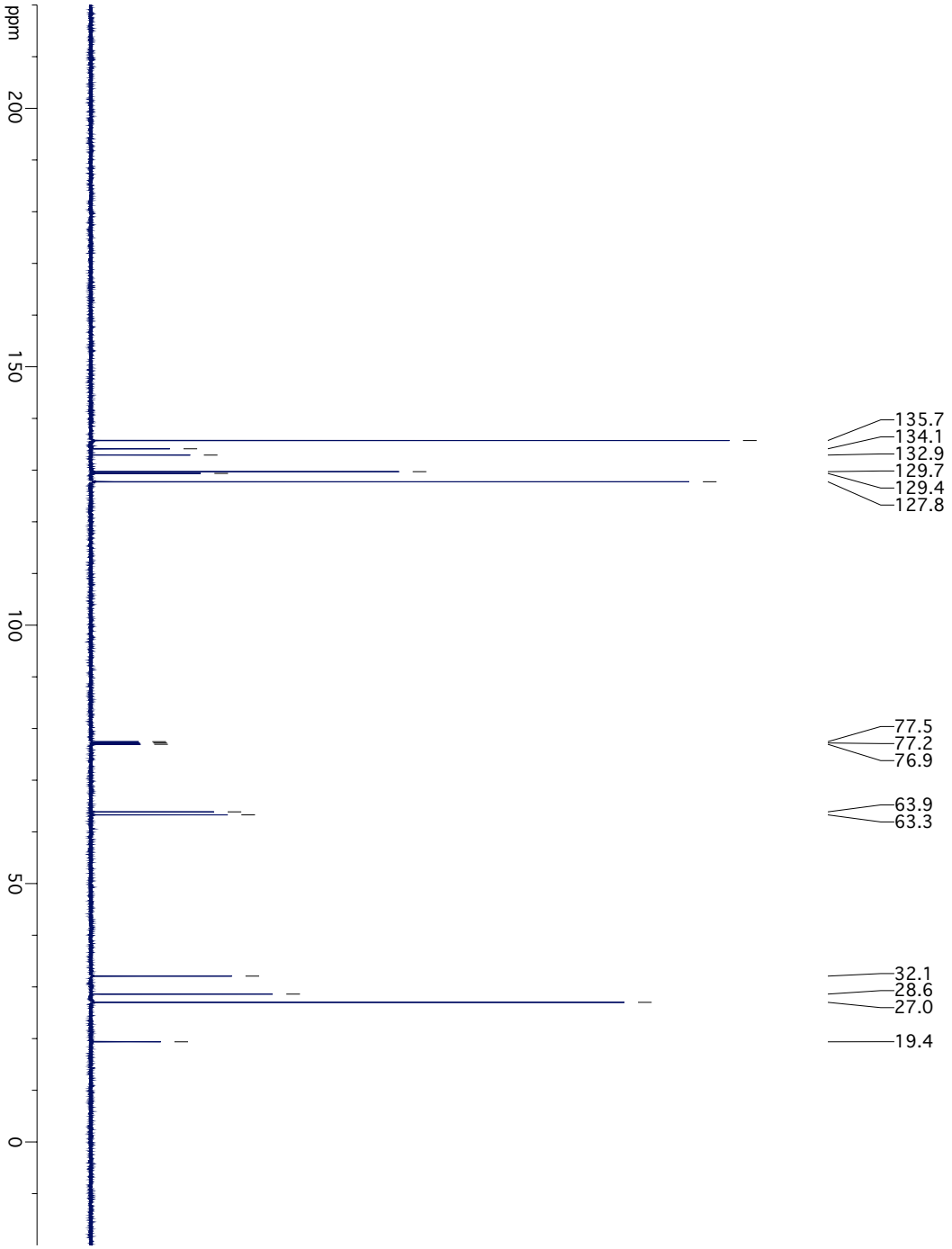

TBDPSO
OH

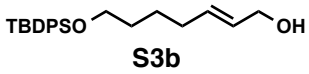
S3a


ppm
8
6
4
2
0
4.05
6.06
2
2
2.02
2.01
2
0.973
8.82
7.71
7.71
7.70
7.70
7.47
7.45
7.45
7.44
7.44
7.44
7.43
7.41
7.40
7.39
7.27
5.72
5.71
5.70
5.69
5.68
5.67
5.66
5.65
5.64
5.63
5.62
4.08
3.72
3.71
3.69
2.20
2.19
2.18
2.16
1.72
1.70
1.69
1.67
1.66
1.46
1.09

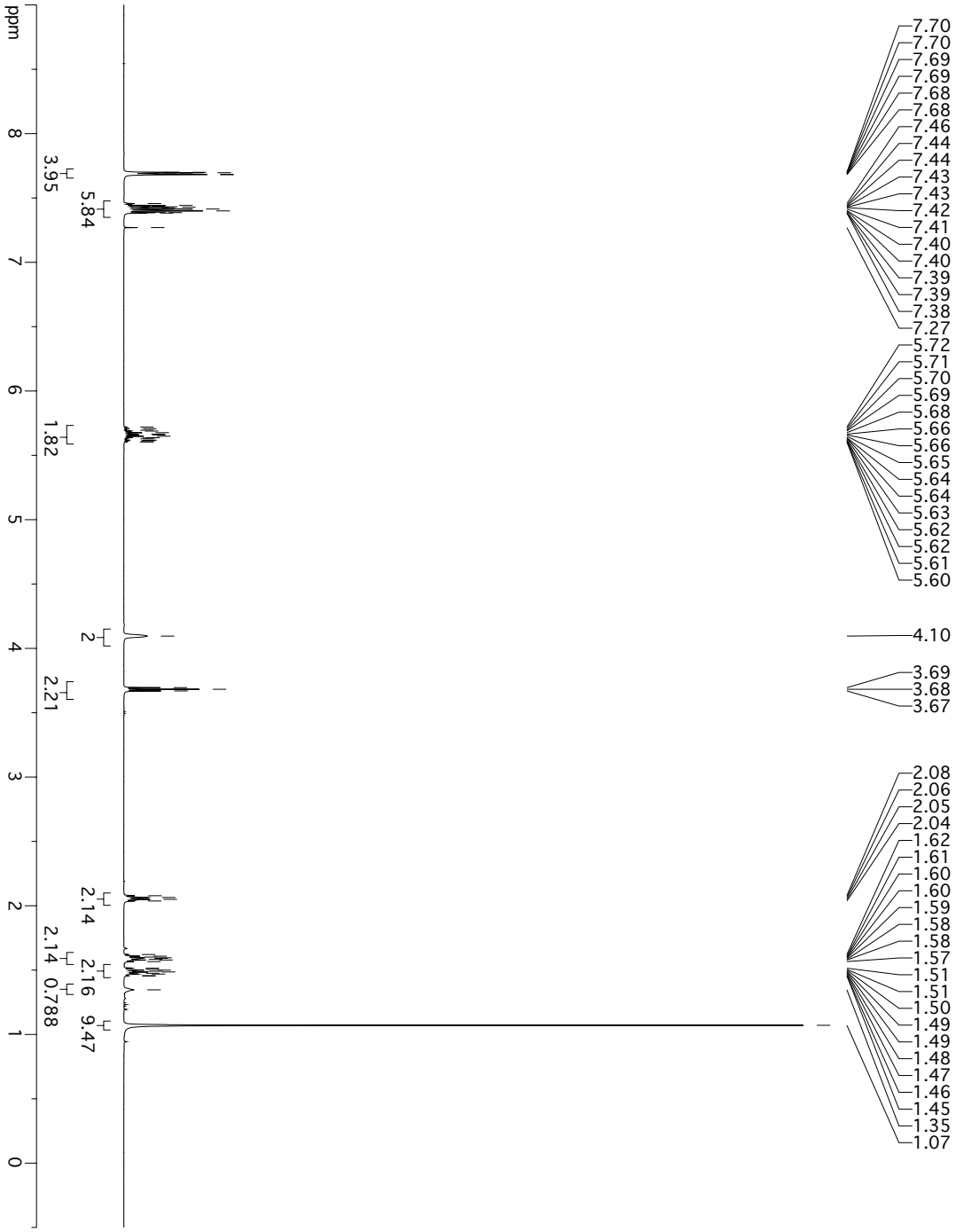

TBDPSO
OH

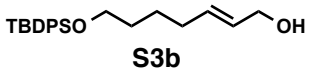
S3a


ppm
200
150
100
50
0
135.7
134.1
132.9
129.7
129.4
127.8
77.5
77.2
76.9
63.9
63.3
32.1
28.6
27.0
19.4

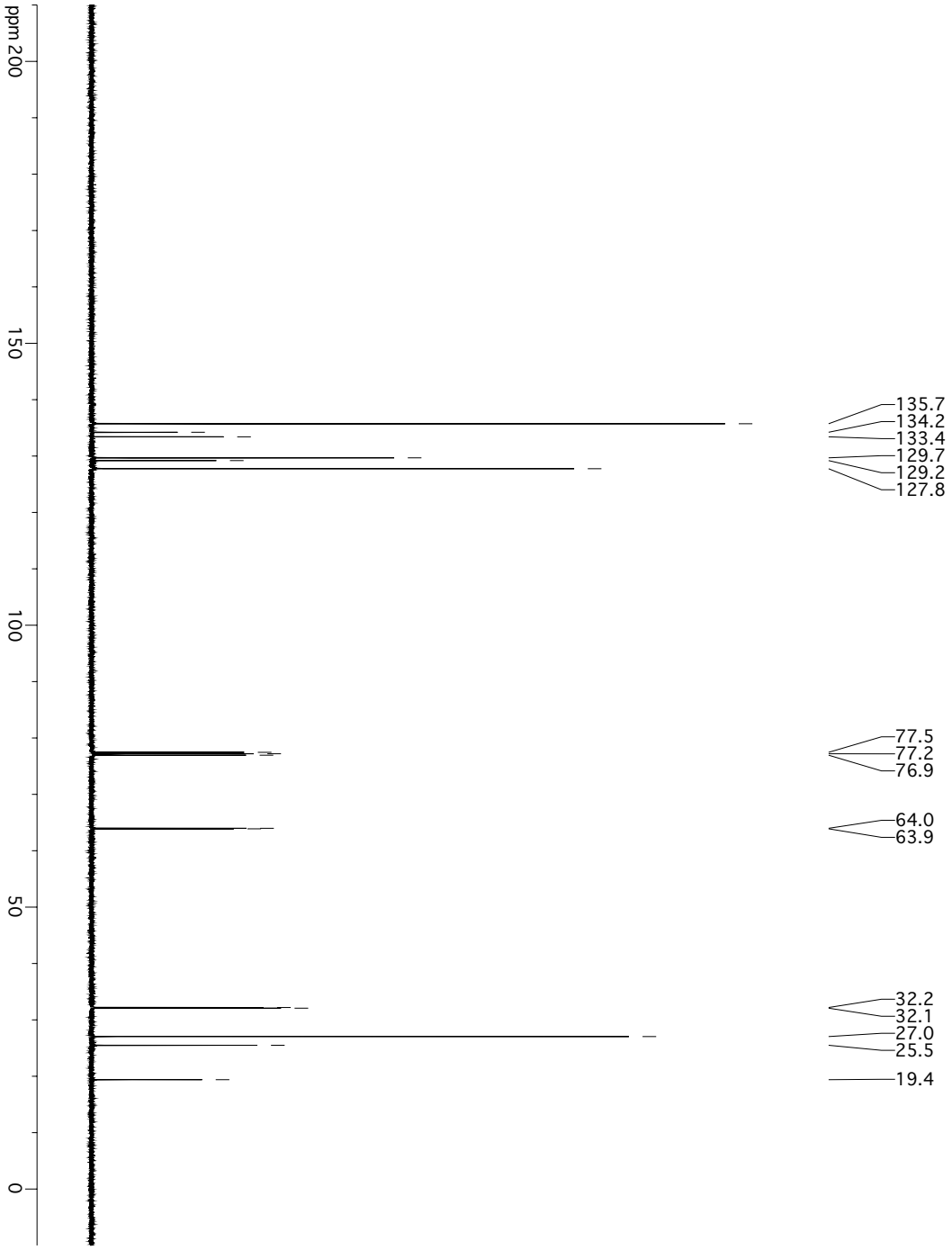

TBDPSO
OH

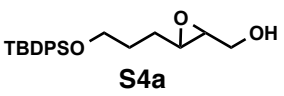
S3b


ppm
8
7
6
5
4
3
2
1
0
3.95
5.84
1.82
2
2.21
2.14
2.14
2.16
0.788
9.47
7.70
7.70
7.69
7.69
7.68
7.68
7.46
7.44
7.44
7.43
7.43
7.42
7.41
7.40
7.40
7.39
7.39
7.38
7.27
5.72
5.71
5.70
5.69
5.68
5.66
5.66
5.65
5.64
5.64
5.63
5.62
5.62
5.61
5.60
4.10
3.69
3.68
3.67
2.08
2.06
2.05
2.04
1.62
1.61
1.60
1.60
1.59
1.58
1.58
1.57
1.51
1.51
1.50
1.49
1.49
1.48
1.47
1.46
1.45
1.35
1.07

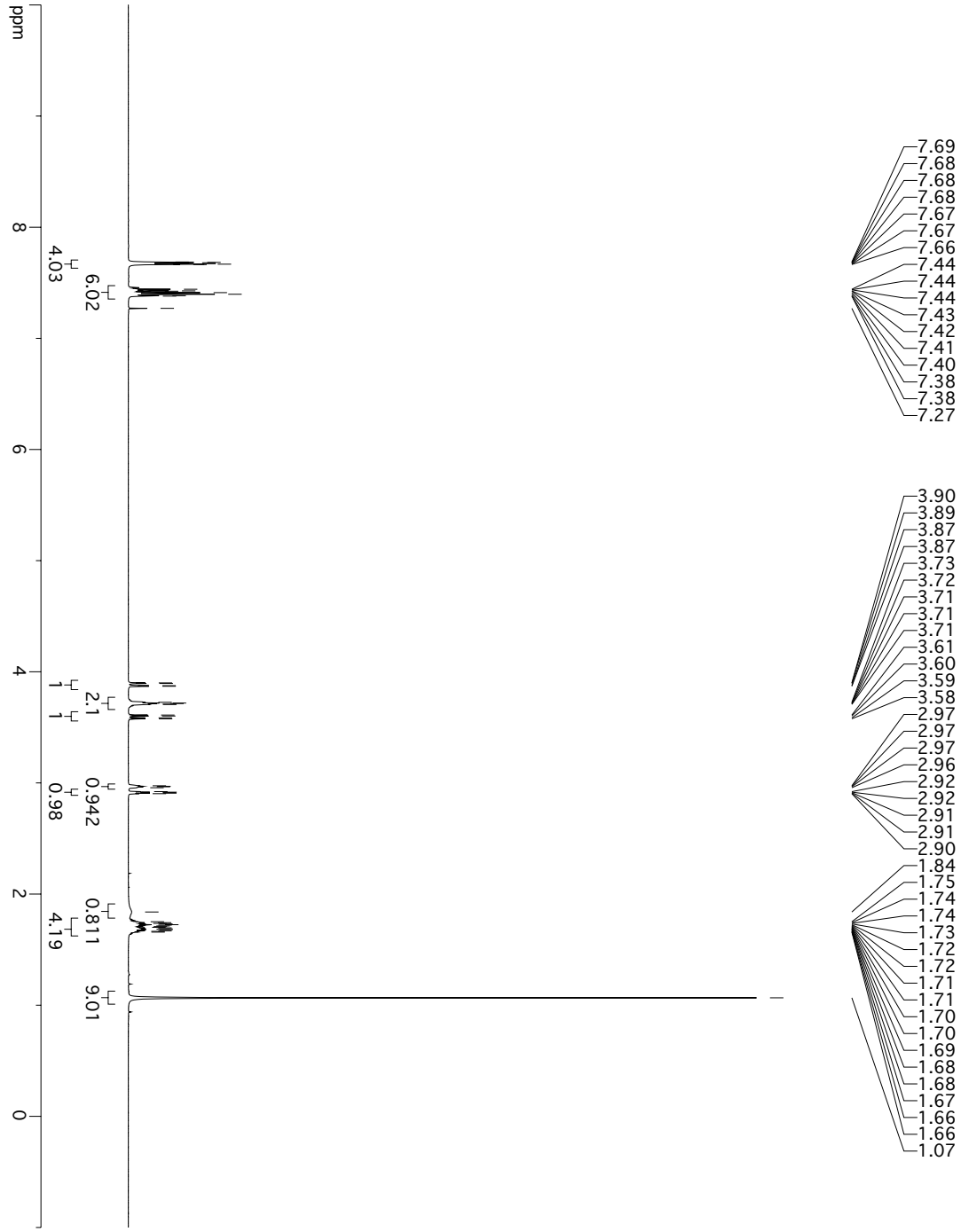

TBDPSO
OH

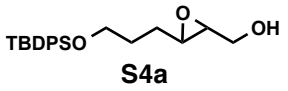
S3b


ppm
200
150
100
50
0
135.7
134.2
133.4
129.7
129.2
127.8
77.5
77.2
76.9
64.0
63.9
32.2
32.1
27.0
25.5
19.4

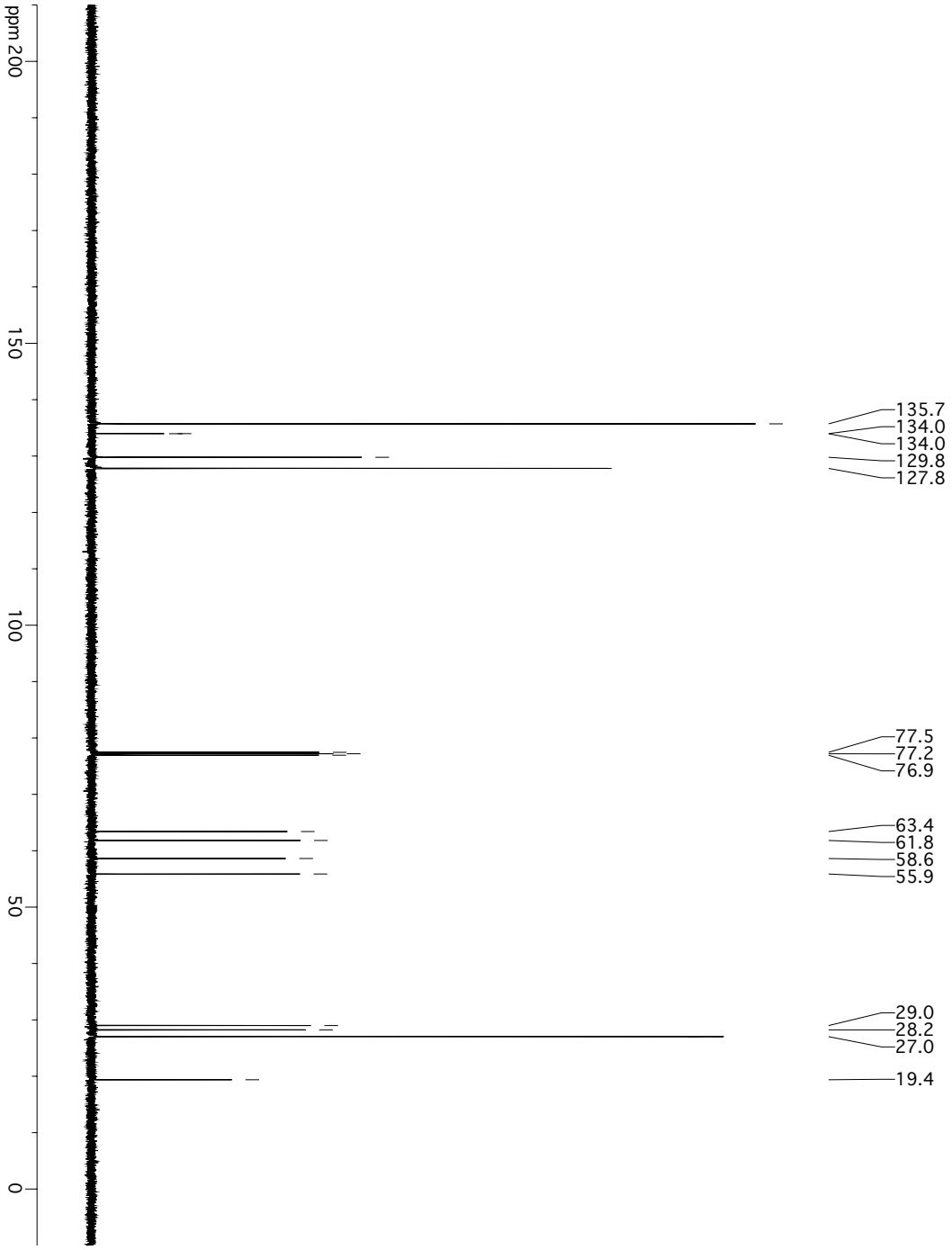

TBDPSO
O
OH

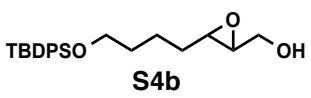
S4a


ppm
8
6
4
2
0
4.03
6.02
1
1
2.1
0.98
0.942
4.19
0.811
9.01
7.69
7.68
7.68
7.68
7.67
7.67
7.66
7.44
7.44
7.44
7.43
7.42
7.41
7.40
7.38
7.38
7.27
3.90
3.89
3.87
3.87
3.73
3.72
3.71
3.71
3.71
3.61
3.60
3.59
3.58
2.97
2.97
2.97
2.96
2.92
2.92
2.91
2.91
2.90
1.84
1.75
1.74
1.74
1.73
1.72
1.72
1.71
1.71
1.70
1.70
1.69
1.68
1.68
1.67
1.66
1.66
1.07

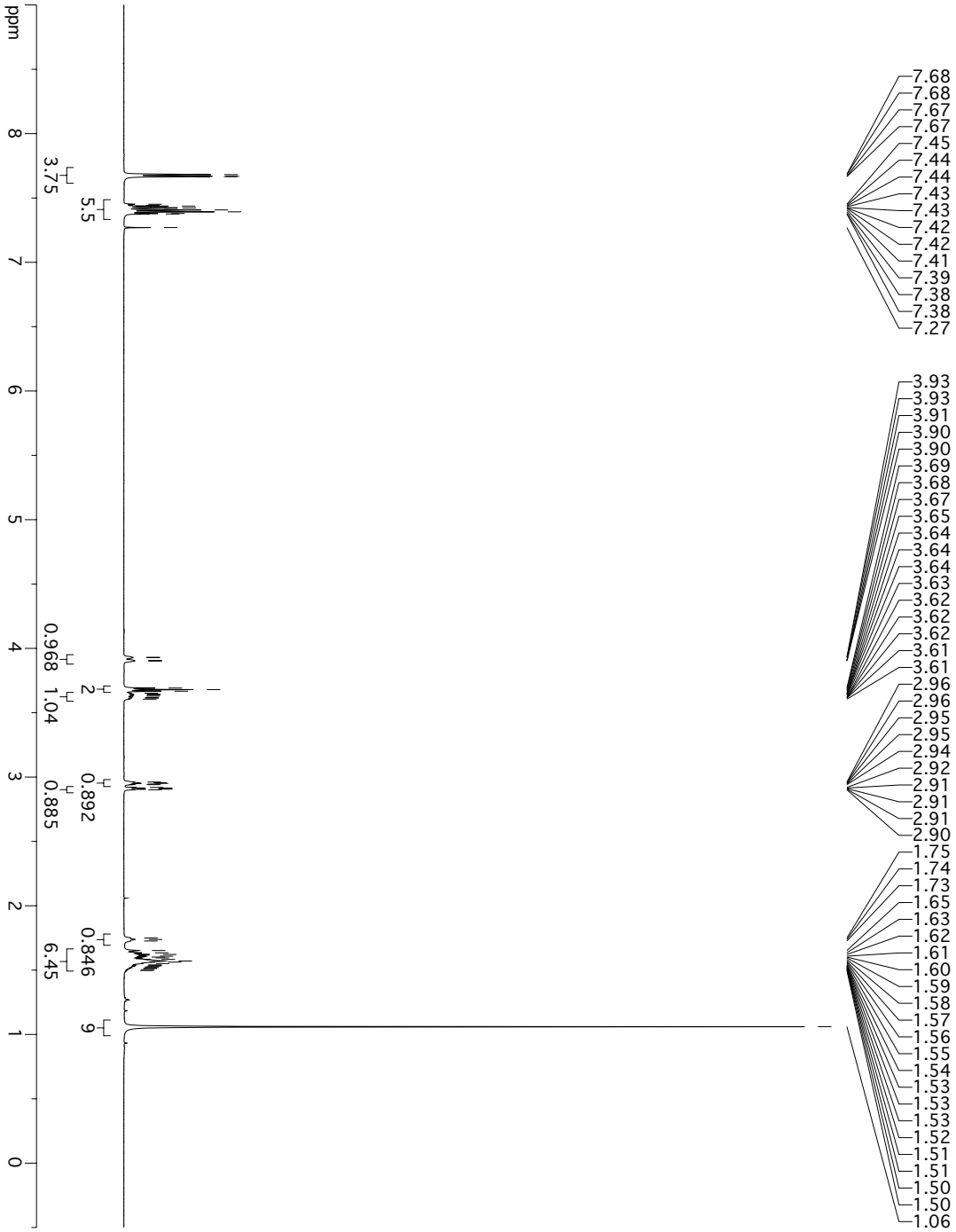

TBDPSO
O
OH

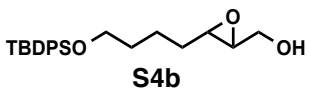
S4a


ppm
200
150
100
50
0
135.7
134.0
134.0
129.8
127.8
77.5
77.2
76.9
63.4
61.8
58.6
55.9
29.0
28.2
27.0
19.4

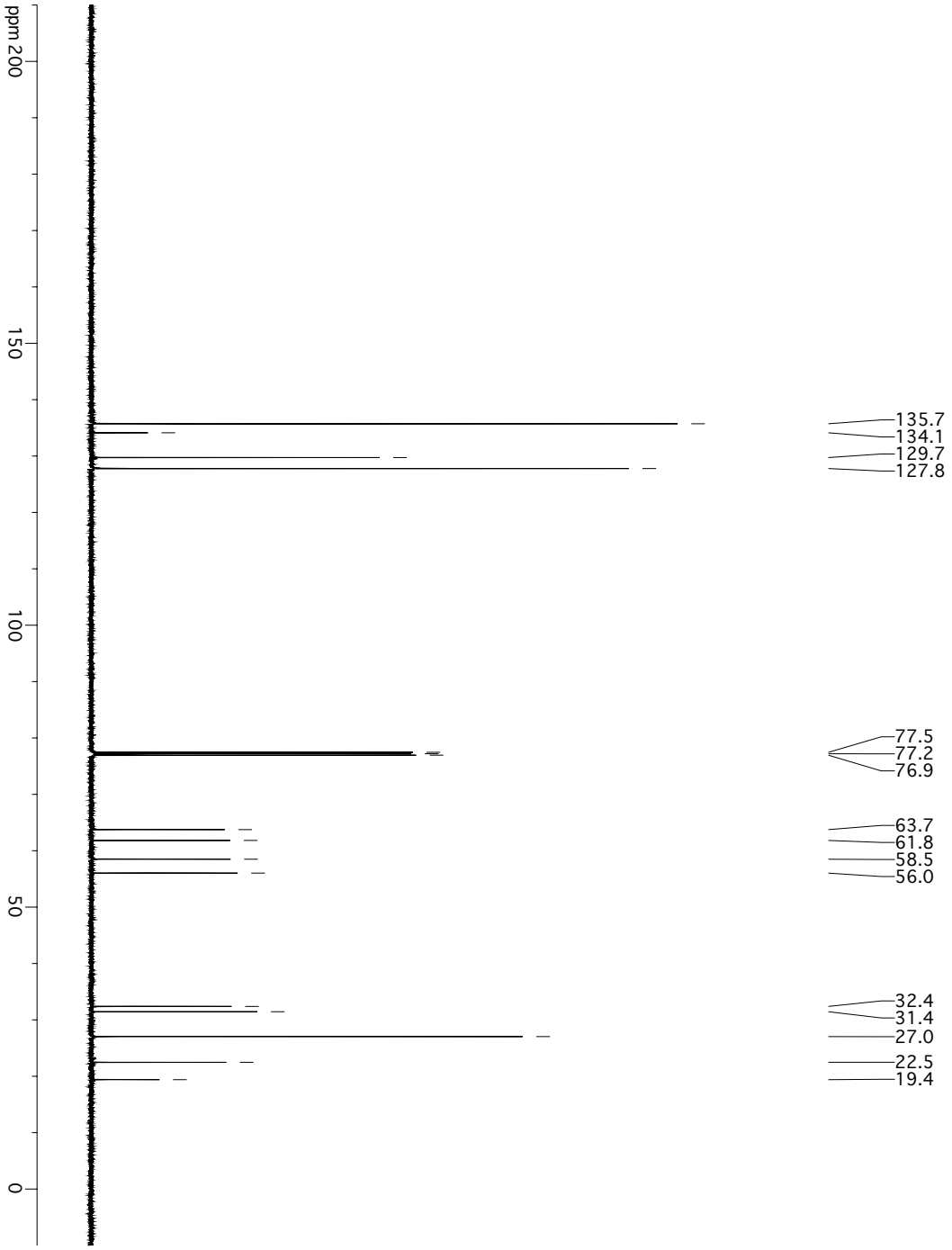

TBDPSO
O
OH

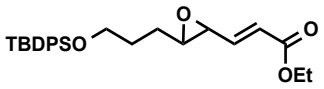
S4b


ppm
8
7
6
5
4
3
2
1
0
3.75
5.5
0.968
2
1.04
0.892
0.885
0.846
6.45
9
7.68
7.68
7.67
7.67
7.45
7.44
7.44
7.43
7.43
7.42
7.42
7.41
7.39
7.38
7.38
7.27
3.93
3.93
3.91
3.90
3.90
3.69
3.68
3.67
3.65
3.64
3.64
3.64
3.63
3.62
3.62
3.62
3.61
3.61
2.96
2.96
2.95
2.95
2.94
2.92
2.91
2.91
2.91
2.90
1.75
1.74
1.73
1.65
1.63
1.62
1.61
1.60
1.59
1.58
1.57
1.56
1.55
1.54
1.53
1.53
1.53
1.52
1.51
1.51
1.50
1.50
1.06

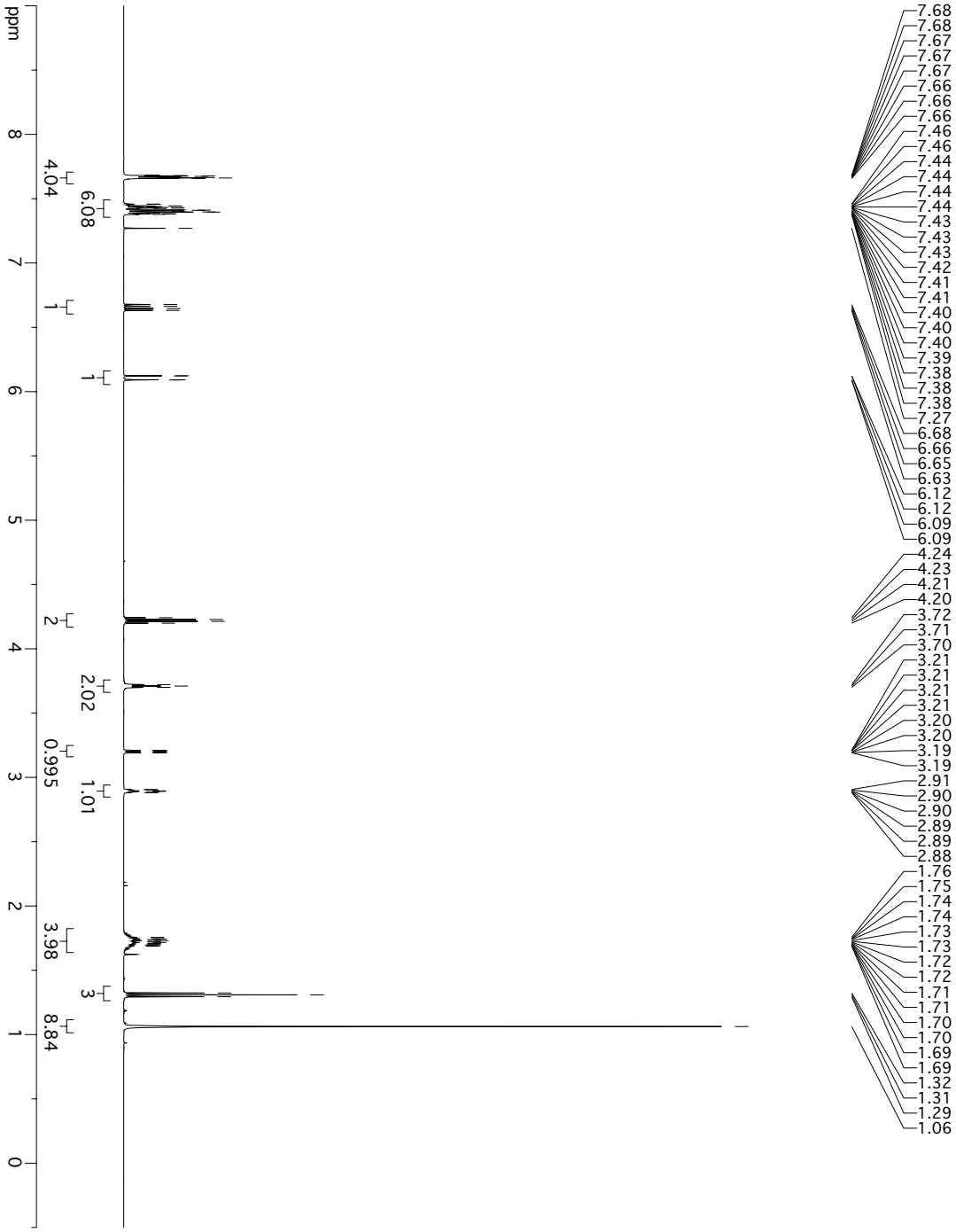

TBDPSO
O
OH

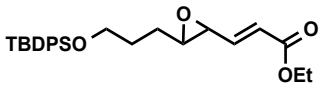
S4b


ppm
200
150
100
50
0
135.7
134.1
129.7
127.8
77.5
77.2
76.9
63.7
61.8
58.5
56.0
32.4
31.4
27.0
22.5
19.4

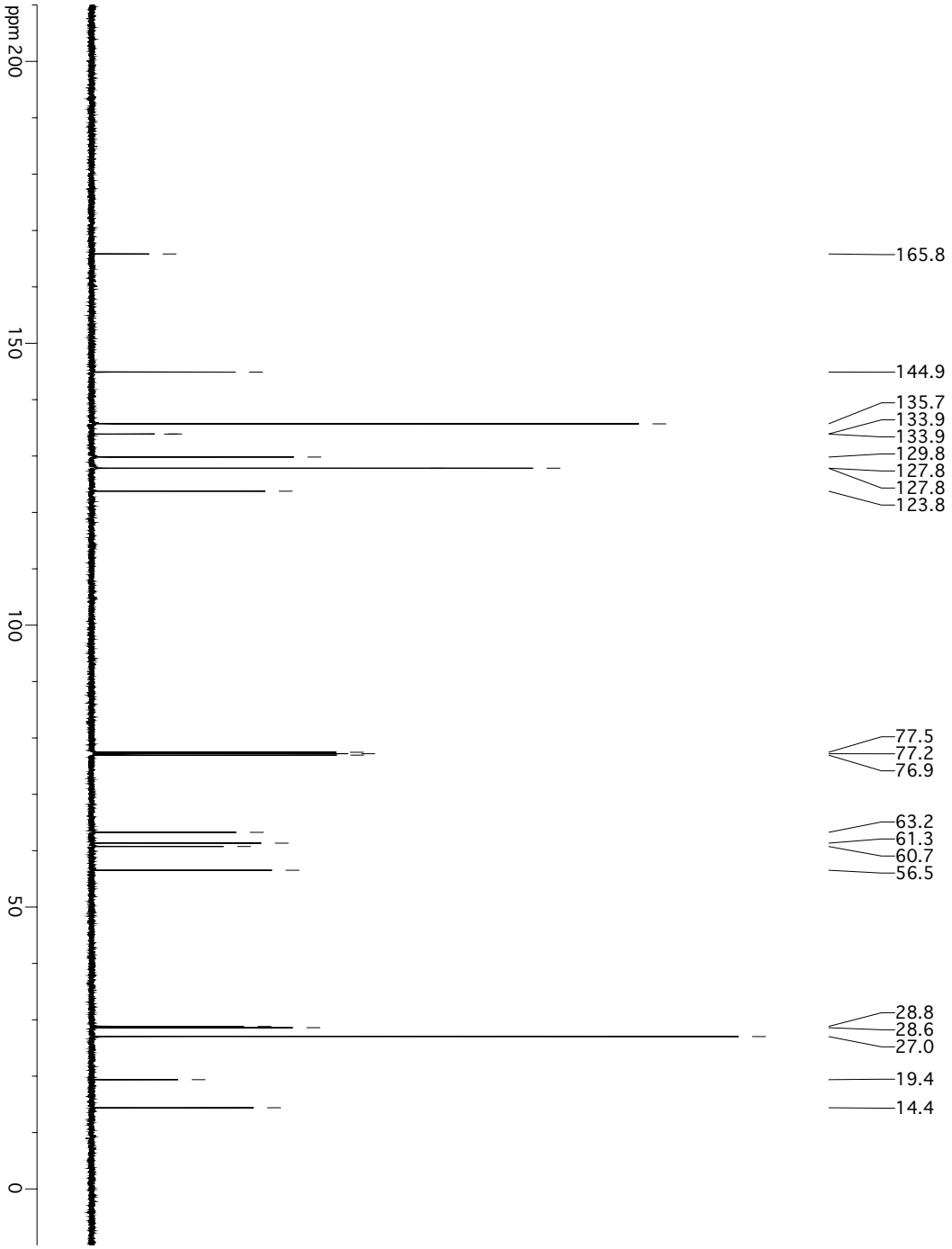

TBDPSO
O
O
OEt

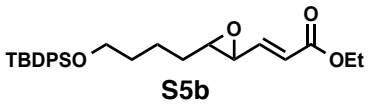
S5a


ppm
8
7
6
5
4
3
2
1
0
4.04
6.08
1
1
2
2.02
0.995
1.01
3.98
3
8.84
7.68
7.68
7.67
7.67
7.67
7.66
7.66
7.66
7.46
7.46
7.44
7.44
7.44
7.44
7.43
7.43
7.43
7.42
7.41
7.41
7.40
7.40
7.40
7.39
7.38
7.38
7.38
7.27
6.68
6.66
6.65
6.63
6.12
6.12
6.09
6.09
4.24
4.23
4.21
4.20
3.72
3.71
3.70
3.21
3.21
3.21
3.21
3.20
3.20
3.19
3.19
2.91
2.90
2.90
2.89
2.89
2.88
1.76
1.75
1.74
1.74
1.73
1.73
1.72
1.72
1.71
1.71
1.70
1.70
1.69
1.69
1.32
1.31
1.29
1.06

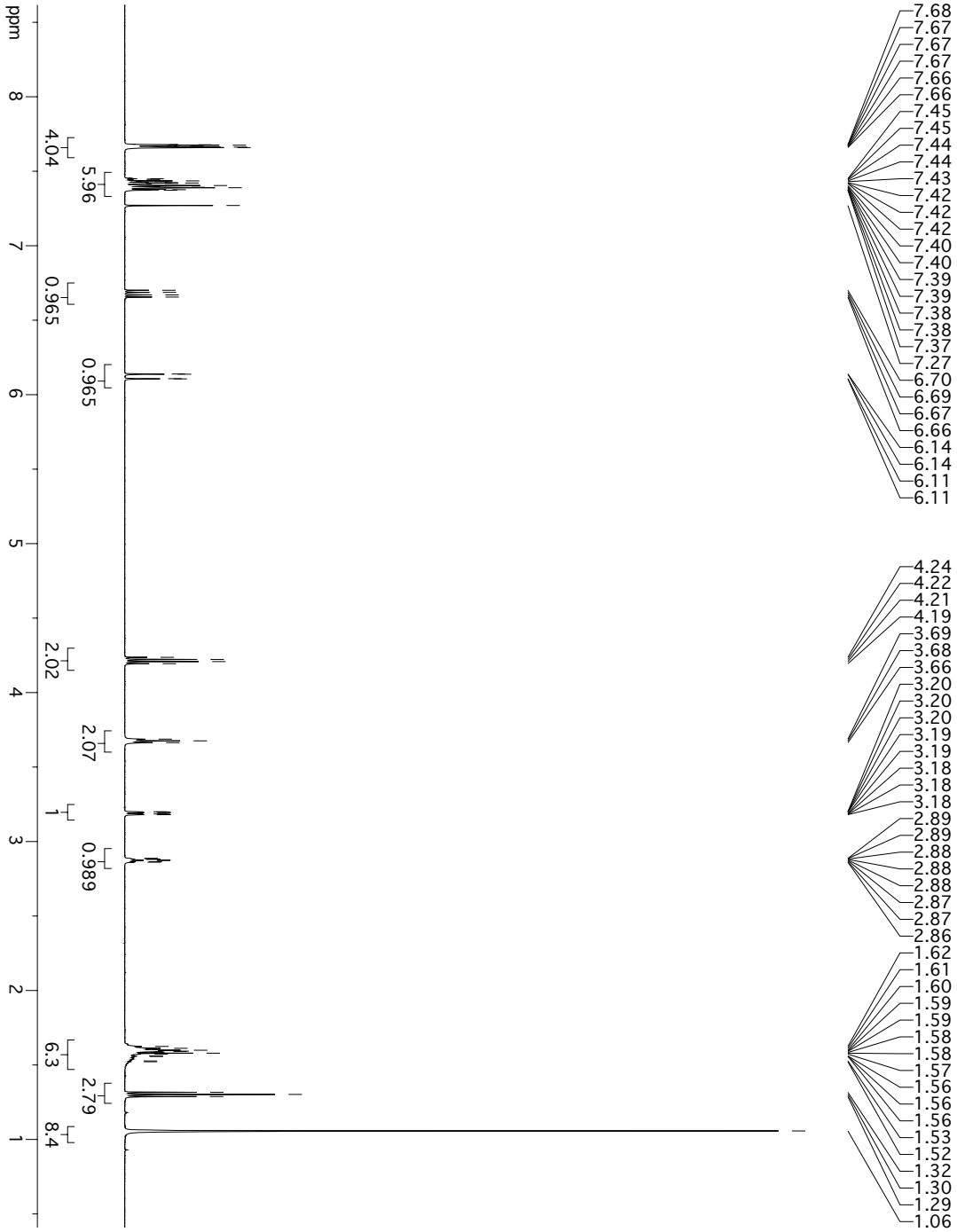

TBDPSO
O
O
OEt

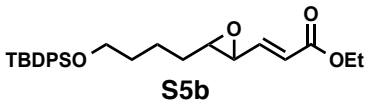
S5a


ppm
200
150
100
50
0
165.8
144.9
135.7
133.9
133.9
129.8
127.8
127.8
123.8
77.5
77.2
76.9
63.2
61.3
60.7
56.5
28.8
28.6
27.0
19.4
14.4

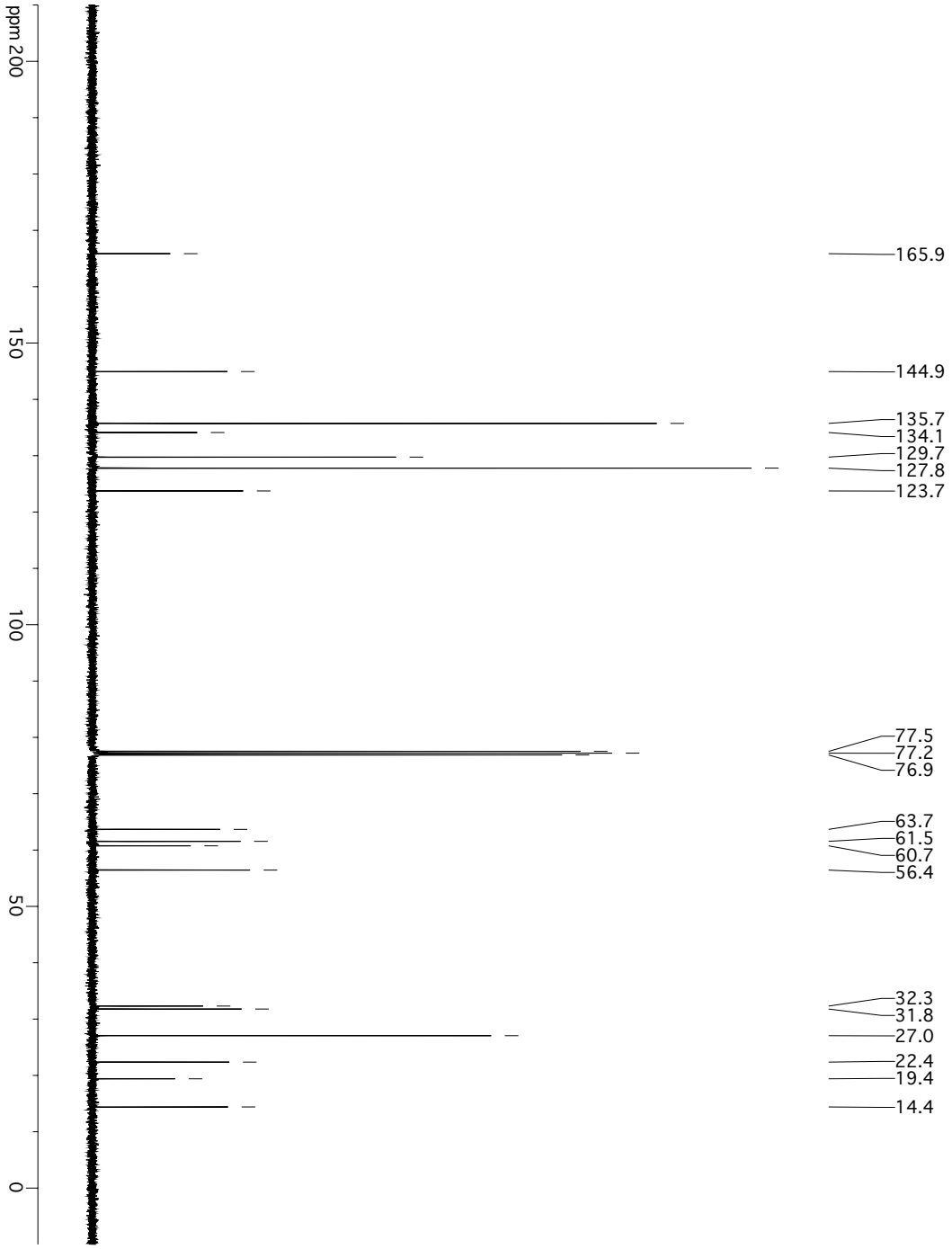

TBDPSO
O
O
OEt

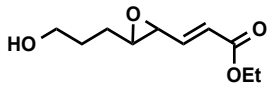
S5b


ppm
8
7
6
5
4
3
2
1
4.04
5.96
0.965
0.965
2.02
2.07
1
0.989
6.3
2.79
8.4
7.68
7.67
7.67
7.67
7.66
7.66
7.45
7.45
7.44
7.44
7.43
7.42
7.42
7.42
7.40
7.40
7.39
7.39
7.38
7.38
7.37
7.27
6.70
6.69
6.67
6.66
6.14
6.14
6.11
6.11
4.24
4.22
4.21
4.19
3.69
3.68
3.66
3.20
3.20
3.20
3.19
3.19
3.18
3.18
3.18
2.89
2.89
2.88
2.88
2.88
2.87
2.87
2.86
1.62
1.61
1.60
1.59
1.59
1.58
1.58
1.57
1.56
1.56
1.56
1.53
1.52
1.32
1.30
1.29
1.06

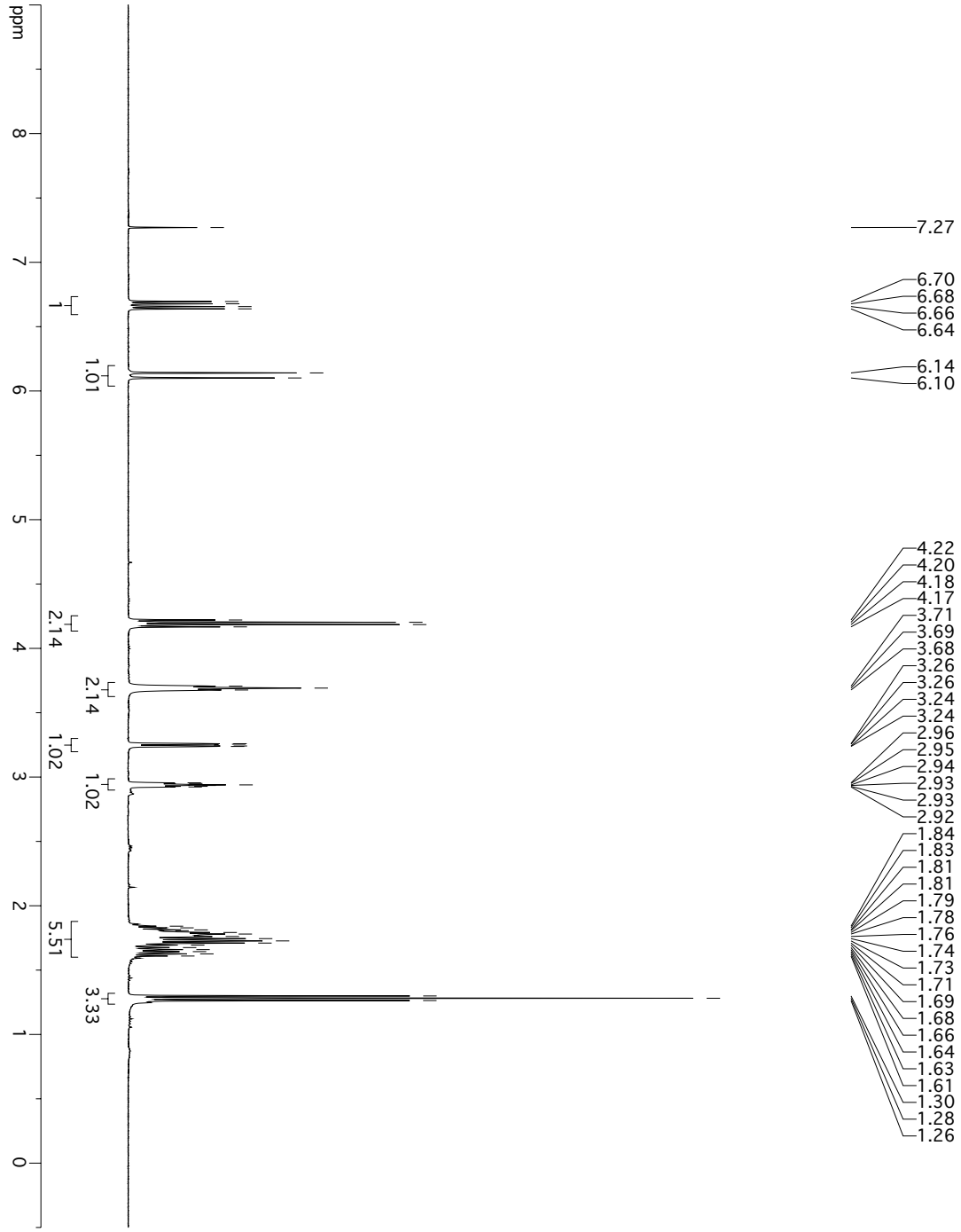

TBDPSO
O
O
OEt

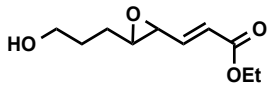
S5b


ppm
200
150
100
50
0
165.9
144.9
135.7
134.1
129.7
127.8
123.7
77.5
77.2
76.9
63.7
61.5
60.7
56.4
32.3
31.8
27.0
22.4
19.4
14.4

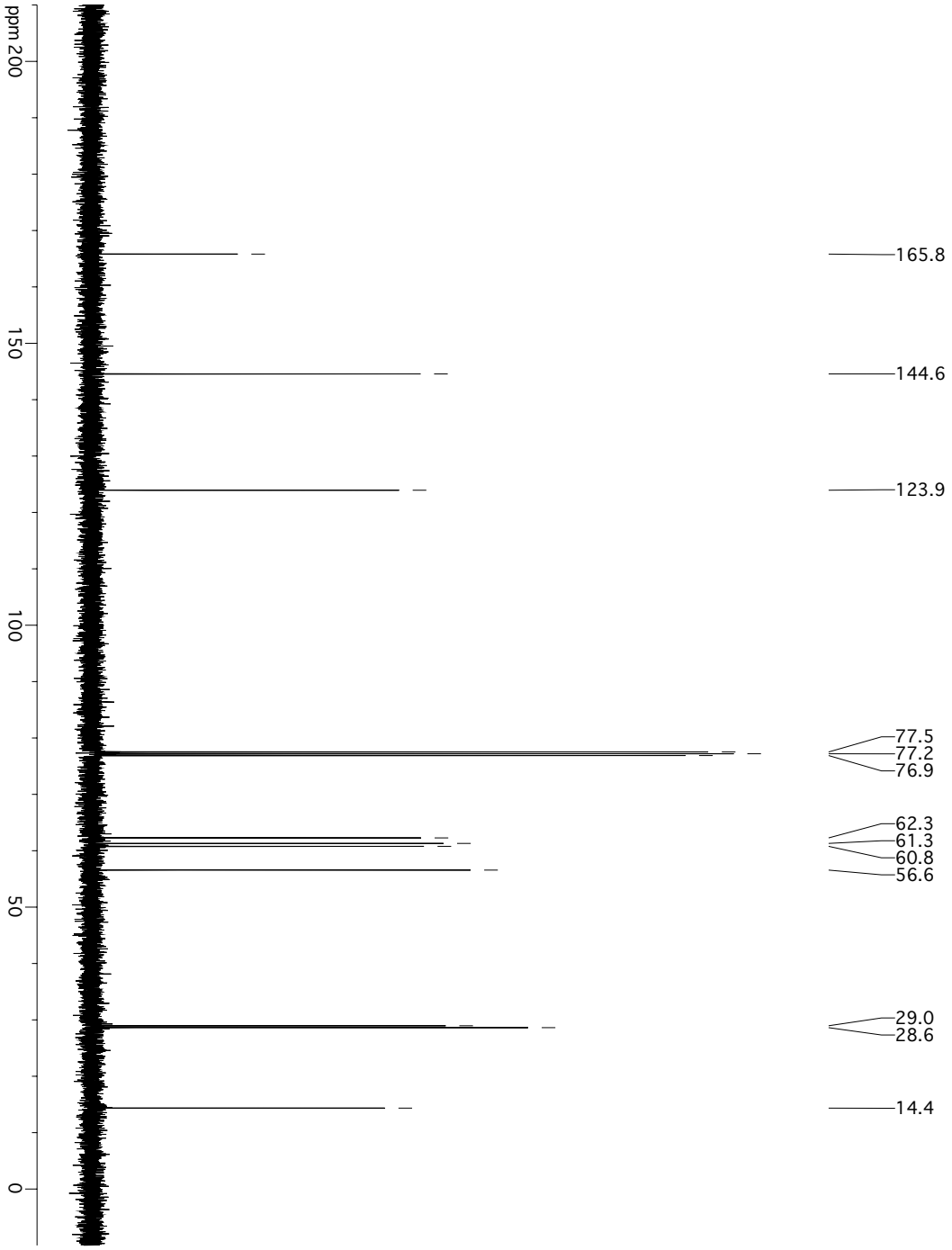

HO
O
O
OEt

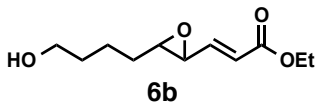
6a


ppm
8
7
6
5
4
3
2
1
0
1
1.01
2.14
2.14
1.02
1.02
5.51
3.33
7.27
6.70
6.68
6.66
6.64
6.14
6.10
4.22
4.20
4.18
4.17
3.71
3.69
3.68
3.26
3.26
3.24
3.24
2.96
2.95
2.94
2.93
2.93
2.92
1.84
1.83
1.81
1.81
1.79
1.78
1.76
1.74
1.73
1.71
1.69
1.68
1.66
1.64
1.63
1.61
1.30
1.28
1.26

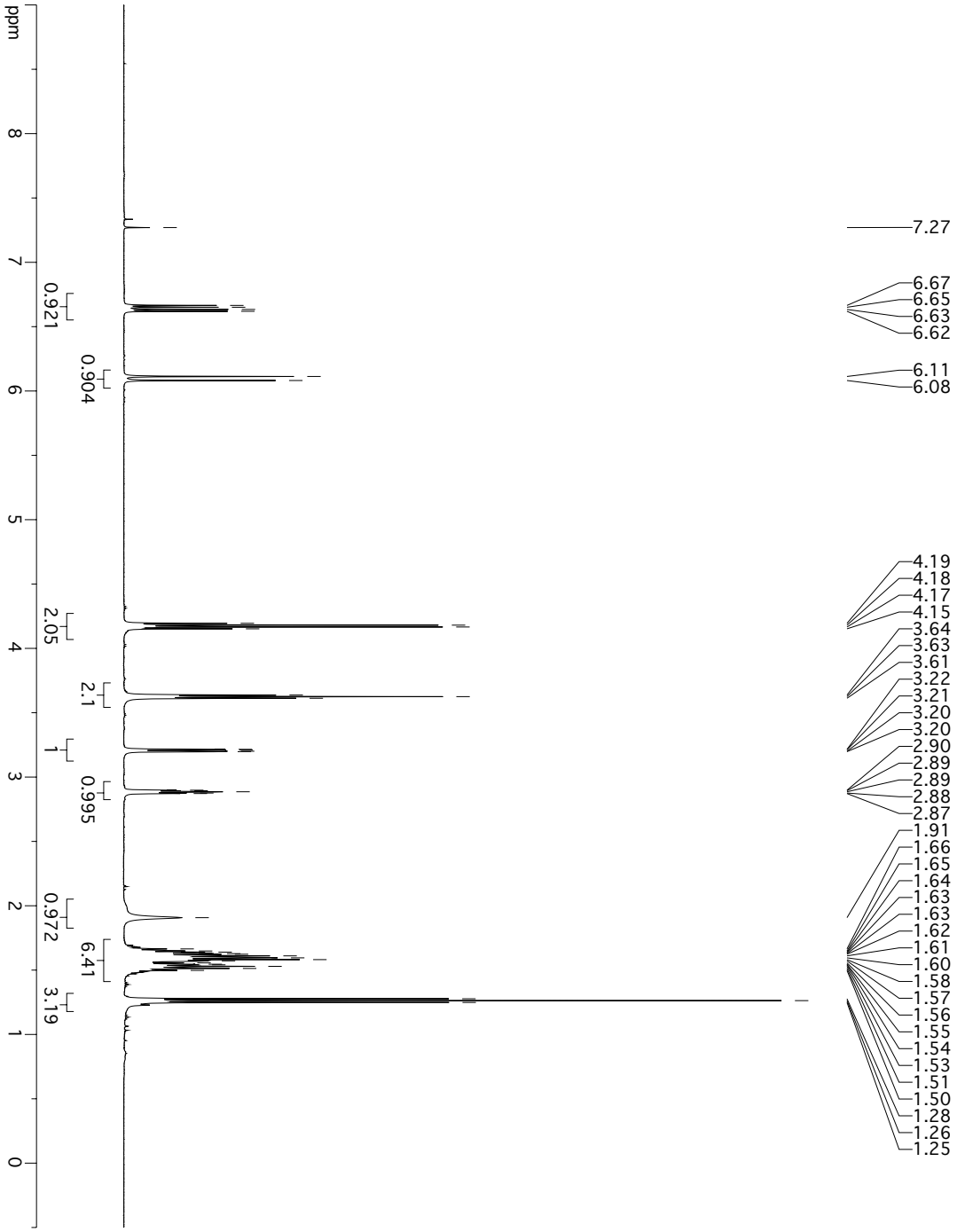

HO
O
O
OEt

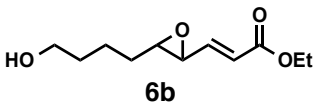
6a


ppm
200
150
100
50
0
165.8
144.6
123.9
77.5
77.2
76.9
62.3
61.3
60.8
56.6
29.0
28.6
14.4

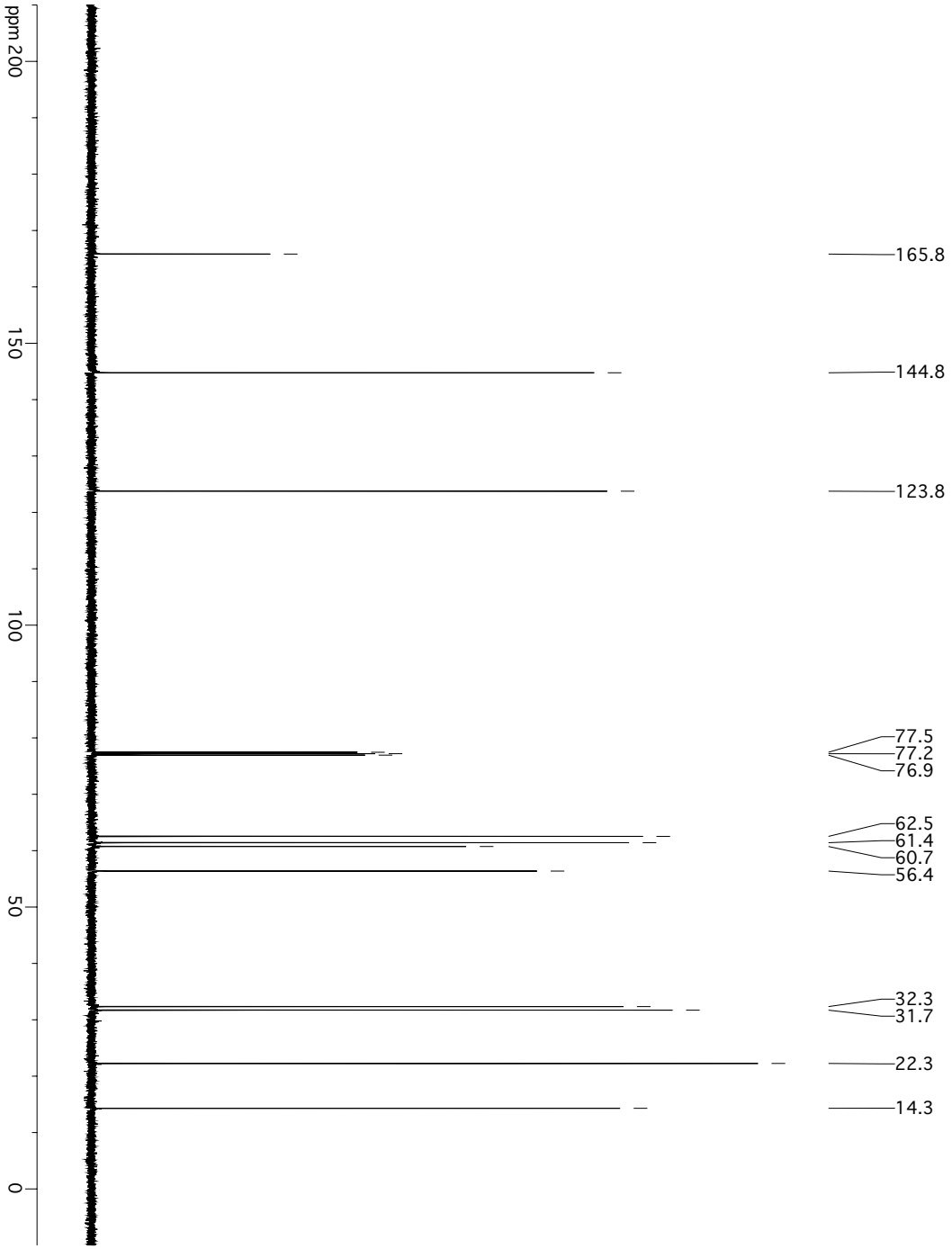

HO
O
O
OEt

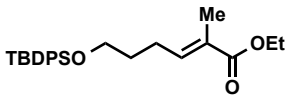
6b


ppm
8
7
6
5
4
3
2
1
0
0.921
0.904
2.05
2.1
1
0.995
0.972
6.41
3.19
7.27
6.67
6.65
6.63
6.62
6.11
6.08
4.19
4.18
4.17
4.15
3.64
3.63
3.61
3.22
3.21
3.20
3.20
2.90
2.89
2.89
2.88
2.87
1.91
1.66
1.65
1.64
1.63
1.63
1.62
1.61
1.60
1.58
1.57
1.56
1.55
1.54
1.53
1.51
1.50
1.28
1.26
1.25

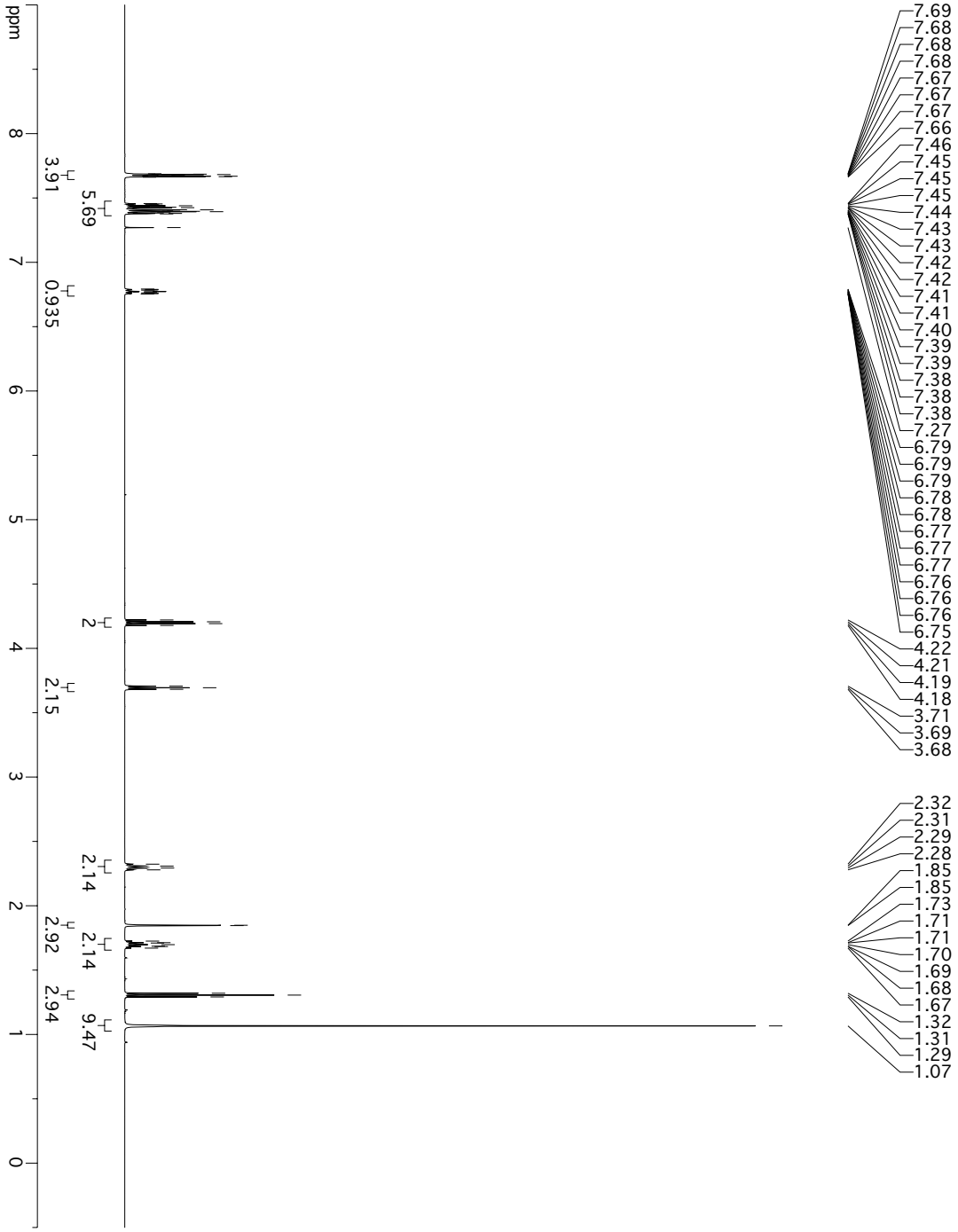

HO
O
O
OEt

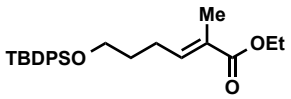
6b


ppm
200
150
100
50
0
165.8
144.8
123.8
77.5
77.2
76.9
62.5
61.4
60.7
56.4
32.3
31.7
22.3
14.3

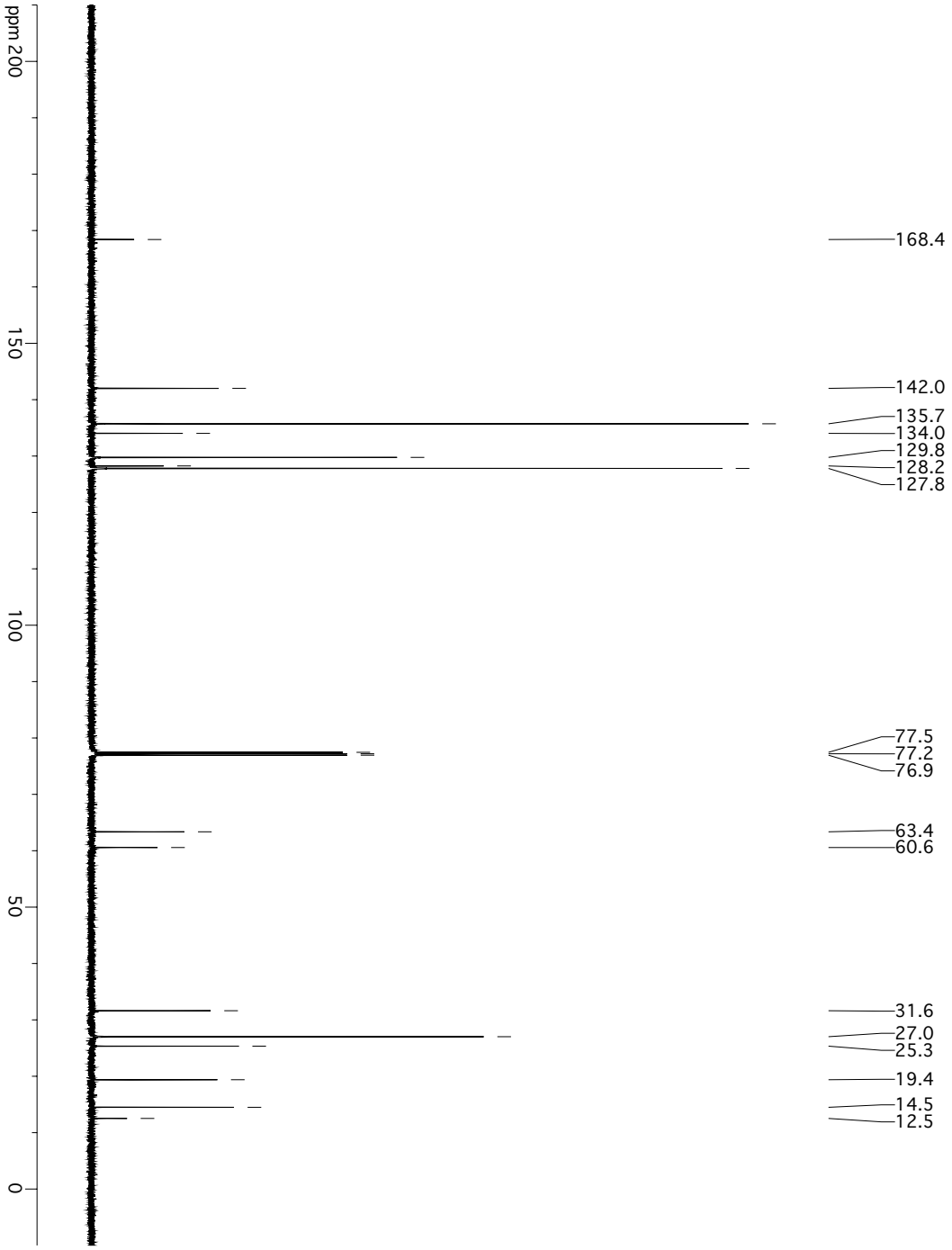

Me
TBDPSO
OEt
O

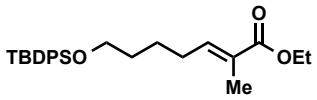
S2c


ppm
8
7
6
5
4
3
2
1
0
3.91
5.69
0.935
2
2.15
2.14
2.92
2.14
2.94
9.47
7.69
7.68
7.68
7.68
7.67
7.67
7.67
7.66
7.46
7.45
7.45
7.45
7.44
7.43
7.43
7.42
7.42
7.41
7.41
7.40
7.39
7.39
7.38
7.38
7.38
7.27
6.79
6.79
6.79
6.78
6.78
6.77
6.77
6.77
6.76
6.76
6.76
6.75
4.22
4.21
4.19
4.18
3.71
3.69
3.68
2.32
2.31
2.29
2.28
1.85
1.85
1.73
1.71
1.71
1.70
1.69
1.68
1.67
1.32
1.31
1.29
1.07

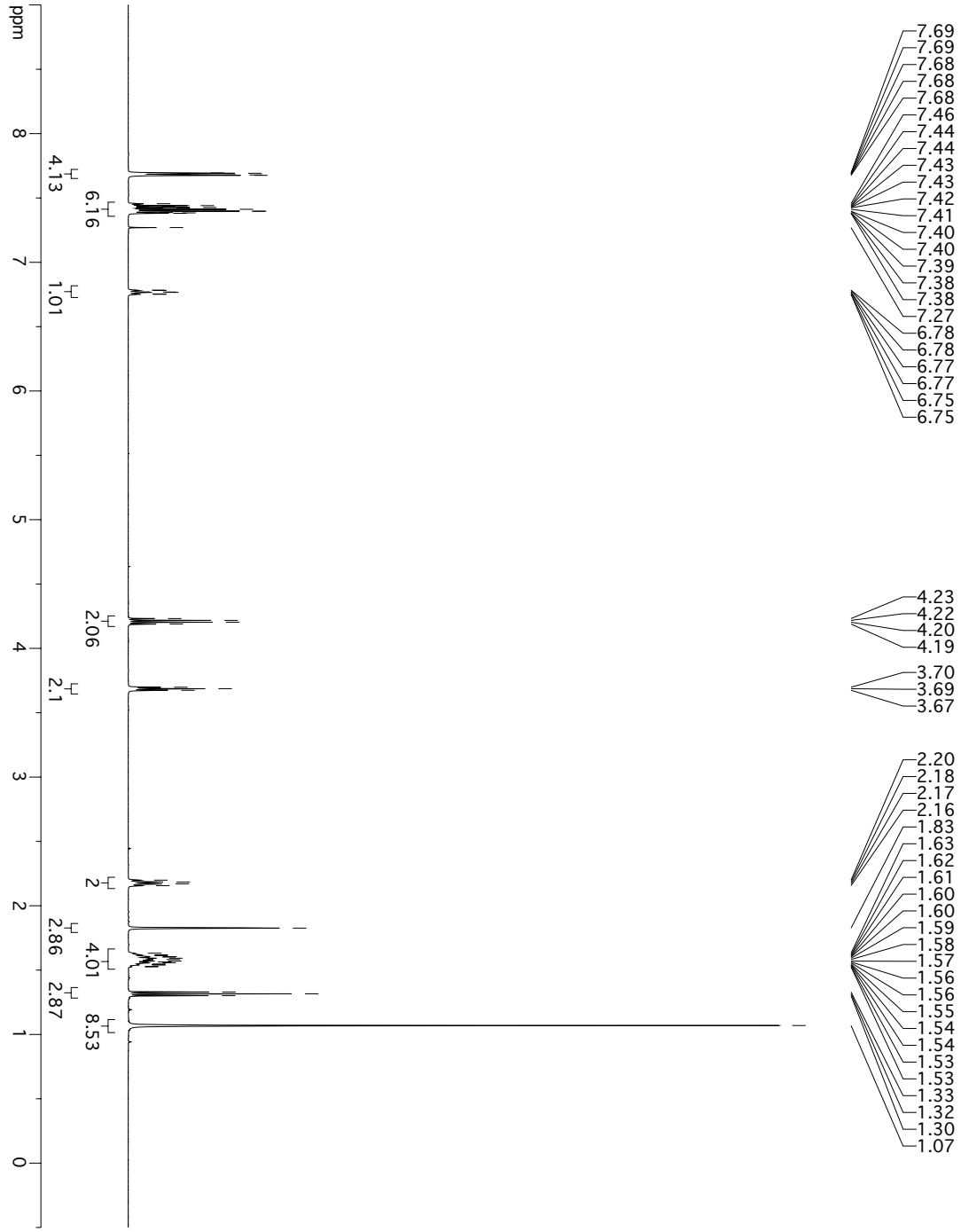

Me
TBDPSO
OEt
O

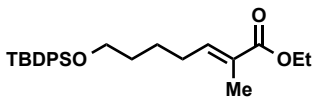
S2c


ppm
200
150
100
50
0
168.4
142.0
135.7
134.0
129.8
128.2
127.8
77.5
77.2
76.9
63.4
60.6
31.6
27.0
25.3
19.4
14.5
12.5

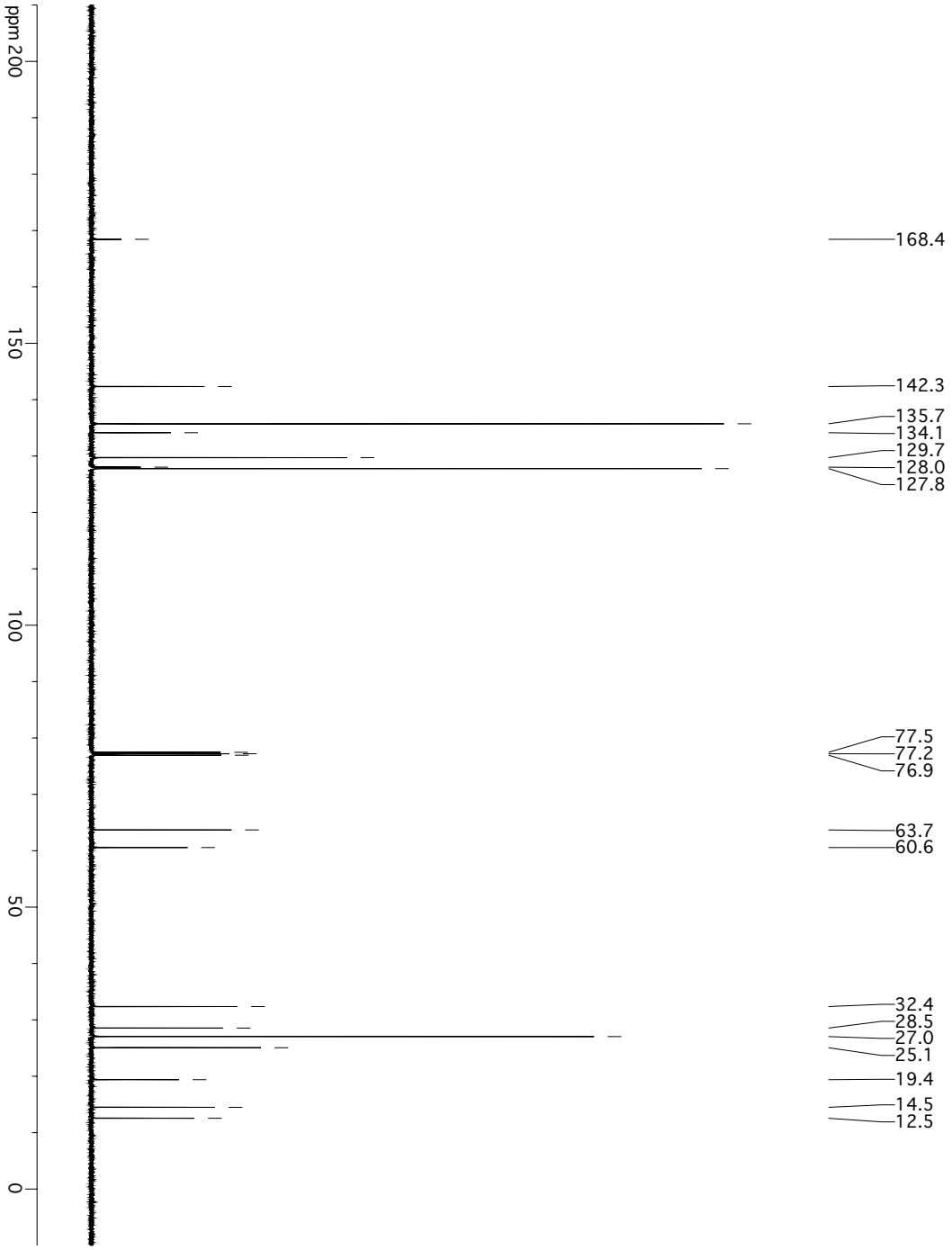

TBDPSO
O
OEt
Me

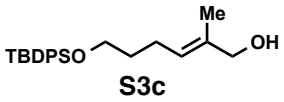
S2d


ppm
8
7
6
5
4
3
2
1
0
4.13
6.16
1.01
2.06
2.1
2
2.86
4.01
2.87
8.53
7.69
7.69
7.68
7.68
7.68
7.46
7.44
7.44
7.43
7.43
7.42
7.41
7.40
7.40
7.39
7.38
7.38
7.27
6.78
6.78
6.77
6.77
6.75
6.75
4.23
4.22
4.20
4.19
3.70
3.69
3.67
2.20
2.18
2.17
2.16
1.83
1.63
1.62
1.61
1.60
1.60
1.59
1.58
1.57
1.56
1.56
1.55
1.54
1.54
1.53
1.53
1.33
1.32
1.30
1.07

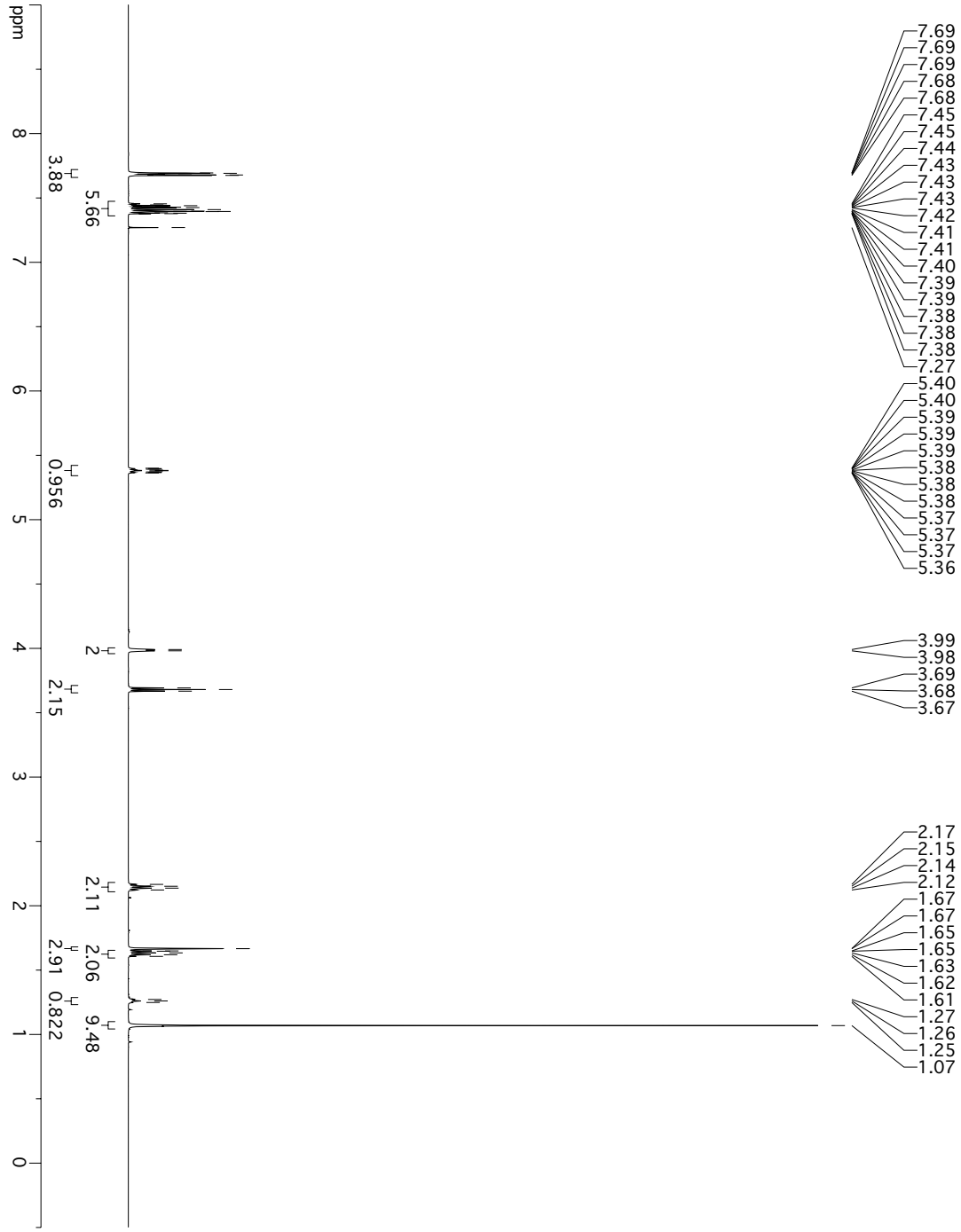

TBDPSO
O
OEt
Me

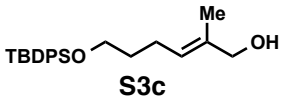
S2d


ppm
200
150
100
50
0
168.4
142.3
135.7
134.1
129.7
128.0
127.8
77.5
77.2
76.9
63.7
60.6
32.4
28.5
27.0
25.1
19.4
14.5
12.5

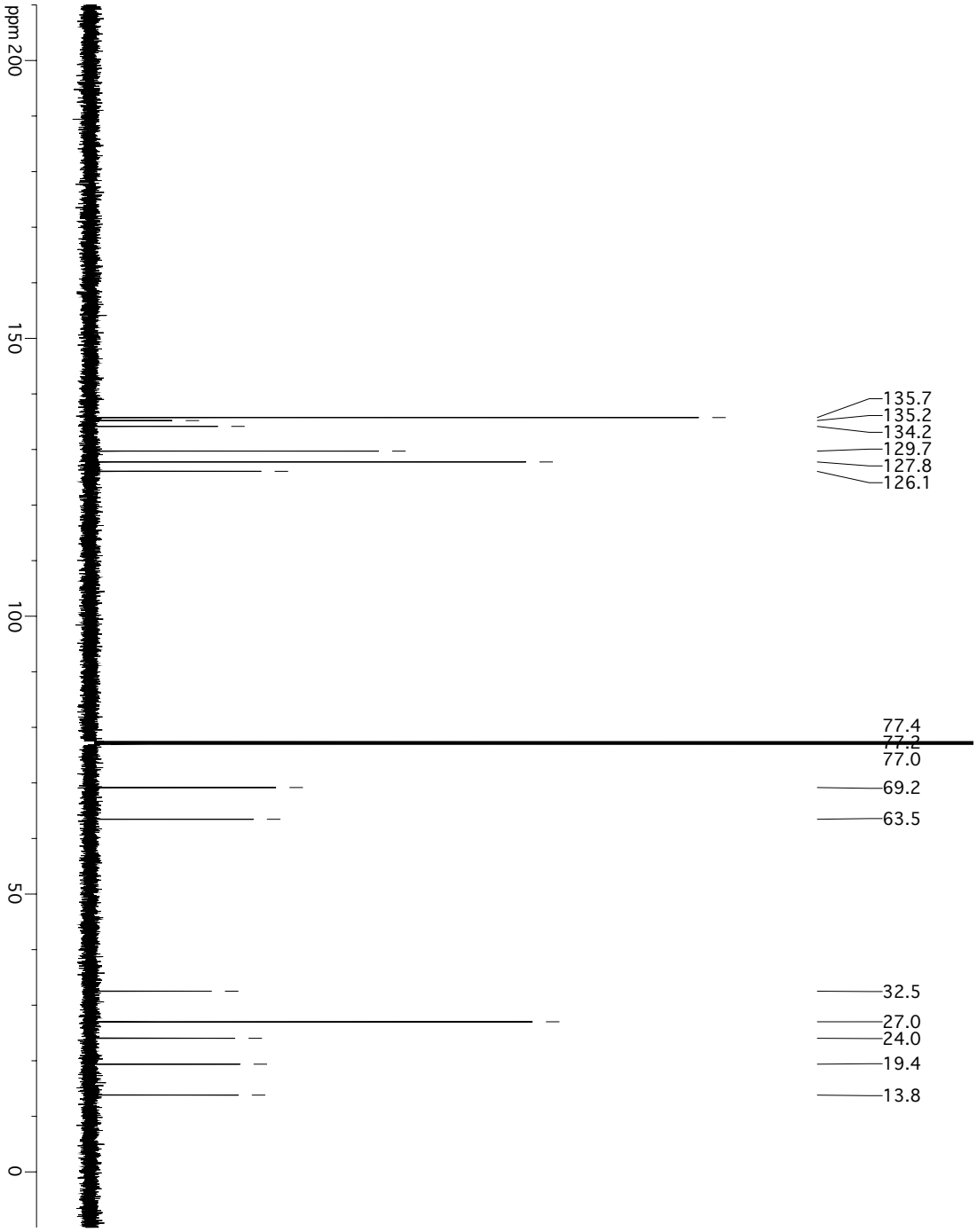

Me
TBDPSO
OH

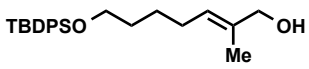
S3c


ppm
8
7
6
5
4
3
2
1
0
3.88
5.66
0.956
2
2.15
2.11
2.06
2.91
0.822
9.48
7.69
7.69
7.69
7.68
7.68
7.45
7.45
7.44
7.43
7.43
7.43
7.42
7.41
7.41
7.40
7.39
7.39
7.38
7.38
7.38
7.27
5.40
5.40
5.39
5.39
5.39
5.38
5.38
5.38
5.37
5.37
5.37
5.36
3.99
3.98
3.69
3.68
3.67
2.17
2.15
2.14
2.12
1.67
1.67
1.65
1.65
1.63
1.62
1.61
1.27
1.26
1.25
1.07

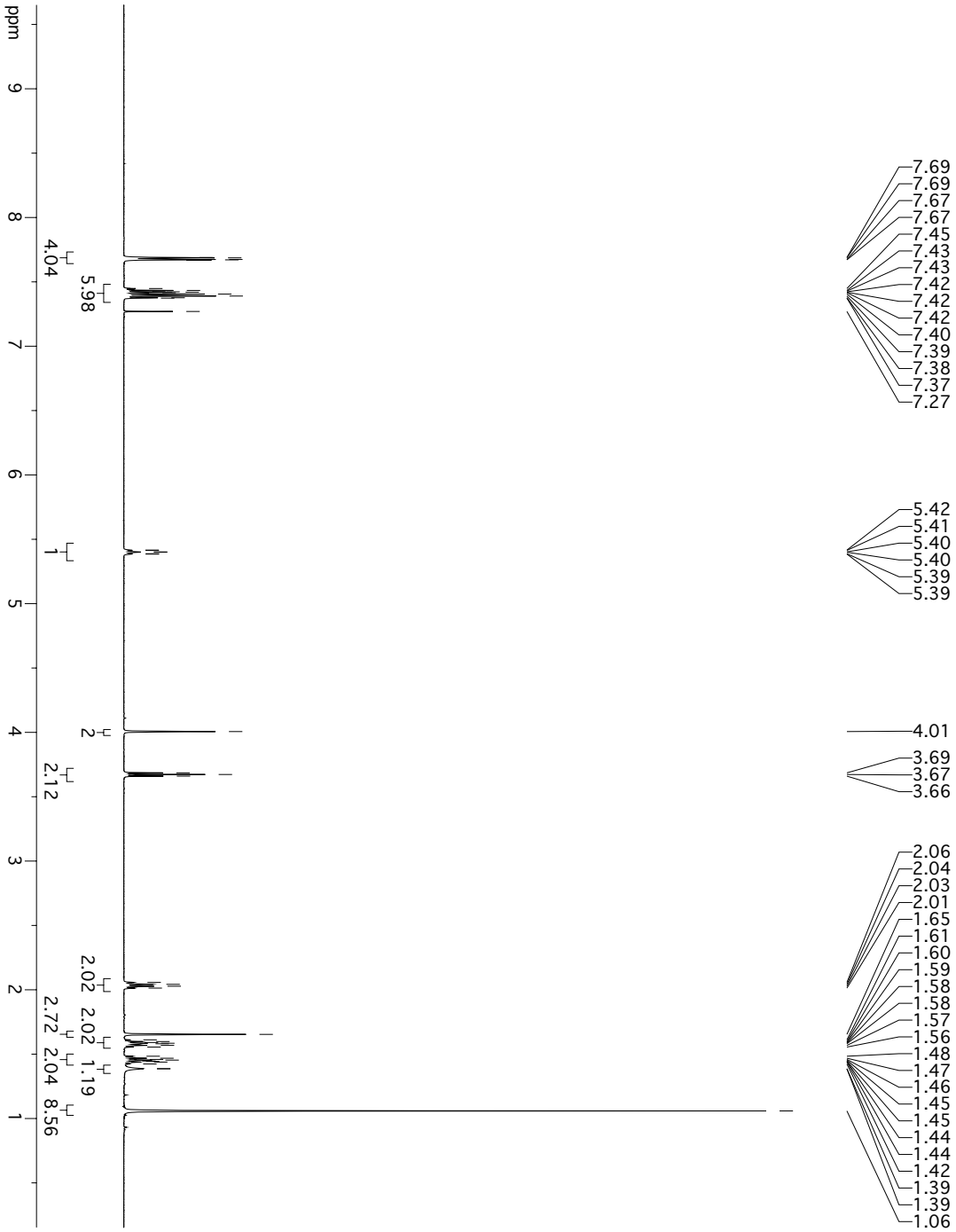

Me
TBDPSO
OH

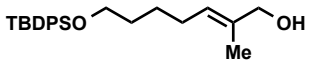
S3c


ppm
200
150
100
50
0
135.7
135.2
134.2
129.7
127.8
126.1
77.4
77.2
77.0
69.2
63.5
32.5
27.0
24.0
19.4
13.8

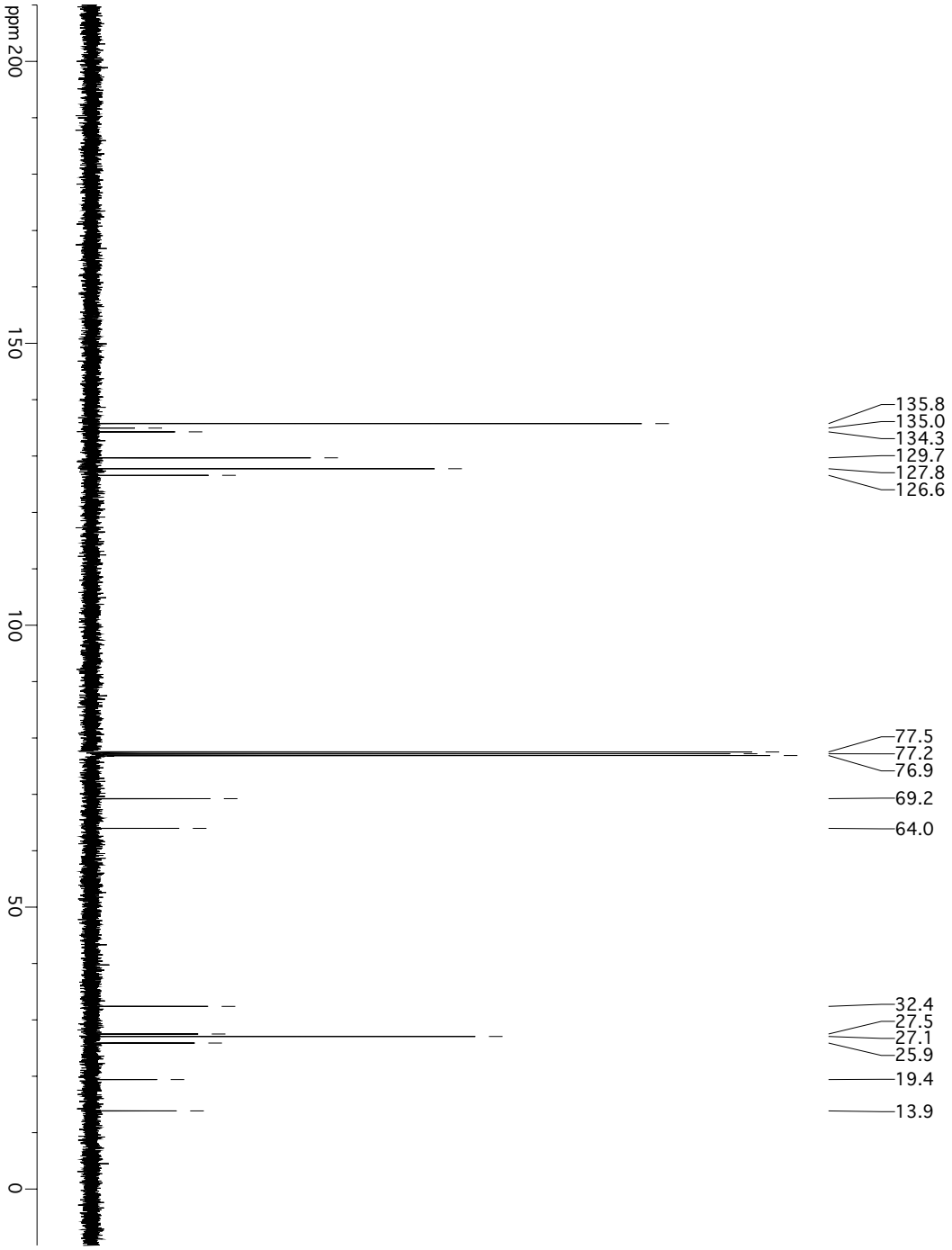

TBDPSO
OH
Me

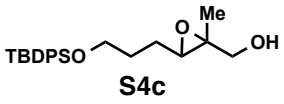
S3d


ppm
9
8
7
6
5
4
3
2
1
4.04
5.98
1
2
2.12
2.02
2.02
1.19
2.72
2.04
8.56
7.69
7.69
7.67
7.67
7.45
7.43
7.43
7.42
7.42
7.42
7.40
7.39
7.38
7.37
7.27
5.42
5.41
5.40
5.40
5.39
5.39
4.01
3.69
3.67
3.66
2.06
2.04
2.03
2.01
1.65
1.61
1.60
1.59
1.58
1.58
1.57
1.56
1.48
1.47
1.46
1.45
1.45
1.44
1.44
1.42
1.39
1.39
1.06

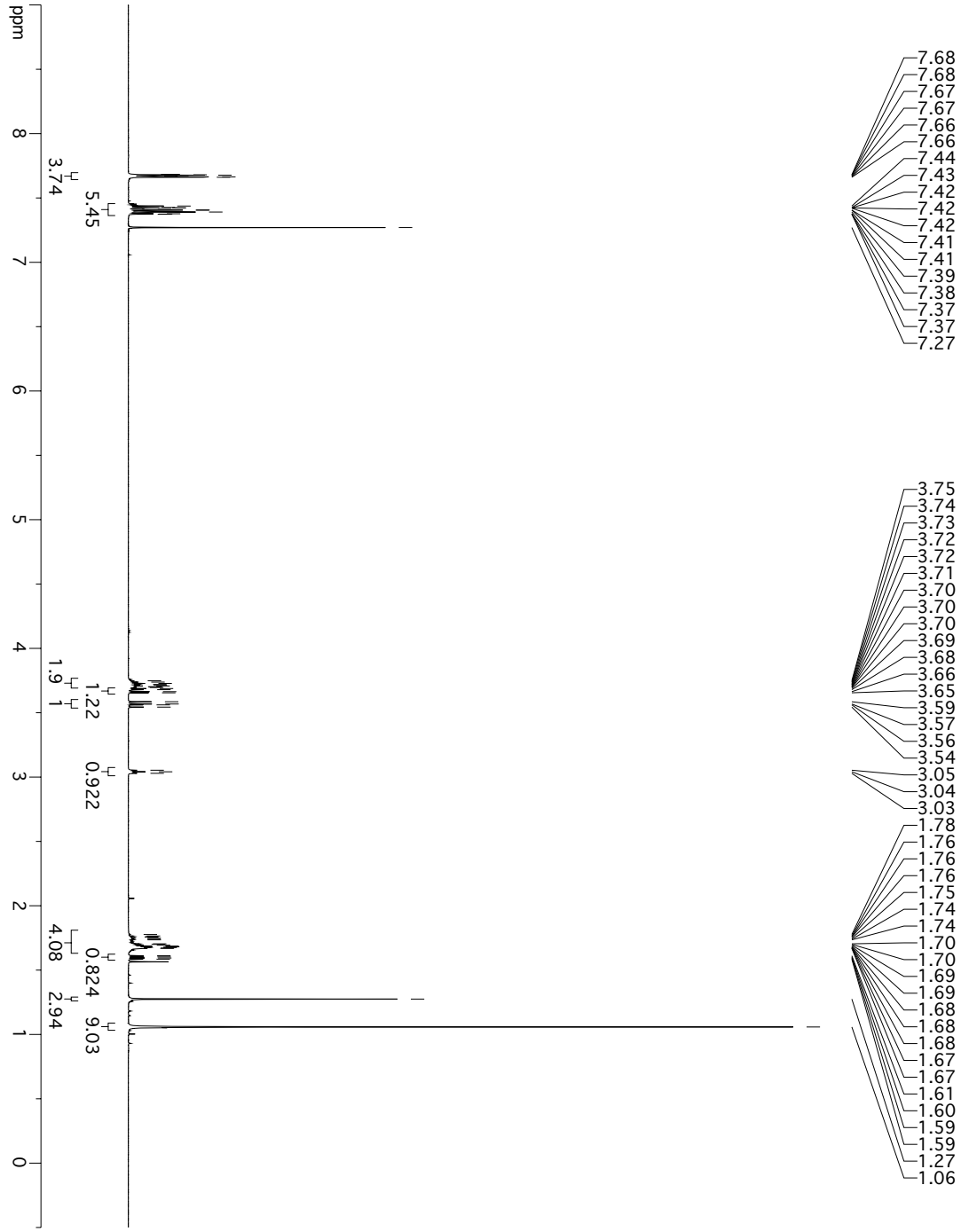

TBDPSO
OH
Me

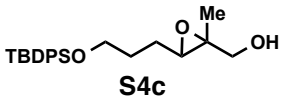
S3d


ppm
200
150
100
50
0
135.8
135.0
134.3
129.7
127.8
126.6
77.5
77.2
76.9
69.2
64.0
32.4
27.5
27.1
25.9
19.4
13.9

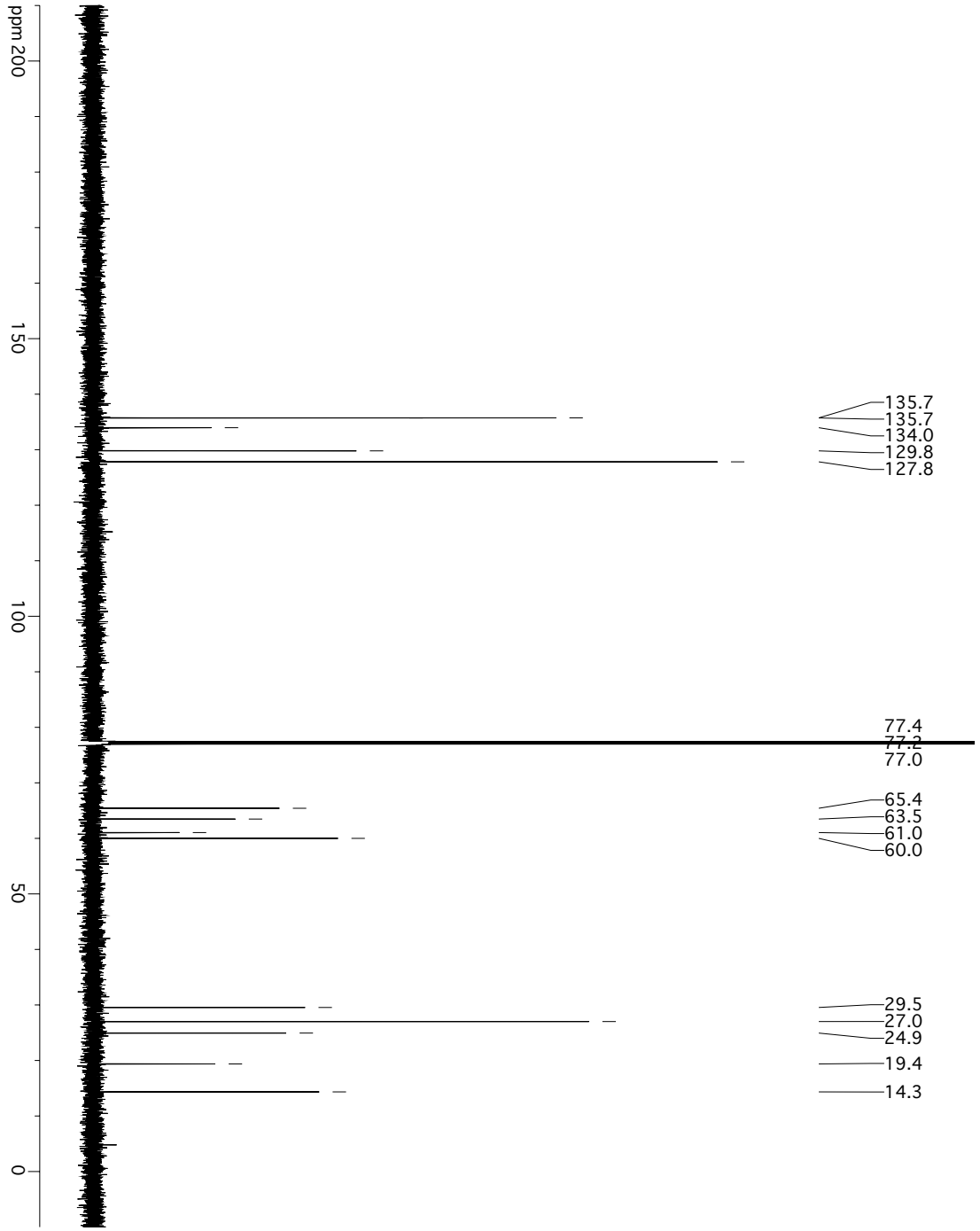

Me
O
TBDPSO
OH

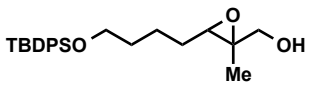
S4c


ppm
8
7
6
5
4
3
2
1
0
3.74
5.45
1.9
1
1.22
0.922
4.08
0.824
2.94
9.03
7.68
7.68
7.67
7.67
7.66
7.66
7.44
7.43
7.42
7.42
7.42
7.41
7.41
7.39
7.38
7.37
7.37
7.27
3.75
3.74
3.73
3.72
3.72
3.71
3.70
3.70
3.70
3.69
3.68
3.66
3.65
3.59
3.57
3.56
3.54
3.05
3.04
3.03
1.78
1.76
1.76
1.76
1.75
1.74
1.74
1.70
1.70
1.69
1.69
1.68
1.68
1.68
1.67
1.67
1.61
1.60
1.59
1.59
1.27
1.06

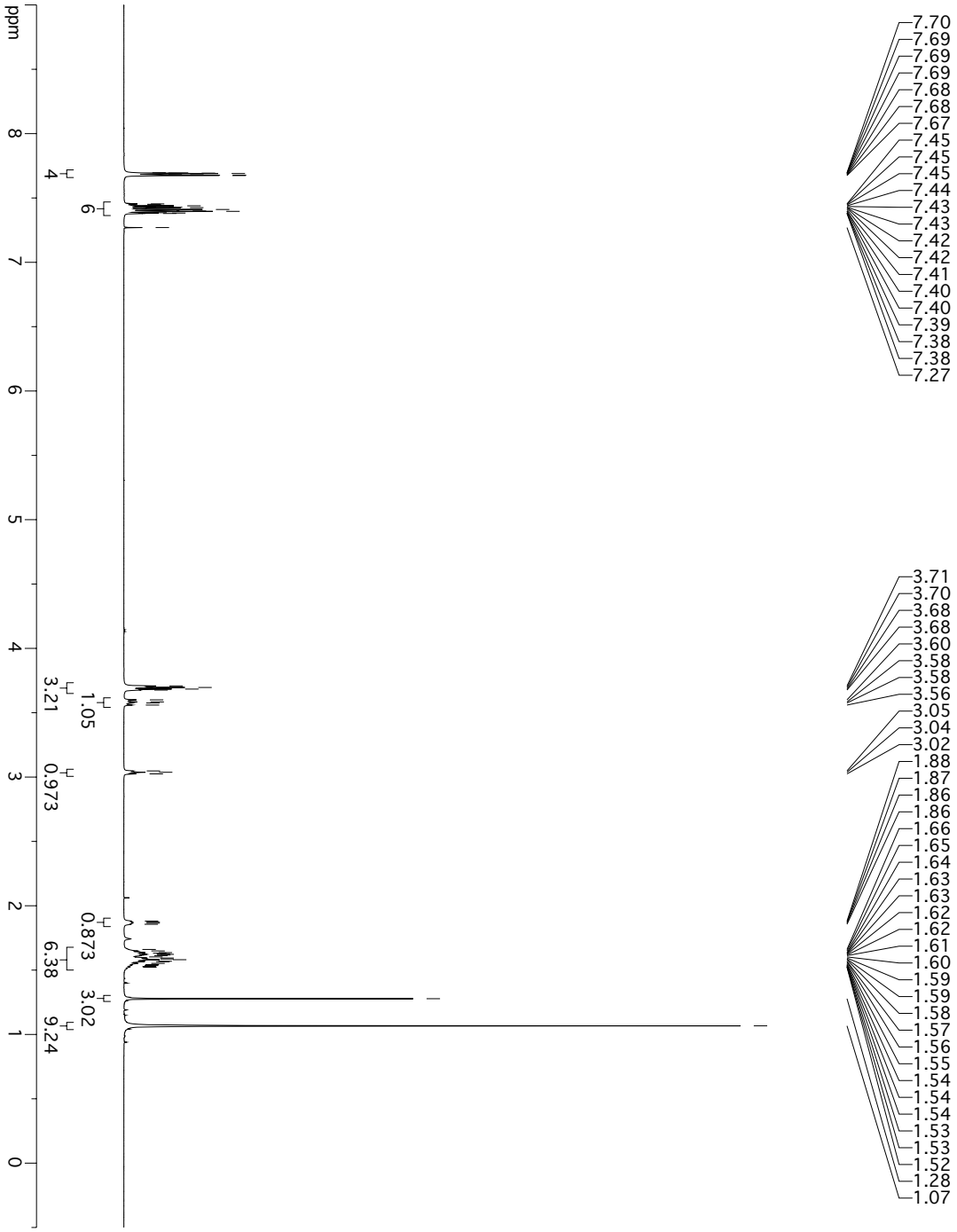

Me
O
TBDPSO
OH

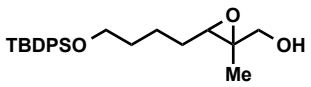
S4c


ppm
200
150
100
50
0
135.7
135.7
134.0
129.8
127.8
77.4
77.2
77.0
65.4
63.5
61.0
60.0
29.5
27.0
24.9
19.4
14.3

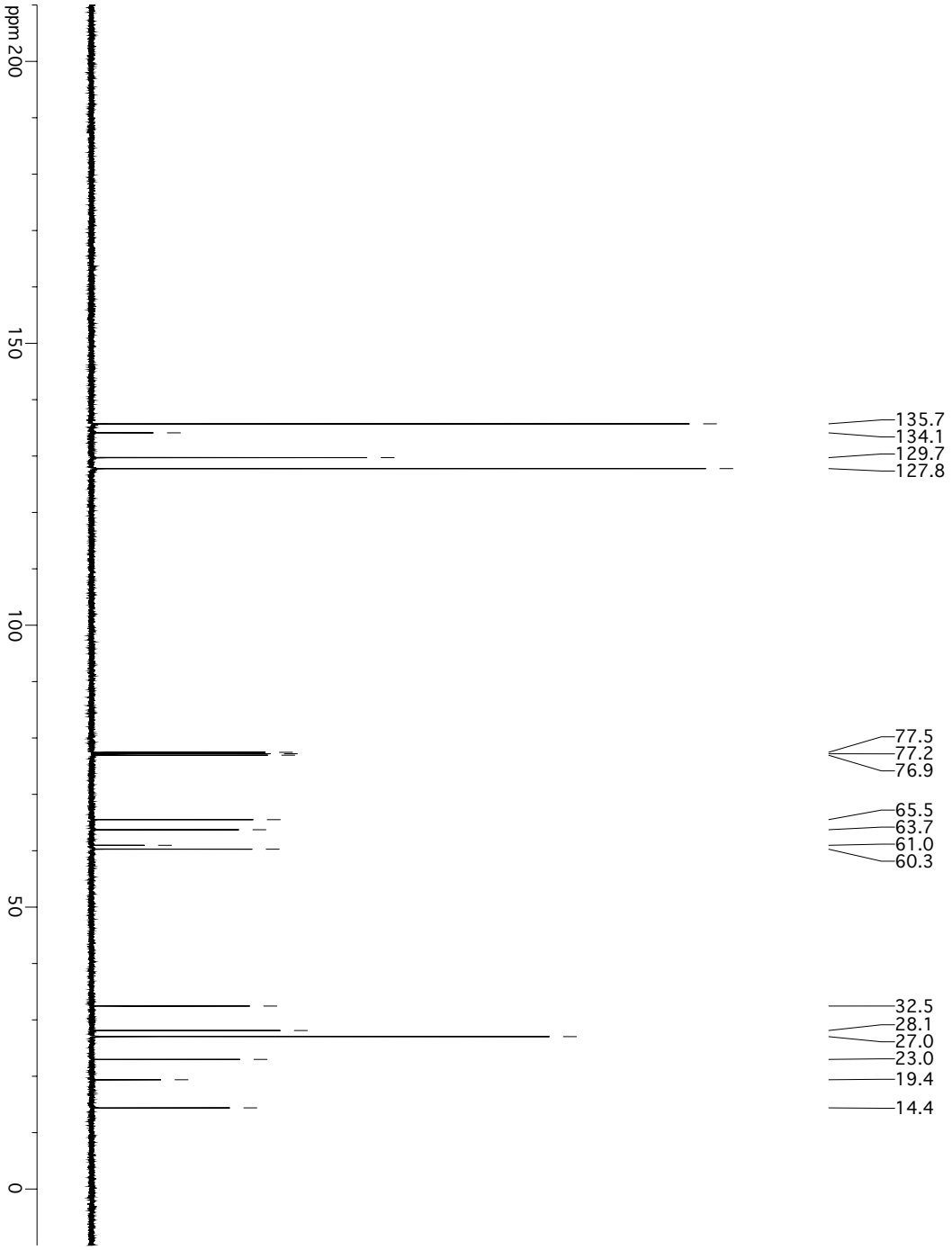

TBDPSO
O
OH
Me

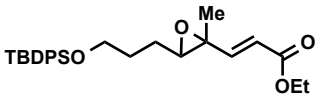
S4d


ppm
8
7
6
5
4
3
2
1
0
4
6
3.21
1.05
0.973
0.873
6.38
3.02
9.24
7.70
7.69
7.69
7.69
7.68
7.68
7.67
7.45
7.45
7.45
7.44
7.43
7.43
7.42
7.42
7.41
7.40
7.40
7.39
7.38
7.38
7.27
3.71
3.70
3.68
3.68
3.60
3.58
3.58
3.56
3.05
3.04
3.02
1.88
1.87
1.86
1.86
1.66
1.65
1.64
1.63
1.63
1.62
1.62
1.61
1.60
1.59
1.59
1.58
1.57
1.56
1.55
1.54
1.54
1.54
1.53
1.53
1.52
1.28
1.07

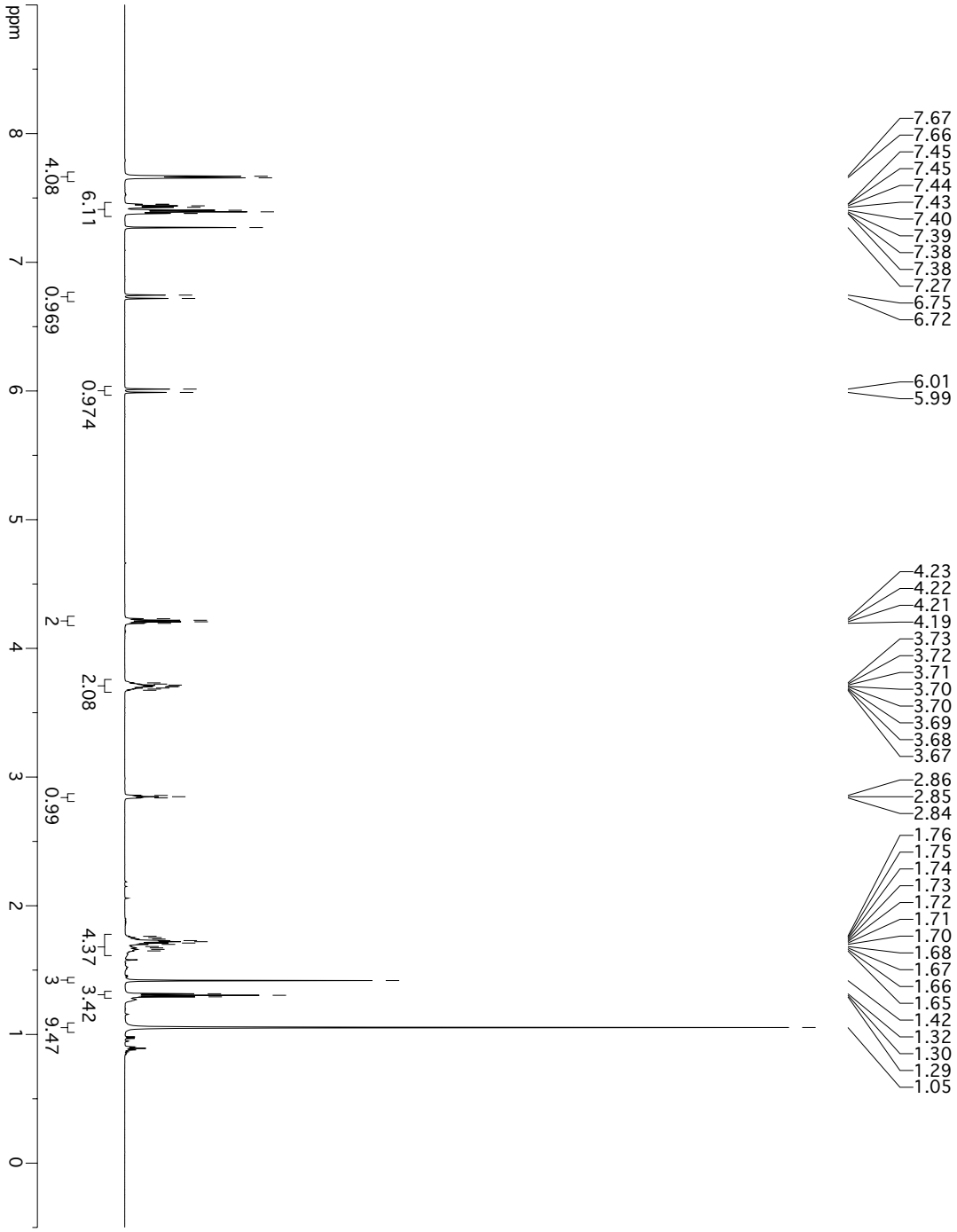

TBDPSO
O
OH
Me

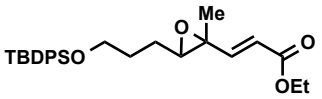
S4d


ppm
200
150
100
50
0
135.7
134.1
129.7
127.8
77.5
77.2
76.9
65.5
63.7
61.0
60.3
32.5
28.1
27.0
23.0
19.4
14.4

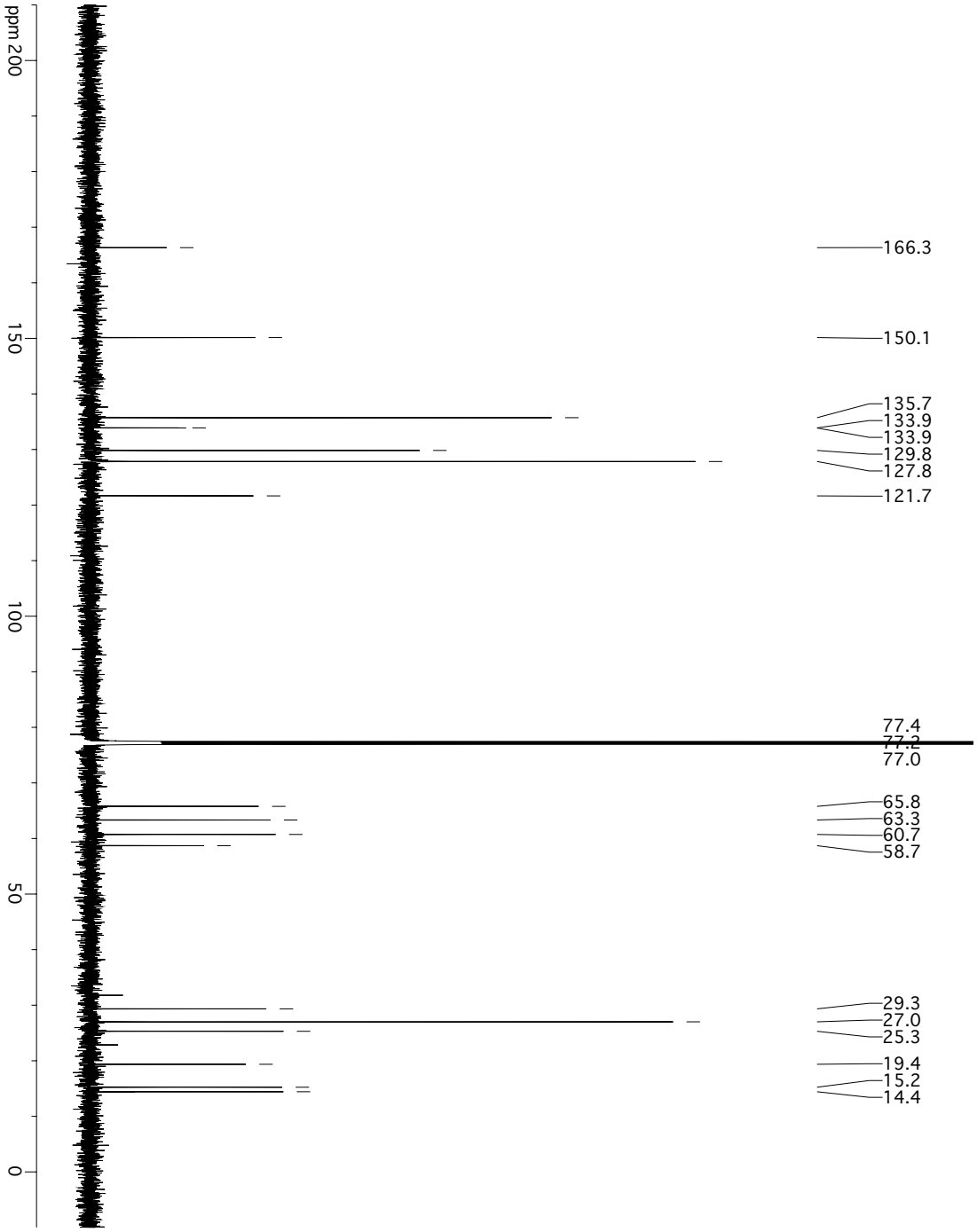

TBDPSO
O
Me
O
O
OEt

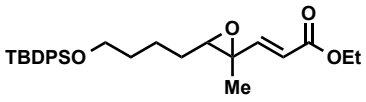
S5c


ppm
8
7
6
5
4
3
2
1
0
4.08
6.11
0.969
0.974
2
2.08
0.99
4.37
3
3.42
9.47
7.67
7.66
7.45
7.45
7.44
7.43
7.40
7.39
7.38
7.38
7.27
6.75
6.72
6.01
5.99
4.23
4.22
4.21
4.19
3.73
3.72
3.71
3.70
3.70
3.69
3.68
3.67
2.86
2.85
2.84
1.76
1.75
1.74
1.73
1.72
1.71
1.70
1.68
1.67
1.66
1.65
1.42
1.32
1.30
1.29
1.05

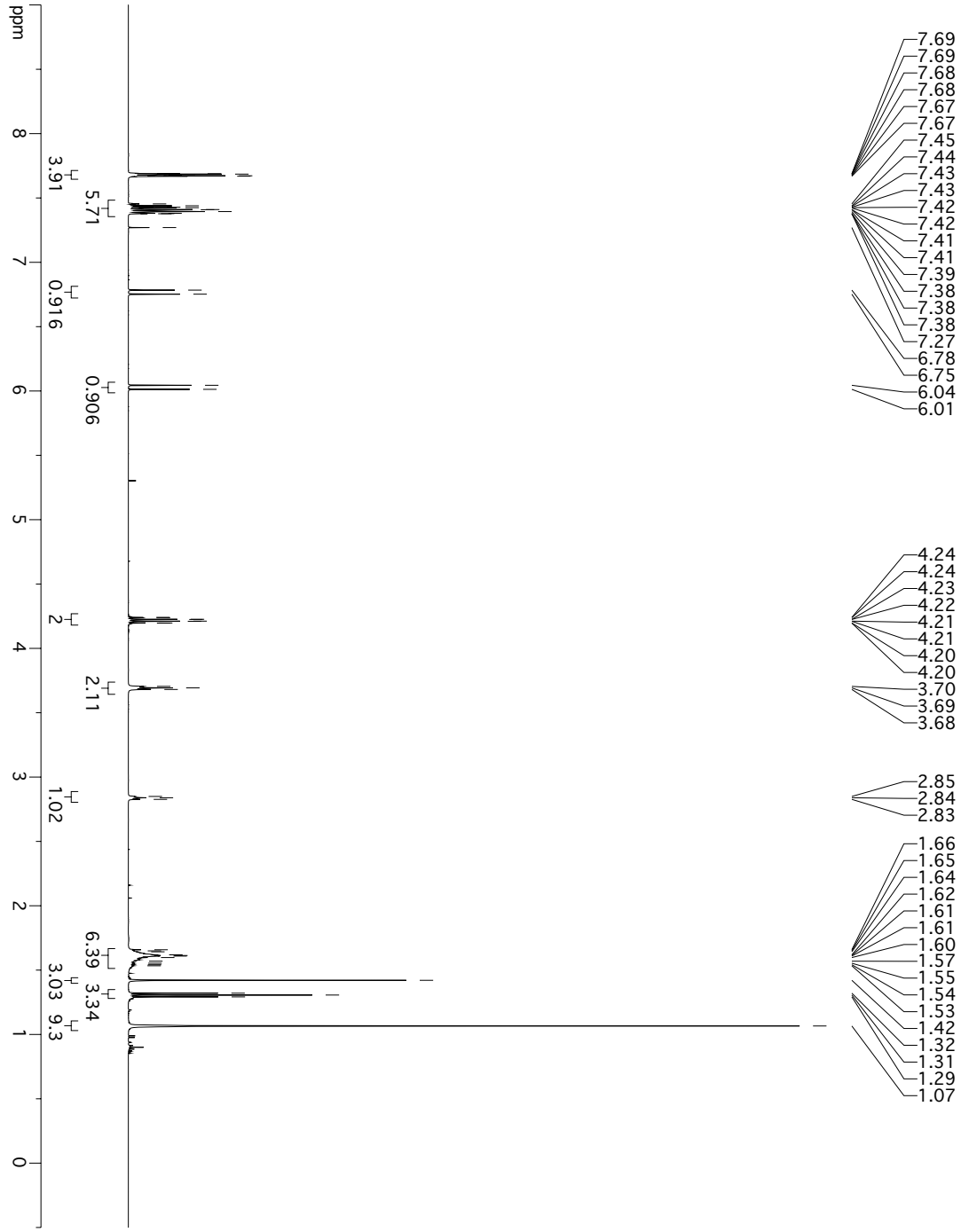

Me
O
TBDPSO
O
OEt

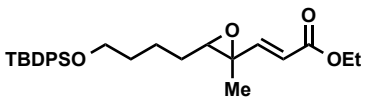
S5c


ppm
200
150
100
50
0
166.3
150.1
135.7
133.9
133.9
129.8
127.8
121.7
77.4
77.2
77.0
65.8
63.3
60.7
58.7
29.3
27.0
25.3
19.4
15.2
14.4

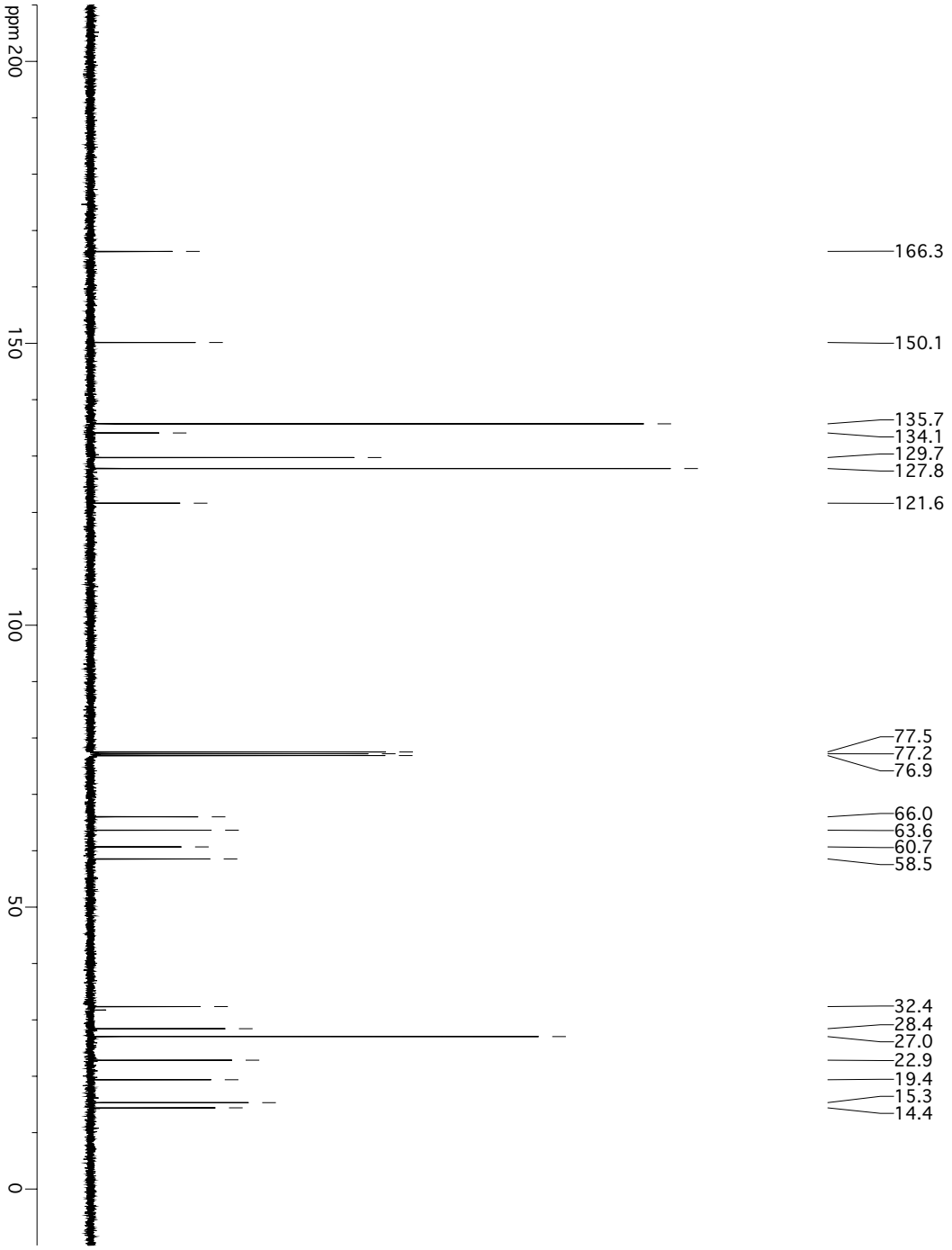

TBDPSO
O
O
OEt
Me

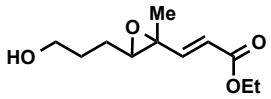
S5d


ppm
8
7
6
5
4
3
2
1
0
3.91
5.71
0.916
0.906
2
2.11
1.02
6.39
3.34
3.03
9.3
7.69
7.69
7.68
7.68
7.67
7.67
7.45
7.44
7.43
7.43
7.42
7.42
7.41
7.41
7.39
7.38
7.38
7.38
7.27
6.78
6.75
6.04
6.01
4.24
4.24
4.23
4.22
4.21
4.21
4.20
4.20
3.70
3.69
3.68
2.85
2.84
2.83
1.66
1.65
1.64
1.62
1.61
1.61
1.60
1.57
1.55
1.54
1.53
1.42
1.32
1.31
1.29
1.07

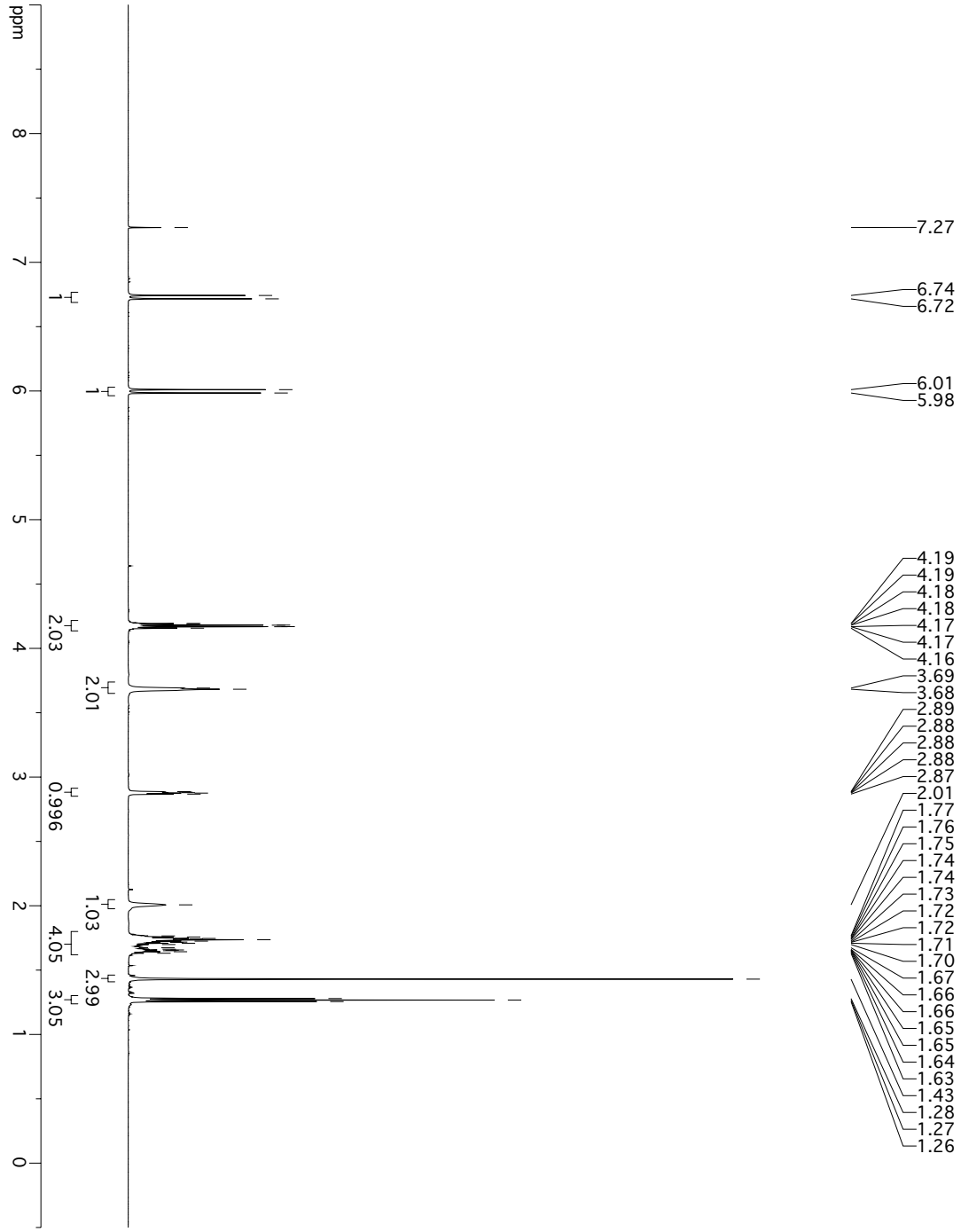

TBDPSO
O
O
OEt
Me

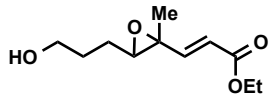
S5d


ppm
200
150
100
50
0
166.3
150.1
135.7
134.1
129.7
127.8
121.6
77.5
77.2
76.9
66.0
63.6
60.7
58.5
32.4
28.4
27.0
22.9
19.4
15.3
14.4

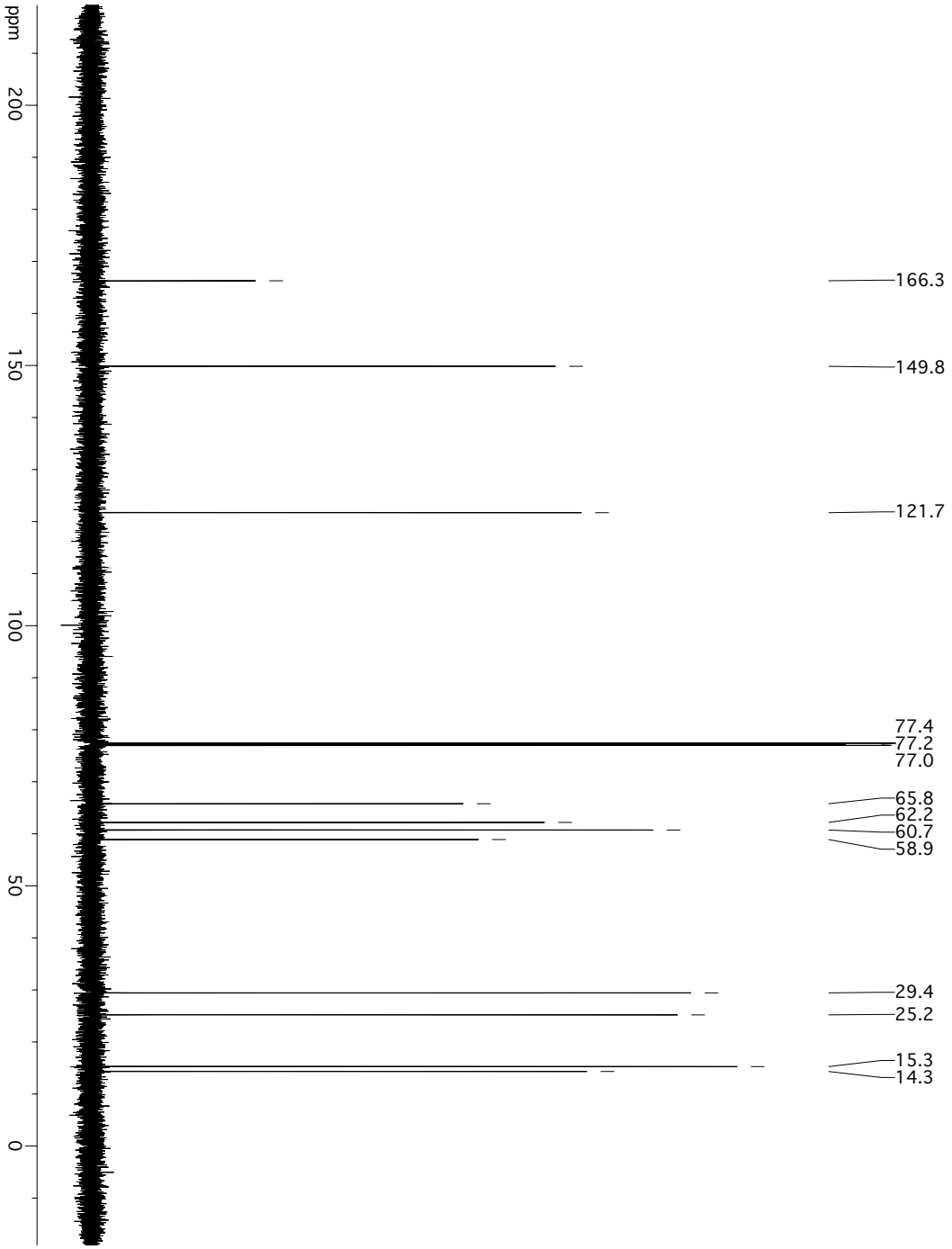

Me
O
HO
O
OEt

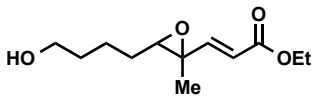
6c


ppm
8
7
6
5
4
3
2
1
0
1
1
2.03
2.01
0.996
1.03
4.05
2.99
3.05
7.27
6.74
6.72
6.01
5.98
4.19
4.19
4.18
4.18
4.17
4.17
4.16
3.69
3.68
2.89
2.88
2.88
2.88
2.87
2.01
1.77
1.76
1.75
1.74
1.74
1.73
1.72
1.72
1.71
1.70
1.67
1.66
1.66
1.65
1.65
1.64
1.63
1.43
1.28
1.27
1.26

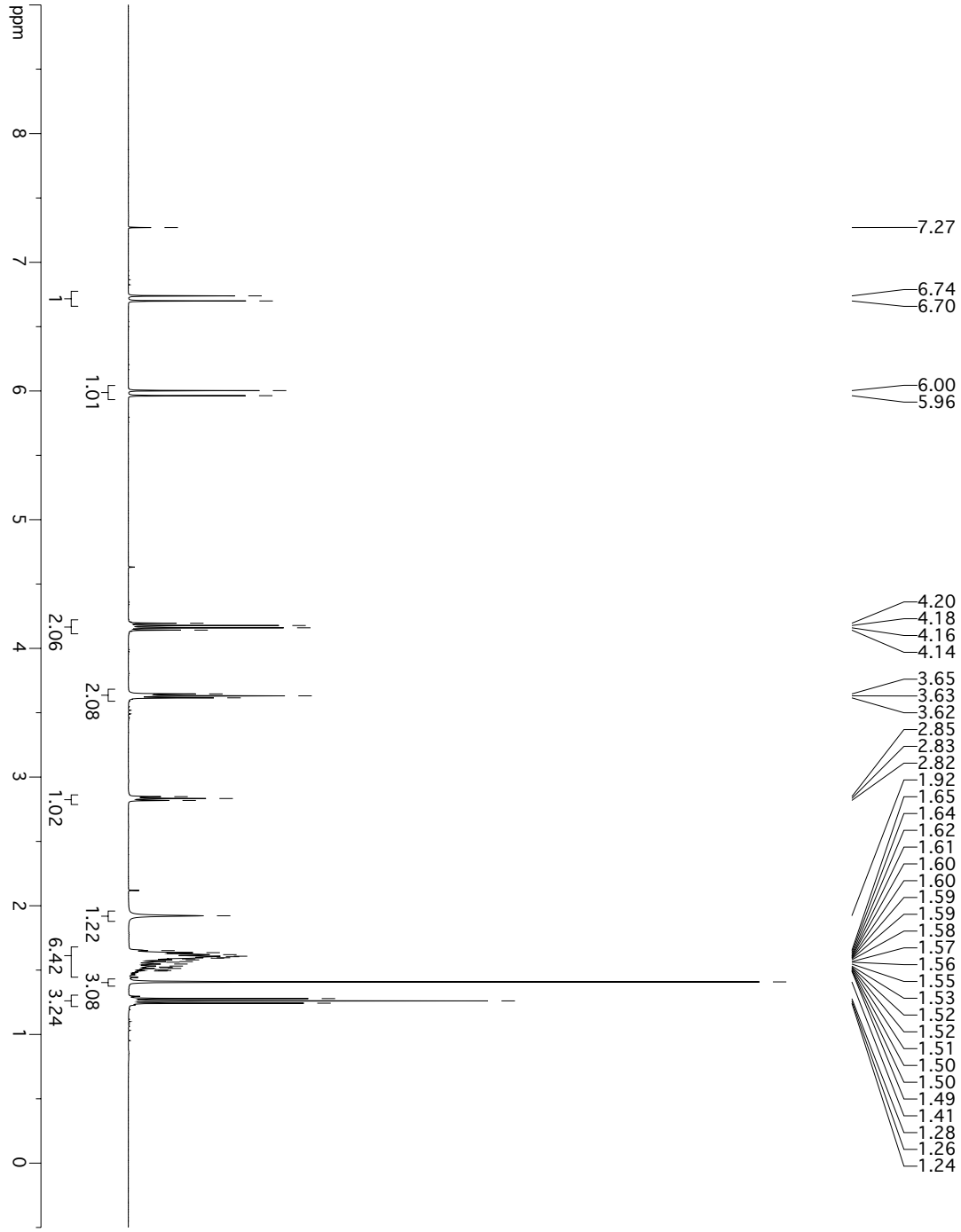

Me
O
HO
O
OEt

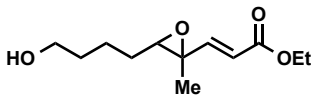
6c


ppm
200
150
100
50
0
166.3
149.8
121.7
77.4
77.2
77.0
65.8
62.2
60.7
58.9
29.4
25.2
15.3
14.3

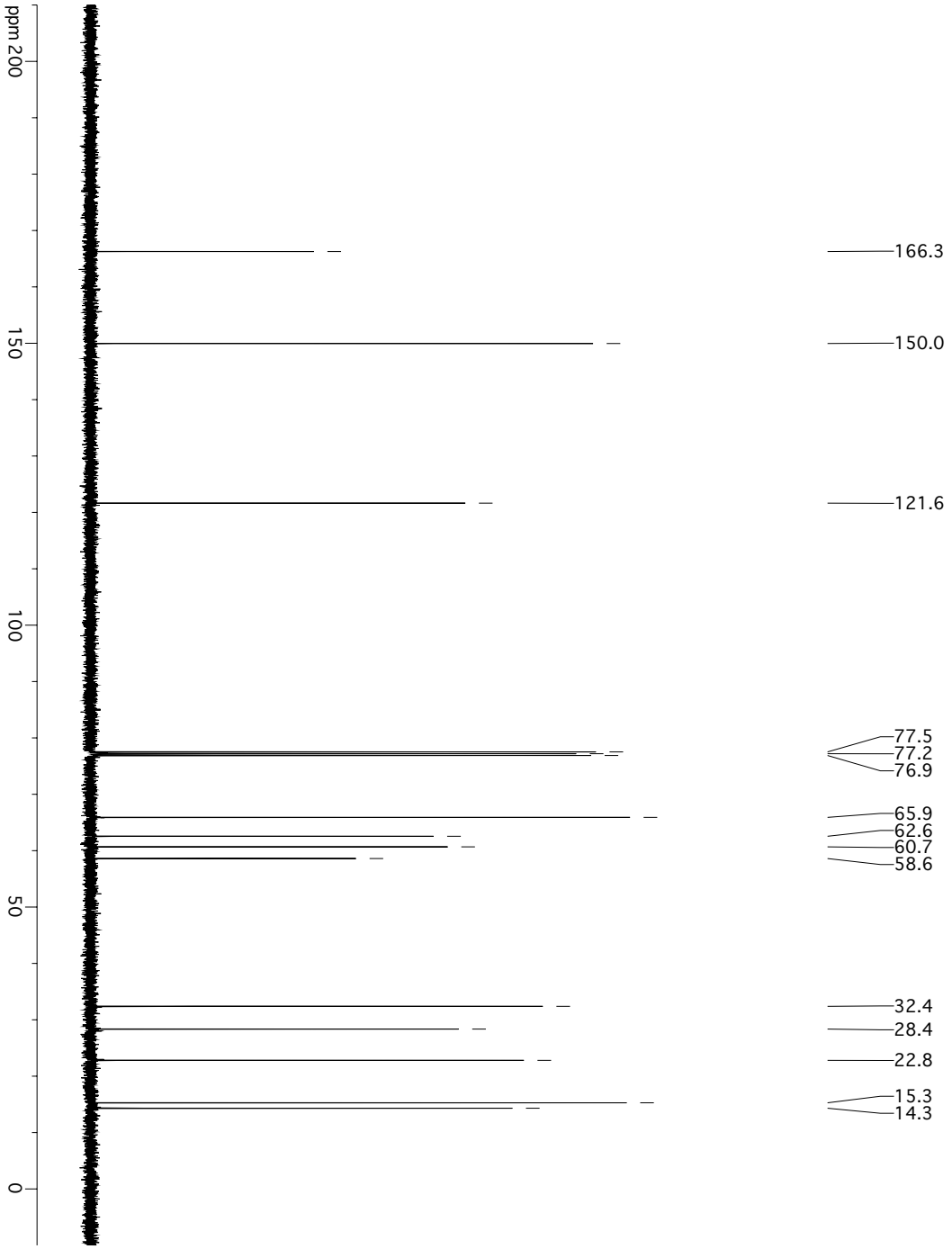

HO
O
O
OEt
Me

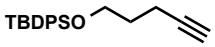
6d


ppm
8
7
6
5
4
3
2
1
0
1
1.01
2.06
2.08
1.02
1.22
6.42
3.08
3.24
7.27
6.74
6.70
6.00
5.96
4.20
4.18
4.16
4.14
3.65
3.63
3.62
2.85
2.83
2.82
1.92
1.65
1.64
1.62
1.61
1.60
1.60
1.59
1.59
1.58
1.57
1.56
1.55
1.53
1.52
1.52
1.51
1.50
1.50
1.49
1.41
1.28
1.26
1.24

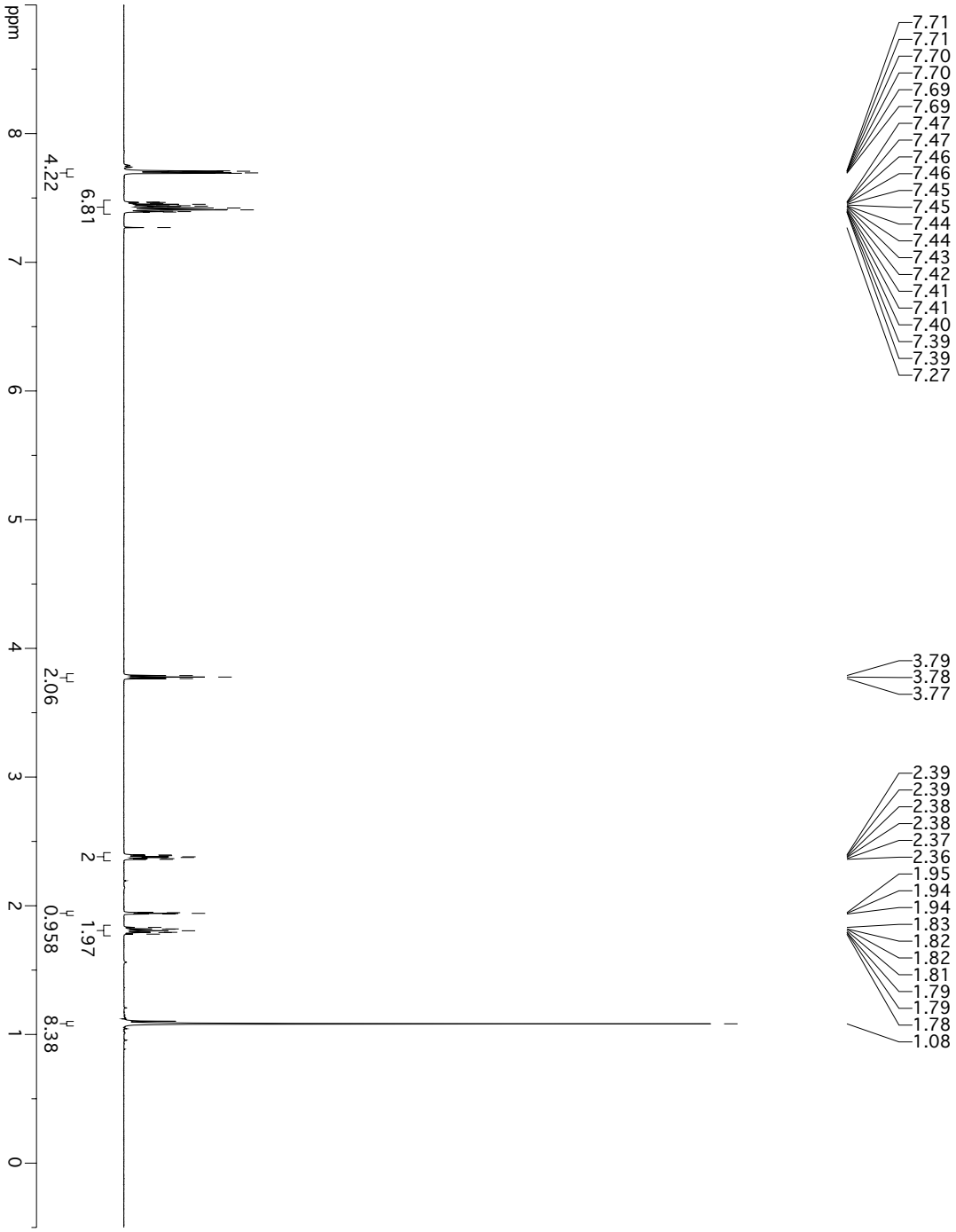

HO
O
O
OEt
Me

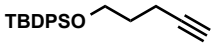
6d


ppm
200
150
100
50
0
166.3
150.0
121.6
77.5
77.2
76.9
65.9
62.6
60.7
58.6
32.4
28.4
22.8
15.3
14.3

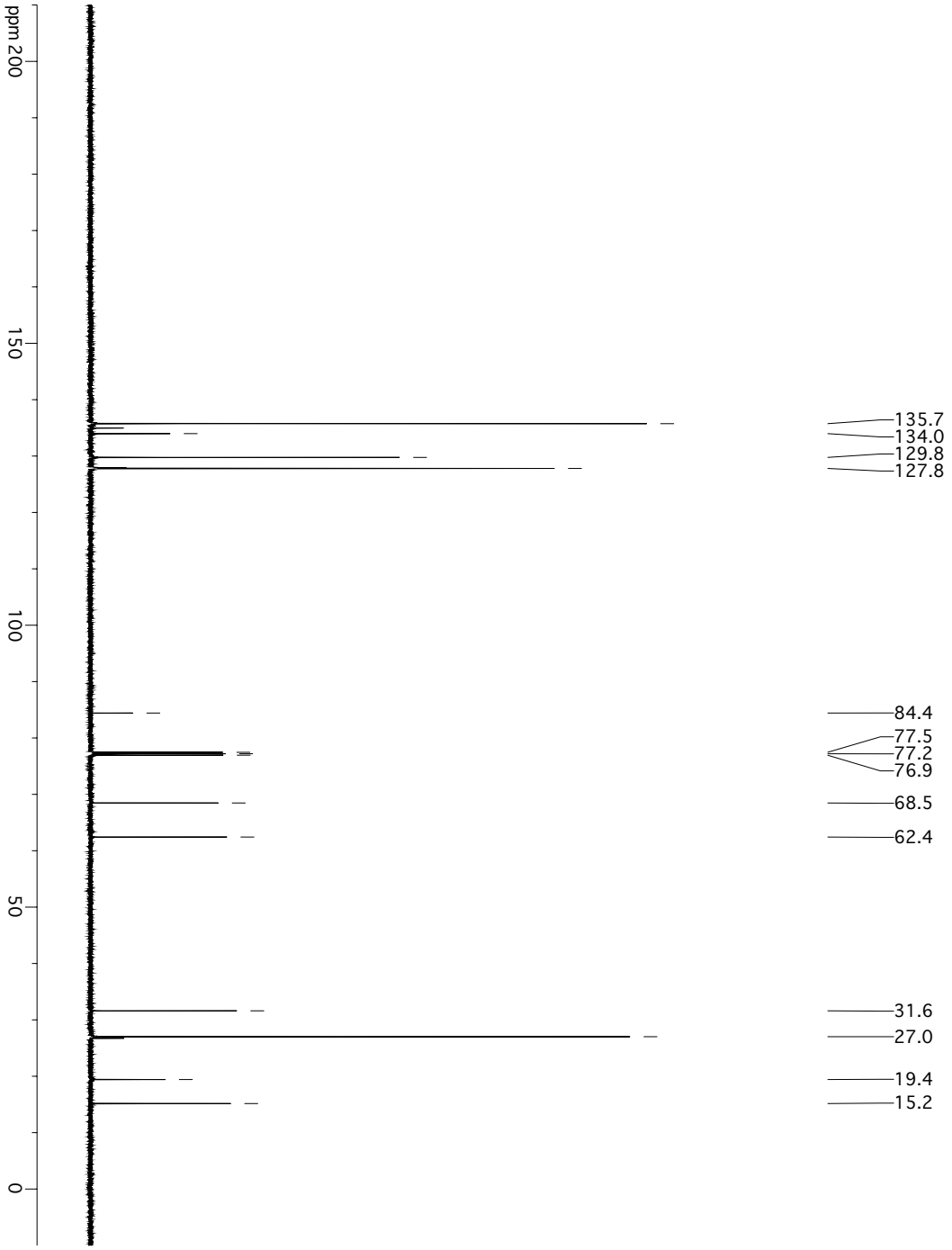

TBDPSO

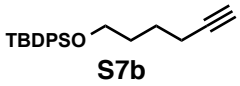
S7a


ppm
8
7
6
5
4
3
2
1
0
4.22
6.81
2.06
2
0.958
1.97
8.38
7.71
7.71
7.70
7.70
7.69
7.69
7.47
7.47
7.46
7.46
7.45
7.45
7.44
7.44
7.43
7.42
7.41
7.41
7.40
7.39
7.39
7.27
3.79
3.78
3.77
2.39
2.39
2.38
2.38
2.37
2.36
1.95
1.94
1.94
1.83
1.82
1.82
1.81
1.79
1.79
1.78
1.08

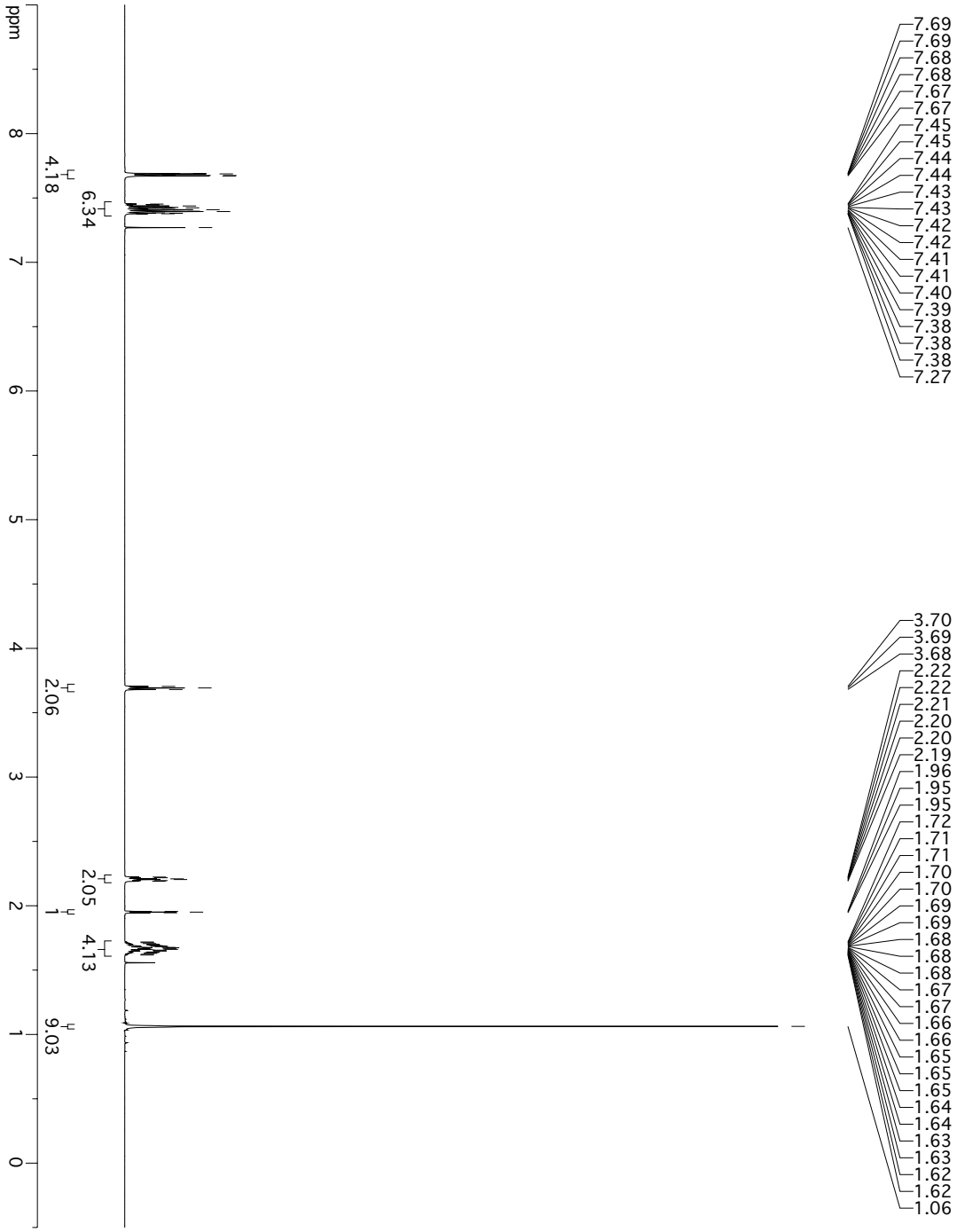

TBDPSO

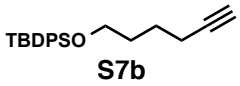
S7a


ppm
200
150
100
50
0
135.7
134.0
129.8
127.8
84.4
77.5
77.2
76.9
68.5
62.4
31.6
27.0
19.4
15.2

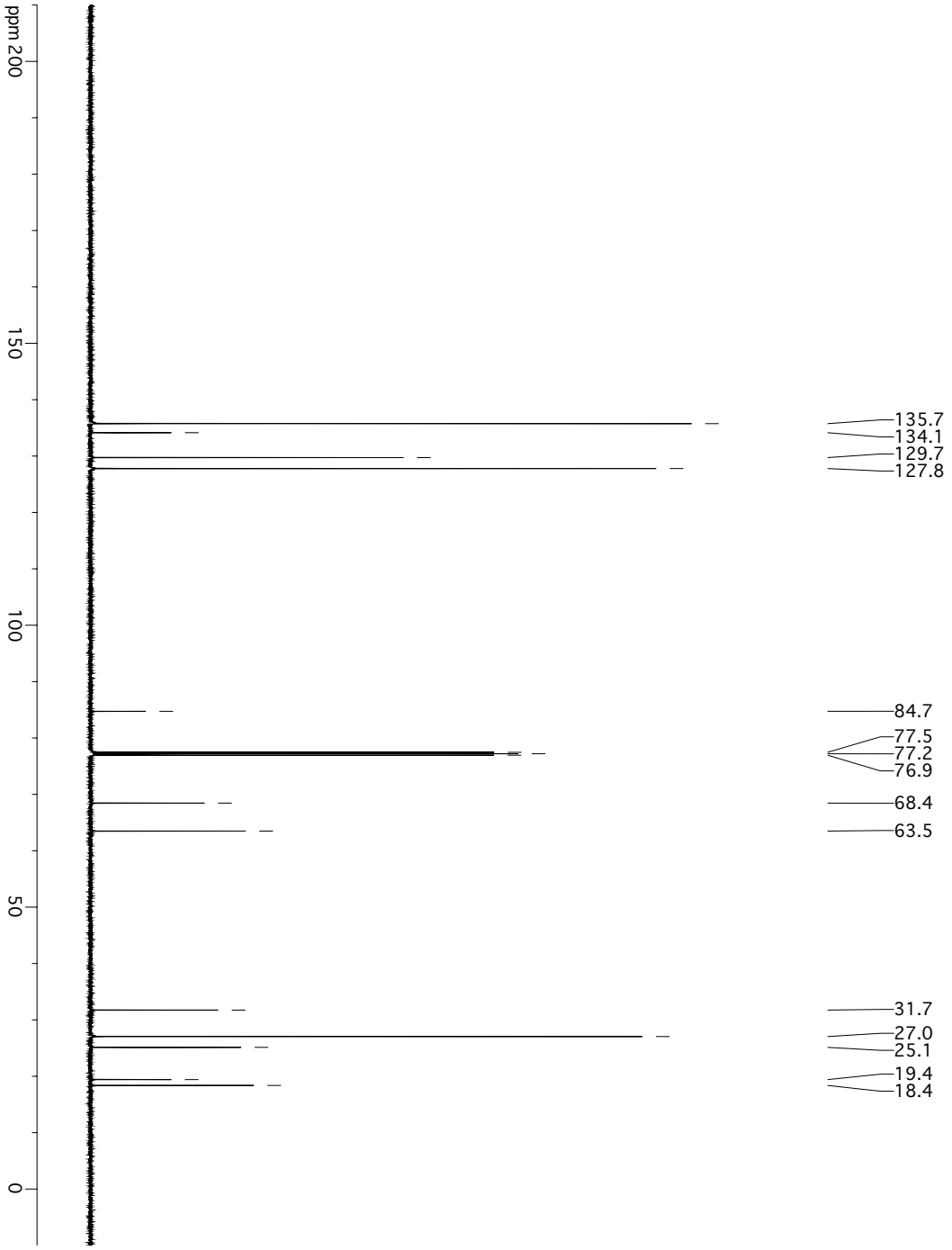

TBDPSO

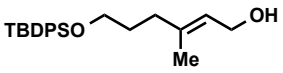
S7b


ppm
8
7
6
5
4
3
2
1
0
4.18
6.34
2.06
2.05
1
4.13
9.03
7.69
7.69
7.68
7.68
7.67
7.67
7.45
7.45
7.44
7.44
7.43
7.43
7.42
7.42
7.41
7.41
7.40
7.39
7.38
7.38
7.38
7.27
3.70
3.69
3.68
2.22
2.22
2.21
2.20
2.20
2.19
1.96
1.95
1.95
1.72
1.71
1.71
1.70
1.70
1.69
1.69
1.68
1.68
1.68
1.67
1.67
1.66
1.66
1.65
1.65
1.65
1.64
1.64
1.63
1.63
1.62
1.62
1.06

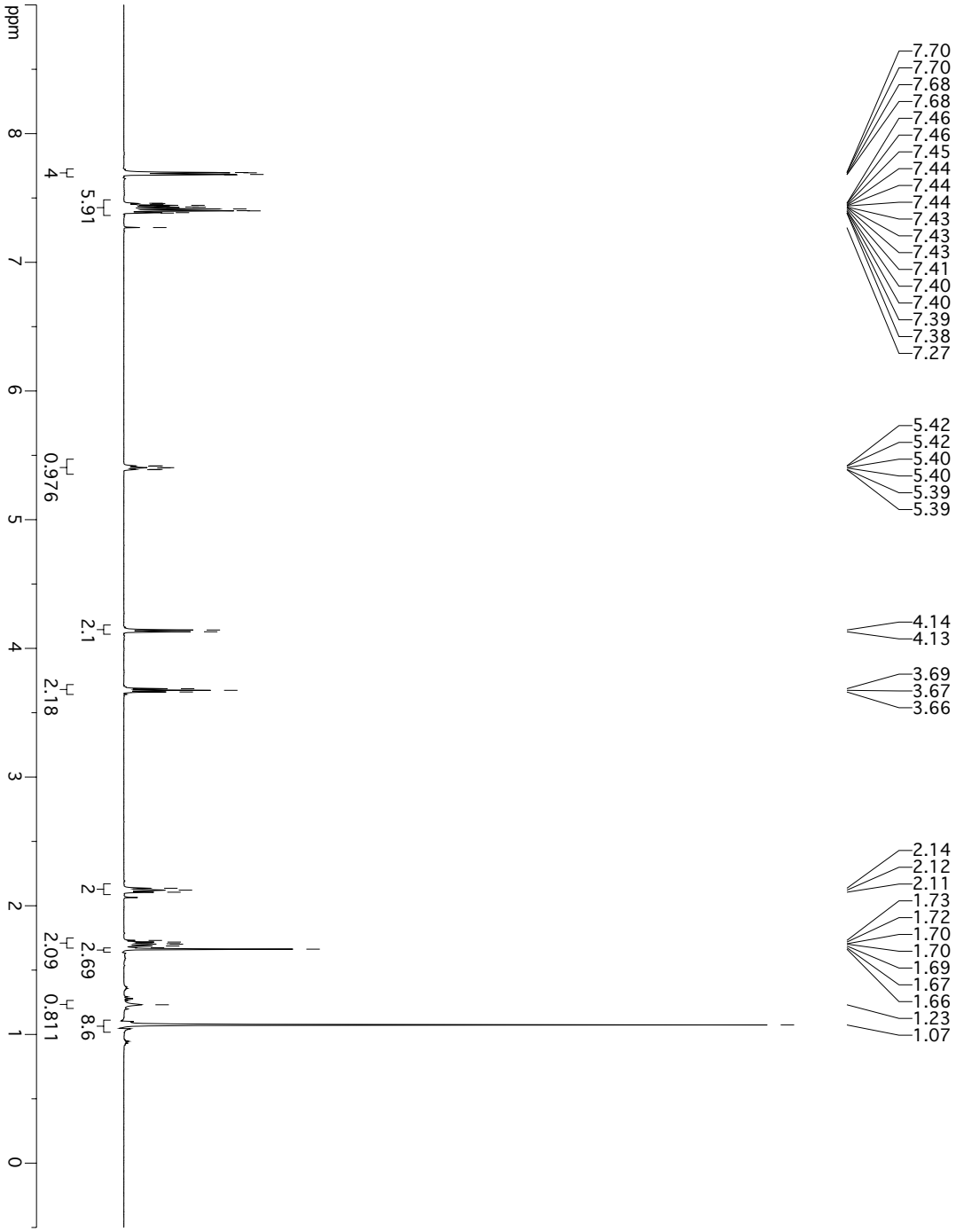

TBDPSO

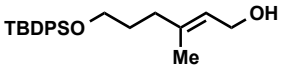
S7b


ppm
200
150
100
50
0
135.7
134.1
129.7
127.8
84.7
77.5
77.2
76.9
68.4
63.5
31.7
27.0
25.1
19.4
18.4

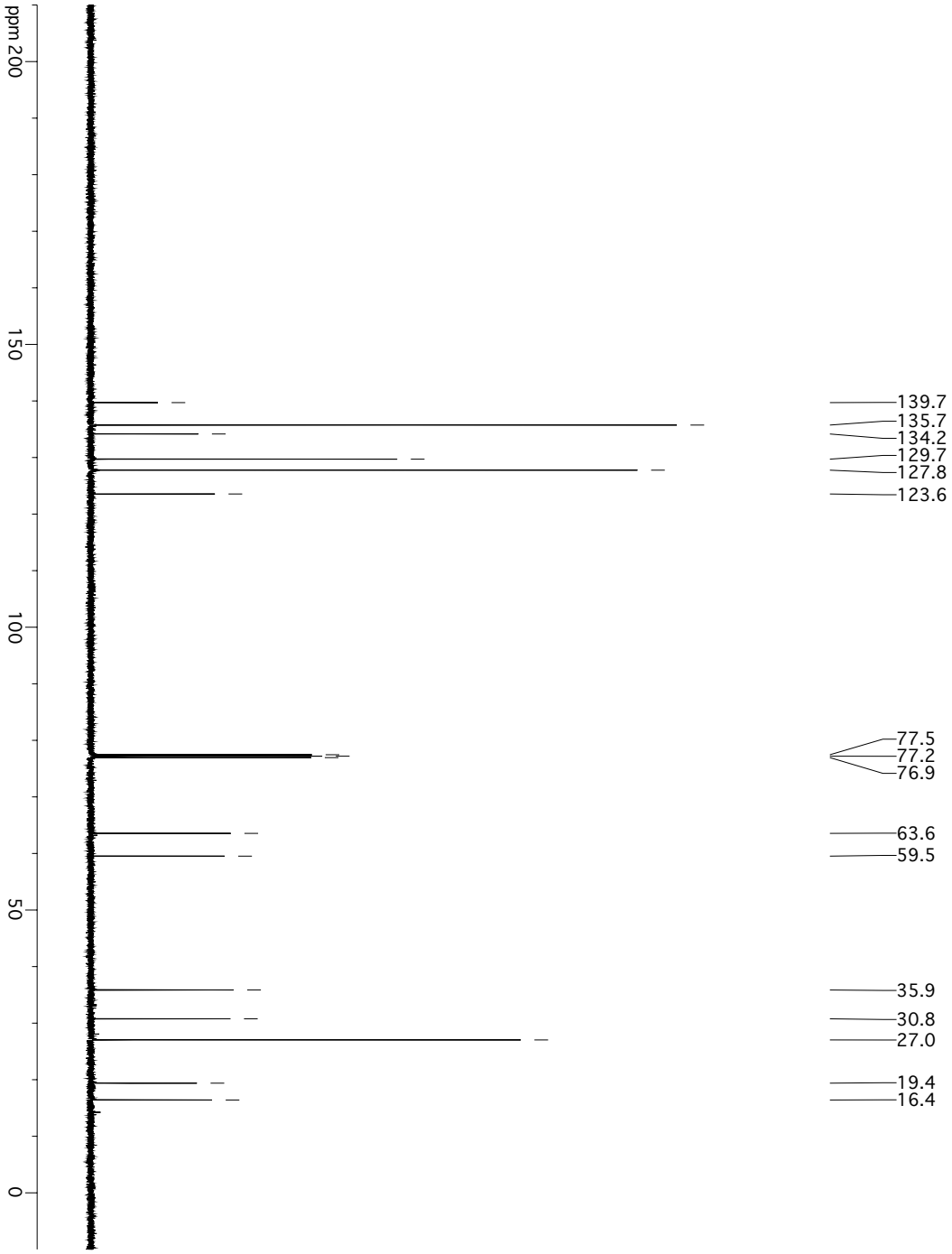

TBDPSO
OH
Me

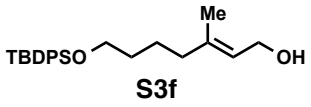
S3e


ppm
8
7
6
5
4
3
2
1
0
4
5.91
0.976
2.1
2.18
2
2.69
2.09
0.811
8.6
7.70
7.70
7.68
7.68
7.46
7.46
7.45
7.44
7.44
7.44
7.43
7.43
7.43
7.41
7.40
7.40
7.39
7.38
7.27
5.42
5.42
5.40
5.40
5.39
5.39
4.14
4.13
3.69
3.67
3.66
2.14
2.12
2.11
1.73
1.72
1.70
1.70
1.69
1.67
1.66
1.23
1.07

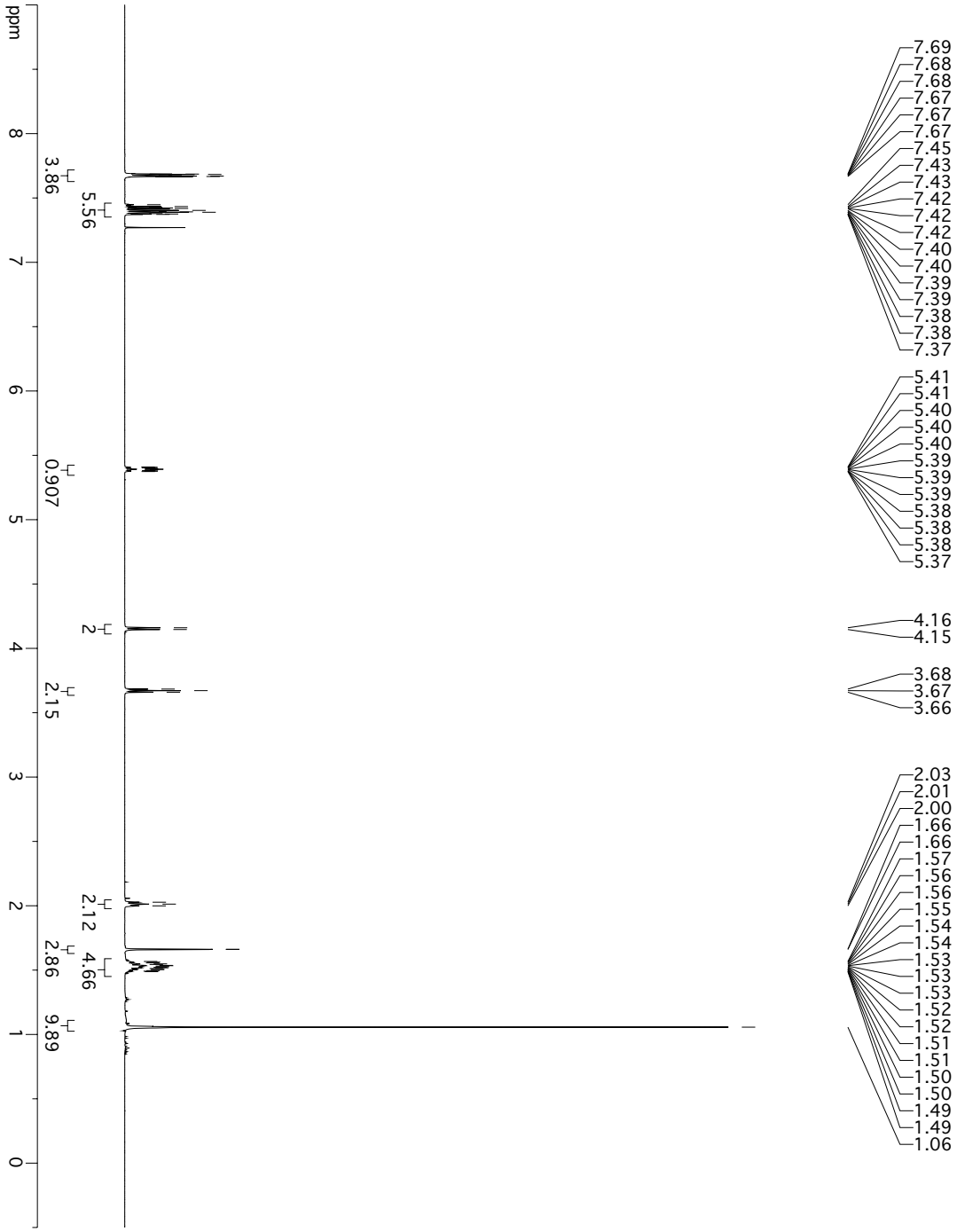

TBDPSO
OH
Me

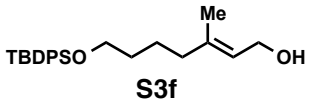
S3e


ppm
200
150
100
50
0
139.7
135.7
134.2
129.7
127.8
123.6
77.5
77.2
76.9
63.6
59.5
35.9
30.8
27.0
19.4
16.4

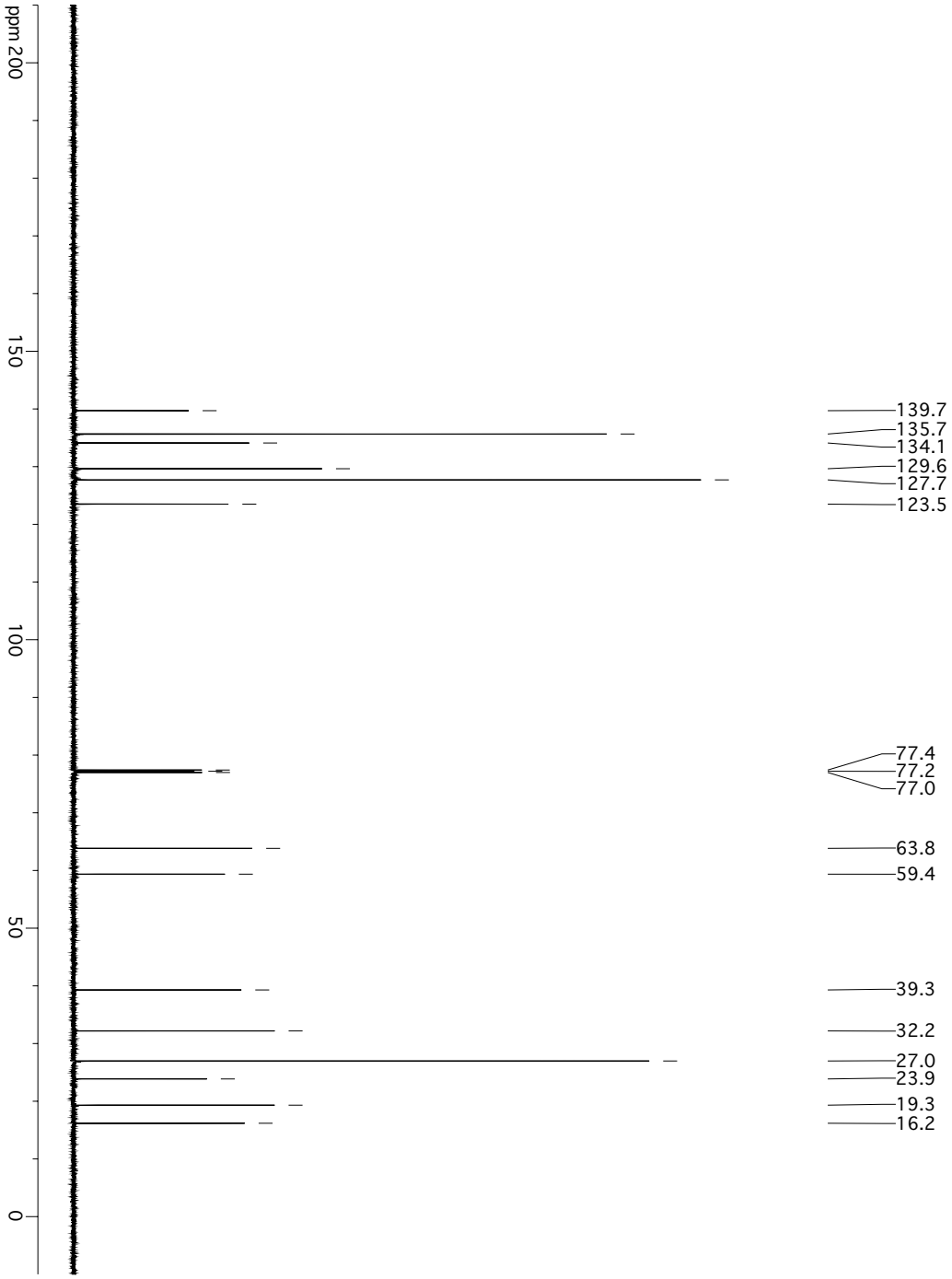

Me
TBDPSO
OH

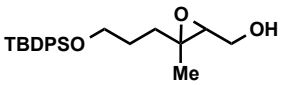
S3f


ppm
8
7
6
5
4
3
2
1
0
3.86
5.56
0.907
2
2.15
2.12
4.66
2.86
9.89
7.69
7.68
7.68
7.67
7.67
7.67
7.45
7.43
7.43
7.42
7.42
7.42
7.40
7.40
7.39
7.39
7.38
7.38
7.37
5.41
5.41
5.40
5.40
5.40
5.39
5.39
5.39
5.38
5.38
5.38
5.37
4.16
4.15
3.68
3.67
3.66
2.03
2.01
2.00
1.66
1.66
1.57
1.56
1.56
1.55
1.54
1.54
1.53
1.53
1.53
1.52
1.52
1.51
1.51
1.50
1.50
1.49
1.49
1.06

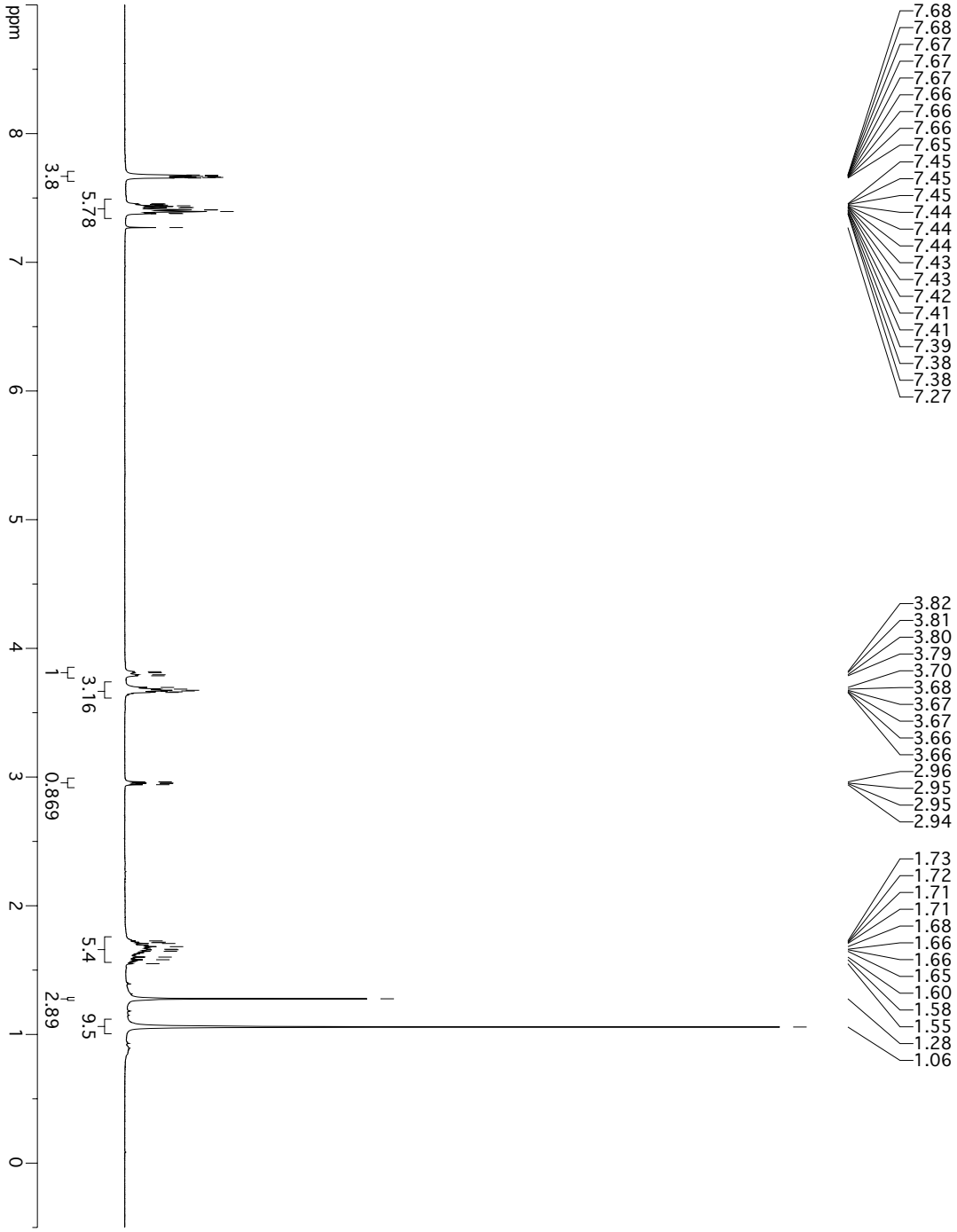

Me
TBDPSO
OH

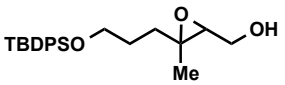
S3f


ppm
200
150
100
50
0
139.7
135.7
134.1
129.6
127.7
123.5
77.4
77.2
77.0
63.8
59.4
39.3
32.2
27.0
23.9
19.3
16.2

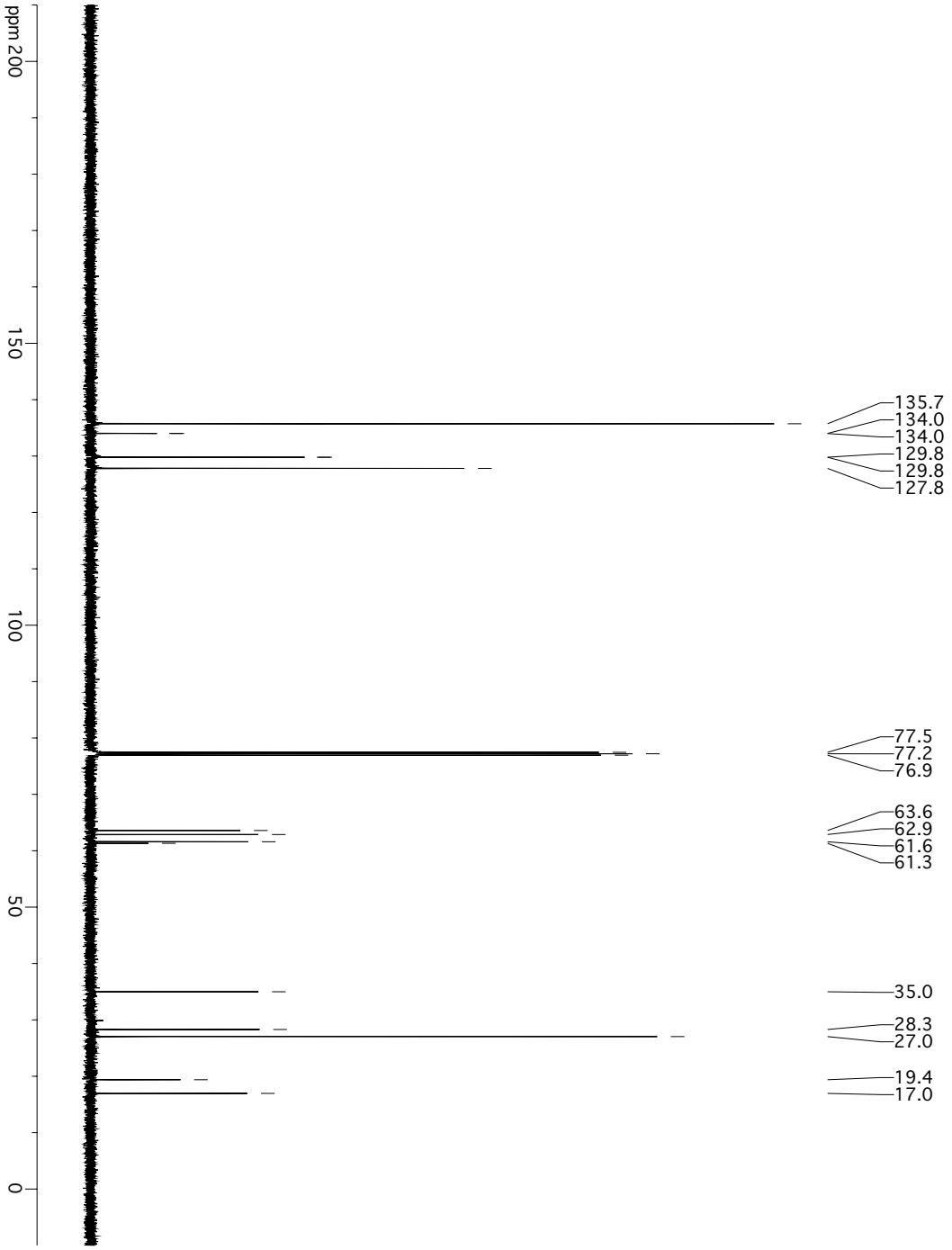

TBDPSO
O
OH
Me

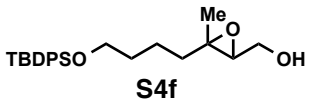
S4e


ppm
8
7
6
5
4
3
2
1
0
3.8
5.78
1
3.16
0.869
5.4
2.89
9.5
7.68
7.68
7.67
7.67
7.67
7.66
7.66
7.66
7.65
7.45
7.45
7.45
7.44
7.44
7.44
7.43
7.43
7.42
7.41
7.41
7.39
7.38
7.38
7.27
3.82
3.81
3.80
3.79
3.70
3.68
3.67
3.67
3.66
3.66
2.96
2.95
2.95
2.94
1.73
1.72
1.71
1.71
1.68
1.66
1.66
1.65
1.60
1.58
1.55
1.28
1.06

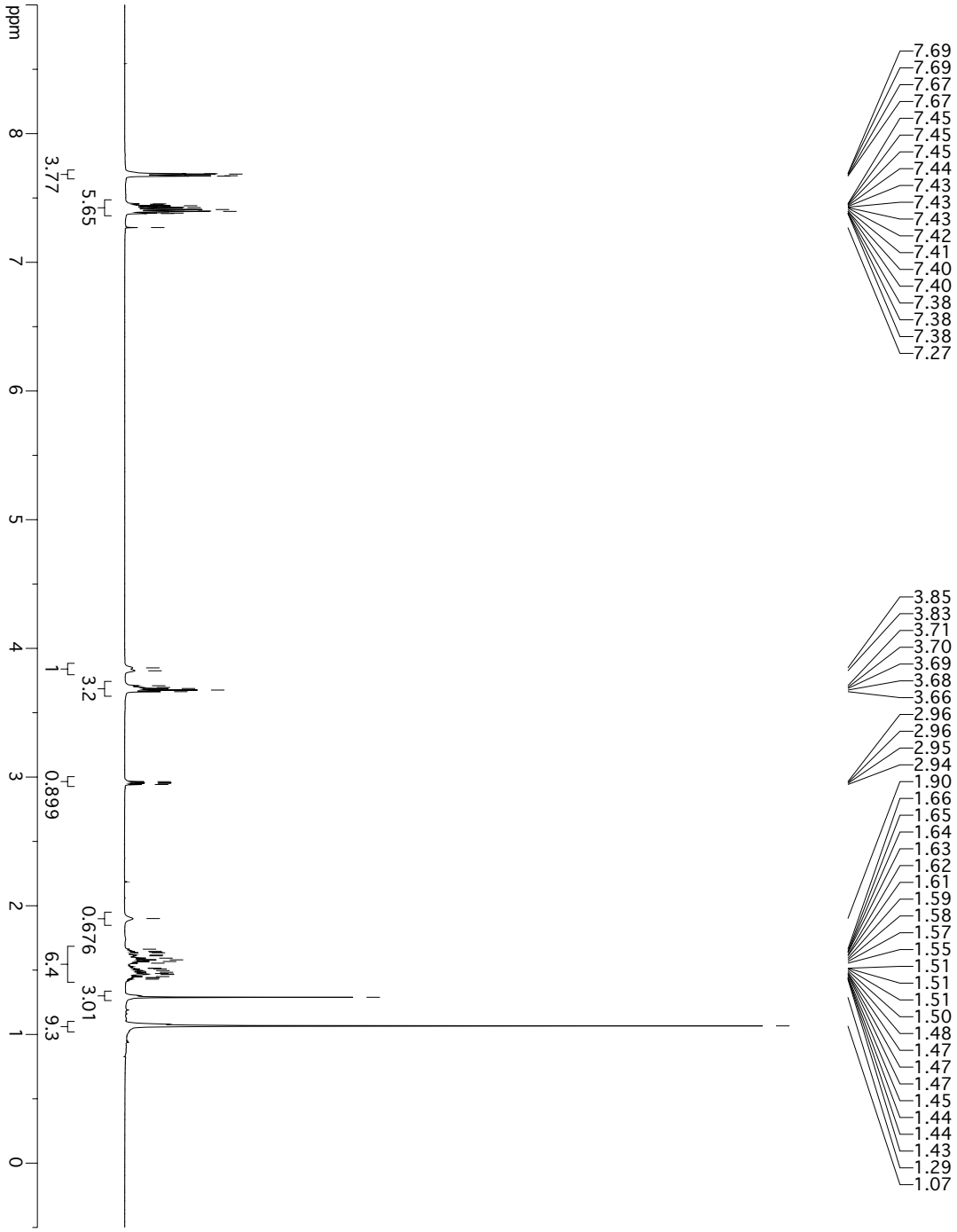

TBDPSO
O
OH
Me

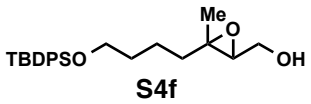
S4e


ppm
200
150
100
50
0
135.7
134.0
134.0
129.8
129.8
127.8
77.5
77.2
76.9
63.6
62.9
61.6
61.3
35.0
28.3
27.0
19.4
17.0

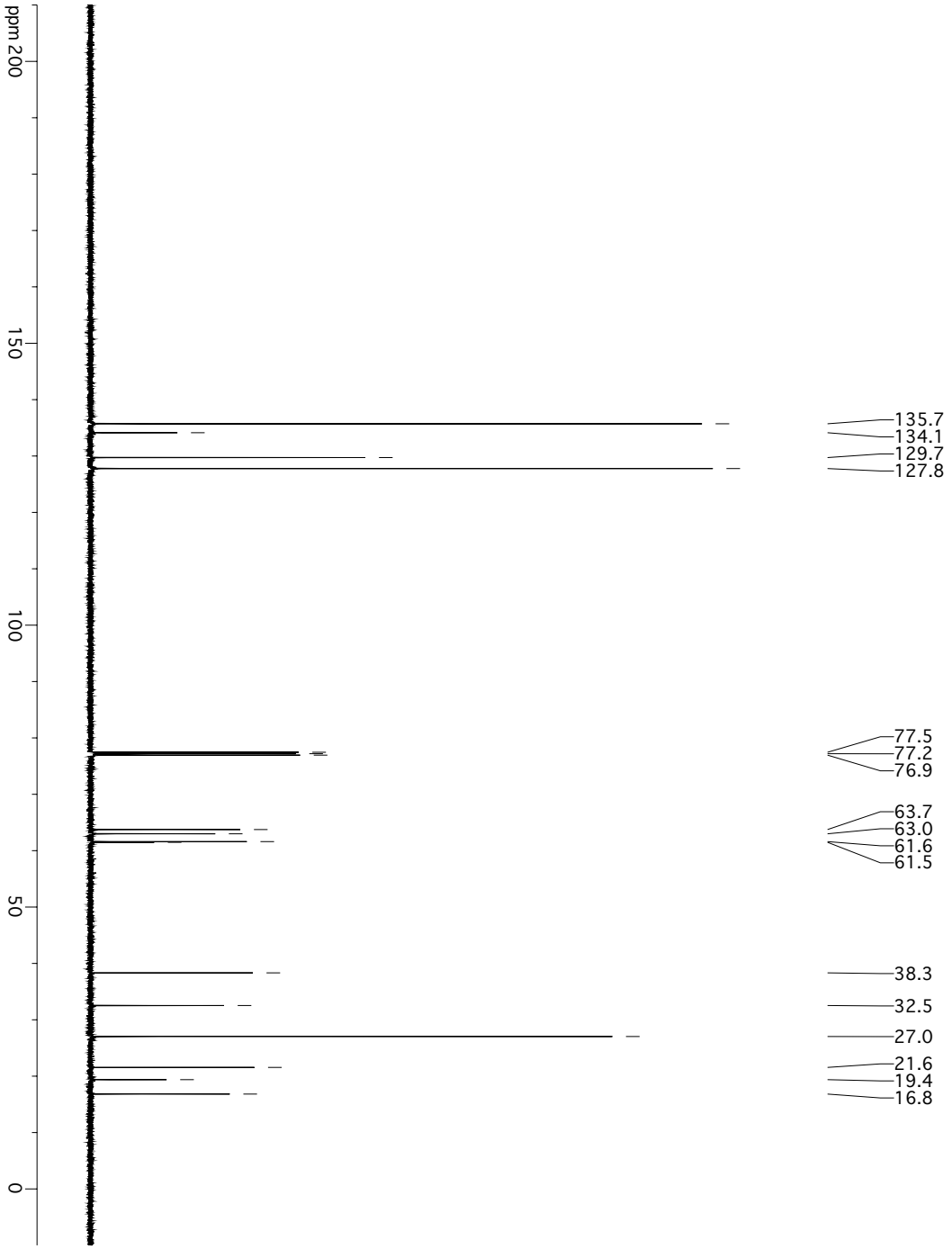

Me
O
TBDPSO
OH

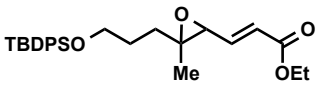
S4f


ppm
8
7
6
5
4
3
2
1
0
3.77
5.65
1
3.2
0.899
0.676
6.4
3.01
9.3
7.69
7.69
7.67
7.67
7.45
7.45
7.45
7.44
7.43
7.43
7.43
7.42
7.41
7.40
7.40
7.38
7.38
7.38
7.27
3.85
3.83
3.71
3.70
3.69
3.68
3.66
2.96
2.96
2.95
2.94
1.90
1.66
1.65
1.64
1.63
1.62
1.61
1.59
1.58
1.57
1.55
1.51
1.51
1.51
1.50
1.48
1.47
1.47
1.47
1.45
1.44
1.44
1.43
1.29
1.07

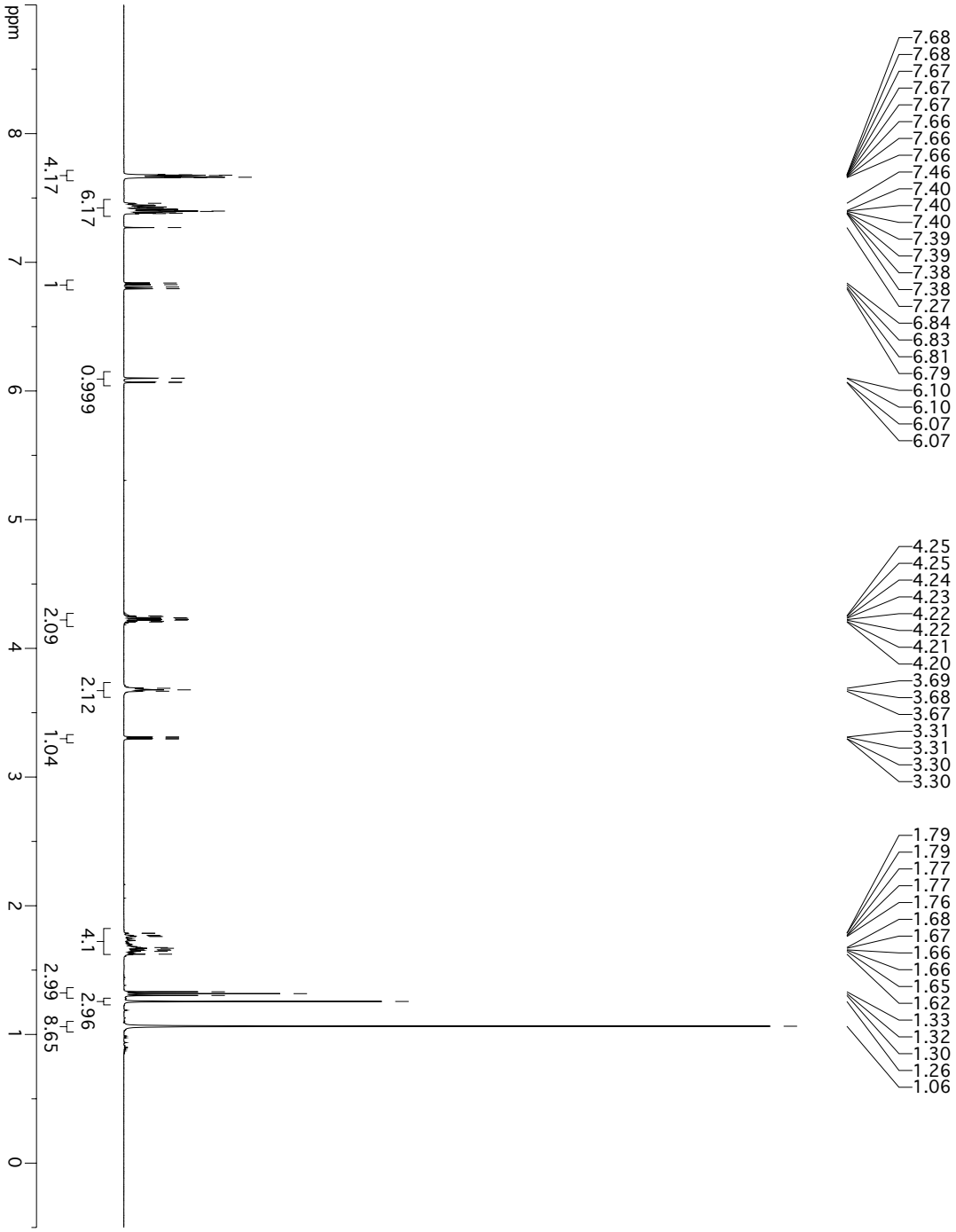

Me
O
TBDPSO
OH

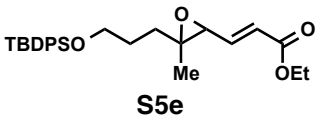
S4f


ppm
200
150
100
50
0
135.7
134.1
129.7
127.8
77.5
77.2
76.9
63.7
63.0
61.6
61.5
38.3
32.5
27.0
21.6
19.4
16.8

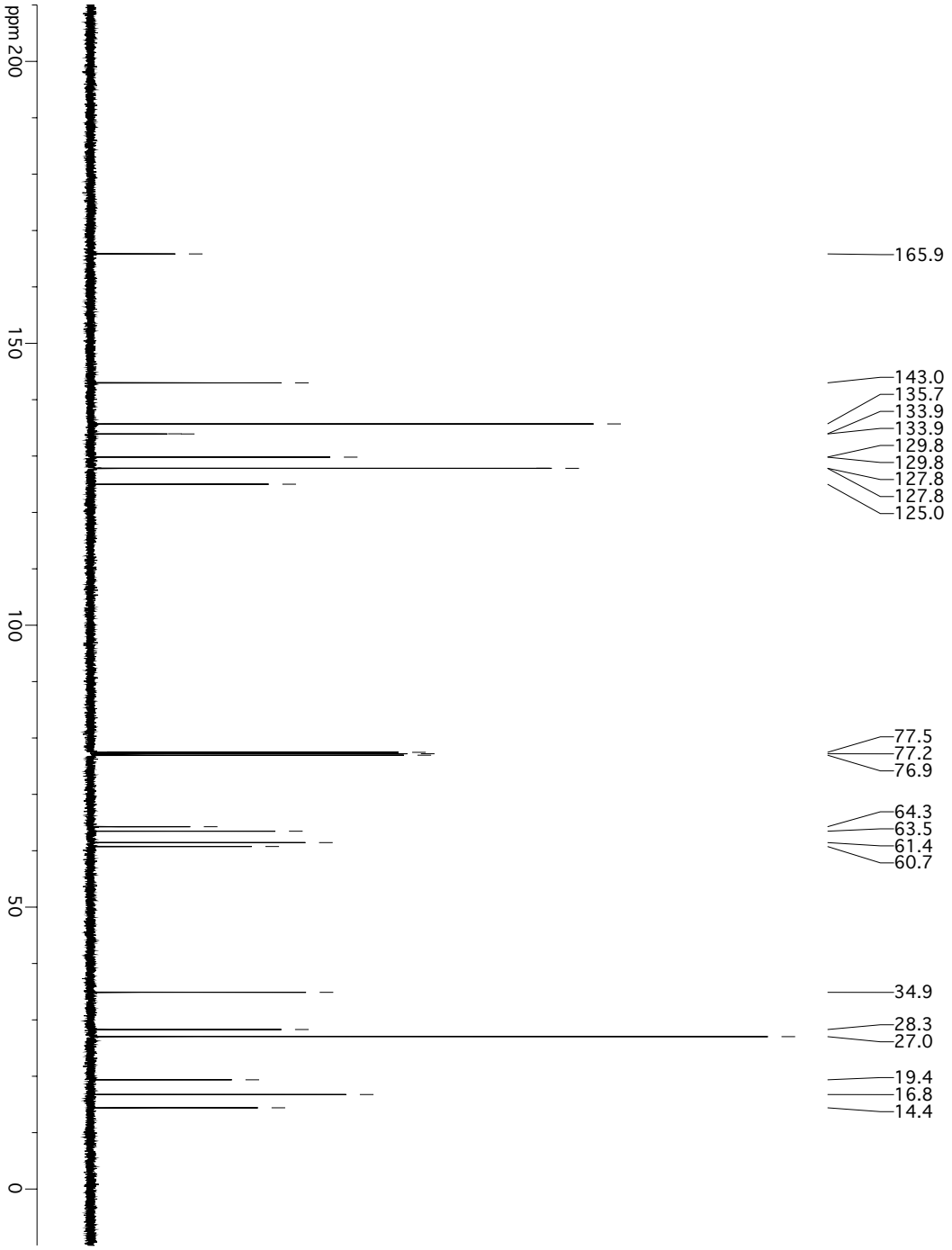

TBDPSO
O
Me
OEt
O

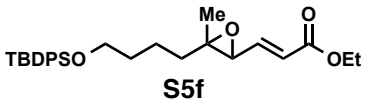
S5e


ppm
8
7
6
5
4
3
2
1
0
4.17
6.17
1
0.999
2.09
2.12
1.04
4.1
2.99
2.96
8.65
7.68
7.68
7.67
7.67
7.67
7.66
7.66
7.66
7.46
7.40
7.40
7.40
7.39
7.39
7.38
7.38
7.27
6.84
6.83
6.81
6.79
6.10
6.10
6.07
6.07
4.25
4.25
4.24
4.23
4.22
4.22
4.21
4.20
3.69
3.68
3.67
3.31
3.31
3.30
3.30
1.79
1.79
1.77
1.77
1.76
1.68
1.67
1.66
1.66
1.65
1.62
1.33
1.32
1.30
1.26
1.06

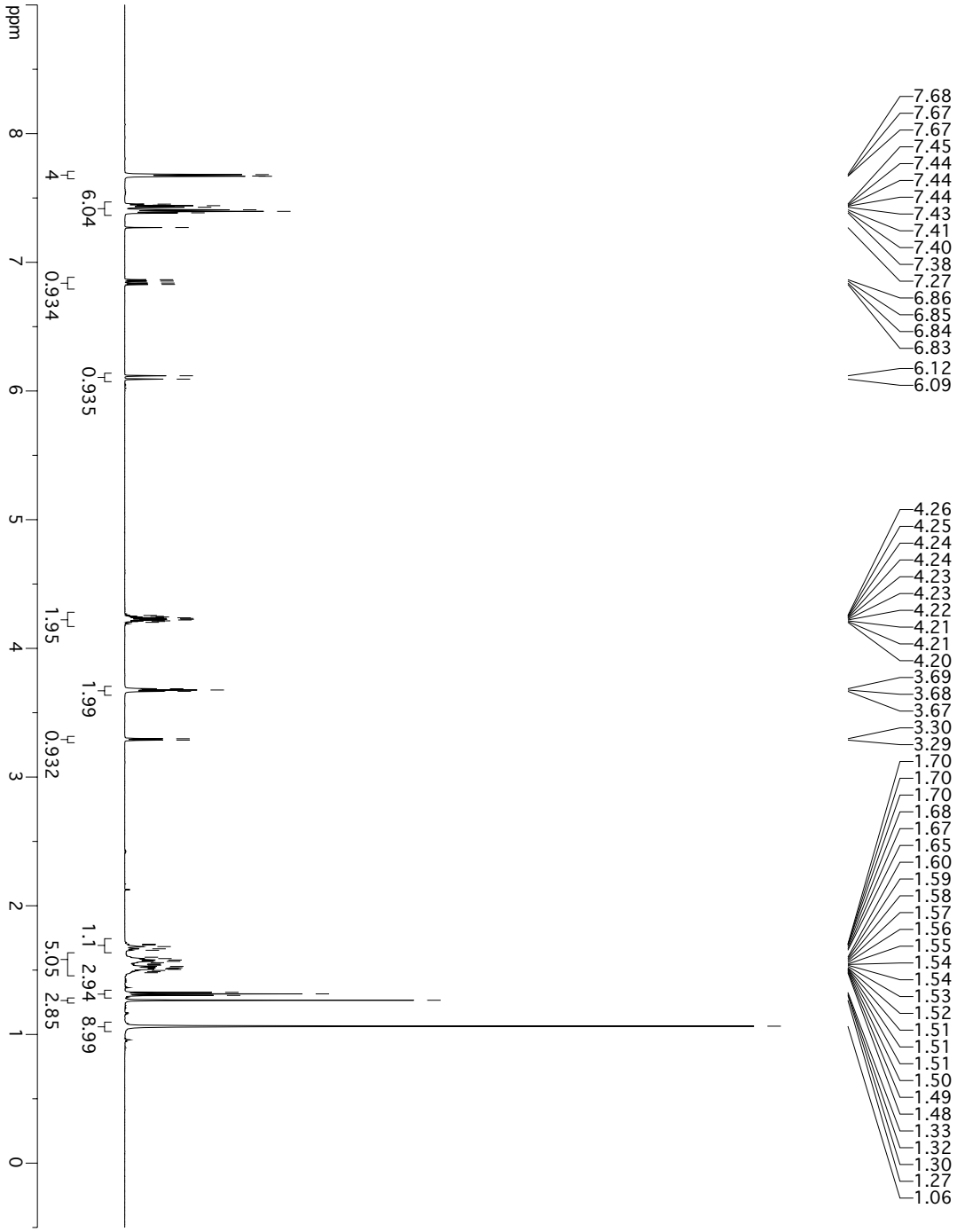

TBDPSO
O
O
Me
OEt

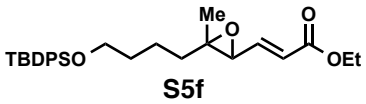
S5e


ppm
200
150
100
50
0
165.9
143.0
135.7
133.9
133.9
129.8
129.8
127.8
127.8
125.0
77.5
77.2
76.9
64.3
63.5
61.4
60.7
34.9
28.3
27.0
19.4
16.8
14.4

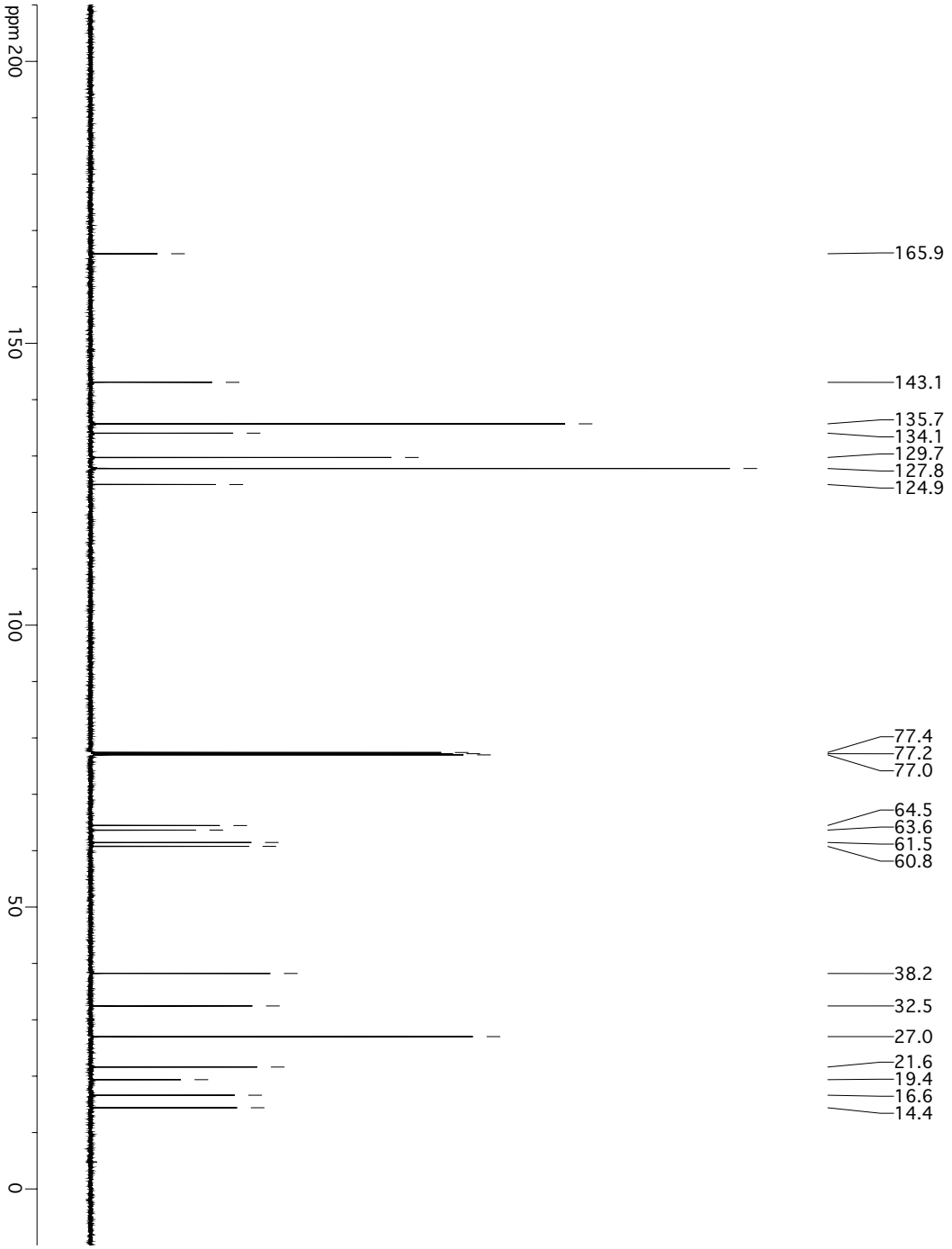

Me
O
O
TBDPSO
OEt

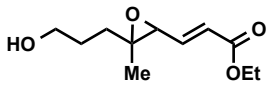
S5f


ppm
8
7
6
5
4
3
2
1
0
4
6.04
0.934
0.935
1.95
1.99
0.932
1.1
5.05
2.94
2.85
8.99
7.68
7.67
7.67
7.45
7.44
7.44
7.44
7.43
7.41
7.40
7.38
7.27
6.86
6.85
6.84
6.83
6.12
6.09
4.26
4.25
4.24
4.24
4.23
4.23
4.22
4.21
4.21
4.20
3.69
3.68
3.67
3.30
3.29
1.70
1.70
1.70
1.68
1.67
1.65
1.60
1.59
1.58
1.57
1.56
1.55
1.54
1.54
1.53
1.52
1.51
1.51
1.51
1.50
1.49
1.48
1.33
1.32
1.30
1.27
1.06

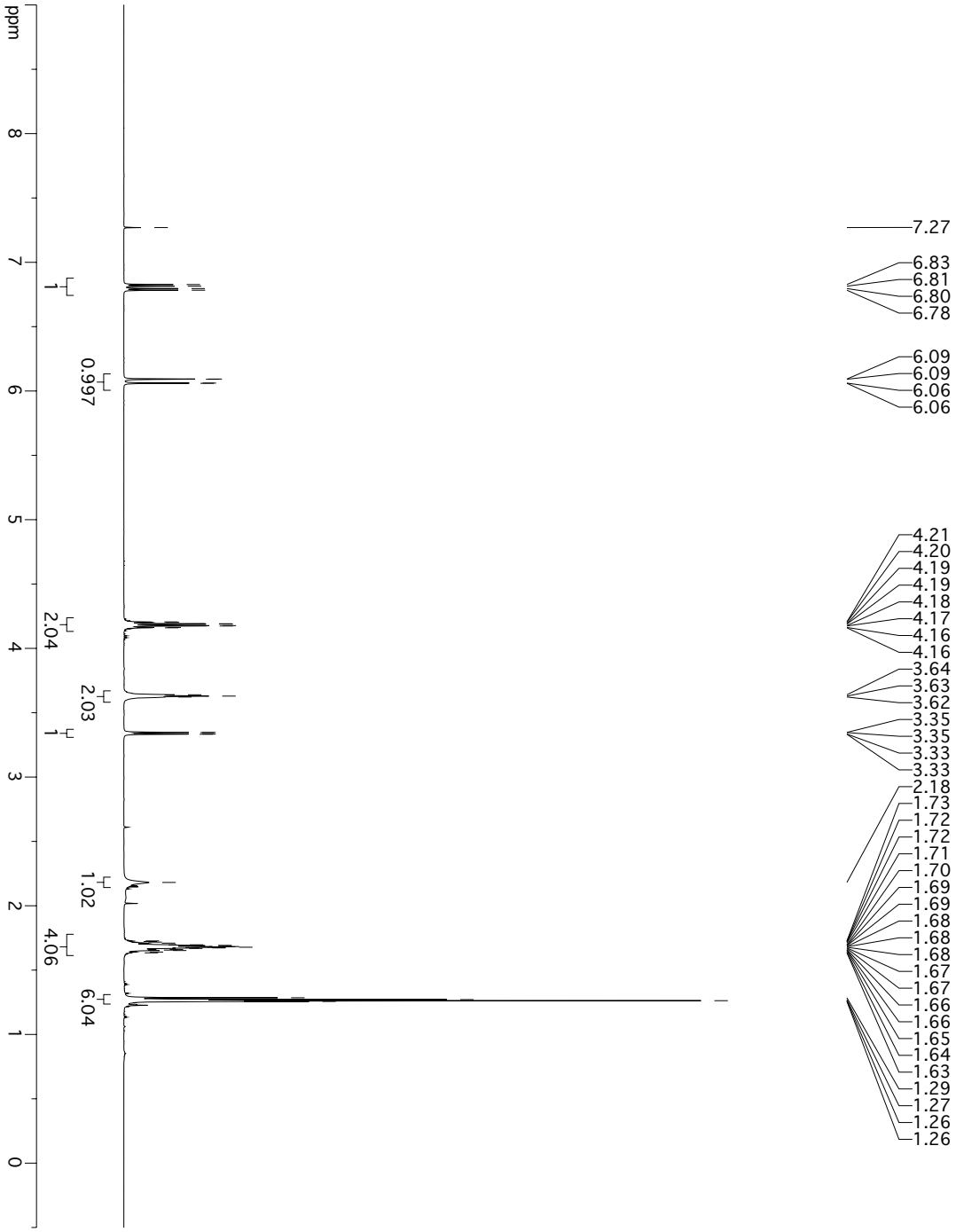

Me
O
O
TBDPSO
OEt

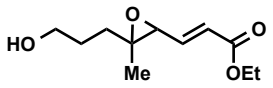
S5f


ppm
200
150
100
50
0
165.9
143.1
135.7
134.1
129.7
127.8
124.9
77.4
77.2
77.0
64.5
63.6
61.5
60.8
38.2
32.5
27.0
21.6
19.4
16.6
14.4

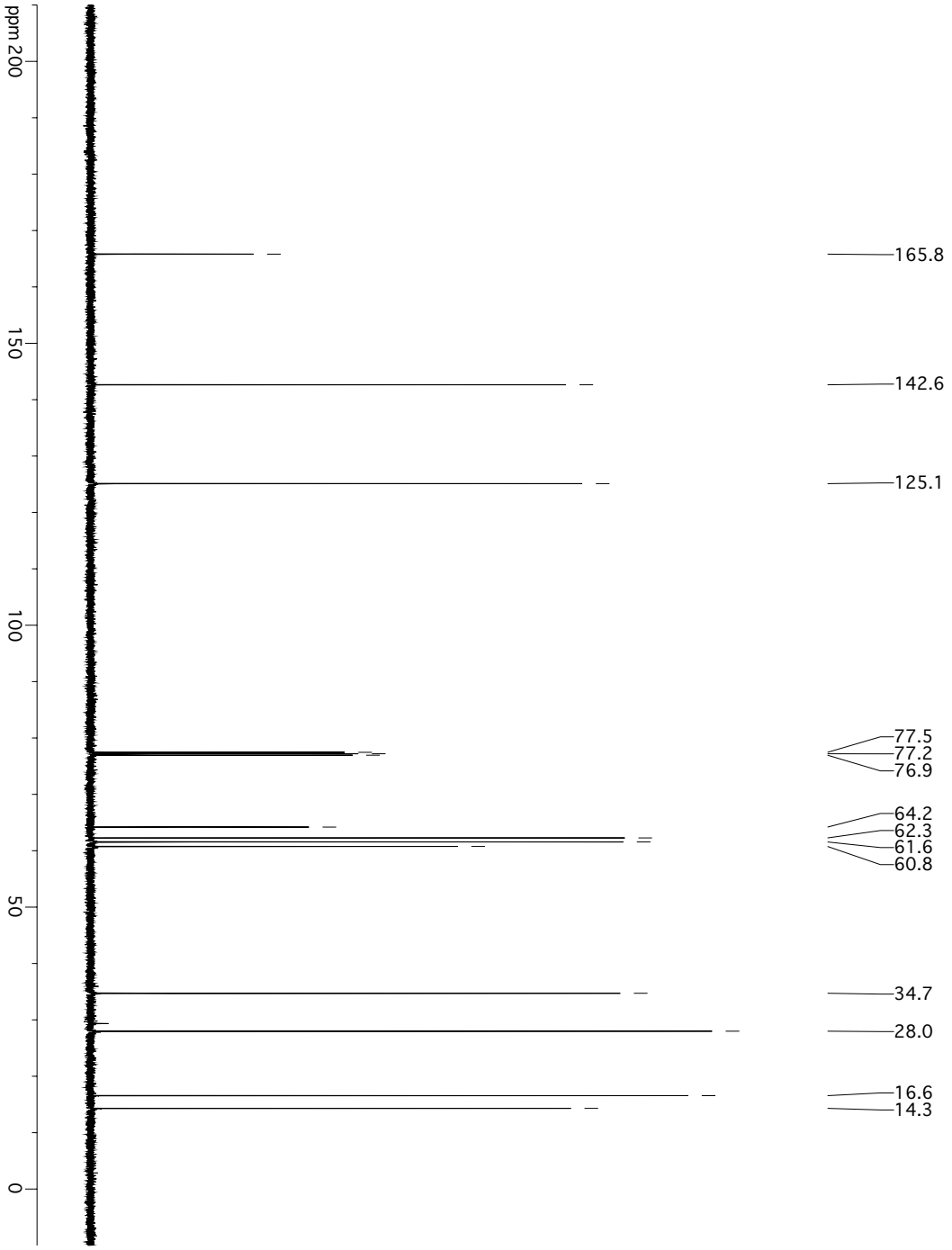

HO
O
Me
OEt
O

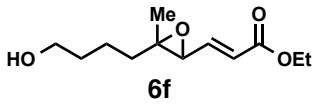
6e


ppm
8
7
6
5
4
3
2
1
0
1
0.997
2.04
2.03
1
1.02
4.06
6.04
7.27
6.83
6.81
6.80
6.78
6.09
6.09
6.06
6.06
4.21
4.20
4.19
4.19
4.18
4.17
4.16
4.16
3.64
3.63
3.62
3.35
3.35
3.33
3.33
2.18
1.73
1.72
1.72
1.71
1.70
1.69
1.69
1.68
1.68
1.68
1.67
1.67
1.66
1.66
1.65
1.64
1.63
1.29
1.27
1.26
1.26

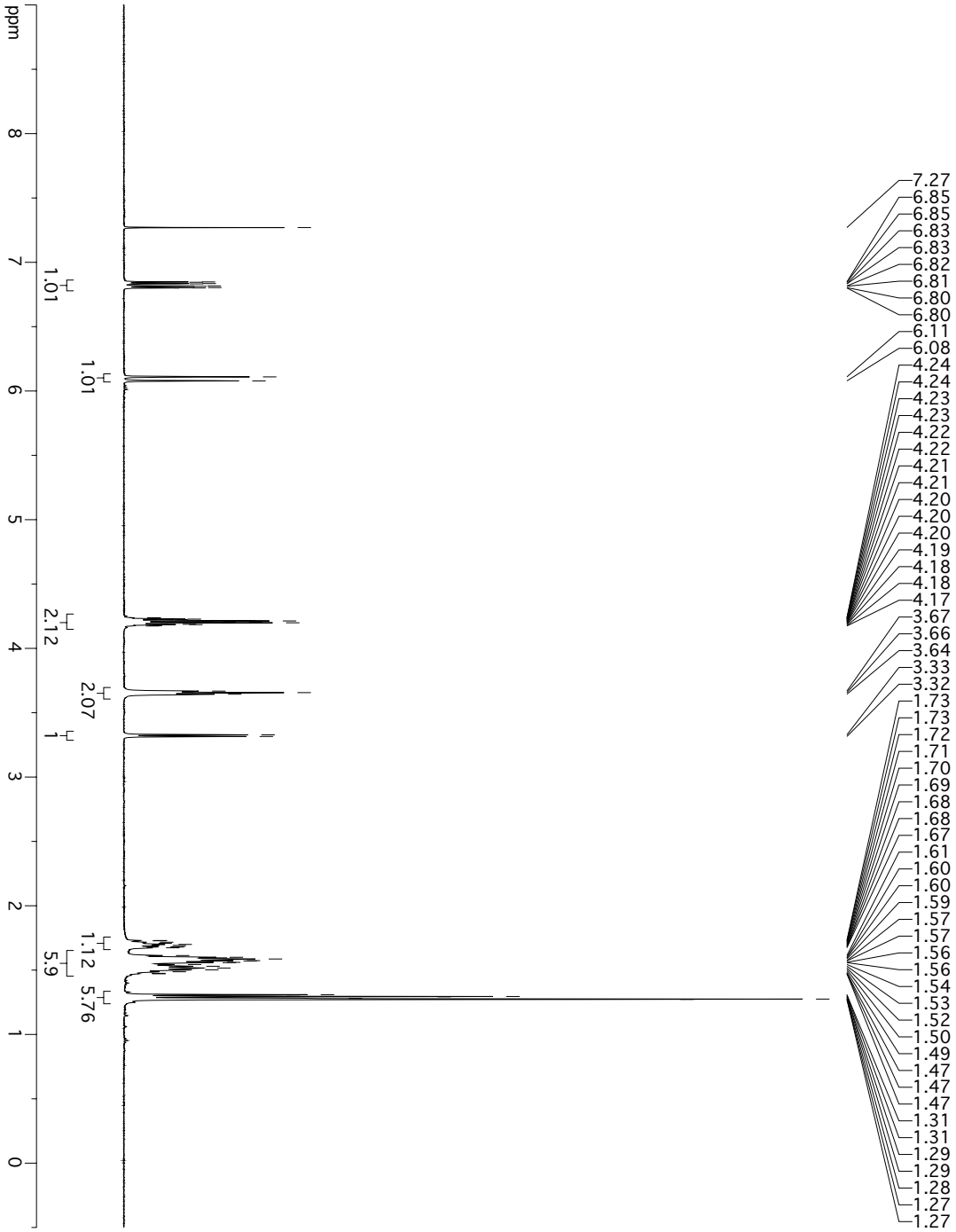

HO
O
Me
OEt
O

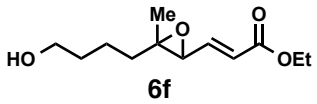
6e


ppm
200
150
100
50
0
165.8
142.6
125.1
77.5
77.2
76.9
64.2
62.3
61.6
60.8
34.7
28.0
16.6
14.3

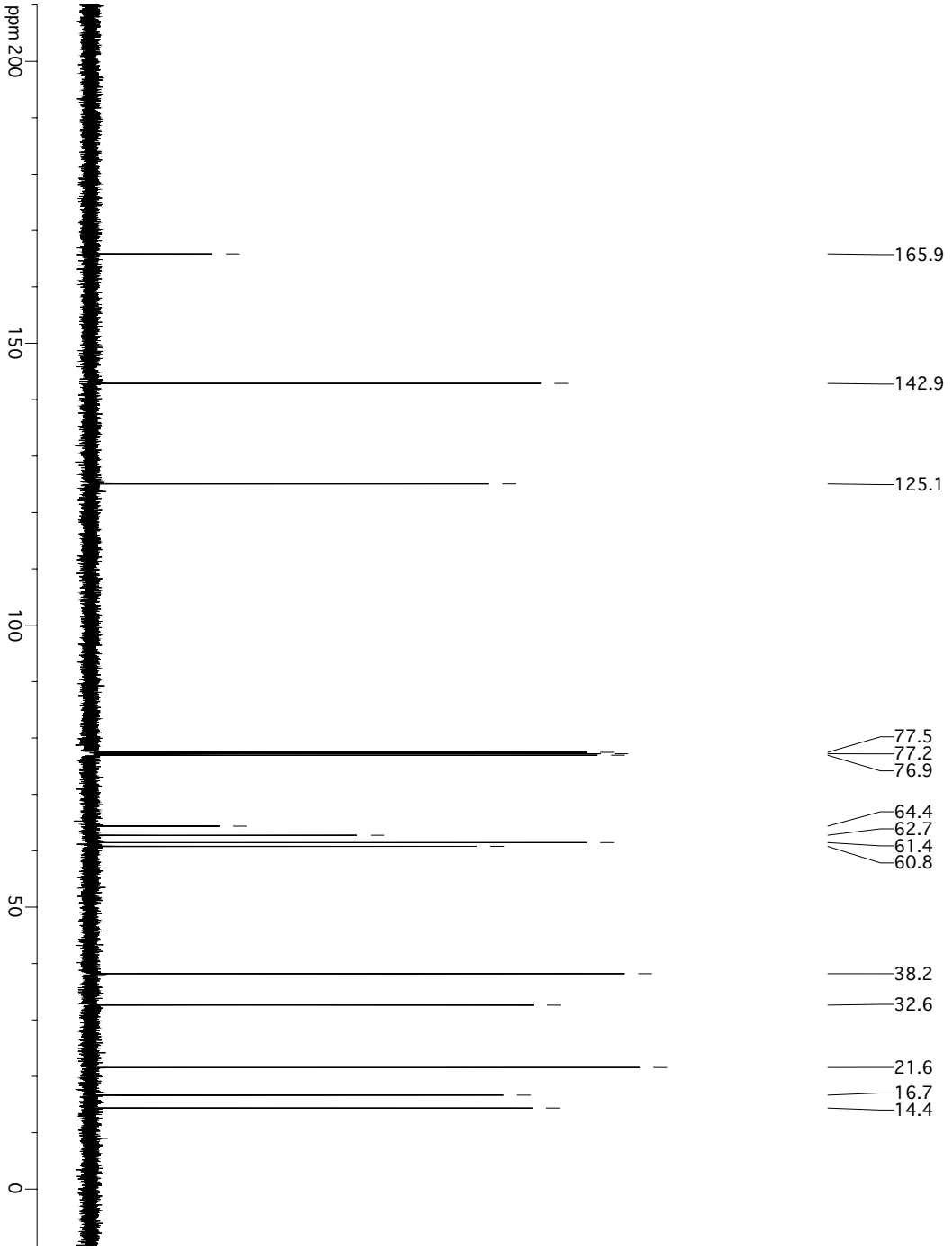

Me
O
O
HO
OEt

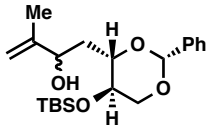
6f


ppm
8
7
6
5
4
3
2
1
0
1.01
1.01
2.12
2.07
1
1.12
5.9
5.76
7.27
6.85
6.85
6.83
6.83
6.82
6.81
6.80
6.80
6.11
6.08
4.24
4.24
4.23
4.23
4.22
4.22
4.21
4.21
4.20
4.20
4.20
4.19
4.18
4.18
4.17
3.67
3.66
3.64
3.33
3.32
1.73
1.73
1.72
1.71
1.70
1.69
1.68
1.68
1.67
1.61
1.60
1.60
1.59
1.57
1.57
1.56
1.56
1.54
1.53
1.52
1.50
1.49
1.47
1.47
1.47
1.31
1.31
1.29
1.29
1.28
1.27
1.27

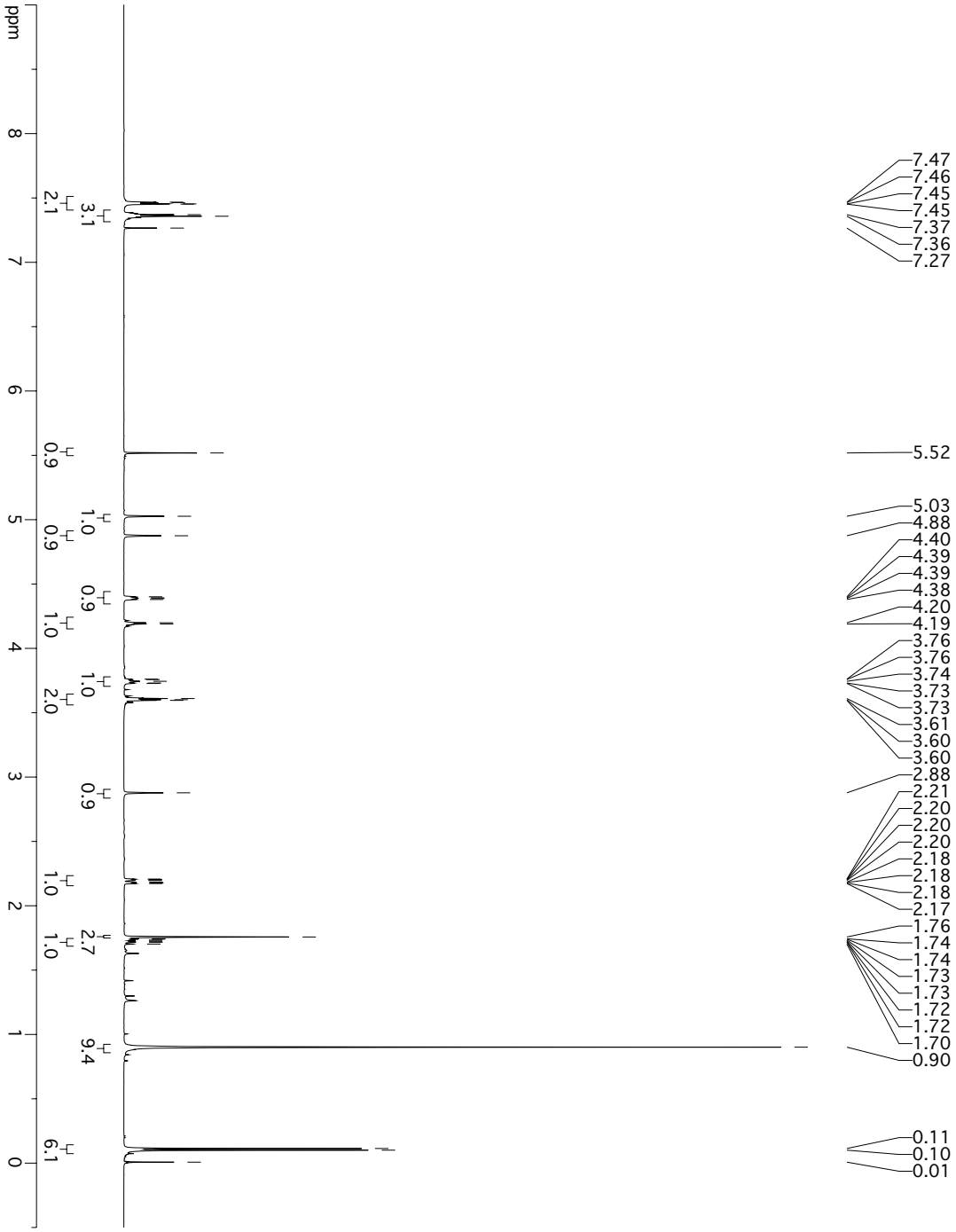

Me
O
O
HO
OEt

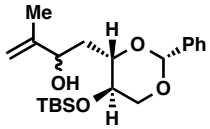
6f


ppm
200
150
100
50
0
165.9
142.9
125.1
77.5
77.2
76.9
64.4
62.7
61.4
60.8
38.2
32.6
21.6
16.7
14.4

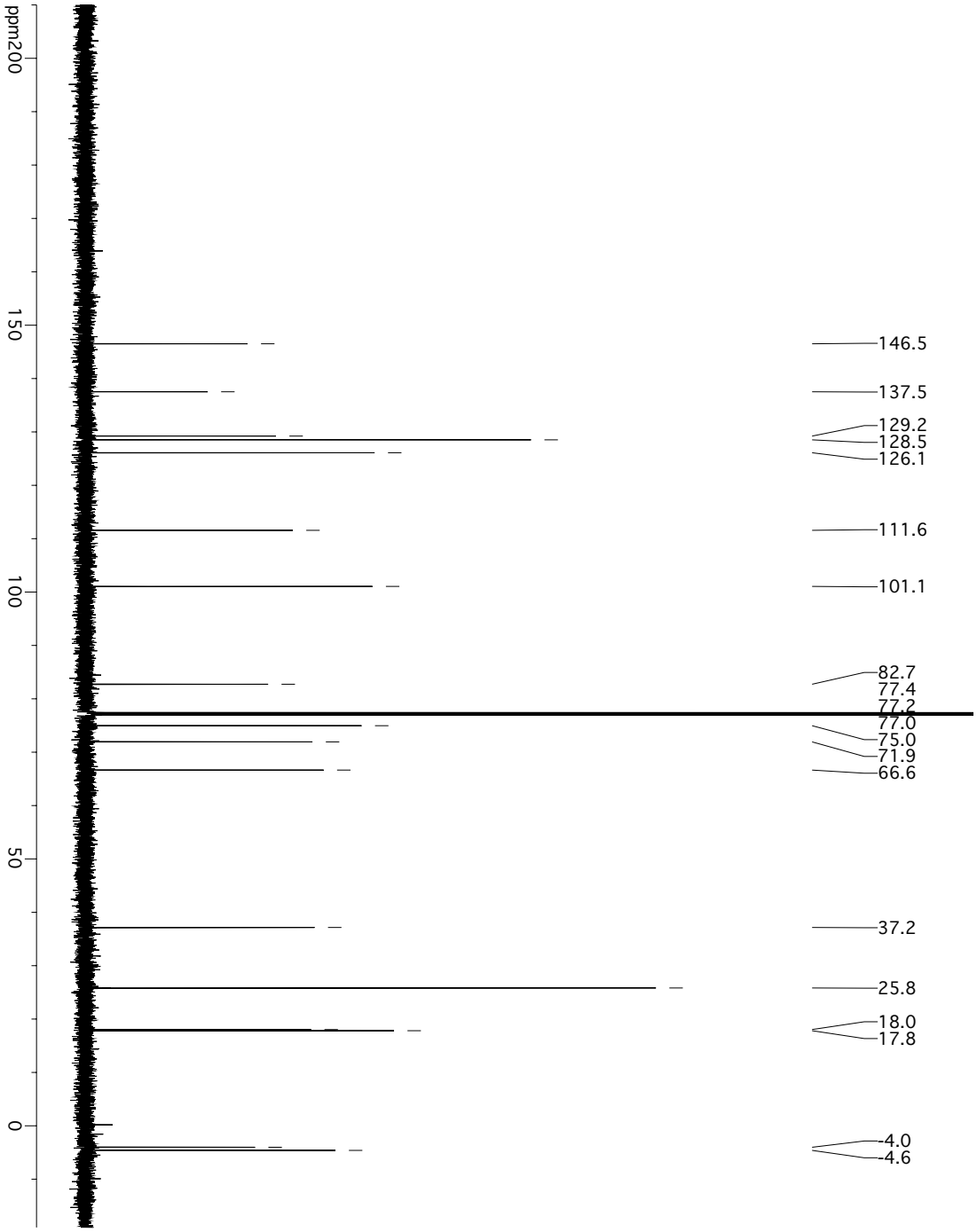

Me
H
O
Ph
OH
O
TBSO
H

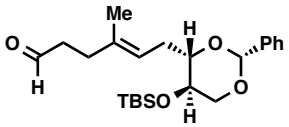
S9


ppm
8
7
6
5
4
3
2
1
0
2.1
3.1
0.9
1.0
0.9
0.9
1.0
1.0
2.0
0.9
1.0
2.7
1.0
9.4
6.1
7.47
7.46
7.45
7.45
7.37
7.36
7.27
5.52
5.03
4.88
4.40
4.39
4.39
4.38
4.20
4.19
3.76
3.76
3.74
3.73
3.73
3.61
3.60
3.60
2.88
2.21
2.20
2.20
2.20
2.18
2.18
2.18
2.17
1.76
1.74
1.74
1.73
1.73
1.72
1.72
1.70
0.90
0.11
0.10
0.01

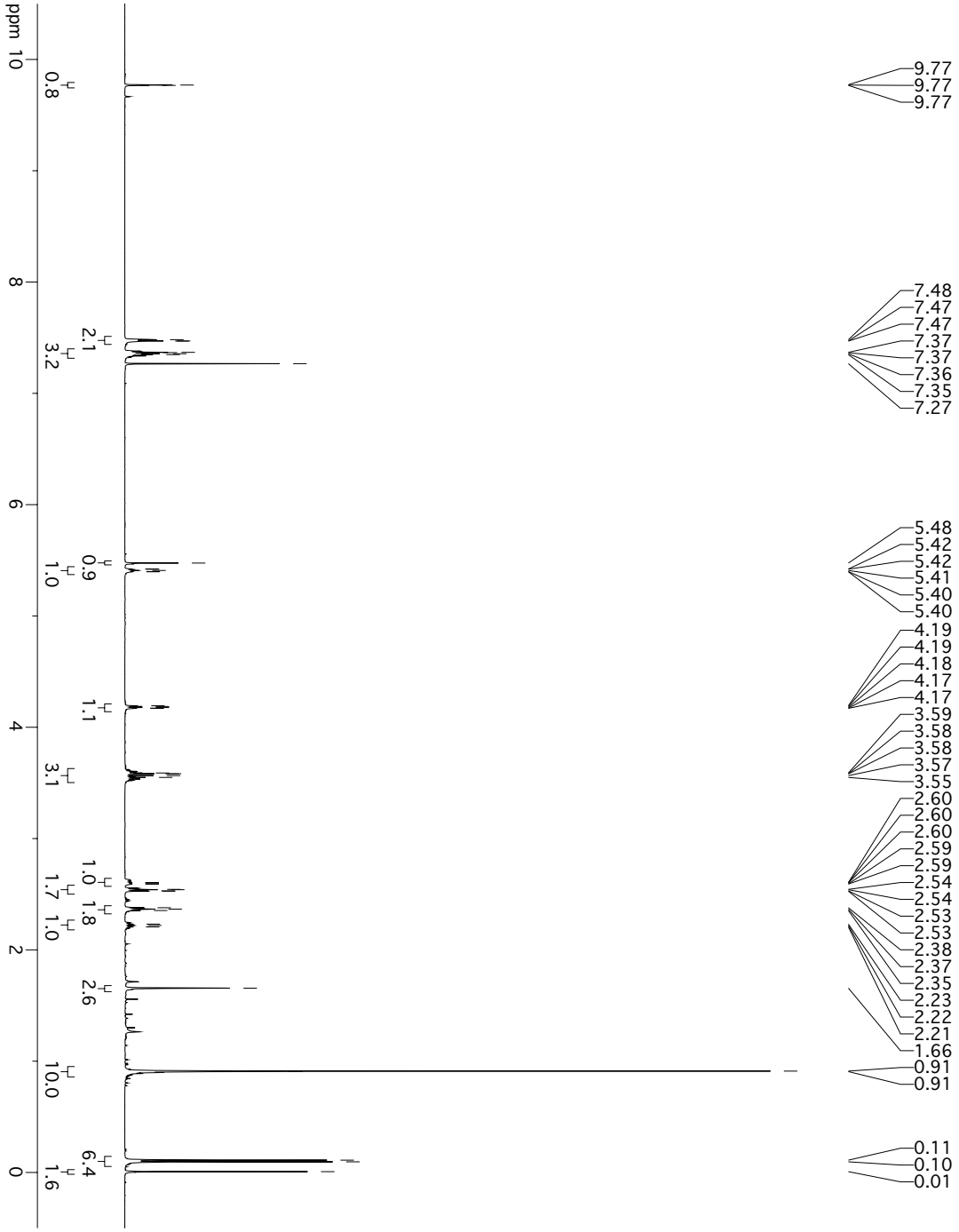

Me
H
O
Ph
OH
O
TBSO
H

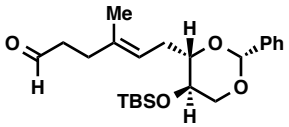
S9


ppm200
150
100
50
0
146.5
137.5
129.2
128.5
126.1
111.6
101.1
82.7
77.4
77.2
77.0
75.0
71.9
66.6
37.2
25.8
18.0
17.8
-4.0
-4.6

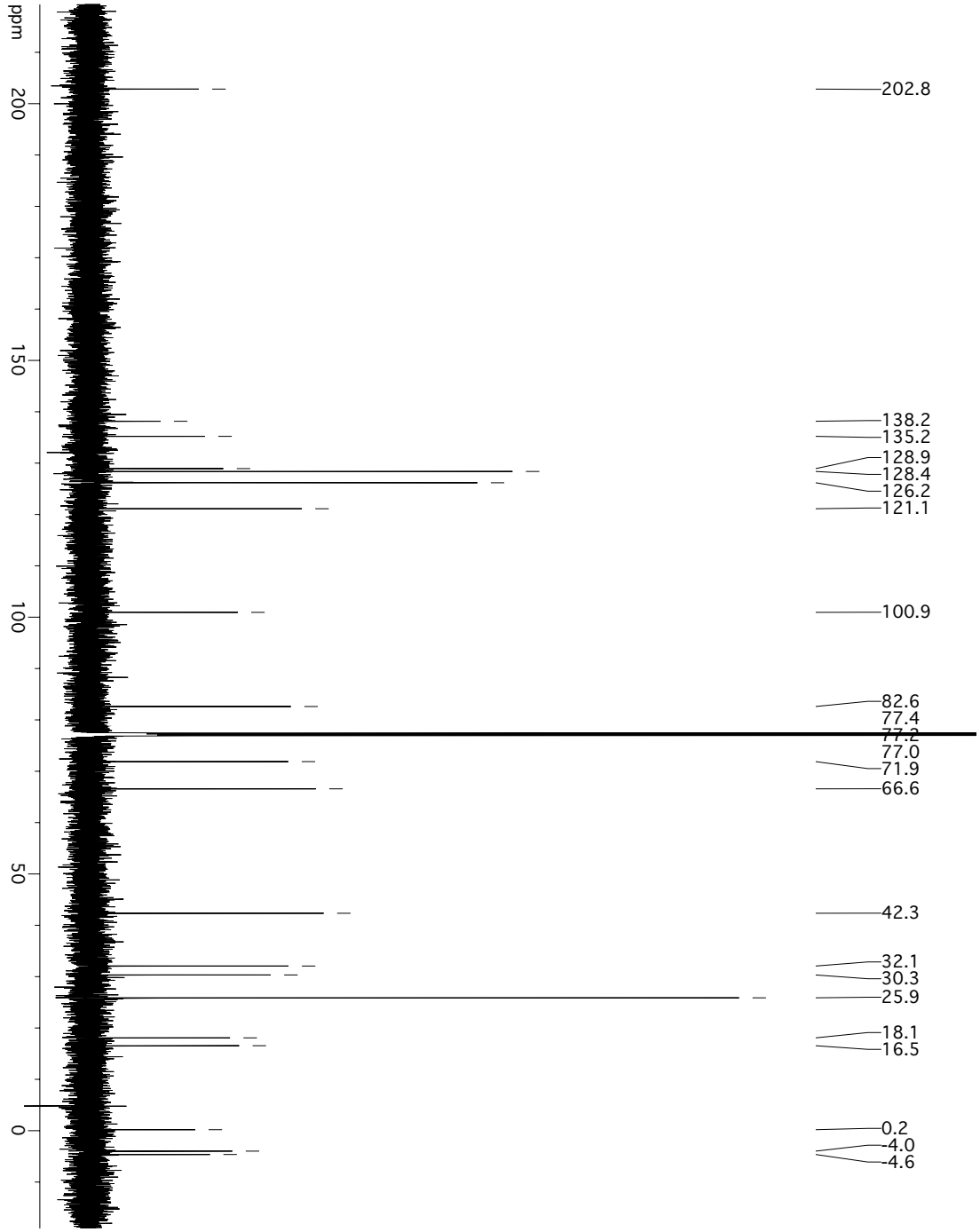

Me
O
H
H
O
Ph
O
TBSO
H

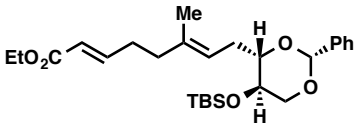
10


ppm
10
8
6
4
2
0
0.8
2.1
3.2
0.9
1.0
1.1
3.1
1.0
1.7
1.8
1.0
2.6
10.0
6.4
1.6
9.77
9.77
9.77
7.48
7.47
7.47
7.37
7.37
7.36
7.35
7.27
5.48
5.42
5.42
5.41
5.40
5.40
4.19
4.19
4.18
4.17
4.17
3.59
3.58
3.58
3.57
3.55
2.60
2.60
2.60
2.59
2.59
2.54
2.54
2.53
2.53
2.38
2.37
2.35
2.23
2.22
2.21
1.66
0.91
0.91
0.11
0.10
0.01

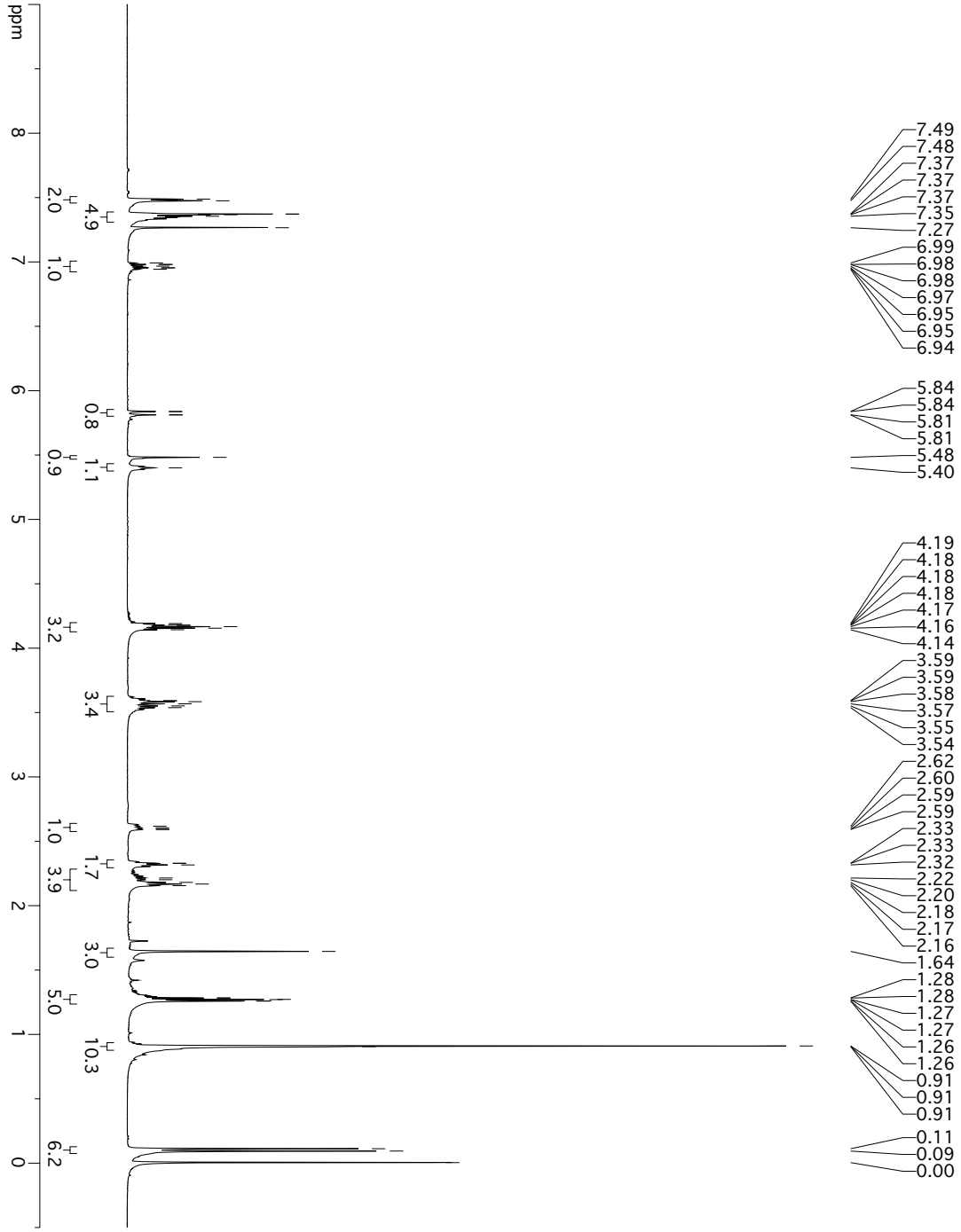

Me
O
H
H
O
Ph
O
TBSO
H

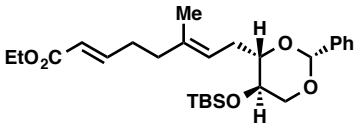
10


ppm
200
150
100
50
0
202.8
138.2
135.2
128.9
128.4
126.2
121.1
100.9
82.6
77.4
77.2
77.0
71.9
66.6
42.3
32.1
30.3
25.9
18.1
16.5
0.2
-4.0
-4.6

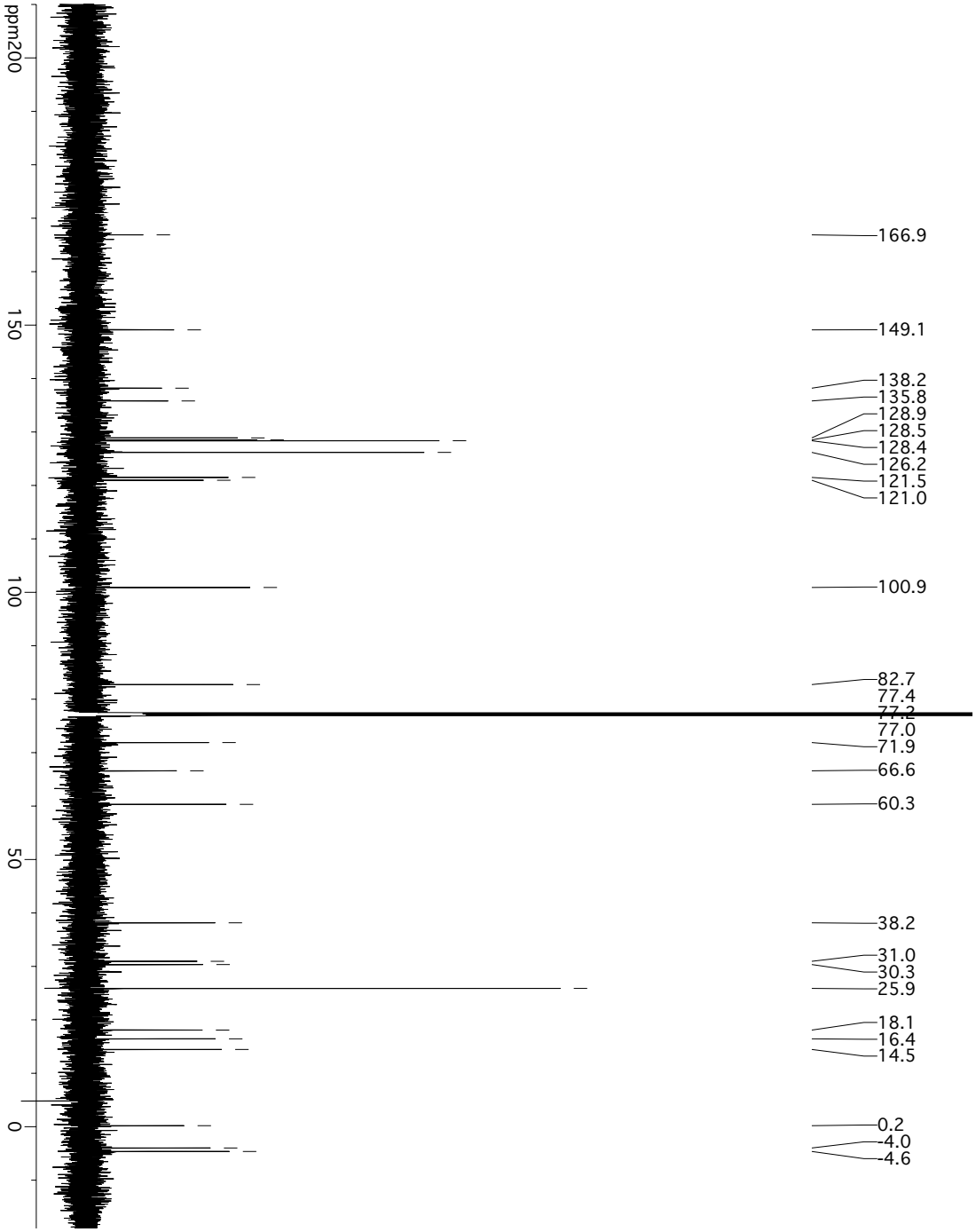

Me
H
O
Ph
EtO2C
O
TBSO
H

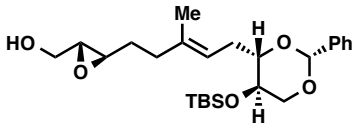
S10


ppm
8
7
6
5
4
3
2
1
0
2.0
4.9
1.0
0.8
0.9
1.1
3.2
3.4
1.0
1.7
3.9
3.0
5.0
10.3
6.2
7.49
7.48
7.37
7.37
7.37
7.35
7.27
6.99
6.98
6.98
6.97
6.95
6.95
6.94
5.84
5.84
5.81
5.81
5.48
5.40
4.19
4.18
4.18
4.18
4.17
4.16
4.14
3.59
3.59
3.58
3.57
3.55
3.54
2.62
2.60
2.59
2.59
2.33
2.33
2.32
2.22
2.20
2.18
2.17
2.16
1.64
1.28
1.28
1.27
1.27
1.26
1.26
0.91
0.91
0.91
0.11
0.09
0.00

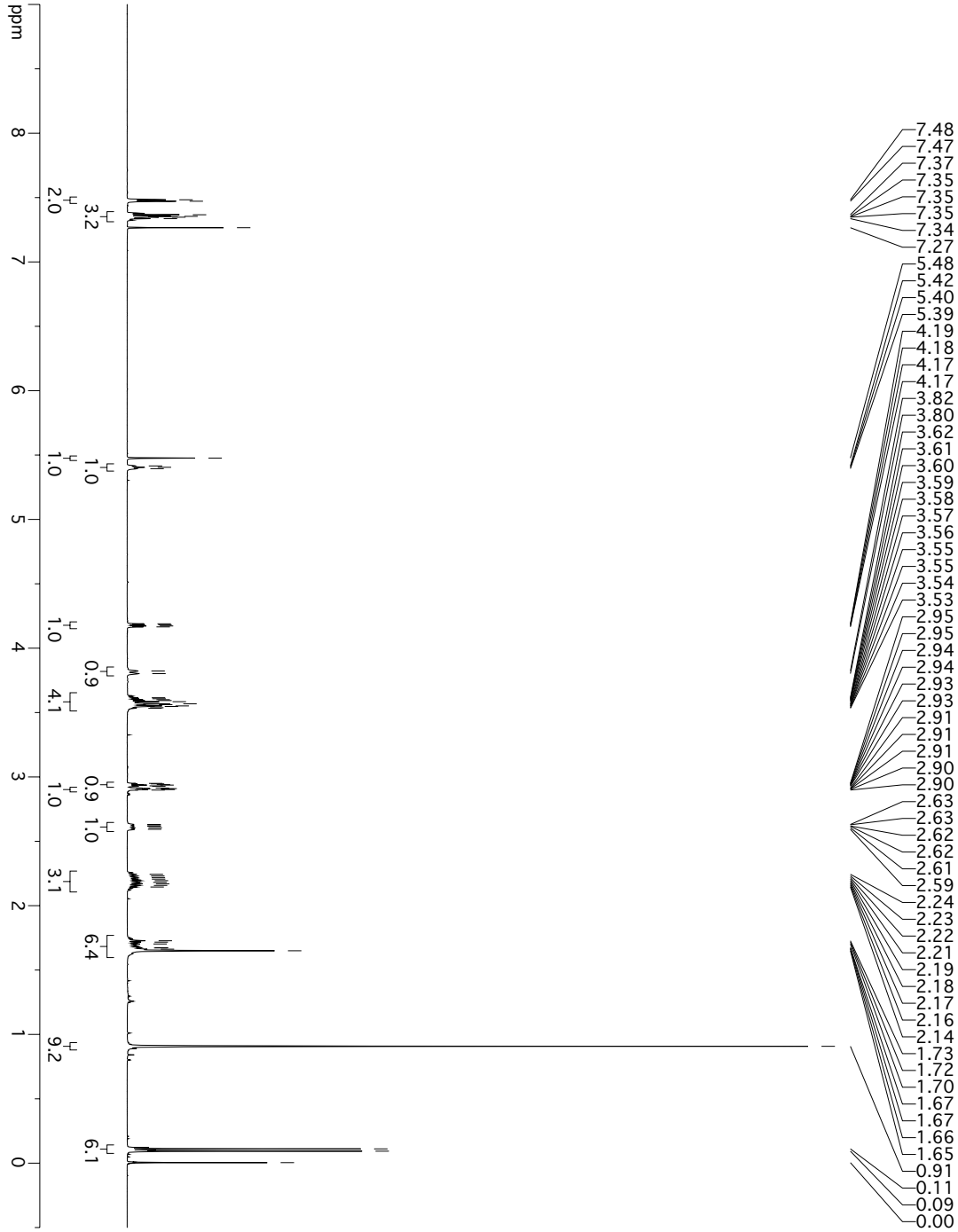

Me
H
O
Ph
EtO2C
O
TBSO
H

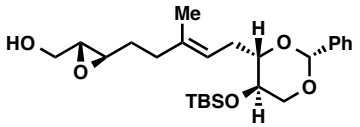
S10


ppm200
150
100
50
0
166.9
149.1
138.2
135.8
128.9
128.5
128.4
126.2
121.5
121.0
100.9
82.7
77.4
77.2
77.0
71.9
66.6
60.3
38.2
31.0
30.3
25.9
18.1
16.4
14.5
0.2
-4.0
-4.6

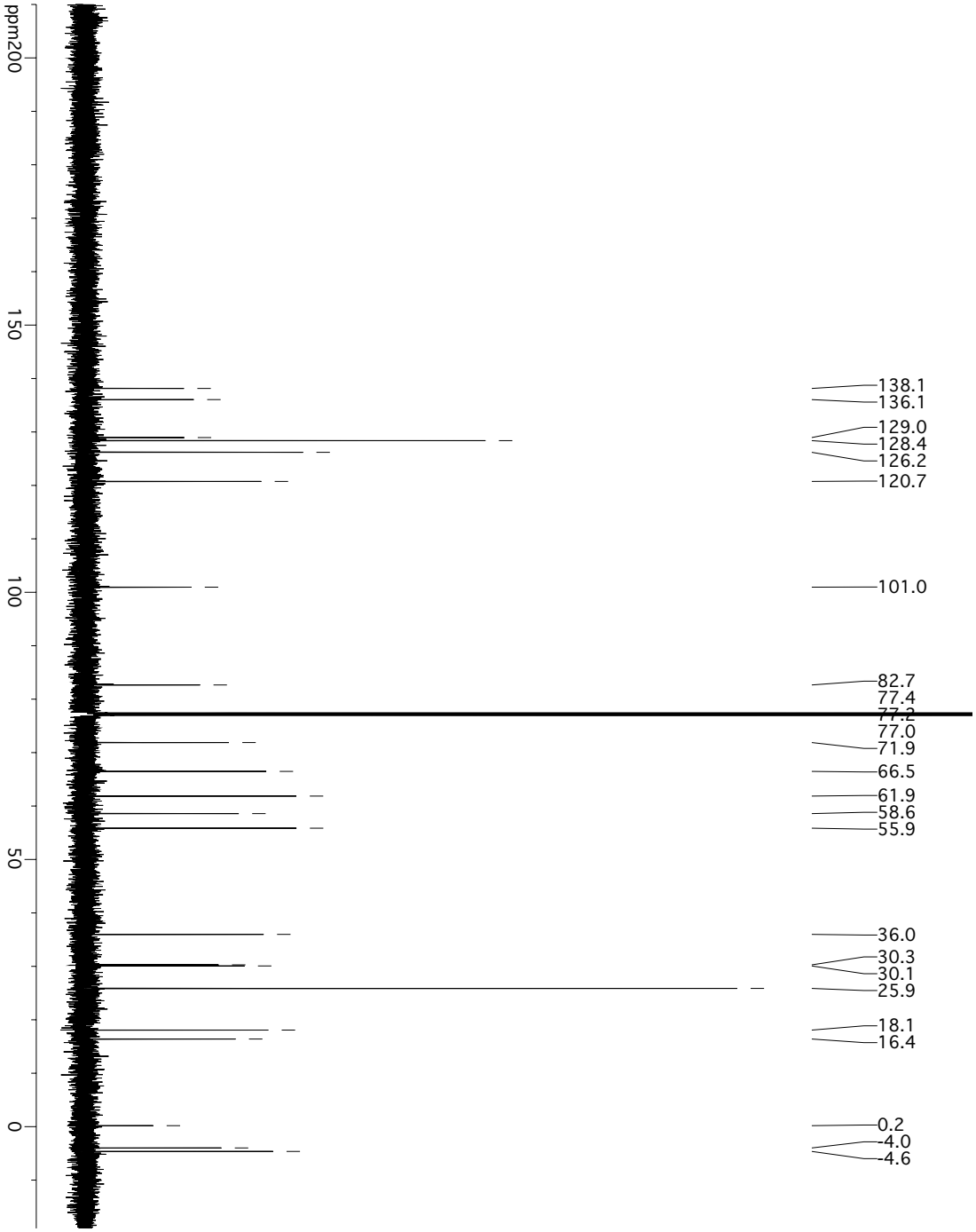

Me
H
HO
O
O
Ph
O
TBSO
H

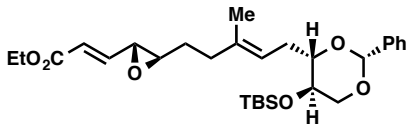
S12


ppm
8
7
6
5
4
3
2
1
0
2.0
3.2
1.0
1.0
1.0
0.9
4.1
0.9
1.0
1.0
3.1
6.4
9.2
6.1
7.48
7.47
7.37
7.35
7.35
7.35
7.34
7.27
5.48
5.42
5.40
5.39
4.19
4.18
4.17
4.17
3.82
3.80
3.62
3.61
3.60
3.59
3.58
3.57
3.56
3.55
3.55
3.54
3.53
2.95
2.95
2.94
2.94
2.93
2.93
2.91
2.91
2.91
2.90
2.90
2.63
2.63
2.62
2.62
2.61
2.59
2.24
2.23
2.22
2.21
2.19
2.18
2.17
2.16
2.14
1.73
1.72
1.70
1.67
1.67
1.66
1.65
0.91
0.11
0.09
0.00

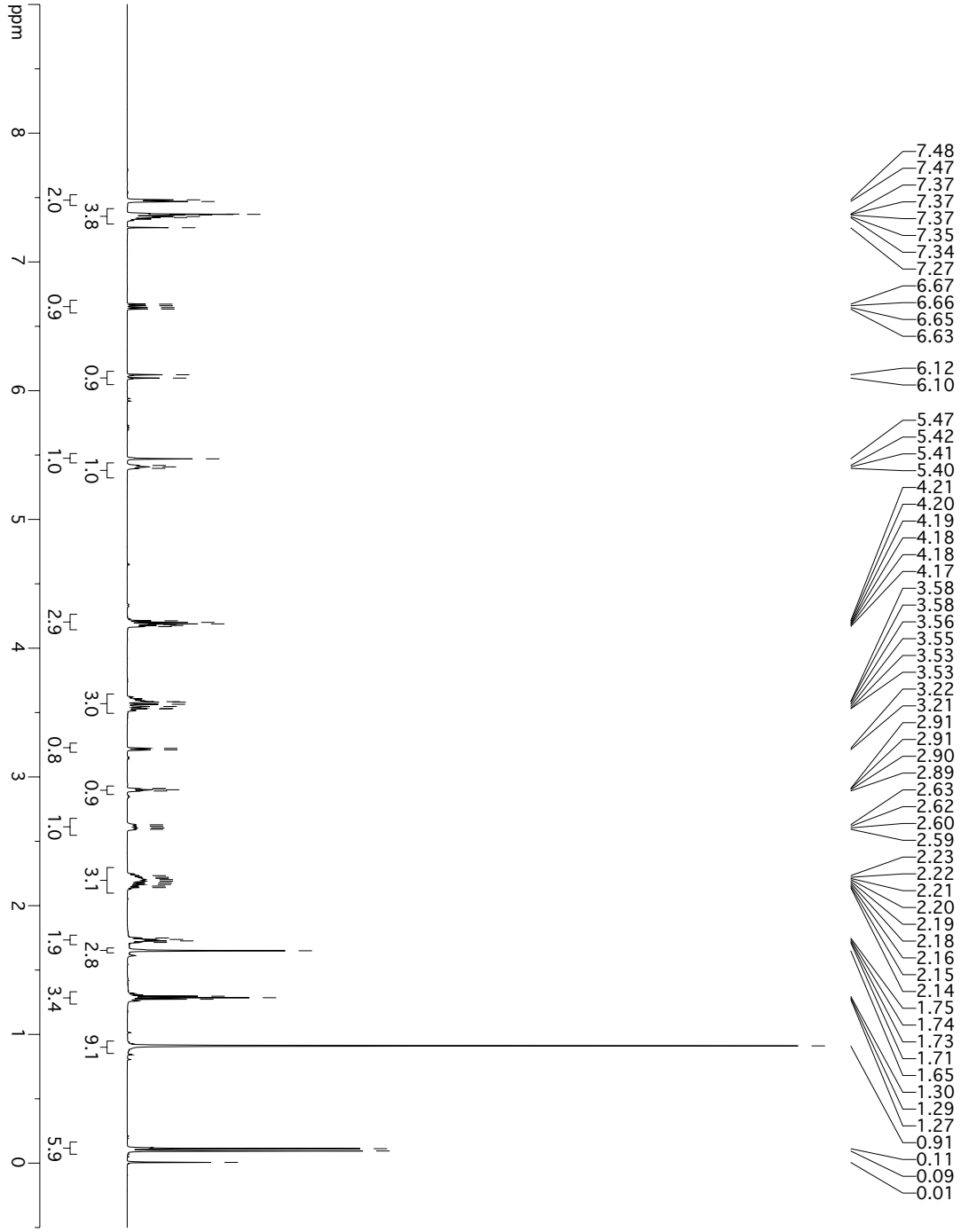

Me
HO
H
O
Ph
O
O
TBSO
H

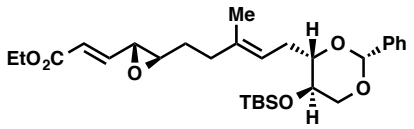
S12


ppm200
150
100
50
0
138.1
136.1
129.0
128.4
126.2
120.7
101.0
82.7
77.4
77.2
77.0
71.9
66.5
61.9
58.6
55.9
36.0
30.3
30.1
25.9
18.1
16.4
0.2
-4.0
-4.6

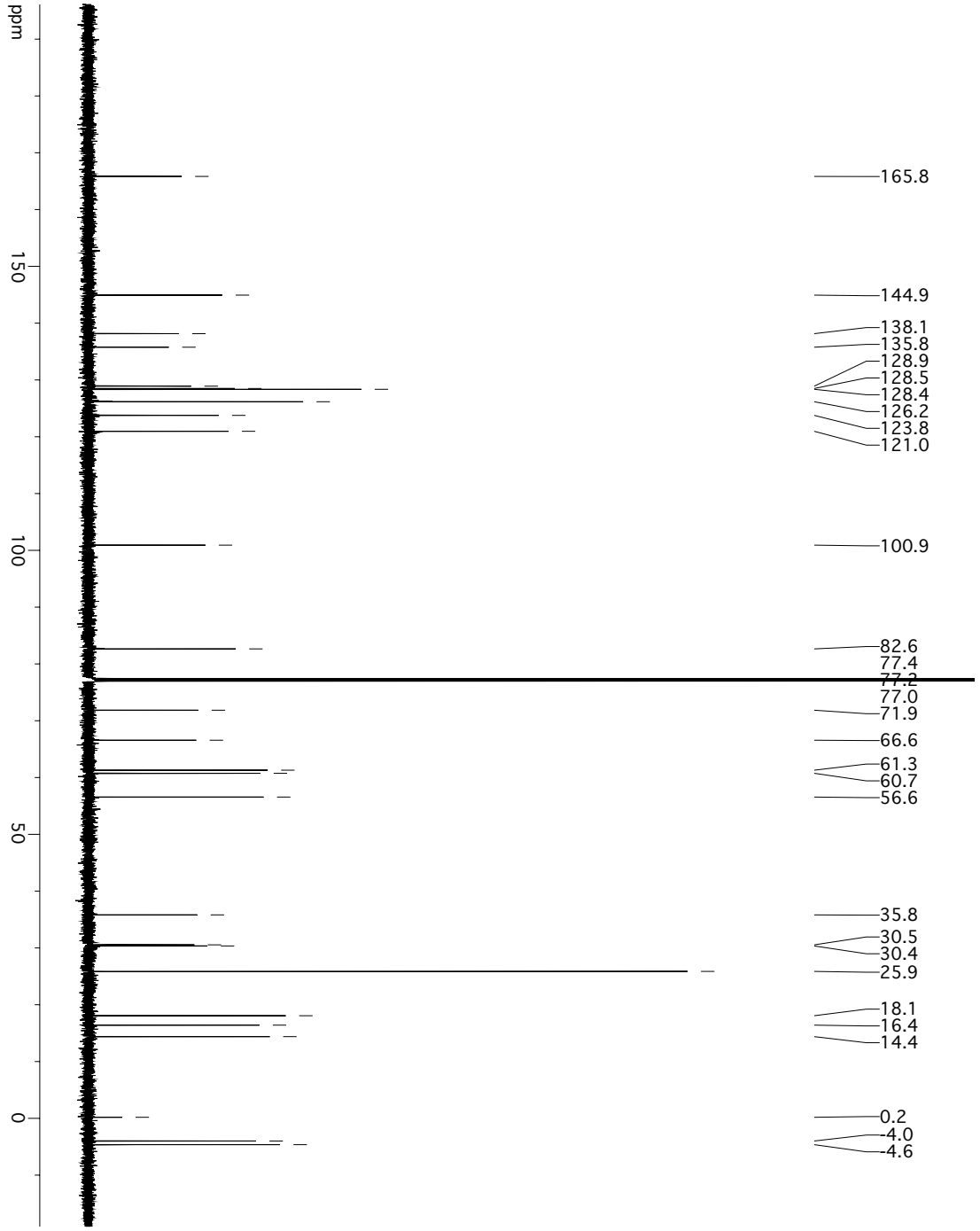

Me
H
O
Ph
EtO2C
O
O
TBSO
H

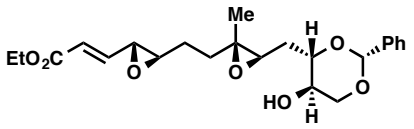
S14


ppm
8
7
6
5
4
3
2
1
0
2.0
3.8
0.9
0.9
1.0
1.0
2.9
3.0
0.8
0.9
1.0
3.1
1.9
2.8
3.4
9.1
5.9
7.48
7.47
7.37
7.37
7.37
7.35
7.34
7.27
6.67
6.66
6.65
6.63
6.12
6.10
5.47
5.42
5.41
5.40
4.21
4.20
4.19
4.18
4.18
4.17
3.58
3.58
3.56
3.55
3.53
3.53
3.22
3.21
2.91
2.91
2.90
2.89
2.63
2.62
2.60
2.59
2.23
2.22
2.21
2.20
2.19
2.18
2.16
2.15
2.14
1.75
1.74
1.73
1.71
1.65
1.30
1.29
1.27
0.91
0.11
0.09
0.01

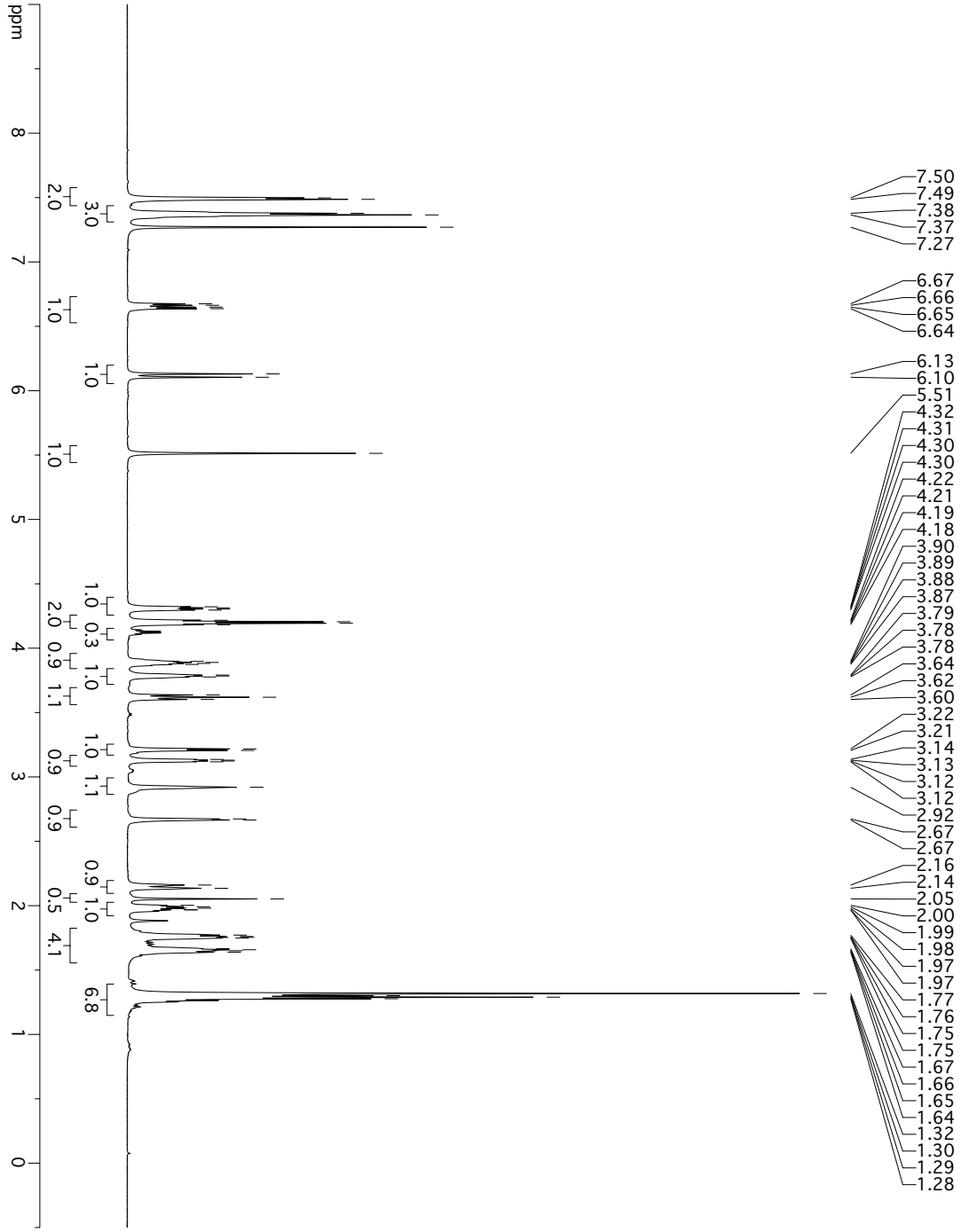

Me
H
O
Ph
EtO2C
O
O
TBSO
H

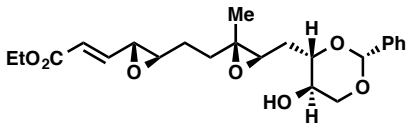
S14


ppm
150
100
50
0
165.8
144.9
138.1
135.8
128.9
128.5
128.4
126.2
123.8
121.0
100.9
82.6
77.4
77.2
77.0
71.9
66.6
61.3
60.7
56.6
35.8
30.5
30.4
25.9
18.1
16.4
14.4
0.2
-4.0
-4.6

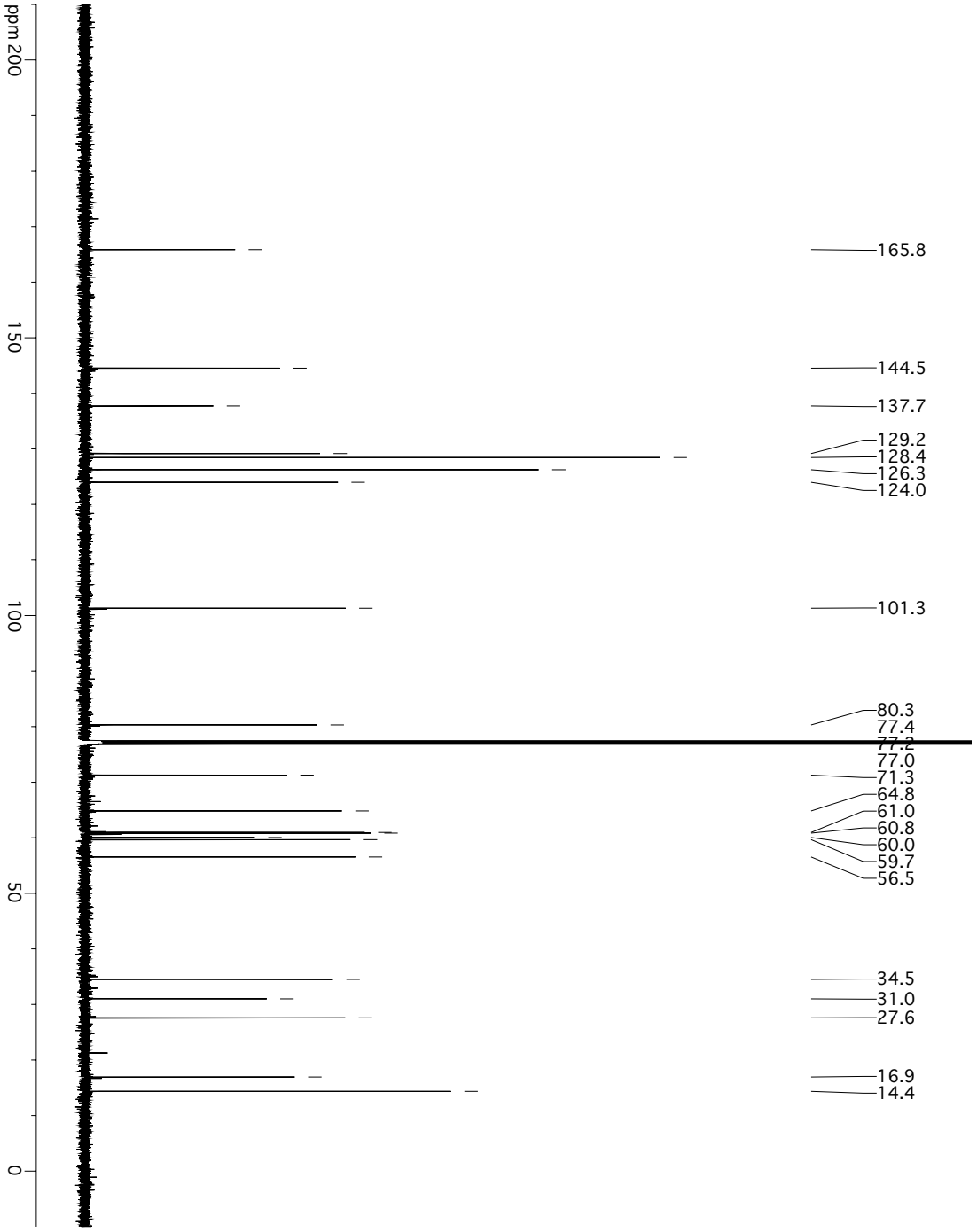

Me
H
O
Ph
EtO2C
O
O
O
HO
H

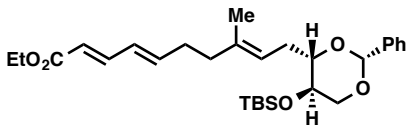
5


ppm
8
7
6
5
4
3
2
1
0
2.0
3.0
1.0
1.0
1.0
1.0
0.3
2.0
0.9
1.0
1.1
1.0
1.1
0.9
0.9
0.9
1.0
0.5
4.1
6.8
7.50
7.49
7.38
7.37
7.27
6.67
6.66
6.65
6.64
6.13
6.10
5.51
4.32
4.31
4.30
4.30
4.22
4.21
4.19
4.18
3.90
3.89
3.88
3.87
3.79
3.78
3.78
3.64
3.62
3.60
3.22
3.21
3.14
3.13
3.12
3.12
2.92
2.67
2.67
2.16
2.14
2.05
2.00
1.99
1.98
1.97
1.97
1.77
1.76
1.75
1.75
1.67
1.66
1.65
1.64
1.32
1.30
1.29
1.28

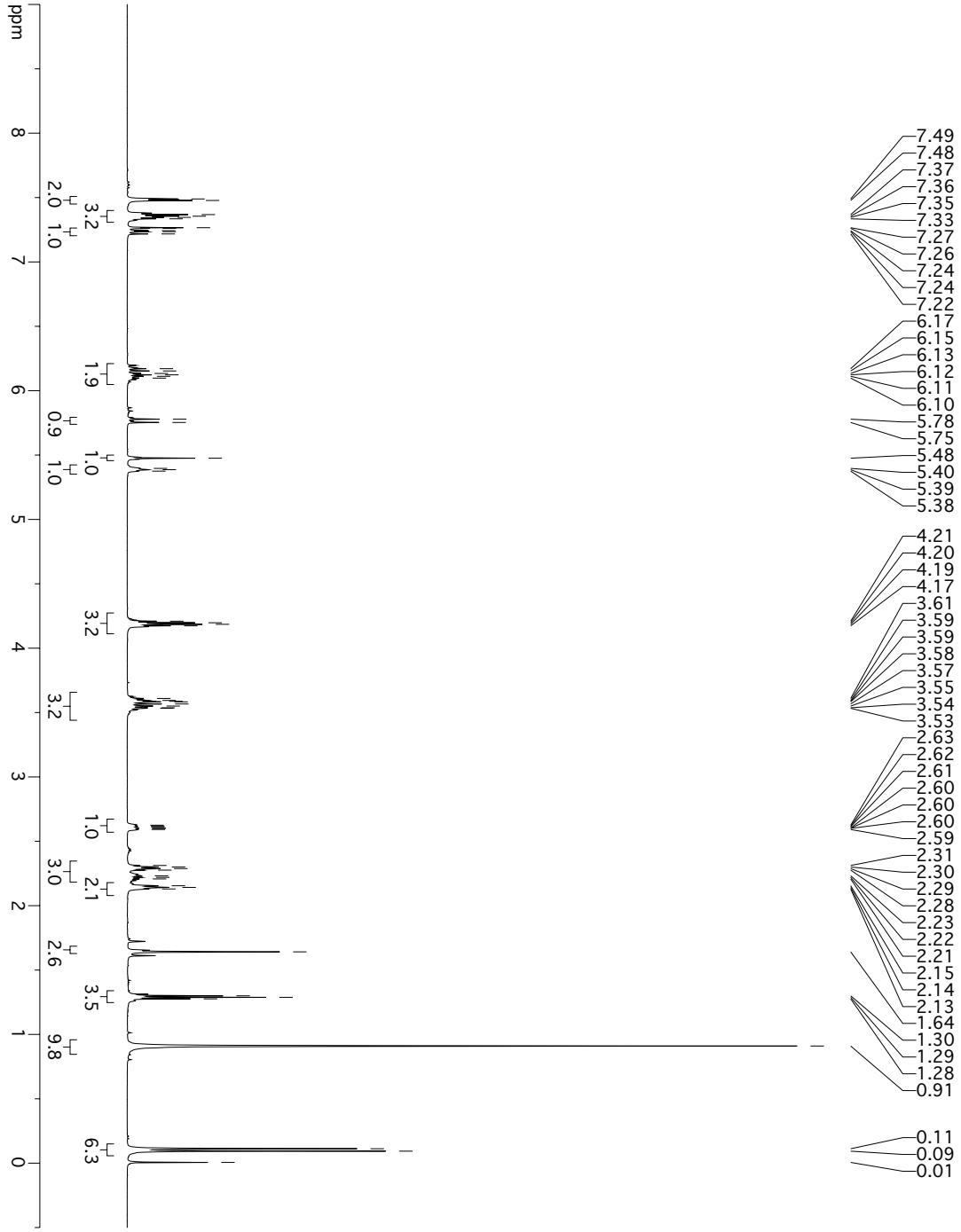

Me
H
O
Ph
EtO2C
O
O
O
HO
H

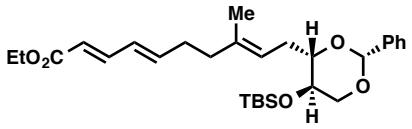
5


ppm
200
150
100
50
0
165.8
144.5
137.7
129.2
128.4
126.3
124.0
101.3
80.3
77.4
77.2
77.0
71.3
64.8
61.0
60.8
60.0
59.7
56.5
34.5
31.0
27.6
16.9
14.4

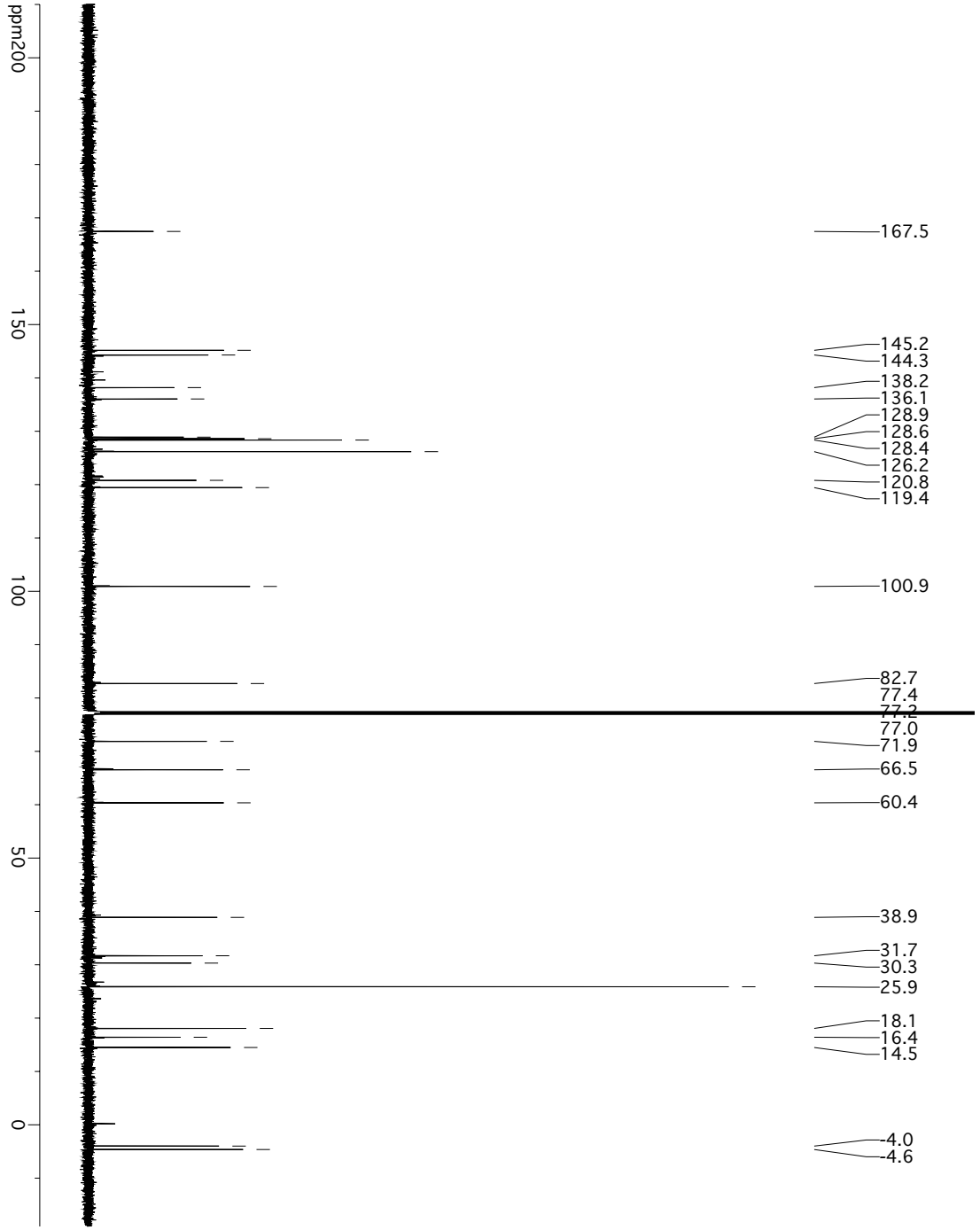

Me
H
O
Ph
EtO2C
O
TBSO
H

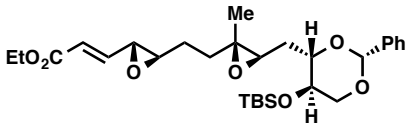
S17


ppm
8
7
6
5
4
3
2
1
0
2.0
3.2
1.0
1.9
0.9
1.0
1.0
3.2
3.2
1.0
3.0
2.1
2.6
3.5
9.8
6.3
7.49
7.48
7.37
7.36
7.35
7.33
7.27
7.26
7.24
7.24
7.22
6.17
6.15
6.13
6.12
6.11
6.10
5.78
5.75
5.48
5.40
5.39
5.38
4.21
4.20
4.19
4.17
3.61
3.59
3.59
3.58
3.57
3.55
3.54
3.53
2.63
2.62
2.61
2.60
2.60
2.60
2.59
2.31
2.30
2.29
2.28
2.23
2.22
2.21
2.15
2.14
2.13
1.64
1.30
1.29
1.28
0.91
0.11
0.09
0.01

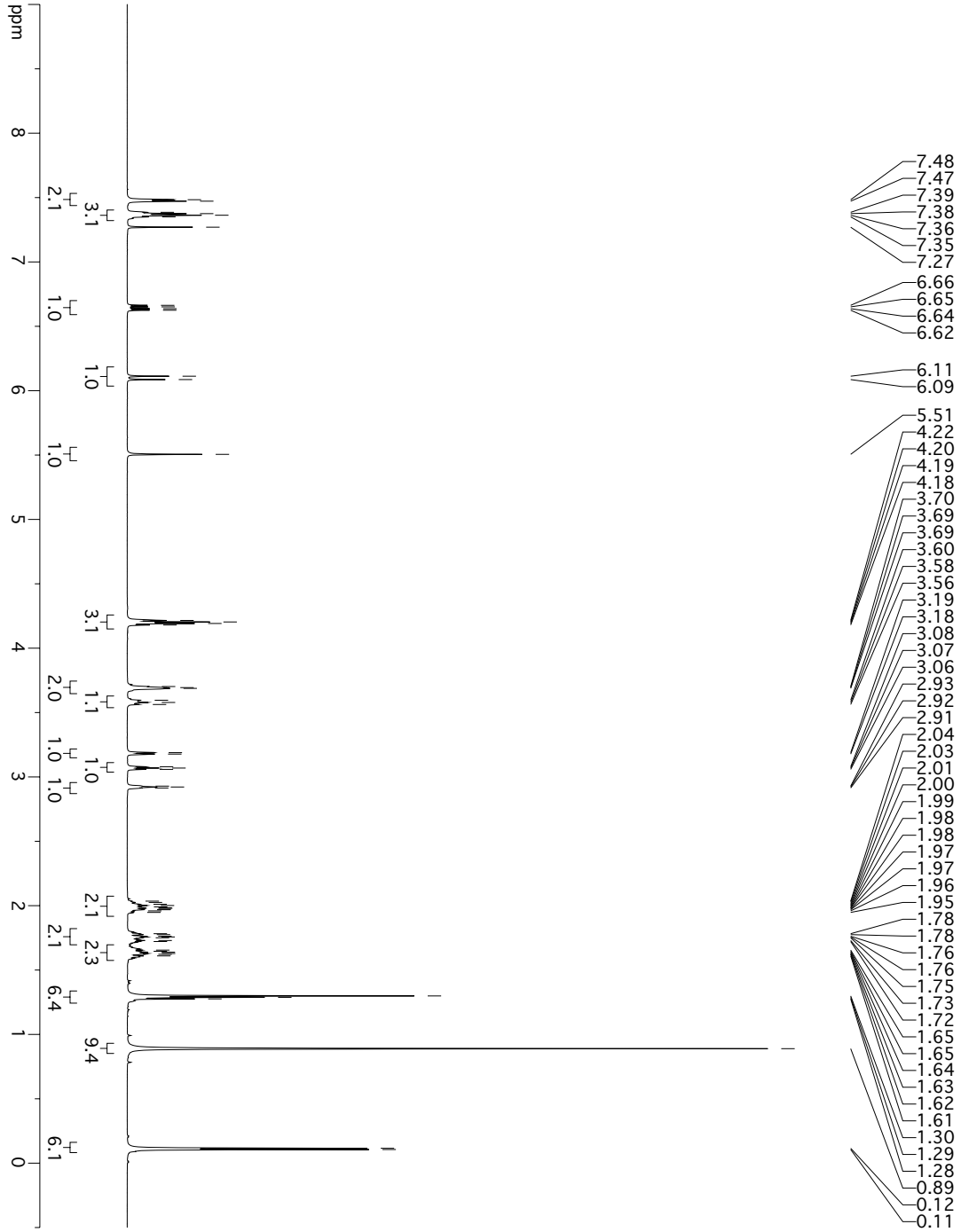

Me
H
O
Ph
EtO2C
O
TBSO
H

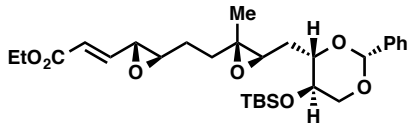
S17


ppm200
150
100
50
0
167.5
145.2
144.3
138.2
136.1
128.9
128.6
128.4
126.2
120.8
119.4
100.9
82.7
77.4
77.2
77.0
71.9
66.5
60.4
38.9
31.7
30.3
25.9
18.1
16.4
14.5
-4.0
-4.6

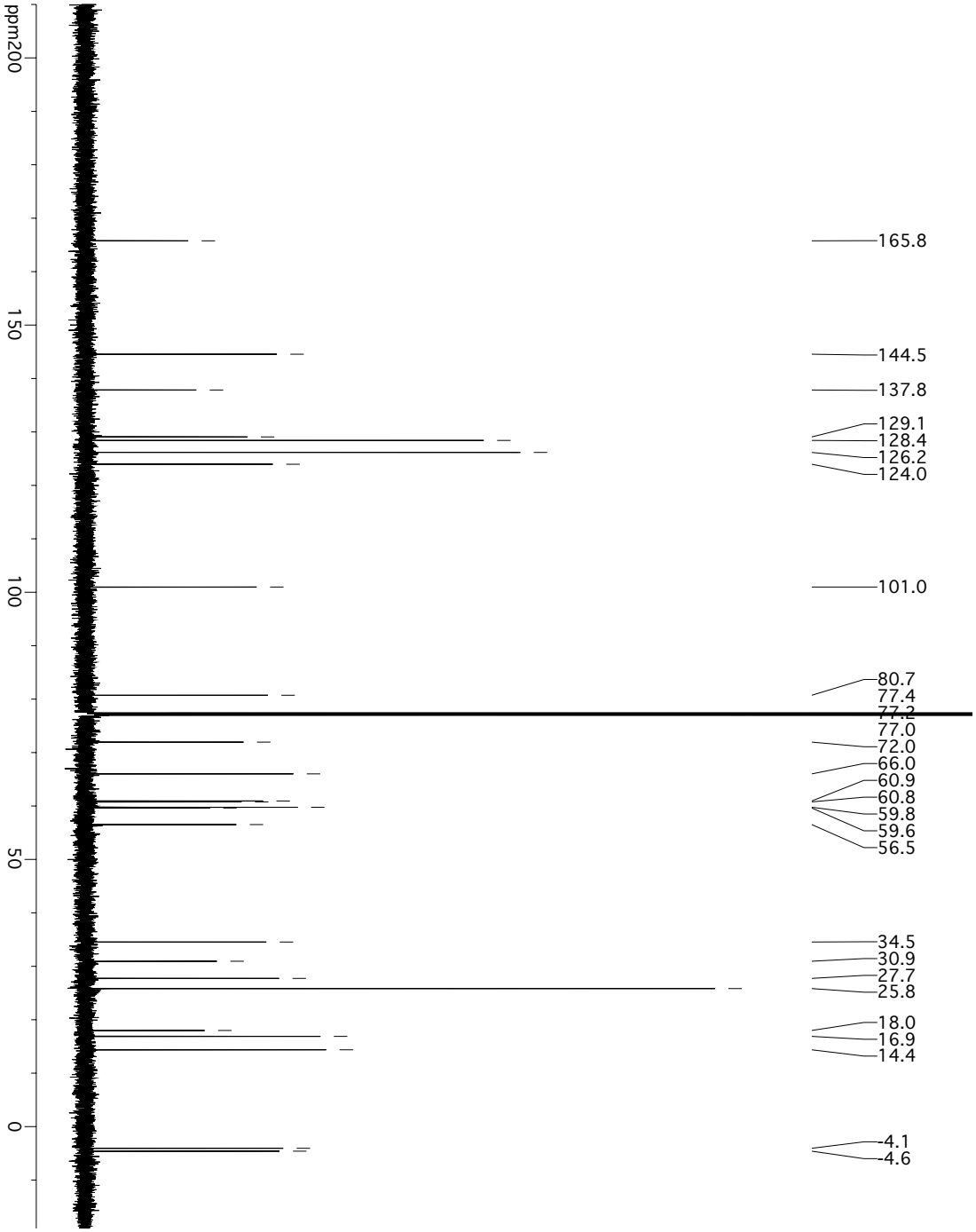

Me
H
O
Ph
EtO2C
O
O
O
TBSO
H

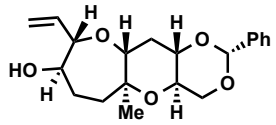
S15


ppm
8
7
6
5
4
3
2
1
0
2.1
3.1
1.0
1.0
1.0
3.1
2.0
1.1
1.0
1.0
2.1
2.1
2.3
6.4
9.4
6.1
7.48
7.47
7.39
7.38
7.36
7.35
7.27
6.66
6.65
6.64
6.62
6.11
6.09
5.51
4.22
4.20
4.19
4.18
3.70
3.69
3.69
3.60
3.58
3.56
3.19
3.18
3.08
3.07
3.06
2.93
2.92
2.91
2.04
2.03
2.01
2.00
1.99
1.98
1.98
1.97
1.97
1.96
1.95
1.78
1.78
1.76
1.76
1.75
1.73
1.72
1.65
1.65
1.64
1.63
1.62
1.61
1.30
1.29
1.28
0.89
0.12
0.11

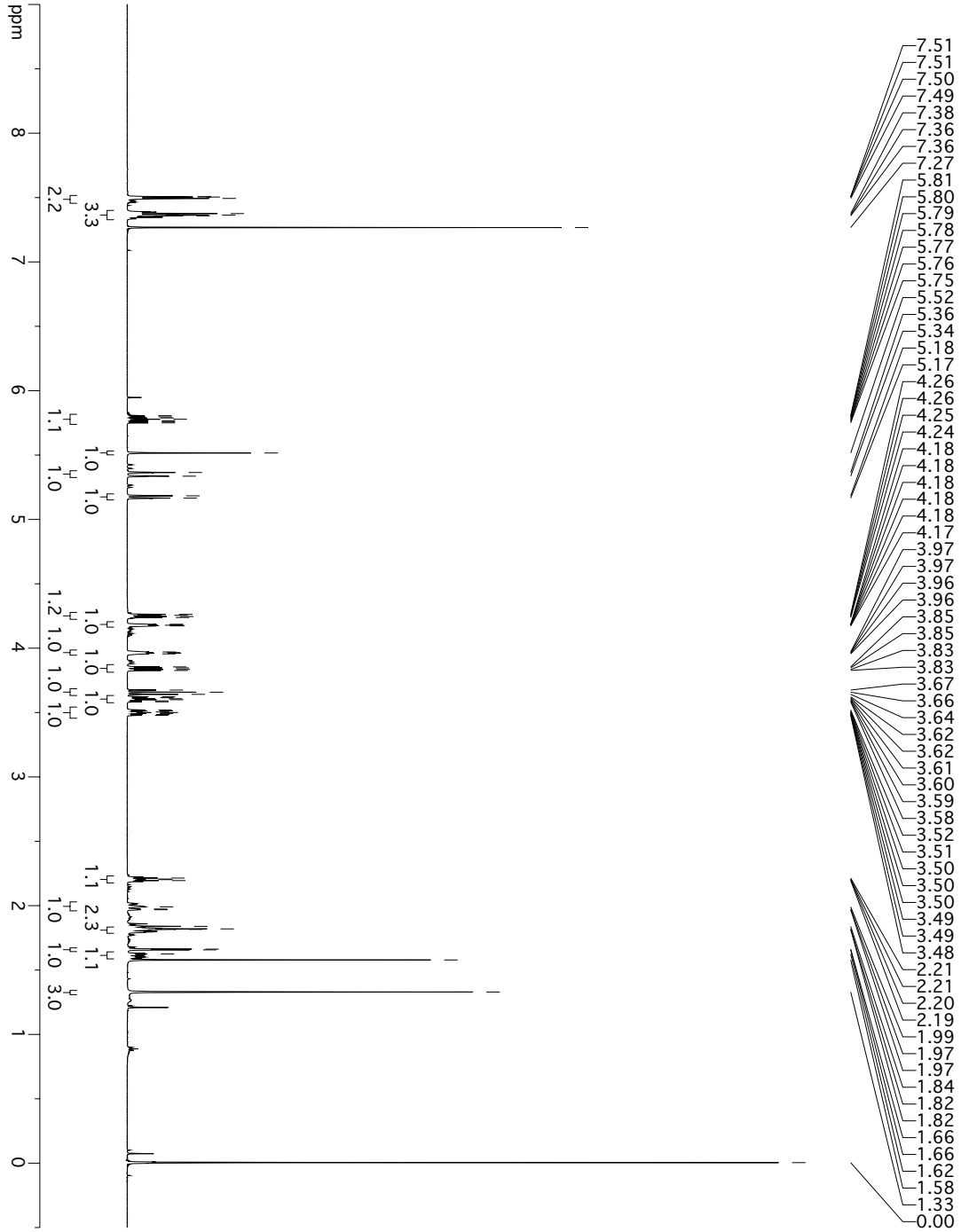

Me
H
O
Ph
EtO2C
O
O
O
TBSO
H

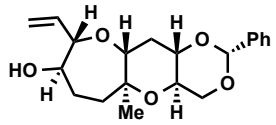
S15


ppm200
150
100
50
0
165.8
144.5
137.8
129.1
128.4
126.2
124.0
101.0
80.7
77.4
77.2
77.0
72.0
66.0
60.9
60.8
59.8
59.6
56.5
34.5
30.9
27.7
25.8
18.0
16.9
14.4
-4.1
-4.6

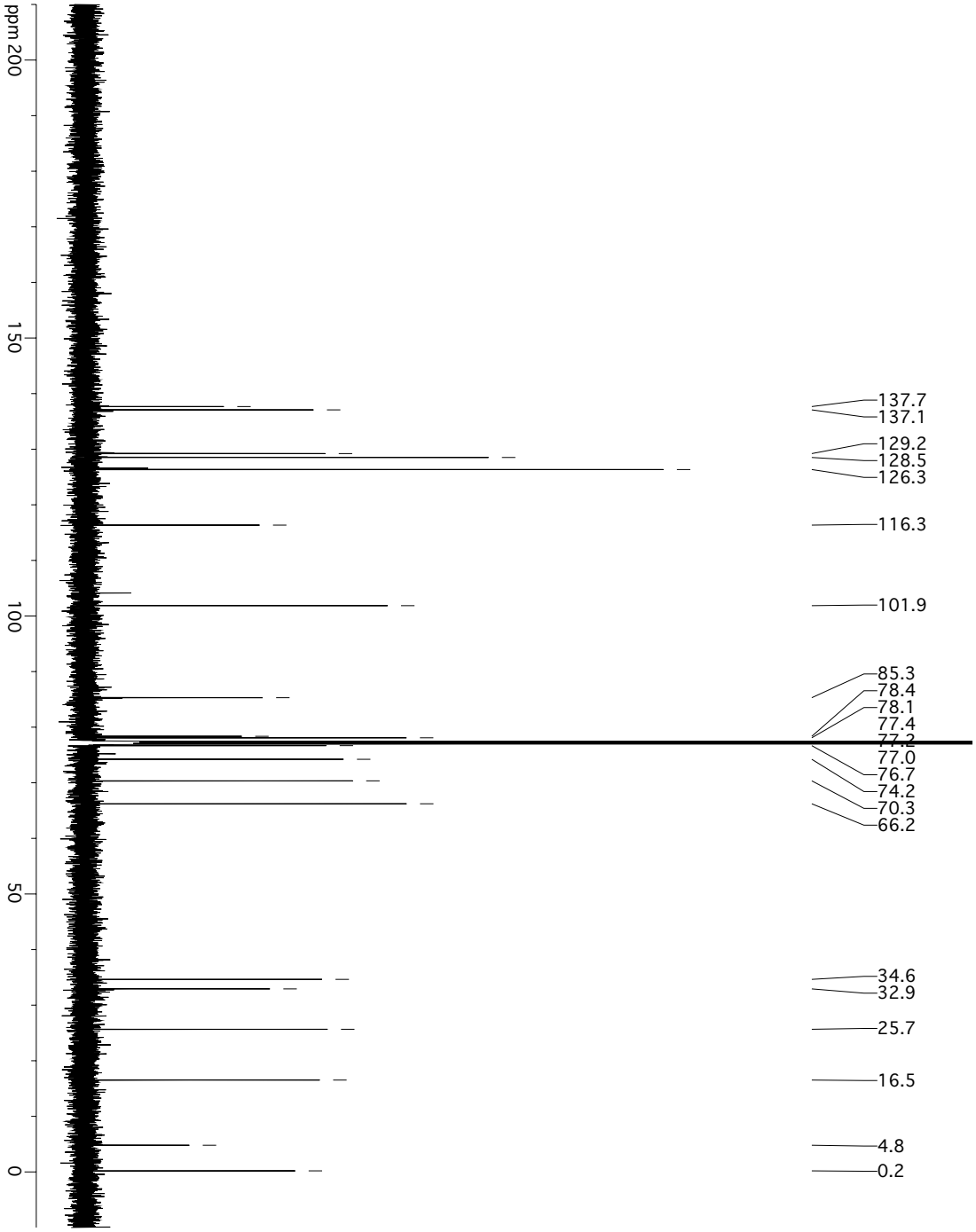

H
H
H
O
O
Ph
HO
H
O
O
Me
H

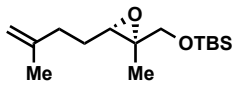
3


ppm
8
7
6
5
4
3
2
1
0
2.2
3.3
1.1
1.0
1.0
1.2
1.0
1.0
1.0
1.0
1.0
1.0
1.1
2.3
1.1
1.0
1.0
3.0
7.51
7.51
7.50
7.49
7.38
7.36
7.36
7.27
5.81
5.80
5.79
5.78
5.77
5.76
5.75
5.52
5.36
5.34
5.18
5.17
4.26
4.26
4.25
4.24
4.18
4.18
4.18
4.18
4.18
4.18
4.17
3.97
3.97
3.96
3.96
3.85
3.85
3.83
3.83
3.67
3.66
3.64
3.62
3.62
3.61
3.60
3.59
3.58
3.52
3.51
3.50
3.50
3.50
3.49
3.49
3.48
2.21
2.21
2.20
2.19
1.99
1.97
1.97
1.84
1.82
1.82
1.66
1.66
1.62
1.58
1.33
0.00

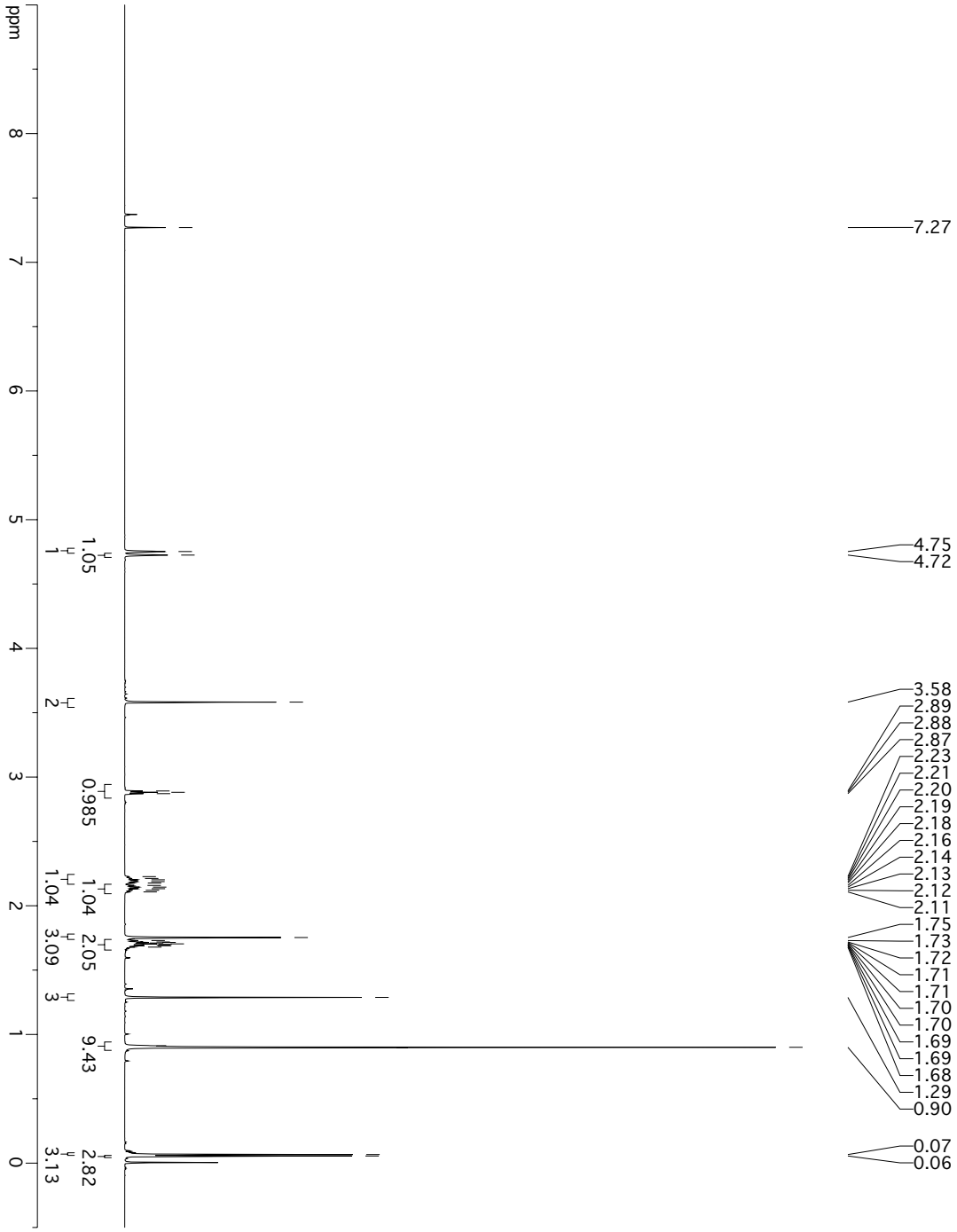

H
O
H
H
O
Ph
HO
H
O
O
Me
O
H

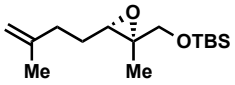
3


ppm
200
150
100
50
0
137.7
137.1
129.2
128.5
126.3
116.3
101.9
85.3
78.4
78.1
77.4
77.2
77.0
76.7
74.2
70.3
66.2
34.6
32.9
25.7
16.5
4.8
0.2

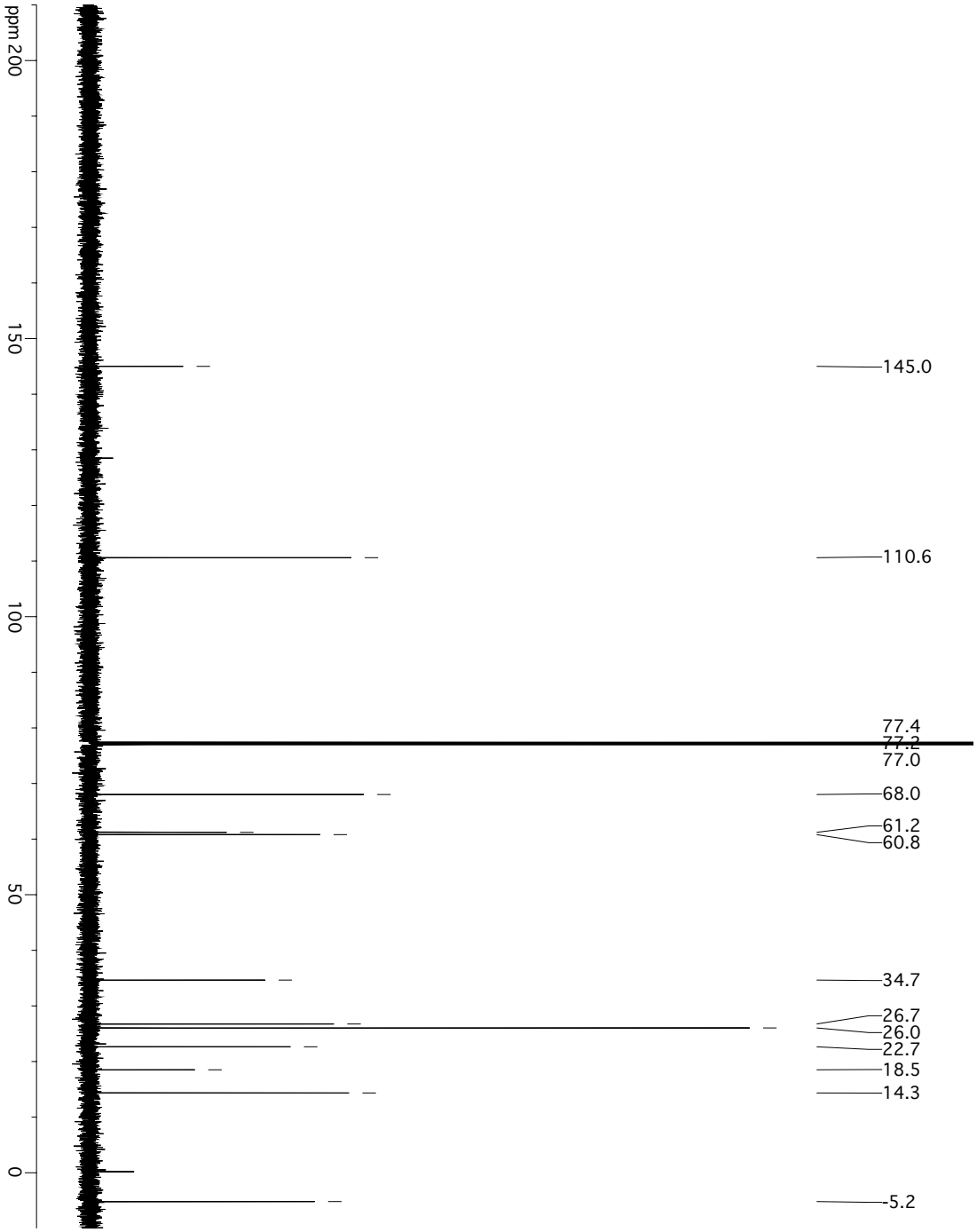

O
OTBS
Me
Me

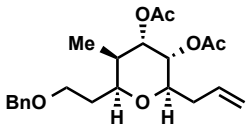
18


ppm
8
7
6
5
4
3
2
1
0
1.05
0.985
1.04
1.04
2.05
3.09
9.43
2.82
3.13
7.27
4.75
4.72
3.58
2.89
2.88
2.87
2.23
2.21
2.20
2.19
2.18
2.16
2.14
2.13
2.12
2.11
1.75
1.73
1.72
1.71
1.71
1.70
1.70
1.69
1.69
1.68
1.29
0.90
0.07
0.06

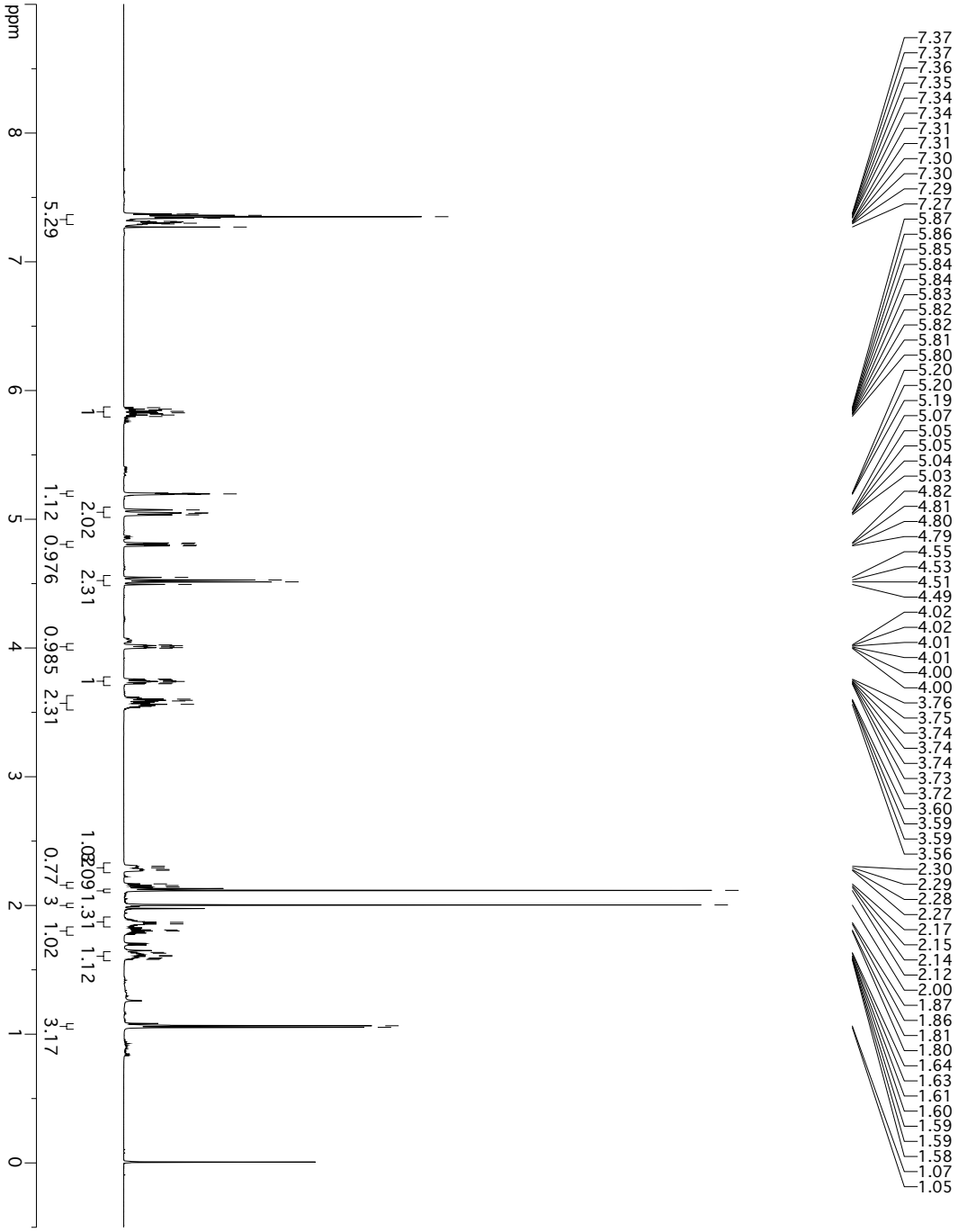

O
OTBS
Me
Me

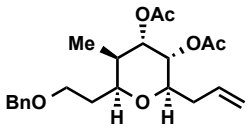
18


ppm
200
150
100
50
0
145.0
110.6
77.4
77.2
77.0
68.0
61.2
60.8
34.7
26.7
26.0
22.7
18.5
14.3
-5.2

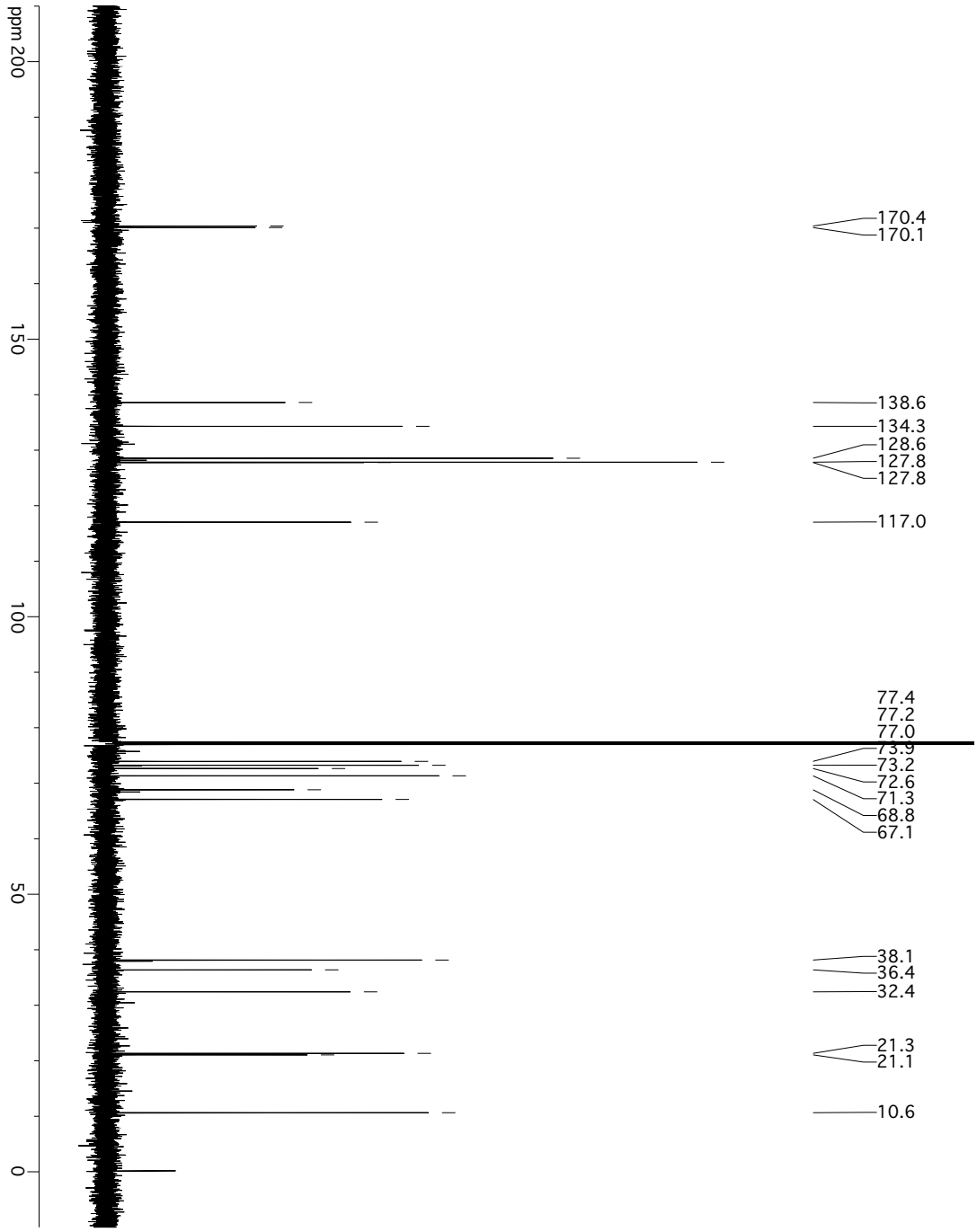

OAc
Me
OAc
BnO
H
O
H

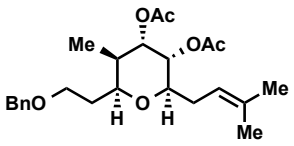
15


ppm
8
7
6
5
4
3
2
1
0
5.29
1
1.12
2.02
0.976
2.31
0.985
1
2.31
1.02
2.09
1.31
1.12
0.77
3
1.02
3.17
7.37
7.37
7.36
7.35
7.34
7.34
7.31
7.31
7.30
7.30
7.29
7.27
5.87
5.86
5.85
5.84
5.84
5.83
5.82
5.82
5.81
5.80
5.20
5.20
5.19
5.07
5.05
5.05
5.04
5.03
4.82
4.81
4.80
4.79
4.55
4.53
4.51
4.49
4.02
4.02
4.01
4.01
4.00
4.00
3.76
3.75
3.74
3.74
3.74
3.73
3.72
3.60
3.59
3.59
3.56
2.30
2.29
2.28
2.27
2.17
2.15
2.14
2.12
2.00
1.87
1.86
1.81
1.80
1.64
1.63
1.61
1.60
1.59
1.59
1.58
1.07
1.05

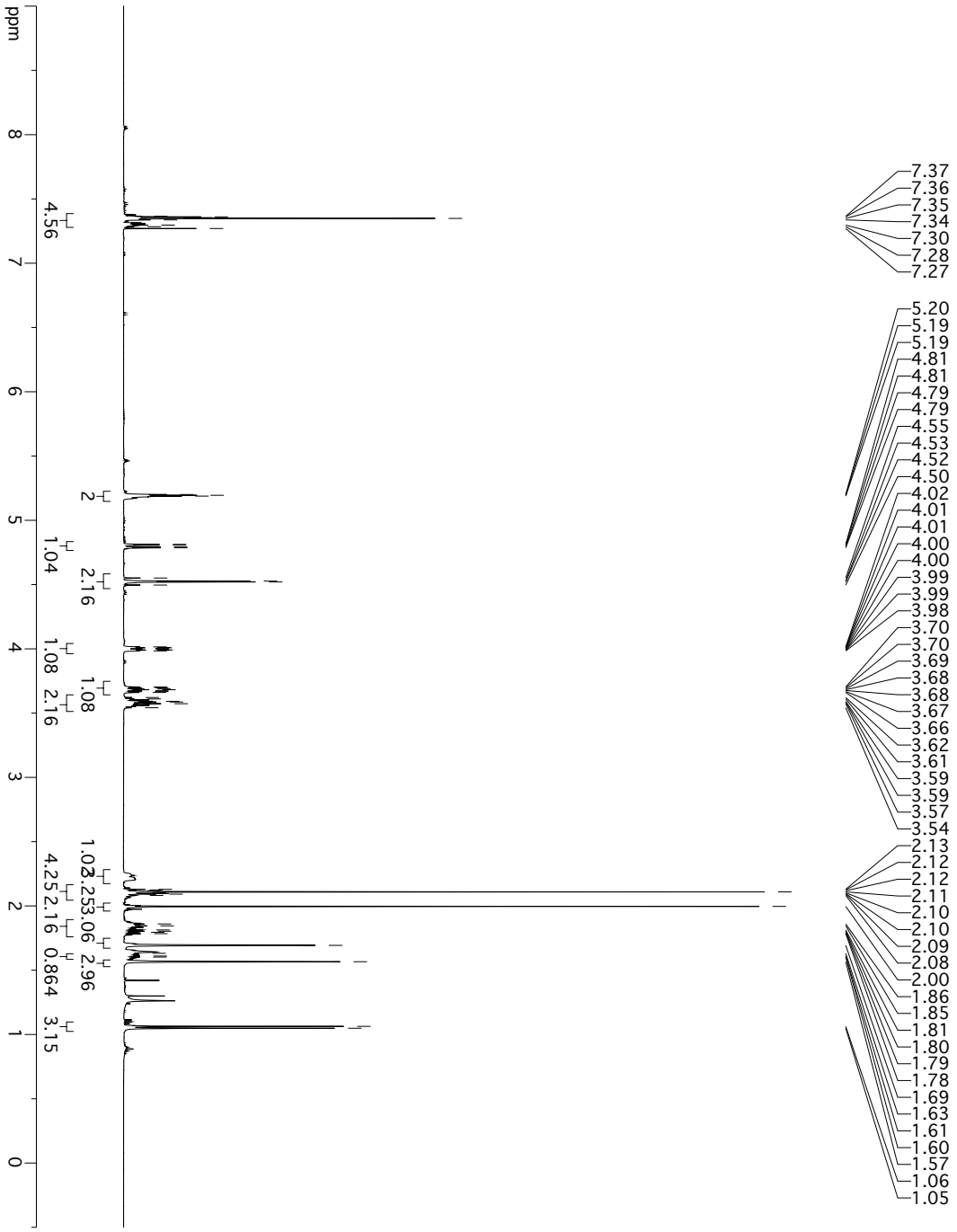

OAc
Me
OAc
BnO
O
H
H

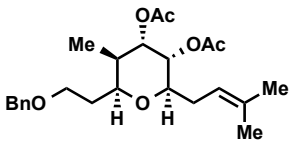
15


ppm
200
150
100
50
0
170.4
170.1
138.6
134.3
128.6
127.8
127.8
117.0
77.4
77.2
77.0
73.9
73.2
72.6
71.3
68.8
67.1
38.1
36.4
32.4
21.3
21.1
10.6

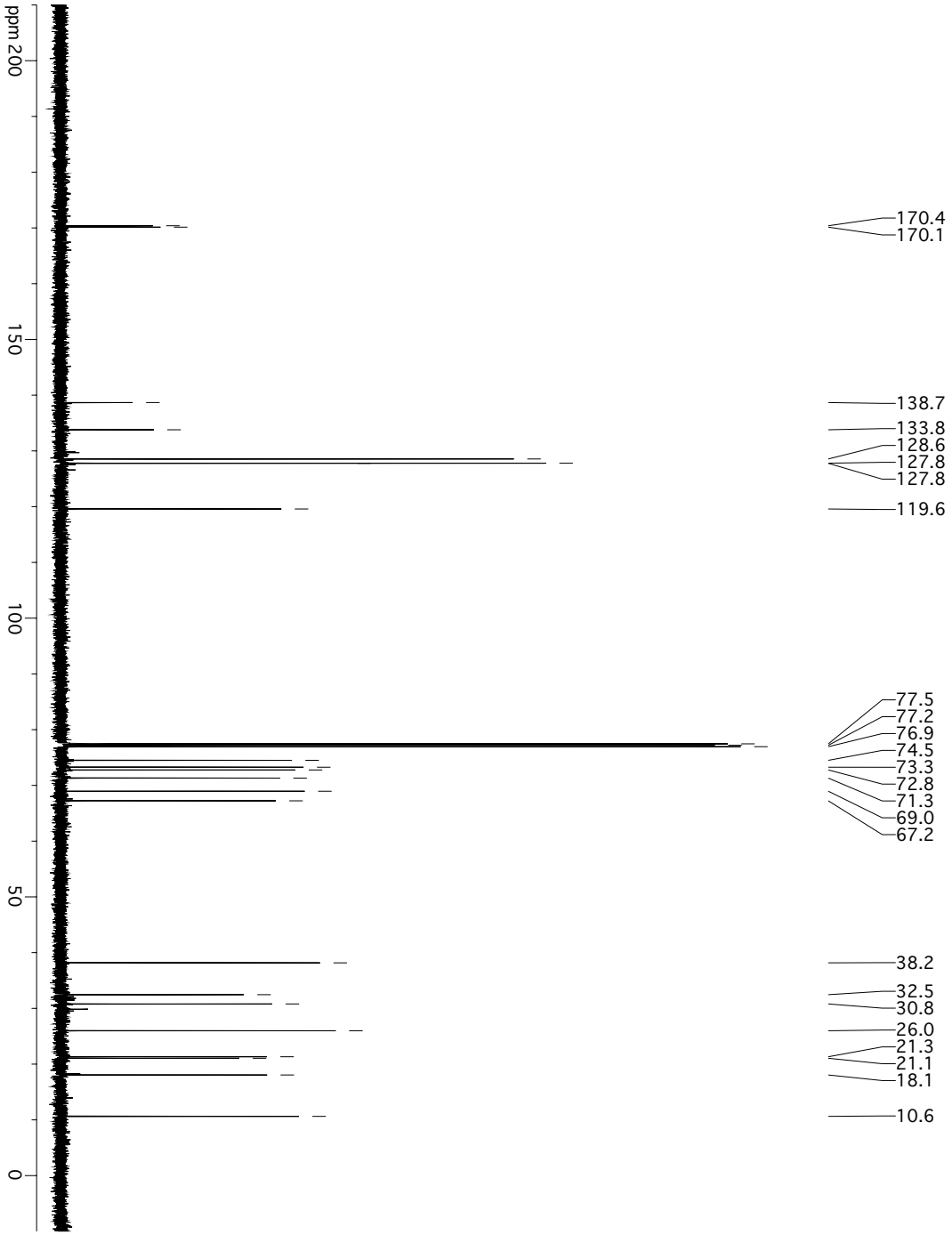

OAc
Me
OAc
BnO
O
H
H
Me
Me

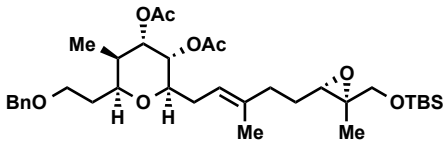
16


ppm
8
7
6
5
4
3
2
1
0
4.56
2
1.04
2.16
1.08
1.08
2.16
1.02
3.25
3.06
2.96
4.25
2.16
0.864
3.15
7.37
7.36
7.35
7.34
7.30
7.28
7.27
5.20
5.19
5.19
4.81
4.81
4.79
4.79
4.55
4.53
4.52
4.50
4.02
4.01
4.01
4.00
4.00
3.99
3.99
3.98
3.70
3.70
3.69
3.68
3.68
3.67
3.66
3.62
3.61
3.59
3.59
3.57
3.54
2.13
2.12
2.12
2.11
2.10
2.10
2.09
2.08
2.00
1.86
1.85
1.81
1.80
1.79
1.78
1.69
1.63
1.61
1.60
1.57
1.06
1.05

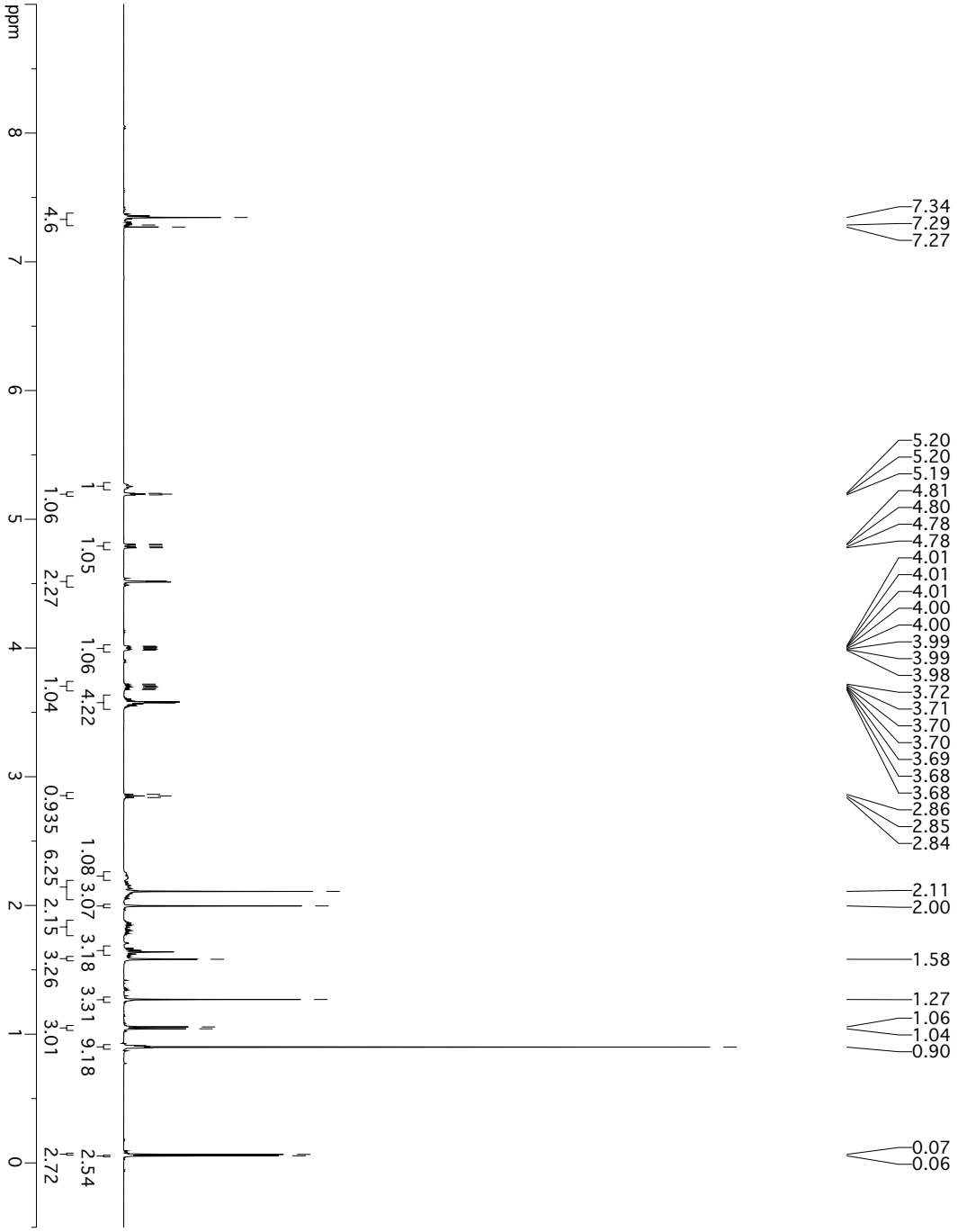

OAc
Me
OAc
BnO
O
H
H
Me
Me

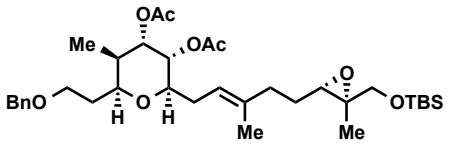
16


ppm
200
150
100
50
0
170.4
170.1
138.7
133.8
128.6
127.8
127.8
119.6
77.5
77.2
76.9
74.5
73.3
72.8
71.3
69.0
67.2
38.2
32.5
30.8
26.0
21.3
21.1
18.1
10.6

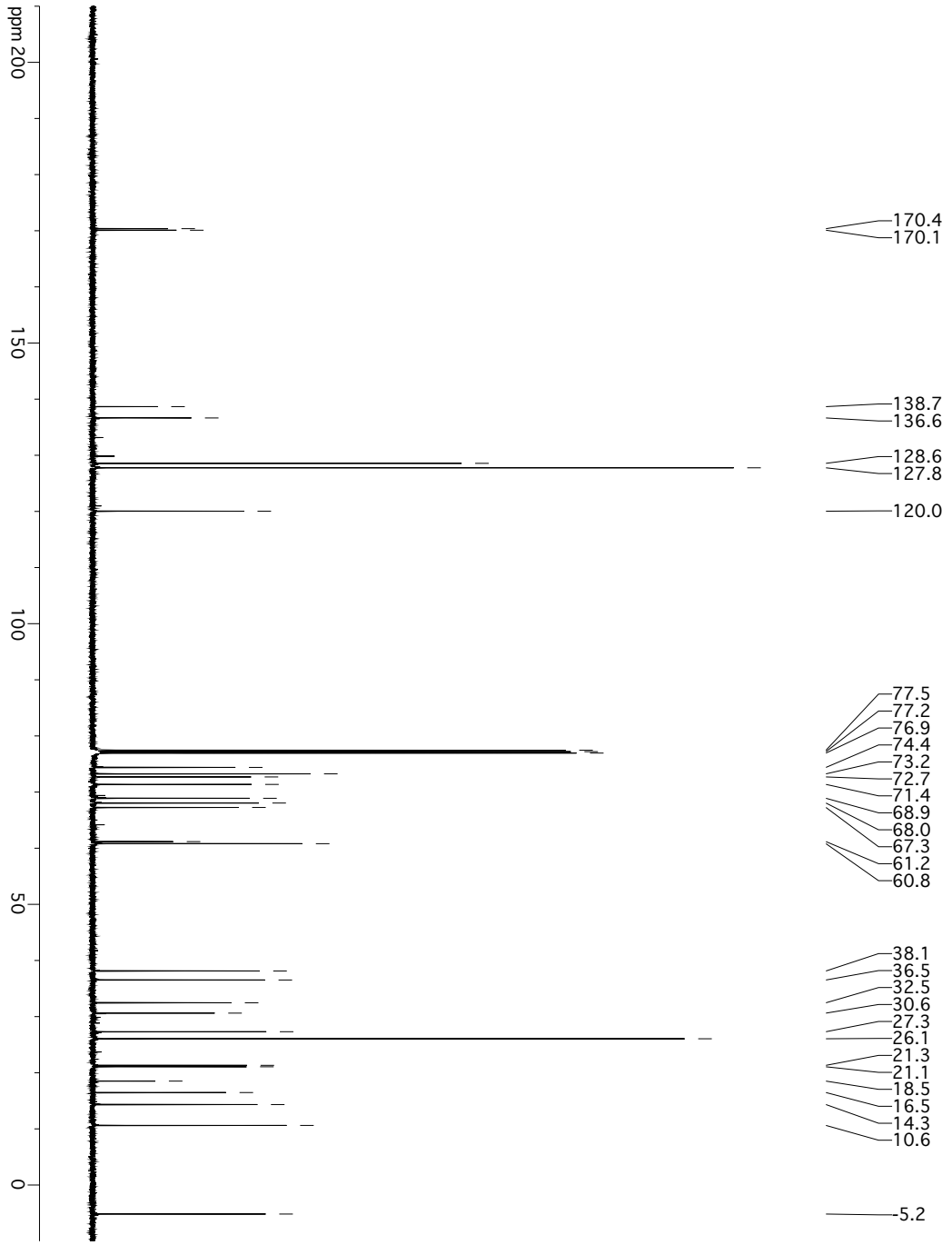

OAc
Me
OAc
BnO
O
H
O
H
Me
Me
OTBS

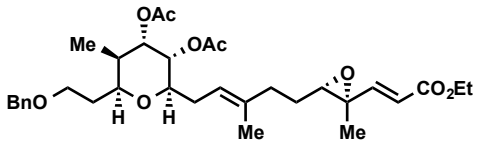
19


ppm
8
7
6
5
4
3
2
1
0
4.6
1
1.06
1.05
2.27
1.06
4.22
1.04
0.935
6.25
1.08
3.07
2.15
3.18
3.26
3.31
3.01
9.18
2.54
2.72
7.34
7.29
7.27
5.20
5.20
5.19
4.81
4.80
4.78
4.78
4.01
4.01
4.01
4.00
4.00
3.99
3.99
3.98
3.72
3.71
3.70
3.70
3.69
3.68
3.68
2.86
2.85
2.84
2.11
2.00
1.58
1.27
1.06
1.04
0.90
0.07
0.06

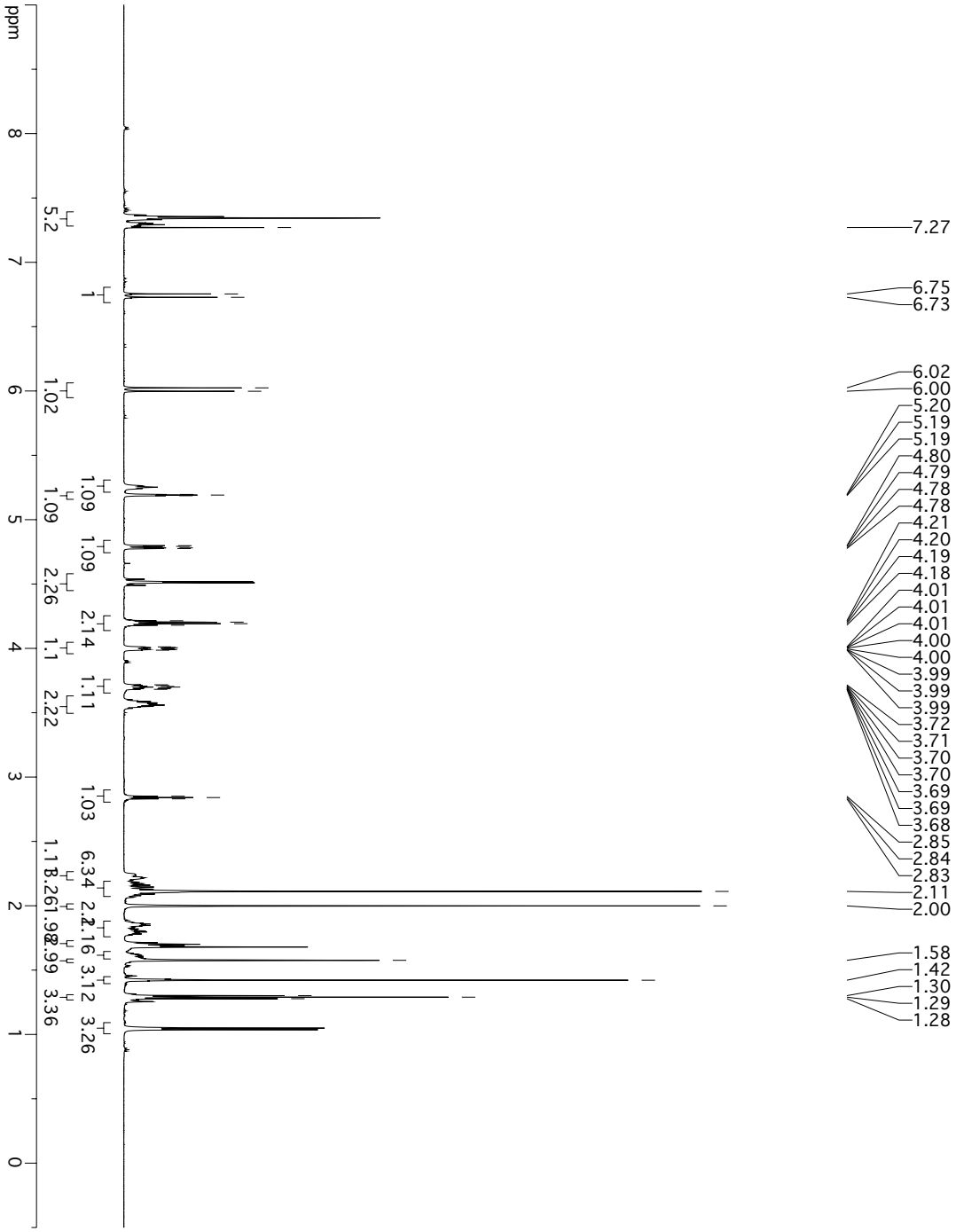

OAc
Me
OAc
BnO
O
H
H
O
Me
Me
OTBS

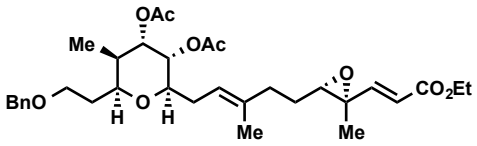
19


ppm
200
150
100
50
0
170.4
170.1
138.7
136.6
128.6
127.8
120.0
77.5
77.2
76.9
74.4
73.2
72.7
71.4
68.9
68.0
67.3
61.2
60.8
38.1
36.5
32.5
30.6
27.3
26.1
21.3
21.1
18.5
16.5
14.3
10.6
-5.2

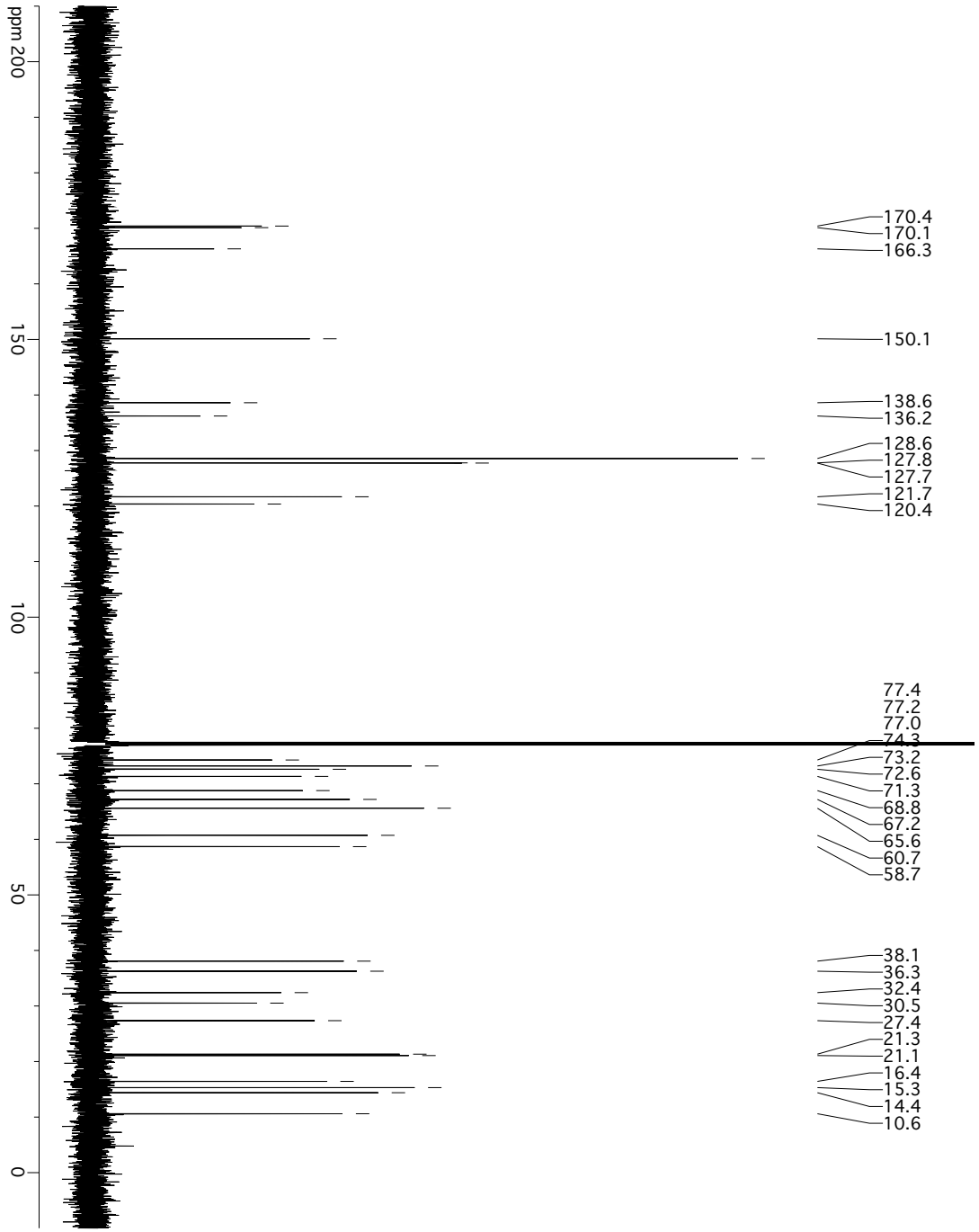

OAc
Me
OAc
BnO
O
H
H
O
Me
Me
CO2Et

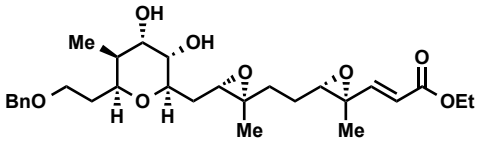
S19


ppm
8
7
6
5
4
3
2
1
0
5.2
1
1.02
1.09
1.09
1.09
2.26
2.14
1.1
1.11
2.22
1.03
6.34
1.1
3.26
2.2
1.98
2.16
2.99
3.12
3.36
3.26
7.27
6.75
6.73
6.02
6.00
5.20
5.19
5.19
4.80
4.79
4.78
4.78
4.21
4.20
4.19
4.18
4.01
4.01
4.01
4.00
4.00
3.99
3.99
3.99
3.72
3.71
3.70
3.70
3.69
3.69
3.68
2.85
2.84
2.83
2.11
2.00
1.58
1.42
1.30
1.29
1.28

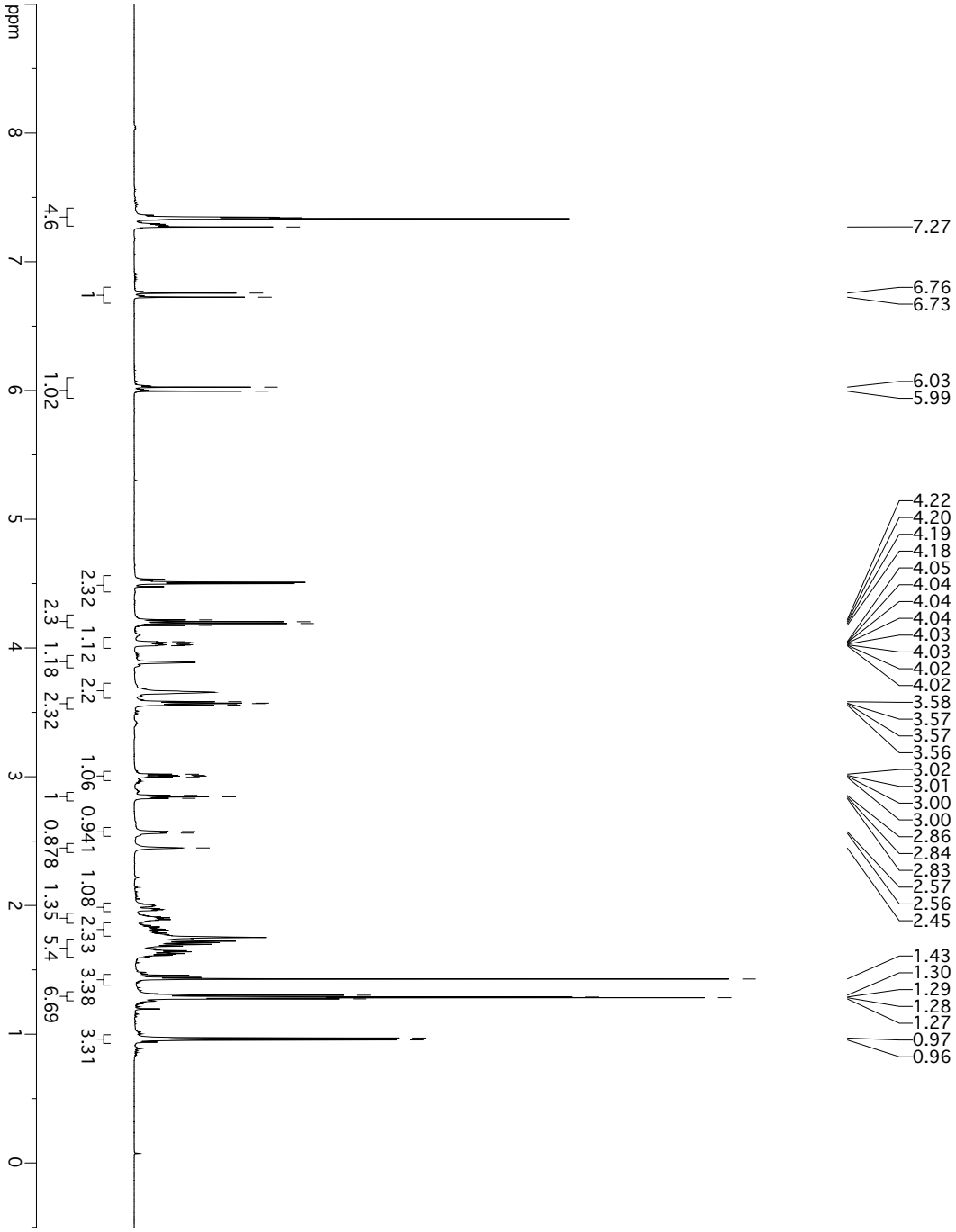

OAc
Me
OAc
BnO
O
H
H
O
Me
Me
CO2Et

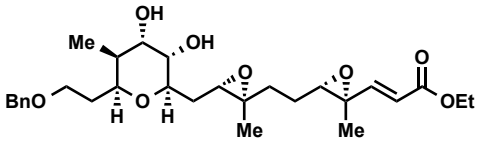
S19


ppm
200
150
100
50
0
170.4
170.1
166.3
150.1
138.6
136.2
128.6
127.8
127.7
121.7
120.4
77.4
77.2
77.0
74.3
73.2
72.6
71.3
68.8
67.2
65.6
60.7
58.7
38.1
36.3
32.4
30.5
27.4
21.3
21.1
16.4
15.3
14.4
10.6

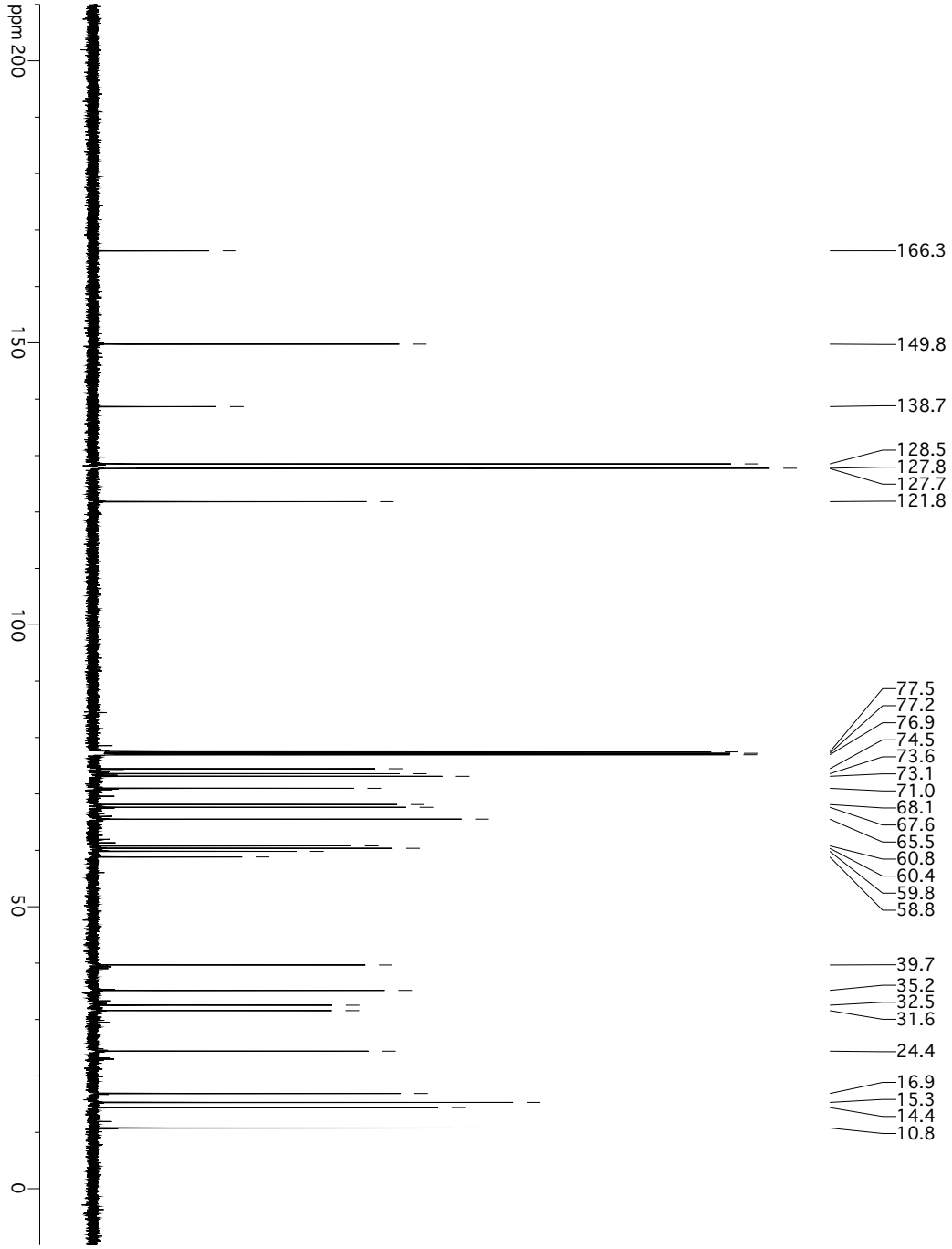

OH
Me
OH
BnO
O
H
H
O
O
O
Me
Me
OEt

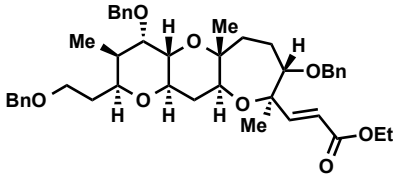
21


ppm
8
7
6
5
4
3
2
1
0
4.6
1
1.02
2.32
2.3
1.12
1.18
2.2
2.32
1.06
1
0.941
0.878
1.08
1.35
2.33
5.4
3.38
6.69
3.31
7.27
6.76
6.73
6.03
5.99
4.22
4.20
4.19
4.18
4.05
4.04
4.04
4.04
4.03
4.03
4.02
4.02
3.58
3.57
3.57
3.56
3.02
3.01
3.00
3.00
2.86
2.84
2.83
2.57
2.56
2.45
1.43
1.30
1.29
1.28
1.27
0.97
0.96

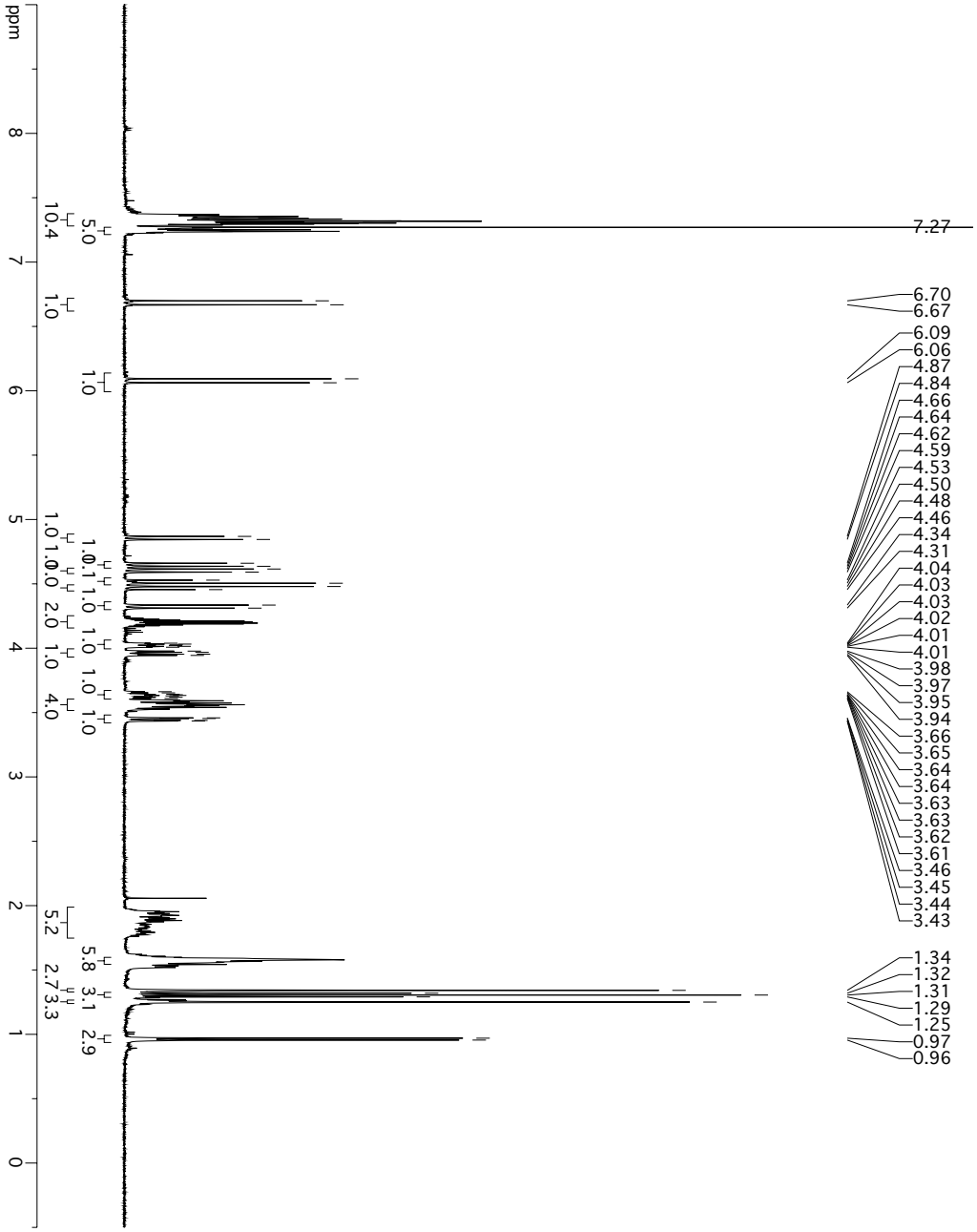

OH
Me
OH
BnO
O
H
O
H
O
O
O
OEt
Me
Me

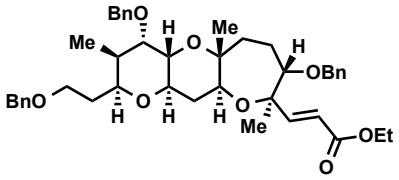
21


ppm
200
150
100
50
0
166.3
149.8
138.7
128.5
127.8
127.7
121.8
77.5
77.2
76.9
74.5
73.6
73.1
71.0
68.1
67.6
65.5
60.8
60.4
59.8
58.8
39.7
35.2
32.5
31.6
24.4
16.9
15.3
14.4
10.8

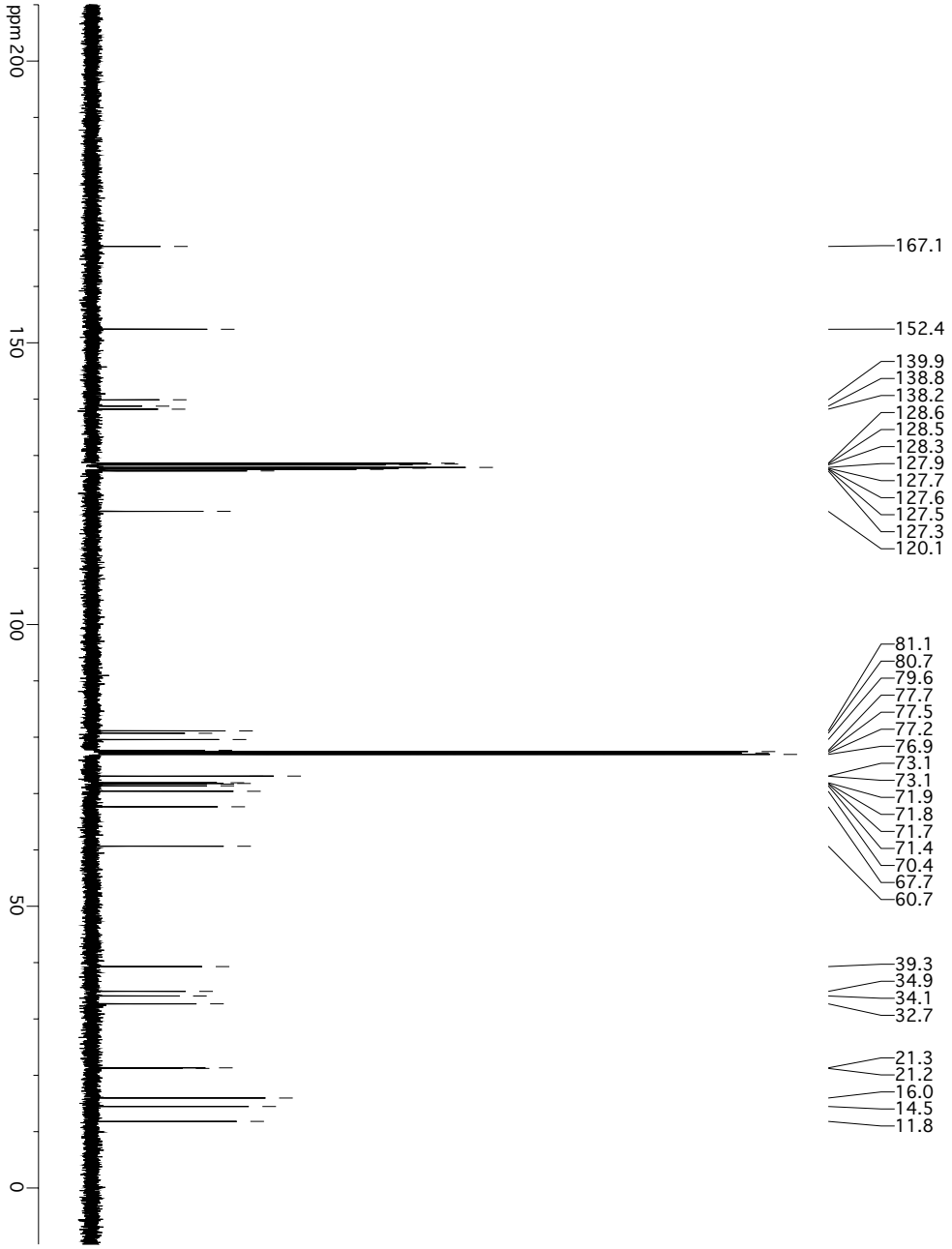

BnO
H
Me
Me
O
H
OBn
BnO
O
H
H
H
O
Me
OEt
O

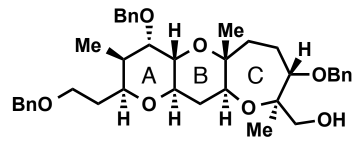
S20


ppm
8
7
6
5
4
3
2
1
0
10.4
5.0
1.0
1.0
1.0
1.0
1.0
1.0
2.0
1.0
1.0
1.0
4.0
1.0
5.2
5.8
3.1
2.7
3.3
2.9
7.27
6.70
6.67
6.09
6.06
4.87
4.84
4.66
4.64
4.62
4.59
4.53
4.50
4.48
4.46
4.34
4.31
4.04
4.03
4.03
4.02
4.01
4.01
3.98
3.97
3.95
3.94
3.66
3.65
3.64
3.64
3.63
3.63
3.62
3.61
3.46
3.45
3.44
3.43
1.34
1.32
1.31
1.29
1.25
0.97
0.96

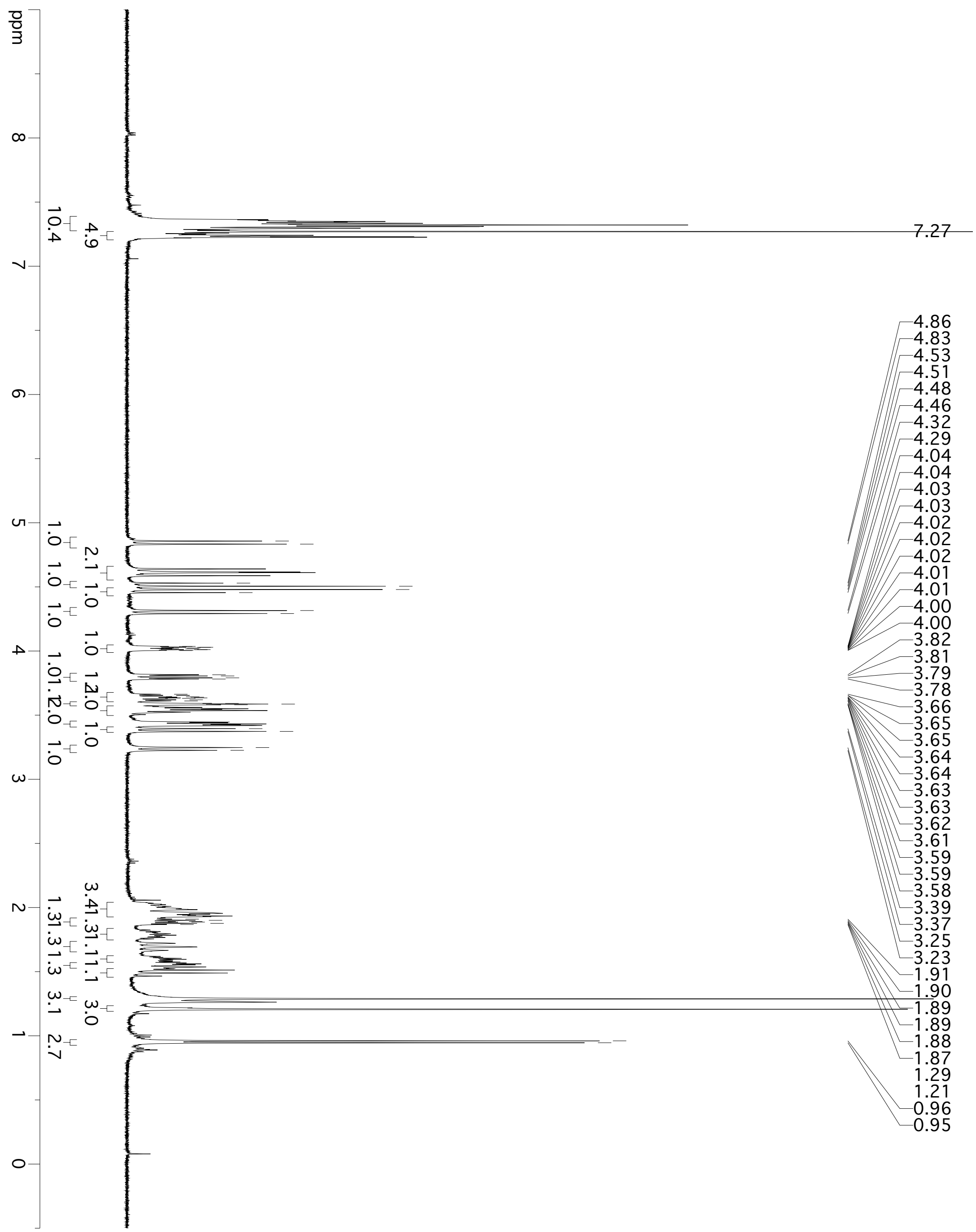

BnO
H
Me
Me
O
H
OBn
BnO
O
H
H
H
O
Me
OEt
O

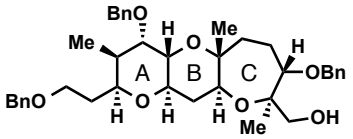
S20


ppm
200
150
100
50
0
167.1
152.4
139.9
138.8
138.2
128.6
128.5
128.3
127.9
127.7
127.6
127.5
127.3
120.1
81.1
80.7
79.6
77.7
77.5
77.2
76.9
73.1
73.1
71.9
71.8
71.7
71.4
70.4
67.7
60.7
39.3
34.9
34.1
32.7
21.3
21.2
16.0
14.5
11.8

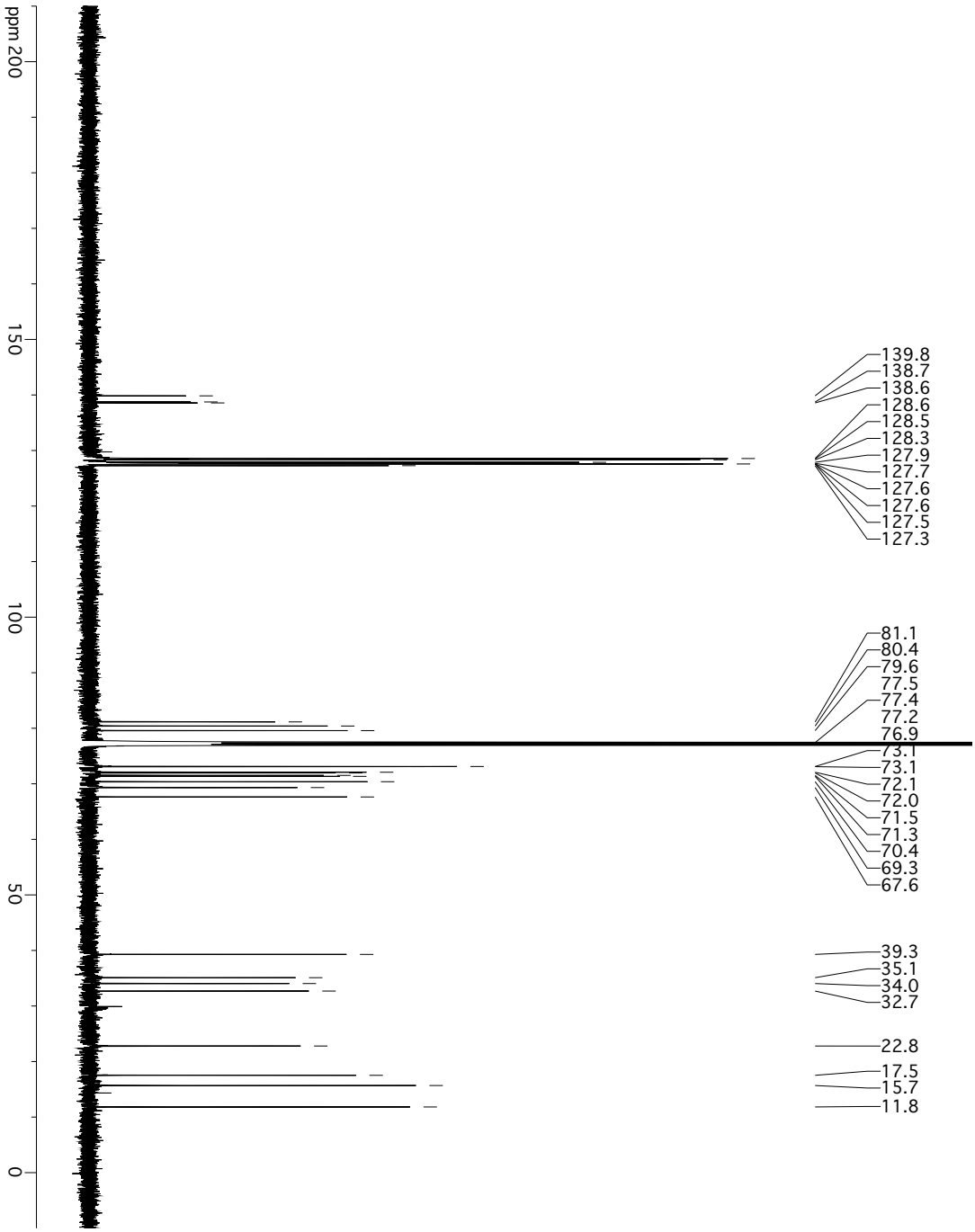

BnO
Me
H
Me
O
H
OBn
A
B
C
BnO
O
O
H
H
H
Me
OH

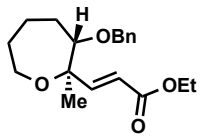
2


ppm
8
7
6
5
4
3
2
1
0
7.27
4.86
4.83
4.53
4.51
4.48
4.46
4.32
4.29
4.04
4.04
4.03
4.03
4.02
4.02
4.02
4.01
4.01
4.00
4.00
3.82
3.81
3.79
3.78
3.66
3.65
3.65
3.64
3.64
3.63
3.63
3.62
3.61
3.59
3.59
3.58
3.39
3.37
3.25
3.23
1.91
1.90
1.89
1.89
1.88
1.87
1.29
1.21
0.96
0.95

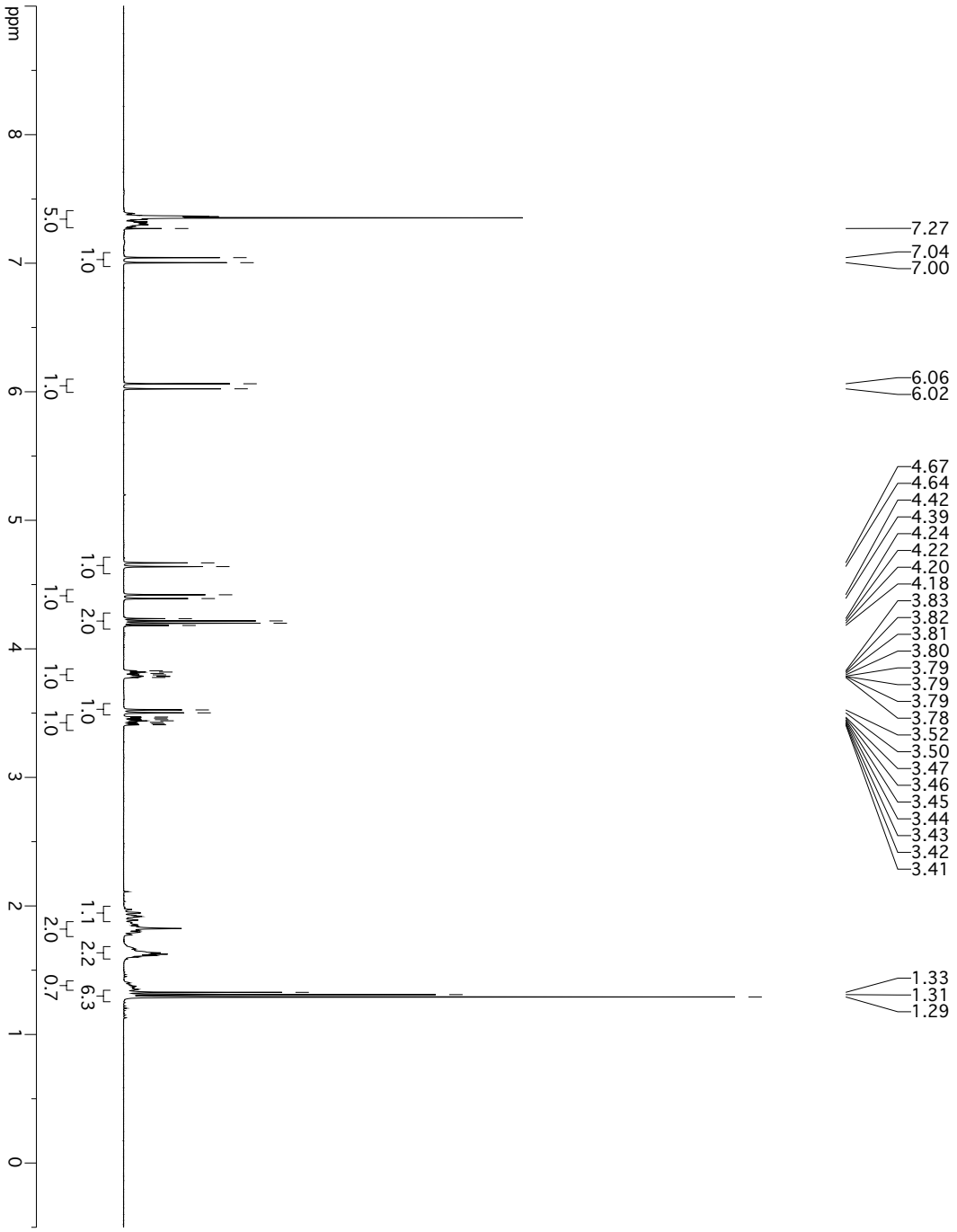

BnO
H
Me
Me
O
H
A
B
C
OBn
BnO
O
O
OH
H
H
H
Me

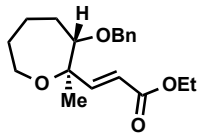
2


ppm
200
150
100
50
0
139.8
138.7
138.6
128.6
128.5
128.3
127.9
127.7
127.6
127.6
127.5
127.3
81.1
80.4
79.6
77.5
77.4
77.2
76.9
73.1
73.1
72.1
72.0
71.5
71.3
70.4
69.3
67.6
39.3
35.1
34.0
32.7
22.8
17.5
15.7
11.8

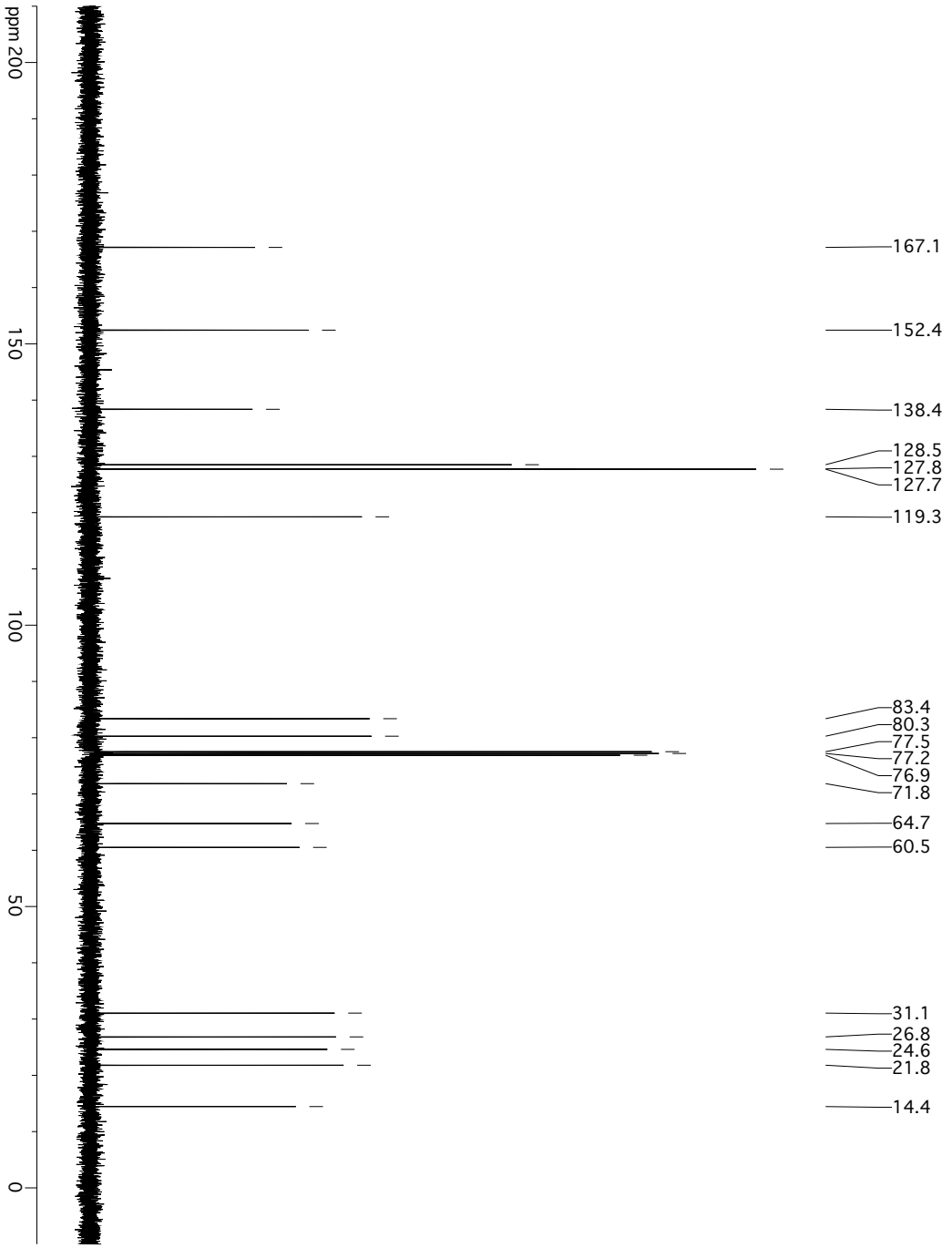

H
OBn
O
Me
OEt
O

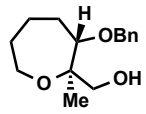
S21


ppm
8
7
6
5
4
3
2
1
0
5.0
1.0
1.0
1.0
1.0
2.0
1.0
1.0
1.0
1.1
2.0
2.2
6.3
0.7
7.27
7.04
7.00
6.06
6.02
4.67
4.64
4.42
4.39
4.24
4.22
4.20
4.18
3.83
3.82
3.81
3.80
3.79
3.79
3.79
3.78
3.52
3.50
3.47
3.46
3.45
3.44
3.43
3.42
3.41
1.33
1.31
1.29

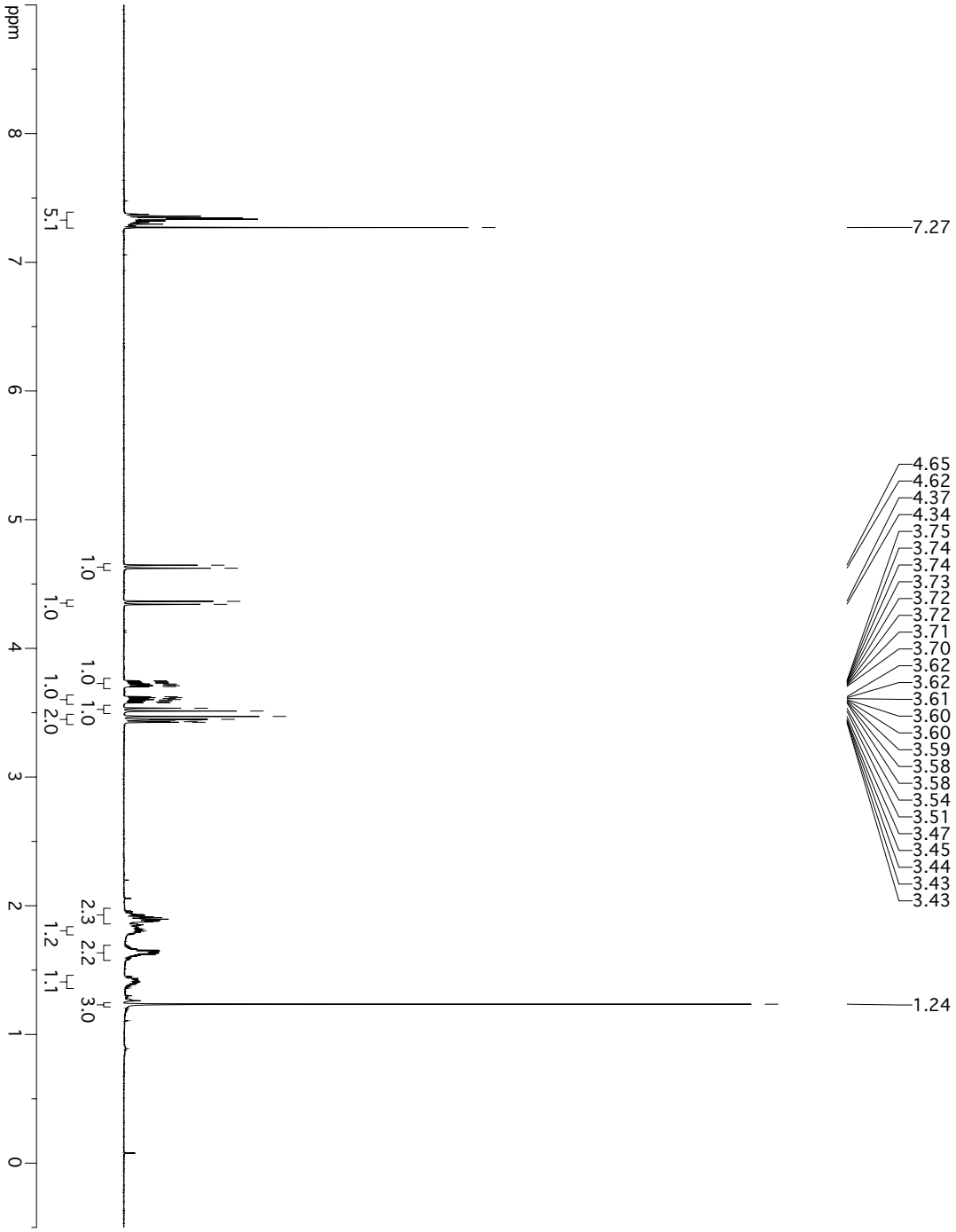

H
OBn
O
Me
OEt
O

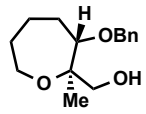
S21


ppm
200
150
100
50
0
167.1
152.4
138.4
128.5
127.8
127.7
119.3
83.4
80.3
77.5
77.2
76.9
71.8
64.7
60.5
31.1
26.8
24.6
21.8
14.4

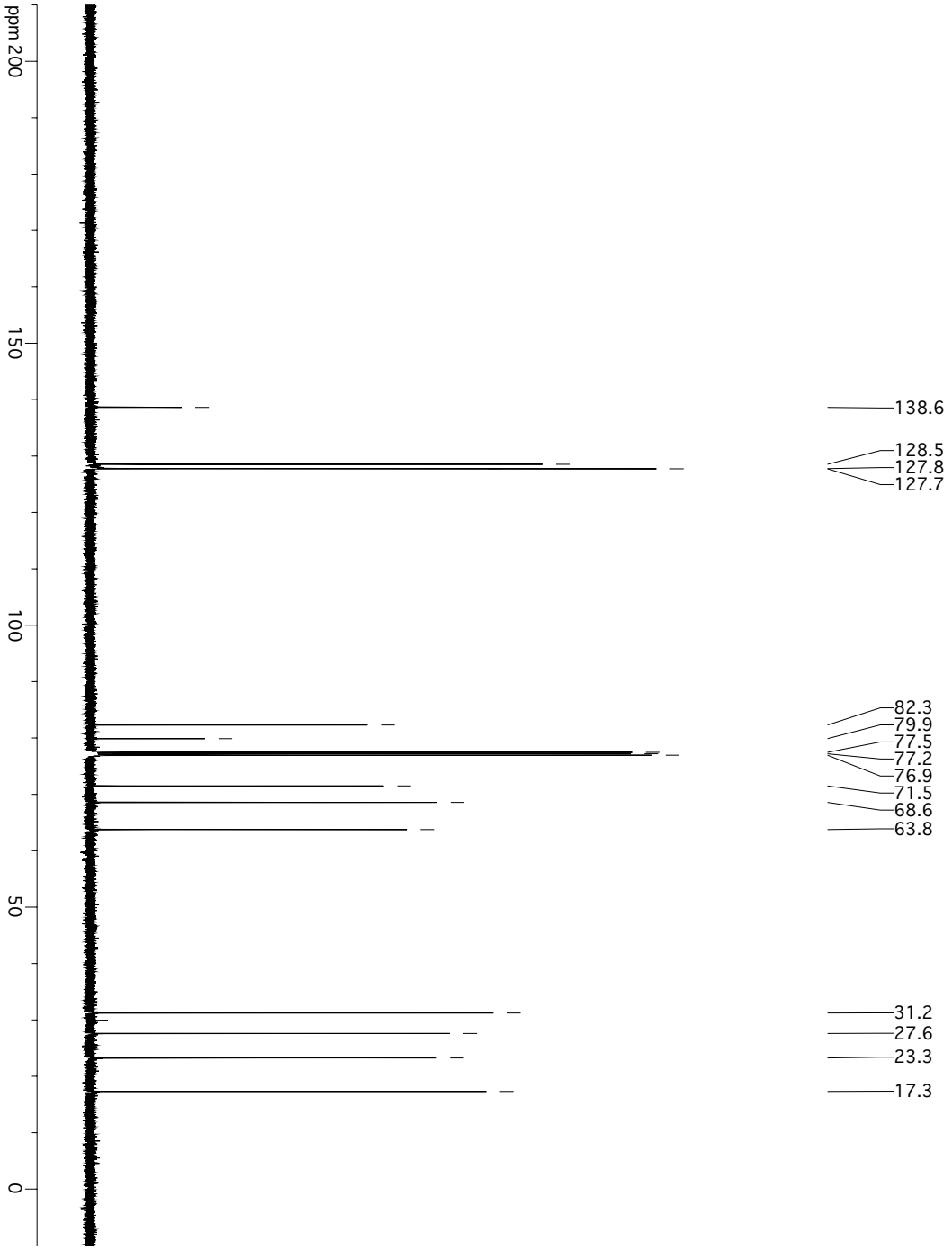

H
OBn
O
OH
Me

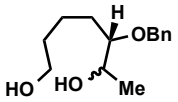
S22


ppm
8
7
6
5
4
3
2
1
0
5.1
1.0
1.0
1.0
1.0
1.0
2.0
2.3
2.2
1.2
1.1
3.0
7.27
4.65
4.62
4.37
4.34
3.75
3.74
3.74
3.73
3.72
3.72
3.71
3.70
3.62
3.62
3.61
3.60
3.60
3.59
3.58
3.58
3.54
3.51
3.47
3.45
3.44
3.43
3.43
1.24

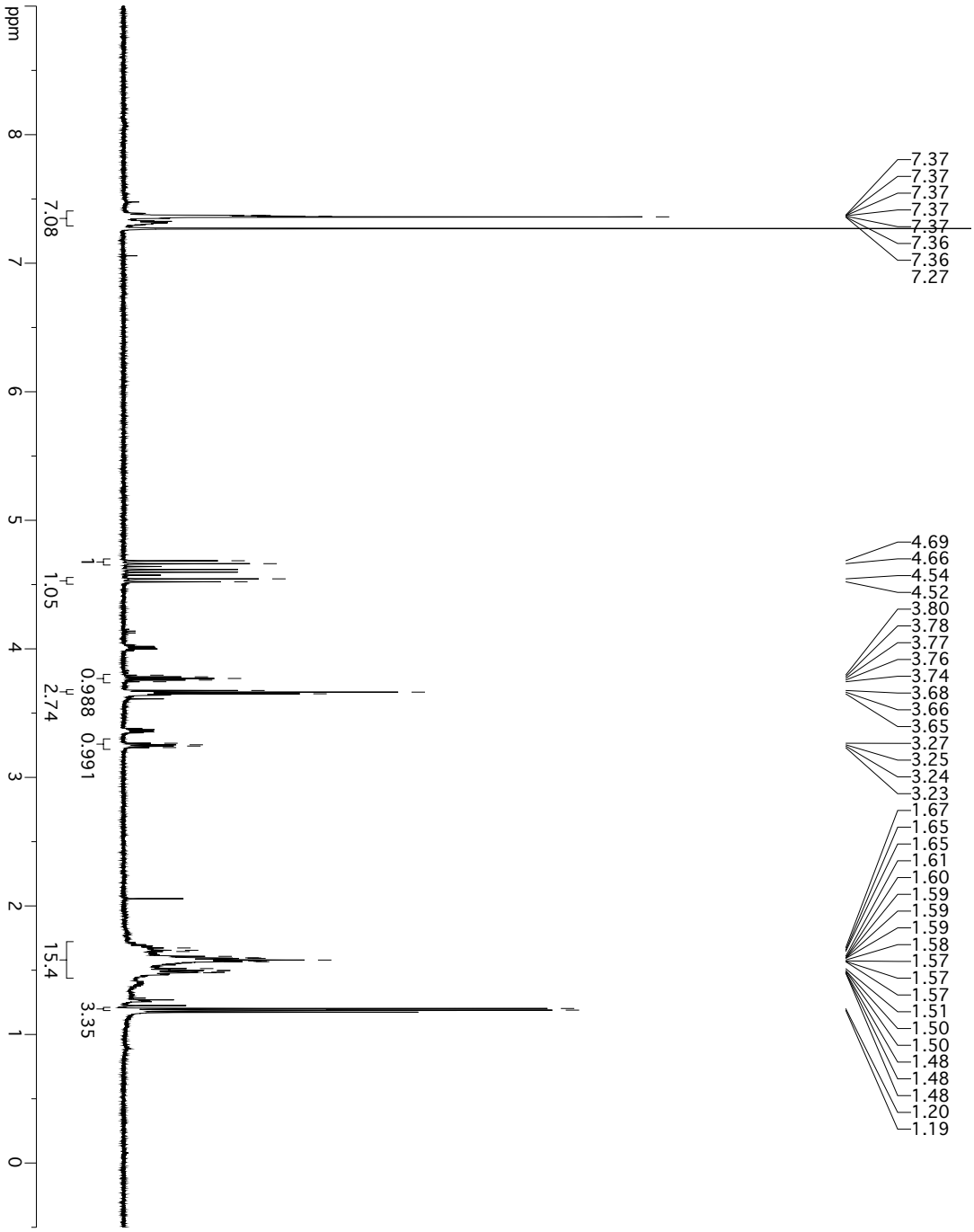

H
OBn
O
OH
Me

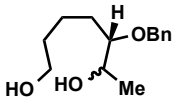
S22


ppm
200
150
100
50
0
138.6
128.5
127.8
127.7
82.3
79.9
77.5
77.2
76.9
71.5
68.6
63.8
31.2
27.6
23.3
17.3

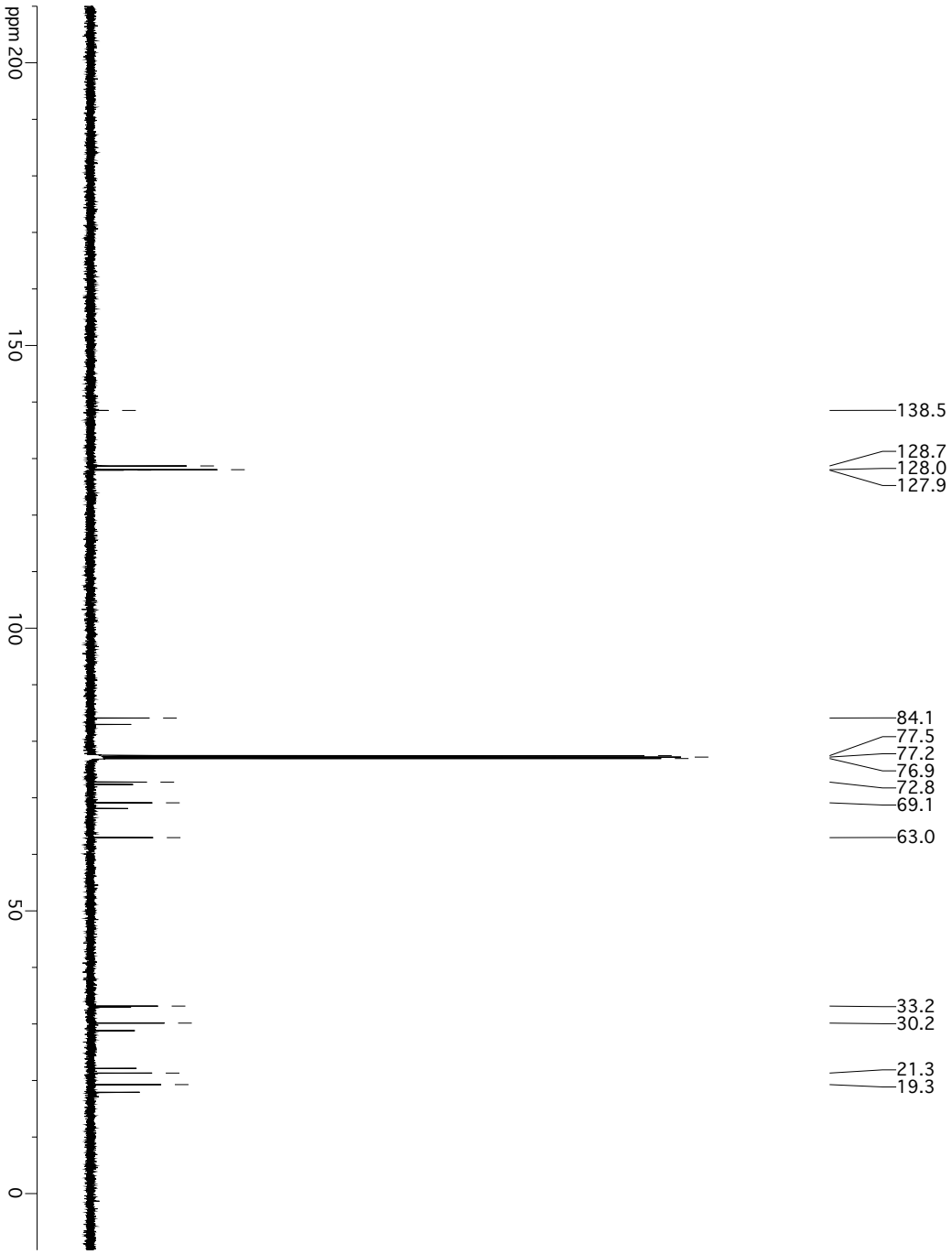

H
OBn
HO
HO
Me

S23


ppm
8
7
6
5
4
3
2
1
0
7.08
1.05
0.988
2.74
0.991
15.4
3.35
7.37
7.37
7.37
7.37
7.37
7.36
7.36
7.27
4.69
4.66
4.54
4.52
3.80
3.78
3.77
3.76
3.74
3.68
3.66
3.65
3.27
3.25
3.24
3.23
1.67
1.65
1.65
1.61
1.60
1.59
1.59
1.59
1.58
1.57
1.57
1.57
1.51
1.50
1.50
1.48
1.48
1.48
1.20
1.19


H
OBn
HO
HO
Me

S23


ppm
200
150
100
50
0
138.5
128.7
128.0
127.9
84.1
77.5
77.2
76.9
72.8
69.1
63.0
33.2
30.2
21.3
19.3